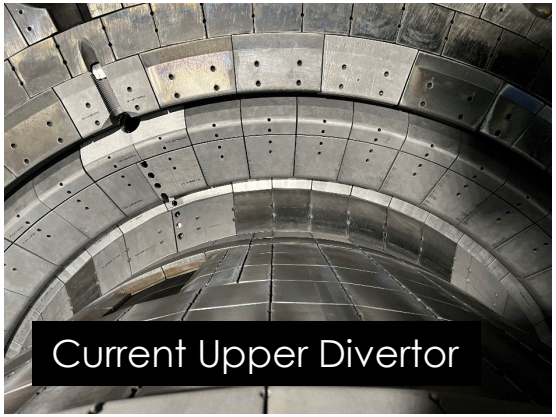
DIII-D Wall Change Engineering Scope

June 12, 2024

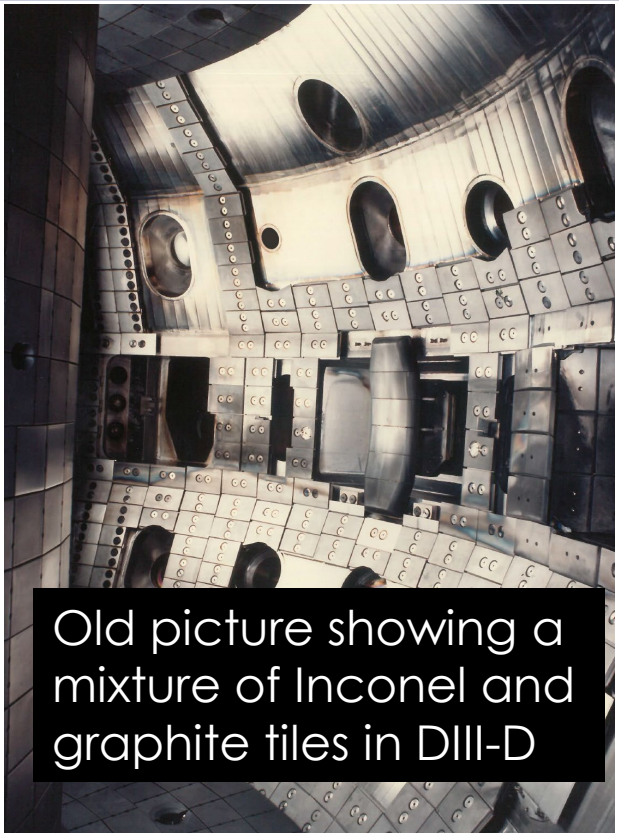
DIII-D Basics

- **The DIII-D Vacuum Vessel is an Inconel Tokamak with water-cooled walls**
  - Currently, all limiting surfaces are graphite/CFC
  - Divertor structures are water-cooled Inconel plates or copper pedestals attached to the cooled wall
  - Initial tiles were Inconel and graphite tiles were introduced in stages

Current Lower Divertor



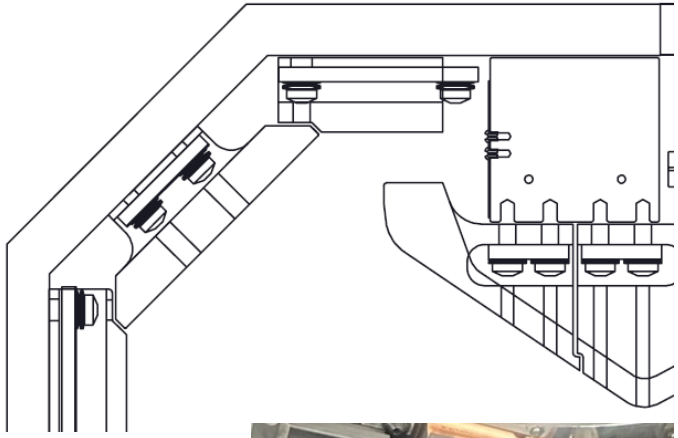
Current Upper Divertor



Old picture showing a mixture of Inconel and graphite tiles in DIII-D

DIII-D Basics

- Inconel studs are spot-welded to the vacuum vessel walls/divertor structures and used as attachment points for tiles
- Grafoil is used as a compliant layer between tiles and the vessel wall/divertor structures
- Nut-bars are attached to the studs and hold tiles against the walls/structure



Upper Divertor Copper Pedestals

Studs, Grafoil & Nutbars

DIII-D Wall Change

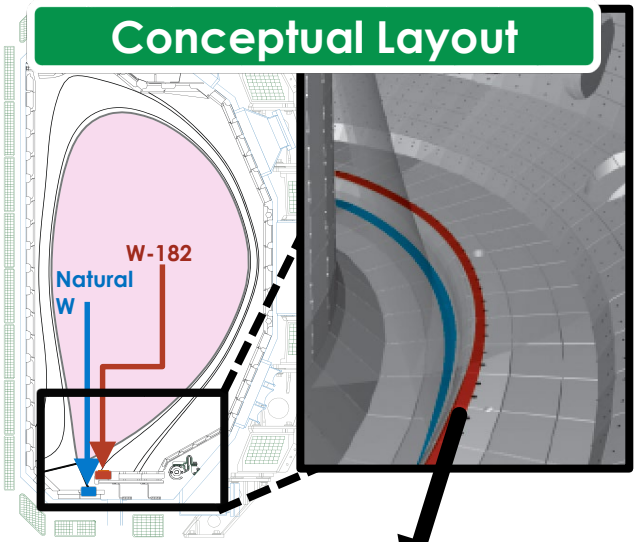
- **Implementation of a full wall change in FY27 for operation in FY28**
- **At the beginning of the full wall change vent in FY27, the lower outer Neg-T divertor is scheduled to be in place**
  - We are investigating options where we would remove the Neg-T divertor and re-install the previous lower outer divertor and have the upper inner divertor in the SVR (Shape Volume Rise) configuration (as it is right now)
- **Approximately 3000 graphite tiles cover the vacuum vessel Inconel wall**
  - We are investigating options to use 5mm solid tungsten (mounted to graphite) in the upper and lower divertor areas and to have the tiles in the non-divertor regions coated in SiC
  - An open question is if areas of the vacuum vessel could be uncovered (as they were many years ago) which would leave the exposed Inconel wall in some places

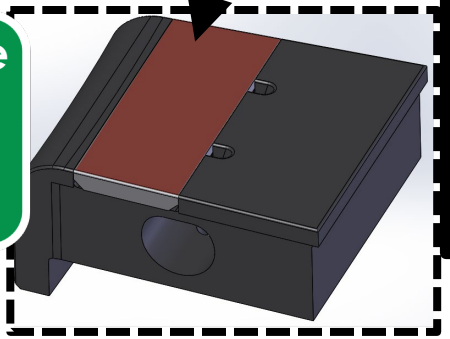
Wall Change Engineering Challenges -Alignment

- **Alignment of tiles likely to be more critical as leading edges will likely lead to exposed graphite (when coatings erode) or significant high-Z impurities from solid W leading edges**
  - Leading edge tolerances we can/have achieve (flat vs curved) (0.5mm/1.0mm) The lower divertor surface is aligned within 0.1mm, but this is likely not repeatable on more complex geometry
  - Vessel armor may be built in larger sections that could reduce the number of pieces to align, but this would be a new design effort
  - Graphite tiles have allowed for in-situ modifications to allow for closer plasma facing surface alignment, this would not be as straightforward with coated tiles or 5mm solid W
  - We may need to consider fish-scaling (single direction operation) to minimize leading edge impact
- **Alignment on simpler shapes (flat divertors) is more easily achieved, some geometric simplification (simpler divertor shapes) could be explored to facilitate better alignment**

DIII-D 2016 Metal Rings Campaign (MRC) used 2 isotopically distinct W Sources Localized at 2 Locations in Outer Lower Divertor Region

Conceptual Layout





Graphite Tile + Metal Insert

- For 2016 brief campaign, TZM inserts retrofit into existing graphite tiles

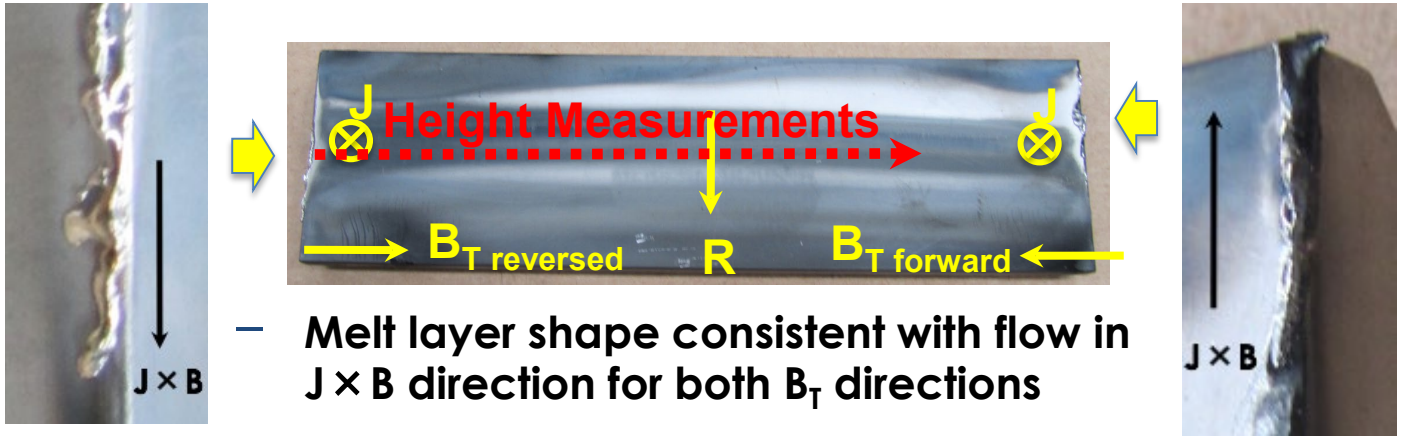
"Floor" Ring
W Coating:
~12μm (up to 40μm)

"Shelf" Ring
W-182 Coating:
2μm (+/-1)*

DIII-D W Tile Arrays

Isotopic ratios resolved via ICP-MS (Donovan, next talk)

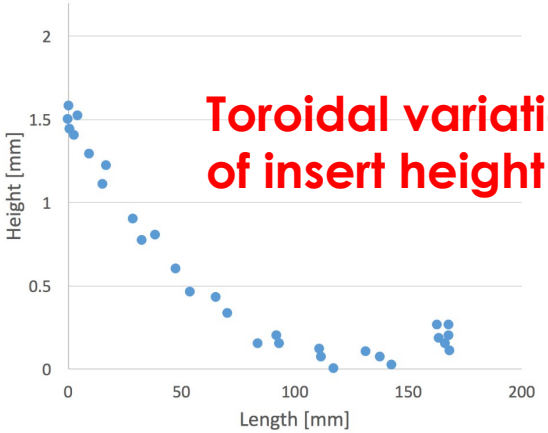
Floor inserts with leading edges had melt layers in J × B direction and were thermo-mechanically deformed



- Melt layer shape consistent with flow in J × B direction for both B_T directions

- Thermo-mechanical strain resulted in upward curvature on inserts with exposed leading edges

Rudakov Phys Scr 2017
Barton Phys Scr 2017
submitted



Wall Change Engineering Challenges - Operations

- Existing tiles are protected from NB shine-through via pyrometers which would need to be adapted to viewing a non-graphite surface
- Magnetic probes could be affected by the addition of solid W armor
- Designs would need to withstand Halo current forces and heat fluxes (up to 10MW/m2)

- DIII-D will be looking for lessons learned from other tokamaks that have transitioned from carbon to W