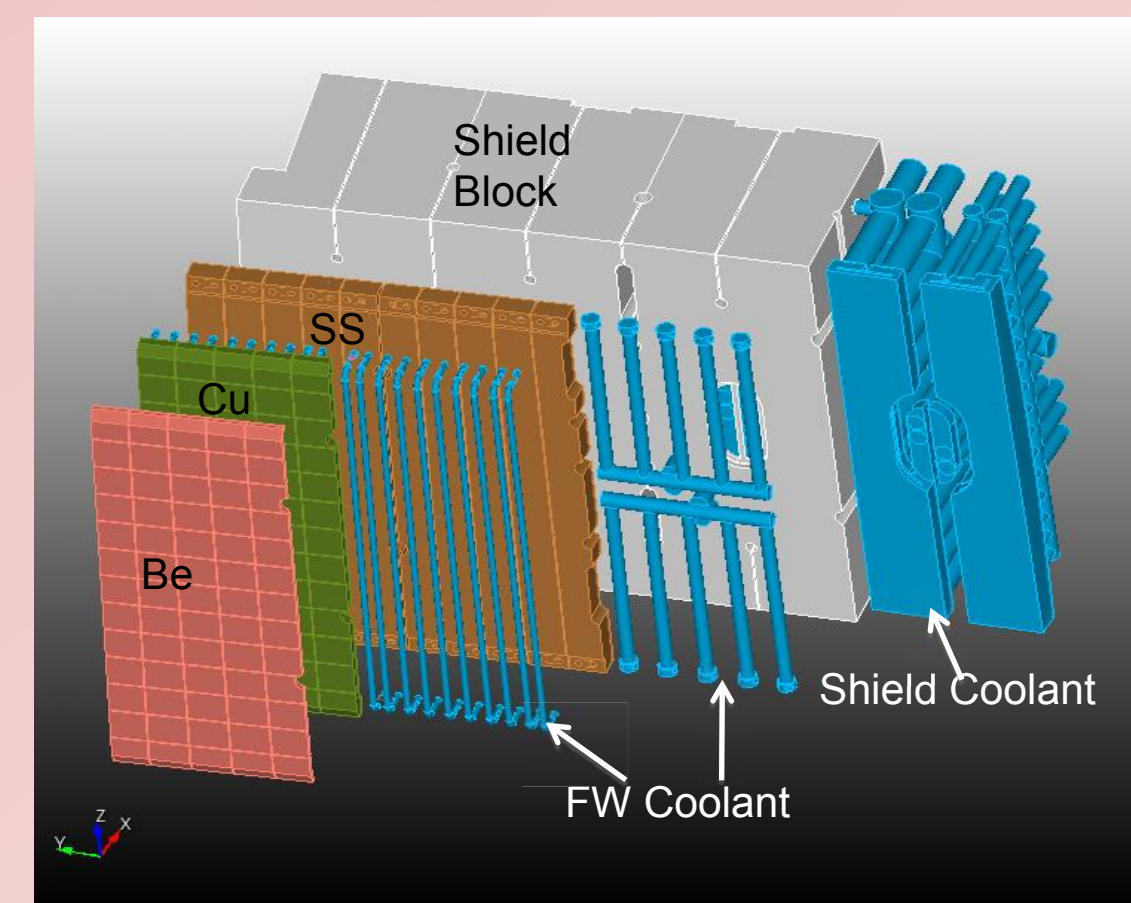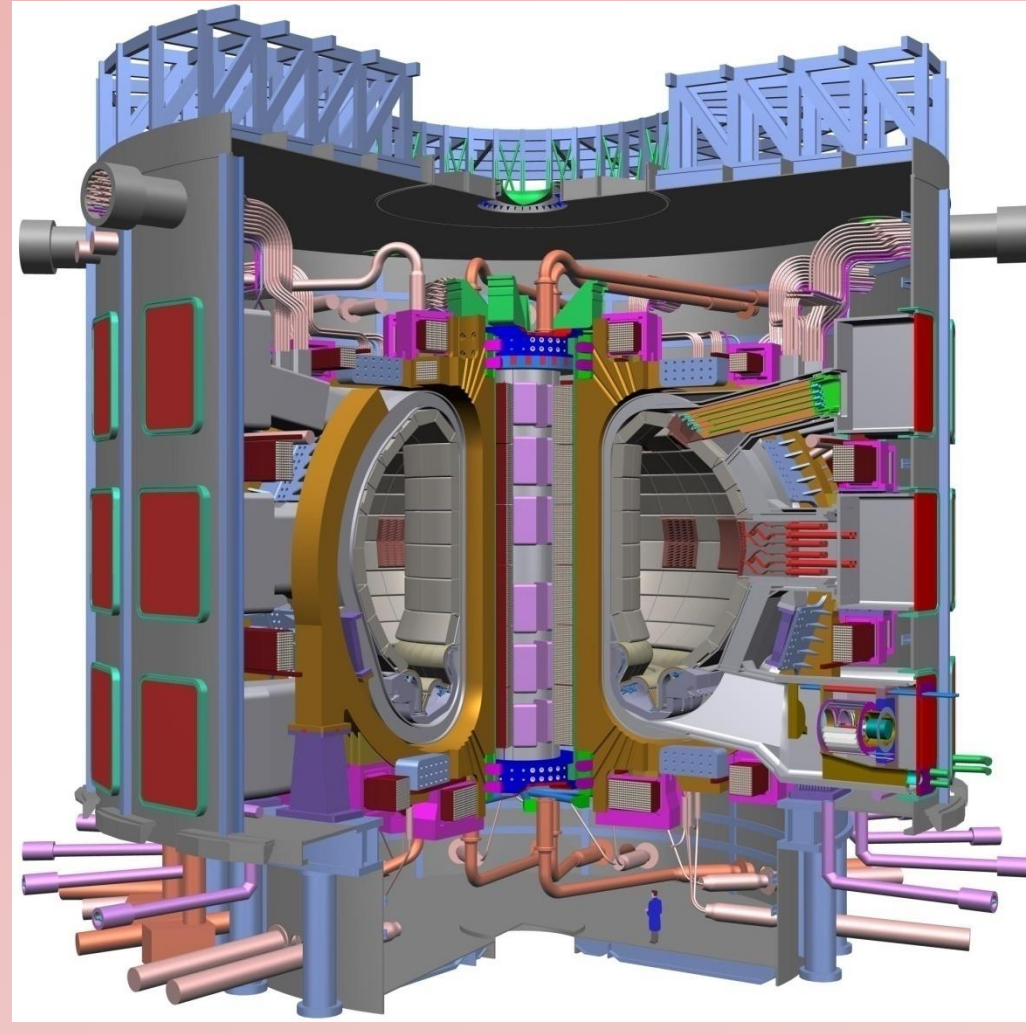# Detailed 3-D Nuclear Analysis of ITER Blanket Modules

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Introduction

- In ITER, Blanket Modules (BMs) are arranged around the plasma to provide thermal and nuclear shielding for the vacuum vessel (VV), magnets, and other external components
- Nuclear heating, radiation damage (dpa), and He production are important parameters needed in the design process of the BMs
- BMs are geometrically complex making a CAD based approach to neutronics analysis ideal
- Goal is to analyze the most critical BMs and regions using a 3-D CAD approach (subject to CAD model availability and cleanliness)
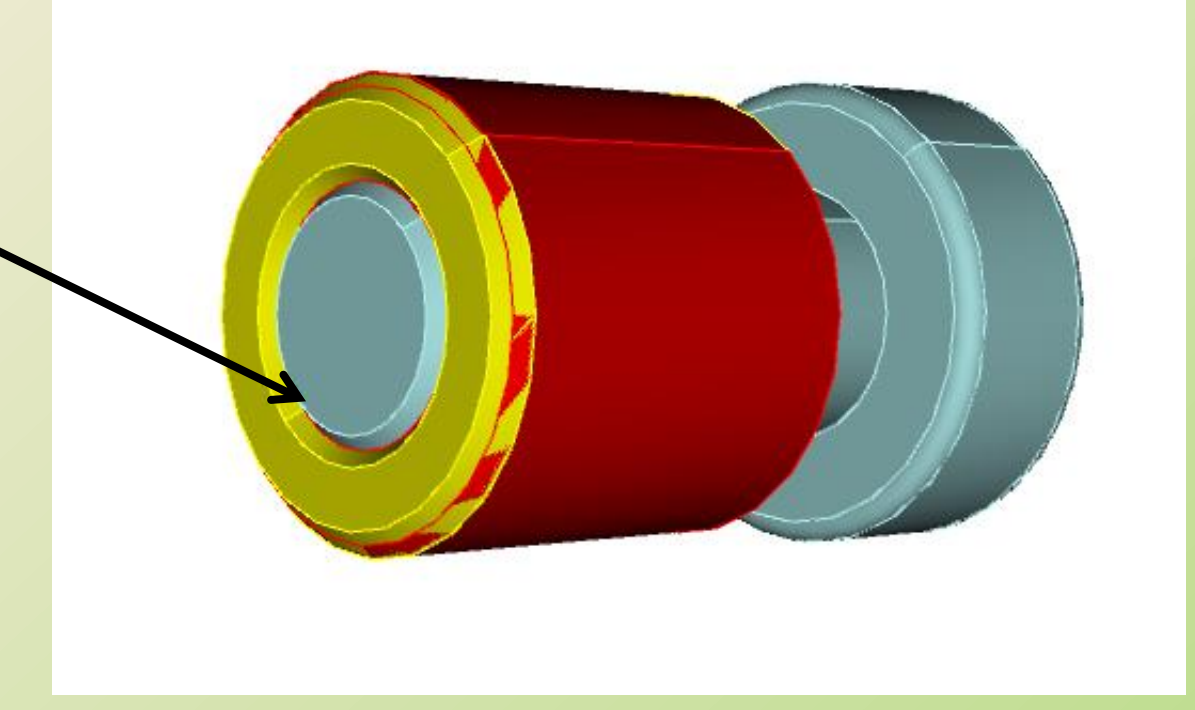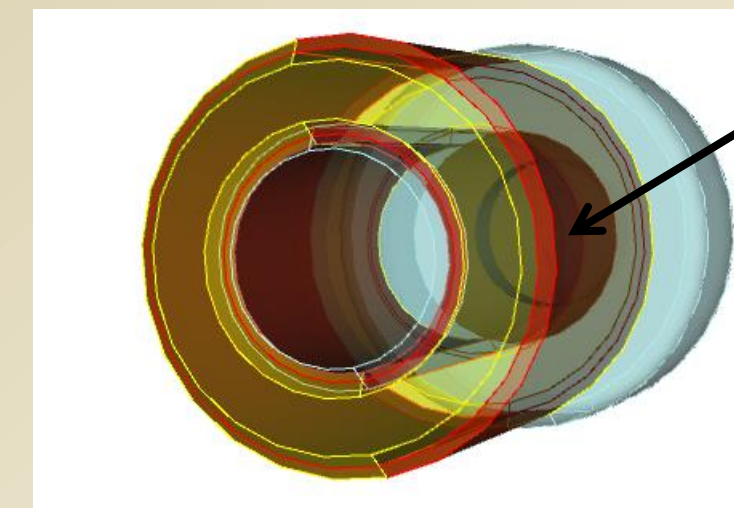- These results will support the ITER BM Final Design Review (FDR)

Schematic of BM design

Blanket Lite (BL-Lite) Model and Approach

- Creating and running a 40° global CAD model of ITER using detailed CAD models of individual components would require too much computer memory
- Instead, create a 40°, simplified CAD model for BM nuclear analysis (BL-Lite)
  ➢ BL-Lite created from ITER's Catia based CAD models
- This BL-Lite model provides the proper nuclear "boundary" environment

VV Shells   VV Fill   Port plugs   Triangular support   EHF BM   NHF BM   Divertor cassettes

BL-Lite Model
724 volumes
12064 surfaces

- **Approach:**
  1) Insert the detailed components into BL-Lite in the region of interest
  2) Generate conformal tetrahedral mesh for mesh tallies of interest
  3) Perform neutronics analysis with DAG-MCNP5
  4) Pass mesh based nuclear results to finite element engineering codes (e.g. ANSYS)

Example: BM01

Combined detailed BM01 and BL-Lite Model
993 volumes
20360 surfaces

NB Nuclear Heating Results

- A simplified model of the NB port region was integrated into BL-Lite
  ▪ Purpose to investigate port liner and VV heating
  ▪ 797 volumes, 13059 surfaces

Port liner nuclear heating:

Cu Heating (W/cm3)

Location of liner

Nuclear heating profile provided to engineers for thermal analysis

Port extension/VV nuclear heating:

Plasma view

Meshed region

SB15 shown for reference

- Part of the port extension/VV exceeds the 0.6 W/cm³ limit:

Possible solution:

Original design

Thicker floor design

Threshold filter applied to results at 0.6 W/cm³
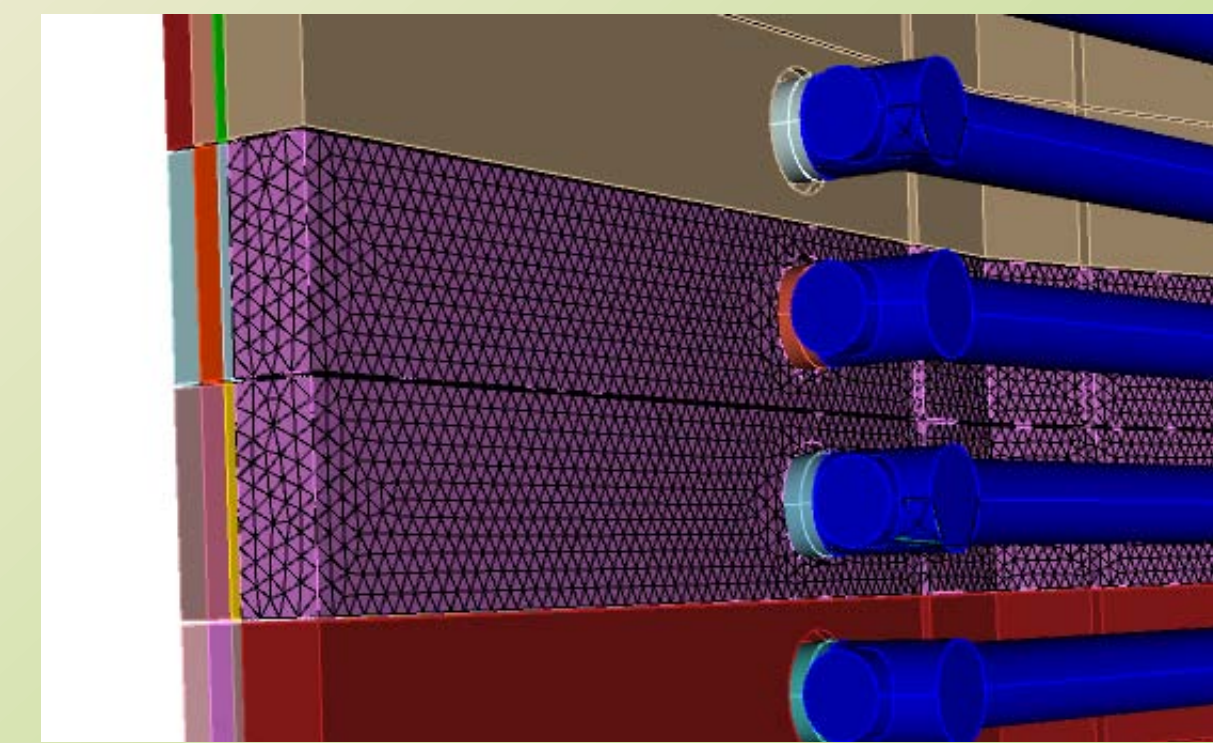
Still some region with excess heating

CAD Based Analysis with DAG-MCNP

- DAG-MCNP transports directly in the CAD geometry (ACIS, .sat format)
- Requires **clean** CAD models (no overlapping volumes)

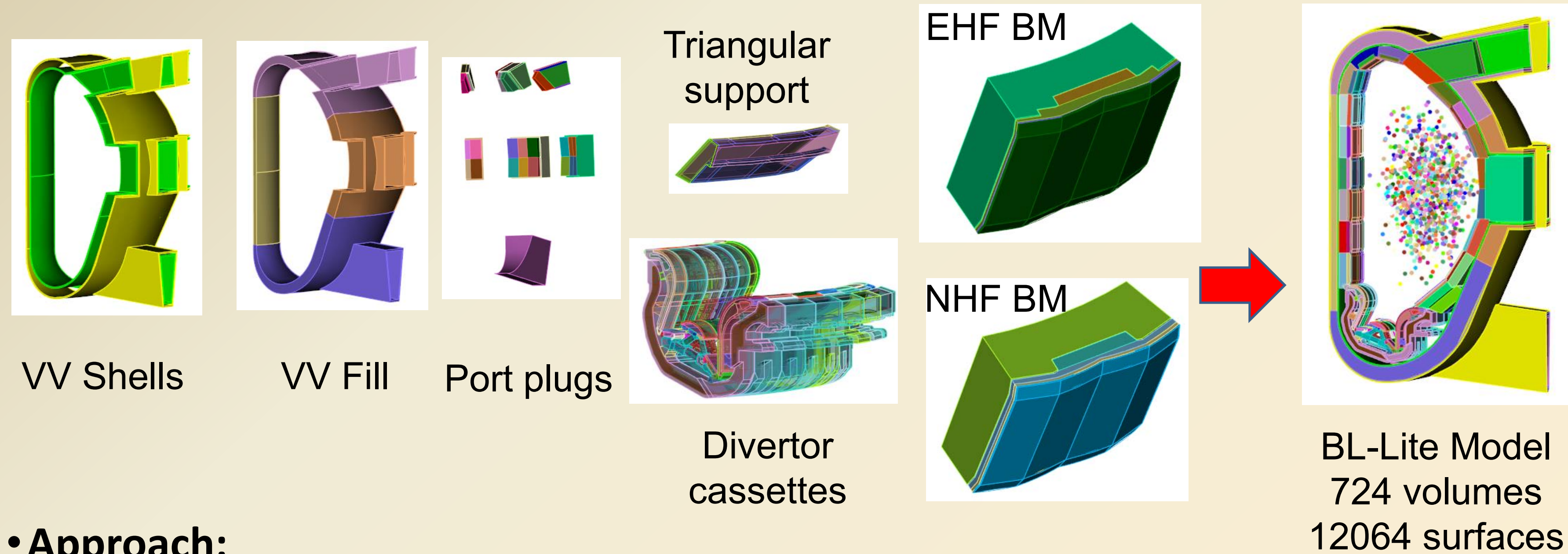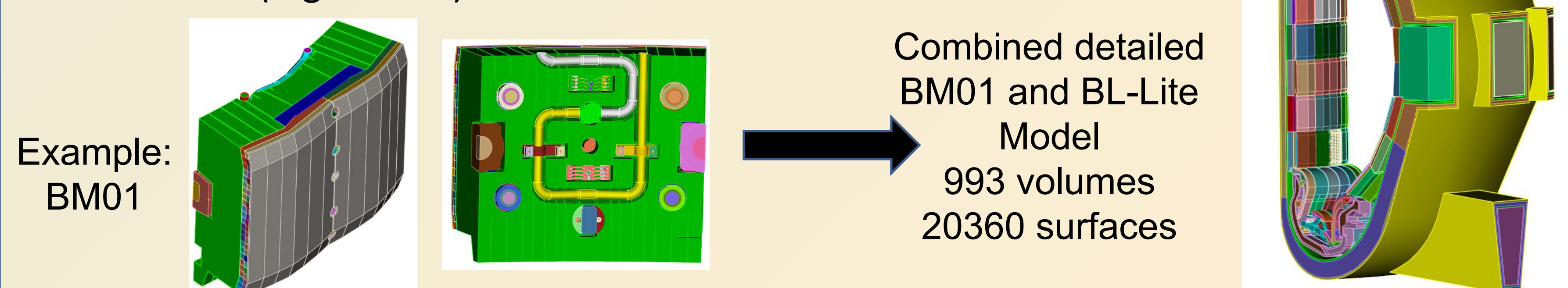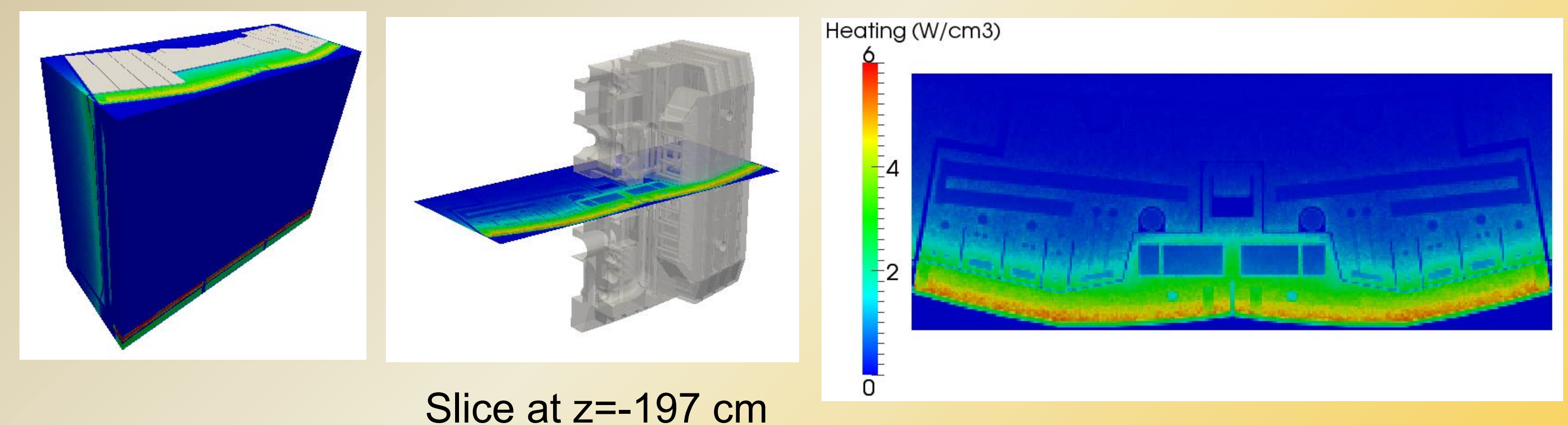BM04 central bolt region showing 2 overlaps (highlighted in red)

- Use DAG-MCNP's conformal mesh tally feature
  ➢ Tally nuclear parameters on a tetrahedral mesh
- Ideally tally nuclear parameters (e.g. heating) on the same mesh needed for other mesh based analysis (e.g. CFD, stress)
  ➢ Can interpolate nuclear parameters from one mesh to another if this is not possible
- Can use Cubit (Sandia National Laboratory) to generate tet meshes

A first wall support meshed to tally nuclear heating

BM01 Nuclear Heating Results

Cartesian mesh tally on BM01 (0.5 x 0.5 x 0.5 cm voxels):

Heating (W/cm3)

Slice at z=-197 cm
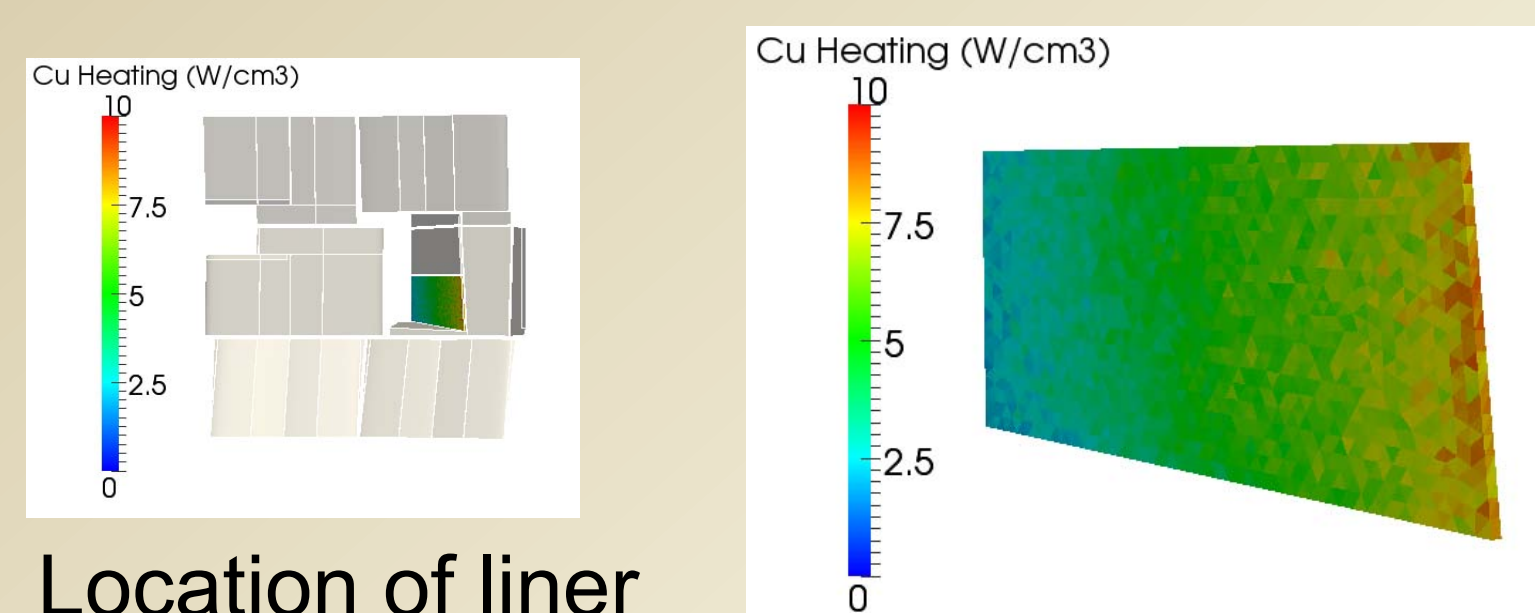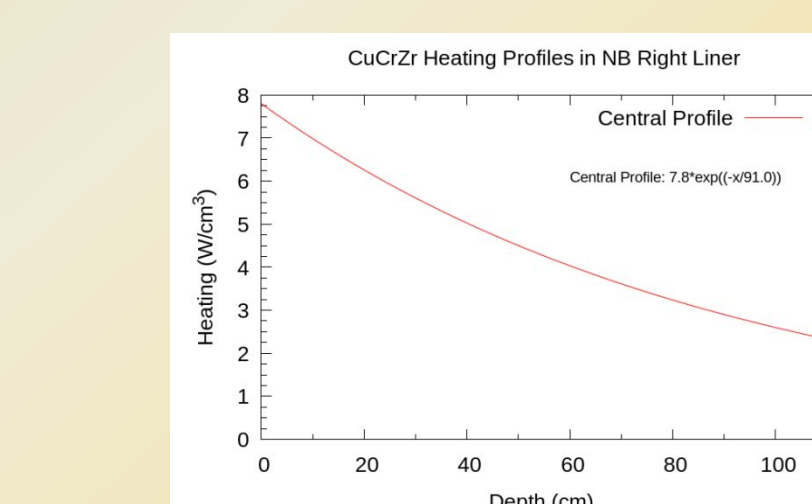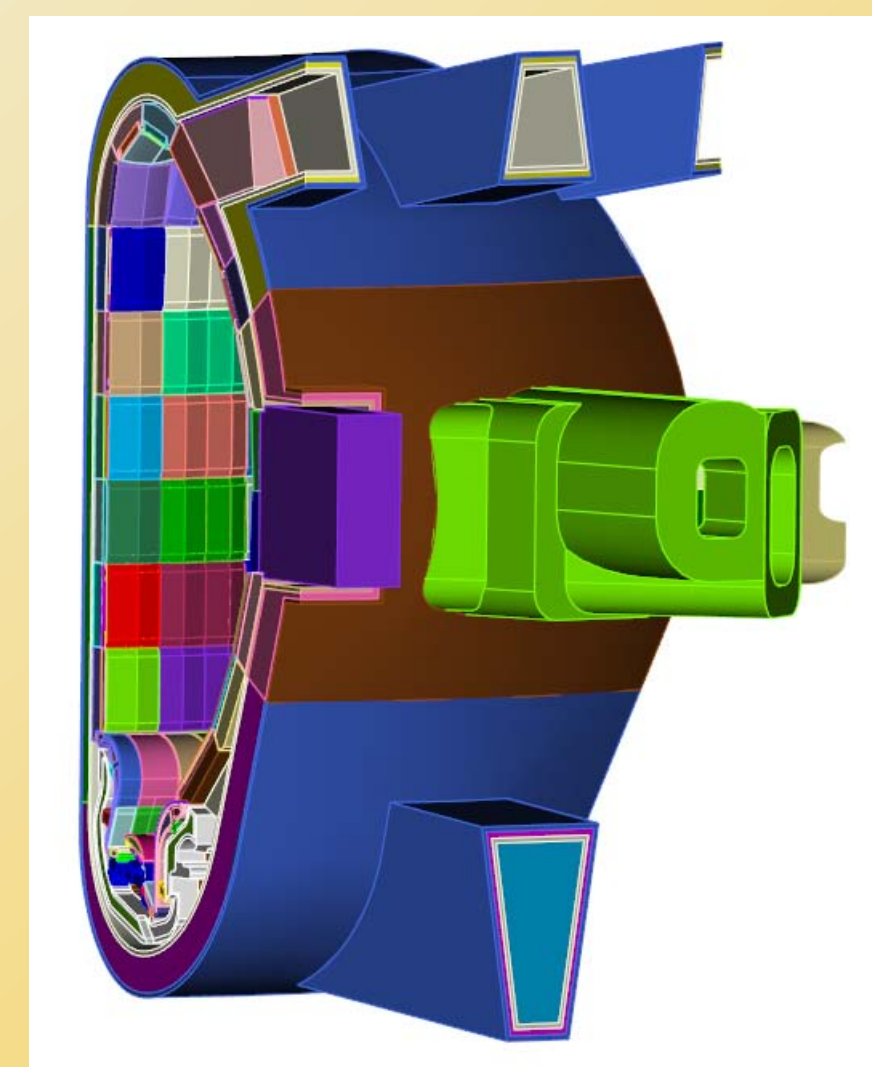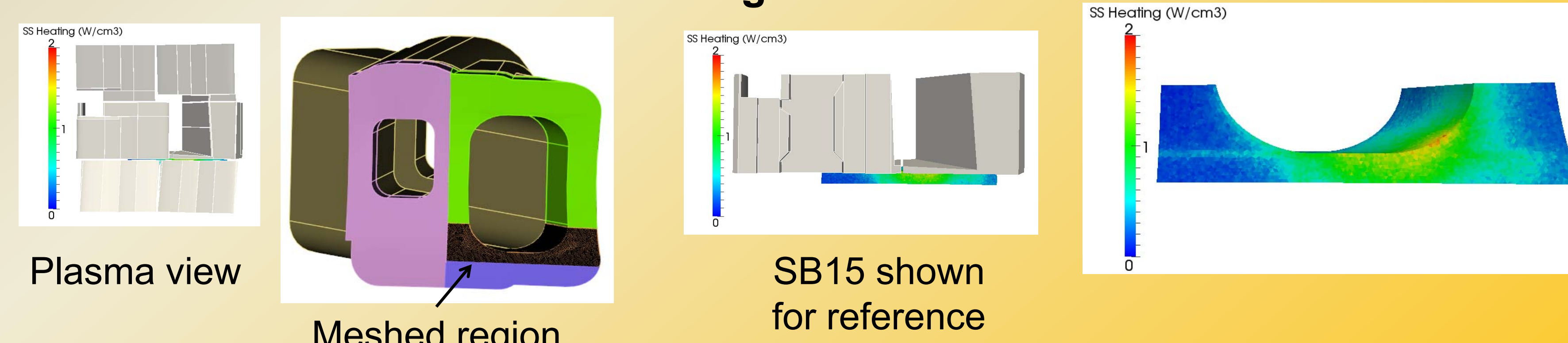
Conformal tetrahedral mesh tally on the VV:

Meshed region

SS Heating (W/cm3)

SB shown for reference
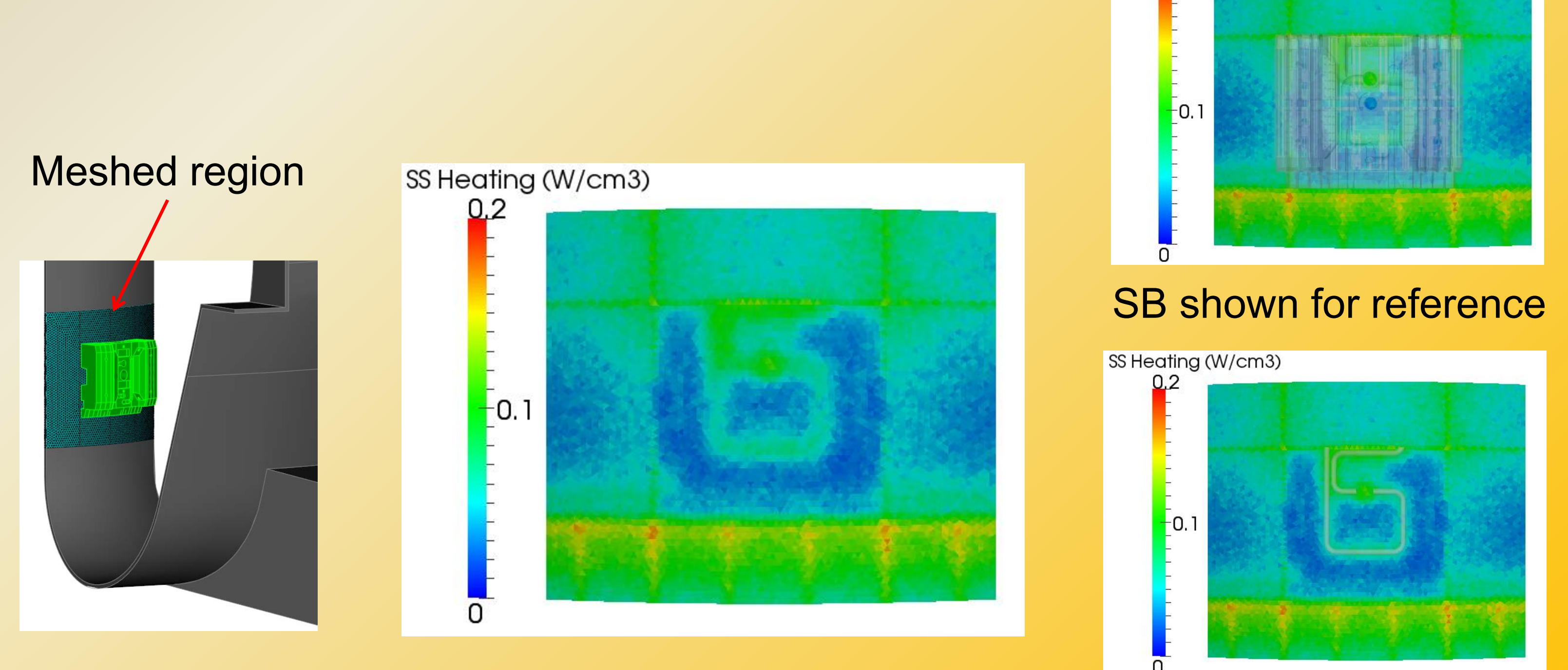
Manifold water shown for reference
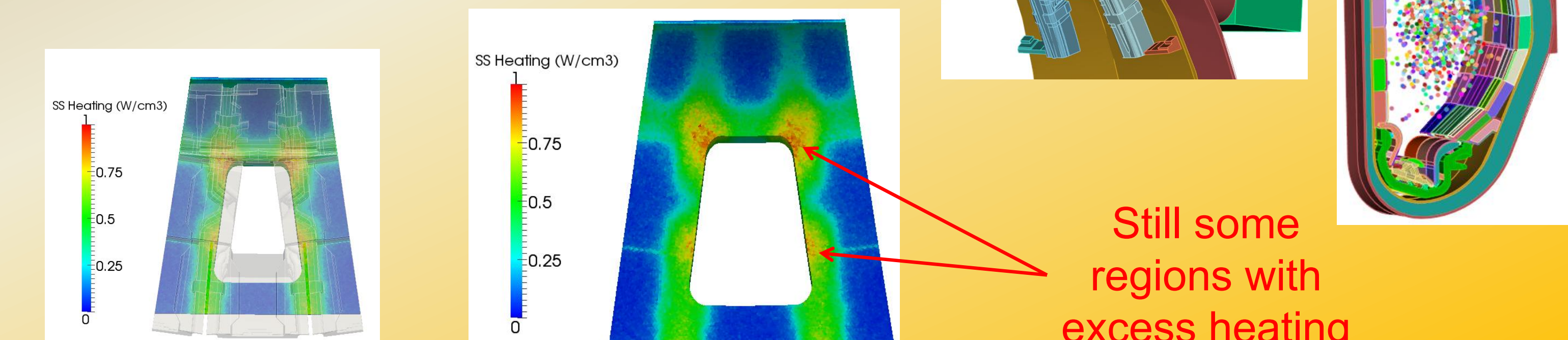
Upper Port Results

- A simplified model of the upper port region was integrated into a 20° version of the BL-Lite model
  ▪ 362 volumes, 7001 surfaces

VV nuclear heating:

SS Heating (W/cm3)

Still some regions with excess heating

Conclusions and Future Work

- Detailed 3-D nuclear analysis is important in the design process for the ITER Blanket Modules and nearby components
- A 40° global model of ITER is the basis of this CAD based approach
- The results of this work are being actively used to refine the design in regions where limits are exceeded
- Future Work: Detailed upper port region, BM11-13 region with ELM coils, He production in FW/SB water connectors for OB BMs