DEPARTMENT OF ENERGY
FY 1999 CONGRESSIONAL BUDGET REQUEST
SCIENCE
(Tabular dollars in thousands, Narrative in whole dollars)

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 of quark-antiquark pairs to form the mesons. Quarks, which are the most elementary building blocks of matter, are bound together in groups of three by the exchange of gluons to form the nucleons.

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

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 User Facility Initiative. Identify participation and contributions by foreign scientists at facilities, and obtain input from user's groups at facilities. Develop appropriate facility funding profiles so as to best provide overall beam availability for the Nuclear Physics program.

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.

6. At least 80 percent of the research programs will be reviewed by appropriate peers.

7. The major upgrade of scientific facilities will be managed to keep them on schedule and within cost.

8. NP will begin operating RHIC at BNL in FY 1999.

SIGNIFICANT ACCOMPLISHMENTS AND PROGRAM SHIFTS:

o The Thomas Jefferson National Accelerator Facility (TJNAF) continues to improve performance and expand experimental capabilities. Simultaneous beams are now available in all three experimental halls.

o In FY 1999 activities at the MIT Bates facility will be refocused to concentrate entirely on the development of large acceptance detector and internal target capabilities to exploit the unique scientific opportunities possible with the very high currents in the South Hall Ring.

o The Relativistic Heavy Ion Collider (RHIC) construction project at Brookhaven National Laboratory (BNL) continues on scope and budget with a completion date of the third Quarter of FY 1999. Following a successful sextant test in February 1996, installation is proceeding rapidly and overall collider construction was over 80% complete at the end of FY 1997. Fabrication of RHIC detectors, including the additional experimental equipment recommended by NSAC for purposes of particle detection and data analysis, also proceeds on schedule.

PROGRAM MISSION - NUCLEAR PHYSICS (Cont'd)

FY 1999 is a transition year. The RHIC Project will be completed in the 3rd Quarter and will begin Operations in the 4th Quarter. The BNL AGS/Booster Complex undergoes a transition from a High Energy Physics-supported facility providing primarily protons for a fixed target program to being an integral part, the injector, of the Nuclear Physics-supported RHIC facility in the 4th Quarter. FY 2000 will be the first full year of RHIC Operations.

- The Radioactive Ion Beam (RIB) facility at Oak Ridge National Laboratory (ORNL) initiated its experimental program in astrophysics and unstable nuclei in FY 1997. In FY 1998 and FY 1999 efforts at this facility will focus on improving performance, developing new beams to address the needs of the experimental program and carrying out high-priority experiments with the developed beams.

- The joint US/Canadian Sudbury Neutrino Observatory (SNO) project will be completed in FY 1998 and will initiate investigation of the solar burning process.

- In FY 1998 Gammasphere will be moved from the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory to the ATLAS facility at Argonne National Laboratory for about a year to carry out research focused on the study of the structure of nuclei far from stability in measurement which utilize Gammasphere coupled with the existing Fragment Mass Analyzer (FMA) at ATLAS.

- The Nuclear Physics request includes $180,279,000 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 will divide the responsibility for obtaining and maintaining security clearances. The Office of Security Affairs, which has been responsible for funding all Federal and contractor employee clearances, will pay only for clearances of Federal employees, both at headquarters and the field. Program organizations will be responsible for contractor clearances, using program funds. This change in policy will enable 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 Energy Research is budgeting $106,000 for estimated contractor clearances in FY 1999 within this decision unit.

NUCLEAR PHYSICS
PROGRAM FUNDING PROFILE
(Dollars in thousands)

Subprogram	FY 1997 Current Appropriation		FY 1998 Original Appropriation		FY 1998 Adjustments		FY 1998 Current Appropriation		FY 1999 Request
Medium Energy Nuclear Physics.........	$111,271		$117,990		-$87	a/	$117,903		$116,918
Heavy Ion Nuclear Physics..................	88,194		95,610		-70	a/	95,540		150,312
Low Energy Nuclear Physics...............	30,290		32,585		-20	a/	32,565		33,200
Nuclear Theory....................................	15,245		15,340		-10	a/	15,330		15,550
Subtotal...	245,000		261,525		-187	a/	261,338		315,980
Construction..	65,000		59,400		0		59,400		16,620
Subtotal, Nuclear Physics.....................	310,000		320,925		-187	a/	320,738		332,600
Adjustment..	-49	b/	-969	c/	0		-969	c/	0
Adjustment..	0		-187	a/	187	a/	0		0
TOTAL, Nuclear Physics.....................	$309,951	d/	$319,769		$0		$319,769		$332,600

a/ Share of Science general reduction for contractor training.

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

c/ 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.

d/ Excludes $5,447,000 which was transferred to the SBIR program and $328,000 which was 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 1997 Current Appropriation	FY 1998 Original Appropriation	FY 1998 Adjustments	FY 1998 Current Appropriation	FY 1999 Request
Albuquerque Operations Office					
Los Alamos National Laboratory	$11,213	$10,290	$0	$10,290	$10,430
Chicago Operations Office					
Argonne National Laboratory	16,257	16,532	0	16,532	16,787
Brookhaven National Laboratory	106,476	107,585	0	107,585	117,905
Idaho Operations Office					
Idaho National Engineering Laboratory	125	90	0	90	100
Oakland Operations Office					
Lawrence Berkeley National Laborator	24,871	22,560	0	22,560	22,960
Lawrence Livermore National Laborat	620	520	0	520	550
Oak Ridge Operations Office					
Thomas Jefferson National Accelerator Facility	68,260	68,600	0	68,600	70,600
Oak Ridge National Laboratory	15,295	15,405	0	15,405	16,396
Oak Ridge Institute for Science & Edu	589	540	0	540	590

Field Offices/Sites	FY 1997 Current Appropriation	FY 1998 Original Appropriation	FY 1998 Adjustments	FY 1998 Current Appropriation	FY 1999 Request
All Other Sites a/	66,294	78,803	-187 b/	78,616	76,282
Subtotal	310,000	320,925	-187	320,738	332,600
Adjustment	-49 c/	-969 d/	0	-969 d/	0
Adjustment	0	-187 b/	187 b/	0 d/	0
TOTAL	######## e/	#######	$0	$319,769	$332,600

a/ Funding provided to universities, industry, other federal agencies and other miscellaneous contractors.
b/ Share of Science general reduction for contractor training.
c/ 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.
d/ Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is app at the appropriation level.
e/ Excludes $5,447,000 which has been transferred to the SBIR program and $328,000 which has been transferred to the STTR program.

NUCLEAR PHYSICS

MEDIUM ENERGY NUCLEAR PHYSICS

(Tabular dollars in thousands, narrative in whole dollars)

I. <u>Mission Supporting Goals and Objectives</u>: The Nuclear Physics Program supports the basic research necessary to identify and understand the fundamental features of atomic nuclei and their interactions. The Medium Energy Nuclear Physics subprogram supports academic fundamental research, and facility operations and research at electron and proton accelerator facilities at the higher energies of interest to nuclear physics. In addition, the subprogram supports research at accelerators operated by other Department of Energy programs (e.g., High Energy Physics and Basic Energy Sciences) and at other unique domestic or foreign facilities. The research programs are ultimately aimed at achieving an understanding of the structure of the atomic nucleus in terms of the quarks and gluons, the objects which 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 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, for example, involves 600 scientists from 17 foreign countries; 81 of these scientists are from Conseil Europeen pour la Recherche Nucleaire (CERN) member states. At TJNAF, foreign collaborators have also made major investments in experimental equipment.

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 1997	FY 1998	FY 1999	$ Change	% Change
University Research	$ 11,278	$ 11,810	$ 11,895	$ +85	+0.7%
National Laboratory Research	14,358	15,256	13,985	-1,271	-8.3%
TJNAF Research	25,100	28,280	28,570	+290	+1.0%
TJNAF Operations	42,650	39,790	41,500	+1,710	+4.3%
MIT Research/Bates Operations	17,885	18,265	16,575	-1,690	-9.3%
SBIR/STTR	0	4,502	4,393	-109	-2.4%
Total, Medium Energy Nuclear Physics	$111,271	$117,903	$116,918	$ -985	-0.8%

III. Performance Summary- Accomplishments:

University Research	FY 1997	FY 1998	FY 1999
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 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 have been carrying out "symmetry violation" studies on the proton in the North Hall. Out-of-plane measurements are being carried out in the South	$ 11,278	$ 11,810	$ 11,895

	FY 1997	FY 1998	FY 1999

Hall on the proton, deuteron, and complex nuclei including measurements of the transition of the proton to its excited state. In FY 1998, important measurements will be completed. There will be a limited experimental program in FY 1999. The future experimental program will be based on a new large acceptance detector and unique new internal targets in the South Hall Pulse Stretcher Ring. 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. A new underground neutrino detector in Arizona is beginning a search for neutrino oscillations near the Palo Verde nuclear power reactors. Education activities for improving science education for students and faculty in America's schools, colleges and universities are also funded in this program.

<u>National Laboratory Research</u>

	FY 1997	FY 1998	FY 1999
Scientists at Argonne National Laboratory have used institutional expertise to develop major spectrometer and detector packages for the new TJNAF 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 and upgraded detector 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	$ 14,358	$ 15,256	$ 13,985

	FY 1997	FY 1998	FY 1999
moved from Los Alamos and the Stanford Linear Accelerator Center. This program may phase out as the Alternating Gradient Synchrotron is increasingly utilized as an injector for the new Relativistic Heavy Ion Collider. 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 the quark structure of the proton at Fermilab. Education activities for improving science education for students and faculty in America's schools, colleges and universities are also funded in this program.			
<u>TJNAF Research</u>			
Scientists at TJNAF, with support of the user community, have completed assembly of new experimental apparatus for Halls A, B, and C in collaboration with university users. All three experimental Halls are now operational; eight experiments have been completed in Hall C. Experimental equipment in Hall A is complete and the experimental program is underway. Three experiments have completed data accumulation in Hall A. The complex large-angle spectrometer in Hall B has been completed and the research program is now underway. TJNAF will maintain and operate the apparatus for safe and effective utilization by the user community and will participate in the research program. Specific attention will be given to providing additional scientific and technical manpower and materials	$ 25,100	$ 28,280	$ 28,570

	FY 1997	FY 1998	FY 1999

needed to integrate rapid assembly, modification, and disassembly of large and complex experiments for optimization of schedules. Research support for rapid implementation of the G0 experiment is not provided. Also at TJNAF, capital equipment funding will be provided for assembling and installing a state-of-the-art polarized electron injector for the accelerator. Capital equipment funds will be used to install ancillary equipment items such as polarized targets for experimental Halls A, B, and C spectrometer systems, complete a major upgrade of the data reduction system to handle massive amounts of raw data, and to continue construction of second generation experiments such as a spectrometer that is designed to investigate the strange quark content of the proton. Education activities for improving science education for students and faculty in America's schools, colleges and universities are also funded in this program.

TJNAF Operations

	FY 1997	FY 1998	FY 1999
TJNAF is presently operating in Halls A, B, and C. Continuous beam for experiments is now available in all three experimental halls at different energies and different currents, simultaneously.	$ 42,650	$ 39,790	$ 41,500

(hours of beam for research)

	FY 1997	FY 1998	FY 1999
TJNAF	4,465	4,500	4,500

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

MIT Research/Bates Operations

	FY 1997	FY 1998	FY 1999
At Bates, MIT scientists have been developing out-of-plane spectrometer (OOPS) measurement capability in collaboration with the university users. The OOPS system and multiple spectrometer systems are carrying out unique spin physics measurements in the South Experimental Hall using a new polarimeter and the new spectrometers and detectors in FY 1998. Use of these South Hall spectrometers will end in FY 1998. 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 and the continuous wave beams of the South Hall Ring. In FY 1999, the Bates effort will concentrate on development of this new and unique facility. Bates operations will be limited until completion of the new internal target area and BLAST detector. At that time, Bates operations will concentrate entirely on the use of this new facility, and will operate at a considerably reduced cost. Levels of these activities will be determined by a major upcoming review of the Bates Laboratory within the context of the world-wide electronuclear program. MIT scientists also utilize other facilities. Significant efforts are underway on the HERMES experiment at the DESY laboratory in Germany, and at TJNAF.	$ 17,885	$ 18,265	$ 16,575

(hours of beam for research)

	FY 1997	FY 1998	FY 1999
MIT/Bates	1,320	2,000	1,000

Present accelerator operations (FY 1998) provides beam for the research programs in the North and South Halls and also for testing of internal

NUCLEAR PHYSICS
MEDIUM ENERGY NUCLEAR PHYSICS

	FY 1997	FY 1998	FY 1999
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.			
SBIR/STTR			
In FY 1997 $4,052,000 and $328,000 were transferred to the SBIR and STTR programs $ 4,393 respectively. The FY 1998 and FY 1999 amounts are the estimated requirement for the continuation of these programs.		$ 0	$ 4,502
Total, Medium Energy Nuclear Physics	$111,271	$117,903	$116,918

EXPLANATION OF FUNDING CHANGES FROM FY 1998 TO FY 1999:

University Research

The university research program effort has been maintained. +$85,000

National Laboratory Research

National Laboratory research support is decreased. Beginning in FY 1999, this program will budget $106,000 for estimated costs of obtaining and maintaining security clearances for contractor employees under the Chicago Operations Office and the Oak Ridge National Laboratory. -$1,271,000

TJNAF Research

Jefferson Laboratory research increases in the area of support for experimental setup, and decreases in capital equipment support.	+$290,000

TJNAF Operations

Funding for Jefferson Laboratory facility Operations maintains FY 1998 operating levels for research.	+$1,710,000

MIT Research/Bates Operations

The decrease in Bates funding reflects limited operations at Bates in FY 1999 while pursuing the construction of BLAST, and the move toward future operations of Bates which is much more narrowly focused.	-$1,690,000

SBIR/STTR

Estimated FY 1999 funds for SBIR decrease compared to FY 1998.
-$109,000

Total Funding Change, Medium Energy Nuclear Physics
-$985,000

NUCLEAR PHYSICS

HEAVY ION NUCLEAR PHYSICS

(Tabular dollars in thousands, narrative in whole dollars)

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

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

NUCLEAR PHYSICS
HEAVY ION NUCLEAR PHYSICS

II. Funding Schedule:

Program Activity	FY 1997	FY 1998	FY 1999	$ Change	% Change
University Research	$ 16,448	$ 16,505	$ 16,705	$ + 200	+1.2%
Laboratory Experimental Support and Research	34,709	36,025	40,215	+4,190	+11.6%
National User Facilities Operations	20,614	17,890	18,162	+272	+ 1.5%
BNL RHIC Pre-Operations/Operations	10,973	19,000	67,680	+48,680	+256.2%
LBNL GPP and GPE	5,450	5,450	5,450	0	0.0%
SBIR	0	670	2,100	+1,430	+213.4%
Total, Heavy Ion Nuclear Physics	$ 88,194	$ 95,540	$ 150,312	$+54,772	+57.3%

III. Performance Summary-Accomplishments:

University Research	FY 1997	FY 1998	FY 1999
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 for studies of high-spin, deformed nuclei at the 88-inch Cyclotron in FY 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 include an emphasis on 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 analysis of data obtained from experiments at the BNL Alternate Gradient Synchrotron (AGS) and CERN Super Proton Synchrotron (SPS) facilities, and (2)	$ 16,448	$ 16,505	$ 16,705

	FY 1997	FY 1998	FY 1999
participation in the planning, construction and implementation of detectors for the RHIC program scheduled to begin in FY 1999. Education activities for improving science education for students and faculty in America's schools, colleges and universities are also funded in this program.			
National Laboratory Experimental Support and Research			
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, (see Major Items of Equipment), recommended in a NSAC review as important for addressing the physics objectives of the RHIC program. Education activities for improving science education for students and faculty in America's schools, colleges and universities are also funded in this program.	$ 34,709	$ 36,025	$ 40,215
National Users Facilities Operations			
Support is provided for three 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, and the Tandem/AGS facility at BNL for studies of the properties of hot, dense nuclear matter. FY 1998	$ 20,614	$ 17,890	$ 18,162

	FY 1997	**FY 1998**	**FY 1999**

ATLAS and 88-inch operations funding (and beam hours) reflected the move of the high priority Gammasphere program to ATLAS in FY 1998. Support is provided for the first three Quarters of FY 1999 to complete the AGS heavy ion research program and to continue the development of the capabilities needed for the Tandem/AGS to act as an injector for RHIC and to provide the beams needed for RHIC commissioning activities. Funding for operations of the RHIC complex in the 4th Quarter of FY 1999 is listed in the next paragraph. These facilities are planned to provide yearly hours of beam for research as indicated below:

	(hours of beam for research)		
	FY 1997	FY 1998	FY 1999
ATLAS	5,369	5,700	5,700
88-inch Cyclotron	6,243	4,500	4,500
Tandem/AGS	1,831	672	500

Both the 88-inch Cyclotron 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.

NUCLEAR PHYSICS
HEAVY ION NUCLEAR PHYSICS

	FY 1997	FY 1998	FY 1999

BNL RHIC Pre-Operations/Operations

Pre-operating, inventory and capital equipment funds are provided for the RHIC project $ 10,973 $ 19,000
$ 67,680
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.) The RHIC Project is scheduled to be completed in the 3rd Quarter of FY 1999. Funding of $31,457,000 is provided for RHIC operations for the 4th Quarter of FY 1999.

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 $5,000,000. In addition, the program has landlord responsibility for providing general purpose equipment (GPE) at LBNL. $ 5,450 $ 5,450 $ 5,450

SBIR

In FY 1997 $540,000 was transferred to the SBIR program. The FY 1998 and FY 1999 $ 0 $ 670
$ 2,100

amounts are the estimated requirement for the continuation of these programs.

Total, Heavy Ion Nuclear Physics	$ 88,194	$ 95,540	$150,312

EXPLANATION OF FUNDING CHANGES FROM FY 1998 TO FY 1999:

University Research

FY 1999 funding for University Research maintains research and educational activities with emphasis on supporting groups working at RHIC. Operations at the two university facilities (Texas A&M and Yale) obtain constant funding compared to FY 1998. +$200,000

Laboratory Experimental Support and Research

FY 1999 operating funding for research at National Laboratories is about constant compared +$4,190,000
with FY 1998, but distributed unequally with enhanced support for detector and computer efforts at BNL to initiate the RHIC research program in the fourth quarter. FY 1999 capital equipment is increased by about $4,200,000 compared with FY 1998, with about $3,700,000 planned for RHIC computing and experimental equipment projects which expand RHIC detector capabilities and the remainder to be directed at high priority initiatives at other National Laboratory and university facilities.

National User Facilities Operations

Operations at the ATLAS and 88-Inch Cyclotron facilities obtained constant effort funding compared to FY 1998 to maintain beam hours for research. The BNL Tandem/AGS is funded for three Quarters in FY 1999 to provide heavy ion beams to complete the AGS research program and to continue developments needed in order to perform as the RHIC injector, to provide beams for RHIC +$272,000

NUCLEAR PHYSICS
HEAVY ION NUCLEAR PHYSICS

commissioning

and to implement the transition from AGS Operations and RHIC Construction to a RHIC Operations organization. Completion at LBNL of accelerator R&D projects and of decommissioning activities related to the terminated Bevalac facility account for some reductions in this area.

BNL RHIC Pre-Operations/Operations

RHIC Pre-Operations increase as planned to $36,223,000 in FY 1999 the last year of construction (See RHIC Data Sheet). +$17,223,000

Funds are provided for RHIC Operations for the 4th Quarter of FY 1999. +$31,457,000

SBIR

Estimated FY 1999 funds for SBIR increase compared to FY 1998. +$1,430,000

Total Funding Change, Heavy Ion Nuclear Physics +$54,772,000

NUCLEAR PHYSICS

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. University-based research is an important feature of the Low Energy subprogram. Since most of the required facilities are relatively small, they are appropriate for siting on university campuses, where they provide unique opportunities for hands-on training of nuclear experimentalists who are so important to the future of this field. Many of these scientists, after obtaining their Ph.D.s, contribute to a wide variety of nuclear technology programs of interest to the DOE. Included in this subprogram are the activities of the National Nuclear Data Center and its support sites that are aimed at providing information services on critical nuclear data and have as a goal the compilation and dissemination of an accurate and complete nuclear data information base that is readily accessible and user oriented.

II. Funding Schedule:

Program Activity	FY 1997	FY 1998	FY 1999	$ Change	% Change
Radioactive Ion Beams (RIB)	$ 12,295	$ 13,730	$ 14,440	$ +710	+5.2%
University Research	9,466	9,355	9,630	+275	+2.9%
National Laboratory Research	3,444	3,475	3,115	-360	-10.4%
Nuclear Data Program	4,780	4,900	4,900	0	0%
SBIR	0	800	810	+10	1.2%
Lawrence and Fermi Awards	305	305	305	0	0%
Total , Low Energy Nuclear Physics	$ 30,290	$ 32,565	$ 33,200	$ +635	+1.9%

	FY 1997	FY 1998	FY 1999

III. Performance Summary- Accomplishments:

Radioactive Ion Beams (RIB) at Oak Ridge National Laboratory

This technically difficult project, which couples the existing cyclotron and tandem accelerators, was completed in FY 1997, and operated with initial beams of arsenic 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, a $2,000,000 device contributed by the United Kingdom, allows separation of the products of nuclear reactions from particles a trillion times more intense, enabling the measurement of nuclear reactions that fuel the explosion of stars. Capital equipment and AIP funds are provided to expand the list of available beam species. The RIB facility is planned to provide yearly hours of beams for research as indicated below:	$ 12,295	$ 13,730	$ 14,440

	(hours of beam for research)		
	FY 1997	FY 1998	FY 1999
RIB	1,415	2,200	2,400

Research at the Oak Ridge Electron Linear Accelerator (ORELA), which is also operated by RIB staff, is aimed at resolving discrepancies in the rate of production of primordial elements compared with theoretical predictions, such as models that predict the formation of heavy elements like carbon, nitrogen, and oxygen in the Big Bang.

	FY 1997	FY 1998	FY 1999
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.	$ 9,466	$ 9,355	$9,630

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. University scientists perform research both on-site at these facilities, as user groups at National Laboratory user facilities, and at the Sudbury Neutrino Observatory (SNO).

Education activities for improving science education for students and faculty in America’s schools, colleges and universities are also funded in this program.

National Laboratory Research

The major effort in FY 1997, was the assembly of the 40 foot diameter plastic (acrylic) $ 3,444 $ 3,475$ 3,115

vessel that will hold 1,000 tons of heavy water for the solar neutrino detector at the SNO laboratory located 6,800 feet underground. The research that will follow the completion of filling the tank in FY 1998, 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

	FY 1997	FY 1998	FY 1999
length) to their underground storage in the ultra low cosmic ray background environment of the SNO mine. They are being stored for a period of time which is sufficient to allow decay to low levels of the radioactivity induced in the detectors by the above ground cosmic ray background.			
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, supports the NNDC in data evaluation and development of on-line access capabilities. After completion of a FY 1997 review, a new activity, jointly supported with the Division of Nuclear Physics research community, will be competed for in order 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.	$ 4,780	$ 4,900	$ 4,900
SBIR			
In FY 1997 $855,000 was transferred to the SBIR program. The FY 1998 and FY 1999 $810 amounts are the estimated requirement for the continuation of these programs.		$0	$800

	FY 1997	FY 1998	FY 1999

	FY 1997	FY 1998	FY 1999
Lawrence and Fermi Awards			
Provides annual monetary awards to honorees selected by the Department of Energy for their outstanding contributions to nuclear science.	$ 305	$ 305	$ 305
Total, Low Energy Nuclear Physics	$ 30,290	$ 32,565	$ 33,200

EXPLANATION OF FUNDING CHANGES FROM FY 1998 TO FY 1999:

Radioactive Ion Beams (RIB)

The RIB facility at Oak Ridge National Laboratory will begin full operation in FY 1998 and increase its available beam hours for users in FY 1999.	+$710,000

University Research

An increase is provided for low energy university research to support increased level of involvement in research using RIBs.	+$275,000

National Laboratory Research

A decrease in laboratory research support reflects the completion of the Sudbury Neutrino Observatory installation phase.	-$360,000

NUCLEAR PHYSICS
LOW ENERGY NUCLEAR PHYSICS

SBIR

Estimated FY 1999 funds for SBIR increase compared to FY 1998.	+$10,000
Total Funding Change, Low Energy Nuclear Physics	+$635,000

NUCLEAR PHYSICS

NUCLEAR THEORY

(Tabular dollars in thousands, narrative in whole dollars)

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

The Nuclear Theory program supports all areas of nuclear physics, and is carried out at universities and National Laboratories. 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 component of the program is the Institute for Nuclear Theory (INT), 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 based technology areas.

NUCLEAR PHYSICS
NUCLEAR THEORY

II. Funding Schedule:

Program Activity	FY 1997	FY 1998	FY 1999	$ Change	% Change
National Laboratory Research	$ 5,221	$ 5,135	$ 5,225	$ +90	+1.8%
University Research	10,024	10,195	10,325	+130	+1.3%
Total, Nuclear Theory	$ 15,245	$ 15,330	$ 15,550	$ +220	+1.4%

III. Performance Summary-Accomplishments:

National Laboratory Research	FY 1997	FY 1998	FY 1999
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 are being developed to analyze experiments at RHIC. A better understanding of effective masses of particles in nuclear matter, fundamental inputs to these cascade codes, has been developed. Properties of few body nuclei have been calculated exactly to allow detailed analysis of experiments at the Thomas Jefferson National Accelerator Facility (formerly CEBAF).	$ 5,221	$ 5,135	$ 5,225

Education activities for improving science education for students and faculty in America's schools, colleges and universities are also funded in this program.

NUCLEAR PHYSICS
NUCLEAR THEORY

	FY 1997	FY 1998	FY 1999
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. Perturbation theories and relativistic theories are being developed to be used to more accurately apply the concepts of QCD and the standard model to nuclear physics questions. The Institute for Nuclear Theory at the University of Washington is recognized as the preeminent international center for theoretical nuclear physics activities. Education activities for improving science education for students and faculty in America's schools, colleges and universities are also funded in this program.	$ 10,024	$ 10,195	$ 10,325
Total, Nuclear Theory	$ 15,245	$ 15,330	$ 15,550

EXPLANATION OF FUNDING CHANGES FROM FY 1998 TO FY 1999:

National Laboratory Research

Continues research program and enhances theory support of RHIC physics. +$90,000

NUCLEAR PHYSICS
NUCLEAR THEORY

University Research

Continues research effort.	+$130,000
Total funding change, Nuclear Theory	+$220,000

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 1997	FY 1998	FY 1999	$ Change	% Change
Construction					
RHIC	$ 65,000	$ 59,400	$ 16,620	$- 42,780	-72.0%
Total, Construction	$ 65,000	$ 59,400	$ 16,620	$- 42,780	-72.0%

III. Performance Summary-Accomplishments:

RHIC	FY 1997	FY 1998	FY 1999
Collider Ring activity during the first half of FY 1997 focused on the completion of five milestones which included injection of gold beams from the AGS and testing of the First Sextant. The Sextant Test was a major project accomplishment. The successful transport of gold beams through the sextant proved the soundness of the collider design, quality of the technical components, and capability of the staff. The test utilized the production technical components such as magnets, cryogenics, electrical vacuum, instrumentation, injection, RF, control and safety, that are being installed in the entire RHIC ring. During the remaining half of FY 1997 assembly and installation work continued at a rapid pace with the remaining 5/6 of	$ 65,000	$ 0	$ 0

	FY 1997	FY 1998	FY 1999
the Collider Ring. The experimental detector portion of the project moved rapidly along. Conventional construction proceeded with the construction of the PHENIX Counting House, procurement of the cooling water systems, and final design of the electrical power installation at the experimental areas. The STAR detector magnets backlegs are assembled, and installation of the power coil is completed. Assembly of the STAR Time Project Chamber and its cosmic ray tests are completed. The PHENIX detector, following the assembly of the Muon ID steel, is focussing on the purchase, fabrication, and installation of individual detector subsystems components.			
Activity in FY 1998 will focus on twelve milestones. Collider construction will emphasize the completion of magnet production, completion of the injection line, cryogenic piping, vacuum system, acceleration RF system, and completion of collider ring installation. These major accomplishments will allow for the start of ring cool-down and set the stage for the debugging and testing which is required before collider operation. The experimental program will be rushing to meet milestones as well. The PHENIX detector is scheduled to complete the prototype data acquisition system, to test and map its magnets, to be well along in the production of detector elements, and to begin installation of the detectors in the west arm of the Central Spectrometer. Following the detailed magnetic field mapping, the STAR detector will be installing the Time Projection Chamber, shipped from LBNL to BNL in the fall 1997, completing the electronics integrated-sector test, and complete work on the magnet and support structure. The PHOBOS detector will enter into its production phase with the award of its magnet contract in October and the test of its readout chips. The BRAHMS detector is focusing on having magnets and its TPC's ready to install by the end of this fiscal year.	$ 0	$ 59,400	$ 0

NUCLEAR PHYSICS
CONSTRUCTION

	FY 1997	FY 1998	FY 1999
FY 1999 is the final year of RHIC construction activity and eighteen milestones are scheduled. The majority of RHIC hardware that is needed to bring the beams into collisions will be in place by the start of FY 1999. In the first quarter most efforts will focus on hardware systems testing. Installation of the final magnets will allow vacuum pumpdown to start in the ring. It is anticipated that portions of the ring will start cooldown sequentially until the full ring is cold in December. The first low intensity beam tests are scheduled for January-March of 1999 with only luminosity monitors in place in the experimental regions. An approximate 10 week shutdown is then planned where the detectors will roll in, and then the initial commissioning of collider operation will start. The Project Complete milestone is set for the end of June. Initial machine commissioning will take place with low-intensity single bunches of beam. For the experimental detector portion of the project, installation and testing of the RHIC detectors will be completed. As a part of this process, each of the detectors (but primarily the large detectors STAR and PHENIX) will be operated for extended periods to establish calibration parameters for the various detector subsystems. The shield walls and access control systems will be in place for the early machine phase. Full operation of RHIC is scheduled for the final quarter of FY 1999.	$ 0	$ 0	$ 16,620
Total Construction	$65,000	$59,400	$16,620

NUCLEAR PHYSICS
CONSTRUCTION

EXPLANATION OF FUNDING CHANGES FROM FY 1998 TO FY 1999:

Construction funds for RHIC are being reduced in coordination with the planned increase in operating funds -$42,780,000 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.

Total Funding Change, Construction	-$42,780,000

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

Capital Operating Expenses	FY 1997	FY 1998	FY 1999	$ Change	% Change
General Plant Projects (Total)	$ 4,570	$ 4,300	$ 4,000	-$ 300	- 7.0%
Accelerator Improvement Projects (Total) .	4,800	4,200	4,900	+ 700	+ 16.7%
Capital Equipment (Total)	24,245	26,620	31,500	+ 4,880	+ 18.3%

Construction Project Summary (both Operating and Construction Funded)

Project Number	Project Title	TEC	Previous Approp.	FY 1997 Approp.	FY 1998 Approp.	FY 1999 Request	Unapprop. Balance
91-G-300	Relativistic Heavy Ion Collider, BNL	$ 486,870	$ 345,850	$ 65,000	$ 59,400	$ 16,620	$ 0
	Total Nuclear Physics	--	$ 345,850	$ 65,000	$ 59,400	$ 16,620	$ 0

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

	TEC	Previous Approp.	FY 1997 Approp.	FY 1998 Approp.	FY 1999 Request	Acceptance Date
1. STAR Silicon Vertex Tracker	$ 7,000	$ 1,450	$ 2,000	$ 1,500	$ 1,300	FY 2000
2. PHENIX Muon Arm Instrumentation	11,400	700	2,625	3,000	1,400	TBD
3. Analysis System for RHIC Detectors	7,900	100	675	1,700	5,425	FY 2000
4. BLAST Large Acceptance Detector	4,900	0	400	900	900	TBD

DEPARTMENT OF ENERGY
FY 1999 CONGRESSIONAL BUDGET REQUEST
(Changes from FY 1998 Congressional Budget Request are denoted with a vertical line in left margin.)

SCIENCE
(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

	Preliminary Estimate	Title I Baseline	Current Baseline Estimate
3a. Date A-E Work Initiated, (Title I Design Start Scheduled):	N/A	N/A	1st. Qtr. FY 1991
3b. A-E Work (Titles I & II) Duration:	N/A	N/A	6 months
4a. Date physical Construction Starts:	N/A	N/A	2nd Qtr. FY 1991
4b. Date Construction Ends:	N/A	N/A	3rd Qtr. FY 1999

	Preliminary Estimate	Title I Baseline	Current Baseline Estimates a/
5. Total Estimated Cost (TEC) --	N/A	N/A	$486,870
6. Total Project Cost (TPC) --	N/A	N/A	$616,530

a/ Current Baseline Estimate is the latest baseline which reflects the approved changes to the Title I baseline.

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

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	59,309
FY 1998	59,400		59,400	67,400
FY 1999	16,620		16,620	25,165

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.

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.

8. Project Description, Justification and Scope (Continued)

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. 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 l00 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 l0 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

8. Project Description, Justification and Scope (Continued)

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

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	$59,309	$67,400	$25,165	$486,870
Total facility cost	$76,048	$59,309	$67,400	$25,165	$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	10,973	19,000	36,223	77,896
Total other project costs	9,500	10,973	19,000	36,223	129,660
Total project cost	$85,548	$70,282	$86,400	$61,388	$616,530

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.