Nuclear Physics

Funding Profile by Subprogram

	(dollars in thousands)		
	FY 2006 Current Appropriation	FY 2007 Request	FY 2008 Request
Nuclear Physics			
Medium Energy Nuclear Physics	103,161	122,781	123,379
Heavy Ion Nuclear Physics	156,657	197,512	203,188
Low Energy Nuclear Physics	67,106	83,899	90,647
Nuclear Theory	28,352	35,348	36,405
Subtotal, Nuclear Physics	355,276	439,540	453,619
Construction	2,480	14,520	17,700
Total, Nuclear Physics	357,756[a]	454,060	471,319

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 Nuclear Physics (NP) program is to foster fundamental research in nuclear physics that will provide new insights and advance our knowledge on the nature of matter and energy and develop the scientific knowledge, technologies and trained workforce that are needed to underpin the Department of Energy's missions for nuclear-related national security, energy, and environmental quality. The program provides world-class, peer-reviewed research results and operates user accelerator facilities in the scientific disciplines encompassed by the Nuclear Physics mission areas under the mandate provided in Public Law 95-91 that established the Department.

Benefits

The Office of Science's (SC) Nuclear Physics program will substantially advance our understanding of nuclear matter and the early universe. It will help the United States maintain a leading role in nuclear physics research, which has been central to the development of various technologies, including nuclear energy, nuclear medicine, and national security. The highly trained scientific and technical personnel in fundamental nuclear physics that are a product of the program are a valuable human resource for many applied fields.

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[a] Total is reduced by $3,707,000 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; $8,284,000, which was transferred to the SBIR program; and $994,000, which was transferred to the STTR program. The funding allocation also reflects an approved reprogramming moving $500,000 from the Medium Energy Nuclear Physics subprogram to Construction to begin Project Engineering and Design for the 12 GeV Upgrade project at the Continuous Electron Beam Accelerator Facility.

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

GPRA Unit Program Goal 3.1/2.47.00—Explore Nuclear Matter - from Quarks to Stars—Understand the evolution and structure of nuclear matter, from the smallest building blocks, quarks and gluons, to the stable elements in the Universe created by stars; to unique isotopes created in the laboratory that exist at the limits of stability and possess radically different properties from known matter.

Contribution to Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science

The NP subprograms (Medium Energy, Heavy Ion, Low Energy, and Nuclear Theory) contribute to these Strategic Goals by supporting innovative, peer-reviewed scientific research to advance knowledge and provide insights into the nature of energy and matter, and in particular, to investigate the fundamental forces that hold the nucleus of the atom together, and determine the detailed structure and behavior of atomic nuclei. The Nuclear Physics program contributes by building and supporting world-leading scientific facilities and state-of-the-art instruments necessary to carry out its basic research agenda. Scientific discoveries at the frontiers of nuclear physics further the Nation's energy-related research capacity, which in turn, provides for the Nation's security, economic growth and opportunities, and improved quality of life. In developing strategies to pursue these exciting research opportunities, the Nuclear Physics program is guided by the present long-range planning report prepared by its primary advisory panel, the Nuclear Science Advisory Committee (NSAC)—Opportunities in Nuclear Science (2002). NSAC is in the process of generating a new long-range plan for nuclear science, due by the end of 2007. The program is also cognizant of opportunities expressed elsewhere; e.g., Connecting Quarks with the Cosmos (2003), a report prepared by the National Research Council and sponsored by DOE, the National Science Foundation (NSF), and National Aeronautics and Space Administration (NASA), and the interagency response to this report, The Physics of the Universe, a Strategic Plan for Federal Research at the Intersection of Physics and Astronomy, prepared by the National Science and Technology Council. The program will be informed by the advice of the National Academies concerning the scientific opportunities with rare isotope beams; a final report from the National Academies will be published in spring 2007. The program is consistent with both the DOE and SC Strategic Plans.

The Medium Energy subprogram will contribute to Strategic Goals 3.1 and 3.2 by investigating the quark and gluon substructure inside the nucleon. Although protons and neutrons can be separately observed, their quark constituents cannot be because they are permanently confined inside the nucleons. Measurements are carried out primarily using electron beams with the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF, or JLab) and using polarized proton collisions at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven

National Laboratory (BNL), as well as other facilities worldwide. The following indicator establishes a specific long-term goal in Scientific Discovery that the NP program is committed to, and progress can be measured against:

- making precision measurements of fundamental properties of the proton, neutron, and simple nuclei for comparison with theoretical calculations to provide a quantitative understanding of their quark substructure.

The Heavy Ion subprogram will contribute to Strategic Goals 3.1 and 3.2 by searching for the predicted novel forms of matter and other new phenomena that might occur in extremely hot, dense bulk nuclear matter. The quarks and gluons that compose each proton and neutron are normally confined within these nucleons. However, if nuclear matter is compressed and heated sufficiently, quarks should become deconfined: individual nucleons will melt into a hot, dense plasma of quarks and gluons. Such plasma is believed to have filled the universe about a millionth of a second after the "Big Bang." Measurements are carried out primarily using relativistic heavy-ion collisions at RHIC. Important measurements will also be made at the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN). The U.S. participation in the heavy ion program at the LHC will provide researchers the opportunity to search for new states of matter under substantially different initial conditions than those provided by RHIC, yet still provide a piece of the puzzle regarding the matter that existed during the infant universe. The following indicator establishes a specific long-term goal in Scientific Discovery that the NP program is committed to, and progress can be measured against:

- searching for, and characterizing the properties of, the quark-gluon plasma by briefly recreating tiny samples of hot, dense nuclear matter.

The Low Energy subprogram will contribute to Strategic Goals 3.1 and 3.2 by investigating nuclei at the limits of stability, nuclear astrophysics, the nature of neutrinos, and fundamental symmetry properties in nuclear systems. The coming decade in nuclear physics may reveal new nuclear phenomena and structure unlike anything known from the stable nuclei of the world around us. Nuclear physics research is essential if we are to solve important problems in astrophysics—the origin of the chemical elements, the behavior of neutron stars, the origin of the highest-energy cosmic rays, core-collapse supernovae and the associated neutrino physics, and galactic and extragalactic gamma-ray sources. Measurements of nuclear structure and nuclear reactions are carried out primarily at the Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL) and the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL). Neutrinos are elusive particles that permeate the universe and hardly interact with matter, yet are believed to play a key role in the explosion of stars. Recent experiments have shown that a neutrino oscillates among all of its three known types as it travels from its source—something that can only happen if neutrinos have tiny masses. Studies to better understand the properties of neutrinos, and in particular their masses, are primarily carried out with specialized detectors located deep underground or otherwise heavily shielded against background radiation. Measurements of symmetry properties, particularly of the neutron, are being developed by nuclear physicists at the Spallation Neutron Source (SNS) at ORNL. The following indicators establish specific long-term goals in Scientific Discovery that the NP program is committed to, and progress can be measured against:

- investigating new regions of nuclear structure, studying interactions in nuclear matter like those occurring in neutron stars, and determining the reactions that created the nuclei of the chemical elements inside stars and supernovae; and
- determining the fundamental properties of neutrinos and fundamental symmetries by using neutrinos from the sun and nuclear reactors and by using radioactive decay measurements.

The Nuclear Theory subprogram will contribute to Strategic Goals 3.1 and 3.2 by providing the theoretical underpinning needed to support the interpretation of a wide range of data obtained from all the other NP subprograms, with the ultimate aim of advancing knowledge and providing insights into the most promising avenues for future research. A major theme of this subprogram is an understanding of the mechanism of quark confinement and de-confinement—while it is expected to be explained by Quantum Chromodynamics (QCD), a quantitative description remains one of this subprogram's great intellectual challenges. New theoretical tools will be developed to describe nuclear many-body phenomena, with important applications to condensed matter and other areas of physics. Understanding what consequences neutrino mass has for nuclear astrophysics and for the current theory of elementary particles and forces is also of prime importance. Computing resources are being developed to tackle challenging calculations of sub-atomic structure, such as those of Lattice Gauge QCD.

The Nuclear Theory subprogram also supports an effort in nuclear data that collects, evaluates and disseminates nuclear physics data for basic nuclear research and for applied nuclear technologies. These extensive nuclear databases are a national resource consisting of carefully organized scientific information that has been gathered over 50 years of low-energy nuclear physics research worldwide.

Funding by Strategic and GPRA Unit 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 3.1/2.47.00 Explore Nuclear Matter - from Quarks to Stars			
Nuclear Physics	357,756	454,060	471,319

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 3.1/2.47.00 – Explore Nuclear Matter, from Quarks to the Stars					
Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 11%, on average, of total scheduled operating time. [Met Goal]	Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 12%, on average, of total scheduled operating time. [Met Goal]	Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 13%, on average, of total scheduled operating time. [Met Goal]	Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 6%, on average, of scheduled operating time. [Met Goal]	Average achieved operation time of the scientific user facilities as a percentage of the total scheduled annual operation time will be greater than 80%.	Average achieved operation time of the scientific user facilities as a percentage of the total scheduled annual operation time will be greater than 80%.
					Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects will be within 10%.
Medium Energy Nuclear Physics					
As elements of the electron beam program, (a) completed commissioning of the BLAST detector at MIT/Bates and initiated first measurements, and (b) completed fabrication, installation and commissioning of the G0 detector, a joint NSF-DOE project at TJNAF. [Mixed Results]	As elements of the electron beam program, (a) collected first data with the BLAST detector at MIT/Bates, studying the structure of nucleons and few body nuclei and (b) collected first data to map out the strange quark contribution to nucleon structure using the G0 detector, utilizing the high intensity polarized electron beam developed at TJNAF. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (2.83), Hall B (8.06), and Hall C (2.11), respectively, at the Continuous Electron Beam Accelerator Facility. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (1.77), Hall B (9.9), and Hall C (1.9), respectively, at the Continuous Electron Beam Accelerator Facility. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (2.2), Hall B (11.6), and Hall C (2.6), respectively, at the Continuous Electron Beam Accelerator Facility.	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (4), Hall B (20) and Hall C (5), respectively, at the Continuous Electron Beam Accelerator Facility.
				Weighted average number (within 30% of baseline estimate) of millions of proton collision events sampled by the PHENIX (120,000) and recorded by the STAR (158) detectors, respectively during the polarized proton run at the Relativistic Heavy Ion Collider.	Weighted average number (within 30% of baseline estimate) of millions of proton collision events sampled by the PHENIX (600,000) and recorded by the STAR (40) detectors, respectively during the polarized proton run at the Relativistic Heavy Ion Collider.

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
Heavy Ion Nuclear Physics					
Completed first round of experiments at RHIC at full energy; achieved the full design luminosity (collision rate) of 2 x 10^{26} cm^{-2} s^{-1} for heavy ions. [Met Goal]	Initiated first round of experiments with collisions with other ions to compare to results of gold-gold collisions. [Met Goal]	Weighted average number (within 30% of baseline estimate of millions of events sampled by the PHENIX (900) and recorded by the STAR (40) detectors, respectively, at the Relativistic Heavy Ion Collider. [Met Goal]	No Target. (The Relativistic Heavy Ion Collider did not operate in heavy ion mode during FY 2006)	Weighted average number (within 30% of baseline estimate) of millions of events sampled by PHENIX (30,000) and recorded by the STAR (100) detectors, respectively during the heavy ion run at the Relativistic Heavy Ion Collider.	Weighted average number (within 30% of baseline estimate) of millions of events sampled by the PHENIX (7,500) and recorded by the STAR (60) detectors, respectively during the heavy ion run at the Relativistic Heavy Ion Collider.
Low Energy Nuclear Physics					
		Weighted average number (within 20% of baseline estimate of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (28.1) and Holifield Radioactive Ion Beam (3.76) facilities, respectively. [Met Goal]	Weighted average number (within 20% of baseline estimate of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (24.6) and Holifield Radioactive Ion Beam (7.1) facilities, respectively. [Met Goal]	Weighted average number (within 20% of baseline estimate of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (22) and Holifield Radioactive Ion Beam (1.8) facilities, respectively.	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (22) and Holifield Radioactive Ion Beam (2.4) facilities, respectively.

Means and Strategies

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

NP will support innovative, peer reviewed scientific research to advance knowledge and provide insights into the nature of energy and matter, in particular to investigate the fundamental forces that hold the nucleus of the atom together and determine the detailed structure and behavior of atomic nuclei. The program also builds and supports the forefront scientific facilities and instruments necessary to carry out that research. All research projects undergo regular peer review and merit evaluation based on procedures set down in 10 CFR 605 for the extramural grant program and under a similar process for laboratory programs and scientific user facilities. All 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 SC mission statements and strategic plans; (2) evolving scientific opportunities, which sometimes emerge in a way that revolutionizes disciplines; (3) results of external program reviews and international benchmarking activities of entire fields or subfields, such as those reviews performed by the National Academy of Sciences; (4) unanticipated failures, for example, in critical components of scientific user facilities, that cannot be mitigated in a timely manner; and (5) strategic and programmatic decisions made by other Federal agencies and by international entities.

NP is closely coordinated with the research activities of the NSF. The major scientific facilities required by NSF-supported scientists are usually the DOE facilities. NSF often jointly supports the fabrication of major research equipment at DOE user facilities. DOE and NSF jointly charter the Nuclear Science Advisory Committee (NSAC).

Scientists supported by NP collaborate with researchers from many countries. Large numbers of foreign scientists, who provide monetary and equipment support, heavily utilize all of the NP national user facilities. The program also supports some collaborative work at foreign accelerator facilities. The program promotes the transfer of the results of its basic research to a broad set of technologies involving advanced materials, national defense, medicine, space science and exploration, advanced computing, and industrial processes. In particular, nuclear reaction data are an important resource for these programs. NP user facilities are utilized by other SC programs, other DOE Offices (e.g., National Nuclear Security Administration and Nuclear Energy), other Federal agencies (e.g., NSF, NASA, and Department of Defense) and industry to carry out their programs.

Validation and Verification

Progress against established plans is evaluated by periodic internal and external performance reviews. These reviews provide an opportunity to verify and validate performance. Periodic assessments 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 NP program has incorporated feedback from OMB and has taken or will take the necessary steps to continue to improve performance.

In the FY 2005 PART assessment, OMB gave the NP program a rating of "Effective". OMB found the program's management to be excellent with a relatively transparent budget justification and a fully engaged advisory committee that produces fiscally responsible advice. The assessment found that NP has developed a limited number of adequate performance measures which are continued for FY 2008. These measures have been incorporated into this budget request, NP 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, SC 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 NSAC are also available on the website. NSAC will review the progress towards achieving the long term Performance Measures every five years. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report.

OMB has previously provided NP with three recommendations to further improve performance:

- Respond to the recommendations of recent advisory committee reports, including implementing a budget-constrained and phased plan for the future of its research facilities.
- Engage the National Academies, including experts outside of nuclear physics, to study the scientific capabilities of a proposed rare isotope accelerator in an international context.
- Maximize operational efficiency of major experimental facilities in response to increasing power costs.

In response to the OMB recommendations, NP:

- Continues to engage its advisory committee in a manner that produces responsible strategic advice within realistic budget scenarios. In 2006, DOE and NSF charged NSAC to develop a new long-range plan for nuclear science; a report is expected by the end of 2007. This 2008 budget request is one of many actions that NP is taking to respond to the recommendations of recent NSAC reports.
- Continues to use external expert assessments (Committee of Visitors [COVs]) to review the quality, relevance, and performance of the program's research portfolio and grant management process. The last COV review was held January 9-11, 2007.
- Engaged the National Academies to study the scientific opportunities of a proposed rare isotope beam facility and has encouraged broad representation from the scientific community. The final Academies report will be available in spring 2007 and posted at http://www.sc.doe.gov/np/.
- Continues to maximize the utilization and efficiency of major experimental facilities to ensure that the Nation's Nuclear Physics program achieves maximum results. In addition to annual science and technology reviews of each of its facilities, NP conducted a focused review on optimizing operational efficiency of its four national user facilities in the summer of 2006.

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

Overview

Nuclear science began by studying the structure and properties of atomic nuclei as assemblages of protons and neutrons. Research focused on nuclear reactions, the nature of radioactivity, and the synthesis of new isotopes and new elements heavier than uranium. Great benefits, especially to medicine, emerged from these efforts. But today, nuclear science is much more than this. Its reach extends from the quarks and gluons that form the substructure of the once-viewed-as-elementary protons and neutrons, to the most dramatic of cosmic events—supernovae. At its heart, nuclear physics attempts to understand the composition, structure, and properties of atomic nuclei; however, the field is driven by the following broad questions as stated by the Nuclear Science Advisory Committee (NSAC) in the *Opportunities in Nuclear Science: A Long-Range Plan for the Next Decade (2002)*.

- *What is the structure of the nucleon?* Protons and neutrons are the building blocks of nuclei and neutron stars. But these nucleons are themselves composite objects having a rich internal structure. Connecting the observed properties of the nucleons with an underlying theoretical framework, known as Quantum Chromodynamics (QCD), is one of the central goals of modern nuclear physics.
- *What is the structure of nucleonic matter?* Nuclear physics strives to explain the properties of nuclei and of nuclear matter. The coming decade will focus especially on unstable nuclei, where we expect to find new phenomena and new structure unlike anything known from the stable nuclei of the world around us. With new theoretical tools, we hope to build a bridge between the fundamental theory of strong interactions and the quantitative description of nuclear many-body phenomena, including the new and exotic properties we expect in unstable nuclei and in neutron stars.
- *What are the properties of hot nuclear matter?* The quarks and gluons that compose each proton and neutron are normally confined within the nucleon. However, QCD predicts that, if an entire nucleus is heated and compressed sufficiently, individual nucleons will lose their identities, the quarks and gluons will become “deconfined,” and the system will behave as a plasma of quarks and gluons. With the Relativistic Heavy Ion Collider (RHIC), the field’s newest accelerator, nuclear physicists are now hunting for this new state of matter.

Other major questions identified by NSAC, of equal importance for nuclear physics as those above, overlap with major questions that drive the fields of astrophysics and particle physics. These are:

- *What is the nuclear microphysics of the universe?* A great many important problems in astrophysics—the origin of the elements; the structure and cooling of neutron stars; the origin, propagation, and interactions of the highest-energy cosmic rays; the mechanism of core-collapse supernovae and the associated neutrino physics; galactic and extragalactic gamma-ray sources—involve fundamental nuclear physics issues. The partnership between nuclear physics and astrophysics will become ever more crucial in the coming decade, as data from astronomy’s “great observatories” extend our knowledge of the cosmos.
- *What is to be the new Standard Model?* The resolution of the solar and atmospheric neutrino puzzles by the Sudbury Neutrino Observatory (SNO) and the SuperKamiokande Detector may require the addition of supersymmetry to the Standard Model. Precision nuclear physics experiments deep underground and at low energies are proving to be an essential complement to searches for new physics in high-energy accelerator experiments.

How We Work

The Nuclear Physics program uses a variety of mechanisms for conducting, coordinating, and funding nuclear physics research. The program is responsible for planning and prioritizing all aspects of supported research, conducting ongoing assessments to ensure a comprehensive and balanced portfolio, regularly seeking advice from stakeholders, supporting the core university and national laboratory programs, and maintaining a strong infrastructure to support nuclear physics research. The R&D Investment Criteria’s relevance principles encourage research community investments in making program priorities. The NSAC and Program Advisory Committees (PACs) at our facilities have served the program well in this respect. Quality and performance are assured by peer-review of research projects and facility operations. The performance data obtained in facility and program reviews, as well as Annual Performance Results and Targets, are used in assuring quality and in making funding decisions.

Advisory and Consultative Activities

To ensure that resources are allocated to the most scientifically promising research, the DOE and its national user facilities actively seek external input using a variety of advisory bodies.

The NSAC provides advice to the DOE and the NSF on a continuing basis regarding the direction and management of the national nuclear sciences basic research program. In FY 2007, the DOE Nuclear Physics program will provide about 90% of the federal support for fundamental nuclear physics research in the Nation. The NSF provides most of the remaining support. One of the most important functions of NSAC is the development of long-range plans that express community-wide priorities for the upcoming decade of nuclear physics research. NSAC regularly conducts reviews that evaluate the scientific productivity of and opportunities in major components of the Office's research program and proposed major new initiatives, and provides advice regarding scientific priorities. In 2005 DOE and NSF requested that NSAC and the High Energy Physics Advisory Panel (HEPAP) jointly appoint a Neutrino Science Assessment Group (NuSAG) to assess and make recommendations concerning opportunities in neutrino science. NuSAG has responded with two reports on these opportunities: on experiments to search for neutrino-less double beta decay and hence discover if the neutrino is its own anti-particle, and determine or limit the neutrino mass; and on the measurement of neutrino oscillation mixing parameters utilizing neutrinos produced by reactors and accelerators. NuSAG is continuing to assess the opportunities for long baseline accelerator experiments to probe non-conservation on CP (charge-parity symmetry) in the neutrino sector. The published reports can be found at http://www.sc.doe.gov/np/nsac/nsac.html. In FY 2006, NSAC was presented with charges for a Committee of Visitors (COV) review of the Office of Nuclear Physics, to evaluate the scientific reach and technical options for a rare isotope beam facility, and to develop a new long-range plan. A report on the COV is expected early in 2007, a report on the rare isotope facility is expected in spring 2007, and the report on the long-range plan is expected by the end of 2007.

The National Academy of Sciences (NAS) was charged with carrying out an independent assessment of the importance of the science portfolio available to a next generation rare isotope beam facility. The draft report, *Scientific Opportunities with a Rare Isotope Facility in the United States,* completed in December 2006, addresses the role of a U.S. world-class rare isotope beam facility for the future of U.S. and international nuclear physics.

Facility directors seek advice from PACs to determine the allocation of scarce scientific resources—the available beam time. The committees are comprised of members mostly external to the host laboratory who are appointed by the facility director. PACs review research proposals requesting time at the facilities and technical resources, and provide advice on a proposal's scientific merit, technical feasibility, and personnel requirements. The PAC also provides recommendations for proposals to be approved, conditionally approved, deferred, or rejected.

Facility Science and Technology Reviews

Science and Technology (S&T) Reviews of the NP program's four National User Facilities – RHIC, CEBAF, ATLAS, and HRIBF – are conducted annually with external experts from U.S. and foreign institutions to assess the performance and scientific productivity of the facilities. The results of the review are compared to goals defined in approved Laboratory Performance Evaluation Management Plans, and the NP program's assessment of the laboratory performance is documented in annual

Laboratory appraisals. During the summer 2006, NP conducted a review focused on optimizing the operating efficiency of NP accelerator facilities.

In addition, the NP program also reviews, with international experts, proposed and ongoing instrumentation projects to assess project plans and performance. These reviews focus on scientific merit, technical status and feasibility, cost and schedule, and effectiveness of management organizations. Such reviews are conducted on an annual basis and provide important input in establishing cost and schedule profiles necessary for budget formulation and execution, and assessing project performance.

Program Reviews

Quality and productivity of university grants are peer reviewed on a three-year basis and laboratory groups performing research are peer reviewed on a four-year basis. NSAC periodically reviews the major elements of the Nuclear Physics program. These reviews examine scientific progress in each program element against the previous long-range plan, assess the scientific opportunities, and recommend reordering of priorities based upon existing budget profiles. The most recent reviews were of the Theory subprogram in 2004, the Heavy Ion subprogram in 2005, and the Medium Energy subprogram in 2006. The Low Energy subprogram will be reviewed in 2007.

Planning and Priority Setting

The strategic plan for NP is set forth in the DOE and SC Strategic Plans. NP develops its strategic plan with input from the scientific community. One of the most important activities of NSAC is the development of long-range plans that serve as a framework for the coordinated advancement of the field for the coming decade. These plans are undertaken every five to six years to review the scientific opportunities in the field, perform retrospective assessments of the major accomplishments by the field, and set priorities for the future. The plan provides guidance and recommends priorities for new construction projects. For example, the 12 GeV CEBAF Upgrade was identified as a high priority in the 2002 NSAC Long-Range Plan, and was incorporated into NP's strategic plan. The Upgrade was identified as a near-term priority in the SC future facilities outlook, (Facilities for the Future of Science: A Twenty-Year Outlook) and is included in the FY 2008 budget with a request for continued support to complete Project Engineering and Design (PED) activities.

The DOE and NSF have charged NSAC to develop a new long-range plan for nuclear science, with the input of the research community, to provide guidance to the agencies into the next decade. This plan will be available by the end of 2007.

Guidance from the NSAC long-range plans are augmented by NSAC reviews of subfields. Priorities identified in NSAC reviews of the Medium Energy and Low Energy subprograms were important input for the programmatic decisions to terminate user facilities operations of the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL) in FY 2004 and of the Bates Linear Accelerator Center at the Massachusetts Institute of Technology in FY 2005. NSAC guidance on scientific opportunities and priorities, provided in reviews of neutron science, the Nuclear Theory and Heavy Ion subprograms, and the FY 2006 review of the Medium Energy subprogram is reflected in the programmatic decisions in the FY 2007 and FY 2008 budget requests. NSAC's guidance from its review of the entire program in the context of constrained funding, transmitted in a June 2005 report, is taken into account for the FY 2008 budget. These decisions have been made to maximize the scientific impact, productivity, quality and cost-effectiveness of the program within the resources available.

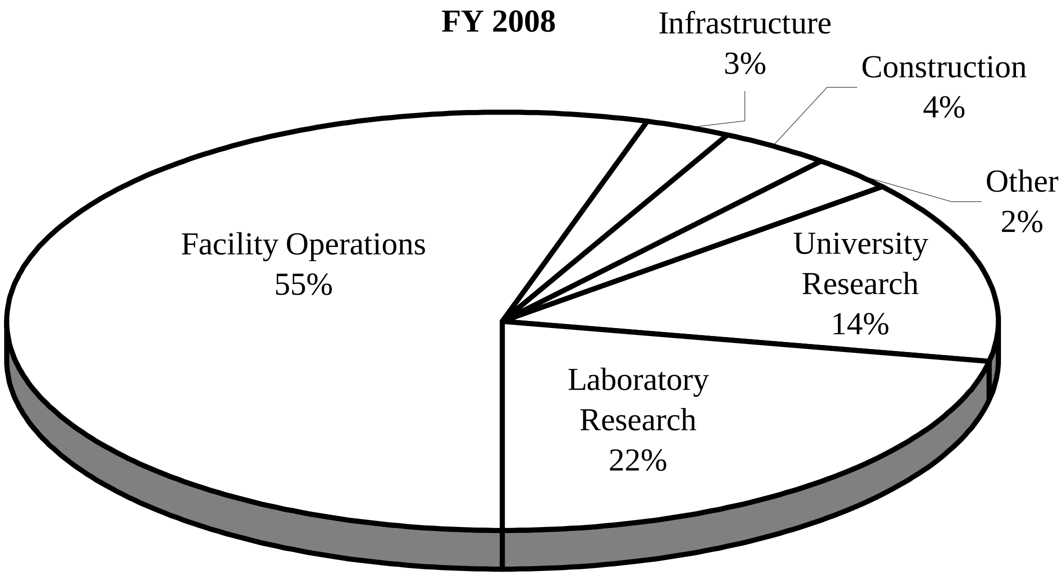
In order to better coordinate interagency activities, NP continues to participate in the Interagency Working Group (IWG) that developed the National Science and Technology Council (NSTC) Report: A 21st Century Frontier for Discovery: The Physics of the Universe—A Strategic Plan for Federal

Research at the Intersection of Physics and Astronomy. NP is playing a leading role in two of the major scientific thrusts identified in this report: Origin of Heavy Elements and High Energy Density Physics. Funding is continued in FY 2008 to partially support the thrust on the Origin of the Heavy Elements at existing low energy facilities and to support aspects of High Energy Density Physics with heavy ions at RHIC and participation in the heavy ion program at the LHC, all in the context of the Nuclear Physics mission.

How We Spend Our Budget

The FY 2008 budget request is focused on optimizing, within the resources available, the scientific productivity of the program by ensuring a proper balance of research workforce, facility operations, and investments in needed tools and capabilities. 36% of the funding is provided for research personnel to utilize the program's user facilities, complete important experiments and to fabricate experimental instrumentation. 55% of the funding is provided for operations of the program accelerator facilities. 7% is provided for infrastructure and for construction projects that are needed to extract the science and improve efficiencies in the outyears and 2% for other activities that include Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) programs.

Nuclear Physics Budget Allocation
FY 2008



Research

About 36% of the program's funding is provided to scientists at universities and laboratories to conceive and carry out the research. The NP program involves over 1,900 researchers and students at over 100 U.S. academic, federal and private sector institutions. The program funds research activities at approximately 85 academic institutions located in 34 states and the District of Columbia and at 7 DOE laboratories in 6 states. Funding is increased by 3.9% compared to FY 2007. National laboratory research scientists work together with the experimental collaborations to collect and analyze data as well as support and maintain the detectors. The laboratories provide state-of-the-art resources for detector and accelerator R&D for future upgrades and new facilities. The division of support between national laboratories and universities is adjusted to maximize scientific productivity.

- **University Research**: University researchers play a critical role in the Nation's research effort and in the training of graduate students. In FY 2007, the DOE Nuclear Physics program supports approximately two-thirds of the Nation's university researchers and graduate students doing fundamental nuclear physics research. Among the 85 academic institutions, DOE supports researchers at university Centers of Excellence that include laboratories with local accelerators (Texas A&M Cyclotron Laboratory, Triangle Universities Nuclear Laboratory (TUNL) at Duke University, and Yale University), the Center for Experimental Nuclear and Particle Astrophysics (CENPA) at the University of Washington, the Research and Engineering Center at the Massachusetts Institute for Technology, and the Institute for Nuclear Theory at the University of Washington. In recent years about 80 Ph.D. degrees have been granted annually to students for research supported by the program. Approximately one-half of those who received nuclear science Ph.D.'s pursue careers outside universities or national laboratories in such diverse areas as nuclear medicine, medical physics, space exploration, and national security.

  The university grants program is proposal driven. The Nuclear Physics program funds the best and brightest of those ideas submitted in response to grant solicitation notices (see http://www.sc.doe.gov/grants/). Proposals are reviewed by external scientific peers and competitively awarded according to the guidelines published in 10 CFR 605.

- **National Laboratory Research**: The Nuclear Physics program supports national laboratory-based research groups at Argonne, Brookhaven, Thomas Jefferson, Los Alamos, Lawrence Berkeley, Lawrence Livermore, and Oak Ridge National Laboratories. The directions of laboratory research programs are driven by the needs of the Department and are highly tailored to the major scientific facilities at the laboratories. Collaborations of laboratory researchers with academic users of the facilities are important for developing and maintaining the large experimental detectors and computing facilities for data analysis. Nuclear Physics program funding plays an important role in supporting basic research that can improve applied programs, such as proton radiography, neutron-capture reaction rates, properties of radioactive nuclei, etc.

  The Nuclear Physics program funds field work proposals from the national laboratories. Performance of the laboratory groups is reviewed approximately every four years to examine the quality 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. In FY 2006, the research of national laboratory Medium Energy groups was reviewed.

Nuclear physics has made important contributions to our knowledge about the universe in which we live and has had great impact on human life. Knowledge and techniques developed in pursuit of fundamental nuclear physics research are extensively utilized in our society today. The understanding of nuclear spin enabled the development of magnetic resonance imaging for medical use. Radioactive isotopes produced by accelerators are used for medical imaging, cancer therapy, and biochemical studies. Particle beams are used for cancer therapy and in a broad range of materials science studies. Advances in cutting-edge instrumentation developed for nuclear physics experiments, such as high-resolution gamma ray detectors, have relevance to technological needs in combating terrorism.

Significant Program Shifts

The FY 2008 budget request continues overall operations of the four National User Facilities and research efforts at universities and laboratories at approximately FY 2007 levels. At this level, the NP-supported user facilities allow researchers to make effective progress towards the program's scientific goals and milestones, and investments are made in new capabilities to address compelling scientific opportunities and maintain U.S. competitiveness in global Nuclear Physics efforts.

New instrumentation initiatives include U.S. contributions to the Italian Cryogenic Underground Observatory for Rare Events (CUORE) project, a neutrino-less double beta decay experiment that will measure the absolute mass of the neutrino, and upgrades to the RHIC PHENIX experiment to install new detectors important for both the heavy ion and spin programs.

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) activity is a set of coordinated investments across all SC mission areas with the goal to achieve breakthrough scientific advances through computer simulation that were impossible using theoretical or laboratory studies alone. By exploiting advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model of multi-discipline collaboration among the scientific disciplines, computer scientists and mathematicians.

In FY 2006 applications for new SciDAC projects were evaluated and the Nuclear Physics program is currently funding grants in the areas of theoretical physics (National Computational Infrastructure for Lattice Gauge Theory), astrophysics (Computational Astrophysics Consortium), grid technology (Open Science Grid), and low energy nuclear structure and reactions (Building a Universal Nuclear Energy Density Functional) that support the scientific goals of the Nuclear Physics subprograms. The National Computational Infrastructure for Lattice Gauge Theory has an aim to make precision numerical calculations of QCD in order to determine the structure and interactions of hadrons and the properties of nuclear matter under extreme conditions. This activity provides results coordinated with a similar activity by the High Energy Physics (HEP) program. The principal goal of the Computational Astrophysics Consortium is to understand in detail the explosion mechanism of Type 1 supernovae that are used as "standard candles" to determine cosmological distances in the universe and to highlight nuclear uncertainties in understanding of nucleosynthesis in stars and supernovae; uncertainties that could guide the program of new rare isotope beam experimental facilities. The Open Science Grid project is allowing nuclear physics experiments to continue the task of replicating and transmitting across the globe thousands of files at high speeds with rates in excess of 3-4 terabytes/week. The Universal Nuclear Energy Density Functional has as its aim the creation of a unified theory of nuclear structure and reactions grounded in fundamental theory by developing a Universal Nuclear Energy Density Functional (UNEDF) to predict nuclear properties and reactions with unprecedented accuracy and clearly-defined uncertainties. This new capability will address old issues of nuclear science but is primarily aimed at the theoretical calculation of the structure and reactions of rare nuclei that will become accessible at new experimental facilities and are important to explore new phenomena in nuclei, and to calculate reactions crucial to understanding the origin of the elements heavier than iron and applied nuclear areas.

Scientific Facilities Utilization

NP's four National User Facilities provide research time for scientists in universities and other Federal laboratories in FY 2008.

- The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL);
- The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF);
- The Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL); and

- The Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL).

These facilities provide beams for research for a user community of about 3,000 U.S. and international scientists. The FY 2008 budget request will support operations at these facilities that will provide an estimated 19,035 hours of beam time for research, similar to the anticipated beam hours in FY 2007.

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

	FY 2006	FY 2007	FY 2008
Number of Facilities	4	4	4
Optimal Hours	22,675	22,675	22,400
Planned Operating Hours	11,435	19,015	19,035
Achieved Operating Hours	16,757	N/A	N/A
Unscheduled Downtime—Major user facilities	6.4%	N/A	N/A
Number of Users[a]	2,670	1,990	3,035

Achieved operating hours in FY 2006 do not include RHIC/BNL running which used non-DOE funds for operating in FY 2006. The achieved operating hours exceeded planned operating hours in FY 2006 because ATLAS/ANL deferred a planned maintenance shutdown period into FY 2007 to permit additional running (which will impact FY 2007 operations), TJNAF focused on lower energy running which is less costly, and HRIBF focused on the less costly stable beam running instead of radioactive beam running.

Construction and Infrastructure

Funding is provided in the FY 2008 request to complete construction of the RHIC Electron Beam Ion Source (EBIS), a joint DOE/NASA project. Critical Decision-2 (CD-2), Approve Performance Baseline, and CD-3, Approve Start of Construction, for the EBIS project were approved in FY 2006. The EBIS will replace the aging Tandems as a new pre-injector for RHIC, offering increased reliability and efficiency, and reduced operating costs.

Project engineering and design funds are provided in FY 2008 for the 12 GeV CEBAF Upgrade at TJNAF to complete design activities; funding is also provided to complete the R&D portion of the project. The Upgrade project will enable scientists to address the mechanism that “confines” quarks together with a scientific portfolio that cannot be addressed at any other machine in the world. The SC Office of Project Assessment conducted a Project Status Review in 2006 of the 12 GeV CEBAF Upgrade project to evaluate the R&D progress and project performance. Critical Decision-1 (CD-1), Approve Alternative Selection and Cost Range, was approved in FY 2006.

The Nuclear Physics program provides funding for general plant projects (GPP) at BNL and TJNAF and general purpose equipment (GPE) at BNL to address laboratory infrastructure needs. Facility capital equipment and accelerator improvement project support is provided to the four NP National User Facilities (RHIC, TJNAF, HRIBF, and ATLAS) to provide modest new capabilities and address facility infrastructure needs. Nuclear Physics will meet the cost and schedule milestones for construction of facilities and fabrication of Major Items of Equipment (MIE) within 10% of baseline estimates.

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[a] The counting of users at the NP facilities has been improved to ensure consistent counting methodology from one facility to the next and to remove possible double counting. The more accurate count is reflected in the FY 2008 column, which is similar to projections for 2007.

Workforce Development

The Nuclear Physics program supports development of the Research and Development (R&D) workforce through support of undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. The R&D workforce developed under this program provides new scientific talent in areas of fundamental research. It also provides talent for a wide variety of technical, medical, security and industrial areas that require the problem-solving abilities and the computing and technical skills developed through an education and experience in a fundamental research field. Scientists trained as nuclear physicists can be found in such diverse areas as nuclear medicine, medical physics, space exploration, and national security. The Outstanding Junior Investigator (OJI) program, initiated in FY 2000, through approximately three new awards each year, has been very successful in identifying, recognizing, and supporting promising young faculty and future leaders of the field.

About 830 postdoctoral research associates and graduate students supported by the Nuclear Physics program in FY 2006 were involved in a large variety of experimental and theoretical research projects. Over one fifth of these researchers are involved in theoretical research. Those involved in experimental research utilize a number of scientific facilities supported by the DOE, NSF, and foreign countries. The majority of the experimental postdoctoral associates and graduate students (~80%) conducted their research at the Nuclear Physics user facilities.

Details of the DOE Nuclear Physics workforce are given below. Almost all university grants are awarded with project periods of three years.

	FY 2006 actual	FY 2007 estimate	FY 2008 estimate
# University Grants	180	190	190
Average size (excluding CE)	$305,000	$340,000	$355,000
# Laboratory Groups	27	27	27
# Permanent Ph.D.'s	590	650	640
# Postdoctoral Associates	344	380	370
# Graduate Students	486	500	490
# Ph.D.'s awarded	92	80	80

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 is financed via the Working Capital Fund to achieve parity on how EIRs are funded and to standardize the administration of these critical activities.

Medium Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Medium Energy Nuclear Physics			
Research			
University Research	15,748	18,103	18,646
National Laboratory Research	15,162	16,983	17,567
Other Research[a]	688	5,684	5,917
Total, Research	31,598	40,770	42,130
Operations			
TJNAF Operations	69,063	80,011	79,249
Bates Facility	2,500	2,000	2,000
Total, Operations	71,563	82,011	81,249
Total, Medium Energy Nuclear Physics	103,161	122,781	123,379

Description

The Medium Energy Nuclear Physics subprogram supports fundamental research directed primarily at answering the first of the five central questions listed in the 2002 Nuclear Science Advisory Committee Long-Range Plan:

> *What is the structure of the nucleon?* A quantitative understanding of the internal structure of the nucleons (protons and neutrons) requires a description of their observed properties in terms of the underlying quarks and gluons of Quantum Chromodynamics (QCD), the theory of "strong" interactions. Furthermore, this understanding would allow the nuclear binding force to be described in terms of the QCD interactions among the quarks.

Benefits

The matter that makes up our world is the result of a unique property of the strong interaction called "confinement" that binds quarks and gluons together to form nucleons, the building blocks of atomic nuclei. Confinement prevents quarks or gluons from ever existing in isolation; they always bind in complex structures to form subatomic particles. Characterizing confinement and how it gives these subatomic particles, specifically protons and neutrons, their particular properties is the focus of the Medium Energy subprogram. By providing precision experimental information concerning the quarks and gluons that form the protons and neutrons, this subprogram, in coordination with the Theory subprogram, seeks to provide a quantitative description of these particles in terms of the fundamental theory of the strong interaction, QCD. This work provides a basis for our description of matter in terms of its fundamental constituents and strengthens scientists' ability to explore how matter will behave under conditions that cannot be duplicated by humans.

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[a] In FY 2006, $3,450,000 has been transferred to the SBIR program and $994,000 has been transferred to the STTR program. This activity also includes $3,615,000 for SBIR and $1,185,000 for STTR in FY 2007 and $3,934,000 for SBIR and $1,224,000 for STTR in FY 2008.

The laws of quantum physics state that the angular momenta of quarks and gluons should add up to the proton's known spin (intrinsic angular momentum), but experimental data hint that quarks by themselves account for about 20% of the proton's spin. During the 2006 RHIC running, polarized protons were accelerated to the highest energies ever recorded—250 billion electron volts (GeV) or two-and-a-half times the typical proton collision energies studied at RHIC. From the preceding proton runs at RHIC, researchers got their first exciting glimpses of results that depend on the contribution of gluons to the proton's spin. The latest run, the first in series of planned runs for amassing high-statistics, will provide accurate results on the gluon contribution and set the stage for colliding protons at much higher energies where the spin-flavor quark structure of nucleon could be measured directly using maximal parity violation for production of W bosons. To accomplish these tasks, the Medium Energy subprogram operates the CEBAF at the Thomas Jefferson National Accelerator Facility (TJNAF), supports research at the RHIC at Brookhaven National Laboratory (BNL), and supports university researchers to carry out the experiments at these facilities and elsewhere. These research activities contribute to the training of the next generation of scientists and engineers that will contribute to the Department's energy and national security missions.

Supporting Information

To achieve an experimental description of the nucleon's substructure, the Medium Energy subprogram supports different approaches that focus on: (1) determining the distribution of up, down, and strange quarks in the nucleons, the role of the "sea" of virtual quarks and gluons (which makes a significant contribution to the properties of protons and neutrons) and the dynamic degrees of freedom of the quarks by measuring the excited states of hadrons (any composite particle made of quarks, such as nucleons); and (2) determining the effects of the quark and gluon spins within the nucleon and the properties of simple, few-nucleon systems, with the aim of describing them in terms of their fundamental components.

Most of this work has been done at the subprogram's primary research facility, TJNAF, as well as a major research effort at RHIC. Individual experiments are supported at the High Intensity Gamma Source (HIGS) at Triangle University Nuclear Laboratory, Fermilab, and facilities in Europe. All these facilities produce beams of sufficient energy (small enough wavelength) to probe at a distance scale within the size of a nucleon. The operation of the National User Facility, CEBAF at TJNAF, annually serves a nationwide community of about 800 DOE and National Science Foundation (NSF) supported scientists and students from over 80 U.S. institutions and about 400 scientists from 19 foreign countries. The NSF and foreign collaborators have made significant investments in experimental equipment. Allocation of beam time at TJNAF has been based on guidance from a Program Advisory Committee that reviews and evaluates proposed experiments regarding their merit and scientific priority.

FY 2006 Accomplishments

Scientists supported by this subprogram have made important discoveries in the past decade with advances in both theory and experiments that spurred interest in quantitatively understanding nucleons in terms of the quarks and gluons of QCD. The NSAC Long-Range Plan summarized important accomplishments of the field up to 2002; since then accomplishments are summarized yearly in the budget submission. Recent Medium Energy subprogram developments include:

- The MiniBooNE neutrino oscillation experiment has completed its neutrino data taking after collecting over 7,000,000 neutrino events, achieving its planned goal. The experiment is now taking data with antineutrinos. Analysis of the neutrino data is in its final phase; these results should resolve the question of whether there is an additional type of neutrino (beyond the three known neutrinos) that is suggested in the results of a previous experiment.

- Recent results obtained at CEBAF in Deeply Virtual Compton Scattering experiments demonstrate the feasibility of the technique for determining the General Parton Distributions (GPDs). GPDs provide the opportunity to produce for the first time 3D images of the internal structure of the nucleon and will be a major component of the planned 12 GeV CEBAF Upgrade scientific program.
- Results from CEBAF have significantly improved our knowledge of the role the strange quark plays in the charge and current distributions of the proton and of the charge distribution of the neutron. These results constitute a major milestone in establishing the fundamental properties of the nucleon.
- Measurements with polarized protons at RHIC indicate that the contribution of the gluons to the proton's spin is small. The 2006 spin data set will allow studies of the gluon polarization with greater sensitivity and may provide first measurements on gluon polarization using direct photons. Measurements indicate that the quarks that form the proton contribute only about 20% to the proton's spin.

FY 2006 Facility and Technical Accomplishments

- The successful implementation and operation of a state-of-the-art Time Project Chamber (TPC) together with frozen spin hydrogen and deuterium "ice" targets represent a significant technical achievement and allowed for the successful completion of the Laser Electron Gamma Source (LEGS) experiment at Brookhaven National Laboratory in 2006. The LEGS measurements will provide unique sensitive tests of models describing the internal structure of protons and neutrons, particularly associated with their spin.
- The first demonstration in the world of atom trapping of radium was demonstrated at the Argonne National Laboratory. This technique opens the door to an electric dipole moment experiment using nuclei that could shed light on the matter over antimatter excess in the universe.
- TJNAF is a world leader in superconducting radiofrequency (SRF) technology. Several technical accomplishments in FY 2006 were realized including: a successful demonstration of a prototype superconducting accelerating cavity for use in next generation high power Free Electron Lasers to produce higher power (by a factor of 10-100) infrared light; modification of TJNAF SRF facilities to allow testing and developing of superconducting cavities for a possible International Linear Collider (ILC) with an electro-polished mirror-like inside surface (in collaboration with High Energy Physics); and development of a new manufacturing method of using high-purity niobium straight from the cast billet at the manufacturer to make high performing accelerating cavities, a method with potential cost savings for future accelerator projects.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Research	**31,598**	**40,770**	**42,130**
▪ **University Research**	**15,748**	**18,103**	**18,646**

These activities comprise a broad program of research, and include support of about 160 scientists and 125 graduate students at 36 universities in 19 states and the District of Columbia. The research efforts utilize not only the accelerator facilities supported under the Medium Energy subprogram, but also other U.S. and foreign accelerator laboratories.

Support is provided for university researchers and groups to effectively carry out the CEBAF and RHIC research programs, complete Bates data analysis and maintain staff at the MIT Research and Engineering (R&E) Center. Of this amount, $2,000,000 supports the R&E Center that is an integral component of MIT's medium energy research effort and utilizes the infrastructure remaining at the MIT/Bates facility to participate in fabrication of instrumentation relevant to the NP program's mission. Efforts at TJNAF are largely focused on the study of nucleon structure and its internal dynamics. In FY 2008, this includes research effort for the Q_{weak} experiment (an NSF/DOE effort with international contributions); a precision determination of the weak mixing angle as a constraint on new physics beyond the Standard Model; mapping out of the magnetic form factor of the deuteron to high momentum transfer; and studying quark-quark spin correlations by measuring polarized quark structure functions. Efforts at RHIC will focus on studies to determine the gluon contribution to the spin of the proton.

▪ **National Laboratory Research**	**15,162**	**16,983**	**17,567**

Support for experimental groups at TJNAF maintains CEBAF efforts at the level needed to effectively carry out the research program at the facility. Support for research efforts at Argonne, Brookhaven, and Los Alamos National Laboratories not associated with TJNAF is at a level that will allow these groups to achieve their planned NP goals.

• **TJNAF Research**	**5,671**	**6,163**	**6,362**

Scientists at TJNAF, with support of the user community, assembled the large and complex experimental detectors for Halls A, B, and C. TJNAF scientists provide necessary experimental support and operation of the detectors for safe and effective utilization by the user community. TJNAF scientists play a lead role in the laboratory's research program and their level of effort is maintained in FY 2008 relative to FY 2007. Due to the improvement of data acquisition infrastructure in the three halls, the data taking capabilities of the experiments have been improved.

• **Other National Laboratory Research**	**9,491**	**10,820**	**11,205**

Support for research activities at accelerator and non-accelerator facilities maintains a constant level of effort relative to FY 2007, with resources directed towards the highest priority activities that include those described below:

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

- ► Argonne National Laboratory scientists will continue their research program at TJNAF. The theme running through this entire effort is the search for a detailed understanding of the internal quark-gluon structure of the nucleon. ANL scientists have also made important advances in a new laser atom-trapping technique, Atom Trap Trace Analysis (ATTA), which will be used in measurements of rare isotopes for precision studies of nuclear structure and a search for an atomic electric dipole moment. ATTA provided the first demonstration in the world of atom trapping of radium in FY 2006. This result opens the door to an electric dipole moment experiment using nuclei that could shed light on the matter over antimatter excess in the universe.
- ► Support will be provided to the RHIC spin physics Medium Energy Research groups at BNL and Los Alamos National Laboratory (LANL). Both of these groups have important roles and responsibilities in the RHIC spin physics program.
- ► The LEGS experiment at BNL was completed in 2006. The FY 2008 request provides reduced support to complete the analysis of data.
- ► At LANL, scientists and collaborators are participating in the MiniBooNE neutrino oscillation experiment at Fermilab that hopes to determine whether a new type of neutrino exists. Support was provided in FY 2007 to complete this analysis. Reduced support in FY 2008 is provided to transition the group to other high-priority efforts or continue on this topic, dependent on the MiniBooNE result.

	FY 2006	FY 2007	FY 2008
▪ **Other Research**	**688**	**5,684**	**5,917**

In FY 2006, $3,450,000 has been transferred to the Small Business Innovation Research (SBIR) program and $994,000 has been transferred to the Small Business Technology Transfer (STTR) program. This activity includes $3,615,000 for SBIR and $1,185,000 for STTR in FY 2007 and $3,934,000 for SBIR and $1,224,000 for STTR in FY 2008 as well as other established obligations that the Medium Energy Nuclear Physics subprogram must meet.

	FY 2006	FY 2007	FY 2008
Operations	**71,563**	**82,011**	**81,249**
▪ **TJNAF Operations**	**69,063**	**80,011**	**79,249**

Funding supports CEBAF operations and Experimental Support for an approximate 34-week, 3-Hall operations schedule.

	FY 2006	FY 2007	FY 2008
• **TJNAF Accelerator Operations**	**46,930**	**53,711**	**52,202**

CEBAF operations are supported for a 34 week (4,705 hour) running schedule, a 6% decrease from estimated running in FY 2007, as funds are redirected towards the 12 GeV CEBAF Upgrade. At this level of funding the accelerator provides beams simultaneously to all three experimental halls. In FY 2008, support ($2,030,000) is directed at continuing necessary accelerator improvement projects (AIP) and General Plant Project (GPP) infrastructure improvements are maintained at levels comparable to FY 2007. Support ($1,630,000) is also provided to maintain efforts in developing advances in superconducting radiofrequency technology.

	FY 2006	FY 2007	FY 2008
(dollars in thousands)			

	FY 2006	FY 2007	FY 2008
CEBAF hours of operation with beam	5,646	4,985	4,705

CEBAF actual hours of operations in FY 2006 exceeded planned operations of 3,405 hours because CEBAF was operated a large fraction of the year at a low energy, which is less expensive than higher energy running, as well as running fewer experimental halls simultaneously. Operations savings were also realized through innovative cost saving techniques in cryogenics.

Funding of $1,000,000 is provided for R&D activities for the upgrade of CEBAF to 12 GeV. The upgrade is recommended as one of the highest priorities for Nuclear Physics in the 2002 NSAC Long-Range Plan for Nuclear Science, was identified as a near-term priority in the SC 20-Year Facilities Outlook, and received Alternate Selection and Cost Range (CD-1) approval by the Department of Energy in February 2006. An SC Office of Project Assessment Project Status Review of the project assessed the R&D plans and project performance, and results from the review are incorporated into this budget request. Project Engineering and Design funding is requested under the Construction section of this budget.

	FY 2006	FY 2007	FY 2008
• **TJNAF Experimental Support**	**22,133**	**26,300**	**27,047**

The FY 2008 request supports Experimental Support efforts at the level needed for a 34-week, 3-Hall operations schedule. Support is provided for the scientific and technical staff, materials, and services needed to support three hall operations and to integrate rapid assembly, modification, and disassembly of large and complex experiments for optimization of schedules. This includes the delivery or dismantling of cryogenic systems, electricity, water for cooling, radiation shielding, and special equipment for specific experiments.

FY 2008 funds for capital equipment ($4,950,000) are used for assembly and installation of ancillary equipment items such as polarized targets for experimental Halls A, B, and C; spectrometer systems; the completion of an upgrade of the data reduction system to handle massive amounts of raw data; and the continuation of the fabrication of second generation experiments. The Q_{weak} detector system is being fabricated to perform a precision measurement of the weak charge of the proton.

	FY 2006	FY 2007	FY 2008
▪ **Bates Facility**	**2,500**	**2,000**	**2,000**

Operation of the MIT/Bates Linear Accelerator Center was phased out and pre-D&D activities were started in FY 2005. Discussions with MIT regarding disposal of property and the final state of the site have been completed. Funds in the amount of $2,000,000 are provided as part of the agreement which turns ownership of the facility over to MIT in exchange for MIT assuming responsibility for all future D&D activities and liability for the facility.

	FY 2006	FY 2007	FY 2008
Total, Medium Energy Nuclear Physics	**103,161**	**122,781**	**123,379**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Research	
▪ **University Research**	
Funding provides support to maintain core university research at near constant effort levels compared to FY 2007.	+543
▪ **National Laboratory Research**	
Funding provides support to maintain laboratory research efforts generally at FY 2007 levels.	+584
▪ **Other Research**	
Increase reflects required SBIR/STTR and other obligations.	+233
Total, Research	**+1,360**
Operations	
▪ **TJNAF Operations**	
• **TJNAF Accelerator Operations**	
FY 2008 funding decreases almost entirely as a result of reduced R&D for the 12 GeV CEBAF Upgrade according to the planned profile as the project moves into final design. Operating hours are reduced by 6% (-280 hours).	-1,509
• **TJNAF Experimental Support**	
The FY 2008 funding request provides a constant level of effort for CEBAF experimental support activities that will support the facility running schedule.	+747
Total, Operations	**-762**
Total Funding Change, Medium Energy Nuclear Physics	**+598**

Heavy Ion Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Heavy Ion Nuclear Physics			
Research			
University Research	11,868	14,013	14,275
National Laboratory Research	19,059	23,326	24,944
Other Research[a]	—	5,014	5,181
Total, Research	30,927	42,353	44,400
Operations			
RHIC Operations	116,447	143,327	146,547
Other Operations	9,283	11,832	12,241
Total, Operations	125,730	155,159	158,788
Total, Heavy Ion Nuclear Physics	156,657	197,512	203,188

Description

The Heavy Ion Nuclear Physics subprogram supports research directed at answering one of the central questions of nuclear science identified in the 2002 Nuclear Science Advisory Committee Long-Range Plan:

> *What are the properties of hot nuclear matter?* At normal temperatures and densities, nuclear matter contains individual protons and neutrons (nucleons), within which the quarks and gluons are confined. However, at extremely high temperatures, such as those that existed in the early universe immediately after the "Big Bang," the quarks and gluons become deconfined and form a quark-gluon plasma. It is the purpose of this research program to recreate extremely small and brief samples of this matter in the laboratory by colliding heavy nuclei at relativistic energies. The distributions and properties of particles emerging from these collisions are studied for the predicted signatures of the quark-gluon plasma to establish its existence and further characterize its properties experimentally.

Benefits

The Heavy Ion Nuclear Physics subprogram supports the mission of the Nuclear Physics program by engaging in fundamental experimental research directed at acquiring new knowledge on the novel properties and the phases of hot, high energy density nuclear matter such as existed in the early universe; by supporting research and development of the next generation particle detectors, advanced accelerator technologies, state-of-the-art electronics, software and computing; and by training scientists needed by the Nation's diverse high-skills industries and academic institutions.

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[a] In FY 2006, $3,573,000 has been transferred to the SBIR program. This activity includes $4,918,000 for SBIR in FY 2007 and $5,117,000 for SBIR in FY 2008.

Supporting Information

Historically, the first major milestone in establishing the idea for the formation of heated nuclear matter was marked in 1984 when scientists working at the LBNL Bevalac accelerator found the first direct evidence that nuclear matter can be compressed to high temperature and density using accelerated beams. This observation led to the studies of hot and extremely dense hadronic matter created in heavy ion collisions with gold beams at the BNL Alternating Gradient Synchrotron (AGS) in 1992 and at the CERN Super Proton Synchrotron (SPS) in 1994. These tiny “fireballs” equilibrated rapidly, suggesting that the right conditions should exist at even higher beam energies to create a new phase of metamorphosed matter called the quark-gluon plasma (QGP)—named in the popular press as the mini “Big Bang,” since this primordial form of matter is thought to have existed shortly after the birth of the universe.

A new program of research on hot nuclear matter began at the Relativistic Heavy Ion Collider (RHIC) at BNL in 2000 when the first collisions of counter-circulating gold nuclei were observed at beam energies ten times higher than those available at any other facility in the world. While the RHIC facility puts heavy ion research at the highest energy frontier, it is also the only facility in the world that provides collisions of polarized protons with polarized protons. This unique capability will allow information to be obtained on the intrinsic arrangement of gluons that bind quarks into a nucleon (a proton or a neutron). At the opposite end of the temperature scale, limited studies into the conditions for inducing the liquid-to-gas phase transition in nuclear matter are underway at the National Superconducting Cyclotron Laboratory (NSF funded) at Michigan State University, at Texas A&M University, and at foreign laboratories.

The construction of RHIC was completed in August 1999 and RHIC has operated over six highly successful running periods: Run 1 in FY 2000 with gold beams; Run 2, in FY 2001-2002, with gold beams and commissioning of polarized protons; Run 3 in FY 2003, with deuteron-gold collisions and the first physics results with polarized proton collisions; Run 4 in FY 2004 with high luminosity gold beams and polarized protons; Run 5 in FY 2005 with high luminosity copper beams and polarized protons; and Run 6 in FY 2006 devoted to high statistics polarized proton operations. This facility is utilized by about 1,200 DOE, NSF, and foreign agency supported researchers.

The NSAC Subcommittee Review of Heavy Ion Nuclear Physics in 2004 found the long-term plans for expanding the scientific reach of the U.S. nuclear physics program in QCD physics were well formulated and had excellent prospects for new discoveries and for developing a deeper understanding of the properties of nuclear matter and of the origins of the universe.

The LHC, nearing completion at CERN, offers opportunities for new discoveries in relativistic heavy ion physics, driven by a 30 fold increase in center-of-mass energy, which generates different initial conditions and a larger kinematic reach for hard probes. A very modest U.S. research and detector development effort at the LHC is supported that will build upon the discoveries made at RHIC. The LHC is expected to commence heavy ion operations in the 2008 time frame.

FY 2006 Accomplishments

The fifth running period in FY 2005 successfully accelerated and delivered the first high intensity beams of copper nuclei—a landmark accomplishment in itself—that provides physicists greater insights into the remarkable properties of the QGP and the Color Glass Condensate (CGC). In FY 2006, the entire sixth running period (Run-6) was dedicated to understanding the proton “spin crisis”, as researchers collided beams of polarized protons at various collision energies.

- RHIC experiments have published results in a special issue of the scientific journal "Nuclear Physics A" that summarize the accomplishments of the first three years of RHIC operation with the description that the medium created at RHIC – which corresponds to the state of the Universe at an early stage of the "Big Bang"—is a perfect and strongly interacting fluid (the sQGP) and not a gas as originally thought. This discovery made the American Institute of Physics list as the top physics story for 2005.
- Preliminary direct photon measurements in gold-on-gold (Au+Au) collisions hint that the spectrum could be the thermal radiation emanating from the sQGP. Researchers believe this thermal effect should be absent in proton-on-proton (p+p) and deuterium-on-gold (d+Au) collisions, as they lack the conditions needed to create the sQGP.
- First indirect hints of the suppression of charm mesons in Au+Au collisions have been observed, indicating that the heavy charm quark loses energy in the sQGP medium. The large suppression, approximately equal to that of the pions, contradicts theoretical expectations and indicates the sQGP medium is so dense that the heavy quarks are not detected in the expected abundances, stimulating further theoretical developments of the "perfect fluid".
- Measurements of anisotropic flow of charm mesons via non-photonic electrons have been made. The results suggest that flow is partonic, that is, arising from early interactions among quarks and gluons.
- First measurements of J/Psi (J/Ψ) particle production from d+Au, copper-on-copper (Cu+Cu) and Au+Au collisions are intriguingly similar to the earlier CERN results. Surprisingly, theoretical models that were successful in describing CERN data fail to describe data at RHIC – a challenge for physicist's conception of the sQGP.

FY 2006 Facility and Technical Accomplishments

- RHIC successfully operated with proton beams. A new beam polarization record of 65% at 100 GeV beam energy was achieved at a luminosity about three times higher than during last year's run. This record breaking performance has exceeded all expectations and accordingly provided significantly more data for the experiments, as well as additional runs at lower beam energies.
- A short test run at full proton beam energy of 250 GeV was successfully concluded. This achievement represents an important technical milestone for the RHIC proton spin program.
- The first successful test of stochastic cooling of high energy, bunched beams was accomplished in one ring at RHIC by using state-of-the-art fiber optic technology for signal processing and powerful narrow-band beam kickers.
- Electron cooling is required for delivering significantly higher beam luminosity. Design of a superconducting high-current cavity capable of record currents of a few amperes for continuous wave (CW) operation was completed in FY 2006. A diamond amplified photocathode has demonstrated a gain of over 50 in emission mode. The accelerator cavity, electron gun, and photocathode are important enabling technologies not only for electron cooling of RHIC, but also for other applications, such as defending Navy ships with a high-power Free Electron Laser, new synchrotron light sources, industrial use of coherent light, and medical imaging.
- The PHENIX experiment built and tested a full scale prototype of the Hadron Blind Detector (HBD) at BNL in collaboration with the Israeli Weizmann Institute. The HBD will measure low mass e+ e- pairs, including the continuum and resonances that auspicate possible mass shifts and other unexplained phenomena observed at CERN. A new detector, the Muon Piston Calorimeter (MPC), was built, tested, calibrated, and installed in PHENIX in FY 2006. The purpose of the MPC is to

measure the production of neutral pions and gamma radiation in p+p and d+A reactions in the forward direction and their spin asymmetries in polarized p+p collisions.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Research	**30,927**	**42,353**	**44,400**
▪ **University Research**	**11,868**	**14,013**	**14,275**

Support is provided for the research of about 120 scientists and 90 graduate students at 27 universities in 21 states. Funding provides support to maintain university research at near constant levels for research efforts at RHIC and the continuation of a modest program at the LHC.

Researchers using relativistic heavy ion beams are focused on the study of the properties of hot, dense nuclear matter created at experiments at RHIC, next generation instrumentation for RHIC, and planning of new experiments at the LHC. The university groups provide scientific personnel and graduate students needed for running the RHIC experiments, data analysis and publishing RHIC results, and designing and fabricating the RHIC and LHC heavy ion detector upgrades.

Support is provided for a small-scale research program conducted at the NSF-supported National Superconducting Cyclotron Laboratory at Michigan State University, at the DOE-supported Texas A&M University, and at facilities in France and Italy.

▪ **National Laboratory Research**	**19,059**	**23,326**	**24,944**

Support is provided for scientists at five national laboratories (BNL, LBNL, LANL, ORNL, and Lawrence Livermore National Laboratory (LLNL). These scientists provide essential personnel for designing, fabricating, and operating the RHIC detectors; analyzing RHIC data and publishing scientific results; conducting R&D of innovative detector designs, integrating electronics designs for high bandwidth data acquisition systems, and software technologies; designing, fabricating, and operating LHC detectors; and planning for future experiments. Also, BNL and LBNL provide substantial computing infrastructure for terabyte-scale data analysis and state-of-the-art facilities for detector and instrument development.

• **BNL RHIC Research**	**8,959**	**11,230**	**11,444**

BNL scientists play a major role in planning and carrying out research using the data acquired from the detectors at RHIC as well as having major responsibilities for maintaining, improving and developing the computing infrastructure for use by the scientific community. The FY 2008 budget request allows BNL scientists to continue to provide adequate maintenance and infrastructure support of the experiments and effectively utilize the beam time for research and to train young scientists. The PHENIX Silicon Vertex Tracker (VTX) MIE (estimated TEC $4,600,000), a joint project with the Japanese, is continued in FY 2008. The PHENIX VTX is a barrel of silicon pixel and strip detectors that will provide precision measurement of heavy quark production to study the thermalization process in the heavy ion collisions. The STAR Time of Flight (TOF) detector requested final funding in FY 2007 and project activities continue in FY 2008 for a FY 2009 completion. Capital equipment funds support the initiation of two MIE's in FY 2008, the PHENIX Nose Cone Calorimeter (NCC) and the PHENIX Forward Vertex Detector (FVTX) . These new detectors are important for both the heavy ion and spin programs. The NCC (estimated TEC $4,700,000) is a fine grained silicon-tungsten sampling calorimeter

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

that will measure the production of heavy quarks in order to characterize the new states of matter created at RHIC. The FVTX (estimated TEC $4,950,000) will provide vertex tracking capabilities to PHENIX and adds two silicon endcaps to the ongoing PHENIX VTX upgrade MIE, to be initiated in FY 2007. Studies directed at developing the scientific case for a potential electron-heavy ion collider facility are supported.

	FY 2006	FY 2007	FY 2008
• **Other National Laboratory Research**	**10,100**	**12,096**	**13,500**

Researchers at LANL, LBNL, LLNL, and ORNL provide unique expertise and facilities for detector upgrades and analyses of data. For example, at LBNL, a large scale computational system, Parallel Distributed Systems Facility (PDSF), is a major resource used for the analysis of RHIC data, in alliance with the National Energy Research Scientific Computing Center (NERSC), and at LLNL substantial computing resources are made available for the PHENIX data analysis. Research efforts are maintained at a near constant level of effort as compared to FY 2007. Capital Equipment funding is provided to continue U.S. participation in the heavy ion program at the LHC (estimated MIE TEC $13,000,000) according to planned profiles. The LHC Heavy Ion MIE adds a calorimeter to the CERN A Large Ion Collider Experiment (ALICE) experiment to provide the capability to study jet physics. Participation in the heavy ion program at the LHC will provide U.S. researchers the opportunity to search for states of matter under substantially different conditions than those provided by RHIC, and to obtain additional information regarding the nature of matter that existed during the earliest moments of the universe.

	FY 2006	FY 2007	FY 2008
▪ **Other Research**	**—**	**5,014**	**5,181**

In FY 2006, $3,573,000 has been transferred to the SBIR program. This activity includes $4,918,000 for Small Business Innovative Research (SBIR) in FY 2007 and $5,117,000 for SBIR in FY 2008 as well as other established obligations that the Heavy Ion Nuclear Physics subprogram must meet.

	FY 2006	FY 2007	FY 2008
Operations	**125,730**	**155,159**	**158,788**
▪ **RHIC Operations**	**116,447**	**143,327**	**146,547**

RHIC operations are supported for an estimated 30-week (91% utilization) running schedule in FY 2008 that greatly expands the opportunities to vary the initial conditions (parameters) for forming the observed new state of matter. Together with the implementation of EBIS and detector upgrades, this will allow the RHIC program to make incisive measurements leading to more definitive conclusions on the discovery of strongly interacting quark gluon matter—the “perfect liquid”—and to establish whether other phenomena, such as a “Color Glass Condensate” or Chiral Symmetry Restoration exists in nature. Program targets and milestones should be achieved in a timely manner.

	FY 2006	FY 2007	FY 2008
• **RHIC Accelerator Operations**	**87,693**	**111,000**	**113,976**

Support is provided for the operation ($110,876,000), capital investments ($1,000,000), and improvement ($2,100,000) of the RHIC accelerator complex. This includes the Tandem, Booster, and AGS accelerators that together serve as the injector for RHIC. FY 2008 funding will support about 30 weeks (3,730 hours) of operations. The initial survey work with gold and lighter nuclear beams at the full energy will be largely completed and the experimental program will be dominated by measurement of yields of rarer signals and characterization of “jets”. These

	FY 2006	FY 2007	FY 2008
(dollars in thousands)			

measurements will require higher integrated luminosity and support is provided for R&D of electron beam cooling and other luminosity enhancement technologies. Total funding for facility capital equipment and accelerator improvement (AIP) projects are increased ($+700,000) relative to FY 2007 levels.

	FY 2006	FY 2007	FY 2008
RHIC Hours of Operation with Beam	—[a]	4,080	3,730

- **RHIC Experimental Support** **28,754** **32,327** **32,571**

  Support is provided for the operation, maintenance, improvement, and enhancement of the RHIC experimental complex, including detectors, experimental halls, computing center, and support for users. The RHIC detectors have reached their initial planned potential and about 1,200 scientists and students from 82 institutions and 19 countries will participate in the RHIC research program in FY 2008. Two detectors will operate in FY 2008 (STAR and PHENIX) that provide complementary measurements, but with some overlap in order to cross-calibrate the measurements. FY 2008 funding will support Experimental Support efforts at the level needed for an estimated 30-week running schedule and to pursue important detector R&D activities. Base capital equipment funding is increased relative to FY 2007 to provide the support for maintaining computing capabilities at the RHIC Computing Facility (RCF) and for instrumentation.

- **Other Operations** **9,283** **11,832** **12,241**

  As steward for Brookhaven National Laboratory (BNL), the Nuclear Physics program provides general plant project (GPP), general purpose equipment (GPE) and other funding for minor new fabrication, other capital alterations and additions, and for buildings and utility systems, needed laboratory equipment, and other expenses. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and for meeting its requirement for safe and reliable facilities operation, and is increased relative to FY 2007 to cover requirements.

Total, Heavy Ion Nuclear Physics **156,657** **197,512** **203,188**

[a] Non-DOE funding enabled RHIC to operate 2,700 hours in FY 2006.

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Research	
▪ **University Research**	
The increase for University Research grants in FY 2008 will provide support for near constant levels of research effort. The major focus of research will be on the RHIC program with data taking with STAR and PHENIX, and data analysis from all detectors, including Phobos and BRAHMS. A modest effort will also be directed towards research at the LHC heavy ion program at CERN.	+262
▪ **National Laboratory Research**	
• BNL RHIC Research: The FY 2008 budget request supports a near constant level of effort. Funding for capital equipment is maintained as the STAR Time-of-Flight (TOF) MIE is completed, the PHENIX Vertex (VTX) detector MIE continues, and the PHENIX Nose Cone Calorimeter (NCC) and the PHENIX Forward Vertex (FVTX) detector MIEs are initiated.	+214
• Other National Laboratory Research: The FY 2008 increase reflects additional capital equipment funds provided for base research infrastructure ($+1,121,000), of which $1,000,000 is provided for upgrades to LHC detectors that will permit a modest U.S. participation in the heavy ion program at the LHC. These additional funds will ensure that National Laboratory researchers continue to provide adequate support to the RHIC experiments and its upgrades, and to effectively utilize the beam time for research and to train students and young scientists.	+1,404
Total, National Laboratory Research	**+1,618**
▪ **Other Research**	
Increase reflects required SBIR obligations.	+167
Total, Research	**+2,047**
Operations	
▪ **RHIC Operations**	
• The FY 2008 request for Accelerator Operations supports operations of the RHIC facility for an approximate 30-week running schedule to meet the program's scientific goals and performance measures.	+2,976

	FY 2008 vs. FY 2007 ($000)
• Experimental Support: Funding is provided for experimental scientific/technical staff and materials and supplies, and capital equipment that effectively support the maintenance and operation of the PHENIX and STAR detectors at RHIC for a 30-week operating schedule.	+244
Total, RHIC Operations	**+3,220**
▪ **Other Operations**	
Increased support is provided for BNL general plant projects and general purpose equipment to increase the level of effort for FY 2008.	+409
Total, Operations	**+3,629**
Total Funding Change, Heavy Ion Nuclear Physics	**+5,676**

Low Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Low Energy Nuclear Physics			
Research			
University Research	17,109	19,113	19,648
National Laboratory Research	22,595	29,789	34,113
Other Research[a]	4,335	5,719	5,761
Total, Research	44,039	54,621	59,522
Operations	23,067	29,278	31,125
Total, Low Energy Nuclear Physics	67,106	83,899	90,647

Description

The Low Energy Nuclear Physics subprogram supports research directed at understanding three of the central questions of nuclear science identified in the NSAC 2002 Long-Range Plan:

What is the structure of nucleonic matter? The forefront of nuclear structure research lies in studies of nuclei at the limits of energy, deformation, angular momentum, and isotopic stability. The properties of nuclei at these extremes are not known and such knowledge is needed to test and drive improvement in nuclear models and theories about the nuclear many-body system.

What is the nuclear microphysics of the universe? Knowledge of the detailed nuclear structure, nuclear reaction rates, half-lives of specific nuclei, and the limits of nuclear existence at both the proton and neutron drip lines is crucial for understanding nuclear astrophysics processes such as the production of the chemical elements in the universe, and the explosive dynamics of supernovae.

Is there new physics beyond the Standard Model? Studies of fundamental interactions and symmetries, including those of neutrino oscillations, are indicating that our current Standard Model is incomplete, opening up possibilities for new discoveries by precision nuclear physics experiments.

Benefits

The Low Energy subprogram supports the mission of the Nuclear Physics program by fostering fundamental research to obtain new insight into the structure of nucleonic matter, the nuclear microphysics of the universe, and fundamental tests for new physics. This subprogram supports a broad range of experiments at two National User Facilities, the Holifield Radioactive Ion Beam Facility (HRIBF) and the Argonne Tandem Linac Accelerator System (ATLAS), one other laboratory accelerator facility (88-Inch Cyclotron at LBNL), university-based accelerators, and non-accelerator based facilities such as the Sudbury Neutrino Observatory (SNO) in Canada and the Kamioka Liquid-scintillator Anti Neutrino Detector (KamLAND) in Japan. The development of advanced accelerator technologies is also

[a] In FY 2006, $1,261,000 has been transferred to the SBIR program. This activity includes $1,344,000 for SBIR in FY 2007, and $1,378,000 for SBIR in FY 2008.

supported, including rare isotope beam R&D relevant to next generation nuclear structure and astrophysics facilities. The Low Energy subprogram is an important source of trained scientific/technical personnel who contribute to a wide variety of nuclear technologies, national security, and environmental quality programs of interest to the DOE.

Supporting Information

Progress in both nuclear structure and nuclear astrophysics studies depends in part upon the availability of rare isotope beams, or beams of short-lived nuclei, to produce and characterize nuclei that lie in unstudied regions of the nuclear chart and are involved in important astrophysics processes. While the U.S. today has facilities with capabilities for these studies, the Department has determined that a facility with next generation capabilities for short-lived radioactive beams will be needed for the U.S. to maintain a leadership role. The Nuclear Physics program is developing a strategic plan for implementing a facility with world-class capabilities that will complement existing and planned rare isotope beam capabilities elsewhere in the world. The National Academy of Sciences (NAS) was charged with carrying out an independent assessment of the importance of the science portfolio available to a next generation rare isotope beam facility, and generated a draft report in December 2006, with a final report expected in early 2007. The NAS report addresses the role of a U.S. world-class rare isotope beam facility. Guidance is being sought from NSAC during the on-going long-range planning process regarding the science opportunities that can be pursued with different combinations of capabilities and configurations for such a facility. The long-range plan will be available by the end of 2007. In FY 2008, support is provided for rare isotope beam R&D and investments in research capabilities at forefront rare isotope beam facilities around the world.

The National User Facilities, HRIBF and ATLAS, are utilized by DOE, NSF, and foreign-supported researchers. Capital equipment funds are provided for detector systems, for data acquisition and analysis systems, and for accelerator instrumentation. Accelerator improvement project (AIP) funds are provided to maintain and improve the reliability and efficiency of operations, and to provide new accelerator capabilities. The 88-Inch Cyclotron at the Lawrence Berkeley National Laboratory is a facility for testing electronic circuit components for radiation “hardness” to cosmic rays, supported by the National Reconnaissance Office (NRO) and the U.S. Air Force (USAF), and for a small in-house research program supported by NP. A Memorandum of Agreement between NP, NRO, and the USAF provides for joint support of the 88-Inch Cyclotron through 2011, and continued utilization of the facility for these activities is proposed for FY 2008. In FY 2008, fabrication continues at Lawrence Berkeley National Laboratory for the Gamma Ray Energy Tracking In-Beam Nuclear Array (GRETINA) MIE, a segmented germanium detector array with improved position resolution and efficiency for studies with fast fragment nuclear beams.

University-based research is an important feature of the Low Energy subprogram. Accelerator operations are supported at Texas A&M University (TAMU), the Triangle Universities Nuclear Laboratory (TUNL), and Yale University; infrastructure is supported at the University of Washington to enable scientific instrumentation projects to be undertaken. Each of these university Centers of Excellence has a critical mass of nuclear physics faculty involved in research that is conducted both on and off campus and about 15-25 graduate students at different stages of their education. These students historically have been an important source of leaders in the field. Many of these scientists, after obtaining their Ph.D.s, contribute to a wide variety of nuclear technology programs of interest to the DOE and the Nation.

The Low Energy subprogram also supports studies of fundamental interactions and symmetries in selected nuclei: “laboratories” that allow precise measurements to test the present understanding of the Standard Model. Some experiments use accelerators in conjunction with special apparatus to study fundamental nuclear and nucleon properties, such as reactions with and decays of cold neutrons. Such experiments are being prepared to mount at cold and ultra-cold beam lines at the SNS. In FY 2008, fabrication continues for the Fundamental Neutron Physics Beamline (FNPB) MIE at the SNS in preparation for these measurements of fundamental properties of the neutron including the electric dipole moment of the neutron (nEDM). Other experiments do not require the use of accelerators: the SNO detector in Canada is studying the production rate and properties of solar neutrinos, while the KamLAND in Japan is studying the properties of anti-neutrinos produced by nuclear power reactors. The SNO detector will conclude its data taking phase in FY 2007 and the collaboration continues data analysis and reporting in FY 2008. In 2007 KamLAND began a new experimental phase to measure lower energy solar neutrinos following an upgrade of the detector.

Research in the Low Energy subprogram continues to evolve to address forefront scientific questions. The 1990's began with research efforts at the 88-Inch Cyclotron, ATLAS, and other facilities to identify and characterize rapidly rotating superdeformed nuclei that have elongated football shapes. These spectroscopic studies have led to a deeper understanding of nuclear structure at high spin and large deformation. Spectroscopic studies are now probing the stability and structure of nuclei at the proton dripline, the structure of neutron-rich nuclei, and the surprising stability of rapidly spinning very heavy nuclei. In 1997, the HRIBF facility became operational and now produces over 150 proton-rich and neutron-rich radioactive beams for research. New radioactive beams are being developed to increase the scientific reach of the facility. Stable beams and the first radioactive beams in the mid-1990's enabled nuclear structure and cross-section experiments to determine the nuclear reaction paths and some rates for the breakout from the stellar carbon-nitrogen-oxygen (CNO) cycle that leads to production of heavier elements. Current experiments are determining the production and destruction rates for long-lived radioactive species produced by supernovae and measured by gamma-ray observatories in space. In neutrino physics, the SNO experiment was designed and built to search for neutrino flavor oscillations with solar neutrinos. It has been spectacularly successful, showing that neutrinos produced in the core of the sun change their character (oscillate) as they traverse solar matter, and thus have mass. SNO's results confirm that the sun indeed draws its energy from nuclear reactions and the number of neutrinos measured agrees well with solar neutrino emission calculated with current models of the sun. The KamLAND experiment, utilizing reactor produced anti-neutrinos, has also demonstrated neutrino oscillations by not only detecting fewer neutrons than are emitted by the reactors, but also by measuring the anti-neutrino energy spectrum shape. At the present level of understanding of neutrino oscillations, KamLAND and SNO results are in excellent agreement and, after final data analyses, will provide well measured oscillation parameters in the solar sector.

FY 2006 Accomplishments

The 2002 NSAC Long-Range Plan summarized the significant achievements of the Low Energy subprogram that are related to the central questions about nuclear structure, nuclear astrophysics, and fundamental interactions and symmetries; since then accomplishments are summarized yearly in the budget submission. The basic knowledge and understanding in these areas have been further extended by these recent highlights:

- The radioactive nuclear species ^{18}F (fluorine-18) is thought to be produced by some types of exploding stars, and gamma-ray spectrometers in space search for its signatures to provide information on these spectacular stellar events. The success of these searches depends critically on the amount of ^{18}F remaining in the explosion remnants, an amount that is dependent on a web of nuclear reactions that create and destroy ^{18}F. Using a beam of radioactive ^{18}F at HRIBF, researchers have recently measured the rates of two nuclear reactions that contribute to the net production of ^{18}F

in novae. They find that the new reaction rates result in almost a factor of two higher production of ^{18}F in a nova envelope, indicating that the number of stars where orbiting gamma-ray observatories might detect ^{18}F could be significantly higher than previously believed.

- The nuclear structure properties of known heavy nuclei are required to accurately predict the existence of, as yet undiscovered, superheavy nuclei. Theoretical predictions of the superheavy nuclei depend on the sequence and energy of proton and neutron single-particle states. These properties are used to predict the major gaps between nuclear levels (shell gaps), which stabilize the heavy nuclei against decay. In experiments at ATLAS, the nuclear structure of the nobelium nuclei $^{250,252,254}No$ is being delineated and the occupation of a proton level that influences the so-called Z=114 shell gap has been observed. These data on nobelium suggest that the Z=114 shell gap is different than has been assumed, and that theoretical calculations predicting a cluster of superheavy nuclei stabilized by the Z=114 shell gap need to be reexamined.

- The discovery and study of the heaviest elements continues to challenge both nuclear physics and nuclear chemistry. Today the identification of a new heavy element can depend on the correct identification of a single atom of that element. Confidence in such a discovery relies on independent confirmation by an independent group, as well as a wealth of systematic information about the reactions on and decays of the nuclei involved. Researchers at LBNL employ the Berkeley Gas-filled Separator (BGS) to select just a few atoms for study from reactions on targets like plutonium. Using the BGS they have recently provided independent confirmation of the production of a new element with 111 protons, measured the excitation functions for production of the known heavy nuclides ^{271}Ds and ^{262}Bh (darmstadtium-271 and bohrium-262), and continued a systematic study of hot fusion reactions—those that release several neutrons—on ^{238}U as a possible mechanism to produce even heavier elements.

- Lorentz invariance states that the laws of physics are the same in different frames of reference even if the frames are moving with a constant velocity with respect to each other. Lorentz invariance is the cornerstone of Einstein's theory of special relativity, and sensitive searches for violations of this proposition are of compelling interest. Recently researchers at the University of Washington used an ingenious torsion pendulum, with an overall non-zero electron spin but essentially no external magnetic field, to search for spin dependent violations of Lorentz invariance. This test is a factor of 100 times more sensitive than previous tests involving electrons, but the group found no evidence that there was a Lorentz invariance violation down to the experiment's sensitivity limit.

FY 2006 Facility and Technical Accomplishments

- The SNO experiment has reported neutrino oscillation results with salt data that confirm the D_2O (water with deuterium instead of hydrogen) neutrino oscillation results. Combined, these results demonstrate that electron neutrinos from the sun oscillate into muon and tau neutrinos and that the total neutrino flux agrees well with theoretical predictions. SNO took data with Neutral Current Detectors (NCDs) in its third and final phase, which has ended.

- A collaboration of LBNL and LLNL scientists have completed the installation and commissioning of the germanium clover detector array and silicon telescope array, STARS. This array is optimized to utilize particle-gamma-ray coincidences to study low energy nuclear structure. This program supports basic research as well as cross-section measurements for stockpile stewardship and homeland security.

- The ^{12}C(alpha, gamma)^{16}O reaction is often called the "Holy Grail" of nuclear astrophysics. It is not only important in the stellar production of carbon and oxygen, critical to all life in the universe, but also determines the fate of a star, ending either as a neutron star or as a black hole. Since the cross sections of this reaction under stellar conditions are extremely small, indirect techniques have been used for measuring its strength. A new ATLAS experiment uses a new approach to the problem by employing for the first time large acceptance gas ionization chambers that eliminate a major source of background which plagued earlier measurements, provides improved detector homogeneity and stability, and results with uncertainties reduced by a factor of two.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Research	**44,039**	**54,621**	**59,522**
▪ **University Research**	**17,109**	**19,113**	**19,648**

Support is provided for the research of about 120 scientists and 94 graduate students at 36 universities. Nuclear Physics university scientists perform research as users at national laboratory facilities, at on-site facilities, and at other specifically fabricated experiments. These activities address a broad range of fundamental issues as diverse as the properties of nuclei, the nature of the weak interaction, the production mechanisms of the chemical elements in stars and supernovae, and the properties of neutrinos.

FY 2008 funding for operation of university accelerator facilities and for researchers and students provides support ($18,716,000) for a level of effort near that of FY 2007. Capital equipment at the university accelerator facilities is maintained at FY 2007 levels for investments in experimental instrumentation and enhanced capabilities.

- University researchers conduct programs using the low energy heavy ion beams and specialized instrumentation at the ATLAS and HRIBF National User Facilities. These efforts at the user facilities involve about two-thirds of the university scientists supported by this subprogram.
- Accelerator operations are supported for in-house research programs at the Triangle Universities Nuclear Laboratory (TUNL) facility at Duke University, Texas A&M University (TAMU), and Yale University. These small university facilities have well-defined and unique physics programs, providing light and heavy ion beams, specialized instrumentation, and opportunities for long-term measurements that complement the capabilities of the national laboratory user facilities. Modest equipment funds are provided for new instruments and capabilities.

  Involvement in other accelerator and non-accelerator experiments directed at fundamental measurements are supported, such as measurements and analyses of data for solar and reactor neutrino rates and the neutrino mass at SNO and KamLAND (jointly with the High Energy Physics program), and development of the fundamental neutron program at the SNS with the Fundamental Neutron Physics Beamline.

▪ **National Laboratory Research**	**22,595**	**29,789**	**34,113**

Support is provided for the research programs of scientists at six national laboratories (ANL, BNL, LBNL, LANL, LLNL, and ORNL).

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
• **National Laboratory User Facility Research**	**13,501**	**10,778**	**11,155**

Scientists at ANL and ORNL have major responsibilities for maintaining, improving, and developing instrumentation for research by the user communities at the ATLAS and HRIBF National User Facilities, as well as playing important roles in carrying out research that addresses the NP program's priorities. In FY 2008, funding for ANL and ORNL research at the user facilities is provided to maintain the level of effort for nuclear structure and astrophysics research with emphasis on high priority projects. Support is provided for the following research activities.

- ► At ANL the research focuses on the use of stable and selected radioactive beams from ATLAS coupled to ion traps; Gammasphere and the Fragment Mass Analyzer to study fundamental processes and properties of nuclei; and the study of nuclei at the extremes of excitation energy, angular momentum, deformation, and isotope stability. Studies are undertaken with the Advanced Penning Trap to measure atomic masses with high precision and search for effects in beta decay outside the standard decay model ($5,893,000).
- ► At ORNL the research focuses on the use of radioactive beams from the HRIBF and specialized spectrometers to study the nuclear structure of nuclei far from stability. Measurements are made of reaction cross sections and nuclear properties, such as half-lives, which are crucial input to detailed astrophysics models that calculate the production of the elements in stars. Specialized equipment is employed, such as a system that integrates gamma-ray and charged-particle detectors with a recoil mass separator. The high-pressure gas target for nuclear astrophysics experiments is being utilized in an experimental program in nuclear astrophysics ($5,262,000).

• **Other National Laboratory Research**	**9,094**	**19,011**	**22,958**

Scientists at BNL, LBNL, LLNL, LANL, and ORNL play important roles in a number of high-priority accelerator- and non-accelerator-based experiments (SNO, KamLAND) directed toward fundamental questions. R&D activities are supported for one or more neutrino-less Double Beta Decay experiments, that will search for the neutrino-less decay mode, to measure the absolute mass of the neutrino and determine whether the neutrino is its own antiparticle. Funds are provided in FY 2008 to initiate U.S. participation in the fabrication of one of the candidate neutrino-less Double Beta Decay experiments, Cryogenic Underground Observatory for Rare Events (CUORE), located in Italy ($500,000).

Additionally, capital equipment funding is provided to support the ongoing GRETINA, FNPB, and nEDM MIEs, according to planned profiles, and for investments in rare isotope beam capabilities at domestic and international facilities to engage the U.S. community in forefront rare isotope beam research during the development of the next generation U.S. facility in nuclear structure and nuclear astrophysics. Funding for scientific/technical staff ($12,277,000) is provided to maintain near constant levels of effort compared to FY 2007 and is directed at the highest priority research, as described below:

(dollars in thousands)

FY 2006	FY 2007	FY 2008

- Support is provided for a LBNL research effort that uses beams from the 88-Inch Cyclotron to conduct an in-house research program that includes heavy element nuclear physics and chemistry, and fundamental symmetry studies, for testing and leadership in the fabrication of the Gamma-Ray Energy-Tracking In-beam Nuclear Array (GRETINA) detector, for R&D efforts in advanced accelerator technologies and techniques and for neutrino astrophysics and neutrino properties including KamLAND ($5,038,000). The KamLAND experiment in Japan measures the rate and properties of anti-neutrinos produced by several distant nuclear power reactors to study neutrino "oscillations. The KamLAND experiment has entered a second phase by greatly reducing the detector radioactivity background, enabling it to detect lower energy solar neutrinos. Nuclear Physics participation in KamLAND involves university researchers and LBNL researchers supported by this subprogram.
- The GRETINA MIE, for which fabrication began in FY 2004, is especially important for the study of the nuclear decay and structure of rare isotope nuclei in fast fragmentation beams. The improved position resolution and higher efficiency for high-energy gamma rays compared with presently available gamma-ray detector arrays enable this new detector system to utilize fragmented nuclear beams to open up a new frontier for understanding rare isotope nuclei that may exist in stars and supernovae, but live only fractions of a second. In FY 2008, funding of $4,400,000 is provided to continue fabrication of GRETINA (TEC $17,000,000).
- Support is provided for groups at BNL, LBNL, and LANL that are involved in the SNO experiment, jointly built by Canada, the United Kingdom, and the U.S., to address the question of whether the observed reduced rate of solar neutrinos reaching the earth results from unexpected properties of the sun, or whether it results from a fundamental property of neutrinos–namely that neutrinos produced in the sun change their nature (that is, oscillate to a new neutrino type) during the time it takes them to reach the earth, and implying that the neutrinos have mass. SNO results to date indicate strong evidence for neutrino oscillations. In FY 2004, the third phase of SNO began utilizing neutral current detectors to provide additional detail and confirmatory information on neutrino oscillations. The data collection is planned to be completed in FY 2007; analysis of data and publication of results continue ($2,307,000).
- Support is provided to ORNL to continue to coordinate and play a leadership role in fabrication and development of the scientific program for the FNPB MIE at the SNS. The FNPB project is a beam-line at the SNS that will deliver record peak currents of cold and ultra-cold neutrons for studying the fundamental properties of the neutron, leading to a refined characterization of the weak force. Fabrication began in FY 2004 and continues in FY 2008 with funding of $1,500,000 (TEC $9,200,000).
- Support is provided ($3,000,000) to pursue the measurement of the electric dipole moment of the neutron (nEDM), a high discovery potential experiment at the FNPB (estimated TEC $18,300,000). The measurement of a non-zero electric dipole moment of the neutron, or a stringent upper limit on its value, will significantly constrain extensions of the Standard Model.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

- Funding is provided within the Low Energy subprogram to support research efforts that are also relevant to the nuclear fuel cycle. Additional funding is provided for this effort in the Theory subprogram for Nuclear Data activities. This effort is carried out in collaboration with the Advanced Scientific Computing Research (ASCR) program and other DOE programs, and a joint workshop was conducted in FY 2006 with ASCR to identify the leading scientific issues for nuclear cross sections, nuclear data, and related computations.
- Funding of $500,000 is provided in FY 2008 to initiate fabrication of the CUORE experiment (estimated TEC $10,000,000) to search for neutrino-less double beta decay (DBD). R&D continues on additional technical approaches to DBD. A successful search for this phenomenon will establish that the neutrino is its own antiparticle and determine the absolute neutrino mass scale, both compelling issues for the Standard Model. The DBD project, with one or more prospective experiments, including CUORE, received CD-0 approval in FY 2006, with an estimated TPC range of $10,000,000 to $75,000,000, depending on the option(s) pursued.
- Funding is provided in FY 2008 for investments in rare isotope beam capabilities at domestic and international facilities ($1,000,000) to engage the U.S. community in forefront rare isotope beam research during the development of the next generation U.S. facility in nuclear structure and nuclear astrophysics. Opportunities for investment will be identified during the long-range planning process and could include investments in R&D accelerator capabilities and multiple MIEs.

▪ **Other Research**	**4,335**	**5,719**	**5,761**
• **Generic Rare Isotope Beam R&D**	**3,960**	**4,000**	**4,000**

Funds are provided for R&D activities aimed at development of rare isotope beam capabilities.

• **SBIR and Other**	**375**	**1,719**	**1,761**

In FY 2006, $1,261,000 has been transferred to the SBIR program. This activity includes $1,344,000 for SBIR in FY 2007, and $1,378,000 for SBIR in FY 2008. Funding is also provided for other established obligations including the Lawrence and Fermi Awards, which provide annual monetary awards to honorees selected by the DOE for their outstanding contributions to science.

Operations	**23,067**	**29,278**	**31,125**
▪ **User Facility Operations**	**22,917**	**25,992**	**27,695**

In FY 2008, support is provided to operate the two National User Facilities, the ATLAS at ANL ($13,767,000) and the HRIBF at ORNL ($13,928,000), for studies of nuclear reactions, structure and fundamental interactions at increased levels compared to FY 2007.

ATLAS provides stable heavy ion beams and selected radioactive ion beams for research. Experiments utilize ion traps, the Fragment Mass Analyzer, Gammasphere, and advanced detectors to study the structure of nuclei at the limits of stability, selected topics in nuclear astrophysics, and fundamental and decay properties of nuclei. In FY 2008, funding supports accelerator operations providing beam hours at FY 2007 levels. Accelerator improvement project funding supports

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

upgrading the accelerator to increase the radioactive beam capabilities of ATLAS with the Californium Rare Ion Breeder Upgrade (CARIBU) project.

HRIBF has coupled the existing cyclotron and tandem accelerator to develop a focused radioactive-ion beam program. Both proton-rich and neutron-rich beams are provided to spectrometer systems, designed for nuclear structure studies, and the Daresbury Recoil Separator and the Silicon Detector array for nuclear astrophysics studies. In FY 2008, funding supports accelerator operations providing increased beam hours compared to FY 2007, and capital equipment and accelerator improvement project funding supports the continued fabrication of a second source and transport beamline (IRIS2) for radioactive ions, started in FY 2006.

In FY 2007, these low energy facilities will carry out about 80 experiments involving over 600 U.S. and foreign researchers. Planned hours of operation in FY 2007 and FY 2008 with beam are indicated below; the FY 2006 hours are actual beam hours provided:

	FY 2006	FY 2007	FY 2008
ATLAS Hours of Operation with Beam	5,896	5,600	5,600
HRIBF Hours of Operation with Beam	5,215	4,350	5,000
Total Beam Hours for Low Energy Facilities	11,111	9,950	10,600

The actual beam hours provided by ATLAS in FY 2006 exceeded planned operations of 4,380 hours because of decisions to delay a maintenance and cryogenic plant upgrade period from FY 2006 to FY 2007, and to defer replacement of departing personnel, enabling additional beam operations. The actual beam hours provided by HRIBF in FY 2006 exceeded planned operations of 3,650 hours because of a substantial shift from radioactive ion beam (RIB) running to the less costly stable ion beam (SIB) running, permitting additional hours of operations. This unanticipated shift was necessitated by a six-month shutdown of the RIB driver accelerator to accomplish extensive repairs.

	FY 2006	FY 2007	FY 2008
▪ **Other Operations**	**150**	**3,286**	**3,430**

The 88-Inch Cyclotron has been jointly operated (under a Memorandum of Agreement valid through 2011) by the NP program and the National Reconnaissance Office (NRO) and the Air Force (USAF) since FY 2004. The beams of the 88-Inch Cyclotron are used by NP supported researchers for a focused in-house program and for NRO and USAF to simulate cosmic ray damage to electronic components to be used in space. In FY 2008, the NRO and USAF will utilize the 88-Inch Cyclotron for approximately 2,000 hours for their testing program, and NP will utilize it for approximately 3,000 hours for an in-house nuclear physics research program. The NRO and USAF will provide a total of $2,200,000 and NP will provide $3,277,000 for joint operations of the facility in FY 2008. In FY 2006, this funding was included under User Facility Operations.

Funding is also provided for maintenance of the Oak Ridge Electron Accelerator (ORELA) for criticality measurements supported by DOE/NNSA.

	FY 2006	FY 2007	FY 2008
Total, Low Energy Nuclear Physics	**67,106**	**83,899**	**90,647**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Research	
▪ **University Research**	
FY 2008 funding supports a near constant level of effort compared to FY 2007. Research concentrates on high priority programs, operations of university accelerators, and non-accelerator initiatives.	+535
▪ **National Laboratory Research**	
• **National Laboratory User Facility Research:** FY 2008 funding supports a constant level of effort compared to FY 2007 for high priority research efforts and activities at the ATLAS and HRIBF, which is needed for effective and productive exploitation of the beams at these user facilities.	+377
• **Other National Laboratory Research:** Increased FY 2008 funding provides a cost of living adjustment for scientific/technical staff to support high priority research efforts ($+488,000) including funding for research activities relevant to the design of next generation nuclear reactors. Funding is also increased for capital equipment ($+3,459,000) for the ongoing fabrication of the GRETINA, FNPB, and nEDM MIEs according to project plans, the initiation of the new CUORE MIE, and investments in rare isotope beam capabilities.	+3,947
Total, National Laboratory Research	**+4,324**
▪ **Other Research**	
The increase reflects required SBIR and other obligations.	+42
Total, Research	**+4,901**
Operations	
▪ **User Facility Operations** budget supports operations of HRIBF ($+359,000) and ATLAS ($+344,000) at operating levels near that of FY 2007; Capital Equipment and AIP investments increase ($+1,000,000) for instrumentation necessary to carry out the experimental program at HRIBF to support continued fabrication of a second source and transport beamline for radioactive ions to enable increased hours of radioactive beams on target with higher beam intensities, and at ATLAS to develop an ion source for unique capabilities for radioactive beams.	+1,703
▪ **Other Operations** maintains NP’s share of the 88-Inch Cyclotron operations at the FY 2007 level of effort.	+144
Total, Operations	**+1,847**
Total Funding Change, Low Energy Nuclear Physics	**+6,748**

Nuclear Theory

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Nuclear Theory			
Theory Research			
University Research	11,132	14,229	14,553
National Laboratory Research	10,636	11,718	12,150
Scientific Discovery through Advanced Computing (SciDAC)	1,485	2,500	2,588
Total, Theory Research	23,253	28,447	29,291
Nuclear Data Activities	5,099	6,901	7,114
Total, Nuclear Theory	28,352	35,348	36,405

Description

Progress in nuclear physics, as in any science, depends critically on improvements in the theoretical techniques and on new insights that will lead to new models and theories that can be applied to interpret experimental data and predict new behavior. The Nuclear Theory subprogram supports research directed at understanding the five central questions identified in the NSAC 2002 Long-Range Plan:

What is the structure of the nucleon? Protons and neutrons are the basic components of all observable matter in the universe that are themselves made up of lightweight, point-like particles, called quarks and gluons. The fundamental theory governing the dynamics of quarks and gluons is known as Quantum Chromodynamics (QCD). A key goal of modern theoretical nuclear physics is to comprehend the intricate structure and properties of the nucleon and ultimately nuclei, in terms of the interactions between the quarks, gluons and the extraordinarily complex vacuum.

What is the structure of nucleonic matter? Nuclear theorists strive to understand the diverse structure and remarkable properties of the nucleus. With the possibility of obtaining new experimental results for unstable nuclei from studies with radioactive beams, theorists will be able to probe nuclei at limits of high excitation energy, deformation, and isotopic stability. Ultimately, this major frontier of research will permit the development of a "comprehensive model" for nuclei that is applicable across the entire periodic table.

What are the properties of hot nuclear matter? The properties of hot, dense nuclear matter, is the central topic of research at the Relativistic Heavy Ion Collider (RHIC) facility. Lattice QCD theory predicts that the physical vacuum "melts" at extremely high temperatures and the underlying symmetries of QCD are restored. Under these conditions, normal nuclear matter should transform into a plasma of nearly massless quarks and gluons—a new form of matter that is believed to have pervaded the primordial universe a few microseconds after the "Big Bang." Theoretical research provides the framework for interpreting the experimental measurements for evidence for this new state of matter, along with other new phenomena. A key goal of the theoretical program is to establish knowledge of the QCD phase diagram of bulk nuclear matter.

What is the microphysics of the universe? The Theory subprogram attempts to understand the nuclear microphysics of the universe that involve fundamental nuclear physics processes, such as the origin of elements; the structure and cooling of neutron stars; the properties of neutrinos from the sun and the mechanism of core-collapse supernovae.

Is there new physics beyond the present Standard Model? The search for a single framework describing all known forces of nature—the so-called "Standard Model" represents a formidable challenge. The current version of the Standard Model has been tested with impressive precision in experiments with atoms, in various nuclear experiments testing Standard Model symmetries, and in high-energy experiments. However, despite its successes, recent experimental observations of neutrino behavior and studies of fundamental symmetries present some conceptual difficulties that lead physicists to believe a more fundamental theory must exist.

Benefits

The Nuclear Theory subprogram cuts across all components of the Nuclear Physics mission to foster fundamental research in nuclear physics that will provide new insights and advance our knowledge on the nature of matter and energy. The theory groups and individual researchers at universities and DOE national laboratories strive to improve the theoretical techniques and gain new insights used to interpret data gathered by Nuclear Physics supported user facilities and the non-accelerator based experimental programs. In addition, theorists play a crucial role in identifying and articulating the scientific questions that lead to the construction of new facilities, and in motivating the upgrades to existing facilities. By doing so, they not only advance our scientific knowledge and technologies, especially in the area of large scale computing, but serve to train the scientific/technical workforce needed for this research and indeed for an increasingly technological society. The mission of the Nuclear Data Program, included within the Theory subprogram, is also directly supportive of the DOE's missions for nuclear-related national security, energy, and environmental quality.

Supporting Information

The research of this subprogram is conducted entirely by groups and individual researchers located at universities and DOE national laboratories. The researchers utilize the high performance computational facility at the National Energy Research Scientific Computing Center (NERSC) at the Lawrence Berkeley National Laboratory and other specialized computers at other institutions. This subprogram also sponsors the national Institute for Nuclear Theory (INT), based at the University of Washington, in Seattle, where visiting scientists focus on key frontier areas in nuclear physics, including those crucial to the success of existing and future experimental facilities and the education of postdoctoral researchers and graduate students. Many foreign theorists participate on advisory groups as peer reviewers. There is large participation in the INT by researchers from Europe and Japan and by researchers in overlapping fields such as astrophysics, atomic and molecular physics, condensed matter physics and particle physics.

The subprogram is responding to the need for large dedicated computational resources for Lattice Quantum Chromodynamics (LQCD) calculations that are critical for understanding the experimental results from RHIC and TJNAF. Together with the High Energy Physics (HEP) and Advanced Scientific Computing Research (ASCR) programs, an approximately 5 teraflop prototype computer was developed and implemented in FY 2005 using the custom QCD On-a-Chip (QCDOC) technology. This platform enabled U.S. researchers to stay competitive with other worldwide efforts in computational QCD research while developing a larger-scale hardware platform. In a joint effort with HEP, development of large-scale facilities (about an additional 13 teraflops) began in FY 2006 to provide computing capabilities based on commodity cluster systems.

The program is enhanced through interactions with complementary programs overseas, efforts supported by the National Science Foundation, programs supported by the High Energy Physics program and Japanese supported theoretical efforts related to RHIC at the RIKEN Center at Brookhaven National Laboratory. JUSTIPEN, the Japan U.S. Theory Institute for Physics with Rare Isotope Nuclei, was formed at RIKEN (in Wako, Japan) in FY 2006. JUSTIPEN's purview will be in the area of the physics of (or with) rare isotope nuclei, including nuclear structure and reaction theory, nuclear astrophysics, and tests of the standard model using rare isotope nuclei. U.S. participation in JUSTIPEN is in the form of travel grants and subsistence grants to individual theorists interested in collaborating with Japanese scientists.

Theory subprogram activities are aimed at providing information services on critical nuclear data and have as a goal the compilation and dissemination of an accurate and complete nuclear data information base that is readily accessible and user oriented.

FY 2006 Accomplishments

The 2002 Long-Range Plan highlights many significant theoretical advances in all of the five major frontiers of research in nuclear physics today. A few of the most recent accomplishments are:

- *Studies of the nucleon-nucleon interaction on the lattice:* This year witnessed a major step toward one of the ultimate goals of nuclear physics – to compute the properties and interactions of nuclei directly from Quantum Chromodynamics (QCD), the underlying theory of the strong interactions. The low energy scattering of two pions with fully dynamical QCD and input quark masses near the physical masses was calculated and agreed with indirect measurements of this important quantity. A similar calculation of the low energy scattering of two nucleons was performed with different values of the mass of unphysically heavy quarks and extrapolated to the measured quantity to learn the quark mass dependence of this theoretical result. Thus, this preliminary and pioneering calculation gives a hint of how nuclear processes depend upon the fundamental constants of nature (quark masses in this case). Further development of this accomplishment would enable the computation of strong-interaction processes of importance in environments not attainable in the laboratory, such as in the interior of neutron stars. These results were obtained by a group of researchers at universities and at LBNL using the configurations partially motivated by high energy needs and calculated on the special purpose computers (QCDOC and clusters of commodity machines) at BNL, FNAL, and TJNAF.
- *Ab initio calculation of a nuclear reaction important in astrophysics and fundamental symmetries:* Precise predictions of the production rate of solar neutrinos from the weak decay of ^{8}B are important for testing solarmodels, and for limiting the allowed neutrino mixing parameters including possible contributions of sterile species. The predicted ^{8}B production rate is based on solar model calculations that incorporate measured reaction rates for each of the solar burning steps following the initial *p+p* reaction, the most uncertain of which is the ^{7}Be (p,γ)^{8}B rate. This rate is characterized by the ^{7}Be(p,γ)^{8}B S-factor which is the subject of intense experimental and theoretical investigation. The first *ab initio* prediction of the ^{7}Be(p,γ)^{8}B S-factor has been achieved at Lawrence Livermore National Laboratory this year and found to be in very good agreement with a recent direct measurement at the NP Center of Excellence at the University of Washington. The nuclear wave functions of the bound states of ^{7}Be and ^{8}B were calculated within the *ab initio* No-Core-Shell-Model framework using a nucleon-nucleon interaction which fits the nucleon-nucleon data to high precision. The "overlap" of the ^{7}Be+p and ^{8}B was determined in two different ways and found to have a small effect on the result; hence one styles this as the first *ab initio* reaction calculation with nuclei more massive than ^{4}He.

- *Formation of the elements in the end game of stars:* Researchers at ORNL with NP supported university collaborators (and others from overseas) have adapted a technique used previously to model the formation of elements (nucleosynthesis) in the Big Bang to the study of nucleosynthesis in the final explosive stages of stellar evolution. It is believed that the heavy elements are born in the violent environment of gravitational core collapse supernovae, ordinary novae, and X-ray bursts and γ-ray bursts, but the details of these processes and the resulting abundances of the nuclides produced remain to be fully worked out. In particular, the sensitivity of abundances to uncertainties in reaction rates measured, yet to be measured at HRIBF or similar facilities, or simply immeasurable is difficult to determine without taking into account all reaction rates in a systematic way. The Monte Carlo technique chooses a random enhancement factor for each reaction rate within the quoted uncertainty, does a complete calculation for the entire chain of reactions, and calculates the final abundances for this trial. After thousands of trials (like flipping a coin multiple times to determine the probability of landing heads up) the average abundances with uncertainties emerge and can be compared with the abundances observed in the universe. This is the significant theoretical step which allows the theorist to identify the most significant reaction or reactions in the chain and make recommendations for priorities among the expensive experiments at the radioactive beam facilities. As these calculations are done in the best educated guesses of the explosive environment that nucleosynthesis takes place, this technique offers for the future more refined studies of that very environment. Perhaps ultimately astrophysicists can even determine where in the universe the so-called r-process nucleosynthesis of the heavy elements takes place.

FY 2006 Technical Accomplishments

- Theoretical calculations for Quantum Chromodynamics (QCD) require enormous computation resources with architectures that are optimized to address this class of nuclear physics problem. NP, with High Energy Physics, international participants, and industrial partners, has contributed to a massively parallel computing technology called QCD On-a-Chip (QCDOC). QCDOC utilizes a six-dimensional machine mesh and system-on-a-chip technology, offering a factor of ten improvement in price per unit performance. The present QCDOC machines are calculating the configurations which are used in final QCD calculations of interest to nuclear and high energy physicists. Furthermore, elements of the QCDOC technology have been adapted by industry and are now employed within the DOE complex and elsewhere as the highest performance computing platforms commercially available.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Theory Research	**23,253**	**28,447**	**29,291**
▪ **University Research**	**11,132**	**14,229**	**14,553**

The research of about 145 university scientists and 105 graduate students is supported through 56 grants at 43 universities in 28 states and the District of Columbia. The range of topics studied is broad, constantly evolving, and each active area of experimental nuclear physics is supported by nuclear theory activities. Graduate student and postdoctoral support is a major element of this program. In FY 2008, funding supports a near constant level of effort compared with FY 2007 for theoretical efforts needed for interpretation of experimental results obtained at the NP facilities. The theoretical efforts are optimized to focus on the high priority activities which are aligned with SC Strategic Plan milestones. Following a recommendation of the NSAC Theory Review subcommittee

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

in its report "A Vision for Nuclear Theory," support continues for investments in Lattice QCD computer capabilities in a joint effort with High Energy Physics.

The Institute for Nuclear Theory (INT) at the University of Washington hosts three programs per year where researchers from around the world attend to focus on specific topics or questions (annual budget approximately $2,000,000). These programs result in new ideas and approaches, the formation of collaborations to attack specific problems, and the opportunity for interactions of researchers from different fields of study. For example, a recent program focused on nuclear structure near the limits of stability where important features of the nuclear many-body problem are magnified and principal uncertainties in the theoretical description of nuclei can be effectively studied. Another program concentrated on the exploration of hadron structure and spectroscopy using Lattice QCD, exploiting various theoretical approaches in the context of lattice calculations to obtain insight into hadron structure, to calculate observables relevant to current experiments, and to guide the future experimental program. Often the key papers on the program subjects are either written during the INT programs or based on discussions that took place at the INT.

	FY 2006	FY 2007	FY 2008
▪ **National Laboratory Research**	**10,636**	**11,718**	**12,150**

Research programs are supported at seven national laboratories (ANL, BNL, LANL, LBNL, LLNL, ORNL, and TJNAF). In FY 2008, funding supports a constant level of effort for scientific/technical staff compared with FY 2007 in order to address theoretical issues important for advancing the national nuclear physics program. The nuclear theory research at a given laboratory provides support to the experimental programs at that laboratory, or takes advantage of some unique facilities or programs at that laboratory. The larger size and diversity of the national laboratory groups make them particularly good sites for the training of nuclear theory postdoctoral associates.

	FY 2006	FY 2007	FY 2008
▪ **Scientific Discovery through Advanced Computing (SciDAC)**	**1,485**	**2,500**	**2,588**

Scientific Discovery through Advanced Computing (SciDAC) is an SC program to address major scientific challenges that require advances in scientific computing using terascale resources. Following the re-competition of SciDAC projects in FY 2006, the Nuclear Physics Theory subprogram currently supports efforts in nuclear astrophysics, grid computing, Lattice Gauge QCD theory, and low energy nuclear structure and nuclear reaction theory. NP partners in various combinations with HEP, ASCR, and NNSA on these projects.

	FY 2006	FY 2007	FY 2008
Nuclear Data Activities	**5,099**	**6,901**	**7,114**

The Nuclear Data program collects, evaluates, archives, and disseminates information on nuclear properties and reaction processes for the physics community and the Nation. The focal point for its national and international activities is the DOE-managed National Nuclear Data Center (NNDC) at Brookhaven National Laboratory. Funding in FY 2008 supports a near constant level of effort at FY 2007 levels for Nuclear Data activities. The NNDC relies on the U.S. Nuclear Data Network (USNDN), a network of DOE supported individual nuclear data professionals located in universities and national laboratories that perform assessment as well as developing modern network dissemination capabilities. The NNDC participates in the International Data Committee of the International Atomic Energy Agency (IAEA).

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Funding is also provided to support ongoing research efforts that are also relevant to nuclear fuel cycle, including covariant matrix studies, cross section evaluations, relevant computations, and other activities. Funding to support related efforts is provided in the Low Energy subprogram. This effort is carried out in collaboration with the ASCR program, and a joint workshop was conducted in FY 2006 to identify the leading scientific issues.			
Total, Nuclear Theory	**28,352**	**35,348**	**36,405**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Theory Research	
▪ **University Research**	
FY 2008 funding supports personnel at a near constant level of effort to carry out the national Nuclear Physics program. Resources will be focused on the theoretical understanding of the research that was identified in SC Strategic Plan Milestones and to implement recommendations from the recent NSAC Subcommittee on Nuclear Theory.	+324
▪ **National Laboratory Research**	
FY 2008 funding provides a constant level of theoretical effort needed to address the national nuclear physics program. Research will be directed toward achieving the scientific goals of the Nuclear Physics program, including the continuation of the Lattice Gauge Quantum Chromodynamics initiative with HEP.	+432
▪ **Scientific Discovery through Advanced Computing (SciDAC)**	
FY 2008 funding allows for continued support in the most promising areas for progress in nuclear physics with terascale computing capabilities.	+88
Total, Theory Research	**+844**
Nuclear Data Activities	
FY 2008 funding supports a near constant level of effort compared to FY 2007.	+213
Total Funding Change, Nuclear Theory	**+1,057**

Construction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Construction			
07-SC-02, Electron Beam Ion Source, BNL	—	7,400	4,200
06-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	500	7,000	13,500
06-SC-02, Electron Beam Ion Source (PED), BNL	1,980	120	—
Total, Construction	2,480	14,520	17,700

Description

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

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
07-SC-02, Electron Beam Ion Source, BNL	**—**	**7,400**	**4,200**

The final year of funding is requested to continue construction of the Electron Beam Ion Source (EBIS) project with a TEC of $13,700,000 and TPC of $14,800,000 and completion in FY 2010. EBIS is supported jointly by NP and NASA and will replace the high maintenance tandems as the RHIC pre-injector, leading to more cost effective operations and new research capabilities. NASA is contributing an additional $4,500,000 above the DOE TPC. EBIS received CD-2 and CD-3 approval in FY 2006. Findings of a Technical, Cost, Schedule and Management Review conducted in FY 2006 were utilized in the formulation of the FY 2008 budget request.

06-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	**500**	**7,000**	**13,500**

Funding is requested to complete PED activities for the 12 GeV CEBAF Upgrade (PED TEC $21,000,000). The upgrade was identified in the 2002 NSAC Long-Range Plan as one of the highest priorities for Nuclear Physics and is a near-term priority in the SC 20-Year Facilities Outlook. The upgrade will enable scientists to address one of the greatest mysteries of modern physics—the mechanism that confines quarks together. The project received CD-1 approval in February 2006. The proposed cost and schedule profiles reflected in this FY 2008 budget request are consistent with the recommendations made by the DOE Office of Project Assessment Review performed in FY 2006.

06-SC-02, Electron Beam Ion Source (PED), BNL	**1,980**	**120**	**—**

PED funding is completed in FY 2007 and the final year of construction funding is requested in FY 2008 in line item 07-SC-02 (see above). EBIS received CD-2 and CD-3 approval in the fourth quarter of FY 2006.

Total, Construction	**2,480**	**14,520**	**17,700**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
07-SC-02, Electron Beam Ion Source, BNL	
Funds are provided for the final year of construction consistent with the CD-2 approved baseline for the Electron Beam Ion Source (EBIS) to replace the aging Tandem Van de Graaff as the heavy ion source for the RHIC complex.	-3,200
06-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	
Support is provided to complete Project Engineering and Design for the 12 GeV CEBAF Upgrade.	+6,500
06-SC-02, Electron Beam Ion Source (PED), BNL	
Project engineering and design (PED) funding for EBIS was completed in FY 2007.	-120
Total Funding Change, Construction	**+3,180**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
General Plant Projects	7,342	7,870	8,147
Accelerator Improvements Projects	4,873	6,200	7,300
Capital Equipment	22,045	30,421	35,853
Total, Capital Operating Expenses	34,260	44,491	51,300

Construction Projects

	(dollars in thousands)					
	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Unappro-priated Balance
07-SC-02, Electron Beam Ion Source, BNL	13,700[a]	—	—	7,400	4,200	—
06-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	21,000[b]	—	500	7,000	13,500	—
06-SC-02, Electron Beam Ion Source (PED), BNL	2,100[a]	—	1,980	120	—	—
Total, Construction			2,480	14,520	17,700	

[a] Includes the TEC for design and construction. Design funding is in 06-SC-02. The project was baselined with CD-2 approval in FY 2006 with a Total Estimated Cost of $13,700,000. CD-3 was approved in FY 2006.

[b] The full Total Estimated Cost (design and construction) ranges between $205,000,000 and $281,500,000 and includes the $21,000,000 for Project Engineering and Design (PED) provided in 06-SC-01; the full Total Project Cost (design and construction) ranges between $225,000,000 and $306,000,000. These estimates are based on preliminary data and should not be construed as a project baseline. CD-1 was approved in FY 2006.

[a] Design TEC estimate only. See 07-SC-02.

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
STAR Time-of-Flight, BNL (61PB)	4,800[a]	4,800[a]	—	2,400	2,424[a]	—	FY 2009
GRETINA Gamma-Ray Detector, LBNL (41NL)	18,200[b]	17,000[b]	3,500	3,000	3,900	4,400	FY 2010
Fundamental Neutron Physics Beamline, ORNL (41NM)	9,288[c]	9,200[c]	2,200	1,900	1,500	1,500	FY 2010
PHENIX Silicon Vertex Tracker, BNL (71RD)	4,600[d]	4,600[d]	—	—	2,000	2,000	FY 2010
Heavy Ion LHC Experiments, LBNL (71RC)	13,295[e]	13,000[e]	—	—	1,000	2,000	FY 2012
Neutron Electric Dipole Moment (nEDM), LANL (71RE)	18,480[f]	18,300[f]	—	—	1,300	3,000	FY 2015
Cryogenic Underground Observatory for Rare Events (CUORE), LBNL	10,000[g]	10,000[g]	—	—	—	500	FY 2012
PHENIX Forward Vertex Detector, BNL	4,950[h]	4,950[h]	—	—	—	1,400	FY 2011
PHENIX Nose Cone Calorimeter, BNL	4,700[h]	4,700[h]	—	—	—	1,000	FY 2011
Total, Major Items of Equipment				7,300	12,124	15,800	

[a] A project Status Review was conducted in September 2006 to assess project plans and performance. The FY 2006 rescission of $24,000 for this MIE was restored during FY 2006 after submission of the FY 2007 Budget negating the need to restore the $24,000 in FY 2007. FY 2007 funding will be adjusted accordingly upon enactment of the FY 2007 Appropriation.

[b] The preliminary TEC is within the $13,000,000 to $18,000,000 range approved at CD-0 and CD-1. The TEC is preliminary and will be baselined at CD-2. The CD-2a for long lead procurements was approved in June 2005. CD-2 for the project as a whole is planned for July 2007.

[c] The TEC of $9,200,000 is within the $8,000,000 to $11,000,000 range approved at CD-0 and has been baselined at CD-2.

[d] The project was baselined at a Technical, Cost, Schedule and Management Review in 2006. Under a year-long FY 2007 Continuing Resolution, new starts may be deferred. Cost and schedule impacts will be determined after passage of an appropriation.

[e] CD-0 was approved in November 2005 with a preliminary TPC range of $5,000,000 - $16,000,000. The TEC and TPC are preliminary and will be baselined at CD-2. Under a year-long FY 2007 Continuing Resolution, new starts may be deferred. Cost and schedule impacts will be determined after passage of an appropriation.

[f] CD-0 was approved in November 2005 with a preliminary TPC range of $12,000,000 - $18,300,000. The TEC and TPC are preliminary and will be baselined at CD-2. Under a year-long FY 2007 Continuing Resolution, new starts may be deferred. Cost and schedule impacts will be determined after passage of an appropriation.

[g] CD-0 for multiple candidate double beta decay experiments was approved in November 2005 with a preliminary TPC range of $10,000,000 - $75,000,000. The TEC and TPC are preliminary and will be baselined at CD-2. CUORE represents one of the candidate experiments. R&D efforts continue on a detector utilizing a different technology.

[h] The TEC and TPC are preliminary and will be baselined at a Technical, Cost, Schedule and Management Review.