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Neutronics as Part of an Integrated Modeling Approach

a CAD-based Domain Representation

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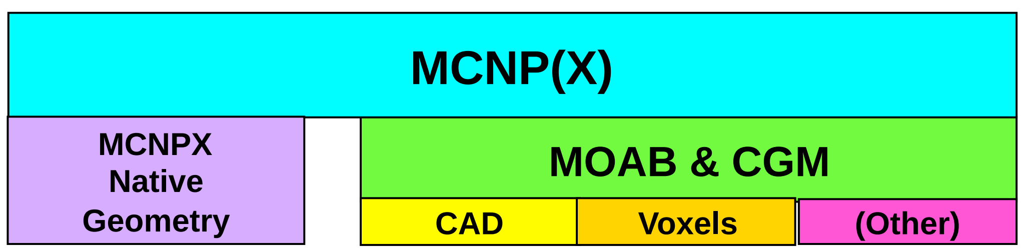
Overview

- DAGMC
  - Ray-tracing acceleration technologies
- ITER First Wall & Shield Analysis
  - Mesh-interpolation for multi-physics analysis
- Future Developments
- Multi-physics Modeling & Simulation
  - Common Domain Representation
  - ITAPS SciDAC Tools

DAGMC

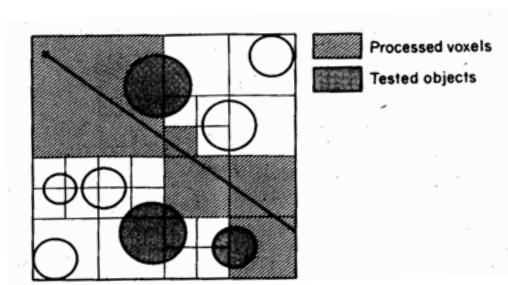
Direct Accelerated Geometry Monte Carlo

- Use MOAB and Common Geometry Module (CGM) to interface MC code *directly* to CAD (& other) geometry data
  - Previous efforts found CAD-based ray tracing to be too slow (20-50x)
  - What's new?
    - Implement ray-tracing approximations to reduce calls to exact CAD function
    - Can be implemented once & reused for all representations

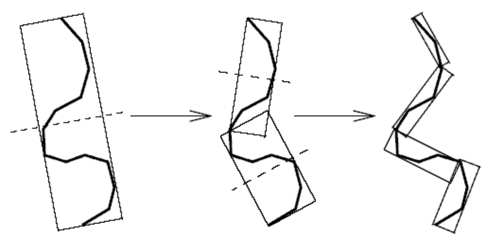


Accelerations

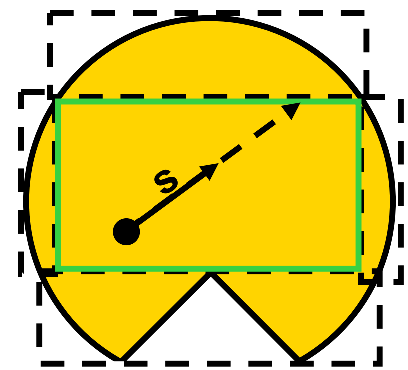
- Key issue: accelerate ray-tracing (fewer & faster)
- Key technology: oriented bounding box trees



Hierarchical Subdivision



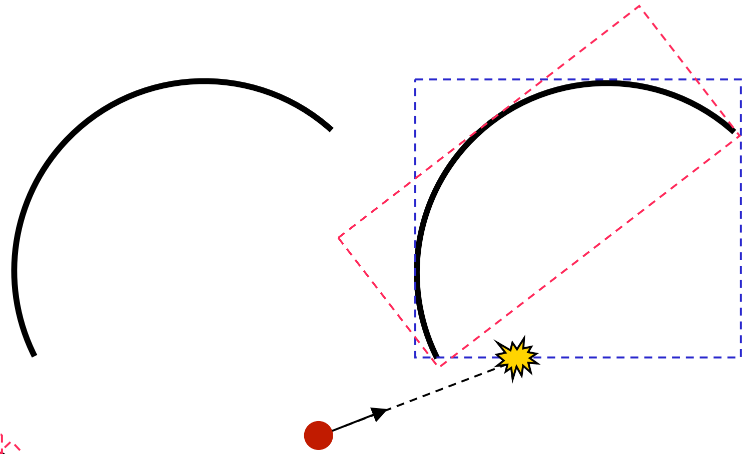
Oriented Bounding Box



Inside Bounding Box (w/ path length limit)

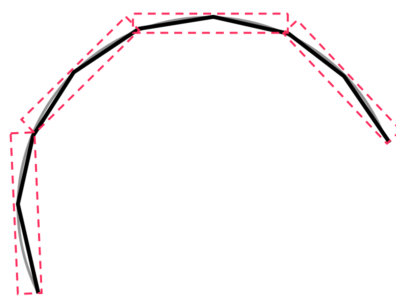
Hierarchical Oriented Bounding Box

- Axis-aligned bounding box often larger than necessary

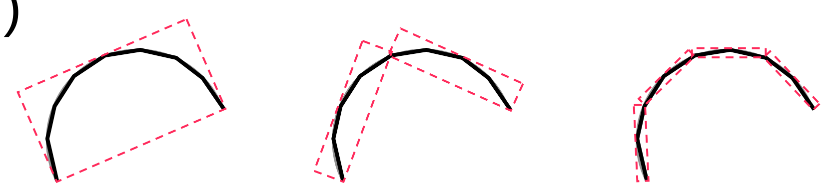


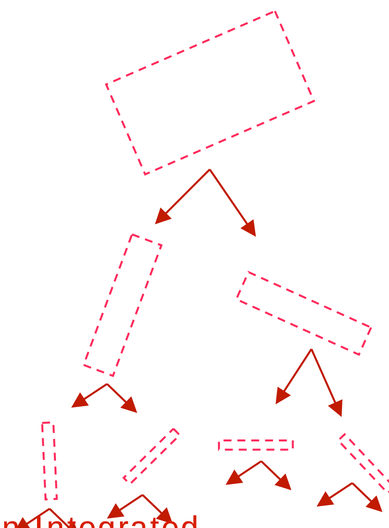
- *Oriented* bounding box makes smaller boxes

- OBB on facets allows finer-granularity boxes



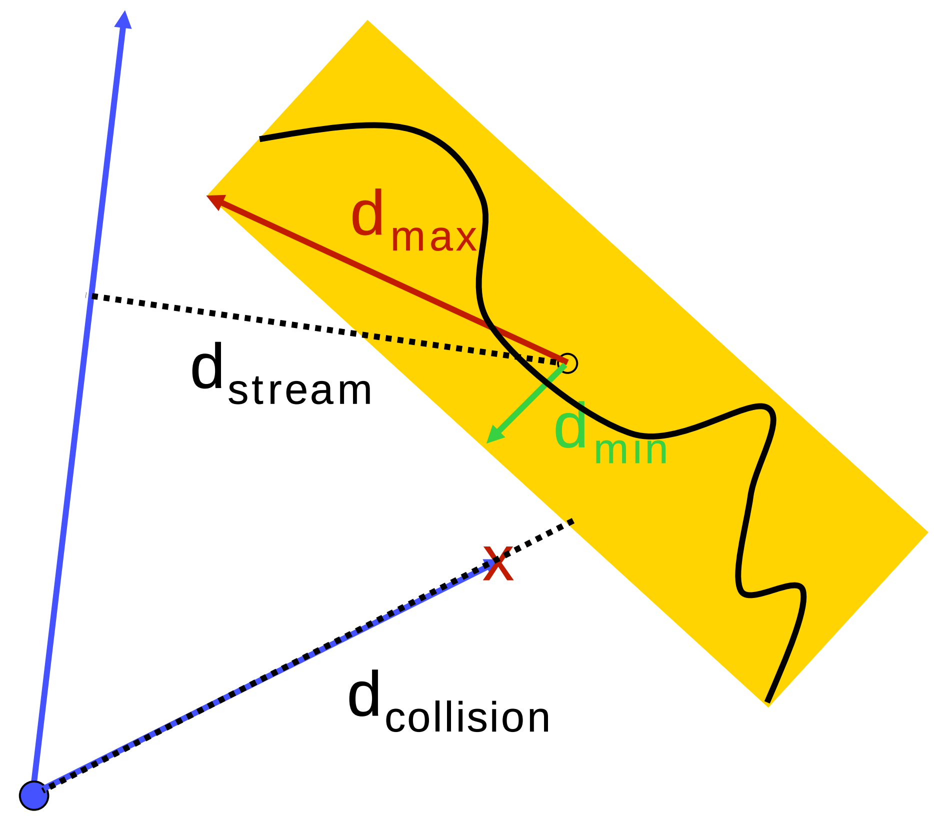
- Tree of OBBs reduces # tests to log(n)





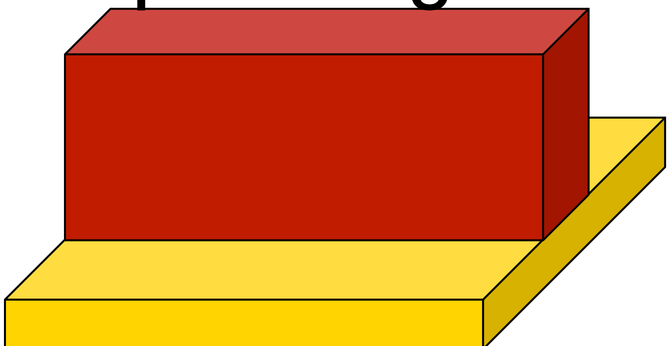
Bounding Box Accelerations

- Simple (inexpensive) bounding box test
  - Streaming distance to closest approach
  - Collision distance to closest approach

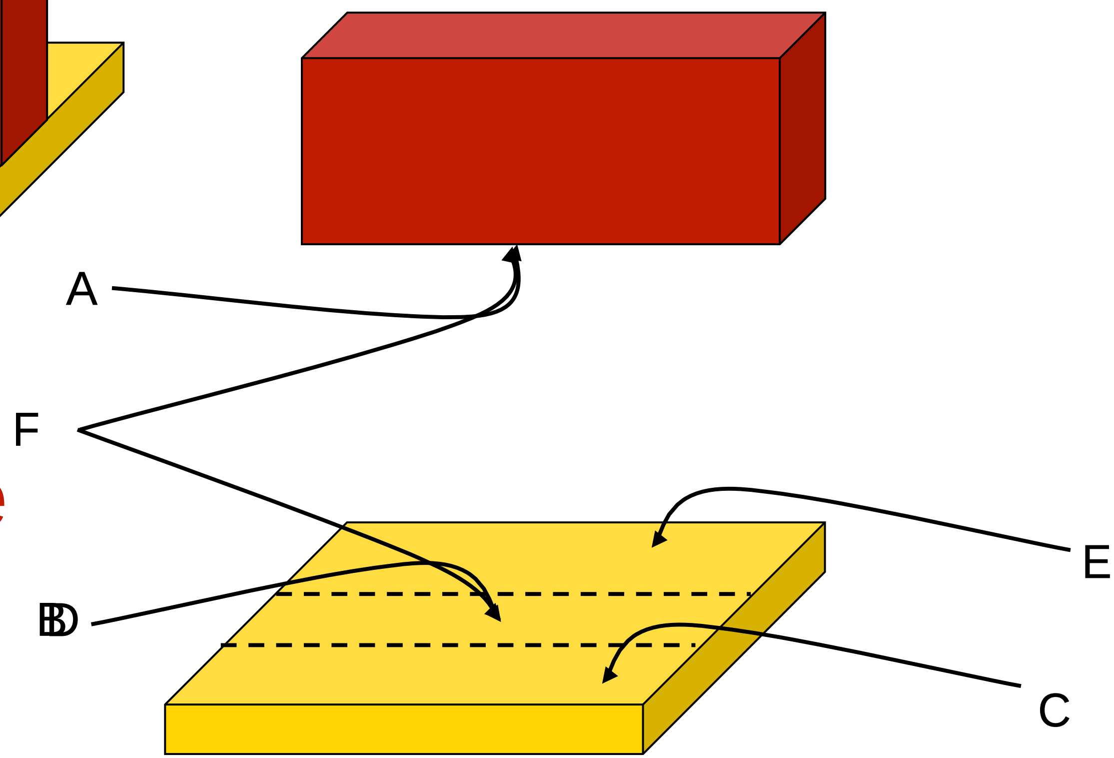


Non-manifold Geometry

- Imprinting



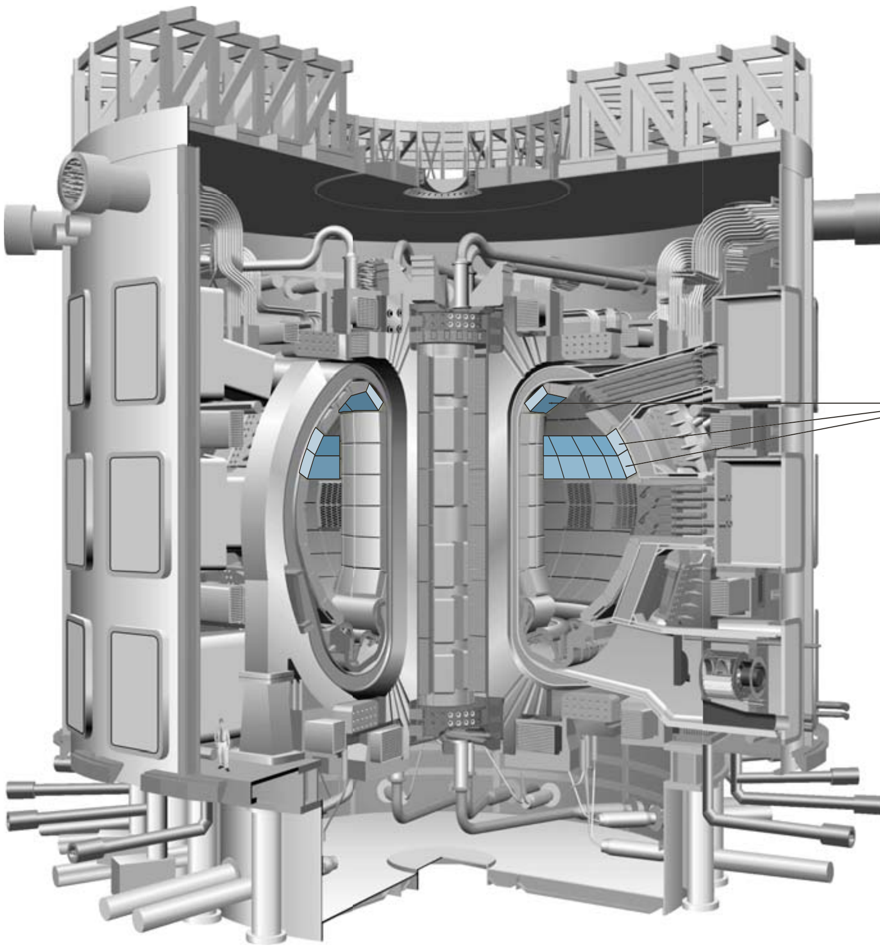
- Merging
- Each surface in max. 2 cells



Implicit Complement

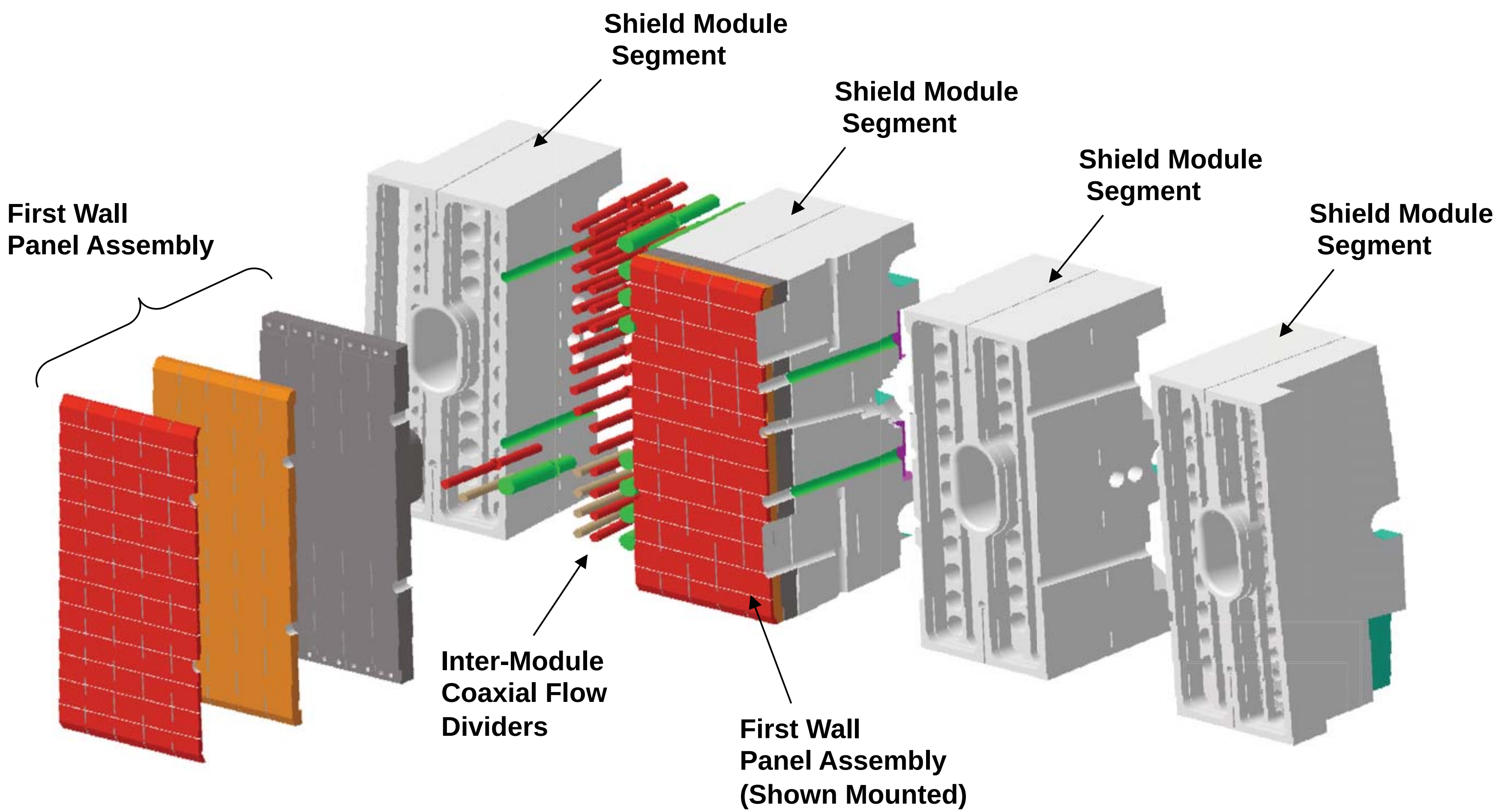
- Defining void space is common source of difficulty
- CUBIT performs imprinting & merging
  - All surfaces have only two volumes/cells
  - Often fails with explicit complement
  - Defines implicit complement = all surfaces with only one cell
- New OBB tree collects all surfaces of each volume into single tree
  - Efficient search of implicit complement
- Standard capability – in production
  - Implicit complement can have material

ITER First Wall & Shield



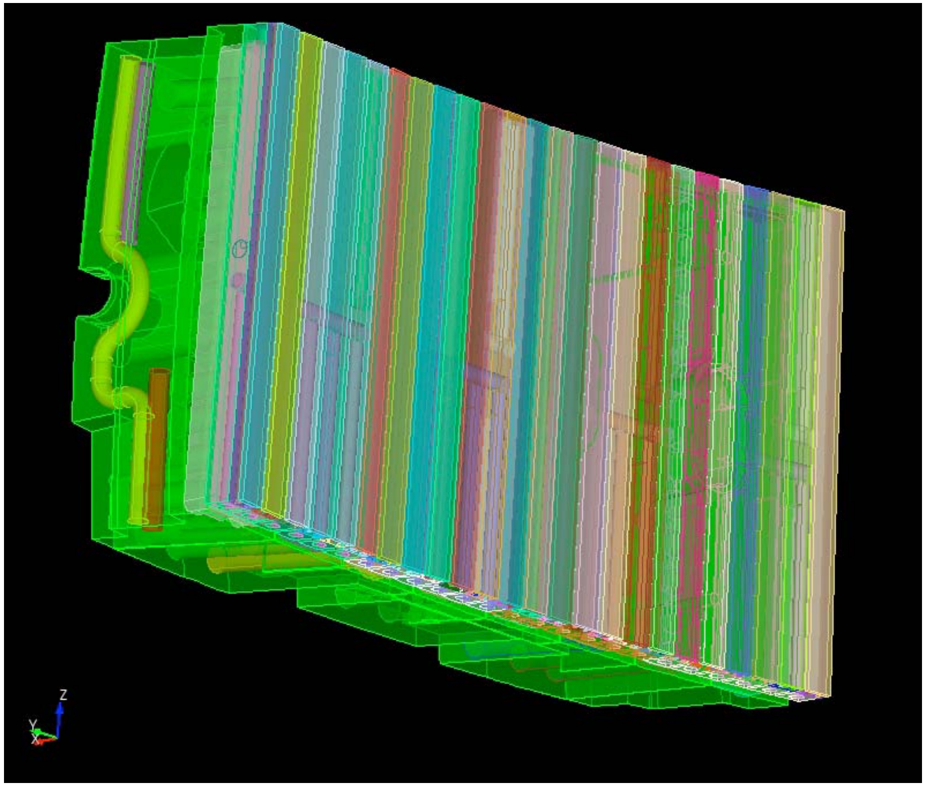
- Modules designed at SNL
  - Includes structural, CFD, EM analyses
- Detailed distribution of nuclear heating
- Mapping of radiation damage and He production

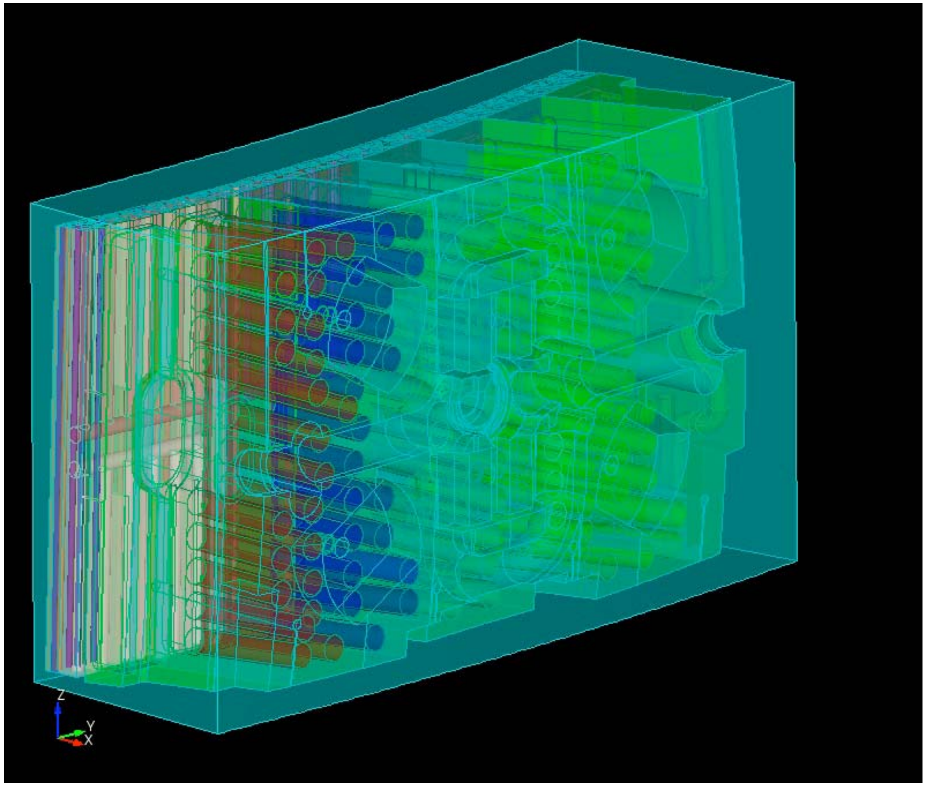
ITER FWS
Module Assembly



Module 13 Mockup

Model generated by designers using common tools facilitates analysis

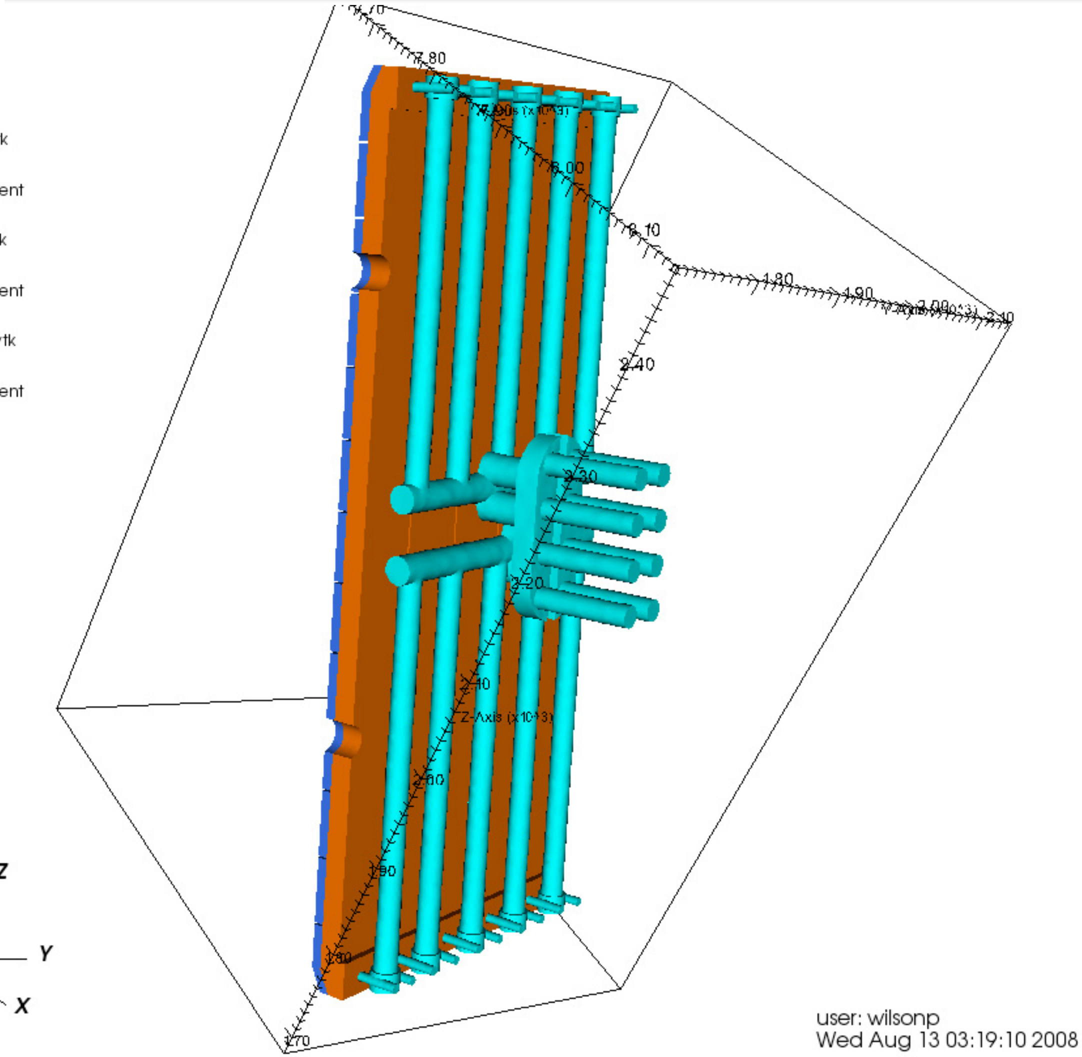


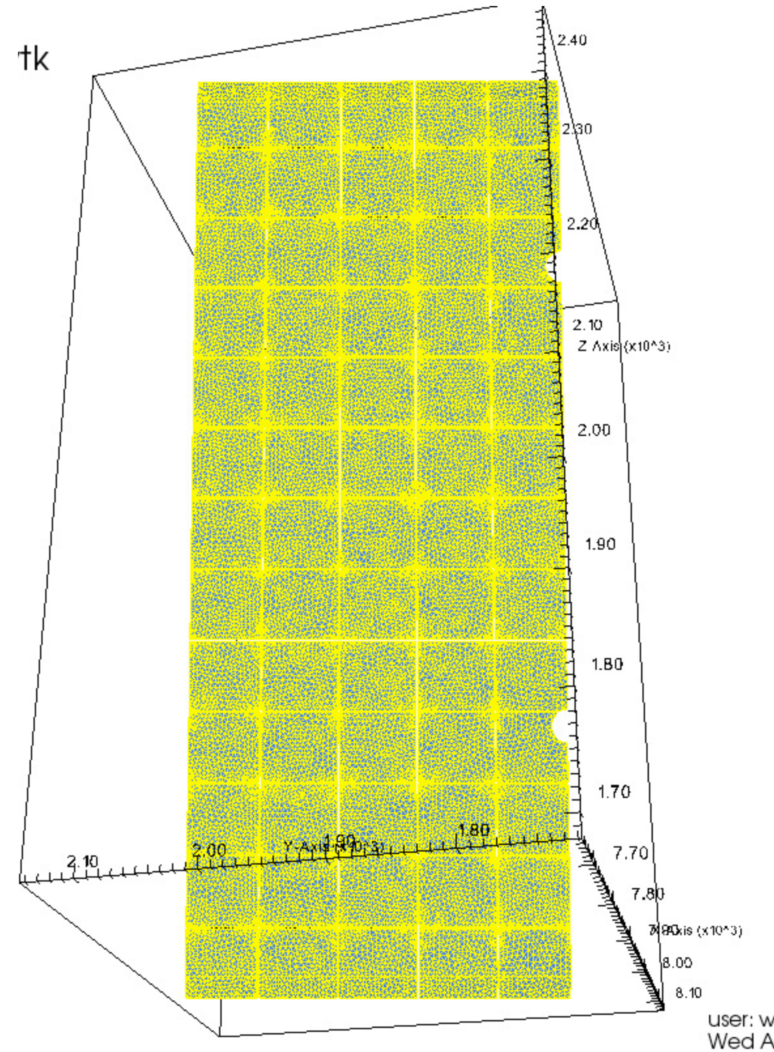


Mesh Interpolation for Multi-Physics Analysis

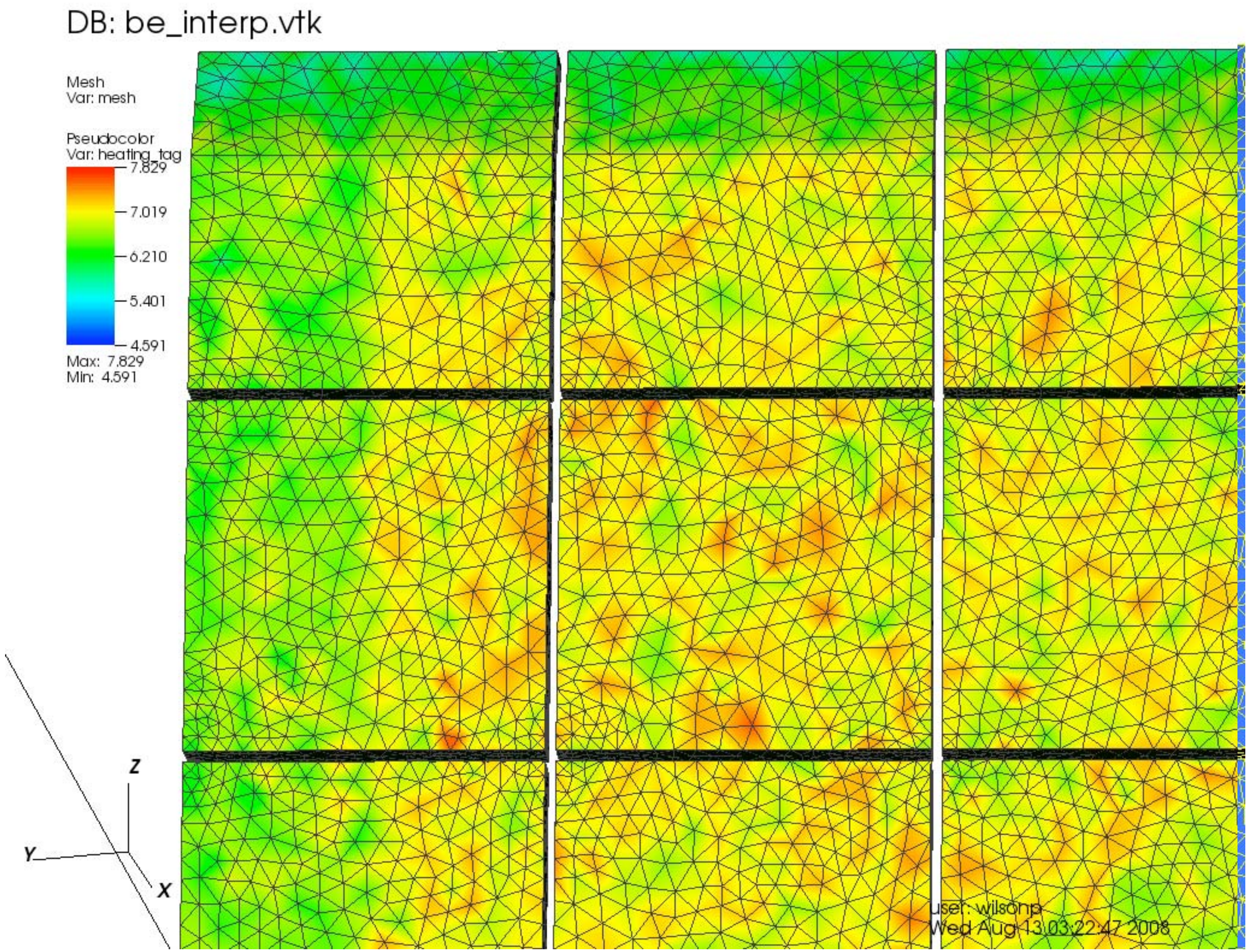
- High-fidelity mesh tallies in MCNP
  - Large orthogonal regular grids (e.g. 26M voxels)
- Interpolate to CFD & heat transfer analysis mesh
  - Large unstructured tet-mesh (e.g. 15M elements)
- Based on MOAB scalable open-source infrastructure
  - KD-tree for MCNP mesh elements
  - Centroid or vertex interpolation on piecewise uniform mesh
  - Store
    - Volumetric heating on vertices, and/or
    - Integral heating on elements

Nuclear Heating
Module 13 CFD Mesh

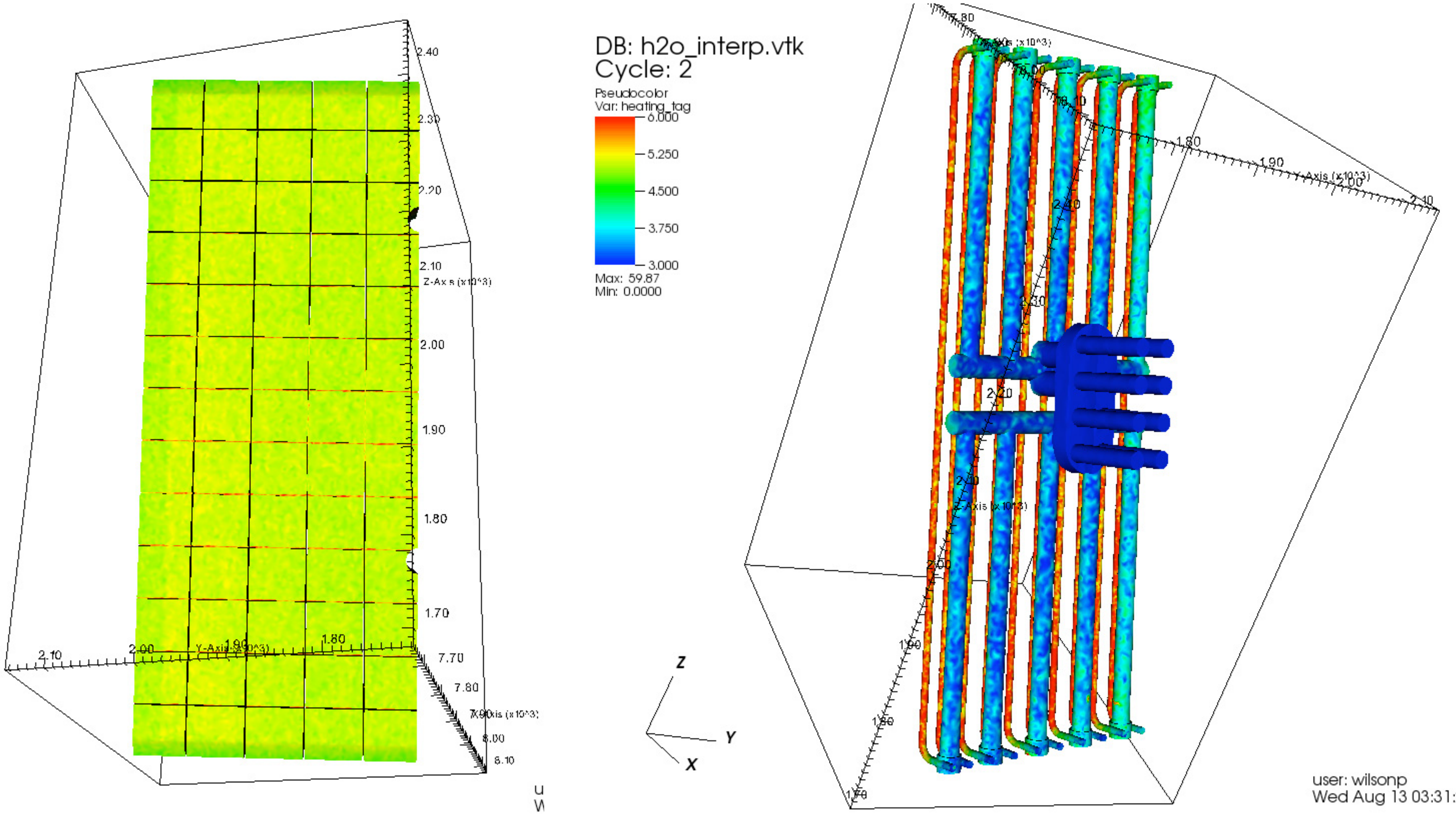




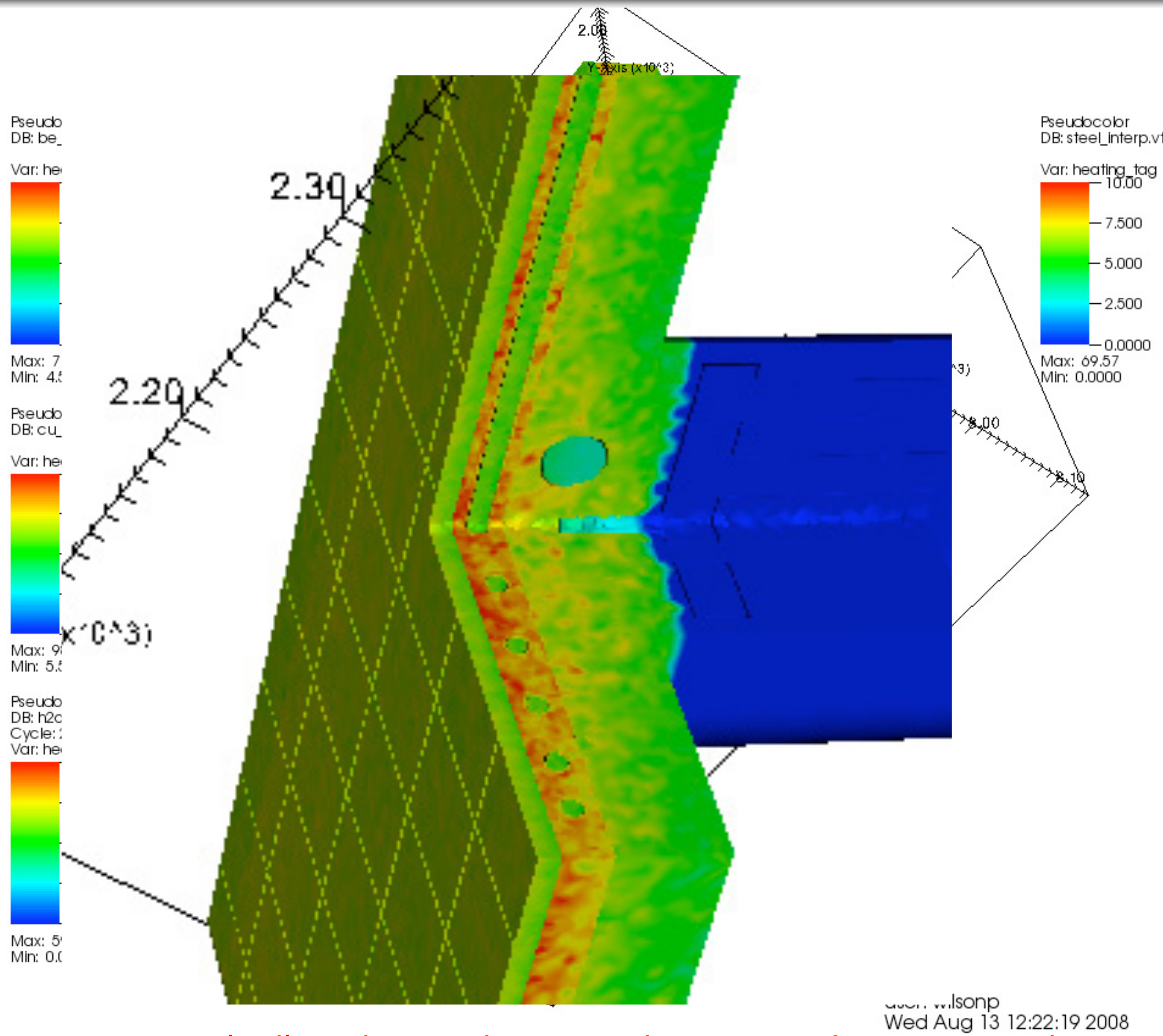
Nuclear Heating
Module 13 CFD Mesh



Nuclear Heating
Module 13 CFD Mesh



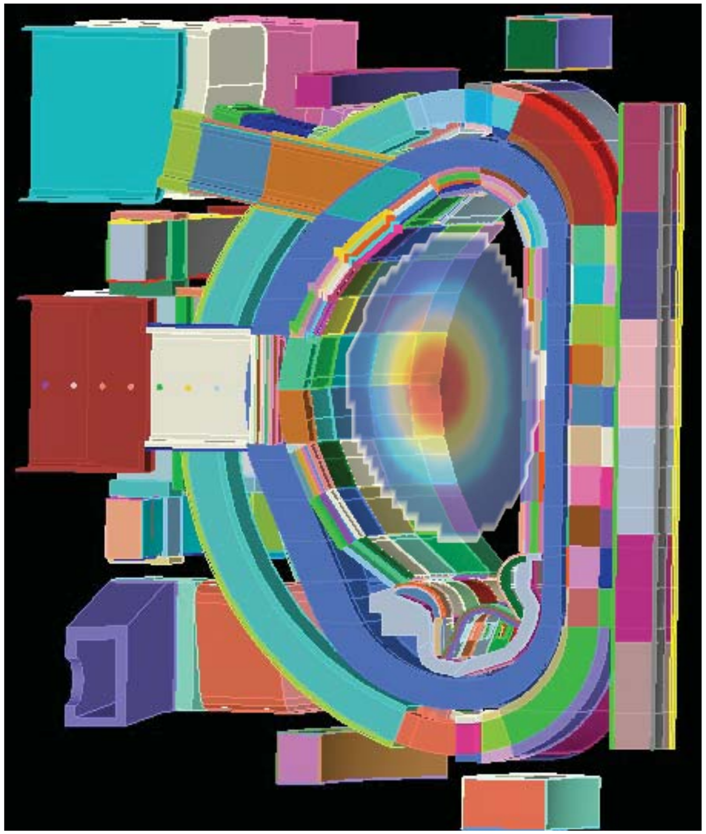
Nuclear Heating
Module 13 CFD Mesh

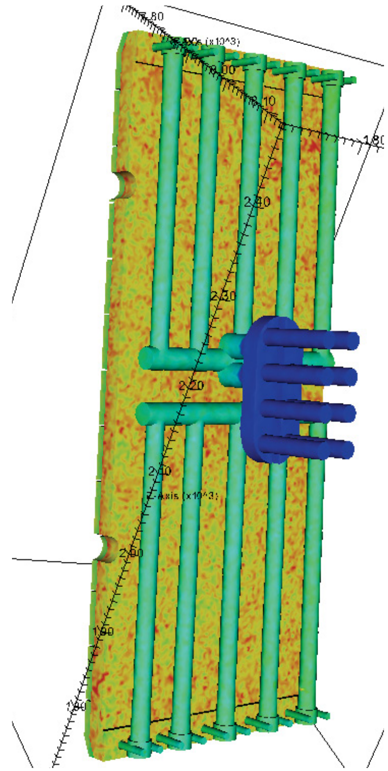


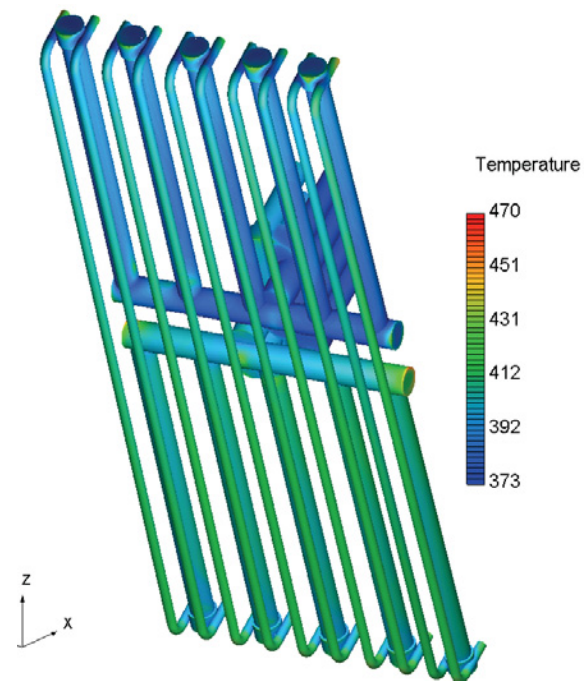
Future Methods Development

- Conformal mesh tallies
  - Efficient ray-tracing through mesh
  - Functional expansion on mesh
  - *hp*-refinement questions
- Robustness to geometric flaws
  - Transport approximations to small overlaps
- Hi-fidelity activation/isotopics
  - Detailed photon dose

Multi-Physics Modeling & Simulation



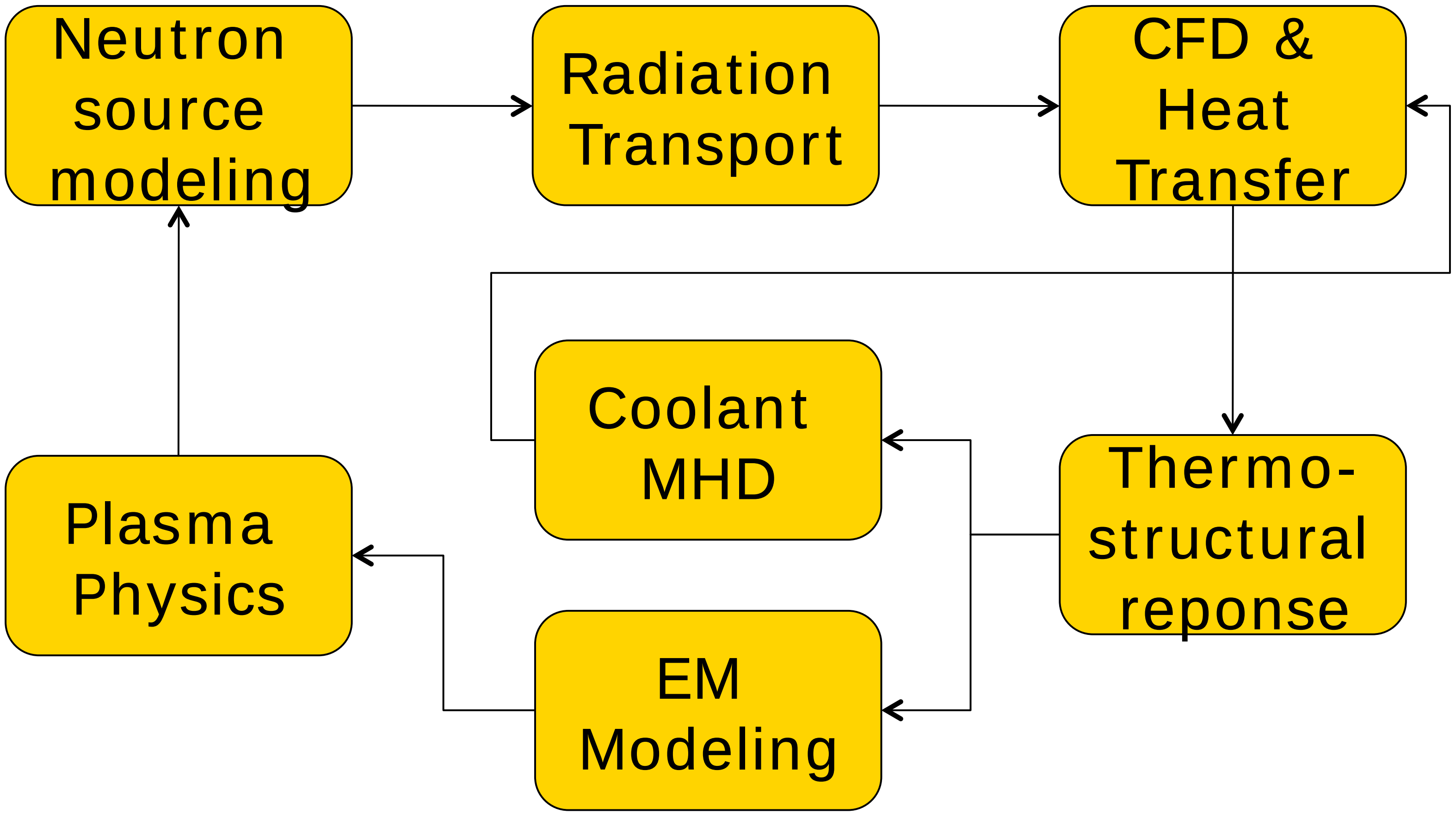




Neutron Source Modeling

Radiation Transport → Nuclear Heating → CFD & Heat Transfer (Alice Ying, UCLA)

Multi-Physics Modeling & Simulation

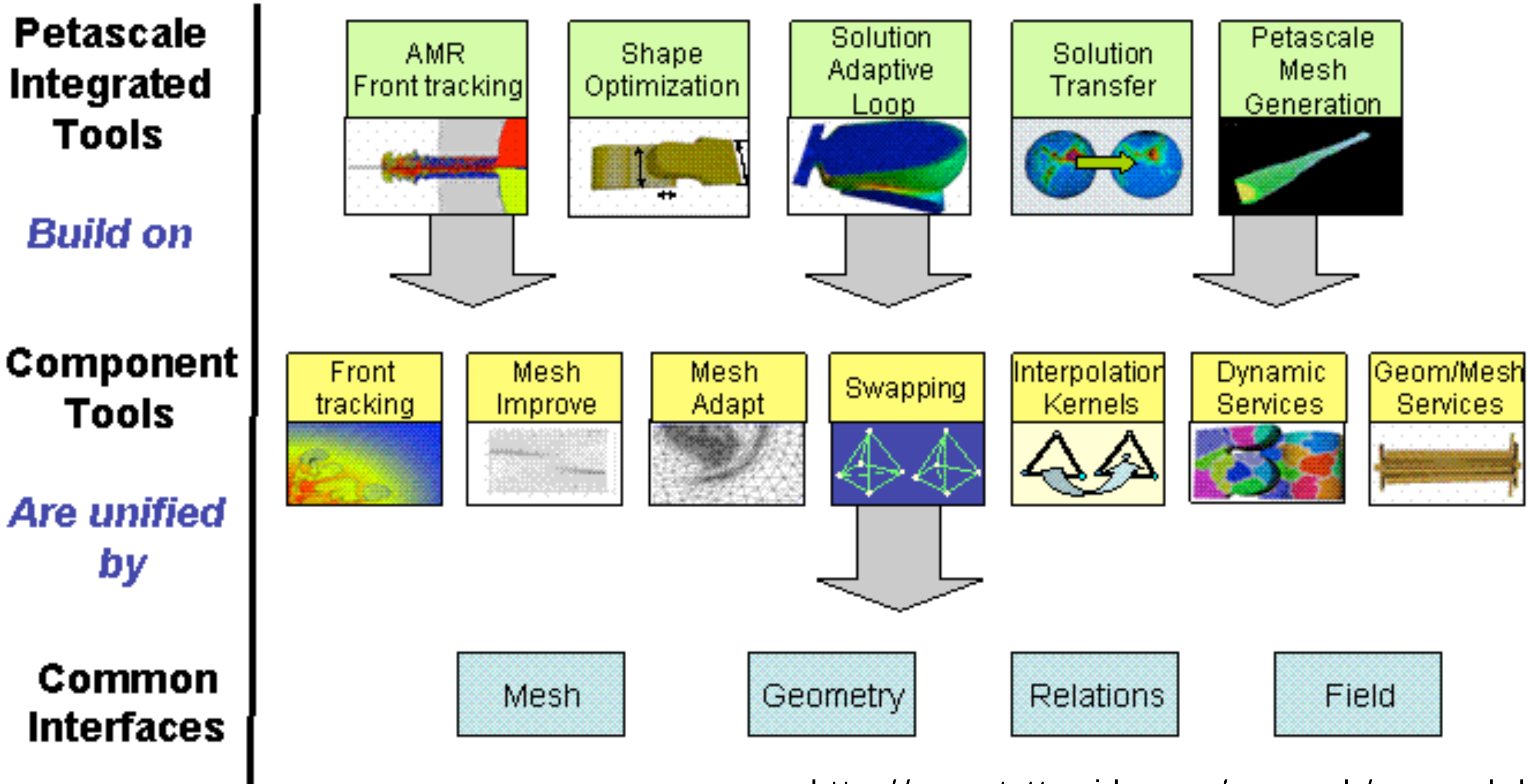


Common Domain Representation

- Develop a common framework for representing the geometric (phase space) domain
- Benefits
  - Facilitate transfer of data among physics modules
  - Take advantage of ongoing development in tools and services
    - Optimization for performance of analysis
    - Optimization for performance of system

Interoperable Technologies for Advanced Petascale Simulations (ITAPS)

- SciDAC-funded effort



http://www.tstt-scidac.org/research/research.html

Questions?

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