High Energy Physics

Funding Profile by Subprogram

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
High Energy Physics		
Proton Accelerator-Based Physics	438,369	411,207
Electron Accelerator-Based Physics	30,212	22,319
Non-Accelerator Physics	97,469	81,852
Theoretical Physics	68,414	68,914
Advanced Technology R&D	156,347	171,908
Subtotal, High Energy Physics	790,811	756,200
Construction	0	41,000
Total, High Energy Physics	790,811[a]	797,200

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

Mission

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.

Background

Research in high energy physics, also called particle physics, has led to a profound understanding of the physical laws that govern matter, energy, space, and time. The Standard Model of particle physics, first established in the 1970s, well describes the behavior of elementary particles and forces, often to very high precision. Nevertheless, the Standard Model is understood to be incomplete since the model fails at high energies—energies now being created in particle accelerators—and describes only a small fraction of the matter and energy filling the universe. Data have revealed that only about 5% of the universe is made of the normal, visible matter described by the Standard Model. The remaining 95% of the universe consists of 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,* where powerful accelerators are used to create new particles, reveal their interactions, and investigate fundamental forces;

[a] Total reduced by $19,672,000: $17,564,000 of which was transferred to the Small Business Innovation Research (SBIR) program and $2,108,000 of which was transferred to the Small Business Technology Transfer (STTR) program.

- *The Intensity Frontier,* where intense particle beams and highly sensitive detectors are used to pursue alternate pathways to investigate fundamental forces and particle interactions by studying events that occur rarely in nature; and
- *The Cosmic Frontier,* where ground and space-based experiments and telescopes are used to make measurements that will offer new insight and information about the nature of dark matter and dark energy to understand fundamental particle properties and discover new phenomena.

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

- *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. If this symmetry exists, it would solve the failure of the standard model at high energies. It predicts a superpartner for every particle currently known. The search for such superparticles will be carried out with accelerators that operate at the Energy Frontier or by observing rare decays or new phenomena 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. This energy, which permeates empty space, must have a quantum explanation. The existence of dark energy was first discovered in 1998 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, and many versions of string theory also predict that supersymmetry is real. Accelerators 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—most of these at DOE national laboratories. Does nature somehow require that there are only three, or are there more? Moreover, the various quarks and leptons have widely different masses and force couplings. These differences suggest there may be an undiscovered explanation that unifies quarks and leptons, just as the discovery of quarks simplified the zoo of composite particle states discovered in the

1960s. Detailed studies that employ Energy Frontier accelerators, as well as precision measurements made at Intensity Frontier facilities, may provide the dramatic insights into this complex puzzle.

- *What is dark matter? How can we make it in the laboratory?*

  Most of the matter in the universe is invisible. We can detect 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 can reveal important clues to the unification of forces and the very early history of the universe. Naturally occurring neutrinos are produced by cosmic ray interactions with the Earth's atmosphere, by supernovae, and in the interior of stars. These can be studied at the Cosmic Frontier. Man-made neutrinos can be studied at the Intensity Frontier using intense neutrino sources such as nuclear reactors and advanced accelerators.

- *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. This has, to date, been borne out by the study of high-energy collisions in the laboratory. Precise Energy and Intensity Frontier accelerator-based measurements of the subtle asymmetries present in the weak nuclear interaction may shed light on how the present day matter-antimatter asymmetry arose.

Because of the strong connections between the key questions in each area, successfully addressing these questions requires coordinated initiatives at each of the frontiers. The HEP program 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.

Subprograms

HEP is divided into five subprograms that are organized around the tools and facilities they employ (such as an electron accelerator or cosmic ray detector) and the knowledge and technology they develop (such as superconducting radio frequency cavities or computational capabilities):

- The *Proton Accelerator-Based Physics subprogram* exploits two major applications of proton accelerators. The protons can be used directly in collisions such as the Large Hadron Collider (LHC) or proton accelerators can also produce other particles (such as antiprotons, K mesons, muons, and neutrinos) by colliding intense proton beams into targets. These particles can then be formed into secondary beams for experiments. The proposed Intensity Frontier program utilizes the high-power proton beam at Fermi National Accelerator Laboratory (Fermilab) to produce intense secondary beams of muons and neutrinos for world-leading experiments.
- The *Electron Accelerator-Based Physics subprogram* utilizes accelerators with high-intensity and ultra-precise electron beams to create and investigate matter at its most basic level. Unlike protons, electrons are low mass, point-like particles that are well-suited for precision measurements of particle properties and exacting beam control. The next-generation Energy Frontier accelerator after the LHC is likely to be a high-energy lepton (electron or perhaps muon) facility that can probe LHC discoveries in detail. In addition, new developments in beam luminosity and interaction region control have yielded designs of Super B Factories which could produce luminosities one hundred times higher than previously available.
- The *Non-Accelerator Physics subprogram* supports particle physics studies that cannot be investigated with accelerators, or are best studied by other means. These activities have provided experimental data, new ideas, and techniques complementary to those provided by accelerator-based research. Scientists in this subprogram investigate topics such as dark matter, dark energy, neutrino properties, proton decay, the highest energy cosmic rays and gamma rays, and primordial antimatter. Some of the non-accelerator particle sources used in this research are cosmic rays, gamma rays, and photons and neutrinos from both astrophysical sources and nuclear power reactors.
- The *Theoretical Physics subprogram* provides the vision and mathematical framework for understanding and extending the knowledge of particles, forces, space-time, and the universe. This subprogram supports activities that range from detailed calculations of the predictions of the Standard Model to advanced computation and simulations to solve otherwise intractable problems. Theoretical physicists play key roles in determining which experiments to perform and explaining experimental results in terms of underlying theories that describe the interactions of matter, energy, and space-time.
- The *Advanced Technology R&D subprogram* develops the next generation of particle accelerator and detector technologies for the future advancement of high energy physics and other sciences, supporting world-leading research in the physics of particle beams, fundamental advances in particle detection, and R&D on new technologies and research methods appropriate for a broad range of scientific disciplines.

Benefits

Seeking answers to big questions drives basic research. It appeals to our deepest human nature. However, 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. Today, those x-rays, along with all the improvements over the years in delivery and imaging systems, are vital tools in service of humanity.

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, as well as for workforce training, are also well known. HEP coordinates acceleratory research investments with the Basic Energy Sciences (BES) and Nuclear Physics (NP) programs.[a]

Looking to the future, 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—where particle accelerators and detectors developed for high energy physics research have the potential for hazardous material detection and non-proliferation verification;
- industry—where, for example, superconducting cables being developed for next generation magnets for high energy physics research could be used to transmit, with minimal power losses, far more electricity than conventional cables;
- internet grid development—where the developments of the international grid capability for data analysis of the large detectors at the LHC may result in a paradigm change in the handling of huge data sets;
- medical treatment and diagnosis—where new, more cost-efficient particle accelerators, detectors, and magnets for cancer treatment and diagnosis should emerge; and
- other scientific fields—where HEP's development of the science and technologies needed for next-generation particle accelerator and detector applications will be transferred and exploited.

Program Planning and Management

Advisory and Consultative Activities

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.

In 2007, HEPAP was charged to examine the options for mounting a world-class U.S. particle physics program at various funding levels. A subpanel called the Particle Physics Project Prioritization Panel (P5) was formed to review progress and future plans of the various research areas of the HEP program and to assess and prioritize the scientific opportunities and proposed projects identified. The HEPAP P5 report[b] submitted in June 2008 has provided important input for setting programmatic priorities for the HEP program. This guidance was further refined in the HEPAP report generated in response to a charge by the agencies to identify and prioritize the scientific opportunities and options that can be pursued at

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[a] For more information, visit http://www.science.doe.gov/hep/benefits.
[b] The full HEPAP report is available at http://www.science.doe.gov/hep/files/pdfs/P5_Report%2006022008.pdf.

different funding levels to achieve an optimum program in particle astrophysics. This Particle Astrophysics Science Assessment Group (PASAG) Report[a] was submitted to the agencies in October 2009. Many of the recommendations contained in these reports have been implemented, and this budget request supports recommendations of the P5 roadmap.

The National Academies Decadal Survey of Astronomy and Astrophysics (Astro2010) report[b] was released in August 2010 recommending priorities for the next decade for the U.S. program in astronomy and astrophysics under various funding scenarios. This study is particularly relevant to the National Aeronautics and Space Administration (NASA) and NSF, the federal stewards of astronomy and astrophysics, on opportunities and priorities in these scientific areas. However, it also provides advice on the opportunities for DOE HEP participation and also provides guidance on scientific/technical aspects of the proposed program. HEP has participated in discussions with NSF (Astronomical Sciences and Physics Divisions), NASA (Astrophysics Division), and the Office of Science and Technology Policy (OSTP) to develop a coordinated agency response to the guidance provided by the Astro2010 Report. HEP's Budget Request and planning for FY 2012 are consistent with guidance 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.

Triennially, HEP 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 second HEP COV review took place in summer 2007. The 2007 COV report[c] had 18 specific recommendations relating primarily to staffing, grants review and processing, and project management, which HEP has addressed or put processes in place to address all of them. The third COV review was held on October 2010. The report has been made public, as has the HEP response[d].

Review and Oversight

The HEP program office 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 to HEP 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 or technology R&D groups are peer-reviewed triennially on a rotating basis, using the same criteria established for the university reviews. In FY 2012, the Proton Accelerator Based Physics and Detector R&D subprograms will be reviewed. Laboratory proposals involving significant new research scope are also subject to peer-review by external experts on an ad hoc basis.

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[a] http://www.science.doe.gov/hep/files/pdfs/HEPAP_2009_10_Ritz_PASAG.pdf
[b] http://www.nap.edu/catalog.php?record_id=12951
[c] The 2007 COV report and HEP's response are available at http://www.science.doe.gov/SC-2/COV-HEP/HEP_Reviews.htm.
[d] The 2010 COV report and HEP's response are available at http://www.science.doe.gov/SC-2/COV-HEP/HEP_Reviews.htm

Basic and Applied R&D Coordination

Many of the broader applications of technology originally developed for HEP research have been serendipitous. In order to obtain guidance on how to better bridge the gap between accelerator research and technology deployment, HEP organized a symposium entitled "Accelerators for America's Future," held in October 2009[a]. The symposium was followed by a two-day workshop in which 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 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.

Budget Overview

The HEP program addresses fundamental questions about the nature of the universe by balancing 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. In this plan there is a continuing shift of focus from the operation of the facilities built at the end of 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. In the FY 2012 Budget Request, investments are prioritized to develop future accelerator-based experimental research facilities.

The Energy Frontier: The Tevatron Collider at Fermilab completes its planned program in FY 2011. Its record-breaking performance in delivering data over the last few years will result in a dataset that can continue to be mined for significant discoveries during the first few years of Large Hadron Collider (LHC) operations at CERN. In FY 2012, HEP will support the analysis needs of researchers to exploit the data obtained. 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 the LHC data now being acquired.

First beam collisions at the LHC occurred in November 2009. The beam energies were raised to 3.5 TeV per beam (7 TeV center of mass energy) in March 2010, a new record for man-made particle collisions. The first run of the LHC is currently planned to end in late 2011. 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 2012, 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. However, CERN is considering delaying the shutdown and extending the run into 2012 for the discovery or exclusion of a Standard Model Higgs. A formal announcement on this is expected in February 2011.

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

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 that will enhance the beam power from approximately 400 kW 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, project engineering and design funding is provided for the Long Baseline Neutrino Experiment (LBNE) and the Muon to Electron Conversion Experiment (Mu2e), which will use the NuMI beam and other auxiliary beamlines before the end of the decade. The HEP program has been developing the LBNE project in coordination with NSF, because the Deep Underground Science and Engineering Laboratory (DUSEL) in the Homestake mine in South Dakota proposed to be built by the National Science Foundation was a possible site for the LBNE far detector. However, based on a National Science Board decision, NSF will not pursue DUSEL as previously proposed. The Project Engineering and Design (PED) request for LBNE has been reduced due to the anticipated delay in achieving Critical Decision 1. High Energy Physics will support activities for minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided by the Nuclear Physics program. High Energy Physics will assess options for a future Long Baseline Neutrino Experiment and dark matter experiments.

The Cosmic Frontier: HEP is partnering with NASA and NSF in world class space-based, and ground-based particle astrophysics observatories for exploration of the Cosmic Frontier. In FY 2012, funding supports existing and ongoing endeavors with NSF (such as VERITAS, Auger, DES, BOSS, and CDMS) and NASA (Fermi and AMS). Looking to the future, HEP has utilized the guidance of HEPAP and the recent National Academies Astro2010 reports on scientific priorities and worked with NASA and NSF to mount a U.S. program that will advance our understanding of dark matter and dark energy. HEP plans to collaborate with NSF on a staged program of research and technology development designed to directly detect dark matter particles using ultra-sensitive detectors located underground. HEP also plans to work with NSF on implementing the Large Synoptic Survey Telescope for studies of dark energy using a ground-based telescope, and plans to support researchers working with NASA on design of a space-based mission. HEP's FY 2012 request supports R&D and conceptual design efforts for these initiatives.

Significant Program Shifts

To position the U.S. to remain among the leaders in particle physics it is critical that investments are made in new U.S. research capabilities that can make significant discoveries and advance our understanding of fundamental properties of matter. In the FY 2012 Budget Request, funds are shifted from facility operations, particle physics research, advanced technology R&D, and Major Items of Equipment to support the increase in the planned funding profiles for two construction projects (LBNE and Mu2e). In this Request, funding for Facility Operations, Particle Physics Research, Advanced Technology R&D, and Major Item of Equipment projects are all significantly reduced, while selected other activities are supported to address key site infrastructure investments at Fermilab. The FY 2012 Budget Request supports a strong, productive program that is making the needed investments for future sustained leadership; however, there will be a downsized research program in the short term that will result in diminished leadership role in a number of endeavors.

The reduction in Facility Operations comes primarily from savings from the completion of Tevatron operations at Fermilab in 2011. FY 2012 funding supports operations of NuMI and smaller neutrino experiments for half a year followed by a half-year shutdown for the accelerator upgrade for the NOvA experiment. Decontamination and decommissioning (D&D) activities for the Tevatron ring and detectors begins in FY 2012. LHC detector operations and support is held at approximately the FY 2010 level of effort to fulfill U.S. responsibilities in this high priority effort. SLAC B-Factory D&D activities start to decrease as detector disassembly is completed. Funding is provided within the Proton Accelerator-based subprogram under Other Facilities to support minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided by the Nuclear Physics program. High Energy Physics will assess options for a future Long Baseline Neutrino Experiment and dark matter experiments.

The reduction in Particle Physics Research is taken across the HEP subprograms, with reductions in most areas of a few percent to accommodate the overall budget constraints noted above, with two notable exceptions: the reduction in Electron Accelerator-Based Physics continues the resizing of U.S. participation in this area since the completion of SLAC B-Factory operations in 2008, and the reduction in funding between FY 2010 and FY 2012 for Non-Accelerator Physics is dominated by the roll-off of funding of the Daya Bay and Dark Energy Survey projects, according to the approved profiles.

The reduction in Advanced Technology R&D reflects the completion of some activities, offset by support for ongoing and planned initiatives. Directed accelerator R&D efforts (ILC R&D and Superconducting RF R&D) ramp down as they near completion of planned activities. Funding for Accelerator Science ramps up to support the research programs of the wakefield plasma demonstration experiments (BELLA/FACET) and for consolidation of muon accelerator R&D activities into a five year muon directed R&D effort to better understand the feasibility of this technology as a possible future energy frontier accelerator. Detector R&D is reduced to approximately the FY 2010 funding level.

The reduction in Major Items of Equipment (MIE) projects reflects the completion or ramp down of ongoing projects in Proton Accelerator-Based and Non-Accelerator Physics and the start of a small Cosmic Frontier MIE (High Altitude Water Cherenkov detector).

Annual Performance Results and Targets

The Department is in the process of updating its strategic plan, and has been actively engaging stakeholders including Congress. The draft strategic plan is being released for public comment concurrent with this budget submission, with the expectation of official publication this spring. The draft plan and FY 2012 budget are consistent and aligned. Updated measures will be released at a later date and available at the following link http://www.mbe.doe.gov/budget/12budget.

Proton Accelerator-Based Physics

Funding Schedule by Activity

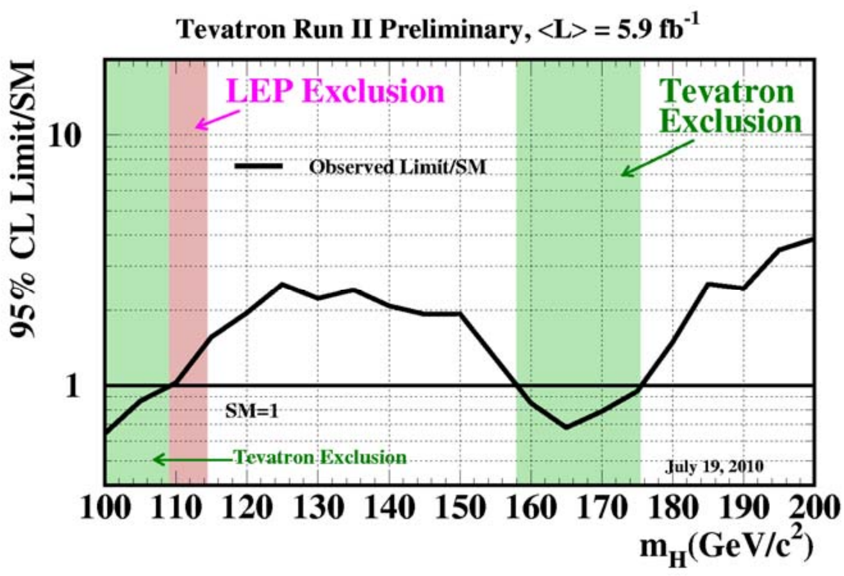
	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Proton Accelerator-Based Physics		
Research	125,743	127,696
Facilities	312,626	283,511
Total, Proton Accelerator-Based Physics	438,369	411,207

Description

The Proton Accelerator-Based Physics subprogram exploits the application of proton accelerators at two of the scientific frontiers. At the Energy Frontier, experiments at the LHC 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 NuMI 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, which is a primary goal of HEP-supported neutrino research.

Selected FY 2010 Accomplishments

- Researchers continue treading on unexplored Higgs territory with the Tevatron Collider experiments at Fermilab. Combined results from the Tevatron Collider experiments now exclude a region of Higgs mass between 158 and 175 times the mass of the proton (see below). As more data is collected



Recent Tevatron Standard Model Higgs exclusion limits. The vertical scale corresponds to the limit in units of the Standard Model (SM) prediction (i.e., 1=experimental limit at the predicted SM level); the horizontal scale corresponds to Higgs mass. The solid jagged line represents the observed experimental result. The Tevatron excludes the Higgs at 95% probability when the observed result curve is below the horizontal SM=1 line for a particular Higgs mass (shaded areas).

and analyzed at the Tevatron, either this exclusion region will expand or the first possible hints of the Higgs boson will appear.

- The Tevatron Collider experiments, CDF and D-Zero, continue to observe rare Standard Model processes such as double Z boson production, simultaneous W and Z boson production, and single top quark production. As more data is collected and better techniques are developed, Tevatron researchers continue to refine their measurements of top quark and W boson parameters, which are used to further constrain new physics theories. The innovative analysis methods employed by CDF and D-Zero scientists and their thorough understanding of detector performance and backgrounds are opening new opportunities for discoveries. For example, the D-Zero collaboration announced in the spring of 2010 indications of a possible anomalous CP violation in the mixing of neutral B mesons.
- Operations of the LHC began in late 2009 after a year-long shutdown to repair electrical problems discovered in its initial start-up. The energy of the machine was ramped up to a center-of-mass energy of 7 TeV in March 2010, surpassing the Tevatron Collider as the world's highest energy accelerator, although initial luminosity was very low as the machine is being carefully commissioned. Both the ATLAS and CMS large detectors are collecting data with full functionality. Results from first data have already been published, and the LHC experiments presented their first Standard Model "re-discovery" results showing observation of expected W and Z boson and top quark events during summer 2010. The LHC has increased its luminosity dramatically over the course of 2010 and is expected to accumulate much more data in 2011 during its first physics run.
- Two Fermilab neutrino experiments, MINOS and MiniBooNE, have collected data with an anti-neutrino beam and reported first results. Although statistically limited, an initial analysis of the data offers tantalizing hints regarding the fundamental properties of neutrinos, which may be an indication of new physics in the neutrino sector.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Research	**125,743**	**127,696**

The major research activities under the Proton Accelerator-Based Physics subprogram are the research programs using the CDF and D-Zero detectors at the Tevatron at Fermilab, the neutrino research program using the MINOS detectors located at Fermilab and at the Soudan Mine site in Minnesota, and the research programs of ATLAS and CMS at the LHC at CERN.

The research program using the Tevatron Collider at Fermilab is being carried out by a collaboration composed of approximately 1,200 scientists from Fermilab, Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), 50 U.S. universities, and institutions in over 20 foreign countries. The major effort in FY 2012 is the analysis of data from the CDF and D-Zero detectors. The physics issues to be addressed include searches for the Higgs boson, supersymmetry, or other new phenomena; B meson studies including charge-parity (CP) violation; and precision measurements of the top quark and the W boson properties. In particular, the direct experimental searches for a Standard Model Higgs boson with a mass in the range expected (based on other indirect experimental data) will require the entire Tevatron data set. With the data

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

collected through FY 2011, the Tevatron Collider experiments will continue their data analysis in FY 2012 of the entire region of the expected Higgs mass range.

The research program using the MINOS facilities at Fermilab and the Soudan Mine is being carried out by a collaboration that includes approximately 250 scientists from Fermilab, ANL, BNL, 16 U.S. universities, and institutions in five foreign countries. The major effort through mid-FY 2012 will be data collection and analysis, along with optimizing accelerator performance to improve beam intensity for higher statistics measurements. The experiment is planned to complete its data taking in FY 2012 to achieve its ultimate sensitivity, approximately a factor of two improvement over its current result, and will search for the as-yet unseen oscillation of muon neutrinos to electron neutrinos.

In FY 2012, U.S. researchers will play a leadership role in the physics discoveries at the high energies enabled by 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. Maintenance of U.S.-supplied detector elements for LHC experiments at CERN will continue.

	FY 2010	FY 2012
▪ **Grants Research**	**60,090**	**61,815**

The grant-based HEP experimental research program consists of groups at more than 60 universities performing experiments at proton accelerator facilities. 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 and funded at levels commensurate with the effort needed to carry out the approved research scope. The detailed funding allocations will take into account the quality and scientific priority of the research proposed.

In the FY 2012 request, grant research funding is held at approximately the FY 2010 level-of-effort, in order to accommodate overall budget constraints. High priority activities within this program will be support of LHC research activities, and growth of a strong neutrino physics programs. High-priority data analysis efforts in the Tevatron Collider program will be maintained but there will be reductions in the broader Tevatron research effort. There will be healthy scientific competition between completion of Run II of the Tevatron Collider program and the LHC experiments. At the same time, university groups are expected to take important roles in developing the design, physics optimization, and analysis techniques for the planned neutrino initiatives, such as NOνA and LBNE, and support the operation and data analysis of the Main Injector Experiment ν-A (MINERνA). U.S. university groups also have leadership roles in the Tokai-to-Kamioka (T2K) neutrino oscillation experiment that complements and extends the physics reach of NOνA.

	FY 2010	FY 2012
▪ **National Laboratory Research**	**64,069**	**64,990**

Proton accelerator research activities concentrate on experiments at the Tevatron complex (collider and neutrino physics programs) at Fermilab and the LHC at CERN. The HEP program conducted a comparative peer review of laboratory research groups in this subprogram in 2009, and findings from this review have been used to inform the funding decisions in the FY 2012 request. In the FY 2012 request, national laboratory research funding is held slightly below the FY 2010 level-of-

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request

effort, in order to accommodate the programmatic priority for construction of new research facilities within the context of overall budget constraints. Within this activity, the priority research efforts will be support of LHC research activities and growth of a strong neutrino physics programs. High-priority data analysis efforts in the Tevatron Collider program will be maintained, but since Tevatron experiments will no longer be taking data, the overall size of the effort is somewhat reduced.

The Fermilab research program includes analysis of the CDF, D-Zero, and MINOS experiments; the CMS research and computing program; and research related to the NOνA, MINERνA, MicroBooNE, and LBNE experiments. Research at LBNL consists of a large and active group in the ATLAS research program. The BNL research group will focus on the ATLAS research and computing program, and an enhanced effort related to future neutrino initiatives, in particular detector design for LBNE. The research group at ANL will be working primarily on the ATLAS research and computing program, analysis of the MINOS data, and research on NOνA. The research group from SLAC on the ATLAS experiment has taken on important roles in data analysis and physics studies for possible detector upgrades.

	FY 2010 Current Appropriation	FY 2012 Request
▪ **University Service Accounts**	**1,584**	**891**

University Service Accounts facilitate the support of university groups working at accelerator facilities. This activity provides funding for these groups to purchase needed equipment and services from the laboratories with a minimum of time and cost overhead. Currently, 45 university groups maintain service accounts at Fermilab and at BNL. Funding for these university service accounts reflects the anticipated need.

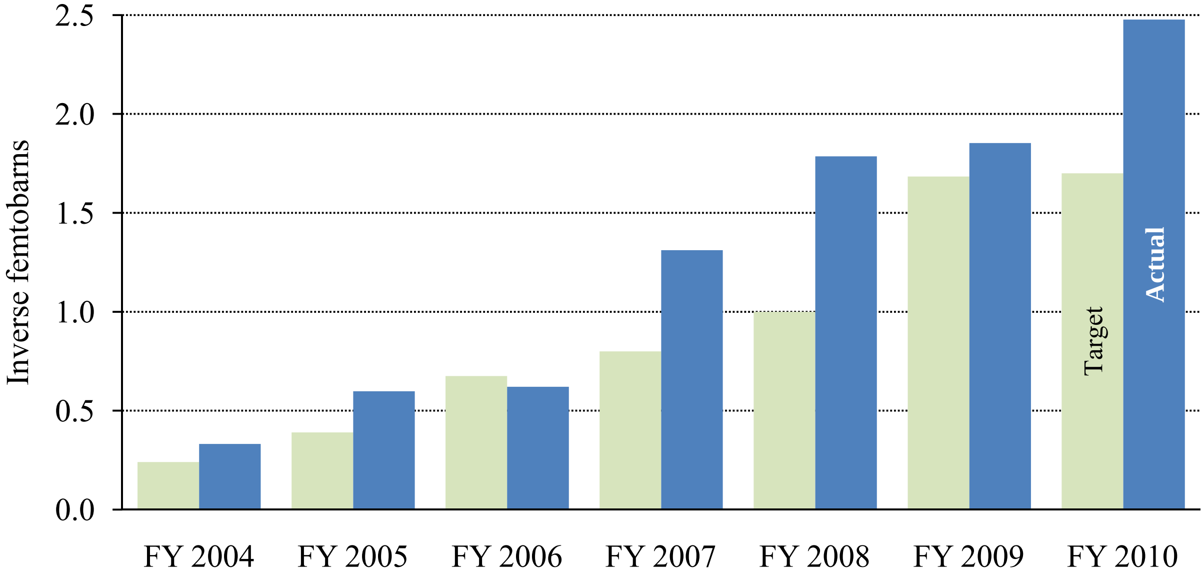
	FY 2010 Current Appropriation	FY 2012 Request
Facilities	**312,626**	**283,511**
▪ **Proton Accelerator Complex Operations**	**125,945**	**103,374**

Fermilab operations include running the Tevatron accelerator complex for both collider and neutrino physics programs comprising two collider detectors and several neutrino experiments, respectively. The performance of the Tevatron collider has continued to improve as the laboratory staff has learned to effectively exploit the upgrades that were completed in FY 2006. Tevatron performance improved significantly in FY 2007 and FY 2008 and reached a steady state of high performance in FY 2009. The plot below shows the annual integrated luminosity delivered to the experiments.

(dollars in thousands)

FY 2010 Current Appropriation	FY 2012 Request

Tevatron Yearly Luminosity, Actual vs. Target



Some of the increase in luminosity in FY 2008 was due to additional running time that was scheduled to maximize the integrated luminosity before the first beam collisions at the LHC. Performance in FY 2009 improved and the yearly total was slightly higher than FY 2008 with a normal length run. Performance in FY 2010 was approximately 2.5 fb^{-1} and should plateau at that level.

In FY 2012, the reduced funding in this category reflects the fact that Tevatron Collider operations will have been completed and the accelerator complex will shut down for a large part of the year to install proton beam intensity upgrades for NOνA and other neutrino experiments. Funding is provided for initiating stand down and decommissioning activities of the Tevatron ring and two detectors. Portions of the collider complex including the recycler, debuncher, and accumulator rings will be reused to raise the intensity of the proton source and create new beams as part of the NOνA and Mu2e projects. The collider ring and detectors will be put into a safe state in preparation for decommissioning.

Operations of the accelerator complex will provide increased intensity beams to the neutrino program, since there will no longer be a need to share protons with the collider program. The NuMI beam will support the MINOS experiment and the small MINERνA experiment which is located in the MINOS near detector hall at Fermilab and is measuring the rates of neutrino interactions with ordinary matter. Its results are important for interpreting the data from MINOS and other neutrino experiments, including NOνA. A lower energy neutrino beam produced with protons from the Booster accelerator will support operations of the MiniBooNE experiment. Both MINOS and MiniBooNE are studying differences in the behavior of neutrinos versus antineutrinos.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

	FY 2010	FY 2012
Proton Accelerator Complex[a]		
Achieved Operating Hours	7,631[b]	N/A
Planned Operating Hours	5,400	2,650
Optimal hours (estimated)	5,400	2,650
Percent of Optimal Hours	141%	100%
Unscheduled Downtime	11%	N/A
Total Number of Users	2,000	1,400

- **Proton Accelerator Complex Support** **13,001** **12,462**

  This category includes funding for accelerator improvements, experimental computing expansion, and other detector support, as well as funds for general plant projects (GPP) and other infrastructure improvements at Fermilab. A backlog of GPP projects was addressed with Recovery Act funding in 2009-10 resulting in reduced need for GPP funds in recent years. Planned GPP funding in FY 2012 is restored to historical levels in order to adequately maintain site infrastructure over the long term, offset by a declining need for accelerator complex infrastructure after completion of the Tevatron program. Improvements to the cooling, shielding, and power supplies in the booster, main injector, and NuMI beam-line will be performed to support the higher beam intensities that become available after the NuMI power upgrade that is being done as part of the NOνA project.

- **Proton Accelerator Facility Projects** **86,591** **75,240**

  - **Current Facility Projects** **79,998** **60,240**

    After the completion of Tevatron Collider Run II, it will be possible to adapt portions of the existing collider complex to support operations of the NuMI beam-line at even higher intensity. Reconfiguration of the recycler, which currently serves as a storage ring for antiprotons, can raise the beam power to the NuMI target from 400 kW to 700 kW and is being done as part of the NOνA project.

    The NOνA detector is optimized to identify electron-type neutrinos and, using the NuMI beam from Fermilab, it will observe for the first time the transformation of muon-type neutrinos into electron-type neutrinos. It will also make important indirect measurements from which we may be able to determine the mass hierarchy of the three known neutrino types (e.g., whether there are two light and one heavier type neutrinos or vice versa). This will be a key piece of information that will help determine the currently unknown masses of neutrinos. The project includes the very large far detector (approximately five stories high with a football-field size

[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 before the LHC turned on.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

footprint), the far detector enclosure, its associated electronics and data acquisition system, and a small near detector on the Fermilab site. The project baseline was approved in September 2008. In FY 2012, the Fermilab accelerator complex will be modified in order to increase the beam power to 700 kW and work will continue on the far detector. Planned funding in FY 2012 for NOνA is $41,240,000. Fabrication will be completed in FY 2014, but the experiment can start taking data with a partially completed detector in FY 2013.

Funding in FY 2012 includes $6,000,000 to continue fabrication of the MicroBooNE experiment. This is a Major Item of Equipment (MIE) project that will fabricate a 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 the work planned for MINERνA and will be important for interpreting data from T2K and the proposed LBNE.

Support for conceptual design and planning of two construction projects is included for LBNE ($7,000,000) and Mu2e ($6,000,000). The planned profiles reflect CD-1 approval in FY 2012 and proceed with Project Engineering and Design work as described in the Construction section.

• **Future Facility R&D**	**6,593**	**15,000**

Pre-conceptual R&D for possible future projects that utilize the Fermilab facility is funded in this category. Specifically, pre-conceptual R&D is supported in FY 2012 for: detector concepts tied to future facilities, possible new experiments using the existing Tevatron complex, and for a superconducting GeV linac. This linac would provide the beam power needed to continue Intensity Frontier experiments using the Fermilab accelerator complex. It would replace the current linac and booster accelerators at Fermilab, which are over 35 years old, and upgrade the beam power approximately 2–3 times beyond the upgrades planned for NOνA.

▪ **Large Hadron Collider Support**	**79,511**	**72,761**

U.S. involvement in the LHC has been regularly endorsed by HEPAP and by a National Academies report (EPP 2010[a]). The overall U.S. LHC effort is jointly supported by DOE and NSF and is one of HEP's highest priorities. HEP resources will be used for LHC software and computing, as well as operations and maintenance of the U.S.-built systems that are part of the LHC detectors. The U.S. also participates in accelerator commissioning and accelerator physics studies that use the LHC, along with R&D for potential future upgrades to both the accelerator and its detectors.

• **LHC Accelerator Research**	**12,390**	**12,390**

The U.S. LHC Accelerator Research Program (LARP) is supported solely by DOE. It will continue to focus its R&D effort on the production of full-scale, accelerator-quality magnets that sustain the highest possible magnetic fields. This R&D effort will provide important technical data to CERN for management decisions on possible future accelerator upgrades to increase the LHC energy and/or luminosity. In late 2009, full-size prototype upgraded high-field LHC interaction region magnets composed of niobium-tin (Nb_3Sn) superconductor material, were

[a] "Revealing the Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics" is available at http://www.nap.edu/catalog.php?record_id=11641.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

demonstrated by the U.S. groups developing this technology. Further development and implementation of these magnets is one avenue for possible U.S. participation in upgrades to the LHC. Special instrumentation such as LHC beam collimation and monitoring systems is also being developed under the LARP program. These instruments will play an important role in improving and achieving reliable LHC accelerator operations.

• **LHC Detector Support**	**58,121**	**60,371**

Funding is provided for operations and maintenance of the U.S.-built detector subsystems. These detectors were commissioned with cosmic ray data until the first LHC beam collisions occurred late in 2009. This effort will support the continuing development, deployment, and improvement of tools and procedures required to collect the detector data at high efficiency and develop the calibration and alignment procedures required in order to understand the detector performance at the level necessary for physics analysis. Support is also provided for technical coordination and program management.

To date, U.S. detector support efforts have focused on hardware commissioning and on the infrastructure needed for full analysis of data using professional-quality software. Grid computing solutions are integrated into the experiment computing models, building on the tools provided by the Scientific Discovery through Advanced Computing (SciDAC) Open Science Grid project. The grid provides U.S. researchers the access and computing power needed to analyze the large and complex data sets. For FY 2012, well-connected computing hardware facilities running grid computing interfaces are essential to enable a rapid analysis of the data from the first full LHC physics run.

Support is also provided for detector R&D, with specific focus on detector technologies needed to accommodate the proposed LHC upgrade in luminosity.

• **LHC Upgrades**	**9,000**	**0**

Fabrication of the Accelerator Project for the Upgrade of the LHC (APUL) was planned to be initiated in FY 2010. The Mission Need (CD-0) was approved October 2008 and conceptual design has been completed, but subsequent changes in the LHC operations schedule announced in the spring of 2010, including a significant delay in the timeframe for LHC upgrades, forced a reconsideration of these plans. Options for a revised U.S. scope of work, with reduced participation in near-term upgrades, were coordinated with CERN management. The analysis of alternatives and conceptual design for the revised project have been completed, and CD-1 was approved in September 2010. No funds will be needed in FY 2012.

▪ **Other Facilities**	**7,578**	**19,674**

This category includes funding for long-term D&D of the Alternating Gradient Synchrotron (AGS) facility at BNL, where operations as a HEP user facility were terminated at the end of FY 2002. Funding for private institutions, government laboratories, and foundations that participate in high energy physics research is also included, as well as recurring contributions to general program operations activities, such as the federal laboratory consortium, financial auditing, support for internal and external program and project reviews, personnel support under the Intergovernmental Personnel Act, and technical consultation on programmatic issues. This category also includes

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
funding to respond to new opportunities and unexpected changes in facilities operations and support. This will be particularly important during FY 2012, considering the inherent uncertainties in estimating the resources needed for a smooth transition at the end of Tevatron operations.		
Funding is also provided within this category to support minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided by the Nuclear Physics program. High Energy Physics will assess options for a future Long Baseline Neutrino Experiment and dark matter experiments.		
Total, Proton Accelerator-Based Physics	**438,369**	**411,207**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research	
▪ **Grants Research**	
Funding for the core grants research program will fully support LHC collider research while growing a strong neutrino physics program to exploit future facilities. To enable this growth in a roughly constant level-of-effort budget, some reductions will be taken in Tevatron research support.	+1,725
▪ **National Laboratory Research**	
Funding is somewhat below the FY 2010 level-of-effort, but will fully support LHC collider research and enhance efforts in the neutrino physics program. Reductions will be taken in Tevatron research support.	+921
▪ **University Accounts**	
Funding reflects anticipated need, including reduced support for Tevatron activities.	-693
Total, Research	**+1,953**
Facilities	
▪ **Proton Accelerator Complex Operations**	
Funding for Proton Accelerator Complex Operations decreases in FY 2012 with the termination of Tevatron Collider operations.	-22,571
▪ **Proton Accelerator Complex Support**	
Proton Accelerator Complex Support operating funds decrease as support needed for the Tevatron Collider program is reduced, but this is mostly offset by increases in planned GPP funding needed to maintain Fermilab site and accelerator infrastructure over the long term.	-539

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **Proton Accelerator Facility Projects**	
• **Current Facility Projects**	
Net funding for Current Facility Projects decreases according to the planned project profiles. Reductions are driven by ramp-down in the NOvA profile, partially offset by funding increases for MicroBooNE and Mu2e. Funding in this category for LBNE decreases as conceptual R&D activities will be shifted to Project Engineering and Design funding, as reflected in the Construction section.	-19,758
• **Future Facility R&D**	
Funding increases reflect expanded activities on pre-conceptual R&D for a superconducting GeV linac in support of the future Intensity Frontier program.	+8,407
Total, Proton Accelerator Facility Projects	**-11,351**
▪ **Large Hadron Collider Support**	
• **LHC Detector Support**	
Support for U.S. activities on LHC experiments, including responsibilities for maintenance and operations of the detectors, and support for data analysis, are maintained at the FY 2010 level-of-effort in order to enable increased pre-conceptual R&D for possible LHC upgrades.	+2,250
• **LHC Upgrades**	
Funding for the LHC upgrade project (APUL) is completed in FY 2011.	-9,000
Total, Large Hadron Collider Support	**-6,750**
▪ **Other Facilities**	
Funding provides for various service and support activities in FY 2012 at a level significantly above FY 2010, mostly to support minimal, sustaining operations for one year at the Homestake mine in South Dakota.	+12,096
Total, Facilities	**-29,115**
Total Funding Change, Proton Accelerator-Based Physics	**-27,162**

Electron Accelerator-Based Physics

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Electron Accelerator-Based Physics		
Research	15,263	13,069
Facilities	14,949	9,250
Total, Electron Accelerator-Based Physics	30,212	22,319

Description

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. Over the last decade, the electron B-factory at SLAC led investigations at the Intensity Frontier, providing precision measurements of different behavior of matter and antimatter observed in the decay products of B-mesons. Physicists consider this asymmetric behavior, called charge-parity (CP) violation, to be vital to understanding the apparent predominance of matter over antimatter, one of the greatest puzzles in comprehending the structure of the universe. In FY 2012, HEP will support U.S. researchers to participate in the Japanese B-factory at KEK and will begin R&D towards an upgrade of the BELLE detector at KEK.

Selected FY 2010 Accomplishment

- Over the past several years, the B-factories in the U.S. and Japan discovered several unexpected new particles which contain a charm quark and a charm antiquark. However, the masses and decay patterns of these new states do not fit within the theoretical expectations from quantum chromodynamics (QCD) for standard strongly bound quark-antiquark states, and the evidence for some of these new states is controversial and in need of independent confirmation. These recently discovered exotic particles may be hybrid quark-antiquark-gluon states, loosely bound “molecules” of conventional charmed mesons, or four quark states. The exploration of this unforeseen new spectroscopy is an essential step towards fully understanding QCD. Studies of these exotic hadrons with the full B-factory datasets are ongoing.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Research	**15,263**	**13,069**

The research program at the B-factory/BaBar Facility at SLAC will continue winding down analysis of the 557 fb^{-1} data set that has been accumulated over the nine-year operational life of the facility. Physicists from approximately 17 universities, three national laboratories (LLNL, LBNL, and SLAC), and seven foreign countries have been actively involved in the data analysis. The physics issues to be addressed include expanding our understanding of CP violation in many particle decay modes and the investigation of the many heavy quark states predicted by QCD.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

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 and recently upgraded electron accelerator facilities in China. A total of three DOE-funded U.S. university groups currently work on the BELLE detector at KEK-B and two groups work at the Beijing Electron-Positron Collider (BEPC). There are also R&D efforts aimed at designing detectors for next-generation off-shore "Super-B factories" in Japan and Italy and possible future high-energy lepton colliders. Two collaborative proposals for participation in off-shore Super-B factory upgrades were reviewed by HEP in 2010, and based on the outcome of that review, HEP plans to support modest participation in the future Japanese Super-B factory upgrades and research program.

▪ **Grants Research**	**5,959**	**5,192**

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 funded based on peer review and at levels commensurate with the effort needed to carry out the experiments.

In the FY 2012 request, funding continues at a reduced level of effort, since the U.S. will have a reduced role in future B-factory facilities. 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.

▪ **National Laboratory Research**	**9,278**	**7,877**

The national laboratory research program consists of groups at four laboratories participating in experiments at electron accelerator facilities with a physics program similar to the grant program described above. Electron accelerator research activities concentrate on experiments at the SLAC B-factory. 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.

In FY 2012, laboratory-based research in this subprogram 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 in FY 2012 as they ramp down activities, complete analyses, and phase into new research activities.

▪ **University Service Accounts**	**26**	**0**

University Service Accounts facilitate the support of university groups working at accelerator facilities by providing funds for these groups to purchase needed supplies and services from the laboratories with minimum time and cost overhead. Currently 12 university groups maintain service accounts at SLAC. It is anticipated that there will be no need for this support in FY 2012.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Facilities	**14,949**	**9,250**
▪ **Electron Accelerator Complex Operations**	**12,019**	**8,350**

B-factory operations ended in FY 2008. Funding in this category supports the transition of the B-factory accelerator complex to a safe and stable maintenance mode and decommissioning and decontamination (D&D) activities. Funding follows the established profile for the D&D activity and is re-evaluated annually.

▪ **Electron Accelerator Complex Support**	**2,930**	**900**

Funding is provided for the necessary maintenance and operation of computing capabilities in order to complete the analysis of the B-factory data.

Total, Electron Accelerator-Based Physics	**30,212**	**22,319**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research	
▪ **Grants Research**	
Funding for electron accelerator-based experimental research is reduced. Only analysis of the highest priority final archival results from BELLE and BaBar data will be completed. Reductions will be taken in BaBar research support.	-767
▪ **National Laboratory Research**	
Funding for electron accelerator-based experimental research is reduced. Only analysis of the highest priority final archival results from BaBar data will be completed. Reductions will be taken in BaBar research support.	-1,401
▪ **University Service Accounts**	
Decreased funding as a result of no planned support in FY 2012.	-26
Total, Research	**-2,194**
Facilities	
▪ **Electron Accelerator Complex Operations**	
Funding for B-factory Operations is reduced according to the planned profile for safe dismantling and decommissioning of the BaBar detector and putting the accelerator into a minimum maintenance configuration.	-3,669

	FY 2012 vs. FY 2010 Current Approp. ($000)
• **Electron Accelerator Complex Support**	
Funding is significantly reduced from the FY 2010 level as BaBar data analysis is completed.	-2,030
Total, Facilities	**-5,699**
Total Funding Change, Electron Accelerator-Based Physics	**-7,893**

Non-Accelerator Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Non-Accelerator Physics		
Grants Research	21,708	21,417
National Laboratory Research	44,933	46,435
Projects	30,828	14,000
Total, Non-Accelerator Physics	97,469	81,852

Description

The Non-Accelerator Physics subprogram provides U.S. leadership in the study of those topics in particle physics that cannot be investigated with accelerators or are best studied by other means. For example, some of the earliest discoveries in particle physics were due to the production of previously unobserved particles in high-energy cosmic rays. Non-Accelerator Physics studies play an important role in the HEP program, 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 understanding the nature of dark matter and dark energy; precision measurements of neutrino properties; and searches for new phenomena such as proton decay and primordial antimatter. These areas of research probe well beyond the Standard Model of particle physics and offer possibilities for discovery of significant new physics phenomena.

Selected FY 2010 Accomplishments

- In FY 2010, the Large Area Telescope (LAT), the primary instrument on NASA's Fermi Gamma-ray Space Telescope (FGST) mission, continued to perform outstandingly. In March 2010, the LAT collaboration showed that less than a third of gamma-ray emission arise from black-hole powered jets from active galaxies, previously suspected as the primary source. Instead it could come from particle acceleration in star-forming galaxies or clusters of galaxies that are merging. Another possibility, which would need much more work to determine, is that it comes from gamma ray production from dark matter particle interactions.
- The FGST identified stringent limits on Lorentz invariance violations (LIV) predicted by some quantum gravity and string models. Lorentz invariance—the idea that the laws of physics are the same to observers everywhere in the universe—is one of the bedrock principles of physics. On May 9, 2009, the FGST observed a gamma-ray burst (GRB) about 10 billion light-years away with a 30 GeV gamma-ray arriving 0.8 seconds after the initial X-ray burst. Since linear LIV models predict a measurable variation of light speed with photon energy, the short delay time between the beginning of the GRB and the gamma-ray arrival severely constrains these models.
- The Cryogenic Dark Matter Search (CDMS) collaboration announced in late 2009, the final results of the first phase of their experiment. The results are based on several years of data taking with a few kilograms of ultra-sensitive silicon and germanium detectors that can detect extremely rare dark matter interactions. They found two events in their signal region, but this could be a statistical fluctuation of the expected background due to naturally-occurring radioactivity. An upgraded 15 kg

detector with improved background rejection is in fabrication (SuperCDMS) and will be installed in the Soudan Mine in Minnesota and operated to confirm or deny the tantalizing initial results. Other experiments using different techniques are also actively exploring this region.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Grants Research	**21,708**	**21,417**

The grant-based program supports research groups at more than 35 universities that perform experiments at non-accelerator-based physics facilities. This program also funds private institutions, government laboratories, and foundations that participate in non-accelerator-based physics research. This subprogram is carried out in collaboration with physicists supported by other government agencies and institutes; among them NSF, NASA, and the Smithsonian Astrophysical Observatory. The selection of research efforts supported is based on peer review.

In FY 2012, the Non-Accelerator Physics grants program will support research on experiments that are now engaged in data collection, as well as preparations for future experiments. Funding is held slightly below the FY 2010 level. The operating experiments include the Very Energetic Radiation Imaging Telescope Array System, a ground-based gamma ray experiment at the Whipple Observatory in Arizona; the Pierre Auger Observatory in Argentina, which studies cosmic rays; and the LAT gamma-ray survey on NASA's FGST space-based mission. Studies of dark energy use data from the Baryon Oscillation Spectroscopic Survey (BOSS) experiment on the Sloan Digital Sky Survey telescope in New Mexico, and data from other telescope facilities detecting and studying supernovae.

Other active research efforts that expect to be taking data in 2012 include searches for direct detection of dark matter using the upgraded "Super" Cryogenic Dark Matter Search (SuperCDMS) at the Soudan Mine in Minnesota and the Large Underground Xenon experiment at the Sanford Lab in South Dakota as well as other dark matter searches using different techniques.

Research on neutrinos continues with Super-Kamiokande, a proton decay and neutrino detector located in the Kamioka Underground Laboratory in Japan; and the Enriched Xenon Observatory (EXO-200), an ultra-low-background detector with 200 kg of isotopically enriched Xenon, which is searching for neutrino-less double beta decay at the DOE Waste Isolation Pilot Plant facility in New Mexico.

New experiments that will be in operation by 2012 are Reactor Neutrino Detector at Daya Bay in China, Dark Energy Survey experiment at the Cerro Tololo Interamerican Observatory in Chile, and the Alpha Magnetic Spectrometer (AMS) experiment which is on the Space Shuttle manifest for launch in 2011 and will begin taking data shortly thereafter.

National Laboratory Research	**44,933**	**46,435**

Groups at several national laboratories (ANL, BNL, Fermilab, LBNL, LLNL, LANL, and SLAC) currently participate in non-accelerator-based physics experiments. With strong laboratory technical resources, the laboratory groups provide invaluable and unique service to the research program in terms of experiment management, design, construction, and operations. Laboratory scientists are also involved in the research. HEP conducted a comparative peer-review of the laboratory research efforts in this subprogram in 2010, and funding allocations reflect the findings of that review.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

In FY 2012, the laboratory research program in non-accelerator physics will continue to support research and operations for ongoing experiments such as the Pierre Auger Observatory, the LAT gamma-ray survey on NASA's FGST, and dark matter search experiments such as SuperCDMS and the Chicagoland Observatory for Underground Particle Physics 60 kg (COUPP-60) experiment. SLAC operates the instrument science operations center for the LAT. Laboratory groups also lead the commissioning, installation, operations and research efforts for various dark energy experiments such as Baryon Oscillation Spectroscopic Survey (BOSS) and Dark Energy Survey (DES).

Laboratory groups also participate in planning and implementation of future experiments that are completing their fabrication phase or initiating, such as the reactor neutrino detector for the Daya Bay experiment and High Altitude Water Cherenkov. The funding for FY 2012 in this category includes new support for the pre-operations and commissioning of DES ($980,000) and initial operations of the Daya Bay experiment ($3,920,000). Therefore, the core research component of this activity is reduced relative to previous years as some scientists move their effort primarily to commissioning and operations.

Projects	**30,828**	**14,000**
▪ **Current Projects**	**21,110**	**2,000**

FY 2012 is the last year of funding for the fabrication of the Reactor Neutrino Detector MIE for Daya Bay. DOE and the Chinese Institute for High Energy Physics are partners in this experiment, which will be located at a site near several commercial nuclear reactors in Daya Bay, China. This experiment will measure and compare the number of neutrinos observed by a detector close to a reactor (the near detector) with the number observed in a far detector about 10 km away. From this data, a crucial neutrino oscillation parameter can be extracted. The U.S. collaboration is led by groups from BNL and LBNL. The project is expected to be completed in FY 2012.

The DES project is expected to be completed in FY 2012. During FY 2012, installation, commissioning and pre-operations activities will take place. DOE supported 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. The DES collaboration is led by Fermilab and also, is a partnership between DOE, NSF, which operates the telescope, and international participants. The data management system and upgrades to the telescope facility are supported by NSF.

In FY 2012, one new major item of equipment (MIE) project is started. The High Altitude Water Cherenkov (HAWC) detector is a new experiment in Mexico (preliminary estimated DOE TPC $2,500,000–$3,500,000) that will survey the sky for sources of TeV gamma-rays in the 10–100 TeV range. This effort was identified in the HEPAP Particle Astrophysics (PASAG) Report as a scientific opportunity that should be pursued even in the case of constrained HEP budgets. This project is being done in collaboration with NSF and Mexican research institutes.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
▪ **Future Projects R&D**	**9,718**	**12,000**

This category provides support for R&D and pre-conceptual design activities for promising proposed future experiments and includes R&D on technical issues and concepts for dark matter, dark energy, and other particle astrophysics experiments. In previous years these have been focused primarily on possible dark matter and dark energy approaches and experiments.

In the FY 2012 Request, funding for future project R&D is increased relative to FY 2010 to position selected projects for the design phase, particularly in the areas of dark matter and dark energy. The available funding will be focused on R&D and pre-conceptual design for the proposed Large Synoptic Survey Telescope (LSST), and will be coordinated with NSF efforts. Consistent with the National Academies' Astro2010 recommendations, HEP will make LSST its highest priority dark energy initiative. DOE will continue to work with NASA in the development of a space-based dark energy observatory that is consistent with a national strategy and available resources.

Total, Non-Accelerator Physics	**97,469**	**81,852**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Grants Research	
Funding for grant-based research decreases somewhat below the FY 2010 level-of-effort, but will fully support research on currently operating experiments or those that will soon reach completion. Reductions will be taken in research support for future cosmic frontier experiments that are not priority efforts, as recommended by scientific community reports.	-291
National Laboratory Research	
Support for pre-operations, operations, and commissioning for projects that have reached or will soon reach completion (SuperCDMS, DES, Reactor Neutrino Detector) is increased, but this is partially offset by a reduction in funding for core research to meet overall budget constraints. Reductions will be taken in research support for future cosmic frontier experiments that are not priority efforts.	+1,502
Projects	
▪ **Current Projects**	
Project funding decreases for the Reactor Neutrino Detector, DES, and SuperCDMS following their planned profiles, partially offset by funds provided in FY 2012 for final design and beginning of fabrication for a new MIE, HAWC.	-19,110

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **Future Projects R&D**	
R&D funding is provided for proposed next-generation experiments in dark energy, dark matter, and other particle astrophysics topics. This funding is increased relative to FY 2010 to ready selected future projects for the design phase.	+2,282
Total, Projects	**-16,828**
Total Funding Change, Non-Accelerator Physics	**-15,617**

Theoretical Physics

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Theoretical Physics		
Grants Research	27,415	27,415
National Laboratory Research	25,838	26,074
Computational HEP	11,476	11,076
Other	3,685	4,349
Total, Theoretical Physics	68,414	68,914

Description

The Theoretical Physics subprogram provides the vision and mathematical framework for understanding and extending the knowledge of particles, forces, space-time, and the universe. This program supports activities that range from detailed calculations of the predictions of the Standard Model to the extrapolation of current knowledge to a new level of understanding and the identification of the means to experimentally search for them. Symmetries play a major role in the current understanding of the subatomic world: discovering how particle symmetries are realized (or broken) in nature has provided many fundamental breakthroughs in the development of the Standard Model. This subprogram supports and advances research at all three high energy physics Frontiers.

Selected FY 2010 Accomplishments

- Theorists continue to improve simulation tools for LHC experiments. In particular, calculations of next-leading-order Standard Model processes using BlackHat (software primarily developed at SLAC and University of California, Los Angeles) and those using other calculation tools primarily developed at Fermilab show excellent agreement with each other.
- In collaboration with their experimental colleagues, theorists at Rutgers University developed a technique for detecting a particle whose decay chain produced only hadronic final states. The search algorithm was tested successfully with top quark data from the Tevatron. This method may prove useful for new particle searches at the LHC.
- Harvard theorists identified a variable called “jet pull” which may be used to distinguish the color flow in jets. If successful, this will make it possible to distinguish b-jets produced in Higgs (color singlet) decay from the b-jets produced in gluon (color octet) decay, thus making it easier to identify a Higgs signal from the vast background.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Grants Research	**27,415**	**27,415**

This program consists of research groups at approximately 70 colleges and universities. It includes funding for private institutions, universities, and foundations that participate in theoretical physics. As part of their research efforts, the 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.

The grants program addresses topics across the full range of theoretical physics research. The main thrust is to 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 these research areas.

In the FY 2012 Request, grant research funding is held constant with the FY 2010 level, in order to accommodate the programmatic priority for construction and fabrication of new research facilities within the context of overall budget constraints. Reductions in the number of research groups supported are anticipated.

National Laboratory Research	**25,838**	**26,074**

The national laboratory theoretical research program currently consists of groups at seven DOE laboratories (Fermilab, SLAC, BNL, ANL, LBNL, LLNL, and LANL). The laboratory theory groups are a resource for the national research program, with a particular emphasis on collaborations with experimental scientists and data interpretation to provide a clear understanding of the significance of measurements from ongoing experiments and to help shape and develop the laboratories' experimental programs. Because of the significant computing capabilities available at national laboratories, the laboratory theory groups make major contributions to the U.S. and worldwide lattice QCD efforts. HEP conducted a comparative peer-review of the laboratory research efforts in this subfield in 2008 whose findings have been used to inform the funding decisions in this budget request; in particular there have been targeted increases in 2010 to support laboratory research programs that reviewed well. HEP plans to review these programs again in 2011.

The laboratory theoretical research groups address topics across the full range of theoretical physics, including the analysis and interpretation of the new data expected from the Tevatron Collider detectors and forthcoming data from the LHC. There are also efforts to understand properties of neutrinos through reactor, accelerator, and non-accelerator neutrino experiments. As data from the LHC becomes available, an increased effort will be made to identify the most promising and sensitive methods for finding signs of new phenomena in these data.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

In the FY 2012 Request, laboratory research funding is maintained at approximately the FY 2010 level, in order to accommodate the programmatic priority for construction and fabrication of new research facilities within the context of overall budget constraints. Accordingly, no new or expanded research efforts are started in FY 2012.

Computational HEP	**11,476**	**11,076**

This budget category provides for high energy physics research activities that require extensive or customized computational resources including R&D, design, fabrication, procurement, maintenance, and operation of computational software and hardware that is not associated with specific high energy physics experiments or research facilities. Current activities in this category include the Scientific Discovery through Advanced Computing (SciDAC) program, the Lattice QCD (LQCD) computing initiative, support for dedicated transatlantic networking, and U.S. contributions to experiment-independent computer codes required for HEP's program.

▪ **SciDAC**	**6,000**	**5,600**

All current HEP-supported SciDAC projects had mid-term continuation reviews in FY 2009 and are planned to be re-competed in FY 2012. The focus of the SciDAC competition will be in targeted areas where computational advances can make a significant contribution to HEP research and technology. The SciDAC program is managed and cooperatively funded by the Advanced Scientific Computing Research program and other SC programs. There are currently four principal HEP-supported SciDAC efforts: Type Ia supernova simulations, a joint effort with Nuclear Physics (NP) and the National Nuclear Security Administration; platform-independent software to facilitate large-scale QCD calculations (see also the Computational QCD computing initiative below), a joint effort with NP; very large scale, fault-tolerant data handling and distributed grid computing which will allow physicists in the U.S. to analyze petabytes of data produced in Europe at the LHC, a joint effort with NP and NSF; and large-scale computational infrastructure for accelerator modeling and optimization, to support design and operations of complex accelerator systems throughout the SC complex, a joint effort with NP and the Basic Energy Sciences program.

▪ **Computational QCD and Network Support**	**5,476**	**5,476**

The interpretation of many HEP experimental results has been limited by a lack of precision in QCD calculations, which describe the underlying physics; these calculations are in turn limited by a lack of computational power. This activity includes funding for the LQCD computing initiative that is a coordinated effort with the NP program aimed toward the development, procurement, and operation of a multi-teraflop computer capability for dedicated LQCD simulations. After successfully completing a dedicated ~10 teraflop "virtual facility" in 2009, researchers are now engaged in a follow-on effort to deploy and implement approximately 100 teraflops of dedicated capacity for QCD computing.

This category also includes funding for the HEP-related transatlantic network requirements between the U.S., CERN, and HEP-related computing facilities in Europe. These requirements are dictated by the unprecedented size of the LHC data set. The dedicated network paths are known as the U.S. LHC Net. In FY 2010, the U.S. LHC Net provided 60 gigabits per second of connectivity between CERN and points of presence in Chicago and New York. U.S. LHC Net is closely integrated with the DOE

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

Energy Science Network, which connects the U.S. LHC Net transatlantic bridge to the main U.S. research network backbone.

In the FY 2012 Request, funding is maintained at the FY 2010 level, in order to accommodate overall budget constraints.

Other	**3,685**	**4,349**

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 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. In the FY 2012 request, this effort is maintained slightly above the FY 2010 funding level to follow the planned increase in support for the PDG effort, including planned computing and software upgrades.

This category also includes funding for the QuarkNet education project which began in FY 1999. 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 real data from an active high energy physics experiment (such as at the Tevatron Collider or 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.

Total, Theoretical Physics	**68,414**	**68,914**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
National Laboratory Research	
The National Laboratory theoretical physics research program is maintained at approximately the FY 2010 funding level due to overall budget constraints, pending a comparative review of the laboratory research groups in 2011.	+236
Computational HEP	
▪ **SciDAC**	
Funding for HEP-related SciDAC projects, to be re-competed in FY 2012, is reduced to meet overall budget constraints. The number and scope of new proposals supported will be reduced.	-400

	FY 2012 vs. FY 2010 Current Approp. ($000)
Other	
Other Theoretical Research is maintained somewhat above the FY 2010 level, in order to support planned computing and software upgrades for the data compilations and summaries provided by the Particle Data Group at LBNL.	+664
Total Funding Change, Theoretical Physics	**+500**

Advanced Technology R&D

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Advanced Technology R&D		
Accelerator Science	42,427	54,117
Accelerator Development	88,712	73,146
Other Technology R&D	25,208	25,481
SBIR/STTR	0	19,164
Total, Advanced Technology R&D	156,347	171,908

Description

The Advanced Technology R&D subprogram fosters world-leading research in the physics of particle beams, accelerator research and development, and particle detection—all necessary for continued progress in high energy physics. High energy physics research relies on the use of high energy and high intensity particle beams generated with charged particle accelerators, storage rings, and their associated tracking and identification detectors. New developments are stimulated and supported through proposal driven, peer reviewed research. Ultimately, these new technological developments are incorporated into construction projects sponsored by HEP. This subprogram supports and advances research at all three particle physics Frontiers. Advanced Technology R&D also provides new technologies and research methods appropriate for a broad range of scientific disciplines, thereby enhancing DOE's broader strategic goals for science.

Selected FY 2010 Accomplishments

- An example of a novel technology developed in 2010 with DOE support is the water based liquid scintillator. By sulfonating linear alkyl benzene, a common chemical used to make detergent, to linear alkylbenzene sulfonate, a water-soluble biodegradable surfactant detergent, a water based scintillator can be created. The characteristics of this scintillator are now being studied at BNL for possible future applications for large scintillator detectors in high energy physics.
- As part of the ILC R&D effort, a consortium of DOE laboratories successfully increased the quality of superconducting radiofrequency (SRF) accelerator cavities, with production accelerator gradients now commonly approaching the benchmark level of 35 MeV per meter. This program also successfully initiated lab-industry partnerships to develop the production of cavities in U.S. industry and improve processing of the cavities at DOE laboratories. SRF is the technology of choice for a number of future accelerator projects and the increasingly higher yields will improve performance and reduce cost for these next generation accelerators.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Accelerator Science	**42,427**	**54,117**

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 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.

▪ **Grants Research**	**8,770**	**10,520**

The FY 2012 budget will continue support for a broad research program in advanced accelerator physics and related technologies. Funding is included for private institutions, universities, industry, and federal research centers that participate in fundamental accelerator physics. As part of their research efforts, these groups train graduate students and postdoctoral researchers. Physicists in this research area often work in collaboration with other university and laboratory groups. For example, university groups are leading the development and execution of the proposals for the experimental program at FACET. Research efforts are selected based on a peer review process.

The grant-based research program will continue to investigate novel acceleration concepts, such as 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; studies of accelerating gradient limits in normal conducting accelerators; development of advanced particle beam sources and instrumentation; and accelerator R&D into the fundamental issues associated with the ionization cooling of muon beams.

Funding is slightly over a constant level-of-effort to support university participation in developing proposals and conducting experiments at new accelerator R&D facilities (BELLA and FACET, see below).

▪ **National Laboratory Research**	**33,657**	**43,597**

This activity supports accelerator R&D efforts and operations of test facilities at ANL, BNL, Fermilab, LBNL and SLAC, and theoretical studies of space-charge dominated beams at the Princeton Plasma Physics Laboratory. HEP conducted a comparative peer-review of the laboratory research efforts in this subfield in 2008, whose findings have been used to inform the funding decisions in this budget request; in particular there are targeted increases to support laboratory research programs which reviewed well. HEP plans to review these programs again in 2011.

The national laboratory accelerator science program explores advanced methods to accelerate charged particles with the goal of more efficient, compact, and inexpensive particle accelerators. In FY 2012, funding is increased to support additional participation of national laboratory scientists in fully exploiting the research potential of the new accelerator R&D facilities, BELLA and FACET.

Efforts in FY 2012 will focus on the development of new accelerating structures and techniques needed to achieve accelerating gradients in excess of 100 MeV/m. This work currently occurs primarily at the Argonne Wakefield Accelerator, the Laser Optical Accelerator Systems Integrated

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

Studies (LOASIS) test facility at LBNL, and the new Facility for Accelerator Science and Experimental Test Beams (FACET) at SLAC. In FY 2011, the first round of experiments will begin at the new FACET facility where an electron bunch (the beam is not a continuous stream of electrons but structured in discrete bunches) is accelerated by plasma wakefields. The goal of this effort will be a demonstration of efficient, full-length accelerating structures with gradients well above 1 GeV per meter. The new BErkeley Lab Laser Accelerator (BELLA) project will be in fabrication in FY 2011 with completion planned for FY 2012. Funding for FACET operations ($6,000,000) and BELLA pre-operations and commissioning ($2,000,000) is included in this category.

The national laboratory groups are also involved in a significant long-range 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 coordinated by Fermilab. A five-year R&D plan for muon-based accelerators, with milestones and deliverables, has been submitted by U.S. research institutions and was reviewed by HEP in 2010. Part of the increased funding in this category is directed towards ramping-up this effort to execute the five-year R&D plan.

BNL is the home of the very successful Accelerator Test Facility. The facility supports HEP-funded research at universities as well as through the Small Business Innovation Research (SBIR) program, based on proposal-driven, peer-reviewed research in accelerator concepts and beam physics. In FY 2012, the facility will continue a program to test advanced accelerator concepts, develop new instrumentation, and further next-generation, high-brightness electron sources that are based on laser-driven photocathodes.

Accelerator Development	**88,712**	**73,146**

The task of this activity is to demonstrate 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, studies of very high intensity proton sources for potential application in neutrino physics research, and R&D relevant to the proposed International Linear Collider.

▪ **General Accelerator Development**	**31,721**	**33,146**

This activity focuses on R&D that can be widely applied to a range of accelerator facilities. The work is primarily done at Fermilab, LBNL, and SLAC. Funding is maintained at approximately the FY 2010 level-of-effort to maintain a robust technology development program as more directed R&D efforts ramp down. The major areas of R&D are superconducting magnet and related materials technology; high-powered RF acceleration systems; instrumentation; beam dynamics, both linear and nonlinear; and development of large simulation programs. The latter effort is coordinated with the SciDAC accelerator simulation project.

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request

The R&D program on high-power RF systems is led by SLAC, including simulation codes for modeling RF system components and high-powered microwave tubes. This program also builds custom high-power RF sources for HEP and other scientific applications.

Fermilab leads the R&D for a future high-intensity neutrino beam facility, in particular developing very high intensity proton sources for neutrino physics research.

The R&D program on superconducting magnets and materials includes efforts at BNL, Fermilab, and LBNL, focusing on demonstrating very high field superconducting magnets using advanced superconducting materials, and an industrially-based program to develop these materials, particularly niobium-tin.

▪ **Superconducting RF R&D**	**22,000**	**17,500**

Superconducting Radio Frequency (SRF) technology is applicable to a variety of future accelerator projects central to the HEP scientific strategy. Centered at Fermilab, the program supports development of the infrastructure necessary for SRF development and includes equipment and facilities 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. Completion of this essential technology infrastructure was accelerated in FY 2009 using Recovery Act funding.

In FY 2012, this effort is ramping down as major infrastructure procurements are completed, but will continue to provide funds for procurement of components and equipment support necessary to develop prototype multi-cavity cryomodules. It also enables continued development of U.S. capabilities for testing individual bare cavities, dressed cavities with all power components attached, and cryomodules. Fermilab is the lead U.S. laboratory and coordinates the national R&D program in this area.

▪ **International Linear Collider R&D**	**34,991**	**22,500**

This R&D effort is driven by the performance requirements of a TeV-scale linear electron-positron collider, but these R&D efforts have wider applicability to other projects supported by the Office of Science, particularly in the production and control of extremely small particle beams.

A TeV-scale linear electron-positron collider is widely considered by the international high energy physics community to be the most desirable successor to the LHC, though the data from the LHC may indicate that an even higher energy accelerator (such as a muon collider) will be needed to understand the new physics that emerges at this energy scale. In 2007, the International Linear Collider (ILC) collaboration under the auspices of the ILC Steering Group and the direction of the Global Design Effort (GDE) completed a detailed review of the R&D to be accomplished worldwide with milestones and priorities for that work. In 2008, the GDE initiated a five-year program to develop a Technical Design Report (TDR) that addresses outstanding R&D issues, complete a baseline design, and provide possible project implementation and governance plans. Throughout FY 2010 the ILC baseline configuration, to be finalized in FY 2011, was optimized for flexibility, cost control, and cost reduction. Selection of the baseline will permit finalizing of the design. Completion of the TDR in 2012 is consistent with worldwide resources currently available for the

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

ILC R&D and coincident with first physics results from the LHC (necessary to finalize operating parameters for a TeV-scale linear collider).

In FY 2012, the ILC R&D program will continue, but with a significantly reduced U.S. role in the comprehensive and coordinated international R&D program. Efforts will focus on the final phases of R&D for systems associated with the generation and maintenance of very bright particle beams, such as particle sources, damping rings, and beam delivery systems at a level consistent with the minimum necessary to complete U.S. contributions.

Other Technology R&D	**25,208**	**25,481**

This category includes R&D on new particle detector technologies, 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 maturity where they can be incorporated into future particle physics experiments.

▪ **Detector Development, Grants Research**	**3,679**	**3,952**

The grants-based R&D program provides support for university physicists to develop new detector technologies or advance technologies that have broad applicability to a wide range of high energy physics experiments. This support includes maintaining university infrastructure to enable state-of-the-art R&D into new detector technologies. Technologies targeted for development are selected based on anticipated applications that require further technological improvements before deployment, and specific proposals are selected based on peer-review. Current areas of investigation include liquid and high pressure noble gas detectors, radiation hard pixel detectors including single crystal diamond detectors, bonding technologies, silicon photomultipliers, large area photodetectors, water based liquid scintillators, and high speed electronics. Funding is maintained at approximately the FY 2010 level-of-effort to emphasize small-scale, university-led initiatives.

▪ **Detector Development, National Laboratory Research**	**21,529**	**21,529**

This activity supports a variety of particle detector R&D efforts and operations of test facilities at ANL, BNL, Fermilab, LBNL and SLAC. Detectors for both accelerator-based and non-accelerator applications are developed by this program. HEP conducted a comparative peer-review of the laboratory research efforts in this subfield in 2009, whose findings have been used to inform the funding decisions in this budget request.

The FY 2012 Request will maintain priority R&D efforts directed toward developing new detectors, including prototyping and in-beam studies. Some larger-scale technology demonstrations will not be renewed. A diverse program will continue, including efforts on particle flow calorimeters, very low-mass trackers, advanced charged-coupled devices, and radiation resistant, fast readout electronics. Prototype detector systems will be operated in the Fermilab test beam, providing a major test of new detector technologies and fabrication techniques. Since the Fermilab test beam is heavily-subscribed, reconfiguration and incremental operations of an old experimental beam line at SLAC as a dedicated test beam for detectors to meet this demand is supported.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
SBIR/STTR	**0**	**19,164**

In FY 2010 $17,564,000 and $2,108,000 was transferred to the congressionally mandated Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, respectively. The FY 2012 amount is estimated requirements for the continuation of these programs.

Total, Advanced Technology R&D	**156,347**	**171,908**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Accelerator Science	
▪ **Grants Research**	
Funding is increased above a constant level of effort to provide support for university groups to work on the new FACET and BELLA facilities.	+1,750
▪ **National Laboratory Research**	
Funding is significantly increased to support operations of the new FACET and BELLA facilities and additional participation of national laboratory scientists in fully exploiting the research potential of the new advanced accelerator R&D facilities and implementation of the muon accelerator R&D plan. Staffing increases will be provided to accelerator research groups based on peer review and programmatic impact.	+9,940
Total, Accelerator Science	**+11,690**
Accelerator Development	
▪ **General Accelerator Development**	
Funding for General Accelerator Development is maintained at approximately the FY 2010 level-of-effort to maintain a robust technology development program as more directed R&D efforts ramp down.	+1,425
▪ **Superconducting RF R&D**	
Funding for Superconducting RF development supports the planned implementation of capabilities at Fermilab but ramps down as major procurements begin to be completed. Reductions will be taken from technical and engineering support in this area.	-4,500

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **International Linear Collider R&D**	
Funding for ILC R&D is significantly reduced to the minimum necessary to complete U.S. contributions to the international Technical Design Report. Reductions will be taken from technical, engineering, and scientific personnel working in this area.	-12,491
Total, Accelerator Development	**-15,566**
Other Technology R&D	
▪ **Detector Development, Grants Research**	
Grant Research funding is restored to FY 2010 level-of-effort to emphasize small-scale, university-led initiatives.	+273
SBIR/STTR	
SBIR/STTR programs are funded at the mandated level.	+19,164
Total Funding Change, Advanced Technology R&D	**+15,561**

Construction

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Construction		
11-SC-40, Long Baseline Neutrino Experiment, PED	0	17,000
11-SC-41, Muon to Electron Conversion Experiment, PED	0	24,000
Total, Construction	0	41,000

Description

This subprogram provides for the Construction and Project Engineering and Design that is needed to meet overall objectives of the High Energy Physics program.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
11-SC-40, Long Baseline Neutrino Experiment, PED	**0**	**17,000**

The Long Baseline Neutrino Experiment will be composed of a neutrino beamline, small (near) detector located near to the neutrino beamline, and a large (far) neutrino detector located a long distance from the neutrino source. In order to build a neutrino beam that passes through the earth, a beam of protons must be transported through a tunnel that points into the ground. At the end of the tunnel the protons hit a target producing neutrinos that then travel through the earth. An existing neutrino beam of this type is the Neutrino at the Main Injector (NuMI) beam at Fermilab. The new LBNE beamline would provide low-energy neutrinos, a more intense beam, and point in a different direction from NuMI in order to provide the needed longer distance to the detector to extend the study of neutrino oscillations.

It is expected that the far detector will also need to be located underground to reduce the background from cosmic rays to a manageable level. The scope of work currently being developed includes a neutrino beamline, a small near detector, one or more large far neutrino detectors, the large underground cavern(s) needed to house the far detector(s), and the infrastructure needed to support the construction and operation of the large detector if housed underground.

The HEP program has been developing the LBNE project in coordination with NSF, because the Deep Underground Science and Engineering Laboratory (DUSEL) in the Homestake mine in South Dakota proposed to be built by the National Science Foundation was a possible site for the LBNE far detector. However, based on a National Science Board decision, NSF will not pursue DUSEL as previously proposed. High Energy Physics will support activities for minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided by the Nuclear Physics program. High Energy Physics will assess options for a future Long Baseline Neutrino Experiment and dark matter experiments.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
11-SC-41, Muon to Electron Conversion Experiment, PED	**0**	**24,000**

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 will construct a new beamline to take protons from the existing 8 GeV Booster synchrotron at Fermilab to a muon production target, a beamline to transport those muons to the detector, a low-mass magnetic spectrometer, which can measure the electron momentum with a resolution of order 0.15%, and a new experimental hall to house the muon production target, muon beamline, and the detector.

Total, Construction	**0**	**41,000**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
11-SC-40, Long Baseline Neutrino Experiment, PED	
Funding provides for PED activities.	+17,000
11-SC-41, Muon to Electron Conversion Experiment, PED	
Funding provides for PED activities.	+24,000
Total, Construction	**+41,000**

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

	(dollars in thousands)	
	FY 2010 Current Approp.	FY 2012 Request
Operating Expenses	676,923	682,952
Capital Equipment	110,376	65,623
General Plant Projects	1,142	7,625
Accelerator Improvement Projects	2,370	0
Construction	0	41,000
Total, High Energy Physics	790,811	797,200

Funding Summary

	(dollars in thousands)	
	FY 2010 Current Approp.	FY 2012 Request
Research	442,126	442,275
Scientific User Facilities Operations	230,999	212,847
Projects		
Major Items of Equipment	91,153	49,240
Construction	18,955	54,000
Total, Projects	110,108	103,240
Other	7,578	38,838
Total, High Energy Physics	790,811	797,200

Scientific User Facilities Operations

	(dollars in thousands)	
	FY 2010 Current Approp.	FY 2012 Request
Tevatron	145,539	130,836
B-factory	14,949	9,250
LHC Detector Support and Operations	70,511	72,761
Total, Scientific User Facilities Operations	230,999	212,847

Total Facility Hours and Users

	FY 2010 Current Approp.	FY 2012 Request
Proton Accelerator Complex[a]		
Achieved Operating Hours	7,631[b]	N/A
Planned Operating Hours	5,400	2,650
Optimal hours (estimated)	5,400	2,650
Percent of Optimal Hours	141%	100%
Unscheduled Downtime	11%	N/A
Total Number of Users	2,000	1,400
SLAC B-factory		
Total Number of Users	600	200
Total Facilities		
Achieved Operating Hours	7,631	N/A
Planned Operating hours	5,400	2,650
Optimal hours (estimated)	5,400	2,650
Percent of Optimal Hours	141%	100%
Unscheduled Downtime	11%	N/A
Total Number of Users	2,600	1,600

Major Items of Equipment (MIE)

(dollars in thousands)

	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
Proton Accelerator-Based Physics						
MINERvA						
Total Estimated Costs (TEC)	9,700	0[c]	0	0	0	9,700
Other Project Costs (OPC)	5,600	0	0	0	0	5,600
Total Project Costs (TPC)	15,300	0	0	0	0	15,300

[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 before the LHC turned on.
[c] Project was completed ahead of schedule and $1,500,000 was redirected to Proton Accelerator, Detector Support activities.

	(dollars in thousands)					
	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
NOνA						
TEC	40,528	59,000	44,220	41,240	19,480	204,468
OPC	71,532	0	2,000	0	0	73,532
TPC	112,060	59,000	46,220	41,240	19,480	278,000
Accelerator Project for the Upgrade of the LHC[a]						
TEC	0	0	250	0	0	250
OPC	2,500	9,000	0	0	0	11,500
TPC	2,500	9,000	250	0	0	11,750
MicroBooNE[b]						
TEC	0	0	2,000	6,000	8,400	16,400
OPC	0	2,043	1,500	0	0	3,543
TPC	0	2,043	3,500	6,000	8,400	19,943
Non-Accelerator Physics						
Reactor Neutrino Detector						
TEC	19,460	11,000	1,740	500	0	32,700
OPC	2,480	0	320	0	0	2,800
TPC	21,940	11,000	2,060	500	0	35,500
Dark Energy Survey						
TEC	10,640	8,610	4,000	0	0	23,250
OPC	11,900	0	0	0	0	11,900
TPC	22,540	8,610	4,000	0	0	35,150

[a] This MIE is not yet baselined, and therefore the TEC and OPC have not been determined. Mission Need (CD-0) was approved November 2008. Delay at the LHC has reduced the need for some of the planned components. The CD-1 of a descoped effort was approved September 2010 with a cost range of $10,000,000-$12,000,000 in the project execution plan.

[b] This MIE is not yet baselined, and therefore the TEC and OPC have not yet been determined. The Mission Need (CD-0) was approved September 2009 and subsequent CD-1 was approved June 2010, with an estimated TPC range of $18,800,000–$20,000,000.

(dollars in thousands)

	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
SuperCDMS at Soudan						
TEC/TPC	1,000	1,500	0	0	0	2,500
HAWC[a]						
TEC/TPC	0	0	0	1,500	1,000	2,500
Advanced Technology R&D						
Advanced Accelerator R&D Test Facility[b]						
BELLA						
TEC	26,798	0	0	0	0	26,798
OPC	420	0	0	0	0	420
TPC	27,218	0	0	0	0	27,218
FACET						
TEC	13,670	0	0	0	0	13,670
OPC	830	0	0	0	0	830
TPC	14,500	0	0	0	0	14,500
Total MIEs						
TEC		80,110	52,210	49,240		
OPC		11,043	3,820	0		
TPC		91,153	56,030	49,240		

Proton Accelerator-Based Physics MIEs:

Main Injector Experiment ν-A (MINERνA) will make precision measurements of neutrino interaction rates in the NuMI beam, an important input to analyze data from neutrino oscillation experiments (such as MINOS and NOνA) and was successfully completed on schedule and within budget in FY 2010. CD-4 was approved June 28, 2010.

[a] This project is not yet baselined. The TPC as well as the OPC/TEC split may change. Funding was not requested in the FY 2011 budget for this project's OPC. Once Mission Need is approved, funds will be redirected from the non-accelerator research program to support conceptual design, and these funds will be included in the TPC.

[b] Two proposals, Berkeley Lab Laser Accelerator (BELLA) Project and the Facility for Accelerator Science and Experimental Test Beams (FACET) were reviewed as candidates for this facility. Both received excellent reviews and using Recovery Act funds, both are proceeding. FACET received only Recovery Act funds and BELLA received both FY 2009 funds and Recovery Act funds. Projects are displayed to capture the correct TPC for each project; $1,500,000 of Recovery Acts (Prior Years) was transferred from BELLA to FACET.

NuMI Off-axis Neutrino Appearance (NOνA) Detector 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 same TPC.

Accelerator Project for the Upgrade of the LHC (APUL) is a project to design and construct selected magnets for the LHC. The Mission Need was approved November 2008 and conceptual design is underway, funded under Other Project Costs. CD-1 was approved September 2010 with a cost range of $10,000,000-$12,000,000 in the project execution plan. Brookhaven National Laboratory is expected to fabricate components and deliver them to CERN for installation in the LHC. The scope of the project has been reduced and no funding is requested in FY 2012.

MicroBooNE is a new MIE planned to begin fabrication in FY 2011. This project will build a large (several hundreds of tons) 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 and the proposed Long Baseline Neutrino experiment for which PED funds are initially requested in FY 2012 (see LBNE project data sheet). This experiment will also be an important demonstration of efficacy of large-scale liquid argon time projection chambers as neutrino detectors.

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 that will help resolve ambiguities in neutrino properties and will be input to setting future directions of neutrino research. A baseline change increasing the TPC from $34,000,000 to $35,500,000 with a planned completion date of April 2013 was approved January 2010. This baseline change was needed to accommodate delays in the civil construction being performed by our Chinese partners. CD-4A, Start of Initial Operations, was approved December 2010.

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.

Super Cryogenic Dark Matter Survey (SuperCDMS) at Soudan is an upgrade of an existing dark matter search experiment (CDMS) to increase sensitivity for direct detection of dark matter over current experiments by a factor of three. The ultra-cold, supersensitive superconducting germanium detectors with a novel design will be manufactured at Stanford University and tested at various U.S. institutions before being installed at the Soudan Underground Laboratory in Minnesota.

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. The project is done in collaboration with NSF and Mexican research institutes. The estimated total DOE cost is $2,500,000–$3,500,000 and the estimated completion date is in FY 2014.

Advanced Technology R&D MIEs:

Advanced Accelerator R&D Test Facility was initiated in FY 2009. Two proposals, Berkeley Lab Laser Accelerator (BELLA) Project at LBNL and the Facility for Accelerator Science and Experimental Test Beams (FACET) at SLAC were reviewed as candidates for this facility. Both received excellent reviews and using Recovery Act funds, both projects are proceeding. FACET received only Recovery Act funds and BELLA is funded with both FY 2009 funds and Recovery Act funds. FACET will fabricate equipment to be installed in the portion of the SLAC linac not utilized by Linac Coherent Light Source. It will support experiments on plasma wakefield acceleration of electrons, a technique that exploits the field created by one electron bunch moving through a plasma to accelerate a second bunch following in the wake of the first. The BELLA Project will utilize a 1 petawatt laser to produce the wakefields in the plasma, instead of a beam of electrons. The goal of the project is to produce 10 GeV electron beams in less than 1 meter of plasma. Both projects have received CD-3 and are in full fabrication.

Construction Projects

(dollars in thousands)

	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
Long Baseline Neutrino Experiment (PED)						
TEC	0	0	0	17,000	116,000	133,000
OPC	12,443	14,178	9,000	7,000	0	42,621
TPC	12,443	14,178	9,000	24,000	116,000	175,621
Muon to Electron Conversion Experiment (PED)						
TEC	0	0	0	24,000	12,500	36,500
OPC	0	4,777	8,000	6,000	0	18,777
TPC	0	4,777	8,000	30,000	12,500	55,277
Total, Construction						
TEC		0	0	41,000		
OPC		18,955	17,000	13,000		
TPC		18,955	17,000	54,000		

Scientific Employment

	FY 2010 actual	FY 2012 estimate
# University Grants	200	195
# Laboratory Groups	45	45
# Permanent Ph.D.'s (FTEs)	1,110	1,065
# Postdoctoral Associates (FTEs)	535	510
# Graduate Students (FTEs)	595	560
# Ph.D.'s awarded	110	105

11-SC-40, Long Baseline Neutrino Experiment (LBNE), Fermi National Accelerator Laboratory, Batavia, Illinois
Project Data Sheet is for PED

1. Significant Changes

The most recent DOE O 413.3A approved Critical Decision (CD) is CD-0 that was approved January 8, 2010 with a cost range of $660,000,000–$940,000,000.

A Federal Project Director (FPD) has not been assigned to this project, but an FPD will be assigned by CD-1.

This PDS is a continuation of a PED PDS. The FY 2012 request is for PED only.

The conceptual design work has begun. The work is shared between Brookhaven, Los Alamos National Laboratories and Fermi National Accelerator Laboratory, which is leading the effort.

The HEP program has been developing the LBNE project in coordination with NSF, because the Deep Underground Science and Engineering Laboratory (DUSEL) in the Homestake mine in South Dakota proposed to be built by the National Science Foundation was a possible site for the LBNE far detector. However, based on a National Science Board decision, NSF will not pursue DUSEL as previously proposed. The PED request has been reduced due to the anticipated delay in achieving CD-1. High Energy Physics will support activities for minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided by the Nuclear Physics program. High Energy Physics will assess options for a future Long Baseline Neutrino Experiment and dark matter experiments.

2. Design, Construction, and D&D Schedule[a]

(fiscal quarter or date)

	CD-0	CD-1	PED Complete	CD-2	CD-3	CD-4	D&D Start	D&D Complete
FY 2011	1/8/2010	1Q FY 2011	4Q FY 2013	TBD	TBD	TBD	TBD	TBD
FY 2012	1/8/2010	2Q FY 2012	2Q FY 2015	TBD	TBD	TBD	TBD	TBD

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

[a] This project does not have CD-2 approval and is not requesting construction funds. The preliminary estimate for the CD-4 date in the Mission Need Statement is the 2nd quarter of FY 2020.

3. Baseline and Validation Status[a]

(dollars in thousands)

	TEC, PED	TEC, Construction	TEC, Total	OPC Except D&D	OPC, D&D	OPC, Total	TPC
FY 2011	102,000	TBD	TBD	22,180	TBD	TBD	TBD
FY 2012	133,000[b]	TBD	TBD	42,621[c]	TBD	TBD	TBD

4. Project Description, Justification, and Scope

The Long Baseline Neutrino Experiment (LBNE) will be composed of a neutrino beamline, a small near detector, and a large neutrino detector located a long distance from the neutrino beam. A neutrino beam designed to pass through earth is built by constructing a downward sloping tunnel that holds the proton beamline, production target, and decay volume where the neutrinos are produced. By the end of this tunnel, the neutrinos have been produced and they then pass through the earth to the far detector. The Neutrinos at the Main Injector (NuMI) beam is an existing example of this. This new beamline would provide low-energy neutrinos, a more intense beam, and point in a different direction from NuMI in order to provide the longer distance to the detector needed for the study of neutrino oscillations.

Depending on the technology used, the detector may also need to be located underground to reduce the background from cosmic rays to a manageable level. The scope of work currently being developed includes: a neutrino beamline, a near detector close to the source of the neutrinos, one or more large neutrino detectors, the large underground cavern(s) needed to house the detector(s), and the infrastructure needed to support the construction and operation of the large detector underground.

Among the technical issues that need to be addressed in the alternatives analysis is the preferred detector technology. Two technologies are presently being considered: water Cerenkov and liquid argon time projection chamber. Water Cerenkov is a well established technology with more than 20 years of use, while liquid argon is a highly promising technology that could prove to be less expensive. Funding will be provided for R&D to answer a number of questions about liquid argon that will allow for a better comparison of the technologies. The possibility to locate the experiment at Homestake is still being considered.

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

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[a] This project is not yet baselined.
[b] This is a preliminary estimate for the planned PED over FY 2012–FY 2015.
[c] This is a preliminary estimate for Other Project Costs (OPC) including R&D, conceptual design, but not commissioning and pre-operations.

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Recovery Act Costs	Costs
Total Estimated Cost (TEC)				
PED				
FY 2012	17,000	17,000	0	16,000
FY 2013	36,000	36,000	0	35,000
FY 2014	38,000	38,000	0	40,000
FY 2015	42,000	42,000	0	42,000
Total, PED	133,000	133,000	0	133,000
Other Project Cost (OPC)				
OPC except D&D				
FY 2009 Recovery Act	12,443[a]	12,443	0	0
FY 2010	14,178	14,178	4,696	6,336
FY 2011[b]	9,000	9,000	7,747	7,842
FY 2012	7,000	7,000	0	11,110
FY 2013	0	0	0	4,890
Total, OPC except D&D	42,621	42,621	12,443	30,178
Total Project Cost (TPC)				
FY 2009 Recovery Act	12,443	12,443	0	0
FY 2010	14,178	14,178	4,696	6,336
FY 2011[b]	9,000	9,000	7,747	7,842
FY 2012	24,000	24,000	0	27,110
FY 2013	36,000	36,000	0	39,890
FY 2014	38,000	38,000	0	40,000
FY 2015	42,000	42,000	0	42,000
Total, TPC	175,621	175,621	12,443	163,178

[a] $13,000,000 of Recovery Act funding was originally planned for the conceptual design; the difference of $557,000 was needed prior to approve mission need (CD-0) for pre-conceptual activities.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

6. Details of Project Cost Estimate[a]

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design (PED)			
Design	101,000	75,000	N/A
Contingency	32,000	27,000	N/A
Total, PED	133,000	102,000	N/A
Total, TEC	133,000	102,000	N/A
Contingency, TEC	32,000	27,000	N/A
Other Project Cost (OPC)			
OPC except D&D			
R&D	6,000	2,000	N/A
Conceptual Planning	13,000	7,000	N/A
Conceptual Design	15,000	9,000	N/A
Contingency	8,621	4,180	N/A
Total, OPC except D&D	42,621	22,180	N/A
Contingency, OPC	8,621	4,180	N/A
Total, TPC	175,621	124,180	N/A
Total, Contingency	40,621	31,180	N/A

7. Funding Profile History

(dollars in thousands)

Request Year		Prior Years	FY 2009 Recovery Act	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	Outyears	Total
FY 2011	TEC	0	0	0	12,000	35,000	55,000	TBD	TBD	102,000
	OPC	0	13,000	9,180	0	0	0	TBD	TBD	22,180
	TPC	0	13,000	9,180	12,000	35,000	55,000	TBD	TBD	124,180
FY 2012[a]	TEC	0	0	0	0	17,000	36,000	38,000	42,000	133,000
	OPC	0	12,443	14,178	9,000[b]	7,000	0	0	0	42,621
	TPC	0	12,443	14,178	9,000[b]	24,000	36,000	38,000	42,000	175,621

8. Related Operations and Maintenance Funding Requirements

Not applicable for PED.

[a] This project is not yet baselined. This is a preliminary estimate for the planned PED over FY 2012–FY 2015.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

9. Required D&D Information

Not applicable for PED.

10. Acquisition Approach

The conceptual design and study of alternatives is being led by Fermi National Accelerator Laboratory with the assistance of Brookhaven National Laboratory and Los Alamos National Laboratory. This work will be used to develop an Acquisition Strategy that will be approved as part of CD-1. It is expected that a new neutrino beamline and neutrino detector will be needed. The technical expertise needed to design and build these components is very specialized and will limit the acquisition approaches.

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

1. Significant Changes

The most recent DOE O 413.3A approved Critical Decision (CD) is CD-0 and was approved November 24, 2009.

A Federal Project Director has not yet been assigned to this project, but will be by CD-1.

This PDS is a continuation of a PED PDS. Conceptual Design has begun, led by Fermi National Accelerator Laboratory.

2. Design, Construction, and D&D Schedule[a]

(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[b]	4Q FY 2013	TBD	TBD	TBD	TBD	TBD

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[c]

(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[d]	TBD	TBD	18,777[e]	TBD	TBD	TBD

4. Project Description, Justification, and Scope

The conversion of a muon to an electron (Mu2e) 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.

[a] This project does not have CD-2 approval and is not requesting construction funds. The estimated CD-4 date is 4th quarter of FY 2016.
[b] The CD-1 date from CD-0 approval is the formal milestone, however it is clear that funding to proceed beyond CD-1 has been delayed and work will be delayed to avoid a gap in funding.
[c] This project is not yet baselined.
[d] This is a preliminary estimate for the planned PED in FY 2012 and FY 2013.
[e] This is a preliminary estimate for the OPC including R&D, conceptual design, but not commissioning, and pre-operations.

This project will construct a new beamline to take protons from the existing 8 GeV Booster synchrotron at Fermilab to a muon production target, a beamline to transport those muons to the detector, a low-mass magnetic spectrometer, which can measure the electron momentum with a resolution of order 0.15%, and a new experimental hall to house the muon production target, muon beamline, and the detector.

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

5. Financial Schedule[a]

(dollars in thousands)

	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
PED			
FY 2012	24,000	24,000	21,000
FY 2013	12,500	12,500	14,000
FY 2014	0	0	1,500
Total, PED	36,500	36,500	36,500
Other Project Cost (OPC)			
OPC except D&D			
FY 2010	4,777	4,777	3,769
FY 2011[b]	8,000	8,000	5,877
FY 2012	6,000	6,000	9,131
Total, OPC except D&D	18,777	18,777	18,777
Total Project Cost (TPC)			
FY 2010	4,777	4,777	3,769
FY 2011[b]	8,000	8,000	5,877
FY 2012	30,000	30,000	30,131
FY 2013	12,500	12,500	14,000
FY 2014	0	0	1,500
Total, TPC	55,277	55,277	55,277

[a] This project has not yet received CD-2 approval. Only PED and OPC excluding D&D are shown.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

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	29,500	28,000	N/A
Contingency	7,000	7,000	N/A
Total, PED	36,500	35,000	N/A
Total, TEC	36,500	35,000	N/A
Contingency, TEC	7,000	7,000	N/A
Other Project Cost (OPC)			
OPC except D&D			
R&D	150	150	N/A
Conceptual Planning	7,350	3,850	N/A
Conceptual Design	8,000	4,000	N/A
Contingency	3,277	2,000	N/A
Total, OPC except D&D	18,777	10,000	N/A
Contingency, OPC	3,277	2,000	N/A
Total, TPC	55,277	45,000	N/A
Total, Contingency	10,277	9,000	N/A

7. Funding Profile History

(dollars in thousands)

Request Year		Prior Years	FY 2010	FY 2011	FY 2012	Outyears	Total
FY 2011	TEC	0	0	5,000	30,000	TBD	35,000
	OPC	0	5,000	5,000	0	TBD	10,000
	TPC	0	5,000	10,000	30,000	TBD	45,000
FY 2012[a]	TEC	0	0	0	24,000	12,500	36,500
	OPC	0	4,777	8,000[b]	6,000	0	18,777
	TPC	0	4,777	8,000[b]	30,000	12,500	55,277

8. Related Operations and Maintenance Funding Requirements

Not applicable for PED.

[a] This project has not yet received CD-2 approval. Only PED and OPC excluding D&D are shown.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

9. Required D&D Information

Not applicable for PED.

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.