LQ Instrumentation and Quench Protection

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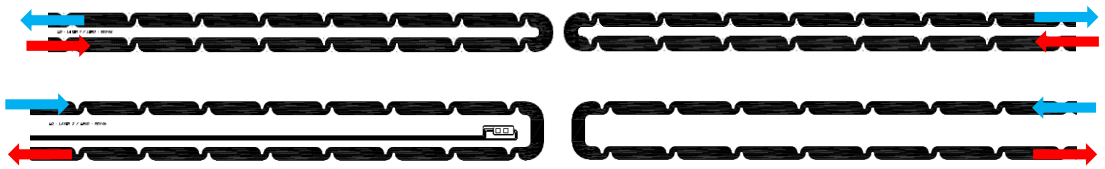
FNAL

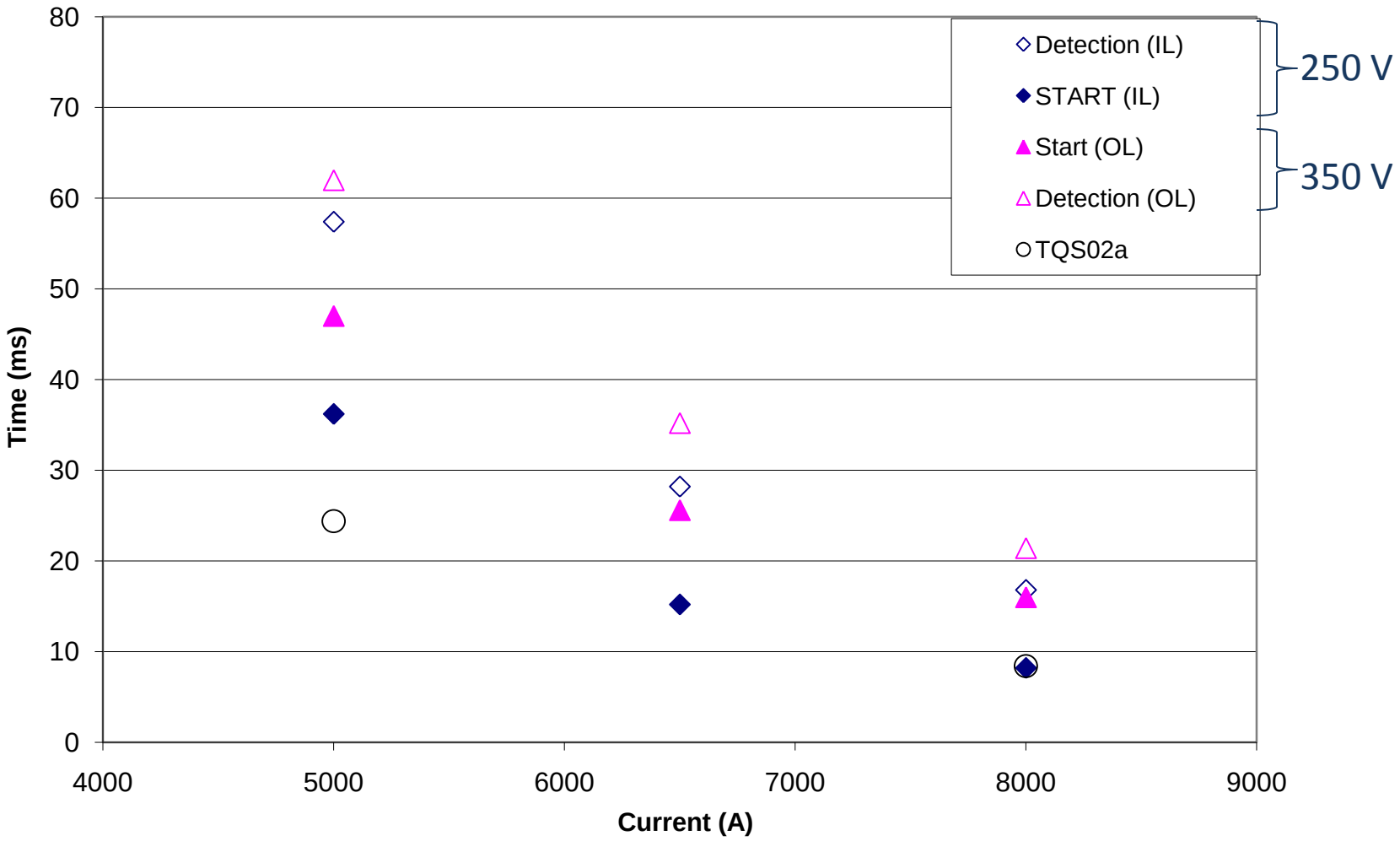
LQS01a Protection



- Hypothesis:
  - Detection time = 5 ms
  - Heater delay time = 12 ms
  - Current = 13.5 kA
  - Stored energy ~ 1.2 MJ
  - Bpeak = 11 T (conservative hypothesis)
  - Quench velocity = 40 m/s in the high field region
- 380 K hot spot T and 7.5 MIITs

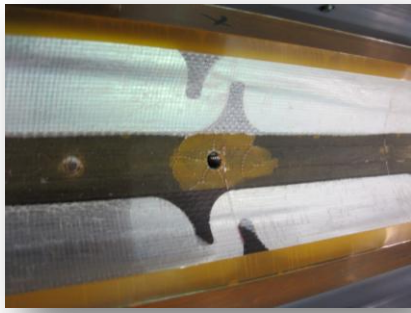
- Heaters design: 4 strips per coil (1 LE and 1 RE for each layer)
- Powering of the heaters:
  - 4 strips in parallel
  - 4 circuits

LQS01a PH performance

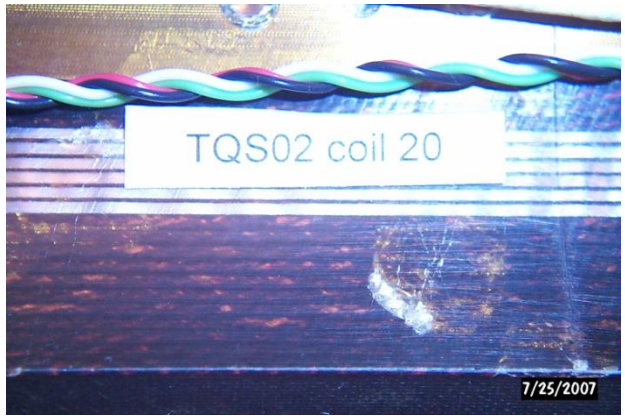


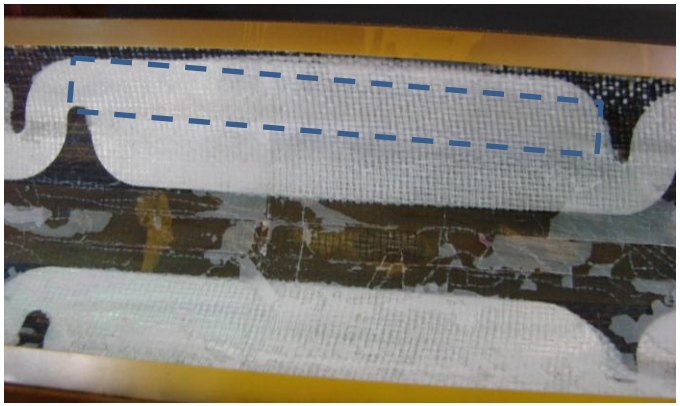
Guram Chlachidze

Coil inspection



- Delamination on coils Inner Diameter
- Different from “TQ-style” bubbles
  - larger => only underneath the large sections of the heaters
  - No conductor exposed
  - Not clear if bubble underneath stainless steel or only glass sheet => impact on heater performance ?
- Possible causes:
  - Superfluid helium + quench (only 2 quenches) <=> TQ
  - Heat from heaters on ID <=> LQ





Coil 6 (showing epoxy “peeling” related to double impregnation, already observed before test)

Possible impact of the bubbles on the PH

HIPOT Before LQS01a test

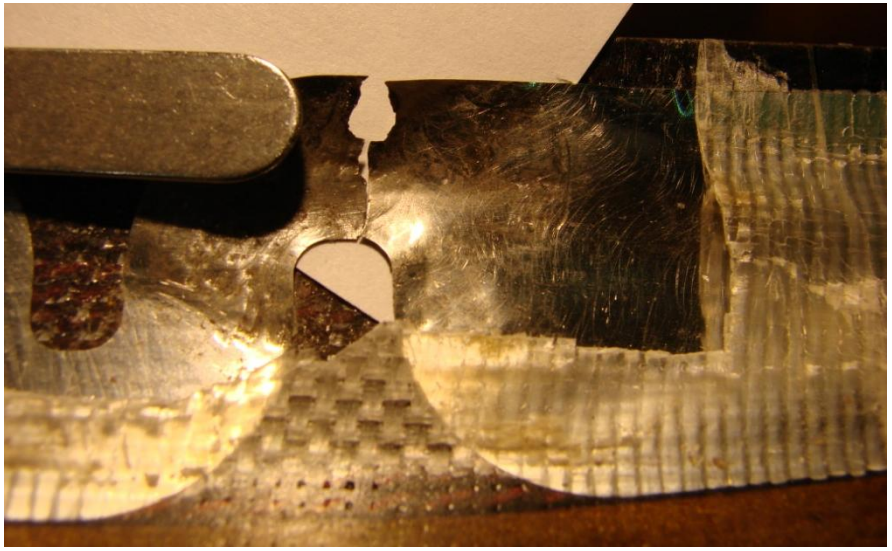
	Coil 8	Coil 7	Coil 6	Coil 9
A01	OK	OK	OK	OK
A02	OK	OK	OK	OK
B01	OK	OK	OK	OK at cold
B02	OK	NO	OK	NO

HIPOT After LQS01a test and disassembly

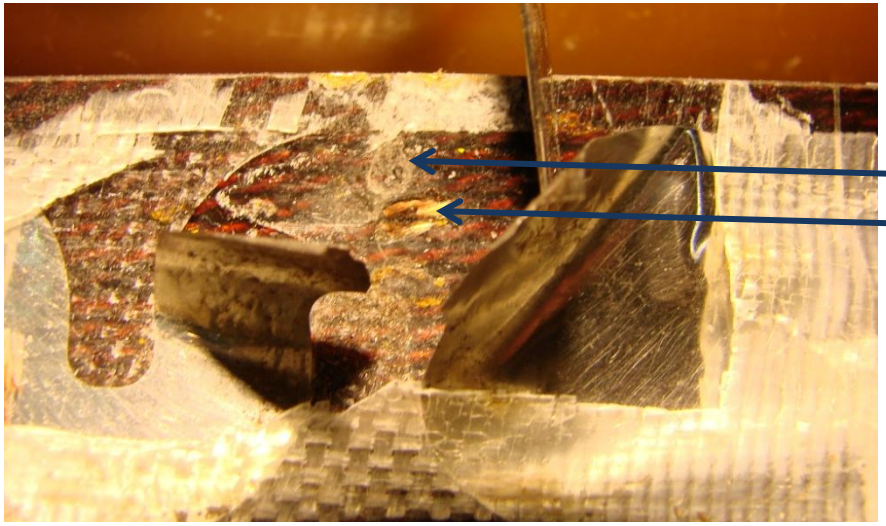
Probably caused by a bubble
Showing a ~ 4MΩ resistance
between PH and coil

	Coil 8	Coil 7	Coil 6	Coil 9
A01	OK at 10 uA	OPEN	OK	OK
A02	OK at 10 uA	OK	OK	NO (27V)
B01	OK	OK at 10 uA	OK	OK at 10 uA
B02	OK	NO (450 V)	OK	OK at 10 uA

Coil 7 PH A01 observation



- Black spot observed on a heating station
- the glass has been peeled off
- the carbon cleaned
- the Kapton underneath the trace has been cleaned/removed

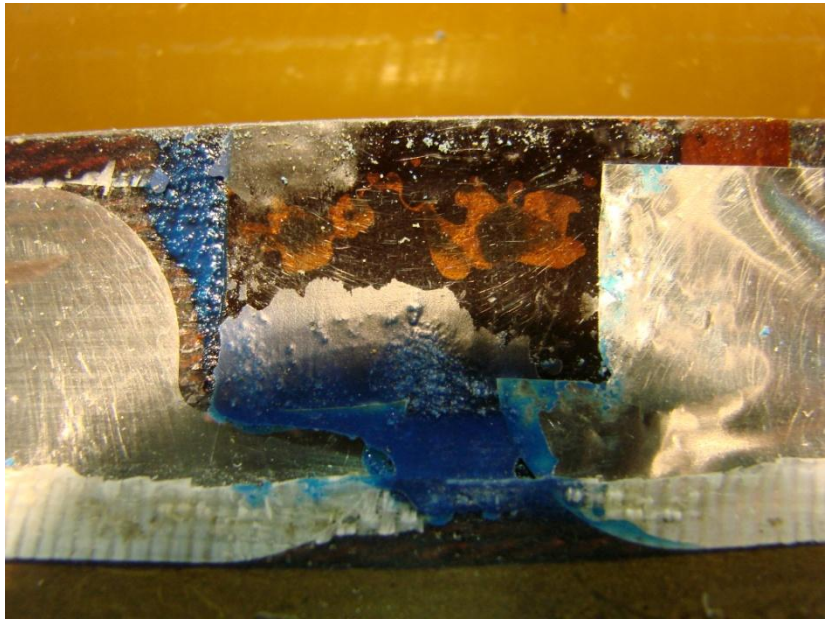


Spot where the heater was burnt

Some conductor exposed

- Hipot performed => OK to 1 kV at 1 μA

Coil 7 PH A01 repair

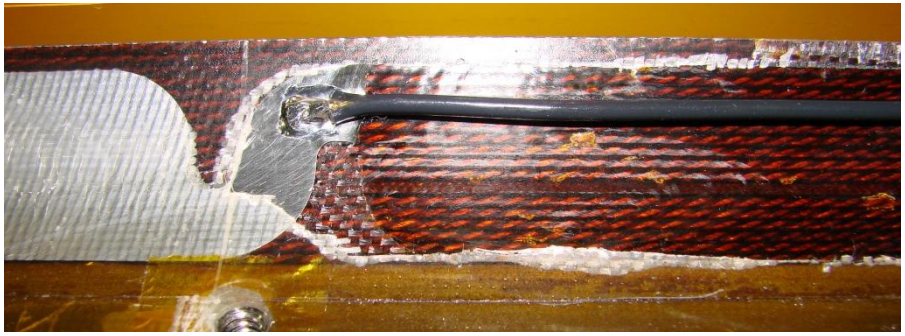


- Exposed area filled with Stycast
- 5 mils kapton on top of it
- Cured with pressure

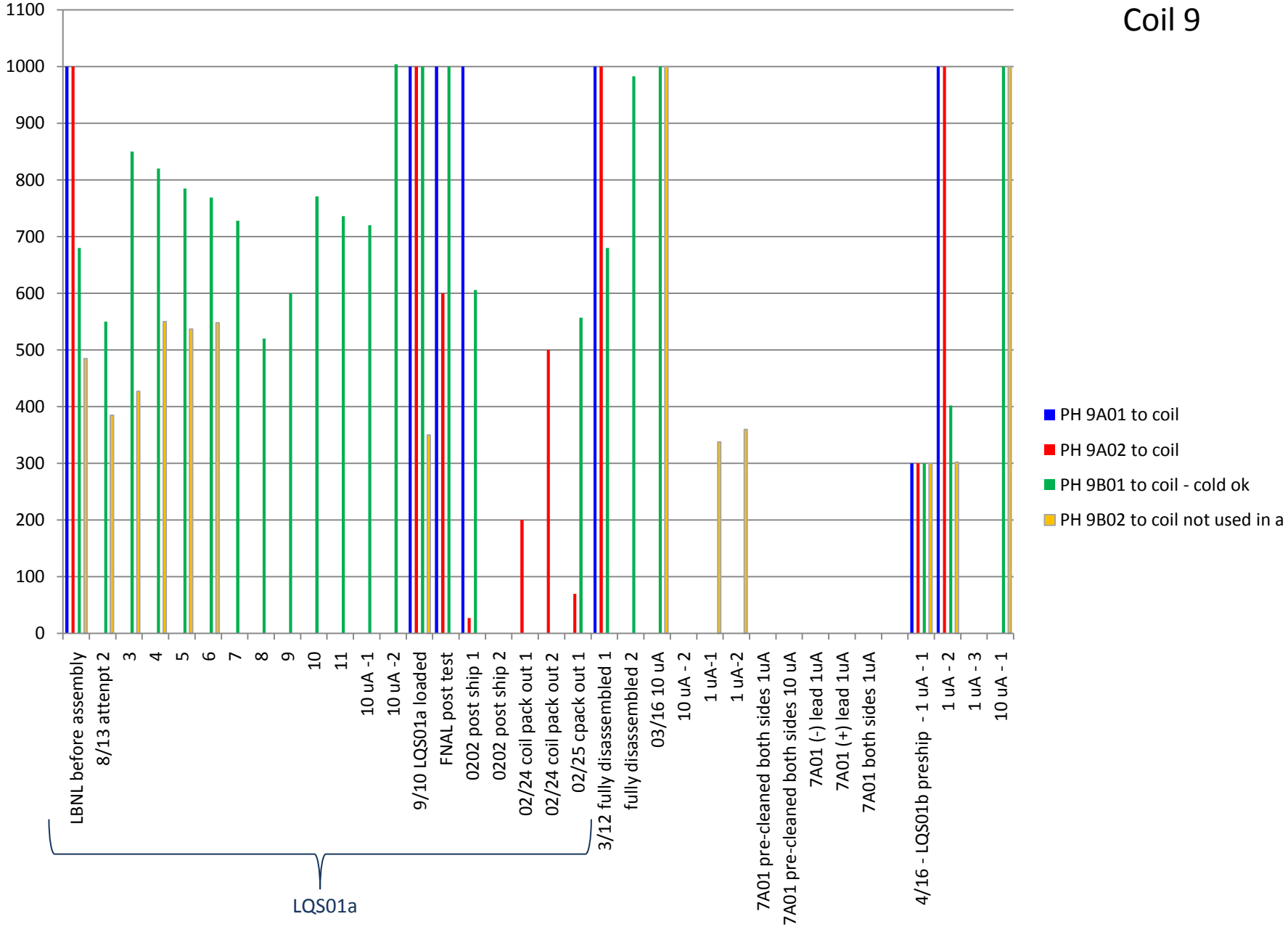
- solder of a copper sheet bridging the 2 sides of the heater => shorted

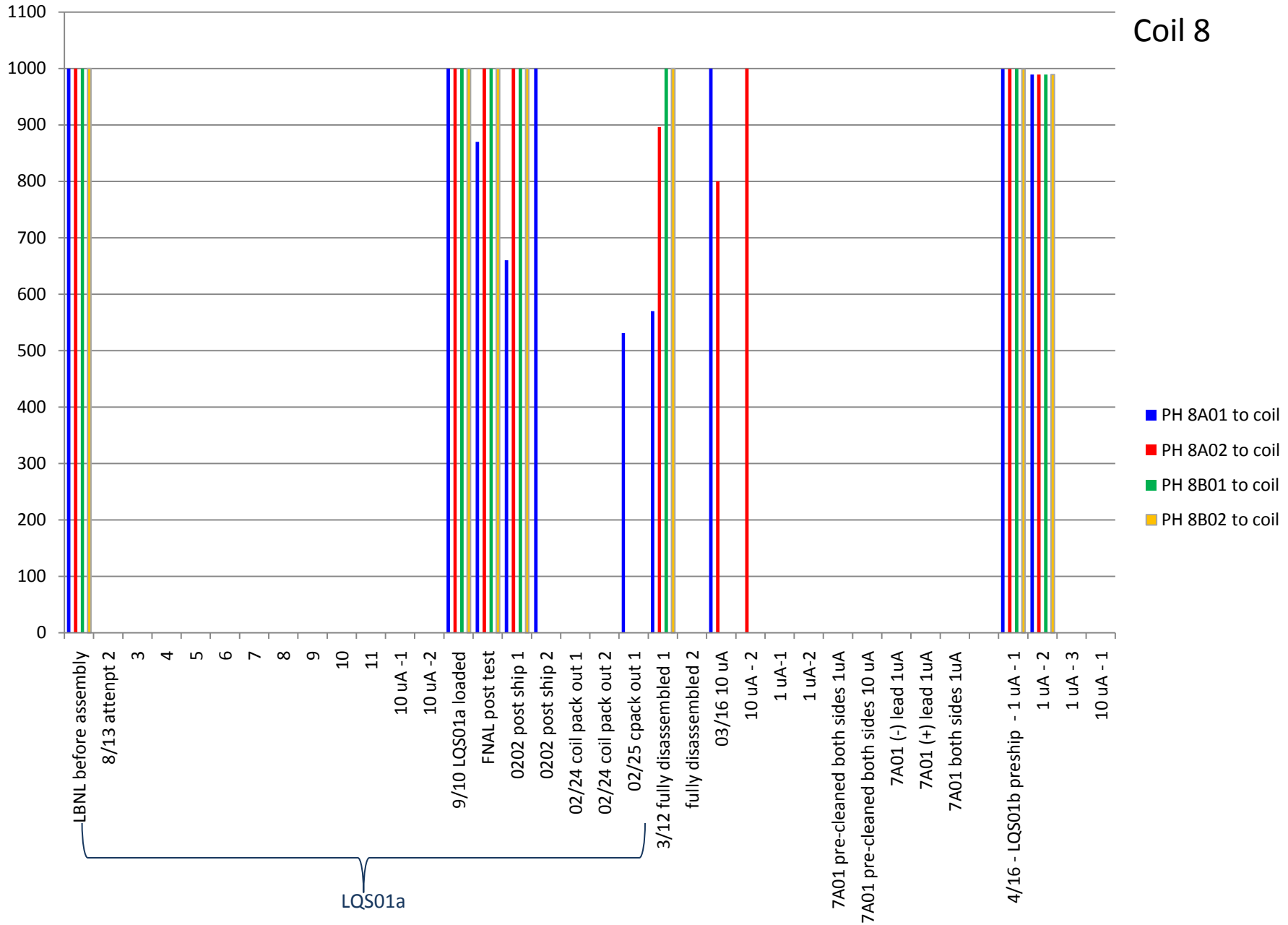
- Strip replaced by a wire ~ 10 cm

  => Hipot ok, Rheater ~ 6.2 ohms



Coil 9


1100
1000
900
800
700
600
500
400
300
200
100
0
LBNL before assembly
8/13 attenpt 2
3
4
5
6
7
8
9
10
11
10 uA -1
10 uA -2
9/10 LQS01a loaded
FNAL post test
0202 post ship 1
0202 post ship 2
02/24 coil pack out 1
02/24 coil pack out 2
02/25 cpack out 1
3/12 fully disassembled 1
fully disassembled 2
03/16 10 uA
10 uA - 2
1 uA-1
1 uA-2
7A01 pre-cleaned both sides 1uA
7A01 pre-cleaned both sides 10 uA
7A01 (-) lead 1uA
7A01 (+) lead 1uA
7A01 both sides 1uA
4/16 - LQS01b preship - 1 uA - 1
1 uA - 2
1 uA - 3
10 uA - 1
LQS01a
PH 9A01 to coil
PH 9A02 to coil
PH 9B01 to coil - cold ok
PH 9B02 to coil not used in a


Coil 8
1100
1000
900
800
700
600
500
400
300
200
100
0
PH 8A01 to coil
PH 8A02 to coil
PH 8B01 to coil
PH 8B02 to coil
LBNL before assembly
8/13 attenpt 2
3
4
5
6
7
8
9
10
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3/12 fully disassembled 1
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03/16 10 uA
10 uA - 2
1 uA-1
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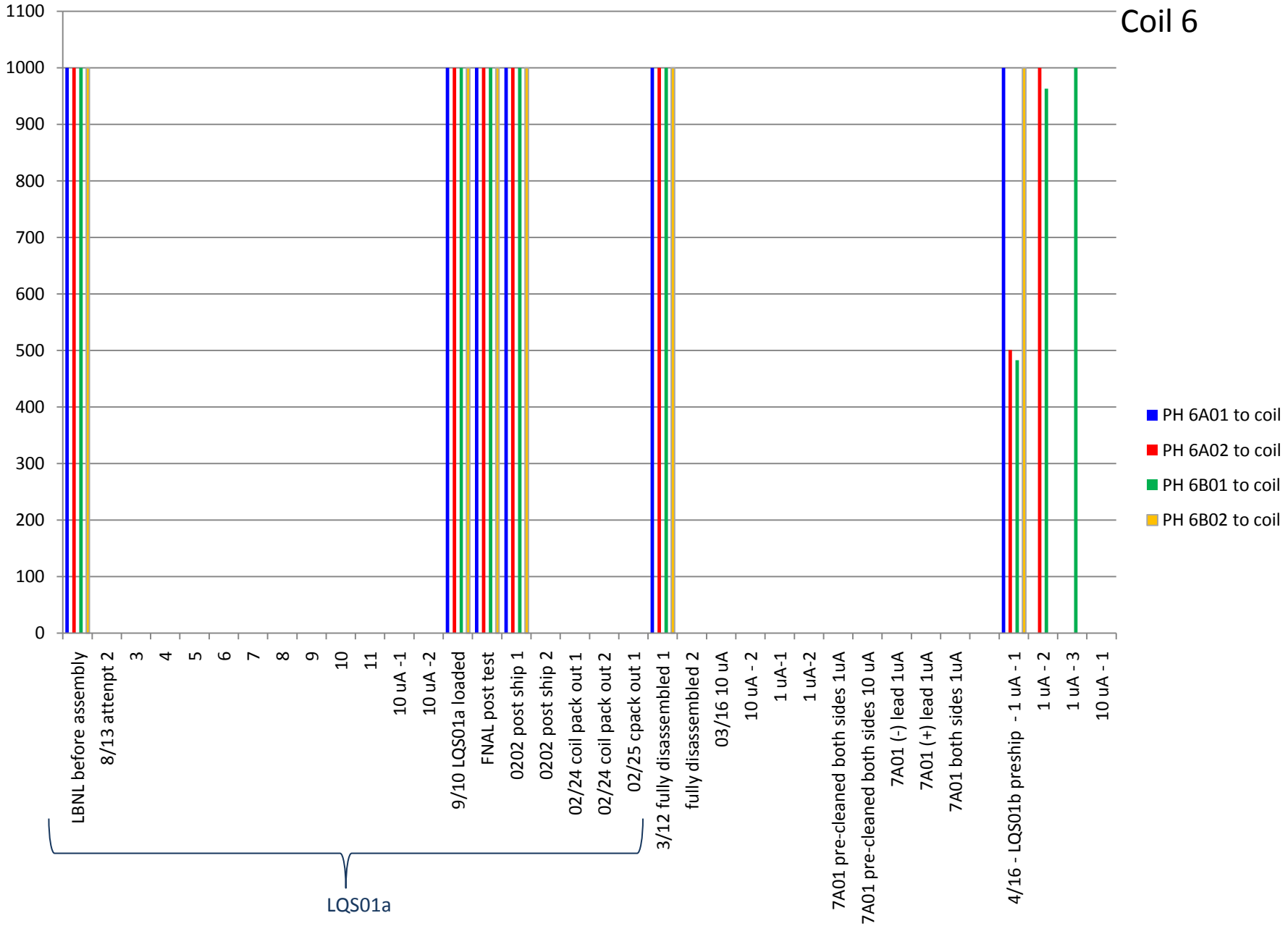
7A01 pre-cleaned both sides 10 uA
7A01 (-) lead 1uA
7A01 (+) lead 1uA
7A01 both sides 1uA
4/16 - LQS01b preship - 1 uA - 1
1 uA - 2
1 uA - 3
10 uA - 1
LQS01a


Coil 6
1100
1000
900
800
700
600
500
400
300
200
100
0
PH 6A01 to coil
PH 6A02 to coil
PH 6B01 to coil
PH 6B02 to coil
LBNL before assembly
8/13 attenpt 2
3
4
5
6
7
8
9
10
11
10 uA -1
10 uA -2
9/10 LQS01a loaded
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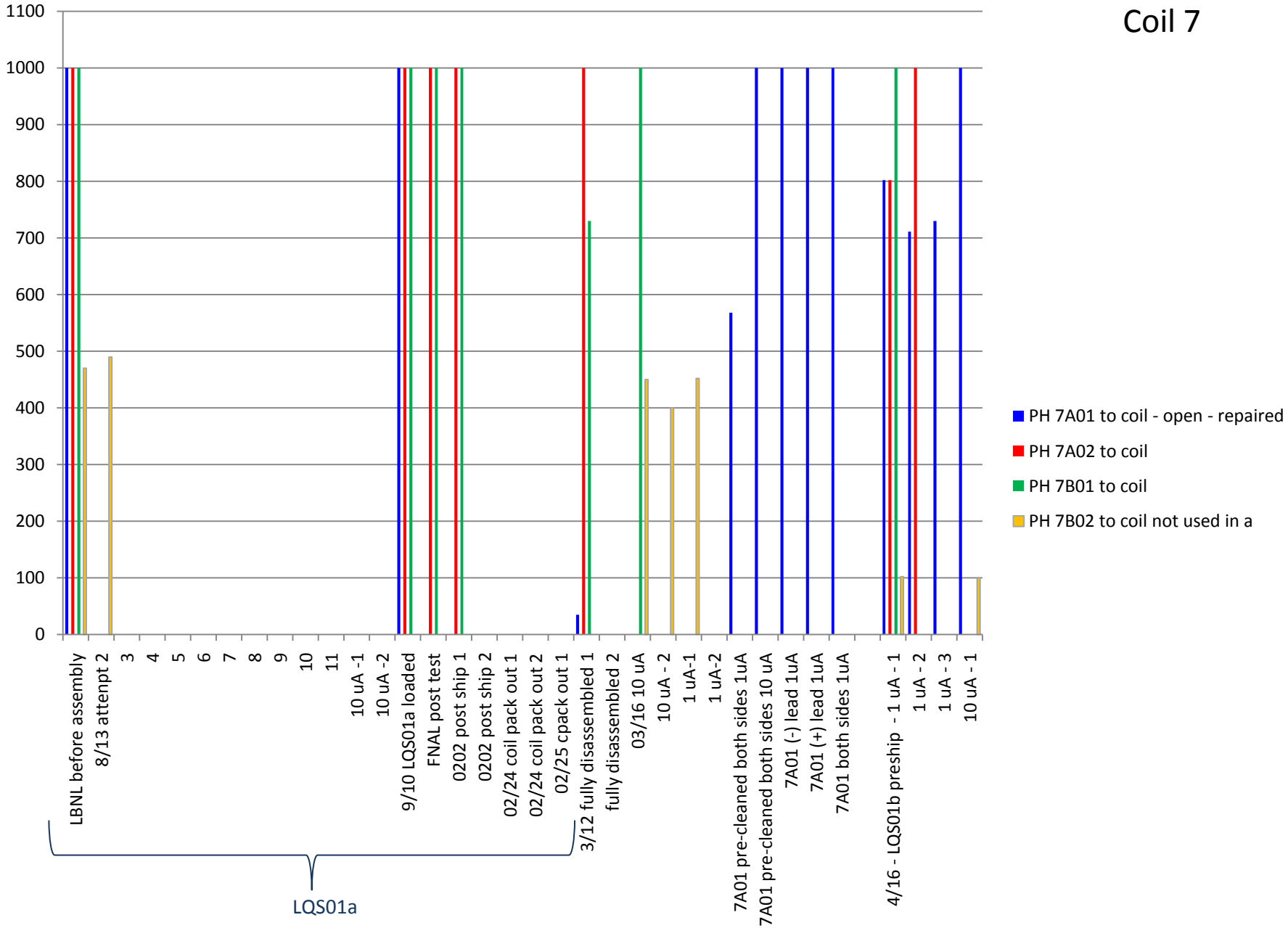
1 uA - 2
1 uA - 3
10 uA - 1
LQS01a

Coil 7


1100
1000
900
800
700
600
500
400
300
200
100
0
LBNL before assembly
8/13 attenpt 2
3
4
5
6
7
8
9
10
11
10 uA -1
10 uA -2
9/10 LQS01a loaded
FNAL post test
0202 post ship 1
0202 post ship 2
02/24 coil pack out 1
02/24 coil pack out 2
02/25 cpack out 1
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fully disassembled 2
03/16 10 uA
10 uA - 2
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7A01 pre-cleaned both sides 10 uA
7A01 (-) lead 1uA
7A01 (+) lead 1uA
7A01 both sides 1uA
4/16 - LQS01b preship - 1 uA - 1
1 uA - 2
1 uA - 3
10 uA - 1
LQS01a
PH 7A01 to coil - open - repaired
PH 7A02 to coil
PH 7B01 to coil
PH 7B02 to coil not used in a

Summary

LQS01b Coils on the table (before assembly)

	Coil 8	Coil 7	Coil 6	Coil 9
A01	OK at 10 uA	open	OK	OK
A02	OK at 10 uA	OK	OK	NO (27V)
B01	OK	OK at 10 uA	OK	OK at 10 uA
B02	OK	NO (450 V)	OK	OK at 10 uA

LQS01b pre-shipment

	Coil 8	Coil 7	Coil 6	Coil 9
A01	OK	OK (repaired)	OK	OK
A02	OK	OK	OK	OK but (27V)
B01	OK	OK	OK	OK at 10 uA
B02	OK	NO (450 V)	OK	OK at 10 uA

OK with 1 uA range

OK with 10 uA range

Not OK because of previous events

- LQS01b PH powering:
  - PH wired separately (14 circuits used)
    - C7 B02 not wired
    - 2 strips in parallel (C6B02 and C8B02)
  - 2 circuits remaining for 2 spot heaters

Next steps for the inner layer PH

- If gap between coil ID and impreg. fixture allows, Coil 13 may implement:
  - Nomex
  - Ceramic cloth
  - S2 glass

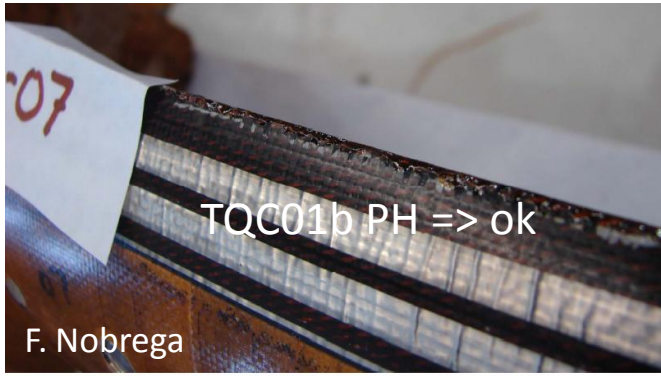
- Set heaters between inner and outer layer
  - Glued by ceramic binder in a sandwich between two S2 or ceramic cloths

- Heating stations do not show such large bubbles => presence of small hole in the Kapton of the trace (?)
  - Additional holes?
  - How?

Status

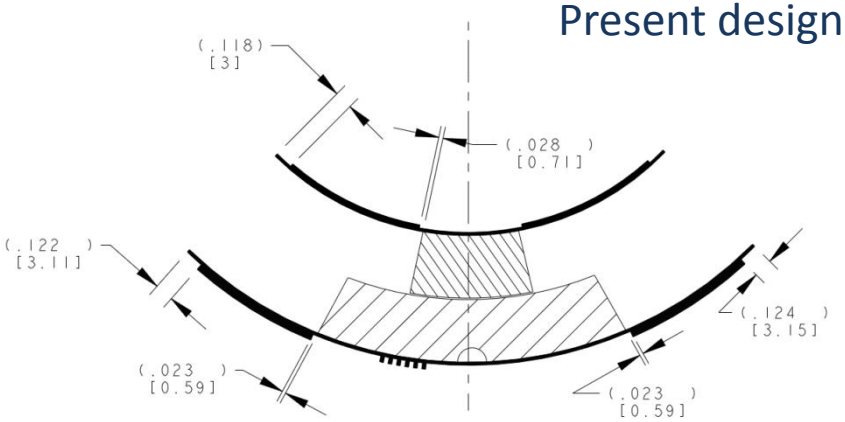
- Repair performed before LQS01b assembly
  - Coil 09 station 4 strain gage repaired
  - Modif of T compensator thickness
  - Rods SG repair

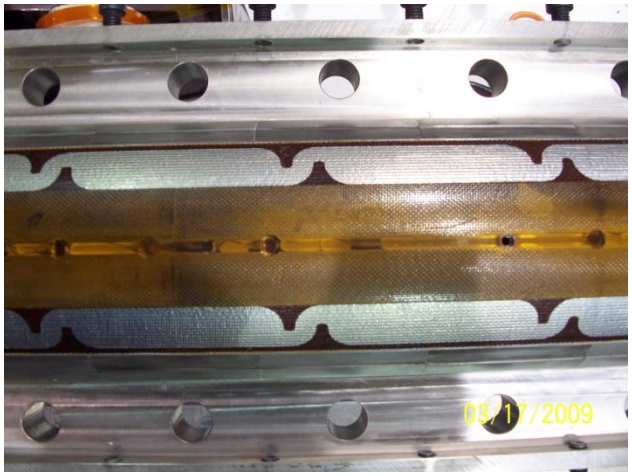
- Coil 10 instrumented
- Coil 11 and 12 at LBL
  - Coil 12 PH post-impregnation visual inspection => wrinkles everywhere along layer 1 PH



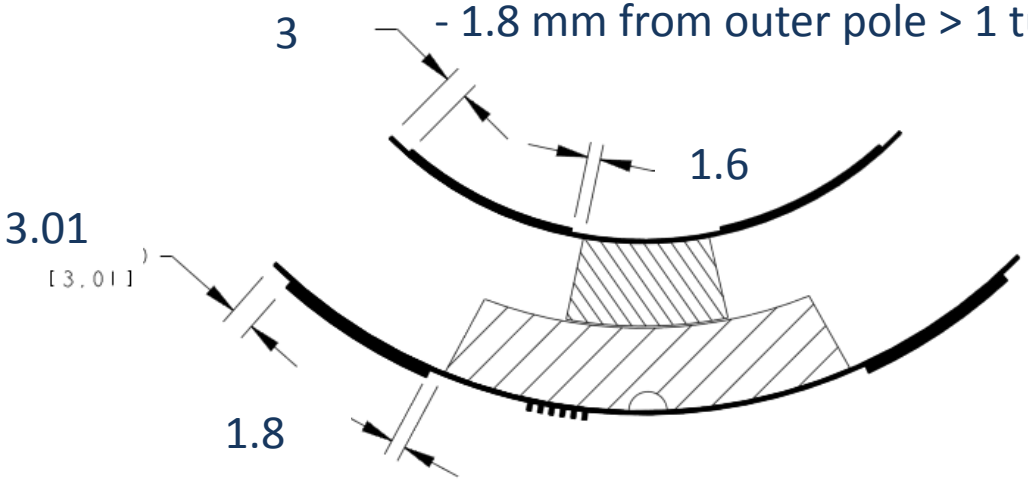
Next trace fabrication

Present design





Revised design 2 (June 09):
- 3 mm from mid-plane
- 1.8 mm from outer pole > 1 turn



New trace fabrication
⇒ possible revision of the design in discussion
⇒ to implement in coil 15