# Test results of MCBXFBP2c

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Test plan: EDMS #2605897
Test results: EDMS #2618334

***WP3 Meeting – 23 June 2022***

https://indico.cern.ch/event/1160170/

# Contents

# 1. About BP2c

- BP2c: First INNER dipole coils produced at Elytt. ICBS06 & ICBS05. Featuring the new design introduced in B01 [1]

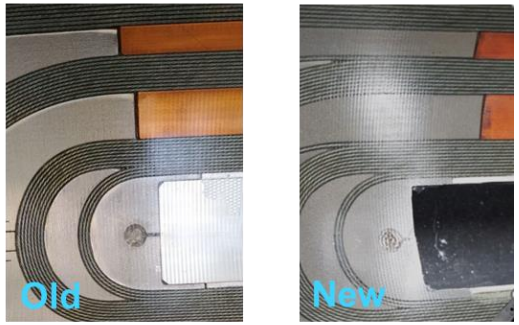
[1] Same outer dipole as BP2, OC4 & OC3

MCBXFB01, MCBXFBP2c & MCBXFAP1:

- 118mm shorter ID coils to match ID pole window length with OD´s (828 vs 946 mm).

- End spacers with longer legs to increase the rigidity at coil extremities.

- Other magnet components:
  - New end spacers with longer legs produced:
    Assembled in OCBS03 & ICBS01.
    To be assembled in ICBS02.







[1] MCBXF Production Status; C. Martins, F. Toral (CIEMAT), J. C. Pérez, E. Todesco (CERN), MCBXF meeting – 10th February 2021
https://indico.cern.ch/event/1005367/contributions/4221559/attachments/2187489/3696346/20210210_MCBXF_status.pdf

# 2. Current leads again

CD #1 was stopped, and the magnet taken out of the cryostat


## Baseline configuration

- Current leads routed by pairs of polarity
- Held with Velcro between them and to the rods
- Guided vertically by means of an ad-hoc stability plate
- Spliced to 13 kA NbTi Rutherford extensions
- The vTap wiring must be keep away from the power cables as much as possible.

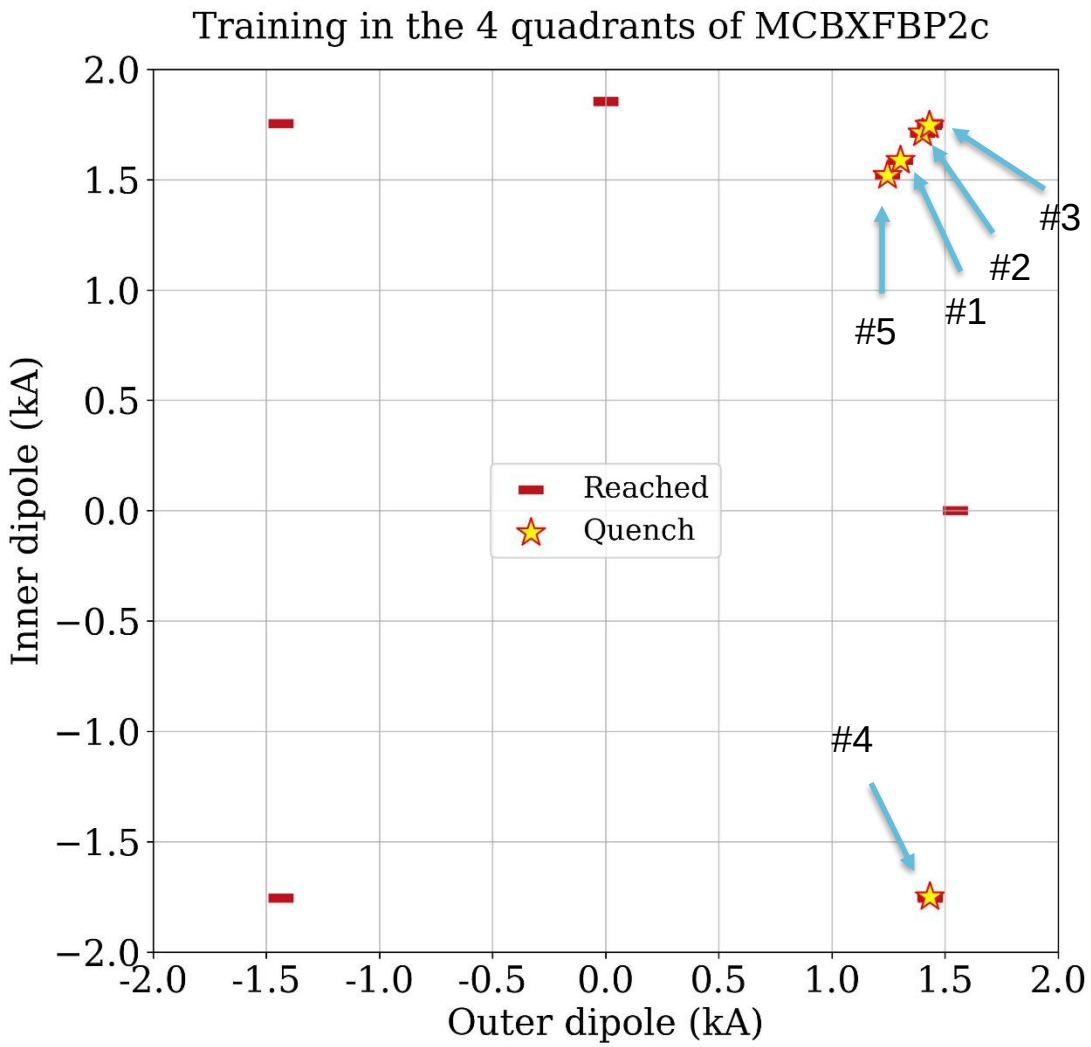
# 3. Test plan at a glance

1. - Training performance in individual and combined powering. Before and after TC.
2. - Assess the quench free working area in the four quadrants for a given integrated field. Before and after TC.
3. - Rest of acceptance tests (splice and inductance measurements, ramp rate dependency, endurance, holding current and RRR)
4. - To perform magnetic measurements. MM presentation

# 4. Cold powering tests

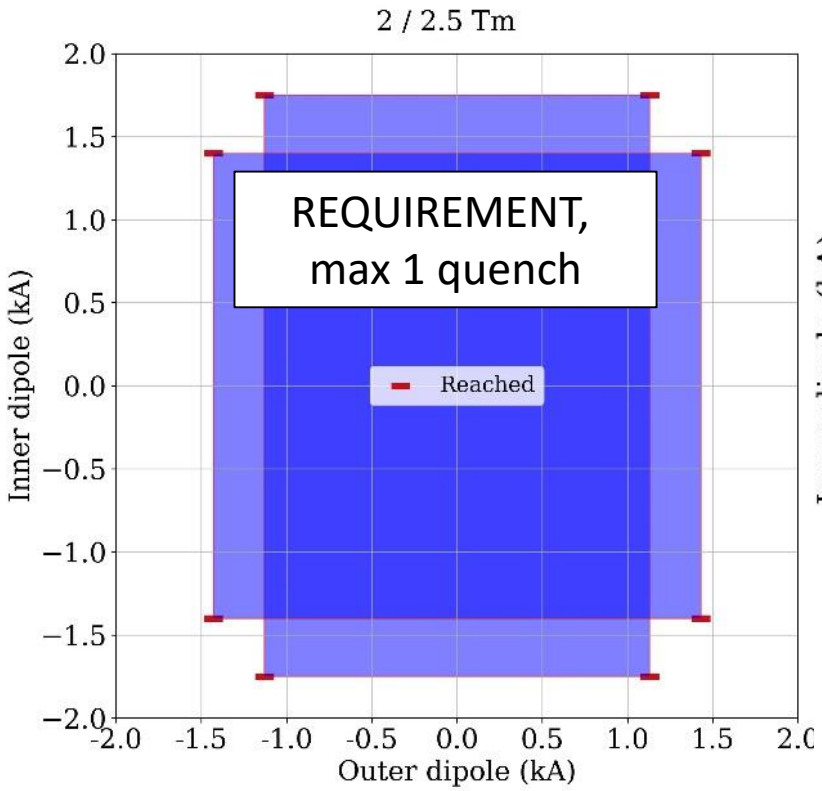
# Training in the 4 quadrants to compare with previous magnets. CD#2. Virgin inner dipole magnet

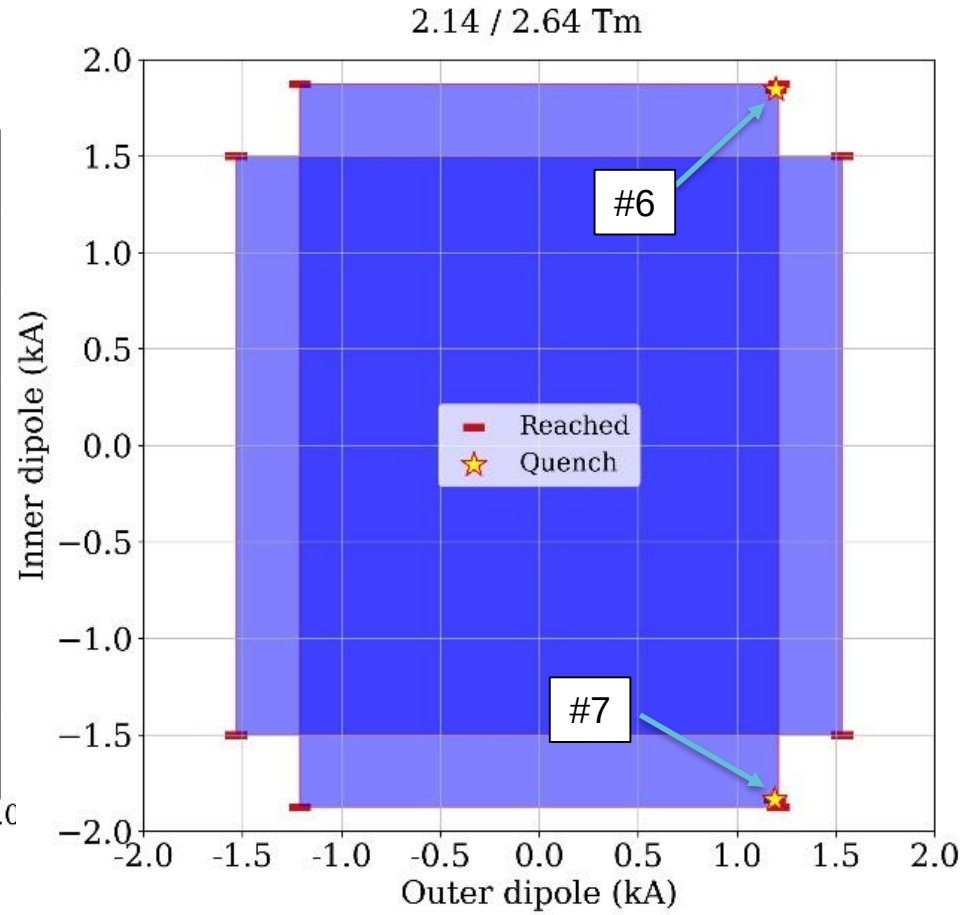
- Nominal ramp rate (5.5/4.5 A/s)
- No quenches in standalone powering up to ultimate current
- 3 training quenches to +nominal/+nominal in combined powering. (MCBXBP2a took 32 quenches, B01 took 3 quenches)
- No quenches to -nominal/-nominal (-1755A/-1535A) (Same as B01)
- (!) No quenches to -nominal/+nominal (-1755A/1535A) in combined powering (1 quench in B01)
- 1 quench at -1749A/1433 A (same amount and same current level as B01). Then reached +nominal/-nominal
- 1 quench at 1588A/1302 A. Then reached +nominal/+nominal



# Quench free working area in the four quadrants for a given integrated field. CD #2

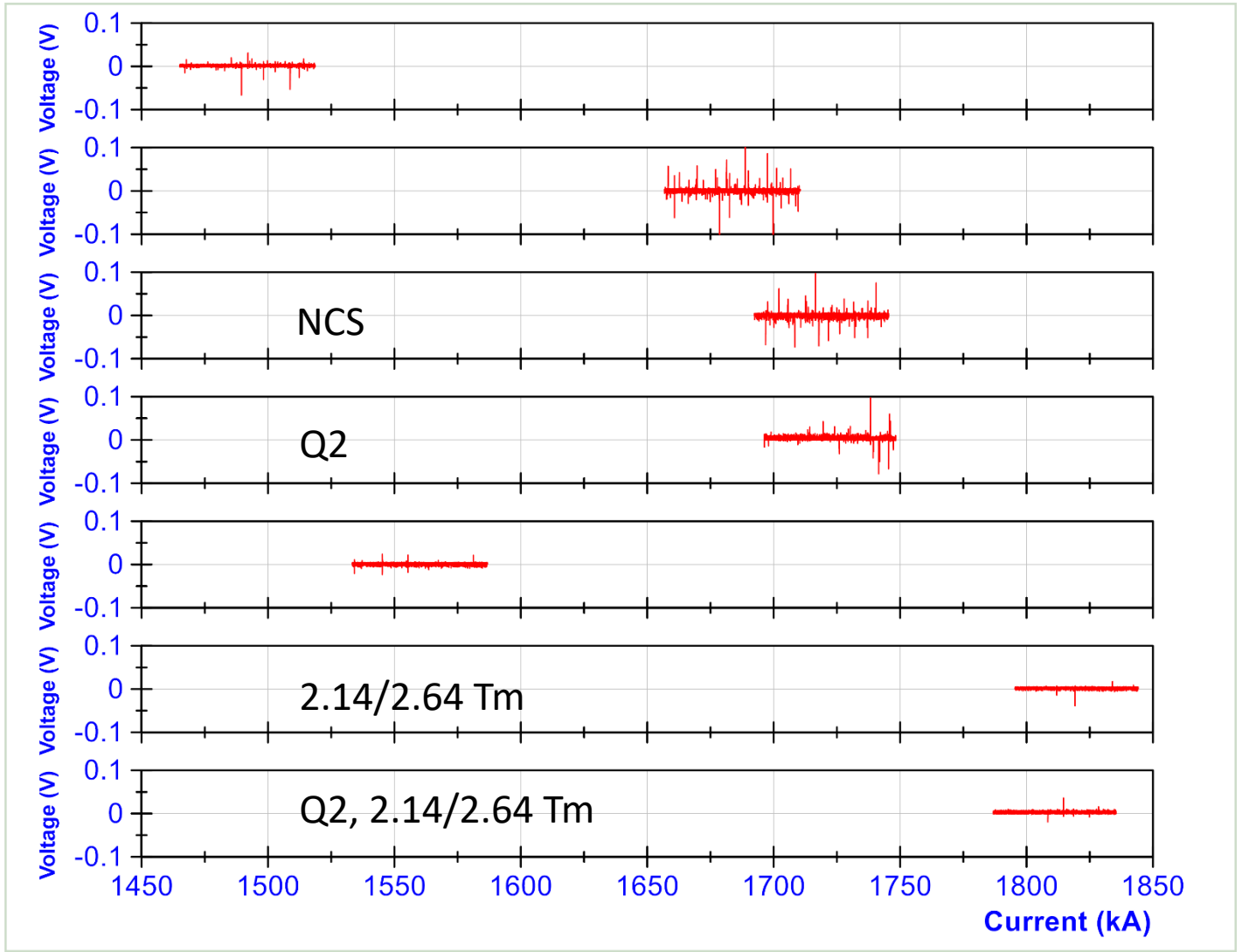
- Max ramp rate (5 A/s)
- No quenches in 2 / 2.5 Tm cycle
- 2 quenches to in the inner dipole at almost ultimate current in the 2.14/2.64 Tm
- After the quench the ramp was restarted and successfully performed



# Note on Quench Signature

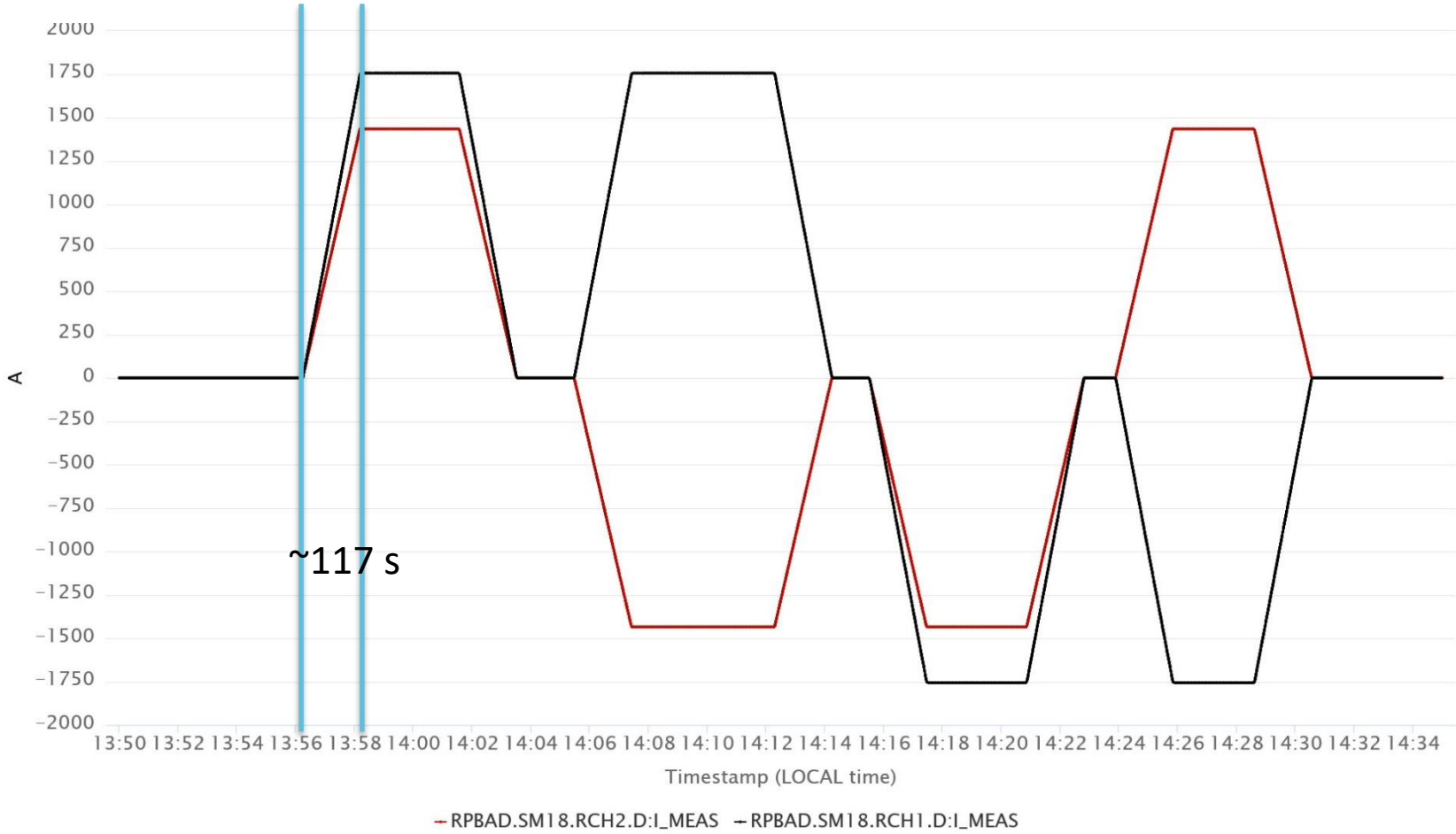
- **7 Quenches in the whole test campaign. No more quenches during RR and magnetic measurements in CD #2. No quenches in CD #3**
- All quenches showed mechanical precursor
- Showing absolute value of the current
- Quench antenna connected in the 5 first quenches
  - CS: 4/5
  - NCS: 1/5
- Quench signatures and location in extra slides



# Ramp rate dependency at 15 A/s

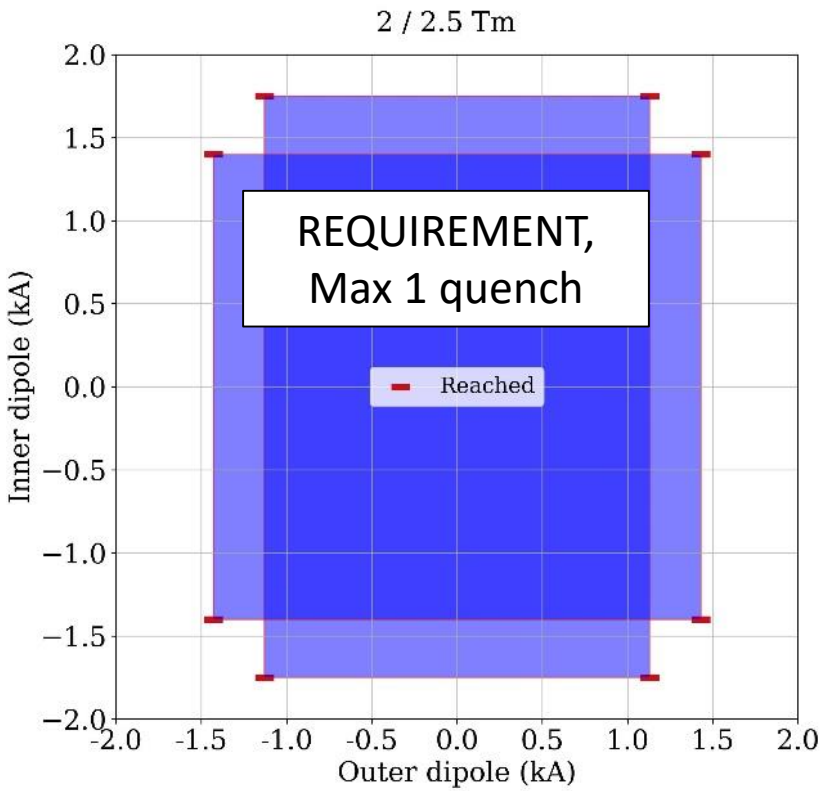
01.06.2022
CD #2

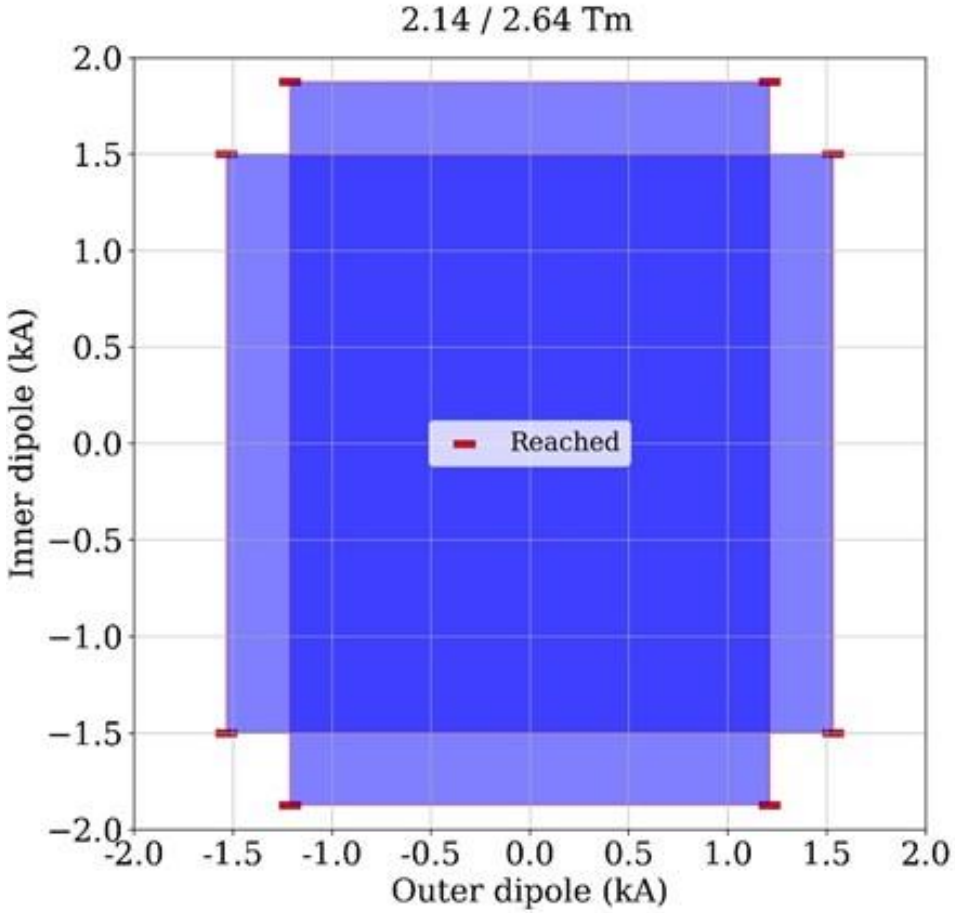
- 4 quadrants up to nominal current
- No quench



# Quench free working area in the four quadrants for a given integrated field. CD #3

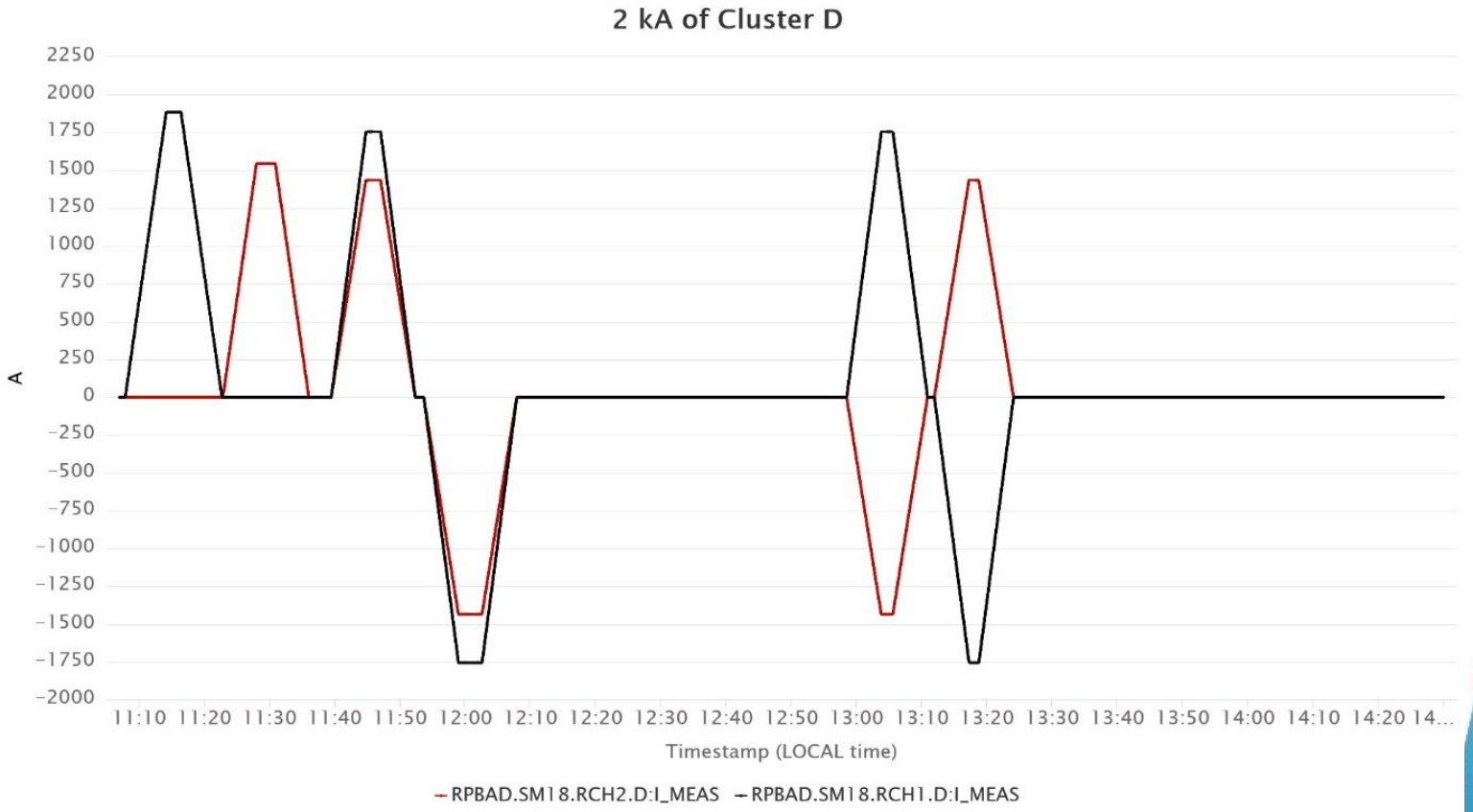
- Max ramp rate (5 A/s)
- No quenches



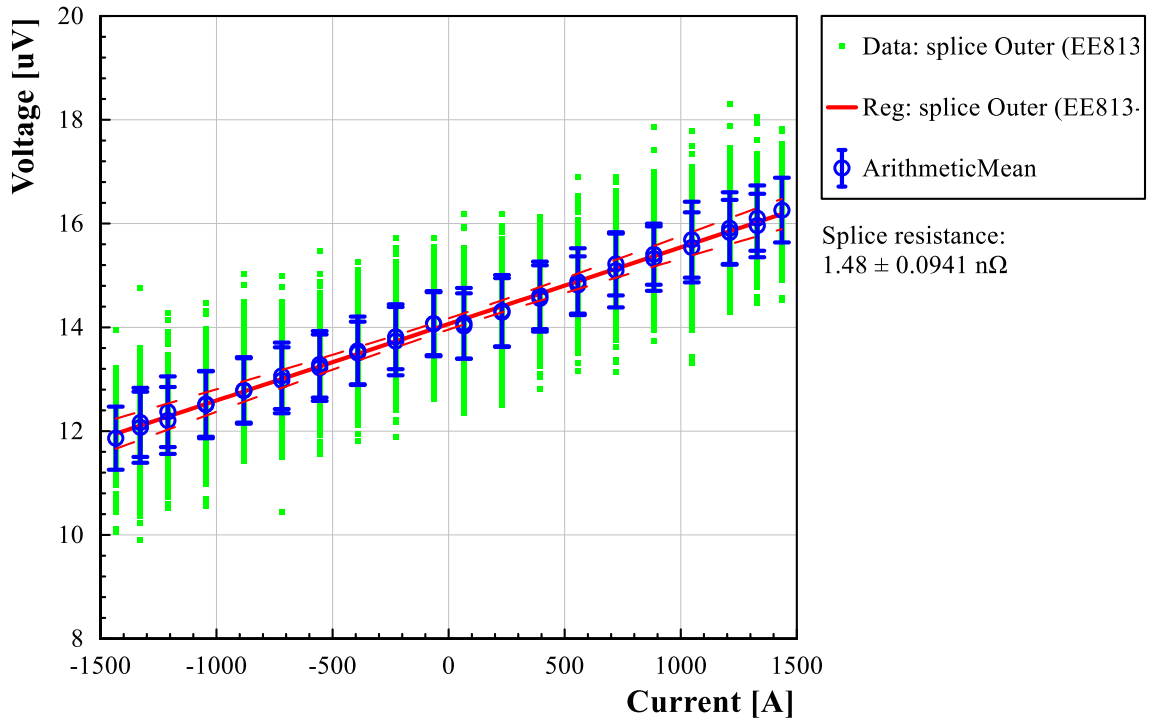



# Training in the 4 quadrants to compare with previous magnets. CD#3

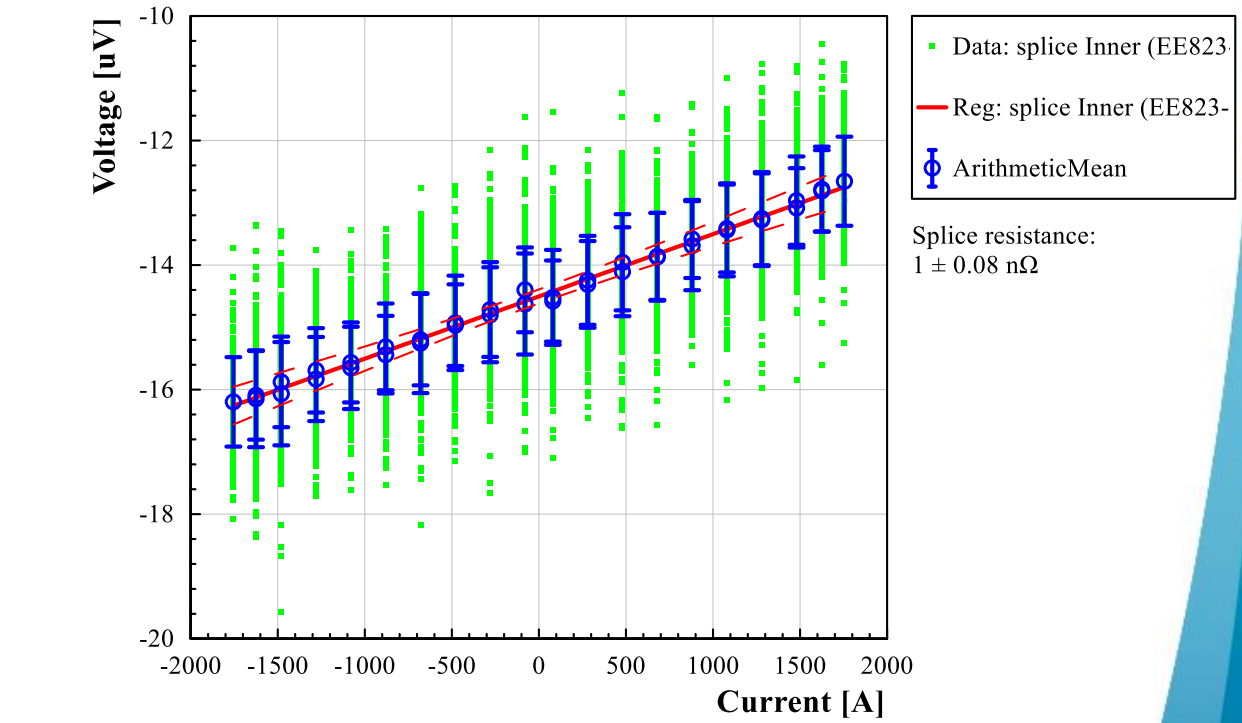
- Nominal ramp rate (5.5/4.5 A/s)
- Standalone and 4 quadrants up to nominal
- No quenches in the whole CD #3, B01 had two and three retraining quenches after each one of the two thermal cycles



# Splice measurements



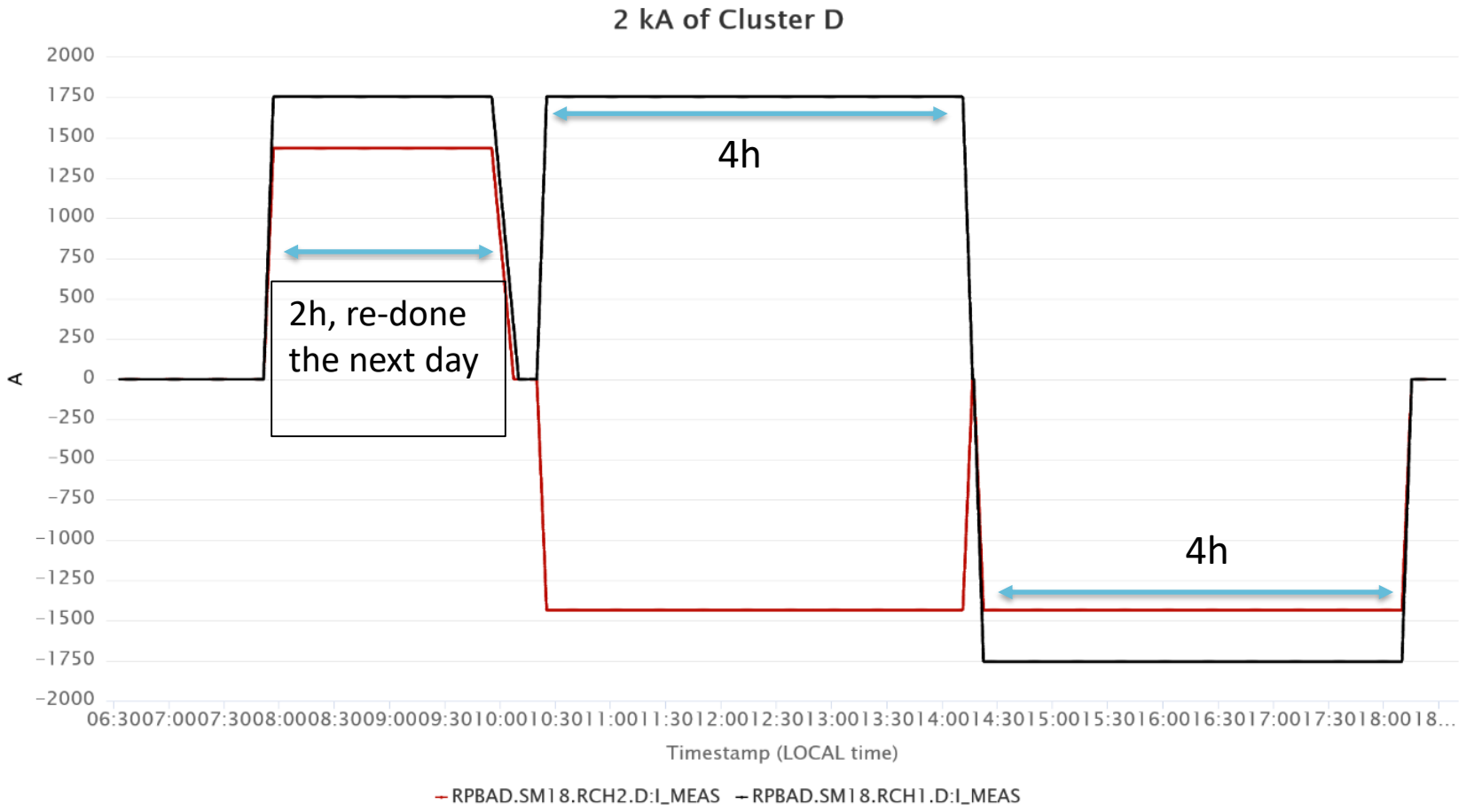


# Other tests and data

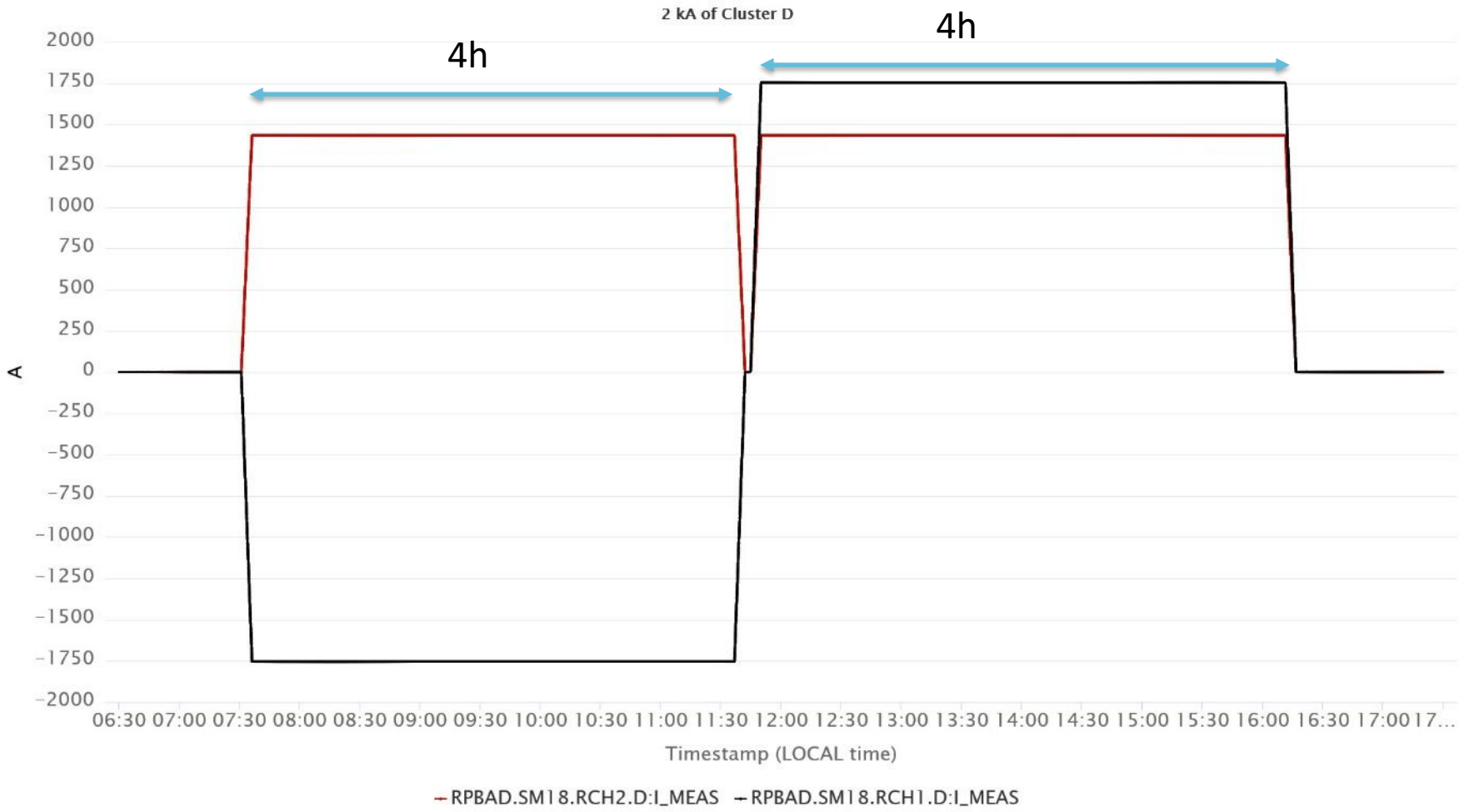
# Holding current test

09.06.2022
CD #3
No quench



# Holding current test

10.06.2022
CD #3
No quench



# Endurance test

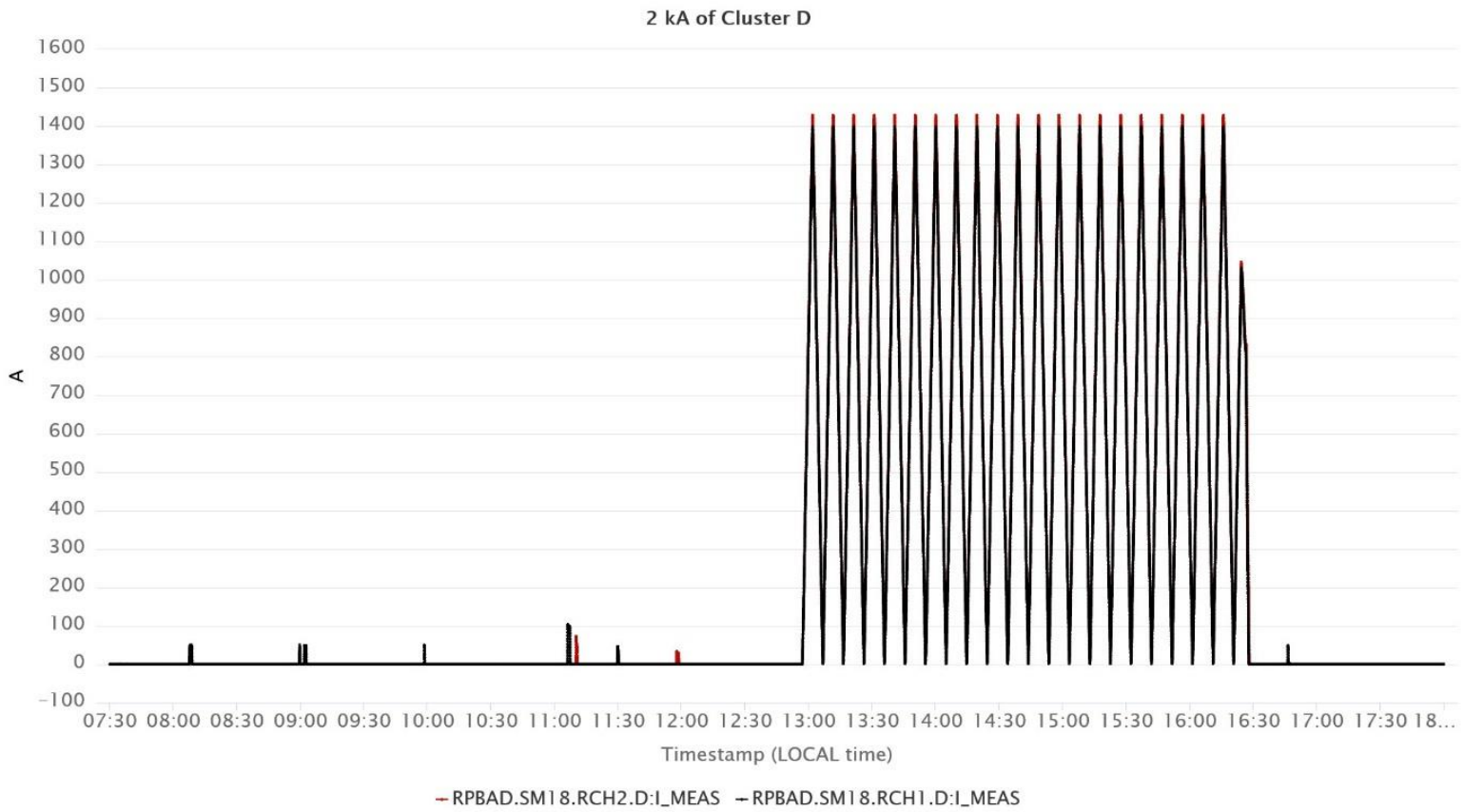
13.06.2022

Inner: +1400 A

Outer: +1430 A

RR: 5 A/s (target was 15 A/s, impossible to ramp faster)

21 cycles , no quench



# Endurance test

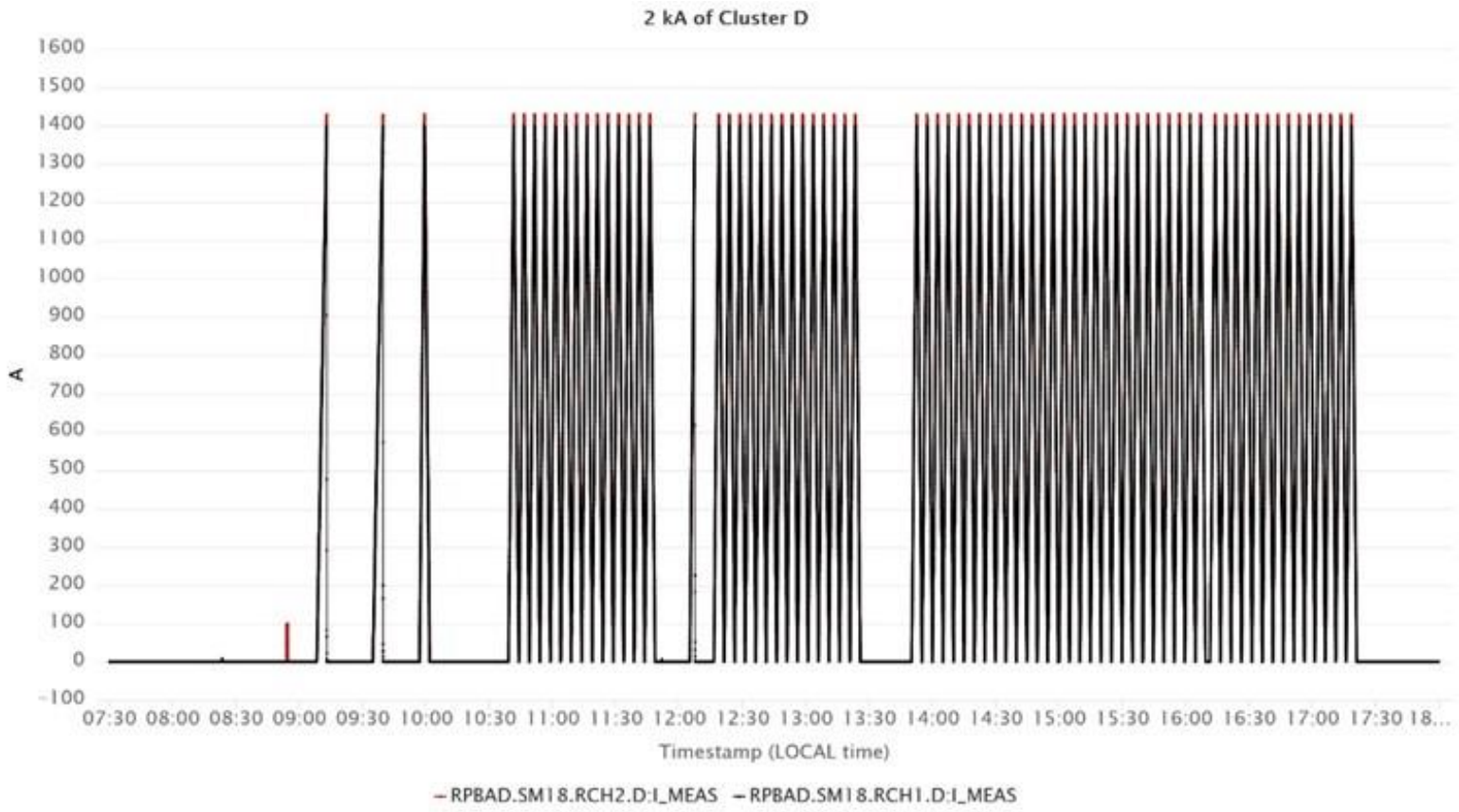
15.06.2022

71 cycles, no quench

Inner: +1400 A

Outer: +1430 A

RR: 10 A/s (target was 15 A/s, impossible to ramp faster)



# Endurance test

16.06.2022

8 cycles, no quench

Inner: +1400 A

Outer: +1430 A

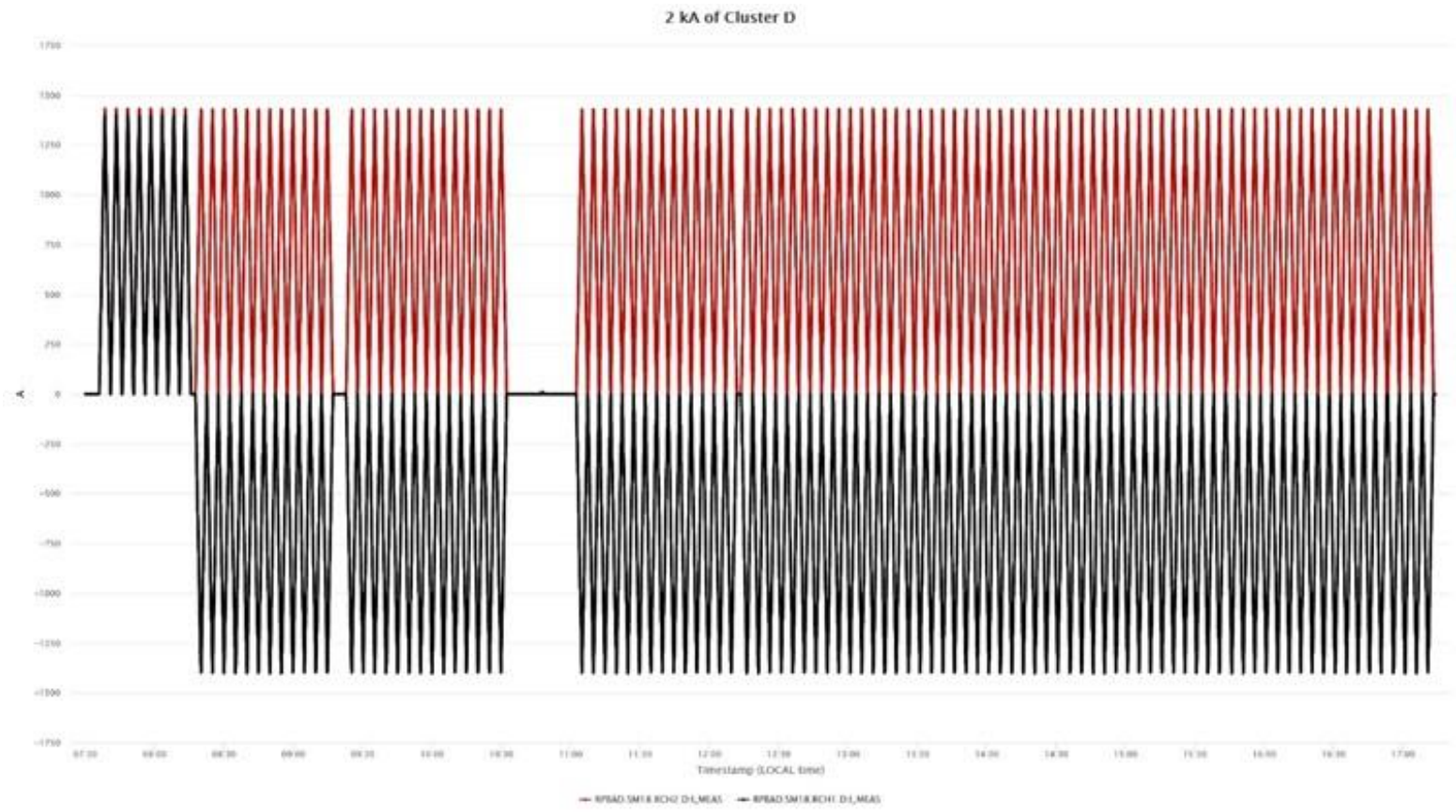
RR: 10 A/s

100 cycles, no quench

Inner: +1400 A

Outer: +1430 A

RR: 10 A/s



# Endurance test

17.06.2022

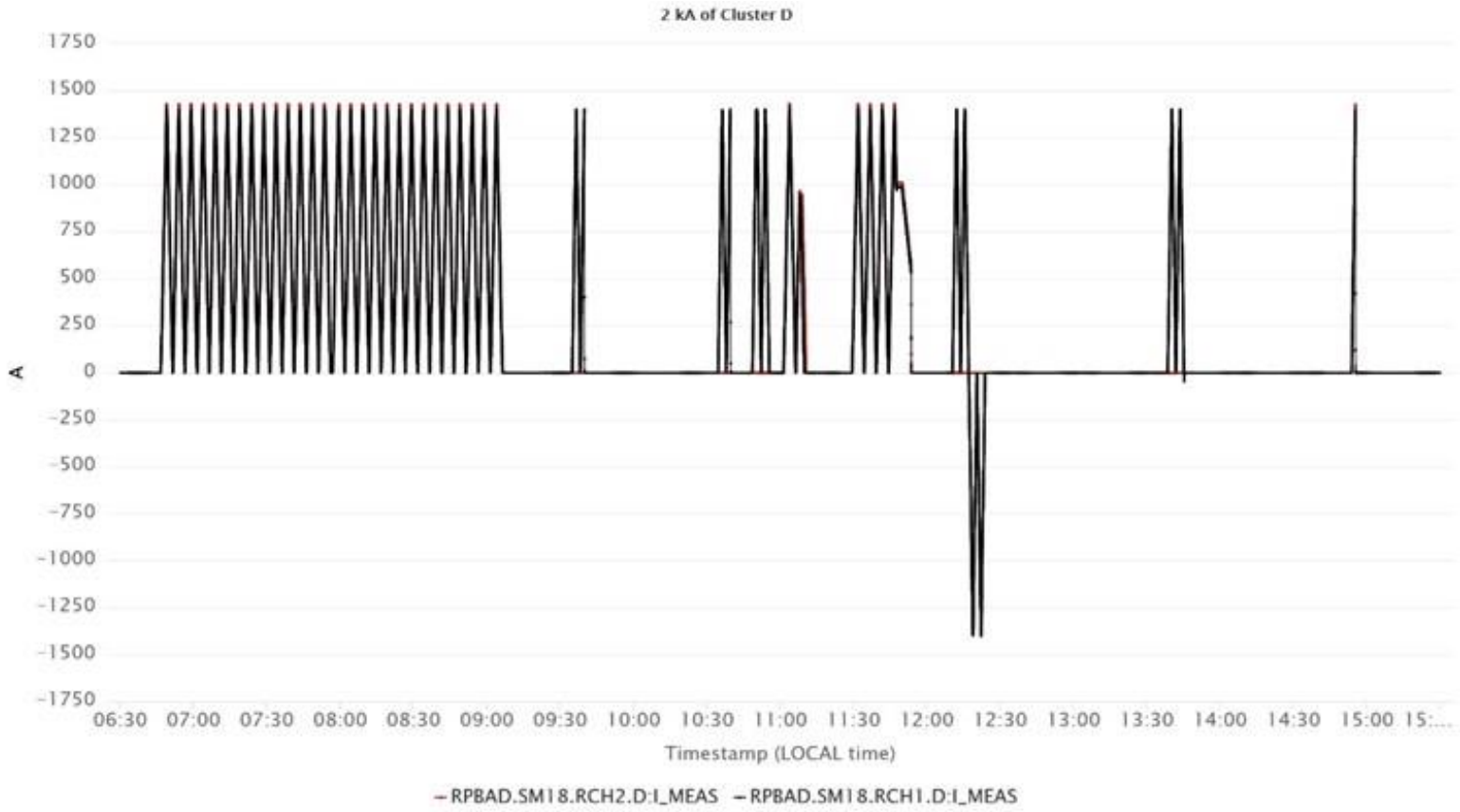
32 cycles, no quench

Inner: +1400 A

Outer: +1430 A

RR: 10 A/s

And tests at 15 A/s



# A word on the effort and lessons learned from the endurance test

- At the beginning of the test phase we experienced a limitation in terms of powering that did not allow to perform the cycling as expected
- It was a combined and good effort from 4 different sections (MTA, EPC, MPE and TM) to get it going
  - Achieved a intermediary setup to ramp at 10 A/s and a automatized cycle of 1.5 h. Managed to do 232 cycles
  - On Friday, after we were told to warmup before the weekend, we allowed ourselves to perform the last tests in order to achieve 15 A/s, which were successful.
    - Power converters tuned to work at those fast ramp rates while inputting a table of points
    - PotAim quench detection adapted to slight overshoots of the total voltage
    - uQDS quench detection also tuned the inductive compensated signal treatment to avoid unintentional triggers. There is only 1 test with uQDS to be done, while powering the OD but which should work as it worked for the detection in the ID.
- We are still working to have this kind of test done outside of working hours. An ad-hoc risk analysis is the next step.

# Electrical insulation test

| | Circuit | V [V] | Time [s] | Resistance [GΩ] |
|---|---|---|---|---|
| @Cryostat Cluster D 1.9 K, He Before test (CD 1) | Inner – GND | 1000 | 120 | 13.3 |
| | Outer – GND | 1000 | 120 | 25.5 |
| @Stand 300 K, Air Before test | Inner – GND | 2000 | 120 | 491 |
| | Outer – GND | 200 | 120 | >100 |
| @Cryostat Cluster D 1.9 K, He CD3 After test | Inner – GND | 1000 | 120 | 65 |
| | Outer – GND | 1000 | 120 | 27.3 |

MIT515, device specs

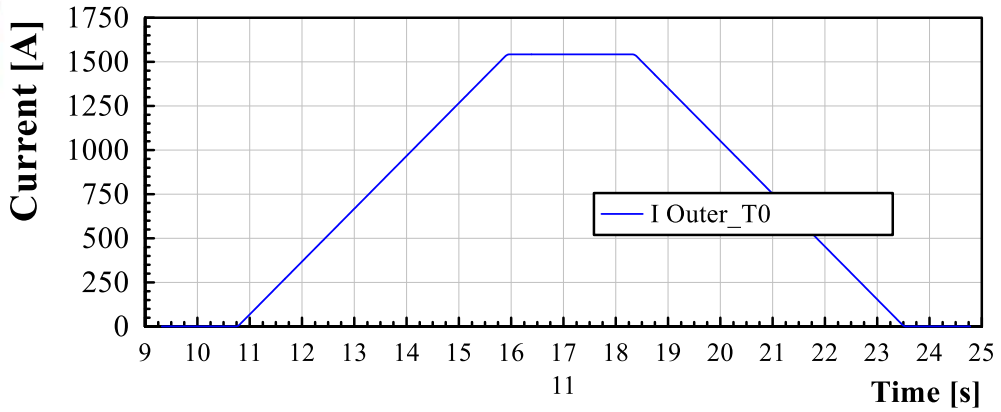
- Voltage: 5 kV (+4%, -0%, ±10 V nominal test voltage at 1 GΩ load (0°C to 30°C)
- Current: ±5% ±0.2 nA at all voltages (20 °C) [1].

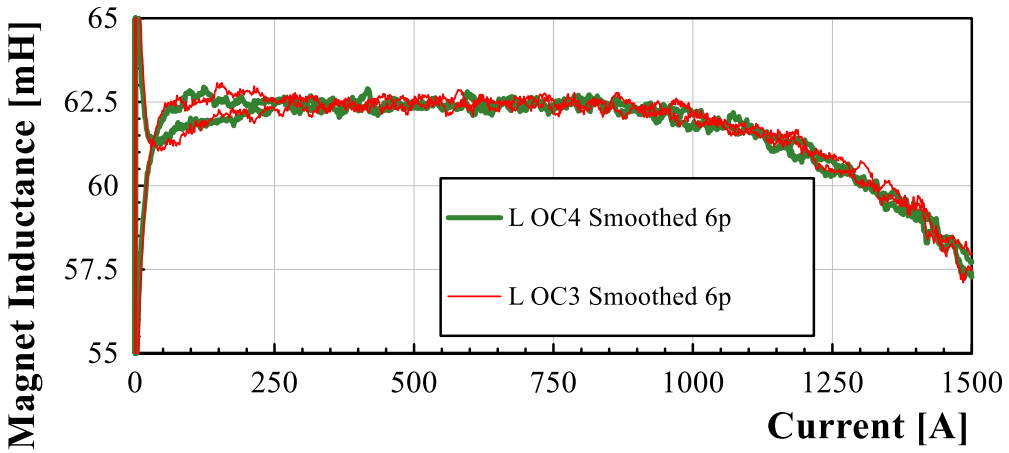
[1] MIT515; 5 kV d.c. Insulation Resistance Testers; https://us.megger.com/5-kv-insulation-resistance-tester-mit525#technical

# Inductance

- Ramp rate: 5 A/s
- Standalone powering
- $L = \frac{V}{dI/dt}$

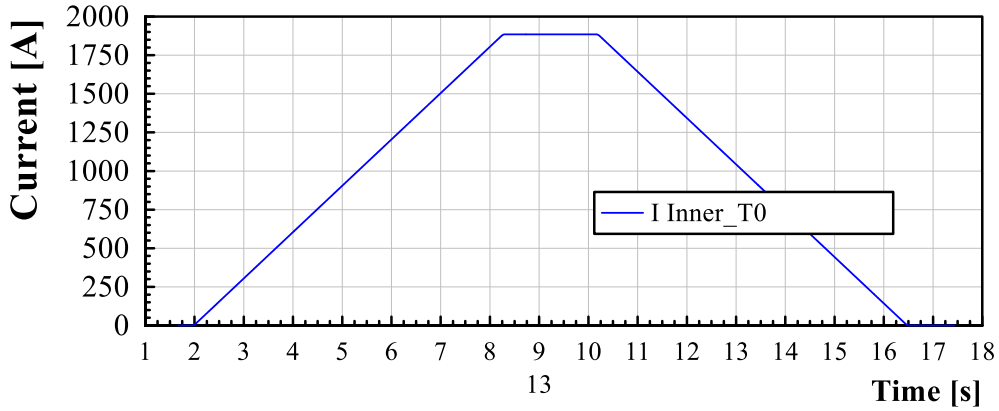
File: inductance_outer

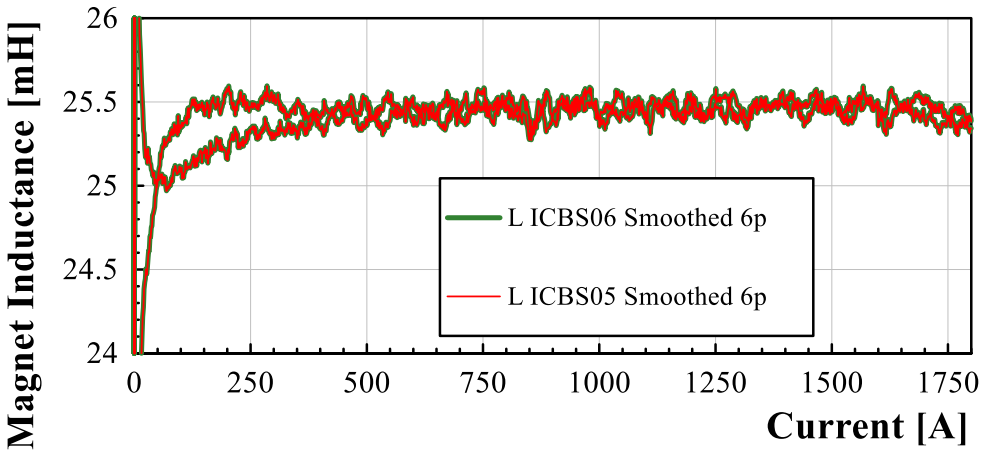





File: HCMCBXFB100-E9000013__C20220531130130__Inductance



# 5. Conclusions

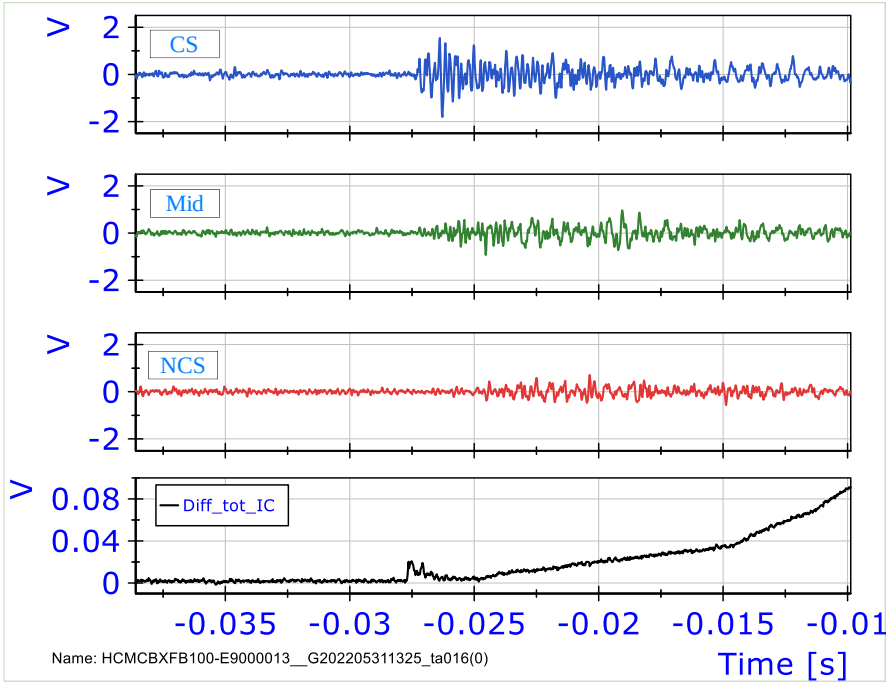
- Good quench performance:
  - 3 training quenches from virgin to +/+ nominal. Then two re-training quenches and the last two ultimate current
  - No quenches in the nominal integrated field area (max accepted 1)
  - Reached the ultimate integrated field requirement with only two quenches in CD #2 and **none** in CD#3
  - No quenches at 15 A/s
  - No quenches in the endurance test of 231 cycles

- Perfect memory after TC
- Splices well below the requirement of 5 nΩ (1 and 1.4 nΩ)

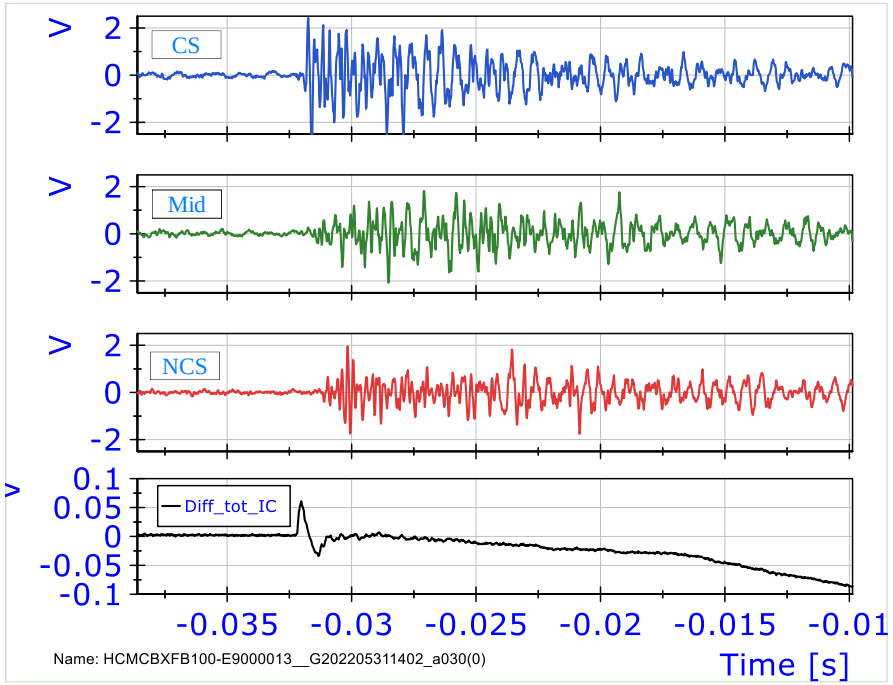
# 6. Extra slides

# Note on Quench Signature

I inner = 1519 A
I outer = 1245 A

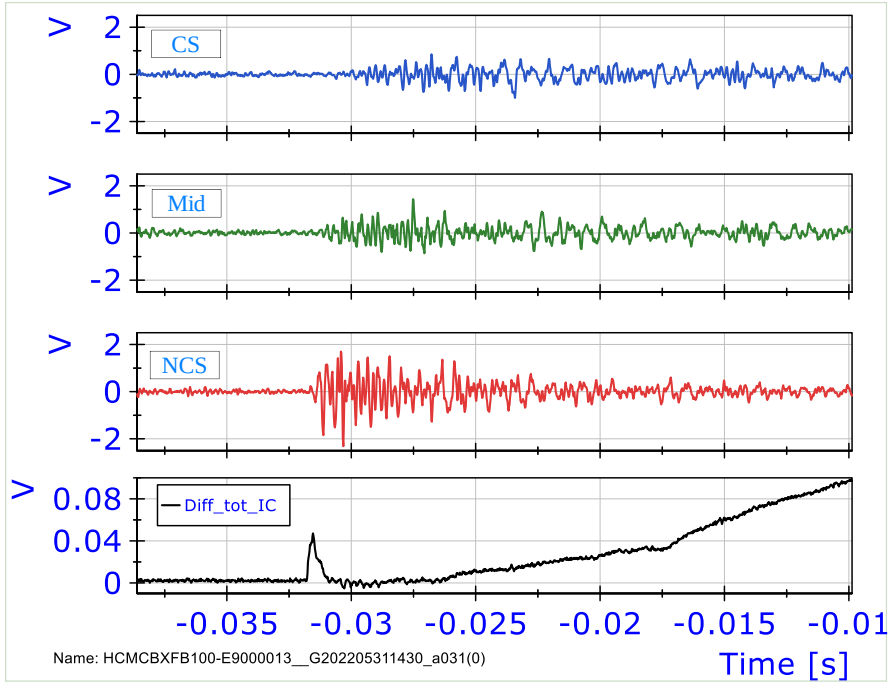



I inner = 1712 A
I outer = 1400 A

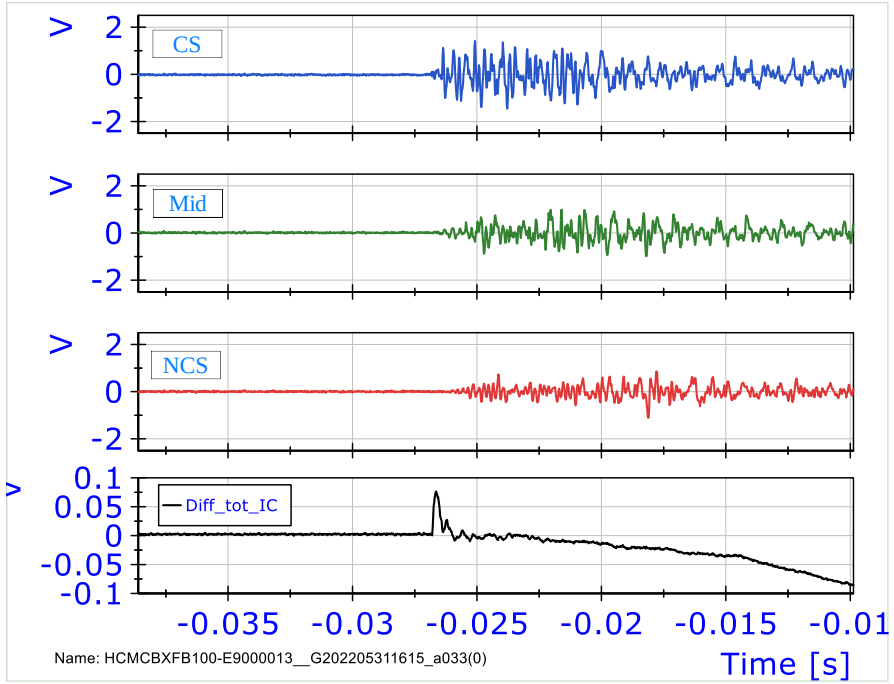


# Note on Quench Signature

I inner = 1747 A
I outer = 1431 A

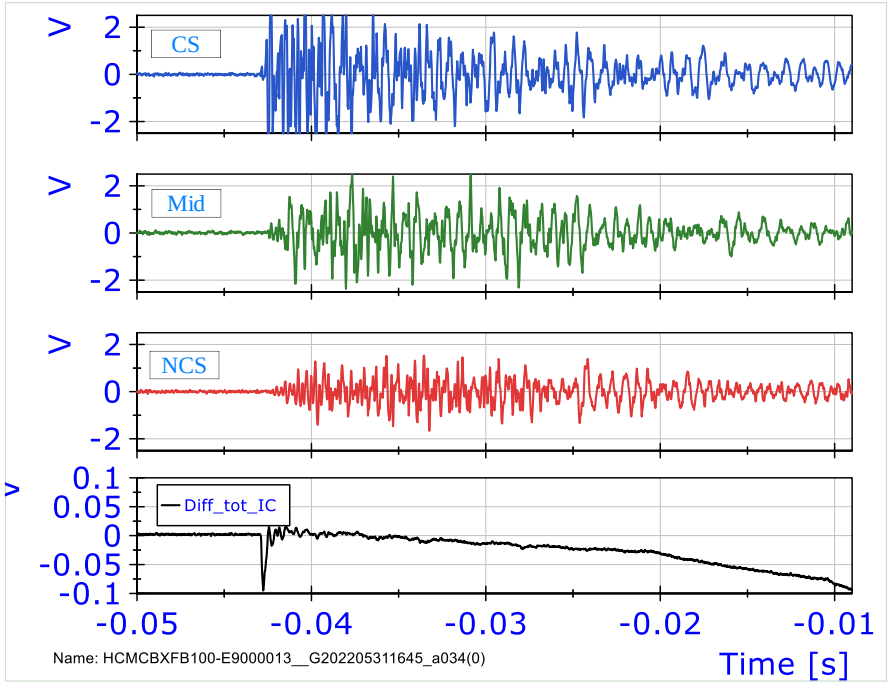



I inner = -1749 A
I outer = 1433 A

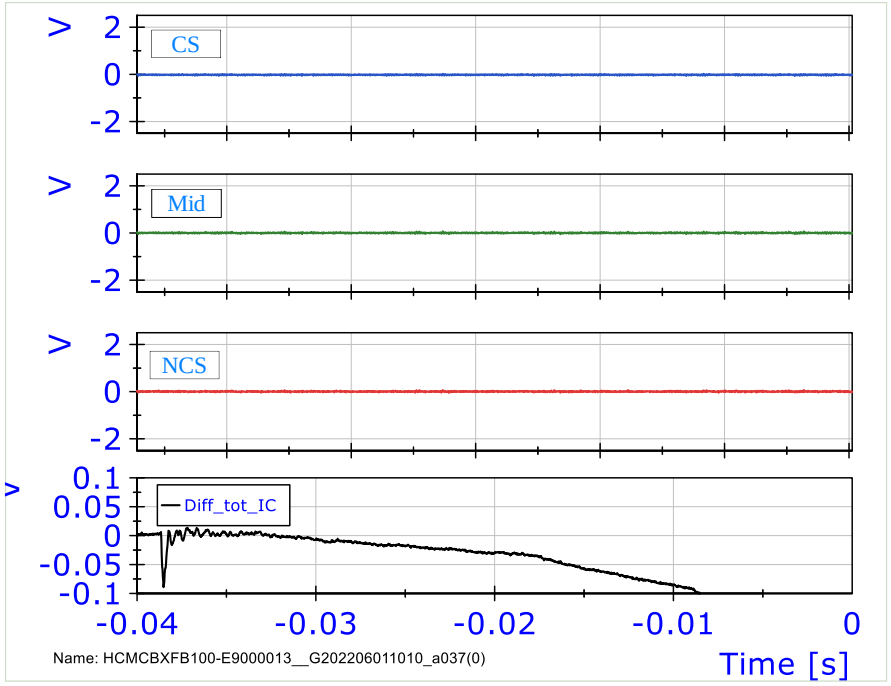


# Note on Quench Signature

I inner = 1588 A
I outer = 1302 A



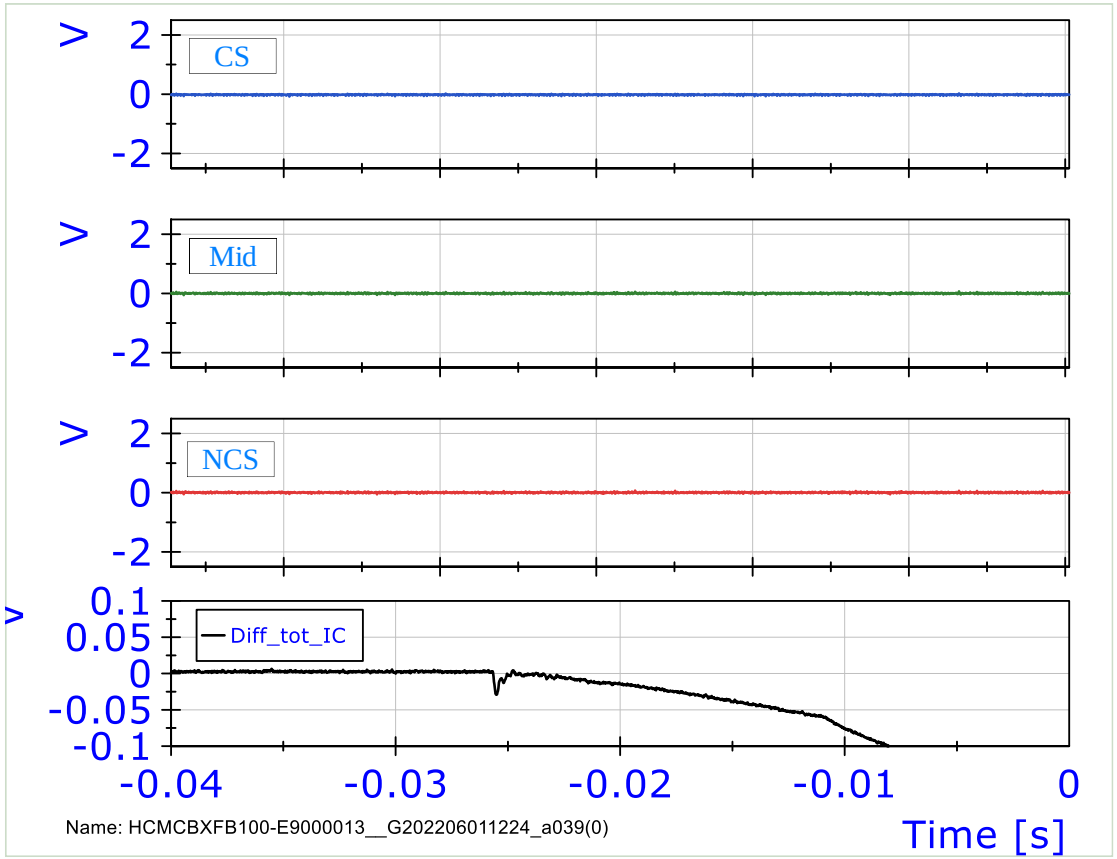

I inner = 1845 A
I outer = 1195 A



# Note on Quench Signature

I inner = -1837 A

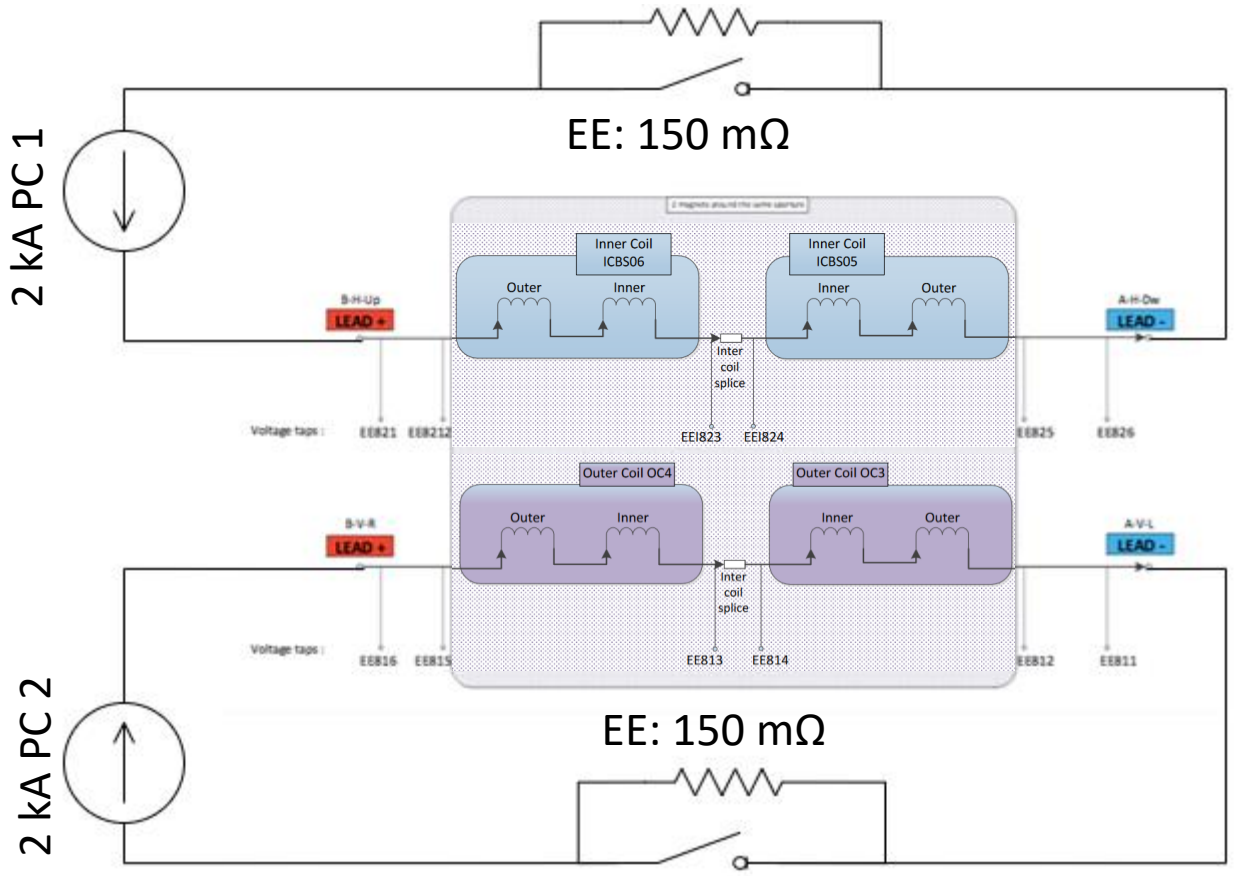
I outer = 1190 A



# Protection scheme

***Baseline protection*** **EE: 150 mOhm**
**Both circuits have a bipolar IGBT EE switch**
**QH: - none**

| *Detection setup* | Name | Vtaps (+, -, mid) | Settings |
|---|---|---|---|
| ***Magnet*** | Diff_Inner_coil (PotAim) | EE821,EE826,EE823 | 10 ms @ 100 mV |
| | Diff_Outer_coil (PotAim) | EE816,EE816,EE814 | 10 ms @ 100 mV |
| | Sum_In_Ind (uQDS, inductive compensation) | EE821,EE823 & Idcct | 10 ms @ 230 mV |
| | Sum_Out_Ind (uQDS, inductive compensation) | EE821,EE823 & Idcct | 10 ms @ 230 mV |
| ***Splices*** | Splices_inter_coil_ID | EE823, EE824 | 8 ms@ 10 mV |
| | Splice_inter_coil_OD | EE814, EE813 | 8 ms@ 10 mV |
| ***Leads and insert*** | Sc Cable | LA2, EE816<br>EE811, LB2 | 8 ms @ 10 mV |
| | Cu Cable | LA1, LA2<br>LB2, LB1 | 80 ms @ 500 mV |




**MCBXFB01**
**HCMCBXFB011-E9000001**
**V1.1**
**EDMS : 2604495**