Update MBHA-001 test results of the first cool down

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M. Bajko

Important support by Abdelhay Azarkan and Bertrand Mouches

2019 December 4 – 11T technical meeting

Appreciation

Interventions at all times of the day and with very rapid response time of everyone

Temperature probes
Nicolas Vauthier

Cabling
Fred Flamand

MSC-LMF
Hervé Prin
Jan Petrik
Et al.

CRG
Nicolas Guillotin
Cryo-operators

EPC
Samer Yammine
Hugues Thiesen

Trim leads
Jerome Fleiter

QPS
Jens Steckert
Surbhi Mundra
Severin Haas

ELQA
Jaromir Ludwin
Mateusz Bednarek
Tiago Rosa

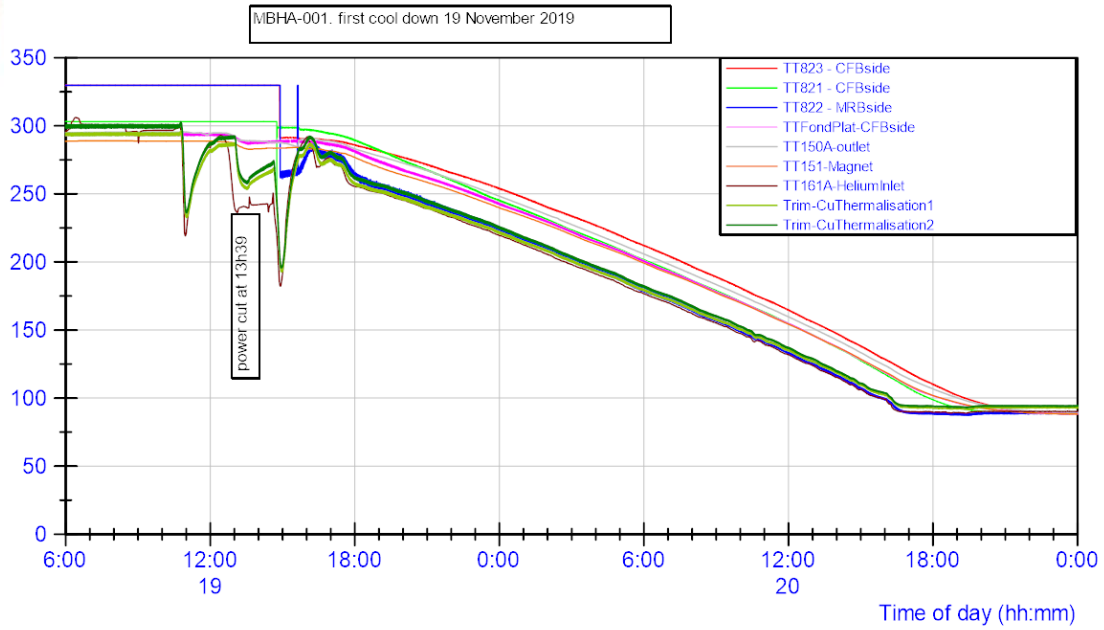
Additional calculations
Emmanuele Ravaioli

Mechanical drawings
Philippe Perret

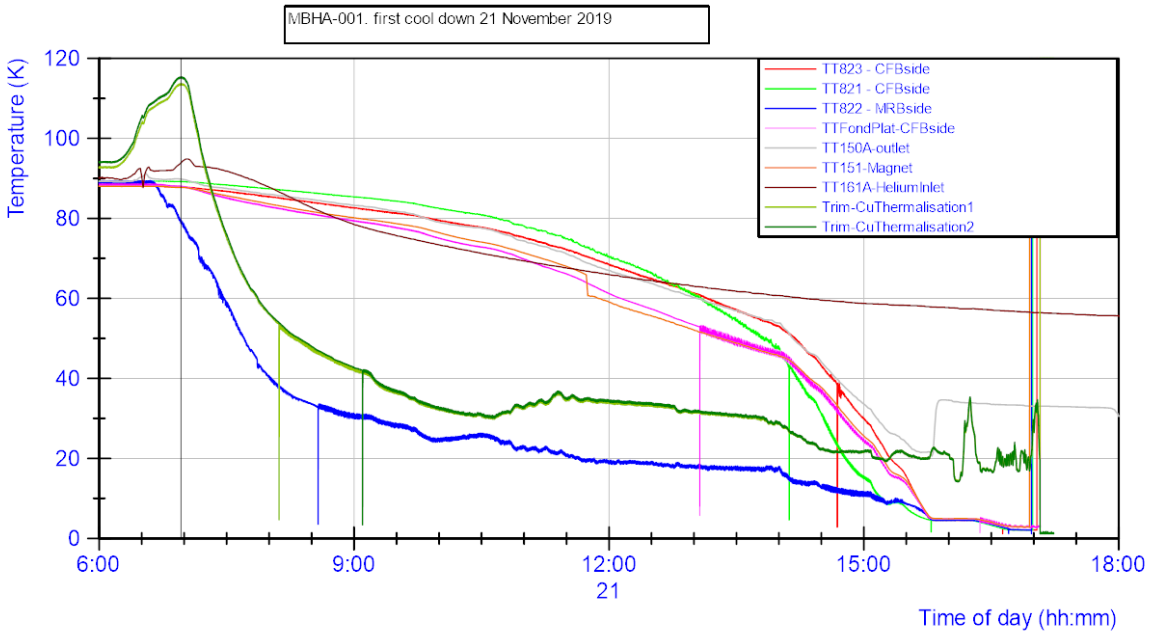
Transport
SM18 transport team

Cool down

Cool down from 300 to 80 K. Delta T of 30 K.

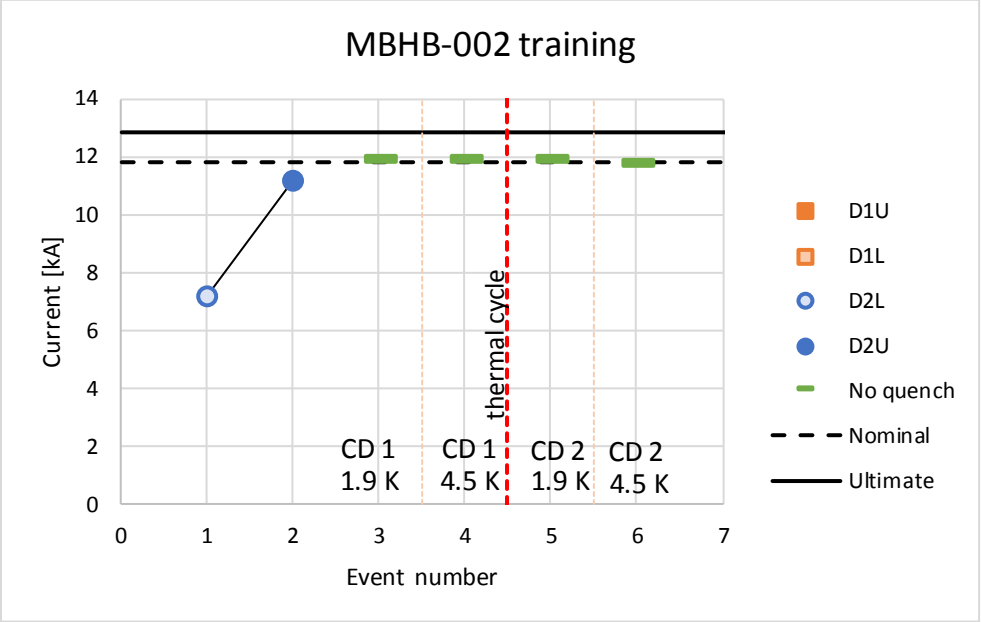


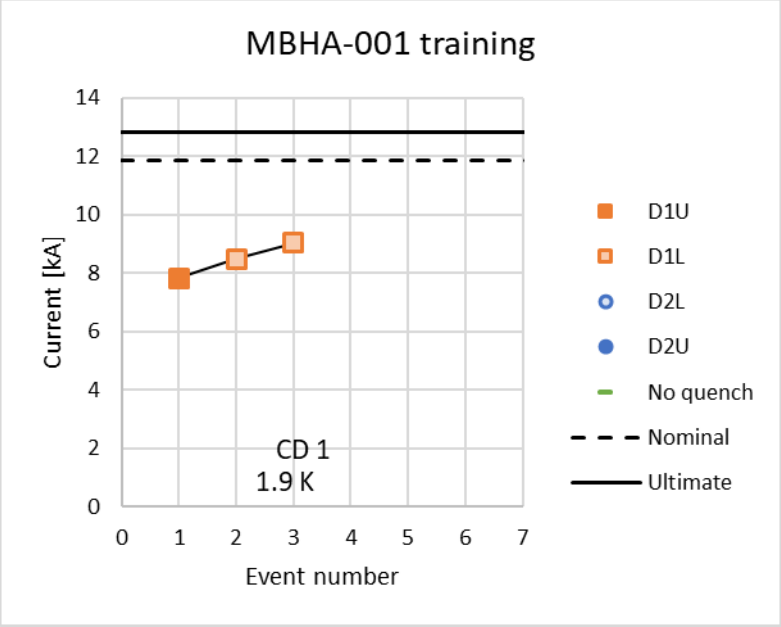
Cool down from 80 K to 1.9 K.



Acknowledgement Nicolas Guillotin and operational team.

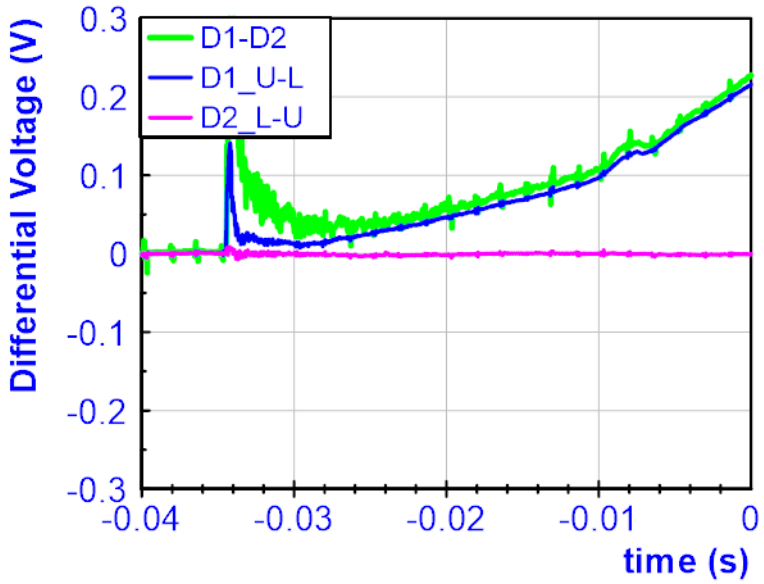
Magnet training

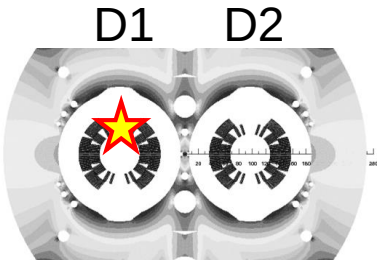


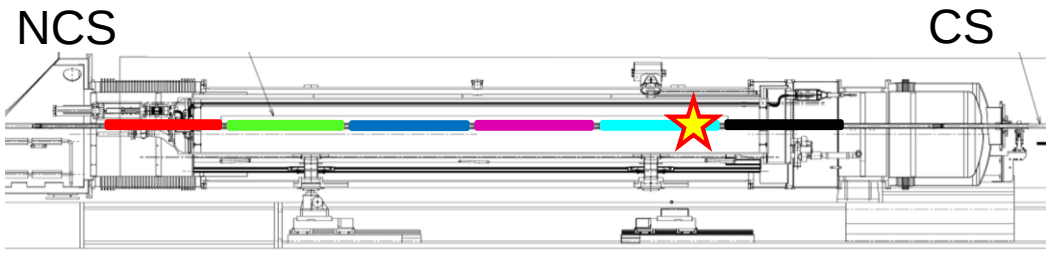


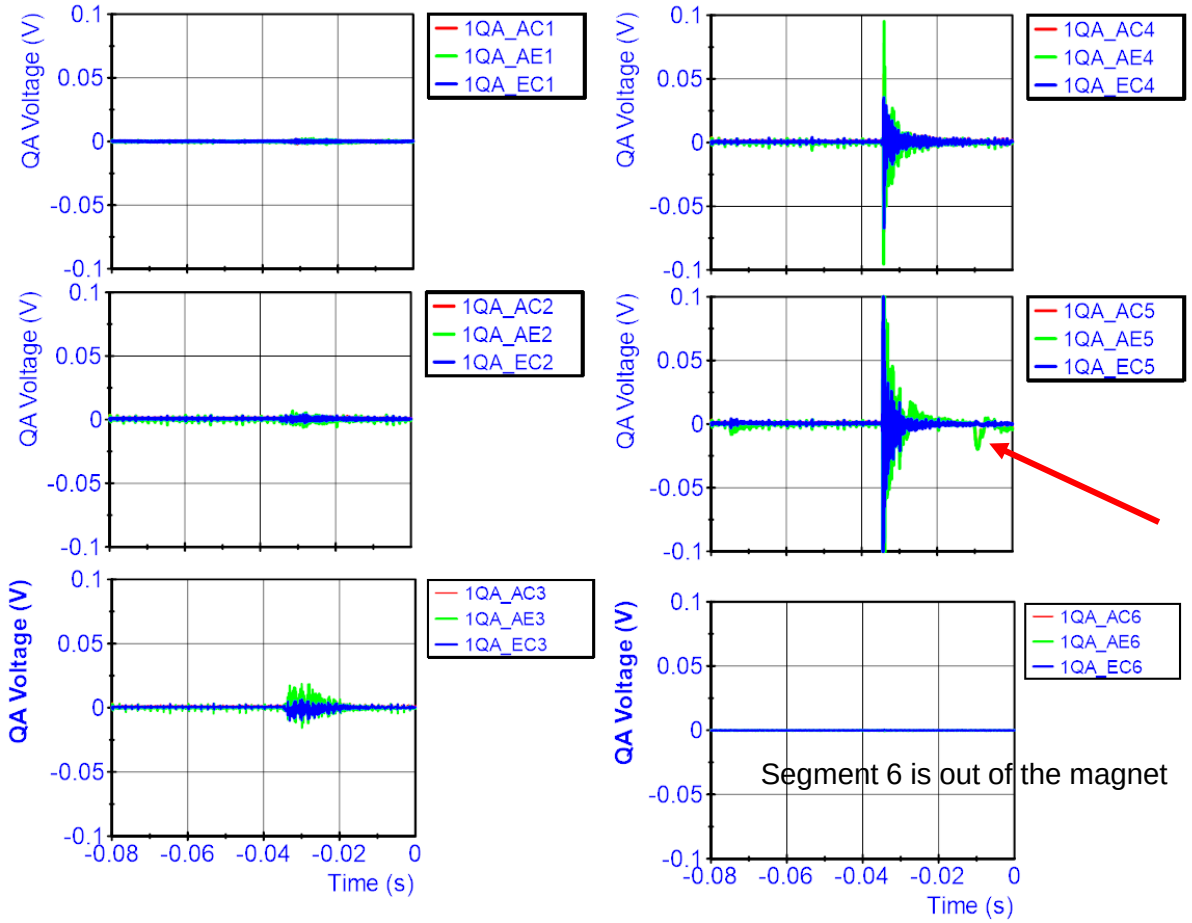
3 training quenches before powering was aborted due to other reasons.
Too few quenches to give any prediction, no show-stopper in training so far.

Quench 1: 7830 A @ 1.9 K





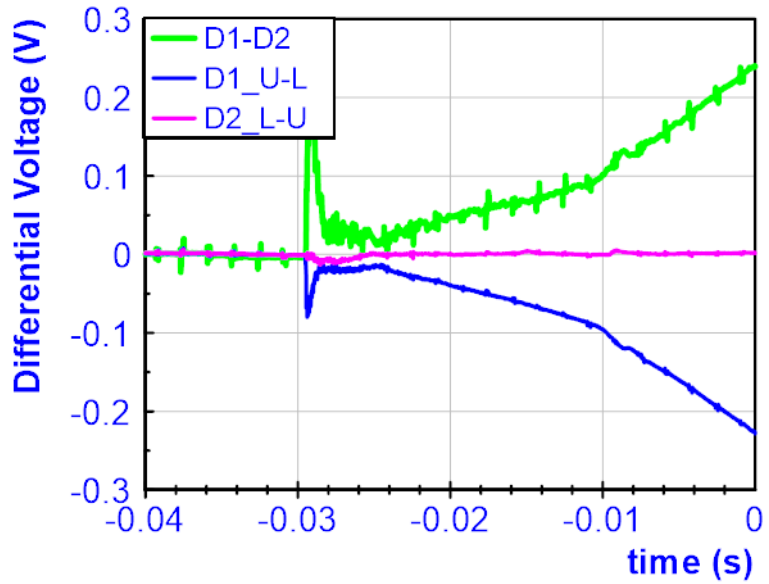


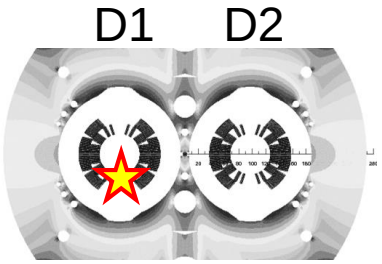


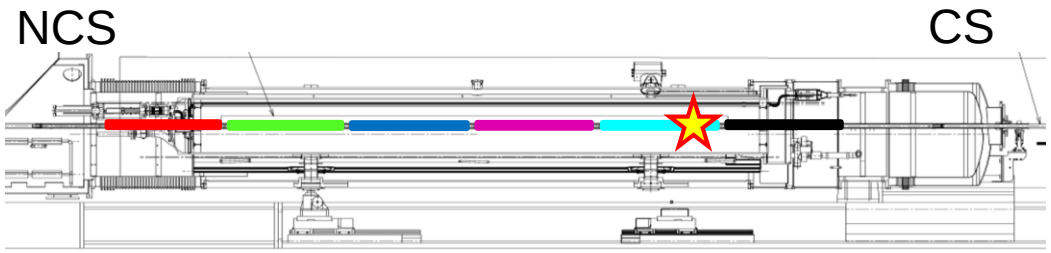
Quench propagation
QA 5A

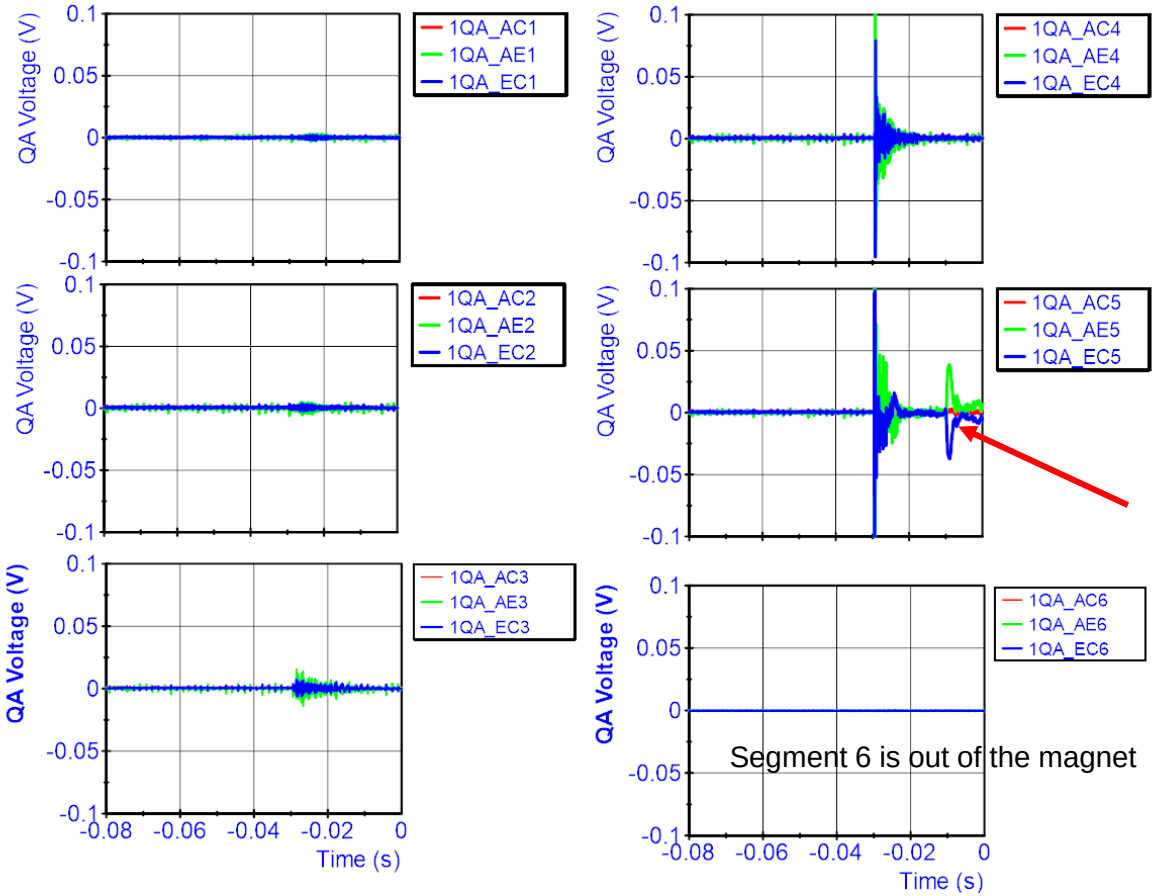
Aperture 1
Upper coil
Head connection side
Precursor: Mechanical origin

Quench 2: 8480 A @ 1.9 K





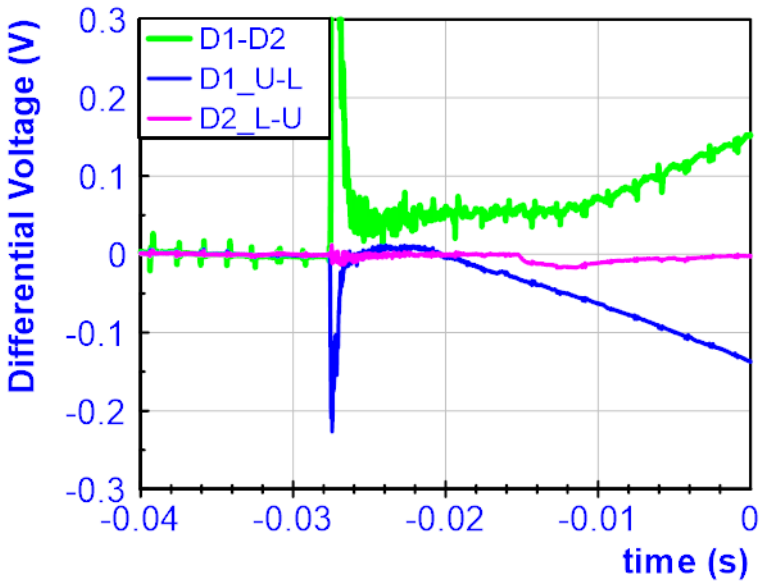


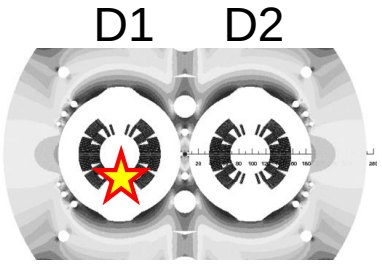


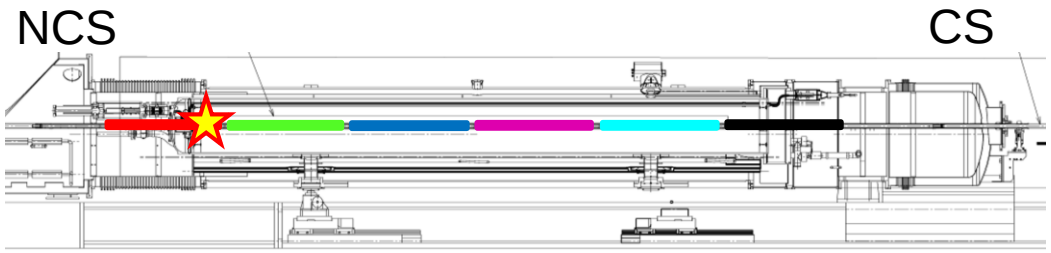
Quench propagation
QA 5E

Aperture 1
Lower coil
Head connection side
Precursor: Mechanical origin

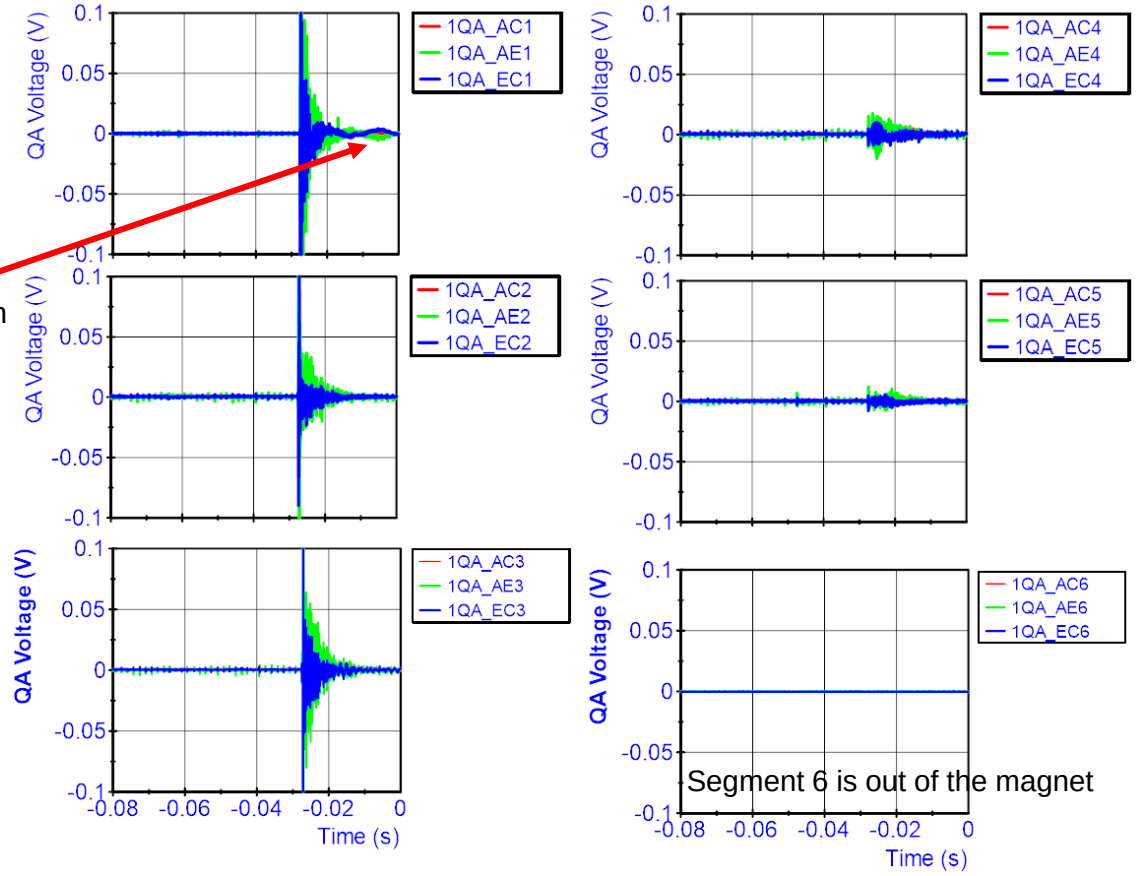
Quench 3: 9040 A @ 1.9 K







Quench propagation
QA 1E



Aperture 1
Lower coil
Head non-connection side
Precursor: Mechanical origin

Flux jumps and protection

Not fully analysed, but no obvious issues found.

1 flux jump trip on the threshold for which we knew it was just too tight and still room for quench detection.

Many thanks to the QPS team for their continued support:
Jens Steckert, Severin Haas, Surbhi Mundra

RRR

MBHA-001

Coil	R293K	R_20K	**RRR_293K/20K**
	Ohm	mOhm	**-**
D1_U	1.261	9.02	**140**
D1_L	1.257	6.09	**206**
D2_L	1.248	7.22	**173**
D2_U	1.255	7.57	**166**

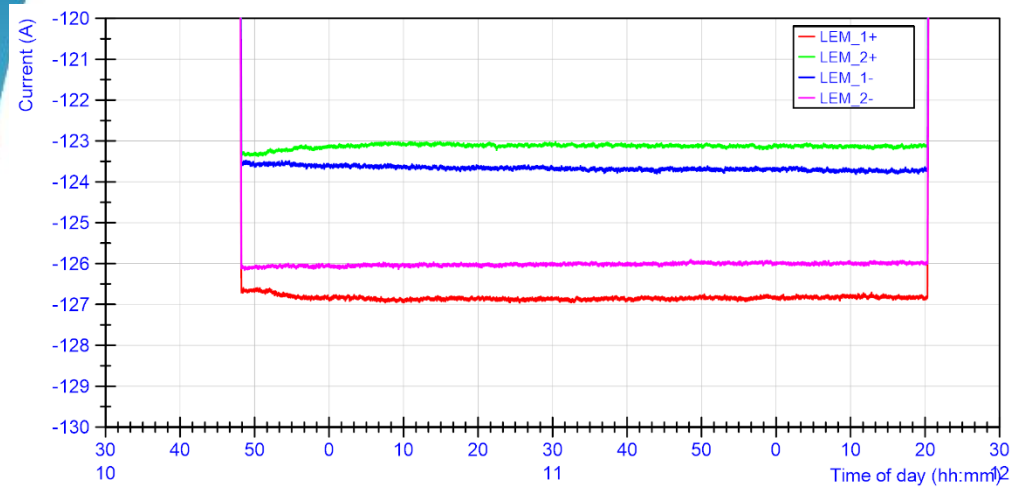
For reference MBHB-002

Coil	R293K	R_20K	**RRR_293K/20K**
	Ohm	mOhm	**-**
D1_U	1.257	7.05	**178**
D1_L	1.266	7.38	**172**
D2_L	1.249	8.24	**152**
D2_U	1.249	8.25	**151**

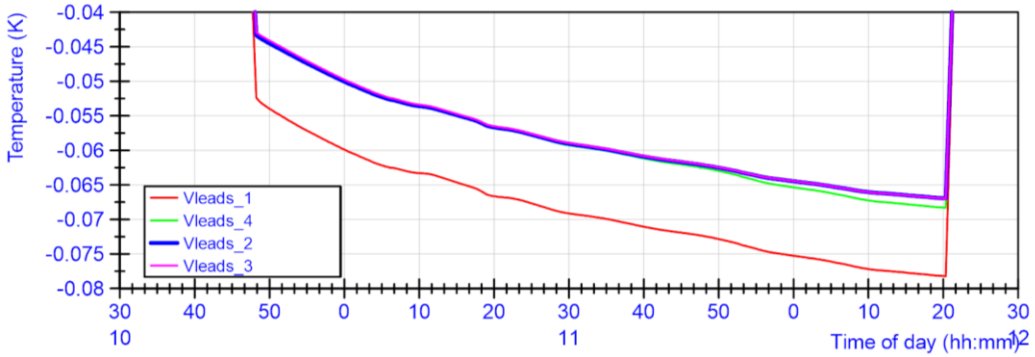
Difference between maximum and minimum of R_293 K is about 1.3 %. *(Cu-SC ratio)*

Difference between maximum and minimum of R_20 K is about 50 %. *(RRR)*

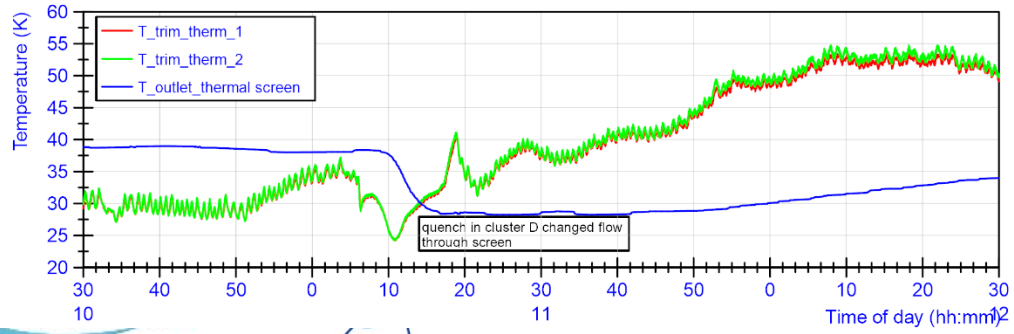
Trim leads



1.5 hours test at 250 A done.



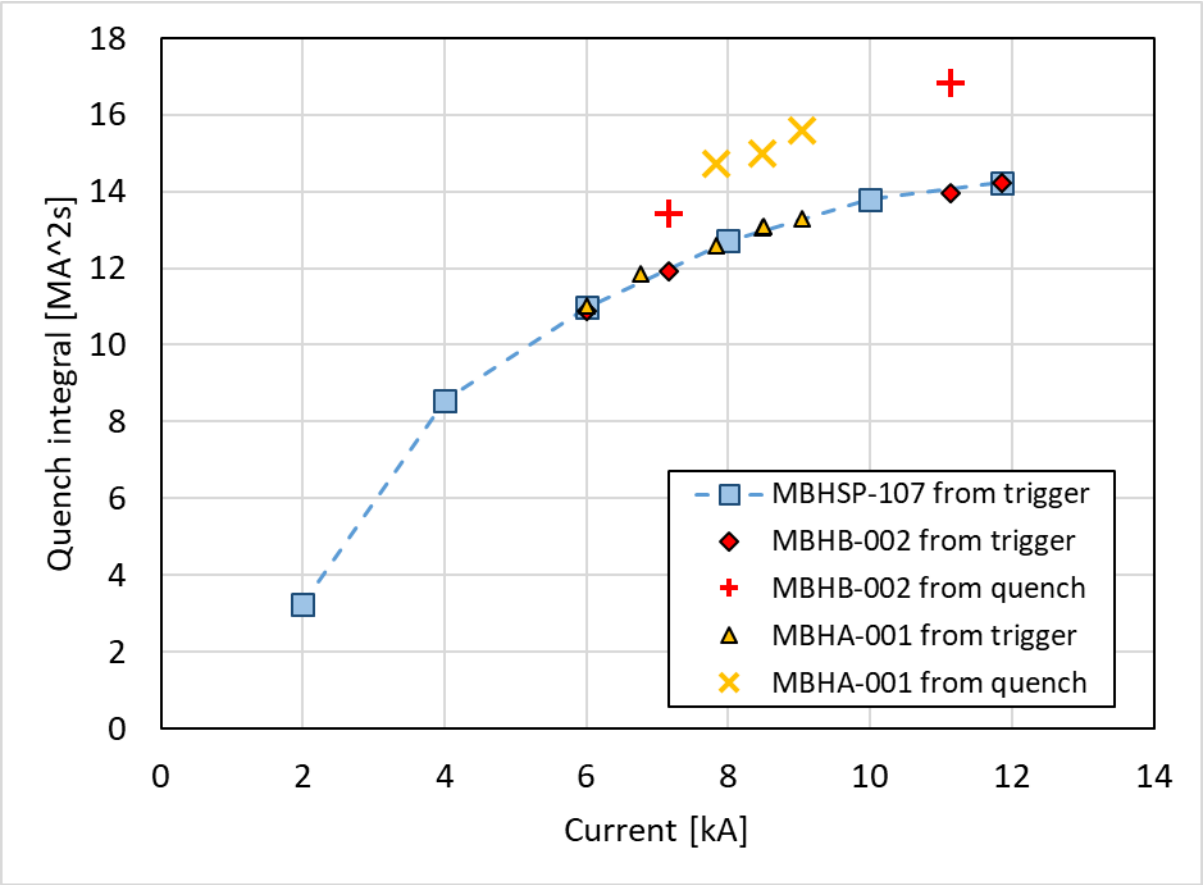
Temperature and voltage still drifting after 1.5 hour.



Helium gas exits the thermal screens (30K-40K depending on pressure of the cryolines in the building) much colder than the trim thermalisation point (up to 53 K). The helium heat capacity is not fully used.

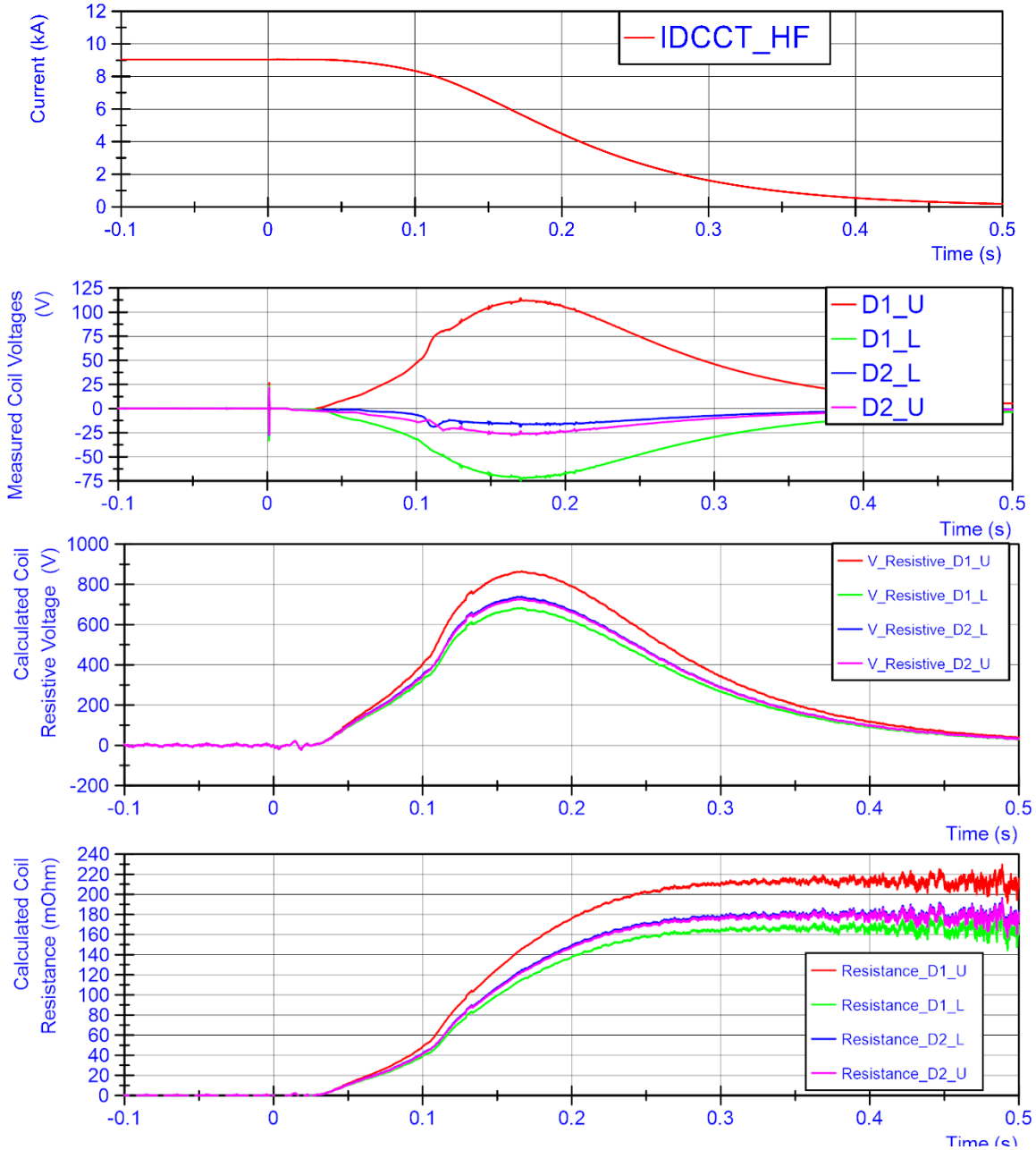
Data not fully analysed.
Two more tests were done.

Quench integral



Quench integral from QH firing as expected

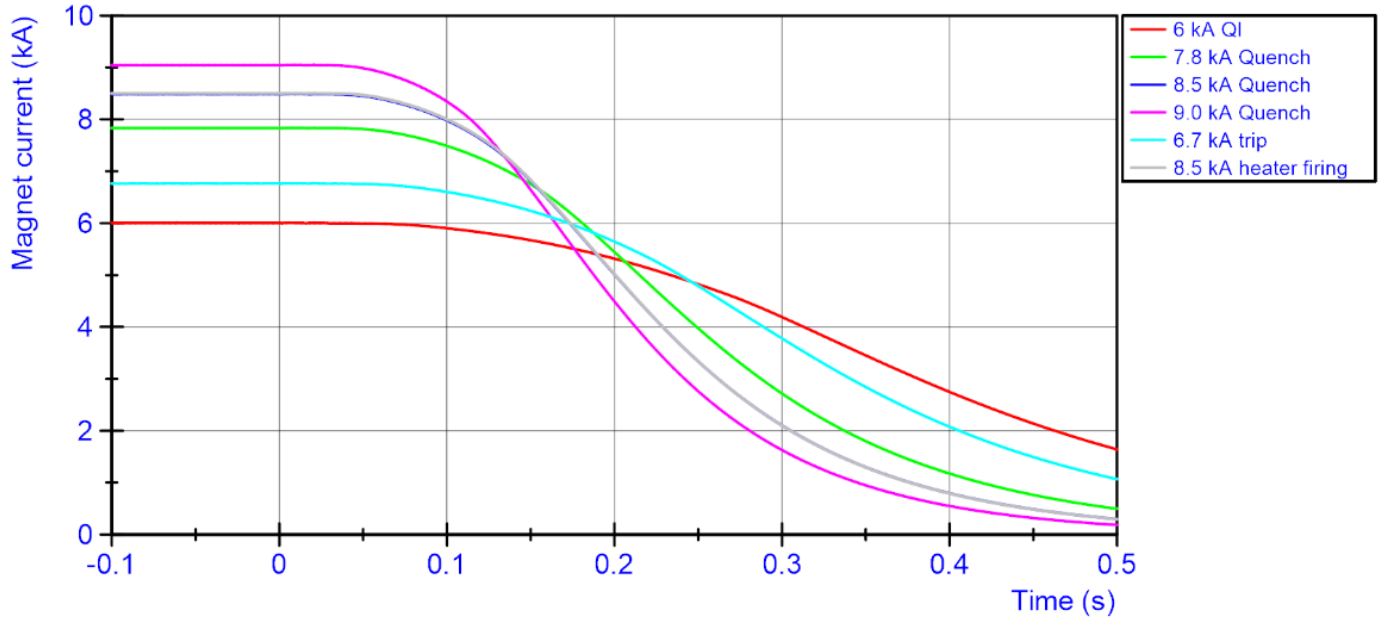
Voltage imbalance following quench

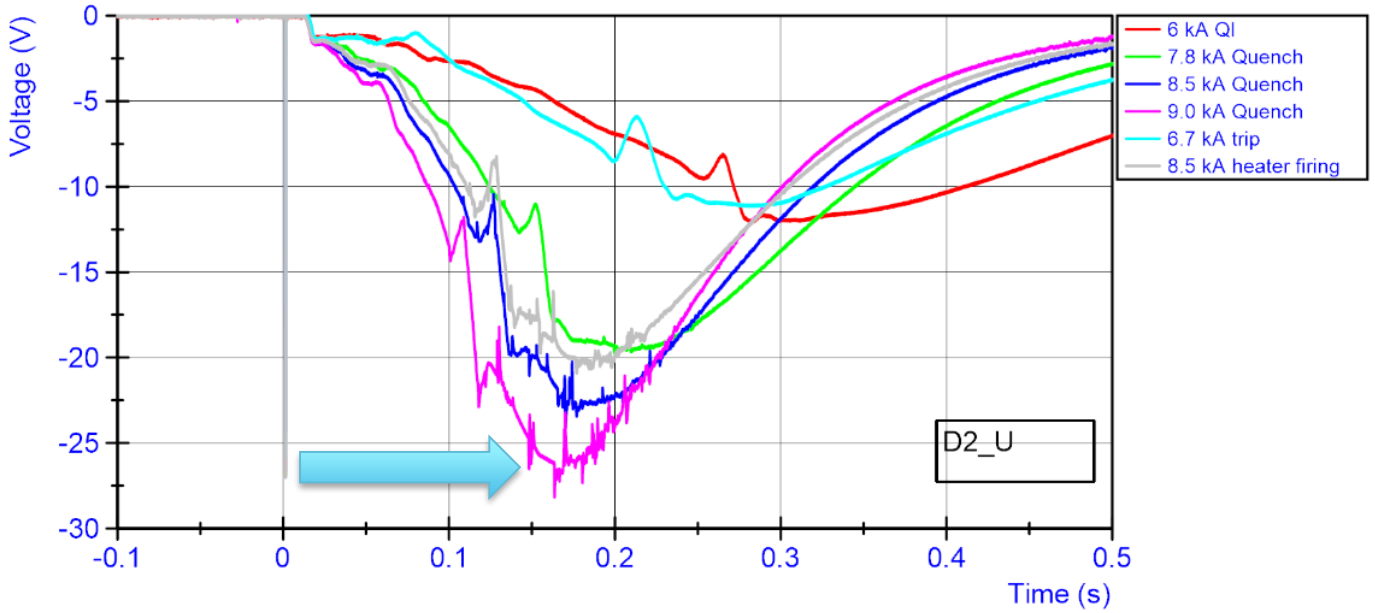


Current decay from 9 kA quench.
With the measured voltage and calculated inductive voltage, the resistive voltage can be calculated.

Consistent with R_20 K (or RRR) measurements, the resistance in coil D1_U is significantly higher than in the other coils.

Spikes in voltage signals following quench

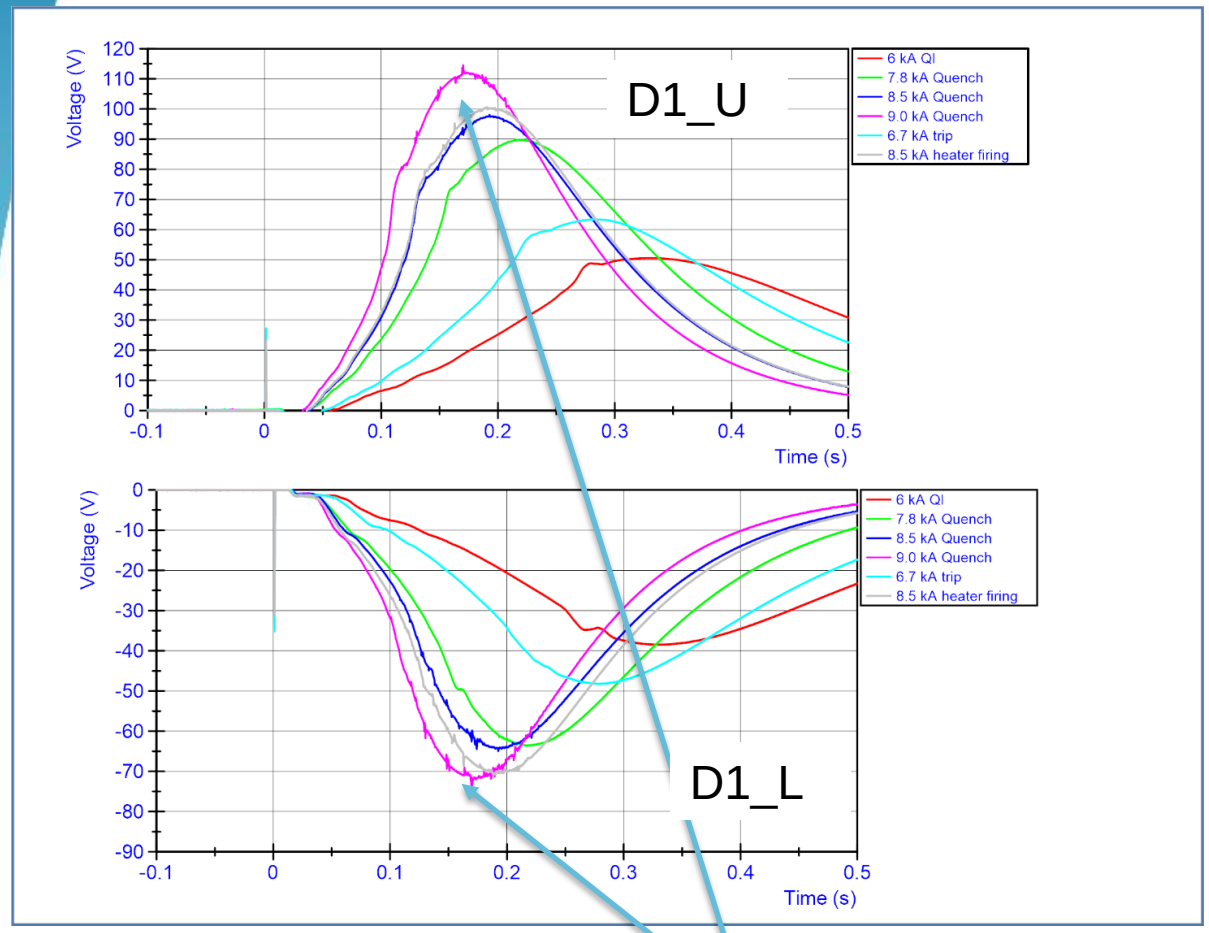


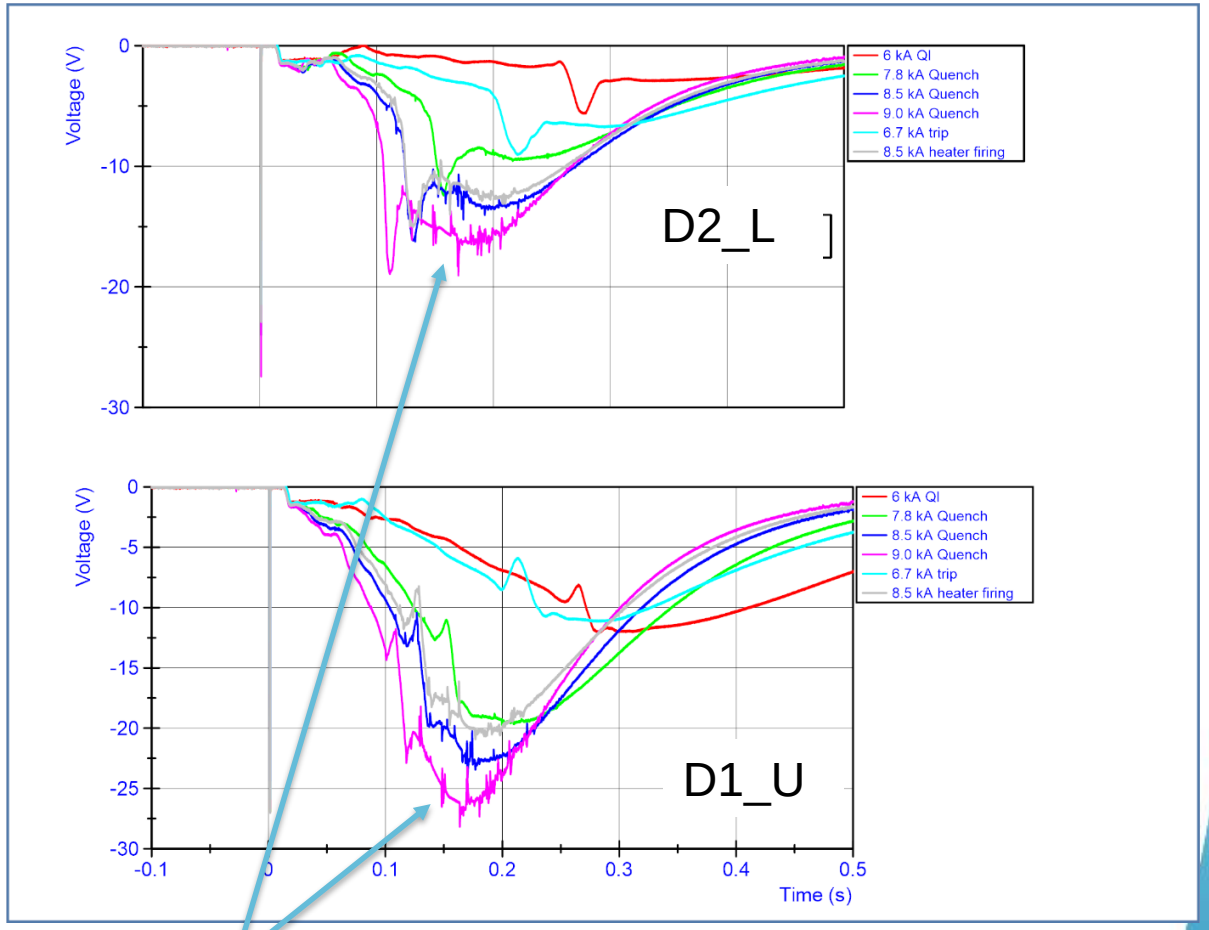


During current decay after a quench or heater firing we discovered spikes on the voltage of all coils, specifically above 8 kA.

Investigation started.

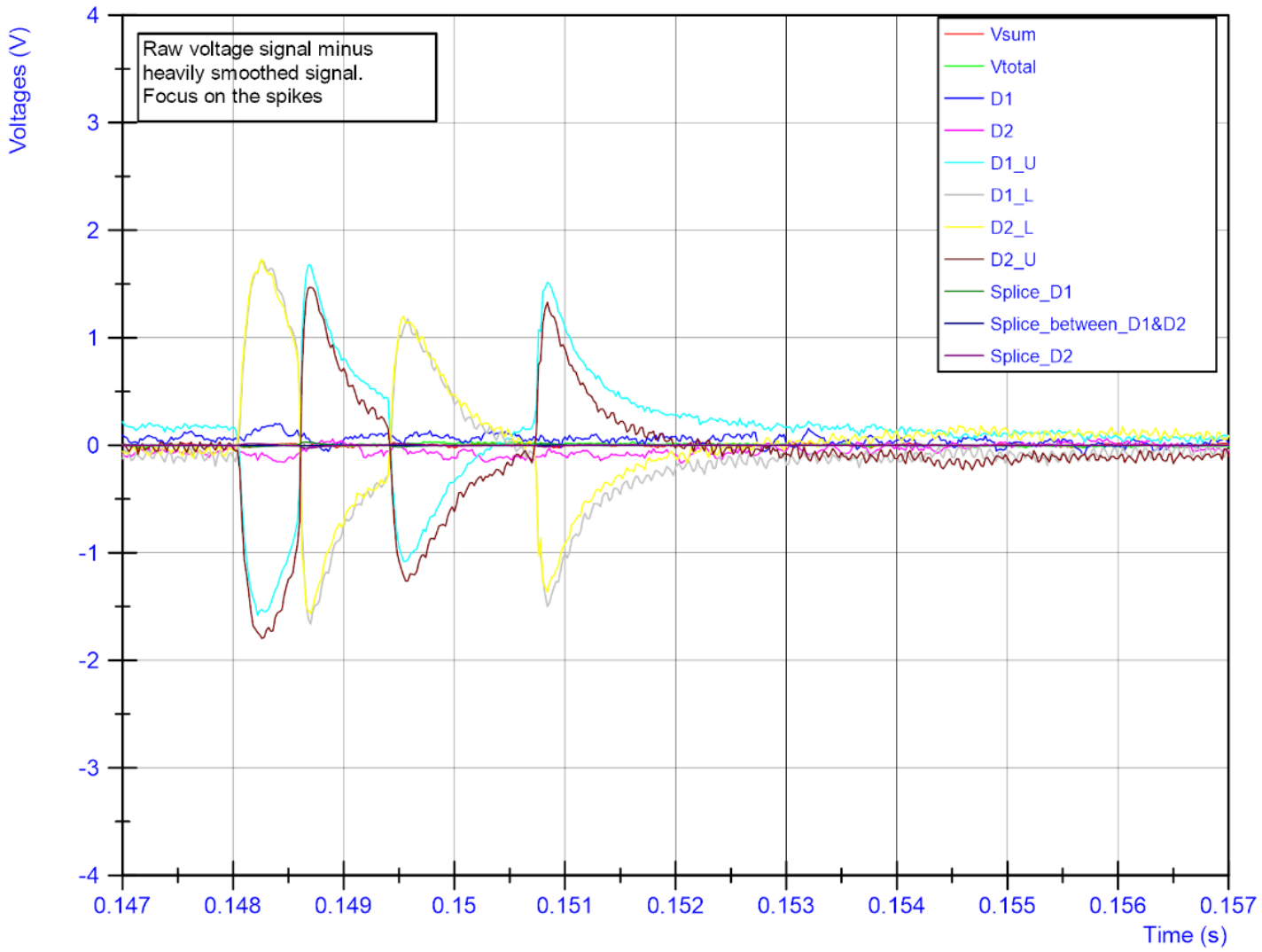
Spikes in voltage signals following quench





The spikes appear in all coils at the same moment.
In the following slide we analyse the spikes following the 9 kA quench in the 4 coils.

Spikes in voltage signals following quench



Removing roughly the quench voltage we keep only the spike voltages.

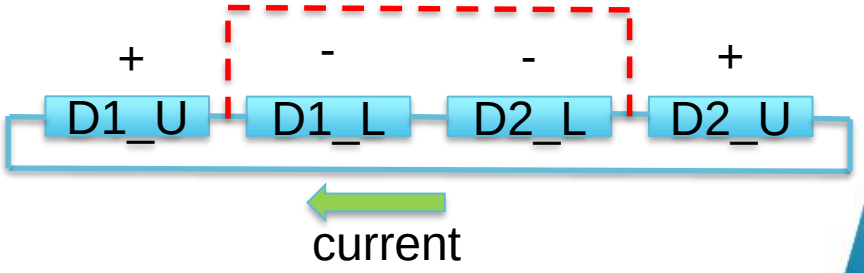
The spikes are symmetric:

D1_U and D2_U always have same sign and same amplitude.

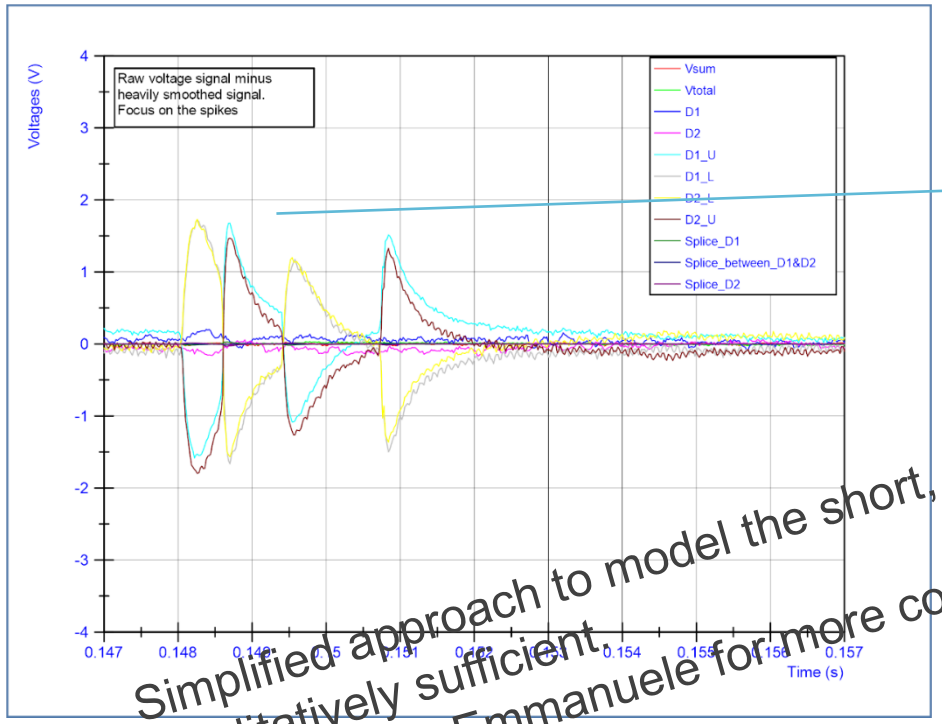
D1_L and D2_L have the same amplitude, but opposite sign to the upper coils.

D1_U+D1_L and D2_U+D2_L show no spikes.

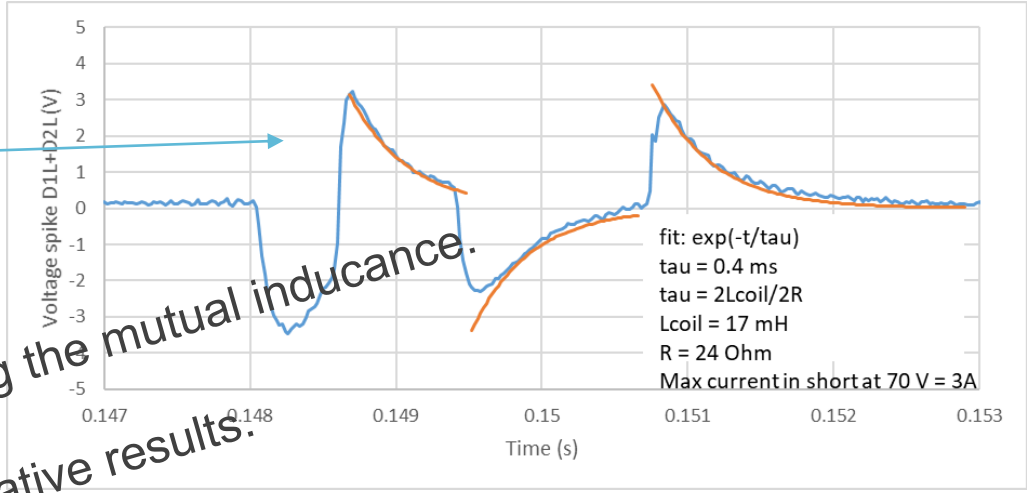
This symmetry, and the spikes appearing and disappearing give immediately the idea of an **intermittent short between the two inter-coil points**



Spikes in voltage signals following quench

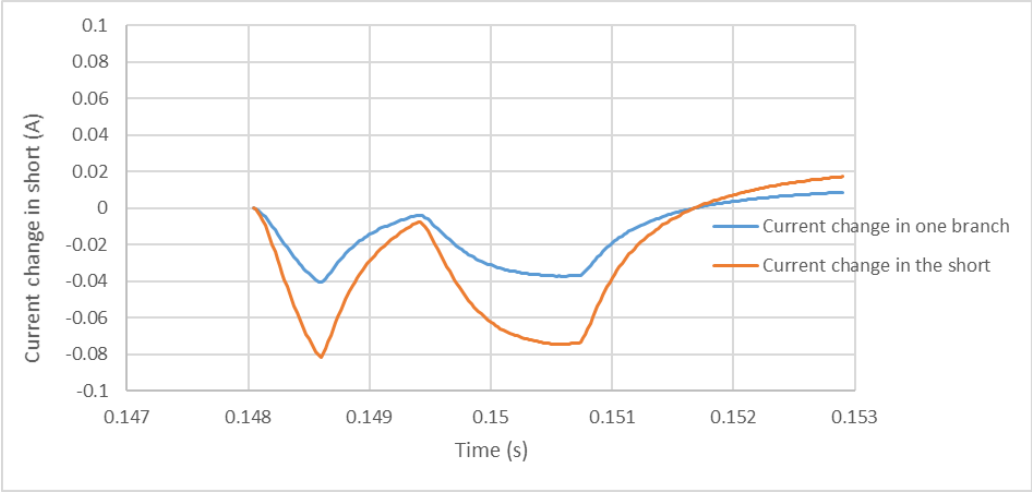


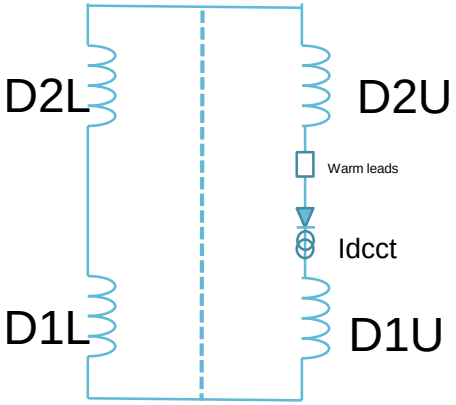
Method 1: time constant and L/R



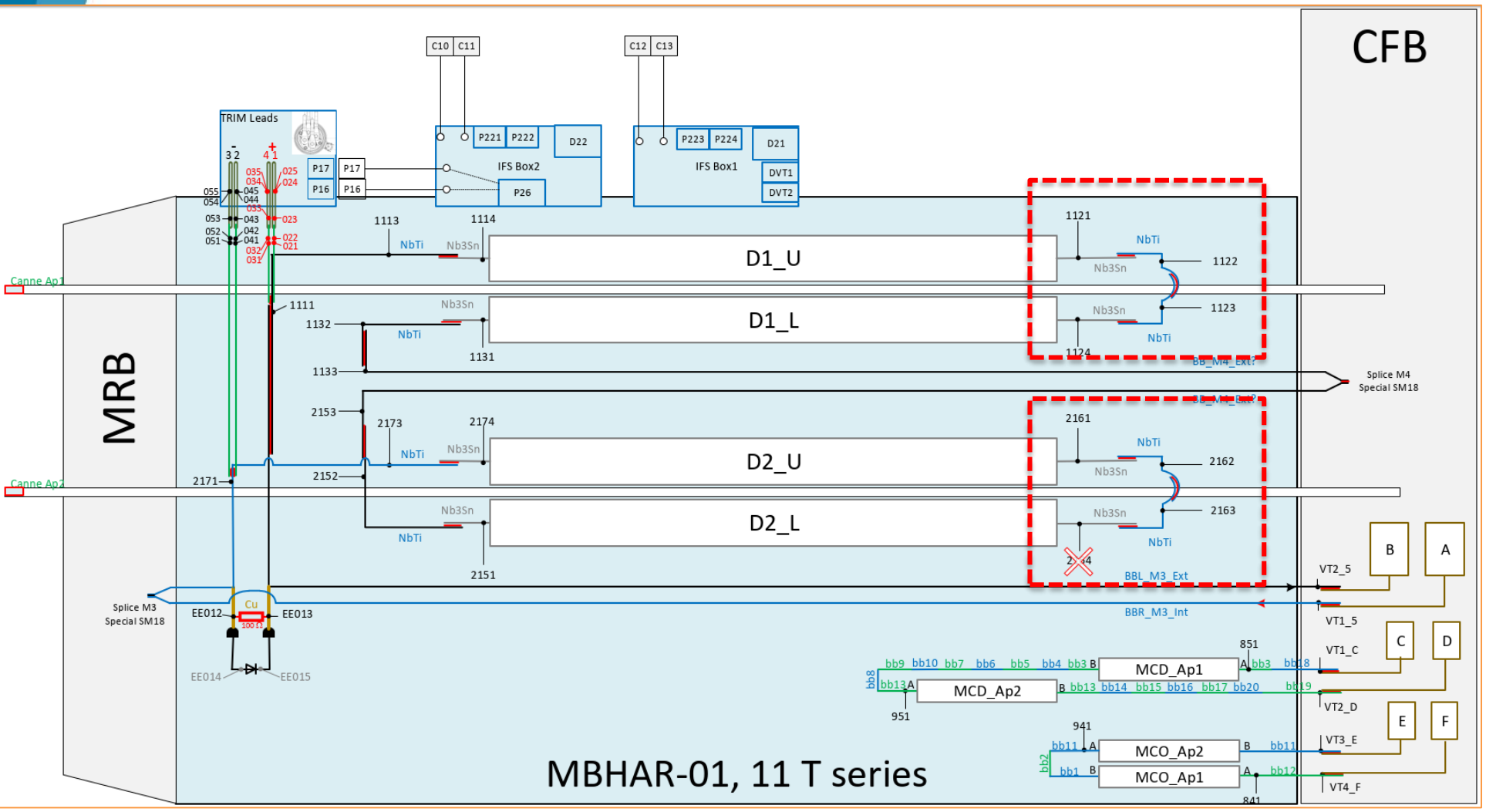
Simplified approach to model the short, not including the mutual inducance.
Qualitatively sufficient.
See slides by Emmanuele for more correct quantitative results.

Method 2: integrate dI/dt and see current change (use V/L)





Discussion on origin of short



The analysis shows the short is between intercoil region of each aperture.

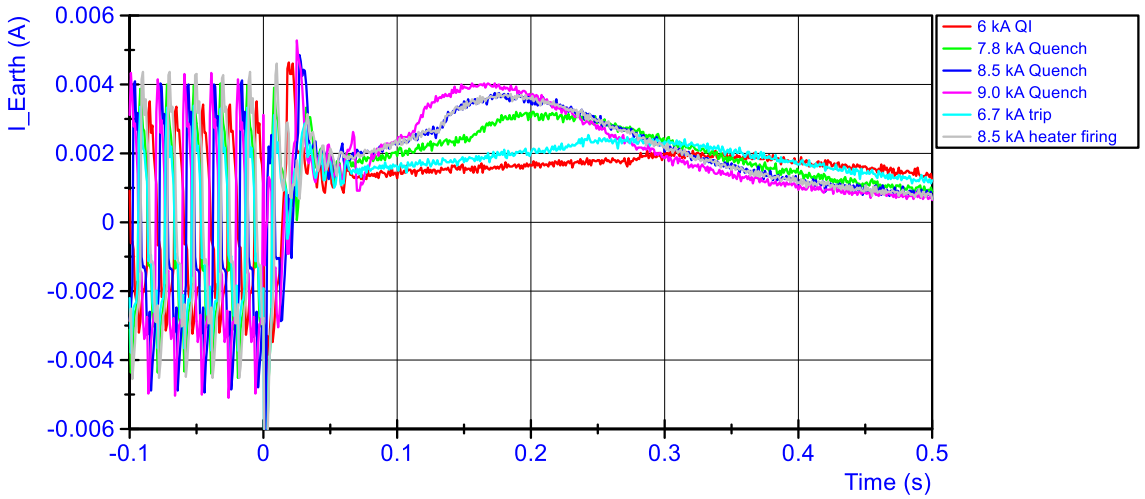
Only the wires towards and inside the capilary are physically close to each other, so they are suspected.

The suspected short is between one of the wires VT1121, VT1122, VT1123, VT1124 to one of the wires VT2161, VT2162, VT2163.

Other info

Earth current measurements shows nothing notable: no short to ground.

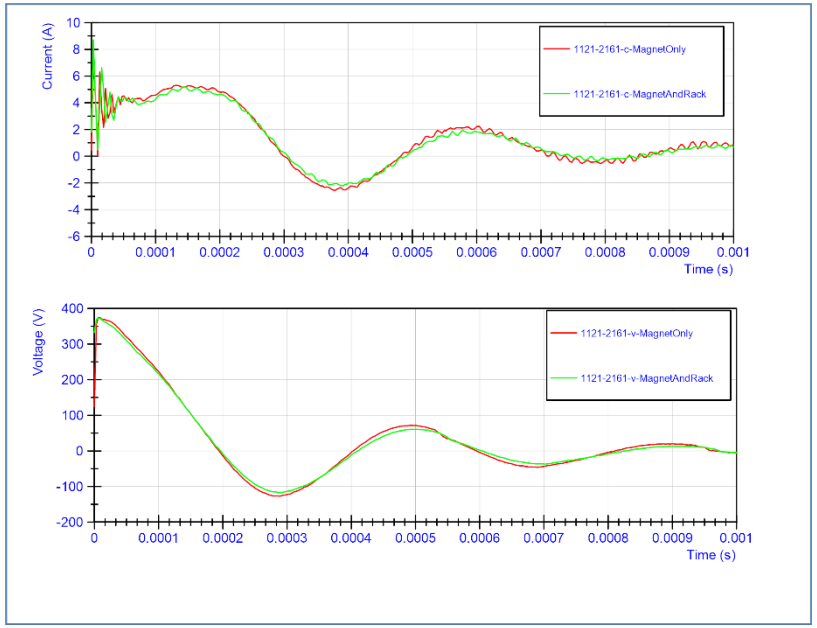
(note that the maximum V to ground is about 120 V during the 9 kA quench).



4uF Capacitive discharge up to 400 V (at 0 A in the magnet) over the suspected short did not show a sign of the short.

(Note that the maximum voltage over suspected short is 60 to 90 V during the quench).

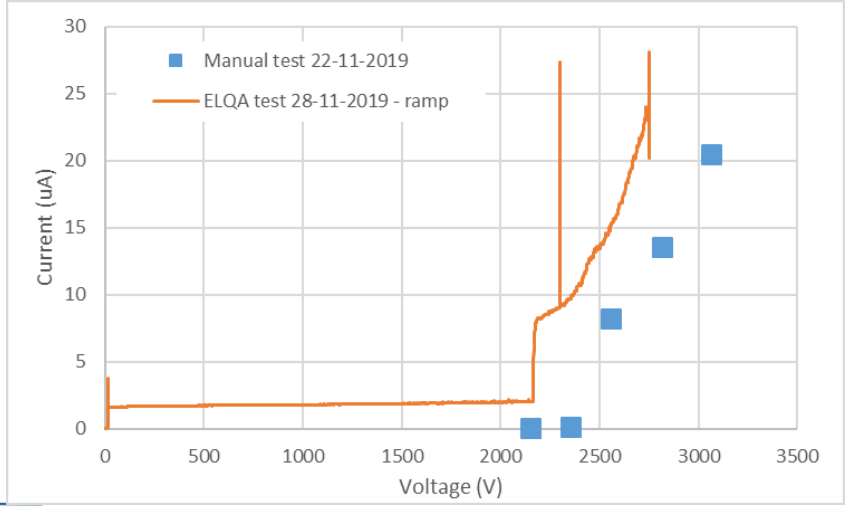
Can we conclude that the short is not there at low current?



HV test

Table with performed HV tests. The striked tests were canceled.

Polarity +	Polarity -	Warm initial	cold	Warm final
Dipole-Quench Heaters	Ground	300/660	300/660/1850/~~3300~~	300/660
Dipole	Quench Heaters - Ground	300/660	300/640/1850/~~3200~~	300/660
Dipole	Ground	300/660	300/660/1850/~~3300~~	300/660
Dipole	All Quench Heaters	300/660	300/640/1850/**3200**	300/660
All Quench Heaters	Ground	300/660	300/660/1850/**3300**	300/660
Dipole	MCS-MCD Correctors	250	250/975	250
MCO/MCD Correctors	Ground	250	250/975	250
Ext/Int Passive Busbar	Ground	600	600/1850/**3075**	600
Ext Passive Busbar	Internal Passive Busbar	600	600/1850/**3075**	600
Cryo Heater	Ground		675	
Cold Temp. Sensor	Ground		25	



HV test before powering (22-november) failed for 3.3 kV from Coil to ground with a high (rather constant) leakage current.

Training was started and after the powering and quenches a new HV test campaign by the ELQA team was launched (November 28)

In the figure to the left, we find the same pattern in jump of the leakage current, but throughout tests the onset varied between 2 and 2.8 kV.

See presentation by Jaromir Ludwin and Mateusz Bednarek for the details.

Summary

Two blocking points:

- Intermittent short, which we think we understand. The wires in/close to capilary are highly suspicious.
- High leakage current to ground. We don't understand.

  We will retest the test bench before christmas break (even though it was verified to 3.9 kV before the MBHA-001 test)

Other performance:

- Coil performance: unknown, no show-stopper up to 9 kA
- Trim: seems OK.

Test of 2 MBHA magnets in parallel in SM18

Cryostat: Additional MBHA cryostat extension needed. Can be done in main workshop in high priority, but not confirmed.
Thermal screen CFB side: Additional piece needed. Can be done in main workshop in high priority, but not confirmed.
Anti-cryostats: 4 available, but only 2 MM-shaft QA.
Cryogenics cooldown-warmup process: To be validated, temperature probes to be installed on new bench.

We propose to pursue two paths:

Prepare Bench C1
1 week of cabling.
Use of existing Data Aquisition, QPS, interlocks, etc.
No possibility of powering simultaneously with C1, but it is possible to prepare and cool down simultaneously.

Prepare Bench A2
Main work for interlocks to be done (4 weeks of cabling + 2 weeks of commissioning) that also serves the MQXF test.

MQXF if foreseen on bench A1, competing for same electronics and power converter.
SC-link Demo2 needs to be powered with same PC.
DAQ upgrade for MQXF postponed to after MBH tests.

Advantage: Redundancy in case of issues on the cluster C.

Note: in all cases the same team is needed to prepare and test the magnets and already with a single MBH magnet shift work is planned.