Detailed Nuclear Analysis of ITER ELM Coils

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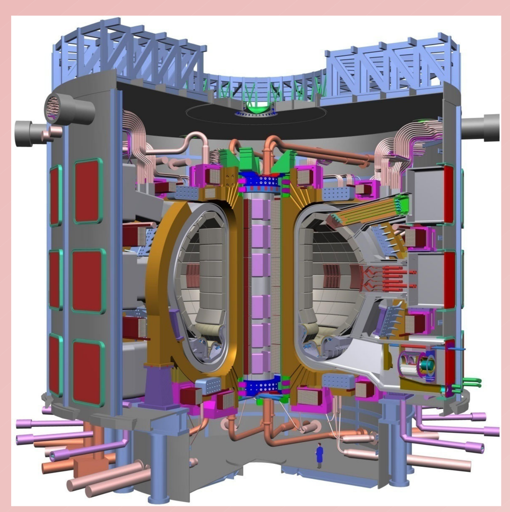
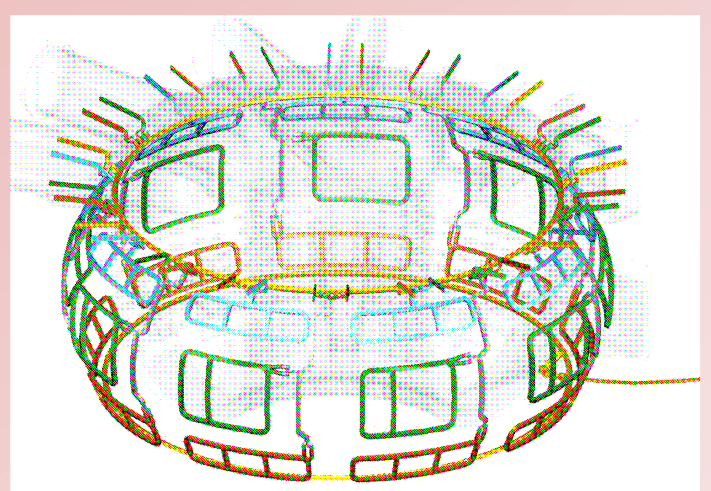
Introduction

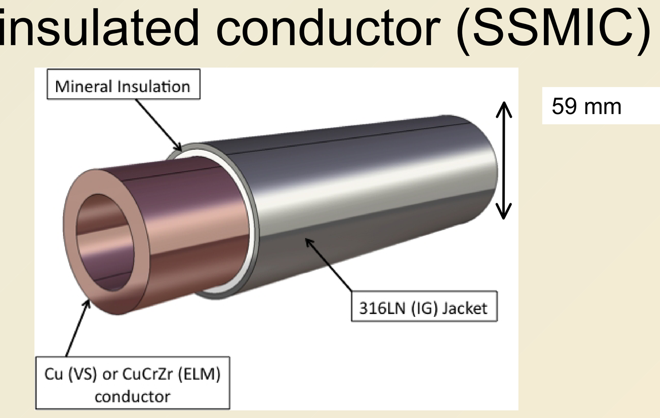
- In-vessel coils are used in ITER to provide control of Edge Localized Modes (ELMs) and for Vertical Stability (VS) of the plasma
- The ELM coils are arranged in 9 sets of 3 picture frame coils on the Outboard side
- The ELM coils are located inside the vacuum vessel in pockets in the Blanket Module
- For these water cooled normal conducting coils the main radiation concerns are:
  - Mechanical and structural degradation in ceramic insulation under long-term neutron fluence
  - Resistivity degradation in ceramic under instantaneous absorbed dose rates (n+γ)
  - Resistivity increase in Cu conductor due to neutron induced transmutations
  - Mechanical and structural degradation in Cu (similar to considerations for ITER FW heat sink)
- Also concerned with total heating (ohmic+nuclear) due to thermal stress, cooling
- Vacuum vessel He production and nuclear heating are additional concerns due to reduced shielding

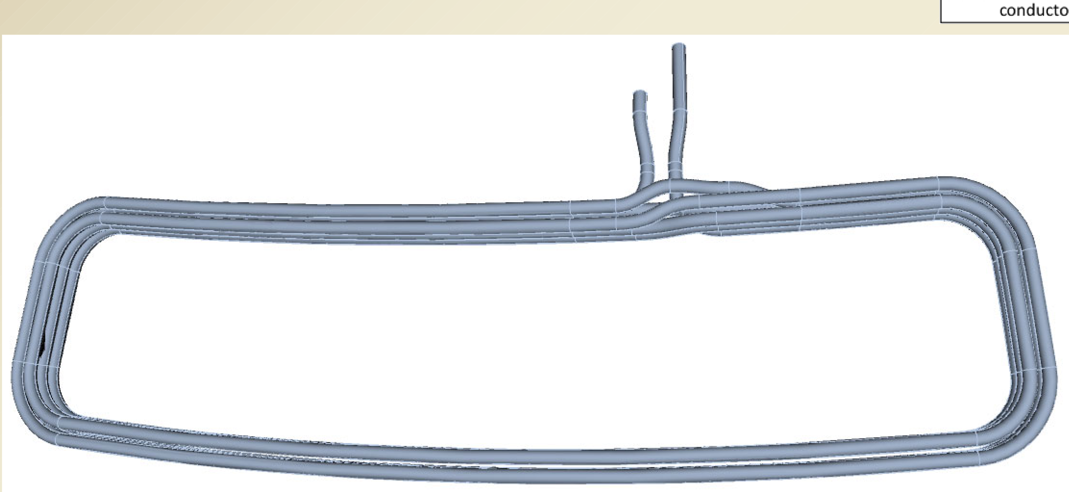




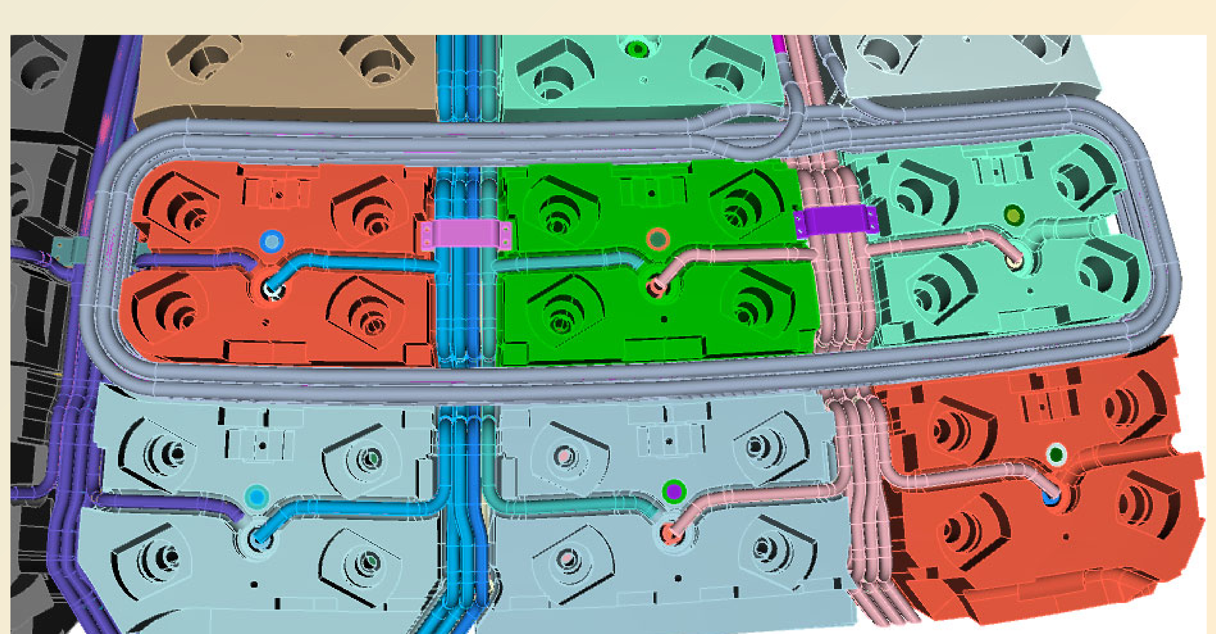
ELM Coil Design Details

- Water cooled stainless steel mineral insulated conductor (SSMIC)
- 59 mm OD
- CuCrZr conductor
- MgO ceramic insulator
- 6 turn coil arranged in a 3x2 array



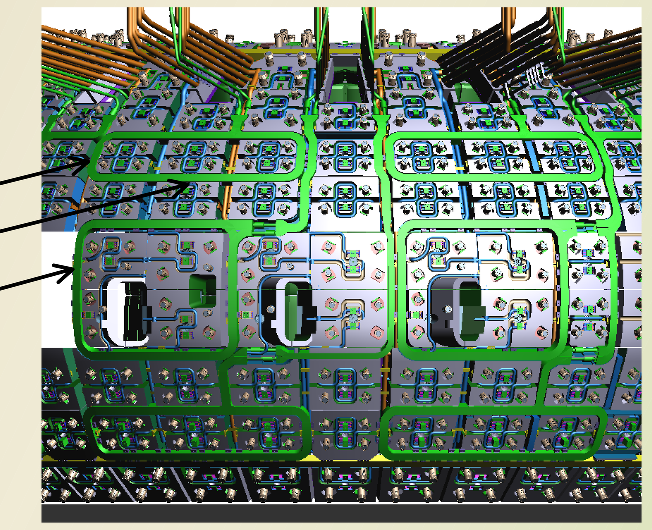


View from vacuum vessel showing integration with blanket modules and poloidal manifolds



Native Geometry MCNP models

Legs Analyzed:
1) 10 pipe poloidal
2) Toroidal
3) 8-pipe poloidal

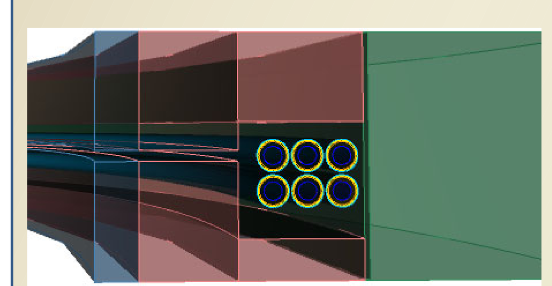


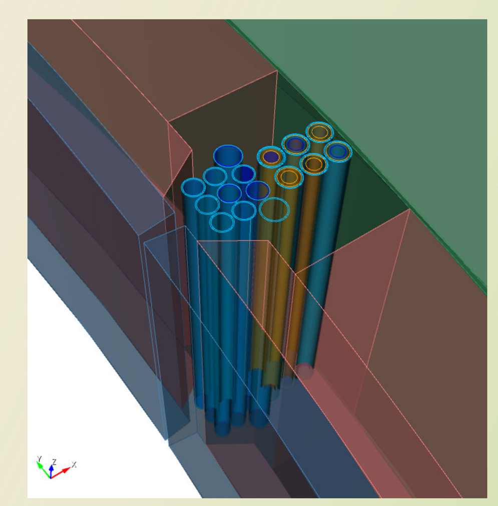
Toroidal Model

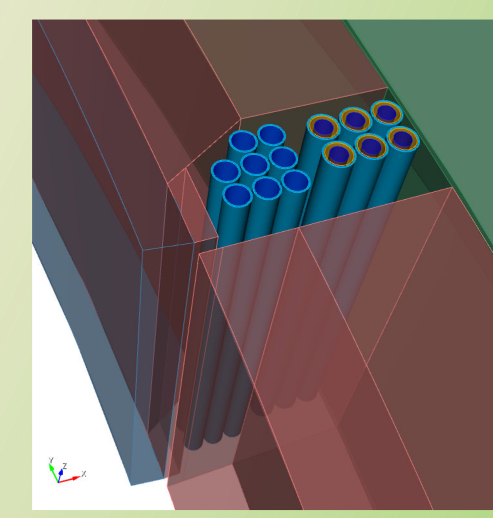
- Cylindrical Model (IB & OB)
- 5 degree sector with 45 cm height
- Uniform source (0.75 MW/m^2)
- Reflecting boundaries
- 2 cm gaps between BL modules
- CuCrZr conductor, MgO
- ELM clamps not modeled

Poloidal Models

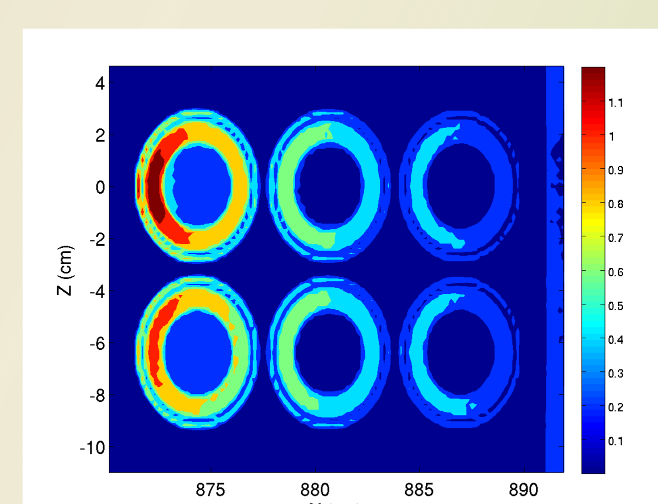
- Cylindrical Model (IB & OB)
- 10 degree sector with 100 cm height
- Uniform source (0.75 MW/m^2)
- Reflecting boundaries
- 2 cm gaps between BL modules
- CuCrZr conductor, MgO
- ELM clamps, Manifold brackets not modeled





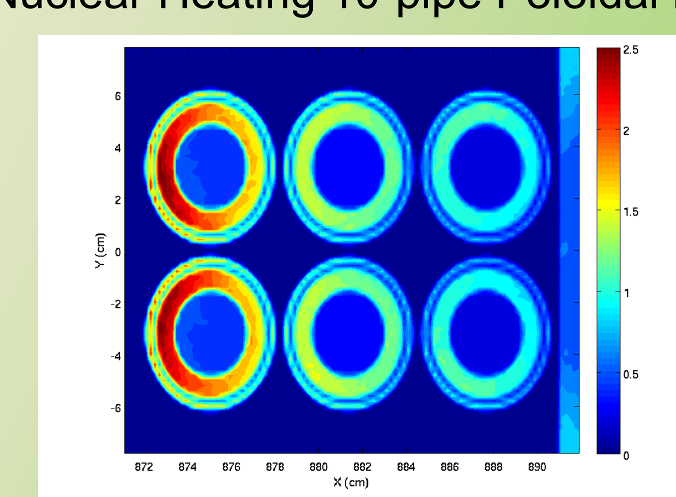


Nuclear Heating Toroidal Leg



Mesh tally peak 1.4 W/cm^3

Nuclear Heating 10-pipe Poloidal Leg

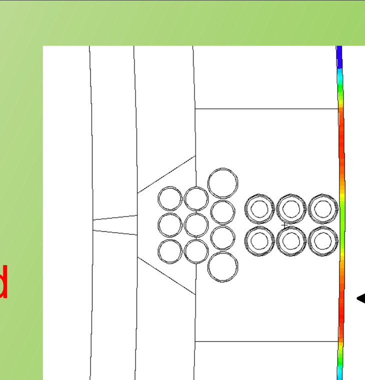


Mesh tally peak 2.6 W/cm^3

Toroidal Leg	Peak Value
MgO Insulator	
Fast neutron fluence (n/cm^2)	2.13e20
Dose rate (Gy/sec)	172
CuCrZr conductor	
CuCrZr dpa (dpa)	0.207
Nuclear heating (W/cm^3)	1.24

10-pipe Poloidal Leg	Peak Value
MgO Insulator	
Fast neutron fluence (n/cm^2)	1.89e20
Dose rate (Gy/sec)	282
CuCrZr conductor	
CuCrZr dpa (dpa)	0.210
Nuclear heating (W/cm^3)	2.39

- He production and nuclear heating on the Vacuum Vessel are also important
  - ➢ VV heating limits (0.4 W/cm^3) exceeded along poloidal leg

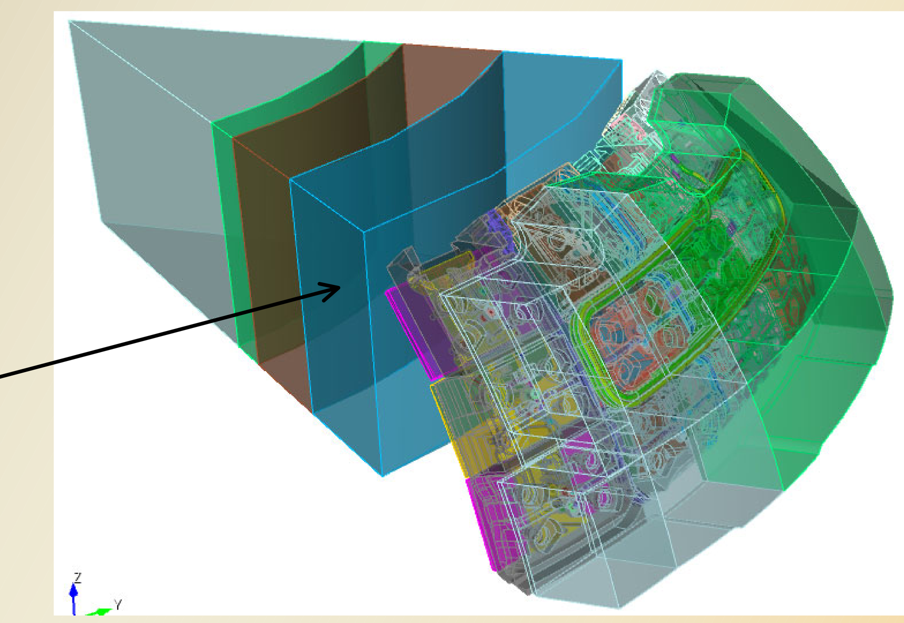


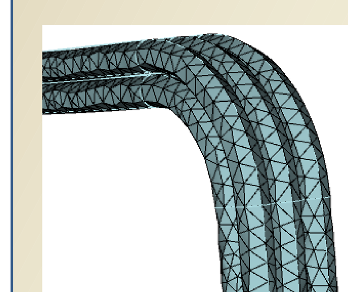
1.2 W/cm^3

CAD Based Analysis (DAG-MCNP)

- Clean CAD models not available for 40° sector of ITER
- Create a "wedge" model of upper ELM:
  - Detailed blanket modules, manifolds, ELM coils
  - Uniform source in plasma region (0.75 MW/m^2)
  - Simplified IB and VV model
  - Reflective boundaries on wedge

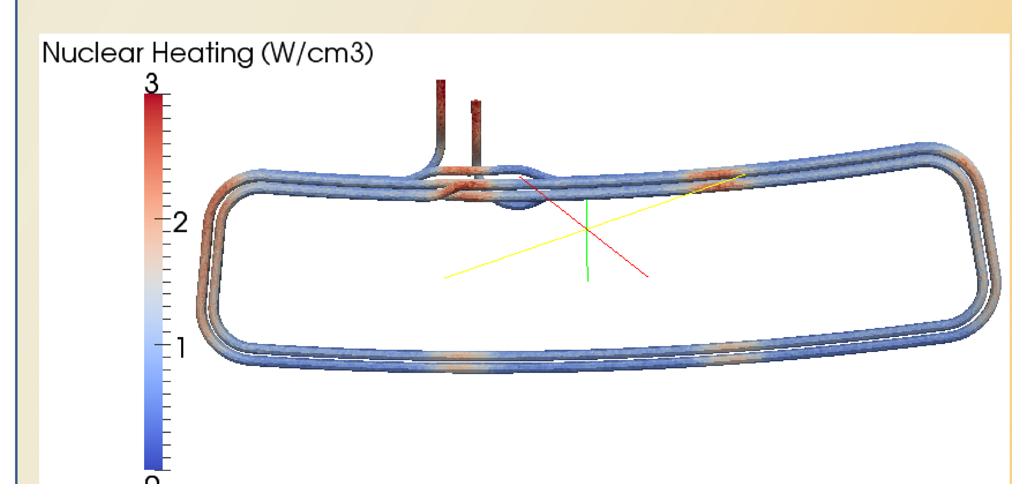
Source region

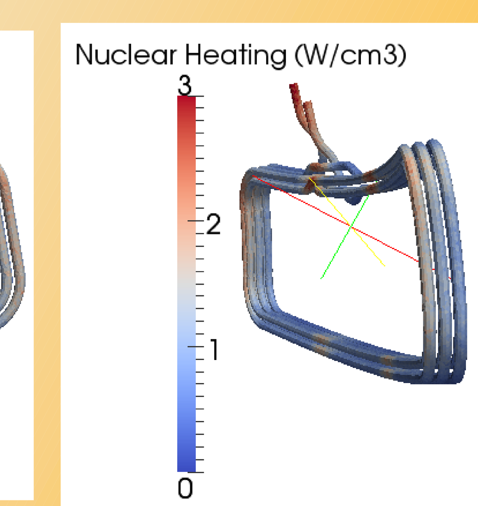




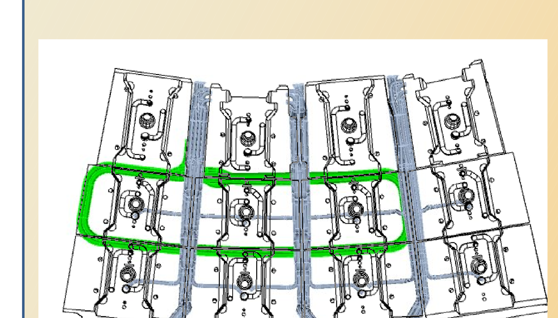
Use DAG-MCNP's new conformal mesh tally feature
- needs tetrahedral meshes (can generate with Cubit)

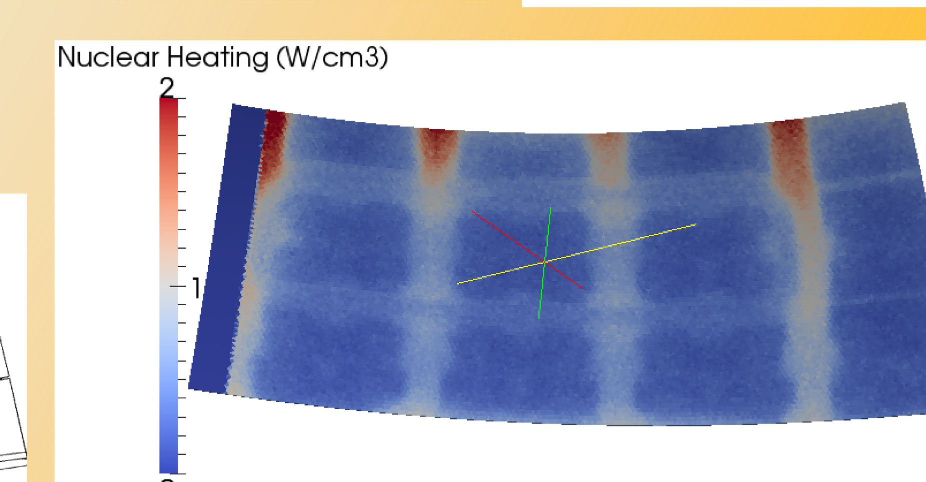
ELM coil conductor:





Front 1 cm of VV:





Conclusions

- The ELM coil design will generally meet the radiation limits
- Radiation induced conductivity in the insulator will require care in the electrical grounding circuit design
- Heating (ohmic+nuclear) levels will require improved design due to thermal stress (note: nuclear heating <20% of total)
- Vacuum vessel heating limits are exceeded and will need further evaluation