NSTX NBI In-Vessel Armor

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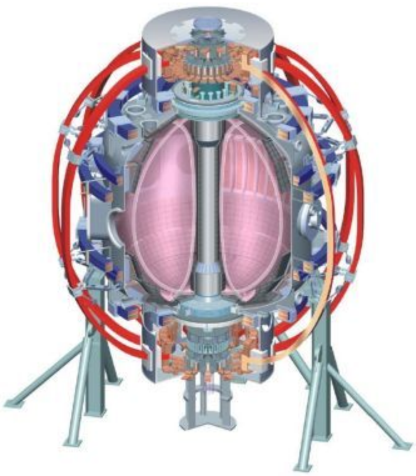
Kelsey Tresemer

NSTX Upgrade Project
Conceptual Design Review
LSB, B318
October 28-29, 2009



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ENEA, Frascati
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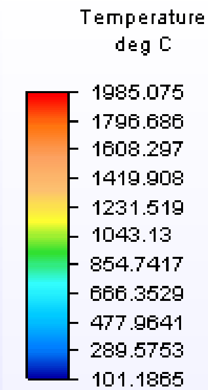
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

Armor Design: the Starting Point

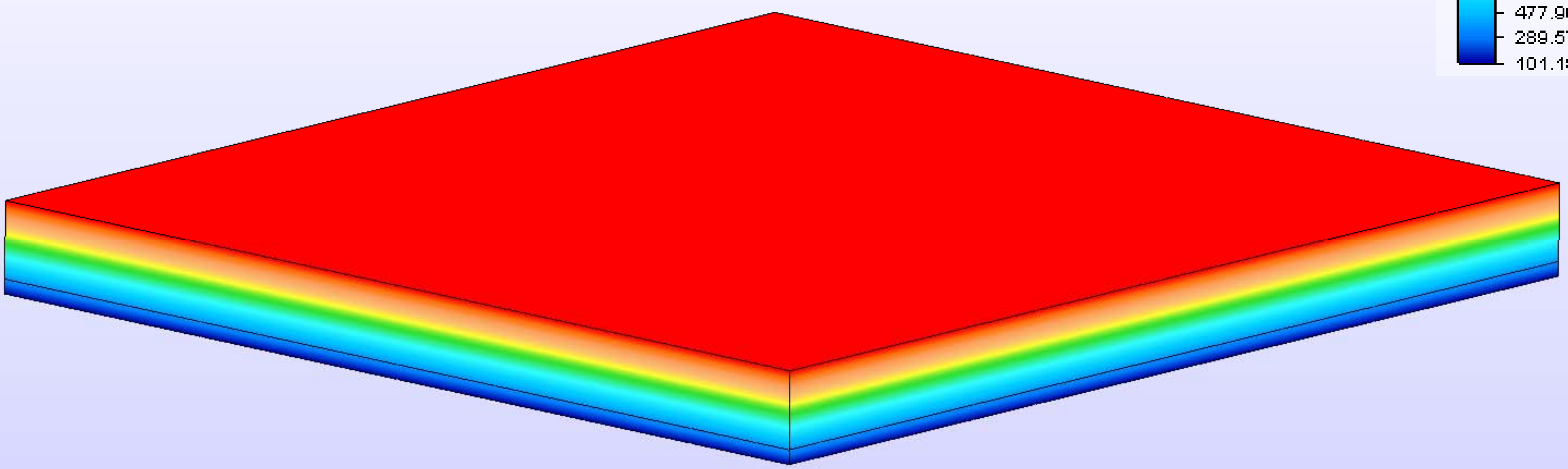
- Previous FDR armor specifications
  - 1 Beamline, 3 Sources
  - Material: Isothermal graphite or ATJ
  - Existing cooling provided with 4 loops at 3.6 GPM, each
  - Conditions of Design:
    - Bakeout temp: 350 deg C
    - Worst Case “Fault”: 2.8 kW/cm^2 for 0.75 second
      - Thermal analysis results for “Fault”:
        - » Max temp = 1985.07 deg C
        - » Max tensile stress = 109.5 MPa
        - » **Our Baseline**

Transient Thermal Analysis Results

ALGOR



- Worst Case “Fault”: 2.8 kW/cm2 for 0.75 second
- Max Temp: 1985.075 deg C



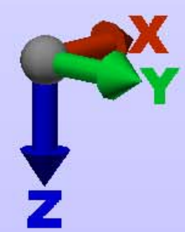
- This shows results of “Fault” conditions. Deemed permissible by previous FDR. Tile surface would be compromised, requiring inspection.

Time: 3.1 s

Time Step: 31 of 100

Maximum Value: 1985.07 deg C

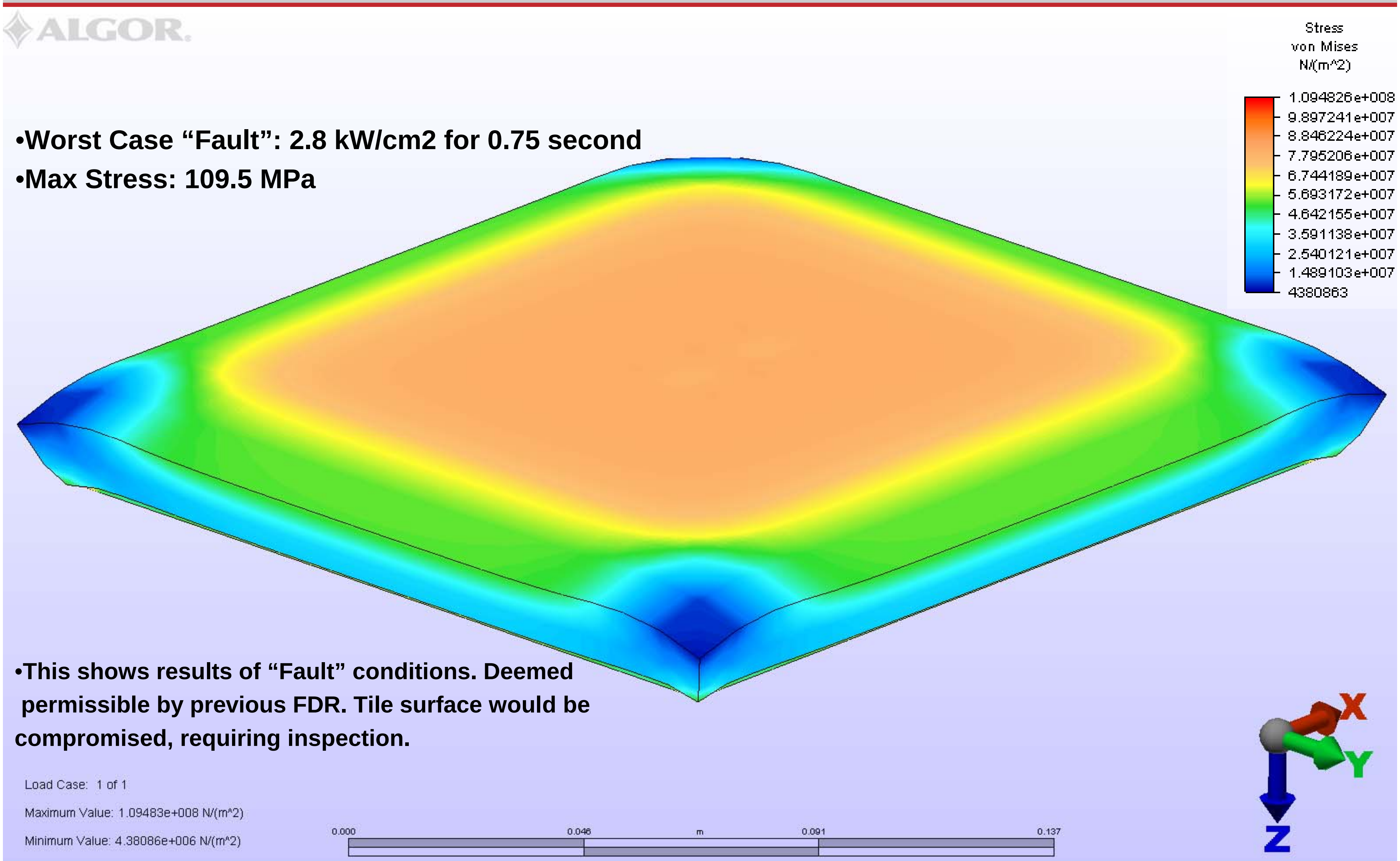
Minimum Value: 101.186 deg C



Stress Analysis Results

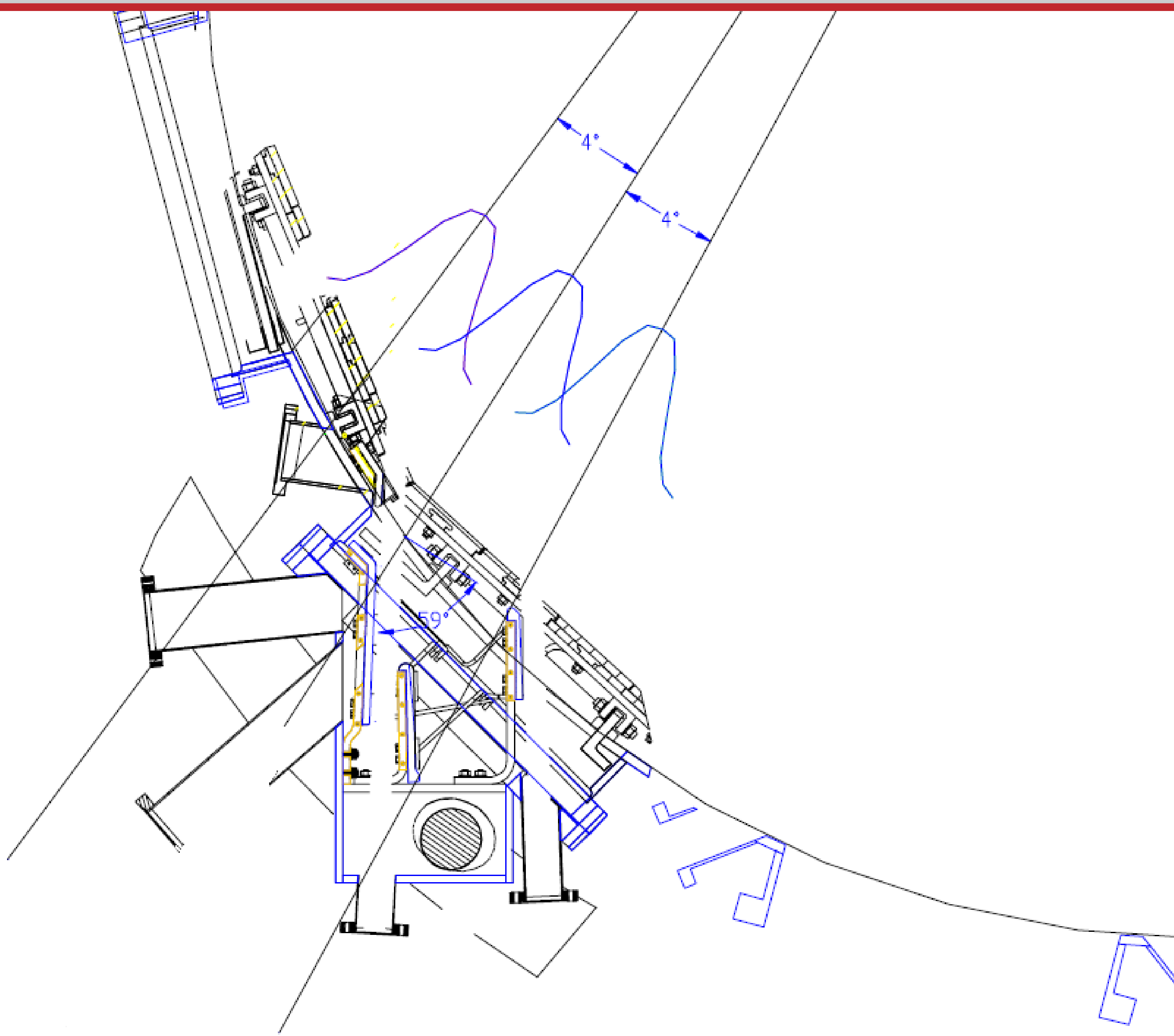
•Worst Case "Fault": 2.8 kW/cm2 for 0.75 second

•Max Stress: 109.5 MPa



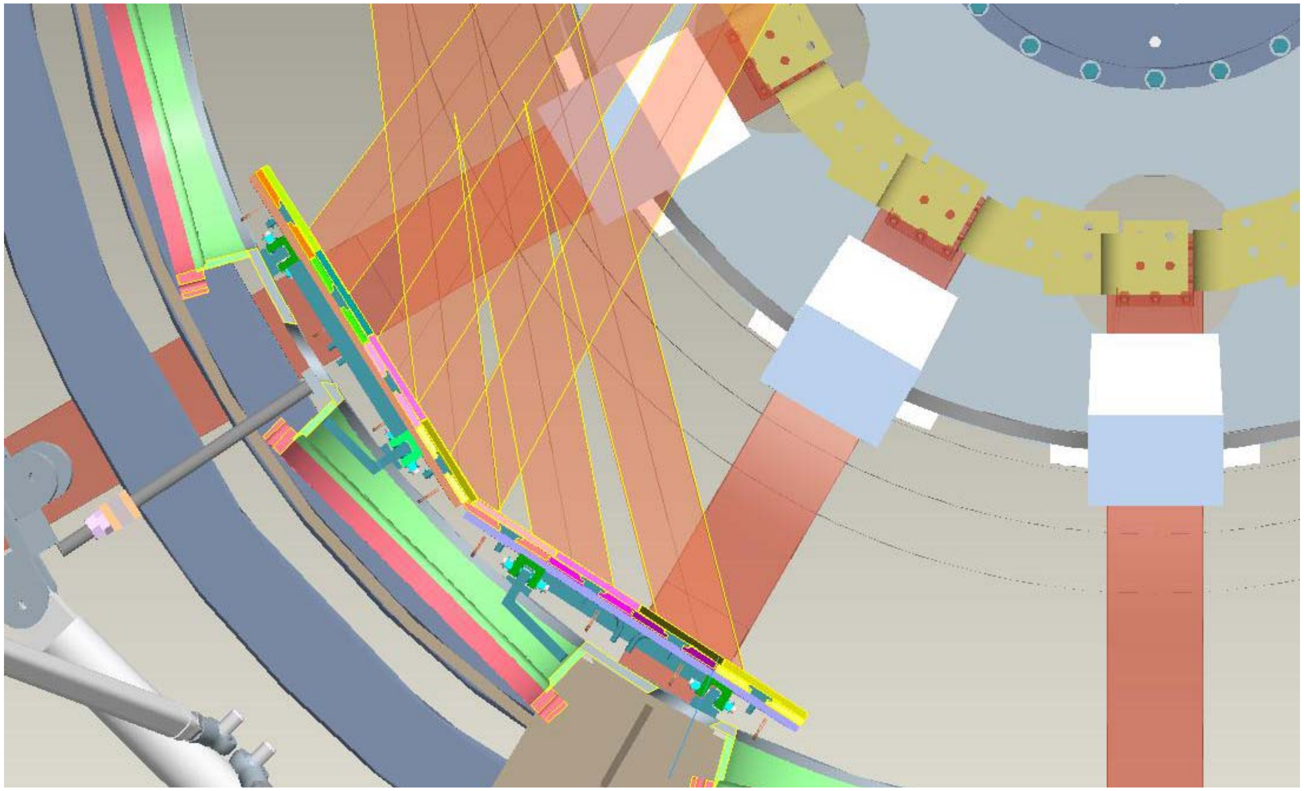
•This shows results of "Fault" conditions. Deemed permissible by previous FDR. Tile surface would be compromised, requiring inspection.

Current Beamline Placement



Armor Upgrade: Pulling Double-Duty

- 2 beamlines, 6 sources
  - » Tangency radii per GRD
  - – Use the existing armor array
    - Shift array counterclockwise to catch both sources

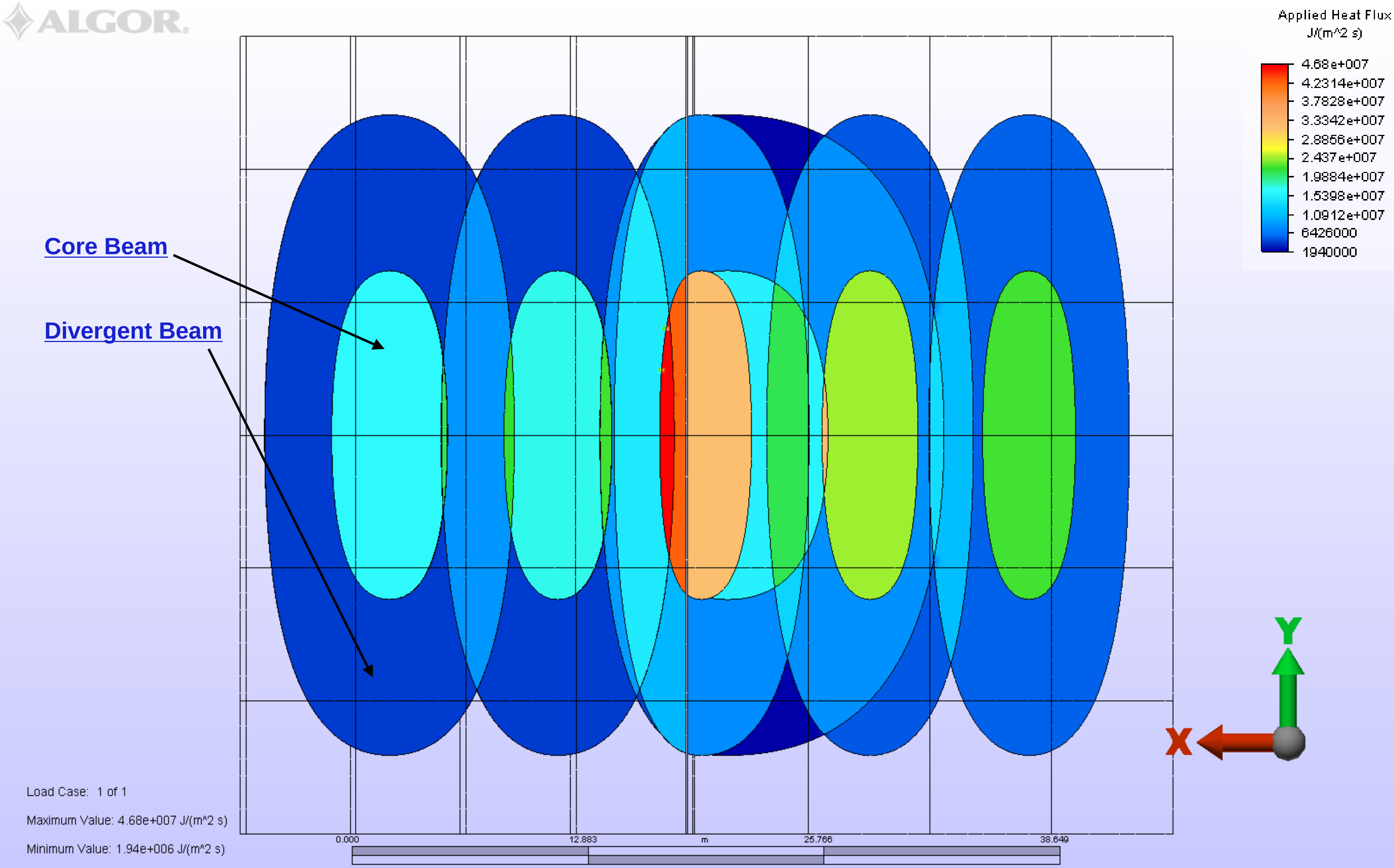


Evaluating Current Armor for Relocation & 6 Sources

- Both beamlines on armor
  - Look at Beam “Footprints”
    - Shows spread of beams, (x and y directions)
  - Compare with projected beam overlapping
    - Core Beam = 80% total beam power
    - Divergent Beam = 20% total beam power
      - Sufficient Clearance!
- Check overlapping heat loads
  - Ran test cases and compared against earlier “Fault” case
      - Design for this case, improve armor in other ways.
- Between-shot cooling required for pulse rate of 1200s
  - Original cooling lines designed for 900s

Existing Armor: Beam Footprints

New Armor: Applied Beam Heat Flux



New Armor Thermal Analysis

- Tested worst case (2 source, full power, overlapping) in ALGOR using a simple tile and various pulse lengths

Pulse length (s)	Heat Flux (W/m^2)	Max Temp (deg C)	Von mises (Mpa)
1	4.68E+07	4439.80	252.00
0.75	4.68E+07	4038.46	220.00
0.5	4.68E+07	3387.69	179.00
0.25	4.68E+07	2622.07	134.00

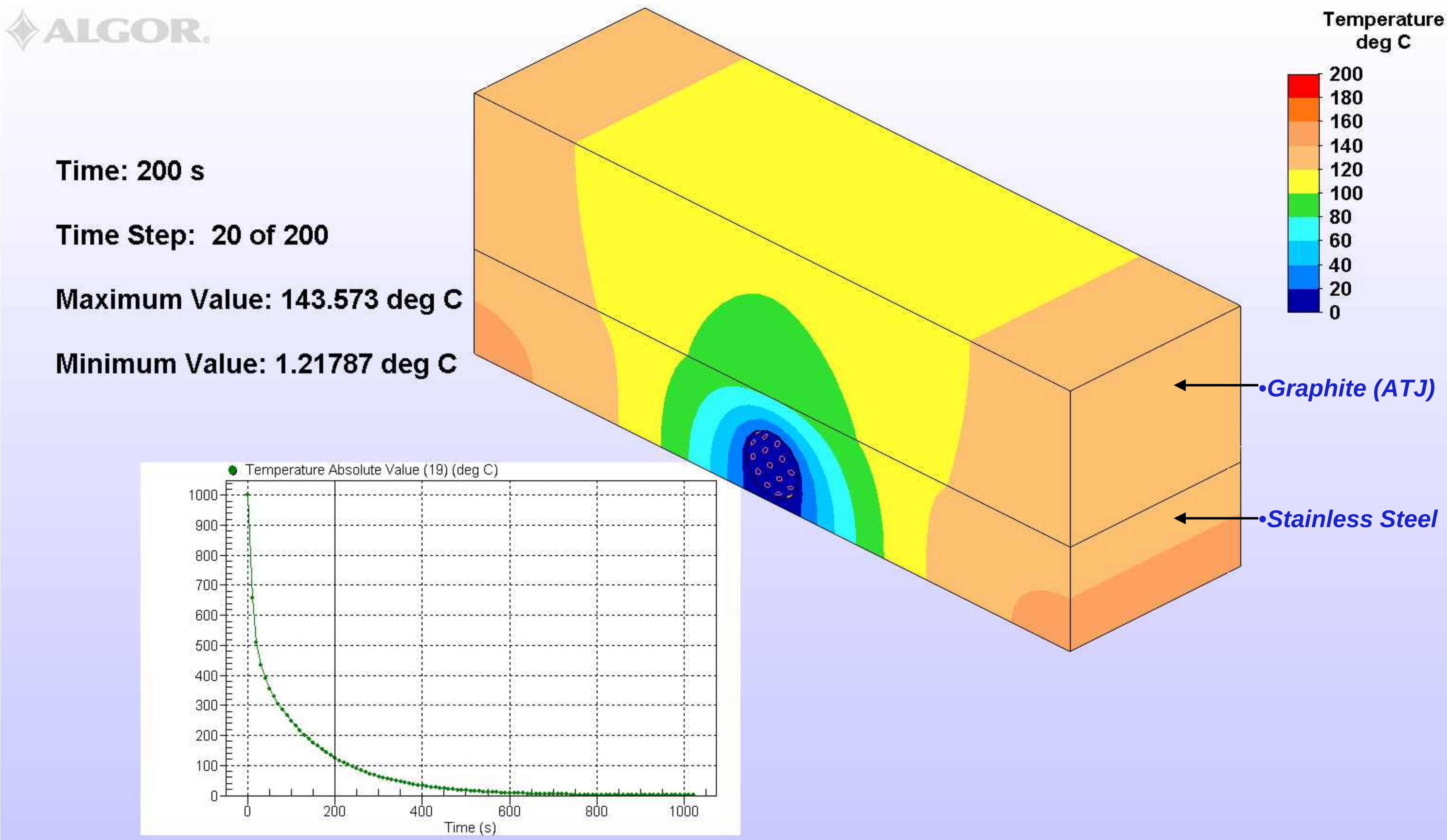
- The results dictate shot conditions. We shall take precautions not to allow a full-power "Fault" beyond 0.25 s
  - Provide a redundant plasma current interlock (beams run w/ plasma only)
  - In-armor thermocouples will be monitored to ensure between-shot cooling
  - Provide mid-plane material in backing plate in hot zones
  - Change armor tile material to CFC in hot zones
    - » ATJ sufficient in cooler regions

- "Fault" condition is unlikely, but if occurs, armor will survive, but will require physical inspection

Thermal Analysis for Between-Shot Cooling

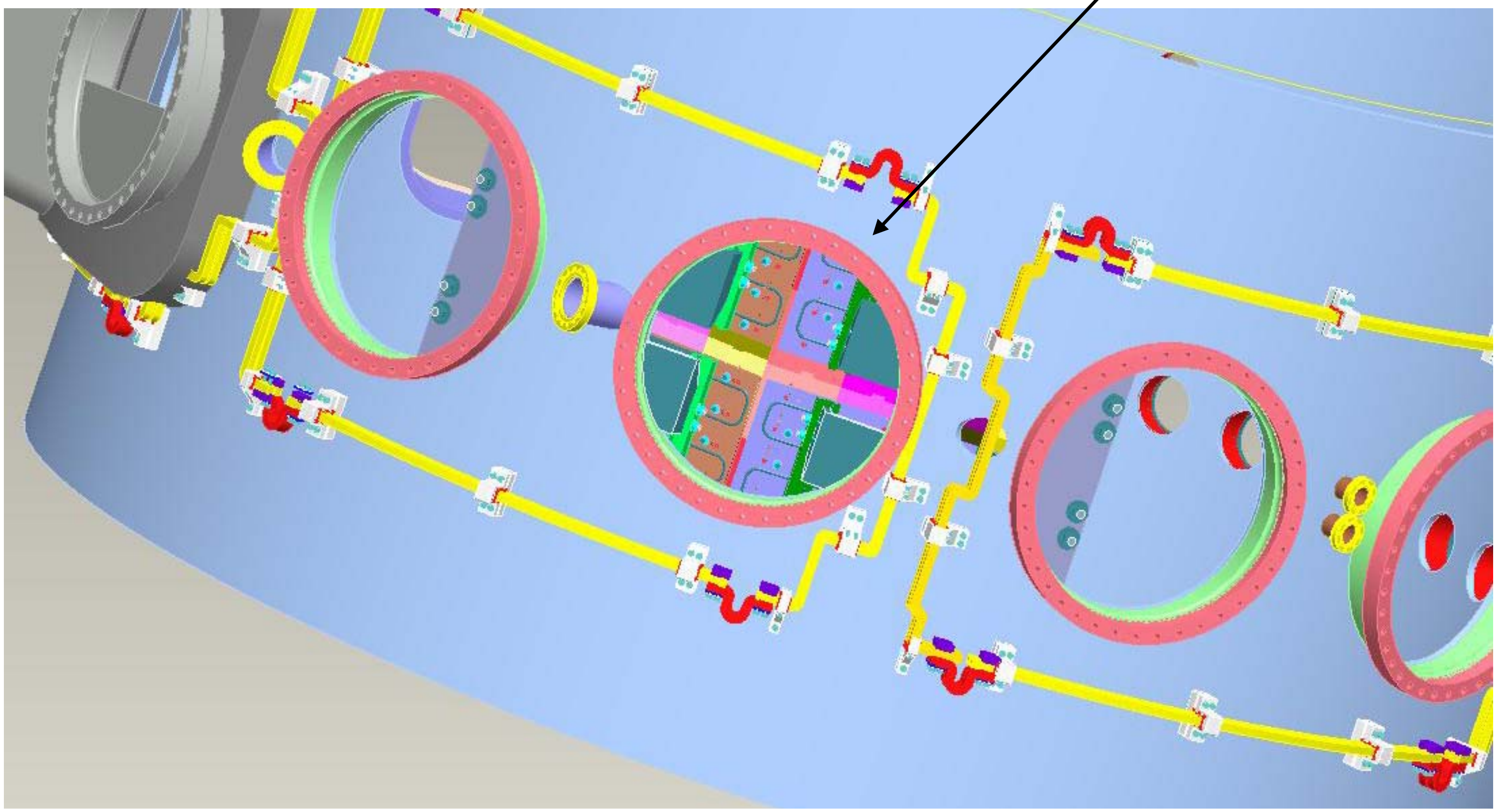
- Worst case heat load on tile and backing plate
  - Ran test sample in ALGOR, simple shape
    - “Back of the envelope” Analysis
    - 3”x1” slice of armor (tile and backing plate), 3/8” cooling tube, 20 minutes between shots
    - Determined time constant for cooling
  - Preliminary results suggest cooling system adequate for in-between shot cooling
    - More tests needed to confirm. Numbers will be updated for FDR as analyses are completed

Thermal Analysis for Between-Shot Cooling



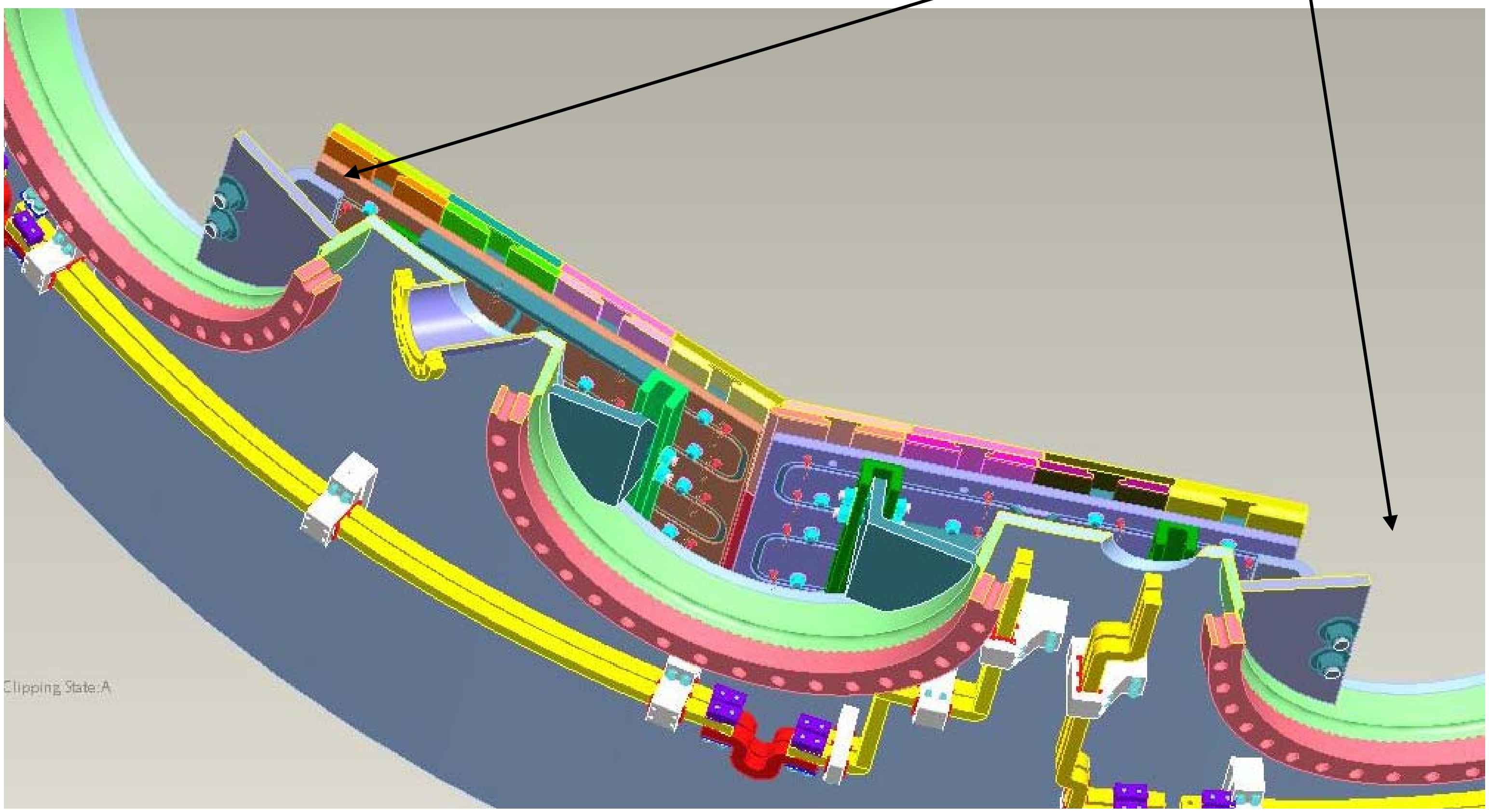
New Armor: Vacuum Vessel Mounting

- Improving existing design for accessibility.
  - After move, armor is now nearly centered on bay H
    - Provides access to center mounts



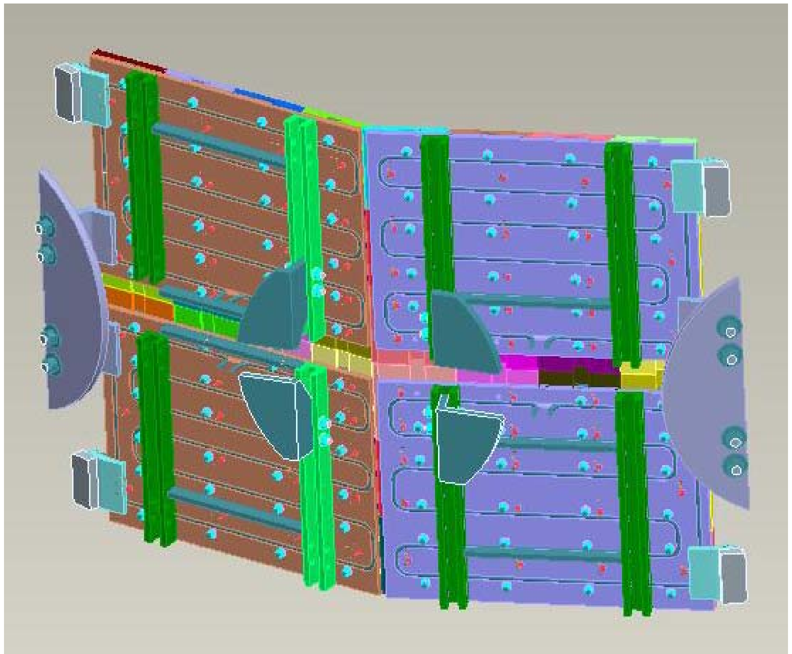
New Armor: Vacuum Vessel Mounting

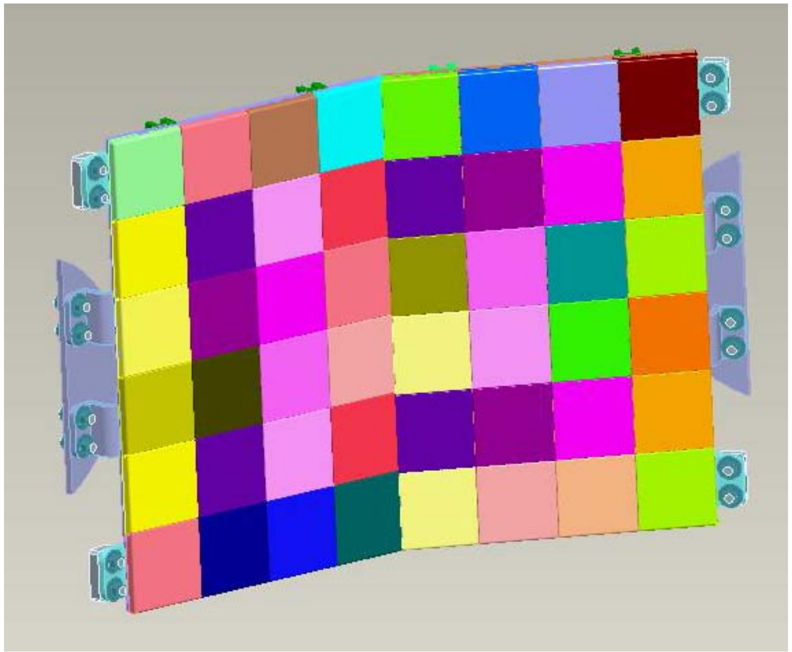
- Improving current design for accessibility.
  - Can access sides of backing plates through Bays I and G
    - Improves access to mid-plane mounts



New Armor: Vacuum Vessel Mounting & Loads

- Mounting scheme results in 16 mounting points for armor
  - Previous FDR disruptive loads on armor = 214000 lbs, radially
    - 13,375 lbs/mount
  - Assume 2X for upgrade
    - 26,750 lbs/mount
      - » These numbers need to be updated for PDR as analyses are completed





In Conclusion…

- We are going to….
  - Relocate existing armor array to accommodate all 6 sources
  - Armor tile material improvement to CFC for hot zones
  - Add backing plate supplementation
  - Provide engineering and administrative control to avoid "Fault"
    - Redundant IP interlock
  - Verify re-use of cooling system for upgrade
  - Improve armor mounting points for accessibility and increase in mechanical forces