



# US LHC Accelerator Research Program

*bnl - fnal- lbl - slac*

## Technology Quadrupole 1 (TQ1)

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# Technology Quadrupole TQ1 - Goals

1. Demonstrate a successful high field quadrupole magnet.
2. Reach predictable “Short-Sample” performance with reduced training.
  - Show through analysis and measurements that we understand the state of the magnet during assembly, cool-down and operation.



# Outline

TQ1 plans for FY05

Work done in FY04



# Plans for FY05

- Build the first two layers of a four layer cross-section.
  - Create a complete 3D model of the quad in CAD, TOSCA and ANSYS
  - Design and build all tooling for a 1m long 90mm bore magnet.
  - Design and build the structure (FY04).
  - Assemble the magnet
- Test
  - Conductor
  - Protection
  - Pre-stress and structure.
  - Field quality



# FY05 continue

- **FNAL**
  - Coil cross-section and tooling design.
  - Wind the first double layer and cure it.
  
- **LBL**
  - Create the quad CAD model,
  - A complete 3D magnetic and structural analysis (TOSCA, ANSYS).
  - React, instrument, and impregnate the coils
  - Assemble and pre-stress the coils in its structure.
  
- **BNL**
  - Test the magnet



# TQ1 - Concept

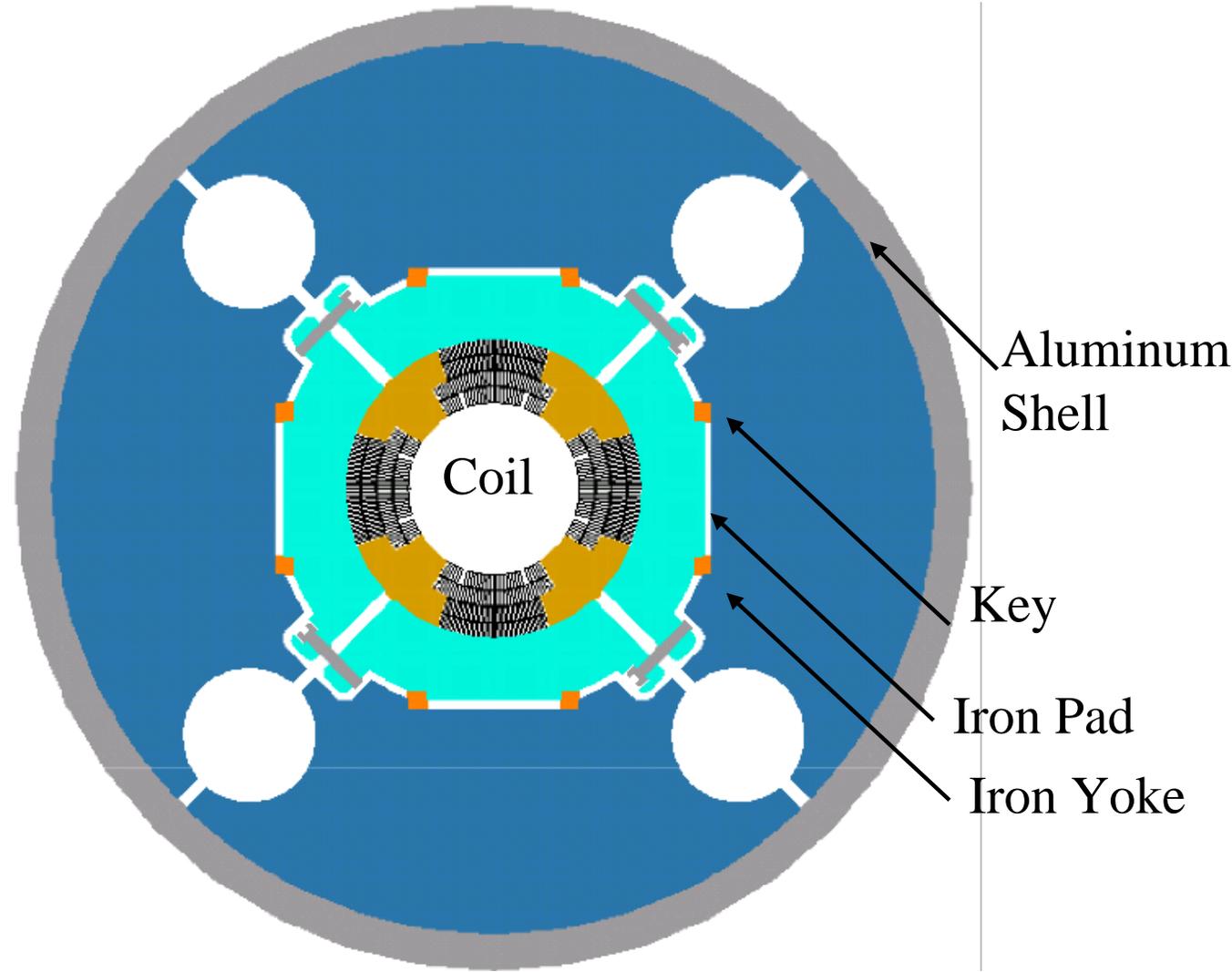
$G_{ss} \sim 270 \text{ T/m}$

20kA

90mm bore

4 layers

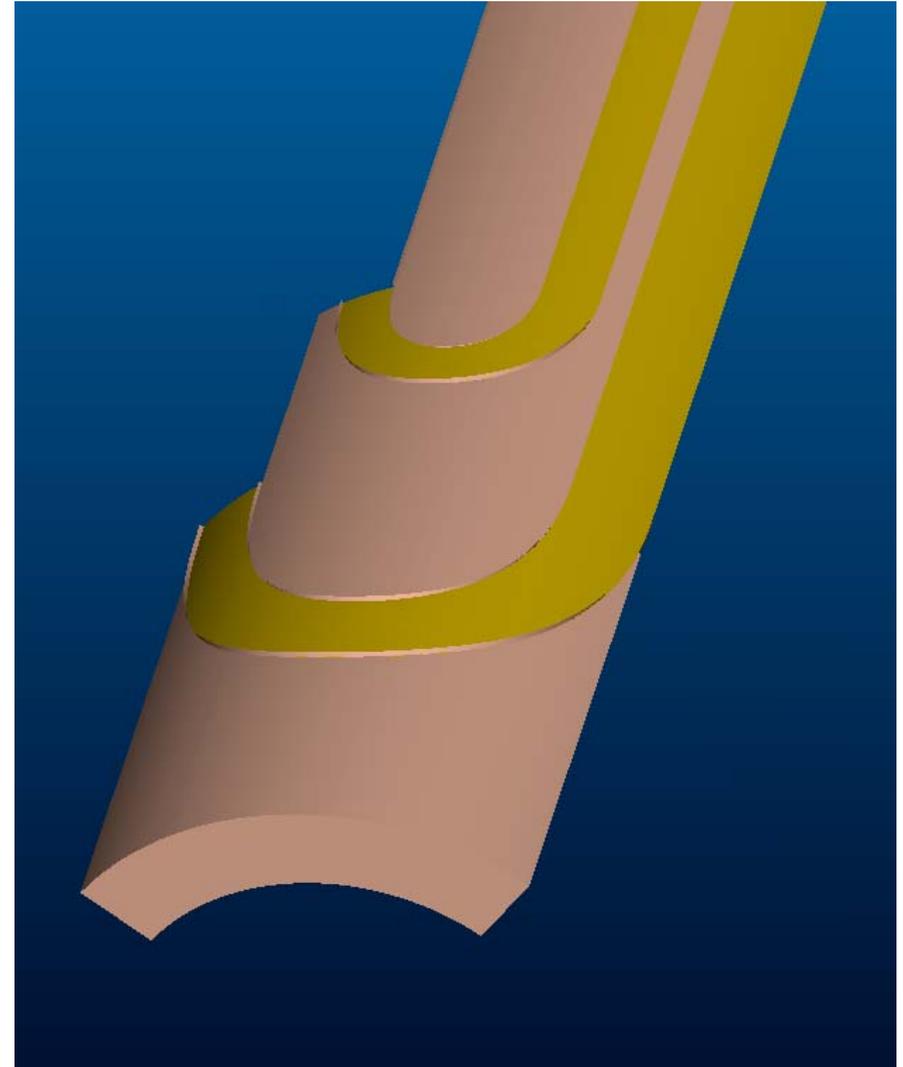
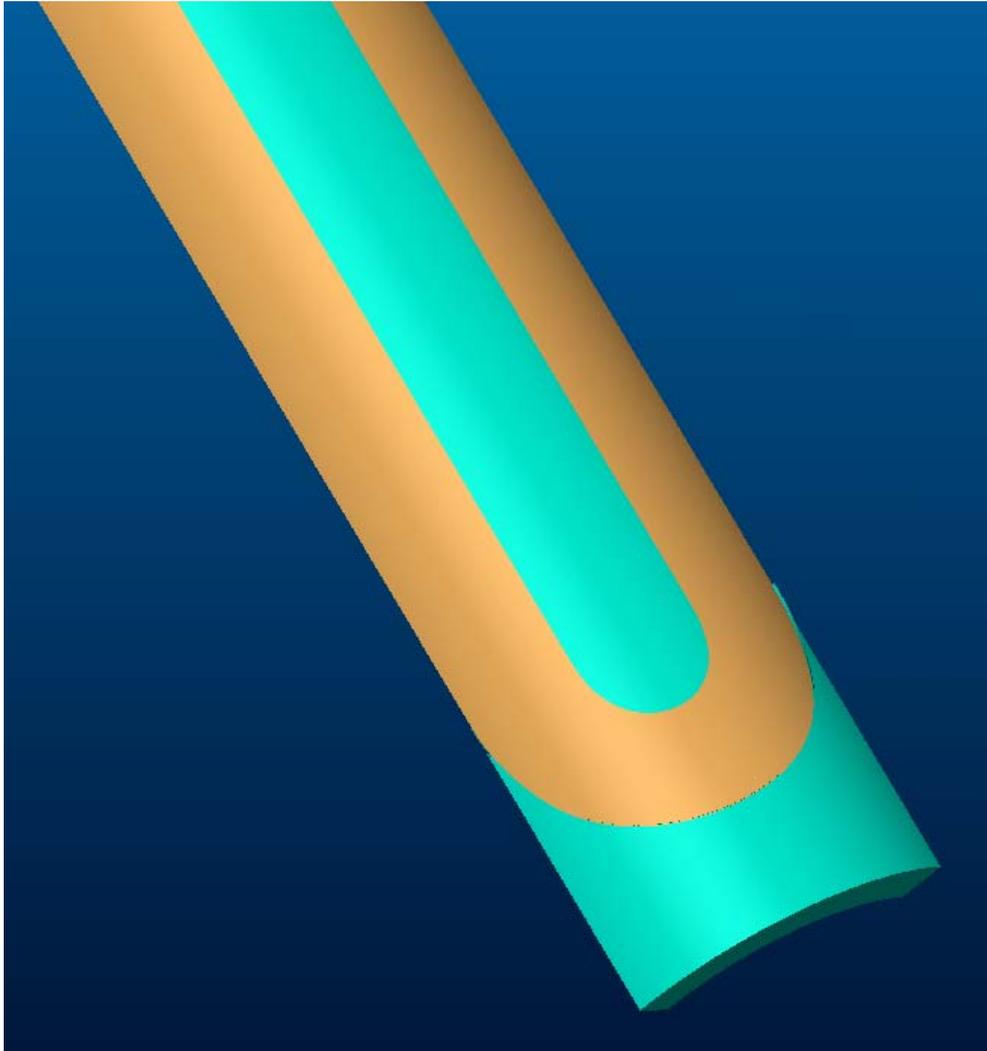
5 MN/m force



1. Pressurize bladders
2. Replace bladders with keys
3. Cool-down - final pre-stress
4. Lorentz forces – 5 MN/m



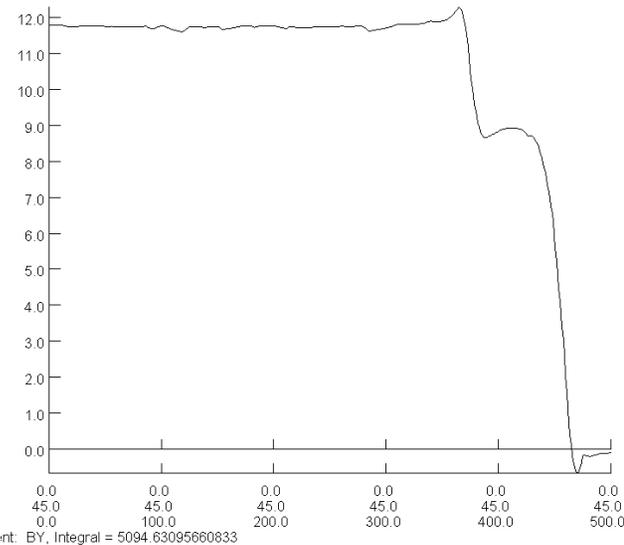
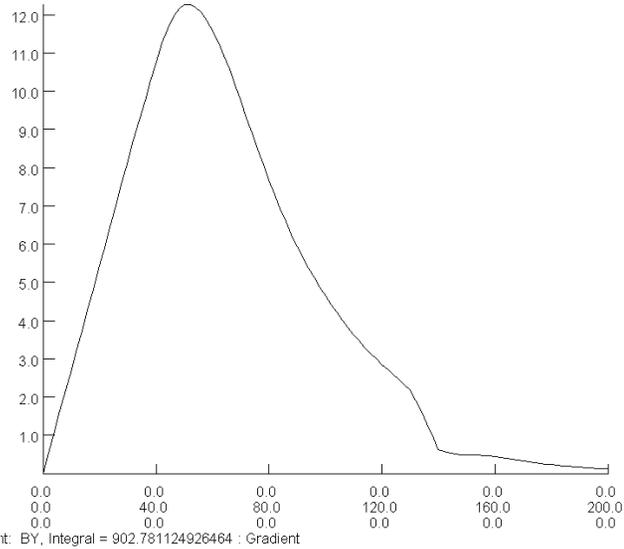
# Conceptual CAD Model – FY05





# Conceptual Magnetic Model – FY05 Tosca – |B|

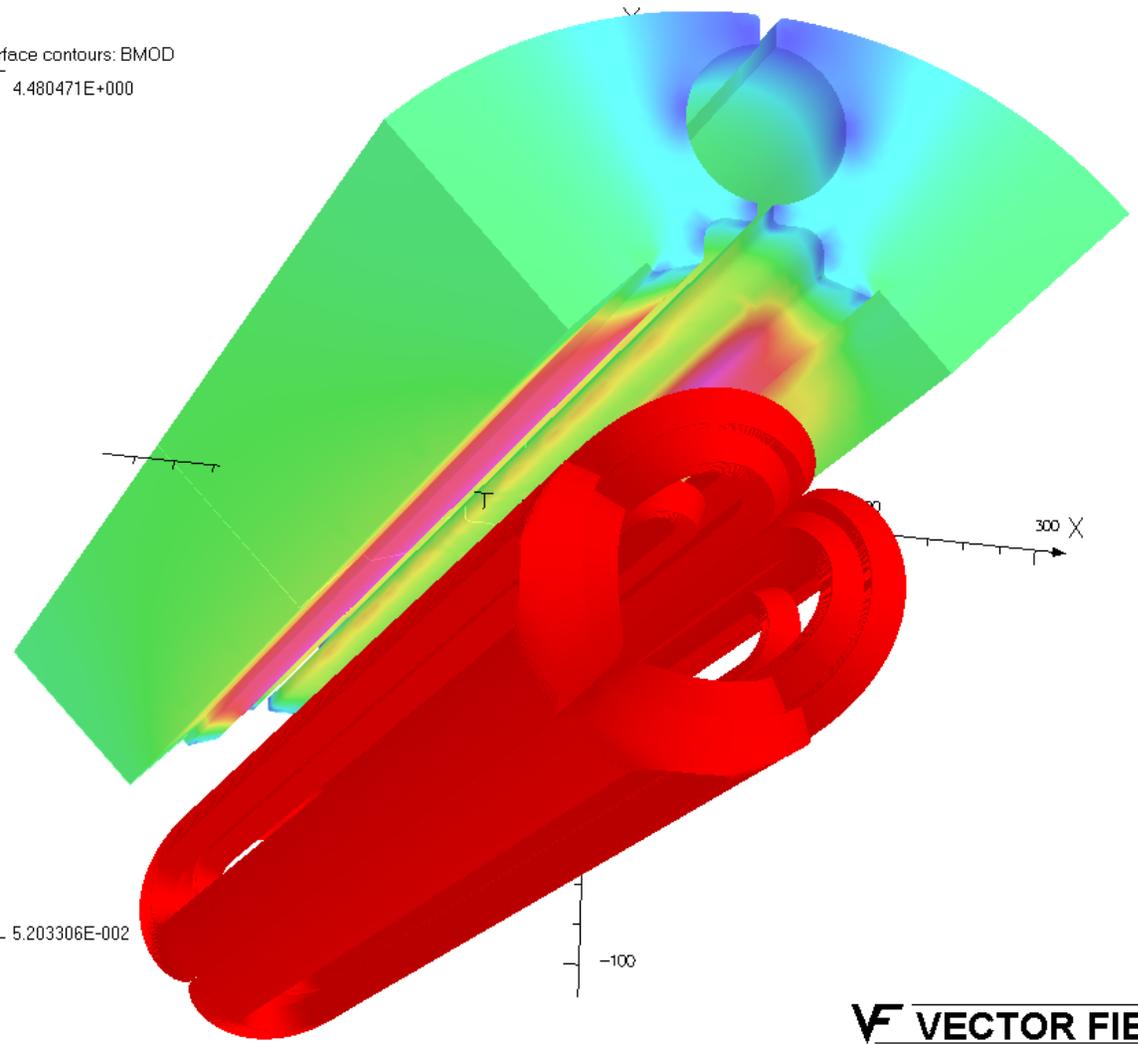
21/Jul/2003 15:24:47



Surface contours: BMOD

4.480471E+000

5.203306E-002



**V VECTOR FIELDS**

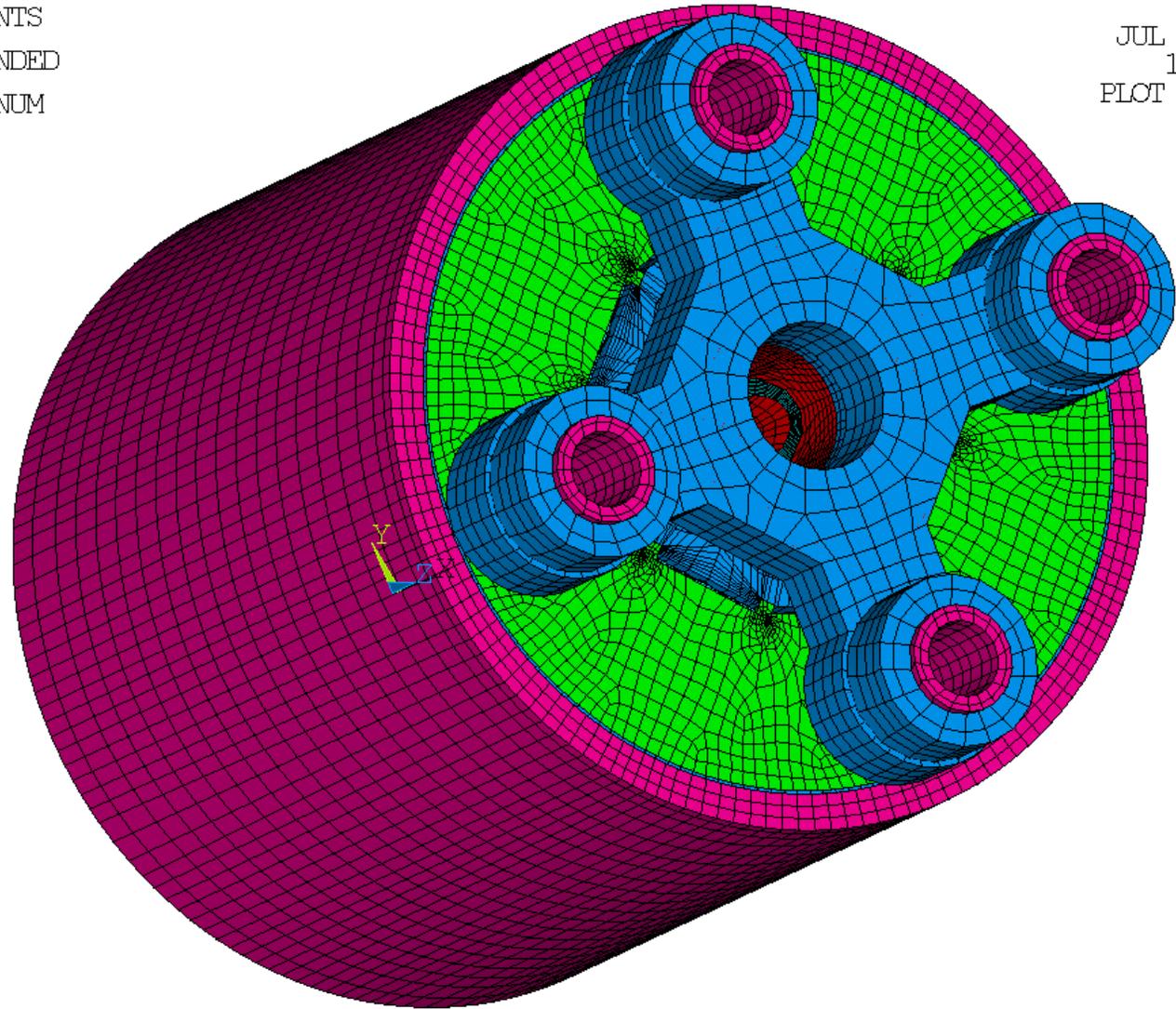


# Conceptual ANSYS Model – FY05

1  
ELEMENTS  
/EXPANDED  
MAT NUM

ANSYS

JUL 21 2003  
16:21:36  
PLOT NO. 1



IRQuad-30MPa no friction

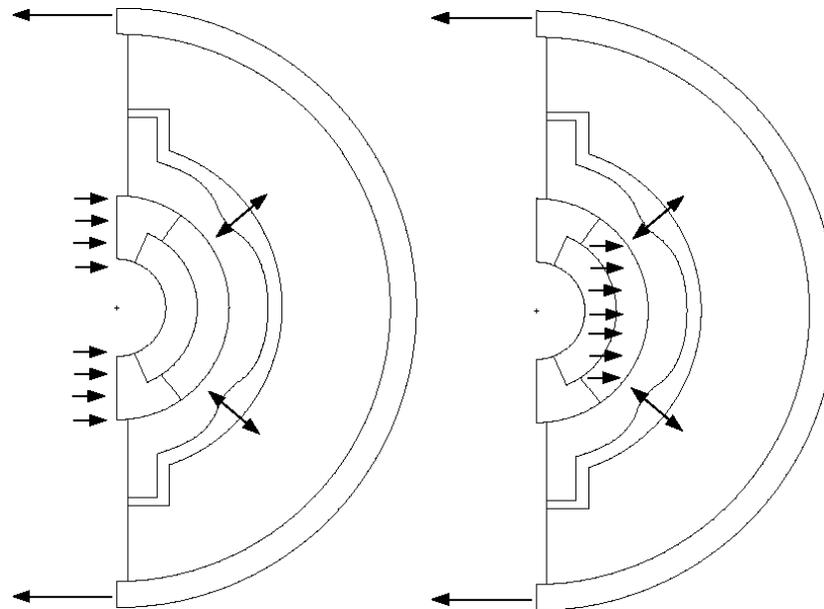


# Azimuthal Assembly and Pre-stress



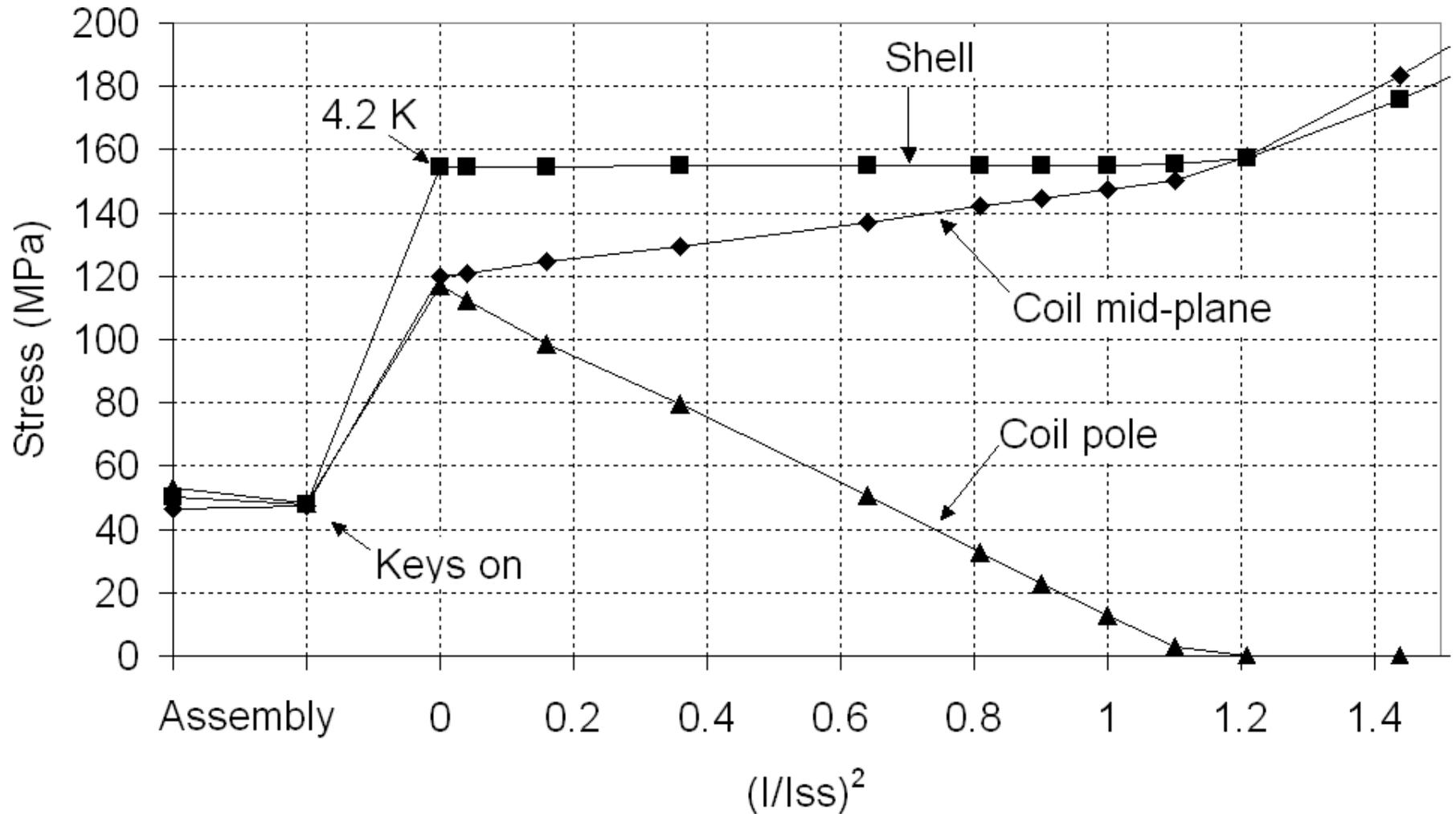
# Shell, Keys, and Bladders

- Force balance between shell and coil
- Mid-plane stress (increase) + pole stress (decrease) = Shell Stress (constant)



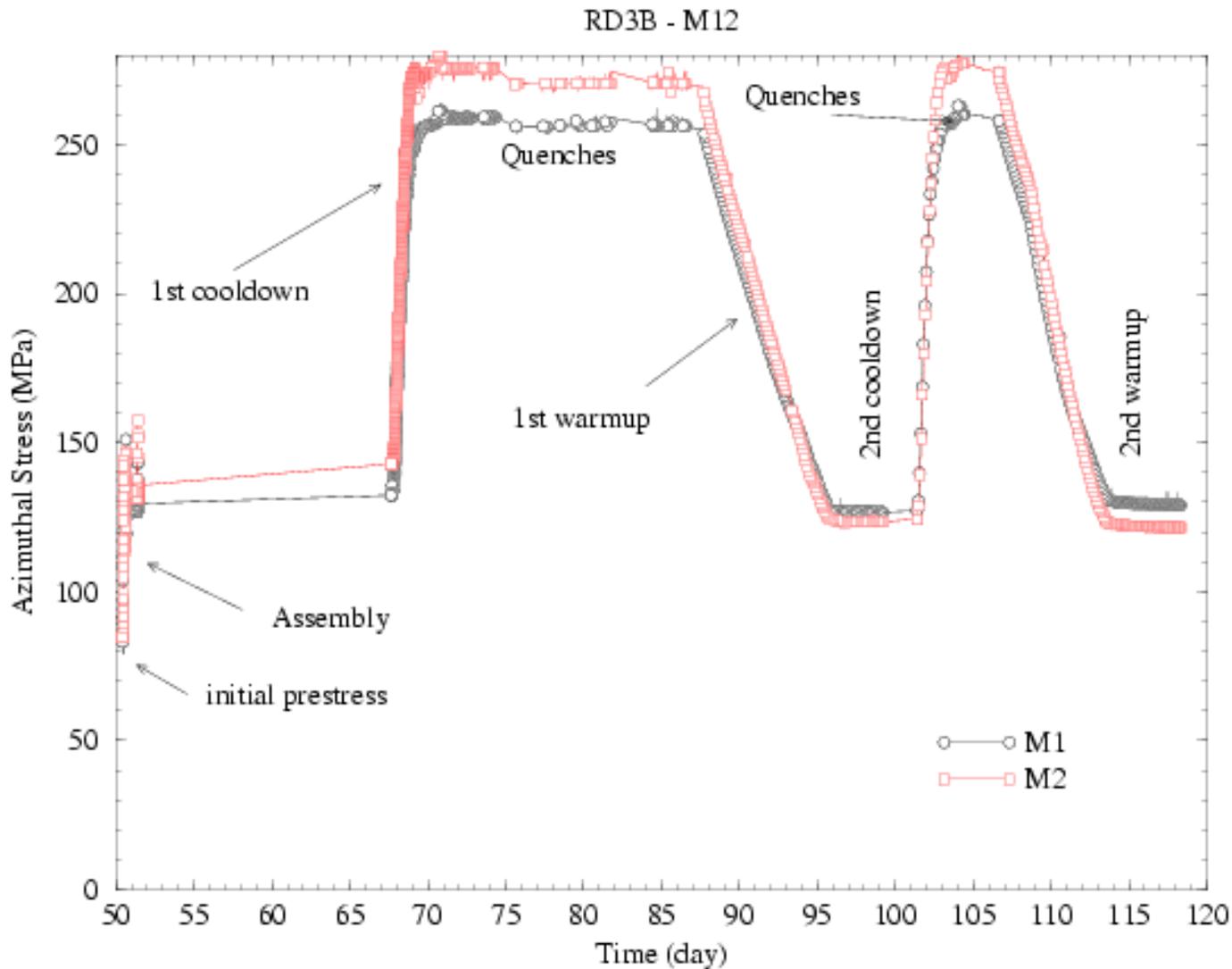


# IRQ: stresses in coil and shell during assembly and excitation





# Shell Stress History – 14.5 T (RD3)



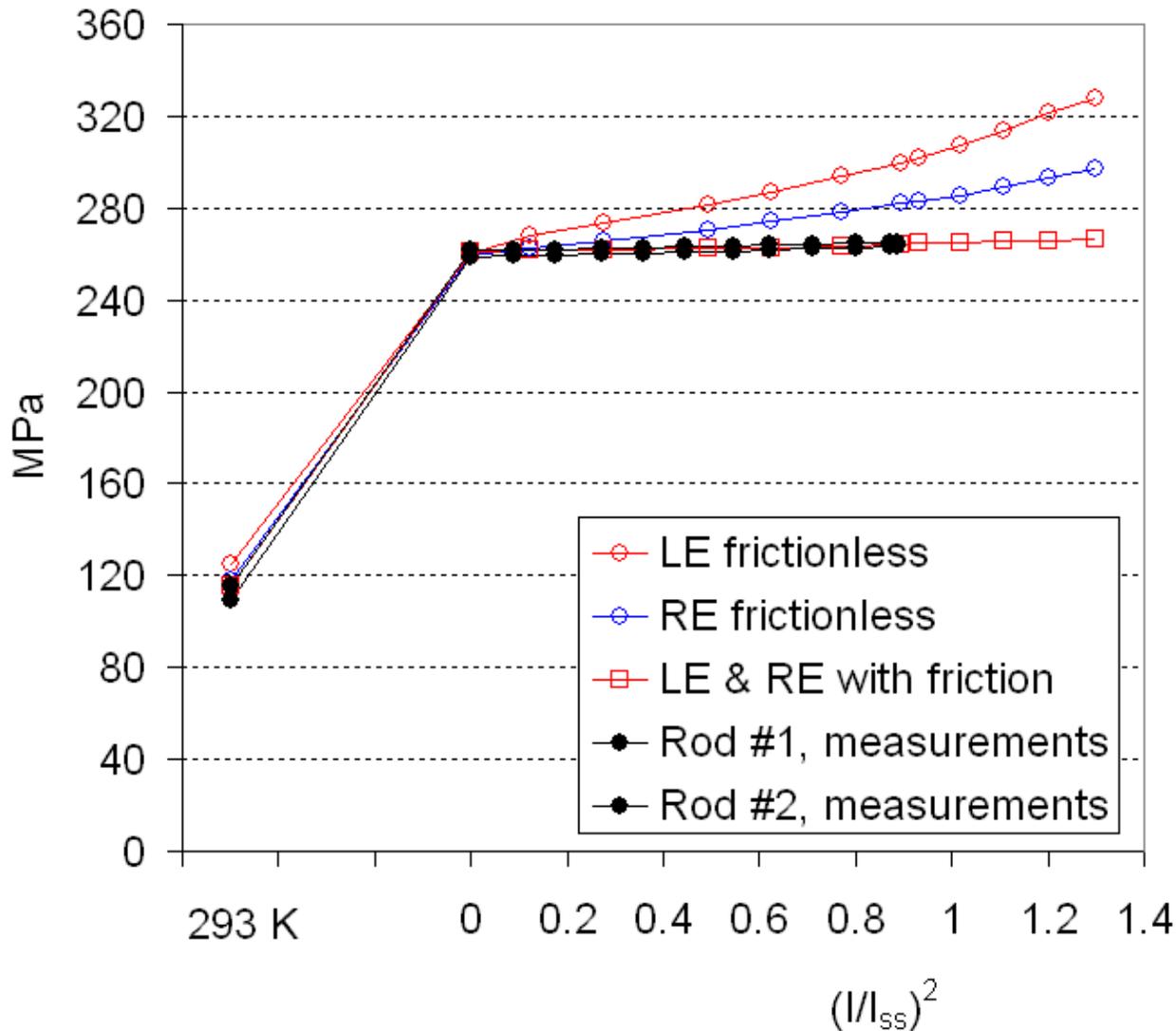
- Initial stress 130 MPa
- No creep
- Gain of 120 MPa during cool-down
- No increase in stress up to 14.5 T
- Reversible stress upon warm-up
- Reversible stress upon 2'nd cool-down



# **Axial Assembly and Pre-stress**



# HD1: Axial forces and rod tension

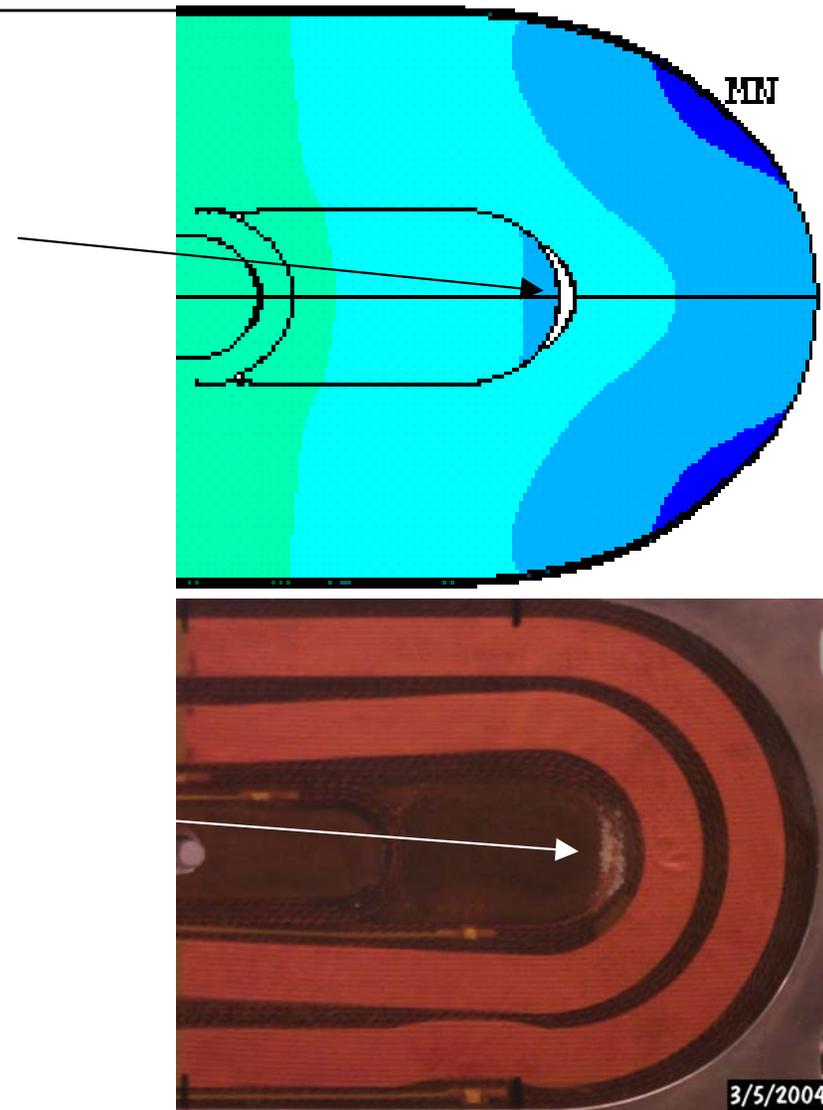


- 3D Analysis
  1. Frictionless
  2.  $\mu = 0.1$



# HD1: Axial Lorentz forces

- 3D analysis
  - 80  $\mu\text{m}$  Gap
  - Most training quenches
- **Visual inspection** after disassembly
  - **Epoxy discoloration**





# 0 friction layer 1

1

NODAL SOLUTION

TIME=1

/EXPANDED

UZ (AVG)

RSYS=0

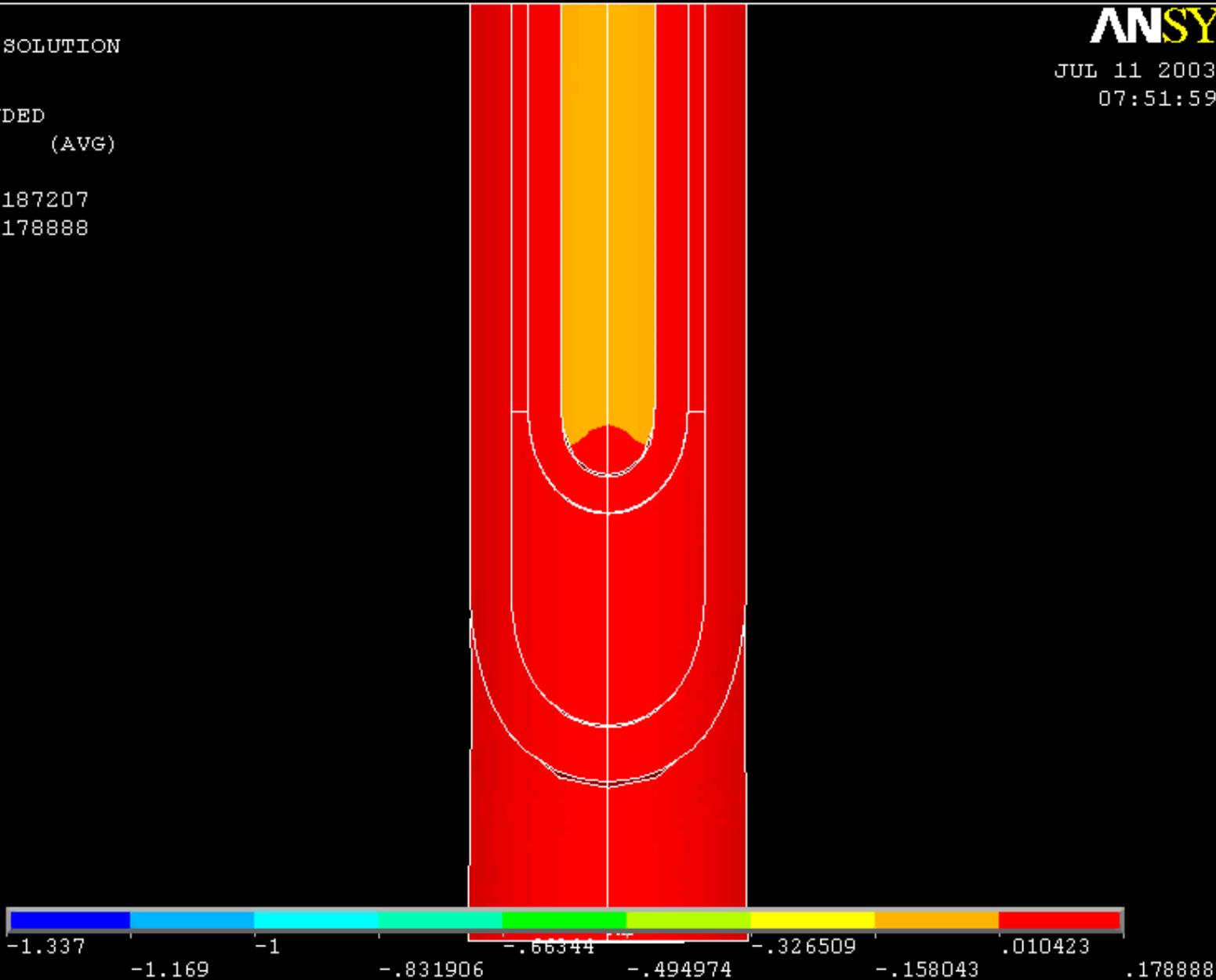
DMX =.187207

SMX =.178888

ANSYS

JUL 11 2003

07:51:59

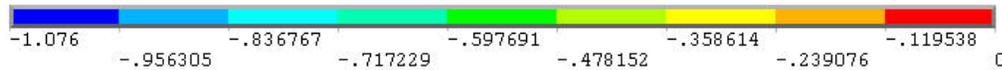
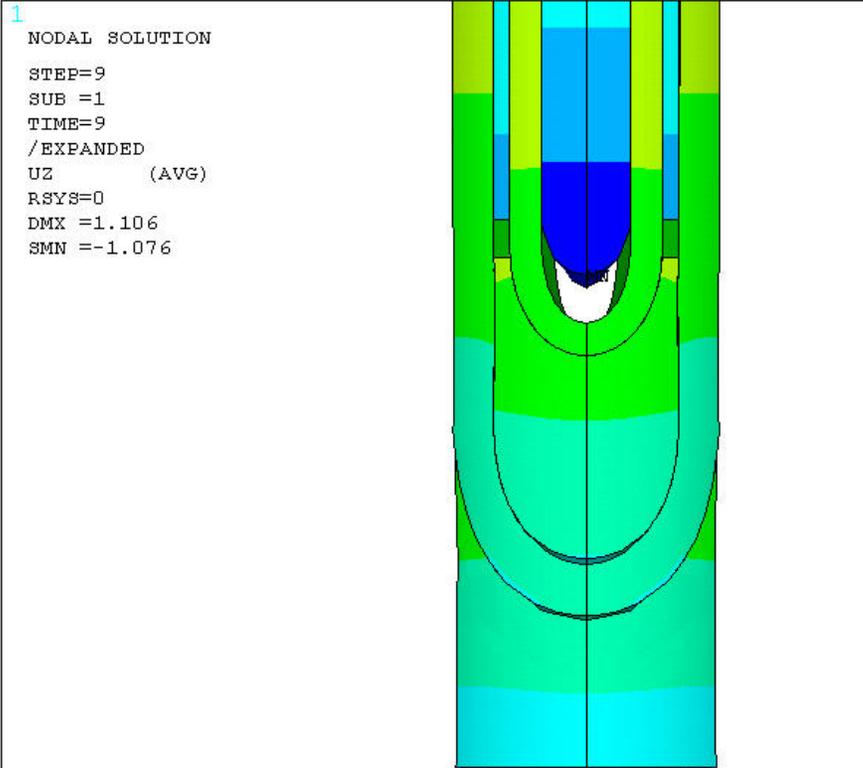


Model ansys\_irq2-a



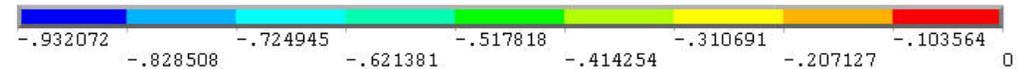
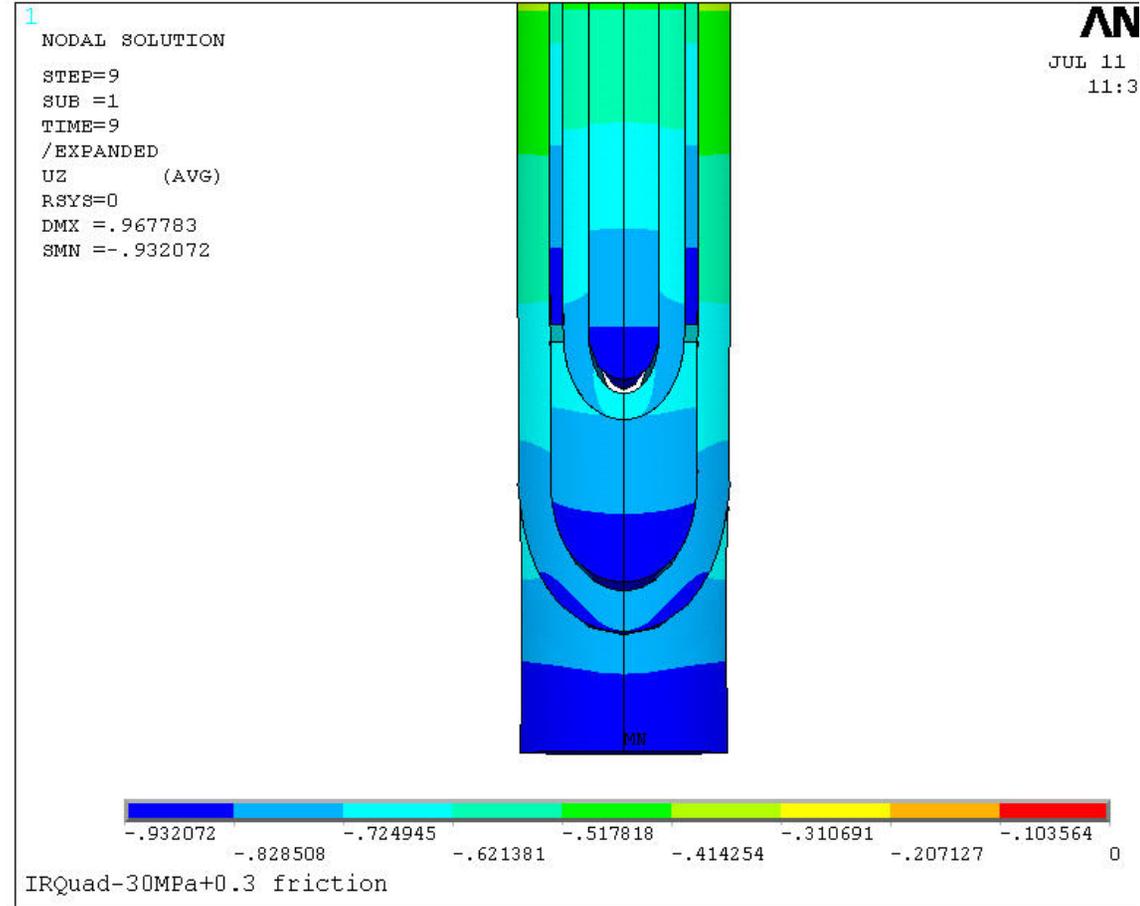
# Layer 1 – Short Sample

0 friction



Model ansys\_irq2-a

0.3 friction



IRQuad-30MPa+0.3 friction



## Completed work in FY04



# Mechanical Model - FY04

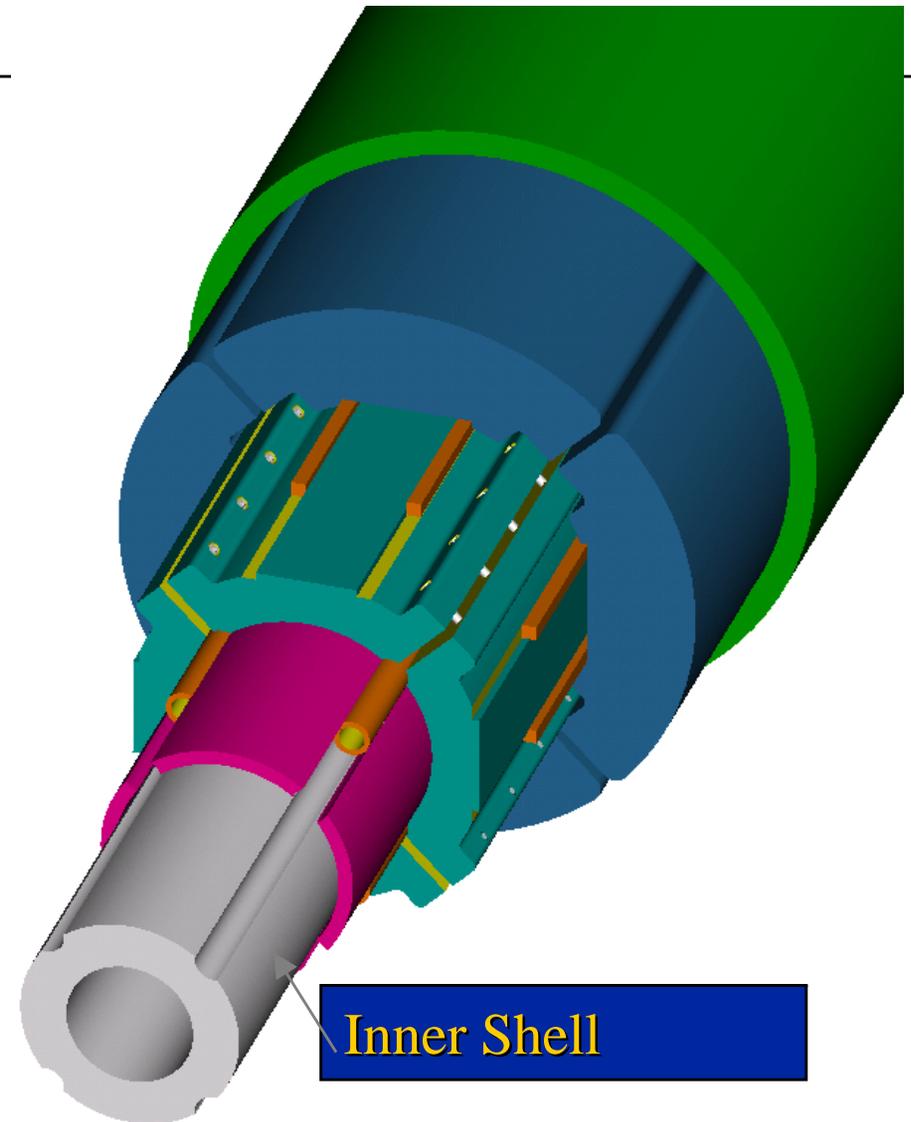
- Develop **strain gauge technology** to monitor stress conditions in coils and structure.
  
- Assemble a **structure** suitable for controlling stress in a  $\text{Nb}_3\text{Sn}$  Cosine-theta quad.



# Mechanical Coil and Structure

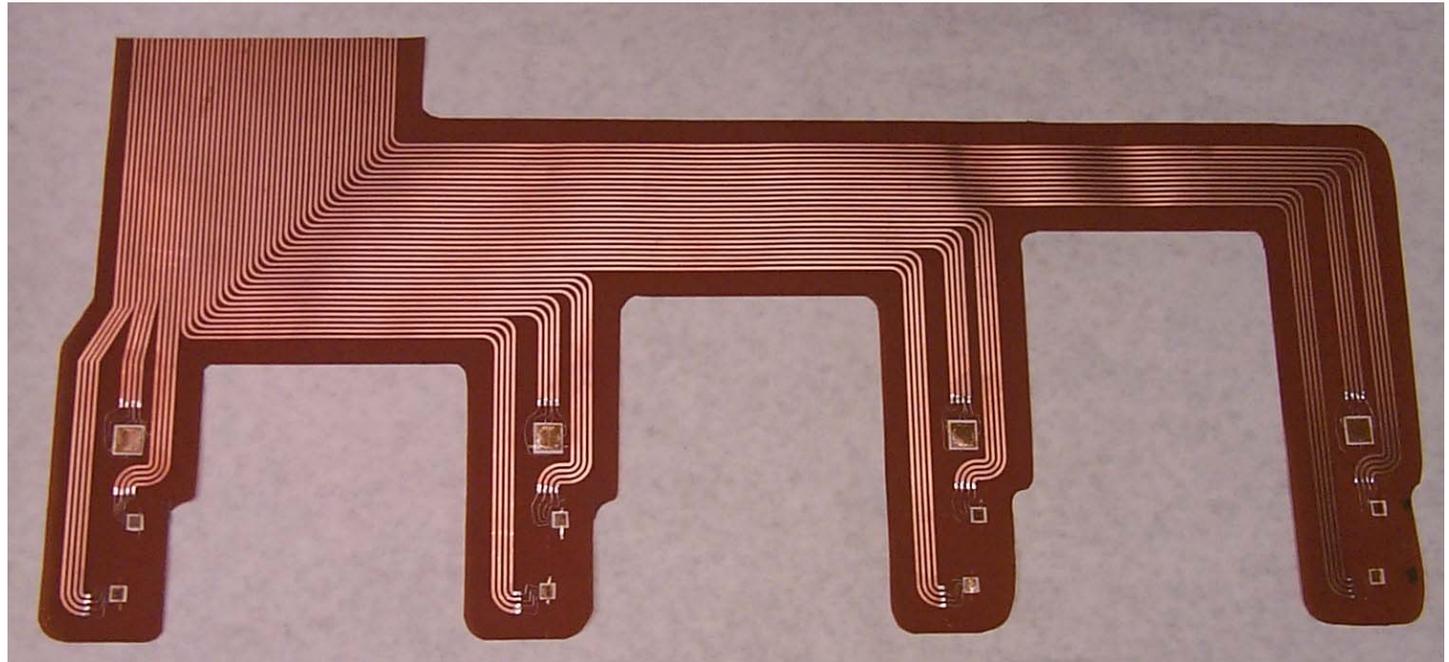
Final assembly of a mechanical coil (tube) within the structure

- Monitor stress relation between outer shell and inner tube during assembly and cool-down

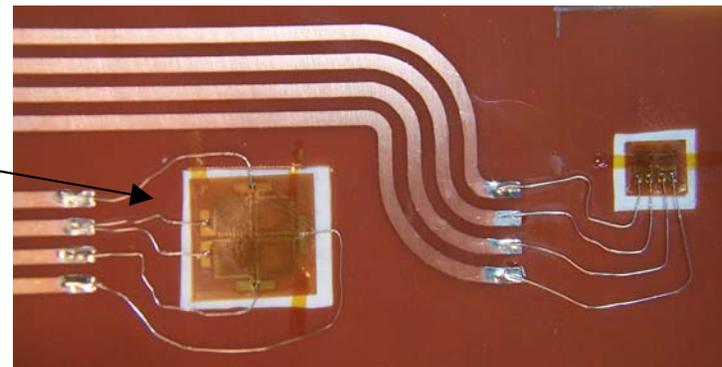




# Strain Gauge Trace Technology



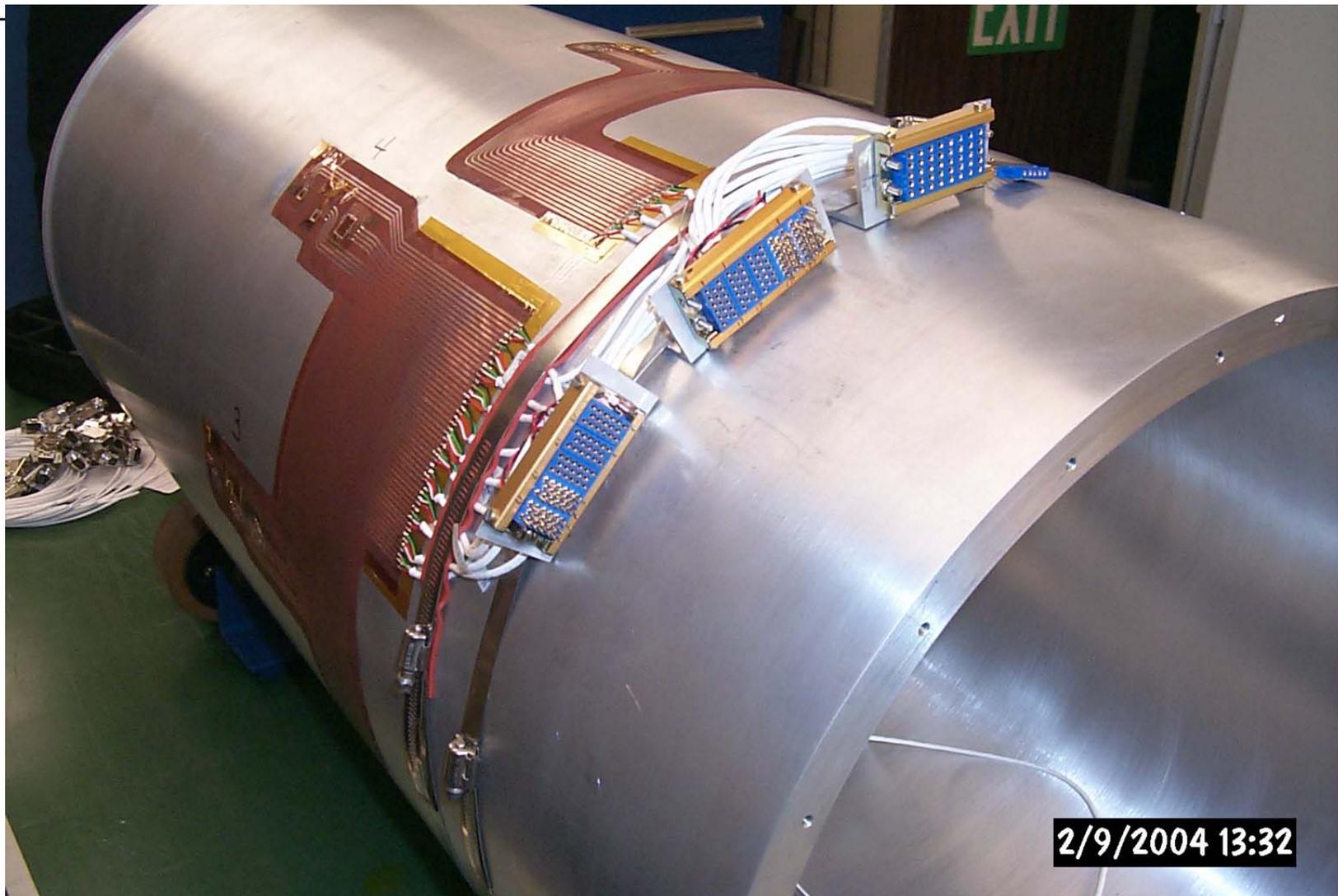
Full bridge



Half bridge



# Shell



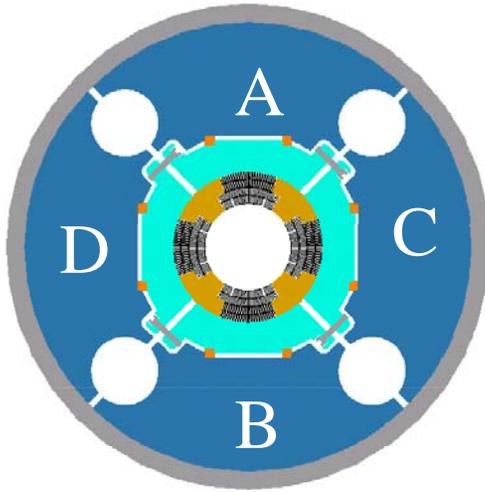


# Assembly

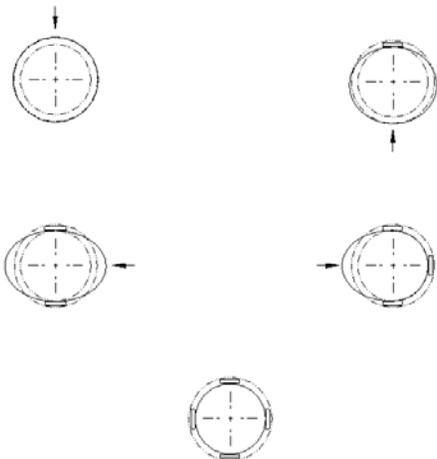




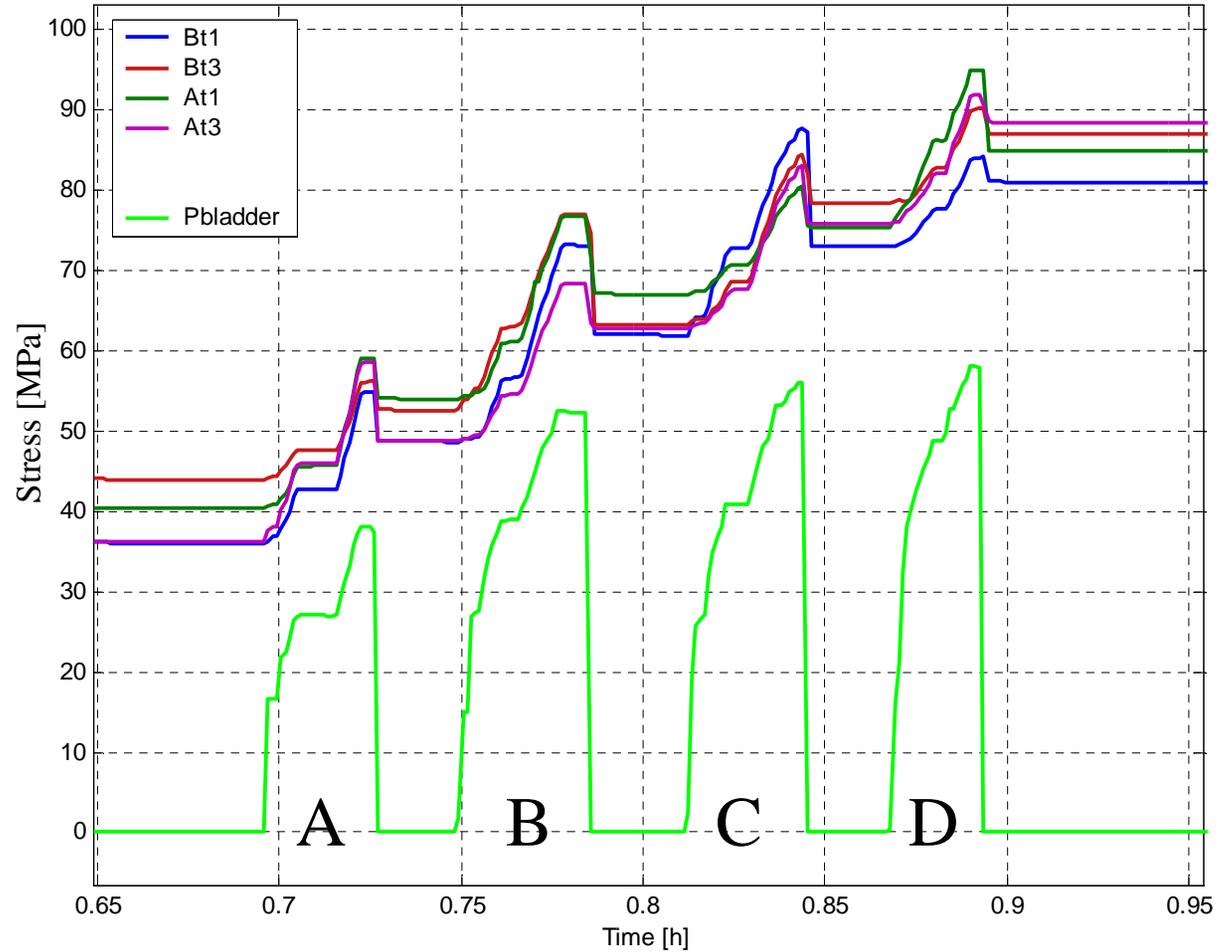
# Shell Assembly



keying order

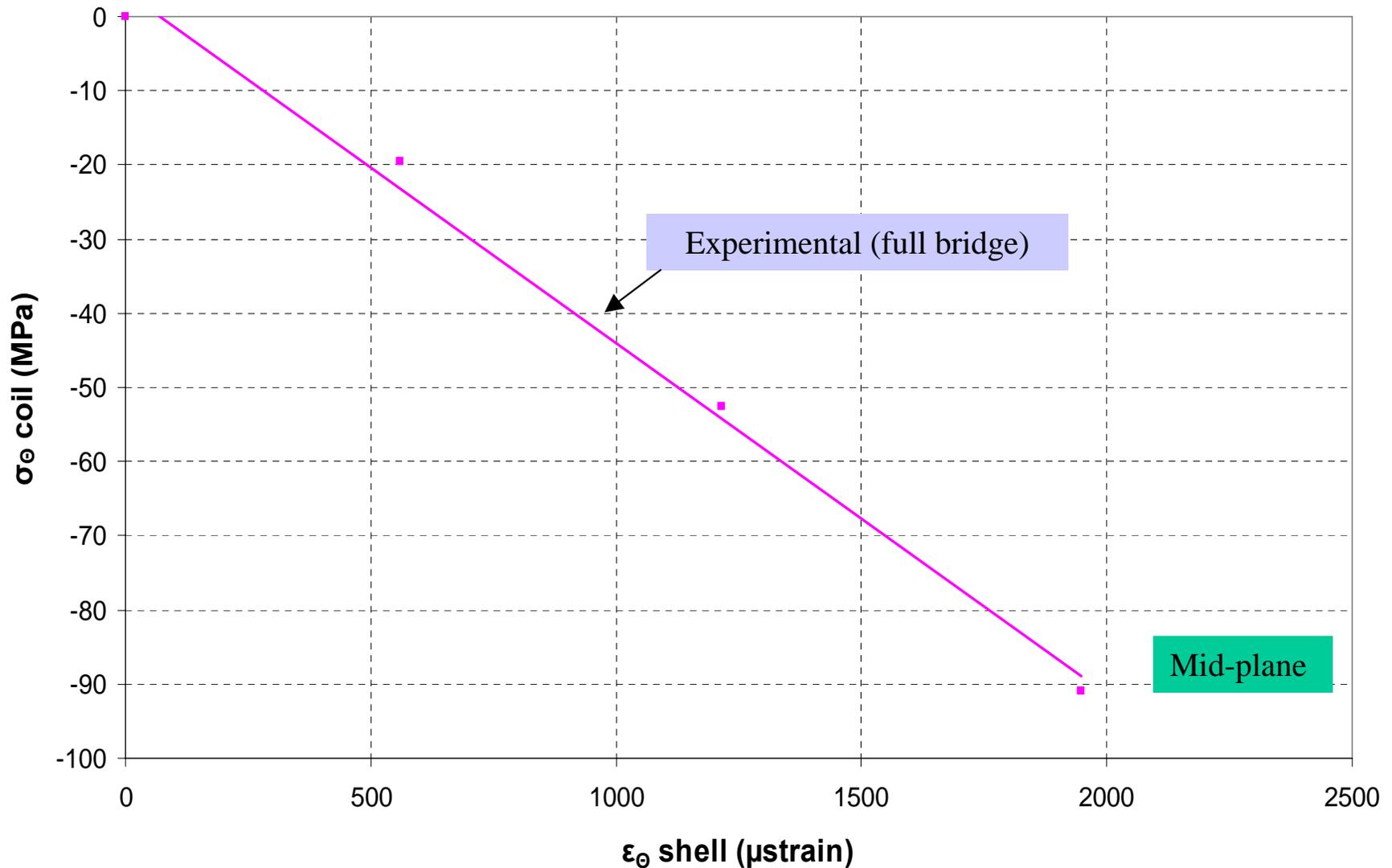


IR Quad Assembly: Mid Plane Azimuthal Stress





# Coil stress vs Shell Strain





# TQ1 – Summary

We are in a good starting position to build and test the first quad model in FY05