RECOMMENDATIONS FOR FY 1982 FACILITY CONSTRUCTION

A Report Submitted to

the DOE/NSF Nuclear Science Advisory Committee

from the

1980 Facilities Subcommittee

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April, 1980

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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 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 good 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 three 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.

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 Sciences, National Research Council - National Academy of Sciences, 1977'."

III. Proposal Summaries

The 5 proposals considered by the Facilities Subcommittee are briefly described below. The summaries include the nature of the facility, the estimated cost of construction, the estimated time for the construction, the projected increase in operating funds, as well as the research area which the proposal facility would serve. The Subcommittee made a special effort to ensure that the basis for estimating the construction costs of each facility is as identical as possible.

1. American University Project at the Stanford Linear Accelerator Center (SLAC)

Forms of this project were submitted to both the 1979 and 1980 Facility Subcommittees. The present submission proposes the construction and installation of a downstream injector on the Stanford linear accelerator to deliver a high intensity electron beam (14 to 27 μA) in the energy range 0.4 to 2.9 GeV. This beam is to be used to perform a 180° elastic electron scattering coincidence experiment as well as an inelastic scattering experiment with deuterium as the target. These experiments seek to extend the elastic and inelastic magnetic form factors of the deuteron to regions of much higher momentum transfers. The cost of the injector is $1.24 M (FY 81 $) while the cost of the experiment is $1.86 M (FY 81 $). The construction and experiment would be accomplished during FY 83 and FY 84.

2. Brookhaven National Laboratory (BNL) renews its proposal to construct a solid pole, room temperature, spiral focused isochronous cyclotron post-accelerator to be injected by ion beams from the existing double MP tandem Van de Graaff accelerator. The design goal is for roughly 150 MeV/amu for projectiles with mass number between 6 and 40 and roughly 30 MeV/amu for heavy projectiles such as uranium. The corresponding design intensities are in the range from 100 to 10 particle nanoamperes. Beams of essentially all nuclei with $A \geq 6$ can be provided by the tandem injector and accepted by the proposed post-accelerator. The total estimated costs in 1981 $ is $12 M, including a building required to house the booster. A considerable saving is obtained through the use of the SREL magnet. Additional costs will be met by reprogramming BNL funds. No immediate need for equipment and data accumulation system is perceived. Incremental operating costs after project completion are estimated to be $0.750 M. The construction could commence in FY 1983 and be completed during FY 1985. The facility will be used primarily for heavy ion physics.

3. Florida State University (FSU) renews its proposal to add a superconducting linear accelerator booster to be injected by its existing 9 MV FN tandem electrostatic accelerator. Heavy ion projectiles with mass numbers up to A = 30 should have an energy of 10 MeV/amu. For larger A, the energy should decrease

to a value of 5.5 MeV/amu at A = 60. The linear accelerator sections will be of the type developed by Argonne National Laboratory and will be provided by that Laboratory. The amount requested in FY 81 $ including ancillary equipment is $3.4 M. Additional funds will come from the operating budget of the present facility. In addition, funds have been and will be provided by the State of Florida and by FSU. The proposed facility would require an increment in operating funds estimated to be between $150 K and $225 K. Construction is scheduled to take 2 years. Typical experiments to be conducted with this facility involve the use of the lighter heavy ion projectiles to study nuclear structure as well as nuclear reaction mechanisms.

4. The Indiana University proposes to construct a storage ring with electron cooling and, in addition, a third stage cyclotron to be injected with beams from the existing facility. The additional cyclotron ("Tripler") would increase the upper energy of light ion beams by a factor of 2 for protons achieving a maximum value of 375 MeV, by a factor of 3 for heavier ions (900 MeV for ^{6}Li) over the present values. The storage ring ("Cooler") would provide CW charged particle beams with very low emittance and small energy spread. It would make practical the use of ultra thin targets without loss in beam luminosity, the use of atomic beam targets, and would make recoil nuclei accessible for measurement. The construction costs for the Cooler in FY 81 $ is estimated to be $4.85 M. Additional costs will be borne by the State of Indiana and Indiana University. Ancillary equipment already requested from the National Science Foundation (NSF) for use with present facility is appropriate for use with the Cooler. Incremental operating costs would be about $0.425 M. The estimated

construction cost of the Tripler in FY 81 \$ is \$9.8 M with additional funds being provided by Indiana University. Incremental annual operating costs in FY 81 \$ upon the Tripler project completion is estimated at \$0.385 M. It is anticipated that the Cooler will take 3 years to complete, the Tripler, 4 years.

5. The Oak Ridge National Laboratory proposes to upgrade the Holifield Heavy Ion Research Facility through the installation of superconducting coils, thereby increasing the magnetic field at the cyclotron (ORIC). As a consequence, it will become possible to accelerate the more massive heavy ions ($A \geq 150$) to energies in the 15-20 MeV/A range, well above the Coulomb barrier. For projectiles with low mass numbers, the energy will be about 38 MeV/A. If begun during FY 83, the project should be finished by early FY 86 with an estimated cost of \$7.36 M. Additional funds would be provided by reprogramming of funds. It is anticipated that there would be no increment in operating costs.

IV. Scientific Opportunities

The proposals under consideration illustrate the broad range of issues which nuclear science must address in order to achieve fundamental understanding of nuclear interactions and their consequences.

The discovery of the internal structure of the nucleon, the associated nucleon excited states, and the proposal that the hadronic interactions can be understood on the basis of quantum chromodynamics present a challenge to the nuclear theorist and experimentalist. The former must revise his description of the nucleon-nucleon interaction currently based on the exchange of bosons between two point nucleons. He must also reconsider his description of nuclear structure particularly because of the finite size of the nucleons, and also because of the possible color dependent interactions important at short internucleon distances. The experimentalist must devise experiments which will be sensitive to these newly revealed aspects of hadronic forces.

At the other end of the scale, collisions between nuclei are under active study. These reactions can be very complex so that an important goal of this research is the determination of the proper measures which will describe most economically the nature of the reaction and so isolate and identify its simpler aspects. Correspondingly, one looks for the degrees of freedom in terms of which the dynamics of the reaction are most appropriately described. It is anticipated that these will depend upon the mass and energy regimes under study as well as energy resolution. Considerable progress, as discussed in last year's report, has been made, but a wide variety of important ranges in the experimental parameters which must be explored remain.

In recent years, the known giant resonances associated with nuclear vector currents have been extended to the quadrupole and especially the monopole modes. Giant resonances associated with axial currents have been observed, and this area of research will unquestionably receive strong emphasis by the community. These new modes of motion have become visible with increasing energy and better resolution in both energy and angle. The use of damping mechanisms, such as "cooling" and beam storage to improve beam quality and beam time structure provides a significant increase in resolution. Ultra thin targets can be used and coincidence experiments become feasible. It can be anticipated that these increased capabilities will lead to a better understanding of the giant resonances already uncovered and may very well lead to the discovery of new structures.

The above briefly describes the issues to which the facilities considered in this report would provide experimental access. Clearly, they would form an important addition to the United States nuclear capability. The new frontier areas which would be opened up to exploration would certainly yield new insights into the nucleus and nuclear interactions.

V. Recommendations

1. The Florida State University Superconducting Linac Booster

The Committee found this proposal to be technically feasible, scientifically valuable, and cost effective. The proposed upgrading will substantially increase the research capability of an important university facility. It will, therefore, provide a significant and needed addition to high quality research opportunities for students and researchers interested in nuclear science. The Committee recommends the funding of the proposal.

2. The Indiana University Cooler-Tripler

The Committee found that this proposal is technically feasible and scientifically important. The Cooler is an innovative application of forefront accelerator technology to nuclear science. It will provide a unique capability which would permit the performance of measurements with ultra-high resolution for processes with very low cross-sections and at relatively high light ion beam energies. The Committee recommends the funding of the Cooler. The Tripler would substantially raise the energy of the light ion beams, thereby making possible high resolution studies in a new energy domain. The Committee felt that the Cooler should be constructed in a manner consistent with the addition of the Tripler, should that facility be recommended for construction at a later time.

3. American University Proposal at SLAC

The Committee found that this proposal is technically sound. The Committee felt that the proposed experiments should be undertaken because they are scientifically important, although, by themselves, they would not lead to decisive interpretations. A program of experimental investigations, of which these would form an important part, is required. Only SLAC presents, now and in the near future, opportunities for implementing such a program. The Committee felt that, in view of the charges that would be levied by SLAC for the use of the beam, the cost of the proposed experiments to the nuclear physics program are too great to justify high priority for this proposal.

4. The Brookhaven and Oak Ridge National Laboratories Facility Proposals

These proposals would add to the national capability in heavy ion physics. In anticipation of the report of its Subcommittee on Heavy Ion Physics, which will evaluate the national need in this area, the Committee does not make any recommendation at this time. On the whole, the Committee favored the Brookhaven proposal because of its cost effectiveness, its reliance on completely known technology, and the relative ease with which the accelerator system would be operated. It would provide needed capability for an important group of users. In addition, it was felt that the first task of the Oak Ridge group should be experimentation with the Holifield facility which is just about to be completed. The Oak Ridge proposal is also cost effective and would produce high quality ion beams. It is a desirable upgrading of the Holifield facility. Both proposals rely upon presently available detection systems. These would need to be upgraded in order to make full use of capabilities of the proposed accelerators.

Final Impact of the Recommendations

The recommendations made by the 1981 Facilities Subcommittee together with those of the 1980 Subcommittee follow rather closely the "Long-Range Plan for Nuclear Science" issued in December 1979. The suggested "High Energy Light Ion Upgrade" referred to in Table II of that report would be realized if the Indiana University proposal were funded. Similarly, the Florida State proposal would be considered one of the heavy ion upgrades. A subcommittee is now considering the need for further construction of heavy ion facilities and will present its report soon.

The incremental operating costs of \$150-225 K for the FSU and \$425 K for the Indiana University "Cooler" do not seem excessive and would not result in important dislocations. However, a firm judgment cannot be made in view of the budget uncertainties.

VI. Evaluation of the Proposals

AMERICAN UNIVERSITY PROJECT AT SLAC

It is proposed to construct and install a downstream injector on the Stanford Linear Accelerator (SLAC) to deliver a high intensity electron beam (14 to 27 μA) in the energy range 0.4 to 2.9 GeV. It is further proposed to use this beam in a 180° elastic electron scattering coincidence experiment and an inelastic experiment on deuterium.

The experiment seeks to obtain the elastic magnetic form factor of the deuteron up to momentum transfers of 10 fm^{-1} and also to extend measurements of the inelastic magnetic form factor to regions of much higher momentum transfers. These high momentum transfers probe the structure of the deuteron at small distances and are, therefore, sensitive to the underlying structure of nucleons and to the short distance interaction between nucleons. The separation of longitudinal and transverse inelastic cross sections can give insights into QCD (Quantum Chromodynamics) effects.

The cost of the injector is $1.24 M (FY 81 $). The cost of the experimental setup and beam time to make the measurement is $1.86 M (FY 81 $). The proposed injector would be a copy of the existing electron source at SLAC. The experiment would be performed in End Station A (ESA) using existing spectrometer magnets reconfigured for a 180° measurement.

The proposed program depends critically on the availability of ESA at SLAC. It now appears certain that this area will be available for nuclear physics experiments from October 1981 to approximately the end of calendar year 1985. The later date is determined by the time that the SLAC Single Pass Collider (SPC) is hoped to become operational. There will be no physical interference between the SPC and the operation of ESA, but supplying simultaneous beams with proper characteristics to both experiments is not possible. Until SPC becomes operational, the beam for nuclear physics can be provided parasitically (subject to paying operational costs) without interfering with other SLAC programs. Thus, the nuclear physics program will have free access to the 3 GeV beam.

This situation would change if parity experiments using polarized electron beams are revived. At present, this is not likely unless future developments in high energy physics would once again make these measurements attractive. In any case, there does not appear to be any serious conflict to carrying out the proposed program and the parity experiment.

The above time window would in all probability be extended if the SPC is delayed or not built. In addition, SLAC will undertake to minimize interference between bringing SPC into operation and the nuclear program. However, once the SPC is operational, the nuclear physics beam will be available only when SPC is not running.

The facilities in ESA will be available for use subject to providing the required maintenance and operating costs. The SLAC management has taken a positive attitude towards implementing the nuclear physics projects.

BROOKHAVEN NATIONAL LABORATORY

The Brookhaven National Laboratory has proposed the construction of a solid pole, room temperature, spiral-focused, isochronous cyclotron post-accelerator to be injected by ion beams from the existing double MP tandem Van de Graaff complex. The design goal is for roughly 150 MeV/amu in the case of projectiles with $6 \leq A \leq 40$, and roughly 30 MeV/amu for very heavy species such as uranium; the corresponding design beam intensities are in the range from 100 - 10 particle nanoamperes. Reflecting continuing progress in the production of negative ions, essentially all ionic species with $A \geq 6$ can be provided by the tandem injector and accepted by the proposed post-accelerator. Hydrogen and helium isotopes will not be available from the post-accelerator.

While incorporating several novel features, the cyclotron design is a conservative one using well-proven technologies; because Brookhaven proposes to utilize the SREL magnet iron, the proposal is a very cost-effective one in the energy, current, and species ranges involved. The Committee believes that the technical feasibility of the proposal has been fully demonstrated.

It is widely recognized that Brookhaven has set the standards by which support of user groups is measured in United States nuclear science; the Committee has every confidence that this high standard would be fully maintained were the cyclotron post-accelerator to be added to the present tandems. Brookhaven has an experienced and effective operation and support staff and a long tradition of excellent support of its researchers--both internal and external. It continues to play a very important role as a base for users from institutions across the Nation, and, particularly, from the Northeast where a substantial fraction of the Nation's scientists active in heavy ion research are located.

These heavy ion research groups in the Northeast, are primarily university-based, and are dependent, entirely, or in part, on the continued viability of the Brookhaven heavy ion program.

The theoretical nuclear physics group at Brookhaven is a strong one and is expected to provide important support to the research performed with the proposed facility.

The estimated cost of construction in FY 81 $ is $8.36 M, to which Engineering Design and Inspection costs of $1.7 M and 20% contingency of $2.0 M should be added, leading to a total funding request of $12 M. In addition, the Laboratory will provide funds by reprogramming. This will involve a transfer of essentially all of Brookhaven's nuclear chemistry activity and a substantial fraction of its neutron physics activity in FY 1985. Additional equipment will be provided from the Laboratory's equipment budget.

Incremental annual operating costs in FY 81 $ are estimated to be $0.75 M.

While the requested funding of $12 M may appear to be a relatively low total for a project of this scope and capability, it must be noted that, were the SREL magnet iron not available, the total for the project would be increased by roughly $8 M (FY 81 $).

Were the project to be funded in FY 1983, Brookhaven proposes that the entire project would be completed so that experimental research could begin toward the end of the third quarter of FY 1985. While the Committee fully understands Brookhaven's desire for such an accelerated schedule, it recognizes that budgetary limitations may require a somewhat more extended construction period. Fortunately, the proposed design is such that for much of this construction period, the research program based on the MP tandems could proceed without interruption.

In considering this proposal, the Committee notes that in the case of heavy projectiles the proposed performance is comparable to that of MSU Phase II--although we believe that the Brookhaven claims of superior energy resolution and more convenient energy variability are justified. The Committee further believes that achievement of the performance goals for very heavy beam species may be more readily accomplished with the conventional technology proposed by Brookhaven. These species have taken on particular importance in that this capability opens up a previously unaccessible region in the experimental parameter space in heavy ion science. In the case of the lighter heavy ions, high resolution studies up to energies of 150 MeV/amu would be made. This would, however, require the construction of a magnetic spectrograph. The presently available

QDDD spectrograph limits the high resolution experiments to energies of almost 30 MeV/amu where the proposed ATLAS and the existing ORNL tandem ORIC are competitive.

A decision to fund this post-accelerator must, therefore, rest predominantly upon an evaluation of the scope of the research demand for heavy ions in the energy ranges involved, and the extent to which this demand will exceed the capacity of facilities now available or under construction. This decision will also depend on an evaluation within the nuclear science community of the relative demands for heavy ions as compared to those for other beams or facilities. An NSAC Subcommittee is currently considering the first of these questions--the demand for heavy ion facilities *per se*.

The Committee concludes that the proposed Brookhaven cyclotron post-accelerator, while not unique, is an entirely feasible, very cost effective facility that would provide greatly enhanced national capability in heavy ion science--and in a singularly effective user environment.

Remarks

1. The Committee believes that exploitation of the full potential of the proposed cyclotron would require the construction of a magnetic spectrograph capable of matching the high resolution 150 MeV/amu cyclotron specifications for the lightest ions available. In addition, it feels that the data acquisition and analysis computer system now available at Brookhaven should be replaced. The belief is based on the perception of the substantially greater complexity and sophistication of the measurements that will be required in the new parameter ranges to be made available by the proposed facility.

2. The Brookhaven management has committed itself to strong support of the cyclotron proposal should it be funded. However, it should be noted that the internal Brookhaven research staff, working with the tandem accelerators, has decreased by about one staff member per year for the past five years; should this trend continue, under budgetary pressures, the Committee would be seriously concerned regarding the adequacy of internal research support for the proposed facility. It also notes that, with the AGS, Brookhaven has the only facility in this country where an active program in kaon nuclear physics could reasonably be mounted. Should the support for such kaon physics, recommended in the NSAC Long Range Plan, become available to Brookhaven, it will be essential that Laboratory management reexamine the priorities assigned to nuclear science and the size of its overall experimental nuclear science research group.

FLORIDA STATE UNIVERSITY: SUPERCONDUCTING LINAC BOOSTER

Florida State University proposes to add a superconducting linear accelerator booster to the existing 9 MV FN tandem accelerator in order to increase the effective acceleration voltage by 12 MV, yielding heavy ions of about 10 MeV/nucleon up to A = 30, decreasing to 5.5 MeV/nucleon at A = 60. The linear accelerator sections will be of the type developed at ANL. Other proposed equipment includes helium refrigerators, beam handling hardware, a time-of-flight facility, a computer for data acquisition, a source for polarized alkali ions, a large scattering chamber, and other items of apparatus. The total funds required, including engineering cost and contingency, is $3.4 M (1981 $). Additional in-house construction costs will be borne by FSU ($0.46 M) and the ongoing NSF operating budget ($0.37 M). The State of Florida and FSU have already provided

$0.80 M for three resonators, for a building addition to house the linear accelerator and a new target area, and for other ancillary equipment. The proposed facility would require an increment in operating funds of between $150 K and $225 K, the range resulting from uncertainties in cryogenic costs. All these figures are in FY 81 $. Construction is scheduled to take 2 years.

This proposal is very cost effective since an existing accelerator is being extended and since there has been a substantial preparatory contribution from the State of Florida. Argonne National Laboratory has stated its intention to provide the superconducting linear accelerator sections and that there will be no substantial conflict with the ATLAS project. Since a linear accelerator of the proposed type is already in operation at ANL, the technical feasibility of the project has been demonstrated. Similarly, the other components of the proposal, including the polarized ion source, are patterned after equipment in operation elsewhere. Nevertheless, the installation, maintenance, and operation of the equipment will require expertise not normally available in nuclear physics laboratories. Certain steps have been taken to provide the required expertise for the operation of the superconducting accelerator. For example, good quality beam bunching has been achieved with the first resonator. However, operation with beam at the required voltage gradient has not yet been demonstrated at FSU. Nevertheless, it appears that the cost estimates are reliably based and any unforseen difficulties are likely to result at most in a delay of operation.

The proposed upgrading will significantly increase the research capability of an important University facility in the southeastern United States. Florida State has a core of good experimentalists who have made significant contributions to the field for 2 decades. The group is sufficiently large to be scientifically and technically self-sustaining and enjoys strong theoretical support. Moreover, FSU draws students from a part of the country with few accelerator facilities. Use of the facility by other researchers in the region is anticipated.

The proposed facility is of a scope well suited to the needs of the nuclear physics program at FSU. The study of resonance effects in heavy ion reactions is one of the open problems of nuclear physics. The FSU group has conducted careful and systematic investigations in the field. Such studies with heavier nuclei, hindered in the past by insufficient particle energy and the unavailability of the needed beam time, are well suited to the proposed facility. The time structure of the beam would allow excellent coincidence or time-of-flight measurements and mass identification. The polarized alkali ion beams would permit measurements not feasible elsewhere. Studies of high spin states, multi-nucleon transfer forming high lying states, fusion, and fragmentation made feasible by the proposed facility will add substantially to our understanding of both nuclear structure and nuclear reactions.

The Committee recommends the funding of this proposal.

OAK RIDGE NATIONAL LABORATORY: THE HOLIFIELD HEAVY ION RESEARCH FACILITY ORIC SUPERCONDUCTING CONVERSION

The conversion proposed by the Oak Ridge National Laboratory includes a new superconducting coil system replacing the existing aluminum magnet coils, a new beam extraction system, and modification of the beam transport system and shielding required because of the higher energy particles to be produced by the upgraded facility. The superconducting coils will permit an increase in the maximum magnetic field of the cyclotron providing an increase in beam energy of the heavier ions (A ≈ 150) to 15-20 MeV/amu and of the lighter ions to 37.5 MeV/amu. These energies substantially exceed those provided by accelerators now operating. The MSU Phase II facility is the only funded accelerator which will provide capability in this energy region, but its maximum energies will be considerably greater. Oak Ridge National Laboratory requests $7.36 M in FY 81 $ for construction costs including engineering design and inspection, and contingency. Additional funds which will be attained by reprogramming funds totaling about $1.7 M. It is anticipated that no incremental operating costs will be required after project completion.

Some of the most interesting results in heavy ion physics have come from the UNILAC accelerator using beams of lead and uranium at energies well above the Coulomb barrier. Research with the heaviest beams is one of the important tasks for heavy ion physics and will be possible with this accelerator.

The Present Holifield Facility

Recent history. The tandem passed one of its important tests in 1980 at 17.5 MV with 10 pμA of I^- beam injected. During the Fall of 1980, the individual sections were conditioned, one at a time, to 90% of the 1 MV/2ft level which would represent 27 MV on the terminal. Some modules were damaged by metal evaporation and had to be replaced. In January 1981, ORIC was injected by the tandem operating at 12.2 MV and the 401-MeV oxygen beams produced had superb characteristics. At the time of the site visit on March 18, conditioning of the machine was going on; with three damaged sections shorted, the terminal voltage seemed to be stable above 20 MV.

Plans for the Immediate Future. The tandem accelerator has not yet passed all of its acceptance tests (25 MV), but seems capable of useful operation. It will be put into research use the summer of 1981 in any case. Work will continue towards achieving specified performance, interspersed with research use. We were very pleased to see this development since it signifies the very near term arrival of a major new facility in heavy ion research and opens up a rich unexplored area of physics to experimental investigation, even before the specified performance levels are reached.

Tandem Performance and the Cyclotron. The exact terminal voltage has only a relatively small impact on the energies to be achieved by the upgraded cyclotron. The performance of the cyclotron for the heaviest ions is somewhat more seriously impacted by use of foil versus gas strippers. For the quoted final beam currents of 10^{11} p/sec, and beams of Pb ions, present terminal foil lifetimes are too short by orders of magnitude, although foil stripping does appear to be practical for currents of $\approx 10^{10}$ p/sec. The 10^{11} p/sec are achievable with gas stripping but at the cost of a 25% loss in energy.

The Cyclotron. The technical evaluation of the cyclotron was generally positive. Questions were raised on the design of the extraction system, the optimization of the trim coil design, the beam transport system, and it was felt that the design for the main magnet coils was perhaps too conservative and the cost estimate on the high side. But, on the whole, there seems little doubt that the proposed upgrading is technically feasible and constitutes a cost effective upgrading of the facility.

Conclusion

To conclude and summarize, the Holifield facility is about to become a very effective accelerator for heavy ion research. The proposed upgrading provides an attractive option for its additional enhancement.

INDIANA UNIVERSITY: TRIPLER/COOLER

The Indiana University Cyclotron Facility (IUCF) proposes the construction of a storage ring with electron cooling and a third stage cyclotron to be injected with beams provided by the presently operating two stage facility. The additional cyclotron ("Tripler") would increase the upper energy of the light ion beams by a factor of two (for protons) to three (for heavier ions) over the present values. The storage ring ("Cooler") introduces a new technology into nuclear science. It would provide charged particle beams with very low emittance, small energy spread, and make practical the use of ultra-thin targets without loss in beam luminosity.

The new installation would be housed in a building addition to the west of the present facility. Funds to construct the building addition, estimated to be about $1.5 M, will be sought by Indiana University from the State of Indiana. Additional support from Indiana University will take the form of a waiver of the indirect charge on about 125 man years of construction salaries. This support is estimated to total $1.7 M.

1. Capability

The capability of the proposed "Tripler" to produce beams of various light nuclei is summarized in the following list:

Particle	Maximum Energy (MeV)
p	375
d	300
^{3}He	750
^{4}He	600
^{6}Li	900

The duty factor in the storage ring cooler will be nearly 100% (macroscopic and microscopic); only very thin targets ($\leq 10^{17}$ atoms/cm^2) can be used in the storage ring but the circulating current will be high enough (perhaps 50 mA) so that counting rates will be similar to more conventional experimental techniques. The very thin targets provide the possibility of very high-energy resolution, accessibility of recoil nuclei for measurement, and the feasibility of using atomic beams as targets. The atomic beam target provides the possibility of many novel and extremely precise experiments.

2. Technical Feasibility

The Tripler is a straightforward extrapolation of the existing IUCF cyclotrons and contains many components very similar to those presently in use. Since present IUCF personnel include a major portion of the team that built the existing facility, the design and construction of the Tripler should be carried out effectively.

The Cooler is an innovative adaptation of forefront accelerator technology for use in a medium energy research facility. The technique of electron cooling has been under study for about a decade, and several detailed experimental studies have been made in the past few years. (This work is still in progress at Fermilab.) Electron cooling is well enough understood so that design of this ring can proceed with confidence.

3. Provision for Users

As noted below, the Indiana effort in the use of the existing facility is strong and at a significant level. Including the in-house effort, the present users organization numbers about 500 members. During the past year, more than 130 scientific personnel (including graduate students) participated in research at the facility. Thus, there is a strong base for use of the new facility by both in-house and external personnel.

4. The Sponsoring Laboratory

The strength of the existing staff at IUCF is impressive. Thus, the number of scientists and engineers involved with the existing IUCF is adequate for continuation of the present operation and to provide a core of key personnel for development and construction of the requested upgrade. The ratio of theoreticians to experimentalists sets a desirable example.

5. Educational Impact

The educational impact of this facility could be significant in that there are many opportunities for "small experiments" (i.e., those requiring only one to three FTE years for experimental work, analysis of data and writeup for publication) at a facility of this type.

During the past 4 years, approximately 16 Ph.D.'s have been granted as a result of work at the cyclotron facility. At the present time, 35 graduate students are participating in research at IUCF. (Thirteen of these are from Indiana U., the remaining 22 from other universities.) An equilibrium Ph.D. production of 6 to 10 per year should be anticipated for the present facility.

6. Cost

The cost estimate for the project is given separately for the "Cooler" and the "Tripler." Funds are requested totaling \$4.85 M in FY 81 \$ for construction of the Cooler facility. As mentioned earlier, the State of Indiana is to be asked for \$1.5 M to fund the building construction while Indiana U. will waive indirect costs on construction labor totaling about \$0.515 M. It is anticipated that the construction of the Cooler facility would be completed and experimentation begun in about three years. Incremental operating costs after project completion is estimated by IUCF to be about \$0.425 M.

The requested construction costs of the Tripler are estimated to be about \$9.8 M (FY 81 \$). Indiana University funds released by waiving indirect costs on construction labor totals \$1.135 M. Construction would take about 4 years. Indiana U. estimates that the incremental operating costs would be about \$0.385 M.

In considering these estimates, one should bear the following in mind:

A. Conceptual design requires significant support which is assumed to be a portion of the IUCF operating budget.

B. The new building addition (\$1.5 M) depends on the approval of state funds.

C. Effective experimental utilization of the Cooler facility requires the existence of a new high-resolution magnetic spectrometer which has been requested as a separate proposal ($934 K).

There is concern that the design effort (both conceptual and preliminary) may be underestimated both in magnitude and in personal costs. The IUCF estimate is correct only if the IUCF operation is supported at the requested operating budget level for the next few years and if state support as indicated will be provided.

The incremental operating costs listed in Table N-3 of the IUCF proposal, while not grossly out of line, are uncomfortably low. The amounts given in this report of $0.425 M for the Cooler and $0.385 M for the Tripler represent a substantial increase of that presented in the proposal.

7. Experimental Opportunities

The proposed Cooler will provide particle beams with very low emittance, small energy spread, and high luminosity. These properties allow the utilization of very thin targets such as provided by atomic beam sources. Use of such atomic beam targets offers the prospect of pure targets (low background) and arbitrary target polarization. Combined with polarized beams, the polarized targets will be employed for complete and accurate measurement of the spin correlation parameters in p-p and p-d scattering.

The thin targets, made practical by the Cooler, allow the detection of recoil target nuclei. This will allow clear, well defined target beams of polarized $\vec{n}$ and low energy pions to be produced. The target pion beams would be particularly useful for more precise studies of the s-wave effect.

For high resolution reaction studies, the thin target feature of the Cooler will allow important high momentum transfer studies where cross sections are very low but show the greatest sensitivity to details of the interaction parameters. The ability to detect recoil nuclei provides an additional control in identifying reaction channels.

8. Recommendations

The IUCF represents this country's sole facility for light-ion research in the 100-200 MeV energy region. The facility management has done a commendable job of operating as a national facility and accommodating user programs. The proposal represents a desirable direction for the long range growth of the laboratory. The innovative application of the electron cooling technique will provide an enhancement offering truly unique experimental capabilities. The construction of the Cooler is the most important step in developing new capabilities for the facility. The extension of facility capabilities to higher energies seems the next logical step in the development of the facility. Its major thrust would be to extend the unique capabilities introduced by the Cooler to an increased range of ion energies. The Committee is not convinced of the urgency for the extended energies. The Committee recommends that the project be phased, the Cooler construction constituting the first phase, and that it should be constructed in a manner to be compatible with the future addition of a Tripler.

DOE/NSF Nuclear Science Advisory Committee Meeting

February 9 and 10, 1981
Forrestal Building, Room 4A104
1000 Independence Avenue, SW
Washington, DC 20585

Tentative Agenda

February 9, 1981

8:00 - 9:00 a.m.	Discussion of NSF and DOE budget situations for FY 1981 and FY 1982
	NSF and DOE guidance to NSAC on FY 1983 prospects for new facility construction
9:00 - 9:30	Discussion of procedures for review of proposals for FY 1983 facility construction
9:30 - 1:00	Discussion of the status of CW electron accelerator proposals and projects--SURA (45 min.), U. of Illinois (45 min.), MIT (30 min.), ANL (30 min.), and LANL/NBS (30 min.)
1:00 - 2:00	LUNCH
	(Discussion and presentation of each proposal for FY 1983 facility construction will consist of 50% of total time for formal presentation by proposer and 50% for discussion and questions.)
2:00 - 3:30	Presentation and discussion of "Florida State University Superconducting Booster" submitted by Florida State University
3:30 - 5:30	Presentation and discussion of "The IUCF Cooler-Tripler; Proposal for an Advanced Light-Ion Facility" submitted by University of Indiana
5:30 - 7:30	DINNER
7:30 - 9:00 p.m.	Presentation and discussion of "A Proposal to Build a New Injector at the Stanford Linear Accelerator Center for Measurement of Electron-Deuteron Scattering at Large Momentum Transfer" submitted by American University

February 10, 1981

8:00 - 9:30 a.m.	Presentation and discussion of "Proposal for a Cyclotron Addition to the Brookhaven Tandem Facility" submitted by Brookhaven National Laboratory

9:30 - 11:30	Presentation and discussion of "Holifield Heavy Ion Research Facility ORIC Superconducting Conversion" submitted by Oak Ridge National Laboratory
11:30 - 12:30	LUNCH
12:30 - 3:00	Discussion of proposals submitted for FY 1983 facility construction
	Selection of proposals to be referred to Facilities Subcommittee
	Composition of charge to Facilities Subcommittee
	Suggestion to DOE and NSF of Facilities Subcommittee membership
	Determination of March date for NSAC meeting at which NSAC recommendations for FY 1983 facility construction will be put into final form
3:00 - 5:00 p.m.	Subcommittee Reports--Heavy Ion Facilities, Manpower, Universities, and Computational Needs of Nuclear Theorists
	ADJOURN

TENTATIVE AGENDA

DOE/NSF Nuclear Science Advisory Committee

March 30, 1981

9:00 am - 10:00 am	Status of NSF and DOE budgets for FY 1981 and FY 1982 and projections for FY 1983
10:00 am - 12:30 pm	Reports of Working Groups on Facility Proposals
12:30 pm - 2:30 pm	LUNCH
2:30 pm - 5:00 pm	Discussion of Facility Proposals and formulation of recommendations

March 31, 1981

9:00 am - 11:00 am	Review of draft of report to NSF and DOE "Recommendations for FY 1983 Facility Construction"
11:00 am - 12:00 pm	Discussion of charge to Subcommittee on Electromagnetic Interactions
12:00 noon - 12:30 pm	LUNCH
12:30 pm - 1:00 pm	Discussion of neutrino experiments at LAMPF (Felix Boehm)
1:00 pm - 2:00 pm	Discussion of procedures for updating Long Range Plan for Nuclear Science
2:00 pm - 5:00 pm	Reports from Subcommittees on Heavy Ion Facilities, Manpower, Universities, and Computational Needs of Nuclear Theorists