Detailed Nuclear Analysis of ITER Blanket Modules (Work In Progress)

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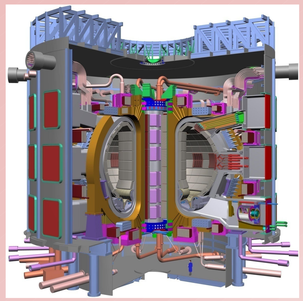
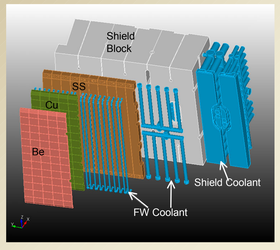
Introduction

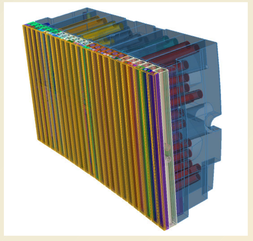
- In ITER, Blanket Modules (BMs) are arranged around the plasma to provide thermal and nuclear shielding for the vacuum vessel (VV), magnets, and other external components
- Nuclear heating, radiation damage (dpa), and He production are important parameters needed in the design process of the BMs
- BMs are geometrically complex making a CAD based approach to neutronics analysis ideal
- Goal is to analyze BM04, BM08, BM12 for Preliminary Design Review (PDR)



Earlier Blanket Module Analysis

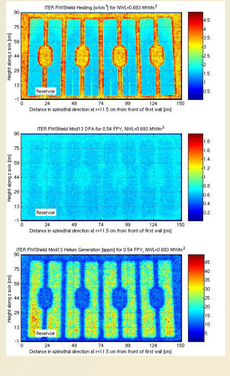


Schematic of early BM design

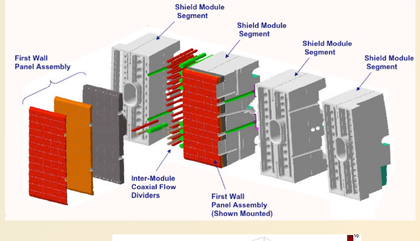


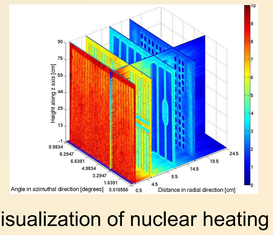
BM13 CAD model used in hybrid 1-D/3-D analysis

Detailed mesh tally results for BM13 (Using non-conformal mesh tallies)



Nuclear heating, dpa, He production at 11.5 cm depth in Module 13





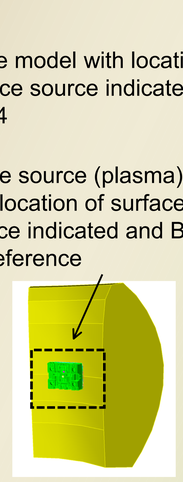
3-D Visualization of nuclear heating in BM13

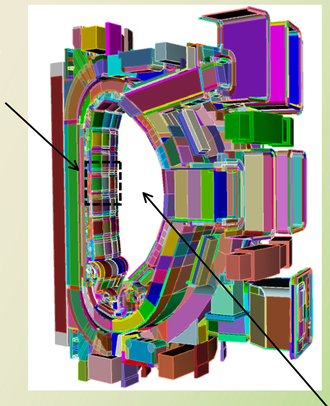
Surface Source based Approach

- The best approach is to place a detailed CAD model of the BM of interest into a 40 degree CAD model of ITER
- Currently, an updated, complete, and clean 40 degree CAD model is not available for ITER
  - ➢ but a native MCNP geometry version is available (B-Lite)
- Therefore, a surface source approach will be used:
  1) Native MCNP with B-Lite model used to generate a source on a surface in front of the BM of interest
  2) DAG-MCNP transports neutrons and photons from this surface source through the detailed CAD model of the BM of interest
- In earlier work we have shown this surface source method to be accurate for BM analysis provided 10-20 cm of surrounding geometry is modeled

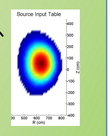
B-Lite model with location of surface source indicated for BM04

B-Lite source (plasma) cell with location of surface source indicated and BM04 for reference

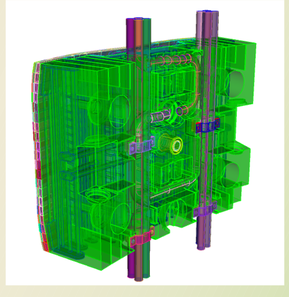


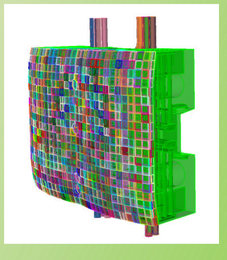


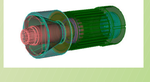
3-D Source



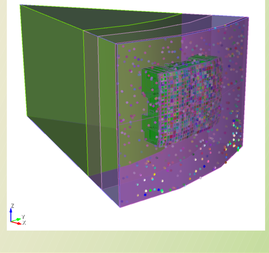
Detailed BM04 CAD model (over 700 volumes)







Flexible mounts



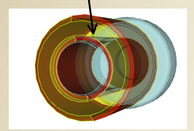
BM04 CAD model with the starting locations of 500 surface source particles (surrounding modules not shown for clarity)

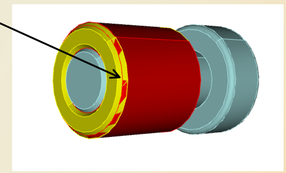
- Surface source calculations with the B-Lite model for BM04 produce about 1e6 source particles per 10 hours of cpu time

CAD Based Analysis with DAG-MCNP

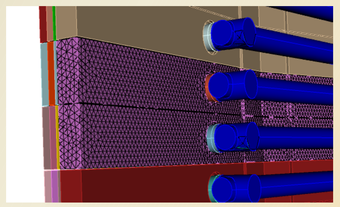
- DAG-MCNP transports particles directly in the CAD geometry
- Requires **clean** CAD models (no overlapping volumes)

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

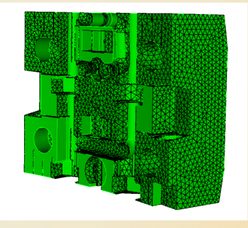




- Will use DAG-MCNP's conformal mesh tally feature
  - ➢ Tally nuclear parameters on a tetrahedral mesh
- Ideally tally nuclear parameters (e.g. heating) on the same mesh needed for other mesh based analysis (e.g. CFD, stress)
  - ➢ Can interpolate nuclear parameters from one mesh to another if this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



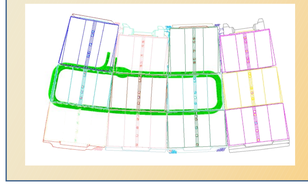
A first wall support meshed to tally nuclear heating

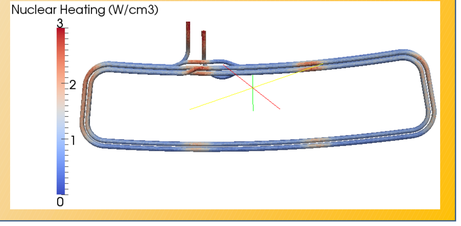


Small features/defects can make meshing difficult

- Conformal mesh tallies can provide key nuclear results for ITER's complex geometries

ITER ELM coil conductor





Conclusions

- Detailed 3-D nuclear analysis is important in the design process for the ITER Blanket Modules
- A CAD based Monte Carlo code (DAG-MCNP) and surface source method are being used
- CAD models of the BMs and their surroundings are being prepared
- Calculations of the surface source for BM04 are underway