SM quadrupole magnet

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LARP Collaboration Meeting
Fermilab
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Outline

- Motivations and goals
- SM quadrupole magnet: design features
- Superconducting cable and coil
- Magnetic analysis
- Mechanical analysis
- Conclusions

Motivations and goals

- Provide early ***feedback*** for IR quadrupole design
  - Support ***structure***
  - Lorentz ***force*** distribution
    - Fy towards the mid-plane
    - Fx outwards
    - High end forces
- Optimize ***assembly procedures***
- Measure the ***mechanical behavior*** of the structure during assembly, cool-down and excitation

Motivations and goals (cont.)

- Cost-effective ***technology development***
  - ***Training studies***
    - Strain gauges attached to the coils
  - Coil ***stress limit*** analysis
  - ***Thermal*** and ***quench protection*** studies
  - Analysis of ***fabrication tolerances*** for Nb_3Sn coils
    - Accuracy and reproducibility of coil fabrication
    - Accuracy and reproducibility of magnet assembly
    - Simultaneous control of pre-stress and coil size
    - Field corrections: coil shims, magnetic shims
  - ***Alignment*** studies

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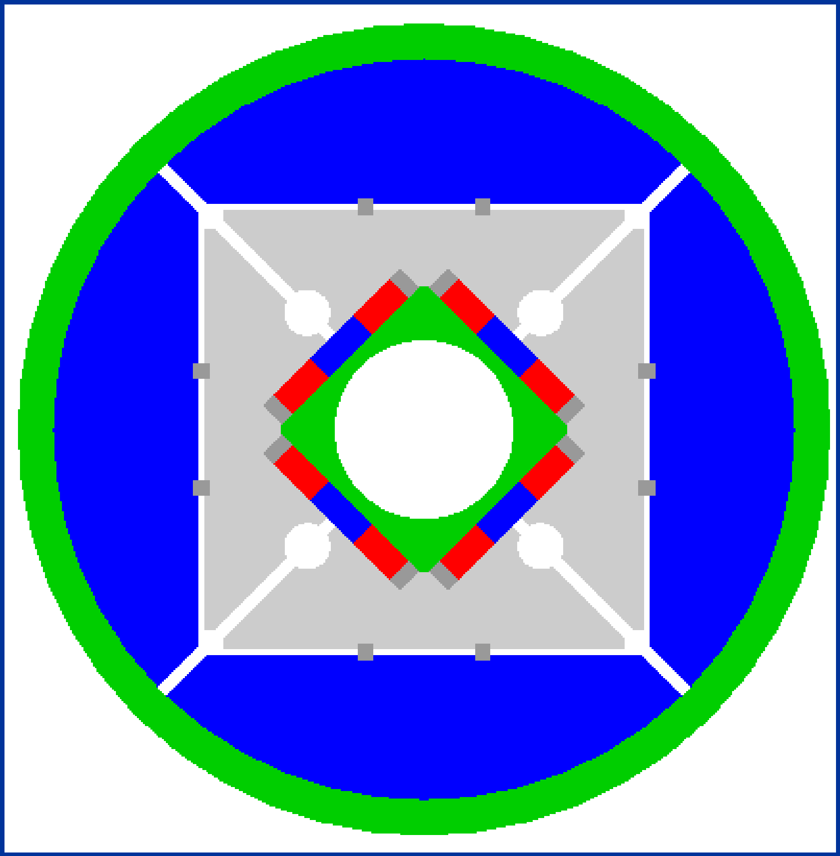
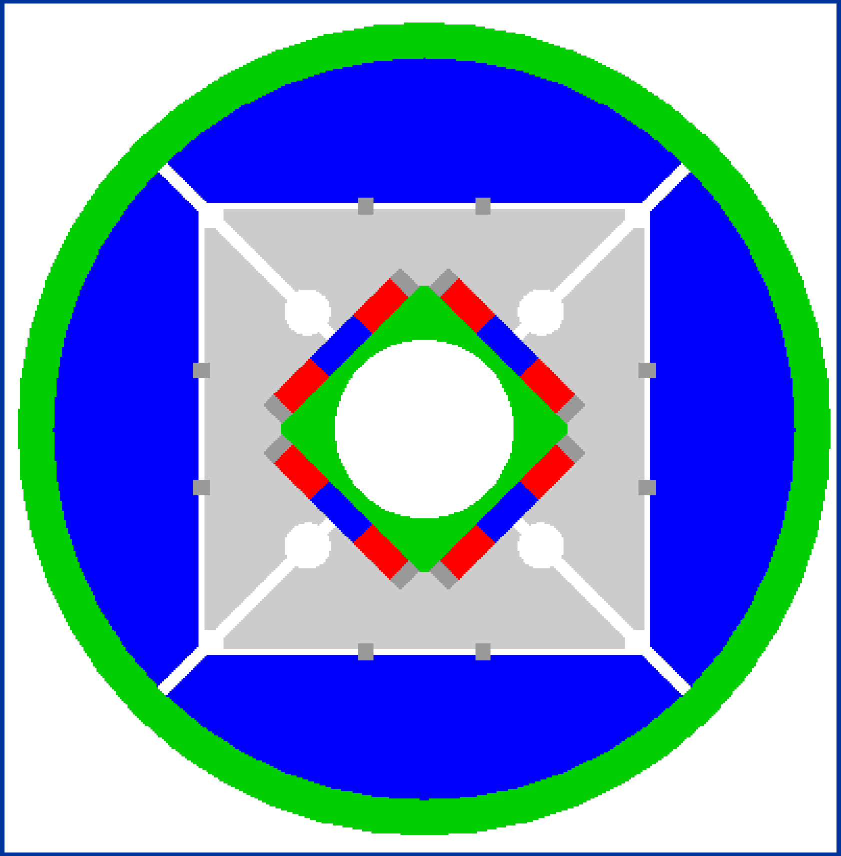
Cross-section



- Magnet components
  - –Aluminum ***shell***
    - Outer diameter: 500 mm
  - –4-piece iron ***yoke***
  - –Stainless steel ***pads***
  - –SM racetrack ***coils***
  - –Aluminum ***bore***
- ***Keys*** and ***bladders*** technology

Performance parameters



- Coil aperture
  - 120 mm
- Bore aperture
  - 110 mm
- I = 11000 A
- G = 95 T/m
- B_{peak} = 11 T
- U = 425 KJ/m
- L = 7 mH/m

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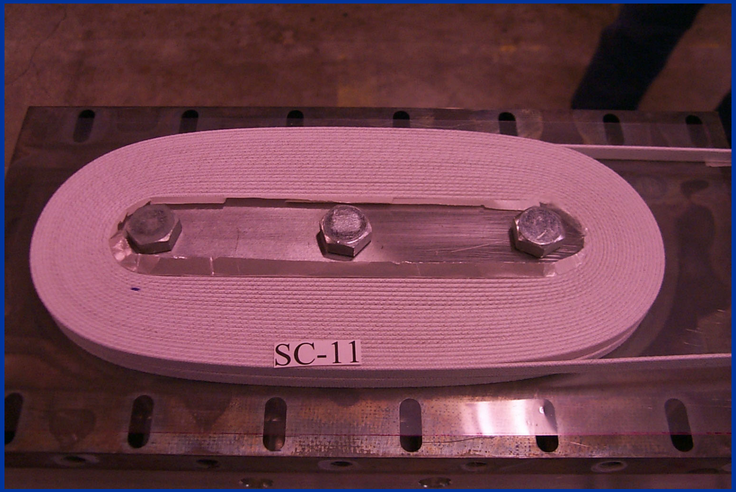
Superconducting cable and coil

- ***Conductor***
  - 20 strands (∅ 0.7 mm)
  - 8 × 1.3 mm
  - 0.1 mm insulation
- ***Coil***
  - Two layers
  - 21 turns per layer
  - Straight section: 150 mm
- Iron ***island***
- Stainless steel ***horseshoe***
- Stainless steel ***end shoe***



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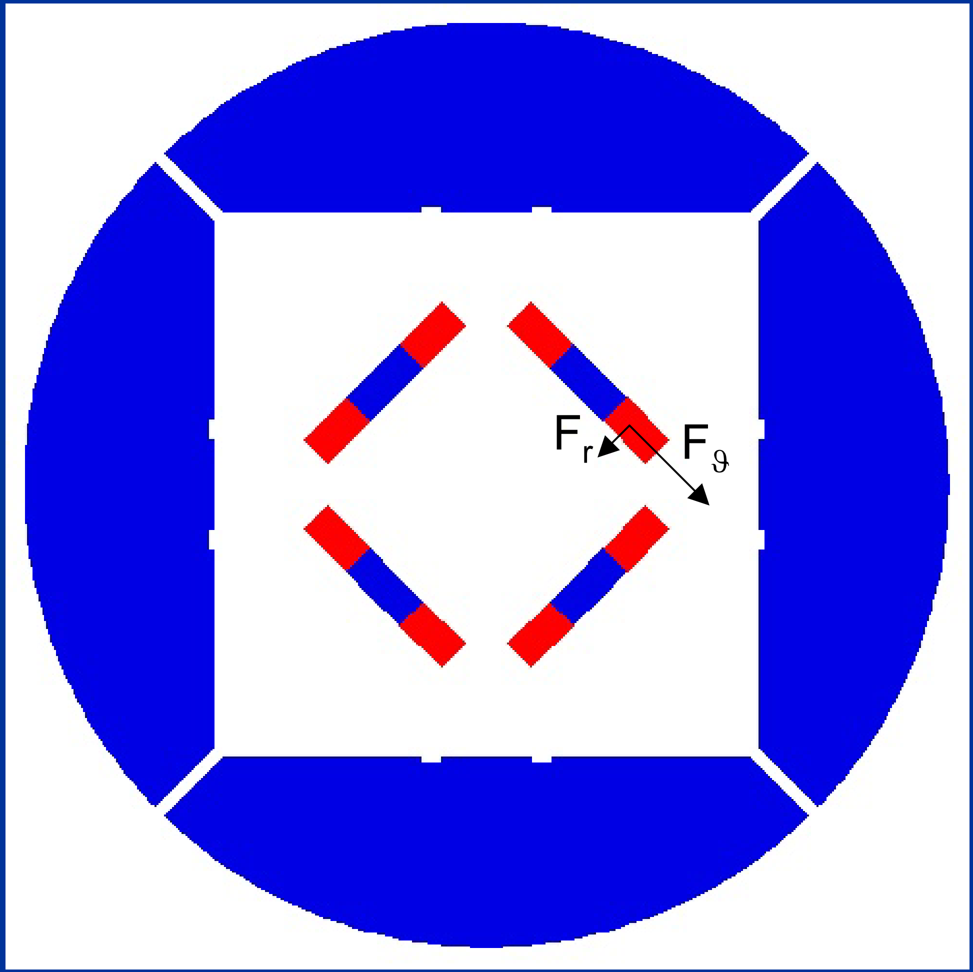
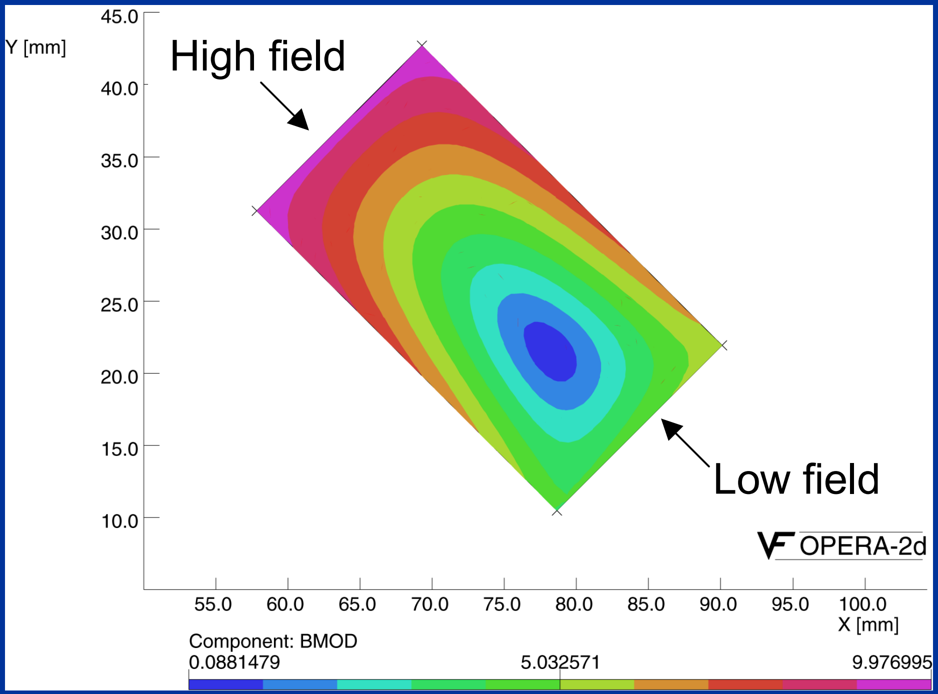
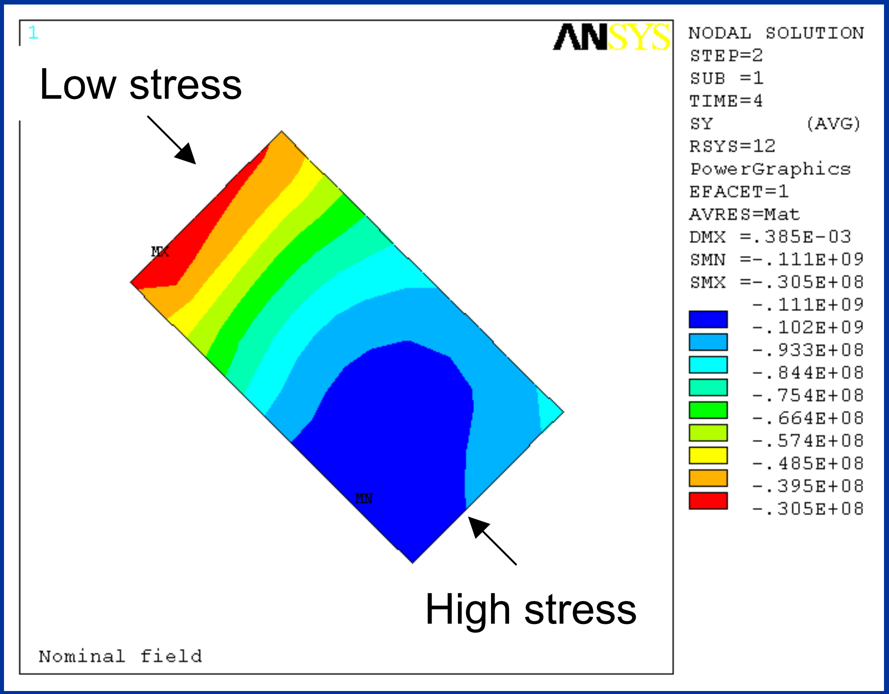
Lorentz forces

- $I = 11000$ A
- $G = 95$ T/m
- $B = \sim 10$ T
- $F_\vartheta = 1210$ N/mm
- $F_r = \quad 150$ N/mm
- $\sigma_{\vartheta coil} = 80$ MPa



Field and stress in the conductor

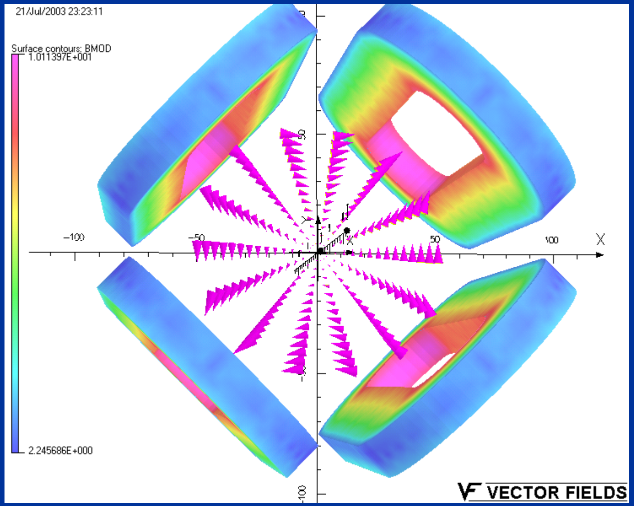


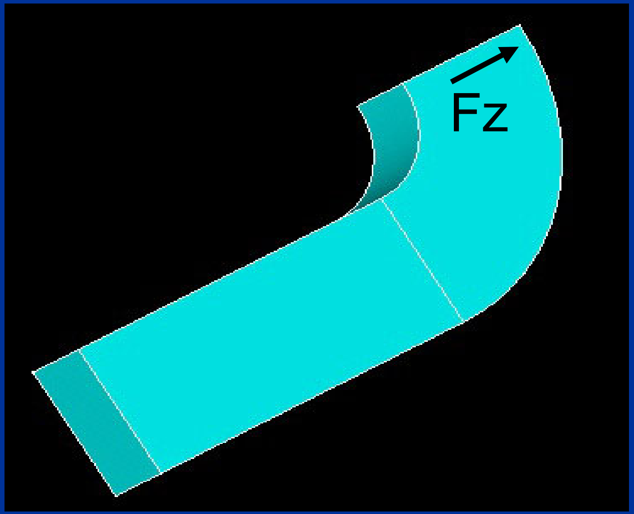


- ***High stress*** point close to the mid-plane
- ***High field*** point close to the island

Field and forces in the end region

- ***Peak field*** in the end region close to the island
  - B = ~ 11 T at 11000 A
- Magnet ***limited*** by ends
- Axial Lorentz ***force***:
  - Fz = 90 kN per coil





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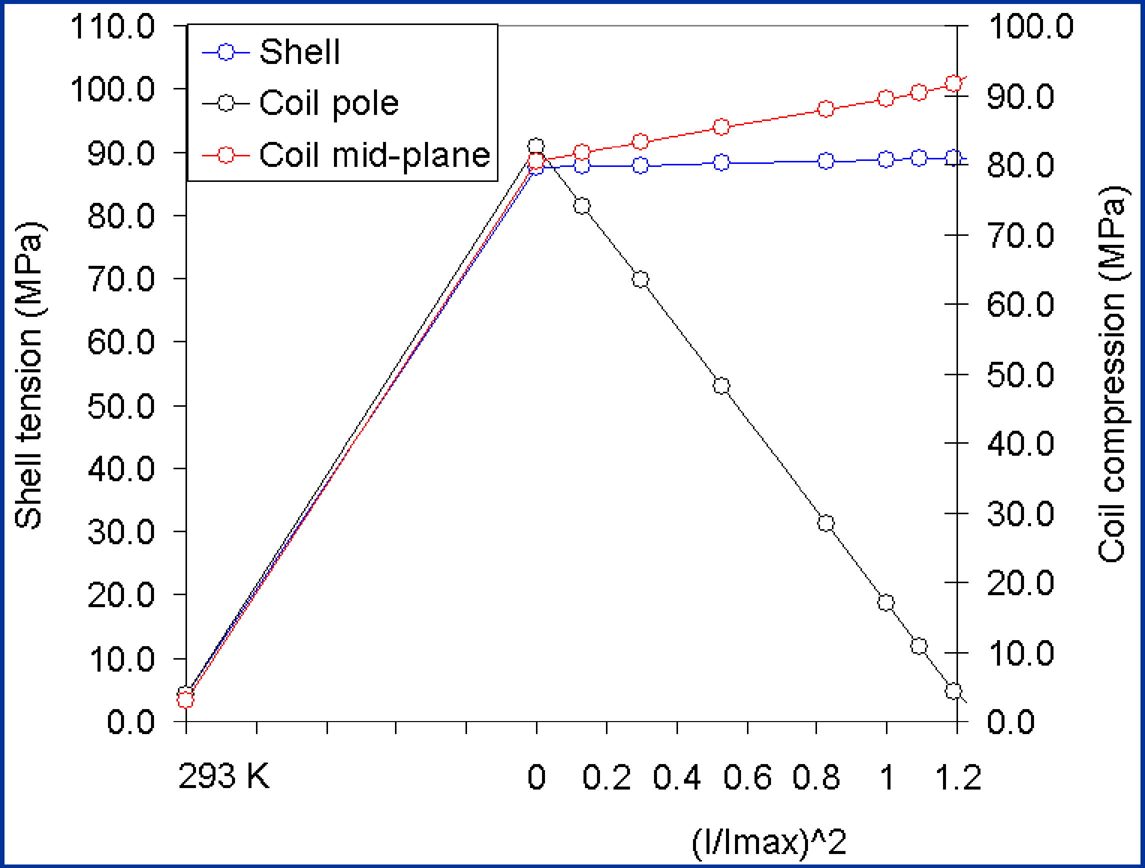
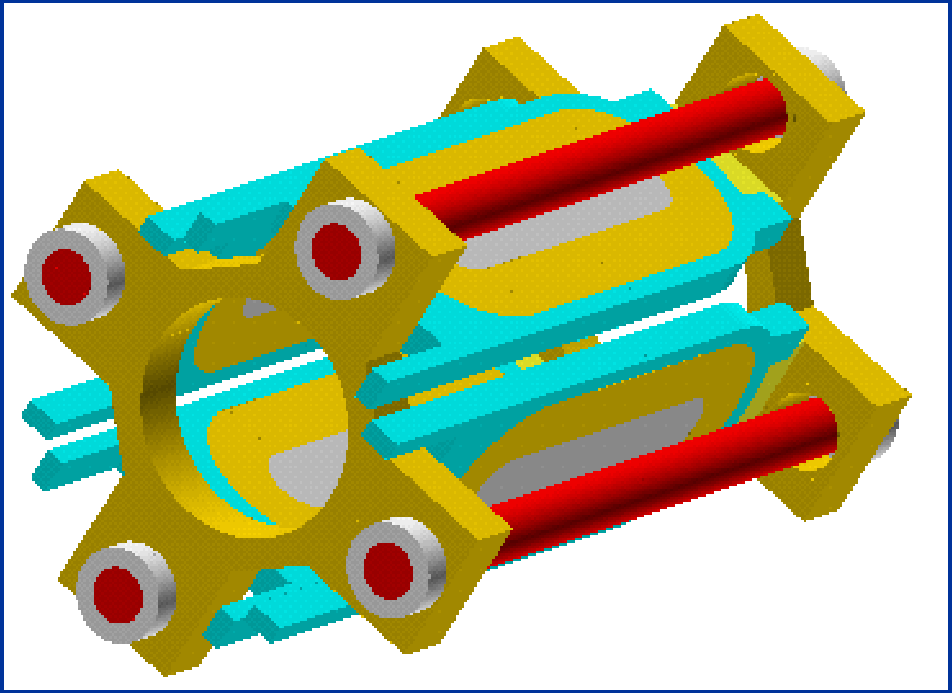
Stress in the shell and in the coil



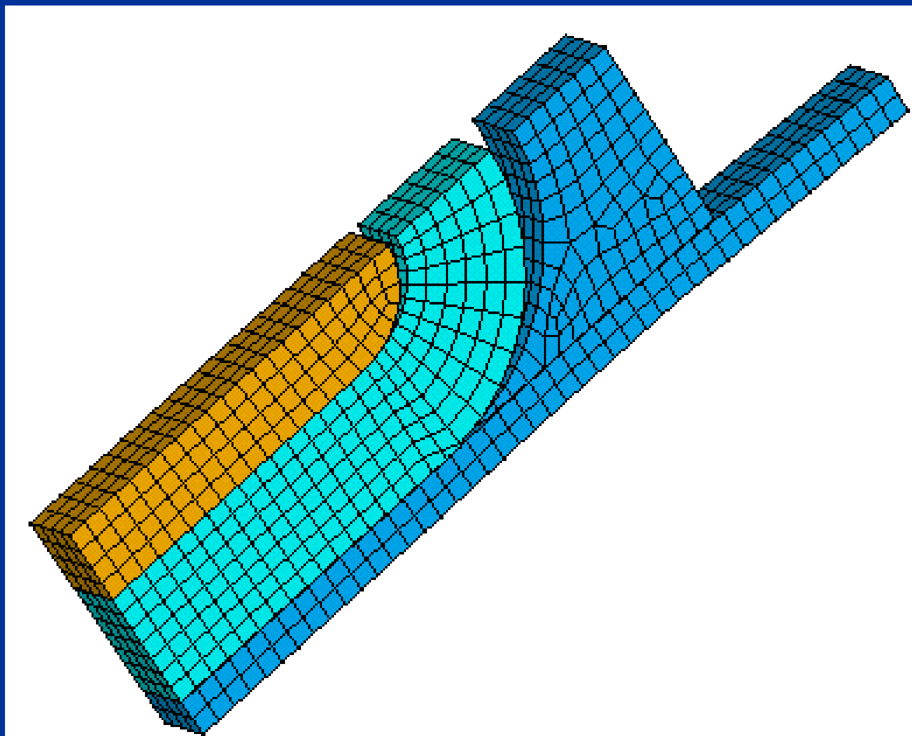
- ***Low stress*** at 293 K
- ***Stress increase*** during cool-down
- During excitation:
  - Shell stress ***almost constant***
  - Pole ***unloading***
  - Mid-plane ***loading***
- Possible to check coil stress limits

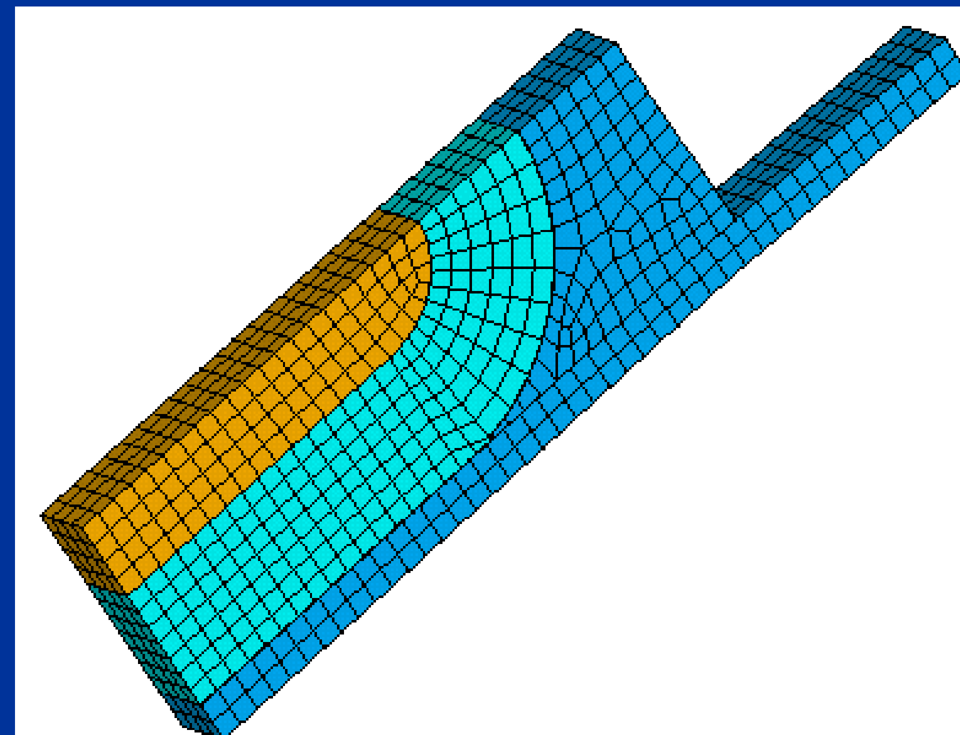
Axial support

- Stainless steel ***end plate***
- Aluminum ***rod***
  - Increase of ***tension*** during cool-down
  - ***Axial support*** during magnet excitation
- ***3D pre-stressing*** already implemented in HD1



Deformation of the coil end region (full field)





- Without axial support
- Gap island-coil: ~ 100 μm

- With axial support
- No gap island-coil

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Conclusions

- ***Feedback*** for IRQ R&D and ***technology development***
- ***SM quadrupole*** magnet ***test*** with existing coils
  - 110 mm bore with 11 T in the conductor
  - 100 MPa of coil azimuthal stress with axial support
  - Quadrupole assembly
  - Training, thermal and quench studies
  - Alignment and fabrication tolerances analysis
  - Validation of mechanical analysis
- ***Schedule***
  - Assembly and test by June 2004