DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
OFFICE OF ENERGY RESEARCH

OVERVIEW

NUCLEAR PHYSICS PROGRAM

The Nuclear Physics program of the Department of Energy (DOE) has the lead responsibility for Federal support of nuclear physics research and supports basic research activities under the mandate provided in Public Law 95-91 which established the Department. The primary goal of the program is to understand the structure of atomic nuclei and the fundamental forces required to hold nuclei together. Nuclear processes determine the essential physical characteristics of our universe and the composition of the matter which forms it. The science of nuclear physics has spawned many diverse technologies such as nuclear medicine, nuclear power, nuclear fusion and nuclear weapons. These technologies have matured to the point where they now operate almost independently of the basic research program. Nevertheless, vital interactions still occur in the development of advanced concepts, in the transfer of improved theoretical models, in the common development of instrumentation, and in the need for more precise nuclear physics data in selected areas. Nuclear Physics accelerators uniquely generate many of the radioisotopes used for medical diagnoses and support several cooperative programs in biomedical research. About 75 percent of the 80 new Ph.D.'s produced each year in the DOE Nuclear Physics program will find careers in these associated areas. In addition, the Nuclear Data program within nuclear physics generates, evaluates, and disseminates information such as neutron cross sections in active support and collaboration with these programs.

A specific example of the diverse and active cooperation between nuclear scientists and other disciplines can be seen in the area of activation analysis. This nondestructive nuclear technique uses small neutron generators to identify in detail the composition of complex materials. For example, the origin of the clays found in archeological potsherds can be specified to individual mine sites. One use of this method was to identify the homeland of the Biblical Philistines as being on the island of Cyprus. The ongoing use of neutron activation is crucial in oil exploration well logging to identify the substances through which a test bore passes. Nuclear scientists were central to the discovery of iridium at the K-T boundary between the cretaceous and tertiary geological eras, of 66 million years ago. The presence of iridium implies that a large meteorite impacted the earth, leading to major climatic changes and causing the extinction of the dinosaurs. Use of this technique for trace element impurity identification is showing great promise to greatly improve the burning of coal in a clean way. And finally, nuclear physicists active in heavy ion research have used their talents to help perfect a process in which activation analysis is used to specifically identify plastic explosives in attempts to smuggle them aboard aircraft in the luggage of terrorists.

Nevertheless, the major activity and essential vitality of the field focuses upon an ever improving fundamental understanding of the material and forces of nature. Over the years, many theoretical models have been developed to describe the structure of the nucleus and its behavior. These models have progressed from simple mechanical models of surface vibrations and rotations to sophisticated descriptions of meson-nucleon interactions. Scientists now know that nucleons (neutrons and protons, the constituents of the nucleus), are composed of smaller constituents called quarks. Based on the ways quarks are confined together in groups of three to make nucleons, or groups of two to make mesons, a more fundamental theory of the nuclear force called quantum chromodynamics (QCD) is emerging. The incorporation of QCD concepts deepens our understanding of nuclear structure and interactions and provides significant new challenges to the experimental program. Many of the characteristics and implications of the new QCD formulation of the nuclear force are addressed by the research programs both of nuclear physics and its daughter science, high energy physics. However, the Nuclear Physics program uniquely approaches the problems by testing the theoretical predictions in the medium of extended nuclear matter provided by nuclei composed of many nucleons. A growing number of problems of mutual interest to nuclear physics and astrophysics include measurements or calculations of supernovae, neutron stars, solar neutrinos, heavy cosmic rays, and the continuing problem of stellar nuclear abundances. Of particular interest is the ability of relativistic heavy ion collisions to create a quark-gluon plasma, simulating a stage of evolution of the universe that ended ten millionths of a second after the initial "big bang."

The strategy of the program is to address the most pressing scientific questions in nuclear physics with new theories, equipment and facilities while maintaining an effective balance between competing and diverse program elements. Essential guidance is provided by the Nuclear Physics Program plan, with continuing advice from the Nuclear Science Advisory Committee (NSAC). Key elements of the plan are reflected in this budget.

The program is centered around an active experimental research program which is continually evaluated and revised to focus on the most basic scientific questions. Necessary for proper conduct of this research are efforts in nuclear theory, design and fabrication of sophisticated detectors and the development and training of creative and skilled personnel. Central to the program are the construction, operation and maintenance of the accelerator facilities which provide the beams of particles upon which the experiments are based. In some areas of nuclear physics, questions are addressed at universities by accelerators dedicated to in-house research, or smaller facilities at some national laboratories. However, many of the newly emerging fundamental problems in nuclear science require large modern facilities designed for the research use of the entire nuclear community.

The DOE Nuclear Physics program supports over 80 percent of the U.S. program of basic research in nuclear physics. In FY 1991 it will maintain a vigorous research program, focusing on current problems of high scientific and technological interest and pointing towards exploitation of the new major facilities. A growing fraction, now about 75 percent, of the scientists supported by the Nuclear Physics program plan experiments and conduct research at the large user dedicated facilities. The strong university component which forms the central core of the facility user activity is augmented by a NSF effort of comparable size. About 110 visiting scientists do experiments at the Bevalac at the Lawrence Berkeley Laboratory each year and a similar number make use of the Tandem/AGS at the Brookhaven National Laboratory. About 320 visiting scientists annually use the multiple beams available at the LAMPF facility at the Los Alamos National Laboratory for one or more experiments. Already, 245 physicists from 60 institutions have submitted 47 research proposals to the Continuous Electron Beam Accelerator Facility (CEBAF). From these proposals a program of experiments will ultimately be selected to be carried out when the facility goes into operation with present focus on the involvement of the user community on equipment fabrication. About 200 scientists from outside of CEBAF are already actively participating in the design of experiments. Special emphasis is placed on effective use of the upgraded accelerators at the University of Washington and Yale University, the ATLAS superconducting heavy ion facility at Argonne National Laboratory (ANL), and Tandem/AGS high energy heavy ion beams at Brookhaven National Laboratory (BNL). Adjustments within the program will be made to accommodate the increased interest of students and postdoctoral fellows in nuclear physics, to enhance the theory component, and to reflect more accurately the highest program priorities and new scientific areas. In addition, much good science can be accomplished with selected smaller improvements of existing facilities such as the South Hall Ring experiment at the MIT/Bates Electron Linac. Other National laboratory and university accelerators will be operated for maximum program effectiveness with selected capital equipment detector projects to optimize facility productivity. Among these are a start of the segmented gamma ray detector for nuclear structure physics (Gammasphere) and joint participation with Canada and the United Kingdom in the Sudbury Neutrino Observatory (SNO) project.

Research and development in support of the next generation accelerators is included in the Nuclear Physics program. Efforts will continue at Brookhaven National Laboratory for the purpose of extending the solid scientific and technical basis for the proposed Relativistic Heavy Ion Collider (RHIC). The R&D necessary to optimize the RHIC project is currently being conducted. The Nuclear Science Advisory Committee (NSAC) has assigned RHIC its highest priority for start of new construction in its Long Range Plan for Nuclear Science of 1983. That priority was endorsed by the National Research Council in its report "Physics through the 1990's." In addition to the core program of quark-gluon plasma investigations, the intense electric and magnetic fields produced in these collisions provide a new mechanism for production of non-strongly interacting particles. $15,000,000 is being requested to start construction of RHIC. NSAC has recently completed its latest long range plan "Nuclei, Nucleons, Quarks - Nuclear Science in the 1990's." It states: "We strongly reaffirm the very high scientific importance of the Relativistic Heavy Ion Collider (RHIC). Since the last long range plan (LRP), theoretical progress has strengthened the case for the existence of a quark-gluon plasma, and recent experiments demonstrate that conditions favorable to its formation will be attained. RHIC will provide unprecedented opportunities to produce and study ultradense matter. Therefore, we strongly endorse the recommendation of the 1983 LRP and subsequent NSAC deliberations that RHIC has the highest priority for new construction in the nuclear physics program. We urge a swift beginning for this important project."

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
OFFICE OF ENERGY RESEARCH
(dollars in thousands)
LEAD TABLE
Nuclear Physics

Activity	FY 1989 Appropriated	FY 1990 Request	FY 1991 Base	FY 1991 Request	Program Change Request vs Base: Dollar	Program Change Request vs Base: Percent
Operating Expenses						
Medium Energy Nuclear Physics	$85,191	$92,388	$92,388	$101,000	$+ 8,612	+ 9%
Heavy Ion Nuclear Physics	66,476	67,516	67,516	72,929	+ 5,413	+ 8%
Low Energy Nuclear Physics	24,461	26,326	26,326	28,100	+ 1,774	+ 7%
Nuclear Theory	10,818	12,226	12,226	13,500	+ 1,274	+ 10%
Capital Equipment	18,500	19,720	19,720	26,700	+ 6,980	+ 35%
Construction	52,500	71,485	71,485	88,500	+ 17,015	+ 24%
Total	257,946	289,661	289,661	330,729	+ 41,068	+ 14%
Operating Expenses	(186,946)a/	(198,456)	(198,456)	(215,529)	+ 17,073	+ 9%
Capital Equipment	(18,500)	(19,720)	(19,720)	(26,700)	+ 6,980	+ 35%
Construction	(52,500)	(71,485)	(71,485)	(88,500)	+ 17,015	+ 24%
Total Program	($257,946)b/c/	($289,661)c/d/e/	($289,661)	($330,729)c/	$+ 41,068	+ 14%
Staffing (FTEs)	(Reference General Science Program Direction)					

Authorization: Section 209, P.L. 95-91.

a/ Total has been reduced by $2,365,000 ($520,000 Medium Energy; $440,000 Heavy Ion; $1,405,000 Low Energy) reprogrammed to Energy Supply for SBIR.

b/ Excludes $3,188,000 which represents applicable portion of $12,000,000 General Reduction contained in FY 1989 Appropriation.

c/ Reflects comparability adjustment for new Environmental Restoration and Waste Management program as follows: FY 1989 - $601,000; FY 1990 - $939,000; FY 1991 - $1,202,000.

d/ Excludes $5,573,000 which represents applicable portion of $21,000,000 General Reduction contained in FY 1990 Appropriation.

e/ FY 1990 reflects final Gramm-Rudman-Hollings sequester adjustments.

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

SUMMARY OF CHANGES

Nuclear Physics

FY 1990 Appropriation..	$289,661
Adjustments - Increased personnel costs..	0
FY 1991 Base...	289,661
- Funding required to maintain a constant overall level of program activity............	+ 9,536
Medium Energy Nuclear Physics	
- Conduct medium energy physics research and operations at about constant level of activity, with increased level of support for CEBAF laboratory........................	+ 4,631
Heavy Ion Nuclear Physics	
- Continue Heavy Ion operations with increased activity in university programs and at the AGS at Brookhaven..	+ 2,678
Low Energy Nuclear Physics	
- Continue nuclear data program and low energy physics operations and research at approximately constant level of activity with additional support for neutrino research..	+ 668
Nuclear Theory	
- Increase level of activity with emphasis on preparation of theoretical guidance for experimental results using new theory institute..................................	+ 761

Capital Equipment

- Provide for initiation of Gammasphere and Sudbury Neutrino Observatory, maintain overall level of instrumentation effort and provide for general purpose equipment to meet laboratory-wide needs of Lawrence Berkeley Laboratory........................	+ 6,152

Construction

- Slightly reduced level of effort for AIP and GPP......................................	- 747
- Contine Continuous Electron Beam Accelerator Facility (CEBAF) project at planned level..	+ 2,389
- Initiate Relativistic Heavy Ion Collider (RHIC) construction project.................	+ 15,000
FY 1991 Congressional Budget Request..	$330,729

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

KEY ACTIVITY SUMMARY

NUCLEAR PHYSICS

I. Preface: Medium Energy Nuclear Physics

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 operations and research at accelerator facilities with sufficient primary beam energy to produce pi mesons (pions) using projectiles no more massive than alpha particles. In addition, the subprogram supports nuclear physics experiments at accelerators operated by other DOE programs (e.g., High Energy Physics and Basic Energy Sciences) and at other unique domestic or foreign facilities. Two national accelerator facilities are operated entirely under the Medium Energy subprogram--the Clinton P. Anderson Meson Physics Facility (LAMPF) at Los Alamos National Laboratory and the Bates Linear Accelerator Center operated by the Massachusetts Institute of Technology. These accelerator facilities serve a nationwide community of scientists from over 100 American institutions, of which over 90% are universities. At proton facilities, support is provided for wide-ranging research activities on the scattering of protons and pions, weak interactions, muonic and pionic atoms, selective excitation of proton/neutron states, and giant resonances. At electron facilities, support is provided for high resolution studies of the electric and magnetic structure of nuclei, the motion of pions inside nuclei, and the role of excited states of nucleons in nuclear structure. R&D activities required for the construction of the Continuous Electron Beam Accelerator Facility (CEBAF) and preparation for operation of the laboratory are also carried out under the Medium Energy subprogram.

II. A. Summary Table: Medium Energy Nuclear Physics

Program Activity	FY 1989 Actual	FY 1990 Estimate	FY 1991 Request	% Change
Research				
LAMPF-Based Research..........................	$ 10,456	$ 10,911	$ 10,921	0
Bates Based Research..........................	3,107	3,282	3,291	0
CEBAF-Based Research..........................	8,922	11,284	12,209	+ 8
Research at Other Sites.......................	11,041	12,188	12,379	+ 2
Subtotal, Research	$ 33,526	$ 37,665	$ 38,800	+ 3
Operations				
LAMPF Operations..............................	$ 41,580	$ 40,426	$ 41,000	+ 1
Bates Operations..............................	6,850	7,000	7,400	+ 6
CEBAF Operations..............................	1,000	6,015	12,400	+106
Other Operations..............................	2,235	1,282	1,400	+ 9
Subtotal, Operations	$ 51,665	$ 54,723	$ 62,200	+ 14
Total, Medium Energy Nuclear Physics	$ 85,191	$ 92,388	$ 101,000	+ 9

II. B. Major Laboratory and Facility Funding

	FY 1989 Actual	FY 1990 Estimate	FY 1991 Request	% Change
Continuous Electron Beam Accelerator Facility ...	$ 10,350	$ 17,255	$ 23,765	+ 38
Los Alamos National Scientific Laboratory	$ 48,180	$ 47,131	$ 47,700	+ 1
Massachusetts Institute of Technology	$ 9,900	$ 10,155	$ 10,705	+ 5

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1989	FY 1990	FY 1991
Medium Energy Nuclear Physics			
Research			
LAMPF-Based Research	Continue use of Clamshell Spectrometer on the Low Energy Pion (LEP) channel and expand use of neutron time-of-flight facility. Initiate research program using medium resolution spectrometer (MRS).	Conduct full experimental program using MRS with beam from new high intensity polarized proton source. Complete preparations on LEP channel for installation of energy spread compressor.	Continue use of MRS with polarized beams. Complete installation of energy spread compressor on LEP channel and begin experiments.
	Analyze data from neutrino oscillation experiment and move detector further from beam stop.	Begin taking longer flight path data for neutrino oscillation experiment, and begin R&D activies for next-generation neutrino experiment.	Complete data taking for neutrino oscillation experiment, and continue R&D activities for new neutrino experiment.
	Continue use of time-of-flight isochronous (TOFI) facility for nuclear mass measurements and develop new detector to resolve heavier isotopes.	Use new detector on TOFI to extend studies to higher masses.	Do selected high mass studies on TOFI.
	Complete preparations for rare muon decay (MEGA) experiment involving 32 scientists from 13 institutions and requiring $3.5M detector.	Start data taking phase of MEGA experiment with intermediate-sensitivity form of detector.	Complete full sensitivity detector for MEGA and continue data taking.

III. Medium Energy Nuclear Physics (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
LAMPF-Based Research (Cont'd)	Continue research programs in nuclear structure and nuclear reactions with incident pions and protons. Continue research on nuclear structure with a polarized nuclear target. Continue measurements of the nucleon-nucleon interaction and tests of charge symmetry breaking.	Continue research programs in nuclear structure and nuclear reactions with incident pions and protons. Continue research using the polarized nuclear target. Expand measurement of the nucleon-nucleon interaction and tests of charge symmetry breaking.	Continue nuclear structure and reaction mechanism studies. Postpone experimental program using both polarized beams and polarized targets.
	The total for LAMPF-Based Research is derived as follows. Of the $6,600 medium energy research budget at LANL, $647 is for research carried out by LANL scientists at locations other than LAMPF, leaving $5,953 for in-house use of LAMPF. To this is added $4,503 of direct medium energy research funds to outside users for their LAMPF research programs.	The total for LAMPF-Based Research is derived as follows. Of the $7,000 medium energy research budget at LANL, $680 is for research carried out by LANL scientists at locations other than LAMPF, leaving $6,320 for in-house use of LAMPF. To this is added $4,591 of direct medium energy research funds to outside users for their LAMPF research programs.	The total for LAMPF-Based Research is derived as follows. Of the $6,700 medium energy research budget at LANL, $780 is for research carried out by LANL scientists at locations other than LAMPF, leaving $5,920 for in-house use of LAMPF. To this is added $5,001 of direct medium energy research funds to outside users for their LAMPF research programs.
	$ 10,456	$ 10,911	$ 10,921
Bates Based Research	Complete parity experiment and begin multi-arm coincidence measurements utilizing the improved polarized electron beam.	Continue coincidence measurements with higher intensity polarized electron beams.	Expand coincidence measurements with polarized electron beams. Emphasize form factor experiments using spin observables.
	Prepare for out-of-plane spectrometer measurements (delta experiment). Continue class IV computer upgrade at the Laboratory for Nuclear Science (LNS).	Carry out delta experiment and continue computer upgrade at LNS.	Carry out experiment on the electromagnetic response of the deuteron and continue computer upgrade at LNS.
	Continue high precision measurements utilizing the energy loss spectrometer system (ELSSY) and coincidence measurements utilizing South Hall spectrometers.	Continue high precision measurements with ELSSY and reduce level of research utilizing South Hall spectrometers during installation of South Hall Ring Experiment.	Expand high precision measurements with ELSSY and continue low level of research in South Hall as South Hall Ring Experiment installation continues.
	Design internal gas-jet target system for use in the South Hall Ring Experiment and continue R&D on pulse stretcher rings with emphasis on maintenance of beam polarization.	Continue R&D on behavior of polarized beams in stretcher rings and design of detector components for use in the South Hall.	Continue R&D on behavior of polarized beams in stretcher rings and detector design.

III. Medium Energy Nuclear Physics (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
Bates Based Research (Cont'd)	The total for Bates-Based Research is derived as follows. Of the $3,050 medium energy research budget at MIT, $1,000 is for research carried out by MIT scientists at locations other than Bates, leaving $2,050 for in-house use of Bates. To this is added $1,057 of direct medium energy research funds to outside users for their Bates research programs.	The total for Bates-Based Research is derived as follows. Of the $3,155 medium energy research budget at MIT, $1,040 is for research carried out by MIT scientists at locations other than Bates, leaving $2,115 for in-house use of Bates. To this is added $1,167 of direct medium energy research funds to outside users for their Bates research programs.	The total for Bates-Based Research is derived as follows. Of the $3,305 medium energy research budget at MIT, $1,105 is for research carried out by MIT scientists at locations other than Bates, leaving $2,200 for in-house use of Bates. To this is added $1,091 of direct medium energy research funds to outside users for their Bates research programs.
	$ 3,107	$ 3,282	$ 3,291
CEBAF-Based Research	Complete a cryomodule, the basic unit of accelerator structure that can be cooled to superconducting temperature.	Complete installation of equipment for front-end testing of the accelerator utilizing 1 1/4 cryomodules, to 25 MeV energy. Perform pre-operational testing of beam diagnostic hardware and software. Prepare for operation of the Central Helium Liquefier.	Continue work on cryomodule diagnostics. Carry out 25 MeV front-end test and extend test to 45 MeV. Operate Central Helium Liquefier. Staff Machine Control Center around the clock.
	Develop the thermionic injector for the accelerator. Implement a magnetic measurement capability for the components of the beam transport system.	Establish a data acquisition system for use in testing and calibrations of components. Provide related systems needed for experimental halls. Expand microVAX cluster.	Expand data acquisition system CPU with additional workstations.
	Carry out detailed development for spectrometer and detector systems.	Prototype and test components for the experimental areas including setting up a magnet test facility, prototyping of quadrupole magnets, and prototyping various detector and counting electronic components.	Complete testing and prototyping of experimental area components.
	Continue activities in superconducting research area at CEBAF.	Continue superconducting research activities and strengthen theoretical efforts.	Continue superconducting research activities and strengthen theoretical efforts.

III. Medium Energy Nuclear Physics (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
CEBAF-Based Research (Cont'd)	The total for CEBAF-Based Research is derived as follows. Of the $9,350 medium energy research budget at CEBAF, $500 is for research carried out by CEBAF scientists at locations other than CEBAF, leaving $8,850 for in-house use of CEBAF. To this is added $72 of direct medium energy research funds to outside users for their CEBAF research programs.	The total for CEBAF-Based Research is derived as follows. Of the $11,240 medium energy research budget at CEBAF, $800 is for research carried out by CEBAF scientists at locations other than CEBAF, leaving $10,440 for in-house use of CEBAF. To this is added $844 of direct medium energy research funds to outside users for their CEBAF research programs.	The total for CEBAF-Based Research is derived as follows. Of the $11,365 medium energy research budget at CEBAF, $800 is for research carried out by CEBAF scientists at locations other than CEBAF, leaving $10,565 for in-house use of CEBAF. To this is added $1,644 of direct medium energy research funds to outside users for their CEBAF research programs.
	$ 8,922	$ 11,284	$ 12,209
Research at Other Sites	Continue data taking phase of rare kaon decay experiments and continue preparations for experiments using new kaon beam line in search for rare two-nucleon structures (H particles).	Begin second phase of rare kaon decay experiments and start taking data for H-particle search.	Complete first phase of H-particle search and begin second experimental approach.
	Continue electron scattering experiments using NPAS and start evaluation of proposed experiments using gas jet target in PEP ring at SLAC.	Suspend NPAS End Station A program and continue evaluation of use of PEP ring at SLAC.	Retain possibility of doing experiments using PEP ring at SLAC.
	Utilize upgraded Low Energy Antiproton Ring (LEAR) facility at CERN for high intensity antiproton experiments.	Complete data taking for crystal barrel experiment LEAR facility. Use CERN 100 GeV muon beam for measurement of spin-dependent structure functions of the neutron and proton.	Continue spin structure function experiment at CERN.
	Initiate data taking phase of the St. Gotthard xenon double beta decay experiment.	Continue xenon phase of St. Gotthard double beta decay experiment.	Conclude xenon phase of St. Gotthard double beta decay experiment.
	Start first round of experiments on the Laser Electron Gamma Source (LEGS) facility at the National Synchroton Light Source at BNL.	Expand experimental program to full planned operating level of BNL group using the LEGS facility and broaden LEGS experimental program to include users from universities and other laboratories.	Continue full use of LEGS facility.

III. Medium Energy Nuclear Physics (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
Research at Other Sites (Cont'd)	Conduct program of selected nuclear physics experiments at other facilities including Fermilab, TRIUMF (Canada), Saclay (France), PSI (Switzerland), and NIKHEF (Netherlands).	Conduct program of selected nuclear physics experiments at other facilities including Fermilab, TRIUMF (Canada), Saclay (France), PSI (Switzerland), and NIKHEF (Netherlands).	Conduct program of selected nuclear physics experiments at other facilities including Fermilab, TRIUMF (Canada), PSI (Switzerland), and NIKHEF (Netherlands).
	$ 11,041	$ 12,188	$ 12,379
Subtotal, Research	$ 33,526	$ 37,665	$ 38,800
Operations			
LAMPF Operations	Operate accelerator and facilities with decreased experimental support; about 2700 hours for nuclear physics research with about seven secondary beams operating simultaneously.	Operate accelerator and facilities about 2400 hours for nuclear physics research with about seven secondary beams operating simultaneously.	Operate accelerator and facilities about 2400 hours for nuclear physics research with a reduced number of secondary beams operating simultaneously.
	Provide beam for approximately 56 nuclear physics experiments involving about 320 scientists.	Provide beam for approximately 52 nuclear physics experiments involving about 300 scientists.	Provide beam for approximately 45 nuclear physics experiments involving about 280 scientists.
	Commission medium resolution spectrometer and continue support for installation of high intensity polarized ion source. Begin construction of energy spread compressor for low energy pion (LEP) channel.	Start operation of high intensity polarized ion source. Begin operation of LEP channel with energy spread compressor.	Utilize newly installed computers for remote analysis capability. Expand operation with high intensity polarized ion source and polarized targets.
	$ 41,580	$ 40,426	$ 41,000
Bates Operations	Operate accelerator and facilities about 2350 hours for nuclear physics research.	Operate accelerator and facilities about 1800 hours for nuclear physics research.	Operate accelerator and facilities about 2000 hours for nuclear physics research.
	Provide beam for approximately 30 experiments involving about 125 scientists.	Provide beam for approximately 30 experiments involving about 125 scientists.	Provide beam for approximately 30 experiments involving about 125 scientists.
	Operate accelerator at 1 GeV for required experiments during selected operating cycles during the year.	Operate accelerator at 1 GeV for required experiments during selected operating cycles during the year.	Operate accelerator at 1 GeV for required experiments during selected operating cycles during the year.

III. Medium Energy Nuclear Physics (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
Bates Operations (Cont'd)	Begin installation and testing of components for South Hall Ring Experiment.	Continue installation and testing of components for South Hall Ring Experiment.	Continue installation and testing of components for South Hall Ring Experiment.
	$ 6,850	$ 7,000	$ 7,400
CEBAF Operations	Provides for startup of laboratory operations and accelerator commissioning.	Provides for startup of laboratory operations and accelerator commissioning.	Provides for startup of laboratory operations and accelerator commissioning.
	$ 1,000	$ 6,015	$ 12,400
Other Operations	Operate Nuclear Physics Injector and facilities at SLAC for 1000 hours. Provide beams of six GeV electrons for experiments involving about 50 scientists.	Suspend operation of NPI at SLAC.	Suspend operation of NPI at SLAC.
	Continue operations support for the Bevalac medium energy research activities (300 hours).	Continue operations support for the Bevalac medium energy research activities (300 hours).	Continue operations support for the Bevalac medium energy research activities (350 hours).
	$ 2,235	$ 1,282	$ 1,400
Subtotal, Operations	$ 51,665	$ 54,723	$ 62,200
Medium Energy Nuclear Physics	$ 85,191	$ 92,388	$ 101,000

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

KEY ACTIVITY SUMMARY

NUCLEAR PHYSICS

I. Preface: Heavy Ion Nuclear Physics

The Heavy Ion Research subprogram is aimed at understanding the behavior of nuclear matter over an ever increasing range of excitation energy, nuclear density, angular momentum, and deformation. These conditions are created in collisions between nuclear beams and nuclear targets. The heavy ion beams are produced by highly sophisticated accelerators located at three large universities (Texas A&M, Yale, University of Washington) and four National laboratories (Argonne, Brookhaven, Lawrence Berkeley, Oak Ridge). At low bombarding energies, studies include the high spin behavior of cold nuclear matter causing severe deformation and eventually fission. Also nuclear orbiting phenomena are studied. Especially intriguing are close encounters of the heaviest nuclei which lead to unexplained spontaneous electron and positron production. The nuclear dynamics of complex phenomena including the evolution of the compound nucleus, deep-inelastic scattering and projectile multifragmentation are studied at intermediate bombarding energies. Radioactive beams are produced to study ground state properties of exotic nuclei out to the very limits of stability. At higher energies, exploration is made of the nuclear matter equation of state for hot dense nuclear matter and the deconfinement of hadronic matter into the quark-gluon plasma. Some consolidation of low energy activities at national laboratories is planned.

II. A. Summary Table: Heavy Ion Nuclear Physics

Program Activity	FY 1989 Actual	FY 1990 Estimate	FY 1991 Request	% Change
Research				
LBL Bevalac Research..........................	$ 5,879	$ 6,000	$ 6,154	+ 3
BNL Tandem/AGS Research.......................	8,509	8,628	9,500	+ 10
National Laboratory Research..................	8,873	9,671	10,056	+ 4
University Research...........................	8,130	8,604	11,019	+ 28
Subtotal, Research	$ 31,391	$ 32,903	$ 36,729	+ 12
Operations				
LBL Bevalac Operations........................	$ 16,690	$ 16,085	$ 17,685	+ 10
BNL/Tandem/AGS Operations.....................	7,350	7,691	9,000	+ 17
ANL, LBL 88", ORNL Operations.................	9,205	8,885	7,315	- 18
University Accelerator Operations.............	1,840	1,952	2,200	+ 13
Subtotal, Operations	$ 35,085	$ 34,613	$ 36,200	+ 5
Total, Heavy Ion Nuclear Physics	$ 66,476	$ 67,516	$ 72,929	+ 8

II. B. Major Laboratory and Facility Funding

	FY 1989 Actual	FY 1990 Estimate	FY 1991 Request	% Change
Argonne National Laboratory	$ 5,433	$ 6,142	$ 6,920	+ 13
Brookhaven National Laboratory	$ 15,859	$ 16,319	$ 18,500	+ 13
Lawrence Berkeley National Laboratory	$ 26,159	$ 25,123	$ 27,620	+ 10
Los Alamos National Scientific Laboratory	$ 890	$ 907	$ 950	+ 5
Oak Ridge National Laboratory	$ 8,070	$ 7,853	$ 8,170	+ 4
Lawrence Livermore National Laboratory	$ 95	$ 123	$ 150	+ 22

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1989	FY 1990	FY 1991
Heavy Ion Nuclear Physics			
Research			
LBL Bevalac Research	Continue experiments at Heavy Ion Superconducting Spectrometer (HISS) and Low Energy beam lines to study fragmentation of very heavy beams. Begin using a reverse kinematics detector for intermediate energy studies. Continue fabrication of time projection chamber (TPC) detector. Continue experiments with the Dilepton Spectrometer (DLS) to explore high energy nuclear dynamics at the earliest stages of the collision process. Continue the analyses of the initial CERN oxygen and sulfur experiments and prepare for next generation experiments with sulfur and future program with lead beams.	Continue experiments at HISS to study multipion production with heaviest beams, exclusive fragmentation of light systems and studies with radioactive beams. Complete fabrication, test components, and start to assemble the HISS TPC. Use pion observables obtained from streamer chamber to extract information on equation of state for Au+Au collisions. Continue to operate and upgrade the DLS to probe the hot high density phase of the collision process. Use heaviest beams available to continue to study multifragmentation processes at the Low Energy Beam line. Start prototyping for next generation intermediate energy detector (IMED) to obtain more complete information on collisions at intermediate energy to study the predicted liquid-gas phase transition. Continue analyses of initial data from CERN and conduct new experiments to learn about strangeness production and energy densities achieved in these collisions. Explore physics potential of lead beam experiments. Continue	Continue testing HISS TPC and begin study of equation of state of nuclear matter at high density and temperature. Finish analysis of pion production from collisions of gold nuclei on gold targets using the streamer chamber and phase out further streamer chamber operation. Continue use of HISS for: radio-active beams, high energy multifragmentation of heavy beams with MUSIC II, neutron production in central collisions, etc. Upgrade DLS with Ring Imaging Cerenkov (RICH) detectors and continue to use this unique probe of the hot, dense phase of collision process. Continue studies of multifragmentation at intermediate energies at Low Energy Beam Line. Continue R&D on new IMEX detector. Analyze new data from latest CERN experiments using sulfur beams and continue discussion and preparation for possible lead beam experiments in 1990's. Continue involvement in R&D for RHIC detectors, and participate in discussions leading toward a proposal for a detector at RHIC.

III. Heavy Ion Nuclear Physics (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
LBL Bevalac Research (Cont'd)		study of possible AGS experiment (e.g., dileptons).	
	$ 5,879	$ 6,000	$ 6,154
BNL Tandem/AGS Research	Continue data taking on experiment E802, complete analysis of initial data, and start upgrade of E802 for future gold beams. Finish testing time projection chamber for E810 and begin experimental program. Complete assembly and testing of E814 and begin experimental program with full complement of detectors. Continue discussion of possible new experimental probes (e.g., dileptons) to study central collisions at AGS energies. Continue R&D towards a RHIC at about $6.2 million.	Continue experimental program at AGS with heavy ions and prepare for gold beams. Use enhanced multiplicity and particle identification capabilities of experiment E802 to look for possible precursors of a baryon-rich quark-gluon plasma. Support upgrade of E802 detectors for gold beams. Concentrate on the physics analysis of E810 time projection chamber for strangeness production. Continue active research program at E814 measuring energy flow and searching for exotic nuclear structures produced in heavy ion collisions. Begin AGS experiment for detection of anti-protons from heavy ion collisions, E858. Continue R&D towards a RHIC at about $6.5 million, and begin active consideration of first-round RHIC detectors.	Continue program at AGS with upgraded tracking system for E802, (E859), to study two-particle interferometry (pion-pion and kaon-kaon) to learn about space-time development of collision. Continue analysis of existing data and continue upgrading detector for Au beams expected in FY 1992. Continue analysis of proton and silicon beam data on energy flow and nuclear stopping from E814 and start upgrading detector for Au beams. Analyze multiparticle data from TPC experiment E810 and study possible upgrade of system for heavy beams. Continue new experiment to measure anti-particle production in nuclear matter. Evaluate installation of new experiment at AGS measuring productions of dileptons providing new probe of high density and temperature phase at AGS energies. Continue R&D towards RHIC at about $6.8 million, and participate in discussions leading toward proposals for detectors at RHIC.
	$ 8,509	$ 8,628	$ 9,500

Program Activity	FY 1989	FY 1990	FY 1991
National Laboratory Research	Continue the experimental program at ATLAS with emphasis on reactions near the Coulomb barrier using the heavier mass projectiles available from the improved injector. Begin design and testing of detector systems for the Fragment Mass Analyzer (FMA) for an experimental program on nuclei far from stability. Begin studies of apparatus to measure electron-positron production with future uranium beams.	Continue active experimental research program to take advantage of enhanced capabilities of ATLAS with emphasis on reaction mechanism studies, studies of highly deformed nuclei and production of nuclei far from stability. Begin experimental program with the FMA and support initial activities for large acceptance detector system to measure electron-positron correlations in uranium-uranium collisions.	Continue active experimental program at ATLAS with emphasis on the new opportunities for physics research possible with beams up to uranium. Operate the FMA to make possible new classes of experiments, particularly when coupled with the ANL/Notre Dame Gamma Ray detector. Begin tests and measurements with the ATLAS Positron-Electron Experiment (APEX). Continue activities related to fabrication of Gammasphere.
	Continue the experimental program at the 88" Cyclotron and study super-deformed bands at very high spin with HERA. Continue technological research on Electron Cyclotron Resonance (ECR) ion sources using strong fields and high frequencies.	Continue the experimental program at the 88" Cyclotron using the HERA gamma-ray detector. Continue the studies of reaction mechanisms induced by heavy ions provided by the ECR ion source. Continue to develop the technology necessary for new ECR-type ion sources at strong fields and high frequencies.	Continue the experimental program at the 88" Cyclotron for high spin studies utilizing the HERA gamma-ray detector, and newly installed ultra-fast data acquisition and analysis system. Continue studies of reaction mechanisms with emphasis on the new classes of studies possible with the heavier mass and higher intensity beams available from the Advanced ECR. Continue activities related to fabrication of Gammasphere.
	Continue the experimental program at HHIRF with emphasis on improved capabilities with gamma-ray detection and a more fully implemented heavy-ion, light-ion detector system. Continue data analysis of CERN WA80 experiment. Begin studying physics potential of lead beam experiments at CERN.	At HHIRF continue the experimental program to measure the properties of superdeformed nuclei. Utilize the enhanced capabilities of the completed heavy-ion, light-ion (HILI) detector to study nuclear reaction mechanisms. Continue the analysis of the CERN WA80 experiment with particular emphasis on measurements from the photon detectors. Continue to explore the physics potential of lead beams at CERN for studying high energy density nuclear matter.	Continue research program at HHIRF studying high spin collective properties of nuclei, and residual nucleon-nucleon interactions using the Compton Suppression Spectrometer System. Study reaction mechanisms using available detector systems, including upgraded HILI detector system. Continue activities related to fabrication of Gammasphere. Continue study of high energy photons using the barium fluoride array to investigate giant dipole resonances and bremsstrahlung-like photon production at HHIRF and other accelerator facilities. Participate in next heavy-ion run at CERN and analysis of data. Continue activities for lead beam experiments. Continue studying

Program Activity	FY 1989	FY 1990	FY 1991
National Laboratory Research (Cont'd)			detector R&D problems for RHIC, and participate in discussions leading toward a proposal for a detector at RHIC.
	At LANL, continue analysis of CERN data, and complete assembly and begin installation of participant calorimeter at BNL for experiment E814.	At LANL, complete the analysis of the data on charged particle production from the HELIOS experiment at CERN. Participate in the operation of the participant calorimeters for E814 at the AGS and begin analysis of initial data. Participate in initial program using new focussing spectrometer at CERN.	At LANL, continue to participate in experiment E814 at BNL and analysis of spectrometer experiment at CERN, and participate in discussions leading toward a proposal for a detector at RHIC.
	At LLNL, continue Bevalac program and develop new counters for future experiment at AGS with heavy ions.	At LLNL, finalize analyses of Bevalac data and develop detector technology in preparation for heavy ion experiment at the Tandem/AGS.	At LLNL, finish up analysis of Bevalac experiments. Participate in the second generation E802 Experiment at AGS. Continue studying detector R&D problems for RHIC, and participate in discussions leading toward a proposal for a detector at RHIC.
	$ 8,873	$ 9,671	$ 10,056
University Research	Continue university user-group research programs and enhance detector R&D efforts. Continue nuclear physics research programs at the Yale Tandem on investigating nuclei far from stability. Use the higher energies of the University of Washington superconducting linac booster to study charged particle emission. Exploit the new capabilities of the Texas A&M superconducting cyclotron to study subthreshold pion production.	Continue and strengthen university user-group research programs at national laboratory accelerators. Continue the nuclear physics program at the upgraded Yale Tandem with emphasis on low-energy heavy ion interactions. At the University of Washington superconducting linac use the higher energy lighter projectiles and upgraded detector systems to continue the study of phenomena of hot nuclear systems. Use the higher energies of the Texas A&M superconducting cyclotron to study the production of subthreshold neutral pions and very energetic photons to probe collective behavior in nuclei. Increase detector studies for a wide range of nuclear problems. $493,000 will be provided for implementation of	Continue strengthening university user research activities at national laboratory accelerators where unique opportunities are available. At the upgraded Yale Tandem continue nuclear physics studies with emphasis on using new detector systems to study nuclear spectroscopy of highly deformed systems, nuclear molecular phenomena, parity nonconservation studies in light systems and nuclear astrophysics. With the University of Washington superconducting linac use improved detectors to probe limits of nuclear deformation and study of hot nuclear systems. Using the higher energies available at the superconducting Texas A&M cyclotron to continue study of subthreshold pions to isolate

III. Heavy Ion Nuclear Physics (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
University Research (Cont'd)		the Energy Sciences Network (ESNET) project, which is identified in the Applied Mathematical Sciences subprogram of the Basic Energy Sciences program.	collective phenomena and study how highly excited systems evolve with energy. Continue emphasis on improving detector systems at all accelerators. Provision of funds to upgrade ESNET to conform to National Research and Education Network standards will continue at an approximately constant or slightly reduced level from FY 1990.
	$ 8,130	$ 8,604	$ 11,019
Subtotal, Research	$ 31,391	$ 32,903	$ 36,729
Operations			
LBL Bevalac Operations	Continue to provide up to 3500 hours of heavy ion beam time for the research program including one-third time for biomedical research. Make full utilization of the specialized low energy, kaon, and secondary radioactive beam lines. Begin to phase out the independent research program at the SuperHILAC.	Continue heavy ion operating time at about 3200 hours for the research program utilizing the full-range of ions and energies available from the Bevalac, including one third time for biomedical research. Make use of the complete complement of beam lines for carrying out experiments at HISS, DLS, streamer chamber, Low Energy beam lines and the Beam 40 area. Start implementing changes to experimental areas and beam delivery to enhance research program. Complete phase-out of SuperHILAC operations for independent research.	Continue facility operation for nuclear physics and biomedical (one third time) research at about 3200 hours. Use full complement of beamlines for program at HISS, dilepton spectrometer, radioactive beams, and Low Energy work. Begin initial experiments with HISS TPC. Phase-out of streamer chamber facility. Continue to upgrade experimental areas and improve the quality (e.g., duty factor, spot size) and quantity of beam delivered for experimental program. SuperHILAC to continue to serve as dedicated injector for Bevalac.
	$ 16,690	$ 16,085	$ 17,685
BNL/Tandem/AGS Operations	Operate Tandem/AGS accelerator system to produce up to 7 weeks of light ions (including protons) for the approved relativistic heavy ion experiments. Complete installation of beamline for E814.	Operate Tandem/AGS system to provide up to 7 weeks of heavy ion operation with ions up to silicon for the approved relativistic heavy ion program. Provide appropriate additions to the beam lines for the future gold beams program and start new beam line for next generation AGS experiment.	Continue to operate Tandem/AGS system for heavy ion research, providing up to 10 weeks for experimental program with beams up to silicon. Continue to provide additions to beam lines for future operation with gold beams. Begin commissioning phase of operation of AGS Booster for heavy ion beams.

Program Activity	FY 1989	FY 1990	FY 1991
BNL/Tandem/AGS Operations (Cont'd)	$ 7,350	$ 7,691	$ 9,000
ANL, LBL 88", ORNL Operations	Provide 3500 hours of ATLAS operation for nuclear physics experiments. Support installation of new beam line for the FMA. Provide 4000 hours of operation of the 88" Cyclotron and continue development of the ECR ion source. Provide 3800 hours of HHIRF operation for nuclear physics program and atomic physics research programs. Operate upgraded accelerator tubes with greater reliability and increasing voltage. Reduce coupled Tandem/Cyclotron operation as Tandem performance improves.	Provide for operation of the ANL ATLAS facility for research programs to utilize the new uranium heavy ion beam capabilities. Provide beams for the complete set of detectors at ATLAS, including the newly developed Fragment Mass Analyses (FMA). Provide operation of the 88" Cyclotron for nuclear physics research and continue with development of ECR ion source. At HHIRF, terminate all but essential operations in the coupled Tandem/Cyclotron mode and continue to improve Tandem operation for nuclear and atomic physics research at HHIRF. Continue to provide beams to all caves and to the upgraded detectors such as HILI and the Spin Spectrometer. Start activities leading to phase out of operations at one of these low energy heavy ion facilities.	Complete upgrade of the ANL ATLAS facility for uranium beam capability. Provide heavy-ion beams for research utilizing all ATLAS detector systems, including newly installed FMA operating with Compton-suppressed Germanium detectors around the target. Provide support for the installation and operation of the APEX detector for positron-electron coincidence measurements. Provide beams for heavy-ion research at the LBL 88" Cyclotron, utilizing newly developed 14.5 GHz Advanced ECR source for production of high intensity beams of masses up to A=200. Provide heavy-ion beams for nuclear physics research at HHIRF utilizing all detector systems, including the barium fluoride array and an expanded capability HILI detector. Support installation of the Recoil Mass Spectrometer (RMS). Continue phase out activities at one of these three facilities.
	$ 9,205	$ 8,885	$ 7,315
University Accelerator Operations	Provide light heavy ion beams for experiments using the upgraded facilities at Yale University. Provide light heavy ion beams for in-house experiments at the University of Washington using the superconducting linac booster. Provide light and medium mass heavy ion beams for experimental programs at Texas A&M University.	Continue to provide light heavy ions at increased energies for the upgraded facilities and detectors at the Yale Tandem for a full research program. Provide light ions from the superconducting linac booster at the University of Washington for its in-house Nuclear Physics program. Continue to provide energetic light to medium mass projectiles for the Nuclear Physics program at the upgraded Texas A&M superconducting cyclotron.	Provide for continuing operation of heavy ion research programs at the three major university accelerator facilities using large range of ions and energies. At Yale Tandem provide light heavy ions with upgraded detectors to carry out a broad program of nuclear physics research. At the University of Washington superconducting linac booster provide light ions for in-house programs including new detector systems. Provide light to medium mass ions at low to intermediate energies for the

III. Heavy Ion Nuclear Physics (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
University Accelerator Operations (Cont'd)			nuclear physics program at the Texas A&M superconducting cyclotron.
	$ 1,840	$ 1,952	$ 2,200
Subtotal, Operations	$ 35,085	$ 34,613	$ 36,200
Heavy Ion Nuclear Physics	$ 66,476	$ 67,516	$ 72,929

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

KEY ACTIVITY SUMMARY

NUCLEAR PHYSICS

I. Preface: Low Energy Nuclear Physics

The basic research part of this subprogram emphasizes experimental investigations of nuclear structure, nuclear decay parameters, and low energy nuclear reaction mechanisms, as well as experimental tests of fundamental theories and symmetries, which often can be accomplished with low energy accelerators, or without the use of accelerators: for example, the study of neutrinos from the sun. University-based research is an important feature of the Low Energy program. Since most of the facilities are relatively small, they are appropriate for siting on university campuses, where they provide excellent opportunities for hands-on training of nuclear experimentalists, many of whom contribute after obtaining Ph.D.s to nuclear technology development of interest to the DOE. The nuclear data part of this subprogram has as its goal the establishment and maintenance of an accurate, complete, and accessible nuclear data base to meet the needs of the DOE nuclear technologies, which include: fission and fusion energy, biomedical and environmental applications of radioactive materials, nuclear waste management, and nuclear weapon development.

II. A. Summary Table: Low Energy Nuclear Physics

Program Activity	FY 1989 Actual	FY 1990 Estimate	FY 1991 Request	% Change
Research				
Research at University Facilities.............	$ 2,710	$ 2,776	$ 3,070	+ 11
Research at National Laboratory Accelerators..	3,515	3,554	3,265	- 8
Research at Reactors..........................	1,036	1,071	1,110	+ 4
Other Research................................	3,177	4,609	5,640	+ 22
Subtotal, Research	$ 10,438	$ 12,010	$ 13,085	+ 9
Operations				
Accelerator Operations........................	$ 3,100	$ 3,194	$ 3,315	+ 4
Subtotal, Operations	$ 3,100	$ 3,194	$ 3,315	+ 4
Nuclear Data				
Nuclear Data Measurements.....................	$ 6,315	$ 6,499	$ 6,748	+ 4
Nuclear Data Compilation and Evaluation.......	4,608	4,623	4,952	+ 7
Subtotal, Nuclear Data	$ 10,923	$ 11,122	$ 11,700	+ 5
Total, Low Energy Nuclear Physics	$ 24,461	$ 26,326	$ 28,100	+ 7

II. B. Major Laboratory and Facility Funding

	FY 1989 Actual	FY 1990 Estimate	FY 1991 Request	% Change
Ames Laboratory	$ 205	$ 202	$ 210	+ 4
Argonne National Laboratory	$ 2,960	$ 2,962	$ 3,100	+ 5
Brookhaven National Laboratory	$ 3,805	$ 3,708	$ 3,930	+ 6
Idaho National Engineering Laboratory - EG&G	$ 335	$ 330	$ 350	+ 6
Lawrence Berkeley National Laboratory	$ 2,130	$ 2,184	$ 2,360	+ 8
Lawrence Livermore National Laboratory	$ 230	$ 227	$ 240	+ 6
Los Alamos National Scientific Laboratory	$ 1,440	$ 1,498	$ 1,415	- 6
Oak Ridge National Laboratory	$ 4,720	$ 4,605	$ 4,995	+ 8

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1989	FY 1990	FY 1991
Low Energy Nuclear Physics			
Research			
Research at University Facilities	Continue utilization of upgraded facilities. At the University of Washington, develop a broader range of polarized and unpolarized beams with improved quality and new instrumentation for light and heavy-ion reaction studies. Continue development of a proton spectrometer at Texas A&M for studies of spin- flip, charge-exchange reactions. Use the new polarized ion source at Duke, with the cryogenic polarized target, to perform much improved measurements of spin-spin effects in neutron- nucleus reactions and to begin time-reversal invariance tests.	At Texas A&M, the proton spectrometer will be commissioned, and experiments using the (d, He-2) reaction will begin; at Duke, begin spin-spin cross-section measurements using a cryogenic polarized target of solid He-3; at Washington, exploit the higher energy lighter heavy-ion beams available from the superconducting Linac booster to study reaction mechanisms at the Coulomb barrier.	At Texas A&M, begin the development of a high-resolution 160 MeV neutron beam to be used with the proton spectrometer for (n,p) studies of the weak interaction; at Duke, continue the spin-spin cross-section measurements and time-reversal invariance tests; at Washington, use the new polarized ion source and the higher energy beams provided by the booster to study the scattering of polarized protons with emphasis on backward angle spin structure measurements.
	$ 2,710	$ 2,776	$ 3,070

III. Low Energy Nuclear Physics (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
Research at National Laboratory Accelerators	Continue low energy research at ANL, LBL, and ORNL. At LBL, high intensity He-3 beams will be used with the RAMA on-line separator to attempt to observe the decay of nuclides which are adjacent to, or are defining of, the proton drip-line in the sd-shell. At ORNL, nuclear structure studies at the UNISOR will be greatly enhanced when a nuclear orientiation facility can be brought into operation which will permit more complete determination of the electromagnetic properties of gamma-ray transitions.	Continue low energy research at ANL, LBL, and ORNL. At LBL, continue to search for nuclei near the proton and neutron drip-lines that may decay by new and exotic radioactivities, and make use of the excellent polarized proton and deuteron beams from the 88-Inch Cyclotron to study spin-polarization effects. At ORNL, the cryogenic nuclear orientation facility will be returned from the manufacturer and experiments on-line at UNISOR should begin.	Continue low energy research at the three laboratories. At LBL, the 88-Inch Cyclotron is used extensively to produce light ions for the nuclear astrophysics group, but some effort will be shifted to the Sudbury Neutrino Observatory project; at ORNL, the nuclear orientation facility should finally come into full operation, initially to determine complete level schemes for odd-mass nuclei in the A=190 region to explore manifestations of boson-fermion symmetries.
	$ 3,515	$ 3,554	$ 3,265
Research at Reactors	Continue support of the BNL-led effort to obtain a systematic understanding of nuclear structure in heavy nuclei, and its evolution with N, Z, A, and the number of valence protons and neutrons. Continue ion source development, particularly for studies of astrophysical interest. The neutron lifetime measurement at the ILL reactor in France should be completed.	Continue to support the BNL-led Participating Research Team at the TRISTAN facility in a unified program of forefront nuclear structure studies, emphasizing the neutron-rich nuclides produced in fission. Measurements of fundamental properties of the neutron are expected to continue at the new cold neutron beam line at the NIST (formerly NBS).	Continue to support the nuclear structure studies at the TRISTAN isotope separator, in particular, the exploitation of a breakthrough in picosecond timing that permits measurement of the life times of nuclear levels for nuclides far from stability, as well as the studies of fundamental properties of the neutron at the NIST (formerly the National Bureau of Standards).
	$ 1,036	$ 1,071	$ 1,110
Other Research	Continue solar neutrino research at an increased level. Strengthen the US effort in support of the Soviet-American Gallium Experiment (SAGE) and continue participation in GALLEX experiment. Transfer support for BNL nuclear group from low energy Tandem based research to relativistic heavy ion reactions at the Tandem/AGS facility in Heavy Ion subprogram.	Provide R&D support for proposed U.S. participation in the Canadian Sudbury Neutrino Observatory (SNO) project, involving a large, deeply buried, heavy-water Cerenkov detector to measure solar neutrino fluxes and higher energy spectra for neutrinos of all types. Preliminary results are expected from the SAGE metallic gallium experiment. Continue support of the joint US/European 35-ton gallium chloride GALLEX experiment.	Based on very favorable reviews, and the anticipated initiation of the SNO project by Canada, provide increased funding for SNO detector R&D at LANL, LBL, and University of Pennsylvania. Conclude effort devoted to Mo/Tc solar neutrino detection at LLNL. Continue support of the GALLEX experiment with first data expected this year.

III. Low Energy Nuclear Physics (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
Other Research (Cont'd)	$ 3,177	$ 4,609	$ 5,640
Subtotal, Research	$ 10,438	$ 12,010	$ 13,085
Operations			
Accelerator Operations	Provide support (together with Heavy Ion Physics) for three university and three national laboratory accelerator facilities at ANL, LBL, and ORNL. Complete construction of the polarized ion source at Duke University.	Continue support for the accelerator facilities at Duke University (Triangle Universities Nuclear Laboratory) and, together with the Heavy Ion program, at Texas A&M, the University of Washington, and three national laboratories. Complete the proton spectrometer at Texas A&M and enhance the cryogenic polarized target facility at Duke, by enabling the use of polarized solid He-3.	Continue support for the three university and three national laboratory accelerator facilities.
	$ 3,100	$ 3,194	$ 3,315
Subtotal, Operations	$ 3,100	$ 3,194	$ 3,315
Nuclear Data			
Nuclear Data Measurements	Continue nuclear data measurement program at about same level. Complete the construction of the large, segmented, full-solid-angle gamma-ray detector to be used at the ORELA as a photon-multiplicity detector. Neutron cross section measurements for structural materials continue at the Fast Neutron Generator (FNG). Operation of the electron linac at NIST terminated with the measurement program transferred to ORELA and WNR (at LANL).	Begin measurements at the ORELA using the new large detector to obtain unadjusted differential measurements of capture cross sections and capture-to-fission ratios for the first time, to meet accuracy requirements of reactor designers, use newly designed detector system to improve measurements of neutron capture cross sections for medium-weight structural materials. At the FNG, begin difficult measurements of cross sections for the production of long-lived activities of interest to the Office of Fusion Energy.	Continue nuclear data measurements at the ORNL/ORELA and the ANL/FNG. At the ORELA, begin an extensive measurement program, including determination of capture-to-fission ratios for all important fissile isotopes, using the photon multiplicity detector. At ANL, continue long-lived activity measurements for fusion, and continue measurements of total and scattering cross sections for fast neutrons on high-temperature materials. At the NIST, with the shut down of the electron linear accelerator, begin phase out of experimental program. At LANL, phase out the successfully completed fusion reaction measurement program.

III. Low Energy Nuclear Physics (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
Nuclear Data Measurements (Cont'd)	$ 6,315	$ 6,499	$ 6,748
Nuclear Data Compilation and Evaluation	Continue nuclear data compilation and evaluation at about the same level. The latest version of the Evaluated Nuclear Data File (ENDF-6) is expected to be nearing completion; a significant advance over previous versions should result from the inclusion of recent data measured for the purpose, and from improvements in nuclear models and evaluation methods. The cycle time for the evaluation of the A-chains for the Evaluated Nuclear Structure Data File (ENSDF) is expected to be shortened as the evaluators take advantage of their experience with computerized methods and as the LBL group resumes its evaluation effort.	Continue nuclear data compilation and evaluation at a slightly reduced level. ENDF-6 should be released by the end of 1989. An effort will be made to improve on-line access to the data files. (Better cooperation with international neutron cross section evaluation efforts is expected following the release of ENDF-6.) Possible improvements will be made to minimize the volume of publications, e.g., Nuclear Data Sheets, and to emphasize on-line access to a more timely updated ENSDF data base.	Continue the Cross Section Evaluation Working Group (CSEWG) to remain responsive to data needs and to continue improvements in coverage and format for ENDF. Support activities for the IAEA project to develop a library (FENDL) for the international fusion reactor program. Continue National Academy of Sciences/National Research Council panel on basic nuclear data compilation to explore improvements to ENSDF and the Nuclear Data Sheets and to respond to new areas of need for nuclear data.
	$ 4,608	$ 4,623	$ 4,952
Subtotal, Nuclear Data	$ 10,923	$ 11,122	$ 11,700
Low Energy Nuclear Physics	$ 24,461	$ 26,326	$ 28,100

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

KEY ACTIVITY SUMMARY

NUCLEAR PHYSICS

I. Preface: Nuclear Theory

The purpose of research in theoretical nuclear physics is to obtain a unified description of atomic nuclei. The research ranges from relating the description of elementary constituent particles and the fundamental forces connecting them, to accounting for the collective interactions of the nucleus as a whole. The long-range objectives of the Nuclear Theory subprogram are to obtain a comprehensive understanding of the foundations of nuclear matter at the most fundamental level, in terms of the properties of the constituent quarks and gluons, as well as the relation between the nucleons in the environment of the nucleus as a whole. These objectives are approached by interpreting results from nuclear physics experiments, and by predicting phenomena and relationships to test this description. The understanding of nuclear phenomena is prerequisite for a description of the material foundations of the universe, including astrophysics phenomena such as formation of the elements in stars and supernovae. Much of nuclear theory requires extensive use of supercomputer capabilities.

II. A. Summary Table: Nuclear Theory

Program Activity	FY 1989 Actual	FY 1990 Estimate	FY 1991 Request	% Change
Nuclear Theory	$ 10,818	$ 12,226	$ 13,500	+ 10
Total, Nuclear Theory	$ 10,818	$ 12,226	$ 13,500	+ 10

II. B. Major Laboratory and Facility Funding

Argonne National Laboratory	$ 930	$ 940	$ 985	+ 5
Brookhaven National Laboratory	$ 1,025	$ 1,040	$ 1,240	+ 19
Lawrence Berkeley National Laboratory	$ 950	$ 960	$ 1,005	+ 5
Los Alamos National Scientific Laboratory	$ 1,075	$ 1,080	$ 1,130	+ 5
Oak Ridge National Laboratory	$ 855	$ 860	$ 950	+ 10

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1989	FY 1990	FY 1991
Nuclear Theory	Emphasize investigation of quark- gluon description of nuclear structure and of very high energy density forms of nuclear matter in preparation for future experimental investigations at the Continuous Electron Beam Accelerator Facility (CEBAF) and a future Relativistic Heavy Ion Collider (RHIC). Do calculations to better understand nuclear astrophysical processes including the emission and properties of neutrinos. Carry out preliminary activities aimed at the establishment of a Nuclear Theory Institute selected from several competing proposals. Continue broad program of theoretical research on properties of atomic nuclei, understanding of nuclear forces, and phase transitions in nuclear matter.	Build the research efforts specifically aimed at providing needed theoretical understanding in preparation for new experimental results from the Continuous Electron Beam Accelerator Facility (CEBAF) and a future Relativistic Heavy Ion Collider (RHIC). Continue a broad program of theoretical research on properties of atomic nuclei ranging among the underlying quark-gluon substructure of nuclear matter, understanding of nuclear forces, both at the nucleon-nucleon level as well as within the nucleus as a whole (such as neutron-proton interaction effects). Commence operation of a Nuclear Theory Institute of broad scope and national character that has been sited at the University of Washington. The Institute will serve as a center for excellence in nuclear theory and provide mechanisms for determining and carrying out research of highest national priorities. The Institute will provide focus and emphasis for the dispersed individual efforts in nuclear theory as these research programs seek to coalesce in addressing the problems at the forefront of the field.	Continue new research efforts in preparation for future experimental results from the Continuous Electron Beam Accelerator Facility (CEBAF) and the Relativistic Heavy Ion Collider (RHIC). These efforts are emphasizing the description of nuclei in terms of the underlying quark-gluon substructure of nuclear matter, including understanding of nuclear forces and phase transitions in nuclear matter. Develop forefront programs at the new Nuclear Theory Institute at the University of Washington. Create new Institute mechanisms for effective interaction with the entire nuclear physics community. Continue broad program of theoretical research on properties of atomic nuclei, understanding of nuclear forces, and expand the understanding of the forces at play in neutron proton interactions and symmetries in nuclei. Establish task oriented activities at national laboratories such as BNL and LBL which will address high impact problems such as RHIC related physics and the theory of chaos.
	$ 10,818	$ 12,226	$ 13,500
Nuclear Theory	$ 10,818	$ 12,226	$ 13,500

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

KEY ACTIVITY SUMMARY

NUCLEAR PHYSICS

I. Preface: Capital Equipment

Capital equipment funds are needed to provide for particle detection systems, for data acquisition and analysis systems, and for instrumentation to improve performance of Nuclear Physics accelerators. These funds are essential for effective utilization of the national accelerator facilities operated by the Nuclear Physics program. In addition, the program has landlord responsibility for providing general purpose capital equipment at the Lawrence Berkeley Laboratory.

II. A. Summary Table: Capital Equipment

Program Activity	FY 1989 Actual	FY 1990 Estimate	FY 1991 Request	% Change
BNL	$ 4,300	$ 3,274	$ 2,775	- 15
LBL	2,755	2,761	1,775	- 36
LANL	3,335	2,840	2,900	+ 2
ANL	1,900	3,096	1,255	- 59
MIT/Bates	1,250	1,542	1,610	+ 4
ORNL	1,130	1,675	972	- 42
CEBAF	1,000	1,479	3,000	+103
University Laboratories	1,295	1,179	1,050	- 11
Sudbury Neutrino Observatory	0	0	2,776	>999
Gammasphere	0	0	5,500	>999
Lawrence Berkeley Laboratory - GPE	1,400	1,479	1,600	+ 8
Other	135	395	1,487	+276
Total, Capital Equipment	$ 18,500	$ 19,720	$ 26,700	+ 35

II. B. Major Laboratory and Facility Funding

Argonne National Laboratory	$ 1,900	$ 3,096	$ 1,255	- 59
Brookhaven National Laboratory	$ 4,300	$ 3,274	$ 2,775	- 15
Lawrence Berkeley National Laboratory	$ 2,755	$ 2,761	$ 1,775	- 36
Los Alamos National Scientific Laboratory	$ 3,355	$ 2,840	$ 2,900	+ 2
Continuous Electron Beam Accelerator Facility	$ 1,000	$ 1,479	$ 3,000	+103
Gammasphere	$ 0	$ 0	$ 5,500	>999
Massachusetts Institute of Technology	$ 1,250	$ 1,542	$ 1,610	+ 4
Oak Ridge National Laboratory	$ 1,130	$ 1,675	$ 972	- 42
Sudbury Neutrino Observatory	$ 0	$ 0	$ 2,776	>999

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1989	FY 1990	FY 1991
Capital Equipment			
BNL	For AGS heavy ion experiment E814, complete installation of the detector system, including the participant calorimeter, tracking chambers and uranium calorimeters, and begin first runs with complete system. Complete construction of the time projection chamber for E810. Provide partial support for a tunnel by-pass to bring heavy ion beams from the Tandem directly to the AGS Booster. At the laser-electron gamma source (LEGS) complete installation of equipment necessary for the first experiment, the photodisintegration of the deuteron. For the kaon beam line, complete fabrication of the electrostatic separators and magnetic elements. Complete modernization of central computer at NNDC.	Begin upgrade of AGS heavy ion experiments to prepare for higher multiplicities from gold beams expected upon completetion of the booster synchrotron. Complete implementation of Tandem/AGS heavy ion by-pass tunnel. At LEGS complete high-energy gamma detector for the E2/M1 experiments and begin construction of neutron detectors for neutron polarizability measurements. At the kaon beam line complete fabrication of components for production target area and install all components.	Continue updating of AGS heavy ion experiments to handle experiments with gold beams. This includes higher segmentation to accommodate the expected high multiplicities, more elaborate trigger schemes, and faster processing times. At LEGS complete neutron detectors necessary for the polarizability measurements.
	$ 4,300	$ 3,274	$ 2,775
LBL	Continue construction of a time projection chamber (TPC) for the HISS spectrometer to measure central collisions with the heavy ion beams from the Bevalac. For the intermediate-energy reaction program at the Bevalac, construct a large scattering chamber with the capability for long flight paths in the forward direction. Install ultra-fast data analysis computer for gamma-ray experiments at the 88" Cyclotron.	Complete construction of the HISS TPC. The microelectronics for the 15,360 pickup pads will be placed entirely on the detector, a new concept that permits the direct measurement of dE/dx from the pad signals. Upgrade the high multiplicity capability of the dilepton spectrometer for the study of heavy mass systems. Replace two VAX computers with a modern file server computer and 15 scientific workstations.	Complete testing of the HISS TPC and begin research program to understand collision dynamics that involve nuclear matter under extreme conditions. Procure data analysis center for 3D detectors with fast array processors and high-performance color graphics. Construct a 4-pi multifragment detector for intermediate energy studies at the Bevalac.
	$ 2,755	$ 2,761	$ 1,775

III. Capital Equipment (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
LANL	Continue construction of the Muon Electron Gamma-ray experiment (MEGA), which measures a very rare decay mode of the muon. This includes installation of beam hardware, positron and photon pair production scintillators, and trigger electronics. Begin construction of the pion beam energy-spread compressor for the low energy pion channel, which will generate a five-fold increase in yield for important pion experiments. This device uses a single-cell superconducting RF cavity.	Begin preliminary experimental runs with MEGA. For the pion beam energy-spread compressor, procure cryogenic refrigerator and perform full-power RF tests. Conduct preliminary experiments with enhanced pion beams that will shed light on the poorly understood transparency of the nucleus to 50-100 MeV pion beams. Procure equipment that enhances data acquisition and analysis capability through greater use of remote computing and computer workstations.	Construct a Neutral Meson Spectrometer, which achieves greatly improved energy resolution over present experiments. The ability to resolve discrete final states is crucial for the understanding the pion-nucleus interaction. Begin full experimental program with the pion beam energy-spread compressor. Modernize accelerator control system by installing equipment for distributed computer processing and networking.
	$ 3,335	$ 2,840	$ 2,900
ANL	Complete construction of the Fragment Mass Analyzer (FMA) for highly selective detection of rare particles from heavy ion reactions at ATLAS. The main ion-optical element will be delivered in 1989.	Begin construction of an electron-positron experiment, APEX, which exploits the high-intensity heavy-mass beams expected to be available from the ATLAS positive ion injector in FY 1991. This second-generation experiment will study the origin of sharp electron-positron coincident peaks observed at the German GSI laboratory in collisions of very heavy ions near the Coulomb barrier. Begin ion-optical studies of FMA using radioactive sources and the ATLAS beam.	Complete the final stage of construction of APEX, and begin preliminary experiments with beam to check operation and to measure background. Begin experiments with the FMA on a regular basis, some of which will be conducted with Compton-suppressed Ge detectors surrounding the target.
	$ 1,900	$ 3,096	$ 1,255
MIT/Bates	At the MIT/Bates Linear Accelerator Center procure beam line vacuum components, magnet power supplies, and cableing for the South Hall Ring Experiment (SHRE), fabricate detector system for the out-of-place spectrometer, and improve the polarized electron source to increase source lifetime.	At MIT/Bates provide additional vacuum components, accelerator controls, beam monitoring equipment, more cableing and radiation safety equipment for the SHRE, and continue work on out-of-plane spectrometer and polarized electron source. Initiate construction of internal target for South Hall Ring Experiment.	At MIT/Bates procure RF equipment (klystrons, modulators and drivers) for the SHRE to compensate for energy loss due to synchrotron radiation, control instrumentation for the linac, and further components for the polarized electron source. Continue construction of internal target for South Hall Ring Experiment.
	$ 1,250	$ 1,542	$ 1,610

III. Capital Equipment (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
ORNL	At ORNL, receive delivery of the major portion of an array of BaF2 detectors and dedicated electronics for detection of energetic photons from medium-energy heavy ion reactions. Initiate construction of a recoil mass spectrometer (RMS). The RMS is particularly useful for the study of low cross section reaction products from inverse heavy ion reactions.	At ORNL, continue construction of the RMS with component fabrication and assembly under way. Upgrade HHIRF computer system with ACP farm for general data processing. Purchase BGO detectors for CERN heavy ion experiment WA-80. Procure replacement klystrons for ORELA.	At ORNL, continue upgrade of computer system with additional distributed processors and work stations. At ORELA, continue procurement of replacement klystrons.
	$ 1,130	$ 1,675	$ 972
CEBAF	Upgrade the VAX 8700 and 785 computer systems to 30 MFLOP capacity to support extensive simulations of experimental equipment and accelerator components. Procure a magnet measurement system, shop equipment, and cryogenic support equipment.	Continue upgrade of computer systems with additional memory, disk drives and tape units. Procure precision equipment for proper alignment of beam lines.	Begin construction of apparatus for the experimental research program at CEBAF. Continue upgrade of computer systems with additional CPUs and work stations. Procure electronic measurement equipment for use with RF systems. Procure data acquisition electronics, CAMAC and Fastbus, for experimental efforts.
	$ 1,000	$ 1,479	$ 3,000
University Laboratories	Continue upgrade of instrumentation at university laboratories. Construct experimental equipment as follows: Texas A&M University (partial funding for momentum achromat recoil spectrometer and barium fluoride detector system), TUNL (expanded data acquisition and analysis facility), University of Washington (barium fluoride and germanium gamma-ray detectors), and Yale University (BGO multiplicity filter and a trigger processor system).	Continue instrumentation upgrade at university laboratories with construction of equipment as follows: Texas A&M University (complete funding for momentum achromat recoil spectrometer and barium fluoride detector system), TUNL (new charging system and stripper for the tandem accelerator), University of Washington (complete funding of gamma-ray detector system), Yale University (a terminal stripper and charge-state separator for the tandem accelerator, and a segmented large solid angle silicon detector array).	Continue instrumentation initiative at university accelerator laboratories to increase amount of available experimental equipment.
	$ 1,295	$ 1,179	$ 1,050

III. Capital Equipment (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
Sudbury Neutrino Observatory	No activity.	No activity.	Begin fabrication of the Sudbury Neutrino Observatory, an observatory for neutrino astrophysics, a collaborative Canadian, U.S. and U.K. project. The observatory will make use of heavy water as its principal sensitive medium, and will be located in a deep underground mine at Sudbury, Ontario. The unique world-class facility has a very high potential for fundamental discoveries in solar physics and for fundamental properties of neutrinos. NSAC enthusiastically recommended that the project be funded immediately. Of the approximately $41 million TEC, the U.S. share would be about $10.6 million.
	$ 0	$ 0	$ 2,776
Gammasphere	No activity.	No activity.	Initiate fabrication of Gammasphere, a world-class high-resolution gamma-ray facility for the study of nuclear structure at high angular momentum, finite temperature and large deformation. Gammasphere is specially designed to observe high-multiplicity coincidence events which are crucially important for the analysis of complex gamma-ray spectra. Five-fold coincidence events will be 8000 times more intense than any existing high resolution detector system. The system consists of 110 large Compton suppressed germanium detectors. The instrument can address a broad range of nuclear physics such as superdeformed nuclei, damping, giant resonances, symmetries in nuclei, correlations in nuclear reactions, fundamental interactions, and certain astrophysics questions. Gammasphere has an estimated total cost of about $17 million. NSAC assigned very high priority to Gammasphere and recommended

III. Capital Equipment (Cont'd):

Program Activity	FY 1989	FY 1990	FY 1991
Gammasphere (Cont'd)			that the project be funded. A review panel recommended siting Gammasphere at Oak Ridge National Laboratory.
	$ 0	$ 0	$ 5,500
Lawrence Berkeley Laboratory - GPE	Provide general purpose equipment at Lawrence Berkeley Laboratory, for which the Nuclear Physics program has landlord responsibility, such as a firetruck and forklifts for the Motor Vehicle group, disk drives for the Administration Division computer, refrigerators and freezers for the cafeteria, optical mass storage system for the Central Computing Facility, high temperature kiln and a scatter plate interferometer for the Engineering Division.	Provide general purpose equipment such as light and heavy trucks for the Motor Vehicle group; cooling towers, boilers, chillers, a CAD system and data processing equipment for the Administrative Division; and equipment used for printing, graphics and photography, and equipment for lab-wide computer networks for the Information and Computing Sciences Division.	Provide general purpose equipment such as trucks, forklifts and a bus for the Motor Vehicle group; cartridge tape controllers and drives, ultrasonic crack detectors for the Administrative Division; and pool of scientific work stations and related servers, lab-wide network accessible printing system, fiber optics computer network lines, disk upgrade for the central computing facility, and a postscript typesetter for the Information and Computing Science Division.
	$ 1,400	$ 1,479	$ 1,600
Other	Provide equipment for the on-line isotope separator at Oak Ridge (UNISOR) program and some participants of the nuclear data measurements program.	Provide equipment for the UNISOR program and some participants of the nuclear data measurements program.	Provide equipment for the UNISOR program, some participants of the nuclear data measurements program, computing equipment at the Nuclear Theory Institute, and more rapid completion of selected experimental systems in the medium energy and heavy ion research program.
	$ 135	$ 395	$ 1,487
Capital Equipment	$ 18,500	$ 19,720	$ 26,700

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

KEY ACTIVITY SUMMARY

NUCLEAR PHYSICS

I. Preface: Construction

II. A. Summary Table: Construction

Program Activity	FY 1989 Actual	FY 1990 Estimate	FY 1991 Request	% Change
Continuous Electron Beam Accelerator Facility (CEBAF)......................................	$ 44,500	$ 62,611	$ 65,000	+ 4
Relativistic Heavy Ion Collider (RHIC)..........	0	0	15,000	>999
Accelerator Improvements and Modifications......	4,300	4,536	4,300	- 5
General Plant Projects..........................	3,700	4,338	4,200	- 3
Total, Construction	$ 52,500	$ 71,485	$ 88,500	+ 24

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1989	FY 1990	FY 1991
Construction			
Continuous Electron Beam Accelerator Facility (CEBAF)	Continue construction of accelerator enclosure. Complete construction of CEBAF Center. Begin procurement of accelerator cavities and klystrons. Begin procurement of cryostats.	Begin end station construction. Continue construction of accelerator enclosure. Continue procurement of cavities and cryostats. Procure arc magnets and power supplies. Begin procurement of experimental equipment.	Continue end station construction and fabrication of research equipment. Continue fabrication of cavities and cryostats. Continue procurement of arc magnets and power supplies. Assemble, test, and install components.
	$ 44,500	$ 62,611	$ 65,000
Relativistic Heavy Ion Collider (RHIC)	No activity.	No activity.	Start construction of RHIC with emphasis on production of superconducting dipole, quadrupole, and sextupole magnets for the accelerator arcs. Initiate procurement of long-lead time items for vacuum, cryogenic and beam instrumentation systems.
	$ 0	$ 0	$ 15,000
Accelerator Improvements and Modifications	Essential modifications and upgrades on an annual basis to maintain and improve the reliability and efficiency of accelerators and experimental facilities. Annual AIP expenditure is less than 1% of total Federal investment in these facilities.	Approximately same level of effort as FY 1989.	Approximately same level of effort as FY 1989.
	$ 4,300	$ 4,536	$ 4,300
General Plant Projects	Essential additions, modifications, and improvements on an annual basis to maintain safety and effectiveness of general laboratory plant and support facilities.	Somewhat higher level of effort due to special needs of programmatic facilities.	Approximately same level of effort as FY 1990.
	$ 3,700	$ 4,338	$ 4,200
Construction	$ 52,500	$ 71,485	$ 88,500

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
OFFICE OF ENERGY RESEARCH
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

KEY ACTIVITY SUMMARY

CONSTRUCTION PROJECTS

Nuclear Physics

IV. A. Construction Project Summary

Project No.	Project Title	Total Prior Year Obligations	FY 1990 Appropriated	FY 1991 Request	Unappropriated Balance	TEC
GPE-300	General Plant Projects	$ ---	$ 4,338	$ 4,200	$ ---	$ 4,200
91-G-301	Accelerator Improvements and Modifications	---	4,536	4,300	---	4,300
91-G-300	Relativistic Heavy Ion Collider	---	---	15,000	382,000	397,000
87-R-203	Continuous Electron Beam Accelerator Facility	94,200	62,611	65,000	43,189	265,000
Total, Nuclear Physics Construction		$ 94,200	$ 71,485	$ 88,500	$425,189	

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
OFFICE OF ENERGY RESEARCH
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

KEY ACTIVITY CONSTRUCTION PROJECT SUMMARY

Nuclear Physics

IV. B. Plant Funded Construction Project

1. Project title and location: GPE-300 General Plant Projects
Various locations

Project TEC: $ 4,200
Start Date: 2nd Qtr. FY 1991
Completion Date: 2nd Qtr. FY 1993

2. Financial schedule:

Fiscal Year	Appropriated	Obligations	Costs
1991	$ 4,200	$ 4,200	$ 1,200
1992	0	0	2,000
1993	0	0	1,000

3. Narrative:

(a) General Plant Projects provide for the many miscellaneous alterations, additions, modifications, replacements, and non-major construction required at the Lawrence Berkeley Laboratory, and the Massachusetts Institute of Technology (Bates Linear Accelerator Center). GPP projects focus on general laboratory facilities whereas the AIP projects focus on the technical facilities.

(b) These projects are required for the general maintenance, modification and improvement of the overall laboratory plant and include minor new construction, capital alterations and additions, and improvements to buildings and utility systems. These projects are essential for maintaining the productivity, increasing the operational cost effectiveness, and ensuring that necessary support services are available to the research program at the DOE-owned facilities.

(c) A description and listing of the major items of work to be performed at the various locations is contained in the Construction Project Data Sheets. Some of these may be located on non-Government owned property. The following is a list of the proposed FY 1991 funding for the various locations:

Lawrence Berkeley Laboratory	$ 2,900
Los Alamos National Laboratory	
(Clinton P. Anderson Meson Physics Facility)	200
Massachusetts Institute of Technology	
(Bates Linear Accelerator Center)	1,100
Total Estimated Cost....................	$ 4,200

4. Total Project Funding (BA):

	Prior Years	FY 1989	FY 1990	FY 1991 Request	To Complete
Construction	$ 0	$ 0	$ 0	$ 4,200	$ 0
Capital Equipment	0	0	0	0	0
Operating Expenses	0	0	0	0	0

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
OFFICE OF ENERGY RESEARCH
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

KEY ACTIVITY CONSTRUCTION PROJECT SUMMARY

Nuclear Physics

IV. B. Plant Funded Construction Project

1. Project title and location: 91-G-301 Accelerator Improvements and Modifications
Various locations

Project TEC: $ 4,300
Start Date: 2nd Qtr. FY 1991
Completion Date: 2nd Qtr. FY 1993

2. Financial schedule:

Fiscal Year	Appropriated	Obligations	Costs
1991	$ 4,300	$ 4,300	$ 3,000
1992	0	0	1,000
1993	0	0	300

3. Narrative:

(a) Accelerator Improvement Projects provide for additions, modifications, and improvements to research accelerators and ancillary experimental facilities. The requested projects are necessary to maintain and improve reliability and efficiency of operations and to provide new experimental capabilities as required for execution of planned nuclear physics research programs. Funds for these projects are needed annually to provide increased performance levels and increased serviceability, thereby decreasing facility downtime, improving the productivity and cost effectiveness of the program.

(b) A description and listing of the major items of work to be performed at the various locations is contained in the Construction Project Data Sheets. Some of these may be located on non-Government owned property. The following is a list of the proposed FY 1991 funding for the various locations:

Argonne National Laboratory (ATLAS)	$ 150
Brookhaven National Laboratory (AGS/Tandem)	1,500
Lawrence Berkeley Laboratory	1,100
Los Alamos National Laboratory (Clinton P. Anderson Meson Physics Facility)	500
Massachusetts Institute of Technology (Bates Linear Accelerator Center)	850
Oak Ridge National Laboratory (Holifield Heavy Ion Research Facility)	200
Total Estimated Costs..................	$ 4,300

4. Total Project Funding (BA):

	Prior Years	FY 1989	FY 1990	FY 1991 Request	To Complete
Construction	$ 0	$ 0	$ 0	$ 4,300	$ 0
Capital Equipment	0	0	0	0	0
Operating Expenses	0	0	0	0	0

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
OFFICE OF ENERGY RESEARCH
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

KEY ACTIVITY CONSTRUCTION PROJECT SUMMARY

Nuclear Physics

IV. C. Plant Funded Construction Project

1. Project title and location: 91-G-300 Relativistic Heavy Ion Collider
Brookhaven National Laboratory
Upton, New York

Project TEC: $ 397,000
Start Date: 2nd Qtr. FY 1991
Completion Date: 3rd Qtr. FY 1997

2. Financial schedule:

Fiscal Year	Appropriated	Obligations	Costs
1991	$ 15,000	$ 15,000	$10,000
1992	50,000	50,000	38,400
1993	80,000	80,000	70,000
1994	90,000	90,000	86,600
1995	90,000	90,000	90,000
1996	72,000	72,000	78,000
1997	0	0	24,000

3. Narrative:

(a) The Relativistic Heavy Ion Collider (RHIC) facility will be a unique, world-class research facility with opposing colliding beams that provide 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) at BNL, and will utilize the experimental halls, support building, and liquid helium refrigerator from the partially completed CBA project.

(b) RHIC will be 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 machine will accelerate ions with atomic masses spanning the periodic table, with the collision energies of 100 GeV/AMU for the heaviest ions, and even high energies for lighter ions. In such collisions, experimenters will be able to study extended volumes of hadronic matter with energy densities more than ten times that of the nuclear ground state, thus creating in the laboratory conditions that are similar to those of the expanding universe moments after the Big Bang. Ultra-relativistic heavy ion collisions are probably the only means of producing such energy densities under controlled laboratory conditions, and offer a unique avenue for both nuclear and particle physicists to test theories of the strong interaction at the high energy density limit. This is the threshold at which hadronic matter is predicted to lose its identity as a collection of neutrons and protons, and to undergo a phase transition to a plasma of quarks and gluons.

(c) Construction of RHIC will proceed in an expeditious manner, consistent with available funds. FY 1991 construction funds will be used for fabrication of arc magnets and directly related items. In other areas, only systems engineering will be carried on during the first year of the project.

4. Total Project Funding (BA):

	Prior Years	FY 1989	FY 1990	FY 1991 Request	To Complete
Construction	$ 0	$ 0	$ 0	$15,000	$382,000
Capital Equipment	0	0	0	0	0
Operating Expenses	8,800	6,200	6,450	6,800	71,850

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
OFFICE OF ENERGY RESEARCH
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)
KEY ACTIVITY CONSTRUCTION PROJECT SUMMARY
Nuclear Physics

IV. B. Plant Funded Construction Project

1. Project title and location: 87-R-203 Continuous Electron Beam Accelerator Facility, Newport News, Virginia

Project TEC: $265,000
Start Date: 2nd Qtr. FY 1987
Completion Date: 4th Qtr. FY 1993

2. Financial schedule:

Fiscal Year	Appropriated	Obligations	Costs
1987	$ 16,200	$ 16,200	$ 7,842
1988	33,500	33,500	41,858
1989	44,500	44,500	29,086
1990	62,611	62,611	62,000
1991	65,000	65,000	63,000
1992	38,189	38,189	49,000
1993	5,000	5,000	12,214

3. Narrative:

(a) The Continuous Electron Beam Accelerator Facility (CEBAF) is a single purpose, basic nuclear physics research facility based on a four billion electron volt (GeV) electron linear accelerator that is capable of providing high intensity, continuous (i.e., not pulsed) electron beams. The facility will include the experimental areas needed to conduct basic nuclear research, and buildings to house the accelerator complex and its operation and maintenance activities. The facility will possess a complement of equipment for initial experiments and supporting facilities to exploit the capabilities of the accelerator.

(b) CEBAF will be the only facility in the world capable of producing electron beams that simultaneously meet the criteria of high energy, high intensity, and continuous nature necessary to advance the frontiers of nuclear physics. CEBAF's electron accelerator with its capability of providing beams at any energy in the range 0.5 to 4 GeV, is designed to study the largely unexplored transition between the nucleon-meson and the quark-gluon description of nuclear matter.

(c) Construction of CEBAF will continue in an expeditious manner, consistent with available funds. FY 1990 construction funds will be used for major hardware fabrication of RF cavities, cryounits, the central helium liquifier and its transfer lines, and the linac and arc magnets. Also, construction of the beam enclosure tunnel and support structures will continue.

4. Total Project Funding (BA):

	Prior Years	FY 1989	FY 1990	FY 1991 Request	To Complete
Construction	$49,700	$44,500	$62,611	$65,000	$43,189
Capital Equipment	0	0	0	0	0
Operating Expenses	21,918	6,000	4,000	4,029	2,600

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
CONSTRUCTION PROJECT DATA SHEETS
GENERAL SCIENCE AND RESEARCH - PLANT AND CAPITAL EQUIPMENT
NUCLEAR PHYSICS
(Tabular dollars in thousands. Narrative material in whole dollars.)

1. Title and location of project: General plant projects various locations

2. Project No. GPE-300

3. Date A-E work initiated: 1st Qtr. FY 1991

3a. Date physical construction starts: 2nd Qtr. FY 1991

4. Date construction ends: 2nd Qtr. FY 1993

5. Previous cost estimate: None
Less amount for PE&D: None
Net cost estimate: None
Date: None

6. Current cost estimate: $4,200
Less amount for PE&D: 0
Net cost estimate: $4,200
Date: May 1989

7. Financial Schedule:

Fiscal Year	Authorization	Appropriations	Obligations	Costs
1991	$ 4,200	$ 4,200	$ 4,200	$ 1,200
1992	0	0	0	2,000
1993	0	0	0	1,000

8. Brief Physical Description of Project

This project provides for minor new construction, other capital alterations and additions, and for improvements to land, buildings, and utility systems. Where applicable, the request also includes the cost of installed capital equipment integral to a subproject. No significant R&D program is anticipated as a prerequisite for design and construction.

Lawrence Berkeley Laboratory.. $ 2,900

Requirements include: new electrical substation and low voltage distribution system for Buildings 74 and 83, outfitting of the Building 77 Plating Shop Addition, switching capability for either firm or interruptible electric power at Building 88, roof replacement on Buildings 55 and 64, seismic rehabilitation of Building 10's roof, rehabilitation of electric power system for Building 51 and 58, second floor addition on Building 25A, and replacement of aging transformers in Building 51.

1. Title and location of project: General plant projects various locations

2. Project No. GPE-300

8. Brief Physical Description of Project (continued)

Los Alamos National Laboratory (LAMPF).. $ 200

Existing experimental facilities will be modified to install advanced detection equipment such as the Neutral Meson Spectrometer and the Liquid Scintillator Neutrino Detector. Changes are required at the beam stop, counting houses, and supporting utilities.

Massachusetts Institute of Technology (Bates Linear Accelerator Center).. $ 1,100

To accommodate the South Hall Ring Experiment, portions of the ring tunnel will be constructed above and below ground. A safety upgrade of the electric distribution system is needed to provide centralized, remote metering and control capability that is accessible from the main accelerator control computers.

9. Purpose, Justification of Need for, and Scope of Project

The distribution of funds requested for FY 1991 is as follows:

Lawrence Berkeley Laboratory..	$ 2,900
Los Alamos National Laboratory (LAMPF)..	200
Massachusetts Institute of Technology (Bates Linear Accelerator Center)..	1,100
Total Estimated Cost..	$ 4,200

Since needs and priorities may change, other subprojects may be substituted for those listed and some of these may be located on non-Government owned property.

CONSTRUCTION PROJECT DATA SHEETS

1. Title and location of project: General plant projects various locations

2. Project No. GPE-300

10. Details of Cost Estimate

See description, item 8. The estimated costs are preliminary and, in general, indicate the magnitude of each program. These costs include engineering, design, and inspection.

11. Method of Performance

Design will be by contractor staff or on the basis of negotiated architect-engineer contracts. To the extent feasible, construction and procurement will be accomplished by firm fixed-price contracts and subcontracts on the basis of competitive bidding.

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
CONSTRUCTION PROJECT DATA SHEETS
GENERAL SCIENCE AND RESEARCH - PLANT AND CAPITAL EQUIPMENT
NUCLEAR PHYSICS
(Tabular dollars in thousands. Narrative material in whole dollars.)

1. Title and location of project: Accelerator improvements and modifications, various locations

2. Project No. 91-G-301

3. Date A-E work initiated: 1st Qtr. FY 1991

3a. Date physical construction starts: 2nd Qtr. FY 1991

4. Date construction ends: 2nd Qtr. FY 1993

5. Previous cost estimate: None
Less amount for PE&D: None
Net cost estimate: None
Date: None

6. Current cost estimate: $4,300
Less amount for PE&D: 0
Net cost estimate: $4,300
Date: May 1989

7. Financial Schedule:

Fiscal Year	Authorization	Appropriations	Obligations	Costs
1991	$ 4,300	$ 4,300	$ 4,300	$ 3,000
1992	0	0	0	1,000
1993	0	0	0	300

8. Brief Physical Description of Project

This project provides for additions, modifications, and improvements to major research accelerators and ancillary experimental facilities. The requested funds are necessary to maintain and improve reliability and efficiency of operations, and to provide new experimental capabilities as required for execution of planned research programs.

Listed below are the laboratories and a description of each subproject:

1. Title and location of project: Accelerator improvements and modifications, various locations

2. Project No. 91-G-301

8. Brief Physical Description of Project (continued)

Argonne National Laboratory (ATLAS).. $ 150

Replace fast tuners on the superconducting resonators with ones of new design and modern components, thus enhancing the tuning range and reliability.

Brookhaven National Laboratory (AGS/Tandem)... $ 1,500

Provide these modifications to the AGS: (1) replace and upgrade the existing RF tuning and monitoring systems; (2) replace the AGS pick-up electrode system with new, precisely located pick-up electrode plates of lower electrical capacitance and superior electrical feed-through design; and (3) install an automatic emittance measurement system to provide systematic and reproducible beam profile and emittance data.

Lawrence Berkeley Laboratory (Bevalac)... $ 1,100

The main magnet power supply of the Bevalac will be modified to permit long flattop operation that increases the beam duty cycle from 25 percent to 80 percent for certain kinds of operation. The motor generator control system will be reconfigured, the filter system will be modified, and two new quadrupole magnets will be constructed and installed. The 80 percent duty cycle operation will be possible up to 9.2 kG, and 60 percent to 10 kG. Uranium beam energies at these fields are 590 to 680 MeV/AMU, respectively.

Los Alamos National Laboratory (LAMPF)... $ 500

Several projects will be undertaken: (1) the accelerator control system will be upgraded by replacing of some of the obsolete RICE interface units with CAMAC units, (2) the 201 MHz RF drive chain up to the 300 Kw level will be upgraded, and (3) laser power for optically-pumped polarized ion source will be increased.

1. Title and location of project: Accelerator improvements and modifications, various locations

2. Project No. 91-G-301

8. Brief Physical Description of Project (continued)

Massachusetts Institute of Technology
(Bates Linear Accelerator Center).. $ 850

For the Energy Compression System, a vacuum system, an accelerating wave guide and an RF drive system will be procured and installed. For the South Hall Ring Experiment, precision DC power supplies will be procured for the magnetic elements of the extraction beam line.

Oak Ridge National Laboratory.. $ 200

Further improvement to the beam transport system of the experimental areas at the heavy ion facility will be accomplished by replacing vacuum pumps, valves, piping, and various beam diagnostic devices with modern equipment. Aluminum piping will be replaced with stainless steel piping, and oil diffusion pumps with cryogenic or turbomolecular units.

9. Purpose, Justification of Need for, and Scope of Project

Argonne National Laboratory (ATLAS)

Replacement of the fast tuners is expected to increase the average accelerating field of the superconducting resonators by at least 20 percent. This will increase the beam energy by an even larger percentage for the heaviest ion species. Further benefits are increased operational reliability and improved beam quality due to reduced phase jitter.

Brookhaven National Laboratory (AGS/Tandem)

These modification are needed to enable the AGS to utilize the heavy-ion capabilities of the new booster synchrotron, which is able to accelerate all ion species produced by the Tandem. New instrumentation is needed to operate with heavy-ion beams which have much smaller intensity, different beam profile, and different modes of acceleration compared to proton beams.

1. Title and location of project: Accelerator improvements and modifications, various locations — 2. Project No. 91-G-301

9. Purpose, Justification of Need for, and Scope of Project (continued)

Lawrence Berkeley Laboratory (Bevalac)

The increase in beam duty cycle will benefit experiments that are computer dead-time limited, because of many parameters and high multiplicities. This upgrade will, in particular, increase the scientific productivity of the dilepton spectrometer, and TPC experiments and neutron experiments at the HISS spectrometer.

Los Alamos National Laboratory (LAMPF)

The upgrade of the accelerator control system will make tuneup and maintenance of tune much easier due to the faster response time of the controls and beam diagnostics. The changes to the 201 MHz RF system will substantially reduce system downtime. The increase in laser power will increase beam current and beam polarization of the ion source, which directly translates into a more productive research program.

Massachusetts Institute of Technology (Bates Linear Accelerator Center)

The Energy Compression System will greatly improve both the energy resolution and the stability of the linac beam, properties that are very important for photo-reaction studies and for coincidence experiments. The power supplies are needed for operation of the extraction beam line of the South Hall Ring Experiment. This experimental system will provide a unique and timely capability for addressing fundamental issues in nuclear physics.

Oak Ridge National Laboratory (Holifield Heavy Ion Research Facility)

The existing beam transport system of the experimental area uses equipment and technology that is more than 20 years old. The equipment is unreliable and replacement parts frequently cannot be obtained. The poor vacuum achieved in the beam lines, 10^{-5} to 10^{-6} Torr, cause losses from charge exchange between beam ions and the residual gas, resulting in beam tails and beam halo.

CONSTRUCTION PROJECT DATA SHEETS

1. Title and location of project: Accelerator improvements and modifications, various locations

2. Project No. 91-G-301

9. Purpose, Justification of Need for, and Scope of Project (continued)

10. Details of Cost Estimate

a. Engineering, design, inspection, construction, procurement, component assembly, and installation .... $ 4,300

Total Estimated Cost .... $ 4,300

The estimated cost of the programs at each laboratory are preliminary and, in general, indicate the magnitude of each program.

11. Method of Performance

Design will be by contractor staff. To the extent feasible, construction and procurement will be accomplished by fixed-price subcontractor awarded on the basis of competitive bidding.

DEPARTMENT OF ENERGY
1991 CONGRESSIONAL BUDGET REQUEST
CONSTRUCTION PROJECT DATA SHEETS
GENERAL SCIENCE AND RESEARCH
NUCLEAR PHYSICS
(Tabular dollars in thousands. Narrative material in whole dollars.)

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

2. Project No. 91-G-300

3. Date A-E work initiated: 1st Qtr. FY 1991

3a. Date physical construction starts: 2nd Qtr. FY 1991

4. Date construction ends: 3rd Qtr. FY 1997

5. Previous cost estimate: None
Less amount for PE&D: None
Net cost estimate: None
Date:

6. Current cost estimate: $397,000
Less amount for PE&D: 0
Net cost estimate: $397,000
Date: June 1989

7. Financial Schedule

Fiscal Year	Authorization	Appropriations	Obligations	Costs
FY 1991	$397,000	$ 15,000	$ 15,000	10,000
FY 1992	0	50,000	50,000	38,400
FY 1993	0	80,000	80,000	70,000
FY 1994	0	90,000	90,000	86,600
FY 1995	0	90,000	90,000	90,000
FY 1996	0	72,000	72,000	78,000
FY 1997	0	0	0	24,000

8. Brief Physical Description of Project

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.

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

2. Project No. 91-G-300

8. Brief Physical Description of Project (continued)

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.

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.

9. Purpose, Justification of Need for, and Scope of Project

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.

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

9. Purpose, Justification of Need for, and Scope of Project (continued)

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.

CONSTRUCTION PROJECT DATA SHEETS

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

2. Project No. 91-G-300

10. Details of Cost Estimate*

		Item Cost	Total Cost
a. Engineering, Design, Inspection and Administration................			$ 72,000
1. Conventional construction at approximately 19% of item b.1..		$ 1,200	
2. Technical components (accelerator system) at approximately 30% of item b.2..		55,600	
3. Technical components (research detectors) at approximately 24% of item b.3..		15,200	
b. Construction Costs..			253,000
1. Conventional Construction..................................		6,300	
a. Site Improvement..................................	$ 1,500		
b. Tunnels and Buildings..............................	3,200		
c. Utilities..	1,600		
2. Technical Components - Accelerator System..................		183,400	
a. Superconducting Magnets............................	89,500		
b. Magnet Electrical System...........................	17,500		
c. Cryogenic System...................................	20,000		
d. Vacuum System......................................	9,700		
e. Beam Transfer and Injection........................	13,900		
f. Beam Dump System...................................	6,400		
g. RF System..	12,600		
h. Beam Instrumentation...............................	4,300		
i. Control System.....................................	9,500		
3. Technical Components - Research Detectors..................		63,300	
c. Contingency at approximately 22% of above costs.................			72,000
Total Estimated Cost...............			$397,000

* Cost estimate based on Conceptual Design Report (May 1989) and escalation rates dated August 1989 from the Office of Independent Cost Estimating.

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

2. Project No. 91-G-300

11. 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.

12. Funding Schedule of Project Funding and Other Related Funding Requirements

a. Total Project Cost	Prior Years	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	Total
1. Total Facility Cost									
Construction line item.	$ 0	$10,000	$38,400	$70,000	$ 86,600	$ 90,000	$ 78,000	$24,000	$397,000
Total Facility Cost....	$ 0	$10,000	$38,400	$70,000	$ 86,600	$ 90,000	$ 78,000	$24,000	$397,000
2. Other Project Costs									
a. R&D necessary to complete construction.........	$21,450	$ 6,800	$ 7,000	$ 7,200	$ 6,000	$ 3,650	$ 0	$ 0	$ 52,100
b. Start-up..............	0	0	0	0	0	7,000	13,000	28,000	$ 48,000
Total Other Project Costs..	$21,450	$ 6,800	$ 7,000	$ 7,200	$ 6,000	$ 10,650	$ 13,000	$28,000	$100,100
Total Project Cost.........	$21,450	$16,800	$45,400	$77,200	$ 92,600	$100,650	$ 91,000	$52,000	$497,100

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

12. Funding Schedule of Project Funding and Other Related Funding Requirements (continued)

b. Other Related Estimated Funding Requirements (FY 1991 dollars)

1. Annual RHIC Facility Operating Costs	$38,200
2. Annual Injector Operating Costs	
AGS	14,900
Booster	2,500
Tandem	1,800
Total Facility Operating Costs	$57,400
3. Annual plant and capital equipment costs related to facility operations	3,500
Total Other Related Annual Funding Requirements*	$60,900

* Not all of these costs are incremental

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

a. Total Project Cost
1. Total facility cost
Explained in items 8, 9 and 10.

2. Other Project Costs
a. R&D necessary to complete construction

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

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

13. Narrative Explanation of Total Project Funding and Other Related Funding Requirements (continued)

This also includes R&D necessary for research detectors. Needed are tests to determine detailed parameters required for large-scale detectors for the heavy-ion experimental facilities, and a continuing effort to develop new techniques of detection and read-out for improved utilization of the collider facility.

b. Start-up costs

These funds are needed for operation training of crew, and early testing and check-out of various systems as their construction is completed. It is anticipated that portions of the cryogenic system and the beam injection system would reach operational status in FY 1995.

b. Other Related Funding Requirements (Estimated life of the facility: 20 years)

1. RHIC facility operating costs assume 38 weeks of operation with appropriate manpower, material, and support services associated with the research program. For this estimate, four experimental areas are assumed in use.

2. Injector operating costs assume that the Tandem/AGS injector complex is not being used for any function other than as the RHIC injector.

3. This item includes plant and capital equipment needed to maintain the research capability of the facility to evolving research requirements as well as funds for accelerator improvement projects and minor general plant projects required to ensure its continued high performance.

DEPARTMENT OF ENERGY
FY 1991 CONGRESSIONAL BUDGET REQUEST
CONSTRUCTION PROJECT DATA SHEETS
GENERAL SCIENCE AND RESEARCH
NUCLEAR PHYSICS
(Tabular dollars in thousands. Narrative material in whole dollars.)

1. Title and Location of Project: Continuous Electron Beam Accelerator Facility; Newport News, Virginia

2. Project No. 87-R-203

3. Date A-E work initiated: 2nd Qtr. FY 1985

3a. Date physical construction starts: 2nd Qtr. FY 1987

4. Date construction ends: 4th Qtr. FY 1993

5. Previous cost estimate: $265,967
Less amount for PE&D: 967
Net cost estimate: $265,000
Date: 8/87

6. Current cost estimate: $265,967
Less amount for PE&D: 967
Net cost estimate: $265,000
Date: 7/88

7. Financial Schedule:

Fiscal Year	Authorization	Appropriations	Obligations	Cost
FY 1987	$ 16,200	$ 16,200	$ 16,200	$ 7,842
FY 1988	33,500	33,500	33,500	41,858
FY 1989	44,500	44,500	44,500	29,086
FY 1990	62,611	62,611	62,611	62,000
FY 1991	65,000	65,000	65,000	63,000
FY 1992	38,189	38,189	38,189	49,000
FY 1993	5,000	5,000	5,000	12,214

8. Brief Physical Description of Project

The Continuous Electron Beam Accelerator Facility (CEBAF) is a single purpose, basic nuclear research facility to be located in Newport News, Virginia on a site which includes the land and buildings once occupied by the Space Radiation Effects Laboratory (SREL). Southeastern Universities Research Association (SURA) is expected to remain operating contractor during design, construction, and later operations phases of this project. The site for this facility is Federally owned.

1. Title and Location of Project: Continuous Electron Beam Accelerator Facility; Newport News, Virginia

2. Project No. 87-R-203

8. Brief Physical Description of Project (continued)

The accelerator facility will include: a 4 billion electron volt (GeV), high intensity, recirculated continuous beam electron linear accelerator (linac); experimental areas and equipment to conduct basic nuclear research; and buildings to house the accelerator complex and its operations and maintenance activities. The facility will possess a complement of equipment for initial experiments and supporting facilities to exploit the capabilities of the accelerator.

a) Improvements to Land and Conventional Construction

Improvements to the site will include such items as drainage, roadways, and the extension of utilities. Support facilities for the accelerator complex will be housed in both new and existing structures. The Virginia Associated Research Center (VARC), an existing single-story structure located on an adjacent site owned by the Commonwealth of Virginia, will provide research and administrative offices. Title to VARC will remain with the Commonwealth of Virginia, which by agreement has made it available to SURA indefinitely for CEBAF use. The Space Radiation Effects Laboratory building, will be renovated to provide shop areas, component test and assembly areas, laboratories, and office space. Support structures include: (1) housing for the linac, recirculator magnets, and beam lines and (2) buildings for the end stations, refrigerator, accelerator service functions, and an office and computer center.

b) Accelerator System

The central research tool of CEBAF will be an electron linear accelerator. It will consist of a 1 GeV superconducting linear accelerator split into two segments. The segments will be connected by a recirculator system to transport the electron beams from one segment of the linac to the other. Four complete passes of acceleration through the linac will provide an energy of 4 GeV. The accelerator complex will also include a beam extraction system to extract three continuous beams from the linac; a beam transport system to take the three beams to three experimental halls; a cryogenic system including helium refrigerator, liquid helium storage vessels, and distribution lines; and instrumentation and control systems for the accelerator complex.

1. Title and Location of Project: Continuous Electron Beam Accelerator Facility; Newport News, Virginia

2. Project No. 87-R-203

8. Brief Physical Description of Project (continued)

c) Research Equipment

The accelerator will service three independent experimental areas. Research equipment will include an initial complement of experimental instrumentation and other support facilities necessary to perform scientific research using CEBAF's high quality electron beams and secondary photon beams.

9. Purpose, Justification of Need for, and Scope of Project

CEBAF will be the only facility in the world capable of producing electron beams which simultaneously meet the criteria of high energy, continuous beams, and high intensity necessary to advance the frontiers of electromagnetic nuclear physics. CEBAF has been identified as the highest priority new accelerator for the U.S. nuclear physics program. The unique combination of beam parameters available at CEBAF will make it a facility of unparalleled capability, and the research at CEBAF will enable the U.S. to maintain its preeminence in this important area of nuclear science. CEBAF's electron linac, with its capability of providing intense continuous beams at any energy in the range of 0.5 to 4.0 GeV, is designed to study the largely unexplored transition between the nucleon-meson and the quark-gluon descriptions of nuclear matter. In particular, it will study the extent to which individual nucleons change their size, shape, and quark structure in the nuclear medium, study how nucleons cluster in the nuclear medium, and study the force which binds quarks into nucleons and nuclei at distances where this force is strong and the quark confinement mechanism is important. CEBAF's continuous beam will make it possible to observe one or more of the reaction products in coincidence with the scattered electron, ensuring that these studies can be carried out accurately. The broad spectrum of physics accessible at CEBAF ensures that it will become and remain one of the important scientific centers in the world.

CONSTRUCTION PROJECT DATA SHEETS

1. Title and Location of Project: Continuous Electron Beam Accelerator Facility; Newport News, Virginia

2. Project No. 87-R-203

10. Details of Cost Estimate*

		Item Cost	Total Cost
a. Engineering, Design, Inspection, and Administration..........			$ 46,000
1. Conventional Construction at approximately 17% of item b.1		$ 9,000	
2. Technical components at approximately 29% of item b.2 ...		37,000	
b. Construction Costs....................................			181,000
1. Conventional Construction..............................		54,000	
a. Accelerator facilities..............................	$ 18,000		
b. Experimental facilities.............................	24,000		
c. Support facilities..................................	12,000		
2. Technical components...................................		127,000	
a. Accelerator components..............................	96,000		
b. Research equipment..................................	31,000		
c. Standard Equipment......................................			2,000
d. Contingency at approximately 16% of above costs.............			36,000
Total Estimated Cost...........			$265,000

11. Method of Performance

Design, construction, and inspection of the facility will be done by the Operating Contractor, subcontracting with an A/E contractor for design and a general contractor for construction of the conventional facilities. To the extent feasible, construction, procurement, and installation will be accomplished by fixed-price contracts and subcontracts awarded on the basis of competitive bidding.

1. Title and Location of Project: Continuous Electron Beam Accelerator Facility; Newport News, Virginia

2. Project No. 87-R-203

12. Funding Schedule of Project Funding and Other Related Funding Requirements

	Prior Years	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993	Total
a. Total project cost										
1. Total facility cost										
a. Construction line item.....	$ 0	$ 0	$ 7,842	$41,858	$29,086	$62,000	$63,000	$49,000	$12,214	$265,000
b. PE&D...........	300	667	0	0	0	0	0	0	0	$ 967
Total facility cost.........	$ 300	$ 667	$ 7,842	$41,858	$29,086	$62,000	$63,000	$49,000	$12,214	$265,967
2. Other project costs										
R&D necessary to complete construction...	$ 4,500	$ 4,918	$ 6,250	$ 6,250	$ 6,000	$ 2,900	$ 1,629	$ 0	$ 0	$ 32,447
Spares.............	0	0	0	0	0	1,100	2,400	2,600	0	6,100
Total other project costs*.	$ 4,500	$ 4,918	$ 6,250	$ 6,250	$ 6,000	$ 4,000	$ 4,029	$ 2,600	$ 0	$ 38,547
Total project cost..........	$ 4,800	$ 5,585	$14,092	$48,108	$35,086	$66,000	$67,029	$51,600	$12,214	$304,514

* Funding required for support functions of this Federally Funded Research and Development Center (FFRDC) is not included.

1. Title and Location of Project: Continuous Electron Beam Accelerator Facility; Newport News, Virginia — 2. Project No. 87-R-203

12. Funding Schedule of Project Funding and Other Related Funding Requirements (continued)

b. Other related funding requirements (FY 1991 dollars)

1. Annual facility operating costs including in-house research....................	$ 35,300
2. Annual plant and capital equipment costs not related to construction but related to the programmatic effort in the facility............................	2,500
Total other related annual funding requirements..............................	$ 37,800

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

a. Total project cost
   1. Total facility cost
      Explained in items 8, 9, and 10
   2. Other projects costs
      R&D necessary to complete construction

The CEBAF linac will use superconducting radiofrequency accelerating cavity technology to generate high energy continuous electron beams. The R&D funds will be used to design, evaluate, and construct prototypes of the technical components which are essential for meeting the design goals for the facility. Funding required for support functions of this Federally Funded Research and Development Center (FFRDC) has not been included.

b. Other related funding requirements

1. Annual facility operating costs upon completion of construction

This item includes the cost of all personnel employed by the facility for its operation, maintenance, and in-house research, together with electric power and materials and services costs. Approximately 300 man-years of effort annually will be required.

2. Annual plant and capital equipment costs upon completion of construction

This item includes capital equipment needed to maintain the research capability of the facility to meet evolving research requirements as well as funds for accelerator improvement projects and minor general plant projects required to ensure its continued high performance.