NML High Energy Beam Absorbers and Dump

29-August-2011

Beams-doc-3928

NML Beam Absorbers
Outline

- System Overview
- Absorber
  - Design and Analysis
  - Assembly
- Dump Shielding
  - Design
  - Installation
- Summary and Status

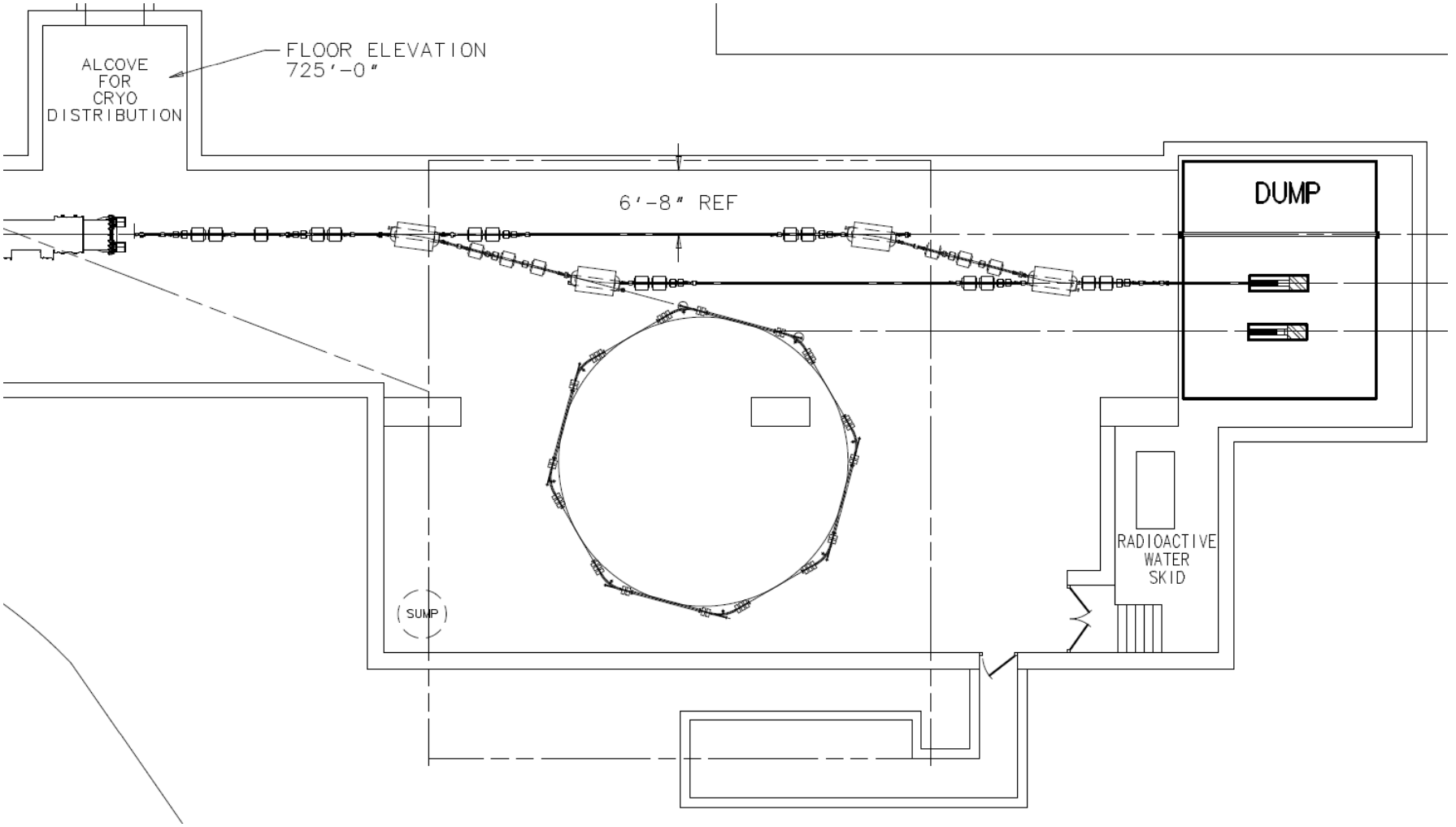
System Overview

- Dump concept, configuration and radiation design by Church and Rakhno

- Dump houses 2 water-cooled absorbers
  - Each absorber contains two independent cooling loops
  - Each circuit accepts 30gpm flow rate

- Single RAW skid can feed multiple cooling circuits simultaneously

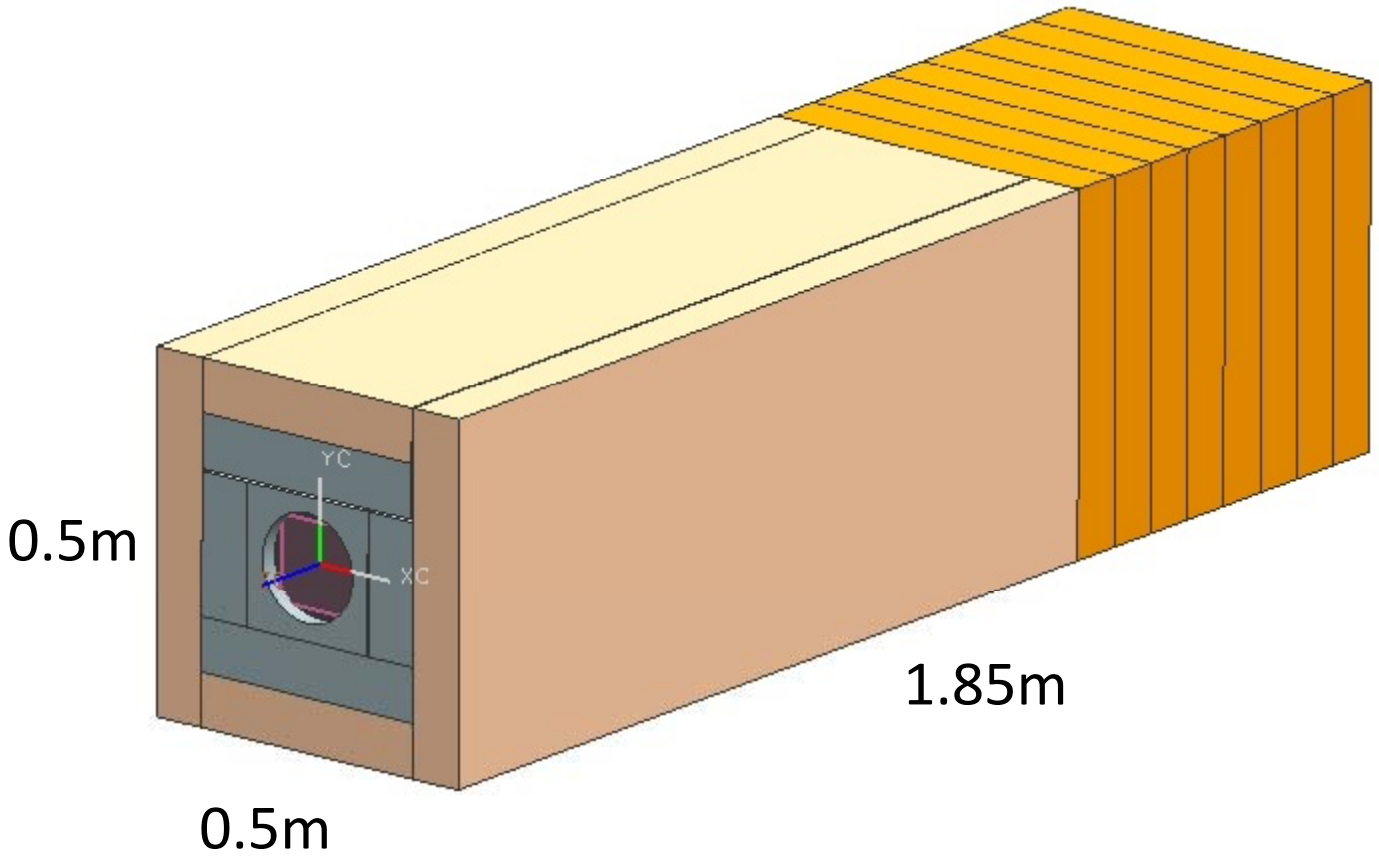
System Overview



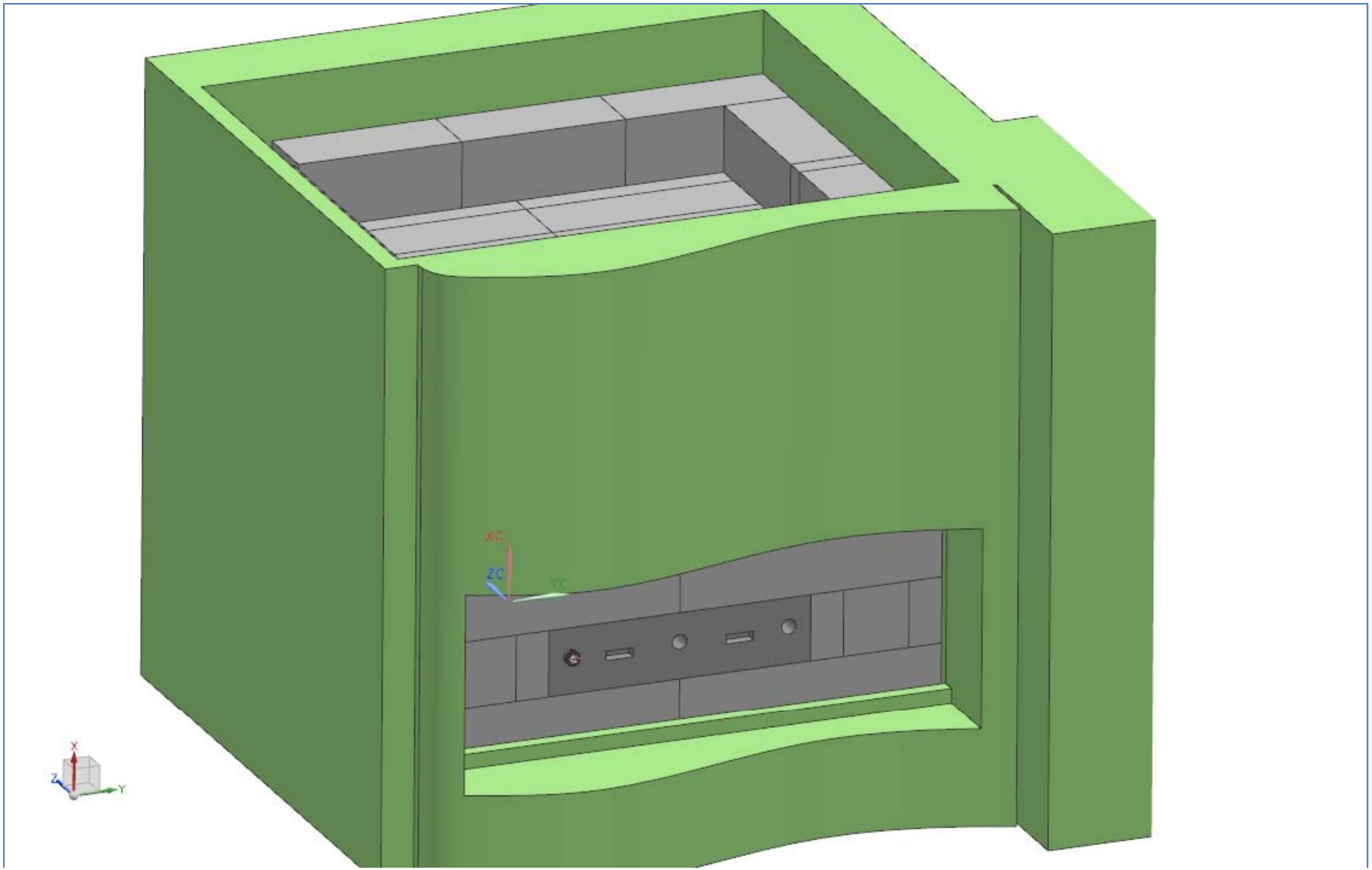
Key Requirements

- Beam Parameters
  - 1.5 GeV, 3.33 nC/bunch, 3MHz, 1ms pulse @ 5Hz
  - 3.12 E14 electrons/s
  - 75kW beam
- Absorber shall be capable of accepting beam continuously (i.e. steady state operation)
- Absorber shall have a design lifetime of 20 years, assuming a 70% operation factor (i.e. 123,000 hours)
- Absorber cores shall not require servicing
- Absorbers shall provide a redundant cooling circuit

Absorber Core Configuration



Absorber Location



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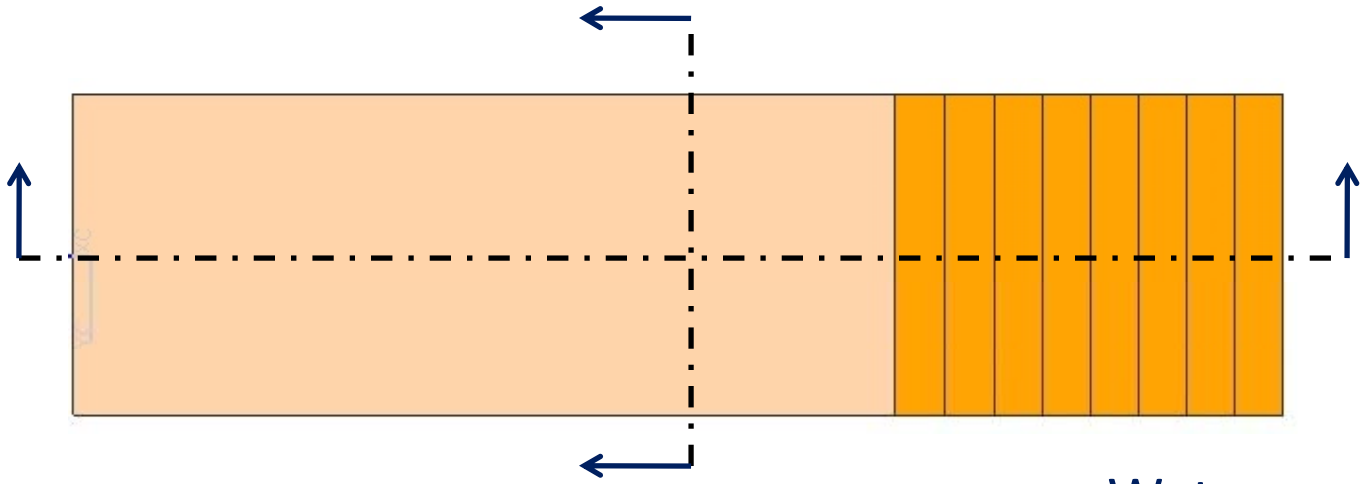
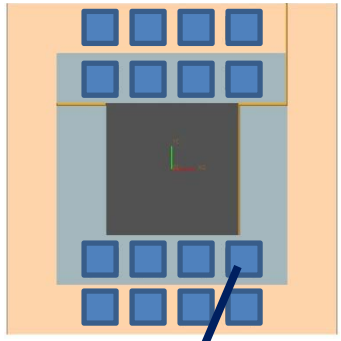
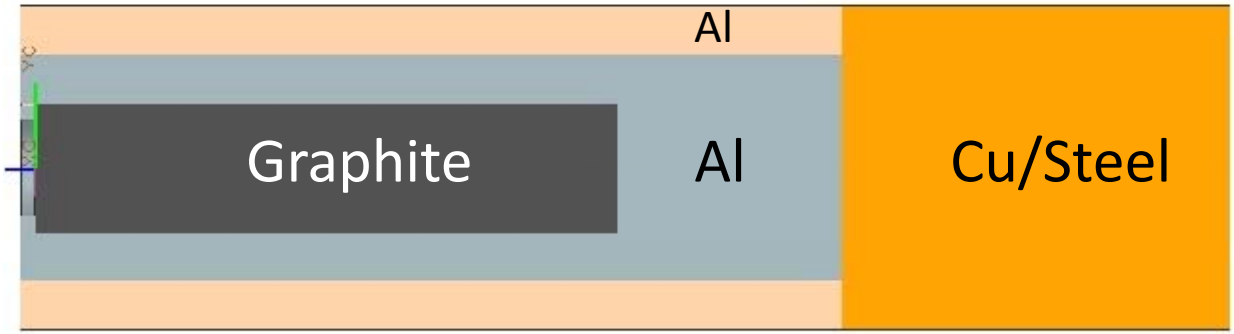
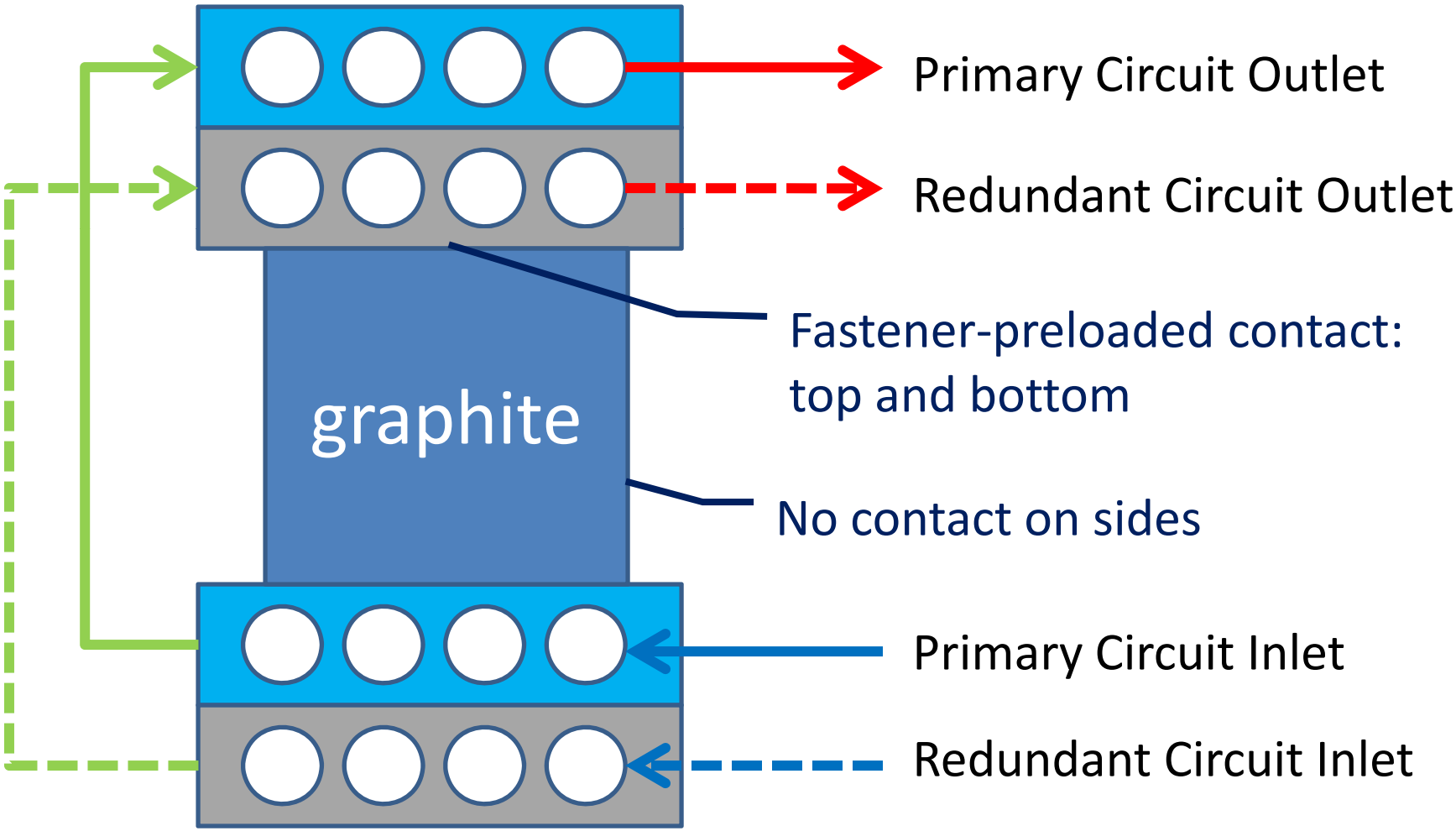




Water cooling in integral channels



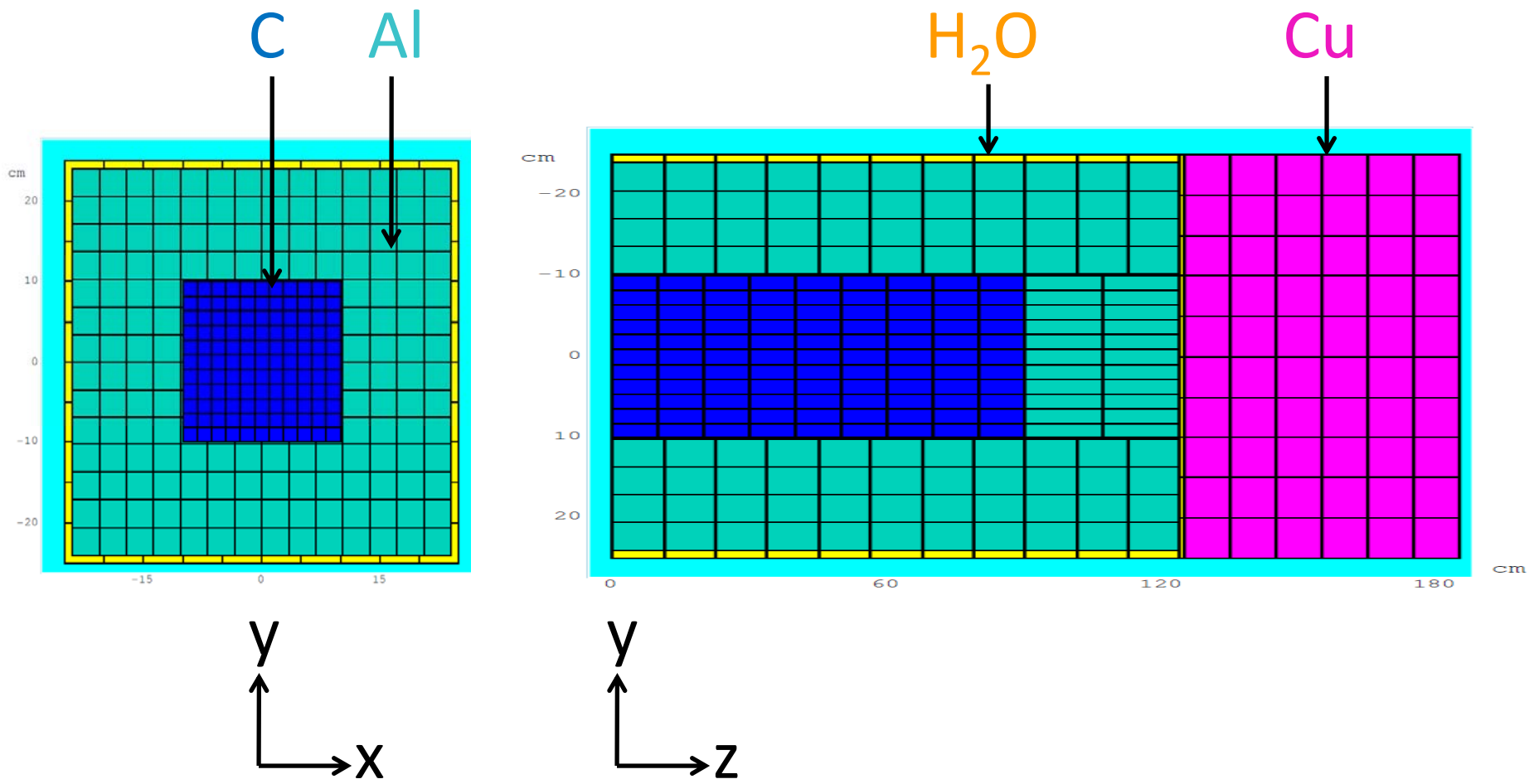
Graphite/Aluminum Contact Architecture



Thermal Analysis Approach

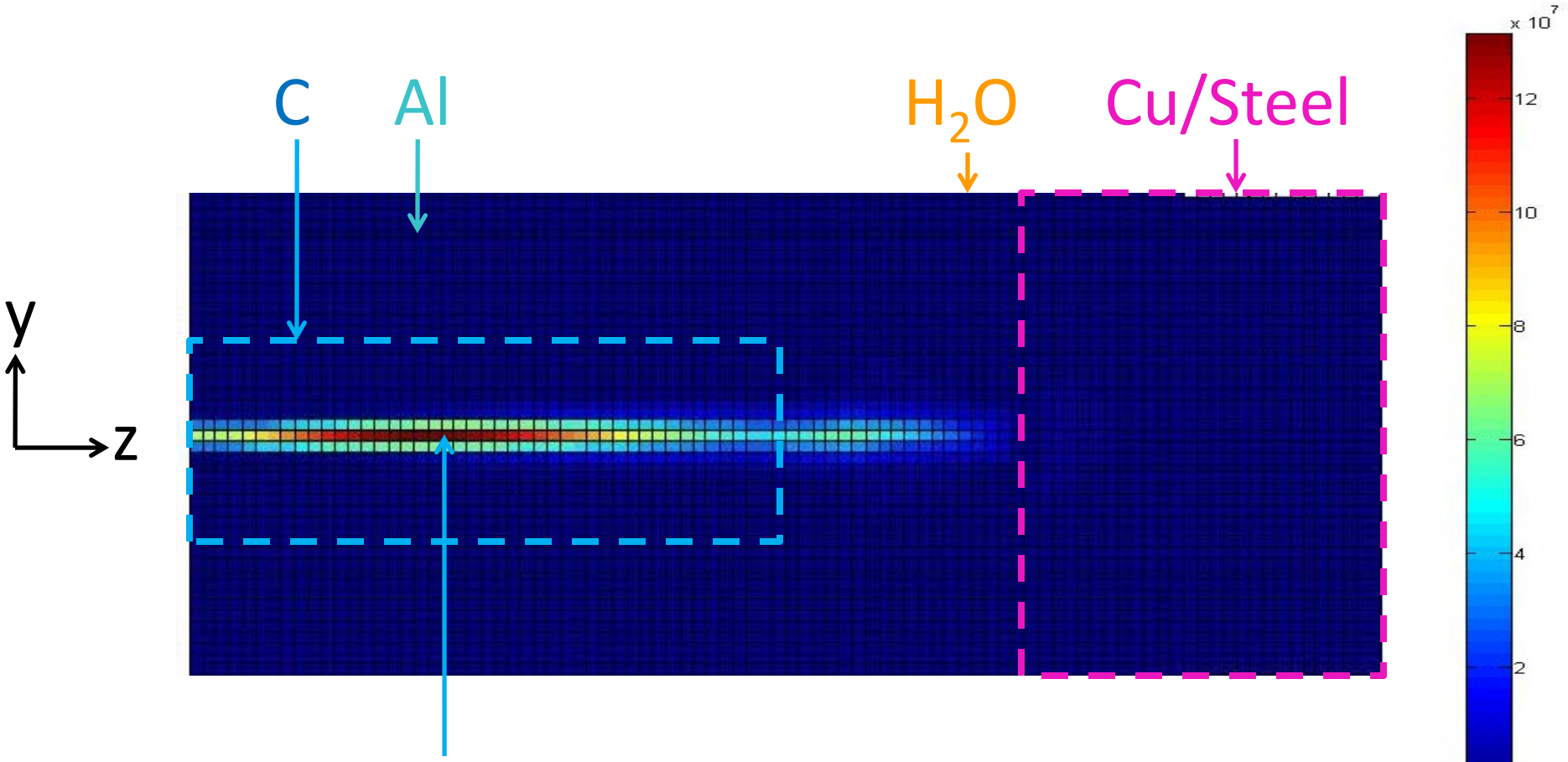
- Step 1: Process MARS results in Excel
  - Tabulate X, Y, Z and heat generation for each MARS element
- Step 2: Generate mechanical FEA models in NX/Ansys
  - Two meshes are used:
    - System Model: assess global effects
    - Axial Section Model: assess localized heating in graphite
  - Tabulate FEA mesh nodal and element XYZ locations
- Step 3: Interpolate MARS results onto FEA mesh in Matlab
  - Use MARS radiation damage estimates to assign material properties
  - Map heat generation results from MARS mesh onto arbitrary FEA mesh
  - Calculate heat generation at each FEA element
  - Generate Ansys text input using BFE/HGEN
- Step 4: Run Ansys to recover temperatures

MARS Model: (I. Rakhno)



MARS Results

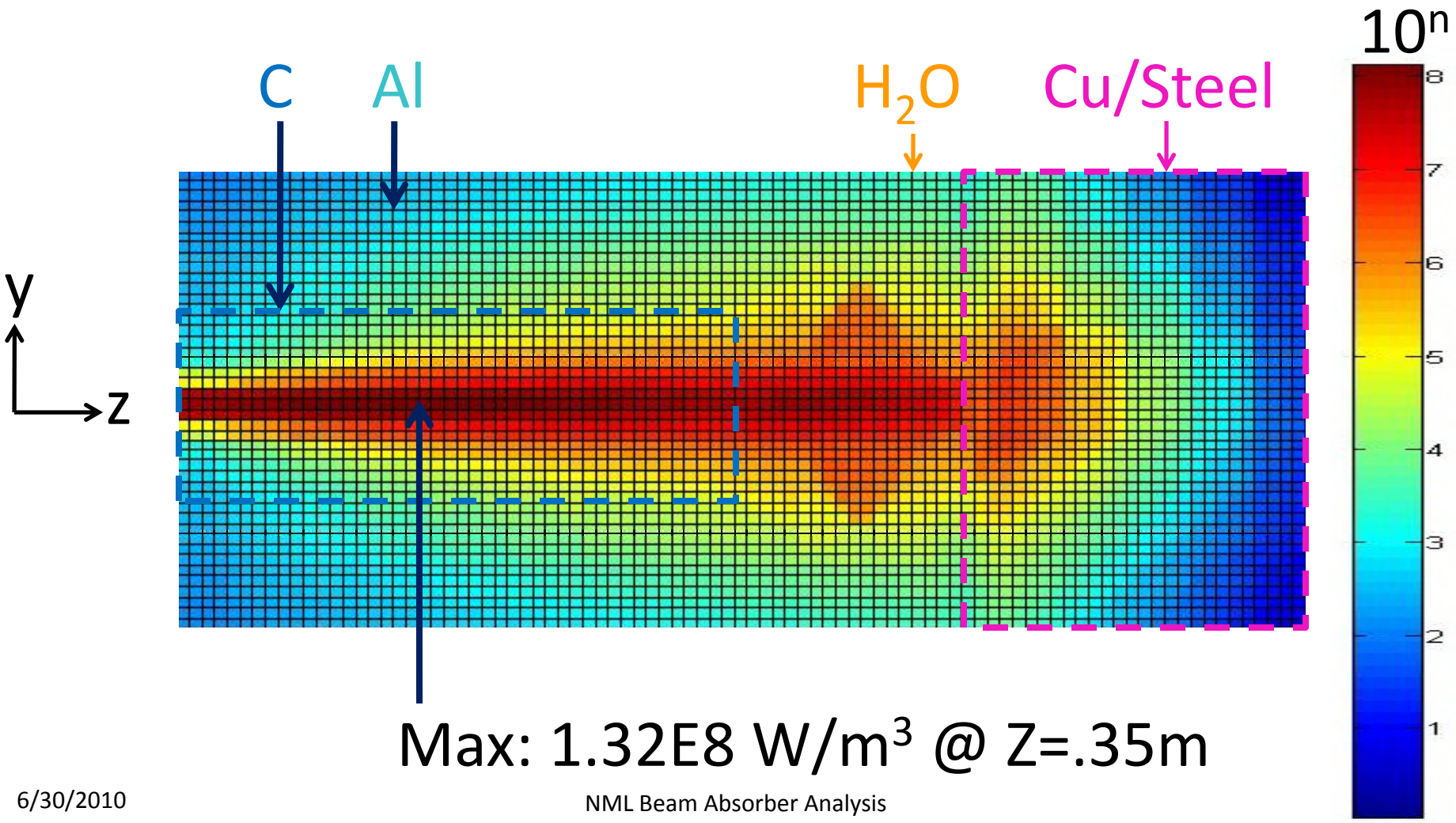
Heat Generation (W/m^3): linear color scale



Max: 1.32E8 W/m^3 @ Z=.35m

MARS Results

Heat Generation (W/m^3): log color scale



Max: 1.32E8 W/m^3 @ Z=.35m

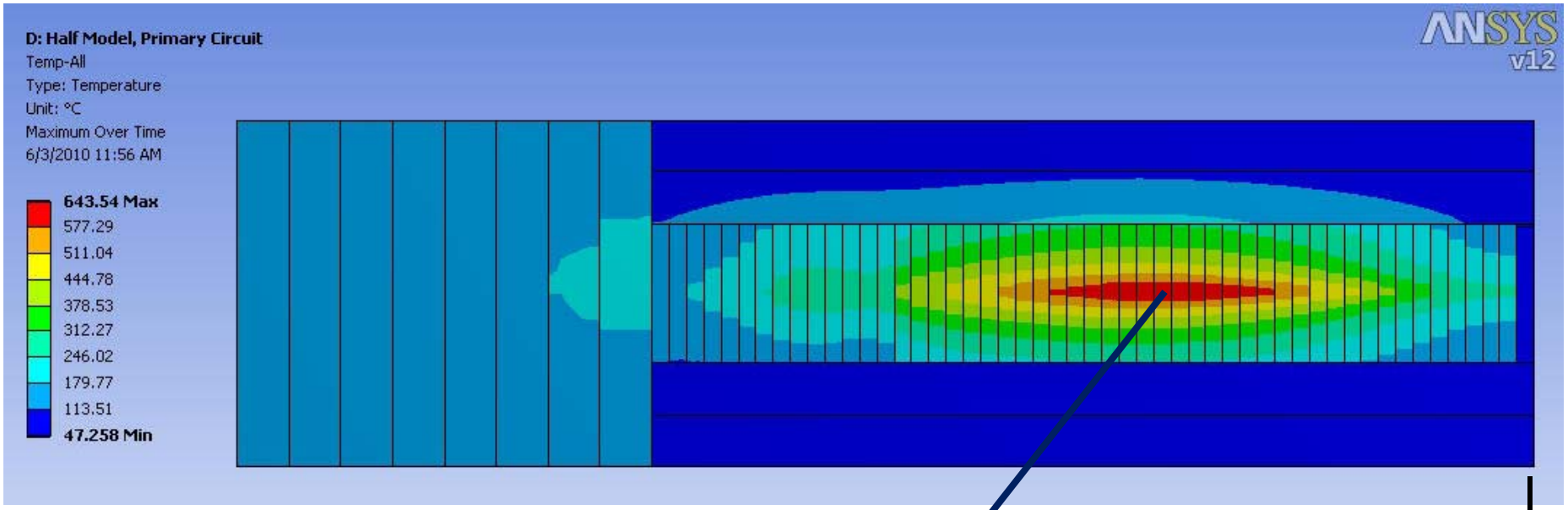
Steady State Analyses

- The steady state thermal analyses neglect the pulsed nature of the energy deposition, and assume constant and continuous beam power
- We use two sets of graphite properties:
  - Beginning of Life (BOL) – graphite properties not degraded by radiation damage (but still fully temperature dependant)
  - End of Life (EOL) – graphite damage categorized in bins, corresponding degraded material properties mapped onto the FEA mesh
- We further use two sets of beam conditions
  - Centered beam – the original, intuitive design concept
  - Off-center beam – implemented to distribute graphite damage and prevent catastrophic failure
- In general, the worst cases are off-center beams at EOL

System Model Steady State

Centered Beam @BOL

Maximum temperature in graphite and system



Z

Max Temperature in Graphite

643°C @ Z=.482m

Radiation Effects:
Graphite Thermal Conductivity Reduction

Example data

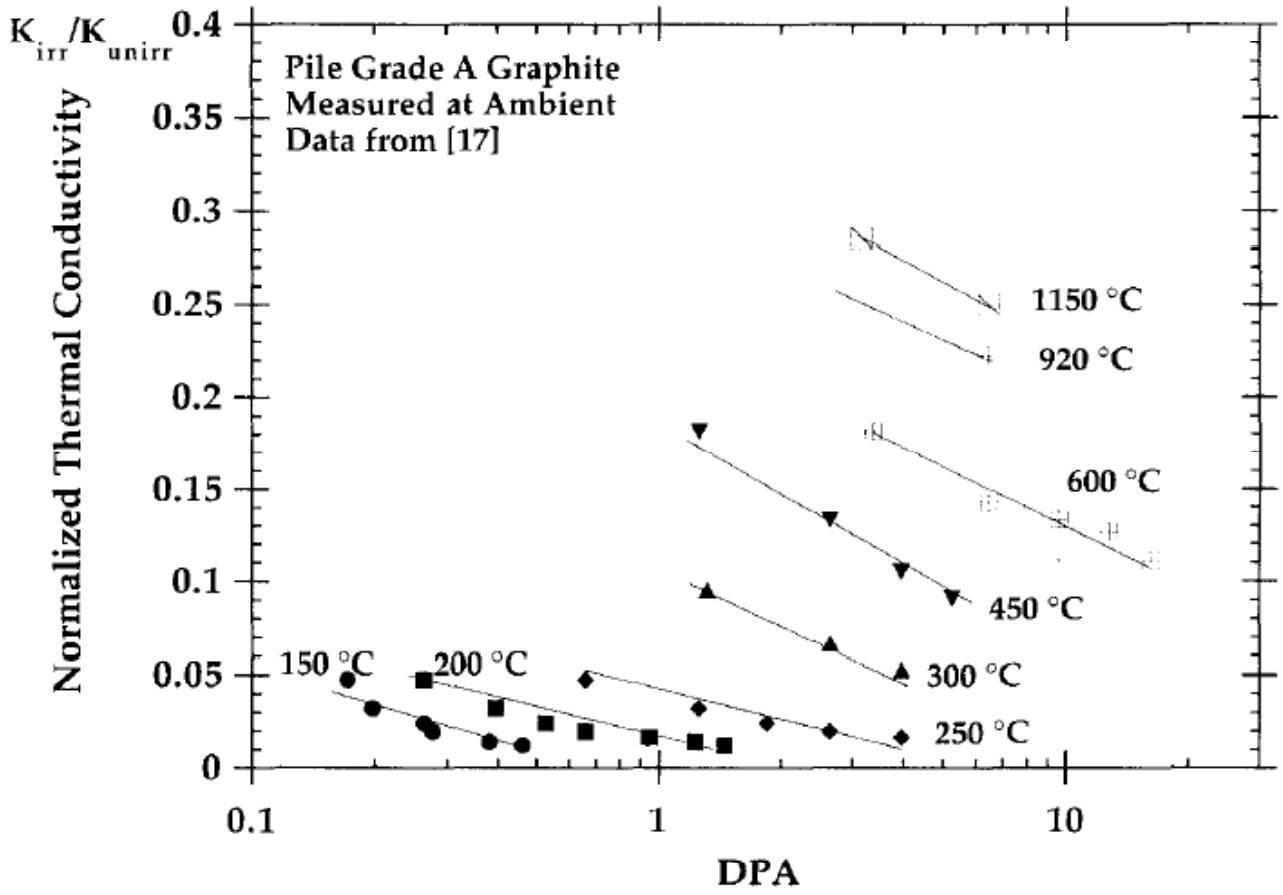
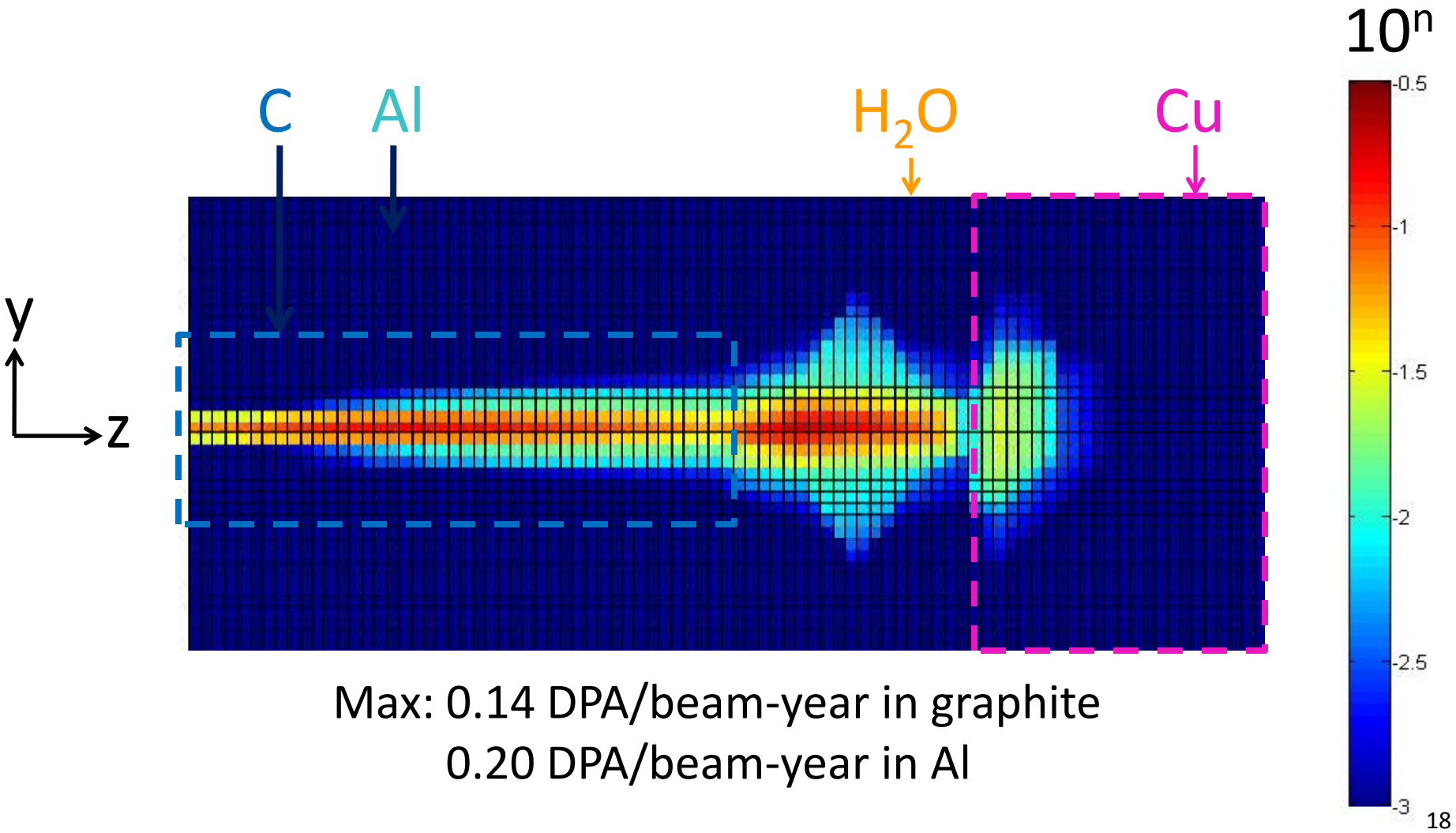


Fig. 5. Normalized thermal conductivity of pile Grade A graphite [17].

L. Snead, T. Burchell / Journal of Nuclear Materials 224 (1995) 222–229

MARS Results (I. Rakhno)

DPA/year for a stationary beam: log color scale

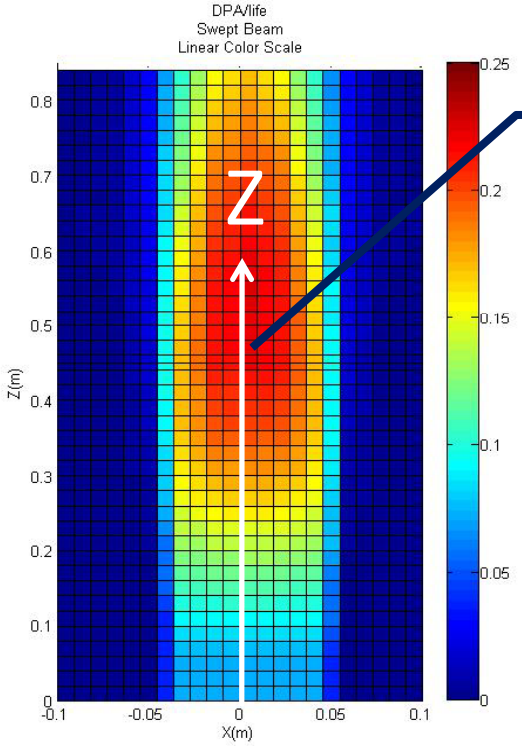


Max: 0.14 DPA/beam-year in graphite

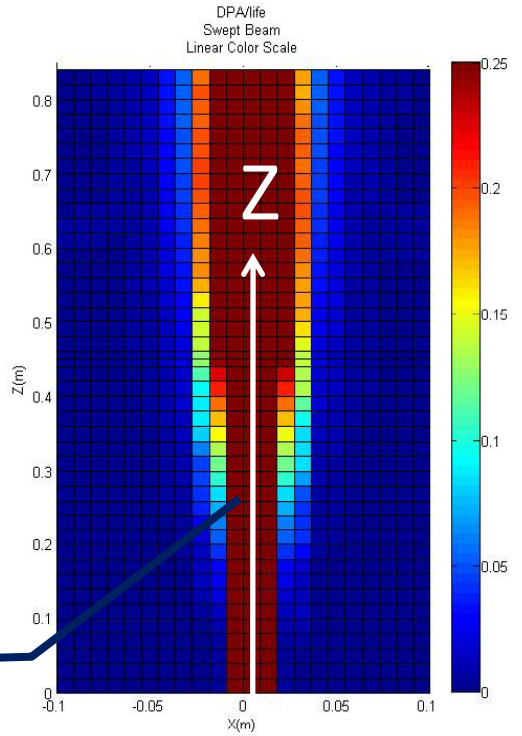
0.20 DPA/beam-year in Al

Cumulative Damage

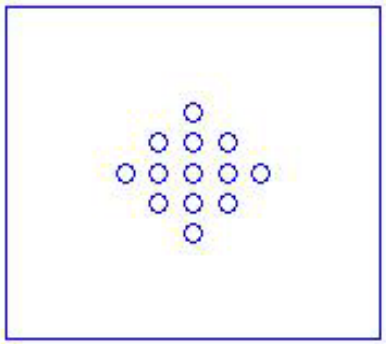
20years, 70% uptime, full beam power

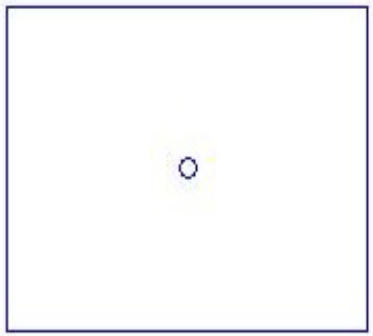


Distributed beam
Maximum damage = 0.22 dpa

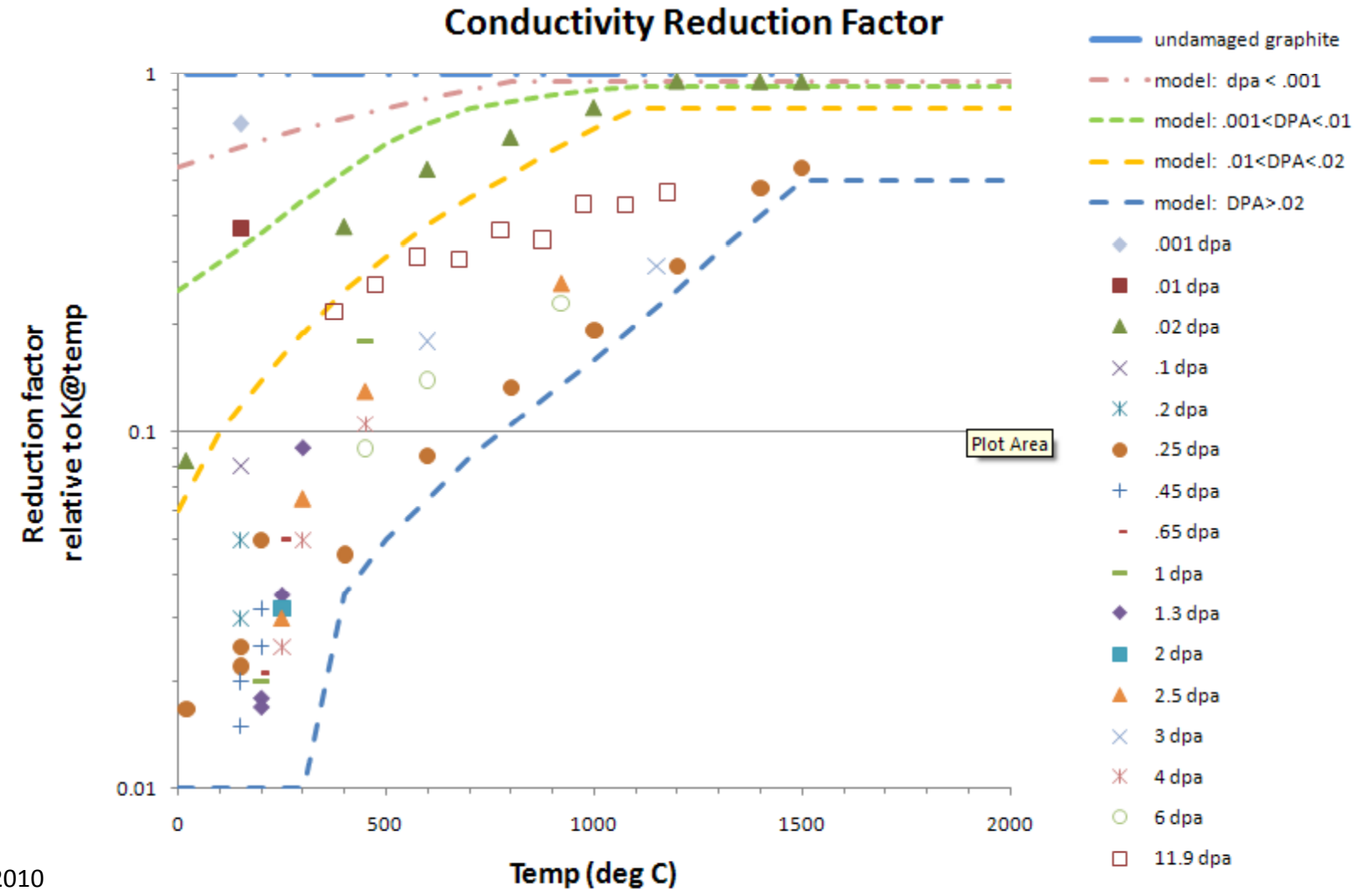


Stationary beam:
Max damage = 2.8 dpa
Maroon area exceeds 0.25 dpa damage threshold





Radiation Effects: Modeled k Reduction Factor



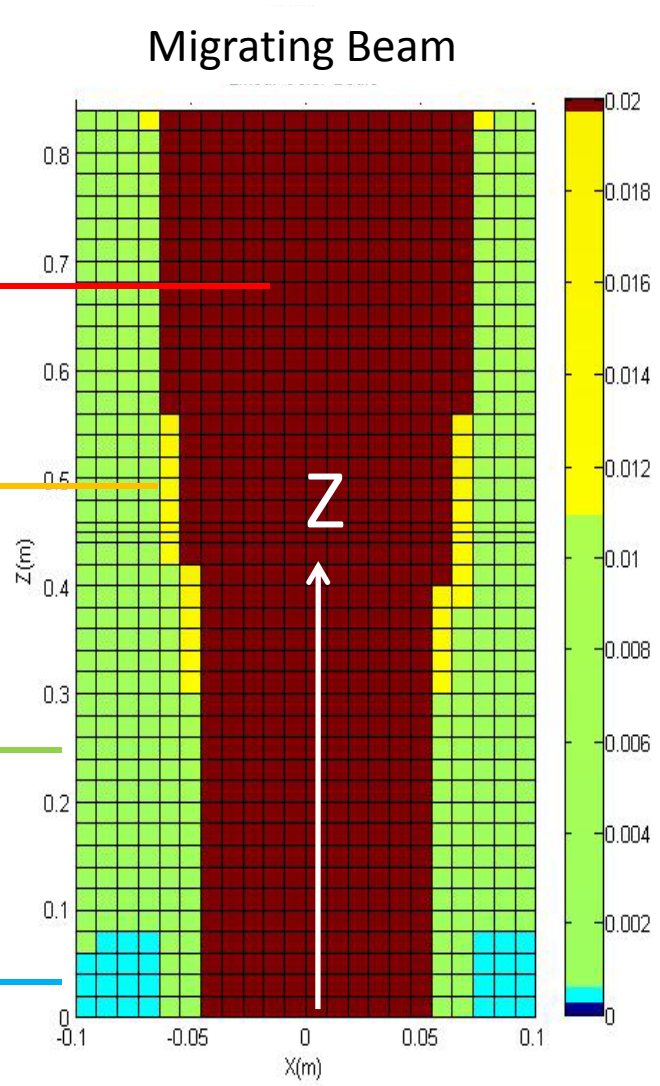
Mapping of k Reduction at EOL on Graphite Core

Material 205
Damage>.02 dpa

Material 204
.01< Damage <.02 dpa

Material 203
.001< Damage <.01 dpa

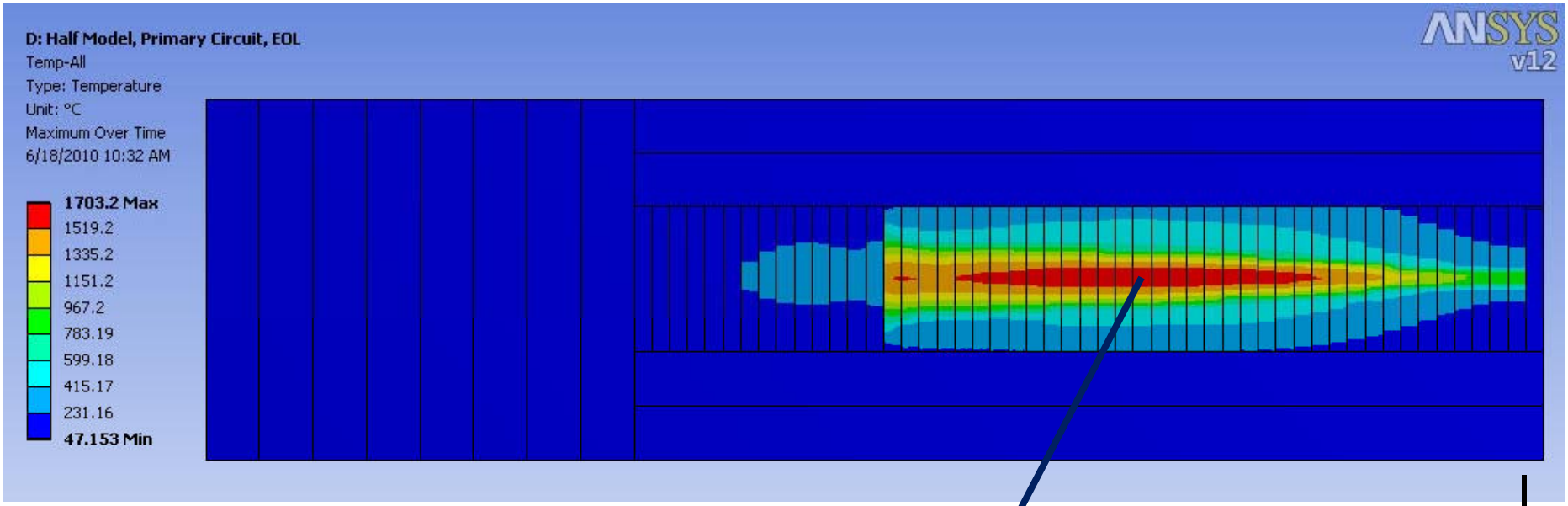
Material 202
.0001< Damage <.001 dpa



System Model Steady State

Centered Beam @EOL

Maximum temperature in graphite and system



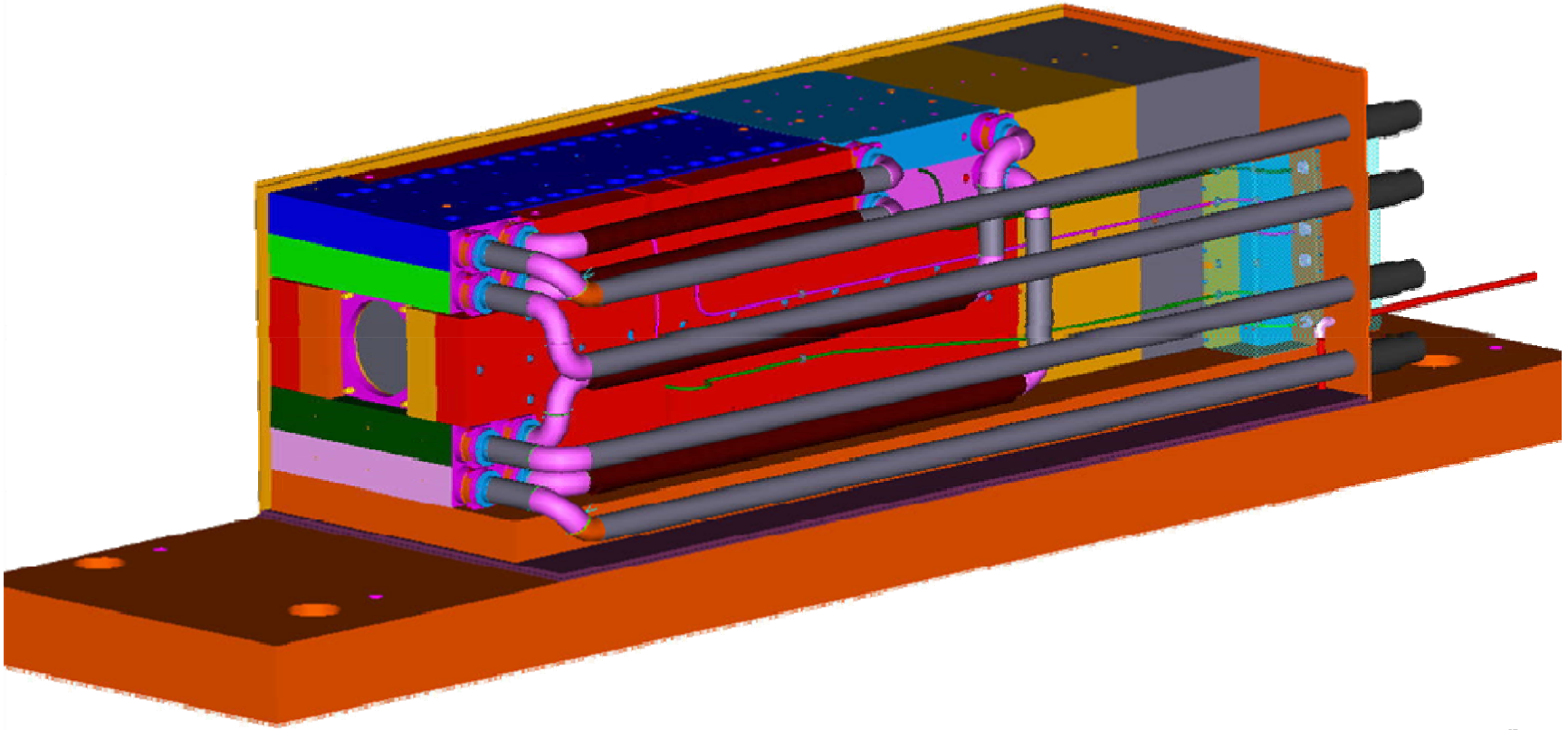
Z

Max Temperature in Graphite = 1703°C

(compare to 643°C @BOL)

Absorber Mechanical Design

- Based on the results and recommendations of the thermal analysis, a detailed mechanical design was completed



Absorber Mechanical Design

Absorber Mechanical Design

- Key design features
  - Contact pressure on graphite is maintained by large-deflection Belleville washers
  - Cooling channels are machined into aluminum plates
  - Transition from aluminum cooling plates to stainless piping is done using roll bonded transition pieces
  - Galvanic corrosion managed by redundant seal features, minimizing free area of stainless

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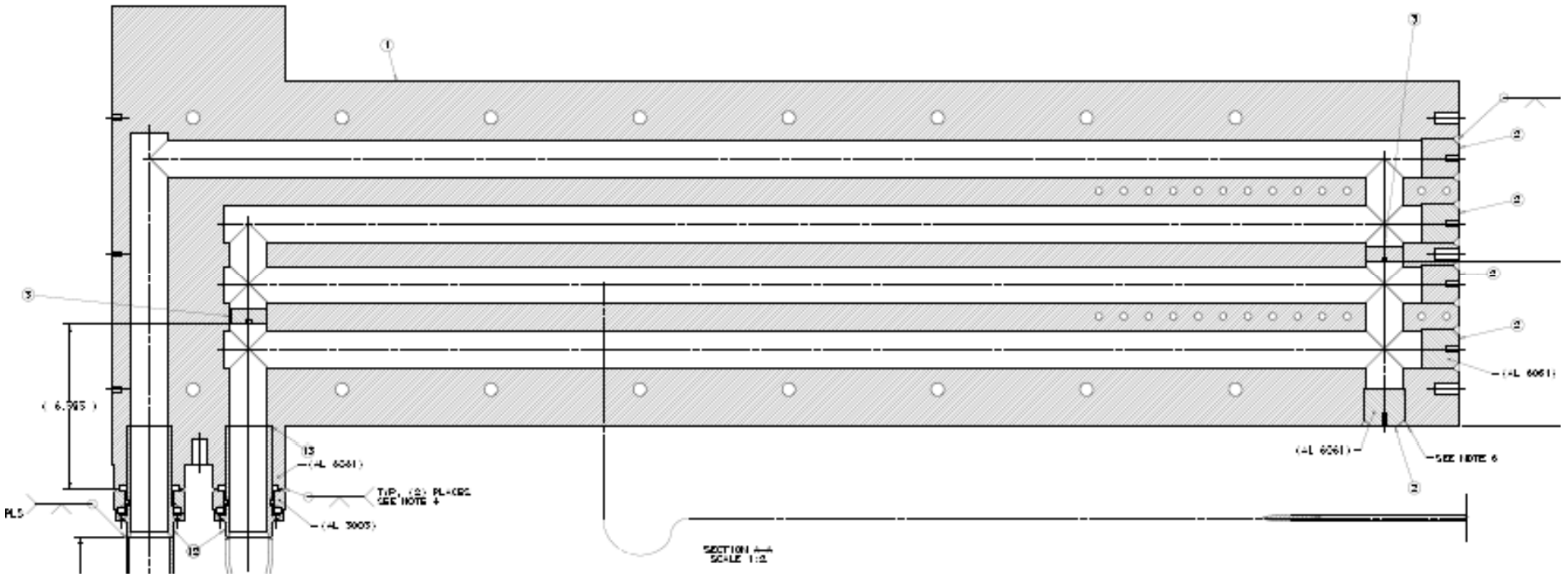
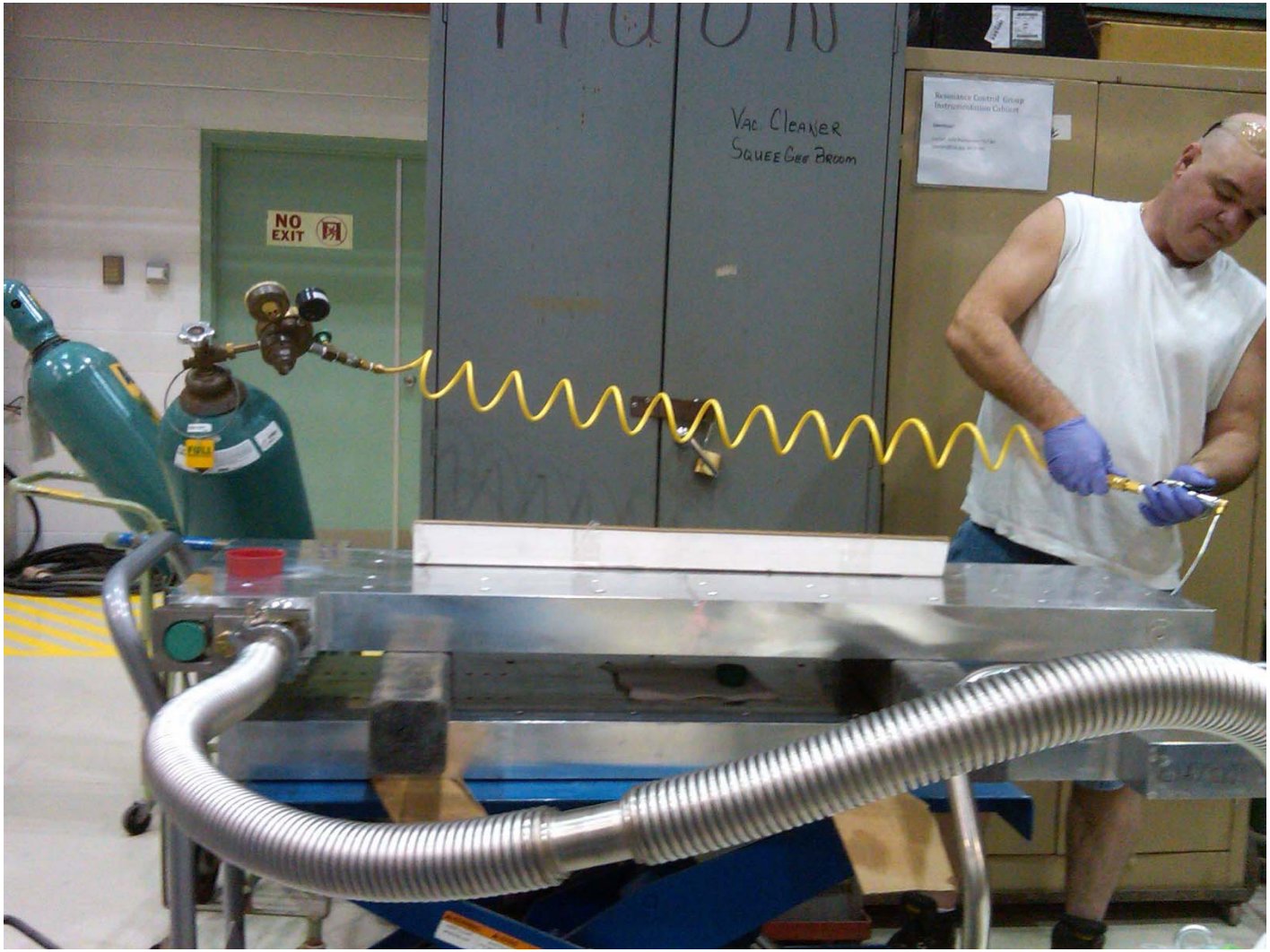
Component-Level Assembly and Test

- Much effort was put into meticulously assembling, sealing, and testing the individual cooling plates



Component-Level Assembly and Test

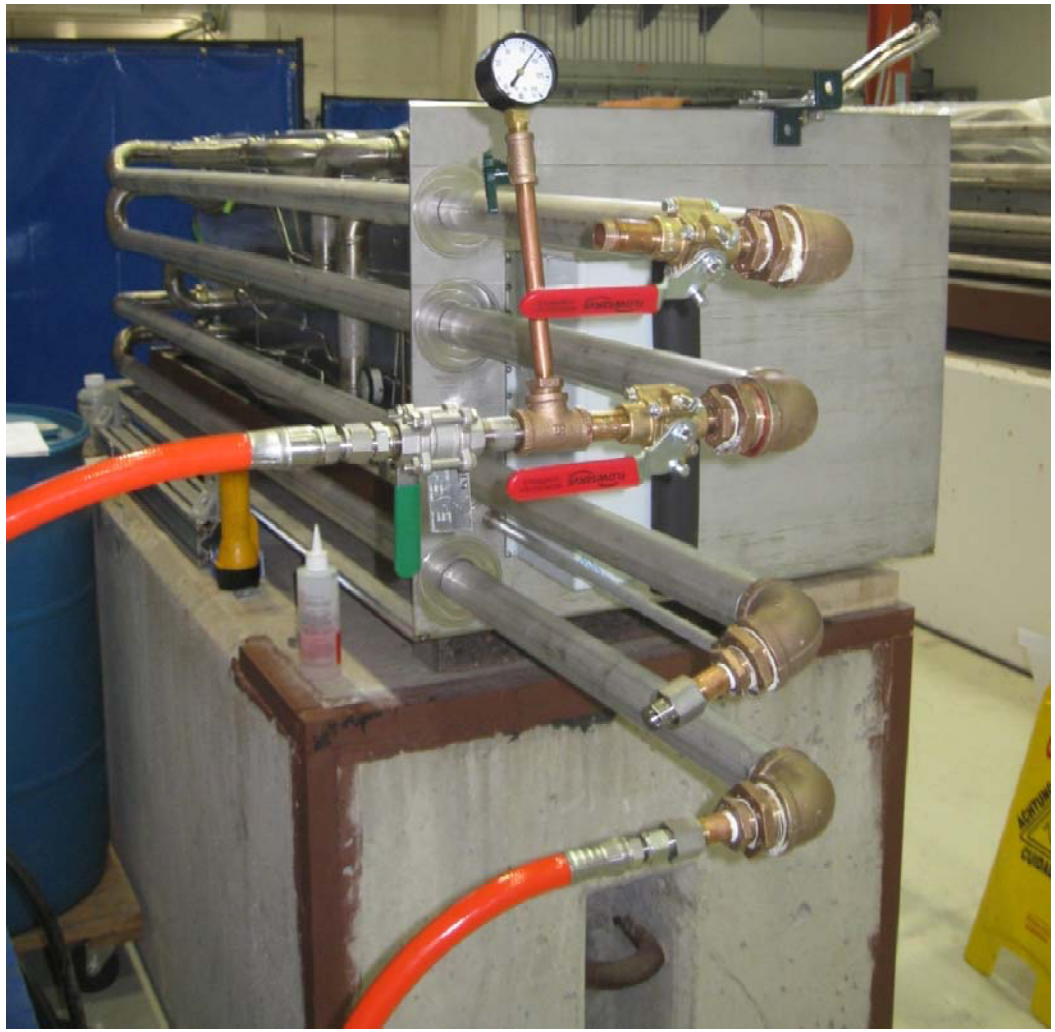


Assembly and Test

- Cooling plates were then assembled and interconnected via 1.5”-Schedule 40 stainless interconnect lines

Assembly and Test

- Completed plumbing circuits were then hydrostatically and pneumatically tested to ensure a leak-tight system



Assembly and Test

- In the final step of absorber assembly, a helium-filled enclosure will be constructed around the absorber cores.

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Dump Shielding Design

- The dump shielding was specified by the Church/Rakhno radiation design

- The shielding around the absorbers is 24’ X 20’ X 24’
  - ~570 tons concrete
  - ~620 tons steel

- Designed following established best-practices
  - seams, gaps carefully managed

Dump Installation Sequence

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Dump Shielding Installation

- The vast majority of the steel was obtained from the railhead
- Steel was measured, labeled, and cut to a common length

Dump Shielding Installation

Dump Shielding Installation

- The first phase of dump installation has been completed
- Second phase awaiting absorber completion

Dump Shielding Installation

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Status

- The assembly of the individual absorbers is nearly complete
- After the helium enclosures are welded and tested, we will install the absorbers in the dump
- Task completion this fall