DEPARTMENT OF ENERGY
FY 1990 CONGRESSIONAL BUDGET REQUEST
OFFICE OF ENERGY RESEARCH

OVERVIEW

NUCLEAR PHYSICS

The Nuclear Physics program of the Department of Energy (DOE) has the lead responsibility for Federal support of nuclear physics research and provides about 80 percent of the funding for the field. One primary goal of the program is to understand the structure and interactions of atomic nuclei. A second goal, using the specialized knowledge, techniques and apparatus available to the program, is to understand the fundamental forces and particles of nature as they manifest themselves in nuclear matter. The knowledge acquired in this basic research is an essential part of the intellectual foundation of other scientific disciplines and technical pursuits. Nuclear processes determine the essential physical characteristics of our universe and the composition of the matter which forms it. An understanding of nuclei and nuclear phenomena is essential to any basic understanding of the world around us and provides the informational basis for many areas of technology, such as nuclear power, nuclear weapons and nuclear medicine. Among the direct applications are nuclear techniques for geophysical exploration, testing of materials, and archeological dating and siting.

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 both by Nuclear Physics and High Energy Physics research programs. However, the nuclear physics program uniquely approaches the problems by testing the theoretical predictions in the medium of extended nuclear matter provided by nuclei composed of many nucleons. A growing number of problems of mutual interest to nuclear physics and astrophysics include measurements or calculations of supernovae, neutron stars, solar neutrinos, heavy cosmic rays, and the continuing problem of stellar nuclear abundances. Of particular interest is the ability of relativistic heavy ion collisions to create a quark-gluon plasma, simulating a stage of evolution of the universe that disappeared a millionth of a second after the initial "big bang."

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

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

The DOE Nuclear Physics program supports about 80 percent of the basic research in nuclear physics; the National Science Foundation provides most of the rest. In FY 1990 it will maintain a vigorous research program, focusing on current problems of high scientific and technological interest and pointing towards exploitation of the new major facilities. A growing fraction, now about 75 percent, of the scientists supported by the Nuclear Physics program plan experiments and conduct research at the large user dedicated facilities supported by the program. More than 200 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. More than 325 visiting scientists annually use the multiple beams available at the LAMPF facility at the Los Alamos National Laboratory for one or more experiments. Over 650 physicists have demonstrated interest in possible future use of the Continuous Electron Beam Accelerator Facility by joining the CEBAF user's group, and 100 of them are actively participating in the design of experiments. Special emphasis is placed on effective use of the upgraded accelerators at the University of Washington and Yale University, the ATLAS superconducting heavy ion facility at Argonne National Laboratory (ANL), and Tandem/AGS high energy heavy ion beams at Brookhaven National Laboratory (BNL). Adjustments have been made within the program to accommodate the increased interest of students and postdoctoral fellows in nuclear physics, to enhance the theory component, and to concentrate the program more accurately on the highest priorities and new scientific areas. In addition, much good science can be accomplished with selected smaller improvements of existing facilities such as the South Target Hall internal target 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.

Research and development in support of next generation accelerators and for advanced detector concepts is included in the Nuclear Physics program. Efforts will continue at Brookhaven National Laboratory for the purpose of confirming the technical basis and further defining the detector configuration for a relativistic heavy ion collider (RHIC). The R&D necessary to optimize such a project is currently being conducted. Emphasis will be placed on prototypes of sextupole and corrector magnets, testing of a full magnet cell, development of ancillary equipment such as beam dumps and beam monitors, and detector R&D. The Nuclear Science Advisory Committee (NSAC) has assigned and reconfirmed the highest scientific merit for the research to be performed at this type of facility. This high priority was supported by the "Brinkman" report ("Physics through the 1990s," National Research Council, 1986) and an ERAB review of that report (Review of the National Research Council Report "Physics through the 1990s," 1987). The focus of the proposed scientific research will be on understanding the equation of the state of nuclear matter and investigating the transition from hot dense nuclear matter to formation of the quark-gluon plasma.

DEPARTMENT OF ENERGY
FY 1990 CONGRESSIONAL BUDGET REQUEST
OFFICE OF ENERGY RESEARCH
(dollars in thousands)

LEAD TABLE

Nuclear Physics

Activity	FY 1988 Actual	FY 1989 Estimate	FY 1990 Base	FY 1990 Request	Program Change Request vs Base: Dollar	Program Change Request vs Base: Percent
Operating Expenses						
Medium Energy Nuclear Physics	$83,487	$85,711	$85,711	$93,700	$+ 7,989	+ 9%
Heavy Ion Nuclear Physics	64,900	67,517	67,517	71,500	+ 3,983	+ 6%
Low Energy Nuclear Physics	24,723	25,866	25,866	27,400	+ 1,534	+ 6%
Nuclear Theory	10,500	10,818	10,818	12,700	+ 1,882	+ 17%
Capital Equipment	17,675	18,500	18,500	20,000	+ 1,500	+ 8%
Construction	41,500	52,500	52,500	74,000	+ 21,500	+ 41%
Total	242,785	260,912	260,912	299,300	+ 38,388	+ 15%
Operating Expenses	(183,610)a/	(189,912)b/	(189,912)	(205,300)	+ 15,388	+ 8%
Capital Equipment	(17,675)	(18,500)	(18,500)	(20,000)	+ 1,500	+ 8%
Construction	(41,500)	(52,500)	(52,500)	(74,000)	+ 21,500	+ 41%
Total Program	($242,785)	($260,912)	($260,912)	($299,300)	$+ 38,388	+ 15%
Staffing (FTEs)	(Reference General Science Program Direction)					

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

a/ Total has been reduced by $2,315,000 ($463,000 Medium Energy; $380,000 Heavy Ion; $1,472,000 Low Energy) reprogrammed to Energy Supply for SBIR.
b/ Excludes $3,188,000 which represents applicable portion of $12,000,000 General Reduction contained in FY 1989 Appropriation.

DEPARTMENT OF ENERGY
FY 1990 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

SUMMARY OF CHANGES

Nuclear Physics

FY 1989 Appropriation	$260,912
Adjustments - Increased personnel costs	0
FY 1990 Base	260,912
- Funding required to maintain a constant overall level of program activity	+ 12,979
Medium Energy Nuclear Physics	
- Conduct medium energy physics research and operations at approximately constant level of activity, with increased level of support for CEBAF laboratory	+ 2,846
Heavy Ion Nuclear Physics	
- Continue Heavy Ion operations and research at approximately constant level of activity	- 62
Low Energy Nuclear Physics	
- Continue nuclear data program and low energy physics operations and research at approximately constant level of activity	- 18
Nuclear Theory	
- Increase level of activity with emphasis on providing needed theoretical understanding in preparation for new experimental results	+ 1,233

Capital Equipment

- Maintain overall level of instrumentation effort and provide for general purpose equipment to meet laboratory-wide needs of Lawrence Berkeley Laboratory..............	+	390

Construction

- Increase level of effort for AIP and GPP..	+	520
- Continuation of Continuous Electron Beam Accelerator Facility (CEBAF) project.........	+	20,500
FY 1990 Congressional Budget Request..		$299,300

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

Program Activity	FY 1988	FY 1989	FY 1990	% Change
Research......................	$ 33,262	$ 34,506	$ 37,700	+ 9
Operations....................	50,225	51,205	56,000	+ 9
Total, Medium Energy Nuclear Physics...........	$ 83,487	$ 85,711	$ 93,700	+ 9

II. B. Major Laboratory and Facility Funding

Los Alamos National Laboratory..	$ 47,837	$ 48,180	$ 49,800	+ 3
Massachusetts Institute of Technology..................	9,440	9,450	10,300	+ 9
Continuous Electron Beam Accelerator Facility...........	9,220	10,350	16,000	+ 55
Other National Laboratories.....	6,809	6,545	6,085	- 7

III. Activity Descriptions

Program Activity	FY 1988	FY 1989	FY 1990
LAMPF-Based Research	Continue use of Clamshell Spectrometer on the Low Energy Pion (LEP) channel and expand use of neutron time-of-flight (NTOF) facility.	Continue use of Clamshell Spectrometer and NTOF. Initiate research program using medium resolution spectrometer (MRS).	Conduct full experimental program using MRS with beam from new high intensity polarized proton source. Initiate program on LEP channel using newly installed energy spread compressor.
	Complete data taking in the short flight path configuration of the neutrino oscillation experiment. Develop conceptual design by broad-based university-laboratory collaboration of Large Cherenkov Detector (LCD) for neutrino experiment for critical test of the standard model.	Analyze data from oscillation experiment and move neutrino detector further from beam stop. Continue preparation activities on LCD for neutrino experiment.	Begin taking longer flight path data for neutrino oscillation experiment, and continue R&D activities on LCD for neutrino scattering experiment.
	Continue use of time-of-flight isochronous (TOFI) facility for nuclear spectroscopy.	Continue use of TOFI facility for nuclear mass measurements and develop new detector to resolve heavier isotopes.	Use new detector on TOFI to extend studies to higher masses.
	Continue preparations for rare muon decay (MEGA) experiment involving 30 scientists from 12 institutions and requiring a $3M detector.	Start data taking phase of MEGA experiment with intermediate-sensitivity form of detector.	Complete full sensitivity detector for MEGA and continue data taking.

Program Activity	FY 1988	FY 1989	FY 1990
LAMPF-Based Research (Cont'd)	Continue research programs in nuclear structure and nuclear reactions with incident pions and protons. Initiate new program with polarized nuclear target. Conduct measurements of the nucleon-nucleon interaction and properties of muonium.	Continue research programs in nuclear structure and nuclear reactions with incident pions and protons. Continue research on nuclear structure with the polarized nuclear target. Continue measurements of the nucleon-nucleon interaction and tests of charge symmetry breaking.	Continue research programs in nuclear structure and nuclear reactions with incident pions and protons. Continue research using the polarized nuclear target. Expand measurement of the nucleon-nucleon interaction and tests of charge symmetry breaking.
	The total for LAMPF-Based Research is derived as follows. Of the $6,512 medium energy research budget at LANL, $835 is for research carried out by LANL scientists at locations other than LAMPF, leaving $5,677 for in-house use of LAMPF. To this is added $4,664 of direct medium energy research funds to outside users for their LAMPF research programs. ($10,341)	The total for LAMPF-Based Research is derived as follows. Of the $6,600 medium energy research budget at LANL, $860 is for research carried out by LANL scientists at locations other than LAMPF, leaving $5,740 for in-house use of LAMPF. To this is added $4,669 of direct medium energy research funds to outside users for their LAMPF research programs. ($10,409)	The total for LAMPF-Based Research is derived as follows. Of the $7,000 medium energy research budget at LANL, $890 is for research carried out by LANL scientists at locations other than LAMPF, leaving $6,110 for in-house use of LAMPF. To this is added $4,945 of direct medium energy research funds to outside users for their LAMPF research programs. ($11,055)
Bates-Based Research	Continue data taking phase of parity experiment and start next round of experiments requiring polarized electrons.	Complete parity experiment and begin multi-arm coincidence measurements utilizing the improved polarized electron beam.	Contirue coincidence measurements with higher intensity polarized electron beams.
	Continue program of coincidence experiments not requiring continuous beams. Initiate Class IV computer upgrade at the Laboratory for Nuclear Science.	Prepare for out-of-plane spectrometer measurements (delta experiment). Continue computer upgrade at the Laboratory for Nuclear Science.	Begin data taking phase for delta experiment and continue computer upgrade at the Laboratory for Nuclear Science.

Program Activity	FY 1988	FY 1989	FY 1990
Bates-Based Research (Cont'd)	Continue electron scattering experiments in South Experimental Hall, and high precision experiments using the energy loss spectrometer system (ELSSY).	Continue high precision measurements utilizing ELSSY and coincidence measurements utilizing South Hall spectrometers.	Continue high precision measurements with ELSSY and reduce level of research utilizing South Hall spectrometers during installation of South Hall Ring Experiment.
	Initiate activities for the South Hall including R&D on pulse stretcher rings for use with polarized and unpolarized gas jet targets.	Design internal gas-jet target system for use in the South Hall Ring Experiment and continue R&D on pulse stretcher rings with emphasis on maintenance of beam polarization.	Continue R&D on behavior of polarized beams in stretcher rings and design of detector components for use in the South Hall.
	The total for Bates-Based Research is derived as follows. Of the $3,100 medium energy research budget at MIT, $1,000 is for research carried out by MIT scientists at locations other than Bates, leaving $2,100 for in-house use of Bates. To this is added $990 of direct medium energy research funds to outside users for their Bates research programs. ($3,090)	The total for Bates-Based Research is derived as follows. Of the $3,000 medium energy research budget at MIT, $1,000 is for research carried out by MIT scientists at locations other than Bates, leaving $2,000 for in-house use of Bates. To this is added $1,018 of direct medium energy research funds to outside users for their Bates research programs. ($3,018)	The total for Bates-Based Research is derived as follows. Of the $3,200 medium energy research budget at MIT, $1,100 is for research carried out by MIT scientists at locations other than Bates, leaving $2,100 for in-house use of Bates. To this is added $1,204 of direct medium energy research funds to outside users for their Bates research programs. ($3,304)
CEBAF-Based Research	Carry out tests on four industrial cryostats.	Complete a cryomodule, the basic unit of accelerator structure that can be cooled to superconducting temperature.	Carry out the 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.

Program Activity	FY 1988	FY 1989	FY 1990
CEBAF-Based Research (Cont'd)	Complete a computer model for the accelerator. Develop and test other accelerator components.	Develop the thermionic injector for the accelerator. Implement a magnetic measurement capability for the components of the beam transport system.	Establish a data acquisition system for use in testing and calibrations of components. Provide related systems needed for experimental halls. Expand microVAX cluster.
	Complete design of the large experimental spectrometer.	Carry out detailed development for spectrometer and detector systems.	Prototype and test components for the experimental areas including setting up a magnet test facility, prototyping of quadrupole magnets, and prototyping various detector and counting electronic components.
	Expand accelerator research activities at CEBAF.	Continue activities in superconducting research area at CEBAF.	Continue superconducting research activities and strengthen theoretical efforts.
	The total for CEBAF-Based Research is derived as follows. Of the $9,220 medium energy research budget at CEBAF, $250 is for research carried out by CEBAF scientists at locations other than CEBAF, leaving $8,970 for in-house use of CEBAF. To this is added $50 of direct medium energy research funds to outside users for their CEBAF research programs. ($9,020)	The total for CEBAF-Based Research is derived as follows. Of the $9,350 medium energy research budget at CEBAF, $300 is for research carried out by CEBAF scientists at locations other than CEBAF, leaving $9,050 for in-house use of CEBAF. To this is added $172 of direct medium energy research funds to outside users for their CEBAF research programs. ($9,216)	The total for CEBAF-Based Research is derived as follows. Of the $11,400 medium energy research budget at CEBAF, $700 is for research carried out by CEBAF scientists at locations other than CEBAF, leaving $10,700 for in-house use of CEBAF. To this is added $344 of direct medium energy research funds to outside users for their CEBAF research programs. ($11,044)
Research at Other Sites	Start data taking phase of rare K meson (kaon) decay experiments and continue preparations for experiments using new kaon beams at the AGS.	Continue data taking phase of rare kaon decay experiments and continue preparations for experiments using new kaon beam line in search for rare two-nucleon structures (H particles).	Begin second phase of rare kaon decay experiments and start taking data for H-particle search.

Program Activity	FY 1988	FY 1989	FY 1990
Research at Other Sites (Cont'd)	Carry out electron scattering experiments in the Nuclear Physics at SLAC (NPAS) program.	Continue electron scattering experiments using NPAS and start evaluation of proposed experiments using gas jet target in PEP ring at SLAC.	Suspend NPAS End Station A program and continue preparations for use of PEP ring at SLAC.
	Prepare detectors for use at upgraded Low Energy Antiproton Ring (LEAR) facility at CERN.	Utilize upgraded LEAR facility for high intensity antiproton experiments.	Complete data taking using LEAR facility.
	Complete fabrication and testing of time projection chamber apparatus for xenon double beta decay experiment in the St. Gotthard tunnel.	Initiate data taking phase of the St. Gotthard xenon double beta decay experiment.	Continue xenon phase of St. Gotthard double beta decay experiment.
	Continue installation of detectors at the Laser Electron Gamma Source (LEGS) facility using laser beam scattered from electron beams circulating in the National Synchrotron Light Source to make high precision high energy gamma rays.	Start first round of experiments on LEGS.	Expand experimental program to full planned operating level of BNL group using the LEGS facility and broaden LEGS experimental program to include users from universities and other laboratories.
	Conduct program of selected nuclear physics experiments at other facilities including Fermilab, TRIUMF (Canada), Saclay (France), PSI (Switzerland), and NIKHEF (Netherlands). ($10,811)	Conduct program of selected nuclear physics experiments at other facilities including Fermilab, TRIUMF (Canada), Saclay (France), PSI (Switzerland), and NIKHEF (Netherlands). ($11,863)	Conduct program of selected nuclear physics experiments at other facilities including Fermilab, TRIUMF (Canada), Saclay (France), PSI (Switzerland), and NIKHEF (Netherlands). ($12,297)
LAMPF Operations	Operate accelerator and facilities about 2850 hours for nuclear physics	Operate accelerator and facilities with decreased experimental support	Operate accelerator and facilities about 2400 hours for nuclear physics

Program Activity	FY 1988	FY 1989	FY 1990
LAMPF Operations (Cont'd)	research with about seven secondary beams. Provide beam for approximately 58 nuclear physics experiments involving about 290 scientists. Continue support for installation of medium resolution spectrometer and polarized ion source. ($41,325)	about 2400 hours for nuclear physics research with about seven secondary beams operating simultaneously. Provide beam for approximately 52 nuclear physics experiments involving about 300 scientists. Commission medium resolution spectrometer and continue support for installation of high intensity polarized ion source. Purchase and install energy spread compressor for low energy pion (LEP) channel. ($41,580)	research with about seven secondary beams operating simultaneously. Provide beam for approximately 52 nuclear physics experiments involving about 300 scientists. Start operation of high intensity polarized ion source. Begin operation of LEP channel with energy spread compressor. ($42,800)
Bates Operations	Operate accelerator and facilities about 3700 hours for nuclear physics research. Provide beam for approximately 35 experiments involving about 135 scientists. Provide beam energies above 1 GeV for experiments requiring the highest energies. ($6,340)	Operate accelerator and facilities about 2000 hours for nuclear physics research. Provide beam for approximately 30 experiments involving about 125 scientists. Operate accelerator at 1 GeV for required experiments during selected operating cycles during the year. Begin installation of components for South Hall Ring Experiment. ($6,450)	Operate accelerator and facilities about 2000 hours for nuclear physics research. Provide beam for approximately 30 experiments involving about 125 scientists. Operate accelerator at 1 GeV for required experiments during selected operating cycles during the year. Continue installation and testing of components for South Hall Ring Experiment. ($7,100)

III. Medium Energy Nuclear Physics (Cont'd)

Program Activity	FY 1988	FY 1989	FY 1990
CEBAF Operations	No activity ($0)	Provides for startup of laboratory operations and accelerator commissioning. ($1,000)	Provides for startup of laboratory operations and accelerator commissioning. ($4,600)
Other Operations	Operate nuclear physics injector (NPI) and facilities at SLAC for 1035 hours. Provide beams of six GeV electrons for experiments involving about 50 scientists. Run only highest priority experiments in coordination with startup of SLC program for High Energy Physics. Continue operations support for the Bevalac medium energy research activities (300 hours). ($2,560)	Operate NPI and facilities at SLAC for 1000 hours. Provide beams of six GeV electrons for experiments involving about 50 scientists. Continue operations support for the Bevalac medium energy research activities (300 hours). ($2,175)	Suspend operation of NPI at SLAC. Reduce operations support for the Bevalac medium energy research activities. ($1,500)
Total Medium Energy Nuclear Physics	$83,487	$85,711	$93,700

I. Preface: Heavy Ion Nuclear Physics

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

II. A. Summary Table

Program Activity	FY 1988	FY 1989	FY 1990	% Change
Research......................	$ 29,600	$ 32,012	$ 34,800	+ 9
Operations....................	35,300	35,505	36,700	+ 3
Total, Heavy Ion Nuclear Physics..................	$ 64,900	$ 67,517	$ 71,500	+ 6

II. B. Major Laboratory and Facility Funding

Argonne National Laboratory....	$ 5,330	$ 5,390	$ 6,770	+ 26
Brookhaven National Laboratory.	14,992	15,780	17,550	+ 11
Lawrence Berkeley Laboratory...	26,515	26,695	28,040	+ 5
Los Alamos National Laboratory.	880	890	950	+ 7
Oak Ridge National Laboratory..	8,120	8,210	8,395	+ 2
Lawrence Livermore National Laboratory..................	50	95	150	+ 58

III. Activity Descriptions

Program Activity	FY 1988	FY 1989	FY 1990
LBL Bevalac Research	Continue the experimental programs on collision dynamics especially using upgraded detector systems for the Heavy Ion Superconducting Spectrometer (HISS). Begin support of HISS-based equation of state (EOS) time projection chamber detector. Continue the experimental program with the Dilepton Spectrometer (DLS) by measuring electron-positron production for intermediate mass	Continue experiments at HISS and Low Energy beamlines to study fission and fragmentation of very heavy beams. Begin using a reverse kinematics detector for intermediate energy studies. Continue fabrication of EOS detector. Continue experiments with the Dilepton Spectrometer to explore high energy nuclear dynamics at the earliest stages of the collision process. Continue the analyses of	Continue experiments at HISS to study multipion production with heaviest beams, exclusive fragmentation of light systems and studies with radioactive beams. Complete fabrication, test components, and start to assemble the EOS detector. Continue to operate the Dilepton Spectrometer to probe the hot high density phase of the collision process. Use heaviest beams available

III. Heavy Ion Nuclear Physics (Cont'd)

Program Activity	FY 1988	FY 1989	FY 1990
LBL Bevalac Research (Cont'd)	systems (e.g., Ca + Ca). Continue the second round of CERN experiments using sulfur beams and analyze the data for information on hot dense nuclear matter. Initiate prototyping of detectors for proposed AGS dilepton experiment. ($5,840)	the initial CERN oxygen and sulfur experiments and prepare for experiments with lead beams. Continue to develop detectors for proposed AGS dilepton experiment. ($5,935)	to continue to study multifragmentation processes at the Low Energy Beamline. Continue analysis of initial data from CERN experiments to learn about strangeness production and the energy densities achieved in these collisions and explore the physics potential of lead beam experiments. Continue testing and prototyping of detectors for a proposed first-generation dilepton experiment at the AGS. ($6,280)
BNL Tandem/AGS Research	Analyze data from initial running of the AGS/Tandem heavy ion experiment E802 for survey of particle yields and continue experimental program. Complete first phase of testing the heavy ion time projection chamber for experiment E810 to measure strangeness production. Continue testing of components of experiment E814 (study of energy flow, nuclear stopping and search for exotic chunks of nuclear matter). Begin designing next generation experiment for AGS. Continue relativistic heavy ion collider (RHIC) R&D on major accelerator systems at about $5.9 million. ($7,677)	Continue data taking on experiment E802, complete analysis of initial data, and start upgrade of E802 for future gold beams. Finish testing time projection chamber for E810 and begin experimental program. Complete assembly and testing of E814 and begin experimental program. Continue design and prototyping detectors for a possible new experiment to measure correlated lepton-antilepton production. Continue R&D towards a RHIC at about $6.2 million. ($8,430)	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. Continue design phase of next generation AGS experiment. Continue R&D towards a RHIC at about $6.6 million. ($9,450)

Program Activity	FY 1988	FY 1989	FY 1990
National Laboratory Research	Continue the experimental program with ATLAS at ANL using the completed gamma-ray detector system. Extend experimental program on heavy ion reaction mechanisms near the Coulomb barrier to heavier mass systems. Begin programmatic support of the Fragment Mass Analyzer detector.	Continue the experimental program at ATLAS with emphasis on reactions near the Coulomb barrier using the heavier mass projectiles available from the improved injector. Begin design and testing of detector systems for the Fragment Mass Analyzer for an experimental program on nuclei far from stability. Begin studies of apparatus to measure electron-positron production with future uranium beams.	Continue active experimental research program to take advantage of enhanced capabilities of ATLAS with emphasis on reaction mechanism studies, studies of highly deformed nuclei and production of nuclei far from stability. Begin experimental program with the Fragment Mass Analyzer and support initial activities for large acceptance detector system to measure electron-positron correlations in uranium-uranium collisions.
	At the 88" Cyclotron at LBL, continue the experimental program on high spin states using the completed gamma-ray detector system, HERA. Continue experimental programs on the study of heavy ion nuclear reaction processes and the production and properties of nuclei far from stability.	Continue the experimental program at the 88" Cyclotron and study superdeformed bands at very high spin with HERA. Continue technological research on Electron Cyclotron Resonance (ECR) ion sources using strong fields and high frequencies.	Continue the experimental program at the 88" Cyclotron using the HERA gamma-ray detector. Continue the studies of reaction mechanisms induced by heavy ions provided by the ECR ion source. Continue to develop the technology necessary for new ECR-type ion sources at strong fields and high frequencies.
	At the Holifield Heavy Ion Research Facility (HHIRF) at ORNL, continue experimental programs on the decay modes of nuclear giant resonances, projectile breakup of heavy ion beams, and the structure of nuclei far from stability. Continue physics analysis of the Plastic Ball experiment WA80 at CERN for possible	Continue the experimental program at HHIRF with emphasis on improved capabilities with gamma-ray detection and a more fully implemented heavy-ion, light-ion detector system. Continue data analysis of CERN WA80 experiment. Begin studying physics potential of lead beam experiments at CERN.	At HHIRF continue the experimental program to measure the properties of superdeformed nuclei. Utilize the enhanced capabilities of the completed heavy-ion, light-ion (HILI) detector to study nuclear reaction mechanisms. Continue the analysis of the CERN WA80 experiment with particular emphasis on measurements

III. Heavy Ion Nuclear Physics (Cont'd)

Program Activity	FY 1988	FY 1989	FY 1990
National Laboratory Research (Cont'd)	nuclear matter phase changes at ultra-relativistic energies.		from the photon detectors. Continue to explore the physics potential of lead beams at CERN for studying high energy density nuclear matter.
	At LANL, continue running and analysis for the HELIOS experiment at CERN and begin constructing calorimeter for BNL Tandem/AGS experiment E814.	At LANL, continue analysis of CERN data, and complete assembly and begin installation of participant calorimeter at BNL for experiment E814.	At LANL, complete the analysis of the data on charged particle production from the HELIOS experiment at CERN. Participate in the operation of the participant calorimeters for E814 at the AGS and begin analysis of initial data.
	At LLNL, begin new program of research with heavy nuclear beams at the Bevalac low energy beamline. ($8,870)	At LLNL, continue Bevalac program and develop new counters for future experiment at AGS with heavy ions. ($9,030)	At LLNL, develop detector technology in preparation for heavy ion experiment at the Tandem/AGS. ($9,705)
University Research	Continue university user-group research programs at national laboratory accelerators. Continue the in-house program on interaction symmetries at the Yale Tandem, the in-house program on giant resonance excitation and sub-barrier fusion at the upgraded University of Washington accelerator system, and the in-house heavy ion programs on the new superconducting cyclotron at Texas A&M.	Continue university user-group research programs and enhance detector R&D efforts. Continue nuclear physics research programs at the Yale Tandem on investigating nuclei far from stability. Use the higher energies of the University of Washington superconducting linac booster to study charged particle emission. Exploit the new capabilities of the Texas A&M superconducting cyclotron to study subthreshold pion production.	Continue and strengthen university user-group research programs at national laboratory accelerators. Continue the Nuclear Physics program at the upgraded Yale Tandem with emphasis on low-energy heavy ion interactions. At the University of Washington superconducting linac use the higher energy lighter projectiles and upgraded detector systems to continue the study of phenomena of hot nuclear systems. Use the higher energies of the Texas A&M

Program Activity	FY 1988	FY 1989	FY 1990
University Research (Cont'd)	($7,213)	($8,617)	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. ($9,365)
LBL Bevalac Operations	Continue to provide relativistic heavy ion beams for the research program including up to 1000 hours for biomedical research. Provide up to 3700 hours of heavy ion beam time for the research program. Emphasize provision of beams in the 100-400 MeV/amu range and secondary beams of unstable species. ($17,265)	Continue to provide up to 3200 hours of heavy ion beam time for the research program including one-third time for biomedical research. Make full utilization of the specialized low energy, kaon, and secondary radioactive beam lines. Begin to phase out the independent research program at the SuperHILAC. ($17,070)	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, Dilepton Spectrometer, streamer chamber, Low Energy beam lines and the Beam 40 area. Complete phase-out of SuperHILAC operations for independent research. ($18,040)
BNL/Tandem/AGS Operations	Operate the Tandem/AGS accelerator system to produce 700 hours (7 weeks) of oxygen and sulfur beams for relativistic heavy ion experiments. Complete installation of beam lines for experiment E802 and continue installation of E814. ($7,315)	Operate Tandem/AGS accelerator system to produce up to 7 weeks of light ions (including protons) for the approved relativistic heavy ion experiments. Complete installation of beamline for E814. ($7,350)	Operate Tandem/AGS system to provide up to 8 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 new beam line for next generation AGS experiment. ($8,100)

Program Activity	FY 1988	FY 1989	FY 1990
ANL, LBL 88", ORNL Operations	Provide 3700 hours of ATLAS operation at ANL for nuclear physics experiments. Begin testing the positive-ion injector. Provide 4000 hours of operation of the 88" Cyclotron at LBL for the nuclear physics program with an improved ECR ion source. Provide 3900 hours of operation of HHIRF at ORNL for nuclear and atomic physics programs. Complete installation of reconfigured accelerator tubes. ($8,870)	Provide 3500 hours to ATLAS operation for nuclear physics experiments. Support installation of new beam line for the fragment mass analyzer (FMA). Provide 4000 hours of operation of the 88" Cyclotron and continue development of the ECR ion source. Provide 3800 hours of HHIRF operation for nuclear physics program and atomic physics research programs. Operate upgraded accelerator tubes with greater reliability and increasing voltage. Reduce coupled Tandem/Cyclotron operation as Tandem performance improves. ($9,195)	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 Analyzer (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. ($8,580)
University Accelerator Operations	Commission upgraded tandem accelerator at Yale University and provide light heavy ion beams for a broad experimental program in nuclear physics. Begin the in-house experimental program on the University of Washington upgraded accelerator system. Provide light and medium mass heavy ion beams up to 125 MeV/amu for the experimental	Provide light heavy ion beams for experiments using the upgraded facilities at Yale University. Provide light heavy ion beams for in-house experiments at the University of Washington using the superconducting linac booster. Provide light and medium mass heavy ion beams for experimental programs at Texas A&M University.	Continue to provide light heavy ions at increased energies for the upgraded facilities and detectors at the Yale Tandem for a full research program. Provide light ions from the superconducting linac booster at the University of Washington for its in-house Nuclear Physics program. Continue to provide energetic light to medium mass projectiles for the

III. Heavy Ion Nuclear Physics (Cont'd)

Program Activity	FY 1988	FY 1989	FY 1990
University Accelerator Operations (Cont'd)	program at Texas A&M University using the state funded superconducting booster cyclotron. ($1,800)	($1,840)	Nuclear Physics program at the upgraded Texas A&M superconducting cyclotron. ($1,980)
Total Heavy Ion Nuclear Physics	$64,900	$67,517	$71,500

I. Preface: Low Energy Nuclear Physics

This subprogram emphasizes experimental investigations of nuclear structure, nuclear decay parameters, and low energy reaction mechanisms. These studies also include general tests of fundamental theories and symmetries, as well as more specific and detailed studies of reactions involved in stellar and cosmologic processes. University-based research is an important feature of the Low Energy program. The facilities required are relatively small and appropriate for siting on university campuses. The university-based programs permit excellent hands-on training of nuclear experimentalists, many of whom contribute after obtaining Ph.D.s to nuclear technology development of interest to the DOE. Beginning in FY 1988, this subprogram also includes the DOE Nuclear Data program, which was previously included in the Basic Energy Sciences program. The Nuclear Data program includes nuclear data measurement and nuclear data compilation, and evaluation activities important for nuclear technologies.

II. A. Summary Table

Program Activity	FY 1988	FY 1989	FY 1990	% Change
Research........................	$ 10,728	$ 11,574	$ 12,520	+ 8
Operations......................	3,105	3,100	3,240	+ 5
Nuclear Data....................	10,890	11,192	11,640	+ 4
Total, Low Energy Nuclear Physics.....................	$ 24,723	$ 25,866	$ 27,400	+ 6

II. B. Major Laboratory and Facility Funding

Ames National Laboratory........	$ 205	$ 205	$ 215	+ 5
Argonne National Laboratory.....	2,940	2,960	3,130	+ 6
Brookhaven National Laboratory..	4,385	3,770	3,890	+ 3
Idaho National Engineering Laboratory....................	335	335	355	+ 6
Lawrence Berkeley Laboratory....	2,090	2,130	2,295	+ 8
Lawrence Livermore National Laboratory....................	225	230	245	+ 7
Los Alamos National Laboratory..	1,385	1,370	1,445	+ 6
Oak Ridge National Laboratory...	4,615	4,720	4,905	+ 4

III. Activity Descriptions

Program Activity	FY 1988	FY 1989	FY 1990
Research at University Facilities	Complete upgrades of accelerator facilities: at Texas A&M the new state-funded K500 superconducting cyclotron) and at the University of Washington (the superconducting LINAC booster). The Washington booster has produced an intense beam of Li-7 ions at 12 MeV/amu, for a scattering study that provided new insights into heavy-ion scattering processes. ($2,602)	Continue utilization of upgraded facilities. At the University of Washington, develop a broader range of polarized and unpolarized beams with improved quality and new instrumentation for light and heavy-ion reaction studies. Use the proton spectrometer at Texas A&M for (d, He-2) studies of spin-flip, charge-exchange reactions. Use the new polarized ion source at Duke, with the cryogenic polarized target, to perform much improved measurements of spin-spin effects in neutron-nucleus reactions and to begin time-reversal invariance tests. ($2,675)	At Texas A&M, begin the development of a high-resolution 160 MeV neutron beam to be used with the proton spectrometer for (n,p) studies of Gamow-Teller matrix elements; at Duke, begin spin-spin cross-section measurements using a cryogenic polarized target of solid He-3; at Washington, exploit the higher energy lighter heavy-ion beams available from the superconducting LINAC booster to study reaction mechanisms at the Coulomb barrier. ($2,835)
Research at National Laboratory Accelerators	Continue low energy research at ANL, LBL, and ORNL at about same level of effort. At LBL, selected gamma-ray production cross sections will be	Continue low energy research at ANL, LBL, and ORNL. At LBL, high intensity He-3 beams will be used with the RAMA on-line separator to	Continue low energy research at ANL, LBL, and ORNL. At LBL, continue to search for nuclei near the proton and neutron drip-lines that may decay by

Program Activity	FY 1988	FY 1989	FY 1990
Research at National Laboratory Accelerators (Cont'd)	measured for use in the interpretation of spectra obtained from observatories in space. At ORNL, the nuclear orientation target will be brought into operation. ($3,515)	attempt to observe the decay of nuclides which are adjacent to, or are defining of, the proton drip-line in the sd-shell. At ORNL, nuclear structure studies at the UNISOR will be greatly enhanced by the use of the nuclear orientation capability to determine the electromagnetic properties of gamma-ray transitions. ($3,515)	new and exotic radioactivities, and make use of the excellent polarized proton and deuteron beams from the 88-inch cyclotron to study spin-polarization effects. At ORNL, use the nuclear orientation facility to obtain complete level schemes for odd-mass nuclei in the A=190 region to explore manifestations of boson-fermion symmetries. ($3,765)
Accelerator Operations	Provide support (together with Heavy Ion Physics) for the operation and maintenance of the four university and three national laboratory accelerator facilities, with an appropriate increase in support for the University of Washington booster and Texas A&M superconducting cyclotron. Continue construction of the proton spectrometer at Texas A&M and of a new powerful polarized ion source at Duke University. ($3,105)	Provide support (together with Heavy Ion Physics) for three university and three national laboratory accelerator facilities at about the same level. Complete, early in FY 89, construction of the proton spectrometer facility at Texas A&M and the polarized ion source at Duke University. ($3,100)	Provide continuing support for the accelerator facilities at Duke University (Triangle Universities Nuclear Laboratory) and, together with the Heavy Ion program, at Texas A&M, the University of Washington, and three national laboratories. Begin additions to the proton spectrometer at Texas A&M to provide for the use of high energy neutron beams. Enhance the cryogenic polarized target facility at Duke, by enabling the use of polarized solid He-3. ($3,240)
Research at Reactors	Continue the research by the Participating Research Team at the BNL HFBR at about the same level. Use the complementary filtered beam and TRISTAN facilities to test a new global parameterization of nuclear structure. Develop picosecond	Continue support of the BNL-led effort to obtain a systematic understanding of nuclear structure in heavy nuclei, and its evolution with N, Z, A, and the number of valence protons and neutrons. Continue ion source development, particularly for	Continue to support the BNL-led Participating Research Team at the TRISTAN facility in a unified program of forefront nuclear structure studies, emphasizing the neutron-rich nuclides produced in fission. Modest ion-source improvements will increase

Program Activity	FY 1988	FY 1989	FY 1990
Research at Reactors (Cont'd)	lifetime techniques to be able to measure transition rates in nuclei far from stability. The neutron lifetime measurement experiment at the high-flux reactor in Grenoble (ILL) will continue. ($1,112)	studies of astrophysical interest. The neutron lifetime measurement at ILL should be completed. ($1,036)	average isotopic beam intensities by a factor of 30. Measurements of fundamental properties of the neutron are expected to continue at the new ultra-cold neutron beam line at the NIST (formerly NBS). ($1,101)
Other Research	Continue support of the LANL Mo/Tc solar neutrino experiment and an expanded collaborative international program of solar neutrino research. First results are expected from the molybdenum-ore experiment. The 60-ton gallium-metal gallium experiment in the USSR, with US participation led by LANL, is expected to begin operation. Continue funding of US participation in Japanese KAMIOKANDE solar neutrino detection project, which resulted in detection of neutrinos from the 1987 Supernova Event. ($3,499)	Continue solar neutrino research at an increased level. Strengthen the US effort in support of the Soviet-American Gallium Experiment (SAGE) and continue participation in GALLEX experiment. Transfer support for BNL nuclear group from low energy Tandem based research to relativistic heavy ion reactions at the Tandem/AGS facility in Heavy Ion subprogram. ($4,348)	Pending further review, provide for possible US participation in the Canadian Sudbury Neutrino Observatory (SNO) project, involving a large, deeply buried, heavy-water Cerenkov detector to measure solar neutrino fluxes and higher energy spectra for neutrinos of all types. Preliminary results are expected from the SAGE metallic gallium experiment. Funding is provided to begin acquisition of isotopically enriched chromium to enable fabrication of a chromium-51 neutrino source to calibrate the joint US/European 35-ton gallium chloride GALLEX experiment. ($4,819)
Nuclear Data Measurements	Continue the nuclear data measurement cross sections at about the same level of effort. Complete the transfer of support from the Office of Nuclear Energy for the ANL Fast Neutron Generator (FNG). Measurements at the FNG will concentrate on cross	Continue nuclear data measurement program at about same level. Complete the construction of the large, segmented, full-solid-angle gamma-ray detector to be used at the ORELA as a photon-multiplicity detector.	Begin measurements at the ORELA using the new large detector to obtain unadjusted differential measurements of capture cross sections and capture-to-fission ratios for the first time, to meet accuracy requirements of reactor designers, beginning with U-235 and Pu-239. At

Program Activity	FY 1988	FY 1989	FY 1990
Nuclear Data Measurements (Cont'd)	sections requested by the Office of Fusion Energy; in particular, total and scattering cross sections of structural materials, and cross sections for the production of long-lived radioactivity from them. ($6,405)	($6,456)	ANL, begin difficult measurements of cross sections for the production of long-lived activities of interest to the Office of Fusion Energy. ($6,830)
Nuclear Data Compilation and Evaluation	Continue at the same level the two major activities that comprise a reasonably balanced nuclear data program that satisfies current nuclear data needs of both basic researchers and technologists. The evaluation of the neutron cross section data for inclusion in Version 6 of the Evaluated Nuclear Data File (ENDF-6) will continue. The LBL group published the Table of Radioactive Isotopes, a 1056-page reference book, containing detailed radiation data in a convenient format tailored to the requirements of medical researchers, biologists, designers and monitors of nuclear reactors. ($4,485)	Continue nuclear data compilation and evaluation at about the same level. ENDF-6 is expected to be nearing completion; a significant advance over previous versions should result from the inclusion of recent data measured for the purpose, and from improvements in nuclear models and evaluation methods. The cycle time for the evaluation of the A-chains for the Evaluated Nuclear Structure Data File (ENSDF) is expected to be shortened as the evaluators take advantage of their experience with computerized methods and as the LBL group resumes its evaluation effort. ($4,736)	Continue nuclear data compilation and evaluation at a slightly reduced level. ENDF-6 should be released, although some continuing effort will be required to incorporate improvements and to extend coverage. An effort will be made to improve on-line access to the data files. (Better cooperation with international neutron cross section evaluation efforts is expected following the release of ENDF-6.) Possible improvements will be made to minimize the volume of publications, e.g., Nuclear Data Sheets, and to emphasize on-line access to a more timely updated ENSDF data base. ($4,810)
Total Low Energy Nuclear Physics	$24,723	$25,866	$27,400

I. Preface: Nuclear Theory

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

II. A. Summary Table

Program Activity	FY 1988	FY 1989	FY 1990	% Change
Nuclear Theory..................	$ 10,500	$ 10,818	$ 12,700	+ 17

II. B. Major Laboratory and Facility Funding

Argonne National Laboratory.....	$ 910	$ 930	990	+ 6
Brookhaven National Laboratory..	1,005	1,025	1,090	+ 6
Lawrence Berkeley Laboratory....	930	950	1,010	+ 6
Los Alamos National Laboratory..	1,039	1,075	1,140	+ 6
Oak Ridge National Laboratory...	835	855	910	+ 6

III. Activity Descriptions

Program Activity	FY 1988	FY 1989	FY 1990
Nuclear Theory	Increase attention to the role of spin in nuclear forces to describe the results of experiments using new polarized beams at DOE-supported facilities. Provide a deeper understanding of the equations describing nuclear matter. Provide theoretical support for the new experimental initiatives in parity	Emphasize investigation of quark-gluon description of nuclear structure and of very high energy density forms of nuclear matter in preparation for future experimental investigations at the Continuous Electron Beam Accelerator Facility (CEBAF) and other next generation machines. Do calculations to better	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). Continue a broad program of theoretical research on properties of atomic nuclei with emphasis on the

III. Nuclear Theory (Cont'd)

Program Activity	FY 1988	FY 1989	FY 1990
Nuclear Theory (Cont'd)	conservation and isospin dependence of nuclei. Concentrate theory of nuclear phase transitions on the formation of quark-gluon plasmas as related to experiments.	understand nuclear astrophysical processes including the emission and properties of neutrinos. Carry out preliminary activities aimed at the establishment of a Nuclear Theory Institute selected from several competing proposals. Continue broad program of theoretical research on properties of atomic nuclei, understanding of nuclear forces, and phase transitions in nuclear matter.	underlying quark-gluon substructure of nuclear matter, including understanding of nuclear forces, and phase transitions in nuclear matter. Establish a Nuclear Theory Institute of broad scope and national character. 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.
Total Nuclear Theory	$10,500	$10,818	$12,700

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

Program Activity	FY 1988	FY 1989	FY 1990	% Change
Capital Equipment..............	$ 17,675	$ 18,500	$ 20,000	+ 8

II. B. Major Laboratory and Facility Funding

Brookhaven National Laboratory..	$ 5,030	$ 4,400	$ 3,285	- 25
Lawrence Berkeley Laboratory....	2,570	2,675	2,800	+ 5
Los Alamos National Laboratory..	2,925	2,910	3,130	+ 7
Argonne National Laboratory.....	1,755	1,900	1,790	- 6
Massachusetts Institute of Technology/Bates.............	1,200	1,250	1,260	+ 1
Oak Ridge National Laboratory...	960	1,130	1,390	+ 23
Continuous Electron Beam Accelerator Facility..........	1,000	1,000	1,500	+ 50
University Laboratories.........	790	1,000	1,000	0
Lawrence Berkeley Laboratory GPE.........................	1,300	1,400	1,500	+ 7
All Other......................	145	835	2,345	+ 181

III. Activity Descriptions

Program Activity	FY 1988	FY 1989	FY 1990
BNL	For AGS heavy-ion experiment E802, install pressure Cerenkov counter for tracking and particle identification and continue major data taking runs. Complete construction of the heavy ion time projection chamber (TPC) for E810 and begin test runs. For E814, install new beam line, some of the detectors and data acquisition systems, and begin initial physics running. Procure major components of the kaon beam line for the study of two nucleon systems. Complete installation of tagging spectrometer	Complete Time Projection Chamber construction for AGS heavy-ion experiment E810. For E814, complete installation and testing of all detectors. Provide partial support for a tunnel by-pass to bring heavy-ion beams from the Tandem directly to the AGS Booster. At LEGS construct the scintillator array for detecting protons and neutrons for the nuclear structure measurements. Continue construction of the kaon beam line. Complete modernization of central computer at NNDC.	Begin upgrade of AGS heavy-ion experiments to prepare for higher multiplicities expected from gold beams. Complete implementation of Tandem/AGS heavy-ion by-pass. Provide control system to connect the Tandem transfer line to the Booster Ring. Complete construction of kaon beam line.

III. Capital Equipment (Cont'd)

Program Activity	FY 1988	FY 1989	FY 1990
BNL (Cont'd)	for the LEGS facility. Begin replacement of central computer at the National Nuclear Data Center (NNDC).		
	($5,030)	($4,400)	($3,285)
LBL	Begin construction of a time projection chamber (TPC) for the HISS spectrometer to measure central collisions with the heavy ion beams from the Bevalac. Perform tests with prototype TPC. Replace existing time-of-flight (TOF) wall at HISS facility with the new high-granularity TOF wall. Replace several VAX data analysis computers at the Bevalac with a modern file server computer.	Continue construction of the HISS TPC, fabricating field cage and pad plane, and procuring custom-designed very large scale integrated (VLSI) circuits. Upgrade multiplicity array and drift chambers of the dilepton spectrometer (DLS). Install ultra-fast data analysis computer for gamma-ray experiments at the 88" Cyclotron.	Complete construction of the HISS TPC and begin testing and initial experiments. Finish upgrade of the dilepton spectrometer for use with the entire range of heavy beams available at the Bevalac. Replace two VAX computers with a modern file server computer and 15 scientific workstations. Provide instrumentation for the new Bevalac central control point, which will coordinate the operation of the Bevatron, transfer line, and SuperHILAC.
	($2,570)	($2,675)	($2,800)
LANL	Complete in-beam tests of prototype detectors for the Muon Electron GAmma-ray experiment (MEGA), which measures a very rare decay mode of the muon. Complete manufacture of components for the Medium Resolution Spectrometer, a major experimental device for the Nucleon Physics Laboratory.	Complete assembly of MEGA detectors including all multi-wire chambers and photon arms. Assemble, test, and commission the Medium Resolution Spectrometer. Begin construction of an energy spread compressor for the low energy pion channel, which uses a single-cell superconducting rf cavity. This device will generate a	Procure superconducting dipole magnet for spin precession of neutron beams at the Nucleon Physics Laboratory (NPL). Purchase VAX data acquisition computers to accommodate the greatly increased data acquisition rates at the NPL due to the new high intensity polarized beams. Begin construction of an energy spread compressor for

III. Capital Equipment (Cont'd)

Program Activity	FY 1988	FY 1989	FY 1990
LANL (Cont'd)	($2,925)	five-fold increase in yield for important pion experiments. ($2,910)	high energy pions in the P3 channel, which utilizes a four-cell superconducting rf cavity. ($3,130)
ANL	Begin construction of major components of the Fragment Mass Analyzer for selective detection of forward-going particles from heavy ion reactions at ATLAS. Add a new microVAX-based DAPHNE system for data acquisition and analysis. ($1,755)	Complete procurement of major components for the Fragment Mass Analyzer and its beam line. Assemble and begin initial tests. ($1,900)	Upon completion of review, begin construction of an electron-positron experiment to exploit the high-intensity heavy-mass beams that will be available from the positive ion injector at ATLAS in FY 1991. ($1,790)
MIT/Bates and ORNL	At Bates, make improvements to the polarized electron source, procure new focal-plane detectors for an electron spectrometer, and procure switch tubes for rf modulators. At ORNL, complete the second half of the heavy-ion/light-ion detector, and provide a data analysis system for CERN experiment WA 80. ($2,160)	Procure beam control and monitoring equipment for the Bates South Hall Ring Experiment. Install beam diagnostic and control equipment for the Bates linac. Develop detector system for an out-of-plane magnetic spectrometer system. At ORNL, initiate construction of a recoil mass spectrometer and expand VAX computer cluster to improve data reduction capability. ($2,380)	Procure vacuum equipment, radiation safety equipment, and beam monitoring equipment for the Bates South Hall Ring Experiment. Construct detectors for out-of-plane spectrometer, and continue upgrade of the linac beam diagnostic and control system. At ORNL, continue construction of recoil mass spectrometer and expansion of VAX computer cluster for data reduction. Procure replacement klystrons for ORELA. ($2,650)
CEBAF	Procure equipment for the rf cryogenic laboratory such as cryogenic plumbing and gas storage systems, procure electrical testing equipment such as rf diagnostic equipment, install array-vector processor to speed design of	Upgrade the VAX 8700 and 785 computer systems to 30 MFLOP capacity to support extensive simulations of experimental equipment and accelerator components. Procure a magnet measurement system, shop equipment such as a large milling	Continue the upgrade of the VAX computer system with a memory upgrade, additional disk drives and tape units. Procure data acquisition equipment, such as CAMAC and FASTBUS, to develop new approaches for experimental data acquisition.

III. Capital Equipment (Cont'd)

Program Activity	FY 1988	FY 1989	FY 1990
CEBAF (Cont'd)	experimental equipment and accelerator components. ($1,000)	machine and welding equipment, and cryogenic support equipment. ($1,000)	Procure general test equipment for testing prototypes of physics research equipment. ($1,500)
University Laboratories	Begin instrumentation initiative at university accelerator laboratories in response to identification of poor level of instrumentation at these facilities. Construct experimental equipment as follows: Texas A&M University (proton spectrometer), Yale University (charged particle array and 2-pi neutron ball), University of Washington (plastic wall gamma-ray setup), and TUNL (radiative capture setup and polarized solid 3-He target). ($790)	Continue instrumentation initiative at university laboratories with construction of devices such as BGO multiplicity spectrometer, high-speed parallel data processor, magnetic spectrometer, and high energy gamma detector. ($1,000)	Continue instrumentation initiative at university accelerator laboratories to raise overall level of available experimental equipment. ($1,000)
LBL	Provide general purpose equipment at Lawrence Berkeley Laboratory, for which the Nuclear Physics program has landlord responsibility, such as data processing equipment used in administrative functions, equipment for the Computing Division, computer aided design and engineering (CAD/CAM) work stations, a chest x-ray machine, and an emergency power plant. ($1,300)	Provide general purpose equipment such as a firetruck and forklifts for the Motor Vehicle group, disk drives for the Administration Division computer, refrigerators and freezers for the cafeteria, optical mass storage system for the Central Computing Facility, high temperature kiln and a scatter plate interferometer for the Engineering Division. ($1,400)	Provide general purpose equipment such as light and heavy trucks for the Motor Vehicle group; cooling towers, boilers, chillers, a CAD system and data processing equipment for the Administrative Division; and equipment used for printing, graphics and photography, and equipment for lab-wide computer networks for the Information and Computing Sciences Division. ($1,500)

III. Capital Equipment (Cont'd)

Program Activity	FY 1988	FY 1989	FY 1990
Other	Provide equipment for the Nuclear Physics Injector program at SLAC, for the Oak Ridge Associated Universities on-line isotope separator (UNISOR), and for some participants of the nuclear data measurements program. ($145)	Provide equipment for the UNISOR program and participants of the nuclear data measurements program. ($835)	Upon completion of the review process, proceed with initial procurement of equipment for several new experiments. Selection will be among the following: prototype high-resolution germanium detectors for gamma detector array, components for the proposed Sudbury Solar Neutrino Observatory, a joint U.S./Canadian/UK project, equipment for measurement of the spin-dependent structure function of the nucleon, experiments with relativistic heavy-ion beams at Brookhaven and CERN, and a spectrometer for the PEP ring at SLAC. Provide equipment for the UNISOR program and participants of the nuclear data measurements program. ($2,345)
Total Capital Equipment	$17,675	$18,500	$20,000

Program Activity	FY 1988	FY 1989	FY 1990
Construction			
Continuous Electron Beam Accelerator Facility (CEBAF)	Prepare for procurement and testing of accelerator cavities and klystrons. Begin fabrication of cryogenic system. Initiate conventional construction of accelerator enclosure and CEBAF center. ($33,500)	Continue construction of accelerator enclosure. Complete construction of CEBAF Center. Begin procurement of accelerator cavities and klystrons. Begin procurement of cryostats. ($44,500)	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. ($65,000)

Program Activity	FY 1988	FY 1989	FY 1990
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. ($4,400)	Slightly lower level of effort as FY 1988. ($4,300)	Same level of effort as FY 1988. ($4,600)
General Plant Projects	Essential additions, modifications, and improvements on an annual basis to maintain safety and effectiveness of general laboratory plant and support facilities. ($3,600)	Same level of effort as FY 1988. ($3,700)	Somewhat higher level of effort due to special needs of programmatic facilities. ($4,400)
Total Construction	$41,500	$52,500	$74,000

DEPARTMENT OF ENERGY
FY 1990 CONGRESSIONAL BUDGET REQUEST
OFFICE OF ENERGY RESEARCH
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

KEY ACTIVITY SUMMARY

CONSTRUCTION PROJECTS

Nuclear Physics

Construction Project Summary

Project No.	Project Title	Total Prior Year Obligations	FY 1989 Request	FY 1990 Request	Unappropriated Balance	TEC
90-R-201	Accelerator Improvements and Modifications	$ ---	$ ---	$ 4,600	$ ---	$ 4,600
87-R-203	Continuous Electron Beam Accelerator Facility	49,700	44,500	65,000	105,800	265,000
GP-E-300	General Plant Projects	---	---	4,400	---	4,400
Total, Nuclear Physics Construction		$ 49,700	$ 44,500	$ 74,000	$105,800	XXX

KEY ACTIVITY CONSTRUCTION PROJECT SUMMARY

Nuclear Physics

IV. B. Plant Funded Construction Project

1. Project title and location: 90-R-201 Accelerator Improvements and Modifications
Various locations

Project TEC: $ 4,600
Start Date: 2nd Qtr. FY 1990
Completion Date: 2nd Qtr. FY 1992

2. Financial schedule:

Fiscal Year	Appropriated	Obligations	Costs
1990	$ 4,600	$ 4,600	$ 3,000
1991	0	0	1,200
1992	0	0	400

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 1990 funding for the various locations:

Argonne National Laboratory (ATLAS)	$ 150
Brookhaven National Laboratory (AGS/Tandem)	1,250
Lawrence Berkeley Laboratory	1,500
Los Alamos National Laboratory (Clinton P. Anderson Meson Physics Facility)	500
Massachusetts Institute of Technology (Bates Linear Accelerator Center)	1,000
Oak Ridge National Laboratory (Holifield Heavy Ion Research Facility)	200
Total Estimated Costs..................	$ 4,600

DEPARTMENT OF ENERGY
FY 1990 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND RESEARCH
(dollars in thousands)

KEY ACTIVITY CONSTRUCTION PROJECT SUMMARY

Nuclear Physics

IV. B. Plant Funded Construction Project

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

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

2. Financial schedule:

Fiscal Year	Appropriated	Obligations	Costs
1987	$ 16,200	$ 16,200	$ 7,842
1988	33,500	33,500	41,858
1989	44,500	44,500	42,000
1990	65,000	65,000	55,000
1991	65,000	65,000	59,000
1992	35,800	35,800	49,000
1993	5,000	5,000	10,300

3. Narrative:

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

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

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

DEPARTMENT OF ENERGY
FY 1990 CONGRESSIONAL BUDGET REQUEST
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: GP-E-300 General Plant Projects
Various locations

Project TEC: $ 4,400
Start Date: 2nd Qtr. FY 1990
Completion Date: 2nd Qtr. FY 1992

2. Financial schedule:

Fiscal Year	Appropriated	Obligations	Costs
1990	$ 4,400	$ 4,400	$ 1,200
1991	0	0	2,100
1992	0	0	1,100

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 1990 funding for the various locations:

Lawrence Berkeley Laboratory	$ 2,750
Los Alamos National Laboratory (Clinton P. Anderson Meson Physics Facility)	400
Massachusetts Institute of Technology (Bates Linear Accelerator Center)	1,250
Total Estimated Cost....................	$ 4,400