Target Hall Shielding Review

Radiation Safety Coordinator

Nancy Grossman
FNAL

July 27, 2001

Outline

- Review Process
- Access
- Prompt Radiation
- Groundwater Protection
- Air Activation
- Residual Dose Rates

Review Process

1. Presentations to NuMI Radiation Safety Advisory Committee (NRSAC)
   - Beams Division and ES&H personnel
   - Initial validation of calculation methods & Target Hall, Decay Region and Hadron Absorber "preliminary" shielding (7/99)
     - Civil construction parameters addressed appropriately
   - Final groundwater methodology presentation (7/00)
   - Future presentations: Hadron Absorber shielding and the residual rate estimation methodology
2. "Preliminary Radiation Shielding Assessment" to Beams Division Radiation Safety for "Civil" review (10/99)**
   - Consensus to start civil construction in 1/00.
3. "Radiation Shielding Assessment" to Beams Division Radiation Safety for review and approval**
   - *Reiterate shielding calculations as necessary when engineering designs are nearly complete,*
   - *NuMI "Internal" Reviews*
   - *Include residual rate estimates, hot job procedures*
   - *Must do before going to the FNAL Senior Radiation Safety Officer (SRSO) for review and approval*
4. "Radiation Shielding Assessment" to SRSO for review and approval** (before operation commences)
   - Sign as built drawings

** required

Access

NuMI Beam, No Access:

- Carrier Tunnel, Pre-Target, Target Hall, Decay Tunnel, Hadron Absorber Cavern, Muon Alcoves

NuMI Beam Access:

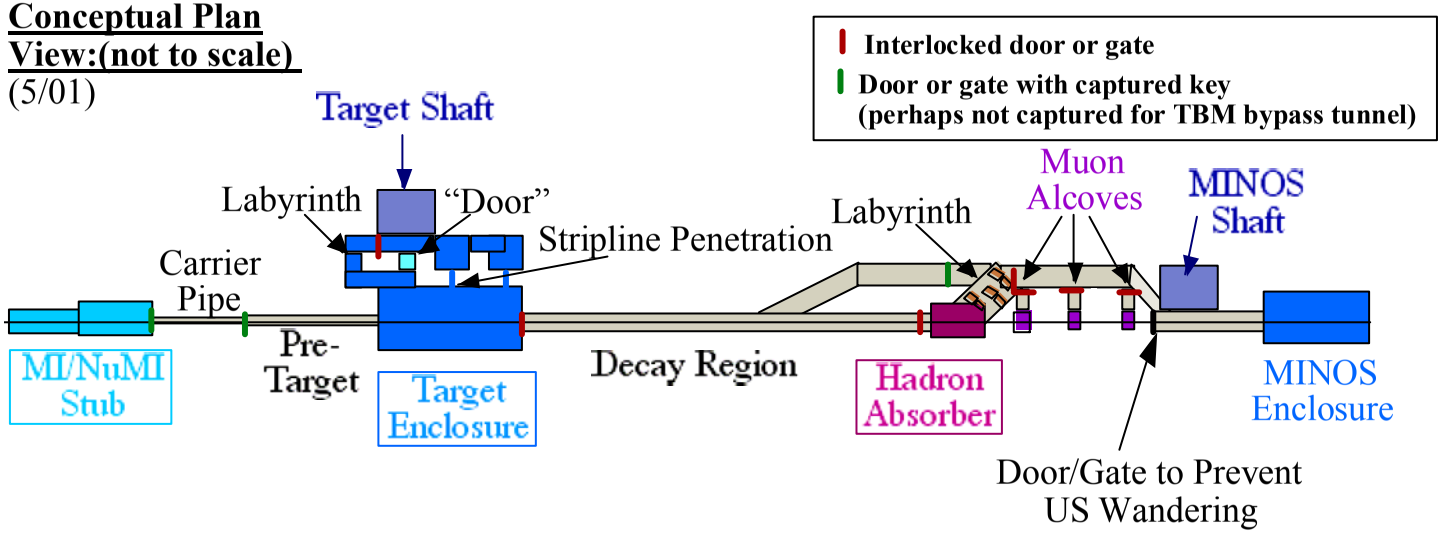
- Base of Target Hall Shaft
- Power Supply & RAW Rooms
  - RAW Room may have locked door.
- Bypass tunnel to some extent (determine final gate location when run and do measurements)
- MINOS Cavern

MI Beam NuMI Access:

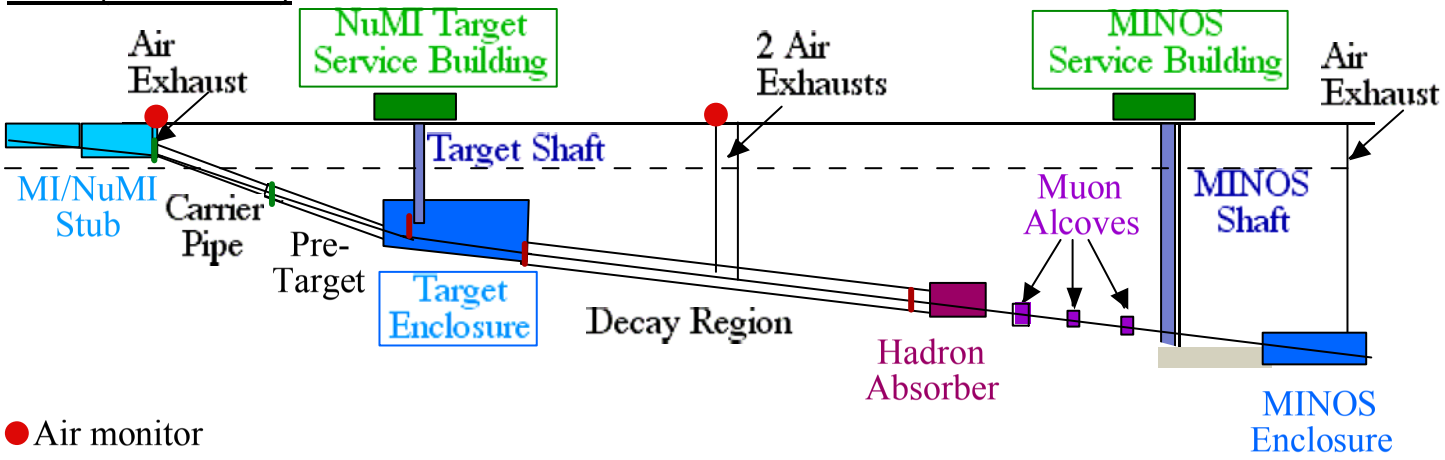
- Everywhere but the Carrier Tunnel (and upstream)
- Carrier Tunnel will have a Captured Key (or similar) door.

Access

Conceptual Plan View:(not to scale)
(5/01)



Conceptual Elevation View:(not to scale)



NUMI MINOS

Prompt Radiation

Labyrinth and penetration exit dose rates :

- Labyrinth source terms where bulk shielding is present (dark blue text) are not well known (factor of ~10)

Access	Normal (mrem/hr)	Accident (mrem/hr)	Accident (mrem/pulse)	Mitigation (possible)
Survey Riser SR-1 (498)	0.15	14765.41	7.79	plug
Exhaust Air Vent EAV-1 (935)	0.03	2852.87	1.51	(fence)
Survey Riser SR-2 (954)	0.03	2852.87	1.51	plug
Target Hall Labyrinth	2.44E-04	24.37	0.013	OK
Target Hall Labyrinth	1.36E-03	-	-	OK
Target Hall Equipment Door	0.02	2476.83	1.31	OK
Target Hall Equipment Door	0.74	-	-	OK
Stripline Penetration (PS Room)	2.77	-	-	(shield)
Raw Penetration	60.80	-	-	plug
Survey Riser SR-3 (1321)	0.002	-	-	plug
Vent EAV-2	0.57	-	-	fence
Vent EAV-3	0.57	-	-	fence
Absorber Labyrinth	0.09	-	-	OK
Bypass Tunnel	0.08	-	-	OK

- MARS simulation of the Target Pile has at least 1 foot less steel on all sides than the present design (yellow shading)
- *Preliminary MARS14 simulation of the present Target Pile shield design is nearly complete*
  - *MARS14 can more accurately determine the source terms outside of thick shielding (factor of 5)*

Groundwater Protection

- Hired several groundwater consultants to determine water levels and flow rates around the unlined regions of the NuMI tunnel.
  - All water within 10' of tunnel flows into the tunnel (within the aquifer region)
  - Most water flows in rapidly through the fractures
  - Determine an average inflow velocity based on groundwater consultant's inflow estimates

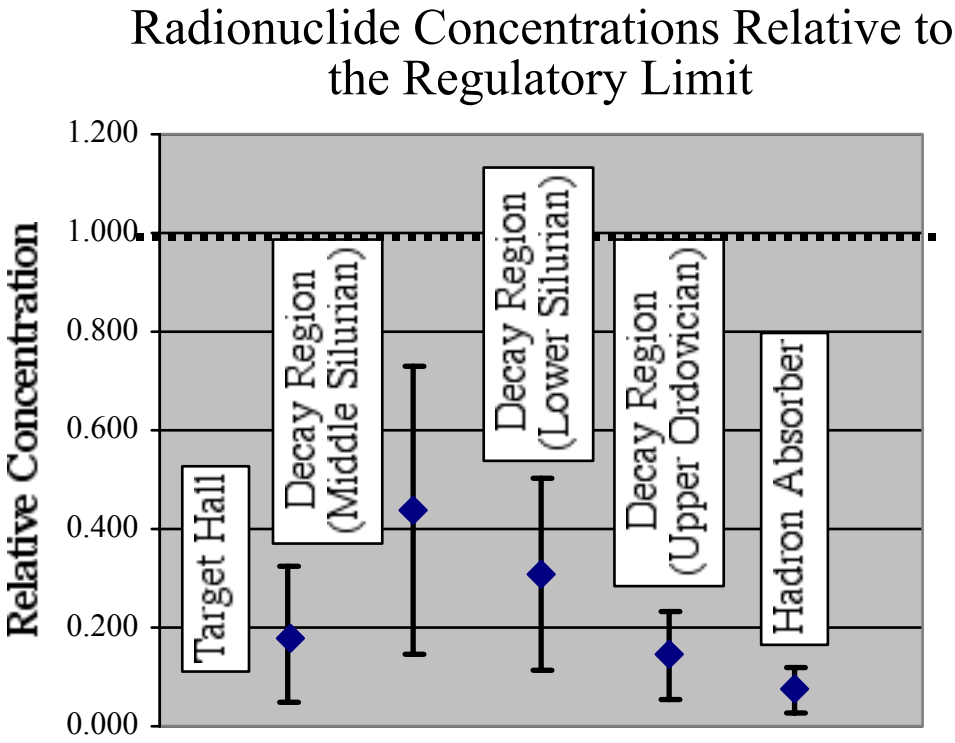
- Use the Fermilab Concentration Model, modified to allow for water flow
  - Fermilab Reports TM1851, TM2092, TM2009 (NuMI).
  - Updated to include our latest understanding of groundwater contamination by ^{22}Na and ^{3}H, the only radionuclides of concern (NuMI-B-495)
  - Flow dependent residency time of water in the region of the beamline (inflow or outflow) where applicable.
  - Irradiation time = residency time of the water in the activation region (not 8 years, lifetime of experiment)
    - Normal operation: time water is in the activation region
    - Accident condition: 1 pulse (1.9 sec repetition rate)

Groundwater Protection

- Must be below the regulatory limit including uncertainties (FNAL, IEPA)
  - Use uncertainties in all parameters to determine overall uncertainty
    - Determine effect on results and add in quadrature
- Conservative:
  - Comparing concentrations in inflow water, which will be pumped to the surface to groundwater limits
  - In "dry" regions, grout less to allow more inflow
  - Model includes worst case conditions, most likely will not encounter
  - Does not include decay during migration to a well
    - Water along the unlined beamline tunnel can not get to any well other than the NuMI beamline "well"
  - Does not include dilution & dispersion in transit to a well
- Monitoring well(s) will be used to monitor contamination (^{22}Na and ^{3}H concentrations)
  - Update flow model to incorporate inflow measurements and geotechnical data obtained during construction
    - Ready to start this process when grouting complete

Groundwater Protection: Secondary Beam

(Hadron Absorber values need to be updated for the present cavern and Hadron Absorber design.)



Airborne Activation

Radioactive Air calculations are being revisited with the present detailed Target Hall design.

- Site-wide permit submitted including NuMI operations in 3/99
- Goal for NuMI is < 45 Ci/year:
  - ~0.025 mrem/year (1/4 continuous monitoring limit)
  - Previous NuMI estimates were ~40 Ci/year
- Majority of the air activation occurs inside the Target Pile
  - **Closed system (air recirculated within the target pile).**
  - **Preliminary calculations based on re-circulation:**
    - **@ 2250 cfm ventilation, leakage @1500 cfm-> ~20 Ci/year**
- Have a variable rate ventilation system from the Target Hall to the decay vent (2 speeds).
- Measurements of air activation will be made early on and the ventilation rate can be adjusted (and the target pile can be better sealed if necessary)

Residual Activation

APO Residual rates (at most 20 mrem/hr on top of steel modules, below concrete)

- Want similar rates in NuMI Target hall
- NuMI beam is an order 10X that at AP0, thus want about a factor of 10 more shielding
- 6' of steel in the modules at AP0, want 7' for NuMI
- Minimize crack sizes and line of sight to "beam" area
- Use sand/poly (10%) bead bags to fill in large cracks/holes where possible
  - Make sure not compromise mechanical aspects of design in the process

Residual Activation

Irradiated samples above and below the steel modules at AP0 to investigate:

- Residual rates versus MARS predictions (in and outside thick shielding).
- Isotope production in the materials we plan to use in the Target Pile (Al, concrete and various kinds of steel) - especially short-lived.
- Cooling curves for the above samples.
- Neutron Fluxes above and below the modules and inside 2" and 6" thick poly cubes above the modules
- MARS predictions of neutron fluxes vs. measurements.

Updated residual code was added to MARS13 -> MARS14

- Can calculate residual activation levels for 3 different energy regimes (including thermal neutrons).
- Can calculate residual activation levels for wide range of irradiation and cool down times.

Residual Activation

Preliminary Results:

- Residual rates versus MARS14 predictions (in and outside thick shielding).
  - Inside and outside thick shielding agreement is within a factor of 2 to 5. (MARS overestimates in nearly all case)
  - Agreement outside thick shielding was very good after 1 day cool down (MARS lacking in simulation of short-lived radionuclides).
- Isotope production in the materials we plan to use in the Target Pile (Al, concrete and various kinds of steel) - especially short-lived.
  - No unexpected isotopes were seen and no unusual levels were scene.
- Cooling curves for the above samples.
  - Have cooling curves from the horn aluminum, structural steel, the 1018 steel and one type concrete.

Residual Activation

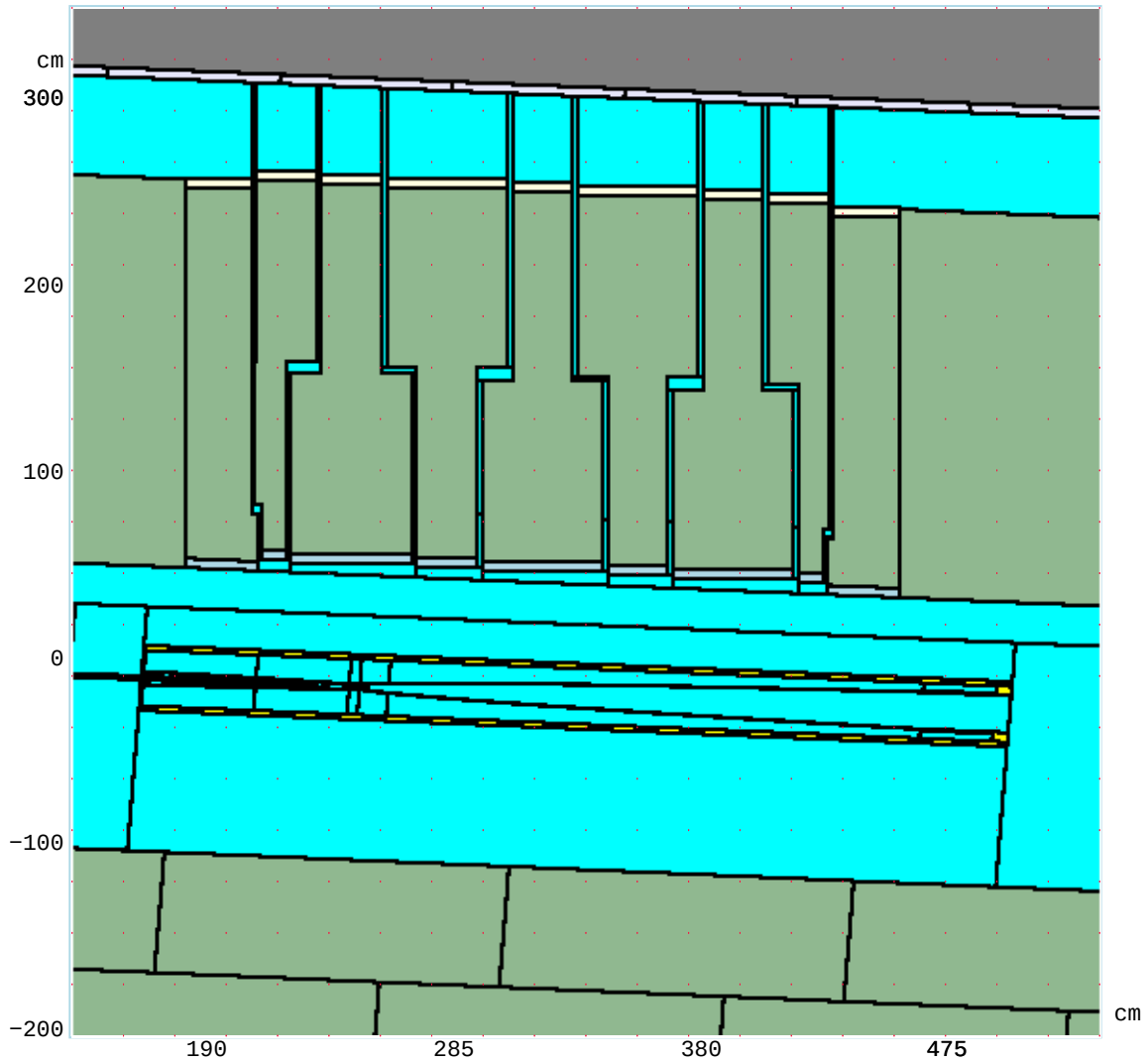
Preliminary Results:

- Concrete activation levels can vary by up to a factor of 50, depending on the amount of sodium in the concrete.
  - Residual dose rates varied from 0.03 mrem/hr to 1.7 mrem/hr (trace to 1.7% by weight ^{23}Na, respectively).

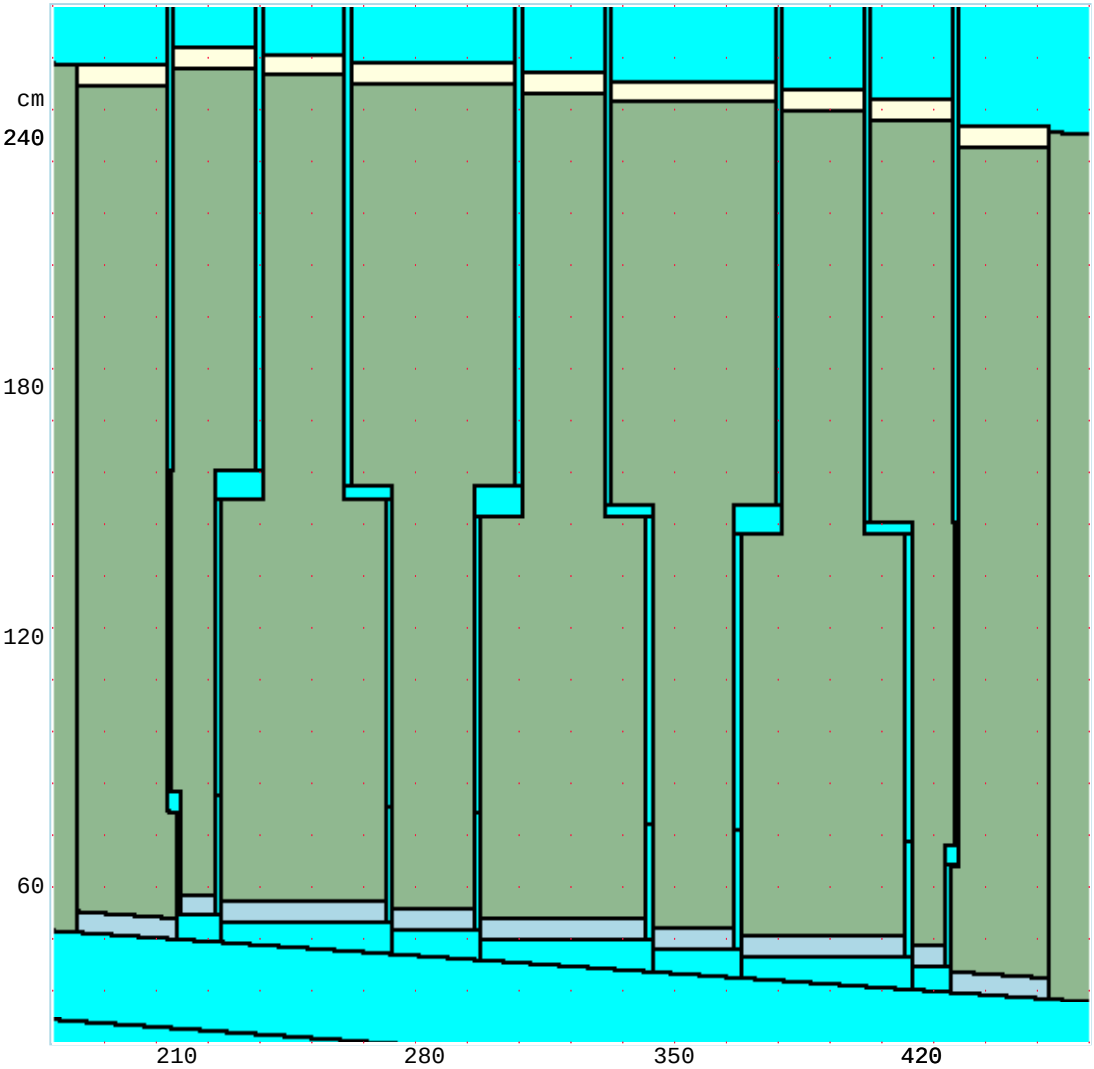
- Neutron Fluxes above and below the modules
  - Relatively good agreement
  - 90% of neutrons below the steel had energy less than 10 MeV.
  - Majority of the neutron flux above the steel was from backscatter off the concrete cap.

- Plan to look at the effect of the cracks at AP0 on residual rates (run with and without cracks)

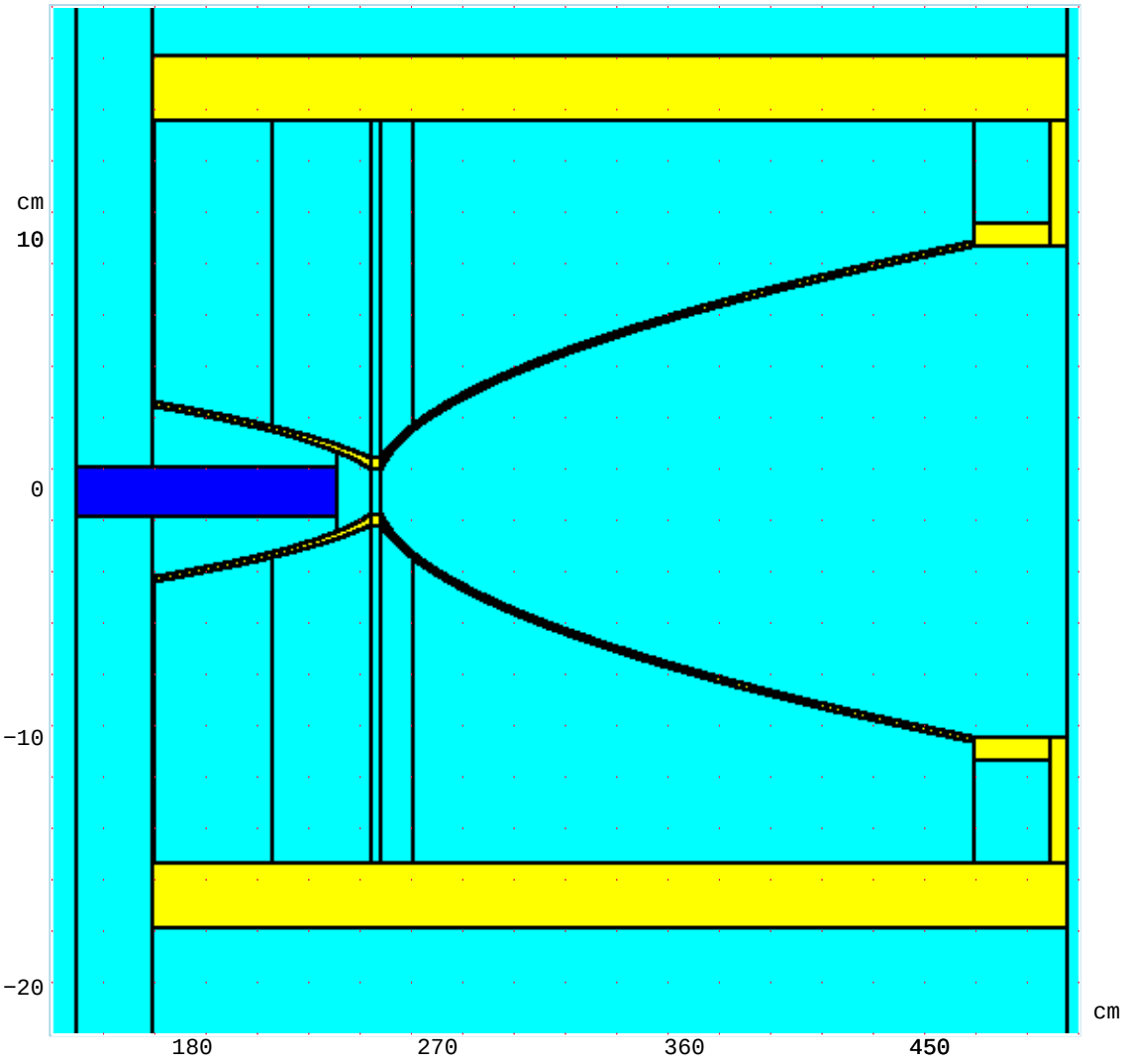
MARS: Horn 1, Module, T-Blocks, Cracks



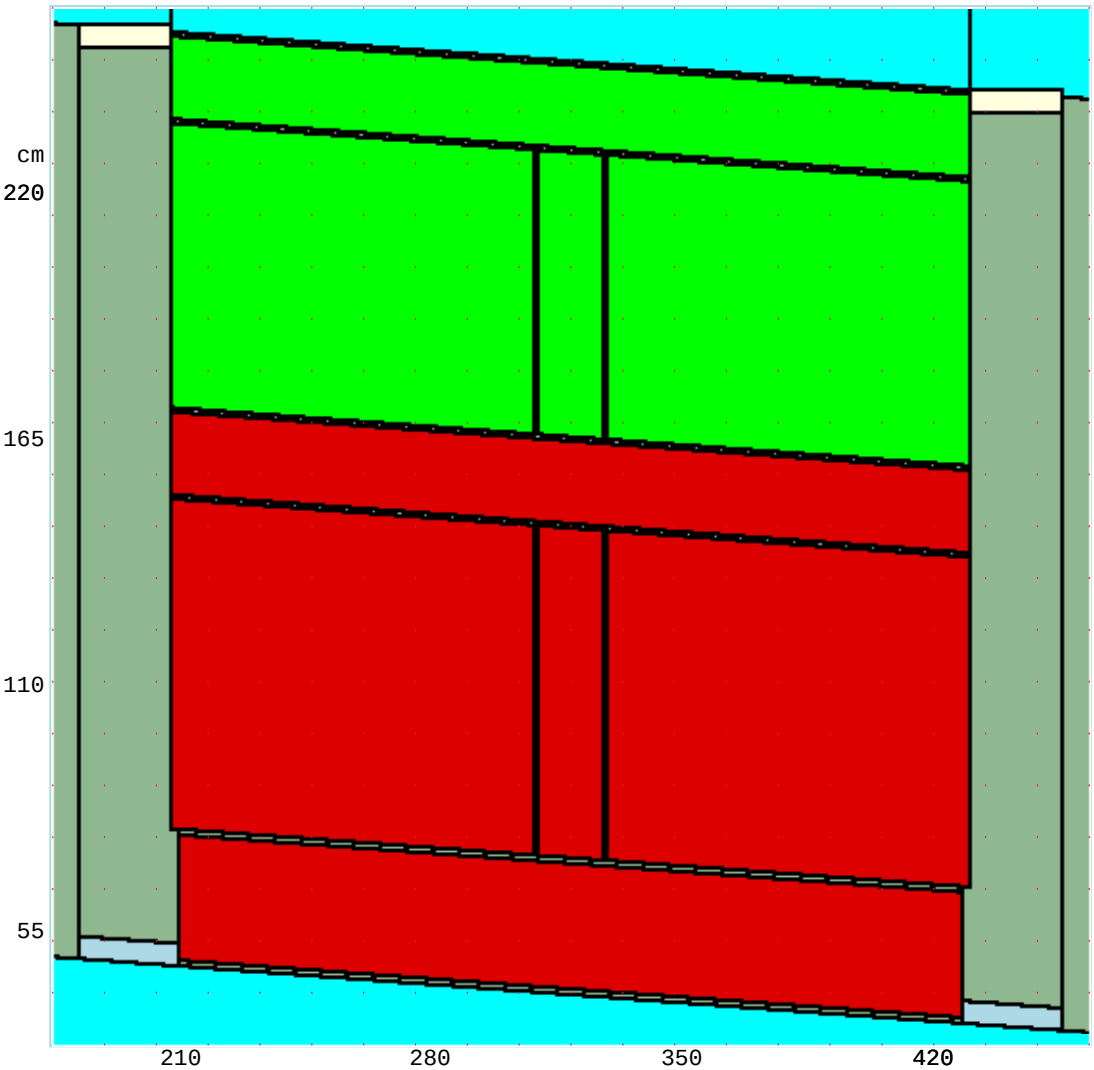
MARS: Horn 1 Module with T Blocks & Cracks



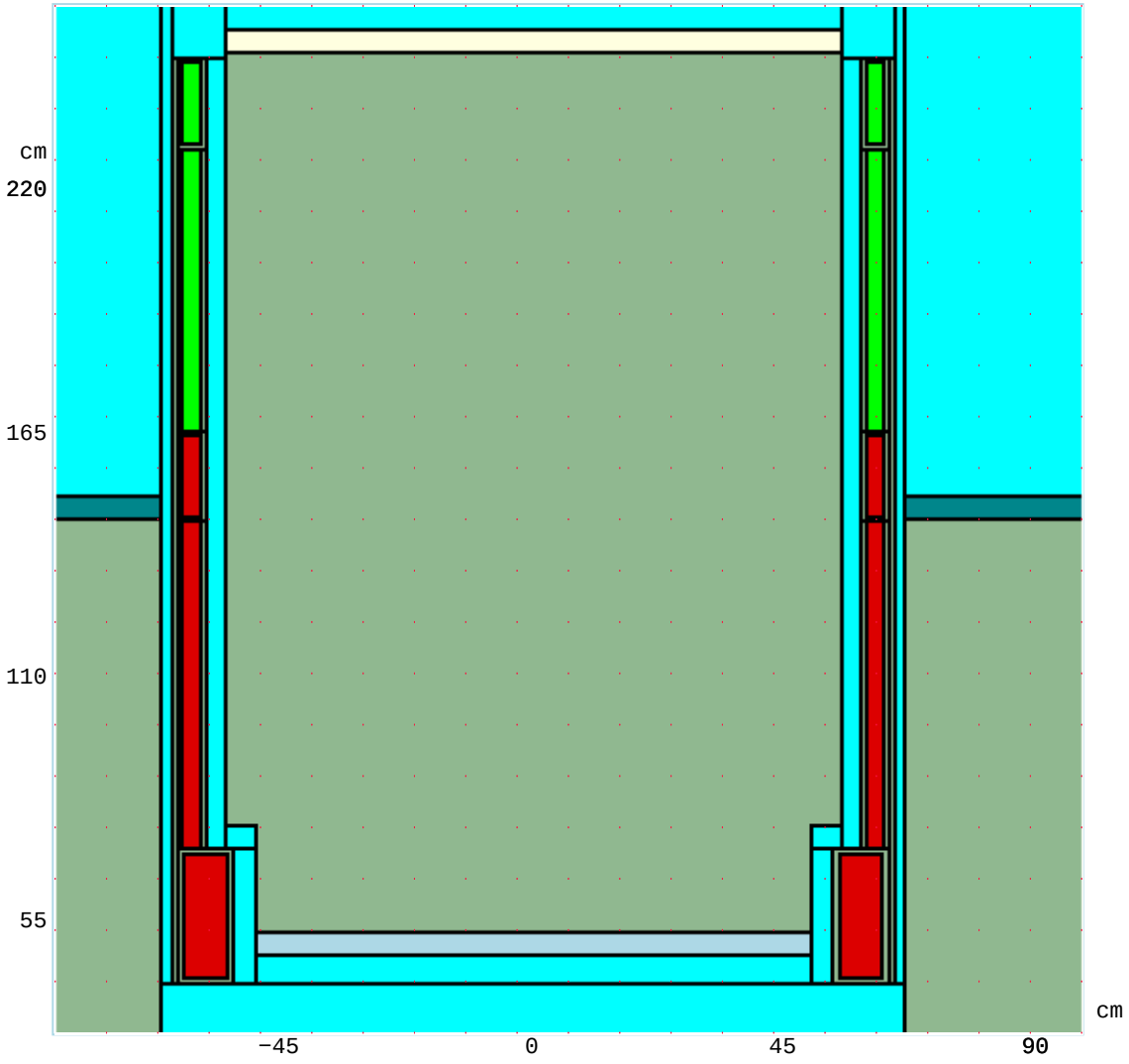
MARS: Horn 1



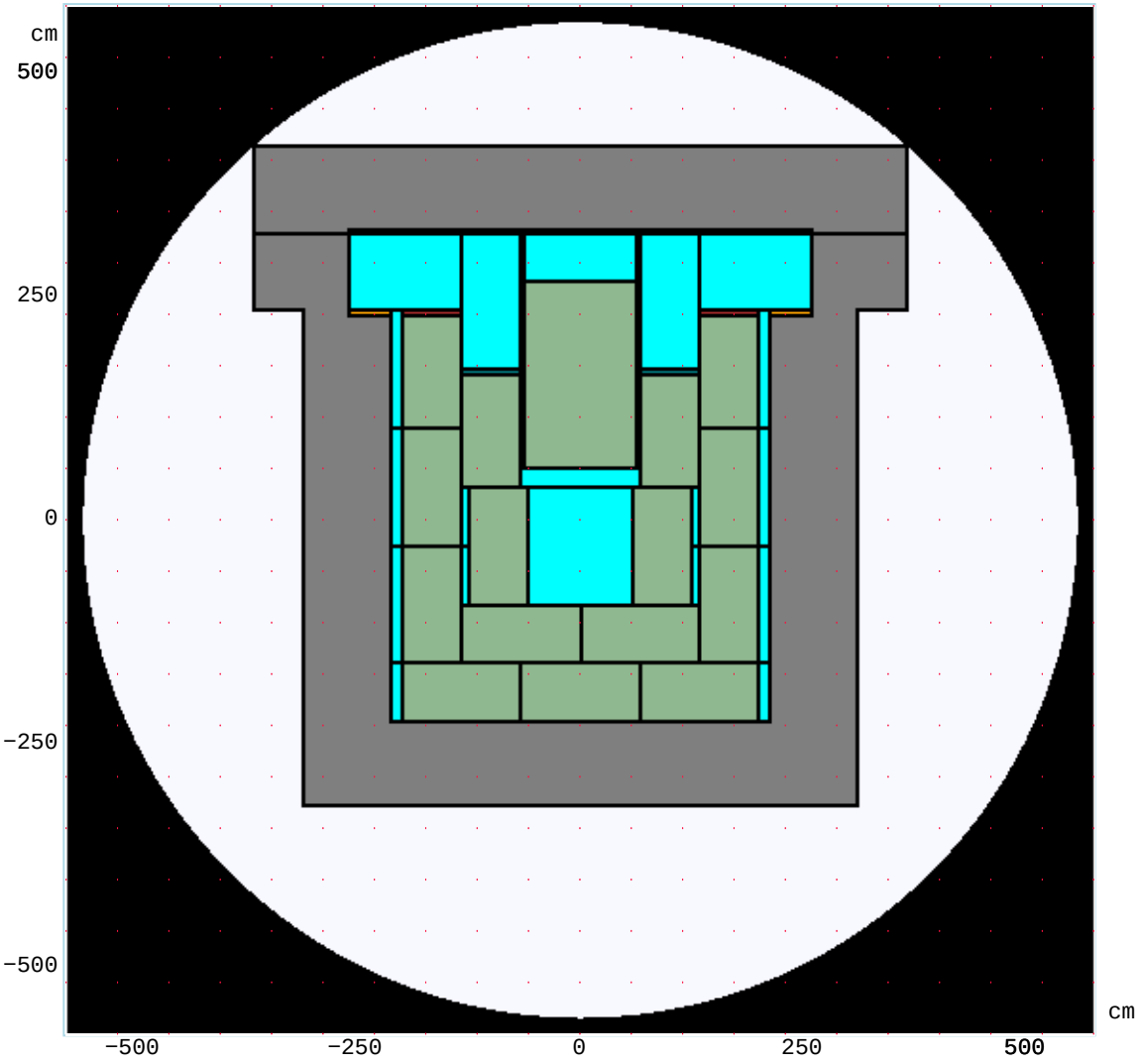
MARS: Horn 1 Module Z Side Slice



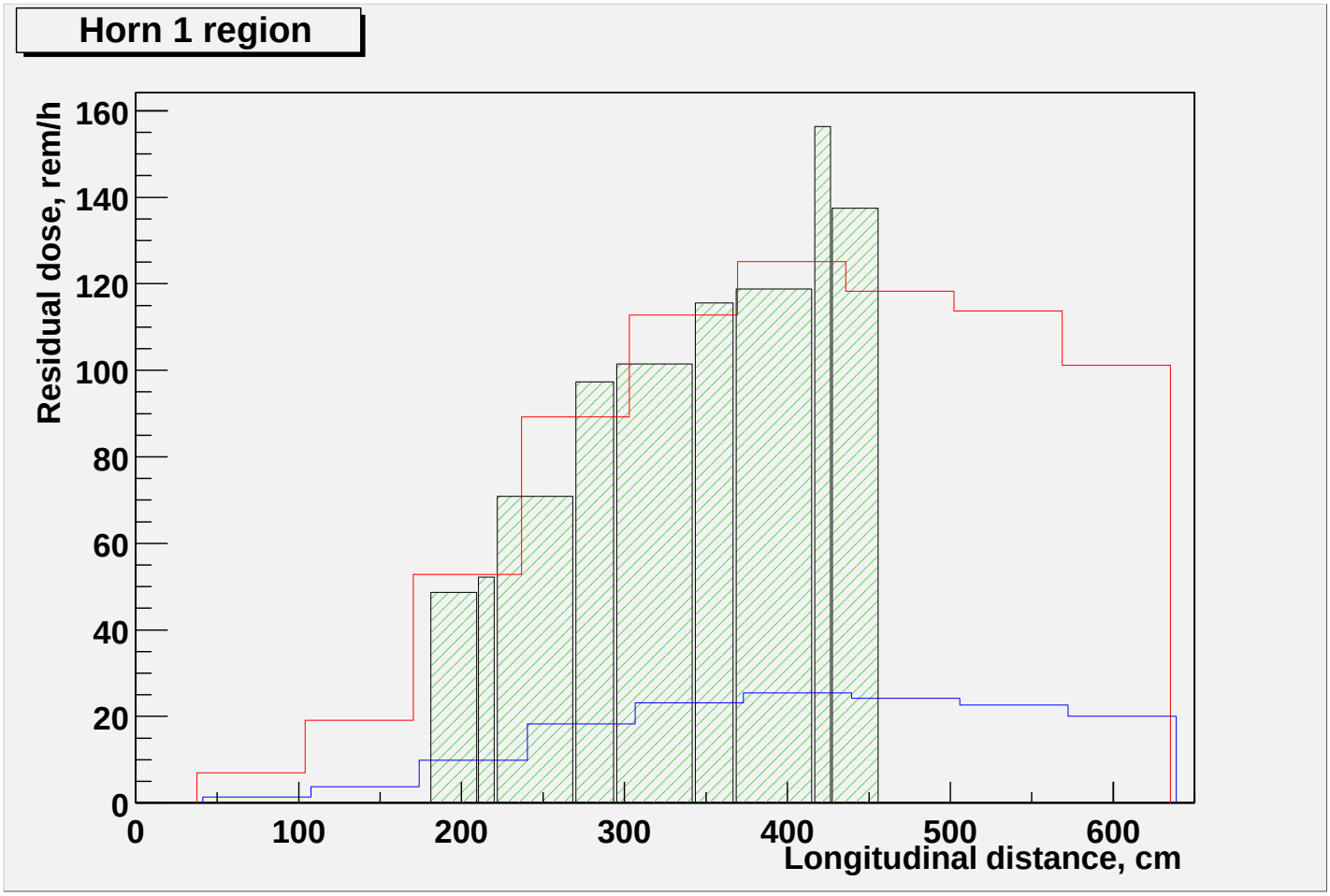
MARS: Horn 1 Module/T Blocks Cross Section



MARS14: Target Chase & Residual Dose Rates



Residual Rate Distributions



Top Curve: inner side of bottom set of steel blocks in chase

Shaded Curve: bottom of T- Blocks

Bottom Curve: inner side of top steel blocks in chase

Residual Activation

MARS Residuals: 30 days irradiation, 1 day cool down (@2E13protons/sec)

Location	Dose Rate (on contact)
Target Hall: concrete floor of work area	< 1 mrem/hr
Target Hall: Top of T-Block (horn 1)	~ 1 mrem/hr
Target Hall: Bottom of concrete "cap"	~ 2 mrem/hr
Target Hall: DS horn baffle	25 rem/hr
Target Hall: bottom of T-Block	100 rem/hr
Target Hall: inside cave	80 rem/hr
Target Hall: horn 1 outer conductor	600 rem/hr
Decay Region: outside edge of concrete	~100 mrem/hr
Hadron Absorber: Labyrinth Side	~100 mrem/hr
Hadron Absorber: Core Sides	~ 10's rem/hr
Hadron Absorber: Core Near Beam	~100's rem/hr
Hadron Absorber: Steel Blocks	~1's rem/hr
Hadron Absorber: Back	< 30 mrem/hr
Hadron Absorber: Front	~ 1's rem/hr

Summary/ Conclusions

Prompt rates:

- Reasonable, but need to be revisited with updated with target hall shield design & MARS14.

Groundwater Protection:

- Activation levels are ~2.5 below limit with present target hall shield design.

Air Activation:

- Current estimates on how well need to seal target pile are reasonable.
- Need to revisit with update target hall shield design with cracks and penetrations (probably very little effect).

Residual Dose Rates:

- So far so good.
- Need to complete updated numbers with stripline penetration,(air handling penetrations?)