Radioactive Waste Processing and Medical Isotope Harvesting Requirements for a New Hot Cell at TRIUMF

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1. Abstract/Introduction

TRIUMF, Canada’s particle accelerator centre, uses 480 MeV protons to produce rare isotope beams (RIBs) through the bombardment of Isotope Separation On-Line (ISOL) targets. These RIBs support a diverse experimental program in nuclear physics, astrophysics, material science, biology, and nuclear medicine. To expand TRIUMF’s scientific output, the Advanced Rare IsotopE Laboratory (ARIEL), a next-generation high-power ISOL facility utilizing both proton and electron driver beams, is currently being designed. Building from experience at existing facilities, ARIEL will follow a modular design paradigm whereby all serviceable beamline equipment is supported below discrete shielding blocks [1],[2].

Optimized for nuclear spallation reactions, far less than 30% of proton beam power is deposited in the ISOL target, with the remaining beam impinging on a cooled copper beam dump. To extend functionality, the ARIEL proton irradiation infrastructure will be leveraged to parasitically produce alpha emitting medical isotopes by integrating a medical target station into the beam dump, as shown in . Thorium targets must be transferred to and from the target station remotely and without disturbing surrounding shielding to allow for uninterrupted operation of the ISOL target. This will be accomplished using a 35 m pneumatic tube transfer system connecting the medical target station to a hot cell with isotope processing capabilities.

![Figure 1](image_url)

**Figure 1**: Proton fluence map of the ISOL and medical targets during 50 kW proton beam irradiation.
2. ARIEL Hot Cell Facility Overview

The ARIEL remote handling facilities will have two adjacent cells, shown in Fig. 1, with beamline equipment and module maintenance occurring in Cell 1. ISOL target disassembly and processing, as well as medical target isotope harvesting and packaging, will occur in Cell 2. Radioactive waste processing will involve a combined process between Cell 1 and Cell 2, with the cells sharing a common wall featuring a pass-through air-locked port. Cell 2 will be divided into three separate containment enclosures (or zones: Z1, Z2, Z3) with independently controlled atmospheres. It will be equipped with a shielded glass window and a pair of telemanipulators, as well as a set of viewing cameras. The walls of both cells will include 23 cm of lead to ensure that ambient dose rates to personnel remain below acceptable limits. Each cell will require interior lifting equipment for the manipulation of objects exceeding the lifting capacity of the telemanipulators.

![ARIEL Hot Cell Facility Diagram](image)

**Figure 2**: ARIEL Hot Cell Facility, with cells, zones, and select equipment labelled. Cell 1 model courtesy of Robatel Industries.

Cell 1 and Cell 2 will be procured through separate contracts with suppliers. Each cell will be designed, manufactured, and installed independently, with Cell 1 intended for commissioning in 2021. Cell 1 is currently being manufactured by Robatel Industries. Cell 2 will go out for tender in mid-2020 and is intended for operation by 2023.

3. ISOL Target Processing and Waste Handling Requirements

After irradiation, ISOL target assemblies (Fig. 3) will be transferred from Cell 1 to Cell 2 Z1 (Zone 1) through the air-locked port. These target assemblies contain the hermetically sealed vacuum enclosures that house the irradiated target materials (various metals, oxides, and carbides [3]). Assemblies may have ambient dose equivalent rates of up to 2.7 Sv/h at 1 m when entering the cell. They will be disassembled in Cell 2, and high active-waste (target material, converter, etc.) from Z1 will be passed into Z2 through a Double-Door-Transfer System (DDTS), sealing the waste inside of a polyethylene container.
This container will be transferred from Z2 to Cell 1 on a conveyor system, where it will be packaged into a 5 US gallon pail and loaded into a shielded Type A transport flask. Canada’s waste facility is only licensed for these specific manually loaded flasks, so commercial flask loading systems, such as the La Calhène PADIRAC, cannot be employed. Low active-waste will be passed from Z1 into Z3 through a separate DDTS, sealing the waste inside of a 55 US gallon drum. These drums will be removed through a shielded drum transfer door.

![Diagram of ARIEL electron beam ISOL target vessel and medical target concept design](image)

Figure 3: (left) ARIEL electron beam ISOL target vessel, (right) ARIEL medical target concept design.

Some of the target materials intended for irradiation, such as uranium carbide, will be pyrophoric and must be oxidized before disposal [4]. The sealed target containers will be opened in Cell 2 using a cutting device and inserted into a high temperature vacuum furnace with a controlled oxygen supply. Some irradiated targets will also be subject to visual post-irradiation examination in the cell. An inert gas environment must be continuously maintained in Cell 2 to avoid the spontaneous, uncontrolled ignition of activated pyrophoric material.

4. Medical Isotope Processing & Packaging Requirements

To facilitate parasitic medical isotope production at ARIEL, Cell 2 will require additional, unique features. The pneumatic transfer line connecting Cell 2 to the medical target station will require a sending/receiving enclosure interfaced with the cell. Upon arrival at Cell 2, some of the irradiated medical targets (Figure 3) may be too radioactive (up to 9 Sv/h at 1 m) to be adequately shielded by the 23 cm thick lead lining the cell. To compensate, the enclosure must provide additional shielding for temporary storage. Once removed from the sending/receiving enclosure, some medical targets will be opened in Cell 2. The irradiated thorium will then be transferred to an in-cell chemistry module which will be used to chemically separate the medical isotope fraction from the bulk target material. This separation process may generate up to 10 l of acid, among other chemicals [5], so the safe handling and removal of this liquid radioactive waste must be considered in the design. Cell 2 will require a second pass-through air-locked transfer port connecting Z1 to the North Access Room to facilitate the transfer of tools, chemistry module components, and consumables into the cell.
References


