FRIB

Activation Levels, Handling, Storage, and Transport of Activated Components in the Target Hall at FRIB

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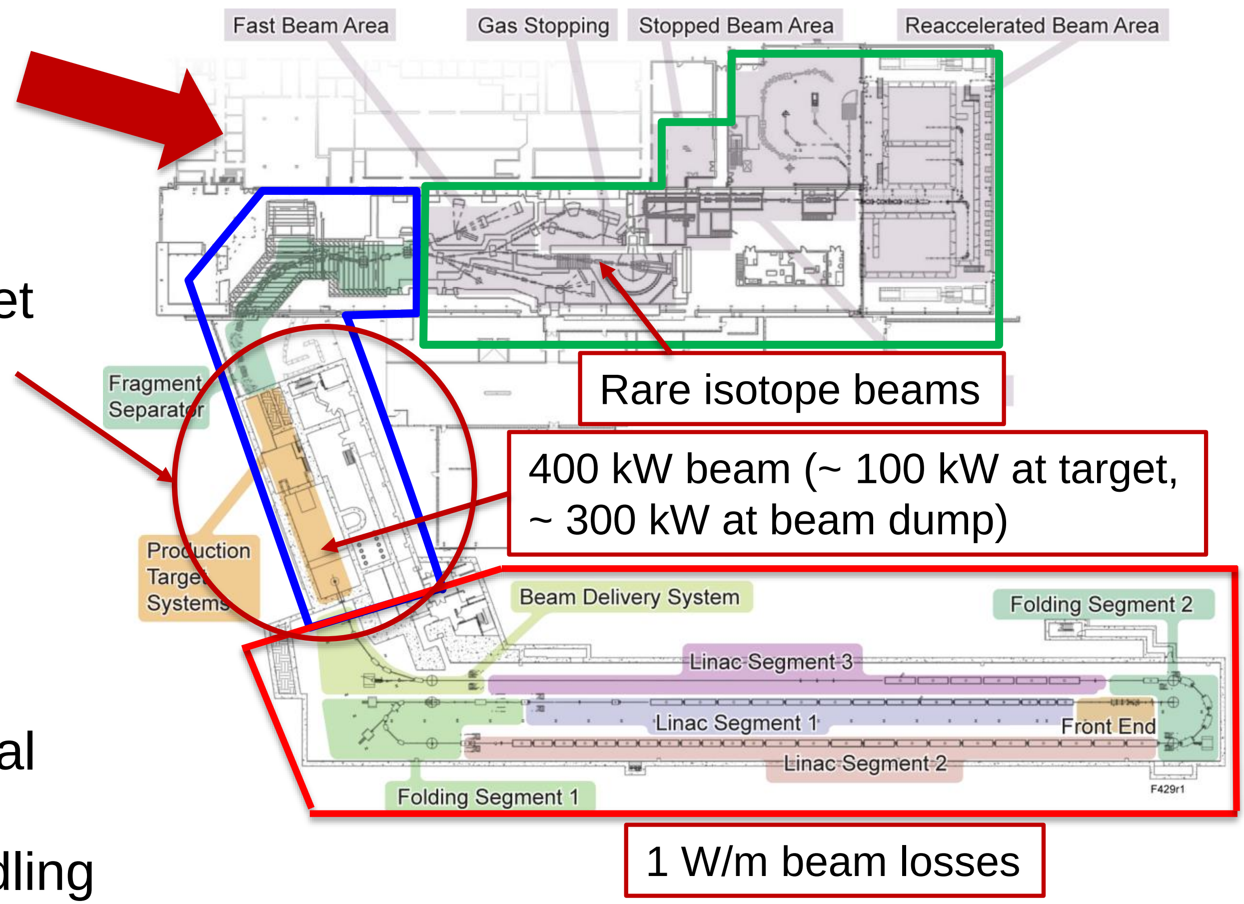
Outline

- Brief introduction to FRIB
  - Radiation transport (RT) scope within the project
- Radiation transport analysis of activated beam line components
  - Highly activated components studied
    - Target module, post-target magnet shield, beam dump module
- Waste handling: Removal and storage
  - Handling of waste in the target hall
  - On-site storage of activated components
  - Removal of waste from target hall
- Summary and conclusions

Radiation Transport Scope

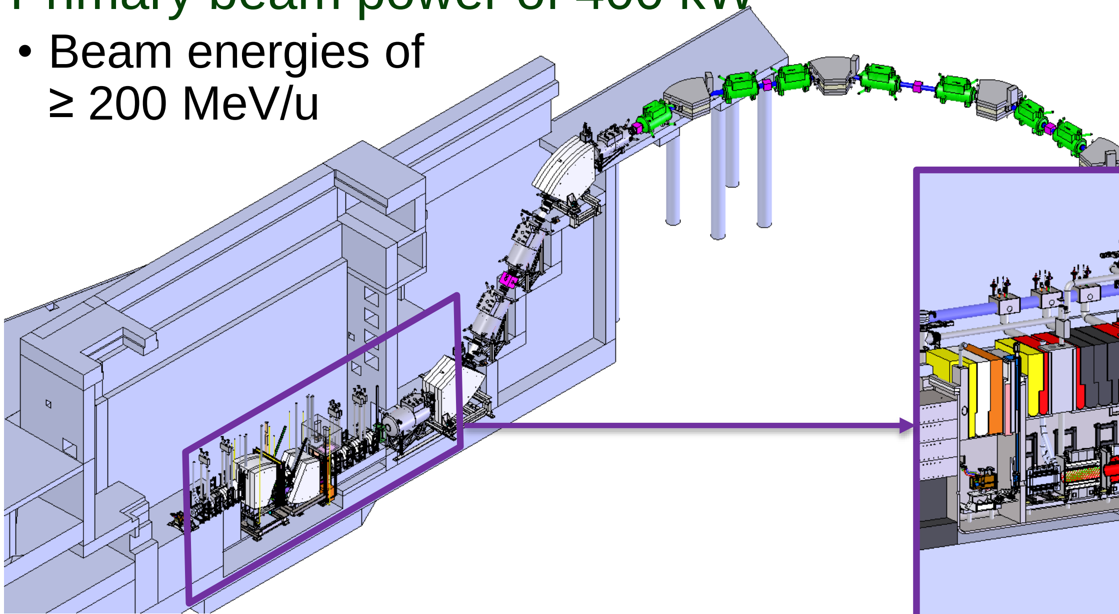
Technical Design and Safe Operation of Entire Project is Supported by Radiation Calculations

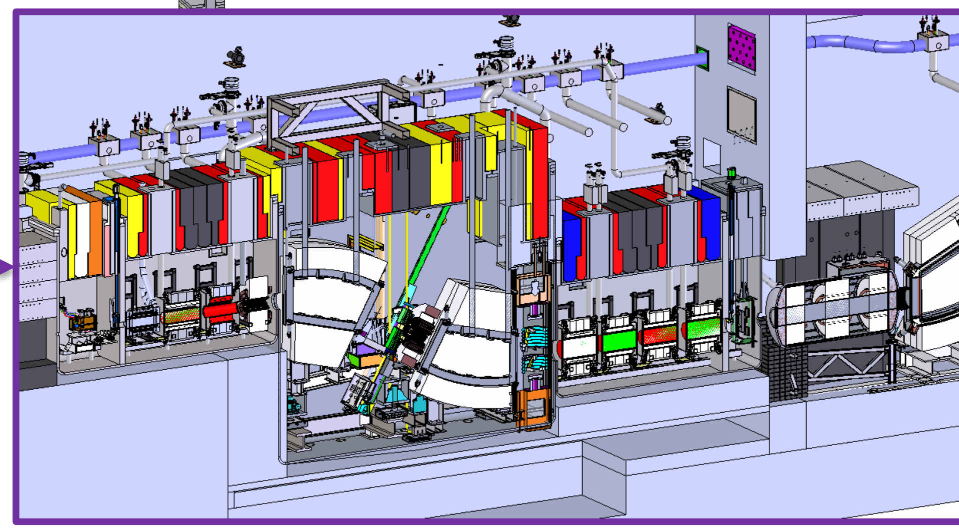
- FRIB facility
  - Accelerator Systems
  - Experimental Systems
  - Experimental areas
- Target facility
  - Encompasses pre-target beam delivery system area, production target systems, fragment separator, building
- Technical scope
  - Bulk, local shielding
  - Component and material choices
  - Hands-on, remote handling
  - Personnel, public doses



Target Hall Beam Line Components

- Three stage fragment separator for production and delivery of rare isotopes with high rates and high purities to maximize FRIB science reach
- Primary beam power of 400 kW
  - Beam energies of ≥ 200 MeV/u





Target hall: High radiation environment

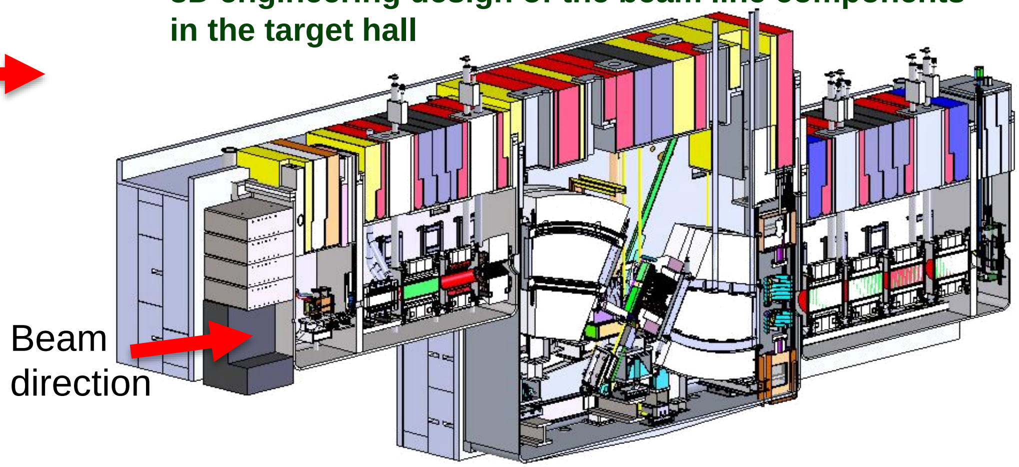
- Two major sources (periodically replaced): beam on target (100 kW) and on beam dump (300 kW)
- The most active component is magnet shield (right after the target)

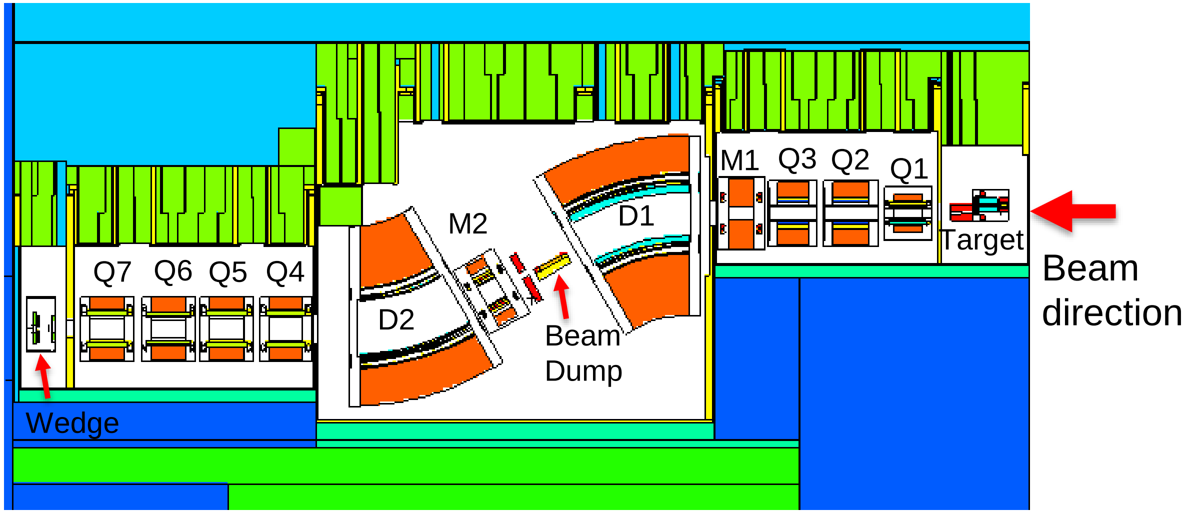
Radiation Transport Model

High Level of Detail Supports Construction and Preparation for Operations

- Calculations are based on models developed from mechanical and facility design
- Model and materials are updated as the project progresses
  - Updates are provided by mechanical design group and magnet systems department
- Capability of the models to transport ions in magnetic fields is important
  - Magnetic fields correspond to those needed for beam optics and are provided by fragment separator group

3D engineering design of the beam line components in the target hall





Radiation transport model of the beam line components in the target hall

Beam Line Component Activation Estimates

- Activation calculations conducted for all equipment
  - Conservative beam/energy choice
    - ^{48}Ca beam, 549 MeV/u, 400 kW total power – updated facility
  - Irradiation/cooling times based on planned component lifetimes
    - Targets will be replaced every two weeks
    - Beam dump will be replaced once a year

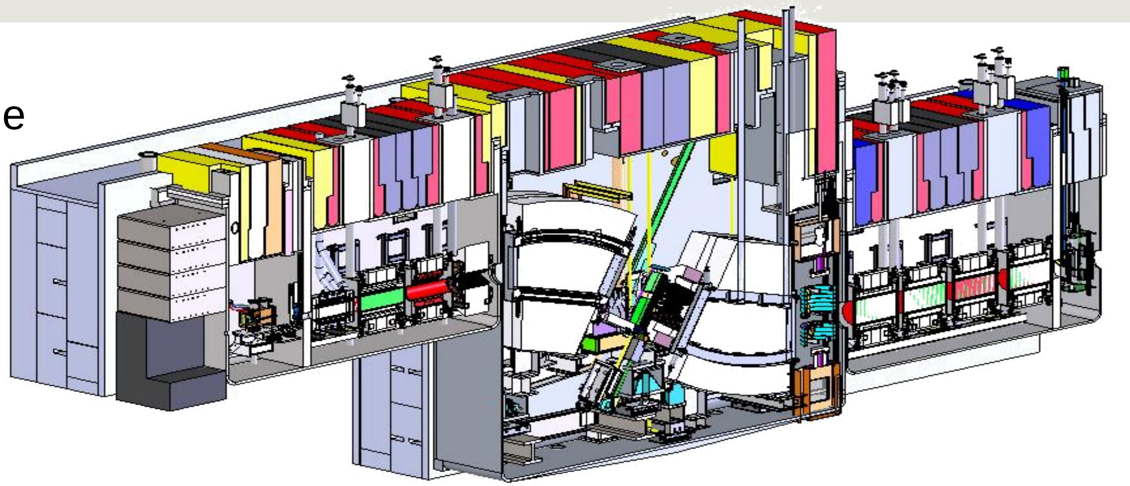
Unshielded dose rates from highest activated components at 30 cm

Component	Irradiation Time	Cooling Time	Dose Rate, rem/h
Target Module	14 days	4 hours	13
Beam Dump	1 year	16 hours	51
Magnet Shield	30 years	2 days	1547

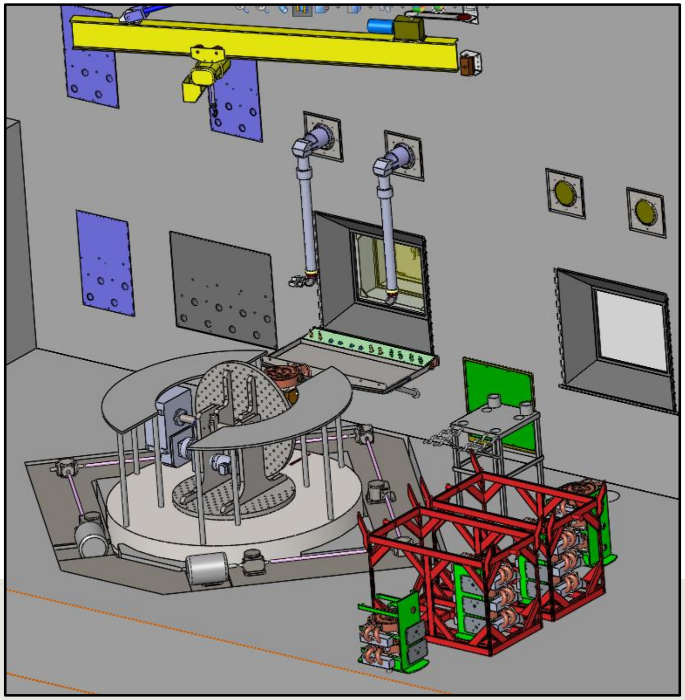
- High residual dose rates impact operational scenarios to limit the exposure to workers
  - These components need to be adequately shielded or personnel access limited during their movement, storage, and disposal

Remote Handling System

- Remote handling
  - Remotely operated bridge 20 ton crane
  - Window workstation (3, 1 installed)
  - Remote viewing system (cameras)
  - Remote handling equipment lift
  - In-cell tooling
  - Waste handling system



- Operations on top of shielding
  - Hands-on access with beam off and shielding in place (estimated 80 hours/year in target hall for target change results in dose to personnel below MSU ALARA limit)
  - Manual utility disconnect; reentrant lid bolting; general cell maintenance

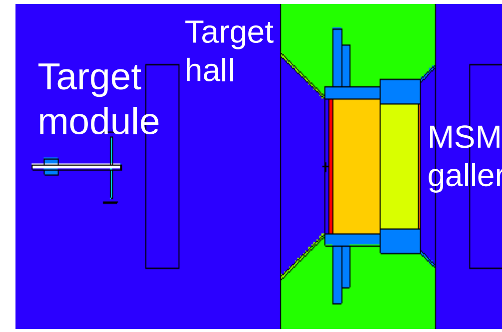


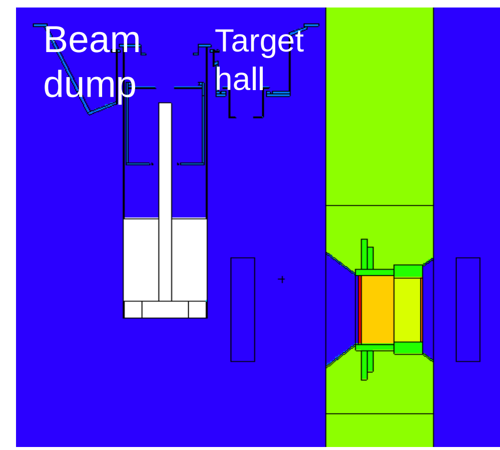
- Remote operations with shielding removed or beam on
  - Remote crane operations
    - » Shield removal; component removal; waste handling
  - Window workstation for all dexterous operations
    - » Component maintenance; waste liner load-out

Dose Rates in the MSM Gallery

Meet Design Goal Limit of 0.1 mrem/h

- Activated components will be brought to the Master Slave Manipulator (MSM) lead glass window for inspection and repair
- Dose rates in the MSM gallery due to activated components help decide whether adequate measures, such as better local shielding or limited access, should be implemented to protect working personnel from radiation
  - Activated components are placed 1 m away from the MSM lead glass window on the target hall side
    - » Irradiation time 30 years (lifetime of the facility)
  - Dose rates are
    - » >0.1 mrem/h for the magnet shield
      - Shield is expected to last for lifetime of facility
    - » ~0.1 mrem/h for the beam dump
    - » <0.1 mrem/h for the target module
  - Dose rates will decrease with heavier beams





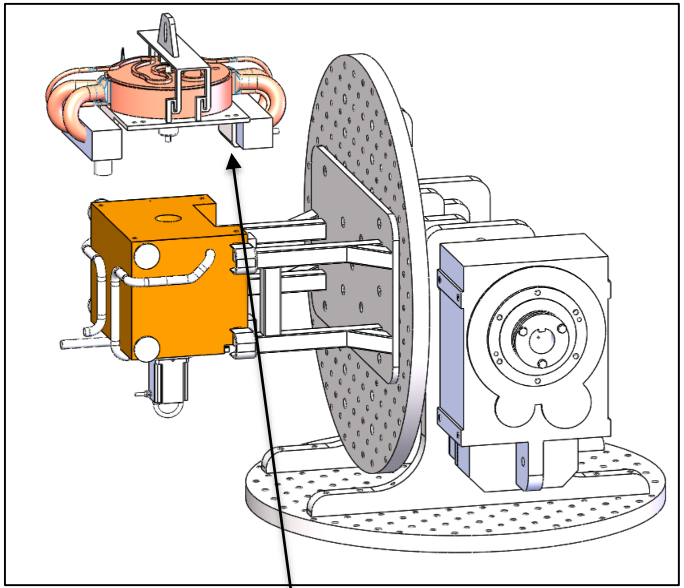
Dose rates in the MSM gallery from highest activated components

^{48}Ca beam	240 MeV/u		549 MeV/u	
	Magnet shield	Target module	Magnet shield	Target module
Cooling time	Dose rate, mrem/h	Dose rate, mrem/h	Dose rate, mrem/h	Dose rate, mrem/h
4 h	0.79	1.5E-2	3.20	4.2E-2
24 h	0.71	1.2E-4	3.04	3.2E-4
5 d	0.67	3.3E-5	2.96	9.3E-5

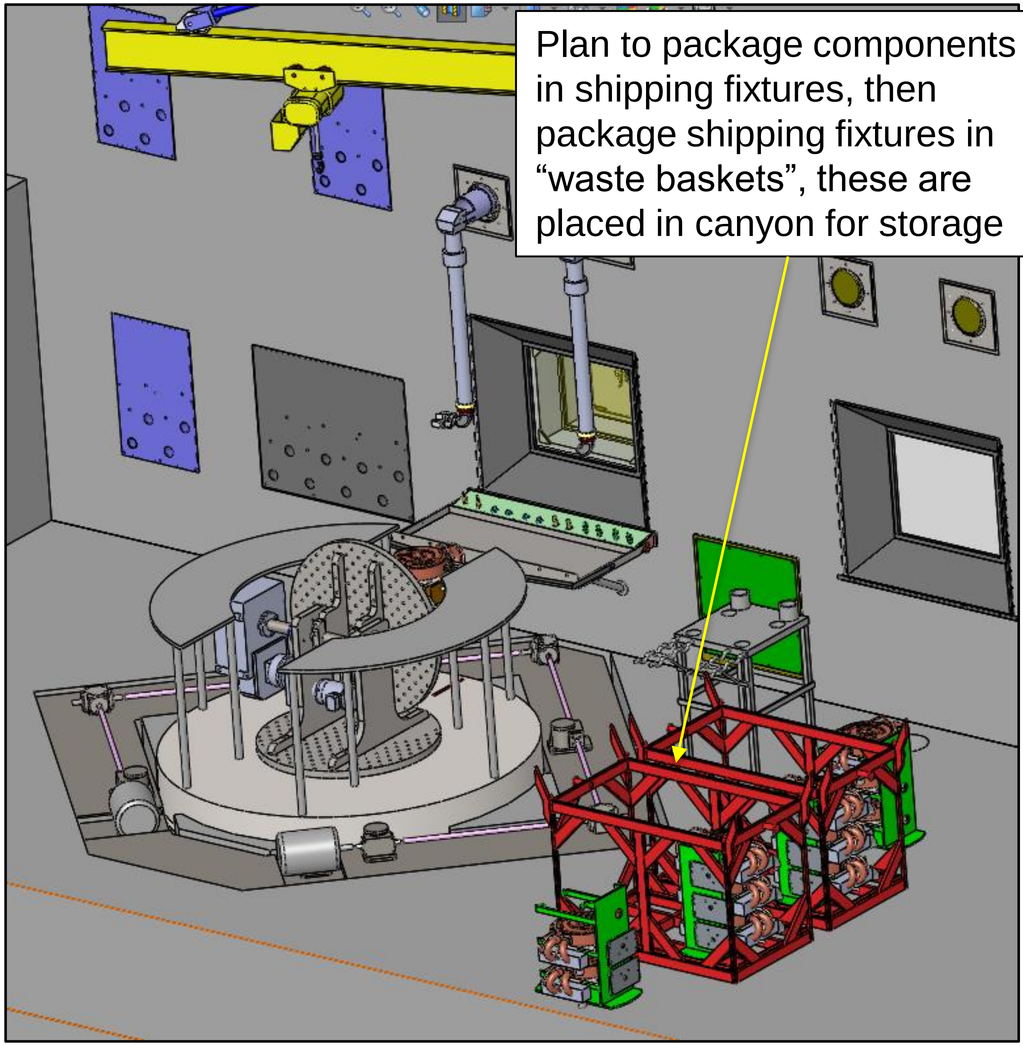
^{48}Ca beam	549 MeV/u
Component	Beam Dump
Cooling Time	Dose Rate, mrem/h
16 h	0.125

Waste Storage

Waste Removed and Packaged for Temporary Storage



In order to minimize waste stream, beam dump and target components are being replaced instead of modules. Need to manage a number of small components rather than a couple of large ones

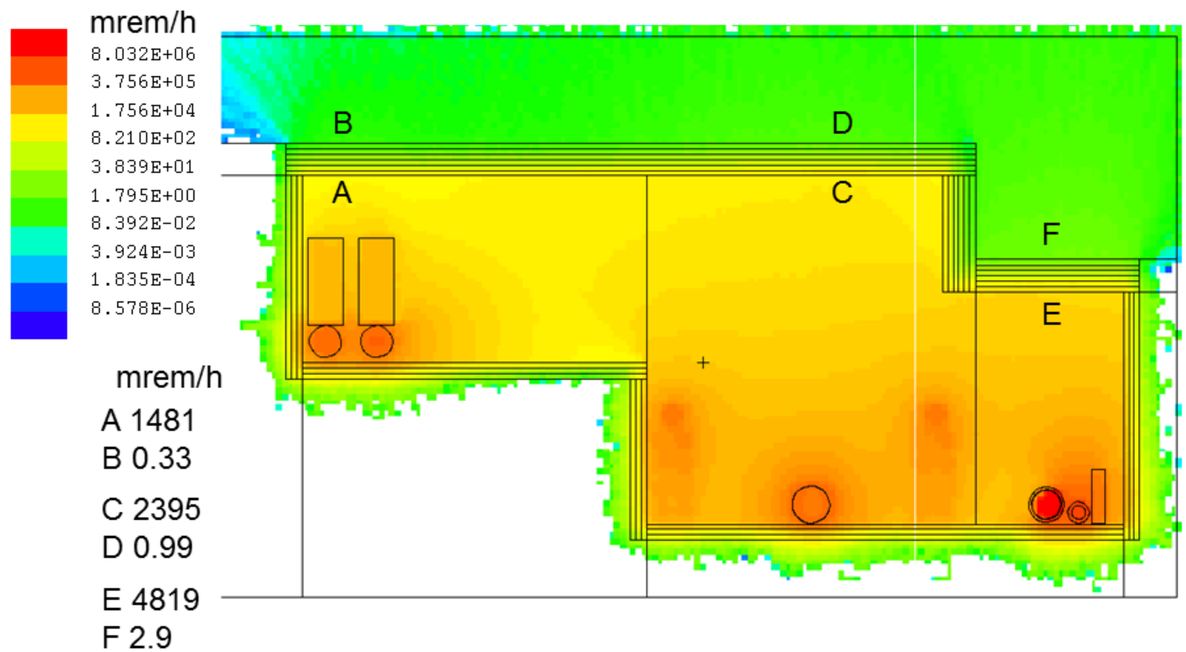


Plan to package components in shipping fixtures, then package shipping fixtures in “waste baskets”, these are placed in canyon for storage

Waste Storage
Target Hall Canyon Shielding

- Activated components and waste are planned to be temporarily stored in target hall 'canyon'
  - Target assemblies
  - Wedge assemblies
  - Target Disk Modules (TDM)
  - Scrap cryostats
- Canyon cover shield thickness optimized so that dose equivalent rates above the cover are below 5 mrem/h
  - At or below that expected from general room activation
- If post-target shield is not in the canyon
  - 2-ft thick concrete cover
- If post-target shield (life-of-facility component) is stored in the canyon
  - 2-ft thick concrete cover and 2-in thick local steel shield

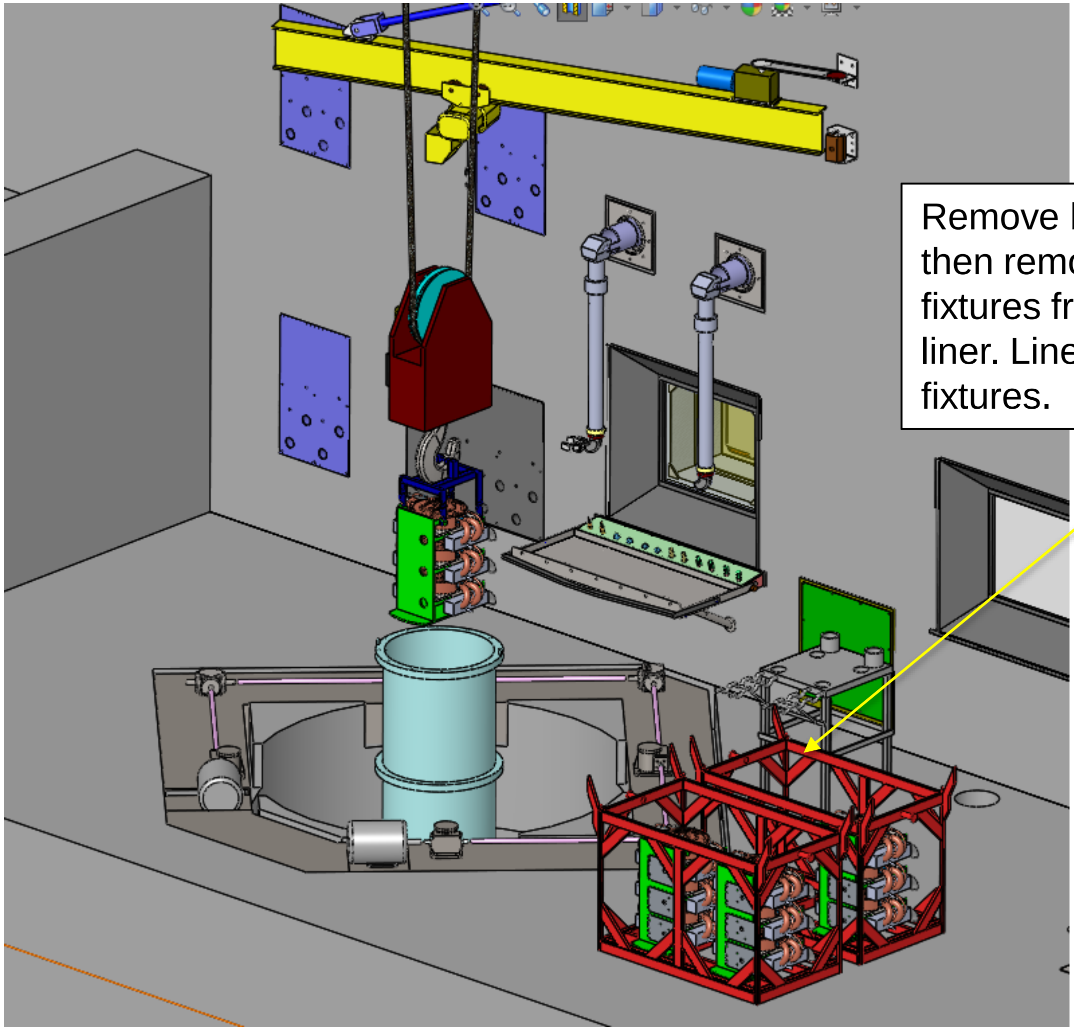
Dose equivalent rates due to activated components



- Assumptions: ^{48}Ca, 549 MeV/u; irradiation time 30 years; cooling time 4 hours

Waste Handling

Transfer of Target Disk Modules (TDMs) to Waste Liner

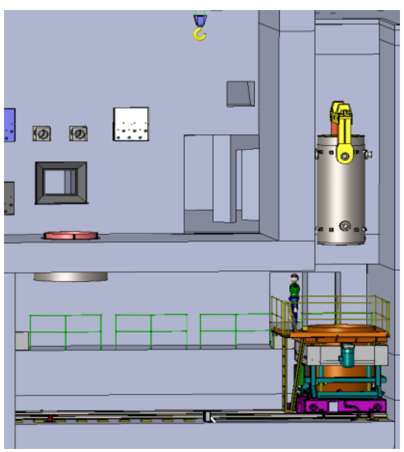


Remove baskets from canyon, then remove TDM storage fixtures from basket and place in liner. Liner will hold 3 storage fixtures.

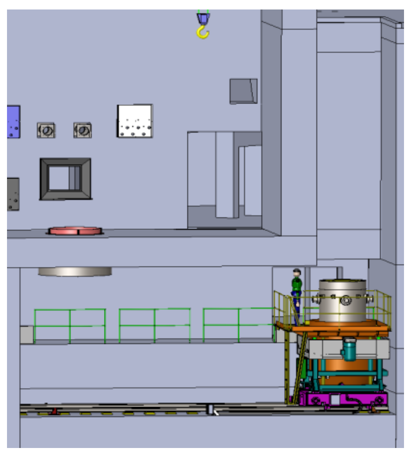
Waste Handling

Removal of Waste from Target Hall

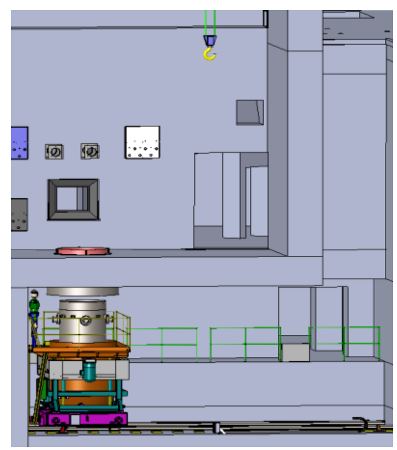
- Removal of waste from target hall is based on SNS design and assumes the use of the TN-RAM cask. The cask cart can also transport the CNS 6-80-2 cask.
- First waste shipment forecast to occur 2-3 years after CD-4.
  - CD-4 is planned in 2022
- Three paths for installing waste shipping liner:
  - Place in TN-RAM cask and transport to Bottom Loading Port with cask cart
  - Lower through target hall roof hatch
  - Use shipping elevator and bring into target hall through shielded door



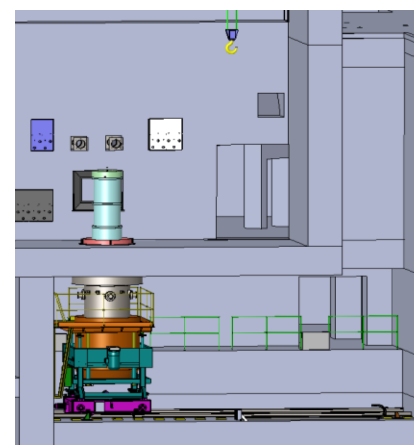
TN-RAM lowered into cart



TN-RAM in cart



TN-RAM under Bottom Loading Port (BLP)



TN-RAM docked to BLP and waste liner installed

Waste Transport

- Regulatory limits on unshielded dose equivalent rates
  - Department of Transportation: 10 mrem/h at 2 m from the cask or
  - 1 rem rem/h at 3 m from the unshielded waste (United States Code of Federal Regulations, Title 49 Part 173)
  - Whichever is more restrictive

- A number of casks evaluated, TN-RAM is appropriate (by AREVA Transnuclear Inc.)
  - Only one available
  - Weight 80,000 lbs (≈36.2 tonne)
  - Shipment cost to Nevada National Security Site for FRIB estimated waste ≈$200k (?)

Component	Unshielded Effective Dose Equivalent Rate (rem/h) at 1 m	Unshielded Effective Dose Equivalent Rate (rem/h) at 2 m	Unshielded Effective Dose Equivalent Rate (rem/h) at 3 m
Targets (17)	4.00E+00	1.00E+00	0.44
Magnet Shield (1)	1.64E+02	4.10E+01	18.2
FSQ1 Cryostat (1)	9.22E+00	2.30E+00	1.0
FSD1 Cryostat (1)	1.72E+00	4.31E-01	0.2
Beam Dump Shells (5)	6.84E+01	1.71E+01	7.6
Beam Dump Drive Components	1.50E+01	3.76E+00	1.6
Wedges (18)	3.38E-01	8.45E-02	0.04

TN-RAM Cask

Waste Handling Summary

- FRIB project radioactive waste stream has been analyzed
- Commercially available casks that are suitable for disposal of FRIB waste have been identified
- The TN-RAM cask is the cask proposed in the baseline design
- The target hall canyon will be used to temporarily store activated components and waste for cooling and disposal
- Long term storage of activated components and waste will occur in the vertical transfer area

Summary and Conclusions

- FRIB being designed and established at MSU as a national user facility to provide fast, stopped, and reaccelerated beams of rare isotopes
- High radiation environment in the project target facility demands analysis of beam line component activation
- Highly activated components that need to be fixed or disposed will be temporarily stored for cooling and/or disposal
- Waste handling techniques and procedures have been developed to deal with highly activated components

Cask Cart – Similar to SNS design