A TRANSPORT LINE TO THE TRIUMF ISAC FACILITY

G. M. Stinson, TRIUMF, Vancouver, British Columbia, Canada

Abstract

Beam to the new Isotope Separation and ACcelerator (ISAC) Facility at TRIUMF will be extracted from extraction port 2A of the cyclotron. Whereas other beam lines at TRIUMF require achromaticity at target locations for both beam size and experimental requirements, this extraction line need not be achromatic provided that a nominal beam diameter of 5 mm is attainable at the target locations. This paper presents a proposed beam line configuration that meets these requirements. Beam spill calculations with the program REVMOC show that no beam loss occurs beyond the cyclotron and the combination magnet.

1 AN OVERVIEW OF THE PROJECT

An ISAC facility for TRIUMF was first proposed in 1984 at the Mount Gabriel Workshop[1] and the Parksville Workshop[2] in 1985 defined the basic accelerator parameters. Subsequently, a Test Isotope Separator On Line (TISOL) Facility was constructed at TRIUMF to provide target/yield and experimental data.

In June 1995 funding approval was given for the construction of an ISAC Facility. This is a five-year project (April 1, 1995 to March 31, 2000) with Federal Government funding for technical construction and Provincial Government funding for conventional construction. TISOL will continue to operate throughout the ISAC construction phase, providing more experience and experimental results as well as a test facility for targets and ion sources.

Initially it was proposed to locate ISAC at the end of beam line 4A in the proton experimental area. However, that beam line is limited to currents below 10 μA and ISAC operation would impact other beam line 4 experiments. Further, there is little space available for future expansion. Consequently, it was decided to pursue a beam line 2A option. This option, although more costly than a beam line 4A facility, allows ISAC operation to be independent of all other beam line operations. In addition, it enables the design of a 100 μA facility with provision for future expansion to higher energy/amu and expanded mass ranges.

The following sections give an overview of the ISAC project. Figure 1 shows the present concept of the layout of the facility.

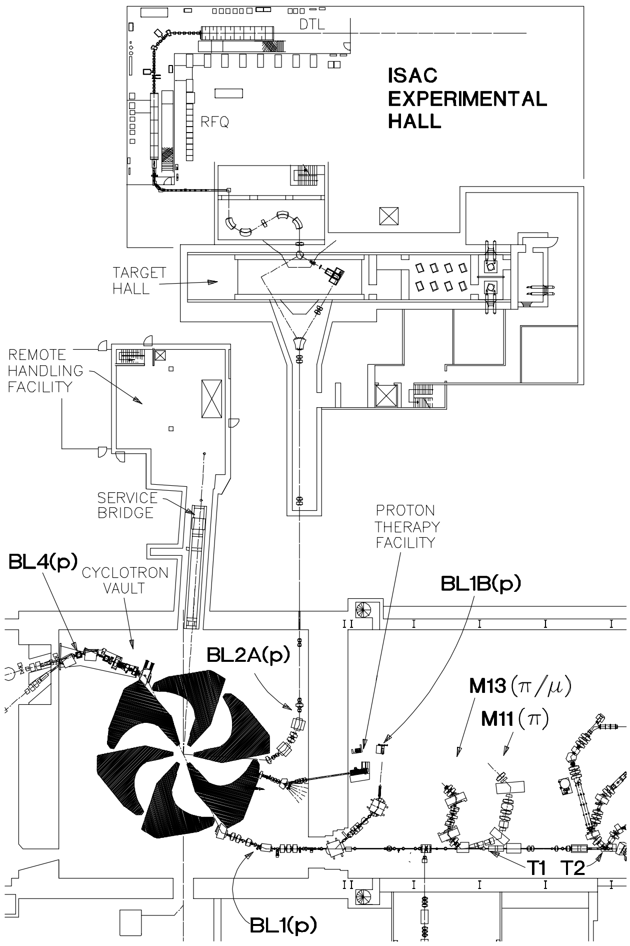

Figure 1: General layout of the TRIUMF ISAC Facility.

1.1 Beam line 2A

Protons extracted from the cyclotron are delivered to the target locations by beam line 2A. The line is designed to allow extraction over an energy range from 480-500 MeV at currents up to 100 μA. As shown in fig. 1, the beam line runs parallel to the east wall of the cyclotron vault and north to the target areas. Beam sizes at the targets are nominally $\pm$2.5 mm in each of the horizontal and vertical planes. More detail of the beam line design is given later in this paper.

1.2 Targets and ion production

Two target stations are provided for enhanced reliability and different source configurations. The production targets can be foils, powders or liquid and are approximately 20 cm in length.

On-line ion sources available will be of the surface, CUSP, ECR, μ-wave, plasma, laser and ^{7}Be types. An ion-source test stand is being constructed with first beam is expected shortly. In addition, an off-line ion source will be built for accelerator commissioning and for the generation of stable isotopes.

1.3 Low energy beam line

This section consists of a preseparator followed by a magnetic mass separator. Allowance has been made for an electrostatic separator to act as an energy analyzer. Electrostatic optics before and following the mass separator yield a mass-independent tune for a given energy. Beam energy is 2 keV/amu for delivery to the accelerators and 60 keV maximum for use in the low-energy experimental area. A prebuncher produces a 11.67 MHz time structure.

The preseparator is used to select the desired ion species, thus localizing unwanted radioactive isotopes. The mass separator accepts ions of $A \leq 240$ and has variable resolution. Resolutions at the final focus vary from 1,450 ($\epsilon_h = \epsilon_v = 160$ mm-mr) to 25,000 ($\epsilon_h = 8$ mm-mr, $\epsilon_v = 80$ mm-mr) depending on the widths of the slit settings (of which there are four). More details of the mass separator are given in the paper of J. Doornbos presented at this conference.

The separator is followed by a switchyard that directs beam to either the accelerators or the low-energy experimental area.

1.4 ISAC accelerators

The accelerator system accepts an input beam energy of 2 keV/amu and ion masses with $|q|/A \geq 1/30$ in an initial charge state of +1. The output beam energy is variable within the range 0.15–1.5 MeV/amu and has an energy spread $\Delta E/E \leq 0.1\%$.

The first element of the accelerator section is a split-ring, four-rod RFQ operating at 35 MHz. The 11.7 MHz prebunching provides both a high acceptance of dc beam (normalized emittance $\epsilon_n = 0.25\,\pi$ mm-mr) and the requested time structure. Beam emerging from the RFQ has an energy of 150 keV/amu.

From the RFQ beam passes through a thin carbon-foil stripper that acts as a charge-state booster $(q/A \geq 1/6)$ to a charge-state selector consisting of two 45° degree dipoles in a QQDQ–slit–QDQQ configuration. A rebuncher (to compensate for debunching) and a 4-quadrupole matching section follow.

The last element of the accelerator system is a drift-tube LINAC operating at 105 MHz. It has an Interdigital H (IH) rf structure and consists of four tanks each with eleven gaps. The tanks are separated by a quadrupole doublet and a buncher. The bunchers preserve the time structure and the energy variability from 0.15 to 1.5 MeV/amu.

1.5 Experimental areas

Layouts of the experimental areas have not yet been finalized. However, in the low-energy experimental area proposed are:

- an area for low background nuclear spectroscopy.
- two areas for general purpose spectroscopy.
- two areas for neutral atom traps.
- an area for collinear laser spectroscopy.
- an area for material science experiments.
- an area for on-line nuclear orientation.
- an area for He jet experiments.

In the accelerated-beam experimental area proposed are areas for:

- a recoil spectrometer.
- a ^{7}Be reaction station.
- a general purpose scattering chamber.
- a Coulomb excitation station.
- a material science station.

2 BEAM LINE 2A

Beam line 2A is the first section of the ISAC facility. Protons are extracted from the TRIUMF cyclotron through extraction port 2A over the restricted energy range 480 MeV $\leq E_p \leq$ 500 MeV. This relatively narrow energy band allows other beam lines to continue to operate during ISAC commissioning and operation. The beam line is designed to allow up to 100 μA of beam to be extracted. Figure 2 shows the configuration of the beamline. This figure is drawn in an x-y coordinate system with its origin at the cyclotron center. Units along the axes are m.

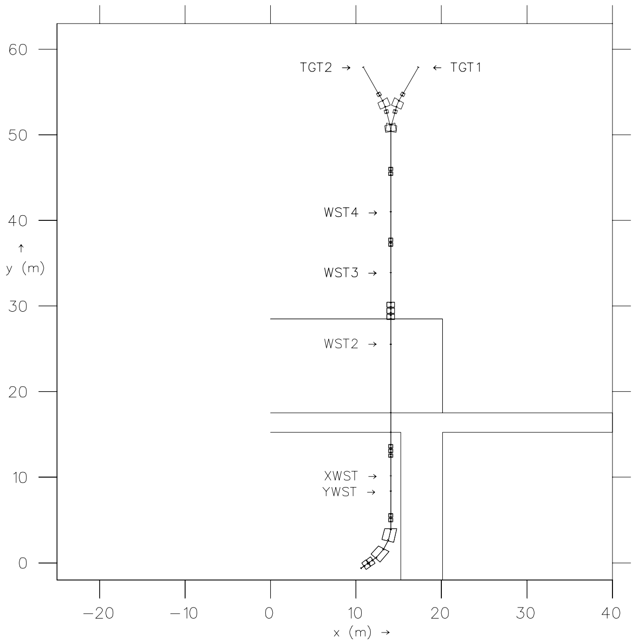

Figure 2: Configuration of beam line 2A.

The T-shaped structure in fig. 2 represents the walls of the cyclotron vault. The rectangle above the T represents an existing earth burm at grade level that extends 12 m from the exterior of the vault wall. Because beam is extracted approximately 8 m below grade, a tunnel will be excavated north from the burm to the target area. Not excavating below the burm results in a considerable saving in construction costs. Consequently, a hole will be cored through the vault wall to the tunnel entrance. This hole will contain an outer iron sleeve inside of which is the beam tube.

On extraction, beam from the cyclotron is directed parallel to the vault wall by two 27.5° dipoles. Two quadrupole doublets, one on either side of the dipoles, produce a split double waist at the locations noted as YWST and XWST.

A quadrupole triplet in the vault near the vault wall is used to contain the beam in the long drift between the cyclotron building and the beam tunnel. The triplet produces a double waist 8 m beyond the vault wall at the point labelled WST2. A second triplet in the tunnel brings the beam to another double waist at the WST3 location. A quadrupole doublet produces another double waist at the WST4 location.

Beam splitting between the two target positions is begun by a $\pm 15°$ switching magnet that directs beam to one of two 15° dipoles downstream. A quadrupole doublet upstream of the switching magnet, a singlet between it and the next dipole and a following singlet are used to produce the required beam sizes at the target locations. In addition, these quadrupoles are used to control vertical beam height in the dipoles and to produce a spatially achromatic condition $(R_{16} = 0)$ at each target.

Beam size at each target has been chosen to be nominally $\pm$2.5 mm in each of the horizontal and vertical planes. Consideration has been given to the production of smaller spot size. Such a tune could be used in conjunction with an ac steering magnet to produce a hollow beam at the targets in order to reduce target heating.

Figure 3 shows the beam envelope along the beam line. In this figure the horizontal (x) half-width is plotted as positive in the upper portion; the vertical (y) half-width is plotted as negative in the lower portion. The locations of the vault wall and of the target are noted. Waist locations are indicated by the short vertical tick-marks along the $x = 0$ axis.

Locations of the beam-transport elements are also indicated along the $x = 0$ axis. The large boxes some 5 m along the beam line are the 27.5° vault dipoles; those near the end of the line are the switching magnet and a second 15° dipole. The remaining elements are quadrupoles, of which two types are used. The second largest boxes in the vault section of the beam line and the first three downstream of the vault wall represent standard 4-in. bore quadrupoles of TRIUMF design that are available on site. The smaller boxes represent a shorter quadrupole—and consequently less costly—that will be manufactured.

It is important that no beam spill occur outside of the cyclotron vault. The program REVMOC[4] was used to determine possible spill locations. REVMOC is a Monte-Carlo beam transport program that includes second-order geometrical optics; because it uses the momenta of individual particles it is valid to all orders in chromatic optics. A total of 1.5×10^6 particles were run through the beam line at energies of 480, 490 and 500 MeV. No beam spill beyond the extraction region was predicted.

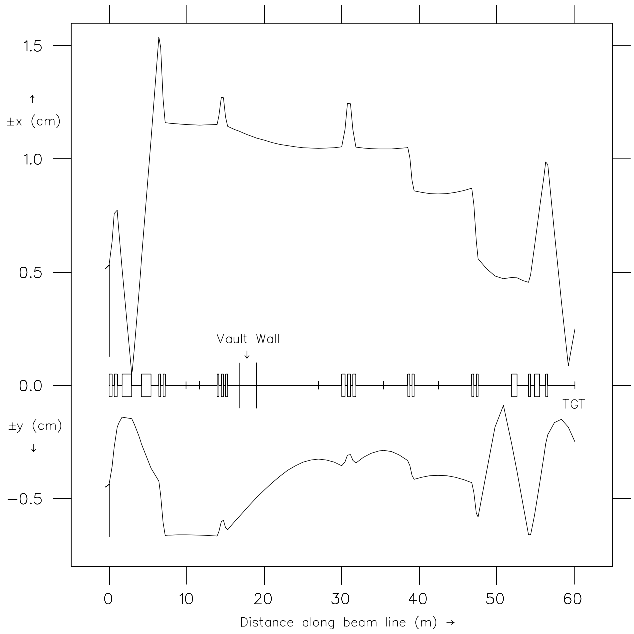

Figure 3: 500 MeV beam envelope on beam line 2A.

3 REFERENCES

[1] 'Proceedings of the TRIUMF-ISOL Workshop', Mt. Gabriel, 1984, eds. J. Crawford and J. M. D'Auria, TRIUMF Report TRI-84-1.

[2] 'Proceedings of the Accelerated Radioactive Beam Workshop', Parksville, 1985, eds. L. Buchmann and J. M. D'Auria, TRIUMF Report TRI-85-1.

[3] 'Mass Separator for the TRIUMF ISAC Project', J. Doornbos, Proceedings of this conference, 1996.

[4] 'REVMOC, A Monte-Carlo Beam Transport Program', C. J. Kost and P. Reeve, TRIUMF Design note TRI-DN-82-28, 1982.