Nuclear Physics

Program Mission

The Nuclear Physics program of the Department of Energy (DOE) has the lead responsibility for Federal support of nuclear physics research and supports fundamental research activities under the mandate provided in Public Law 95-91 which established the Department. The primary mission of the program is to develop and support the basic research scientists and facilities, and to foster the technical and scientific activities needed to understand the structure and interactions of atomic nuclei, and to understand the fundamental forces and particles of nature as manifested in nuclear matter. Atomic nuclei can be described as a collection of nucleons (protons and neutrons), bound together by the mechanism of exchange of mesons, mainly pi mesons (pions). The research forefront in nuclear physics now includes incorporation of the quark substructure of the nucleon into the understanding of nuclear structure and of quark-antiquark pairs to form the mesons. Quarks, which are the most elementary building blocks of matter, are bound together in groups of three by the exchange of gluons to form the nucleons.

Attendant upon this core mission are responsibilities to enlarge and diversify the Nation's pool of technically trained talent and to facilitate transfer of technology and knowledge acquired to support the Nation's economic base. The program works in close coordination with the Nuclear Physics program at the National Science Foundation (NSF), and jointly with the NSF charters the Nuclear Science Advisory Committee to advise on setting scientific priorities.

The high quality of the research in this program is continuously evaluated through the use of merit based peer review and scientific advisory committees.

Program Goal

Understand the structure of atomic nuclei and the fundamental forces required to hold their constituents in place, based on a series of systematic experimental and theoretical scientific investigations.

Program Objectives

- Conduct a program of maximum effectiveness to provide new insights into the nature of energy and subatomic matter, based on evaluation by rigorous peer review.
- Conceive, develop, construct, and operate world class scientific accelerator facilities in a timely, and effective manner. In the execution of this responsibility, together with other Science organizations, act as the Nation's leader in developing standards and management techniques to optimize construction and operations of facilities in a cost effective, safe, and environmentally benign way.
- Leverage United States objectives by means of international cooperation through exchanges of scientists and participation in internationally cooperative projects.
- Continue the advanced education and training activities of young scientists to maintain the skills and conceptual underpinning of the Nation's broad array of nuclear related sciences and technologies.

Performance Measures

- Evaluate the scientific quality and appropriateness of the total DOE Nuclear Physics program to maintain the United States position as world leader in nuclear physics research. Evaluations will be based on rigorous peer reviews conducted by internationally recognized scientific experts. Maintain the highest quality research by taking appropriate corrective management actions based on results of the reviews.
- Determine the production trends of diverse, highly trained young scientists - an essential ingredient for the vitality of the nation's technological base-using the Nuclear Physics annual census of scientific personnel. Funding patterns of university grants will include consideration of the optimum production rate of scientists.
- Use the assistance of technical experts to monitor the performance in scope, costs and schedule of construction projects for world class nuclear physics facilities such as the Relativistic Heavy Ion Collider. Measure project performance against cost and schedule milestones contained in project plans. Working with the relevant DOE project manager and laboratory project management, identify and establish programmatic modifications needed to enable projects to meet schedules and costs.
- Review at least 80 percent of the research projects by appropriate peers and selected through a merit-based competitive process.
- Use peer reviews and user feedback to monitor the effectiveness of facility operations. Evaluate facility performance against objectives set in program guidance based on funding availability, and measure achieved beam hour availability against guidelines developed for the Scientific User Facility Initiative. Identify participation and contributions by foreign scientists at facilities, and obtain input from user's groups at facilities. Develop appropriate facility funding profiles so as to best provide overall beam availability for the Nuclear Physics program.
- Measure overall program against the scientific priorities recommended in the long range plans that are regularly provided by the DOE/NSF Nuclear Science Advisory Committee (NSAC). Obtain assessments from NSAC and other community forums on the overall direction of the DOE Nuclear Physics program and its coordination with the NSF Nuclear Physics program. Based on this feedback, programmatic changes will be made, where necessary, to assure the Nuclear Physics program is appropriately directed towards highest priority topics in the long range plan.
- Upgrades of scientific facilities will be managed to keep them on schedule and within cost.
- Nuclear Physics will begin the research program at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) in FY 2000.

Significant Accomplishments and Program Shifts

Medium Energy Nuclear Physics

- In FY 2000, operations of the MIT/Bates Linear Accelerator Center facility will be terminated and Decommissioning and Decontamination (D&D) activities will begin.

- All three experimental halls at the Thomas Jefferson National Accelerator Facility are now operational for research. Beams of widely differing energies and currents can be delivered simultaneously to each of the halls to meet the specific requirements of the experiments. The laboratory is now also able to deliver polarized beam to any of the experimental halls.

Heavy Ion Nuclear Physics

- The Relativistic Heavy Ion Collider (RHIC) construction project at Brookhaven National Laboratory (BNL) continues on scope and budget with a completion date of the third Quarter of FY 1999. Fabrication of RHIC detectors, including the additional experimental equipment recommended by NSAC for purposes of particle detection and data analysis, also proceeds on schedule.

  In FY 2000 RHIC initiates its first full year of Operations and its research program will begin with four experiments (STAR, PHENIX, BRAHMS and PHOBOS) involving over 900 researchers and students from 80 institutions and 15 countries. The BNL Tandem/AGS/Booster accelerator complex, which acts as the injector for RHIC, will terminate routine operations of its fixed-target heavy-ion research program.

Low Energy Nuclear Physics

- Construction of the US/Canadian Sudbury Neutrino Observatory (SNO) detector, which sits in a nickel mine 6,800 feet below the surface of the earth, was completed in FY 1998. A dedication of the laboratory was held in Sudbury, Ontario, on May 28, 1998, with Stephen Hawking as one of the speakers. The filling of the region around the detector with water, and the central part of the detector with "heavy water" (D_2O), is now underway and initial measurements using the detector have commenced early in calendar year 1999.
- Gammasphere was moved from the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL) to the ATLAS facility at Argonne National Laboratory (ANL) in FY 1998. A research program at ATLAS was initiated which is focused on the study of the structure of nuclei far from stability utilizing Gammasphere coupled with the existing Fragment Mass Analyzer (FMA). It is now planned that Gammasphere will operate at ATLAS in FY 1999 and move back to the 88-inch Cyclotron in FY 2000.
- The Radioactive Ion Beam (RIB) facility at Oak Ridge National Laboratory (ORNL) successfully developed new beams in FY 1998 and has initiated a series of experiments directed at measuring cross sections important to astrophysics.

Nuclear Theory

- In FY 2000 the Nuclear Theory Institute at the University of Washington continues its activities as a premier international center for new initiatives and collaborations in nuclear theory research.

Scientific Facilities Utilization

The Nuclear Physics request includes $234,000,000 to maintain support of the Department's scientific user facilities. This funding will provide research time for thousands of scientists in universities, Federal agencies, and U.S. companies. It will also leverage both Federally and privately sponsored research consistent with the Administration's strategy for enhancing the U.S. National science investment.

Funding of Contractor Security Clearances

In FY 1999, the Department divided the responsibility for obtaining and maintaining security clearances. The Office of Security Affairs, which was responsible for funding all Federal and contractor employee clearances, now pays only for clearances of Federal employees, both at headquarters and the field. Program organizations are now responsible for contractor clearances, using program funds. This change in policy enables program managers to make the decisions as to how many and what level clearances are necessary for effective program execution. In this way, it is hoped that any backlog of essential clearances which are impeding program success can be cleared up by those managers most directly involved. The Office of Science is budgeting $106,000 and $88,000 for estimated contractor security clearances in FY 1999 and FY 2000, respectively, within the decision unit.

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Nuclear Physics					
Medium Energy Nuclear Physics	113,400	118,698	-155	118,543	111,130
Heavy Ion Nuclear Physics	94,736	150,592	-185	150,407	181,810
Low Energy Nuclear Physics	31,872	33,360	-135	33,225	34,170
Nuclear Theory	15,330	15,830	-70	15,760	15,830
Subtotal, Nuclear Physics	255,338	318,480	-545	317,935	342,940
Construction	59,400	16,620	0	16,620	0
Subtotal, Nuclear Physics	314,738	335,100	-545	334,555	342,940
Use of Prior Year Balances	-971 [a]	-776 [a]	0	-776 [a]	0
General Reduction	0	-545	+545	0	0
Total, Nuclear Physics	313,767 [b]	333,779	0	333,779	342,940

Public Law Authorization:

Public Law 95-91, “Department of Energy Organization Act”

[a] Share of Science general reduction of use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Excludes $5,660,000 which has been transferred to the SBIR program and $340,000 which has been transferred to the STTR program.

Funding by Site

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	10,783	9,750	10,260	+510	+5.2%
Chicago Operations Office					
Argonne National Laboratory	16,845	16,045	17,485	+1,440	+9.0%
Brookhaven National Laboratory	110,851	115,900	135,549	+19,649	+16.9%
Total, Chicago Operations Office	127,696	131,945	153,034	+21,089	+16.0%
Idaho Operations Office					
Idaho National Engineering Laboratory	90	80	80	0	0.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	21,965	22,118	18,080	-4,038	-18.3%
Lawrence Livermore National Laboratory	845	660	950	+290	+43.9%
Stanford Linear Accelerator Center	9	0	0	0	0.0%
Total, Oakland Operations Office	22,819	22,778	19,030	-3,748	-16.4%
Oak Ridge Operations Office					
Thomas Jefferson National Accelerator Facility	68,850	70,305	73,669	+3,364	+4.8%
Oak Ridge National Laboratory	16,215	15,017	16,665	+1,648	+11.0%
Oak Ridge Institute for Science & Education	719	565	820	+255	+45.1%
Total, Oak Ridge Operations Office	85,784	85,887	91,154	+5,267	+6.1%
All Other Sites [a]	67,566	84,115	69,382	-14,733	-17.5%
Subtotal, Nuclear Physics	314,738	334,555	342,940	+8,385	+2.5%
Use of Prior Year balances	-971 [b]	-776 [b]	0	+776 [b]	+100.0%
Total, Nuclear Physics	313,767	333,779	342,940	+9,161	+2.7%

[a] Funding provided to universities, industry, other federal agencies and other miscellaneous contractors.

[b] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

Site Description

Argonne National Laboratory (ANL)

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. At Argonne, the Nuclear Physics program supports: (1) the Heavy Ion group, which operates the ATLAS Heavy Ion accelerator as a national user facility, and carries out related research; (2) the Medium Energy group, which carries out a program of research at TJNAF, Fermilab, and DESY in Germany; also supported are activities leading to a "spin" physics program at RHIC; (3) R&D directed at a proposed Isotope Separator On-Line accelerator facility (ISOL); (4) the Nuclear Theory group which carries out theoretical calculations and investigations in subjects supporting the experimental research programs in Medium Energy and Heavy Ion physics; and (5) data compilation and evaluation activities as part of the national data program.

Brookhaven National Laboratory (BNL)

Brookhaven National Laboratory is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The major effort at BNL, supported by the Heavy Ion Program, is the new Relativistic Heavy Ion Collider (RHIC) which uses the entire Tandem/Booster and Alternating Gradient Synchrotron (AGS) as an injector. RHIC is a major new and unique international user facility. RHIC will search for the predicted "quark-gluon plasma," a form of nuclear matter not previously observed. The Medium Energy group has been supported to carry out a program of hypernuclear physics and baryon resonance research using proton beams from the AGS. The Laser Electron Gamma Source (LEGS) group uses a unique polarized photon beam to carry out a program of photonuclear spin physics at the National Synchrotron Light Source (NSLS). The BNL Nuclear Theory group provides theoretical support and investigations primarily in the area of relativistic heavy ion physics. Low Energy support is provided for detector and chemical analysis development for the Sudbury Neutrino Observatory (SNO) and involvement in the SNO research program. BNL is also the central U.S. site for the American and international nuclear data and compilation effort. The National Nuclear Data Center is housed at BNL.

Idaho National Engineering & Environmental Laboratory (INEEL)

Idaho National Engineering and Environmental Laboratory is a Multiprogram Laboratory located on 572,000 acres in Idaho Falls, Idaho. At INEEL, a program of nuclear data and compilation is supported.

Lawrence Berkeley National Laboratory (LBNL)

Lawrence Berkeley National Laboratory is a Multiprogram Laboratory located in Berkeley, California. The Lab is on a 200 acre site adjacent to the Berkeley campus of the University of California. At LBNL, the Nuclear Physics program supports: (1) operations and research at the 88-inch Cyclotron, a heavy ion accelerator which is run as a national user facility; (2) the Relativistic Nuclear Collisions group, with activities at CERN/SPS, BNL/AGS, and RHIC, where they have been major players in the development of the large STAR detector for the new RHIC facility; (3) the Low Energy group, which plays a major role in the construction and implementation of the Sudbury Neutrino Observatory (SNO) detector; (4) the Nuclear Theory group, which carries out a program with emphasis on theory of relativistic heavy ion physics; and (5) the Nuclear Data group whose activities support the National Nuclear Data Center at BNL.

Lawrence Livermore National Laboratory (LLNL)

Lawrence Livermore National Laboratory is a Multiprogram Laboratory located on a 821 acre site in Livermore, California. Low Energy Research support is provided for the setup and use of the GENIE detector for a program of neutron research using LANSCE beams at Los Alamos National Laboratory. A nuclear data and compilation effort is supported at LLNL.

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) the Liquid Scintillation Neutrino Detector (LSND) experiment which is searching for evidence of neutrino oscillations, and a program of neutron beam research investigating parity violation in nuclei; these activities utilize beams from the LANSCE proton accelerator; (2) a major effort to build components of the PHENIX detector for the new Relativistic Heavy Ion Collider (RHIC) at Brookhaven, as well as to carry out a program of heavy ion research; (3) research is supported to study the quark substructure of the nucleon in experiments at Fermilab, and to plan for the detectors and research for a “spin” physics program at RHIC which will utilize polarized proton beams; (4) the development of the Sudbury Neutrino Observatory (SNO) detector as well as involvement in the planned research program; (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.

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 new Radioactive Ion Beam Facility (RIB) 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 new Radioactive Ion Beam Facility (RIB), which is run as a national user facility. RIB allows a program of experimental research investigating a number of issues in astrophysics. Also supported is a heavy ion group which is involved in PHENIX detector development activities for RHIC and the development of the RHIC research program. The theoretical nuclear physics effort at ORNL emphasizes investigations of low energy nuclear structure. Nuclear data and compilation activities are also supported as part of the national nuclear data effort.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center (SLAC) is a program-dedicated laboratory (High Energy Physics) located on 426 acres in Menlo Park, California. SLAC uses computational tools (i.e. simulations, interactive techniques, remote access to instrumentation for data collection and manipulation), in partnership with educational institutions, for teaching and learning science as it relates to the Office of Science's Nuclear Physics mission.

Thomas Jefferson National Accelerator Facility (TJNAF)

Thomas Jefferson National Accelerator Facility is a program-dedicated laboratory (Nuclear Physics) located on 273 acres in Newport News, Virginia. Major Medium Energy program support is provided for the operation and research program of TJNAF, a new and unique international user facility for the investigation of nuclear and nucleon structure based on the underlying quark substructure. Also supported is a nuclear theory group whose program of investigations support the experimental program of the laboratory. The Nuclear Physics program provides most of the support for this new single purpose laboratory.

All Other Sites

The Nuclear Physics program funds research at 83 colleges/universities located in 35 states. This line also includes funding of research awaiting distribution pending completion of peer review results.

Medium Energy Nuclear Physics

Mission Supporting Goals and Objectives

The Nuclear Physics Program supports the basic research necessary to identify and understand the fundamental features of atomic nuclei and their interactions. The Medium Energy Nuclear Physics subprogram supports academic fundamental research, and facility operations and research at electron and proton accelerator facilities at the higher energies of interest to nuclear physics. In addition, the subprogram supports research at accelerators operated by other Department of Energy programs (e.g., High Energy Physics and Basic Energy Sciences) and at other unique domestic or foreign facilities. The research programs are ultimately aimed at achieving an understanding of the structure of the atomic nucleus in terms of the quarks and gluons, the objects which are believed to combine in different ways to make all the other sub-atomic particles. Just as important is the achievement of an understanding of the "strong force", one of only four forces in nature, and the one which holds the nucleus of the atom together. Research efforts include studies of the role of excited states of protons and neutrons in nuclear structure, investigations of the role of specific quarks in the structure of protons and neutrons, studies of the symmetries in the behavior of the laws of physics, investigations of how the properties of protons and neutrons change when imbedded in the nuclear medium, measurements with beams of electrons or protons whose "spins" have all been lined up in the same direction (polarizing the beams) to determine unique "structure functions", and studies of how particles interact with each other inside the nucleus. Two national accelerator facilities are operated entirely under the Medium Energy subprogram - the Thomas Jefferson National Accelerator Facility (TJNAF) in Newport News, Virginia, operated by the Southeastern Universities Research Association and the Bates Linear Accelerator Center in Middleton, Massachusetts, operated by the Massachusetts Institute of Technology. These accelerator facilities serve a nationwide community of Department of Energy and National Science Foundation supported scientists from over 100 American institutions, of which over 90% are universities. Both facilities provide major contributions to American education at all levels. 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 planned research program at the new TJNAF, for example, involves 600 scientists from 17 foreign countries; 81 of these scientists are from Conseil Europeen pour la Recherche Nucleaire (CERN) member states. At TJNAF, foreign collaborators have also made major investments in experimental equipment. Nuclear Physics will provide opportunities for college faculty and students to spend time at DOE laboratories, to participate in world-class research projects. Faculty/Student Science Teams will visit our DOE Laboratories during the academic summer/semesters, be involved in conducting research, writing proposals, utilizing technology and pursuing technical or scientific careers. Primary goals of the Science Teams are to build long-term partnerships among DOE laboratories and provide faculty/students with a deeper understanding of DOE science associated needs for research and development. Funds will be provided to pay for faculty/student stipends, travel, housing and subsidize laboratory scientists' time for this activity ($973,000).

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Research					
University Research	16,080	17,085	15,662	-1,423	-8.3%
National Laboratory Research	19,713	20,124	19,985	-139	-0.7%
Other Research	987	6,064	5,748	-316	-5.2%
Subtotal, Research	36,780	43,273	41,395	-1,878	-4.3%
Operations					
TJNAF Operations	62,720	64,170	67,235	+3,065	+4.8%
Bates Operations	13,550	10,800	2,500	-8,300	-76.9%
Other Operations	350	300	0	-300	-100.0%
Subtotal, Operations	76,620	75,270	69,735	-5,535	-7.4%
Total, Medium Energy Nuclear Physics	113,400	118,543	111,130	-7,413	-6.3%

Detailed Program Justification

(dollars in thousands)

FY 1998	FY 1999	FY 2000

Research

University Research

These activities comprise a broad program of research, and includes 40 grants at 32 universities in 17 states and the District of Columbia. These research efforts utilize not only each of the accelerator facilities supported under the Medium Energy program, but also use other U.S. and international accelerator laboratories. Included in "Bates Research" is 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 MIT activities which are not carried out at Bates.

- **Bates Research:** At the MIT/Bates accelerator, university researchers have been carrying out "symmetry violation" studies on the proton in the North Experimental Hall. Out-of-plane measurements are being carried out using new spectrometers in the South Experimental Hall on the proton, deuteron, and complex nuclei including measurements of the transition of the proton to its excited state.
  - In FY 1999, important measurements will be completed in a limited experimental program.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
▸ In FY 2000, the Bates accelerator will terminate operations. Supported MIT scientists will transition to other research facilities.	2,900	4,600	1,500
■ **Other University Research:**			
▸ University scientists are collaborating on important ongoing and future experiments at TJNAF. In FY 2000 activities include studies of the charge structure of the neutron in Hall C, planned measurements of the electric form factor of the proton, and a series of planned studies of the excited states of the proton in Hall B. First parity-violation measurements to look for the "strange quark" content of the proton in Hall A are already underway.			
▸ A number of university groups are collaborating in experiments using the new out-of-plane spectrometers in the South Experimental Hall at the Bates Laboratory. In FY 2000 Bates will cease operations; MIT and other university scientists will transition to other research facilities. Part of the Bates research funds are being added to other university research to support this transition.			
▸ University scientists and National Laboratory collaborators will continue to carry out the HERMES experiment at the DESY laboratory in Hamburg, Germany. This experiment will measure what components of the proton or neutron determine the "spin" of these particles, an important and timely scientific issue. In FY 2000, HERMES will utilize a new Ring Imaging Cerenkov counter for particle identification.			
▸ A new underground neutrino detector in Arizona is beginning a search for neutrino oscillations using the Palo Verde nuclear power reactors as the source of neutrinos. If neutrino oscillations are observed, implying neutrinos have mass, there would be a major impact on our understanding of the laws of physics. In FY 2000, the program will be completing its data-taking phase, and analysis will be underway.	13,180	12,485	14,162
Total, University Research	16,080	17,085	15,662

(dollars in thousands)

FY 1998	FY 1999	FY 2000

National Laboratory Research

Included is: (1) the research supported at the Thomas Jefferson National Accelerator Facility, which houses the Nation's new and unique high intensity continuous wave electron accelerator and (2) research efforts at Argonne, Brookhaven, and Los Alamos National Laboratories. The National Laboratory groups carry out research at various world facilities as well as at their home institutions

- **TJNAF Research:**
  - Scientists at TJNAF, with support of the user community, have completed assembly of new experimental apparatus for Halls A, B, and C. All three experimental Halls are now operational. TJNAF scientists provide experimental support and operate the apparatus 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.
  - Eight experiments have been completed in Hall C. Experimental equipment in Hall A is complete and the experimental program is underway. Four experiments have completed data accumulation in Hall A. The complex large-acceptance spectrometer in Hall B has been completed and the research program is now underway. One experiment has been completed. In FY 2000, the experimental program will run routinely in all three Halls.
  - Capital equipment funding will be provided for assembling and installing polarized electron injector improvements for the accelerator. Capital equipment funds will be used to install ancillary equipment items such as polarized targets for experimental Halls A, B, and C spectrometer systems, complete a major upgrade of the data reduction system to handle massive amounts of raw data, and to continue fabrication of second generation experiments such as a spectrometer that is designed to investigate the strange quark content of the proton. 5,600 5,600 5,700

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Other National Laboratory Research:**			
▸ Argonne National Laboratory scientists are pursuing research programs at TJNAF, at the DESY Laboratory in Germany, and have proposed measurements of the quark structure of the nucleon at the new Main Injector at Fermilab. The theme running through this entire effort is the search for a detailed understanding of the internal structure of the nucleon.			
▸ At Brookhaven National Laboratory, scientists at the Alternating Gradient Synchrotron have been working with university researchers on experiments to look at the behavior of strange quarks in nuclei, and other work has been investigating the spectroscopy of strongly interacting particles. These efforts involve large detectors which were recently moved from Los Alamos and the Stanford Linear Accelerator Center. In FY 2000, efforts involving analysis of data obtained in prior years will be supported. The AGS will be primarily utilized as an injector for the new Relativistic Heavy Ion Collider (RHIC).			
▸ Also at Brookhaven, Laser Electron Gamma Source (LEGS) scientists are developing a new spectrometer and polarized target for a new program of spin physics. This unique facility produces its high energy polarized "gammas" by back scattering laser light from the circulating electron beam at the National Synchrotron Light Source (NSLS). In FY 2000, the research program utilizing the new equipment, will be fully underway.			
▸ At Los Alamos National Laboratory, scientists and collaborators may continue to carry out highly interesting but controversial measurements in search of neutrino oscillations. If oscillations are found, then neutrinos would have mass, in disagreement with our present understanding of the laws of physics.			
▸ Los Alamos National Laboratory scientists and collaborators are also developing detectors for the Relativistic Heavy Ion Collider which will enable use of polarized protons and which builds upon an experiment to measure the quark structure of the proton at Fermilab. . .	14,113	14,524	14,285
Total, National Laboratory Research	19,713	20,124	19,985

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
Other Research			
■ **SBIR/STTR:** Amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs and other established obligations which the Medium Energy Nuclear Physics subprogram must meet.			
▸ In FY 1998 $4,165,000 and $340,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	987	6,064	5,748
Total, Research	36,780	43,273	41,395

Operations

TJNAF Operations

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

■ **TJNAF Accelerator Operations:**

▸ The accelerator is now capable of delivering beams of differing energies and currents simultaneously to the three experimental halls. Polarized beam capability is now also available and is being used for experiments.

(hours of beam for research)

	FY 1998	FY 1999	FY 2000
TJNAF	4,500	4,500	4,500

▸ AIP funding will provide for polarized injector and beam handling components which enable simultaneous polarized beam capability with varied operating parameters in the three experimental halls. AIP funding also supports other additions and modifications to the accelerator facilities. GPP funding is provided for minor new construction and utility systems. 39,755 41,200 43,360

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
■ **TJNAF Experimental Support:**			
▸ Support is provided for the scientific and technical manpower, materials, and services needed to integrate rapid assembly, modification, and disassembly of large and complex experiments for optimization of schedules. This includes the delivery or dismantling of cryogenic systems, electricity, water for cooling, radiation shielding, and special equipment for specific experiments.	22,965	22,970	23,875
Total, TJNAF Operations	62,720	64,170	67,235

Bates Operations

■ Funding is provided to support accelerator operations at the MIT/Bates Linear Accelerator Center.

▸ Bates operations will terminate in FY 2000. Funding is provided for Decommissioning and Decontamination activities.

(hours of beam for research)

	FY 1998	FY 1999	FY 2000
Bates	2,000	1,000	0

▸ Accelerator operations in FY 1998 provided beams for the research programs in the North and South Halls, for testing of internal continuous beams in the South Hall Ring, and for development of extracted continuous beams for delivery to the existing South Hall spectrometers.

▸ AIP funding has supported additions and modifications to the accelerator facilities; GPP funding has provided for minor new construction and utility systems. No AIP/GPP will be provided in FY 2000. . . . . 13,550 10,800 2,500

Other Operations

■ This category includes facility operations funding at other facilities when the importance of the science justifies the partial support of another research facility.

▸ No operations support of other facilities is planned in FY 2000. . . . . 350 300 0

Total, Operations	76,620	75,270	69,735
Total, Medium Energy Nuclear Physics	113,400	118,543	111,130

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Research	
■ **University Research**	
▸ Since Bates facility operations will be terminated in FY 2000, Bates research has been reduced allowing for completion of data analysis only. MIT scientists will transition to other nuclear physics facilities	-3,100
▸ Other university research is increased by the addition of part of the Bates research funds, since a number of the MIT scientists will transfer their research efforts to other facilities.	+1,677
Total, University Research	-1,423
■ **National Laboratory Research**	
▸ TJNAF research support is increased to maintain level of TJNAF scientists in experimental research.	+100
▸ Other National Laboratory research is slightly reduced	-239
Total, National Laboratory Research	-139
■ **Other Research**	
▸ Estimated SBIR/STTR obligations decrease slightly.	-316
Total Research	-1,878
Operations	
■ **TJNAF Operations**	
▸ Funding for the Thomas Jefferson National Accelerator Facility operations is increased to cover increased cost of experiments and cost of living increases.	+2,160
▸ TJNAF experimental support is increased to provide more effective and efficient experimental setup and disassembly to improve scientific output.	+905
Total, TJNAF Operations	+3,065
■ **Bates Operations**	
▸ The MIT/Bates Linear Accelerator Center will cease operations. All planned Capital Equipment, AIP, and GPP funding has been eliminated	-8,300
■ **Other Operations**	
▸ No operations support of other facilities is expected in FY 2000.	-300
Total, Operations	-5,535
Total Funding Change, Medium Energy Nuclear Physics	-7,413

Heavy Ion Nuclear Physics

Mission Supporting Goals and Objectives

The Heavy Ion Nuclear Physics subprogram supports research directed at understanding the properties of atomic nuclei and nuclear matter over the wide range of conditions created in nucleus-nucleus collisions. Using beams of accelerated heavy ions at low bombarding energies, research is focused on the study of the structure of nuclei which are only gently excited (cool nuclear matter), but taken to their limits of deformation and isotopic stability. With higher energy heavy-ion beams it is possible to study highly excited nuclei (warm nuclear matter) which, when sufficiently heated, are expected to vaporize in a process analogous to the liquid-gas phase transition of heated water. At relativistic bombarding energies the properties of hot**,** dense nuclear matter are studied with a goal of observing the deconfinement of normal matter into a form of matter, a quark-gluon plasma, which is believed to have existed in the early phase of the universe, a millionth of a second after the Big Bang.

Scientists and students at universities and national laboratories are funded to carry out this research on Department of Energy (DOE) supported facilities, as well as on National Science Foundation (NSF) and foreign supported accelerator facilities. The Heavy Ion Nuclear Physics subprogram supports and maintains accelerator facilities located at two universities (Texas A&M and Yale) and three National Laboratories (Argonne, Brookhaven and Berkeley) for these studies. The Relativistic Heavy Ion Collider (RHIC), under construction at Brookhaven National Laboratory since FY 1991, is scheduled to begin operations in the 4th Quarter of FY 1999, initiating a high-priority research program addressing fundamental questions about the nature of nuclear matter. In FY 2000 resources will be directed towards initiating RHIC's research program in its first full year of operation. All the National Laboratory facilities are utilized by DOE, NSF and foreign supported researchers whose experiments undergo peer review prior to approval for beam time. 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 experimental facilities to maintain and improve the reliability and efficiency of operations, and to provide new experimental capabilities. The Heavy Ion Nuclear Physics subprogram also provides General Purpose Equipment (GPE) and General Plant Project (GPP) funds, for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems, for the Brookhaven National Laboratory (BNL) as part of Nuclear Physics' landlord responsibilities for this laboratory.

Performance Measures

- Nuclear Physics will begin the research program at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) in FY 2000.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Research					
University Research	17,197	16,685	16,965	+280	+1.7%
National Laboratory Research	35,178	38,425	33,450	-4,975	-12.9%
Other Research	86	2,505	2,808	+303	+12.1%
Subtotal, Research	52,461	57,615	53,223	-4,392	-7.6%
Operations					
RHIC Operations	25,520	74,800	106,100	+31,300	+41.8%
National Laboratory Facility Operations	10,805	12,542	13,127	+585	+4.7%
Other Operations	5,950	5,450	9,360	+3,910	+71.7%
Subtotal, Operations	42,275	92,792	128,587	+35,795	+38.6%
Total, Heavy Ion Nuclear Physics	94,736	150,407	181,810	+31,403	+20.9%

Detailed Program Justifications

(dollars in thousands)

FY 1998	FY 1999	FY 2000

Research

University Research

Support is provided for the research of scientists and students from over 30 universities.

- Research using relativistic heavy ion beams, involving about two-thirds of the university scientists supported by the Heavy Ion program, is focused on the study of the production and properties of hot, dense nuclear matter with priorities on the initial experiments at RHIC where an entirely new regime of nuclear matter will become available for study for the first time. University researchers are involved in all aspects (construction, installation and operation) of the four detector systems (STAR, PHENIX, BRAHMS, and PHOBOS) at RHIC.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ Research using low energy heavy ion beams, involving about a third of the university scientists, is focused on the study of the structure of nuclei with priorities on studies of highly excited nuclear systems, properties of unstable nuclear systems near the limits where protons and neutrons become unbound and reactions involving unstable nuclei that are of particular importance in nuclear astrophysics. These studies utilize the Gammasphere and Fragment Mass Analyzer Detectors with beams from the ATLAS and 88-inch Cyclotron facilities and complementary studies using the smaller university facilities (Yale and Texas A&M) whose in-house research programs also include an emphasis on student training.	17,197	16,685	16,965
National Laboratory Research			
Support is provided for the research programs of scientists at five National Laboratories (ANL, BNL, LBNL, LANL and ORNL).			
■ **BNL RHIC Research:** Laboratory researchers at BNL play a major role in planning and carrying out the research on the four experiments (STAR, PHENIX, BRAHMS and PHOBOS) at RHIC and have major responsibilities for maintaining, improving and developing this instrumentation for use by the user community. Activities will be focused on initiating a research program in the first full year of RHIC operations. FY 2000 will be a critical year involving continued integration of many different subsystems in the four RHIC detectors to facilitate the beginning of studies of the expected new forms of nuclear matter that will be created in heavy ion collisions at RHIC. The priority for the capital equipment included in this funding is on additional experimental equipment for RHIC, (see Major Items of Equipment) which includes a start in FY 2000 of the Electromagnetic Calorimeter enhancement for STAR whose preliminary TEC is about $5 million. This has been recommended in a NSAC review as important to enhance the physics objectives of the RHIC program. Included are funds for computing for off-line analysis, and enhancements to the baseline STAR and PHENIX detectors that address new physics.	15,247	17,870	12,400

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Other National Laboratory Research:** Laboratory researchers associated with accelerator facilities at ANL (ATLAS) and LBNL (88-inch Cyclotron) have major responsibilities for maintaining, improving and developing instrumentation for use by the user community at their facilities, as well as playing important roles in carrying out research that address the Program's priorities. Activities will be focused on studies of the properties of short-lived nuclei using specialized instrumentation, studies of nuclear structure with Gammasphere and R&D efforts for the proposed next generation Isotopic Separation On-Line (ISOL) facility for radioactive beams. Researchers at LANL, LBNL, and ORNL will utilize their laboratory competencies in undertaking R&D, management and construction responsibilities for major initiatives such as RHIC detectors (e.g., STAR and PHENIX) and play leadership roles in carrying out research utilizing them. Activities will be focused on initiating a research program in the first full year of RHIC operations. The priorities for capital equipment in this funding are for support for the ongoing research activities at the supported accelerator facilities.	19,931	20,555	21,050
Total, National Laboratory Research	35,178	38,425	33,450

Other Research

■ Amounts shown are the estimated requirements for the continuation of the SBIR and STTR programs and other established obligations. In FY 1998 $695,000 was transferred to the SBIR program. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	86	2,505	2,808
Total, Heavy Ion Nuclear Physics Research	52,461	57,615	53,223

Operations

RHIC Operations

■ The RHIC Project is scheduled to be completed in the 3rd Quarter with commissioning operations beginning in the 4th Quarter of FY 1999. RHIC will be a unique facility whose colliding relativistic heavy ion beams will permit exploration of hot, dense nuclear matter and recreate the transition from

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
quarks to nucleons which characterized the early evolution of the universe. Studies with colliding heavy ion beams will provide researchers with their first laboratory opportunity to explore this new regime of nuclear matter and nuclear interactions which up to now has only been studied theoretically.			
▸ **RHIC/AGS Accelerator Operations:** Support is provided for the operation, maintenance, improvement and enhancement of the RHIC accelerator complex. The RHIC complex includes the Tandem/AGS facility whose fixed-target heavy-ion research program will be terminated in FY 2000 and which will serve as the injector for RHIC. RHIC will begin its first full year of operations with a 33 week running schedule and the goal of 22 weeks (3,300 hours) for research and 11 weeks for accelerator studies. .	25,520	66,800	76,675

(hours of beam for research)

	FY 1998	FY 1999	FY 2000
AGS	672	0	0
RHIC	0	500	3,300

▸ **RHIC Experimental Support:** 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. RHIC will initiate its research program in FY 2000 with four experimental detectors (STAR, PHENIX, BRAHMS and PHOBOS). Approximately 1,000 scientists and students from 81 institutions and 15 countries will participate in the research programs of these four experiments.	0	8,000	29,425
Total, RHIC Operations	25,520	74,800	106,100

National Laboratory Facility Operations

Support is provided for two National User Facilities: the ATLAS facility at ANL and the 88-inch Cyclotron facility at LBNL for studies of nuclear reactions, structure and fundamental interactions.

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
▸ Support is provided for the operation, maintenance, improvement and enhancement of the ATLAS and 88-inch Cyclotron accelerator facilities. FY 2000 ATLAS and 88-inch operations funding (and beam hours shown below) reflect the move of the Gammasphere program back to the 88-inch Cyclotron and the continued development of radioactive beam capabilities at ATLAS. These facilities are planned to provide yearly hours of beam for research as indicated below. In FY 2000 each facility will carry out about 40 experiments conducted by about 270 researchers.			

(hours of beam for research)

	FY 1998	FY 1999	FY 2000
ATLAS	5,700	5,700	5,300
88-inch Cyclotron	4,500	4,500	5,500

▸ Accelerator Improvement Project (AIP) funds and capital equipment are provided for the maintenance and upgrade of these facilities.	10,805	12,542	13,127

Other Operations

■ **GPP/GPE:** GPP funding will be provided for minor new construction, other capital alterations and additions, and for buildings and utility systems at Brookhaven National Laboratory (BNL). 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. Since it is difficult to detail this type of project in advance, a continuing evaluation of requirements and priorities may result in additions, deletions, and changes in the currently planned projects. The total estimated cost of each project will not exceed $5,000,000. In addition, the program has landlord responsibility for providing general purpose equipment (GPE) at BNL.	5,950	5,450	9,360
Total, Operations	42,275	92,792	128,587
Total, Heavy Ion Nuclear Physics	94,736	150,407	181,810

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Research	
■ **University Research**	
▸ FY 2000 funding for University Research provides for almost constant effort compared to FY 1999 for research and educational activities.	+280
■ **National Laboratory Research**	
▸ The $3,000,000 of FY 1999 funding provided for experimental support for RHIC detector and computer efforts is shifted in FY 2000 to RHIC Experimental Support Operations. The plans made early in the project to procure computing equipment just prior to operations to secure the most powerful and up-to-date system at the lowest cost, are on schedule. In FY 2000 about $2,500,000 of the capital equipment funding provided in FY 1999 for RHIC computing and experimental equipment projects which expand RHIC scientific capabilities are shifted to RHIC Experimental Support Operations. The buildup of scientific and technical support and infrastructure needed for the RHIC detectors when they become operational in FY 2000, was supported in research in the years preceding the start of RHIC operations. This manpower and infrastructure belongs in RHIC Experimental Support and Operations in FY 2000. FY 2000 operating funding for research at National Laboratories other than BNL is up about $500,000 when compared with FY 1999 and distributed with emphasis on enhanced support for R&D efforts directed towards issues relevant to the proposed ISOL facility for radioactive beams.	-4,975
■ **Other Research**	
▸ Estimated funding for SBIR and other obligations increases from FY 1999. . . .	+303
Total, Research	-4,392
Operations	
■ **RHIC Operations**	
▸ First full year of RHIC operations commences. FY 1999 RHIC Construction funds of $16,620,000 are redirected to Operations. Approximately $5,500,000 of funds provided in FY 1999 to BNL RHIC Research for experimental support activities in preparation of start of RHIC Operations are transferred in FY 2000 to RHIC Operations. The FY 2000 funding provides for an estimated 33 week running schedule	+31,300

	FY 2000 vs. FY 1999 ($000)
■ **National Laboratory Facility Operations**	
▸ In FY 2000 funding for operations of the 88-Inch Cyclotron facility is increased to provide more beam hours for Gammasphere after its arrival from ATLAS. ATLAS operation will be slightly less than the FY 1999 level of effort.	+585
■ **Other Operations**	
▸ With the beginning of RHIC operations the program assumes landlord responsibility for providing general plant projects (GPP) and general purpose equipment (GPE) at BNL and ceases these responsibilities at LBNL.	+3,910
Total, Operations	+35,795
Total Funding Change, Heavy Ion Nuclear Physics	+31,403

Low Energy Nuclear Physics

Mission Supporting Goals and Objectives

The Low Energy Nuclear Physics subprogram supports research directed at addressing issues in nuclear astrophysics, the understanding of the behavior of nucleons at the surface of the nucleus as well as the collective behavior of the entire ensemble of nucleons acting in concert; nuclear reaction mechanisms; and experimental tests of fundamental symmetries. Part of this work can often be accomplished without the use of accelerators. The study of neutrinos from the sun, whose rate of production is not understood, is an example. University-based research is an important feature of the Low Energy subprogram. Since most of the required facilities are relatively small, they are appropriate for siting on university campuses, where they provide unique opportunities for hands-on training of nuclear experimentalists who are so important to the future of this 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. Included in this subprogram are the activities of the National Nuclear Data Center and its support sites 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.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
University Research	9,447	9,810	10,050	+240	+2.4%
National Laboratory Research	8,468	8,770	8,725	-45	-0.5%
Nuclear Data	5,096	4,900	5,000	+100	+2.0%
RIB Operations	8,840	8,630	9,250	+620	+7.2%
Other	21	1,115	1,145	+30	+2.7%
Total, Low Energy Nuclear Physics	31,872	33,225	34,170	+945	+2.8%

Detailed Program Justifications

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
University Research			
■ The three main components of research at universities in this subprogram are nuclear astrophysics, fundamental interactions in nuclei, and the structure of nuclei. The support level for this activity is determined by juxtaposing the peer review assessment of the worth and priority of the project with the researchers request for the number of graduate students, postdoctoral fellows, other staff and necessary items to complete the proposed work.			
■ Two university accelerators are supported in Low Energy: the University of Washington, Nuclear Physics Laboratory (NPL), and the Triangle Universities Nuclear Laboratory (TUNL) facility at Duke University. These small university facilities fit within the low energy program by providing a source of light ion and neutron physics beams. Long term measurements of a detailed nature are possible at these dedicated facilities and they are used to make measurements that address questions of a fundamental physics nature.			
■ University scientists perform research at on-site facilities, as user groups at National Laboratory facilities, and at the Sudbury Neutrino Observatory (SNO). These activities address fundamental issues essential to the long term goal of understanding the production and constituents of stars.	9,447	9,810	10,050
National Laboratory Research			
■ **Radioactive Ion Beam Facility Research:**			
▸ The RIB facility will focus mainly on nuclear astrophysics problems bearing on the creation of the elements and nuclear properties with extreme proton/neutron ratios.			
▸ Installation of the Daresbury Recoil Separator, a $2,000,000 device contributed by the United Kingdom, allows separation of the products of nuclear reactions from particles a trillion times more intense, enabling the measurement of nuclear reactions that fuel the explosion of stars.			
▸ Capital equipment funds are provided to expand the list of available beam species.			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
▸ There will be an increased level of effort dedicated to research and development leading to an advanced RIB facility.	5,313	4,615	5,400
■ **Other National Laboratory Research:**			
▸ In a major effort to study the processes that control our sun, the Sudbury Neutrino Observatory (SNO) was created. This observatory consists of a 40 foot diameter plastic (acrylic) vessel that holds 1,000 tons of heavy water that is the solar neutrino detector. The SNO laboratory is located 6,800 feet underground. The detector water fill will be completed in FY 1999 and data taking will start. The level of SNO support at the national laboratories is at a continuing level of effort that allows the systematic and efficient collection and analysis of data.			
▸ The research that follows after the completion of filling the tank will determine whether the observed dearth of solar neutrinos results from unexpected properties of the sun, or whether it results from a fundamental new property of neutrinos—namely that neutrinos produced in radioactive decay change their nature during the time it takes them to reach the earth from the sun.			
▸ Capital equipment funds were used to construct and transport special rare gas Helium-3 neutron counters (800m total length) to their underground storage in the ultra low cosmic ray background environment of the SNO mine. They are being stored for a period of time which is sufficient to allow decay to low levels of the radioactivity induced in the detectors by the above ground cosmic ray background.	3,155	4,155	3,325
Total, National Laboratory Research	8,468	8,770	8,725

Nuclear Data

- This is a service function of the Nuclear Physics program which collects, evaluates, stores, and disseminates nuclear information. Its single national and international center point is the United States National Nuclear Data Center (US-NNDC) at Brookhaven National Laboratory. The level of effort is at an ongoing level and was peer reviewed by a panel of experts that addressed the activity level.

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
■ The NNDC uses a network of individual nuclear data professionals located in universities and at other national laboratories who assist in assessing data as well as developing new novel, user friendly electronic network capabilities.			
■ The U.S. Nuclear Data Network (USNDN), a collaboration of DOE supported nuclear data scientists, reports to and supports the NNDC in data evaluation and development of on-line access capabilities.			
■ After completion of a review, a new activity, jointly supported with the Nuclear Physics research community, was established in order to serve the nuclear astrophysics community. This will be a joint activity between the US-NNDC and a consortium of researchers and data scientists. This new project, whose level of activity was established by user demand and input, will be an ongoing activity of the Data program.	5,096	4,900	5,000

RIB Operations

■ The RIB facility is planned to provide beam hours for research as indicated below:

(hours of beam for research)

	FY 1998	FY 1999	FY 2000
RIB	2,200	2,400	2,400

■ Research at the Oak Ridge Electron Linear Accelerator (ORELA), which is also operated by RIB staff, is aimed at resolving discrepancies in the rate of production of primordial elements compared with theoretical predictions, such as models that predict the formation of heavy elements like carbon, nitrogen, and oxygen in the Big Bang.			
■ This technically difficult project, which couples the existing cyclotron and tandem accelerators, was fully operational in FY 1998, and now is operating with radioactive ion beams of arsenic and fluorine as well as beams of Nickel-56.	8,840	8,630	9,250

Other

■ Amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs. The Lawrence and Fermi Awards which are funded under this line, provide annual monetary awards to honorees selected by the Department of Energy for their outstanding contributions to nuclear science.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **SBIR/STTR:** In FY 1998 $800,000 was transferred to the SBIR program. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	21	1,115	1,145
Total, Low Energy Nuclear Physics	31,872	33,225	34,170

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ **University Research**	
▸ Research associated with RIB experiments and nuclear astrophysics research activities will increase while SNO construction activities will be completed. . . .	+240
■ **National Laboratory Research**	
▸ Increased research in high priority nuclear astrophysics measurements will replace a diminished activity in solar neutrino research.	-45
■ **Nuclear Data**	
▸ Support will increase for activities to provide data and services on-line to replace data and services previously supplied in hard copy.	+100
■ **RIB Operations**	
▸ RIB operations will be maintained with a cost-of-living increase thereby providing a constant amount of beam time.	+620
■ **Other**	
▸ Estimated FY 2000 funds for SBIR increase compared to FY 1999.	+30
Total Funding Change, Low Energy Nuclear Physics	+945

Nuclear Theory

Mission Supporting Goals and Objectives

Theoretical Nuclear Physics is a program of fundamental scientific research that provides new insight into the observed behavior of atomic nuclei. From continuing interaction with experimentalists and experimental data, solvable mathematical models are developed which describe observed nuclear properties, and the predictions of the models are tested with further experiments. From this process evolves a deeper understanding of the nucleus. Traditionally, there are two generic types of nuclear models: (1) microscopic models where the nucleus is viewed as a system of interacting discrete protons and neutrons, and (2) collective models where the nucleus is treated as a drop of fluid. With the establishment of the Quantum Chromodynamics and the standard model, the ultimate goal of nuclear theory now is to understand nuclear models, and hence nuclei, in terms of quarks and gluons. An area of increasing interest recently is in nuclear astrophysics-topics such as supernova explosions, nucleosynthesis of the elements, and the properties of neutrinos from the sun.

The Nuclear Theory program supports all areas of nuclear physics, and is carried out at universities and National Laboratories. Some of the investigations depend crucially on access to forefront computing, and to the development of efficient algorithms to use these forefront devices. Components of the program are selected primarily on the basis of peer review by internationally recognized experts. A very significant component of the program is the Institute for Nuclear Theory (INT), where there is an ongoing series of special topic programs and workshops. The Institute is a seedbed for new collaborations, ideas, and directions in nuclear physics.

Significant progress has been made in the past year. Three examples of particular accomplishments in that period are: (1) University theorists made a significant step forward in our understanding of how and where the heavier elements observed in nature were originally produced, producing strong evidence that they were produced in neutron rich gas at the core of supernova explosions. (2) Theorists at universities and the national laboratories, in several collaborative efforts, have developed increasingly sophisticated models of the reactions between ultra relativistic heavy ions, such as will be produced in the soon to be operating Relativistic Heavy Ion Collider facility at the Brookhaven National Laboratory. In the past year, several new and potentially clear signals of the creation of the quark-gluon plasma in such collisions were suggested by these models. (3) Recently, national laboratory theorists have found, quite unexpectedly, that effects due to special relativity can explain a symmetry in the low lying states of nuclei that is observed in a large number of nuclei, but for which there was previously no satisfactory explanation.

The program is greatly enhanced through interactions with complementary programs overseas and those supported by the National Science Foundation. Many foreign theorists participate on advisory groups and as peer reviewers. There is large participation in the INT by researchers from Europe and Japan.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
University Research	9,974	10,464	10,510	+46	+0.4%
National Laboratory Research	5,356	5,296	5,320	+24	+0.5%
Total, Nuclear Theory	15,330	15,760	15,830	+70	+0.4%

Detailed Program Justifications

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
University Research			
■ Research is conducted through individual grants to faculty at roughly 50 universities.			
■ The range of topics studied through these grants is broad, and each of the active areas of experimental nuclear physics is supported by at least some of the nuclear theory grants.			
■ The overall character of the research program evolves with time to reflect changes in the overall nuclear physics program through redirecting some individual programs, phasing out other programs and starting new programs.			
■ Almost 100 Ph.D. students are supported by the Theory program, the major source of new Ph.D.s in nuclear physics in this country.			
■ The level of effort in this activity has been essentially constant in recent years. The bulk of the funds provided are used for salary support for faculty, postdocs, and students doing thesis research. Thus, a constant level of effort depends on a cost-of-living increase.			
■ The number of nuclear theorists supported in this activity is consistent with the recommendations for manpower levels in the report of the DOE/NSF Nuclear Science Advisory Committee Subcommittee on Nuclear Theory-1988.	9,974	10,464	10,510
National Laboratory Research			
■ Through this activity, small groups of theoretical nuclear physicists are supported at 6 National Laboratories.			
■ 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.			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ In all cases, the nuclear theory research at a given laboratory provides support to the experimental programs at the laboratory, or takes advantage of some unique facilities/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.			
■ The level of effort in this activity has been essentially constant in recent years. The bulk of the funds provided are used for salary support for staff. Thus, a constant level of effort depends on a cost-of-living increase.			
■ The number of nuclear theorists supported in this activity is consistent with the recommendations for manpower levels in the report of the DOE/NSF Nuclear Science Advisory Committee Subcommittee on Nuclear Theory-1988.	5,356	5,296	5,320
Total, Nuclear Theory	15,330	15,760	15,830

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ **University Research**	
▸ Continue program at slightly reduced level of effort, consistent with less than cost-of-living increase in funding.	+46
■ **National Laboratory Research**	
▸ Continue program at slightly reduced level of effort, consistent with less than cost-of-living increase in funding.	+24
Total Funding Change, Nuclear Theory	+70

Capital Operating Expense and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
General Plant Projects	4,610	4,000	5,655	+1,655	+41.4%
Accelerator Improvement Projects	4,200	4,900	3,900	-1,000	-20.4%
Capital Equipment	26,110	29,586	30,355	+769	+2.6%
Total, Capital Operating Expense	34,920	38,486	39,910	+1,424	+3.7%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1998	FY 1999	FY 2000	Accept-ance Date
STAR Silicon Vertex Tracker	7,000	3,450	1,500	1,300	750	FY 2000
PHENIX Muon Arm Instrumentation	11,400	3,375	2,800	2,400	2,525	FY 2001
Analysis System for RHIC Detectors	7,900	775	2,000	3,600	1,525	FY 1999
BLAST Large Acceptance Detector	4,900	400	900	900	0	TBD
STAR EM Calorimeter	TBD [a]	0	0	0	1,800	FY 2002
Total, Major Items of Equipment		8,000	7,200	8,200	6,600	

[a] Preliminary TEC is estimated to be about $5 million.