2nd Joint HiLumi LHC-LARP Annual Meeting

LARP QXF 150mm Structure

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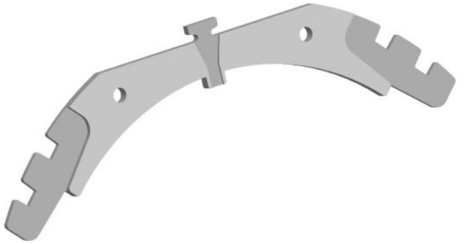
Outline

- 2-D structure
- 3-D structure
- Summary

2-D structure

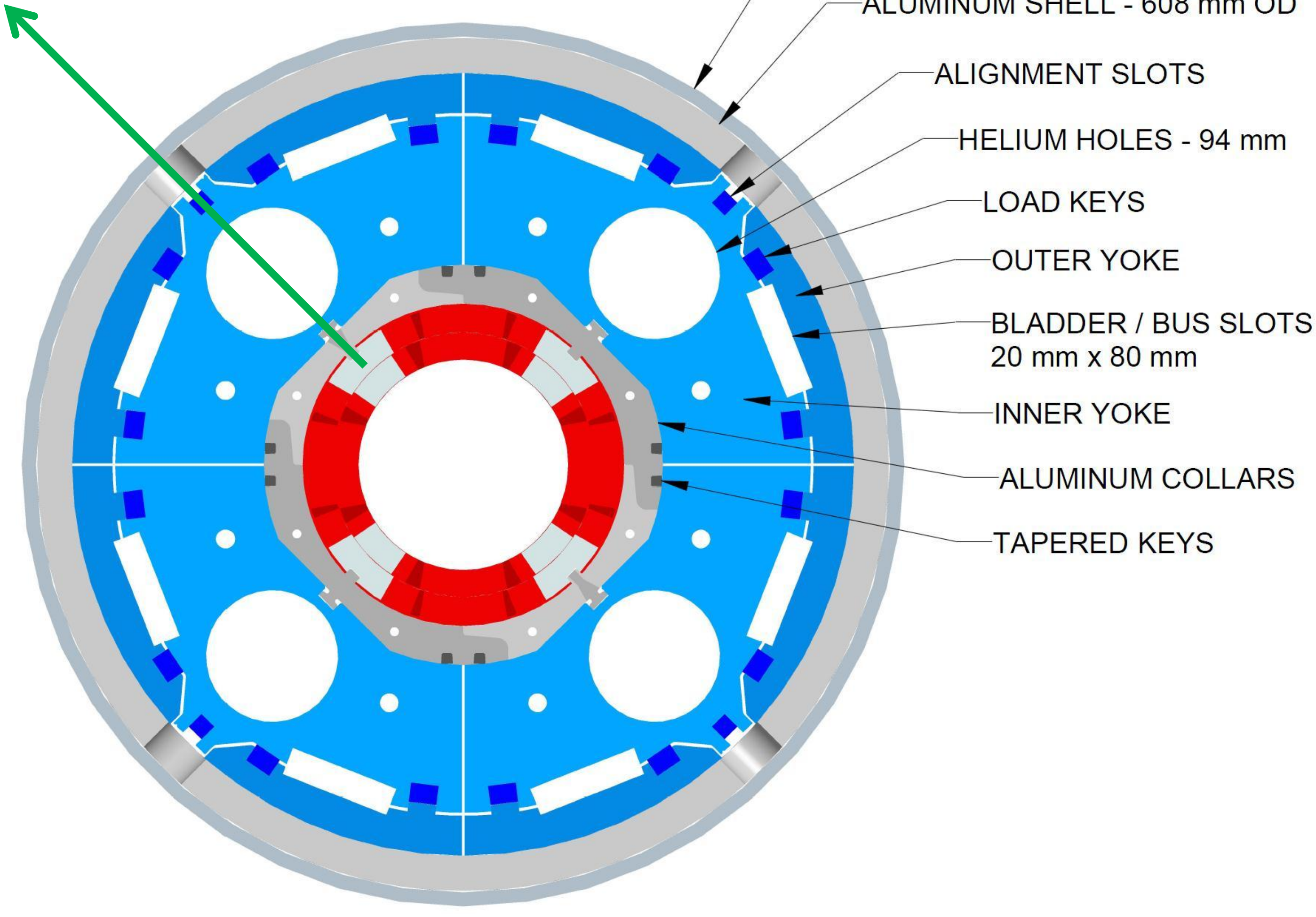
2-D Structure Design Features (1)



- Aluminum Collar
  - Standard 6061-T6 grade
  - Stamped laminations; single part design
    - Precise features stamped, engagements machined in a secondary operation
    - Eliminates need for accurate pinning or welding
  - Gaps between keys to coils, grooves accommodate 4% helium space
  - Mid-plane stop to prevent over-compressing coil during yoke assembly
- Stamped inner and outer iron yoke laminations
  - Large slots for hydraulic bladders (also serve as bus slots)
  - Yoke alignment key in-line with coil pole tabs
  - Large helium bypass holes (94 mm dia.)
- 25mm thick Aluminum shell
- 10mm thick stainless steel helium vessel shell (not modeled here)

2-D Structure Design Features (2)

4x Direct alignment from coil to fiducial in stainless steel vessel

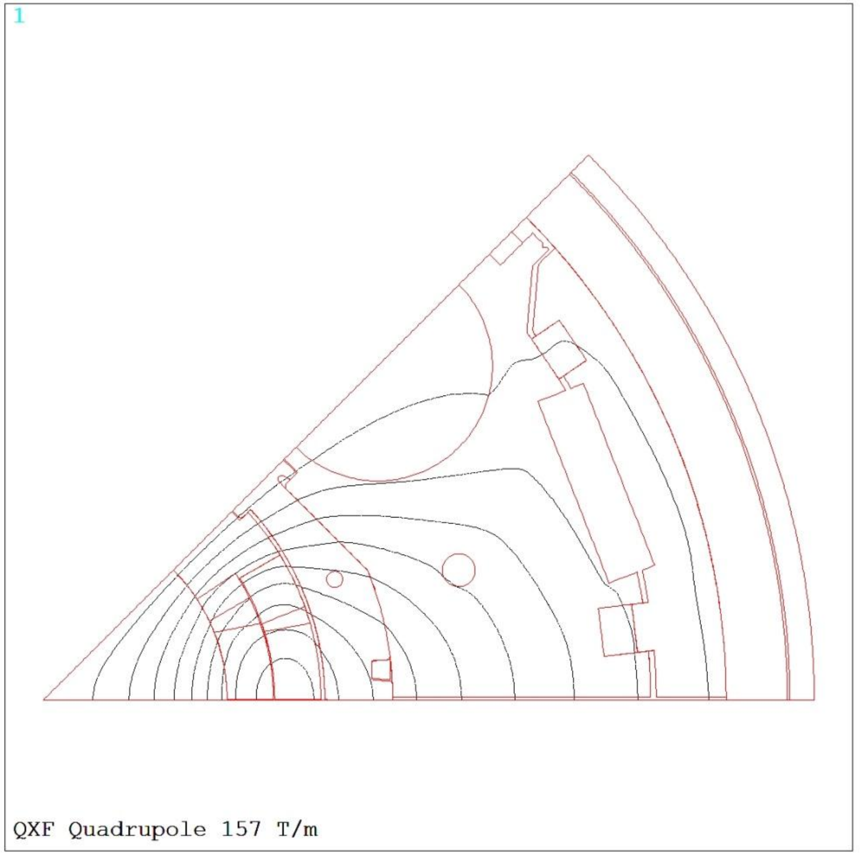


Clearance fit between aluminum shell and stainless steel vessel

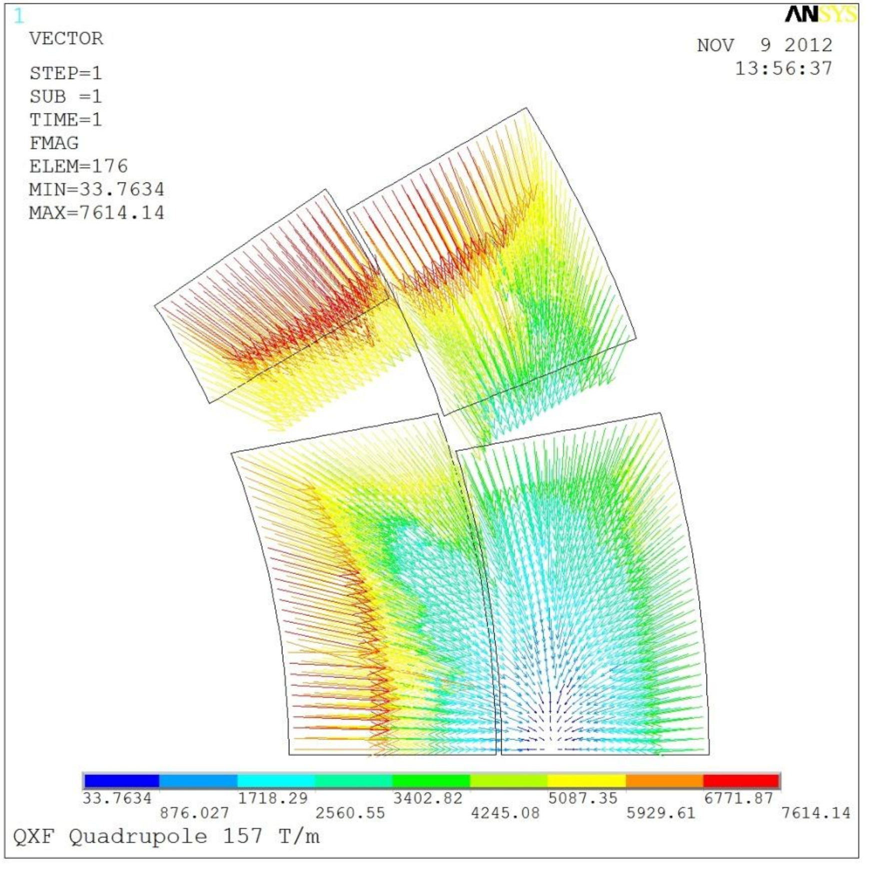
2-D Analysis

- Basic FE model features
  - CERN coil cross section
  - 2-D 8 or 6-node structural solid elements as well as contact elements at interfaces
  - Frictionless model (for now)
- Five Load Steps
  - 1. Collared (coil stress from 2-D collared coil model)
  - 2. Apply full bladder pressure (30 MPa) against slots
    - Also apply collar OD shim at mid-plane (0.1 mm radial thickness)
  - 3. Install yoke shims
    - Bladder pressure removed
  - 4. Cool-down to 4.3 K
  - 5. Power to 140 T/m followed by 157 T/m peak flux gradient (apply Lorentz forces from magnetic model)

2-D Magnetic Analysis



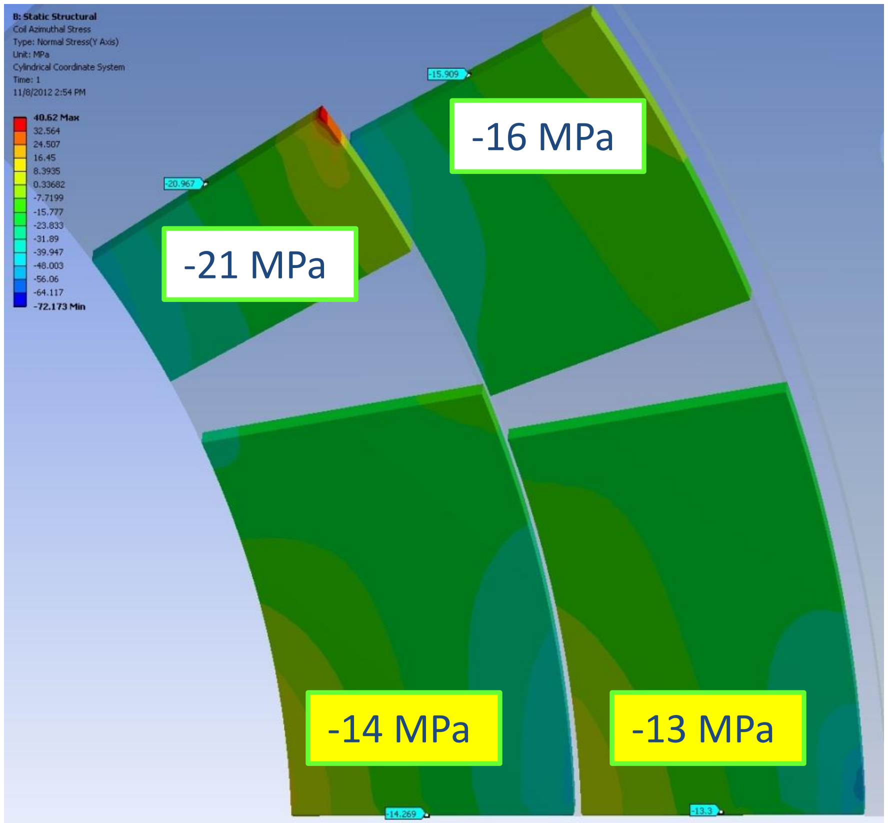
Magnetic Flux Contour Plot



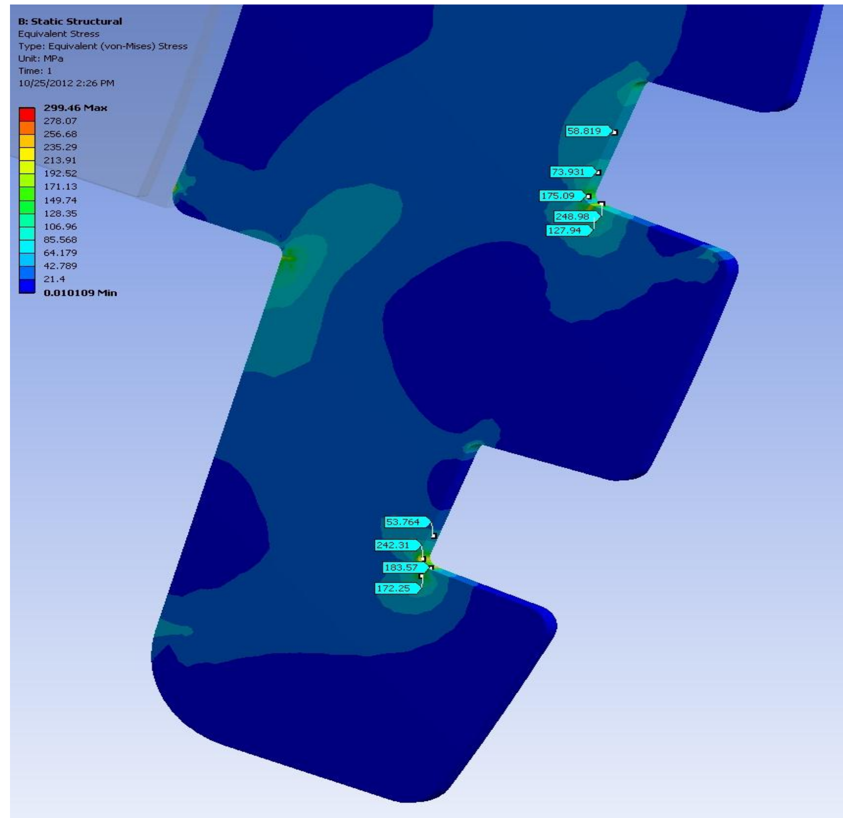
Coil Nodal Force Vector Plot

2-D Mechanical Analysis (1)

Step 1 – Collaring



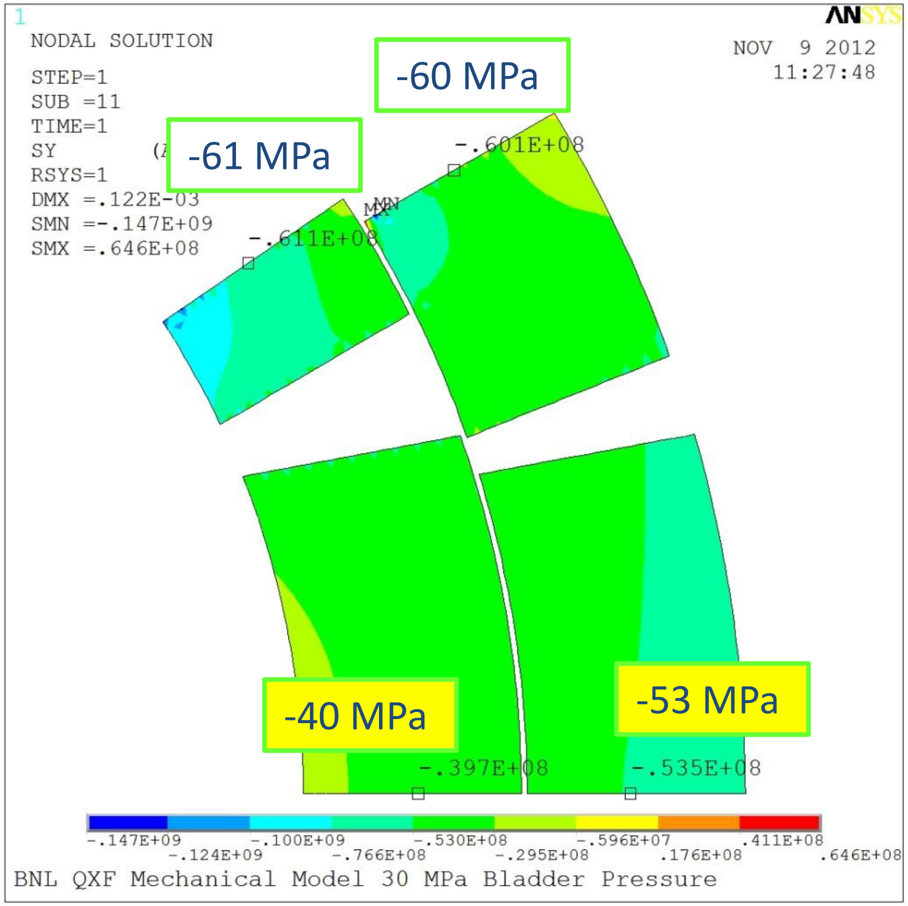
Azimuthal Coil Stress (MPa)



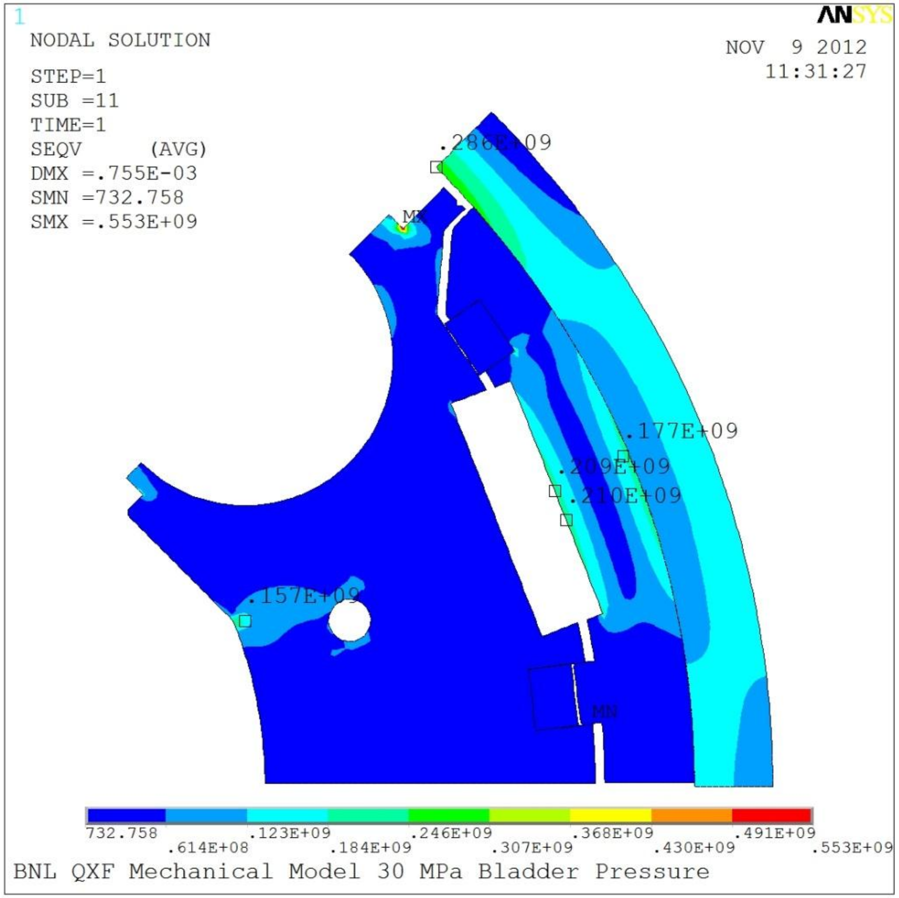
Collar Lug Equivalent Stress (MPa)

2-D Mechanical Analysis (2)

Step 2 - Apply 30 MPa bladder pressure



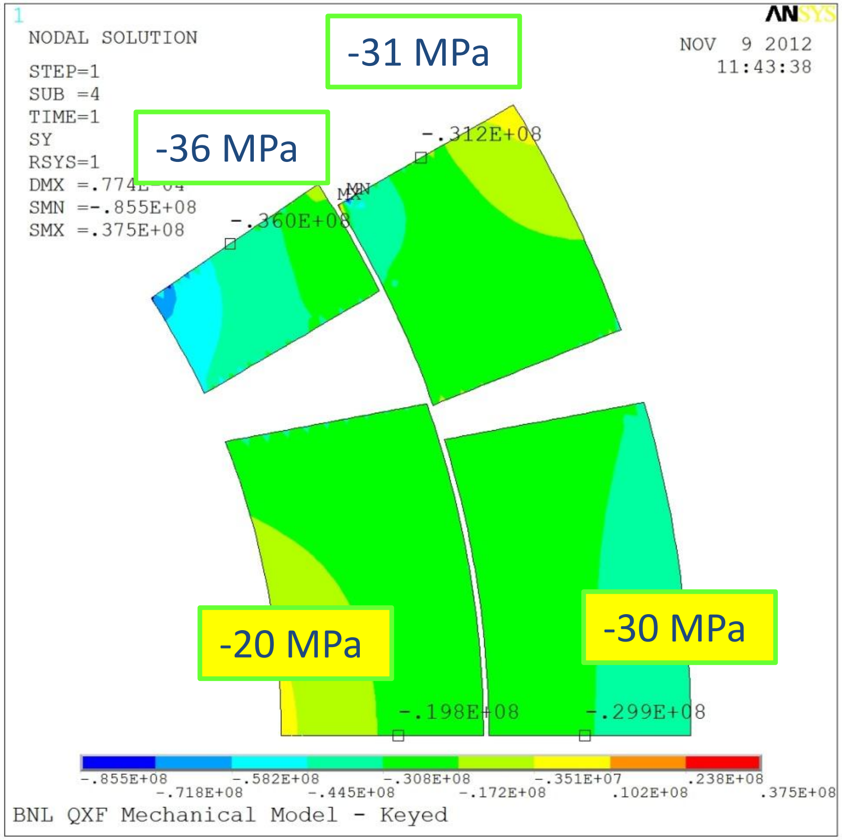
Coil Azimuthal Stress (Pa)



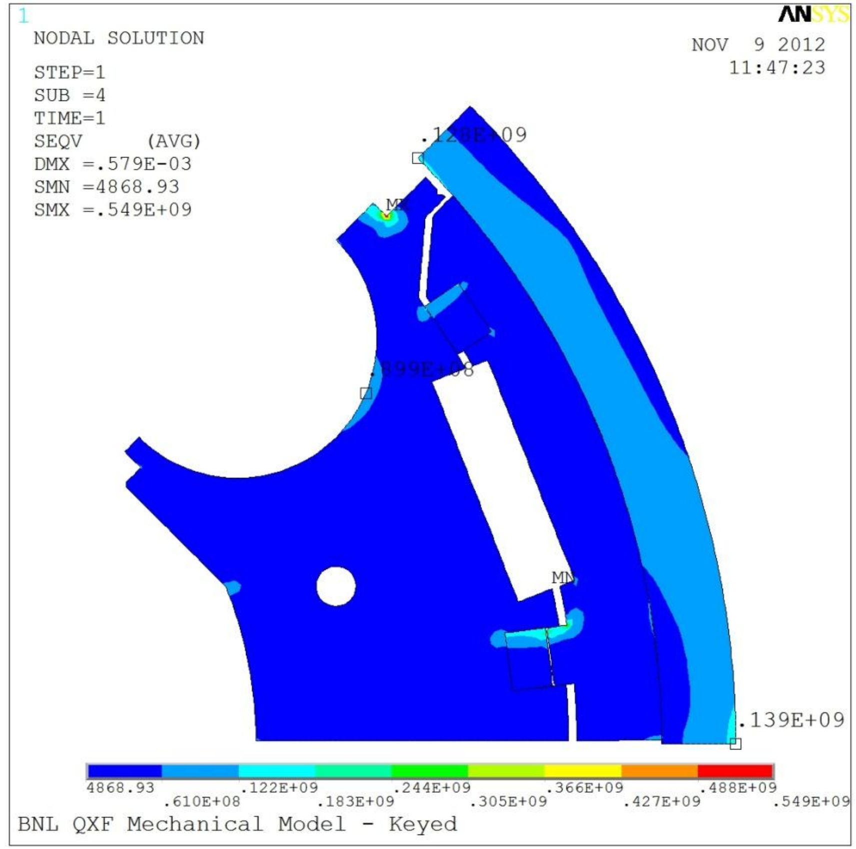
Yoke and Shell Equivalent Stress (Pa)

2-D Mechanical Analysis (3)

Step 3 – Insert Shims, Remove Bladder Pressure



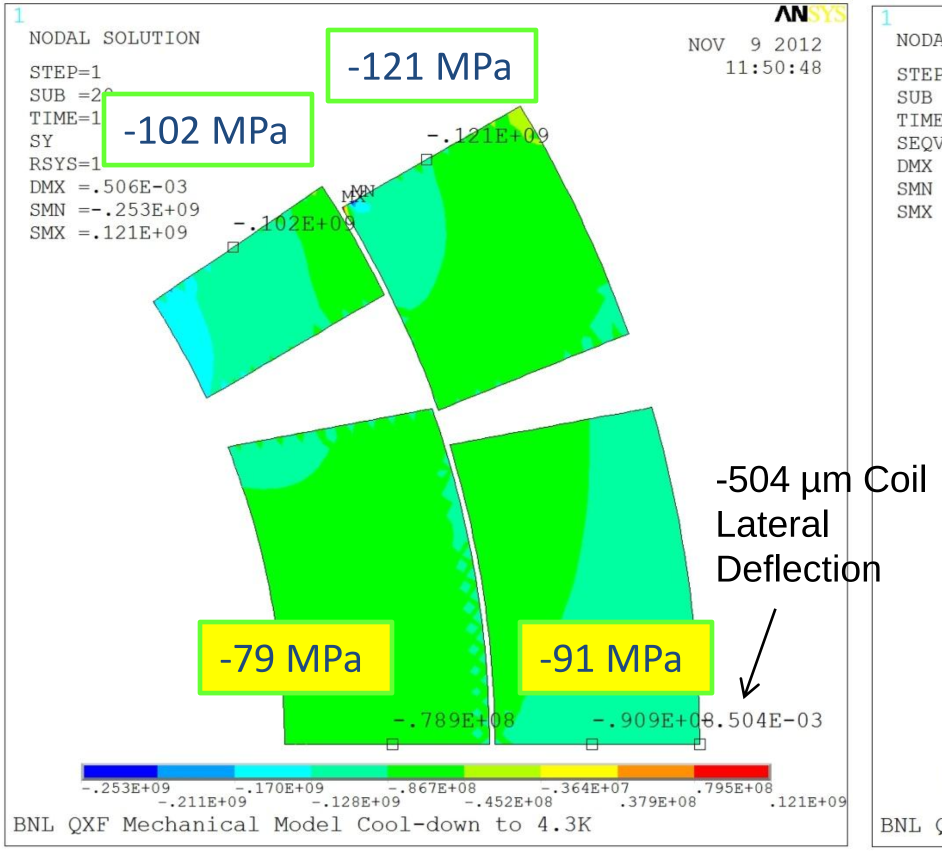
Coil Azimuthal Stress (Pa)



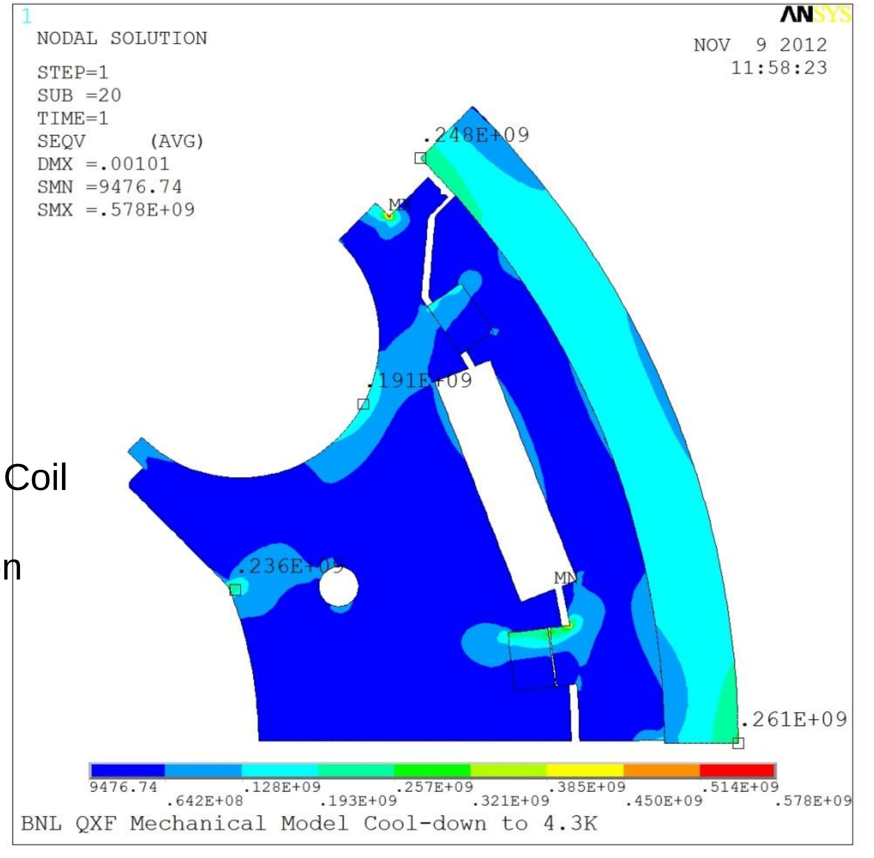
Shell and Yoke Equivalent Stresses (Pa)

2-D Mechanical Analysis (4)

Step 4 – Cool-Down to 4.3 K



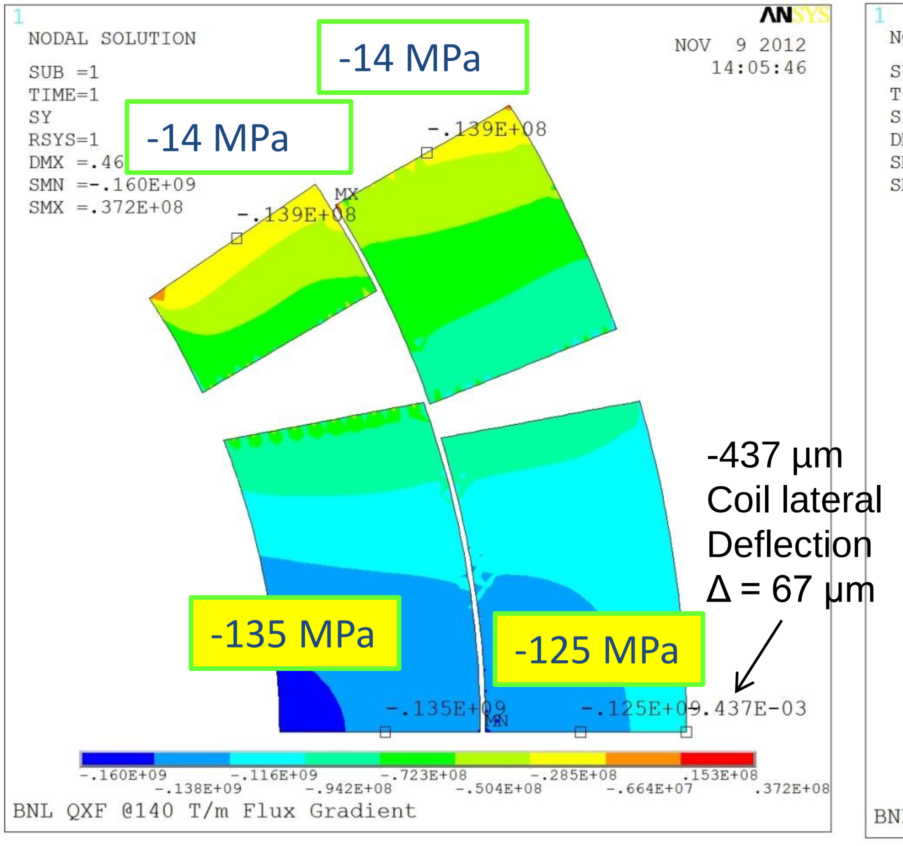
Coil Azimuthal Stress (Pa)



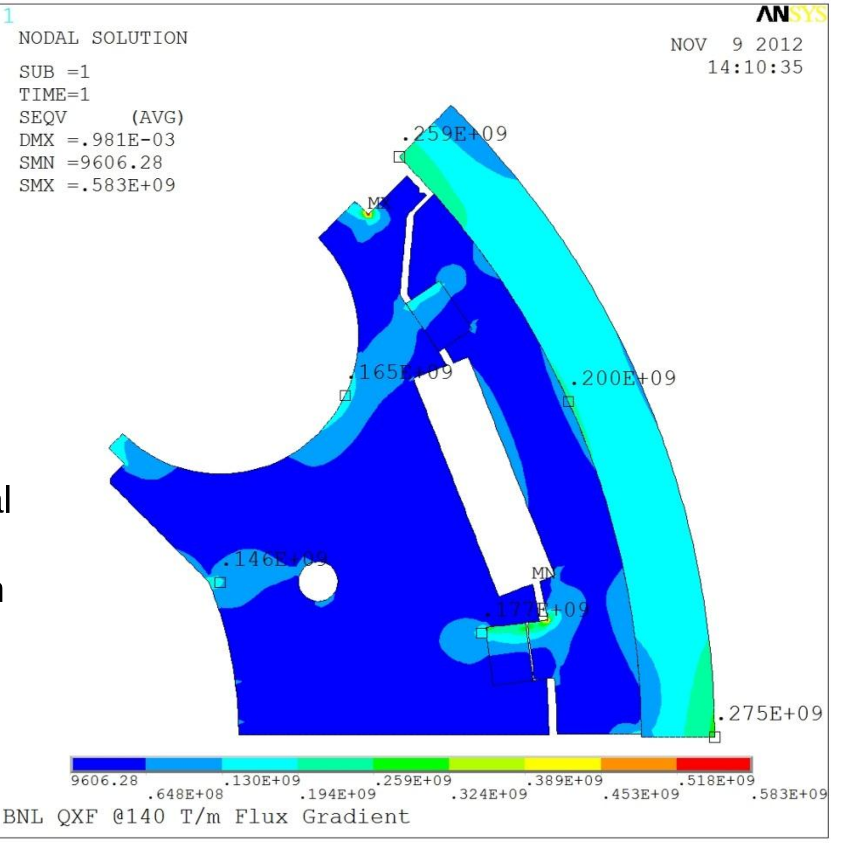
Shell and Yoke Equivalent Stresses (Pa)

2-D Mechanical Analysis (5a)

Step 5a – Apply Current to reach 140 T/m peak flux gradient



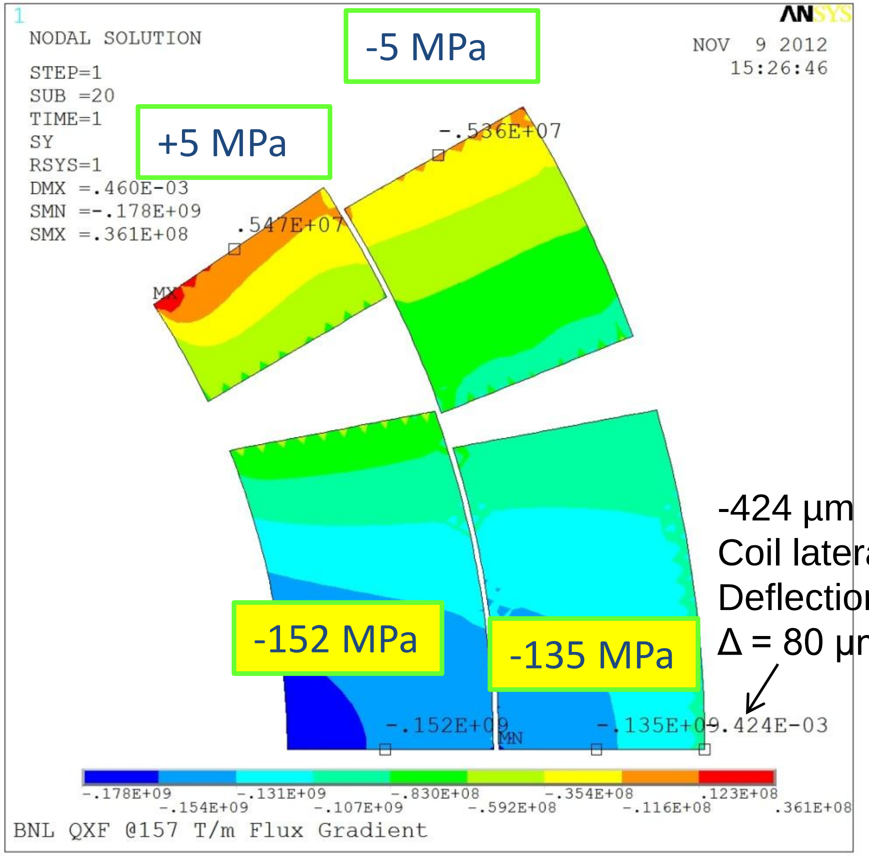
Coil Azimuthal Stress (Pa)



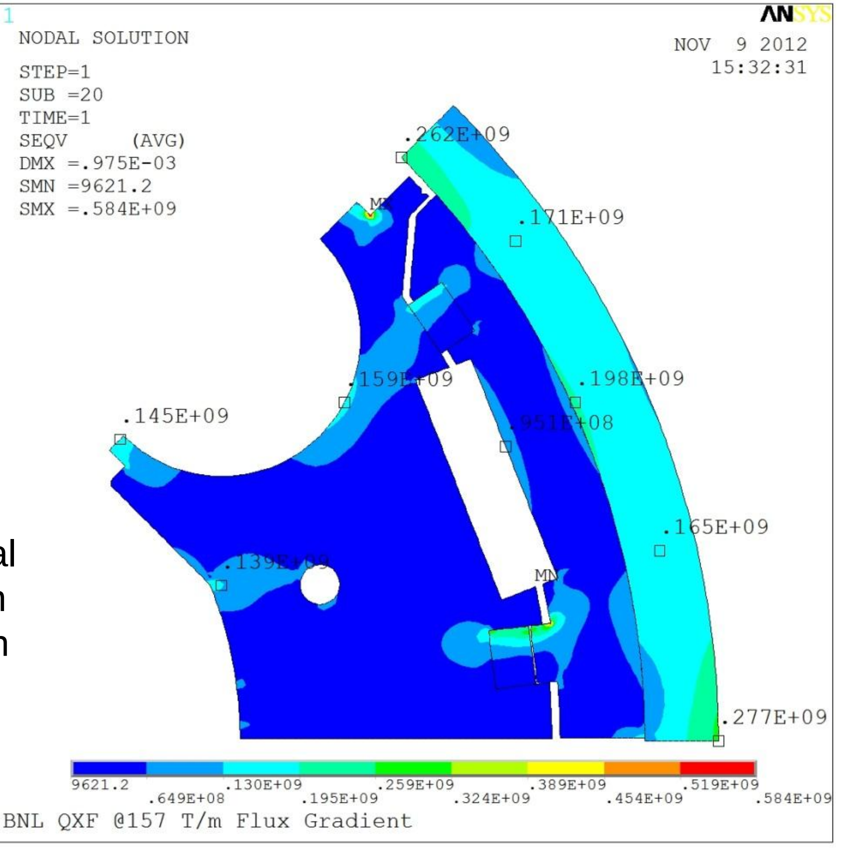
Shell and Yoke Equivalent Stresses (Pa)

2-D Mechanical Analysis (5b)

Step 5b – Apply Current to reach 157 T/m peak flux gradient



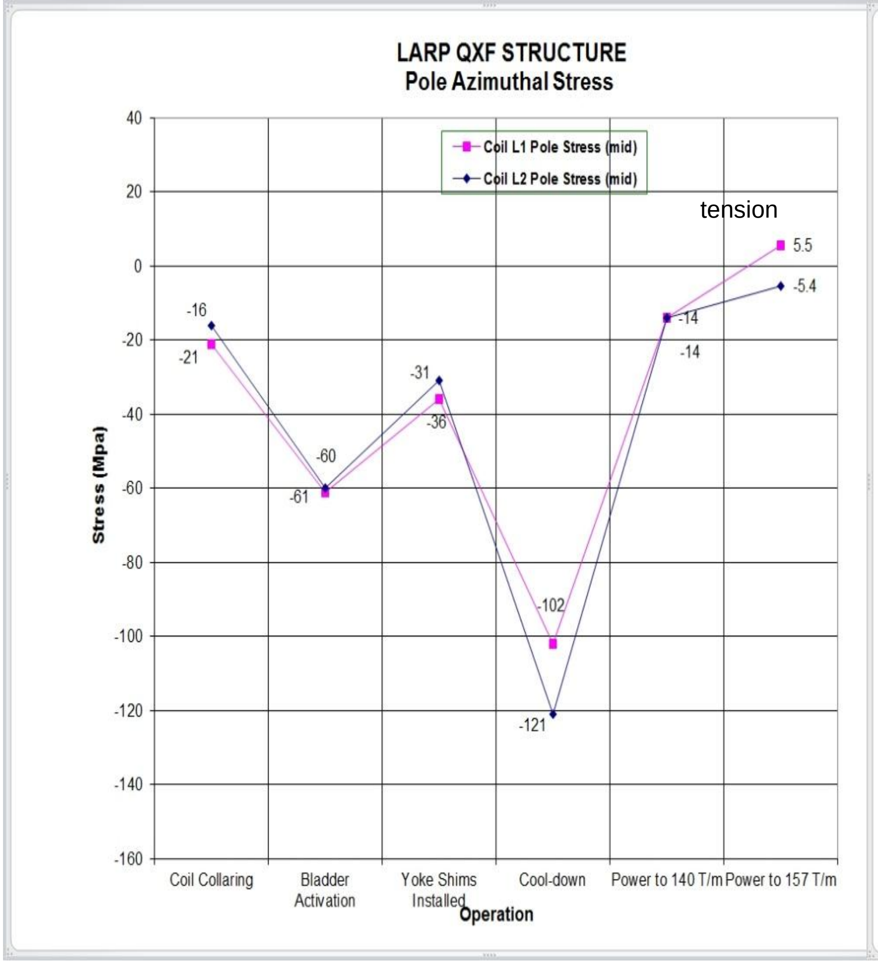
Coil Azimuthal Stress (Pa)

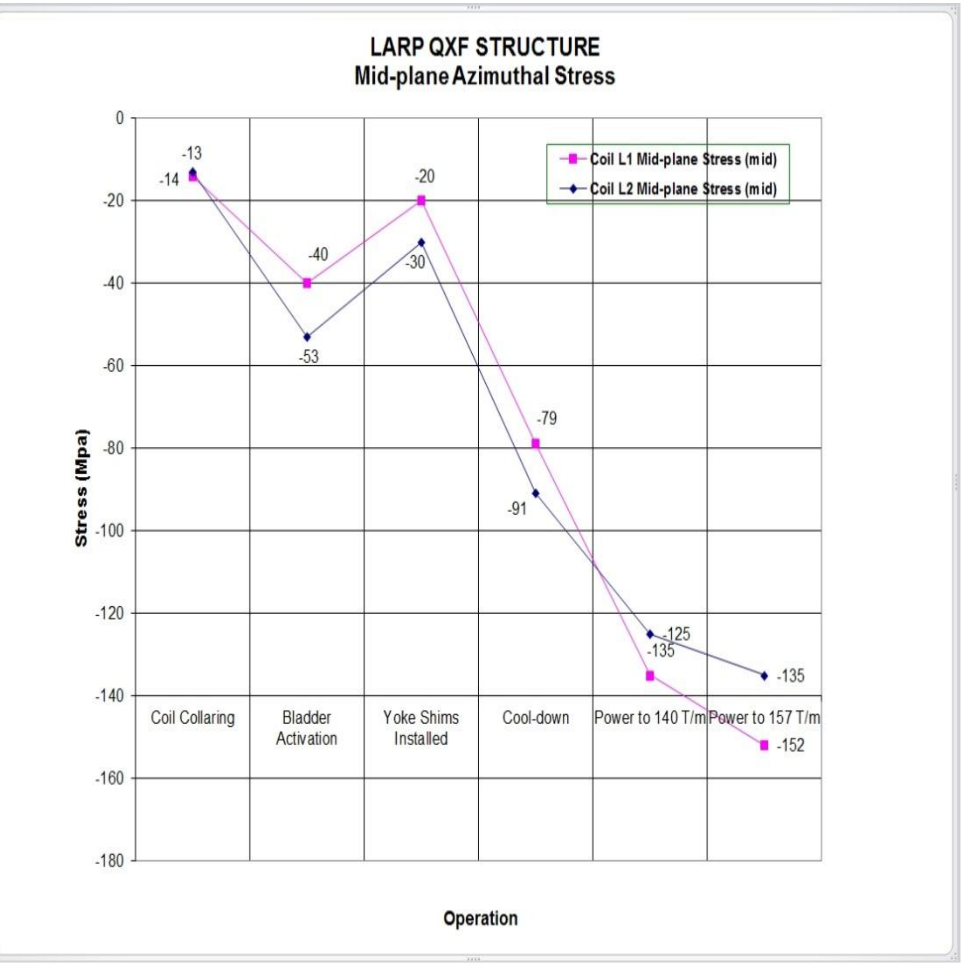


Shell and Yoke Equivalent Stresses (Pa)

2-D Mechanical Analysis - summary

Summary of Coil Stresses at coil midpoint during Assembly and Operation





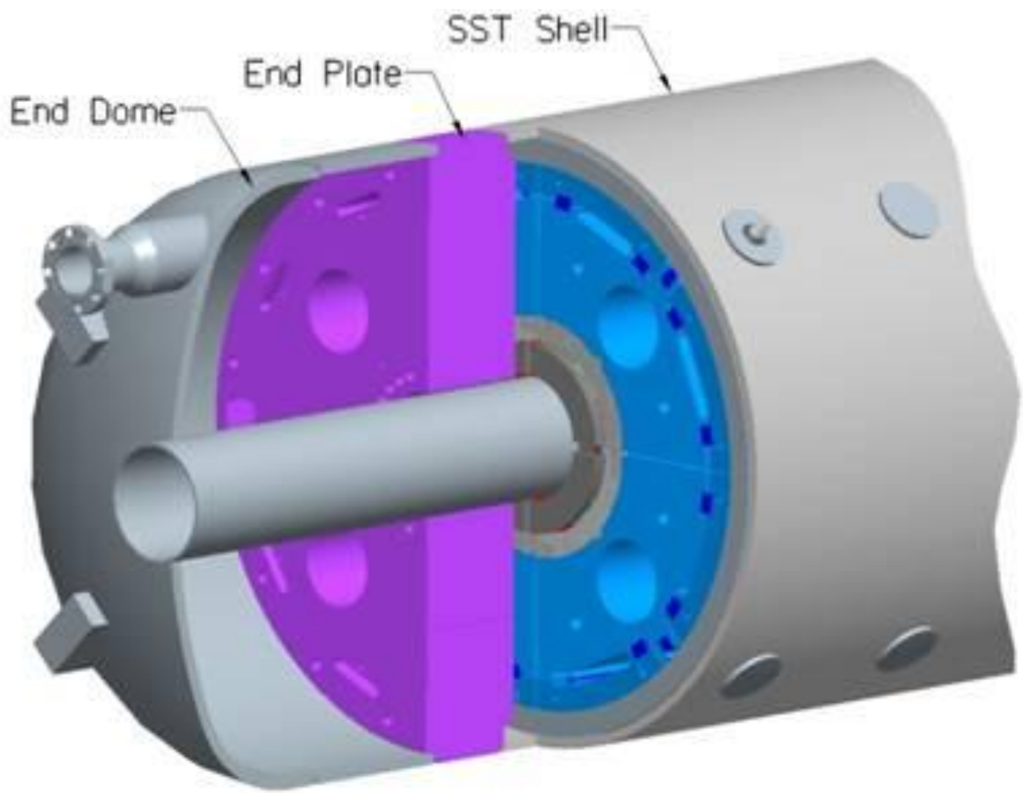
Future Work

- Run analysis using LBNL version of coil cross section
- Add 0.2 coefficient of sliding friction to model

3-D structure

3-D design features

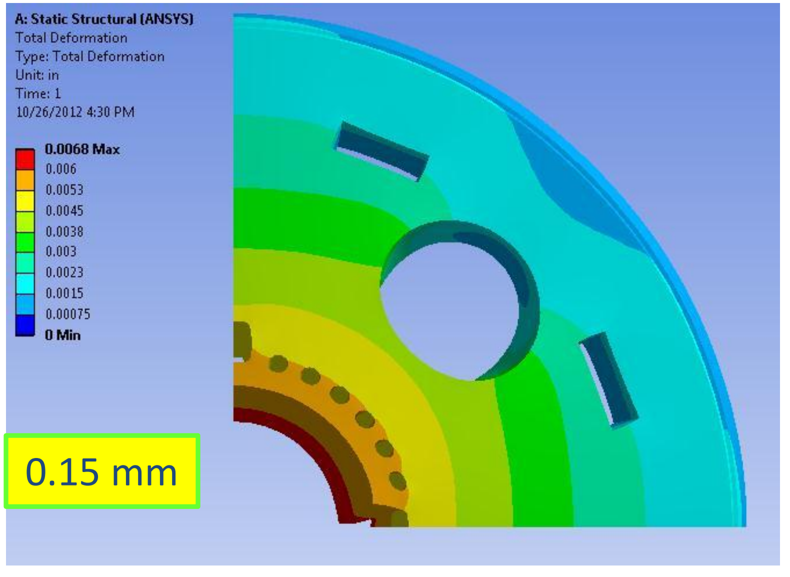
- Stainless steel “inertia tube” supports axial forces
- End plate welded to sst tube
- force transmitted from coils to end plate through “bullet”” strain gauge transducers / set screws



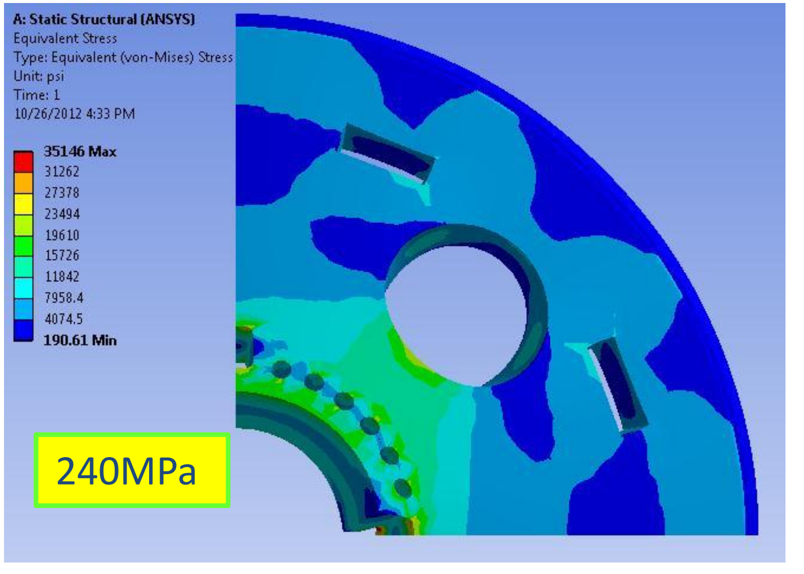
Axial Support

- 1.4MN applied load
- 150 mm end plate
- Stress is within limits of 300 series stainless steel

End Plate Deflection



End Plate Stress



- Stainless steel shell elongation = 1.5 mm

  → total axial strain = (2x0.15+1.5)÷4000x100=0.045% *for 1.4 MN*

Summary

2-D

- Precision stampings, small # of parts = cheap, reliable assembly, good alignment
- Ø94 mm holes permit heat exchangers, secondary helium space
- 20 mm x 80 mm bladder/busbar slots provide low working pressure - 30 MPa – and additional secondary helium space
- At 140 T/m coil radial deflection is 67 microns outward at the mid-plane. At 157 T/m coil radial deflection is 80 microns; compensating for the initial 100 micron inward radial deflection at yoke loading.
- At 157 T/m the inner coil pole goes into tension (5 MPa at midpoint).
- At 157 T/m the coil mid-plane stress range is 135 – 178 MPa.

Same "scale" of baseline structure = equivalent mechanical behavior and support of coils

3-D

- Use of stainless steel tube effectively replaces axial rods, freeing volume for heat exchangers and helium
- End plate stress, deflection are acceptable
- Axial conductor strain << allowable