High Energy Physics
Funding Profile by Subprogram and Activity

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR*	FY 2014 Request
Energy Frontier Experimental Physics			
Research	91,757	—	96,129
Facility Operations and Experimental Support	68,240	—	58,558
Projects	0	—	0
Total, Energy Frontier Experimental Physics	159,997	—	154,687
Intensity Frontier Experimental Physics			
Research	53,261	—	53,562
Facility Operations and Experimental Support	143,844	—	180,481
Projects	86,570	—	37,000
Total, Intensity Frontier Experimental Physics	283,675	—	271,043
Cosmic Frontier Experimental Physics			
Research	47,840	—	62,364
Facility Operations and Experimental Support	11,207	—	12,022
Projects	12,893	—	24,694
Total, Cosmic Frontier Experimental Physics	71,940	—	99,080
Theoretical and Computational Physics			
Research			
Theory	55,929	—	51,196
Computational HEP	8,536	—	8,474
Total, Research	64,465	—	59,670
Projects	2,500	—	3,200
Total, Theoretical and Computational Physics	66,965	—	62,870
Advanced Technology R&D			
Research			
HEP General Accelerator R&D	59,280	—	57,856
HEP Directed Accelerator R&D	46,587	—	23,500
Detector R&D	28,139	—	23,947
Total, Research	134,006	—	105,303

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR*	FY 2014 Request
Facility Operations and Experimental Support	23,100	—	17,150
Total, Advanced Technology R&D	157,106	—	122,453
Accelerator Stewardship			
Research	0	—	6,581
Facility Operations and Experimental Support	2,850	—	3,350
Total, Accelerator Stewardship	2,850	—	9,931
SBIR/STTR	0	—	21,457
Subtotal, High Energy Physics	742,533	767,529	741,521
Construction			
Long Baseline Neutrino Experiment	4,000	4,025	0
Muon to Electron Conversion Experiment	24,000	24,147	35,000
Total, Construction	28,000	28,172	35,000
Total, High Energy Physics[a]	770,533	795,701	776,521

*FY 2013 amounts shown reflect the P.L. 112-175 continuing resolution level annualized to a full year. These amounts are shown only at the "congressional control" level and above; below that level a dash (—) is shown.

[a] SBIR/STTR funding:

- FY 2012 Appropriation: SBIR $17,915,000 and STTR $2,412,000 (transferred out of HEP in FY 2012 Current column)
- FY 2014 Request: SBIR $18,775,000 and STTR $2,682,000

Public Law Authorizations

Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 102-468, "Energy Policy Act of 1992"
Public Law 109-58, "Energy Policy Act of 2005"
Public Law 110-69, "America COMPETES Act of 2007"
Public Law 111-358, "America COMPETES Reauthorization Act of 2010"

Overview

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

The knowledge acquired in this pursuit also yields substantial benefits of a more tangible nature for society as a whole–for example, the discovery of x-rays was driven not by physicians in search of a better way to diagnose bone fractures but by physicists engaged in basic research.

The Standard Model of particle physics, first established in the 1970s, describes the behavior of elementary particles and forces, often to very high precision. Nevertheless, the Standard Model fails at the high energies now being created in particle accelerators and describes only normal visible matter—only about 5% of the universe. Astronomical observations indicate that the remaining 95% of the universe consists of "dark matter" and "dark energy"; the fundamental nature of which remains a mystery.

A world-wide program of particle physics research is underway to explore what lies beyond the Standard Model. To this end, HEP supports a program focused on three scientific frontiers:

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

Together, these complementary discovery frontiers offer the opportunity to answer some of the most basic questions about the world around us, including:

- *Are there undiscovered principles of nature, such as new symmetries or new physical laws?*

  The laws of quantum physics that describe elementary particles and forces are based on underlying symmetries of nature. Some of these symmetries prevail only at very high energies. A possible new symmetry, called supersymmetry, predicts a superpartner for every particle currently known. The search for such superparticles will be carried out with experiments at the Energy Frontier or indirectly with measurements at the Intensity or Cosmic Frontiers.

- *Why are there so many kinds of particles?*

  Three different pairings, or families, of quarks and leptons have been discovered. Does nature require that there are only three families, or are there more? The various quarks and leptons also have widely different masses and force couplings. These differences suggest there may be an undiscovered explanation that unifies quarks and leptons. Detailed studies that employ Energy Frontier accelerators, as well as precision measurements made at Intensity Frontier facilities, may provide dramatic insights into this complex puzzle.

- *Do all the forces become one?*

  All the basic forces in the universe could be various manifestations of a single unified force. Unification was Einstein's great, unrealized dream and advances in string theory give hope of achieving it. The discovery of superpartners or extra dimensions at Energy Frontier accelerators, or hints of them at the Intensity or Cosmic Frontiers, would lend strong support to current ideas about unification.

Some investigations are best suited to the tools and techniques of one of the Frontiers; but, the strong connections and overlaps among many key questions necessitate coordinated initiatives across the three frontiers. HEP creates new technologies and pushes current technologies to new limits to answer these questions and to meet the challenges of research at the frontiers. HEP supports theoretical and experimental studies by individual investigators and large collaborative teams—some who gather and analyze data from accelerator facilities in the U.S. and around the world, and others who develop and deploy ultra-sensitive instruments to detect particles from space and observe astrophysical phenomena that advance our understanding of fundamental particle properties.

The continuous improvement of accelerator and detector technology necessary to pursue high energy physics as well as the scale of the science itself has had transformative impacts on the Nation's economy, security, and society. HEP, as the primary steward of accelerator science and advanced accelerator technology R&D in the Office of Science has developed knowledge and technologies that are the foundation for Office of Science major accelerator user facilities. HEP's contributions to the underlying technologies now used in medicine, science, industry, and national security are also well known. HEP coordinates accelerator research investments with the Advanced Scientific Computing Research (ASCR), Basic Energy Sciences (BES) and Nuclear Physics (NP) programs and plans to expand its coordination role in FY 2014.

Development of accelerator, detector, electronics, and magnet technologies is likely to have a significant impact in a number of areas where accelerators use is expanding, including: homeland and national security where accelerators and detectors enable hazardous material detection and non-proliferation verification; industry; and medicine where research could help lower the cost of accelerators, detectors, and magnets for cancer treatment and diagnosis.

The HEP budget has been restructured to align with the long-range plan developed by the HEPAP subpanel, Particle Physics Project Prioritization Panel (P5), in their report *US Particle Physics: Scientific Opportunities A Strategic Plan for the Next Ten Years*[a] (June 2008). The three experimental physics subprograms are Energy Frontier, Intensity Frontier, and Cosmic Frontier, as described in the P5 report. These replace the Proton Accelerator-based Physics, Electron Accelerator-based Physics, and Non-accelerator Physics subprograms. The Theoretical Physics subprogram is renamed the Theoretical and Computational subprogram to more accurately reflect its activities. There are also changes to the Advanced Technology R&D subprogram; the accelerator technology R&D activities that have a broad benefit beyond high energy physics are identified in the Accelerator Stewardship subprogram and SBIR/STTR activities are moved into a separate subprogram. The purpose of these changes is to increase transparency of the HEP budget and demonstrate clear goals and progress along the scientific thrusts of the field.

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 can 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 convened a task force 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 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.

Program Accomplishments and Milestones

FY 2012 saw major, paradigm-shifting accomplishments on all three frontiers of particle physics that reaffirmed the power of basic research to inspire innovation and redefine the future directions of scientific inquiry.

LHC experiments announced the discovery of a new particle compatible with the Standard Model Higgs boson (Energy Frontier). The LHC luminosity increased by an order of magnitude in 2012, and one of the primary results is the discovery of a new particle observed at about 125 GeV. This new particle is compatible, within the achieved statistical accuracy, with being the long-sought Standard Model Higgs boson. Other recent results, include strong limits on the masses of supersymmetric particles that are substantially tighter than those from the Tevatron. HEP supported researchers at home and abroad have leading roles in the operations of the detectors and the LHC data analyses. Further data from the LHC will determine if this is the Standard Model Higgs Boson or another particle predicted by supersymmetry or other beyond the Standard Model theories.

Nobel Prize in Physics awarded for discovery of dark energy (Cosmic Frontier). Saul Perlmutter of Lawrence Berkeley National Laboratory was awarded the 2011 Nobel Prize in Physics along with Adam Reiss and Brain Schmidt for the discovery of the acceleration of the expansion of the universe. This expansion has been attributed to a new force called "dark energy", which is now one of the most active areas of research in cosmology and high energy physics. In 2012 a new instrument, the DOE-supported Dark Energy Camera (DECam), was completed and installed on the Blanco telescope in Chile, and a new technique to measure dark energy was demonstrated by the Baryon Oscillation Spectroscopic Survey.

Daya Bay Experiment makes the first definitive measurement of the remaining unknown neutrino mixing

[a] http://science.energy.gov/~/media/hep/pdf/files/pdfs/p5_report_06022008.pdf

angle (Intensity Frontier). In China, the Reactor Neutrino Experiment detectors are installed and taking data. Using a partially complete experiment, the collaboration led by U.S. and Chinese physicists has reported a measurement of the mixing angle responsible for changing muon neutrinos to electron neutrinos. The Daya Bay result definitively confirms results from European and Japanese experiments that suggested a large mixing angle. This means that, in the current neutrino oscillation model, the possibility of matter-antimatter asymmetry and the hierarchy of neutrino masses can be definitively explored with new experiments, including the soon-to-be-completed NOvA experiment.

Milestones	Date
First light for DECam, the DOE contribution to the Dark Energy Survey (DES) experiment (Cosmic Frontier Experimental Physics, Research)	4th Qtr, FY 2012
Shutdown of the Fermi National Accelerator Laboratory (Fermilab) accelerator complex for installation of the NuMI Off-Axis Neutrino Appearance (NOvA) Accelerator Upgrades: These upgrades will raise the beam power available for Neutrinos at the Main Injector (NuMI) beam from 320 kilowatts to 700 kilowatts. (Intensity Frontier Experimental Physics, Projects)	3rd Qtr, FY 2012
Completion of NOvA Accelerator Upgrades and resumption of operations of the Fermi accelerator complex (Intensity Frontier Experimental Physics, Facility Operations and Experimental Support, and Projects)	3rd Qtr, FY 2013
Improve the measurement of the mixing angle between muon neutrinos and electron neutrinos ($\sin^2(2\theta_{13})$) by measuring disappearance of electron antineutrinos with Daya Bay Reactor Experiment at an increased accuracy (the measurement of $\sin^2(2\theta_{13})$ should have uncertainty of 0.0075 or smaller) (Intensity Frontier Experimental Physics, Research)	4th Qtr, FY 2013

Milestones	Date
Start of operations of the NOvA experiment with the full detector in order to continue the study of neutrino mixing, study the neutrino mass hierarchy, and search for violation of charge-parity (CP) symmetry. The NOvA experimental program is planned to last six years.	4th Qtr, FY 2014

Program Planning and Management

To ensure that resources are allocated to the most scientifically promising experiments and projects and program are run effectively and efficiently, HEP actively seeks external input and evaluation using a variety of advisory bodies. The High Energy Physics Advisory Panel (HEPAP), jointly chartered by DOE and the National Science Foundation (NSF) under the provisions of the Federal Advisory Committee Act (FACA), provides advice regarding the scientific opportunities and priorities of the national high energy physics research program. HEPAP and its subpanels undertake special studies and planning exercises in response to specific charges from the funding agencies.

The HEPAP P5 report[a] provided important input informing HEP programmatic priorities. A subsequent HEPAP report to identify and prioritize the scientific opportunities and options that can be pursued at different funding levels to achieve an optimum program in particle astrophysics refined this guidance. The National Academies Decadal Survey of Astronomy and Astrophysics (Astro2010) report[b] (August 2010) recommended priorities for the next decade for the U.S. program in astronomy and astrophysics under various funding scenarios. This study provides advice on the opportunities for HEP participation in astrophysics experiments and also provides guidance on scientific and technical aspects of the proposed program. HEP's budget and planning for FY 2014 are consistent with the advice obtained from the scientific community and the implementation of a coordinated interagency national program that will deliver the best science with the available resources in this scientific area. The Astronomy

[a] http://science.energy.gov/~/media/hep/pdf/files/pdfs/p5_report_06022008.pdf
[b] http://www.nap.edu/catalog.php?record_id=12951

and Astrophysics Advisory Committee (AAAC) reports annual and on a continuing basis to DOE, NSF, National Aeronautics and Space Administration (NASA) and Congress with advice on the direction and management of the national astronomy and astrophysics research programs as well as coordination between the agencies. The AAAC operates similarly to HEPAP, and the two advisory bodies have been charged to form joint task forces or subpanels to address research issues at the intersection of high energy physics, astrophysics, and astronomy, such as dark energy and dark matter and the study of high energy cosmic and gamma rays. HEP's budget and planning for FY 2014 are consistent with the advice obtained from the scientific community and the implementation of a coordinated interagency national program that will deliver the best science with the available resources in this scientific area.

Consistent with Office of Science best practices for program management and evaluation, and the President's management agenda[a], HEP triennially convenes a Committee of Visitors (COV) to perform an independent review of HEP's solicitation, proposal, and research management processes, as well as an evaluation of the quality, performance, and relevance of the research portfolio, including an assessment of its breadth and balance. The fourth HEP COV review is planned for fall 2013.

HEP reviews and provides ongoing oversight of its research portfolio. All university research proposals are subject to an external peer review process to ensure high quality research and relevance to achieving the goals of the national program. Proposals for grant support are peer-reviewed by external technical experts, as they are for all Office of Science research programs, following the guidelines established by 10 CFR Part 605.

Following recommendations of recent COV panels, HEP has implemented a new review process for high energy physics research and basic technology R&D efforts at both universities and DOE laboratories. Laboratory high energy physics research and technology R&D groups are peer-reviewed triennially on a rotating basis using the same criteria established for the university reviews. In 2013, HEP plans to review the Intensity Frontier, Cosmic Frontier, and Advanced Technology R&D subprograms; in 2014 we plan to review the Theoretical and Computational Physics subprogram. Laboratory proposals involving significant new research scope are also subject to peer-review by external experts on an ad hoc basis. University grant proposals are now comparatively reviewed against their peers in the specific research areas that they are proposing to investigate in order to identify and select the strongest proposals and improve the overall quality of the program.

Program Goals and Funding

Offices of Science performance expectations (and therefore funding requests) are focused on four areas:

- *Research*: Carry out research across the three experimental frontiers of particle physics to address the most basic questions about the world around us.
- *Facility Operations*: Support optimal utilization of the HEP user facilities to deliver maximum data to the user community, while carrying out a maintenance and improvement program to keep the facilities productive well into the future.
- *Future Facilities*: Develop new facilities and instrumentation for the Energy, Intensity and Cosmic Frontiers for a scientific leadership program in the U.S. All construction projects and MIEs are within 10% of their specified cost and schedule baselines.
- *Scientific Workforce*: Contribute to the effort aimed at ensuring that DOE and the Nation have a sustained pipeline of highly skilled and diverse science, technology, engineering, and mathematics (STEM) workers.

[a] http://www.whitehouse.gov/sites/default/files/omb/memoranda/2012/m-12-14.pdf

Goal Areas by Subprogram

	Research	Facility Operations	Future Facilities	Workforce
Energy Frontier Experimental Physics	60%	40%	0%	0%
Intensity Frontier Experimental Physics	20%	70%	10%	0%
Cosmic Frontier Experimental Physics	65%	10%	25%	0%
Theoretical and Computational Physics	95%	0%	5%	0%
Advanced Technology R&D	85%	15%	0%	0%
Accelerator Stewardship	65%	35%	0%	0%
Construction	0%	0%	100%	0%
Total, High Energy Physics	50%	35%	15%	0%

Performance Measures

Performance Goal (Measure)	**HEP Facility Operations**—Average achieved operation time of HEP user facilities as a percentage of total scheduled annual operation time		
Fiscal Year	**2012**	**2013**[a]	**2014**
Target	≥ 80%	≥ 80%	≥ 80%
Result	Met		
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.		

[a] 2013 targets reflect DOE's FY 2013 Budget Request to Congress. FY 2013 target updates can be found in the upcoming FY 2012–2014 Annual Performance Plan and Report.

Performance Goal (Measure)	**HEP Neutrino Model**—Carry out series of experiments to test the standard 3-neutrino model of mixing		
Fiscal Year	**2012**	**2013**[a]	**2014**
Target	N/A	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
Result	N/A		
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.		

[a] 2013 targets reflect DOE's FY 2013 Budget Request to Congress. FY 2013 target updates can be found in the upcoming FY 2012–2014 Annual Performance Plan and Report.

Explanation of Funding and Program Changes

In the FY 2014 Request, funds are shifted from research categories to support: full operations of existing HEP facilities and experiments; the planned construction funding profile for the Muon to Electron Conversion Experiment (Mu2e); and a new MIE for the Muon g-2 experiment. This new Intensity Frontier MIE to fabricate an experiment to measure the muon anomalous magnetic moment,is planned to utilize the proton beam from the accelerator complex at Fermilab to produce the muons. Capital equipment funding is requested to support the planned funding profiles for the camera for the Large Synoptic Survey Telescope (LSSTcam) and a U.S. contribution to the upgrade of the Belle detector at the Super B-Factory in Japan (Belle-II).

(dollars in thousands)

	FY 2012 Current	FY 2014 Request	FY 2014 Request vs. FY 2012 Current
Energy Frontier Experimental Physics	159,997	154,687	-5,310
Reductions in funding are due to the continued ramp-down of Tevatron research and reduced demand for LHC detector operations activities during the planned LHC shutdown in FY 2014.			
Intensity Frontier Experimental Physics	283,675	271,043	-12,632
Reductions are dominated by the ramp-down of funding associated with Current Projects (particularly NOvA). This is 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 R&D and fabrication of other experiments.			

	(dollars in thousands)		
	FY 2012 Current	FY 2014 Request	FY 2014 Request vs. FY 2012 Current
Cosmic Frontier Experimental Physics	71,940	99,080	+27,140
Funding for operations of current facilities is increased to accommodate new and ongoing experiments. Funding for research activities increases to support these investments. Funding increases for the LSST MIE according to its planned profile.			
Theoretical and Computational Physics	66,965	62,870	-4,095
Funding for theory research is reduced consistent with the overall programmatic direction that provides more resources for investments in future facilities within the overall budget constraints. Computational HEP activities are maintained with approximately constant funding.			
Advanced Technology R&D	157,106	122,453	-34,653
Reductions are due to the completion of International Linear Collider R&D program in FY 2012, the reduced funding for accelerator testing infrastructure at Fermilab in 2013 as that effort nears completion, and the reallocation of some R&D efforts to the Accelerator Stewardship subprogram.			
Accelerator Stewardship	2,850	9,931	+7,081
This new 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. Funding comes from redirection of some broadly applicable research activities away from HEP-only focused activities.			
SBIR/STTR	0	21,457	+21,457
Funding is provided in accordance with the legislatively directed percentage of HEP operating budgets.			
Construction	28,000	35,000	+7,000
Funding is provided for the completion of the Mu2e PED and the beginning of construction.			
Total, High Energy Physics	770,533	776,521	+5,988

Energy Frontier Experimental Physics
Funding Profile by Activity

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Research	91,757	—	96,129
Facility Operations and Experimental Support	68,240	—	58,558
Total, Energy Frontier Experimental Physics	159,997	—	154,687

Overview

The Energy Frontier Experimental Physics subprogram supports LHC research and ongoing analysis of data from the Tevatron experiments at Fermilab with the goal of determining whether the Standard Model continues to be the correct description of 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 2014 will primarily be focused on the LHC. In 2014, 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 14 TeV. Data collected during this period will be used to determine answers to many fundamental questions in particle physics, including:

- *Have we discovered the 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. More data are required to measure its properties such as decay rates in the various channels (γγ, ZZ, WW, bb and ττ) and ultimately its spin and parity and thereby ascertain whether it is indeed the Standard Model Higgs boson or the result of new physics beyond the standard model.

- *Are there undiscovered principles of nature, such as new symmetries or new physical laws?*

  Researchers at the LHC hope to find evidence of what lies beyond the Standard Model or significantly constrain current models of new physics such as Supersymmetry, mechanisms for black hole production, extra dimensions, and other exotic phenomena.

LHC hosts two large multi-purpose particle detectors, CMS and ATLAS, that were fabricated and now maintained and operated by scientific collaborations consisting of thousands of research scientists from universities and national laboratories around the world who analyze the data and publish their results. U.S. researchers make up approximately 20% of the ATLAS collaboration and approximately 30% of the CMS collaboration. Results from multiple experiments are often combined as appropriate to improve the statistical significance of the results, including results obtained from Tevatron analyses.

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.

Explanation of Funding Changes

The decreases in the overall level of funding for the Energy Frontier is due to the end of the Tevatron Collider operations in September 2011. In FY 2014 activities are concentrated on research at the LHC and a few legacy analyses using Tevatron data. Legacy analysis of the Tevatron data will continue at a modest level.

	(dollars in thousands)		
	FY 2012 Current	FY 2014 Request	FY 2014 Request vs. FY 2012 Current
Research	91,757	96,129	+4,372
Research activities at the Energy Frontier in FY 2014 will primarily be focused on LHC Efforts include foundational research that will lead to the development of upgraded LHC detectors that will be needed in several years.			
Facility Operations and Experimental Support	68,240	58,558	-9,682
LHC Detector Operations are funded in this activity. Funding is reduced due to a long shutdown of the LHC accelerator, which will extend into FY 2014.			
Total, Energy Frontier Experimental Physics	159,997	154,687	-5,310

Research

Overview

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 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 when their laboratory hosts large computing centers 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.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	Research funding at the Energy Frontier was dominated by activities at the LHC (operating at 8 TeV) and data analysis at the Tevatron. High priority data analysis efforts in the Tevatron Collider program were maintained, but there was a reduction in the broader Tevatron research effort. Research efforts were selected based on a comparative peer-review process in order to maintain activities with the highest scientific impact and potential.	91,757
FY 2013	The FY 2013 Request proposed $97,667,000. While scientists analyze the large data samples collected in more than two years of running, the LHC will shut down early in the fiscal year to perform repairs that will allow it to operate at its design energy of 14 TeV.	—
FY 2014	The LHC will resume operations in FY 2014 after completion of machine repairs and detector maintenance to allow collecting data at the design energy of 14 TeV. U.S. university and laboratory scientists will participate in the preparation of components built in the United States for operation at higher energy and higher data rates. Funding is reduced for Tevatron legacy analyses as they are completed. Research efforts will be selected based on a comparative peer-review process in order to maintain activities with the highest scientific impact and potential.	96,129

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Grants	48,446	—	41,449
National Laboratories	42,861	—	51,830
University Service Accounts	450	—	300
Other Research	0	—	2,550
Total, Research	91,757	—	96,129

Facility Operations and Experimental Support

Overview

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 pre-conceptual detector R&D to support eventual upgrades of ATLAS and CMS enabling runs at higher energies and data rates and Tier 1 computing centers at Fermilab and the Brookhaven National Laboratory (BNL). Achieving a U.S. leadership role at the Energy Frontier requires effective integration of U.S. researchers in the LHC detector calibration and data analysis efforts and implementation and optimization of the U.S. data handling and computing capabilities needed for full participation in the LHC research program.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	The LHC Detector Operations program continued and included LHC detector support and R&D and pre-conceptual design for LHC Upgrades.	68,240
FY 2013	The FY 2013 Request proposed $63,069,000 for the LHC Detector Operations program. The funding level is decreased compared to FY 2012, reflecting the shutdown for maintenance and upgrades to reach the design energy.	—
FY 2014	Funding for the LHC Detector Operations program is decreased approximately $10 million compared to the FY 2012 level, reflecting the fact that the LHC will not operate for part of the year to allow for maintenance and upgrades to reach the design energy	58,558

(dollars in thousands)

	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
LHC Detector Operations			
ATLAS Detector and Computing Support	30,335	—	26,044
CMS Detector and Computing Support	34,511	—	30,730
Total, LHC Detector Operations	64,846	—	56,774
Other Facilities	3,394	—	1,784
Total, Facility Operations and Experimental Support	68,240	—	58,558

Intensity Frontier Experimental Physics
Funding Profile by Activity

(dollars in thousands)

	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Research	53,261	—	53,562
Facility Operations and Experimental Support	143,844	—	180,481
Projects	86,570	—	37,000
Total, Intensity Frontier Experimental Physics	283,675	—	271,043

Overview

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 measure.

Activities at the Intensity Frontier in FY 2014 will be focused primarily on operating new and existing facilities while continuing investments to maintain a world-leading program in the future. These facilities and investments are concentrated primarily in the areas of neutrino and muon physics, making use of extensive experience and infrastructure at Fermilab. In 2014, the Daya Bay Reactor Neutrino Experiment will continue its operation, and the NOvA neutrino detector will be completed and start taking data with the upgraded NuMI beamline from Fermilab. Fabrication funding is initiated 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 the 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. Many trillions of neutrinos can pass through an area the size of a postage stamp every second with little or no interaction with their surroundings and their detection requires intense neutrino sources and large detectors. HEP supports research into fundamental neutrino properties; because, they may reveal important clues to 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 nuclear reactions 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 nuclear interaction may shed light on how this matter-antimatter asymmetry arose.

Many of the experiments in this subprogram are done in coordination with international partners. Experiments at U.S. facilities are managed and primarily supported by DOE and the NSF, with experiments at foreign facilities managed and primarily supported by the host country and institution.

Explanation of Funding Changes

Increases in operations support for the Intensity Frontier are offset by decreases in the Energy Frontier due to completion of Tevatron Collider operations in September 2011, as the Fermilab accelerator complex pivots its focus to new experiments. Completion of the NOvA project in FY 2014 and the transition of the Mu2e project from the R&D phase to the design and construction phase lead to a reduction in Projects funding. Programmatically, the latter is offset by increases in Construction funding for Mu2e.

	(dollars in thousands)		
	FY 2012 Current	FY 2014 Request	FY 2014 Request vs. FY 2012 Current
Research	53,261	53,562	+301
Intensity Frontier research is held approximately constant to support the major initiatives on the Intensity Frontier, the beginning of the NOvA and MicroBooNE experiment programs as well as scientific support of the design for the Mu2e project and ongoing research in support of the Long Baseline Neutrino Experiment (LBNE).			
Facility Operations and Experimental Support	143,844	180,481	+36,637
Funding for the Fermilab Accelerator Complex is increased to implement infrastructure improvements needed to support the shift from Energy Frontier to Intensity Frontier operations. Funding is provided for Accelerator Improvement Project (AIP) and General Plant Project (GPP) facility enhancements to support new experiments with muons, and a program of equipment replacement for the oldest part of the complex is started to increase the reliability of the complex. Funding is provided for safety and maintenance activities and support of the LUX and Majorana demonstrator experiments at the Homestake Mine.			
Projects	86,570	37,000	-49,570
The funding ramps down due to the completion of the NOvA and MicroBooNE MIEs and the end of Other Project Costs (OPC) funding for Mu2e. All remaining funding for Mu2e is in the Construction subprogram. Muon g-2 receives initial Total Equipment Cost (TEC) funding in FY 2014. Funding is also provided for LBNE OPC and for exploratory R&D for possible future projects.			
Total, Intensity Frontier Experimental Physics	283,675	271,043	-12,632

Research

Overview

The HEP experimental research activity at the Intensity Frontier consists of groups at over 50 academic institutions, and physicists from 8 national laboratories, performing experiments at a variety of locations. As discussed in the Energy Frontier subprogram, the laboratory groups typically have a portfolio of responsibilities ranging from detector operations and maintenance to computing and data analysis. HEP will conduct 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. All research grants are selected using external peer review.

Intensity Frontier activity at Fermilab uses beams from the proton accelerator complex to measure neutrino oscillations with increasing precision and different experimental approaches (Main Injector Neutrino Oscillation Search [MINOS] and NOvA) and to measure neutrino interaction cross-sections in different energy ranges and various detector technologies (MiniBooNE, Main Injector Experiment v-A [MINERvA], and MicroBooNE). The Fermilab muon program uses beams from the Booster beamline to search for muon to electron conversion (Mu2e), and as a source for the Muon g-2 measurement.

The Intensity Frontier studies of rare decays include participation in the upgrade of the Belle detector at the Japanese B-Factory (Belle-II) at the National Laboratory for High Energy Physics (KEK). The Japanese B-Factory is scheduled for a major upgrade in FY 2014–2015 that will improve its luminosity by a factor of 50–100 in order to increase its sensitivity to physics beyond the Standard Model. Additional studies of neutrino oscillations are taking place at accelerators (Tokai to Kamioka [T2K], at JPARC in Tokai, Japan) and at nuclear reactors (Double Chooz in France and Daya Bay in China).

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	Research activities supported include data analysis of the accelerator-based neutrino oscillation and neutrino cross-section experiments, reactor neutrino experiments, and completion of final analyses from the previous generation of B-factory detectors as noted above. Physics studies for possible future experiments were also supported.	53,261
FY 2013	The FY 2013 Request proposed $56,427,000. First data with the partially-completed NOvA detector will be calibrated and analyzed. Analyses of ongoing neutrino experiments are continued. Researchers will also provide some support for neutrino experiment maintenance during the shutdown for the upgrade of the NuMI beamline.	—
FY 2014	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. Final analyses of the Double Chooz reactor data will be completed.	53,562

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Grants	20,493	—	20,729
National Laboratories	32,226	—	28,833
University Service Accounts	542	—	0
Other Research	0	—	4,000
Total, Research	53,261	—	53,562

Facility Operations and Experimental Support

Overview

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. In FY 2014, the major experimental efforts will be the NOvA and MicroBooNE experiments utilizing the NuMI and Booster neutrino beams.

HEP also supports the operation of the Homestake Mine which currently houses a dark matter experiment and a technology demonstration for neutrinoless double beta decay experiment supported by the Nuclear Physics program. Homestake is proposed as the primary site of the large detector for the LBNE project. Supported activities include pumping water to maintain the mine, operation of the hoists to transport personnel and materials, and safety related maintenance.

The remaining activities are the disassembly and removal of the PEP-II accelerator components from the accelerator tunnel at SLAC and the detector operation and maintenance and computing for experiments that are not located at DOE national laboratories such as the Daya Bay reactor neutrino experiment in China.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	The Fermilab Accelerator Complex, the operation of the Homestake Mine, and the disassembly of the PEP-II accelerator were all supported.	143,844
FY 2013	The FY 2013 Request proposed $162,979,000 to support all of the above activities. An increase in funding for the Fermilab Accelerator Complex is provided to begin a program of equipment replacement to improve the reliability of the complex. The replacements will be targeted at the oldest part of the complex, which are now over 40 years old.	—
FY 2014	Funding is increased for the Fermilab accelerator complex to support GPP and AIP projects to develop the common infrastructure needed to carry out muon experiments. Funding is increased for safety and maintenance activities and support of the LUX and Majorana demonstrator experiments at the Homestake Mine.	180,481

(dollars in thousands)

	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Experimental Operations and Support	6,615	—	7,245
Fermilab Complex Operations			
Accelerator Operations	83,348	—	107,334
Detector and Computing	29,021	—	34,556
Other Complex Support	7,175	—	14,548
Total, Fermilab Complex Operations	119,544	—	156,438

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
B-Factory			
Accelerator Operations	2,839	—	3,000
Detector and Computing	6,892	—	1,600
Other Complex Support	300	—	0
Total, B-Factory	10,031	—	4,600
Homestake[a]	5,478	—	10,000
Other Facilities	2,176	—	2,198
Total, Facility Operations and Experimental Support	143,844	—	180,481

[a] Per a Memorandum of Understanding between DOE and NSF, HEP provided LHC detector operations funding ($4,022,000) to offset NSF contributions for Homestake Dewatering activities during the FY 2012 Continuing Resolution.

Projects

Overview

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

The Muon g-2 project is a new MIE in FY 2014. The project will utilize an existing muon storage ring from a previous experiment at BNL, but it will be located at Fermilab in order to utilize the high intensity proton beam.

The Belle-II Project is an MIE to build detector subsystems for the Belle-II detector at KEK.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	The NOvA and MicroBooNE projects were in full fabrication. The Belle-II project received CD-1 approval and OPC funding was provided. FY 2012 was the last year of project funding for the Daya Bay Reactor Neutrino Project, CD-4 approval received August 20, 2012. Funding was provided for the LBNE and Mu2e OPC.	86,570
FY 2013	The FY 2013 Request proposed $61,337,000. FY 2013 is the final year for funding of both the NOvA and MicroBooNE projects. Funding for the Belle-II TEC begins in FY 2013. Also, funding is provided for the LBNE and Mu2e OPC.	—
FY 2014	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. Preconceptual R&D for possible upgrade of the front-end of the Fermilab accelerator complex to significantly enhance the beam power is included. R&D for LBNE continues.	37,000

(dollars in thousands)

	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Current			
MIE			
NOvA	41,240	—	0
MicroBooNE	6,000	—	0
Reactor Neutrino Detector at Daya Bay	500	—	0
Belle-II	1,030	—	8,000
Muon g-2	0	—	9,000
Total, MIE	48,770	—	17,000

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Line Item OPC			
LBNE	17,000	—	10,000
Mu2e	8,000	—	0
Total, Line Item OPC	25,000	—	10,000
Total, Current	73,770	—	27,000
Future Project R&D	12,800	—	10,000
Total, Projects	86,570	—	37,000

Cosmic Frontier Experimental Physics
Funding Profile by Activity

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Research	47,840	—	62,364
Facility Operations and Experimental Support	11,207	—	12,022
Projects	12,893	—	24,694
Total, Cosmic Frontier Experimental Physics	71,940	—	99,080

Overview

The Cosmic Frontier Experimental Physics subprogram supports the study of high energy physics through measurements of astrophysical phenomena. The activities in this subprogram use diverse tools and technologies, from ground-based telescopes and space-based probes to large detectors deep underground, to probe fundamental physics questions associated with naturally occurring phenomena.

Experiments in this subprogram can be classified into three main categories: searches for dark matter, studies of the nature of dark energy, and measurements of high-energy cosmic and gamma rays. 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 overcomes 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 all point to the existence of a new species of matter that does not have a place in the Standard Model of particle physics. This "dark matter", so-called because it does produce or reflect light, likely 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.

Most of the experiments in this subprogram are done in partnership or coordination with other U.S. agencies and/or international partners. Some are carried out by providing the necessary instrumentation for use on telescope facilities or observatories belonging to other agencies or private institutions, and some are conducted in domestic or foreign underground laboratories. Partner federal institutions include NSF and NASA.

Explanation of Funding Changes

Overall, funding for Cosmic Frontier activities ramps up due to the increase for the Large Synoptic Survey Telescope (LSST) experiment camera (LSSTcam), and for facilities operations for dark energy and dark matter research. Experimental operations and research funding increase to support the increased activities in this area.

	(dollars in thousands)		
	FY 2012 Current	FY 2014 Request	FY 2014 Request vs. FY 2012 Current
Research	47,840	62,364	+14,524
Funding for research activities increases to support pre-conceptual design efforts on new projects and data analysis for current and newly completed projects.			
Facility Operations and Experimental Support	11,207	12,022	+815
Funding for operations increases as the small experiments completed in recent years continue in their operating phase and the newly completed HAWC experiment begins its operating phase. The Dark Energy Survey experiment moves from commissioning into its fully operational phase.			
Projects	12,893	24,694	+11,801
Funding for Projects ramps up to support engineering and design for LSSTcam.			
Total, Cosmic Frontier Experimental Physics	71,940	99,080	+27,140

Research

Overview

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. As discussed in the Energy Frontier subprogram, these groups typically have a broad portfolio of responsibilities including experimental design, fabrication, operations and maintenance, led by the scientific collaborations, as well as computing and data analysis. HEP will conduct 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. All research grants are selected using scientific peer review.

Ongoing research is supported on several small "first-generation" direct-detection dark matter experiments that implement a wide variety of cutting-edge particle detection technologies to identify the rare interactions of dark matter with ordinary matter. In parallel, research will be supported to enable "second-generation" dark matter (DM-G2) experiments that are expected to have at least 10 times the detection sensitivities of first-generation experiments.

The dark energy program uses several complementary observational methods to constrain the nature of this mysterious force that seems to pervade the universe. Ground-based telescopes are the primary tool used, often with specialized instrumentation for imaging or spectroscopic surveys. Research activities support the currently operating experiments, including the Baryon Oscillation Spectroscopic Survey (BOSS), the Dark Energy Survey (DES) which starts its science survey in FY 2014, and science studies in preparation for the LSST and other future experiments.

Studies of high energy gamma rays are being done by several experiments covering different energy ranges, including HAWC which starts its science operations in FY 2014. This data will be used to search for dark matter particles that decay to gamma rays. Data analysis continues on studies of cosmic rays using the Pierre Auger observatory in Argentina and the Alpha Magnetic Spectrometer (AMS) experiment on the International Space Station. AMS data will also be used for searches of dark matter and antimatter in the universe and will provide the world's largest data set on the energy, abundance and other properties of cosmic rays. Small efforts continue on studies of the properties of the early universe using cosmic microwave background measurements.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	Support was provided for research on Cosmic Frontier experiments described above.	47,840
FY 2013	The FY 2013 Request proposed $49,107,000. The DES experiment starts data-taking. R&D is supported for the competitively selected DM-G2 experiments.	—
FY 2014	Data-taking is completed on BOSS, though data analysis continues. Scientific activities increase to support the LSSTcam, which ramps up its engineering and design efforts in FY 2014. Data analysis continues on other supported experiments.	62,364

(dollars in thousands)

	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Grants	12,880	—	11,775
National Laboratories	34,960	—	47,065
Other Research	0	—	3,524
Total, Research	47,840	—	62,364

Facility Operations and Experimental Support

Overview

This activity supports the personnel, data processing, and other expenses necessary for the commissioning, 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 and subsequent reviews are being used to inform decisions concerning the continuation of specific activities in subsequent years.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	Support was provided for operations expenses for the Cosmic Frontier experiments, including DES for installation and commissioning phase and continued operations for BOSS, supernova surveys, and small dark matter experiments. Operations continued for the AMS and Pierre Auger cosmic ray experiments and the VERITAS and FGST high energy gamma ray experiments.	11,207
FY 2013	The FY 2013 Request proposed $9,376,000. The DES experiment begins its data-taking phase.	—
FY 2014	Data-taking ends for BOSS, with data processing and analysis expected to continue for another year. Some selected experiments will ramp down or end their DOE-supported operations activities this year, based in part on outcomes from the 2012 operations review. HAWC starts full scientific operations.	12,022

(dollars in thousands)

	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Experimental Operations and Support	8,405	—	7,500
Other Facilities	2,802	—	4,522
Total, Facility Operations and Experimental Support	11,207	—	12,022

Projects

Overview

This activity supports all costs for design and fabrication of Cosmic Frontier projects, including major items of equipment (MIEs) and small experiments. The selection of projects is based on the HEPAP/P5 and the Particle Astrophysics Scientific Assesment Group (PASAG) report supplemented with advice from Federal Advisory Committees and National Academy panels followed by merit reviews of individual proposals. The Cosmic Frontier subprogram currently supports the fabrication of several MIEs. In FY 2012 fabrication was begun on the High Altitude Water Cerenkov (HAWC) project, which is designed to study TeV scale gamma and cosmic rays. In FY 2013, engineering and design funding ramps up for the DOE's responsibility on the LSST experiment, a 3 billion pixel camera (LSSTcam) with fabrication starting for long-lead procurements in FY 2014.

HEP issued a solicitation in FY 2012 for R&D proposals enabling next-generation dark matter (DM-G2) detectors. Successful proposals were funded for one year of R&D and pre-conceptual design work in FY 2013. Increased R&D funding in FY 2013 for DM-G2 experiments was requested to enable these efforts.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	The HAWC MIE project began fabrication and the DES project ended its fabrication phase. Preliminary design studies continued for LSSTcam. R&D and fabrication support for small dark matter and other experiments continued.	12,893
FY 2013	The FY 2013 Request proposed $26,463,000. With these funds, the MIE funding for HAWC fabrication is completed. The increase in overall support is due to two efforts: ramp up of engineering and design for LSSTcam; and, support for R&D leading to second-generation dark matter (DM-G2) experimental concepts.	—
FY 2014	LSSTcam fabrication begins.	24,694

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Current			
MIE			
HAWC	1,500	—	0
Large Synoptic Survey Telescope (LSSTcam) Camera	5,500	—	22,000
Total, MIE	7,000	—	22,000
Other Projects	2,513	—	1,200
Total, Current	9,513	—	23,200
Future Project R&D	3,380	—	1,494
Total, Projects	12,893	—	24,694

Theoretical and Computational Physics
Funding Profile by Activity

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Research			
Theory	55,929	—	51,196
Computational HEP	8,536	—	8,474
Total, Research	64,465	—	59,670
Projects	2,500	—	3,200
Total, Theoretical and Computational Physics	66,965	—	62,870

Overview

The Theoretical and Computational Physics subprogram provides the mathematical and phenomenological framework to understand and extend our knowledge of the dynamics of particles and forces, and the nature of space and time.

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 and the identification of experimental signatures that would validate these new ideas. This subprogram also supports computational approaches to advance understanding the fundamental physics of the HEP program, 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.

Explanation of Funding Changes

The Theoretical and Computational Physics subprogram is decreased compared to the FY 2012, consistent with the overall programmatic direction that provides more resources for investments in future facilities within overall budget constraints. Computational HEP activities are maintained with approximately constant funding.

	(dollars in thousands)		
	FY 2012 Current	FY 2014 Request	FY 2014 Request vs. FY 2012 Current
Research	64,465	59,670	-4,795

This activity funds research at university and laboratory groups as well as activities in computational HEP and the Particle Data Group. Funding is reduced consistent with overall programmatic reductions in HEP Research activities, resulting in support for fewer researchers in this area.

	FY 2012 Current	FY 2014 Request	FY 2014 Request vs. FY 2012 Current
	(dollars in thousands)		
Projects	2,500	3,200	+700
Increased funding is provided for the LQCD computational project according to its planned profile.			
Total, Theoretical and Computational Physics	66,965	62,870	-4,095

Theory

Overview

The HEP theory research activity supports groups at over 70 academic and research institutions supported by research grants. University research groups play leading roles in addressing the leading research areas discussed above. Research grant proposals are selected based on external peer review.

HEP theory research also currently supports physicists from 7 national laboratories focusing on data modeling and interpretation. This work helps to provide a clear understanding of the significance of measurements from ongoing experiments and assists in shaping and developing the laboratories' experimental high energy physics programs. Using the unique computing capabilities available at national laboratories, theory groups also make major contributions to the lattice quantum chromodynamics (LQCD) and computational cosmology efforts. HEP conducted an external peer-review of all laboratory research efforts in 2011, whose findings have been used to inform the funding decisions in this request.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	Funding for theoretical research supported the ongoing program described above. Research efforts were selected based on comparative peer review to maintain the activities with the highest scientific impact and potential.	55,929
FY 2013	The FY 2013 Request proposed $54,406,000 to support the ongoing program described above, at a somewhat reduced level-of-effort.	—
FY 2014	Funding for theoretical research supports the ongoing program described above, at a reduced level of effort. Research efforts will be selected based on comparative peer review to maintain the activities with the highest scientific impact and potential.	51,196

(dollars in thousands)

	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Grants	27,746	—	24,123
National Laboratories	24,720	—	24,340
Other Research	3,463	—	2,733
Total, Theory	55,929	—	51,196

Computational HEP

Overview

Scientific computing, simulation, and computational science expertise are critical for the success of the HEP mission. Along with experiment and theory, computation is one of the primary paths forward in our understanding the nature of matter and the universe through the Energy, Intensity, and Cosmic Frontiers. Computation is necessary at all stages of an 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 research in two broad categories: collaborations providing crucial computational tools and techniques to specific targeted HEP research topics and scientific computing infrastructure supporting the broader HEP community. The Scientific Discovery through Advanced Computing (SciDAC) program generally supports the first category and the Scientific Computing category supports the latter. The SciDAC portfolio focuses on computational science research requiring leadership class computing to solve fundamental science questions and computing research funded via partnerships. Scientific Computing supports computing R&D, frameworks, networks, data resources, and related infrastructure and expertise at the laboratories; and community software.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	The SciDAC Program was re-competed jointly with the Advanced Scientific Computing Research program in FY 2012 as SciDAC 3 and some other partnerships with ASCR were funded. Distributed computing and data tools for LHC experiments were funded in partnership with NSF along with some Proof of Concept Scientific Computing projects.	8,536
FY 2013	The FY 2013 Request proposed $8,112,000. With these funds, SciDAC and other collaborative projects continue. A limited number of new research and R&D initiatives in computational HEP will be supported.	—
FY 2014	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. Other computational activities will continue at approximately the FY 2012 level of effort.	8,474

(dollars in thousands)

	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
SciDAC	4,794	—	4,916
Scientific Computing	3,742	—	3,558
Total, Computational HEP	8,536	—	8,474

Projects

Overview

The Projects activity funds dedicated hardware for the Lattice QCD (LQCD) computing initiative in partnership with the Office of Nuclear Physics.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	Funding was provided for the LQCD computational project.	2,500
FY 2013	The FY 2013 Request ($2,500,000) is in accordance with the project's approved baseline.	—
FY 2014	Funding continues according to the approved baseline.	3,200

Advanced Technology R&D
Funding Profile by Activity

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Research			
HEP General Accelerator R&D	59,280	—	57,856
HEP Directed Accelerator R&D	46,587	—	23,500
Detector R&D	28,139	—	23,947
Total, Research	134,006	—	105,303
Facility Operations and Experimental Support	23,100	—	17,150
Total, Advanced Technology R&D	157,106	—	122,453

Overview

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 proposal driven, peer reviewed research. This subprogram supports and advances research at all three Frontiers.

Advanced Technology R&D comprises both HEP programmatic mid-term and long-term R&D on accelerator 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 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.

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. Research efforts within this activity are generally limited in time and have concrete milestones. For FY 2014, there are two components of the HEP Directed Accelerator R&D activity: LHC Accelerator Research Program (LARP) and the Muon Accelerator Program (MAP).

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.

Facility Operations and Experimental Support provides operations funding for user facilities like the Facility for Advanced Accelerator Experimental Tests (FACET) as well laboratory experimental and test facilities. The Berkeley Lab Laser Accelerator (BELLA) facility and the Superconducting Radio-Frequency (SRF) infrastructure at Fermilab fall into these categories.

Explanation of Funding Changes

Overall funding for this subprogram is reduced due to redirection of long-term accelerator R&D with broader applications to the Accelerator R&D Stewardship subprogram, the reduction of liquid argon detector R&D as this effort moves to LBNE-related research, and completion of funding for the development of the SRF Infrastructure at Fermilab.

	(dollars in thousands)		
	FY 2012 Current	FY 2014 Request	FY 2014 Request vs. FY 2012 Current
Research	134,006	105,303	-28,703
The major driver of the decrease in funding is the completion of the R&D program for the International Linear Collider and redirection of selected long-term accelerator R&D to the Accelerator R&D Stewardship subprogram. Funding in other program components will support research with FACET, the electron-beam driven plasma wakefield accelerator test facility at SLAC, and BELLA, the laser driven plasma wakefield accelerator facility at LBNL. Other activities are maintained at approximately the FY 2012 level-of-effort.			
Facility Operations and Experimental Support	23,100	17,150	-5,950
The decrease reflects the final increments of funding for development of the SRF Infrastructure at Fermilab. Operation of the SRF processing and test facilities is supported.			
Total, Advanced Technology R&D	157,106	122,453	-34,653

HEP General Accelerator R&D

Overview

This activity supports research at 8 DOE national laboratories and about 30 academic or other research institutions. Funding is awarded based on external peer reviews. The program also trains new accelerator physicists with approximately 50 graduate students supported per year and supports the U.S Particle Accelerator School, which is held twice a year at rotating institutions to bring accelerator physics classes to students and practicing accelerator physicists who do not have regular access to such training.

Research efforts are also focused on the long-range development of new accelerating structures and techniques needed to achieve very high accelerating gradients. There are three different facilities to study wakefield acceleration techniques. At Argonne, the wakefields are created in a dielectric, while at LBNL and SLAC the wakefields are created in plasmas using a laser (BELLA) and electron beam (FACET) respectively. Normal conducting high gradient structures are tested at SLAC.

Research activities supported include: improving properties of advanced superconducting materials and magnet technology including niobium-tin and high temperature superconductors; studies of surface physics affecting the performance of SRF cavities to achieve higher accelerating gradients and/or quality factors; and a broad program on the physics of beams including numerical simulations and modeling. These efforts develop concepts and technology needed to realize the higher energy and intensity accelerators needed by the HEP program.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	Supported major accelerator R&D efforts at national laboratories and universities as described above, including the first user run at FACET to study beam driven plasma wakefields.	59,280
FY 2013	The FY 2013 Request proposed $64,942,000 to support major accelerator R&D efforts at national laboratories and universities at approximately the FY 2012 level of effort. Increased funding was requested to support optimal utilization of the FACET plasma wakefield accelerator facility at SLAC. Research begins with the laser driven plasma wakefields using BELLA.	—
FY 2014	Support for ongoing major accelerator R&D efforts at national laboratories and universities in this subprogram continue at approximately FY 2012 level-of-effort. Decreased funding reflects redirection of selected long-term, grant-based R&D to the Accelerator Stewardship subprogram.	57,856

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Grants	10,729	—	7,896
National Laboratories	48,550	—	45,960
Other Research	1	—	4,000
Total, HEP General Accelerator R&D	59,280	—	57,856

HEP Directed Accelerator R&D

Overview

This activity demonstrates the feasibility of HEP accelerator concepts and technical approaches on an engineering scale. 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. The efforts that comprise this activity are the LHC Accelerator Research Program (LARP) and the Muon Accelerator Program (MAP). The research program for the International Linear Collider was completed in FY 2012 and the Technical Design Report (TDR) was delivered in FY 2013.

The work is primarily done at four national laboratories and seven universities. The major areas of R&D are superconducting magnet and related materials technology; beam cooling and instrumentation; normal and superconducting accelerator systems; beam dynamics; and development of large simulation programs. The latter effort is coordinated with the SciDAC accelerator simulation project.

The LARP program supports superconducting magnet and accelerator instrumentation development needed to increase the luminosity at the Large Hadron Collider (LHC).

The MAP R&D plan for muon-based accelerators includes milestones and deliverables aimed at demonstrating the advanced technologies needed to realize muon-based accelerators for future muon colliders and neutrino factories. These programs are peer reviewed annually to evaluate the scientific quality of their work, progress against their milestones, and performance of the program management at the national laboratories.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	Supported major directed R&D efforts as discussed above. In addition, FY 2012 was the last year of funding the ILC R&D program.	46,587
FY 2013	The FY 2013 Request proposed $23,090,000 to support major directed R&D efforts as discussed above. The completion of the Technical Design Report concludes the five-year ILC R&D program. No funds were requested for the ILC R&D program in FY 2013.	—
FY 2014	MAP and LARP are the only activities in this category supported in FY 2014 and they are funded at a constant level of effort. LARP will be developing prototype superconducting quadrupole magnets with large apertures needed to increase luminosity at the LHC. MAP will be studying the operation of RF accelerating cavities in magnetic fields, a critical technology for the collection of muons into beams usable in an accelerator.	23,500

(dollars in thousands)

	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
LHC Accelerator Research	12,390	—	11,500
International Linear Collider	21,497	—	0
Muon Accelerators	12,700	—	12,000
Total, HEP Directed Accelerator R&D	46,587	—	23,500

Detector R&D

Overview

The Detector R&D activity addresses fundamental scientific challenges in particle detection, measurement, and data processing and provides support for developing and prototyping detector systems to bring the technologies to maturity and be incorporated into future particle physics experiments.

This activity is supported at 5 national laboratories and 25 universities. Efforts supported tend to be "generic" detector development with the potential for wide applicability and/or high-payoff. Research grants are selected using external peer review. Research groups work on a range of new technologies, including: silicon strip and pixel trackers that can work in high radiation environments and accommodate prodigious data rates; techniques for increasing the energy and directional sensitivities in neutrino detectors using new detector media (such as liquid argon) while significantly reducing their cost; and developing ever more sensitive charge-coupled devices (CCD) for telescope cameras.

Notable recent projects include research in producing a photo-detector with large area coverage but compact and inexpensive readout and the development of an inexpensive solvent to add to water to make it scintillate (emit light) in the presence of high energy charged particles. This work on the large area photo-detector was carried out at ANL and received an R&D 100 award in 2012. HEP conducted an external peer review of all laboratory research groups in this activity in 2012, and findings from this review are used to inform subsequent funding decisions.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	Funding enabled a broad research program in advanced detector concepts and related technologies as noted above. New awards were made for successful proposals in response to a targeted funding opportunity announcement for Collider Detector Research and Development.	28,139
FY 2013	The FY 2013 Request proposed $29,856,000 to continue support of Detector R&D efforts, with selection of activities based in part on findings from the review of the laboratory research program in 2012. Funding is increased to support the ramp up of funding for new detector R&D activities. Emphasis will shift towards the R&D needs of Intensity Frontier experiments such as liquid argon detector development.	—
FY 2014	Funding for liquid argon detector R&D is reduced.	23,947

(dollars in thousands)

	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Grants	2,944	—	3,206
National Laboratories	25,195	—	20,741
Total, Detector R&D	28,139	—	23,947

Facility Operations and Experimental Support

Overview

BELLA, FACET, and the SRF infrastructure at Fermilab are now transitioning into their operation phase to support user experiments and testing. FACET, an accelerator R&D user facility, supports experiments driven by its high-energy, ultrashort electron beam, including plasma wakefield acceleration, dielectric wakefield acceleration, terahertz radiation generation, beam diagnostics, and ultra fast magnetic switching in materials. In 2012, FACET had its first user run for eight peer-reviewed experiments conducted by 50 users from 16 institutions.

The BELLA laser-driven accelerator test facility supports research carried out by LBNL staff and their collaborators. Funding from this subprogram covers the operations and maintenance of the facility.

The Fermilab SRF Infrastructure supports the processing and testing of individual SRF cavities and modules of assembled cavities. The SRF infrastructure includes: cleaning systems, clean room assembly areas, cryogenic systems, RF power generation and distribution, instrumentation, and beam sources which can be used for the development of SRF cavities and modules for future accelerators and research on the performance of such cavities.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	Supported facility operations, commissioning and experimental supports at FACET, BELLA, and the SRF Infrastructure at Fermilab.	23,100
FY 2013	The FY 2013 Request proposed $23,700,000 to continue support of facility operations, commissioning and experimental supports at FACET and BELLA. Funding for FACET operation is increased, while commissioning support for the Fermi SRF infrastructure is reduced.	—
FY 2014	Support for activities at FACET and BELLA is held constant. Funding for the SRF Infrastructure is decreased as this facility transitions to operation.	17,150

Accelerator Stewardship
Funding Profile by Activity

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Research	0	—	6,581
Facility Operations and Experimental Support	2,850	—	3,350
Total, Accelerator Stewardship	2,850	—	9,931

Overview

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 programs in the Office of Science 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.

The need for a national, coordinated program has been highlighted by past advisory committee reports, the Accelerators for America's Future workshop in late 2009, language in the FY 2012 Congressional appropriation bill report, and a subsequent community task force that provided input[a] on specific R&D topics that could benefit from a sustained and coordinated approach that reaches out to accelerator users beyond the traditional HEP community. This budget request has been formulated using that input.

The research supported by this subprogram, together with making available laboratory accelerator test facilities and infrastructure for non-HEP users and providing increased support at beam test facilities, will help advance applications in energy and the environment, medicine, industry, national security, and discovery science.

Research activities are grouped into eight areas: superconducting radio frequency (SRF); new accelerator concepts; accelerator, beam, and computational physics; superconducting magnets; normal-conducting, high-gradient accelerator structures; particle sources; beam instrumentation and control; and RF sources.

Explanation of Funding Changes

This subprogram was created as part of the HEP budget restructuring effort in FY 2013. This subprogram captures HEP Accelerator R&D efforts that would be appropriately reclassified as Accelerator Stewardship activities, including university-based research, national laboratory research, and operations of existing accelerator test facilities that can provide access to users conducting research on accelerator stewardship topics. Prior year funding that would have been classified as supporting Accelerator Stewardship activities has been estimated.

[a] http://www.acceleratorsamerica.org/report/accelerator_task_force_report.pdf

	(dollars in thousands)		
	FY 2012 Current	FY 2014 Request	FY 2014 Request vs. FY 2012 Current
Research	0	6,581	+6,581
Reclassification of research activities identified as Accelerator Stewardship efforts, which benefit areas broader than HEP.			
Facility Operations and Experimental Support	2,850	3,350	+500
Provides a modest increase in support for FACET Operations for stewardship research.			
Total, Accelerator Stewardship	2,850	9,931	+7,081

Research

Overview

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. Research topics include superconducting radio frequency (SRF); new accelerator concepts; accelerator, beam, and computational physics; superconducting magnets; normal-conducting, high-gradient accelerator structures; beam instrumentation and control; particle sources; and RF sources. This activity incorporates the research program of approximately 20 university grants in advanced accelerator science, beam physics and related technologies that had previously been supported under Advanced Technology R&D.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2014	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: beam physics and accelerator modeling and computation at SLAC and PPPL.	6,581

(dollars in thousands)

	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Grants	0	—	5,481
National Laboratories	0	—	1,100
Total, Research	0	—	6,581

Facility Operations and Experimental Support

Overview

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. During FY 2012, 34 users from 12 institutions set up and conducted a total of eleven experiments and received a total of 188 run-days.

This stewardship subprogram also provides incremental support for the Facility for Accelerator Science and Experimental Test Beams (FACET) at SLAC.

Experiments at these facilities are selected using a peer review process managed by the laboratories.

Funding and Activity Schedule

Fiscal Year	Activity	Funding (dollars in thousands)
FY 2012	Supported facility operation at the ATF.	2,850
FY 2013	The FY 2013 Request proposed $2,900,000 to support facility operations at the ATF.	—
FY 2014	Supports facility operation at the ATF and modest incremental support for FACET Operations for stewardship research.	3,350

SBIR/STTR
Funding Profile by Activity

(dollars in thousands)

	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
SBIR/STTR[a]	0	—	21,457

[a] SBIR/STTR funding:
- FY 2012 Appropriation: SBIR $17,915,000 and STTR $2,412,000 (transferred out of HEP in FY 2012 Current column)
- FY 2014 Request: SBIR $18,775,000 and STTR $2,682,000

Overview

SBIR/STTR funding is set at 3.2% of non-capital funding in in FY 2014. The FY 2012 funding was set at 2.95%.

Explanation of Funding Changes

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

(dollars in thousands)

	FY 2012 Current	FY 2014 Request	FY 2014 Request vs. FY 2012 Current
SBIR/STTR	0	21,457	+21,457

In FY 2012, $17,915,000 and $2,412,000 were transferred to the Small Business Innovation Research (SBIR) and Small Business Technology (STTR) programs, respectively. SBIR/STTR funding is set at 3.2% of non-capital funding in FY 2014. FY 2012 was set at 2.95%.

Construction
Funding Profile by Activity

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Long Baseline Neutrino Experiment	4,000	4,025	0
Muon to Electron Conversion Experiment	24,000	24,147	35,000
Total, Construction	28,000	28,172	35,000

Overview

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 to study their conversion to electrons in order to determine if charged leptons can change identity in flight like neutrinos do. This process is forbidden In the Standard Model, so observation of events of this type would be a clear signal of new physics.

The Mu2e cost estimate has been revised and CD-1 was approved on July 11, 2012. Preliminary engineering design for Mu2e has commenced. The PED funds requested in FY 2013–2014 will be used to complete the engineering design, and the construction funds requested 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.

The HEP program has been developing the Long Baseline Neutrino Experiment (LBNE) project, with the Homestake Mine in South Dakota as a possible site for a far detector. The National Science Foundation was a potential partner in development and operations of the LBNE far detector but has chosen not to participate. During FY 2011 and early FY 2012, DOE worked to refine the scientific scope that can be achieved by DOE alone. In the spring of 2012, the Daya Bay Reactor Neutrino experiment, a U.S.-China collaboration reported a new measurement of an important (and previously unknown) neutrino parameter that determines the physics "reach" of experiments such as LBNE. Original LBNE designs had accommodated a value as much as ten times smaller than that reported by the Daya Bay collaboration, requiring much larger detectors to be certain of achieving physics goals. Knowledge of this parameter has allowed the current LBNE conceptual design to be re-optimized. The LBNE project team developed a conceptual design during FY 2012 that includes a new neutrino beam at Fermilab pointed at the Homestake Mine in South Dakota and an approximately 10 kiloton liquid argon detector on the surface at Homestake. This conceptual design received CD-1 approval on December 10, 2012. DOE is continuing to review this project mindful of ongoing community planning exercises.

Explanation of Funding Changes

The increase of PED funding for Mu2e takes into account the planned profiles. Mu2e and LBNE received PED funding in FY 2012.

Construction funding for Mu2e will increase in FY 2014 as construction (TEC) funding replaces the FY 2012 PED and OPC/R&D funding.

	(dollars in thousands)		
	FY 2012 Current	FY 2014 Request	FY 2014 Request vs. FY 2012 Current
Long Baseline Neutrino Experiment	4,000	0	-4,000

No PED is requested in FY 2014.

	(dollars in thousands)		
	FY 2012 Current	FY 2014 Request	FY 2014 Request vs. FY 2012 Current
Muon to Electron Conversion Experiment	24,000	35,000	+11,000
Funding is provided for continuing project engineering and design activities and to initiate long-lead procurements and construction.			
Total, Construction	28,000	35,000	+7,000

Supporting Information

Capital Operating Expenses

Capital Operating Expenses Summary

(dollars in thousands)

	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Capital equipment over $500,000, including major items of equipment (MIEs)	63,295	—	50,222
General plant projects (GPP) (under $10 million)	7,475	—	14,548
Accelerator improvement projects (AIP)	0	—	6,200
Total, Capital Operating Expenses	70,770	—	70,970

Capital Equipment over $500,000 (including MIEs)

(dollars in thousands)

	Total	Prior Years	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Major items of equipment (TEC over $2 million)					
Intensity Frontier Experimental Physics					
NOνA					
TEC	204,468	143,748	41,240	—	0
OPC	73,532	73,532	0	—	0
TPC	278,000	217,280	41,240	—	0
MicroBooNE[a]					
TEC	14,760	2,903	6,000	—	0
OPC	5,140	5,140	0	—	0
TPC	19,900	8,043	6,000	—	0
Reactor Neutrino Detector at Daya Bay					
TEC	32,700	32,200	500	—	0
OPC	2,800	2,800	0	—	0
TPC	35,500	35,000	500	—	0

[a] 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.

(dollars in thousands)

	Total	Prior Years	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Belle-II[a]					
TEC	10,970	0	0	—	8,000
OPC	5,030	0	1,030	—	0
TPC	16,000	0	1,030	—	8,000
Muon g-2 Experiment[b]					
TEC	32,150	0	0	—	2,000
OPC	7,850	0	0	—	7,000
TPC	40,000	0	0	—	9,000
Cosmic Frontier Experimental Physics					
HAWC[c]					
TEC	3,000	0	1,500	—	0
OPC	0	0	0	—	0
TPC	3,000	0	1,500	—	0
Large Synoptic Survey Telescope (LSSTcam) Camera[d]					
TEC	160,800	0	0	—	22,000
OPC	12,200	1,900	5,500	—	0
TPC	173,000	1,900	5,500	—	22,000
Total MIEs					
TEC			49,240	—	32,000
OPC			6,530	—	7,000
TPC			55,770	—	39,000
Other capital equipment projects under $2 million TEC			14,055	—	18,222
Total, Capital equipment (excludes MIE OPC)			63,295	—	50,222

[a] This project is not yet baselined. Critical Decision CD-1 for the Belle-II Project's Conceptual Design was approved on September 18, 2012. Initial long-lead procurement was approved (CD-3a) on November 8, 2012.

[b] Critical Decision CD-0 for the Muon g–2 Project was approved on September 18, 2012. The TPC range is $30,000,000 to $60,000,000.

[c] The HAWC project falls below the $10,000,000 TPC threshold that requires a CD-0. The TPC as well as the OPC/TEC split may change.

[d] This project is not yet baselined and the OPC/TEC split is not yet determined. This project received CD-1 on April 12, 2012.

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. Funding planned for the outyears was reduced to maintain the TPC. The NOvA Project will complete fabrication in FY 2014.

The MicroBooNE Project Fabrication began 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.

Reactor Neutrino Detector, located in Daya Bay, China, has been fabricated in partnership with research institutes in China. This experiment uses anti-neutrinos produced by commercial power reactors to measure a fundamental parameter to help resolve ambiguities in neutrino properties and help set future directions of neutrino research. The TPC is $35,500,000. An Independent Project Review for CD-4B has been conducted and CD-4B was approved August 20, 2012. Data-taking began December 2010 with a subset of the detectors and an important, world-leading measurement of the oscillation properties of electron antineutrinos was published in March 2012.

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 the 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* is a new MIE in FY 2014. This experiment seeks to improve the measurement of the muon anomalous magnet moment, which is sensitive to new physical interactions such as supersymmetry. The project will utilize 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. Critical Decision CD-0 was approved on September 18, 2012. The preliminary estimated cost range for this project is $30,000,000 to $60,000,000. FY 2014 funding will fully fund project design, the transfer of the BNL storage rings to Fermilab and the testing and reassembly of those rings.

Cosmic Frontier Experimental Physics MIEs:

The *High Altitude Water Cherenkov (HAWC)* detector is an experiment in Mexico that will survey the sky for sources of TeV 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. The total DOE cost is $3,000,000 and the estimated completion date is in FY 2014.

The *Large Synoptic Survey Telescope Camera (LSSTcam*) is a digital camera for a next-generation, wide-field, ground-based optical and near-infrared 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 astronomical topics 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.

General Plant Projects (GPP) (TEC under $10 million)

(dollars in thousands)

	Total	Prior Years	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Liquid Argon Test Facility	6,583	69	4,347	—	2,167
MC-1 Building	9,000	0	500	—	1,000
Muon Campus Beamline Enclosure	9,700	0	0	—	3,700
Other projects under $5 million TEC	n/a	n/a	2,628	—	7,681
Total, General Plant Projects (GPP)			7,475	—	14,548

Accelerator Improvement Projects (AIP)

(dollars in thousands)

	Total	Prior Years	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Muon Campus Cryogenics	8,800	0	0	—	4,200
Recycler RF Upgrades	8,100	0	0	—	1,000
Other projects under $5 million TEC	n/a	n/a	0	—	1,000
Total, AIP			0	—	6,200

Construction Project Summary

Construction Projects

(dollars in thousands)

	Total	Prior Years	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Long Baseline Neutrino Experiment					
TEC	TBD	0	4,000	4,025	0
OPC	TBD	34,434	17,000	—	10,000
TPC	TBD	34,434	21,000	—	10,000
Muon to Electron Conversion Experiment					
TEC	223,000	0	24,000	24,147	35,000
OPC	26,177	13,177	8,000	8,049	0
TPC	249,177	13,177	32,000	32,196[a]	35,000
Total, Construction					
TEC			28,000	28,172	35,000
OPC			25,000	—	10,000
TPC			53,000	—	45,000

Construction Project Outyears

(dollars in thousands)

	FY 2015	FY 2016	FY 2017	FY 2018	Outyears to Completion
Muon to Electron Conversion Experiment					
TEC/TPC	32,000	44,000	45,000	23,000	0

[a] The FY 2013 amount shown reflects the P.L. 112-175 continuing resolution level annualized to a full year. The TEC, OPC, and TPC total and outyear appropriation assumptions have not been adjusted to reflect the final FY 2013 level; the FY 2013 Request level of $25,000,000 ($20,000,000 TEC and $5,000,000 OPC) is assumed instead.

Other Supporting Information

Funding Summary

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Research	391,329	—	383,609
Facilities Operations			
Scientific User Facilities Operations	201,921	—	226,812
Other Facilities	45,788	—	43,186
Total, Facilities Operations	247,709	—	269,998
Projects			
Major Items of Equipment	55,770	—	39,000
Other Projects	21,193	—	15,894
Construction[a]	53,000	—	45,000
Total, Projects	129,963	—	99,894
Other	1,532	—	23,020
Total, High Energy Physics	770,533	—	776,521

Scientific User Facility Operations

	(dollars in thousands)		
	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request
Fermilab Accelerator Complex	119,544	—	156,438
FACET	7,500	—	9,000
B-Factory	10,031	—	4,600
LHC Detector Support and Operations	64,846	—	56,774
Total, Scientific User Facilities Operations	201,921	—	226,812

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

Facilities Users and Hours

	FY 2012 Actual	FY 2013 Annualized CR Estimate	FY 2014 Request Estimate
Fermilab Accelerator Complex[a]			
Achieved operating hours	4,236	—	N/A
Planned operating hours	2,650	—	4,500
Optimal hours (estimated)	2,650	—	4,500
Percent of optimal hours	159.8%	—	100%
Unscheduled downtime percentage	N/A	—	N/A
Total number of users	1,400	—	1,400
FACET			
Achieved operating hours	2,363	—	N/A
Planned operating hours	2,380	—	2,800
Optimal hours (estimated)	2,800	—	2,800
Percent of optimal hours	84.4%	—	100%
Unscheduled downtime percentage	N/A	—	N/A
Total number of users	48	—	48
B-Factory			
Total number of users	200	—	100
Total Facilities			
Achieved operating hours	6,599	—	N/A
Planned operating hours	5,030	—	7,300
Optimal hours (estimated)	5,450	—	7,300
Percent of optimal hours (funding weighted)	155.4%	—	100%
Unscheduled downtime percentage	N/A	—	N/A
Total number of users	1,648	—	1,548

[a] Only NuMI runs FY 2012 and beyond.

Scientific Employment

	FY 2012 Actual	FY 2013 Estimate	FY 2014 Estimate
Number of university grants	225	—	280
Number of laboratory groups	45	—	40
Number of permanent Ph.D.'s (FTEs)	1,045	—	955
Number of postdoctoral associates (FTEs)	450	—	410
Number of graduate students (FTEs)	555	—	490
Number of Ph.D.'s awarded	105	—	105

High Energy Physics
Funding Profile by Subprogram and Activity

Non-Comparable Structure[a]

	(dollars in thousands)	
	FY 2012 Current	FY 2014 Request
Proton Accelerator-Based Physics		
Research	126,562	0
Facilities	296,170	0
Total, Proton Accelerator-Based Physics	422,732	0
Electron Accelerator-Based Physics		
Research	10,816	0
Facilities	11,061	0
Total, Electron Accelerator-Based Physics	21,877	0
Non-Accelerator Physics		
Research	70,000	0
Projects	13,393	0
Total, Non-Accelerator Physics	83,393	0
Theoretical Physics		
Research		
Grants Research	27,746	0
National Laboratory Research	24,720	0
Computational HEP	11,036	0
Other	3,463	0
Total, Theoretical Physics	66,965	0
Advanced Technology R&D		
Accelerator Science	42,459	0
Accelerator Development	76,968	0
Other Technology R&D	28,139	0
Total, Advanced Technology R&D	147,566	0

[a] The Office of Science received OMB and Congressional approval to restructure the High Energy Physics program. The execution initiated in FY 2013; the FY 2014 Budget Request is the initial presentation. The restructure aligns with the long-range plan developed by the HEPAP subpanel, Particle Physics Project Prioritization Panel, in their report *U.S. Particle Physics: Scientific Opportunities A Strategic Plan for the Next Ten Years*.

	(dollars in thousands)	
	FY 2012 Current	FY 2014 Request
Energy Frontier Experimental Physics		
Research	0	96,129
Facility Operations and Experimental Support	0	58,558
Total, Energy Frontier Experimental Physics	0	154,687
Intensity Frontier Experimental Physics		
Research	0	53,562
Facility Operations and Experimental Support	0	180,481
Projects	0	37,000
Total, Intensity Frontier Experimental Physics	0	271,043
Cosmic Frontier Experimental Physics		
Research	0	62,364
Facility Operations and Experimental Support	0	12,022
Projects	0	24,694
Total, Cosmic Frontier Experimental Physics	0	99,080
Theoretical and Computational Physics		
Research		
Theory	0	51,196
Computational HEP	0	8,474
Total, Research	0	59,670
Projects	0	3,200
Total, Theoretical and Computational Physics	0	62,870
Advanced Technology R&D		
Research		
HEP General Accelerator R&D	0	57,856
HEP Directed Accelerator R&D	0	23,500
Detector R&D	0	23,947
Total, Research	0	105,303
Facility Operations and Experimental Support	0	17,150
Total, Advanced Technology R&D	0	122,453
Accelerator Stewardship		
Research	0	6,581
Facility Operations and Experimental Support	0	3,350

	(dollars in thousands)	
	FY 2012 Current	FY 2014 Request
Total, Accelerator Stewardship	0	9,931
SBIR/STTR	0	21,457
Subtotal, High Energy Physics	742,533	741,521
Construction		
Long Baseline Neutrino Experiment	4,000	0
Muon to Electron Conversion Experiment	24,000	35,000
Total, Construction	28,000	35,000
Total, High Energy Physics[a]	770,533	776,521

[a] SBIR/STTR funding:

- FY 2012 Appropriation: SBIR $17,915,000 and STTR $2,412,000 (transferred out of HEP in FY 2012 Current column)
- FY 2014 Request: SBIR $18,775,000 and STTR $2,682,000

11-SC-41, Muon to Electron Conversion Experiment (Mu2e), Fermi National Accelerator Laboratory, Batavia, Illinois Project Data Sheet (PED and Construction)

1. Summary and 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 has been assigned to this project.

This Project Data Sheet is for PED and construction. It does not include a new start for the Budget Year.

This PDS is an update of the FY 2013 PDS.

The initial cost estimate developed in FY 2011 was deemed too high for proceeding to CD-1, and the project team was charged with developing a scope with a lower cost. The effort was completed successfully and CD-1 was approved on July 11, 2012. The lower-cost scope has one-third the proton beam power which enables a significantly simpler configuration of accelerators and beam lines, eliminates entirely the use of the Fermilab Accumulator Ring and permits the Accumulator Ring's existing electromagnets to be reused elsewhere at great cost savings for the project, and significantly reduces the amount of concrete shielding necessary for radiation protection.

This budget Request supports the continuation of the preliminary engineering design phase for setting the project performance baseline (with CD-2) during FY 2014. Critical Decision CD-3A is planned for initiating advance procurements in FY 2014 consisting of superconducting solenoid magnet conductor, solenoid prototypes and site preparation work, using construction and/or PED funds.

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

(fiscal quarter or date)

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

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

[a] Schedule estimates are preliminary, based on CD-1, since this project has not received CD-2 approval.

3. Baseline and Validation Status

(dollars in thousands)

	TEC, PED	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[a]	162,000	223,000	26,177	0	26,177	249,177[a b]

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] The TEC, PED and TPC totals reflect funding through FY 2012 and the FY 2013 Request level, plus planned amounts in FY 2014. These totals and the project schedule will be reviewed and revised as necessary after FY 2013 funding is finalized.
[b] This project has not received CD-2 approval. No construction, excluding long-lead procurement, will be performed until the project performance baseline has been validated and CD-3 has been approved.

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
PED			
FY 2012	24,000	24,000	0
FY 2013	24,147[a]	20,000[b]	20,000
FY 2014	15,000	15,000	20,000
FY 2015	2,000	2,000	21,000
Total, PED	61,000	61,000	61,000
Construction			
FY 2014	20,000[c]	20,000	6,000
FY 2015	30,000	30,000	20,000
FY 2016	44,000	44,000	35,000
FY 2017	45,000	45,000	35,000
FY 2018	23,000	23,000	30,000
FY 2019	0	0	21,000
FY 2020	0	0	10,000
FY 2021	0	0	5,000
Total, Construction	162,000	162,000	162,000

[a] The FY 2013 amount shown reflects the P.L. 112-175 continuing resolution level annualized to a full year. The TEC, OPC and TPC total and outyear appropriation assumptions have not been adjusted to reflect the final FY 2013 level; the FY 2013 Request level of $25,000,000 ($20,000,000 TEC and $5,000,000 OPC) is assumed instead.
[b] The FY 2013 amount reflects the FY 2013 Request level and does not reflect the final FY 2013 level.
[c] $20,000,000 is requested for long lead procurements for the superconducting magnet systems and civil construction.

(dollars in thousands)

	Appropriations	Obligations	Costs
TEC			
FY 2012	24,000	24,000	0
FY 2013	24,147[a]	20,000[b]	20,000
FY 2014	35,000	35,000	26,000
FY 2015	32,000	32,000	41,000
FY 2016	44,000	44,000	35,000
FY 2017	45,000	45,000	35,000
FY 2018	23,000	23,000	30,000
FY 2019	0	0	21,000
FY 2020	0	0	10,000
FY 2021	0	0	5,000
Total, TEC	223,000	223,000	223,000
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	8,049[a]	5,000[b]	6,728
Total, OPC	26,177	26,177	26,177

[a] The FY 2013 amount shown reflects the P.L. 112-175 continuing resolution level annualized to a full year. The TEC, OPC and TPC total and outyear appropriation assumptions have not been adjusted to reflect the final FY 2013 level; the FY 2013 Request level of $25,000,000 ($20,000,000 TEC and $5,000,000 OPC) is assumed instead.
[b] The FY 2013 amount reflects the FY 2013 Request level and does not reflect the final FY 2013 level.

(dollars in thousands)

	Appropriations	Obligations	Costs
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	32,196[a]	25,000[b]	26,728
FY 2014	35,000	35,000	26,000
FY 2015	32,000	32,000	41,000
FY 2016	44,000	44,000	35,000
FY 2017	45,000	45,000	35,000
FY 2018	23,000	23,000	30,000
FY 2019	0	0	21,000
FY 2020	0	0	10,000
FY 2021	0	0	5,000
Total, TPC	249,177[c]	249,177	249,177

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
PED			
Design	40,000	31,000	N/A
Contingency	21,000	13,000	N/A
Total, PED	61,000	44,000	N/A

[a] The FY 2013 amount shown reflects the P.L. 112-175 continuing resolution level annualized to a full year. TheTEC, OPC and TPC total and outyear appropriation assumptions have not been adjusted to reflect the final FY 2013 level; the FY 2013 Request level of $25,000,000 ($20,000,000 TEC and $5,000,000 OPC) is assumed instead.

[b] The FY 2013 amount reflects the FY 2013 Request level and does not reflect the final FY 2013 level.

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

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Construction			
Site Work	2,000	N/A	N/A
Construction	17,000	N/A	N/A
Equipment	99,000	N/A	N/A
Contingency	44,000	N/A	N/A
Total, Construction	162,000	N/A	N/A
Total, TEC	223,000	44,000	N/A
Contingency, TEC	65,000	13,000	N/A
Other Project Cost (OPC)			
OPC except D&D			
R&D	2,500	150	N/A
Conceptual Planning	4,350	7,750	N/A
Conceptual Design	12,727	12,000	N/A
Contingency	6,600	4,277	N/A
Total, OPC	26,177	24,177	N/A
Contingency, OPC	6,600	4,277	N/A
Total, TPC	249,177	68,177	N/A
Total, Contingency	71,600	17,277	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

Request Year		Prior Years	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	Total
		(dollars in thousands)								
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[a]	35,000	32,000	44,000	45,000	23,000	249,177

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)

(dollars in thousands)

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

[a] The FY 2013 amount shown reflects the P.L. 112-175 continuing resolution level annualized to a full year. The TEC, OPC and TPC total and outyear appropriation assumptions have not been adjusted to reflect the final FY 2013 level; the FY 2013 Request level of $25,000,000 ($20,000,000 TEC and $5,000,000 OPC) is assumed instead.

9. Required D&D Information

Area	Square Feet
Area of new construction	Approximately 25,000 SF
Area of existing facilities being replaced	N/A
Area of any additional space that will require D&D to meet the "one-for-one" requirement	N/A (see below)

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 sufficient excess space to accommodate the new Mu2e 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 Fermilab. Fermilab 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.