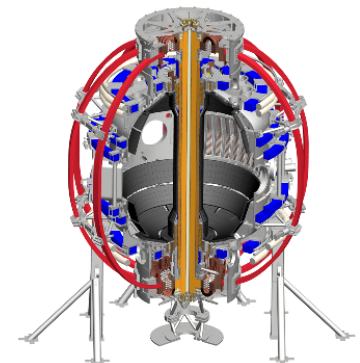


NSTX-U Team Meeting

R. Hawryluk, J. Menard,
S. Gerhardt, M. Reinke, R. Maingi

MBG Auditorium
April 28, 2017



Agenda

- FES perspective on Recovery / Research: Josh King
- Organizational Diagnosis Status / Next Steps: Rich and Jon
- Recovery:
 - DVVR / EoC status and next steps (Rich Hawryluk)
 - Updates on divertor heat flux and PF coil requirements (Jon Menard)
 - Recent engineering design activities in polar regions (Stefan Gerhardt)
- Research:
 - Status and plans for PFC Requirements working group (Matt Reinke)
 - Impact of polar region options on research ops flexibility (Matt/Jon/Stefan)
 - Overview of upcoming FESAC and NAS workshops (Rajesh Maingi + Jon)

Role of the 96 scenarios

- Physics design computed 288 free-boundary equilibria
 - $3 \times 96 = 288$: $\beta_N = 1, 5$ (baseline), 8 to **quantify poloidal field requirements** for wide range of power / confinement states
- Heat fluxes at plasma facing components were not computed for most of these equilibria
 - Majority of outboard divertor (OBD) PFCs not in Upgrade scope \rightarrow OBD plasmas constrained by NSTX tile capabilities
 - Time duration limits from plasma exhaust onto OBD were not computed, but in retrospect should have been in order to:
 - Explicitly document that not all 2MA plasma equilibria can operate for 5s
 - Inform operators, physicists, stakeholders about operational boundaries
- 2MA, 5s requires high enough confinement, high κ , δ
 - \rightarrow NSTX-U scenarios focus on inboard divertor target

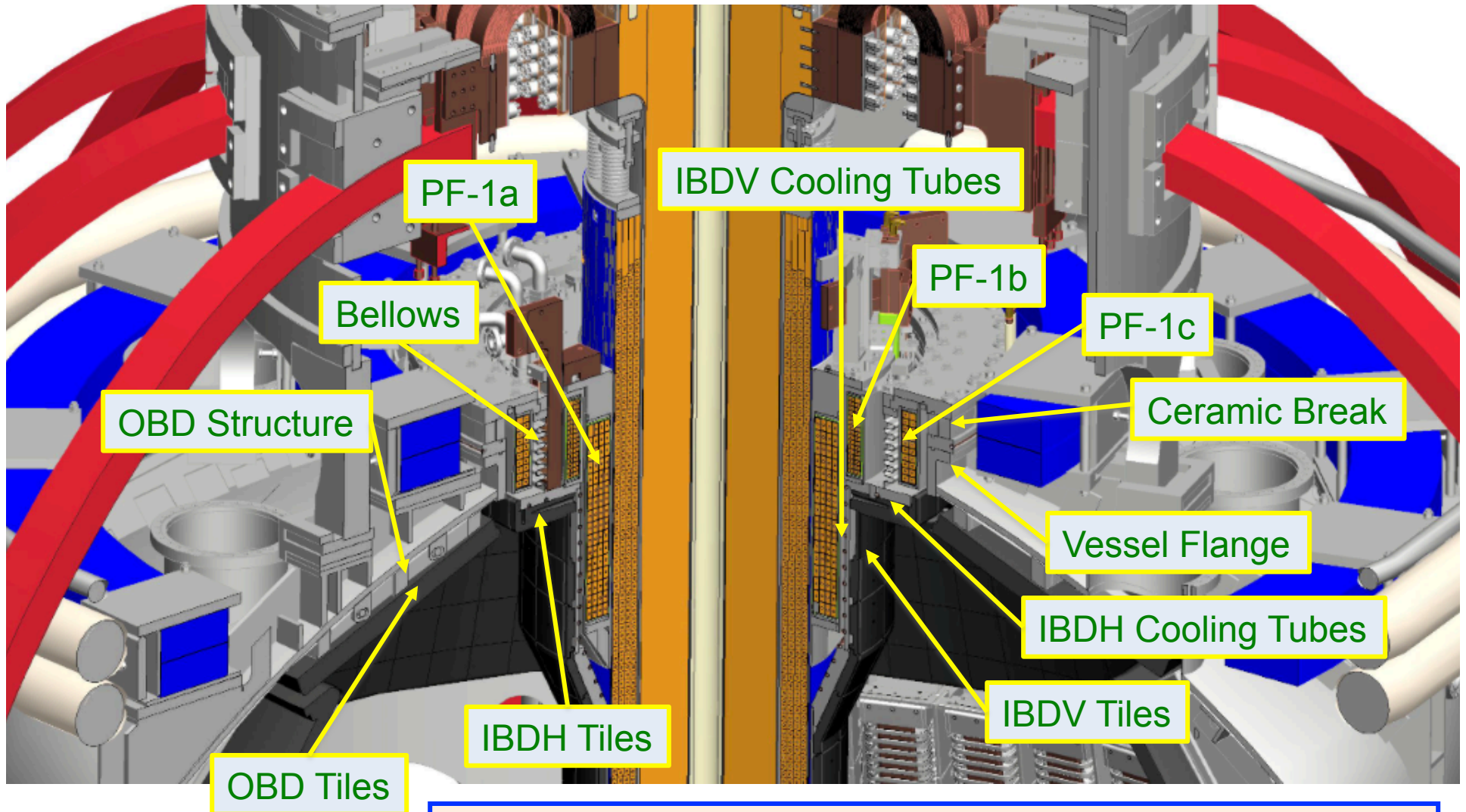
Summary of updated requirements

- Extensive additional analysis performed coupling free-boundary equilibria and coil currents, projected heat-fluxes, and vertical stability (not shown)
- 2MA / 5s / 10MW operation requires operation of divertor legs on inboard horizontal/vertical tiles
- Heat fluxes from systematic scans used to inform / generate updated requirements for PFCs
- Required PF1 coil currents for high-flux expansion or swept scenarios are significantly below GRD maxima
- Highest PF1 currents are set by scenarios that will be limited by PFC heat fluxes (or core stability)
- Next steps: Looking into PF4/5 current requirements

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This is the Polar Region

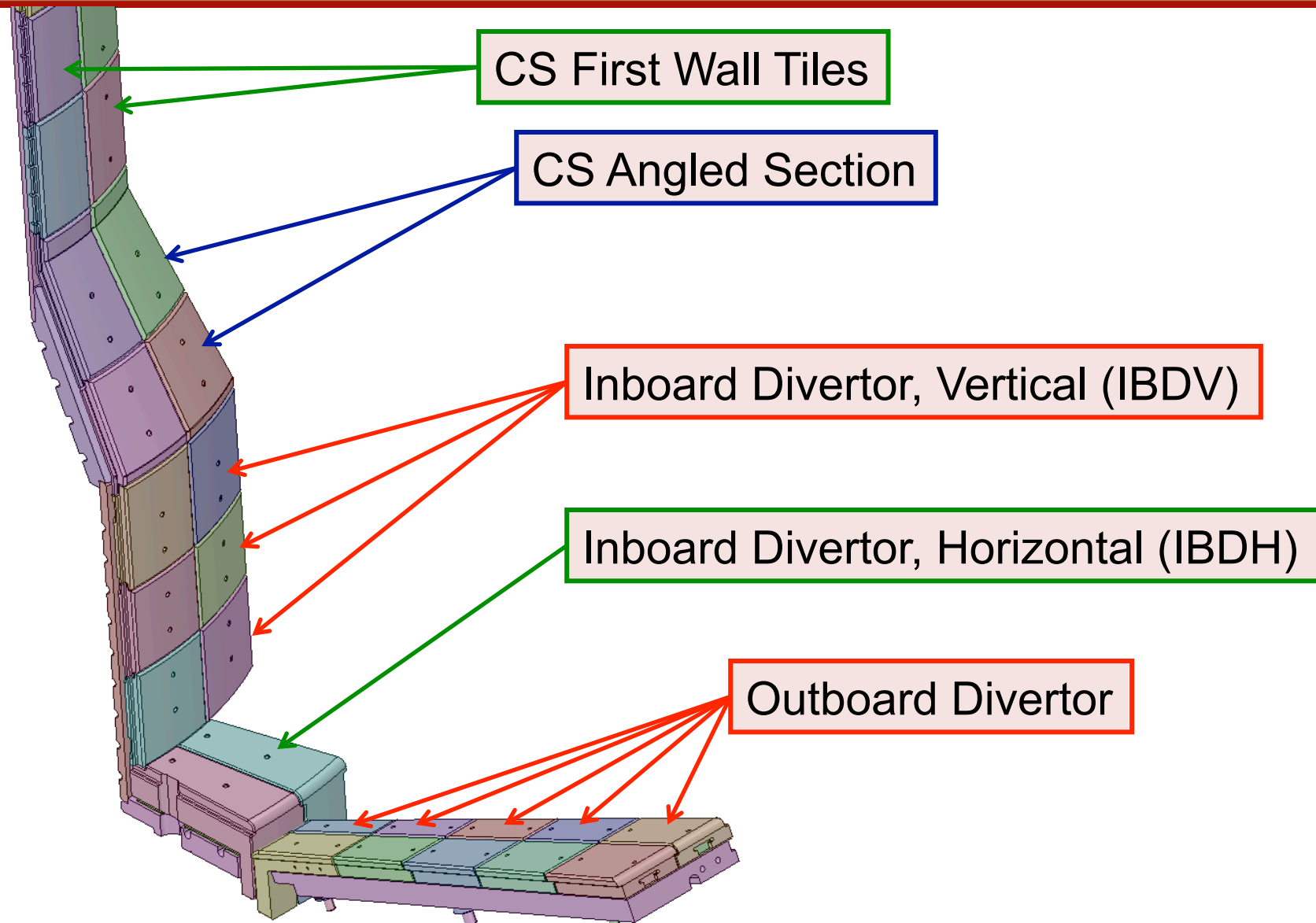


This review dominantly about the vessel and PFCs, not coils

Review Goals: PFCs and Cooling

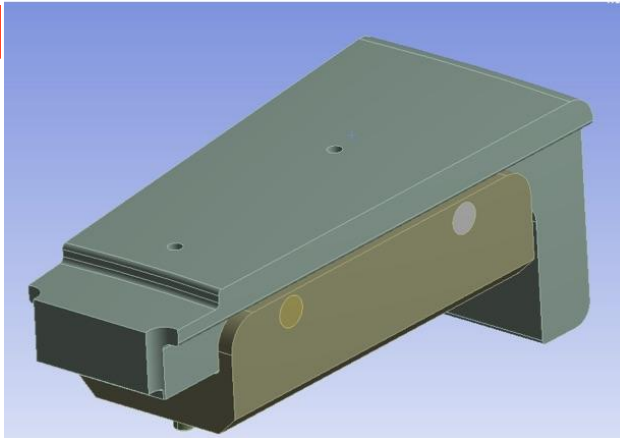
- DVVRs: Various tiles are not simultaneously qualified for disruption and thermal loads
 - **Review Directive:** Assess designs for the Horizontal Divertor tiles, including potential requirements for casing modifications.
 - **Review Directive:** Assess status of other CS tiles.
- Operations & DVVRs: Heating/Cooling lines on the inner vertical and horizontal targets have failed and/or may be inadequate.
 - **Review Directive:** Develop conceptual ideas for the replacement of those cooling lines.

These are the Polar Region Tiles

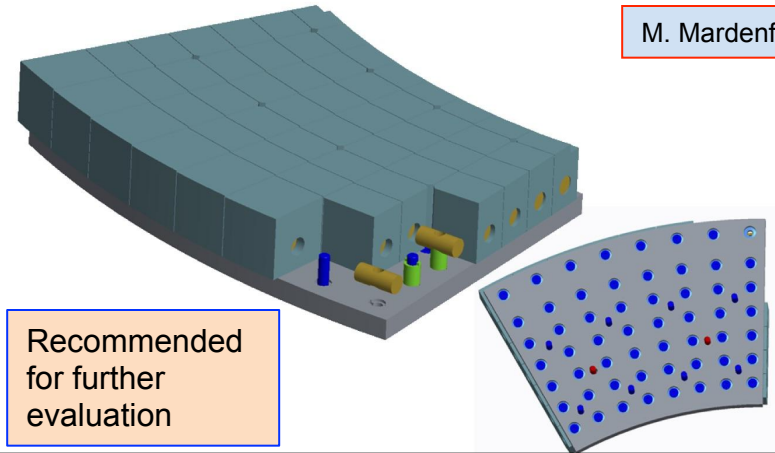


Assessed Two Concepts For New Inner Horizontal Target Tiles

A. Brooks



M. Mardenfeld



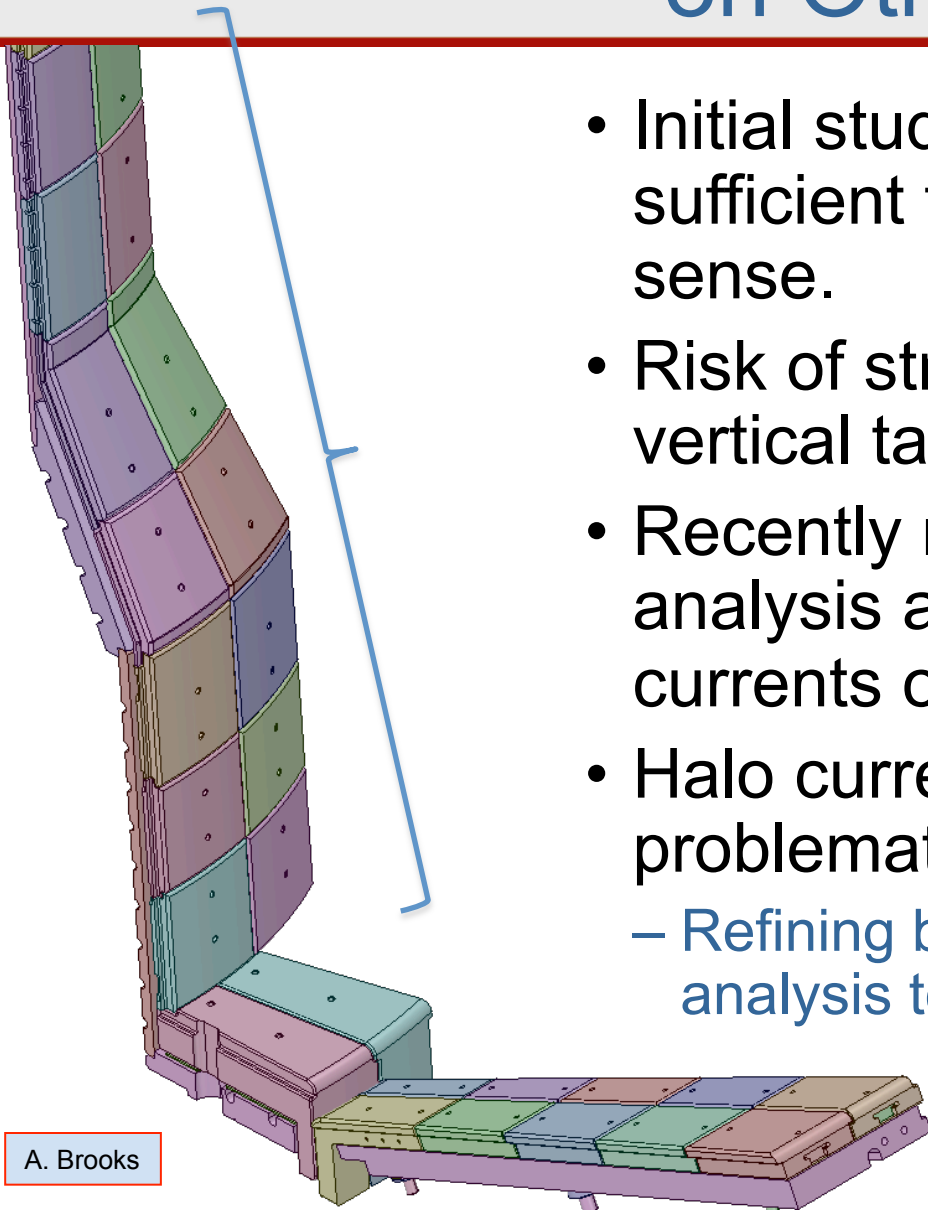
Recommended for further evaluation

Simple Cassette, Sigrafine, 1 or 2 sub-tiles		Fake Monoblock (Mardenblock)	
Advantage	Disadvantage	Advantage	Disadvantage
Meets GRD heat flux, especially with subdivided tiles	Will be thermal stress limited, likely less operating space	No surface features if fishscaled <ul style="list-style-type: none"> • No Leading Edges • No Stress Concentrators 	Tends toward wanting fishscaling
Pins react radial halo currents force	Stress concentrations, surface features for bolt holes, diagnostic	Limited by max T	Substantial diagnostic redesign
		Replace cubes to change helicity	
		Halo Current Forces Smaller	

We continue to evaluate the optimal path forward, including optimal fish-scaling angles

Still Working to Resolve Our Final Position on Other Tiles

- Initial studies indicate that there may be sufficient thermal margin in an average sense.
- Risk of strong leading edge heating on vertical target
- Recently revised both physics and analysis assumptions regarding halo currents on the CS.
- Halo current loads are large and likely problematic
 - Refining both the requirements and the analysis to better assess this issue.

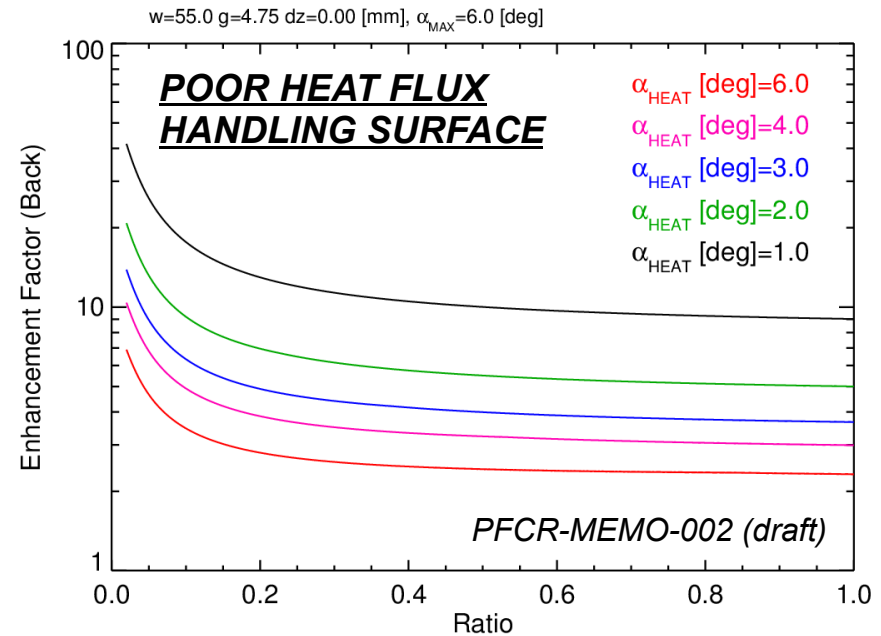
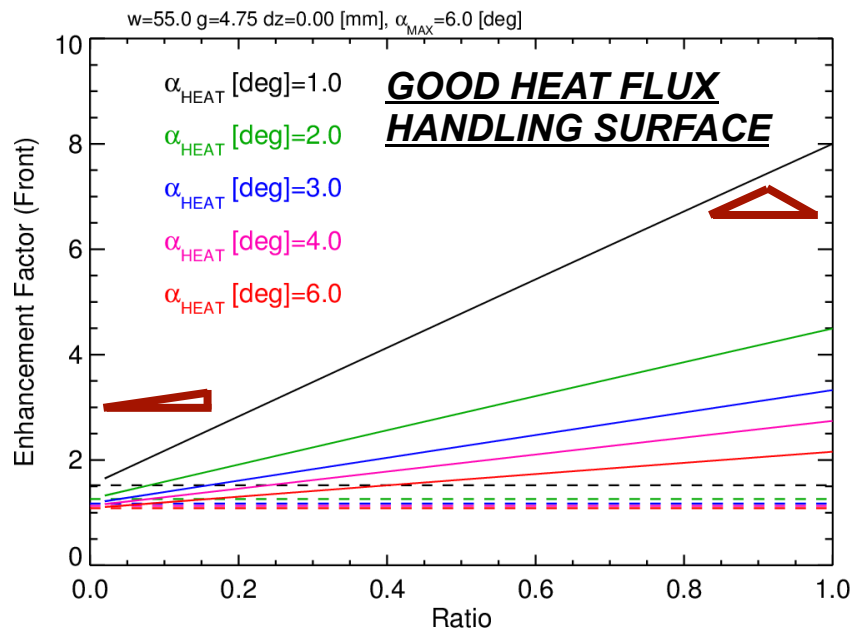


A. Brooks

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Challenge to Shape Tiles for Flexibility



- high heat flux divertors typically shape tiles toroidally to hide leading edges created by tooling gaps, diagnostics and installation/fabrication tolerance
 - necessarily give up heat flux handling to gain operational flexibility
 - ‘fish-scaling’ (uni-directional) or ‘roof-top’ (bi-directional)
- plotted ‘enhancement factor’ qualitatively means either dropping heat flux (proportionally) or operational time (squared) [it’s really a bit more complicated than this]
- optimal tile shape driven by desired operational space
 - desired range of field line angles, expected heat flux on forward/rear surfaces
 - even if we decided on an optimized case, still need operational space to get to it!

Impact of polar region options on research flexibility

- No ceramic breaks would eliminate CHI capability
- Tile fish-scaling required in several regions to manage high heat fluxes of 2MA/10MW/5s → Eliminates reversed B_T
 - Langmuir probes, gas feeds / divertor MGI, other sensors in tiles will also need to be redesigned in concert with PFCs
- (Near) perfect snowflake divertors (SFDs), other advanced divertors will have reversed helicity for some tile regions
 - Need requested SFD equilibria ASAP to assess tile impact / options
 - Bi-directional tiles may be an option for lower q_{\perp} divertor regions
- Pedestal/ELM/H-mode threshold studies - need additional specs of requested range of ΔR_{SEP} , duration, κ , δ , R_{strike}
 - Up/down asymmetric boundary increases q_{peak} , reduces Δt_{flat}
- BP SG/TT TSG charged to provide info to PFCR-WG/JEM