98-111R1 -- CONCEPT DEVELOPMENT AND OPTIMIZATION FOR AN EXOTIC BEAM FACILITY

Associate Lab Director Area: Physical, Biological, and Chemical Sciences

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Purpose: Since the early 1990's in the field of low energy nuclear science there has been worldwide interest in an advanced facility capable of producing energetic, high quality beams of radionuclides. The scientific case for such a facility led to its recommendation in the 1996 Nuclear Science Long Range Plan as the highest priority for new construction following the completion of RHIC at Brookhaven. At the present time the plans for the National ISOL (isotope-separator on-line) Facility are still considered site independent by the DOE, but because of the technology being considered, ANL is currently the primary contender. However, a state of Michigan initiative to have the facility sited at Michigan State University is being proposed as an alternative. A call for proposals and the site selection is expected to follow.

An evaluation of various possible technical approaches to the implementation of such a facility was carried out during 1999 by a subcommittee of NSAC called the ISOL Task Force. A report was presented to NSAC on November 22, 1999. A facility based on the ANL concept of a multi-beam (heavy ion) driver was recommended. The Task Force recommended a driver with intense beams as heavy as uranium at energies up to 400 MeV/u. The cost of such a facility is expected to be in the $500M range, including experimental apparatus. However, there is worry that the cost of this proposed facility is not well documented and could continue to rise. The purpose of this LDRD project is to solidify the design concepts to provide the background on which to base a more solid cost estimate. The preliminary design concepts developed under this project will be the basis for the DOE to proceed with authorizing and funding a conceptual design report. A variety of technical concepts are involved as described below.

Approach: An advanced exotic beam facility of the ISOL type involves several technological challenges that must be addressed before the DOE is likely to provide funding. The major components to be investigated include the type of driver accelerator

to be used to produce the radionuclides, a target/ion-source complex and associated shielding and remote handling, and the post accelerator for the radionuclides. Developing an overall facility integration plan, including infrastructure, is also an important component of this effort.

The present concept for the high power driver is a CW superconducting linear accelerator that is flexible enough to deliver a variety of light and heavy ion beams for production of radionuclides utilizing several different nuclear reaction mechanisms. The present LDRD project involves detailed computer simulations of the radionuclide production rates that are benchmarked against existing data when possible. Physics Division staff do some of these simulations and others are carried out with the help of Itacil Gomes in Technology Development Division. The linac study also involves design, construction, and testing of model superconducting resonators of the two types that are required to cover this new ion velocity range. An outside collaborator, Jean Delayen of Thomas Jefferson National Accelerator Facility, is involved in this effort. Work on the target/ion source complex involves developing new approaches to enable the use of primary beam powers of 100 kW. In particular, engineering concepts and test versions for two-step target geometries must be developed. An ion source test stand is being constructed at the Physics Division's Dynamitron facility to demonstrate the two-step, neutron generator approach and to help us establish credibility in this field. Some experiments with two-step target geometries for heavy ion fragmentation will also be carried out in collaboration with Russian scientists at Gatchina (St. Petersburg). The ANL concept for the exotic beam post accelerator involves a unique low frequency CW RFQ. To demonstrate its viability, a full-scale test assembly was designed, constructed, and is currently undergoing beam tests at the Dynamitron. A post-doctoral appointee, R. Kaye, was involved in the early stages of this work, and his successor, Michael Kelly, is continuing the tests. Preliminary work on other components of a proposal is also being carried out. This involves preliminary calculations of the neutron shielding requirements and evaluation of radioactive contamination control techniques. A post-doctoral appointee, M. Petra, is carrying out this work. Configuration options for a cost-effective integration of the new components with the existing ATLAS facility are also being studied. The technical requirements of the buildings and the relative locations of the major components must be specified before serious architectural design can begin.

Technical Progress and Results:

1. Engineering concepts for three types of high power production targets have been developed. Two of these incorporate liquid lithium cooling technology and have been developed building on technology previously developed in the TD and ET Divisions of ANL. The third involves large area, thin targets for direct heavy-ion irradiation. These concepts alleviated fears that the full beam power of 100 kW heavy ion beams could not be fully utilized.

2. The ANL proposal was based on a multi-beam superconducting heavy ion linac with a maximum beam energy of 100 MeV/u for beams with masses up to krypton. Beams up to uranium would have been available at reduced intensities and energies. The Task

Force has recommended an expanded scope to include high power uranium beams up to approximately 400 MeV/u. During 1999 a Task Force subcommittee considered various options for the technology of the driver accelerator. The two final candidates were the full energy superconducting linac advocated by Argonne and a large separated sector cyclotron advocated by Michigan State University. During this process a detailed proposal for accelerating up to five charge states simultaneously in the linac was prepared. This feature gave the linac a clear advantage over the cyclotron so it was adopted as the preferred option of the committee. Milestones reached by mid-1999 include the completion and testing of the first two spoke-type superconducting resonators. Both resonators (two different velocity parameters) were tested successfully at gradients of 5 MV/m, the initial design goal.

3. The low-charge-state, CW RFQ test model constructed during 1998 reached a major milestone by mid-1999. The design beam, 132Xe, was successfully accelerated at the PHY Dynamitron facility to the design energy.

4. Systematic calculations of radionuclide production rates have been carried out and validated by comparison with existing data wherever possible. This work was crucial in demonstrating that the heavy ion driver could be competitive with the "proven" high-energy-proton-based approach of the ORNL proposal. The Task Force then recognized that the heavy ion fragmentation mechanism was unique in its chemical independence and fast separation times when used with a helium or argon gas catcher/ion guide.

5. The concept of a magnetic fragment separator followed by a gas catcher/ion guide was developed and some critical preliminary tests were carried out. Heavy ion fragments stopped in helium or argon gas slow down to thermal energies, but remain in the 1+ charge state due to the high ionization potentials of these gases. In tests carried out at ATLAS, high efficiencies for extraction of radioactive ions from the stopping gas and very fast extraction times were demonstrated. Further development of this concept is expected to lead to a highly productive method that combines the best features of the fragmentation production mechanism with the excellent beam quality of the traditional ISOL method.

6. Several options for facility layouts in the area north of the present ATLAS facility have been developed. These have evolved into a very credible layout that occupies the space recently vacated by the clearing of the building 207 site. The layout, including the required new infrastructure buildings, is consistent with a facility investment in the $500M range. The site can accommodate a high energy fragmentation physics area in addition to the ISOL capabilities initially envisioned, giving the U.S. a facility unparalleled world-wide serving both radioactive beam scientific communities.

Specific Accomplishments: There have been several publications, seminars, invited papers, and contributions to international conferences and workshops based on the work done under this LDRD project. Items 1-7 below are based on the work begun in 1998. Items 8-19 are based on work done primarily in 1999.

1. The ANL Concept for an Advanced ISOL Facility, J. Nolen, seminar at Michigan State University (October, 1998).
2. The ANL Concept for an Advanced ISOL Facility, J. Nolen, seminar at LANL (October, 1998).
3. Production Mechanisms and Acceleration of Radioactive Beams from 1+ Ion Sources, J. Nolen, Conference on Applications of Accelerators in Research and Industry, Denton, TX (November, 1998).
4. High Intensity Superconducting Linear Accelerators for Heavy Ions, J. Nolen, International Workshop on Future Heavy Ion Fragmentation Facilities, GSI, Darmstadt, Germany (November, 1998).
5. Beam Tests of the 12 MHz RFQ RIB Injector for ATLAS, R.A. Kaye, K.W. Shepard, B.E. Clifft, and M. Kedzie, Proc. of the 1999 Particle Accelerator Conference, New York (March 29th - April 2nd, 1999).
6. Prototype 350 MHz Niobium Spoke-Loaded Cavities, K.W. Shepard, M. Kedzie, J.R. Delayen, J. Mammosser, C. Piller, Proceedings of the 1999 Particle Accelerator Conference, New York (March 29th - April 2nd, 1999).
7. Superconducting Driver Linac for a Rare Isotope Facility, K.W. Shepard, J.R. Delayen, C.M. Lyneis, J. Nolen, P. Ostroumov, J.W. Staples, J. Brawley, C. Hovater, M. Kedzie, M. P. Kelly, J. Mammosser, C. Piller, M. Portillo, Proceedings of the 9th Workshop on RF Superconductivity, Santa Fe, New Mexico (November 1-5, 1999).
8. High power driver accelerator for radioactive ion beam production, P.N. Ostroumov, K.W. Shepard, J.A. Nolen, and R.C. Pardo, ICFA Beam Dynamics Newsletter, no. 20, p. 60 (August, 1999).
9. Multi-charge beam dynamics in an ion linac, P.N. Ostroumov, and K.W. Shepard, submitted to Phys Rev Special Topics (September, 1999) (refereed paper).
10. Radiation Shielding an Containment Issues for the U.S. Rare Isotope Accelerator Project, J. Nolen, invited talk at the Workshop on Radiation Protection Aspects of High Intensity Proton/Deuteron Accelerators, Legnaro, Italy (September 27-29, 1999).
11. Capturing Recoils from Fragmentation Reactions: Getting the Best of Both Worlds, G. Savard, Colloquium given at the NSCL, East Lansing, MI (April 1999).
12. Performance of the Argonne Electric Field Ion Guide and RF Gas Cooler System, G. Savard, Invited Talk given at the International Workshop on Ion Chemical Aspects in Ion Guide Systems, Mainz, Germany (September 30-October 2, 1999).
13. The Argonne Rare Isotope Accelerator Project, Colloquium given at TUNL, Duke University, NC (November 1999).
14. Production Mechanisms and Predicted Yields of Exotic Beams at the Proposed Rare Isotope Accelerator, J. Nolen, B. Back, C.-L. Jiang, K.-E. Rehm, G. Savard, A. Heinz, and I. Gomes, paper presented at the Fall meeting of the Division of Nuclear Physics, American Physical Society, Asilomar, CA (October, 1999).
15. ISOL Beams from Fragmentation, the Best of Both Worlds, G. Savard, paper presented at the Fall meeting of the Division of Nuclear Physics, American Physical Society, Asilomar, California (October, 1999).
16. An Advanced ISOL Facility Based on ATLAS, J. A. Nolen, K. W. Shepard, R.C. Pardo, G. Savard, K.E. Rehm, J.P. Schiffer, W. F. Henning, C.-L. Jiang,

I. Ahmad, B.B. Back, R.A. Kaye, M. Petra, M. Portillo, J.P. Greene, B.E. Clifft, J.R. Specht, R.V.F. Janssens, R. H. Siemssen, I. Gomes, C.B. Reed, and A.M. Hassanein, Proceedings of the Eighth International Conference on Heavy Ion Accelerator Technology (October 5-9, 1998).

17. Liquid lithium cooling for 100 kW ISOL and fragmentation targets, J. Nolen, invited talk to be presented at the Fifth International Conference on Radioactive Nuclear Beams, Geneva, Switzerland (April 3-8, 2000).
18. Heavy-ion Driver Accelerator for a Rare Isotope Facility, K.W. Shepard, invited talk to be presented at the Fifth International Conference on Radioactive Nuclear Beams, Geneva, Switzerland (April 3-8, 2000).
19. Perspectives and physics with high intensity beam, J.A. Nolen, invited talk to be presented at the Seventh International Conference on Nucleus-Nucleus Collisions, Strasbourg, France (July 3-7, 2000).