High Energy Physics

Funding Profile by Subprogram

	(dollars in thousands)		
	FY 2006 Current Appropriation	FY 2007 Request	FY 2008 Request
High Energy Physics			
Proton Accelerator-Based Physics	362,157	376,536	389,672
Electron Accelerator-Based Physics	112,291	117,460	79,763
Non-Accelerator Physics	54,205	59,271	72,430
Theoretical Physics	47,984	52,056	56,909
Advanced Technology R&D	121,601	159,476	183,464
Subtotal, High Energy Physics	698,238	764,799	782,238
Construction	—	10,300	—
Total, High Energy Physics	698,238[a]	775,099	782,238
Stanford Linear Accelerator Center (SLAC) Linac Operations (non-add)[b]	(56,100)	(52,100)	(32,500)
High Energy Physics, excluding SLAC Linac Operations (non-add)[b]	(642,138)	(722,999)	(749,738)

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 103-62, "Government Performance and Results Act of 1993"
Public Law 109-58, "Energy Policy Act of 2005"

Mission

The mission of the High Energy Physics (HEP) program is to understand how our universe works at its most fundamental level. We do this by discovering the most elementary constituents of matter and energy, exploring the basic nature of space and time itself, and probing the interactions between them. These fundamental ideas are at the heart of physics and hence all of the physical sciences. To enable these discoveries, HEP supports theoretical and experimental research in both elementary particle physics and fundamental accelerator science and technology. HEP underpins and advances the DOE missions and objectives through this research, and by the development of key technologies and trained manpower needed to work at the cutting edge of science.

[a] Total is reduced by $7,239,000 for a rescission in accordance with P.L. 109-148, the Emergency Supplemental Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006; $16,479,000, which was transferred to the SBIR program; and $1,977,000, which was transferred to the STTR program.
[b] The SLAC linear accelerator (linac) supports operations of the B-factory (funded by HEP) and will also support operations of the Linac Coherent Light Source (currently under construction and funded by Basic Energy Sciences (BES)). With the completion of B-factory operations in FY 2008, SC has been transitioning funding of the SLAC linac from HEP to BES, with FY 2008 representing the third and final year of joint funding with BES. HEP totals without SLAC linac funding are presented to display program growth exclusive of this functional transfer.

Benefits

HEP supports the Department of Energy's (DOE's) mission of world-class scientific research capacity by providing facilities and advancing our knowledge of high energy physics and related fields, including particle astrophysics and cosmology. Research advances in any one of these fields often have a strong impact on research directions in another. These fields also have a substantial overlap in technological infrastructure, including particle accelerators and detectors, data acquisition, and computing. Technology that was developed in response to the demands of high energy physics research has also become critical to other fields of science and has found wide applications in industry and medicine, often in ways that could not have been predicted when the technology was first developed. Examples include: medical imaging, radiation therapy for cancer using particle beams, ion implantation of layers in semiconductors, materials research with electron microscopy, and the World Wide Web. The accelerator technologies of high-power x-ray light sources, from synchrotron radiation facilities to the new coherent light sources, are derived from high energy physics accelerator technology.

Strategic and GPRA Unit Program Goals

The Department's Strategic Plan identifies five Strategic Themes (one each for nuclear, energy, science, management, and environmental aspects of the mission) plus 16 Strategic Goals that tie to the Strategic Themes. The High Energy Physics program supports the following goals:

Strategic Theme 3, Scientific Discovery & Innovation
Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.

Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory infrastructure required for U.S. scientific primacy.

The HEP program has one GPRA Unit Program Goal which contributes to Strategic Goal 3.1 and Strategic Goal 3.2 in the "goal cascade."

GPRA Unit Program Goal 03.1/2.46.00: 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 Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science

The HEP program contributes to these Strategic Goals 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 2008 address all of these challenges.

The FY 2008 budget request also contributes to this program goal by placing high priority on operations, upgrades, and infrastructure for the three major HEP user facilities: the Tevatron Collider and Neutrinos at the Main Injector (NuMI) at the Fermi National Accelerator Laboratory (Fermilab), and the B-factory at the Stanford Linear Accelerator Center (SLAC), to produce maximum scientific data to address these fundamental questions. HEP and Basic Energy Sciences (BES) will jointly support B-factory accelerator operations at SLAC throughout the construction phase of the Linac Coherent Light Source (LCLS). FY 2008 will be the final year of the SLAC linac operations transition to BES.

The following indicators establish 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.”

These indicators spell out some of the important scientific goals of the HEP program for the next decade and can only be evaluated over a period of several years. However, each of these long-term goals is supported by one or more of the annual performance targets in Facilities Operations or Construction/Major Items of Equipment listed in the following table. Achieving success in these annual targets will be an important component of making progress towards the long-term goals.

Funding by Strategic and Program Goal

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 03.1/2.46.00, Explore the Fundamental Interactions of Energy, Matter, Time and Space			
High Energy Physics	698,238	775,099	782,238

Annual Performance Results and Targets

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
GPRA Unit Program Goal 03.1/2.46.00—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. [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. [Goal Not Met]	Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time.	Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time.
Proton Accelerator-Based Physics/Facilities					
Delivered data as planned (225 pb^{-1}) to CDF and D-Zero detectors at the Tevatron. [Met Goal]	Delivered data as planned within 20% of the baseline estimate (240 pb^{-1}) to CDF and D-Zero detectors at the Tevatron. [Met Goal]	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]	Deliver data as planned within 20% of the baseline estimate (800 pb^{-1}) to CDF and D-Zero detectors at the Tevatron.	Deliver data as planned within 20% of the baseline estimate (800 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]	Deliver data as planned within 20% of the baseline estimate ($1.5 x10^{20}$ protons on target) for the MINOS experiment using the NuMI facility.	Deliver data as planned within 20% of the baseline estimate ($2.0 x10^{20}$ protons on target) for the MINOS experiment using the NuMI facility.
Electron Accelerator-Based Physics/Facilities					
Increased the total data delivered to BaBar at the SLAC B-factory by delivering 45 fb^{-1} of total luminosity. [Goal Not Met]	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]	Deliver data as planned within 20% of the baseline estimate (150 fb^{-1}) to the BaBar detector at the SLAC B-factory.	Deliver data as planned within 20% of the baseline estimate (220 fb^{-1}) to the BaBar detector at the SLAC B-factory
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 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]	Maintain cost and schedule milestones for major items of equipment and new construction projects within 10% of baseline estimates.	Maintain cost and schedule milestones for major items of equipment and new construction projects within 10% of baseline estimates.

Means and Strategies

The HEP program will use various means and strategies to achieve its program goals. However, various external factors may impact the ability to achieve these goals.

The HEP program supports fundamental, innovative, peer-reviewed research to create new knowledge in areas important to the HEP mission, i.e., in experimental and theoretical particle physics, particle astrophysics, cosmology, and technology R&D. HEP also plays a critical role in constructing and operating a wide array of scientific user facilities for the Nation's researchers. All research projects undergo regular peer review and merit evaluation based on procedures set down in Office of Science Regulation 10 CFR 605 for the extramural grant program, and under a similar process for the laboratory programs and scientific user facilities. New projects are selected through peer review and merit evaluation.

External factors that affect the programs and performance include: (1) changing mission needs as described by the DOE and Office of Science (SC) mission statements and strategic plans; (2) evolving scientific opportunities that sometimes emerge in a way that revolutionizes disciplines; (3) results of external program reviews and international benchmarking activities of entire fields or sub fields, such as those performed by the National Academy of Sciences; (4) unanticipated failures, for example, in critical components of scientific user facilities, which cannot be mitigated in a timely manner; and (5) strategic and programmatic decisions made by other Federal agencies and by international entities.

The HEP program in fundamental science is closely coordinated with the activities of other federal agencies (e.g., the National Science Foundation [NSF] and the National Aeronautics and Space Administration [NASA]). HEP also promotes the transfer of the results of its basic research to contribute to DOE missions in areas of nuclear physics research and facilities; basic energy sciences facilities, (contributing to research in materials science, molecular biology, physical chemistry, and environmental sciences); and mathematical and computational sciences.

Validation and Verification

Progress against established plans is evaluated by periodic internal and external performance reviews. These reviews provide an opportunity to validate and verify performance. Quarterly, semiannual, and annual reviews consistent with specific program management plans are held to ensure technical progress, cost and schedule adherence, and responsiveness to program requirements.

Program Assessment Rating Tool (PART)

The Department has implemented a tool, the PART Assessment, to evaluate selected programs. PART was developed by the Office of Management and Budget (OMB) to provide a standardized way to assess the effectiveness of the federal government’s portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. The HEP program has incorporated feedback from OMB and has taken or will take the necessary steps to continue to improve performance.

In the FY 2003 PART review for the FY 2005 Budget, OMB gave the HEP program a score of 84% overall which corresponds to a rating of “Moderately Effective”. OMB found performance improvements at Fermilab and an ongoing prioritization process. The assessment also found that HEP has developed a limited number of adequate performance measures which are continued for FY 2008. These measures have been incorporated into this budget request, HEP grant solicitations, and the performance plans of senior managers. As appropriate, they will be incorporated into the performance based contracts of M&O contractors. To better explain these complex scientific measures, the Office of

Science has developed a website (http://www.sc.doe.gov/measures/) that answers questions such as "What does this measure mean?" and "Why is it important?" Roadmaps, developed in consultation with the High Energy Physics Advisory Panel (HEPAP) and also available on the website, will guide reviews, every three years by HEPAP, of progress toward achieving the long-term performance measures. The annual performance targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report.

OMB previously provided HEP with three recommendations to further improve performance:

- Implement the recommendations of past and new external assessment panels, as appropriate.
- Develop a strategy and implementation plan for particle accelerator research and development, including a potential international linear collider.
- Engage the National Academies to help develop a realistic long-term plan for the program that is based on prioritized scientific opportunities and input from across the scientific community.

In response to OMB's recommendations HEP has:

- Established a Committee of Visitors (COV) that provides outside expert validation of the program's merit based review processes for impact on quality, relevance, and performance. Within 30 days of receiving a COV report, HEP develops an action plan to respond to its findings and recommendations. The COV reports are available on the web (http://www.science.doe.gov/hep/HEPAPCOVReportfinal.pdf). Action plans are also available on the web at (http://www.sc.doe.gov/hep/OfficeofHEPResponsetoCOVreport.shtm).
- Formally charged the HEPAP to establish panels to assess progress toward the long-term goals of the HEP program.
- Started implementing recommendations from the National Academies study of elementary particle physics ("EPP2010") to develop a prioritized long-term plan.
- Initiated a planning process, with the high energy physics community's input, to develop a strategy for accelerator R&D within DOE that incorporates the challenges of a potential international linear collider.
- Begun actively working to implement recommendations from expert panels as appropriate. HEP plans for future facilities, based upon that input, are reflected in this budget request.

To improve public access to PART assessments and follow up actions, OMB has created the ExpectMore.gov website. Information concerning HEP PART assessments and current follow up actions can be found by searching on "high energy physics" at http://www.ExpectMore.gov.

Overview

What is the nature of the universe and what is it made of?

What are matter, energy, space, and time?

We have been asking basic questions like these throughout human history. Today, many of these questions are addressed scientifically through research in high energy physics, also known as particle physics. The DOE and its predecessors have supported research into these fundamental questions for more than five decades.

This research has led to a profound understanding of the physical laws that govern matter, energy, space, and time. This understanding is encompassed in a "Standard Model," first established in the 1970's, which predicts the behavior of particles and forces. The model has been subjected to countless experimental tests since then and its predictions have consistently been verified. The Standard Model is one of the great scientific triumphs of the 20^{th} century and the discoveries that led to it have been recognized with more than a dozen Nobel Prizes.

But startling new data have revealed that only about 5% of the universe is made of the normal, visible matter described by the Standard Model. The other 95% of the universe consists of matter and energy whose fundamental nature is a mystery. The Standard Model's orderly and elegant view of the universe must somehow be incorporated into a broader and deeper theory where these new phenomena take their natural places. A revolution in particle physics, and in our understanding of the universe in which we live, is coming.

Questions and the Quest for Answers

A world-wide program of particle physics research is underway to explore the new scientific landscape. The new long-term plan for the U.S. HEP program prepared by the National Academy of Sciences ("Revealing the Hidden Nature of Space and Time") recommends the thoughtful pursuit of a high-risk, high-reward strategy to explore the energy frontier, called the "Terascale". At Terascale (meaning 10^{12} electron volts, or TeV for short) energies, questions in cosmology and particle physics are closely connected: the history, nature, and ultimate fate of the universe depend intimately on elementary particles and their interactions.

Here are some of the key questions the HEP program is addressing, and how we are seeking the answers:

- Are there undiscovered principles of nature: new symmetries, 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 particle energies. One new symmetry, called supersymmetry, relates particles and forces. It predicts a "superpartner" for every particle we know, the lightest of which should be produced and observed at accelerators operating at the Terascale.

- How can we solve the mystery of dark energy?

  The "dark energy" that permeates empty space and accelerates the expansion of the universe must have a quantum explanation, in the same way that the quantum theory of light and the atom explained mysterious atomic spectra. More precise experimental data on dark energy, along with new theoretical ideas, are necessary to make progress on this fundamental problem.

- Are there extra dimensions of space?

  "String theory" is an attempt to unify physics by explaining particles and forces as the vibrations of tiny strings. String theory requires supersymmetry and seven extra dimensions of space. Evidence of such extra dimensions which support string theory could be seen at Terascale accelerators.

- 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 Terascale accelerators 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. Moreover, quarks and leptons have widely different masses and force couplings. These variations suggest there may be undiscovered simplifying principles that connect quarks and leptons, just as the discovery of quarks simplified the “zoo” of composite particle states discovered in the 1960’s. Detailed studies at accelerators will provide the clearest 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 and interacts very rarely with normal matter. This “dark matter” is thought to consist of exotic particles that have survived since the Big Bang. They may be reproduced and studied at Terascale accelerators, or detected in cosmic rays by using ultra-sensitive detectors.

- What are neutrinos telling us?

  Of all the known particles, neutrinos are perhaps the most mysterious. They played an essential role in the evolution of the universe, and flood otherwise empty space, but most pass right through the Earth undeflected and void of interaction. Their tiny masses may imply new physics and provide important clues to the unification of forces. Neutrinos are produced by cosmic rays, where they can be studied, as well as with experiments at accelerators and nuclear reactors.

- How did the universe come to be?

  The Big Bang (our universe) began with a singular disturbance of space-time, followed by a burst of inflationary expansion of space itself. The universe then expanded more slowly and cooled, allowing the formation of stars, galaxies, and ultimately life. Understanding the very early evolution of the universe will require a breakthrough in physics: the theoretical reconciliation of quantum mechanics with gravity.

- What happened to the antimatter?

  By all observation the universe appears to contain very little antimatter, although the Big Bang should have produced equal amounts of matter and antimatter, a fact that is supported by high-energy collisions in the laboratory. Precise accelerator-based measurements of the subtle asymmetries present in the weak nuclear interaction may shed light on how this asymmetry arose.

All these questions are addressed at some level by the existing and planned HEP program described in the rest of this budget request. Theoretical research, technology development, and a wide variety of experimental approaches are working hand-in-hand to provide new opportunities for further discoveries about the fundamental nature of the universe.

How We Work

The HEP program coordinates and funds high energy physics research. In FY 2006, HEP provided about 90% of the federal support for high energy physics research in the nation; the NSF provides most of the remaining support. HEP is responsible for: planning and prioritizing all aspects of its supported research; conducting ongoing assessments to ensure a comprehensive and balanced portfolio, regularly seeking advice from stakeholders; supporting university and national laboratory programs; and maintaining a strong infrastructure to support high energy physics research.

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) provides advice to the DOE and the NSF on a continuing basis regarding the direction and management of the national high energy physics research program. HEPAP regularly meets to advise the agencies on their research programs, assess their scientific productivity, and evaluate the scientific case for new facilities. HEPAP (or a subpanel thereof) also 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) assesses and prioritizes proposals for mid-sized projects that have been endorsed by laboratory program advisory committees or other advisory committees. Priorities recommended by P5 and other subpanels will have an important influence on long-range planning (see Planning and Priority Setting, below). A subpanel called the Neutrino Scientific Assessment Group (NuSAG), reporting jointly to HEPAP and the Nuclear Science Advisory Committee (NSAC), is advising DOE and NSF on specific questions concerning the U.S. neutrino program. A HEPAP subpanel reviewing the DOE advanced accelerator R&D program reported in the summer of 2006, and one on the university HEP research programs of DOE and NSF will report in spring 2007.

The Astronomy and Astrophysics Advisory Committee (AAAC) now reports on a continuing basis to the DOE, as well as to the NSF and NASA, with advice on the direction and management of the national astronomy and astrophysics research programs. The AAAC operates similarly to HEPAP and the two advisory bodies may form joint task forces or subpanels as needed to address research issues at the intersection of high energy physics, astrophysics and astronomy, such as dark energy and dark matter. For example, Task Forces on the cosmic microwave background and dark energy reported in spring 2006, and a Scientific Assessment Group for Dark Matter has recently been formed and is scheduled to report late in spring 2007.

The National Academy of Sciences was chartered by Congress in 1863 to advise the federal government on scientific and technical matters. It fulfills this function principally through the National Research Council (NRC), which conducts decadal surveys of research directions in all fields of physics and astronomy, as commissioned by its Board on Physics and Astronomy. A seminal new study carried out for the DOE and the NSF by the NRC in 2005-2006 assesses and prioritizes opportunities in high energy physics and the tools needed to realize them in the next 15 years. The committee's report, *Revealing the Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics* emphasized the primary importance of the LHC and ILC in the context of a broad and balanced program that also includes among its elements particle astrophysics and neutrino physics. The report is available at http://www7.nationalacademies.org/bpa/EPP2010.html.

Laboratory directors seek advice from their Program Advisory Committees (PACs) to determine the scientific justifications and priorities for the allocation of an important scientific resource—available accelerator beam time. Committee members, most of them external to the laboratory, are appointed by the director. PACs review research proposals requesting beam time and technical resources, judging each proposal's scientific merit and technical feasibility, and recommending whether the proposal should be approved, conditionally approved, deferred, or rejected.

Review and Oversight

The HEP program office provides review and oversight for its research portfolio. All university research proposals are subjected to an intensive and multistage review process to ensure high quality research and an appropriate mix of research efforts in the national program. Proposals to DOE for grant support are peer-reviewed by external technical experts. Once a university group is funded, regular site visits and peer reviews are performed to ensure that the quality of the research is maintained. Proposals by university groups to perform an experiment at a laboratory facility are reviewed by the laboratory PAC as described above.

The program also conducts annual in-depth reviews of the high energy physics program at each laboratory, using a panel of external technical experts. These on-site reviews examine the programmatic health of the laboratory, its high energy physics research, and, as appropriate, the state of its user facilities. The results are used in setting priorities both at the laboratory and within the national program. Proposals to initiate significant new research activities at laboratories may also undergo a peer review process, in addition to the annual laboratory reviews, to assess in detail the quality and relevance of the specific proposal. In addition, the HEP program office began in FY 2004 to conduct regular, dedicated reviews of operations at its major user facilities in order to maintain high standards of performance and reliability. The HEP program office also participates in the annual SC reviews of each of its laboratories.

Review and oversight of construction activities are done by integrated technical, cost, schedule, and management reviews using teams of experts versed in the areas of activity pertinent to the particular project. These reviews are chaired by SC federal employees from outside the HEP program who are expert in project management, and the review results are provided directly to the project's DOE Acquisition Executive.

As noted above in the PART section, the HEP program has also instituted a formal Committee of Visitors that will provide 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 first such review took place in the second quarter of 2004, and a second review is planned for 2007. The committee report praised the program strongly, but also pointed to several areas that could be improved.

Planning and Priority Setting

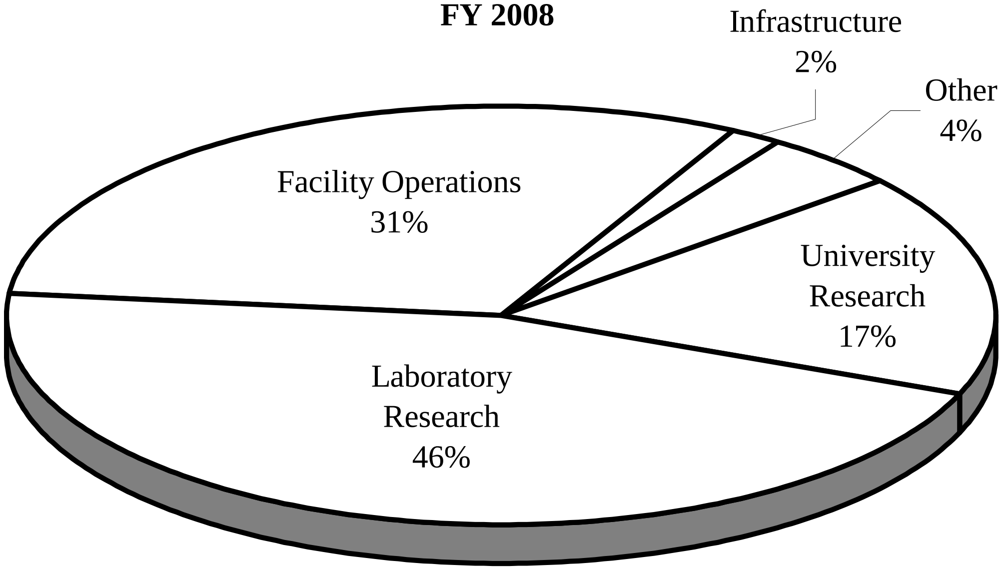
One of the most important functions of HEPAP is the development of long-range plans that express community-wide priorities for future research. The original plan for U.S. high-energy physics in 2010 and beyond was developed by HEPAP in 2002 and presented a "roadmap" for the field, laying out the physics opportunities envisioned for the next 20 years. This plan has since been reviewed and updated by the 2006 National Academies study of particle physics (see Advisory and Consultative Activities, above) which delineated the broad priorities for the future of the field, beginning with the physics enabled by the LHC and the ILC.

HEPAP has recommended a mechanism to update the roadmap and set research priorities across the program. This recommendation has been implemented in the form of the P5 subpanel that is charged with advising the funding agencies on priorities for new facilities. P5 is now playing an important role in determining which new facilities appear on the HEP roadmap in future years. Several scientific review panels (including P5) are currently meeting to evaluate specific proposed future HEP facilities and recommend a detailed programmatic roadmap.

How We Spend Our Budget

The HEP budget has three major program elements: research, facility operations, and laboratory infrastructure support. About 31% of the FY 2008 budget request is primarily provided to the three major HEP facilities for facility operations (Tevatron Collider and NuMI at Fermilab and B-factory at SLAC); a total of 46% is provided to laboratories, including multipurpose laboratories, in support of their HEP research and advanced technology R&D activities; 17% is provided for university-based physics research and advanced technology R&D; 2% for infrastructure improvements (general plant projects [GPP] and general purpose equipment [GPE]); and 4% for other activities (including Small Business Innovative Research [SBIR] and Small Business Technology Transfer [STTR]). It is notable that DOE provides about 70% of the Federal core support for university-based research groups working in high energy physics, including most of the support for students and postdoctoral researchers. The FY 2008 budget request is focused on facility operations and research at Fermilab with the CDF and D-Zero detectors at the Tevatron, and the Main Injector Neutrino Oscillation Search (MINOS) detector using the NuMI beam; and facility operations and research at SLAC with the BaBar detector at the B-factory. Priority is also given to the ramp-up of the LHC research program to support operations and maintenance activities in anticipation of the initial startup of the LHC in the fall of 2007; and to a significant increase in R&D efforts focused on research in superconducting RF technology and development needed for future accelerator facilities including an International Linear Collider.

High Energy Physics Budget Allocation
FY 2008



Research

The DOE HEP program supports approximately 2,400 researchers and students at more than 100 U.S. universities located in 36 states, Washington, D.C., and Puerto Rico, and 10 DOE national laboratories located in 6 states. In addition, the HEP research program includes significant participation from university scientists supported by the NSF, a substantial number of scientists from foreign institutions, and scientists supported by NASA. These physicists conceive and carry out the high energy physics research program. Typically, they work together in large international collaborations, involving hundreds of scientists from many institutions, to carry out a program that may take a decade or more to complete. A long time scale is one of the signature features of high energy physics research. Funding for most university and laboratory research is maintained at approximately the FY 2007 level-of-effort, with the main emphasis on supporting analysis of the large datasets now being generated by our user facilities, and enhancing long-range accelerator science research. Research scientists at national laboratories and universities work together in the experimental collaborations to collect and analyze data as well as support and maintain the detectors. The laboratories also maintain state-of-the-art resources needed for future upgrades and new facilities, and together with the university-based research program, perform R&D for future detectors and accelerator facilities.

- **University Research:** University researchers play a critical role in the national high energy physics research effort and in the training of graduate students and postdoctoral researchers, only about half of whom remain in the field, the rest going into industry, commerce and government where they are well-received. This highly trained human resource is part of the Nation’s economic and strategic strength. During FY 2006, the DOE High Energy Physics program supported approximately two-thirds of the nation’s university researchers engaged in fundamental high energy physics research, and approximately 90% of the researchers engaged in accelerator R&D. Typically, about 100 Ph.D.

degrees are granted annually to students for research supported by the high energy physics program and 10 per year in the accelerator physics program.

The university grants program is proposal driven, and funds the best and brightest of those ideas submitted in response to grant solicitation notices. Proposals are reviewed by external scientific peers and grants are competitively awarded according to the guidelines published in Office of Science Regulation 10 CFR 605. Thereafter, the research is monitored to ensure that a high quality of research is maintained (see Review and Oversight, above).

- **National Laboratory Research**: The HEP program supports research groups at the Fermi National Accelerator Laboratory; at Lawrence Berkeley, Lawrence Livermore, Argonne, Brookhaven, Oak Ridge, and Los Alamos National Laboratories; and at the Princeton Plasma Physics Laboratory, SLAC and the Thomas Jefferson National Accelerator Facility. The directions of laboratory research programs are driven by the needs of the Department and are tailored to the major scientific facilities at the laboratories. Laboratory researchers collaborate with academic users of the facilities and play a key role in developing and maintaining the accelerators, large experimental detectors, and computing facilities for data analysis. Laboratory researchers play a critical role in the national high energy physics research effort and in the training of postdoctoral researchers, engineers and technical personnel, many of whom spend much of their later careers in industry.

  The HEP program funds selected field work proposals from the national laboratories. Performance of the laboratory groups is reviewed annually by program staff assisted by an external panel of technical experts (see Review and Oversight, above) to examine the quality and balance of their research and identify needed changes, corrective actions, or redirection of effort. Individual laboratory groups have special capabilities or access to laboratory resources that can be profitably utilized in the development of the scientific program.

Significant Program Shifts

The U.S. HEP program in FY 2008 will continue to lead the world with forefront user facilities at Fermilab and SLAC that help answer the key scientific questions outlined above, but these facilities are scheduled to complete their scientific missions by the end of the decade. The mid-term HEP program supported by this request continues to develop new cutting-edge facilities in targeted areas (for example, neutrino physics) that will establish a U.S. leadership role in these areas in the next decade, when the centerpiece of the world HEP program will be the LHC at the European Organization for Nuclear Research (CERN). For the long-term, we have prioritized our current R&D efforts to select those that will provide the most compelling science opportunities in the coming decade within the available resources.

For these reasons, our highest priority R&D effort is the development of the proposed International Linear Collider (ILC) followed by efforts to expand the program in particle astrophysics and pursue an internationally coordinated, staged program in neutrino physics. In making these decisions we have carefully considered the recommendations of the National Academy of Sciences, HEPAP, and planning studies produced by the U.S. HEP community. This prioritization process will continue as the R&D programs evolve.

- The planned operational improvements, equipment, upgrades and infrastructure enhancements for the Tevatron program at Fermi National Accelerator Laboratory will be completed by FY 2007. The luminosity improvements of the Tevatron Collider have been successfully carried out while still running the collider at high efficiency. As part of its ongoing development of a U.S. HEP program "roadmap" for the upcoming decade, the HEP prioritization subpanel (P5) will consider the scientific importance of outyear (FY 2009 and beyond) Tevatron running in spring 2007.

- Much of the accelerator improvement effort at Fermilab will move to the neutrino program, which began in 2005 with the commissioning of the NuMI neutrino beam. The NuMI beam uses the proton source section of the Tevatron complex, and puts high performance demands on that set of accelerators. A new program of enhanced maintenance, operational improvements, and equipment upgrades has been developed to meet these demands. An initial set of accelerator improvements will be completed in 2008 to upgrade the NuMI beam power from its design value of about 250 kW to about 400 kW. Additional improvements are being developed that would further enhance the NuMI beam power and provide a platform for a world-leading neutrino program at Fermilab into the next decade. Since these improvements will most directly benefit the NuMI Off-axis Neutrino Appearance (NOνA) detector[a], the upgrade of the NuMI beam power from 400 kW to 700 kW will be incorporated into the NOνA project using standard DOE project management protocols.
- In order to exploit the unique opportunity to expand the boundaries of our understanding of the fundamental and asymmetry between matter and antimatter in the universe, a high priority is given to completing the physics program of the B-factory at SLAC. Final upgrades to the accelerator and detector are scheduled for completion in FY 2007, and B-factory operations will conclude in FY 2008. As part of its ongoing development of a U.S. HEP program "roadmap" for the upcoming decade, the HEP prioritization subpanel (P5) evaluated the scientific importance of the final year (2008) of B-factory running, and has recommended that B-factory operations continue through 2008. The transition of SLAC from primarily supporting B-factory operations to construction and operations of the Linac Coherent Light Source in Basic Energy Sciences is discussed in the Facilities Summary, below.
- As the LHC accelerator nears its turn-on date in 2007, U.S. activities related to fabrication of detector components will be completed and new activities related to commissioning and pre-operations of these detectors, along with software and computing activities needed to analyze the data, will ramp-up significantly. Support of an effective role for U.S. research groups in LHC discoveries will continue to be a high priority of the HEP program. R&D for possible future upgrades to the LHC accelerator and detectors will also be pursued.
- R&D for the ILC is maintained at the FY 2007 request level to support U.S. participation in a comprehensive, coordinated international R&D program, and to provide a basis for U.S. industry to compete successfully for major subsystem contracts should the ILC be built. The long-term goal of this effort is to provide robust cost and schedule baselines to support design and construction decisions for an international electron-positron linear collider near the beginning of the next decade. The ILC Reference Design Report will be completed in early 2007, and further work toward the design, including some site-specific studies and detector studies, will be performed during FY 2007. In FY 2008, further work toward a final design of both accelerator systems and detector studies will be performed.
- Accelerator technology R&D will be increasingly focused on superconducting radiofrequency (RF) structures in view of their potentially wide applicability to many scientific and other applications. A broad spectrum of SC programs need a domestic industrial capability, not presently available, to produce cost competitive and reliable superconducting RF components for possible future electron and proton accelerators that serve the science mission. The FY 2008 request supports further research and development of superconducting RF technology in the United States.

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[a] This project was originally proposed as a line-item construction project in the FY 2007 Congressional Budget under its original generic name of EνA for Electron Neutrino Appearance.

- A coordinated neutrino program developed from an American Physical Society study and a joint HEPAP/NSAC subpanel review is well underway, and includes the NOνA Detector, a large new detector optimized to detect electron neutrinos, and a new reactor-based neutrino experiment in China. In FY 2008 fabrication will begin on two small new neutrino experiments: Main Injector Experiment ν-A (MINERνA) in the MINOS near detector hall at Fermilab, which will measure the rates of neutrino interactions with ordinary matter, and Tokai-to-Kamioka (T2K) in the near detector hall of the Japanese J-PARC neutrino beam in Tokai. R&D will continue for a possible large double beta decay experiment to measure the mass of the neutrino.
- Support for R&D on ground- and space-based dark energy experimental concepts, begun in FY 2007, will be continued in FY 2008. These experiments will provide important new information about the nature of dark energy, leading to a better understanding of the birth, evolution, and ultimate fate of the universe. For example, SNAP will be a mission concept proposed for a potential interagency-sponsored experiment with NASA, and possibly international partners, the Joint Dark Energy Mission (JDEM). DOE and NASA are jointly funding a National Academy of Sciences study to determine which of the proposed NASA "Beyond Einstein" missions should launch first, with technical design of the selected proposal to begin at the end of this decade; JDEM is one of the candidate missions in this study.
- In spring 2006, the Dark Energy Task Force, a subpanel of both HEPAP and the AAAC, recommended a mix of experiments with independent and complementary measurements to address the nature of dark energy. Later in the year, the P5 prioritization subpanel of HEPAP recommended that DOE and NSF jointly pursue the Dark Energy Survey (DES) project, a small-scale ground-based experiment that can provide significant advances in our knowledge of dark energy in the near term. In FY 2008, fabrication will begin for DES subject to successful agency review. P5 also recommended that R&D be done for large-scale ground-based and space-based dark energy experiments to get them to a preliminary design stage.
- The apparent changes in many subprogram areas reflect a change in the way that certain program overhead-type expenses (e.g., management, computing and networking, and engineering support) are charged at Fermilab. As an almost entirely HEP-only laboratory (99% HEP and 1% other SC programs), Fermilab has not previously assessed these expenses across program elements, instead directly assessing Facility Operations for the full cost of these activities. With the planned completion of Tevatron collider operations on the horizon, reconsideration of this approach was warranted. Beginning in FY 2007 (after enactment of an appropriation), Fermilab will assess these expenses through a proportional allocation across all Fermilab activities, resulting in redistribution of funds among HEP categories. The FY 2008 funding request reflects the expected redistribution: while Research and Technology R&D activities at Fermilab reflect an increase as a result of this change, there are corresponding decreases reflected in Facility Operations at Fermilab, so there is no net programmatic impact. Since HEP funds about 99% of Fermilab's activities, impacts outside of HEP are negligible.

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) program is a set of coordinated investments across all SC mission areas with the goal of achieving scientific breakthroughs via advanced computer science and simulations that are unattainable using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. Advances in high-end computing technology, together with innovative algorithms and software, are being exploited as intrinsic tools for scientific discovery. SciDAC has also pioneered an effective new model of multidisciplinary collaboration among discipline-specific scientists, computer scientists, computational scientists, and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can productively exploit Terascale computing and networking resources. The program is bringing computation and simulation into parity with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate modeling and prediction, plasma physics, particle physics, accelerator design, astrophysics, chemically reacting flows, and computational nanoscience.

More details on the specific scientific impact of HEP contributions to SciDAC programs on lattice gauge Quantum Chromodynamics (QCD) calculations, grid technology and deployment, accelerator simulation and modeling, and astrophysical simulations, as well as the FY 2008 work plan, can be found below in the description of the Theoretical Physics subprogram.

Scientific Facilities Utilization

The High Energy Physics request supports the Department's scientific user facilities. This investment will provide significant research time for several thousand scientists based at universities and other Federal laboratories. It will also leverage both federally and privately sponsored research, consistent with the Administration's strategy for enhancing the U.S. national science investment.

The proposed funding will support operations at the Department's three major high energy physics facilities: the Tevatron Collider at Fermilab, the NuMI neutrino beam line at Fermilab, and the B-factory at SLAC. The Tevatron Collider provided a total of 4,531 hours of beam time in FY 2006 for a research community of about 700 U.S. scientists in HEP and another 700 researchers from foreign countries, testifying to the fact that this is a unique, world-leading experimental facility. Operation of NuMI began in FY 2006 and served more than 250 researchers, of whom about two-thirds are U.S. researchers. Approximately 500 researchers world-wide participate in Fermilab's other experimental and theoretical research and R&D programs. The FY 2008 request will support facility operations at Fermilab that will provide about 5,040 hours of beams for the Tevatron Collider and for NuMI, including an allowance for increased power costs and incremental upgrades. The B-factory provided a total of about 5,130 hours of beam time in FY 2006 for a research community of about 300 U.S. scientists in HEP and a comparable number of users from foreign countries. SLAC also hosts approximately 500 researchers world-wide who are active in its other experimental and theoretical research and R&D programs. The FY 2008 request will support facility operations at SLAC that provide about 5,720 hours of beams for the B-factory. For additional details on SLAC linac operations funding, see the Facilities Summary below.

High Energy Physics will maintain and operate its major scientific user facilities so that the unscheduled operational downtime will be kept below 20%, on average, of total scheduled operating time.

	FY 2006	FY 2007	FY 2008
Tevatron Complex at Fermilab			
Optimal hours (estimated)	4,320	4,560	5,400
Scheduled Beam Hours - Tevatron	4,531	4,560	5,040
Unscheduled Downtime - Tevatron	23%	<20%	<20%
Scheduled Beam Hours - NuMI	4,531	4,560	5,040
Unscheduled Downtime - NuMI	23%	<20%	<20%
Total Number of Users	2,125	2,160	2,160

	FY 2006	FY 2007	FY 2008
B-factory at SLAC			
Optimal hours (estimated)	5,200	5,200	5,850
Scheduled Beam hours	5,130	5,200	5,720
Unscheduled Downtime	18%	<20%	<20%
Total Number of Users	1,100	1,100	1,100

Construction and Infrastructure

A new Major Item of Equipment (MIE), the NuMI Off-axis Neutrino Appearance (NOνA) Detector is planned to begin fabrication in FY 2007. The NOνA detector was originally proposed as a line-item construction project in the FY 2007 Congressional Budget (under its original generic name of EνA for Electron Neutrino Appearance). It has been re-configured as a MIE to reflect a revised acquisition strategy that requires associated civil construction activities to be provided by a financial assistance vehicle to a third party, funded through operating funds in the Proton Accelerator-Based Physics subprogram, described in the Detailed Justification section that follows. The project also includes improvements to the proton source to increase the intensity of the NuMI beam.

New MIEs included in this request to begin fabrication in FY 2008, subject to successful agency reviews, are the Dark Energy Survey project; the Reactor Neutrino Detector[a]; MINERνA, a small experiment to measure neutrino interaction rates in the MINOS near hall; and U.S. contributions to the T2K neutrino oscillation experiment. A new AIP project will begin in FY 2008 to relocate an experimental test region for accelerator science research from its original site at the end of the SLAC Linac to the South Arc area of the unused SLAC Linear Collider, which completed operations in 1998. Funding for GPP is provided to improve site-wide infrastructure at Fermilab, SLAC, and Lawrence Berkeley National Laboratory (LBNL).

Workforce Development

The HEP program supports development of the R&D workforce through support of graduate students working toward a doctoral degree and postdoctoral associates developing their research and management skills. The R&D workforce developed under this program does more than provide new scientific talent in areas of particle physics research, it provides unparalleled talent for a wide variety of technical, medical, and industrial areas that require the incisive thinking and problem solving abilities and the computing and technical skills that are developed through education and experience in a fundamental research field. Scientists trained as high energy physicists can be found working in industry, academia, and government, in such diverse areas as hospitals (radiation therapy, medical imaging, and medical physics), national security, space exploration, software and computing, telecommunications, finance, and many other fields.

About 1,125 postdoctoral associates and graduate students supported by the HEP program in FY 2006 were involved in a large variety of theoretical and experimental research, including advanced technology R&D. About one-fifth are active in theoretical research. Of those involved in experimental research, about 85% utilize a number of scientific accelerator facilities supported by the DOE, NSF, and foreign countries; and about 15% participate in non-accelerator research.

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[a] The Department plans to submit a request when the FY 2007 appropriation is enacted to reprogram $3,000,000 of MIE funds towards ongoing R&D.

Details of the High Energy Physics program workforce are given below. These numbers include people employed by universities and laboratories. The university grants include both Physics Research and Accelerator Technology grants. In FY 2006, there were about 135 university grants with average funding of $750,000 per year. Most of these are multi-task grants with an average of three tasks. The duration of the grants is three years. The number of laboratory groups is an estimate of the number of distinct HEP research groups (experiment, theory, accelerator R&D) at the laboratories, which is a collection of single- and multi-task efforts.

	FY 2006 actual	FY 2007 estimate	FY 2008 estimate
# University Grants	135	140	140
# Laboratory Groups	47	47	47
# Permanent Ph.D.'s (FTEs)	1,210	1,250	1,250
# Postdoctoral Associates (FTEs)	540	595	600
# Graduate Students (FTEs)	585	620	635
# Ph.D.'s awarded	115	110	110

In addition, there is a joint DOE/HEP and NSF research-based physics education program ("QuarkNet") aimed at professional development for high school teachers. In this program, active researchers in high energy physics serve as mentors for high school teachers to provide long-term professional development based on participation in frontier high energy physics research. Through these activities, the teachers enhance their knowledge and understanding of science and technology research. They transfer this experience to their classrooms, engaging their students in both the substance and processes of contemporary research as appropriate for the high school classroom. For more details see the Detailed Justification section that follows.

Facilities Summary

Fermilab

In FY 2008, Fermilab plans 5,040 hours of running for both the Tevatron Collider program and the Tevatron neutrino physics program. The annual goal for the Tevatron Collider program is to achieve a performance goal of 800 inverse picobarns (pb^{-1}) of data delivered to the major Tevatron Collider experiments. Approximately 900 people are involved in day-to-day Tevatron Collider operations that include operation of the Tevatron accelerator complex and the CDF and D-Zero detectors for the collider program. This is one of the major data collection periods for the Collider experiments studying fundamental properties of matter and their interactions and also searching for supersymmetry, extra dimensions, and possible observation of the long-awaited Higgs boson at the world's energy frontier facility. Tevatron Collider operations are currently scheduled to end after FY 2009, when the Large Hadron Collider should be running at its design luminosity.

Tevatron operations also include running the Tevatron complex in fixed target mode in parallel with Tevatron Collider operations. This mode is used for physics data taking by the MINOS experiment and for test beam runs (both using 120 GeV protons extracted from the Main Injector). During FY 2008, the MINOS experiment will be operating its beam line and detectors to collect data. Test beam runs will be scheduled as needed. These functions do not interfere with the high-priority Tevatron Collider operations.

Fully achieving the physics goals of the Tevatron program over the next few years has required a series of significant performance improvements to the accelerator complex. These efforts are proceeding in parallel with current Tevatron operations and research program. The technical scope, cost and schedule of work for the accelerator upgrades is periodically reviewed by the SC Office of Project Assessment and the reports from their reviews are available on the HEP website at http://www.science.doe.gov/hep/TevatronReports.shtm. The most recent review of the Tevatron operations was conducted in March 2006.

Fermilab facilities operations funding is summarized in the table below:

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Tevatron Complex Operations	169,390	191,500	158,000
Tevatron Complex Improvements	40,135	24,255	58,220
Total, Tevatron Complex	209,525	215,755	216,220

SLAC

In FY 2008, SLAC plans 5,720 hours of running to achieve a performance goal of 220 inverse femtobarns (fb^{-1}) of data delivered to the BaBar experiment. Approximately 450 people are involved in day-to-day B-factory and BaBar operations. This will be the priority HEP research program at SLAC, in its final year of operation in FY 2008. The collected data will provide: a significant enhancement to the BaBar dataset for precision studies of Charge-Parity (CP) violation in the B-meson system, a phenomenon related to the excess of matter over antimatter in the universe; measurements of the defining parameters of the Standard Model of particle physics; and high precision searches for possible small violations of the predictions of the Standard Model in rare decays of heavy quark systems. These efforts are more fully described in the Detailed Justification sections that follow.

For decades, SLAC has been one of the world’s leading research laboratories in the design, construction, and operation of state-of-the-art electron accelerators and related experimental facilities for use in high-energy physics and synchrotron radiation research. With the advent of the Linac Coherent Light Source (LCLS) project, the role that SLAC plays in x-ray science has greatly expanded. Indeed, after the planned shutdown of the B-factory at the end of FY 2008, the SLAC linac will be dedicated to the world’s first x-ray free electron laser. The potential applications of this new experimental tool are legion: nanotechnology, solid-state physics, biology, energy production, medicine, electronics, and fields that do not yet exist. Recognizing the importance of the SLAC linac to the BES program, the Office of Science has been transitioning support for the SLAC linac from HEP to BES, with FY 2008 marking the third and final year of split funding.

HEP funding for SLAC linac operations is contained within the B-factory Operations and B-factory Improvements lines within the Electron Accelerator-Based Physics/Facilities activity. The following tables identify the SLAC linac funding amounts within HEP and overall.

SLAC Linac Operations Funding within HEP

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Electron Accelerator-Based Physics/Facilities			
B-factory Operations			
Linac Operations	42,800	44,100	21,900
Other B-factory Operations	29,824	38,792	20,964
Total, B-factory Operations	72,624	82,892	42,864
B-factory Improvements			
Linac Improvements	13,300	8,000	10,600
Other B-factory Improvements	3,800	2,000	2,338
Total, B-factory Improvements	17,100	10,000	12,938
Total, Electron Accelerator-Based Physics/Facilities	89,724	92,892	55,802
(Total, HEP SLAC Linac Operations and Improvements)	(56,100)	(52,100)	(32,500)
(Other Electron Accelerator-Based Physics/Facilities)	(33,624)	(40,792)	(23,302)

Total SLAC Linac Operations Funding

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Basic Energy Sciences SLAC Linac Operations	29,400	40,000	61,500
High Energy Physics SLAC Linac Operations and Improvements	56,100	52,100	32,500
Total, SLAC Linac Operations	85,500	92,100	94,000

External Independent Reviews

The costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $100,000,000 within SC are funded by SC. Examples of EIRs include conducting Performance Baseline EIRs prior to Critical Decision-2 (CD-2) to verify the accuracy of cost and schedule baseline estimates and conducting Construction/Execution Readiness EIRs, which are done for all Major System projects prior to CD-3. These funds, which are managed by the Office of Engineering and Construction Management, are exclusively used for EIRs directly related to these projects funded within SC. Beginning in FY 2007 the EIR business line will be financed via the Working Capital Fund to achieve parity on how EIRs are funded and to standardize the administration of these critical activities.

Proton Accelerator-Based Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Proton Accelerator-Based Physics			
Research	80,939	79,738	94,658
Facilities	281,218	296,798	295,014
Total, Proton Accelerator-Based Physics	362,157	376,536	389,672

Description

The mission of the Proton Accelerator-Based Physics subprogram is to foster fundamental research in high energy physics using proton accelerators that will provide new insights into the basic constituents of matter and the forces between them, thereby advancing the DOE's strategic goals for science.

Benefits

The Proton Accelerator-Based Physics subprogram exploits U.S. leadership at the energy frontier by conducting experimental research at high energy proton collider facilities. This experimental research program 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.

The Proton Accelerator-Based Physics subprogram also includes precise, controlled measurements of basic neutrino properties performed at accelerator facilities, since neutrino beams are generated from primary proton beams. These measurements will provide important clues and constraints to the new world of matter and energy beyond the Standard Model. This subprogram addresses five of the six long-term indicators that contribute to the Program Goal as well as the majority of the key questions outlined in the HEP Overview section above.

Supporting Information

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. This is expected to occur at an energy scale of about one trillion electron volts or 1 TeV. The Standard Model has successfully explained almost all particle physics phenomena below 1 TeV in energy, but beyond that energy range a new physical mechanism must be present to prevent Standard Model predictions from becoming unphysical. Originally it was proposed that a single Higgs boson is the solution to this "TeV scale" problem, but newer theories such as supersymmetry, extra hidden dimensions, and technicolor could also solve the TeV scale problem in the Standard Model, either in place of or in combination with, one or more Higgs bosons. No matter which of these theories is shown to be correct, it will provide a deeper understanding of the fundamental nature of matter, energy, space, and time. One thing is clear, however: new physics must occur at the Terascale.

Because of the high energy of the collisions at the Tevatron Collider (2 TeV) and the LHC (14 TeV), and the fact that the particles interact in different ways, these facilities can be used to study a wide variety of physics topics. All of the six known types of quarks can be produced in these interactions, but the heaviest, the top and bottom quarks, are of the greatest interest. Most of the force-carrying particles are also produced in these collisions, and if the masses of predicted—but as yet unobserved—particles, such as the Higgs boson or supersymmetric particles are small enough, they will also be discovered. Whether the Tevatron or the LHC is the first accelerator to observe new physics at the TeV scale will depend on the configuration nature has chosen for these phenomena.

Proton accelerators are capable of producing the highest-energy particle beams made by man, and by colliding proton beams into targets, large samples of other particles like antiprotons, K mesons, muons, and neutrinos can also be produced and formed into beams for experiments. The Proton Accelerator-Based Physics subprogram uses both aspects of proton accelerators.

The major activities under the Proton Accelerator-Based Physics subprogram are broad research programs using the CDF and D-Zero detectors at the Tevatron at Fermilab; the neutrino research program using the NuMI/MINOS facility at Fermilab and at the Soudan Mine site in Minnesota; the LHC program; and maintenance and operation of these facilities.

Physics at the energy frontier is the primary thrust of the Proton Accelerator-Based Physics subprogram. In FY 2008, the energy frontier moves to the LHC in Europe. The LHC program will substantially increase the ability of U.S. high energy physicists to explore physics beyond the Standard Model and will enable the U.S. to remain involved as a key player at the energy frontier. But while the LHC experiments will be just beginning to acquire experience with their first physics-quality data, the well-understood CDF and D-Zero experiments will continue to perform forefront searches for new physics at the TeV scale, such as the Higgs, and making precision measurements of known particles—like the mass of the W boson and the top quark—that will indicate where the Higgs or other new physics is likely to be found. The number of top quarks accumulated and studied during the previous Tevatron collider run from 1992 to 1996 was less than 100. The new run (started in 2001) has already produced an order of magnitude more top quarks, and will provide far more precise measurements of its mass, spin, and couplings.

Today, neutrino physics presents one of the most promising avenues to probe for extensions of the Standard Model. In the last decade, a number of interesting new results have been reported by several different experiments, including the Super-K and KamLAND experiments in Japan and the Sudbury Neutrino Observatory (SNO) experiment in Canada. These experiments provide compelling evidence that neutrinos do have mass and do change their identities (the different neutrino species “mix”) as they travel. These properties of neutrinos are neither required nor predicted by the Standard Model. Unfortunately, the neutrinos used by these experiments have a wide range of energies and are produced in insufficient numbers to precisely measure their mixing parameters. One of the unique opportunities in the Proton Accelerator-Based Physics subprogram is to explore and make high precision measurements of neutrinos generated at dedicated proton beam facilities in a well-controlled environment (e.g., the NuMI beam at Fermilab). The NuMI/MINOS program is making decisive controlled measurements of fundamental neutrino properties, including neutrino mixing, and will provide important clues and constraints to the theory of matter and energy beyond the Standard Model.

The National Academy of Sciences “EPP2010” report recommended a diverse HEP program using a variety of tools to attack the exciting opportunities in elementary particle physics, including a staged internationally coordinated program in neutrino physics. One of those opportunities, the observation of electron neutrinos from a muon neutrino beam, can be met by the proton accelerator-based research program. A new detector optimized to detect electron neutrinos, NuMI Off-axis Neutrino Appearance (NOνA) Detector, is planned to begin fabrication in FY 2007 and will utilize the NuMI beam.

Research and Facilities

The Research activity in the Proton Accelerator-Based Physics subprogram supports university-based and laboratory-based scientists performing experimental research at proton accelerator facilities in the

U.S. and abroad. Experimental research in this area is a collaborative effort undertaken by research groups from Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Fermilab, LBNL, SLAC, and about 60 colleges and universities. The research activities include: planning, design, fabrication and installation of experiments and associated computing infrastructure; preparation for experimental operations and conduct of experiments; analysis and interpretation of data; and publication of results. These research programs are carried out at various facilities where the accelerators and detectors are located, and at universities where many of the scientists are located. The university program also provides a small amount of funds at national laboratories (University Service Accounts) to allow university groups to travel and perform specific tasks connected with the experimental research program, such as purchasing needed supplies from laboratory stores.

The Facilities activity in the Proton Accelerator-Based Physics subprogram supports maintenance, operation, and technical improvements for proton accelerator facilities in the U.S. In addition, this category supports the U.S. share of detector maintenance and operations, software and computing infrastructure, and directed technical R&D for international proton accelerator facilities such as the LHC at CERN. Facilities activities include: installation, commissioning, maintenance and operations of accelerators and experiments; provision of computing hardware and software infrastructure to support the experiments and the accelerators, and provision of platforms for data analysis; and directed R&D for accelerator and detector enhancements and performance improvements. Since physicists are often involved in these activities as well as research activities, some are partially supported by both categories of funding where appropriate.

The proton accelerator facilities support personnel are based primarily at ANL, BNL, Fermilab, and LBNL, working together with experimental groups from various universities and institutions.

Highlights

Recent accomplishments include:

- The CDF and D-Zero detectors at Fermilab have collected over 20 times more data in Run II of the Tevatron collider than that of all of Run I (1992-1996). CDF has reported the world's first observation of the very rapid particle-antiparticle oscillations of the heavy B mesons that contain a strange quark (called "B_s mesons"). D-Zero has a slightly less sensitive measurement that is in agreement with the CDF result. The results are based on 1.0 fb^{-1} of integrated luminosity, about two-thirds of the collected data. This result supplies additional information independent of the precision measurements of B-meson mixing done at the B-factory. The measured rate of B_s-meson oscillations is consistent with the Standard Model range of predictions.
- The MINOS collaboration has announced their first observation of the oscillation of muon neutrinos using the NuMI beamline. This result validates the performance of the MINOS detector and the NuMI beam, based on the neutrinos produced by 1×10^{20} protons colliding with the neutrino production target. The measurement is the most precise in the world, and is consistent with previous measurements, reaffirming the current picture of neutrino masses and oscillations. The experiment is planned to run through FY 2010 to achieve its ultimate sensitivity, about a factor of two improvement over its current result.

The major planned efforts in FY 2008 are:

- *The research program using the Tevatron at Fermilab*. This research program is being carried out by a collaboration including 1,400 scientists from Fermilab, ANL, BNL, LBNL, 56 U.S. universities, and institutions in over 20 foreign countries. The major effort in FY 2008 will be data taking with the fully upgraded 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. The involvement of researchers will decrease somewhat as the LHC effort commences.

- *The research program using the NuMI/MINOS Facilities at Fermilab and the Soudan Mine*. This research program is being carried out by a collaboration including 250 scientists from Fermilab, ANL, BNL, Lawrence Livermore National Laboratory (LLNL), 16 U.S. universities, and institutions in 4 foreign countries. The major effort in FY 2008 will be data taking and analysis, along with optimizing accelerator performance to improve beam intensity for higher statistics. A new experiment, Main Injector Experiment ν-A (MINERνA), which will make precision measurements of neutrino interaction rates in the NuMI beam (an important input to analyze MINOS and NoνA data), begins fabrication in FY 2008.
- *A new detector for neutrino physics.* Fabrication is planned to begin in FY 2007[a] for a new Major Item of Equipment, the NuMI Off-axis Neutrino Appearance (NOνA) Detector. The NOνA detector will use the NuMI beam from Fermilab to directly observe and measure the transformation of muon neutrinos into electron neutrinos over distances of hundreds of miles. 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 that MINOS is studying. Funding for NOνA will ramp-up in FY 2008.
- *Planning and preparation for the U.S. portion of the research program of the LHC*. A major effort in FY 2008 will be the implementation and optimization of the U.S. data handling and computing capabilities needed for full participation in the LHC research program. Commissioning and maintenance of U.S.-supplied detectors for LHC experiments at CERN will continue as a top priority.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Research	**80,939**	**79,738**	**94,658**
▪ **University Research**	**47,541**	**47,694**	**50,865**

The HEP university research program consists of groups at more than 60 universities doing experiments at proton accelerator facilities. These university groups plan, build, execute, analyze, and publish results of experiments; develop the physics opportunities and preliminary designs for future experiments; and train graduate students and postdoctoral researchers. University-based scientists typically constitute about 75% of the personnel needed to create, run, and analyze an experiment, and they usually work in collaboration with other university and

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[a] The EνA detector was originally proposed as a line-item construction project ($10,300,000) in the FY 2007 Congressional Budget but has been renamed NOνA and has been reconfigured as a MIE to reflect a revised acquisition strategy that requires associated civil construction activities to be funded by a financial assistance agreement with a participating research institution. The Department plans to submit a reprogramming request when the FY 2007 appropriation is enacted to transfer EνA construction funds to operating funding under Proton Accelerator-Based Physics for the NOνA MIE, including TEC of $2,300,000 and OPC of $8,000,000.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

laboratory groups. University personnel are fully integrated into the operations of the detector facilities, performing various service functions, and these facilities could not operate without them. University-based research efforts are funded in a manner based on peer review, and at an overall level commensurate with the effort needed to carry out the experiments. Proton accelerator activities concentrate mainly on experiments at the Tevatron Collider at Fermilab; development of the physics program for the LHC; and the MINOS, NOνA, and MINERνA neutrino experiments at Fermilab and the Soudan Mine.

In FY 2008, the overall level of support is at about the FY 2007 level-of-effort to maintain strong participation in the Tevatron, LHC, and neutrino physics programs. Within the total, there will be some continued redirection of effort to LHC activities in FY 2008. Strong participation of university physicists is needed to exploit the physics potential of the very active collider and neutrino program at the Tevatron during FY 2008, and there will be healthy scientific competition between completion of the Run II of the Tevatron Collider program and commencement of the LHC experiments. 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. These include research efforts related to the Tevatron experiments CDF and D-Zero; the NuMI neutrino experiments MINOS, NOνA, and MINERνA; and U.S. participation in the LHC research program. U.S. university researchers are also contributing to a new accelerator-based neutrino oscillation experiment (T2K) in Japan. A new MIE project to build a detector for the T2K beam line begins fabrication ($2,000,000) in FY 2008 (estimated TEC $3,000,000).

	FY 2006	FY 2007	FY 2008
▪ **National Laboratory Research**	**32,219**	**30,548**	**42,312**

The national laboratory research program consists of groups at several laboratories participating in experiments at proton accelerator facilities. These groups participate in all phases of the experiments, with the focus of the physics program being similar to that of the university groups described above. Although they lack the specific educational mission of their colleagues at universities, they are embedded in the laboratory structure and therefore provide invaluable service to the research program in detector design, construction, and operations. The DOE HEP program office reviews laboratory research groups annually with input from independent peer reviewers. Proton accelerator activities concentrate on experiments at the Tevatron complex (collider and neutrino physics programs) at Fermilab and the LHC at CERN.

In FY 2008, the national laboratory research program is increased above the FY 2007 level of effort to maintain strong participation in the Tevatron, LHC, and neutrino physics programs. However, approximately 45% of the increase is due to an accounting change at Fermilab that moves costs for direct program support from Operations to Research and Technology R&D funding categories, as described in the Significant Program Shifts section above. The activities supported by these costs include computing support, general engineering and technical support, program management, and business office expenses.

The remaining increase in laboratory research supports enhanced participation of laboratory physicists in the ATLAS and CMS experiments as LHC operations and data analysis begin. Full participation of national laboratory physicists is also needed to exploit the physics potential of the research program at the Tevatron during FY 2008, and there will be healthy scientific

		(dollars in thousands)	
	FY 2006	FY 2007	FY 2008

competition between the completion of the Run II of the Tevatron Collider program and commissioning of the LHC experiments. HEP will monitor progress in these areas, and balance resources as needed to optimize the national program.

The Fermilab research program includes data taking 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. This research by physicists at the host laboratory provides the necessary close linkages between the Research and the Facilities activities in the Proton Accelerator-Based Physics subprogram.

Research at LBNL will be dominated by the ATLAS research and computing program, along with analyzing data from the CDF experiment.

The BNL research group will focus on the ATLAS research and computing program, data taking and analysis of the D-Zero experiment, and a small effort on the MINOS experiment and research related to future neutrino initiatives.

The research group at ANL will be working on data taking and analysis of the CDF experiment, 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 small research group from SLAC joined the ATLAS experiment in 2006 and will be engaged in LHC research and data analysis.

	FY 2006	FY 2007	FY 2008
▪ **University Service Accounts**	**1,179**	**1,496**	**1,481**

University Service Accounts facilitate the support of university groups working at accelerator facilities, providing 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 U.S. proton accelerator facilities. Funding for these university service accounts is maintained at about the FY 2007 level, reflecting the overall size of the University Research program, and work at the new LHC Physics Center at Fermilab.

	FY 2006	FY 2007	FY 2008
Facilities	**281,218**	**296,798**	**295,014**
▪ **Tevatron Complex Operations**	**169,390**	**191,500**	**158,000**

Operations at Fermilab will include operation of the Tevatron accelerator complex for both collider and neutrino physics programs, including two collider detectors and a neutrino experiment. This will be a major physics run for the D-Zero and CDF detectors with the higher intensity available from the upgraded Main Injector. The Tevatron performance has continued to improve according to plan through FY 2006 and this is to be one of the major data collection periods for the collider experiments pursuing physics topics from the energy frontier facility.

Tevatron operations also include running the Tevatron complex in fixed target mode in parallel with Tevatron collider operations. This running mode will be primarily for the physics data taking of the MINOS experiment using the NuMI beamline.

In FY 2008, the decrease in this category is due largely to accounting changes at Fermilab that move costs for direct program support from Operations to Research and Technology R&D funding categories, as described in the Significant Program Shifts section above. The activities

	FY 2006	FY 2007	FY 2008

(dollars in thousands)

supported by these costs include computing support, general engineering and technical support, program management, and business office expenses. About 85% of the decrease is due to these changes. The remainder is due to actual reductions in operations and commissioning activities as the NuMI proton improvement plan to increase the intensity of the proton source from 250 kW to about 400 kW is completed. Funding for these upgrades decreases from $6,258,000 in FY 2007 to $1,050,000 in FY 2008, the final year of funding. Additional funding for these upgrades is included in Tevatron Complex Improvements below.

	FY 2006	FY 2007	FY 2008
Tevatron Complex Operations in hours	4,531	4,560	5,040

- **Tevatron Complex Improvements** **40,135** **24,255** **58,220**

The funding in this category includes funds for GPP projects and other infrastructure improvements at Fermilab, funding for accelerator improvements, experimental computing expansion and other detector support, and new detector fabrication. Accelerator improvements to increase the luminosity performance of the Tevatron Collider were completed in FY 2006, and the laboratory began to focus effort on improving the intensity of the NuMI beamline beyond its design power of 250 kW via a phased plan of incremental upgrades referred to as the NuMI proton improvement plan. The plan involves upgrading beam controls and collimation so that the Tevatron complex can accommodate higher proton intensities and NuMI can provide more neutrinos to the MINOS experiment. In FY 2008, the third and final year of the proton improvement plan funding ($500,000) will support deployment and commissioning of these improvements to increase the intensity of the proton source to about 400 kW. FY 2007 funding was $5,578,000 and additional funding for the proton improvement plan is included under Tevatron Complex Operations above.

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 than is possible during Run II. The Recycler, which currently serves as a storage ring for antiprotons, can be reconfigured to accept protons and provide a higher net proton throughput than is possible with the current accelerator configuration. This reconfiguration 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.

The increase in neutrino intensity that can be achieved with this reconfiguration will be very important to support the physics goals of the NuMI Off-axis Neutrino Appearance (NOνA) Detector, so this collection of upgrades and improvements has been added to the scope of the NOνA project (see below) in order to ensure appropriate project management oversight and integration. Since these accelerator improvements were part of the outyear facilities planning for Fermilab, this change has no net budgetary impact. FY 2008 funding for this activity ($10,000,000) primarily supports procurement of needed materials.

	FY 2006	FY 2007	FY 2008

(dollars in thousands)

The fabrication of the NOνA Detector is planned to begin in FY 2007 and ramps up significantly in FY 2008. The upgrades to improve NuMI beam intensity to 700 kW (described above) have been added to the scope of the NOνA MIE project and have increased its estimated TPC by approximately $60,000,000. The TPC and TEC for NOνA will not exceed $260,000,000 and $155,200,000, respectively. The NOνA detector was originally proposed as a line-item construction project in the FY 2007 Congressional Budget under its original generic name of EνA for Electron Neutrino Appearance[a]. Funding for this project is included in this category starting in FY 2008. This 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 into electron-type neutrinos.

NOνA will also make important indirect measurements from which we may be able to determine the mass hierarchy for the three known neutrino types (i.e., whether there are two "light" and one "heavier" type of neutrino or vice versa), which will be a key piece of information in determining the currently unknown masses of neutrinos. The project includes the very large "far" detector itself (approximately football-field size and five stories high), the far detector enclosure, its associated electronics and data acquisition system, and a small "near" detector on the Fermilab site. FY 2008 funding for the NOνA detector ($21,150,000) supports the first year of a cooperative agreement to build an enclosure for the detector and participate in the NOνA research program, along with final design and initial fabrication of detector elements ($4,900,000).

	FY 2006	FY 2007	FY 2008
NOνA (TEC)	—	—[a]	4,900
NOνA (OPC)			
Proton Improvements (400 kW to 700 kW)	—	—	10,000
Other Projects Costs (R&D and cooperative agreement)	4,300	—[a]	21,150
Total, NOνA (OPC)	4,300	—	31,150
Total, NOνA (TPC)	4,300	—[a]	36,050

[a] $10,300,000 was originally requested in FY 2007 as a line item construction project for EνA. The project has since been reconfigured as the NOνA MIE to reflect a revised acquisition strategy that requires associated civil construction activities to be funded by a financial assistance agreement with a participating research institution. The Department plans to submit a reprogramming request when the FY 2007 appropriation is enacted to transfer the EνA construction funds to operating funding under Proton Accelerator-Based Physics for the NOνA MIE, including TEC of $2,300,000 and OPC of $8,000,000.

	(dollars in thousands)	
FY 2006	FY 2007	FY 2008

Also included in this category is $5,000,000 to begin fabrication of a new MIE called MINERνA (estimated TEC $10,000,000). This is a small experiment in the MINOS near detector hall at Fermilab that will measure the rates of neutrino interactions with ordinary matter. This is useful input data for MINOS and other neutrino experiments including NOνA, and can be measured with much better precision than previous experiments using the powerful NuMI beam.

	FY 2006	FY 2007	FY 2008
▪ **Large Hadron Collider Project**	**7,440**	**3,180**	**—**

Under the agreement with CERN regarding U.S. participation in the LHC program, DOE has provided $450,000,000 to the LHC accelerator and detectors (with an additional contribution of $81,000,000 from the NSF). The DOE total provided was separated into detectors ($250,000,000) and accelerator ($200,000,000), with the accelerator funding consisting of $88,500,000 for direct purchases by CERN from U.S. vendors, and $111,500,000 for fabrication of components by U.S. laboratories.

In addition to the $450,000,000 DOE and $81,000,000 NSF contributions to the fabrication of LHC accelerator and detector hardware, U.S. participation in the LHC involves a significant fraction of its physics community in the research program at the LHC. This involvement, supported by the core research funds of the DOE and the NSF has grown dramatically, with over 900 U.S. scientists anticipated as members of the U.S.-ATLAS detector collaboration, the U.S.-CMS detector collaboration or the U.S.-LHC accelerator consortium by FY 2008. Most of the effort in FY 2008 will be devoted to the U.S. LHC Research Program, which will deploy the infrastructure needed for exploiting the rich physics opportunities presented by the new energy frontier to be opened as the LHC ramps up to full energy in 2008, see LHC Support below.

The overall U.S. LHC Project reached a status of 97% complete by the end of FY 2005, in compliance with the “CD-4a” project-completion requirement prescribed by the DOE. Essentially all of the equipment is already at CERN, and the remaining portion of the accelerator project was completed in 2006. The two detector projects, tied to the final stages of the CERN schedule, will be completed before the end of FY 2008. The latter activities are related primarily to the final assembly, testing, and installation of the completed detectors, as well as to the purchase of computing hardware for data acquisition. Under the current schedule, completion of these two detector projects will take place in calendar year 2007, in full agreement with the U.S. DOE deadline for the completion of the project. The overall result of previous delays in the CERN schedule was a stretch-out by two years in the planned U.S. contributions to the LHC detectors. The final cost of each detector remains unchanged, and the final year of DOE funding for all aspects of the U.S. participation in fabrication of the LHC is FY 2007.

U.S. LHC Accelerator and Detectors Funding Profile

(dollars in thousands)

Fiscal Year	Department of Energy			National Science Foundation (Detectors)
	Accelerator	Detectors	Total	
1996[a]	2,000	4,000	6,000	—
1997[a]	6,670	8,330	15,000	—
1998[a]	14,000	21,000	35,000	—
1999	23,491	41,509	65,000	22,150
2000	33,206	36,794	70,000	15,900
2001	27,243	31,627	58,870	16,370
2002	21,303	27,697	49,000	16,860
2003	21,310	37,900	59,210	9,720
2004	29,330	19,470	48,800	—
2005	21,447	11,053	32,500	—
2006	—	7,440	7,440	—
2007	—	3,180	3,180	—
Total	200,000[b]	250,000	450,000	81,000

LHC Detectors Funding Summary

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
LHC Detectors			
ATLAS Detector			
Operating Expenses	1,642	1,034	—
Capital Equipment	1,598	846	—
Total, ATLAS Detector	3,240	1,880	—
CMS Detector			
Operating Expenses	1,300	50	—
Capital Equipment	2,900	1,250	—
Total, CMS Detector	4,200	1,300	—
Total, LHC Detectors	7,440	3,180	—

[a] The FY 1996 and FY 1997 LHC funding was for R&D, design and engineering work in support of the proposed U.S. participation in LHC. Beginning in FY 1998 funding was used for: fabrication of machine and detector hardware, supporting R&D, prototype development, and purchases by CERN from U.S. vendors

[b] Includes $111,500,000 for LHC supporting R&D and accelerator components to be fabricated by U.S. laboratories and $88,500,000 for purchases by CERN from U.S. vendors.

	FY 2006	FY 2007	FY 2008
▪ **Large Hadron Collider Support**	**52,641**	**56,820**	**62,000**

(dollars in thousands)

With final preparations for LHC turn-on in late 2007, the U.S. LHC program, jointly supported by the DOE and the NSF, will enter a critical phase in FY 2008. An increase of 9% in DOE support above FY 2007 is planned. The main use of the resources will be for LHC software and computing, and pre-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 using the LHC, along with R&D for potential upgrades to both the machine and the detectors. These efforts are described in more detail below. The U.S. LHC effort is one of the highest priority components of the HEP program, endorsed repeatedly by HEPAP, and by the recent National Academy of Sciences study. With quality data expected before the end of FY 2008, it is imperative to focus attention on the needs anticipated during the ramp-up of operations in FY 2008.

• **LHC Software and Computing**	**19,984**	**22,596**	**24,369**

The LHC software and computing effort will enable U.S. physicists to analyze the vast quantities of LHC data in a transparent manner, and empower them to play a leading role in exploiting the physics opportunities presented by the LHC. The LHC Software and Computing program will also enter a critical stage in FY 2008, when the combination of software development, facilities hardware and support, and grid computing must come together. Prior to FY 2008, the U.S. effort will be focused on data and service challenges, with testing of the hardware and infrastructure needed for full LHC data analysis using professional-quality software on simulated data. These systems have to grow rapidly from prototypes to fully functional systems in 2007. The funding ramp-up in FY 2008 will provide equipment purchases, computing personnel, and user support at Tier 1 and Tier 2 computing and data handling centers in the U.S. This will allow U.S. physicists, especially at universities, to maintain the central role during data analysis that they played during fabrication of detectors. Grid computing solutions will continue to be integrated in the LHC computing model, building on the tools provided by the SciDAC Open Science Grid project, and providing U.S. researchers the access and computing power needed to analyze the large and complex LHC data. In FY 2008, full-scale analysis with physics-quality data will form the final testing ground for the completed systems.

• **LHC Experimental Support**	**21,657**	**23,224**	**25,631**

Funding for operations and maintenance of the LHC detector subsystems built by U.S. physicists will increase somewhat in FY 2008 as the first year of LHC data will fully test the capabilities of these detectors. This effort will support the continuing development and deployment of tools for control, calibration, and exploitation of LHC data, including remote detector monitoring and control systems. These tools will facilitate remote participation by U.S. physicists in the pre-startup activities at the LHC, ensuring proper commissioning and operation of U.S.-supplied components. U.S. LHC collaborators will perform integration tests of the major detector subsystems using final data-acquisition systems and fully commission their detector

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

subsystems. The effort on detector R&D, with specific focus on detector technologies needed to accommodate a possible LHC upgrade in luminosity, will start to increase. Support will also be provided for technical coordination and program management, both at the participating U.S. national laboratories and at CERN.

	FY 2006	FY 2007	FY 2008
• **LHC Accelerator Research**	**11,000**	**11,000**	**12,000**

The U.S. LHC Accelerator Research Program (LARP), supported solely by the DOE, will continue to focus R&D on producing full-scale accelerator-quality magnets with the highest possible sustained magnetic fields. This R&D also provides important technical data to CERN for management decisions on possible future LHC accelerator upgrades to increase luminosity. This effort ramped-up significantly in FY 2006. In FY 2008, funding is increased by 9%, as fabrication begins on advanced prototypes of state-of-the-art LHC interaction region magnets made of optimized niobium-tin (Nb_3Sn) superconductor material. Special instrumentation is also being provided for collimation and monitoring of the LHC beams that will play an important role during the accelerator commissioning phase.

	FY 2006	FY 2007	FY 2008
▪ **Alternating Gradient Synchrotron (AGS) Support**	**650**	**650**	**650**

Operations at BNL for HEP experiments using the AGS facility were terminated at the end of FY 2002. Funding continues for close-out costs and long-term decontamination and decommissioning (D&D).

	FY 2006	FY 2007	FY 2008
▪ **Other Facilities**	**10,962**	**20,393**	**16,144**

Includes funding for private institutions and other government laboratories and institutions 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.

Includes $1,154,000 for General Purpose Equipment and $4,535,000 for General Plant Projects at LBNL for landlord related activities. Also includes $2,300,000 for LHCNet, the transatlantic data link between the U.S. and CERN.

	FY 2006	FY 2007	FY 2008
Total, Proton Accelerator-Based Physics	**362,157**	**376,536**	**389,672**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Research	
▪ University Research is increased to maintain strong participation in the Tevatron, LHC and neutrino physics programs. Full participation of HEP researchers is needed to exploit the physics potential of the very active program at the Tevatron during FY 2008, in parallel with initial operations of the LHC experiments ($1,171,000). Also includes the first year of funding to begin fabrication of the T2K Near Detector MIE ($+2,000,000).	+3,171
▪ National Laboratory Research is increased to maintain strong participation in the Tevatron, LHC and neutrino physics programs. About 45% of the increase is due to accounting changes at Fermilab that moves costs for direct program support from Operations to Research and Technology R&D funding categories; the remainder is redirection of research effort to the LHC program and new neutrino experiments.	+11,764
▪ University Service Accounts at Fermilab decrease as some research effort moves to the LHC program.	-15
Total, Research	**+14,920**
Facilities	
▪ Funding for Tevatron Complex Operations is decreased due to accounting changes at Fermilab where the direct support costs for the entire laboratory had been 100% assigned under Facilities Operations and are now being distributed to Research and Technology R&D activities. The net effect is that funding for Tevatron Operations decreases and funding for all Fermilab Research and Technology R&D activities increases. About 85% of the decrease in this category is due to these changes; the remainder ($-5,208,000) is due to reductions in operations and commissioning activities as the improvements to raise the NuMI proton intensity from 250 kW to about 400 kW are completed.	-33,500
▪ Funding for Tevatron Complex Support increases due to the reclassification of the NOνA experiment as a Major Item of Equipment (from EνA, a line item construction project in the FY 2007 request), and the ramp-up of that project, including accelerator improvements to further increase NuMI proton intensity to about 700 kW ($+36,050,000); as well as the beginning of fabrication for the MINERνA experiment ($+5,000,000). These increases are somewhat offset as the support for the NuMI proton improvements to 400 kW is completed ($-5,078,000) and general support activities ($-2,007,000) are slightly reduced.	+33,965
▪ In the LHC Project, U.S. contributions to the ATLAS and CMS detectors are completed in FY 2007 as scheduled.	-3,180

	FY 2008 vs. FY 2007 ($000)
▪ In the LHC Support effort, U.S. contributions to LHC software and computing, maintenance and operations of the ATLAS and CMS detectors, and LHC accelerator research increase in FY 2008 as the LHC turns on for its first year of physics data.	+5,180
▪ In Other Facilities, resources held pending completion of peer and/or programmatic review decrease.	-4,249
Total, Facilities	**-1,784**
Total Funding Change, Proton Accelerator-Based Physics	**+13,136**

Electron Accelerator-Based Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Electron Accelerator-Based Physics			
Research	22,567	24,568	23,961
Facilities	89,724	92,892	55,802
Total, Electron Accelerator-Based Physics	112,291	117,460	79,763

Description

The mission of the Electron Accelerator-Based Physics subprogram is to foster fundamental research in high energy physics using electron accelerators that will provide new insights into the basic constituents of matter and the forces between them, thereby advancing the DOE's strategic goals for science.

Benefits

The Electron Accelerator-Based Physics subprogram utilizes accelerators with high-energy and ultra-precise beams to create and investigate matter at its most basic level. It was the electron accelerator at SLAC that, in the 1960's, first identified the existence of quarks as the inner constituents of the proton and neutron. During the 1980's, electron accelerators—in tandem with proton machines—were instrumental in establishing the Standard Model as the precise theory of particle interactions.

Over the last few years, the electron B-factory at SLAC has provided precision measurements of how matter and antimatter behave differently in the decay products of B-mesons. This asymmetric behavior is called "CP [charge-parity] violation" and is considered by physicists to be vital to understanding why the universe appears to be predominantly matter, rather than equal quantities of matter and antimatter, one of the greatest puzzles we face in comprehending the universe. This subprogram addresses two of the six long-term indicators that contribute to the Program Goal and several of the key questions identified in the HEP Overview section above.

Supporting Information

While electron accelerators can be used to study a wide variety of physics topics, and historically have been so used, the current Electron Accelerator subprogram is focused on the study of charm and bottom quarks and the tau lepton. These particles are all heavier than the particles of everyday matter and well suited for studying rare processes. The most interesting of these processes is CP violation.

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, it has been possible to do a systematic study of the process and test whether our current theoretical explanation of CP violation, the Standard Model, is correct. 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 measurements of these other properties have been used as inputs to the theoretical calculations of CP violation, as our current knowledge of those properties limits our understanding of CP violation.

In addition to studies of CP violation, the BaBar experiment at the SLAC B-factory has pursued a broad program of research on particles containing bottom or charm quarks. The Belle experiment at the KEK B-factory has carried out a similar program, with a small number of U.S. university researchers participating. There has been regular cooperation as well as competition between the BaBar and Belle experiments, leading to more precise measurements and a better understanding of the experimental results. The CLEO-c experiment at the Cornell Electron Storage Ring (CESR) has been concentrating on certain measurements of particles containing charm quarks that are difficult to do at the B-factory. These results test theories used to interpret the CP violation measurements and to provide key inputs to the physics analyses done at the B-factory. The CLEO-c research program will be extended at the recently upgraded Beijing Electron Positron Collider to improve precision measurements of charm quarks and tau leptons.

Research and Facilities

The Research activity in the Electron Accelerator-Based Physics subprogram supports the university and laboratory based scientists performing experimental research at electron accelerator facilities in the U.S. and abroad. Experimental research activities are collaborative efforts by research groups from LBNL, LLNL, SLAC, and about 40 colleges and universities, along with a large number of foreign research institutions, and include analysis and interpretation of data and publication of results. The university program also includes a small amount of funds at national laboratories (University Service Accounts) to allow university groups to perform specific tasks connected with the experimental research program.

The Facilities activity in the Electron Accelerator-Based Physics subprogram supports the maintenance and operations of, and technical improvements to, electron accelerator facilities in the U.S., including: installation, commissioning, maintenance, and operations of accelerators and experiments; providing computing hardware and software infrastructure to support the experiments and the accelerators, and provide platforms for data analysis; and directed R&D for accelerator and detector enhancements and performance improvements. Since physicists are often involved in these activities as well as research, some are partially supported by both categories of funding where appropriate.

The electron accelerator facilities support personnel are based primarily at LBNL, LLNL, and SLAC, working together with the experimental groups from U.S. universities and foreign institutions.

Highlights

Recent accomplishments include:

- In FY 2006, the SLAC B-factory delivered 100 fb^{-1} (inverse femtobarns) of which the BaBar detector recorded 98 fb^{-1}. The BaBar collaboration promptly analyzed and presented the latest results, with 74 papers submitted for publication in peer-reviewed journals in 2006, a record for the collaboration. At the major biennial summer research conference in 2006, the BaBar collaboration contributed 114 papers and 26 talks on a full spectrum of new results.
- BaBar has made substantial progress on a comprehensive set of measurements for CP-violating asymmetries, a systematic exploration of rare decay processes, and detailed studies to elucidate the dynamics of processes involving heavy quarks. Combined data from BaBar and Belle have continued to explore hints of possible new physics beyond the Standard Model which were present in the early data in a class of B meson decays to particles (such as K mesons) which contain the strange quark. Though most of these hints of new physics have not increased in significance in the interim, neither have they gone away. These detectors will double their current datasets by 2008, which will provide ample opportunities for discovery.

The major planned efforts in FY 2008 are:

- *The research program at the B-factory/BaBar Facility at SLAC*. This research program is being carried out by a collaboration of approximately 600 physicists including scientists from LBNL, LLNL, SLAC, 40 U.S. universities, and institutions from 7 foreign countries. In FY 2008 this effort will focus on final data taking with the upgraded accelerator and detector. The physics issues to be addressed include expanding our understanding of CP violation in many particle decay modes.
- *The research program at other electron accelerator facilities*. This program complements the B-factory/BaBar efforts and consists of a group of experimental research activities using the CESR and the KEK-B electron accelerator facilities. A total of 4 U.S. university groups work at KEK-B, and 22 U.S. university groups work at CESR. CESR, operated by the NSF, will also complete running in FY 2008.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Research	**22,567**	**24,568**	**23,961**
▪ **University Research**	**14,036**	**15,539**	**15,539**

The HEP university research program includes groups at about 40 universities doing experiments at electron accelerator facilities. These university groups analyze and publish results of experiments; develop the physics rationale and preliminary designs for future experiments; and train graduate students and postdoctoral researchers. The current Electron Accelerator-Based Physics subprogram is focused on the study of charm and bottom quarks and the tau leptons, all of which are heavier than the particles of everyday matter and well suited for studying rare processes. The most interesting of these processes is CP violation, which is needed to explain the fact that our universe is mostly made of matter and not antimatter. The BaBar experiment at the SLAC B-factory has been pursuing a broad program of physics studies on particles containing bottom or charm quarks with CP violation measurements and other measurements that support or complement the CP violation program.

U.S. university scientists constitute about 50% of the personnel needed to analyze the BaBar experiment at the B-factory, and they work in collaboration with groups from national laboratories and foreign institutions. They are fully integrated into the operations of the detector facility, and perform many service functions for the detector.

The university program also supports groups that work at CESR at Cornell University; and groups that work at the KEK-B accelerator complex in Japan. The CLEO-c experiment at CESR is concentrating on certain precise measurements of particles containing charmed quarks that are difficult to perform at the B-factory. There is regular cooperation, as well as competition between the SLAC and KEK experiments, which has led to better data analysis and more precise results. University-based research efforts will be selected based on peer review.

In FY 2008, funding for the university program is maintained at the FY 2007 level, in order to support analysis of the unprecedented amount of physics data generated by the B-factory, and physics simulations for other electron accelerators. The detailed funding allocations will take into account the involvement of university based research groups in targeted physics research activities. These include research efforts related to high priority efforts in BaBar research.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
▪ **National Laboratory Research**	**8,293**	**8,698**	**8,094**

The national laboratory research program consists of groups at several laboratories participating in experiments at electron accelerator facilities with a physics program similar to the university program described above. The experimental research groups from national laboratories provide invaluable service in the operation of the detector as well as analysis of the data. The DOE HEP program office reviews laboratory research groups annually with input from independent peer reviewers. The experimental research group from SLAC participates in all phases of the experiments. Because they are embedded in the laboratory structure, they provide invaluable service in the upgrade, calibration, and operation of the detector as well as reconstruction and analysis of the data. The experimental research group at LBNL makes significant contributions to the physics analysis of the data and the computing system needed to reconstruct the data into physics quantities used for analysis. The LLNL research group contributed to the fabrication of the BaBar detector and is now primarily engaged in data analysis.

In FY 2008, the electron-based national laboratory research program is decreased somewhat as some research effort at SLAC moves to the LHC program. Overall SLAC will continue to maintain strong participation in the B-factory research program, and efficiently maintain B-factory operations.

▪ **University Service Accounts**	**238**	**331**	**328**

University Service Accounts facilitate the support of university groups working at accelerator facilities, providing funding for these groups to purchase needed supplies and services from the laboratories with a minimum of time and cost overhead. Currently 16 university groups maintain service accounts at U.S. electron accelerator facilities.

Facilities	**89,724**	**92,892**	**55,802**
▪ **B-factory Operations**	**72,624**	**82,892**	**42,864**
• **Linac Operations**	**42,800**	**44,100**	**21,900**
• **Other B-factory Operations**	**29,824**	**38,792**	**20,964**

Funding for operations supports the final scheduled year of running of the B-factory accelerator complex and the operation of the BaBar detector. Total operations time scheduled for data collection in FY 2008 is 5,720 hours. In addition to the $21,900,000 requested within this activity for SLAC Linac operations, $10,600,000 is requested in B-factory Improvements below, and $61,500,000 is requested in support of the Linac Coherent Light Source (LCLS) project by the Basic Energy Sciences (BES) program (see the Facilities section of the BES Materials Science and Engineering subprogram). The BES contribution to linac operations is increased by $21,500,000 over FY 2007, while total HEP funding for SLAC linac operations decreases by $19,600,000.

Direct program support costs at SLAC will be charged to Research and Technology R&D funding categories in FY 2008, instead of under Operations, similar to the accounting changes at Fermilab described under Tevatron Complex Operations above. The activities supported by these costs include computing support, general engineering and technical support, program management and business office expenses. The change relative to FY 2007 is a reduction of about $7,500,000 in this funding category.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

BaBar will be the priority HEP research program at SLAC in FY 2008. It is anticipated that the collected data will ensure a U.S. leadership role in the study of CP violation, allowing researchers to determine whether remaining discrepancies in physics results between the SLAC B-factory and the KEK-B are signs of new physics, and to search for other discoveries that may be revealed.

	FY 2006	FY 2007	FY 2008
B-factory Operations in hours	5,130	5,200	5,720

	FY 2006	FY 2007	FY 2008
▪ **B-factory Improvements**	**17,100**	**10,000**	**12,938**
• **Linac Improvements**	**13,300**	**8,000**	**10,600**
• **Other B-factory Improvements**	**3,800**	**2,000**	**2,338**

Funding is provided for the necessary enhancement of computing capabilities in order to support the timely analysis of the flood of data the B-factory has provided over the past few years. Activities in this category also include support for GPP funding to renew site-wide infrastructure, as well as general accelerator support and maintenance activities.

Overall funding is increased over FY 2007, mainly to support a new accelerator improvement (AIP) project ($2,500,000) to relocate an experimental test region for accelerator science research to the South Arc area of the unused SLAC Linear Collider, which completed operations in 1998. The existing test facility had occupied a site at the end of the SLAC Linac, where part of the new Linac Coherent Light Source (LCLS) is now being constructed. Beam from the SLAC Linac can be switched to the South Arc when LCLS is not operating. The relocated experimental capability is called the South Arc Beam Experimental Region, or SABER. SABER will provide a unique experimental capability that will enable a wide variety of research projects in advanced beam and plasma physics.

In the first phase of SABER, it will operate parasitically with LCLS, using Linac pulses that are not needed for LCLS operations. Potential upgraded configurations under consideration for the future would provide positrons to SABER and allow for independent LCLS and SABER operations. The total cost for SABER (including potential future upgrades, should they be approved, as well as its initial configuration) is estimated to be approximately $17,000,000, though it may be possible to re-use some B-factory accelerator components to reduce the overall cost.

	FY 2006	FY 2007	FY 2008
Total, Electron Accelerator-Based Physics	**112,291**	**117,460**	**79,763**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Research	
National Laboratory Research and University Service Accounts at SLAC decrease as some research effort at SLAC moves to the LHC program.	-607
Facilities	
▪ HEP funding for B-factory Operations decreases significantly as increased support is provided for SLAC Linac operations by the Basic Energy Sciences (BES) program, and direct program support costs move from Operations to Research and Technology R&D funding categories.	-40,028
▪ Funding for B-factory Improvements is increased over FY 2007 to support the first phase of SABER ($+2,500,000), an AIP project to relocate an accelerator science research capability to the South Arc area of the unused SLAC Linear Collider, for continued use as an experimental test region, along with a modest increase ($+438,000) to maintain the FY 2007 level-of-effort in B-factory support activities in the final year of accelerator operations.	+2,938
Total, Facilities	**-37,090**
Total Funding Change, Electron Accelerator-Based Physics	**-37,697**

Non-Accelerator Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Non-Accelerator Physics			
University Research	17,977	17,271	18,205
National Laboratory Research	27,536	25,957	35,662
Projects	8,349	15,554	17,941
Other	343	489	622
Total, Non-Accelerator Physics	54,205	59,271	72,430

Description

The mission of the Non-Accelerator Physics subprogram is to foster fundamental research in elementary particle physics using naturally occurring particles and phenomena that will provide new insights into the basic constituents of matter and the forces between them, thereby advancing the DOE's strategic goals for science.

Benefits

The Non-Accelerator Physics subprogram provides U.S. leadership in the study of those topics in particle physics that cannot be investigated completely with accelerators, or are best studied by other means. These activities—including the search for or measurement of dark matter and dark energy—have provided experimental data, new ideas, and techniques complementary to those provided by accelerator-based research. These research activities align with the program mission on investigations of elementary particles and their interactions. This subprogram addresses two of the six long-term indicators that contribute to the Program Goal and several of the key questions identified in the HEP Overview section above.

Supporting Information

Non-Accelerator Physics is playing an increasingly important role in High Energy Physics, using ever more sophisticated techniques to probe fundamental physics questions using naturally occurring particles and phenomena. University and laboratory scientists in this subprogram investigate topics such as dark matter, dark energy, neutrino properties, proton decay, the highest energy cosmic rays, and primordial antimatter. In addition, high energy gamma ray observations yield information about active galactic nuclei, gamma ray bursters, massive black holes, and particle acceleration mechanisms that are far beyond the capabilities of any accelerators on earth. 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-based particle sources used in this research are neutrinos from the sun, galactic supernovae, terrestrial nuclear reactors, and cosmic rays in the earth's atmosphere. These experiments utilize particle physics techniques and scientific expertise, as well as the infrastructure of our national laboratories; and are often located at remote sites, such as in deep underground laboratories, on mountain tops, across deserts, or in space, either as dedicated satellites or as instruments attached to NASA facilities such as the International Space Station.

Research and Facilities

The Non-Accelerator Physics subprogram supports the university and laboratory scientists performing experimental particle physics, astrophysics, and cosmology research in the U.S. and abroad that does not directly involve the use of high-energy accelerator particle beams. The research groups are based at about 35 universities. This program is carried out in collaboration with physicists from DOE national laboratories and other government agencies and institutes including NSF, NASA, the Naval Research Laboratory (NRL), and the Smithsonian Astrophysical Observatory. Strong interagency coordination and collaboration is one of the hallmarks of the efforts in this subprogram. As in the rest of the HEP portfolio, most projects involve international collaboration in all phases of the experiment.

The Non-Accelerator Physics subprogram includes support for special facilities and research groups to perform experimental measurements. While research activities (including remote site operations of Non-Accelerator Physics experiments) are covered under the Research activities, the Projects activity in the Non-Accelerator Physics subprogram supports the technical R&D, engineering and design, and fabrication of detector apparatus. Remote sites where U.S. groups are participating in research include: the Soudan Mine in Minnesota; the Sudbury Mine in Ontario, Canada; the Kamiokande Mine in Japan; the Whipple Observatory and Kitt Peak National Observatory in Arizona; the Pierre Auger Observatory in Argentina; the Cerro-Tololo Inter-American Observatory (CTIO) in Chile; the Apache Point observatory in New Mexico; the Waste Isolation Pilot Project (WIPP) in Carlsbad, New Mexico; the Boulby Mine in the United Kingdom (UK); and the Gran Sasso Underground Laboratory in Italy. Other research supported includes space-based projects such as participation in NASA's Gamma-ray Large Area Space Telescope (GLAST) mission, and the Alpha Magnetic Spectrometer (AMS) led by the Massachusetts Institute of Technology.

Highlights

Recent accomplishments include:

- The Large Area Telescope (LAT), a DOE and NASA partnership and the primary instrument on NASA's GLAST mission, was completed in 2006 and is scheduled for launch from Kennedy Space Center in fall 2007. It will begin full data operations in FY 2008. SLAC led the DOE participation in the fabrication of the LAT and will run the instrument science operations center during the data-taking phase.
- The DOE contribution to the fabrication of the Very Energetic Radiation Imaging Telescope Array System (VERITAS) was completed in 2006, with the telescope installed on a temporary basis at the Whipple Observatory in Arizona, while NSF is completing the arrangement for a permanent site for the final installation. The array will undergo engineering operations at this site through FY 2008 before moving to a permanent site by FY 2009.
- The Cryogenic Dark Matter Search (CDMS II) experiment completed installation of its full complement of 5 kg-sized towers of silicon and germanium detectors in the Soudan Mine in Minnesota beginning in mid-2005. Preliminary results were reported in 2005 from data-taking with two towers (comprising about 2 kg of active detectors), setting new world-record limits on the existence of massive dark matter particles in our galaxy, entering the realm of supersymmetric masses and interaction cross sections. The full experiment will take data through 2007, setting limits about 10 times more sensitive than its existing ones in the search for dark matter particles, well into the realm where new particles are predicted by many models of supersymmetry.

The major planned efforts in FY 2008 are:

- *Operation of the Large Area Telescope*, the primary instrument on NASA's GLAST mission. The goals of the LAT are to observe and understand the highest energy gamma rays observed in nature and yield information about extreme particle accelerators in space, including Active Galactic Nuclei and Gamma Ray Bursters, as well as to search for dark matter candidates. It is complementary to the ground-based VERITAS experiment, sampling a lower energy region of the gamma ray spectrum. This research program is being carried out by a collaboration, which includes particle physicists and astrophysicists from SLAC, NASA research centers, the Naval Research Laboratory, U.S. universities, and institutions in Italy, France, Japan, and Sweden.
- *Initial Operations of the VERITAS Telescope Array*. VERITAS is a new ground-based multi-telescope array that will study astrophysical sources of high energy gamma rays, from about 50 GeV to about 50 TeV. The primary scientific objectives are the detection and study of sources that could produce these gamma-rays such as black holes, neutron stars, active galactic nuclei, supernova remnants, pulsars, the galactic plane, and gamma-ray bursts. VERITAS will also search for dark matter candidates. The experimental technique was developed by the DOE/HEP-supported researchers at the Harvard-Smithsonian Whipple Observatory on Mt. Hopkins in Arizona, and the project is supported by a partnership between DOE, NSF, and the Smithsonian Institution. While awaiting installation at its permanent site at Kitt Peak National Observatory, the array is undergoing engineering operations at Whipple Observatory through FY 2008.
- *Fabrication of the Dark Energy Survey (DES) Project.* The FY 2008 request includes a new Major Item of Equipment, the Dark Energy Survey (DES) project. This effort will provide the next step in determining the nature of dark energy, which is causing the universe to expand at an accelerating rate, by measuring the distances to approximately 300 million galaxies. DES employs several methods to measure the effects of dark energy on the distribution of these galaxies and other astrophysical objects. The DES scientific collaboration will begin fabrication of a new charge coupled device (CCD) camera and associated lenses, electronics and data management system to be installed on the Blanco Telescope at the CTIO in Chile. The project is planned as a partnership between DOE and the NSF, which operates the telescope. The scientific collaboration is led by Fermilab and includes participants from laboratories and universities in the U.S., England and Spain. Funding for fabrication in FY 2008 is contingent on successful scientific and technical readiness reviews by the interested funding agencies.
- *R&D for future dark energy experiment(s)*. In order to fully determine the nature of dark energy, the Dark Energy Task Force (DETF), a subpanel of both HEPAP and the Astronomy and Astrophysics Advisory Committee (AAAC) recommended a mix of experiments with independent and complementary measurements. In FY 2008, R&D and/or conceptual design will be performed for proposed experiments that can increase our knowledge of dark energy using ground- or space-based facilities. These facilities could include new detectors on existing ground telescopes, or space-based experiments, such as the SuperNova Acceleration Probe (SNAP) Experiment, a mission concept proposed for a space-based DOE/NASA Joint Dark Energy Mission (JDEM). The DETF report will be used to aid in the development of a coordinated dark energy research program containing specific experiments.
- *Participation in a reactor neutrino experiment*. The FY 2008 request includes U.S. contributions for the design and fabrication of a Major Item of Equipment, a Reactor Neutrino Detector located in Daya Bay, China. This project is supported by a partnership between DOE and research institutes in China. Both the National Academies study and the HEPAP prioritization subpanel (P5) have

identified opportunities in neutrino physics and recommended a reactor-based experiment as part of an overall neutrino research program. This experiment will use anti-neutrinos produced from reactors to precisely measure a crucial parameter needed to pursue new physics opened up by the discovery of neutrino mass and mixing. The value and precision of this parameter will help resolve ambiguities in determinations of other neutrino properties, and will be a key input to determining the directions for further research in the neutrino sector.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
University Research	**17,977**	**17,271**	**18,205**

The university program consists of groups at more than 35 universities doing experiments at Non-Accelerator Physics facilities, using ever more sophisticated techniques to probe fundamental physics questions using naturally occurring particles and phenomena.

These university groups plan, build, execute, analyze, and publish results of experiments; develop the physics rationale and preliminary designs for future experiments; develop new theoretical models and provide interpretations of existing experimental data; and train graduate students and postdoctoral researchers.

University physicists in this research area often work in collaboration with other university and laboratory groups. University-based research efforts will be selected based on peer review.

In FY 2008, the university program in Non-Accelerator Physics will support several experiments (e.g., VERITAS, Pierre Auger, AMS, and GLAST/LAT) that have completed their fabrication phase in recent years and are moving into operations and data analysis. The detailed funding allocations will take into account the discovery potential of the proposed research. Other research efforts that will be continuing in this subprogram include: KamLAND, an underground neutrino oscillation detector in Japan that detects reactor-produced neutrinos; Super-Kamiokande, a proton decay, solar and atmospheric neutrino detector located in the Kamioka Underground Laboratory in Japan; CDMS-II in the Soudan Mine in Minnesota; a direct search for dark matter particles (ADMX-I) at LLNL; a 200 kg neutrinoless double beta decay experiment (EXO-200) at WIPP; and R&D for ground- and space-based concepts for dark energy experiments. Pre-conceptual R&D will continue on a next-generation dark matter search experiment, including extensions of the CDMS solid-state technology to larger detector sizes (25 kg), and alternative technologies based on liquid or gaseous Xenon detectors. University groups will also participate in the design and R&D efforts for the Dark Energy Survey and the Reactor Neutrino Detector, as described above. Finally, R&D for a larger-scale (about 1,000 kg) neutrinoless double beta decay experiment will be supported. This experiment would measure the absolute mass of the neutrino and determine whether the neutrino is its own antiparticle. University groups are leading these efforts.

National Laboratory Research	**27,536**	**25,957**	**35,662**

The national laboratory research program consists of groups at several laboratories participating in Non-Accelerator Physics experiments similar to the university physics program described above. With strong laboratory technical resources, they provide invaluable service to the research program in experiment design, construction, and operations, in addition to scientists involved in the research. The DOE HEP program office reviews laboratory research groups annually with input from independent peer reviewers.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

In FY 2008, the laboratory research program in Non-Accelerator Physics will significantly increase in order to support research activities directed at new initiatives in dark energy and neutrino physics (e.g., the Dark Energy Survey and the Reactor Neutrino Detector), and ongoing R&D of next-generation detectors, including a large-scale double beta decay experiment. The laboratory experimental physics research groups will be focused mainly on supporting the instrument science operations center and data-taking and research for the GLAST/LAT telescope ($3,960,000); operations and data analysis for the Pierre Auger cosmic ray detector array and the CDMS-II dark matter detector; operations of ADMX-I and EXO-200; R&D for ground- and space-based concepts for dark energy experiments; analysis of data from Sloan Digital Sky Survey (SDSS) and continued operation of the follow-on SDSS-II.

Approximately 25% of the apparent increase is due to an accounting change at Fermilab that moves costs for direct program support from Operations to Research and Technology R&D funding categories. The activities supported by these costs include computing support, general engineering and technical support, program management, and business office expenses.

Projects	**8,349**	**15,554**	**17,941**

In FY 2008, this effort will be focused on R&D for the SNAP dark energy mission concept and other potential dark energy experiments; fabrication of the Dark Energy Survey (DES), a Major Item of Equipment (MIE); and R&D and fabrication for the Reactor Neutrino Detector. This activity also included funding for fabrication of the VERITAS telescope, which was completed in FY 2006; telescope operations are funded under the Other activity below. Funding for new MIE projects is contingent on successful scientific and technical readiness reviews by the interested funding agencies.

In the spring of 2006, the Dark Energy Task Force (DETF), a subpanel of both HEPAP and the AAAC, recommended a mix of experiments with independent and complementary measurements to address dark energy. Later in the year, the P5 prioritization subpanel of HEPAP recommended that DOE and NSF jointly pursue the DES project, a small-scale ground-based experiment that can provide significant advances in our knowledge of dark energy in the near term in a cost-effective manner. The FY 2008 request includes $3,610,000 to begin fabrication of DES as a MIE (estimated TEC $15,500,000).

This request also supports R&D for investigating a variety of methods and technologies for dark energy measurements using ground- and/or space-based facilities. The application of this R&D funding will be determined incorporating advice from subpanels of the relevant Federal scientific advisory panels as well as assessment of specific proposals.

As part of this effort, the FY 2008 SNAP R&D activities ($3,500,000) will focus on the conceptual design needed for a potential future space-based mission. NASA's latest "Beyond Einstein" program includes JDEM as one of five proposed Einstein Probe missions. A determination should be made late in 2007 as to which of the five missions will go first. If NASA decides that JDEM will be their first Beyond Einstein mission, the selection of a specific concept for the JDEM mission will take place in 2009. The selected concept would then begin the technical design phase near the end of the decade, leading to fabrication and launch near the middle of the next decade.

The R&D effort to determine technology choices and optimize the detector design for the Reactor Neutrino Detector will continue in FY 2008 ($2,000,000). In addition, MIE funding ($3,000,000) is provided to initiate fabrication (estimated TEC $27,000,000). This experiment will measure a crucial

	FY 2006	FY 2007	FY 2008

(dollars in thousands)

unknown neutrino property by precisely measuring the disappearance of electron antineutrinos generated by the reactor as they travel several hundred meters through the Earth to the underground detector. The MIE project will include the DOE contribution to the fabrication of the experiment. In 2006, HEP, in cooperation with Chinese research institutes, decided to pursue this experiment at a site in Daya Bay, China. The U.S. collaboration is led by groups from BNL and LBNL. The total U.S. TPC for this project will be $29,000,000 per discussions with the Chinese partners.

	FY 2006	FY 2007	FY 2008
Other	**343**	**489**	**622**

This category includes funding mainly for research activities that have not yet completed peer review, and to respond to new and unexpected physics opportunities. It also includes funding for private institutions and other government laboratories and institutions that participate in Non-Accelerator Physics research, including support of the Smithsonian Institute for operations and research using the VERITAS telescope array ($494,000).

	FY 2006	FY 2007	FY 2008
Total, Non-Accelerator Physics	**54,205**	**59,271**	**72,430**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
University Research	
The University Research program is maintained at about the FY 2007 level-of-effort to support ongoing non-accelerator-based research.	+934
National Laboratory Research	
The National Laboratory Research program increases significantly, reflecting increased activity in non-accelerator-based research by the national laboratories, particularly in the areas of dark energy, including research on the Dark Energy Survey, SNAP/JDEM, and other concepts; and in cosmology and particle astrophysics at the Kavli Institute at SLAC. About 25% of the apparent increase is due to accounting changes at Fermilab; the remainder is redirection of research effort to the initiatives in non-accelerator-based research program areas.	+9,705
Projects	
Funding increases as the Dark Energy Survey fabrication begins ($+3,610,000) and R&D continues and fabrication begins for the Reactor Neutrino Detector ($+2,000,000). This is offset by a decrease in dark energy R&D funding, including SNAP/JDEM ($-3,223,000).	+2,387

	FY 2008 vs. FY 2007 ($000)
Other	
Resources held pending completion of peer and/or programmatic review increase slightly to be able to respond to new developments.	+133
Total Funding Change, Non-Accelerator Physics	**+13,159**

Theoretical Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Theoretical Physics			
University Research	23,404	24,043	24,900
National Laboratory Research	16,590	17,242	20,720
SciDAC	2,670	5,000	5,300
Other	5,320	5,771	5,989
Total, Theoretical Physics	47,984	52,056	56,909

Description

The mission of the Theoretical Physics subprogram is to foster fundamental research in theoretical high energy physics that will provide new insights into the basic constituents of matter and the forces between them, thereby advancing the DOE's strategic goals for science.

Benefits

The Theoretical Physics subprogram provides the vision and mathematical framework for interpreting, understanding, and extending the knowledge of particles, forces, space-time, and the universe. It includes activities ranging from detailed calculations of the predictions of the Standard Model of elementary particles to the extrapolation of current knowledge to a new plane of physical phenomena and the identification of the means to experimentally search for them. The Theoretical Physics subprogram also includes a major effort to incorporate Einstein's theory of gravity and space-time geometry into a unified description of all the forces of nature and cosmology, to illuminate the origin and evolution of the universe. Because theoretical interpretation and analysis underpins almost all progress in HEP, this subprogram addresses all of the six long-term indicators that contribute to the Program Goal and all of the key questions identified in the HEP Overview section above.

Supporting Information

Though they are typically not directly involved in the planning, fabrication, or operations of experiments, theoretical physicists play key roles in determining what kinds of experiments would likely be the most interesting to perform, and in explaining experimental results in terms of a fundamental underlying theory that describes all of the components and interactions of matter, energy, and space-time. Our understanding of the universe relies on the active, integrated participation of theorists in interpreting the results of particle physics experiments. The research activities supported by the Theoretical Physics subprogram include: calculations in the quantum field theories of elementary particles that constitute the Standard Model and 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; developing and exploiting new mathematical and computational methods for analyzing theoretical models; and constructing and exploiting powerful computational facilities for theoretical calculations of importance for the experimental program. Major themes are symmetry and unification in the description of diverse phenomena.

Research at Universities and National Laboratories

The University and National Laboratory activities of the Theoretical Physics subprogram support scientists performing research in theoretical high energy physics and related areas. The research groups are based at approximately 75 colleges and universities and at 6 DOE laboratories (Fermilab, SLAC, BNL, ANL, LBNL, and LANL).

The Theoretical Physics subprogram involves collaborations between scientists based at different universities and laboratories, and also collaborations between scientists supported by this program and others whose research is supported by other Offices of the DOE and by other federal agencies, including NSF and NASA. There are also many international collaborations in theoretical physics research. These collaborations are typically smaller and less formal than the efforts required to mount large experiments.

The Theoretical Physics subprogram also includes support for special facilities for numerical and algebraic computation of developed theories, and for research groups to carry out these activities.

Scientific Discovery through Advanced Computing

In FY 2005, the HEP program completed the original SciDAC programs in the areas of accelerator modeling and design (Advanced Computing for 21st Century Accelerator Science and Technology), theoretical physics (National Computational Infrastructure for Lattice Gauge Theory), astrophysics (SciDAC Center for Supernova Research and Shedding New Light on Exploding Stars: TeraScale Simulations of Neutrino-Driven Supernovae and their Nucleosynthesis), and applying grid technology (Particle Physics Data Grid Collaborative Pilot). Each of these projects has made significant strides in forging new and diverse collaborations among different disciplines of physics and between physicists and computational scientists; enabling the development and use of new and improved software for large-scale simulations. Examples include the development of algorithms to solve the underlying algebraic equations for multidimensional radiation transport for supernova simulations; the first complete three-dimensional calculation of the complete evolution of a core collapse supernova; the first parallel beam-beam simulation code that includes, in a single application, weak-strong and strong-strong models, finite crossing angle, longitudinal effects, and long-range collisions via a new shifted Green function algorithm; development of a full Applications Programming Interface (API) for running Lattice Gauge calculations on a variety of hardware platforms; and improvement and use of grid technology in running experiments.

To build on these successes, the HEP program re-competed its SciDAC portfolio in FY 2006 to obtain significant new insights through computational science into challenging problems that have the greatest impact in HEP mission areas. Successful new proposals were selected in the areas of theoretical physics, astrophysics, and grid technology. A call for new SciDAC proposals in accelerator modeling and design was issued in December 2006.

Highlights

Recent accomplishments include:

- High precision numerical simulations of the strong interactions of quarks and gluons, Quantum Chromodynamics (QCD), are producing accurate and reliable predictions of strong interaction decay constants and mass differences. These results, which use supercomputer simulations of QCD, include the important but difficult to calculate “virtual quark” effects in the underlying field theory. In some important cases, the agreement between the calculated and experimental values has reached the experimental uncertainty itself. This is a major success of the theory of strong interactions, and is an improvement by nearly an order of magnitude over previous calculations. These breakthroughs have been accomplished by the application of new, highly efficient algorithms combined with the use of today's supercomputers and dedicated clusters of PC's.

- Recently, powerful new techniques have been developed to reliably calculate high-energy strong interaction processes that will be measured at the LHC. These procedures came from studying the most esoteric branch of theoretical high energy physics: "string theory." In traditional calculations, one calculates only one or two of the largest terms in an infinite series; but these new approaches, some of which are based on analytic methods that had their origins in quantum gravity or string theory, calculate the entire infinite set of terms so that more accurate predictions can be made.

By its nature, progress in theoretical physics cannot be predicted in advance. Nevertheless, there are some current major thrusts in theoretical physics that we expect to continue in FY 2008:

- *LHC Phenomenology.* As the start of LHC operations approaches, a greatly 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. Many attractive ideas have been proposed for the solution of fundamental problems such as the mysteries of the origin of the masses of the elementary particles and the mechanisms through which fundamental symmetries are broken in nature. Identifying which ideas are true will entail the calculation of detailed predictions of many suggested models for extensions of the Standard Model.

- *Lattice QCD*. QCD is a very successful theory that describes the strong interactions between quarks and gluons. Although the equations that define this theory are in principle exact, none of the analytical methods that are so successful elsewhere in theoretical physics are adequate to analyze it. The reason that QCD is so intractable is that the coupling strength is near zero at very short distances but very strong at large distances (where "large" means the size of an atomic nucleus). The lack of precision in current QCD calculations is now limiting the understanding of many experimental results. It has long been known that QCD can be analyzed to any desired precision by numerical methods, given enough computational power. Recent advances in numerical algorithms coupled with the ever-increasing performance of computing have now made some QCD calculations feasible with quite high precision (one to two percent). Some of the computational tools for this effort are provided through the SciDAC program. Progress during FY 2008 will come from the continuation of the major IT investment to procure the necessary computer hardware clusters in partnership with the Nuclear Physics program.

- *New Ideas*. Theoretical physicists are speculating on whether there might be additional space dimensions that are normally hidden from us. These ideas are motivated by the effort to unify Einstein's theory of gravity with quantum mechanics in a mathematically consistent way. It is even possible that some of these dimensions and their consequences are accessible to experiment, perhaps manifesting themselves at the LHC in the production of mini-black holes, or so-called Kaluza-Klein excitations, named after the physicists who first suggested in the 1920's that we actually live in a 5-dimensional universe. Perhaps these ideas can explain the nature of dark matter, or dark energy, or even suggest new cosmologies explaining the history and evolution of the universe.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
University Research	**23,404**	**24,043**	**24,900**

The university program consists of groups at approximately 75 colleges and universities doing theoretical physics research. These university groups develop new theoretical models and provide interpretations of existing experimental data; they identify where new physical principles may be required and determine how to confirm their presence, thereby providing guidance for new experiments; they develop new mathematical and computational methods for analyzing theoretical models; and they are deeply involved in the SciDAC activities described below. The university groups train graduate students and postdoctoral researchers. University physicists in this theoretical research area often work in collaboration with other university and laboratory groups. University-based research efforts will be selected based on peer review.

The theory program addresses problems across the full range of theoretical physics research. There is currently a "window of opportunity" to interpret and understand the exciting new physics results expected from the Fermilab Tevatron, currently searching for new physics at the energy frontier, and from the LHC, which will extend the energy frontier when it begins full-power operations. The detailed funding allocations will take into account the involvement of university-based research groups in these targeted physics research activities.

In FY 2008, the university theory program is maintained at about the FY 2007 level-of-effort to support university research personnel participating in analysis of current and previous experiments, and in the design and optimization of new experiments, so that these experiments can fulfill their maximum potential.

National Laboratory Research	**16,590**	**17,242**	**20,720**

The national laboratory research program consists of groups at several laboratories. The scientists in these groups pursue a research agenda quite like that pursued at universities. In addition, the laboratory groups are a general resource for the national research program. Through continuing interaction with experimental scientists, they provide a clear understanding of the significance of measurements from ongoing experiments and help to shape and develop the laboratory's experimental program. The DOE HEP program office reviews laboratory research groups annually with input from independent peer reviewers.

In FY 2008, the laboratory theoretical research groups will address problems across the full range of theoretical physics research, including the analysis and interpretation of the new data expected from the Tevatron Collider detectors, CDF and D-Zero, and preparation for the new higher energy data from the LHC. About 80% of the increase is due to accounting changes at Fermilab which result in direct support costs being charged to the Theoretical Physics subprogram. In FY 2008, actual funding for the laboratory theory program will be maintained at about the FY 2007 level-of-effort to support laboratory research personnel participating in analysis of current and previous experiments, and design and optimization of new experiments, so that these experiments can fulfill their potential to make new discoveries about the nature of the universe.

	FY 2006	FY 2007	FY 2008
	(dollars in thousands)		
SciDAC	**2,670**	**5,000**	**5,300**

In FY 2008, HEP will continue support for successful new proposals selected in the re-competition of the SciDAC program in FY 2006, as well as any successful new proposals solicited in FY 2007. Proposals are selected based on peer review. In FY 2006 there were three principal new HEP-supported SciDAC efforts in the areas of Type Ia supernova simulations (to generate supernova light curves appropriate for dark energy measurements); platform-independent software to facilitate large-scale QCD calculations (see Other below); and very large scale, fault-tolerant data handling and "grid" computing that can respond to the serious data challenges posed by modern HEP experiments. Funding in FY 2006 was for a six-month period only as the awards were made late in the fiscal year; funding in FY 2007 and beyond will be for the full twelve-month period.

Other	**5,320**	**5,771**	**5,989**

This activity includes funding for the Lattice QCD Computer Program, as well as for education and outreach activities, compilations of HEP data and reviews of data by the Particle Data Group at LBNL, conferences, studies, workshops, funding for research activities that have not yet completed peer review, and responding to new and unexpected physics opportunities.

A coordinated effort with the Nuclear Physics and Advanced Scientific Computing Research programs is aimed toward the development of a multi-teraflops computer facility for Lattice QCD simulations. During FY 2006, a joint effort with NP to develop a dedicated Lattice QCD facility with about 13 teraflop capacity was started, and in FY 2008 this program will proceed as planned.

In each year of the Lattice QCD investment, procurement of computers employing the most cost-effective option will be undertaken. Given current projections of price performance for this kind of high-performance computing, commodity clusters are the most effective investment. The HEP contribution of $2,000,000 to this effort in FY 2008 will correspond to about 3 teraflops of sustained computing performance, in addition to 6.5 teraflops of computing power acquired in previous years.

This category also includes support for the QuarkNet education project ($795,000). 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 allow students to understand and analyze real data from an active HEP experiment (such as the Tevatron or LHC experiments). Each center has 2 physicist mentors and, over a 3 year period, goes through several stages to a full operating mode with 12 high school teachers. The project began in 1999 with an initial complement of 12 centers starting in the first of three yearly stages of development. The full complement of 52 centers, with 625 teachers, was in place in FY 2004. Several centers have retired and new ones have started in the last few years. In FY 2008, most of the centers will be in stage 3, which is the full operations mode. QuarkNet operations will continue through the life of the LHC program at CERN.

Total, Theoretical Physics	**47,984**	**52,056**	**56,909**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
University Research	
University Research is maintained at about the FY 2007 level-of-effort to support university researchers participating in analysis of current and previous experiments, and design and optimization of new experiments.	+857
National Laboratory Research	
About 80% of the increase is due to accounting changes at Fermilab which result in direct support costs being charged to the Theoretical Physics subprogram. The remainder is a modest increase to support national laboratory researchers participating in analysis of current and previous experiments, and in the design, optimization, and analysis of new experiments.	+3,478
SciDAC	
Funding for the SciDAC program is increased to maintain an approximately constant level-of-effort for proposals that were successful in the re-competition of the HEP SciDAC portfolio in FY 2006 and FY 2007.	+300
Other	
Reflects an increase in funds held for theoretical physics activities, including conferences and workshops, pending completion of peer and/or programmatic review.	+218
Total Funding Change, Theoretical Physics	**+4,853**

Advanced Technology R&D

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Advanced Technology R&D			
Accelerator Science	27,355	33,016	41,004
Accelerator Development	72,050	88,030	107,591
Other Technology R&D	22,196	18,568	14,962
SBIR/STTR	—	19,862	19,907
Total, Advanced Technology R&D	121,601	159,476	183,464

Description

The mission of the Advanced Technology R&D subprogram is to foster world-leading research into the science of particle accelerators, as well as particle acceleration and detection techniques and instrumentation. These in turn provide enabling technologies and new research methods to advance scientific knowledge in a broad range of energy-related fields, including high energy physics, thereby advancing the DOE's strategic goals for science.

Benefits

The Advanced Technology R&D subprogram provides the technologies needed to design and build the accelerator and detector facilities used to carry out the experimental program essential to accomplish the programmatic mission in high energy physics. This is accomplished by supporting proposal driven, peer reviewed research in the fundamental sciences underlying the technologies used for HEP research facilities. These efforts focus on new concepts and inventions and their reduction to practice; that is, developing new technologies to the point where they can be successfully incorporated into construction projects that will significantly extend the research capabilities. Because accelerator and detector R&D underpins almost all progress in HEP experimental research, this subprogram addresses all of the six long-term indicators that contribute to the Program Goal and all of the key questions identified in the HEP Overview section.

The Advanced Technology R&D subprogram includes not only R&D to bring new accelerator and detector concepts to the stage where they can be considered for use in existing or new facilities, but also advancement of the basic sciences underlying the technology. Most of the technology applications developed for high energy physics that prove useful to other science programs and to industry, flow from the work carried out in this subprogram.

Supporting Information

High energy physics research is strongly dependent on the use of high energy particle beams provided by charged particle accelerators, storage rings, and their associated detectors. Operating in the extreme domains essential for successful particle physics research demands very specialized technology that takes substantial time and expense to invent, design, build, maintain and upgrade. The R&D programs that support such technology development are unavoidably costly and long term.

Since few of the core technologies used in high energy physics research are directly marketable, industry has little or no motivation to develop the necessary expertise or to do the essential R&D. Consequently, the DOE HEP program has supported a very successful program of technology R&D that has ensured the availability of the most technically advanced research facilities and a world-class U.S. HEP program. Since in many cases the same technologies find applications to synchrotron light sources, intense neutron sources, very short pulse, high brightness electron beams, and computational software for accelerator and charged particle beam optics design, they are widely used in nuclear physics, materials science, chemistry, medicine, and industry.

Accelerators have migrated into general usage for medical therapy and diagnostics, and for preparation of radionuclides used in medical treatment facilities, electronics and food industries. They are also now finding homeland security applications.

Possible future accelerators were one of the main concerns of the recent National Academies study of high-energy physics. This study[a] recommended that the U.S. HEP program "plan and initiate a comprehensive program to become the world-leading center for research and development on the science and technology of a linear collider." The same goal has been re-affirmed by HEPAP. The FY 2008 request includes a major effort to ensure that the U.S. is among the leaders in all aspects of the International Linear Collider (ILC), with a strong emphasis on technology R&D, not only for the ILC, but also for a diverse array of other world-leading efforts in technology development that has a broad range of science applications.

Active world-wide, inter-regional cooperation on linear collider accelerator systems, physics studies, and detector development has been underway for the past decade. The International Linear Collider Steering Committee (ILCSC) coordinates scientific and organizational aspects of the activities directed toward an international proposal to construct a linear collider. These activities include establishing a standard set of operating parameters and organizing an international collaboration. The ILCSC also selected superconducting radiofrequency accelerating cavities as the preferred technology for the main ILC Linac. The international Global Design Effort (GDE) was established to coordinate and provide leadership in the international R&D effort. The GDE has delivered a baseline configuration document for the ILC, established a controlled configuration change process, and is developing a reference ILC design and cost to be released in February 2007. The cost provided at that time will be in currency-free value units so that each country can do a translation into its own currency using its accounting standards and procedures.

The ILC reference design process will include a preliminary cost estimate, first steps to industrialization of the components, development of sample sites in the U.S. and elsewhere, and physics detector concepts. In parallel with the steps taken toward reaching a design for the ILC, an informal ad hoc group of senior science program officials from funding agencies in a dozen developed nations has been formed to provide support for the GDE and discuss how one might formally organize a future ILC project, should a decision be made to go forward, as well as coordinating other proposed large scale international facilities.

Future electron and proton accelerators are expected to be based upon the superconducting radiofrequency (RF) acceleration technology pioneered by HEP researchers, which is now being applied in nuclear physics, basic energy sciences, biology, and fusion facilities. Further development of this technology can enable cost reductions and enhanced capability across the broad spectrum of SC programs.

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[a] *Revealing the Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics* (aka "EPP2010"), National Academies Press, 2006. Available online at http://www7.nationalacademies.org/bpa/EPP2010.html

Accelerator Science

The Accelerator Science activity in this subprogram focuses on the science underlying the technologies used in particle accelerators and storage rings. There is an emphasis on future-oriented, high-risk R&D, particularly in the development of new accelerating concepts, but essential infrastructure to support the HEP technology R&D programs is also addressed. Examples of the latter include standards for testing of advanced superconducting materials, instrumentation standards, the physics of charged particle beams and optics, and user facilities for general support of accelerator research, such as the Accelerator Test Facility (ATF) at BNL.

Accelerator Development

The larger task of reducing new concepts and technical approaches to the stage of proven engineering feasibility, so that they can be incorporated into existing or new facilities, is done under Accelerator Development. Included in this activity is work on developing very high field superconducting magnet technology, studies of very high intensity proton sources for potential application in neutrino physics research or heavy ion studies, and muon accelerator proof-of-principle research. When concepts develop enough to be viewed as part of a larger system, or as potentially leading to a proposal for a construction project, they are given special attention. The ILC is the current R&D activity in this area.

Other Technology R&D

This category includes funding at universities under Advanced Detector Research and at national laboratories under Detector Development. Advanced Detector Research is similar to Accelerator Science in that it addresses the development and application of an underlying science to foster new technologies in particle detection, measurement, and data processing. The Detector Development program provides funding to national laboratories and some universities to bring new detection and data processing concepts to an engineering readiness state so that they can be incorporated into an existing detector or into a new experiment.

Highlights

Recent accomplishments include:

- There has been significant progress on alternate physical mechanisms of charged particle acceleration. In particular, current experiments at SLAC address the potential feasibility of a particle-driven plasma wakefield “afterburner” that could one day potentially double the energy of a linear accelerator beam in only a few meters of plasma. An accelerating gradient 1,000 times that now possible in conventional accelerators has been measured in an 85 centimeter long plasma channel for a net energy gain in excess of 40 GeV. The acceleration of positrons (anti-electrons) by particle driven plasma wake fields has also been demonstrated, an essential step if the plasma accelerators are to ever be applied to electron-positron colliders.
- At LBNL, a laser-driven plasma wakefield experiment has successfully trapped a bunch of electrons in a plasma and accelerated them to energies of 1 GeV in a few millimeters. The process creates an electron bunch in which the distribution of individual electron energies is very narrow, within a few percent of the average energy of the bunch. This is an important step forward from the earlier experiments that produced bunches with 100% energy spread and is an essential step in developing a useful accelerator.

The major Advanced Technology R&D efforts in FY 2008 are:

- *International Linear Collider R&D.* A TeV scale linear electron-positron collider has been identified by the recent National Academies' "EPP2010" study as "the essential component of U.S. leadership in particle physics in the decades ahead." In FY 2008, the R&D activities addressing critical performance and cost issues will be expanded on a coordinated international basis and steps will be taken to industrialize the key components. The ILC R&D program in FY 2008 supports a strong U.S. role in a comprehensive and coordinated international R&D program, and provides the basis for U.S. industry to compete successfully for major subsystem contracts, should the ILC be built. The work needed to develop U.S. leadership in various technical areas will be continued. A strong international collaborative design effort, conducted under an international memorandum of understanding, will proceed.

  The Department will consult with our international partners about entering into formal negotiations to establish an international agreement to direct the engineering design phase of the proposed ILC, should the U.S. and partner governments choose to proceed to a fully-costed engineering design for the project. This agreement would be similar in spirit to the ITER Engineering Design Activities (EDA) agreement (http://www.iter.org/EDA.htm). The information provided by the activities would inform future decisions on the construction of and U.S. participation in the proposed ILC.

- *Research and Development of Superconducting RF technology.* A broad spectrum of SC programs need a rigorous research and development program and domestic industrial capability, not presently available, to produce cost competitive and reliable superconducting RF components for possible future accelerators that serve the science mission. The industrial development will require extensive testing capability in our national laboratories to stimulate new techniques, to demonstrate the quality of commercial products and to feed back crucial information needed for process improvements and quality control. This growing R&D effort is now separately tracked and reported in the FY 2008 request.

- *Accelerator Science.* The pursuit of new acceleration concepts at universities and laboratories will be intensified to develop more options for future high-energy accelerators beyond the ILC. New concepts will be explored through simulations, and promising candidates will be tested with experiments at universities and at laboratory-based user facilities. The test capabilities of user facilities will be enhanced and operation will be expanded to meet user demand.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Accelerator Science	**27,355**	**33,016**	**41,004**
▪ **University Research**	**9,527**	**13,037**	**16,556**

The increase in funding in FY 2008 will support a renewed university research program in advanced accelerator physics and related technologies. The research program will continue to pursue development of niobium-tin and similar superconductors and their application, as well as R&D in the application of high temperature superconductors; investigations of the use of plasmas and lasers to accelerate charged particles, which will focus on the use of laser driven plasma wakefields; development of novel high power radiofrequency (RF) sources for driving accelerators and for conducting high gradient research including studies of vacuum breakdown phenomena and material

	FY 2006	FY 2007	FY 2008

(dollars in thousands)

properties; and R&D into the issues of much higher accelerating gradient in RF superconductors. Development of advanced particle beam instrumentation; theoretical studies in advanced beam dynamics, including the study of non-linear optics; space-charge dominated beams and plasmas; and development of new computational and simulation methods and programs will also be continued. Accelerator R&D into the fundamental issues associated with the ionization cooling of muon beams is included in this effort and will be continued.

The FY 2008 budget will continue the expanded university accelerator science program begun in FY 2007 at a level that can provide support needed for enhanced long-term R&D, in parallel with overall program increases aimed at nearer-term R&D for future facilities. New research initiatives, including an expanded program in the physics of very high accelerating gradients, will continue to be supported. Funds will also be directed at bringing the research infrastructure at some of the small university-based facilities up-to-date.

University-based research programs are selected based on review by well-qualified peers, and progress is monitored through a system of formal site visits, presentations at appropriate workshops, participation in conferences, and publications.

	FY 2006	FY 2007	FY 2008
▪ **National Laboratory Research**	**16,398**	**18,323**	**22,676**

There are areas of Accelerator Science research that require the more extensive or specialized research facilities located at DOE national laboratories. National laboratory research efforts are selected based on review by appropriate peers, laboratory program advisory committees, and special director-appointed review committees. Measurement of progress includes the annual HEP program review supported by well-qualified peers, publications in professional journals, and participation in conferences and workshops.

BNL is the home of the very successful Accelerator Test Facility (ATF), supporting research that HEP funds at universities and in industry including research funded through the Small Business Innovation Research (SBIR) Program. In FY 2008, the ATF will continue a program of testing advanced accelerator concepts, developing new instrumentation, and developing next generation high brightness electron sources based on laser-driven photocathodes. R&D on the muon production target experiment at CERN will also be funded.

The Center for Beam Physics at LBNL is supported in FY 2008 for research in laser-driven plasma acceleration, advanced RF systems, laser manipulation and measurement of charged particle beams, and a broad program in instrumentation development, accelerator theory, and computation. R&D on muon ionization cooling and theoretical studies of alternative muon acceleration schemes will also be carried out.

Fermilab maintains a small advanced accelerator R&D program focused on high-brightness photoinjectors and research on muon acceleration. In previous years this effort was reported under Accelerator Development (see below); in FY 2008 it is captured under Accelerator Science to improve consistency of reporting with other laboratory accelerator R&D programs. As a result, most of the funding increase in National Laboratory Accelerator Science Research in FY 2008 is due to this reclassification. The overall FY 2008 request for laboratory advanced accelerator research activities is maintained at about the FY 2007 level-of-effort, excluding the Fermilab reclassification described above. In FY 2008, R&D in support of the international muon cooling collaboration with

	FY 2006	FY 2007	FY 2008
(dollars in thousands)			

Rutherford Appleton Laboratory in the UK will continue. Fermilab is the lead laboratory for R&D and test infrastructure needed to develop superconducting RF electron- and proton-based accelerators for a wide range of applications, as outlined above.

The advanced accelerator R&D program at SLAC in FY 2008 will continue to support R&D into advanced particle acceleration technologies, and work with BES on R&D for new experimental capabilities at SLAC that take advantage of the unique qualities of the Linac beam. R&D into ultra high-frequency microwave systems for accelerating charged particles will be focused on high field breakdown phenomena and new accelerating geometries that support very high gradients. Very advanced electron-positron collider concepts and theoretical studies in advanced beam dynamics methods and new computer computation and simulation codes will continue. Much of the work on advanced accelerator concepts at SLAC is done in collaboration with universities funded by the Accelerator Science activity.

Other activities supported in FY 2008 include theoretical studies of space-charge dominated beams at PPPL and research on new means of generating high-brightness electron beams, and the use of charged particle wakefields to generate microwaves for particle acceleration at ANL.

	FY 2006	FY 2007	FY 2008
▪ **Other**	**1,430**	**1,656**	**1,772**

This subactivity includes funding for Accelerator Science at sites other than universities and national laboratories. These include interagency agreements with NRL and the National Institute of Standards and Technology (NIST) and funding of industrial grants. Also included is funding for Accelerator Science activities that are awaiting approval pending the completion of peer review and program office detailed planning.

	FY 2006	FY 2007	FY 2008
Accelerator Development	**72,050**	**88,030**	**107,591**
▪ **General Accelerator Development**	**28,250**	**23,130**	**24,136**

This research includes R&D to bring new concepts to a stage of engineering readiness where they can be incorporated into existing facilities, used in upgrading existing facilities, or applied to the design of new facilities. The work is mostly done at Fermilab, LBNL, SLAC, and BNL, with supporting activities at TJNAF, ANL, LLNL, and LANL. The major areas of R&D are superconducting magnet and related materials technology; high-powered RF acceleration systems; instrumentation; stochastic and electron cooling technologies; beam dynamics, both linear and nonlinear; and development of large simulation programs. Research on superconducting RF acceleration systems and related RF power systems was previously included in this subactivity but is now reported separately below.

The R&D program at Fermilab in FY 2008 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.

The LBNL R&D supported in FY 2008 includes work on very high field superconducting magnets using niobium-tin and similar superconductors, on new beam instrumentation for use at Fermilab and SLAC, and on extensive beam dynamics and simulation studies with particular emphasis on the electron cloud instability and related efforts in proton and electron colliders. The very successful

	FY 2006	FY 2007	FY 2008

(dollars in thousands)

industrially-based program to develop advanced superconductors, particularly niobium-tin, for the very high field superconducting magnet R&D program will continue to be supported.

The FY 2008 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.

In FY 2008, the national laboratory program is maintained at about the FY 2007 level. The funding increase is due to accounting changes at Fermilab that move costs for direct program support from Operations to Research and Technology R&D funding activities. The areas supported by these costs include computing support, general engineering and technical support, program management and business office expenses.

	FY 2006	FY 2007	FY 2008
▪ **Superconducting RF R&D**	**14,100**	**4,900**	**23,455**

Because of increasing emphasis on superconducting RF technology for accelerators, and its potential application to a broad range of SC programs, R&D on superconducting RF acceleration systems and related RF power systems is now separately reported in this request.

In FY 2008, this effort will provide funds to make industrial procurements of prototype accelerating cavities, high power RF input couplers, and RF power klystrons and modulators. This request also enables development of U.S. capability for testing individual bare cavities, and dressed cavities with all power components attached. Separate test stands are needed to develop the high power RF systems that feed the accelerating cavities. Test areas for accelerating systems will be built upon existing infrastructure at Fermilab, ANL, TJNAF, LANL, and Cornell University. Those supporting the RF power system tests will be located at SLAC and LLNL. Fermilab is the lead U.S. laboratory coordinating the national R&D program in this area.

	FY 2006	FY 2007	FY 2008
▪ **International Linear Collider R&D**	**29,700**	**60,000**	**60,000**

The International Linear Collider (ILC) as currently conceived will collide beams of electrons and positrons head-on at very high energies (500 GeV–1 TeV). This will permit precise and clean measurements of currently undiscovered particles and forces.

Panels worldwide have all strongly recommended that the ILC is the tool that is needed to make the next scientific steps forward after the LHC starts operations in Europe in 2007. There are powerful reasons to believe that the LHC could open the door to a new domain of particles and forces. Building a coherent and compelling understanding that describes these particles and forces will require the precise and clean measurements that the ILC can provide. For example, the ILC would answer questions such as: Is one of these new particles stable, with properties consistent with the cosmic dark matter that makes up a quarter of the universe? Is whatever is found at the LHC really the long sought after Higgs boson? Does it give mass to the other particles? Are the particles found at the LHC related to those we already know through a newly discovered symmetry of nature?

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

In FY 2007, the ILC international collaboration under the direction of the Global Design Effort will complete a detailed review of the R&D to be accomplished world wide, milestones and priorities for that work, a pre-conceptual design document, and cost estimate. These documents will be submitted to the sponsoring governments for review, and will serve as the basis for the detailed design study that will proceed in FY 2008.

The Department will consult with our international partners about entering into formal negotiations to establish an international agreement to direct the engineering design phase of the proposed ILC, should the U.S. and partner governments choose to proceed to a fully-costed engineering design for the project. This agreement would be similar in spirit to the ITER Engineering Design Activities (EDA) agreement (http://www.iter.org/EDA.htm). The information provided by the activities would inform future decisions on the construction of and U.S. participation in the proposed ILC.

Starting in FY 2007, all ILC funding was consolidated in this budget category including both accelerator and detector R&D efforts, as well as support of GDE management activities (see Detector Development below).

In FY 2008, the U.S. collaboration will continue to focus its R&D efforts on developing the electron and positron sources, the damping rings needed to prepare the high brightness beams and the high-gradient accelerating components associated with the main Linacs. R&D will continue on designing and testing the critical elements needed to bring the beams into collisions and developing the instrumentation for monitoring the beam properties. Particular attention will be given to R&D aimed at cost reduction and value engineering of present baseline systems, and developing alternate low-risk components with prospects for cost reduction, where appropriate. Work will continue on developing the machine controls and large-scale simulations of the full accelerator complex.

The detailed design, aimed at a complete Technical Design Report in 2009, will be conducted throughout FY 2008 in collaboration with our international partners through the newly created international EDA agreement. R&D on critical components for the experimental detectors will be conducted to position U.S. scientists for leadership in the ILC scientific program. Prototype calorimeter and tracking systems will be studied in the Fermilab test beam, providing a major test of particle flow algorithms and detector construction techniques.

A detailed set of site requirements will be developed in FY 2007 and published by the GDE. To prepare for a potential U.S. bid to host the ILC, should it be built, detailed conventional construction studies related to potential U.S. site(s) will be performed in FY 2008. Site specific studies relating to geological conditions, environmental and safety impact, and machine design issues that arise at a specific site are needed by about the end of FY 2008 to permit completion of the technical design report in the succeeding year.

Other Technology R&D	**22,196**	**18,568**	**14,962**
▪ **Advanced Detector Research**	**836**	**1,421**	**1,469**

The Advanced Detector Research (ADR) program supports university physicists to develop new detector technologies, or technology advances which would be generally applicable to a wide range of HEP experiments. The chosen technologies are motivated by the needs of conceptually foreseen but not yet developed experimental applications. Approximately six to eight grants a year are

	FY 2006	FY 2007	FY 2008
(dollars in thousands)			

awarded through a competitive peer review program. Final funding levels will depend on the number and quality of proposals received. This program complements the detector development programs of the national laboratories.

The FY 2008 request reflects the continued interest of the HEP community in early-stage detector development aimed at the detection challenges of new experimental initiatives. The challenges posed by new accelerator and non-accelerator based experiments drive the need for: tolerance to high radiation environments, high resolution detectors with very fast readouts, lower-cost implementations of existing technologies, and novel detection techniques.

	FY 2006	FY 2007	FY 2008
▪ **Detector Development**	**21,003**	**13,628**	**13,493**

New experiments frequently depend on advancements in technologies. This funding supports detector development work at the national laboratories and about 40 universities to advance these technologies to a point where there is reasonable chance that an experiment can adopt the technology successfully. Current areas of investigation include R&D on detector technologies that could be used to pursue new opportunities in particle astrophysics and neutrino physics. In FY 2006 these efforts included funds ($5,848,000) for detector R&D related to the International Linear Collider (ILC) program, coordinated with the NSF; ILC-related detector R&D is included in the ILC R&D budget subactivity above in FY 2007 and FY 2008.

The FY 2008 request will maintain R&D efforts directed toward developing new detectors including much needed prototyping and in-beam studies. A diverse program applicable to dark matter and dark energy studies, as well as accelerator-based programs will be continued, including efforts on particle flow calorimeters, liquid noble gas detectors, transducer technology (e.g., advanced charged-coupled devices, silicon photomultipliers), and radiation resistant, fast readout electronics.

	FY 2006	FY 2007	FY 2008
▪ **Other**	**357**	**3,519**	**—**

This subactivity included funding for research activities that had not yet completed peer review, or to respond to new and unexpected physics opportunities. In FY 2006 and FY 2007, targeted efforts were funded to develop new accelerator and detector concepts related to neutrino physics. In FY 2008, these activities have transitioned out of the R&D stage as new experiments have begun fabrication and are funded largely in the Proton Accelerator-Based Physics subprogram (NOνA and T2K).

	FY 2006	FY 2007	FY 2008
SBIR/STTR	**—**	**19,862**	**19,907**

The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) set-asides are mandated by Congress. The HEP program manages topics related to accelerator science and technology and two topics related to detector science and technology in the annual procurement solicitation. The contents of each topic are based on material provided in response to an annual HEP solicitation for suggestions from scientists and engineers in universities and DOE national laboratories working in support of the HEP Advanced Technology R&D programs. There is also coordination with the DOE Nuclear Physics and Fusion Energy Sciences programs concerning areas of mutual interest. The selection of the R&D topics to be included in the annual solicitation is treated as an important and

	FY 2006	FY 2007	FY 2008

(dollars in thousands)

integral component of the advanced accelerator R&D program, and selections of grants are made based on a combination of the recommendations of the peer reviewers and the importance to the HEP programs in Accelerator Science and Accelerator Development. In FY 2006, $16,479,000 was transferred to the SBIR program and $1,977,000 was transferred to the STTR program.

	FY 2006	FY 2007	FY 2008
Total, Advanced Technology R&D	**121,601**	**159,476**	**183,464**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Accelerator Science	
▪ The increase in funding in FY 2008 will support a renewed and expanded University Research program in advanced accelerator physics and related technologies.	+3,519
▪ Most National Laboratory Research activities are maintained at about the FY 2007 level-of-effort ($+403,000). The rest of the funding increase in FY 2008 ($+3,950,000) is due to the reclassification of Fermilab R&D efforts into this subactivity from General Accelerator Development.	+4,353
▪ Other resources held pending completion of peer and/or programmatic review increase slightly to be able to respond to new developments.	+116
Total, Accelerator Science	**+7,988**
Accelerator Development	
▪ General Accelerator Development efforts are held at approximately the FY 2007 level. The funding increase is due to accounting changes at Fermilab that moves costs for direct program support from Operations to Research and Technology R&D funding activities.	+1,006
▪ The increase in Superconducting RF technology provides funds to support research and development for possible future accelerators and enables development of superconducting RF test capabilities at national laboratories and universities, supporting the needs of a full range of future applications.	+18,555
Total, Accelerator Development	**+19,561**
Other Technology R&D	
▪ Advanced Detector R&D efforts increase slightly to reflect anticipated proposal levels in this area of R&D. Final funding levels will depend on the number and quality of proposals received.	+48

	FY 2008 vs. FY 2007 ($000)
▪ Detector development funding decreases slightly to reflect anticipated proposal levels in this area of R&D. Final funding levels will depend on the number and quality of proposals received.	-135
▪ Other R&D funding decreases as targeted R&D activities for neutrino physics have transitioned out of the R&D stage, and new experiments have begun fabrication and are funded in other subprograms of the HEP request.	-3,519
Total, Other Technology R&D	**-3,606**
SBIR/STTR	
The changes reflect the mandated funding for the SBIR and STTR programs.	+45
Total Funding Change, Advanced Technology R&D	**+23,988**

Construction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Construction			
07-SC-07, Electron Neutrino Appearance (EνA) Detector, PED	—	10,300[a]	—

Description

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

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
07-SC-07, Electron Neutrino Appearance (EνA) Detector, PED	**—**	**10,300[a]**	**—**

The Electron Neutrino Appearance (EνA) Detector is a very large detector, to be fabricated by Fermilab and collaborating universities, which would be sited in northern Minnesota. The EνA detector was originally proposed as a line-item construction project in the FY 2007 Congressional Budget but has been reconfigured as a MIE to reflect a revised acquisition strategy for this project that does not require DOE to fund the associated civil construction activities. See the Detailed Justification under the Proton Accelerator-based Physics subprogram for MIE details.

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
07-SC-07, Electron Neutrino Appearance (EνA) Detector, PED	
The EνA detector was originally proposed as a line-item construction project in the FY 2007 Congressional Budget but has been reconfigured as a MIE to reflect a revised acquisition strategy for this project. Thus, line-item construction funding is not requested for FY 2008.	-10,300

[a] EνA detector, proposed as a line-item construction project in the FY 2007 Congressional Budget has been reconfigured as a MIE under project name NOνA to reflect a revised acquisition strategy that requires associated civil construction activities to be funded by a financial assistance agreement with a participating research institution. The Department plans to submit a reprogramming request when the FY 2007 appropriation is enacted to transfer EνA construction funds to operating funding under Proton Accelerator-Based Physics for the NOνA MIE, including TEC of $2,300,000 and OPC of $8,000,000.

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
General Plant Projects	13,135	15,495	12,635
Accelerator Improvement Projects	7,800	—	2,900
Capital Equipment	52,228	39,927	55,766
Total, Capital Operating Expenses	73,163	55,422	71,301

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Unappro-priated Balance
07-SC-07, Electron Neutrino Appearance (EνA) Detector, PED	10,300	—	—	10,300[a]	—	—

Major Items of Equipment *(TEC $2 million or greater)*

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Completion Date
Large Hadron Collider– ATLAS Detector, CERN (01CA)	102,950[b]	55,549	53,105	1,598	846	—	FY 2007
Large Hadron Collider– CMS Detector, CERN (01CB)	147,050[c]	71,789	67,639	2,900	1,250	—	FY 2007
Very Energetic Radiation Imaging Telescope Array System (VERITAS), Amado, Arizona (41NF)	7,399[d]	4,799	3,650	1,149	—	—	FY 2006
BaBar Instrumented Flux Return (IFR) Upgrade, SLAC (41NQ)	4,900	4,900	4,200	700	—	—	FY 2006

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[a] The Department plans to submit a reprogramming request when the FY 2007 appropriation is enacted to transfer the EνA construction funds to operating funding under Proton Accelerator-Based Physics for the NOνA MIE, including TEC of $2,300,000 and OPC of $8,000,000.
[b] The total U.S. contribution (TPC) for this project is $163,750,000, including $60,800,000 from NSF.
[c] The total U.S. contribution (TPC) for this project is $167,250,000, including $20,200,000 from NSF.
[d] The total TPC for this project is $17,534,000 including $7,333,000 from NSF, $2,000,000 from the Smithsonian Institution, and $802,000 from foreign partners. NSF is completing the arrangements for a permanent site.

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Completion Date
Reactor Neutrino Detector, Daya Bay, China	29,000[a]	27,000	—	—	3,000[a]	3,000	FY 2011
NuMI Off-axis Neutrino Appearance (NOνA) Detector, Fermilab	260,000[bc]	155,200	—	—	—[d]	4,900	FY 2012
Dark Energy Survey, Cerro-Tololo Inter-American Observatory, Chile	20,000[b]	15,500	—	—	—	3,610	FY 2011
Main Injector Experiment ν–A (MINERνA), Fermilab	15,000[e]	10,000	—	—	—	5,000	FY 2010
Tokai-to-Kamioka (T2K) Near Detector, Tokai, Japan	4,700[f]	3,000	—	—	—	2,000	FY 2009
Total, Major Items of Equipment				6,347	5,096	18,510	

[a] The total U.S. TPC for this project will be $29,000,000 per discussions with the Chinese partners. The Department plans to submit a request when the FY 2007 appropriation is enacted to reprogram $3,000,000 of MIE funds towards ongoing R&D for the Daya Bay detector. No funding will be used for fabrication until approval and validation of the Performance Baseline and approval of Start of Construction in FY 2008.
[b] No funding will be used for fabrication until approval and validation of the Performance Baseline and approval of Start of Construction.
[c] The TPC of the project includes NuMI proton improvements as described under the Proton Accelerator-Based Physics subprogram and will not exceed $260,000,000.
[d] The EνA detector was originally proposed as a line-item construction project ($10,300,000) in the FY 2007 Congressional Budget but has been renamed NOνA and has been reconfigured as a MIE to reflect a revised acquisition strategy that requires associated civil construction activities to be funded by a financial assistance agreement with a participating research institution. The Department plans to submit a reprogramming request when the FY 2007 appropriation is enacted to transfer EνA construction funds to operating funding under Proton Accelerator-Based Physics for the NOνA MIE, including TEC of $2,300,000 and OPC of $8,000,000.
[e] Mission Need (CD-0) was approved June 2006 with a TPC range of $10,000,000-$15,000,000. The baseline TPC will be approved at CD-2 (Approve Performance Baseline). The FY 2008 Budget Request is for engineering design only. Engineering design may include limited fabrication and testing of design concepts. Funds for full fabrication will be requested after validation of Performance Baseline.
[f] Preliminary estimated DOE TEC and TPC are shown. No funding will be used for fabrication until approval and validation of the Performance Baseline and approval of Start of Construction.