OPERA and MAXWELL: Comparison and a Worked Example

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TOSCA vs MAXWELL (as advertised by the respective companies)

- Opera/Tosca
  - Opera is widely used by the scientific community for designing magnets for use in particle accelerators, ion-beam devices, MRI/NMR and a wide variety of other magnetic devices.
  - The application-focused software has evolved over the years and today provides comprehensive multi-physics simulation capable of investigating thermal and stress in addition to electromagnetics.
- Maxwell
  - ANSYS Maxwell is the industry-leading electromagnetic field simulation software for the design and analysis of electric motors, actuators, sensors, transformers and other electromagnetic and electromechanical devices.
  - With Maxwell, one can precisely characterize the nonlinear, transient motion of electromechanical components and their effects on the drive circuit and control system design.
  - Maxwell's advanced electromagnetic field solvers and seamlessly can be linked to the integrated circuit and systems simulation technology, one can understand the performance of electromechanical systems long before building a prototype in hardware.

TOSCA vs MAXWELL (as we understand so far)

Opera/Tosca	Maxwell
Standard coil geometry for various magnet design, easier to make accelerator/detector coils.	There are no standard coil geometry, coils can either be drawn by defining the points or can be imported from CAD software.
Uses Biot-Savart law to caluclate field from the coils, the just coil only model results are very accurate and quick.	Even for coils only model, results are based on mesh size.
ROXIE the software widely used for accelerator magnet design gives an output for OPERA2D and 3D.	Not sure about that, model can be importaed from CAD software
Superconducting materials are very well defined for their Tc, Jc, Bc and also standard material properties given up to cryogenic temperatures	Superconducting materials are not defined in the software, we are not sure how to define these material in MAXWELL.
Other system components (like vessels and structural components can be brought in using step file from CAD software). These components can be defined for their material properties for transient analysis.	Other system components (like vessels and structural components can be brought in using step file from CAD software). These components can be defined for their material properties for transient analysis.
Standard quench modeler included.	No standard quench modeler. We are not sure how easy or difficult and authentic it would be to define your own equation and material properties to simulate the quench.
Standard stress modeler is available, but we haven't used/verfied the accuracy of this module.	Interface to full thermal and mechanical analysis (ANSYS) is very smooth.

Opera versus Maxwell

Comparison Items	Opera	Maxwell
Predefined conductors	Yes	No
Imported CAD conductors	No	Yes
Adaptive meshing for Magnetostatic Solver	No	Yes
Direct force and temperature transfer to ANSYS	No	Yes
Quench	Yes	No
Eddy current	Yes	Yes
Optimetric study	Yes (Optimizer licence required)	Yes (Licence required)
Brick elements	Yes	No

Magnetic Scalar Potential

- Opera/Tosca
  - Reduced potential is required for volumes where currents flow.
  - A separate space is needed to indicate the reduced potential.
  - Total potential is for everywhere else.

- Maxwell
  - No concept of total/reduced scalar potential.

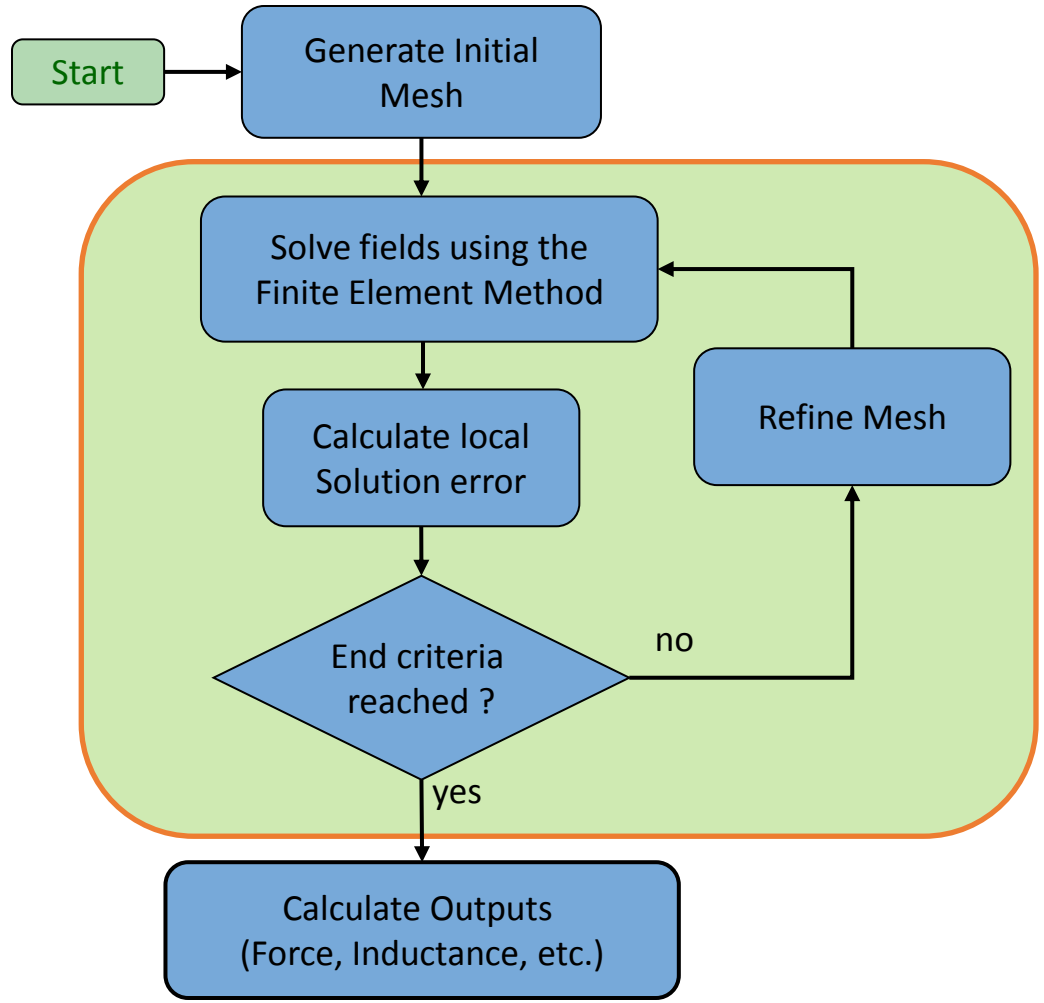
Elements and Meshing

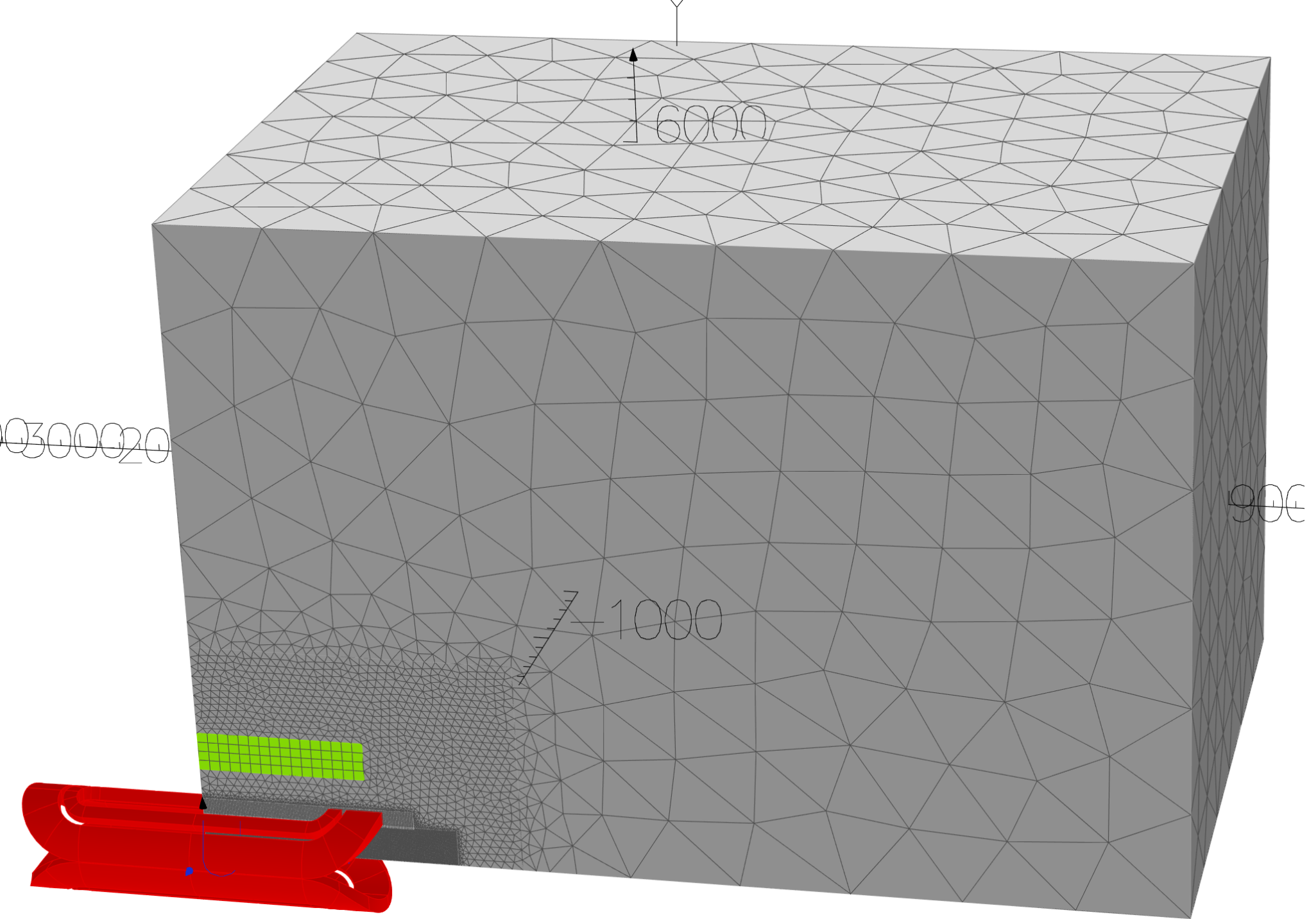
- Opera
  - Brick elements – less number of nodes
  - Tetrahedral elements
  - Meshing is manual
  - Elements can be linear or quadratic

- Maxwell
  - Quadratic tetrahedral elements only
  - Adaptive meshing – less solving time – for static solver
  - Automated mesh refinement per the convergence requirements
  - Initial mesh can be coarse

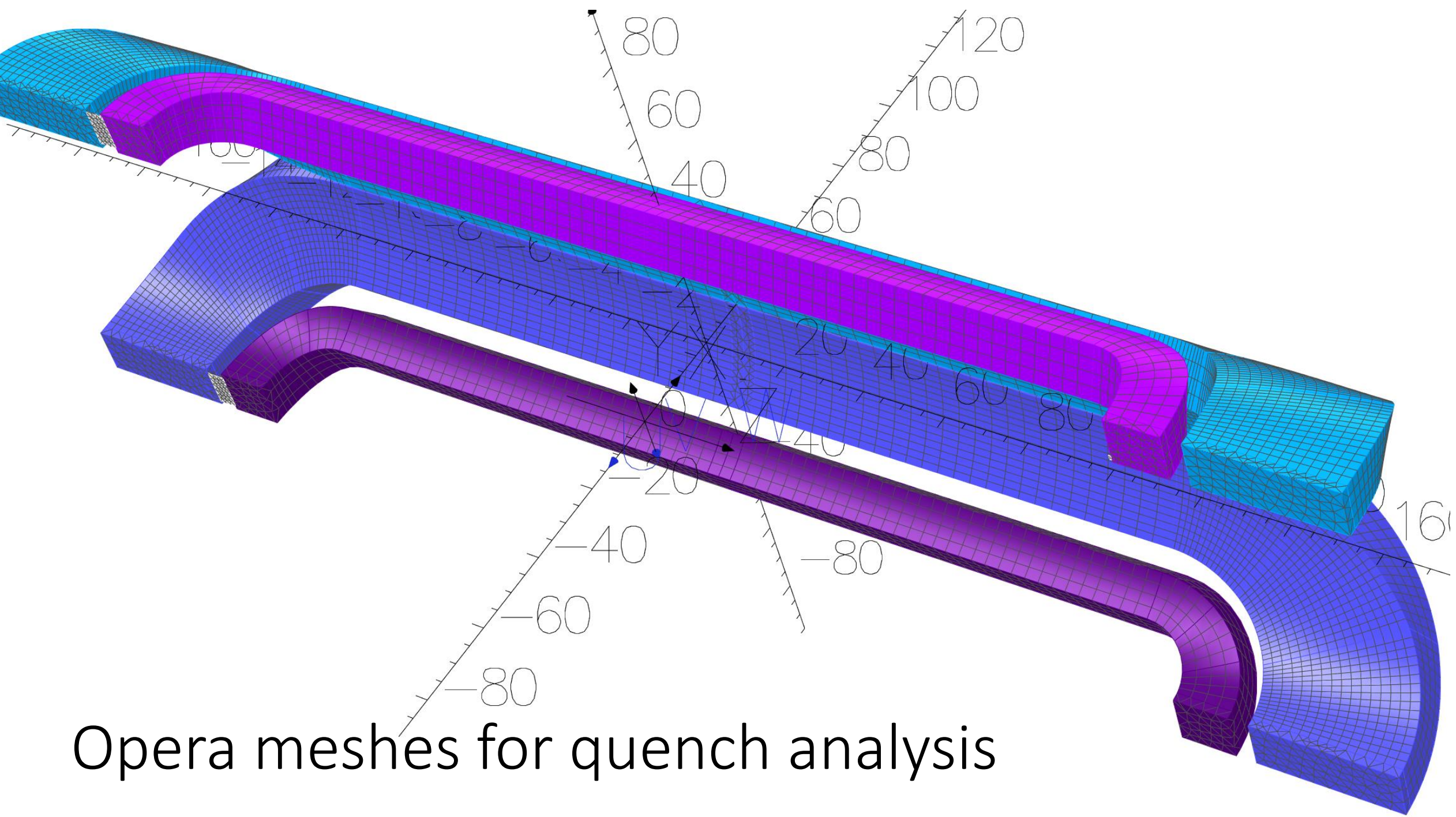
Maxwell Adaptive Meshing

- **Adaptive Meshing Workflow**
  - **Adaptive meshing technique starts with initial mesh and refines it until required accuracy (Energy % error) is met or Maximum number of passes is reached**

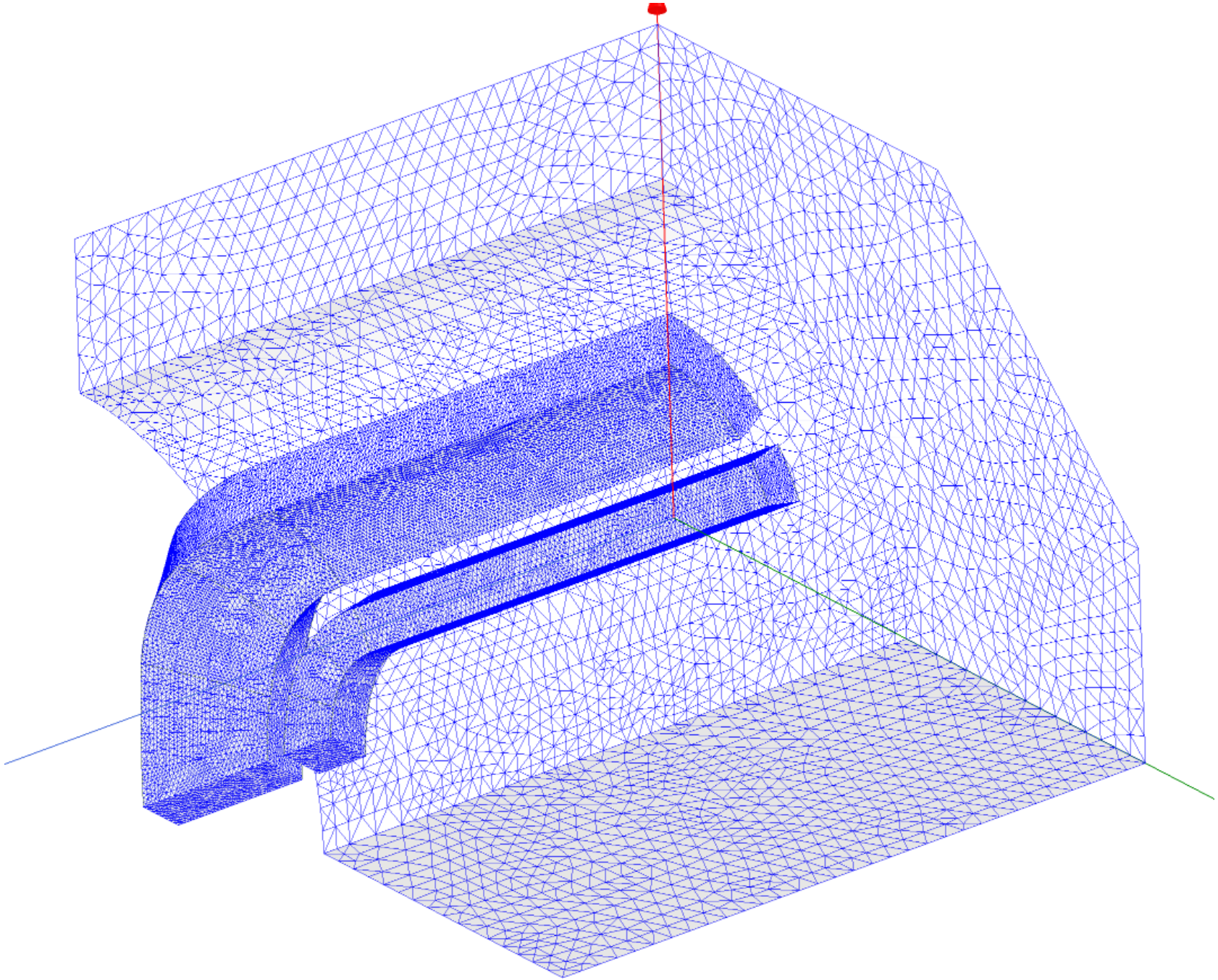




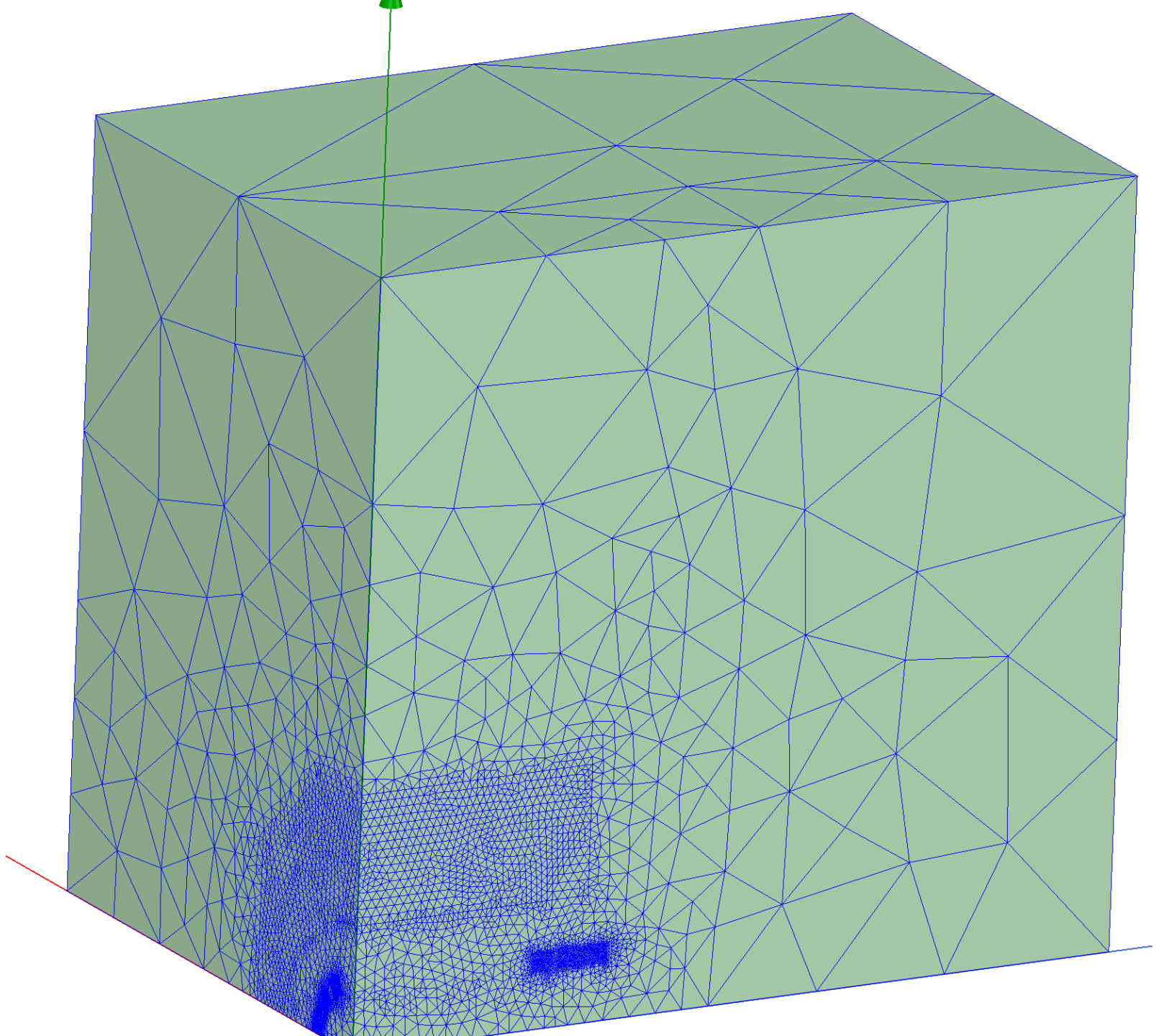
Opera Meshes for Tosca



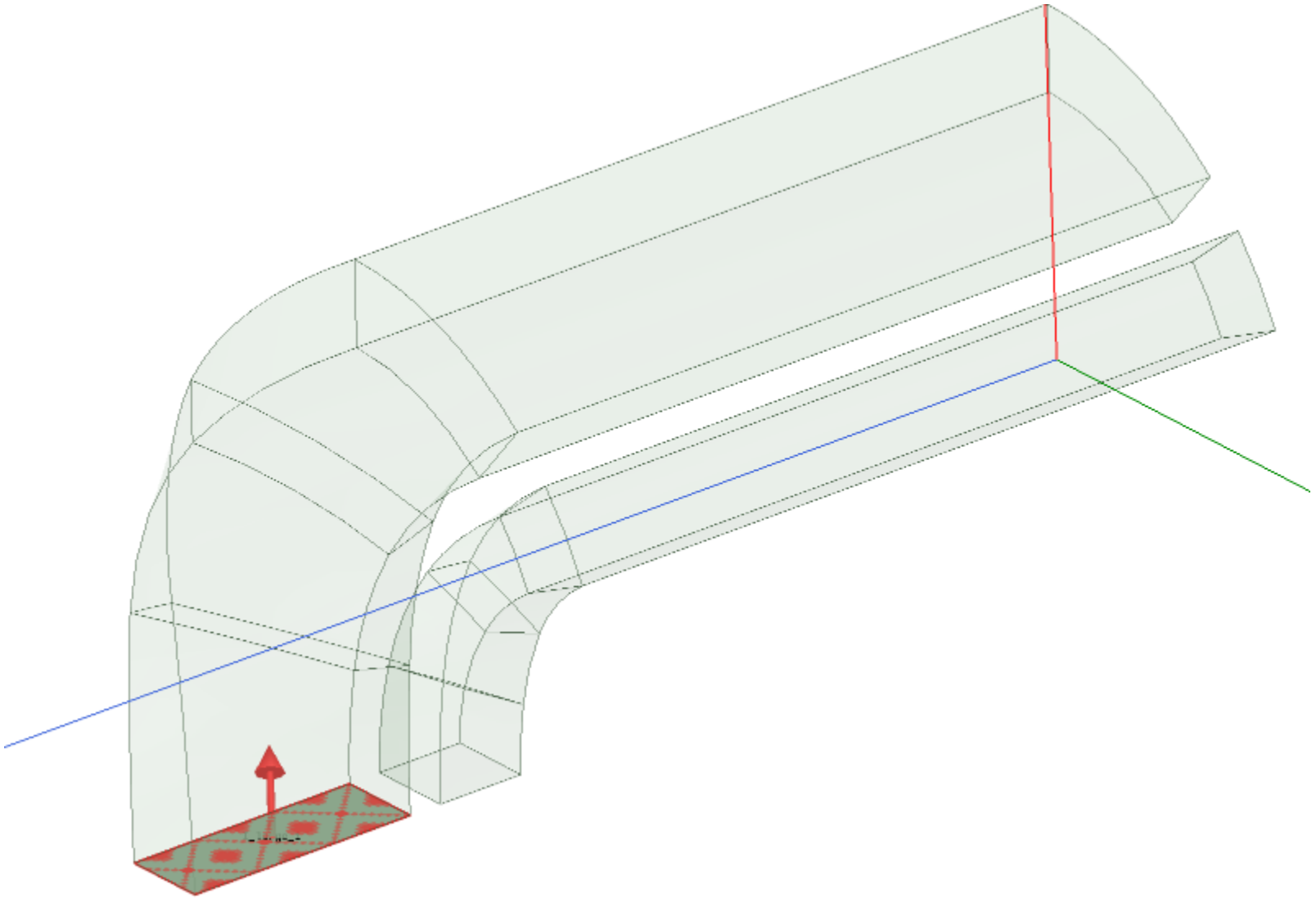
Opera meshes for quench analysis

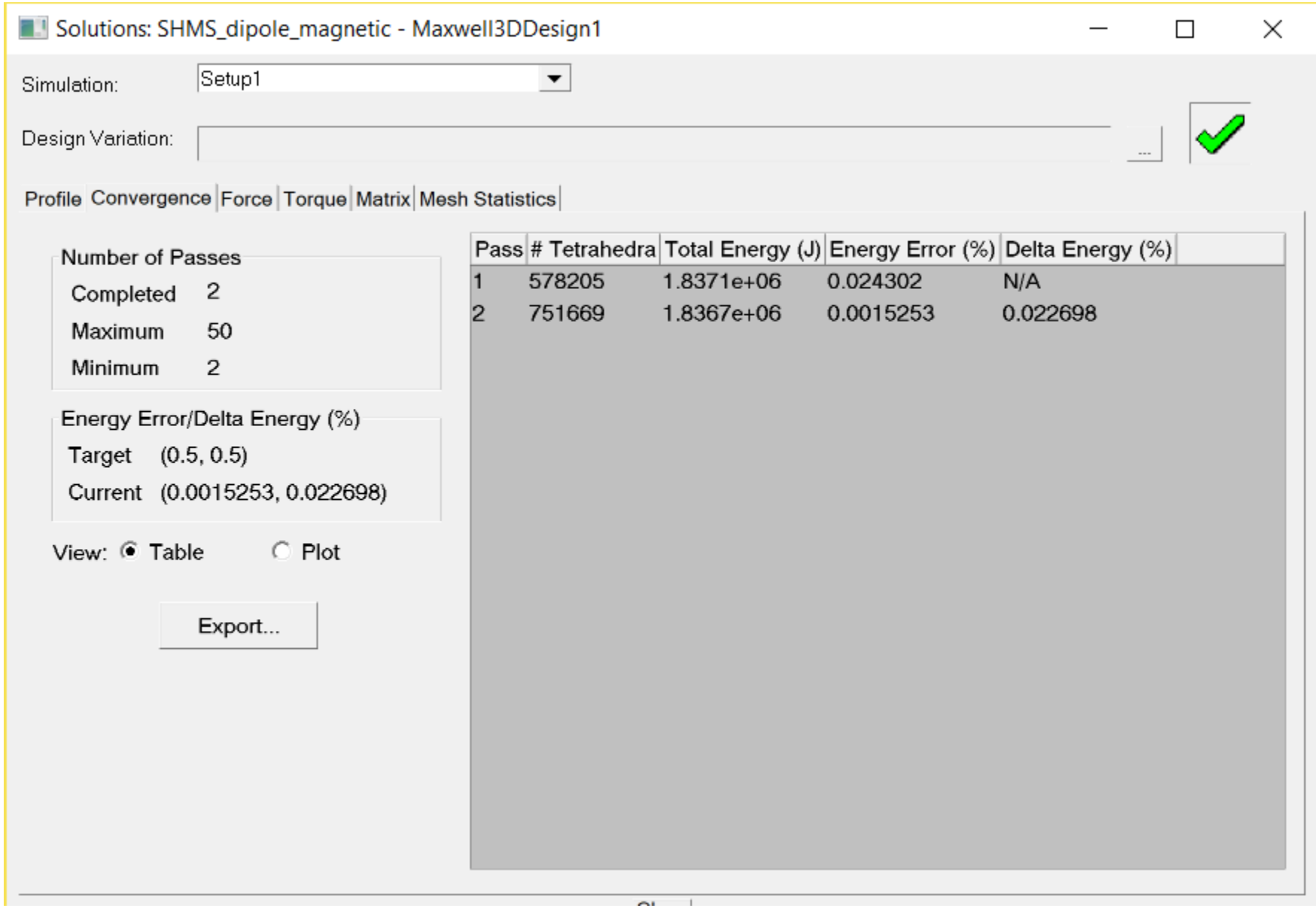


Meshes of iron and coils (Maxwell)



Excitations in Maxwell

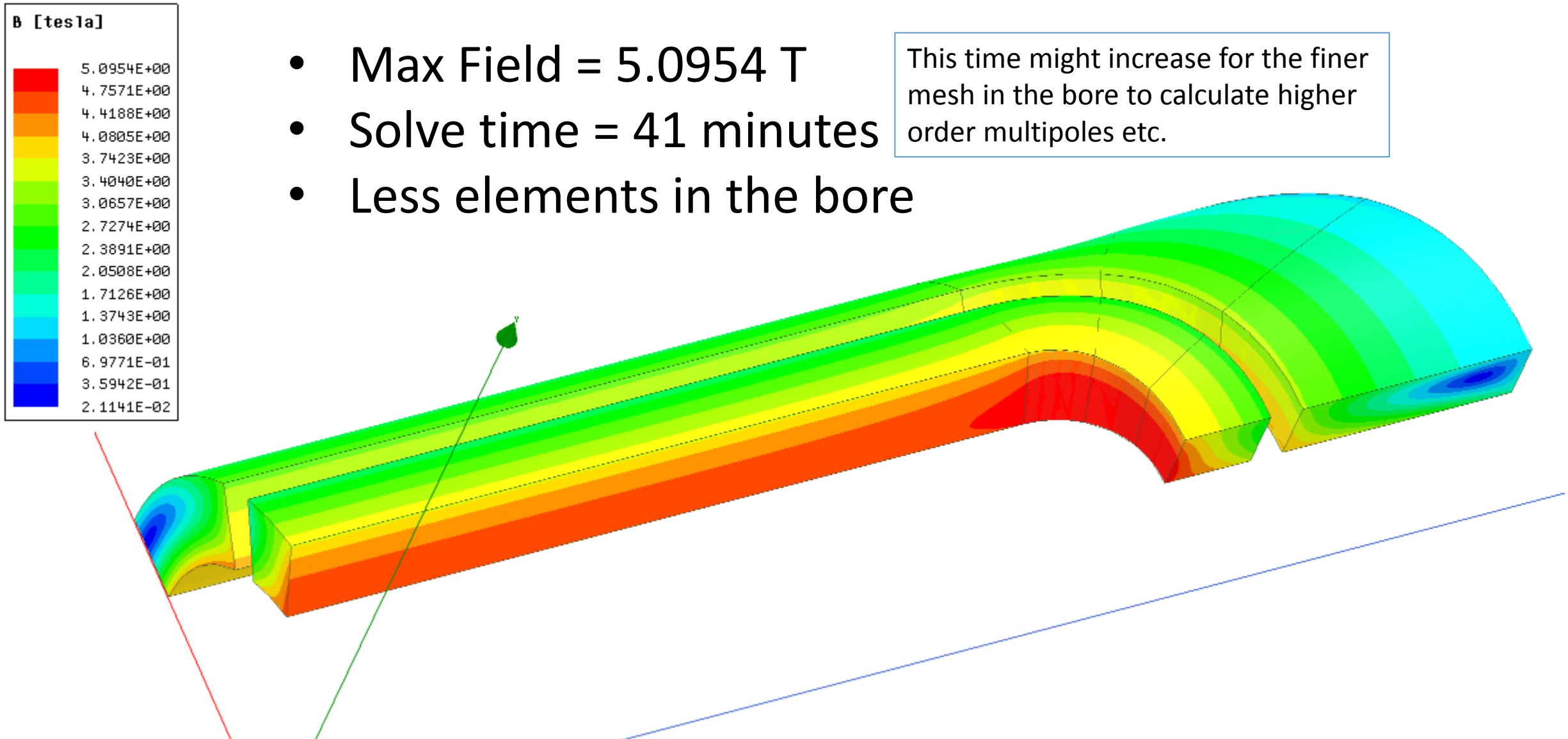



Solutions: SHMS_dipole_magnetic - Maxwell3DDesign1
Simulation:
Setup1
Design Variation:
...
Profile
Convergence
Force
Torque
Matrix
Mesh Statistics
Number of Passes
Completed 2
Maximum 50
Minimum 2
Energy Error/Delta Energy (%)
Target (0.5, 0.5)
Current (0.0015253, 0.022698)
View: Table Plot
Export...
Pass # Tetrahedra Total Energy (J) Energy Error (%) Delta Energy (%)
1 578205 1.8371e+06 0.024302 N/A
2 751669 1.8367e+06 0.0015253 0.022698

Magnetic Field (Maxwell)

- Max Field = 5.0954 T
- Solve time = 41 minutes
- Less elements in the bore

This time might increase for the finer mesh in the bore to calculate higher order multipoles etc.



Magnetic Field (Opera)

- Max field = 4.9697 T
- Difference = 2.5%
- Solve time = 1 hour 44 min with much more elements in the bore