





August 2026 | Target and MRA FDR

Beam-off Dose Rates for Target and MRA Maintenance

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STS Neutronics



U.S. DEPARTMENT
of **ENERGY**

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Topics

- Overview
- Methodology
- Results:
 - Configuration 1: Nominal after 8 hours decay
 - Configuration 2: Single Target Segment Removed
 - Configuration 3: Third Target Segment Removal
 - Configuration 4: MRA Pipe Cutting
 - Configuration 4A: MRA Pipe Cutting with Downstream Target Segments Hole
 - Configuration 4B: MRA Pipe Cutting with Upstream Target Segments Hole
 - Configuration 5: MRA Removed
- Conclusions

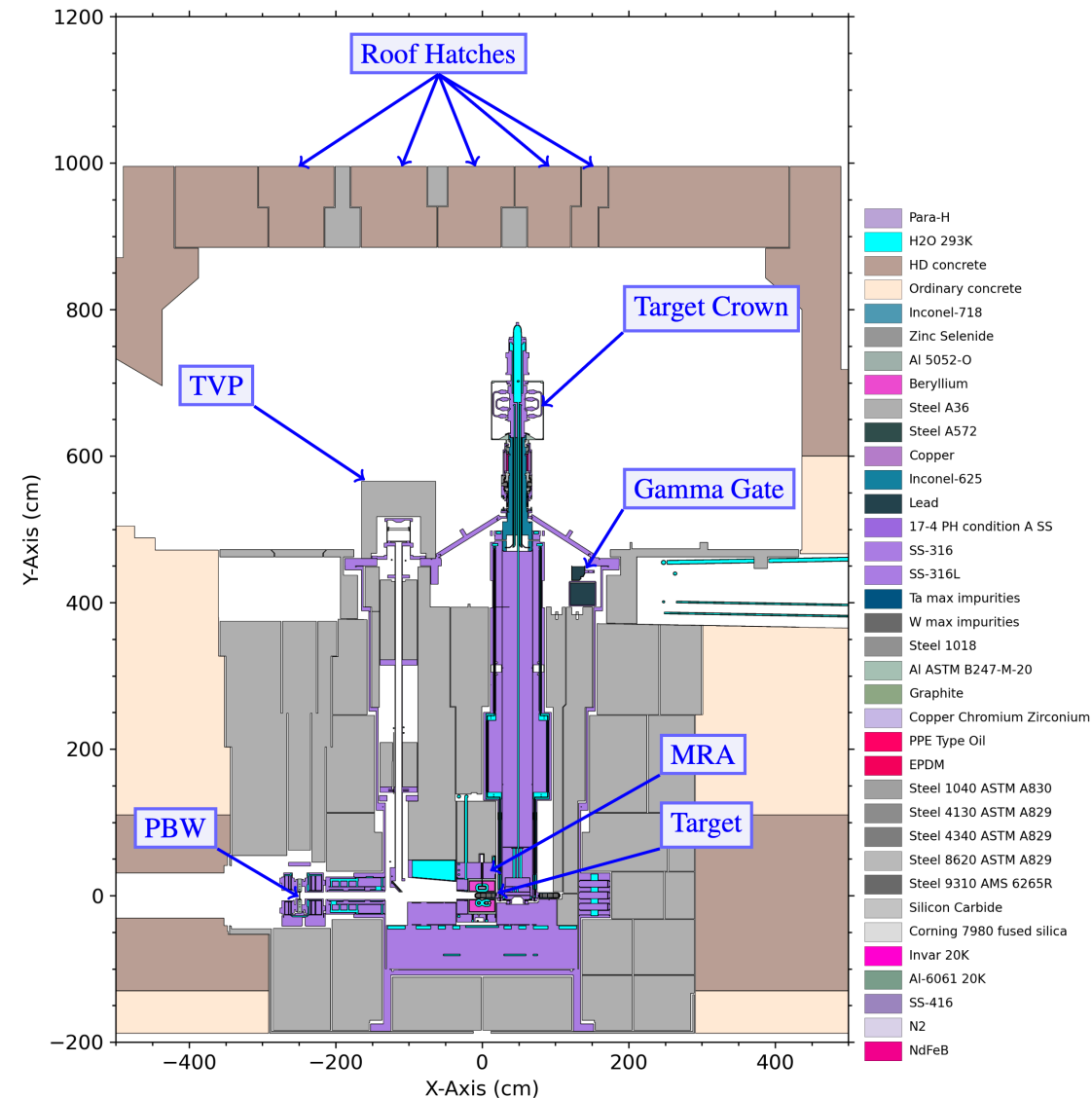
Charge Question 2: Has the design been shown to meet the requirements?

Charge Question 3: Do DACs and other supporting documentation adequately support the final design?

Charge Question 5: Is the design sufficiently mature to proceed with finalizing the procurement package?

Beam Off Maintenance Dose Rates

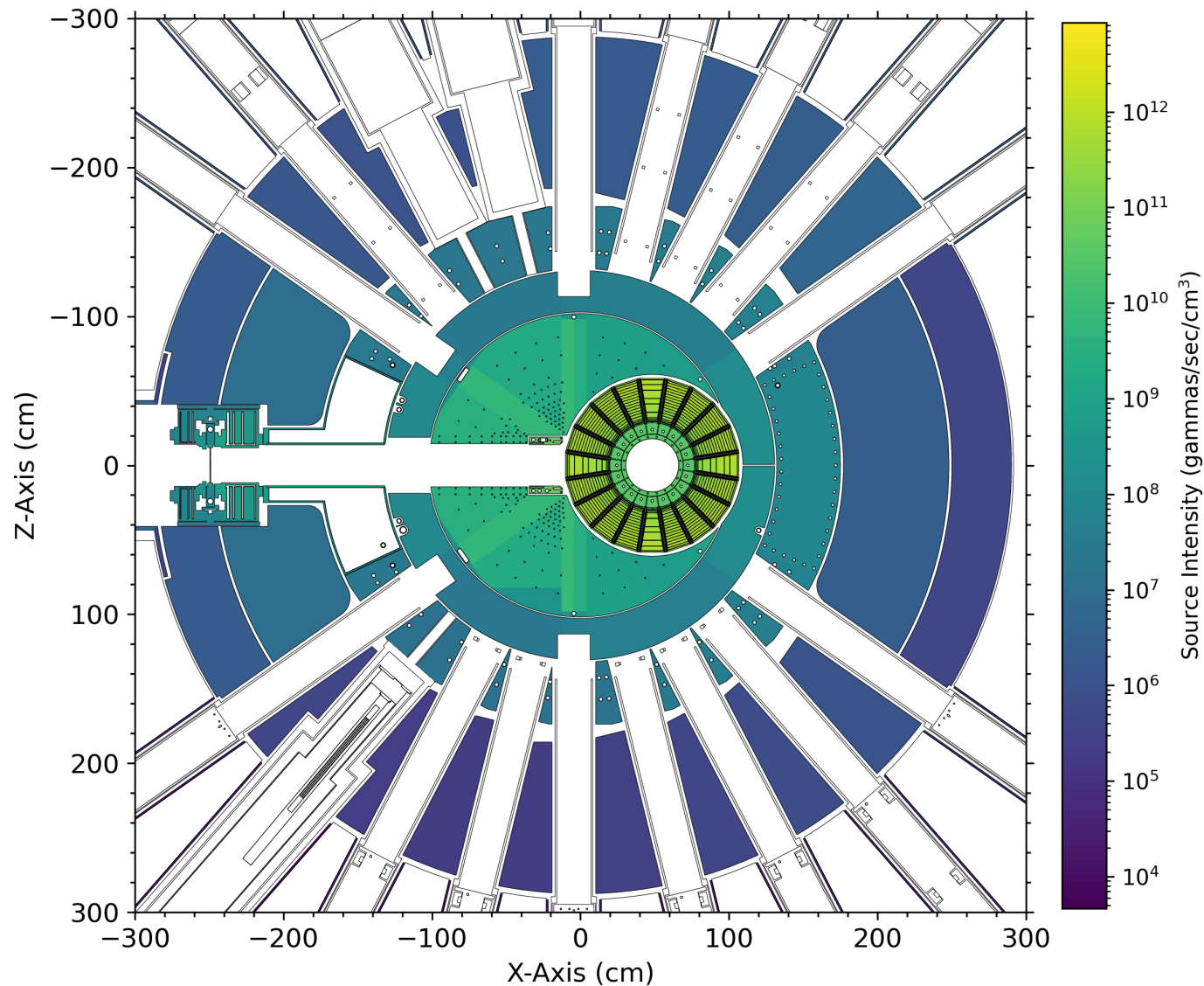
- Goal:
 - Estimate dose rates in the target drive room in support of the target segment and MRA removal procedure development
- Methods:
 - Calculate neutron fluxes and spallation products throughout systems within core vessel with proton beam on target with MCNP
 - Calculate decay gamma sources at 8 hours and 2 weeks of decay with CINDER2008
 - Estimate decay gamma dose with:
 - Discrete Ordinates Method with Denovo
 - Monte Carlo Method with MCNP
 - Note: None of the results include contributions from photoneutrons



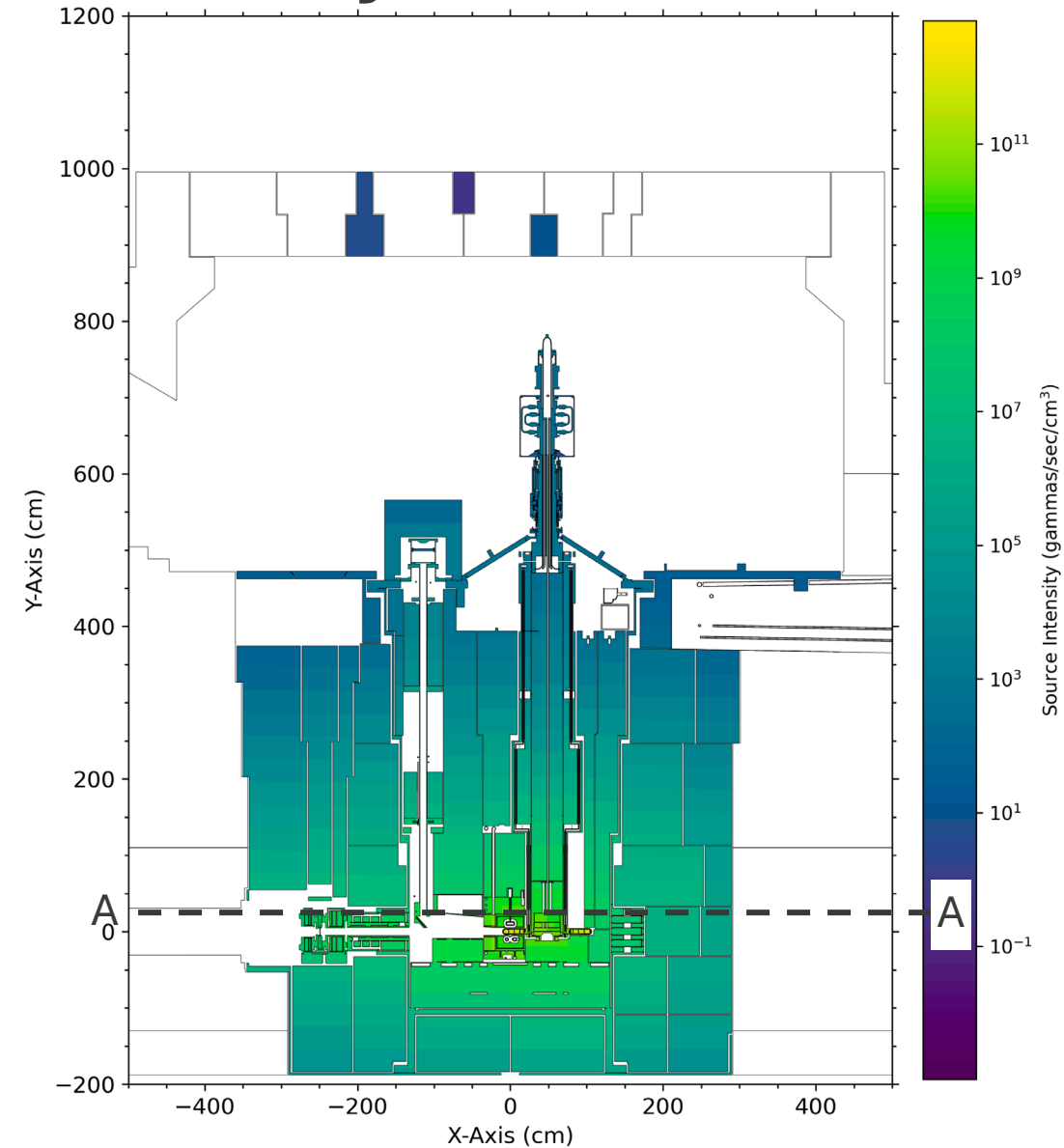
Cross Section View of Target Segment Removal Geometry Nominal Configuration

Configuration 1: Nominal after 8 hours decay

Decay Gamma Sources after 8 Hours of Decay

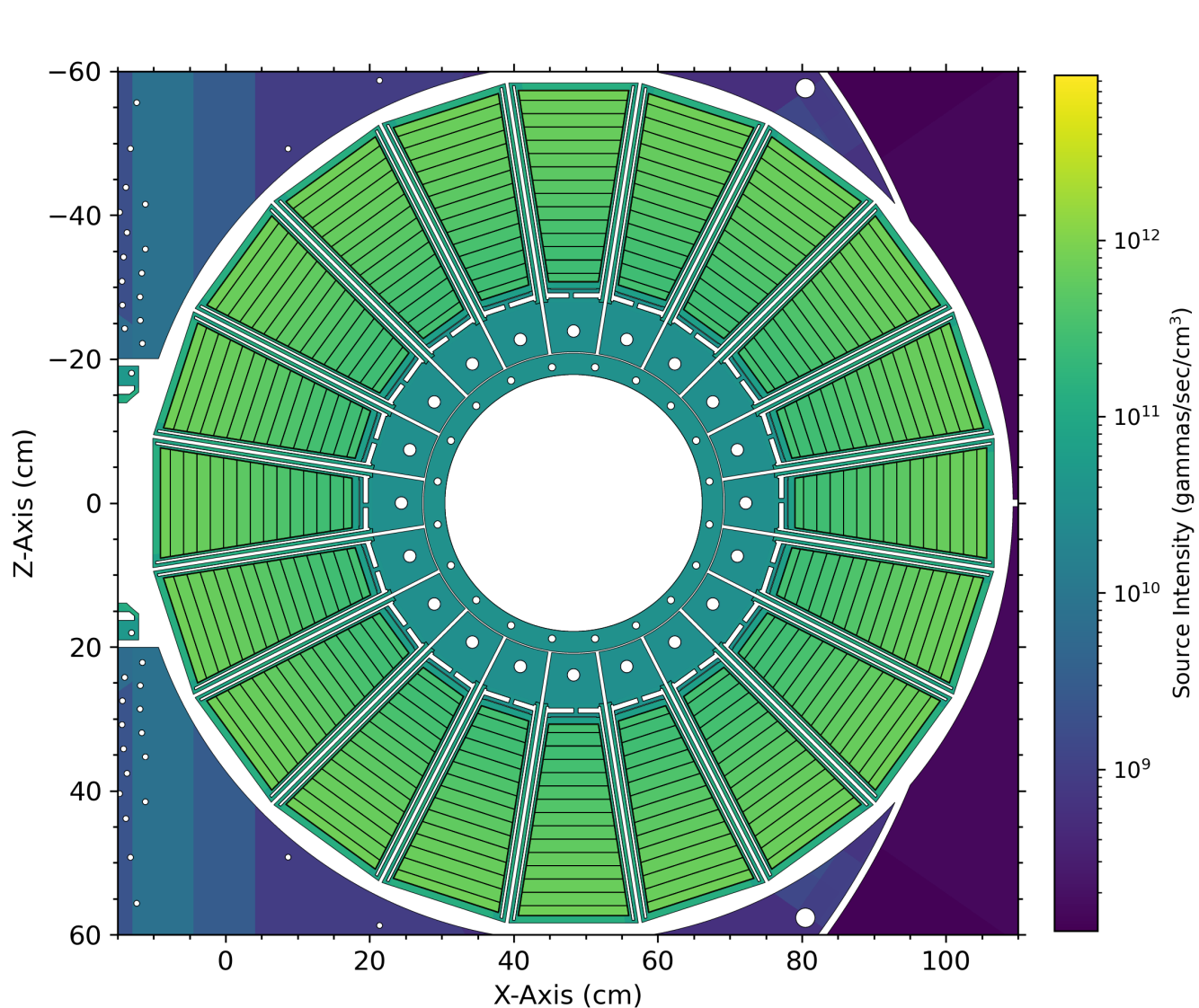


Section A-A: Plan View of Target Systems Decay Gamma Sources

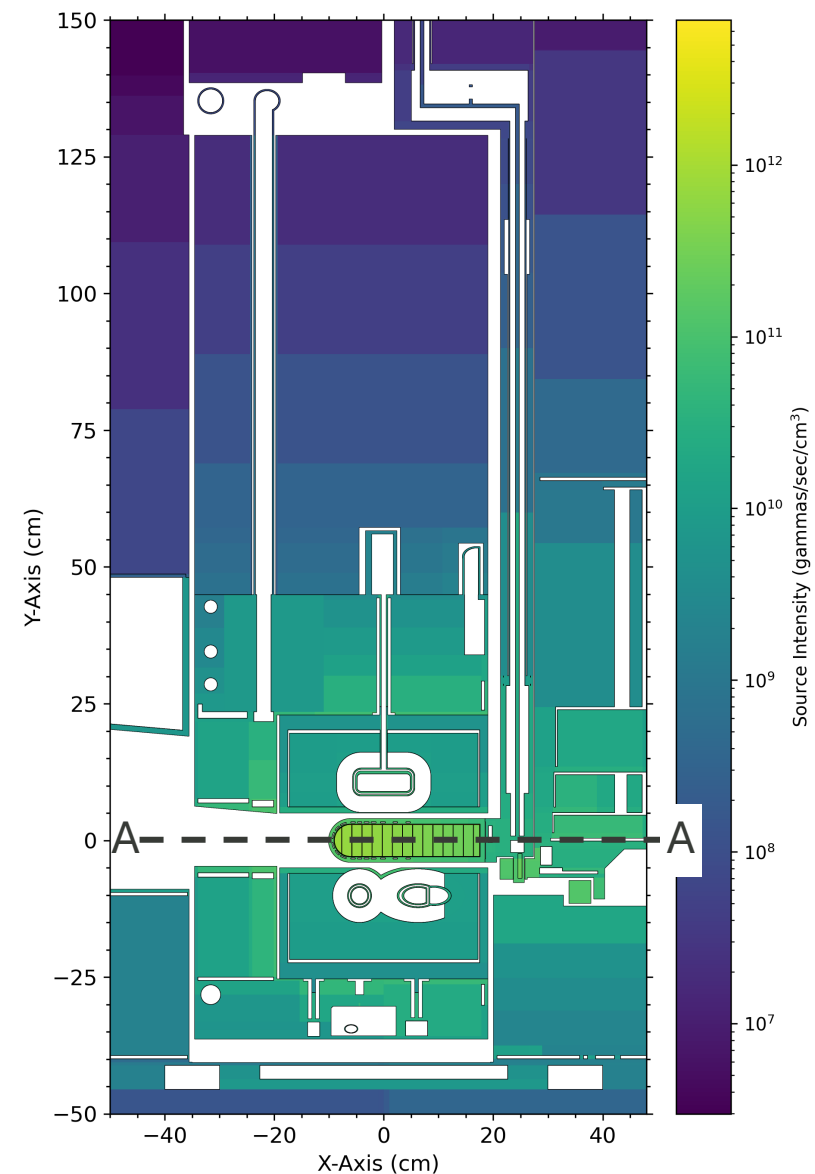


Cross Section View of the Gamma Sources
after 8 Hours of Decay

Decay Gamma Sources after 8 Hours of Decay

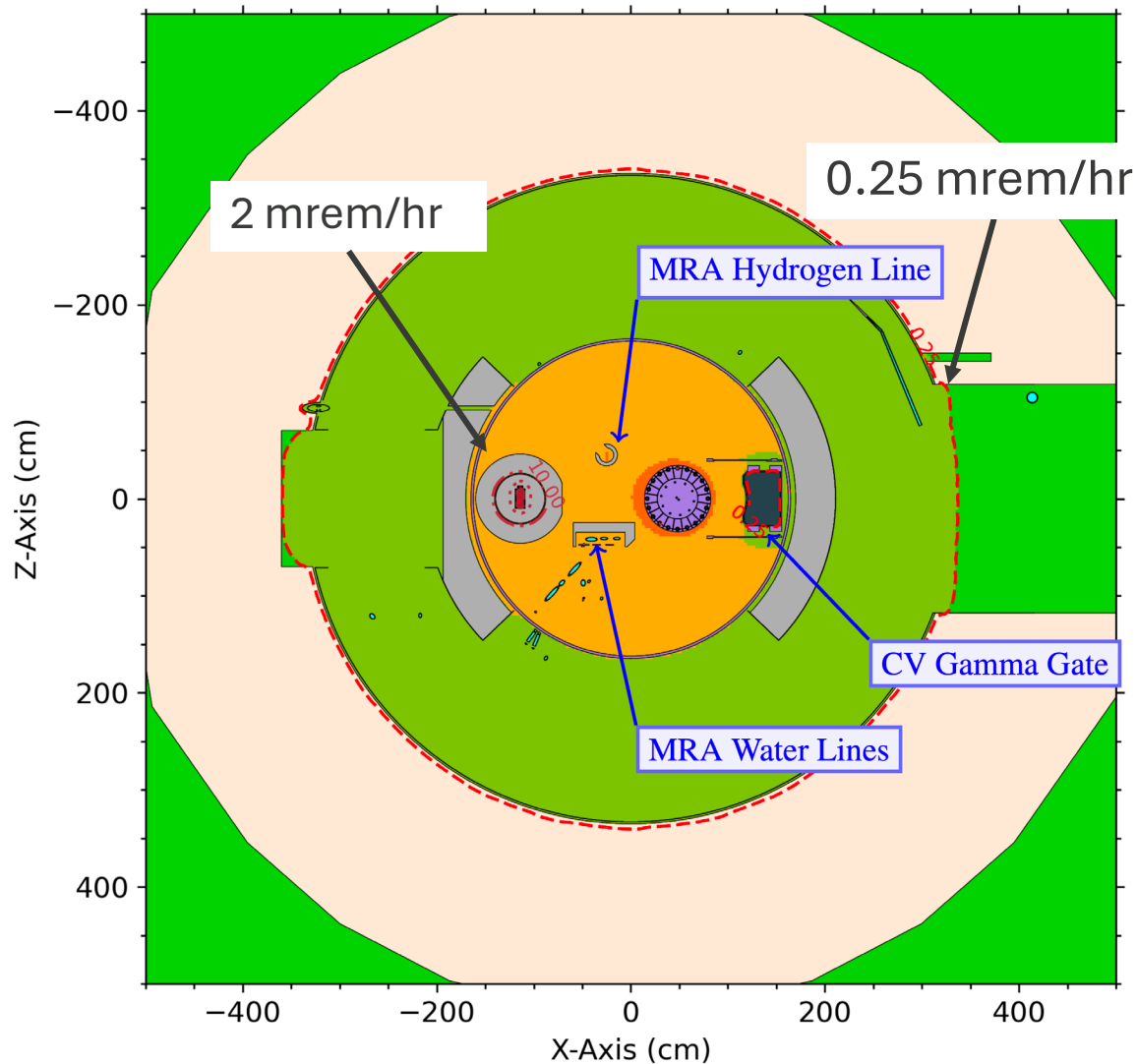


Section A-A: Plan View of Target Wheel Decay Gamma Sources

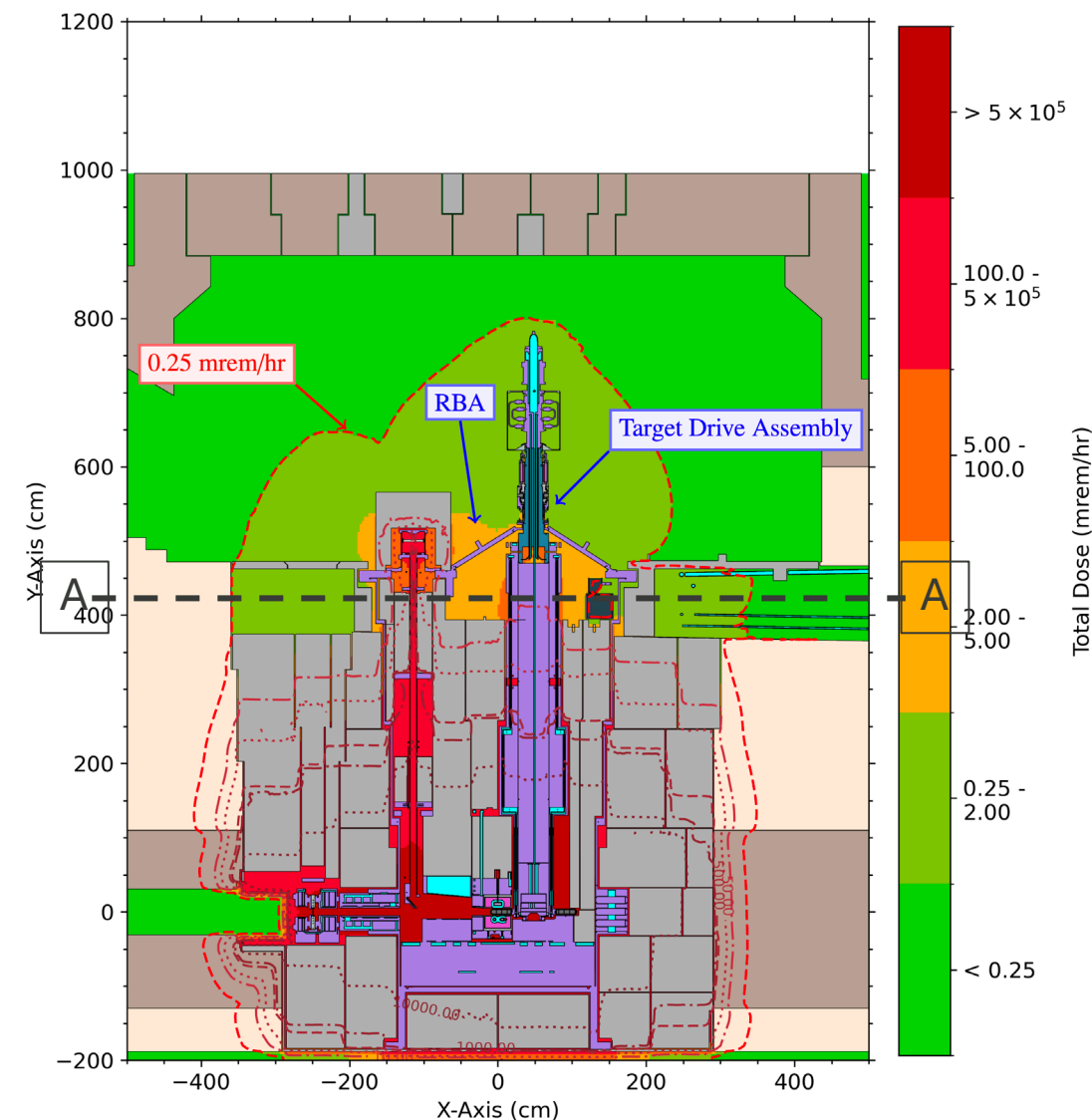


Detailed Cross Section View of the Gamma Sources after 8 Hours of Decay

TDR is < 5 mrem/hr after 8 Hours of Decay



Section A-A: Plan View at 4.15 m above beam elevation of **Denovo** Decay Gamma Dose Rates

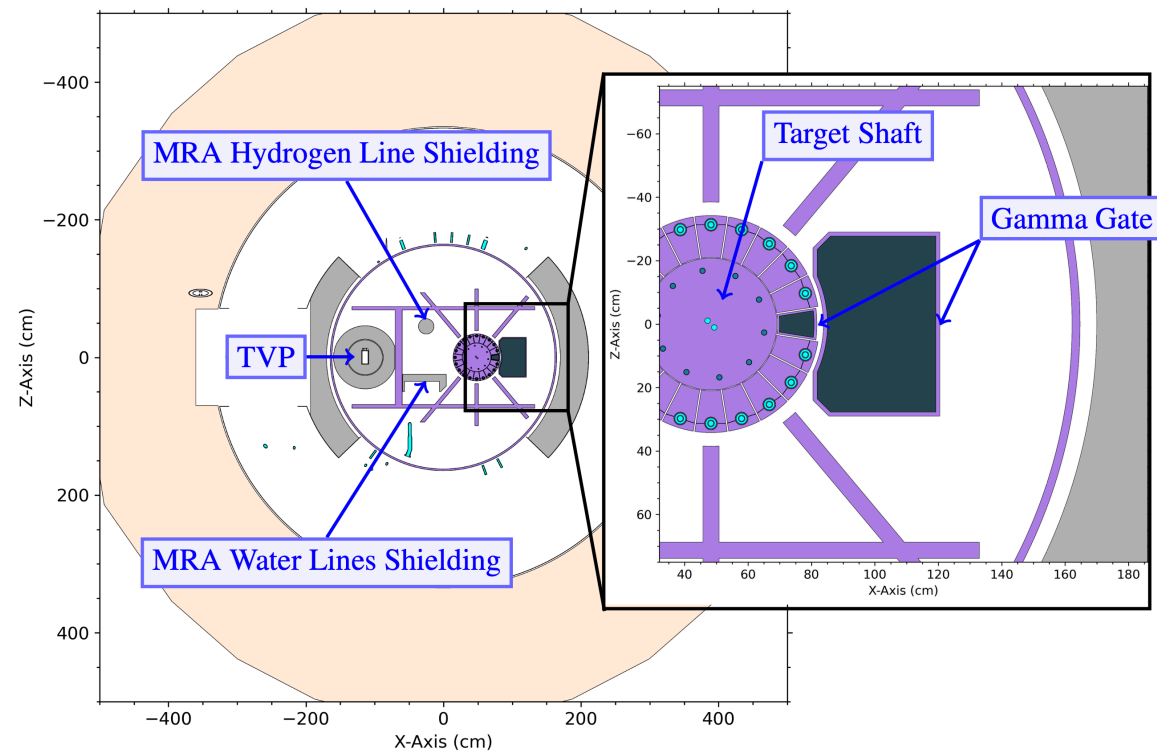


Cross Section View of the **Denovo** Decay Gamma Doses after 8 Hours of Decay

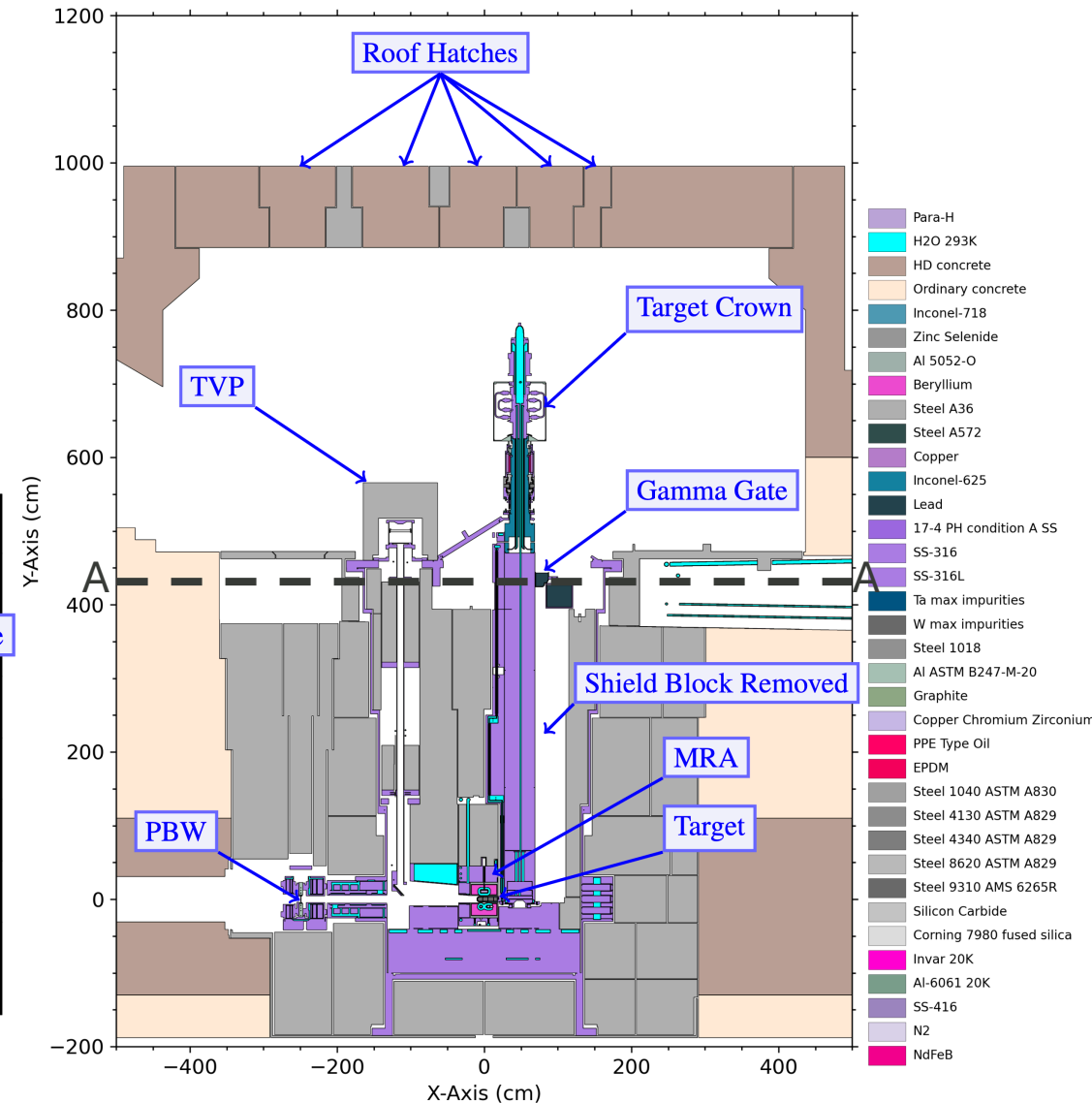
Configuration 2: Single Target Segment Removed

Configuration 2: Single Segment Removed

- Removable target segment access shield block is removed
- Gamma gate deployed with arm also deployed
- Core vessel tent hatch removed for the target
- Single target segment removed (downstream segment)
- 8 Hours of Decay



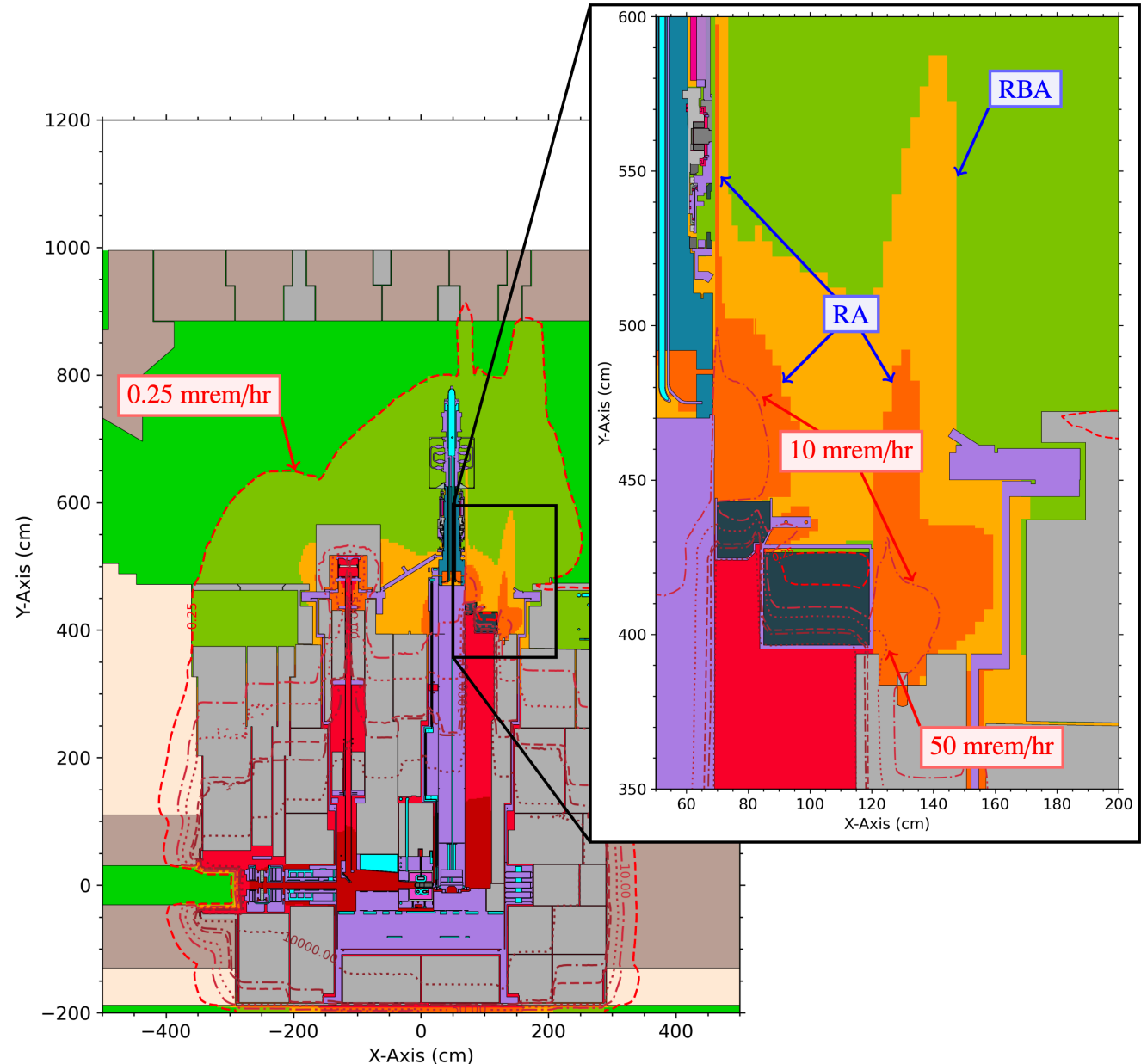
Plan View A-A of Configuration 2



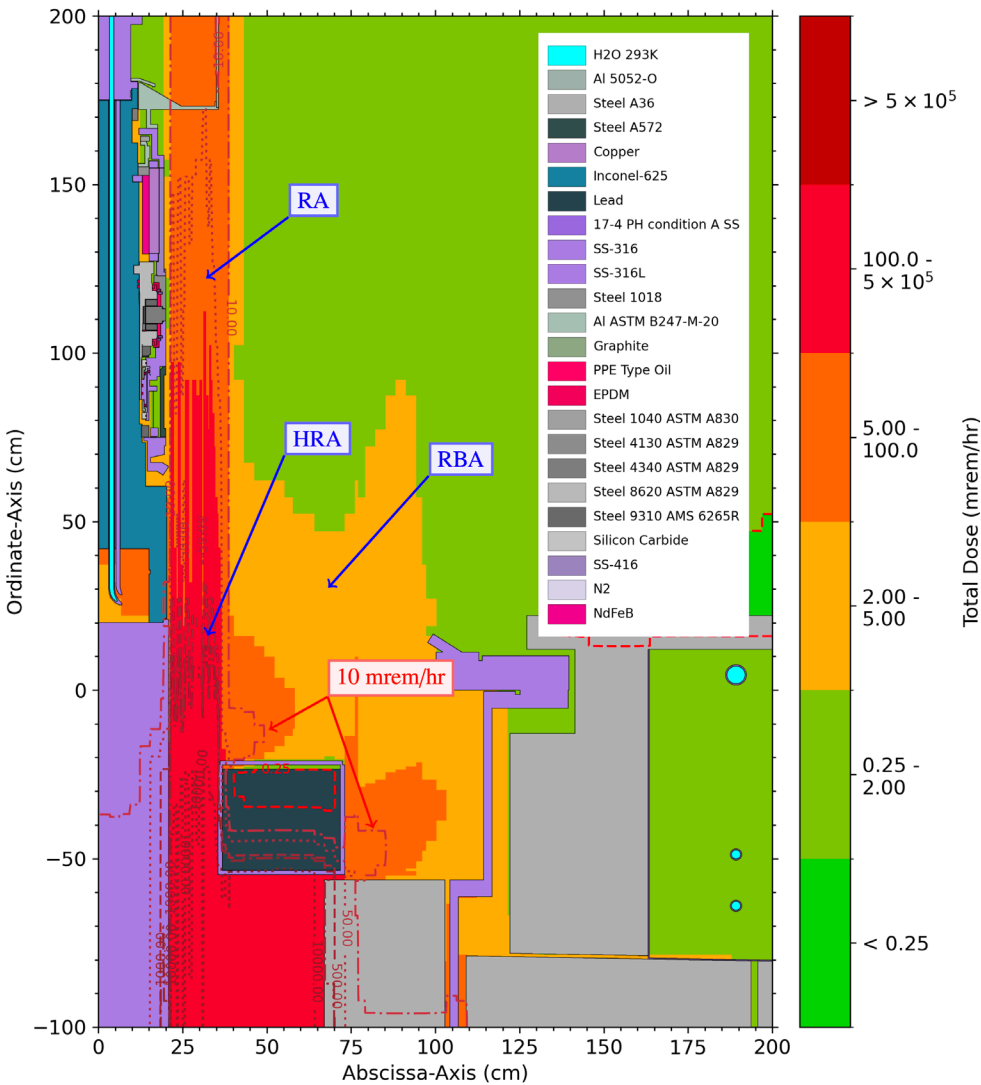
Cross Section View of Configuration 2

Configuration 2 Dose Rates after 8 Hours of Decay

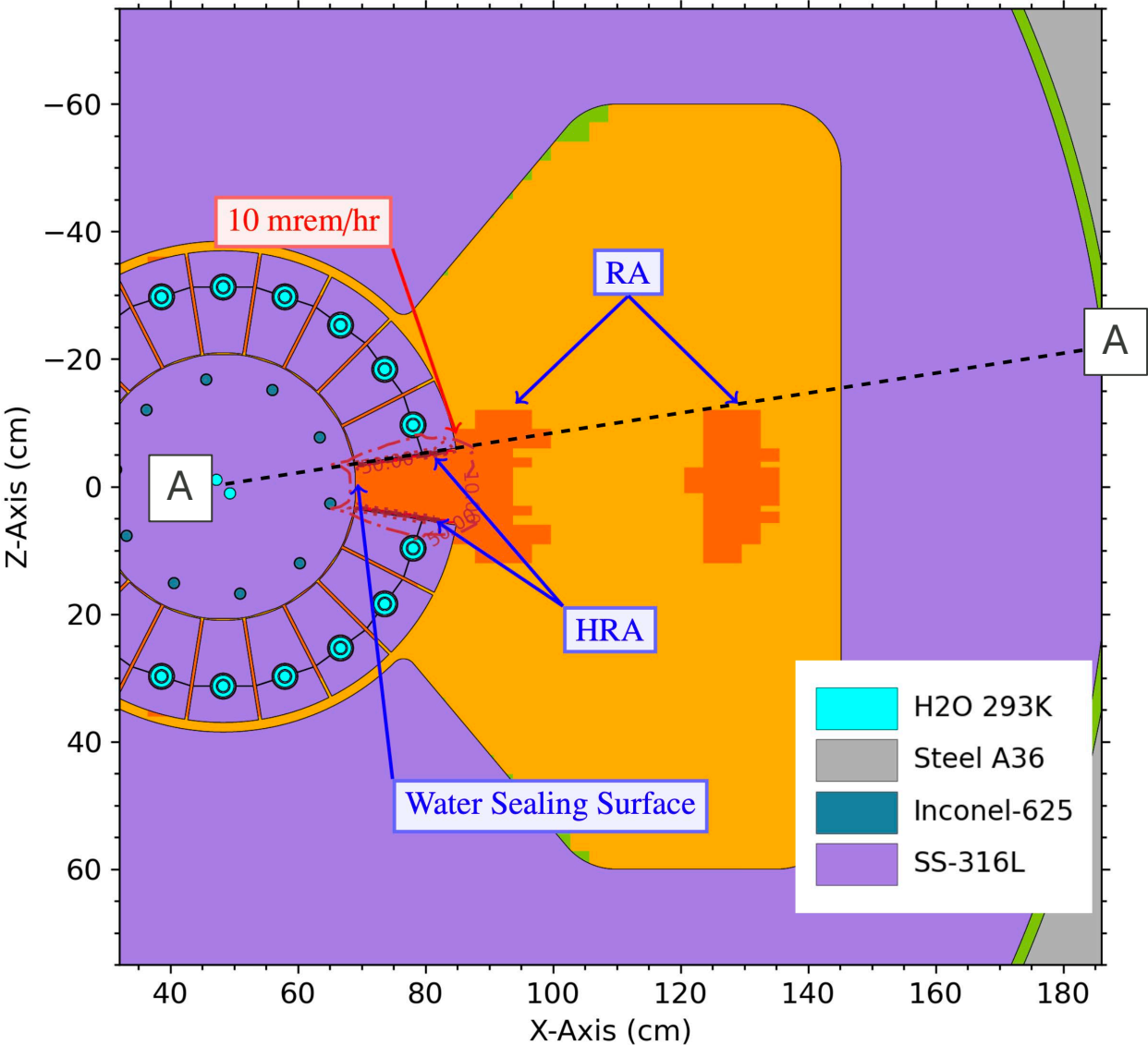
- Working area downstream of the target is largely a radiation area
- Most of TDR is controlled area
- Gaps around gamma gate lead to elevated dose rates
- Dose rates calculated with Denovo (discrete ordinates)



Configuration 2 Dose Rates after 8 Hours of Decay



Elevation View A-A of Configuration 2 **Denovo**
Decay Dose Rates

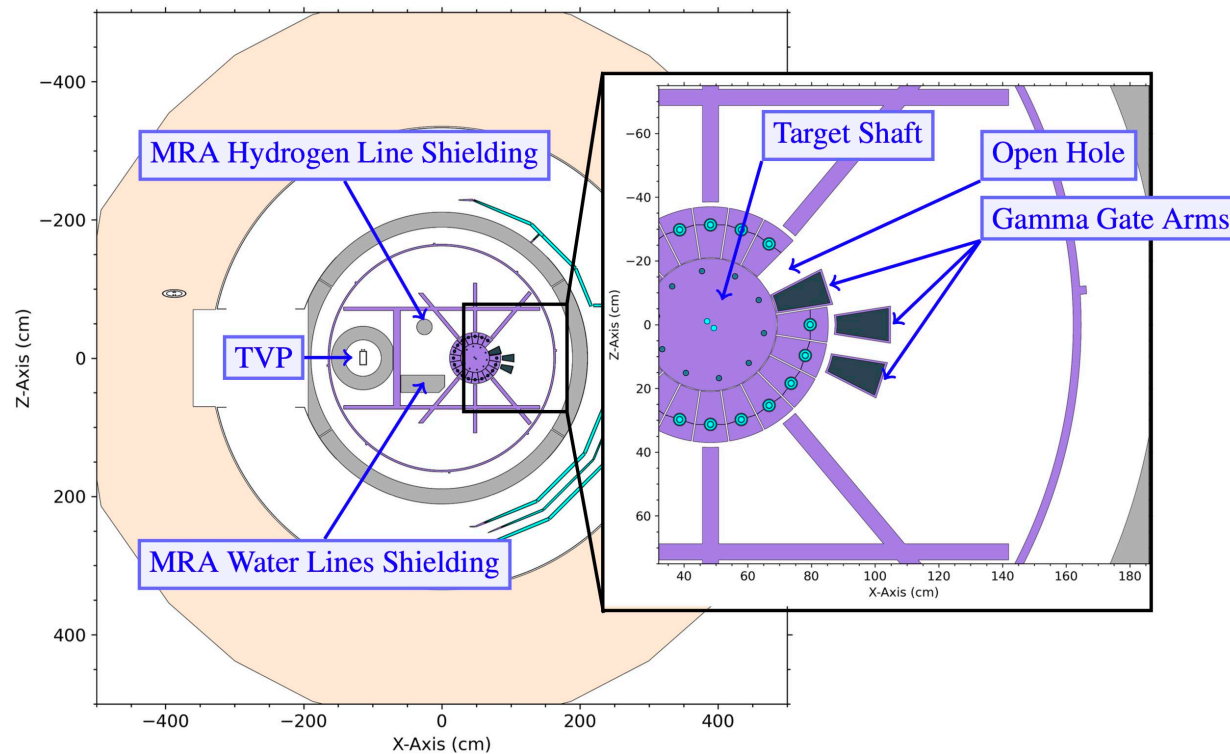


Plan View of Configuration 2 **Denovo** Decay Dose Rates at
an Elevation of 15 cm Below TDR Floor (Y=455 cm)

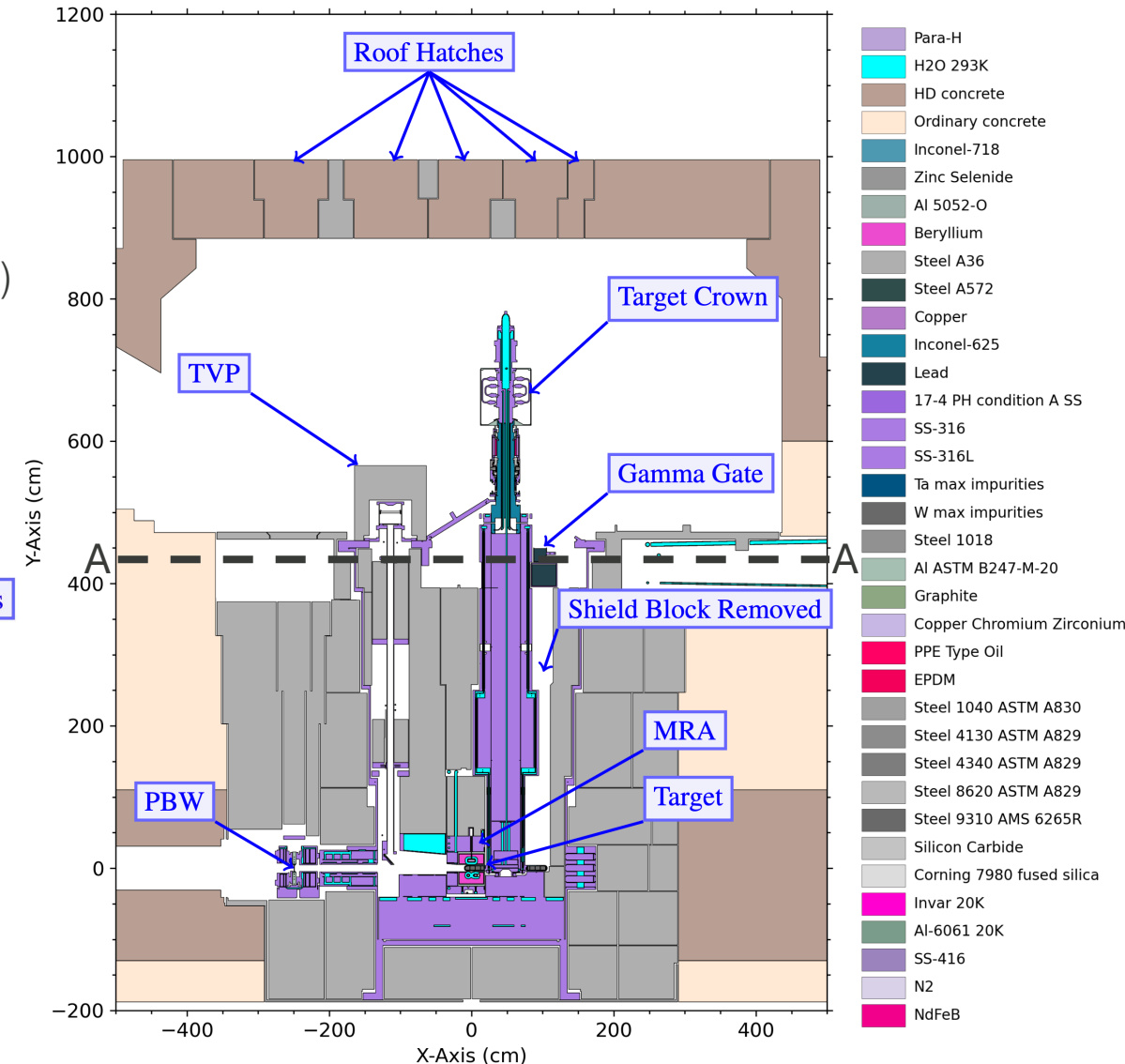
Configuration 3: Third Target Segment Removal

Configuration 3: Third Target Segment Removal

- Removable target segment access shield block is removed
- Gamma gate deployed with third arm also deployed
- Core vessel tent hatch removed for target
- Two target segments removed (downstream segment in place)
- 8 Hours of Decay

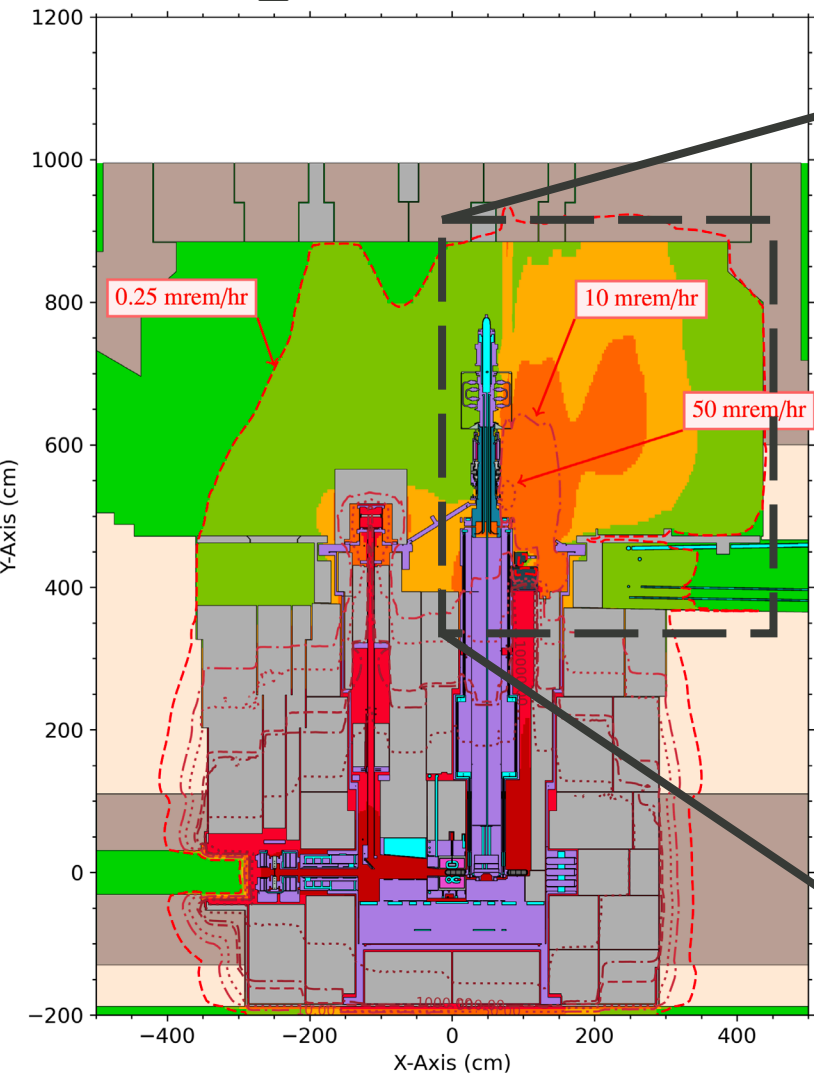


Plan View A-A of Configuration 3

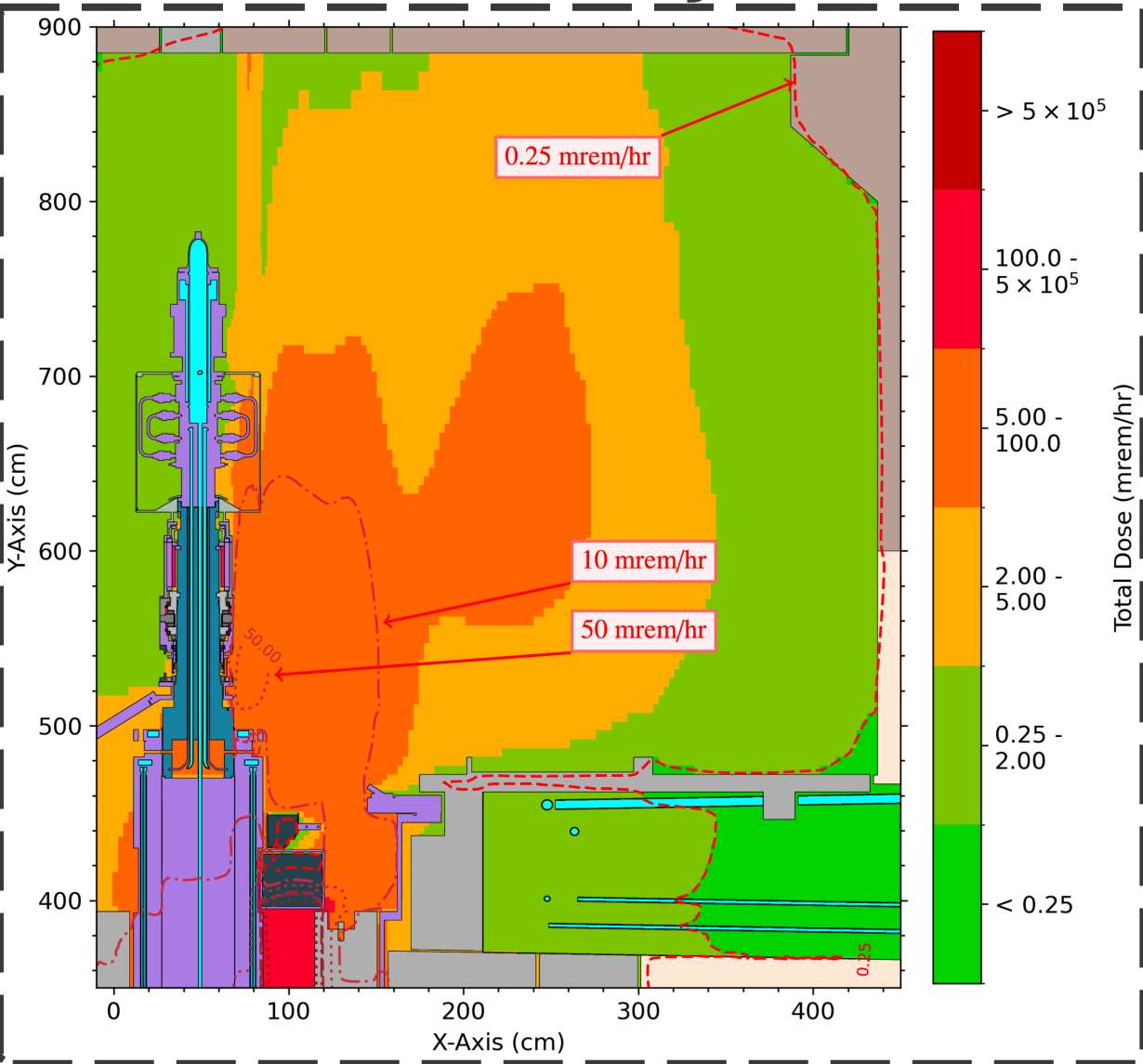


Cross Section View of Configuration 3

Configuration 3 Dose Rates after 8 Hours of Decay



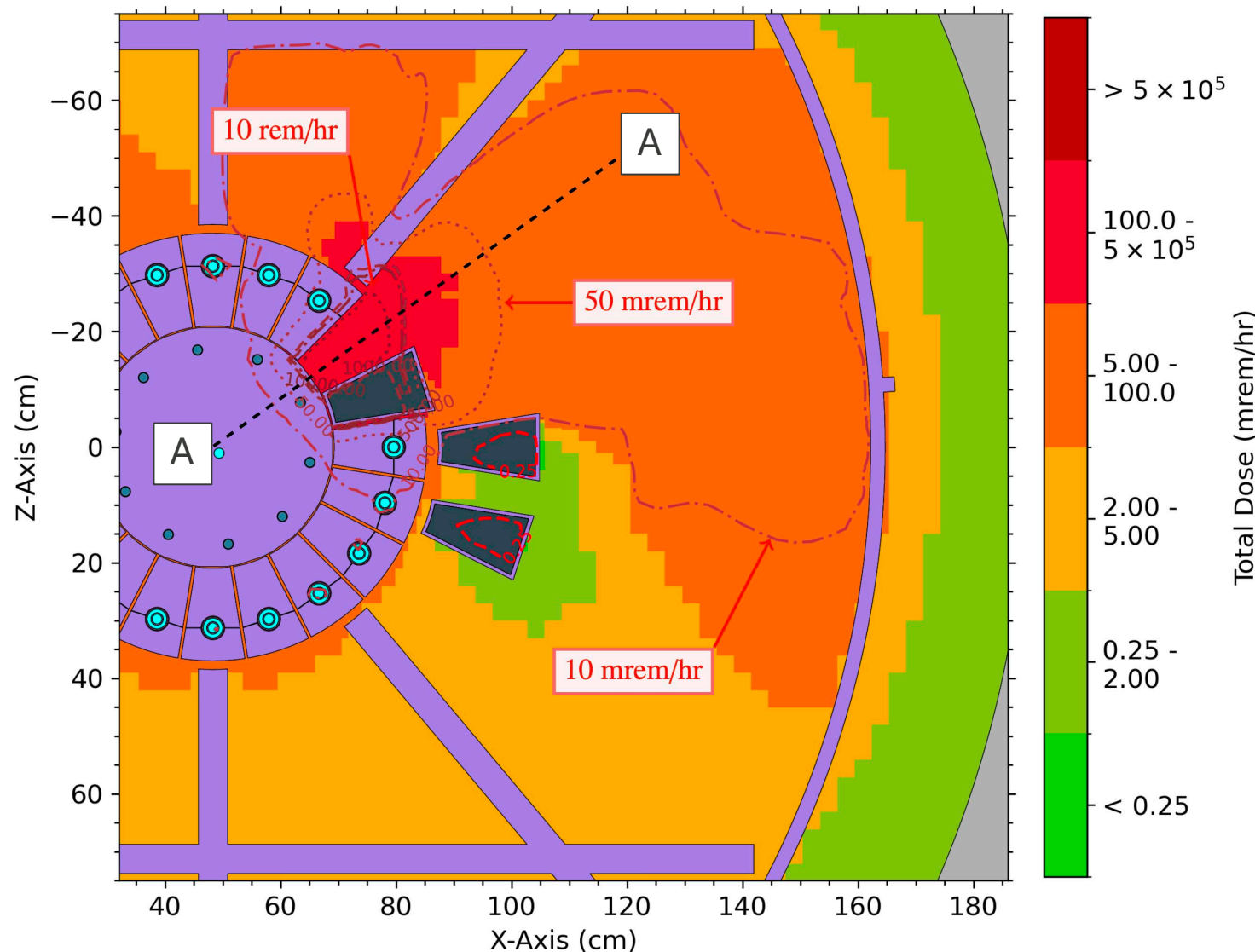
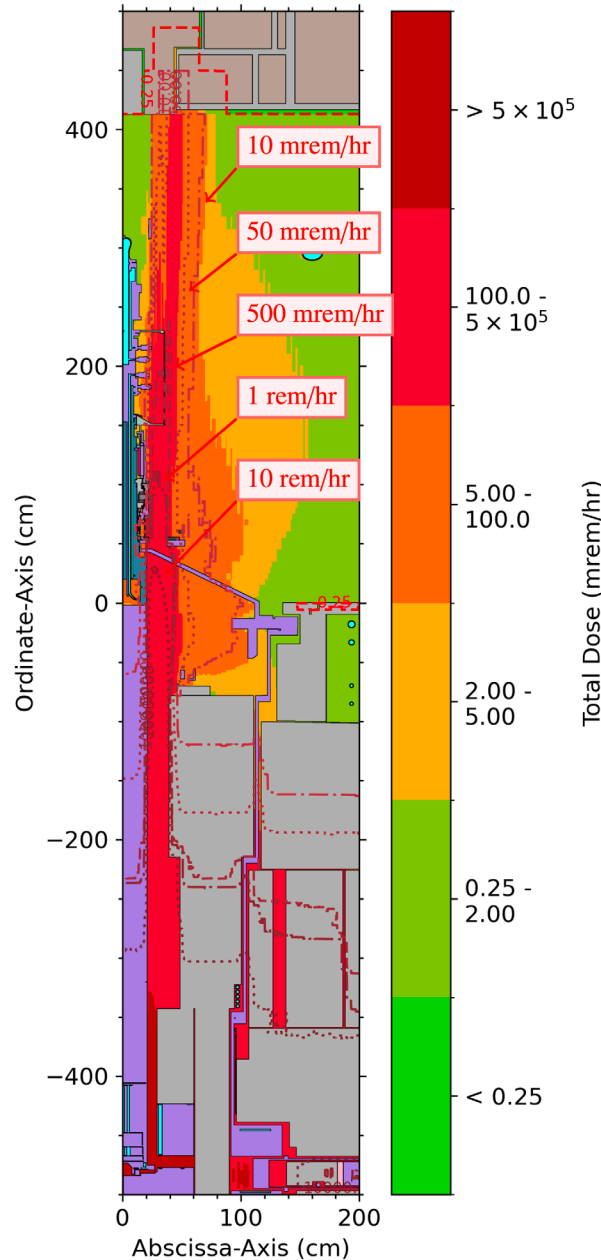
Cross Section View of Configuration 3
Denovo Decay Dose Rates



Detail View of Configuration 3 **Denovo** Decay Dose Rates
Downstream of Target Assembly

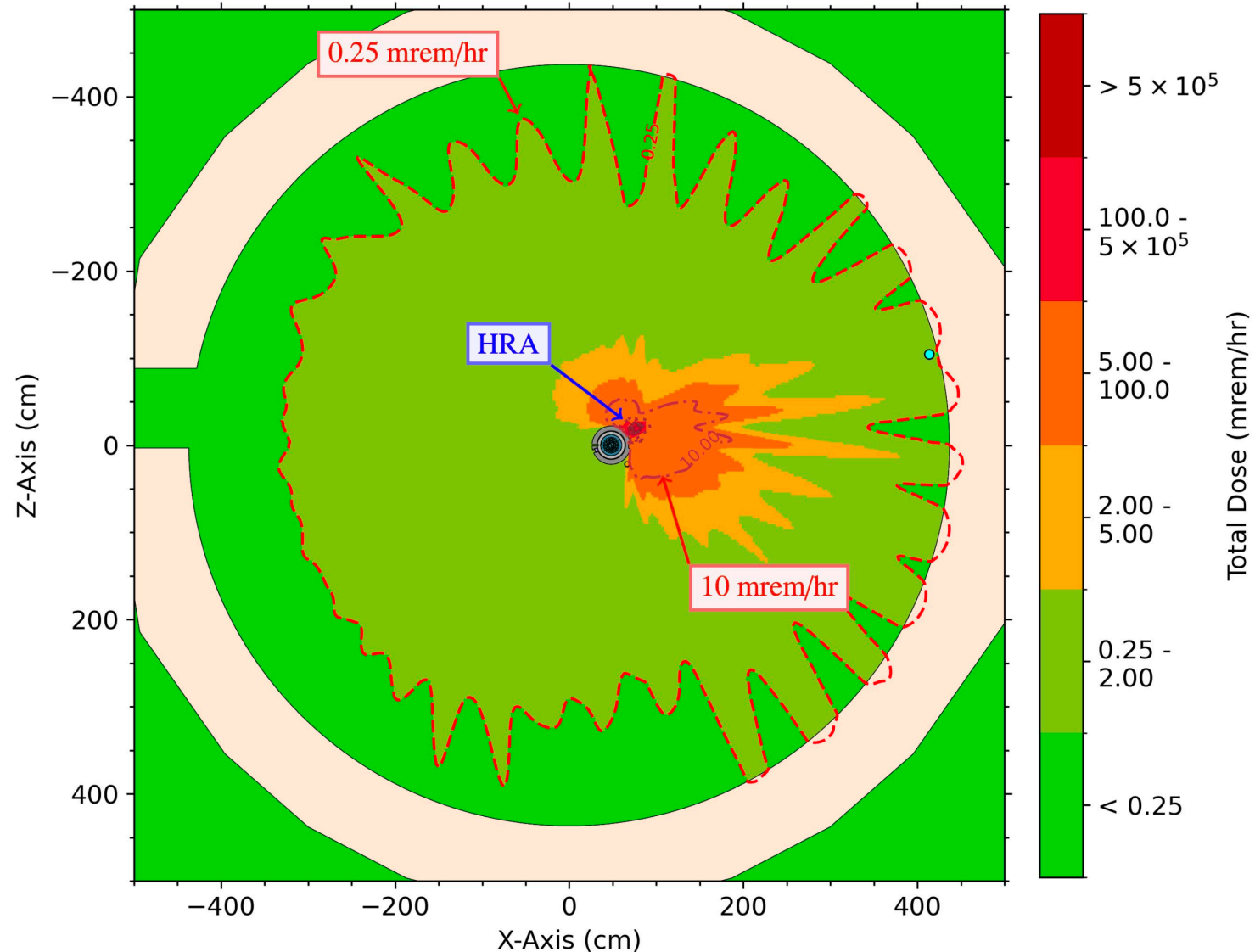
Configuration 3 Dose Rates after 8 Hours of Decay

Elevation View
A-A of
Configuration 3
Denovo Decay
Dose Rates



Plan View of Configuration 3 **Denovo** Decay Dose Rates at an elevation of 32 cm below TDR Floor (Y=438 cm)

Configuration 3 Dose Rates after 8 hours of decay

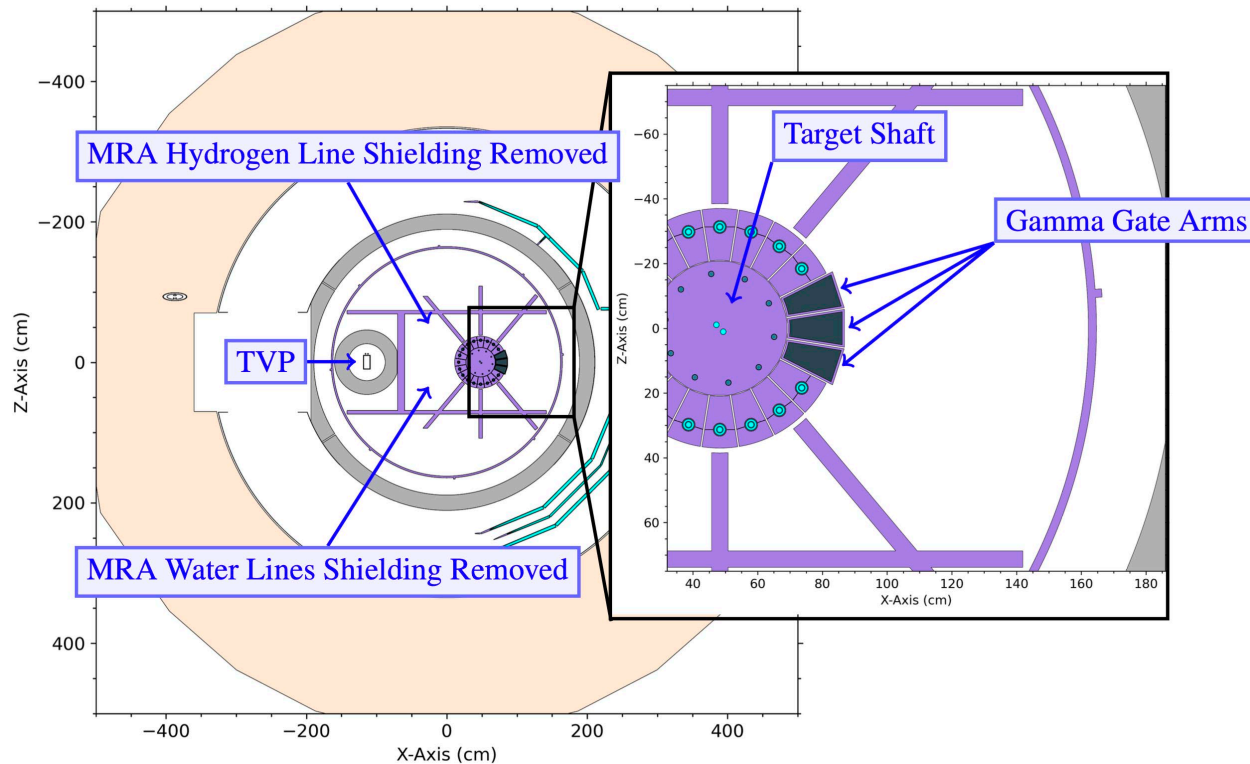


Plan View of Configuration 3 **Denovo** Decay Dose Rates at an elevation of 1 m above TDR Floor

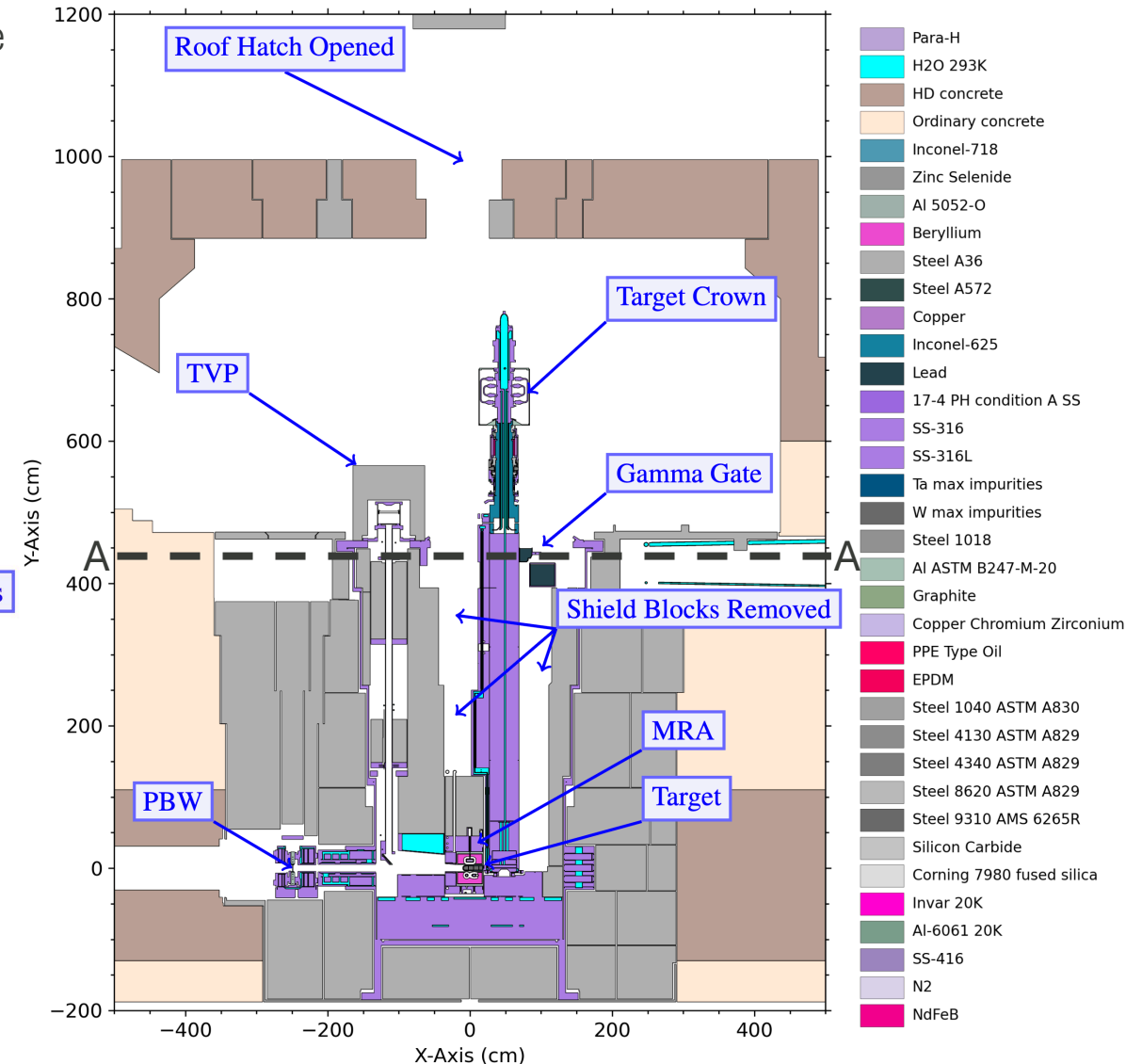
Configuration 4A: MRA Pipe Cutting with Downstream Target Segments Holes

Configuration 4A: MRA Pipe Cutting after 2 weeks of decay

- Removable target segment and MRA access shield blocks are removed
- Gamma gate deployed with all three arms deployed
- Core vessel tent hatch removed for both target and MRA
- 3 target segments removed (holes located downstream)

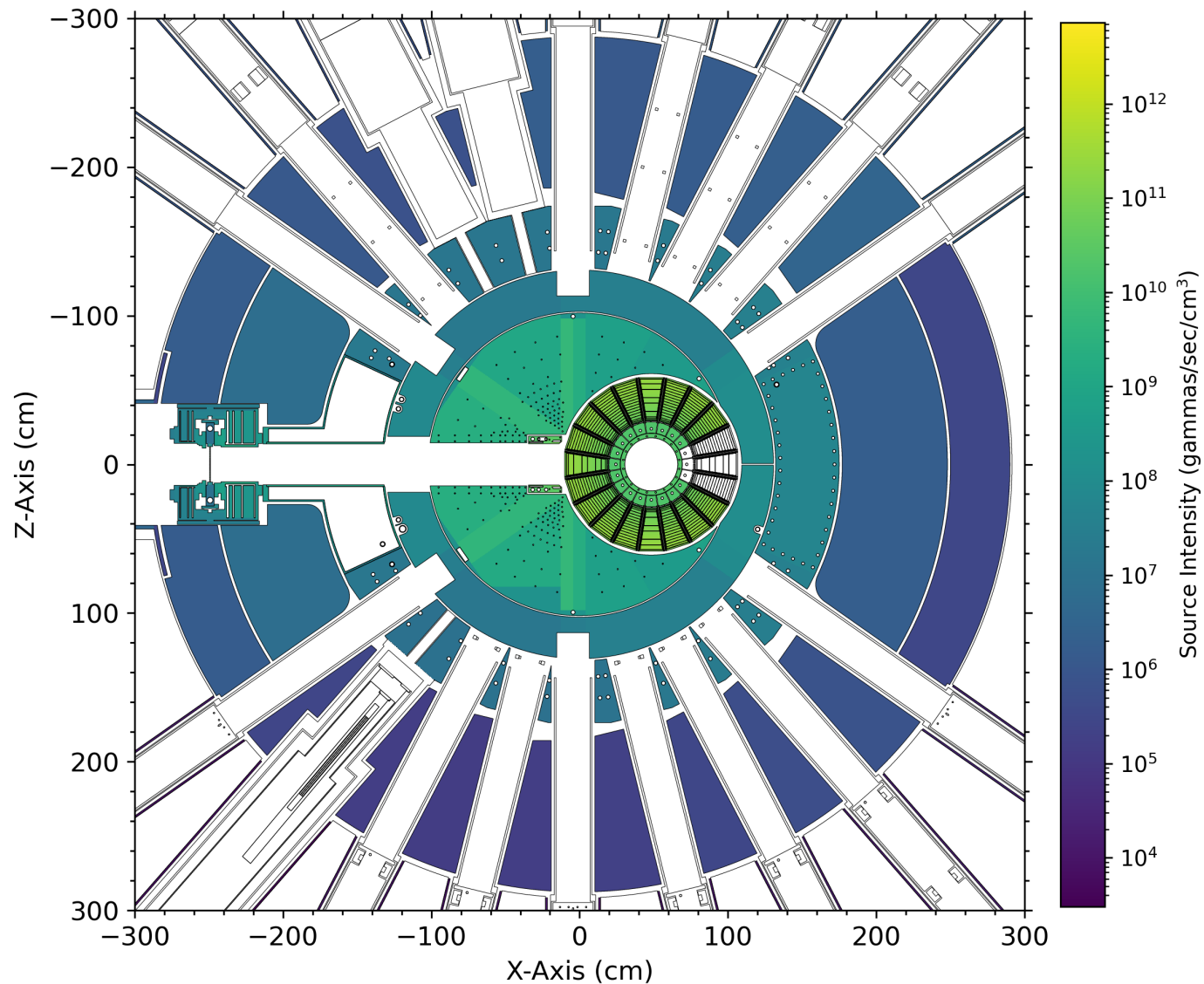


Plan View A-A of Configuration 4A

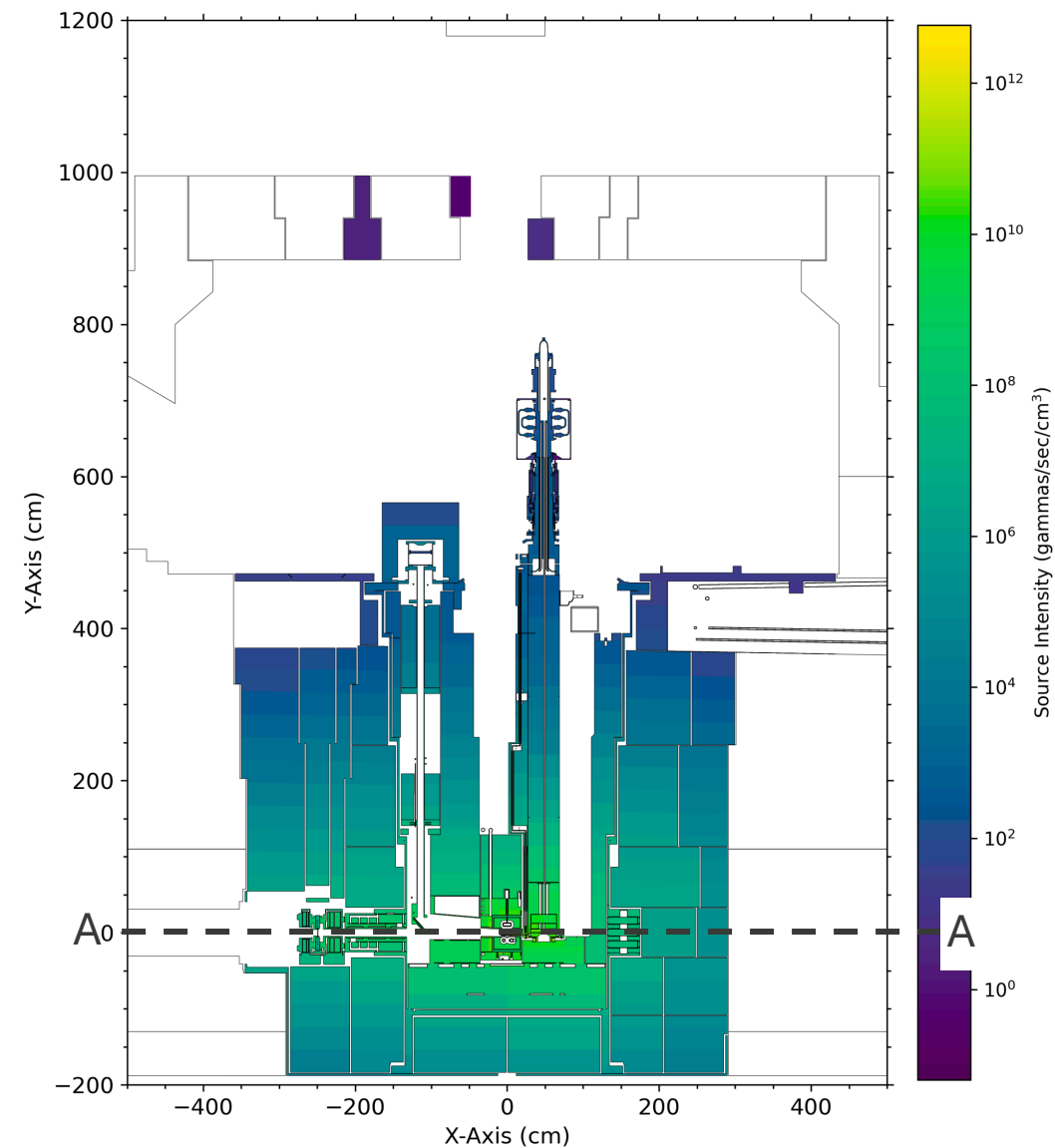


Cross Section View of Configuration 4A

Decay Gamma Sources after 2 Weeks of Decay

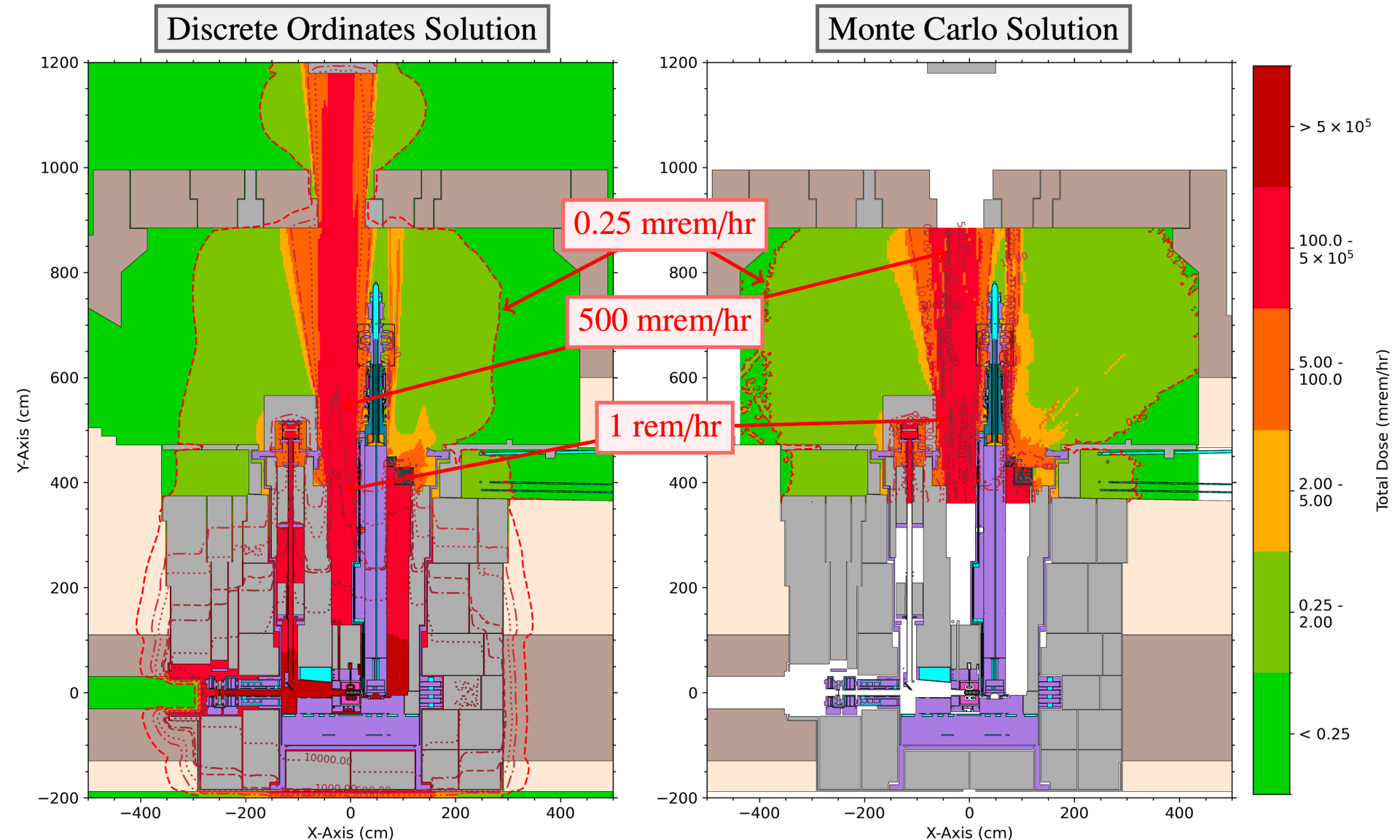


Plan A-A: Plan View of Target Systems Decay Gamma Sources



Cross Section View of the Gamma Sources
after 2 Weeks of Decay

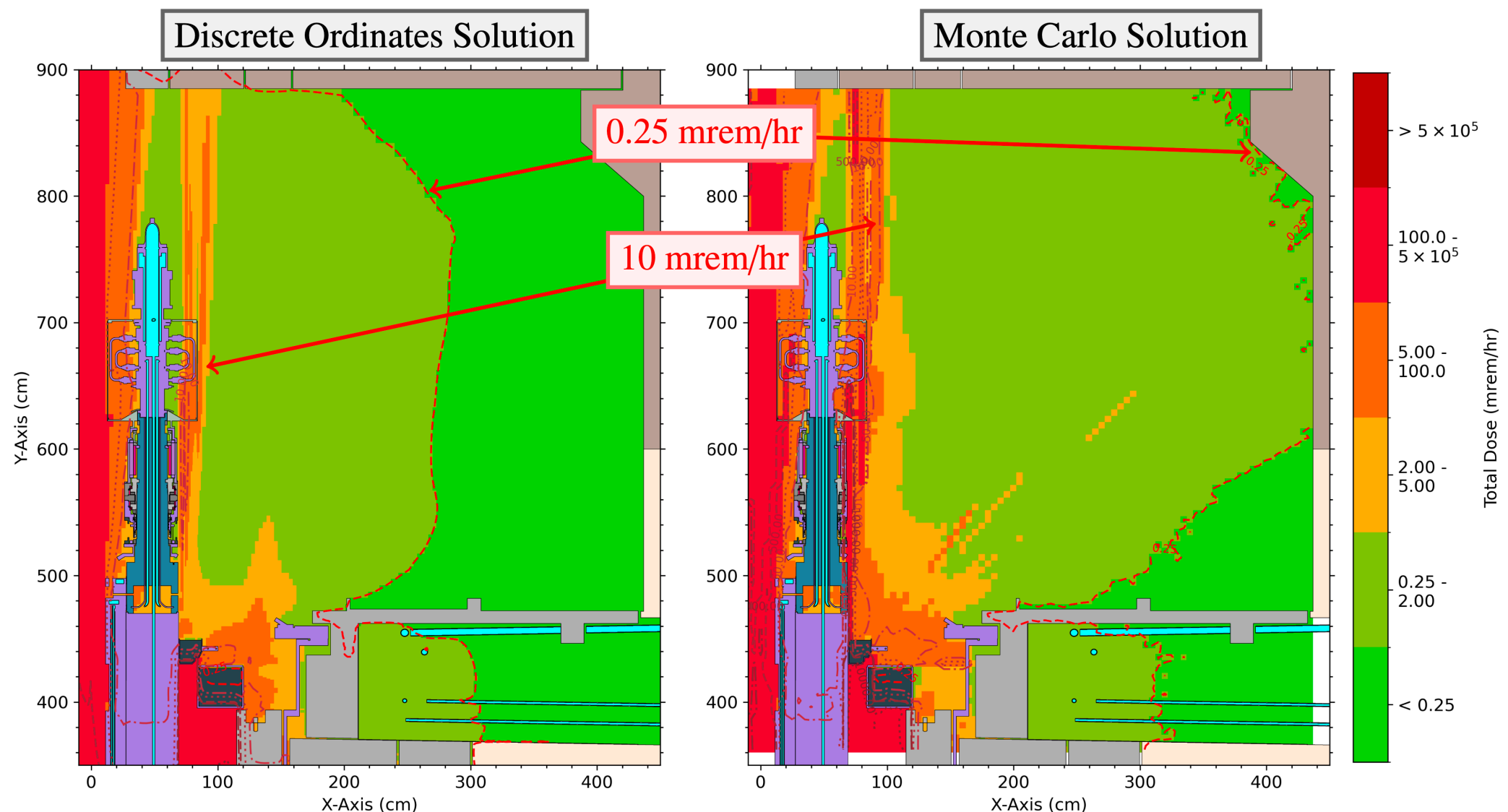
Configuration 4A Dose Rates after 2 Weeks



Cross Section View of Configuration 4A
Denovo Decay Dose Rates

Cross Section View of Configuration 4A
MCNP Decay Dose Rates

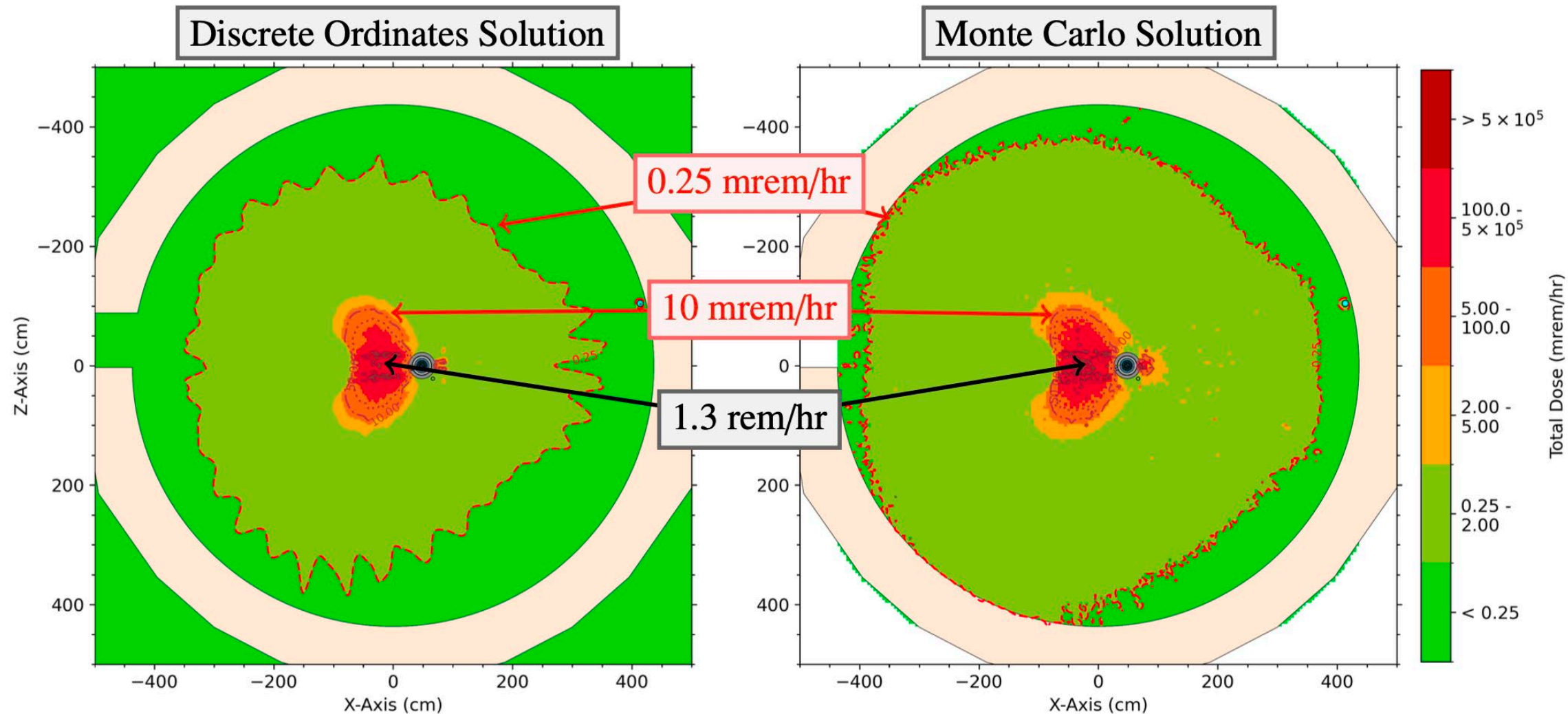
Configuration 4A Dose Rates after 2 Weeks



 Cross Section View of Configuration 4A **Denovo**
Decay Dose Rates Downstream of Target

Cross Section View of Configuration 4A **MCNP**
Decay Dose Rates Downstream of Target

Configuration 4A Dose Rates after 2 Weeks



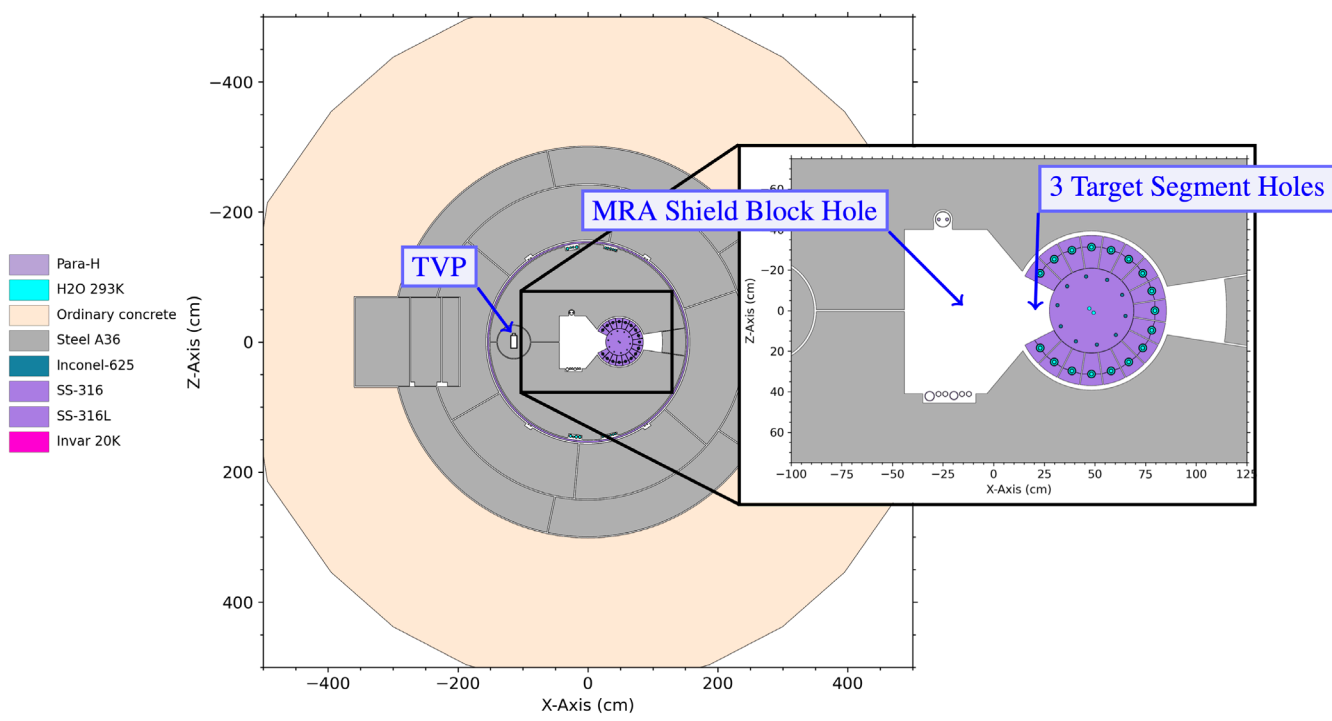
Plan View of Configuration 4A **Denovo**
Decay Dose Rates at elevation 1m above
TDR Floor

Plan View of Configuration 4A **MCNP** Decay
Dose Rates at elevation 1m above TDR
Floor

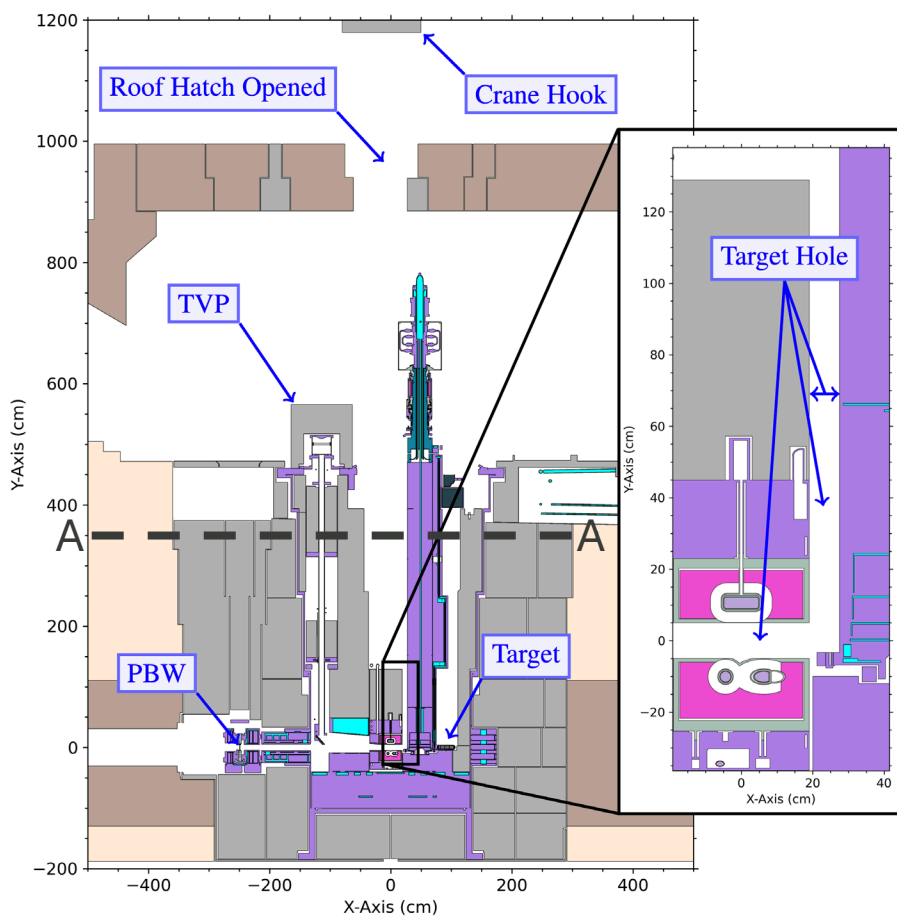
Configuration 4B: MRA Pipe Cutting with Upstream Target Segments Holes

Configuration 4B: MRA Pipe Cutting after 2 weeks of decay

- Removable target segment and MRA access shield blocks are removed
- Gamma gate deployed without arms deployed
- Core vessel tent hatch removed for both target and MRA
- 3 target segments removed (holes located upstream)

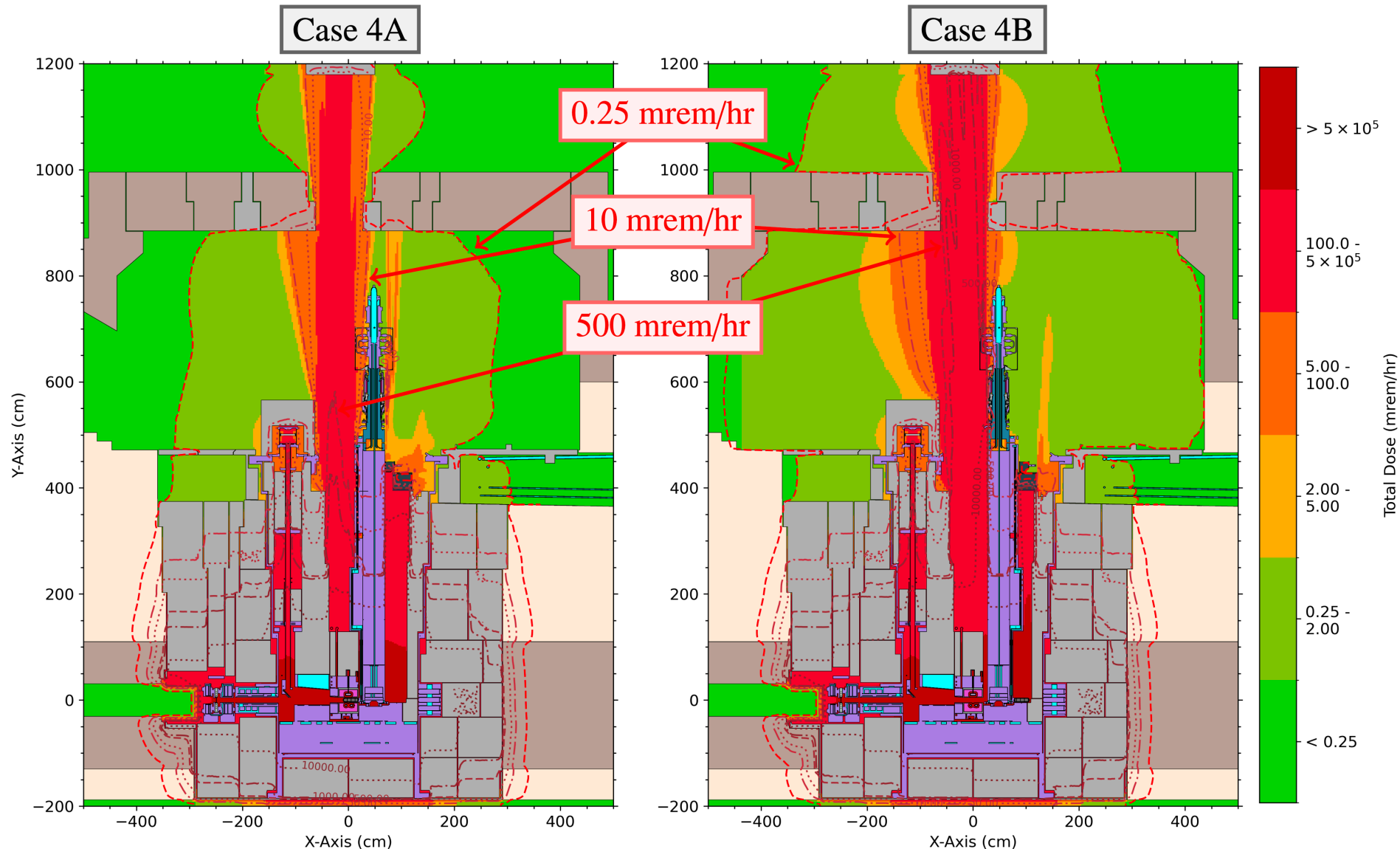


- Para-H
- H2O 293K
- HD concrete
- Ordinary concrete
- Inconel-718
- Zinc Selenide
- Al 5052-O
- Beryllium
- Steel A36
- Steel A572
- Copper
- Inconel-625
- Lead
- 17-4 PH condition A SS
- SS-316
- SS-316L
- Ta max impurities
- W max impurities
- Steel 1018
- Al ASTM B247-M-20
- Graphite
- Copper Chromium Zirconium
- PPE Type Oil
- EPDM
- Steel 1040 ASTM A830
- Steel 4130 ASTM A829
- Steel 4340 ASTM A829
- Steel 8620 ASTM A829
- Steel 9310 AMS 6265R
- Silicon Carbide
- Corning 7980 fused silica
- Invar 20K
- Al-6061 20K
- SS-416
- N2
- NdFeB



Comparing Configurations 4A vs. 4B Dose Rates after 2 Weeks

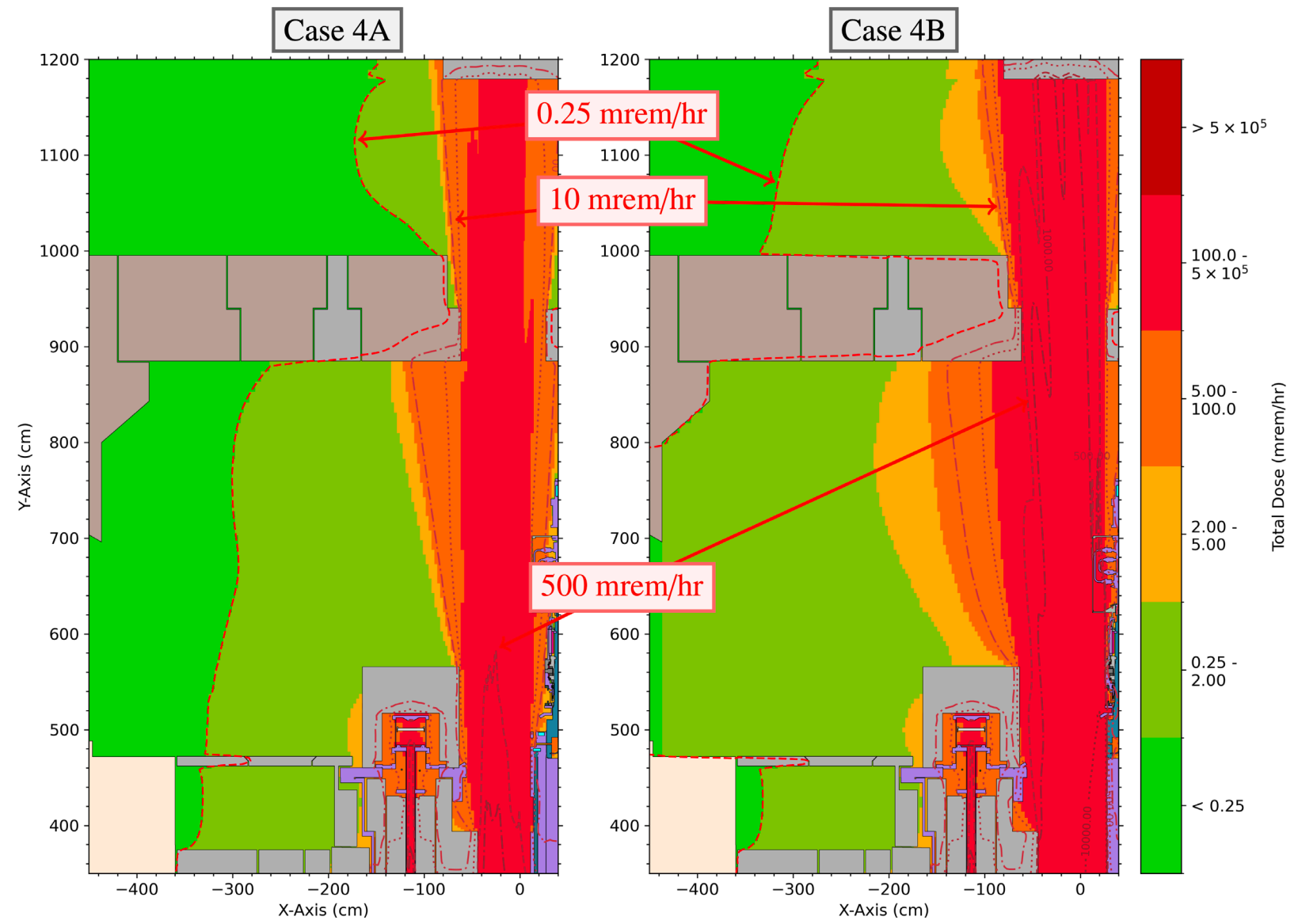
- Comparing location of target segments during the MRA pipe cutting
- Case 4A (target segments located upstream) will be the plan going forward



Cross Section View of Configuration 4A
Denovo Decay Dose Rates

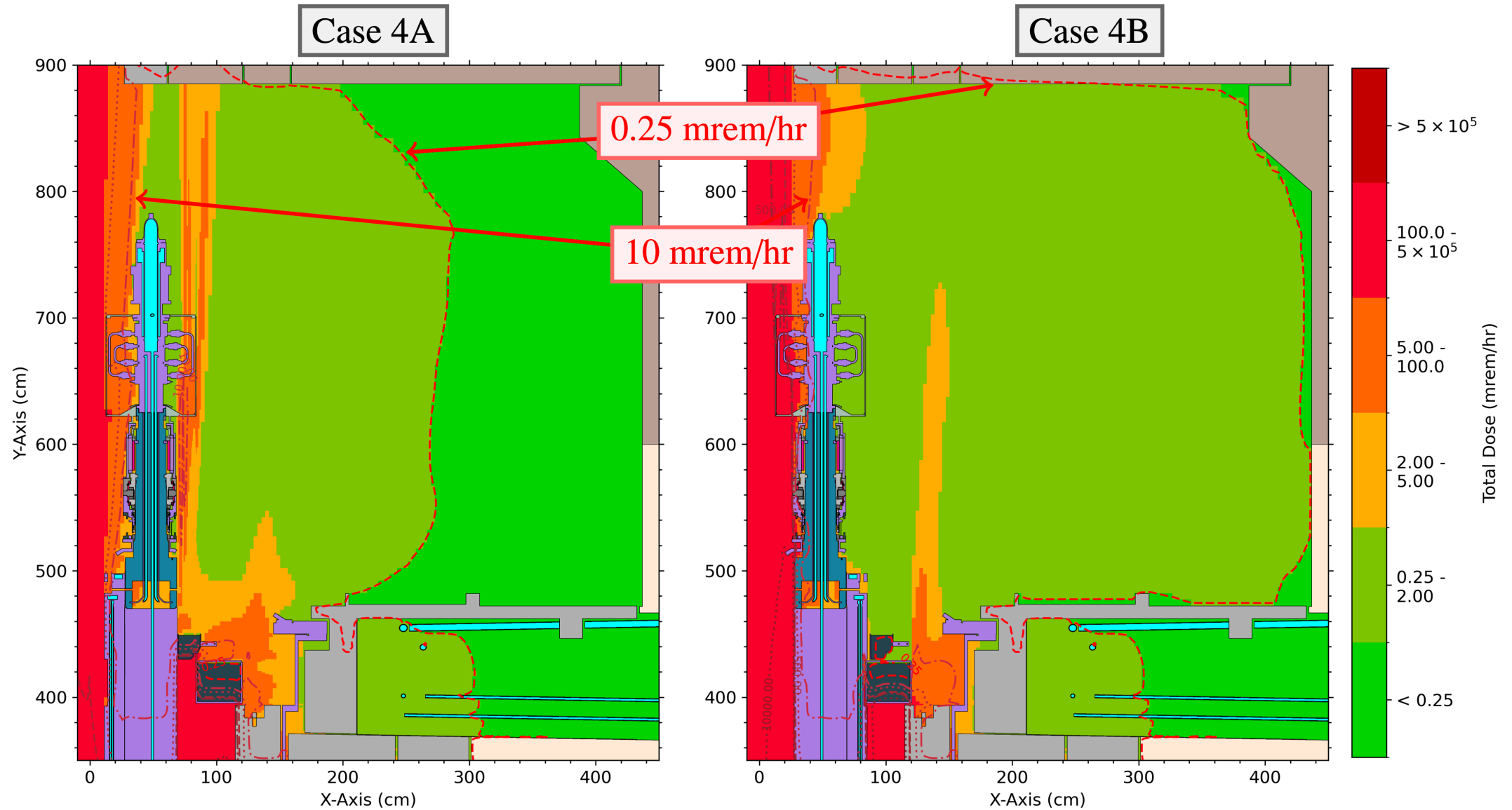
Cross Section View of Configuration 4B
Denovo Decay Dose Rates

Comparing Configurations 4A vs. 4B Dose Rates after 2 Weeks

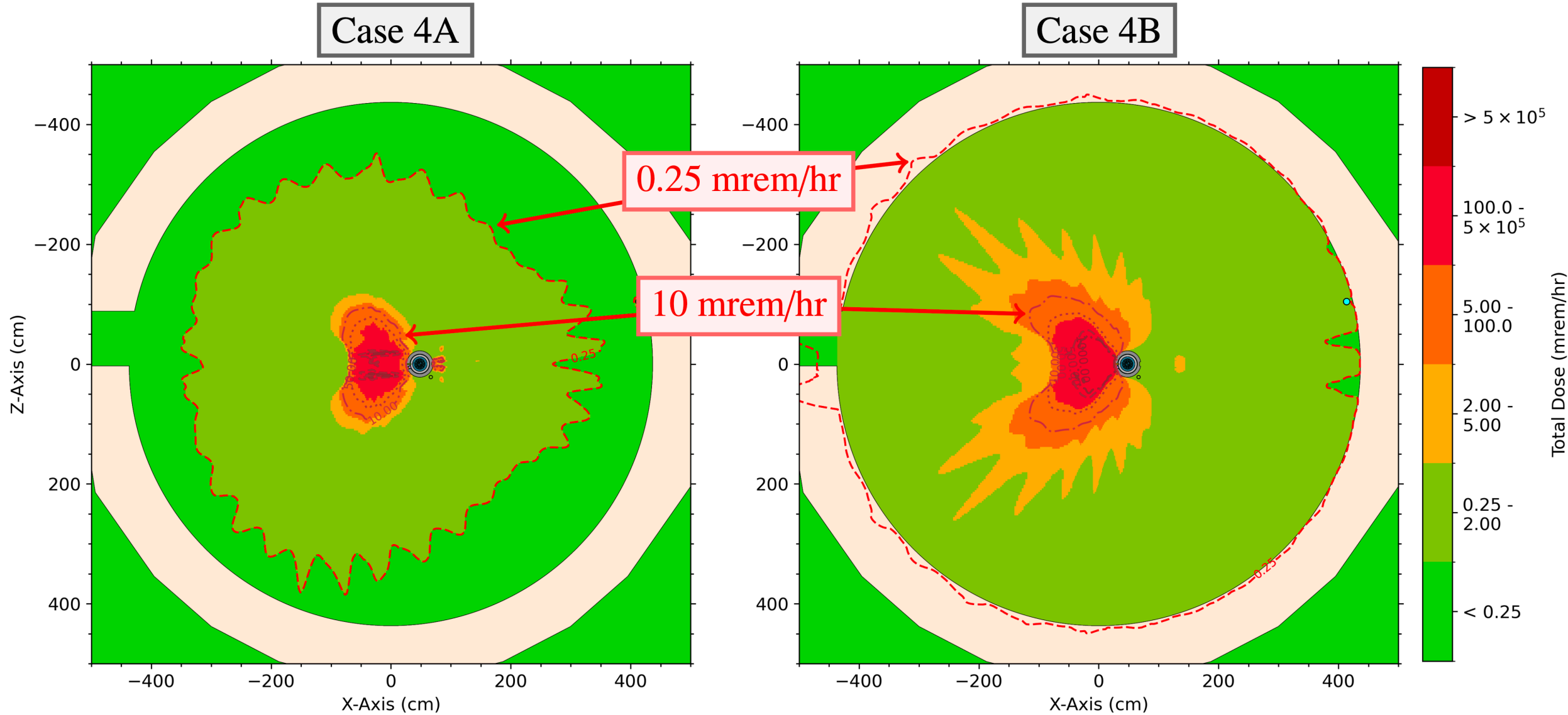


Cross Section View of Configuration 4A Denovo Decay Dose Rates Cross Section View of Configuration 4B Denovo Decay Dose Rates

Comparing Configurations 4A vs. 4B Dose Rates after 2 Weeks



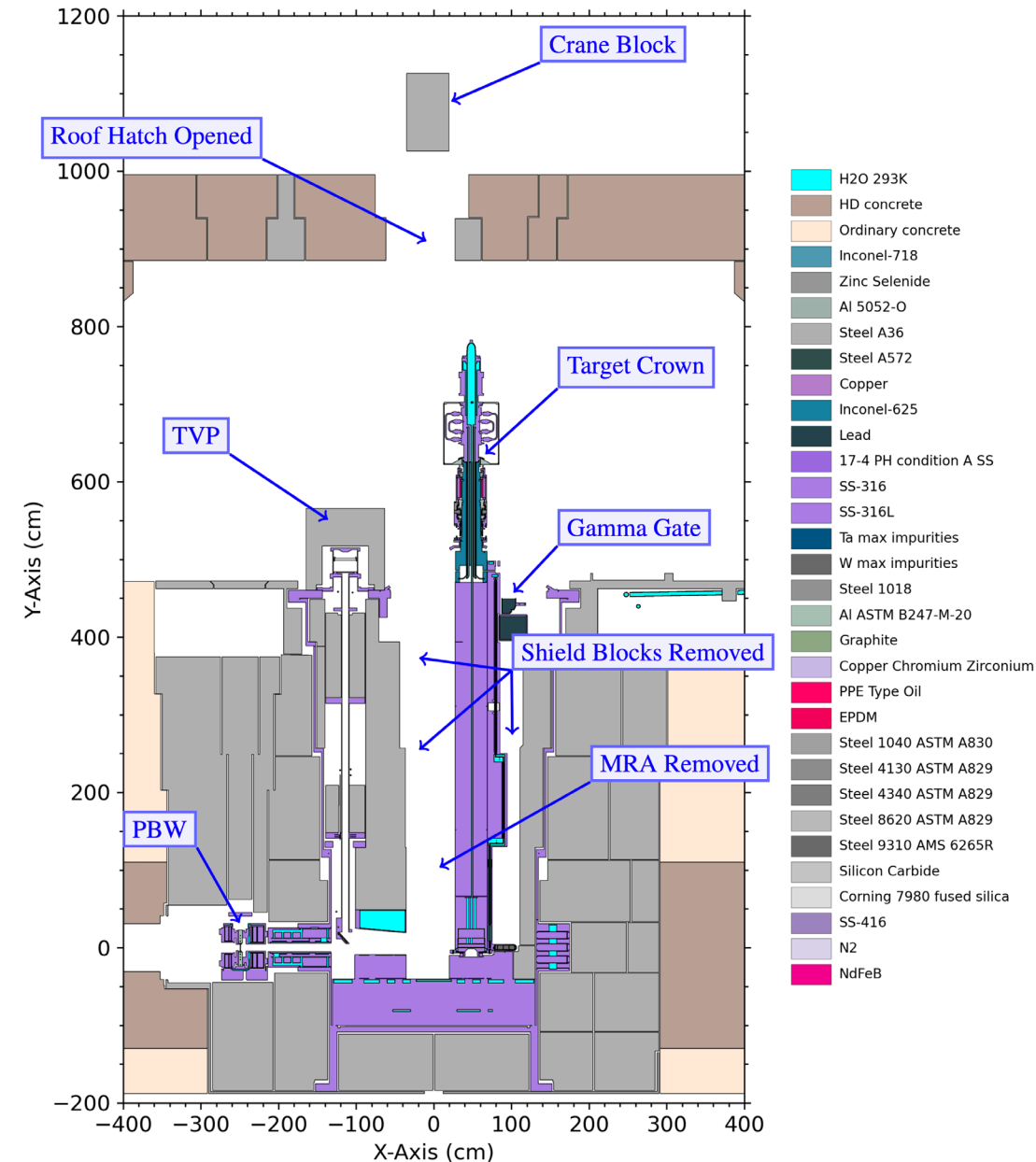
Comparing Configurations 4A vs. 4B Dose Rates after 2 Weeks



Configuration 5: MRA Removed

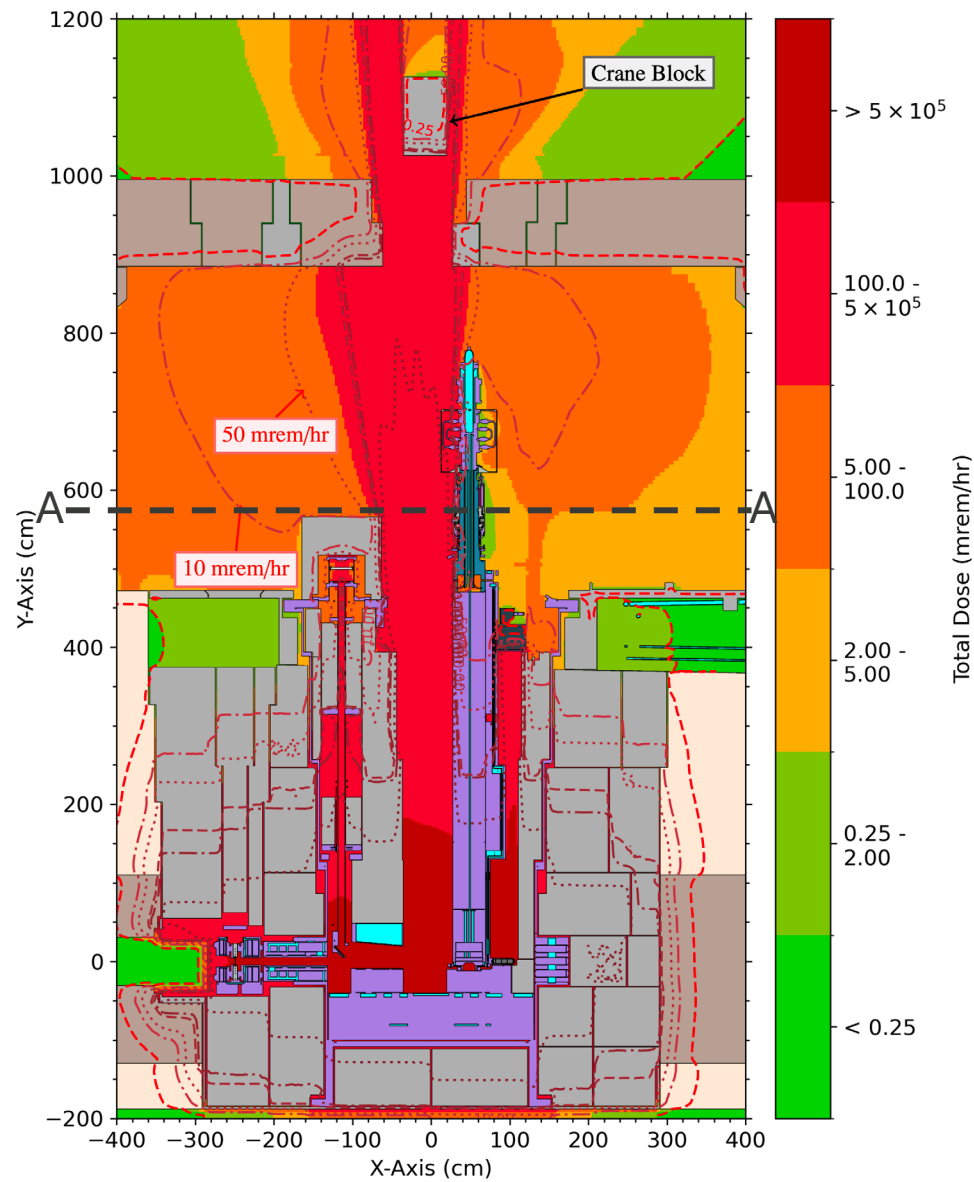
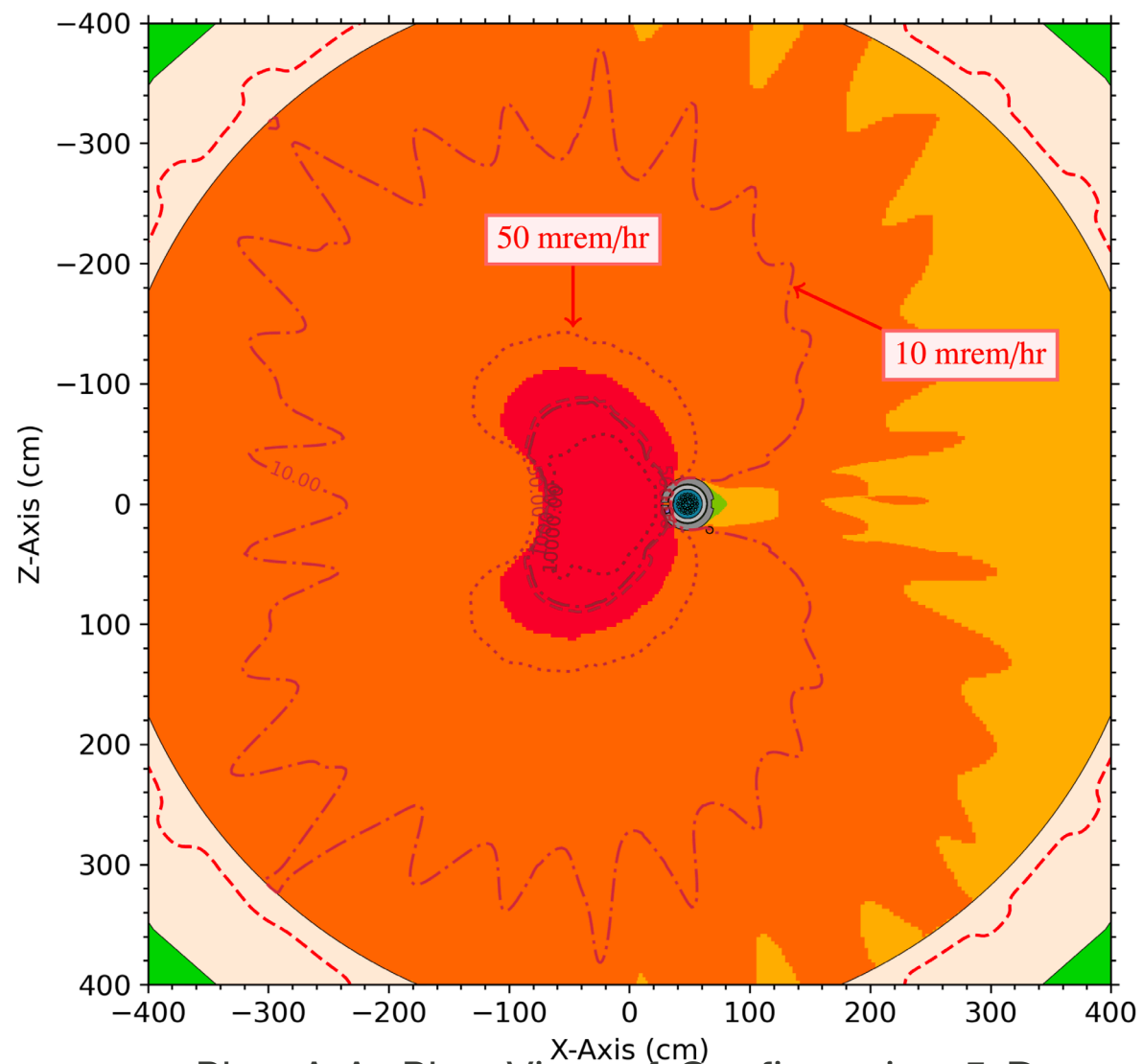
Configuration 5: MRA Removed

- Removable target segment and MRA access shield blocks are removed
- Gamma gate deployed without arms deployed
- Core vessel tent hatch removed for both target and MRA
- 3 target segments removed (holes located upstream)
- MRA Removed
- 2 Weeks of Decay



Cross Section View of Configuration 5

Configuration 5 Dose Rates after 2 Weeks



Conclusions and Discussion of Evaluated Requirements

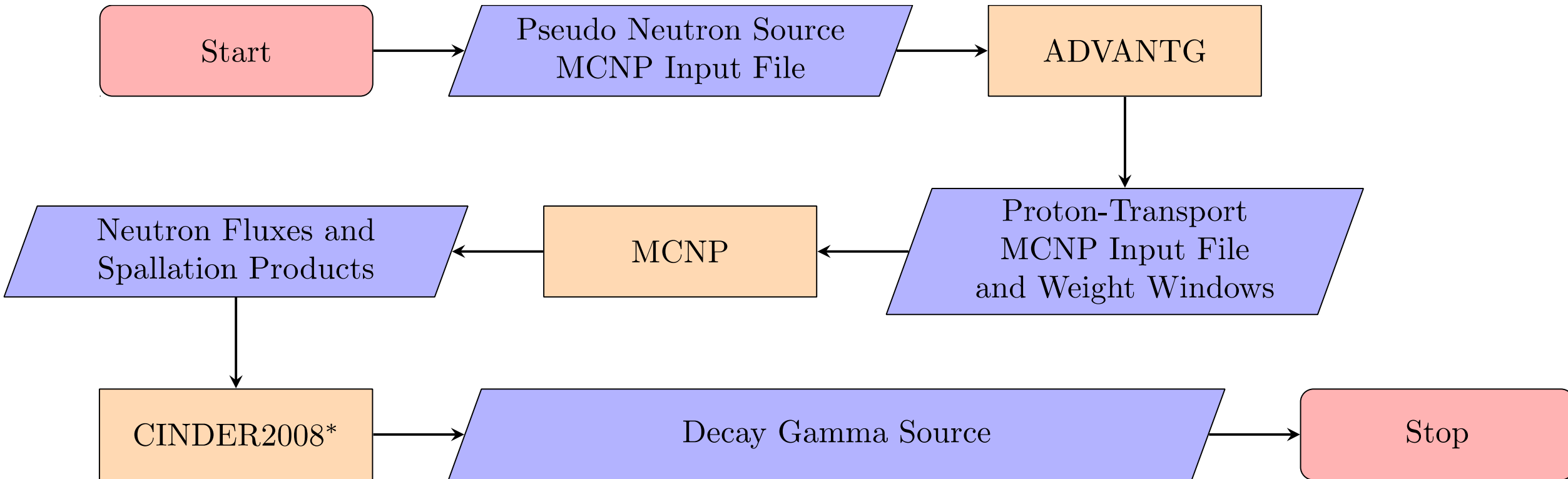
Requirement Number	Description	Slide Number(s)	Pass/Fail
NA	Effective dose rates in the target drive room in nominal configuration shall be less than 5 mrem/hr after 8 hours after last beam-on-target	8	Pass
1774	In operating configuration of the target assembly and core vessel, the drive components shall be at or below 100 mrem/hr on contact within 8 hours of cessation of the beam.	8	Pass
S.03.06-7125	Vessel Systems shall allow for hands-on maintenance at the top of the target segment with the target removable shield block removed. Assuming hands-on maintenance is below 100 mrem/hr at 30 cm.	11-12, 15-17, 21-23, 32	Pass
S.03.04-10944	The dose rates at 30 cm from the MRA hydrogen transfer line connection and water line connections shall be 100 mrem/hour or less after MRA operation and decay time of 8 hours to allow for hands on replacement of these connections with the target station in nominal operating configuration with the exception of the removal of the Core Vessel MRA hatch.	8	Pass

Conclusions and Discussion of Supported Requirements

Requirement Number	Description	Slide Number(s)	Support Status
S.03.10.04-10938	A single worker shall not receive more than 600 mrem (TED) while performing a single target segment removal and replacement operation.	8, 11-12	Yes
S.03.10.04-10943	A single worker shall not receive more than 1000 mrem (TED) while performing a target drive removal and replacement operation.	8	Yes
S.03.10.05-10942	A single worker shall not receive more than 1000 mrem (TED) while performing a MRA removal and replacement operation.	8, 11-12, 15-17, 21-23, 26-29, 32	Yes
S.03.10.03-10940	A single worker shall not receive more than 1000 mrem (TED) while performing either a PBW or TVP removal and replacement operation.	8	Yes

Backup

R2S Transmutation Workflow

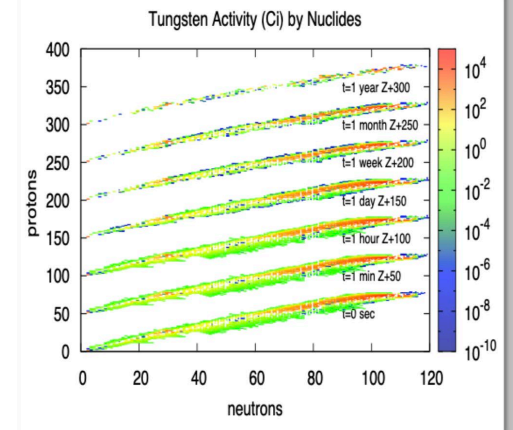


R2S Transmutation Workflow where CINDER2008* refers to using the Position-Averaged Method¹

CINDER2008 Details

- Cross-section Libraries
 - Three ENDF/B-VII.0-based multigroup libraries:
 - **321-group flat spectrum**
 - 180-group fusion spectrum
 - 66-group fission spectrum
 - 1E-11 to 20 MeV energy range
 - Library maker
 - AARE Activation Script
 - Perl wrapper for CINDER2008
 - RNUCS MCNP patch
 - Tally high-energy physics production/destruction rates
- MCNP6 and MCNPX Compatible with Activation Script
- Currently maintained by AARE Developer group

AARE_ACTIVATION Script Version 2.0 User Guide



Approved for public release

Franz. X Gallmeier
Michael Wohlmuther

July 2018

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AARE Activation Script Manual

Variance Reduction Details Using ADVANTG 3.2.0

- Neutron Flux Calculations

- ADVANTG is used in FW-CADIS mode to generate neutron weight windows to improve convergence of neutron fluxes in all the significant activation sources. Cell tallies in important activation sources are used as the adjoint source locations.
- The Denovo calculations in ADVANTG used the following discretizations:
 - Spatial Mesh:
4 x 3 x 4 cm (24 million mesh voxels)
 - Multigroup Cross-Section Library:
HILO2k-STS ENDF/B-VII.0-based multigroup cross section library
 - Angular Quadrature:
Midpoint Gauss quadrature with 26 polar angles and 166 total angles per octant - designed to provide accurate angular discretization for problems with significant axial streaming.¹

- Shutdown Gamma Dose Rate Calculations

- ADVANTG is used in FW-CADIS mode to generate photon weight windows and source biasing parameters to improve the convergence of photon fluxes throughout the model for each of ~150 shutdown gamma source definitions.
- The Denovo calculations in ADVANTG used the following discretizations:
 - Spatial Mesh:
3 x 2 x 3 cm (54 million mesh voxels)
 - Multigroup Cross-Section Library:
27n19g ENDF/B-VII.0-based multigroup cross section library
 - Angular Quadrature:
Midpoint Gauss quadrature with 26 polar angles and 166 total angles per octant - designed to provide accurate angular discretization for problems with significant axial streaming.¹