

Tungsten Tile Testing (T³) Campaign Overview

Opportunities for Large-scale Sample Exposures during W Tile Testing Campaign

Presented by Jonathan Coburn

Together with C. Murphy, K. Schultz, K. Teixeira, S. Hong, G. Sips, I. Bykov, T. Wauters, L. Chen, Q. Deliege

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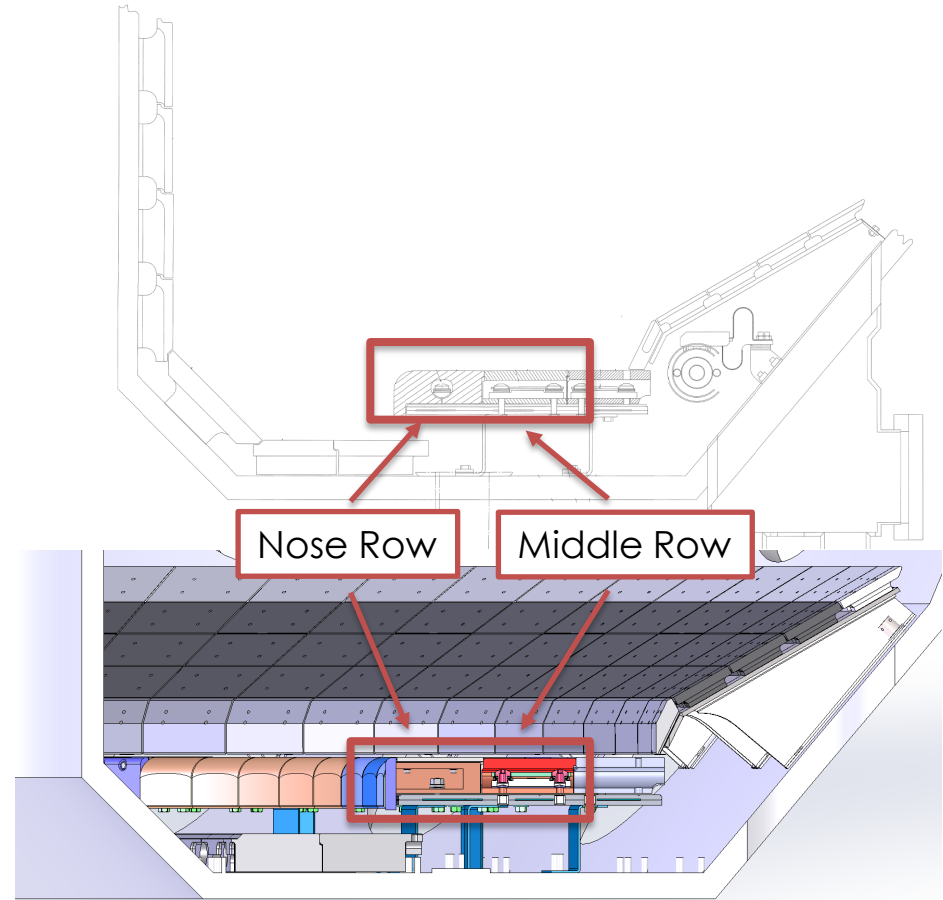
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Tungsten Tile Testing (T³) Campaign Overview

- Department of Energy has requested that DIII-D decarbonize through a First Wall Change Out (FWCO) project
- The **Tungsten Tile Testing (T³)** campaign will test a range of materials, coating techniques, and tile designs to reduce risks for FWCO
- Two rows of tiles will be replaced along the lower divertor shelf
- W tiles for DIII-D will be selected based on expected needs of the FWCO



T³ Campaign – Scope

- **~2 weeks of installation, 2 weeks of operation (June 2026)**
 - **1st Phase:** lower heat flux tests on nose tile ring → surface T cycling from 300 – 800 °C
 - **2nd Phase:** higher heat flux tests on middle shelf ring → T cycling > 800 °C

T³ is primarily an ENGINEERING Experiment Campaign

- **Engineering (+ some research) Scope:**
 - Material integrity (macroscopic) of bulk W and coatings from various manufacturers
 - Tile shaping and alignment tolerances in high heat flux regions
 - Suitable high power operating scenarios with W
 - Impact of W on diagnostics
 - Qualification of ITER W PFCs for Start of Research Operations (SRO)
 - And probably much more...

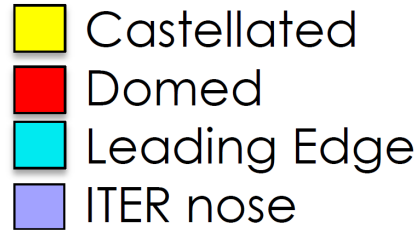
T³ Campaign – Experiment Plan

Nose tile ring

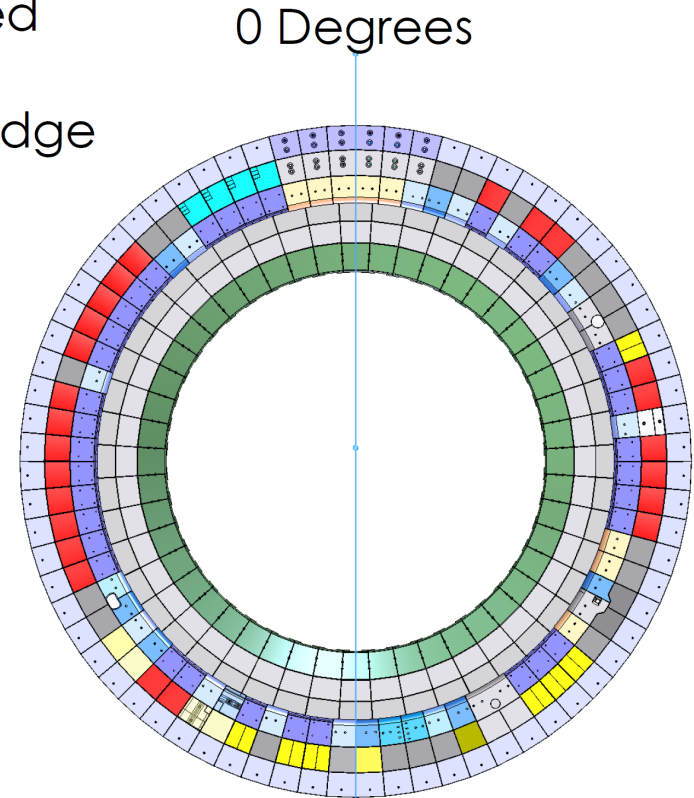
- Predominantly **ITER** tiles
- Mimic ITER low heat flux zone to test coatings + W-alloys
 - VPS, PVD, cold-spray, W heavy alloy, etc.

Middle ring

- Predominantly **GA** tiles
 - GA: W alloys, W on TZM, W on SS, W heavy alloys
 - Some ITER tiles (~20): bulk W, W heavy alloys
- Mimic DIII-D high-power ops, ITER loads at startup areas
- Here, there will be opportunities for including **novel tiles from industry**



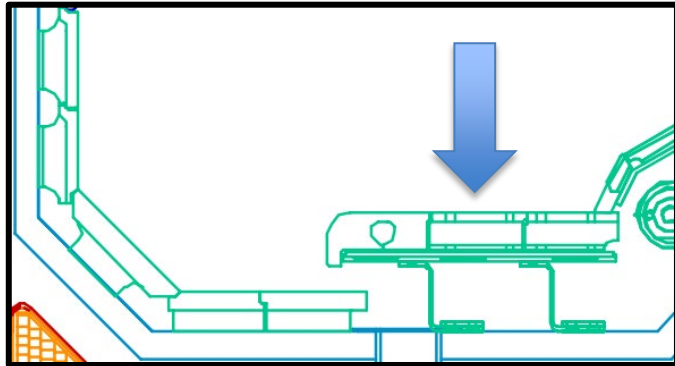
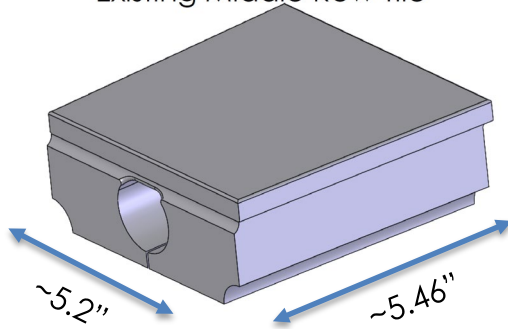
72 tiles
per row



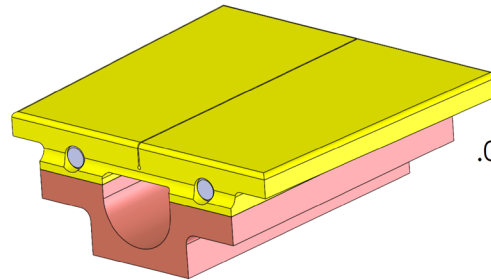
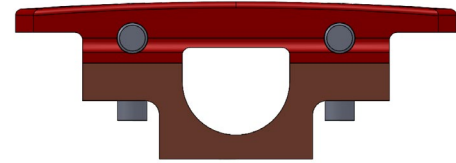
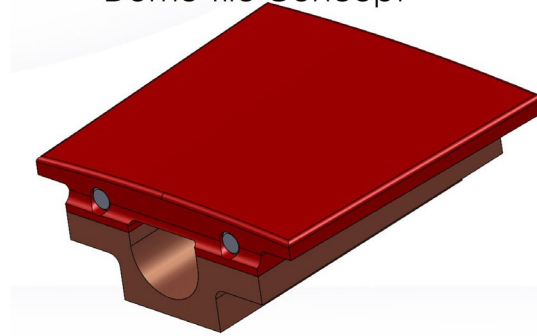
T³ Campaign – Experiment Plan

Middle Row tile designs being considered:

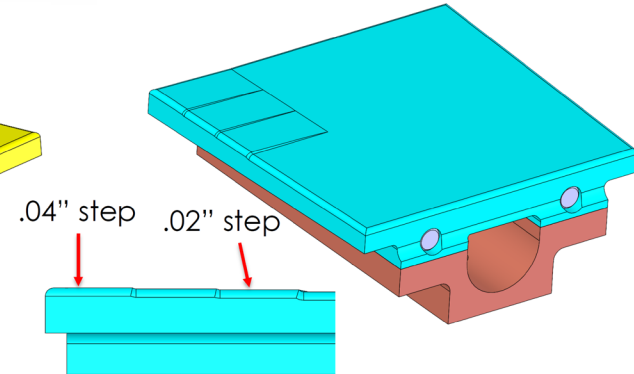
Existing Middle Row Tile



Dome Tile Concept



Castellated Tile



T³ Campaign – Research Opportunities

Runtime Guidance invites opportunity for **limited number of novel tiles for testing by public and private partners**

- **Main campaign focus is divertor, but wall tiles are also fair game**
- **Various materials and tile designs can be considered (i.e. not just W), with caveats:**
 - Single-tile tests
 - Tile design must conform to current middle row design envelope (i.e. sizing)
 - Proposed materials must have reactor-relevant testing history (TRL > 2). Examples:
 - Prior DIII-D tests (DiMES, tiles), other tokamak exposures
 - Lab-scale fusion-relevant heat/particle flux tests (laser, e-beam, linear plasmas)
 - Tile concepts must complete Design Review process
- **To apply: contact **J. Coburn** and **F. Effenberg****
 - Application will be a 2-3 slide template in SharePoint folder: [Tile Testing Campaign](#)
 - Proposals will be evaluated and prioritized by Research Division

T³ Campaign – Research Opportunities

In addition to novel tile testing, the T³ campaign will afford many piggyback opportunities for Research

- **Plasma-material interaction of fusion-relevant W tiles**
 - In-situ and post-experiment analysis of DIII-D/ITER tile performance
 - Piggyback DiMES & MiMES testing
- **Explore diagnostic impacts (reflection, impurities)**
 - Inform mitigation strategies for diagnostic systems in FWCO
 - Piggyback tests of diagnostic systems and changes
- **Scenario development for high power operation with W**
 - Modifying 2-3 reference discharges during 2-week campaign to combat W difficulties

Supplemental

T³ Campaign – Experiment Plan

Early thoughts on the 2-week experiment plan being developed:

- ~80 hours of operation → ~240 non-startup shots → 30 shots a day
 - **1st Phase: lower heat flux tests on nose tile ring**
 - Goal is to cycle surface temperature from 300 – 800 °C, at least 100 cycles
 - Start with low power L-mode plasmas, $q_{\perp} \sim 1 \frac{MW}{m^2}$
 - Transition to H-mode. Loading (ITER-driven): $q_{\perp} \approx 2 - 3 \frac{MW}{m^2}$, 3s duration, with ELMs
 - **2nd Phase: higher heat flux tests on middle shelf ring**
 - Test material integrity with temperature cycling > 800 °C
 - L-mode → mid-power H-mode → High-power H-mode
 - Peak loading conditions (DIII-D driven): $4 - 5 \frac{MW}{m^2}$, 3s duration, with ELMs
 - Increasingly impactful/misaligned tile features more radially outward
 - Reference shots need to be high power, but not rely on large set of diagnostics to run...
- We're narrowing down reference shots, but let us know if you have suggestions!

T³ Campaign – Analysis Plan

- ❑ **Before measurements**
 - ❑ Bond strength, cuts, etc... --> measured by the coating supplier for all techniques
 - ❑ Possible additional measurements on spares to have the same measurement conditions
 - ❑ Measure surface roughness using confocal microscopy system, surface height map scan --> for a selection of tiles
 - ❑ Metrology scan of installed tiles pre-exposed (< 1 day)
- ❑ **All tiles after experiment (IO staff onsite, together with DIII-D staff)**
 - ❑ Visual inspection and pictures --> all tiles, in situ and after tile removal? (needed for PDR)
 - ❑ Hand held XRF, LIBS for elemental composition
- ❑ **Selection of coating and alloys tiles: ~10 in total, incl failed (1-2 per tech) and successful ones (1 per tech)**
 - ❑ Detailed surface inspection --> looking for cracks etc (needed for PDR)
 - ❑ 1st optical
 - ❑ SEM for selection of tiles/locations (top, together with cut measurement)
 - ❑ Possible additional, surface roughness using confocal microscopy system, surface height map scan
 - ❑ Metallographic cross sections --> looking for defects at interface of coating, structure of alloys (needed for PDR)
 - ❑ Optical microscopy to observe the grain structure, phase distribution, and defects
 - ❑ SEM (cut) micrographs (backscattered electrons) for more fine resolution
 - ❑ Combined with EDX at cross section
 - ❑ Hand-held XRF, LIBS for elemental composition --> identify origin of surface discoloration etc (needed for PDR)
 - ❑ Bond strength measurement and scratch tests --> looking for hidden defects (needed for PDR)
 - ❑ only of successful coatings (5 max)
- ❑ **Longer term - outside of first analysis 'contract' scope**
 - ❑ Thermal screening : only of successful coatings, looking for hidden defects (desired for FDR)
 - ❑ Retention