High Energy Physics

Funding Profile by Subprogram

(dollars in thousands)

	FY 2008 Current Appropriation	FY 2009 Original Appropriation	FY 2009 Adjustments	FY 2009 Current Appropriation	FY 2009 Additional Appropriation[a]	FY 2010 Request
High Energy Physics						
Proton Accelerator-Based Physics	371,680	410,343	-7,863[b]	402,480	+107,990	442,988
Electron Accelerator-Based Physics	57,206	48,772	-17,789[b]	30,983	+1,400	26,420
Non-Accelerator Physics	75,784	86,482	+14,389[b]	100,871	+4,445	99,321
Theoretical Physics	60,032	63,036	+1,768[b]	64,804	+5,975	67,240
Advanced Technology R&D	138,143	187,093	+9,495[b]	196,588	+112,580	183,031
Total, High Energy Physics	702,845[cd]	795,726	—	795,726	+232,390	819,000

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"

Program Overview

Mission

The High Energy Physics (HEP) program's mission is to understand how our 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 itself.

Background

Research in high energy physics, often called particle physics, has led to a profound understanding of the physical laws that govern matter, energy, space, and time. This understanding has been formulated in the Standard Model of particle physics, first established in the 1970s, which successfully describes all known behavior of particles and forces, often to very high precision. Nevertheless, the Standard Model is understood to be incomplete. The model fails at extremely high energies—energies just now being created in particle accelerators—and describes only a small fraction of the matter and energy filling the universe. Startling new data reveal that only about 5% of the universe is made of the normal, visible

[a] The Additional Appropriation column reflects the planned allocation of funding from the American Recovery and Reinvestment Act of 2009, P.L. 111–5. See the Department of Energy Recovery website at http://www.energy.gov/recovery for up-to-date information regarding Recovery Act funding.
[b] Reflects a reallocation of funding in accordance with the explanatory statement for the Energy and Water Development and Related Agencies Appropriations Act, 2009, P.L. 111–8.
[c] Includes $32,000,000 provided by the Supplemental Appropriations Act, 2008, P.L. 110–252.
[d] Total is reduced by $18,486,000: $16,505,000 of which was transferred to the Small Business Innovative Research (SBIR) program and $1,981,000 of which was transferred to the Small Business Technology Transfer (STTR) program.

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, the 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;
- *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. 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. It 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 ground- and space-based instruments to detect particles from space and observe astrophysical phenomena that advance our understanding of fundamental particle properties. Here are some of the key questions the HEP program addresses, and how we seek answers at the three frontiers:

- *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 prevail only at very high energies. A possible and well motivated new symmetry, called supersymmetry, relates particles and forces. It predicts a superpartner for every particle we know. If such superparticles exist, it may be possible to produce the lightest of them with accelerators that operate at the Energy Frontier or infer their existence from 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 six billion years, the universe has been expanding at an accelerating rate due to a mysterious dark energy that now dominates over gravitational attraction. This energy, which permeates empty space and accelerates the expansion of the universe, must have a quantum (or particle) explanation. 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 requires supersymmetry and seven extra dimensions of space. 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 recent 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 families of quarks and leptons have been discovered, all 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 direct 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 the most elusive. The three known varieties of neutrinos were all discovered by HEP researchers working at U.S. facilities. Trillions pass through the Earth every moment with little or no interaction. Their detection requires intense neutrino sources and large detectors. Their tiny masses may imply new physics and provide important clues to the unification of forces. 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. They can also be studied at the Intensity Frontier using intense neutrino sources such as nuclear reactors and advanced accelerators.

- *How did the universe come to be?*

  Our 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. The history of the universe is explored at all three Frontiers.

- *What happened to the antimatter?*

  The universe appears to contain very little antimatter. Its existence is transient. It 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 is 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 matter-antimatter asymmetry arose.

Subprograms

The High Energy Physics program is divided into five subprograms that are organized around the tools and facilities they employ (e.g., an electron accelerator or cosmic ray detector), and/or the knowledge and technology they develop (e.g., superconducting radio frequency cavities or computational capabilities):

- The *Proton Accelerator-Based Physics subprogram* exploits two major applications of proton accelerators. Due to the high energy of the collisions at the Tevatron Collider (2 TeV) and the Large Hadron Collider (LHC, 14 TeV) and the fact that the particles interact differently at different energies, these facilities can be used to study a wide variety of scientific issues. Proton accelerators are also capable of producing, by colliding intense proton beams into fixed targets, large samples of other particles (e.g., antiprotons, K mesons, muons, and neutrinos) which can be formed into beams for experiments. The proposed Intensity Frontier program utilizes the high-power proton beam at Fermilab to produce intense secondary beams of neutrinos and muons 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. Since electrons are light, point-like particles (unlike protons, which are relatively heavy composites of quarks and gluons) they are well-suited to precision measurements of particle properties and exacting beam control. Over the last few years, the electron B-factory at the SLAC National Accelerator Laboratory has provided sensitive searches for new phenomena and definitive measurements of the behavior of matter and antimatter observed in the decay products of B-mesons. The next-generation Energy Frontier accelerator after the LHC is likely to be a high-energy electron facility that can probe LHC discoveries in detail.
- 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. These activities have provided experimental data, new ideas, and techniques complementary to those provided by accelerator-based research; some of the earliest discoveries in particle physics were due to the production of previously unobserved particles in high-energy cosmic rays. Scientists in this subprogram investigate topics such as dark matter, dark energy, neutrino properties, proton decay, the highest energy gamma rays, and primordial antimatter. Some of the non-accelerator particle sources used in this research are cosmic rays, neutrinos from commercial nuclear power reactors, the Sun, and galactic supernovae.
- 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 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 above, and the knowledge acquired in their pursuit, also yield substantial benefits of a more tangible nature for society as a whole. 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. The contributions of high energy physics to the underlying technologies now used in medicine, science, industry, homeland and national security, as well as for workforce training, are well known. (For more information, visit http://www.science.doe.gov/hep/benefits)

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: medical treatment and diagnosis—where new, more cost-efficient particle accelerators, detectors, and magnets for cancer treatment and diagnosis should emerge; homeland and national security—where particle accelerators and detectors developed for high energy physics research have the potential for border 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; and other scientific fields—where the underlying R&D needed for next-generation particle accelerators and detectors will be carried out by HEP's accelerator and advanced technology science programs.

An important benefit to the Nation provided by the HEP program is the recruitment and training of a highly motivated, highly trained scientific and technical work force. In particle physics, roughly one sixth of those completing doctoral degrees ultimately pursue careers in high energy physics research. The rest find their way to diverse sectors of the national economy such as industry, national defense, information technology, medical instrumentation, electronics, communications, and biophysics—wherever the workforce requires highly developed analytical and technical skills, the ability to work in large teams on complex projects, and the ability to think creatively to solve unique problems.

Program Planning and Management

- *Advisory and Consultative Activities*

  To ensure that resources are allocated to the most scientifically promising experiments, DOE and its national laboratories actively seek external input using a variety of advisory bodies. The High Energy Physics Advisory Panel (HEPAP), jointly chartered by the DOE and the National Science Foundation (NSF), provides advice regarding the scientific opportunities and priorities of the national high energy physics research program. HEPAP or one of its subpanels undertakes special studies and planning exercises in response to specific charges from the funding agencies.

  A HEPAP subpanel called the Particle Physics Project Prioritization Panel (P5) was formed to assess and prioritize scientific opportunities and proposed projects. HEPAP subpanels are also convened to review progress and/or future plans in particular research areas or elements of the HEP program. In 2007, HEPAP/P5 was charged to examine the options for mounting a world-class U.S. particle physics program at various funding levels. This HEPAP report[a] was submitted in June 2008 and has

[a] The full HEPAP report is available at http://www.science.doe.gov/hep/files/pdfs/P5_Report%2006022008.pdf.

provided important input for setting programmatic priorities for the HEP program. Many of the recommendations contained in the report are implemented in this budget request.

The Astronomy and Astrophysics Advisory Committee (AAAC) now reports on a continuing basis to the DOE, as well as to the NSF and National Aeronautics and Space Administration (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 and astrophysics and astronomy, such as dark energy and dark matter.

The HEP program has also instituted Committee of Visitors (COV) that provides an independent review of its responses to proposals and its research management process, as well as an evaluation of the quality, performance, and relevance of the research portfolio and an assessment of its breadth and balance. The second triennial HEP COV review took place in summer 2007. The 2007 COV report[a] has 18 specific recommendations relating primarily to staffing, grants review and processing, and project management. HEP has completed six of the recommendations, particularly in regard to staffing; seven recommendations are in-process; and five recommendations are on-going.

- *Review and Oversight*

  The HEP program office reviews and provides oversight for its research portfolio. All university research proposals are subjected to a multistage review process to ensure high quality research and relevance to achieving the goals of the national program. Proposals to DOE for grant support are peer-reviewed by external technical experts, 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. This is a comparative review that assesses the relative strengths and weaknesses of the various laboratory groups in particular research subfields. In FY 2010, the Electron Accelerator-Based and Non-Accelerator Physics subprograms will be reviewed.

Basic and Applied R&D Coordination

Many of the broader applications of technology originally developed for HEP research have been serendipitous. In order to provide a more direct connection between fundamental accelerator technology and applications, the HEP program is sponsoring a workshop in 2009 to assess the R&D needs of these various stakeholders and identify the significant challenges that could benefit from future technology R&D initiatives. An output of this workshop will be a report that articulates the role of accelerators in the nation's efforts in science, medicine, national security, and industry; identifies the opportunities and research challenges for next generation accelerators; suggests the most promising avenues for new or enhanced R&D efforts; and develops a path forward to stronger coordination between basic and applied research. HEP will use this report to develop a strategic plan for accelerator technology R&D that recognizes its broader societal impacts.

Budget Overview

The HEP program addresses the 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

[a] The 2007 COV report and HEP's response are available at http://www.science.doe.gov/SC-2/COV-HEP/HEP_Reviews.htm.

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.

The HEP program, 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 shift of focus from the operation of the facilities built at the end of the 1990s (SLAC B-factory, Tevatron Collider) to the design and construction of new research capabilities, meanwhile maintaining a world-leading scientific program and identifying targeted long-range R&D for the future. This strategic plan allows the Nation to play an important role at all three frontiers of particle physics:

The Energy Frontier: The Tevatron Collider at Fermi National Accelerator Laboratory (Fermilab) continues operations in FY 2010. Its record-breaking performance over the last few years means that it remains competitive with the LHC, for significant discoveries. The primary scientific goals of the HEP program over the next five years are to enable these discoveries—for example, the Higgs boson and supersymmetric particles—either at the Tevatron or the LHC. The first beam collisions at the LHC are anticipated in the fall of 2009. Support for LHC detector operations, maintenance, computing, and R&D is necessary to maintain a U.S. leadership role in the LHC program.

The HEP strategic plan includes U.S. participation in the LHC accelerator and detector upgrades, currently envisioned as a two-stage process. Phase I, which is planned to begin fabrication in FY 2010, provides a two-fold increase in the LHC luminosity (a measure of the number of physics interactions per second), which will significantly lower statistical uncertainties and improve the chances of observing rare events. Data from Phase I will guide the choice of the most promising physics to pursue in Phase II, which includes a ten-fold increase in luminosity. To handle the increased data rate, LHC detectors will also be upgraded. Physics results from the LHC will also help guide research and development for the proposed International Linear Collider (ILC). The ILC's internationally-coordinated R&D plan will address the current technical challenges and complete a pre-conceptual design by 2012.

The Intensity Frontier: The Neutrinos at the Main Injector (NuMI) beamline at Fermilab will operate in its current configuration through FY 2011 for ongoing neutrino experiments and then will be subject to a year-long upgrade from approximately 400 kW to 700 kW of beam power for the NuMI Off-Axis Neutrino Appearance (NOνA) experiment. The NOνA project will enable key measurements of neutrino properties; it is under construction and will be in full operation in 2014. During FY 2010, R&D for proposed new experiments using the NuMI beam and other auxiliary beamlines, such as the Long Baseline Neutrino oscillation experiment (LBNE) and the Muon to Electron Experiment (Mu2e), will be underway so these experiments can be ready for operation before the end of the next decade.

Significant results from the neutrino experiments currently being implemented (e.g., NOνA, the Reactor Neutrino Detector at Daya Bay, and other precision measurements in which the U.S. is involved) will emerge over the next decade, keeping the U.S. at the forefront of these studies and determining the future direction of this research. At the same time, the infrastructure needed for a world-leading program in neutrino studies and for rare decay searches in the U.S. will have been put into place. This plan will provide the U.S. with a robust, continuous program of world-leading physics at the Intensity Frontier centered at Fermilab in the decade after the end of the Tevatron Collider program.

The Cosmic Frontier: DOE is partnering with the NASA and the NSF in world class, space-based and ground-based particle astrophysics observatories for exploration of the Cosmic Frontier. HEP and NASA are presently jointly supporting analysis of data from NASA's Fermi Gamma-ray Space Telescope (FGST) that detects gamma-rays emanating from astrophysical sources, and HEP continues support for commissioning and integration activities for the Alpha Magnetic spectrometer (AMS) experiment which is on NASA's Space Shuttle manifest for launch in 2010. HEP is collaborating with NSF on the ground-based Dark Energy Survey (DES) telescope, currently in fabrication, as well as R&D aimed at developing large, next-generation survey telescopes that can significantly advance our knowledge of dark energy. HEP will continue to collaborate with NSF on a phased program of research and technology development that is designed to directly detect dark matter particles (rather than indirectly observe their effects on normal matter) using ultra-sensitive detectors located underground.

Significant Program Shifts

Following the recommendations of HEPAP, a continued leadership role for the U.S. HEP program requires investments in new facilities to exploit the scientific opportunities at the research frontiers. In this budget request, there is a significant increase in funding for fabrication of new major items of equipment to enable future discoveries.

Strategic and GPRA Unit Program Goals

The HEP program has one Government Performance and Results Act (GPRA) Unit Program Goal which contributes to Strategic Goals 3.1 and 3.2 in the "goal cascade."

- GPRA Unit Program Goal 3.1/2.46.00: Explore the Fundamental Interactions of Energy, Matter, Time and Space - Understand the unification of fundamental particles and forces, and the mysterious forms of unseen energy and matter that dominate the universe; search for possible new dimensions of space; and investigate the nature of time itself.

Contribution to GPRA Unit Program Goal 3.1/2.46.00, Explore the Fundamental Interactions of Energy, Matter, Time and Space

HEP contributes to this goal by advancing our understanding of the basic constituents of matter and the forces between them, deeper symmetries in the laws of nature at high energies, and mysterious phenomena that pervade the universe, such as dark energy and dark matter. HEP uses particle accelerators and very sensitive detectors to study fundamental particle interactions at the highest possible energies. Because particle physics is deeply connected to the origin and evolution of the universe itself, the HEP program also supports non-accelerator studies of cosmic particles and phenomena including experiments conducted deep underground, on mountains, or in space. This research at the frontier of science may discover new particles, forces, or undiscovered dimensions of space and time; explain how matter came to have mass; and reveal the underlying nature of the universe. In particular, the HEP program seeks to identify the mysterious dark matter that holds galaxies together and the even more mysterious dark energy that is stretching space apart; explain why there is any matter in the universe at all; and show how the tiniest constituents of the universe play a leading role in shaping its birth, growth, and ultimate fate. Our goals in FY 2010 address all of these questions.

The FY 2010 budget request places high priority on operations, upgrades, and infrastructure for the two major HEP user facilities: the Tevatron Collider and Neutrinos at the Main Injector (NuMI) at Fermilab, to produce maximum scientific data to address these fundamental questions.

In 2004, the HEPAP established the following indicators for specific long-term (10 year) goals in scientific advancement to which the HEP program is committed. They do not necessarily represent the research goals of individual experiments in the field. The order of the indicators corresponds roughly to current research priorities, and is meant to be representative of the program, not comprehensive.

- Measure the properties and interactions of the heaviest known particle (the top quark) in order to understand its particular role in the Standard Model, our current theory of particles and interactions.
- Measure the matter-antimatter asymmetry in many particle decay modes with high precision.

- Discover or rule out the Standard Model Higgs particle, thought to be responsible for generating the mass of elementary particles.
- Determine the pattern of the neutrino masses and the details of their mixing parameters.
- Confirm the existence of new supersymmetric (SUSY) particles or rule out the minimal SUSY Standard Model of new physics.
- Directly discover or rule out new particles that could explain the cosmological “dark matter.”

Annual Performance Results and Targets

FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Results	FY 2009 Targets	FY 2010 Targets
GPRA Unit Program Goal 3.1/2.46.00—Explore the Fundamental Interactions of Energy, Matter, Time and Space					
All HEP Facilities					
Maintained and operated HEP facilities such that unscheduled downtime was on average less than 20% of the total scheduled operating time. [Met Goal]	Maintained and operated HEP facilities such that unscheduled downtime was on average less than 20% of the total scheduled operating time. [Goal Not Met	Maintained and operated HEP facilities such that unscheduled downtime was on average less than 20% of the total scheduled operating time. [Met Goal]]	Achieve greater than 80% average operation time of the scientific user facilities (the Fermilab Tevatron and the Stanford Linear Accelerator (SLAC) B-factory) as a percentage of the total scheduled annual operating time. [Met Goal]	Achieve greater than 80% average operation time of the scientific user facility (the Fermilab Tevatron) as a percentage of the total scheduled annual operating time.	Achieve greater than 80% average operation time of the scientific user facility (the Fermilab Tevatron) as a percentage of the total scheduled annual operating time.
Proton Accelerator-Based Physics/Facilities					
Delivered data as planned within 20% of the baseline estimate (390 pb^{-1}) to CDF and D-Zero detectors at the Tevatron. [Met Goal]	Delivered data as planned within 20% of the baseline estimate (675 pb^{-1}) to CDF and D-Zero detectors at the Tevatron.[Met Goal]	Delivered data as planned within 20% of the baseline estimate (800 pb^{-1}) to CDF and D-Zero detectors at the Tevatron. [Met Goal]	Deliver within 20% of baseline estimate a total integrated amount of data (800 pb^{-1}) to CDF and D-Zero detectors at the Tevatron. [Met Goal]	Deliver within 20% of baseline estimate a total integrated amount of data (1,200 pb^{-1}) to CDF and D-Zero detectors at the Tevatron.	Deliver within 20% of baseline estimate a total integrated amount of data (1,700 pb^{-1}) to CDF and D-Zero detectors at the Tevatron.
	Delivered data as planned within 20% of the baseline estimate ($1x10^{20}$ protons on target) for the MINOS experiment using the NuMI facility.[Met Goal]	Delivered data as planned within 20% of the baseline estimate (1.5 $x10^{20}$ protons on target) for the MINOS experiment using the NuMI facility. [Met Goal]	Measure within 20% of the total integrated amount of data (2.0 $x10^{20}$ protons on target) delivered to the MINOS detector using the NuMI facility. [Met Goal]	Measure within 20% of the total integrated amount of data (2.7 $x10^{20}$ protons on target) delivered to the MINOS detector using the NuMI facility.	Measure within 20% of the total integrated amount of data (2.7 $x10^{20}$ protons on target) delivered to the MINOS detector using the NuMI facility.
Electron Accelerator-Based Physics/Facilities					
Delivered data as planned within 20% of baseline estimate (45 fb^{-1}) to the BaBar detector at the SLAC B-factory. [Met Goal]	Delivered data as planned within 20% of baseline estimate (50 fb^{-1}) to the BaBar detector at the SLAC B-factory. [Met Goal]	Delivered data as planned within 20% of the baseline estimate (100 fb^{-1}) to the BaBar detector at the SLAC B-factory.[Met Goal]	Delivered data as planned within 20% of the baseline estimate (54 fb^{-1}) to the BaBar detector at the SLAC B-factory. [Met Goal]		
Construction/Major Items of Equipment					
Maintained cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. [Met Goal]	Maintained cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. [Met Goal]	Maintained cost and schedule milestones for major items of equipment and new construction projects within 10% of baseline estimates. [Met Goal]	Achieve less than 10% for both the cost-weighted mean percentage variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects. [Met Goal]	Achieve less than 10% for both the cost-weighted mean percentage variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects.	Achieve less than 10% for both the cost-weighted mean percentage variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects.

Proton Accelerator-Based Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Proton Accelerator-Based Physics			
Research	122,882	125,734	127,228
Facilities	248,798	276,746	315,760
Total, Proton Accelerator-Based Physics	371,680	402,480	442,988

Description

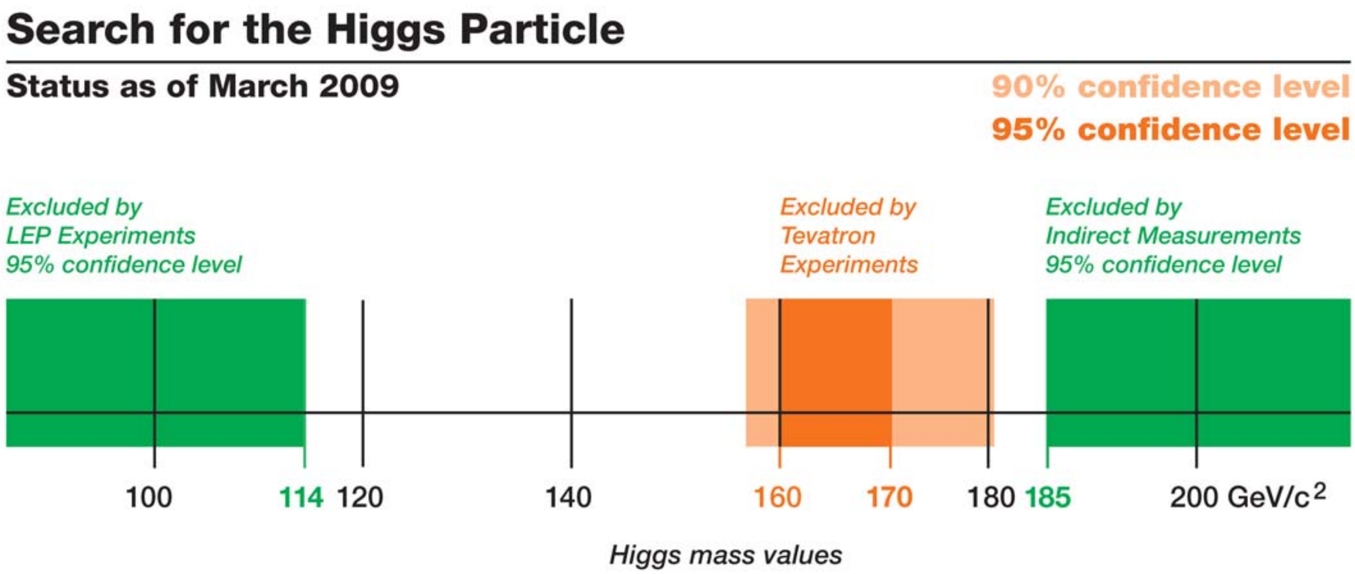
The Proton Accelerator-Based Physics subprogram will determine whether the Standard Model correctly predicts the mechanism that generates mass for all fundamental particles and will search for the first clear evidence of new physics beyond the Standard Model. This experimental research program also includes precise, controlled measurements of basic neutrino properties performed at accelerator facilities. These measurements, performed with neutrino beams generated from primary proton beams, will provide important clues and constraints to the new world of matter and energy beyond the Standard Model.

The most immediate goal on the particle physics roadmap is to fully understand the unification of the electromagnetic and weak nuclear interactions into a single, electroweak force at the Energy Frontier. The fact that this force is unified at high energies but separated or their symmetry broken at lower energies gives rise to masses for the fundamental particles. Originally it was proposed that a single Higgs boson was the solution to this problem and hence the source of mass. Newer theories, however, such as supersymmetry and extra hidden dimensions, may also solve this problem without or with one or more Higgs bosons. It will take experimental results to decide between competing theories. One expectation, however, is clear: new physics must occur at the Energy Frontier. Whether the Tevatron or the LHC is the first accelerator to observe this new physics will depend on the configuration that nature has chosen for these phenomena.

The Energy Frontier will begin to shift from the U.S. to Europe with the first beam collisions at LHC planned in late FY 2009. However, it is likely that first LHC physics results won’t appear until FY 2011 due to the expected difficulty of commissioning such large and complex accelerator and detector systems. In contrast, after many years of operation, the Fermilab experiments are able to rapidly deliver physics results, providing a window of opportunity for Fermilab to make discoveries at the Energy Frontier during initial LHC operations.

Selected FY 2008 Accomplishments

- For the first time since the Large Electron-Positron (LEP) collider at CERN last operated in 2000, researchers are again treading on unexplored Higgs territory with the Tevatron Collider experiments at Fermilab. Recently, combined results from the Tevatron Collider experiments have started to exclude a region of Higgs mass between 160 and 170 GeV/c^2 (see figure below). As more data is collected 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, have observed rare Standard Model processes such as double Z boson production, simultaneous W and Z boson production, and single top quark production. The observation of these rare processes is a necessary precursor for the discovery of the Higgs boson. In addition, the Tevatron has also recently produced the most precise 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 the thorough understanding of detector performance and backgrounds displayed in these results bode well for future discoveries.
- In the area of neutrino physics, the Main Injector Neutrino Oscillation Search (MINOS) experiment at Fermilab has produced new measurements that include the best measurement of the mass difference between neutrinos and a competitive measurement of the mixing angle that determines the neutrino oscillations.

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Research	**122,882**	**125,734**	**127,228**

The major 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 NuMI/MINOS detectors located at Fermilab and at the Soudan Mine site in Minnesota, and the research programs of ATLAS and CMS at the Large Hadron Collider (LHC) at CERN.

The research program using the Tevatron Collider at Fermilab is being carried out by a collaboration composed of 1,400 scientists from Fermilab, Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), 56 U.S. universities, and institutions in over 20 foreign countries. The major effort in FY 2010 will be the collection of data with 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

	(dollars in thousands)	
FY 2008	FY 2009	FY 2010

boson with a mass in the range expected (based on other indirect experimental data) will require the entire Tevatron data set. The Tevatron Collider experiments will collect data in FY 2010 to provide the two experiments access to a significant region of the expected Higgs mass range.

The research program using the NuMI/MINOS Facilities at Fermilab and the Soudan Mine is being carried out by a collaboration that includes 250 scientists from Fermilab, ANL, BNL, Lawrence Livermore National Laboratory (LLNL), 16 U.S. universities, and institutions in four foreign countries. The major effort in FY 2010 will be data collection and analysis, along with optimizing accelerator performance to improve beam intensity for higher statistics measurements. The experiment is planned to run through FY 2011 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 2010, 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 2008	FY 2009	FY 2010
▪ **Grants Research**	**55,365**	**57,025**	**57,725**

The grant-based HEP experimental research program consists of groups at more than 60 universities performing experiments at proton accelerator facilities. Grant-based 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 experiments.

In FY 2010, the grant research effort is maintained at the FY 2009 level. LHC research activities will be supported while maintaining participation in the Tevatron and neutrino physics programs. Strong participation of university physicists is needed to carry out the collider and neutrino program at the Tevatron during FY 2010. There will be healthy scientific competition between completion of Run II of the Tevatron Collider program and commencement of the LHC experiments, although the level of this competition will depend on how quickly the LHC will be brought into operation. Some migration of U.S. university researchers from the LHC back to the Tevatron Collider program has been observed in FY 2009 due to the delayed startup of the LHC. The detailed funding allocations will take into account the quality of research as well as the involvement of grant-based research groups in the targeted physics research activities.

	FY 2008	FY 2009	FY 2010
▪ **National Laboratory Research**	**66,303**	**67,771**	**68,565**

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 will conduct a comparative peer review of laboratory research groups in this subprogram in 2009.

In FY 2010, U.S. laboratory physicists will participate in and play important roles in the A large Toroidal LHC ApparatuS (ATLAS) and Compact Muon Solenoid (CMS) experiments, as LHC operations and data analysis move past the commissioning phase into steady-state operations. Strong involvement of physicists from the national laboratories will also be needed to carry out

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

the research program at the Tevatron during FY 2010. The HEP program will monitor progress in these areas and balance resources in order to optimize the national program.

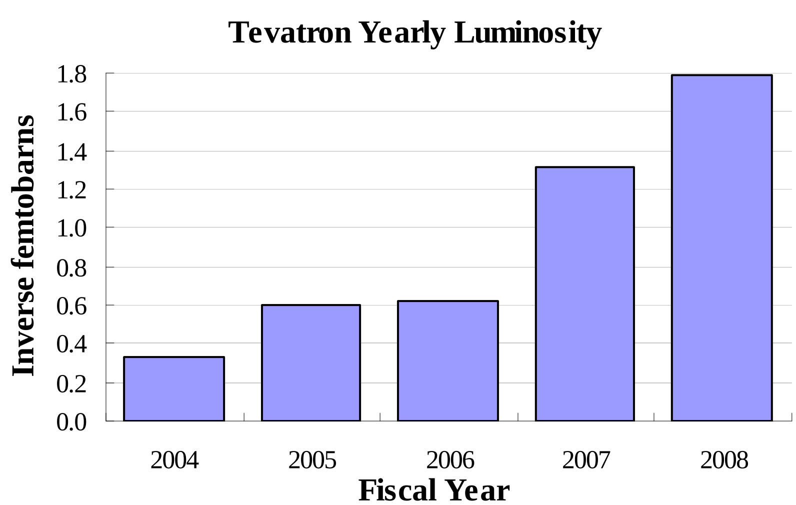
The Fermilab research program includes data collection and analysis of the CDF, D-Zero, and MINOS experiments; the CMS research and computing program; and research related to the new neutrino initiatives, such as the NOνA and MINERνA experiments. Research at LBNL consists of a large and active group in the ATLAS research program. The BNL research group will focus on the ATLAS research and computing program, with a small effort on D-Zero and a small effort related to future neutrino initiatives. The research group at ANL will be working primarily on the ATLAS research and computing program, data taking and analysis of the MINOS detector, and research related to the new neutrino initiatives, such as the NOνA experiment. A research group from SLAC has joined the ATLAS experiment and is expanding its efforts in order to take on important roles in LHC research and data analysis.

	FY 2008	FY 2009	FY 2010
▪ **University Service Accounts**	**1,214**	**938**	**938**

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 is maintained at the FY 2009 level, reflecting the anticipated need.

	FY 2008	FY 2009	FY 2010
Facilities	**248,798**	**276,746**	**315,760**
▪ **Proton Accelerator Complex Operations**	**132,688**	**128,485**	**123,985**

Fermilab operations include running the Tevatron accelerator complex for both collider and neutrino physics programs comprised of two collider detectors and a neutrino experiment, 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 as can be seen in the plot below. The vertical axis represents the amount of beam delivered to the experiments.



	(dollars in thousands)	
FY 2008	FY 2009	FY 2010

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 and FY 2010 should plateau around 2 inverse femtobarns per year, so the total delivered luminosity for Run II will be about two-thirds higher than the total recorded by the end of FY 2008.

In FY 2010, the decrease of funding in this category reflects the fact that stable running has been achieved and that less person-power is needed to run the accelerator. Increased automation of data collection with the CDF and D-Zero detectors has also reduced person-power required for detector operations.

Operations of the Tevatron complex include simultaneous provision of beam for fixed target and collider programs. This dual running mode is necessary for the MINOS experiment, which uses neutrinos from the NuMI beamline.

	FY 2008	FY 2009	FY 2010
Proton Accelerator Complex[a]			
Achieved Operating Hours	6,500	N/A	N/A
Planned Operating Hours	5,040	5,040	5,400
Optimal hours (estimated)	5,400	5,400	5,400
Percent of Optimal Hours	120%	93%	100%
Unscheduled Downtime	16%	N/A	N/A
Total Number of Users	2,160	2,160	2,000

- **Proton Accelerator Complex Support** **17,930** **16,662** **14,161**

This category includes funds for general plant projects (GPP) and other infrastructure improvements at Fermilab, funding for accelerator improvements, experimental computing expansion and other detector support. A backlog of GPP projects is being addressed with 2009 Recovery Act funding, and overall needs for small accelerator improvements are reduced as the Tevatron Collider is in steady-state operations.

- **Proton Accelerator Facility Projects** **19,584** **45,177** **80,173**
  - **Current Facility Projects** **19,184** **32,666** **59,800**

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. Improvements to the cooling, shielding, and power supplies in the booster, main injector, and NuMI beam-line would also be done to support the higher beam intensity.

Since the increase in neutrino intensity that can be achieved with this reconfiguration will be very important to support the physics goals of the NOνA detector, this collection of upgrades and

[a] Tevatron and NuMI operations run in parallel.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

improvements has been included as part of the scope of the NOνA project in order to ensure appropriate project management oversight and integration.

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 (i.e., 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 a football-field size footprint that is five stories high), 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 2010, TEC funds provided ramp up significantly. Fabrication will be completed in FY 2014, and the detector will start taking data in the same fiscal year.

Also included in this category is $800,000 to complete fabrication of MINERνA. This small experiment in the MINOS near detector hall at Fermilab will measure the rates of neutrino interactions with ordinary matter. MINERνA will use the powerful NuMI beam to measure these interactions with greater precision than previous experiments. Results from MINERνA will have a significant impact on MINOS and other neutrino experiments, including NOνA. This project is planned to be completed and taking data in FY 2010.

• **Future Facility Projects R&D**	**400**	**12,511**	**20,373**

In FY 2010, R&D and conceptual design is supported for a long baseline neutrino experiment, recommended by HEPAP/P5 as a high priority initiative at the Intensity Frontier. The experiment will require both a new neutrino beam and large detector. The detector is envisioned to be significantly larger than the NOνA detector, and located over 1000 kilometers from the neutrino beam. The large increase in size will greatly improve sensitivity to key neutrino parameters. A Critical Decision 1 (Selection of Alternatives) approval is expected by the end of FY 2010 or early FY 2011.

Pre-conceptual R&D for possible future projects that utilize the Fermilab facility is also funded in this category. Specifically, pre-conceptual R&D for an experiment to search for lepton flavor violation by observing the conversion of a muon into an electron within the electromagnetic field of a nucleus is supported, based on the recommendation of HEPAP/P5.

In addition, pre-conceptual R&D on a superconducting 8 GeV linac is supported. This linac would provide the beam power needed to continue high intensity 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 from 700 kilowatts (as planned for NOνA) to 2000 kilowatts.

	FY 2008	FY 2009	FY 2010
▪ **Large Hadron Collider Support**	**65,572**	**74,437**	**86,520**

(dollars in thousands)

U.S. involvement in this effort has been regularly endorsed by HEPAP and by a National Academies report (EPP 2010 [a]). The 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**	**11,918**	**15,500**	**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. Special instrumentation that will play an important role during the LHC accelerator commissioning and operation phase, such as beam collimation and monitoring systems, is also being developed. In FY 2009, LARP has delivered a luminosity monitoring system to CERN for the LHC. This R&D effort will provide important technical data to CERN for management decisions on possible future LHC accelerator upgrades to increase luminosity. In FY 2009, funding was provided for R&D on prototypical LHC interaction region magnets composed of optimized niobium-tin (Nb_3Sn) superconductor material. The development of these magnets is in preparation for U.S. participation in a second phase of upgrades to LHC.

• **LHC Detector Support**	**53,654**	**56,437**	**58,130**

Funding is provided for operations and maintenance of the U.S.-built detector subsystems. Installation of the hardware was completed in 2008 and will be commissioned with cosmic ray data until the first LHC beam collisions occur. This effort will support the continuing development and deployment 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 for both participating U.S. national laboratories and CERN will also be 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 simulated and cosmic ray 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 2010, computing hardware facilities running grid computing interfaces are essential to enable a rapid development cycle for processing and analyzing the data and improving analysis algorithms in the wake of first collisions and physics-quality data.

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

[a] Report EPP 2010: Elementary Particle Physics in the 21st Century is available at http://www7.nationalacademies.org.\bpa\EPP2010.html.

	FY 2008	FY 2009	FY 2010
term replacements of major elements of the detectors are ongoing, with proposals expected by the end of 2010. The proposals should cover two planned phases (targeted towards installation in 2014 and 2017) for upgraded LHC luminosity and will emphasize areas where U.S. groups have particular expertise and technical capability.			
• **LHC Upgrades**	**—**	**2,500**	**16,000**
Fabrication of the Accelerator Project for the Upgrade of the LHC (APUL) is initiated in FY 2010. The project will construct components needed for the planned increase of the luminosity of the LHC by a factor of two to three. The Mission Need (CD-0) was approved October 2008 and conceptual design is underway. The expected scope of the project includes the design and fabrication of magnets, collimators, and beam instrumentation. The intent is to have these components built by BNL, LBNL, Fermilab and SLAC and delivered to CERN for installation in the LHC. The U.S. scope has been coordinated with CERN management and takes advantage of U.S. expertise in the particular technical areas.			
▪ **Alternating Gradient Synchrotron (AGS) Support**	**644**	**644**	**644**
Funding continues for long-term D&D of the AGS facility at BNL, as operations as a HEP user facility were terminated at the end of FY 2002.			
▪ **Other Facilities**	**12,380**	**11,341**	**10,277**
This category includes funding for private institutions, government laboratories, and foundations that participate in high energy physics research, 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 funding to respond to new opportunities and unexpected changes in facilities operations and support.			
Total, Proton Accelerator-Based Physics	**371,680**	**402,480**	**442,988**

(dollars in thousands)

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Research	
▪ **Grants Research**	
Funding for the core grant research program provides an approximately 3% increase compared to FY 2009, offset by a $1,000,000 decrease due to the completion of fabrication for the T2K experiment in FY 2009.	+700

	FY 2010 vs. FY 2009 ($000)
▪ **National Laboratory Research**	
Funding for laboratory-based research increases by about 1.2%, maintaining efforts at FY 2009 levels.	+794
Total, Research	**+1,494**
Facilities	
▪ **Proton Accelerator Complex Operations**	
Funding for Proton Accelerator Complex Operations is decreased in FY 2010 due to reduced person-power needs. Standardized running procedures and increased automation allow operation with less person-power.	-4,500
▪ **Proton Accelerator Complex Support**	
Proton Accelerator Complex Support funding decreases overall due to a reduced need for GPP and accelerator infrastructure enhancements.	-2,501
▪ **Proton Accelerator Facility Projects**	
• **Current Facility Projects**	
Net funding for Current Facility Projects increases for the ramp up of NOνA ($+31,234,000) offset by the final year of funding for MINERνA ($-4,100,000).	+27,134
• **Future Facility Projects R&D**	
Funding increases to support pre-conceptual design work on the long-baseline neutrino detector, a lepton number violation experiment and Project X.	+7,862
▪ **Total, Proton Accelerator Facility Projects**	**+34,996**
▪ **Large Hadron Collider Support**	
LHC Support funding increases primarily for the Accelerator Project for the Upgrade of the LHC that will contribute to doubling or tripling of the LHC luminosity. Also, funding for LHC Detector Support maintains a constant level of effort.	+12,083
▪ **Other Facilities**	
Funding decreases for activities pending completion of peer review and/or programmatic decisions.	-1,064
Total, Facilities	**+39,014**
Total Funding Change, Proton Accelerator-Based Physics	**+40,508**

Electron Accelerator-Based Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Electron Accelerator-Based Physics			
Research	20,724	16,512	14,361
Facilities	36,482	14,471	12,059
Total, Electron Accelerator-Based Physics	57,206	30,983	26,420

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 few years, the electron B-factory at SLAC has been leading 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.

CP violation has been observed in the decays of particles containing strange quarks (K mesons) and most recently in particles containing bottom quarks (B mesons). After the observations of CP violation in B mesons were made early in this decade at the SLAC B-factory and a similar accelerator at the Japanese national laboratory for high energy physics (the High Energy Accelerator Research Organization [KEK] B-factory [KEK-B]), a systematic study of the process has been performed to test the current theoretical explanation of CP violation in the Standard Model. This ongoing study requires both new measurements of CP violation in other B meson decays, as well as measurements of other properties of particles containing bottom or charm quarks.

The B-factory has been decommissioned and is awaiting disassembly, following completion of its scientific program in FY 2008. The BaBar detector will have major components removed in 2009 and the PEP-II collider will be kept in a low maintenance configuration awaiting decisions on the possible reuse of its components at domestic labs (Fermilab and Thomas Jefferson National Accelerator Facility) and abroad. The data, which has been accumulated over the B-factory's nine year operating lifetime, will continue to be analyzed by the B-Factory staff, university groups, and foreign collaborators for a few more years.

Selected FY 2008 Accomplishment

In FY 2008, the SLAC B-factory delivered 57 fb^{-1} (inverse femtobarns) of data of which the BaBar detector captured 54 fb^{-1}. The strategy of the FY 2008 run was modified to accommodate the shortened schedule dictated by budget constraints, and most of the collisions were accumulated at beam energies below the B-meson production threshold, unlike the data-taking strategy of the last few years. The science highlight of this run was the discovery of the ground state of the b-quark/anti-b-quark system. Its mass was measured to a fraction of one percent, and its hyperfine mass spitting, a precision test of quantum chromodynamics (QCD), to 4% accuracy. The entire accumulated B-factory data is being investigated for additional heavy quark states. Lengthy, systematic analyses have begun to determine the consistency of CP violation measurements with the numerous decay processes involving bottom quarks.

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Research	**20,724**	**16,512**	**14,361**

The research program at the B-factory/BaBar Facility at SLAC is now entering a phase of intense analysis of the 557 fb^{-1} data set that has been accumulated over the nine-year operational life of the facility. The number of physicists involved in this effort is expected to fall to approximately 200 over the course of the year now that the B-Factory has completed taking data. Physicists from approximately 30 universities, three national laboratories (LLNL, LBNL, and SLAC) and seven foreign countries will be actively involved in the final 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 Quantum Chromodynamics.

The research program at other electron accelerator facilities complements the B-factory/BaBar efforts and consists of a group of experimental research activities using the Cornell Electron Storage Ring (CESR) accelerator at Cornell University, the KEK-B electron accelerator facilities in Japan, and recently upgraded electron accelerator facilities in China. A total of four U.S. university groups work at KEK-B, four groups work at the Beijing Electron-Positron Collider (BEPC), and 22 U.S. university groups work at CESR. CESR, operated by the NSF, also completed running in FY 2008. In FY 2010, the work will concentrate on the final analysis of data taken at CESR. Smaller efforts will be devoted to operations of the Belle detector at KEK-B in Japan and the Beijing Spectrometer at BEPC and analysis of the data taken.

▪ **Grants Research**	**9,231**	**7,357**	**6,621**

Grant-based 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 FY 2010, funding continues at a reduced level of effort to complete analysis of physics data from BaBar and the CLEO-c experiment at CESR. Included is a small research program devoted to physics studies of much higher performance, higher intensity B-factory. The Italian government is supporting pre-conceptual R&D aimed at developing a proposal for such a facility. The detailed funding allocations will take into account the quality of research as well as the involvement of university-based research groups in the targeted physics research activities.

▪ **National Laboratory Research**	**11,424**	**9,124**	**7,709**

The national laboratory research program consists of groups at three 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 will conduct a comparative peer review of laboratory research groups in this subprogram in 2010.

In FY 2010, laboratory-based research in this subprogram continues at a reduced level of effort to complete data analysis from BaBar and CLEO-c. SLAC will continue to maintain strong participation in the B-factory research program, which will be completing a two-year period of intense analysis of the entire B-factory data set. Research groups at LBNL and LLNL have mostly

	FY 2008	FY 2009	FY 2010

(dollars in thousands)

transitioned to other activities. A small research program at Fermilab and SLAC devoted to physics studies of the ILC is also supported.

- **University Service Accounts** — **69** | **31** | **31**

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.

Facilities — **36,482** | **14,471** | **12,059**

- **Electron Accelerator Complex Operations** — **24,632** | **12,091** | **11,179**

B-factory operations ended in FY 2008 with a significantly shortened physics run due to budget constraints. Faced with a very limited final run for the B-factory, the BaBar collaboration decided to optimize its science output by moving the B-factory energy to a nearby resonance below the B meson production threshold where they had traditionally operated to study CP violation and B meson decays. This strategy has generated a unique data set that can be used for detailed studies of QCD processes, rather than only marginally add to the already large existing data set.

Funding for operations supports the transition of the B-factory accelerator complex to a safe and stable maintenance mode and includes D&D activities. This funding category also supports ongoing BaBar computing operations and data analysis. Starting in FY 2009 all funding for SLAC Linac operations became part of Linac Coherent Light Source (LCLS) commissioning supported by the Basic Energy Sciences (BES) program (see the Facilities section of the BES Scientific User Facilities subprogram).

	FY 2008	FY 2009	FY 2010
SLAC B-Factory			
Achieved Operating Hours	2,359	—	—
Planned Operating hours	1,300	—	—
Optimal hours (estimated)	5,850	—	—
Percent of Optimal Hours	40%	—	—
Unscheduled Downtime	15%	—	—
Total Number of Users	1,000	800	600

- **Electron Accelerator Complex Support** — **11,850** | **2,380** | **880**

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

Total, Electron Accelerator-Based Physics — **57,206** | **30,983** | **26,420**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Research	
Funding for electron accelerator-based experimental research is reduced to a level necessary to complete analysis of physics data from BaBar and CLEO-c. Intensive analysis of the major results from BaBar and CLEO-c data will be completed in 2010.	-2,151
Facilities	
▪ **Electron Accelerator Complex Operations**	
Funding for B-factory Operations is reduced to support the planned profile for safe dismantling and decommissioning of the BaBar detector and putting PEP II into a minimum maintenance configuration.	-912
▪ **Electron Accelerator Complex Support**	
This category is now focused on providing the computing capabilities needed to finish BaBar data analysis.	-1,500
Total, Facilities	**-2,412**
Total Funding Change, Electron Accelerator-Based Physics	**-4,563**

Non-Accelerator Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Non-Accelerator Physics			
Grants Research	20,385	20,744	21,156
National Laboratory Research	36,913	40,297	41,106
Projects	18,486	36,630	37,059
Other	—	3,200	—
Total, Non-Accelerator Physics	75,784	100,871	99,321

Description

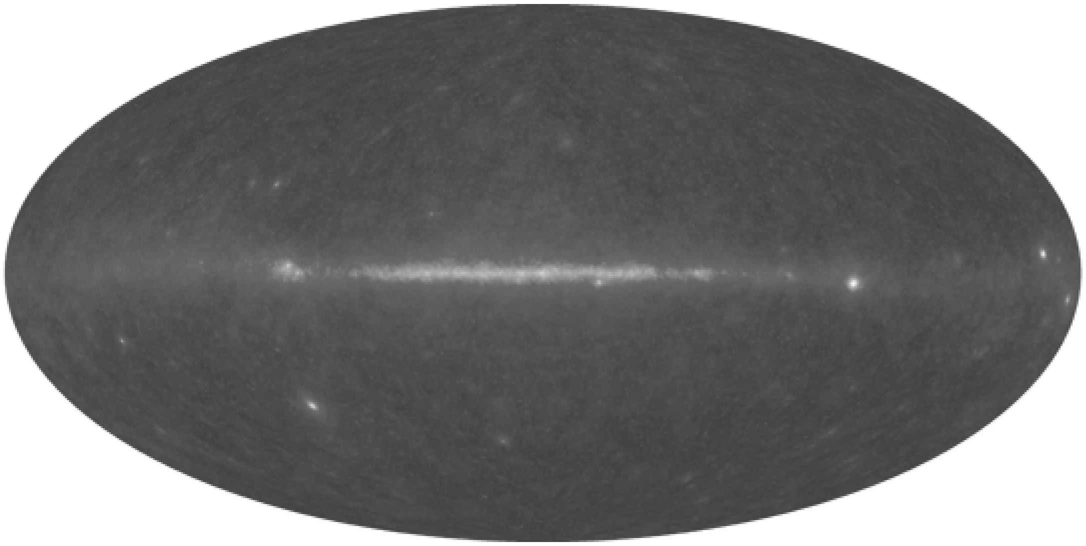
The Non-Accelerator Physics subprogram provides U.S. leadership in the study of those topics in particle physics that cannot be investigated with accelerators or are best studied by other means. Non-Accelerator Physics is playing an increasingly important role in HEP, using ever more sophisticated techniques to probe fundamental physics questions with naturally occurring particles and phenomena. Scientists in this subprogram investigate topics at both the Intensity and Cosmic Frontiers, such as dark matter, dark energy, neutrino properties, proton decay, the highest energy cosmic and gamma rays, 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.

Some of the non-accelerator particle sources used in this research are cosmic rays and neutrinos from commercial nuclear power reactors, the Sun, and galactic supernovae. Other sources are the light (photons) emitted by supernovae, galaxies and other celestial objects. These experiments utilize particle physics techniques and scientific expertise, as well as the infrastructure of the national laboratories. Experiments are often located at remote sites, such as in deep underground laboratories, on mountain tops, in deserts, or in space.

This subprogram is carried out in collaboration with physicists supported by other government agencies and institutes, among them NSF, NASA, the Naval Research Laboratory (NRL), and the Smithsonian Astrophysical Observatory. Strong interagency coordination and collaboration is one of the hallmarks of this effort. As with the rest of the HEP portfolio, most projects involve international collaboration in all phases of the experiment.

Selected FY 2008 Accomplishments

- The Large Area Telescope (LAT) launched from Kennedy Space Center in June 2008. This project was a DOE and NASA partnership to build the primary instrument on NASA’s Fermi Gamma-ray Space Telescope (FGST) mission. The international LAT collaboration announced “first light” in August 2008 along with its first all-sky survey which shows the universe as seen in high-energy gamma rays (see the figure below). SLAC led the DOE participation in the fabrication of the LAT and operates the instrument science operations center while data are taken.



Fermi Gamma-ray Space Telescope image of the night sky as seen in high-energy gamma rays

- The Pierre Auger Observatory, located in Argentina, studies the highest energy cosmic rays. It is a collaborative effort between DOE, NSF, and international partners. The American Institute of Physics included results from this facility as one of its top ten physics stories in 2008. Although operations began several years ago with a partial detector array, the full array, covering an area of 3,000 square kilometers, was completed in 2008. Recent results showed a decrease in the number of cosmic rays at the very highest energies, which confirms that there is a physical limit on cosmic ray energies from distant sources.

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Grants Research	**20,385**	**20,744**	**21,156**

This 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.

Physicists in this research area often work in collaboration with other university and laboratory groups. The selection of research efforts supported is based on peer review. The amount of funding a grant receives takes into account the discovery potential of the proposed research.

In FY 2010, the Non-Accelerator Physics grants program will support research on experiments that finished their fabrication phase in recent years and are now engaged in data collection. These experiments include the Very Energetic Radiation Imaging Telescope Array System (VERITAS), a ground-based gamma ray experiment at the Whipple Observatory in Arizona; the Pierre Auger Observatory discussed above; and the LAT gamma-ray survey on NASA’s FGST mission. Other active research efforts include searches for dark matter using the Cryogenic Dark Matter Search (CDMS) at the Soudan Mine in Minnesota and the Axion Dark Matter eXperiment (ADMX) at LLNL. Studies of dark energy use data from the Baryon Oscillation Spectroscopic Survey (BOSS) experiment on the Sloan Digital Sky Survey III (SDSS-III). Research also continues with Super-Kamiokande, a proton decay and neutrino detector located in the Kamioka Underground Laboratory in Japan and the

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

Enriched Xenon Observatory (EXO), which is searching for neutrino-less double beta decay at the DOE Waste Isolation Pilot Plant facility.

These groups also participate in the research and planning for the Dark Energy Survey (DES) experiment in Chile, the Reactor Neutrino Detector at Daya Bay in China, SuperCDMS at Soudan, the proposed space-based Joint Dark Energy Mission (JDEM), and the proposed ground-based Large Synoptic Survey Telescope (LSST); the latter two will both be used to study dark energy. The DES and Reactor Neutrino experiments are in the fabrication phase and SuperCDMS plans to begin fabrication in 2009. DOE-supported university groups also lead the commissioning and integration for NASA's Alpha Magnetic Spectrometer (AMS) experiment which is on the Space Shuttle manifest for launch in 2010.

HEP also supports research groups participating in the design and R&D efforts for experiments that may be located in NSF's proposed Deep Underground Science and Engineering Laboratory (DUSEL), including next-generation dark matter experiments and a next-generation neutrino-less double beta decay experiment.

National Laboratory Research	**36,913**	**40,297**	**41,106**

Groups at several national laboratories 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. The HEP program will conduct a comparative peer-review of the laboratory research efforts in this subprogram in 2010.

In FY 2010, the laboratory research program in non-accelerator physics will continue to support research and operations for ongoing experiments such as the Pierre Auger Observatory, CDMS, the Chicagoland Observatory for Underground Particle Physics 60 kg (COUPP-60) experiment at Fermilab, and ADMX dark matter experiments, the EXO experiment, and the LAT gamma-ray survey on NASA's FGST. SLAC runs the instrument science operations center for the LAT. Laboratory groups also lead the operations and research for various dark energy surveys that use existing telescope facilities.

Laboratory groups participate in the research planning for future experiments in the fabrication phase such as DES, SuperCDMS, and the Reactor Neutrino Detector at Daya Bay. The laboratory program also focuses on the R&D and design efforts for other future projects such as the COUPP-500kg dark matter experiment, other next generation dark matter experiments, and the proposed JDEM and LSST experiments to study dark energy.

Projects	**18,486**	**36,630**	**37,059**
▪ **Current Projects**	**12,440**	**22,700**	**21,110**

Fabrication of the Reactor Neutrino Detector will continue in FY 2010. DOE and the Chinese Institute for High Energy Physics are partners for 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. From this data, a crucial neutrino oscillation parameter can be extracted. The U.S. collaboration is led by groups from BNL and LBNL. Construction is expected to be completed in FY 2012.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

Fabrication of the DES will continue in FY 2010. 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. The DES project 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. The planned completion for this project is in FY 2011.

Fabrication of the SuperCDMS detector at Soudan will continue in FY 2010. This is an upgrade of an existing dark matter search experiment (CDMS) located in the Soudan Mine to increase sensitivity for direct detection of dark matter over current experiments by a factor of about three. The upgraded detector will have the sensitivity to confirm or rule out many theoretical models of physics beyond the Standard Model involving new supersymmetry particles which may be the source of the dark matter.

	FY 2008	FY 2009	FY 2010
▪ **Future Projects R&D**	**6,046**	**13,930**	**15,949**

This category provides support for R&D and pre-conceptual design activities for promising proposed future experiments. In FY 2010, this includes support for activities involving R&D associated with the DOE and NASA JDEM project as well as support for R&D on technical issues related to the camera (DOE’s proposed contribution) for the LSST project. Both NSF and DOE await the priority given to LSST in the National Academies’ Decadal Survey for Astronomy and Astrophysics.

	FY 2008	FY 2009	FY 2010
Other	**—**	**3,200**	**—**

FY 2009 funding provides for completion of EXO-200 experiment at the Waste Isolation Pilot Plant.

	FY 2008	FY 2009	FY 2010
Total, Non-Accelerator Physics	**75,784**	**100,871**	**99,321**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Grants Research	
Funding for grant-based research continues at approximately a constant level of effort to support experiments that are currently active in commissioning, operations, and/or data analysis.	+412
National Laboratory Research	
Funding for laboratory-based research is increased, driven by research support for the Reactor Neutrino Detector and LSST.	+809

	FY 2010 vs. FY 2009 ($000)
Projects	
▪ **Current Projects**	
Following the project profiles, funding decreases for Reactor Neutrino Detector and DES, offset by an increase for SuperCDMS at Soudan.	-1,590
▪ **Future Projects R&D**	
R&D funding for JDEM, LSST, dark matter, and other astrophysical experiment increases.	+2,019
Total, Projects	**+429**
Other	
One-time directed funding in FY 2009 for completion of the EXO-200 experiment at WIPP.	-3,200
Total Funding Change, Non-Accelerator Physics	**-1,550**

Theoretical Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Theoretical Physics			
Grants Research	24,497	25,410	25,912
National Laboratory Research	23,897	25,220	25,753
Computational HEP	7,241	9,100	10,400
Other	4,397	5,074	5,175
Total, Theoretical Physics	60,032	64,804	67,240

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 plane of physical phenomena 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 have provided many fundamental breakthroughs in the development of the Standard Model. This subprogram supports and advances research at all three high energy physics Frontiers.

Theoretical physicists play key roles in determining which experiments to perform and in explaining experimental results in terms of underlying theories that describe the interactions of matter, energy, and space-time. The research activities supported by the Theoretical Physics subprogram include, but are not limited to, performing calculations in the quantum field theories of elementary particles that comprise the Standard Model; developing other models for elementary particle processes; interpreting results of measurements in the context of these models; identifying where new physical principles are needed and what their other consequences may be; and constructing and exploiting powerful computational facilities for theoretical calculations of importance for the experimental program.

The Theoretical Physics subprogram supports collaborations between scientists based at different universities and national laboratories. Collaborations with scientists from other federal agencies, such as NSF and NASA, and international partners are supported.

Selected FY 2008 Accomplishments

- The 2008 Nobel Prize in Physics was shared by Yoichiro Nambu for his theoretical work discovering how symmetry breaking can manifest itself in nature. His work was supported by HEP before he retired from the University of Chicago.
- The processes underlying collisions at particle energies expected to be achieved by the LHC can involve many particles (partons). Calculating such multi-parton scattering probabilities is a challenging task and is important for interpreting LHC data. Various methods have been introduced to compute these amplitudes, some involving techniques derived from string theory. Recently, major advances have been achieved making precision calculations of these probabilities possible.

Calculating quantities relevant to LHC data—such as multi-parton scattering—is an active area of current theoretical work.

- The HEP-supported efforts in the Scientific Discovery through Advanced Computing (SciDAC) program have made significant accomplishments in the past year, including the use of accelerator modeling codes to explain operational instabilities in, and improve the design of, the 12 GeV upgrade of the Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility.

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Grants Research	**24,497**	**25,410**	**25,912**

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. A particularly interesting topic considers additional space-time dimensions that are normally hidden from us. 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 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 are playing leading roles in addressing these research areas.

In FY 2010, the Theoretical Physics grant program is maintained at about a constant level of effort to support the analysis of current and previous experiments, and in the design and optimization of new experiments, so that these experiments can fulfill their maximum potential. It will also support theorists who explore new ideas of physics at the Energy Frontier.

National Laboratory Research	**23,897**	**25,220**	**25,753**

The national laboratory theoretical research program consists of groups at six DOE laboratories (Fermilab, SLAC, BNL, ANL, LBNL, 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. HEP conducted a comparative peer-review of the laboratory research efforts in this subfield in 2008.

In FY 2010, the laboratory theoretical research groups will 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 the time of the first beam collisions at the LHC approaches, an increased effort will be made to identify the most promising and sensitive methods for finding signs of new phenomena in the voluminous data that will be produced.

	FY 2008	FY 2009	FY 2010

(dollars in thousands)

It is also possible that certain dark matter particles may be produced at the LHC. Detailed calculations are required to identify effective ways to detect and study their properties.

Funding for the laboratory theory program will be maintained at about a constant level of effort. This is to support laboratory research personnel who participate in the analysis of current and previous experiments so that these experiments can fulfill their potential to make new discoveries and pave the way for the next generation of experiments.

	FY 2008	FY 2009	FY 2010
Computational HEP	**7,241**	**9,100**	**10,400**

This new budget category includes funding for specific high energy physics research activities that require extensive or customized computational resources. This category includes costs for design, fabrication, procurement, maintenance, and operation of computational 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 trans-atlantic networking, and U.S. contributions to experiment-independent computer codes required for HEP's program.

	FY 2008	FY 2009	FY 2010
▪ **SciDAC**	**5,243**	**5,600**	**5,600**

In FY 2010, HEP will continue supporting SciDAC projects and the accelerator simulation solicitation. All SciDAC projects will have mid-term continuation reviews in FY 2009. The SciDAC program is managed and cooperatively funded by the SC program offices, including the Advanced Scientific Computing Research program. There are four principal HEP-supported SciDAC efforts: Type Ia supernova simulations, to better understand the thermonuclear explosions that create supernovae and to generate supernova light curves appropriate for dark energy measurements, 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 LQCD 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 the 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.

	FY 2008	FY 2009	FY 2010
▪ **Computational QCD and Network Support**	**1,998**	**3,500**	**4,800**

The understanding 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-teraflops computer capability for dedicated LQCD simulations. During FY 2009, the first phase of this joint effort will be completed and provide on average about 13 teraflops of capacity. This investment is coordinated with the SciDAC QCD effort described above to ensure that the software codes developed can be run on a variety of available hardware platforms and used by a wide community of researchers. There is a follow-on proposal to deploy approximately 100 teraflops of dedicated capacity for QCD computing, which is currently under review.

In FY 2010, this activity will support the second phase of the LQCD computing initiative, which will provide approximately 100 teraflops of computing capacity. This category also includes funding for

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

the HEP-related trans-atlantic 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 2008, the U.S. LHC Net provided 40 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 Energy Science Network, which does not procure trans-oceanic networking.

	FY 2008	FY 2009	FY 2010
Other	**4,397**	**5,074**	**5,175**

This activity includes funding for education and outreach activities, compilations of high energy physics data, reviews of data by the Particle Data Group 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. This category also includes $750,000 for the QuarkNet education project in FY 2010. 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. The project began in 1999, has been very successful, and will continue through the life of the LHC program.

	FY 2008	FY 2009	FY 2010
Total, Theoretical Physics	**60,032**	**64,804**	**67,240**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Grants Research	
The Theoretical Physics grant program is maintained at about a constant level of effort to support the analysis of current and previous experiments, and in the design and optimization of new experiments.	+502
National Laboratory Research	
The National Laboratory Research program is maintained at about a constant level of effort to support the analysis of current and previous experiments, and in the design and optimization of new experiments.	+533
Computational HEP	
Funding for LQCD increases to support the second phase of the computing initiative.	+1,300
Other	
The increase is primarily due to funding for the Particle Data Group to upgrade their computer systems.	+101
Total Funding Change, Theoretical Physics	**+2,436**

Advanced Technology R&D

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Advanced Technology R&D			
Accelerator Science	45,076	53,224	47,324
Accelerator Development	70,173	98,520	90,501
Other Technology R&D	22,894	24,456	24,701
SBIR/STTR	—	20,388	20,505
Total, Advanced Technology R&D	138,143	196,588	183,031

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 high energy 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. These technologies find applications in synchrotron light sources; intense neutron sources; very short pulse, high-brightness electron beams; and computational software for accelerator and charged particle beam optics design. As a result, the technologies find wide use in nuclear physics, materials science, chemistry, medicine, and industry. Particle accelerators and detectors have migrated into general usage for medical therapy and diagnostics, for preparation of radio-nuclides used in medical treatment facilities, and for the electronics and food industries, to name a few applications. They are also now finding use in defense applications and homeland security.

Selected FY 2008 Accomplishments

- A collaboration of laboratories, universities, and small businesses has significantly advanced the state of the art for accelerating gradients in normal-conducting accelerating cavities, which is approximately 50 MeV per meter. This effort is directed towards reducing the size and cost of future TeV-scale lepton colliders. At ANL, an intense pulse of electrons was used to excite a microwave field of 100 MeV per meter in a dielectric-loaded accelerating structure. An MIT-designed photonic band-gap accelerating structure also achieved 100 MeV per meter. SLAC has demonstrated 150 MeV per meter in a single-cell, standing-wave copper structure.
- U.S. research groups from national laboratories and universities played a major role in the successful Mercury Intense Target Experiment (MERIT) experiment at CERN, which established the feasibility of using a mercury-jet target for muon production in an intense proton beam. This clears one of the major technical hurdles towards establishing high energy muon colliders.

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Accelerator Science	**45,076**	**53,224**	**47,324**

This activity focuses on the science underlying the technologies used in particle accelerators and storage rings, as well as the fundamental physics of charged particle beams. National laboratory research efforts are selected based on peer review, laboratory program advisory committees, and special ad hoc review committees. Grant-based research programs are selected based on peer review. Progress is monitored through a system of formal site visits, presentations at appropriate workshops, participation in conferences, and publications.

▪ **Grants Research**	**11,252**	**9,466**	**9,652**

The FY 2010 budget will continue support for a broad research program in advanced accelerator physics and related technologies. There are 30 accelerator science grants supporting approximately 80 scientists and 45 graduate students. The 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.

▪ **National Laboratory Research**	**33,824**	**35,758**	**37,672**

This activity supports accelerator R&D efforts and operations of test facilities at ANL, BNL, Fermilab, LBNL and SLAC.

The Accelerator Science program at ANL explores advanced methods to accelerate charged particles with the goal of more efficient, compact, and inexpensive particle accelerators. Efforts in FY 2010 will focus on the development of dielectric wakefield accelerating structures needed to achieve accelerating gradients up to 200 MeV/m. This will be accomplished by upgrading the Argonne Wakefield Accelerator to provide high-charge electron bunches to excite wakefields in the structures.

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. In FY 2010, 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.

In FY 2010, LBNL as part of its Laser, Optical Accelerator Systems Integrated Studies (LOASIS) program will conduct research in laser-driven plasma acceleration, with a focus on exploring concepts for cascading GeV wakefield accelerating modules, a promising path to higher gradients and energies. Research and development of muon ionization cooling and theoretical studies of alternative muon acceleration schemes will also be performed.

At Fermilab, the FY 2010 budget will support muon acceleration research, electron beam physics experiments with a high-brightness photo-injector, and beam theory and accelerator simulation

	FY 2008	FY 2009	FY 2010

(dollars in thousands)

studies performed at the Accelerator Physics Center. R&D in support of the Muon Ionization Cooling Experiment (MICE) at Rutherford Appleton Laboratory, U.K., will also continue.

In FY 2010, SLAC plans to complete fabrication of the Facility for Accelerator Science and Experimental Test Beams (FACET) (supported by Recovery Act funds) and begin preparations for the first round of experiments in which an electron bunch (the beam is not a continuous stream of electrons but structured in discrete bunches) is accelerated by plasma wakefields. Much of the work on advanced accelerator concepts at SLAC is done in collaboration with universities funded by the Accelerator Science activity. The goal of the high gradient effort will be a demonstration of efficient, full-length accelerating structures with gradients above 100 MeV/m.

Also supported in FY 2010 are theoretical studies of space-charge dominated beams at PPPL.

	FY 2008	FY 2009	FY 2010
▪ **Projects**	**—**	**8,000**	**—**

Funding was provided in the FY 2009 Appropriation and in the FY 2009 Recovery Act for the Berkeley Lab Laser Acceleration Project (BELLA). BELLA will further advance the world-leading laser-driven plasma acceleration program, with a focus on exploring concepts for cascading GeV wakefield accelerating modules, a promising path to higher gradients and energies. LOASIS has already accelerated high-quality electron beams to energy exceeding 1 GeV in a one-meter long structure. BELLA will initially improve this by a factor of ten, to 10 GeV.

	FY 2008	FY 2009	FY 2010
Accelerator Development	**70,173**	**98,520**	**90,501**

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. 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.

	FY 2008	FY 2009	FY 2010
▪ **General Accelerator Development**	**46,940**	**39,520**	**33,501**

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, SLAC, and BNL. 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 R&D program at Fermilab in FY 2010 will address a broad spectrum of technology needs for that facility, including advanced superconducting magnet R&D, R&D for a high-intensity neutrino beam facility, advanced beam instrumentation, and simulation codes to provide improved modeling of all aspects of accelerator operations. Among these topics, emphasis will be placed on developing very high intensity proton sources for neutrino physics research. In particular, funding in this category in FY 2010 decreases as some of these activities move to project-oriented R&D under Proton Accelerator Facility Operations above, and some effort is redirected to other new projects.

The LBNL R&D supported in FY 2010 includes work on very high field superconducting magnets using niobium-tin and similar advanced superconductors, advanced RF systems, laser manipulation and measurement of charged particle beams, and instrumentation development, accelerator theory,

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

and computation. The very successful industrially-based program managed by LBNL to develop advanced superconductors, particularly niobium-tin, for the very high field superconducting magnet R&D program will continue to be supported.

The FY 2010 program at SLAC encompasses high-powered RF systems, beam instrumentation, generic electron-positron collider R&D, and advanced beam dynamics and machine simulation code development. Simulation codes for modeling RF system components and high-powered microwave tubes will receive special R&D focus.

The R&D program at BNL includes work on superconducting magnet R&D and associated superconducting magnet materials measurement facility.

	FY 2008	FY 2009	FY 2010
▪ **Superconducting RF R&D**	**8,399**	**24,000**	**22,000**

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.

In FY 2010, this effort will 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. FY 2010 funding will also be used to support a fundamental research effort in SRF cavity design that aims to enhance the performance capability, gradient, production yield, reliability, lifetime, and cost of the fundamental RF accelerating structures.

	FY 2008	FY 2009	FY 2010
▪ **International Linear Collider R&D**	**14,834**	**35,000**	**35,000**

A TeV-scale linear collider is widely considered by the international high energy physics community to be the successor to the LHC and essential for advancing scientific progress at the Energy Frontier. In FY 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 FY 2008, the GDE initiated a five-year program to develop a Technical Design Report (TDR) that will address outstanding R&D issues, complete a baseline design, and provide a project implementation plan. Completion of the TDR in 2012 is consistent with worldwide resources currently available for the ILC R&D and coincident with first physics from the LHC (necessary to finalize operating parameters for the next linear collider).

In FY 2010, the ILC R&D program will continue to support an important, leading U.S. role in the comprehensive and coordinated international R&D program. Accordingly, efforts will focus on R&D for systems associated with the generation and maintenance of very bright particle beams, such as electron sources, damping rings, beam dynamics development, and beam delivery systems. Support will also be provided for development and prototyping of high level RF equipment and components

	FY 2008	FY 2009	FY 2010

(dollars in thousands)

associated with the main linac accelerator, including ILC cryomodules. These R&D efforts also have wider applicability to other projects supported by the Office of Science.

Other Technology R&D	**22,894**	**24,456**	**24,701**

This category includes R&D on new particle detector technologies. Advanced Detector Research addresses fundamental scientific problems to foster new technologies in particle detection, measurement, and data processing. The Detector Development activity provides funding to national laboratories and universities to bring new particle detection and data processing concepts to engineering readiness so they can be incorporated into existing or new facilities, analogous to the Accelerator Development subprogram.

▪ **Advanced Detector Research**	**709**	**1,737**	**1,769**

The Advanced Detector Research program provides short-term 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. Technologies are selected based on anticipated applications that require further technological improvements before deployment. In recent years, three to eight grants a year have been awarded through a competitive peer review program. Final funding levels depend on the number and quality of proposals received.

▪ **Detector Development**	**22,185**	**22,719**	**22,932**

This activity provides long-term detector development work at the national laboratories and at about 40 universities. The goal is to advance these technologies to a point where there is an opportunity for experiments to successfully adopt the technology. Current areas of investigation include R&D on detector technologies that could be used to pursue new opportunities in future lepton colliders, particle astrophysics, neutrino physics, and experiments that require underground facilities, such as dark matter detection.

The FY 2010 request will maintain R&D efforts directed toward developing new detectors, including prototyping and in-beam studies. A diverse program will be continued, including efforts on particle flow calorimeters, very low-mass trackers, liquid noble gas detectors, transducer technology (e.g., advanced charged-coupled devices, silicon photomultipliers), large area photodetectors, picosecond timing techniques, and radiation resistant, fast readout electronics. Prototype calorimeter tracking and muon detection systems will be studied in the Fermilab test beam, providing a major test of particle flow algorithms and detector construction techniques.

SBIR/STTR	**—**	**20,388**	**20,505**

In FY 2008, $16,505,000 and $1,981,000 was transferred to the congressionally mandated Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, respectively. The FY 2009 and FY 2010 amounts are estimated requirements for the continuation of these programs.

Total, Advanced Technology R&D	**138,143**	**196,588**	**183,031**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Accelerator Science	
▪ **Grants Research**	
Funding for grant-based research maintains efforts at FY 2009 levels.	+186
▪ **National Laboratory Research**	
Funding for the base research program at the laboratories is about the same as FY 2009, after one-time investments ($3,000,000) in FY 2009 in infrastructure and the commissioning costs ($+5,100,000) for FACET in FY 2010 are taken into account.	+1,914
▪ **Projects**	
Project funding for BELLA is completed in FY 2009.	-8,000
Total, Accelerator Science	**-5,900**
Accelerator Development	
▪ **General Accelerator Development**	
Funding for General Accelerator Development activities decreases because work on conceptual design for a long-baseline neutrino beam has been reassigned to Proton Accelerator facility operations, and some effort is redirected to R&D on other new proton accelerator facility projects.	-6,019
▪ **Superconducting RF R&D**	
Planned funding for Superconducting RF development is reduced since additional funds are provided from the FY 2009 Recovery Act.	-2,000
Total, Accelerator Development	**-8,019**
Other Technology R&D	
Funding for Other Technology R&D is approximately the same as FY 2009.	+245
SBIR/STTR	
SBIR/STTR programs are funded at the mandated level.	+117
Total Funding Change, Advanced Technology R&D	**-13,557**

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Operating Expenses	642,398	713,308	723,546
Capital Equipment	46,579	74,961	91,082
General Plant Projects	9,568	4,417	2,952
Accelerator Improvement Projects	4,300	3,040	1,420
Total, High Energy Physics	702,845	795,726	819,000

Funding Summary

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Research			
National Laboratories	279,152	320,675	313,195
Universities	121,101	127,633	130,000
Other	2,264	3,913	6,371
Total, Research	402,517	452,221	449,566
Scientific User Facilities Operations	253,072	244,066	241,098
Major Items of Equipment	34,232	67,066	96,910
Other	13,024	32,373	31,426
Total, High Energy Physics	702,845	795,726	819,000

Scientific User Facilities Operations

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Tevatron	151,018	157,658	158,519
B-factory	36,482	14,471	12,059
LHC Detector Support and Operations	65,572	71,937	70,520
Total, Scientific User Facilities Operations	253,072	244,066	241,098

Total Facility Hours and Users

	FY 2008	FY 2009	FY 2010
Proton Accelerator Complex[a]			
Achieved Operating Hours	6,500	N/A	N/A
Planned Operating Hours	5,040	5,040	5,400
Optimal hours (estimated)	5,400	5,400	5,400
Percent of Optimal Hours	120%	93%	100%
Unscheduled Downtime	16%	N/A	N/A
Total Number of Users	2,160	2,160	2,000
SLAC B-factory			
Achieved Operating Hours	2,359	—	—
Planned Operating hours	1,300	—	—
Optimal hours (estimated)	5,850	—	—
Percent of Optimal Hours	40%	—	—
Unscheduled Downtime	15%	—	—
Total Number of Users	1,000	800	600
Total Facilities			
Achieved Operating Hours	8,859	N/A	N/A
Planned Operating hours	6,340	5,040	5,400
Optimal hours (estimated)	11,250	5,400	5,400
Percent of Optimal Hours	78%	93%	100%
Unscheduled Downtime	15%	N/A	N/A
Total Number of Users	3,160	2,960	2,600

[a] Tevatron and NuMI operations run in parallel.

Major Items of Equipment (MIE)

(dollars in thousands)

	Prior Years	FY 2008	FY 2009	FY 2009 Additional Approp.	FY 2010	Out-Years	Total
Proton Accelerator-Based Physics							
MINERνA							
Total Estimated Costs (TEC)	—	5,000	4,900	—	800	—	10,700
Other Project Costs (OPC)	3,950	2,150	—	—	—	—	6,100
Total Project Costs (TPC)	3,950	7,150	4,900	—	800	—	16,800
NOνA							
TEC	1,000	—	15,106	14,936	59,000	107,340	197,382
OPC	15,860	12,034	12,660	40,064	—	—	80,618
TPC	16,860	12,034	27,766	55,000	59,000	107,340	278,000
T2K							
TEC	—	1,848	1,000	—	—	—	2,848
OPC	1,200	660	—	—	—	—	1,860
TPC	1,200	2,508	1,000	—	—	—	4,708
Accelerator Project for the Upgrade of the LHC							
TEC	—	—	—	—	TBD[a]	TBD	TBD
OPC	—	—	2,500	—	16,000[a]	TBD	TBD
TPC	—	—	2,500	—	16,000	6,500–8,500	25,000–27,000
Non-Accelerator Physics							
Reactor Neutrino Detector							
TEC	500	4,960	13,000	—	10,780	1,960	31,200
OPC	500	1,980	—	—	220	100	2,800
TPC	1,000	6,940	13,000	—	11,000	2,060	34,000

[a] This MIE is not yet baselined, and therefore the TEC and OPC have not been determined. Mission Need (CD-0) was approved on November 20, 2008, with an estimated cost range of $25,000,000–$27,000,000. The FY 2010 Budget Request is for engineering design only. Engineering design may include limited fabrication and testing of design concepts. Fund for full fabrication will be requested after approval of the Performance Baseline, CD-2.

	(dollars in thousands)						
	Prior Years	FY 2008	FY 2009	FY 2009 Additional Approp.	FY 2010	Out-Years	Total
Dark Energy Survey							
TEC	—	1,650	7,990	—	8,410	5,000	23,050
OPC	7,040	3,950	910	—	200	—	12,100
TPC	7,040	5,600	8,900	—	8,610	5,000	35,150
SuperCDMS at Soudan[a]							
TEC/TPC	—	—	1,000	—	1,500	—	2,500
Advanced Technology R&D							
Advanced Accelerator R&D Test Facility[b]							
BELLA							
TEC	—	—	8,000	18,718	—	—	26,718
OPC	—	—	—	2,000	—	—	2,000
TPC	—	—	8,000	20,718	—	—	28,718
FACET							
TEC	—	—	—	11,000	—	—	11,000
OPC	—	—	—	2,000	—	—	2,000
TPC	—	—	—	13,000	—	—	13,000
Total MIEs							
TEC		13,458	50,996	44,654	80,490		
OPC		20,774	16,070	44,064	16,420		
TPC		34,232	67,066	88,718	96,910		

[a] This MIE appeared as CDMS-25 in the FY 2009 budget request. See the text for details of the changes. Mission Need (CD-0) was approved on September 28, 2007, with an estimated cost range of $6,000,000–$7,000,000. Funds for full fabrication will be requested after approval of the project baseline.

[b] Two proposals, Berkeley Lab Laser Acceleration (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, it will be possible to do both. FACET will receive only Recovery Act funds and BELLA will receive both FY 2009 funds and Recovery Act funds. Neither project is baselined yet, so the split between TEC and OPC funds is not yet determined. Mission Need (CD-0) was approved on February 27, 2008 with an estimated cost range of $32,000,000–$37,000,000 for both projects. This early estimate did not explicitly include OPC costs. Funds for full fabrication will be requested after approval of the Performance Baseline, CD-2.

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). The planned completion for this project is in FY 2010.

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. This is $8,000,000 more than that documented in the FY 2009 request. The project was delayed for approximately one year due to zero funding in the FY 2008 Omnibus appropriation, when the work was rescheduled for later completion, the Total Project Cost increased due to escalation. The planned completion for this project is in 2014.

Tokai-to-Kamioka (T2K) Near Detector is a new accelerator-based neutrino oscillation experiment in Japan. This experiment utilizes neutrino beams from the Japanese proton accelerator facility, measured both in a nearby detector and in the Super-Kamiokande detector approximately 300 km away, to study neutrino oscillations in a manner complementary to NOνA. The planned completion for this project is in FY 2009.

Accelerator Project for the Upgrade of the LHC (APUL) is a new MIE planned to begin fabrication in FY 2010. The scope of the project is to design and construct selected magnets, power systems, and beam instrumentation needed for increasing the LHC luminosity by a factor of two to three. The Mission Need was approved October 2008 and conceptual design is underway, funded under Other Project Costs. Brookhaven National Laboratory and Fermilab are expected to fabricate components and deliver them to CERN for installation in the LHC.

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. The planned completion for this project is in FY 2012.

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. The planned completion of this project is in FY 2011.

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 will be manufactured at Stanford University and tested at various U.S. institutions before being installed at the Soudan Underground Laboratory in Minnesota. This project has been reduced in size compared to the FY 2009 budget request in order to complete the experiment more quickly and maintain scientific competitiveness with other dark matter detection technologies.

Advanced Technology R&D MIEs:

Advanced Accelerator R&D Test Facility was initiated in FY 2009. Two proposals, Berkeley Lab Laser Acceleration (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, it will be possible to do both. FACET will receive only Recovery Act funds and BELLA will receive 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.

Scientific Employment

	FY 2008 actual	FY 2009 estimate	FY 2010 estimate
# University Grants	200	200	200
# Laboratory Groups	47	45	45
# Permanent Ph.D.'s (FTEs)	1,135	1,135	1,140
# Postdoctoral Associates (FTEs)	525	550	550
# Graduate Students (FTEs)	585	595	595
# Ph.D.'s awarded	110	110	110