LARP

TQ Shell - Details

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DOE Review Santa Rosa

November 2-4 2005

Statement of work – TQS01

Main Objectives and Features:

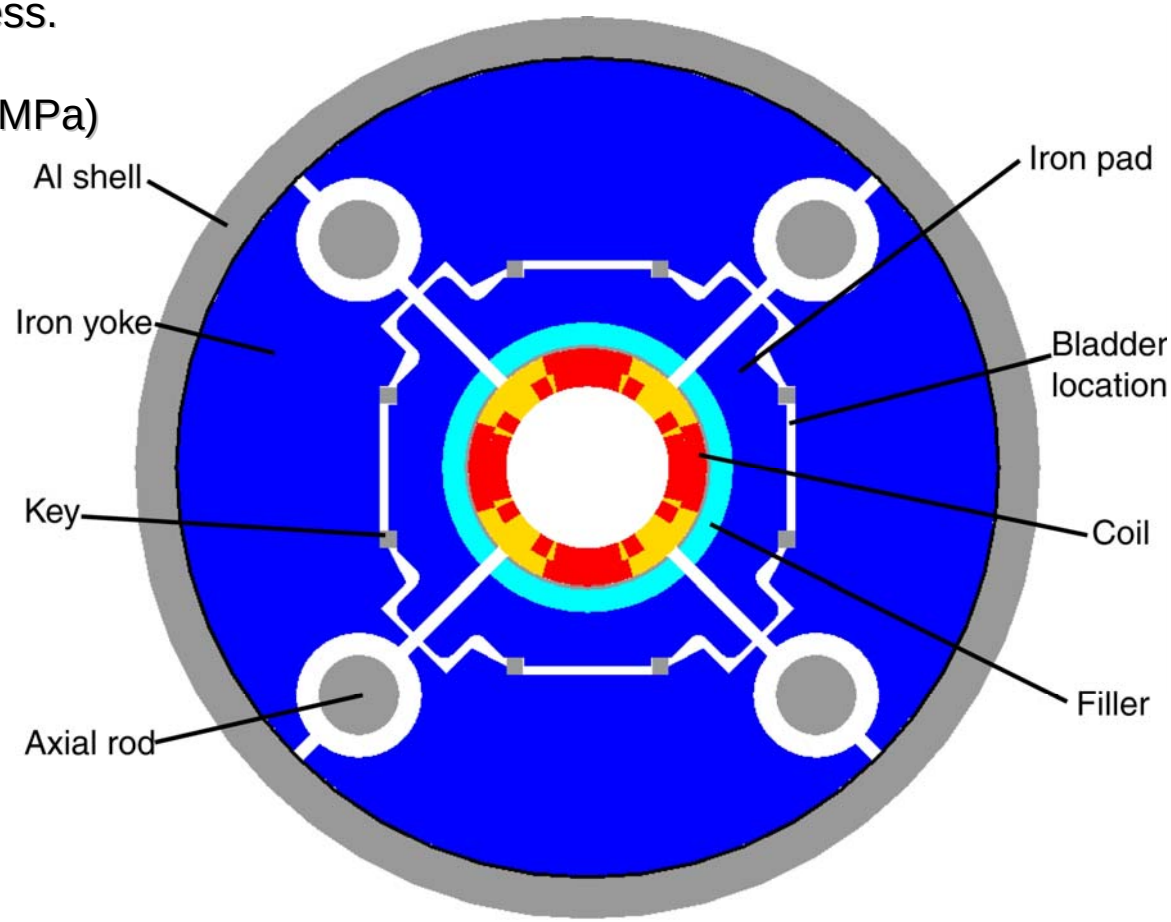
- Compare the magnet performance with the design parameters.
- Comparison between the properties of an Al shell-based structure and a collar-based structure.

Work Plan, Distribution, and Schedule:

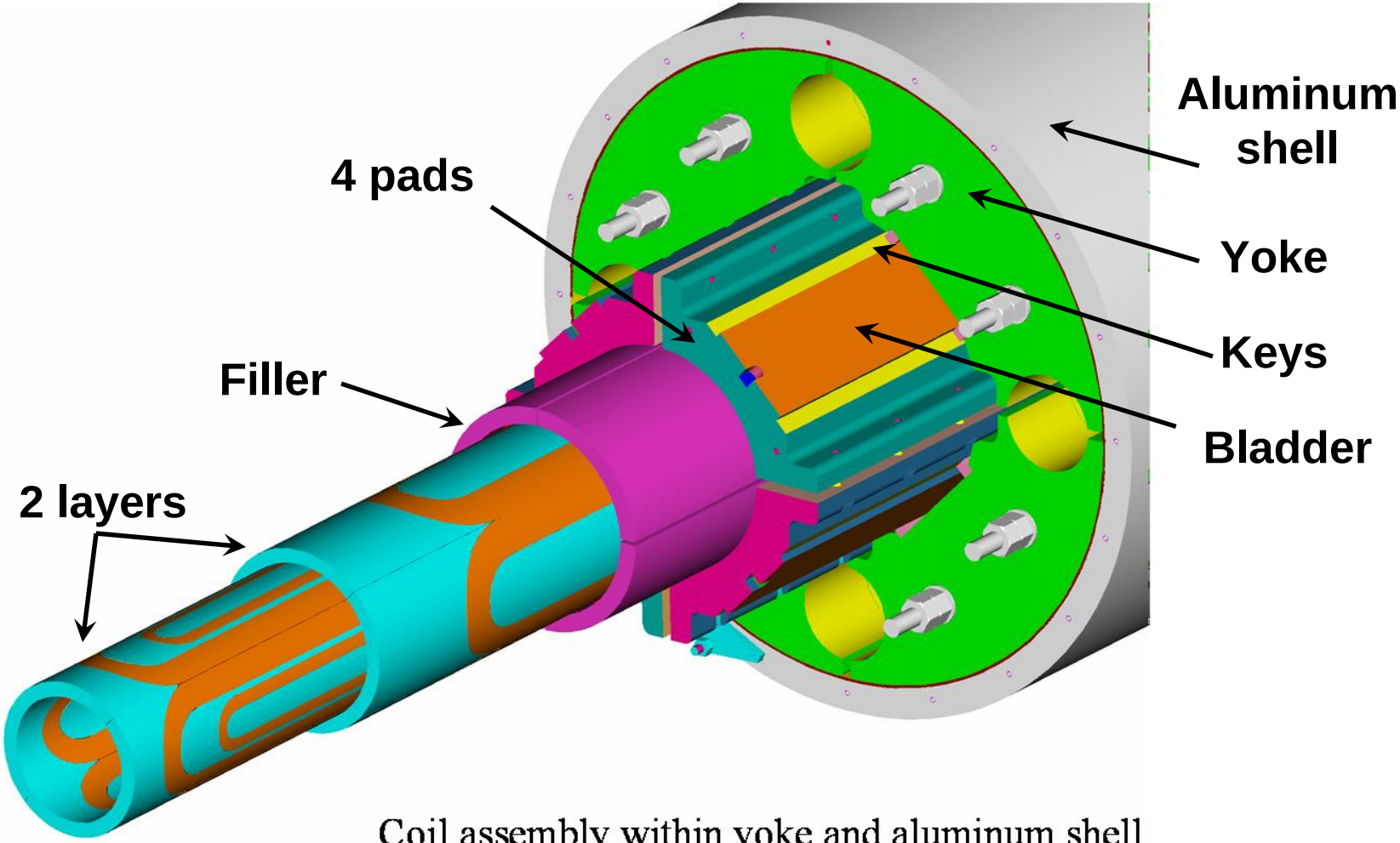
✓ Design of cable, coil, and tooling:	FNAL+LBNL	
✓ Fabricate/Insulate cable:	LBNL	
✓ Procure coil fabrication tooling/parts:	FNAL	
✓ Design and fabricate pad inserts	LBNL	
✓ Design and fabricate axial rods + end plates LBNL		
✓ 4 Practice coils	FNAL+LBNL	
• Assemble and test mechanical model:	LBNL	12/21/2005
• Fabricate TQS01 coils 1-4:	FNAL+LBNL	12/21/2005
• Assemble magnet:	LBNL	01/31/2006
• Test magnet:	LBNL	03/14/2006

TQS01 – shell, keys, rods

- No collars – islands attached to coil
- Bladders for coil azimuthal pre-stress.
- Hhydraulic piston for coil axial pre-stress.
- Lowl assembly pre-stress (<50MPa).
    - High azimuthal cold stress (~150MPa)
    - High axial cold stress (~50MPa)



TQS01

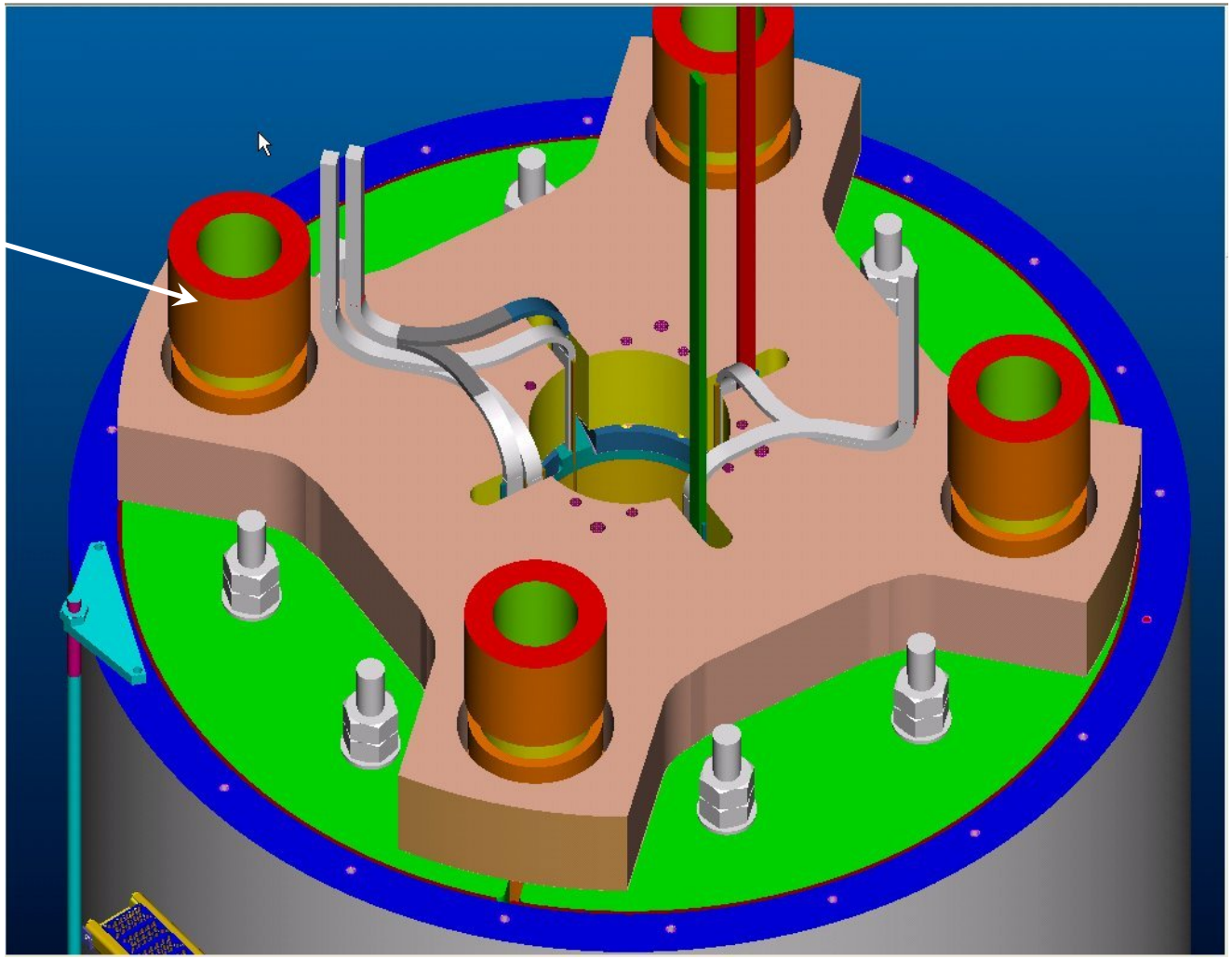


Coil assembly within yoke and aluminum shell

End Plate and Rods

Axial

Aluminum rods



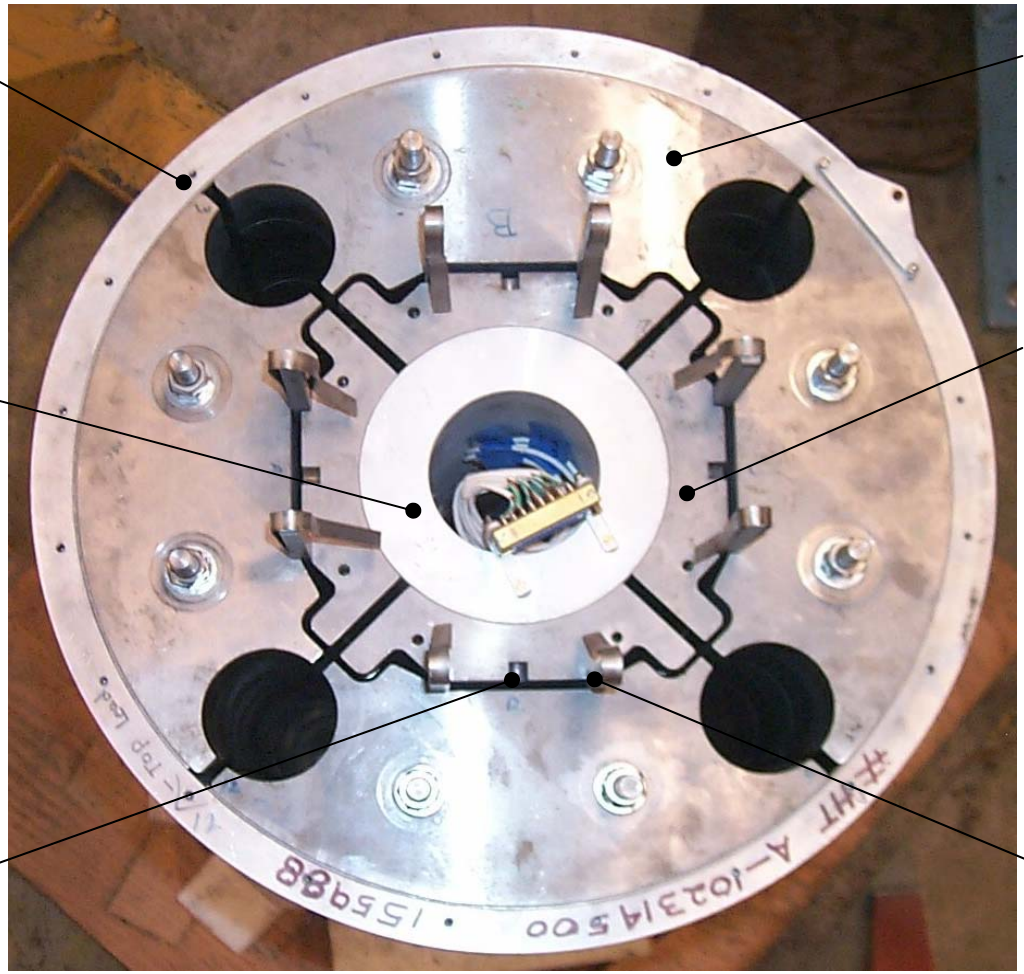
Strand and Cable

	Unit	Layer 1	Layer 2
STRAND			
Type		MJR	
Diameter	mm	0.7	
Cu/Sc		0.89	
Assumed J_{sc} (4.2 K, 12 T)	A/mm^2	2000	
CABLE			
N strands		27	
Mid-thickness bare	mm	1.26± 0.01	
Width bare	mm	10.025± 0.05	
Keystone angle	Degree	1.0± 0.1	
Insulation thickness	mm	0.125	

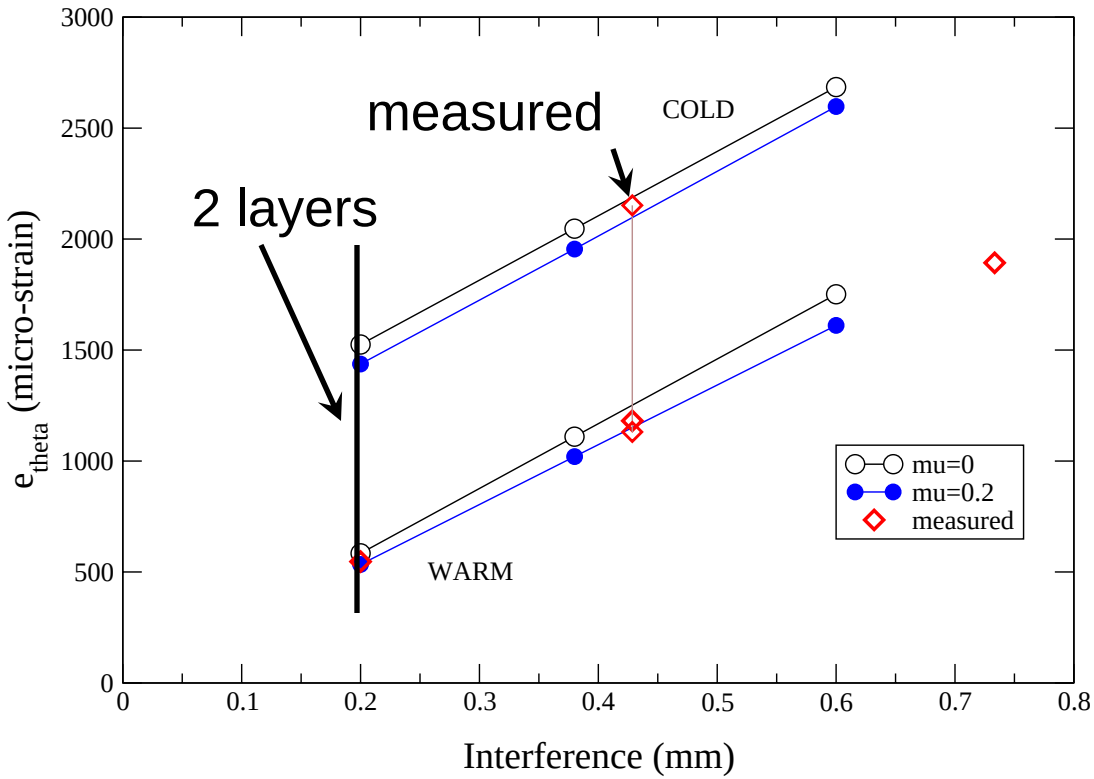
Coil and Structure

	Unit	Layer 1	Layer 2
Turns per block		6/12	16
Mandrel diameter	mm	90	
Shell thickness	mm	22	
Shell outer diameter	mm	500	
OPERATING EXPECTATIONS at 4.2 K (1.9 K):			
Short sample current	kA	12.5 ±0.25 (13.55 ±0.2)	
Peak conductor field (2D)	T	11.38±0.18 (12.25±0.15)	9.96 (10.8)
G_{ss}	T/m	222±3 (239±3)	
Stored energy	kJ/m	392 (456)	
Applied Coil azimuthal stress warm	MPa	33	34
Applied Coil azimuthal stress cold	MPa	125	130
Coil azimuthal stress short-sample pole/mid-plane	MPa	25/155 (10/160)	80/145 (70/150)
Axial force all coils (same as Lorentz)	kN	351 (413)	
Average axial stress (contact area with end plate)	MPa	51 (60)	

TQS01 – Structure test

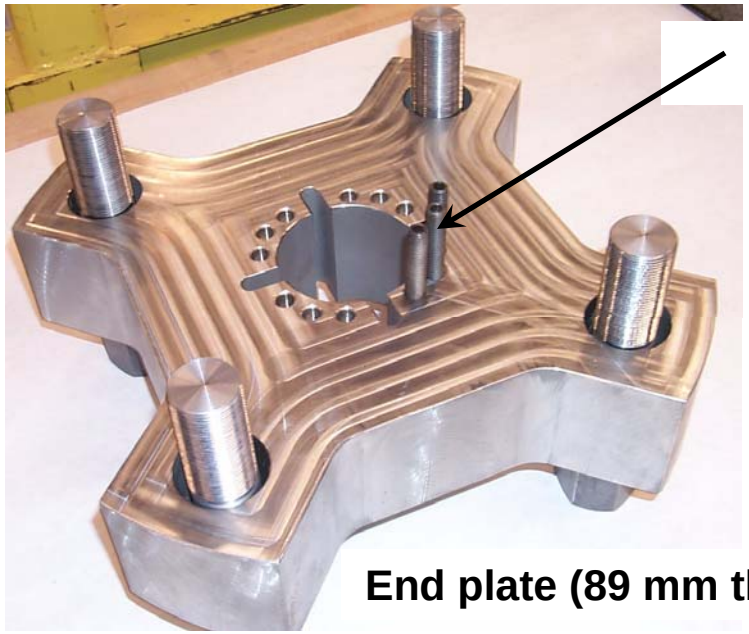


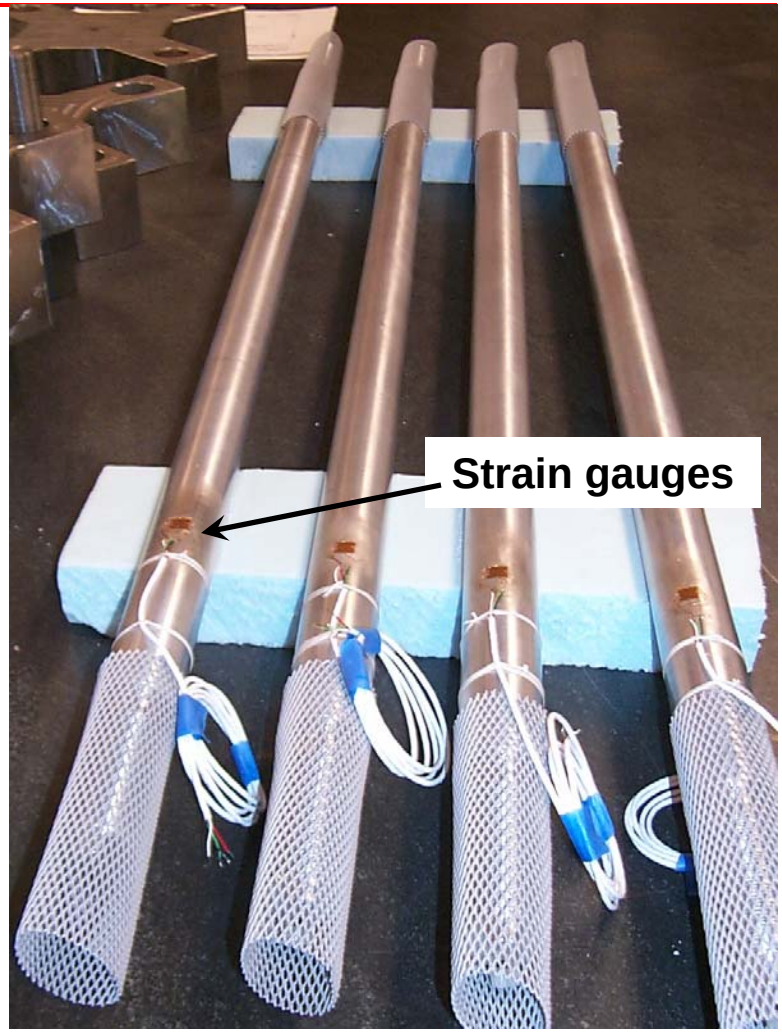
TQS01 – Assembly Test



Transverse strain in the shell versus key interference: numerical and measured (frictionless and with friction).

End Support



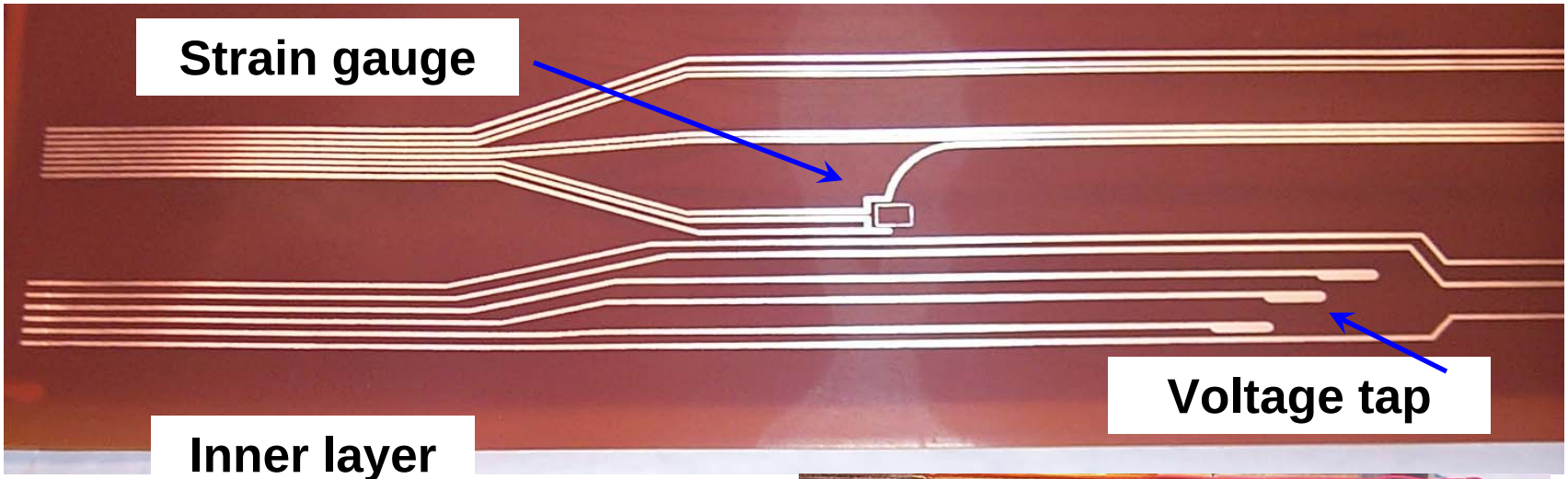


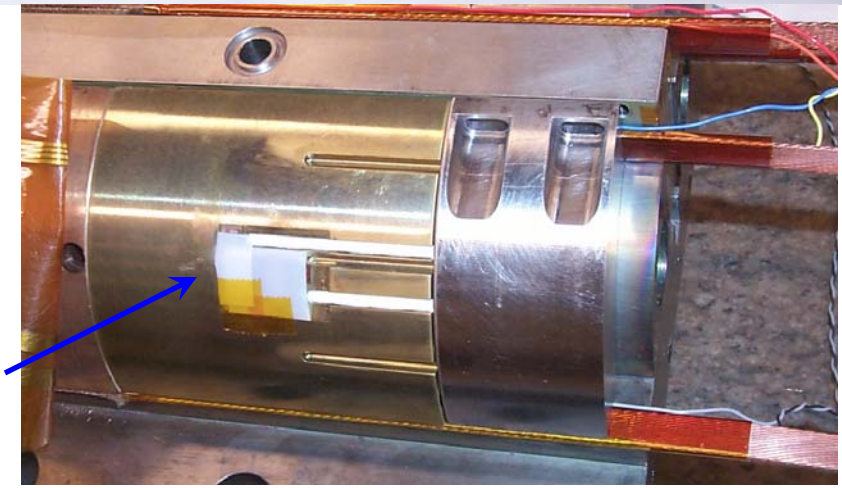
Axial Aluminum rods (44 mm dia.)

Practice Coil

One out of four practice coils to be used in an assembly test

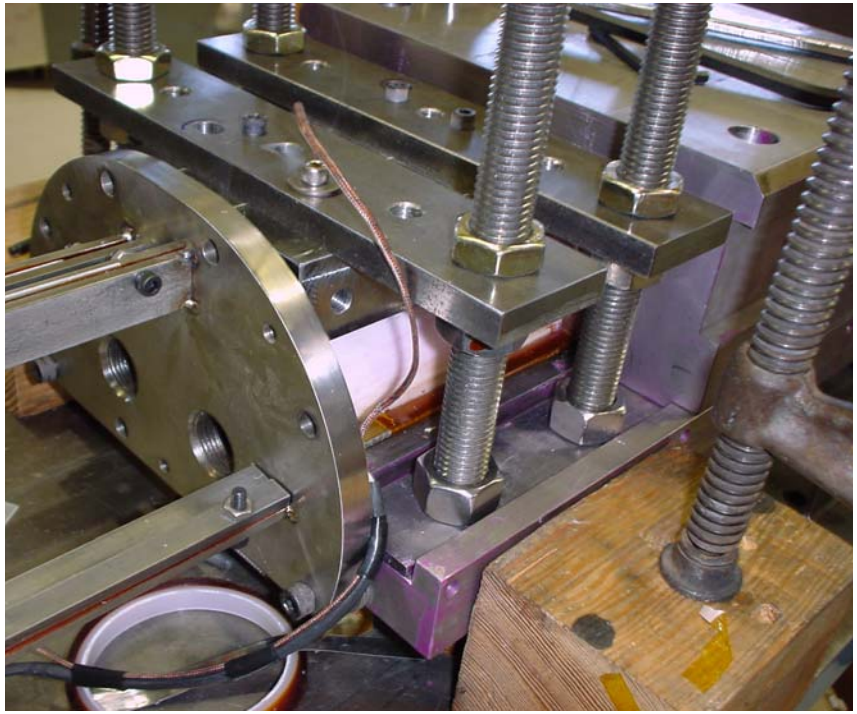
Coil Traces – voltage taps and sg





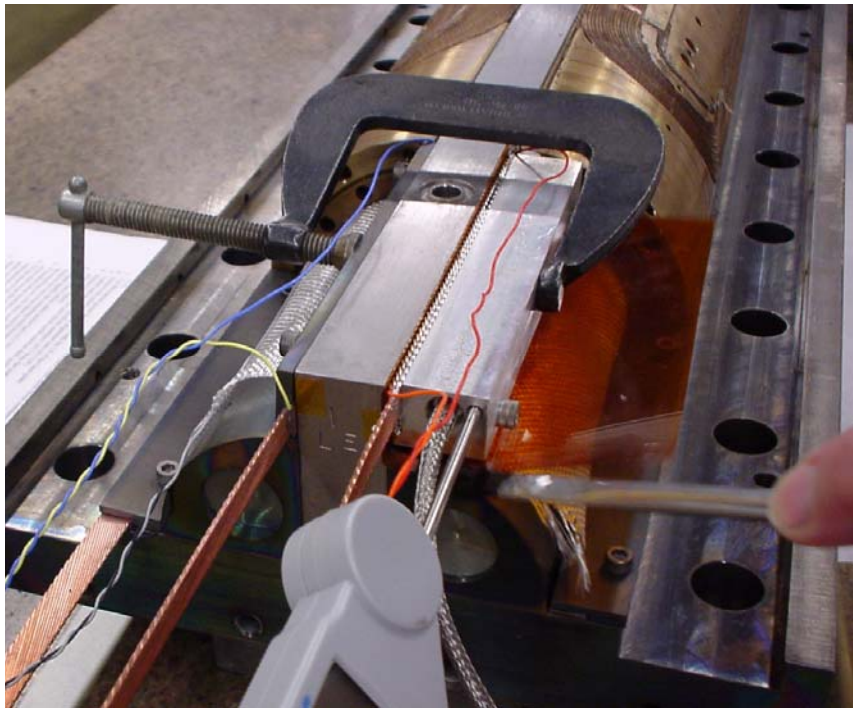
Layer 2 axial and azimuthal strain gauges

NbTi-Nb_3Sn Lead Joint tooling



Original

Improved



Reaction Time and Temperature

Reaction Target

48 h at 210

48 h at 400

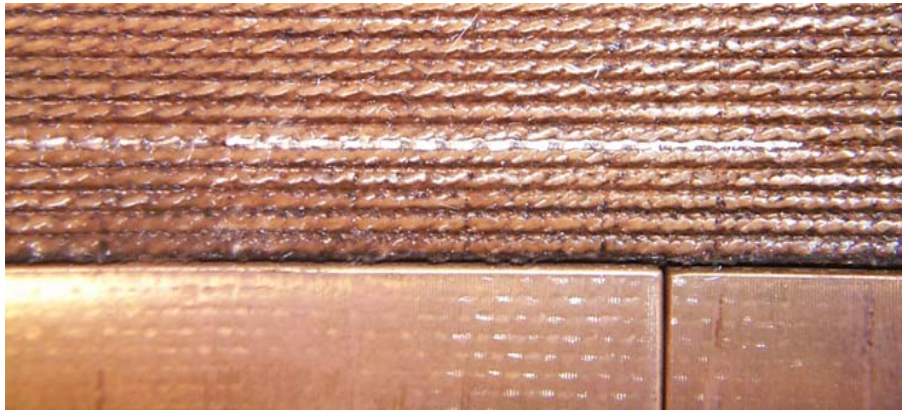
48 h at 645

	SQ02		TQ-PC Coils #2 and #4		TQ-PC Coils #1 and #3	
	Time h	Coil Ave. Temp.	Time h	Coil Ave. Temp.	Time h	Coil Ave. Temp.
Ramp from RT to Step 1	8.5		20		21	
Soak time	47	206.5	37	206	42.5	210
Ramp from 210 to Step 2	5		11		11.5	
Soak time	46	394.5	40.5	395	38	400
Ramp from 400 to Step 3	4		5.5		6.3	
Soak time	47.5	637.5	45	638	44	645

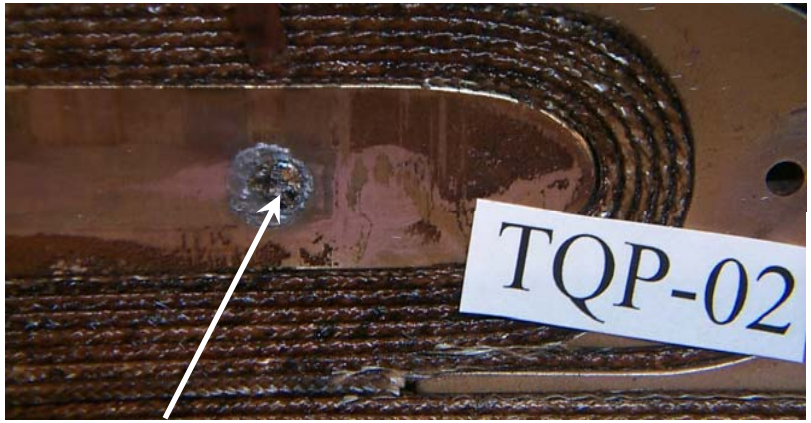
Practice coils #2 and #4

Coils #2 and #4 were reacted and inspected before impregnation

- **Tin leaks observed in coil #2. Possible causes:**
  - ***Known damage in coil #2 during winding***
  - ***HER conductor – used only for practice***
  - ***Heat treatment not optimum***
- **No leaks in coil #4 (or coils #1 and #3)**



Tin leak-layer 2 return end



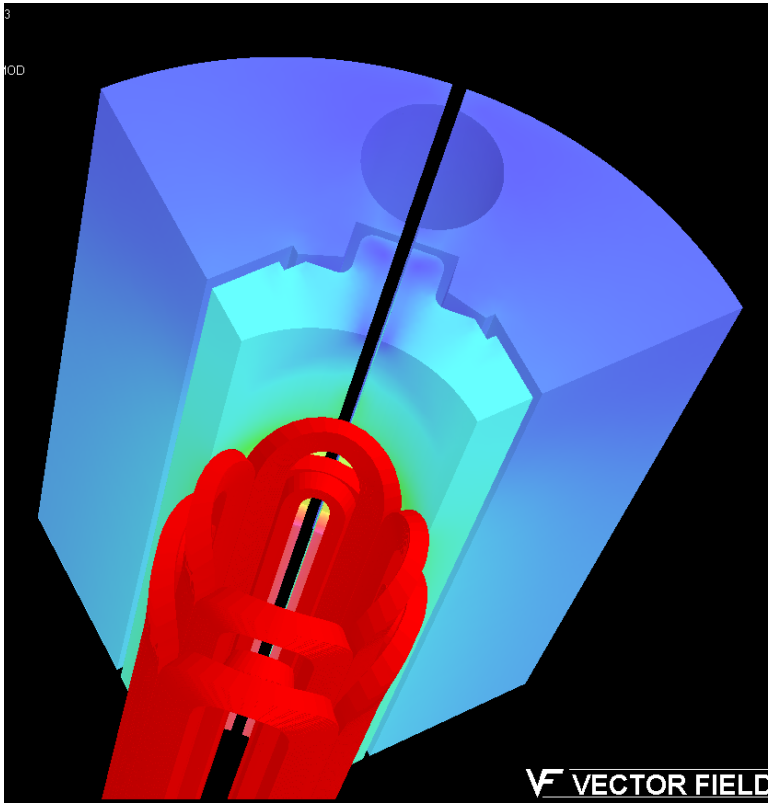
Tin leak-layer 1 lead end

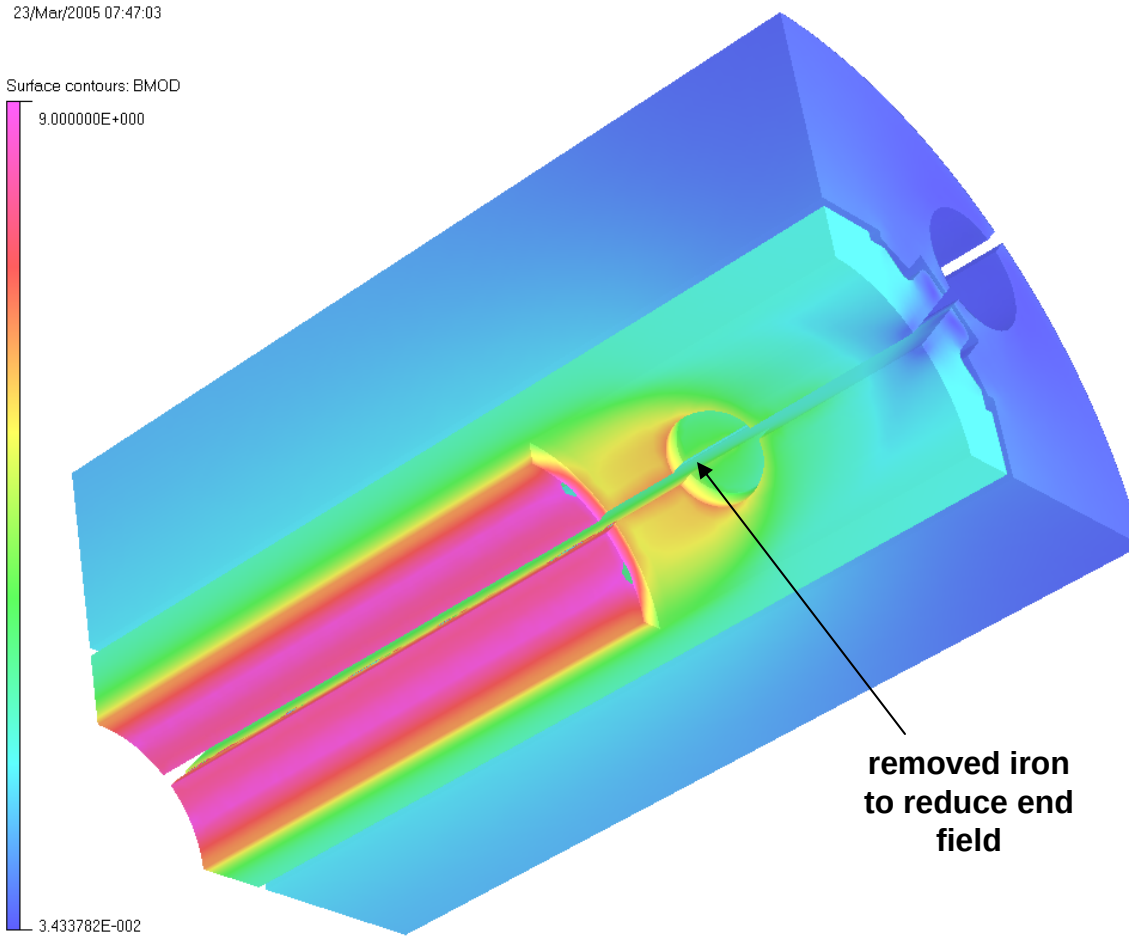
Analysis - details

Magnetic

Structural

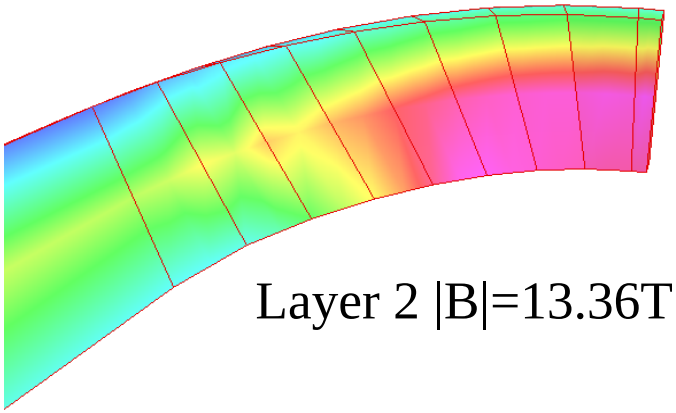
Yoke and modified pads



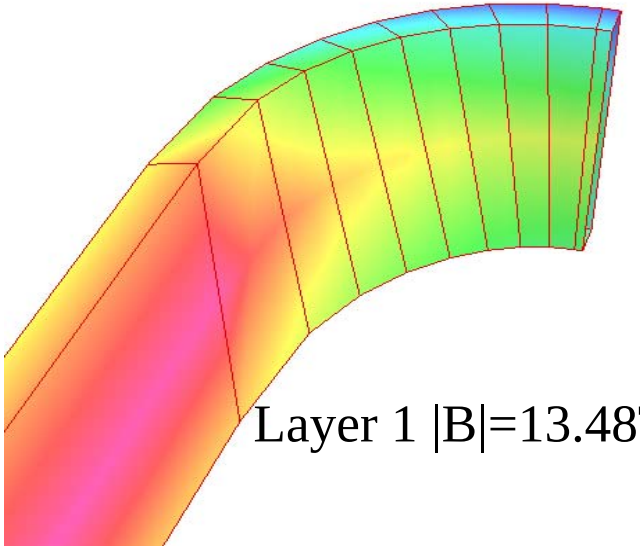


TOSCA

I=15kA



Layer 2 |B|=13.36T END



Layer 1 |B|=13.48T in SS

Maximum field:

Layer 1 - straight section

Layer 2 - end

Structural Analysis - ANSYS

More than 20 different cases analyzed with 3D ANSYS model.

Assembly.

Cool-down.

Lorentz forces 10-15 kA

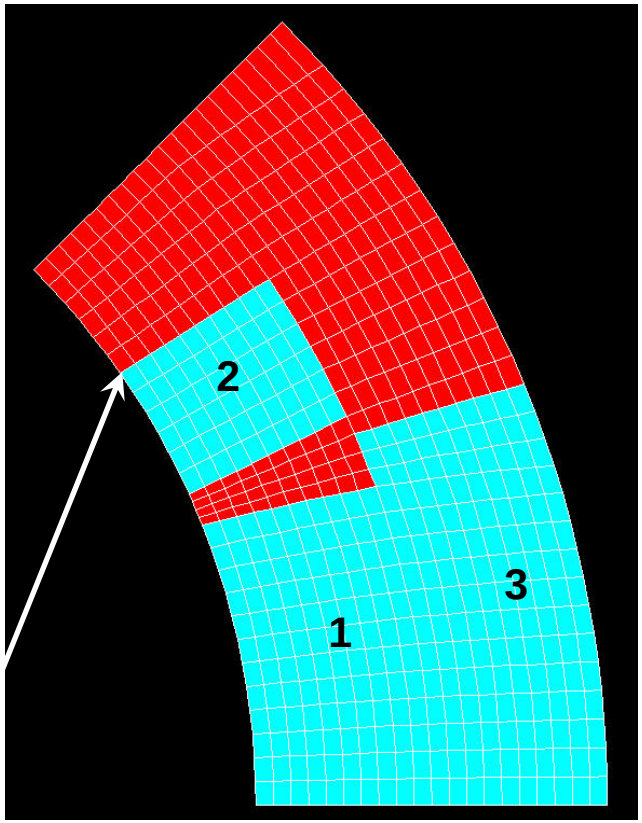
(each run requires ~1.6 Gb of data storage)

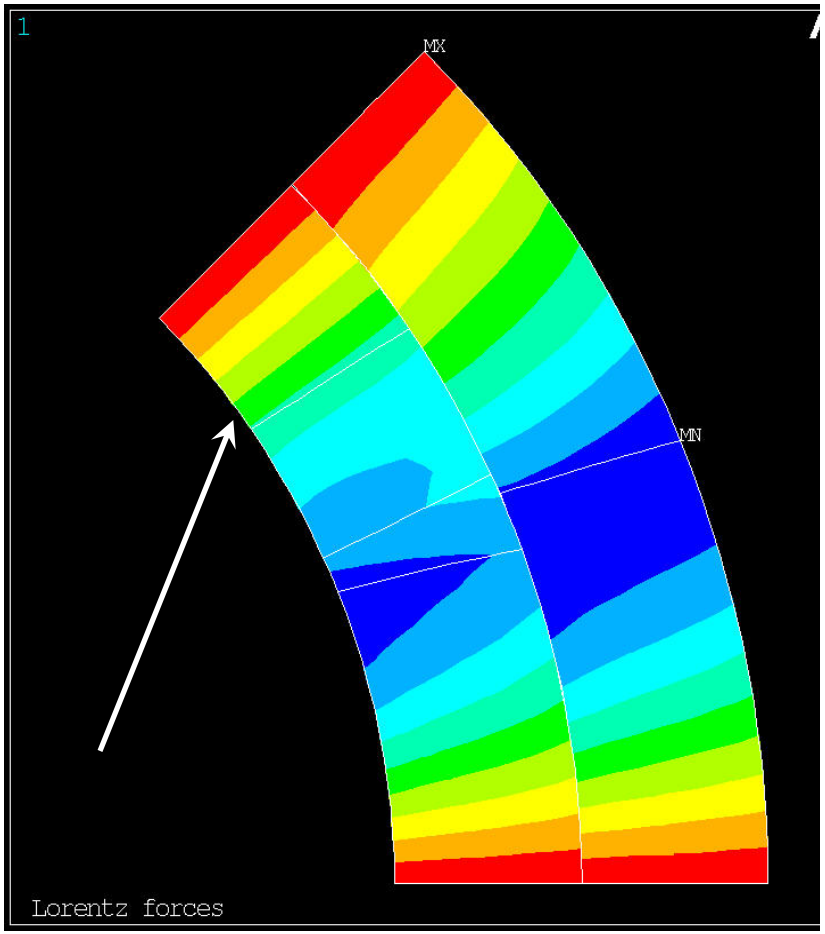
Conditions:

- Different combination of azimuthal and axial pre-stress
- Model with and without friction or glued
- Blocked turns and individual turns
- Past dependence of Lorentz forces (quench simulation)

ANSYS model – straight section

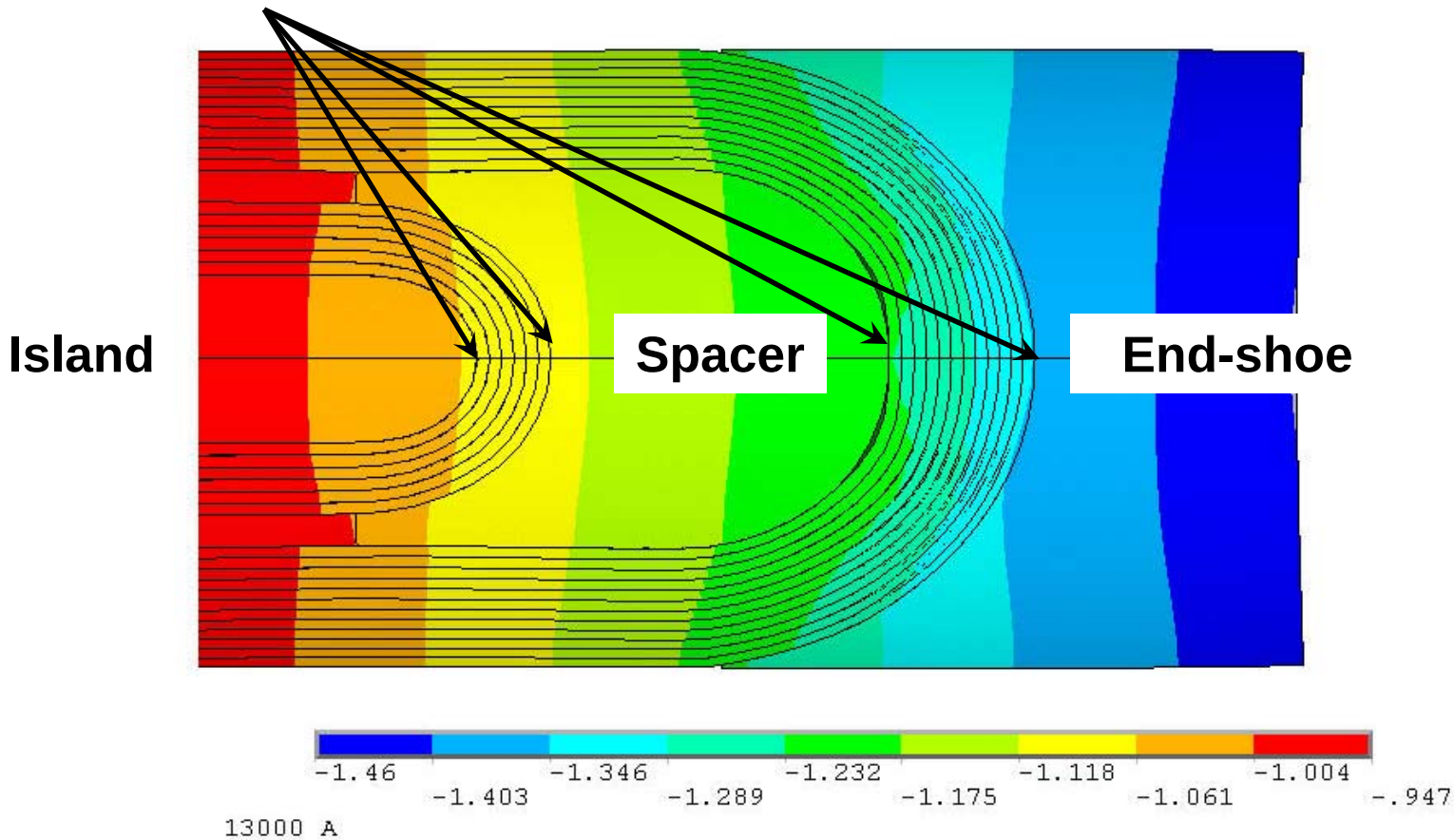
No azimuthal separation at the pole





ANSYS model – coil ends

No axial separation between island, spacer, end-shoe and coil blocks

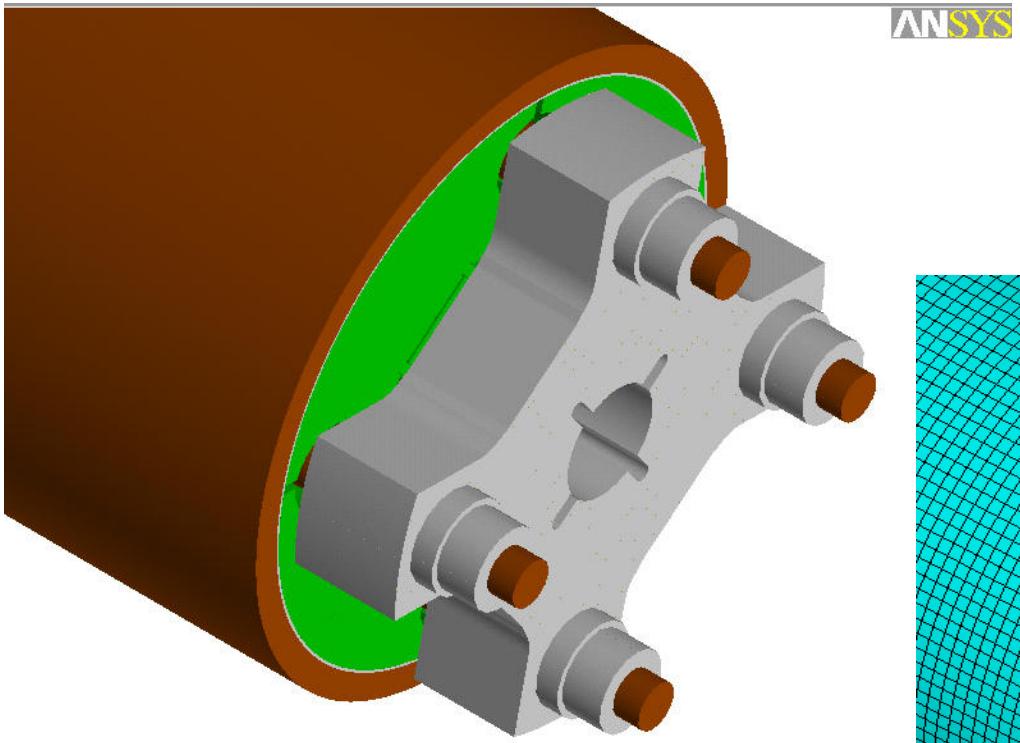


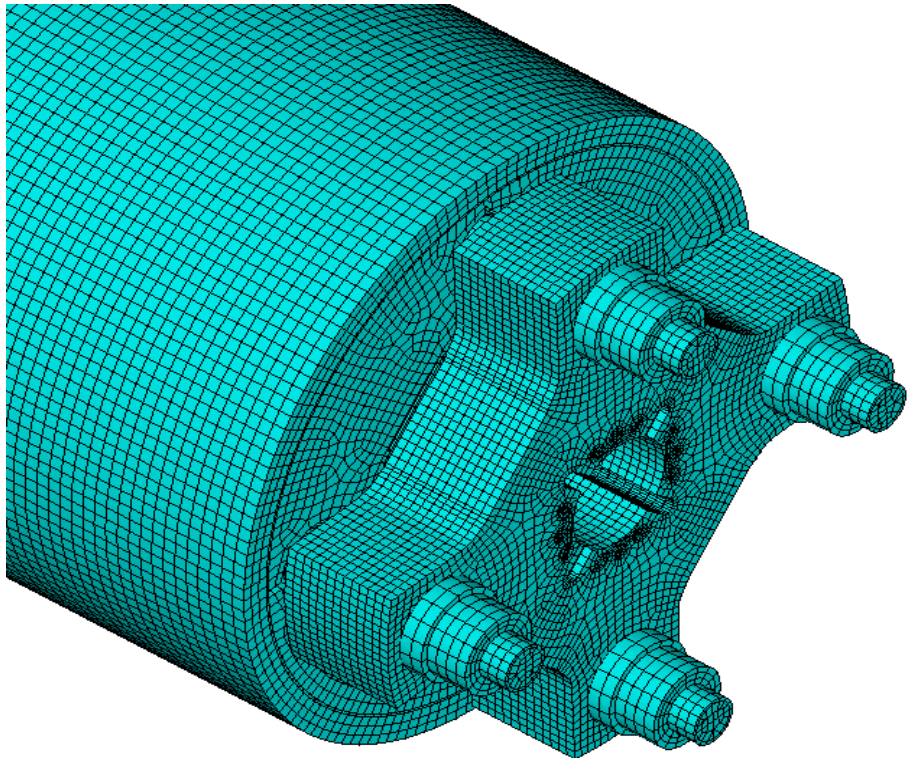
TQS01 – Assembly procedure

- Sub-assemble coils and pads.
- Place sub-assembly into yoke and shell
- Add axial rods and “end-plates”
- Lightly pressurize bladder and insert keys - Shell 5 Mpa
- Pressurize axial piston - Rod 65 MPa
- Pressurize azimuthal bladder to full load – Shell 35 MPa
- Cool-down

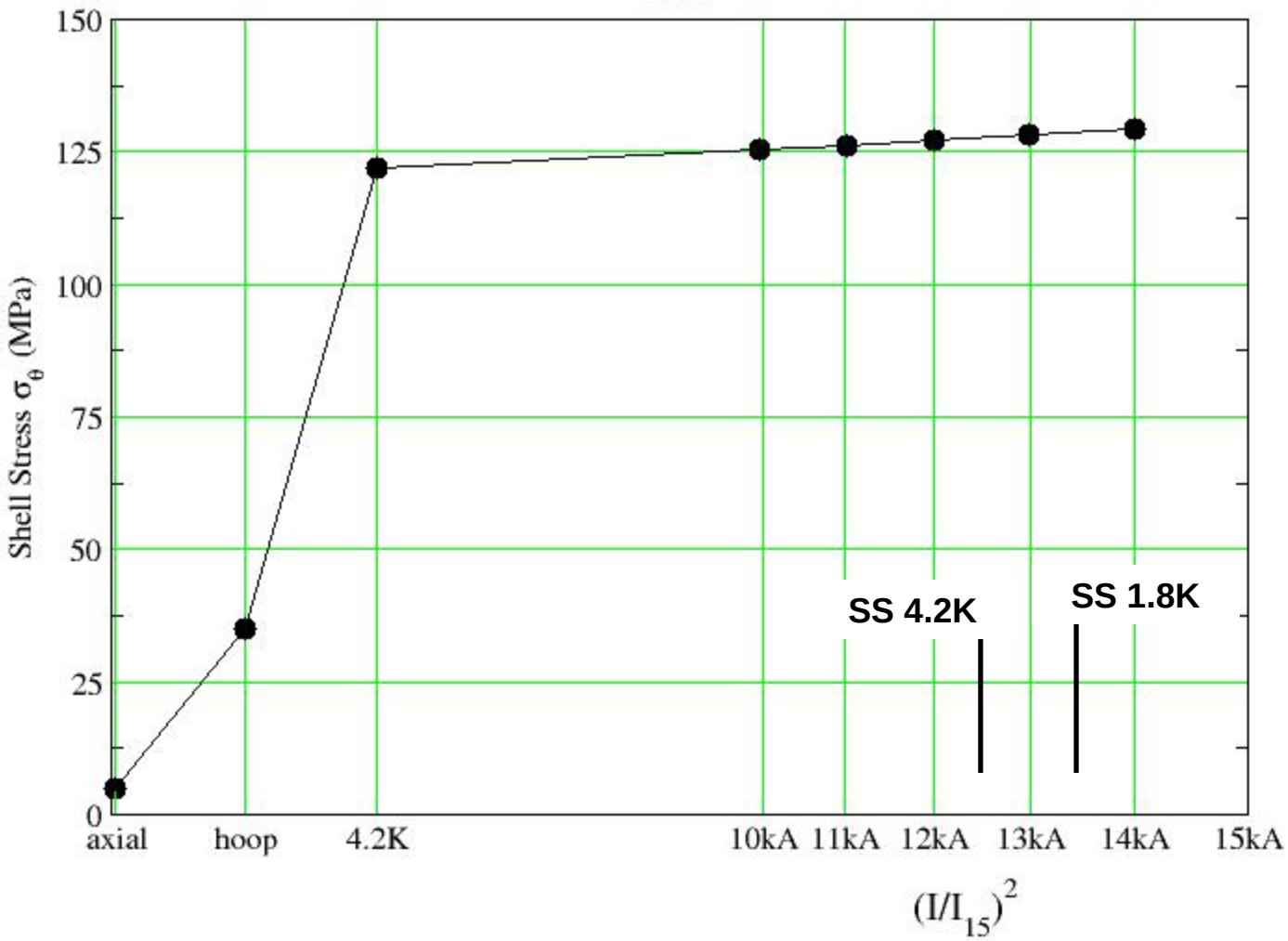
- Coil final (300K) St=-33 MPa, Sz=-23 MPa

3D model

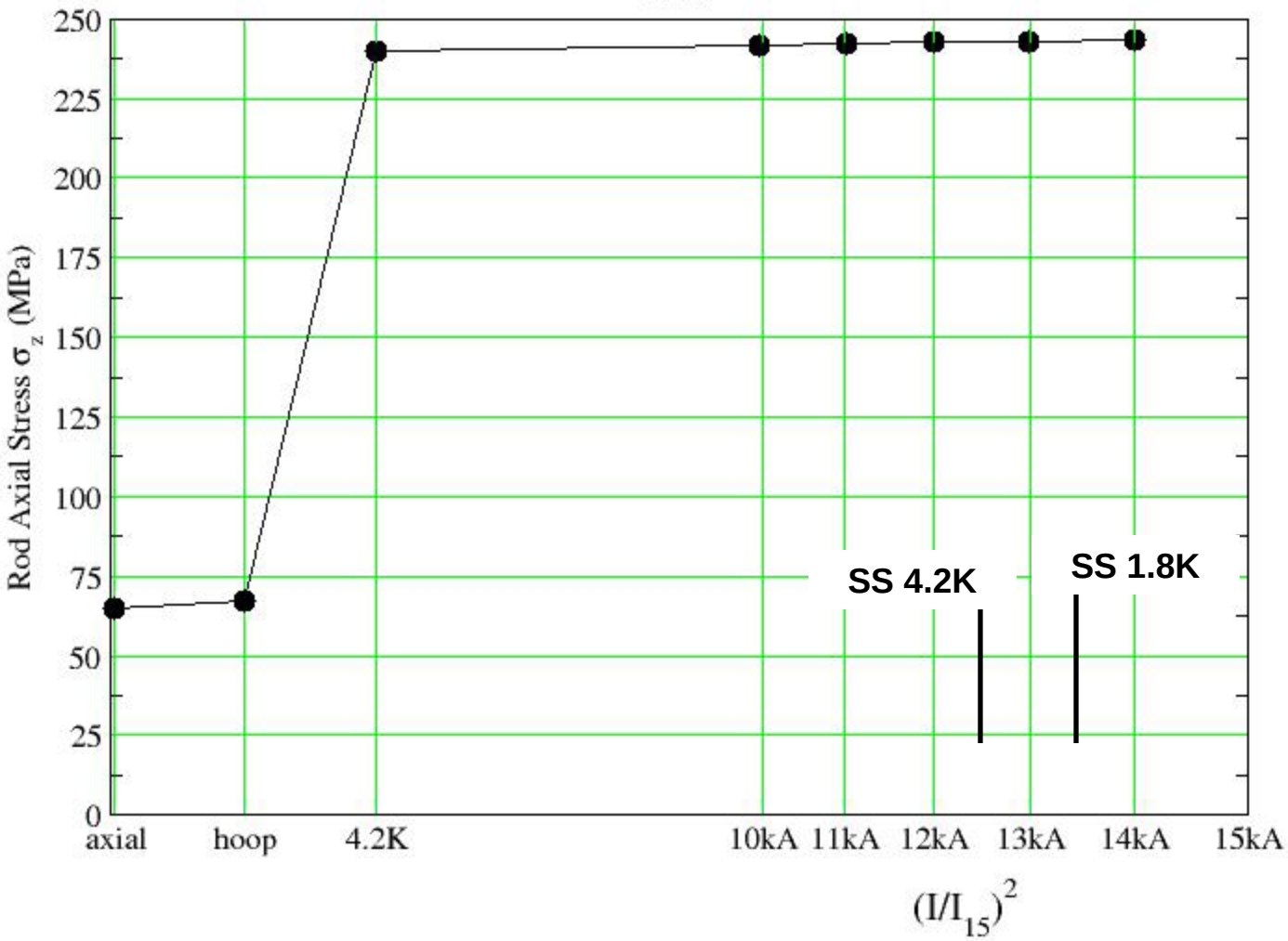




Structure - Shell

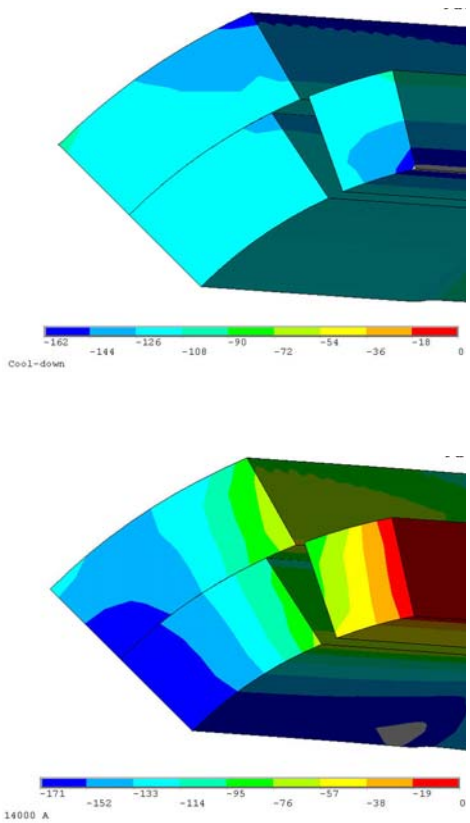


Structure – Axial rods

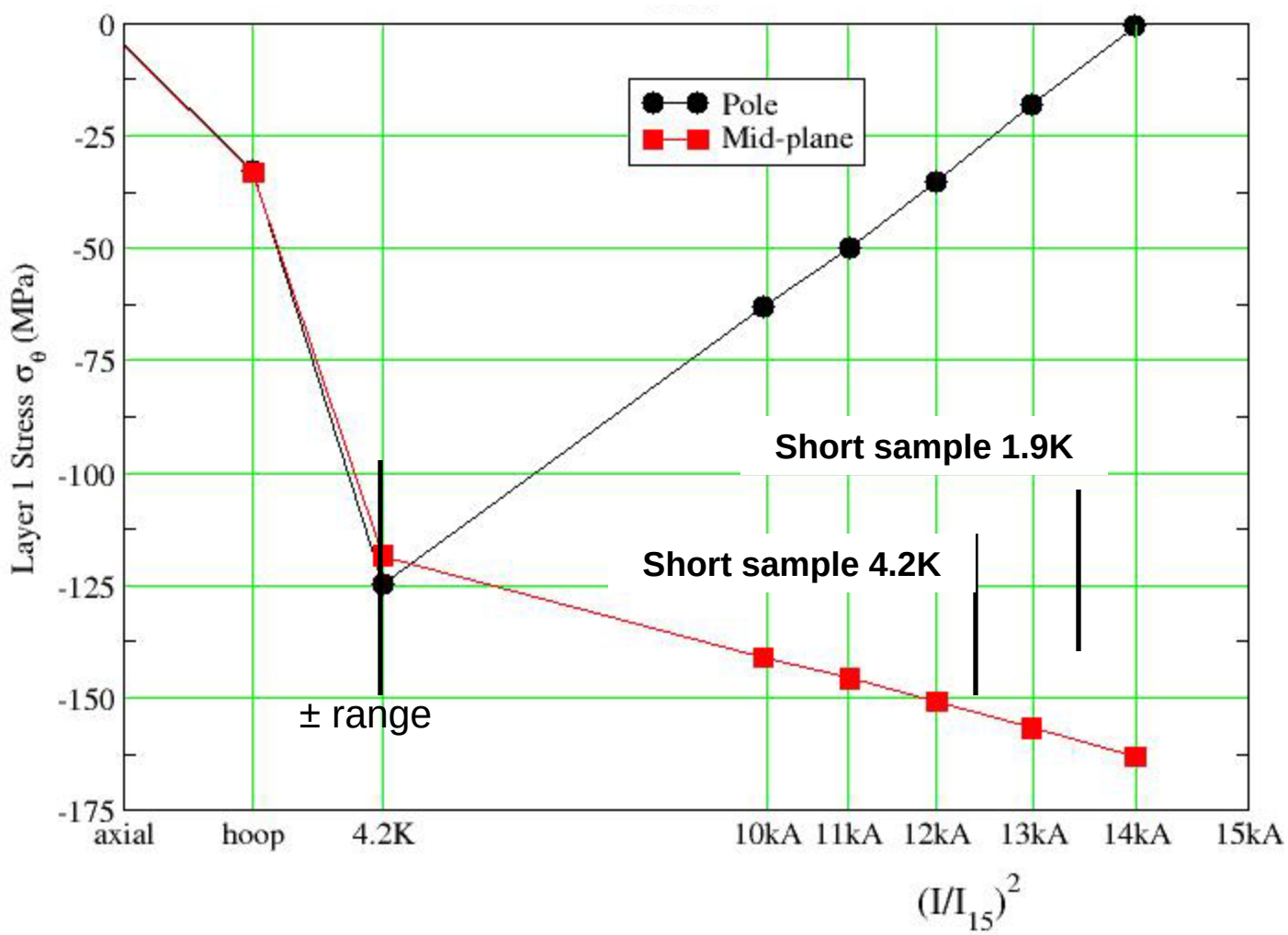


Azimuthal stress in layer 1 (with friction)

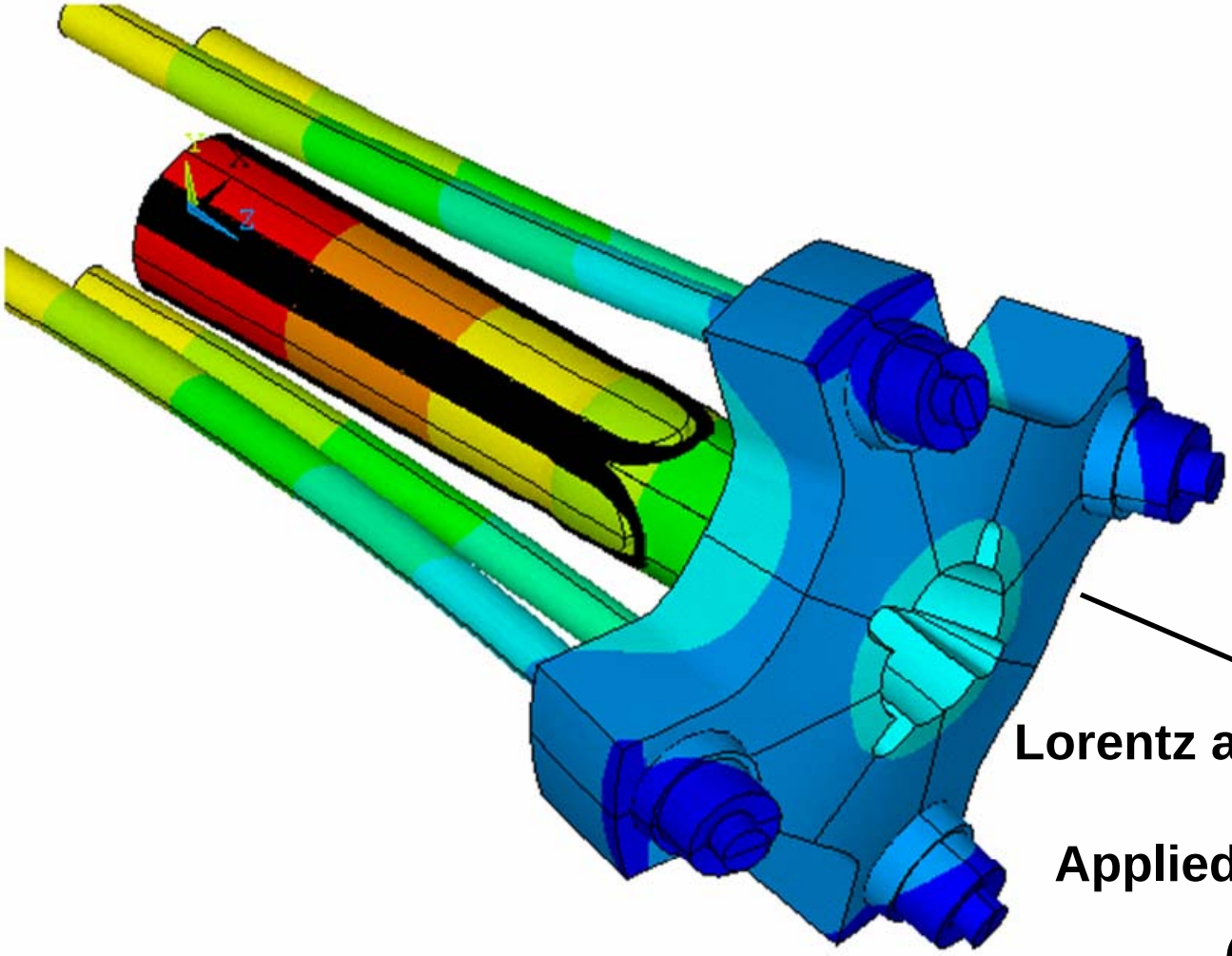
4.2 K



14kA



Axial Lorentz Force

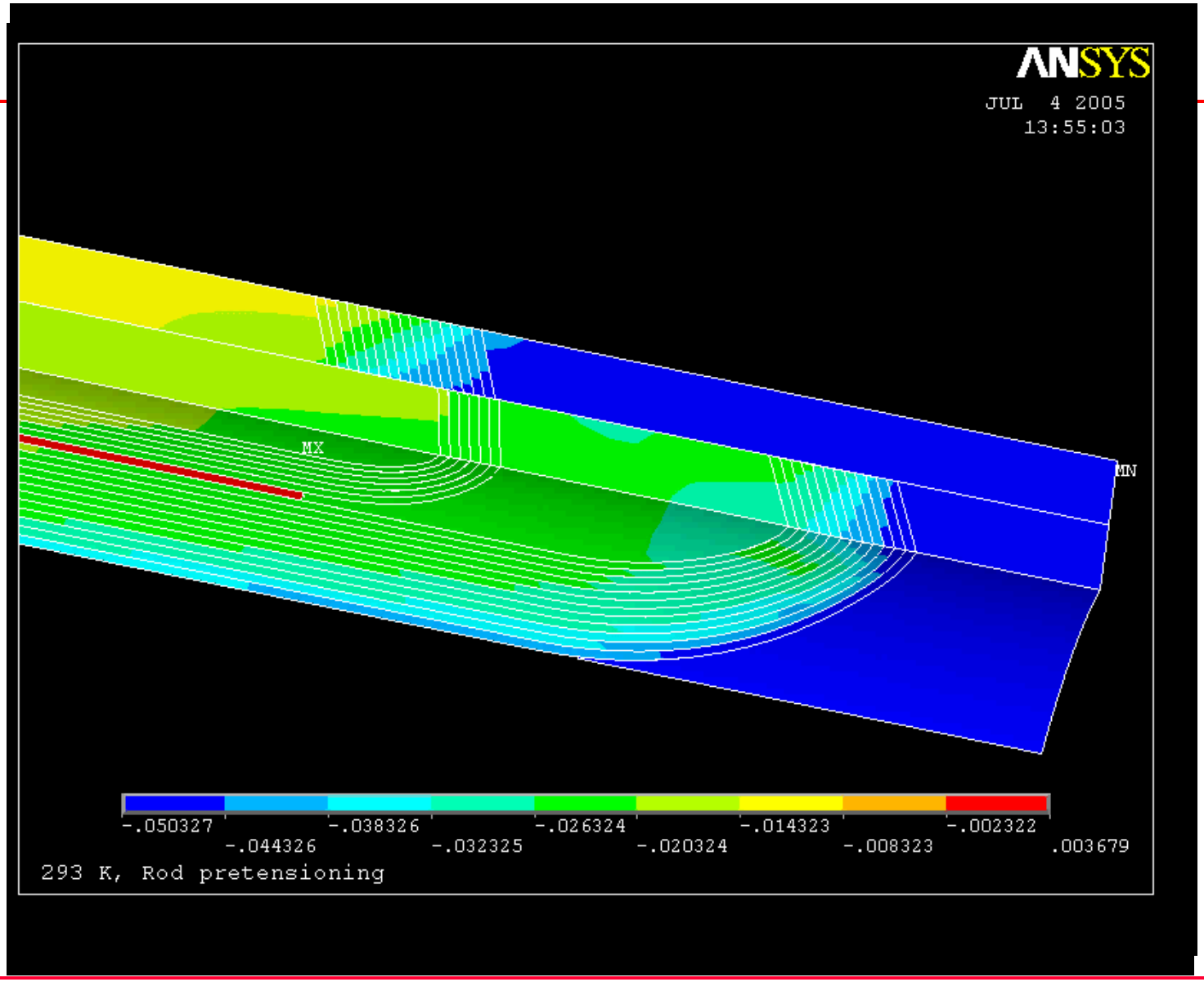


Lorentz axial force 351/413 (kN)

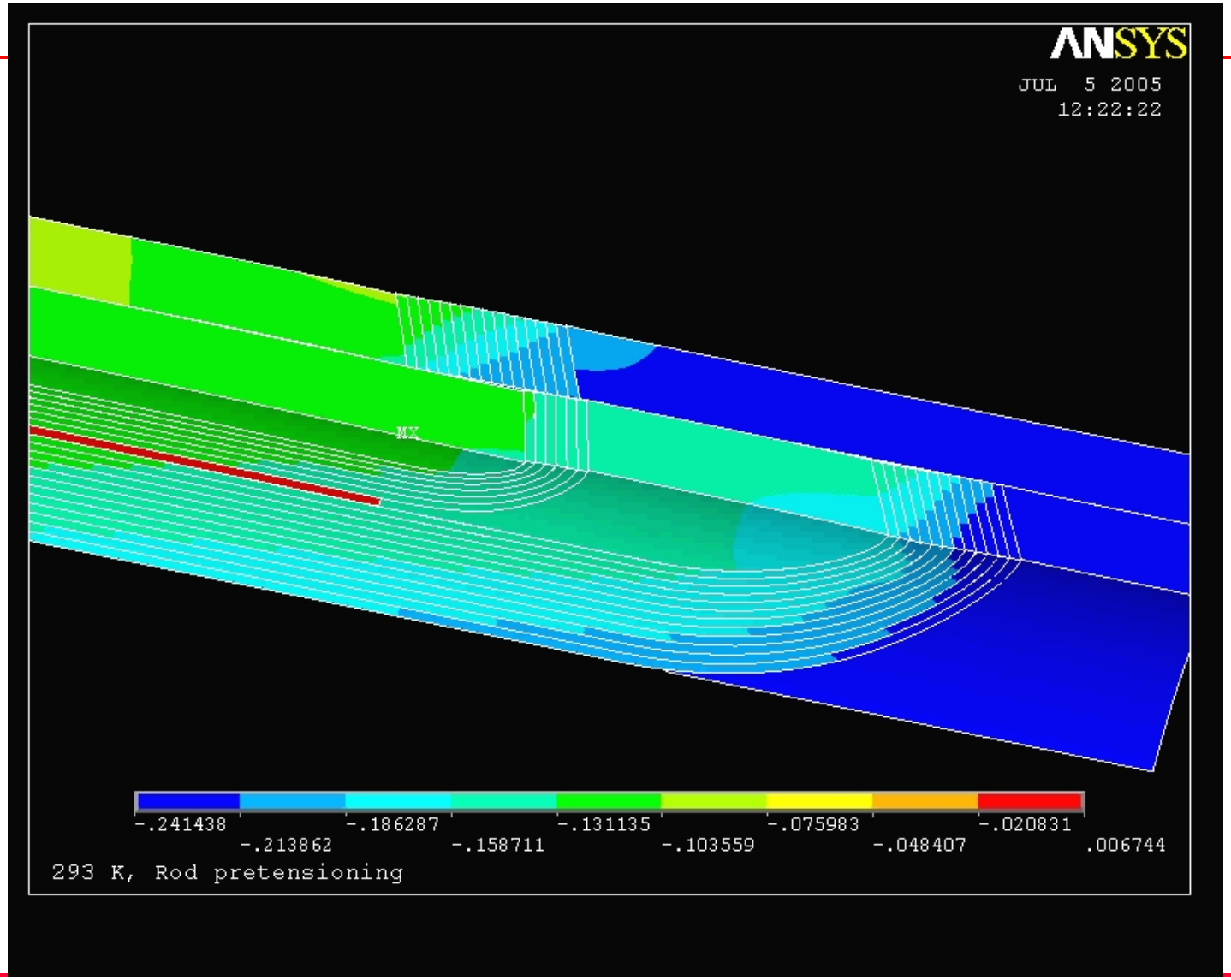
Applied axial force 800 (kN)

(with friction)

0 friction, limited axial load

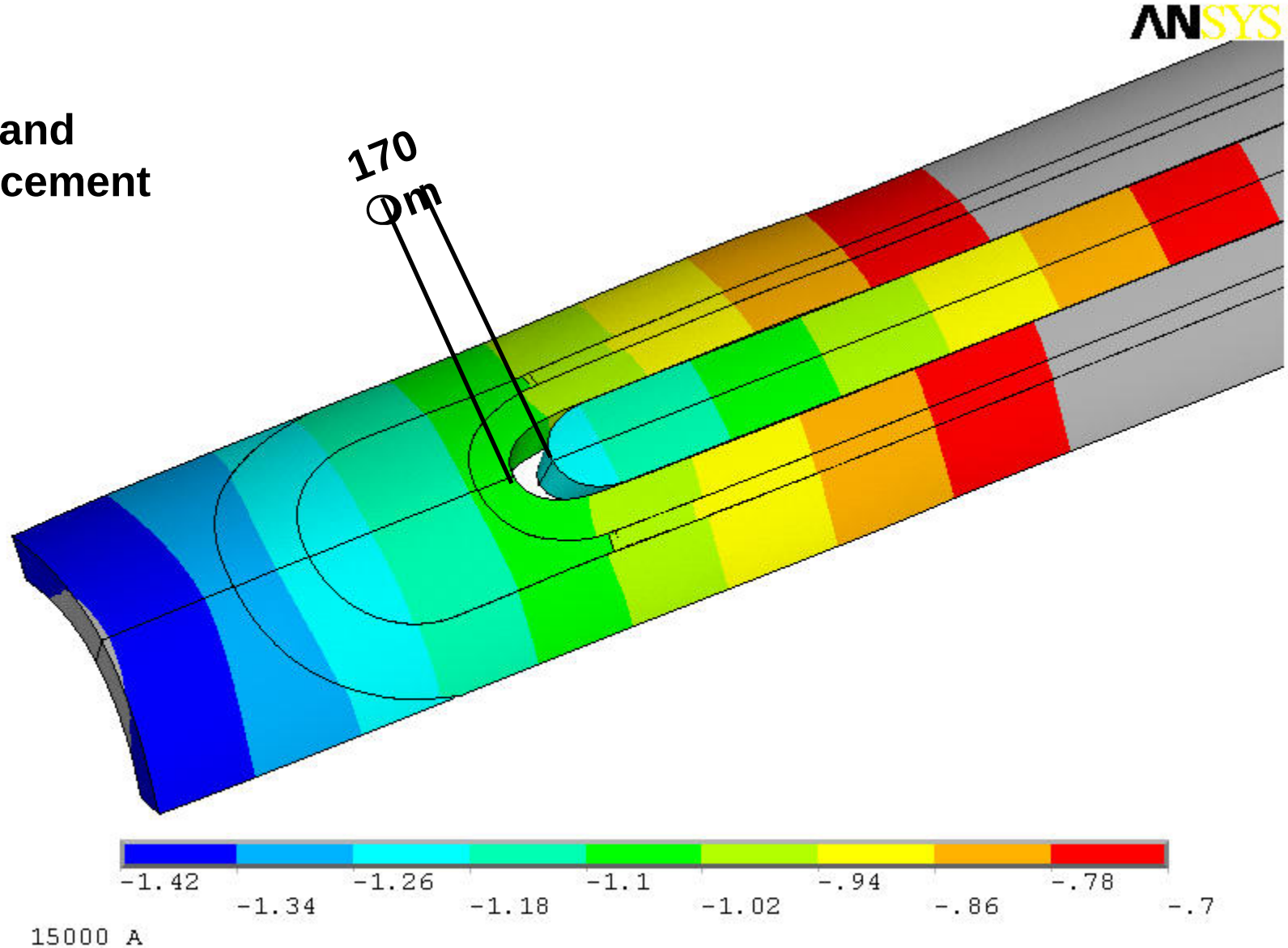


0 friction, Full axial support to short-sample



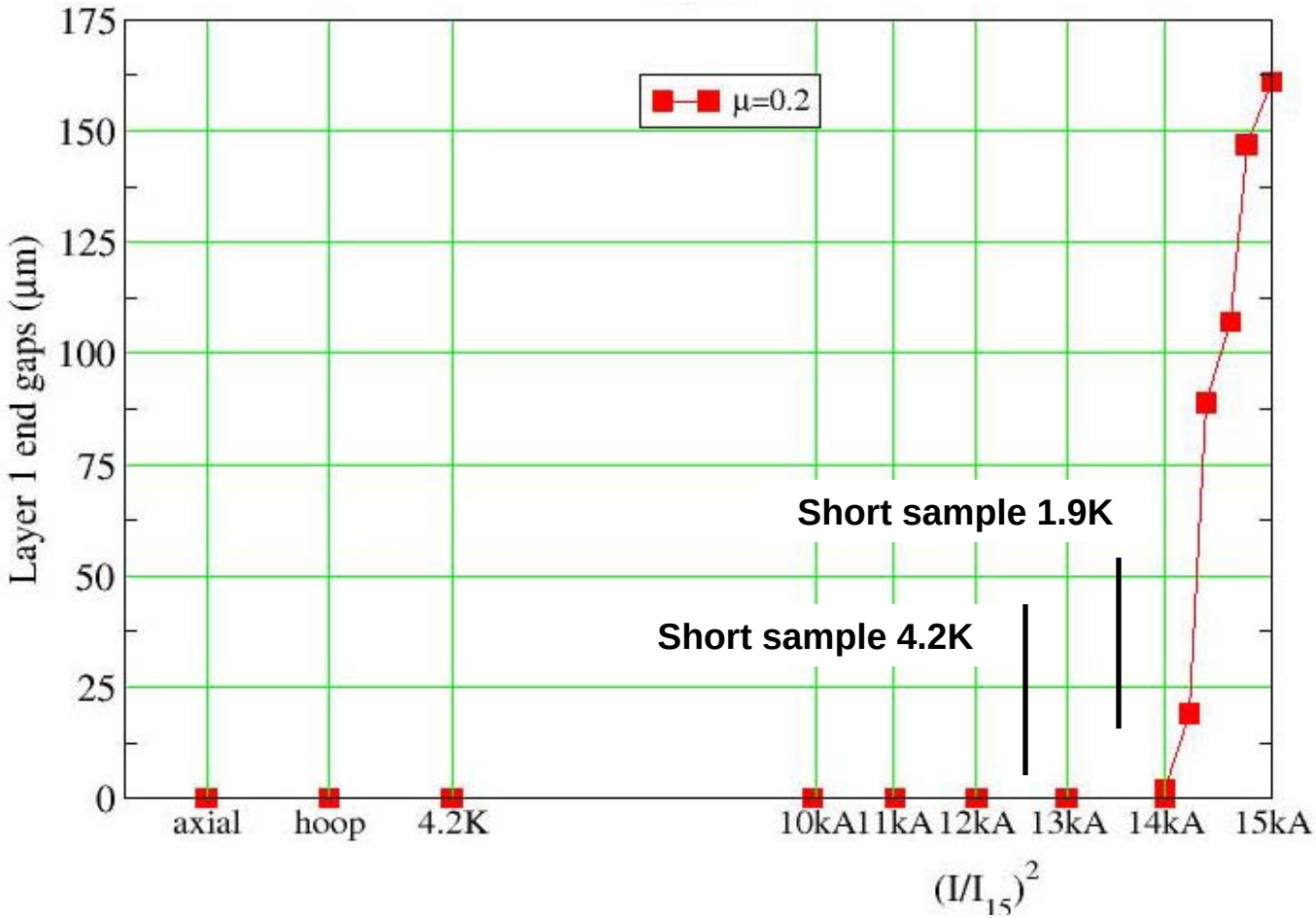
Axial displacement - solid pole (with friction)

Island displacement

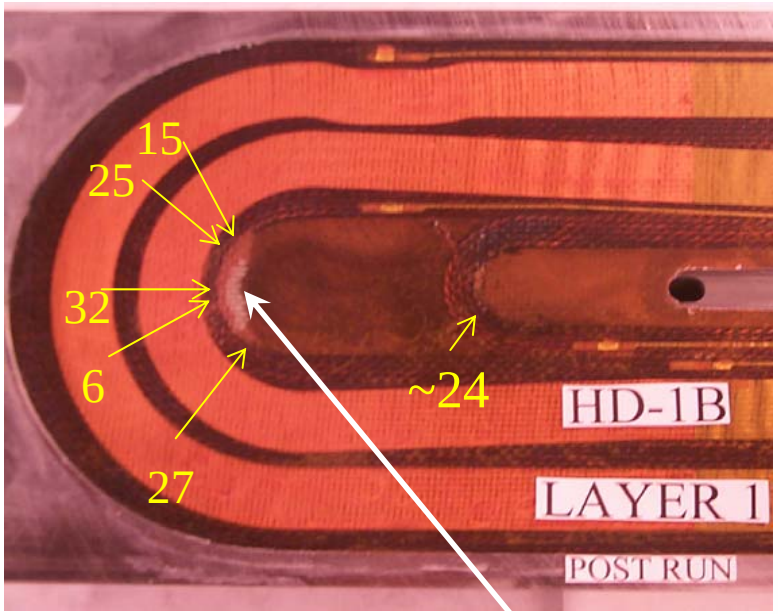


Layer 1 end gaps (0.2 friction)

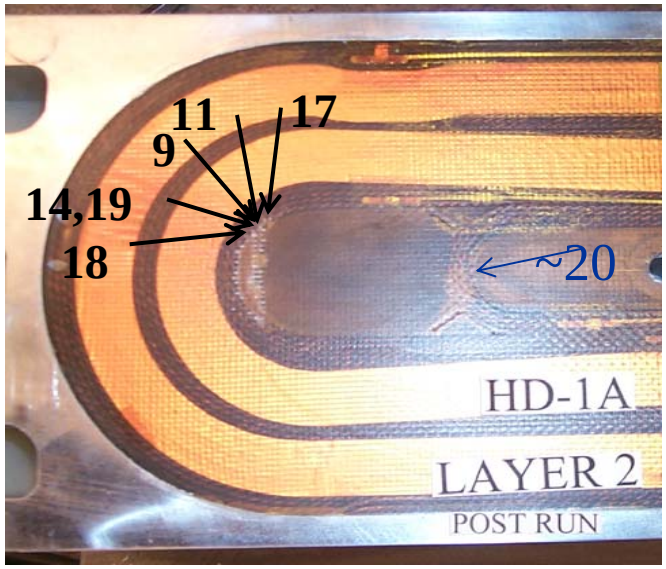
Gap opens as the island slides axially due to azimuthal Lorentz forces

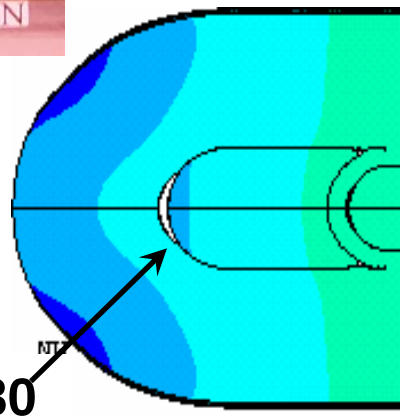


Axial displacements and quench location (Magnet HD1)



Epoxy discoloration





Gap: 80 μm

Summary

- Completed CAD modeling, magnetic and structural analysis.
- TQS01 structure ready – Shell, Yoke, Pads, fillers, axial rods and end-plates.
- Assembly procedure to minimize motion up-to short sample
- Assembly and cool-down using mechanical coils by the end of the 2005.
- Final assembly and test early 2006