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Radioactivation Studies of the LBNF Focusing Horns

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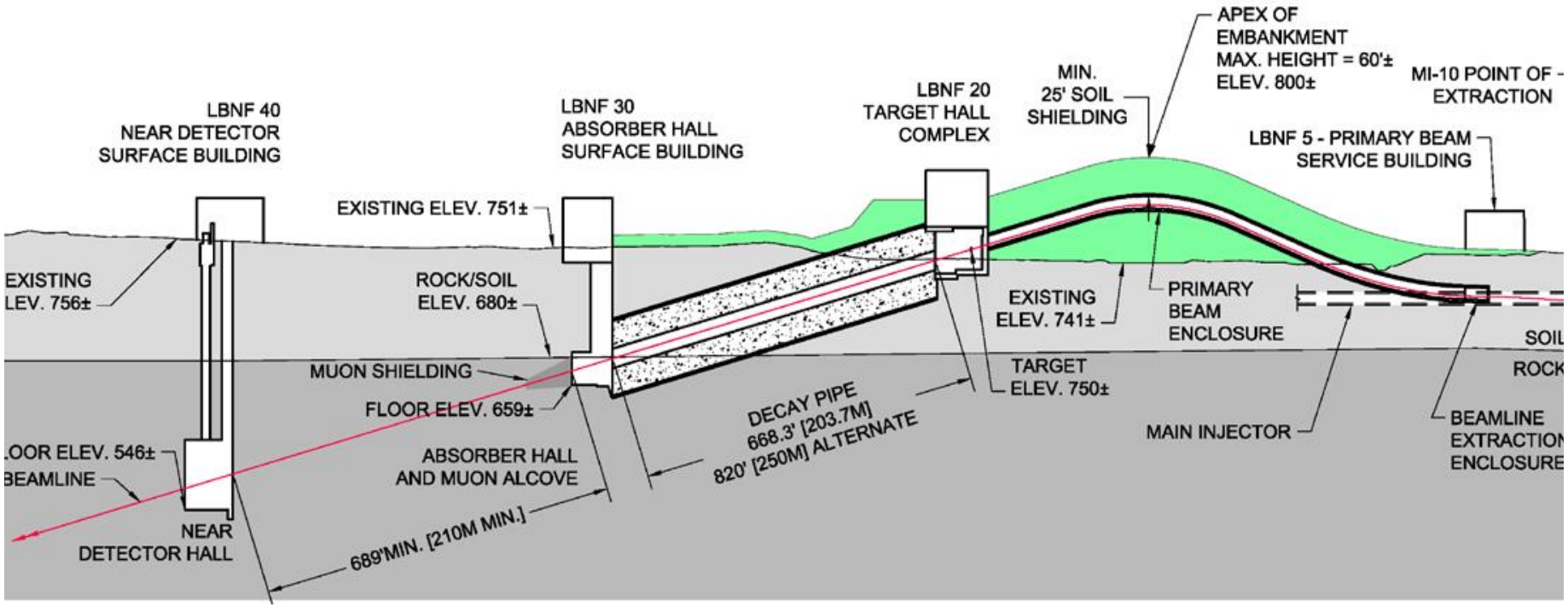
Outline

- Introduction
- LBNF Description
- Horn 1 Description
- MARS Simulation
- Simulation Results
- Summary

Introduction

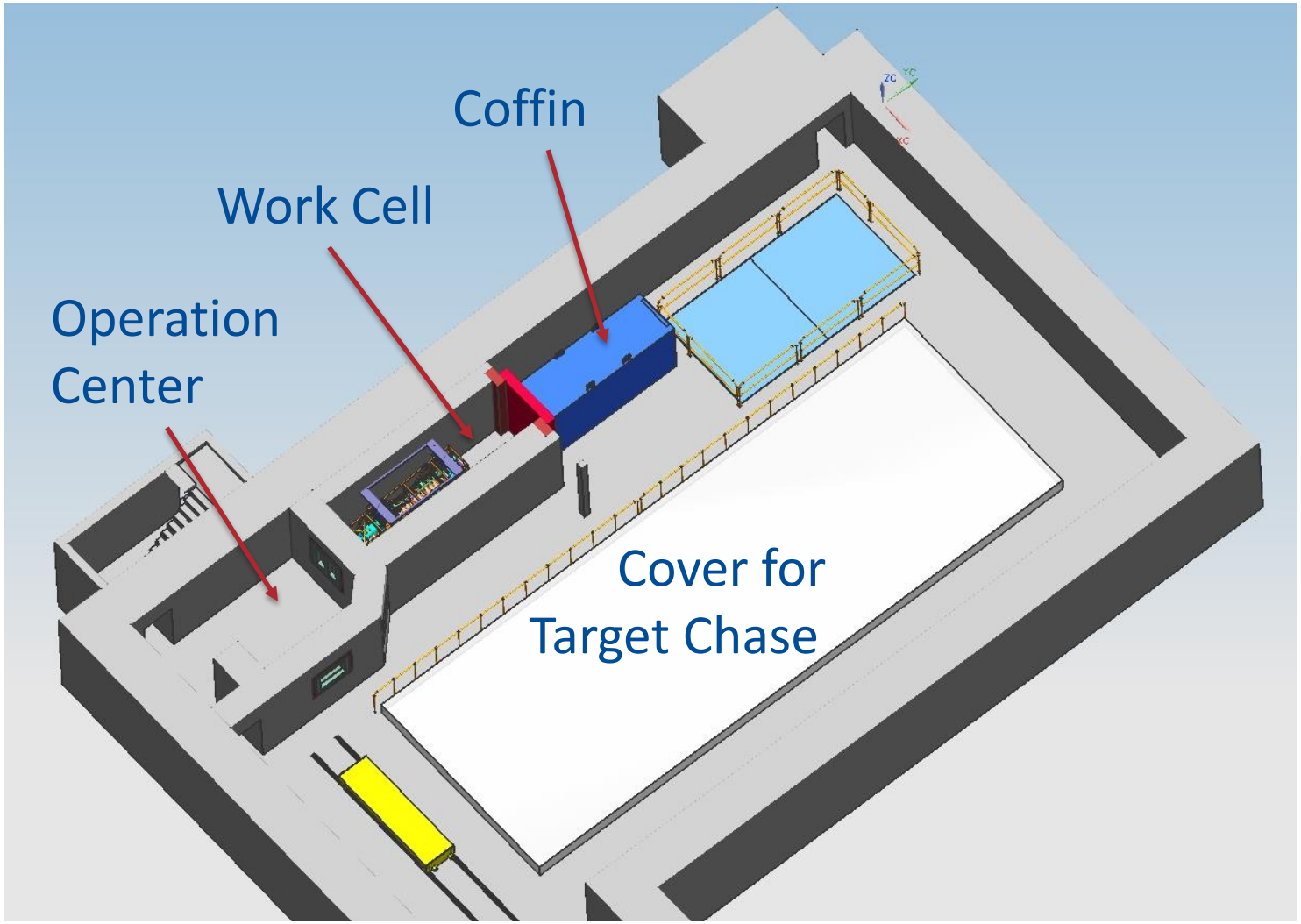
- Operation of the LBNF/DUNE beamline will produce highly radioactive beamline components which will need servicing in a shielded work cell.
  - Need to estimate how much shielding for the workcell is required.
- Decommissioned beamline components may need to be placed in an on-site morgue for a few years before they are cool enough to be shipped off-site to a permanent storage facility.
  - Must plan on how much storage space will be needed.
- Estimate these values from radioactivation studies on a large beamline component.

LBNF Beamline

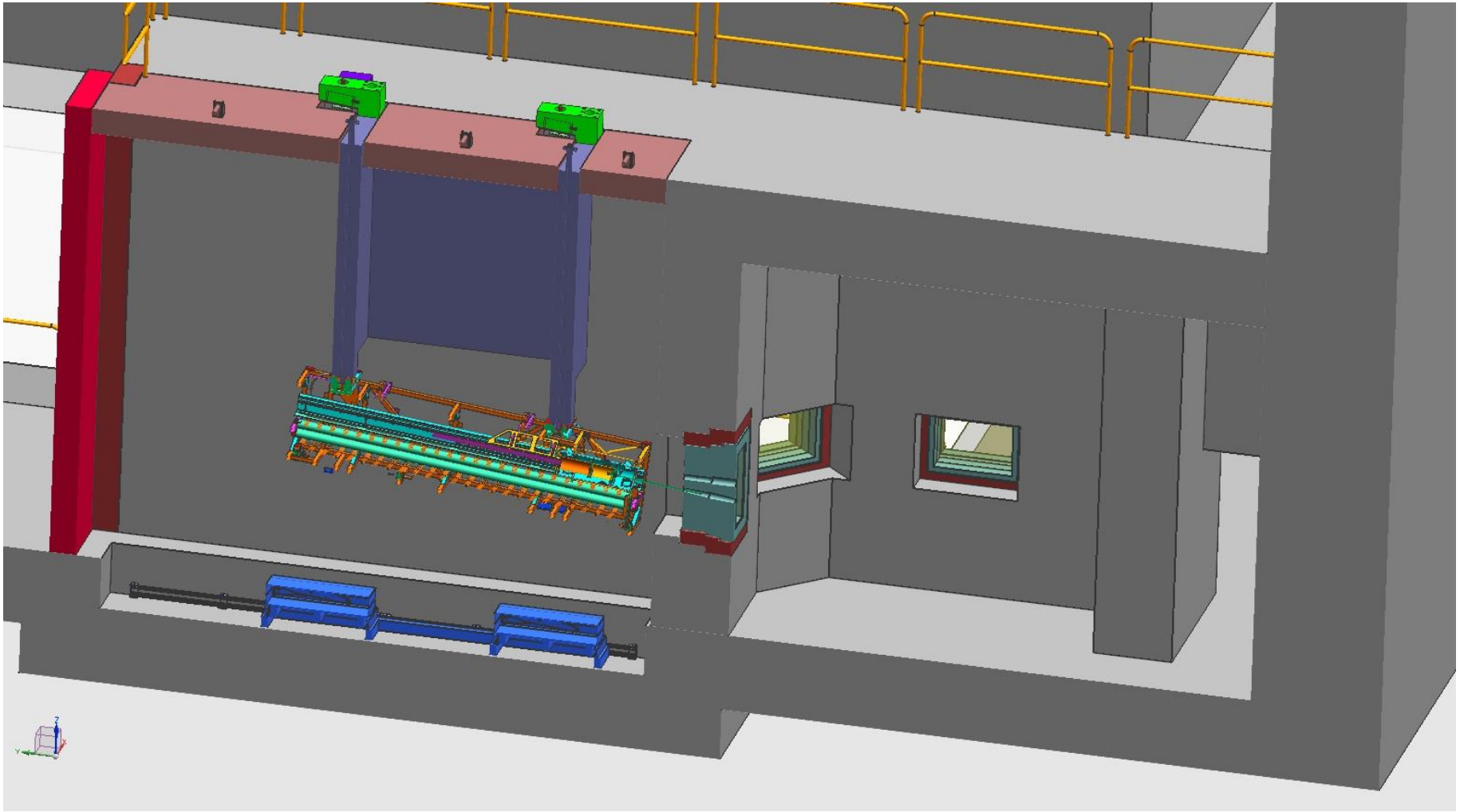


LBNF will produce a neutrino beam for the DUNE experiment from a 60-120GeV proton beam incident on a graphite target. Resultant particles will be focused with two magnetic horns. Operation will initially start at a beam power of 1.2 MW which will be upgraded to 2.4 MW later.

Location of Work Cell in Target Hall



Interior Work Cell View



Methodology

- Estimate shielding and storage needs from radioactivation studies on magnetic focusing horns.
  - The horns have significant mass compared to other similarly activated components.
  - The upstream horn (horn 1) is exposed to greater prompt radiation than the downstream horn (horn 2) due to the target location inside the upstream end of horn 1.
- Several peripheral components (water tank, stripline, clamps) are attached to the horn need to be included in the model.
  - These stay with the horn during servicing and decommissioning
  - Contribute to the overall activity.
  - Large numbers of small steel components are included due to the high specific activity of steel.

Water Lines

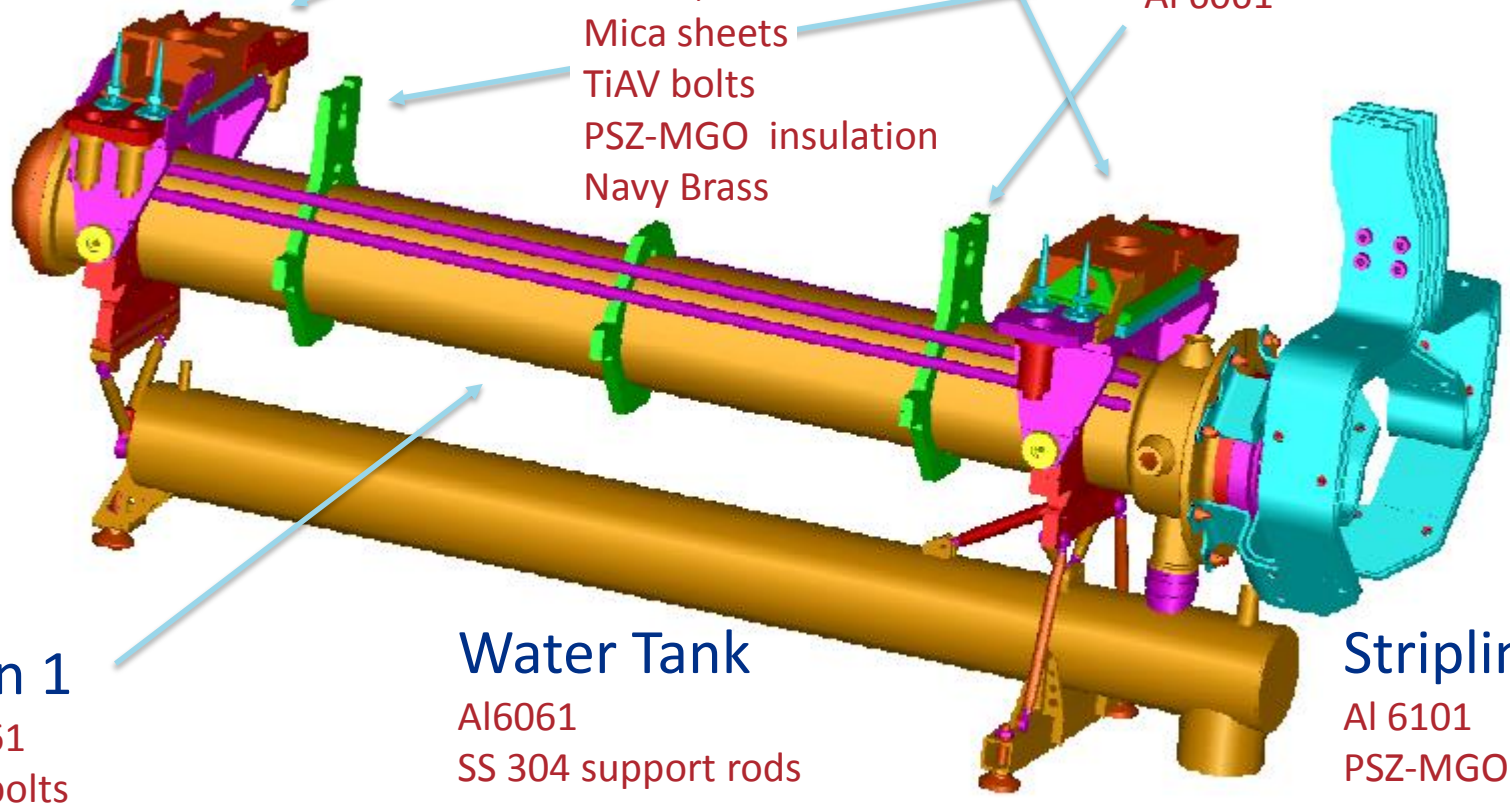
SS 316, 304

Support Clamps

Al 6061
SS 316, 304
Mica sheets
TiAV bolts
PSZ-MGO insulation
Navy Brass

Lift Clamps

Al 6061



Horn 1

Al 6061
TiAV bolts
PSZ-MGO and A_2O_3 insulation
SS 316 in spider support bolts

Water Tank

Al6061
SS 304 support rods

Stripline

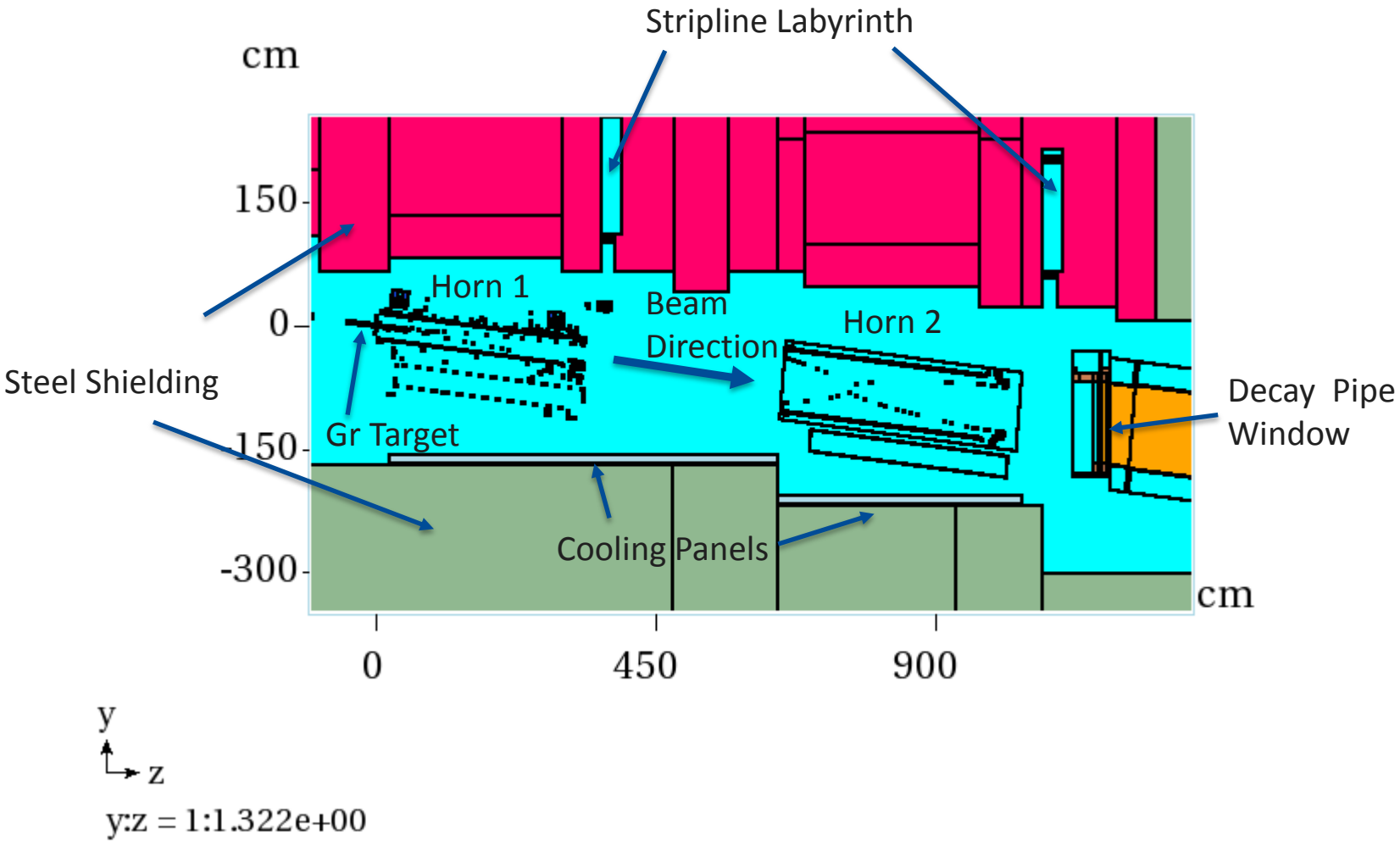
Al 6101
PSZ-MGO insulating spacers
TiAV bolts

LBNF Horn 1 currently is the same design in use for NuMI and NoVA

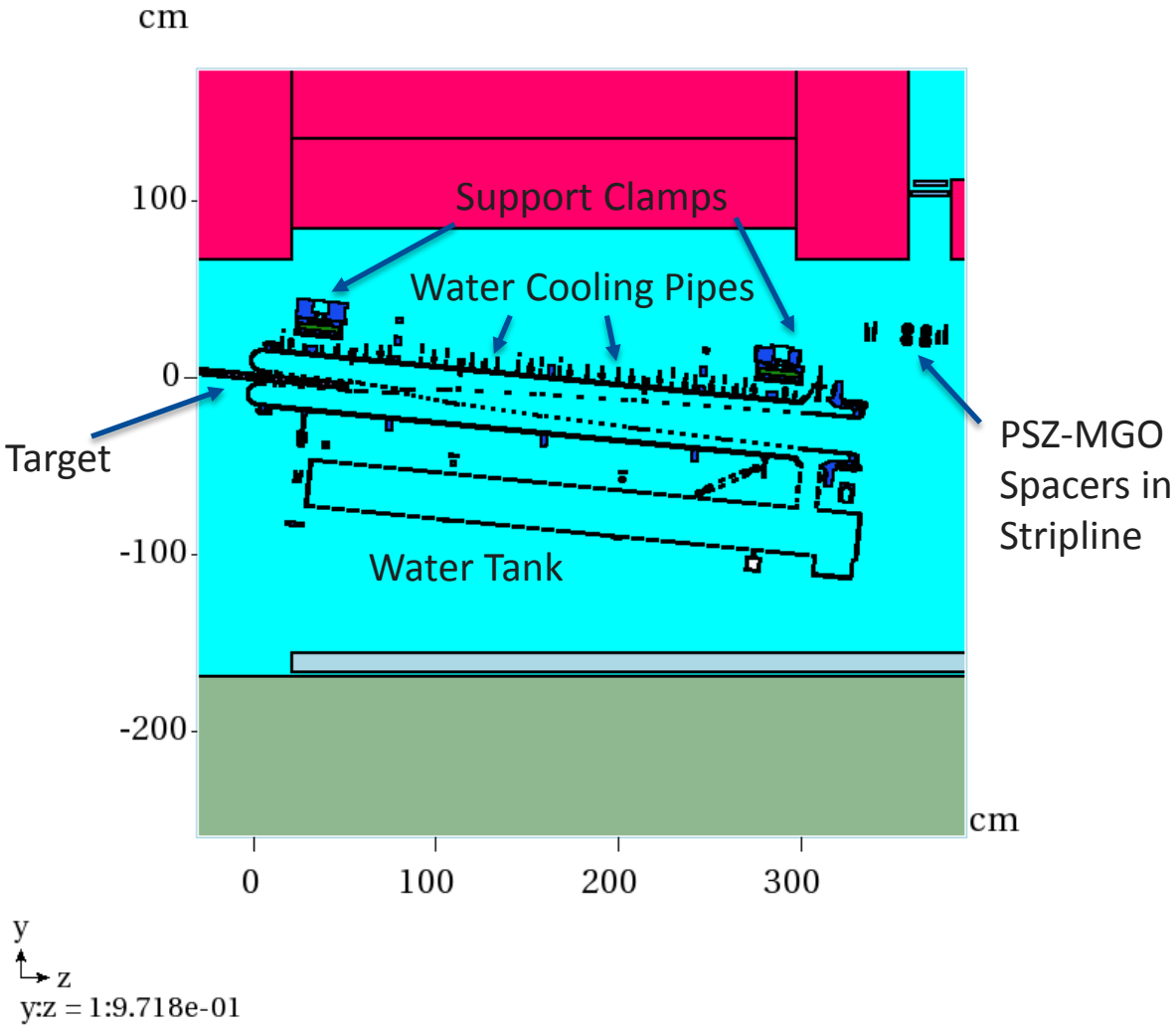
Simulation

- Use MARS15 to model radionuclide production in the materials comprising horn 1
  - Horn 1 components too thin to use default residual activation estimate.
  - Geometry too complex to employ correction factors to residual dose results.
- Include activity from smaller pieces of steel, titanium, brass and PSZ-MGO (zirconia).
- Use DeTra to on MARS output to estimate activity for various irradiation and cooling times.

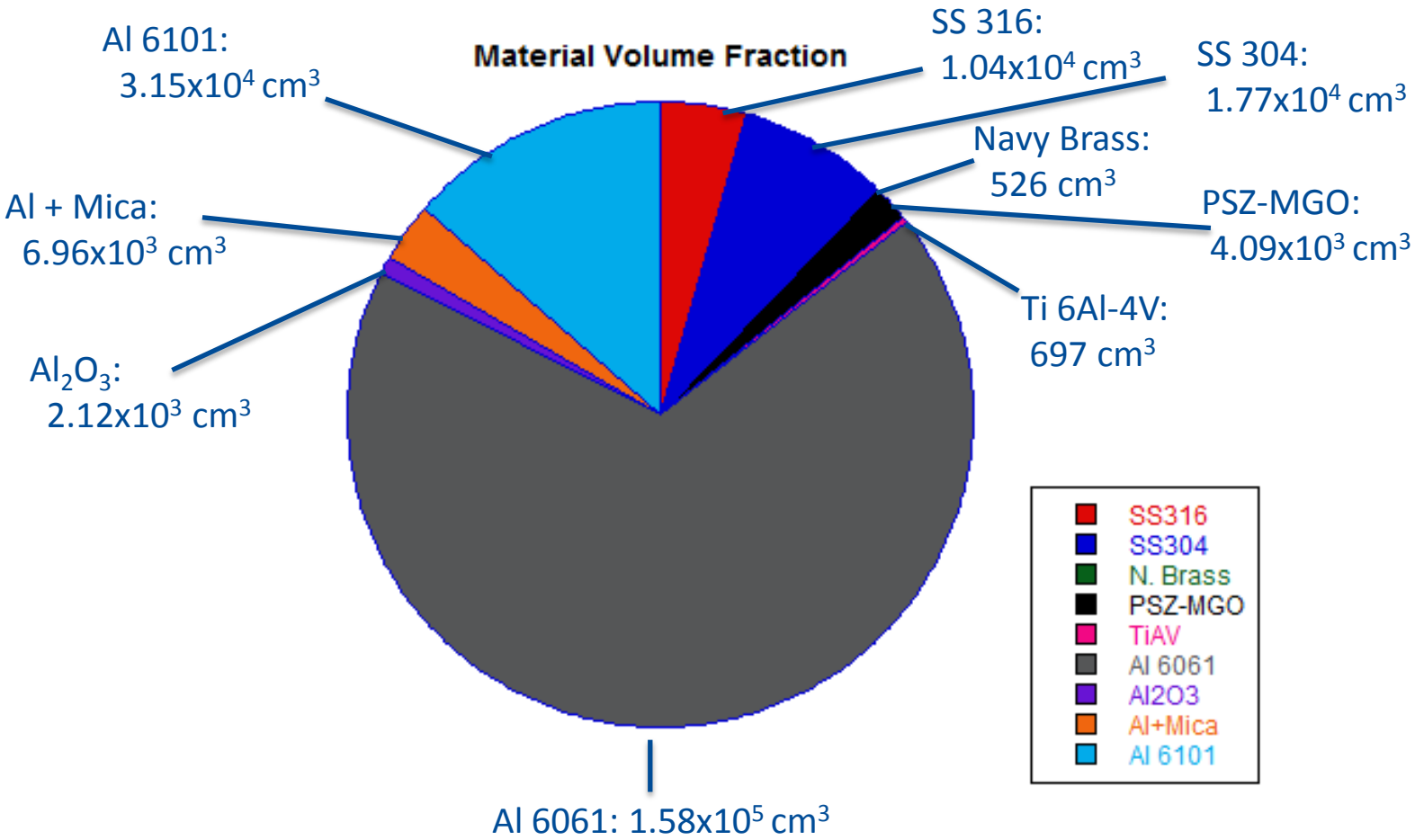
MARS Model of Target Chase



MARS Model of Horn 1



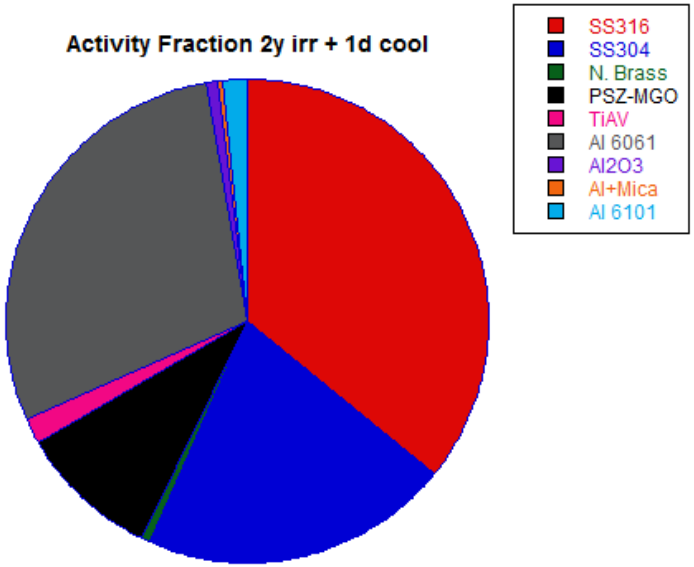
Volume Fraction of Materials in Horn 1 Model

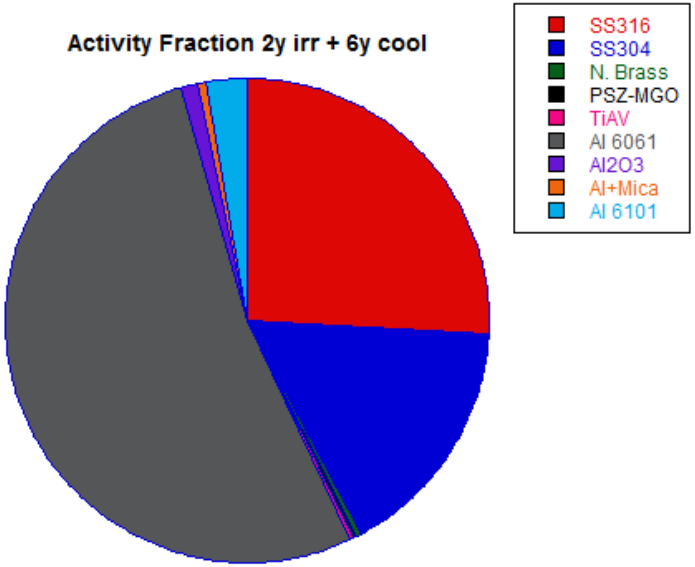


Activation Results

- Obtain nuclide production results per proton for each material in horn 1.
- Estimate for 2 years irradiation at 2.4 MW.
  - 120 GeV proton beam on target
  - 1.25×10^{14} protons/s
- Cooling period of:
  - 1 day:
    - Minimum time to place horn in workcell
    - Total activity: 8.9×10^{13} Bq
  - 6 years:
    - Morgue space estimate
    - Total activity: 6.2×10^{12} Bq

Activity Fraction from Materials

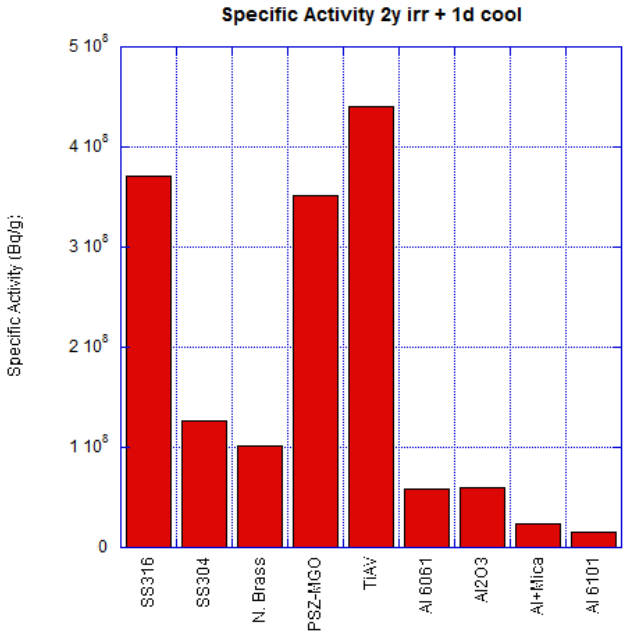




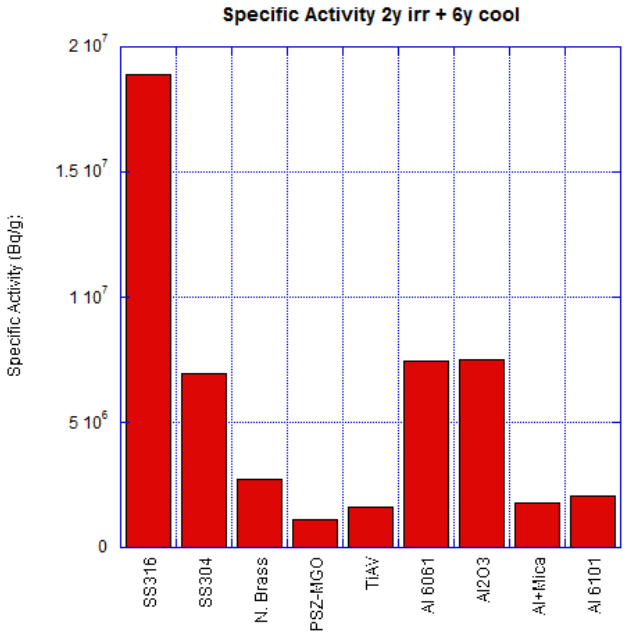
Activity fraction after 2y irradiation and 1 day cooling.

Activity fraction after 2y irradiation and 6 years cooling.

Specific Activity of Materials

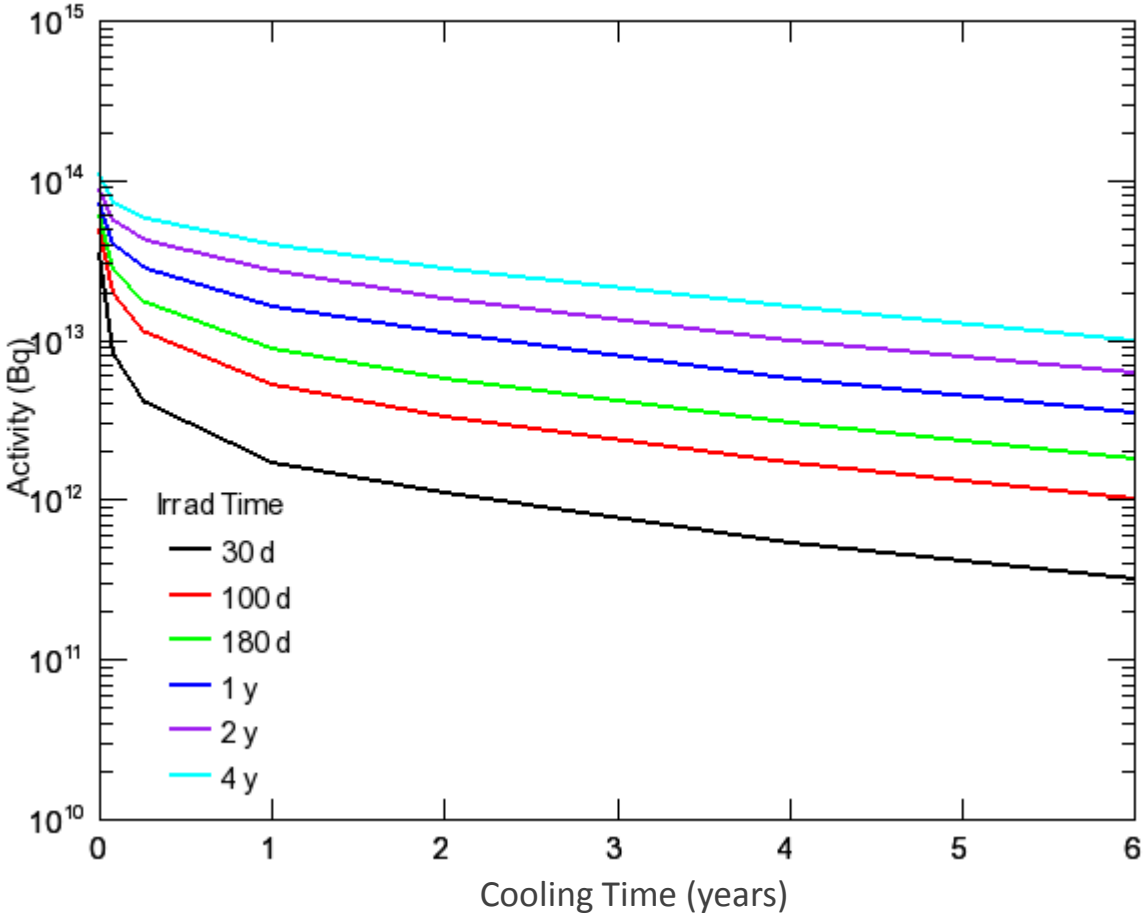


Specific Activity of various horn 1 materials after 2y irradiation and 1d cooling.

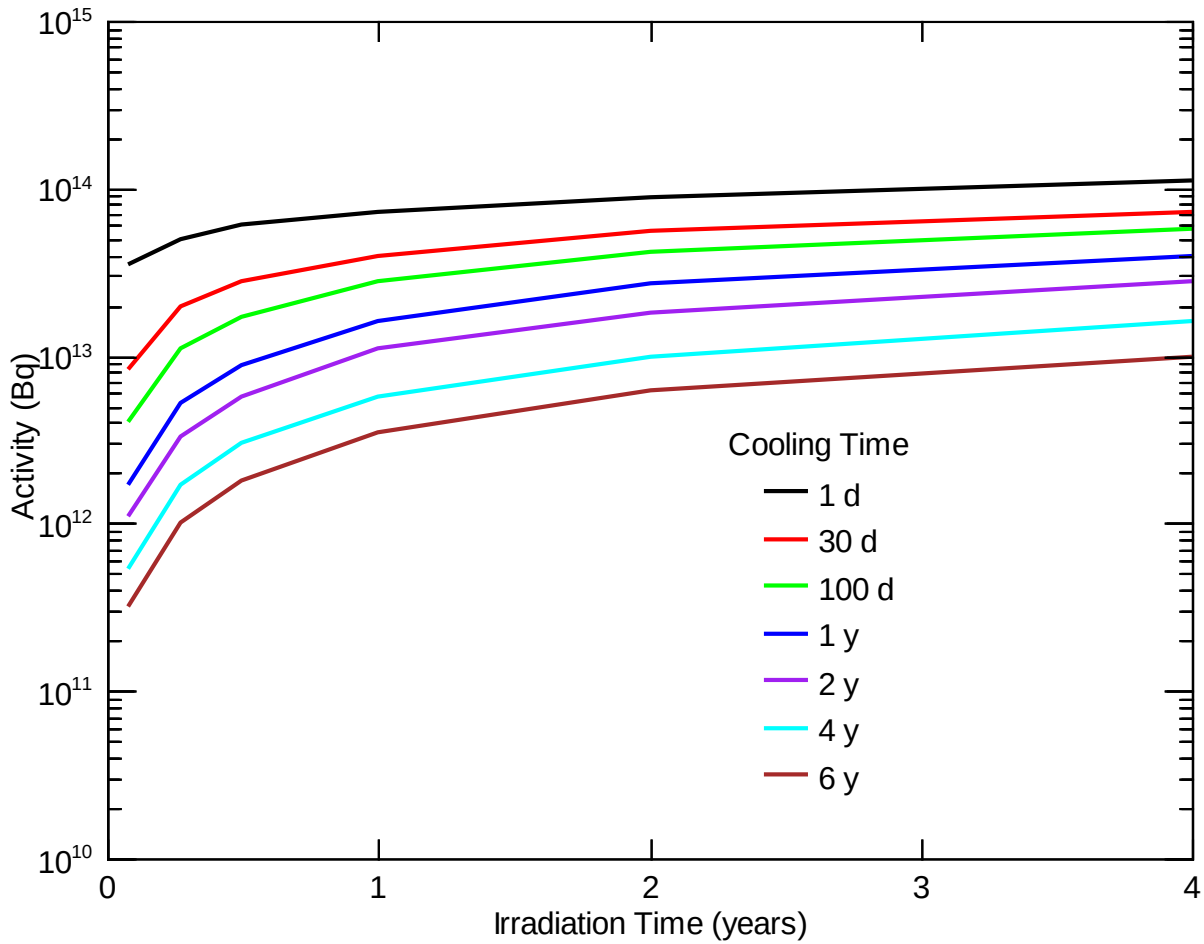


Specific Activity of various horn 1 materials after 2y irradiation and 6y cooling.

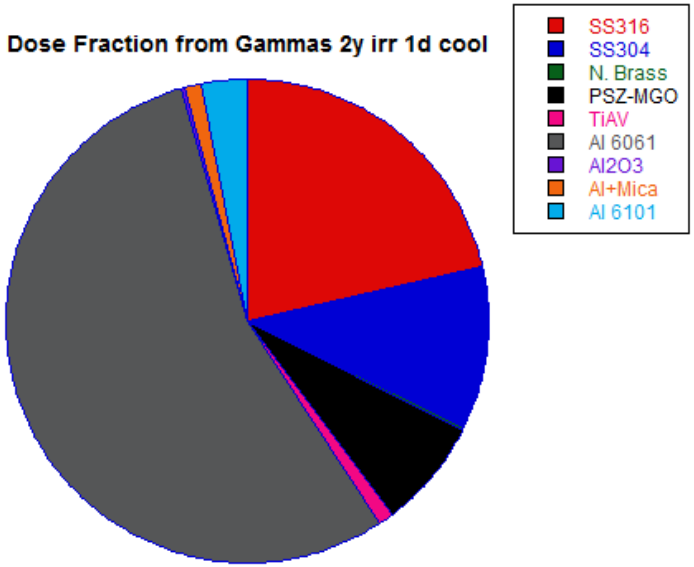
Total Activity vs Cooling Time

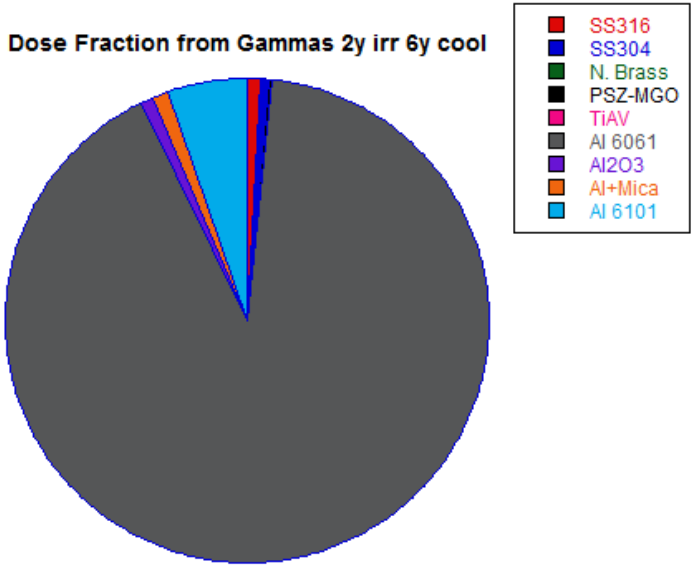


Total Activity vs Irradiation Time



Dose Fraction from Materials

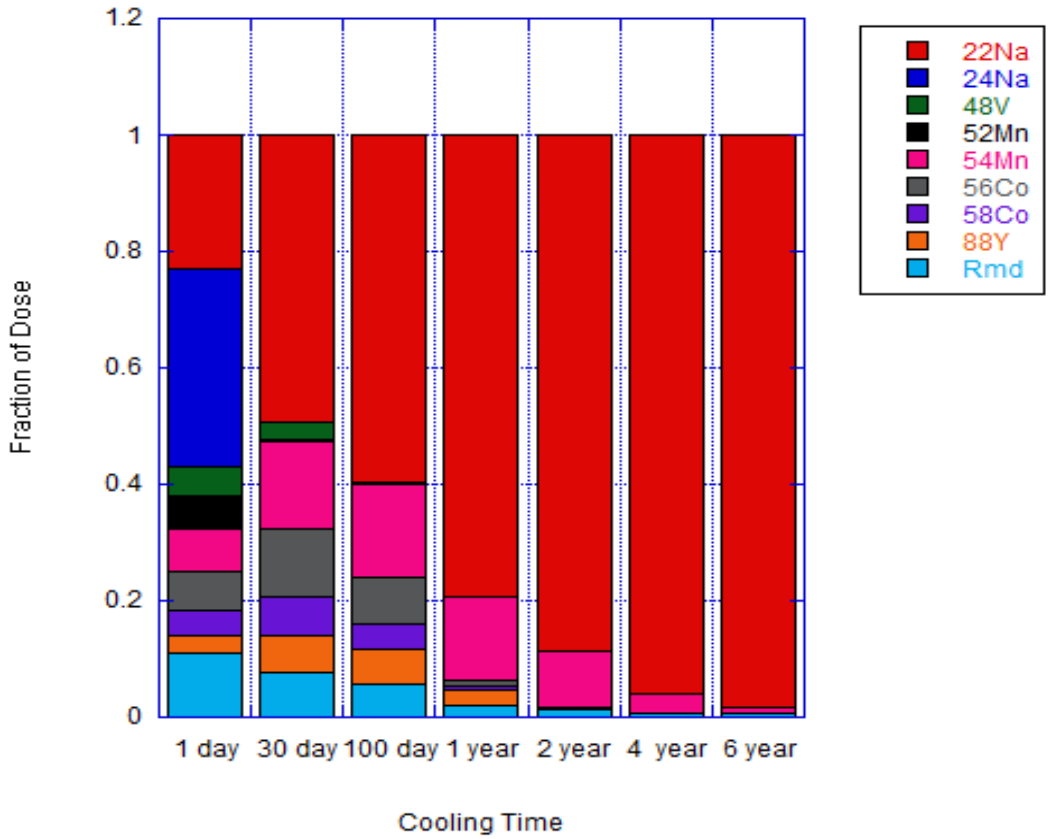




Fraction of dose after 1d cooling. Significant contribution to dose from: ^{24}Na (34%), ^{22}Na (22%), ^{54}Mn (7%), ^{52}Mn(6%), ^{56}Co(7%), and ^{48}V(5%)

Fraction of dose after 6y cooling. 98% of dose received from ^{22}Na.

Fraction of Isotope Contributions to Total Dose

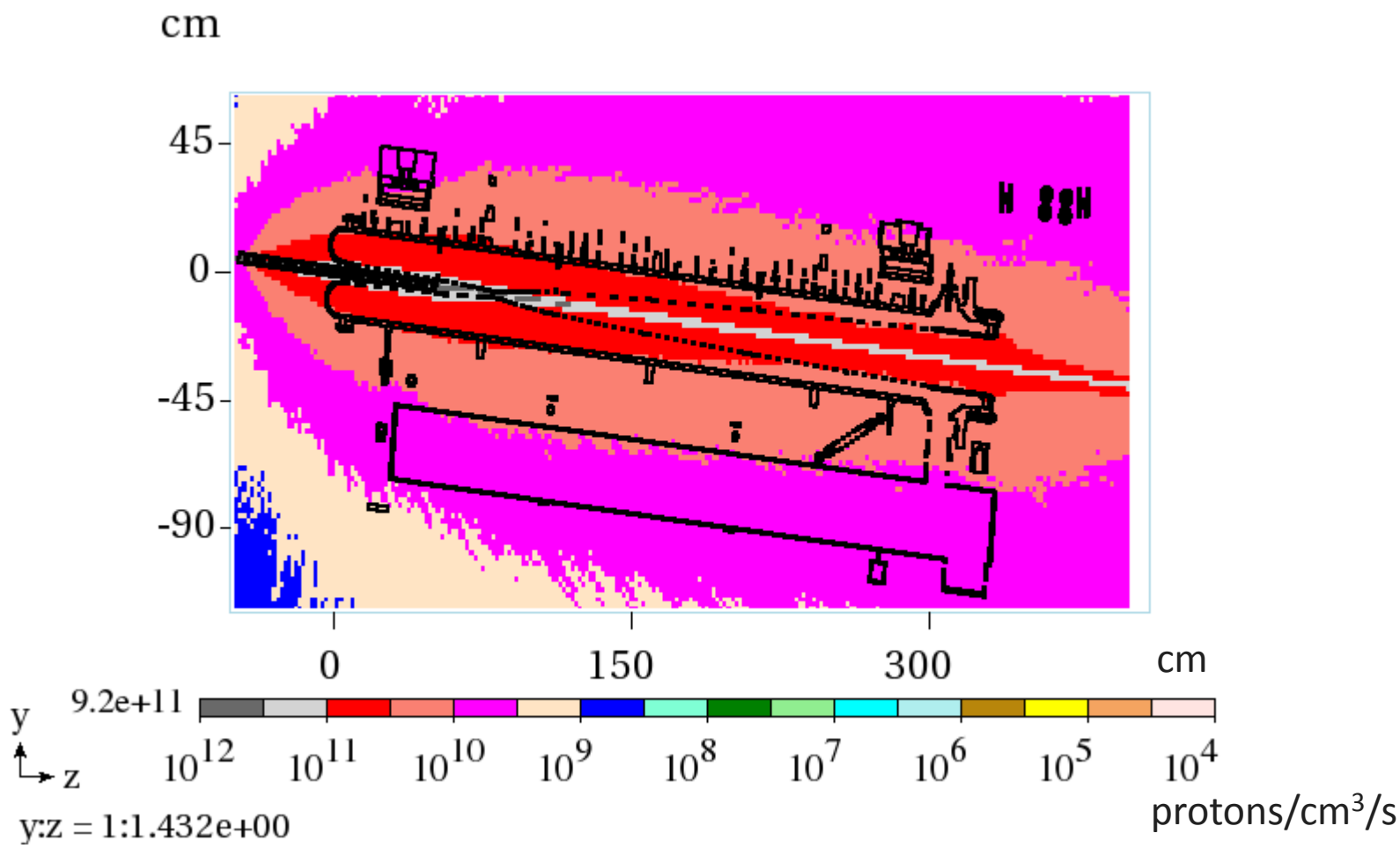


Summary

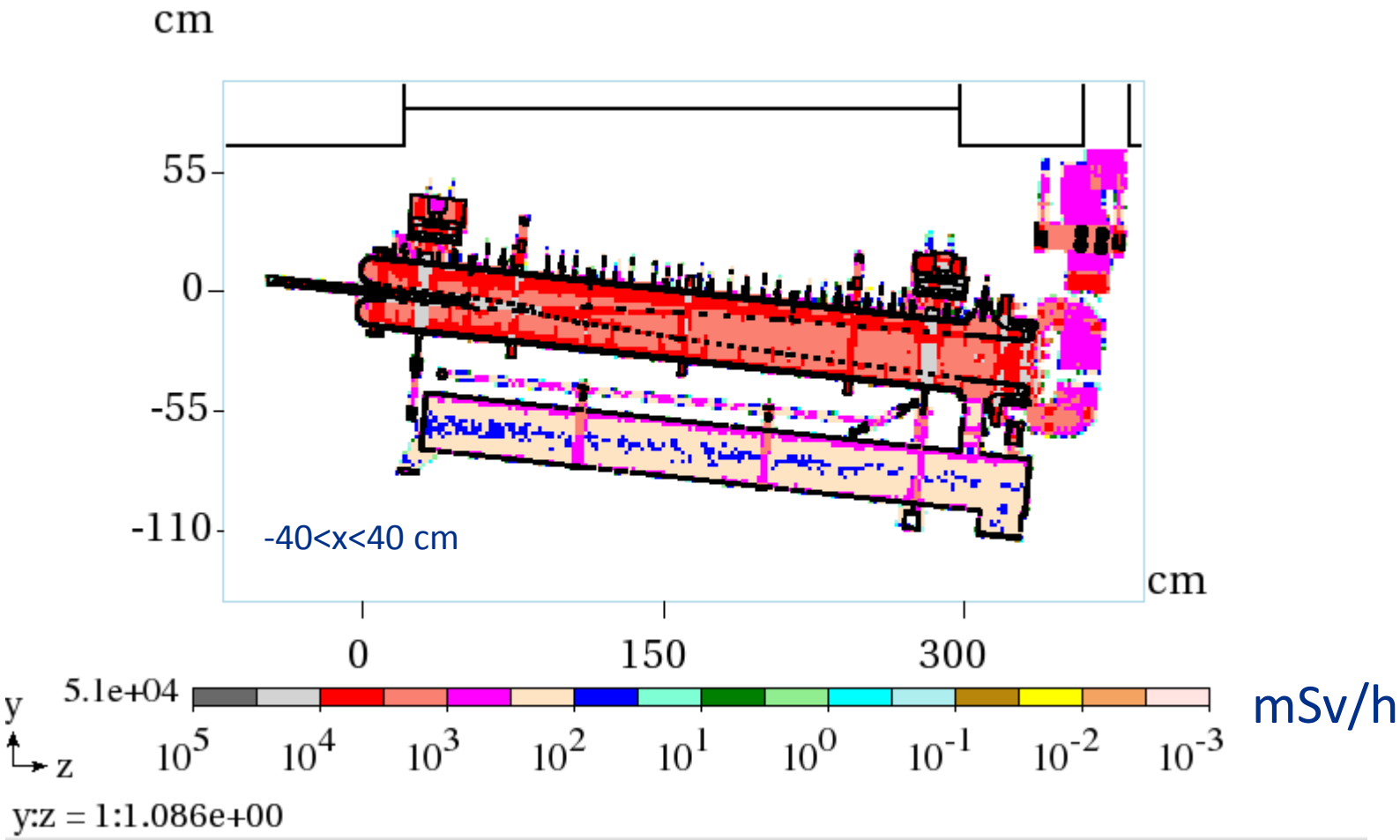
- Wall thickness on LBNF target hall work cell will need to be sufficient to shield to hottest objects that are serviced.
- Morgue space for LBNE neutrino beamline decommissioned components must be sufficient.
- Radionuclide production in horn 1 is estimated using MARS15.
  - Results processed with DeTra to calculate activity for various irradiation and cooling periods.
- Significant contributions to activity for short term cooling periods (days) from Al, steel and PSZ-MGO
- Activity over long term cooling periods (years) from Al and steel.
  - ^{22}Na dominant contribution to dose.

Backup Slides

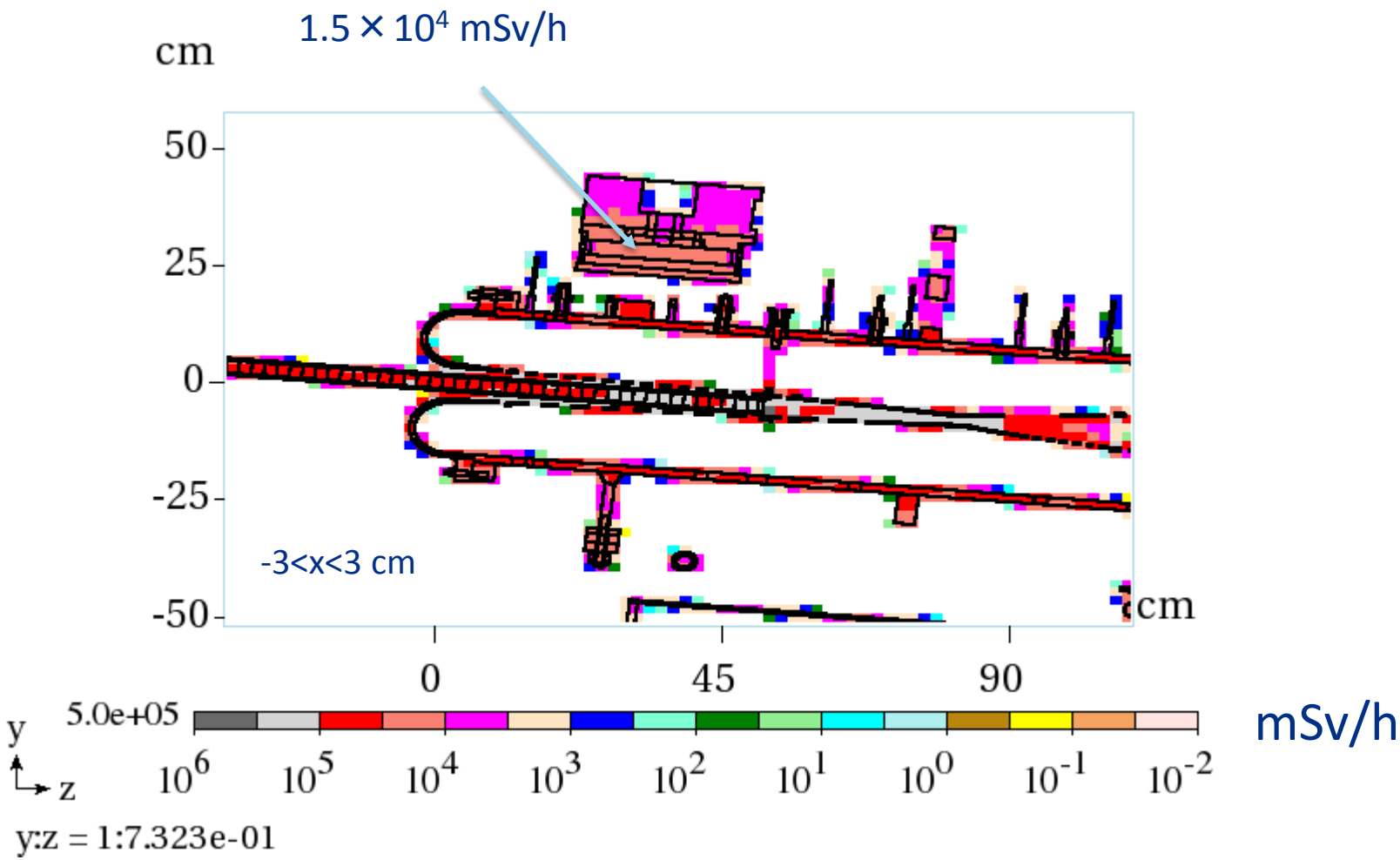
Proton Flux


cm
45
0
-45
-90
0
150
300
cm
9.2e+11
y
z
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
protons/cm^3/s
y:z = 1:1.432e+00

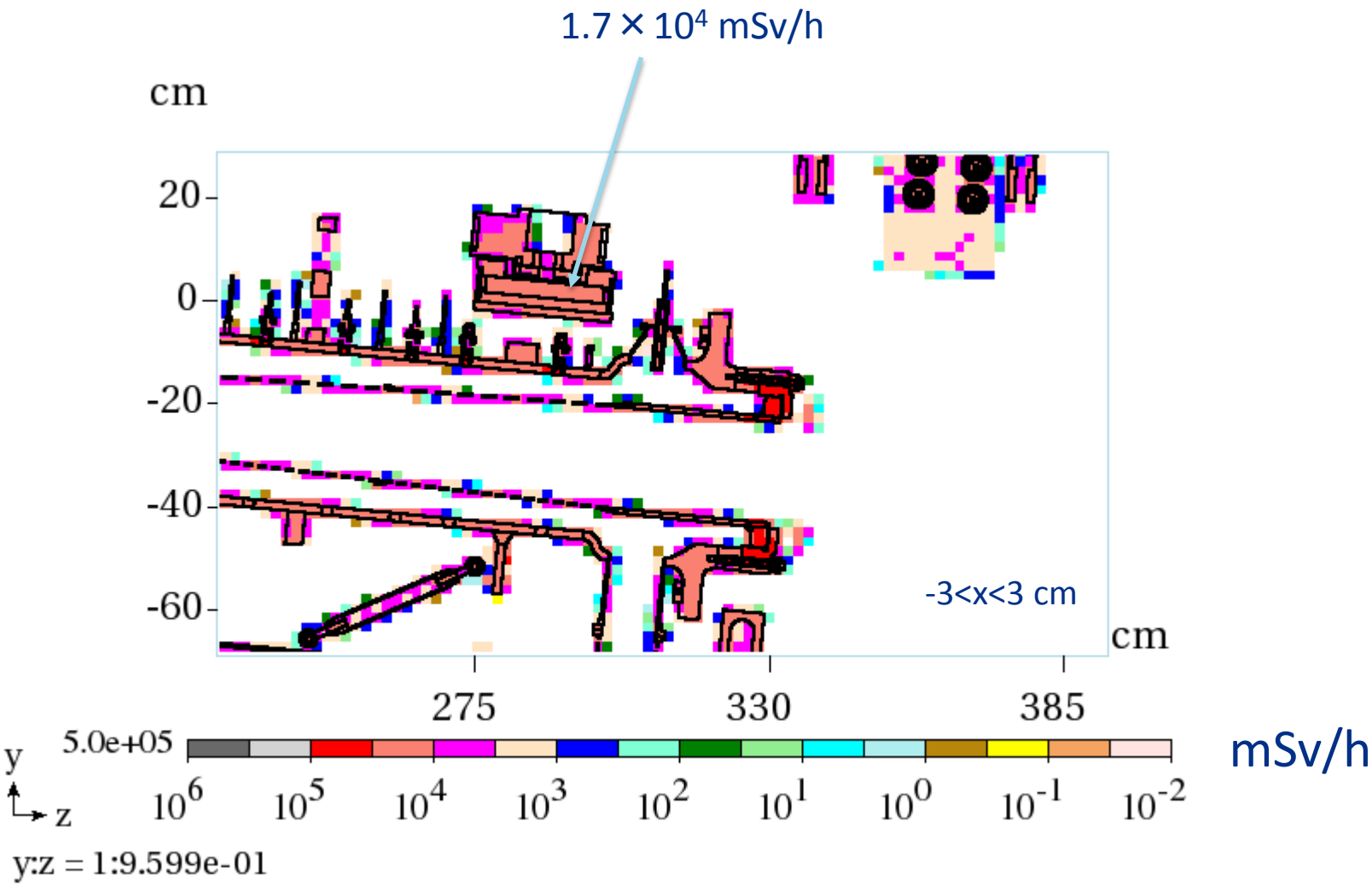
Residual Dose on Contact



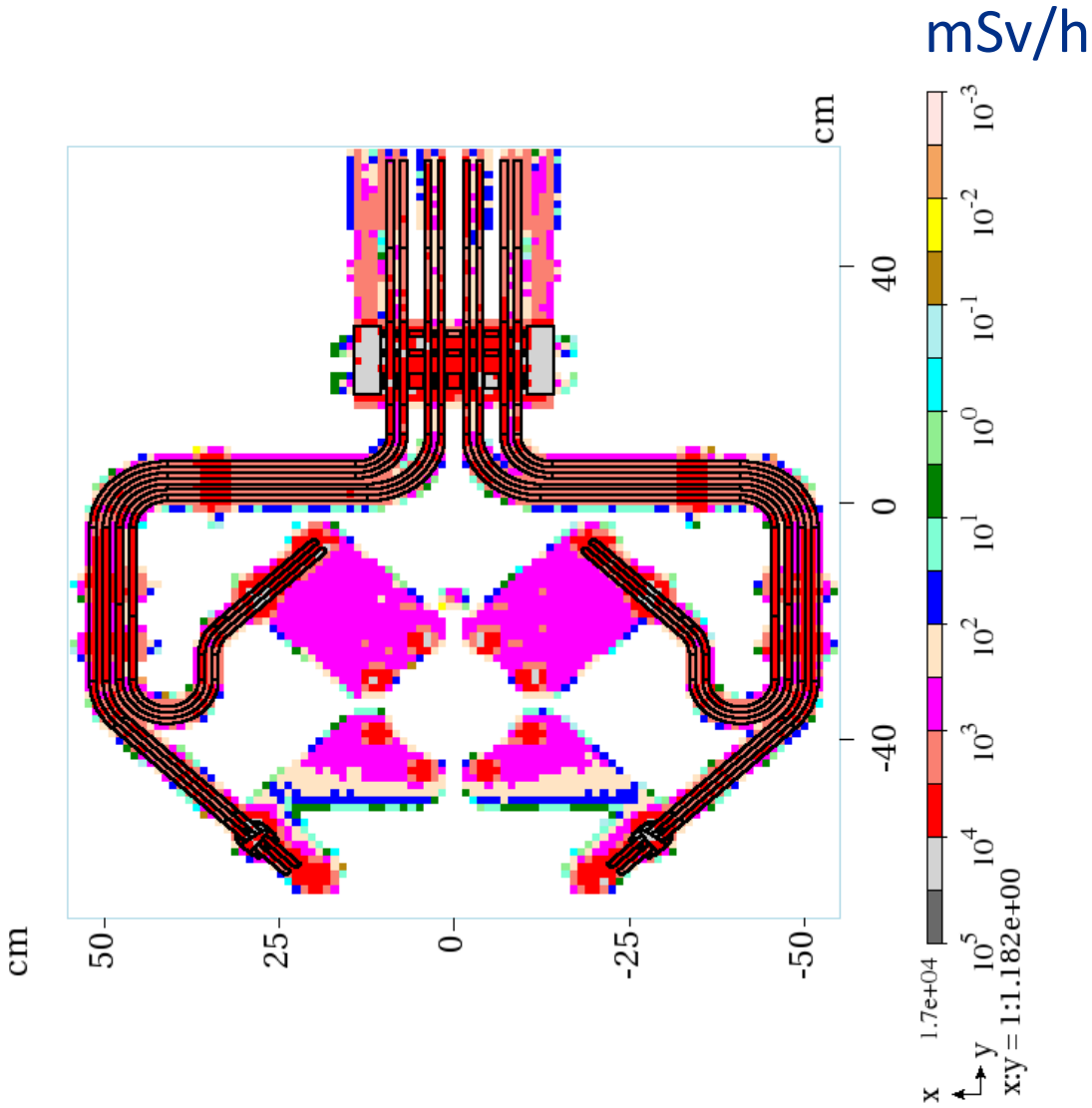
Residual Dose



Residual Dose



Residual Dose on Contact

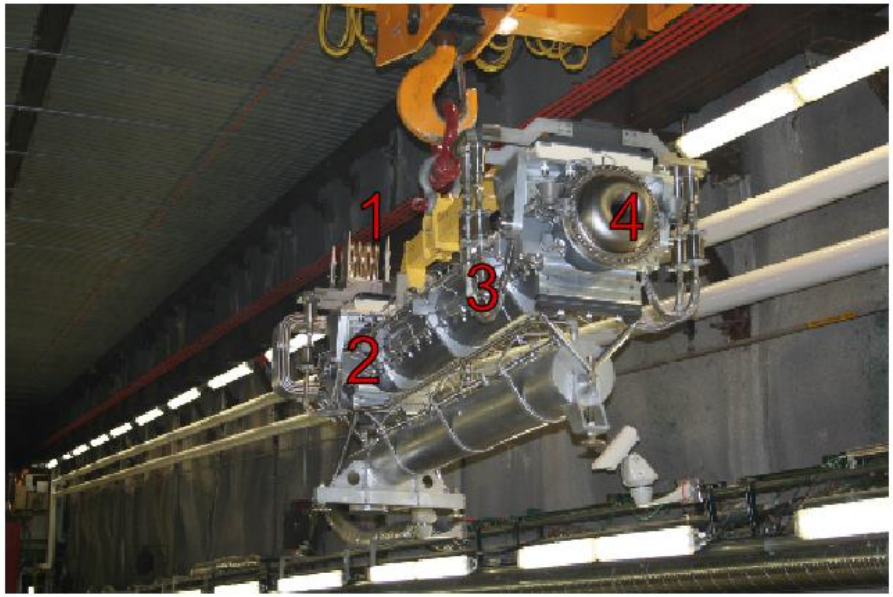


Radiation Survey for NuMI Horn

FERMILAB
ACCELERATOR
DIVISION

DATE: 1/8/14	TIME: 1000	PURPOSE: informational survey	RWP #

NUMI Horn #1-01



Point	Doserate @~ 1 foot (mr/hour)
1	4000
2	5000
3	7500
4	6500

Note:All survey numbers taken on the beam right side in the CO Storage vault.

All Dose Rates Below N/A mR/hr Unless Noted.

Inst Type: teletector
Inst No: 6
Batt/Source Chk: sat
Cal. Due Date: 8/2014

LEGEND
Numbers appearing on map are mR/hr @ 1 ft readings unless denoted with symbols below
* = mR/hr @ contact
A = Air Sample ◯ = Wipe Ⓕ = Floor wipe

Bkgd _____ cpm

Wipe #	Reading	Wipe #	Reading
	ccpm		ccpm
	ccpm		ccpm
	ccpm		ccpm

N/A

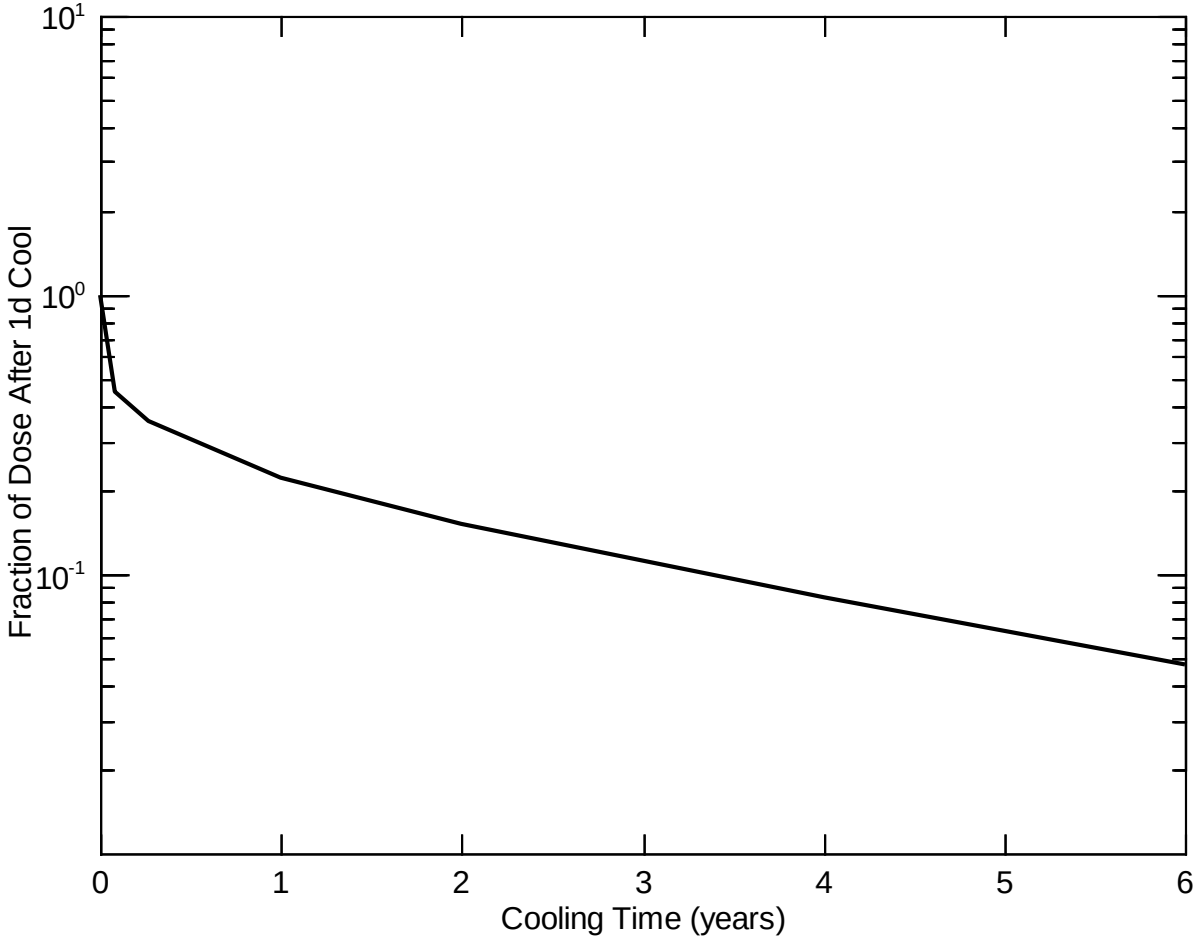
Beam Off:
Date:
Time:
Intensity

Highest Dose Rate Found 7500 mR/hr at 1 ft.

Note: RSO approval required to work in areas where it is: >100 mR/hr @ 1 foot OR >100 CCPM on a wipe.

Comments:

Surveyed By: Busch
Reviewed By:

REVISED 8/6/09

Fraction of Total Dose vs Cooling Time