HQ Progress and Plan

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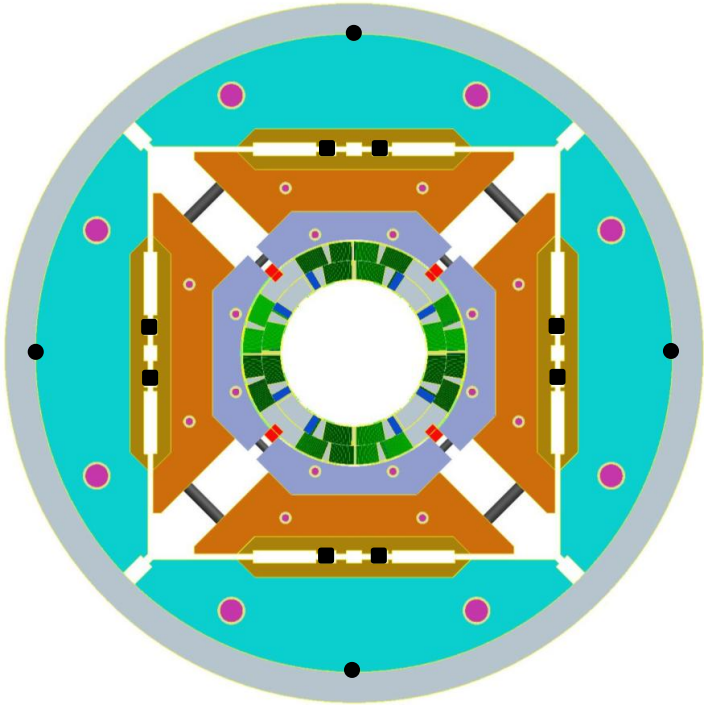
LARP Collaboration Meeting 14

April 26-28 2010

FNAL

OUTLINE

- **Coil Fabrication status and plan**
  - Coil fabrication summary
  - Instrumentation
- **HQ01a Magnet**
  - Characteristics
  - Assembly
  - Cool-down
- **1 meter tests schedule**
- **2 meter extension**

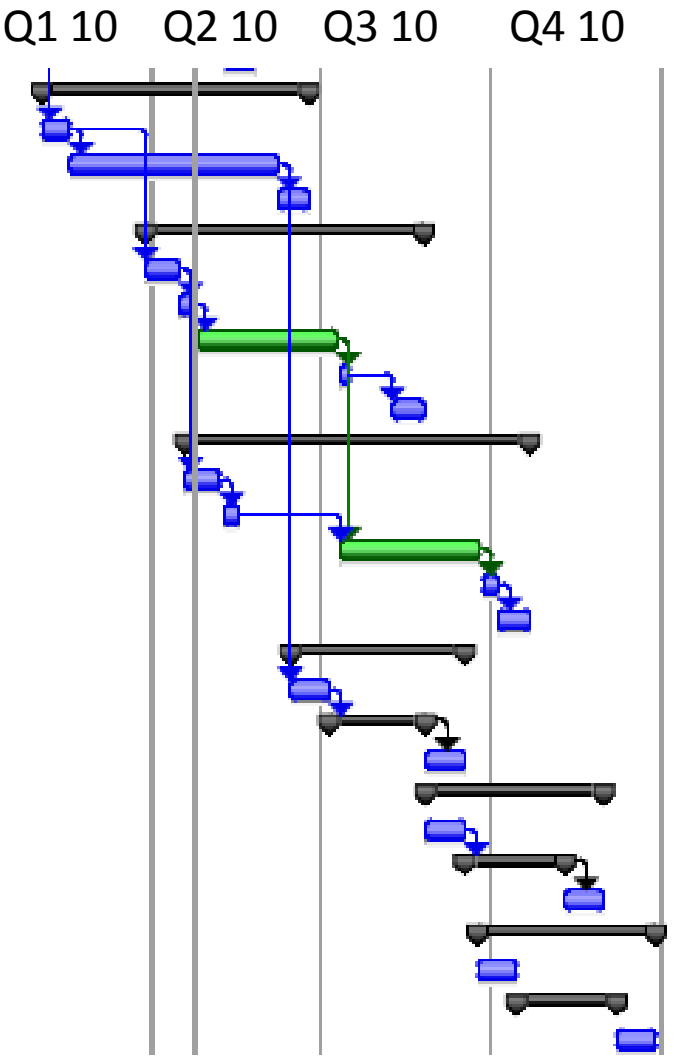


Coil Fabrication Status

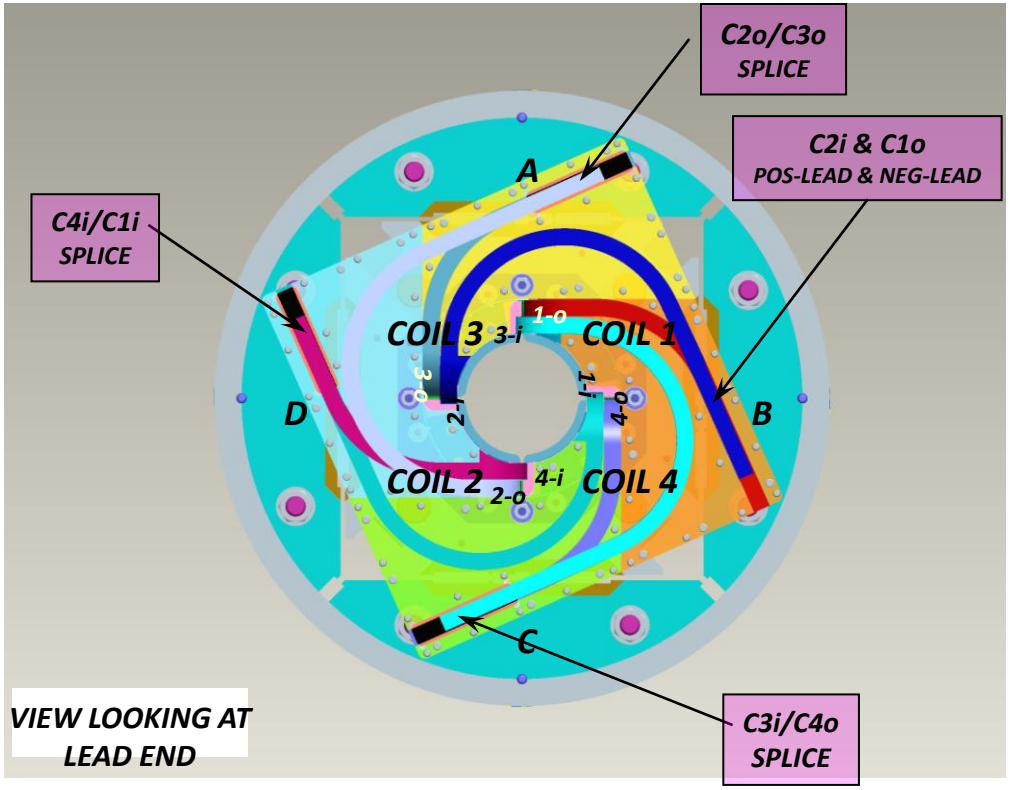
Coil #	Cable number	Strand type	Gap during winding and curing	L1/L2 pinning	Reaction Potting	Status
1	992R	54/61	N	Y	LBL	HQ01a
2	992R	54/61	N	Y	BNL	HQ01a
3	991R	108/127	Y	Y	LBL	HQ01a
4	1000R	108/127	Y	Y	BNL	HQ01a
5	1000R	108/127	Y	N	BNL	instrumented
6	1000R	108/127	Y	Y	BNL	potted
7	1000R	108/127	Y	Y	LBL	reacted
8	996R	54/61	Y	Y	BNL	wound and shipped
9	996R	54/61			BNL	winding prep
10	996R	54/61			LBL	
11		108/127 Ti dopped			LBL	
12		54/61 Ta dopped 1 pass			LBL	

FY10 coil fabrication schedule

Coil 7	**Mon 2/1/10**	**Thu 6/24/10**	**104 days?**
Coil 7 Wind/Cure	Mon 2/1/10	Mon 2/15/10	11 days?
Coil 7 React / Impreg LBL	Tue 2/16/10	Mon 6/7/10	80 days?
Coil 7 Instrum - Elec	Tue 6/8/10	Thu 6/24/10	13 days?
Coil 8	**Mon 3/29/10**	**Wed 8/25/10**	**108 days?**
Coil 8 Wind/Cure	Mon 3/29/10	Thu 4/15/10	14 days?
Coil 8 Shipping to BNL	Fri 4/16/10	Fri 4/23/10	6 days?
Coil 8 React / Impreg /Instrum BNL	Mon 4/26/10	Fri 7/9/10	55 days
Coil 8 shipping to LBL	Mon 7/12/10	Fri 7/16/10	5 days
Coil 8 Instrum - Elec	Mon 8/9/10	Wed 8/25/10	13 days
Coil 9	**Mon 4/19/10**	**Thu 10/21/10**	**134 days?**
Coil 9 Wind/Cure	Mon 4/19/10	Fri 5/7/10	15 days?
Coil 9 Shipping to BNL	Mon 5/10/10	Mon 5/17/10	6 days?
Coil 9 React / Impreg / Instrum BNL	Mon 7/12/10	Fri 9/24/10	55 days?
Coil 9 Shipping to LBL	Mon 9/27/10	Mon 10/4/10	6 days
Coil 9 Instrum - Elec	Tue 10/5/10	Thu 10/21/10	13 days?
Coil 10	**Tue 6/15/10**	**Thu 9/16/10**	**68 days?**
Coil 10 Wind/Cure	Tue 6/15/10	Mon 7/5/10	15 days?
Coil 10 React / Impreg LBL	**Tue 7/6/10**	**Thu 8/26/10**	**38 days?**
Coil 10 Instrum - Elec	Fri 8/27/10	Thu 9/16/10	15 days?
Coil 11	**Fri 8/27/10**	**Tue 11/30/10**	**68 days?**
Coil 11 Wind / Cure	Fri 8/27/10	Thu 9/16/10	15 days
Coil 11 React / Impreg LBL	**Fri 9/17/10**	**Tue 11/9/10**	**38 days?**
Coil 11 Instrum - Elec	Wed 11/10/10	Tue 11/30/10	15 days?
Coil 12	**Fri 9/24/10**	**Tue 12/28/10**	**68 days?**
Coil 12 Wind / Cure	Fri 9/24/10	Thu 10/14/10	15 days?
Coil 12 React / Impreg LBL	**Fri 10/15/10**	**Tue 12/7/10**	**38 days?**
Coil 12 Instrum - Elec	Wed 12/8/10	Tue 12/28/10	15 days?



HQ01a Magnet parameters



HQ01a:

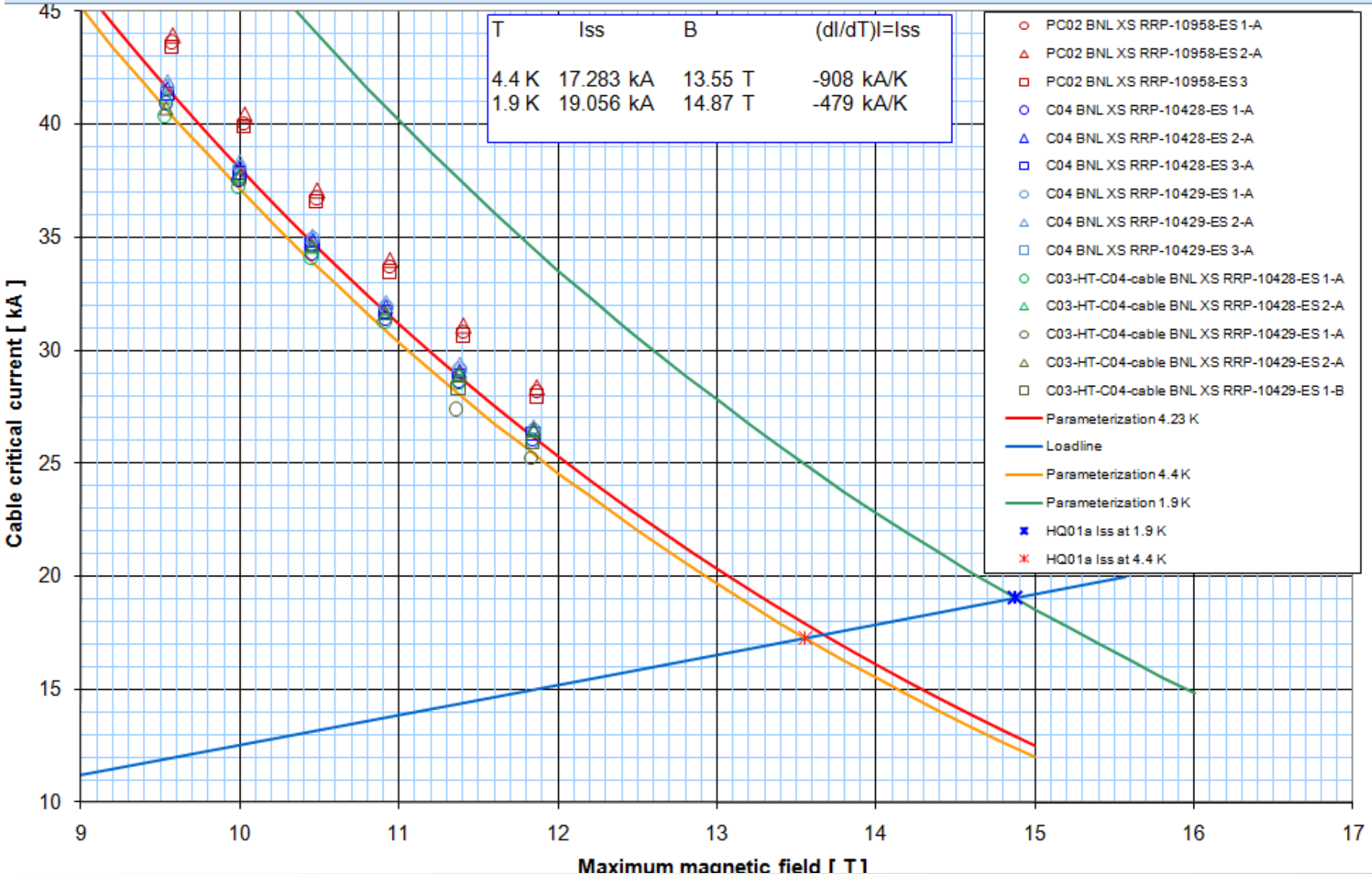
⇒ Coils 1 and 2: 54/61 strand

⇒ Coils 3 and 4: 108/127 strand

⇒ should be the limiting coils
⇒ short sample current computed based on 108/127 witness samples

	4.4 K	1.9 K
Short sample current Iss (kA) (54/61)	17.3 (17.7)	19 (19.5)
Gradient at Iss (T/m) (54/61)	195 (199)	214 (218)
Stored energy (MJ)	0.9	1.1
Inductance (mH)	6	

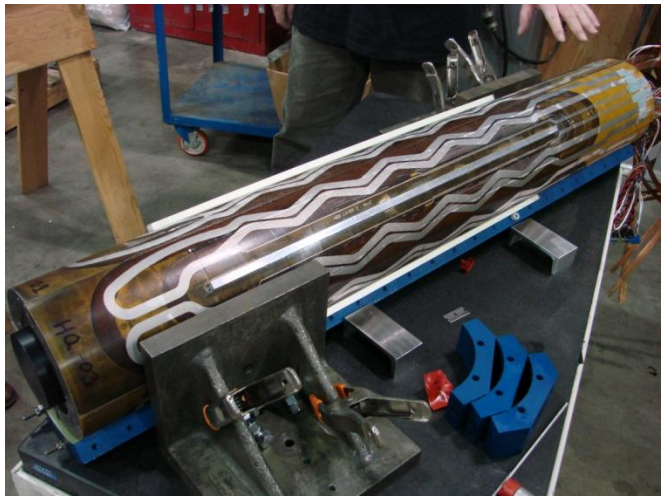
HQ01 Short sample estimate

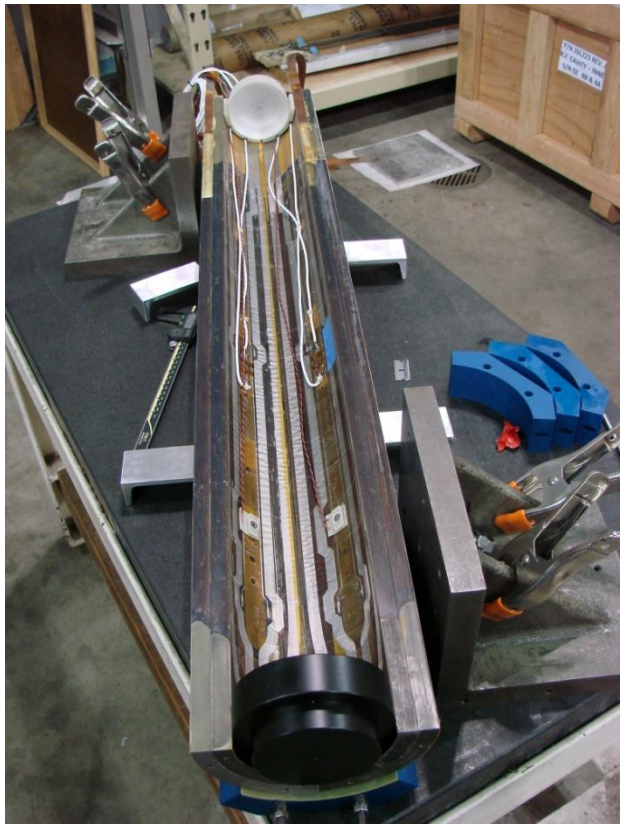


Instrumentation

Instrumentation per coil:

- 20 Vtaps: 10 IL and 10 OL
- 1 SG station measuring θ and Z components located in the center: full bridge T compensated
- 1 spot heater
- 4 strips of protection heaters





Vtaps circuits + protection heaters circuits => trace
SG + spot heaters => wired externally

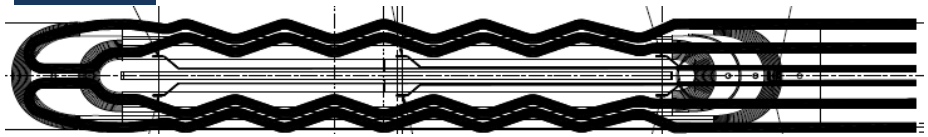
Protection

Protection heaters design:

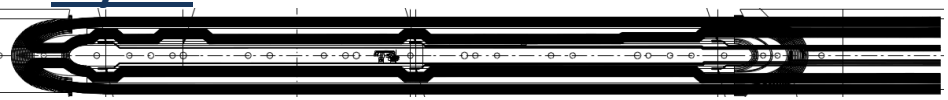
Coverage = 60 %

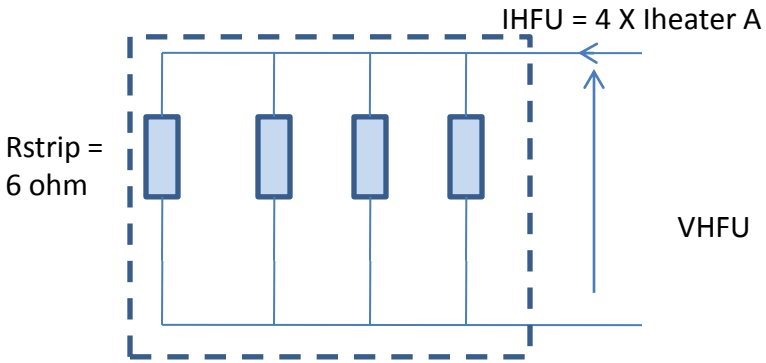
4 strips connected in parallel

Layer 1



Layer 2

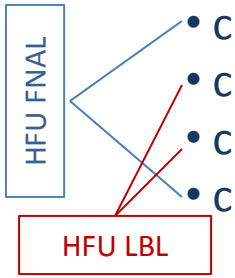




PH circuits based on hipot:

Coil 1 A02: failed 300 K magnet hipot

Coil 1 B01 B02: passed hipot despite short to endshoe



- circuit #1: C1B01 – C1B02 – C2B01 – C3B01 => problematic OL PH belong to the same circuit
- circuit #2: C4B01 – C2B02 – C3B02 => no C4B02 to avoid loosing both heaters C4 OL
- circuit #3: C1A01 – C2A01 – C3A01 – C4A01
- circuit #4: C2A02 – C3A02 – C4A02 – C4B02

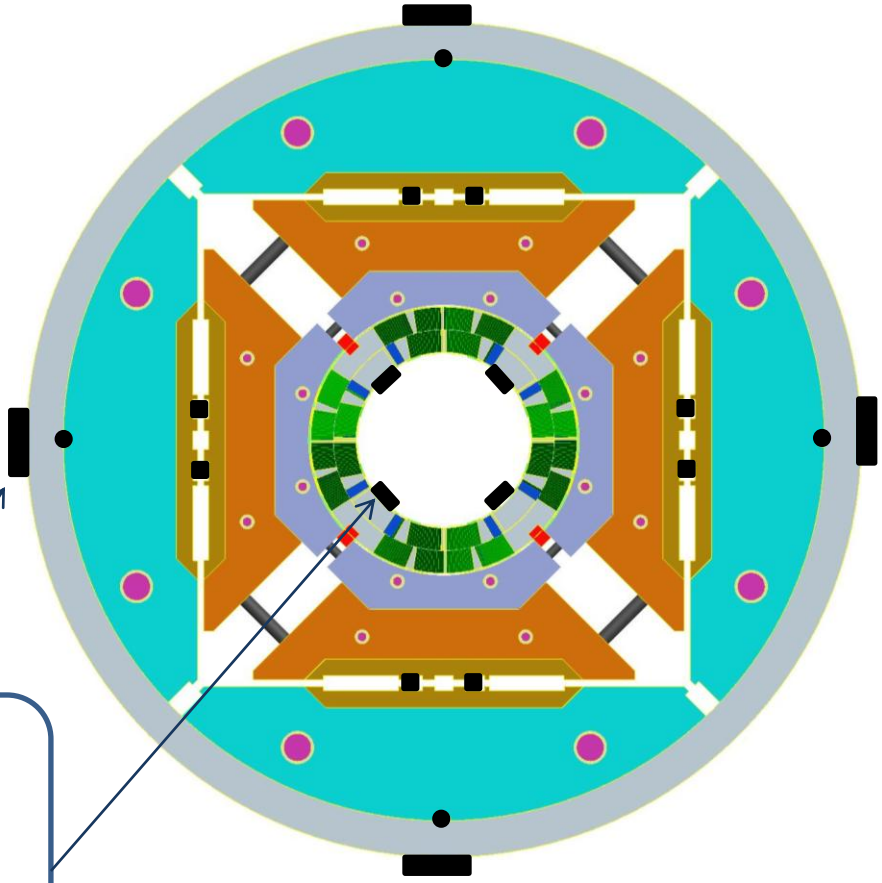
HQ01a Strain gauge station location

Assembly with Al dummy coils

- with Fuji paper

Assembly of HQ01a

- coil pack with Fuji
- azimuthal loading up to half of coil target
- axial loading
- azimuthal loading completion



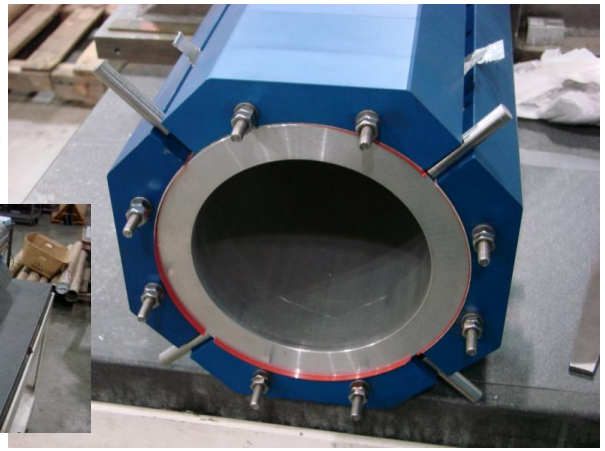
- 4 SG stations on the shell
  - θ and Z
- 1 SG station per coil
  - θ and Z

Dummy Assembly – Coil pack

Collar-pack assembly

	Inches
Dummy coil OD	7.198
G10 nominal shim	0.037
Medium P Fuji	0.004
Shimmed Dummy OD	7.280
Collar ID	7.276

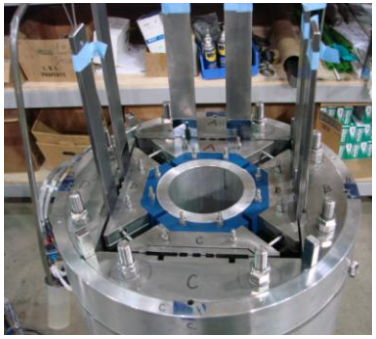
Slot for the key



2 mils radial interference between dummy and shimmed collar
=> ~ 1.5 mils per side of the key
=> ~ 1 mils average measured after torque

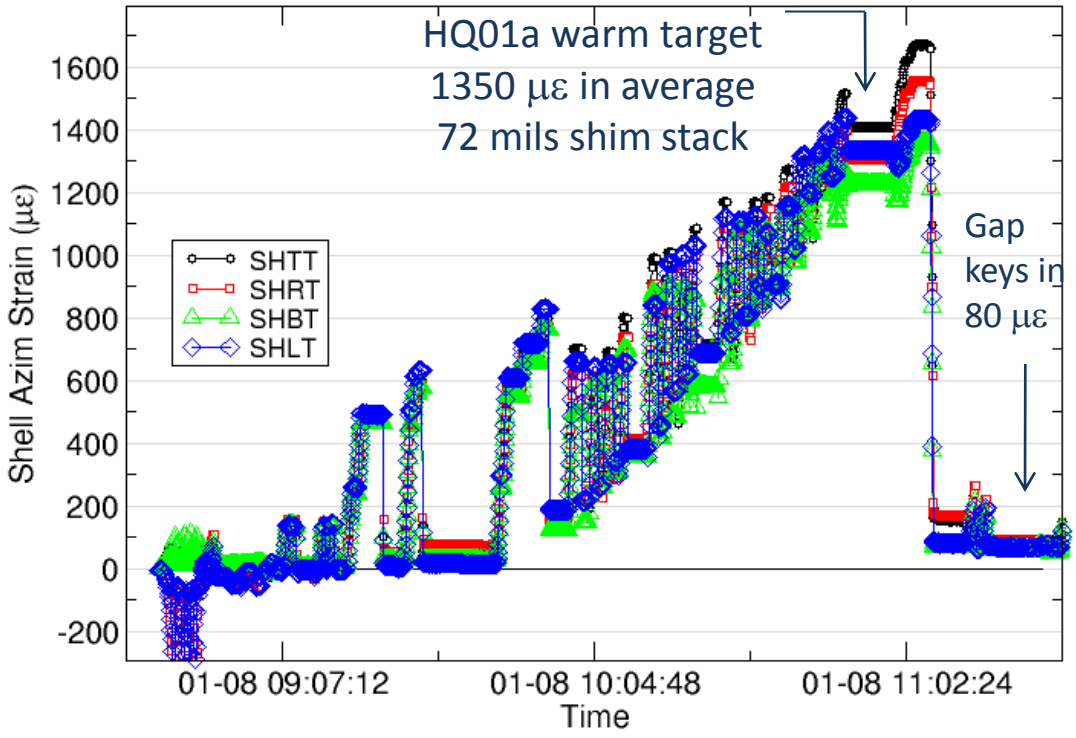
Coil-pack assembly

Insertion in the vertical yoke-shell subassembly



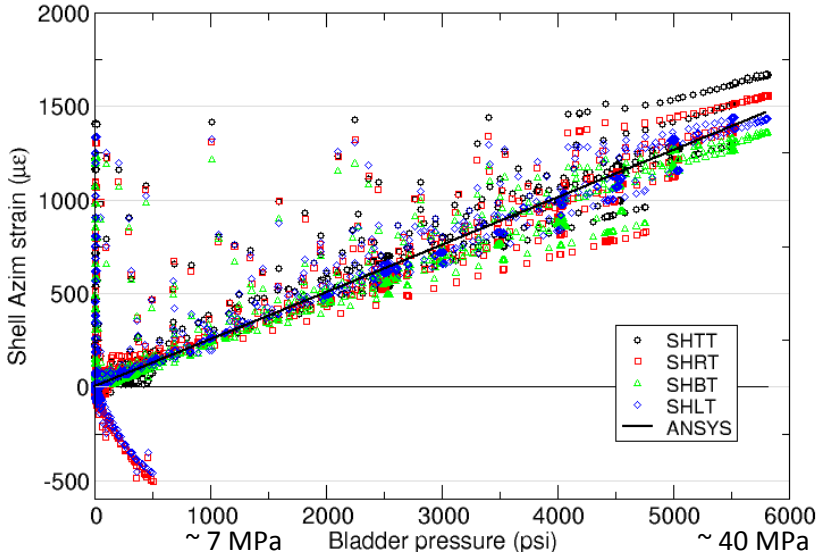
Dummy Assembly

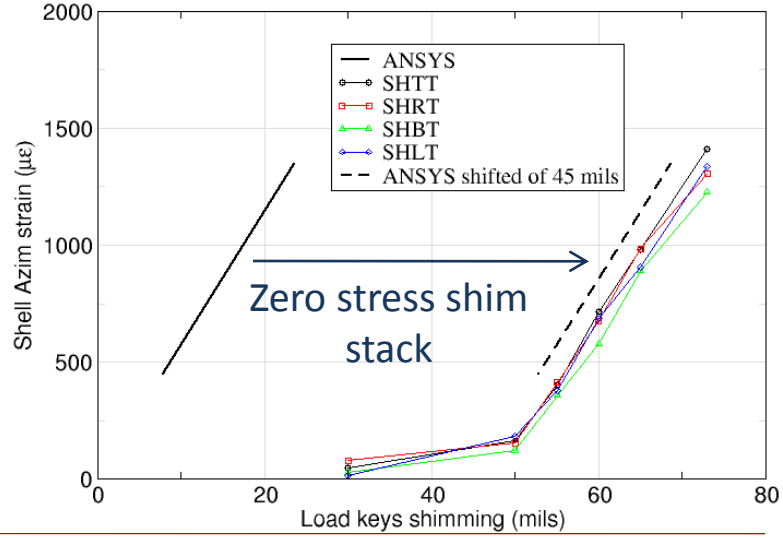
Bladder operation



Fuji paper test shows a good contact between collar and coil during bladder operation

Comparison with ANSYS

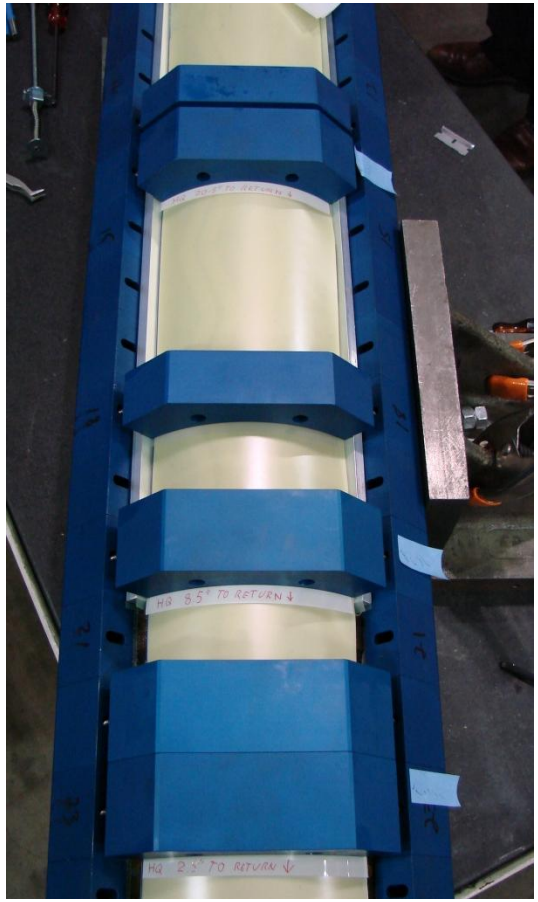


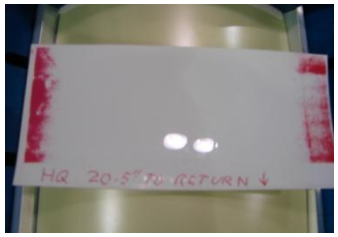


HQ01a – Fuji test I – 3 laminations

Layout	
Coil theoretical OD	7.198”
G10 nom. / Shim stack	0.037” / 0.034”
Mylar shim / Low P Fuji	0.004” / 0.007”
Nom. Shimmed coil OD	7.280”
Collar ID	7.276”

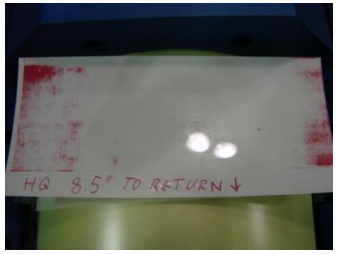
- 41 mils of total shimming
  => 2 mils of radial interference coil/collar
- Pressure pattern similar to LQS01a in the straight section
- In the end: contact at the mid-plane because end part at nominal size

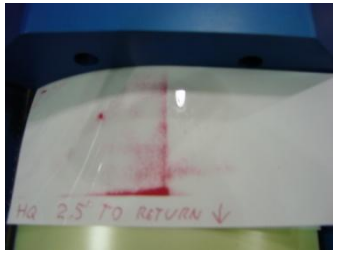




20.5” from RE

8.5” from RE

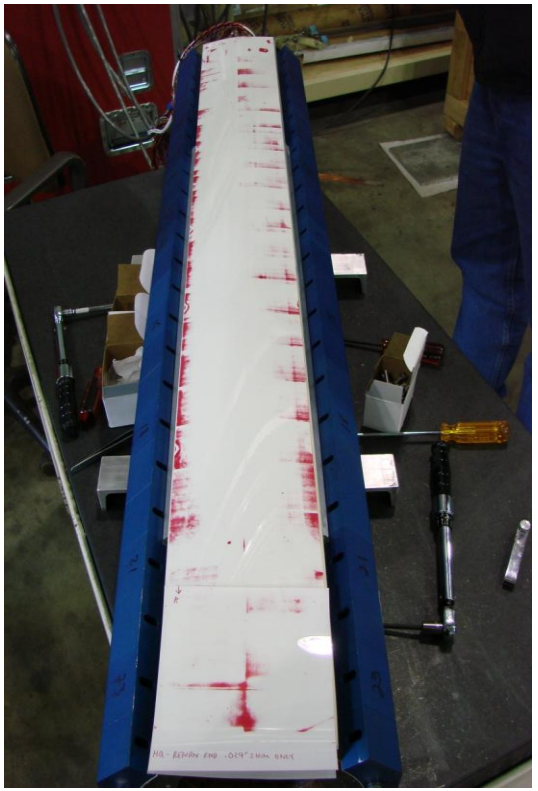




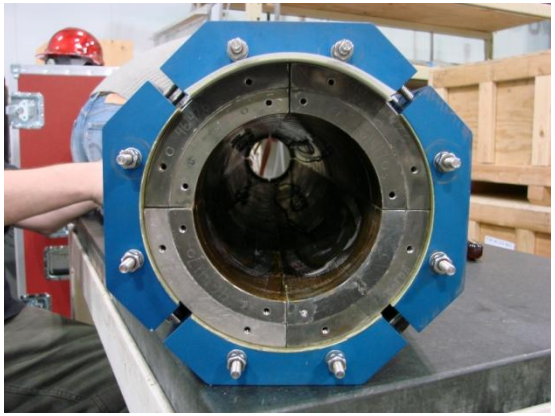
2.5” from RE

HQ01a – Fuji test II – Nominal shim – Full length

Layout	
Coil theoretical OD	7.198”
G10 nom. Shim / Shim stack	0.037” / 0.029”
No addition. Shim / Low P Fuji paper	0.008”
Nominal Shimmed coil OD	7.272
Collar ID	7.276



Nominally: no interference between coil and shimmed collar



RE

No key in the end + endshoe

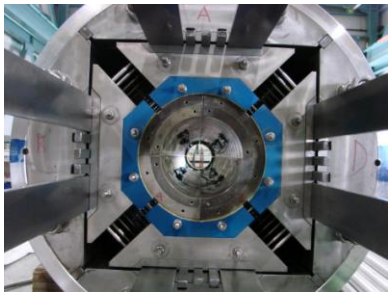
=> No clearance

Center

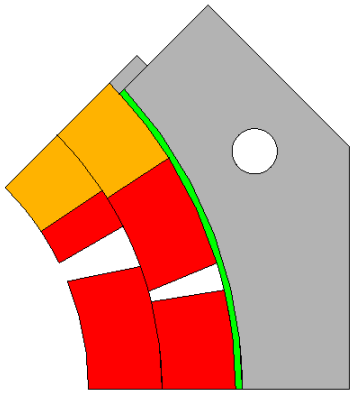
=> 8 mils clearance measured between key and collar per side

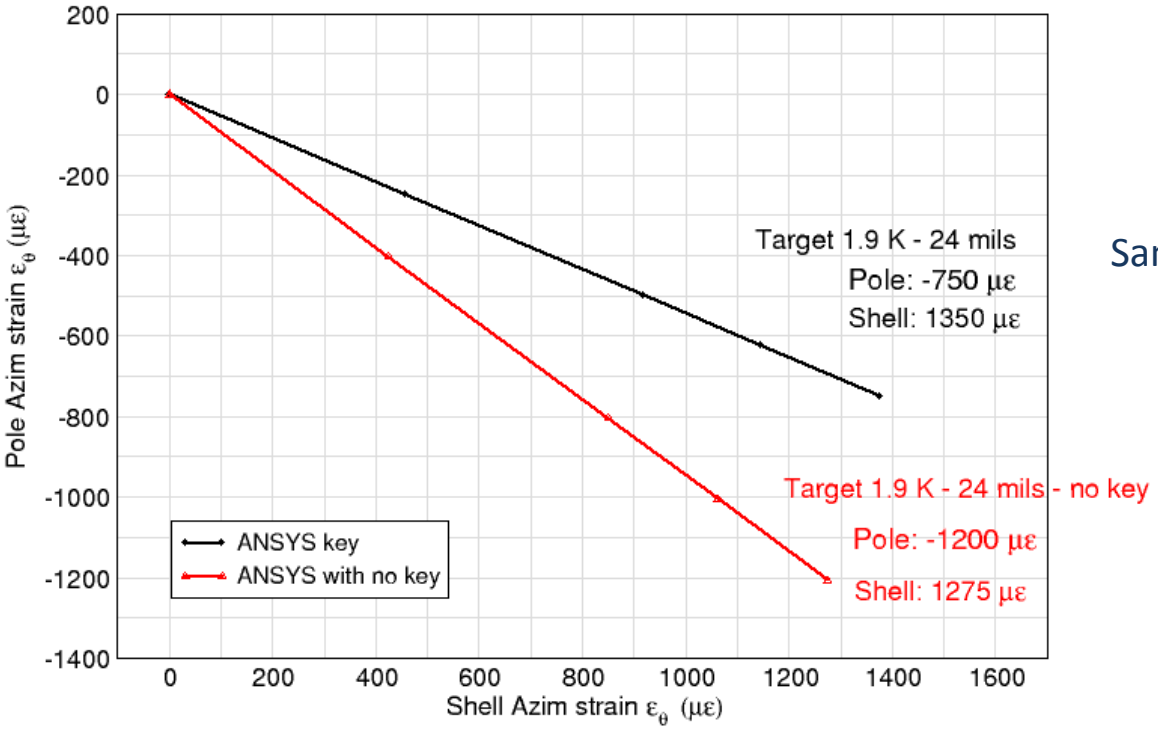
- Coil pack oversize in the center : agreement with coil measurements
- Decision to go ahead with nominal shim 37 mils

ANSYS 2D – Bladder operation Targets (I)



- Coil pack is oversized in the center
- gap key / collar gap of ~ 8 mils
  => behavior “no key”
- Decision to pre-stress to 1.9 K short sample: 19.05 kA



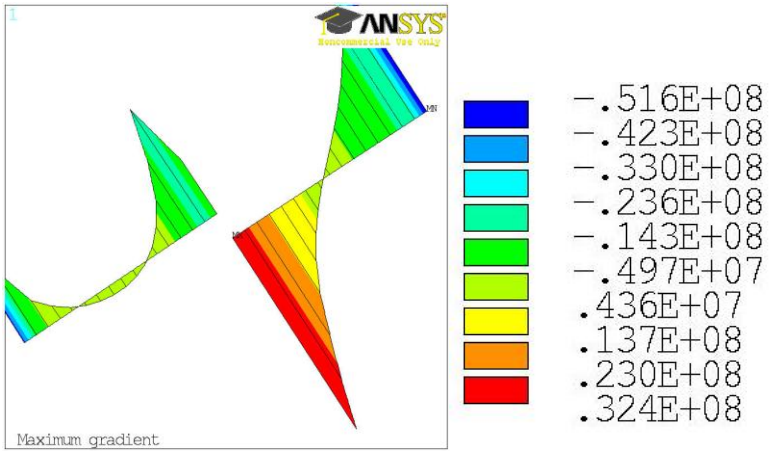


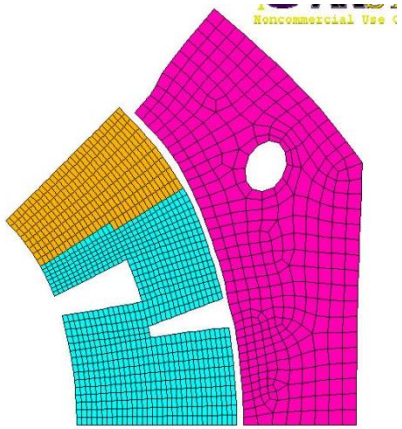
Same shim stack needed: 24 mils

- Similar shell strain
  - same stretching of the shell in both cases
- Much higher pole strain in “no key” case

ANSYS 2D – Bladder operation Targets (II)

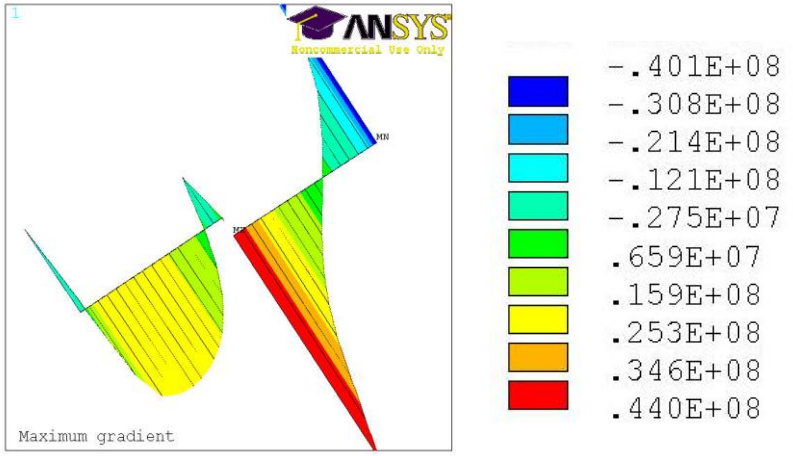
Coil/Pole contact elements at Iss 1.9 K <u>with key</u>

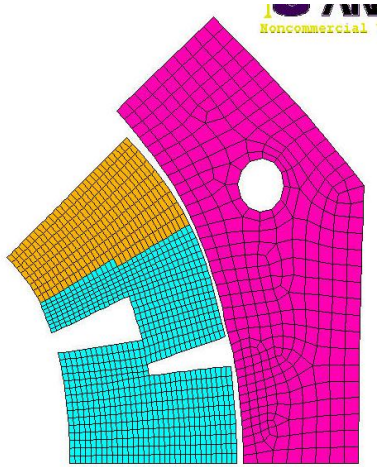




Displacement scaling 100

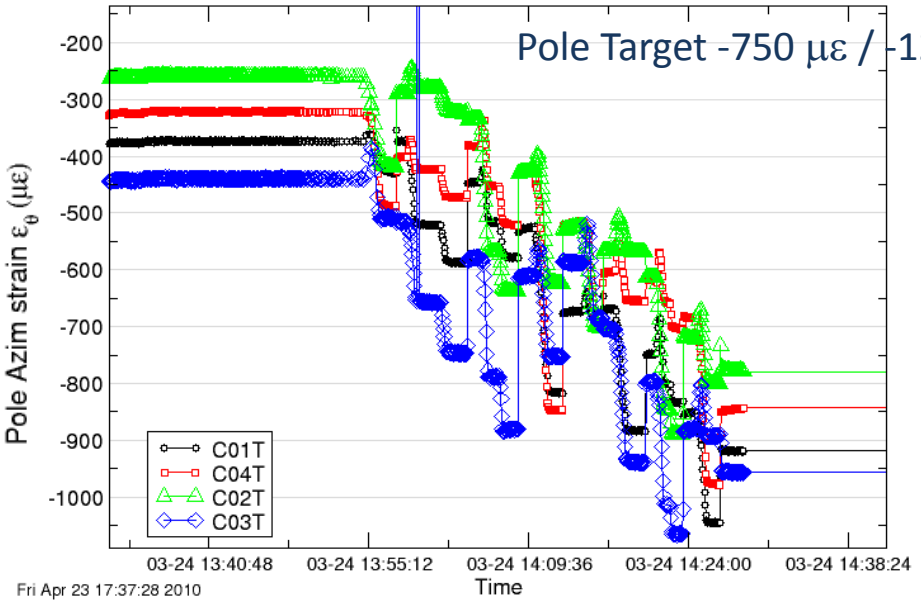
Coil/Pole contact elements at Iss 1.9 K <u>without key</u>



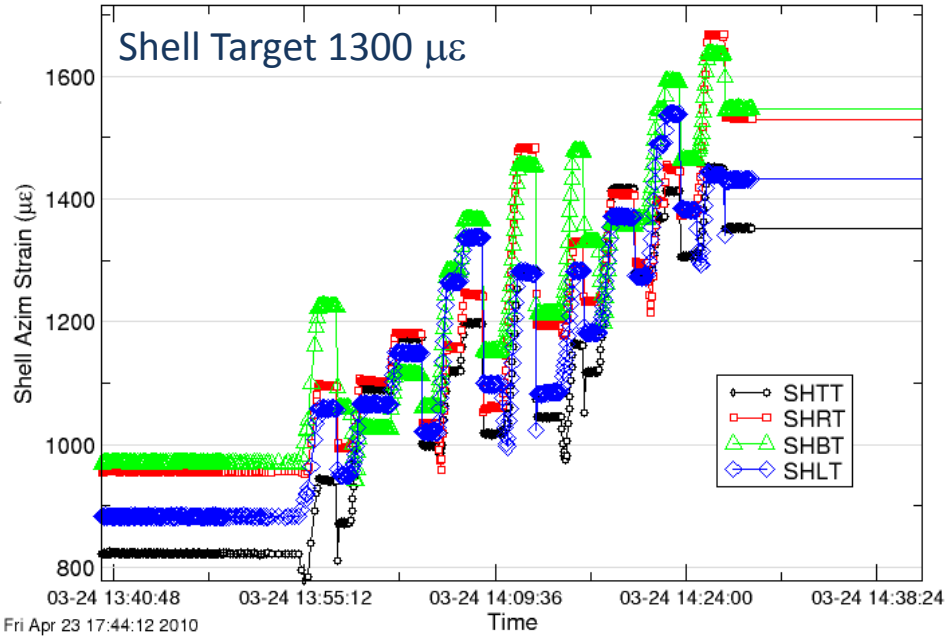


Displacement scaling 100

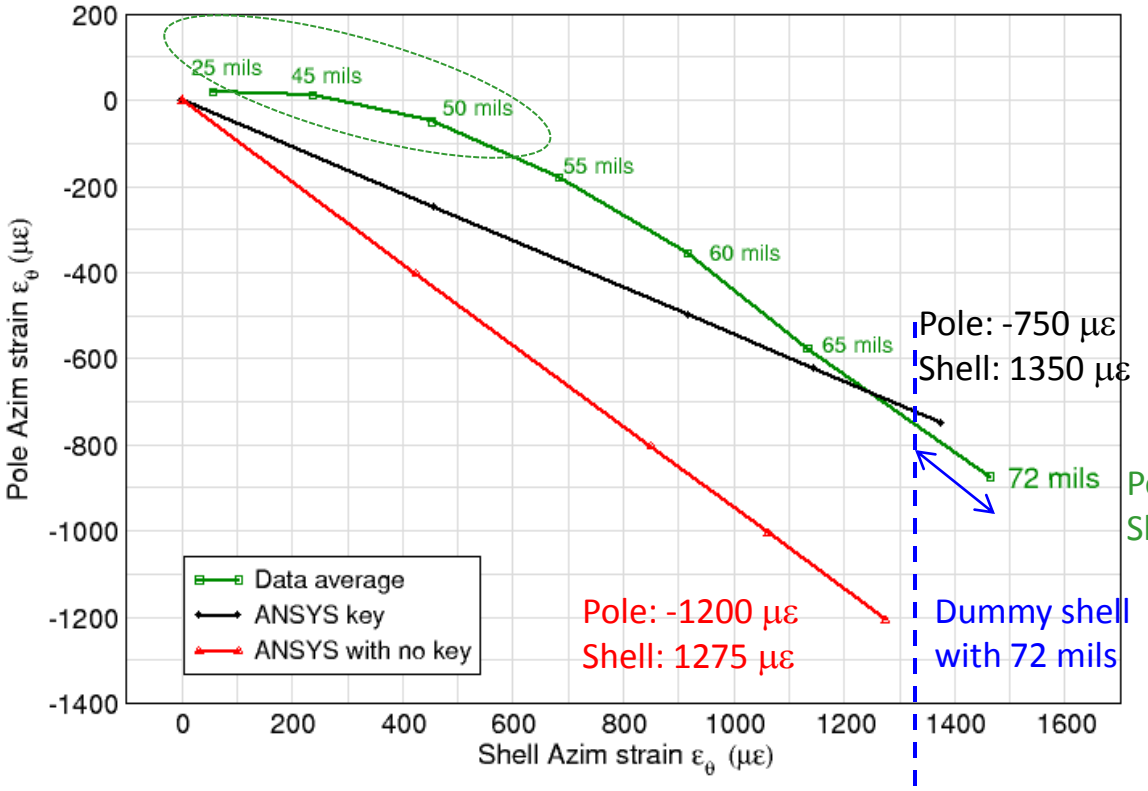
SG data during bladder operation



Coil gauges responding to the bladder pressure and to the shimming of the load keys



HQ01a SG data during assembly

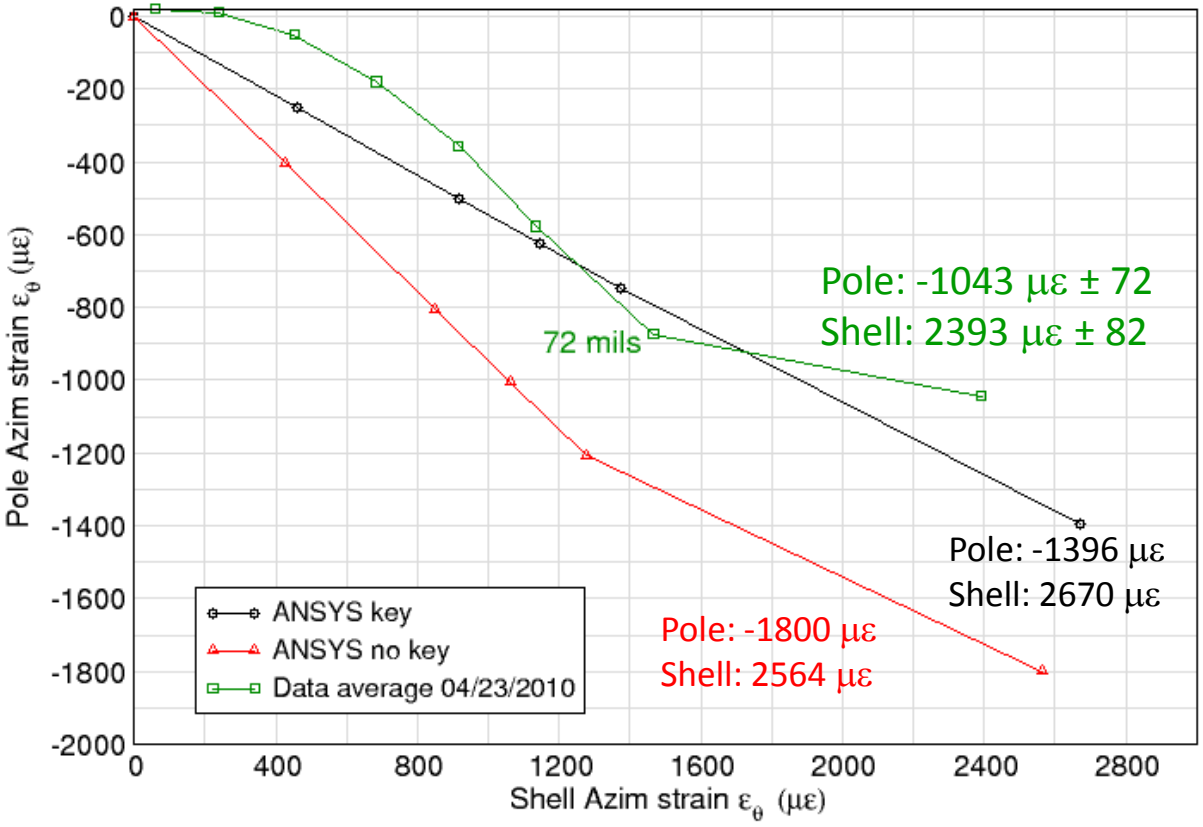


- Some shimming needed to straighten the coil?
- The slope => no contact with the key

Comparison with Dummy
=> coil pack 3 mils bigger on the radius than dummy coil / nominal pack

	ANSYS With key MPa		ANSYS Without key MPa		SG measur. (MPa)
	L1	L2	L1	L2	
Warm avg preload on the coil	-61	-37	-91	54	
Peak stress in the coil	-92		-150		
Pole SG location	-97		-157		-114 ± 9
Shell SG location	96		89		115 ± 7.6

HQ01a Cool-down SG data



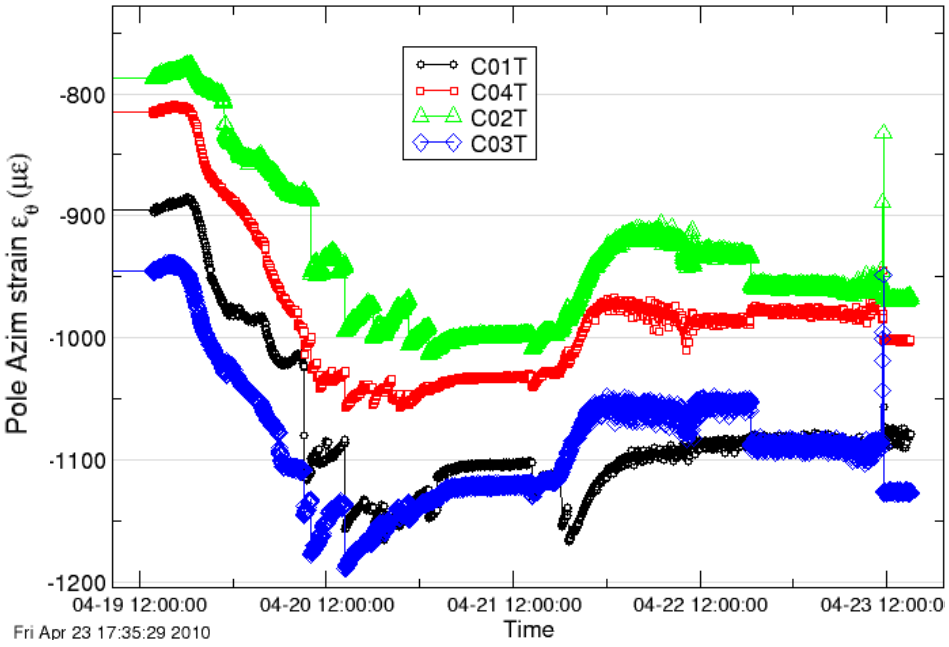
- Only 60 to 75 % of the coil target
- 90 % of the shell target

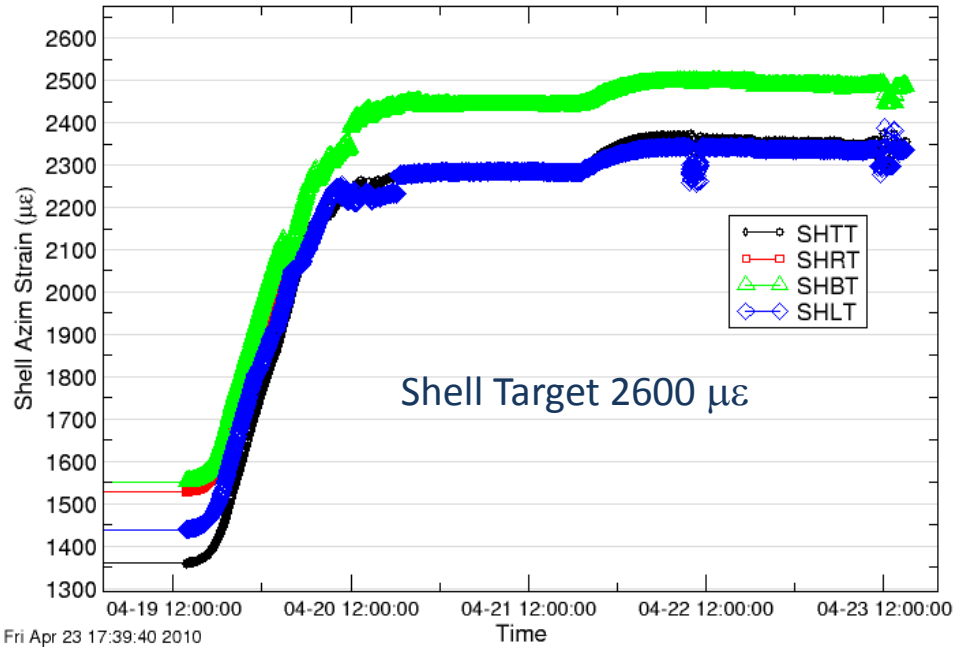
$\sigma_{\theta \text{ pole SG}}$ ~ -150 MPa ± 8

$\Rightarrow \sigma_{\theta \text{ layer 1}}$ ~ -110 Mpa

$\Rightarrow$ Pre-stress required for 17.3 kA

SG data during cool down

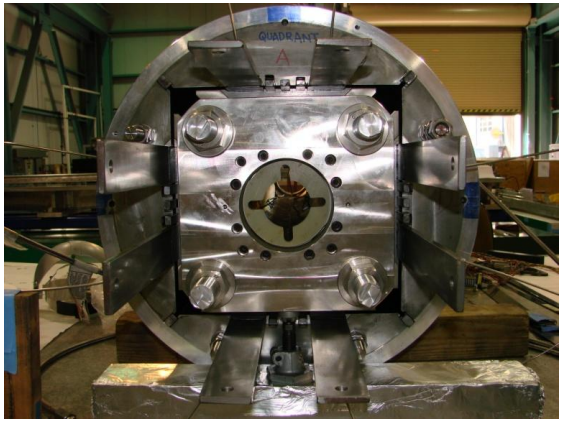




Axial Loading

Target piston:
1260 με / 90 Mpa

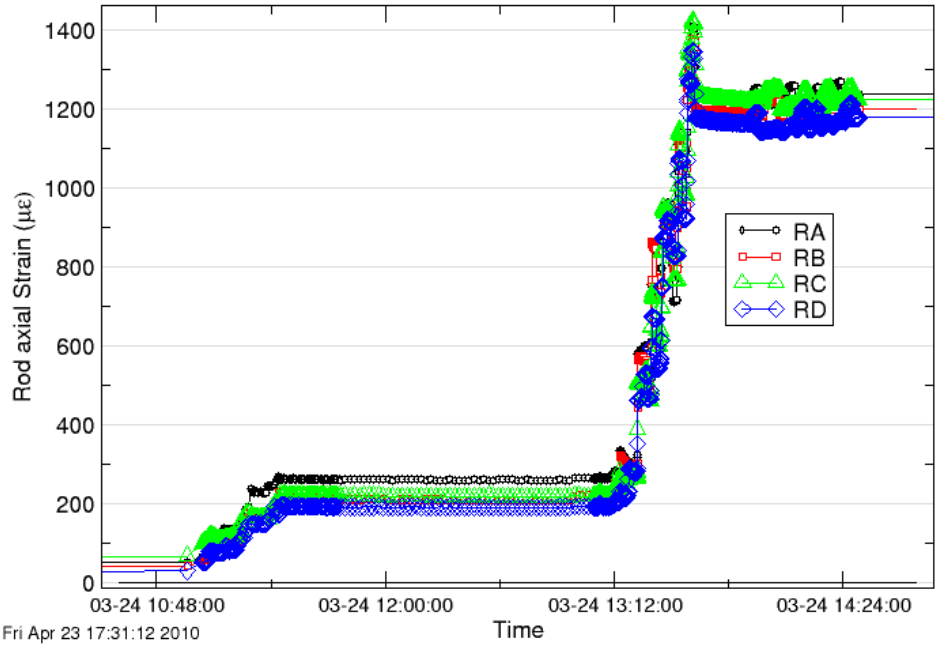
Average measured:
1211 με / 85 MPa

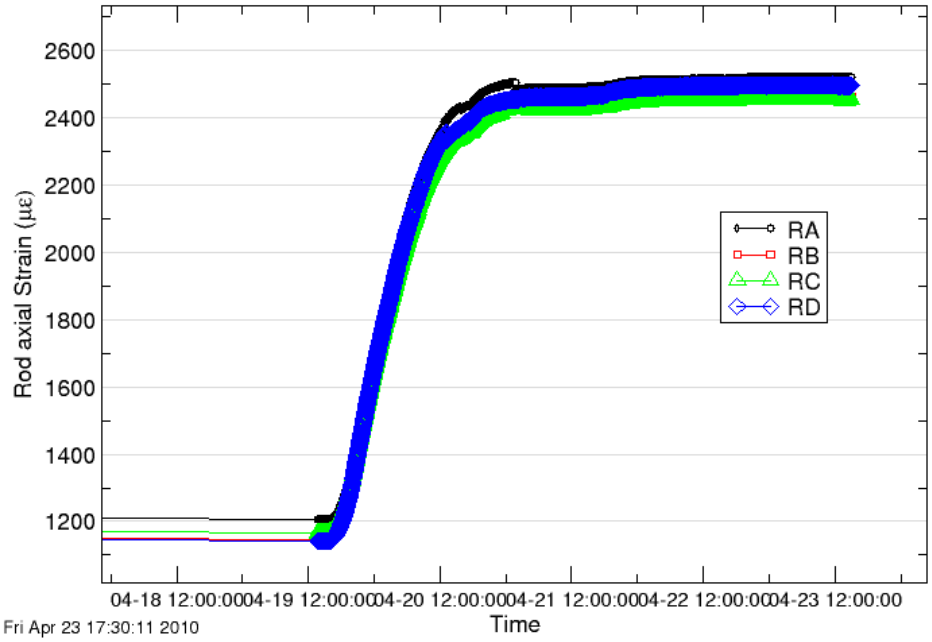


Target cold:
2280 με / 180 Mpa

Average measured:
2483 με /190 Mpa

Total axial force applied ~ 600 kN





HQ01 Testing Plans / Next steps

- **Test #1: HQ01a test at LBNL**
  - Ongoing until mid-May
  - Based on performance
    - Disassembly of HQ01a
    - Replacement of some coils: 5 and 6 should be available by then
    - Adjustments of the mechanical structure
    - Re-assembly as HQ01b

Coils 1, 2, 3 and 4

- **Test #2 CERN in summer 2010**
  - Motivation to test at CERN: 1.9 K
    - Current leads limitation at FNAL
  - Discussion with CERN about HQ compatibility with test facility
    - Cryostat size
    - Magnet stored energy (?)

Coils 5 and 6 available

- **Test#3 at FNAL in Fall 2010**

Coils 7,8 and 10 available
Possibly 9

HQ Next steps – 2-meter extension

Goal: comparison with the NbTi models on all issues that may be relevant to a technology decision in 2013-2014

Several changes may be required:

- **Coil design**
  - Cross-section iteration for field quality
  - End optimization
  - Cooling channels in the pole

- **Coil fabrication and tooling**
  - Correction to oversized coils
  - Protection heaters design

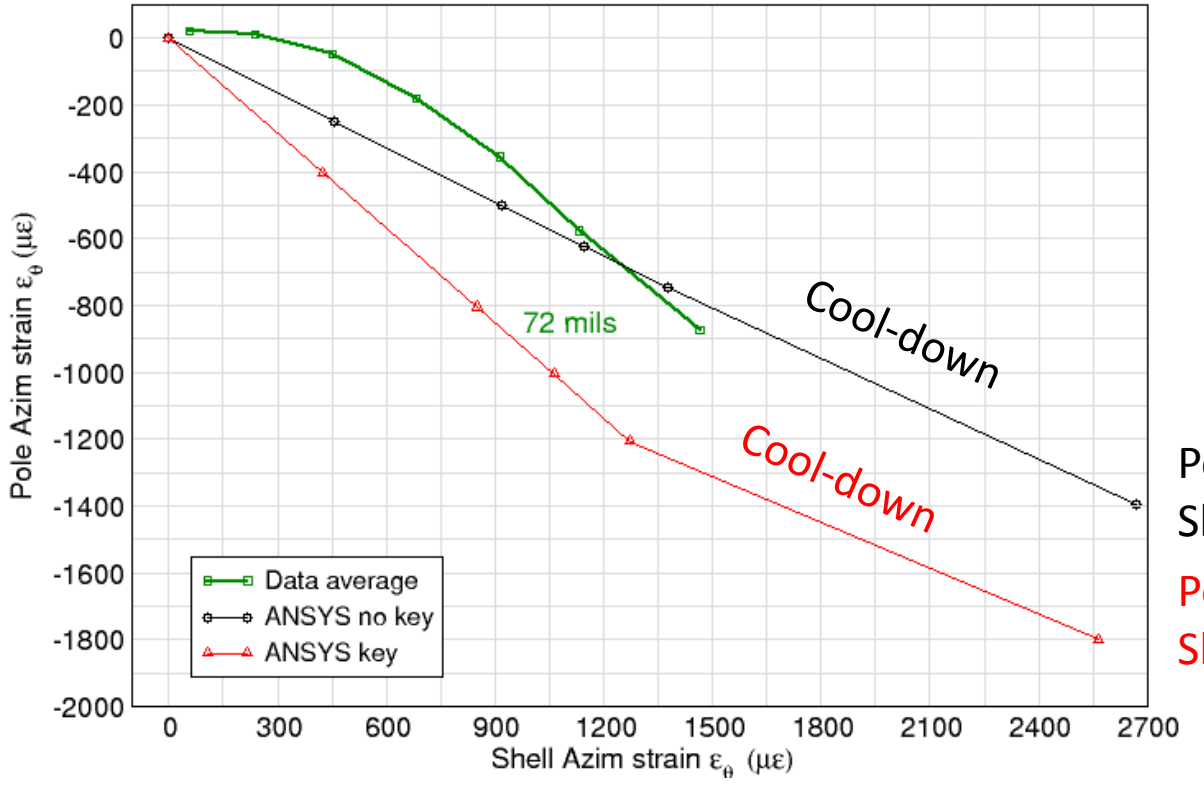
HQ 2-meter extension

- **Structure**
  - Segmented aluminum shell
    - Required to minimize variation of azimuthal stress along the magnet length
  - LQ-like modular assembly
    - In preparation for further length extension
  - Collar design
  - Pad and yoke design optimization
    - Include Phase-type I cooling areas and features
  - Compatibility with external SS cylinder for LHe containment
  - Fiducials external cylinder to yoke
  - Axial support
    - End plate and axial rods
    - End plate welded to SS cylinder

HQ 2-meter extension

- Implementation
  - Coil fabrication:
    - Use existing 1 meter parts when possible:
      - Winding mandrel
      - Reaction / Impregnation tooling
  - Structure
    - Extension of the existing shell? Yoke? Pads?
- Capability to continue making 1 meter models?
- Schedule/cost

ANSYS 2D – Cool down Targets



Pole: -1396 με
Shell: 2670 με

Pole: -1800 με
Shell: 2564 με

With key – σθ at 4.2 K	L1	L2
Avg preload on the coil	-143	-96
Peak stress in the coil	-193	
Pole SG location	-181	
Shell SG location	211	

Without key – σθ at 4.2 K	L1	L2
Avg preload on the coil	-169	-112
Peak stress in the coil	-227	
Pole SG location	-234	
Shell SG location	202	