High Energy Physics

Overview

The High Energy Physics (HEP) program mission is to understand how the universe works at its most fundamental level by discovering the elementary constituents of matter and energy, probing the interactions between them, and exploring the basic nature of space and time.

HEP offers research opportunities for individual investigators and small-scale collaborations, as well as very large international collaborations, chosen for their scientific merit and potential for significant impact. More than 20 HEP-supported physicists have received the Nobel Prize. Moreover, many of the advanced technologies and research tools originally developed for high energy physics have proven widely applicable to other sciences as well as industry, medicine, and national security.

Our current understanding of the elementary constituents of matter and energy is captured in what is called the Standard Model of particle physics. It is incredibly successful, yet known to be incomplete. It describes the elementary particles comprising ordinary matter, and forces that govern them, with very high precision. Astronomical observations indicate, however, that ordinary matter makes up only about 5% of the universe, the remainder being 70% dark energy and 25% dark matter, both “dark” because they are either nonluminous or unknown. Neither is described by the Standard Model. The observation of very small but non-zero masses of the elementary particles known as neutrinos provides further hints of new physics beyond the Standard Model.

A world-wide program of particle physics research is underway to discover what lies beyond the Standard Model. HEP supports a research program that can be described by three scientific frontiers:

- *The Energy Frontier,* using the highest energy accelerators available to create particles never before seen in the laboratory, revealing their interactions, and investigating fundamental forces using the highest energy accelerators available;
- *The Intensity Frontier,* using intense particle beams, massive detectors, and/or high precision detectors to investigate fundamental forces and particle interactions by studying events that occur rarely in nature; and
- *The Cosmic Frontier,* using advanced telescopes and underground detectors to measure astrophysical phenomena that offer new insight and information about the nature of dark matter and dark energy and about fundamental forces and particle properties.

Together, these complementary discovery frontiers, along with critical supporting thrusts in advanced accelerator and detector technologies, and theory and computation, offer the opportunity to answer some of the most basic questions about the world around us, including:

- How does mass originate?
- Why is the world made of matter and not anti-matter?
- What is dark energy? Dark matter?
- What are the origins of the universe? Can particle physics explain earliest moments of the universe when the four fundamental forces were still unified?

The experimental subprograms are supported by the Theoretical and Computational Physics and the Advanced Technology R&D subprograms. Theoretical and Computational Physics provides the theoretical models needed to explain the experimental data as well as predictions for experimental tests. That subprogram also provides simulations and data analysis tools. The Advanced Technology R&D subprogram supports the development of new accelerator and detector technologies to extend the capabilities of the experimental physics programs.

The Accelerator Stewardship subprogram is unique in the High Energy Physics program in that its mission is to explicitly support long–term research and development with application beyond the HEP program, including the needs of the rest of the Office of Science, other government agencies, and industry.

Highlights of the FY 2015 Budget Request

DOE and the National Science Foundation (NSF) have charged the High Energy Physics Advisory Panel with developing an updated strategic plan for the field of U.S. high energy physics that can be executed over a ten-year timescale. This report is expected in May 2014. The FY 2015 budget request supports full operation of existing HEP facilities and experiments; the planned construction funding profile for the Muon to Electron Conversion Experiment (Mu2e); and initiate fabrication for new major items of equipment (MIEs) for the LHC ATLAS (A Large Toroidal LHC Apparatus) Detector Upgrade and the LHC Compact Muon Solenoid (CMS) Detector Upgrade. Capital equipment funding is requested to support the planned funding profiles for the camera for the Large Synoptic Survey Telescope (LSST), the Muon g-2 Experiment, and a U.S. contribution to the upgrade of the Belle detector at the Super B-Factory in Japan (Belle II).

Energy Frontier Experimental Physics

Operations of the Large Hadron Collider (LHC) at CERN will resume in 2015 at energies of at least 13 TeV, a substantial increase from 8 TeV in the last run. This will increase the reach of the LHC to the search for new physics, particularly in high-impact topics such as supersymmetry, dark matter candidates, and evidence for extra space-time dimensions. Investments for U.S. contributions to future planned LHC detector upgrades that will exploit the full physics potential of the higher luminosities.

Intensity Frontier Experimental Physics

FY 2015 will feature the first full year of operations for the NOvA detector in the world’s most intense neutrino beam. The physics goals of this experiment include improved measurements of neutrino mixing and first results on the neutrino mass hierarchy and the search for CP violation in the neutrino sector.

The Mu2e construction project and the Muon g-2 major item of equipment will be in the fabrication phase. These experiments will probe energy scales beyond the LHC through the study of rare processes and precision measurements. U.S. contributions to the Belle II will be complete in FY 2015. The Belle II detector is located at the Japanese B-factory and will study rare decays and CP violation in the heavy quark systems.

Cosmic Frontier Experimental Physics

The Dark Energy Survey continues operations in FY 2015, leading to the next-generation experiment. The LSST camera MIE in its second year of fabrication. The experiments performing direct searches for dark-matter particles will be in transition, as a large suite of first-generation experiments are planned to complete operations by FY 2015. In FY 2015, HEP will fund the research needed to develop a second generation of dark matter experiments and respond to recommendations of the community planning effort to be completed in FY 2014.

Theoretical and Computational Physics

The current high priority thrusts of the Theoretical Physics subprogram are to understand the LHC data and develop new search strategies that can be used at the LHC in the future; developing new models of dark matter; and other topics.

The computational physics effort supports research on computation, simulation, data tools, and software that cut across all HEP programs. An extension of the Lattice Quantum Chromodynamics (LQCD) project is planned in FY 2015. The LQCD IT Project is jointly funded by HEP and NP to provide optimized and dedicated computer hardware to simulate the fundamental interactions of quarks and gluons via the strong interaction that underlies many of the physics processes studied in both programs. Coordination with NP on LQCD ensures that the research results are productively used by both communities and avoids the potential for duplicative efforts.

Advanced Technology R&D

HEP built the FACET (Facility for Advanced Accelerator Experimental Tests at SLAC) and BELLA (Berkeley Lab Laser Accelerator at LBNL) facilities to support research on using plasmas to accelerate charged particles more effectively. Both have begun successful operation, reported first results, and are supported in the FY 2015 budget request. This technique has the promise of reducing the size of particle accelerators by 90–99%, making them less expensive. The energy to drive the plasma can come either from lasers (BELLA) or electron beams (FACET). As of the summer of 2013 both techniques have successfully accelerated beams without degrading their structure. These discoveries will be followed with comprehensive research programs to determine if practical particle accelerators can be built with these techniques.

The LHC Accelerator Research Program (LARP) focuses on research for the construction of the powerful focusing magnets made from niobium-tin superconductor which have higher magnetic fields than magnets currently in the LHC. Successful development of these magnets will allow the U.S. to make a unique and critical contribution to the upgrade of the LHC to produce more particle collisions per second, which will provide more data for the experimenters. Funding for this effort is increased in FY 2015.

Accelerator Stewardship

The Accelerator Stewardship subprogram supports long-term multi-purpose accelerator research applicable to fields beyond HEP. This includes extensions of the accelerator science research conducted under the HEP General Accelerator R&D portfolio, which is broadly applicable to other fields of science and seeks to identify and support R&D in specific technological areas important to a variety of accelerator applications, such as high-power lasers. In FY 2015, funding is increased to support new research activities for selected technology areas such as laser, ion-beam therapy, and green RF sources, with priorities informed by workshops held by HEP.

Construction

Two construction projects are underway to support Intensity Frontier Physics. The Muon to Electron Conversion Experiment (Mu2e), which will search for violation of charged lepton conservation, will complete its design phase in FY 2015 and move into full construction. The Long Baseline Neutrino Experiment continues its design phase.

High Energy Physics
Funding ($K)

	FY 2013 Current	FY 2014 Enacted	FY 2014 Current	FY 2015 Request	FY 2015 vs. FY 2014 Enacted
Energy Frontier Experimental Physics					
Research	89,172	96,129	96,129	81,132	-14,997
Facility Operations and Experimental Support	60,274	58,558	58,558	57,507	-1,051
Projects	0	0	0	15,000	+15,000
Total, Energy Frontier Experimental Physics	**149,446**	**154,687**	**154,687**	**153,639**	**-1,048**
Intensity Frontier Experimental Physics					
Research	52,860	52,562	52,562	51,459	-1,103
Facility Operations and Experimental Support	158,058	185,481	185,481	174,816	-10,665
Projects	63,494	37,000	37,000	24,970	-12,030
Total, Intensity Frontier Experimental Physics	**274,412**	**275,043**	**275,043**	**251,245**	**-23,798**
Cosmic Frontier Experimental Physics					
Research	48,652	62,364	62,364	48,553	-13,811
Facility Operations and Experimental Support	12,252	12,022	12,022	11,692	-330
Projects	19,159	24,694	24,694	41,000	+16,306
Total, Cosmic Frontier Experimental Physics	**80,063**	**99,080**	**99,080**	**101,245**	**+2,165**
Theoretical and Computational Physics					
Research					
Theory	54,621	51,196	51,196	49,630	-1,566
Computational HEP	8,577	8,474	8,474	8,220	-254
Total, Research	63,198	59,670	59,670	57,850	-1,820
Projects	3,200	3,200	3,200	1,000	-2,200
Total, Theoretical and Computational Physics	**66,398**	**62,870**	**62,870**	**58,850**	**-4,020**
Advanced Technology R&D					
Research					
HEP General Accelerator R&D	60,705	57,694	57,694	47,620	-10,074
HEP Directed Accelerator R&D	22,692	23,500	23,500	26,000	+2,500
Detector R&D	27,405	23,947	23,947	23,229	-718
Total, Research	110,802	105,141	105,141	96,849	-8,292

	FY 2013 Current	FY 2014 Enacted	FY 2014 Current	FY 2015 Request	FY 2015 vs. FY 2014 Enacted
Facility Operations and Experimental Support	31,489	17,150	17,150	17,393	+243
Total, Advanced Technology R&D	**142,291**	**122,291**	**122,291**	**114,242**	**-8,049**
Accelerator Stewardship					
Research	82	6,581	6,581	16,384	+9,803
Facility Operations and Experimental Support	3,050	3,350	3,350	2,800	-550
Total, Accelerator Stewardship	**3,132**	**9,931**	**9,931**	**19,184**	**+9,253**
SBIR/STTR	0	21,619	21,619	20,595	-1,024
Subtotal, High Energy Physics	**715,742**	**745,521**	**745,521**	**719,000**	**-26,521**
Construction					
Long Baseline Neutrino Experiment	3,781	16,000	16,000	0	-16,000
Muon to Electron Conversion Experiment	8,000	35,000	35,000	25,000	-10,000
Total, Construction	**11,781**	**51,000**	**51,000**	**25,000**	**-26,000**
Total, High Energy Physics	**727,523**	**796,521**	**796,521**	**744,000**	**-52,521**

SBIR/STTR:

- FY 2013 transferred: SBIR: $18,405,000; STTR: $2,386,000
- FY 2014 projected: SBIR: $18,916,000; STTR: $2,703,000
- FY 2015 Request: SBIR: $18,098,000; STTR: $2,497,000

High Energy Physics
Explanation of Major Changes ($K)

	FY 2015 vs. FY 2014 Enacted
Energy Frontier Experimental Physics: Reductions in research funding are due to the completion of the Tevatron research program, and overall programmatic reductions in research activities to support current and future experimental capabilities. This is offset by an increase in funding for initial LHC detector upgrade activities, scheduled for completion by 2018.	-1,048
Intensity Frontier Experimental Physics: Reductions are dominated by the ramp-down of funding associated with current projects (particularly NOvA). Funding for the SLAC B-factory operations is eliminated as planned disassembly work is completed. This is partially offset by increases in funding for initial operations of the upgraded NuMI beamline for NOvA, refurbishment of the oldest portions of the Fermilab accelerator complex, and support for R&D and fabrication of current and future experiments.	-23,798
Cosmic Frontier Experimental Physics: Funding increases are dominated by the ramp-up of the LSSTcam MIE according to its planned profile. Funding for research activities decreases and is redirected to R&D and planning efforts for the next generation of dark matter and dark energy experiments.	+2,165
Theoretical and Computational Physics: Funding for theoretical and computational HEP research is reduced to offset increased investments in future facilities.	-4,020
Advanced Technology R&D: Research activities are reduced to offset increased project funding, as well as a shift towards more directed R&D activities to develop future experimental capabilities.	-8,049
Accelerator Stewardship: This subprogram focuses on the fundamental physics of charged particle beams and on accelerator technology that can broadly benefit fields both within and outside of HEP. Additional funding is requested to start new R&D effort on ion beam acceleration for medical use, the development of high power/high repetition rate lasers for the manipulation of charged particle beams, and higher efficiency RF power sources. Funding is also sought to allow the accelerator industry access to specialized test facilities at the national laboratories.	+9,253
SBIR/STTR: Funding is provided in accordance with the legislatively directed percentage of HEP operating budgets.	-1,024
Construction: Funding is provided consistent with the planned profile for construction of the Muon to Electron Conversion Experiment. No construction funding is provided for LBNE.	-26,000
Total, High Energy Physics	**-52,521**

Basic and Applied R&D Coordination

Many applications of technology developed by HEP research have been unforeseen. Although it has been recognized that many of these technology developments have transformative impacts in the areas of national security, medicine, energy and environment, industry, and discovery science (including accelerator science), there has been no systematic way of enhancing technology transfer to these other fields.

In order to better leverage possible future applications of accelerators, as well as key technical areas, HEP requested that SLAC convene the Accelerator Stewardship Task Force consisting of accelerator R&D experts drawn from universities, national laboratories, and industry to help identify specific research areas and infrastructure gaps where HEP investments could have significant impacts beyond the "traditional" HEP program.

HEP coordinates its program with other offices and agencies with related programs and missions. The U.S. LHC program is supported by HEP and NSF Physics Division and overseen by a Joint Oversight Group (JOG). Dark matter research is also jointly sponsored by those agencies, and the agencies are coordinating their planning on next generation experiments. Both HEP and NSF Physics use the High Energy Physics Advisory Panel (HEPAP) as part of their advisory structure. HEP also coordinates with NSF Astronomy on the Dark Energy Survey experiment and the Large Synoptic Survey Telescope Project, each of which is overseen by a JOG. Both agencies as well as NASA receive advice from the Astronomy and Astrophysics Advisory Committee on areas of joint interest.

HEP coordinates with other offices with the Office of Science to identify common interests and to avoid duplication. For example, Lattice Quantum Chromodynamics is a technique to perform calculations involving the strong interaction, which binds quarks into hadrons such as protons, neutrons, and pions studied by HEP; and protons and neutrons into nuclei studied by NP. HEP and NP jointly support acquisition and operation of the dedicated computer hardware needed for these calculations but separately support research on the different topics of concern to each program.

Program Accomplishments

FY 2013 saw confirmations of the paradigm-shifting accomplishments of FY 2012 on many frontiers of particle physics.

LHC experiments confirm the Standard Model Higgs boson has been found (Energy Frontier). The LHC experiments announced discovery of a new particle compatible with the long-sought Standard Model Higgs boson in 2012. In 2013, additional data made the signal for the Higgs Boson indisputable and provided additional measurements of its fundamental properties consistent with the predictions of the Standard Model.

Daya Bay Experiment makes the first definitive measurement of the remaining unknown neutrino mixing angle (Intensity Frontier). Using a partially complete infrastructure, the Daya Bay collaboration led by U.S. and Chinese physicists reported in 2012 a first measurement of the "mixing angle" responsible for changing the flavor of electron antineutrinos over short baselines. In 2013, after careful calibration and systematic studies of the antineutrino detectors, the Daya Bay collaboration announced a new result measuring both the amplitude and frequency of this oscillation and providing precision values for the neutrino mixing angle and the associated mass splitting between the neutrino states.

Electron acceleration using beam-based plasma wakefields (Advanced Technology R&D). An experiment at the FACET facility at SLAC National Accelerator Laboratory demonstrated that accelerator-quality electron beams are capable of reaching high energies much faster than in conventional accelerators by riding on a wake in a plasma created by another electron beam. This is the first demonstration of beam-based plasma wakefield acceleration that maintains a good energy spread in a high-energy accelerated beam.

In addition, the so-called *"AdS/CFT (anti de Sitter/conformal field theory) correspondence,"* originally conceived by HEP-supported theorists in 1997, continues to grow in value. This technique has not only provided hitherto-inaccessible insights into the nature of Quantum Chromodynamics and its supersymmetric extensions, but has also increasingly been applied to other areas, including nuclear physics experiments performed at the Relativistic Heavy Ion Collider and condensed matter theories to explain the complex behavior of electrons in superconductors.

High Energy Physics
Energy Frontier Experimental Physics

Description

The Energy Frontier Experimental Physics subprogram supports LHC research and final analysis of data from the Tevatron experiments at Fermilab with the goal of determining to what extent the Standard Model correctly describes the natural world. Discoveries made and experimental techniques introduced at the Tevatron over the years are now the foundation for much of the LHC research program.

Research activities at the Energy Frontier in FY 2015 will be focused primarily on the LHC. In 2015, the LHC experiments will come back on-line after a planned shutdown that began in FY 2013 to bring the LHC to the full design energy of at least 13 TeV. Data collected during this period will be used to determine answers to many fundamental questions in particle physics, including:

- *Have we really discovered the Standard Model Higgs boson?*

  The Higgs boson is thought to be responsible for generating the mass for all fundamental particles. In July 2012, CERN announced the discovery of a new particle consistent, within the limited statistical accuracy, with being the Standard Model Higgs boson. Since the discovery, experiments at the LHC continue to actively measure the particle's properties to ascertain whether it is indeed the Standard Model Higgs boson. In March 2013, new results strongly indicated consistency with the Standard Model picture. However, more data are required to precisely measure its properties. Through such studies, scientists will be able to establish the particle's exact character or understand if the initial observation is the result of new physics beyond the Standard Model.

- *Are there undiscovered principles of nature, such as new symmetries or new physical laws governing the nature and interaction of fundamental particles?*

  Researchers at the LHC hope to find evidence of what lies beyond the Standard Model or significantly constrain postulated modifications to the Standard Model such as supersymmetry, mechanisms for black hole production, extra dimensions, and other exotic phenomena. With the start of the second run in FY 2015, the LHC detectors will be much more sensitive to deviations from the Standard Model due to the increase in energy from 8 TeV to at least 13 TeV.

The LHC hosts two large multi-purpose particle detectors, CMS and ATLAS used by large collaborations of international scientists. U.S. researchers make up approximately 20% of the ATLAS collaboration and approximately 30% of the CMS collaboration and play critical leadership roles in all aspects of each experiment.

The Energy Frontier Experimental Physics subprogram also supports the LHC detector operations program, which covers the maintenance of U.S. supplied detector systems for the ATLAS and CMS detectors at the LHC and the U.S. based computer infrastructure for the analysis of LHC data by U.S. physicists.

Research

University-based Energy Frontier research is carried out by groups at over 60 institutions performing experiments at the LHC and legacy analyses of data collected at the Tevatron. Grant-supported scientists typically constitute about 50–75% of the personnel needed to create, run, and analyze an experiment, usually working in collaboration with other university and laboratory groups. Grant-based research efforts are selected based on external comparative peer review; funding allocations take into account the quality and scientific priority of the research proposed. Energy Frontier research also supports physicists from five national laboratories. These are typically large groups that also have significant responsibilities for detector operations, maintenance, and upgrades, particularly at the laboratories that host large computing and analysis-support centers. HEP conducted an external peer review of laboratory research groups in this activity in 2012, and findings from this review were used to inform the funding decisions in subsequent years. HEP will review this activity again in 2015 and evaluate progress.

Facility Operations and Experimental Support

U.S. LHC Detector Operations supports the maintenance of U.S. supplied detector systems for the CMS and ATLAS detectors at the LHC and for the U.S. based computer infrastructure used by U.S. physicists to analyze LHC data, including Tier 1 computing centers at Fermi National Accelerator Laboratory (Fermilab) and the Brookhaven National Laboratory (BNL). There are 11 LHC Tier 1 computing centers around the world. They provide round-the-clock support for the Grid, and are responsible for storing a proportional share of raw and reconstructed data, as well as performing large-scale data reprocessing and storing the corresponding output.

Projects

This activity will support the fabrication of major items of equipment (MIE) for the Energy Frontier subprogram, namely upgrades to the ATLAS and CMS detectors.

CERN plans to upgrade the LHC machine to produce 2-3 times the instantaneous luminosity currently delivered. This work is planned to be completed in 2018. The objective of the two detector upgrade projects is to enable each experiment to fully exploit the physics opportunities offered by the LHC for exploration of new physics and to make precision measurements of properties of known phenomena.

A new MIE is requested in FY 2015 for the fabrication of the ATLAS Detector Upgrade Project. Upgrades are needed to the Muon Subsystem, the Liquid Argon Calorimeter Detector and Trigger and Data Acquisition System to take advantage of the increased luminosity.

A new MIE is requested in FY 2015 for the fabrication of the CMS Detector Upgrade Project. Upgrades are needed to the Pixelated Inner Tracking Detector, the Hadron Calorimeter Detector, and Trigger System to take advantage of the increased luminosity.

Energy Frontier Experimental Physics

Activities and Explanation of Changes

FY 2014 Enacted	FY 2015 Request	Explanation of Changes FY 2015 vs. FY 2014 Enacted
Research		
U.S. university and laboratory scientists will continue the analysis of LHC data taken during the first 2009–2012 run. They will also participate in the maintenance of the detectors during the LHC shutdown in order to optimize the detector's performance in the next run at higher energy and higher data rates. Final analyses of Tevatron data are supported.	The LHC will resume operations in FY 2015 after completion of machine repairs and detector maintenance to allow collecting data at energies of at least 13 TeV. U.S. university and laboratory scientists will focus on continuing research activities in conducting high-profile studies, including precision measurements of the recently discovered Higgs boson and search for new physics.	Funding for the Energy Frontier research is reduced as the Tevatron research program is completed and due to overall programmatic reductions in research activities to support current and future experimental capabilities. Some research staff previously supported under Research will be redirected to the LHC Detector Upgrade projects.
Facility Operations and Experimental Support		
During FY 2014, the LHC is shut down for maintenance. There are significant maintenance activities for the detectors. The major computer centers at Fermilab and BNL are being used for continuing analysis of the existing data and the simulation of the data expected at higher energies in the next run. The maintenance of dedicated network links between CERN and the computing centers is also supported.	The LHC run resumes in FY 2015, and supported activities shift to routine maintenance and calibration of the detectors. The computing centers will shift to processing of the newly acquired data in addition to data analysis and simulation.	Major maintenance activities carried out in FY 2014 allow for a small reduction in operating costs in FY 2015.
Projects		
	In order to take advantage of the increased LHC luminosity, two new MIEs are requested. The LHC ATLAS Detector Upgrade will provide upgrades to the Muon Subsystem, the Liquid Argon Calorimeter Detector, and Trigger and Data Acquisition System.	Two new MIE projects are started and funds are provided accordingly, to support engineering, design, and fabrication for the two LHC Detector Upgrades.

FY 2014 Enacted	FY 2015 Request	Explanation of Changes FY 2015 vs. FY 2014 Enacted
	The CMS Detector Upgrade will provide upgrades to the Pixelated Inner Tracking Detector, the Hadron Calorimeter Detector, and Trigger System.	

High Energy Physics
Intensity Frontier Experimental Physics

Description

The Intensity Frontier Experimental Physics subprogram investigates some of the rarest processes in nature including unusual interactions of fundamental particles or subtle effects requiring large data sets to observe and measure. This subprogram in particular shares some deep intellectual connections with Nuclear Physics. Generally this HEP subprogram focuses on using high-power particle beams or other intense particle sources to make precision measurements of fundamental particle properties. These measurements in turn probe for new phenomena than cannot be directly observed at the Energy Frontier, either because they occur at much higher energies and their effects only be seen indirectly; or because they are due to interactions that are too weak to be detected in a high-background environment.

Activities at the Intensity Frontier in FY 2015 will be focused primarily on operating new and existing facilities while continuing investments to maintain a world-leading program into the future. These facilities and investments are concentrated primarily in the areas of neutrino and muon physics at Fermilab. The NOvA neutrino detector will be completed in FY 2014 and have a full run in FY 2015 with the upgraded NuMI beam, the world's most powerful neutrino beam. Operation of the Daya Bay Reactor Neutrino Experiment in China will continue. Fabrication funding continues for the Muon g-2 Experiment. Data collected during this period will be used to determine answers to fundamental questions in particle physics, including:

- *What are neutrinos telling us?*

  Of all known particles, neutrinos are perhaps the most enigmatic and certainly the most elusive. The three known varieties of neutrinos were all discovered by HEP researchers working at U.S. facilities. HEP supports research into fundamental neutrino properties that may reveal important clues about the unification of forces and the very early history of the universe.

- *What happened to the antimatter?*

  The universe today appears to contain very little antimatter. Antimatter is continually produced by naturally occurring radioactivity, only to undergo near immediate annihilation. The Big Bang, however, should have produced equal amounts of both matter and antimatter, which agrees with the study of high-energy collisions in the laboratory, so the lack of antimatter observed today is a mystery. Precise Intensity Frontier measurements of the subtle asymmetries present in the weak interactions of fundamental particles may shed light on how this matter-antimatter asymmetry arose.

Research

The HEP experimental research activity at the Intensity Frontier consists of groups at over 50 academic institutions and physicists from eight national laboratories, performing experiments at a variety of locations. The laboratory groups typically have a portfolio of responsibilities ranging from detector operations and maintenance to computing and data analysis. Research efforts will be selected based on a comparative peer-review process in order to maintain activities with the highest scientific merit and potential impact. HEP conducted an external peer review of all laboratory research groups in this subprogram in 2013, and findings from this review will be used to inform the funding decisions in subsequent years. The next review is planned for FY 2016.

Facility Operations and Experimental Support

There are several distinct facility operations and experimental support efforts in the Intensity Frontier subprogram. The largest is the Fermilab Accelerator Complex User Facility. The operation of the accelerator, detectors, and computing are included in this activity. Maintenance and improvements of the facility is supported (General Plant Project (GPP) and Accelerator Improvement Project (AIP) funding). In FY 2015, the major experimental efforts will be the NOvA and

MicroBooNE experiments utilizing the NuMI and Booster neutrino beams. Operation of the Homestake Mine for the LUX and Majorana demonstrator experiments is provided under this activity.

Projects

This activity supports the fabrication of major items of equipment for the Intensity Frontier subprogram. It also covers preconceptual R&D for proposed new Intensity Frontier effort and the other project costs (OPC) of line item construction for the Intensity Frontier.

The Muon g-2 project is an MIE to provide equipment needed to adapt an existing muon storage ring from Brookhaven National Laboratory (BNL) to utilize the higher intensity proton beam at Fermilab. The storage ring was successfully moved from BNL to Fermilab in FY 2013. New detectors, a muon production target, and muon beam transport will be fabricated.

The Belle II Project is an MIE to build detector subsystems for the Belle II detector at the High Energy Accelerator Research Organization in Tsukuba, Japan, known as KEK. KEK is upgrading their B-Factory to produce an order of magnitude more data. The U.S. is providing new particle identification detectors designed to handle the increased data rates.

The Other Project Costs for LBNE are funded to support the project team working on the design in response to recommendations of the community planning effort to be completed in FY 2014.

Intensity Frontier Experimental Physics

Activities and Explanation of Changes

FY 2014 Enacted	FY 2015 Request	Explanation of Changes FY 2015 vs. FY 2014 Enacted
Research		
Datataking and analysis with the completed NOvA detector will begin to enable key measurements of neutrino properties. In parallel, the MicroBooNE experiment will study important low energy neutrino cross sections using the Booster neutrino beam at Fermilab. Ongoing datataking and physics analysis with the ongoing experiments of Daya Bay, Tokai to Kamioka (T2K), Main Injector Neutrino Oscillations Study (MINOS+) and MINERvA; research and development for the future experiments of Muon g-2, Mu2e and LBNE are supported. Final analyses of the data from the Double Chooz Reactor Neutrino and MiniBooNE experiments will be completed. Funding is reduced for the SLAC support of BaBar legacy analyses as they are completed.	Commissioning of the Belle II detector, datataking and physics analysis with the ongoing experiments of NOvA, MicroBooNE, T2K, MINOS+ and MINERvA; research and development for the future experiments of Muon g-2, Mu2e are all supported. LBNE design work will reflect the recommendations of the community planning exercise to be completed in FY 2014. Research activities for Daya Bay Reactor Neutrino experiment will begin to ramp down. Funding is further reduced for the SLAC BaBar legacy analyses as they are completed.	Intensity Frontier research is decreased to offset investments in new facilities.

FY 2014 Enacted	FY 2015 Request	Explanation of Changes FY 2015 vs. FY 2014 Enacted
Facility Operations and Experimental Support		
Fermilab will operate the accelerator complex for a 4,500 hour run for neutrino physics. GPP projects at the Fermilab accelerator complex to develop the common infrastructure needed to carry out muon experiments are fully underway and supported. Funding is provided for safety and maintenance activities and support of the LUX and Majorana demonstrator experiments at the Homestake Mine.	The Fermilab Accelerator complex will continue to run for neutrino physics. The GPP projects to support the muon physics program ramp down and AIP projects ramp up. There are two GPP projects in the Muon Campus (MC) complex in FY 2015 (Beamline Enclosure and MC Infrastructure) whose funding is planned at $6,100,000. In addition, there are four AIP projects in the Muon Campus in FY 2015 (Cryogenics, Recycler RF, Beam Transport and Delivery Ring) whose funding is planned at $13,300,000. The Homestake Mine is operated for the LUX and Majorana demonstrator experiments. No funding is provided to SLAC to decommission the BaBar detector since that work has been completed.	Total funding for Facility Operations decreases because of the decommissioning of the SLAC B Factory and the completion of the analysis of its data set.
Projects		
The Muon g-2 project is a new MIE in FY 2014. Funding is also provided to continue Belle II activities. Funding for the Mu2e OPC was completed in FY 2013. Other Project Costs for LBNE are included. Preconceptual R&D for possible upgrade of the front-end of the Fermilab accelerator complex to significantly enhance the beam power is included.	FY 2015 is the final year of funding for Belle II detector upgrade. All other activities supported in FY 2014 continue to be supported.	Belle II ramps down by $7,030,000 as the project is completed. Funding for preconceptual R&D on the Fermilab accelerator upgrade is reduced by $5,000,000.

High Energy Physics
Cosmic Frontier Experimental Physics

Description

The Cosmic Frontier Experimental Physics subprogram supports the study of high energy physics through measurements of naturally occurring cosmic particles and observations of the universe. The activities in this subprogram use diverse tools and technologies, from ground-based telescopes and space-based experiments to large detectors deep underground, to probe fundamental physics questions and offer new insight about the nature of dark matter, dark energy and other phenomena. In FY 2015, a varied suite of complementary, staged experiments are planned that will lead to measurements with greater precision as the operations and analysis of current experiments continues, while the next generation of experiments are being planned and built.

Experiments in this subprogram can be classified into three main categories: direct-detection searches for dark matter; studies of the nature of dark energy; and measurements of high-energy cosmic and gamma rays to search for indirect signals of dark matter and the presence of primordial antimatter and other fundamental phenomena. Data collected will be used to determine answers to fundamental questions in particle physics, including:

- *How can we solve the mystery of dark energy?*

  Observations of supernovae suggest that, for approximately the last six billion years, the universe has been expanding at an accelerating rate due to a mysterious "dark energy" that appears to overcome gravitational attraction. This acceleration was discovered in 1998 as a result of observations made by HEP-supported researchers among others. The Nobel Prize in Physics in 2011 was awarded for the discovery of the acceleration of the expansion of the universe.

- *What is dark matter?*

  A wide variety of astronomical data suggest that there could be large quantities of matter in the universe unexplained by the Standard Model. This dark matter, so-called because it does not appear to emit electromagnetic radiation that we can detect, played a dominant role in the formation of structures in the Universe. Direct-detection experiments search for dark matter particles' rare interactions with atomic nuclei, while indirect-detection observatories search for signatures in high-energy cosmic particles.

Research

The Cosmic Frontier experimental research program consists of groups at over 35 academic and research institutions and 7 national laboratories performing experiments at a wide variety of locations. These groups, as part of scientific collaborations, typically have a broad portfolio major of responsibilities and leadership roles including experimental design, fabrication, commissioning, operations, and maintenance, as well as computing and data analysis on the experiments in the subprogram. Research efforts will be selected based on a comparative peer-review process in order to maintain activities with the highest scientific merit and potential impact. HEP conducted an external peer review of all laboratory research groups in this subprogram in 2013, and findings from this review are being used to inform the funding decisions in subsequent years.

Facility Operations and Experimental Support

This activity supports the personnel, data processing, and other expenses necessary for the maintenance, operations, and data production of Cosmic Frontier experiments. Many experiments have large multi-national collaborations and DOE's fraction of the support cost is based on the magnitude of U.S. roles and responsibilities. In addition, there are DOE-only experiments and partnerships with NSF and NASA. HEP conducted a scientific peer review of Cosmic Frontier operations in 2012. Findings from this review are being used to inform decisions concerning the continuation of specific activities in subsequent years.

Projects

This activity supports all costs for design and fabrication of Cosmic Frontier projects, including major items of equipment (MIEs) and small experiments. The FY 2015 Request supports the 3 billion pixel precision camera (LSSTcam), which is the DOE contribution to the DOE-NSF LSST Project.

Cosmic Frontier Experimental Physics

Activities and Explanation of Changes

FY 2014 Enacted	FY 2015 Request	Explanation of Changes FY 2015 vs. FY 2014 Enacted
Research		
U.S. university and laboratory scientists participate in datataking and analysis of the current experiments, including cosmic-ray experiments, high-energy gamma-ray telescopes, dark energy surveys such as the Dark Energy Survey (DES) and the Baryon Oscillation Spectroscopic Survey (BOSS), and the first generation dark matter (DM-G1) experiments. There will be a review of currently funded R&D efforts on DM-G2 experiments that are developing conceptual designs to determine which are ready to proceed to preliminary design.	Research activities continue on the operating experiments and in support of projects in the subprogram. Data analysis continues on BOSS, which completes its survey in FY 2014.	Research efforts decrease as R&D and design efforts for the LSSTcam move fully to MIE fabrication efforts.
Facility Operations and Experimental Support		
Telescope operations end for BOSS with data processing and analysis expected to continue for another year. Operations continue for ongoing cosmic ray and high-energy gamma ray experiments as well as DES, which started its survey at the end of FY 2013.	The currently running dark matter searches complete operations, with data processing and analysis expected to continue for another year. Operations are supported for AMS-II, DES, and the Fermi Gamma Ray Space Telescope.	Funding for operations decreases slightly as the data analysis for small experiments completed in recent years begins to ramp down.
Projects		
LSSTcam fabrication begins.	LSSTcam fabrication activities continue to ramp up ($35,000,000). Design work will continue on the DM-G2 experiments selected in FY 2014.	Funding for Projects ramps up to support fabrication for LSSTcam and R&D related project costs.

High Energy Physics
Theoretical and Computational Physics

Description

The Theoretical and Computational Physics subprogram provides the mathematical, phenomenological, and computational framework to understand and extend our knowledge of the dynamics of particles and forces, and the nature of space and time. This research is essential for proper interpretation and understanding of the experimental research activities described in other HEP subprograms.

This subprogram supports theoretical research ranging from detailed calculations of the predictions of the Standard Model to the formulation and exploration of possible theories of new phenomena such as dark matter and dark energy and the identification of experimental signatures that would validate these new ideas. This subprogram also supports computational approaches to advance understanding of fundamental physical laws describing the elementary constituents of matter and energy, including computational science and simulations for scientific discovery and computing and software tools to enable and advance experimental and theoretical research at the three High Energy Physics frontiers.

Major research thrusts include the search for a more complete theory that goes beyond the Standard Model—in particular, theories that can explain why there are so many “fundamental” particles and forces, why (most of) these particles have mass, and the nature of dark matter and dark energy and how they relate to particle physics.

Theory

The HEP theory research activity supports groups at over 70 academic and research institutions supported by research grants and 7 national laboratory research groups. Both university and laboratory research groups play important roles in addressing the leading research areas discussed above, with laboratory groups typically more focused on data-driven theoretical investigations and model-building, and university groups typically focused on more formal or mathematical theory. Research efforts will be selected based on comparative peer review to maintain the activities with the highest scientific impact and potential. HEP will conduct an external peer review of all laboratory research groups in this subprogram in 2014, and findings from this review are being used to inform the funding decisions in subsequent years.

Computational HEP

Computation is necessary at all stages of a HEP experiment—from planning and constructing accelerators and detectors, to theoretical modeling, to supporting computationally intensive experimental research and large-scale data and data analysis. In addition, scientific simulation and advanced computing help extend the boundaries of scientific discovery to regions not directly accessible by experiments, observations, or traditional theory. Computational HEP supports partnership (SciDAC) projects with the Advanced Scientific Computing Research program, and directed efforts to develop and maintain and HEP specific computational tools (Scientific Computing).

Projects

The Projects activity currently funds acquisition and operation of dedicated hardware for the Lattice QCD (LQCD) computing effort. Since lattice techniques can address both nuclear and high energy physics topics, and to avoid any duplication of effort, this program is managed in partnership with the Office of Nuclear Physics. The LQCD Project provides dedicated computer hardware for the simulation of the strong interaction of gluons and quarks in bound states. Within the HEP program, its goals are most directly applicable to the Intensity and Energy Frontiers, and the results generated by its users are critical for the interpretation of data from the HEP experimental program in these Frontiers.

Theoretical and Computational Physics

Activities and Explanation of Changes

FY 2014 Enacted	FY 2015 Request	Explanation of Changes FY 2015 vs. FY 2014 Enacted
Theory		
This activity funds theoretical research for university and laboratory groups as well as the Particle Data Group.	This activity funds research for university and laboratory groups as well as the Particle Data Group.	Funding is reduced consistent with overall programmatic reductions in HEP Research activities.
Computational HEP		
SciDAC projects will be reviewed for progress toward their milestones in accelerator modeling, computational cosmology, and lattice QCD algorithm and software development. Programmatic emphasis may be modified based on the outcomes of this review.	HEP is currently planning a new solicitation for FY 2015 in partnership with ASCR.	Funding is reduced consistent with overall programmatic reductions in HEP Research activities.
Projects		
The Lattice QCD Project delivers dedicated computer hardware for the simulation of the strong interaction of gluons and quarks in bound states. The hardware is optimized for these calculations and can be either custom hardware or commercial hardware adapted to the task. The current five-year hardware project will be completed in FY 2014.	The Lattice QCD Project is extended. Funds are supplied to continue operation of the existing hardware, while planning for the acquisition of new hardware is carried out.	No new hardware acquisitions are planned for FY 2015.

High Energy Physics
Advanced Technology R&D

Description

The Advanced Technology R&D subprogram fosters world-leading research in the physics of particle beams, accelerator research and development (R&D), and particle detection—all necessary for continued progress in high energy physics. New developments are stimulated and supported through peer reviewed research. This subprogram supports and advances research at all three experimental Frontiers.

Advanced Technology R&D includes particle accelerator, detector, and beam physics areas. Long-term multi-purpose accelerator research, applicable to fields beyond HEP, is carried out under the Accelerator Stewardship subprogram.

HEP General Accelerator R&D

HEP General Accelerator R&D focuses on understanding the science underlying the technologies used in particle accelerators and storage rings, as well as the fundamental physics of charged particle beams. Long-term research goals include developing technologies to enable breakthroughs in particle accelerator size, cost, beam intensity, and control.

This activity supports research at 8 DOE national laboratories and about 30 academic or other research institutions. Funding is awarded based on external comparative peer reviews. The program also trains new accelerator physicists with approximately 50 graduate students supported per year through research grants. Graduate level training for students and laboratory staff in areas of accelerator physics and technology is supported in this program.

HEP Directed Accelerator R&D

HEP Directed Accelerator R&D supports innovative technologies for possible future HEP accelerator projects, with proof-of-principle demonstrations, prototype component development, and other milestones advancing technical readiness. This includes R&D and prototyping to bring new concepts to a stage of engineering readiness where they can be incorporated into existing facilities or be applied to the design of new facilities. Research efforts within this activity are generally limited in time and have concrete milestones. The components of the HEP Directed Accelerator R&D activity are the LHC Accelerator Research Program (LARP) and the Muon Accelerator Program (MAP).

LARP is carrying out R&D needed for possible U.S. deliverables to the High Luminosity LHC (HL-LHC) that CERN is planning to begin building late in this decade. LARP is investigating how to build niobium-tin superconducting magnets to decrease the size of the beam, "crab" cavities that causes the beam to meet head on rather than at an angle, and feedback systems to keep the intense beams in a compact configuration. MAP is carrying out R&D on the feasibility of creating and accelerating muon beams for either the production of neutrinos or an Energy Frontier lepton collider. It is necessary to determine if very high field magnets (over 30 Tesla) can be built and whether RF cavities can be operated inside high field magnets.

Detector R&D

Detector R&D addresses the need for continuing development of the next generation instrumentation and detectors at the Energy, Intensity, and Cosmic Frontiers. New instrumentation and detectors must be developed with increased capabilities while keeping the cost and time from conception to operation at a minimum. To meet these challenges, HEP actively supports investment in innovative, generic instrumentation and detector research with the potential for wide applicability and/or high payoff. This activity supports research at 6 DOE national laboratories and about 20 academic or other research institutions.

Facility Operations and Experimental Support

Facility Operations and Experimental Support provides operations funding for proposal-driven user facilities like the Facility for Advanced Accelerator Experimental Tests (FACET), as well as laboratory experimental and test facilities, including the Berkeley Lab Laser Accelerator (BELLA) facility and the Superconducting Radio-Frequency (SRF) fabrication and test facilities at Fermilab. BELLA, FACET, and the SRF infrastructure at Fermilab are all in operation. FACET supports experiments driven by its high-energy, ultra-short electron beam, including plasma wakefield acceleration, dielectric wakefield acceleration, terahertz radiation generation, beam diagnostics, and ultra fast magnetic switching in materials.

Advanced Technology R&D

Activities and Explanation of Changes

FY 2014 Enacted	FY 2015 Request	Explanation of Changes FY 2015 vs. FY 2014 Enacted
HEP General Accelerator R&D		
Supports research needed to develop new accelerators for use by HEP. Topics include novel acceleration concepts, beam instrumentation, beam physics and simulation, superconducting magnets, radiofrequency power sources, and superconducting radiofrequency accelerator cavities.	All topics for FY 2014 continue to be supported, but there is a shift in emphasis as some of the accelerator personnel with expertise in superconducting magnets, beam simulations, and beam physics are being redirected to support HEP Directed Accelerator R&D.	The decrease in funding is due to overall reduction in HEP research and continued redirection of effort to HEP Directed Accelerator R&D.
HEP Directed Accelerator R&D		
LARP is beginning a program to demonstrate the large aperture high gradient focusing magnets can be built with niobium-tin superconductor. MAP studies the operation of RF accelerating cavities in magnetic fields, a critical technology for the collection of muons into beams usable in an accelerator.	LARP will develop a prototype superconducting quadrupole magnets with the large apertures needed to increase luminosity at the LHC. MAP will be commissioning the Muon Ionization Cooling Experiment (MICE) that will demonstrate critical technologies for the collection of muons.	The increase in funding represents a shift of funding from General Accelerator R&D to support the timely delivery of LARP and MAP prototypes and experiment tests.
Detector R&D		
The LHC and future lepton colliders need radiation hardness and fast readout, so R&D on those topics is supported. Very large scale dark matter search experiments require detectors with very low radioactive impurities as well as lower cost per volume, and R&D on these topics is given high priority. The Large Area Picosecond Photodetector (LAPPD), an example of focused detector R&D, will continue to be supported.	Research activities will continue at U.S. universities and national laboratories. HEP programmatic decisions informed by the community planning exercise to be completed in FY 2014 will be a factor in setting priorities in detector development at a time of budget constraints.	The decrease in funding is due to the shift of funding to current and future facilities activities.

FY 2014 Enacted	FY 2015 Request	Explanation of Changes FY 2015 vs. FY 2014 Enacted
Facility Operations and Experimental Support		
These funds support activities for FACET, BELLA and SRF Infrastructure. In FY 2014, FACET plans 2,800 hours of runtime, delivering beam for peer reviewed experiments.	Support for activities at FACET, BELLA and SRF Infrastructure is held approximately constant.	The increase primarily supports FACET operations.

Description

This subprogram supports long-term accelerator R&D that underpins future accelerator concepts and technologies for applications that may extend beyond high energy physics. HEP manages this program in consultation with other Office of Science programs, including Nuclear Physics and Basic Energy Sciences, that develop and build particle accelerators.

HEP and other Office of Science programs will continue to conduct programmatic near- and mid-term R&D on accelerator and beam physics issues related to the scientific facilities they operate. This subprogram is not intended to replace those directed R&D efforts, which are driven by program-specific goals and priorities.

This program provides support for research and increased access for non-traditional users to the laboratory accelerator test facilities to help advance applications in energy and the environment, medicine, industry, national security, and discovery science.

Accelerator Stewardship will pursue targeted R&D to develop new applications of accelerator technology with broad applicability. Initial workshops have identified two target application areas with broad impact: accelerator technologies for ion beam therapy of cancer and laser technologies for accelerators. A third target area in Energy and Environmental applications of accelerator technology is being developed. As the program evolves, new and cross-cutting areas of research will be developed based on strategic opportunities identified by the communities that benefit from particle accelerator technologies, as well as technology practitioners, including possible applications in basic science, medicine, security, and energy.

Research

This research category supports activities that have been identified for applications in areas broader than just HEP. Research is conducted at national laboratories and universities. The stewardship program focuses on long-term accelerator R&D that promotes scientific innovations to enable breakthroughs in particle accelerator size, cost, beam intensity, and control. This activity supports approximately 20 university grants in broadly applicable advanced accelerator science, beam physics and related technologies.

Facility Operations and Experimental Support

The Accelerator R&D Stewardship subprogram supports facility operations and experimental support at the Accelerator Test Facility (ATF) at BNL. Experiments at ATF are studying the interactions of high power electromagnetic radiation and high brightness electron beams, including free-electron lasers and laser acceleration of electrons and the development of electron beams with extremely high brightness, photo-injectors, electron beam and radiation diagnostics and computer controls. Beam time at the ATF is awarded based on a merit-based peer review process.

Accelerator Stewardship

Activities and Explanation of Changes

FY 2014 Enacted	FY 2015 Request	Explanation of Changes FY 2015 vs. FY 2014 Enacted
Research		
Based upon an internal Office of Science review, a number of activities are moved into the Accelerator Stewardship subprogram because of their potential applicability beyond the HEP program. The activities include accelerator R&D efforts at national laboratories, such as beam physics and accelerator modeling and computation at SLAC and PPPL.	Continue to support research activities at laboratories and universities. Initiate research support for selected technology areas such as laser, ion-beam therapy and green RF sources that have been identified through Office of Science led workshops.	Funding is increased to support new research activities for selected accelerator technologies.
Facility Operations and Experimental Support		
Supports facility operation at the ATF and modest incremental support for FACET operations for stewardship research.	Supports facility operation of the ATF for a broad program of long-term accelerator research.	Support experimental operation for ATF at approximately constant level, and the incremental support of FACET is shifted to Advanced Technology R&D.

High Energy Physics
SBIR/STTR

Description

The SBIR/STTR amount is adjusted to mandated percentages for non-capital funding.

Activities and Explanation Changes

FY 2014 Enacted	FY 2015 Request	Explanation of Changes FY 2015 vs. FY 2014 Enacted
SBIR/STTR		
SBIR/STTR funding is set at 3.2% of non-capital funding in FY 2014.	In FY 2015, SBIR/STTR funding is set at 3.3% of non-capital funding.	The SBIR/STTR amount is adjusted to mandated percentages for non-capital funding.

Description

The Muon to Electron Conversion Experiment (Mu2e) will be built at Fermilab and is an important component of the Intensity Frontier subprogram. It will utilize a proton beam to produce muons and determine if those muons can change into electrons. There is no mechanism for such interactions of charged leptons (called flavor changing) in the Standard Model, but flavor-changing processes have been observed in neutrinos. Evidence of muon to electron flavor change would further probe this physics beyond the Standard Model.

The Mu2e CD-1 was approved on July 11, 2012. Preliminary engineering design for Mu2e has commenced. PED funds in FY 2013–2014 will be used to complete the engineering design, and construction funds in FY 2014 will be used to initiate long-lead procurement of technical materials in order to reduce cost and schedule risk. The project is planned to be baselined (CD-2) in FY 2014.

Construction

Activities and Explanation of Changes

FY 2014 Enacted	FY 2015 Request	Explanation of Changes FY 2015 vs. FY 2014 Enacted
Long Baseline Neutrino Experiment		
Funding is provided to support design activities.	Construction funding is not requested in FY 2015.	Funding is reduced while HEP develops program plans in response to recommendations of the community planning effort to be completed in FY 2014.
Muon to Electron Conversion Experiment		
Funding of $15,000,000 is provided for design. Funding of $20,000,000 is provided for construction. Critical Decisions CD-2, 3A and 3B are planned during FY 2014. Critical Decision CD-3A approval will allow advance procurements of superconducting solenoid magnet conductor and solenoid prototypes, as well as site preparation work.	Construction funds are requested for construction of the detector hall and fabrication of the accelerator beamline and detector components.	Funding is provided consistent with the established project profile.

High Energy Physics
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program. For more information, refer to the Department's FY 2013 Annual Performance Report. The following table shows the targets for FY 2013 through FY 2015.

	2013	2014	2015
Performance Goal (Measure)	**HEP Facility Operations—Average achieved operation time of HEP user facilities as a percentage of total scheduled annual operation time**		
Target	≥ 80%	≥ 80%	≥ 80%
Result	Not Met	TBD	TBD
Endpoint Target	Many of the research projects that are undertaken at the Office of Science's scientific user facilities take a great deal of time, money, and effort to prepare and regularly have a very short window of opportunity to run. If the facility is not operating as expected the experiment could be ruined or critically setback. In addition, taxpayers have invested millions or even hundreds of millions of dollars in these facilities. The greater the period of reliable operations, the greater the return on the taxpayers' investment.		
Performance Goal (Measure)	**HEP Construction/MIE Cost & Schedule— Cost-weighted mean percentage variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects**		
Target	< 10%	< 10%	< 10%
Result	Met	TBD	TBD
Endpoint Target	Adhering to the cost and schedule baselines for a complex, large scale, science project is critical to meeting the scientific requirements for the project and for being good stewards of the taxpayers' investment in the project.		

	2013	2014	2015
Performance Goal (Measure)	**HEP Neutrino Model—Carry out series of experiments to test the standard 3-neutrino model of mixing**		
Target	Measure mixing angle between muon neutrinos and electron neutrinos ($\sin^2(2\theta_{13})$) by measuring disappearance of electron antineutrinos with Daya Bay Reactor Experiment (should have uncertainty of 0.0075 or smaller)	Begin operation of full NOvA detector using neutrino beam from Fermilab for purpose of measuring mixing angle between muon neutrinos and electron neutrinos ($\sin^2(2\theta_{13})$) using the appearance of electron neutrinos.	Physics analyses results from the first year of datataking with the full detector will be presented by the NOvA and MicroBooNE experimental collaborations at the FY 2015 summer conferences.
Result	Met	TBD	TBD
Endpoint Target	Similar to quarks, the mixing between neutrinos is postulated to be described by a unitary matrix. Measuring the independent parameters of this matrix in different ways and with adequate precision will demonstrate whether this model of neutrinos is correct. Such a model is needed to correctly extract evidence for CP violation in the neutrino sector.		

High Energy Physics Capital Summary ($K)

	Total	Prior Years	FY 2013 Current	FY 2014 Enacted	FY 2014 Current	FY 2015 Request	FY 2015 vs. FY 2014 Enacted
Capital Operating Expenses Summary							
Capital equipment	n/a	n/a	36,327	50,222	50,222	71,832	+21,610
General plant projects (GPP)	n/a	n/a	20,700	14,548	14,548	9,826	-4,722
Accelerator improvement projects (AIP)	n/a	n/a	2,100	6,200	6,200	13,300	+7,100
Total, Capital Operating Expenses	**n/a**	**n/a**	**59,127**	**70,970**	**70,970**	**94,958**	**+23,988**
Capital Equipment							
Major items of equipment							
Energy Frontier Experimental Physics							
LHC ATLAS Detector Upgrades[a]	25,500	0	0	0	0	7,500	+7,500
LHC CMS Detector Upgrades[b]	25,500	0	0	0	0	7,500	+7,500
Intensity Frontier Experimental Physics							
NOνA (TPC $278,000)	206,860	187,380	19,480	0	0	0	0
MicroBooNE[c] (TPC $19,900)	14,760	8,903	5,857	0	0	0	0
Belle II[d]	8,970	0	0	8,000	8,000	970	-7,030
Muon g-2 Experiment[e]	27,150	0	0	2,000	2,000	9,000	+7,000
Cosmic Frontier Experimental Physics							
High Altitude Water Cherenkov (HAWC)[f]	3,000	1,500	1,500	0	0	0	0

[a] Critical Decision CD-1 for the LHC CMS Detector Upgrade Project was approved on October 17, 2013. The TPC range is $29,200,000 to $35,900,000.

[b] Critical Decision CD-1 for the LHC ATLAS Detector Upgrade Project was approved on October 17, 2013. The TPC range is $32,200,000 to $34,500,000.

[c] The MicroBooNE Project received CD-2/3a approval for its performance baseline and long-lead procurements on September 27, 2011. CD-3b approval for all fabrication was on March 29, 2012. The TPC is $19,900,000.

[d] This project is not yet baselined. Critical Decision CD-1 for the Belle II Project's Conceptual Design was approved on September 18, 2012 with a cost range of $12,000,000 to $16,000,000. Initial long-lead procurement was approved (CD-3A) on November 8, 2012.

[e] Critical Decision CD-1 for the Muon g–2 Project was approved on December 19, 2013. The TPC range is $43,000,000 to $50,100,000.

[f] The HAWC project falls below the $10,000,000 TPC threshold that required a CD-0. DOE funding was completed in FY 2013, with the project completed and operations starting in FY 2014.

	Total	Prior Years	FY 2013 Current	FY 2014 Enacted	FY 2014 Current	FY 2015 Request	FY 2015 vs. FY 2014 Enacted
Large Synoptic Survey Telescope (LSSTcam) Camera[a]	159,600	0	0	22,000	22,000	35,000	+13,000
Total MIEs	**n/a**	**n/a**	**26,837**	**32,000**	**32,000**	**59,970**	**+27,970**
Other capital equipment projects under $2 million TEC	n/a	n/a	9,490	18,222	18,222	11,862	-6,360
Total, Capital equipment	**n/a**	**n/a**	**36,327**	**50,222**	**50,222**	**71,832**	**+21,610**
General Plant Projects (GPP)							
MC-1 Building	9,000	500	7,500	1,000	1,000	0	-1,000
Muon Campus Beamline Enclosure	9,700	0	400	3,700	3,700	5,600	+1,900
Other projects under $5 million TEC	n/a	n/a	12,800	9,848	9,848	4,226	-5,622
Total, Plant Project (GPP)	**n/a**	**n/a**	**20,700**	**14,548**	**14,548**	**9,826**	**-4,722**
Accelerator Improvement Projects (AIP)							
Muon Campus Cryogenics	9,700	0	1,100	4,200	4,200	2,200	-2,000
Recycler RF Upgrades	8,700	0	600	1,000	1,000	3,900	+2,900
Other projects under $5 million TEC	n/a	n/a	400	1,000	1,000	7,200	+6,200
Total, Accelerator Improvement Projects	**n/a**	**n/a**	**2,100**	**6,200**	**6,200**	**13,300**	**+7,100**

[a] This project is not yet baselined and the OPC/TEC split is not yet determined. This project received CD-1 on April 12, 2012 with a cost range of $120,000,000 to $175,000,000.

Major Items of Equipment Descriptions

Energy Frontier Experimental Physics MIEs:

By 2019, CERN plans to increase the LHC luminosity by 100–200% compared to its 2015–2017 running period. The increase will result in higher particle rates and densities as well as a large increase in the number of overlapping collisions. Consequently, this can lead to more rapid radiation damage to individual detector subsystems, larger volumes of data, and challenging event conditions. In order to cope with these effects and continue to fully exploit the physics opportunities offered at the LHC, the detectors will need upgrades. DOE supported part of the original construction of two of the four LHC detectors (CMS and ATLAS), and proposes to support the upgrade of those detectors to maintain their capabilities at the higher luminosity LHC.

The ATLAS Detector Upgrade Project will be a new MIE in FY 2015. Upgrades are needed to the muon subsystem, the liquid argon calorimeter detector, and the trigger and data acquisition system to take advantage of the increased luminosity. The LHC ATLAS Detector Upgrade Project received CD-1, Approve Alternative and Cost Range, on October 17, 2013, with an estimated cost range of $32,200,000 to $34,500,000 and estimated completion date of FY 2018.

The CMS Detector Upgrade Project will be a new MIE in FY 2015. Upgrades are needed to the pixelated Inner tracking detector, the hadron calorimeter detector, and trigger system to take advantage of the increased luminosity. The LHC CMS Detector Upgrade Project received CD-1, Approve Alternative and Cost Range on October 17, 2013, with an estimated cost range of $29,200,000 to $35,900,000 and estimated completion date of FY 2018.

Intensity Frontier Experimental Physics MIEs:

The *NuMI Off-axis Neutrino Appearance (NOνA) Project* will use the NuMI beam from Fermilab to directly observe and measure the transformation of muon neutrinos into electron neutrinos over a distance of 810 km (500 miles). The project also includes improvements to the Fermilab proton accelerator to increase the intensity of the neutrino NuMI beam to the detector in Ash River, Minnesota. The occurrence of neutrino flavor changes is expected to be much rarer than the phenomenon under study with MINOS. The baseline was approved in September 2008 with a TPC of $278,000,000. A total of $55,000,000 was provided under the Recovery Act to advance the project. Fabrication was approved by CD-3A and CD-3B in FY 2009. Final funding for NOvA was provided in FY 2013. The NOvA Project will complete fabrication (CD-4) in FY 2014.

The MicroBooNE Project began fabrication in FY 2012. This project will build a multi-hundred ton liquid-argon neutrino detector to be used in the Booster neutrino beam at Fermilab for the measurement of low energy neutrino cross-sections. These cross sections will be measured at lower neutrino energy than MINERνA and will be important for future neutrino oscillation experiments such as T2K. This experiment will also be an important demonstration of the efficacy of large-scale liquid argon time projection chambers as neutrino detectors. This is a new technology with improved track resolution and background discrimination. CD-3b approval for all fabrication was on March 29, 2012. The TPC is $19,900,000. Fabrication started in FY 2012 and the last year of funding is FY 2013. The MicroBooNE Project will complete fabrication in FY 2015.

The *Belle II Project* will fabricate detector subsystems for the upgraded Belle detector located at the Japanese B-Factory, which is currently being upgraded to deliver higher luminosity. This project is not yet baselined. Critical Decision CD-1 for Conceptual Design was approved on September 18, 2012. Initial long-lead procurement was approved (CD-3A) on November 8, 2012. The TPC range is $12,000,000 to $16,000,000.

The *Muon g-2 Project* will fabricate an experiment that seeks to improve the measurement of the muon anomalous magnet moment, which is sensitive to new physical interactions such as supersymmetry. The project will repurpose a storage ring from a previous experiment at Brookhaven National Laboratory with upgraded detectors to be located at Fermilab in order to utilize the high intensity proton beam available there to produce the needed muons. CD-1 was approved on December 19, 2013, with a TPC range of $43,000,000 to $50,100,000. Transfer of the BNL storage ring to Fermilab occurred in FY 2013. The Muon g-2 Project plans for CD-2 in FY 2015. Funding in FY 2014 and FY 2015 will pay for project design and the reassembly and testing of the BNL storage ring at Fermilab. New instrumentation for the storage ring will be provided, in part, by in-kind contributions from non-DOE sources including NSF. The Muon g−2 experiment offers a strategic opportunity to search for new physics that may be inaccessible to the LHC.

Cosmic Frontier Experimental Physics MIEs:

The *High Altitude Water Cherenkov (HAWC)* project is for an experiment in Mexico to survey the sky for sources of gamma-rays in the 10–100 TeV range. HAWC's wide field of view and continuous duty cycle will provide unique capabilities that are complementary to other gamma-ray experiments. The project is being carried out in collaboration with NSF and Mexican research institutes. MIE funding for the fabrication started in FY 2012 and completed in FY 2013. The total DOE cost was $3,000,000 and the full project will be completed and start science operations in FY 2014.

The *Large Synoptic Survey Telescope Camera (LSSTcam*) was a new MIE start in FY 2014. It is a digital camera for a next-generation, wide-field, ground-based optical and near-infrared LSST observatory, located in Chile, and is designed to provide deep images of half the sky every few nights. It will open a new window on the universe and address a broad range of topics in astronomy with an emphasis on enabling precision studies of the nature of dark energy. LSST was identified by the National Research Council's (NRC) Astro2010 decadal survey panel as its highest priority ground-based astrophysics initiative. The project is carried out in collaboration with NSF, along with private and foreign contributions. DOE will provide the camera for the facility. CD-1 for the LSSTcam project was approved in April 2012, with an estimated total DOE cost range of $120,000,000–$175,000,000 and estimated completion date of FY 2021.

High Energy Physics Construction Project Summary ($K)

	Total	Prior Years	FY 2013 Current	FY 2014 Enacted	FY 2014 Current	FY 2015 Request	FY 2015 vs. FY 2014 Enacted
Long Baseline Neutrino Experiment							
TEC	TBD	4,000	3,781	16,000	16,000	0	-16,000
OPC	TBD	51,432	14,107	10,000	10,000	10,000	0
TPC	TBD	55,432	17,888	26,000	26,000	10,000	-16,000
Muon to Electron Conversion Experiment							
TEC	209,900	24,000	8,000	35,000	35,000	25,000	-10,000
OPC	23,677	21,177	2,500	0	0	0	0
TPC	233,577	45,177	10,500	35,000	35,000	25,000	-10,000
Total, Construction							
TEC	n/a	n/a	11,781	51,000	51,000	25,000	-26,000
OPC	n/a	n/a	16,607	10,000	10,000	10,000	0
TPC	n/a	n/a	28,388	61,000	61,000	35,000	-26,000

Funding Summary ($K)

	FY 2013 Current	FY 2014 Enacted	FY 2015 Request	FY 2015 vs. FY 2014 Enacted
Research	361,766	370,447	352,227	-18,220
Facilities Operations				
Scientific User Facilities Operations	200,023	227,312	216,983	-10,329
Other Facilities	63,553	47,686	47,225	-461
Total, Facilities Operations	**263,576**	**274,998**	**264,208**	**-10,790**
Projects				
Major Items of Equipment	48,687	51,000	65,970	+14,970
Other Projects	23,559	15,894	6,000	-9,894
Construction[a]	28,388	61,000	35,000	-26,000
Total, Projects	**100,634**	**127,894**	**106,970**	**-20,924**
Other	1,547	23,182	20,595	-2,587
Total, High Energy Physics	**727,523**	**796,521**	**744,000**	**-52,521**

[a] Includes Other Project Costs funding for LBNE and Mu2e.

Scientific User Facility Operations ($K)

	FY 2013 Current	FY 2014 Enacted	FY 2015 Request	FY 2015 vs. FY 2014 Enacted
Fermilab Accelerator Complex	**$132,928**	**$156,438**	**$152,096**	**-$4,342**
Achieved operating hours	503	N/A	N/A	
Planned operating hours	520	4,500	4,500	0
Optimal hours (estimated)	520	4,500	4,500	0
Percent of optimal hours	100%	100%	100%	
Unscheduled downtime percentage	96%	N/A	N/A	
Total number of users	1,850	1,400	1,400	0
FACET	**$8,589**	**$9,500**	**$9,365**	**-$135**
Achieved operating hours	2,155	N/A	N/A	
Planned operating hours	2,544	2,800	2,800	0
Optimal hours (estimated)	2,544	2,800	2,800	0
Percent of optimal hours	85%	100%	100%	
Unscheduled downtime percentage	15%	N/A	N/A	
Total number of users	141	48	48	0
B-Factory	**$1,594**	**$4,600**	**0**	**-$4,600**
Total number of users	100	100	0	-100
LHC	**$56,912**	**$56,774**	**$55,522**	**-$1,252**
Total number of users	0	0	0	0
Total Facilities	**$200,023**	**$227,312**	**$216,983**	**-$10,329**
Achieved operating hours	2,658	N/A	N/A	
Planned operating hours	3,064	7,300	7,300	0
Optimal hours (estimated)	3,064	7,300	7,300	0
Percent of optimal hours (funding weighted)	96%	100%	100%	
Unscheduled downtime percentage	111%	N/A	N/A	
Total number of users	2,091	1,548	1,448	-100

Scientific Employment

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Estimate	FY 2015 vs. FY 2014
Number of laboratory groups	45	40	40	0
Number of permanent Ph.D.'s (FTEs)	965	955	905	-50
Number of postdoctoral associates (FTEs)	415	410	370	-40
Number of graduate students (FTEs)	530	505	495	-10
Number of Ph.D.'s awarded	110	105	95	-10

11-SC-41, Muon to Electron Conversion Experiment (Mu2e), Fermi National Accelerator Laboratory, Batavia, Illinois
Project is for Design and Construction

1. Significant Changes

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-1 that was approved on July 11, 2012 with a preliminary cost range of $200,000,000–$310,000,000 and CD-4 of FY 2021.

A Federal Project Director with a certification level 4 has been assigned to this project.

This Project Data Sheet (PDS) does not include a new start for the Budget Year.

This PDS is an update of the FY 2013 Reprogramming PDS. In FY 2013, Congress approved a reprogramming[a] that reduced the FY 2013 funding to $8,000,000 from the $22,685,000 that was appropriated. The project had significant carryover of funds from FY 2012. Consequently, the reprogramming did not limit the project's progress in FY 2013, and allowed other activities at Fermilab to be maintained at the planned levels.

Design work was slowed in FY 2013 while several technical issues were resolved. It took longer than expected to find qualified vendors of the advanced superconducting cable required for the project's magnets, and simulation of the detector was improved to provide better input to the experiment's design. Design work is now expected to be completed within budget, but the start of construction will be delayed. The request for construction funds in FY 2015 has been reduced by $7,000,000 relative to the prior year plan. This funding is redistributed into later years.

Critical Decisions CD-2, 3A and 3B are planned during FY 2014. In accordance to DOE O 413.3B, long lead procurements of superconducting solenoid magnet conductor and solenoid prototypes, as well as site preparation work will take place after Critical Decision CD-3A. CD-3B is planned at the end of FY 2014 for initiating civil construction in FY 2015.

2. Critical Decision (CD) and D&D Schedule

(fiscal quarter or date)

	CD-0	CD-1	Design Complete	CD-2	CD-3A	CD-3B	CD-4	D&D
FY 2011	11/24/2009	4Q FY 2010	4Q FY 2012	TBD	N/A	TBD	TBD	TBD
FY 2012	11/24/2009	4Q FY 2011	4Q FY 2013	TBD	N/A	TBD	TBD	TBD
FY 2013	11/24/2009	4Q FY 2012	4Q FY 2014	4Q FY 2013[b]	N/A	4Q FY 2014[b]	4Q FY 2018[b]	N/A
FY 2014	11/24/2009	7/11/2012	2Q FY 2015	2Q FY 2014[b]	3Q FY 2013[b]	4Q FY 2015[b]	2Q FY 2021[b]	N/A
FY 2013 Reprogramming[a]	11/24/2009	7/11/2012	2Q FY 2015	2Q FY 2014[b]	3Q FY 2013	4Q FY 2015[b]	2Q FY 2021[b]	N/A
FY 2015	11/24/2009	7/11/2012	2Q FY 2015	4Q FY 2014[b]	3Q FY 2014	4Q FY 2014[b]	2Q FY 2021[b]	N/A

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3A – Approve Long-Lead Procurement/Limited Construction
CD-3B – Approve Full Construction

[a] The FY 2013 reprogramming was approved by Congress.
[b] Schedule estimates are preliminary since this project has not received CD-2 approval.

CD-4 – Approve Start of Operations or Project Closeout
D&D Start – Start of Demolition & Decontamination (D&D) work
D&D Complete – Completion of D&D work

3. Baseline and Validation Status

(dollars in thousands)

	TEC, Design	TEC, Construction	TEC, Total	OPC Except D&D	OPC, D&D	OPC, Total	TPC
FY 2011	35,000	TBD	TBD	10,000	TBD	TBD	TBD
FY 2012	36,500	TBD	TBD	18,777	TBD	TBD	TBD
FY 2013	44,000	N/A	N/A	24,177	0	24,177	68,177
FY 2014	61,000	162,000	223,000	26,177	0	26,177	249,177
FY 2013 Reprogramming	49,000	162,000	211,000	23,677	0	23,677	234,677
FY 2015	47,000	162,900	209,900	23,677	0	23,677	233,577[a]

4. Project Description, Scope, and Justification

Mission Need

The conversion of a muon to an electron in the field of a nucleus provides a unique window for discovery of charged lepton flavor symmetry violation and allows access to new physics at very high mass scales. The Particle Physics Project Prioritization Panel (P5) recommended this type of experiment for the Intensity Frontier of particle physics. This project provides accelerator beam and experimental apparatus to identify unambiguously neutrinoless muon-to-electron conversion events.

Scope and Justification (11-SC-41, Muon to Electron Conversion Experiment)

This project will construct a new beamline for protons using the existing 8 GeV Booster Synchrotron at Fermilab: a system for producing, transporting and stopping secondary muons (from the proton beam); an experimental detector, a low-mass magnetic spectrometer that can measure the electron momentum with a resolution of order 0.15%; and a new conventional facility to house the secondary production target, muon-stopping beamline, and the detector.

The project is being conducted in accordance with the project management requirements in DOE 413.3B, Program and Project Management for the Acquisition of Capital Assets, and all appropriate project management requirements have been met.

[a] This project has not received CD-2 approval. No construction, other than long-lead procurement and site preparation, will be performed until the project performance baseline has been validated and CD-3B has been approved.

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
Design			
FY 2012	24,000	24,000	0
FY 2013	8,000[a]	8,000	14,653
FY 2014	15,000	15,000	25,347
FY 2015	0	0	7,000
Total, Design	47,000	47,000	47,000
Construction			
FY 2014	20,000[b]	20,000	6,000
FY 2015	25,000	25,000	20,000
FY 2016	42,000	42,000	35,000
FY 2017	43,000	43,000	35,000
FY 2018	32,900	32,900	31,000
FY 2019	0	0	21,000
FY 2020	0	0	12,000
FY 2021	0	0	2,900
Total, Construction	162,900	162,900	162,900
TEC			
FY 2012	24,000	24,000	0
FY 2013	8,000	8,000	14,653
FY 2014	35,000	35,000	31,347
FY 2015	25,000	25,000	27,000
FY 2016	42,000	42,000	35,000
FY 2017	43,000	43,000	35,000
FY 2018	32,900	32,900	31,000
FY 2019	0	0	21,000

[a] Congress approved a reprogramming that reduced the FY 2013 funding to $8,000,000 from the $22,685,000 that was originally appropriated.
[b] $20,000,000 is for long lead procurements for the superconducting magnet systems.

(dollars in thousands)

	Appropriations	Obligations	Costs
FY 2020	0	0	12,000
FY 2021	0	0	2,900
Total, TEC	209,900	209,900	209,900
Other Project Costs (OPC)			
OPC except D&D			
FY 2010	4,777	4,777	3,769
FY 2011	8,400	8,400	8,940
FY 2012	8,000	8,000	6,740
FY 2013	2,500	2,500	1,020
FY 2014	0	0	3,208
Total, OPC	23,677	23,677	23,677
Total Project Cost (TPC)			
FY 2010	4,777	4,777	3,769
FY 2011	8,400	8,400	8,940
FY 2012	32,000	32,000	6,740
FY 2013	10,500	10,500	15,673
FY 2014	35,000	35,000	34,555
FY 2015	25,000	25,000	27,000
FY 2016	42,000	42,000	35,000
FY 2017	43,000	43,000	35,000
FY 2018	32,900	32,900	31,000
FY 2019	0	0	21,000
FY 2020	0	0	12,000
FY 2021	0	0	2,900
Total, TPC	233,577[a]	233,577[a]	233,577[a]

[a] This project has not yet received CD-2 approval.

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design			
Design	40,000	40,000	N/A
Contingency	7,000	9,000	N/A
Total, Design	47,000	49,000	N/A
Construction			
Site Work	2,000	2,000	N/A
Construction	17,000	17,000	N/A
Equipment	99,000	99,000	N/A
Contingency	44,900	44,000	N/A
Total, Construction	162,900	162,000	N/A
Total, TEC	209,900	211,000	N/A
Contingency, TEC	51,900	53,000	N/A
Other Project Cost (OPC)			
OPC except D&D			
R&D	6,600	2,500	N/A
Conceptual Planning	4,350	4,350	N/A
Conceptual Design	12,727	12,727	N/A
Contingency	0	4,100	N/A
Total, OPC	23,677	23,677	N/A
Contingency, OPC	0	4,100	N/A
Total, TPC	233,577	234,677	N/A
Total, Contingency	51,900	57,100	N/A

7. Schedule of Appropriation Requests

(dollars in thousands)

Request Year		Prior Years	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	Total
FY 2011	TEC	5,000	30,000	0	0	0	0	0	0	35,000
	OPC	10,000	0	0	0	0	0	0	0	10,000
	TPC	15,000	30,000	0	0	0	0	0	0	45,000
FY 2012	TEC	0	24,000	12,500	0	0	0	0	0	36,500
	OPC	12,777	6,000	0	0	0	0	0	0	18,777
	TPC	12,777	30,000	12,500	0	0	0	0	0	55,277
FY 2013	TEC	0	24,000	20,000	0	0	0	0	0	44,000
	OPC	13,177	6,000	5,000	0	0	0	0	0	24,177
	TPC	13,177	30,000	25,000	0	0	0	0	0	68,177
FY 2014	TEC	0	24,000	24,147	35,000	32,000	44,000	45,000	23,000	223,000
	OPC	13,177	8,000	8,049	0	0	0	0	0	26,177
	TPC	13,177	32,000	32,196	35,000	32,000	44,000	45,000	23,000	249,177
FY 2013 Repro-gramming	TEC	0	24,000	8,000	35,000	32,000	44,000	45,000	23,000	211,000
	OPC	13,177	8,000	2,500	0	0	0	0	0	23,677
	TPC	13,177	32,000	10,500	35,000	32,000	44,000	45,000	23,000	234,677
FY 2015	TEC	0	24,000	8,000	35,000	25,000	42,000	43,000	32,900	209,900
	OPC	13,177	8,000	2,500	0	0	0	0	0	23,677
	TPC	13,177	32,000	10,500	35,000	25,000	42,000	43,000	32,900	233,577

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	FY 2021
Expected Useful Life	10 years
Expected Future Start of D&D of this capital asset	FY 2031

Operations and maintenance of this experiment will become part of the existing Fermilab accelerator facility. Annual related funding estimates are for the incremental cost of five years of full operation, utilities, maintenance and repairs with the accelerator beam on. Five subsequent years are planned for further analysis of the data while the detector and beam line are maintained in a minimal maintenance state (with annual cost of approximately 3% of full operations) to preserve availability for future usage with much smaller annual cost.

(Related Funding Requirements)

	Annual Costs		Life Cycle Costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations	3,100	3,100	16,000	16,000
Utilities	2,400	2,400	12,400	12,400
Maintenance & Repair	100	100	600	600
Recapitalization	0	0	0	0
Total	5,600	5,600	29,000	29,000

9. Required D&D Information

	Square Feet
Area of new construction	Approximately 25,000 SF
Area of existing facility(ies) being replaced and D&D'd by this project	0
Area of other D&D outside the project	0
Area of any additional D&D space to meet the the "one-for-one" requirement taken from the banked area.	Approximately 25,000 SF

The one-for-one replacement has been met through banked space. A waiver from the one-for-one requirement to eliminate excess space at Fermilab to offset the Mu2e project was approved by DOE Headquarters on November 12, 2009. The waiver identified and transferred to Fermilab 575,104 square feet of excess space to accommodate the new Mu2e facilities and other as yet unbuilt facilities from space that was banked at other DOE facilities.

10. Acquisition Approach

The acquisition approach is fully documented in the Acquisition Strategy approved as part of CD-1. This is a high-level summary of material from that document.

DOE has awarded the prime contract for the Mu2e project to the Fermi Research Alliance (FRA), the Fermilab Management and Operating (M&O) contractor, 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 Fermilab scientists and engineers. This arrangement will facilitate close cooperation and coordination between the Mu2e scientific collaboration and an experienced team of project leaders managed by FRA. FRA will have primary responsibility for oversight of all subcontracts required to execute the project. These subcontracts are expected to include the purchase of components from third party vendors as well as subcontracts with university groups to fabricate detector subsystems.

The largest procurements will be the magnet systems and the civil construction. The superconducting solenoid magnets are divided into three systems that could be procured independently but which must ultimately perform as a single integrated magnetic system. Two of the systems are similar to systems that have been successfully built in private industry, so the engineering design and fabrication for two of the solenoids may be subcontracted to third party vendors, if a planned study of industrial vendor capabilities confirms that the technical risks are acceptable. The third solenoid is relatively unique, and no good industrial analog exists. This solenoid will be designed and fabricated at Fermilab, though most of the parts will be procured from third party vendors.

There will be two major subcontracts for the civil construction for Mu2e. An architecture and engineering (A&E) contract will be placed on a firm-fixed-price basis for Preliminary (Title I) Design, and Final (Title II) Design with an option for construction (Title III) support. The general construction subcontract will be placed on a firm-fixed-price basis. It is expected that the design specifications will be sufficiently detailed to allow prospective constructors to formulate firm-fixed-price offers without excessive contingency and allowances.

All subcontracts will be competitively bid and awarded based on best value to the government. Chicago 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.