Nuclear Physics

Funding Profile by Subprogram

(dollars in thousands)

	FY 2005 Current Appropriation	FY 2006 Original Appropriation	FY 2006 Adjustments	FY 2006 Current Appropriation	FY 2007 Request
Nuclear Physics					
Medium Energy Nuclear Physics	118,596	109,640	-1,106[a]	108,534	122,781
Heavy Ion Nuclear Physics	170,363	161,761	-1,618[a]	160,143	197,512
Low Energy Nuclear Physics	74,725	68,902	-679[a]	68,223	83,899
Nuclear Theory	30,865	28,438	-284[a]	28,154	35,348
Subtotal, Nuclear Physics	394,549	368,741	-3,687	365,054	439,540
Construction	—	2,000	-20[a]	1,980	14,520
Total, Nuclear Physics	394,549[b]	370,741	-3,707	367,034	454,060

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act"
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] Reflects a rescission in accordance with P.L. 109-148, the Emergency Supplemental Appropriations Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006.

[b] Total is reduced by $3,262,000 for a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005; $9,133,000, which was transferred to the SBIR program; and $1,096,000, which was transferred to the STTR program.

Strategic and Program Goals

The Department's Strategic Plan identifies four strategic goals (one each for defense, energy, science, and environmental aspects of the mission) plus seven general goals that tie to the strategic goals. The NP program supports the following goal:

Science Strategic Goal
General Goal 5, World-Class Scientific Research Capacity: Provide world-class scientific research capacity needed to ensure the success of Department missions in national and energy security; advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences; or provide world-class facilities for the Nation's science enterprise.

The NP program has one program goal which contributes to General Goal 5 in the "goal cascade":
Program Goal 05.20.00.00 – Explore Nuclear Matter, from the Quarks to the 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 Program Goal 05.20.00.00 Explore Nuclear Matter, from the Quarks to the Stars

The NP subprograms (Medium Energy, Heavy Ion, Low Energy, and Nuclear Theory) contribute to Program Goal 05.20.00.00 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 program builds and supports 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, provide 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 Long-Range planning report prepared by its primary advisory panel, the Nuclear Science Advisory Committee (NSAC)–Opportunities in Nuclear Science (2002). 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 is consistent with both the DOE and SC Strategic Plans and with the SC 20-year facilities plan, Facilities for the Future of Science (2003).

The Medium Energy subprogram will contribute to Program Goal 05.20.00.00 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) 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 World-Class Scientific Research Capacity 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 Program Goal 05.20.00.00 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 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 World-Class Scientific Research Capacity 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 Program Goal 05.20.00.00 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 carried out at the Los Alamos Neutron Science Center (LANSCE) and are being developed by nuclear physicists at the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory. The following indicators establish specific long-term goals in World-Class Scientific Research Capacity 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 Program Goal 05.20.00.00 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 that dwarf current capabilities 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, such as the design of reactors and national and homeland security. 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 General and Program Goal

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 05.20.00.00 Explore Nuclear Matter from the Quarks to the Stars (Nuclear Physics)	394,549	367,034	454,060

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Targets	FY 2007 Targets
Program Goal 05.20.00.00 – 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 11% 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]	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%.
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 (2.4), Hall B (7.2), and Hall C (2.1), 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 (2.8), Hall B (8.1), and Hall C (2.1), 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 (1.45), Hall B (7.7), and Hall C (1.7), 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 (2.2), Hall B (11.6), and Hall C (2.6), 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 (127,000) and recorded by the STAR (158) detectors, respectively during the polarized proton run at the Relativistic Heavy Ion Collider.
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]	Weighted average number (within 30% of baseline estimate) of millions of events sampled by the PHENIX (8600) and recorded by the STAR (117) detectors, respectively, at the Relativistic Heavy Ion Collider. [Met Goal]	No Target. (The Relativistic Heavy Ion Collider is not operating in heavy ion mode during FY 2006)	Weighted average number (within 30% of baseline estimate) of millions of events sampled by the PHENIX (30,000) and recorded by the STAR (100) detectors, respectively during the heavy ion run at the Relativistic Heavy Ion Collider.

FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Targets	FY 2007 Targets
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 (25) and Holifield Radioactive Ion Beam (5.3) 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 (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 (17.5) and Holifield Radioactive Ion Beam (1.375) 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 (1.8) 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.

The NP program 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.

The NP program is closely coordinated with the research activities of the National Science Foundation (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 the NP program collaborate with researchers from many countries. Large numbers of foreign scientists, who provide monetary and equipment support, heavily utilize all of the NP 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, 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. Quarterly, semiannual, and annual reviews consistent with specific program management plans are held to ensure technical progress, cost and schedule adherence, and responsiveness to program requirements.

Program Assessment Rating Tool (PART)

PART is a tool 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, and implemented by the Department to assess its programs including Nuclear Physics. 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 into the FY 2007 Budget Request and has taken the necessary steps to continue to improve performance.

In the PART review, OMB gave the NP program a score of 85% overall which corresponds to 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 2007. 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 and also available on the website, will guide review of progress toward achieving the long term Performance Measures every five years by NSAC. The Annual Performance Targets are tracked through the Department’s Joule system and reported in the Department’s Annual Performance Report.

For the FY 2007 Budget, OMB has developed PARTWeb—a new interface for PART that facilitates collaboration between agencies and OMB. PARTWeb will link to the http://ExpectMore.gov website and will improve public access to PART assessments and follow up actions. For 2006 there are three actions for Nuclear Physics:

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

This budget request is one of many actions that NP is taking to respond to the recommendations of recent Nuclear Science Advisory Committee reports. NP will continue to work to maximize the utility and efficiency of major experimental facilities to ensure that the Nation's Nuclear Physics program achieves maximum results. NP has already engaged the National Academies to study the scientific opportunities of a proposed rare isotope accelerator and will encourage broad representation from the scientific community. The Academies report is expected October 2006.

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 Nuclear Science Advisory Committee 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 2005, the DOE Nuclear Physics program provided about 90% of the federal support for fundamental nuclear physics research in the Nation. The NSF provided 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 FY 2005 NSAC responded to DOE/NSF charges with four reports: (1) a review of Heavy Ion Nuclear Physics; (2) education in Nuclear Science; (3) the Neutrino Scientific Assessment Group (NuSAG) (with the High Energy Physics Program advisory committee (HEPAP)); and (4) the implementation of the 2002 Long-Range Plan. The reports can be found at http://www.sc.doe.gov/np/nsac/nsac.html.

The National Academy of Sciences (NAS) has been charged with carrying out an independent assessment of the importance of the science portfolio available to a next generation facility in nuclear structure and astrophysics, the Rare Isotope Accelerator (RIA). The report, expected by the fall of 2006, will address the role of RIA for the future of nuclear physics, and the need for RIA within the international context of the field.

Facility directors seek advice from Program Advisory Committees (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. To supplement the S&T reviews, Facility Management and Operations Reviews are performed, where bottoms up evaluations are performed to better understand the costs and effectiveness of operations. Such reviews were conducted in FY 2002 for the Relativistic Heavy Ion Collider (RHIC) facility and Continuous Electron Beam Accelerator Facility (CEBAF), and in FY 2003-2004 for the Holifield Radioactive Ion Beam Facility (HRIBF) and the Argonne Tandem Linac Accelerator System (ATLAS) facility.

In addition, the NP program also reviews, with international experts, proposed and ongoing equipment 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.

Program Reviews

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 was the review of the Heavy Ion subprogram in 2004. Quality and productivity of university grants are peer reviewed on an approximately three-year basis and laboratory groups performing research are peer reviewed on an approximately four-year basis.

Planning and Priority Setting

The strategic plan for NP is set forth in the DOE and SC Strategic Plans. The Office of Nuclear Physics 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 major facility initiatives identified in the 2002 NSAC Long-Range Plan, the RIA and the 12 GeV CEBAF Upgrade, were incorporated into NP's strategic plan and are identified as near-term priorities in the SC future facilities plan, Facilities for the Future of Science: A Twenty-Year Outlook. Both of these initiatives have obtained Mission-Need approval by the Department.

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 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, and the Nuclear Theory and Heavy Ion subprograms, is reflected in the programmatic decisions in FY 2005 and FY 2006 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 2007 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 participated 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 provided in FY 2007 to partially support the thrust on the Origin of the Heavy Elements at existing low-energy facilities and to support High Energy Density Physics with heavy ions at RHIC and participation at the LHC.

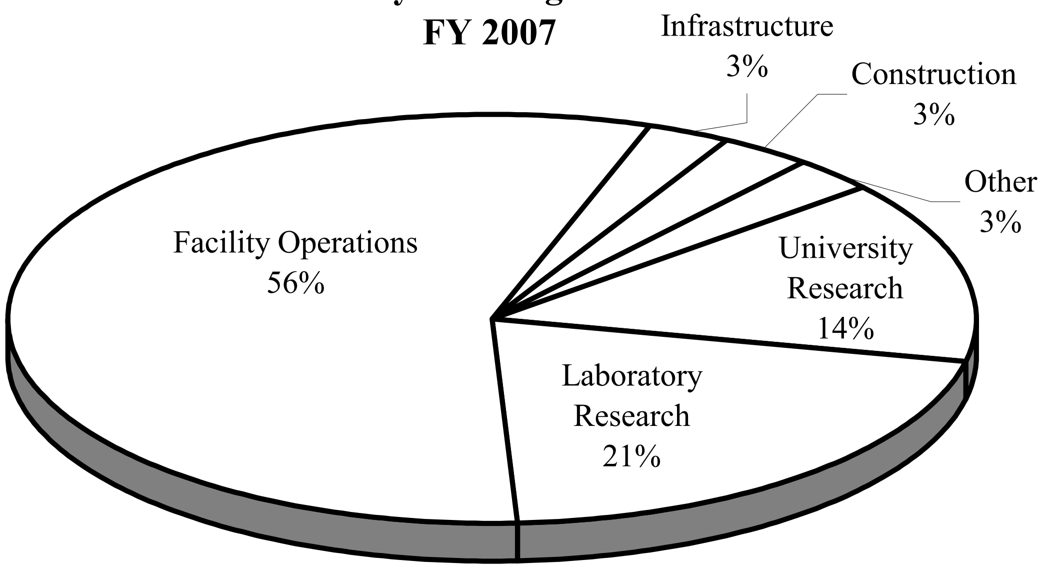
Committee of Visitors

A Committee of Visitors (COV), appointed by the NSAC, reviewed the management practices of the Nuclear Physics program in FY 2004. The committee examined the Office's overall operations and output, and in particular the decision process for awarding grants and for determining priorities of funding among the various activities within the Nuclear Physics program. The Committee found that the Nuclear Physics program "carries out its duties in an exemplary manner," but suggested "a number of minor operational changes which may benefit the program managers and reviewers in carrying out their tasks more efficiently." Among these was the allocation of more travel funds for program managers that has occurred in FY 2005.

How We Spend Our Budget

The FY 2007 budget request is focused on optimizing, within the resources available, the scientific productivity of the program by ensuring a proper balance of research scientists and technicians, facility operations, and investments in needed tools and capabilities. Approximately 35% of the funding is provided for research personnel to utilize the program's user facilities, complete important experiments and to fabricate experimental instrumentation. Approximately 56% of the funding is provided for operations of the program user facilities, and for support of NP's share of the in-house program at the 88-Inch Cyclotron. Approximately 6% is provided for infrastructure and for construction projects that are needed to extract the science and improve efficiencies in the outyears and approximately 3% for other activities that include Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) programs.

Nuclear Physics Budget Allocation
FY 2007



Research

About 35% of the program's funding is provided to scientists at universities and laboratories to conceive and carry out the research. The DOE Nuclear Physics 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 over 85 academic institutions located in 35 states and at 7 DOE Laboratories in 6 states. Funding is increased by ~20% compared to FY 2006. 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 2006 the DOE Nuclear Physics program supported approximately two-thirds of the Nation's university researchers and graduate students doing fundamental nuclear physics research. Among the 85 academic institutions, DOE supported 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 newly established 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/production/grants/grants.html). 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. Laboratory researchers collaborating 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.

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.

The DOE Nuclear Physics program focuses its scientific thrusts at fundamental questions identified by the scientific community primarily through NSAC. To most effectively address these topics, the Nuclear Physics program is structured into four subprograms: the Medium Energy Nuclear Physics subprogram seeks to understand the structure of the nucleon; the Heavy Ion Nuclear Physics subprogram studies the properties of hot, dense nuclear matter; the Low Energy Nuclear Physics subprogram focuses on the structure of nucleonic matter, the nuclear microphysics of the universe, and addresses the possibility of new physics beyond the Standard Model; and the Nuclear Theory subprogram provides the fundamental theories, models and computational techniques to address these science topics.

Significant Program Shifts

The FY 2007 budget request increases support for operations and research by ~21% compared to FY 2006. At this funding level, overall operations of the four National User Facilities and research efforts at universities and laboratories are restored to approximately FY 2005 levels. At this level, the NP-supported user facilities allow researchers to make effective progress towards the program's scientific goals and milestones. This budget request allows for the initiation of research efforts in the CERN LHC heavy ion program and the start of support for project engineering and design (PED) activities for the 12 GeV CEBAF Upgrade project. Modest funding for generic exotic beam R&D is supported in FY 2007.

The Low Energy subprogram and the Theory subprogram, through their activities at the Nuclear Data Center, will support increased basic research efforts relevant to advanced nuclear fuel cycle issues. These subprograms will support nuclear data efforts and selected experiments that will lead to improvements in nuclear reaction cross-sections to reduce uncertainties needed to calculate the transmutation behavior for proposed advanced fuel cycles.

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.

The Nuclear Physics program funds SciDAC programs in the areas of theoretical physics (National Computational Infrastructure for Lattice Gauge Theory), astrophysics (Shedding New Light on Exploding Stars: TeraScale Simulations of Neutrino-Driven Supernovae and their Nucleosynthesis), and grid technology (Particle Physics Data Grid Collaborative Pilot) that support the scientific goals of the Nuclear Physics subprograms. The principal goal of the Tera Scale Supernova simulations is to understand the mechanism responsible for the explosions of massive stars–arguably, the dominant source of most elements in the Periodic Table between oxygen and iron. The National Computational Infrastructure for Lattice Gauge Theory has as 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 complementary to a similar activity by the High Energy Physics program. The Particle Data Grid project has allowed Nuclear Physics experiments to tackle the task of replicating thousands of files at high speeds with rates in excess of 3-4 terabyte/week. In FY 2006 proposal applications will be evaluated for new or renewal grants under the SciDAC program.

Lattice Quantum ChromoDynamics Computing

Quantum ChromoDynamics is a very successful theory that describes the fundamental strong interactions between quarks and gluons. The lack of precision in current QCD calculations is now limiting the understanding of many experimental results in high-energy and nuclear physics, including measurements at the RHIC, TJNAF, Stanford Linear Accelerator Center (SLAC) B-Factory, and the Fermi National Accelerator Laboratory (FNAL) Tevatron. Recent advances in numerical algorithms coupled with the ever-increasing performance of computers have now made a wide variety of QCD calculations feasible, though most calculations of interest still require very significant computing resources ($\sim 10^{12\text{-}14}$ computational operations per second or 1-100 teraflops).

Together with the High Energy Physics (HEP) and Advanced Scientific Computing Research (ASCR) programs, a ~5 teraflop prototype computer was developed and implemented in FY 2005 using the custom QCD On-a-Chip (QCDOC) technology. This platform will enable 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 computing capabilities (~ an additional 13 teraflops) began in FY 2006 to provide computing capabilities based on the most promising technology.

Scientific Facilities Utilization

In FY 2005 Nuclear Physics operated five National User Facilities including the Bates Linear Accelerator Center at the Massachusetts Institute of Technology which ceased operations in mid-FY 2005. NP's remaining four National User Facilities provide research time for scientists in universities and other Federal laboratories in FY 2006. In FY 2007, the program will support operations of these four facilities:

- 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 1,990 U.S. and international scientists. The FY 2007 Budget Request will support operations at these facilities that will provide ~19,015 hours of beam time for research, a ~66% increase over the anticipated beam hours in FY 2006.

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 2005	FY 2006	FY 2007 Request
Number of Facilities	5	4	4
Optimal Hours	25,800	22,675	22,675
Planned Operating Hours	21,660	11,435	19,015
Achieved Operating Hours	24,541	N/A	N/A
Unscheduled Downtime – Major user facilities	3,443	N/A	N/A
Number of Users[a]	2,240	2,100	1,990

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.

[a] Due to multiple facilities some users may be multiply counted.

Origin of Heavy Elements

While we have a relatively good understanding of the origin of the chemical elements in the cosmos lighter than iron, the production of the elements from iron to uranium remains a puzzle. A sequence of rapid neutron captures by nuclei known as the *r*-process (where *r* is for rapid), is clearly involved, as may be seen from the observed abundances of the various elements. Supernovae explosions, neutron-star mergers, or sources of gamma-ray bursts are possible locales for this process. Tremendous forces create the conditions that synthesize heavy elements from light elements, but our incomplete understanding of these events leaves the question open. The approach to understanding the origin and role of the heavy elements in the cosmos involves advances on several fronts including astrophysical observations of nucleosynthesis signatures in all spectral regions, studies of the abundances of elements in stars and supernovae, large-scale computer simulations for better theoretical interpretation of nuclear processes, and measurement of properties of exotic nuclei.

NP supports this area of research with studies of exotic nuclei and reactions at its existing facilities and by development of plans for exotic beam facilities.

High Energy Density Physics

When the Universe was a billionth of a second old, nuclear matter is believed to have existed in its most extreme energy density form called the quark-gluon plasma. Experiments at RHIC are searching to find and characterize this new state.

The High Energy Density Physics activities include the support of the operations of RHIC and the accompanying research program at universities and laboratories. Research and development activities, including the development of an innovative electron beam cooling system at RHIC, are expected to demonstrate the feasibility of increasing the luminosity or collision rate of the circulating beams by a factor of ten. Such an increase will allow measurements of the production rate of the J/ψ and other "charmonium" mesons that are believed to be a key indicator of possible new phenomena. With very large data samples, more precise studies will become possible of particles emanating from the hot, dense matter during its very brief existence.

The High Energy Density Physics activities include Nuclear Physics contributions to enhance the heavy ion triggering and measurement capabilities of existing LHC experiments and the accompanying research program at universities and laboratories. Experiments at the LHC are under construction that would permit measurements of the earliest highest energy density stage in the formation and development of matter at different conditions than those created at RHIC. The interplay of the different research programs at the LHC and the ongoing RHIC program will allow a detailed tomography of the hot, dense matter as it evolves from the "perfect fluid" (a fluid with zero viscosity) discovered at RHIC.

Construction and Infrastructure

In FY 2007, the increases in capital equipment (~26%) and accelerator improvement projects (~42%) are focused on projects at ATLAS and HRIBF. Funding of $7,520,000 is provided in the FY 2007 request for completion of Preliminary Engineering Design (PED) and initiation of construction for the RHIC Electron Beam Ion Source (EBIS), a joint DOE/NASA project. A Technical, Cost, Schedule, and Management review was conduced and a Critical Decision-1 (CD-1: Approve Alternative Selection and Cost Range) for the EBIS project was approved in FY 2005. The SC Office of Project Assessment conducted a Conceptual Design Review of the proposed 12 GeV CEBAF Upgrade Project to evaluate the conceptual design of the project, and assess project costs and schedules. The results of the peer review have been incorporated into the FY 2007 request, and funding of $7,000,000 is requested to initiate PED efforts in FY 2007. A CD-1 review is planned 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. Overall GPP increases by ~7% compared to FY 2006.

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 finely-honed thinking and 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 900 postdoctoral research associates and graduate students supported by the Nuclear Physics program in FY 2005 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. In FY 2005 there were about 270 faculty researchers supported at the universities (~1.5 per grant), with an average award of ~$205,000 per faculty researcher. Almost all grants are awarded with project periods of three years.

	FY 2005	FY 2006 estimate	FY 2007 estimate
# University Grants	185	180	190
Average size (excluding CE)	$310,000	$306,000	$340,000
# Laboratory Groups	28	27	27
# Permanent Ph.D.'s	652	590	650
# Postdoctoral Associates	388	340	380
# Graduate Students	509	420	500
# Ph.D.'s awarded	80	80	80

External Independent Reviews

Beginning in FY 2005, the costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $5,000,000 within SC have been funded by SC. Examples of EIRs include conducting Performance Baseline EIRs prior to Critical Decision-2 (CD-2) to verify the accuracy of cost and schedule baseline estimates and conducting Construction/Execution Readiness EIRs, which are done for all Major System projects prior to CD-3. These funds, which are managed by the Office of Engineering and Construction Management, are exclusively used for EIRs directly related to these projects funded within SC. Beginning in FY 2007, the EIR business line will be financed via the Working Capital Fund to achieve parity on how EIRs are funded and to standardize the administration of these critical activities.

Medium Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Medium Energy Nuclear Physics			
Research			
University Research	15,283	15,858	18,103
National Laboratory Research	16,009	15,567	16,983
Other Research[a]	531	5,003	5,684
Total, Research	31,823	36,428	40,770
Operations			
TJNAF Operations	77,365	69,606	80,011
Bates Facility	9,408	2,500	2,000
Total, Operations	86,773	72,106	82,011
Total, Medium Energy Nuclear Physics	118,596	108,534	122,781

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 program, 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

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[a] In FY 2005, $3,772,000 has been transferred to the SBIR program and $1,096,000 has been transferred to the STTR program. This activity also includes $3,380,000 for SBIR and $986,000 for STTR in FY 2006 and $3,615,000 for SBIR and $1,185,000 for STTR in FY 2007.

under conditions that cannot be duplicated by man. To accomplish this task, the Medium Energy subprogram has operated the CEBAF at the Thomas Jefferson National Accelerator Facility (TJNAF), supports research at the RHIC at Brookhaven National Laboratory, and supports university researchers to carry out the experiments at these facilities. These research activities contribute to the training of the next generation of scientists and engineers that will contribute to the Department's nuclear and energy missions, as well as areas of national security.

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) measuring 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 National Synchrotron Light Source at Brookhaven, 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, has annually served a nationwide community of about 300 DOE and about 300 National Science Foundation (NSF) supported scientists and students from over 80 U.S. institutions and about 300 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 Program Advisory Committees that review and evaluate proposed experiments regarding their merit and scientific priority.

FY 2005 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:

- Approximately ten experiments world-wide, including TJNAF, have reported observing a pentaquark state while a corresponding number of experiments have not. This state, if confirmed, would be the first evidence of a particle consisting of five quarks. A new experiment at TJNAF with an order of magnitude more sensitivity finds no evidence for the pentaquark seen in previous data. This result negates earlier positive results from TJNAF and another laboratory and sets a new upper limit on the existence of the pentaquark, which challenges the significance of the remaining positive results from other laboratories.
- The TJNAF G^0 experiment, a joint DOE/NSF project with strong international participation, has completed its first phase of running to measure the contribution of strange quarks in the proton for this textbook measurement. This is the most comprehensive measurement to date that will determine the role of strange quarks in the proton's charge and magnetic distributions.

- Researchers at Argonne National Laboratory have measured the radius of the ^{6}He nucleus to be two trillionths of a millimeter with an accuracy of 0.7% by using a novel technique (Atomic Trap Trace Analysis – ATTA) of laser trapping individual atoms produced using an accelerator. The measurement will be a key benchmark because it is the first model-independent determination of the ^{6}He charge radius. The accuracy makes it possible to exclude several previous model calculations and differentiate between different three-body potentials. The group continues to develop the ATTA technology for use in fields outside of Nuclear Physics, such as geology and medicine.
- The MiniBooNE experiment, which seeks to confirm the existence of a new type of neutrino, successfully achieved its milestone of collecting neutrino events from a total proton fluence of 5×10^{20} on the production target and completed data taking in FY 2005. The experiment is expected to make public its results regarding whether a new kind of neutrino exists in FY 2006.
- The BLAST detector at the MIT/Bates facility has completed its data taking for precise measurements of the charge distribution inside the neutron and the higher order angular momentum component to the deuteron. These data will discriminate between different models of the quark structure of the neutron and different models of how the proton and neutron bind together to make the deuteron. Analysis of the data on nucleon and deuteron structure are underway.

FY 2005 Facility and Technical Accomplishments:

- TJNAF is a world-leader in superconducting radio frequency (SRF) technology. Several technical accomplishment in FY 2005 were realized including: the completion of state-of-the-art SRF cavities for the Spallation Neutron Source project; the development of particle accelerating modules that have enabled the production of the world's highest power infrared light (by a factor of more than 100) for use in the TJNAF Free Electron Laser (supported by DOD); the development of a particle accelerating module able to double the energy and resolving power of the CEBAF in preparation for the 12 GeV Upgrade; and the development and testing of particle accelerating cavities based on new superconducting material in the form of large crystals of pure Niobium that have reached close to the ultimate capability of superconducting Niobium technology in a cost-effective way, allowing the United States to take leadership in the design of an affordable potential future particle collider to understand the origins of matter and forces in nature (ILC-International Linear Collider).
- A special magnet called the "Warm Snake," designed and built in Japan by the RIKEN Research Institute, was successfully installed and commissioned in the Alternating Gradient Synchrotron (AGS) at RHIC. With this device, the average polarization of the proton beam in the RHIC ring has increased to 45%. A new complex geometry "Cold Snake" magnet using superconducting technology was successfully installed in the AGS in 2005 and is expected to further increase the absolute proton beam polarization to 60% starting in 2006.
- A new frozen deuterium target that has been in development for several years has been used in the Laser Electron Gamma Source (LEGS) experiment at Brookhaven National Laboratory to successfully acquire data for the first time. These data should resolve inconsistencies from previous measurements about the neutron's structure when it is in its first excited state. The LEGS collaboration plans to complete taking data in 2006.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Research	**31,823**	**36,428**	**40,770**
▪ **University Research**	**15,283**	**15,858**	**18,103**

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.

• **Bates Research**	**1,985**	**—**	**—**

The BLAST detector was used to complete measurements on deuteron structure and the charge distribution of the neutron in FY 2005. With the termination of MIT/Bates operations as a National User Facility in FY 2005, funding for MIT scientists and other university researchers involved in the BLAST detector program to complete their analyses in FY 2006 and FY 2007 is shifted to Other University Research.

• **Other University Research**	**13,298**	**15,858**	**18,103**

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 will be an integral component of MIT's medium energy research effort and utilize the infrastructure remaining at the MIT/Bates facility. The unique skills of the personnel at the R&E Center enable them to effectively participate in fabrication of instrumentation and R&D 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 2007, these research efforts include 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 of the origin of spin in the proton.

▪ **National Laboratory Research**	**16,009**	**15,567**	**16,983**

Support for experimental groups at TJNAF restores CEBAF efforts to 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**	**5,729**	**5,623**	**6,163**

Scientists at TJNAF, with support of the user community, assembled the large and complex experimental detectors for Halls A, B, and C. TJNAF scientists have provided necessary experimental support and operation of the detectors for safe and effective utilization by the user community. TJNAF scientists played a lead role in the laboratory's research program. In FY 2007 funding is increased relative to FY 2006 to effectively carry out the research program.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
• **Other National Laboratory Research**	**10,280**	**9,944**	**10,820**

Support for research activities at accelerator and non-accelerator facilities is increased relative to FY 2006, with resources directed towards the highest priority activities that include those described below:

- 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. Support is provided for these activities, as well as efforts with the Hermes experiment at Deutsches Electron-Synchrotron (DESY) that are expected to be nearing conclusion.
- Support will be provided to the RHIC spin physics Medium Energy Research groups at BNL and LANL. Both of these groups have important roles and responsibilities in the RHIC spin physics program.
- The LEGS experiment at BNL is expected to be completed in FY 2006. The FY 2007 Request provides support to complete the analysis of data.
- At LANL, scientists and collaborators are participating in the MiniBooNE neutrino oscillation experiment at FNAL that hopes to determine whether a new type of neutrino exists. Preliminary results are expected in FY 2006 and support will be provided in FY 2007 to complete these efforts.

▪ **Other Research**	**531**	**5,003**	**5,684**

In FY 2005, $3,772,000 has been transferred to the Small Business Innovation Research (SBIR) program and $1,096,000 has been transferred to the Small Business Technology Transfer (STTR) program. This activity includes $3,380,000 for SBIR and $986,000 for STTR in FY 2006 and $3,615,000 for SBIR and $1,185,000 for STTR in FY 2007 as well as other established obligations that the Medium Energy Nuclear Physics subprogram must meet.

Operations	**86,773**	**72,106**	**82,011**
▪ **TJNAF Operations**	**77,365**	**69,606**	**80,011**

Funding supports TJNAF operations and Experimental Support for a ~36-week, 3-Hall operations schedule.

• **TJNAF Accelerator Operations**	**51,015**	**47,578**	**53,711**

CEBAF operations are supported for a 4,985 hour running schedule, a ~46% increase over estimated running in FY 2006. At this level of funding the accelerator provides beams simultaneously to all three experimental halls. In FY 2005, CEBAF operations exceeded estimated maximum operations; TJNAF made the decision to utilize time normally dedicated to facility maintenance and AIP installation into running time to fulfill a major commitment to a Japanese hypernucleus experiment. In FY 2007, support is directed at continuing necessary accelerator improvement projects (AIP) and General Plant Project (GPP) infrastructure

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

improvements at an increased level compared to FY 2006. Support is also provided to restore efforts in developing advances in superconducting radio-frequency technology to FY 2005 levels.

	FY 2005	FY 2006	FY 2007
CEBAF hours of operation with beam	6,067	3,405	4,985

Funding of $2,500,000 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 Plan, and received Mission Need (CD-0) approval by the Department of Energy in March 2004. An SC Office of Project Assessment Conceptual Design Review of the project assessed the R&D plans and costing profiles for the project, and results from the review are incorporated into this budget request. Project engineering and design funding is also requested under the Construction section of this budget.

• **TJNAF Experimental Support**	**26,350**	**22,028**	**26,300**

The FY 2007 request supports Experimental Support efforts at the level needed for a 36-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 2007 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.

▪ **Bates Facility**	**9,408**	**2,500**	**2,000**

MIT/Bates Linear Accelerator Center is provided funding related to the transfer of the Bates Center property to MIT and to indemnify DOE of any future liabilities.

	FY 2005	FY 2006	FY 2007
Bates hours of operation with beam	4,442	—	—

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 that 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.

Total, Medium Energy Nuclear Physics	**118,596**	**108,534**	**122,781**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Research	
▪ **University Research**	
Funding includes support to complete analyses of the MIT/Bates experiments and for the Research and Engineering (R&E) Center ($+2,000,000) located at MIT that capitalizes on the infrastructure and unique skills of research staff at MIT/Bates. Funding restores core university research efforts to FY 2005 levels.	+2,245
▪ **National Laboratory Research**	
Overall support for Laboratory research groups restores research efforts to FY 2005 levels. These efforts will be focused on TJNAF activities and allow more rapid completion of analyses of RHIC spin and MiniBooNE data.	+1,416
▪ **Other Research**	
Increase reflects required SBIR/STTR and other obligations	+681
Total, Research	**+4,342**
Operations	
▪ **TJNAF Operations**	
• **TJNAF Accelerator Operations**	
The FY 2007 funding request restores CEBAF accelerator operations ($+7,483,000) to near FY 2005 levels and supports a 4,985 hour running schedule. Accelerator science R&D for superconducting radio-frequency technology is increased relative to FY 2006 levels ($+585,000) and R&D for the12 GeV CEBAF Upgrade is reduced compared to FY 2006 ($-1,955,000) according to the planned profile. AIP/GPP is increased ($+20,000) compared to FY 2006.	+6,133
• **TJNAF Experimental Support**	
The FY 2007 funding request increases TJNAF experimental support by 19% relative to FY 2006 to support the facility running schedule.	+4,272
Total, TJNAF Operations	**+10,405**
▪ **Bates Facility**	
The decrease is consistent with the MIT/DOE agreement for the transfer of the Bates Center property to MIT and to indemnify DOE of any future liabilities.	-500
Total, Operations	**+9,905**
Total Funding Change, Medium Energy Nuclear Physics	**+14,247**

Heavy Ion Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Heavy Ion Nuclear Physics			
Research			
University Research	12,399	11,993	14,013
National Laboratory Research	16,573	18,491	23,326
Other Research[a]	—	3,573	5,014
Total, Research	28,972	34,057	42,353
Operations			
RHIC Operations	130,624	115,451	143,327
Other Operations	10,767	10,635	11,832
Total, Operations	141,391	126,086	155,159
Total, Heavy Ion Nuclear Physics	170,363	160,143	197,512

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 2005, $3,917,000 has been transferred to the SBIR program. This activity includes $3,573,000 for SBIR in FY 2006 and $4,918,000 for SBIR in FY 2007.

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 Bevalac (LBNL) 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 Alternating Gradient Synchrotron (BNL) 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—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 five 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; and Run 5 in FY 2005 with high luminosity copper beams and polarized protons. This facility is utilized by ~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 2005 Accomplishments

The NSAC Long-Range Plan summarized important accomplishments of the field up to 2002; since then accomplishments are summarized yearly in the budget submission. The fourth running period in FY 2004 with high luminosity gold beams produced high statistics data that afford observations of rare processes, and 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 will provide physicists with the control tests. This intermediate mass nucleus, copper, allows the RHIC experiments (BRAHMS, PHENIX, Phobos and STAR) to study system size dependence. The 2004 and 2005 data will provide greater insights into the remarkable properties of the Quark-Gluon Plasma (QGP) and the

Color Glass Condensate (CGC) matter mentioned below. Some of the highlights from the gold-gold and deuteron-gold programs are:

- The universe may have begun as a “perfect” liquid, not a gas. In April 2005, nuclear physicists working on the four experiments at RHIC presented “White Papers” documenting details of and summarizing the evidence for an extraordinary new state of matter obtained from the first 3 years of RHIC operations. These latest results show that a new state of hot, dense matter was created out of quarks and gluons, but quite different and even more remarkable than had been previously predicted. The matter created in heavy-ion collisions appears to behave like a near “perfect” liquid rather than a fiery gas of free quarks and gluons. The word “perfect” refers to the liquid’s viscosity—a friction-like property that impedes a fluid’s ability to flow. A perfect liquid has no viscosity. The RHIC results are consistent with “ideal” hydrodynamic calculations suggesting that the lowest viscosity possible in a “QGP fluid” may be achieved—a stunning discovery that could revise physicist’s conception of the earliest moments of the universe.

- Color Glass Condensate (CGC) is the name for an extreme form of nuclear matter that may have been glimpsed at RHIC in deuteron-gold collisions. In these asymmetric collisions, the deuteron is too light to create a QGP. However, according to Einstein's special theory of relativity, when a nucleus travels at near-light speed, it flattens like a pancake in its direction of motion. Also, the high energy of an accelerated nucleus may cause it to spawn a large number of gluons, the particles that hold together its quarks. These factors may transform a heavy spherical nucleus into a flattened "wall" made mostly of gluons reminiscent of a Bose-Einstein condensate. This wall, 50-1,000 times more dense than ordinary nuclei, is the CGC. Some researchers believe the QGP emerges when two CGC’s collide. While nuclear physicists are debating the evidence for a CGC, the concept itself is an accepted, if evolving, theoretical idea that might describe a universal condition of matter at relativistic energies.

- The measurements of particles emerging from RHIC collisions behave as though they had coalesced from a bath of collectively flowing, but thermally equilibrated constituent quarks. These unexpected results demonstrate that the matter produced at RHIC is dominated by sub-nucleon processes, a major milestone along the path to demonstrating the formation of the QGP.

- The matter produced at RHIC is largely opaque to quarks and gluons, as revealed most dramatically by the disappearance of high momentum jet fragments emerging in the opposite direction from a detected jet fragment in gold-gold collisions. This back-to-back correlation is present in deuteron-gold collisions. One explanation presumes that dual jets are, in fact, created near the surface of the hot, dense collision zone where one of the jets plows into an unusually opaque form of matter while the other jet escapes unimpeded in the opposite “matter-free” direction. New results indicate that the observed jet suppression depends on the orientation of the in-bound jet and thus on its path length in the opaque medium. Scientists hope to exploit this behavior using the high statistics gold data accumulated in FY 2004 and the copper data in FY 2005 to build a more detailed “tomographic” image of this hot opaque medium.

- First measurements have been made of energetic gamma rays emanating from head-on gold collisions. These “direct” photons are not suppressed and their rate is in agreement with theoretical expectations of radiation emitted from quarks and gluons.

- D mesons and J/ψ (psi) particles containing at least one heavy charm quark have been reconstructed in analysis of deuteron-gold collisions. These results will allow scientists to study the behavior and energy loss of heavy quarks in the dense, hot matter created in gold-gold collisions using the high statistics data acquired in FY 2004.

Of great interest to researchers following the progress at RHIC is the emerging connection to other fields of science. Einstein's "Equivalence Principle," states that no experiment can distinguish the acceleration due to gravity from the inertial acceleration due to a change of velocity. In the same way, the rapid deceleration of RHIC ions as they plow into each other over a very short period of time is similar to the extreme gravitational environment in the vicinity of a black hole. This implies that RHIC collisions should emit thermal particles similar to the "Hawking radiation" emitted by a black hole. The connection between RHIC results and recent calculations using String Theory, an approach that attempts to explain the properties of the universe using 10 dimensions, is unexpected and could have a profound impact. These intriguing connections are further elaborated under the Nuclear Theory Accomplishments.

FY 2005 Facility and Technical Accomplishments:

- RHIC successfully accelerated a copper beam in FY 2005. RHIC, in its latest run with 100 GeV/nucleon copper (Cu) beams, delivered twice the planned beam luminosity of 15 inverse nanobarns ($\sim 15nb^{-1}$) and set a new machine record. This record breaking performance has exceeded all expectations and accordingly provided significantly more data for the experiment, as well as two additional Cu runs, one at 31 GeV/nucleon and the other at 11.2 GeV/nucleon beam energy.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Research	**28,972**	**34,057**	**42,353**
▪ **University Research**	**12,399**	**11,993**	**14,013**

Support is provided for the research of about 120 scientists and 90 graduate students at 27 universities in 21 states. Support for university research funding increases ~17% compared to FY 2006, which restores university research to levels needed to maintain effective research efforts at RHIC and the initiation 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**	**16,573**	**18,491**	**23,326**

Support is provided for scientists at five national laboratories (BNL, LBNL, LANL, LLNL, and ORNL). 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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

for terabyte-scale data analysis and state-of-the-art facilities for detector and instrument development.

• **BNL RHIC Research**	**6,417**	**8,869**	**11,230**

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 2007 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 to and train young scientists. Capital equipment funds increase by $2,000,000 compared to FY 2006 to start the fabrication of the PHENIX Silicon Vertex Tracker detector (VTX) upgrade MIE (TEC ~$4,500,000), a joint project with the Japanese. 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. Funding ($2,424,000) is provided for the STAR Time of Flight (TOF) MIE, a joint project with the Chinese, at near the same level as FY 2006 to complete this project. The STAR TOF detector is a cylindrical array of Multi-gap Resistive Plate Chambers that will significantly improve particle identification capabilities of the existing STAR detector. Studies directed at developing the scientific case for a potential electron-heavy ion collider facility are supported.

• **Other National Laboratory Research**	**10,156**	**9,622**	**12,096**

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 increased compared to FY 2006, funding National Laboratory Research to maintain a constant level of effort compared with FY 2005 and to selectively support high priority research. Capital Equipment funding ($+1,000,000) is provided to enable U.S. participation in the heavy-ion program at the LHC (MIE TEC ~$5,000,000). The LHC Heavy-Ion MIE received CD-0 approval and Conceptual Design and R&D are supported in FY 2006. The upgrades will provide U.S. researchers the opportunity to search for states of matter under substantially different conditions than those provided by RHIC, and obtain additional activities information regarding the nature of matter that existed during the earliest moments of the universe.

▪ **Other Research**	**—**	**3,573**	**5,014**

In FY 2005, $3,917,000 has been transferred to the SBIR program. This activity includes $3,573,000 for Small Business Innovative Research (SBIR) in FY 2006 and $4,918,000 for SBIR in FY 2007.

Operations	**141,391**	**126,086**	**155,159**
▪ **RHIC Operations**	**130,624**	**115,451**	**143,327**

RHIC operations are supported for a ~34-week running schedule in FY 2007 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

(dollars in thousands)			
	FY 2005	FY 2006	FY 2007

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 shall be achieved in a timely manner.

• **RHIC Accelerator Operations**	**98,276**	**86,816**	**111,000**

Support is provided for the operation, maintenance, and improvement of the RHIC accelerator complex. This includes the Tandem, Booster and AGS accelerators that together serve as the injector for RHIC. FY 2007 funding will support ~34 weeks (4,080 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 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 ($+999,000) relative to FY 2006 levels.

	FY 2005	FY 2006	FY 2007
RHIC Hours of Operation with Beam	3,862	—	4,080

• **RHIC Experimental Support**......................................	**32,348**	**28,635**	**32,327**

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 900 scientists and students from 82 institutions and 19 countries will participate in the RHIC research program in FY 2007. With the completion of the planned scientific program of the Phobos detector in FY 2005, it is planned that three detectors will operate in FY 2007 (STAR, PHENIX and BRAHMS; described in the Office of Science Site Descriptions) that provide complementary measurements, but with some overlap in order to cross-calibrate the measurements. FY 2007 funding will support Experimental Support efforts at the level needed for a ~34-week running schedule and to pursue important detector R&D activities. Base capital equipment funding is reduced relative to FY 2006 and redirected to the PHENIX VTX MIE project.

▪ **Other Operations**	**10,767**	**10,635**	**11,832**

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, for 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 2006 to cover requirements.

Total, Heavy Ion Nuclear Physics	**170,363**	**160,143**	**197,512**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Research	
▪ **University Research**	
The increase for University Research grants in FY 2007 will restore efforts to FY 2005 levels. The major focus of research will be on the RHIC program with data taking with STAR, PHENIX and BRAHMS and data analysis from all detectors, including Phobos. A modest effort will also be directed towards the initiation of an LHC heavy -ion program at CERN.	+2,020
▪ **National Laboratory Research**	
• BNL RHIC Research: Funding for capital equipment is increased by $2,000,000, to start the fabrication of the PHENIX Vertex Detector upgrade (VTX) Major Item of Equipment (MIE). Funding for the STAR TOF MIE is increased by $48,000 compared to FY 2006 to restore reductions from the FY 2006 general rescission in order to maintain the TEC and project scope. Funding for research scientific personnel is increased by 4.8% above FY 2006 ($+313,000)	+2,361
• Other National Laboratory Research: The FY 2007 request restores research efforts ($+1,353,000) to near FY 2005 levels. Additional capital equipment funds are provided for base research infrastructure ($+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.	+2,474
Total, National Laboratory Research	**+4,835**
▪ **Other Research**	
Increase reflects required SBIR obligations.	+1,441
Total, Research	**+8,296**
Operations	
▪ **RHIC Operations**	
• The FY 2007 request for Accelerator Operations supports operations of the RHIC facility for a ~34-week running schedule to meet the program's scientific goals and performance measures.	+24,184
• Experimental Support: Funding is increased by $4,583,000 for experimental scientific/technical staff and materials and supplies that effectively support the maintenance and operation of the PHENIX and STAR detectors at RHIC for a 34-week operating schedule. Offsetting the increase is a reduction of $891,000 in	

	FY 2007 vs. FY 2006 ($000)
capital equipment funds to reflect the redirection to fund the fabrication of the PHENIX Silicon Vertex Tracker detector upgrade.	+3,692
Total, RHIC Operations	**+27,876**
▪ **Other Operations**	
Increased support is provided for BNL general plant projects and general purpose equipment to increase the level of effort for FY 2007.	+1,197
Total, Operations	**+29,073**
Total Funding Change, Heavy Ion Nuclear Physics	**+37,369**

Low Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Low Energy Nuclear Physics			
Research			
University Research	18,863	17,139	19,113
National Laboratory Research	23,757	22,549	29,789
Other Research[a]	7,111	5,592	5,719
Total, Research	49,731	45,280	54,621
Operations	24,994	22,943	29,278
Total, Low Energy Nuclear Physics	74,725	68,223	83,899

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 2005, $1,444,000 has been transferred to the SBIR program. This activity includes $1,261,000 for SBIR in FY 2006 and $1,344,000 for SBIR in FY 2007.

supported, including generic exotic beam R&D relevant to next generation nuclear structure and astrophysics facilities, such as the proposed Rare Isotope Accelerator (RIA) facility. 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 astrophysics studies depends upon the availability of exotic 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 limited capabilities for these studies, a facility with next generation capabilities for short-lived radioactive beams will be needed for the U.S. to maintain a leadership role. The NSAC 2002 Long-Range Plan identified the RIA as the highest Nuclear Physics priority for a major new construction project. The Nuclear Physics program is developing a strategic plan for implementing its vision for the future. Guidance was sought from NSAC regarding opportunities and priorities for the Nuclear Physics program in the context of fiscal constraints. This guidance on the implementation of the 2002 Long-Range Plan was articulated in an NSAC report submitted in June 2005. Highest priority was recommended for the effective utilization of the program's major facilities, RHIC and CEBAF, including the planned upgrades in detector and accelerator capabilities. The report reaffirms the recommendation of the 2002 NSAC Long-Range Plan that RIA is the highest priority for new construction and that significant additional resources would be needed before proceeding with the RIA project. In FY 2007, support is provided for generic exotic beam R&D.

In FY 2007 the Low Energy Nuclear Physics subprogram supports the operation of two National User Facilities: the HRIBF at Oak Ridge National Laboratory (ORNL) and the ATLAS facility at Argonne National Laboratory (ANL). These facilities are utilized by DOE, NSF, and foreign-supported researchers. The allocation of beamtime is made with the guidance of Program Advisory Committees, consisting of scientists who review and evaluate proposed experiments regarding their merit and scientific priority. Capital equipment funds are provided for detector systems, for data acquisition and analysis systems, and for accelerator instrumentation. In FY 2007, fabrication continues for the Gamma Ray Energy Tracking In-Beam Nuclear Array (GRETINA) MIE at Lawrence Berkeley National Laboratory, a segmented germanium detector array with improved position resolution and efficiency for studies with fast fragment nuclear beams. 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 made the transition in FY 2004 from a National User Facility to 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 2007.

University-based research is an important feature of the Low Energy subprogram. Accelerator operations have been supported at Texas A&M University (TAMU), the Triangle Universities Nuclear Laboratory (TUNL), University of Washington, and Yale University. 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, for example the ultra-cold neutron trap at the Lujan Center at the Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Laboratory; the neutron experiments at LANSCE are expected to be completed in FY 2006. In FY 2007, fabrication continues for the Fundamental Neutron Physics Beamline (FNPB) MIE at the Spallation Neutron Source that will enable measurements of fundamental properties of the neutron. Other experiments do not require the use of accelerators: the Sudbury Neutrino Observatory (SNO) detector in Canada is studying the production rate and properties of solar neutrinos, while the Kamioka Large Anti-Neutrino Detector (KamLAND) in Japan is studying the properties of anti-neutrinos produced by nuclear power reactors. It is anticipated that the SNO and KamLAND detectors will be concluding their data taking phases in FY 2007.

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 100 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. In 2001, SNO reported its first physics results, which together with other experimental results, made a persuasive case for neutrino oscillations among their different types (or "flavors") and thus showed that neutrinos have mass. These results have been confirmed by new SNO measurements reported in 2002-2005, which are sensitive to the different types of neutrinos, and measurements from the KamLAND experiment with reactor produced anti-neutrinos. These results have stimulated an increasing interest in non-accelerator experiments that study neutrino properties. Studies with both SNO and KamLAND continue in order to extend and refine measurements of neutrino oscillation parameters.

FY 2005 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:

- Measurements at ATLAS establish the limits of gamma-ray satellite searches for stellar objects where the rapid proton capture process (*rp*-process) that creates elements up to at least iron has occurred. A series of measurements utilizing ATLAS beams and specialized instrumentation were able to accurately establish the probabilities for production and destruction of ^{22}Na (sodium) for the dominant reaction process. These results combined with other data, place an upper limit of 2 kilo-parsecs for the "horizon" of the INTEGRAL satellite. This puts out of observational reach objects such as the Crab Nebula that INTEGRAL was hoping to investigate.

- Results from the SNO and KamLAND provide additional information significantly constraining the neutrino oscillation parameters in the Large Mixing Angle (LMA) parameter space. SNO's second phase measurements provide the best determination yet of the neutrino mixing parameter θ_{12} (theta) describing the mixing of electron neutrinos with muon and tau neutrinos. KamLAND's results found evidence of distortion of the neutrino energy spectrum, a sensitive indicator of neutrino oscillations and a strong constraint on the neutrino mass. The KamLAND collaboration has recently reported a first measurement of neutrinos from the uranium and thorium in the earth (geo-neutrinos) that will provide information on its geophysical properties.
- Particle transfer reactions with radioactive ion beams at HRIBF have identified the energetic $i_{13/2}$ single-particle proton state in ^{135}Te (tellurium), the first time this state has been observed in a nucleus near doubly-magic ^{132}Sn (tin) (completely filled shells for both protons and neutrons). The use of low-intensity radioactive beams required the development of techniques so that the experiments could be done in inverse kinematics, with the beam of heavy particles impinging on light targets, i.e. ^{9}Be (beryllium) (^{134}Te,^{135}Te)^{8}Be transfers a single neutron to ^{135}Te. The ^{8}Be target residue decays into two alpha particles, uniquely indicating that the neutron transfer has occurred.
- The measurement of gamma-ray transition in neutron-rich Sn nuclei out to ^{134}Sn indicate that the collectivity (degree to which many nucleons act together) of doubly-magic ^{132}Sn is higher than that of the neighbors ^{130}Sn and ^{134}Sn, an unexpected result based on the systematics of nearby nuclei that have more protons than Sn. Recent advances in the intensity and purity of Sn radioactive ion beams and measurement techniques at HRIBF have enabled Coulomb excitation studies of the collectivity of core excitations of these radioactive Sn nuclei. This higher collectivity for ^{132}Sn had been qualitatively predicted with theoretical calculations using the quasi-particle random phase approximation model.
- Recent data on the structure of the thulium (Tm) nuclei at the proton dripline require model calculations can now take the departure from axial symmetry into account in the description of the observed proton decay rate and fine structure branching ratio. The structure of $^{145\text{-}147}$Tm has been mapped out and strong changes in structure as a function of mass have been uncovered utilizing Gammasphere and the Fragment Mass Analyzer at ATLAS. These structure changes in turn affect the rate of proton emission. In particular, the degree to which these deformed nuclei depart from axial symmetry was quantified and the data serve as a new, severe test of calculations of the proton decay rate and fine structure branching ratio.
- Measurements at ATLAS have established that ^{64}Ge (germanium) is not and that ^{68}Se (selenium) definitely is a "waiting point" nucleus in the astrophysical (*rp*-process). Knowledge of such "waiting point" nuclei is critical for understanding how the elements were produced in stellar burning and other astrophysical events. These are nuclei with the same number of protons and neutrons which lie on the proton drip line, at the very limits of nuclear stability, whose mass plays an important role in determining whether they will slow the process to synthesize heavier species. This then in turn affects the light curve and energy output of X-ray bursters and the distribution of the elements that are finally synthesized. The measurements are an order of magnitude more precise and free of many systematic errors that affect previous determinations.

FY 2005 Facility and Technical Accomplishments

- At LBNL, the VENUS electron cyclotron resonance (ECR) ion source, which uses superconducting technology, has been successfully commissioned with 18 and 28 giga-hertz gyrotrons providing ionized beams of metal elements up to bismuth. Preliminary data taken with bismuth beams indicate that VENUS already meets the required intensities (eight times previous ion sources) and emittance required for RIA and is relevant to ion accelerator facilities world-wide.
- In 2005 a prototype RIA gas catcher fabricated at ANL was tested with full RIA-like energy beams at the Gesellschaft fur Schwerionenforschung (GSI) facility in Germany and performed as predicted, with an extraction efficiency close to 45%. The capability to slow down fast (400 MeV/nucleon) rare fragments, stop them in a high purity gas-cell and extract them efficiently for re-acceleration is one of the major technical advances that would enable an exotic beam facility to study nuclei very far from stability.
- The fabrication of the High Power Target Laboratory (HPTL) at HRIBF was completed in FY 2005, commissioned and put into operation. The HPTL enhances the capability of the HRIBF to conduct the research necessary to develop new radioactive rare beams, increase intensity, improve isotopic purity, and explore new technologies in target/ion source combinations including laser ionization. In addition, HPTL will eventually house a second production target/ion source station that will provide increased hours of radioactive ion beam operation for experiments at HRIBF.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Research	**49,731**	**45,280**	**54,621**
▪ **University Research**	**18,863**	**17,139**	**19,113**

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 2007 funding for operation of university accelerator facilities, for capital equipment and for researchers and students is increased compared to FY 2006, providing support near the FY 2005 level. This allows for selected increases in university accelerator facility operations and enhanced research efforts in high priority areas.

- Research programs are conducted using the low energy heavy-ion beams and specialized instrumentation at the National Laboratory User facilities supported by this subprogram (the ANL-ATLAS and ORNL-HRIBF facilities). 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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

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. Equipment funds are provided for new instruments and capabilities.

- Involvement in other accelerator and non-accelerator experiments directed at fundamental measurements, such as measurements of solar neutrino rates and the neutrino mass at SNO and KamLAND (jointly with the High Energy Physics program) are supported.

	FY 2005	FY 2006	FY 2007
▪ **National Laboratory Research**	**23,757**	**22,549**	**29,789**

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

	FY 2005	FY 2006	FY 2007
• **National Laboratory User Facility Research**...........	**14,085**	**13,415**	**10,778**

Scientists at ANL and ORNL have major responsibilities for maintaining, improving and developing instrumentation for research by the user communities at the user facilities, as well as playing important roles in carrying out research that addresses the NP program's priorities. Operations of the 88-Inch Cyclotron as a National User Facility were terminated in FY 2004 and funding in FY 2005-2006 was provided to LBNL scientists to complete analyses of data taken in prior years at the 88-Inch Cyclotron. Support for LBNL scientists is shifted in FY 2007 to Other National Laboratories ($4,158,000 in FY 2006). In FY 2007 funding for ANL and ORNL research at the user facilities is increased to enhance the level of effort at these national centers for nuclear structure and astrophysics research with emphasis on high priority projects. Support is provided for the following research activities.

- ► 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.
- ► 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 to study 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.

	FY 2005	FY 2006	FY 2007
• **Other National Laboratory Research**........................	**9,672**	**9,134**	**19,011**

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. Conceptual design and R&D activities are supported for a neutrinoless Double Beta Decay experiment that would measure the absolute mass of the neutrino and determine whether the neutrino is its own antiparticle.

(dollars in thousands)		
FY 2005	FY 2006	FY 2007

The increase in FY 2007 funding for Other National Laboratory Research reflects the shift in funding for the LBNL scientists involved in the 88-Inch Cyclotron in-house experimental program and support for research efforts that are also relevant to the design of next generation nuclear reactors. An increase in capital equipment funding ($+500,000) provides support to the ongoing GRETINA and FNPB MIEs, according to planned profiles, and support is also provided to initiate fabrication of a neutron Electric Dipole Moment (EDM) MIE ($+1,300,000). Resources for scientific/technical staff are increased compared to FY 2006 and are directed at the highest priority research, as described below:

- 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 GRETINA (MIE) detector, and for R&D efforts in advanced accelerator technologies and techniques.
- The Gamma-Ray Energy-Tracking In-beam Nuclear Array (GRETINA) MIE, for which fabrication began in FY 2004, is especially important for the study of the nuclear decay and structure of exotic 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 exotic nuclei that may exist in stars and supernovae, but live only briefly (fractions of a second). In FY 2007 funding of $3,900,000 (TEC of $17,000,000; with project completion in 2010) is provided to continue fabrication of GRETINA.
- Support is provided for groups at BNL, LBNL, and LANL that are involved in the SNO experiment, jointly built by Canada, England 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 expected to be complete in FY 2007; analysis of data and publication of results will continue.
- A LBNL effort, together with that of university groups supported by this subprogram, is supported to participate in the KamLAND and experiment in Japan that is measuring the rate and properties of anti-neutrinos produced by several distant nuclear power reactors to study neutrino “oscillations” KamLAND and has the advantage of comparing the measured fluxes to known sources. New results were reported in FY 2005 providing significant constraints on neutrino masses. Data collection is expected to be complete in FY 2007; analysis of data and publication of results will continue. The U.S. participation in KamLAND is supported jointly with the High Energy Physics program.

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

- 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 Spallation Neutron Source (SNS). The FNPB will provide a world-class capability to study neutron properties, leading to a refined characterization of the weak force. Fabrication began in FY 2004 and continues in FY 2007 with funding of $1,500,000 (TEC $9,200,000).
- Support is provided in FY 2007 ($1,300,000) to pursue the measurement of the electric dipole moment (EDM) of the neutron, a high discovery potential experiment at the FNPB (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. The EDM MIE received CD-0 approval and Conceptual Design and R&D activities are supported in FY 2006.
- Funding is provided within the Low Energy subprogram to support research efforts that are also relevant to the design of next generation nuclear reactors. This research can help to provide the nuclear data and knowledge required for advanced nuclear fuel cycles. Additional funding is provided for this effort in the Theory subprogram for Nuclear Data activities. This effort is carried out in collaboration with the BES program, and a joint workshop will be conducted in FY 2006 to identify the leading scientific issues.

	FY 2005	FY 2006	FY 2007
▪ **Other Research**	**7,111**	**5,592**	**5,719**
• **Exotic Beam R&D**	**6,736**	**3,960**	**4,000**

Funds are provided for generic R&D activities aimed at development of exotic beam capabilities.

	FY 2005	FY 2006	FY 2007
• **SBIR and Other**	**375**	**1,632**	**1,719**

In FY 2005, $1,444,000 has been transferred to the SBIR program. This activity includes $1,261,000 for SBIR in FY 2006, and $1,344,000 for SBIR in FY 2007. Funding is also provided for other established obligations ($371,000) including the Lawrence and Fermi Awards, which provide annual monetary awards to honorees selected by the DOE for their outstanding contributions to science.

	FY 2005	FY 2006	FY 2007
Operations	**24,994**	**22,943**	**29,278**
▪ **User Facility Operations**	**24,844**	**22,793**	**25,992**

Support is provided for the operation of two National User Facilities, the ATLAS at ANL and the HRIBF at ORNL, for studies of nuclear reactions, structure and fundamental interactions. In FY 2005 and 2006, funding was provided in this budget category also for the operations of the 88-Inch Cyclotron at LBNL. Operations at the 88-Inch Cyclotron as a Nuclear Physics National User Facility were terminated in FY 2004 and since that time it has provided beams for applied researcher users and a limited in-house program. In FY 2007 NP support of operations of the 88-Inch Cyclotron ($3,000,000 in FY 2006) for an in-house program is moved to Other Operations to reflect its current status.

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

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

Array for nuclear astrophysics studies. In FY 2007, funding restores accelerator operations to near FY 2005 levels, 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.

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, and fundamental and decay properties of nuclei. In FY 2007, funding restores accelerator operations to near FY 2005 levels. Accelerator improvement project funding supports upgrading the accelerator to increase the radioactive beam capabilities of ATLAS.

In FY 2006 these low energy facilities will carry out about 80 experiments involving about 300 U.S. and foreign researchers. Planned hours of operation in FY 2006 and FY 2007 with beam are indicated below; the FY 2005 hours are actual beam hours provided:

	FY 2005	FY 2006	FY 2007
ATLAS Hours of Operation with Beam	5,301	4,380	5,600
HRIBF Hours of Operation with Beam	4,869	3,650	4,350
Total Beam Hours for Low Energy Facilities	10,170	8,030	9,950

▪ **Other Operations**	**150**	**150**	**3,286**

Operations at the 88-Inch Cyclotron made a transition in FY 2004 from a National User Facility to a facility providing beams for applied researcher users and a limited in-house program. This was done to provide resources to optimize the utilization and science productivity of the remaining user facilities, consistent with the recommendations of the NSAC Low Energy Program Review in 2001. In late FY 2003 the National Reconnaissance Office (NRO) and the Air Force (USAF) determined that operation of the 88-Inch Cyclotron was essential for production of heavy-ion beams that could be used to simulate cosmic ray damage to electronic components that would be used in space, and joint operations was undertaken by the three agencies. A continued need for the beam capabilities of the 88-Inch Cyclotron has been identified by the NRO and the USAF, and a Memorandum of Agreement (MOA) for the continuation of the joint operations for FY 2006-2011 has been signed. In accord with the MOA, in FY 2007 the NRO and USAF will utilize the 88-Inch Cyclotron for approximately 2,000 hours for their testing program, and Nuclear Physics will utilize it for an approximately 3,000 hour in-house nuclear physics research program. The NRO and USAF will provide a total of $2,200,000 and NP will provide $3,136,000 for joint operations of the facility. This funding was included under User Facility Operations through FY 2006.

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

Total, Low Energy Nuclear Physics.......................................	**74,725**	**68,223**	**83,899**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Research	
▪ **University Research**	
FY 2007 funding increases by ~11% compared to FY 2006, providing for a return to the FY 2005 level of effort and allowing for increased operations of university accelerators, more effective extraction of science from the user facilities operated by the program and enhanced efforts in high-priority non-accelerator initiatives.	+1,974
▪ **National Laboratory Research**	
• **National Laboratory User Facility Research:** FY 2007 funding increases ($+1,521,000) compared to FY 2006 for high priority research efforts and activities at the ATLAS and HRIBF, which are needed for effective and productive exploitation of the beams at these user facilities. Funding for the LBNL 88-Inch Cyclotron activities is shifted to Other National Laboratory Research ($4,158,000 in FY 2006).	-2,637
• **Other National Laboratory Research:** FY 2007 funding provides an increase ($+1,967,000) for scientific/technical staff support compared to FY 2006, to restore research efforts for low energy accelerator activities to FY 2005 levels. Funding is also increased for capital equipment ($+2,322,000), including the ongoing fabrication of the GRETINA and FNPB MIEs, and the funding for initiation of the new EDM neutron MIE. The increase includes support for the LBNL scientists involved in the 88-Inch Cyclotron in-house experimental program ($4,158,000 in FY 2006) previously funded in National Laboratory User Facility Research. Finally, funding ($+1,430,000) is provided for research activities relevant to the design of next generation nuclear reactors.	+9,877
Total, National Laboratory Research	**+7,240**
▪ **Other Research**	
The increase reflects required SBIR/STTR and other obligations.	+127
Total, Research	**+9,341**

Operations

▪ **User Facilities Operations:** Support for 88-Inch Cyclotron operations ($3,000,000 in FY 2006) is transferred to Other Operations. The change from FY 2006 for HRIBF & ATLAS Operations, including AIP and CE, is $+6,199,000 as follows: increases for operations for HRIBF ($+1,508,000) and ATLAS ($+2,560,000) restores running time to planned FY 2005 levels (9,950 hours); CE investments ($+1,416,000) are aimed at instrumentation necessary to carry out the experimental program; investments in AIP at HRIBF ($+117,000) support continued fabrication

	FY 2007 vs. FY 2006 ($000)
of a second source and transport beamline for radioactive ions and at ATLAS ($+598,000) to develop an ion source for unique capabilities for radioactive beams....	+3,199
▪ **Other Operations** increases due to the transfer of funding for the 88-Inch Cyclotron in FY 2007 from User Facility Operations.	+3,136
Total, Operations	**+6,335**
Total Funding Change, Low Energy Nuclear Physics..	**+15,676**

Nuclear Theory

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Nuclear Theory			
Theory Research			
University Research	13,054	11,018	14,229
National Laboratory Research	10,389	10,570	11,718
Scientific Discovery through Advanced Computing (SciDAC)	1,985	1,485	2,500
Total, Theory Research	25,428	23,073	28,447
Nuclear Data Activities	5,437	5,081	6,901
Total, Nuclear Theory	30,865	28,154	35,348

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 new 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 sponsors the national Institute for Nuclear Theory (INT), based at the University of Washington, in Seattle, Washington, 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. The subprogram is responding to the need for large dedicated computational resources for Lattice Quantum ChromoDynamical (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, a ~5 teraflop prototype computer was developed and implemented in FY 2005 using the custom QCD On-a-Chip (QCDOC) technology. This platform will enable 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 (~an additional 13 teraflops) will begin in FY 2006 to provide computing capabilities based on the most promising technology.

The program is enhanced through interactions with complementary programs overseas, with efforts supported by the National Science Foundation, with programs supported by the High Energy Physics program and with the Japanese supported theoretical efforts related to RHIC at the RIKEN Center at Brookhaven National Laboratory. 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.

Included in the theory subprogram are the activities that 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.

Progress in Nuclear Theory is included as a component in reviews of the three major experimental subprograms within the Nuclear Physics program.

FY 2005 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:

- *Indicators of quark-gluon plasma formation:* It has recently been pointed out by NP supported theorists at BNL that collisions at Brookhaven's RHIC produce the analog of a black hole. This is due to a mathematical similarity between the physics of RHIC collisions and the physics that is used to describe a black hole in a multi-dimensional world. This stems from Einstein's Equivalence Principle: the rapid deceleration of RHIC ions as they smash into each other is similar to the extreme gravitational environment in the vicinity of a black hole. This means that RHIC collisions should emit thermal particles similar to the Hawking radiation emitted by a black hole. The "black hole thermalization" scenario naturally explains the rapid thermalization that occurs, and provides a set of further predictions that can be tested at RHIC.
- *New regions of nuclear structure:* Superheavy nuclei represent the limit of nuclear mass and charge; they inhabit the remote corner of the nuclear landscape, whose extent is unknown. The existence of such heavy nuclei hangs on a subtle balance between the attractive nuclear force and the disruptive Coulomb repulsion between protons that favors fission. Theorists supported by NP have modeled the interplay between these forces in an approach that accounts for shape deformation through the Jahn–Teller effect, a general description of spontaneous symmetry breaking. These theorists predict that the long-lived superheavy elements can exist in a variety of shapes, including spherical, axial and triaxial configurations. In some cases, they anticipate the existence of metastable states and shape isomers that can affect decay properties and hence nuclear half-lives.
- *Studies of Fermi gases: superfluids and nearly perfect fluids:* Determining the properties of Fermi gases is an intriguing topic for many-body physics, with applications to phenomena such as the outer crust of neutron stars, pairing in neutron rich nuclei, ultracold atomic gases trapped in controllable laboratory experiments, and to the predicted color superconducting phase in dense quark matter. A crossover from the Bardeen-Cooper-Schrieffer (BCS) superfluid state to a Bose-Einstein condensation (BEC) state is expected to occur if the force between the fermions (nucleons, quarks, alkali atoms) is attractive. When interactions are strong enough so that a bound state is possible, the fermions first form bound states (bosons). As the attraction increases they start to condense into the bosonic zero-mode at some critical temperature T_c. If the bound state occurs at threshold, universal behavior is expected and the crossover temperature could be experimentally attainable. Theoretical study of this limit is difficult because it occurs at strong coupling. Lattice field theory provides a first principles approach to the study of nonrelativistic strongly interacting systems such as this through Monte Carlo simulation. Preliminary results in the universal region have been obtained for the critical temperature T_c from such a study.

- *Experimental indication of an almost perfect fluid produced at RHIC:* The current understanding of almost perfect fluids arises from a mathematical relationship known as the Maldacena duality which relates gauge theories (such as QCD) to ten-dimensional gravity within string theory. Recently NP supported theorists combined the Maldacena duality with hydrodynamics. That marriage enabled them to calculate a plasma's coefficient of shear viscosity, a parameter that describes how forces are transmitted transversely in fluids. This year they sharpened an earlier conjecture that there exists a lower bound to the ratio of shear viscosity to entropy density for a wide class of fluids. The result can be expressed in terms of fundamental constants and is many orders of magnitude lower than this ratio in water, for example. Results from RHIC and observations of strongly interacting lithium-6 atoms suggest that the extremely low viscosities calculated from this analogy with string theory may be more than just a theoretical curiosity. The post-collision medium seems to behave more like a strongly interacting fluid than a gas; detailed results of RHIC collisions are in excellent accord with the hydrodynamic limit of zero shear viscosity.
- *Studies of hadronic structure on the lattice:* The simulation of light dynamical quarks constitutes one of the major challenges in contemporary lattice gauge theory research. The computational obstacle has in the past been addressed by investigating new algorithms. Recently, a new approach has been attempted employing a so-called "hybrid" scheme where different types of sea and valence quarks are used. This new approach has been applied to the proton form factor and the nucleon axial coupling, g_A. Calculations in a fixed volume underestimate g_A when the pion becomes too light to fit in the chosen volume, but a sequence of calculations in three volumes using this new method produces a locus of points that smoothly extrapolate to the experimental result. Encouraged by the successes reported here, researchers are continuing the calculation of hadronic observables using improved staggered sea quarks and domain-wall valence quarks.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Theory Research	**25,428**	**23,073**	**28,447**
▪ **University Research**	**13,054**	**11,018**	**14,229**

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 2007 funding is increased compared with FY 2006 for theoretical efforts needed for interpretation of experimental results obtained at the program facilities. The program will be optimized to focus efforts on the high priority activities which are aligned with SC Strategic Plan milestones. Following a recommendation of the NSAC Theory Review subcommittee 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. 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, recent programs have resulted in a new research effort that fuses modern shell model

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

technology with effective field theory to potentially provide a tractable, rigorous solution for low energy properties of nuclei. Another program on the "Quark and Gluon Structure of Nucleons and Nuclei" contributed significantly to the development of the concept of generalized parton distributions. The key papers on the subject were either written at the workshop or based on discussions that took place at the INT.

▪ **National Laboratory Research**	**10,389**	**10,570**	**11,718**

Research programs are supported at seven national laboratories (ANL, BNL, LANL, LBNL, LLNL, ORNL, and TJNAF). In FY 2007 funding for scientific/technical staff is increased compared with FY 2006 in order to address theoretical issues important for advancing the national nuclear physics program. The range of topics in these programs is broad, and each of the active areas of experimental nuclear physics is supported by at least some of these nuclear theory activities. 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.

▪ **Scientific Discovery through Advanced Computing (SciDAC)**	**1,985**	**1,485**	**2,500**

Scientific Discovery through Advanced Computing (SciDAC) is an SC program to address major scientific challenges that require advances in scientific computing using terascale resources. In FY 2001 several major multi-institutional grants in high-priority topical areas were awarded through this program for the first time by the then combined High Energy and Nuclear Physics (HENP) programs. Currently theoretical nuclear physics supports the National Computation Infrastructure for Lattice Gauge Theory (the gauge theory relevant to contemporary nuclear physics is QCD) and an award titled Shedding New Light on Exploding Stars: Terascale Simulation of Neutrino-Driven Supernovae and their Nucleosynthesis-TSI. The former award led to one of the achievements noted earlier, and the TSI endeavor appears to be in line with meeting an SC 2006 milestone to "develop three-dimensional computer simulation for the behavior of supernovae, including core collapse and explosion, which incorporate the relevant nuclear reaction dynamics." All current SciDAC projects were completed in FY 2005 and a new competition is being held in FY 2006. In FY 2007 funding for SciDAC activities is increased compared to FY 2006, allowing for enhanced efforts in the most promising areas for progress in nuclear physics with terascale computing capabilities.

Nuclear Data Activities	**5,437**	**5,081**	**6,901**

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 is increased ($+820,000) relative to FY 2006, allowing for retentions and recruitment of skilled personnel that are needed to maintain the Nation's nuclear data base. This is a critical issue, with over 50% of the compilers and evaluators over 60 years old, retired and working part-time. 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

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

who perform data assessment as well as developing modern network dissemination capabilities. The NNDC participates in the International Data Committee of the International Atomic Energy Agency (IAEA).

Funding is also provided within the Nuclear Data activities in the Theory subprogram to support ongoing research efforts that are also relevant to the design of next generation nuclear reactors, including covariant matrix studies, cross section evaluations and other activities. Additional funding is provided for this effort in the Low Energy subprogram. This effort is carried out in collaboration with the BES program, and a joint workshop will be conducted in FY 2006 to identify the leading scientific issues.

	FY 2005	FY 2006	FY 2007
Total, Nuclear Theory	**30,865**	**28,154**	**35,348**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Theory Research	
▪ **University Research**	
FY 2007 funding is increased compared to FY 2006, funding personnel at levels needed to support the national Nuclear Physics program. Resources will be focused on the theoretical understanding of the research that was identified in SC Strategic Plan Milestones and to implement recommendations from the recent NSAC Subcommittee on Nuclear Theory.	+3,211
▪ **National Laboratory Research**	
FY 2007 funding is increased compared to FY 2006 to provide needed theoretical efforts for the national nuclear physics program. Research will be directed toward achieving the scientific goals of the Nuclear Physics program, including the continuation of the Lattice Gauge Quantum ChromoDynamics initiative with HEP.	+1,148
▪ **Scientific Discovery through Advanced Computing (SciDAC)**	
FY 2007 funding allows for enhanced efforts in the most promising areas for progress in nuclear physics with terascale computing capabilities.	+1,015
Total, Theory Research	**+5,374**
Nuclear Data Activities	
FY 2007 funding is increased ($+820,000) compared to the FY 2006 level, which allows for the recruitment of skilled personnel that are needed to maintain the Nation's nuclear data base. Funding ($+1,000,000) is provided for Nuclear Data activities which are also relevant to the design of next generation nuclear reactors.	+1,820
Total Funding Change, Nuclear Theory	**+7,194**

Construction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Construction			
07-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	—	—	7,000
07-SC-02, Electron Beam Ion Source, BNL	—	—	7,400
06-SC-02, Electron Beam Ion Source (PED), BNL	—	1,980	120
Total, Construction	—	1,980	14,520

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 2005	FY 2006	FY 2007
07-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	**—**	**—**	**7,000**

Funding is requested for PED for the 12 GeV CEBAF Upgrade (PED TEC ~$21M). The upgrade was identified in the 2002 NSAC LRP as one of the highest priorities for the Nation's nuclear science program, is a near-term priority in the SC 20-Year Facilities Outlook, and has obtained Mission Need approval. The upgrade will enable scientists to address one of the greatest mysteries of modern physics—the mechanism that "confines" quarks together. The project is preparing for a CD-1 review in FY 2006. Findings of a DOE Office of Project Assessment Review in FY 2005 which evaluated project plans, proposed performance and cost and schedule profiles are reflected in the FY 2007 budget request.

07-SC-02, Electron Beam Ion Source, BNL	**—**	**—**	**7,400**

Funds are provided to begin construction of the Electron Beam Ion Source (EBIS) project with a preliminary estimated TEC of $13,700,000 and TPC of $14,800,000 and completion in 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 will contribute an additional $4,500,000 above the DOE TPC. Findings of a Technical, Cost, Schedule and Management Review conducted in FY 2005 were utilized in the formulation of the FY 2007 budget request.

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

PED funding was reduced by $20,000 as a result of the FY 2006 rescission. 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. EBIS has received CD-0 and CD-1 approval, and is preparing for CD-2.

Total, Construction	**—**	**1,980**	**14,520**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
07-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	
Support is provided for project engineering and design for the 12 GeV CEBAF Upgrade.	+7,000
07-SC-02, Electron Beam Ion Source, BNL	
Funds are provided to initiate construction of the Electron Beam Ion Source (EBIS) to replace the aging Tandem Van de Graaff as the heavy-ion source for the RHIC complex.	+7,400
06-SC-02, Electron Beam Ion Source (PED), BNL	
Project engineering and design (PED) funds decrease consistent with the planned profile.	-1,860
Total Funding Change, Construction	**+12,540**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
General Plant Projects	7,407	7,342	7,870
Accelerator Improvements Projects	6,917	4,363	6,200
Capital Equipment	23,731	24,071	30,421
Total, Capital Operating Expenses	38,055	35,776	44,491

Construction Projects

	(dollars in thousands)					
	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2005	FY 2006	FY 2007	Unappro-priated Balance
07-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	21,000[a]	—	—	—	7,000	14,000
07-SC-02, Electron Beam Ion Source, BNL	13,700[b]	—	—	—	7,400	4,200
06-SC-02, Electron Beam Ion Source (PED), BNL	2,100[c]	—	—	1,980	120	—
Total, Construction			—	1,980	14,520	

[a] The full Total Estimated Cost (design and construction) ranges between $205,000,000 and $275,000,000; and the full Total Project Cost (design and construction) ranges between $225,000,000 and $300,000,000. These estimates are based on preliminary data and should not be construed as a project baseline. A CD-1 review is anticipated early in FY 2006.
[b] Includes the preliminary estimated TEC for design and construction. Design funding is in 06-SC-02. At the time of CD-1 approval, the full Total Estimated Cost (design and construction) ranges between $12,000,000 and $17,500,000. This estimate is based on preliminary data and should not be construed as a project baseline.
[c] 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 2005	FY 2006	FY 2007	Completion Date
STAR Time-of-Flight....................	4,800[a]	4,800[a]	—	—	2,376	2,424	FY 2009
GRETINA gamma-ray detector....	18,200	17,000[b]	1,000	2,500	3,000	3,900	FY 2010
Fundamental Neutron Physics Beamline.......................................	9,300	9,200[c]	1,000	1,200	1,900	1,500	FY 2010
PHENIX Vertex Tracker...............	4,500[d]	4,500[d]	—	—	—	2,000	FY 2009
Heavy Ion LHC Experiments	5,000[e]	5,000[e]	—	—	—	1,000	FY 2010
Electron Dipole Moment (EDM)...	18,300[f]	18,300[f]	—	—	—	1,300	FY 2013
Total, Major Items of Equipment....................................				3,700	7,276	12,124	

[a] A Technical, Cost, Schedule and Management Review was conducted in August 2005 to assess project plans and performance.
[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 estimated costs are preliminary and will be baselined at a Technical, Cost, Schedule and Management Review in the Spring 2006.
[e] CD-0 was approved in November 2005 with a preliminary TPC range of $5,000,000 - $16,000,000. The TEC is preliminary and will be baselined at CD-2.
[f] CD-0 was approved in November 2005 with a preliminary TPC range of $12,000,000 - $18,300,000. The TEC is preliminary and will be baselined at CD-2.