New Tool to generate Surface Heat Flux Data to 3D-shaped PFCs

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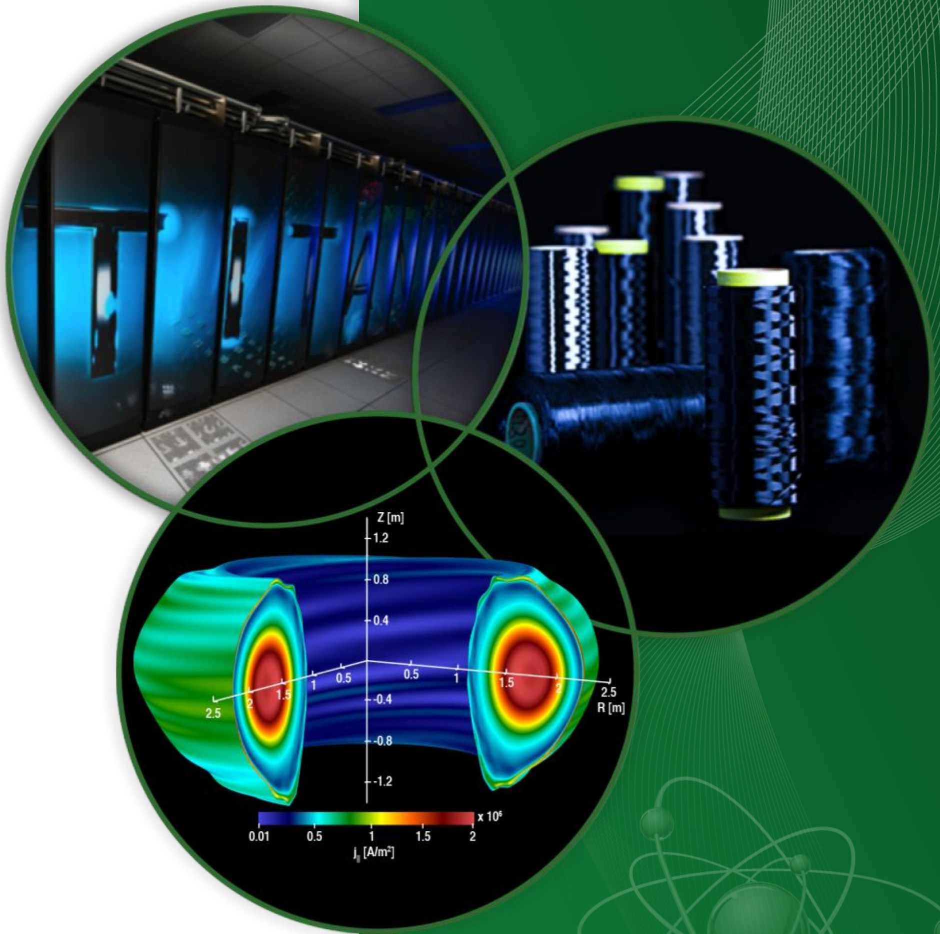

PFC working group meeting
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New tool: Surface Heat Flux Tracer

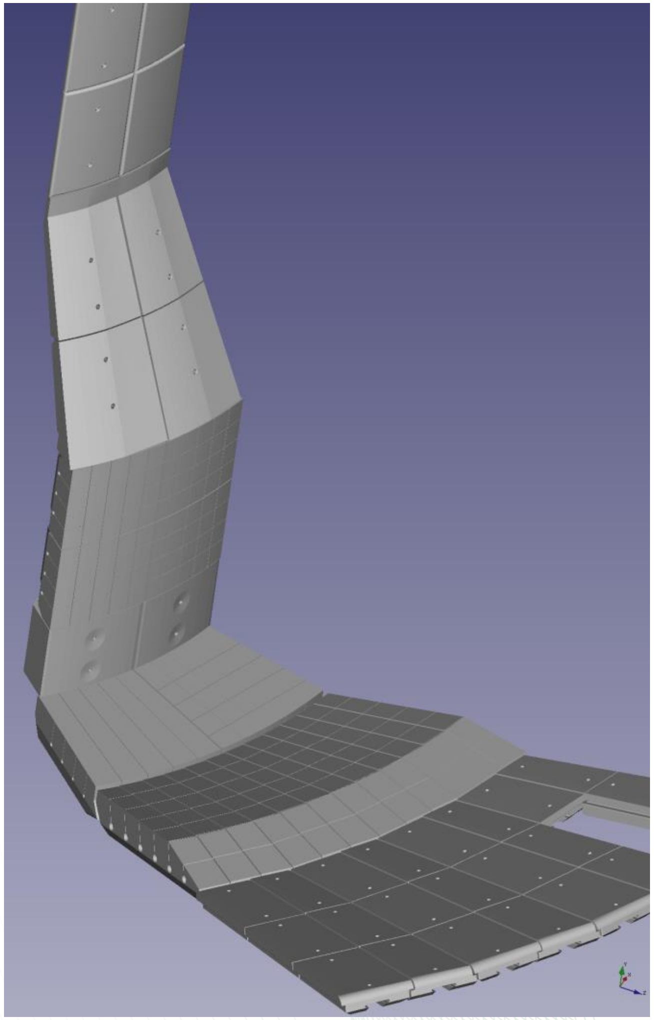
✓ Import a standard class of CAD output format.	➢ Reads STL file.
✓ Import equilibria from standard GEQDSK format.	➢ Reads standard EFIT g-files.
✓ Run double & near double null geometries and specify the power sharing separately between all four divertor regions. (Enhanced: also 3D equilibria or snowflake)	➢ Runs with any NSTX geometry. (3D & snowflake too)
✓ Specify the heat flux profile to the PFCs, e.g. [Eich, PRL 2011].	➢ Uses Eich profile for now. Other can easily be added.
✓ Complete the computation of the heat flux pattern for a single equilibrium in < 5 minutes. (Enhanced: < 60s)	➢ Grid generation: 40s } Field line tracing: 60s } 20 CPUs Heat flux: 7s
✓ Deployable and maintainable for computing systems similar to those available at PPPL. (Enhanced: scalable on Cluster)	➢ Uses C++ and Python 2.7 on Linux cluster (fully parallel with MPI)

x (Enhanced: Add radiative heat flux)

PFCR-MEMO-020-00

Use NSTX-U CAD models in generation of surface heat flux data

- Inner half of the wall, up-down symmetric
- ~30° toroidal segment
- Hundreds of thousands of faces represent PFCs with holes, gabs and substructures
- Outer target PFCs have small fishscaling to counteract leading edge heating.
- Inner target tiles are curved cylindrically, outer target tiles are mostly flat.



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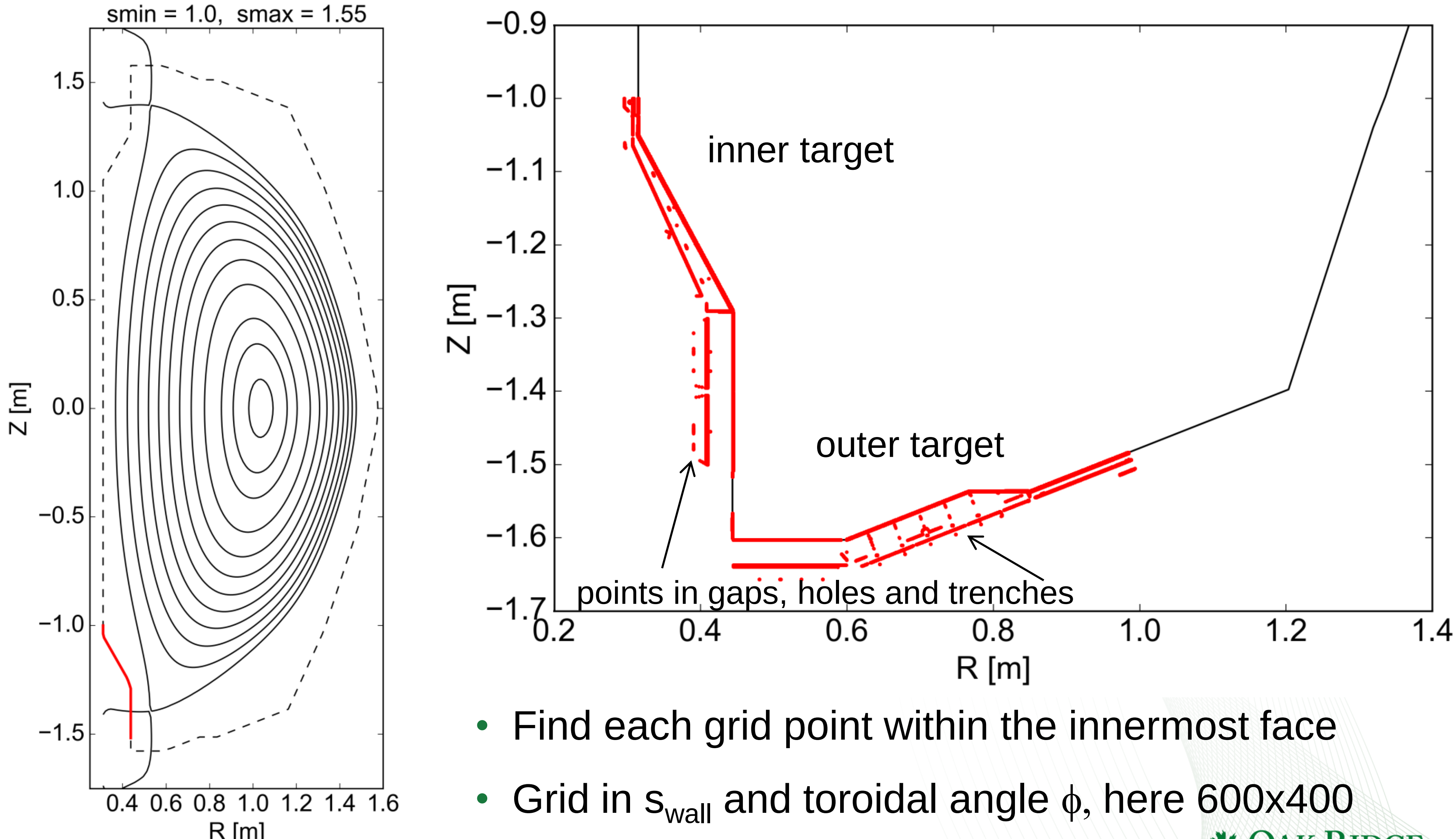
New tool consists of 3 distinct steps

1. Generate grid points on top of the PFCs using a CAD
   - the STL format represents the CAD as a mesh of triangles (faces), here: 150 000
   - typically independent of equilibrium → one-time task

2. Trace field lines from each grid point to determine penetration depth (ψ_{min})
   a. include 3D wall structure for trace termination to capture shadow effects.
      - generated from CAD in a one-time preprocessing task

3. Assign heat flux from profile $q(\psi)$

Generate grid points on top of the PFCs using the CAD

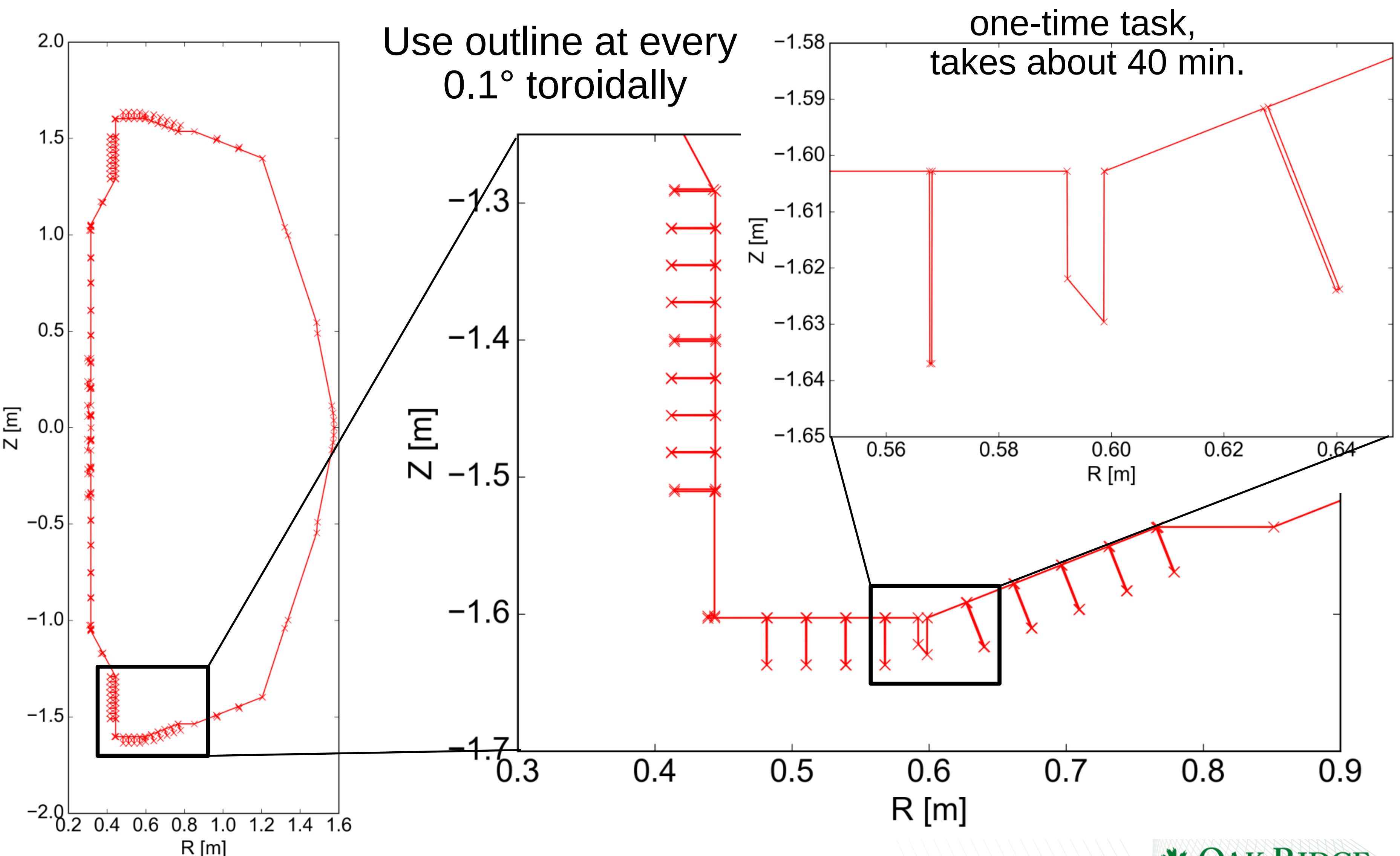


- Find each grid point within the innermost face
- Grid in s_{wall} and toroidal angle ϕ, here 600x400
- Independent of equilibrium

Trace field lines from each grid point to determine penetration depth

- Uses existing capability, the MAFOT code [A.Wingen, Nucl. Fusion (2009)] to trace field lines.
  - see backup slide for details
- Independent of how the grid was generated
- Runtime depends only on grid size
- Fully parallel with MPI
- For trace termination only: reads 3D wall data, given as partially linear outlines in (R,Z) at discrete toroidal angles.

3D wall structure for trace termination to capture shadow effects



partially linear with all gaps, holes and trenches from CAD

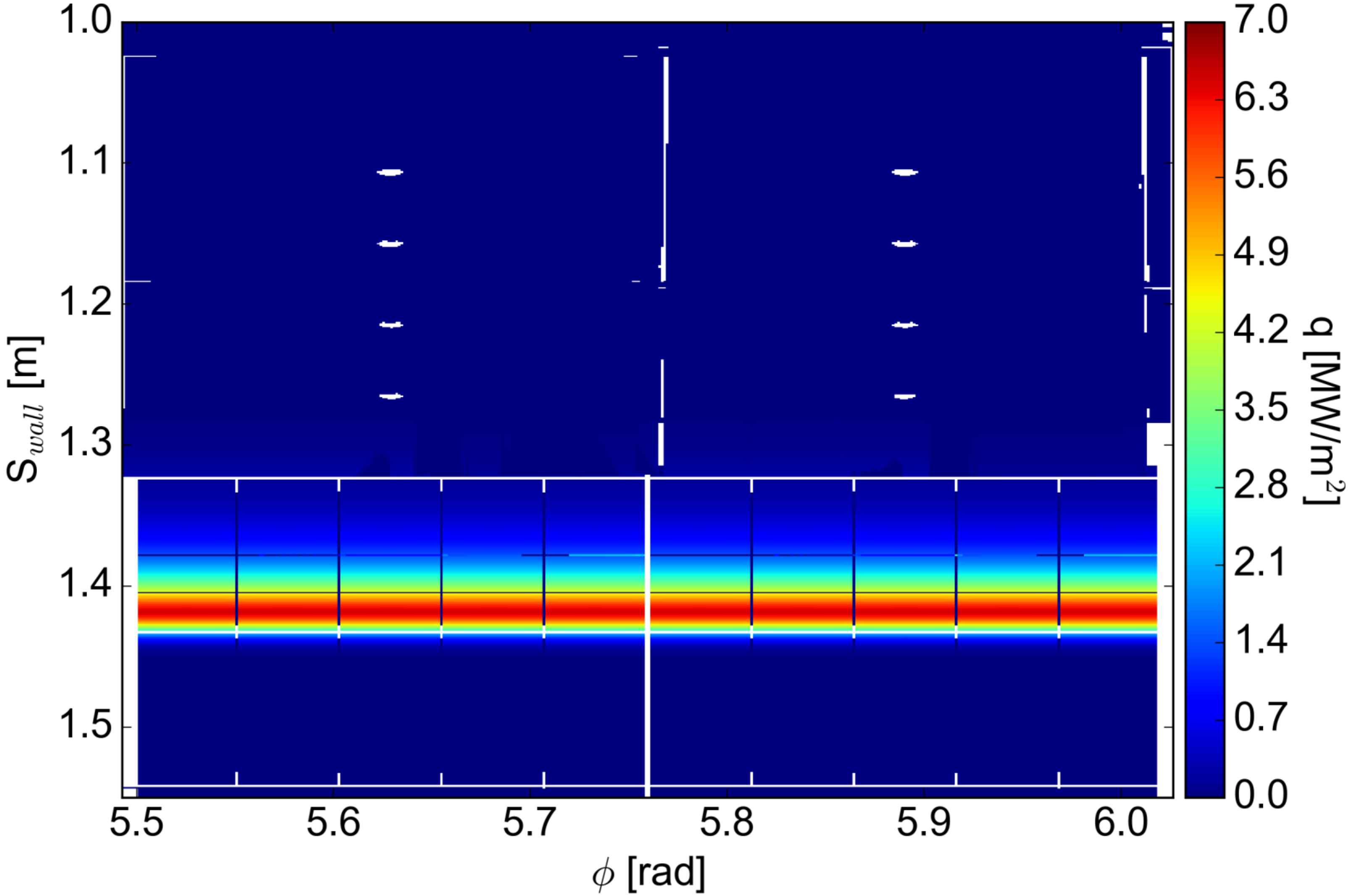
Assign heat flux from profile

- Assume upstream profile $q_{||}(\psi)$ at midplane
  - scaled by power exhaust, here:
    inner: 0.7 MW   outer: 2.8 MW
- At each target plate grid point, assign:

$$q = q_{||}(\psi_{min})\ n \cdot B \,/\, |n \cdot B|$$

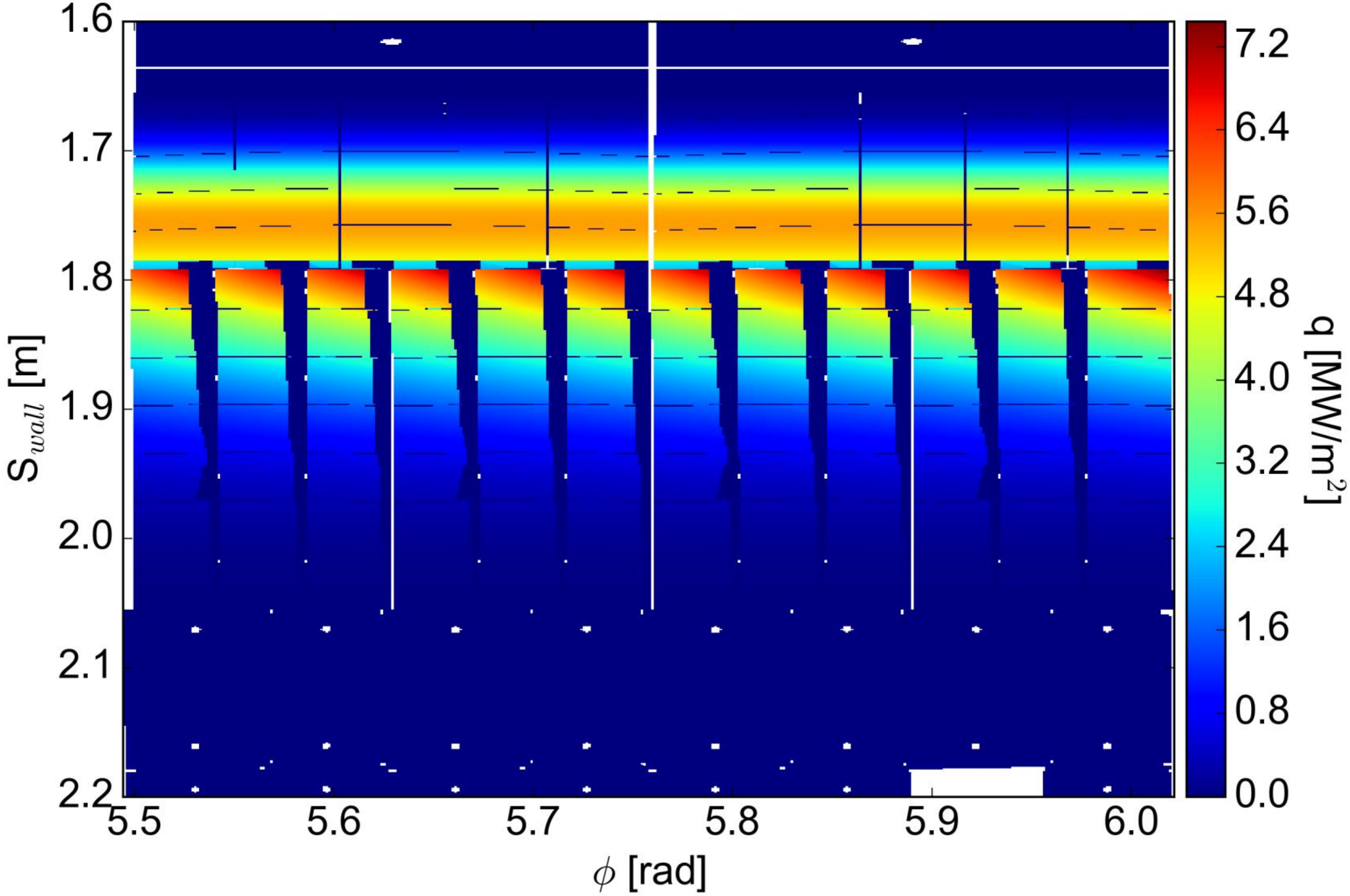
  - n is normal vector to face, B is magnetic field vector

Heat flux is uniform on inner target



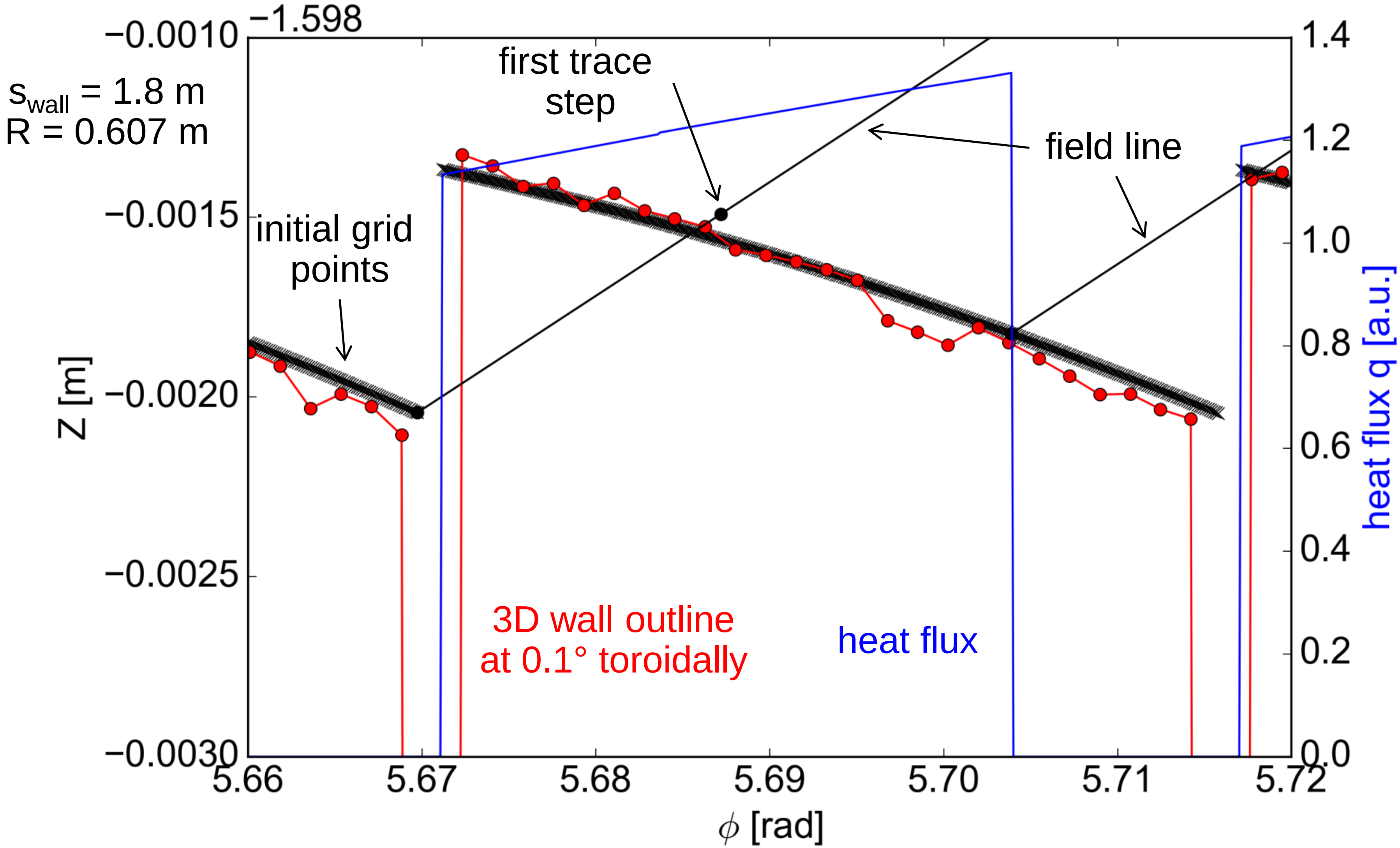
- white areas are holes and gaps in the CAD

Heat flux varies and is partially shadowed on outer target



- fishscaling of tiles causes shadows

Field lines in shadowed areas intersect with 3D wall during the first trace step



Heat flux not constant, because n·B changes toroidally

Future work

- Test on relevant equilibria → axisymm., snowflake, 3D
  - tested on one axisymmetric double-null equilibrium so far
  - If 3D: NSTX specific model for 3D fields needs to be added to MAFOT
- Deploy on PPPL computer systems
- Automation → maybe add a GUI
  - so far all steps are done separately and by hand
- Fine tune and/or add models(s) for heat flux profile
- Add a model for radiative heat flux
  - or other desired capabilities

Backup

MAFOT: a parallel field line and drift orbit tracer

MAFOT can calculate:

- Poincaré plots
- Connection length
- Penetration depth
- Manifolds of separatrix or island chains
- full 3-D orbits
- B-fields outside of VMEC & SIESTA last closed surface

in tokamaks:
DIII-D, ITER, NSTX & MAST

Control GUI available

in:

- Poloidal cross-sections: (R,Z) & (θ,ψ) coordinates
- Footprints on divertor targets

for:

- magnetic field lines
- relativistic particles in a guiding center drift approx.

with:

- RMP vacuum fields of coils
- M3D-C1 plasma response
  - linear & non-linear
  - single & multimode
- VMEC & SIESTA B-fields
  - any configuration
- arbitrary individual current filaments

developed by Andreas Wingen

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