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 that established the Department. The primary mission of the program is to support the basic research scientists, develop and operate the facilities, and foster the technical and scientific activities needed to understand the structure and interactions of atomic nuclei, and 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 provide advice on scientific opportunities and 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 properties and behavior of atomic nuclei and nuclear matter, and the fundamental forces involved, 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 Office of Science organizations, act as the Nation's leader in developing management techniques to optimize construction and operation of facilities in a cost effective, safe, and environmentally responsible manner.
- Leverage United States objectives by means of international cooperation through exchanges of scientists and participation in 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 capability 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 recognized scientific experts.
- 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 of construction projects for world class nuclear physics facilities and instrumentation. 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.
- Select research projects through a peer-reviewed, 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. Develop appropriate facility funding profiles to best provide overall research productivity for the Nuclear Physics program. Operate research facilities in a manner that meets user requirements as indicated by achieving performance specifications while protecting the safety of the workers and the environment, and by the level of endorsement by user organizations.
- Measure the progress and success of the Nuclear Physics program in responding to priorities and recommendations contained within the long range plan of the DOE/NSF Nuclear Science Advisory Committee (NSAC), as measured by NSAC's evaluation letter to the Nuclear Physics program.
- Continue collaborative efforts with NASA to use beams at Brookhaven National Laboratory to study the effects of radiation on biological and electronic systems in space.
- Complete fabrication of the BLAST detector at MIT/Bates in FY 2001 in accordance with the established baseline and as measured against the detailed project milestones.

Significant Accomplishments and Program Shifts

- In FY 2000, the Nuclear Physics Program initiated an Outstanding Junior Investigator (OJI) program to recognize and support young promising scientists pursuing nuclear physics research.

Medium Energy Nuclear Physics

- In FY 1999, the Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility (TJNAF) provided beams up to 5.5 GeV to all three experimental halls for research with polarized and unpolarized beams. Application of improved conditioning of the accelerator cavities is expected to increase the energy to 6 GeV by FY 2001.
- Precision measurements performed with new world-class polarized electron beams at TJNAF in FY 1999 provide important new insight into the role of the strange quark in determining the fundamental properties of the nucleon.

- An international collaboration (HERMES), involving several US Nuclear Physics Groups, presented results in FY 1999 indicating that gluons are responsible for a significant fraction of the observed spin of the nucleon, based on measurements performed at the DESY accelerator in Germany.
- In FY 1999, over 80 milliamperes of a 660 MeV stored electron beam in the Bates South Hall Ring was directed through a hydrogen internal gas target at the location of the BLAST detector. This was a significant milestone in the development of capabilities for the planned BLAST research program.
- In FY 2001, the BLAST detector at the MIT/Bates Linear Accelerator Center facility will be completed and will initiate commissioning for a research program in FY 2002-2004 studying the structure of the nucleon and few-body nuclei. Upon completion of the BLAST research program in FY 2004, the Bates facility will begin a 2-year phaseout.
- In FY 2001, the Brookhaven Medium Energy Group will be re-directed to emphasize a program directed at understanding the origin of the spin of the proton at the new RHIC facility. A limited program of fixed target experiments will be supported at the AGS.

Heavy Ion Nuclear Physics

- In FY 1999, the following performance goal was fully met:
  - Complete construction and begin operation of the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory.
- In FY 1999, the Relativistic Heavy Ion Collider (RHIC) construction project at Brookhaven National Laboratory (BNL) was completed on schedule and within budget. In FY 2001, RHIC will approach full luminosity following initial operation in FY 2000. Fabrication of detectors, including the additional experimental equipment recommended by NSAC for purposes of particle detection and data analysis, will be largely completed, as scheduled. Four experiments (STAR, PHENIX, BRAHMS and PHOBOS) involving over 950 researchers and students from 90 institutions and 19 countries will pursue a vigorous research program.
- In FY 1999, observations of two new elements (Z=116 and 118) were reported in measurements performed at the LBNL 88-Inch Cyclotron using the Berkeley Gas-filled Spectrometer (BGS). Continued measurements are planned for FY 2000 and FY 2001.
- In FY 1999, the NSAC Isotope Separation On-Line (ISOL) Task Force, identified an optimal configuration for a next generation Rare Isotope Accelerator (RIA). RIA is a facility where short-lived nuclei (with lifetimes of greater than a thousandth of a second) are produced in nuclear reactions using intense beams of stable nuclei, then extracted and accelerated in a post-accelerator to be used in experiments. RIA would provide unique, world-class capabilities for the low energy, nuclear astrophysics and nuclear structure communities for several decades. R&D and preconceptual design activities will continue in FY 2000 and FY 2001.
- In FY 1999, Gammasphere coupled with the Fragment Mass Separator at the ANL ATLAS facility, provided surprising results on the structure of the Nobelium isotope (^{254}No) showing that nuclear shell structures, which are entirely responsible for the stability of nuclei with charges greater than 100, persist up to very high deformation.
- In FY 2000, Gammasphere will be moved from the ANL ATLAS facility to the LBNL 88-Inch Cyclotron facility for a research program that will utilize the capabilities of the 88-Inch Cyclotron.
- Measurements performed in FY 1999 at the ATLAS facility have established properties of nuclei and reaction processes that allow for more stringent tests of models for supernova collapses and improved predictions for chemical element production in stellar burning and supernovae.

- In FY 1999, researchers at the Texas A&M Cyclotron facility developed a new method for establishing very low energy proton capture cross sections that are critical to astrophysical modeling of the production of the chemical elements of our universe. This is expected to lead to significantly improved astrophysics predictions.

Low Energy Nuclear Physics

- The US/Canadian Sudbury Neutrino Observatory (SNO) detector was completed and initiated data taking in FY 1999. Initial results, of measurements of solar neutrinos fluxes relevant to the question of whether neutrinos have mass, are anticipated in FY 2001.
- In FY 1999, the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL) completed a series of experiments that provide input to refined astrophysical calculations for the breakout from the Carbon-Nitrogen-Oxygen (CNO) cycle responsible for element production beyond oxygen. An expanded series of measurements will be carried out in FY 2000-2001 as new beam species are developed and beam intensities increase.
- In FY 1999, at the ORNL Oak Ridge Electron Linear Accelerator (ORELA) facility, precision measurements of neutron capture cross sections on Neodymium and Barium isotopes have provided the critical data necessary to use precision meteorite abundance results to test the new astrophysical Red Giant Stardust Model for heavy element production.

Nuclear Theory

- University theorists made a significant step forward in our understanding of how and where the heavier elements observed in nature were originally produced with strong evidence that they were created in neutron rich gas at the core of supernova explosions.
- 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 Relativistic Heavy Ion Collider facility at the Brookhaven National Laboratory. In the past year, several new and potentially clear signals indicative of the creation of the quark-gluon plasma in such collisions were suggested by these models.
- 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.
- In FY 2001, 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 $250,180,000 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 $88,000 for estimated contractor security clearances in FY 2000 and FY 2001; respectively, within this decision unit.

Workforce Development

The Nuclear Physics program supports development of the 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 not only provides new scientific talent in areas of fundamental research, but also in a wide variety of technical, medical, and industrial areas requiring the finely honed thinking and problem solving abilities and 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 hospitals (nuclear medicine and medical physics), space exploration, and the stock market.

The 814 post-doctoral Associates and graduate students supported by the Nuclear Physics program in FY 1999 were involved in a large variety of experimental and theoretical research. Nearly one third 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 510 postdoctoral associates and graduate students doing experimental research in FY 1999 did their work at the six Nuclear Physics Scientific User Facilities: ATLAS (ANL), 88-Inch Cyclotron (LBNL), HRIBF (ORNL), Bates Accelerator Center (MIT), RHIC (BNL), and Jefferson Lab (TJNAF in Virginia).

Funding Profile

(dollars in thousands)

	FY 1999 Current Appropriation	FY 2000 Original Appropriation	FY 2000 Adjustments	FY 2000 Current Appropriation	FY 2001 Request
Nuclear Physics					
Medium Energy Nuclear Physics	115,695	121,250	-2,400	118,850	125,405
Heavy Ion Nuclear Physics	146,905	180,775	-1,365	179,410	192,360
Low Energy Nuclear Physics	32,308	34,145	-366	33,779	33,970
Nuclear Theory	15,640	15,830	-155	15,675	18,155
Subtotal, Nuclear Physics	310,548	352,000	-4,286	347,714	369,890
Construction	16,620	0	0	0	0
Subtotal, Nuclear Physics	327,168	352,000	-4,286	347,714	369,890
Use of Prior Year Balances	-776[a]	0	0	0	0
General Reduction	0	-2,407	2,407	0	0
Contractor Travel	0	-695	695	0	0
Omnibus Rescission	0	-1,184	1,184	0	0
Total, Nuclear Physics	326,392[b]	347,714	0	347,714	369,890[c]

Public Law Authorization:

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

Public Law 103-62, “Government Performance Results Act of 1993”

[a] 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.

[b] Excludes $6,969,000 that has been transferred to the SBIR program and $418,000 which has been transferred to the STTR program.

[c] Includes $5,957,000 for Waste Management activities at Brookhaven National Laboratory that was previously budgeted in FY 1999 and FY 2000 in the Environmental Management program.

Funding by Site

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	10,505	9,986	10,095	+109	+1.1%
Chicago Operations Office					
Argonne National Laboratory	17,039	16,304	16,965	+661	+4.1%
Brookhaven National Laboratory	117,305	132,463	145,783	+13,320	+10.1%
Chicago Operations Office	52,218	48,507	50,016	+1,509	+3.1%
Total, Chicago Operations Office	186,562	197,274	212,764	+15,490	+7.9%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	80	0	0	0	0.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	23,222	17,232	17,250	+18	+0.1%
Lawrence Livermore National Laboratory	710	564	785	+221	+39.2%
Oakland Operations Office	14,425	16,246	16,283	+37	+0.2%
Total, Oakland Operations Office	38,357	34,042	34,318	+276	+0.8%
Oak Ridge Operations Office					
Oak Ridge Institute for Science & Education	585	559	650	+91	+16.3%
Oak Ridge National Laboratory	16,094	15,173	16,120	+947	+6.2%
Thomas Jefferson National Accelerator Facility	71,673	72,730	74,715	+1,985	+2.7%
Oak Ridge Operations Office	123	81	64	-17	-21.0%
Total, Oak Ridge Operations Office	88,475	88,543	91,549	+3,006	+3.4%
Richland Operations Office					
Richland Operations Office	1,900	0	0	0	0.0%
Washington Headquarters	1,289	17,869	21,164	+3,295	+18.4%
Subtotal, Nuclear Physics	327,168	347,714	369,890	+22,176	+6.4%
Use of Prior Year Balances	-776[a]	0	0	0	0.0%
Total, Nuclear Physics	326,392[b]	347,714	369,890[c]	+22,176	+6.4%

[a] 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.

[b] Excludes $6,969,000 that has been transferred to the SBIR program and $418,000 which has been transferred to the STTR program.

[c] Includes $5,957,000 for Waste Management activities at Brookhaven National that was previously budgeted in FY 1999 and FY 2000 in the Environmental Management program.

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. 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 advanced Rare Isotope Accelerator (RIA) facility; (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 Tandem, Booster and Alternating Gradient Synchrotron (AGS) accelerators in combination as an injector. The RHIC facility 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 program will use polarized protons in RHIC to understand the internal "spin" structure of the protons and pursue a limited program of fixed target experiments at 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's DOE-managed National Nuclear Data Center is the central U.S. site for the American and international nuclear data and compilation effort.

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, the program of nuclear data and compilation directly supported by the Nuclear Physics program, has been phased out.

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 primarily at RHIC, where they have been major players in the development of the large STAR detector; (3) the Low Energy group, which plays a major role in the implementation and operation 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 nuclear structure studies carried out primarily at the GENIE detector at the LANSCE facility at Los Alamos National Laboratory, and for nuclear data and compilation activities.

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 which 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 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 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), which is run as a national user facility. HRIBF allows a program of experimental research in nuclear structure and reaction processes important for astrophysics. Also supported is a relativistic heavy ion group which is involved in a research program using the PHENIX detector at RHIC. The theoretical nuclear physics effort at ORNL emphasizes investigations of nuclear structure and astrophysics. Nuclear data and compilation activities are also supported as part of the national nuclear data effort.

Thomas Jefferson National Accelerator Facility (TJNAF)

Thomas Jefferson National Accelerator Facility (TJNAF) 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 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 160 research grants at 87 colleges/universities located in 35 states. Also included are funds for 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 fundamental research that is ultimately aimed at achieving an understanding of the structure of the atomic nucleus in terms of the quarks and gluons, the objects that are believed to combine in different ways to make all the other sub-atomic particles. Equally important is the achievement of an understanding of the "strong force;" one of only four forces in nature, and the force that 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, and investigations of how the properties of protons and neutrons change when embedded in the nuclear medium. Measurements are often carried out 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 other indicators of the details of nuclear structure.

This research is generally carried out using higher energy electron and proton beams provided by accelerator facilities operated by this subprogram, other Department of Energy programs (e.g., High Energy Physics and Basic Energy Sciences) and at other unique domestic or foreign facilities. The Medium Energy Nuclear Physics subprogram supports the operations of two national user facilities - the Thomas Jefferson National Accelerator Facility (TJNAF) and the Bates Linear Accelerator Center 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 research program at the new TJNAF, for example, involves over 250 scientists from 19 foreign countries; many 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.

Performance Measures

- Complete fabrication of the BLAST detector at MIT/Bates in accordance with the project milestones.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Research					
University Research	16,729	16,422	16,945	+523	+3.2%
National Laboratory Research	19,649	19,961	20,430	+469	+2.3%
Other Research	399[a]	5,067	5,355	+288	+5.7%
Subtotal, Research	36,777	41,450	42,730	+1,280	+3.1%
Operations					
TJNAF Operations	65,418	66,515	68,400	+1,885	+2.8%
Bates Operations	13,500	10,885	12,775	+1,890	+17.4%
Other Operations	0	0	1,500	+1,500	+100.0%
Subtotal, Operations	78,918	77,400	82,675	+5,275	+6.8%
Total, Medium Energy Nuclear Physics	115,695	118,850	125,405	+6,555	+5.5%

Detailed Program Justification

(dollars in thousands)

FY 1999	FY 2000	FY 2001

Research

University Research

These activities comprise a broad program of research, and include 42 grants at 33 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 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.

Bates Research:

- At the MIT/Bates accelerator, MIT scientists along with other university researchers have completed “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

[a] Excludes $4,059,000 which has been transferred to the SBIR program and $418,000 which has been transferred to the STTR program.

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
Experimental Hall on the proton, deuteron, and complex nuclei including measurements of the transition of the proton to its excited state.			
‣ Preparations are being made for a new program of research utilizing the new BLAST large acceptance detector whose fabrication will be completed in FY 2001. BLAST will be used in conjunction with thin gas targets and the high current circulating electron beam in the South Hall Pulse Stretcher Ring.	4,700	4,500	4,200
Other University Research:			
‣ University scientists are collaborating on important ongoing and future experiments at TJNAF. FY 2001 activities include the completion of studies of the charge structure of the neutron in Hall C, planned measurements include 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 have been completed. Plans are also underway to carry out a program of high resolution hypernuclear spectroscopy in Hall A. Scientists are participating in a major new detector being assembled for the "G0" experiment in cooperation with the National Science Foundation. "G0" 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 Out-of-Plane spectrometers in the South Experimental Hall at the MIT/Bates Linear Accelerator Center. BLAST will be completed in FY 2001 and university research support will be provided.			
‣ University scientists and National Laboratory collaborators will continue to carry out the HERMES experiment at the DESY laboratory in Hamburg, Germany. This experiment is measuring what components of the proton or neutron determine the "spin" of these particles, an important and timely scientific issue. In FY 2001, HERMES will continue to utilize a new Ring Imaging Cerenkov counter for particle identification.			

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
‣ The Palo Verde neutrino detector has been searching for neutrino oscillations using the Palo Verde nuclear power reactors near Phoenix, Arizona as the source of neutrinos. Recent measurements suggesting that such oscillations exist, implying neutrinos have mass, have a major impact on our understanding of the laws of physics. In FY 2001, the experimental program will be complete and data analysis will be underway.	12,029	11,922	12,745
Total, University Research.....	16,729	16,422	16,945

National Laboratory Research

Included is: (1) the research supported at the Thomas Jefferson National Accelerator Facility (TJNAF), that houses the Nation's and World's 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, assembled the large and complex new experimental apparatus for Halls A, B, and C. All three experimental Halls are 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.
- As of FY 2000, twelve experiments will have been completed in Hall C. Ten experiments will have been completed in Hall A. The complex large-acceptance spectrometer in Hall B is complete and the research program is well underway. Three major experiments will have been completed, and partial data will have been accumulated on many more.
- TJNAF scientists are participating in the assembly of a new detector for the "G0" experiment, in cooperation with the National Science Foundation. 5,760 5,680 5,800

(dollars in thousands)

FY 1999	FY 2000	FY 2001

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, the Medium Energy Research group, that in previous years has concentrated on hadron beam experiments at the AGS, will change its emphasis. Since the AGS will now serve as a heavy ion and proton injector for the new RHIC accelerator, the group's scientific emphasis will shift 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. In FY 2001, additional funding is being provided to this group to assure that maximum scientific effort has been assembled in support of the RHIC Spin effort. A limited program of fixed target experiments will continue at the AGS, including an important study of hypernuclei for which the Japanese are major collaborators.
- Also at Brookhaven, Laser Electron Gamma Source (LEGS) scientists will be utilizing a new spectrometer and polarized target for a program of spin physics at low energies. 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 2001, the research program utilizing the new equipment will be fully underway.
- At Los Alamos National Laboratory, scientists and collaborators will be preparing to carry out a next generation neutrino oscillation experiment (BooNE), that builds on the experience of the Liquid Scintillator Neutrino Detector (LSND) experiment at Los Alamos that detected a signal of neutrino oscillations. If oscillations are proven, then neutrinos would have mass, requiring changes in our present understanding of the laws of physics. BooNE will be built at the Fermi

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
National Accelerator Laboratory (Fermilab), and will use neutrinos generated by the proton beam from the Fermilab Booster.			
‣ Los Alamos National Laboratory scientists and collaborators are also developing unique cold and ultra-cold neutron facilities at the Los Alamos Neutron Science Center (LANSCE). Difficult new experiments using these "very low energy" techniques will be supported and promise to provide important new information on some of the fundamental laws of physics.			
‣ Los Alamos scientists will also continue to be involved in experiments at Fermilab and at RHIC (RHIC Spin), that continue to try to unravel the mysteries of the internal components and spin of the nucleon. 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.	13,889	14,281	14,630
Total, National Laboratory Research	19,649	19,961	20,430

Other Research

Other Research: Amounts include funds for the FY 2000 and FY 2001 SBIR and STTR programs and other established obligations which the Medium Energy Nuclear Physics subprogram must meet.

‣ In FY 1999 $4,059,000 and $418,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts include the estimated requirement for the continuation of the SBIR and STTR programs.	399	5,067	5,355
Total, Research	36,777	41,450	42,730

Operations

TJNAF Operations

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.

(dollars in thousands)

FY 1999	FY 2000	FY 2001

TJNAF Accelerator Operations:

- The accelerator is now capable of delivering beams of differing energies and currents simultaneously to the three experimental halls. A maximum beam energy of 5.5 GeV has been delivered to experiments, and by FY 2001, 6 GeV will be readily available. Polarized beam capability is now also available and is being used for experiments.

	(hours of beam)		
	FY 1999	FY 2000	FY 2001
TJNAF.....	4500	4500	4500

- AIP funding will provide for polarized injector and beam handling components that 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..... 41,500 42,405 44,075

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.
- The G0 detector, a major item of equipment with a Total Estimated Cost of $6,992,000 is being assembled. DOE's contribution is $3,387,000 and the National Science Foundation is contributing $3,605,000 to this detector. Capital equipment funding is also being used for assembly and installation of polarized electron injector improvements for the accelerator. Capital equipment funds will be used to install other ancillary equipment items such as polarized targets for experimental Halls A, B, and C, spectrometer systems,

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
complete a major upgrade of the data reduction system to handle massive amounts of raw data, and to continue fabrication of second generation experiments.....	23,918	24,110	24,325
Total, TJNAF Operations	65,418	66,515	68,400

Bates Operations

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

- Bates will operate 2000 hours in FY 2001, to carry out a program of research and for commissioning activities for the BLAST detector. The laboratory will complete fabrication of the new BLAST detector, that will observe collisions in thin gas targets located on the South Hall Pulse Stretcher Ring. When the scientific program of BLAST commences at the end of FY 2001, the Bates research effort will concentrate on this new experimental facility. Upon completion of the BLAST research program in FY 2004, the Bates facility will begin a 2-year phaseout with operating funding reaching a D&D level of $2,500,000 in FY 2006. The total D&D cost and schedule will be determined at that time.

(hours of beam)

	FY 1999	FY 2000	FY 2001
Bates	1000	2000	2000

- Accelerator operations in FY 2001 are providing beams for research programs in the South Hall utilizing the OOPS spectrometers, for testing of internal, polarized, continuous beams in the South Hall Ring, and for development of extracted continuous beams for delivery to the existing South Hall spectrometers.
- AIP funding supports additions and modifications to the accelerator facilities; GPP funding supports minor new construction and utility systems. 13,500 10,885 12,775

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
Other Operations			
Funding is provided to support accelerator operations at other facilities.			
‣ Funding is provided for 600 hours of beam, to carry out a limited program of high priority experiments at the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory including an important study of hypernuclei for which the Japanese made a major investment in detector fabrication.	0	0	1,500
Total, Operations	78,918	77,400	82,675
Total, Medium Energy Nuclear Physics	115,695	118,850	125,405

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Research	
▪ **University Research**	
‣ The MIT/Bates research activity decrease reflects the funding profile of BLAST detector system.	-300
‣ Increase reflects effort to increase support for university scientists involved in research at TJNAF	+823
Total, University Research	+523
▪ **National Laboratory Research**	
‣ TJNAF research is increased to partially maintain level of effort.	+120
‣ Other National Laboratory research is increased to enhance the BNL Medium Energy Group's efforts in the RHIC Spin program, and to support National Laboratory scientists carrying out research at TJNAF.	+349
Total, National Laboratory Research	+469
▪ **Other Research**	
‣ Estimated SBIR/STTR and other obligations increase	+288
Total Research	+1,280

	FY 2001 vs. FY 2000 ($000)
Operations	
▪ **TJNAF Operations**	
‣ Funding for the Thomas Jefferson National Accelerator Facility allows accelerator operations to keep pace with inflation.	+1,670
‣ TJNAF experimental support funding nearly maintains level of effort.	+215
Total, TJNAF Operations	+1,885
▪ **Bates Operations**	
‣ MIT/Bates Linear Accelerator Center operations are being supported to complete a program of research with the Out-of-Plane (OOPS spectrometer system) and to develop the capabilities needed for the research program of the BLAST detector. When the BLAST detector is finished, the research effort will focus on this new detector facility.	+1,890
▪ **Other Operations**	
‣ A limited program of high priority experiments is being supported at the Brookhaven AGS commencing in FY 2001 including an important study of hypernuclei for which the Japanese made a major investment in detector fabrication.	+1,500
Total, Operations	+5,275
Total Funding Change, Medium Energy Nuclear Physics	+6,555

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 that are only gently excited (cool nuclear matter), but taken to their limits of energy, deformation, and isotopic stability. Such studies, as well as those directed at measuring nuclear reaction processes are important in understanding the production of the elements in stellar burning and supernovae. At much higher relativistic bombarding energies, the properties of hot, dense nuclear matter are studied with the 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 at Department of Energy (DOE) supported facilities, as well as at 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 Lawrence Berkeley) for these studies. The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory, with initial production operation in FY 2000, is a unique world-class facility that addresses fundamental questions about the nature of nuclear matter. At the low-energy heavy ion national facilities (ANL-ATLAS and LBNL-88" Cyclotron) an expanded program of R&D and preconceptual design activities will be undertaken in support of a next generation low-energy facility, the Rare Isotope Accelerator (RIA). 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 to Brookhaven National Laboratory (BNL) as part of Nuclear Physics' landlord responsibilities for this laboratory. These funds are for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems. In FY 2001, responsibility for BNL waste management activities has been transferred from the DOE Environmental Management Program (EM) to the Nuclear Physics program.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Research					
University Research	17,507	17,426	17,973	+547	+3.1%
National Laboratory Research	36,146	33,595	33,330	-265	-0.8%
Other Research	375[a]	2,826	2,960	+134	+4.7%
Subtotal, Research	54,028	53,847	54,263	+416	+0.8%
Operations					
RHIC Operations	74,870	102,480	108,210	+5,730	+5.6%
National Laboratory Facility	12,557	13,023	13,090	+67	+0.5%
Other Operations	5,450	10,060	10,840	+780	+7.8%
BNL Waste Management	0	0	5,957	+5,957	+100.0%
Subtotal, Operations	92,877	125,563	138,097	+12,534	+10.0%
Total, Heavy Ion Nuclear Physics	146,905	179,410	192,360	+12,950	+7.2%

Detailed Program Justifications

(dollars in thousands)

FY 1999	FY 2000	FY 2001

Research

University Research

Support is provided for the research of scientists and students at 33 universities in 21 states.

- 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 at initial experiments at RHIC where an entirely new regime of nuclear matter now becomes available to study for the first time. University researchers are involved in all aspects of the four RHIC detectors; STAR, PHENIX, BRAHMS, and PHOBOS.
- 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 specialized instrumentation at the ANL-ATLAS and

[a] Excludes $2,100,000 which has been transferred to the SBIR program.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
LBNL-88-inch Cyclotron facilities. Complementary studies are carried out using smaller university facilities (Yale and Texas A&M) whose in-house research programs focus on speciality areas of study and provide an emphasis on student training.	17,507	17,426	17,973
National Laboratory Research			
Support is provided for the research programs of scientists at six National Laboratories (ANL, BNL, LBNL, LANL, LLNL and ORNL).			
▪ **BNL RHIC Research:** 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. FY 2001 will be a critical year as all four RHIC detectors reach their full potential for studies of the expected new forms of nuclear matter that will be created in the heavy ion collisions. The priority for the capital equipment included in this funding is on additional experimental equipment for RHIC, (see Major Items of Equipment) primarily for the Electromagnetic Calorimeter enhancement for STAR and for muon instrumentation for PHENIX.	18,055	13,252	11,275
▪ **Other National Laboratory Research:** ANL (ATLAS) and LBNL (88-inch Cyclotron) scientists have major responsibilities for maintaining, improving and developing instrumentation for use by the user communities at their facilities, as well as playing important roles in carrying out research that addresses the program's priorities. Activities will be focused on studies of the properties of nuclei far from stability using specialized instrumentation, studies of nuclear structure with Gammasphere and support of a new Rare Isotope Accelerator (RIA) facility including R&D and preconceptual design. FY 2001 funding of $3,100,000 is provided for RIA activities. Researchers at LANL, LBNL, and ORNL will utilize their laboratory competencies in undertaking the development of and data analysis from RHIC detectors (e.g., STAR and PHENIX) and will play leadership roles in carrying out research utilizing them. The priorities for funding in research will be the RHIC program, and R&D and preconceptual design activities for a proposed Rare Isotope Accelerator (RIA).	18,091	20,343	22,055
Total, National Laboratory Research	36,146	33,595	33,330

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Other Research			
▪ In FY 1999 $2,100,000 was transferred to the SBIR program. Amounts include the estimated requirements for the continuation of the FY 2000 and FY 2001 SBIR and STTR programs and other established obligations.	375	2,826	2,960
Total, Heavy Ion Nuclear Physics Research	54,028	53,847	54,263

Operations

RHIC Operations

- The Relativistic Heavy Ion Collider (RHIC) will initiate data taking operations during FY 2000 and is anticipated to reach nearly full data production capabilities by the end of FY 2001. 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 will provide researchers with their first laboratory opportunity to explore this new regime of nuclear matter and nuclear interactions that up to now has only been studied theoretically.

‣ **RHIC Accelerator Operations:** Support is provided for the operation, maintenance, improvement and enhancement of the RHIC accelerator complex. The RHIC complex includes the Tandem, Booster and AGS accelerators that together serve as the injector for RHIC and that individually or in combination have additional capabilities for providing beams for research. In FY 2001 RHIC will operate with a 4800 hour running schedule. About 1600 hours of this schedule is anticipated to be used for beam studies and to commission operations with polarized protons.	66,800	75,170	78,885

RHIC Operations

	(hours of beam)		
	FY 1999	FY 2000	FY 2001
Research	0	1330	3200
Beam Studies	500	2720	1600
Total	500	4050	4800

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
‣ **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 detectors (STAR, PHENIX, BRAHMS and PHOBOS) will reach their initial planned potential in FY 2001. Approximately 950 scientists and students from 90 institutions and 19 countries will participate in the research programs of these four detectors.	8,070	27,310	29,325
Total, RHIC Operations.....	74,870	102,480	108,210

▪ **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.

‣ Support is provided for the operation, maintenance, improvement and enhancement of the ATLAS and 88-inch Cyclotron accelerator facilities. FY 2001 operations (and beam hours shown below) reflect emphasis on the complementary Gammasphere program at the 88-inch Cyclotron and the development of radioactive beam capabilities at ATLAS. A vigorous program in search of new elements near the recently discovered elements (Z=116 and 118) will be pursued.

	(hours of beam)		
	FY 1999	FY 2000	FY 2001
Total beam hours (ATLAS/88-inch Cyclotron).....	10200	10200	10350

‣ In FY 2001 these low-energy facilities will carry out about 70 experiments conducted by about 400 researchers. Accelerator Improvement Project (AIP) funds and capital equipment are provided for the maintenance and upgrade of these facilities and their research capabilities. 12,557 13,023 13,090

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
▪ **Other Operations:** As Landlord for Brookhaven National Laboratory (BNL), the Nuclear Physics program provides GPP funding for minor new construction, other capital alterations and additions, and for buildings and utility systems. 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 these types of projects 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.			
▪ At Brookhaven National Laboratory, modifications to the Booster Synchrotron (part of the RHIC complex) and development of a beam line are underway to provide beams for studies of radiation effects on biological and electronic systems in space. This Booster Applications Facility (BAF) is funded by NASA under a work-for-others agreement at no cost to the Nuclear Physics program.	5,450	10,060	10,840
▪ **BNL Waste Management:** Funding is provided in support of activities related to the packaging, shipment, and disposition of hazardous, radioactive or mixed waste generated in the course of normal operations at Brookhaven National Laboratory.	0	0	5,957
Total, Operations	92,877	125,563	138,097
Total, Heavy Ion Nuclear Physics	146,905	179,410	192,360

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Research	
▪ **University Research**	
‣ FY 2001 funding for University Research provides for a constant level of effort compared to FY 2000 for research and educational activities. Priority in the program will be given to research using RHIC and with exotic nuclei far from stability.	+547
▪ **National Laboratory Research**	
‣ Research funding for RHIC, including capital equipment for detectors, is reduced by about $2,000,000 relative to FY 2000 as several Major Items of Equipment are completed. In FY 2001 there will be an increase of $1,500,000 in funding allocated to R&D and preconceptual design activities for the Rare Isotope Accelerator (RIA) project, bringing the total effort in this subprogram to $3,100,000. (An additional $400,000 for RIA R&D and design activities is provided in the Low Energy subprogram where needed expertise resides.) Other research efforts at the National Laboratories are reduced somewhat and will be focused towards the priority areas of the program.	-265
▪ **Other Research**	
‣ Estimated funding for SBIR and other obligations increase from FY 2000.	+134
Total, Research	+416
Operations	
▪ **RHIC Operations**	
‣ FY 2001 funding provides for an estimated 4800 hours running schedule (3200 hours for research), compared to 4050 hours (1330 hours for research) in FY 2000. Capital Equipment and AIP funding are provided at levels approaching what was recommended as appropriate in the RHIC Operations Review carried out by NSAC.	+5,730
▪ **National Laboratory Facility Operations**	
‣ In FY 2001, funding for operations of ATLAS and the 88-Inch Cyclotron is increased by about 4% compared with FY 2000, resulting in an increase in beam hours. Capital Equipment and AIP funding are decreased by approximately the same percentage.	+67
▪ **Other Operations**	
‣ FY 2001 GPP for Brookhaven National Laboratory is increased to support projects that will enhance the usefulness of aging facilities.	+780

	FY 2001 vs. FY 2000 ($000)
▪ **BNL Waste Management**	
‣ As part of the landlord responsibilities for Brookhaven National Laboratory the program assumes responsibility for the waste treatment program previously budgeted for by Environmental Management.	+5,957
Total, Operations	+12,534
Total Funding Change, Heavy Ion Nuclear Physics	+12,950

Low Energy Nuclear Physics

Mission Supporting Goals and Objectives

The Low Energy Nuclear Physics subprogram supports research directed at understanding the structure of nuclei, nuclear reaction mechanisms, and experimental tests of fundamental symmetries. At the present time, emphasis is placed on addressing issues in nuclear astrophysics. This research is generally conducted using beams provided by accelerator facilities operated by this subprogram, other Department of Energy programs, or at other domestic or foreign facilities. The Low Energy Nuclear Physics subprogram supports the operation of the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory. 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. 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. Included in this 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. In FY 2001, funding will be provided for an expanded program of R&D and preconceptual design activities in support of an advanced Rare Isotope Accelerator (RIA) facility (partially funded in Heavy Ion Nuclear Physics subprogram).

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
University Research	9,895	9,727	10,475	+748	+7.7%
National Laboratory Research	8,038	9,086	8,360	-726	-8.0%
Nuclear Data	4,775	4,880	5,050	+170	+3.5%
Other	290[a]	1,145	965	-180	-15.7%
RIB Operations	9,310	8,941	9,120	+179	+2.0%
Total, Low Energy Nuclear Physics	32,308	33,779	33,970	+191	+0.6%

[a] Excludes $810,000 which has been transferred to the SBIR program.

Detailed Program Justifications

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
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.			
▪ 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 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 a broad range of fundamental issues as diverse as properties of nuclei, the nature of the weak-interaction and the production mechanisms of chemical elements in stars and supernovae.....	9,895	9,727	10,475
National Laboratory Research			
▪ **Radioactive Ion Beam Facility Research:**			
‣ The RIB facility focuses mainly on nuclear astrophysics problems bearing on the creation of the elements and on the properties of nuclei with extreme proton/neutron ratios.			
‣ The Daresbury Recoil Separator, a $2,000,000 device contributed by the United Kingdom, is being utilized to separate the products of interest from particle backgrounds that are a trillion times more intense, enabling the measurement of the important nuclear reactions that fuel the explosion of stars.			
‣ Capital equipment funds are provided to develop new beam species and for research instrumentation.			
‣ Research and Development (R&D) activities leading to an advanced Rare Isotope Accelerator (RIA) will continue	4,808	4,254	4,985

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
▪ **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 holding 1,000 tons of heavy water that is the solar neutrino detector. SNO is located 6,800 feet underground. The detector water fill was completed in FY 1999 and data taking has started. The level of SNO support at the national laboratories is at a level of effort that allows for efficient collection and analysis of data.			
‣ The SNO detector, whose first results are expected in FY 2001, addresses the question of whether the observed dearth of solar neutrinos results from unexpected properties of the sun, or whether it results from a fundamental property of neutrinos-namely that neutrinos produced in radioactive decay in the sun change their nature during the time it takes them to reach the earth. This latter explanation would imply that the neutrinos have mass.			
‣ Funds are also provided for R&D and preconceptual design activities directed at the development of an advanced Rare Isotope Accelerator (RIA).	3,230	4,832	3,375
Total, National Laboratory Research	8,038	9,086	8,360

Nuclear Data

- This is a service function of the Nuclear Physics program that collects, evaluates, stores, 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 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

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
scientists, reports to and supports the NNDC in data evaluation and development of on-line access capabilities.....	4,775	4,880	5,050

Other

- In FY 1999 $810,000 was transferred to the SBIR program. The FY 2000 and FY 2001 amounts include the estimated requirement for the continuation of the FY 2000 and FY 2001 SBIR and STTR programs and other established obligations. The Lawrence and Fermi Awards that are funded under this line, provide annual monetary awards to honorees selected by the Department of Energy for their outstanding contributions to nuclear science. 290 1,145 965

RIB Operations

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

	(hours of beam)		
	FY 1999	FY 2000	FY 2001
RIB	2400	2400	2300

- The RIB facility is a technically difficult project, that couples the existing cyclotron and tandem accelerators. Becoming fully operational in FY 1998, it is now routinely providing radioactive ion beams of arsenic, fluorine and Nickel-56 for a user community of over 200 researchers.
- Research at the Oak Ridge Electron Linear Accelerator (ORELA), that 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..... 9,310 8,941 9,120

Total, Low Energy Nuclear Physics.....	32,308	33,779	33,970

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
▪ **University Research**	
‣ FY 2001 funding provides constant effort support for research, and additional capital equipment support for new initiatives in neutrino related research, such as the KamLAND experiment, and nuclear astrophysics related projects.	+748
▪ **National Laboratory Research**	
‣ Research support is reduced compared to FY 2000 with high priority on nuclear astrophysics studies and involvement in the KamLAND experiment. Support at the level of $400,000 continues for R&D and preconceptual design activities for a next generation Rare Isotope Accelerator (RIA). Capital equipment investments for activities in National Laboratory Research are reduced due to completion of SNO related projects.	-726
▪ **Nuclear Data**	
‣ Funding provides a limited increase in operating costs for the nuclear data facilities and a new initiative in nuclear astrophysics data services.	+170
▪ **Other**	
‣ Estimated FY 2001 funds for SBIR decrease compared to FY 2000	-180
▪ **RIB Operations**	
‣ Operations are funded at slightly less than a constant effort than in FY 2000.	+179
Total Funding Change, Low Energy Nuclear Physics	+191

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 interactions 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 which include experimentalists. The Institute is a seedbed for new collaborations, ideas, and directions in nuclear physics.

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 1999	FY 2000	FY 2001	$ Change	% Change
University Research	10,363	10,113	10,535	+422	+4.2%
National Laboratory Research	5,277	5,562	7,620	+2,058	+37.0%
Total, Nuclear Theory	15,640	15,675	18,155	+2,480	+15.8%

Detailed Program Justifications

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
University Research			
▪ Research is conducted through individual grants to researchers at roughly 40 universities.			
▪ The range of topics studied through these grants is broad, and each of the active areas of experimental nuclear physics is supported by nuclear theory activities.			
▪ 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; a 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.	10,363	10,113	10,535
National Laboratory Research			
▪ Funding provides for new activities to model and calculate complex astrophysical nuclear processes, for example, in stellar supernovae explosions, and the quark/gluon-based structure of nuclei using "lattice gauge" techniques. Both efforts require investments in new computational modeling and simulation research and show great promise in pushing our understanding of the physics of these processes to new levels.			
▪ Through this activity, theoretical nuclear physics groups 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 1999	FY 2000	FY 2001
▪ 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.	5,277	5,562	7,620
Total, Nuclear Theory	15,640	15,675	18,155

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
▪ **University Research**	
‣ Funding level reflects an increased level of support for the university grants program.	+422
▪ **National Laboratory Research**	
‣ Funding provides for new efforts which require investments in computational modeling and simulation activities which show great promise for pushing our understanding of the physics to new levels. These activities will model and calculate complex astrophysical nuclear processes, for example, in stellar supernovae explosions, and the quark/gluon based structure of nuclei using "lattice gauge" techniques.	+2,058
Total Funding Change, Nuclear Theory	+2,480

Capital Operating Expense and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
General Plant Projects	4,000	5,855	6,735	+880	+15.0%
Accelerator Improvement Projects	5,520	4,400	5,500	+1,100	+25.0%
Capital Equipment	30,070	30,880	34,155	+3,275	+10.6%
Total, Capital Operating Expenses	39,590	41,135	46,390	+5,255	+12.8%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1999	FY 2000	FY 2001	Accept-ance Date
STAR Silicon Vertex Tracker	7,000	4,950	1,300	750	0	FY 2000
PHENIX Muon Arm Instrumentation	12,900	5,975	2,635	2,525	800	FY 2002
Analysis System for RHIC Detectors	7,900	2,775	3,600	1,525	0	FY 2000
BLAST Large Acceptance Detector	5,200	900	1,600	1,500	1,200	FY 2001
STAR EM Calorimeter	8,600	0	0	1,800	2,800	TBD
G0 Experiment Detector [a]	3,387	400	1,064	1,004	874	FY 2002
Total, Major Items of Equipment		15,000	10,199	9,104	5,674	

[a] The G0 Experiment Detector at TJNAF began as an NSF project with a small contribution of DOE funds (below MIE threshold). Subsequently, the cost estimate for the detector increased, leading to increased DOE and NSF contributions. The DOE contribution was raised above the MIE threshold. Therefore a MIE has been identified in the FY 2001 budget. The NSF contribution to this effort in actual year dollars is $3,605,000.