High Energy Physics
Funding Profile by Subprogram with Activity

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Proton Accelerator-Based Physics			
Research	135,128	122,894	125,394
Facilities	303,727	298,700	286,138
Total, Proton Accelerator-Based Physics	438,855	421,594	411,532
Electron Accelerator-Based Physics			
Research	14,645	12,550	13,946
Facilities	9,809	10,475	15,200
Total, Electron Accelerator-Based Physics	24,454	23,025	29,146
Non-Accelerator Physics			
Research	70,355	69,562	70,962
Projects	19,712	14,500	26,463
Total, Non-Accelerator Physics	90,067	84,062	97,425
Theoretical Physics			
Research			
Grants Research	27,423	28,222	29,072
National Laboratory Research	25,638	23,778	24,501
Computational HEP	10,842	10,963	10,963
Other	4,147	3,887	3,986
Total, Theoretical Physics	68,050	66,850	68,522
Advanced Technology R&D			
Accelerator Science	42,104	44,150	46,850
Accelerator Development	86,801	75,400	52,600
Other Technology R&D	25,247	27,739	29,856
SBIR/STTR	0	20,040	20,590
Total, Advanced Technology R&D	154,152	167,329	149,896
Subtotal, High Energy Physics	775,578	762,860	756,521

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Construction			
Long Baseline Neutrino Experiment	0	4,000	0
Muon to Electron Conversion Experiment	0	24,000	20,000
Total, Construction	0	28,000	20,000
Total, High Energy Physics	775,578[a]	790,860[b]	776,521

[a] Total is reduced by $19,842,000: $17,716,000 of which was transferred to the Small Business Innovation and Research (SBIR) program and $2,126,000 of which was transferred to the Small Business Technology Transfer (STTR) program.
[b] The FY 2012 appropriation is reduced by $840,000 for the High Energy Physics share of the DOE-wide $73,300,000 rescission for contractor pay freeze savings. The FY 2013 budget request reflects the FY 2013 impact of the contractor pay freeze.

Public Law Authorizations

Public Law 95–91, “Department of Energy Organization Act”, 1977
Public Law 109–58, “Energy Policy Act of 2005”
Public Law 110–69, “America COMPETES Act of 2007”
Public Law 111–358, “America COMPETES Act of 2010”

Program Overview and Benefits

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.

At the same time, the new technologies created to answer the questions that high energy physicists seek to answer, and the knowledge acquired in their pursuit, also yield substantial benefits of a more tangible nature for society as a whole. The discovery of x-rays was driven not by surgeons in search of a better way to diagnose bone fractures but by scientists 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. The remaining 95% of the universe consists of “dark” matter and energy whose fundamental nature 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 new particles, revealing their interactions, and investigating fundamental forces;
- *The Intensity Frontier,* investigating fundamental forces and particle interactions by studying events that rarely occur in nature; and
- *The Cosmic Frontier,* making measurements offering new insight and information about the nature of dark matter and dark energy to understand fundamental particle properties and discover new phenomena.

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

- *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, relates particles and forces. It 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.

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

  The structure of the universe today is a result of two opposing forces: gravitational attraction and cosmic expansion. 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. The existence of dark energy was first proposed in 1998 to explain observations made by HEP-supported researchers (among others). More and other types of data, gathered from the Cosmic Frontier, along with new theoretical ideas, are necessary to make progress in understanding its fundamental nature.

- *Are there extra dimensions of space?*

  String theory is an attempt to unify physics by explaining particles and forces as the vibrations of sub-microscopic strings. String theory predicts that space has more than three dimensions, although the extra ones are too small to be observed directly. Experiments at the Energy Frontier may find evidence for extra dimensions, requiring a completely new paradigm for thinking about the structure of space and time.

- *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.

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

  Three different pairings, or families, of quarks and leptons have been discovered. Does nature somehow 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.

- *What is dark matter?*

  Astronomical data suggest that most matter in the universe is unseen. We know of its existence only through its gravitational interactions with normal matter. This dark matter is thought to consist of exotic particles (relics) that have survived since the Big Bang. Experiments are being mounted to try to directly detect these exotic particles via observations of relic dark matter at the Cosmic Frontier or by producing them at Energy Frontier accelerators that briefly recreate the conditions of the Big Bang.

- *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. 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.

- *How did the present universe come to be?*

  The universe began with a massive explosion known as the Big Bang followed by a burst of expansion of space itself. The universe then expanded more slowly and cooled, which allowed the formation of stars, galaxies, and ultimately life. Understanding the very early evolution of the universe will require a breakthrough in physics: the theoretical reconciliation of quantum mechanics with gravity.

- *What happened to the antimatter?*

  The universe 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. Precise Intensity Frontier measurements of the subtle asymmetries present in the weak nuclear interaction may shed light on how the present day matter-antimatter asymmetry arose.

The strong connections between these key questions necessitates coordinated initiatives across the frontiers. HEP invents new technologies 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, have 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 the knowledge and technologies that are the basis of 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 Basic Energy Sciences (BES) and Nuclear Physics (NP) programs and will expand its coordination role in FY 2013.

HEP's ongoing and future development of accelerator, detector, electronics, and magnet technologies is anticipated to have significant impact in a number of areas:

- homeland and national security—particle accelerators and detectors are increasingly valuable for hazardous material detection and non-proliferation verification;
- industry—superconducting cables being developed for next generation magnets could be used to transmit, with minimal power losses, far more electricity than conventional cables;
- internet grid development—development of grid capability for analysis of Large Hadron Collider (LHC) data may result in a paradigm change in the handling of huge data sets; and
- medical treatment and diagnosis—more cost-efficient particle accelerators, detectors, and magnets for cancer treatment and diagnosis should emerge.

Basic and Applied R&D Coordination

Many broader applications of technology developed by HEP research have been unforeseen. In order to obtain guidance on how to better bridge the gap between accelerator research and technology deployment, HEP held an "Accelerators for America's Future" symposium in October 2009, followed by a two-day workshop where more than 100 experts familiar with accelerator needs and requirements met to identify technological and policy issues that, if overcome, could have transformative impacts in the areas of national security, medicine, energy and environment, industry, and discovery science (including accelerator science).

The report from this workshop[a] identifies possible future applications of accelerators, as well as key technical areas where focused additional R&D efforts as well as dedicated user and demonstration facilities would advance the broad beneficial uses of accelerators in society. HEP will use the workshop report to develop a strategic plan for accelerator technology R&D in collaboration with BES and NP that recognizes its broader societal impacts.

Program Accomplishments and Milestones

The Fermi National Accelerator Laboratory (Fermilab) Tevatron Collider completed its Run II at the end of FY 2011. The total integrated luminosity over the 10 year run is 12 inverse femtobarns (fb^{-1}). This large dataset, collected by the Collider Detector at Fermilab (CDF) and D-Zero detectors, was used to measure the top quark mass, make precision measurements of the W and Z bosons, exclude portions of allowed mass range for Higgs Boson, discover new particles containing b quarks, study the decay properties of B mesons, and study the properties of quantum chromodynamics.

The LHC luminosity increased by an order of magnitude in 2011 and the experiments at the LHC produced a flood of results with over 100 papers published already. These results included strong limits on the allowed mass range for the Higgs boson—with possible hints of where the Standard Model Higgs may be hiding—and limits on the

[a] http://www.acceleratorsamerica.org

masses of supersymmetric particles that are substantially better than those from the Tevatron. U.S. researchers at home and abroad have leading roles in the operations of the detectors and the LHC data analyses.

The Alpha Magnetic Spectrometer was launched into space on the Space Shuttle in May 2011 and is successfully taking data. In China, the first four Reactor Neutrino Experiment detectors are installed and taking data. Other neutrino experiments in Europe and Japan reported initial measurements of the remaining unknown neutrino mixing angle which indicate this mixing is large; these exciting preliminary results are being followed up by reactor experiments as well as the accelerator-based neutrino experiments at Fermilab. Other recent interesting but controversial neutrino results (such as "faster-than-light" neutrinos) are also being cross-checked by Fermilab experiments.

Milestone	Date
First light for the Dark Energy Camera	September 2012
Shutdown of the Fermilab accelerator complex for installation of the NOvA Accelerator Upgrades: These upgrades will raise the beam power available for NuMI beam from 320 kilowatts to 700 kilowatts	3rd Quarter, FY 2012

Explanation of Changes

In the FY 2013 request, funds are shifted from proton facility operations and advanced technology R&D to support the planned funding profile for Muon to Electron Conversion Experiment (Mu2e), to conduct R&D targeted for future intensity and cosmic frontier projects, and to maintain the level-of-effort in HEP research. No construction funds are requested for the Long Baseline Neutrino Experiment (LBNE). Capital equipment funding is requested for two new major items of equipment (MIEs): 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.

Program Planning and Management

To ensure that resources are allocated to the most scientifically promising experiments, DOE actively seeks external input using a variety of advisory bodies. The High Energy Physics Advisory Panel (HEPAP), jointly chartered by DOE and the National Science Foundation (NSF), 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] (June 2008) 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 2013 are consistent with this 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 and Astrophysics Advisory Committee (AAAC) reports on a continuing basis to DOE, NSF, and NASA with advice on the direction and management of the national astronomy and astrophysics research programs. 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.

For the HEP research programs, 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 third HEP COV review took place in fall 2010.

[a] http://go.usa.gov/Xgf

[b] http://www.nap.edu/catalog.php?record_id=12951

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 the 2007 COV, HEP implemented a new review process for high energy physics research and basic technology R&D efforts at 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 FY 2013, HEP plans to review the Electron Accelerator Based Research and Non Accelerator Based Research subprograms. Laboratory proposals involving significant new research scope are also subject to peer-review by external experts on an ad hoc basis.

Program Goals and Funding

HEP balances the scientific priorities of the research community with the constraints of the facilities, tools, and resources available. Research facilities for high energy physics generally require significant investments over many years and the coordinated efforts of international teams of scientists and engineers to realize accelerators and detectors that push the frontiers of energy, intensity, and cosmic exploration.

HEP, with input from the scientific community, has developed a long-range plan which maintains a leadership role for the U.S. within this global context. The plan shifts focus from the operation of the facilities built in the 1990s to the design and construction of new research facilities and instruments, while maintaining a world-leading scientific program and supporting advanced technology R&D for the future. This strategic plan positions the Nation to play a role at all three frontiers of particle physics. Proposed FY 2013 investments will develop capabilities for future accelerator-based experimental research facilities.

The Energy Frontier: The Tevatron Collider at Fermilab completed operations in 2011. Its record-breaking performance in data delivery resulted in a dataset that will continue to be mined for significant discoveries during the first few years of Large Hadron Collider (LHC) operations at CERN. In FY 2013, HEP will support the needs of researchers to continue to exploit the Tevatron data. HEP's primary scientific goals over the next five years are to enable such discoveries—for example, the Higgs boson and supersymmetric particles—either from Tevatron data or LHC data now being acquired, by supporting the best researchers working in this area. No new Energy Frontier facility investments are anticipated until plans for LHC upgrades are decided.

First beam collisions at the LHC occurred in November 2009. The first run of the LHC is currently planned to end in late 2012 with a dataset comparable in size to the entire Tevatron Collider run. After a year-long consolidation and maintenance period, it is planned to resume running at its design energy (14 TeV center of mass). In FY 2013, HEP will provide support for LHC detector operations, maintenance, computing, and R&D necessary to maintain a significant U.S. role in the LHC program, including the operations of large U.S. data centers for the two major LHC experiments. CERN may delay the shutdown and extend the run into 2013 if it is warranted by the emergence of new physics as the data are analyzed.

The Intensity Frontier: The Neutrinos at the Main Injector (NuMI) beamline at Fermilab will operate in its current configuration through mid-FY 2012 for ongoing neutrino experiments and then will shut down for a year-long upgrade to enhance the beam power from approximately 400 to 700 kW for the NuMI Off-Axis Neutrino Appearance (NOvA) experiment. The NOvA project, currently under fabrication, will be in full operation in 2014 to enable key measurements of neutrino properties. In FY 2012, engineering and design funding is provided for the Long Baseline Neutrino Experiment (LBNE) and the Muon to Electron Conversion Experiment (Mu2e).

The HEP program has been developing the 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. Since DOE would now be responsible for the full development, operation, and maintenance of the Homestake site, the estimated costs associated with the LBNE far detector have risen significantly. The Office of Science is undertaking a thorough review of the costs and alternatives to LBNE and expects to make decisions concerning a future intensity frontier project in 2012.

During FY 2012, High Energy Physics will support activities for minimal, sustaining operations at the Homestake mine in South Dakota while completing existing experiments at Homestake. HEP is requesting continued funding for these maintenance activities in FY 2013. The Nuclear Physics program provides additional funding in FY 2012 only.

The Cosmic Frontier: HEP is coordinating its program of world class space-based and ground-based particle astrophysics experiments and observatories for exploration of the Cosmic Frontier with NASA and NSF. The effects of dark energy and dark matter were both first discovered in astronomical observations, but most of the proposed causes of these effects are due to the properties of elementary particles or fields, and this has drawn the interest of particle physicists. They have brought new instrumentation and data handling techniques from high energy physics to astronomy and particle astrophysics to support these studies of dark matter and dark energy.

In FY 2013, funding supports existing and ongoing endeavors studying cosmic rays, gamma rays, dark energy and searching for dark matter. Looking to the future, HEP has utilized HEPAP guidance and the Astro2010 report on scientific priorities to mount a U.S. program that will advance our understanding of dark matter and dark energy. HEP is collaborating with NSF on a staged program of research and technology development and experiments designed to directly detect dark matter particles using ultra-sensitive detectors located underground. HEP is also working with NSF on implementing the Large Synoptic Survey Telescope (LSST) for studies of dark energy using a new ground-based telescope facility. The FY 2013 request supports a ramp up of engineering and design efforts for the camera for LSST (LSSTcam) as well as R&D and scientific studies for dark matter experiments and other possible future initiatives.

Office 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 maximal data to the user community, while carrying out a maintenance and improvement program that will keep the facility productive well into the future.
- *Future Facilities*: Develop new facilities and instrumentation for the 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.

Goal Areas by Subprogram

	Research	Facility Operations	Future Facilities	Workforce
Proton Accelerator-Based Physics	30%	55%	15%	0%
Electron Accelerator-Based Physics	50%	30%	20%	0%
Non-Accelerator Physics	75%	0%	25%	0%
Theoretical Physics	100%	0%	0%	0%
Advanced Technology R&D	100%	0%	0%	0%
Construction	0%	0%	100%	0%
Total, High Energy Physics	55%	30%	15%	0%

Explanation of Funding and Program Changes

(Dollars in Thousands)

	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Proton Accelerator-Based Physics	421,594	411,532	-10,062
The end of Tevatron Collider running in September 2011 and planned shutdown to install neutrino beamline upgrades in 2013 drive the changes in Proton Accelerator-Based Physics.			
Electron Accelerator-Based Physics	23,025	29,146	+6,121
The beginning of the U.S. contribution to the Belle-II detector upgrade as an MIE accounts for the funding increase for Electron Accelerator-Based Physics.			
Non-Accelerator Physics	84,062	97,425	+13,363
Engineering and design efforts ramp up for the Large Synoptic Survey Telescope camera project and R&D funding for next-generation dark matter experiments are the major drivers of the increase in this subprogram.			
Theoretical Physics	66,850	68,522	+1,672
Funding is approximately constant with Computational HEP and theory research increases slightly.			
Advanced Technology R&D	167,329	149,896	-17,433
The International Linear Collider (ILC) R&D program is completed in calendar year 2012, which is the driver for the significant decrease in this funding category.			
Construction	28,000	20,000	-8,000
Project Engineering and Design (PED) funding continues for the Muon to Electron Conversion Experiment according to the planned profile. No PED funding is requested in FY 2013 for the Long Baseline Neutrino Experiment. HEP will assess costs, scientific priorities, and capabilities in the intensity frontier.			
Total, High Energy Physics	790,860	776,521	-14,339

Proton Accelerator-Based Physics
Funding Profile by Activity

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Research	135,128	122,894	125,394
Facilities	303,727	298,700	286,138
Total, Proton Accelerator-Based Physics	438,855	421,594	411,532

Overview

The Proton Accelerator-Based Physics subprogram exploits the application of proton accelerators at two of the primary scientific frontiers of High Energy Physics:

- At the Energy Frontier, LHC experiments will be used to determine whether the Standard Model correctly predicts the mechanism that generates mass for all fundamental particles and will search for the first clear evidence of new physics beyond the Standard Model.
- At the Intensity Frontier, experiments using the beams from Fermilab and the Japanese proton accelerator facility, Japan Proton Accelerator Research Complex (J-PARC), will make precise, controlled measurements of basic neutrino properties and will provide important clues and constraints on the new world of matter and energy beyond the Standard Model.

The Energy Frontier activity supports LHC research and analysis of legacy data from the Tevatron experiments at Fermilab with the aim of determining whether the Standard Model is a correct description of the natural world. In addition, research carried out at universities and national laboratories will either find evidence of new physics beyond the Standard Model or significantly constrain current models of Supersymmetry, black hole production, extra dimensions, and other exotic phenomena. LHC hosts two large multipurpose particle detectors that are fabricated, maintained and operated by scientific collaborations of hundreds to thousands of research scientists who analyze the data and publish their results. Results from multiple experiments are often combined as appropriate to improve the statistical significance of the results.

The Intensity Frontier program in proton accelerator-based research utilizes multiple experimental approaches to understand new physics associated with fundamental questions about neutrino properties, the predominance of matter in the universe, and why there are so many kinds of “fundamental” particles. This program includes a series of neutrino experiments that measure neutrino oscillations with increasing precision and different experimental approaches (Main Injector Neutrino Oscillation Search [MINOS], Tokai to Kamioka [T2K], and NuMI Off-Axis Electron Neutrino Appearance [NovA]); neutrino interaction cross-sections in different energy ranges and various detector technologies (MiniBooNE, Main Injector Experiment v-A [MINERvA], and MicroBooNE); precision measurements of rare decay processes involving muons (the proposed g-2 and Mu2e) and kaons (K0TO) that provide opportunities to discover new phenomena. These are typically smaller experiments, with tens to a few hundred scientists collaborating, that are optimized to make a small number of key measurements. One unifying theme that connects these diverse experiments is they all require intense particle beams to search for processes that occur rarely in nature.

Explanation of Funding Changes

In FY 2013, analysis of legacy Tevatron data will continue, although at a reduced level. Most Tevatron research efforts will be re-directed to either the LHC or the Intensity Frontier. Research activities at the Energy Frontier in FY 2013 will primarily be focused on the LHC. Operation and data taking of the NOvA experiment commence in 2013. The MicroBooNE experiment completes its project funding in 2013.

	(Dollars in Thousands)		
	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Research	122,894	125,394	+2,500
Overall funding for the research program at universities and national laboratories is maintained at approximately the FY 2012 level of effort.			
Facilities	298,700	286,138	-12,562
In FY 2013, the Fermilab accelerator complex will be shut down for approximately half the year while the accelerator upgrades for the NOvA project will be completed. There will be a three month commissioning period followed by a three month run to support the neutrino program including the first data-taking with the partially completed NOvA detector.			
Total, Proton Accelerator-Based Physics	421,594	411,532	-10,062

Research

Overview

The grant-based HEP experimental research program at the Energy Frontier consists of groups at over 60 institutions performing experiments at proton accelerator facilities. Intensity Frontier research supports about 30 university-based groups. Grant-supported scientists typically constitute about 50–75% of the personnel needed to create, run, and analyze an experiment, and they usually work in collaboration with other university and laboratory groups. Grant-based research efforts are selected based on peer review. The detailed funding allocations will take into account the quality and scientific priority of the research proposed.

Proton Accelerator-Based Physics research also supports physicists from 5 national laboratories (Argonne, Berkeley Brookhaven, Fermi, and SLAC) for Energy Frontier and the Intensity Frontier. These can be large groups that also have significant responsibilities for detector operations, maintenance, and upgrades, particularly when their laboratory is hosting the experiment. HEP conducted a comparative peer review of laboratory research groups in this subprogram in 2009, and findings from this review were used to inform the funding decisions in subsequent years. HEP will review this subprogram again in 2012 and evaluate progress.

U.S. researchers will continue to play a leadership role in the physics discoveries at the LHC. Achieving this goal 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. These latter efforts are supported under the Facilities activity.

The neutrino program includes several experiments in differing stages of completion. Current neutrino experiments that are expected to complete data taking by 2012 include MINOS and MiniBooNE. The data analysis from MINOS and MiniBooNE will wind down within a few years, and research will be redirected to the next generation of neutrino oscillation experiments. Current experiments that continue operations are MINERvA at Fermilab and T2K in Japan. Experiments in the fabrication and commissioning phase are NOvA and MicroBooNE. LBNE is in the conceptual design phase, but as noted above, the Office of Science is carefully reviewing costs and alternatives before making any critical decisions. Many research groups work on analysis from one or more experiments while also pursuing R&D for future experiments.

Recent results from MINOS and T2K strongly suggest that the remaining—as yet unmeasured—neutrino mixing parameter may be large enough that NOvA will also have unique sensitivity to resolve a number of outstanding questions in the neutrino sector.

The Intensity Frontier also includes support for research on properties of muons. Two experiments are currently planned: the Muon to Electron Conversion Experiment and the measurement of the muon anomalous magnetic moment, also called muon g-2. These use precision measurements to probe new physics beyond the Standard Model.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
2011 Current	Research funding for Proton Accelerator-based physics was dominated by the Energy Frontier of the Tevatron and the LHC. The remaining activities were Intensity Frontier experiments in neutrino physics such as the MINOS, MINERvA, and MiniBooNE experiments at Fermilab.	135,128
2012 Enacted	Grant and laboratory energy frontier research funding are reduced in order to accommodate the expected ramp-down of Tevatron research and a redirection to Intensity Frontier research. High-priority data analysis efforts in the Tevatron Collider program will be maintained but there will be reductions in the broader Tevatron research effort, while remaining scientific staff will refocus efforts from detector operations to data analysis.	122,894

Fiscal Year	Activity	Funding ($000)
2013 Request	A further reduction in Tevatron research is planned, reflecting completion of several precision measurements and legacy searches for new physics; this is offset by continued investments in the Intensity Frontier. Within this activity, the priority efforts in FY 2013 will be in support of LHC research and growth of a strong neutrino physics program. 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. U.S. university and laboratory scientists will also participate in the maintenance and preparation for high energy and high intensity running of components built in the United States. Initial NOvA data taking (with a partially completed detector) begins. Support for the accelerator-based research in the Intensity Frontier program is also a high priority.	125,394

(dollars in thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Grants Research	57,505	61,584	62,834
National Laboratory Research	74,811	61,225	62,475
University Service Accounts	2,812	85	85
Total, Research	135,128	122,894	125,394

Facilities

Overview

The Proton Accelerator-Based Physics Facilities activity supports the operation of the Fermilab accelerator complex and experiments that utilize it, as well as research and development to improve the operation of the complex. The complex currently operates two neutrino beams with different energies needed for different experiments: the Booster neutrino beam using 8 GeV protons from the Booster accelerator to make neutrinos and the Neutrinos at the Main Injector (NuMI) beam using 120 GeV protons from the Main Injector to make neutrinos. Major Items of Equipment that will utilize the Fermilab accelerator complex are also included, which currently are NOvA and MicroBooNE.

The LHC Operations program is also funded in this activity. It supports the maintenance of U.S. supplied detector systems for the Compact Muon Solenoid (CMS) and A Toroidal LHC ApparatuS (ATLAS) detectors at the LHC and the U.S. based computer infrastructure for the analysis of LHC data by U.S. physicists, including Tier 1 computing centers at Fermilab and Brookhaven National Laboratory.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
2011 Current	The Tevatron and the neutrino program both operated for 5,400 hours (44 weeks) in FY 2011. This was the last year of operations for the Tevatron. The LHC operations program continues. HEP prepositioned $500,000 to support minimal, sustaining operations awaiting the final FY 2012 appropriation for DOE-supported activities at the Homestake mine in South Dakota; the funding was used for this purpose after passage of the appropriation.	303,727
2012 Enacted	The accelerator complex will run for 2,650 hours (22 weeks) for the neutrino program and then shut down for the installation of the accelerator upgrade portion of the NOvA project. This will raise the beam power delivered to the NuMI neutrino production target from 400 kilowatts to 700 kilowatts. The LHC operations program is held constant. The Other Facilities category is increased to support pumping water from the Homestake mine to preserve the investments there in the Lux dark matter and Majorana demonstrator experiments, while the Office of Science determines if it can be used for its own initiatives in underground Science, including neutrino physics and dark matter searches. $9,500,000 is provided by the High Energy Physics program; an additional $4,500,000 is provided from the Nuclear Physics program. The National Science Foundation funded dewatering activities in FY 2011 and the first quarter of FY 2012.	298,700
2013 Request	The shutdown for the installation of the accelerator upgrade portion of the NOvA project continues. The complex will be restarted in the middle of the year with 12 weeks planned for commissioning and run for 2,400 hours (20 weeks) for the neutrino program. Final funding for the NOvA MIE and the MicroBooNE MIE is provided. A portion of the NOvA detector will begin operations, while the remainder is installed. Capital equipment funding in Proton Accelerator Complex Support is increased to carry out refurbishment of the Booster accelerator, which is the oldest portion of the complex dating back to the early 1970s. General plant project funding is increased for a new experimental hall to house experiments utilizing muon beams.	286,138

Fiscal Year	Activity	Funding ($000)

The State of Illinois has provided a grant to construct a new building at Fermilab that will bring together the diverse strengths of the laboratory in accelerator R&D and related technology developments, and enable closer ties with industry and other partners who benefit from broader applications of accelerator technology. HEP is supporting refurbishment of existing laboratory space using facilities infrastructure funding that will abut the new building and provide excellent work space to enable larger-scale R&D efforts.

Funding is increased for future Intensity Frontier facilities and experiments, in response to the many scientific opportunities identified by the HEP community workshop held in December 2011.

Funding for the LHC operations program is held at approximately the FY 2012 level.

Funding for de-watering and minimal operations of the Homestake mine continues ($10,000,000).

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Proton Accelerator Complex Operations	129,910	102,376	107,201
Proton Accelerator Complex Support	14,360	21,865	27,088
Proton Accelerator Facility Projects			
Current Facility Projects	68,388	70,240	40,337
Future Facility R&D	10,700	14,400	18,915
Total, Proton Accelerator Facility Projects	79,088	84,640	59,252
Large Hadron Collider Support			
LHC Accelerator Research	12,350	12,390	12,390
LHC Detector Support	58,804	60,754	61,024
LHC Upgrades	1,500	0	0
Total, Large Hadron Collider Support	72,654	73,144	73,414
Other Facilities	7,715	16,675	19,183
Total, Facilities	303,727	298,700	286,138

Electron Accelerator-Based Physics
Funding Profile by Activity

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Research	14,645	12,550	13,946
Facilities	9,809	10,475	15,200
Total, Electron Accelerator-Based Physics	24,454	23,025	29,146

Overview

The Electron Accelerator-Based Physics subprogram utilizes accelerators with high-intensity and ultra-precise beams to create and investigate matter at its most basic level. In FY 2013, HEP will support U.S. researchers' participation in the Japanese B-Factory at the National Laboratory for High Energy Physics (KEK) and a collaboration of U.S. researchers will be engaged in R&D and fabrication of components for U.S. contributions to an upgrade of the Belle detector at 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 and make it complementary to the Large Hadron Collider (LHC) at CERN.

The SLAC B-Factory completed operations in 2008 and this facility is in a decommissioning and disassembly phase. This effort will increase in FY 2013 as disassembly of the accelerator complex begins.

Explanation of Funding Changes

The "steady analysis" period dedicated to completing the major discovery and analysis topics in the SLAC B-Factory data set comes to an end in FY 2012. The analysis effort will shrink by approximately 50% in FY 2013 and the effort will focus on long term data analysis and data archiving. This decrease is offset by a ramp-up in research and R&D activities associated with U.S. participation in the Japanese B-Factory program.

The decommissioning and decontamination (D&D) of the B-Factory detector will be completed in FY 2013. Components of the detector will be ready for reuse at other facilities or for disposal. The D&D of the B-Factory accelerator will begin in FY 2013 with disassembly of accelerator components and is planned for completion in FY 2017.

Funding for fabrication of the U.S.-supplied components for the upgrade of the Japanese B-Factory detector begins in FY 2013 and is scheduled to complete in FY 2014.

(Dollars in Thousands)

	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Research	12,550	13,946	+1,396

Funding increases for U.S. researchers beginning work on U.S. contributions to the Belle II upgrade at the Japanese KEK facility, offset by the ramp-down of the analysis of the SLAC B-Factory data set, as it begins a smaller archival analysis phase.

	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
	(Dollars in Thousands)		
Facilities	10,475	15,200	+4,725
The MIE fabrication for the U.S. contribution to the Belle detector upgrade at the Japanese B-Factory begins (estimated TPC $12,650,000) and is the major driver of the increase in funding. In FY 2013, the D&D of the SLAC B-Factory detector will be complete and the disassembly of the accelerator complex starts to ramp up.			
Total, Electron Accelerator-Based Physics	23,025	29,146	+6,121

Research

Overview

The research program at the B-Factory/BaBar Facility at SLAC, which is centered on the analysis of the very large data set that has been accumulated over the nine-year operational life of the facility, will continue winding down. Physicists from approximately 20 universities, 3 national laboratories (Berkeley, Livermore, and SLAC), and 7 foreign countries have been actively involved in the data analysis. The research programs at other electron accelerator facilities complement the B-Factory/BaBar efforts and consist of a group of experimental research activities using the KEK-B electron accelerator facilities in Japan (currently supporting 5 university groups) and recently upgraded electron accelerator facilities in China (supporting 6 university groups). There are also small R&D efforts aimed at designing detectors for next-generation off-shore "Super-B factories." HEP is supporting modest participation in the future Japanese Super-B factory upgrades and research program. That effort has begun and a U.S. Belle II collaboration has formed and is being coordinated through the Pacific Northwest National Laboratory (PNNL). Funding for the U.S.-supplied detector components is included as a major item of equipment in this Request (Belle-II, estimated TPC $12,650,000).

The national laboratory research program consists of modest-sized groups participating in experiments at electron accelerator facilities with a physics program similar to the research program described above. Electron accelerator research activities concentrate on experiments at the SLAC B-Factory and the detector upgrade at the Japanese KEK-B facility. HEP conducted a comparative peer review of laboratory research groups in this subprogram in FY 2010 and funding allocations reflect the findings of that review.

A new small scale initiative, the Heavy Photon Search (HPS), is an accelerator-based search experiment that focuses on weakly-coupled, light particles that may explain anomalies seen in some earlier experiments, including connections to Dark Matter. HPS was reviewed favorably in March 2011 and will test equipment at Thomas Jefferson National Accelerator Facility (TJNAF) in the summer of 2012. The scientific collaboration includes university researchers and scientists at SLAC and TJNAF. If the test runs are successful, a full scale search may occur in FY 2014-2015 at TJNAF.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
2011 Current	Research funding for Electron Accelerator-based physics was dominated by data analysis for the BaBar detector. Smaller research efforts on the Japanese Belle detector and the Chinese Beijing Electron Positron Collider (BEPC) program, and R&D for future facilities, were also supported.	14,645
2012 Enacted	Funding continues at a reduced level of effort as BaBar analysis continues to ramp-down. Support is provided to complete the final analysis of physics data from Belle and BaBar. Smaller efforts devoted to operations and data analysis at the Beijing Spectrometer at BEPC will also be supported. Laboratory-based research in this activity continues at a reduced level of effort and will be focused on completing the highest-priority data analysis from BaBar. The research groups at SLAC, as well as the other laboratories, will be in transition as they ramp down activities, complete analyses, and phase into new research activities.	12,550
2013 Request	The research efforts on the BaBar data set will enter their archival analysis phase and will decrease accordingly. Those efforts are anticipated, however, to involve several dozen graduate students and are expected to produce between 20 and 30 publications. The research efforts on the Belle II detector at the Japanese KEK-B facility are expected to grow modestly.	13,946

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Grants Research	5,024	4,754	6,150
National Laboratory Research	9,551	7,738	7,738
University Service Accounts	70	58	58
Total, Research	14,645	12,550	13,946

Facilities

Overview

The SLAC B-Factory completed operations in the spring of 2008. The decommissioning and decontamination (D&D) of the B-Factory detector will be completed in FY 2013. The components of the detector will be ready for reuse at other facilities or for disposal. The D&D of the B-Factory accelerator will begin in FY 2013 and is planned for completion in FY 2017. A small but growing effort on the design and fabrication of the upgraded Belle II detector at the Japanese Super KEK-B facility will be coordinated through the Pacific Northwest National Laboratory (PNNL).

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
2011 Current	The D&D of the BaBar detector began ramping down and planning for the D&D of the PEP-II accelerator continued. Funding included ongoing support for maintenance and operations of computing infrastructure to complete analysis of the very large dataset.	9,809
2012 Enacted	The funding level increases modestly as R&D activities for the Belle detector upgrade ramp-up, offset by the completion of the “steady analysis phase” of the BaBar data set.	10,475
2013 Request	The D&D of the PEP-II accelerator starts to ramp up. The archiving of the BaBar data set begins. The MIE fabrication for the U.S. contribution to the Belle detector upgrade at the Japanese B-Factory begins (estimated TPC $12,650,000) and is the major driver of the increase in funding.	15,200

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Electron Accelerator Complex Operations	8,880	8,925	8,925
Electron Accelerator Complex Support	900	900	275
Electron Accelerator Facility Projects			
Current Facility Projects	0	650	6,000
Future Facility R&D	29	0	0
Total, Electron Accelerator Facility Projects	29	650	6,000
Total, Facilities	9,809	10,475	15,200

Non-Accelerator Physics
Funding Profile by Activity

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Research	70,355	69,562	70,962
Projects	19,712	14,500	26,463
Total, Non-Accelerator Physics	90,067	84,062	97,425

Overview

The Non-Accelerator Physics subprogram provides U.S. leadership in the study of topics in high energy physics that cannot be investigated with accelerators or are best studied by other means. The activities in this subprogram are complementary to accelerator-based research and play an important role in the HEP program, providing experimental data and new ideas, as well as using ever more sophisticated techniques to probe fundamental physics questions with naturally occurring particles and phenomena.

Scientists in this subprogram investigate topics central to both the Intensity and Cosmic Frontiers, such as dark matter, dark energy, neutrino properties, the highest energy cosmic rays and gamma rays, studies of inflation in the early universe and primordial antimatter. These areas of research probe well beyond the Standard Model of particle physics and offer possibilities for discovery of major new physics phenomena. This subprogram supports both university and national laboratory researchers who collaborate on conducting experiments.

Cosmic frontier 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 cosmic and gamma rays. Small experiments to search for dark matter are being carried out using a variety of technologies in order to determine which is most effective. These experiments have started to probe the range of cross-sections and masses that have been predicted by theories of supersymmetry.

Current studies of dark energy have concentrated on using two techniques: type Ia supernovae and baryon acoustic oscillations. These are being done on existing telescopes with either new or upgraded instruments. High energy cosmic and gamma rays can be studied from the ground while lower energy particles need to be studied in space.

Intensity Frontier experiments in the non-accelerator physics subprogram are currently all related to neutrinos. These include studies of neutrino oscillations using neutrinos from nuclear reactors and searches for neutrinoless double beta decay, which are carried out in deep underground laboratories.

The Non-Accelerator Physics subprogram supports the fabrication of several major items of equipment. The Dark Energy Survey (DES) and the Reactor Neutrino Detector at Daya Bay experiment are completing fabrication in 2012. The High Altitude Water Cherenkov (HAWC) experiment, which will study gamma rays, started fabrication in FY 2012. Engineering and design efforts ramp up for the Large Synoptic Survey Telescope camera (LSSTcam) project, which will be used for dark energy measurements.

Explanation of Funding Changes

In the Non-Accelerator Physics subprogram, funding is increased primarily for the LSSTcam MIE and support for second-generation dark matter experiments.

(Dollars in Thousands)

	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Research	69,562	70,962	+1,400
Research for non-accelerator physics is maintained at approximately the FY 2012 level-of-effort.			
Projects	14,500	26,463	+11,963
Project funding is increased in FY 2013 due to the ramp up of engineering and design for the LSSTcam MIE and for technology and design studies for second-generation dark matter experiments.			
Total, Non-Accelerator Physics	84,062	97,425	+13,363

Research

Overview

The research activity supports groups at more than 35 universities and private institutions and 7 national laboratories (Argonne, Berkeley, Brookhaven, Fermi, Livermore, Los Alamos, and SLAC) that perform Cosmic Frontier experiments and at more than 20 universities and 4 national laboratories (Argonne, Berkeley, Brookhaven, and SLAC) that perform Intensity Frontier experiments at non-accelerator based facilities.

The funds provided support scientific efforts to operate the detectors, analyze the data, and develop scientific simulations and data modeling. In addition, support for the technical personnel and other expenses are provided for the maintenance and operation of experiments. Scientists supported by the research program also contribute to the R&D needed for new experiments.

The research is carried out in collaboration with other government agencies, including NSF, NASA and the Smithsonian Astrophysical Observatory. The selection of supported research efforts is based on peer review.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
2011 Current	At the Cosmic Frontier, operations and data analysis activities were supported on the Alpha Magnetic Spectrometer (AMS) detector, which was launched and installed on the International Space Station in May 2011. At the Intensity Frontier, support was provided for the Enriched Xenon Observatory (EXO)-200 neutrinoless double beta decay experiment, including the start of its operations; and for commissioning and initial data taking on the Reactor Neutrino Detector experiment at Daya Bay.	70,355
2012 Enacted	The research activity continues support of the ongoing program. In FY 2012, it includes the support of research on the Dark Energy Survey (DES) experiment, which begins integration and commissioning activities, and the Reactor Neutrino Detector at Daya Bay which begins its full data-taking phase.	69,562
2013 Request	Support will be provided for research on the DES experiment, which will begin its full operations phase and in support of current and promising future experiments. The Reactor Neutrino Detector at Daya Bay experiment will continue taking data with its full set of antineutrino detectors, enabling the world best measurement (or limit) on the as-yet-unmeasured neutrino mixing angle. Within this activity, the priority effort in FY 2013 will be analysis and support for currently operating experiments.	70,962

(Dollars in thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Grants Research	19,488	19,330	19,730
National Laboratory Research	50,867	50,232	51,232
Total, Research	70,355	69,562	70,962

Projects

Overview

The Projects activity funds support for technical, engineering and other professional personnel, as well as materials and supplies for small projects as well as MIE projects. Support is provided for R&D, design studies, and fabrication of the projects and experiments.

MIE projects include DES, which completes fabrication in FY 2011; the Reactor Neutrino Detector at Daya Bay, which completes fabrication in FY 2012; and HAWC, which begins fabrication in FY 2012. In FY 2013, engineering and design funding ramps up for a 3 billion pixel camera, which is DOE's responsibility in the LSST project for the study of the nature of dark energy. DOE and NSF are collaborating on the DES, HAWC, and LSSTcam projects. The activity also includes R&D and fabrication for small experiments and prototypes, as well as funding for R&D of potential future second-generation dark matter experiments, dark energy experiments, and other particle astrophysics topics. These efforts identify the most promising technical approaches in these areas. Funding decisions for these activities are based on peer review and programmatic priorities.

HEP plans to issue a solicitation in FY 2012 for R&D proposals enabling next-generation dark matter detectors. This is a very active area of R&D and technical progress where the U.S. is leading several efforts in a very competitive scientific environment. Successful proposals will be funded for one year of R&D and pre-conceptual design work in FY 2013, leading to a down-select of the most promising technologies at the end of 2013.

The selection of supported projects is based on peer review, including grant proposal reviews, laboratory comparative reviews, and advisory committee studies and reports.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
2011 Current	At the Cosmic Frontier, the last year of MIE support was provided for the DES project. R&D efforts were supported on future dark energy experiments, including conceptual design for LSSTcam, on dark matter technologies, and in other areas including R&D on HAWC. At the Intensity Frontier, MIE support was provided for the Reactor Neutrino Detector.	19,712
2012 Enacted	The HAWC MIE project begins fabrication and the DES project ends its fabrication phase. Preliminary design studies begin for LSSTcam. Technology R&D and activities are supported on promising second-generation dark matter experiments and promising future experiments in dark energy and other areas. The final year of MIE support is provided for the Reactor Neutrino Detector.	14,500
2013 Request	The MIE funding for HAWC fabrication is completed, with full operations starting in FY 2014. The increase in overall support is due to two priority efforts: LSSTcam ramp up of engineering and design and support for R&D leading to second-generation dark matter experimental concepts.	26,463

(dollars in thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Current Projects	7,960	7,500	11,500
Future Projects R&D	11,752	7,000	14,963
Total, Projects	19,712	14,500	26,463

Theoretical Physics
Funding Profile by Activity

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Research			
Grants Research	27,423	28,222	29,072
National Laboratory Research	25,638	23,778	24,501
Computational HEP	10,842	10,963	10,963
Other	4,147	3,887	3,986
Total, Theoretical Physics	68,050	66,850	68,522

Overview

The Theoretical Physics subprogram provides the mathematical framework for understanding and extending the knowledge of particles, forces, and the nature of space and time. This subprogram supports activities that range 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 the means to experimentally search for them. The subprogram also includes computational approaches to understanding the fundamental physics of the HEP program, through simulation and numerical calculation of experimental and theoretical results. This subprogram supports and advances research at all three high energy physics Frontiers.

Explanation of Funding Changes

The Theoretical Physics subprogram is maintained at approximately the FY 2012 level-of-effort. Some computational support efforts have moved into (or out of) the Computational HEP activity to Detector and Computing Operations in the Facilities activity based on a reclassification suggested by the laboratory scientific computing review held by HEP in 2011, but the net cost impact is minor.

	(Dollars in Thousands)		
	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Grants Research	28,222	29,072	+850
University grants are maintained at approximately the FY 2012 level-of-effort.			
National Laboratory Research	23,778	24,501	+723
Laboratory research efforts are maintained at approximately the FY 2012 level of effort. Detailed allocations will reflect assessments resulting from the 2011 comparative review of the national laboratory theory program.			
Computational HEP	10,963	10,963	0
Funding is unchanged.			
Other	3,887	3,986	+99
The Request increases education activities including physics conferences and workshops, and the Particle Data Group.			
Total, Theoretical Physics	66,850	68,522	+1,672

Grants Research

Overview

Grant research addresses topics across the full range of theoretical physics research. New and renewing research proposals are evaluated through a peer review process to assess scientific merit and final selection of grants to be awarded is based on these reviews as well as whether they align with programmatic priorities and overall portfolio balance. A major thrust is the search for a more complete theory that encompasses the Standard Model; in particular, a theory that can explain the underlying mechanism of electroweak symmetry breaking, the origin of particle mass, and the origin of quark and lepton flavors. A particularly interesting topic is the possibility of additional space-time dimensions that are normally hidden. This is motivated by the effort to unify Einstein's theory of gravity with quantum mechanics in a consistent way. Some of these extra dimensions and their consequences may be accessible to experimental investigation and may manifest themselves at the LHC as so-called Kaluza-Klein excitations, named after the physicists who first suggested, in the 1920s, that we might live in a 5-dimensional universe. Another topic of current research interest is the nature of dark matter and dark energy in the context of high energy physics.

University research groups play leading roles in addressing all the above research areas. This activity supports research groups at approximately 70 colleges and universities. It includes funding for private institutions, universities, and foundations that participate in high energy theoretical physics. As part of their research efforts, university groups train graduate students and postdoctoral researchers. Physicists in this theoretical research area often work in collaboration with other university and laboratory groups. Research efforts are selected based on a peer review process.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
2011 Current	Research funding for Theoretical Physics grants supported the ongoing program described above.	27,423
2012 Enacted	Grant research funding is increased somewhat above the FY 2011 level to accommodate current research solicitations still under review.	28,222
2013 Request	Grant research funding is increased to accommodate anticipated solicitations.	29,072

National Laboratory Research

Overview

The national laboratory theoretical research program currently consists of groups at 7 national laboratories (Argonne, Berkeley, Brookhaven, Fermi, Livermore, Los Alamos, and SLAC). The laboratory theory groups are a resource for the national research program in high energy physics, with a particular emphasis 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.

Laboratory theoretical research groups address topics across the full range of theoretical physics, including the analysis and interpretation of the new data from the LHC, accelerator and non-accelerator neutrino experiments, and dark matter detection experiments. Using the significant computing capabilities available at national laboratories, laboratory theory groups make major contributions to the U.S. and worldwide lattice quantum chromodynamics (LQCD) and computational cosmology efforts.

HEP conducted a comparative peer-review of laboratory research efforts in this subfield in 2011, findings from which have been used to inform the funding decisions in this budget request.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
2011 Current	Research funding for Theoretical Physics grants supported the ongoing program described above.	25,638
2012 Enacted	Laboratory research funding is decreased compared to the FY 2011 level to reflect non-recurring reductions due to temporary reassignments and retirements of some laboratory staff.	23,778
2013 Request	Funding is maintained at approximately the FY 2012 level-of-effort.	24,501

Computational HEP

Overview

Scientific computing, simulation, and computational science expertise are critical for the success of theory and experiment to fulfill the HEP mission. They are necessary at all stages of an experiment—from planning and constructing accelerators and detectors, to theoretical modeling, to supporting computationally intensive experimental research, and to 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 HEP research topics, and scientific computing infrastructure supporting the broader HEP community. The Scientific Discovery through Advanced Computing (SciDAC) program supports the first category and other directed research projects support the latter. The SciDAC portfolio focuses on computational science research requiring leadership class computing to solve fundamental science questions and is mostly funded via partnerships. The latter category provides for computing R&D, frameworks, networks, data resources, and related infrastructure and expertise at the laboratories; dedicated hardware for the LQCD computing initiative; and community software that is widely used throughout HEP and sometimes in other applications (such as GEANT 4 and accelerator modeling codes).

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
2011 Current	Current HEP SciDAC projects were funded at the planned level and supported the LQCD computing project, the LHC NET to provide data links between LHC and U.S. experiments, and the GEANT 4 software effort.	10,842
2012 Enacted	The SciDAC projects are being re-competed jointly with the Advanced Scientific Computing Research program in FY 2012 and a partnership with NSF addresses distributed computing for LHC experiments and other scientific applications. The dedicated LHC networking link is moved to the LHC Operations category while community-wide scientific computing support at SLAC and Fermilab previously supported under Facility Detector Operations is moved into Computational HEP. The LQCD project and GEANT 4 software effort are held constant.	10,963
2013 Request	The funding profile for computing partnership projects and scientific computing infrastructure activities are held at the FY 2012 funding level.	10,963

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
SciDAC	5,130	5,735	5,735
Scientific Computing	5,712	5,228	5,228
Total, Computational HEP	10,842	10,963	10,963

Other

Overview

This activity includes funding for education and outreach activities, compilations of high energy physics data, reviews of data by the Particle Data Group (PDG) at Lawrence Berkeley National Laboratory (LBNL), conferences, studies, workshops, funding for theoretical physics research activities to be determined by peer review, and for responding to new and unexpected physics opportunities.

This category also includes funding for the QuarkNet education project. This project takes place in QuarkNet centers which are set up at universities and laboratories around the country. The purpose of each center is to engage high school physics teachers in the analysis of data from an active high energy physics experiment (such as LHC). The experience these teachers garner is taken back to their classrooms in order to expose high school students to the world of high energy physics. A peer review of the QuarkNet effort is planned for 2012.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
2011 Current	The QuarkNet project introduced over 500 high school physics teachers to high energy physics experimental techniques. Funding for the PDG effort included a phased computing upgrade.	4,147
2012 Enacted	The appropriation supports somewhat reduced efforts in education and outreach activities, including physics conferences and workshops. The data compilations and summaries provided by the PDG will be funded according to the planned profile. The QuarkNet project will be reviewed jointly with the National Science Foundation and future funding will be determined based on that review.	3,887
2013 Request	The PDG data compilation activity will follow the planned funding profile. Other efforts are expected to continue at approximately the FY 2012 level of effort.	3,986

Advanced Technology R&D
Funding Profile by Activity

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Accelerator Science	42,104	44,150	46,850
Accelerator Development	86,801	75,400	52,600
Other Technology R&D	25,247	27,739	29,856
SBIR/STTR	0	20,040	20,590
Total, Advanced Technology R&D	154,152	167,329	149,896

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 particle physics Frontiers.

The long-term study of physics of beams, new acceleration methods, and the limiting physical properties of accelerating cavities and superconducting magnets is supported under Accelerator Science. The Accelerator Development activity looks to select a few promising new technologies for possible future accelerator projects and conduct directed R&D for these projects, with proof-of-principle demonstrations, prototype component development, and other milestones advancing technical readiness.

Advanced Technology R&D also develops or enhances new technologies—such as superconducting magnets, superconducting radio-frequency accelerating cavities, high gradient and high power accelerators, and detection techniques—that are appropriate for a broad range of scientific disciplines, thereby enhancing DOE's broader strategic goals of science for Innovation, Energy, and Security.

Other Technology R&D addresses the need for the ever increasing capability of instrumentation and detectors at the Energy, Intensity, and Cosmic Frontiers. New instrumentation and detectors must constantly be developed with increased capabilities while keeping the cost and time from conception to operation at a minimum. To meet these sometimes contradictory goals, instrument builders must be constantly searching for new technologies and new ways to utilize existing technologies. To meet these challenges, HEP actively supports investment in generic instrument and detector research. These activities will benefit the detectors needed to respond to new research challenges in all three frontiers.

Explanation of Funding Changes

Overall funding for this subprogram is reduced, primarily due to completion of International Linear Collider (ILC) R&D in the Accelerator Development activity.

	(Dollars in Thousands)		
	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Accelerator Science	44,150	46,850	+2,700

FACET, the electron-beam driven plasma wakefield accelerator test facility at SLAC will be in full operation, and support of research using this new facility will be a priority. Other activities are maintained at approximately the FY 2012 level-of-effort.

	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
	(Dollars in Thousands)		
Accelerator Development	75,400	52,600	-22,800
The budget reflects the completion of the ILC R&D funding and the planned profile of funding of SRF Infrastructure at Fermilab. Muon collider R&D has been reorganized following the consolidation of research activities under the Muon Accelerator Program and continues somewhat below the FY 2012 funding level.			
Other Technology R&D	27,739	29,856	+2,117
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 the Cosmic and Intensity Frontier experiments such as liquid argon detector development.			
SBIR/STTR	20,040	20,590	+550
In FY 2011, $17,716,000 and $2,126,000 were transferred to the Small Business Innovation Research (SBIR) and Small Business Technology (STTR) programs, respectively. SBIR/STTR funding is set at 2.95% of non-capital funding in FY 2012 and 3.05% in FY 2013.			
Total, Advanced Technology R&D	167,329	149,896	-17,433

Accelerator Science

Overview

This activity 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 that promote scientific innovations to enable breakthroughs in particle accelerator size, cost, beam intensity and control. Funding in this category includes costs for operating university and laboratory-based accelerator R&D test facilities.

The grant-based research category investigates novel acceleration concepts, including the use of plasmas and lasers to accelerate charged particles; theoretical studies in advanced beam dynamics, including the study of non-linear optics and space-charge dominated beams; development of advanced particle beam sources and instrumentation; and accelerator R&D into the fundamental issues associated with the ionization cooling of muon beams. Research efforts are selected based on a peer review process. This program supports 30 accelerator science grants with approximately 80 scientists and 45 graduate students.

The national laboratory accelerator science category explores advanced methods to accelerate charged particles with the goal of more efficient, compact, and inexpensive particle accelerators. Efforts are focused on the long-range development of new accelerating structures and techniques needed to achieve accelerating gradients in excess of 100 MeV per meter. This work is carried out primarily at the Argonne Wakefield Accelerator at ANL; the Facility for Accelerator Science and Experimental Test Beams (FACET) and the Dielectric Laser Accelerator at SLAC; and the Berkeley Lab Laser Accelerator (BELLA), and the Lasers, Optical Accelerator Systems Integrated Studies test facility at LBNL. BNL is also the home of the highly productive Accelerator Test Facility. This facility supports HEP-funded research in accelerator concepts and beam physics, with users from academia and industry, based on a proposal-driven, peer-review process.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
2011 Current	Supported a broad research program in advanced accelerator physics and related technologies to investigate novel acceleration concepts. SLAC completed the Facility for Accelerator Science and Experimental Test Beams (FACET) and started its user-assisted commissioning and the first round of experiments. LBNL started to develop diagnostics and instrumentation needed for the Berkeley Lab Laser Accelerator (BELLA) facility currently under fabrication.	42,104
2012 Enacted	Continue support for the broad research program in advanced accelerator physics and related technologies to investigate novel acceleration concepts. Expect more university participation in developing proposals and conducting experiments at the new BELLA and FACET facilities.	44,150
2013 Request	Continue support for a broad research program in advanced accelerator physics and related technologies. Accelerator R&D involving the fundamental issues associated with muon colliders and neutrino factories is now supported under the Muon Accelerator Program within Accelerator Development. Increased funding is provided to support optimal utilization of the FACET plasma wakefield accelerator facility at SLAC.	46,850

Fiscal Year	Activity	Funding ($000)
	Grants are maintained at approximately the FY 2012 level-of-effort. Priority will be given to support university participation in developing proposals and conducting experiments at the new advanced plasma accelerator R&D facilities, BELLA and FACET.	

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Grants Research	8,269	11,007	11,307
National Laboratory Research	33,835	33,143	35,543
Total, Accelerator Science	42,104	44,150	46,850

Accelerator Development

Overview

This activity demonstrates the feasibility of 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, upgrade existing facilities, or applied to the design of new facilities. Carrying out development of advanced high-technology components at this level often requires significant investments in research infrastructure. Major thrusts in this activity are superconducting radio frequency (RF) infrastructure development and studies of very high intensity proton sources for potential application in neutrino physics research.

The General Accelerator Development focuses on R&D that can be widely applied to a range of accelerator facilities. The work is primarily done at 4 national laboratories (Berkeley, Brookhaven, Fermi, and SLAC). The major areas of R&D are superconducting magnet and related materials technology; high-powered RF acceleration systems; instrumentation; linear and nonlinear beam dynamics; and development of large simulation programs. The latter effort is coordinated with the SciDAC accelerator simulation project. There is also a preconceptual R&D effort to demonstrate the advanced technologies needed to realize muon-based accelerators—this is a global R&D program with major U.S. participation at Fermilab and Brookhaven National Laboratory (BNL).

Superconducting Radio Frequency (SRF) technology is applicable to a variety of future accelerator projects central to the HEP scientific strategy. The SRF program is centered at Fermilab, supporting the development of infrastructure necessary for accelerator cavity processing, assembly, and testing and for cryomodule assembly and testing. The infrastructure will be utilized to improve cavity and cryomodule performance and prototype cryomodules for future projects. Information on processing and construction will be of use to a broad spectrum of projects throughout the Office of Science.

The ILC is a proposed TeV-scale linear electron-positron collider, widely considered by the international high energy physics community to be the successor to the LHC and essential for advancing scientific progress at the Energy Frontier. Since 2008 there has been a worldwide R&D effort, which included the U.S, to develop a Technical Design Report (TDR). The TDR is expected to be finished by the end of 2012 and combined with first physics results from the LHC will form the basis for governments to make a construction decision.

The Muon Accelerator Program (MAP) provides a five-year R&D plan for muon-based accelerators, including milestones and deliverables aimed at demonstrating the advanced technologies needed to realize muon-based accelerators for future muon colliders and neutrino factories. Research activities in muon colliders and neutrino factories under the national Neutrino Factories and Muon Collider Collaboration (NFMCC) and Muon Collider Task Force (MCTF) at Fermilab were consolidated under one single program in 2011.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
2011 Current	Major directed R&D efforts supported the ILC R&D program; Muon Accelerator Program; high-power RF systems R&D at SLAC; a national R&D program on superconducting magnets and materials including coordinated efforts at BNL, Fermilab and LBNL; and superconducting RF development and infrastructure at Fermilab.	86,801
2012 Enacted	Funding for General Accelerator Development is maintained at an approximately constant level of effort to continue the robust technology development program as more directed R&D efforts ramp down. The SRF effort is ramping down as major infrastructure procurements at Fermilab are completed, but continues to provide funds for procurement of components and equipment support necessary to develop prototype multi-cavity cryomodules.	75,400

Fiscal Year	Activity	Funding ($000)
	The ILC R&D program continues but with a significantly reduced U.S. role in the comprehensive and coordinated international R&D program. The MAP effort increases activities in the muon ionization cooling experiment (MICE) at the Rutherford-Appleton Laboratory and the MuCool Test Area (MTA) at Fermilab.	
2013 Request	Funding for General Accelerator Development continues at the same level as FY 2012. Funding for the SRF effort plateaus as major component procurements at Fermilab are completed; this activity will continue to develop prototype multi-cavity cryomodules, and enable continued development of U.S. capabilities for testing cavities and cryomodules. The completion of the TDR in 2012 concludes the five-year ILC R&D program. No funds are provided for the ILC R&D program in FY 2013. Funding for the MAP effort is provided slightly below the FY 2012 level in support of the R&D activities at the MICE and MTA. The R&D efforts move into a commissioning and demonstration phase with the delivery of the major experimental items such as large superconducting coupling coils and 201 MHz RF cavities.	52,600

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
General Accelerator Development	27,766	27,900	27,900
Superconducting RF R&D	19,864	13,500	13,500
International Linear Collider R&D	28,289	22,000	0
Muon Accelerators	10,882	12,000	11,200
Total, Accelerator Development	86,801	75,400	52,600

Other Technology R&D

Overview

Other Technology R&D includes addressing fundamental scientific problems to foster new technologies in particle detection, measurement, and data processing; and providing support for prototyping and detector systems development to bring the technologies to the maturity where they can be incorporated into future particle physics experiments.

The Detector Research and Development community is based at 5 national laboratories (Argonne, Berkeley, Brookhaven, Fermi, and SLAC) and multiple universities. For future detectors at the Energy Frontier, groups are working on new techniques for silicon and pixel trackers where radiation tolerance, finer segmentation, better signal to noise ratios, better heat management, and reduced mass are all very important. At the Intensity Frontier, work is directed at increasing the energy and tracking measurement sensitivities using new detector media (such as liquid argon) while, at the same time, significantly reducing the cost per ton of detector. At the Cosmic Frontier, work includes ever more sensitive charge-coupled devices for telescope cameras while increasing their versatility and reducing the cost for such detectors. Some notable projects are: research in producing a photo-detector with large area coverage but compact and inexpensive readout; development of an inexpensive solvent to add to water to make it scintillate (emit light) in the presence of high energy charged particles; and research into novel data readout using open-air laser optics, eliminating the need for much of the copper wires and fiber optic cables out of the densely packed inner regions of collider detectors.

Much of the research conducted under Other Technology R&D is applicable to other areas within the Office of Science such as the NP and BES programs. This research also leads to applications in detectors for medical uses and for national security.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
2011 Current	Funding supported Detector R&D, enabling a broad research program in advanced detector concepts and related technologies.	25,247
2012 Enacted	Funding will continue supporting Detector R&D efforts; in addition there will be new awards for successful proposals responding to a targeted solicitation for Collider Detector Research and Development conducted late in FY 2011.	27,739
2013 Request	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 the Cosmic and Intensity Frontier experiments such as liquid argon detector development.	29,856

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Detector Development, Grants Research	3,079	6,646	3,763
Detector Development, National Laboratory Research	22,168	21,093	26,093
Total, Other Technology R&D	25,247	27,739	29,856

Construction
Funding Profile by Activity

(Dollars in Thousands)	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Long Baseline Neutrino Experiment	0	4,000	0
Muon to Electron Conversion Experiment	0	24,000	20,000
Total, Construction	0	28,000	20,000

Overview

In FY 2012, engineering and design funding was provided for the Long Baseline Neutrino Experiment (LBNE) to complete conceptual design studies. Because of concerns about the total project and operations costs for LBNE that could be incurred by DOE, no construction funds are requested for FY 2013, and the Office of Science will thoroughly review the costs and alternatives to LBNE.

The Muon to Electron Conversion Experiment will be built at Fermilab and is an important component of the Intensity Frontier program. It will utilize a proton beam there to produce muons and then study the conversion of those muons to electrons in order to determine if charged leptons conserve flavor. In the Standard Model, lepton flavor was assumed to be conserved, but neutrino oscillations have demonstrated that it is not conserved in neutral leptons, thus calling into question comservation by the charged leptons.

Explanation of Funding Changes

The decrease of PED funding for construction projects takes into account the planned profiles. PED funding was initially appropriated in FY 2012 for LBNE and Mu2e.

(dollars in thousands)	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Long Baseline Neutrino Experiment	4,000	0	-4,000
No PED funding is requested in FY 2013.			
Muon to Electron Conversion Experiment	24,000	20,000	-4,000
Funding is provided for continuing project engineering and design activities.			
Total, Construction	28,000	20,000	-8,000

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Operating Expenses	692,027	678,413	675,089
Capital Equipment	80,374	75,772	66,532
General Plant Projects	3,177	8,675	14,900
Construction	0	28,000	20,000
Total, High Energy Physics	775,578	790,860	776,521

Funding Summary

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Research	454,082	426,145	423,093
Scientific User Facilities Operations	235,933	221,610	235,818
Projects			
Major Items of Equipment	61,680	55,390	42,837
Construction[a]	16,168	51,000	35,000
Total, Projects	77,848	106,390	77,837
Other	7,715	36,715	39,773
Total, High Energy Physics	775,578	790,860	776,521

Scientific User Facilities Operations

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Fermilab Accelerator Complex	154,970	138,641	153,204
B-Factory	9,809	9,825	9,200
LHC Detector Support and Operations	71,154	73,144	73,414
Total, Scientific User Facilities Operations	235,933	221,610	235,818

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

Total Facility Hours and Users

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Proton Accelerator Complex[a]			
Achieved Operating Hours	6,585[b]	N/A	N/A
Planned Operating Hours	5,400	2,650	2,400
Optimal hours (estimated)	5,400	2,650	2,400
Percent of Optimal Hours	122%	100%	100%
Unscheduled Downtime	19%	N/A	N/A
Total Number of Users	1,400	1,400	1,400
SLAC B-Factory			
Total Number of Users	300	200	150
Total Facilities			
Achieved Operating Hours	6,585	N/A	N/A
Planned Operating hours	5,400	2,650	2,400
Optimal hours (estimated)	5,400	2,650	2,400
Percent of Optimal Hours	122%	100%	100%
Unscheduled Downtime	19%	N/A	N/A
Total Number of Users	1,700	1,600	1,550

Major Items of Equipment (MIE)

(dollars in thousands)

	Prior Years	FY 2011 Current	FY 2012 Enacted	FY 2013 Request	Outyears	Total	Completion
Proton Accelerator-Based Physics							
NOνA							
TEC	99,528	44,220	41,240	19,480	0	204,468	1Q FY 2015
OPC	71,532	2,000	0	0	0	73,532	
TPC	171,060	46,220	41,240	19,480	0	278,000	

[a] Only NuMI runs FY 2012 and beyond.
[b] Additional operating hours were added during the year to maximize the amount of data taken at the Tevatron.

(dollars in thousands)

	Prior Years	FY 2011 Current	FY 2012 Enacted	FY 2013 Request	Outyears	Total	Completion
Accelerator Project for the Upgrade of the LHC (APUL)							
TEC	2,000	1,500	0	0	0	3,500	2Q FY 2014
OPC	8,016	0	0	0	0	8,016	
TPC	10,016[a]	1,500	0	0	0	11,516	
MicroBooNE[b]							
TEC	0	0	6,000	5,857	0	11,857	3Q FY 2015
OPC	2,043	6,000	0	0	0	8,043	
TPC	2,043	6,000	6,000	5,857	0	19,900	
Electron Accelerator-Based Physics							
Belle-II[c]							
TEC	0	0	0	6,000	6,000	12,000	3Q FY 2015
OPC	0	0	650	0	0	650	
TPC	0	0	650	6,000	6,000	12,650	
Non-Accelerator Physics							
Reactor Neutrino Detector at Daya Bay							
TEC	30,460	1,740	500	0	0	32,700	3Q FY 2013
OPC	2,480	320	0	0	0	2,800	
TPC	32,940	2,060	500	0	0	35,500	
Dark Energy Survey (DES)							
TEC	19,250	4,000	0	0	0	23,250	4Q FY 2012
OPC	11,900	0	0	0	0	11,900	
TPC	31,150	4,000	0	0	0	35,150	

[a] In FY 2011, $1,484,000 was withdrawn from prior year obligations to account for the reduced Total Project Cost identified in the baseline.
[b] The Mission Need (CD-0) was approved September 2009 and subsequent CD-1 was approved June 2010. CD-2/3a was approved September 27, 2011 with a TPC of $19,900,000.
[c] This project is not yet baselined. The Mission Need Statement was approved July 28, 2011 and the CD-0 was approved August 29, 2011.

(dollars in thousands)

	Prior Years	FY 2011 Current	FY 2012 Enacted	FY 2013 Request	Outyears	Total	Completion
HAWC[a]							
TEC	0	0	1,500	1,500	0	3,000	4Q FY 2014
OPC	0	0	0	0	0	0	
TPC	0	0	1,500	1,500	0	3,000	
Large Synoptic Survey Telescope (LSSTcam) Camera[b]							
TEC	0	0	0	7,000	142,600	149,600	4Q FY 2020
OPC	0	1,900	5,500	3,000	0	10,400	
TPC	0	1,900	5,500	10,000	142,600	160,000	
Total MIEs							
TEC		51,460	49,240	39,837			
OPC		10,220	6,150	3,000			
TPC		61,680	55,390	42,837			

[a] This project is not yet baselined. The TPC as well as the OPC/TEC split may change. This project falls below the $10,000,000 TPC threshold that requires a CD-0.

[b] This project is not yet baselined and the OPC/TEC split is not yet determined. This project received CD-0 on June 20, 2011.

Proton Accelerator-Based 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 700 km. The project also includes improvements to the proton source to increase the intensity of the NuMI beam. The occurrence of these particular 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.

Accelerator Project for the Upgrade of the LHC (APUL) is a project to design and construct selected magnets for the LHC. CD-2/3 was approved July 2011. Brookhaven National Laboratory is expected to fabricate components and deliver them to CERN for installation in the LHC.

MicroBooNE was originally planned to start in FY 2011, but was deferred after the FY 2011 appropriation did not support new project starts. Fabrication now begins in FY 2012. This project will build a several 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 efficacy of large-scale liquid argon time projection chambers as neutrino detectors.

Electron Accelerator-Based Physics MIEs:

The *Belle-II* project is a new MIE planned to begin fabrication in FY 2013. The 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. Mission Need (CD-0) was approved in August 2011 with a TPC range of $12,000,000–$14,000,000.

Non-Accelerator Physics MIEs:

Reactor Neutrino Detector, located in Daya Bay, China, is being fabricated in partnership with research institutes in China. This experiment will use anti-neutrinos produced by commercial power reactors to precisely 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 with a planned completion date of April 2013. CD-4A, Start of Initial Operations, was approved in December 2010. Data-taking with the full set of detectors starts in FY 2012.

The *Dark Energy Survey (DES)* project will provide the next step beyond the discovery of dark energy by making more detailed studies using several different observational methods. DOE is supporting the fabrication of a new camera to be installed and operated on the existing Blanco four-meter telescope at the Cerro Tololo Inter-American Observatory (CTIO) in Chile. This project is a partnership between DOE and the NSF, which operates the telescope, along with international participation. MIE funding ended in FY 2011 (TPC $35,150,000) and the experiment will start taking scientific data at the beginning of FY 2013.

The *High Altitude Water Cherenkov (HAWC)* detector is a new experiment in Mexico that will survey the sky for sources of TeV gamma-rays in the 10–100 TeV range. It was identified in the HEPAP PASAG report as a scientific opportunity that should be pursued even in the case of constrained HEP budgets. 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 done in collaboration with NSF and Mexican research institutes. MIE funding for the fabrication starts in FY 2012. The estimated total DOE cost is $2,500,000–$3,500,000 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 variable 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 done as a collaboration with NSF, in addition to private and foreign contributions. The DOE MIE will provide the camera for the facility. Mission Need (CD-0) for the LSSTcam project was approved in June 2011, with the estimated total DOE cost range of $120,000,000–$160,000,000 and estimated completion date of FY 2020.

Construction Projects

(dollars in thousands)

	Prior Years	FY 2011 Current	FY 2012 Enacted	FY 2013 Request	Outyears	Total	Completion
Long Baseline Neutrino Experiment (PED)							
TEC	0	0	4,000	0	TBD	TBD	TBD
OPC	26,666	7,768	17,000	10,000	TBD	TBD	
TPC	26,666	7,768	21,000	10,000	TBD	TBD	
Muon to Electron Conversion Experiment (PED)							
TEC	0	0	24,000	20,000	0	44,000	4Q FY 2018[a]
OPC	4,777	8,400	6,000	5,000	0	24,177	
TPC	4,777	8,400	30,000	25,000	0	68,177[b]	
Total, Construction							
TEC		0	28,000	20,000			
OPC		16,168	23,000	15,000			
TPC		16,168	51,000	35,000			

Scientific Employment

	FY 2011 Actual	FY 2012 Estimate	FY 2013 Estimate
# University Grants	192	195	195
# Laboratory Groups	45	45	45
# Permanent Ph.D.'s (FTEs)	1150	1170	1170
# Postdoctoral Associates (FTEs)	480	490	490
# Graduate Students (FTEs)	560	610	610
# Ph.D.'s awarded	120	105	110

[a] Estimated completion date for PED and construction.

[b] This project has not received CD-2 approval. Only PED and OPC excluding D&D are shown.

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

1. Significant Changes

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-0 was approved on November 24, 2009 with a preliminary cost range of $145,000,000–$205,000,000 and CD-4 of FY 2018.

A Federal Project Director has been assigned to this project.

This PDS does not include a new start for the budget year.

This PDS is an update of the FY 2012 PDS.

When costs for the conceptual design were re-estimated in FY 2011 in anticipation of CD-1, the accelerator portion of the project was shown to be significantly more expensive than estimated at CD-0. A task force of accelerator experts was brought in by the contractor to review the design. Multiple cost savings were identified and new designs are being developed. This will extend the design period and increase the design costs, but the cost range at CD-1 is expected to be within 10% of the CD-0 cost range.

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

(fiscal quarter or date)

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

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3 – Approve Start of 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

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[b]

[a] Schedule estimates are preliminary since this project has not received CD-2 approval.
[b] This project has not received CD-2 approval. Only PED and OPC excluding D&D are shown.

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 on the structure of potential new physics discoveries and allows access to new physics at very high mass scales. The Particle Physics Project Prioritization Panel (P5) identified this opportunity as a top priority for the Intensity Frontier of particle physics. This project provides accelerator beam and experimental apparatus to identify unambiguously events of neutrinoless muon-to-electron conversion.

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

This project will construct a new beamline for protons from the existing 8 GeV Booster Synchrotron at Fermilab, a system for producing, transporting and stopping secondary muons (from the proton beam) and 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.

Key Performance Parameters

Key Parameters	Performance
Stopped-muon production system capable of delivering at least 10^{11} stopped muons per second to the experimental detector system	Installed and ready for commissioning
Experimental detector spectrometer system consisting of tracking and calorimetric detectors	Installed, tracking cosmic rays and ready for commissioning with stopped muons
Conventional facilities consisting of beam-line tunnel, detector hall below grade, surface building and cryogenics building	Over 30,000 square feet

The Key Performance Parameters will be updated at a subsequent CD approval. The project is being conducted in accordance with the project management requirements in DOE O 413.3B, Program and Project Management for the Acquisition of Capital Assets, and all appropriate project management requirements have been met.

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
PED			
FY 2012	24,000	24,000	18,000
FY 2013	20,000	20,000	17,200
FY 2014	0	0	8,800
Total, PED	44,000	44,000	44,000

(dollars in thousands)

	Appropriations	Obligations	Costs
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	6,000	6,000	6,000
FY 2013	5,000	5,000	5,468
Total, OPC	24,177	24,177	24,177
Total Project Cost (TPC)			
FY 2010	4,777	4,777	3,769
FY 2011	8,400	8,400	8,940
FY 2012	30,000	30,000	24,000
FY 2013	25,000	25,000	22,668
FY 2014	0	0	8,800
Total, TPC	68,177[a]	68,177[a]	68,177[a]

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design (PED)			
Design	31,000	29,500	N/A
Contingency	13,000	7,000	N/A
Total, PED	44,000	36,500	N/A
Contingency, TEC	13,000	7,000	N/A

[a] This project has not yet received CD-2 approval. Only PED and OPC excluding D&D are shown.

	(dollars in thousands)		
	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Other Project Cost (OPC)			
OPC except D&D			
R&D	150	150	N/A
Conceptual Planning	7,750	7,350	N/A
Conceptual Design	12,000	8,000	N/A
Contingency	4,277	3,277	N/A
Total, OPC	24,177	18,777	N/A
Contingency, OPC	4,277	3,277	N/A
Total, TPC	68,177	55,277	N/A
Total, Contingency	17,277	10,277	N/A

7. Schedule of Appropriation Requests

(dollars in thousands)

Request		Prior Years	FY 2011	FY 2012	FY 2013	Total
FY 2011	TEC	0	5,000	30,000	TBD	35,000
	OPC	5,000	5,000	0	TBD	10,000
	TPC	5,000	10,000	30,000	TBD	45,000
FY 2012	TEC	0	0	24,000	12,500	36,500
	OPC	4,777	8,000	6,000	0	18,777
	TPC	4,777	8,000	30,000	12,500	55,277
FY 2013[a]	TEC	0	0	24,000	20,000	44,000
	OPC	4,777	8,400	6,000	5,000	24,177
	TPC	4,777	8,400	30,000	25,000	68,177

8. Related Operations and Maintenance Funding Requirements

Not applicable for PED.

9. Required D&D Information

Not applicable for PED.

[a] This project has not received CD-2 approval. Only PED and OPC excluding D&D are shown.

10. Acquisition Approach

The conceptual design is being performed by Fermilab, and it will inform the acquisition approach that will be documented in the Acquisition Strategy required for CD-1. It is already known that beamlines, detectors, and an experimental hall will be needed, and that the specialized expertise in those areas will limit the range of acquisition options.