Nuclear Physics

Funding Profile by Subprogram

(dollars in thousands)

	FY 2004 Comparable Appropriation	FY 2005 Original Appropriation	FY 2005 Adjustments	FY 2005 Comparable Appropriation	FY 2006 Request
Nuclear Physics					
Medium Energy Nuclear Physics	118,854	125,875	-1,044[a]	124,831	111,660
Heavy Ion Nuclear Physics	161,451	175,933	-1,383[a]	174,550	161,879
Low Energy Nuclear Physics	71,053	76,567	-585[a]	75,982	68,537
Nuclear Theory	28,434	29,665	-250[a]	29,415	26,665
Subtotal, Nuclear Physics	379,792	408,040	-3,262	404,778	368,741
Construction	0	0	0	0	2,000
Total, Nuclear Physics	379,792[b]	408,040	-3,262	404,778	370,741

Public Law Authorizations:

Public Law 95-91, "Department of Energy Organization Act"

Public Law 103-62, "Government Performance and Results Act of 1993"

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

SC's 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 the nuclear stockpile. Highly trained scientific/technical personnel in fundamental nuclear physics is another important result of the program. This valuable human resource is essential for many applied fields, such as nuclear medicine, space exploration, and national security.

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:

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[a] Reflects a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005.
[b] Includes reductions of $2,307,000 rescinded in accordance with P.L. 108-137 the Consolidated Appropriations Act, 2004, $8,778,000, which was transferred to the SBIR program, and $1,053,000, which was transferred to the STTR program.

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 Nuclear Physics 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: Nuclear Science Advisory Committee (NSAC) - Opportunities in Nuclear Science (2002), and by the program's cognizance 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 SC 20-Year Facility Plan.

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 normally they are permanently confined inside the nucleons. Measurements are carried out primarily using electron beams at the Thomas Jefferson National Accelerator Facility (TJNAF) and polarized proton collisions at the Relativistic Heavy Ion Collider (RHIC). The following indicator establishes a specific long-term goal in World-Class Scientific Research Capacity that the Nuclear Physics 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 expected quark-gluon plasma 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 will 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. The following indicator establishes a specific long-term goal in World-Class Scientific Research Capacity that the Nuclear Physics 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. Neutrinos are mysterious particles that permeate the universe and hardly interact with matter, yet play a key role in the explosion of stars. Recent experiments have shown that a neutrino oscillates among all of its three types as it travels from its source. This remarkable metamorphosis can only happen if neutrinos, long thought to have no mass at all, actually do have tiny masses. Measurements of nuclear structure and nuclear reactions are carried out primarily at the Argonne Tandem Linac Accelerator System (ATLAS) and the Holifield Radioactive Ion Beam Facility (HRIBF). Neutrino studies are primarily carried out with specialized detectors located deep underground or otherwise heavily shielded against background. Measurements of symmetry properties, particularly of the neutron, are carried out at the Los Alamos Neutron Science Center (LANSCE) and are being developed using the Spallation Neutron Source (SNS). The following indicators establish specific long-term goals in World-Class Scientific Research Capacity that the Nuclear Physics 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 Nuclear Physics subprograms, with the ultimate aim of advancing knowledge and providing insights into the most promising avenues for future research. An over-arching theme of this subprogram is an understanding of the mechanism of quark confinement and de-confinement—while it is qualitatively 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 compilation and evaluation that serves a broad community of users much larger than the nuclear physics community.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Program Goal 05.20.00.00 – Explore Nuclear Matter, from Quarks to the Starts					
Maintained and operated Nuclear Physics scientific user facilities so that the unscheduled operational downtime was 15%, 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 12%, on average, of total scheduled operating time. [Met Goal]*	*Maintained and operated Nuclear Physics scientific user facilities to the unscheduled operational downtime was 11% 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%.*
Met the cost and schedule milestones for construction of facilities and Major Items of Equipment within 10% of baseline estimates. Completed on schedule the Analysis System for Relativistic Heavy Ion Collider (RHIC) Detectors and RHIC Silicon Vertex Detector. [Met Goal]		Met the cost and schedule milestones for the construction of facilities and Major Items of Equipment within 10% of baseline estimates; completed on schedule the Solenoidal Tracker at RHIC (STAR) Electro-Magnetic Calorimeter (EMCAL). [Met Goal]			
Medium Energy Nuclear Physics					
As elements of the electron beam program, (a) completed fabrication of the BLAST detector at MIT/Bates in accordance with project milestones, and (b) conducted precise studies of nucleon structure, including studies of the proton's internal charge distribution and role of Quantum ChromoDynamics (QCD) in nuclear structure by delivering high intensity (140 micro amps), highly polarized (75%) electron beams with Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility (TJNAF). [Met Goal]	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 (2.9), Hall B (9.6), and Hall C (2.8), 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 (2.1), Hall B (6.8), and Hall C (2.0), respectively, at the Continuous Electron Beam Accelerator Facility.
	Commissioned polarized protons at RHIC. [Met Goal]	Collected first data with polarized protons with the RHIC STAR, PHENIX and pp2pp detectors. [Met Goal]			

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Heavy Ion Nuclear Physics					
Produced first heavy-ion collisions at the Relativistic Heavy Ion Collider (RHIC – construction completed FY 1999) at 10% of its design luminosity, as planned, with four experimental detectors. Published first results of heavy-ion collisions. [Met Goal]	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 (1800) and recorded by the STAR (40) detectors, respectively, at the Relativistic Heavy Ion Collider.	Weighted average number (within 30% of baseline estimate) of millions of events sampled by the PHENIX (18,000) and recorded by the STAR (60) detectors, respectively, at the Relativistic Heavy Ion Collider.
Continued major accelerator improvement projects at RHIC in order to improve machine reliability and efficiency. [Met Goal]	Completed Helium Storage addition and liquid nitrogen standby cooling system at RHIC leading to better cost effectiveness ($0.5M savings) and operational efficiency (10% increase). [Mixed results]	Upgraded the RHIC cryogenics system by replacing turbine oil skids and removing seal gas compressor, eliminating a single point failure. [Met Goal]			
	Met the cost and schedule milestones for the PHENIX Muon Arm Instrumentation (Major Item of Equipment) within 10% of baseline estimates. [Met Goal]				
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 (25) and Holifield Radioactive Ion Beam (3) facilities, respectively.	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (21) and Holifield Radioactive Ion Beam (2.8) facilities, respectively.
Produced first results on the solar neutrino flux with the Sudbury Neutrino Observatory (SNO). SNO measures properties of solar neutrinos. [Met Goal]	Collected the first data from neutral current interactions from the Sudbury Neutrino Observatory (SNO). [Met Goal]	Collected the first data from the Kamioka Large Anti-Neutrino Detector (KamLAND), a joint U.S.-Japan experiment measuring neutrinos produced in nuclear reactors. [Met Goal]			

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Tested low-energy prototype of Rare Isotope Accelerator (RIA) fast catcher and tested low-beta accelerator cavities. [Met Goal]	Constructed a prototype high energy, high power gas catcher for the possible Rare Isotope Accelerator (RIA). [Met Goal]	Delivered the prototype high energy, high power gas catcher to the GSI facility in Germany and prepared it for testing. Completed tests of prototype targets for RIA. Complete prototype Electron Cyclotron Resonance ion source and fabricated prototypes of the high-beta superconducting radio frequency (RF) cavities for RIA. [Met Goal]			

Means and Strategies

The Nuclear Physics 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 Nuclear Physics 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 Nuclear Physics 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 Nuclear Physics program collaborate with researchers from many countries. Large numbers of foreign scientists, who provide monetary and equipment support, heavily utilize all of the Nuclear Physics user facilities, especially RHIC at the Brookhaven National Laboratory (BNL) and CEBAF at TJNAF. 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 (e.g., High Energy Physics and Basic Energy Sciences), other DOE Offices (e.g., National Nuclear Security Administration and Nuclear Energy), other Federal agencies (e.g., National Science Foundation, National Aeronautics and Space Administration 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)

The Department implemented a tool to evaluate selected programs. PART was developed by the Office of Management and Budget (OMB) to provide a standardized way to assess the effectiveness of the Federal Government's portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. The

Nuclear Physics (NP) program has incorporated feedback from OMB into the FY 2005 and FY 2006 Budget Requests and has taken the necessary steps to continue to improve performance.

In the PART review, OMB gave the NP program a high 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 2006. 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 Nuclear Science Advisory Committee (NSAC) and also available on the website, will guide reviews, every five years by NSAC, of progress toward achieving the long term Performance Measures. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance Report. In response to PART findings, NP established a Committee of Visitors (COV) to provide outside expert validation of the program's merit based review processes for impact on quality, relevance, and performance. The COV report is available on the web (http://www.sc.doe.gov/henp/np/nsac/docs/COV_nsac_report_022604.pdf). NP developed and submitted an action plan to respond to the findings and recommendations of the COV. NSAC conducted an assessment and comparison of the capabilities of the Rare Isotope Accelerator (RIA) and the Gesellschaft für Schwerionenforschung (GSI) Future Facility in FY 2004. Their report is available on the web (http://www.sc.doe.gov/henp/np/nsac/docs/RIA-GSI-nsac-022604.pdf).

Funding by General and Program Goal

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 05.20.00.00 Explore Nuclear Matter in All its Forms			
Medium Energy Nuclear Physics	118,854	124,831	111,660
Heavy Ion Nuclear Physics	161,451	174,550	161,879
Low Energy Nuclear Physics	71,053	75,982	68,537
Nuclear Theory	28,434	29,415	26,665
Construction	0	0	2,000
Total General Goal 5, World-Class Scientific Research Capacity	379,792	404,778	370,741

Overview

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

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

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

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

How We Work

The Nuclear Physics program uses a variety of mechanisms for conducting, coordinating, and funding nuclear physics research. The program is responsible for planning and prioritizing all aspects of supported research, conducting ongoing assessments to ensure a comprehensive and balanced portfolio, regularly seeking advice from stakeholders, supporting 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 (NSAC) and Program Advisory Committees (PACs) at our facilities have served the program well in this respect. Quality and performance are assured by peer-review of research projects and facility operations. The performance data obtained in facility and program reviews, as well as Annual Performance Results and Targets are used in assuring quality and in making funding decisions.

Advisory and Consultative Activities

To ensure that resources are allocated to the most scientifically promising research, the DOE and its national user facilities actively seek external input using a variety of advisory bodies. The Nuclear Physics research program needs to produce the scientific knowledge, technologies and trained personnel that underpin the Department's missions in national security, energy, and environmental quality.

The **Nuclear Science Advisory Committee** (NSAC) provides advice to the DOE and the National Science Foundation on a continuing basis regarding the direction and management of the national basic nuclear sciences research program. In FY 2004, the DOE Nuclear Physics program provided about 90% of the federal support for fundamental nuclear physics research in the nation. The National Science Foundation (NSF) provided most of the remaining support. NSAC regularly conducts reviews that evaluate the scientific productivity and opportunities of major components of the Office's research program and proposed major new initiatives and provide advice regarding scientific priorities. One of the most important functions of NSAC is development of long-range plans that express community-wide priorities for the upcoming decade of nuclear physics research.

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 Operations Reviews

In FY 2002 the Nuclear Physics program conducted operations reviews of its two largest national user facilities: the Relativistic Heavy Ion Collider (RHIC) and Continuous Electron Beam Accelerator Facility (CEBAF). Conducted by SC's Construction Management Support Division, these reviews enlisted experts from DOE national laboratories and NSF-supported university nuclear physics facilities to evaluate present performance and costs of operations. The Office of Nuclear Physics conducted operations reviews of the Holifield Radioactive Ion Beam Facility (HRIBF) in FY 2003 and the Argonne Tandem Linac Accelerator System (ATLAS) facility in FY 2004, using such external experts. Annual reviews of the RHIC, CEBAF, ATLAS and HRIBF programs with external reviewers are also conducted to assess the performance and scientific productivity of the facilities.

Program Reviews

NSAC, on a rotating schedule, 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 Medium Energy subprogram was reviewed in 1998, the Low Energy subprogram in 2001, and the Theory subprogram in 2003. A review of the Heavy Ion subprogram was completed in 2004. Quality and productivity of university grants are peer reviewed on an approximately three-year basis and laboratory groups performing research will be peer reviewed on an approximately four-year basis. The first review of laboratory research groups occurred for the Heavy Ion subprogram in January, 2004.

Planning and Priority Setting

The strategic plan for NP is set forth in the recently completed DOE and SC Strategic Plans. The objectives in this plan have been developed with the assistance of NSAC. Indeed, 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. NSAC recommended as its highest priority the effective utilization of its existing facilities, especially the recently completed facilities, to extract the science for which they were built. This includes adequate support for facility operations and for university and laboratory research efforts. Priority was also given to making investments for capabilities needed to mount a forefront program in the future. Guidance from the NSAC long range plan has been augmented by NSAC reviews of subfields. Priority within the recent budgets has been given to implementing these recommendations made in the NSAC reviews of the Medium Energy and Low Energy subprograms by making tough programmatic decisions. In FY 2004, the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory ceased to operate as a national nuclear physics user facility and transitioned to a facility supported jointly by the National Reconnaissance Office (NRO) and the Air Force (USAF) for testing electronic components and by NP for a small in-house research program. In FY 2005, operations of the MIT/Bates Linear Accelerator Center will be terminated with completion of the research program using the Bates Large Acceptance Spectrometer Toroid (BLAST) detector. NSAC recommendations on scientific opportunities and priorities, provided in recent reviews of neutron science and the Nuclear Theory and Heavy Ion subprograms, are reflected in the programmatic decisions in FY 2005 and FY 2006 budget requests. These decisions have been made to maximize the scientific impact, productivity, quality and cost-effectiveness of the program with the resources available. The NSAC Long Range Plan identified the proposed Rare Isotope Accelerator (RIA) as the highest priority for major new construction. RIA was identified as a near-term priority in SC future facilities plan, Facilities for the Future of Science: A Twenty-Year Outlook. Furthermore, the NSAC Long-Range Plan recommended an upgrade of CEBAF from 6 to 12 GeV; this project was also identified as a near-term priority in SC facilities plan. In an era of constrained budgets the Nuclear Physics program needs to develop a strategic plan for implementing its vision for the future. Guidance will be sought from NSAC regarding opportunities and priorities for the Nuclear Physics program in the context of fiscal constraints. 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 2006 to support these initiatives.

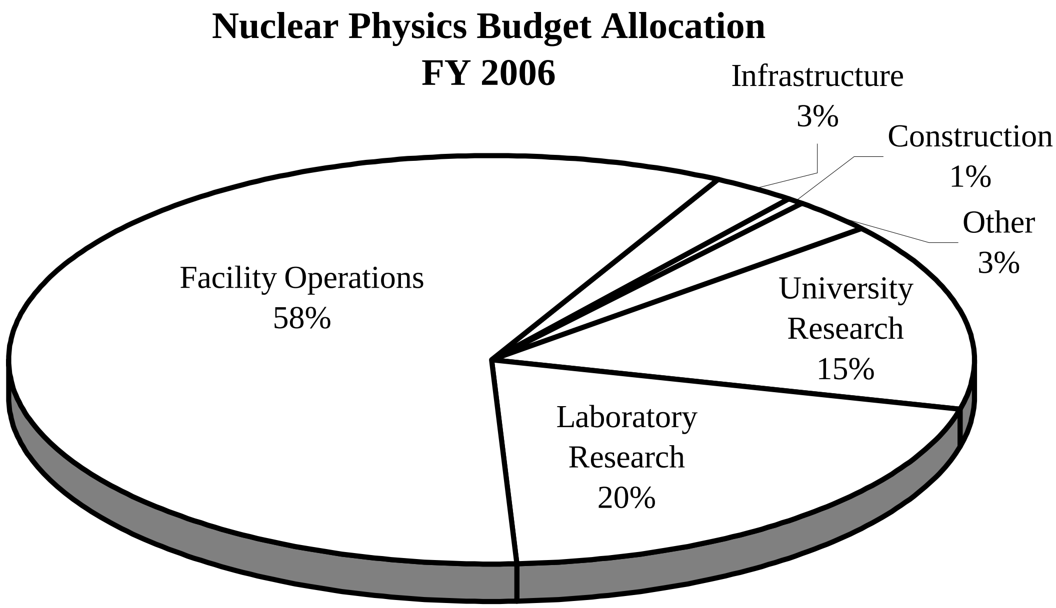
Committee of Visitors

A Committee of Visitors was appointed by the Nuclear Science Advisory Committee to review the management practices of the Nuclear Physics program and made its visit in December, 2003. In particular they examined 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 suggests “a number of minor operational changes which may benefit the program managers and reviewers in carrying out their tasks more efficiently.”

How We Spend Our Budget

The FY 2006 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 58% of the funding is provided for operations of the program user facilities, for support of NP’s share of the in-house program at the 88-Inch Cyclotron and to carry out decontamination and decommissioning (D&D) activities at the

MIT/Bates facility. Approximately 4% is provided for infrastructure and for construction projects that are needed to extract the science and improve efficiencies in the outyears at RHIC and TJNAF and 3% for other activities that includes Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) programs.



Research

Over one-third 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 1900 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 for university and national laboratory research (excluding capital equipment, proposed RIA R&D, and Lattice QCD computing investments) is decreased ~6.5% compared to FY 2005, resulting in ~9% decrease in personnel. 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 2004 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 supports researchers in 5 university laboratories with local accelerators (Texas A&M Cyclotron Laboratory, Triangle Universities Nuclear Laboratory (TUNL) at Duke University, MIT Laboratory for Nuclear Science, University of Washington, and Yale University). DOE also supports 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. One-half of those who received nuclear science Ph.D.'s between 1980 and 1994 are pursuing 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. At the weapons laboratories, Nuclear Physics program funding plays an important role in supporting basic research that can improve the 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 every year 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 natural universe 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 along the high priority nuclear science 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

In the FY 2006 budget request the scientific scope of the nation's nuclear physics program is maintained. In the context of an overall 8.4% reduction in funding, priority has been given to maintaining a productive program focused on attaining the scientific goals of the program. This requires a balance in on-going facility operations and research support and investments in capabilities needed to successfully attain these goals. Funding required for MIT/Bates in FY 2006 decreases with its termination of operations in FY 2005. In keeping with PART findings and principles, this will allow resources for the remaining user facilities (BNL/RHIC, TJNAF/CEBAF, ANL/ATLAS, and ORNL/HRIBF) with operations at these facilities at 65% of optimum utilization. The investments in these facilities are allocated to optimize their scientific programs. FY 2006 investments in capital equipment addresses opportunities identified in the 2002 NSAC Long Range Plan and in subsequent NSAC recommendations. At RHIC, funding is provided for needed detector upgrades by redirecting funds available for operations of the facility and existing detectors. At TJNAF, funding is provided for 12 GeV CEBAF Upgrade R&D and conceptual design activities. These investments in capabilities are critical for the scientific viability of the facilities and their program in the outyears. At ATLAS and HRIBF, the priority is on minimizing the impacts of the reductions on the facility operations. In the Memorandum of Understanding for the 88-Inch Cyclotron developed for FY 2004-2005, NRO and USAF provide $2,000,000 for 2,000 hours for their tests and NP provides $3,000,000 for a 3,000 hour in-house nuclear physics program. Following evaluations in the summer of 2004 by NRO, USAF, and NP, it was determined that a continued need for 88-Inch Cyclotron beams exists and a Memorandum of Agreement (MOA) for the continuation of this arrangement for FY 2006-2011 is being developed for signature. In FY 2006, NP funding is requested to support 88-Inch operations for an in-house nuclear physics program consistent with the NRO/USAF/DOE MOA. The research programs at the major user facilities are integrated partnerships between DOE scientific laboratories and the university community, and the planned experimental research activities are considered essential for scientific productivity of the facilities. Funding for university and national laboratory researchers and graduate students decreases 6.8% compared to the FY 2005 appropriation. R&D activities for the proposed RIA are maintained at the FY 2005 Congressional budget request level.

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 Quantum ChromoDynamics (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.

Lattice Quantum ChromoDynamics Computing

Quantum ChromoDynamics (QCD) 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 many measurements at the Stanford Linear Accelerator Center (SLAC) B-Factory, the Fermilab Tevatron, the Brookhaven Relativistic Heavy Ion Collider (RHIC) and the Thomas Jefferson National

Accelerator Facility (TJNAF). Recent advances in numerical algorithms coupled with the ever-increasing performance of computing have now made a wide variety of QCD calculations feasible, though most calculations of interest still require very significant computing resources (~10^{12-14} computational operations or 1-100 Teraflops).

An effort with the High Energy Physics (HEP) and Advanced Scientific Computing Research (ASCR) programs is aimed towards the development of a ~5 Teraflops prototype computer by the end of 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 (~20 Teraflops) will begin in FY 2006 for providing computing capabilities based on the most promising technology. This effort will be captured in a single Major IT investment.

Scientific Facilities Utilization

The Nuclear Physics request for FY 2006 supports the Department's scientific user facilities. In FY 2004 Nuclear Physics operated five national user facilities, which provided research time for scientists in universities and other Federal laboratories. In FY 2005, the program supports operations at:

- The Relativistic Heavy Ion Collider (RHIC) complex at Brookhaven National Laboratory;
- The Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility;
- The Bates Linear Accelerator Center at Massachusetts Institute of Technology;
- 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 2,240 scientists. The FY 2006 Budget Request will support operations of four facilities (operation of MIT/Bates is terminated in FY 2005) that will provide ~14,695 hours of beams for research, a ~32% decrease from the anticipated beam hours in FY 2005 that includes MIT/Bates operations. (The operating facilities will overall operate ~21% less than in FY 2005.)

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 2004	FY 2005	FY 2006 Request
Number of Facilities	5	5	4
Optimal Hours	27,675	25,800	22,675
Planned Operating Hours	21,265	21,660	14,695
Achieved Operating Hours	24,280	–	–
Unscheduled Downtime – Major user facilities	11%	–	–
Number of Users[a]	2,290	2,240	2,100

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.

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 capture 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 gamma ray bursters are possible locales for this process. Tremendous forces must fuse lighter elements into the heavier ones, 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 scientific initiative with studies of exotic nuclei and reactions at its existing facilities and by development of plans for the proposed Rare Isotope Accelerator (RIA) that will enable study of exotic nuclei at the very limits of stability and make almost all the relevant r-process nuclei accessible for study. DOE has approved mission need (CD-0) for RIA. Funding is provided in FY 2006 for R&D.

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 underway to find and characterize this state of matter. In the future, a luminosity upgrade at RHIC would permit measurements of the earliest highest energy-density stage in the formation and development of the quark-gluon plasma, the study of which is facilitated by measurements with rare-particle probes.

The High Energy Density Physics activities include the support of the operation 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 10. Such an increase will allow measurements of the production rate of the J/ψ and other

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

"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. This will allow a detailed tomography of the hot matter as it evolves.

Construction and Infrastructure

In FY 2006, funding for capital equipment is increased by 0.7% and for accelerator improvement projects is decreased by 37% (after $2,000,000 is redirected to initiate the Electron Beam Ion Source (EBIS) project) compared to FY 2005. Project Engineering and Design (PED) funding is provided in FY 2006 for the EBIS at BNL that will replace the aging Tandem Van de Graaff accelerator as the injector for RHIC. The Nuclear Physics program, as part of its responsibilities as the landlord for BNL and TJNAF, will provide funding for general plant projects (GPP) to both sites and general purpose equipment (GPE) to BNL only. Funding for GPP is increased by 2.9% in FY 2006 compared to FY 2005.

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 ~4 new awards each year, has been very successful in identifying, recognizing, and supporting promising young faculty.

About 875 postdoctoral research associates and graduate students supported by the Nuclear Physics program in FY 2004 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 manpower are given below. In FY 2004 there were about 270 faculty researchers supported at the universities (~1.4 per grant), with an average award of ~$220,000 per faculty researcher. Almost all grants are awarded with project periods of three years.

	FY 2004	FY 2005 est.	FY 2006 est.
# University Grants	190	185	175
Average size (excluding CE)	$309,000	$327,000	$312,000
# Laboratory Groups	28	28	27
# Permanent Ph.D.'s (manpower count)	746	745	690
# Postdoctoral Associates (manpower count)	403	400	340
# Graduate Students (manpower count)	473	470	420
# Ph.D.'s awarded	66	66	60

Medium Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Medium Energy Nuclear Physics					
Research					
University Research	15,179	15,542	14,751	-791	-5.1%
National Laboratory Research	15,288	15,411	15,015	-396	-2.6%
Other Research	350	5,477	5,053	-424	-7.7%
Total, Research	30,817	36,430	34,819	-1,611	-4.4%
Operations					
TJNAF Operations	75,543	78,996	72,341	-6,655	-8.4%
Bates Operations	12,494	9,405	4,500	-4,905	-52.2%
Total, Operations	88,037	88,401	76,841	-11,560	-13.1%
Total, Medium Energy Nuclear Physics	118,854	124,831	111,660	-13,171	-10.6%

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 Medium Energy subprogram seeks to advance our knowledge of the internal structure of protons and neutrons, the basic constituents of all nuclear matter, 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, Quantum ChromoDynamics. This work provides a basis for our description of matter in terms of its fundamental constituents and strengthens scientists' ability to explore how matter will behave under conditions that cannot be duplicated by man. To accomplish this task, the Medium Energy subprogram operates the Thomas Jefferson National Accelerator Facility (TJNAF), supports research at the Relativistic Heavy Ion Collider (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.

Supporting Information

To achieve the experimental description, the Medium Energy subprogram supports different approaches that focus on:

(1) determining the distribution of up, down, and strange quarks in the nucleons,
(2) determining dynamic degrees of freedom of the quarks by measuring the excited states of hadrons (any composite particle made of quarks, such as nucleons),
(3) measuring the effects of the quark and gluon polarizations within the nucleon,
(4) determining the role of the “sea” of virtual quarks and gluons, which also contributes to the properties of protons and neutrons, and
(5) measuring the properties of simple, few-nucleon systems, with the aim to describe them in terms of their fundamental components.

Most of this work is done at this subprogram’s primary research facility, TJNAF, but the program also has 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 at several facilities in Europe. All these facilities produce beams of sufficient energy (small enough wavelength) to probe at a scale within the size of a nucleon.

The operation of the national user facility, TJNAF, serves yearly a nationwide community of about 300 DOE and about 300 National Science Foundation (NSF) supported scientists and students from over 140 U.S. institutions and about 300 scientists from 19 foreign countries. Many of these scientists are from the European Center for Nuclear Research (CERN) member states. At TJNAF, the NSF has made a major contribution to new experimental apparatus in support of the large number of NSF users. Foreign collaborators have also made a significant investment in experimental equipment. Allocation of beam time at TJNAF is based on guidance from Program Advisory Committees that review and evaluate proposed experiments regarding their merit and scientific priority.

FY 2004 Accomplishments

Scientists supported by this subprogram have made important discoveries in the past decade. The assembly of a large set of precision nucleon-nucleon scattering data, for example, has provided critical input for theoretical models that now produce a significantly more quantitative description of nuclei, making possible the development of a “Standard Model for Nuclei.” The past decade has seen a growing interest by the field to understand nucleons in terms of the quarks and gluons of QCD. Advances in both theory and experiment have spurred this interest. The NSAC Long-Range Plan singled out three significant achievements of the Medium Energy subprogram related to the important central question of the structure of the nucleon:

- The combined discovery that the spins of the quarks alone account for only one third of the proton’s overall spin and the observed increasing density of gluons inside the proton with increasing beam resolving power has increased the importance of the role of gluons in understanding nucleon structure.
- The discovery of a significant imbalance between antiquarks of different types inside the proton suggests that fleeting particles composed of quark-antiquark pairs called pions play as important a role inside the nucleon (via the “sea” of virtual quarks) as they do in theories of the nuclear force.
- The discovery in a new high-resolution spatial map of the proton of an unexpected depletion of charge near its center, a fact not yet explained by current models.

Recent developments include:

- Continuing the search for five-quark states: Data collection for a new search for a five-quark (pentaquark) state called the θ^+ (theta-plus) with over an order of magnitude more sensitivity has just been completed at TJNAF.
- Connecting individual and coherent quark-gluon behavior in the nucleon: A major question in understanding the behavior of the quarks and gluons (partons) that are tightly bound inside the proton is how the individual behavior of the partons relates to their coherent behavior through the response of the proton as a whole to external probes. New data from TJNAF indicate that a relatively simple relationship previously seen in specific situations appears to hold universally. This result was somewhat surprising in that scientists expected the relationship to be much more complicated.
- First direct evidence for nucleon-nucleon correlations inside light nuclei: Data on the breakup of helium-3 nuclei (two protons and one neutron) by electrons from the CEBAF Large Acceptance Spectrometer (CLAS) detector at TJNAF have, for the first time, demonstrated a strong correlation between the velocities of the neutron and one of the protons emitted in the breakup. This correlation information is important for the ab-initio calculations of light nuclei.
- The MiniBooNE experiment is proceeding on schedule: This experiment started collecting data in October 2002 and has collected 50% of the expected minimum number of neutrino events needed for a statistically significant measurement of neutrino oscillations. These data are important for determining whether or not sterile (non-interacting) neutrinos exist.

FY 2004 Facility and Technical Accomplishments:

- The BLAST Detector at the MIT/Bates facility has produced preliminary results: The Bates Large Acceptance Spectrometer Toroid (BLAST) has produced preliminary results on precision measurements of the electromagnetic form factors for the proton and neutron as well as a precision determination of the spin structure of the deuteron.
- Development of a new “frozen-spin” polarized target: The Laser Electron Gamma Source (LEGS) experiment at BNL has successfully commissioned a revolutionary new polarized frozen hydrogen-deuterium target that will make possible the highest quality measurements ever made of the spin structure of the proton and neutron at energies near the threshold for excitation of these nucleons.
- Atom Trapping Trace Analysis finds new uses: A novel technique using lasers has been developed that allows scientists to identify and count individual atoms of the rare isotopes at sensitivities of one atom per billion of the naturally occurring abundance. This technique has been successfully used to date ground water in an ancient Egyptian aquifer to determine the flow of water in the aquifer and in medical research for measuring bone density in human subjects.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Research	**30,817**	**36,430**	**34,819**
▪ **University Research**	**15,179**	**15,542**	**14,751**

These activities comprise a broad program of research, and include support of about 150 scientists and 95 graduate students at 32 universities in 17 states and the District of Columbia. These research efforts utilize not only each of the accelerator facilities supported under the Medium Energy subprogram, but also other U.S. and foreign accelerator laboratories. Support for university research decreases by 5.1%, resulting in a ~9% reduction in existing Ph.D. researchers and graduate students supported.

• **Bates Research**	**2,400**	**2,500**	**2,152**

MIT scientists along with other university researchers used the BLAST to make measurements in FY 2004 and FY 2005 to obtain information about the structure of the nucleon and the nature of the nucleon-nucleon force. In FY 2006 support is provided to complete data analysis.

• **Other University Research**	**12,779**	**13,042**	**12,599**

Most of the university research activities are associated with the main facilities at TJNAF and RHIC. At TJNAF the experiments are largely focused on the study of nucleon structure and its internal dynamics. Hall A experiments are expected to make a sensitive measurement of the radial extent of the neutron distribution in the lead-206 nucleus. Hall B experiments are expected to perform a pentaquark search and to make a precision measurement of the half life of the neutral pion. Hall C expects to complete the G0 experiment which will determine the strange quark contribution to the proton electromagnetic structure.

A number of university groups are collaborating in experiments using the BLAST detector at the MIT/Bates Linear Accelerator Center that are completed in FY 2005. Support is provided for data analysis from BLAST precision polarization measurements of the proton and nuclear structure measurements on light nuclei.

University scientists and national laboratory collaborators will continue to develop the RHIC Spin program at Brookhaven National Laboratory. This program is expected to provide critical information on the contribution of gluons to the nucleon's intrinsic spin. Complementary research efforts that will have reduced support in FY 2006 include: the HERMES (HERa MEasurements with Spin) experiment at the DESY laboratory in Hamburg, Germany; the Crystal Ball detector at the MAMI (MAinzer MIkrotron) electron accelerator in Mainz, Germany; and the precision experiments in weak decay at the Paul Scherrer Institute, Switzerland.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **National Laboratory Research**	**15,288**	**15,411**	**15,015**

Included are: (1) the research supported at the TJNAF, that houses the world's most powerful high intensity continuous wave electron accelerator and (2) research efforts at Argonne, Brookhaven, and Los Alamos National Laboratories. The national laboratory groups carry out research at various world facilities as well as at their home institutions.

• **TJNAF Research**	**5,187**	**5,236**	**5,057**

Scientists at TJNAF, with support of the user community, assembled the large and complex experimental detectors for Halls A, B, and C. TJNAF scientists provide experimental support and operate the detectors for safe and effective utilization by the user community. TJNAF scientists participate in the laboratory's research program. Support is reduced by 3.4% compared to FY 2005, resulting in scientific and technical staff reductions.

• **Other National Laboratory Research**	**10,101**	**10,175**	**9,958**

Support for research activities at accelerator and non-accelerator facilities at national laboratories is reduced by 2.1% compared to FY 2005. Resources are directed towards the highest priority activities that include support for efforts at TJNAF and RHIC, and completion of the LEGS experiment at BNL. The activities supported are described below:

- ► Argonne National Laboratory scientists will pursue research programs 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), that will be used in measurements of rare isotopes for precision studies of nuclear structure.
- ► At Brookhaven National Laboratory, the Medium Energy Research group will continue to play a leading role in the RHIC-Spin research program. This is the set of experiments at RHIC that use colliding polarized proton beams to investigate the spin content of the nucleon and, in particular, the role of gluons.
- ► Also at Brookhaven, Laser Electron Gamma Source (LEGS) scientists are operating a new spectrometer and a recently developed polarized frozen hydrogen-deuterium target for a program of spin physics at low energies to measure the structure of the nucleon. This unique facility produces polarized gamma-rays by back scattering laser light from the circulating electron beam at the National Synchrotron Light Source.
- ► At Los Alamos National Laboratory, scientists and collaborators are participating in a next-generation neutrino oscillation experiment that builds on the experience of the Liquid Scintillator Neutrino Detector (LSND) experiment at Los Alamos, which detected a signal consistent with the existence of neutrino oscillations. The Mini Booster Neutrino Experiment (MiniBooNE) uses neutrinos generated from the Fermi National Accelerator Laboratory Booster proton beam; data collection began in FY 2002. Approximately half of the minimum expected required amount of data for a statistically significant measurement had been collected as of May 2004. Preliminary results are expected at the end of FY 2005.

	FY 2004	FY 2005	FY 2006

(dollars in thousands)

- ► Los Alamos scientists also are involved in experiments at RHIC (RHIC Spin) that will probe the gluonic contribution to the spin of the proton. The Los Alamos group has also been instrumental in providing major components of the PHENIX detector at RHIC that are crucial in carrying out the RHIC Spin program of research.

The FY 2006 Request will provide resources to complete the LEGS experiment at BNL, and efforts at TJNAF and RHIC will be continued but with reductions in productivity because of staff reductions. Other activities are phased out as measurements are completed.

	FY 2004	FY 2005	FY 2006
▪ **Other Research**	**350**	**5,477**	**5,053**

In FY 2004, $3,807,000 was transferred to the SBIR program and $1,053,000 was transferred to the STTR program. This activity includes $3,771,000 for SBIR and $1,096,000 for STTR in FY 2005 and $3,414,000 for SBIR and $996,000 for STTR in FY 2006 and other established obligations that the Medium Energy Nuclear Physics subprogram must meet.

	FY 2004	FY 2005	FY 2006
Operations	**88,037**	**88,401**	**76,841**
▪ **TJNAF Operations**	**75,543**	**78,996**	**72,341**

Included is the funding that supports: (1) operation of the Continuous Electron Beam Accelerator Facility (CEBAF) at TJNAF, and (2) major human resources, equipment, and staging support for the assembly and dismantling of complex experiments.

	FY 2004	FY 2005	FY 2006
• **TJNAF Accelerator Operations**	**48,592**	**52,276**	**47,161**

Accelerator operations in FY 2006 support a 3,545 hour running schedule; a decrease of ~29% in operating hours compared to FY 2005 that corresponds to ~66% utilization of the facility. At this level of funding the accelerator provides beams of differing energies and currents simultaneously to all three experimental halls. Recent investments in AIP projects have improved the reliability of CEBAF resulting in a decrease in unscheduled downtime from 17.8% in FY 2002 to 11.6% in FY 2004, a significant improvement. Support in FY 2006 is directed at continuing necessary accelerator improvement projects (AIP) and infrastructure improvements at a reduced level compared to FY 2005. Efforts in developing advances in superconducting radiofrequency technology are slowed down and focused on the highest priority new capabilities for SC missions.

	FY 2004	FY 2005	FY 2006
TJNAF Hours of Operation with Beam	5,238	4,985	3,545

Funding of $1,500,000 is provided for R&D and conceptual design 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 in March 2004.

	FY 2004	FY 2005	FY 2006
(dollars in thousands)			
• **TJNAF Experimental Support**	**26,951**	**26,720**	**25,180**

These funds provide 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. In FY 2006, funding for experimental support is decreased by 5.8% compared to FY 2005.

Capital equipment funds ($5,706,000) are used towards assembly and installation of ancillary equipment items such as polarized targets for experimental Halls A, B, and C; spectrometer systems; the completion of a major 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 developed to perform a precision measurement of the weak charge of the proton.

▪ **Bates Operations**	**12,494**	**9,405**	**4,500**

MIT/Bates Linear Accelerator Center is provided funding for phase-out and decontamination and decommissioning (D&D) activities.

	FY 2004	FY 2005	FY 2006
Bates Hours of Operation with Beam............................	5,177	3,125	0

Operations of the MIT/Bates Linear Accelerator Center will be phased out in FY 2005, and D&D activities will be started in FY 2005. Discussions are underway with MIT regarding disposal of property and the final state of the site. Costs of D&D range up to ~$16,000,000 for decontamination of all buildings and removal of their contents. Costs may decrease depending on the final disposition plan and whether ownership of the buildings and some of the equipment are transferred to MIT.

Total, Medium Energy Nuclear Physics	**118,854**	**124,831**	**111,660**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)

Research

▪ **University Research**

Funding supports the continuation of the MIT/Bates research effort focused on analysis of BLAST data. Phase out of support for Bates research staff continues in FY 2006..	-348

	FY 2006 vs. FY 2005 ($000)
The research support at other universities decreases by 3.4% relative to FY 2005 and is focused on those university programs that support TJNAF and RHIC Spin-physics research programs.	-443
Total, University Research	**-791**
▪ **National Laboratory Research**	
Funding for capital equipment decreases by $77,000 from FY 2005. Funding for research support decreases ($319,000) reducing support to efforts in RHIC Spin and MiniBooNE.	-396
▪ **Other Research**	
Estimated SBIR/STTR and other obligations decrease.	-424
Total, Research	**-1,611**
Operations	
▪ **TJNAF Operations**	
TJNAF Accelerator Operations: Accelerator operating funds are decreased by 7.4% ($3,736,000) and support for accelerator science R&D for superconducting radiofrequency technology is reduced ($-1,250,000) relative to FY 2005. This funding supports a 3,545 hour running schedule (66% of optimum utilization) and R&D and conceptual design activities for a possible 12 GeV upgrade. Included is funding for AIP/GPP ($1,871,000) that is decreased by $129,000 compared to FY 2005.	-5,115
TJNAF Experimental Support: The decrease of 5.6% ($-1,146,000) for Experimental Support relative to FY 2005 supports the reduced running schedule. Capital equipment funding ($5,706,000) is reduced $394,000 compared to FY 2005.	-1,540
Total, TJNAF Operations	**-6,655**
▪ **Bates Operations**	
With the termination of operations, the funding for Bates is decreased from FY 2005. Funds are provided for decontamination and decommissioning (D&D) activities.	-4,905
Total, Operations	**-11,560**
Total Funding Change, Medium Energy Nuclear Physics	**-13,171**

Heavy Ion Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Heavy Ion Nuclear Physics					
Research					
University Research	12,392	12,720	12,113	-607	-4.8%
National Laboratory Research	17,984	16,673	17,546	+873	+5.2%
Other Research	0	3,917	3,609	-308	-7.9%
Total, Research	30,376	33,310	33,268	-42	-0.1%
Operations					
RHIC Operations	120,547	130,473	117,868	-12,605	-9.7%
Other Operations	10,528	10,767	10,743	-24	-0.2%
Total, Operations	131,075	141,240	128,611	-12,629	-8.9%
Total, Heavy Ion Nuclear Physics	161,451	174,550	161,879	-12,671	-7.3%

Description

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

(1) 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 phase of 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 all elements of the Nuclear Physics mission 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 developing and operating the world-class facility, the Relativistic Heavy Ion Collider (RHIC), at which most of the world's research in relativistic heavy-ion nuclear physics is performed; by supporting research and development of the next generation particle detectors, advanced accelerator technologies such as electron beam cooling, state-of-the-art electronics, software and computing; and by training scientists needed by the Nation's diverse high-skills industries and academic institutions.

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 10 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 four successful running periods have been completed: Run 1 in FY 2000 with gold beams; Run 2, which spanned the end of FY 2001 and the beginning of FY 2002, with gold beams and commissioning of polarized protons; and Run 3 in FY 2003, with deuteron-gold collisions and the first physics results with polarized proton collisions; and Run 4 in FY 2004 with high luminosity gold beams and polarized protons. This facility is utilized by over 1,100 DOE, NSF and foreign agency supported researchers. Capital equipment and accelerator improvement project (AIP) funds are provided for additions, modifications and improvements to various accelerator components and systems that comprise the RHIC complex and ancillary experimental facilities, in order to maintain safety, improve the reliability and efficiency of operations, and provide new experimental capabilities. Beam time at the RHIC facility is allocated with guidance from a Program Advisory Committee, consisting of scientists that review and evaluate experiments regarding their merits and scientific priority. An annual review of the effectiveness of RHIC operations and its research is conducted by the program office and its recommendations are used to improve the RHIC program.

The Heavy Ion Nuclear Physics subprogram also provides general purpose equipment (GPE), general plant project (GPP), and other funding as part of Nuclear Physics' stewardship responsibilities for Brookhaven National Laboratory. These funds are for general purpose equipment, minor new capital fabrication, alterations and additions, improvements to land, buildings, and utility systems, and other normal operations that are needed for effective laboratory operations.

FY 2004 Accomplishments

The NSAC Long-Range plan identified several discoveries that support the goals of the Heavy Ion subprogram:

- Production of small regions of space with energy densities more than twenty times that of atomic nuclei. Matter under these extreme conditions may well be in the quark-gluon plasma phase.

- Observation of a strong “flow” of matter in relativistic heavy-ion collisions, indicating that the initial kinetic energy of the beams is rapidly converted to heating the nuclear matter created in the collision zone, putting it under immense internal pressure.
- Observation of a deficit of high transverse-energy particles in relation to proton-proton collisions. This result indicates that high-energy particles suffer energy losses much larger than those expected for the partons (making up the particles) passing through normal nuclear matter – hinting at the formation of the plasma phase in the collision.
- Measurements of anti-matter to matter ratio. Since the number of anti-baryons (anti-matter) is almost equal to the number of baryons (matter), it is concluded that the collision zone immediately after the collision consists of almost pure energy, from which particle-antiparticle pairs are produced.

These discoveries have been extended by the wealth of exciting new results reported from subsequent running periods at RHIC. The third running period in FY 2003 successfully collided deuterons with gold nuclei—a landmark technical accomplishment in itself—allowing scientists to report preliminary, but tantalizing results of central importance to the whole RHIC program. The fourth running period in FY 2004 with high luminosity gold beams produced large volumes of data that will afford observations of rare processes. In FY 2004, RHIC produced record luminosities. Some of the highlights from the gold-gold and deuteron-gold programs are:

- First measurements of jet tomography: Measurements of a spray of highly energetic particles emitted back-to-back (“jets”) have been measured with gold-gold collisions. Because “jet” phenomena occur at very early times, they are harbingers of the environment in which they are born. In the most violent head-on collisions one jet is “lost”. 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 suppression depends on the orientation of the in bound jet and thus on its path length in the opaque media. Scientists hope to exploit this behavior using the large amount of data accumulated in FY 2004 to build a more detailed “tomographic” image of the opaque matter.
- Direct photons observed: 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.
- Reconstruction of charmed mesons: D mesons and J/ψ 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.
- Opposite behaviors observed in gold-gold and deuteron-gold collisions: One of the most dramatic results to emerge from RHIC has been the observation of a suppression of high momentum particles in gold-gold collisions relative to the expected scaling from proton-proton collisions. This behavior is not seen in the deuteron-gold control experiment where high density matter is not expected to be created. These results suggest the gold-gold collisions are influenced by new effects, such as those leading to the formation of quark-gluon plasma or other new forms of matter.
- First results reported from low energy gold-gold collisions: With the use of high speed computers to process and analyze large volumes of data, RHIC experimenters have obtained preliminary results

from 31 GeV/nucleon gold collisions in a record short time. This "energy scan" allows scientists to control the density and initial temperature of the collisions.

FY 2004 Facility and Technical Accomplishments:

- RHIC sets new machine record surpassing its design luminosity: RHIC in its latest run with 100 GeV/nucleon gold beams delivered twice the luminosity called for in its design goal. This record breaking performance in FY 2004 has exceeded all expectations and accordingly provided significantly more data for the experiments. Building on its past 4 years of technical achievements, RHIC has increased its delivered integrated luminosity per run by almost 200-fold.
- RHIC provides collisions of low energy gold beams: After the full energy gold run, RHIC successfully delivered first gold beams at 31 GeV/nucleon. Collisions were quickly established with luminosities high enough that allowed collection of new physics data.
- Proton beams with increased polarization achieved at RHIC: Following the deployment of complex magnets, called "Helical Spin Rotators" in FY 2003, a special magnet called the "Warm Snake," built in collaboration with RIKEN (Japan) scientists and engineers, was installed in the Alternating Gradient Synchrotron (AGS). With this device, the average polarization of the proton beam in the RHIC ring has increased to 45%, almost double last year's performance. A new polarized hydrogen jet target which will allow an absolute and accurate measurement of the proton beam polarization has been commissioned at RHIC.
- The STAR detector Electromagnetic Calorimeter Enhancement is completed: This MIE project was completed within cost and on schedule in FY 2004. Installation tasks will be completed in FY 2005, as planned.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Research	**30,376**	**33,310**	**33,268**
▪ **University Research**	**12,392**	**12,720**	**12,113**

Support is provided for the research of about 120 scientists and 75 graduate students at 26 universities in 18 states. Support for university research is decreased by 4.8% ($607,000) compared with FY 2005.

- Researchers using relativistic heavy-ion beams are focused on the study of the production and properties of hot, dense nuclear matter at experiments at RHIC, where an entirely new regime of nuclear matter might be created for the first time. The university groups provide scientific personnel needed for the operation of the RHIC detectors, data analysis and publication of results.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

- Research conducted at the NSF supported National Superconducting Cyclotron Laboratory at Michigan State University, at the DOE supported Texas A&M University, and at foreign facilities in France and Italy, that investigate nuclear reactions at intermediate energies with the aim of studying the fragmentation of nuclei and the behavior of nuclear matter at high baryon density has successfully addressed the most compelling questions and will be phased out.

  A limited effort in R&D and computer simulations directed at the relativistic heavy-ion program at the Large Hadron Collider at CERN is supported.

	FY 2004	FY 2005	FY 2006
▪ **National Laboratory Research**	**17,984**	**16,673**	**17,546**

Support is provided for scientists at five national laboratories (BNL, LBNL, LANL, LLNL and ORNL). These scientists provide essential manpower for the operations of the RHIC detectors: analyzing data and publishing scientific results; conducting R&D of innovative detector designs, integrated electronics designs for high bandwidth data acquisition systems and software technologies; as well as planning for future experiments. Also, BNL, LBNL, and LLNL provide substantial computing infrastructure for terabyte-scale data analysis and state-of-the-art facilities for detector and instrument development. Support is provided for computer simulations and R&D for a proposed relativistic heavy-ion program at the Large Hadron Collider at CERN that will begin data taking in 2008.

	FY 2004	FY 2005	FY 2006
• **BNL RHIC Research**	**8,171**	**6,231**	**8,474**

BNL scientists play a major role in planning and carrying out research with the four detectors (STAR, PHENIX, BRAHMS and Phobos) at RHIC and have major responsibilities for maintaining, improving and developing this instrumentation for use by the user community. In FY 2006 funding for capital equipment increases by $2,400,000 (partly from redirected facility operations), to start fabrication of the STAR Time-of-Flight (TOF) detector MIE project (TEC and TPC of $4,800,000). Support for researchers decreases by 6.5% ($422,000), resulting in the phaseout of support for the smaller detectors BRAHMS and Phobos. The initial survey work with gold and lighter nuclear beams at the full energy will be largely complete by FY 2005 and measurements of the yields of rarer signals, such as the expected J/ψ (psi) suppression due to its breakup by the quark-gluon plasma, and the characterization of “jets” will dominate the experimental program with the utilization of the currently enhanced RHIC detectors. Research, development, and design for detector upgrades is being performed by scientists from BNL, and other national laboratories, and universities, to add or enhance measurement capabilities that will allow the extraction of a broader variety of rare, but detectable signals that could become measurable at high RHIC luminosity.

The STAR Time-of-Flight (TOF) outer barrel detector MIE, based on Multi-gap Resistive Plate Chamber (MRPC) technology developed at CERN for A Large Ion Collider Experiment (ALICE), at the Large Hadron Collider, will extend particle identification of the particles tracked in the existing Time Projection Chamber (TPC) to much higher transverse momentum (up to 10 GeV/c) and provide electron tagging capability. Excellent results (timing resolution) have been obtained from a prototype unit (covering 1/60 of the barrel circumference) from the FY 2003 deuteron-gold run.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
• **Other National Laboratory Research**	**9,813**	**10,442**	**9,072**

Researchers at LANL, LBNL, LLNL, and ORNL provide unique expertise and facilities in the development of new technologies for RHIC detector upgrades, as well as playing leadership roles in the on-going research program. 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). At LLNL substantial computing resources are made available for the PHENIX data analysis. Compared to FY 2005 support for laboratory research decreases by 13.1% resulting in significant reductions in laboratory research groups.

▪ **Other Research**..	**0**	**3,917**	**3,609**

In FY 2004 funds were transferred to the SBIR program ($3,879,000). This section includes $3,917,000 for SBIR in FY 2005 and $3,609,000 for SBIR in FY 2006.

Operations	**131,075**	**141,240**	**128,611**
▪ **RHIC Operations**...	**120,547**	**130,473**	**117,868**

The Relativistic Heavy Ion Collider (RHIC) is a unique world-class scientific research facility that started its research program in 2000. Its colliding beams of relativistic heavy ions allow scientists an opportunity to explore and understand the nature of hot, dense matter and to recreate conditions under which nuclear matter dissolves into the predicted quark-gluon plasma. The first 3 initial survey runs have already produced 70 refereed journal papers, creating interest in the scientific community. Run 4 in FY 2004 set a new record for delivered integrated luminosity with gold beams that has surpassed the design goal by a factor of 2. This high level of performance allowed sufficient time to run RHIC at the lower beam energy of 31 GeV/nucleon. During the later part of Run 4 RHIC provided 100 GeV polarized proton beams. The successful installation of the “warm snake” magnet in the AGS has increased the beam polarization in the RHIC rings to 45%. Initial measurements with the new polarized gas-jet target, needed for an absolute calibration of the spin polarization of the proton beam, were completed. The RHIC facility, the first collider using two intense ion beams since the CERN Intersecting Storage Ring (ISR) of the 1970’s, is providing new information in the development of accelerator technology that will be directly useful in the operation of the Large Hadron Collider at CERN that will begin operation of the LHC heavy ion program in 2008.

• **RHIC Accelerator Operations**	**90,435**	**98,375**	**88,193**

Support is provided for the operation, maintenance, improvement and enhancement of the RHIC accelerator complex. This includes the Tandem, Booster and AGS accelerators that together serve as the injector for RHIC. FY 2006 funding will support 1,400 hours of operations, a 31% utilization of the collider. Increases in power costs and in medical insurance rates in FY 2006 contribute to the reduction in operating hours. Effective operation will be achieved by combining FY 2006-FY 2007 running into a single back-to-back run bridging the two Fiscal Years. This funding also supports $1,850,000 for R&D activities towards increasing the luminosity of the collider beyond its baseline design specifications. Capital equipment is reduced by 6.5% to $1,122,000 compared to FY 2005 and accelerator improvement (AIP) funding is decreased by $2,100,000 to $1,000,000.

	FY 2004	FY 2005	FY 2006
	(dollars in thousands)		

The accelerator improvement funds are being redirected to provide $2,000,000 towards the construction of the Electron Beam Ion Source (EBIS) that will replace the aging Tandem Van de Graaff as the heavy-ion source for the RHIC complex, providing higher intensities, better reliability and savings of ~$2,000,000 per year in RHIC operations. NASA has indicated interest in partially supporting this project because of the benefits to its Space Radiation Laboratory.

	FY 2004	FY 2005	FY 2006
RHIC Hours of Operation with Beam................	3,186	3,600	1,400

	FY 2004	FY 2005	FY 2006
• **RHIC Experimental Support**......................	**30,112**	**32,098**	**29,675**

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 (STAR, PHENIX, BRAHMS and Phobos) have reached their initial planned potential and about 1,100 scientists and students from 82 institutions and 19 countries participate in the RHIC research program. These four detectors (described in the Site Descriptions) provide complementary measurements, but with some overlap in order to cross-calibrate the measurements. Compared with FY 2005, funding for researchers and material supplies in experimental support is reduced by -$1,531,000 (-5.6%) reflecting staff reductions, the phaseout of BRAHMS and Phobos operations, and a shorter running period in FY 2006. In FY 2006, funding for capital equipment is decreased by $892,000 (-20%) to $3,633,000 compared with FY 2005 and redirected to start the STAR TOF MIE.

	FY 2004	FY 2005	FY 2006
▪ **Other Operations**	**10,528**	**10,767**	**10,743**

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 system, 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. In FY 2006 funding for GPP is increased by 4.1% ($260,000) to $6,617,000 relative to FY 2005.

	FY 2004	FY 2005	FY 2006
Total, Heavy Ion Nuclear Physics............................	**161,451**	**174,550**	**161,879**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Research	
▪ **University Research**	
FY 2006 funding for grants for University Research decreases by 4.8%, with the phase out of research that investigates nuclear reactions at intermediate energies with the aim of studying the fragmentation of nuclei and the behavior of nuclear matter at high baryon density. The focus of research will be on the RHIC program with the two large detectors STAR and PHENIX as the analysis of data from the two smaller detectors will be nearing completion.	-607
▪ **National Laboratory Research**	
• BNL RHIC Research: Research support for scientific/technical personnel is decreased by 2.5% ($157,000) from FY 2005. Funding for capital equipment is increased by $2,400,000, with the start of the STAR Time-of-Flight (TOF) Major Item of Equipment (MIE) detector project.	+2,243
• Other National Laboratory Research: Support for research operations is decreased by 13.8% (-$1,402,000) compared to FY 2005, with reductions of scientific/ technical staff in laboratory groups. Funding for capital equipment increases by $32,000 to $307,000, compared to FY 2005.	-1,370
Total, National Laboratory Research	**+873**
▪ **Other Research**	
Estimated SBIR obligations decrease.	-308
Total, Research	**-42**
Operations	
▪ **RHIC Operations**	
• Accelerator Operations decrease 10.3% compared with FY 2005. This includes decreases of: $2,100,000 in accelerator improvement project (AIP) funds to $1,000,000 (of which $2,000,000 was redirected to the EBIS); $7,884,000 in accelerator operating funds for 31% of optimal operations; $120,000 in R&D activities relating to the collider luminosity; and $78,000 in capital equipment funds.	-10,182

	FY 2006 vs. FY 2005 ($000)
• Experimental Support: A 5.6% (-$1,531,000) decrease in funding for experimental scientific/technical staff and materials support compared with FY 2005 provides for running at 31% utilization with two detectors operating. A decrease of $892,000 in capital equipment funds reflects the decreased support for computing needed with the shorter FY 2006 run, and are redirected to start the STAR TOF MIE.	-2,423
Total, RHIC Operations	**-12,605**
▪ **Other Operations**	
FY 2006 funding for general plant projects at Brookhaven National Laboratory is increased by 4.1% ($260,000) to $6,617,000, compared with FY 2005, to address the backlog of needed infrastructure improvements. Funding for general purpose equipment at Brookhaven National Laboratory is decreased by $284,000 compared with FY 2005.	-24
Total, Operations	**-12,629**
Total Funding Change, Heavy Ion Nuclear Physics	**-12,671**

Low Energy Nuclear Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Low Energy Nuclear Physics					
Research					
University Research	18,334	18,776	17,113	-1,663	-8.9%
National Laboratory Research	22,273	24,550	23,440	-1,110	-4.5%
Other Research	6,655	8,555	5,649	-2,906	-34.0%
Total, Research	47,262	51,881	46,202	-5,679	-10.9%
Operations	23,791	24,101	22,335	-1,766	-7.3%
Total, Low Energy Nuclear Physics	71,053	75,982	68,537	-7,445	-9.8%

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:

(1) 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.

(2) 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.

(3) 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 and the Argonne Tandem Linac Accelerator System, one other laboratory accelerator facility, four university-based accelerators, and non-accelerator based facilities such as the Sudbury Neutrino Observatory in Canada and KamLAND in Japan. The development of advanced accelerator technologies is also supported, including key technologies needed for the proposed new Rare Isotope Accelerator (RIA) facility. The Low Energy subprogram is an important source of trained scientific/technical personnel which contributes 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 depend upon the availability of exotic beams, or beams of short-lived nuclei, to produce and study 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, it was already noted in the NSAC 1996 Long Range Plan for Nuclear Science that a facility with next generation capabilities for short-lived radioactive beams will be needed in the future for the U.S. to maintain a leadership role. In FY 1999, a NSAC Taskforce established the optimal technical option for such a facility, the Rare Isotope Accelerator (RIA) facility. The NSAC 2002 Long Range Plan identified RIA as the highest Nuclear Physics priority for a major new construction project. Starting in FY 2000, R&D activities have been supported in preparation for a possible request for approval for construction. Continued funding for R&D activities is provided in FY 2006. In an era of constrained budgets the Nuclear Physics program needs to develop a strategic plan for implementing its vision for the future. Guidance will be sought from NSAC regarding opportunities and priorities for the Nuclear Physics program in the context of fiscal constraints.

The research of this subprogram is generally conducted using beams provided by accelerator facilities either operated by this subprogram or by other domestic or foreign facilities. In FY 2006 the Low Energy Nuclear Physics subprogram supports the operation of two national user facilities: the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory and the Argonne Tandem Linac Accelerator System (ATLAS) facility at Argonne National Laboratory. 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 2006, fabrication continues for the Major Item of Equipment (MIE) project, the Gamma Ray Energy Tracking In-Beam Nuclear Array (GRETINA), 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 for additions, modifications, and improvements to the research accelerators and ancillary equipment facilities to maintain and improve the reliability and efficiency of operations, and to provide new accelerator capabilities. The 88-Inch Cyclotron (LBNL) made the transition in FY 2004 from a user facility to a facility for testing electronic circuit components for radiation "hardness" to cosmic rays, supported by the National Reconnaissance Office and the Air Force, and a small in-house research program supported by NP. Continued utilization of the facility for these activities is proposed for FY 2006.

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. In FY 2006 the case for terminating support of operations of one of these university facilities in order to provide resources to optimize the scientific productivity of the remaining facilities will be examined. 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.

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 Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Laboratory. In FY 2006, 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 in Low Energy nuclear physics do not require the use of accelerators: the Sudbury Neutrino Observatory (SNO) detector is studying the production rate and properties of solar neutrinos, while the Kamioka Large Anti-Neutrino Detector (KamLAND) is studying the properties of anti-neutrinos produced by nuclear power reactors.

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. In 1997, the HRIBF facility became operational and is now producing over 100 proton-rich and neutron-rich radioactive beams. Research at these three facilities has explored nuclei at the extremes of nuclear spin, deformation, stability, and excitation energy. 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. In neutrino physics, following the pioneering work on solar neutrinos with radiochemical experiments, the SNO experiment, conceived in the late 1980's to search for neutrino flavor oscillations, was designed and built in the 1990's. 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 measurements reported in 2002 and 2003 from SNO that are sensitive to the different types of neutrinos, and from the first KamLAND results with reactor produced anti-neutrinos. These results have stimulated an increasing interest in non-accelerator experiments, particularly those that study neutrino properties. Studies with both SNO and KamLAND continue in order to extend and refine measurements of neutrino oscillation parameters.

FY 2004 Accomplishments

The NSAC Long-Range Plan identified significant achievements of the Low Energy subprogram that are related to the important central questions about nuclear structure, nuclear astrophysics, and fundamental interactions and symmetries:

- Studies of nuclei at extreme conditions are pointing to alterations of the nuclear shell structure, the ability of heavy nuclei to sustain rapid rotation demonstrating unexpected stability, and evidence for phase transitional behavior between spherical and deformed nuclei.
- Nuclear measurements of very neutron-rich, unstable nuclei, combined with new computational techniques, are leading to a better identification of the r-process site or sites for nucleosynthesis in stars and to quantitative models for the production of heavy elements.
- Measurements of solar and reactor neutrinos have indicated that neutrinos change their identity on the way from their source to the experiment detector, implying that they have mass, and providing a key to the fundamental structure of the forces of nature.

The basic knowledge and understanding in these areas have been further extended by these recent highlights:

- Measurement of the $^{14}N(p,\gamma)^{15}O$ reaction rate: The $^{14}N(p,\gamma)^{15}O$ reaction rate is the slowest among the carbon-nitrogen-cycle reactions in stars, and impacts stellar structure and evolution. Recent measurements at the Triangle Universities Nuclear Laboratory indicate that the reaction rate currently used in stellar models is 20-40% too high. Use of the new value in stellar evolution models results in an increase in the age of globular clusters of stars from 10.1 gigayears to 10.9 gigayears, implying an increase in the lower limit of the age of the universe to 12 gigayears. The result, deduced using this independent approach, strengthens arguments that the globular-cluster ages rule out the possibility of a flat, matter-dominated universe.
- Dependence of the spin-orbit potential on neutron excess: The spin-orbit potential describes how the interaction of single-particle states in a nucleus depends on the coupling of a particle's spin with its angular momentum. A study by Argonne National Laboratory and Yale University researchers indicates a decrease in the spin-orbit strength for the $g_{7/2}$ and $h_{11/2}$ proton orbitals in nuclei with increasing numbers of neutrons beyond stability. The spin-orbit strength was previously believed to be independent of neutron number.
- Experiments with radioactive germanium beams: Neutron-rich germanium nuclei lie along the stellar r-process pathway that leads to the production of heavy elements in stars. The first single-particle transfer reaction and Coulomb excitation measurements have been carried out with chemically-purified, mass-separated short-lived ^{82}Ge nuclei (half life of 4.6 seconds) at the Oak Ridge National Laboratory. These experiments provide some of the first nuclear structure data for these germanium nuclei that are relevant to understanding the r-process.
- Measurement of the g-factor of an accelerated radioactive nucleus: The magnetic moment (g-factor) of a nuclear level depends on its detailed nuclear structure, and can indicate nuclear structure evolution with a change in the number of neutrons or protons. The first measurement with an accelerated radioactive beam of the g-factor of a short-lived nucleus has been carried out by a collaboration of university and laboratory researchers at the 88-Inch Cyclotron lead by Rutgers University. The experiment with 15-hour ^{76}Kr determined the g-factor of the first 2+ state in that nucleus to be similar to those of the heavier stable krypton nuclei.

FY 2004 Facility and Technical Accomplishments

- A new class of superconducting accelerating cavities: Double-spoke superconducting accelerating cavities, a new class of accelerating structures for linear accelerators, have been developed at the Argonne National Laboratory. These cavities, designed to accelerate heavy-ion particles traveling 40-60% the speed of light, have demonstrated superior performance in both high accelerating gradient and low sensitivity to vibration.
- Neutral current detectors installed in the Sudbury Neutrino Observatory (SNO) detector: Neutral current detectors (NCDs), consisting of strings of ^{3}He neutron counters, have been installed in the SNO detector that contains 1,000 tons of heavy water, water with ordinary hydrogen replaced by deuterium. The NCDs will enable the SNO experiment to make an independent measurement of neutrinos as they change from one type to another (oscillate), and reduce the uncertainties on oscillation parameters. The NCD system underwent commissioning, and started taking data in the fall of 2004 for a two year running period. The NCDs were fabricated by a collaboration of U.S. universities and laboratories led by the University of Washington. The SNO experiment involves scientists from Canada, the United States, and the United Kingdom and is located in a deep nickel mine in Canada.

- Fabrication of GRETINA: In FY 2004, the Gamma-Ray Energy-Tracking In-beam Nuclear Array (an MIE) was started. GRETINA is a segmented germanium detector array that offers increased position resolution and efficiency for measuring high energy gamma rays. GRETINA is being fabricated at the Lawrence Berkeley National Laboratory in collaboration with Argonne National Laboratory and Oak Ridge National Laboratory.
- Fabrication of the Fundamental Neutron Physics Beamline (FNPB): In FY 2004, the FNPB (an MIE) was started at the Spallation Neutron Source. The beamline, being fabricated at Oak Ridge National Laboratory, will allow the measurement of fundamental properties of the neutron.
- Detection techniques and methods to measure a radiological release: Techniques and methods have been developed at the Lawrence Berkeley National Laboratory to use automotive air filters to determine the severity and extent of a radiological release. Filters from vehicles that travel defined routes or areas, such as police cars, are assayed by sensitive radiation detectors to map and quantify radioactivity in the environment. This work could make possible a low-cost method to implement a nation-wide system to respond to radiological release events.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Research	**47,262**	**51,881**	**46,202**
▪ **University Research**	**18,334**	**18,776**	**17,113**

Support is provided for the research of about 110 scientists and 85 graduate students at 25 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 2006 funding for operation of university accelerator facilities and for researchers and students is decreased 6.1% compared to FY 2005, resulting in a ~9% reduction in existing Ph.D. researchers and graduate students. Research activities are described below.

- 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). The effort at the user facilities involves about two-thirds of the university scientists supported by this subprogram.
- Accelerator operations are supported for in-house research programs at universities: the University of Washington, the Triangle Universities Nuclear Laboratory (TUNL) facility at Duke University, Texas A&M University (TAMU) and Yale University. Each of these small university facilities has a well-defined and unique physics program, 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.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

- Involvement in other accelerator and non-accelerator experiments directed at fundamental measurements, such as measurements of solar neutrino rates and the neutrino mass at the Sudbury Neutrino Observatory (SNO) in Canada, are supported. The U.S. effort with the Kamioka Large Anti-Neutrino Detector (KamLAND) in Japan is being supported jointly with the High Energy Physics program.

	FY 2004	FY 2005	FY 2006
▪ **National Laboratory Research**	**22,273**	**24,550**	**23,440**

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

	FY 2004	FY 2005	FY 2006
• **National Laboratory User Facility Research**...	**13,797**	**14,034**	**13,350**

Scientists at ANL, LBNL, 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 program's priorities. In FY 2006 funding is decreased by 4.9% for personnel compared with FY 2005. 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, the successor to the Canadian Penning Trap, to measure atomic masses with high precision and search for effects in beta decay outside the standard decay model.
- ► At LBNL the research focuses on completion of data analyses; leadership in the fabrication of the GRETINA (MIE) detector and conduct of an in-house research program that includes heavy element nuclear physics and chemistry, and fundamental symmetry studies.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
• **Other National Laboratory Research**	**8,476**	**10,516**	**10,090**

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. FY 2006 funding for scientific/technical staff decreases by 13.6% compared to FY 2005 for low energy accelerator and non-accelerator R&D activities significantly impacting what activities can be pursued. Critical personnel at LBNL are retained. Capital equipment investments increase from FY 2005 by $265,000 to $5,371,000, primarily for the fabrication of the GRETINA and FNPB MIEs. These activities are described below.

- ► The Sudbury Neutrino Observatory (SNO) experiment in Canada. The SNO detector, jointly built by Canada, England and the U.S., addresses 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. This latter explanation would imply that the neutrinos have mass. In FY 2002, and 2003, the results from SNO with the heavy water detector were reported, indicating strong evidence for neutrino oscillations. In FY 2004, the third phase of SNO began; it will provide additional detail and confirmatory information on neutrino oscillations. Results from this phase are expected to be reported in FY 2007.
- ► The KamLAND experiment in Japan will measure the rate and properties of anti-neutrinos produced by several distant nuclear power reactors to study neutrino "oscillations." KamLAND has the advantage of comparing the measured fluxes to known sources. Commissioning of the KamLAND detector began in FY 2002, with data collection continuing through FY 2005 with refined physics results likely to be reported in FY 2006. The U.S. participation in KamLAND is supported jointly with the High Energy Physics program.
- ► Research and development activities for the next generation neutrino detectors are being pursued at LBNL, PNNL and LANL as part of the possible suite of detectors to be located at the planned NSF-supported underground laboratory or other underground laboratory. There is also a limited advanced accelerator R&D effort at LBNL focused on ion sources.
- ► Neutron beams at the LANSCE facility at LANL are "cooled" to very low energies for new cold and ultra-cold neutron experiments, which will allow very precise measurements of fundamental neutron properties. Commissioning of neutron experiments with these beams began in FY 2004 and acquisition of first data is anticipated in FY 2005.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

- ► The Gamma-Ray Energy-Tracking In-beam Nuclear Array (GRETINA), 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 will allow 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 2006 funding of $3,000,000 (TEC of $17,000,000; TPC of $18,200,000) is provided to continue fabrication of GRETINA (a Major Item of Equipment).
- ► The Fundamental Neutron Physics Beamline MIE at the Spallation Neutron Source will allow measurements of the fundamental properties of the neutron. Fabrication began in FY 2004 and continues in FY 2006 with funding of $1,900,000 (TEC of $9,200,000; TPC of $9,300,000).

	FY 2004	FY 2005	FY 2006
▪ **Other Research**..	**6,655**	**8,555**	**5,649**
• **RIA R&D Activities**.....................................	**5,905**	**6,736**	**4,000**

Funds are provided at the FY 2005 Congressional Request level for R&D activities aimed at a possible future Rare Isotope Accelerator (RIA) facility.

	FY 2004	FY 2005	FY 2006
• **SBIR and Other**...	**750**	**1,819**	**1,649**

In FY 2004 $1,092,000 was transferred to the SBIR program. This section includes $1,444,000 for SBIR in FY 2005 and $1,274,000 for SBIR in FY 2006 and other established obligations. The Lawrence and Fermi Awards, funded under this line, provide annual monetary awards to honorees selected by the DOE for their outstanding contributions to science.

	FY 2004	FY 2005	FY 2006
Operations	**23,791**	**24,101**	**22,335**
▪ **User Facility Operations**...................................	**23,641**	**23,951**	**22,185**

Support is provided for the operation of two National User Facilities, the Argonne Tandem Linac Accelerator System (ATLAS) at ANL and the Holifield Radioactive Ion Beam Facility (HRIBF) at ORNL, for studies of nuclear reactions, structure and fundamental interactions, with operations at 76% of optimal utilization, and for operation of the 88-Inch Cyclotron for an in-house nuclear physics program.

HRIBF has coupled the existing cyclotron and tandem accelerator to develop a focused radioactive-ion beam program. Both proton-rich and neutron-rich beams are provided to spectrometer systems, designed for nuclear structure studies, and the Daresbury Recoil Separator and the Silicon Detector Array for nuclear astrophysics studies. In FY 2006 accelerator improvement project funding is provided ($1,300,000) of which $1,100,000 will be used for the fabrication of a second source and transport beamline for radioactive ions.

	FY 2004	FY 2005	FY 2006
(dollars in thousands)			

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 2006 accelerator improvement project funding is directed towards upgrading the accelerator to increase the radioactive beam capabilities of ATLAS.

Operations at the 88-Inch Cyclotron made a transition in FY 2004 from a national user facility to a facility providing beams for applied researchers and a limited in-house program. This was done to provide resources to optimize the utilization and science productivity of the remaining user facilities and to be 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. In this way circuits could be tested to determine if they were appropriately "hardened" to radiation in space. In the Memorandum of Understanding that was developed these offices would provide a total of $2,000,000 annually to maintain operations for 2,000 hours of operation of the Cyclotron for these tests in FY 2004 and FY 2005 and Nuclear Physics would provide $3,000,000 for a 3,000 hour in-house nuclear physics research program. A continued need for the beam capabilities of the 88-Inch Cyclotron has been determined and a Memorandum of Agreement for the continuation of this arrangement for FY 2006-2011 is being developed by the three parties for signature.

Included in the funding are capital equipment and accelerator improvement project funds provided to each of the operating facilities for the enhancement of the accelerator systems and experimental equipment. 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 with beam are indicated below:

	FY 2004	FY 2005	FY 2006
ATLAS Hours of Operation with Beam	6,195	5,600	5,700
HRIBF Hours of Operation with Beam	4,484	4,350	4,050
Total Beam Hours for Low Energy Facilities	10,679	9,950	9,750

▪ **Other Operations**	**150**	**150**	**150**

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

Total, Low Energy Nuclear Physics	**71,053**	**75,982**	**68,537**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Research	
▪ **University Research**	
FY 2006 funding for researchers and students is decreased 6.1% ($-1,055,000) compared to FY 2005 and capital equipment by 40% ($-608,000).	-1,663
▪ **National Laboratory Research**	
National Laboratory User Facility Research: FY 2006 funding decreases 4.9% compared to FY 2005 for research efforts and activities at the user facilities.	-684
Other National Laboratory Research: Research funding for personnel decreases 13.6% ($-741,000) in FY 2006 compared with FY 2005. Equipment funds are increased by $315,000 to address scientific opportunities identified in the NSAC 2002 Long Range Plan for Nuclear Science, such as the Fundamental Neutron Physics Beamline at the Spallation Neutron Source and the fabrication of the GRETINA gamma-ray tracking detector	-426
Total, National Laboratory Research	**-1,110**
▪ **Other Research**	
RIA R&D activities are supported at the FY 2005 Congressional Budget Request level ($4,000,000); a decrease of $-2,736,000 compared to FY 2005 Appropriations. Estimated SBIR and other obligations decrease by $-170,000.	-2,906
Total, Research	**-5,679**
Operations	
In FY 2006 operating funds are decreased by 9.6% ($1,642,000) compared to FY 2005 for ATLAS and HRIBF operations to provide an estimated 9,750 hours of beam time. Funding for capital equipment and accelerator improvement projects decreases by $124,000 compared to FY 2005.	-1,766
Total Funding Change, Low Energy Nuclear Physics	**-7,445**

Nuclear Theory

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Nuclear Theory					
Theory Research					
University Research	12,174	12,645	10,929	-1,716	-13.6%
National Laboratory Research	9,257	9,376	9,097	-279	-3.0%
Scientific Computing (SciDAC)	1,988	1,985	1,500	-485	-24.4%
Total, Theory Research	23,419	24,006	21,526	-2,480	-10.3%
Nuclear Data Activities	5,015	5,409	5,139	-270	-5.0%
Total, Nuclear Theory	28,434	29,415	26,665	-2,750	-9.3%

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:

(1) 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.

(2) 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.

(3) 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 of the quark-gluon plasma and other new phenomena. A key goal of the theoretical program is to establish knowledge of the QCD phase diagram of bulk nuclear matter.

(4) 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.

(5) Is there new physics beyond the 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. 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 will be useful for understanding the experimental results from RHIC and TJNAF.

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 reviewed as a component in reviews of the three other major program components of the Nuclear Physics program.

FY 2004 Accomplishments:

The 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:

- Quantum Monte Carlo studies of Fermi gases: 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, and to atomic gases trapped in controllable laboratory experiments. Recently researchers have conducted quantum Monte Carlo calculations of superfluid Fermi gases with short-range two-body attractive interactions with infinite scattering length. The energy of such gases is estimated to be (0.44 ± 0.01) times that of the noninteracting gas, and their pairing gap is approximately twice the energy per particle.
- Studies of hadronic structure on the lattice: An important question about the nucleon and its excited state, Δ, is whether they are spherical or deformed. Recent experiments carried out at TJNAF have accurately measured the electric and Coulomb quadrupole and magnetic dipole multipoles of the nucleon-to-Δ transition form factor, which directly reflect the presence of deformation. This form factor has recently been calculated using lattice QCD, a technique which solves the equations of QCD numerically on a granular space-time "lattice." The calculated magnetic dipole form factor and electric quadrupole amplitude were consistent with experimental results, but systematic errors due to limitations of this technique with present day computer resources (lattice artifacts) prevented a determination of the Coulomb quadrupole form factor. Further study of these lattice artifacts is needed for better control of systematic errors.
- Indicators of quark-gluon plasma formation: Over twenty years ago it was suggested that fast partons (quarks and gluons) traveling through a quark-gluon plasma (QGP) might lose a large amount of energy by elastic scattering with the plasma constituents, resulting in the suppression of jets from the interior of the collision fireball in relativistic heavy-ion collisions. Such a suppression of energetic particles has been observed in central gold-gold collisions at RHIC. The far-side partners of the observed jets are completely suppressed in central gold-gold collisions, but they are not suppressed in the collision of a very light nucleus (the deuteron) with a gold nucleus. The deuteron-gold results prove that these suppression patterns in gold-gold collisions are caused by final state interaction of hard partons with the produced dense medium. Theorists can now analyze the observed jet quenching phenomena with the aid of perturbative QCD to extract properties of the dense matter produced, an early step toward a tomographical picture of the hot and dense matter formed in heavy-ion collisions at RHIC. A recent study concludes that the initial gluon (energy) density of the hot matter produced in central gold-gold collisions that causes jet quenching at RHIC is about 30-100 times higher than in a cold gold nucleus. Combined with data on bulk and collective properties of the hot matter, the observed jet quenching provides strong evidence for the formation of a strongly-interacting quark-gluon plasma in central gold-gold collisions at RHIC.
- Origin of elements: Spectacular core-collapse supernovae explosions represent the violent end of a massive star's life, and create and disperse many elements – but the explosion mechanism remains elusive. Theoretical nuclear astrophysics, coupled with results from a variety of nuclear physics measurements, represents the foundation of an emerging generation of sophisticated, computationally intensive models of astrophysical phenomena. For example, nuclear theorists working under the DOE Scientific Discovery through Advanced Computing (SciDAC) program on simulations of exploding stars are continuing to make rapid progress on many fronts. An analytic reformulation of general relativistic kinetic theory has allowed the development of a new Boltzman

neutrino transport code suitable for two- and three-dimensional models of stellar collapse. Less sophisticated neutrino transport codes have previously been utilized in one-dimensional (spherical) models of stars. This large collaboration has also discovered in their numerical simulations two new fluid instabilities that may play an important role in supernova dynamics. These new computational tools could also be applied to other fields of research.

- In the past five years, the availability of enormous computing power has allowed theorists to make spectacular progress on problems that were previously thought intractable. It is now possible to simulate complex nuclear physics processes at extreme length scales ranging from astrophysical objects, to nuclei, to the quark structure of matter. The development of the Green's Function Monte Carlo Technique and the No-Core Shell Model as solutions to the nuclear many-body system for small numbers of nucleons, and the Monte Carlo Shell Model of nuclei are state-of-the-art computational methods that could provide a framework for a "Standard Nuclear Model" in the near future. In the last few years, large-scale parallel processor machines have been exploited to simulate QCD problems on a space-time lattice.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Theory Research	**23,419**	**24,006**	**21,526**
▪ **University Research**	**12,174**	**12,645**	**10,929**

The research of about 145 university scientists and 85 graduate students is supported through 58 grants at 46 universities in 26 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. Funding is decreased by 13.6% ($1,716,000) compared with FY 2005 resulting in ~14% reduction in the number of Ph.D. researchers and graduate students supported in FY 2006. Lower priority activities will be phased out in order 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," university funding has been redirected to begin investment in Lattice QCD capabilities.

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 technology with effective field theory to potentially provide a tractable, rigorous solution for low energy properties of nuclei.

▪ **National Laboratory Research**	**9,257**	**9,376**	**9,097**

Research programs are supported at 7 national laboratories (ANL, BNL, LANL, LBNL, LLNL, ORNL and TJNAF). Funding for scientific/technical staff is decreased by 8.3% (-$779,000) compared with FY 2005. This decrease is offset, in part, by a significant program shift to begin a major IT investment in Lattice Quantum ChromoDynamics to establish new national computing

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

resources. The nuclear physics part of this effort, undertaken as a joint project with the High Energy Physics program, is an investment of $500,000.

- 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.
- In all cases, the nuclear theory research at a given laboratory provides support to the experimental programs at that laboratory, or takes advantage of some unique facilities or programs at that laboratory.
- The larger size and diversity of the national laboratory groups make them particularly good sites for the training of nuclear theory postdoctoral associates.

	FY 2004	FY 2005	FY 2006
▪ **Scientific Computing (SciDAC)**	**1,988**	**1,985**	**1,500**

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. All current SciDAC projects will be completed in FY 2005 and a new competition will be held in FY 2006. 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. Each award led to two 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.” These activities will be supported at a reduced level compared to FY 2005.

	FY 2004	FY 2005	FY 2006
Nuclear Data Activities	**5,015**	**5,409**	**5,139**

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 decreased 5.0% ($270,000) resulting in personnel reductions for this activity. To protect training of new compilers for this activity, lower priority activities will be phased out at both universities and national laboratories, and one university grant and one task will be terminated. 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 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).

	FY 2004	FY 2005	FY 2006
Total, Nuclear Theory	**28,434**	**29,415**	**26,665**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Theory Research	
▪ **University Research**	
FY 2006 funding is decreased 13.6% compared to FY 2005 resulting in reductions in the Ph.D. researchers and graduate students supported. 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.	-1,716
▪ **National Laboratory Research**	
FY 2006 funding overall is decreased 3.0% compared to FY 2005 resulting in reductions in scientific staff supported. Research will be directed toward achieving the scientific goals of the Nuclear Physics program, including implementing the Lattice Gauge Quantum ChromoDynamics initiative with HEP.	-279
▪ **Scientific Computing (SciDAC)**	
FY 2006 funding is decreased by 24.4% compared to FY 2005. There will be a reduction in the scope of activities supported utilizing the guidance of peer-review.	-485
Total, Theory Research	-2,480
▪ **Nuclear Data Activities**	
FY 2006 funding is decreased 5.0% compared to FY 2005 resulting in reductions in scientific researchers supported at universities and national laboratories. Efforts will be focused on maintaining capabilities to effectively evaluate, compile and disseminate nuclear data needed for basic and applied research	-270
Total Funding Change, Nuclear Theory	**-2,750**

Construction

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Construction (PED only)					
Electron Beam Ion Source (PED)	0	0	2,000	+2,000	--

Description

This provides for Project Engineering and Design for an upgrade at the Relativistic Heavy Ion Collider that is needed to meet overall objectives of the Nuclear Physics program.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Construction	**0**	**0**	**2,000**
▪ **Electron Beam Ion Source (PED)**	**0**	**0**	**2,000**

Funding of this line-item construction project would provide for Project Engineering and Design (PED) funding (TPC~$3,700,000, TEC~$3,500,000) of the Electron Beam Ion Source (EBIS). It is funded from redirected RHIC accelerator improvement project funds in order to replace the Tandem Van de Graaff as the source for heavy ions for RHIC, improving reliability and efficiency of operations, avoiding inevitable costly repairs of the aging tandem, thereby leading to more cost-effective operations. The full Total Estimated Cost (design and construction) ranges between $12,000,000 and $17,500,000; and the full Total Project Cost estimate (design and construction) ranges between $16,000,000 and $19,500,000. These estimates are based on preliminary data and should not be construed as a project baseline. NASA has indicated interest in possibly partially supporting this project. Additional information is contained in construction project datasheet 06-SC-02.

Total, Construction	**0**	**0**	**2,000**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Construction	
▪ **Electron Beam Ion Source (PED)**	
Project engineering and design (PED) funds are provided for the Electron Beam Ion Source (EBIS) from re-directed AIP funds, to replace the aging Tandem Van de Graaff as the heavy-ion source for the RHIC complex.	+2,000

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
General Plant Projects	8,254	7,157	7,365	+208	+2.9%
Accelerator Improvement Projects	7,028	6,024	3,823[a]	-2,201	-36.5%
Capital Equipment	27,453	26,298	26,112	-186	-0.7%
Total, Capital Operating Expenses	42,735	39,479	37,300	-2,179	-5.5%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2004	FY 2005 Approp.	FY 2006 Request	Unappro-priated Balances
06-SC-02 PED, BNL, Electron Beam Ion Source	3,500[b]	0	0	0	2,000	1,500

[a] At BNL, Accelerator Improvement Funds are redirected to start the Electron Beam Ion Source Project.
[b] The full Total Estimated Cost (design and construction) ranges between $12,000,000 and $17,500,000; and the full Total Project Cost (design and construction) ranges between $16,000,000 and $19,500,000. These estimates are based on preliminary data and should not be construed as a project baseline.

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 2004	FY 2005	FY 2006	Accept-ance Date
STAR EM Calorimeter Enhancement	4,830	4,830	2,750	2,080	0	0	FY 2005
STAR Time-of-Flight	4,800	4,800[a]	0	0	0	2,400	FY 2008
GRETINA gamma-ray detector	18,200	17,000[b]	0	1,000	2,500	3,000	FY 2010
Fundamental Neutron Physics Beamline at Spallation Neutron Source	9,300	9,200[c]	0	1,000	1,200	1,900	FY 2010
Total, Major Items of Equipment				4,080	3,700	7,300	

[a] The total estimated cost is preliminary and will be baselined at a Technical, Cost and Schedule Review.
[b] The preliminary TEC was refined in the conceptual design effort and has increased by $2 million to $17 million during FY 2004, still within the $13 to $18 million 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 is planned for May 2005. CD-2 for the project as a whole is planned for July 2007.
[c] The preliminary TEC of $9.2 million is within the $8 to $11 million range approved at CD-0 and has been baselined at CD-2.