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 extended 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 requires incorporation of the quark substructure of the nucleon into the understanding of nuclear structure and in quark-antiquark pairs to form the mesons. Quarks, which are the most elemental 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 assist in setting scientific priorities. The programs intent is to be closely aligned with the Administration's science policies as put forward in "Science in the National Interest."

The GOAL of the Nuclear Physics program is to:

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 MISSION - NUCLEAR PHYSICS (Cont'd)

The OBJECTIVES related to the goal are to:

1. 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.

2. 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 Energy Research 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.

3. Leverage United States objectives by means of international cooperation through exchanges of scientists and participation in internationally cooperative projects.

4. 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:

1. 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.

2. 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.

3. 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.

PROGRAM MISSION - NUCLEAR PHYSICS (Cont'd)

4. 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 Facility User 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.

5. 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.

SIGNIFICANT ACCOMPLISHMENTS AND PROGRAM SHIFTS:

- The CEBAF construction project has been completed and the experimental program has begun. The facility has been dedicated and its name changed to the Thomas Jefferson National Accelerator Facility (TJNAF).

- The Relativistic Heavy Ion Collider (RHIC) construction project continues on scope and budget with a completion date of the third Quarter of FY 1999. All superconducting magnets produced by industry have been delivered, every one substantially exceeded specifications and most have been installed in the accelerator tunnel. Progress according to schedule has occurred in the fabrication of RHIC detectors, including the additional experimental equipment recommended by NSAC for purposes of particle detection and data analysis.

- Completion of the Radioactive Ion Beam (RIB) facility at Oak Ridge National Laboratory (ORNL) permits initiation of the experimental program in astrophysics and unstable nuclei in FY 1997.

- The joint US/Canadian Sudbury Neutrino Observatory (SNO) project will be completed in FY 1997 to initiate investigation of the solar burning process.

PROGRAM MISSION - NUCLEAR PHYSICS (Cont'd)

- With transferral of operation of the Clinton P. Anderson Meson Physics Facility (LAMPF) at Los Alamos National Laboratory (LANL) to Defense Programs in FY 1996 and termination of the research program in the main experimental area, research efforts have been refocused on thermal and ultra-cold neutron experiments at the Los Alamos Neutron Scattering Center (LANSCE) facility, use of the HERA gamma-ray detector for nuclear structure studies, and continuation of the LSND neutrino detector which has observed preliminary evidence for neutrino masses.

- Utilization of the new Gammasphere detector at Lawrence Berkeley National Laboratory (LBNL) has produced sensitive measurements of super-deformed nuclear states, whose lengths are 2 times as big as their widths. Gammasphere will be temporarily relocated to the Argonne National Laboratory in FY 1997 and coupled with the existing mass spectrometer there to expand research capabilities into new scientific areas.

- The Nuclear Physics request includes $135,488,000 to maintain support of the Department's scientific user facilities. This funding will significantly 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.

NUCLEAR PHYSICS

PROGRAM FUNDING PROFILE

(Dollars in thousands)

Subprogram	FY 1996 Current Appropriation	FY 1997 Original Appropriation	FY 1997 Adjustments	FY 1997 Current Appropriation	FY 1998 Request
Medium Energy Nuclear Physics.....	$109,836	$115,325	$0	$115,325	$115,250
Heavy Ion Nuclear Physics.....	80,878	89,962	0	89,962	95,075
Low Energy Nuclear Physics.....	29,362	30,438	0	30,438	30,950
Nuclear Theory.....	14,870	15,200	0	15,200	15,250
Subtotal.....	234,946	250,925	0	250,925	256,525
Construction.....	65,000	65,000	0	65,000	76,020 a/
Subtotal, Nuclear Physics.....	299,946	315,925	0	315,925	
Adjustment.....	0	0	0	0	
TOTAL, Nuclear Physics.....	$299,946 b/	$315,925	$0	$315,925	

a/ Includes $76,020,000 for full FY 1998-1999 funding for completion of the Relativistic Heavy Ion Collider construction.

b/ Excludes $4,097,000 which has been transferred to the SBIR program and $307,000 which has been transferred to the STTR program.

Public Law Authorization:

Pub. Law 95-91, DOE Organization Act

NUCLEAR PHYSICS
(Dollars in thousands)

PROGRAM FUNDING BY SITE

Field Offices/Sites	FY 1996 Current Appropriation	FY 1997 Original Appropriation	FY 1997 Adjustments	FY 1997 Current Appropriation	FY 1998 Budget Request
Albuquerque Operations Office					
Los Alamos National Laboratory	$12,514	$10,713	$0	$10,713	$10,680
Chicago Operations Office					
Argonne National Laboratory	15,771	16,107	0	16,107	16,720
Brookhaven National Laboratory	100,001	104,380	0	104,380	123,155
Idaho Operations Office					
Idaho National Engineering Laboratory	115	120	0	120	100
Oakland Operations Office					
Lawrence Berkeley National Laboratory	24,610	23,670	0	23,670	23,590
Lawrence Livermore National Laboratory	690	535	0	535	425
Oak Ridge Operations Office					
Thomas Jefferson National Accelerator Facility	67,375	67,955	0	67,955	67,350
Oak Ridge National Laboratory	14,053	14,565	0	14,565	14,835
All Other Sites a/	64,817	77,880	0	77,880	75,690
Subtotal	299,946	315,925	0	315,925	332,545
Adjustment	0	0	0	0	0
TOTAL	$299,946 b/	$315,925	$0	$315,925	$332,545

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

b/ Excludes $4,097,000 which has been transferred to the SBIR program and $307,000 which has been transferred to the STTR program.

MEDIUM ENERGY NUCLEAR PHYSICS

(Tabular dollars in thousands, narrative in whole dollars)

I. **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 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 apparently 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 (previously the Continuous Electron Beam Accelerator Facility), 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/CEBAF and Bates, the National Science Foundation 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/CEBAF, 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/CEBAF, foreign collaborators have also made major investments in experimental equipment.

Since FY 1996, operation of the Clinton P. Anderson Meson Physics Facility (LAMPF) has been supported by DOE Defense Programs.

II. Funding Schedule:

Program Activity	FY 1996	FY 1997	FY 1998	$ Change	% Change
University Research	$ 11,488	$ 11,520	$ 11,605	$+ 85	+ 0.7%
National Laboratory Research	14,160	14,345	14,563	+ 218	+ 1.5%
TJNAF/CEBAF Research	27,300	25,350	24,850	- 500	- 2.0%
TJNAF/CEBAF Operations	39,575	42,100	42,000	- 100	- 0.2%
MIT Research/Bates Operations	17,313	17,651	18,151	+ 500	+ 2.8%
SBIR/STTR	0	4,359	4,081	- 278	+ 6.4%
Total, Medium Energy Nuclear Physics	$109,836 *	$115,325	$115,250	$- 75	- 0.1%

* Excludes $1,965,000 which has been transferred to the SBIR program and $307,000 which has been transferred to the STTR program.

III. Performance Summary- Accomplishments:

University Research	FY 1996	FY 1997	FY 1998
The university research program supports a broad program in Medium Energy Nuclear Physics at 33 universities utilizing not only each of the accelerator facilities supported under the Medium Energy program, but also using other U.S. and international accelerator laboratories. For example, university scientists are collaborating on important ongoing and future experiments at TJNAF/CEBAF which include studies of the charge structure of the neutron in Hall C, planned measurements of the electric form factor of the proton in Hall A, and a series of planned studies of the excited states of the proton in Hall B. At the MIT/Bates accelerator, university researchers are carrying out important experiments on "symmetry violation" studies on the proton and deuteron in the North Hall. Out-of-plane measurements will be carried out in the South Hall on the proton, deuteron, and complex nuclei including measurements of the transition of the proton to its excited state.	$ 11,488	$ 11,520	$ 11,605

	FY 1996	FY 1997	FY 1998
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.			
National Laboratory Research			
Scientists at Argonne National Laboratory have used institutional expertise to develop major spectrometer and detector packages for the new TJNAF/CEBAF experimental program in Hall C, as well as for the HERMES experiment which is being carried out at the DESY laboratory in Hamburg, Germany. At Brookhaven National Laboratory's Laser Electron Gamma Source (LEGS), which generates high quality gamma rays by back-scattering laser light from electron beams at the National Synchrotron Light Source, scientists and university collaborators are developing a unique new polarized hydrogen ice target for a program of spin physics. Also at Brookhaven, scientists at the Alternating Gradient Synchrotron are working with university researchers on experiments to look at the behavior of strange quarks in nuclei and to do spectroscopy of other particles. These efforts involve large detectors which were recently moved from Los Alamos and the Stanford Linear Accelerator Center. At the Clinton P. Anderson Meson Physics Facility, Los Alamos National Laboratory scientists and collaborators may continue to carry out highly interesting but controversial measurements in search of neutrino oscillations, depending on review of existing results and whether DOE Defense Programs will continue operating the high intensity proton beam into Area A. If oscillations are found, then neutrinos would have mass, in disagreement with our present understanding of the laws of physics. Los Alamos scientists and collaborators are developing detectors for the Relativistic Heavy Ion Collider which will enable use of polarized protons and which builds upon an experiment to measure quark structure of the proton at Fermilab.	$ 14,160	$ 14,345	$ 14,563

	FY 1996	FY 1997	FY 1998
TJNAF/CEBAF Research			
Scientists at TJNAF/CEBAF are heavily involved in the continuing assembly of new experimental apparatus for Halls A, B, and C in collaboration with university users. Hall C is presently operational; six experiments have been completed. Experimental equipment in Hall A is being tested and commissioned. The complex large-angle spectrometer in Hall B is presently being assembled. All three Halls will be fully operational in FY 1998. Also at TJNAF/CEBAF, 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 construction of second generation experiments such as a spectrometer that is designed to investigate the strange quark content of the proton.	$ 27,300	$ 25,350	$ 24,850
TJNAF/CEBAF Operations			
TJNAF/CEBAF is presently preparing for operation in Halls A, B, and C. Continuous beam for experiments is presently available in Hall C.	$ 39,575	$ 42,100	$ 42,000

(hours of beam for research)

	FY 1996	FY 1997	FY 1998
TJNAF/CEBAF	4,500	4,500	4,500

Tests are being done to establish parameters and procedures for the delivery of simultaneous continuous beams to Halls C and A. By FY 1998, the continuous electron beam will be simultaneously deliverable to all three experimental Halls and the laboratory will have the ability to carry out different research studies in all three areas at

	FY 1996	FY 1997	FY 1998

the same time. AIP funding is supporting additions and modifications to the accelerator facilities. GPP funding is provided for minor new construction and utility systems.

MIT Research/Bates Operations

At MIT/Bates, MIT scientists have been developing out-of-plane spectrometer (OOPS) measurement capability in collaboration with the university users. The full OOPS gantry and multiple spectrometer systems will carry out unique spin physics measurements in the South Experimental Hall using a new polarimeter and the new spectrometers and detectors. Capital equipment funds will be used for construction of a new internal target and a new large acceptance detector (BLAST) needed to conduct a physics program using polarized internal targets in the South Hall Ring. MIT research also utilizes other facilities. Significant efforts are underway on the HERMES experiment at the DESY laboratory in Germany, and at TJNAF/CEBAF.

	$ 17,313	$ 17,651	$ 18,151

	(hours of beam for research)		
	FY 1996	FY 1997	FY 1998
MIT/Bates	2,000	2,500	2,000

Both research operations and continuing upgrading of the accelerator complex will be underway. Present accelerator operations provide beam for the research programs in the North and South Halls and also for testing of internal continuous beams in the South Hall Ring, and extracted continuous beams for delivery to the existing South Hall spectrometers. AIP funding is supporting additions and modifications to the accelerator facilities; GPP funding is provided for minor new construction and utility systems.

	FY 1996	FY 1997	FY 1998
SBIR/STTR			
In FY 1996 $1,965,000 and $307,000 were transferred to the SBIR and STTR programs respectively. The FY 1997 estimate is for both SBIR and STTR. The FY 1998 estimate is for SBIR only since Part D, Section 110 of P.L. 104-208, making Omnibus Consolidated Appropriations for FY 1997 reauthorized STTR for FY 1997 only."	$ 0	$ 4,359	$ 4,081
Total, Medium Energy Nuclear Physics	$109,836	$115,325	$115,250

EXPLANATION OF FUNDING CHANGES FROM FY 1997 TO FY 1998:

University Research

The university program has been increased to support the possibility of one new grant.	+$85,000

National Laboratory Research

Increased support for national laboratory research is provided..	+$218,000

TJNAF/CEBAF Research:

The TJNAF/CEBAF program of support for experimental facilities is being reduced to allow enhanced participation of the university user community in detector operations.	-$500,000

TJNAF/CEBAF Operations

This change represents an increase of $1,000,000 in accelerator operations, and a decrease of $1,100,000 in AIP, due to completion of funding for a backup cold box in the Main Helium Liquefier.	-$100,000

MIT Research/Bates Operations

This increase supports the commencement of a Major Item of Equipment (MIE) to build a new large acceptance detector (BLAST) at the Bates laboratory.	+$500,000

SBIR/STTR

The FY 1998 SBIR/STTR estimate decreased by $278,000 compared to FY 1997, because no STTR estimate is included for FY 1998.	-$278,000
Total Funding Change, Medium Energy Nuclear Physics	$-75,000

NUCLEAR PHYSICS

HEAVY ION NUCLEAR PHYSICS

(Tabular dollars in thousands, narrative in whole dollars)

I. **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 focussed 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 excited or 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 National Laboratory facilities are utilized by DOE, NSF and foreign supported researchers whose experiments undergo peer review prior to approval for beam time. A significant number of the researchers supported by this subprogram are involved in the fabrication and installation of detectors for experiments at the Relativistic Heavy Ion Collider (RHIC) under construction at Brookhaven National Laboratory (BNL). Capital Equipment funds are provided for detector systems, for data acquisition and analysis systems and for accelerator instrumentation for effective utilization of the national accelerator facilities operated. 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 Lawrence Berkeley National Laboratory (LBNL) as part of Nuclear Physics' landlord responsibilities for this laboratory.

II. Funding Schedule:

Program Activity	FY 1996	FY 1997	FY 1998	$ Change	% Change
University Research	$ 15,899	$ 16,320	$ 16,320	$ 0	0%
Laboratory Experimental Support and Research	31,024	36,537	35,880	- 657	- 1.8%
National User Facilities Operations	19,155	20,155	17,755	- 2,400	- 11.9%
BNL RHIC Pre-Operations	9,500	11,000	19,000	+ 8,000	- 72.7%
LBNL GPP and GPE	5,300	5,450	5,450	0	0%
SBIR	0	500	670	+ 170	+ 34%
Total, Heavy Ion Nuclear Physics	$ 80,878 *	$ 89,962	$ 95,075	$ + 5,113	+ 5.7%

* Excludes $945,000 which has been transferred to the SBIR program.

III. Performance Summary-Accomplishments:

University Research	FY 1996	FY 1997	FY 1998
Support is provided for the research of scientists and students at over 30 universities. Research using low energy heavy ion beams, involving about a third of the university scientists, is focussed on the study of the structure of nuclei with priorities on (1) use of the Gammasphere detector (completed in FY 1996) for studies of high-spin, deformed nuclei at the 88-inch Cyclotron in FY 1996-1997 and short-lived nuclei at the limits of isotopic stability when moved to ATLAS in FY 1998, and (2) operation and utilization of university accelerator facilities (Yale and Texas A&M) for in-house research programs that emphasize student training. Research using relativistic heavy ion beams is focussed on the study of the production and properties of hot, dense nuclear matter with priorities on (1) completion of ongoing experiments at the BNL Alternate Gradient Synchrotron (AGS) and CERN Super Proton Synchrotron (SPS) facilities, and (2) participation in the planning, construction and implementation of detectors for the RHIC program scheduled to begin in FY 1999.	$ 15,899	$ 16,320	$ 16,320

National Laboratory Experimental Support and Research	FY 1996	FY 1997	FY 1998
Support is provided for the research programs of scientists at five National Laboratories. Laboratory researchers associated with accelerator facilities at ANL (ATLAS), LBNL (88-inch Cyclotron) and BNL (Tandem AGS and RHIC) have major responsibilities for maintaining, improving and developing instrumentation for use by the user community at their facilities. Researchers at LANL, LBNL, and ORNL utilize their laboratory competencies in undertaking R&D, management and construction responsibilities for major initiatives such as RHIC detectors (e.g., STAR and PHENIX). The priorities for Capital Equipment funding are: (1) support for the ongoing research activities at the supported accelerator facilities, and (2) additional experimental equipment for RHIC, recommended in NSAC review as important for addressing the physics objectives of the RHIC program. The RHIC additional experiment equipment includes three major items of equipment: STAR Silicon Vertex Tracker, PHENIX Muon Arm Instrumentation, and Analysis System for RHIC Detectors (MIE).	$ 31,024	$ 36,537	$ 35,880

National Users Facilities Operations

	FY 1996	FY 1997	FY 1998
Support is provided for three National User Facilities: the ATLAS facility at ANL for nuclear reaction mechanism and structure studies, the 88-inch Cyclotron facility at LBNL for studies of nuclear structure and fundamental interactions, and the Tandem/AGS facility at BNL for studies of the properties of hot, dense nuclear matter. These facilities are planned to provide yearly hours of beam for research as indicated below:	$ 19,155	$ 20,155	$ 17,755

(hours of beam for research)

	FY 1996	FY 1997	FY 1998
ATLAS	5,000	4,600	4,600
88-inch Cyclotron	5,400	5,100	4,500
Tandem/AGS	1,000	1,000	500

	FY 1996	FY 1997	FY 1998
The FY 1998 beam hours at the BNL Tandem/AGS depend on coordination with the RHIC Project. Both the 88-inch Cyclotron (hours included above) and BNL Tandem injector provide heavy ion beams for non-Nuclear Physics supported applied programs including susceptibility of space-based electronics circuits to cosmic rays and production of "micro-pore" filters for medical use.			
Accelerator Improvement Project (AIP) funds and Capital Equipment are provided for the maintenance and upgrade of these facilities.			
BNL RHIC Pre-Operations			
Pre-operating, inventory and capital equipment funds are provided for the RHIC project as part of the Total Project Costs (TPC) to conduct beam tests and collider commissioning, to procure special-process, magnet element spares, and to acquire equipment that serves project operations. (See Data Sheet for RHIC Project Number 91-G-300.)	$ 9,500	$ 11,000	$ 19,000
LBNL GPP and GPE			
GPP funding will be provided for minor new construction, other capital alterations and additions, and for buildings and utility systems at Lawrence Berkeley National Laboratory (LBNL). 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 $2,000,000. In addition, the program has landlord responsibility for providing general purpose equipment (GPE) at LBNL.	$ 5,300	$ 5,450	$ 5,450

	FY 1996	FY 1997	FY 1998
SBIR			
In FY 1996 $945,000 was transferred to the SBIR program. The FY 1997 estimate is for SBIR. The FY 1998 estimate is for SBIR only since Part D, Section 110, of P.L. 104-208, making Omnibus Consolidated Appropriations for FY 1997 reauthorized STTR for FY 1997 only.	$ 0	$ 500	$ 670
Total, Heavy Ion Nuclear Physics	$ 80,878	$ 89,962	$ 95,075

EXPLANATION OF FUNDING CHANGES FROM FY 1997 TO FY 1998:

Laboratory Experimental Support and Research

FY 1998 funding for research programs at National Laboratories is essentially constant from FY 1997 with some shifts (e.g., Gammasphere operating funds move from LBNL to ANL with Gammasphere). FY 1998 funding for Capital Equipment is reduced by over $500,000 compared with FY 1997. -$657,000

National User Facilities Operations

Tandem/AGS Operations for research will be reduced by $2,400,000. This reduction is offset with an increase in RHIC Project funding for RHIC pre-operations as shown below. Effort will be made to maximize utilization of the Tandem/AGS for research in coordination with RHIC pre-operations. -$2,400,000

	FY 1997	FY 1998	
RHIC Construction	$ 65,000	$ 59,400	*
RHIC Pre-Operations	11,000	19,000	
Tandem/AGS Operations	7,470	5,070	
Total	$ 83,470	$ 83,470	

* Note: FY 1998 Fixed Assets Funding request of $76,020,000 for RHIC construction includes $16,620,000 to be obligated in FY 1999.

The total funding for other Heavy Ion Nuclear Physics funded Facility Operations is constant from FY 1997, with a shift in funds from the 88-inch Cyclotron to the ATLAS facility to optimize the utilization of Gammasphere while it resides at ATLAS. Operations for the 88-inch Cyclotron are decreased by $200,000 to $3,715,000 and operations for ATLAS are increased by $200,000 to $5,240,000. The beam hours (displayed earlier) for the two facilities reflect this shift as well as the effects of increased cost-of-living. +$0

BNL RHIC Pre-Operations

RHIC Pre-Operations reflects the $8,000,000 planned increase in funding for the RHIC Project which is coordinated with a reduction in RHIC Construction (See RHIC Data Sheet).	+$8,000,000

SBIR

Estimated FY 1998 funds for SBIR increase by $170,000 compared to FY 1997.	+$170,000
Total Funding Change, Heavy Ion Nuclear Physics	+$5,113,000

LOW ENERGY NUCLEAR PHYSICS

(Tabular dollars in thousands, narrative in whole dollars)

I. **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. The last of these categories 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. Since most of the required facilities are relatively small, they are appropriate for sitting 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 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.

II. **Funding Schedule:**

Program Activity	FY 1996	FY 1997	FY 1998	$ Change	% Change
Radioactive Ion Beams (RIB)	$ 11,050	$ 11,825	$ 12,290	$+ 465	+ 3.9%
University Research	9,054	8,885	8,985	+ 100	+ 1.1%
National Laboratory Research	4,456	3,673	3,670	- 3	- 0.1%
Nuclear Data Program	4,602	4,900	4,900	0	0%
SBIR	0	850	800	- 50	- 5.9%
Lawrence and Fermi Awards	200	305	305	0	0%
Total , Low Energy Nuclear Physics	$ 29,362 *	$ 30,438	$ 30,950	$+ 512	+ 1.7%

* Excludes $1,187,000 which has been transferred to the SBIR program.

III. Performance Summary- Accomplishments:

Radioactive Ion Beams (RIB) at Oak Ridge National Laboratory	FY 1996	FY 1997	FY 1998
This technically difficult project, which coupled the existing cyclotron and tandem accelerators, was completed in FY 1996, will operate with initial beams of radioactive arsenic and fluorine ions. 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 (DRS), a $2,000,000 device contributed by the United Kingdom, will allow 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 and AIP are provided to expand the list of available beam species.	$ 11,050	$ 11,825	$ 12,290

(hours of beam for research)

	FY 1996	FY 1997	FY 1998
RIB	0	2,000*	2,000*

* Includes 1000 hours of stable beam operation.

Results obtained at the Oak Ridge Electron Linear Accelerator (ORELA), which is also operated by RIB staff, have resolved a discrepancy in the rate of production of primordial lithium compared with theoretical predictions, and are consistent with models that predict the formation of heavy elements like Carbon, Nitrogen, and Oxygen in the Big Bang.

University Research			
The three main components of research topics at the universities in this subprogram are nuclear astrophysics, fundamental interactions in nuclei, and the structure of nuclei.	$ 9,054	$ 8,885	$ 8,985

	FY 1996	FY 1997	FY 1998
Two university accelerators are supported in Low Energy: the University of Washington and the Triangle Universities Nuclear Laboratory (TUNL) facility at Duke University. University scientists perform research both on-site at these accelerators, as user groups at National Laboratory user facilities, and at other facilities world-wide including a joint US-Canadian-British project, the Sudbury Neutrino Observatory (SNO). For the first time, direct measurements of reaction rates (cross sections) that determine the energy production rate in the sun will be made down to energies where these reactions occur in the sun and other stars. Precision measurements with polarized gamma-ray beams and polarized proton targets that will be available at TUNL will test the implications of the quantum chromodynamic theory at a new level of sensitivity.			
National Laboratory Research			
The major effort in FY 1996, was assembly of the remaining 4,700 ultra-sensitive light detectors in a frame in the SNO laboratory which is 6,800 feet underground in the Creighton Nickel Mine near Sudbury, Canada. The central element of the observation is an acrylic vessel which is 40 feet in diameter and holds 1000 tons of heavy water. The vessel is planned for completion in FY 1997. The research 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 (800 m total length) to their underground storage in the ultra low cosmic ray background environment of the SNO mine. They will be 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.	$ 4,456	$ 3,673	$ 3,670

	FY 1996	FY 1997	FY 1998
Nuclear Data Program			
This is a service function of the Nuclear Physics program which collects, evaluates, stores, and disseminates nuclear information. Its main national and international center point is the United States National Nuclear Data Center (US-NNDC) at Brookhaven National Laboratory. In addition, the NNDC uses a network of individual investigators that assist in assessing data as well as developing new novel, user friendly electronic network and CD-ROM capabilities. The U.S. Nuclear Data Network (USNDN), a collaboration of DOE supported nuclear data scientists which supports the NNDC, has produced and released for general use, a new CD-ROM that provides users with capability to search for nuclear information about 2,600 nuclides and over 140,000 references. Also, for the first time, the Table of Isotopes, a comprehensive reference of nuclear structure information, has been published (as the 8th edition) and made available on a CD-ROM and, in a joint LBNL-BNL effort is being melded with the main U.S. data base. In FY 1997 a new activity, jointly supported with the Division of Nuclear Physics research community, will begin to serve the nuclear astrophysics community. This will be a joint activity between the US-NNDC and a collection site, which will be determined by peer review.	$ 4,602	$ 4,900	$ 4,900
SBIR			
In FY 1996 $1,187,000 was transferred to the SBIR program. The FY 1997 estimate is for SBIR. The FY 1998 estimate is for SBIR only since Part D, Section 110 of P.L. 104-208, making Omnibus Consolidated Appropriations for FY 1997 reauthorized STTR for FY 1997 only.	$ 0	$ 850	$ 800

	FY 1996	FY 1997	FY 1998
Lawrence and Fermi Awards			
Provides annual monetary awards to honorees selected by the Department of Energy for their outstanding contributions to nuclear science.	$ 200	$ 305	$ 305
Total, Low Energy Nuclear Physics	$ 29,362	$ 30,438	$ 30,950

EXPLANATION OF FUNDING CHANGES FROM FY 1997 TO FY 1998:

Radioactive Ion Beams (RIB)	
The RIB facility at Oak Ridge National Laboratory will receive increased Capital Equipment and operating funds to provide a wider variety of radioactive beams for research.	+$465,000
Research	
A $100,000 increase is provided for low energy university research support while funding at national laboratories is reduced $3,000.	+$97,000
SBIR	
This represents a decrease to the SBIR assessment in the Low Energy Program.	-$50,000
Total Funding Change, Low Energy Nuclear Physics	+$512,000

NUCLEAR PHYSICS

NUCLEAR THEORY

(Tabular dollars in thousands, narrative in whole dollars)

I. **Mission Supporting Goals and Objectives:** In the Nuclear Theory program solvable mathematical models are developed which describe observed nuclear properties, and the predictions of the models are tested with further experiments. This requires a continuing interaction with experimentalists and experimental data. From this process evolves a deeper understanding of the nucleus. 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 developments in recent years of 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. With the development of the solar neutrino observatory (SNO) and the Radioactive Ion Beam (RIB) facility there is an increasing theoretical activity 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. Many of the programs 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 recent addition to the program was the establishment of the National Institute for Nuclear Theory (INT) at the University of Washington (Seattle), where there is an ongoing series of special topic programs, workshops and visitor programs. 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.

A major output of the Nuclear Theory program is the development of a group of highly trained young scientists, many of whom go on to make major contributions in areas outside nuclear physics - particularly in many nuclear related sciences and technologies.

II. Funding Schedule:

Program Activity	FY 1996	FY 1997	FY 1998	$ Change	% Change
National Laboratory Research	$ 5,005	$ 5,080	$ 5,080	$ 0	0%
University Research	9,865	10,120	10,170	+ 50	+ 0.3%
Total, Nuclear Theory	$ 14,870	$ 15,200	$ 15,250	$+ 50	+ 0.3%

III. Performance Summary-Accomplishments:

National Laboratory Research	FY 1996	FY 1997	FY 1998
Theoretical nuclear physicists at six National Laboratories carry out research programs aimed at developing a fundamental understanding of the properties of nucleons, nuclei, and nuclear matter. Parts of the theory research at laboratories relate directly to experimental programs at local facilities. Computer programs based on cascade models have been developed to analyze relativistic heavy ion collisions, and have been used to accurately describe results from experiments at CERN and the AGS. The programs will be modified to be applicable to experiments at RHIC. The nuclear shell model has been extended to deal with nuclei under extreme conditions, such as those with large neutron or proton excesses. This is important for understanding nucleosynthesis, and will be studied at the Holifield Radioactive Ion Beam Facility.	$ 5,005	$ 5,080	$ 5,080
University Research			
Faculty at over 50 universities carry out research programs aimed at developing a fundamental understanding of the properties of nucleons, nuclei, and nuclear matter. Almost 100 Ph.D. students are supported in these programs, the major source of new Ph.D.s in nuclear physics. Lattice gauge calculations have been refined and used to develop simple	$ 9,865	$ 10,120	$ 10,170

	FY 1996	FY 1997	FY 1998
quark-gluon based models of nucleons. The Institute for Nuclear Theory at the University of Washington was recognized, in the first five-year review of the program, as the preeminent international center for theoretical nuclear physics activities.			
Total, Nuclear Theory	$ 14,870	$ 15,200	$ 15,250

EXPLANATION OF FUNDING CHANGES FROM FY 1997 TO FY 1998:

To enhance nuclear theory research programs at universities.	+$50,000

NUCLEAR PHYSICS

CONSTRUCTION

(Tabular dollars in thousands, narrative in whole dollars)

I. **Mission Supporting Goals and Objectives:** The Construction subprogram funds the necessary activities that enable the Nuclear Physics program to maintain a set of world-leading accelerator facilities which are essential for forefront scientific investigation. The major activity is completion of the Relativistic Heavy Ion Collider (RHIC) facility and the start of its research program in FY 1999.

II. **Funding Schedule:**

Program Activity	FY 1996	FY 1997	FY 1998	$ Change	% Change
Construction					
RHIC	$ 65,000	$ 65,000	$ 76,020	$ + 11,020	+ 16.9%
Total; Construction	$ 65,000	$ 65,000	$ 76,020	$ + 11,020	+ 16.9%

III. Performance Summary-Accomplishments:

RHIC	FY 1996	FY 1997	FY 1998
Continue construction of RHIC collider ring and major detectors. Complete STAR detector Assembly Building and 2,500 ton PHENIX detector iron structure.	$ 65,000	0	0
Complete construction of all standard bore ring magnets, and continue construction of accelerator components and major detectors. Test the first sextant of the collider ring with gold beam from the AGS. Mount 1,200 tons of magnet iron for the STAR detector.	0	$ 65,000	0

NUCLEAR PHYSICS
CONSTRUCTION

	FY 1996	FY 1997	FY 1998
Finish installation of the RHIC collider rings in preparation for their first use as particle accelerators in FY 1999. Complete preparation for cool down of the full collider ring with liquid helium. Funding is needed for accelerator components such as the radio frequency accelerator system, beam steering equipment, beam diagnostics, computer controls, and beam dumps. Bring close to completion the construction of the major RHIC detectors. Funds are needed to prepare the STAR detector for initial physics experiments during early operation of the collider with stored beams, and to complete one of the two muon arms in the PHENIX detector. The FY 1998 request includes $16,620,000 needed to complete construction of all elements of the RHIC collider and detectors in FY 1999.	0	0	$ 76,020
Total Construction	$65,000	$65,000	$76,020

EXPLANATION OF FUNDING CHANGES FY 1997 TO FY 1998:

Construction funds for RHIC are being reduced in coordination with the planned increase in operating funds as explained in item 12(a)2(b) of the RHIC Data Sheet. The increases in operating funds are needed for the start of beam tests and collider commissioning. Total Project Cost for RHIC remains unchanged.	-$5,600,000
Further, in accord with Administration policy to provide full funding for fixed assets, project funding for B/A requirements in FY 1999 are now requested in the FY 1998 budget request.	+$16,620,000
Total Funding Change, Construction	$+11,020,000

NUCLEAR PHYSICS
CAPITAL OPERATING EXPENSE & CONSTRUCTION SUMMARY
(Dollars in thousands)

Capital Operating Expenses	FY 1996	FY 1997	FY 1998	$ Change	% Change
General Plant Projects (Total)	$ 3,900	$ 3,800	$ 3,800	$ 0	+0.0 %
Accelerator Improvement Projects (Total)	2,575	5,400	4,200	- 1,200	-22.2 %
Capital Equipment (Total)	26,470	26,300	26,500	+ 200	+0.8 %

Construction Project Summary (both Operating and Construction Funded)

Project Number	Project Title	TEC	Previous Approp.	FY 1996 Approp.	FY 1997 Approp.	FY 1998 Request	Unapprop. Balance
91-G-300	Relativistic Heavy Ion Collider, BNL	$ 486,870	$ 280,850	$ 65,000	$ 65,000	$ 76,020	$ 0
	Total Nuclear Physics	--	$ 280,850	$ 65,000	$ 65,000	$ 76,020	$ 0

Major Items of Equipment (TEC $2 Million and Above)

	TEC	Previous Approp.	FY 1996 Approp.	FY 1997 Approp.	FY 1998 Request	Acceptance Date
1. STAR Silicon VertexTrackerr	$ 6,000	$ 450	$ 1,100	$ 2,000	$ 1,500	FY 1999
2. PHENIX Muon Arm Instrumentation	11,400	350	400	2,650	$ 3,000	TBD
3. Analysis System for RHIC Detectors	7,900	0	100	700	1,700	TBD
4. BLAST Large Acceptance Detector	4,900	0	0	400	900	TBD

DEPARTMENT OF ENERGY
FY 1998 CONGRESSIONAL BUDGET REQUEST
(Changes from FY 1997 Congressional Budget Request are denoted with a vertical line in left margin.)

(Tabular dollars in thousands. Narrative material in whole dollars.)

NUCLEAR PHYSICS

1. Title and location of project:	Relativistic Heavy Ion Collider Brookhaven National Laboratory Upton, New York	2a. Project No. 91-G-300 2b. Construction Funded

SIGNIFICANT CHANGES

- Estimated annual facility operating costs upon project completion increased from $78,900,000 per year to $99,800,000 per year following a review by the DOE/NSF Nuclear Science Advisory Committee. Of this $20,900,000 increase, $8,900,000 are for activities that had been planned to be supported by Research funding. Hence there is a $12,000,000 increase over what had been planned, arising from an increase of $6,000,000 in the estimated costs for facility operations and an additional $6,000,000 in the estimated costs for experimental program support.

- Project Scope has not changed.

- Project funding for B/A requirements in FY 1999 are now requested in the FY 1998 budget request, consistent with the Administration policy to provide full funding for fixed assets.

DEPARTMENT OF ENERGY
FY 1998 CONGRESSIONAL BUDGET REQUEST
(Changes from FY 1997 Congressional Budget Request are denoted with a vertical line in left margin.)

(Tabular dollars in thousands. Narrative material in whole dollars.)

NUCLEAR PHYSICS

1. Title and location of project: Relativistic Heavy Ion Collider
Brookhaven National Laboratory
Upton, New York

2a. Project No. 91-G-300
2b. Construction Funded

3a. Date A-E Work Initiated: 1st Qtr. FY 1991

3b. A-E Work (Title I & II) Duration: 6 months

5. Previous Cost Estimate:
Total Estimated Cost (TEC) -- $475,250
Total Project Cost (TPC) -- $595,250

4a. Date Physical Construction Starts: 2nd Qtr. FY 1991

4b. Date Construction Ends: 3rd Qtr. FY 1999

6. Current Cost Estimate:
TEC -- $486,870
TPC -- $616,530

7. Financial Schedule (Federal Funds):

Fiscal Year	Appropriations	Adjustments	Obligations	Costs
FY 1991	$ 15,000	- 1,500 a/	$ 13,500	$ 6,000
FY 1992	49,350		49,350	23,265
FY 1993	71,400	- 1,400 b/	70,000	60,839
FY 1994	78,000		78,000	82,244
FY 1995	70,000		70,000	86,600
FY 1996	65,000		65,000	76,048
FY 1997	65,000		65,000	68,000
FY 1998	76,020		59,400	64,400
FY 1999	0		16,620	19,474

a/ Reflects the reduction of funds resulting from the FY 1991 sequester and general reduction.
b/ Application of a portion of the FY 1993 General Science and Research general reduction of $30,000,000 for use of prior year balances.

1. Title and location of project:	Relativistic Heavy Ion Collider Brookhaven National Laboratory Upton, New York	2a. Project No. 91-G-300 2b. Construction Funded

8. Project Description, Justification and Scope

The Relativistic Heavy Ion Collider (RHIC) facility will be a unique, world-class research facility with opposing colliding beams that provides collision energies of 100 GeV/AMU per beam for heavy ions as massive as gold. RHIC will use the existing Alternating Gradient Synchrotron (AGS) and Tandem Van de Graaff complex as an injector. The new accelerator will be built in the existing Colliding Beam Accelerator (CBA) tunnel (3.8 km circumference), and will utilize the experimental halls, support building and liquid helium refrigerator from the partially completed CBA project.

The collider consists of two rings of superconducting magnets for accelerating and storing beams at variable energies up to 100 GeV/AMU for the heaviest ions. The collider will have the flexibility of using the full range of ion species from protons to gold which will be available from the AGS. With protons, energies of up to 250 GeV in each beam are expected. The capability for collisions between different masses in each ring will be provided. The collider is expected to have an average luminosity (a measure of the collision rate) of about 10^{26} cm^{-2} sec^{-1} for gold-on-gold collisions at full energy.

Most of the conventional construction for the collider exists, including a ring tunnel and an operating helium refrigeration system. The existing Collider Center (50,000 sq. ft. of usable area) will contain the accelerator control center, offices, technical shops, and refrigeration plant.

The existing tunnel configuration provides for six experimental areas where the circulating beams cross. Three of the experimental areas presently have completed experimental halls and support buildings for utilities. Another experimental area is an "open area" complete with support buildings and is suitable for experiments that use internal stationary targets. New construction is needed at two areas to close gaps in the ring. The standard tunnel cross section and support buildings will be constructed. Some general site work such as the paving of roads and the stabilization of the berm will also be provided.

1. Title and location of project:	Relativistic Heavy Ion Collider Brookhaven National Laboratory Upton, New York	2a. Project No. 91-G-300 2b. Construction Funded

8. Project Description, Justification and Scope (Continued)

The funds requested will provide an initial complement of research detectors at beam intersection regions necessary for the first-round research program with the high-energy heavy-ion collider.

RHIC is a two-ring colliding beam accelerator dedicated to the study of nuclear matter at very high temperatures and densities where the quark-gluon degrees of freedom are expected to be directly revealed. The purpose of RHIC is to accelerate, store, and bring into collision two circular beams of very high energy heavy ions. For the heaviest ions (e.g., nuclei of gold atoms) the energies will range up to 100 GeV/AMU in each of the two colliding beams, providing a total collision energy which exceeds by more than an order of magnitude the capability of any other existing or proposed accelerator of heavy nuclear beams.

In such collisions experimenters will be able to study extended volumes of nuclear matter with energy densities greater than 10 times that of the nuclear ground state, achieving conditions of temperature and density at which this matter loses its identity as a collection of neutrons and protons and is predicted to undergo a phase transition to a plasma of quarks and gluons. This state of matter has not yet been observed. Its existence and properties are predicted by the theory of Quantum Chromodynamics (QCD), the theory of the strong interaction which has been developed over the past two decades of progress and discovery in high energy and nuclear physics.

At present the highest energy man-made heavy ion collisions are achieved with nuclear beams impinging on stationary targets, utilizing the Brookhaven AGS and CERN Super Proton Synchrotron accelerators. Recent experiments at these facilities have confirmed expectations that very energetic collisions produce increased densities and temperatures in nuclear matter. These experiments support the predictions that at much higher energies, which can be achieved only with the colliding beams of heavy ions at the RHIC facility, the most extreme temperatures and energy densities are produced in bursts of particles formed purely from the energy in the collision. These are the sought-for thermodynamic conditions which can be directly compared with QCD calculations, and which approximate the conditions that existed before the universe condensed from a plasma of quarks and gluons to a gas of hadrons.

RHIC is designed to meet the requirements for carrying out a wide-ranging program of experiments which will open up the heretofore unexplored physics of hot dense nuclear matter and to isolate and study the new states of matter thus created. These requirements are not met by any other existing or proposed high energy colliding beams facility, all of which are designed for the acceleration of light, singly-charged particles such as protons, antiprotons, or electrons.

1. Title and location of project:	Relativistic Heavy Ion Collider Brookhaven National Laboratory Upton, New York	2a. Project No. 91-G-300 2b. Construction Funded

9. Details of Cost Estimate		Item Cost	Total Cost
a. Engineering design inspection and administration of item b			$ 83,982
1. Engineering, design and inspection at 18% of construction costs		$ 50,172	
2. Construction management at 12% of construction costs, item b		33,810	
b. Construction Costs			279,920
1. Conventional Construction		9,640	
a. Site Improvement	1,160		
b. Tunnels and Buildings	6,260		
c. Utilities	2,220		
2. Technical Components - Collider		270,280	
a. Collider Installation	31,120		
b. Magnet System	141,240		
c. Magnet Electrical System	11,640		
d. Cryogenic System	20,390		
e. Vacuum System	10,750		
f. Injection System	11,370		
g. Beam Dump System	6,030		
h. RF System	12,140		
i. Beam Instrumentation	11,080		
j. Control System	12,260		
k. Safety System	2,260		
c. Contingencies on Collider at approximately 2.2 percent of above costs			7,968
Subtotal			$371,870
d. Research Detectors (including EDIA and Contingency)			115,000
Total line item costs			$486,870

1. Title and location of project:	Relativistic Heavy Ion Collider Brookhaven National Laboratory Upton, New York	2a. Project No. 91-G-300 2b. Construction Funded

10. Method of Performance

This type of construction project is a unique facility and therefore the design, assembly and testing will be done by the staff of the Brookhaven National Laboratory (with the assistance of an architectural-engineering (A-E) firm). Component parts, wherever possible, will be fabricated by industry under fixed-priced, competitively obtained, procurement actions. Some components may be fabricated in the existing shops at BNL. Building design will be on the basis of a negotiated A-E contract, and its construction will be by a competitively obtained lump-sum contract.

11. Schedule of Project Funding and Other Related Funding Requirements

a. Total project costs	Prior Years	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995
1. Total Facility Cost						
Construction line item	$ 0	$ 6,000	$23,265	$60,839	$ 82,244	$86,600
Total facility cost	$ 0	$ 6,000	$23,265	$60,839	$ 82,244	$86,600
2. Other project costs						
a. R&D necessary to complete construction	$21,450	$ 6,614	$ 7,000	$ 7,200	$ 5,880	$ 3,620
b. Start-up, Invent. & Equip.	0	0	0	0	0	2,200
Total other project costs	$21,450	$ 6,614	$ 7,000	$ 7,200	$ 5,880	$ 5,820
Total project cost	$21,450	$12,614	$30,265	$68,039	$ 88,124	$92,420

a. Total project costs	FY 1996	FY 1997	FY 1998	FY 1999	Total
1. Total Facility Cost					
Construction line item	$76,048	$68,000	$64,400	$19,474	$486,870
Total facility cost	$76,048	$68,000	$64,400	$19,474	$486,870
2. Other project costs					
a. R&D necessary to complete construction	$ 0	$ 0	$ 0	$ 0	$ 51,764
b. Start-up, Invent. & Equip.	9,500	11,000	19,000	36,196	77,896
Total other project costs	9,500	11,000	19,000	36,196	129,660
Total project cost	$85,548	$79,000	$83,400	$55,670	$616,530

1. Title and location of project:	Relativistic Heavy Ion Collider Brookhaven National Laboratory Upton, New York	2a. Project No. 91-G-300 2b. Construction Funded

11. Schedule of Project Funding and Other Related Funding Requirements (Continued)

b. Related annual funding requirements (FY 1999 dollars)*

1. Annual RHIC Collider Operating Costs	$44,400
2. Annual Injector Operating Costs	
AGS	19,300
Booster	3,200
Tandem	2,300
Total injector operating costs	$24,800
3. Annual plant and capital equipment costs related to facility operations	6,900
4. Annual RHIC Experimental Program Support	$23,700
Total related annual funding	$99,800

* The estimated total annual funding requirements described are based on the report from the DOE/NSF Nuclear Science Advisory Committee on the Operating Costs of the Brookhaven Relativistic Heavy-Ion Collider, dated August 14, 1996. Experimental program support includes some functions not included in the previous estimate. Support for the research program is not included.

12. Narrative Explanation of Total Project Funding and Other Related Funding Requirements

a. Total project funding

1. Total facility costs

Explained in items 8, 9 and 10.

2. Other project costs

a. R&D necessary to complete construction

This included supporting R&D work on critical accelerator components before and during the construction phase. The funds covered the development of full-length (9.7 m) dipole magnets, quadrupole magnets, insertion magnets, and trim/correction spool pieces.

12. Narrative Explanation of Total Project Funding and Other Related Funding Requirements (Continued)

This also included R&D necessary for research detectors. Tests were needed to determine detailed parameters required for large-scale detectors for the heavy-ion experimental facilities, and a continued effort to develop new techniques of detection and read-out for improved utilization of the collider facility.

b. Start-up, Inventory and Equipment

These funds are needed for operation training of crew, early testing and check-out of various systems, as well as to establish a special process spares inventory as their construction is completed. Capital equipment is identified within other project costs for acquiring equipment to serve project operations and the experimental program. Portions of the cryogenic system and the beam injection system reached operational status in FY 1996.

b. Related annual costs (Estimated life of the facility: 20 years)

1. RHIC facility operating costs assume 37 weeks of operation with appropriate manpower, material, and support services associated with the Tandem/Booster/AGS injector complex and the superconducting collider.

2. RHIC Experimental Program Support includes costs for appropriate manpower and materials needed for running and maintaining the apparatus and costs of operating the on-site computing facilities for the experimental program, as well as funds that ensure that health and safety needs are covered. For this estimate, four experimental areas are planned.

3. This item includes plant and capital equipment needed to maintain and improve reliability and efficiency of the facility and associated experimental equipment for the planned research programs.

4. The updated estimate of RHIC Operations costs ($99,800,000 per year) evaluated by NSAC differs from the previous estimate ($78,900,000 per year)* by $20,900,000. Of this $20,900,000, $8,900,000 are for activities that were planned to be supported by Research funding. Hence there is a $12,000,000 increase over what had been planned, arising from an increase of $6,000,000 in the estimated costs for facility operations and an additional $6,000,000 in the estimated costs for experimental program support.

* The previous estimate was based on the RHIC Conceptual Design Report published in May 1989.