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

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TRIUMF
TRIUMF was founded in 1968 and has delivered nearly 50 years of science and innovation for Canada.
520 MeV cyclotron, ~4000 hours of protons per year to:
- Medical isotope research
- Muon & Pion beams (60 kW)
- Cold neutrons (20 kW)
- Radioactive isotope beams (RIB’s) via ISOL – two 50 kW proton stations at ISAC

Four smaller (13 – 42 MeV) cyclotrons for commercial medical isotope production.
• ARIEL will add two new beamlines and target stations for ISOL production
  • 100 kW $e^{-}$ target station → photofission
  • 50 kW $p^{+}$ target station → spallation → fragmentation → fission → parasitic medical isotopes
• Once completed
  • Combined (ISAC + ARIEL) 9000 RIB hours per year
ARIEL Target Hall

- Remote handling crane
- Hot cell facility
- Beamline tunnel
- Target pit shielding
- Electron target
- Proton target
- Modules

~15 m
ARIEL Targets

Proton Target

Electron Target

$\leq 2.7 \text{ Sv/hr}$

@1 meter after 2-year cooldown

$\phi = 17.5 \text{ cm}$

$22.5 \text{ cm}$

Preliminary $p^+$ target design based on CERN ISOLDE target
ARIEL Targets

\( p^+ \) irradiation: 500 MeV \( \bullet \) 100 \( \mu \)A \( \rightarrow \) 50 kW

Complementary techniques to existing ISAC.

\( e^- \) irradiation: 50 MeV \( \bullet \) 10 mA \( \rightarrow \) 100 kW

Hi power target, ISOL production driven by photofission.

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ARIEL Medical Isotopes

- Thorium spallation targets placed in ARIEL proton beam dump $\rightarrow ^{232}\text{Th}(p, p6n)^{225}\text{Ac}$
- 520 MeV beam loses $< 30\%$ energy in ISOL target $\rightarrow ^{232}\text{Th}^{225}\text{Ac}$ cross-section $\checkmark$
- Target transferred between beam dump and hot cell through pneumatic tube
- Up to $8.5\ kW$ of thermal power deposited in thorium
- Parasitic $\rightarrow$ No impact on ARIEL scientific output

ARIEL Medical Isotope Targets

- Metal Gasket
- Welded End Cap
- H$_2$O Cooling Supply Channel
- Thorium Disks
- Inner Body w/ Cooling Fins
- Aluminum Outer Body
- Brass End Cap
- Ø ≈ 10 cm

~ 13 cm
ARIEL Medical Module

Beam Diagnostics
ISOL Target
“Medical Module”
Beam Dump Module

Pneumatic Pipeline
Leadscrew Coupling Actuator Mechanism
Engagement Rod
H₂O Coupling
Thorium Target

~3 m
~3 m

p⁺ Beam Diagnostics ISOL Target”
Medical Target Transfer Pipeline

- Hot Cell 2
- Irradiation Area
- Pneumatic Transfer Pipe
- p+
ARIEL Hot Cell Facility
ARIEL Hot Cell Facility

Cell 1
- Robatel Industries
- Module maintenance/repair
- Clean (non-contaminated) cell
- Commissioning → 2021

Cell 2
- Tender specs in development
- Integrated into existing facility
- Dirty (contaminated) cell
- Waste processing and removal
- Interface w/ medical transfer pipe
- Medical target isotope harvesting
- Target post-irradiation examination
Target Waste Stream

- Primary targets into Cell 1 from target hall
- Cell 1 in-cell hoist lifts target onto air-locked inter-cell transfer port tray
- Cell 1 manipulators push tray into air-lock
- Air-lock separates “clean” air in Cell 1 from “dirty” inert gas in Cell 2
- Cell 2 hoist lifts target from air-lock to work table
- Work table → locating pins → lockable rotation
- Target disassembled, separated into low and high active waste
Low Active Waste Stream

- Activated metals, low contamination (mSv/hr range)
- Lowered through double-door transfer system into 55-gallon drum
- Area under shelf remains “clean”
- Drum removed through Waste Transfer Door on pallet

Example DDTS – La Calhène DPTE Drumliner

Cell 1 & Transfer Ports – courtesy of Robatel Industries
High Active Waste Stream

- Irradiated target materials, high activation and contamination (Sv/hr range)
  - Uranium carbide
  - Tantalum
  - Silicon Carbide
  - Others, and new technologies

- Pyrophoric materials (ignition in air)
  - Target container opened using custom device
  - Target into apparatus for controlled oxidation
  - Once oxidized → target through smaller DDTS into PE container (ex. La Calhène DPTE 190)

- Post-irradiation target inspection and testing

Controlled Inert Gas Environment in Cell

Required to prevent spontaneous ignition
Waste Conveyor System

- Sealed high active waste conveyed from Cell 2 to Cell 1 for packaging
  - 5-gallon steel pails
  - Shielded transport flasks
- Under-shelf cell spaces connected
  - Cell 1 provided with removeable wall panels
- Conveyor must:
  - Disengage containers at DDTS
  - Lower containers
  - Shield under-shelf space
  - Move container between cells
  - Lift container into cell 1
  - Be maintainable
  - Be remotely operated
Medical Target Receiving Enclosure

- Interface with pneumatic transfer system
  - Send and receive medical targets
  - Sealed from hot cell environment
  - Manipulator access for target removal/insertion
  - Targets will be **HOT** after irradiation, extra shielding required for intermediate storage

Preliminary Dose Rate Studies

*Cell 1 & Transfer Ports – courtesy of Robatel Industries*
Medical Isotope Harvesting

- Irradiated thorium processed in chemistry module
  → $^{225}$Ac/$^{225}$Ra multistage purification process R&D currently underway @TRIUMF & partners
  → Dissolve irradiated thorium in strong acid
  → Removal of 5-10 litres of active acid waste from Cell 2
  → Chemistry consumables passed in/out through north air-locked transfer port.
  → Process gases (nitrogen, helium, air, etc.)
Cell 2 – Other Features

In-cell lifting equipment
- Crane, hoist, etc.
- To lift loads heavier than manipulator capacity

Roof hatch
- Stepped to minimize radiation shine
- In-cell access for target hall crane

In-cell viewing cameras
- Pan-tilt-zoom, to complement operator viewing window

Cell shielding walls
- Minimum thickness → 23 cm Pb (or equiv. reduction factor)

Fire detection and response system
- To alert and respond to ignition of target material, etc.

Telemanipulators
- Minimum capacity → 22 kg (50 lb)

Operator platform

Shielding window

Cell 1 & Transfer Ports – courtesy of Robatel Industries
Thank you
Merci

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