

# **Radiation Issues**

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- . Radiation Shielding Issues**
- . Radioactivity Inventory**
- . Facility Classification**
- . System Costs**

# Shielding Requirements

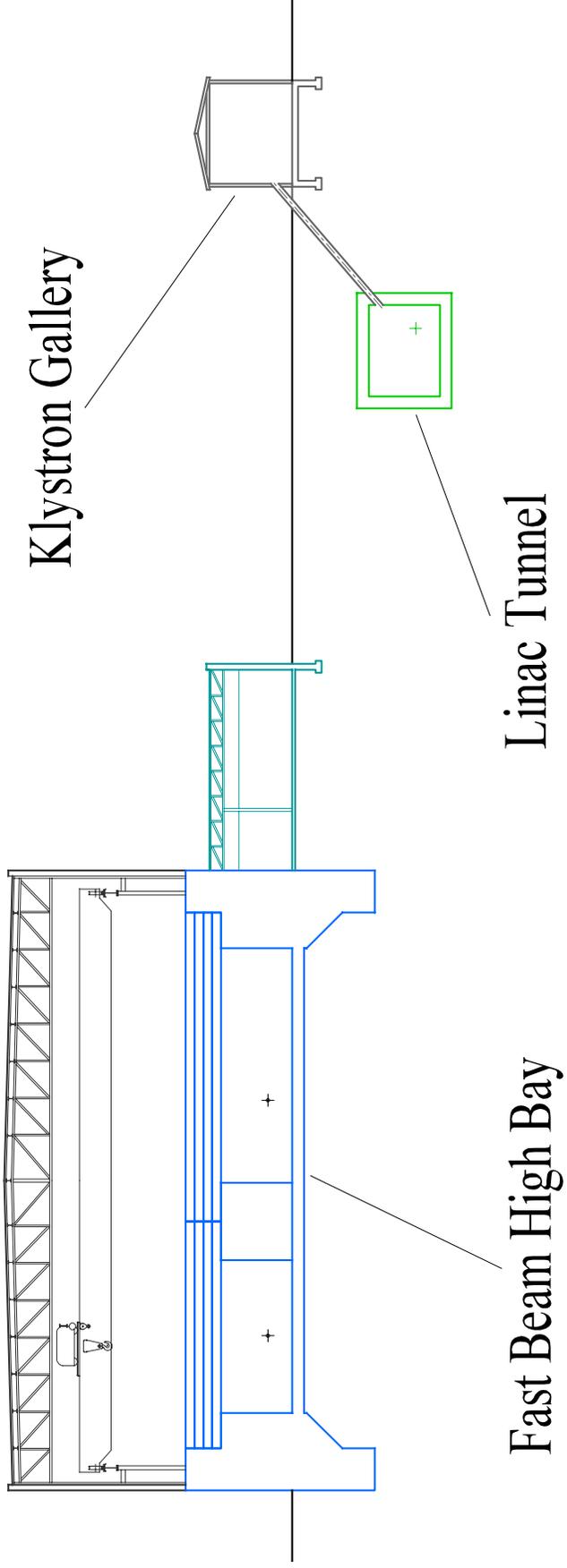
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- **Protect the General Public**
  - *e.g., 100 mrems annual limit*
- **Protect the Staff**
  - *e.g., 0.25 mrem in an hour limit in areas accessible to Radiation Workers*
  - *Limit of 5 mrem in an hour for full-beam loss*
- **Protection of the Environment**
  - *e.g., 20 pCi/ml limit on tritium in public drinking water (EPA)*
- **800 MeV proton and 612 MeV/u  $^3\text{He}$  beams are the most penetration and intense**
  - *Shielding can be estimated using semi-empirical and Monte Carlo calculations for proton and  $^3\text{He}$  beams*

# Source Terms

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- **Stripping points at ~ 12 MeV/nucleon and ~ 100 MeV/nucleon**
  - *20% loss in a local, point source*
- **Stopped, full-power beams at four places:**
  - *Two ISOL target stations*
  - *Two fragmentation target/ beam dump stations*
    - *Prompt radiation*
    - *Radioactivity inventory*
- **Experimental Hall for Fast-Beam Experiments**
  - *Assumed 400A MeV Ne at  $10^{10}$  particles per second*
- **Post-ISOL**
  - *Pre-separator neutral atom radioactivity build-up*
  - *Post-separator Slits*
  - *LINAC x-rays, prompt radiation hazards*



# LINAC Tunnel-Bulk Shielding

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## 1. LINAC Tunnel Shielding (WBS 2 3.1)

- *LINAC will be below grade*
- *Shielding above is 0.61 meters of concrete and 4 meters of soil*
  - Sufficient for 0.013% loss/meter line-source at full energy: 0.25 mrem/hr at surface
  - Sufficient for 100 kW point (800 MeV) loss for 0.1 second: 1.1 mrems
- *Shielding below is 0.61 meters of concrete*
  - $10^{-6}$ /meter line-source loss at full energy gives less than 20 pCi/ml tritium production in soil in 10 years of operation
- *Additional shielding (if necessary) is not a cost-driver:*
  - The cost of an additional 1-meter-thick soil berm over last 700 ft of LINAC is about \$56K
  - 1-meter-thick soil represents about a factor of 7 dose reduction at 800 MeV

# LINAC Tunnel-Bulk Shielding

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## 1. Local Shielding at Stripping Points (WBS 2.3.1)

- *At stripping points (12 MeV/nucleon and 100 MeV/nucleon) 20% point losses assumed*
- *Local shielding required*
  - **For 100A MeV Ne: about 2 meters (total) concrete and 1 meter steel local shielding will reduce dose rate at grade to 0.25 mrem/hr**
  - **This local shielding will reduce neutron fluence to acceptable levels to mitigate soil activation**

# Production Target Bulk Shielding

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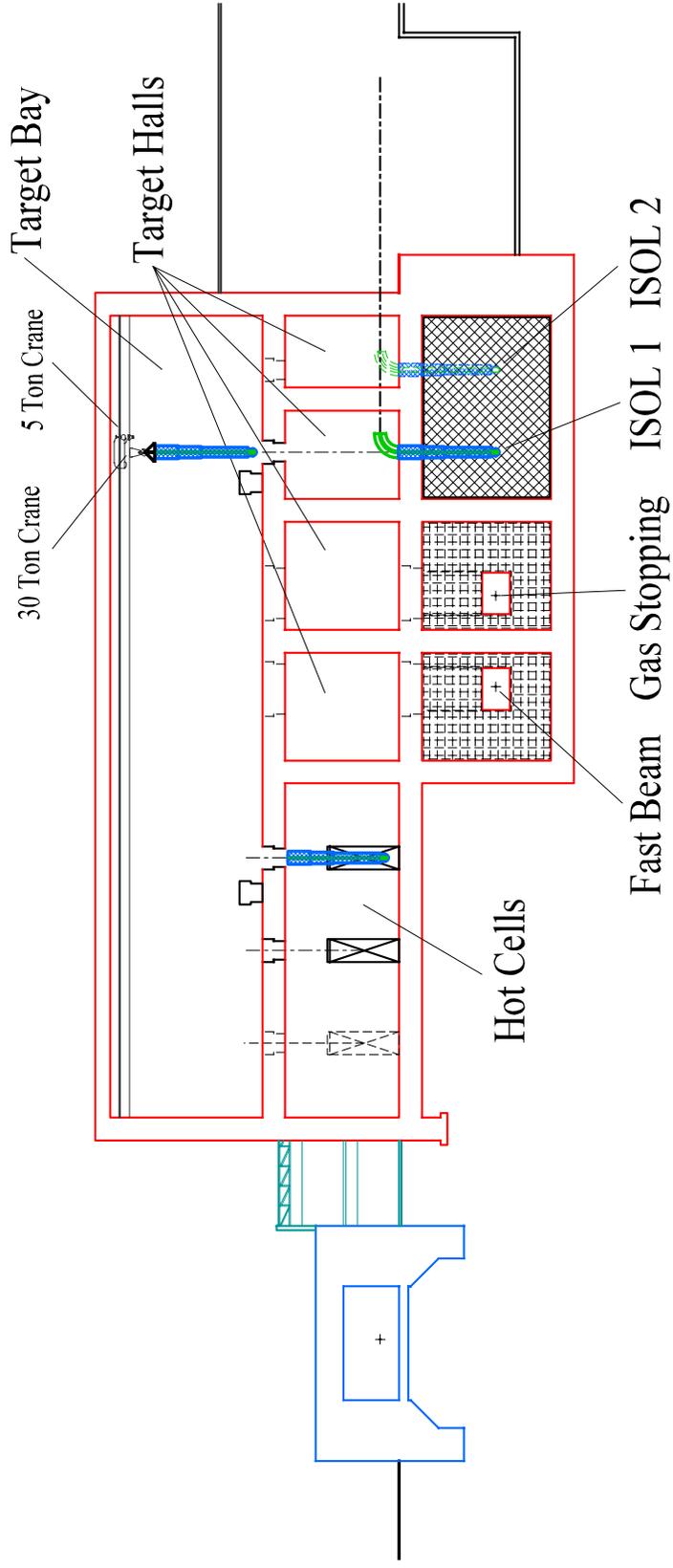
## 1. ISOL Target Shielding

- *Targets will be below grade*
- *Shielding: 2 meters of concrete and 4 meters of iron*
- *Shielding forward and below sufficient for soil, water protection*
- *Additional iron shielding (if necessary) is not a cost-driver:*
  - *Iron shielding available from a company in Oak Ridge, TN for shipping costs (~ \$0.05/lb)*

## 2. HE Fragmentation Target Shielding

- *Bulk shielding amount similar to the above, i.e. same power requirements*
- *Requirements differ as to how it is distributed*
  - *Primary beam passes through target (~ 10% energy loss), then is stopped downstream*

# Target Gallery



# **Fast-Beam Experimental Vault Shielding**

## **1. Fast-Beam Experimental Vault Bulk Shielding**

- ***Vaults will be above grade***
- ***Desire to allow vault to be occupied if adjacent vault is taking beam***
- ***Dose rate limit: 0.25 mrem/hr***
- ***Assumed source term of 400 MeV/nucleon beam of Ne at  $10^{10}$  pps***
- ***Shielding:***
  - **1 meter of iron local shielding**
  - **4 meters of concrete in 0-degree direction, 2.5 meters laterally**

# Post-ISOL LINAC, Facilities

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## 1. LINAC

- *X-rays from RF cavities*

## 2. Shielding

- *Commensurate with existing “at-the-Coulomb-barrier”-to- ~15 MeV/u facilities, e.g. ANL’s ATLAS*

## 3. Access Control and Monitoring

- *Most issues well understood from existing facilities*
- *New issues may be present, e.g. prompt neutrons from neutron-rich beams*

# Facility Classification

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## 1. Nuclear Hazard Analysis Concerns

- *Hazardous material inventory*

## 2. Category 1:

- *Potential for significant off-site consequences*

## 3. Category 2:

- *Potential for significant on-site consequences*

## 4. Category 3:

- *Potential for significant localized consequences*

## 5. Much work has already been done on significant issues:

***A 50 kW facility exists: ISAC at TRIUMF, on the University of British Columbia campus in Vancouver***

# Facility Classification

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## 1. ISOL Targets are:

- *Highly Contained*
- *Remotely Handled*
- *Only Opened in Hot Cells*

## 2. Must carefully study inventories, especially alpha-emitters

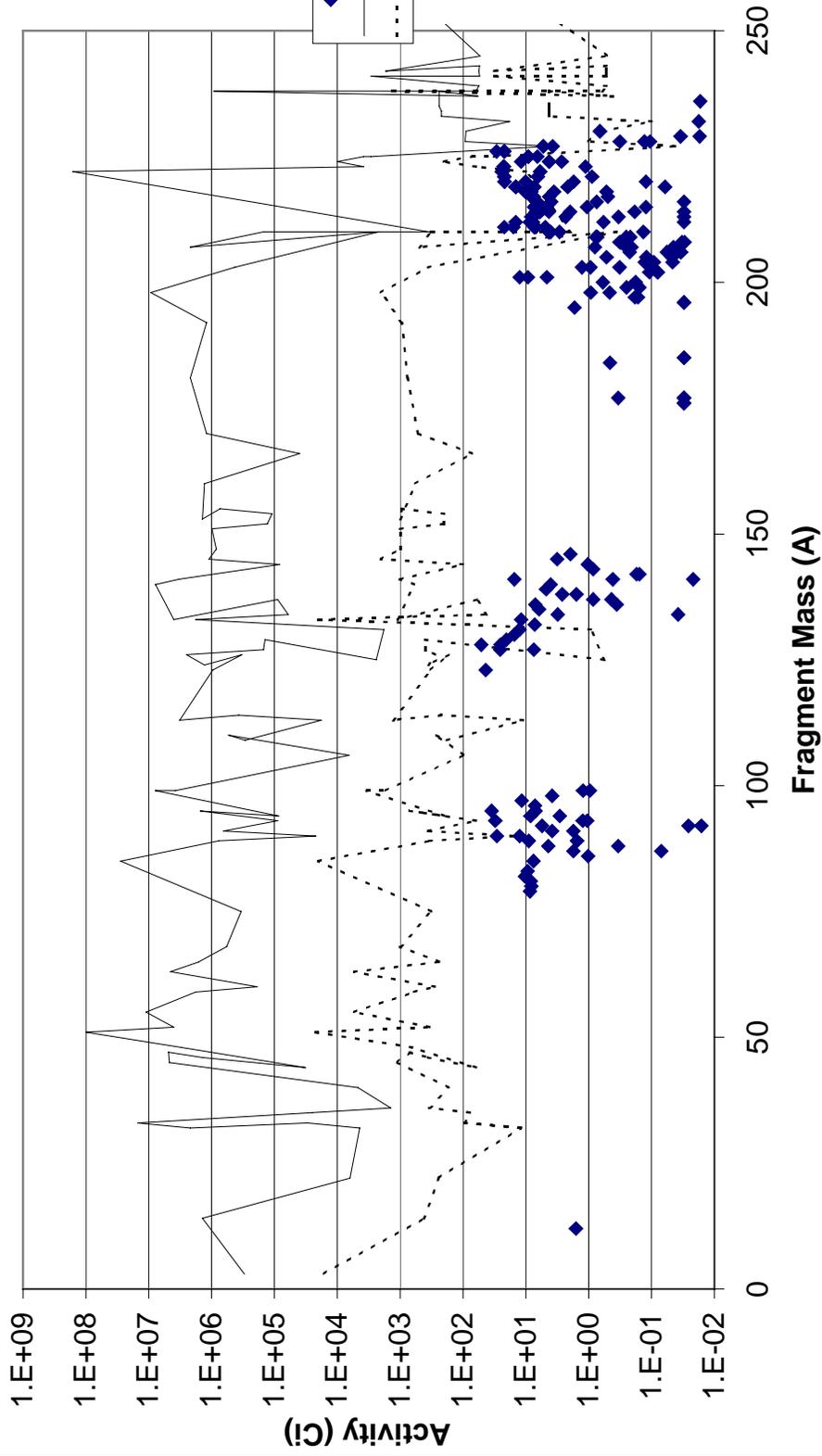
## 3. Operations scenarios must be studied:

- *e.g. Beam-On 1 week, followed by 1-day cool, then replace target*

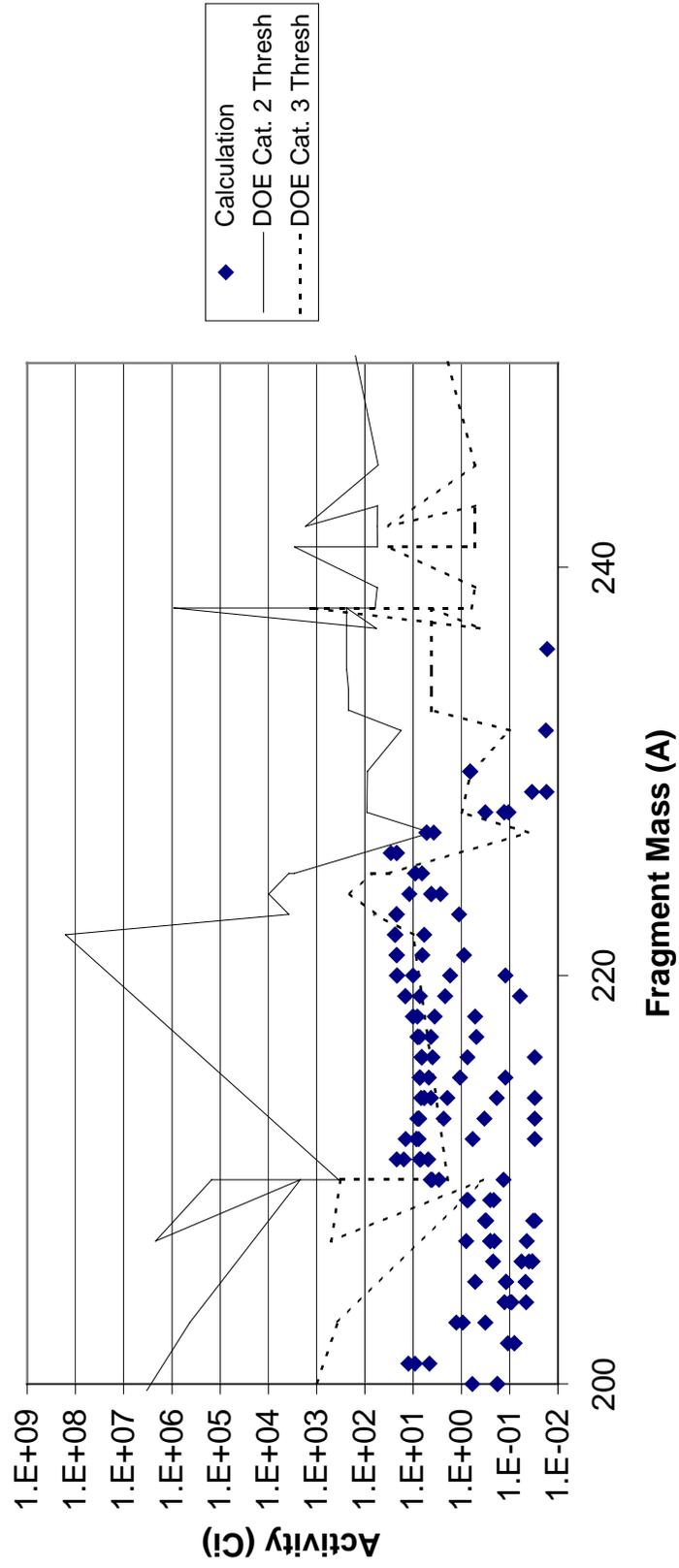
## 4. Facility can probably operate as DOE Category 3

- *Most stringent: target, hot cell, pre-separator areas Cat. 2, the rest of the facility Cat.3*

Spallation of UC2 Target  
1836 MeV 3He, 100 kW, Stopping Target  
7-Day Irradiation, 1-Day Cool  
LAHET+MCNP+ORIHET



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# Cost Summary

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<b>System</b>	<b>Cost (no contingencies) (\$K)</b>
ISOL Target Systems	\$ 8,368
Gas Stopping Target Systems	\$ 6,632
Fragmentation Target Systems	\$ 7,148
Hot Cells	\$ 2,345
Crane	\$ 369
Decontamination Room	\$ 72
Storage Pit	\$ 105
Target Storage	\$ 189
Water, Exhaust Services	\$ 1,024
Safety Monitoring, Systems	\$ 2,261
Project Support	\$ 5,390
<b>Total</b>	<b>\$33,903</b>

# ISOL Targets

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## 1. Target Systems

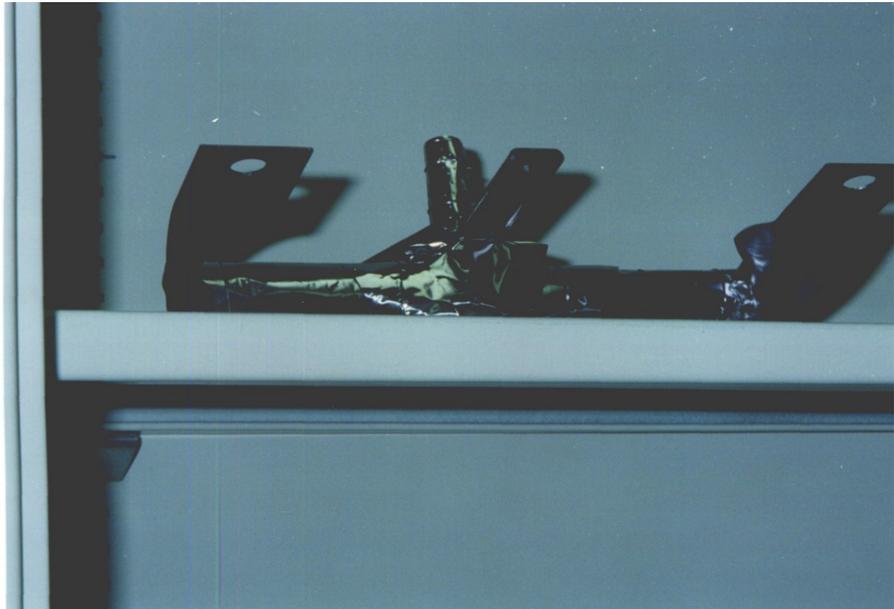
- *Two ISOL Target Systems*
- *Entrance module*
- *Target module - four*
- *Exit module - four*
- *Dump module*
- *Vacuum system, tank*
- *Water cooling system*

## 2. Costs and Basis

- *ISOL Target Systems: \$8,368K*
- *Basis: TRIUMF ISAC actual costs*

# ISOL Targets

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# Target Module at TRIUMF's ISAC Facility

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# Fast-Beam Target Costs

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## 1. Fast Beam Targets

- *Two target systems: one for HE facility, one for LE facility from gas-stopping target*
- *Fragments from one HE target are used for in-flight experiments*
- *Fragments from one HE target stop in gas target*
- *Each system consists of a target module, dump and shielding*
- *Each system has water cooling*
- *Remote handling for target modules*
- *Shielding*

## 2. Vacuum Systems

- *System requirements are similar to ISOL targets: staged storage tanks for inventory handling/decay purposes*

## 3. Cost Estimates and Bases:

- *Two target systems: \$6,632K (gas), \$7,148K (fragmentation)*
- *Scaled up estimates for 6 kW liquid Li target currently being designed by ANL and the NSCL*
- *Scaled up estimates for gas stopping target currently under construction at the NSCL*
- *TRIUMF ISAC direct costs*

# Hot Cells

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## 1. Hot Cells

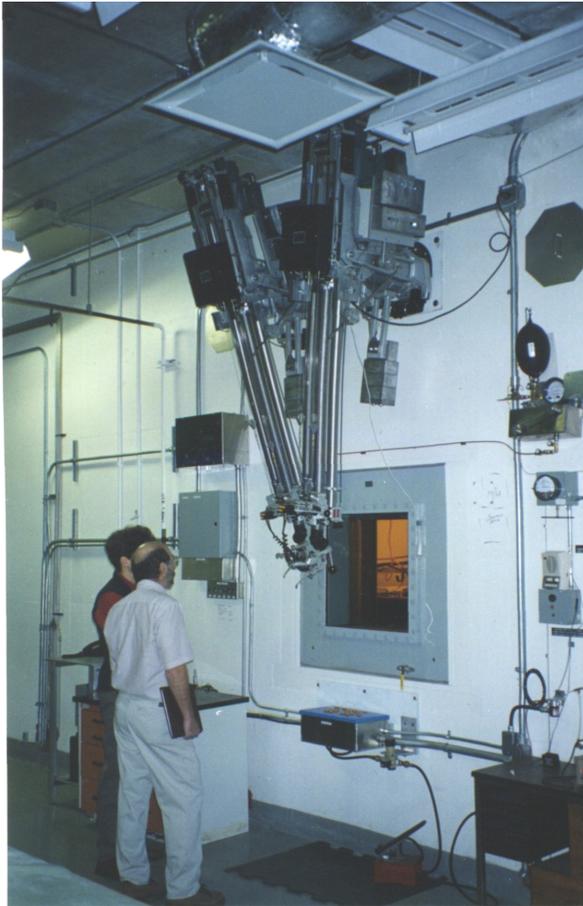
- *Two cells are planned*
- *Access doors*
- *Roof and Concrete Fill*
- *Pb-Glass windows*
- *Manipulators*
- *Scissor lift tables*
- *Turn-tables*
- *Alignment gear*

## 2. Costs and Basis

- *Hot Cells: \$2,345K*
- *TRIUMF ISAC costs*

# Hot Cell at TRIUMF

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# Crane

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## 1. Crane

- ***Overhead (30 ton)***
- ***Auxiliary (5 ton)***
- ***Remote console and controls***
- ***Remote power***
- ***Redundant motor drive systems, independent winches***

## 2. Costs and Basis

- ***Crane: \$369K***
- ***TRIUMF ISAC actual costs***

# Water Services

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## 1. Water Cooling (Low-Conductivity)

- *Primary Active - targets, beam stops*
- *Secondary Low-Active - magnets*
- *Tertiary Raw – power supplies, pumps, LE equipment*

## 2. Nuclear Exhaust System

- *Filtered*
- *Decay Storage Tanks*
- *All air is checked for radioactivity*

## 3. Costs and Basis

- *Water Cooling Systems + Nuclear Exhaust: \$1,024K*
- *ISAC actual cost*
- *Primary active costs are in target systems*
- *Sumps are in the civil cost estimates*

# Air Handling Services

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## 1. Air Handling

- *Triple-Pressure Zoning*

**Must understand air flow patterns, currents**

- *Filtered – Double, Triple HEPA Filtering*
- *Decay Storage Tanks*
- *Exhaust Monitoring – particulate, noble, iodine, alpha, tritium*

## 2. Costs and Basis

- *Nuclear Exhaust System: \$745K*
- *TRIUMF ISAC actual costs*
- *Exhaust Monitoring costs are under Safety Systems*

# **Safety Systems and Monitoring**

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## **1. Safety Processors, Computers**

## **2. Access Control**

- *Target Hall controls*
- *Portal monitoring*

## **3. Interlock systems**

## **4. Radiation Monitoring**

- *Area: Neutron, alpha, beta, gamma, beam-spill*
- *Air-Stack: Particulate, noble, iodine, alpha, tritium*
- *Sump water*
- *Waste*

## **5. Costs and Basis**

- *Safety Systems and Monitoring: \$2,261*
- *Safety and Computing Systems: NISOL estimate*
- *Target Hall Systems: ISAC actual costs*
- *Monitoring Systems: estimated from commercial sources*

# Decontamination, Storage Rooms

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## 1. Decontamination Room

- *Electrical services*
- *Vacuum services*
- *Vacuum exhaust services*

## 2. Storage Pit

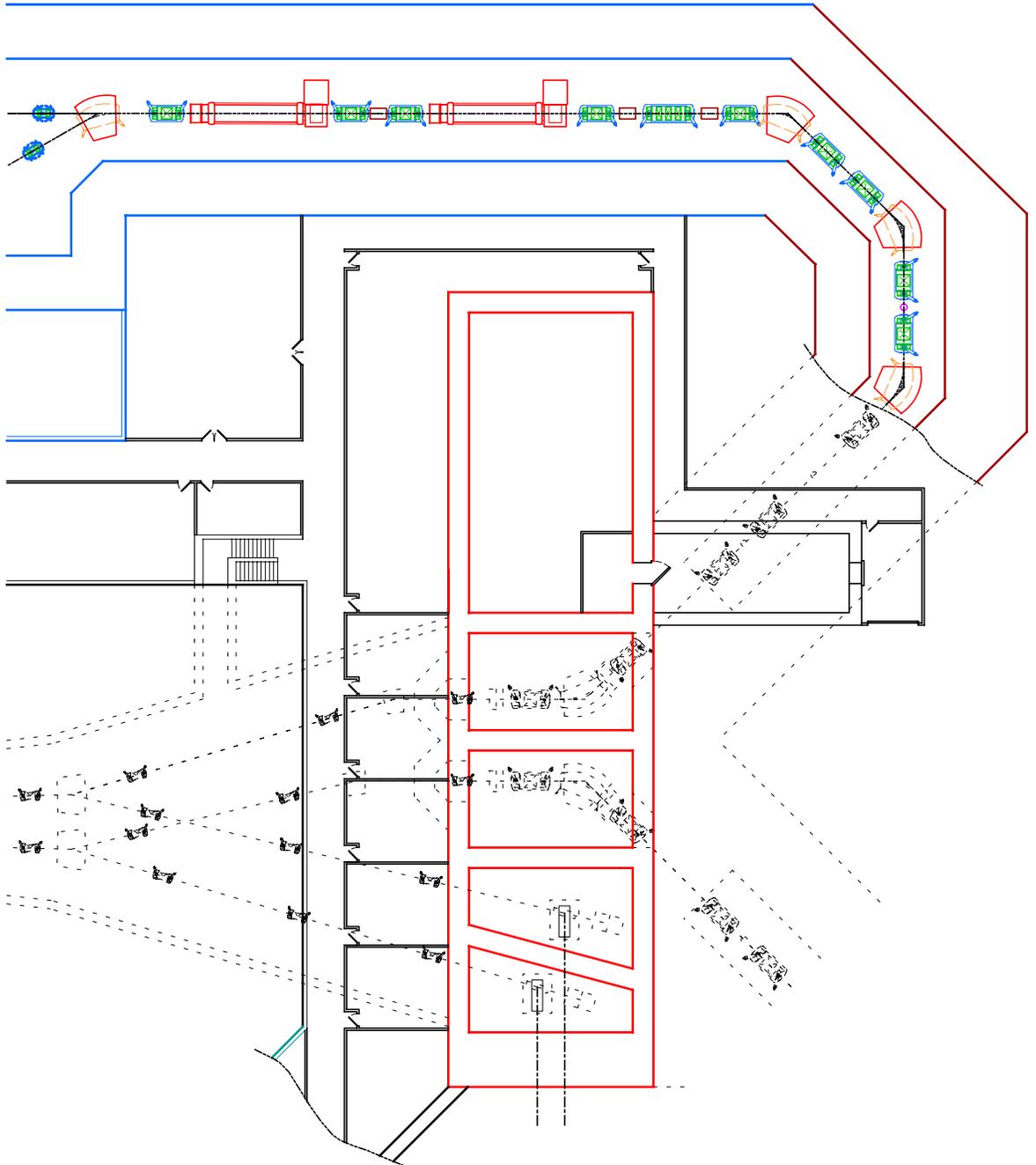
- *Decontamination tank*
- *Storage silos*
- *Target alignment frame*

## 3. Target Storage Room

- *Spent target vault shielding*
- *Mechanical services*
- *Electrical services*

## 4. Costs and Basis

- *Decontamination Room: \$72K*
- *Storage Pit: \$105K*
- *Target storage room: \$189K*
- *TRIUMF ISAC actual costs*



# Project Support

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## 1. Safety Support

- *Environmental Workups*
- *Systems Design and Integration*
- *Quality Assurance*
- *Regulatory Compliance*
- *Training*
- *Management and Administration*

## 2. Costs and Basis

- *Safety Support: \$5,390K*
- *NISOL estimated costs*