RECOMMENDATIONS FOR FY 1984 FACILITY CONSTRUCTION

DOE/NSF Nuclear Science Advisory Committee

April 1982

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PREAMBLE

Research in nuclear science confronts a truly impressive set of challenges of wide ranging importance. In nearly every subfield, the investigations which have been conducted over roughly the last decade have brought each to the threshold of unusually significant advances in the understanding of nuclear structure and reactions. By and large, the issues involved are not parochial. They are fundamental in nature and, correspondingly, are broadly applicable to other branches of physics and to science generally. It would be unfortunate (and ironic) if United States nuclear scientists whose dedicated efforts have done so much to bring the field to this turning point were not able to participate in the discoveries which lie ahead.

The full panorama of opportunities will be presented in a report now being prepared by the Committee which revises and brings up to date the chapter on Scientific Opportunities in its December 1979 "Long Range Plan for Nuclear Science." In this preamble, we shall cite a few examples which bear directly upon the proposals whose evaluation by the Committee form the main body of this report.

1. The nature of the strong interactions is a fundamental problem of modern physics. Its study has continued to be a major component of the nuclear research program. The discovery of the quark structure of nucleons and the quark interaction via the gluons, the color vector field, as contained in quantum chromodynamics (QCD) present a set of challenges to the nuclear physicist and, at the same time, the opportunity to provide insights into QCD of decisive importance, particularly to the understanding of confinement. Nuclear studies of the transition from the

regime dominated by quark degrees of freedom will be of unique value in this regard. Electron scattering by the lightest nuclei seems to be an effective probe. Important information can also be extracted from nucleon-nucleon scattering and the collision of ultra-relativistic protons and nuclei with nuclei. In the former case, the production of dibaryon systems predicted by current models might occur while, for the ultra-relativistic protons, the possibility of color exchange as revealed by the consequent hadronization process is an intriguing prospect. In the case of ultra-relativistic nuclei, there is the possibility, much more speculative in nature, of the formation of regions in which the nucleon bags have dissolved and in which a new type of matter consisting of quarks, gluons, and glue balls may be formed.

On the other hand, there is the complementary impact of the structure of the hadrons on our picture of nuclear structure and nuclear matter. At the present time, this is usually based upon a point description of nucleons and mesons. What is the effect of the finite size and internal structure of these hadrons upon the theory of nuclear matter, upon the microscopic basis of the shell and optical models, upon the residual interactions? The simplest manifestation of the internal hadron structure is the role played by the Δ, the excited state of the nucleon in nuclear phenomena, observable in pion-production experiments as well as pion interaction with nuclei.

Recent years have witnessed the discovery of new giant resonances, the electric monopole and quadrupole, and the Gamow-Teller (GT) resonances. Much research needs to be done to delineate the properties of each. In addition, one would like to understand their decay, at a macroscopic and microscopic level. A more global question asks: To what extent can these giant resonances be considered the "elementary particles" of nuclear physics in the sense that excitations of nuclear systems can be built up from these primitive excitations?

Are there other families of giant resonances? We know that resonances are exhibited in the collision of light nuclei. And there are intriguing indications that these extend up much further in the periodic table, an issue which the proposed accelerators with their high resolution will help resolve. But, in any event, are they examples of the shape isomer resonances seen in fissioning nuclei or would they be better described as nuclear molecules?

Heavy ion collisions present another research approach into questions of a fundamental nature. At the lower energies at which deep inelastic scattering was discovered, these collisions can be related to fundamental questions in nonequilibrium quantum statistical mechanics. At one level, this research will reveal the nature of the appropriate macroscopic variables and the equations which determine their dynamical behavior and the relevant observables such as energy, momentum, angular momentum, charge and mass transfer, for example. At another level, one seeks the microscopic justification and understanding of these variables. These considerations must generally be statistical in nature because of the large variety of paths which the system can follow from the entrance channel to the final state. These questions persist to higher energies where one finds new phenomena occurring such as precompound or "fast" fission, as well as the possibility of limiting momentum transfer to the fissioning system. It becomes very important to detect in coincidence the light particles emitted in the reaction. As the nucleon velocity goes above the velocity of sound in nuclear matter, one may hope to generate regions of high density. At still higher energies, we must begin to take into account the production of pions, kaons, etc. Relativistic effects become most important. One finds a very curious constancy in branching ratios of fragmentation products as a function of energy over an extraordinarily wide energy range. For central collisions, coincidence measurements must be made in order to obtain sufficient sensitivity to the reaction mechanism. More generally, one is faced in this domain with the problem of the observation of multiparticle final states. In this regime, as at lower energies, one needs to search for the relevant macroscopic variables. Considerable progress is being made with respect to these last two issues.

2. Weak Interactions

Studies of nuclei have made essential contributions to our understanding of the weak interactions. First delineated by the study of nuclear β decay, the modern insight into weak interactions relies, to a great extent, upon nuclear experiments testing CVC, PCAC, and the structure of the β decay Hamiltonian, such as its parity nonconserving nature, induced interaction terms, second class currents, etc. The observation of the weak component of nuclear forces has been of special interest to nuclear physicists. As its strength is of the order of 10^{-7} of the strength of the strong interaction, this research has presented a difficult challenge to the experimentalists which has been successfully met. Direct observation of parity nonconserving electromagnetic transitions in nuclei have been made. More recently, this weak force has been observed in polarized nucleon-nucleon scattering and, in due course, one may expect to observe its effect in nucleon-nucleus reactions. The immediate goal is the phenomenological description of the spatial and symmetry properties, presenting, thereby, a quantitative benchmark against which the theory of weak interactions can be tested. On the other hand, once the properties of the weak nucleon-nucleon interactions are known, one has potentially a new probe of nuclear properties analogous to that provided by the electromagnetic interaction. Developing experimental techniques so that this class of experiments become more routine is an obviously important goal.

Much of the present-day discussion of the weak interactions employs the unification achieved by gauge theories of which the Weinberg-Salam formulation is the foremost example. Of particular interest is the neutral current predicted by these theories. Important quantitative tests will be made by experiments now in progress scattering polarized electrons from nuclei. These experiments will determine the spin and isospin dependence, as well as the spatial character of these currents. Experiments with neutrino $(\nu_e, \nu_e, \nu_\mu, \nu_\mu)$ beams, scattering elastically, and inelastically from nuclei would provide another source of information on the structure of the weak interaction. The solar neutrino problem, using nuclear neutrino absorption as the detecting mechanism, remains most intriguing. Its resolution may very well impact on the understanding of the weak interaction.

This relatively small selection of research opportunities, motivated in large part by its relevance to the proposals discussed in the main body of the report, demonstrates the richness and importance of nuclear research. It is an integral and essential component of the program of modern physics to deepen and extend its description of interacting matter and radiation, and of the history and structure of our universe.

I. INTRODUCTION

The 1982 DOE/NSF Nuclear Science Advisory Committee met on February 16-17 and March 22-23, 1982, to evaluate seven facility proposals as requested by the Department of Energy and the National Science Foundation. Appendix A of this report contains the agenda of these meetings. The seven proposals are summarized in Section III. During the first meeting, the proposals were presented orally by their sponsors who were interrogated by the Committee with respect to various scientific and technical aspects of their plans as well as the budgetary and manpower requirements. In the period between February 17 and March 22, working groups of the Committee, including consultants,* examined each proposal carefully, paying particular attention to technical feasibility, performance goals, and costs. In two cases, site visits were made. Each group prepared a written analysis with recommendations which were discussed during the March 22-23 meeting during which final recommendations were developed. These are given in Section IV.

II. EVALUATION CRITERIA

The evaluation criteria are identical with those adopted by the FY 1982 Facilities Subcommittee. We quote from that Subcommittee report submitted in April 1980:

> "The Subcommittee's evaluations of the accelerator proposals (see Section III) were focused on the following issues: scientific value of the research goals which the facility addressed; cost-effectiveness, technical feasibility, and projected performance capability of the proposed facility; scientific and technical

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strength of the sponsoring laboratory and its research program; the strength of its associated nuclear theory effort; user involvement both current and potential; support of the project by the sponsoring institution; construction time and operating cost after completion; and the project's impact upon the education of students in nuclear science and upon other aspects of the ongoing and future national program. An important component of the Subcommittee's deliberations was concerned with whether the proposed facility was consistent with the Long-Range Plan of the Nuclear Science Advisory Committee, both in the science addressed by the facility and in its funding pattern.

"The following questions were considered by the Subcommittee: Does the facility provide capabilities for carrying out new and important research? To what degree would the proposed facility have unique capabilities? Can the accelerator be built in the projected cost and time frames? Are there technical aspects of the proposal which are as yet not understood and could advisably be studied further? What is the range of experimental parameters which the projected system will provide? Can the energy be varied easily? What are the intensities, the energy resolution, and the time structure of the beam? What ancillary equipment will be required and what is the optimum arrangement of the target areas? How many experiments can be performed simultaneously? In view of the fact that the number of heavy-ion and electron accelerators which will be constructed is small and demand will be great, what provision is made for users at these facilities? What will be the strength and vitality of the user program at the facility? What is the ability of the sponsoring laboratory to carry out the proposed program in terms of availability of experienced personnel to participate in construction and in bringing the facility into operation? How great is the dedication of the in-house staff to the project? What is the relevant scientific capability of the resident scientific staff, who will perform and interpret experiments upon completion of the facility? What is the support of the host institution, as manifested by partial provision of construction funds, by provision of new faculty and staff positions, and by other demonstrations that the project has high priority within the institutional framework? What is the strength of nuclear physics in the host institution? The study of these and many other such questions formed the basis for the Subcommittee's decisions."

The following documents provided essential information, background material, and guidance for the Subcommittee in its studies and deliberations that led up to the evaluations and recommendations presented in this Report. These five documents are reports of the DOE/NSF Nuclear Science Advisory Committee:

"A Long Range Plan for Nuclear Science," December 1979;

"Recommendations for FY 1980 Facility Construction," April 1978;

"Recommendations for FY 1981 Facility Construction," April 1979;

"Recommendations for FY 1982 Facility Construction," April 1980;

"Recommendations for FY 1983 Facility Construction," April 1981.

Also of importance in the studies is the earlier report:

"Future of Nuclear Science," Ad Hoc Panel, Committee on Nuclear Science, Assembly of Mathematical and Physical Science, National

Research Council - National Academy of Sciences, 1977.

III. PROPOSAL SUMMARIES

The seven proposals which the DOE and NSF have asked the NSAC to evaluate are summarized below. The nature of the facility and the research area it would serve, the estimated cost of construction, and the estimated time for its completion, as well as the estimate of the increase in the operating costs, are given. Costs are given in 1982 dollars, together with contingency but not including escalation.

1. American University Proposal for Construction of an Electron Injector at the Stanford Linear Accelerator (SLAC)

Forms of this proposal have been considered by the DOE/NSF Nuclear Science Advisory Committee in 1979, 1980, and 1981. The present submission proposes the construction of a downstream injector at SLAC which would produce high intensity electron beams, 13.5-27 μA average current, in the energy range from 0.4 to 2.9 GeV, an improvement in intensity by a factor of about 100 over that now available at SLAC in this energy range. The construction cost is estimated to be $1.3 M. Construction time is estimated to be about two years. Measurements of the elastic, quasi-elastic, and inelastic scattering of electrons by ^{2}H, ^{3}H, ^{3}He, and ^{4}He would be made with this facility, thereby extending knowledge of the elastic and inelastic form factors of these systems to higher momentum transfers. The cost of 90 shifts of running time is estimated to be $1.5 million.

2. Heavy Ion Facility at Brookhaven: Cyclotron addition, Future Injector for AGS and ISABELLE

The Brookhaven National Laboratory renews its proposal to construct a room temperature post accelerator to be injected from its double MP tandem Van de Graaff electrostatic accelerator yielding heavy ion beams with energies ranging from 150 MeV/amu for the light elements using a gas stripper and using foil stripping up to 45 MeV/amu for mass 200 beams and achieving 33 MeV/amu for uranium ions. A new feature of the proposal is its presentation of the possibility of the tandem-cyclotron system injecting into the AGS and ISABELLE providing beams with 100 GeV/amu.

The proposed accelerator (tandem and cyclotron) would provide very heavy ion beams in an unexplored mass and energy range above the velocity of sound in nuclear matter where abnormally high nuclear densities may be obtained and where pionic degrees of freedom begin to become important. The ultra-relativistic heavy ion beams would be unique as there is now no dedicated facility available to explore the energy domain at these energies where the nuclear quark-gluon degrees of freedom will possibly become manifest. Including the costs of in-house effort, the construction cost of the cyclotron post-accelerator is estimated to be $13.2 million. Ancillary equipment costs will total about $4.0 million. Incremental operating costs of the facility are estimated to total $1.27 million. The present extensive user operation would be continued. Construction time is about 3 1/2 years. The cost of coupling to the AGS-ISABELLE is roughly estimated to be $5.4 million.

3. University of Illinois - 450 MeV Cascade Microtron

The University of Illinois proposes to construct a 100% duty factor electron accelerator producing electron beams with energies extending up to 450 MeV. The accelerating structure to be used is that used at Mainz. Coincidence detection of decay products following nuclear excitation by electron scattering or monoenergetic photon absorption would become possible. Properties of nuclear bound states, of the giant resonances, of transition densities, exchange currents, quasi-free nuclear reactions, pion production and interaction could then be determined. The fundamental question of the medium modification of the electromagnetic and pionic interaction with nucleons would be addressed. The project is expected to cost $16.9 million with the University contributing about $1.3 million. Incremental operating costs are estimated to be at least $0.5 million. Construction time is five years.

4. Los Alamos National Laboratory Proposal for a High Intensity Neutrino Source

The Los Alamos National Laboratory proposes the construction of a high intensity neutrino source, a large high-sensitivity neutrino detector, and associated experimental areas to utilize that source. The design assumes a current of 100 μA of 800 MeV protons from LAMPF which, in most cases, will pass through the Proton Storage Ring now under construction and will be spilled on the production target. Beams of muon and electron neutrino and anti-neutrinos would be produced. The 500 ton detector would be appropriate for the study of neutrino oscillations and neutrino-electron scattering. The construction of a detector for the study of neutrino-hadron and neutrino-nuclear interactions is not included in this proposal but is an option for future use of the source. The cost of the project is $25.1

strength and uniqueness to the first two of these research categories. The cost of the construction is estimated to be $7.1 million of which the University of Washington will contribute $0.8 million. Incremental operating costs are about $0.6 million. Added equipment will not be needed. Construction time is about four years.

7. Yale University - A Proposal for Conversion of the Yale MP Tandem Accelerator to ESTU Status

Yale University has resubmitted a proposal for conversion of their 13 MV tandem accelerator to a 20 MV, ESTU. Major features include replacement of the existing MP pressure vessel with a larger one, lengthening the column structure, and enlarging the high voltage terminal. A subnanosecond beam pulsing system and a polarized ion source are included. The facility will provide research capability which will permit high resolution studies of possible resonances in the collision of light ions, of the structure of nuclei, and of dynamical symmetries. Time of flight capability will make it feasible to study the emission of neutrons. The construction cost is $8.5 million. Operating costs will rise by about $0.15 million. Construction time is about two years.

IV. RECOMMENDATIONS

The Committee finds that the proposals presented to it for the construction of facilities to be funded in FY 1984 are of high quality, directed toward the advancement of United States capability in areas of significant scientific importance, and generally worthy of support. The proposals are in substantial accordance with the recommendations of the NSAC Long Range Plan of December 1979. Their authorization will, however, million while the incremental operating costs will total $1.5 million. Construction time will be about 2-1/2 years.

5. Oak Ridge National Laboratory - The Holifield Heavy Ion Research Facility--Phase II

This proposal requests an expansion of the Holifield Facility through the additions of an MSU Phase II superconducting cyclotron post acceleration to the existing NEC tandem. For the lighter ions, energies to 200 MeV/amu would be produced while, for the heavier ions, energies up to 40 MeV/amu would be available for all species. The proposed facility would provide ion beams in an unexplored mass and energy range above the velocity of sound in nuclear matter where abnormally high nucleon densities may be obtained and where pionic degrees of freedom become more important. The projected cost is $20.5 million. Ancillary equipment costs are not included. Increased operating costs would be about $0.7 million. The presently extensive user operation would be continued. Construction would take about three years.

6. University of Washington - Proposal for a Superconducting Booster

The University of Washington proposes the addition of a superconducting booster to be injected by the presently operating FN tandem Van de Graaff accelerator. The superconducting booster is a linac, the resonators which will be chosen to be of either the ATLAS or the Stony Brook/Cal Tech design. The accelerator will emphasize the acceleration of protons and light ions, providing 36 MeV protons, 22 MeV/amu ^{16}O, and 10 MeV/amu ^{40}Ca beams. Research emphasis will be on fundamental aspects of the nucleon-nucleon interaction, radiative capture, and light heavy-ion reactions. The availability of a high-intensity polarized source lends depend on the level of funding for construction. The Committee reiterates its request that the nuclear science construction budget be at the level recommended by the NSAC Long Range Plan; a level which, it should be recalled, was set so as to maintain constant scientific effectiveness of the field. In the opinion of the Committee, a vigorous construction program at this time is essential for the future health of the United States nuclear science program.

The first two recommendations will be made with respect to the facilities involving electromagnetic interactions with nuclei.

(1) <u>A Proposal to Build a New Injector at SLAC for a Program of Research in Experimental Nuclear Physics -- American University</u>

The proposal is accorded high scientific priority. It would form an extension of a productive program which uses high energy electrons for nuclear investigations. The proposed experiments would form a bridge between those which can be performed with present-day pulsed lower energy beams to those which the steady beams from a high intensity GeV electron accelerator, projected in the 1979 Long Range Plan, would make possible.

We recommend that the proposed injector be considered as a facility for a continuing nuclear program at SLAC: it is recommended that a commitment be made <u>beyond</u> 1986 for the allocation of a definite fraction of SLAC beam time for the use of the proposed facility. This recommendation is considered to be essential because the proposed facility is scheduled to become operational in 1986, at a time close to when SLC may begin to be used. Secondly, we recommend the appointment of a program advisory committee to set priorities for the allocation of time on the new beam line.

With respect to operational and construction costs, we recommend to the DOE that they request the SLAC management to reconsider SLAC's policy of charging beam time for nuclear physics at SLAC. We further recommend that shared support of construction funds with SSRL continue to be sought.

(2) <u>Nuclear Physics Research with 450 MeV Cascade Microtron -- University of Illinois</u>

The Committee gives this project high scientific priority. A facility of this type and energy was projected in the 1979 Long Range Plan. The NBS/Los Alamos linac structure originally proposed cannot be used, and another possibility has been identified but has not yet received a thorough study. The Committee recommends that an increase in the technical strength of the project be sought and a more definite plan including cost estimates for a strong user participation be formulated. The Committee recommends that a definite decision regarding this proposal be postponed until the technical problems are firmly in hand and until the current study by an NSAC Subcommittee of the role of electromagnetic interaction in nuclear science is completed, permitting consideration of the complement of accelerators required to implement the research program and facility needs developed in that report.

(3) <u>A High Intensity Los Alamos Neutrino Source -- Los Alamos National Laboratory</u>

The Committee finds this project, recommended in the 1979 Long Range Plan, would add significantly to the understanding of the weak interactions. The neutrino-hadron and neutrino-nuclear physics are not to be carried out with the proposed facility but, rather, represented options for the future requiring the development and construction of fine grain detectors. The Committee recommends to the agencies that a joint study of this proposal by the nuclear and particle physics communities be authorized as the expert knowledge of both is required in order to obtain a definitive evaluation.

(4) <u>A Proposal for a Superconducting Booster -- University of Washington</u>

This proposal is evaluated by the Committee as being scientifically valuable and technically feasible. The Committee considers the continuation of forefront research at the University of Washington of great importance as an essential component of the university program supported by the DOE. This proposal is strongly endorsed by the Committee.

(5) <u>A Proposal for Conversion of the Yale MP Tandem Accelerator to ESTU Status -- Yale University</u>

This proposal is evaluated by the Committee as being scientifically valuable and technically feasible. As in the case of the University of Washington, the Committee regards the continuation of forefront research of great importance as an essential component of the university program supported by the DOE. This proposal is strongly endorsed by the Committee.

Both Proposals (4) and (5) are projected by the Long Range Plan.

(6) <u>Proposals for a Heavy Ion Facility at Brookhaven -- Brookhaven National Laboratory and Holifield Heavy Ion Research Facility Phase II -- Oak Ridge National Laboratory</u>

Both proposals respond to an important need of the field, filling an important gap in energy and mass of heavy ion projectiles, as described in the 1979 Long Range Plan and recently confirmed by an NSAC study of heavy ion nuclear science. The Committee evaluates these proposals to be of unique importance scientifically and technically feasible and finds both to be meritorious.

If only one of these post-accelerators is to be authorized, the Committee expressed a preference for the BNL proposal because of lower cost, its reliance on a more conventional technology, and the increase in heavy ion facilities available for experiment which would result. The continuation of forefront nuclear research by a strong national laboratory group with strong university user involvement played an important role in this recommendation.

The Committee urges continued study of the possibility proposed by Brookhaven of injecting the beam from the post accelerator into the AGS and then into ISABELLE providing, thereby, beams with energies of the order of 100 GeV/amu. The study should include an evaluation of the option of injection into the AGS only.

V. BUDGETARY CONSIDERATIONS

The proposals presented to the Committee are unusually strong, responding directly to the scientific needs and opportunities of the field of nuclear science. They conform remarkably closely to the construction program delineated in the "Long Range Plan for Nuclear Science" issued in December 1979. We are pleased that several features of that program are in the process of being implemented including: (1) MSU phase II, (2) Bates Electron Recirculator, (3) ATLAS, (4) Florida State upgrade, and (5) Indiana University cooler. The last two are in the NSF

FY 1983 Presidential request which is currently under consideration by Congress. These new facilities will provide important new opportunities for forefront physics research. However, overall, these projects fall substantially short of the desired rate of construction recommended in the Long Range Plan which was designed to maintain the scientific effectiveness of the United States program. The Committee strongly urges that several of the proposals be funded so that this goal be approached. It is particularly important that this be done in FY 1984.

There is one important caveat. The new facilities will require eventual provision for increased operating funds. Because of the erosion of United States capability in recent years, it is no longer possible to generate operating funds by closing facilities without causing irreversible damage to the fabric of nuclear science research. We, therefore, urge the agencies in making their projections for the future development of the field to include explicitly the required incremental operating funds as an addition to the operations budget.

VI. EVALUATION OF PROPOSALS

PROPOSAL SUBMITTED BY AMERICAN UNIVERSITY FOR CONSTRUCTION OF AN ELECTRON INJECTOR AT THE STANFORD LINEAR ACCELERATOR CENTER

Description of the proposal

The essence of parts of this proposal has been considered by NSAC three times in the past--in 1979, 1980, and 1981. The objective is construction of a new electron injector, referred to as Injector East, between sections 25 and 26 of the Stanford Linear Accelerator to produce high-intensity electron beams in the energy range from 0.4 to 2.9 GeV.

The intensities are expected to be 50-100 mA peak currents, or 13.5-27 μA average currents, about a factor of 100 greater than the currents now available at SLAC in this energy range. The beam would be accelerated in the last five sections of the linear accelerator and would be ejected into End Station A, where the existing spectrometers and detectors would be used for the proposed electron scattering experiments.

Construction of the electron gun would begin in October 1983 and be completed within no more than two years at an estimated cost of $1.3 million (FY 1982 dollars) for fabrication and installation.

The experimental program proposed for this new facility centers around elastic, quasielastic, and inelastic scattering of electrons from deuterium and from nuclei with three and four nucleons (^3H, ^3He, and ^4He). These measurements are intended to extend elastic and inelastic form factors for these simple systems to higher momentum transfers.

The cost of 90 shifts of dedicated running time, including the initial experimental setup and checkout, is estimated at $1.5 million (FY 1982 dollars).

The Stanford Synchrotron Radiation Laboratory has indicated its interest in using the new electron gun, with minor modifications, in order to provide more reliable and better quality electron beams for its dedicated runs when high energy physics programs are not in operation.

Scientific program

The objective of this proposal is the establishment of an electron beam in the energy range from 0.4 to 2.9 GeV to measure elastic, quasi-elastic, and inelastic scattering cross sections for targets of ^2H, ^3H, ^3He, and ^4He at forward and backward angles. From these measurements, elastic and inelastic form factors will be determined at high longitudinal and transverse momentum transfers. Since the cross sections for these electromagnetic probes are extremely small, the extension of measurements of this type to the region of high momentum transfer requires intense electron beams. The proposed electron beam at SLAC would have no competitor for such measurements at any other accelerator facility.

The proposed experimental program would begin with a measurement of the elastic scattering of electrons from deuterium at 180° under conditions in which the nuclear recoil would be measured in coincidence with the scattered electron. These measurements are sensitive primarily to the elastic magnetic form factor of the deuteron and will extend its determination to much higher momentum transfers than heretofore possible; thus, much shorter distances of the deuteron structure are probed. Even with the relatively intense new beam, these measurements are time-consuming and comparable in style to typical high energy physics counter experiments rather than the more conventional nuclear physics experiments.

In three- and four-nucleon systems, forward and backward elastic and inelastic scattering are to be measured to sort out electric and magnetic form factors, also in an energy and momentum transfer range that has so far been inaccessible.

The results of these experimental programs are expected to be useful in placing significant constraints on the development of the theory of nuclear interactions and of the short distance structures of light nuclei. The measurements could discriminate among competing theoretical models and shed light on the relative importance of the meson exchange currents, isobars, and quark substructure in light nuclei. They will bring nuclear physics closer to its overlap with elementary particle physics.

Evaluation

Taken together, the proposed experiments form the beginning of a reasonable program of substantial scientific interest, since they would extend the range of our knowledge of nuclear form factors and structure toward much higher momentum transfers. The results can be expected to benefit the understanding of basic nuclear interactions and their connections to particle physics theories such as QCD. SLAC is prepared to host this program, but the states that the financial commitments and scientific priorities would have to be determined by the nuclear physics community. The construction of the new electron gun is seen as a reasonable activity for the existing laboratory.

The proposal is accorded high scientific priority because we envision it as the beginning of a program which uses high energy electrons for nuclear investigations. The experiments bridge the gap from present-day pulsed lower energy electron beams to the future high-duty-cycle beams from a high intensity electron accelerator in the GeV range, as projected in the 1979 Long Range Plan for Nuclear Science.

In order to implement this program using SLAC for nuclear investigations, we recommend that: (1) a (nuclear) program advisory committee be established to set priorities for the allocation of time on the new beam line; (2) the proposed injector be considered as a facility for a continuing nuclear physics program at SLAC. In particular, we are concerned that a commitment be made beyond 1986 (which is only a short time after the facility becomes operational and SLC may begin to be used) for the allocation of a definite fraction of beam time for the use of the proposed facility; (3) DOE request the laboratory to reconsider the policy of charging beam time for nuclear physics uses of SLAC; and (4) shared support for construction funds with SSRL continue to be sought.

HEAVY ION FACILITY AT BROOKHAVEN: CYCLOTRON ADDITION, FUTURE INJECTOR FOR AGS AND ISABELLE

The Brookhaven National Laboratory proposes the construction of a room temperature cyclotron post-accelerator to be injected by heavy ions from its double MP tandem Van de Graaff electrostatic accelerator yielding energetic heavy ion beams with energies ranging from as much as 150 MeV/amu for the light elements (e.g. ^{16}O) using a gas stripper and using foil stripping, up to 45 MeV/amu for mass 200 beams, and achieving 33 MeV/amu for uranium ions. The proposal raises the possibility of coupling the resulting accelerator to the AGS and ISABELLE which would provide heavy ion beams with 10 GeV/amu.

The Accelerator

The design of the accelerator is sound and relatively conservative using well-proven technologies. It represents a well considered reuse of the capital resource of the SREL (Space Radiation Effects Laboratory) magnet. The pole tip design employed is a significant contribution to magnet technology. Beam extraction would be easier than beam extraction from a compact superconducting design.

The Research Program

The proposed accelerator would be a unique facility providing very heavy ion beams with energies extending from that corresponding to the velocity of sound in nuclear matter to energies where abnormally high densities may be obtained and where pionic degrees of freedom begin to become important. It will make possible the study of nuclear dynamics in a so far unexplored regime of mass number and energy. It would, thereby, provide the data from which the nature of the reaction mechanisms involved and the properties of nuclear matter under unusual conditions of density and excitation would be extracted.

Staff

Brookhaven's staff in experimental nuclear physics is a national resource, highly experienced with an outstanding reputation. The present tandem facility is well run. Gradual upgrading has been excellently managed. We can, thus, expect effective management of the construction of this facility, its operation as well as important research initiatives by the Brookhaven staff. The theory group is of high quality and committed to the support of the experimental program.

User Program

Brookhaven is justly proud of their record in supporting the work of outside users. Major contributions have been made in supporting graduate education in nuclear physics, especially at universities in the northeast, and the strong MIT group in particular. One has every reason to expect this highly beneficial interaction to continue.

Proposed Equipment

The equipment costs allowed are minimally reasonable and indicate an awareness of some of the problems. Additional allowance should have been made for a computer system since it seems unlikely that the present one will remain viable on the time scale projected.

Budgets

The estimate has been revised slightly to include costs of in-house effort--the construction cost is now $13.2 million (in FY 1982 dollars). As nearly as one can judge, this is reasonable. The estimates on equipment funds and operating and research budgets appear to be very lean but not completely unreasonable--perhaps 10-20% higher would have been more realistic, that is closer to $4.0 million for equipment and $1.2 million for incremental operating costs.

The Ultra-High Energy Option

This is clearly a very important feature of the proposal that requires serious consideration. With the closing of the heavy ion option at ISR, ISABELLE may be the only place for exploring phenomena requiring several tens of TeV of energy within a nuclear volume. Entirely new classes of physics may, thus, become available for study transcending present high energy and nuclear physics. However, considerable additional study is required before the feasibility of this option can be reliably determined. We recommend continued study.

The High Energy Option

The 10^8-10^9 particles per pulse in the AGS for ~ 12 GeV/amu is somewhat closer to reality. It would provide an important step over the LBL capability, for instance, amply sufficient to copiously produce antinucleons in heavy ion collisions, but about two orders of magnitude below the qualitatively new regime of ISABELLE energies.

Summary

This is a strong proposal. It will strengthen the national program in nuclear physics research by providing unique capabilities and may allow for an inexpensive future option for exploring a new field of ultra high energy physics with ISABELLE.

UNIVERSITY OF ILLINOIS: 450 MeV CASCADE MICROTRON

This high duty factor electron facility would provide a unique capability for nuclear physics. At Mainz in Germany, a 180 MeV, high-duty-factor electron microtron is under construction, but funding has not been approved for the next stage (800 MeV).

The electromagnetic probe is of great importance to nuclear physics since the interaction is known and weak. But, until recently, the use of the electron probe has been limited by the lack of high duty factor accelerators. In contrast, from the beginning, the hadronic facilities have nearly all been high-duty-factor accelerators.

The availability of a high-duty-factor electron accelerator would open up a large area of very important research that has lain dormant for many years. The value and significance of this research has been documented in several recent studies. This proposed facility is also in accord with the Long Range Plan of NSAC, which calls for a high-duty-factor electron facility in this energy range.

The measurements planned with the proposed 450 MeV, 100% duty-factor electron beam are centered around: (1) electron scattering coincidence studies of the giant multipole resonances and nuclear bound states and (2) tagged bremsstrahlung studies in the intermediate energy region in which scattered gamma rays, nucleons, and pions are detected. The experimental equipment to be used includes magnetic spectrometers for electron and charged pion detection, solid state detector arrays for nuclear fragments, time-of-flight neutron detection, and sodium iodide crystals for high energy gamma rays from nuclear decay and neutral pion decay. Data acquisition electronics with on- and off-line computers complete the proposed measurement systems.

The unique characteristic of this proposal lies in the high-duty-factor of the electron beam. This property permits coincidence detection of decay products following nuclear excitation by electron scattering or monoenergetic photon absorption. The level of detail in the information on nuclear structure and dynamics contained in these measurements is considerably higher than that inferred from single-arm studies as are now carried out at most existing electron accelerators.

In the excitation region 0 - 50 MeV, the interacting shell model of nuclear structure and the optical model of nuclear reactions have served well as the basis for a partial solution of the many body problem. However, clarification is needed in the topics of single nucleon-hole interactions, meson exchange currents, and the time evolution of nuclear reactions. The electromagnetic probe offers a number of well-known advantages for supplying interpretable data on these problems. Coincidence measurement as described in the Illinois proposal will give insight on these subjects because they can distinguish between different multipole excitations and give their relative phases and transition densities.

The excitation region 50 - 150 MeV is often characterized as dominated by nucleon-nucleon correlations. If, as has been theoretically conjectured, photon absorption in this energy region can occur on interacting neutron-proton pairs (quasi-deuteron), the measurement of the energy and angular distribution of photonuclear reaction products will reflect ground and excited state correlations. This information is vital in the interpretation of all quasi-free nuclear reactions in this energy range.

In the nuclear excitation region, 150 - 450 MeV pion and nucleon isobar production, propagation, and decay are the main topics of interest. Since electrons and photons penetrate the nuclear volume uniformly, they offer unique advantages in studying meson-nucleus interactions. Threshold reactions emphasize the role of nuclear structure while reactions near the 300 MeV delta resonance depend more on average nuclear properties. Charged and neutral pion studies, as outlined in the proposal, will address the questions of how the fundamental photon-nucleon and pion-nucleon interactions are modified by the nuclear medium, nonpionic decay of the delta resonance and possible dibaryon resonances.

On the whole, the subcommittee found the experimental program described in the proposal well conceived. However, three points raise some concern: (1) the planning for electron scattering coincidence measurements with nuclear decay products in the 50 - 450 MeV region, (2) the degree of theoretical support needed to interpret the data on complex final states, and (3) the optimum energy. Our recommendation on the first is that design of the experimental halls not preclude using two or more magnetic spectrometers on one pivot. Our recommendation on the second is that the proposers attempt to strengthen the University commitment to balancing the experimental and theoretical efforts in electromagnetic nuclear research. The chairman of the department has, indeed, given strong assurances of such a commitment. Finally, the optimum energy for this facility should receive further study; this study should include agency input on realistic assumptions for construction/operating budgets, further evaluation of the physics programs, and consideration of the technical problems associated with higher energies. In any case, the facility design should include provision for eventual increase in beam energy.

It was quite clear that the authors of the proposal, as well as the physics department and the University, have a deep commitment to this project. A tangible measure of the University's commitment is their significant financial support during the construction phase.

The existing proposal reflects the preliminary planning work of the past few months; it is expected that these plans will change in detail due to the technical uncertainty described below as well as during the expected evolution of the project. Professor L. S. Cardman will be responsible for the technical direction of the project while planning for the physics program and various administrative tasks will be the responsibility of Professor P. Axel. Both have been released from their teaching and research obligations by the University so that they may devote full time to this project. Professor Cardman has had significant experience in instrumentation development as well as in research. Despite these favorable arrangements, it appears that the project would need an assistant project director, especially if it becomes necessary to fabricate the linac structures at Illinois (see below).

A major technical problem has emerged since the February 1982 NSAC meeting with the realization that the disc and washer accelerating structure cannot be used for this application.* Another solution must be found for the NBS machine presently under construction. At Los Alamos, AT Division is searching for the appropriate substitute structure. The Illinois group argues that the structure used at Mainz is a viable alternative which has been demonstrated to work in this application. However, use of the Mainz structure requires a different RF system which adds about $0.5 million to the construction cost (before escalation and contingency); it may also require significant engineering effort at Illinois since the complete RF systems and structures will probably not be available from Mainz.

The construction budget is shown in Table I. The input to this budget comes from cost estimates made at Illinois, independent architectural engineering studies, and cost estimates from NBS, Los Alamos, and Argonne.

The contingency allowance used has been 20%. The input data represents the best available data and does not, for example, reflect the extremely optimistic estimates presently available from the construction industry due to the economic conditions of the moment. An allowance has been made for the extra cost due to the possible change in the RF power structure system.

Other areas of concern in the cost estimate are the relatively low effort estimates used for the required software development, the

* This problem is caused by a near degeneracy of a deflecting mode with the accelerating mode and the coupling mode in long disc and washer structures; this cannot be removed by tuning.

assumption that something like \$0.5 million (not shown in Table I) of vacuum and control equipment can be salvaged from the existing facility, an incomplete search for surplus magnets, and the manpower implications of the accelerating structure problem. However, even in the worst case, these concerns are estimated to result in a cost increase of perhaps 5% of the total budget.

A very favorable cost aspect of this proposal is the low cost of an FTE at Illinois (\$37,000 per year including fringe and overhead), the availability of inexpensive student labor, and the existence of excellent University shops which are available at a rate of \$24 per hour. Further, there is an extremely strong electronics effort in the Illinois physics department which has amply demonstrated its capability of producing modern electronics at a fraction of the commercial cost.

The projected operating budget of \$2.6 million (in FY 1982 dollars) does not include the power cost nor the cost of the required health physics staff which will be provided by the University. This level of operation is the minimum which might be imagined for such a facility. In the opinion of the subcommittee, this level is inappropriate and the operations budget should be closer to that provided for the Indiana University Cyclotron Facility (about \$4 million) so that the Illinois facility can become an effective tool for a diverse community of users. The proponents are not opposed to building up a strong users community and a users organization. The concept of a program advisory committee to set research priorities is also acceptable. There can be little doubt that this unique facility will attract a large number of able scientists. The present low-duty-factor electron accelerator at Bates is heavily oversubscribed.

There is concern that the student program at Illinois will suffer during the construction of this facility. However, it is quite clear that this will be a superb facility for training nuclear physicists as well as a major research program once it is in operation.

Because this facility would produce excellent physics in a strong university setting and because of its unique characteristics, this project should have high priority. At the same time, we urge the agencies and the laboratory management to insure that the necessary technology be available either at Illinois or elsewhere, that the project be pursued vigorously, and that strong laboratory support, along with the necessary funding, be devoted to building a strong users program.

Table I
(dollars in thousands)

Total Construction and Ancillary Equipment Costs and Illinois Direct Effort.

			Funding Sources		
Year	Effort (FTE)	All Costs	Present Operating Budget	University Contribution	Incremental NSF
1982-83	11.5	$ 1,160	$ 1,160	$ 0	$ 0
1984	17.5	3,161	660	260	2,241
1985	25.0	3,400	900	260	2,240
1986	25.0	3,438	900	260	2,278
1987	29.0	3,484	1,048	260	2,176
1988	17.0	2,225	641	260	1,324
Total	125.0	$16,868	$ 5,309	$ 1,300	$10,259

NOTE: All costs include a 20% contingency.

LOS ALAMOS NEUTRINO FACILITY

The Los Alamos National Laboratory proposes the construction of a high intensity neutrino source, a large high sensitivity neutrino detector, and associated experimental areas to utilize that source. The design assumes a current of 100 μA of 800 MeV protons from LAMPF, which, in most cases, will pass through the Proton Storage Ring now under construction and will be spilled on the production target. Beams of muon and electron-neutrinos and anti-neutrinos would be produced. The proton detector would be appropriate for the study of neutrino oscillation and neutrino-electron scattering.

This proposal for a facility for nuclear and particle physics studies with neutrinos is well conceived and, as far as we can judge, technically sound. The experiments to be pursued are described in sufficient detail for two topics: neutrino oscillations and neutrino-electron scattering. Both constitute important fundamental physics issues. Accordingly, this review will focus on these aspects.

As to neutrino oscillations, we find the goals of the experiment described in the proposal worthwhile. This experiment provides an order of magnitude greater sensitivity to Δm^2 (full mixing) for both ν_μ-ν_e and ν_μ-X channels as compared to the most sensitive experiments currently planned (see Table II). However, with regard to its sensitivity to small mixing angles in the ν_μ-ν_e channel, the Los Alamos experiment appears less competitive with other planned work. Estimates of the backgrounds, which have cosmic ray and beam related (μ decay) components, presented in the proposal seem reasonable in light of experience of others at LAMPF.

Although there is little guidance as to the most promising region in the parameter space of Δm^2 and $\sin^2 2\theta$, an order of magnitude improvement in any one is a valuable contribution to this fundamental problem. The proposed detector seems adequate for this test. We understand that the detector's design is in constant evolution and more detailed design studies are now in progress. We notice that it will be important to insure that other distances besides 3.8 km, as well as a 30% variation of the mean neutrino energy, are possible for added flexibility in order to best match the physics parameters, the signal-to-noise, or to establish a positive effect.

Muon-neutrino-electron scattering, on the other hand, faces competition in event rate from experiments now in progress at BNL and CERN. The BNL work with 1 GeV neutrinos using a 200 ton detector has recently taken data which should contain a registered 100 events to date and aims for 200. The stated goal in the Los Alamos proposal is 500 events. The CERN Charm collaboration has 89 events now for the $\bar{\nu}_\mu$ electron channel. We note that the ν_μ electron event rate per ton of detector is the same at BNL and Los Alamos, as also is the duty cycle of 10^{-6} when the PSR is utilized. The rate for $\bar{\nu}_\mu$ electron scattering will be down by a factor of 3-4 in Los Alamos compared to BNL.

The main difference between the Los Alamos proposal, and the BNL-CERN work has to do with background-related systematic errors. While these errors, mainly due to π^0 production and K decay, may limit the accuracy with which $\sin^2\theta_W$ can be extracted to about ± 7% in the BNL work, the low energy Los Alamos work is less affected by these systematic errors and is essentially statistics limited, this as well as possible other systematic errors, allowing a $\sin^2\theta_W$ measurement of ± 3% after 200 days running time. An accurate measurement of the Weinberg angle, as determined in this clean, pure-leptonic process, is of great current interest. "y" distributions can be constructed, if the detector has the finest segmentation, from which additional information such as neutral current coupling constants can be obtained.

A unique feature available at Los Alamos is the ν_e beam from the beam stop and possibly from an eventual muon bottle. The former is straightforward with a detector at the 90° position and can take full advantage of the low duty cycle. We anticipate that detailed studies of a muon bottle will be supported by the laboratory in the event that the facility is approved.

A description of neutrino-hadron physics including neutrino-nucleus physics is sketched in this proposal. However, this program will require additional funding as the feasibility of these experiments depends on the design of appropriate fine grain detectors not included in the proposal. These will be an object for future studies if the facility is approved. Neutrino-nucleus reactions leading to appropriate specific final states are a promising area for selective studies of different pieces of the electroweak interaction. Such selective reactions have been identified for a few states in light nuclei. Neutrino-nucleus (nucleon) physics, aside from neutrino-proton scattering, suffers at present from a lack of data. We see such experiments, including neutrino-proton scattering at low momentum transfer, as a genuine opportunity for important physics. As such, it represents an important option for the use of this facility in the future.

Los Alamos is able to provide strong technical support. The laboratory also has an active theory division. A long users tradition exists at LAMPF which, presumably, will extend to include the proposed facility.

As to the budget, the following is a brief summary in FY 1982 dollars:

- o Cost of facility and detector, including 20% contingency--$25 million
- o Contribution pledged by laboratory director--$1.0 million*
- o Operating incremental costs--$1.5 million.

We have reviewed the physics portion of the proposal and conclude that many of the physics problems to be addressed are fundamental. Except for the ν_e-e and ν-nucleus areas, they are also being addressed elsewhere. However, should such a facility be built, Los Alamos could contribute through: (1) extending the Δm^2 limit in $\nu_\mu \to X$ and $\nu_\mu \to \nu_e$ by an order of magnitude over presently proposed or approved experiments, (2) extending ν-p to very low Q^2, and (3) measuring $d\sigma/dy$ for ν_μ-e scattering. It should be mentioned that the single detector whose cost is estimated in the proposal will not serve all of these experiments because they require different properties; consequently, several detectors, at least one more finely segmented than the one costed, will be needed, thereby adding to the total cost.

Whether or not many of these physics questions are still timely when the facility is ready is a concern.

* As per letter from Zachariasen.

TABLE II

Proposed Limits from Neutrino Oscillation Program
at the AGS, CERN, and Los Alamos

Experiment	Channel	Detector	$Sin^2 2\theta$	Δm^2	Schedule
BNL E 775	$\nu_\mu - \nu_e$	100T	$< 1.5 \times 10^{-3}$	$< 0.6\ eV^2$	Approved
(BNL/Brown/	$\nu_\mu - X$	100T	$< 0.2 - 0.1$	$10 \leq \Delta m^2 < 100\ eV^2$	Run Oct. 82
Penn/Japan/					
Irvine/Stony Brook)	$\nu_\mu - \nu_e$	2 x 100T	$< 4 \times 10^{-2}$	$\leq 0.06\ eV^2$	Proposed
	$\nu_\mu - X$	2 x 100T	< 0.09	$\leq 0.09\ eV^2$	(1984?)
BNL E 776, Phase II	$\nu_\mu - \nu_e$	40T	$< 10^{-3}$	≤ 0.03	Proposed
(Columbia/					(1984?)
Ill./J. Hopkins)	$\nu_\mu - X$	+375T	0.03	0.5	
CERN/BEBC	$\nu_\mu - \nu_e$	BEBC	≤ 0.02	≤ 0.1	Approved
PSCC/P33					(1984?)
CERN/CDHS	$\nu_\mu - X$		≤ 0.2	≤ 0.25	Approved
					(1984?)
Los Alamos	$\nu_\mu - \nu_e$	500T	$\leq 2 \times 10^{-3}$	≤ 0.002	
Proposal	$\nu_\mu - X$	500T	≤ 0.01	≤ 0.02	

THE HOLIFIELD HEAVY ION RESEARCH FACILITY -- PHASE II

This proposal requests an expansion of the Holifield Facility capabilities through addition of a Michigan State University (MSU) phase II type superconducting cyclotron post-accelerator ($K_{eff} \sim 1200$) to the existing NEC tandem. This combination will provide a unique research potential in terms of the total energy that it can impart to beams of all species above A ~ 100 while maintaining beam intensities (~ 10^{11} pps) adequate for all classes of envisaged experiments. Recent results with lighter ions have already shown tantalizing evidence for collective nuclear effects emphasizing the importance of total energy as opposed to energy-per-nucleon delivered by a projectile. The proposed facility would be complementary to all others, worldwide, either available or under construction, for the heavier ionic species, and for lighter species, with MSU phase II, opens up the new and important region of 200 MeV/A where supersonic and density anomaly effects are anticipated in nuclear collisions.

The Oak Ridge National Laboratory has a long tradition of experience in both electrostatic accelerator and cyclotron design and technology and has one of the country's largest groups of experts in these areas. Because of its special role in the Nation's magnetic confinement fusion program, it has parallel expertise in superconducting technology that will be an essential part of the proposed expansion.

The Holifield Facility, through such activities at the UNISOR project and the Heavy Ion Research Institute, has demonstrated its effectiveness as a base for user activity and already has a national--and international--user constituency. The unique features of the proposed facility would attract a greatly increased number of users.

The Oak Ridge group has done pioneering work on computer control of accelerator systems and its successful coupling of the tandem and ORIC cyclotron augurs well for the proposed expansion. The on-site, computer-based data acquisition and analysis system is at state-of-the-art and is such that it can be maintained in that state through judicious replacement and modification.

The Committee, however, is concerned that, while existing research instrumentation in the facility will give access to some of the new science, not enough attention has been devoted either to the new generation of instrumentation that would be required to exploit fully the unique high energy, very heavy ion aspects of the facility or to the research space that will be required to house it. The Committee urges expansion in both areas.

Because the Holifield tandem has not yet demonstrated design performance at 25 MV, the Committee believes that it would be prudent, in terms of long-term reliability, to plan on injector operation in the 20 to 22 MV range, and shares the Oak Ridge confidence that this reliability will be demonstrated. The MSU phase II design upon which the present proposal rests is not yet entirely final, and, while significant differences exist in going from a cyclotron to a tandem injector, we foresee no serious problems.

We believe that this proposal is scientifically important and technically feasible (subject to the completion of the MSU phase II design and a demonstration of its feasibility) and that the Oak Ridge group is very well qualified to execute it. The projected cost of $20.5 million in 1982 dollars for the cyclotron, beam transport, and other items included in the proposal has been carefully developed and, we believe, is reliable. The Committee, however, would recommend that an additional amount, in the

3.5 to 4.5 million dollar range, be added to this cost to cover additional research instrumentation and possible research space.

SUPERCONDUCTING BOOSTER FOR THE UNIVERSITY OF WASHINGTON TANDEM

The University of Washington proposes to add a superconducting linac booster to the presently operating FN Tandem Van de Graaff. In contrast to other projects of this type at Argonne, Stony Brook, and Florida State University, the Washington proposal places special emphasis upon the acceleration of protons and the very light ions. The design aim is for 36 MeV protons and extends upwards in mass and down in energy providing beams such as 22 MeV/amu ^{16}O and 10 MeV/amu at ^{40}Ca. The University of Washington proposes to do this using existing technology and resonators to be purchased. Although a specific choice between the ATLAS resonators or the Stony Brook/Cal Tech design is not yet firm, the price estimate is conservatively based on the ANL resonators. The proposal appears technically sound since the ATLAS system is a proven design and little new development is needed.

The proposed beam characteristics and the scientific justification build upon the present work of the University of Washington laboratory, with emphasis on light heavy ion reaction studies, radiative capture, and studies of fundamental aspects of the nucleon-nucleon interaction. The latter two topics draw significant strength and uniqueness from a high-intensity polarized ion source which will become available in 1983. The University facility would provide a capability for high risk and long experiments. The high quality polarized beams will be used for improved structure studies, nuclear force symmetry problems and will permit parityviolation studies exploiting longitudinal analyzing power measurements in systems like p+p and n+p. Instrumentation such as a large NaI detector and a new isochronous momentum filter are already in place. Although some of the proposed research will most likely have been completed before the proposed facility would be operational, one can feel certain that, in the tradition of the University of Washington laboratory, imaginative physics and inventive experiments will be done with the new facility. Nevertheless, since the proposal does stipulate beams which, except for polarized protons, are generally available now, it could be important to accomplish construction on the fastest possible schedule.

The University of Washington and the physics department demonstrate their strong support for this proposal by pledging significant contributions in funds, technical personnel, and faculty lines toward the construction. The University of Washington has a long, distinguished history in the training of outstanding graduate students who now occupy positions in nuclear physics in a wide variety of universities and research laboratories. It is clearly important to preserve this resource for the future of the field.

The extensive in-house construction work required by this proposal will interfere to some degree with the students' education, although the tandem can be used for experiments during construction and it is reasonable to assume an ongoing visiting program at outside facilities. Again, the impact on the faculty and on the ongoing program could be minimized by rapid construction. Although the Washington proposal is for a four-year construction schedule, reduction to three years might be feasible since the project, as presented, requires little technical innovation or new design. The main effort of directing the construction program will be carried by two research faculty members, Derek Storm and Tom Trainor, who have an extensive technical background. In addition, it seems mandatory for the success of an in-house project of this kind that senior faculty commit themselves in a direct way. Both R. Vandenbosch and J. Cramer will take major responsibilities for its successful completion. Overall, the budget provides for salaries for 14 man-years of technical manpower and about 18 man-years of scientific and professional effort. This total level of effort appears appropriate for the construction project.

The responsibility of Argonne in the production of resonators (if the ATLAS design is selected) is limited. In addition to shop fabrication, the ANL responsibility is in the nature of assistance and advice rather than provision of a commercially guaranteed project. It would probably be of great value for University of Washington scientists to be at ANL in the very near future to observe and participate in the actual construction of ATLAS. (This involvement shouldn't wait for possible funding to begin in FY 1984.)

The complement of instruments now existing or under construction will satisfy most of the needs of the physics proposed. (Some part of the heavy ion reaction work proposed would be enhanced with a high resolution, heavy ion magnetic spectrometer.) Thus, the proposal does not contain any request for monies for instruments. High resolution spectometer aside, it is reasonable that specific new instrument money not be requested now--although it should be assumed that before the end of the decade, of order $1.0 million (1982 dollars) be spent on instruments for the new facility as the physics needs are clarified.

The total cost of the booster project has been reassessed by the University of Washington in accordance with the guidelines given NSAC in February. We have no serious questions to this budget. It is based on a four-year construction schedule. The costs are derived in accordance with recent experience at ANL (and are generally in line with item costs at Stony Brook). The detailed budget is given in the following table. We have been informed that the University of Washington estimates total operating costs for the facility at $2.0 million (in 1982 dollars) when it becomes operational. That involves an increment to present operating costs of about $0.6 million. It is also estimated that, in the last year of the project, about $0.2 million (1982 dollars) would be required for run-in costs.

A summary of the cost follows:

FY 1982 Dollars (May 1982)

	Dollars in Millions
Accelerator	3.020
Refrigeration	0.507
Ion Source Platform	0.250
Beam Lines and Transport	0.645
Technical Personnel (at Univ. of Wash.)	0.360
	4.782
Building Mods. and Utilities	0.130
	4.912
Engineering, design and inspection (~ 15% of above)	0.737
State Tax	0.291
	5.940
Contingency (@ 20%)	1.188
TOTAL	7.128

Components:	DOE Construction Project:	5.921
	Redirected Operating Costs:	0.394
	Univ. of Wash. Contribution*:	0.813
		7.128
	Incremental Operating Costs during construction:	0.200

University of Washington purchase schedule results in an escalation of these costs as follows (assuming 5% escalation from May 1982 costs to beginning FY 1983 and 10% per year following):

		Dollars in Millions
Escalated costs:	DOE Construction Project	7.500
	Redirected Operating Costs:	0.504
	Univ. of Wash. Contribution:	1.028
	Total Escalated Costs	9.032

The proposed annual schedule for the DOE construction project is as follows:

FY 1984	FY 1985	FY 1986	FY 1987
2.978	2.153	1.463	0.906

YALE UNIVERSITY UPGRADE PROJECT

The Wright Nuclear Structure Laboratory (WNSL) at Yale University has resubmitted its proposal for conversion of their existing 13 MV MP tandem Van de Graaff accelerator to a 20 MV ESTU. The essential elements of this proposal are little changed from the proposal submitted to the 1980 Facilities Subcommittee which shared the Subcommittee's highest recommendation for FY 1982 construction. Earlier versions of this proposal had received NSAC endorsement in reviews for FY 1980 and FY 1981 projects but had been precluded from funding by budgetary limitations. While partial funding for the previous proposal was included in the FY 1982

* The University of Washington contribution has been promised in letter from Provost Beckmann, included at the end of the proposal. We have also been told by Vandenbosch that the University of Washington agrees to relieve the project of University overhead on the construction project.

Presidental Budget, later budget actions led to its cancellation. These events have led to the submission of the present proposal for reconsideration.

The performance capabilities of the proposed ESTU conversion will increase research opportunities extending from traditional areas of the study of light-ion and heavy-ion induced reactions to those areas where nuclear physics interfaces with other disciplines such as atomic physics, astrophysics, geophysics, etc. The ongoing research program at Yale is involved actively in all these areas, has made significant--sometimes pioneering--contributions, and is in a very strong position to capitalize quickly and effectively on the new energies and beams made available by the ESTU. The intrinsic flexibility of the proposed large electrostatic accelerator make it particularly attractive for such a broad program.

The use of both light- and heavy-ion beams in spectroscopy studies that search for the underlying symmetries in the structure of nuclei promises to be one of the most exciting areas of research in the coming decade. This is a research opportunity well suited to the capabilities of the ESTU and complemented strongly by the nuclear theory program at Yale for which an expansion is in progress. The proposed time-of-flight capabilities will add an important new dimension to the study of reaction processes in both light- and heavy-ion systems that proceed with emission of neutrons. The addition of the polarized ion source will open new opportunities to study the basic features of the nuclear interaction as evidenced through searches for parity violations in proton scattering and charge symmetry breaking in the nuclear force.

An important facet of this proposal is its impact on graduate education. Yale has distinguished itself by the number and quality of the experimental nuclear physics Ph.D.'s it has awarded. The training of these students, including work in applied areas, has provided an important resource for industry as well as academia. The proposed conversion should noticeably enhance this program. It will also provide increased strength to an already outstanding program of training and experience provided to postdoctoral and junior faculty appointees. The scope of the proposed facility is well suited to operation in the environment of a university laboratory.

The proposed conversion of the Yale MP tandem to an ESTU tandem involves the following modifications: (1) the present 80-foot-long by 18-foot-diameter pressure vessel will be removed and a new vessel, 25 feet in diameter and 100 feet in length, will be installed. The existing accelerator vault at Yale was sized initially to accommodate such a vessel; (2) the number of standard HVEC column sections on each side of the high-voltage terminal will be increased from four to five; (3) the standard 72-inch HVEC acceleration tubes will be replaced with 88-inch tubes. Each column section in the ESTU will contain an 88-inch long acceleration tube; (4) the high voltage terminal will be lengthened from its present 8-foot length to 10 feet. This will allow addition of equipment, particularly a foil stripper and a quadrupole lens in the terminal; (5) a rotating shaft mechanical power system, running parallel with the charging chains, will be installed in the column. This will allow the charging chains to provide additional capacity to ensure adequate charging at the higher potentials; (6) a commercially supplied beam pulsing system will be installed to provide time-of-flight capabilities with resolutions in the subnanosecond region; (7) a commercially available polarized ion source for protons and deuterons will be installed. It is anticipated that polarized beams with currents in excess of 1 μA on target will be provided; (8) the present 90° analyzing magnet, the high energy quadrupole lens, and the 45° switching magnet will be replaced with more powerful elements. These are required to accommodate the higher rigidity ion beams produced with the ESTU accelerator. The remaining beam transport magnets appear to have adequate capabilities for the new beams; and (9) an additional 45° switching magnet will be added to provide additional experiment stations in the second target room.

The only significant change in the technical aspects between this and the previous proposal is a change in design of the support structure for the end sections of the column structure. This design change was precipitated by High Voltage Engineering's recent announcement that they will no longer undertake large accelerator projects, including design and fabrication of special electrostatic structures--such as the previously proposed end sections for the ESTU column. The present proposal is based on a support structure using standard MP column components along with radial bracing provided by standard column sections from HVEC K series accelerators. This provides an acceptable solution to the component availability problem since HVEC has also announced their intention to continue supplying standard replacement parts for all of their existing accelerators.

The technical feasibility of this proposal appears to be soundly based on existing technology. The proposed 88-inch extended tubes, first installed on MP-10 at Strasbourg and more recently on MP-7 at Brookhaven National Laboratory, have been operated successfully to the gradients proposed for the ESTU (4 MV/unit). The new design for providing additional support to the column structure by utilizing standard HVEC components (as discussed above) is a clever solution for producing the mechanical stability required. It should be noted, however, that the change of degree of participation by HVEC will place a larger burden of project supervision and engineering responsibilities on the WNSL staff. The technical competence and prior experience of this staff should allow the completion of the project in a timely fashion.

It is particularly encouraging that two significant additions to the experimental facilities at Yale have been realized since the time of the previous submission of this proposal: (1) a new magnetic spectrograph is under construction and is due for installation in late 1982. This modified split-pole design features a large solid angle (~ 12.8 msr) and a maximum mass-energy product of about 210; and (2) the data acquisition system has been enhanced substantially by the addition of an IBM-4341 CPU, an IBM-3370 disk storage unit (571 MBYTE capacity), a Memorex-1270 terminal controller (allows access by eight time-shared terminals), and additional peripherals.

From the perspective of the national program, this proposal would strengthen the research capabilities both for light-ion and heavy-ion research by one of the leading university groups in nuclear science, one which has an ongoing tradition of supporting a substantial program in graduate education. The Committee noted the continued strong support of the University for the nuclear physics program and for this project. The

Yale group has also announced its intentions to make the ESTU facility available to the national community and to seek input from representatives of interested users outside the Laboratory on the allocation of beam time and use of facilities.

The estimated cost of the proposed facility is \$7.09 million in FY 1982 dollars. Of this amount, \$6.14 million represents the cost of the ESTU conversion and the remaining \$0.95 million is the cost of proposed additional ancillary equipment (polarized source, beam buncher, new magnet and beam lines, etc.). Addition of a 20% allowance for contingencies brings the total, in FY 1982, to \$8.51 million. Although it is not anticipated that additional funds will be required to operate the accelerator for the resident program, it seems reasonable to project a modest increase in operating costs associated with providing technical assistance to nonresident users of the facility. The WNSL staff has proposed the addition of three new technicians during the installation period. Following resumption of facility operations, these technicians would assume responsibilities related to outside users. The estimated cost of the additional support would be about \$150,000 annually.

The time schedule for this proposal, assuming FY 1984 funding, calls for operation of the present facility to end October 1, 1985, completion of installation on April 1, 1986, and resumption of the research program with the ESTU on July 1, 1986. Thus, ony a nine-month interruption of the experimental program is envisioned. This should have only a slight to moderate impact on graduate program.

The Committee gives its very strong endorsement to this project.

DOE/NSF NUCLEAR SCIENCE ADVISORY COMMITTEE

February 16 and 17, 1982
Room A-410
U. S. Department of Energy
Germantown, Maryland

Tentative Agenda

February 16, 1982

9:00 - 10:00 a.m.	Discussion of NSF and DOE budget situations for FY 1982 and FY 1983 NSF and DOE guidance to NSAC on FY 1984 prospects for new facility construction
10:00 - 10:30 a.m.	Discussion of procedures for review of proposals for FY 1984 facility construction

(Discussion and presentation of each proposal for FY 1984 facility construction will consist of 50% of total time for formal presentation by proposer and 50% for discussion and questions.)

10:30 - 12:30 p.m.	Presentation and discussion of "Nuclear Physics Research with a 450 MeV Cascade Microtron" submitted by the University of Illinois
12:30 - 1:30 p.m.	LUNCH
1:30 - 3:30 p.m.	Presentation and discussion of "High Intensity Los Alamos Neutrino Source" submitted by Los Alamos National Laboratory
3:30 - 4:45 p.m.	Presentation and discussion of "A Proposal for a Superconducting Booster" submitted by the University of Washington
4:45 - 6:00 p.m.	Presentation and discussion of "A Proposal for Conversion of the Yale MP Tandem Accelerator to ESTU Status" submitted by Yale University

February 17, 1982

8:30 - 9:45 a.m.	Presentation and discussion of "Holifield Heavy Ion Research Facility Phase II" submitted by Oak Ridge National Laboratory
9:45 - 11:00 a.m.	Presentation and discussion of "Proposal for a Heavy Ion Facility at Brookhaven--Cyclotron Addition" submitted by Brookhaven National Laboratory
11:00 - 12:15 p.m.	Presentation and discussion of "Proposal to Build a New Injector at SLAC for a Program of Research in Experimental Nuclear Physics" submitted by American University
12:15 - 1:15 p.m.	LUNCH
1:15 - 5:00 p.m.	Discussion of proposals submitted for FY 1984 facility construction
	Subcommittee Reports--Manpower, and Computational Capabilities for Nuclear Theory
	Other Business
5:00 p.m.	ADJOURN

Revised
March 18, 1982

DOE/NSF Nuclear Science Advisory Committee

March 22 and 23, 1982
Room 4A-104
Forrestal Building
U. S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D. C.

Tentative Agenda

March 22, 1982

9:00 - 9:30 a.m.	Status of NSF and DOE budgets
9:30 - 12:00 noon	Report from the Subcommittee on Electromagnetic Interactions--P. Barnes
12:00 - 1:00 p.m.	LUNCH
1:00 - 6:00 p.m.	Reports of working groups on facility proposals - University of Illinois - American University - Los Alamos National Laboratory - Oak Ridge National Laboratory - Brookhaven National Laboratory - University of Washington - Yale University

March 23, 1982

9:00 - 10:00 a.m.	Further discussion of the report from the Subcommittee on Electromagnetic Interactions
10:00 - 12:30 p.m.	Discussion of facility proposals and formulation of recommendations
12:30 - 1:30 p.m.	LUNCH
1:30 - 5:00 p.m.	Review of draft report to NSF and DOE "Recommendations for FY 1984 Facility Construction"
5:00 p.m.	ADJOURN