# A 500 MeV-100µA PROTON TARGET FOR THE ISAC RADIOACTIVE ION BEAM FACILITY

Pierre Bricault, Marik Dombsky, Paul Schmor, Guy Stanford, Ian Thorson and Jaroslav Welz
TRIUMF, 4004 Wesbrook Mall, Vancouver, BC, Canada

*Abstract*
The construction phase of the ISAC radioactive ion beam (RIB) facility is now completed. The ISAC RIB facility utilizes the Isotopic Separation On Line (ISOL) production method. The ISAC facility includes: a new building with 5000 $m^2$ of floor space, a beam line with adequate shielding to transport up to 100 µA of proton at 500 MeV from the $H^-$ TRIUMF cyclotron to two target stations, remote handling facilities for the targets, a high resolution mass separator, a linear accelerator and experimental facilities. A novel approach for the target/ion source station is described. The target/ion source assembly and heavy ion optic components are located in a shield canyon under 2 m of steel shielding plug. A separator is to be coupled with either a low energy experimental area or to a linear accelerator for post-acceleration up to 1.5 A MeV.

## 1 INTRODUCTION

The TRIUMF's ISAC uses the isotope separation on line (ISOL) technique to produce radioactive ion beams (RIB). The ISOL system consists of a primary production beam, a target/ion source, a mass separator, and a separated beam transport system. These systems together act as the source of radioactive ion beams to be provided to the accelerator or the low-energy experimental areas. We utilize the 500 MeV - 100µA primary proton beam extracted from the H- cyclotron [1]. A new beam line has been built to transport this beam to one of the two target stations followed immediately by a residual proton beam dump. The target station contains proton beam monitoring equipment, production target and ion source, a beam dump, and the front-end heavy ion beam optics. A strategy has been adopted in which the target station is contained in a heavily shielded building connected directly to a hot cell facility. This approach is based on the successful experience at TRIUMF of vertically servicing and remote handling of modular components embedded in a close-packed radiation shield, coupled with the requirement for quick access to the production target and of containment of any mobile activity. Careful design of both the modular components and the remote-handling systems was carried out to ensure the operational viability of this system.

The effective operation of the ISOL system is crucial to the overall ISAC facility performance. It is therefore essential that we build in as much flexibility as possible. The target/ion source module is the key component. It must be serviced, or modified and exchanged on a regular basis to satisfy the varying demands of the physics program. Its design addresses many difficult aspects, including high voltage services, containment of radioactivity, accommodation of different target/ion source combinations, radiation-hard components, and ease of remote handling.

Existing target designs can accommodate up to 10 µA beam intensities and the available intensities of many radionuclides can be expected to scale with the proton beam currents. But, production targets capable of withstanding proton beam intensities up to 100 µA without compromising the yield of radioactive isotopes will be a future challenge. Several approaches to the dissipation of the power deposited in such targets by the proton beam have been investigated and a realistic solution for the removal of the heat from the target container seems possible. The heat transfer within the target material itself, however, is highly target dependent and it is clear that 100 µA operation will be limited at least initially to only a few target's materials. Some of the problems may have to be addressed near the 10 µA level but, in general, heat has to be supplied to the target system to maintain the prescribed temperature. The development of high power target is the subject of a development program at TRIUMF.

## 2 TARGET STATION

The ISAC target-handling concept and the ISAC target facility is based on fifteen years of experience at operating meson factories. The meson production target and beam stop areas of these facilities have power dissipation and radiation levels similar to, or greater than, those expected at ISAC. Meson factory experience shows that the correct approach to handle components in high-current and thick-target areas is to place them in tightly shielded canyons. Access to the components is done vertically and repair and service is made in dedicated hot cells.

Three important factors not encountered in the meson factory targets have to be addressed. These are: the containment of large amounts of mobile radioactivity; the high voltage required for beam extraction; and quick routine replacement of short-lived target systems. In the present design these issues are solved by placing the target in a sealed self-contained module which can be transferred directly to the hot cell facility for maintenance.

The target stations are located in a sealed building serviced by an overhead crane. The target maintenance facility includes a hot cell, warm cell, decontamination facilities and a radioactive storage area. The target area is sufficiently shielded so that the building is accessible during operation at the maximum proton beam current.

Beam-line elements near the target are installed inside a large T-shaped vacuum chamber surrounded by close-packed iron shield. This general design eliminates the air activation problem associated with high current target areas by removing all the air from the surrounding area. Figure 1 shows a plan view of the target stations area. The design breaks naturally into modules; an entrance module containing the primary beam diagnostics, an entrance collimator and a pump port; a beam dump module containing a water cooled copper beam dump; a target module containing the target/ion source, extraction electrodes and first steering component and heavy ion diagnostics; and two exit modules containing the optics and the associated diagnostics for the transport of heavy ion beams. Figure 2 shows a three-dimensional view of the target/ion-source module. Each module represents 2 m of shielding steel. The target and the two exit module are identical in size and each of them has a service cap and a containment box where most of the volatile contamination will be contained. Figures 3 and 4 show a section view along the proton beam and heavy-ion beam axis respectively. On those figures we can notice the close

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packed iron and concrete shielding which will allow us to operate the target at 100 μA.

The vacuum design seeks to eliminate the need for radiation-hard vacuum connections at beam level by using a single vessel approach. The front-end components, with their integral shields, are inserted vertically into the T shaped single large vacuum vessel. Most vacuum connections are situated where elastomer seals may be used. Only two beam-level connections exist: one at the proton beam entrance and one at the heavy ion beam exit.

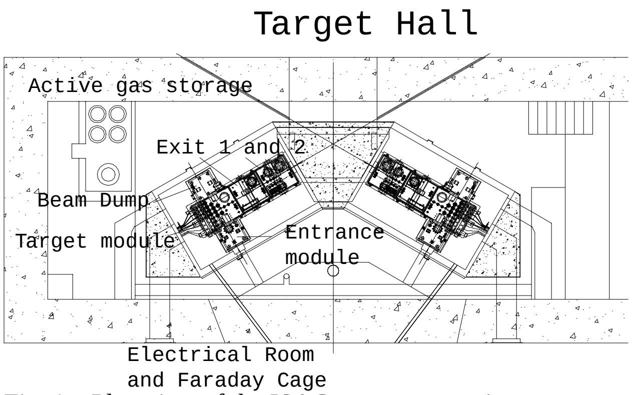


Fig. 1 – Plan view of the ISAC two target stations.

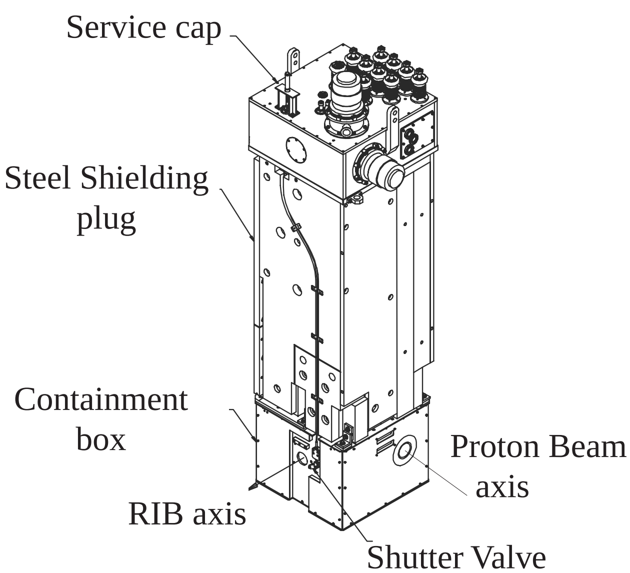


Fig. 2 – Three dimensional view of the target/ion source module.

## 3 REMOTE HANDLING

An effective remote handling and servicing system will be required to bring about quick and frequent target changes. All modules in the target area will have high levels of residual activity and will be potentially contaminated with mobile activity. Both aspects are considered in the handling design.

Target component maintenance involves disconnecting services and craning the module to the hot cell. Removing the concrete blocks covering the target station gives the overhead crane access to the modules. While the target module is pulled out of the canyon personnel are excluded from the target hall. Target module transfers to the hot cell must therefore be done completely remotely. The connection and disconnection of the target module services can be done manually since the shielding of the module is thick enough to allow hand-on operation.

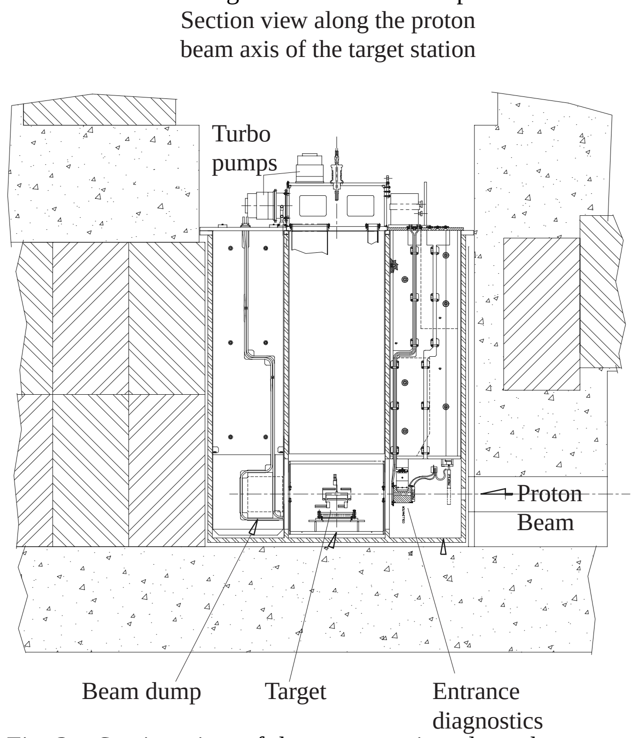


Fig. 3 – Section view of the target station along the proton beam axis.

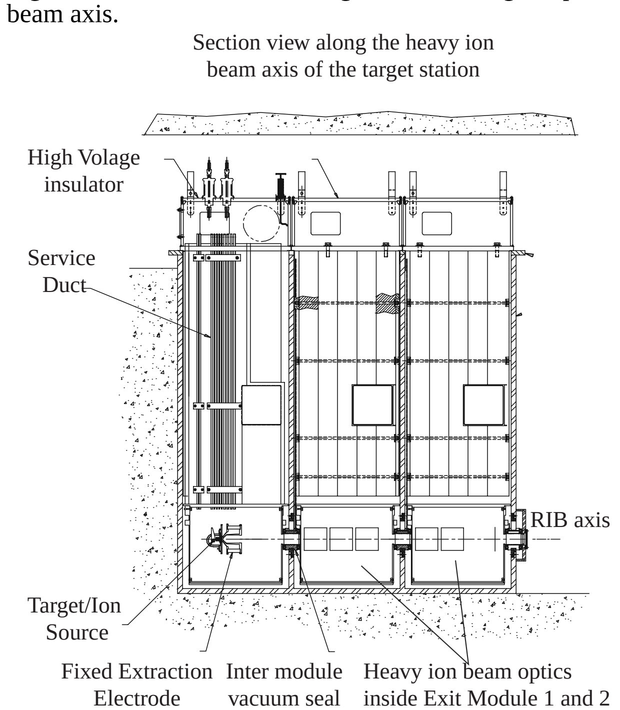


Fig. 4 – Section view of the target station along the heavy ion beam axis.

The mobile contamination produced in the target area is normally contained within the target module. The target module and the two exit modules are equipped with a containment box, which is sealed with pillow-seals to avoid migration of the mobile activity. Nevertheless, contamination of the target building is considered possible. This building must therefore be considered as an extension of the hot cell complex and all entrances must be controlled and provided with appropriate contamination control. The air within the building must be maintained at reduced pressure and HEPA-filtered. The interior surfaces are painted to allow easy decontamination. All fluid drains will go to sump tanks for monitoring before disposal. See reference [2] for more detail on the procedure.

A module storage area is located between the hot cell and the target station. One silo will be provided with the necessary services for the testing and preconditioning of targets before installation for a beam run. This area is fully accessible during beam operation; servicing and testing of modules will therefore be possible during beam production.

The hot cell provides facilities to remotely maintain; replace, decontaminate or inspect the highly radioactive components removed from the target area. It is a conventional design with concrete shielding walls, lead glass viewing windows and sealable roof ports to allow crane access to the hot cell. Personnel access to the top of the cell is possible, if required. The hot cell bay is provided with direct actuated master slave manipulators. The mechanical bay includes remote viewing, service equipment and an elevating turntable to support and position the component being serviced. The hot cell is kept under negative pressure by its own HEPA-filtered air handling system.

A support annex houses the remote handling control room, offices, personnel change rooms, radiation safety monitoring equipment and target hall entry air-locks. All the equipment needed to control the remotely operated crane, viewing systems and other devices is in the control room. Cameras are mounted in strategic locations throughout the building and on the cranes. An air lock is provided for transfer of equipment into the target hall.

## 4 TARGET SERVICES

### *4.1 Vacuum System*

The vacuum system of the target station consists of two separated vacuum stages; the primary vacuum which will contain all the exhaust gasses escaping the target/ion source and a secondary vacuum which will surround the target and the extraction and the heavy ion beam transport system installed into the two exit modules. The primary vacuum is expected to be very contaminated by radioactive species produced in the target while the secondary vacuum is expected to be less contaminated. All the exhaust will be stored into two tanks.

### *4.2 Ventilation*

In addition to supplying fresh air and removing stale or contaminated air, the ventilation systems for ISAC building will maintain the prescribed pressure differentials that will prevent the inadvertent leakage of airborne radioactivity. These are the short-lived hadron spallation products of oxygen and nitrogen in the air around the high power targets. There are two exhaust systems for the radioactive areas. A small one of 100 $m^3$/min, which is dedicated to maintain a depression in the proton beam, line tunnel.

The other is the main ventilation system for the ISAC building. It is designed to exhaust 660 $m^3$/min of air from six independently regulated exhaust pick-up points each with a capacity of 110 $m^3$/min. The air flows through HEPA filtration system.

### *4.3 Cooling system*

The power in the beam line and target will be dissipated in a raw water evaporator. All the cooling circuits for components will use de-ionized water in closed loop systems that transfer their heat to the raw water through heat exchangers. This design maintains water purity and prevents the release of any radioactivity that is produced by nuclear reactions in the cooling circuit. There are three de-ionized water systems. They cool equipment as follows:

- non-active low conductivity water,
- active low conductivity water,
- high-active low conductivity water.

The first system cools all components which are considered non-radioactive or where the radioactivity contamination probability is expected to be very low. The system services all water-cooled power supplies and vacuum pumps and mass separator beam line components. The second system cools all components, which are radioactive, but not in direct contact with the target/ion source vacuum chamber and thus is not exposed to high level of neutron radiation fields. This system services the primary proton beam line, the high-active heat exchanger, the target assembly components outside the vacuum tank, the target module storage area, the pre-separator magnet, and the high voltage lines from the Faraday cage to the target. The third system cools all components inside the target assembly vacuum tank. As this water is exposed to the intense radiation fields from the target bombardment, it will contain tritium at concentrations similar to those in the existing meson production target cooling systems.

## 5 STATUS OF THE ISAC PROJECT

The T-shaped vacuum tank was installed last September, and pumped down to $5 \times 10^{-7}$ mbar in less than 2 days. First stable beams were extracted from a surface ion source September 24th. In November 3rd first high resolution mass scan was obtained in the mass separator. Stable beam of $^{39}$K was tuned to the low energy experimental area by November 19th. November 30th a proton beam of 1µA was tuned on the production target and first radioactive beams were produced at ISAC. A week later, December 5th/1998, we started delivering potassium beams to the TRINAT experiment at 15 keV extraction energy. The beam intensities were $6.6 \times 10^6$ for $^{37}$K and $6. \times 10^8$ for $^{38}$K at 1µA proton beam intensity. The second round of experiments will resume April 8th with $^{38}$K for TRINAT and $^{37-38}$K for _ decay experiment.

## 6 REFERENCE


[1] P. G. Bricault, M. Dombsky, P. W. Schmor, and G. Stanford, *Radioactive ion beams facility at TRIUMF*, Nuclear Instruments and Methods, **B126** (1997) p. 213.

[2] L. E. Moritz, Radiation protection considerations in the design of accelerated radioactive beam facilities. Proc. Cyclotron and theirs applications conf. Caen, France, 1998, to be published