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Volume 4 of 7

Congressional Budget Request

General Science and Research
Uranium Enrichment
Geothermal Resources Development Fund

Volume 4

FY 1987

U.S. Department of Energy
Assistant Secretary,
Management and Administration
Office of the Controller
Washington, D.C. 20585

February 1986

DEPARTMENT OF ENERGY

FISCAL YEAR 1987 CONGRESSIONAL BUDGET REQUEST

GENERAL SCIENCE AND RESEARCH

URANIUM ENRICHMENT

GEOTHERMAL RESOURCES DEVELOPMENT FUND

VOLUME 4

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DEPARTMENT OF ENERGY

FISCAL YEAR 1987 CONGRESSIONAL BUDGET REQUEST

SUMMARY OF ESTIMATES BY APPROPRIATIONS

(in thousands of dollars)

	FY 1985 Actual BA	FY 1986 Estimate BA	FY 1987 Request BA
Appropriations Before The Energy and Water Development Subcommittees:			
Energy Supply Research and Development	1,967,490	1,696,298	1,254,162
Uranium Enrichment	237,956	190,512	---
General Science and Research	724,860	655,928	773,400
Atomic Energy Defense Activities ..	7,322,321	7,231,664	8,230,000
Departmental Administration	128,602	150,319	151,082
Alaska Power Administration	3,233	3,245	2,881
Bonneville Power Administration ...	284,771	330,000	276,100
Southeastern Power Administration .	35,744	---	19,647
Southwestern Power Administration .	31,208	29,191	25,337
Western Area Power Administration .	218,230	195,910	240,309
Western Area Power Emergency Fund .	---	---	---
Federal Energy Regulatory Commission	54,543	41,989	20,325
Nuclear Waste Fund	327,669	499,037	769,349
Geothermal Resources Development Fund	121	69	72
Subtotal, Appropriations Before the Energy and Water Development Subcommittees	$11,336,748	$11,024,162	$11,762,664

DEPARTMENT OF ENERGY

FISCAL YEAR 1987 CONGRESSIONAL BUDGET REQUEST

SUMMARY OF ESTIMATES BY APPROPRIATIONS

(in thousands of dollars)

	FY 1985 Actual BA	FY 1986 Estimate BA	FY 1987 Request BA
Appropriations Before Interior and Related Agencies Subcommittees:			
Alternative Fuels Production	$ 1,169,895	$ ---	$ ---
Clean Coal Technology	---	---	---
Fossil Energy Research and Development	289,048	311,954	82,767
Naval Petroleum and Oil Shale Reserves	156,874	13,002	127,108
Energy Conservation	457,436	427,512	39,433
Energy Regulation	27,139	23,423	21,850
Emergency Preparedness	6,045	5,750	6,044
Strategic Petroleum Reserve	2,049,550	107,533	---
Energy Information Activities	60,919	57,724	59,651
Subtotal, Interior and Related Agencies Subcommittees	4,216,906	946,898	336,853
Subtotal, Energy and Water Development Subcommittees	11,336,748	11,024,162	11,762,664
Subtotal, Department of Energy	15,553,654	11,971,060	12,099,517
Permanent - Indefinite Appropriations:			
Payments to States	1,052	570	570
Total, Department of Energy	$15,554,706	$11,971,630	$12,100,087

Department of Energy
FY 1987 Congressional Staffing Request
Total Work Force

	FY1985 FTE USAGE	FY1986 CONGR REQ	FY1987 -FY86	FY1987 CONGR REQ
ENERGY & WATER SUBCOMMITTEE				
HEADQUARTERS	4,865	4,965	-18	4,947
FIELD	9,133	9,185	111	9,296
SUBCOMMITTEE TOTAL	13,998	14,150	93	14,243
INTERIOR SUBCOMMITTEE				
HEADQUARTERS	1,353	1,304	-166	1,138
FIELD	907	896	-226	670
SUBCOMMITTEE TOTAL	2,260	2,200	-392	1,808
GRAND TOTAL	16,258	16,350	-299	16,051
ADJUSTMENT		-132	-198	-330
ADJUSTED TOTAL	16,258	16,218	-497	15,721

Department of Energy
F Y 1987 Congressional Staffing Request
Total Work Force

	FY1985 FTE USAGE	FY1986 CONGR REQ	FY1987 -FY86	FY1987 CONGR REQ
10:ENERGY SUPPLY RESEARCH AND DEV	937	934	-34	900
HEADQUARTERS	811	820	-28	792
FIELD	126	114	-6	108
15:URANIUM ENRICHMENT	69	66	1	67
HEADQUARTERS	58	55	1	56
FIELD	11	11	0	11
20:GENERAL SCIENCE AND RESEARCH	37	39	0	39
HEADQUARTERS	37	39	0	39
25:ATOMIC ENERGY DEFENSE ACTIVITI	2,618	2,702	131	2,833
HEADQUARTERS	496	518	9	527
FIELD	2,122	2,184	122	2,306
30:DEPARTMENTAL ADMINISTRATION	3,307	3,332	-5	3,327
HEADQUARTERS	1,721	1,726	0	1,726
FIELD	1,586	1,606	-5	1,601
34:ALASKA POWER ADMINISTRATION	37	38	0	38
FIELD	37	38	0	38
36:BONNEVILLE POWER ADMIN	3,510	3,480	0	3,480
FIELD	3,510	3,480	0	3,480
38:SOUTHEASTERN POWER ADMIN	38	40	0	40
FIELD	38	40	0	40
42:SOUTHWESTERN POWER ADMIN	186	186	0	186
FIELD	186	186	0	186
46:WESTERN AREA POWER ADMIN	1,181	1,160	0	1,160
FIELD	1,181	1,160	0	1,160
50:WAPA - COLORADO RIVER BASIN	219	219	0	219
FIELD	219	219	0	219
52:FEDERAL ENERGY REGULATORY COMM	1,617	1,659	0	1,659
HEADQUARTERS	1,617	1,659	0	1,659
54:NUCLEAR WASTE FUND	238	292	0	292
HEADQUARTERS	123	147	0	147
FIELD	115	145	0	145
56:GEOTHERMAL RESOURCES DEV FUND	2	1	0	1
HEADQUARTERS	2	1	0	1
65:FOSSIL ENERGY RESEARCH AND DEV	714	700	-161	539
HEADQUARTERS	151	135	-26	109
FIELD	563	565	-135	430
70:NAVAL PETROL & OIL SHALE RES	104	104	-9	95
HEADQUARTERS	23	23	0	23
FIELD	81	81	-9	72
75:ENERGY CONSERVATION	333	352	-134	218
HEADQUARTERS	208	227	-79	148
FIELD	125	125	-55	70
80:EMERGENCY PREPAREDNESS	74	71	0	71
HEADQUARTERS	74	71	0	71
81:ECONOMIC REGULATION	377	340	-50	290
HEADQUARTERS	377	340	-50	290
85:STRATEGIC PETROLEUM RESERVE	178	152	-32	120
HEADQUARTERS	40	27	-5	22
FIELD	138	125	-27	98
90:ENERGY INFORMATION ACTIVITIES	480	481	-6	475
HEADQUARTERS	480	481	-6	475
94:ADVANCES FOR CO-OP WORK	2	2	0	2
FIELD	2	2	0	2
GRAND TOTAL	16,258	16,350	-299	16,051
ADJUSTMENT		-132	-198	-330
ADJUSTED TOTAL	16,258	16,218	-497	15,721

DEPARTMENT OF ENERGY

FISCAL YEAR 1987 CONGRESSIONAL BUDGET REQUEST

GENERAL SCIENCE AND RESEARCH

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GENERAL SCIENCE AND RESEARCH

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DEPARTMENT OF ENERGY
FY 1987 CONGRESSIONAL BUDGET REQUEST
LEAD TABLE
NUCLEAR PHYSICS
GENERAL SCIENCE AND RESEARCH
(Tabular dollars in thousands. Narrative material in whole dollars.)

	FY 1985 Appropriation	FY 1986 Appropriation	FY 1987 Base	FY 1987 Request	Request vs Base
Nuclear Physics (NP)					
Medium Energy Nuclear Physics					
Operating Expenses..	$ 73,810a/	$ 73,131	$ 73,131	$ 85,000	$+11,869
Subtotal..........	73,810	73,131	73,131	85,000	+11,869
Heavy Ion Nuclear Physics					
Operating Expenses..	49,008	50,150	50,150	63,700	+13,550
Subtotal..........	49,008	50,150	50,150	63,700	+13,550
Low Energy Nuclear Physics					
Operating Expenses..	13,322	12,087	12,087	15,700	+ 3,613
Subtotal..........	13,322	12,087	12,087	15,700	+ 3,613
Nuclear Theory					
Operating Expenses..	9,300	8,999	8,999	10,500	+ 1,501
Subtotal..........	9,300	8,999	8,999	10,500	+ 1,501
Capital Equipment.....	12,700	13,403	13,403	16,000	+ 2,597
Construction..........	23,300	6,702	6,702	33,300	+26,598
Total					
Operating Expenses....	145,440c/	144,367	144,367	174,900	+30,533
Capital Equipment.....	12,700	13,403	13,403	16,000	+ 2,597
Construction..........	23,300	6,702	6,702	33,300	+26,598
Nuclear Physics.....	$181,440b/d/	$164,472d/e/f/	$164,472	$224,200d/	$+59,728

Staffing Total FTE's .... (Reference General Science Program Direction Decision Unit)

Authorization: Section 209, Public Law 95-91.

a/ Includes $3,100,000 Defense Programs support of Clinton P. Anderson Meson Physics Facility (LAMPF) operations.

b/ FY 1985 total reflects a reduction of $835,000 for ADP general reduction.

c/ FY 1985 total does not include $1,425,000 transferred to the SBIR program.

d/ Totals reflect a reduction of $1,300,000 in FY 1985, $2,500,000 in FY 1986, and $2,700,000 in FY 1987 for management initiative savings.

e/ $100,000 has been transferred to Assistant Secretary for Environmental Safety and Health.

f/ Total reduced by $7,328,000 in accordance with P.L. 95-177, the Balanced Budget and Emergency Deficit Control Act of 1985 (Gramm/Rudman/Hollings).

Department of Energy

FY 1987 Congressional Budget Request

Adjustments to FY 1986 Appropriations

	FY 1986 Confer. (1)	General Reduction (2)	Management Initiatives (3)	Pay Cost Restoration (4)	FTE General Reduction (5)	Gramm-Rudman-Hollings (6)	ES&H Transfer/ Reprogramming (7)	Subtotal (8)	Comparability Adjustments (9)	Total (10)
Nuclear Physics (ER)										
Medium Energy Nuclear Physics										
Operating Expenses	76,480					-3,299	-50	73,131		73,131
Heavy Ion Nuclear Physics										
Operating Expenses	52,650	-875				-2,235	-40	50,150		50,150
Low Energy Nuclear Physics										
Operating Expenses	13,400	-775				-538		12,087		12,087
Nuclear Theory										
Operating Expenses	8,900					-401		8,499		8,499
Capital Expenses	14,000					-597		13,403		13,403
Construction	7,000					-298		6,702		6,702
Subtotal, Nuclear Physics	172,500	-1,000				-7,238	-200	164,072		164,072
General Reduction:										
Operating Expenses	-1,000	1,000								
Capital Equipment	0	0								
Construction	0	0								
Total, General Reductions	-1,000	1,000								
Management Initiatives:										
Operating Expenses										
Capital Equipment										
Construction										
Total, Management Initiatives										
Pay Restoration										
Use of Prior Year Balances (NP)										
Operating Expenses										
Capital Equipment										
Construction										
Total, Prior Year Bal. (NP)										

DEPARTMENT OF ENERGY
1987 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND RESEARCH
NUCLEAR PHYSICS

(In thousands of dollars)

1986 Appropriation enacted	$171,800
1986 Gramm-Rudman reduction	- 7,328
1986 adjusted	$164,472
o Provide a cost-of-living increment to maintain a constant level of research activities and facility utilization	+ 9,870
o Implement Continuous Electron Beam Accelerator Facility (CEBAF) construction and continue R&D which supports the project	+26,180
o Using recently completed upgrade, conduct AGS heavy ion nuclear research program with 1000 beam hours for research and complete funding for initial complement of detectors	+ 7,150
o Provide for accelerator improvement and facility maintenance projects to meet programmatic needs and provide for general purpose equipment to meet laboratory-wide needs of Lawrence Berkeley Laboratory	+ 1,620
o Conduct program operations with overall facility utilization at 55% in FY 1987	+ 8,230
o Provide for university component of research at 25% of operating expenses and provide for internationally collaborative efforts in solar neutrino research	+ 4,058
o Conduct R&D in order to maintain U.S. leadership in accelerator technology	+ 2,620
1987 budget request	$224,200

Nuclear Physics

The Nuclear Physics program supports the basic research necessary to identify and understand the fundamental features of atomic nuclei and their interactions. Nuclear processes have guided the evolution of the universe, fueled solar burning, and determined the elemental composition of the earth. The nucleus is the arena of interplay of the primary forces of nature -- the strong nuclear force, the electromagnetic force, and the weak force. Nuclear studies continuously interact with other disciplines in order to maintain their currency in emerging problems. The study of nuclear physics consequently lies at the core of fundamental scientific research.

In terms of trained manpower, new knowledge, and advanced instrumentation, the Nuclear Physics program continues to be a vital factor in America's long-term investment in its technological future. Nuclear knowledge, techniques, instruments, and applications are an integral part of American society. These serve as the basis for our national defense strategy, for therapeutic and diagnostic medical applications, for generation of electricity with nuclear reactors (fission now and fusion in the future), and for a large and diverse array of applications in industry. Approximately 80% of the total Federal support of basic nuclear research is provided through the DOE Nuclear Physics program. Thus, the Department of Energy has the primary responsibility for this important area of basic science and its role in high technology.

The broad scope of the Nuclear Physics research program requires a variety of accelerator facilities, experimental equipment, and manpower skills. Different aspects of the questions being asked by scientists are addressed by beams of low energy light ions, heavy ions, electrons, medium energy protons, and relativistic (very high energy) heavy ions. Additional information is obtained by use of secondary beams (created by impinging primary beams on suitable targets) of neutrons, pi mesons (pions), K mesons (kaons), muons, photons, neutrinos, and radioactive nuclei. The new scientific challenges now facing basic nuclear research require advanced accelerators designed to provide the beams needed for the research.

The devices needed for detection of the products emitted in nuclear reactions also vary widely. At low energies, solid-state detectors made of germanium or silicon and scintillation counters using large transparent crystals are common. At higher energies, arrays of wire proportional chambers, drift chambers, plastic scintillator hodoscopes, and Cerenkov radiation detectors are used. At all energies, the use of magnetic spectrometers for measuring the momentum of charged particles is vital. A substantial R&D effort is devoted towards developing new detector techniques, and a significant commitment of resources is required to develop the new detectors which are essential to the success of planned experiments. However, in the final analysis, the most important ingredient for success is the continued presence of skilled and imaginative scientists -- experimentalists and theoreticians -- dedicated to solving the mysteries of the nucleus. The Nuclear Physics program relies upon a strong university component to provide scientists for basic nuclear research and to help meet America's need for manpower with high technology skills.

Long range planning, scientific community input, and coordination of Department of Energy work with National Science Foundation (NSF) activities will continue to take place through a variety of channels. The most important of these channels are external and internal review of specific research areas, frequent staff contact with counterparts at NSF, and the work of the DOE/NSF Nuclear Science Advisory Committee (NSAC).

Program Highlights

The body of knowledge in basic nuclear research has grown systematically over the years. Old problems have been resolved, and new questions have been asked. The path to new knowledge has had its share of surprises and frustrations. Sometimes the intractability of the problems has virtually stifled advancement. In other cases, a theoretical breakthrough or availability of new facilities or equipment has led to rapid progress. Advanced knowledge of nuclear structure has been enhanced by the availability of intense beams of polarized protons and deuterons. The use of polarized beams allows the determination of spin parameters of nuclear excitations in addition to knowledge of energies and decay modes. Sophisticated new gamma-ray spectrometers have been or are being installed at the Oak Ridge National Laboratory, at Argonne National Laboratory, and at the Lawrence Berkeley Laboratory's 88-Inch Cyclotron. These are leading to a new wealth of data on the mechanism by which nuclei become platter shaped when spinning at very high rates.

It has long been recognized that mesons, especially pions, provide the cement that holds nuclei together. Recent measurement of the rate of production of pions in high energy nucleus-nucleus collisions at the Lawrence Berkeley Laboratory's Bevalac has once again emphasized their omnipresent role. At the Bevalac, enhanced production of kaons and reduced production of pions tested the models of absorption of mesons in nuclear matter. The systematic study of the interaction of beams of free pions with nuclear targets at the Clinton P. Anderson Meson Physics Facility (LAMPF) at the Los Alamos National Laboratory has been a mainstay of the LAMPF program. In recent LAMPF experiments, pions have been used in double charge exchange measurements to explore new symmetries in nuclear excitations. At the Holifield Heavy Ion Research Facility (HHIRF) at Oak Ridge National Laboratory, pions have been detected emerging from nuclear collisions at beam energies far lower than previously believed possible. At the Massachusetts Institute of Technology's Bates Linear Accelerator Center, the delta particle (a close association of pions, protons, and neutrons) has been calculated to be a significant component of nuclei. And at Brookhaven National Laboratory's Alternating Gradient Synchrotron (AGS), beams of kaons have been used to make new states in hypernuclear images of conventional nuclei. The role of mesons as nuclear constituents and their utility as nuclear probes continues to be an important component of nuclear physics research.

Beyond the mesonic description however, new theoretical concepts are opening the door to a more profound level of understanding. Neutrons and protons are now described as composites of quarks and gluons, while mesons are composites of quark-antiquark pairs. Nuclear theorists, along with high energy theorists, are investigating the ways in which quarks are confined together in "bags" of three to make up neutrons and protons. A more fundamental theory of the nuclear force is emerging based on the quantum chromodynamics (QCD) model of quarks and gluons. This new theory alters in ever expanding ways the concepts and phenomena of nuclear physics. Exploring these concepts requires higher energies than have been available to the Nuclear Physics program. The theory provides a microscopic view of the way that mesons perform their binding function in nuclei. A glimpse into the role that quarks play in nuclei is being pursued using electron beams at the off-axis injector at the Stanford Linear Accelerator Center. The Continuous Electron Beam Accelerator Facility (CEBAF) is expressly designed to examine the transition region from pion-dominated to quark-dominated effects. It will generate precise beams of high energy electrons that will probe the quark structure of nucleons embedded in finite nuclei.

Another very different approach into the role of quarks in nuclei will be made possible by the Tandem/AGS Heavy Ion Transfer Line project at Brookhaven's AGS accelerator. This facility upgrade, scheduled for start of experiments in FY 1987, will allow the AGS to accelerate atomic nuclei to energies of up to 14 billion electron volts per atomic mass unit (GeV/AMU). These beams will collide with massive nuclei at rest in the laboratory to produce hot, dense nuclear matter, relaxing the confinement conditions which prevent the quarks from escaping from their nucleonic bags.

At even higher energies, collisions of heavy ions would permit formation of a quark-gluon plasma, in which the quarks and gluons interact freely over the volume of the entire nucleus. Calculations simulating this plasma have been a major theoretical activity over the last few years. This plasma would create conditions in the laboratory which existed only a few millionths of a second after the "Big Bang" of creation. A preliminary glimpse into this area of physics will be provided by cooperative experiments at the CERN Laboratory in Geneva, Switzerland. In FY 1987, CERN plans two 17-day experimental running periods in which oxygen nuclei (16 atomic mass units) will be accelerated to energies up to 225 GeV/AMU. American scientists supported by the Nuclear Physics program are leaders in many of the experiments designed to capitalize on this window of opportunity.

Just as theory has made dramatic advances, so has the technology of accelerators and experiments improved. Superconducting linear accelerator elements have been designed, installed, and put into research use at the Argonne Tandem/Linac Accelerator System (ATLAS) at Argonne National Laboratory and are being installed at the University of Washington. New high-voltage capability is being installed at the Yale University tandem. A cyclotron using superconducting coils is being built at Texas A&M University using State of Texas funds and private Welch Foundation funds. A powerful, new electron-cyclotron resonance ion source at the Berkeley 88-Inch Cyclotron opens the way for acceleration of an extended range of heavy ion species, and an innovative metal vapor ion source at the Lawrence Berkeley Laboratory's SuperHILAC is providing a dramatic increase in the intensities of the heaviest nuclei. The program maintains a vigorous accelerator R&D effort to ensure that its facilities operate at maximum efficiency and scientific effectiveness.

Continuous Electron Beam Accelerator Facility

The highest priority for new construction in basic nuclear research in the United States is the Continuous Electron Beam Accelerator Facility (CEBAF). The FY 1987 request includes $25,000,000 for initiation of construction plus $6,250,000 in operating expense funds for continuation of supporting research and development. Total estimated cost of CEBAF construction is $236,000,000.

CEBAF will be a new, single-purpose facility for basic nuclear research. Its combination of continuous beam, high intensity, and high energy will be unique in the world. Thus, CEBAF's construction will be an important step in maintaining America's position of leadership in basic nuclear research. It will be operated as a user facility attracting a worldwide community of nuclear scientists. The central instrument of CEBAF will be a high intensity, high duty factor electron accelerator with an energy range of 0.5-4.0 billion electron volts (GeV). The construction project includes an initial complement of experimental equipment and support facilities necessary to perform scientific experiments using CEBAF's high-quality electron and photon beams.

Upon completion of construction, scientists can investigate the ways in which the quarks bound in neutrons and protons influence the makeup and behavior of nuclei, determine how quarks interact while embedded within nuclear matter, and test quantum chromodynamics as the fundamental theory of the strong nuclear force. Experiments in which electrons knock protons or neutrons out of nuclei will yield information about how energy and momentum is distributed among the nucleons (generic name for neutrons and protons) bound inside nuclei and will tell us about correlations among nucleons in nuclei. At the high energy limit of electron scattering, experiments are, to a good approximation, only sensitive to effects of electrons scattering from individual quarks within the nuclei. Under these circumstances, nuclei can be described as a loose collection of free quarks. At energies below 1 GeV, electron scattering from nuclei can accurately be described as electrons scattering from the protons, neutrons, and mesons known to be in nuclei. The energy capability of CEBAF would permit quantitative examination of the transition between these complementary descriptions of nuclei.

The requested $25,000,000 in FY 1987 construction funds is essential for a timely construction project schedule. Specific FY 1987 construction activities will include: (1) acquisition of the Space Radiation Effects Laboratory building site in accordance with Executive Order 12348 and in compliance with regulation 41 CFR Part 101-47; (2) architectural and engineering work; (3) site preparation and utilities including AC power distribution equipment; (4) rehabilitation of existing structures; (5) start of construction on one of the tunnels which will house the linac; (6) engineering and design work on accelerator components, helium refrigerators, and cryogenic systems; and (7) acquisition of initial components of the accelerator. The requested $6,250,000 in operating expenses is necessary for continuation of work to optimize design of CEBAF's cryogenic and helium refrigerator systems, beam extraction systems, accelerator components, and control systems. FY 1987 research and development work will include fabrication and testing of prototypes of critical accelerator and cryogenic subsystems. Also, the FY 1987 R&D effort will include detailed planning for CEBAF's initial complement of research equipment.

Accelerator Facility Operations

The Nuclear Physics program requires the existence and effective operation of large and complex accelerator facilities. These facilities provide the variety of projectile beams upon which virtually all experimental nuclear research depends. Their capabilities determine which experiments can be performed.

Seven accelerator facilities are operated by the Nuclear Physics program as national facilities. These facilities are made available to all the nation's scientists on the basis of scientific merit and technical feasibility of proposals. These national facilities are: the Clinton P. Anderson Meson Physics Facility (LAMPF) at Los Alamos National Laboratory (LANL); the Bates Linear Accelerator Center at Massachusetts Institute of Technology (MIT); the SuperHILAC/Bevalac at Lawrence Berkeley Laboratory (LBL); the Holifield Heavy Ion Research Facility at Oak Ridge National Laboratory (ORNL); the 88-Inch Cyclotron at LBL; the Tandem/Linac Facility at Argonne National Laboratory (ANL); and the Double MP Tandem Van de Graaff facility at Brookhaven National Laboratory (BNL). The off-axis injector at the Stanford Linear Accelerator Center (SLAC) is now operational and serves the nation's scientists on the same basis as a national facility. Upon completion of the Tandem/AGS Heavy Ion Transfer Line construction project, heavy ion beams accelerated by BNL's Alternating Gradient Synchrotron (AGS) will also be available, beginning in FY 1987, on a national facility basis.

In addition to its internal research program, each of the national facilities accommodates major university-based user group research programs. Typically, an outside user group plans experiments, fabricates detectors and other instrumentation at the home institution, executes and partially analyzes experiments at the national facility, and then completes analyses and publication of results at the home institution. Nuclear Physics directly supports 70 university-based user groups who conduct most or all of their research at these national facilities.

To complement the national facilities, the Nuclear Physics program supports on-campus accelerators at Yale University, Duke University, University of Washington, and Texas A&M University. The Duke Cyclograaff serves a consortium of three universities (Duke University, University of North Carolina of Chapel Hill, and North Carolina State University) called the Triangle Universities Nuclear Laboratory. While each of the on-campus facilities has an important visitor program, these accelerators are operated principally for the research use of the host university's faculty, junior scientists, and graduate students.

In FY 1987, a total of $93,330,000 in operating expenses is requested for operation of accelerator facilities. In FY 1987, the national facilities are expected to have an overall utilization factor of 55%, approximately the same as in FY 1985. Within the FY 1987 accelerator operations total, $1,800,000 is budgeted for 900 beam hours of SLAC injector operations for nuclear research, and $8,670,000 is budgeted for AGS/Tandem facility operations. Also, in the FY 1987 operating expenses request, $71,070,000 is planned for experimental research and $10,500,000 for theoretical research. Within this experimental research total, $260,000 is budgeted for E. O. Lawrence ($60,000) and Enrico Fermi ($200,000) Awards.

Of the total FY 1987 operating expenses request, $44,372,000 is planned as direct support to the university program including university-based users of American and international facilities, accelerator operations and research at on-campus facilities (including MIT Bates), advanced accelerator technology research at MIT, continuation of research and development in support of the CEBAF construction project, and research by university-based theorists.

Additional support to the university program, in an amount comparable to the direct support, is provided through the accelerator centers in the form of services in support of experiments by university scientists and delivery of particle beams to these experiments. The Nuclear Physics program supports numerous research contracts in which there is substantial cost sharing by the universities. The universities' contributions are provided by a number of mechanisms -- for example, salaries to investigators, provision of work space, local machine shop time and labor, computer time, and equipment. The Nuclear Physics program encourages such cost sharing policies to achieve maximum utilization of available Federal funds.

	FY 1985	FY 1986	FY 1987 Request
Medium Energy Nuclear Physics .n.............	$ 73,810	$ 73,131	$ 85,000

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 an international community of scientists including those from more than 100 American institutions, of which over 90% are universities.

Of the accelerators for which operations support is provided under Medium Energy, the largest nuclear physics program is carried out at LAMPF. The facility is centered around a linear accelerator which is capable of accelerating very intense beams of protons to 800 MeV. A primary role of this facility is to provide intense secondary beams of pions, muons, neutrons, and neutrinos. The ability to provide 10 or more simultaneously operating beams of protons, neutrons, pions, muons, or neutrinos enables LAMPF to be a highly cost-effective basic nuclear research facility. In addition to providing beams for nuclear research, LAMPF provides beams for basic materials research and weapons development at the Weapons Neutron Research (WNR) facility.

The other accelerator facility entirely supported under the Medium Energy subprogram is the Bates accelerator facility. The accelerator is capable of producing electron beams of excellent quality at energies up to 750 MeV. The Bates nuclear research program emphasizes high resolution nuclear structure studies with electrons and studies of the momentum distribution of neutrons and protons moving inside nuclei. Bates is the premier facility in the world for nuclear structure studies involving high resolution electron scattering.

The High Energy Physics electron accelerator at the Stanford Linear Accelerator Center (SLAC) is now also operated on a part-time basis for nuclear physics research using an off-axis source and injector. SLAC operations for nuclear research are supported under the Medium Energy subprogram. In FY 1987, 900 beam hours are planned for nuclear research.

Research activities in medium energy nuclear physics range over an extremely broad selection of topics, including studies of: the fundamental symmetries of nature; distribution of electric charge and magnetic fields inside nuclei; interactions of protons, mesons, and neutrons with nuclei; neutrino oscillations and the neutrino mass; interactions between nucleons; and nuclear structure.

An ultimate goal of all nuclear physics is a complete description of the fundamental particles and forces of nature. Recently, theoretical descriptions of the electromagnetic and weak forces have been unified. This means that these two seemingly disparate interactions have been shown to be different manifestations of the same, basic "electroweak" force. This represents a giant step along the road towards this ultimate goal.

The electroweak interaction actually has three manifestations: the familiar electromagnetic interaction, the charged weak interaction responsible for beta decay, and the neutral weak interaction recently discovered in neutrino scattering. One of the most striking predictions of the "standard model" of the electroweak interaction is that in the elastic scattering of electron-type neutrinos from electrons, the charged and neutral weak interactions will destructively interfere so that the probability of such scattering will be less than that expected if neutral weak interactions were not present. However, prior to a recent LAMPF experiment, the elastic scattering of electron-type neutrinos from electrons had not been observed, mostly because there have been no appropriate sources of these neutrinos. (Note that neutrino-electron elastic scattering is an extremely rare process.) At the LAMPF beam stop (a strong source of electron-type neutrinos), nuclear physicists mounted a large experiment to detect the elastic scattering and measure the interference. The detector is a 15-ton sandwich of scintillation counters and flash chambers specifically designed to detect the recoil electron from elastic scattering and to discriminate against background processes. During the first run of the experiment, 1.6×10^{19} neutrinos passed through the apparatus and 20 neutrino-electron elastic scattering events were detected. This number agrees with the standard model prediction with destructive interference. This experiment paves the way for two other major neutrino experiments in preparation at LAMPF. In FY 1987, execution of neutrino experiments will have a high priority within the overall LAMPF research program.

The nuclear force between protons and neutrons (nucleons) in atomic nuclei has long been understood to be dominated by the exchange of bound mesons, with the pi-meson (or pion) being by far the most important in determining the nature of the nuclear force. Pions can also be produced in a free state, and their properties can be directly measured. When a free pion with an energy of a few hundred MeV interacts with a nucleon it often forms a new particle named the delta. The properties of these particles are well described within a theoretical framework of quarks and gluons; the nucleons contain three quarks each and the mesons are composed of quark-antiquark pairs. In this framework, the delta has a particularly simple structure, closely related to that of the nucleon; it consists of three quarks but with a simple rearrangement of quark spins. Introducing a free pion into an atomic nucleus thus can change the quark structure of that nucleus and permit the exploration of quark effects within the many-body nuclear system. Recent work by a collaboration of university and laboratory scientists using LAMPF has provided new information on how introduction of a pion into a nucleus modifies the quark structure of that nucleus. Earlier experiments had indicated that the introduction of the pion into the nuclear medium leads to two possible reaction processes. A free pion may be reemitted, in a process that seems to occur primarily in the outer fringes of the nucleus where a delta is formed on one of the nucleons and subsequently decays back into a nucleon and a pion. Alternatively, the pion may simply disappear, absorbed in the sea of bound pions in the nuclear medium, giving up its mass and energy to nuclear excitation. Such an absorption process also starts with a delta, perhaps in a region of higher nucleon density further inside the nucleus, where the delta interacts with other nucleons and eventually turns back into a nucleon without ever reemitting a free pion. It had been thought for a long time that, in an absorptive interaction, the delta would interact with only one other nucleon with the original energy of the pion eventually shared among only two final nucleons. The recent LAMPF work has shown that, in heavy nuclei, the number of nucleons participating in a pion absorption reaction is typically four. The quark substructure of nucleons is showing itself here, but a full explanation is just beginning to emerge. In FY 1987, investigations of the ways in which pions interact with nuclei and studies of the formation and motion of deltas inside nuclei will continue to be a major theme of LAMPF research.

The users of the facilities of the MIT-Bates Linear Accelerator Center are engaged in a systematic study of nuclear dynamics by exploiting the known properties of the electromagnetic field to probe the detailed behavior of nuclear charges and currents. The electromagnetic field is carried by high energy beams of electrons and photons of high intensity and precision to nuclear targets located in two principal experimental areas. The nuclear interactions are studied by means of a complex of magnetic and other spectrometer systems which detect the scattered electrons and photons and/or the reaction products which include protons, mesons, deuterons, and alpha particles. Systems to detect neutrons are in development. By selecting the energy of the incident beam and the direction, energy, and nature of the detected reaction products, it is possible to answer with great specificity questions about different aspects of nuclear dynamics. The data thus obtained provide the least ambiguous tests of and guidance for the development of nuclear theory. With the upgrade of experimental facilities at Bates, a whole new class of studies has begun. These are broadly distinguished by the detection of a strongly interacting particle in the final state, sometimes with an associated scattered electron. Whereas earlier studies were concerned primarily with the distribution in space of nuclear stationary states, these new programs are designed to study, among other properties, the momentum distribution of nucleons moving inside nuclei. In a study of electron scattering from carbon nuclei, scientists working at Bates have observed significant departures from the expectations of a single nucleon knock-out picture and see evidence for correlated two-nucleon motion.

The best quantitative measurements for testing the theory that protons and neutrons are made up of quarks come from precision scattering experiments carried out with various high energy beams of electrons or muons. Results of these precision scattering experiments have given detailed information about the quarks and their motion inside the proton and neutron. Recently, the European Muon Collaboration (EMC) at CERN used muon beams to bombard nuclei spanning the periodic table from hydrogen to uranium. Researchers observed that the high energy muons scattered differently from the quarks bound inside nuclei than from the quarks in free protons and neutrons. This unexpected observation, called the EMC effect, has been verified with high precision by more recent work at CERN and at the Stanford Linear Accelerator Center. Several different theoretical models have been proposed to explain the EMC effect, such as (1) an increased size of the three-quark bag (nucleon) within the nucleus; (2) the existence of six-quark bags within the nucleus; (3) enhancement of the number of pions within the nucleus; and (4) conventional nuclear structure effects from momentum and binding energy distributions. Since each of these theoretical models can explain the existing electron and muon data, it is important to test with further experiments the differences identified in the various models. A set of complementary nuclear physics studies using medium energy and high energy particles as probes will investigate phenomena arising from the larger variety of configurations available to quarks in heavy nuclei as compared to configurations in individual nucleons.

In FY 1987, $85,000,000 in operating expenses is requested for the Medium Energy Nuclear Physics subprogram. The costs of facility operations at the LAMPF, Bevalac Bates, and SLAC facilities require 62% of the FY 1987 Medium Energy Nuclear Physics request. In addition to supporting the operation of the accelerators themselves, these operations costs also provide for the maintenance and operation of secondary beam lines, major spectrometer systems, and other permanently installed experimental equipment. The remaining 38% of the budget supports costs directly attributable to executing individual experiments, support of participating research scientists, R&D in support of the Continuous Electron Beam Accelerator Facility construction project, and advanced accelerator physics studies. Of the total operating expenses request in FY 1987, $25,285,000 will be for direct support of university research programs, including the Southeastern Universities Research Association (SURA). In addition, much indirect support is provided by the accelerator facilities at which much of this research is performed.

To operate the LAMPF facility in FY 1987, $42,920,000 is required. This total will permit LAMPF to operate 2800 beam hours for research. In addition to these operations costs, $10,900,000 is required for the conduct of research at LAMPF by Los Alamos scientists and by outside user groups, including university groups.

To operate Bates in FY 1987, $6,440,000 is required, and in addition $3,000,000 is required for the conduct of research at Bates by MIT scientists and outside user groups. Operation of the SLAC nuclear physics injector and associated experimental area requires $1,800,000 in FY 1987, with an additional $1,200,000 being budgeted for support of outside groups using the facility. R&D activities by SURA in support of the CEBAF project will require $6,250,000 in FY 1987.

Medium energy nuclear physics research, including the university component, using kaons from a separated secondary beam at the Brookhaven AGS will continue as an important component of this subprogram and will require $3,500,000 in operating expenses in FY 1987. Other Medium Energy activities for FY 1987 include: research at unique foreign facilities; research using polarized, tagged photons at the National Synchrotron Light Source (NSLS); advanced accelerator research and development projects at the National Bureau of Standards, MIT, and LANL; and Fermi Awards. For these research activities, $8,990,000 is requested in FY 1987.

	FY 1985	FY 1986	FY 1987 Request
Heavy Ion Nuclear Physics	$ 49,008	$ 50,150	$ 63,700

The Heavy Ion subprogram supports accelerator facilities and research programs that cover a broad range of topics which are currently expanding our knowledge about the properties of nuclear matter. In combination, these facilities based at national laboratories and major universities provide beams of atomic nuclei ranging in mass from lithium to uranium and in energy from a few MeV to several hundred thousand MeV. In general, each accelerator complex provides beams and experimental facilities for in-house research groups as well as a nationwide community of scientists who travel to the host laboratory to conduct their research. The program makes use of unique properties of heavy ion beams for developing research in such diverse areas as microscopic nuclear properties, macroscopic nuclear interactions, and searches for exotic phases of nuclear matter predicted by theory.

In late FY 1986, the Tandem/AGS Heavy Ion Transfer Line construction project at Brookhaven National Laboratory (BNL) will be completed. In FY 1987, implementation of research programs to study relativistic heavy ion collisions with this new facility in a previously inaccessible energy regime is the highest priority in the Heavy Ion subprogram. The Transfer Line couples the BNL Tandem and Alternating Gradient Synchrotoon (AGS) accelerators to provide heavy ion beams up to energies of 14 billion electron volts per atomic mass unit (GeV/AMU) for atomic nuclei up to mass 32 AMU (sulfur). This AGS/Tandem facility will provide beams approximately seven times more energetic than have been previously available anywhere in the world. Research programs in FY 1987 will allow scientists to enter the regime of energy and mass density which could lead to the production of states of nuclear matter which have never before been observed. In FY 1987, the development of detectors and experimental programs at BNL which were begun in FY 1985 will continue. First experiments will be performed during the 1000 hours of beam time planned for FY 1987. Effort will be given to the development of the accelerator complex so that it can provide the variety of beams with characteristics necessary to support the proposed research programs. Both the research and accelerator programs draw heavily on previous experience with heavy ions at lower energies and on experience from High Energy Physics programs. At Lawrence Berkeley Laboratory (LBL) a vigorous research program on heavy ion collisions will continue utilizing beams with masses up to 238 AMU (uranium) and energies up to 2.1 GeV/AMU from the SuperHILAC/Bevalac accelerator complex. The Bevalac remains unique in its capability for providing high energy beams of the heaviest nuclei.

Very active research programs utilizing lower energy heavy ion beams (5-25 MeV/AMU) are supported by complementary facilities at Argonne National Laboratory, Oak Ridge National Laboratory, and Lawrence Berkeley Laboratory (ANL, ORNL, and LBL). At ANL, the new ATLAS facility with its superconducting linac will begin full operation in FY 1986 and provide medium mass heavy ion beams with very precise energy and excellent time profiles for use in a new generation of experiments. The Holifield Heavy Ion Research Facility at ORNL is a state-of-the-art tandem accelerator (designed to achieve 25 million volts on the terminal) coupled with the Oak Ridge Isochronous Cyclotron. The Holifield facility provides precision beams and a wide variety of projectiles. The LBL 88-Inch Cyclotron supplies beams of light to medium mass heavy ions. Its capabilities have been enhanced significantly by the recent addition of an Electron Cyclotron Resonance ion source. This source provides a broad selection of highly charged heavy ion species which can be accelerated to energies appropriate for nuclear studies. This facility is complementary to the tandem facilities because, unlike the ANL and ORNL facilities, the 88-Inch Cyclotron uses positive ions throughout its acceleration cycle. Each of these national laboratory-based accelerators is operated as a national facility. Access to machine time and experimental equipment is open to all qualified scientists on the basis of proposals reviewed for scientific merit and technical feasibility. In addition to the national laboratory accelerators, state-of-the-art facilities are shared with the Low Energy Nuclear Physics subprogram at three universities--Yale University, University of Washington, and Texas A&M University. Each of these accelerators provides a combination of light ion and heavy ion beams, and each of the three university facilities is being upgraded to provide additional research capability. These projects and the research that they will make possible are discussed under Low Energy Nuclear Physics.

The heavy ion beams from these accelerator facilities are used in a wide range of nuclear research programs. At one extreme, heavy ion reactions can produce a broad spectrum of nuclei with precise values of excitation energy and angular momentum for systematic studies of the properties of nuclei near their normal ground states. At another extreme, heavy ion collisions can produce for a brief instant small amounts of nuclear matter at temperatures and densities far from those of normal stable nuclei.

Many forefront spectroscopic studies of nuclear properties concentrate on experiments that measure the shapes of nuclei as their angular momentum and excitation energy are changed. This area is currently undergoing a renaissance as a result of major improvements in capabilities and sophistication of new gamma ray detection facilities. At ORNL, studies of the gamma ray decay of the Giant Quadrupole Resonance has led to new information on the shapes and structure of low-lying excited states in a variety of nuclei. These resonances correspond to a particularly simple class of nuclear excitations which arise from large scale oscillations of the nuclear surface. Precise studies of their decay modes give new insights into the underlying structure of the excited nuclei. Utilizing sophisticated new gamma ray detector arrays, scientists at LBL have been able to extend their studies of the nuclear shape transitions that occur at high spins, thus providing sensitive new tests for nuclear models.

Recent progress at Lawrence Berkeley Laboratory's Bevalac includes the first experimental determination of the compressibility of hot nuclear matter by studying the emission of pions from colliding nuclear systems. LBL scientists also made the first measurement of hydrodynamical flow effects in heavy ion collisions. Recent experiments have used the Plastic Ball detector to detect and measure over one hundred particles simultaneously emitted when nuclei accelerated to high energy collide with nuclei stationary in the laboratory. These programs mark the beginning of quantitative studies to determine the equation of state of hot, dense nuclear matter. Research of this type is essential for providing the overall framework within which experiments at higher energies can be planned and interpreted. Information on the equation of state for nuclear matter provides the input necessary to the theoretical models of stellar evolution leading to supernova explosions and neutron stars.

In FY 1987, the first particle beams with very high energies will become available at Brookhaven National Laboratory. Brookhaven's Tandem/AGS facility will deliver beams of nuclei as massive as sulfur (mass = 32 AMU) and with energies up to 14 GeV AMU. The extreme nuclear conditions created using these beams may yield the first identifiable relaxation of the quark confinement conditions in nuclear matter. The first major heavy ion experiment at the Brookhaven facility is based on a single-arm magnetic spectrometer with high-multiplicity tracking and particle identification. Characteristics of hot dense nuclear matter will be obtained by measurement of effective temperatures and reaction cross sections. A second major experiment involves a Time Projection Chamber mounted in a large volume magnet. This system is designed to measure essentially all charged particles emerging from collisions to look for rare events that would indicate the onset of quark deconfinement.

At energies of tens of billions of electron volts per atomic mass unit and above, heavy ion central collisions may create an entirely new form of matter called a quark-gluon plasma. At sufficiently high temperatures and densities, it is expected that the nucleons which are the normal constituents of nuclei will dissolve into a plasma consisting of their internal substructures, the quarks and gluons. This plasma will then rapidly expand and decay into large numbers of more familiar nuclear constituents--nucleons and mesons. A vigorous theoretical effort is under way to specify the experimental signatures of this state of nuclear matter. These theoretical studies will guide experiments in distinguishing desired events from more prolific background processes. In addition to their value to basic nuclear research, present and planned research on properties of hot, dense nuclear plasmas are becoming increasingly relevant for understanding how our universe behaved in the first instants after the "Big Bang."

At the Super Proton Synchrotron (SPS) at CERN two 17 day running periods are planned with 50 GeV/AMU and 225 GeV/AMU beams of oxygen (16 AMU). Nuclear Physics-supported scientists are leading participants in several CERN experiments which are designed to get a first glimpse of the evidence of a phase transition of nuclear matter to a quark-gluon plasma. These new research efforts involve large collaborations involving university and national laboratory groups from the United States, Europe, and Japan and from both the Nuclear Physics and High Energy Physics communities.

The highest priority effort in FY 1987 in the Heavy Ion Nuclear Physics subprogram will be initiation of heavy ion nuclear research at the AGS. The Heavy Ion operating expenses request includes $8,670,000 for AGS/Tandem facility operations. Of the Heavy Ion total request, $25,680,000 supports research activities; the remaining $38,020,000 request is for facility operations. Also included is $2,000,000 for advanced accelerator R&D at Brookhaven National Laboratory for the heavy ion program. This accelerator R&D program is expected to define the parameters of a facility dedicated to production and examination of the quark-gluon plasma. Of the $25,680,000 request for research funds, $6,525,000 is planned as direct support to universities. Additional university support is provided through the national laboratories in the form of services in support of experiments and provision of beam time.

Of the $38,020,000 requested for accelerator facility operations, $18,540,000 is budgeted for operation of the Bevalac; $8,670,000 is requested for operation of Brookhaven's Tandem/AGS accelerator complex; and $9,315,000 is requested for operation of ATLAS, the 88-Inch Cyclotron, and Holifield. For heavy ion operations at accelerator facilities at Yale University, Texas A&M University, and the University of Washington, $1,495,000 is planned.

The accelerator facilities whose operations are supported by the Heavy Ion subprogram also provide unique capabilities for fundamental research in other fields of physics. Important recent examples include atomic physics studies of one-electron atoms for nuclei as heavy as uranium at the Bevalac and studies of the behavior of highly ionized atoms at low velocities using a novel acceleration-deceleration mode with the two tandems at BNL. Nuclear fragmentation studies at the Bevalac are providing important data for the interpretation of cosmic-ray results. Heavy ion accelerator facilities also have important applications in biomedical research and human cancer therapy. Bevalac heavy ion beams are used to evaluate the effectiveness of heavy ions in destroying human cancer cells while doing minimum damage to intervening healthy cells. This research is supported and managed by the National Cancer Institute and the Department's Nuclear Medicine Applications subprogram in the Biological and Environmental Research programs. (All facility operations costs of the Bevalac, including those for biomedical research, however, are supported by the Nuclear Physics program.)

	FY 1985	FY 1986	FY 1987 Request
Low Energy Nuclear Physics	$ 13,322	$ 12,087	$ 15,700

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 subprogram. In FY 1987, 34% of operating expenses is planned for direct support of university research. FY 1987 marks the initiation of research programs based on major upgrades at each of Nuclear Physics' four dedicated on-campus accelerator facilities. These upgrades include major additions and improvements to the accelerator facilities at the University of Washington and Yale University, a new booster cyclotron at Texas A&M University, and high intensity polarized ion sources at Duke University and the University of Washington.

Nuclear research at the University of Washington will be greatly strengthened when the new superconducting linac booster becomes available in late FY 1987. The booster has been optimized for the acceleration of light ions and heavy ions up to about mass 60 AMU. The new polarized ion source will make possible a wide variety of high precision particle and photon asymmetry measurements for parity violation studies, electromagnetic multipole-mixing determinations, and those polarization measurements which are sensitive probes of nuclear reaction mechanisms. The booster will also make it possible to generate pulsed, monoenergetic neutron beams which can be used to study the E2 isovector giant resonance and other high-lying resonances in a variety of nuclei.

The upgrade of the Yale facility, scheduled for completion in September 1986, will provide an substantial increase in the range of ion energies and masses available for experiments. The anticipated maximum terminal voltage of 22.5 million volts will make it possible to study properties of much heavier nuclear systems with higher excitation energies and more angular momentum. To distinguish more precisely between electric and magnetic transitions in heavier nuclei, a mini-orange-type electron spectrometer is under development for on-line direct detection of conversion electrons. Yale also plans to construct a "silicon box" detector, consisting of a large solid-angle array of semiconductor charged-particle detectors, which will be used to study the excitation spectrum of heavy nuclei by coincidences between gamma rays.

Completion of the construction of a K=500 superconducting cyclotron at Texas A&M University late in 1986 will permit expansion of experimental capabilities there. The new cyclotron, whose construction has been funded by the State of Texas and the private Welch Foundation, will be used alone or as a heavy-ion injector for the existing K=147 cyclotron. The energy range that will be made accessible by coupled operation of the two cyclotrons will provide unique opportunities at Texas A&M. For example, it will permit the production of a high-resolution polarized neutron beam in the 100-160 MeV range that can be used to investigate (n,p) charge exchange reactions and to determine Gamow-Teller matrix elements. They will emphasize nuclei that are candidates for double beta decay which provide sensitive tests of non-zero neutrino masses. These neutron beams will also be used to determine the parameters of neutron-proton scattering in the 80-160 MeV neutron energy region where few reliable measurements exist. The availability of higher energy alpha particle beams, 200-300 MeV, will greatly enhance studies of giant resonances and will permit the creation of rare, unstable nuclides that have not been available for studies heretofore.

The high-intensity polarized ion source at the Duke University accelerator facility will provide an increased intensity that can be used to great advantage in the current experimental program of measurements using polarized protons, deuterons, and polarized neutrons. Polarized neutron experiments, which use secondary beams of neutrons derived from reactions induced by polarized deuterons, will greatly benefit from the more intense beams of deuterons made available by the source. Especially enhanced will be the research using polarized neutrons incident on a cryogenic polarized target. The effects of neutron-nucleus spin-spin forces that are one of the main objects of study are predicted by nuclear theory to be much smaller than the spin-independent forces. Use of the new source should reduce running times for these experiments by a factor of 10. Tests of fundamental symmetries, such as parity conservation and time reversal invariance, are also planned using the polarized target and new polarized ion source.

The conversion of hydrogen to helium by nuclear fusion in the deep interior of the sun is believed to be the primary source of solar energy. Neutrinos are the only particles that escape directly from the solar interior, and thus they provide the only immediate probe of the deep interior of the sun. A unique experiment by Brookhaven scientists, employing a chlorine detector designed to measure the flux of neutrinos from the sun, discovered that the number of neutrino-induced events is about a factor of three lower than one expects from models that correctly reproduce other properties of the sun. This observation implies either that we do not have an adequate understanding of the nature of processes or conditions inside the sun, and hence of stellar processes in general, or that we do not have an adequate understanding of the neutrinos.

An August 1985 report of the NSAC Solar Neutrino subcommittee discussed several alternative experimental approaches for obtaining increased information, including the capture of neutrinos on gallium-71. International collaborative experiments are being formulated to resolve this solar neutrino puzzle.

The low-energy nuclear physics subprogram also supports light-ion research at the LBL 88-Inch Cyclotron, ORNL, and ATLAS. At the 88-Inch Cyclotron, light nuclei far from stability are studied with an on-line mass analysis system. Nuclear scientists are searching for nuclei near the proton and neutron limits of particle stability that may decay by new radioactivities such as beta-delayed two-proton decay. At Oak Ridge, physicists are investigating the mechanisms by which nuclei are excited into giant resonance states and the properties of giant resonance states. At ATLAS, research teams are using proton and other light-ion beams to determine electroweak interaction parameters in nuclei. For example, a high-precision measurement to study the vector-coupling coefficients in 0^+ to 0^+ Fermi decay will be undertaken using the reaction $^{10}B(p,n)^{10}C$.

In FY 1987, $15,700,000 in operating expenses is requested for the Low Energy subprogram. Of this total, $1,500,000 is requested for solar neutrino research and $4,285,000 is budgeted for research and operations at the four dedicated on-campus accelerator facilities to permit them to make productive use of their expanded capabilities. For other university-based research, $1,017,000 is requested. For low energy nuclear research and facility operations at the national laboratories, Small Business Innovation Research, and the Lawrence and Fermi Awards, $8,898,000 is requested in FY 1987.

	FY 1985	FY 1986	FY 1987 Request
Nuclear Theory	$ 9,300	$ 8,999	$ 10,500

Nuclear physics deals with phenomena submicroscopic in origin. It is therefore particularly dependent on theory for the interpretation of experimental results. More importantly, the field is motivated to consider many new exciting experimental possibilities based on the ideas generated and developed by theorists. Questions of how quark substructure of the nucleus might be manifested in experiments at the planned electron machine (CEBAF) or how a phase transition to the quark-gluon plasma would be seen in high energy heavy ion collisions are just two of the exciting new directions.

The Nuclear Theory subprogram is strongly interactive with all three experimental Nuclear Physics subprograms: Medium Energy, Heavy Ion, and Low Energy. Major theory efforts are supported in each of the institutions at which the Nuclear Physics program's national accelerator facilities are sited: Massachusetts Institute of Technology, Argonne National Laboratory, Brookhaven National Laboratory, Los Alamos National Laboratory, Lawrence Berkeley Laboratory, and Oak Ridge National Laboratory.

In addition, a larger number of theoretical nuclear physicists are supported at 28 universities across the nation. In FY 1987, $5,765,000, 55% of the total amount, is budgeted for direct support of university-based nuclear theory programs.

At the heart of much of nuclear theory research is the nuclear many-body problem. Although crucial breakthroughs that allowed the development of a theory of strong interactions occurred three decades ago, only recently have the technical difficulties been sufficiently overcome to allow separation of two-body and three-body effects in nuclear matter calculations. This achievement occurred through years of development of mathematical techniques by theorists, and through the increasing access to supercomputers by the nuclear theory community] In FY 1985 over 1000 hours of supercomputer time was made available at the MFE Computer Center at Livermore by Energy Research's Office of Scientific Computing for nuclear physics research, and more than 2500 hours will be available at Livermore and at SCRI at Florida State University in FY 1986.

Special relativity has been found to play a much more important role in nuclear matter and proton-nucleus scattering than previously expected. Recent results in nuclear theory show that, even at low energies, the traditional nonrelativistic nucleon-nucleus potential may be better described in terms of a relativistic theory. Effects of very-short-lived particle-antiparticle pairs are new phenomena predicted by the relativistic theory. These effects are especially important in the calculation of antiprotons as they react with stable nuclei. Another rapidly developing aspect of nuclear-matter theory relates to nuclear astrophysics. Knowledge of the nuclear equation of state, in particular the compressibility of nuclear matter, determines our ability to understand collapsing stars as they consume all of their nuclear fuel. Astrophysical calculations require that nuclei have a "soft" equation of state (very easily compressed) in order to bounce back from a gravitationally driven implosion, creating a shock wave that may lead to a supernova explosion. Results from high energy heavy ion collisions, however, indicate that nuclear matter is very "hard." This disparity leads to a distinct, unresolved scientific dilemma.

Attempts to understand how quarks, gluons, and their interactions determine the makeup and behavior of nuclei will be a central theme of nuclear theory in FY 1987. The basic underlying theory of quarks is known to be quantum chromodynamics (QCD) but the implementation of this theory in the prediction of properties of nuclei is challenging. In all experiments so far, quarks have been found together only in triplets or in quark-antiquark pairs, never alone. The theoretical implication of that experimental result is that quarks are confined and can never be isolated. An outstanding problem of nuclear and high-energy theory is how to generate such a confining force from QCD. Current development of quark models incorporating phenomenological confinement provides physical insight and suggests that a full quark description of nuclei will eventually be obtained. Nuclear theorists bring their particular expertise in many-body physics to the problem of understanding how the behavior of quarks in a nucleus of many nucleons differs from the behavior of quarks in a single neutron or proton.

A recent intriguing result from nuclear theory is that at sufficiently high temperature and pressure a nucleus can change character from being primarily triplets of quarks confined within nucleons into a quark-gluon phase. The entire nucleus becomes, in effect, the confining region, with the quarks released from the individual nucleon to form a "quark-gluon plasma." Such a transition is predicted to occur in nucleus-nucleus (heavy ion) reactions at sufficiently high energy. One problem that is currently challenging theorists is to determine an experimental signature of the phase transition from nuclear matter to a quark-gluon plasma.

In FY 1987, $10,500,000 in operating expenses is required for Nuclear Theory to provide the essential underpinning of theory for the new experimental initiatives discussed earlier in the Medium Energy, Heavy Ion, and Low Energy subprograms. New and basic theoretical developments can point the way to new experiments and complex experimental results must be interpreted and understood in terms of fundamental theory. Development of QCD into a precise, quantitative description of the strong nuclear force, and then into a quantitative description of nuclear interactions and structure is indeed a worthy challenge to nuclear theorists.

	FY 1985	FY 1986	FY 1987 Request
Capital Equipment	$ 12,700	$ 13,403	$ 16,000

Capital equipment funds are needed to provide for instrumentation to improve performance of Nuclear Physics accelerators for particle detection systems, and for data acquisition and analysis systems. These funds are essential for effective utilization of the national accelerator facilities operated by the Nuclear Physics program. In FY 1987, $14,770,000 in programmatic capital equipment funds is required for Nuclear Physics research initiatives and for maintenance of the overall productivity of the Nuclear Physics program. In addition, $1,230,000 is requested for general purpose equipment at Lawrence Berkeley Laboratory (LBL), for which the Nuclear Physics program has laboratory-wide landlord responsibility. Of the $14,770,000 requested for programmatic capital equipment, $4,600,000 is requested for Brookhaven National Laboratory (BNL), primarily in support of heavy ion nuclear research at the AGS; $2,630,000 is requested for Los Alamos National Laboratory (LANL) in support of LAMPF experiments and accelerator operations; and $2,840,000 is planned for experiments and operations at the Lawrence Berkeley Laboratory (Bevalac and 88-Inch Cyclotron). The remaining $4,700,000 is budgeted for the ATLAS facility at Argonne National Laboratory (ANL), the Bates Linear Accelerator Center at the Massachusetts Institute of Technology (MIT), the Holifield Heavy Ion Research Facility at Oak Ridge National Laboratory (ORNL), and Nuclear Physics programs at Duke University and the Stanford Linear Accelerator Center (SLAC).

Nuclear physics research requires carefully prepared beams of protons, neutrons, antiprotons, pions, kaons, muons, photons, electrons, and massive nuclei (such as oxygen, sulfur, iron, gold, and uranium). Detection and interpretation of the results of collisions of these probes with target nuclei requires scientific instrumentation at the limits of present day technology. In addition, the new scientific questions being asked are more discerning and thus require experiments of greater sophistication. An example of this occurs in the field of relativistic heavy ion nuclear physics, where large, fine-grained detector systems must be constructed to confront the complexity of energetic heavy ion reactions in which hundreds of fragments are produced in a single collision.

At Brookhaven National Laboratory, the Tandem/AGS Heavy Ion Transfer Line construction project is creating the opportunity for an exciting experimental program with 14 GeV/AMU beams of heavy ions. Particle beams as massive as sulfur (32 atomic mass units) will be available in late FY 1986 from the Alternating Gradient Synchrotron. Two complementary large experiments have been approved for running. These experiments are designed to provide the first broad look at the physics with 14 GeV/AMU heavy ion beams at the AGS. One of them utilizes a single-arm magnetic spectrometer with high-multiplicity tracking chambers and particle identification detectors. The primary goal is to determine effective temperatures reached in central nucleus-nucleus collisions and to measure particle production cross sections in the forward hemisphere. The funding of this system (Total Estimated Cost = $4,200,000) will be completed in FY 1987. The second major approved experiment utilizes a time projection chamber mounted in the existing Multi-Particle Spectrometer magnet. The objective of this experiment is to measure all charged particles emerging from central collisions of nuclei. Anomalous behavior will be searched for in the observables as an indication of quark deconfinement effects. Completion of funding for this $1,300,000 experimental system is planned for FY 1987.

At Los Alamos National Laboratory, a neutron time-of-flight facility (TEC = $900,000; $550,000 in prior years and $350,000 in FY 1987) and a magnetic spectrometer (TEC = $1,100,000; $500,000 in FY 1986 and $600,000 in FY 1987) are needed as part of an expanded inelastic nucleon-nucleon scattering research program. These improvements will make possible a complete determination of the isospin-zero nucleon-nucleon scattering amplitudes as a function of energy and angle.

At Lawrence Berkeley Laboratory, a large solid-angle detector for the products of energetic heavy ion collisions is needed. The main physics thrust of this detector will be the study of central heavy ion collisions up to the highest Bevalac energies. With this device, the equation of state of nuclear matter can be well studied, since it will be possible to measure simultaneously many interesting hydrodynamic properties of nuclear matter, such as compressibility and thermal conductivity at high pressures and temperatures. A system based on a time projection chamber in conjunction with a time-of-flight array is planned. The device (TEC = $2,100,000; $300,000 in FY 1986 and $1,800,000 in FY 1987) will permit complete event reconstruction, enable the acquisition of data with good statistics since it can operate at high data rates, allow particle identification for protons, pions, kaons, and lambdas, and have good two-particle separation.

At Argonne National Laboratory, the MIT/Bates Linear Accelerator Center, Oak Ridge National Laboratory, and the Stanford Linear Accelerator Center, capital equipment funds are requested for a variety of needs which include high performance gamma-ray detectors, high pressure gas targets, spectrometer magnets and detector systems, the upgrading of computer systems for data acquisition and analysis, and for small equipment items for the operation of the accelerator facilities. Completion of funding for a high-intensity polarized ion source at the Triangle Universities Nuclear Laboratory (Duke University) is planned for FY 1987.

The Nuclear Physics program has responsibility for providing all of Lawrence Berkeley Laboratory's general purpose equipment. For efficient operation of the Laboratory plant and for personnel safety, obsolete equipment must be replaced on a continuing basis. In FY 1987, $1,230,000 is requested for all capital equipment that is required at this laboratory and is not specific to any one program. Examples include: spectrum analyzers and corona detectors for the electronics engineering group, film thickness measuring instruments for the mechanical shops, equipment for Computer-Aided Engineering, radiation detection equipment for LBL's environmental health and safety service groups, a UNIX 16-user work station for the information services group, a precision crane-load positioner for the plant and facilities group, and high-speed nonimpact printer systems for the accounting and financial management group.

	FY 1985	FY 1986	FY 1987 Request
Construction	$ 23,300	$ 6,702	$ 33,300

The total FY 1987 request for construction funds for Nuclear Physics is $33,300,000.

Nuclear Physics
Summary of Construction
(Dollars in Thousands)

Project Title	Project Number	FY 1987 Request	Total Estimated Cost
Continuous Electron Beam Accelerator Facility..................................	87-R-203	$ 25,000	$236,000
Accelerator Improvements and Modifications...............................	87-R-201	4,300	4,300
General Plant Projects....................	87-R-202	4,000	4,000
Total..................................		$ 33,300	

Authorization and appropriation are requested to initiate construction of the Continuous Electron Beam Accelerator Facility (CEBAF). Research and development and A/E activities for the CEBAF project are now under way to better define the project's scope, schedule, and total cost. This effort will provide the technical base necessary for initiation of construction on a cost effective schedule in FY 1987. The CEBAF project is the highest priority construction project for basic nuclear research in the United States. CEBAF's unique combination of continuous beam, high intensity, and high energy will provide the opportunity for studying the largely unexplored transition between the nucleon-meson and quark-gluon descriptions of the nuclear force. Accelerator Improvement and General Plant funds are required in FY 1987 in order to meet the demands of frontier nuclear research, to improve efficiency of facility operations, and to maintain high standards of personnel safety.

Continuous Electron Beam Accelerator Facility

In FY 1987, $25,000,000 is requested to start construction of CEBAF. Upon completion CEBAF will feature an electron accelerator complex capable of delivering intense, continuous beams in the energy range from 0.5 to 4.0 billion electron volts (GeV). The intensity, energy range, and continuous nature of CEBAF's beams will make this facility unmatched in the world.

The accelerator complex will consist of: a 1 GeV superconducting linear accelerator (linac) which is split into two 0.5 GeV segments; a beam transport system to guide the electron beams from one segment to the other for up to four complete passes of acceleration through the linac to attain a maximum energy of 4 GeV at a design beam current of 200 microamperes; cryogenic systems and refrigerators to support operation of the superconducting linac; a beam transport system to deliver the continuous beams of electrons from the linac to the experimental halls; and instrumentation and control systems for the accelerator complex. The accelerator will service three independent experimental areas--two buildings for experiments using high intensity electron beams and a smaller area primarily designed for experiments using photon beams.

The conventional construction needed for the facility will include tunnels to house the superconducting linac, beam transport systems, and beam extraction systems; buildings for accelerator operations, cryogenic support systems, helium refrigerator systems, experimental areas, and general office/light laboratory space; beam dumps; and utilities. General office, laboratory, and shop space will also be provided by rehabilitation of existing structures.

In addition to the accelerator complex and buildings to house the research activities, this project will also provide an initial complement of experimental equipment to exploit the capabilities of the accelerator. This equipment includes several large spectrometers, and data acquisition and analysis computers.

FY 1987 activities will include: acquisition of the Space Radiation Effects Laboratory site; rehabilitation of existing structures to provide space for fabrication and testing of prototypes; site preparation and utilities extension; detailed design of accelerator components, helium refrigerators, and cryogenic systems; architectural and engineering work; start of construction on one of the tunnels which will house the linac; and acquisition of long lead components of the accelerator. To avoid delays in later years in installation and testing of accelerator components, these activities should occur in FY 1987.

Accelerator Improvements and Modifications

Accelerator facilities have continuous need during their operating life for small modifications or upgrades to enhance their performance for research use and to improve reliability and efficiency of operation. In FY 1987, a total of $4,300,000 is requested or these activities under Accelerator Improvements and Modifications.

At Argonne National Laboratory, $950,000 is requested for a new positive ion injector for the ATLAS facility. This injector, which uses a new type of superconducting resonator, will provide increased beam current, will improve operating reliability of the facility, and will provide heavier mass heavy ions to begin research in the area of quantum electrodynamics.

At Brookhaven National Laboratory, $500,000 is requested for a new AGS beam line to transport heavy ion beams from the accelerator to experimental stations. This new beam line will have the high vacuum capability and sensitive instrumentation necessary for heavy ion nuclear research.

At the Lawrence Berkeley Laboratory, $1,000,000 is needed for projects at the SuperHILAC/ Bevalac and the 88-inch Cyclotron. On the SuperHILAC, drift-tube quadrupole magnets will be replaced. These have been damaged from running at the high fields needed to focus very heavy ion beams such as uranium. A second project is an intensity upgrade of the Electron Cyclotron Resonance ion source at the 88-inch Cyclotron. This will be accomplished by raising the microwave frequency of the source from 6.4 to 14 GHz and increasing the microwave power level.

At Los Alamos National Laboratory, $1,500,000 is requested for LAMPF. Work will include final installation of an optically pumped polarized proton source and improvements of beam lines in the Nuclear Physics Laboratory so that high priority nucleon-nucleon scattering experiments can be conducted with polarized beams.

At the Bates Linear Accelerator Center, $350,000 is budgeted for two projects which are part of the polarized electron beam experimental program: a high voltage supply for the polarized source and a device for on-line measurement of beam polarization in the experimental area.

General Plant Projects

The Construction request includes $4,000,000 for General Plant Projects (GPP) at the Lawrence Berkeley Laboratory, the Bates Linear Accelerator Center at MIT, and the LAMPF facility at Los Alamos National Laboratory. At these laboratories, the Nuclear Physics program has responsibility for GPP funds which provide for minor conventional construction such as building additions and alterations, and other improvements as well as improvements to land and utility systems. A total of $2,600,000 is requested for projects at the Lawrence Berkeley Laboratory, including the replacement of an emergency power system, replacement of roofs on three buildings, building additions for light labs, and major electrical equipment replacement. At the LAMPF facility, $970,000 is planned for additions and improvements to the Nuclear Physics Laboratory for nucleon-nucleon scattering experiments and to the beam stop for weak interaction experiments with neutrinos. At Bates, $430,000 is requested to complete the upgrade of the accelerator cooling system and a microwave link to the MIT campus computers.

DEPARTMENT OF ENERGY
1987 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: Accelerator improvements and modifications, various locations

2. Project No. 87-R-201

3. Date A-E work initiated: 1st Qtr. FY 1987

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

4. Date construction ends: 2nd Qtr. FY 1989

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

6. Current cost estimate: $4,300
Less amount for PE&D: 0
Net cost estimate: $4,300
Date: 5/85

7. Financial Schedule:

Fiscal Year	Authorization	Appropriations	Obligations	Costs
1987	$ 4,300	$ 4,300	$ 4,300	$ 3,000
1988	0	0	0	1,100
1989	0	0	0	200

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.

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

2. Project No. 87-R-201

8. Brief Physical Description of Project (continued)

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

Argonne National Laboratory (ATLAS) .... $ 950

A positive ion injector will be installed at the Argonne Tandem/Linac Accelerator System (ATLAS) facility. The injector will utilize a completely new type of superconducting resonator especially developed to accelerate very-low-velocity ions and will provide 3 million volts of acceleration. An associated cryogenic system and beam line are part of the project.

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

This subproject provides for a new AGS beam line for heavy ion experiments. Dipole and quadrupole magnets, vacuum systems, shielding, security gates, and highly sensitive beam instrumentation are included in the project.

Lawrence Berkeley Laboratory (SuperHILAC/Bevalac, 88-Inch Cyclotron) .... $ 1,000

This subproject provides for the replacement of about one-third of the drift-tube quadrupole magnets in the prestripper section of the SuperHILAC. The new quadrupoles will use a new technology based on rare-earth permanent magnets. These magnets will have 20% greater focusing strength than existing quadrupole magnets.

Also, the Electron Cyclotron Resonance (ECR) source at the 88-Inch Cyclotron will be upgraded by raising its operating frequency from 6.4 GHz to 14 GHz. New solenoid magnets and a new octupole magnet will be constructed and installed; a 14 GHz klystron will be installed.

CONSTRUCTION PROJECT DATA SHEETS

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

2. Project No. 87-R-201

8. Brief Physical Description of Project (continued)

Los Alamos National Laboratory (LAMPF) .... $ 1,500

This subproject provides for the installation of an optically pumped polarized proton source in the Clinton P. Anderson Meson Physics Facility's injector room. This new source has a peak intensity of nearly 100 times that of the existing Lamb-shift source.

Additions and revisions to the permanent proton beam lines in the Nucleon Physics Laboratory are provided for by this project. These include a four-magnet beam swinger system at the time-of-flight facility which will permit variation of the incident angle of the proton beam and a new proton beam line to service the new Medium Resolution Spectrometer.

Massachusetts Institute of Technology (Bates Linear Accelerator Center) .... $ 350

An Isolation Core Transformer is needed to power the new polarized electron source at Bates. Also, for the polarized electron beam program, construction of a Moller spectrometer in Bates' South Hall is planned.

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

Argonne National Laboratory (ATLAS)

The new positive ion injector will increase the beam intensities and provide better operational reliability for almost all ion species now accelerated by ATLAS. The intensity increase will be especially great (100 times) for projectiles such as the calcium isotopes that are difficult to produce with the present tandem injector.

CONSTRUCTION PROJECT DATA SHEETS

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

2. Project No. 87-R-201

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

Brookhaven National Laboratory (AGS/Tandem)

The new AGS beam line will transport heavy ion beams from the accelerator to experiment stations. It will have the high vacuum capability and sensitive instrumentation necessary for heavy ion nuclear research.

Lawrence Berkeley Laboratory (SuperHILAC/Bevalac, 88-Inch Cyclotron)

A major limitation in the ability of the SuperHILAC to transport high mass beams efficiently is the loss rate due to damaged quadrupoles in the prestripper section. The existing drift tube quadrupoles were originally designed to provide the highest field gradients possible with the then-current (1970) technology. Since the addition of the ABLE injector these magnets have been run at the highest possible current levels to transmit the high mass beams (e.g., gold, uranium). This has resulted in an increased failure rate for the aged magnets and reduced transmission through the SuperHILAC for the highest mass beams by about 50%.

The higher RF frequency in the Electron Cyclotron Resonance ion source at the 88-Inch Cyclotron will allow efficient coupling of microwave power to higher density plasmas and is expected to increase the intensity of the very high charge state ions such as Ne^{10+} and Ar^{16+}. Making higher charge states with sufficient intensity will significantly increase the energies of heavy ion beams from the cyclotron.

Los Alamos National Laboratory (LAMPF)

The optically pumped polarized proton source and improvement of beam lines in the Nucleon Physics Laboratory will provide capability for execution of high priority neutron-proton and proton-proton scattering experiments.

CONSTRUCTION PROJECT DATA SHEETS

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

2. Project No. 87-R-201

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

Massachusetts Institute of Technology (Bates Linear Accelerator Center)

The Isolation Core Transformer now powering the polarized source is on loan and a permanent one is needed. efore coincidence measurements can be performed in the South Hall, it is necessary to be able to determine the beam polarization as it is delivered on target. Use of a Moller spectrometor is a convenient and conventional method for obtaining this information.

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 land.

10. Details of Cost Estimate

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

Total Estimated Cost .... $ 4,300

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
1987 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: General plant projects
various locations

2. Project No. 87-R-202

3. Date A-E work initiated: 1st Qtr. FY 1987

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

4. Date construction endse 2nd Qtr. FY 1989

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

6. Current cost estimate: $4,000
Less amount for PE&D: 0
Net cost estimate: $4,000
Date: 5/85

7. Financial Schedule	Fiscal Year	Obligations	Costs FY 1985	FY 1986	FY 1987	After FY 1987
	Prior Year Projects	xxx	$ 2,300	$ 100	$ 0	$ 0
	1985	$ 3,500	800	1,700	1,000	0
	1986	3,351	0	800	1,000	1,551
	1987	4,000	0	0	1,000	3,000
			$ 3,100	$ 2,600	$ 3,000	$ 4,551

8. Brief Physical Description of Project

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

CONSTRUCTION PROJECT DATA SHEETS

1. Title and location of project: General plant projects various locations | 2. Project No. 87-R-202

8. Brief Physical Description of Project (continued)

Lawrence Berkeley Laboratory .... $ 2,600

Requirements include: Replacement of the emergency power system in the Building 50 complex; replacement of roofs on Buildings 70A, 77 and 88; extension of the service yard adjacent to Building 77; an addition to Building 74 for light labs; new switching station, feeder cables, and reconfiguration of emergency power switching for the Upper Hill area; and replacement of PCB insulated transformers in Buildings 50A and 50B. The Lawrence Berkeley Laboratory (Berkeley, California) is located on non-Government owned property.

Los Alamos National Laboratory (Clinton P. Anderson Meson Physics Facility).......................... $ 970

This project includes improvements to the LAMPF Nucleon Physics Laboratory to prepare for an expanded experimental program involving the new, high-intensity polarized beam. Specific requirements include: a new floor, additional cooling water and electrical power, added radiation shielding, a counting area to service a new magnetic spectrometer, and a longer flight path and new shielding for the neutron time-of-flight facility. Also, minor additions to and modifications of the main beam stop are needed for conduct of neutrino experiments.

Massachusetts Institute of Technology (Bates Linear Accelerator Center) .... $ 430

Requirements include: Upgrade of the accelerator cooling system by replacement of a deteriorated evaporative cooler and a microwave link between the Bates and the MIT campus computers to permit higher data transmission rates. The Bates Linear Accelerator Center (Middleton, Massachusetts) is located on non-Government owned property.

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

Projects at the Lawrence Berkeley Laboratory, the LAMPF facility at Los Alamos National Laboratory, and at the Bates Linear Accelerator Center at the Massachusetts Institute of Technology are needed to improve efficiency and productivity of these installations and to assure continuation of safe and reliable operations for both personnel and instrumentation.

CONSTRUCTION PROJECT DATA SHEETS

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

2. Project No. 87-R-202

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

The distribution of funds requested for FY 1987 is as follows:

Lawrence Berkeley Laboratory	$ 2,600
Los Alamos National Laboratory (Anderson Meson Physics Facility)	970
Massachusetts Institute of Technology (Bates Linear Accelerator Center)	430
Total Estimated Cost	$ 4,000

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.

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
1987 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 Start: 2nd Qtr. FY 1987

4. Date Construction Ends: 2nd Qtr. FY 1992

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

6. Current cost estimate: $236,300
Less amount for PE&D: 300
Net cost estimate: $236,000*
Date: 12/85

7. Financial Schedule:

Fiscal Year	Authorization	Appropriations	Obligations	Cost
FY 1987	$236,000	$ 25,000	$ 25,000	$ 14,000
FY 1988	0	65,000	65,000	42,000
FY 1989	0	65,000	65,000	56,000
FY 1990	0	55,000	55,000	58,000
FY 1991	0	26,000	26,000	45,000
FY 1992	0		0	21,000

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 be the operating contractor during design, construction, and later operations phases of this project. The site for this facility will be Federally owned.

* Cost estimate based on December 1985 preconceptual design report.

CONSTRUCTION PROJECT DATA SHEETS

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, control center, and accelerator service functions. The SREL buildings and a surrounding 10 acre site will be acquired in accordance with Executive Order 12348 and implementing regulation 41 CFR 101-47.

b) Accelerator System

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

CONSTRUCTION PROJECT DATA SHEETS

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..........			$ 38,300
1. Conventional Construction at approximately 22% of item b.2		$ 10,800	
2. Technical components at approximately 28% of item b.3 ...		27,500	
b. Construction Costs			140,900
1. Land and Land Rights (Acquisition of the SREL site)..		1,700	
2. Conventional Construction..................................		49,800	
a. Accelerator facilities..................................	$ 8,600		
b. Experimental facilities................................	15,300		
c. Support facilities......................................	10,200		
d. Utilities and site preparation........................	15,700		
3. Technical components......................................		97,400	
a. Accelerator components..............................	67,000		
b. Research equipment....................................	30,4		
c. Standard Equipment...			1,900
			189,100
d. Contingency at approximately 25% of above costs, excluding item b.1			46,900
Total Estimated Cost..........			$236,000

* Cost estimate based on December 1985 preconceptual design report.

CONSTRUCTION PROJECT DATA SHEETS

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

2. Project No. 87-R-203

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.

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

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	Future Years	Total
a. Total project cost								
1. Total facility cost								
a. Construction line item.....	$ 0	$ 0	$ 0	$14,000	$42,000	$56,000	$124,000	$236,000
b. PE&D...........	0	300	0	0	0	0	0	300
Total facility cost.........	$ 0	$ 300	$ 0	$14,000	$42,000	$56,000	$124,000	$236,300
2. Other project costs								
R&D necessary to complete construction...	$ 1,000	$ 3,500	$ 4,787	$ 6,250	$ 6,213	$ 4,500	$ 0	$ 26,250
Total other project costs..	$ 1,000	$ 3,500	$ 4,787	$ 6,250	$ 6,213	$ 4,500	$ 0	$ 26,250
Total project cost...........	$ 1,000	$ 3,800	$ 4,787	$20,250	$48,213	$60,500	$124,000	$262,550

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 (continued)

b. Other related funding requirements (FY 1986 dollars)

1. Annual facility operating costs including in-house research.....................	$ 27,000
2. Annual plant and capital equipment costs not related to construction but related to the programmatic effort in the facility.............................	4,000
Total other related annual funding requirements..............................	$ 31,000

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.

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 operationg maintenance, and in-house research, together with electric power and materials and services costs. Approximately 230 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.