DEPARTMENT OF ENERGY
FY 1992 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND 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 and in conformance with the developing National Energy Strategy. 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 and atomic physics. They provide the framework for the training of Health Physicists who are especially dedicated to the maintenance of a radiation-free environment. Over one half 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.

Nevertheless, the major activity and vitality of the field focuses upon an ever improving fundamental understanding of the material and forces of nature. These activities are an essential component of the National Energy Strategy in fortifying the foundations of the nation's scientific and technological base. 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 special current interest are measurements of the solar neutrino flux which permits the measurement of small neutrino masses. 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", will play an increasing role in the program.

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, which is based on the 1989 Long Range Plan for Nuclear Science developed by 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 with which the experiments are performed. 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 85 percent of the U.S. program of basic research in nuclear physics. In FY 1992 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 carry out 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 an 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 an initial program of experiments has been selected to be carried out when the facility comes into operation. The present focus is 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 to be carried out in the three experimental halls.

Special emphasis is placed on effective use of the upgraded accelerators at the University of Washington and Yale University 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 continuation 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. The Institute for Nuclear Theory, sited in FY 1990 at the University of Washington, will continue its development in FY 1992 with new forefront scientific programs and the creation of additional mechanisms for effective interaction with the entire nuclear physics community.

In FY 1992, the largest construction project in the Nuclear Physics program will be the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory as major superconducting magnet procurements begin. Construction funding for CEBAF will be past its peak; the primary activities on the accelerator components will be assembly and installation. There will be significant activity in the fabrication of experimental detectors for both facilities in FY 1992. These two projects received the highest priority for support in the NSAC Long Range Plan for Nuclear Science.

DEPARTMENT OF ENERGY
FY 1992 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)
LEAD TABLE
Nuclear Physics

Activity	FY 1990 Enacted	FY 1991 Enacted	FY 1992 Base	FY 1992 Request	Program Change Request vs Base: Dollar	Program Change Request vs Base: Percent
Operating Expenses						
Medium Energy Nuclear Physics	$91,748	$98,200	$98,200	$108,100	$+ 9,900	+ 10%
Heavy Ion Nuclear Physics	67,023	70,929	70,929	74,700	+ 3,771	+ 5%
Low Energy Nuclear Physics	24,988	27,300	27,300	28,391	+ 1,091	+ 4%
Nuclear Theory	12,226	13,100	13,100	14,000	+ 900	+ 6%
Capital Equipment	19,720	24,100	24,100	28,000	+ 3,900	+ 16%
Construction	71,485	79,700	79,700	89,199	+ 9,499	+ 12%
Total	287,190	313,329	313,329	342,390	+ 29,061	+ 9%
Operating Expenses	(195,985)a/	(209,529)	(209,529)	(225,191)	(+ 15,662)	+ 7%
Capital Equipment	(19,720)	(24,100)	(24,100)	(28,000)	(+ 3,900)	+ 16%
Construction	(71,485)	(79,700)	(79,700)	(89,199)	(+ 9,499)	+ 12%
Total	($287,190)	($313,329)	($313,329)	($342,390)	(+ 29,061)	+ 9%

Staffing (FTEs).............(Reference General Science Program Direction)

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

a/ Total has been reduced by $2,471,000 ($640,000 Medium Energy, $493,000 Heavy Ion, $1,338,000 Low Energy) reprogrammed to Energy Supply for SBIR.

DEPARTMENT OF ENERGY
FY 1992 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

SUMMARY OF CHANGES

Nuclear Physics

FY 1991 Enacted Appropriation..	$313,329
Adjustments - Increased personnel costs..	0
FY 1992 Base..	313,329
- Funding required to maintain a constant overall level of program activity............	+ 10,618
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........................	+ 5,579
Heavy Ion Nuclear Physics	
- Continue Heavy Ion operations at approximately constant level of acitivity..........	+ 650
Low Energy Nuclear Physics	
- Continue nuclear data program and low energy physics operations and research at approximately constant level of activity	- 110
Nuclear Theory	
- Slightly increased level of activity with emphasis on preparation of theoretical guidance for experimental results using new theory institute..................................	+ 324

Capital Equipment

- Provide for initiation of special beam lines for R&D on RHIC detectors at BNL, procure components for the High Resolution Spectrometer at CEBAF, maintain overall level of instrumentation effort and provide for general purpose equipment to meet laboratory-wide needs of Lawrence Berkeley Laboratory	+ 2,840

Construction

- Constant level of effort for AIP and GPP	+ 10
- Continue Continuous Electron Beam Accelerator Facility (CEBAF) project at planned level	- 26,700
- Continue Relativistic Heavy Ion Collider (RHIC) construction project at planned level	+ 35,850
FY 1992 Congressional Budget Request	$342,390

DEPARTMENT OF ENERGY
FY 1992 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 1990 Enacted	FY 1991 Enacted	FY 1992 Request	% Change
Research				
LAMPF-Based Research..........................	$ 10,911	$ 10,936	$ 11,452	+ 5
Bates Based Research..........................	3,282	3,396	3,644	+ 7
CEBAF-Based Research..........................	11,284	11,744	12,181	+ 4
Research at Other Sites.......................	11,548	12,024	12,723	+ 6
Subtotal, Research	$ 37,025	$ 38,100	$ 40,000	+ 5
Operations				
LAMPF Operations..............................	$ 40,426	$ 39,900	$ 41,800	+ 5
Bates Operations..............................	7,000	7,195	7,500	+ 4
CEBAF Operations..............................	6,015	12,060	18,800	+ 56
Other Operations..............................	1,282	945	0	-100
Subtotal, Operations	$ 54,723	$ 60,100	$ 68,100	+ 13
Total, Medium Energy Nuclear Physics	$ 91,748	$ 98,200	$ 108,100	+ 10

II. B. Major Laboratory and Facility Funding

	FY 1990 Enacted	FY 1991 Enacted	FY 1992 Request	% Change
Continuous Electron Beam Accelerator Facility ...	$ 17,002	$ 23,110	$ 29,800	+ 29
Los Alamos National Scientific Laboratory	$ 47,648	$ 46,400	$ 48,560	+ 5
Massachusetts Institute of Technology	$ 10,455	$ 10,525	$ 10,963	+ 4

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

Program Activity	FY 1990	FY 1991	FY 1992
Medium Energy Nuclear Physics			
Research			
LAMPF-Based Research	Conduct full experimental program using Medium Resolution Spectrometer (MRS) and the Neutron Time of Flight (NTOF) facility with beam from the new high intensity polarized proton source. Complete preparations on the Low Energy Pion (LEP) channel for installation of the energy spread compressor.	Continue use of MRS and NTOF with polarized beams. Complete installation of energy spread compressor on LEP channel and begin experiments. Assemble new neutral meson spectrometer.	Continue use of MRS and NTOF with polarized beams. Use energy spread compressor on LEP channel for experiments. Begin use of neutral meson spectrometer.
	Begin taking longer flight path data for neutrino oscillation experiment, and begin R&D activies for next-generation neutrino experiment.	Continue R&D activities for new neutrino experiment and detector.	Develop new Liquid Scintillator Neutrino Detector, LSND. Plan use for neutrino-proton scattering and higher sensitivity neutrino oscillation studies.
	Use new detector on Time-of-Flight Isochronous Spectrometer facility (TOFI) for nuclear mass measurements to extend extend studies to higher masses.	Do selected high mass studies of neutron-rich isotopes on TOFI.	Do selected high mass studies of neutron-rich isotopes on TOFI. Investigate ways to improve intrinsic mass resolution to enable mass measurements of fission products.
	Start data taking phase of rare muon decay experiment (MEGA) with a reduced sensitivity form of detector.	Continue data taking with a more complete partial MEGA detector. The electron detection arm and part of the photon detection arm will be complete.	Complete detector and perform full sensitivity data accumulation on the MEGA experiment.

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

Program Activity	FY 1990	FY 1991	FY 1992
LAMPF-Based Research (Cont'd)	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. Plan R&D efforts for an improved neutral meson spectrometer.	Continue nuclear structure and reaction mechanism studies. Resume polarized target development for spin-dependent nuclear reaction studies. Continue development of program for a new neutral meson spectrometer.
	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 $6,500 medium energy research budget at LANL, $731 is for research carried out by LANL scientists at locations other than LAMPF, leaving $5,769 for in-house use of LAMPF. To this is added $5,167 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 $6,760 medium energy research budget at LANL, $761 is for research carried out by LANL scientists at locations other than LAMPF, leaving $5,999 for in-house use of LAMPF. To this is added $5,453 of direct medium energy research funds to outside users for their LAMPF research programs.
	$ 10,911	$ 10,936	$ 11,452
Bates Based Research	Continue coincidence measurements with higher intensity polarized electron beam. Begin out-of-plane detection, in collaboration with the University of Illinois, and use of polarized targets.	Expand coincidence measurements with polarized electron beams. Emphasize form factor experiments using spin observables. Utilize new out-of-plane detection techniques and polarized targets. Begin building focal plane polarimeter for the proton spectrometer (OHIPS) in the South Hall.	Continue coincidence measurement program with polarized electron beams. Emphasize form factor experiments using spin observables utilizing new OHIPS focal plane polarimeter. Begin phasing in experiments with the South Hall Ring Experiment internal targets.
	Continue high precision measurements with the electron spectrometer (ELSSY) in the North Hall and reduce level of research utilizing the South Hall spectrometers during installation of the 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.	Continue high precision measurements with ELSSY while completing South Hall Ring installation and beginning research in South Hall utilizing newly completed South Hall Ring Experiment.
	Continue R&D on behavior of polarized beams in stretcher rings and on design of detector components for use in the South Hall.	Continue R&D on behavior of polarized beams in stretcher rings and on design of detector components for use in the South Hall.	Complete R&D on behavior of polarized beams in stretcher rings and on design of detector components for use in the South Hall.

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

Program Activity	FY 1990	FY 1991	FY 1992
Bates Based Research (Cont'd)	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 $3,330 medium energy research budget at MIT, $1,233 is for research carried out by MIT scientists at locations other than Bates, leaving $2,097 for in-house use of Bates. To this is added $1,299 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 $3,463 medium energy research budget at MIT, $1,181 is for research carried out by MIT scientists at locations other than Bates, leaving $2,181 for in-house use of Bates. To this is added $1,463 of direct medium energy research funds to outside users for their Bates research programs.
	$ 3,282	$ 3,396	$ 3,644
CEBAF-Based Research	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.	Carry out testing of North Linac components and associated RF, cryogenic, and facility safety systems.
	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 with additional workstations.	Utilize data acquisition system for testing of components and systems during accelerator assembly.
	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 electronics components.	Continue testing and prototyping of experimental area components. Begin experimental equipment assembly.	Assemble and begin testing of experimental equipment components. Emphasis will be on completion of Hall C and Hall A detectors to be ready for data taking upon completion of commissioning of the accelerator in early 1995.
	Continue superconducting research activities and strengthen theoretical efforts.	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 1990	FY 1991	FY 1992
CEBAF-Based Research (Cont'd)	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 $11,050 medium energy research budget at CEBAF, $774 is for research carried out by CEBAF scientists at locations other than CEBAF, leaving $10,276 for in-house use of CEBAF. To this is added $1,468 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 $11,000 medium energy research budget at CEBAF, $770 is for research carried out by CEBAF scientists at locations other than CEBAF, leaving $10,230 for in-house use of CEBAF. To this is added $1,951 of direct medium energy research funds to outside users for their CEBAF research programs.
	$ 11,284	$ 11,744	$ 12,181
Research at Other Sites	Continue data taking phase of rare kaon decay experiment at Brookhaven National Laboratory and continue preparations for experiments using new kaon beam line in search for rare two-nucleon structures (H-particles) in collaboration with Carnegie-Mellon University.	Begin second phase of rare kaon decay experiments. Complete equipment installation and start taking data for H-particle search.	Continue data taking phase and analysis of H-particle search.
	Support Nuclear Physics End Station A program and continue evaluation of the 15 GeV collider ring (PEP) at the Stanford Linear Accelerator Center (SLAC) for nuclear physics experiments.	Retain possibility of doing experiments using end station A and the PEP ring at SLAC.	Retain possibility of doing experiments using end station A and the PEP ring at SLAC.
	Complete data taking for crystal barrel experiment at LEAR facility. Plan for the use of the CERN 100 GeV muon beam for measurement of spin-dependent structure functions of the neutron and proton.	Begin joint Nuclear Physics/High Energy Physics spin structure function experiment at CERN involving five U.S. Nuclear Physics university groups.	Continue spin structure function experiment at CERN. Experiment should help solve the mystery of which of the sub-nuclear structures (quarks and gluons) carry the known spins of the nucleons.
	Continue St. Gotthard tunnel (Italy/Switzerland) germanium double beta decay experiment and prepare for study of double beta decay modes in xenon.	Continue xenon phase of St. Gotthard double beta decay experiment.	Conclude xenon phase of St. Gotthard double beta decay experiment.

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

Program Activity	FY 1990	FY 1991	FY 1992
Research at Other Sites (Cont'd)	Start first round of experiments on the Laser Electron Gamma Source (LEGS) facility at the National Synchrotron Light Source at Brookhaven National Laboratory. Concentrate on initial measurements of deuteron photodisintegration.	Expand experimental program to planned operating level of group using the LEGS facility and broaden the LEGS experimental effort to include users from universities and other laboratories. Begin measurements on helium-3.	Establish full utilization of the LEGS facility. Commence measurements of the delta resonance.
	Conduct program of selected nuclear physics experiments at other facilities including Fermilab, TRIUMF (Canada), Saclay (France), Paul Scherrer Institute (PSI) (Switzerland), and NIKHEF (Netherlands).	Conduct program of selected nuclear physics experiments at other facilities including Fermilab, TRIUMF (Canada), PSI (Switzerland), and NIKHEF (Netherlands).	Conduct program of selected nuclear physics experiments at other facilities including Fermilab, TRIUMF (Canada), PSI (Switzerland), and NIKHEF (Netherlands).
	$ 11,548	$ 12,024	$ 12,723
Subtotal, Research	$ 37,025	$ 38,100	$ 40,000
Operations			
LAMPF Operations	Operate accelerator and facilities about 2400 hours for nuclear physics research with about seven secondary beams operating simultaneously.	Operate accelerator and facilities about 1900 hours for nuclear physics research with a reduced number of secondary beams operating simultaneously.	Operate accelerator and facilities about 1900 hours for nuclear physics research with about seven secondary beams operating simultaneously.
	Provide beams for approximately 52 nuclear physics experiments involving about 300 scientists.	Provide beams for approximately 45 nuclear physics experiments involving about 280 scientists.	Provide beam for approximately 45 nuclear physics experiments involving about 280 scientists.
	Start operation of high intensity polarized ion source. Begin operation of low energy pion (LEP) channel with energy spread compressor.	Utilize newly installed computers for remote analysis capability. Delay operation with high intensity polarized ion source and polarized targets.	Operate with high intensity polarized ion source and polarized targets.
	$ 40,426	$ 39,900	$ 41,800
Bates Operations	Operate accelerator and facilities about 1800 hours for nuclear physics research.	Operate accelerator and facilities about 1200 hours for nuclear physics research.	Operate accelerator and facilities about 500 hours for nuclear physics research during commissioning of new South Hall Ring.

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

Program Activity	FY 1990	FY 1991	FY 1992
Bates Operations (Cont'd)	Provide beam for approximately 6 experiments involving about 50 scientists. Operate accelerator at 1 GeV for required experiments during selected operating cycles during the year. Continue installation and testing of components for South Hall Ring Experiment.	Provide beam for approximately 5 experiments involving about 45 scientists. Operate accelerator at 1 GeV for required experiments during selected operating cycles during the year. Continue installation and testing of components for South Hall Ring Experiment.	Provide beam for approximately 3 experiments involving about 30 scientists. Operate accelerator at 1 GeV for required experiments during selected operating cycles during the year. Complete installation and testing of components for South Hall Ring Experiment.
	$ 7,000	$ 7,195	$ 7,500
CEBAF Operations	Provides for startup of laboratory operations and accelerator commissioning. Carry out cryomodule testing and operate part of the injector at 5 MeV.	Provides for startup of laboratory operations and accelerator commissioning. Carry out Front-End-Test of the injector in the accelerator tunnel at 25 MeV. Extend test to 45 MeV.	Provides for startup of laboratory operations and accelerator commissioning. Operate and test major sections of the full injector and the North Linac along with associated systems.
	$ 6,015	$ 12,060	$ 18,800
Other Operations	Suspend operation of the Nuclear Physics Injector (NPI) at the Stanford Linear Accelerator Center (SLAC). Continue operations support for the Bevalac medium energy research activities (300 hours).	Continue suspension of operation of NPI at SLAC. Provide general operations support of medium energy programs.	Continue suspension of operation of NPI at SLAC. Operations support for the Bevalac medium energy program has been terminated.
	$ 1,282	$ 945	$ 0
Subtotal, Operations	$ 54,723	$ 60,100	$ 68,100
Medium Energy Nuclear Physics	$ 91,748	$ 98,200	$ 108,100

DEPARTMENT OF ENERGY
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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 nucleus - nucleus collisions induced by beams of heavy ions. 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 leading to severe deformation and eventually fission. 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 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 1990 Enacted	FY 1991 Enacted	FY 1992 Request	% Change
Research				
LBL Bevalac Research..........................	$ 6,249	$ 6,215	$ 6,625	+ 7
BNL Tandem/AGS Research.......................	8,821	9,340	9,745	+ 4
National Laboratory Research..................	9,225	9,520	9,910	+ 4
University Research...........................	7,856	9,892	10,920	+ 10
Subtotal, Research	$ 32,151	$ 34,967	$ 37,200	+ 6
Operations				
LBL Bevalac Operations........................	$ 15,845	$ 16,945	$ 17,545	+ 4
BNL/Tandem/AGS Operations.....................	7,691	8,080	9,100	+ 13
Other Operations (including ANL, LBL, ORNL)...	9,385	8,895	8,700	- 2
University Accelerator Operations.............	1,951	2,042	2,155	+ 6
Subtotal, Operations	$ 34,872	$ 35,962	$ 37,500	+ 4
Total, Heavy Ion Nuclear Physics	$ 67,023	$ 70,929	$ 74,700	+ 5

II. B. Major Laboratory and Facility Funding

	FY 1990 Enacted	FY 1991 Enacted	FY 1992 Request	% Change
Argonne National Laboratory	$ 6,227	$ 6,570	$ 7,320	+ 11
Brookhaven National Laboratory	$ 16,512	$ 17,420	$ 18,845	+ 8
Lawrence Berkeley National Laboratory	$ 25,564	$ 26,755	$ 28,235	+ 6
Lawrence Livermore National Laboratory	$ 123	$ 145	$ 154	+ 6
Los Alamos National Scientific Laboratory	$ 907	$ 925	$ 977	+ 6
Oak Ridge National Laboratory	$ 7,883	$ 6,970	$ 7,094	+ 2

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

Program Activity	FY 1990	FY 1991	FY 1992
Heavy Ion Nuclear Physics			
Research			
LBL Bevalac Research	Continue experiments at the Heavy Ion Spectrometer System (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 Time Projection Chamber (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 Dilepton Spectrometer (DLS) to probe the hot high density phase of the collision process. Continue to study multifragmentation processes at the Low Energy Beam line. Start prototyping for next generation InterMediate Energy Detector (IMED) to study the predicted liquid-gas phase transition. Continue analyses of data from CERN and conduct experiments to study strangeness production and energy densities achieved. Explore physics potential of lead beam experiments.	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 IMED 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.	Continue with the HISS TPC studies of multifragmentation and the equation of state of nuclear matter at high densities and temperature. Continue analysis of DLS data and begin studies of the hot dense phase of collision processes for heavier systems using the upgraded front Cerenkov counters. Continue studies of the properties of radioactive nuclei produced in projectile fragmentation. Continue studies of multifragmentation at intermediate energies on the Low Energy Beam Line. Continue ultra-relativistic heavy ion program at AGS and CERN. Analyze new data from latest CERN experiment using sulfur beams and continue preparation for lead beam experiments in 1993-1994. Continue involvement in RHIC detector R&D projects and pursue development of a proposal for a RHIC experiment.

Program Activity	FY 1990	FY 1991	FY 1992
LBL Bevalac Research (Cont'd)	$ 6,249	$ 6,215	$ 6,625
BNL Tandem/AGS Research	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. Continue R&D towards RHIC at about $6.6 million, and participate in discussions leading toward proposals for detectors at RHIC.	At BNL, continue relativistic heavy ion program at AGS with first Au beams. These approved experiments will extend to heavier systems measurements of energy flow, nuclear stopping, two-particle correlations, and strangeness production, as well as possible searches for strange matter and production rates of anti-particles. Continue analyses of data obtained in previous measurements with protons and Si beams in experiments E810, E814, and E859. Continue R&D directed toward RHIC accelerator and detector projects at a level of about $7.0 million. Participate vigorously in the development of proposals for RHIC experiments.
	$ 8,821	$ 9,340	$ 9,745
National Laboratory Research	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 Fragment Mass Analyzer (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.	At ANL, continue experimental program at ATLAS utilizing the heavy ion species and intense high quality beams that are unique to this facility. Continue program with the FMA to address the broad range of physics that this device makes accessable. Continue the measurements begun last year with APEX to study the origin of the anomalous electron-positron peaks observed in heavy nucleus collisions. Continue support of the fabrication, installation, and operation of Gammasphere.

Program Activity	FY 1990	FY 1991	FY 1992
National Laboratory Research (Cont'd)	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 advanced 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.	At LBL, continue the experimental program at the 88 inch cyclotron, including the high spin studies which utilize the HERA detector array, the program of studies of transuranic nuclei, and reaction mechanism studies which utilize the heavier mass and higher intensity beams available from the Advanced ECR. Coordinate activities related to the fabrication, installation, and operation of Gammasphere.
	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 detector R&D problems for RHIC, and participate in discussions leading toward a proposal for a detector at RHIC.	At ORNL, continue research program studying high spin properties of nuclei and the reaction mechanism of nucleus-nucleus interactions using existing detectors which include the Compton Suppressed Spectrometer System (CSS), Spin Spectrometer (SS), Heavy-Ion Light Ion (HILI) array. Continue study of energetic photons using the BaF2 array in Giant Dipole Resonance and bremsstrahlung studies. Continue activities related to the fabrication, installation, and operation of Gammasphere. Continue program of relativistic heavy ion studies, including analysis of data obtained in the latest run at CERN with sulfur beams and strong involvement of this group in leading RHIC detector R&D at the AGS and in the development of a proposal for a RHIC experiment.

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

Program Activity	FY 1990	FY 1991	FY 1992
National Laboratory Research (Cont'd)	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 analyze data from experiment E814 at BNL and the NA44 spectrometer experiment at CERN, and participate in discussions leading toward a proposal for a detector at RHIC.	At LANL, continue participation in data taking and analysis of previous data from the NA44 experiment at CERN. Continue participation in RHIC detector R&D and involvement in development of a proposal for a RHIC experiment.
	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.	At LLNL, continue participation in the E859 research program at AGS and in the RHIC detector R&D program. Participate actively in the development and writing of a proposal for a RHIC experiment.
	$ 9,225	$ 9,520	$ 9,910
University Research	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.	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 collective phenomena and study how highly excited systems evolve with energy. Continue emphasis on improving detector systems at all accelerators.	Continue to strengthen university user research activities at national laboratories where unique opportunities are available. At the upgraded University facilities (namely, Yale's upgraded tandem, University of Washington's superconducting linac booster, and Texas A&M's superconducting cyclotron) continue nuclear physics studies with emphasis on utilization of the new detector systems acquired. These detector systems include at Yale, the large-solid angle magnetic spectrometer, the Gamma-X array, the neutron-ball, and the Si-Triensphere; at Washington, the new BGO Compton Suppressed Ge detectors, the Plastic-well Phoswich array, and the BaF2 array; and at Texas A&M, the neutron-ball, the BaF2 array, and the Recoil Mass Spectrometer. Continue emphasis on development and improvement of detector systems at all accelerator facilities.

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

Program Activity	FY 1990	FY 1991	FY 1992
University Research (Cont'd)	Implemented plans for the Energy Sciences Network (ESNET) project, identified in the applied mathematical sciences subprogram of the Basic Energy Sciences program will proceed. This subprogram's share for the implementation of ESNET is $493,000.	Upgrades of ESNET to conform to the National Research and Education Network Standards will continue to be pursued and will be shared among ER programs that benefit from ESNET.	ESNET will be fully supported in the Applied Mathematical Sciences subprogram of the Basic Energy Sciences Program.
	$ 7,856	$ 9,892	$ 10,920
Subtotal, Research	$ 32,151	$ 34,967	$ 37,200
Operations			
LBL Bevalac Operations	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.	Continue facility operation for nuclear physics and biomedical (one third time) research at about 3200 hours. Use full complement of beamlines for program with the DiLepton Spectrometer (DLS), the HISS TPC, and radioactive beams, and for Low Energy work with emphasis on a strong program for the major experimental stations. Continue to improve beam qualities and intensities to optimize the experimental program. The SuperHILAC continues to serve as a dedicated injector for the Bevalac.
	$ 15,845	$ 16,945	$ 17,545
BNL/Tandem/AGS Operations	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 6 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.	Pursue heavy ion commissioning of the AGS Booster and begin operation of Tandem/AGS system for heavy ion research with Au beams providing up to 10 weeks for experimental program. Provide the support necessary to insure the implementation and initiation of the new Au beam experiments. Begin construction of beamline for R&D on RHIC detectors.
	$ 7,691	$ 8,080	$ 9,100

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

Program Activity	FY 1990	FY 1991	FY 1992
Other Operations (including ANL, LBL, ORNL)	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. Support installation and operation of the APEX detector for positron-electron coincidence measurements. Provide beams for 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 beams for 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.	Continue modifications of components of the ANL ATLAS facility to optimize performance and reliability for heavy ion acceleration. Provide heavy ion beams up to uranium for research utilizing all detector systems, including the FMA, and APEX. At the LBL 88" cyclotron, continue R&D work on ECR sources and provide heavy ion beams for research utilizing the 14.5 GHz Advanced ECR source for production of high intensity beams. At Oak Ridge National Laboratory, provide computing systems, mechanical design, and other support for Gammasphere. Continue to consolidate operations at these three facilities.
	$ 9,385	$ 8,895	$ 8,700
University Accelerator Operations	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 nuclear physics program at the Texas A&M superconducting cyclotron.	Provide heavy ion beams and support for carrying out nuclear physics research programs at the three major university accelerator facilities using large range of ions and energies. At the Yale Tandem, provide light heavy ions to an expanded array of detector systems in order to carry out a broad program of nuclear physics research. At the University of Washington superconducting linac booster, provide light heavy ion beams for in-house program. At the Texas A&M superconducting cyclotron, provide light to medium mass heavy ions at low to intermediate energies for a nuclear physics program utilizing the new detection systems installed.
	$ 1,951	$ 2,042	$ 2,155

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

Program Activity	FY 1990	FY 1991	FY 1992
Subtotal, Operations	$ 34,872	$ 35,962	$ 37,500
Heavy Ion Nuclear Physics	$ 67,023	$ 70,929	$ 74,700

DEPARTMENT OF ENERGY
FY 1992 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 1990 Enacted	FY 1991 Enacted	FY 1992 Request	% Change
Research				
Research at University Facilities............	$ 2,776	$ 3,024	$ 3,153	+ 4
Research at National Laboratory Accelerators..	3,614	3,170	3,295	+ 4
Research at Reactors.........................	1,071	1,067	910	- 15
Other Research...............................	3,454	5,444	5,862	+ 8
Subtotal, Research	$ 10,915	$ 12,705	$ 13,220	+ 4
Operations				
Accelerator Operations.......................	$ 3,194	$ 3,225	$ 3,350	+ 4
Subtotal, Operations	$ 3,194	$ 3,225	$ 3,350	+ 4
Nuclear Data				
Nuclear Data Measurements....................	$ 6,473	$ 6,531	$ 6,803	+ 4
Nuclear Data Compilation and Evaluation.......	4,406	4,839	5,018	+ 4
Subtotal, Nuclear Data	$ 10,879	$ 11,370	$ 11,821	+ 4
Total, Low Energy Nuclear Physics	$ 24,988	$ 27,300	$ 28,391	+ 4

II. B. Major Laboratory and Facility Funding

	FY 1990 Enacted	FY 1991 Enacted	FY 1992 Request	% Change
Ames Laboratory	$ 202	$ 204	$ 0	-100
Argonne National Laboratory	$ 2,962	$ 3,010	$ 3,125	+ 4
Brookhaven National Laboratory	$ 3,708	$ 3,810	$ 3,960	+ 4
Idaho National Engineering Laboratory - EG&G	$ 330	$ 340	$ 350	+ 3
Lawrence Berkeley National Laboratory	$ 2,184	$ 2,420	$ 2,515	+ 4
Lawrence Livermore National Laboratory	$ 227	$ 235	$ 245	+ 4
Los Alamos National Laboratory	$ 1,498	$ 1,725	$ 1,790	+ 4
Oak Ridge National Laboratory	$ 4,605	$ 4,845	$ 5,035	+ 4

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

Program Activity	FY 1990	FY 1991	FY 1992
Low Energy Nuclear Physics			
Research			
Research at University Facilities	At Texas A&M, commission the proton spectrometer and begin experiments using the (d, He-2) reaction; at Duke, use newly commissioned intense polarized ion source to search for P-even time reversal violation from cryogenically aligned holmium nuclei; at Washington, exploit the higher energy lighter ion beams available from the superconducting linac booster to study reaction mechanisms at the Coulomb barrier.	At Texas A&M, experimental studies of the electroweak interaction will concentrate on intermediate mass nuclei in the Fe region, which are important for nucleosynthesis in stellar formation, and on Zr-90, which is important for the electroweak sum rule; at Duke, spin-spin cross sections will be made using cryogenic targets of polarized hydrogen and polarized solid He-3; at Washington, the new high intensity polarized ion source and higher energy beams will be used to study the scattering of polarized protons with emphasis on backward angle spin structure measurements.	At Texas A&M, begin the development of a high-resolution 160 MeV polarized neutron beam to be used with the proton spectrometer for (n,p) studies of the weak interaction; at Duke, use high-intensity beams of polarized positive ions from the high-efficiency ECR ionizer of the new polarized ion source to measure the spin sensitivity of nuclear reactions between very light nuclei at very low energies, of astrophysical interest; at Washington, use the new polarized ion source and booster to study a variety of nuclear structure problems and to search for violations of fundamental symmetries.
	$ 2,776	$ 3,024	$ 3,153

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

Program Activity	FY 1990	FY 1991	FY 1992
Research at National Laboratory Accelerators	Continue low energy research at ANL, LBL, and ORNL. At ANL, heavy ion research continues; at LBL, the search for nuclei near the proton and neutron limits of stability that may decay by new and exotic radioactivities continues, and participation in the Sudbury Neutrino Observatory (SNO) collaboration has begun; at ORNL, the cryogenic Nuclear Orientation Facility (NOF) has been brought into full operation at the on-line isotope separator (UNISOR) and several on-line experiments have been started.	Continue low energy research at the three national laboratories. At ANL, continue heavy ion research; at LBL, use the 88-inch cyclotron to provide light ions for the astrophysics group, which will now be heavily involved in work, including materials selection and radioactivity assessment, for the SNO collaboration; at ORNL, continue experiments with the NOF to determine complete level schemes for odd-mass nuclei in the A=190 region to explore manifestations of boson-fermion symmetries.	Continue low energy research at the three national laboratories. At ANL, heavy ion research will continue; At LBL, a broad program of nuclear astrophysics will be pursued, with the main effort devoted to the SNO collaboration (described below, under Other Research); at ORNL, use of the NOF will be extended to nuclear quadrupole orientation and Nuclear Magnetic Resonance (NMR) experiments.
	$ 3,614	$ 3,170	$ 3,295
Research at Reactors	The BNL-led Participating Research Team at the TRISTAN facility has not acquired more data because of the shut-down of the HFBR, although some work is being accomplished by using European facilities, eg, at the Institute Laue Langevin (ILL), Grenoble. At the NIST (formerly, NBS) the experiment to improve the determination of the mass of the neutron will continue at the recently developed cold neutron beam line.	Continue to support the BNL nuclear structure research, which may have to be moved overseas: continue the precision neutron mass measurements at the NIST. At BNL, if the HFBR resumes operation, TRISTAN and capture gamma programs will continue, with studies of the p-n interaction, nuclear symmetries, test of the shell model, and measurements of properties of nuclei crucial to the understanding of nucleosynthesis.	Continue both the BNL nuclear structure research and the fundamental neutron measurements at the NIST. At BNL, if the HFBR resumes operation, it will be timely to upgrade the TRISTAN facility by locating the ion source nearer to the reactor core and thereby gaining a factor of thirty in intensity of the separated mass beams. Proposals will be developed to begin collaborative work at the University of Koeln, FRG, and at Daresbury Lab, England.
	$ 1,071	$ 1,067	$ 910
Other Research	Provide R&D support for U.S. participation in the Joint Canadian-US-UK Sudbury Neutrino Observatory (SNO) project, involving a large, deep underground, heavy-water Cerenkov detector to measure solar neutrino fluxes and higher energy spectra for neutrinos of all types. Preliminary results are expected from the Soviet American Gallium Experiment (SAGE) metallic gallium solar neutrino experiment. Continue support of the US participation by BNL nuclear chemists	Begin U.S. participation in the construction of the large detector for the SNO project, with increased funding for participants at LANL, LBL, and University of Pennsylvania. Continue support for BNL participation in the GALLEX project and LANL participation in the SAGE project. Support will end for the University of Pennsylvania's participation in the completed KAMIOKANDE experiment.	Continue support for solar neutrino research, chiefly the Sudbury Neutrino Observatory (SNO) and Gallium Experiment (GALLEX) projects. For the SNO project, LANL has major responsibilities for R&D on the large acrylic vessel for the 1,000 tons of heavy water, on data-acquisition codes, and for acquisition of photomultipliers and computer hardware; LBL, for the design and fabrication of the critical radioactivity-free photomultiplier (thousands) support structure; and

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

Program Activity	FY 1990	FY 1991	FY 1992
Other Research (Cont'd)	in the European gallium chloride solar neutrino experiment (GALLEX). Final results are expected from the Mo/Tc solar neutrino experiment at LANL in its final year of support. The US(Pennsylvania)/Japan KAMIOKANDE collaboration has provided the first proof that the high energy "B-8" neutrinos do come from the Sun, and confirm that their flux is less than that calculated by the standard solar model.		Penn, for optimization of the photomultipliers and participation of BNL nuclear chemists in GALLEX. The participation of LANL scientists in the Soviet American Gallium Experiment (SAGE) at the underground lab in the USSR will diminish as the operation of the detection system becomes routine and the early results are published.
	$ 3,454	$ 5,444	$ 5,862
Subtotal, Research	$ 10,915	$ 12,705	$ 13,220
Operations			
Accelerator Operations	Continue support for the accelerator facilities at Duke University and, together with the Heavy Ion program, those at Texas A&M and the University of Washington; continue support, together with the Heavy Ion program, of national facilities at ANL and LBL.	Continue support for the three university accelerator facilities and the national laboratory facilities. These facilities support most of the research activities described in the preceding sections, that is, the bulk of the low energy nuclear physics research.	Continue support for the three university accelerator facilities: at Duke University (Triangle Universities Nuclear Laboratory) and, together with the Heavy Ion program, those at Texas A&M and the University of Washington. Provide support for the low energy programs at national laboratory facilities, at ANL (ATLAS) and at LBL (88-inch Cyclotron).
	$ 3,194	$ 3,225	$ 3,350
Subtotal, Operations	$ 3,194	$ 3,225	$ 3,350
Nuclear Data			

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

Program Activity	FY 1990	FY 1991	FY 1992
Nuclear Data Measurements	At ORELA, continue construction of a large, segmented BaF2 photon-multiplicity detector and complete redesign of the capture gamma-ray detector system; at ANL begin measurements of cross sections for the production of long-lived activities, which are of interest to the Office of Fusion Energy. At the LANL/Weapons Neutron Research facility (WNR), continue higher energy neutron-induced fission cross section measurements, as well as the required improvement of the standard cross section, B-10(n,alpha).	Continue neutron cross-section measurements at the ORNL/ORELA, ANL/FNG, and LANL/WNR. At ORELA, commission the large BaF2 photon-multiplicity detector, and begin measurements of the capture-to-fission ratios. Begin capture cross-section measurements using the redesigned detection system. The NIST (formerly NBS) experimenters, with the shut-down of their linear accelerator, will continue a reduced measurement effort at the ORELA and WNR. At ANL, continue activation cross section measurements and begin neutron scattering measurements for high-temperature metals that are of interest for space-power applications. At LANL, phase out the successfully completed fusion reaction measurement program and continue measurements at WNR.	Continue neutron cross-section measurements at the ORNL/ORELA, ANL/FNG, and LANL/WNR. Continue experiments at the Oak Ridge Electron Linear Accelerator (ORELA) using the new photon-multiplicity detector to obtain unadjusted differential measurements of capture-to-fission ratios for the first time, and which are required to meet accuracy requirements of reactor designers. Use a carefully redesigned capture cross-section measurement system to redo important structural materials. ORELA measurements will include gamma-ray production from materials incorporated in superconducting magnets, of interest to the Office of Fusion Energy (OFE) and others. At the ANL/Fast Neutron Generator (FNG), continue difficult measurements of cross sections for the production of long-lived activities, which are of interest to the Office of Fusion Energy for reactor materials selection, and continue neutron scattering measurements for high-temperature metals. At the WNR, continue measurements of cross sections for higher energy neutrons, in particular for (n,p) and (n,alpha) reactions, to derive level density information for use in calculations of cross sections of importance to fusion and weapons technologies.
	$ 6,473	$ 6,531	$ 6,803

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

Program Activity	FY 1990	FY 1991	FY 1992
Nuclear Data Compilation and Evaluation	All but a few scraps of the latest comprehensive revision of the Evaluated Nuclear Data File (ENDF-6), essentially a library of computer accessible neutron cross sections for nuclear technologists, will be released for general use. A Working Group on International Evaluation Cooperation, including the US, Europe, and Japan, has been established under the auspices of the Organization for Economic Cooperation and Development/Nuclear Energy Agency Committee on Reactor Physics/Nuclear Energy Agency Nuclear Data Committee (OECD/NEACRP/NEANDC); six high priority projects have been identified. The National Academy of Sciences/ National Research Council panel of basic nuclear data compilation is exploring improvements to the Evaluated Nuclear Structure Data File (ENSDF) and the associated publication, Nuclear Data Sheets; decreased paper, increased on-line access, and better timeliness are goals.	Continue the Cross Section Evaluation Working Group (CSEWG) to remain responsive to data needs and to continue improvements in accuracy, coverage, and format for ENDF. Continue international cooperative efforts under the auspices of the NEA and IAEA. Continue support for the NAS/NRC Panel on Basic Nuclear Data Compilation.	Continue the compilation and evaluation activities to improve the nuclear data libraries, their access, and the methods of their production. Give increased attention to the Data Request List, including outreach and followup activities. Continue participation in the Working Group on International Evaluation Cooperation to maintain the coordination of nuclear data evaluation activities and free exchange of the results. Continue to support the IAEA project to develop an international Fusion Energy Nuclear Data Library (FENDL), to assist in the design of an internationally supported fusion reactor. Continue support of the NAS/NRC Panel's activities with respect to ENSDF and the Nuclear Data Sheets (NDS), with attention given to identifying needs for nuclear structure and decay data.
	$ 4,406	$ 4,839	$ 5,018
Subtotal, Nuclear Data	$ 10,879	$ 11,370	$ 11,821
Low Energy Nuclear Physics	$ 24,988	$ 27,300	$ 28,391

DEPARTMENT OF ENERGY
FY 1992 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 constitutent 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 prerequesite for a description of the material foundations of the universe, including astrophysics phenomena such as the 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 1990 Enacted	FY 1991 Enacted	FY 1992 Request	% Change
Nuclear Theory.................................	$ 12,226	$ 13,100	$ 14,000	+ 7
Total, Nuclear Theory	$ 12,226	$ 13,100	$ 14,000	+ 7

II. B. Major Laboratory and Facility Funding

Argonne National Laboratory	$ 940	$ 935	$ 970	+ 4
Brookhaven National Laboratory	$ 1,040	$ 1,083	$ 1,125	+ 4
Lawrence Berkeley National Laboratory	$ 960	$ 1,050	$ 1,090	+ 4
Los Alamos National Scientific Laboratory	$ 1,080	$ 1,070	$ 1,110	+ 4
Oak Ridge National Laboratory	$ 860	$ 900	$ 940	+ 4

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

Program Activity	FY 1990	FY 1991	FY 1992
Nuclear Theory	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 nuclei under extreme conditions.	Continue broad program of theoretical research on properties of atomic nuclei particularly aimed at the understanding of nuclear forces. Provide a more fundamental understanding of the forces involved in the interaction between protons and neutrons as well as their further manifestations such as symmetries in nuclei. Continue new theory research efforts aimed at aiding the preparation for future experiments at the Continuous Electron Beam Accelerator Facility (CEBAF), the Relativistic Heavy Ion Collider (RHIC), and the Gammasphere facility and interpretation of expected results from planned experiments. These require the development of theories that address the description of nuclei in terms of their underlying quark-gluon substructure of nuclear matter, including the understanding of nuclear forces and phase transitions in nuclear matter. Continue staffing and conduct leading edge programs at the new Institute of Nuclear Theory at the University of Washington. Support its interaction with the entire nuclear community that will provide such activities as a workshops on critical areas. Pursue forefront activities at national laboratories which will address high impact problems such as RHIC related physics and nuclei under extreme conditions.
	$ 12,226	$ 13,100	$ 14,000
Nuclear Theory	$ 12,226	$ 13,100	$ 14,000

DEPARTMENT OF ENERGY
FY 1992 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 1990 Actual	FY 1991 Estimate	FY 1992 Request	% Change
BNL	$ 3,335	$ 2,590	$ 3,775	+ 46
LBL	2,778	1,490	1,500	+ 1
LANL	2,840	2,910	3,340	+ 15
ANL	3,196	1,182	850	- 28
MIT/Bates	1,372	1,494	1,725	+ 15
ORNL	1,675	873	720	- 18
CEBAF	1,650	2,700	3,400	+ 26
University Laboratories	1,190	879	1,000	+ 14
Sudbury Neutrino Observatory	0	2,649	2,900	+ 9
Gammasphere	0	4,850	5,500	+ 13
Lawrence Berkeley Laboratory - GPE	1,479	1,515	1,700	+ 12
Other	205	968	1,590	+ 64
Total, Capital Equipment	$ 19,720	$ 24,100	$ 28,000	+ 16

II. B. Major Laboratory and Facility Funding

Argonne National Laboratory	$ 3,196	$ 1,182	$ 850	- 28
Brookhaven National Laboratory	$ 3,335	$ 2,590	$ 3,775	+ 46
Lawrence Berkeley National Laboratory	$ 4,257	$ 3,005	$ 3,200	+ 6
Los Alamos National Scientific Laboratory	$ 2,840	$ 2,910	$ 3,340	+ 15
Continuous Electron Beam Accelerator Facility	$ 1,650	$ 2,700	$ 3,400	+ 26
Massachusetts Institute of Technology	$ 1,372	$ 1,494	$ 1,725	+ 15
Oak Ridge National Laboratory	$ 1,675	$ 873	$ 720	- 18

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

Program Activity	FY 1990	FY 1991	FY 1992
Capital Equipment			
BNL	For AGS heavy-ion experiment E859, complete construction of new multi-wire proportional counters and begin shakedown run. For experiment E810, begin running with three time projection chambers. Complete implementation of Tandem/AGS heavy-ion by-pass tunnel, which brings heavy-ion beams from the Tandem directly to the AGS Booster. For the kaon beam line, complete assembly of magnets and electrostatic separators. At LEGS install Nd-YAG laser to increase gamma ray intensity and polarization.	Begin preparation for AGS heavy ion experiments that will use the gold beam expected upon completion of the booster synchrotron. Complete construction and begin commissioning of the kaon beam line. At LEGS modify the liquid hydrogen target for E2/M1 and polarizability experiments. Begin construction of a RHIC detector test beam.	Continue preparation of AGS heavy ion experiments that will use gold beams. This includes preparing new experiments which look for particles of strange matter or antimatter as well as modifying existing experiments. Nuclear reactions with the gold beam will present very rewarding and exciting physics opportunities, but also very large experimental difficulties. It can be expected that there will be about four times as many particles (about 1000) in a central gold on gold collision as in a silicon on gold collision. This large multiplicity places difficult experimental constraints on the number and segmentation of the detectors. Continue construction of a special beam line for R&D on RHIC detectors. Start regular use of kaon beam line for H-particle searches.
	$ 3,335	$ 2,590	$ 3,775
LBL	Continue construction of the time projection chamber (TPC) for the HISS spectrometer at the Bevalac. The microelectronics for the 15,360 pickup pads of the TPC will be placed entirely on the detector, a new concept that permits the direct measurement of dE/dx from the pad signals.	Complete construction of the HISS TPC detector and begin initial experiments which study reaction dynamics with heavy ion beams and the nuclear matter equation of state. Construct a neutron hodoscope to be used with the HISS facility for projectile fragmentation experiments with neutron-rich secondary beams.	Complete construction of neutron hodoscope for use with HISS facility and begin experimental use. This detector will be useful for a variety of projectile fragmentation experiments with neutron-rich secondary beams. Procure data acquisition and analysis computer that is adequate for dealing with TPC and streamer chamber data, which is characterized by large event size and needs 3-dimensional viewing for event reconstruction.
	$ 2,778	$ 1,490	$ 1,500

III. Capital Equipment (Cont'd):

Program Activity	FY 1990	FY 1991	FY 1992
LANL	Complete construction of the pion beam energy-spread compressor and begin physics experiments with increased intensity pion beams. These experiments are expected to shed light on the poorly understood transparency of the nucleus for 50-100 MeV pions. Provide upgrades to data acquisition system that emphasizes the needs of the MEGA experiment.	Begin construction of one or two major detectors which will provide significant new physics capabilities for the LAMPF experimental program. Begin full experimental program with the pion beam energy-spread compressor. Modernize accelerator control system by installing equipment for distributed data processing and networking of control computers.	Continue construction of the Liquid Scintillation Neutrino Detector and/or the Neutral Meson Spectrometer. The Liquid Scintillator Neutrino Detector is designed to provide the world's best terrestrial limit on neutrino oscillations, and the Neutral Meson Spectrometer provides an order of magnitude improvement over previous apparatus for the pion research effort at LAMPF. Upgrade data analysis system through greater use of remote computing capability at computer workstations. Continue to modernize the accelerator control system.
	$ 2,840	$ 2,910	$ 3,340
ANL	Begin construction of the electron-positron experiment, APEX, which exploits high-intensity heavy-mass beams that will be available from the ATLAS positive ion injector in FY 1991. Complete construction of the Fragment Mass Analyzer (FMA) and begin ion-optical studies using radioactive sources and the ATLAS beam.	Complete construction of APEX and begin preliminary experiments with heavy ion beams to check operation and to measure background. Begin experiments on a regular basis with the FMA, which opens new possibilities for the production of exotic neutron-rich and neutron-deficient nuclei.	Begin experimental program with APEX. This second-generation detector will study the origin of sharp electron-positron coincident peaks observed at the German Gesellschaft fur Schwerionenforschung (GSI) laboratory in collisions of very heavy ions near the Coulomb barrier. Upgrade the 7 year old data acquisition system with a computer which has an up-to-date architecture.
	$ 3,196	$ 1,182	$ 850
MIT/Bates	At MIT/Bates Linear Accelerator Center, provide additional vacuum components, accelerator controls, beam monitoring equipment, cabling and radiation safety equipment for the South Hall Ring Experiment (SHRE). Initiate construction of polarized He3 internal target for the ring by procuring a prototype laser system. Initiate construction of a focal plane polarimeter for one hundred inch proton spectrometer (OHIPS), acquiring electronics for development of wire	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 components for the polarized electron source. Continue construction of polarized He3 internal target system for SHRE, procuring vacuum equipment, Helmholtz coils, and control system. Continue with construction of focal plane polarimeter, purchasing additional wire chamber electronics.	At MIT/Bates complete procurement of control system hardware and electronics for the SHRE in preparation for experiments with first electron beams circulating in the ring. Included are readout electronics packages for x-y monitors, lutes, toroids, and synchrotron light monitors as well as magnet power supply controllers. Complete polarized He3 internal target system for SHRE by purchase of high-speed turbo-molecular pumps. Complete OHIPS focal plane polarimeter

III. Capital Equipment (Cont'd):

Program Activity	FY 1990	FY 1991	FY 1992
MIT/Bates (Cont'd)	chamber and testing of software.		by purchasing the remainder of the wire chamber readout system.
	$ 1,372	$ 1,494	$ 1,725
ORNL	Complete delivery of an array of 78 BaF2 detectors and dedicated electronics for detection of high-energy photons from medium-energy heavy ion reactions. Initiate construction of a Recoil Mass Spectrometer (RMS).	Continue component fabrication and assembly of the Recoil Mass Spectrometer. Upgrade HHIRF computer system with RISC-based data processing and analysis stations. Procure replacement klystrons for Oak Ridge Electron Linear Accelerator (ORELA).	Complete construction of the Recoil Mass Spectrometer. The RMS will detect nuclides with specific mass and atomic charge emitted in heavy ion induced reactions at zero degrees relative to the beam direction, and is particularly useful in the studies of low cross section reaction products from inverse heavy-ion reactions. Continue upgrade of research computer system with additional work stations. At ORELA, upgrade time-of-flight electronics.
	$ 1,675	$ 873	$ 720
CEBAF	Upgrade VAX 8700 and 785 computer systems with additional memory, disk drives and tape units to support extensive simulations of experimental equipment and accelerator components. Procure general test equipment and fast logic electronics for testing of experimental equipment prototypes.	Initiate procurement of components for the High Resolution Hadron Spectrometer in Hall A. Continue upgrade of computer systems with additional Unix-based CPUs and work stations. Procure electronic measurement equipment for use in testing RF systems. Procure mechanical support equipment such as machine shop equipment, leak detectors and residual gas analyzers.	Continue procurement of components for the High Resolution Hadron Spectrometer in Hall A, including the detector system and the support structure. This spectrometer permits a major program of coincidence experiments in which both scattered electrons and hadrons are detected under conditions of high momentum resolution. Initiate procurement of long lead components for the Large Acceptance Spectrometer in Hall B. Upgrade computer systems with additional memory, disk drives, tape units, and archival storage system. Procure mechanical support equipment such as turbo pump stations, electrical equipment such as network analyzers.
	$ 1,650	$ 2,700	$ 3,400

III. Capital Equipment (Cont'd):

Program Activity	FY 1990	FY 1991	FY 1992
University Laboratories	Continue upgrade of instrumentation at university laboratories. Construct experimental equipment as follows: Texas A&M University (complete momentum achromat recoil spectrometer and barium fluoride detector system), Triangle Universities Nuclear Laboratory (TUNL) (accelerator tubes and charging system), University of Washington (complete barium fluoride and germanium gamma-ray detectors), and Yale University (silicon triensphere detector and terminal stripper).	Continue instrumentation initiative at university accelerator laboratories to increase amount of available experimental equipment.	Continue instrumentation initiative at university accelerator laboratories with construction of devices such as low- and high-energy gamma detectors, Compton-suppression gamma-ray spectrometer, and data analysis facility.
	$ 1,190	$ 879	$ 1,000
Sudbury Neutrino Observatory	No activity.	Begin construction of the Sudbury Neutrino Observatory. Begin procurement of photomultiplier tubes, their supporting structure, and data handling equipment.	Continue construction of the Sudbury Neutrino Observatory (SNO) located in a deep underground mine at Sudbury, Ontario. SNO is a collaborative Canadian, U.S. and U.K. project, using heavy water as its principal sensitive medium. This unique world-class facility for neutrino astrophysics has a very high potential for fundamental discoveries in solar physics and in the properties of neutrinos. Of the approximately $41 million TEC (1990 $'s), the U.S. share is $10.6 million. Continue procurement of photomultiplier tubes, their supporting structure, and data handling equipment.
	$ 0	$ 2,649	$ 2,900

III. Capital Equipment (Cont'd):

Program Activity	FY 1990	FY 1991	FY 1992
Gammasphere	No activity.	Initiate construction of a large high-resolution gamma-ray facility for the study of high-spin nuclear physics. The Gammasphere design is the leading design option. However, rapidly changing physics opportunities may require that a variation on this design be implemented. Begin procurement of large volume germanium detectors, BGO Compton-suppressor elements, and fabrication of the detector support frame.	Continue construction of 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 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 $17 million. Continue procurement of germanium detectors and BGO elements, and begin procurement of electronics.
	$ 0	$ 4,850	$ 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 light and heavy trucks for the Motor Vehicle group; cooling towers, boilers, chillers, a computer aided design (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, fibre optics computer network lines, disk upgrade for the central computing facility, and a postscript typesetter for the Information and Computing Science Division.	Provide general purpose equipment such as motor vehicles and data processing equipment for the Administrative Division; equipment for laboratory-wide video capability, switches for the LBLnet, and a fiber optical data network for the Information and Computing Sciences Division; and CAD workstations and drafting plotters, tooling for surface-mount integrated circuit technology, digital test and measurement equipment for the Engineering Division.
	$ 1,479	$ 1,515	$ 1,700

III. Capital Equipment (Cont'd):

Program Activity	FY 1990	FY 1991	FY 1992
Other	Provide equipment for the University Isotope Separator Oak Ridge (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, and more rapid completion of selected experimental systems in the medium energy or heavy ion research program.	Provide equipment for some participants of the nuclear data measurements program, and more rapid completion of selected experimental systems in the medium energy, heavy ion, and low energy research programs. Continue development of a time projection chamber for use in a lead beam experiment at CERN. This detector would transfer to the future experimental program at RHIC.
	$ 205	$ 968	$ 1,590
Capital Equipment	$ 19,720	$ 24,100	$ 28,000

DEPARTMENT OF ENERGY
FY 1992 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 1990 Enacted	FY 1991 Enacted	FY 1992 Request	% Change
Continuous Electron Beam Accelerator Facility (CEBAF)	$ 62,611	$ 58,500	$ 31,800	- 46
Relativistic Heavy Ion Collider (RHIC)	0	13,500	49,350	+266
Accelerator Improvements and Modifications	4,536	3,780	4,100	+ 8
General Plant Projects	4,338	3,920	3,949	+ 1
Total, Construction	$ 71,485	$ 79,700	$ 89,199	+ 12

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

Program Activity	FY 1990	FY 1991	FY 1992
Construction			
Continuous Electron Beam Accelerator Facility (CEBAF)	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.	Complete end station construction. Complete installation of accelerator and end station cryogenic transfer lines. Begin detector installation. Do pre-operational checkout of North Linac and continue assembly of South Linac. Complete accelerator control software.
	$ 62,611	$ 58,500	$ 31,800
Relativistic Heavy Ion Collider (RHIC)	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.	Continue construction of RHIC with main emphasis on production of superconducting dipole, quadrupole and sextupole magnets for the accelerator arcs. Start procurement of cryogenic distribution system, magnet electrical system, and accelerator control system.
	$ 0	$ 13,500	$ 49,350
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 10% lower level of effort as FY 1990.	Approximately same level of effort as FY 1991.
	$ 4,536	$ 3,780	$ 4,100
General Plant Projects	Essential additions, modifications, and improvements on an annual basis to maintain safety and effectiveness of general laboratory plant and support facilities.	Approximately 10% lower level of effort as FY 1990.	Approximately same level of effort as FY 1991.
	$ 4,338	$ 3,920	$ 3,949
Construction	$ 71,485	$ 79,700	$ 89,199

DEPARTMENT OF ENERGY
FY 1992 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 1991 Appropriated	FY 1992 Request	Unappropriated Balance	TEC
GPE-300	General Plant Projects	$ ---	$ ---	$ 3,949	$ 0	$ 3,949
92-G-301	Accelerator Improvements and Modifications	---	---	4,100	0	4,100
91-G-300	Relativistic Heavy Ion Collider	---	13,500	49,350	333,500	397,000
87-R-203	Continuous Electron Beam Accelerator Facility	156,811	58,500	31,800	22,489	270,000
Total, Nuclear Physics Construction		$156,811	$ 72,000	$ 89,199	$355,989	XXX

DEPARTMENT OF ENERGY
FY 1992 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: $ 3,949
Start Date: 1st Qtr. FY 1992
Completion Date: 2nd Qtr. FY 1994

2. Financial schedule:

Fiscal Year	Appropriated	Obligations	Costs
1992	$ 3,949	$ 3,949	$ 1,200
1993	0	0	2,000
1994	0	0	749

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	$ 3,050
Los Alamos National Laboratory (Clinton P. Anderson Meson Physics Facility)	219
Massachusetts Institute of Technology (Bates Linear Accelerator Center)	680
Total Estimated Cost....................	$ 3,949

4. Total Project Funding (BA):

	Prior Years	FY 1990	FY 1991	FY 1992 Request	To Complete
Construction	$ 0	$ 0	$ 0	$ 3,949	$ 0
Capital Equipment	0	0	0	0	0
Operating Expenses	0	0	0	0	0

DEPARTMENT OF ENERGY
FY 1992 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: 92-G-301 Accelerator Improvements and Modifications
Various locations

Project TEC: $ 4,100
Start Date: 1st Qtr. FY 1992
Completion Date: 2nd Qtr. FY 1994

2. Financial schedule:

Fiscal Year	Appropriated	Obligations	Costs
1992	$ 4,100	$ 4,100	$ 3,000
1993	0	0	800
1994	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	$ 400
Brookhaven National Laboratory (AGS/Tandem)	1,250
Lawrence Berkeley Laboratory	1,000
Los Alamos National Laboratory (Clinton P. Anderson Meson Physics Facility)	1,000
Massachusetts Institute of Technology (Bates Linear Accelerator Center)	450
Total Estimated Costs....................	$ 4,100

4. Total Project Funding (BA):

	Prior Years	FY 1990	FY 1991	FY 1992 Request	To Complete
Construction	$ 0	$ 0	$ 0	$ 4,100	$ 0
Capital Equipment	0	0	0	0	0
Operating Expenses	0	0	0	0	0

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: 1st Qtr. FY 1991
Completion Date: 3rd Qtr. FY 1997

2. Financial schedule:

Fiscal Year	Appropriated	Obligations	Costs
1991	$ 13,500	$ 13,500	$10,000
1992	49,350a/	49,350a/	37,950a/
1993	81,500	81,500	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 higher 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 1992 construction funds will be used for production of superconducting dipole, quadrupole and sextupole magnets for the accelerator arcs, procurement of cryogenic distribution system, magnet electrical system, and accelerator control system.

4. Total Project Funding (BA):

	Prior Years	FY 1990	FY 1991	FY 1992 Request	To Complete
Construction	$ 0	$ 0	$13,500	$49,350a/	$333,500
Capital Equipment	0	0	0	0	0
Operating Expenses	15,000	6,450	6,614	7,000	67,036

a/ Reflects savings of $650,000 BA and $450,000 BO due to proposed Davis Bacon Amendment.

IV. B. Plant Funded Construction Project

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

Project TEC: $270,000
Start Date: 2nd Qtr. FY 1987
Completion Date: 4th Qtr. FY 1994

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	53,441
1991	58,500	58,500	62,000
1992	31,800a/	31,800a/	44,600a/
1993	15,500	15,500	20,000
1994	6,989	6,989	10,773

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 1992 construction funds will be used to complete end station construction, complete installation of accelerator and end station cryogenic transfer lines, begin detector installation, perform pre-operational checkout of North Linac, continue assembly of South Linac, and complete accelerator control software.

4. Total Project Funding (BA):

	Prior Years	FY 1990	FY 1991	FY 1992 Request	To Complete
Construction	$94,200	$62,611	$58,500	$31,800a/	$22,489
Capital Equipment	0	0	0	0	0
Operating Expenses	27,918	4,000	4,029	2,600	0

a/ Reflects savings of $400,000 BA and $400,000 BO due to proposed Davis Bacon Amendment.

CONSTRUCTION PROJECT DATA SHEETS

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)..............................$ 219

Upgrade the electrical power distribution system that feeds the Line A Switchyard and Experimental Areas B and C. New magnets and polarized target support systems associated with the Nucleon Physics Laboratory place have caused the primary 13.2 KV cables which feed this area to exceed their nominal rated capacity.

Massachusetts Institute of Technology (Bates Linear Accelerator Center)..................................$ 680

For the South Hall Ring Experiment, this project provides four metal utility building to house an RF transmitter and control system, power supplies for the magnetic elements, and electrical switch gear; and also a roadway ramp that will permit forklift service to the South Experimental Hall.

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

The distribution of funds requested for FY 1992 is as follows:

Lawrence Berkeley Laboratory..	$ 3,050
Los Alamos National Laboratory (LAMPF)................................	219
Massachusetts Institute of Technology (Bates Linear Accelerator Center)	680
Total Estimated Cost..	$ 3,949

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.

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 1992 CONGRESSIONAL BUDGET SUBMISSION
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. 92-G-301

3. Date A-E work initiated: 1st Qtr. FY 1992

3a. Date physical construction starts: 2nd Qtr. FY 1992

4. Date construction ends: 2nd Qtr. FY 1994

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

6. Current cost estimate: $4,100
Less amount for PE&D: 0
Net cost estimate: $4,100
Date: May 1990

7. Financial Schedule:

Fiscal Year	Authorization	Appropriations	Obligations	Costs
1992	$ 4,100	$ 4,100	$ 4,100	$ 3,000
1993	0	0	0	800
1994	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. 92-G-301

8. Brief Physical Description of Project (continued)

Argonne National Laboratory (ATLAS).......................... $ 400

Provide for various modifications to the ATLAS linac which improve reliability and optimize it for running with very heavy beams. These include completing the upgrade of the fast tuners on the resonators, equipment to permit the use of two successive strippers which increase the energy of uranium ions, modifying the velocity profile by changing characteristics of six resonators, and improving the helium cooling of the two front-end cryostats.

Brookhaven National Laboratory (AGS/Tandem).................... $ 1,250

As part of a general upgrade of the AGS for heavy ion operation, replace existing long-tune quadrupole magnets with new half-length horizontal and vertical tune quadrupole magnets for the purpose of regulating the horizontal and vertical tunes, upgrade the control system of the Main Magnet Power Supply, install instrumentation at the Booster which is necessary for heavy ion operation, and replace segments of the RF system with ones which have a wider frequency range needed to accelerate the heaviest ions.

Lawrence Berkeley Laboratory (Bevalac)........................ $ 1,000

To reduce the halo and emittance of Bevalac beams, the beamlines will be equipped with monitor diagnostics that will enable operators to routinely minimize the beam halo during tuneup. In addition new collimators to minimize halo will be installed at precisely located positions. Some of these collimators will be of a new "Halo Stripper" type that can fully strip unstripped beams thereby drastically altering the rigidity of the beam halo. Install beamline monitors in new locations to allow the development of new beamline tunes.

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

2. Project No. 92-G-301

8. Brief Physical Description of Project (continued)

Los Alamos National Laboratory (LAMPF)........................ $ 1,000

Install permanent radiation shielding in the 44 shafts through which RF power is conveyed to the accelerating structures of the main LAMPF linac. Only minimal shielding is now in place in the 25 foot shafts. In the injector area of LAMPF, install equipment that permits simultaneous acceleration of H+ and H- beams. The equipment consists of a pulsed deflector system to tailor the beam current envelope in a controlled fashion. On the accelerator control system, replace most of the Remote Interface and Control Equipment (RICE) modules in high-traffic areas.

Massachusetts Institute of Technology
(Bates Linear Accelerator Center)............................ $ 450

For the Energy Compression System, dipole magnets, power supplies, and an associated vacuum system will be procured and installed. For the South Hall Ring Experiment, 35 one-kilowatt power supplies to energize the quadrupole and sextupole magnets in the ring will be installed. For the Central Control Room, cabinets, racks and lighting will be procured as well as an "expert" computer system capable of learning accelerator tuning procedures.

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

Argonne National Laboratory (ATLAS)

The design of the ATLAS linac was optimized to best accelerate ions in the lower half of the periodic table. When the positive-ion injector is complete, the main thrust of the research program at ATLAS will involve studies with ions in the upper half of the periodic table including uranium. The proposed modifications of ATLAS would ensure that adequate beam energies and intensities of the very heavy ions are available under routine operatng conditions, and therefore make it more likely that experimental runs will be successful.

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

2. Project No. 92-G-301

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

Brookhaven National Laboratory (AGS/Tandem)

The AGS upgrade program is designed to provide a machine that will satisfactorily perform as a source of heavy ions for both fixed target and for RHIC injector operation over the next 20 years. Due to the advanced age of many existing components, significant alternation is required.

Lawrence Berkeley Laboratory (Bevalac)

The reduction of background is critical to the success of many experiments that are run at the Bevalac, and a substantial contribution to the background is the beam halo. The monitors and collimators requested to reduce halo will allow experimental access to the small forward angle of parameter space and reduce experimental background. Intensity improvements over the last several years will allow collimation while retaining sufficient beam intensity.

Los Alamos National Laboratory (LAMPF)

The permanent radiation shielding will eliminate the need for reliance upon instrumentation to detect accidental beam spill conditions due, for example, to a quadrupole failure. The new shielding will provide adequate personnel protection from worst-case spills in a service area which need occasional access. Simultaneous acceleration of H+ and H- beams permits an increase in the beam duty factor, which benefits many experiments in Area A. Replacing RICE units in the high-use areas will greatly alleviate the obsolescence problem in the accelerator control system.

Massachusetts Institute of Technology (Bates Linear Accelerator Center)

The Energy Compression System will substantially reduce the beam energy spread at the output of the accelerator. In addition to providing a very small energy spread for experiments that need to resolve nuclear final states, the lower energy spread will also decrease the amount of RF power required in the electron storage ring. The magnet power supplies generate the highly stabilized currents need for operation of the ring quadrupoles and sextupole magnets. Changes are needed in the Central Control Room to adapt it for installation of the planned computer control system.

CONSTRUCTION PROJECT DATA SHEETS

1. Title and location of project: Accelerator improvements and modifications, various locations — 2. Project No. 92-G-301

10. Details of Cost Estimate

a. Engineering, design, inspection, construction, procurement, component assembly, and installation	$ 4,100
Total Estimated Cost	$ 4,100

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
FY 1992 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	$ 13,500	$ 13,500	$ 13,500	10,000
FY 1992	383,500	49,350a/	49,350a/	37,950a/
FY 1993	0	81,500	81,500	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.

a/ Reflects savings of $650,000 BA and $450,000 BO due to proposed Davis Bacon Amendment.

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 of item b....			$ 57,500
1. Conventional construction at approximately 19% of item b.1..		$ 1,100	
2. Technical components (accelerator system) at approximately 30% of item b.2........		56,400	
b. Construction Costs........			191,500
1. Conventional Construction........		5,900	
a. Site Improvement........	$ 1,400		
b. Tunnels and Buildings........	3,000		
c. Utilities........	1,500		
2. Technical Components - Collider........		185,600	
a. Collider Installation........	21,900		
b. Magnet System........	79,700		
c. Magnet Electrical System........	10,900		
d. Cryogenic System........	16,400		
e. Vacuum System........	8,300		
f. Injection System........	12,000		
g. Beam Dump System........	6,700		
h. RF System........	12,100		
i. Beam Instrumentation........	4,400		
j. Control System........	13,200		
c. Contingency on Collider at approximately 20% of above costs.....			51,000
Subtotal Estimated Cost........			$300,000
d. Research Detectors (including EDIA and Contingency)........			97,000
Total Estimated Cost........			$397,000

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

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	$37,950	$70,000	$ 86,600	$ 90,000	$ 78,000	$24,000	$397,000
Total Facility Cost	$ 0	$10,000	$37,950	$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	$ 6,614	$ 7,000	$ 7,200	$ 6,000	$ 3,836	$ 0	$ 0	$ 52,100
b. Start-up	0	0	0	0	0	9,000	13,000	28,000	$ 50,000
Total Other Project Costs	$21,450	$ 6,614	$ 7,000	$ 7,200	$ 6,000	$ 12,836	$ 13,000	$28,000	$102,100
Total Project Cost	$21,450	$16,614	$44,950	$77,200	$ 92,600	$102,836	$ 91,000	$52,000	$499,100

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. These funds will also provide spare components for the Collider.

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 1992 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 1994

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

6. Current cost estimate: $270,967
Less amount for PE&D: 967
Net cost estimate: $270,000
Date: 12/90

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	53,441
FY 1991	58,500	58,500	58,500	62,000
FY 1992	31,800a/	31,800a/	31,800a/	44,600a/
FY 1993	15,500	15,500	15,500	20,000
FY 1994	6,989	6,989	6,989	10,773

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.

a/ Reflects savings of $400,000 BA and $400,000 BO due to proposed Davis Bacon Amendment.

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 0.8 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. Five 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..........			$ 46,500
1. Conventional Construction at approximately 17% of item b.1		$ 9,000	
2. Technical components at approximately 28% of item b.2 ...		37,500	
b. Construction Costs..			185,500
1. Conventional Construction..................................		54,000	
a. Accelerator facilities..................................	$ 18,000		
b. Experimental facilities................................	24,000		
c. Support facilities.....................................	12,000		
2. Technical components.......................................		131,500	
a. Accelerator components.................................	97,000		
b. Research equipment.....................................	34,500		
c. Standard Equipment..			2,000
d. Contingency at approximately 15% of above costs..............			36,000
Total Estimated Cost...........			$270,000

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.

CONSTRUCTION PROJECT DATA SHEETS

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	FY 1994	Total
a. Total project cost											
1. Total facility cost											
a. Construction line item.....	$ 0	$ 0	$ 7,842	$41,858	$29,086	$53,441	$62,000	$44,600	$20,000	$10,773	$270,000
b. PE&D...........	300	667	0	0	0	0	0	0	0	0	$ 967
Total facility cost.........	$ 300	$ 667	$ 7,842	$41,858	$29,086	$53,441	$62,000	$44,600	$20,000	$10,773	$270,967
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	$ 0	$ 32,447
Spares.............	0	0	0	0	0	1,100	2,400	2,600	0	0	6,100
Total other project costs*.	$ 4,500	$ 4,918	$ 6,250	$ 6,250	$ 6,000	$ 4,000	$ 4,029	$ 2,600	$ 0	$ 0	$ 38,547
Total project cost...........	$ 4,800	$ 5,585	$14,092	$48,108	$35,086	$57,441	$66,029	$47,200	$20,000	$10,773	$309,514

* 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 1994 dollars)

1. Annual facility operating costs including in-house research....................	$ 38,200
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..............................	$ 40,700

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.