98-111N -- Concept Development and Optimization for the Exotic Beam Facility

Associate Laboratory Director Area: Physical Research

Principal Investigators: J.A. Nolen, R.C. Pardo, K.W. Shepard, C.-L. Jiang, K.E. Rehm, Physics

Funding Profile:

FY 1996	-0-
FY 1997	-0-
FY 1998	$992.5K
FY 1999	$1300.0K
FY 2000	-0-

Purpose: The Argonne National Laboratory Institutional Plan, July 1997, has the construction of an Exotic Beam Facility as one of the Major Strategic Initiatives. The plan, as spelled out in that document is to "Develop a facility to accelerate beams of unstable nuclei, capitalizing on the capabilities of the Laboratory's existing heavy-ion accelerator, the Argonne Tandem-Linac Accelerator System (ATLAS), by using it as the post-accelerator in a two-accelerator design." The goal of this LDRD project, covering FY 1998 and FY 1999 is to develop technical solutions for the most challenging components of such an advanced facility. The DOE is currently using a two-step process to first choose the optimal technology and then the site for this new $200-$250M national users facility. The technology evaluation is taking place during FY 1999 by the ISOL Task Force, a sub-committee of the DOE/NSF Nuclear Science Advisory Committee. A call for proposals and the site selection is expected to follow.

Approach: 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 RIC at Brookhaven.

An advanced exotic beam facility of the Isotope-separator on-line (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 [AGC1] of the radionuclide production rates that are benchmarked against existing data when possible. The linac study also involves design, construction, and testing of prototype

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 prototypes 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. Some experiments with two-step target geometries for heavy ion fragmentation will also be carried out in collaboration with French scientists at GANIL in Caen. The ANL concept for the exotic beam post accelerator involves a unique low frequency CW RFQ. To demonstrate its viability, a full-scale model has been designed, constructed, and is currently being prepared for beam tests at the Dynamitron. A post-doctoral appointee, R. Kaye, has been hired to carry out this work. Preliminary work on other components is also being carried out. This involves preliminary calculations of the neutron shielding requirements and evaluation of radioactive contamination control techniques. A new 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 also be specified.

Technical Progress and Results: Significant progress was made during FY 1998 in the beam optics design and resonator prototyping for the high power driver linac. The optics calculations were carried out with new software that includes space charge effects. It was shown that two types of 3-gap resonators could be used efficiently to cover an adequate range of charge-to-mass ratios, from protons to $^{40}Ar^{14+}$ ions. Testing of niobium resonator structures for this new velocity regime was begun by fabricating a two-gap structure during FY 1998. Cold testing of this resonator will be done during FY 1999, followed by completion and testing of a similar structure optimized for the other end of this velocity range. The first three-gap structure will be built with modifications, if necessary, based on the results of these tests. A preliminary engineering design of a fast tuner and cryostat structure for these resonators was also completed during FY 1998.

Many simulations of target geometries for neutron generator configurations were carried out during FY 1998. Calculations were done for both 200 MeV proton and deuteron beams on beryllium, tungsten, and uranium targets. For optimal production of fission products via secondary neutrons a cylindrical secondary target of uranium carbide surrounding a primary target of tungsten was chosen. Engineering design of a cooling scheme for such a target configuration, possibly based on liquid lithium cooling technology will be pursued during FY 1999.

Much progress was made with the commissioning of a neutron-generator/ion source test facility at the Physics Division's Dynamitron facility during FY 1998. The 3.5 MeV deuteron beam was used on beryllium and boron targets to demonstrate production rates of ^{24}Na and other light radioactive species via (n,p) and (n,α) reactions. The yields of neutron-rich fission products from neutron irradiation of ^{238}U were also

measured. A newly constructed surface ionization source was commissioned and its emittance measured with a new apparatus at the Dynamitron. The emittance was excellent and the mass resolution achieved with the newly installed dipole magnet was also very good. However, the source efficiency for alkali's lighter than potassium was poor. This problem required modification of the source to achieve higher ionizer temperature. A radioactive beam of ^{24}Na is expected to be demonstrated in FY 1999, followed by measurements of release efficiencies of radioactive sodium from several forms of Al_2O_3, including microfibers and nanospheres.

A very important milestone for the project was reached when the full-scale model CW RFQ was operated successfully at full design voltage. This device is the first of its type in the world to operate successfully at this low frequency (12 MHz) with a vane voltage adequate for the acceleration of mass 132, 1+ ions. At the end of FY 1998 the RFQ was being set up at the Dynamitron for beam tests with ^{132}Xe ions.

Specific Accomplishments: There have been several seminars, invited papers, and contributions to international conferences and workshops based on the work done under this LDRD project.

1. A review of ion source options for ISOL-type radioactive beam facilities, J. Nolen, International Workshop on Targets and Ion Sources, Caen, France (March 1998).
2. Production Mechanisms and Yields for Medium Energy Protons and Light Ions, G. Savard, International Workshop on Targets and Ion Sources, Caen, France (March 1998).
3. A low-charge-state CW RFQ, K. Shepard and R. Kaye, XIV International Linac Conference, Chicago (August 1998).
4. Development of Niobium Spoke Cavities for a Superconducting Light-ion Linac, K. Shepard, M. Kedzie, J. Delayen, C. Piller, and A. Porcellato, XIV International Linac Conference, Chicago (August 1998).
5. The Status of Radioactive Beam Facilities in North America, J. Nolen, International Conference on Exotic Beams and Atomic Masses, Belaire, MI (May 1998).
6. The ANL Concept for an Advanced ISOL Facility, J. Nolen, seminar at Texas A&M University (June 1998).
7. The ANL Concept for an Advanced ISOL Facility, J. Nolen, seminar at LBNL (July 1998).
8. The ANL Concept for an Advanced ISOL Facility, J. Nolen, seminar at Michigan State University (October 1998).
9. The ANL Concept for an Advanced ISOL Facility, J. Nolen, seminar at KEK-Tanashi, Japan (June 1998).
10. Influence of the Incident Particle Energy on the Fission Product Mass Distribution, I. Gomes and J.A. Nolen, 2nd International Topical Meeting on Nuclear Applications of Accelerator Technology) Gatlinburg, TN (September 1998).
11. The ANL Concept for an Advanced ISOL Facility, J. Nolen, seminar at LANL

(October 1998).

12. 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).
13. High Intensity Superconducting Linear Accelerators for Heavy Ions, J. Nolen, International Workshop on Future Heavy Ion Fragmentation Facilities, GSI, Darmstadt, Germany (November 1998).
14. Beam Tests of the 12 MHz RFQ RIB Injector for ATLAS, R.A. Kaye, K.W. Shepard, B.E. Clifft, and M. Kedzie, 1999 Particle Accelerator Conference (March 1999).