International review of the HL-LHC 11T Dipole for DS Collimation

Coil production data

Coil Technology

Debriefing

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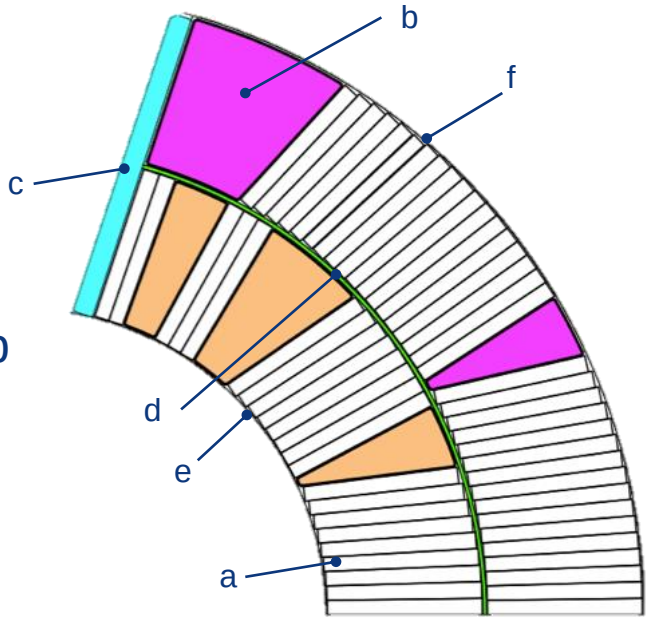
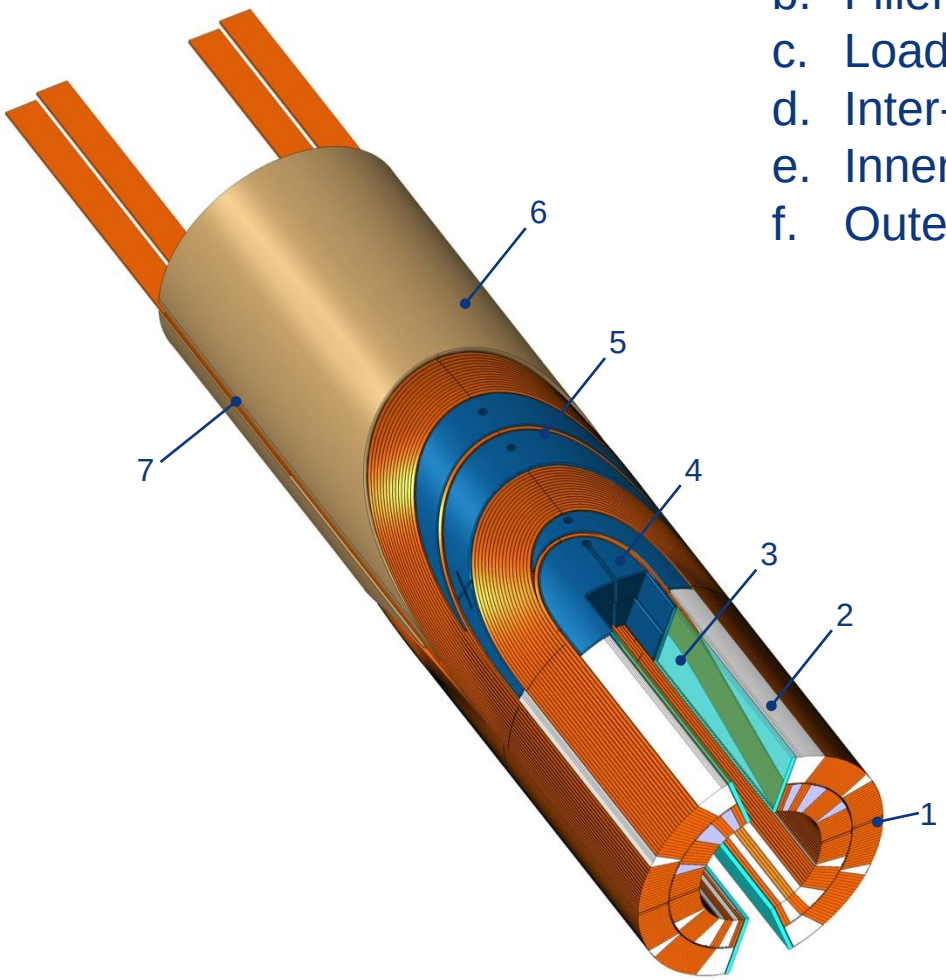
Coil Production Status

Coil ID →	101	102	103	104	105	106	107	108	109	110	111
Cable	Cu DUMMY	Cu DUMMY	WST DUMMY	RRP 54/61 DUMMY	RRP 108/127	RRP 108/127	RRP 108/127	RRP 132/169	RRP 132/169	RRP 132/169 DUMMY	RRP 132/169
Winding Start Date	Jan 2011	Oct 2011	Nov 2012	Feb 2013	May 2013	June 2013	Sept 2013	June 2014	Aug 2014	Sept 2014	Nov 2104
Winding	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD
Curing	GOOD	GOOD	**BAD**	Difficult	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD
Reaction	GOOD	GOOD	-	Difficult	Difficult	GOOD	GOOD	**BAD**	GOOD		
Impregn.	GOOD	GOOD	-	Difficult	Difficult	GOOD	Difficult	Difficult			
Impregn. End Date	Jan 2014	Feb 2013		Aug 2013	Jan 2014	Feb 2014	April 2014	Sept 2014			
Assembly (pairing)	101 105	-	-	-	101 105	106 107					
Cold Tests Date:	-	-	-	-	GOOD Jul14	GOOD Nov14	**BAD** Nov14				
Autopsy Date:			Done Mar-13	On going							
Magnet	MBH SM101				MBH SM101	MBHSP101					

Inside Coils: Naming conventions

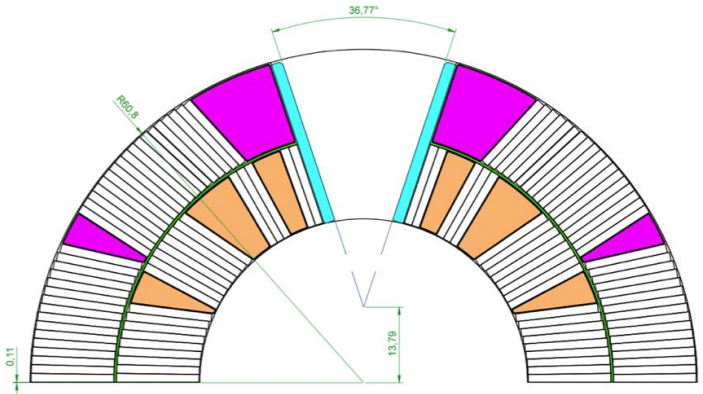
a. Insulated cable
b. Filler Wedge
c. Loading plate
d. Inter-layer
e. Inner ground wrap
f. Outer ground wrap

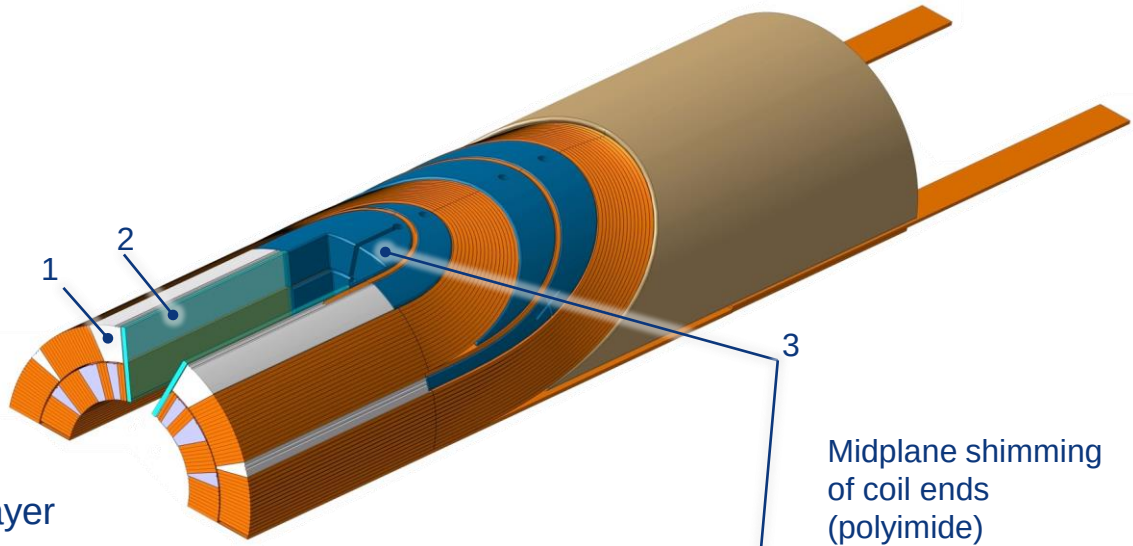




1. Mid-Plane
2. Filler Wedge
3. Loading Plate
4. Key
5. SLS Spacer w/Flex Legs
6. Saddle with integrated splice block
7. Nb_3Sn / Nb-Ti Splice

Loading Plate, Keys and Filler wedge





1. Filler Wedge

Aligns the outer layer with the inner layer
Encase the layer-jump

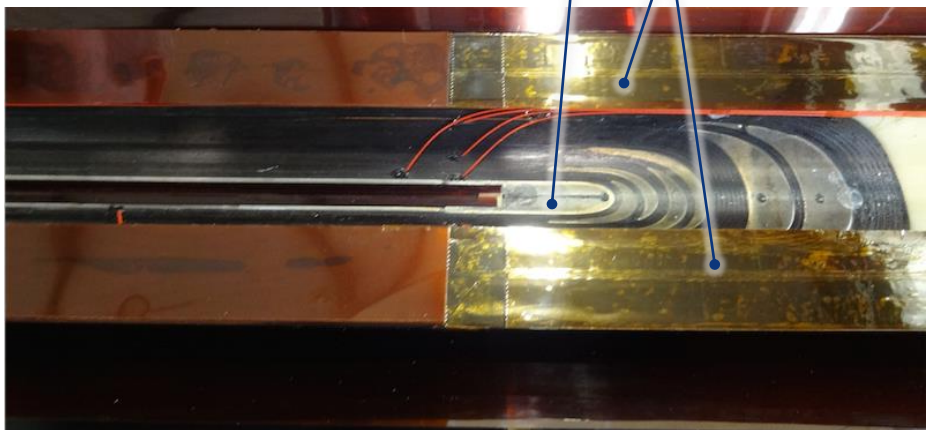
2. Loading Plate

Protects the turns of the inner layer's last block
Distribute the azimuthal stress between both layers and minimize shear during collaring
Protects the layer jump

3. Keys

Makes the transition between the straight section (compression by shimming the poles) and the coil ends (shimming at mid-plane or radially)

Midplane shimming of coil ends (polyimide)



Coil 106 (view from inside bottom, inner layer)
The mid plane shimming of the coil end starts gradually at the end of the straight section

Implementation of Features, timeline

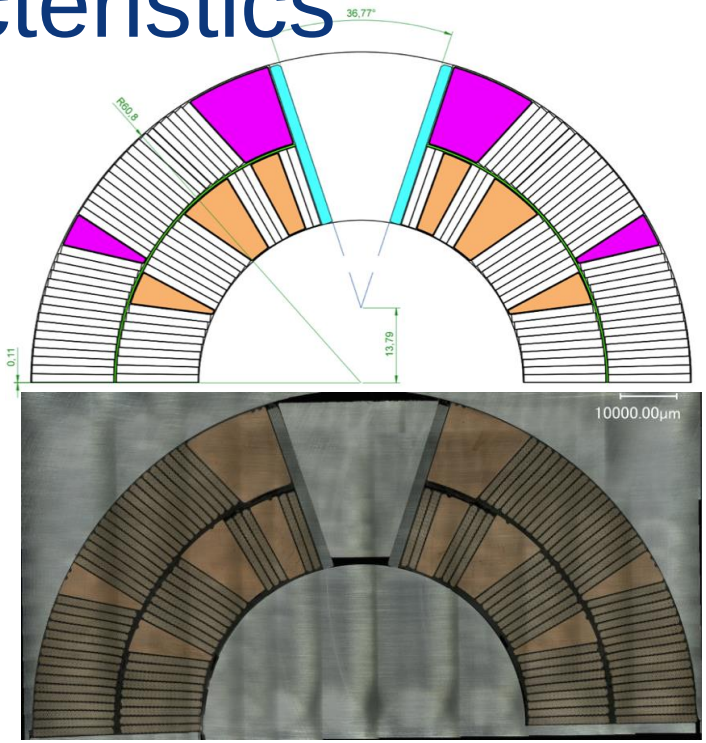
Coil ID →	101	102	103	104	105	106	107	108	109&111
Cable	Cu	Cu	WST	RRP 54/61	RRP 108/127	RRP 108/127	RRP 108/127	RRP 132/169	RRP 132/169
Insul. Thick. [mm]	S2/Mica 0.115	S2 only ~ 0.115	S2/Mica >0.15	S2/Mica >0.15	S2/Mica 0.115	S2/Mica 0.115	S2/Mica 0.115	S2/Mica 0.107	S2/Mica 0.107
Spacers	SLS	SLS	SLS	SLS-Flex	SLS-Flex	SLS-Flex	SLS-Flex	SLS-Flex	SLS-Flex
Saddles	SLS	SLS	SLS	SLS	SLS	G11	G11	G11	G11
Wedges	316L	316L	316L	ODS-Cu	ODS-Cu	ODS-Cu	ODS-Cu	ODS-Cu	ODS-Cu
Inter_layer	Nextel	E-Glass	Mica-QH	S-Glass	S-Glass	S-Glass	S-Glass	S-Glass	S-Glass
Binder	CTD1202	CTD1202	CTD1202	CTD1202	CTD1202	CTD1202	CTD1202	CTD1202	CTD1202
Splice	Pb-Ag	Pb-Ag	-	Pb-Ag	Pb-Sn	Pb-Sn	Pb-Sn	Pb-Sn	Pb-Sn
Gr.Wr. OD Gr. Wr. ID	Glass 0.1 Glass 0.1	Glass 0.1 Glass 0.1	-	Glass 0.1 Glass 0.1	Glass 0.1 Glass 0.1	None None	Glass 0.1 Glass 0.1	Glass 0.1 Glass 0.1	
Epoxy Impreg.	CTD 101K	CTD 101K	-	CTD 101K	CTD 101K	CTD 101K	CTD 101K	CTD 101K	CTD 101K
Remark	Short with spacers	Short with spacers - Splicing difficult	Insulation oversized- Disposed after curing	Insulation oversized- Splicing difficult	Short with saddle, Popped Strand, Azim. Oversized	ELQA OK - OK (no ground wrap)	ELQA OK - Dry spots after impreg.	ELQA OK - Impregn. defects	No binder in ends (In progress)

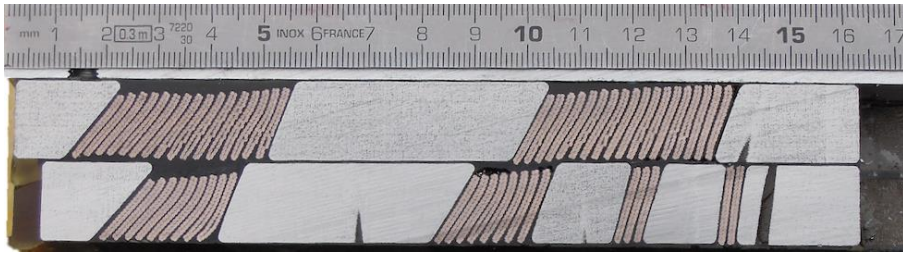
Winding – Curing: Characteristics

Winding Characteristics for 105-106-107

- Cable Tension IL: 350 N / OL : 250N
- Cable behaviour: RRP Stable
- Binder+ heat gun to stabilize the cable in the heads
- Respect of Coil Overall Length: ~ 6.. 10 mm extra length
- Curing process: cables compressed to nominal above midplane
- Electrical integrity: good

105 collapsed cable, 106, 107 OK

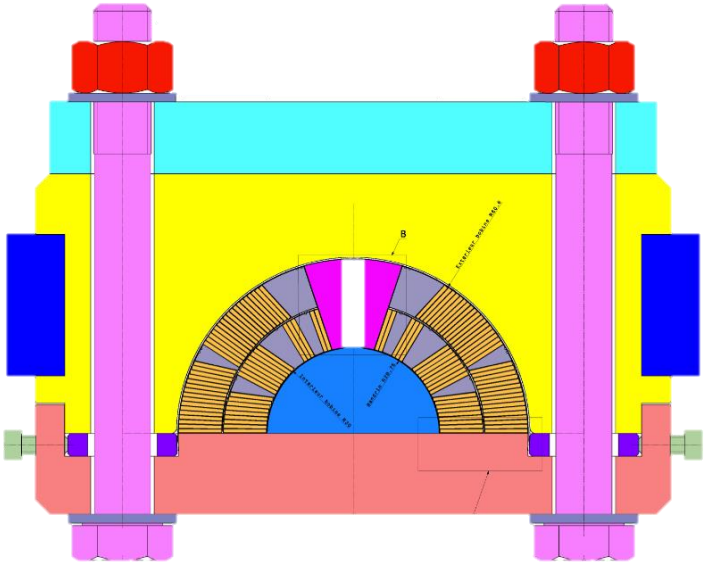




Nota: Correct position of the turns in the ends is now achieved (since coil 108)

Photographs :courtesy of X. Sarasola Martin, N Peray, L. Lambert

Reaction Fixture



Difference between coils 105-106-107

Coil 105 reacted in tool #1

Coil 106 reacted in tool #2

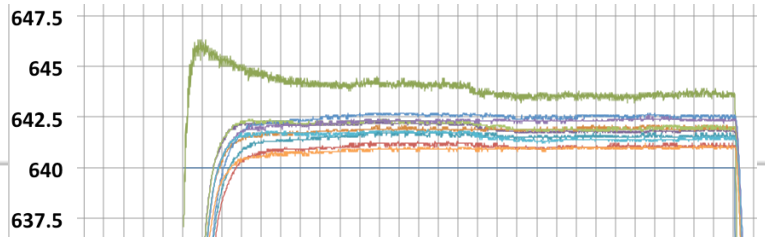
Coil 107 reacted in tool #2

Mica setup, cavity size: similar

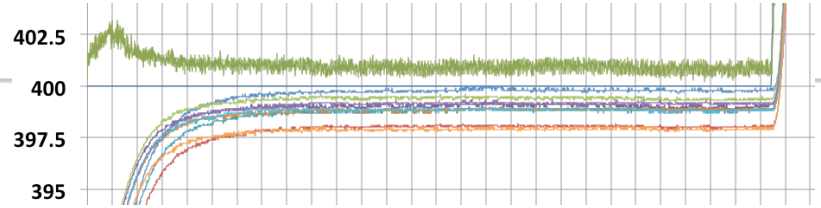
105,106,107 NOSIG

NOSIG: No SIGnificant change

Reaction Cycle 105

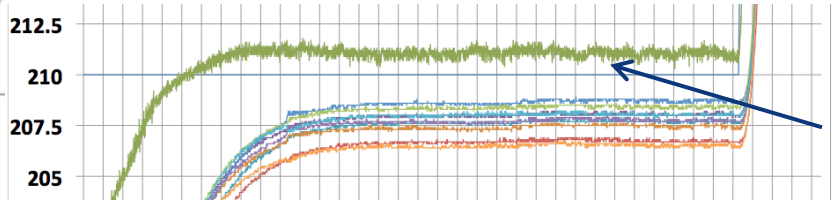


Coil 105
OST RRP108/127
48h 210°C / 48h 400°C / 48h 640°C
Reaction date coil 105: Oct 2013



Dwell duration
corrected to compensate for the inertia of the oven
71h 210°C / 57h 400°C / 54h 640°C

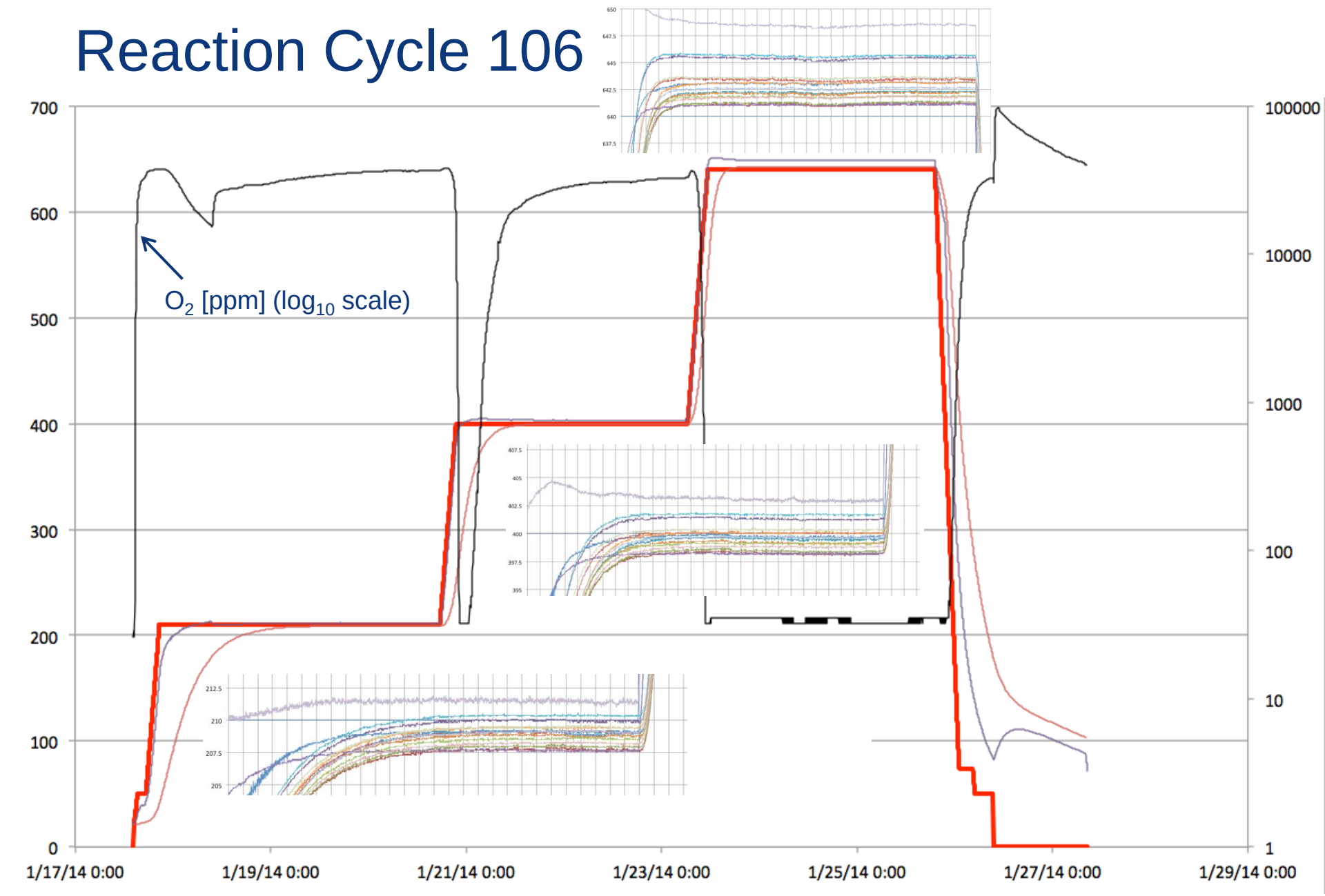
Sensor Calibration:
Previous calib. date: Sept.2012
Latest calibration: Nov. 2014
measured calibration drift at 640C : +6C



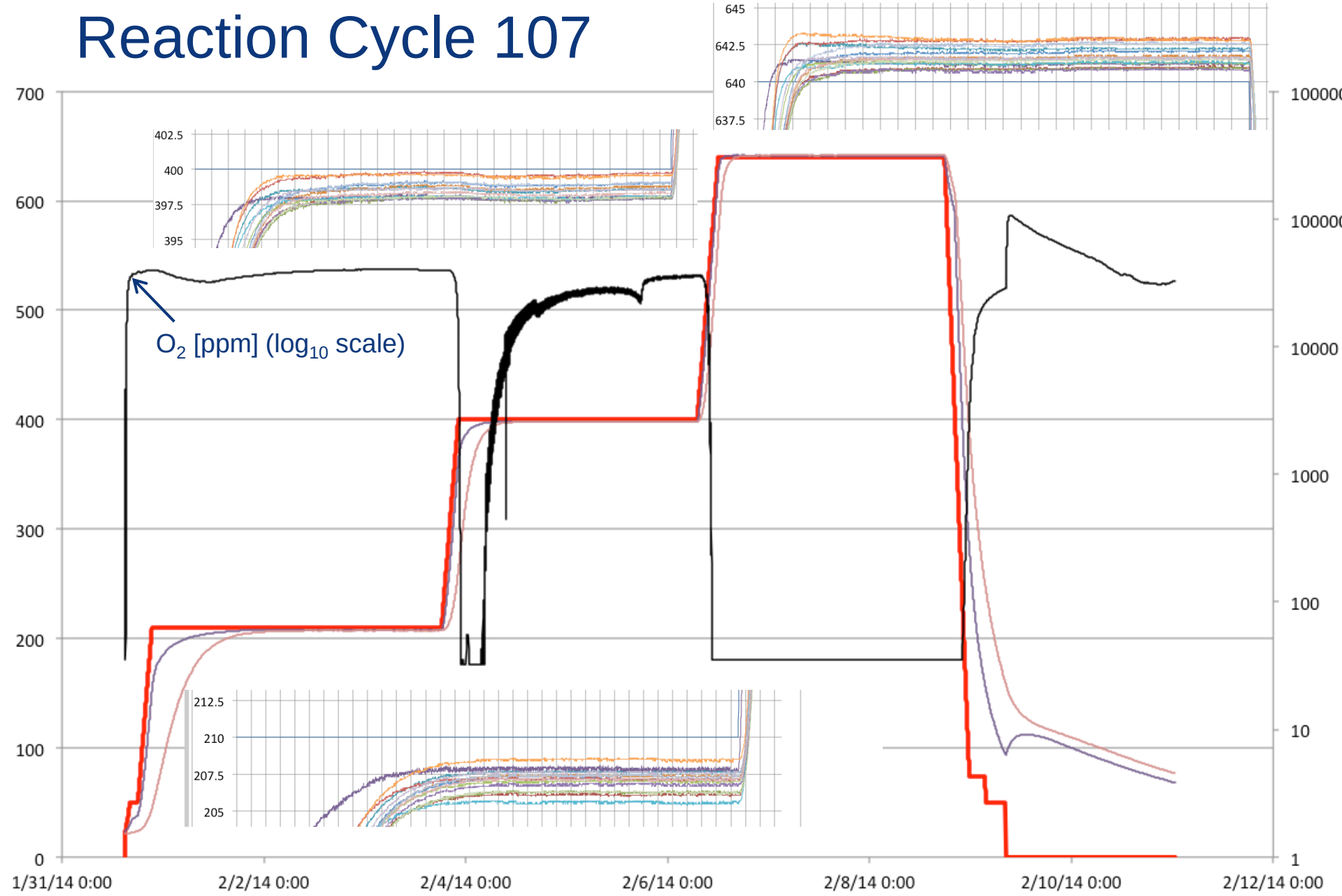
O_2 [ppm] ($\log_{10}$ scale)

Green curve: Gas T in retort

Reaction Cycle 106

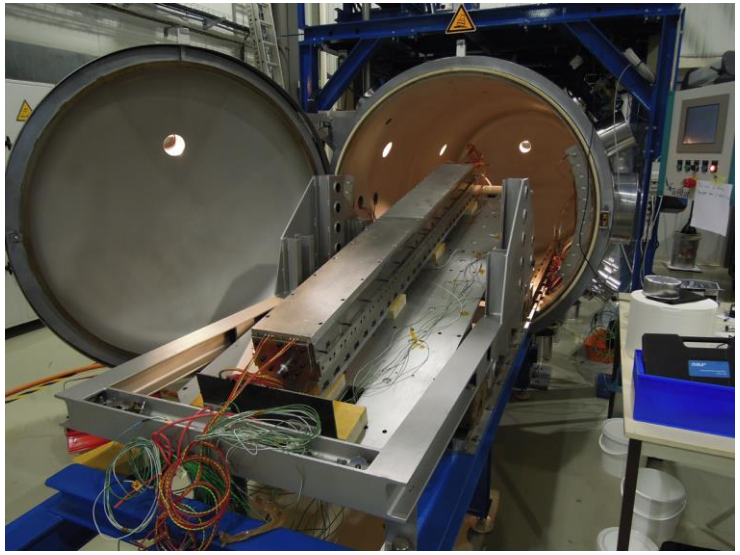


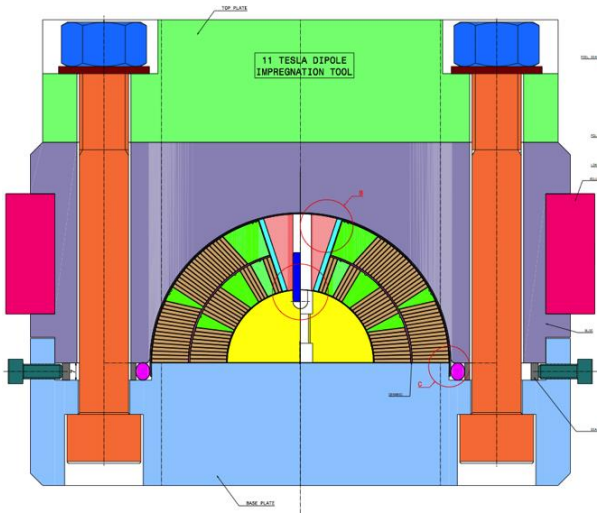
Reaction Cycle 107

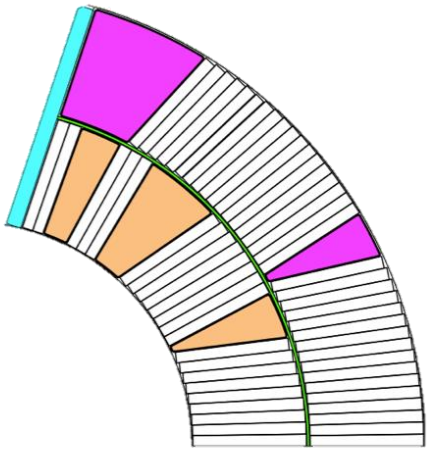


105,106,107 NOSIG ; (O2 Sensor ?)

Tooling: Impregnation







Coil 105,106 and 107 potted in tool #1

Tool#1: cavity radius 0.04 mm too small, and cavity center is 0.052 mm too low;

Cable Insulation is slightly oversized (0.115 instead of 0.1 mm wall thickness)

105,106,107, each followed a different solution to fit tool size

	105	106	107
Insulated cable, ovesized insul.	+2%	+2%	+2%
Overcompression at curing	none	none	none
Ground wrap IL/OL	0.1 / 0.1	0 / 0	0.1 / 0.1
Mitigation	Tool closed w/ shim	No ground wrap	Shorter seal foil
Result	Coil oversized	Good	Dry Spots

Summary

- Coil generation 105/106/107 was made in 2013; improvements were already envisaged and some have already been implemented (see next slide);
- 105/106/107 are very similar coils, apart from ground wrap/impregnation quality;
- Investigation on problems with coil 107 is based on data mining . No specific issue spotted for coil 107 apart from its dry spots
- Waiting for coils 106 & 107 to be out of the magnet to detect anomalies;

- Study of the geometry of impregnation tools is ongoing. Likely, impregnation tool #1 should be reworked (or not used anymore)

What's going on and What's next?

- Winding:
  - 0.107 mm instead of 0.115 (coil 108>)
  - Layer jump not clamped *(1)* (coil 111>)
  - No binder in the heads (no heatgun) *(2)* (coil 108>)
  - Reduce Gap for wedges *(3)* (coil 112>)
  - Wedges placed against spacers*(3)* (coil 112>)
  - Wedges not segmented (1.5 m long) (coil 112>) (option, tbc)
- Curing:
  - Over-compression @ curing (+0.5mm) (coil 108>)
- Reaction
  - Regularly Calibrated thermocouples (coil 109>)
  - More Witness samples (coil 109>)
  - O2 monitoring replacement (coil 112>) (tbc)
- Impregnation
  - Better filling of gaps with dry fibre *(3)* (coil 109>)
  - Layer Jump support made from G11 *(4)* (coil 109>)
  - **No ground wrap OL** (coil 109>) (tbc)
- Instrumentation
  - New Trace generation (VT) (coil 108>)
  - Less VTs on OL (coil 109>) (tbc)
  - Less glue to fix the trace (coil 109>) (tbc)