Nuclear Physics

Program Mission

The mission of the Nuclear Physics 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 manpower 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.

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 benefit, especially to medicine, emerged from these efforts. But today, nuclear science is much more than this. Today, its reach extends from the quarks and gluons that form the substructure of the once-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. The field is driven by the following broad questions as stated recently by the Nuclear Sciences Advisory Committee 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 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 Super-Symmetry to the Standard Model. Precision experiments by nuclear physicists 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.

Advisory and Consultative Activities:

To ensure that resources are allocated to the most scientifically promising research, the Department of Energy 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 manpower that underpin the Department's missions in national security, energy, and environmental quality.

The ***Nuclear Sciences Advisory Committee*** (NSAC) provides advice to the Department of Energy and the National Science Foundation on a continuing basis regarding the direction and management of the national basic nuclear sciences research program. In FY 2002, 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 of the operations of individual university and national laboratory facilities to assess their scientific productivity, major components of the Division's research program, and evaluates the scientific case for new facilities. 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 comprise members mostly external to the host lab who are appointed by the director. PACs review research proposals requesting time at the facilities and technical resources; they provide advice on a proposal's scientific merit, technical feasibility, and manpower requirements. The PAC also provides a recommendation for the proposal to be approved, conditionally approved, deferred, or rejected.

Facility Operations Reviews:

The Nuclear Physics program has undertaken a series of operations reviews of its two largest national user facilities: Relativistic Heavy Ion Collider (RHIC) and Continuous Electron Beam Accelerator Facility (CEBAF). Conducted by the Office of Science'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 Division has also conducted an operations review of the Holifield Radioactive Ion Beam Facility (HRIBF) using similar external experts. Annual reviews of the RHIC and CEBAF programs with external reviewers are conducted to access the performance and scientific productivity of the facility.

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. In 1998, the Medium Energy program was reviewed. In 2001, the Low Energy program was reviewed. Results of these reviews are discussed later in the context of the requests for the Medium Energy and Low Energy physics programs. Continuing the cycle of reviews, it is planned that the Theory and Heavy Ion programs will be reviewed. Quality and productivity of university grants and laboratory groups performing research are peer reviewed on an approximately three-year basis.

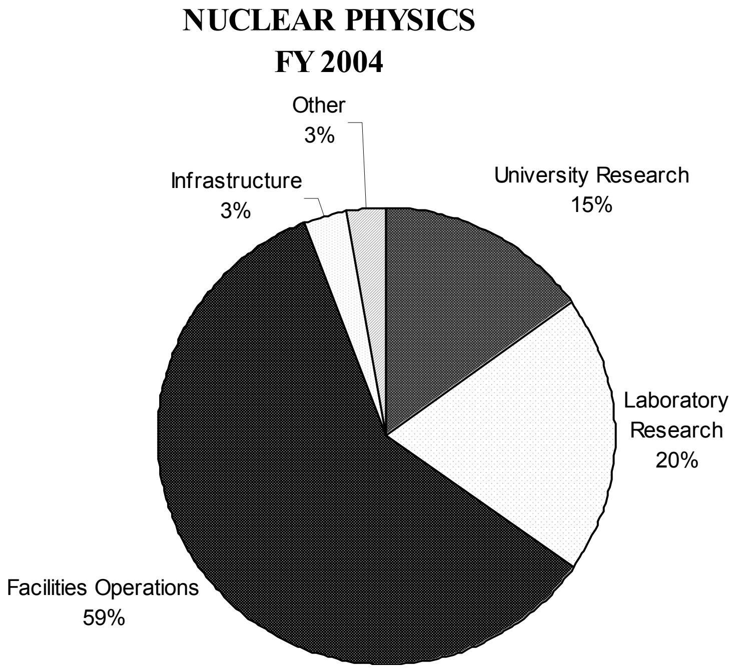
Planning and Priority Setting:

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 5-6 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 has identified increased support for the operations of the recently completed facilities as one of the highest priorities for DOE's Nuclear Physics program, as well as increased support for Nuclear Theory and computation. In the President's FY 2004 budget, funding supports operations at the newer major nuclear physics scientific user facilities. Operations are terminated at the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory as a nuclear physics user facility in order to provide enhanced support for the remaining Low Energy user facilities and to make investments in instruments and to enhance capabilities. Theory support is enhanced and experimental research efforts are maintained at FY 2003 levels to collect and analyze data, at the operating facilities. The long-range plan also identifies the Rare Isotope Accelerator (RIA) as the highest priority for major new construction; the President's FY 2004 budget requests continuing funding of $3.5 million for RIA R&D.

How We Spend Our Budget:

The Nuclear Physics budget has three major components: research, facility operations and experimental support, and construction and laboratory infrastructure support. The FY 2004 budget request is focused on optimizing the utilization of its major user facilities and increasing the support for Nuclear Theory. Facility operations are provided a 1.1% increase in funding in FY 2004 that will result in a 5% increase in beam hours for research compared to FY 2003. With the completion of RHIC construction in FY 1999, no major nuclear physics projects are under construction.

Research:



Over one-third of the program's funding was 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) is increased about 4.2% compared to FY 2003, providing a small restoration to the recent erosion of effort. 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. During FY 2002, 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 five 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. Typically about 90 Ph.D. degrees are 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 labs in such diverse areas as nuclear medicine, medical physics, space exploration, and national security.

  The university grants program is proposal driven, in much the same way as is the nuclear physics program at the NSF. 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, 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 collaborate with academic users of the facilities and 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. Proposals are reviewed by external scientific peers and awarded according to a modified version of the 10 CFR 605 guidelines used for the grants program. 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 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 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; the Nuclear Theory subprogram provides the fundamental theories, models and computational techniques to address these science topics.

Program Strategic Performance Goals

SC2-1: Manage a productive and sustainable program that provides world-class research results in the scientific disciplines encompassed by the Nuclear Physics mission areas cognizant of DOE needs as well as the needs of the broad scientific community. (Medium Energy Nuclear Physics, Heavy Ion Nuclear Physics, Low Energy Nuclear Physics and Nuclear Theory subprograms)

Performance Indicators

Validation of results by merit review with external peer evaluation; validation of program directions by Nuclear Science Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
		At least 80% of all new research projects will be peer reviewed and deemed excellent (of highest quality) and relevant, and annually 30% of all ongoing projects will be subject to peer review with merit evaluation. (SC2-1-1) Respond to priorities and recommendations for the DOE Nuclear Physics program in the 2002 Nuclear Science Advisory Committee Long Range Plan: • increase support for research and operations in order to exploit the opportunities made possible by recent investments at the new and upgraded facilities, for university research and infrastructure, and for nuclear theory; • maintain support for R&D activities to prepare for the future construction of the possible major new facility, the Rare Isotope Accelerator (RIA); • maintain R&D funding and prepare for the upgrade of the Continuous Electron Beam Accelerator Facility at Jefferson Lab to 12 GeV. (SC2-1-2)

SC7-2: Manage all Nuclear Physics facility operations and construction to the highest standards of overall performance, using merit evaluation with independent peer review. (Medium Energy Nuclear Physics, Heavy Ion Nuclear Physics, and Low Energy Nuclear Physics subprograms)

Performance Indicators

Percent on time/on budget; percent unscheduled downtime.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
Maintain and operate Nuclear Physics scientific user facilities so the unscheduled operational downtime will be kept to less than 20%, on average, of total scheduled operating time. (SC7-2-1) [Met Goal]	Maintain and operate Nuclear Physics scientific user facilities so the unscheduled operational downtime will be kept to less than 20%, on average, of total scheduled operating time. (SC7-2-1)	Maintain and operate Nuclear Physics scientific user facilities so the unscheduled operational downtime will be kept to less than 20%, on average, of total scheduled operating time. (SC7-2-1)

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
		Conduct annual reviews of the Thomas Jefferson National Accelerator Facility and the Relativistic Heavy Ion Collider facility; use results of reviews to identify areas where increased efficiency and scientific productivity can be obtained. (SC7-2-2)
Complete Helium Storage addition and liquid nitrogen standby cooling system at RHIC leading to better cost effectiveness ($0.5M savings) and operational efficiency (10% increase). (SC7-2-3)	Upgrade the RHIC cryogenics system by replacing turbine oil skids and removing seal gas compressor, eliminating a single point failure. (SC7-2-3)	
Meet the cost and schedule milestones for the PHENIX Muon Arm Instrumentation (Major Item of Equipment) within 10% of baseline estimates. (SC7-2-4) [Met Goal]	Meet the cost and schedule milestones for the construction of facilities and Major Items of Equipment within 10% of baseline estimates. Complete the Solenoidal Tracker at RHIC (STAR) Electro-Magnetic Calorimeter (EMCAL). (SC7-2-4)	Fabrication of the STAR EMCAL Enhancement, the Fundamental Neutron Physics Beamline at the Spallation Neutron Source, and the Gamma-Ray Energy-Tracking In-beam Nuclear Array (GRETINA) (Major Items of Equipment) will not exceed 10% of cost and schedule baseline estimates. (SC7-2-4)

Program Assessment Rating Tool (PART) Assessment

The Nuclear Physics program was evaluated with the OMB Program Assessment Rating Tool (PART). It was found that, "The program received a perfect score in the purpose section and a high score in the management section, mainly as a result of standard management practices within the Office of Science that lead the Nuclear Physics program to have a well defined mission, merit-based reviews for awarding contracts and grants, and highly-regarded large project management practices. The primary cause for the lower scores for planning and results is the program's current lack of adequate long-term and annual performance measures. Nevertheless, the program has made significant strides toward developing such measures despite the problems inherent in measuring and then predicting scientific progress." Other findings include, "The program is well-managed with a strong focus on training nuclear scientists and utilizing existing facilities in order to maximize scientific results," and, "The program coordinates its research strategy with the National Science Foundation through a jointly sponsored advisory committee (NSAC); however, the program does not yet have regular reviews of its research portfolio and processes by ad hoc panels composed of outside experts external to its advisory committee."

To address these findings, 1) The Nuclear Physics program will work with OMB to improve the performance goals and measures for the FY 2005 Budget request utilizing the Research and Development Investment Criteria developed by OMB; 2) Towards maximizing scientific productivity the FY 2004 Budget request provides funds to operate the program's user facilities at 83 percent of maximum capacity (compared with 80 percent in FY 2003 and 72 percent in FY 2002), while ceasing operations at one of its smaller user facilities; and 3) The Nuclear Physics program will institute a formal committee of visitors process by September, 2003.

Significant Program Shifts

In the FY 2004 budget request the scientific scope of the nation's nuclear physics program is maintained. The FY 2004 budget request terminates operations of one of the program's productive user facilities (the LBNL 88-Inch Cyclotron) in order to provide resources to optimize the utilization and science productivity of the remaining user facilities (BNL/RHIC, TJNAF/CEBAF, MIT/Bates Linear Accelerator Center, ANL/ATLAS, and ORNL/HRIBF). Facility operations at the remaining five facilities are provided a 2.7% increase in funding in FY 2004 that will result in a 29% increase in beam hours for research at these five facilities compared to FY 2003, (but only a 5% increase in beam hours overall because of the termination of the 88-Inch Cyclotron operation). The research programs at these 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 research is increased about 4.2% compared to FY 2003, maintaining approximately constant effort for experimental efforts and enhancing theory efforts. Support for theory groups at the National Laboratories has been increased significantly at BNL, TJNAF, and ANL, by reallocation of some experimental support funds. The necessity for this increased support was identified in the 2002 NSAC Long Range Plan and is critical for the interpretation of the extensive new data coming from RHIC and TJNAF. Recognizing the exciting developments in research at the interface of nuclear physics and astronomy, the program increases support for non-accelerator-based research in the Low Energy subprogram. Funding for capital equipment will address opportunities identified in the recently completed 2002 NSAC Long Range Plan, while R&D activities for RIA are kept constant.

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) activity is a set of coordinated investments across all Office of Science mission areas with the goal to achieve breakthrough scientific advances through computer simulation that were impossible using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. 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 product of this collaborative approach is a new generation of scientific simulation codes that can fully exploit terascale computing and networking resources. The program will bring simulation to a parity level with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate prediction, plasma physics, particle physics, astrophysics and computational chemistry.

Scientific Facilities Utilization

The Nuclear Physics request for FY 2004 supports the Department's scientific user facilities. In FY 2002 Nuclear Physics operated seven National User Facilities, which provide research time for scientists in universities and other Federal laboratories. In FY 2003 the program supports operations at:

- The Relativistic Heavy Ion Collider (RHIC) complex and the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory. (The AGS is not operating in FY 2003 and FY 2004 for Nuclear Physics.);
- 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;
- The Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory; and
- The 88-Inch Cyclotron at Lawrence Berkeley National Laboratory. (The 88-Inch Cyclotron terminates operation in FY 2004.)

These facilities provide beams for research for a user community of about 2,400 scientists. The FY 2004 President's Budget Request will support operations of five facilities that will provide ~21,760 hours of beams for research, an increase of ~5% over the anticipated beam hours in FY 2003.

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.

(hours)	FY 2000	FY 2001	FY 2002	FY 2003 Request	FY 2004 Request
Number of Facilities	7	7	7	6	5
Maximum Hours	31,500	31,600	31,600	32,275	26,260
Planned Operating Hours	23,150	20,285	17,510	20,700	21,760
Achieved Operating Hours	19,365	24,575	26,750	–	–
Unscheduled Downtime – Major user facilities	18%	18%	13%	–	–
Number of Users*	2,976	3,020	2,440	2,355	2,230

* Due to use of multiple facilities some users may be multiple counted.

In FY 2002, the achieved operating hours have well exceeded the planned operating hours for several reasons: increased operation of the Alternate Gradient Synchrotron for the Medium Energy program in order to finish experiments prior to termination of operations for this program, doubling the running hours of the MIT/Bates Electron Linear Accelerator to allow completion of the SAMPLE experiment prior to shutdown of this facility, and significantly increased operation of Low Energy facilities to take advantage of scientific opportunities by deferring maintenance.

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. Earned-value tracking is not maintained for MIE projects under $20,000,000; however, quarterly progress reviews are used to help ensure that projects remain on track.

Construction and Infrastructure:

Funding for capital equipment is reduced by ~5% compared to FY 2003 and R&D activities directed at RIA are kept constant. The Nuclear Physics program as part of its responsibilities as the landlord for Brookhaven National Laboratory and Thomas Jefferson National Accelerator Facility (TJNAF) provides funding for general plant projects (GPP) to both sites and general purpose equipment (GPE) to BNL only.

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 ~5 new awards each year, has been very successful in identifying, recognizing, and supporting promising young faculty. About 800 postdoctoral research associates and graduate students supported by the Nuclear Physics program in FY 2002 were involved in a large variety of experimental and theoretical research projects. About one quarter 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. The FY 2004 funding level will support approximately the same number of postdoctoral research associates and graduate students as supported in FY 2003. Details of the DOE nuclear physics human capital are given below. In FY 2002 there were about 302 faculty researchers supported at the universities (~1.7 per grant), with an average award of ~$183,000 per faculty researcher. Almost all grants have a duration of three years.

	FY 2000	FY 2001	FY 2002	FY 2003, est.	FY 2004, est.
# University Grants*	171	180	181	185	185
Average size (excl. CE)	$314,000	$310,000	$306,000	$294,000	$307,000
# Lab groups	27	28	28	28	28
# Permanent Ph.D.'s	676	683	702	700	700
# Postdocs	363	362	364	360	360
# Graduate students	408	408	442	440	440
# Ph.D.'s awarded	87	67	100	~90	~90

*Tasks in multitask grants to university laboratories are counted separately.

Funding Profile

(dollars in thousands)

	FY 2002 Comparable Appropriation	FY 2003 Request	FY 2004 Request	$ Change	% Change
Nuclear Physics					
Medium Energy Nuclear Physics	111,218	123,590	124,198	+608	+0.5%
Heavy Ion Nuclear Physics	151,273	167,977	167,805	-172	-0.1%
Low Energy Nuclear Physics	62,769	66,158	69,289	+3,131	+4.7%
Nuclear Theory	25,329	24,645	28,138	+3,493	+14.2%
Total, Nuclear Physics	350,589 [a] [b]	382,370	389,430	+7,060	+1.8%

Public Law Authorization:

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

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

[a] Excludes $7,777,000 that has been transferred to the SBIR program and $467,000 that has been transferred to the STTR program.

[b] Excludes $202,000 for the FY 2002 rescission contained in Section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to Terrorist attacks on the United States.

Funding by Site [a]

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	9,652	9,123	9,104	-19	-0.2%
Chicago Operations Office					
Argonne National Laboratory	18,453	17,548	18,709	+1,161	+6.6%
Brookhaven National Laboratory	140,108	149,004	149,588	+584	+0.4%
Fermi National Accelerator Laboratory	231	0	0	0	--
Chicago Operations Office	53,029	52,111	52,655	+544	+1.0%
Total, Chicago Operations Office	211,821	218,663	220,952	+2,289	+1.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	19,943	18,615	15,840	-2,775	-14.9%
Lawrence Livermore National Laboratory	664	507	700	+193	+38.1%
Oakland Operations Office	16,682	16,278	16,258	-20	-0.1%
Total, Oakland Operations Office	37,289	35,400	32,798	-2,602	-7.4%
Oak Ridge Operations Office					
Oak Ridge Institute for Science & Education	607	189	194	+5	+2.6%
Oak Ridge National Laboratory	15,974	16,870	19,330	+2,460	+14.6%
Thomas Jefferson National Accelerator Facility	74,761	79,138	82,247	+3,109	+3.9%
Total, Oak Ridge Operations Office	91,342	96,197	101,771	+5,574	+5.8%
Richland Operations Office					
Pacific Northwest National Laboratory	20	0	0	0	--
Washington Headquarters	465	22,987	24,805	+1,818	+7.9%
Total, Nuclear Physics	350,589 [bc]	382,370	389,430	+7,060	+1.8%

[a] On December 20 2002, the National Nuclear Security Administration (NNSA) disestablished the Albuquerque, Oakland, and Nevada Operations Offices, renamed existing area offices as site offices, established a new Nevada Site Office, and established a single NNSA Service Center to be located in Albuquerque. Other aspects of the NNSA organizational changes will be phased in and consolidation of the Service Center in Albuquerque will be completed by September 30, 2004. For budget display purposes, DOE is displaying non-NNSA budgets by site in the traditional pre-NNSA organizational format.

[b] Excludes $7,777,000 that has been transferred to the SBIR program and $467,000 that has been transferred to the STTR program.

[c] Excludes $202,000 for the FY 2002 rescission contained in Section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to Terrorist attacks on the United States.

Site Description

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. The major Nuclear Physics program activity at ANL supported by the Low Energy subprogram is the operation and research program at the ATLAS national user facility. Other activities include: (1) a Medium Energy group which carries out a program of research at TJNAF, Fermilab, RHIC and DESY in Germany; (2) R&D directed towards the possible Rare Isotope Accelerator (RIA) facility; (3) a Nuclear Theory group, which carries out theoretical calculations and investigations in subjects supporting the experimental research programs in Medium Energy and Low Energy physics; and (4) data compilation and evaluation activities as part of the National Nuclear Data Program.

The **Argonne Tandem Linac Accelerator System (ATLAS)** facility provides variable energy, precision beams of stable ions from protons through uranium, at energies near the Coulomb barrier (up to 10 MeV per nucleon) using a superconducting linear accelerator. Most work is performed with stable heavy-ion beams; however, about 6% of the beams are exotic (radioactive) beams. The ATLAS facility features a wide array of experimental instrumentation, including a world-leading ion-trap apparatus. The Gammasphere detector, which ATLAS shares on a rotating basis with the LBNL 88-Inch Cyclotron, coupled with the Fragment Mass Analyzer is a unique world facility for measurement of nuclei at the limits of angular momentum (high-spin states). ATLAS is a world leader in superconducting linear accelerator technology, with particular application to the possible Rare Isotope Accelerator (RIA) facility. The combination of versatile beams and powerful instruments enables the ~230 users annually at ATLAS to conduct research in a broad program in nuclear structure and dynamics, nuclear astrophysics, and fundamental interaction studies.

Brookhaven National Laboratory (BNL)

Brookhaven National Laboratory is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The major Nuclear Physics program effort at BNL, supported by the Heavy Ion subprogram, is the operation and research program of the new Relativistic Heavy Ion Collider (RHIC). Other activities include (1) a Medium Energy group that uses polarized protons in RHIC to understand the internal "spin" structure of the protons, (2) the Laser Electron Gamma Source (LEGS) group, supported by the Medium Energy subprogram, that uses a unique polarized photon beam to carry out a program of photonuclear spin physics at the National Synchrotron Light Source (NSLS), (3) a Nuclear Theory group that does research primarily in the area of relativistic heavy ion physics, (4) a Low Energy group that plays an important role in the research program at the Sudbury Neutrino Observatory (SNO) that is measuring the solar neutrino flux, and (5) the DOE managed National Nuclear Data Center (NNDC) that is the central U.S. site for national and international nuclear data and compilation efforts.

The Relativistic Heavy Ion Collider (RHIC) Facility, completed in 1999, is a major new and unique international facility used by about 1,100 scientists from 19 countries. RHIC uses the Tandem Van de Graaff, Booster Synchrotron, and Alternating Gradient Synchrotron (AGS) accelerators in combination to inject beams into two rings of superconducting magnets of almost 4 km circumference with 6 intersection regions where the beams collide. It can accelerate and collide a variety of heavy ions, including gold beams, up to an energy of 100 GeV per nucleon. RHIC will search for the predicted "quark-gluon plasma," a form of nuclear matter thought to have existed microseconds after the "Big

Bang." Operations began in FY 2000 and first results have already been published. RHIC can also accelerate and collide polarized protons at energies up to 250 GeV for a research program directed at understanding the quark structure of the proton. Four detectors have been fabricated to provide complementary measurements, but with some overlap in order to cross-calibrate the measurements: (1) The core of the Solenoidal Tracker At RHIC (STAR) detector, built at a cost of ~$80,000,000, is a large Time Projection Chamber (TPC) located inside a solenoidal magnet that tracks thousands of charged particles emanating from a single head-on gold-gold collision. A large modular barrel Electro-Magnetic Calorimeter (EMCal), being fabricated with completion in FY 2003, measures deposited energy for high-energy charged and neutral particles and contains particle-photon discrimination capability. An enhancement to this calorimeter is underway for the RHIC Spin program, with completion in FY 2004. An end-cap Calorimeter, also for the RHIC Spin program, is being funded by the NSF (TEC~$6,910,000; completion in FY 2004). A Silicon Vertex Tracker has very high tracking resolution for charged particles close to the collision vertex that greatly increases the tracking capabilities for the very short-lived multi-strange particles. (2) The Pioneering High-Energy Nuclear Interacting eXperiment (PHENIX) detector, built at a cost of ~$87,000,000, has a particular focus on the measurement of rarer probes at high event detection rate. It consists of two transverse smaller acceptance spectrometer arms that can track charged particles within a magnetic field especially to higher momentum; it provides excellent discrimination among photons, electrons, and hadrons. A Silicon Multiplicity Vertex Detector is used to locate the precise location of the collision point (different for each event), essential for measurement of the particle momenta with the spectrometer arms. There are also two large muon tracking and identification systems in the forward and backward directions. (3) The PHOBOS detector, built at a cost of ~$7,600,000, is a very compact detector that uses mostly silicon pad sensors for charged particle detection and tracking, with a focus on measurements to very low momentum. It consists of two small-acceptance tracking arms located within a magnetic field and a very large coverage multiplicity detector that measures the total event charged-particle multiplicity and distribution. (4) The Broad Range Hadron Magnetic Spectrometer (BRAHMS) built at a cost of ~$6,200,000, has two very small acceptance magnetic spectrometer arms that can be rotated to scan the broadest range of angles. It is especially designed to study the charged particle distributions in the forward and backward directions. Significant contributions (~$60,000,000) have been made by foreign institutions to these RHIC detectors and to implement the polarized proton capability.

The **Alternating Gradient Synchrotron (AGS)** provides high intensity pulsed proton beams up to 33 GeV on fixed targets and secondary beams of kaons, muons, pions, and anti-protons. The AGS is the injector of (polarized) proton and heavy-ion beams into RHIC, and its operations are supported by the Heavy Ion subprogram as part of the RHIC facility. Operation of the AGS for fixed targets and secondary beams for medium energy physics experiments is terminating in FY 2003; however, the AGS will still be utilized to produce beams for tests of proton radiography for NNSA and for radiation damage studies to electronic systems for NASA supported work, among a variety of uses, with the support for these activities being provided by the relevant agencies.

The **Booster** Synchrotron, part of the RHIC injector, will provide heavy-ion beams to a dedicated beam line (Booster Application Facility, TPC~$33,900,000) for biological and electronic systems radiation studies funded by NASA as a Work-for-Others project to be completed in FY 2003. Upon completion operational costs will be supported by NASA.

The **National Nuclear Data Center (NNDC)** is the central U.S. site for national and international nuclear data and compilation efforts. The U.S. Nuclear Data program is the United States repository for information generated in low- and intermediate-energy nuclear physics research worldwide. This information consists of both bibliographic and numeric data. The NNDC is a resource that maintains the U.S. expertise in low- and intermediate-energy nuclear physics by providing evaluated nuclear data for the user community. The NNDC is assisted in carrying out this responsibility by other Nuclear Data program funded scientists at U.S. National Laboratories and universities.

Lawrence Berkeley National Laboratory (LBNL)

Lawrence Berkeley National Laboratory is a Multiprogram Laboratory located in Berkeley, California. The laboratory is on a 200 acre site adjacent to the Berkeley campus of the University of California. A major Nuclear Physics effort at LBNL, supported by the Low Energy (LE) subprogram, has been the operations and the research program of the 88-Inch Cyclotron, a national user facility. A major activity of this Low Energy group is the development of a next-generation gamma-ray detector system. Other activities include (1) a Relativistic Nuclear Collisions group, with activities primarily at RHIC, where the group has been a major player in the development of the STAR detector; (2) a Low Energy group which has a major role in the implementation and operation of the Sudbury Neutrino Observatory (SNO) detector in Canada and the KamLAND detector in Japan that are performing neutrino studies; (3) a Nuclear Theory group that carries out a program with emphasis on the theory of relativistic heavy ion physics; (4) a Nuclear Data group whose activities support the National Nuclear Data Center at BNL; and (5) a technical effort involved in RIA R&D.

The **88-Inch Cyclotron** facility provides high intensity stable beams from protons to bismuth at energies above the Coulomb barrier (up to 15 MeV per nucleon). The electron-cyclotron resonance (ECR) ion sources at the facility are state-of-the-art and copied around the world. The Gammasphere array, widely regarded as the world's most powerful gamma-ray detector, is used to study nuclei at the extremes of angular momentum and excitation energy. The Berkeley Gas-filled Separator, a world-class instrument, is used for discovery experiments in superheavy elements. The 88-Inch Cyclotron is used annually by a community of about 230 scientists. Operation of the 88-Inch Cyclotron as a Nuclear Physics user facility will be terminated in FY 2004.

Lawrence Livermore National Laboratory (LLNL)

Lawrence Livermore National Laboratory is a Multiprogram Laboratory located on an 821 acre site in Livermore, California. Nuclear Physics supports research in nuclear structure studies, in relativistic heavy ion experiments as part of the PHENIX collaboration, for nuclear data and compilation activities, and for a technical effort involved in RIA R&D.

Los Alamos National Laboratory (LANL)

Los Alamos National Laboratory is a Multiprogram Laboratory located on a 27,000 acre site in Los Alamos, New Mexico. Nuclear Physics supports a broad program of research including: (1) a program of neutron beam research that utilizes beams from the LANSCE facility; (2) a relativistic heavy ion effort using the PHENIX detector at the new Relativistic Heavy Ion Collider (RHIC); (3) research directed at the study of the quark substructure of the nucleon in experiments at Fermilab, and at the "spin" structure of nucleons at RHIC using polarized proton beams; (4) the development of the Sudbury Neutrino Observatory (SNO) detector as well as involvement in the SNO and MiniBoone research programs; (5) a broad program of theoretical research into a number of topics in nuclear physics; (6) nuclear data and compilation activities as part of the national nuclear data program; and (7) a technical effort involved in RIA R&D.

Oak Ridge Institute for Science and Education (ORISE)

Oak Ridge Institute for Science and Education is located on a 150 acre site in Oak Ridge, Tennessee. Nuclear Physics support is provided through ORISE for activities in support of the Holifield Radioactive Ion Beam Facility (HRIBF) and its research program.

Oak Ridge National Laboratory (ORNL)

Oak Ridge National Laboratory is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The major effort at ORNL is the Low Energy program support for research and operations of the Holifield Radioactive Ion Beam Facility (HRIBF) that is operated as a national user facility. Also supported is (1) a relativistic heavy ion group that is involved in a research program using the PHENIX detector at RHIC; (2) a theoretical nuclear physics effort at ORNL that emphasizes investigations of nuclear structure and astrophysics; (3) nuclear data and compilation activities that support the national nuclear data effort; and (4) a technical effort involved in RIA R&D.

The **Holifield Radioactive Ion Beam Facility (HRIBF)** is the only radioactive nuclear beam facility in the U.S. to use the isotope separator on-line (ISOL) method and is used annually by about 100 scientists. It provides a wide range of both proton-rich and neutron-rich nuclei to a suite of instruments designed for studies in nuclear structure, dynamics and astrophysics using radioactive beams. The HRIBF accelerates secondary radioactive beams to higher energies (up to 10 MeV per nucleon) than any other facility in the world with such a broad selection of ions. The HRIBF conducts R&D on ion sources and low energy ion transport for radioactive beams.

Thomas Jefferson National Accelerator Facility (TJNAF)

Thomas Jefferson National Accelerator Facility (TJNAF) is a laboratory operated by the Nuclear Physics program located on 162 acres in Newport News, Virginia. Constructed over the period FY 1987-1995 at a cost of $513,000,000, TJNAF began operations in FY 1995. Support for the research and operations of TJNAF are provided by the Medium Energy subprogram. The centerpiece of TJNAF is the **Continuous Electron Beam Accelerator Facility (CEBAF)**, a unique international electron-beam user facility for the investigation of nuclear and nucleon structure based on the underlying quark substructure that has a user community of ~1200 researchers and is used annually by ~700 U.S. and foreign researchers. CEBAF consists of two multi-pass, superconducting linear accelerators connected by recirculating magnetic arcs. Polarized and unpolarized electron beams up to 5.7 GeV can be provided by CEBAF simultaneously to 3 different experimental halls, Halls A, B, and C. Hall A is designed for spectroscopy and few-body measurements. There are two high-resolution spectrometers, one for detection of the scattered electron from the beam and another for detection of the scattered particle. Hall B has a large acceptance detector, CLAS, for detecting multiple charged particles coming from a scattering reaction. Hall C is designed for flexibility to incorporate a wide variety of different experiments. Its core equipment consists of two medium resolution spectrometers for detecting high momentum or unstable particles. A large variety of major instruments are available for studying the scattering of and particle production from the electrons with fixed gas and solid targets. Fabrication of the G0 detector, a joint NSF-DOE project in Hall C that will allow a detailed mapping of the strange quark contribution to nucleon structure, was completed during FY 2002. Support is also provided by the nuclear theory subprogram for a group whose program of investigations supports the experimental program of the laboratory. An accelerator R&D group is supported for projects important to the Nuclear Physics program (e.g., the proposed 12 GeV upgrade of CEBAF, and R&D for RIA). The proposed upgrade to

CEBAF is one of the highest priority recommendations in the recently completed 2002 NSAC Long Range Plan for Nuclear Science.

All Other Sites

The Nuclear Physics program funds 181 research grants at 85 colleges/universities located in 35 states. Among these is a cooperative agreement with the Massachusetts Institute of Technology (MIT) for the operation of the ***Bates Linear Accelerator Center*** as a national user facility used by about 110 scientists. The Bates facility, with electron beams up to 1 GeV, conducts experiments to study the properties and constituents of protons and light nuclei at energies below those of CEBAF. The research program probes the properties of the proton such as its shape and polarizability, and the charge distribution and magnetism of the deuteron. A major instrument for making these measurements is the Bates Large Acceptance Spectrometer Toroid (BLAST) detector, whose fabrication was completed in FY 2001, underwent commissioning in FY 2002, and will begin its research program in FY 2003. BLAST will be used to observe collisions of polarized electrons in thin polarized gas targets located in the South Hall Pulse Stretcher Ring. The Bates experimental program is planned to terminate in 2005 with the completion of the BLAST program.

Grants for the operation of accelerator facilities at four university laboratories are supported by the Low Energy subprogram for research in selected and specialized areas conducted primarily by the in-house faculty members and students. The ***Triangle Universities Nuclear Laboratory (TUNL)*** utilizes a tandem Van de Graaff and polarized beams and targets to test and refine the theory of the nuclear force and its currents. A suite of instrumentation has been built up to take advantage of this unique combination of capabilities and to study fundamental symmetries and reactions important to nuclear astrophysics. A new facility for producing intense photon beams using a free-electron laser (High Intensity Gamma Source) for studying photonuclear processes is just beginning its experimental program. ***The Texas A&M (TAMU) Cyclotron Institute*** operates a superconducting cyclotron to deliver a wide range of stable and selected radioactive beams for medium energy heavy-ion reaction studies, tests of fundamental constants of the standard model, and nuclear astrophysics. Modern instrumentation takes advantage of the heavy-ion beams, and a number of foreign collaborators use the facility. ***The Yale Tandem Van de Graaff*** provides a variety of stable beams for an extensive suite of instruments that, along with the opportunity for extended running times, provides the capability for detailed experiments on symmetry, collective structures, and evolution of properties in nuclei and nuclear astrophysics. The ***University of Washington Tandem Van de Graaff*** provides precisely characterized proton beams for extended running periods for research in fundamental nuclear interactions and nuclear astrophysics. These four accelerator facilities offer niche capabilities and opportunities not available at the national user facilities, or many foreign low-energy laboratories, such as specialized sources and targets, opportunities for extended experiments, and specialized instrumentation. These facilities operate in a university environment and thus provide a unique setting for the training and education of graduate students in the U.S., where they have the opportunity to be involved in all aspects of low energy nuclear research. These centers of excellence have in the past and continue today to produce the next generation of national leaders in nuclear science research.

The ***Institute for Nuclear Theory (INT)*** at the University of Washington is the premier international center for new initiatives and collaborations in nuclear theory research. Established in 1990, the INT conducts three programs each year on topics identified by an international advisory committee. U.S. and foreign researchers spend varying lengths of time at the Institute during the 2-3 month period of each program to establish collaborations and carry out projects. The institute also supports several workshops per year, some of which are hosted on-site. Currently, approximately 350 physicists visit the Institute per year, with an average stay of 3.5 weeks. Of these, approximately 20% are experimentalists, indicating the broad influence of the INT on nuclear physics research. About one-third of the attendees come from abroad, demonstrating the international stature of the Institute and its world leadership.

There are several major impacts of the INT operations. The first is that it fosters collaboration among researchers. These collaborative efforts, often multidisciplinary in nature, would not arise without the opportunity to spend an extended time focusing on specialty topics in an intellectually stimulating environment. A second major impact is the training of young people. Of the postdoctoral researchers who have been associated with the Institute over the last seven years, seven are now in academic positions and three more have staff positions at national laboratories. There are additional faculty, postdocs, and students in the local University of Washington nuclear theory group who synergistically interact with the INT activities, providing additional student and postdoctoral training. The third major impact is the work of the research group associated with the INT. The senior members of this group have a significant international stature and play a scientific leadership role both in their research work and in activities serving the scientific community.

Medium Energy Nuclear Physics

Mission Supporting Goals and Measures

The Medium Energy Nuclear Physics subprogram supports fundamental research directed primarily at answering the first of the five broad 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 Chromo-Dynamics (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.

To achieve the experimental description, the Medium Energy program 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 the basic components.

Most of this work is done at this subprogram’s primary research facility, Thomas Jefferson National Accelerator Facility (TJNAF), but the program also supports research at the MIT/Bates Linear Accelerator Center and the Relativistic Heavy Ion Collider at Brookhaven National Laboratory. Individual experiments are supported at the National Synchrotron Light Source at Brookhaven, the High Intensity Gamma Source at Triangle University Nuclear Laboratory, Fermilab, and at several facilities in Europe. All these facilities produce beams of sufficient energy (small enough wavelength) that they can probe at a scale within the size of a nucleon.

The operations of the two national user facilities, TJNAF and MIT/Bates, supported by Medium Energy Nuclear Physics, serve a nationwide community of about 300 Department of Energy and about 300 National Science Foundation supported scientists and students from over 140 American institutions, of which over 80% are colleges and universities. At both TJNAF and Bates, the National Science Foundation (NSF) has made a major contribution to new experimental apparatus in support of the large number of NSF users. A significant number of foreign scientists collaborate in the research programs of both facilities. The research program at the TJNAF, for example, involves about 300 scientists per year from 19 foreign countries; many of these scientists are from European Center for Nuclear Research (CERN) member states. At TJNAF foreign collaborators have made significant investment in experimental equipment. Allocation of beam time at both Bates and TJNAF are based on guidance from Program Advisory Committees that review and evaluate proposed experiments regarding their merit and scientific priority.

The DOE Nuclear Physics program has made important discoveries in the past decade. The assembly of a large set of precision nucleon-nucleon scattering data has provided critical input for theoretical models that now produce a significantly more quantitative description of nuclei, now 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 recent long-range plan singled out three significant achievements of the Medium Energy program 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 particles of quark-antiquark pairs called pions play as important a role inside the nucleon (via the virtual "sea" of quarks) as they do in theories of the nuclear force.
- The discovery in a new high-resolution spatial map of the proton points to an unexpected depletion of charge near its center, a fact not yet explained by current models.

These discoveries have been further extended by these recent highlights:

- *New precision results on the charge distribution of the neutron will test different models of the quark structure of the neutron:* Although a neutron has no net charge, it does have an internal distribution of charge due to the charged quarks inside. The precise determination of this charge distribution has been a major goal of nuclear physics for many years. Two dedicated experiments at TJNAF have obtained precise, high-resolution data on this distribution providing, for the first time, strong constraints for quark models of the neutron.
- *Data from disintegration of the deuteron by photons show a transition from quark to hadronic degrees of freedom:* New data from TJNAF on the breakup of the deuteron using gamma rays provide evidence that with increasing spatial resolution (power of magnification) one can see how the deuteron evolves from looking like a proton and a neutron bound together to an assembly of six quarks (the proton and neutron each containing three quarks). This result is important for scientists trying to understand when the individual quarks become important in describing the properties of the deuteron, the simplest compound nucleus.
- *Role of the strange quark in the proton's spin:* It had been thought that the strange quark should provide a negative contribution to the proton's internal "spin," or rotational angular momentum, of about 10%. Recent results from HERMES indicate that the contribution is consistent with zero or perhaps slightly positive. The near zero result rejects the hypothesis that the negative contribution of the strange quarks to the proton's spin could explain why the contribution of the 3 core quarks' spin does not add up to the proton's overall spin value.

Facility and Technical Accomplishments:

- *Fabrication of the BLAST Detector at the MIT/Bates facility is complete*: In FY 2002 the BLAST detector began commissioning activities; a unique research program will be initiated in FY 2003 to study the structure of the nucleon and few-body nuclei.
- *Fabrication of the G0 Detector is complete*: At the Thomas Jefferson National Accelerator Facility (TJNAF) the G0 Detector is complete and initiated commissioning at the end of FY 2002. It utilizes

the very high intensity polarized electron beam developed at TJNAF in mapping out the strange quark contribution to nucleon structure over a wide kinematic range.

- *The MiniBooNE detector fabrication is completed and operations begin:* Running of this jointly supported high-energy and nuclear physics experiment at Fermilab began in FY 2002 to look for the disapperance of muon neutrinos in an attempt to confirm the earlier result of the LSND experiment's observation of the disapperance of muon anti-neutrinos. With the observation of electron neutrino oscillations by the SNO experiment, this experiment becomes important for determining whether or not 'sterile' or non-interacting neutrinos exist.
- *The first Hydrogen-Deuterium frozen spin target is successfully demonstrated by the LEGS collaboration:* The LEGS collaboration at Brookhaven National Laboratory has demonstrated for the first time that an "ice" target made of hydrogen and deuterium can be polarized and operated in a beam of photons. This development is important for experiments on the structure of the proton and neutron for such "ice" targets have significantly cleaner experimental signatures than conventional polarized targets.

Subprogram Goal

Determine the structure of nucleons in terms of bound states of quarks and gluons; measure the effects of this structure on the properties of atomic nuclei.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
As elements of the electron beam program, (a) complete commissioning of the BLAST detector at MIT/Bates and initiate first measurements, and (b) complete 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) collect first data with the BLAST detector at MIT/Bates, studying the structure of nucleons and few body nuclei and (b) collect 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.	At MIT/Bates complete high-priority experiments with BLAST studying structure of nucleons and few body nuclei. At Thomas Jefferson National Accelerator Facility perform experiments, analyze data, and/or publish results by carrying out a peer-reviewed and prioritized research program directed towards determining the structure of nucleons, including: • the first experiment to study new theoretical functions that describe the proton structure (Generalized Parton Distributions), • measurements of the form factor of the pion and of the charge distribution of the ^{4}He nucleus, and • measurements to complete the first phase of the study of the excited states of the nucleon.

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
Commission polarized protons at RHIC. [Met Goal]	Collect first data with polarized protons with the RHIC STAR, PHENIX and pp2pp detectors.	At the Brookhaven Relativistic Heavy Ion Collider, perform experiments, analyze data, and/or publish results by carrying out a peer-reviewed research program studying the internal structure of the proton, including: • asymmetry measurements of pion production in collisions of polarized protons at high energy.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Research					
University Research	15,670	15,575	15,432	-143	-0.9%
National Laboratory Research	14,554	16,815	15,708	-1,107	-6.6%
Other Research	315	5,405	5,405	0	0%
Subtotal, Research	30,539	37,795	36,545	-1,250	-3.3%
Operations					
TJNAF Operations	67,200	72,513	75,128	+2,615	+3.6%
Bates Operations	12,424	13,282	12,525	-757	-5.7%
Other Operations	1,055	0	0	0	0%
Subtotal, Operations	80,679	85,795	87,653	+1,858	+2.2%
Total, Medium Energy Nuclear Physics	111,218	123,590	124,198	+608	+0.5%

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
Research	**30,539**	**37,795**	**36,545**
▪ **University Research**	**15,670**	**15,575**	**15,432**

These activities comprise a broad program of research, and include support of about 165 scientists and 110 graduate students at 35 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 program, but also use other U.S. and foreign accelerator laboratories. Included in University Research is Bates Research, the effort performed at the MIT/Bates Linear Accelerator Center by MIT scientists. Other University Research includes all other university-based efforts using many research facilities, including activities by MIT scientists that are not carried out at Bates.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▸ **Bates Research**	**2,130**	**2,835**	**2,500**

MIT scientists along with other university researchers are beginning a new program of research, starting in FY 2003, to study the structure of the nucleon and the nature of the nucleon-nucleon force, utilizing the new Bates Large Acceptance Spectrometer Toroid (BLAST) detector and the South Hall Ring. Effort at Bates remains essentially constant.

▸ **Other University Research**	**13,540**	**12,740**	**12,932**

Most of the university research supports the activities associated with our main facilities at Bates, TJNAF and RHIC. At TJNAF the experiments are largely focused on the study of nucleon structure and its internal dynamics. Planned measurements in Hall A include the electric form factor of the neutron and the pion. The latter will provide new information to better understand the transition from the quark degrees of freedom to the hadronic degrees of freedom. Hall B will complete its initial experimental program on the excited states of the nucleon and focus on two new experiments, one to determine the half-life of the neutral pion and the other to explore a new technique called Deeply Virtual Compton Scattering (DVCS) for measuring quark structure functions called "Generalized Parton Distribution Functions". In Hall C, the G0 experiment, which will begin its experimental program in FY 2003, will allow a "complete mapping" of the strange quark content of the nucleon using parity-violation techniques.

A number of university groups are collaborating in experiments using the new BLAST detector and the South Hall Ring at the MIT/Bates Linear Accelerator Center. 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 presently carried out by the HERMES (HERa MEasurements with Spin) experiment at the DESY laboratory in Hamburg, Germany will be reduced as the RHIC-spin physics program grows.

In FY 2004 other university research funds are effectively increased by 2.3% compared to FY 2003 after correcting for shifts ($430,000) in grants in FY 2003 to the Theory and Low Energy subprograms. This will maintain an approximately constant effort for university research.

▪ **National Laboratory Research**	**14,554**	**16,815**	**15,708**

Included is: (1) the research supported at the Thomas Jefferson National Accelerator Facility (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**.**

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▸ **TJNAF Research**	**5,770**	**5,945**	**5,405**

Scientists at TJNAF, with support of the user community, assembled the large and complex new 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, and collaborate in research at other facilities. When a planned shift in FY 2003 of funds ($685,000) to the Theory Subprogram for enhanced theoretical effort at TJNAF is taken into account the FY 2004 funding provides a 2.8% increase from FY 2003.

As of FY 2002, Hall A will have completed 25 experiments and Hall C will have completed 17. The complex large-acceptance spectrometer in Hall B will have completed 65% of the data taking for 54 experiments. TJNAF researchers participate in all of these experiments.

TJNAF scientists are participating in the running of a new detector for the G0 experiment, in cooperation with the National Science Foundation. Beginning commissioning in FY 2002, the G0 detector will map out the contribution of the strange quark to the nucleon.

▸ **Other National Laboratory Research**	**8,784**	**10,870**	**10,303**

Support for research activities at accelerator and non-accelerator facilities at National Laboratories provides constant effort relative to FY 2003. These activities include:

- Argonne National Laboratory scientists will pursue research programs at TJNAF and at the DESY Laboratory in Germany. The theme running through this entire effort is the search for a detailed understanding of the internal quark-gluon structure of the nucleon. They have also made important advances in the technique of Atom Trap Trace Analysis to be used in measurements of rare isotopes for precision studies of nuclear structure and a new search for an electric dipole moment of the neutron.

- At Brookhaven National Laboratory, the Medium Energy Research group, which in previous years has concentrated on hadron beam experiments at the AGS, has changed its major emphasis to "RHIC Spin". This is the set of experiments planned for RHIC that will use colliding polarized proton beams to investigate the spin content of the nucleon and, in particular, the role of gluons. In FY 2003-2004, additional funding is being provided to this group to assure that appropriate scientific effort has been assembled in support of the RHIC Spin effort.

- Also at Brookhaven, Laser Electron Gamma Source (LEGS) scientists will be completing a new spectrometer and a recently developed polarized "ice" target for a program of spin physics at low energies. This unique facility produces polarized gamma-rays by back scattering laser light from the circulating electron beam at the National Synchrotron Light Source (NSLS).

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

- At Los Alamos National Laboratory, scientists and collaborators have developed 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. This experiment, the Mini Booster Neutrino Experiment (MiniBooNE), uses neutrinos generated from the Fermi National Accelerator Laboratory Booster proton beam; data collection began in FY 2002.

  Los Alamos scientists also are involved in experiments at Fermilab and at RHIC (RHIC Spin) that will probe the structure of the virtual quark "sea" of the nucleon and the gluonic contribution to its spin, respectively. 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.

	FY 2002	FY 2003	FY 2004
▪ **Other Research**..	**315**	**5,405**	**5,405**

In FY 2002 $4,219,000 was transferred to the SBIR program and $467,000 was transferred to the STTR program. This section includes $4,346,000 for SBIR and $510,000 for STTR in FY 2003 and $3,802,000 for SBIR and $1,048,000 for STTR in FY 2004 and other established obligations that the Medium Energy Nuclear Physics subprogram must meet.

	FY 2002	FY 2003	FY 2004
Operations	**80,679**	**85,795**	**87,653**
▪ **TJNAF Operations**..	**67,200**	**72,513**	**75,128**

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

	FY 2002	FY 2003	FY 2004
▸ **TJNAF Accelerator Operations**.................................	**43,040**	**46,413**	**48,753**

Funding for accelerator operations in FY 2004 supports a 4000 hour running schedule. In FY 2002, the accelerator routinely delivered beams of differing energies and currents simultaneously to the three experimental halls. This funding level provides approximately constant effort in operations.

	(hours of operation with beam)		
	FY 2002	FY 2003	FY 2004
TJNAF	3960	4200	4000

Funding of $1,000,000 is provided for R&D activities that include $500,000 for the proposed upgrade of CEBAF to 12 GeV. This upgrade is recommended as one of the highest priorities for Nuclear Physics in the 2002 NSAC Long Range Plan for Nuclear Science. AIP funding includes polarized injector and beam handling components as well as other additions and modifications to the accelerator facilities. GPP funding is increased by $20,000 from FY 2003 providing for minor new construction and utility systems.

	FY 2002	FY 2003	FY 2004
	(dollars in thousands)		
▸ **TJNAF Experimental Support**	**24,160**	**26,100**	**26,375**

Operating and equipment funding is provided for the experimental support needed to effectively carry out the TJNAF experimental program.

In FY 2004 support is maintained for the scientific and technical manpower, 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 and for cooling, radiation shielding, and special equipment for specific experiments. When a proposed shift in FY 2003 of funds ($315,000) for enhanced theoretical effort at TJNAF is taken into account, the FY 2004 funding level will provide a ~3% increase compared to FY 2003.

The G0 detector fabrication was completed in FY 2002. TJNAF is shifting their base capital equipment ($6,100,000) towards assembly and installation of ancillary equipment items such as polarized targets for experimental Halls A, B, 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.

▪ **Bates Operations**	**12,424**	**13,282**	**12,525**

Funding for operations of the MIT/Bates Linear Accelerator Center are provided in FY 2004 to complete the BLAST scientific program. Termination of Bates is planned for FY 2005. During FY 2004 an evaluation will be made of the options for disposition of this facility and equipment, and of the associated Decommissioning and Decontamination cost and schedule.

	(hours of operation with beam)		
	FY 2002	FY 2003	FY 2004
Bates	5560	2700	4000

▪ **Other Operations**	**1,055**	**0**	**0**

Operation of the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory for a limited fixed-target program in medium energy physics was funded in FY 2002. No funds are provided for operation of the AGS in FY 2003 or FY 2004.

Total, Medium Energy Nuclear Physics	**111,218**	**123,590**	**124,198**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Research	
▪ **University Research**	
▸ Funding maintains the MIT/Bates research effort focused on effective collection and analysis of BLAST data. The level of effort remains essentially constant at Bates.	-335
▸ The research support at Other Universities is increased by 1.5% from FY 2003. As a result of transfer ($430,000) in FY 2003 of grant activities to Theory and Low Energy subprograms, this funding provides an approximately constant level of effort that is focused on the TJNAF and RHIC spin-physics research programs.	+192
Total, University Research	-143
▪ **National Laboratory Research**	
▸ Funding for capital equipment decreases by $691,000 from FY 2003 as projects are completed. Funding research support decreases by $416,000. The FY 2004 funding level for research support is effectively a ~2.6% increase from FY 2003 when the proposed shift of operating funds (~$835,000) to the Theory subprogram for enhanced theoretical effort in FY 2003 is taken into account.	-1,107
Total Research	-1,250
Operations	
▪ **TJNAF Operations**	
▸ **TJNAF Accelerator Operations:** Funding for accelerator operations is increased by $1,520,000 (3.4%) relative to FY 2003 in order to provide a 4000 hour running schedule. While the increase provides for somewhat less operating hours, actual scientific productivity is expected to increase due to higher beam reliability resulting from the increased funding. Funding for R&D is increased from FY 2003 by $500,000 (to $1,000,000, with $500,000 provided for the proposed 12 GeV upgrade) to maintain needed accelerator R&D manpower. AIP/GPP is increased by $320,000 compared to FY 2003 to maintain accelerator/physical infrastructure.	+2,340
▸ **TJNAF Experimental Support:** The increase of $275,000 for Experimental Support is effectively a ~3.0% increase relative to FY 2003 (after accounting for the proposed shift in FY 2003 of $315,000 to the Theory subprogram) in order to provide an approximately constant effort for supporting the experimental program. Overall capital equipment funding ($6,100,000) remains the same as FY 2003.	+275
Total, TJNAF Operations	+2,615

	FY 2004 vs. FY 2003 ($000)
▪ **Bates Operations**	
▸ The funding for Bates operations is decreased from FY 2003 since FY 2004 will be the last year of running to complete the BLAST program. Operating funds are increased (+$818,000) and capital equipment and accelerator improvement projects (AIP) funds are decreased (-$1,575,000).	-757
Total Operations	+1,858
Total Funding Change, Medium Energy Nuclear Physics	+608

Heavy Ion Nuclear Physics

Mission Supporting Goals and Measures

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. At extremely high temperatures, however, 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 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. At much lower temperatures, nuclear matter passes through another phase transition from a Fermi liquid to a Fermi gas of free roaming nucleons; understanding this phase transition is also a goal of this program.

Historically, the study of hot and extremely dense hadronic matter became possible with the advent of gold beams at the Alternating Gradient Synchrotron in 1992 and lead beams at the CERN SPS in 1994, where the U.S. played a substantial role in major experiments. The "fireball" systems formed in these collisions equilibrated rapidly and at a high temperature and density, producing conditions that indicated that the new phase of nuclear matter, the predicted quark-gluon plasma, would likely be formed at the even higher energies that would be available with the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. First gold-gold collisions were observed at RHIC in 2000. The Heavy Ion research program, now almost exclusively performed at RHIC, is leading the world effort in creating and characterizing the quark-gluon plasma, a new form of matter that is thought to have existed shortly after the "Big Bang." Limited studies of the conditions for inducing the liquid-to-gas phase transitions in nuclear matter are also going on at the National Superconducting Cyclotron Laboratory (NSF funded) at Michigan State University, at Texas A&M University, and at foreign laboratories.

The Heavy Ion Nuclear Physics subprogram supports operation of the RHIC facility at Brookhaven National Laboratory. This is a unique world-class facility that addresses fundamental questions about the nature of nuclear matter. With it one can study collisions of heavy nuclei at energies over 10 times of that previously available at any other facility in the world, namely at CERN. The RHIC is also the only accelerator facility in the world that provides collisions of polarized protons with polarized protons. From these collisions, important and unique information can be obtained regarding the composition of the gluons that provide the binding of the quarks to make the nucleons, the protons and neutrons that make up the nucleus. The construction of RHIC was completed in August 1999, and first collisions were observed in June 2000. Two successful running periods have been completed, Run 1 in FY 2000 and Run 2 which spanned the end of FY 2001 and the beginning of FY 2002. The RHIC facility is utilized by over 1,100 DOE, NSF, and foreign supported researchers. capital equipment and accelerator improvement project (AIP) funds are provided for additions, modifications, and improvements to the various accelerators that make up the RHIC complex and to the ancillary experimental facilities, in order to maintain and improve the reliability and efficiency of operations, and to provide new experimental capabilities. The allocation of beam time at RHIC is made with the guidance of a Program Advisory Committee, consisting of distinguished scientists, that reviews and evaluates proposed experiments regarding their merit and scientific priority. An annual peer review of the effectiveness of RHIC operations and its research program is conducted by the program office; the recommendations from these reviews are used to improve RHIC operations.

The recent NSAC long-range plan identified several recent discoveries that support the goals of the Heavy Ion Program:

- Production of small regions of space with energy densities more than twenty times that of atomic nuclei. Matter under these extreme conditions is believed to be in the quark-gluon plasma phase.
- Observation of a strong "flow" of matter in relativistic heavy-ion collisions, that indicates 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 only pure energy, out of which the particles are produced.

These discoveries have been further extended by these recent highlights:

- *First lepton measurements – open charm:* First measurements of high-energy electrons at RHIC show that their yields are consistent with the electrons originating from decays of D-mesons, which contain a single heavy charm quark. The study of charmed quark production and the survival probability of J/ψ-mesons (consisting of a pair of charm and anti-charm quarks) in the hot collision zone is expected to be a critical signal for demonstrating that the quark-gluon plasma has been formed.
- *Observation of the liquid-gas phase transition in nuclear matter* – At low temperatures nuclear matter behaves like a quantum mechanical (Fermi) liquid, but it is expected that it will go through a phase transition (start to boil) when heated to sufficiently high temperatures and assume the characteristics of a (Fermi) gas. Recently, this long-predicted phase transition has been observed in experiments where gold nuclei are heated by absorbing anti-protons or pions from the AGS into gold nuclei. The results show that this phase transition occurs in nuclear matter at a temperature of 4-6 MeV.

Facility and Technical Accomplishments:

- *The Relativistic Heavy Ion Collider (RHIC) reaches full luminosity:* At Brookhaven National Laboratory commissioning of RHIC started in FY 1999 and data taking started in FY 2000, as scheduled. During the FY 2000 run RHIC reached about 10% of its design luminosity (collision rate) and beam energies of 65 GeV per nucleon, as planned. RHIC operated at full beam energies of 100 GeV per nucleon for gold-gold collisions in late FY 2001 and in early FY 2002 full luminosity (collision rate) was achieved. Both running periods supported very successful physics research programs.
- *RHIC obtains first collisions of polarized protons from two colliding beams:* The RHIC Spin program at Brookhaven National Laboratory successfully accelerated polarized protons in the two RHIC rings with about 25% polarization at energies of 100 GeV in early CY 2002. The polarization

was between 80-100% of injection polarization. This demonstrated that polarized protons can be successfully accelerated in the rings and set a new record for the highest energy polarized proton beam ever achieved as well as the first collisions of polarized protons.

- *RHIC detector enhancements remain on cost and schedule:* In FY 2002, a Critical Decision-4 (CD-4, Start of Operations) was approved for the STAR Silicon Vertex Detector (SVT), a high resolution, high granularity, charged-particle tracking system very close to the collision region. A CD-4 was also obtained for the first PHENIX muon arm (MIE); the second arm (funded substantially by the Japanese collaborators) was completed in FY 2002. The Electromagnetic Calorimeter (EMCAL) of STAR is on schedule for completion of the planned system in FY 2003.

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 this laboratory. These funds are for general purpose equipment, minor new capital construction, alterations and additions, improvements to land, buildings, and utility systems, and other normal operations that are needed for effective laboratory operations.

Subprogram Goal

Determine the behavior and properties of hot, dense nuclear matter as a function of temperature and density; establish whether a quark-gluon plasma can be created in the laboratory and, if so, characterize its properties.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
Complete first round of experiments at RHIC at full energy; achieve the full design luminosity (collision rate) of 2 x 10^{26} cm^{-2} s^{-1} for heavy ions. [Met Goal]	Initiate first round of experiments with collisions with other ions to compare to results of gold-gold collisions.	At the Relativistic Heavy Ion Collider, perform experiments, analyze data, and/or publish results by carrying out a peer-reviewed and prioritized research program directed towards determining the behavior and properties of hot, dense nuclear matter, including: • Measurements of the thermodynamic and hydrodynamic properties of hot nuclear matter; and • Measurements of the yields of high transverse momentum particles through hot and cold nuclear matter.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Research					
University Research	11,530	11,635	12,083	+448	+3.9%
National Laboratory Research	18,903	21,194	18,873	-2,321	-11.0%
Other Research	0	3,291	3,902	+611	+18.6%
Subtotal, Research	30,433	36,120	34,858	-1,262	-3.5%
Operations					
RHIC Operations	103,344	117,497	121,057	+3,560	+3.0%
Other Operations	17,496	14,360	11,890	-2,470	-17.2%
Subtotal, Operations	120,840	131,857	132,947	+1,090	+0.8%
Total, Heavy Ion Nuclear Physics	151,273	167,977	167,805	-172	-0.1%

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
Research	**30,433**	**36,120**	**34,858**
▪ **University Research**	**11,530**	**11,635**	**12,083**

Support is provided for the research of about 130 scientists and 75 graduate students at 26 universities in 18 states. *There is a $448,000 increase compared to FY 2003 that provides a 3.9% increase in grant funding.*

- 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 now becomes available to study for the first time. The university groups provide core manpower for the operation of and data analysis for the RHIC detectors.
- Researchers using primarily 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, Germany, and Italy, investigate nuclear reactions at intermediate energies, with the aim of studying the fragmentation of nuclei and the flow of nuclear matter in violent collisions.

	FY 2002	FY 2003	FY 2004
▪ **National Laboratory Research**	**18,903**	**21,194**	**18,873**

Support is provided for scientists from five National Laboratories (BNL, LBNL, LANL, LLNL and ORNL). These scientists provide essential manpower for the operations of the RHIC detectors and in analyzing data. 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.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▸ **BNL RHIC Research**	**9,177**	**9,153**	**8,696**

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 2003 with RHIC operating at its design luminosity (collision rate), all four detectors will contribute to the search for signatures of any new forms of nuclear matter produced in heavy-ion collisions. *In FY 2004 funding for capital equipment decreases by $703,000 to $2,300,000, with the completion of projects, while support for manpower increases 4.0%.* Funding for production of modules for the Electromagnetic Calorimeter Enhancement for the STAR RHIC-spin program is beginning in FY 2003; the enhancement will be completed in FY 2004. The survey work with gold ions at the full energy will be substantially complete by FY 2004 and measurements of the yields of rarer signals, such as J/ψ suppression due to its breakup by the quark-gluon plasma, will dominate the experimental program. Two new major detector subsystems will be ready for these investigations in FY 2004:

- The muon instrumentation for PHENIX allows measurement of the yields of muons ("heavy electrons") that (1) probe the early stages of quark-gluon plasma formation in heavy-ion collisions, and (2) perform critical measurements in the PHENIX RHIC Spin program. Completed in FY 2002, this system will be used for the FY 2003 Run-3 running period. Japanese and French collaborators are contributing substantial support for the muon arms.
- The Electromagnetic Calorimeter for STAR provides capability to distinguish electrons from photons, and extends the measurement to higher particle energies. The detector system is also a critical component for the RHIC Spin program for STAR. Production of calorimeter modules began in FY 2000 and will be completed in FY 2003. An enhancement to the Electromagnetic Calorimeter, providing additional modules for full coverage of the barrel as well as improved electron/photon discrimination required for the RHIC Spin program, will be initiated in FY 2003 and be completed in FY 2004.

▸ **Other National Laboratory Research**	**9,726**	**12,041**	**10,177**

Researchers at LANL, LBNL, LLNL, and ORNL provide leadership in the commissioning of the PHENIX muon arms and the STAR electromagnetic calorimeter, as well as play leadership roles in carrying out the research utilizing these detectors. At LBNL an analysis system for RHIC data, in alliance with the National Energy Research Scientific Computing Center (NERSC), is a major resource for data analysis by the STAR collaboration and at LLNL substantial computing resources are made available for PHENIX data analysis. A decrease in funding of $2,065,000 to $275,000 for capital equipment compared to FY 2003 reflects the completion of projects; support for manpower increases by 2.1% for about constant effort.

▪ **Other Research**..	**0**	**3,291**	**3,902**

In FY 2002 $2,903,000 was transferred to the SBIR program. This section includes $3,291,000 for SBIR in FY 2003 and $3,902,000 for SBIR in FY 2004.

	FY 2002	FY 2003	FY 2004
	(dollars in thousands)		
Operations	**120,840**	**131,857**	**132,947**
▪ **RHIC Operations**	**103,344**	**117,497**	**121,057**

The Relativistic Heavy Ion Collider (RHIC) program nearly reached its full planned capabilities by the end of the planned running period Run 2 in FY 2002. RHIC is a unique facility whose colliding relativistic heavy ion beams will permit exploration of hot, dense nuclear matter and recreate the transition from quarks to nucleons that characterized the early evolution of the universe. Studies with colliding heavy ion beams provide researchers with an opportunity to explore a new regime of nuclear matter and nuclear interactions that up to now has only been described theoretically. Already during the first runs in FY 2000 (Run 1) and FY 2001/FY 2002 (Run 2), new features were observed in the data indicating that conditions are favorable for quark-gluon plasma formation and hints of some characteristic signatures of its existence. The scientific papers that have been published from these results have generated much attention in the community. During the Run 2, operation with 100 GeV polarized protons was accomplished and some initial measurements for the spin-physics program were completed.

	FY 2002	FY 2003	FY 2004
▸ **RHIC Accelerator Operations**	**75,823**	**86,950**	**90,232**

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. RHIC produced its first collisions in June 2000. Operations in FY 2003 are expected to increase to 22 weeks (3300 hours) from the 18-week operating schedule (2110 hours) in FY 2002. *FY 2004 funding will support a 29-week schedule (3480 hours) for research, about a 5% increase in hours from FY 2003. After accounting for an anticipated shift of $400,000 to the Theory subprogram in FY 2003 for enhanced theoretical effort, in response to the NSAC Long Range Plan recommendation, there is a 4.3% increase in FY 2004 for operations. Capital equipment funding is increased from FY 2003 by $100,000 to $1,100,000* and AIP funding of $2,900,000 is maintained at the same level as FY 2003, providing for needed improvements especially to legacy systems such as the AGS main magnet power supply as well as for design efforts for the Electron Beam Ion Source (EBIS).

RHIC Operations

	(hours of operation with beam)		
	FY 2002	FY 2003	FY 2004
RHIC	2110	3300	3480

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▸ **RHIC Experimental Support**......................................	**27,521**	**30,547**	**30,825**

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) nearly reached their initial planned potential by FY 2002. 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. After accounting for a proposed shift of $200,000 in FY 2003 to the Theory subprogram there is a 1% increase in support in FY 2004. Capital equipment is increased by $228,000 from FY 2003.

▪ **Other Operations**	**17,496**	**14,360**	**11,890**

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 construction, 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 in meeting its requirement for safe and reliable facilities operation. In FY 2004 funding for GPP and GPE is decreased by $50,000 (-0.3%) relative to FY 2003, by reducing usage of motor vehicles.

Total, Heavy Ion Nuclear Physics..	**151,273**	**167,977**	**167,805**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Research	
▪ **University Research**	
▸ FY 2004 funding for grants for University Research increases by 3.9%, maintaining an approximately constant effort relative to FY 2003 focused on carrying out an effective and productive research program at RHIC..	+448
▪ **National Laboratory Research**	
▸ **BNL RHIC Research:** Research support is increased by $246,000 (+4.0%) to effectively carry out research with the enhanced detectors at full luminosity at RHIC. Funding for capital equipment is decreased by $703,000 because of completion of projects...	- 457

	FY 2004 vs. FY 2003 ($000)
▸ **Other National Laboratory Research:** Research support for operations is increased by $201,000 (+2.1%) compared to FY 2003, maintaining approximately constant manpower. Funding for capital equipment decreases by $2,065,000 compared with FY 2003, with the completion of projects.	-1,864
Total, National Laboratory Research	-2,321
▪ **Other Research:**	
▸ Estimated SBIR and other obligations increase.	+611
Total, Research	-1,262
Operations	
▪ **RHIC Operations**	
▸ **Accelerator Operations:** An increase of $3,182,000 (+3.8%) in operating funds provides an enhancement of effort resulting in ~3,480 hours of beam for research, about 5% greater than in FY 2003. Funding of capital equipment is increased $100,000 relative to FY 2003 to maintain accelerator capabilities.	+3,282
▸ **Experimental Support:** The increase provides a funding level for experimental support that is needed to carry out the RHIC experimental program.	+278
Total, RHIC Operations	+3,560
▪ **Other Operations**	
▸ FY 2004 funding for general plant projects to Brookhaven National Laboratory is increased by $60,000 (+1%) compared with FY 2003. Funding for general purpose equipment is decreased by $110,000 (-2.4%). Other operations decrease by $2,420,000.	-2,470
Total, Operations	+1,090
Total Funding Change, Heavy Ion Nuclear Physics	-172

Low Energy Nuclear Physics

Mission Supporting Goals and Measures

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 the nuclear astrophysics processes responsible for 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 experiments.

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 that 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 1996 NSAC 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 2002 NSAC 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 these pre-conceptual R&D activities is supported in FY 2004.

The research of this subprogram is generally conducted using beams provided by accelerator facilities either operated by this subprogram or at other domestic or foreign facilities. In FY 2004 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. Operations at the 88-Inch Cyclotron (LBNL) are terminated as a nuclear physics user facility in order to provide resources to optimize the utilization and science productivity of the remaining user facilities. 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 distinguished 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 for effective utilization of all the national accelerator facilities operated by this subprogram. 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. University-based research is an important feature of the Low Energy subprogram. Accelerator operations are supported at Texas A&M University (TAMU), the Triangle Universities Nuclear Laboratory (TUNL), University of Washington, and Yale University. Each of these university centers of excellence has a critical mass of nuclear physics faculty involved in research that is conducted both on and off campus, about 15-25 graduate students at different stages of their education. These students historically have become a large fraction of the 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 exquisite 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, as for example the ultra-cold neutron trap at the Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Laboratory. 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 in solar neutrinos with radiochemical experiments, the SNO experiment, conceived in the late 1980's to search for neutrino flavor oscillations due to their having mass, 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 that neutrinos have mass. These results have been confirmed by new measurements reported in 2002 from SNO that are sensitive to the different types of neutrinos, and from the first KamLAND results with reactor produced anti-neutrinos. Both of these experiments have shown that neutrinos "oscillate" or change flavor as they propagate from the source to detector – this property requires that they have mass. These results have stimulated an increasing interest in non-accelerator experiments, particularly those that study neutrino properties. A priority in the FY 2004 request is increased support for this research area.

The 2002 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 and to quantitative models for the production of heavy elements.

- Measurements of solar neutrinos have indicated that neutrinos change their identity on the way to earth, 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:

- *Identification of hyper-intruder states*: Scientists at LBNL have identified the gamma-ray decay of nuclear states based on very extended shapes in ^{108}Cd. These structures may correspond to the most deformed nuclei observed to date. Microscopic calculations suggest that the proton orbitals that are the basis of the new structures in ^{108}Cd are the same as those involved in superdeformed structures of the much heavier mass 150 nuclei and the ground states of much heavier uranium nuclei. These newly discovered "hyper-intruder" states are thought to be a key ingredient for stabilizing football-like shapes with a 3:1 axis ratio in some nuclei.
- *First studies with re-accelerated neutron-rich radioactive ion beams*: Beams of re-accelerated radioactive tin and tellurium have been used at ORNL's Holifield Radioactive Ion Beam Facility to perform Coulomb excitation and transfer reaction studies of nuclear structure in the vicinity of ^{132}Sn, a nucleus with closed shells of both protons and neutrons. The initial Coulomb excitation results suggest that present theoretical models may not be able to adequately describe the low-lying structure of ^{136}Te, a nucleus with just two neutrons beyond the closed N = 82 shell.
- *First neutral current results from SNO:* Researchers at the Sudbury Neutrino Observatory reported the first neutral current measurements of neutrinos from the sun, a measurement made possible by the SNO detector's heavy water medium. The neutral current results show for the first time that the measured solar neutrino flux agrees with theoretical estimates. These results, together with the charged current results (sensitive to only the electron neutrino) SNO reported last year, provide evidence that the electron neutrinos originating in the sun change to one or both of the other neutrino types (muon and tau) by the time they are detected on earth, and indicate that neutrinos have a mass.

Facility and Technical Accomplishments:

- *Performance of the gas cell fast ion catcher:* The gas cell fast ion catcher is an essential component of the Rare Isotope Accelerator that will allow that facility to combine the best features of the fragmentation and isotope-separator-on-line techniques for production of exotic nuclei. At ANL a quarter-scale version of the gas cell has provided an efficiency of about 45% for stopping, collecting, and delivering charge 1+ radioactive ions for further study. A mean delay time of 10 milliseconds has been demonstrated for this device. A full-scale version of the gas cell fast ion catcher has been fabricated for high power tests to be conducted at the GSI accelerator facility in Germany.
- *Kamioka Large Anti-Neutrino Detector (KamLAND) begins operations*: The construction of this joint Japanese/U.S. detector project was completed and began operation in FY 2002. This experiment will detect anti-neutrinos from Japanese nuclear power plants and will provide complementary information regarding neutrino properties to the recent Sudbury Neutrino Observatory (SNO) results. U.S. participation in KamLAND is supported jointly with the High Energy Physics program
- *Development of segmented Germanium detectors:* Preconceptual design of a detector cluster module consisting of three Ge crystals in a cryostat was completed. The crystals are divided into 36 electrically isolated segments. This represents the final step in developing the technology for a 4π array that will be up to 1000 times more sensitive than Gammasphere, presently the most powerful gamma-ray detector in the world.

Subprogram Goal

Determine the low energy properties of nuclei, particularly at their limits of stability; use these properties to understand energy generation and the origin of the elements in stars, and the fundamental symmetries of the "Standard Model" of elementary particle physics.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
		Perform experiments, analyze data, and/or publish results by carrying out a peer-reviewed and prioritized research program, including: • at the Argonne Tandem Linac Accelerator System (ATLAS) measure masses with high precision of nuclear astrophysically important radioactive nuclei, identify collective excitations in actinide nuclei, and develop new exotic beams for nuclear astrophysics and structure studies; • at the Holifield Radioactive Ion Beam Facility (HRIBF), use stable and radioactive ion beams (RIBs) to measure the properties of reactions that are important for understanding the synthesis of elements in stellar explosions and necessary for interpretation of solar neutrino experiments, and measure shapes of neutron-rich nuclei.
Collect the first data from neutral current interactions from the Sudbury Neutrino Observatory (SNO). [Met Goal]	Collect the first data from the Kamioka Large Anti-Neutrino Detector (KamLAND), a joint U.S.-Japan experiment measuring neutrinos produced in nuclear reactors.	With KamLAND, perform experiments, analyze data, and publish results, completing the first measurement of reactor-produced neutrinos with this detector.
Construct a prototype high energy, high power gas catcher for the possible Rare Isotope Accelerator. [Met Goal]	Deliver the prototype high energy, high power gas catcher to the GSI facility in Germany and prepare it for testing. Complete tests of prototype targets for RIA. Complete prototype Electron Cyclotron Resonance ion source and fabricate prototypes of the high-beta superconducting radio frequency (RF) cavities for RIA.	As part of R&D for the possible RIA, complete test of the high-beta superconducting RF cavities.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Research					
University Research	17,123	17,591	18,312	+721	+4.1%
National Laboratory Research	20,109	20,044	23,244	+3,200	+16.0%
Other Research	3,150	4,743	4,903	+160	+3.4%
Subtotal Research	40,382	42,378	46,459	+4,081	+9.6%
Operations	22,387	23,780	22,830	-950	-4.0%
Total, Low Energy Nuclear Physics	62,769	66,158	69,289	+3,131	+4.7%

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
Research	**40,382**	**42,378**	**46,459**
▪ **University Research**	**17,123**	**17,591**	**18,312**

Support is provided for the research of about 140 scientists and 90 graduate students at 32 universities in 23 states. 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 2004 funding for operation of university accelerator facilities, and for researchers and students is increased by 6.8% compared to FY 2003, with priority given to non-accelerator research. Funding for capital equipment projects is decreased by $353,000. Research activities include:

- Research programs 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 at four universities: the University of Washington, the Triangle Universities Nuclear Laboratory (TUNL) facility at Duke University, Texas A&M University (TAMU) and at 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, including an energy and intensity upgrade to the High Intensity Gamma-ray Source (HIγS) facility at TUNL.

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

- 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. 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 2002	FY 2003	FY 2004
National Laboratory Research	**20,109**	**20,044**	**23,244**

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

	FY 2002	FY 2003	FY 2004
National Laboratory User Facility Research	**14,123**	**14,455**	**14,345**

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 2004 funding is increased ~0.6% for manpower while investments in equipment decrease by $200,000 from FY 2003. In FY 2004 the three user facilities support 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 has been built, and 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 traps to measure atomic masses with high precision and search for effects in beta decay outside the standard decay model. The Advanced Penning Trap is being tested and the experimental program initiated.
- At LBNL the research focuses on the completion of data analysis from the terminated research program at the 88-Inch Cyclotron and the use of DOE user facilities to study nuclei at high angular momentum and deformation. Development and of a high-sensitivity gamma-ray tracking detector, 1000 times more sensitive than Gammasphere, is continuing. Test modules, electronics and data analysis algorithms are undergoing development.

	FY 2002	FY 2003	FY 2004
Other National Laboratory Research	**5,986**	**5,589**	**8,899**

Scientists at BNL, LBNL, LLNL and LANL play important roles in a number of high-priority accelerator- and non-accelerator-based experiments directed towards fundamental questions. *FY 2004 funding for manpower increases by ~2.6% from FY 2003 with priority given to non-accelerator research. Capital equipment investments increase from FY 2003 by $3,176,000 to $3,641,000.* These activities include:

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

- 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 2001 and 2002, the first results from SNO with the heavy water detector were reported, indicating strong evidence for neutrino oscillations. Results from the second phase measurements of neutrino types to which the solar neutrinos have been transformed will be reported in FY 2003. In FY 2003, 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 2004-2005.
- 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 in FY 2003 and FY 2004. The U.S. participation in KamLAND is supported jointly with the High Energy Physics program.
- 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 will begin in FY 2004. Funds ($500,000) are provided in FY 2004 to begin development of a beamline for neutron studies at the Spallation Neutron Source (SNS) (an MIE).
- Development and fabrication of a segmented germanium gamma-detector array, the Gamma-Ray Energy-Tracking In-beam Nuclear Array (GRETINA) begins, that is especially useful for the study of the nuclear decay and structure of exotic nuclei in fast fragmentation beams, and a smaller version of the proposed GRETA detector for the Rare Isotope Accelerator. 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 2004 funding of $1,000,000 is provided to begin fabrication of GRETINA (a Major Item of Equipment).

	FY 2002	FY 2003	FY 2004
▪ **Other Research**..	**3,150**	**4,743**	**4,903**
▸ **RIA R&D Activities**...	**2,800**	**3,500**	**3,500**

Funds are provided for R&D and pre-conceptual design activities directed at the development of an advanced Rare Isotope Accelerator (RIA) facility. A next-generation facility for beams of short-lived, radioactive nuclei for nuclear structure, reaction and astrophysics studies is identified in the 2002 Nuclear Science Advisory Committee (NSAC) Long Range Plan as a compelling scientific opportunity and as the highest priority for new construction. The possible RIA facility is a new paradigm for producing intense beams of very short-lived nuclei that emerged from the 1999 NSAC Taskforce study involving international experts. This facility would position the

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

U.S. to play a leadership role in an area of study with the potential for new discoveries about basic properties of nuclei and to significantly advance our understanding of astrophysical phenomena. Funding for FY 2004 supports some of the needed R&D activities in both critical accelerator components and experimental station development.

▸ **SBIR and Other**	**350**	**1,243**	**1,403**

In FY 2002 $655,000 was transferred to the SBIR program. This section includes $868,000 for SBIR in FY 2003 and $1,028,000 for SBIR in FY 2004 and other established obligations. The Lawrence and Fermi Awards, funded under this line, provide annual monetary awards to honorees selected by the Department of Energy for their outstanding contributions to science.

Operations	**22,387**	**23,780**	**22,830**
▪ **User Facility Operations**	**22,387**	**23,780**	**22,680**

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.

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 such as CHARMS, designed for nuclear structure studies, and the Daresbury Recoil Separator and the Silicon Detector Array for nuclear astrophysics studies. Accelerator improvement project funding is increased from FY 2003 by $1,000,000 in order to fabricate a platform for development and testing targets and ion sources.

ATLAS provides stable heavy-ion beams and selected radioactive-ion beams for research. Experiments utilize ion traps, the Fragment Mass Analyzer, and advanced detectors to study the structure of nuclei at the limits of stability, and fundamental and decay properties of nuclei.

Operations at the 88-Inch Cyclotron as a Nuclear Physics user facility are terminated in FY 2004 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 FY 2003 options for this facility will be evaluated and the estimated cost and schedule for the appropriate Decommissioning and Decontamination (D&D) activities will be developed. Funds of $3,000,000 are provided in FY 2004 for these phaseout activities. While the final D&D cost and schedule have not been established, it can be anticipated that these activities will continue for 2-4 years.

Included in the funding shown are capital equipment and accelerator improvement project (AIP) funds provided to each of the operating facilities for the enhancement of the accelerator systems and experimental equipment.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

In FY 2004 these low energy facilities will carry out about 95 experiments involving over 360 U.S. and foreign researchers. Planned hours of operation with beam are indicated below:

	(hours of operation with beam)		
	FY 2002	FY 2003	FY 2004
ATLAS	5,485	4,050	6,500
HRIBF	4,250	2,600	3,780
88-Inch Cyclotron	4,480	3,850	0
Total Beam Hours for Low Energy Facilities	14,215	10,500	10,280

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▪ **Other Operations**	**0**	**0**	**150**
Funding is provided for maintenance of the Oak Ridge Electron Accelerator (ORELA) for criticality measurements supported by DOE/NNSA.	0	0	150
Total, Low Energy Nuclear Physics	**62,769**	**66,158**	**69,289**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)

Research

- **University Research**
  - FY 2004 funding for researchers and students is increased by 6.8% ($1,074,000) from FY 2003. Priority will be given to supporting non-accelerator research activities such as SNO and KamLAND. Additional support is provided for operating university accelerator facilities and utilizing national user facilities. Funding for capital equipment decreases by $353,000 compared to FY 2003 as projects are completed. .... +721
- **National Laboratory Research**
  - **National User Facilities Research:** FY 2004 funding provides about constant funding of +0.6% ($90,000) for research efforts and activities at the user facilities while capital equipment funds are reduced by $200,000. Because of the proposed transfer in FY 2003 of $380,000 to the Theory subprogram from this funding category, the effective increase for research efforts is $450,000 (+3.4%). .... -110

	FY 2004 vs. FY 2003 ($000)
▸ **Other National Laboratory Research**: Research funding increases about 2.6% ($134,000) in FY 2004 compared with FY 2003. Manpower and effort will be focused on the high priority non-accelerator research activities including SNO and KamLAND. Equipment funds are increased by $3,176,000 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 GRETINA gamma-ray tracking detector.	+3,310
Total, National Laboratory Research	+3,200
▪ **Other Research**	
▸ **SBIR and Other:** Estimated SBIR and other obligations increase.	+160
Total, Other Research	+160
Total Research	+4,081
Operations	
▪ In FY 2004 operating funds are increased by ~6.1% ($900,000) compared to FY 2003 for ATLAS and HRIBF operations to provide an estimated 10,280 hours of beam time. Funding for capital equipment and accelerator improvement projects at these facilities increases by $1,300,000 compared to FY 2003. Operations of the 88-Inch Cyclotron at LBNL is terminated with a reduction of $3,300,000 in operations and equipment costs.	-1,100
▪ Other operations are increased by $150,000 to provide maintenance of the Oak Ridge Electron Accelerator (ORELA) for criticality measurements supported by DOE/NNSA.	+150
Total Operations	-950
Total Funding Change, Low Energy Nuclear Physics	+3,131

Nuclear Theory

Mission Supporting Goals and Measures

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 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 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.

The research of this program 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 program is greatly 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 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.

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

- *Structural phase transitions in nuclei:* Nuclei are known to exhibit exotic shapes, but describing the detailed properties of nuclei in the phase-transition region has been a long standing challenge. An analytical model, called the X(5) symmetry, has been developed to predict the properties of various spherical nuclei that transform into a rugby-ball shape during a phase transition. This theory could also be applied to metallic clusters, molecules and polymers. Recently, experimenters have found ^{152}Sm co-exists as a spherical and rugby-ball nucleus; an observation that is in agreement with the X(5) symmetry model. This exciting confirmation could lead to a new direction in nuclear physics research when more exotic nuclei becoming readily available at radioactive beam facilities.
- *Left-handed nuclei:* Nuclear theorists have predicted that triaxial nuclei with odd numbers of both protons and neutrons could have handedness. In particular, observing the so-called chirality would provide solid evidence for stable triaxial shapes, while also establishing handedness as a new property of nuclei. Recently, experimenters and nuclear structure theorists using 3D tilted axis cranking calculations have found evidence for handedness in odd-odd nuclei in ^{55}Cs, ^{57}La, and ^{61}Pm, N = 75 isotones (same number of neutrons) of ^{134}Pr.
- *New Theoretical Tool Ties Together Many Different Phenomena:* A new comprehensive framework, called the Generalized Parton Distributions (GPD's) has been developed that allow for the first time, to describe and relate a large variety of complex high-energy electromagnetic reactions to the internal quark and gluon structure of the nucleon.
- *Indicators of quark-gluon plasma formation:* Theoretical calculations using a hydrodynamic model appear to be in excellent agreement with the first and second year RHIC data on "elliptic flow." When two heavy nuclei collide, the initial fireball created in the "little bang" has the shape of an almond or more precisely, the fireball is said to be elliptically deformed. The subsequent near light-speed explosion of this 'deformed' fireball results in an anisotropy of the final transverse momentum distribution of the emitted particles. This effect is called elliptic flow. It is remarkable that the majority of the data (low momentum particles) are seen to coincide with the upper limit of the hydrodynamical calculations. This unexpected agreement suggests that a significant thermal pressure existed on a time scale too short to be explained by conventional collision dynamics, but rather it

seems plausible that the early stage of the nuclear collision might implicate the appearance of a new phenomenon.

- *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 on the DOE Scientific Discovery through Advanced Computing (SciDAC) program on simulations of exploding stars are continuing to make rapid progress on many fronts. Neutrino transport is now being utilized in one-dimensional (spherical) models of stars. Recent progress has also been made in calculating electron-capture rates crucial to the understanding stellar collapse. Multi-dimensional stellar models are now able to explore effects such as convention induced by neutrino heating. 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, as a solution to the nuclear many-body system, 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.

Subprogram Goal

Provide a theoretical program that supports the Medium Energy, Heavy Ion, and Low Energy strategic goals, by developing models, computational techniques, interpreting data, and finding new directions for profitable investigation; provide reliable nuclear data in formats that are useful for a wide range of activities in nuclear and astrophysics research, nuclear medicine, nuclear stockpile stewardship, national security and space exploration.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
		Develop models, interpret data, and find new research directions relevant to the Nuclear Physics mission, and publish results. At the National Nuclear Data Center, complete database migration project, performing a generational step to a modern relational database management system.

Funding Schedule

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Theory Research					
University Research	10,923	11,045	11,811	+766	+6.9%
National Laboratory Research	7,618	6,590	9,165	+2,575	+39.1%
Scientific Computing (SciDAC)*	2,000	2,000	2,000	0	0%
Subtotal Theory Research	20,541	19,635	22,976	+3,341	+17.0%
Nuclear Data Activities	4,788	5,010	5,162	+152	+3.0%
Total, Nuclear Theory	25,329	24,645	28,138	+3,493	+14.2%

*In FY 2002 funding for the NP portion of the SciDAC program was distributed between University ($854,200) and National Laboratory Research ($1,145,800).

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Theory Research	**20,541**	**19,635**	**22,976**
▪ **University Research**	**10,923**	**11,045**	**11,811**

The research of about 170 university scientists and 80 graduate students is supported through 54 grants at 41 universities in 25 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 postdoc support is a major element of this program. *Support increases by 4.7% from FY 2003, after accounting for shifts of $241,000 in grants from the Medium Energy and Low Energy subprograms.*

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**	**7,618**	**6,590**	**9,165**

Research programs are supported at six National Laboratories (ANL, BNL, LANL, LBNL, ORNL and TJNAF). *The increase in the request for Nuclear Theory in FY 2004 is in direct response to the recommendation in the 2002 Nuclear Science Advisory Committee Long Range Plan. These increased funds will be used to hire additional theorists to work on high priority topics and to expand computing. It is proposed that redirection of $2,155,000 to theory will be made in FY 2003 in order to respond effectively to this recommendation. When this is taken into account there is an effective 4.8% increase in funding in FY 2004 compared to FY 2003.*

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

- ▸ 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 postdocs.

	FY 2002	FY 2003	FY 2004
▪ **Scientific Computing**	**2,000**	**2,000**	**2,000**

The Scientific Discovery through Advanced Computing (SciDAC) program is an Office of Science program to address major scientific challenges that require advances in scientific computing using terascale resources. An effort managed by the High Energy and Nuclear Physics (HENP) programs identified the most compelling opportunities for advancements and for coordinated efforts in these two scientific fields by the application of terascale computing resources. This effort resulted in the identification of two such challenge areas within the domain of theoretical nuclear physics, and in FY 2001 several major multi-institutional grants in high-priority topical areas were awarded through this program for the first time. One topical area is Lattice QCD. The scientific goal is to solve Quantum Chromodynamics (QCD), the fundamental theory of the strong interaction, on a 'lattice' of space-time points using advanced numerical methods. This is an extremely active area of inquiry world-wide, with major ongoing efforts in Europe and Japan. Of particular relevance to nuclear physics are the activities focused on solving QCD in two domains: the structure of the proton and neutron and their excited states, and the quark-gluon plasma that is anticipated to be produced at RHIC. A second topical area is Theoretical Nuclear Astrophysics, particularly focusing on supernova phenomena. Two types of supernova explosions are being modeled: Type Ia explodes because of nuclear reaction processes; types II, Ib, and Ic, are thought to explode through core collapse, fueled by neutrino energy transport. These problems are intrinsically multidisciplinary, involving nuclear physics, general relativity, neutrino science, hydrodynamics and transport theory, and advanced computing techniques. This is an ideal challenge to push the frontiers of advanced computing.

	FY 2002	FY 2003	FY 2004
Nuclear Data	**4,788**	**5,010**	**5,162**

The Nuclear Data program collects, evaluates, archives, and disseminates information on nuclear properties and reaction processes for the community and the nation. The focal point for its national and international activities is at the DOE-managed National Nuclear Data Center (NNDC) at Brookhaven National Laboratory.

The NNDC relies on the U.S. Nuclear Data Network (USNDN), a network of DOE supported individual nuclear data professionals located in universities and at other 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 2002	FY 2003	FY 2004
Total, Nuclear Theory	**25,329**	**24,645**	**28,138**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
▪ **University Research**	
▸ FY 2004 funding level is increased by 4.7% compared to FY 2003 once shifts of $241,000 in grants from the Medium Energy and Low Energy subprograms are taken into account. This provides increased funding for students and focused funding for priority research that was identified in the NSAC 2002 Long Range Plan for Nuclear Science.	+766
▪ **National Laboratory Research**	
▸ FY 2004 funding level is increased by 4.8% compared to FY 2003, once proposed shifts of $2,155,000 in FY 2003 are accounted for. This addresses the need for enhanced theoretical efforts to interpret the results obtained at our new facilities. Such enhanced support was strongly recommended in the NSAC 2002 Long Range Plan for Nuclear Science.	+2,575
▪ **Nuclear Data**	
▸ FY 2004 funding level is increased by 3.0% compared to FY 2003 to enhance efforts to effectively disseminate nuclear data needed for basic and applied research.	+152
Total Funding Change, Nuclear Theory	+3,493

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
General Plant Projects	6,649	6,560	6,640	+80	+1.2%
Accelerator Improvement Projects	5,450	5,400	5,800	+400	+7.4%
Capital Equipment	29,617	30,220	27,727	-2,493	-8.2%
Total, Capital Operating Expenses	41,716	42,180	40,167	-2,013	-4.8%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp- riations	FY 2002	FY 2003	FY 2004 Request	Accept- ance Date
STAR EM Calorimeter	8,600	4,997	3,300	303	0	FY 2003
STAR EM Calorimeter Enhancement	4,700	0	0	2,400	2,300	FY 2004
G0 Experiment Detector	3,965	3,906	59	0	0	FY 2002
GRETINA gamma-ray detector	15,000	0	0	0	1,000	TBD
Fundamental Neutron Physics Beamline	9,800	0	0	0	500	FY 2011
Total, Major Items of Equipment		8,903	3,359	2,703	3,800	