MBHA-002 results
Quick upate
05 Febuary 2020

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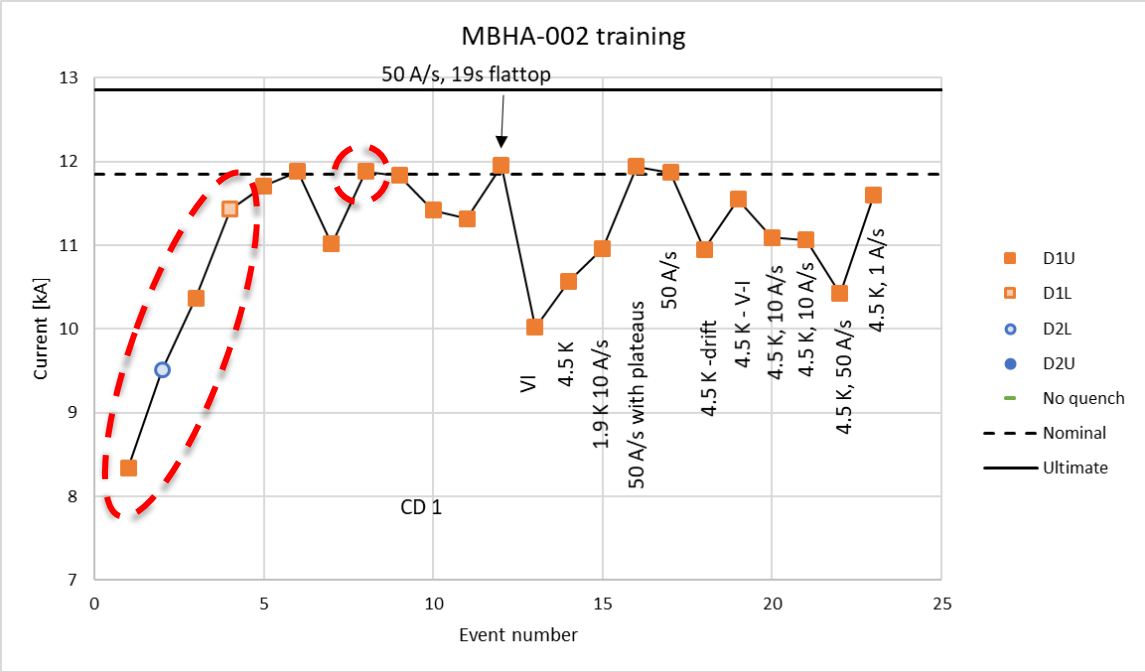
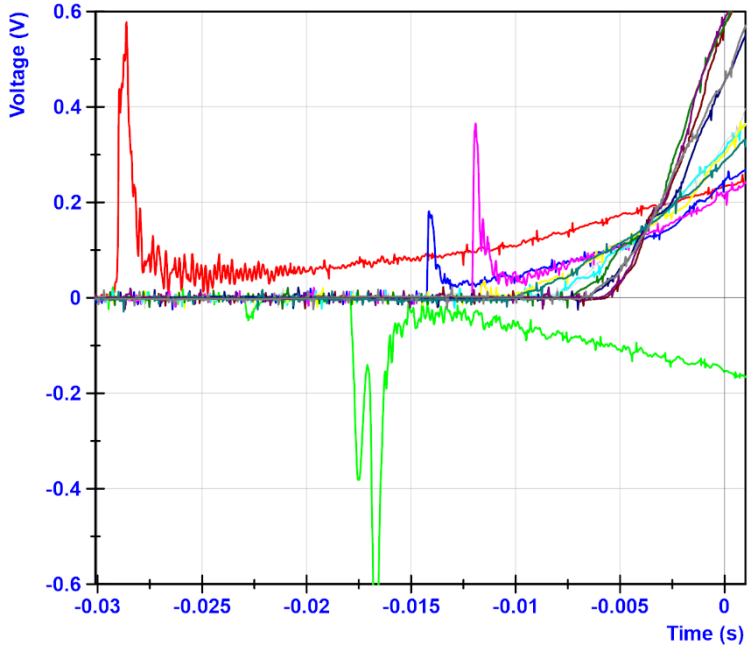
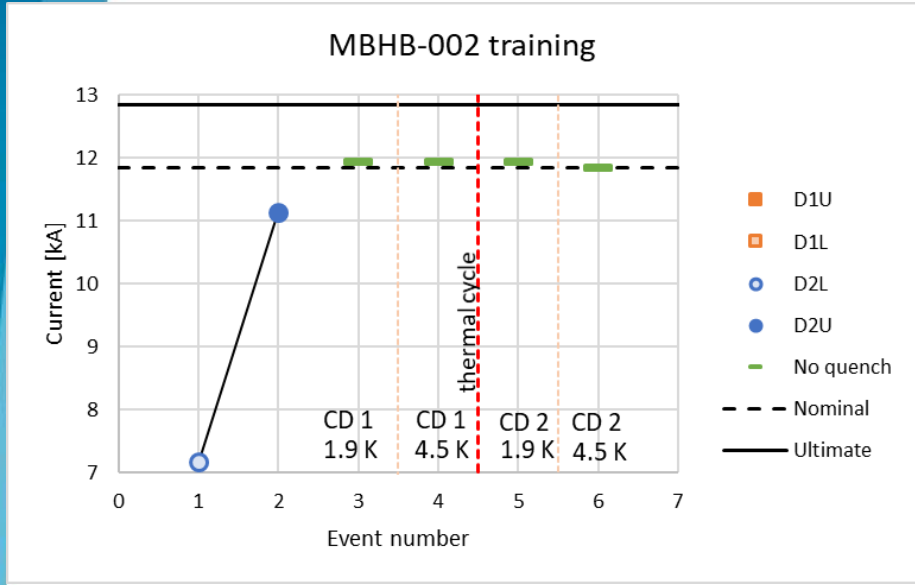
Training

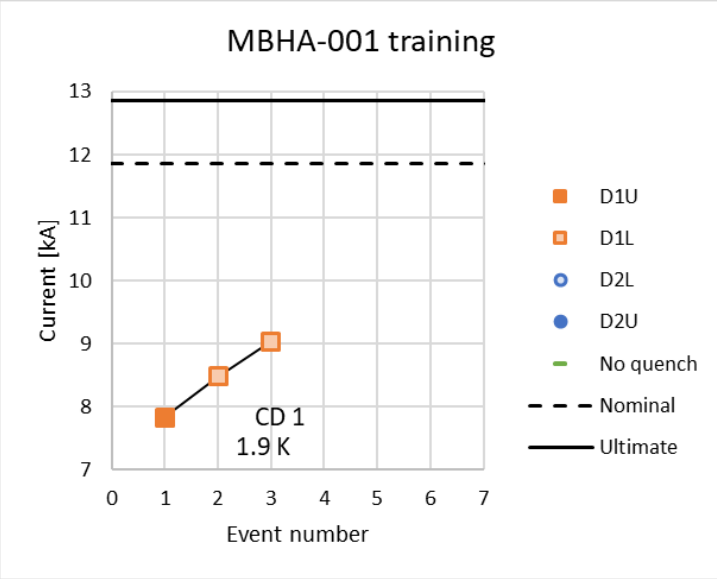


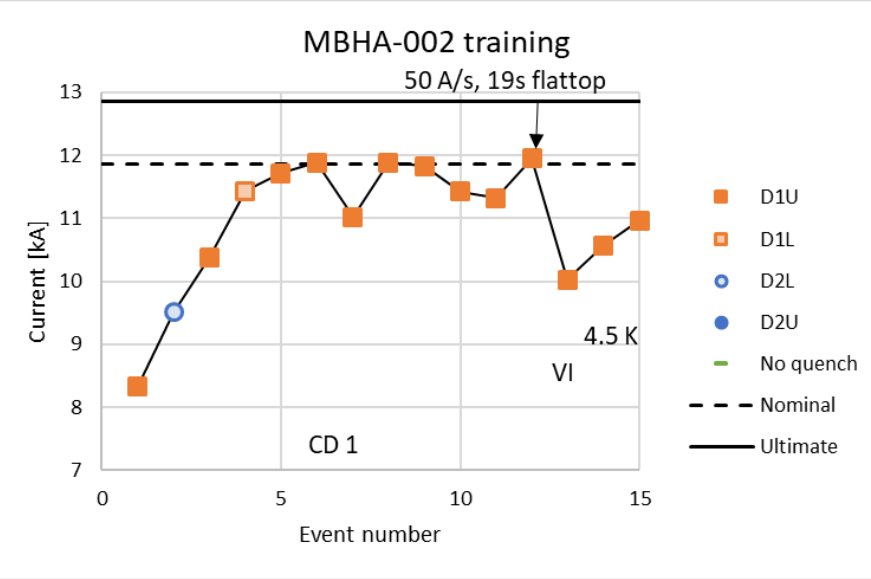


Fast training, 5 training quenches in the heads on the connection side, showing vibration precursors.
1 in D2L
1 in D1L
3 in D2U

Training overview







MBHB-002

Only 2 quenches
No retraining after thermal cycle
4.5 K no quench, showing conductor margin.

Qualified.
Test report, see EDMS 2211895

MBHA-001

3 training quenches
Issue identified (wiring, see next slides) and training was stopped.

Test report first cool down, see EDMS 2281449

Coming back to SM18 end of this week.

MBHA-002

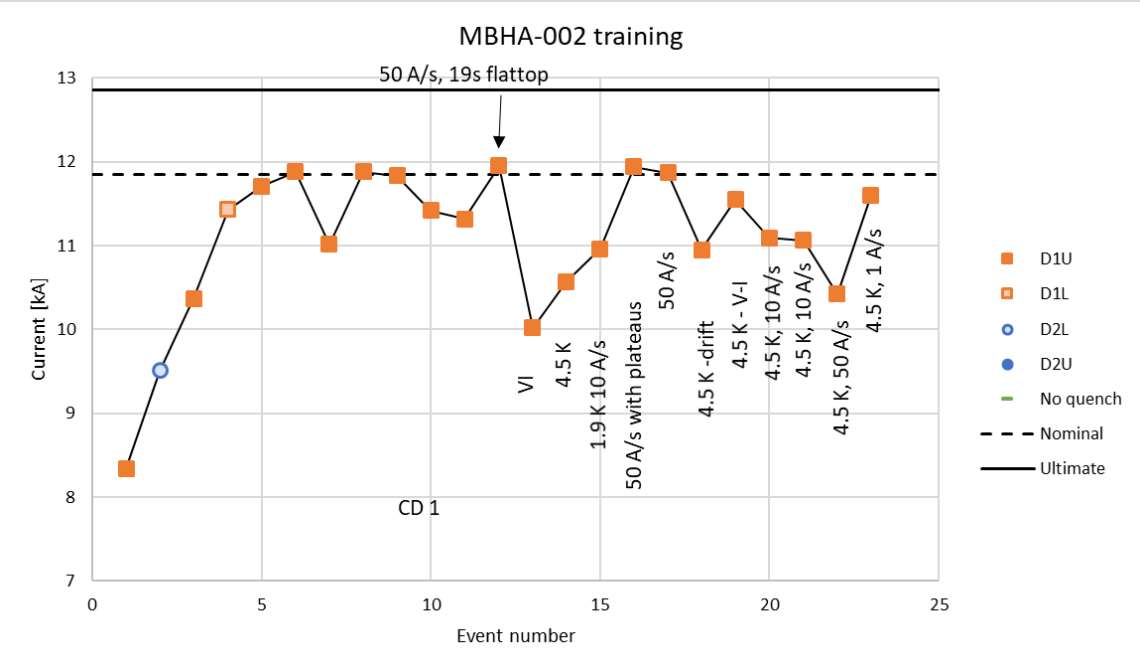
Fast training to 11.5 kA, then showing quenches varying between 11 and 11.9 kA at 1.9 K, 10 A/s.

50 A/s reached target of 11.95 kA, but with flattop quench after 19 seconds.

V-I cycle (15 minutes at stable current of 2, 4, 6, 8 and 10 kA) quenched at 10015 A.

10.5 kA at 4.5 K

Quench history

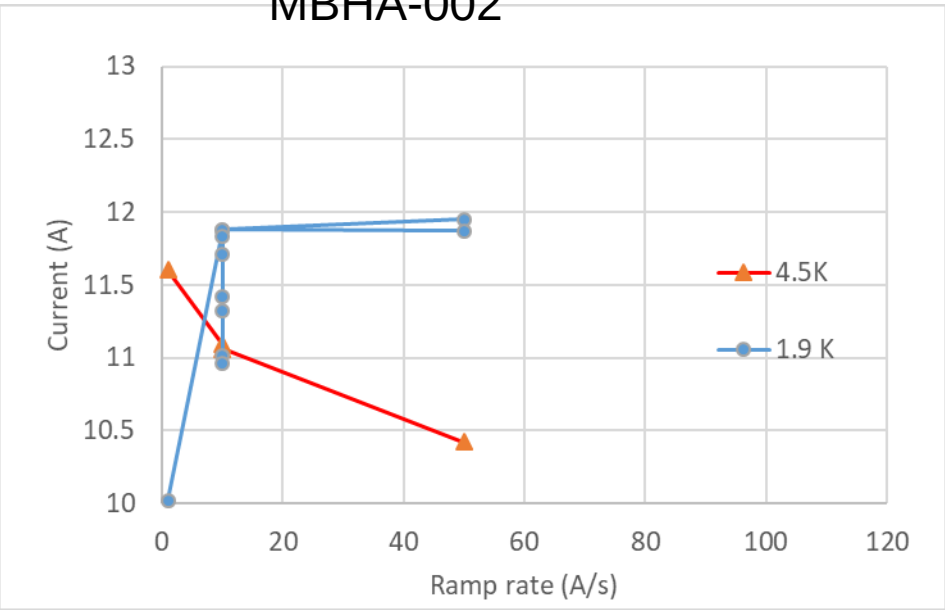


	Ramp rate	Temperature	Current	Precursor	Location	Location		QA	LQA
1	10	1.9	8.34	Yes	D1U	CS	head	1 and 2	
2	10	1.9	9.51	Yes	D2L	CS	head	1	
3	10	1.9	10.37	Yes	D1U	CS	head	1	
4	10	1.9	11.43	Yes	D1L	CS	head	1	
5	10	1.9	11.71	No	D1U	NCS		5	
6	10	1.9	11.88	No	D1U	NCS		5	
7	10	1.9	11.015	No	D1U	NCS		5	
8	10	1.9	11.88	Yes	D1U	CS	head	1	
9	10	1.9	11.83	No	D1U	NCS		5	
10	10	1.9	11.42	No	D1U	NCS		5	
11	10	1.9	11.32	No	D1U	NCS	head		<1 (shifted)
12	50	1.9	11.95	No	D1U	NCS	head		3
13	VI	1.9	10.02	No	D1U	NCS	head		3
14	10	4.5	10.57	No	D1U	Straight	~40-50 cm from head		>11
15	10	1.9	10.96	No	D1U	NCS	head		3
16	flattops	1.9	11.938	No	D1U	Straight	~40-50 cm from head		
17	50	1.9	11.87	No	D1U	NCS	head		<1
18	10	4.5	10.95	No	D1U	Straight	~40-50 cm from head		>11
19	V-I	4.5	11.55	No	D1U	Straight	~105 to 115 cm from head		>11 (shifted)
20	10	4.5	11.09	No	D1U	NCS	head		<1 (shifted)
21	10	4.5	11.06	No	D1U	NCS	head		<1 (shifted)
22	50	4.5	10.42	No	D1U	NCS	head		<1 (shifted)
23	1	4.5	11.6	No	D1U	Straight	~105 to 115 cm from head		>11

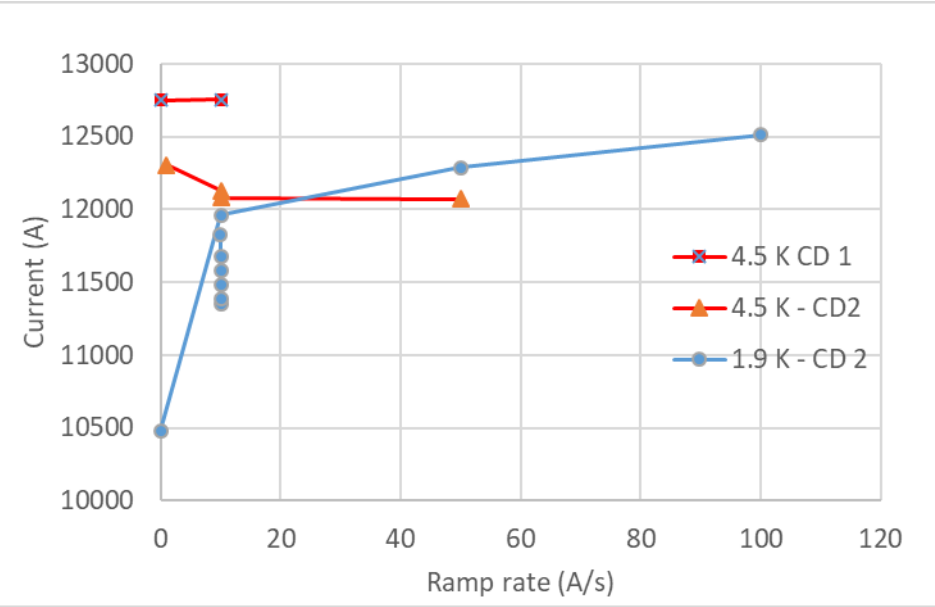
Some issues appeared with erratic quench patterns.
Coil D1U does not show stable performance.

Ramp rate and temperature dependency

MBHA-002



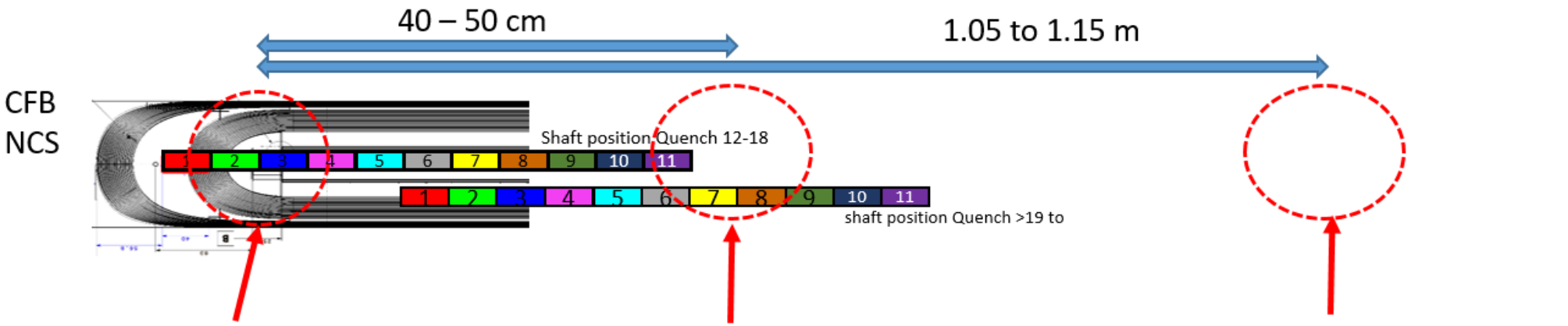
For comparison MBHB-001 hybrid



Instability at 1.9 K at 10 A/s.
Reproducibility at 4.5 K at 10 A/s.

4.5 K higher ramp rate gives lower quench current
4.5 K highest quench current with very low ramp rates

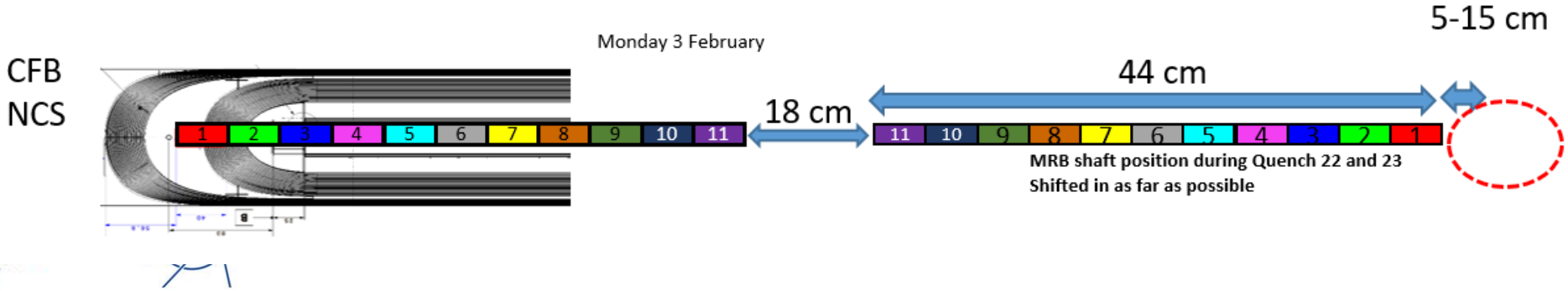
Quench Location



1.9 K, 10 A/s – all quenches
1.9 K, 50 A/s+ 19seconds plateau
1.9 K V-I cycle
4.5 K, 10 A/s – 2 quenches
4.5 K, 50 A/s

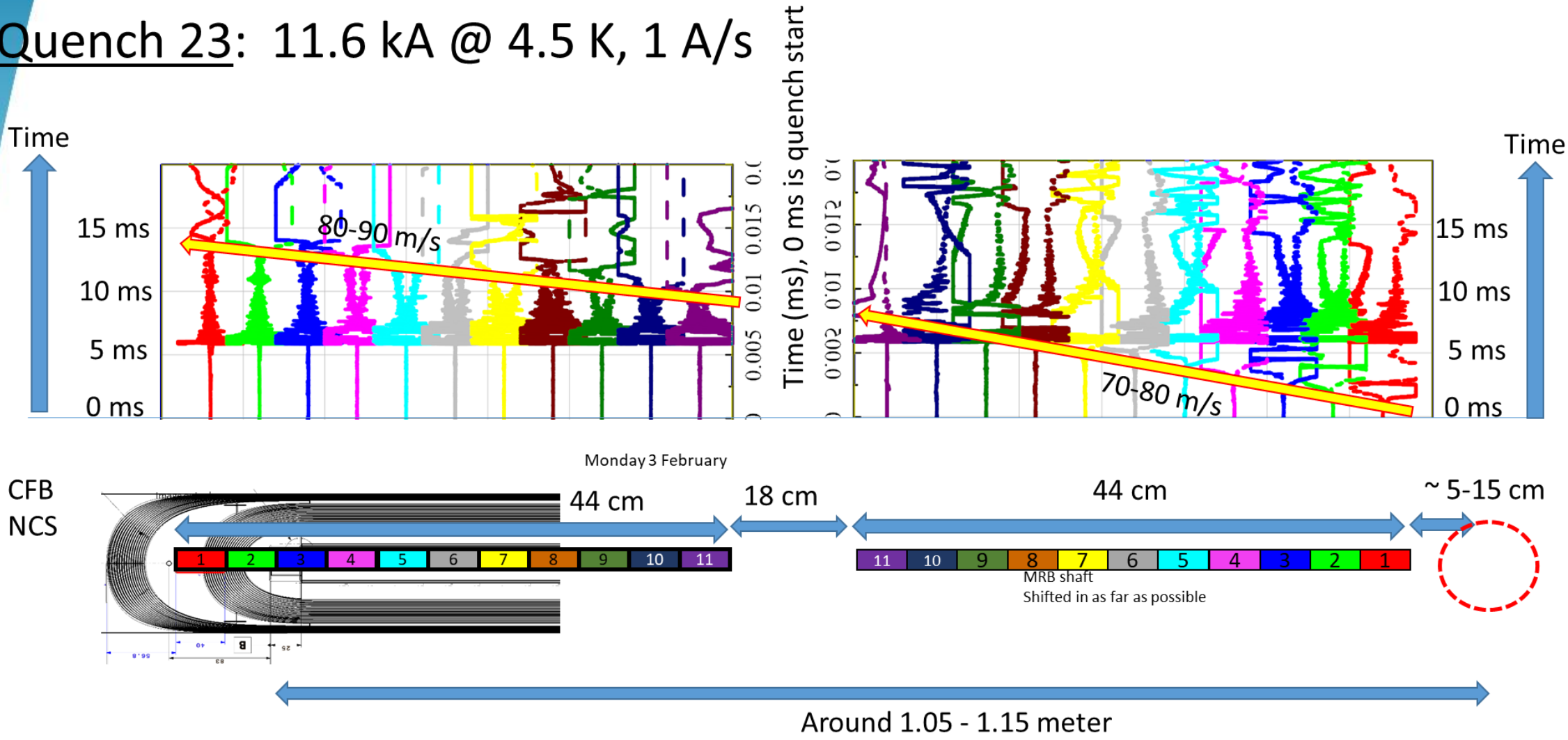
1.9 K, 50 A/s
4.5 K after drift from 1.9 k (2 times)

4.5 K V-I cycle
4.5 K 1A/s ramp (special cycle)



Quench propagation

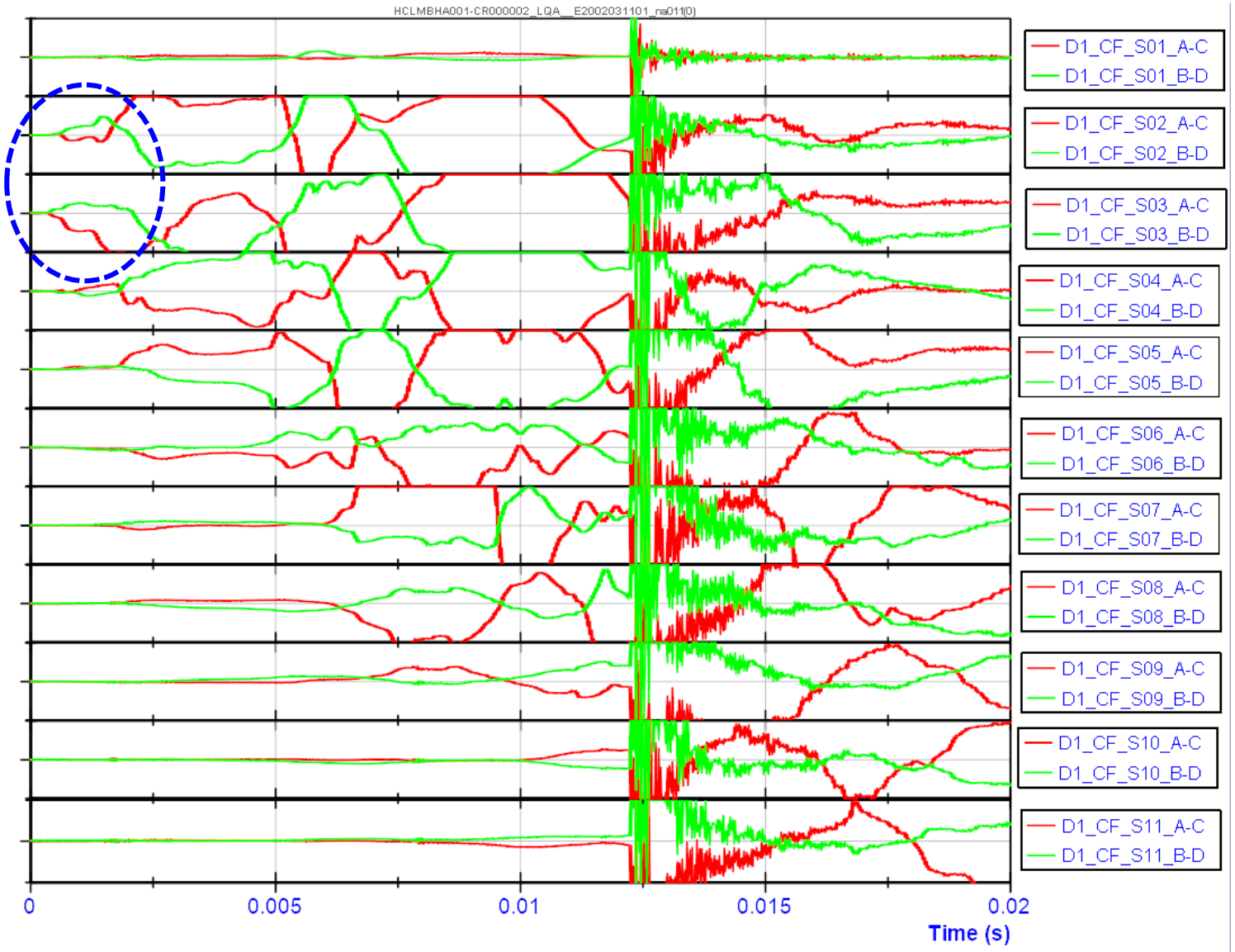
Quench 23: 11.6 kA @ 4.5 K, 1 A/s

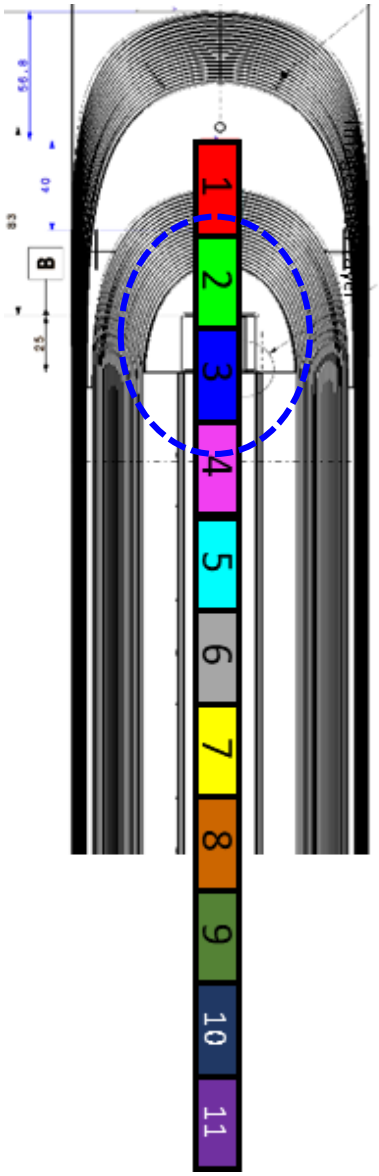


Very fast propagation

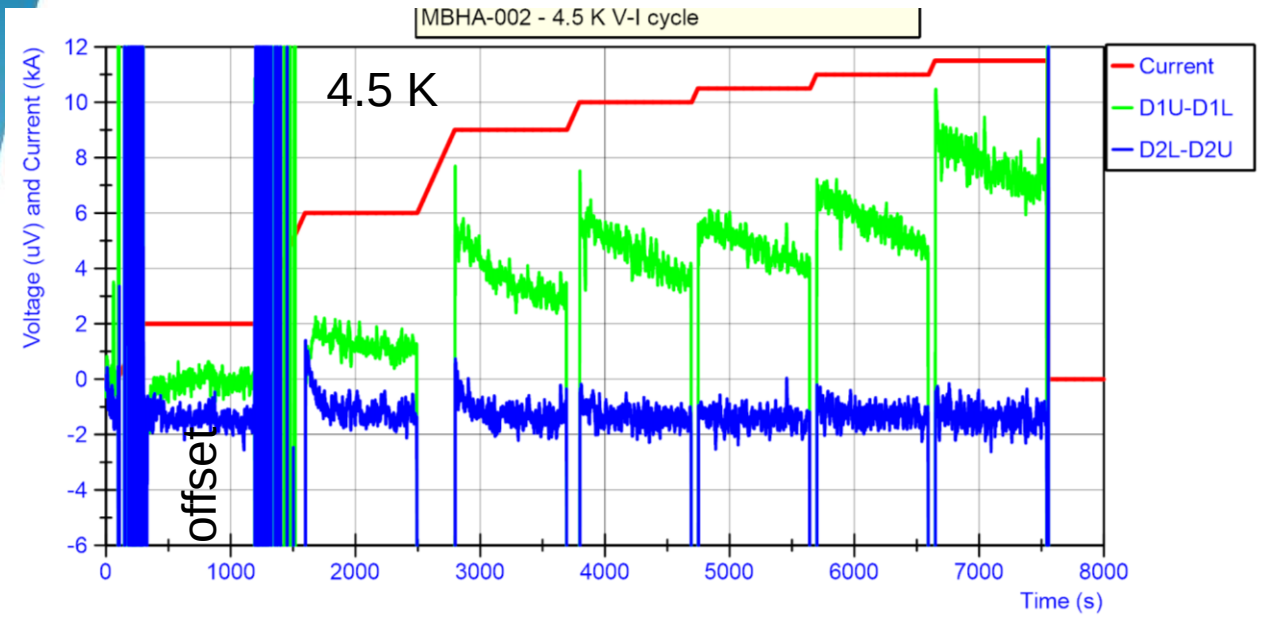
Quench 22: 10.43 kA @ 4.5 K, 50 A/s

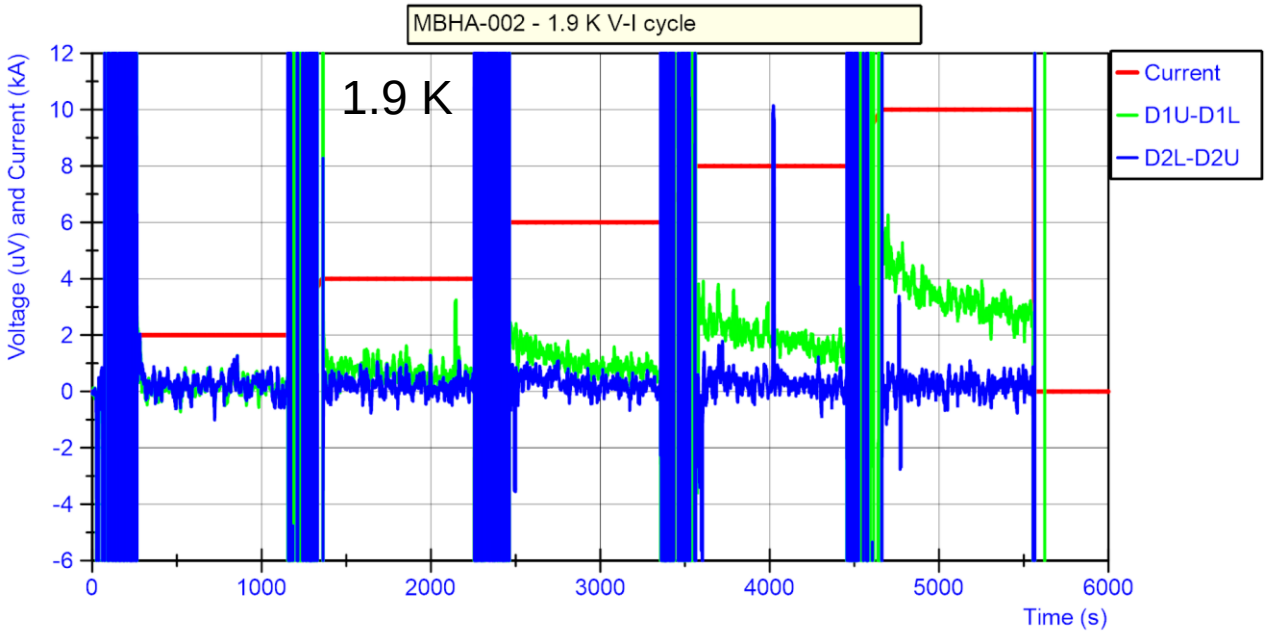
Abnormal propagation:

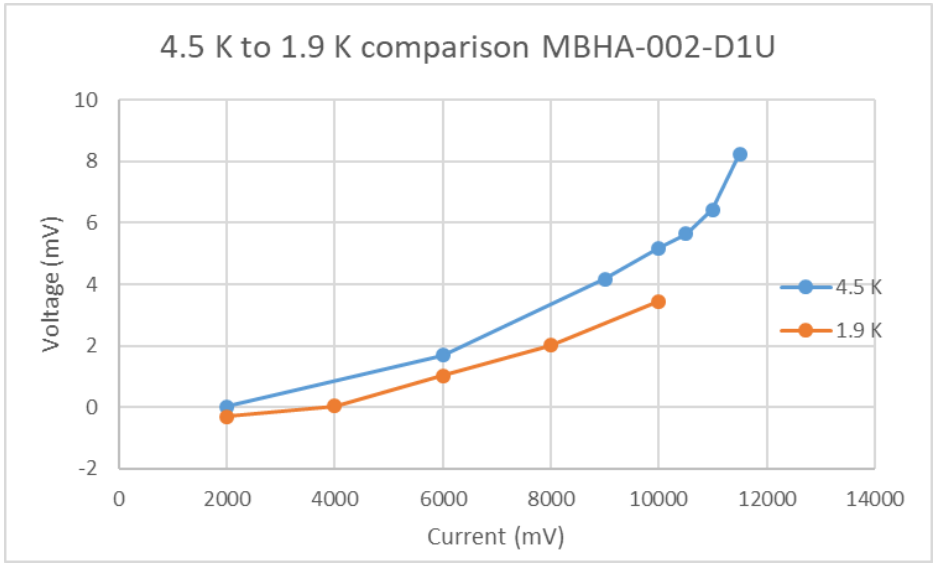




V-I measurements



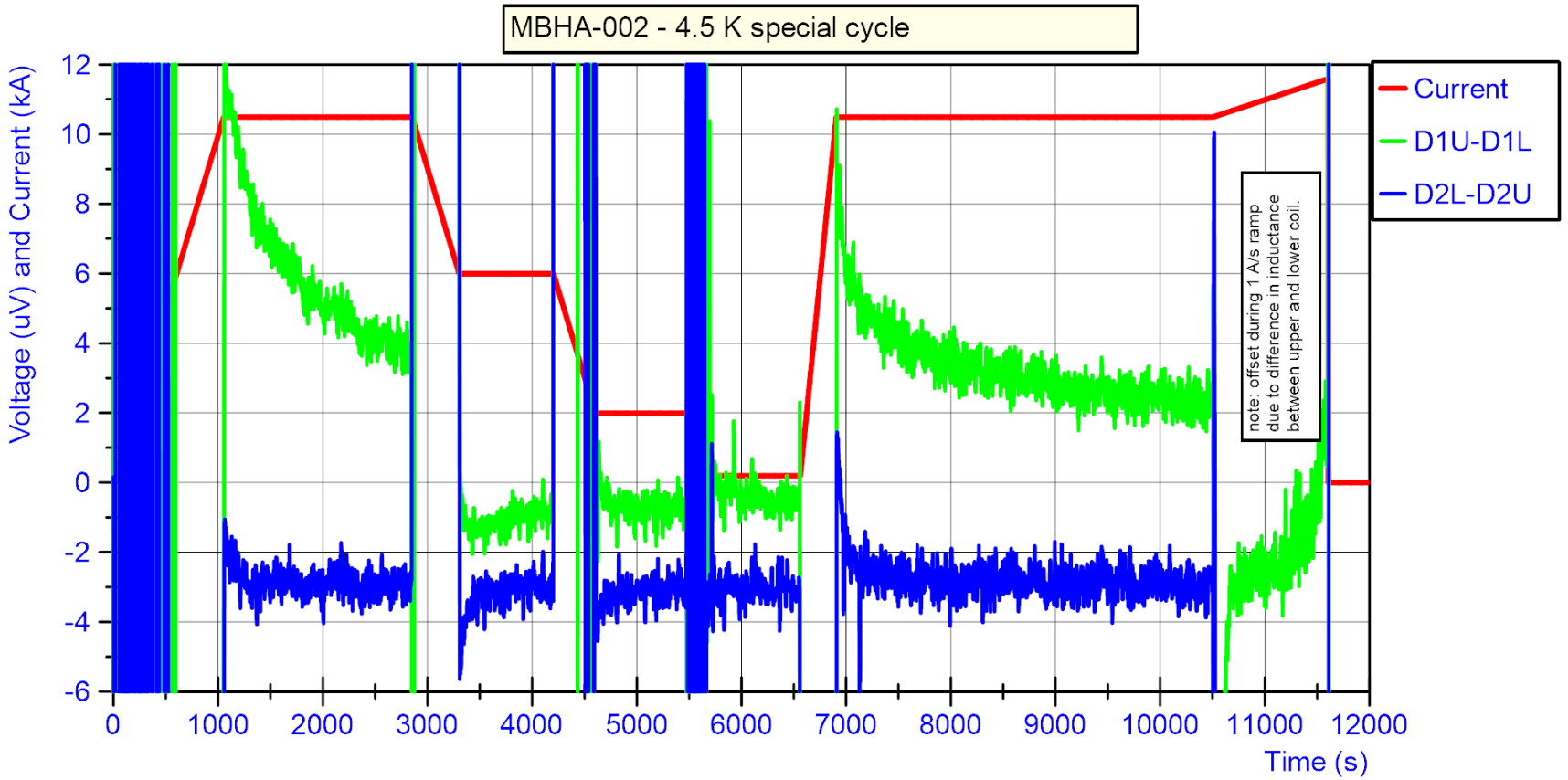




- Significant voltage buildup in voltage in coil D1U
- Voltage buildup starts from very low current of 6 kA
- Clear decay of voltage on current plateaus.

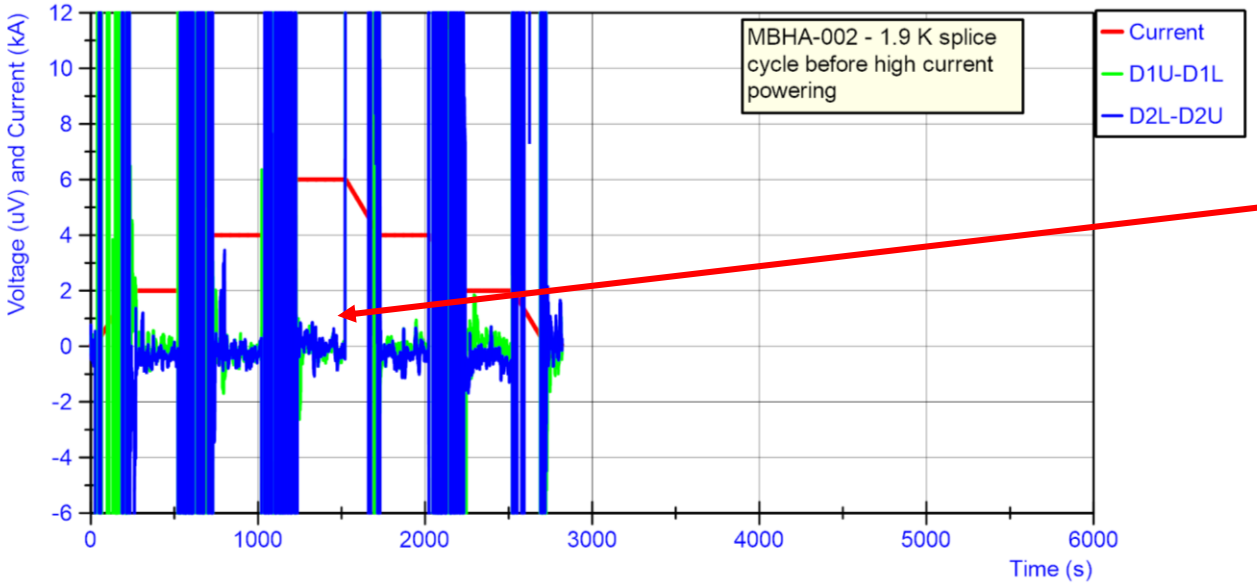
- No sign of degradation in aperture 2, nor in coil D1L

Additional V-I measurements



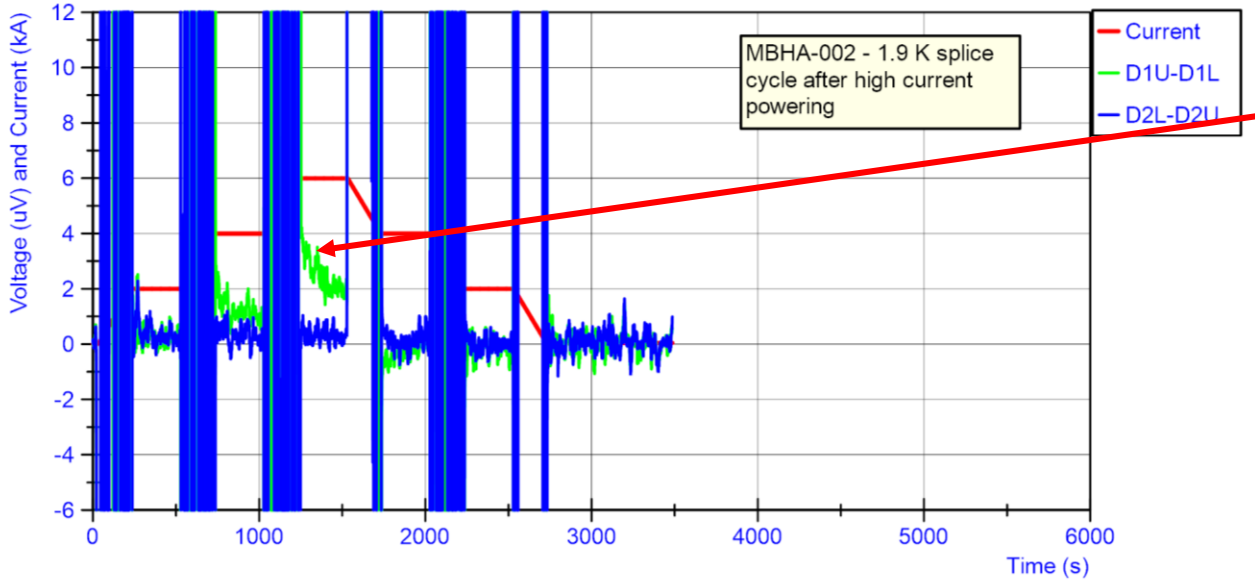
Several features:

- 10 A/s ramp straight to 10.5 kA, reaching 12 uV, showing decay time constant on 30 minutes plateau
- Ramp down to 6 kA, shows **negative voltage**
- 30 A/s ramp to 10.5 kA (lower voltage than 10 A/s ramp, this can be influenced by pre-cycles).



First powering to 6 kA was a splice cycle including V-I measurements.
No sign of any voltage.

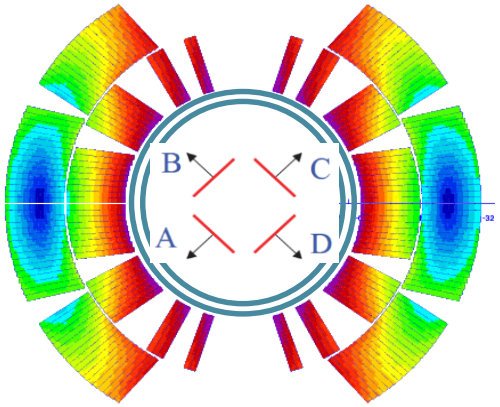
This was the first time this magnet reached 6 kA.



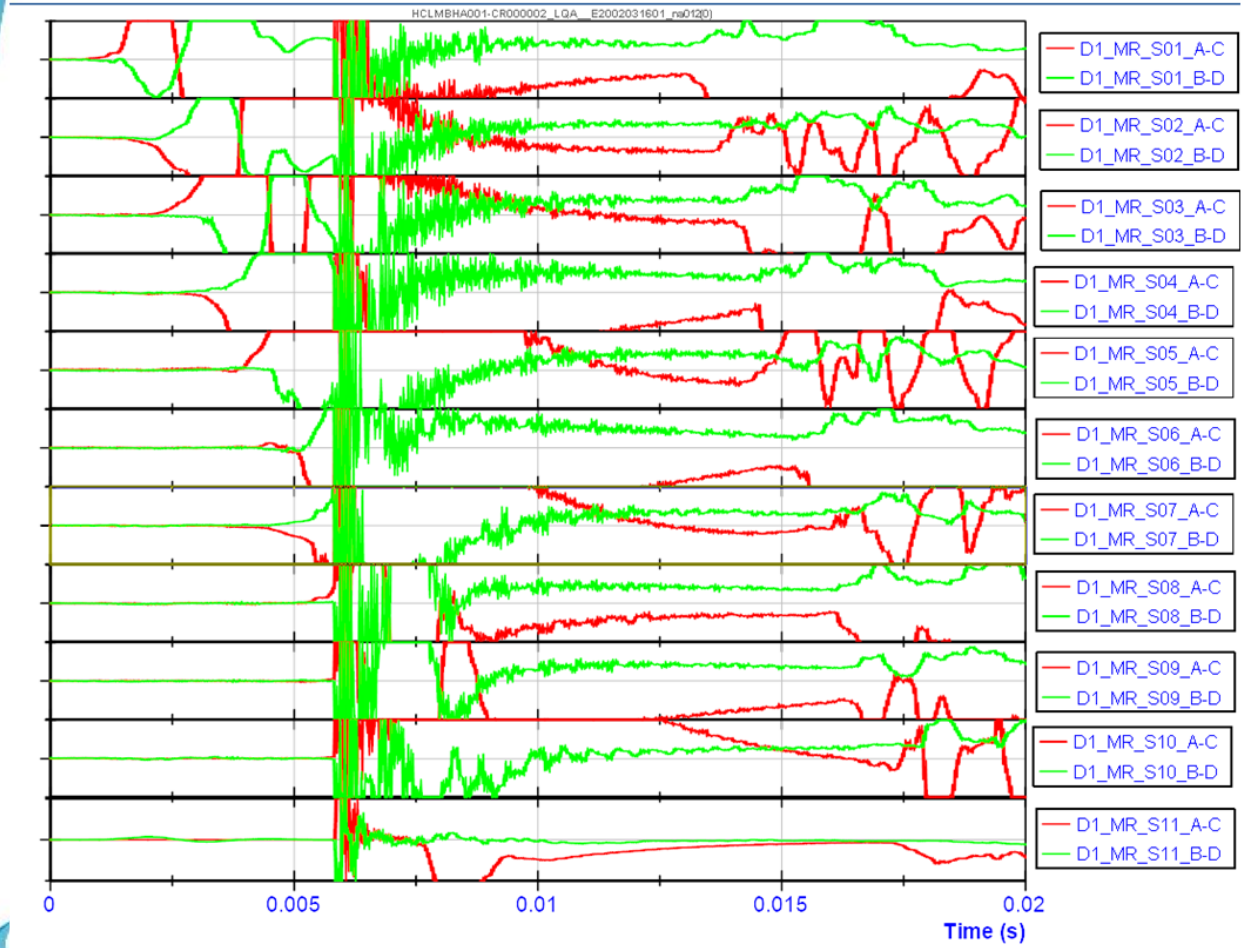
Clear voltage at 6 kA
This was the last powering before warm up.

Conclusion: a weakness appeared, or an existing weaknes degraded more during the powering/quenching.

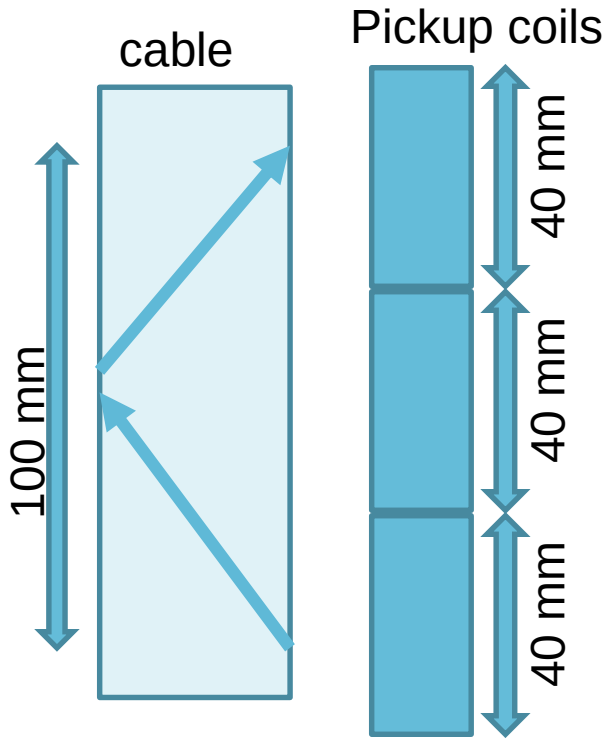
Anomaly in LQA signals



Quench 23: 11.6 kA @ 4.5 K, 1 A/s (start 1.1 meter from the head, MRB shaft inserted towards CFB end)
Abnormal propagation:
Curves A-C flip sign for most segments. (transposition pitch 100 mm, pickup coil length 40 mm)



To be studied:
Can a quench propagate through a single strand (or a few strands)



To check
Quench signal should repeat each 5 segments.

If always the same strand has propagating quench, repeatibitly between quench.

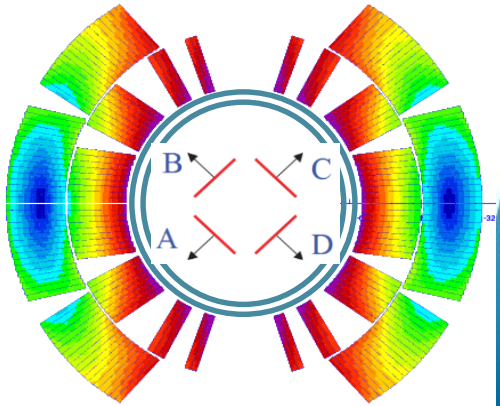
Conclusion

- Coil D1U has a clear damage
- Decay in V-I curves indicate current redistribution -> Local defect
- Voltage buildup starts at very low current -> severe damage to some of the conductor

- 3 quench locations:
  - We believe that the 50 A/s ramp at 4.5 K forces the current through the defect the most and may indicate the location of the defect. The defect is therefore most likely in the head.
  - At 1.9 K the large variation in quench current indicates self-field instabilities
  - Quenches in the straigth segment are assumed to result from current redistribution effects caused by the defect.

- The pickup coils give propagation signals on the straigth part inconsistent with any earlier proposed model.

There are no good models for localizing quenches in the head.
Difficult to pinpoint the defect to a single turn.



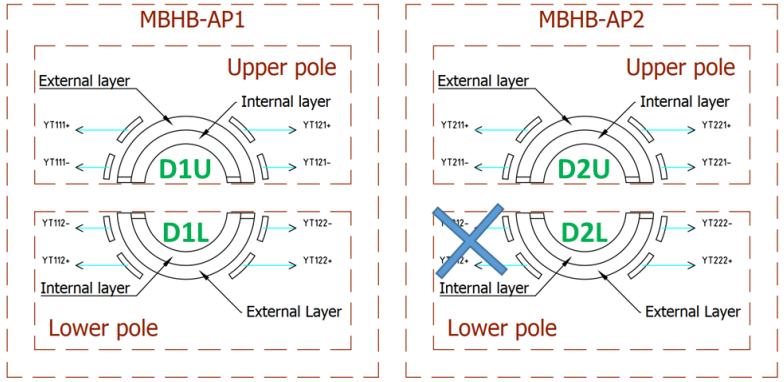
QH discharges and protection

MBHA-002 Quench heater failure

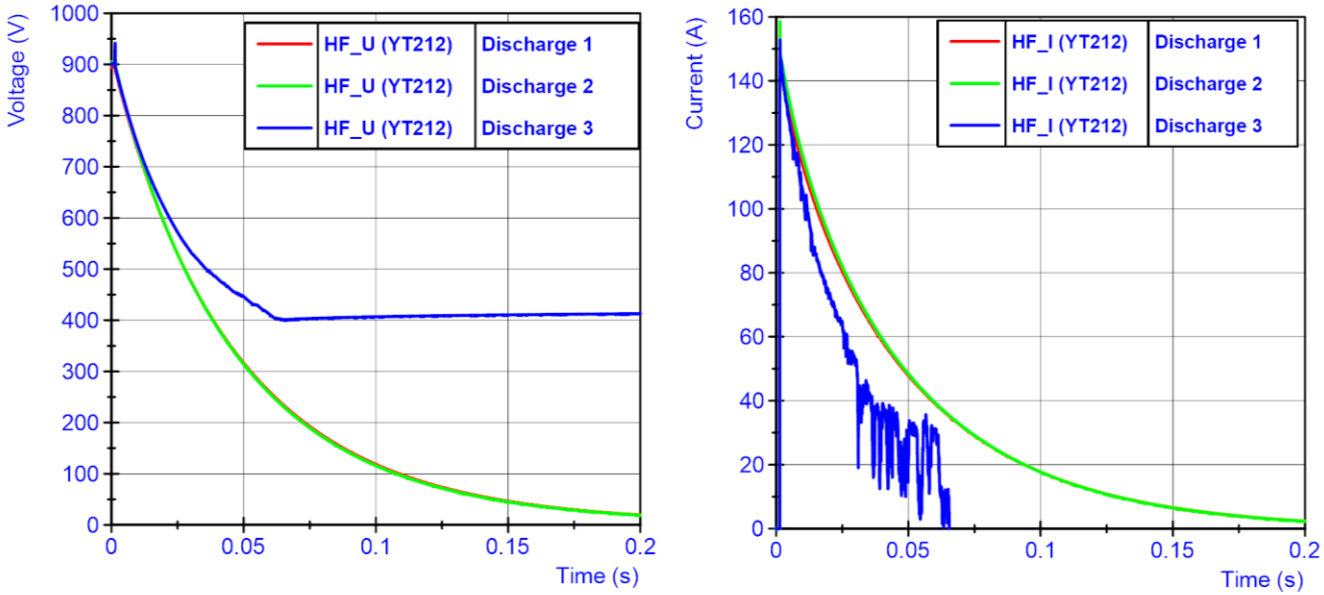
Quench Heater circuit failed in the 3rd heater firing.

- No sign of weakness in discharge 1 and 2.
- Circuit now shows an open loop. Identified with reflectrometry to be about 5 ± 1 m from the IFS box.
- HV insulation test from this heater circuit to coil and ground OK at 1 kV after failure, so test continued with 7 out of 8 QHs.

- First heater to fail in 11T magnet (including models)



QH circuit YT212, Coil D2L, right.



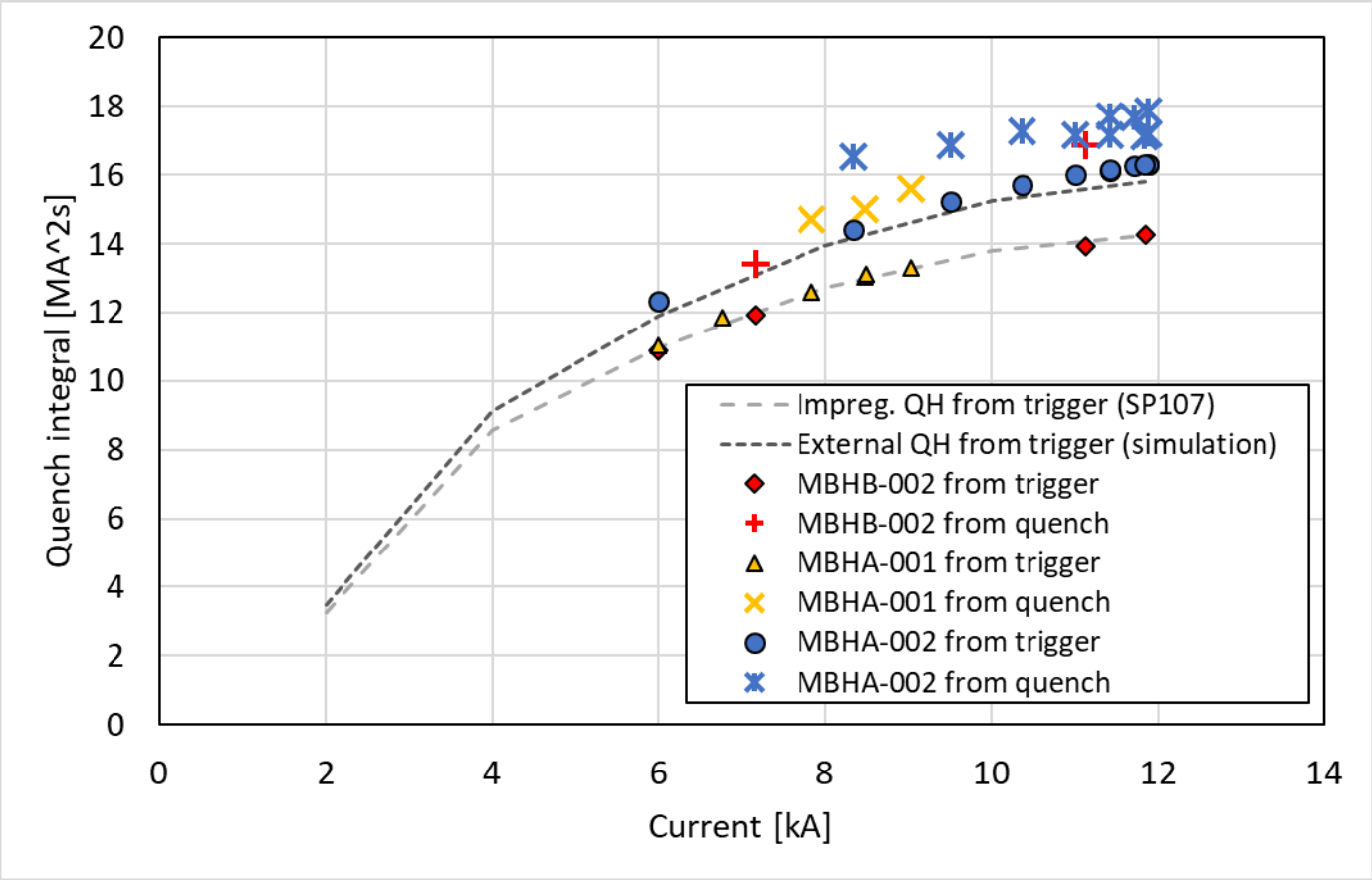
QH firing at 200 A

After all powering test, the heaters YT111 and YT121 (on coil D1U) were tested with a QH current of 200 A with three discharges with good results.

Additional HV tests at 200 K

Today the magnet is at 200 K. HV tests will be performed on heaters YT111 and YT121 (coil D1U).
Test levels: 1 kV, 1.3 kV, 1.6 kV
Helium pressure during test: 10 bar, 3 bar, 1.3 bar.

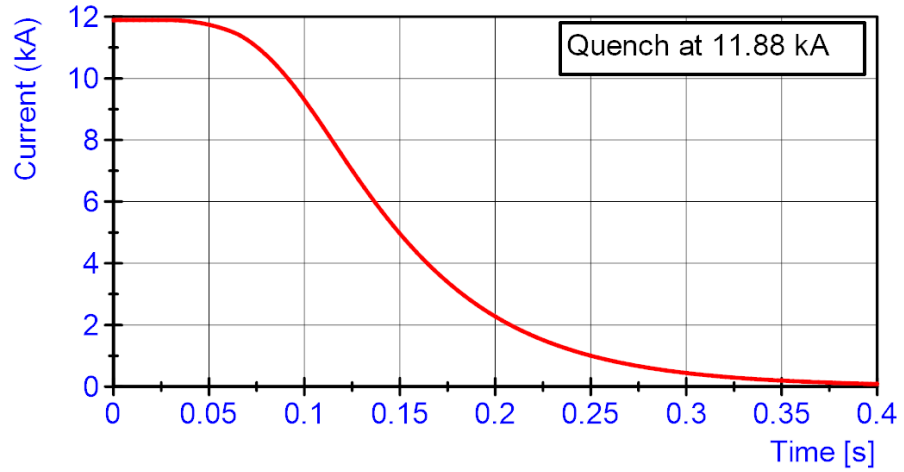
Quench Integral

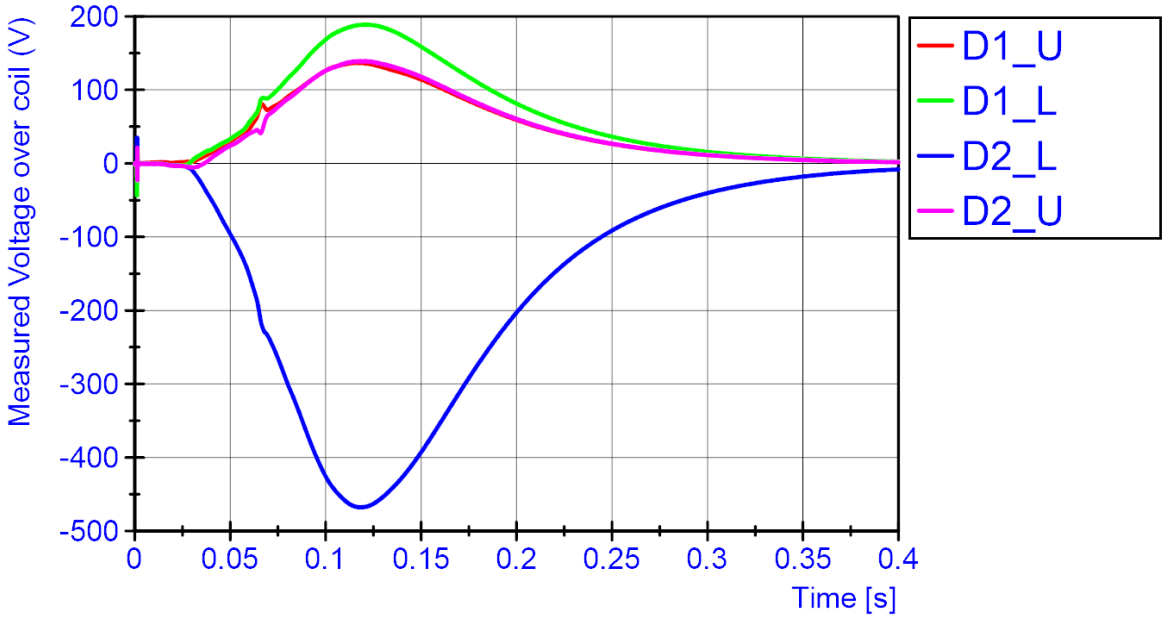


With the quench heaters outside of the impregnation, the QI is higher as predicted.

For MBHA-002 the values are with 7 out of 8 quench heaters.

Voltage imbalance following quench

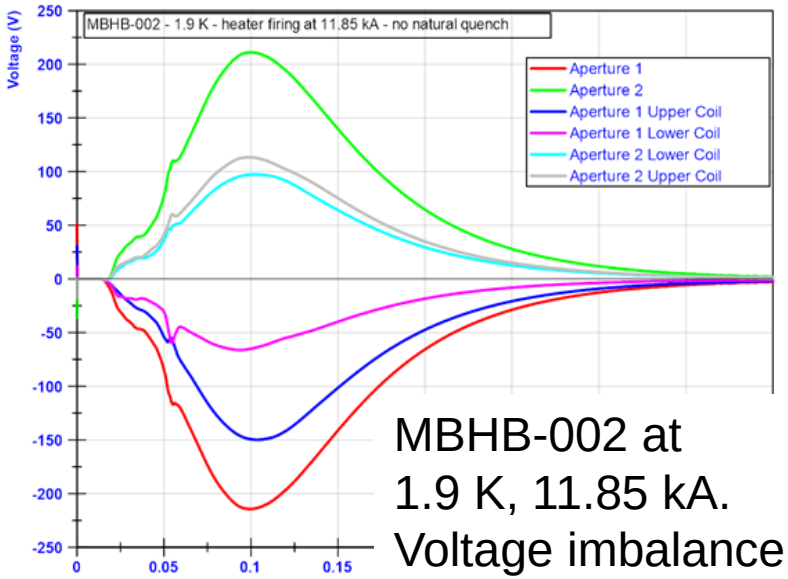




MBHA-002 training was performed with 7 out of 8 heaters.The failed heater was in coil D2_L (aperture 2, lower coil)

This leads to a voltage imbalance: in coil D2_L we measure -460 V, while in other coils we measure 130 to 190 V.

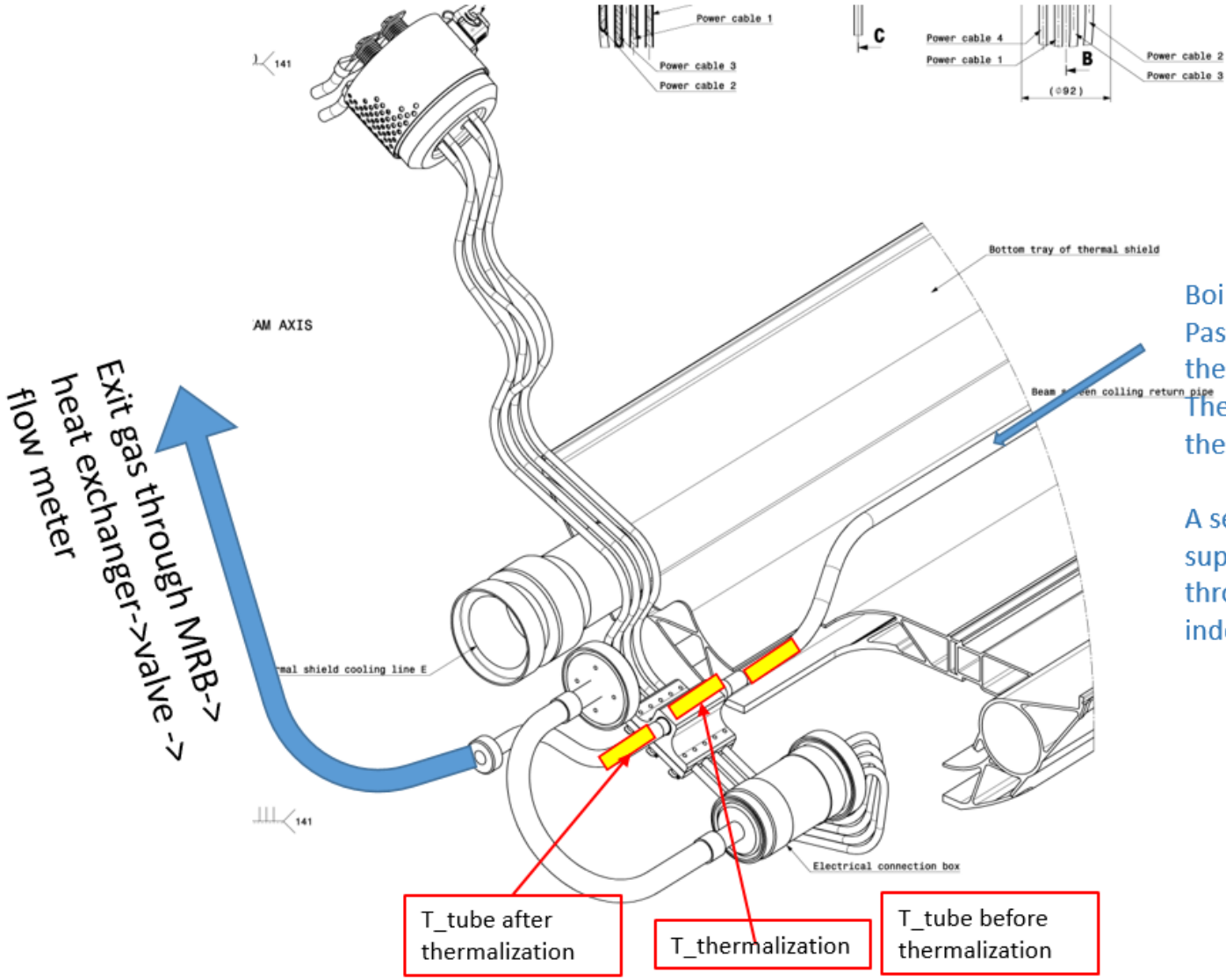
This imbalance plays a role in the discussion for the HV insulation test levels.



MBHB-002 at 1.9 K, 11.85 kA. Voltage imbalance caused by RRR and Cu content variation.

Special trim circuit test

MBHA-002: Trim temperature and He-flow measurement

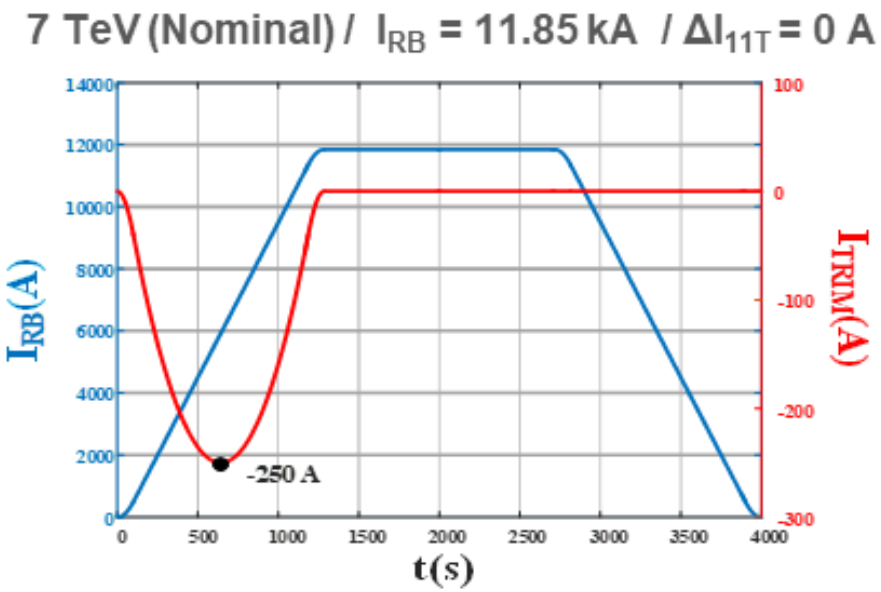


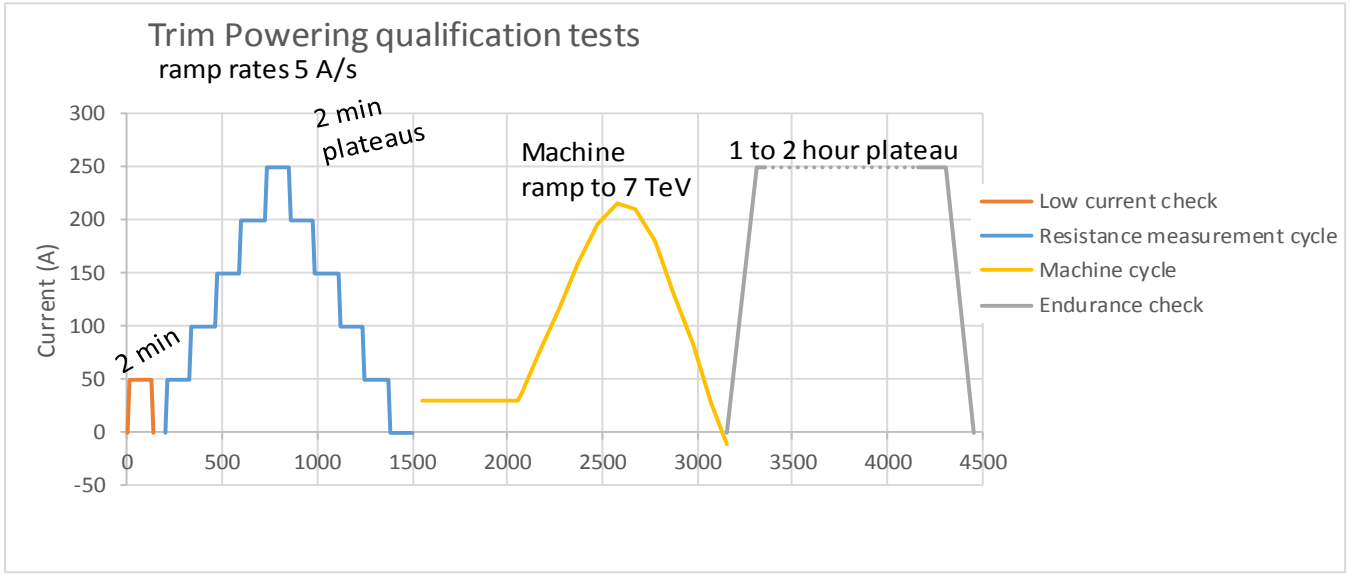
Boil-off from CFB He-gas Passing through the feet of the magnet
Then through the thermalisation of the trim.

A second line is installed to supply helium gas flow through the thermal shield independently.

Trim circuit

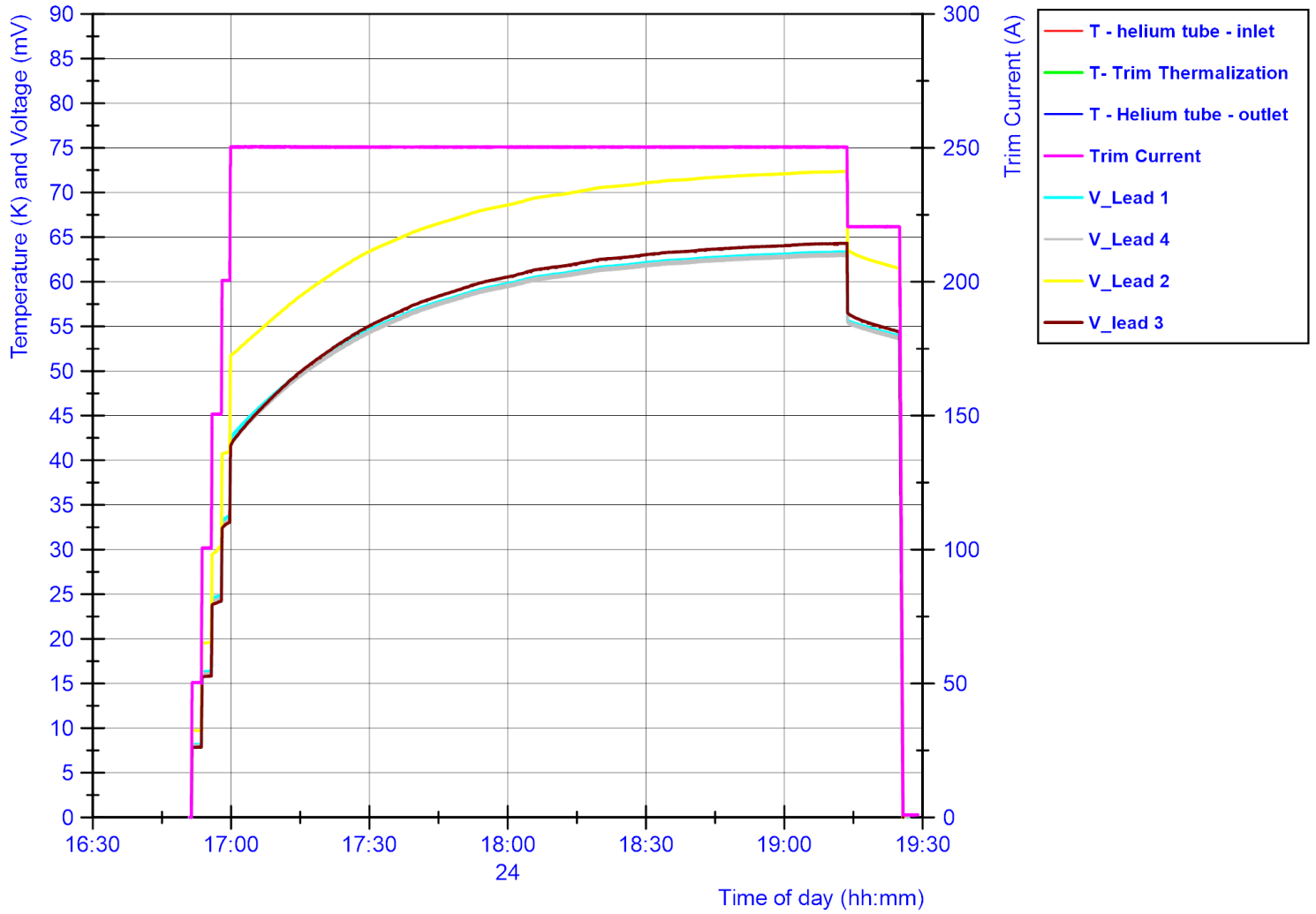
Trim design current = 250 A
Expected maximum LHC current needed in trim is <220 A
(extrapolation from magnetic measurements in MBHB-002)
Given nominal He-flow is 0.9 g/sE





MBHA-001: No flow control, no flow measurement
MBHA-002: Flow control and flow measurement

MBHA-002 Trim endurance test result

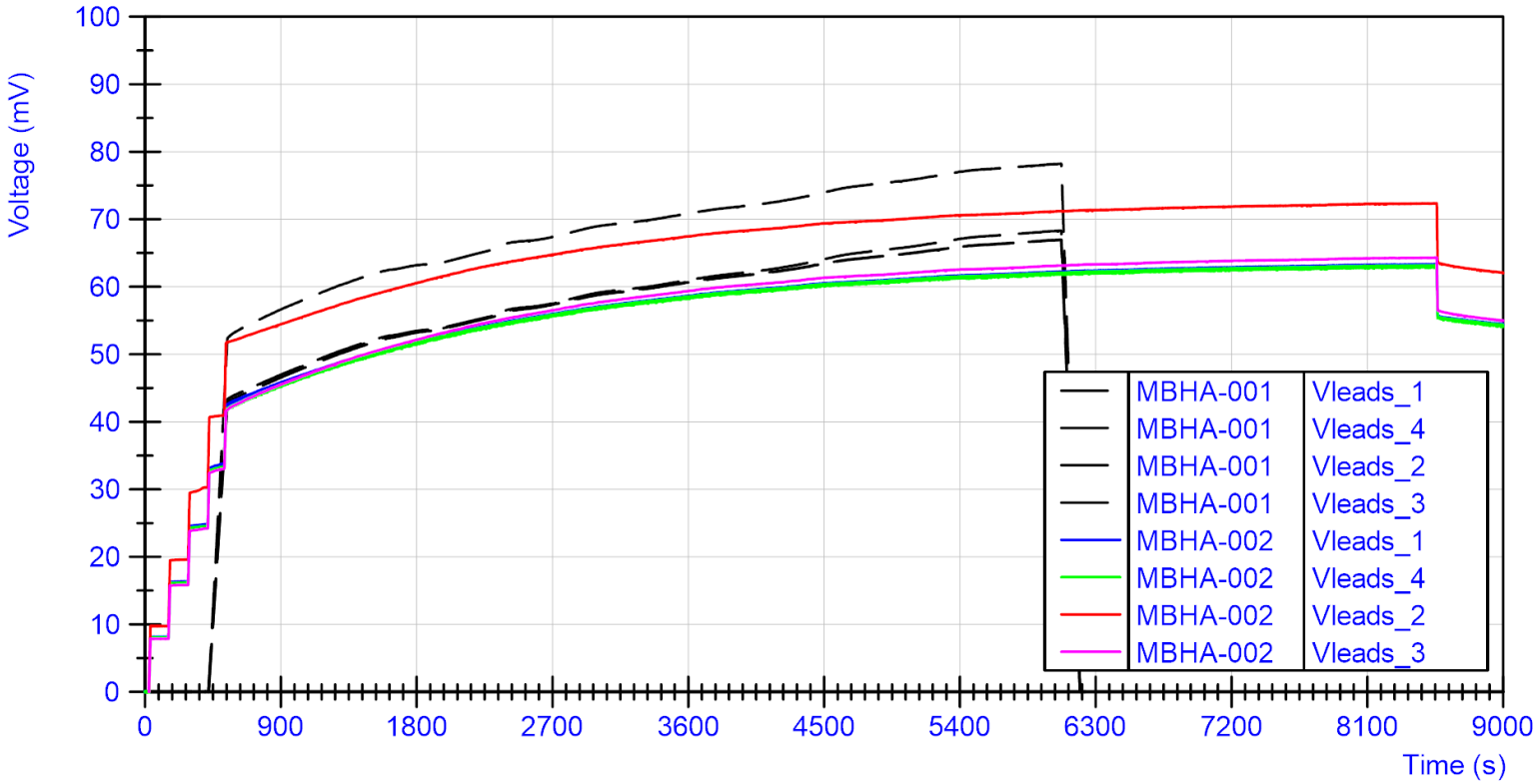


MBHA-002:
At 0.9 g/s, nominal helium flow
Stable trim thermalization of 32 K
Voltage stabilizing at 65 mV (threshold is 150 mV)

Reducing current to 220 A -> Voltage stabilizing below 55 mV….

Very good result!

Trim MBHA-001 vs MBHA-002



In MBHA-001 the start temperature of the thermalization block was higher. Stabilizatoin took longer and to a higher temperature.
Trim thermalization at about 32 K.

MBHA-001: not a bad result.
In hindsight: likely the He-flow was lower than the nominal 0.9 g/s.
Trim thermalization > 50 K.

This proves the technology.

Test status

MBHB-002: Qualified

MBHA-001: Training aborted due to suspicious signals and HV insulation issue detected coil to ground. Repaired. Prepared for powering in the week of February 17th.

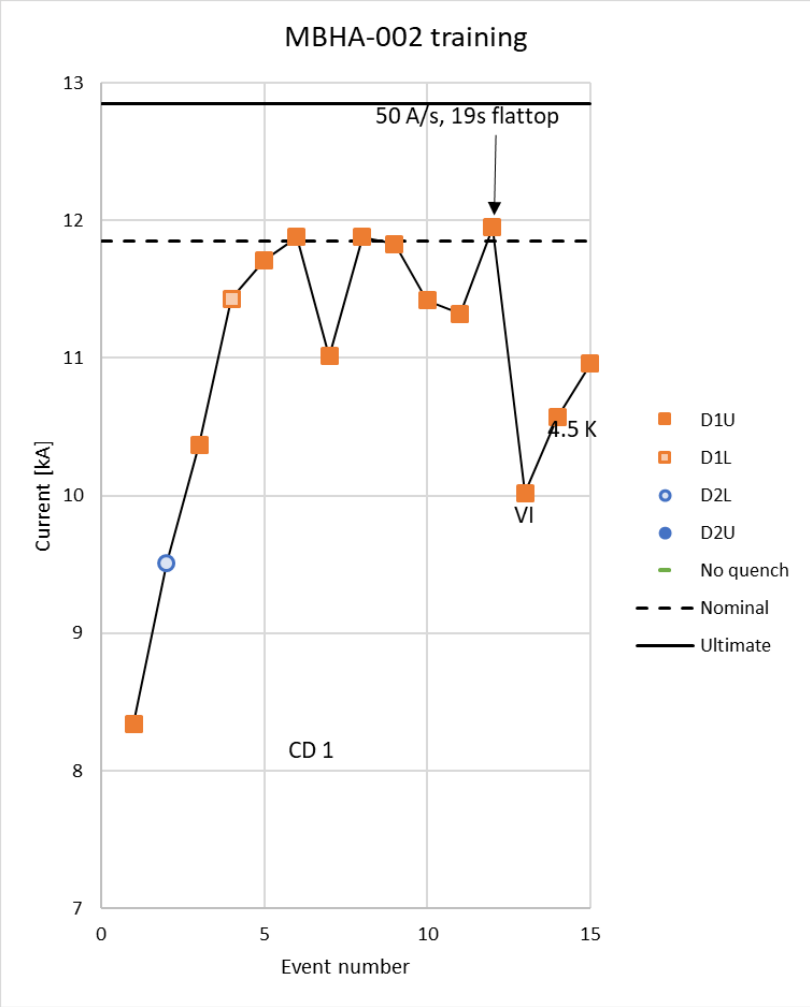
MBHA-002: Coil D1U seems lost beyond repair. Magnet cannot be qualified.
Quench heater circuit on coil D2L in open loop. Exact location to be identified.

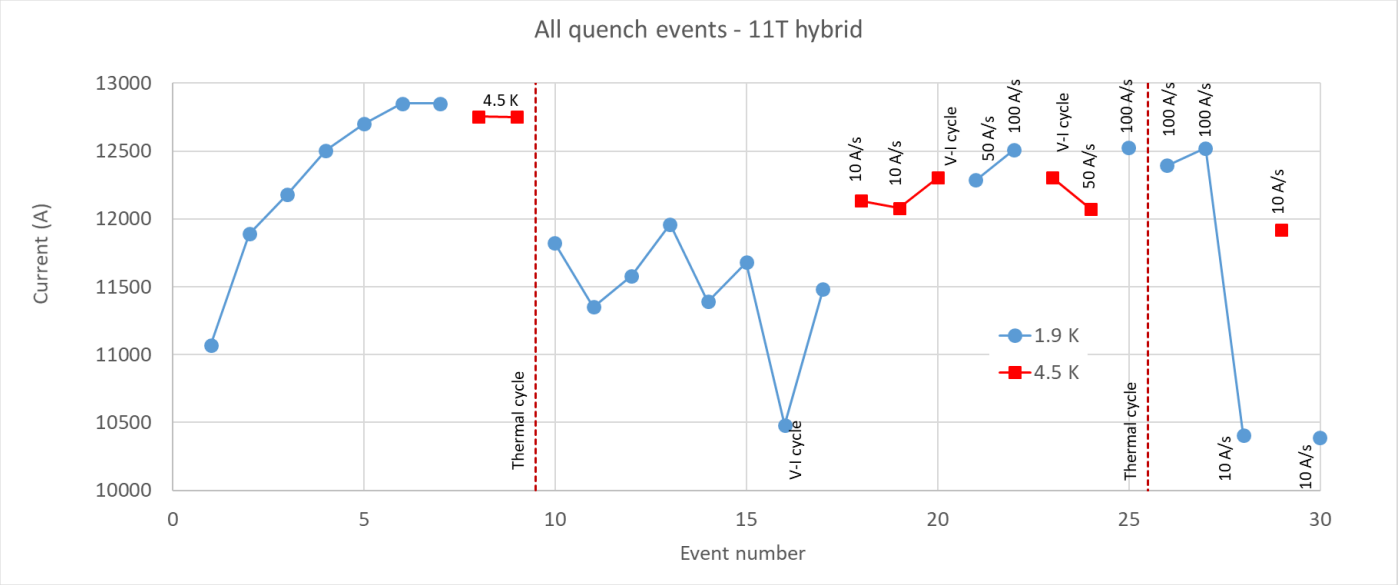
MBHB-003: Will arrive soon in SM18. To be installed on second bench, but needs to wait for MBHA-001 to be finished.

Trim leads: Qualified with nominal flow in MBHA-002.

Backup

MBHA-002 and MBH-hybrid (after TC)





Similarities

- Erratic behavior at 1.9 K, 10 A/s between 11 and 12 kA.
- V-I cycle gives the lowest quench current
- Higher ramp rates give higher quench current

Differences

- 4.5 K quenches in MBHA-002 at lower current.

- MBHA-002 in non-connection side
- MBH-hybrid in connection side