The Superconducting Solenoid Rare Isotope Beamline: Description and Installation

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General Description of the Line

The large-bore 7-Tesla superconducting solenoid (BigSol) of the University of Michigan was moved to the Cyclotron Institute in May 2001 and is being installed as the major component of a line to produce and separate rare isotope beams (RIB). The characteristics of the solenoid and its use to measure yields of fragments at medium energy have been described previously [1]. A schematic representation of the Solenoid line being installed in the MARS cave is given in Fig. 1.

Following a bending magnet, used in common with the MARS line (not shown in Fig. 1), is a C-shaped magnet (first element in Fig. 1) used to bend the beam to the left by 14.5 degrees in order to keep the superconducting solenoid magnet away from the MARS magnets and to obtain a long, straight time-of-flight path downstream of the solenoid. Unlike the MARS beam line, which has a quadrupole doublet before the MARS target to get a horizontal stripe for the beam spot, the solenoid beam line uses three quadrupoles, (a quadrupole followed by a quadrupole doublet) for the final beam focus to get a circular beam spot at the solenoid primary target. A circular beam spot is more compatible with the azimuthally symmetric solenoidal magnet optics. The beam magnifications from the first set of collimators (located in the first beam box just outside the cyclotron) to the solenoid target are 0.6 for the x-axis and 1.2 for the y-axis. However, including the effects of the momentum dispersion, the beam spot size should be equal in both x and y axes. So, starting with a 2mm beam spot at the first object collimators, it should image to about 2.4 mm at the primary target.

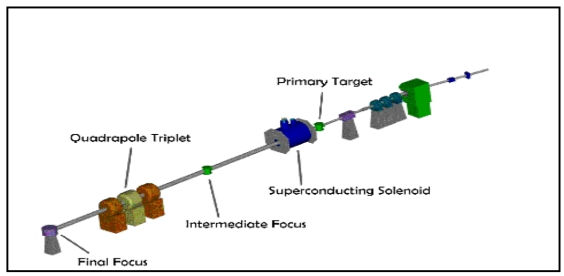

Figure 1: Schematic diagram of the Superconducting Solenoid Rare Isotope Beamline.

The main components of the RIB line are the superconducting solenoid (BigSol) and a large-bore room temperature quadrupole triplet (assembled from refurbished quadrupole magnets). The primary production target will be placed approx. 1m upstream from the superconducting solenoid and will be bombarded with high-intensity beams from the K500 Superconducting Cyclotron. The unreacted beam will be collected on a cylindrical Faraday cup placed 30 cm after the target. The geometry and reaction kinematics will be such that fragments emitted in the range 1-5 degrees will enter the solenoid and will be focused 4m after it (Intermediate Image). At this location, groups of fragments may be selected using a circular aperture. The fragments will then be transported through a 7-meter line and focused at the end of the line (Final Image) with the aid of the quadrupole triplet. This straight time-of-flight section will provide a 1-to-1 object-to-image magnification. Using 8″ aperture quadrupoles with 8″ beam pipes for this section, the angular acceptance is expected to be 2.0 degrees, adequate to accommodate the angular dispersion of the fragments at the intermediate image location.

We have performed Monte Carlo calculations of fragment production and separation using the solenoid line [2]. The calculations indicated that we can achieve efficient fragment collection from deep-inelastic collisions induced by beams at the K500 energies. However, the inherently small dispersion of the solenoid magnet (compared to conventional fragment separators) leads to mixtures of radioactive isotopes. The placement of an aperture at the Intermediate Image will provide a first selection of rare isotope groups. The subsequent part of the line will then provide a second clean-up stage and adequate flight path to perform time-of-flight tagging of the rare isotopes. We have investigated the possibility of using degraders at the Intermediate Image to enhance the selection ability of the line. In addition, we plan to use a multistage ionization chamber at this location, simultaneously functioning as degrader and as Z identifier.

With simultaneous ΔE and TOF tagging of the produced rare isotope beam mixtures, among other possibilities, we will be able to perform reaction studies at the end of the line, where a number of reacting systems may be studied simultaneously. As a stand-alone device, we plan to use the solenoid line for rare isotope search, and for fusion-evaporation reactions in a gas-filled mode. Apart from the various in-flight possibilities, we plan to use the solenoid line as a separator to produce, separate, decelerate (with degraders) and focus rare isotopes before a gas-cell to develop an Ion-Guide-based RIB concept at TAMU (see also [3]).

Status and details of installation

As already mentioned, the solenoid magnet and its beamline are being installed in experimental cave 2 (MARS cave) of the laboratory. The major difficulty to be overcome in making BigSol operational at the Cyclotron Institute is to provide liquid helium in sufficient quantity to keep up with the heat leak of the solenoid magnet and the heat leak of the cryogenic transfer line which is being built in-house to supply cryogens to the solenoid.

The CCI 200 watt helium refrigerator liquifier which supplies the K500 superconducting solenoid at the north end of the lab has an approximate capacity of 60 L/hr. piston/cylinder set in the warm expansion engine of the refrigerator system. Liquid production is highly dependent upon the efficiency of the expansion engine. Normal operation of the K500 cyclotron with its liquid helium-cooled cryopanels requires approximately 40 L/hr. which, if all is working well, leaves approximately 20 L/hr. to supply the BigSol transfer line and magnet system.

To supply cryogens to cave 2 in the south end of the lab where BigSol is installed, we are constructing 186 feet of 4 inch O.D. liquid nitrogen traced, multilayer insulated vacuum-jacketed liquid helium transfer line. The anticipated heat leak of this line is .015 watts/ft. The line includes three special expansion joints to allow for the contraction of the inner lines.

In order to pre-cool the solenoid to near liquid nitrogen temperatures, we are building a valve box/distribution tank which includes a 300

Figure 2: Valve Box/Distribution Tank

liter liquid nitrogen dewar into which 200 feet of rifled bore copper tubing is immersed. Helium gas will be flowed through the tubing and cooled to near 77° K and this gas will be flowed through BigSol until the magnet is as cold as reasonably possible, at which time liquid helium will be brought into BigSol through the transfer line.

Presently, BigSol and the beam line to BigSol is essentially installed and the Phase I beam line downstream of the solenoid is nearly complete and scheduled for initial experiments in early August 2002. This operation phase also includes installation of a position sensitive and Bragg Curve gas ionization0 detector system [1] approximately 5 meters downstream of the solenoid.

Phase II beam line downstream of BigSol includes, as already mentioned, an 8-inch bore quad triplet approximately 8.25 meters downstream from BigSol and a detector chamber 3.6 meters downstream of the triplet. The triplet is built and installed and the detector chamber is on hand.

References

[1] T. W. O'Donnell *et al.,* Nucl. Instr. and Meth. Phys. Res. A **422**, 513 (1999). See also T. W. O'Donnel, Ph.D. thesis, University of Michigan, at http://www-personal.umich.edu/~twod/thesis/ (2000).

[2] Rare Beam Estimates and Possibilities at Texas A&M University, G. A. Souliotis, *Progress in Research*, Cyclotron Institute, Texas A&M University (2000-2001), p. V-16.

[3] *A Proposed Facility Upgrade for the Texas A&M University Cyclotron Institute*, accessible at: http://cyclotron.tamu.edu/facility_upgrade.htm.

[4] A. Moroni, I. Iori, L. Yu, G. Prete, G. Viesti, F. Gramegna, and A. Dainelli, Nucl. Instr. and Meth. in Phys. Res. A **225**, 57-64 (1984).