Control of the Rotating Beam on RIB Targets at TRIUMF

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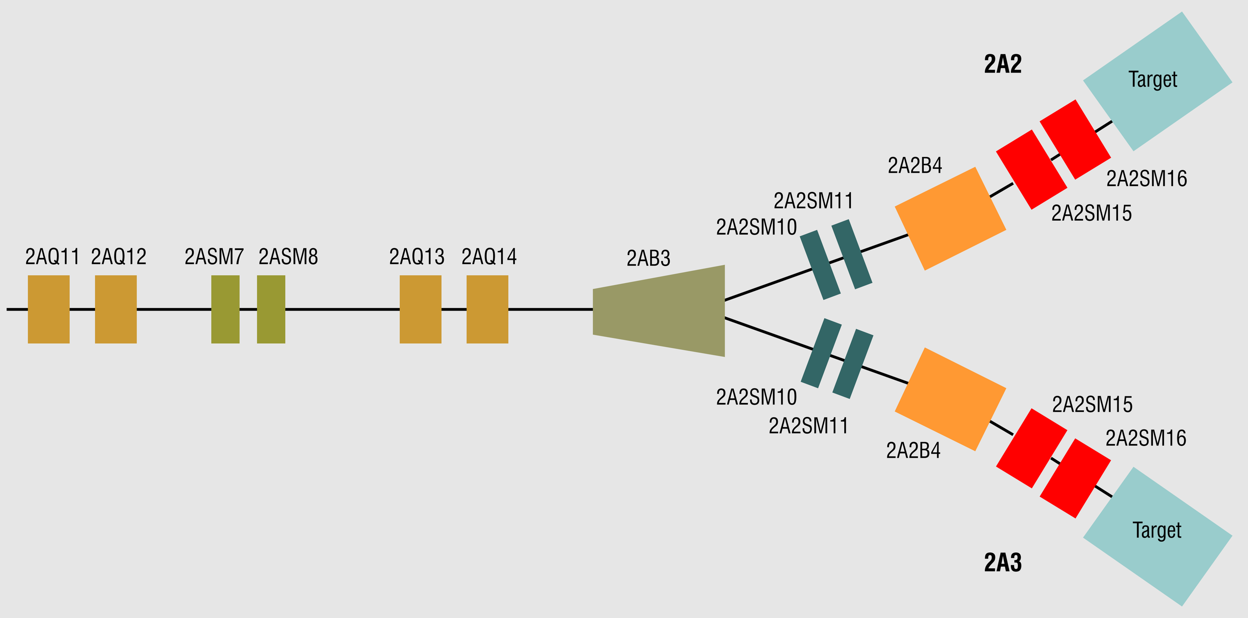
Abstract

Modelling of the radioactive ion beam (RIB) targets at TRIUMF has suggested that rotating the high energy proton beam in a circle on the face of the target may provide a greater source of radioactive ions than a static incident beam. To explore this idea a system has been configured to allow the beam of protons in the primary beamline to be steered in a circle and to permit various parameters to be changed. A description of the system and initial experience in operating the rotating beam are included.

System Configuration

- Protons are extracted from the cyclotron and delivered down beamline 2A.
- There are two beamline legs 2A2 and 2A3, each has a RIB target (only one at a time is in operation).
- Horizontal and vertical steering magnets were added to each leg.
- By varying the horizontal and vertical steering, the beamspot can be moved in a circular pattern.
- Two methods of controlling the beam have been implemented, 1) software controlled, and 2) using an arbitrary function generator.
- Both methods vary the control signals to the magnet power supplies.
- The beamline tune is set up to provide a smaller, more intense beamspot, as indicated by the modelling.
- Diagnostic hardware combined with machine protection software provide protection in case of failure.



Beamline layout with dedicated horizontal and vertical steering magnets.

Control by Software

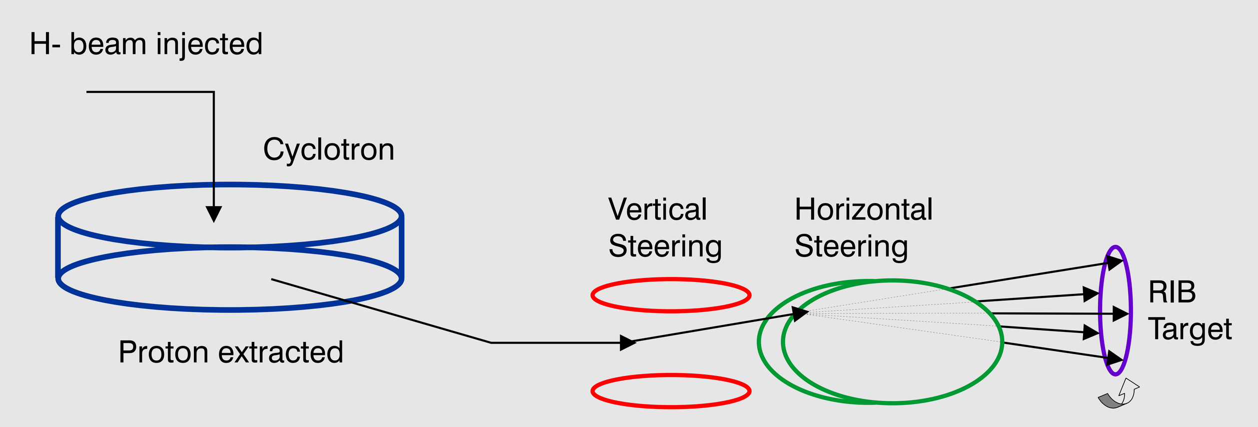
- A software application and user interface were developed to prototype the required functionality.
- Parameter values can be varied (rotation frequency, radius, and offsets).
- The software sets power supply values to move the beam in a circle.
- 20 points (x,y) are used to approximate the circle.
- Power supply changes between points are relatively large and caused some ringing in the output current.
- 20 points on the circle at 25 hertz is 500 power supply settings per second per power supply.
- This application is run in a standalone computer.

Diagnostics and Interlocks

- RIB target damage may occur if the beam stops rotating while tuned to the small spot size and at the higher beam current.
- Hardware diagnostics were developed to detect beam rotation problems.
- Software interlocks monitor the diagnostics and can disable proton beam delivery.
- Diagnostics monitor rotation frequency, power supply currents, and phase angle.
- Interlocks trigger beam termination within 200 milliseconds.

Introduction

- TRIUMF’s 500 MeV cyclotron simultaneously extracts three proton beams.
- One high energy proton beam goes to the ISAC RIB facility.
- Protons strike the target heating it and releasing atoms for the attached ion source.
- The amount of RIB produced is affected by a number of factors; proton beam current, target temperature, target geometry, etc.
- Modelling suggests rotating the beam on target may allow increased RIB yield.
- Care must be taken because the beamspot is smaller than normal and the proton current higher.
- Target damage may occur when the proton beam current exceeds the target current limit.
- Target damage may also be increased with thermal cycling (proton beam on/off transitions).



Using horizontal and vertical steering to rotate the beam.

Control by Arbitrary Function Generator

- An arbitrary function generator (AGF) was configured to drive the steering magnet power supplies.
- It generates two sine waves 90 degrees out of phase.
- The AFG has a network connection for remote control and monitoring.
- AFG outputs vary smoothly using frequent, small, changes to produce the sine waves.
- AFG problems were overcome using firmware upgrades and relocation onto a VLAN.

User interface.

Summary

Modelling indicates rotating the proton beam on a radioactive ion beam target may increase the production of extracted radionuclides. Two techniques for controlling the rotation of a TRIUMF 500 MeV proton beam on an ISAC RIB target have been developed. These techniques both paint the high energy protons on the RIB target in a circle. Both configurations use horizontal and vertical steering magnets, with the associated power supplies varying according to the same frequency sine wave (10 Hz) but 90 degrees out of phase. The first approach uses a software application discretely controlling digital-to-analog converters, which are connected to the steering magnet power supplies. The second approach uses an Arbitrary Function Generator with its two outputs connected to the steering magnet power supplies. The former setup has been used in production running and the latter configuration is waiting for more development time to explore its robustness. Diagnostic hardware was developed and is used to monitor the power supply outputs to ensure the magnet currents (steering) are changing as expected. Interlock software monitors the diagnostic hardware and stops beam delivery if the frequency or phase angle of the power supply outputs is incorrect.

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