MQXFS-3 test result

Hugo Bajas *et. Al.*

6th HL-LHC Collaboration Meeting
Espace Saint Martin, Paris, 15th Nov. 2016

MQXFS-3 test report

- Magnet set-up in SM-18 HFM test bench
- Powering tests overview
- Magnet performances
- Quench Localionsation
- Magnet Protection main outcome

Set-Up in the SM-18 HFM test bench

- High Field Magnet facility
  - Cluster D
    - Commissioning in Dec.
  - HFM
    - (FreSCa2)
    - Commissioning
      - Jun-August-October
    - 4.3 K OK
    - 1.9 K not reached in October
    - Limited to 2.1 K
    - Investigation on-going

Set-Up in the SM-18 HFM test bench

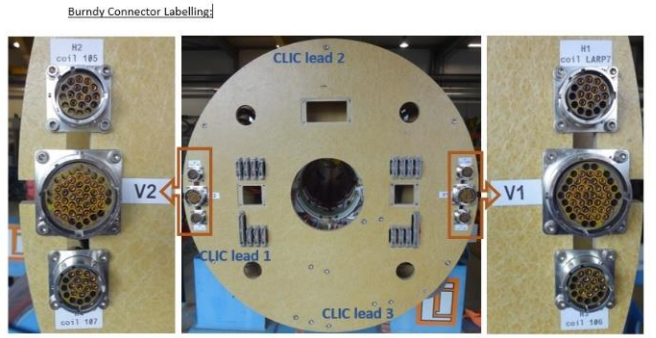
- High Field Magnet facility
  - Cluster D
    - Commissioning in Dec.
  - HFM
    - (FreSCa2)
    - Commissioning
      - Jun-August-October
    - 4.3 K OK
    - 1.9 K not reached in October
    - Limited to 2.1 K
    - Investigation on-going

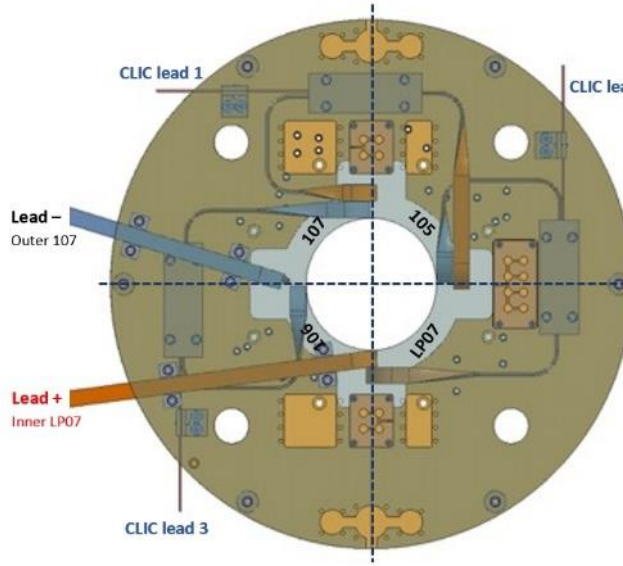
- High Voltage test results
  - Facility Integrity check without magnet
    - (Jun-August)
    - at warm, at cold
    - OK up to 3000 V
  - MQXFs-3
    - HL-LHC requirements
    - At warm up to 3000 V (I_{leak}< 1 μA)
    - At cold limited to 1200 V
    - Enough to test the magnet (1kV)

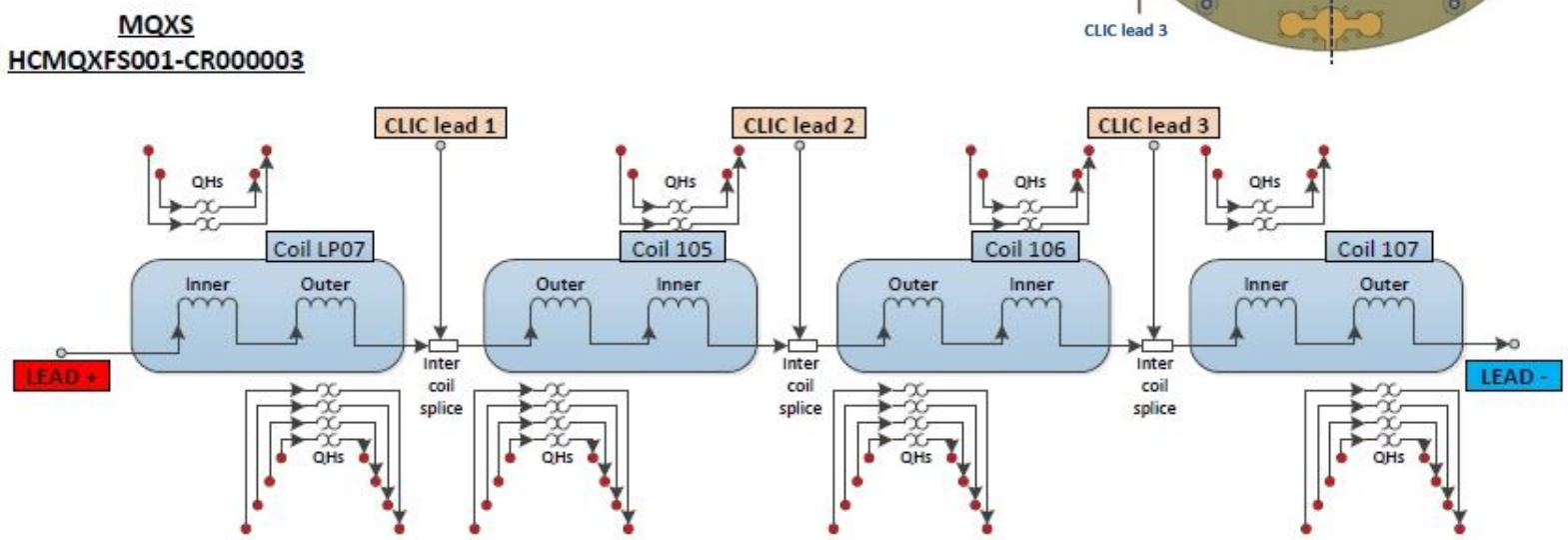
Circuit Element	U_{max} [V]	V hi-pot [kV]	I hi-pot [μA]	Minimum time duration [s]
Coil to Ground at RT *	n.a.	3	10	30
Coil to QH at RT *	n.a.	3	10	30
Coil to Ground at LHe	520	1.5	10	30
Coil to QH at LHe	900	2.3	10	30

Set-Up in the SM-18 HFM test bench

- Voltage taps
  - **64 voltage taps** (8 on the inner layer and 9 on the outer layer)
- Quench Heaters
  - 2 Inner Layer
  - 4 Outer Layer
  - 24 stripes
  - 8 circuits
  - 150 A , 900 V, 1.2
- CLIQ
  - (40 or 80 mF ; 0 to 500 V)
- Dump resistor (60 mΩ)



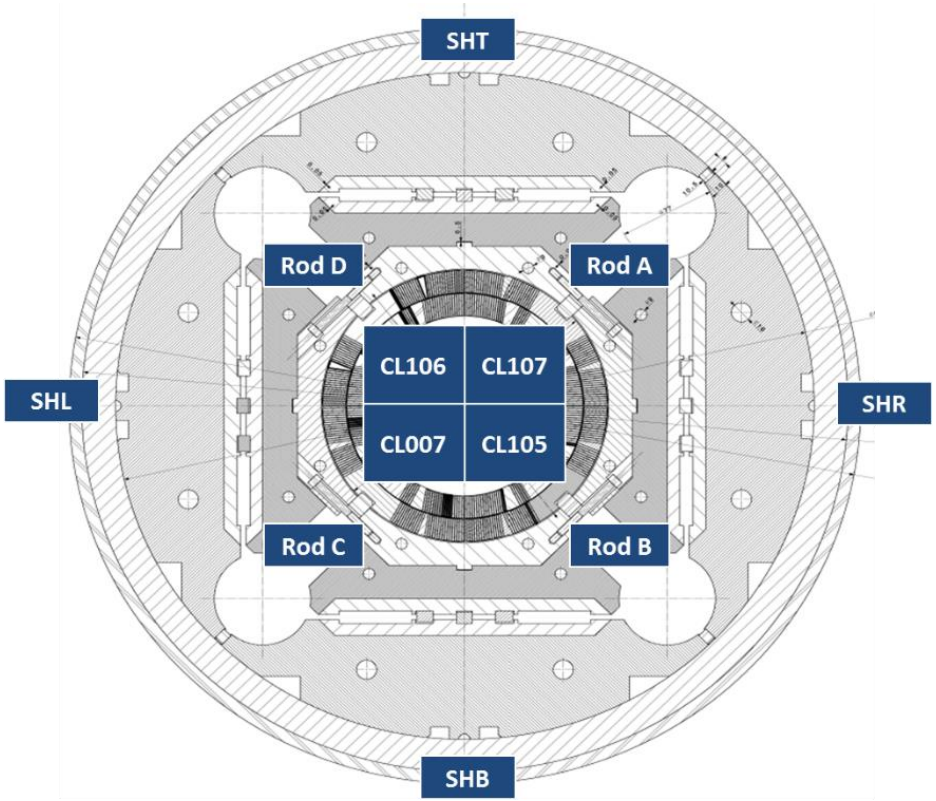




Set-Up in the SM-18 HFM test bench

Set-Up in the SM-18 HFM test bench

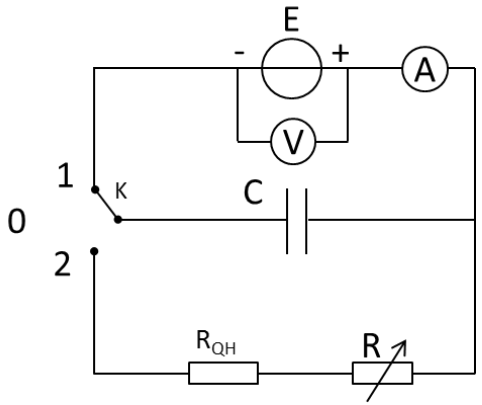
- **20 strain gauges** (4-wires resistive)
  - 8 on the shell
    - 4 axial and 4 azymuthal)
  - one per rod
  - 2 per coil
    - 1 axial and 1 azymuthal).



Powering tests overview

Powering tests overview

- Preliminary tests
  - RRR measurement
    - C105(140), C106(140), C107(140), Lp7(170)
  - Low current discharge

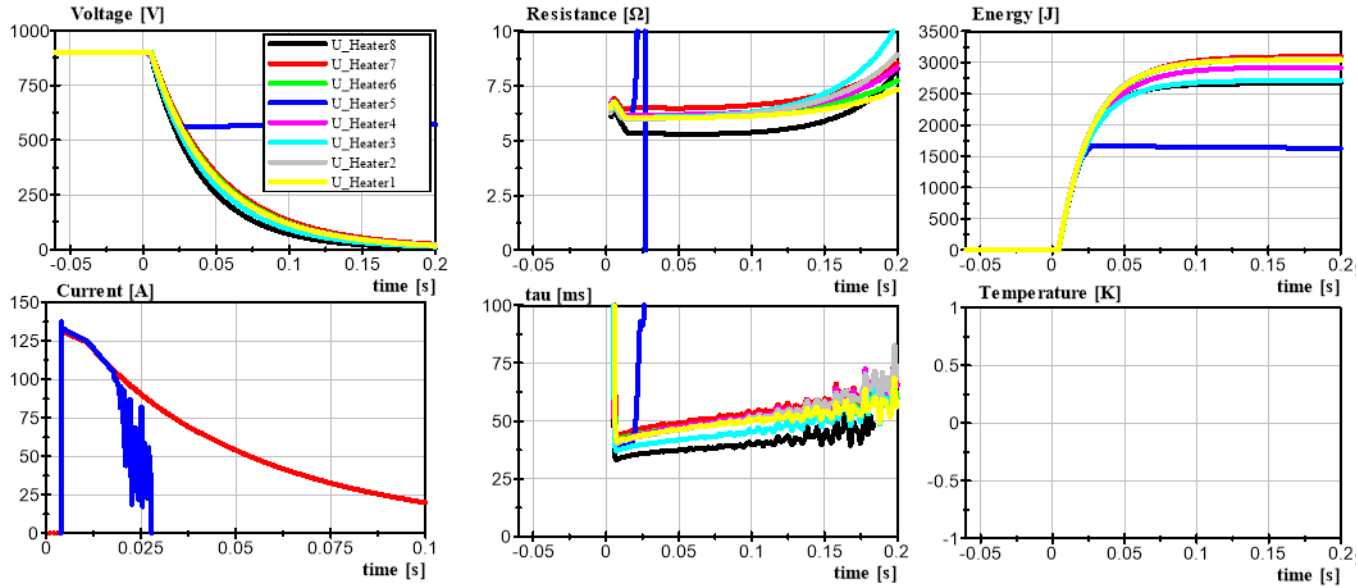


Quench Heater automatic diagnostic

AQA_DIAdem

File: HCMQXFS001-CR000003__HFM1610131732_a002(0)_cmpt_lin

Imax = 4.134 kA



Parameters	tfire	tmaxV	Vmax	Vinit	Imax	tminV	Imin	Vmin	Rinit	Rmax	Rrel	E	C
Max	6	6	900	900	160	1600	2	10	10	15	2	3600	8
Min	-2000	0	700	800	100	0	0	0	5	8	1	2000	6
U_Heater8	-0.0	4.1	900.0	900.0	147.4	189.7	1.5	9.0	6.1	7.0	1.1	2664.9	6.6
U_Heater7	-0.0	4.1	900.0	900.0	136.3	276.2	1.4	9.0	6.6	10.9	1.7	3098.8	7.7
U_Heater6	-0.0	4.3	900.0	900.0	140.0	254.3	1.4	9.0	6.4	9.1	1.4	3050.5	7.5
U_Heater5	-0.0	4.1	900.0	900.0	137.3	-200.0	1.6	900.0	6.6	354.3	54.1	1667.7	4.1
U_Heater4	-0.0	3.9	900.0	900.0	138.2	267.2	1.4	9.0	6.5	10.3	1.6	2926.8	7.2
U_Heater3	-0.0	4.1	900.0	900.0	142.2	224.7	1.4	8.9	6.3	9.7	1.5	2710.9	6.7
U_Heater2	-0.0	4.1	900.0	900.0	143.1	268.6	1.4	9.0	6.3	10.7	1.7	3055.4	7.5
U_Heater1	-0.0	4.1	900.0	900.0	138.5	241.8	1.4	8.9	6.5	8.4	1.3	3049.1	7.5

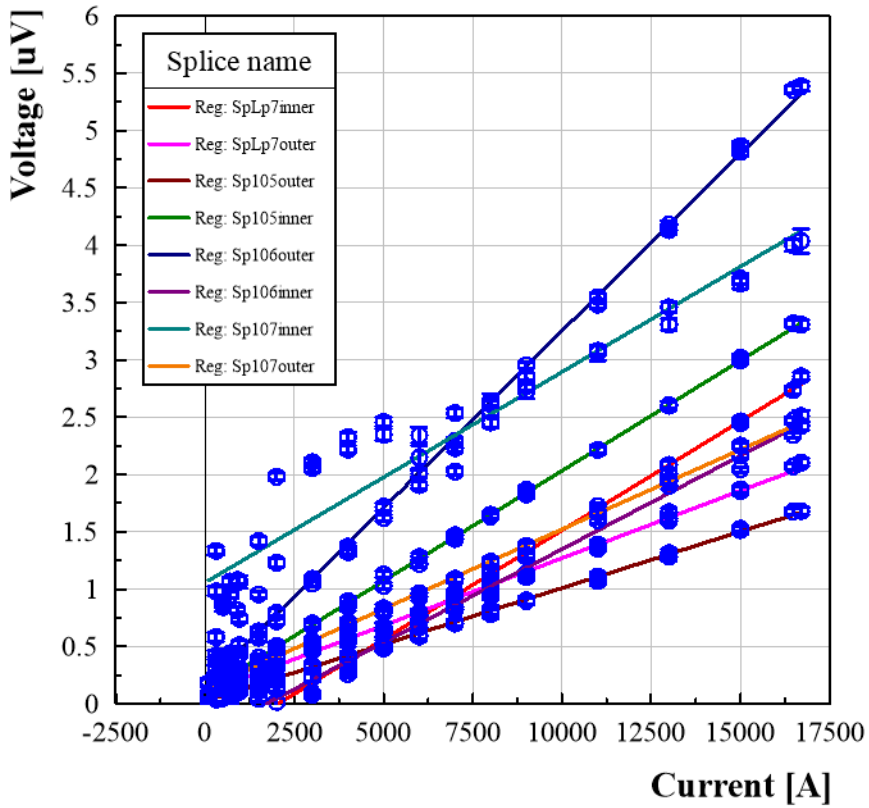
11/15/2016 TE-MSC-TF H. Bajas

Powering tests overview

- Preliminary tests
  - RRR measurement
    - C105(140), C106(140), C107(140), Lp7(170)
  - Low current discharge
  - Splice resistances

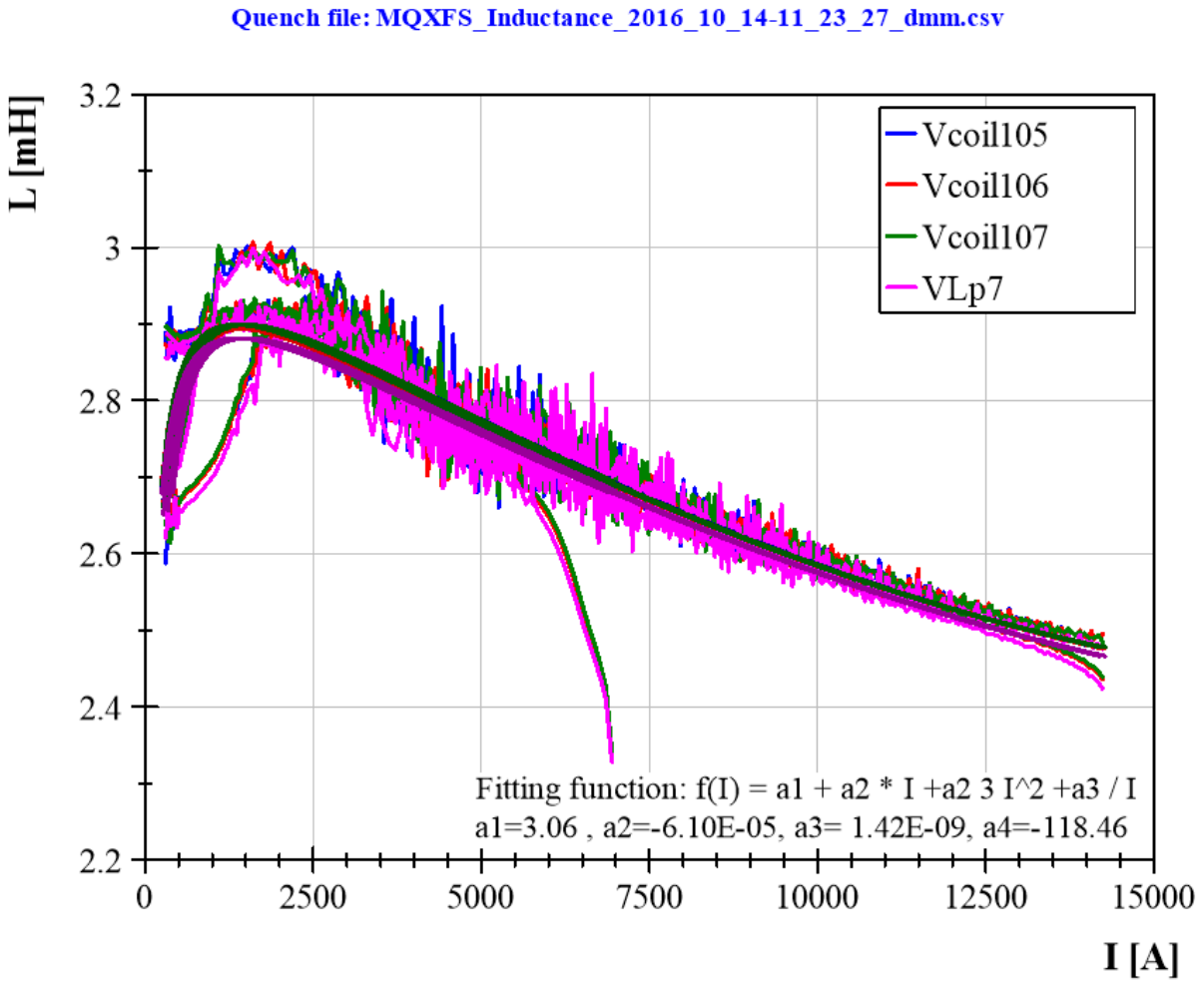
MQXFS_Splices_2016_10_25-11_19_36_dmm.csv

Splice name	Splice resistance [nΩ]
SpLp7inner	0.190
SpLp7outer	0.117
Sp105outer	0.0984
Sp105inner	0.192
Sp106outer	0.309
Sp106inner	0.163
Sp107inner	0.184
Sp107outer	0.139



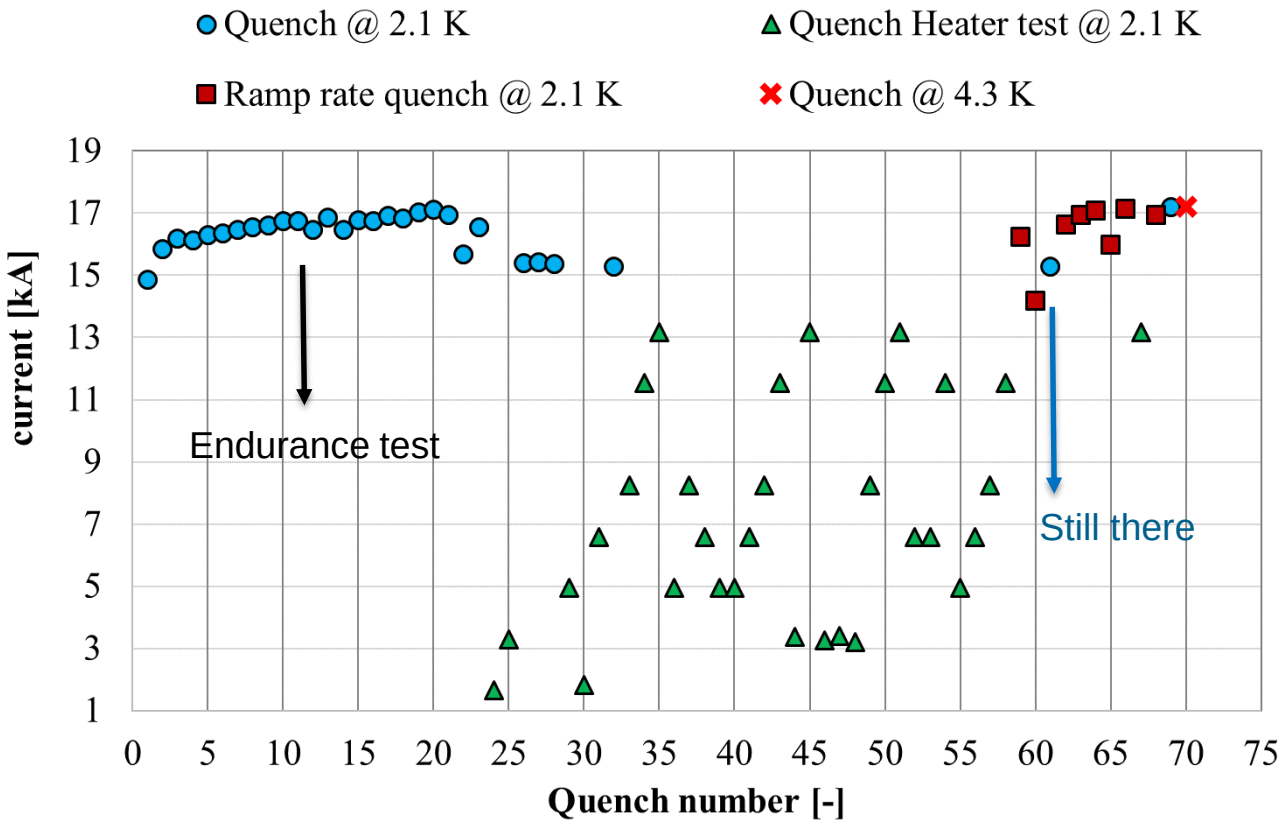
Powering tests overview

- Preliminary tests
  - RRR measurement
    - C105(140), C106(140), C107(140), Lp7(170)
  - Low current discharge
  - Splice resistances
  - Coils Inductances
    - Non-linear behavior
      - magnetisation < 2.5 kA
      - Iron saturation without stabilisation)



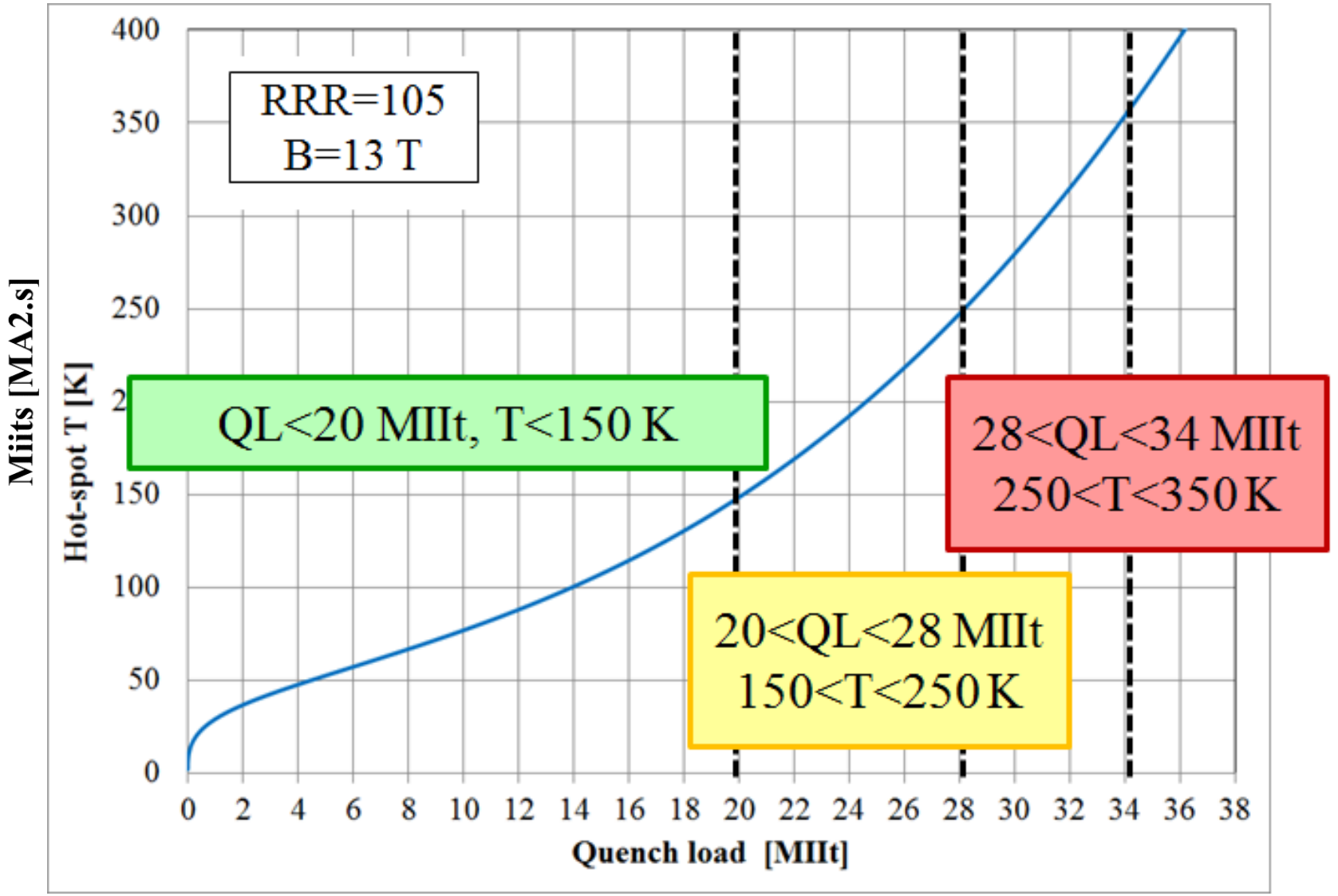
Powering tests overview

- **Training @ 2.1 K**
  - 30 quenches done
- **Endurance test @ I nom**
  - 8 hour intended
  - 1 stop due to cryogenics loss
  - 1 stop due to Power Supply fuse
  - 4 hours eventually done
- **Quench Heater tests @ 2.1 K**
  - 32 provoked quenches
  - All heaters, OL only, OL-HF only, IL only
- **Ramp rate dependence**
  - 8 quenches to check degradation
- **Performance check @ 4.3 K**
  - 1 quench done



- Magnetic measurements
  - Stair-case cycle
  - Machine cycle (2.1 K and 4.3 K)
  - Ramp Rate effect

Powering tests overview



Powering tests overview

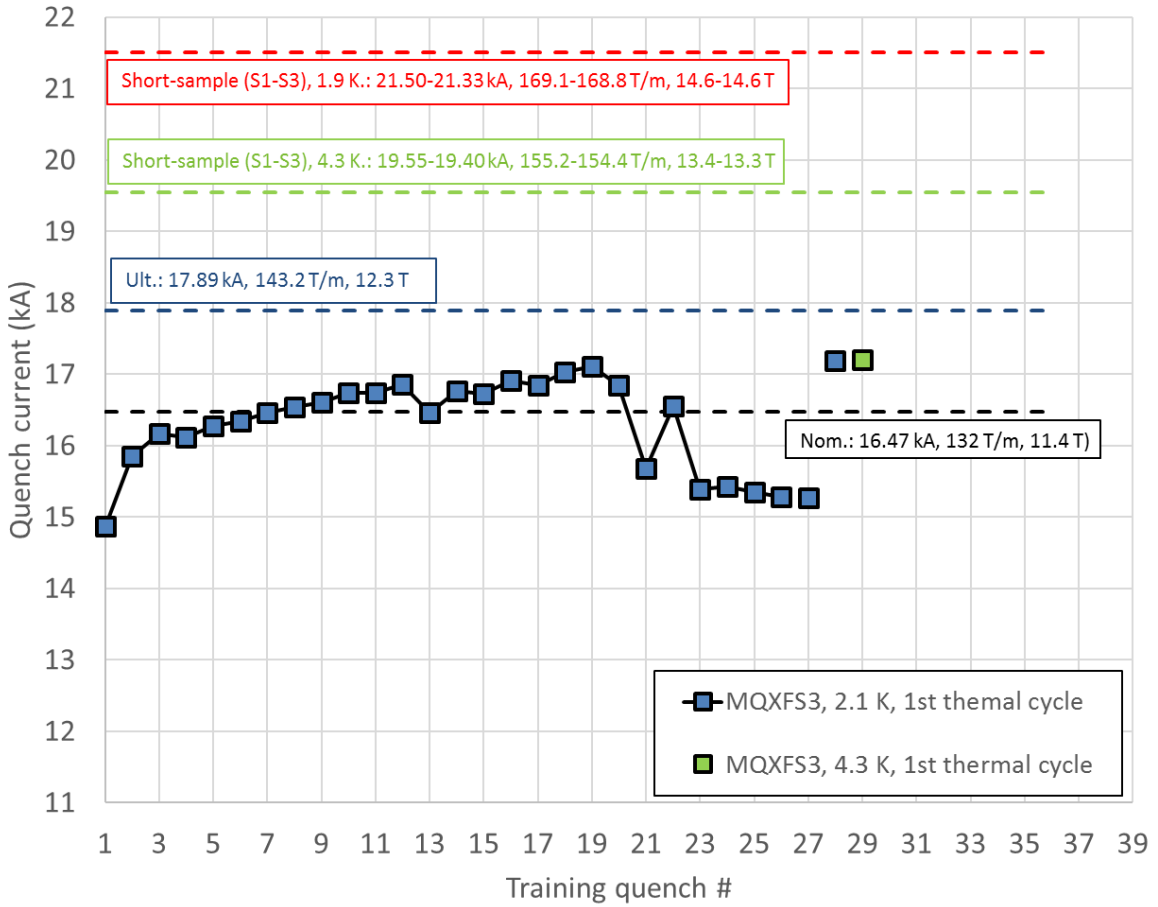
- Test foreseen but not done
  - Higher Miits protection test
  - AC loss measurement
  - CLIQ discharge
  - Training to ultimate
- … Let us see run 2

Magnet performances

Magnet performances

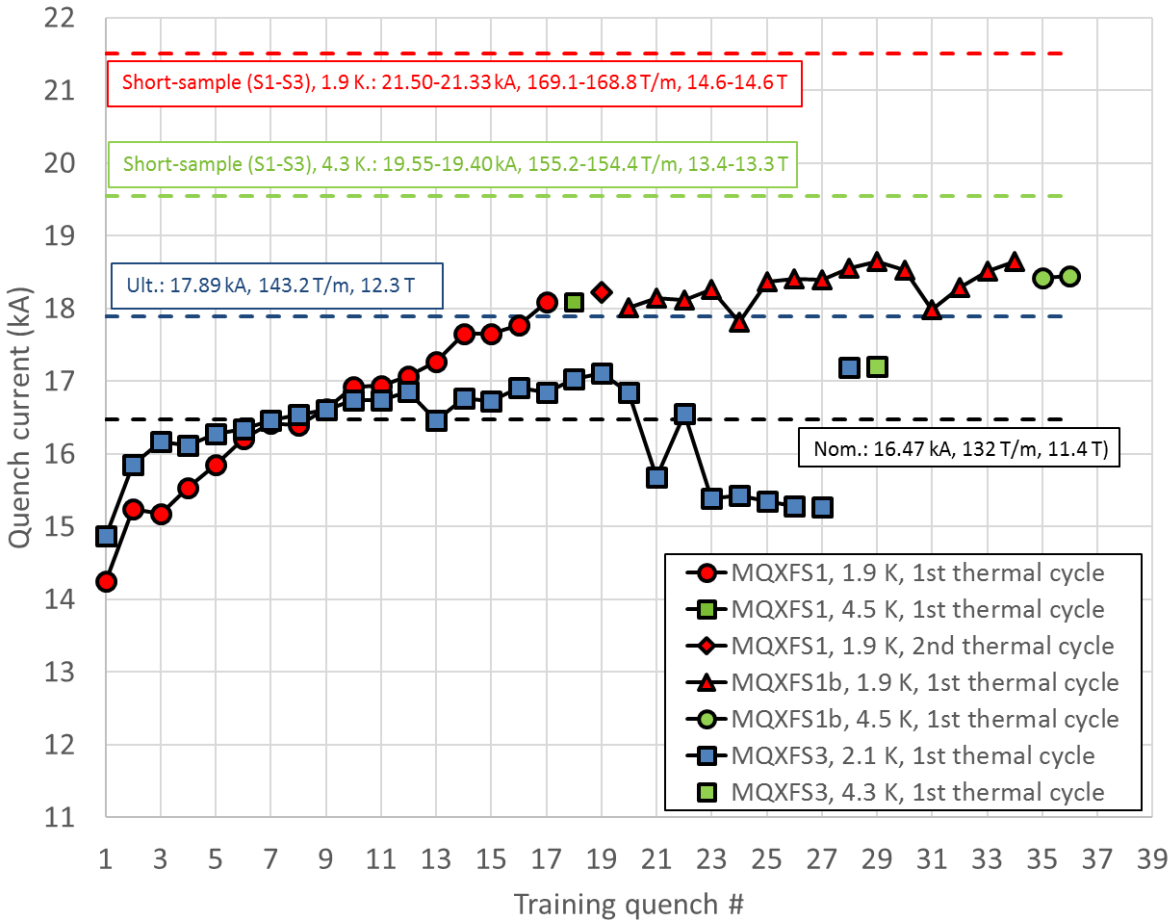
- Magnet performances
  - @ 2.1 K
  - 1st quench at 91% Inom
  - Highest quench
    - 104 % Inom, 96% Iult, 81% Iss

- Performance check @ 4.3 K
  - 89% Iss



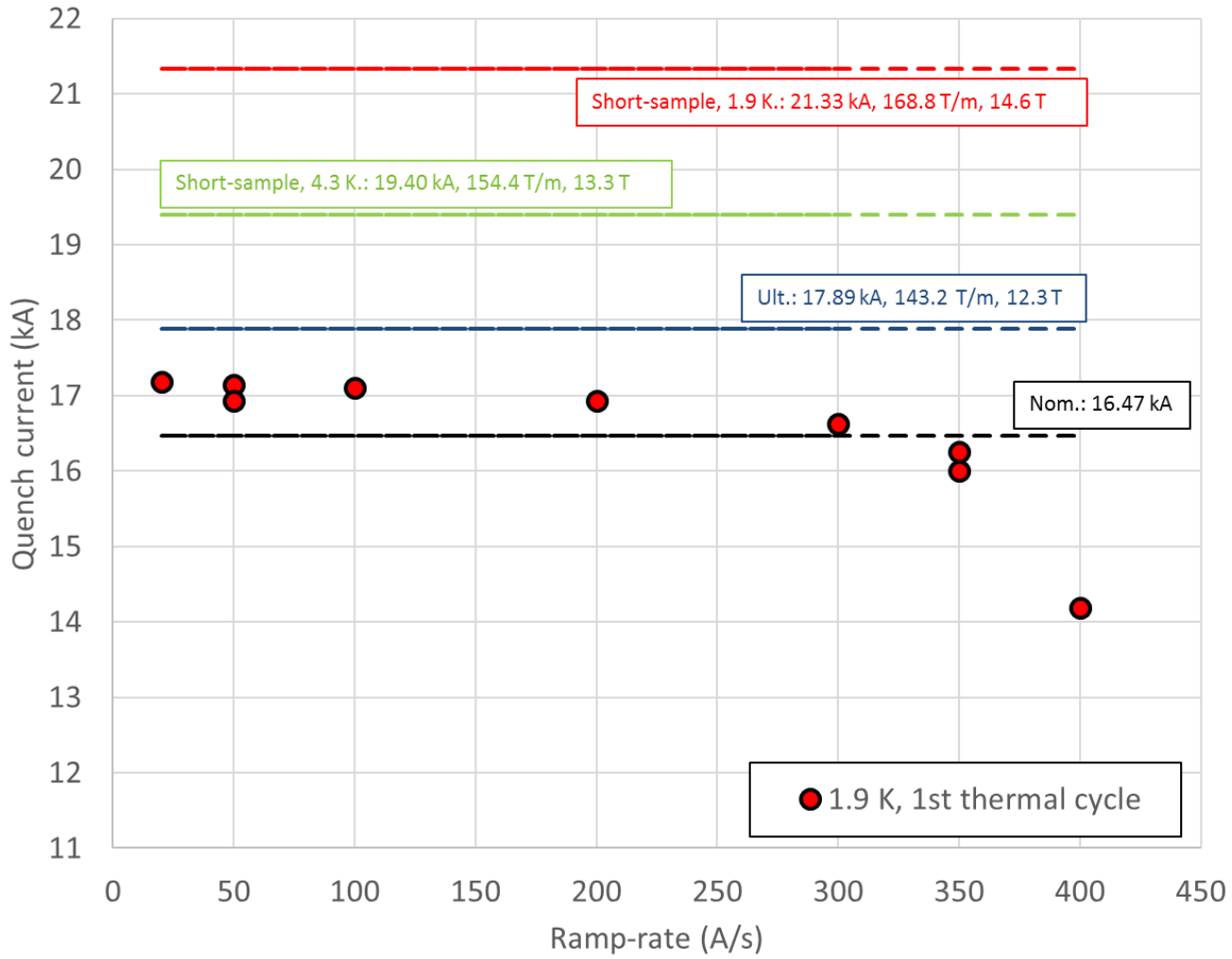
Magnet performances

- Magnet performances
  - @ 2.1 K
  - 1st quench at 91% Inom
  - Highest quench
    - 104 % Inom, 96% Iult, 81% Iss
- Performance check @ 4.3 K
  - 89% Iss



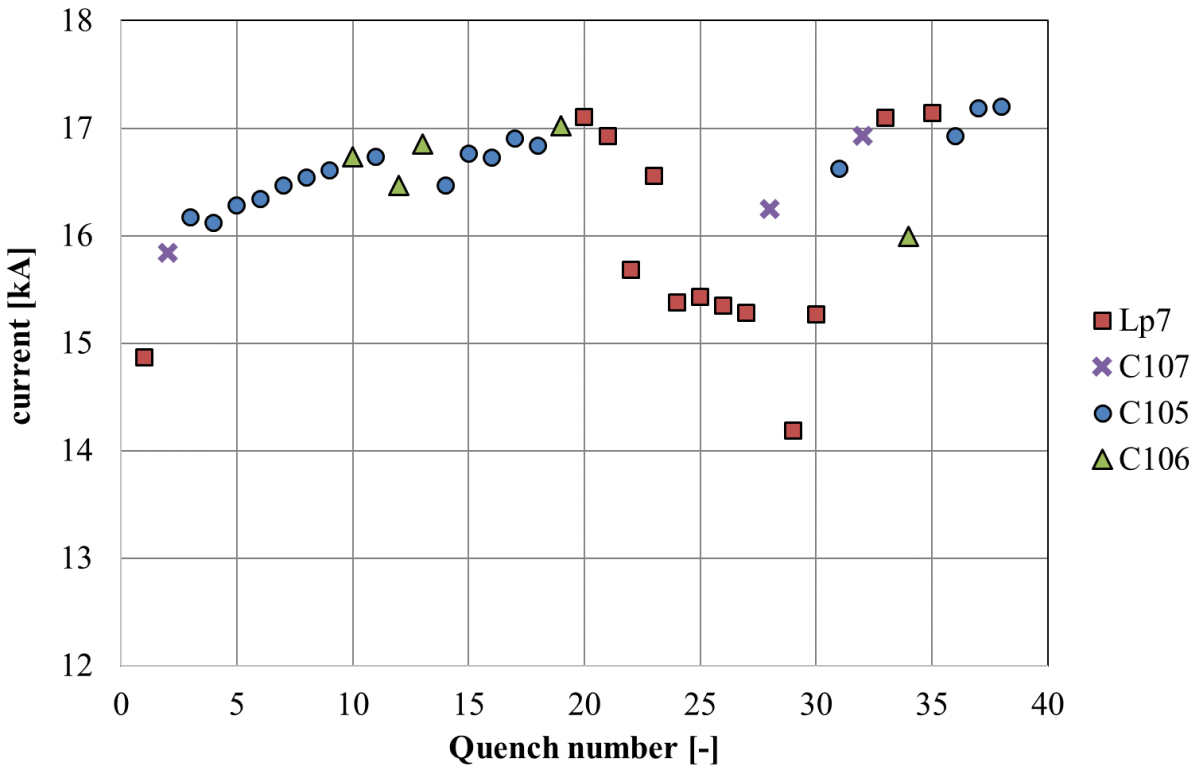
Magnet performances

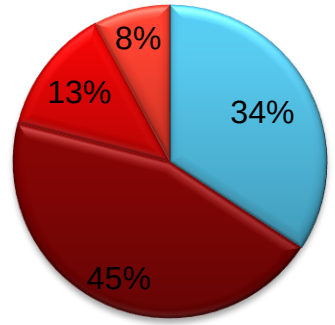
- Ramp rate dependence
  - Almost no impact up to 300 A/s
  - Core cable
  - In line with MQXFs1 behavior

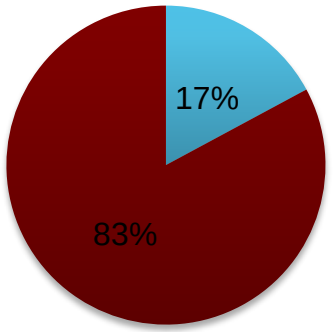


Quench Localisation and performance limitation

- Limiting coils

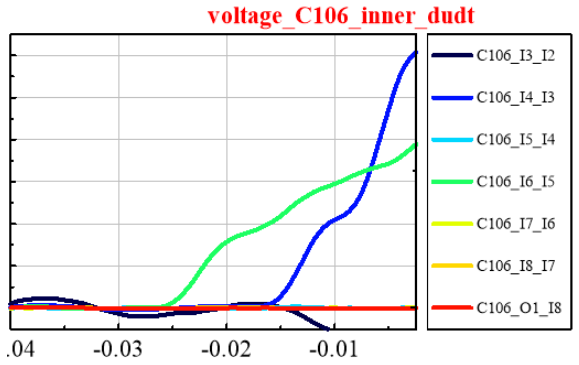




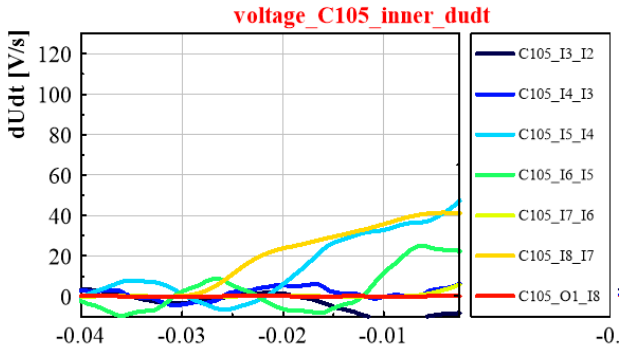


Quenches in the straight part with transverse propagation to first block (I3-I4)

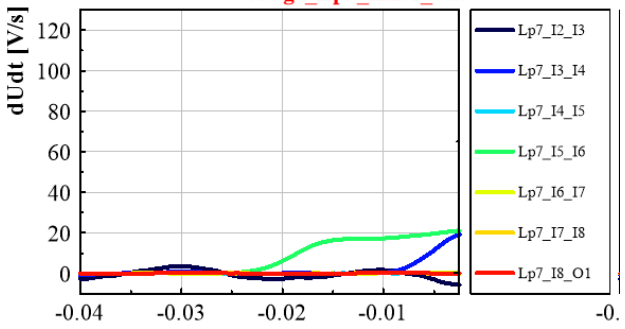
File: HCMQXFS001-CR000003__HFM1610251436_a036



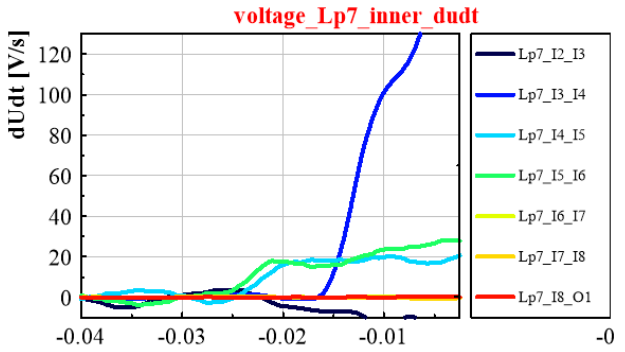
File: HCMQXFS001-CR000003__HFM1610141413_a017

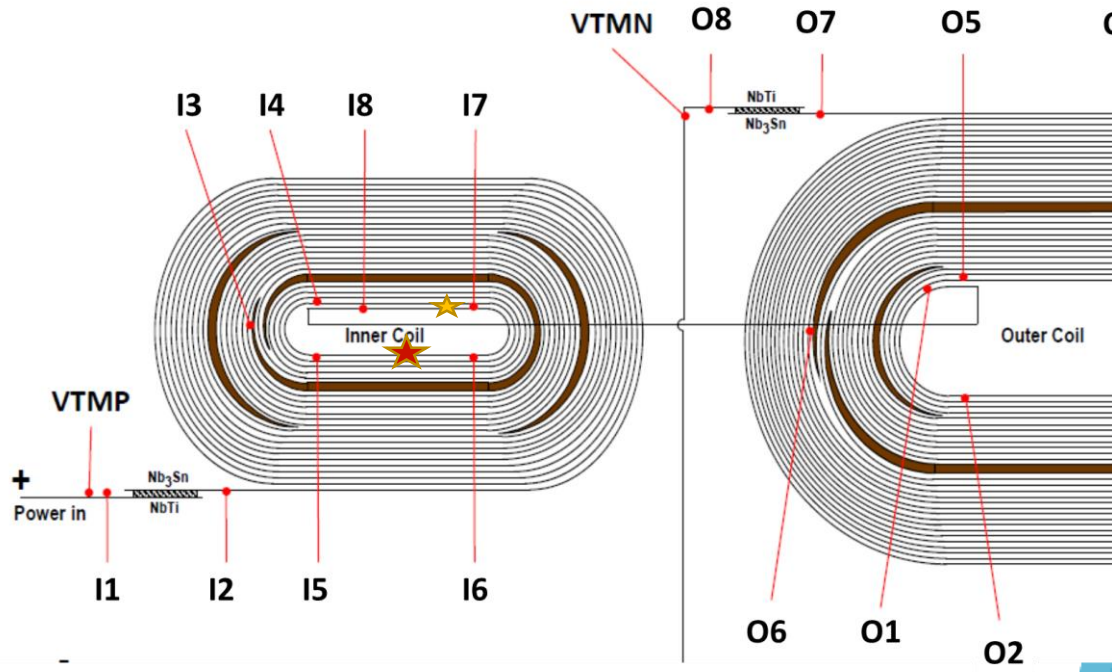


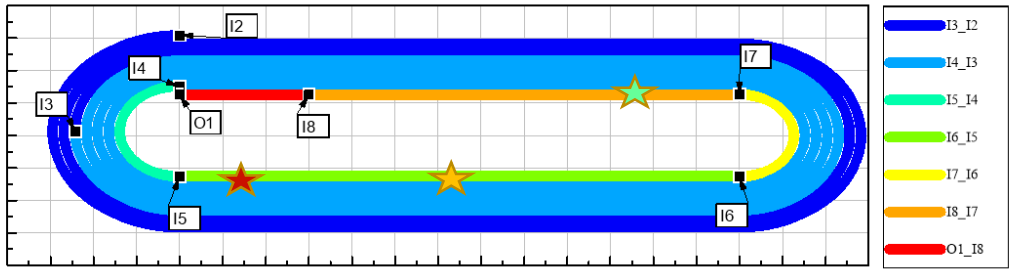
File: HCMQXFS001-CR000003__HFM1610131621_a001



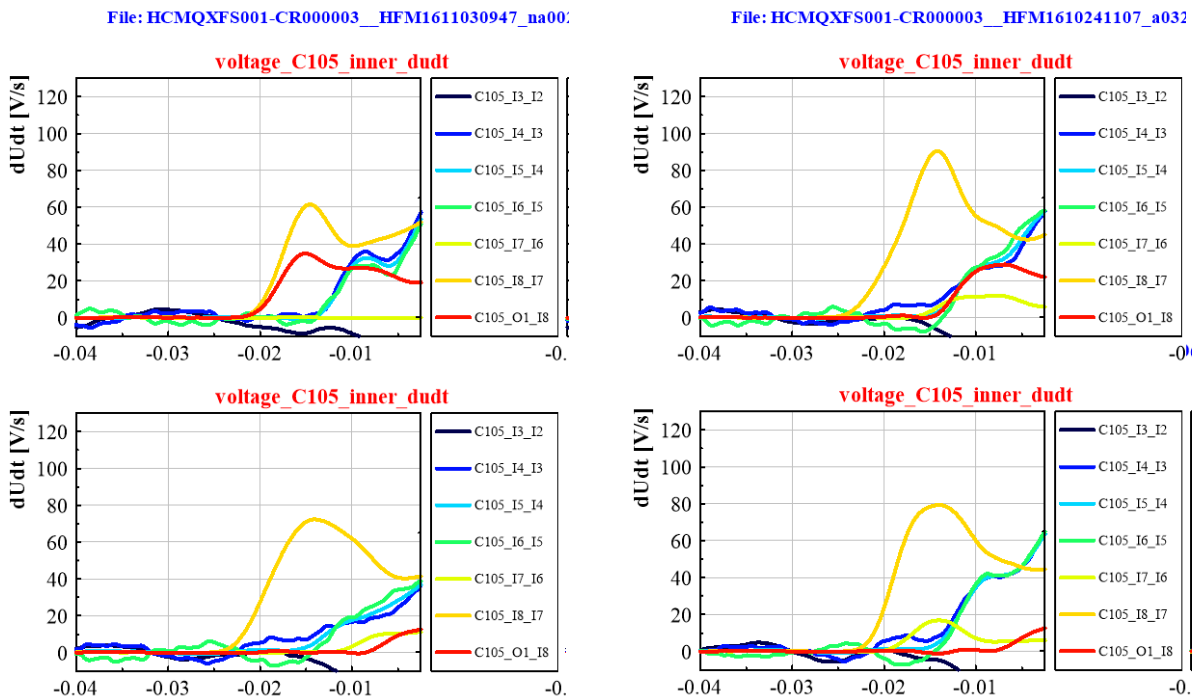
File: HCMQXFS001-CR000003__HFM1610251836_a037

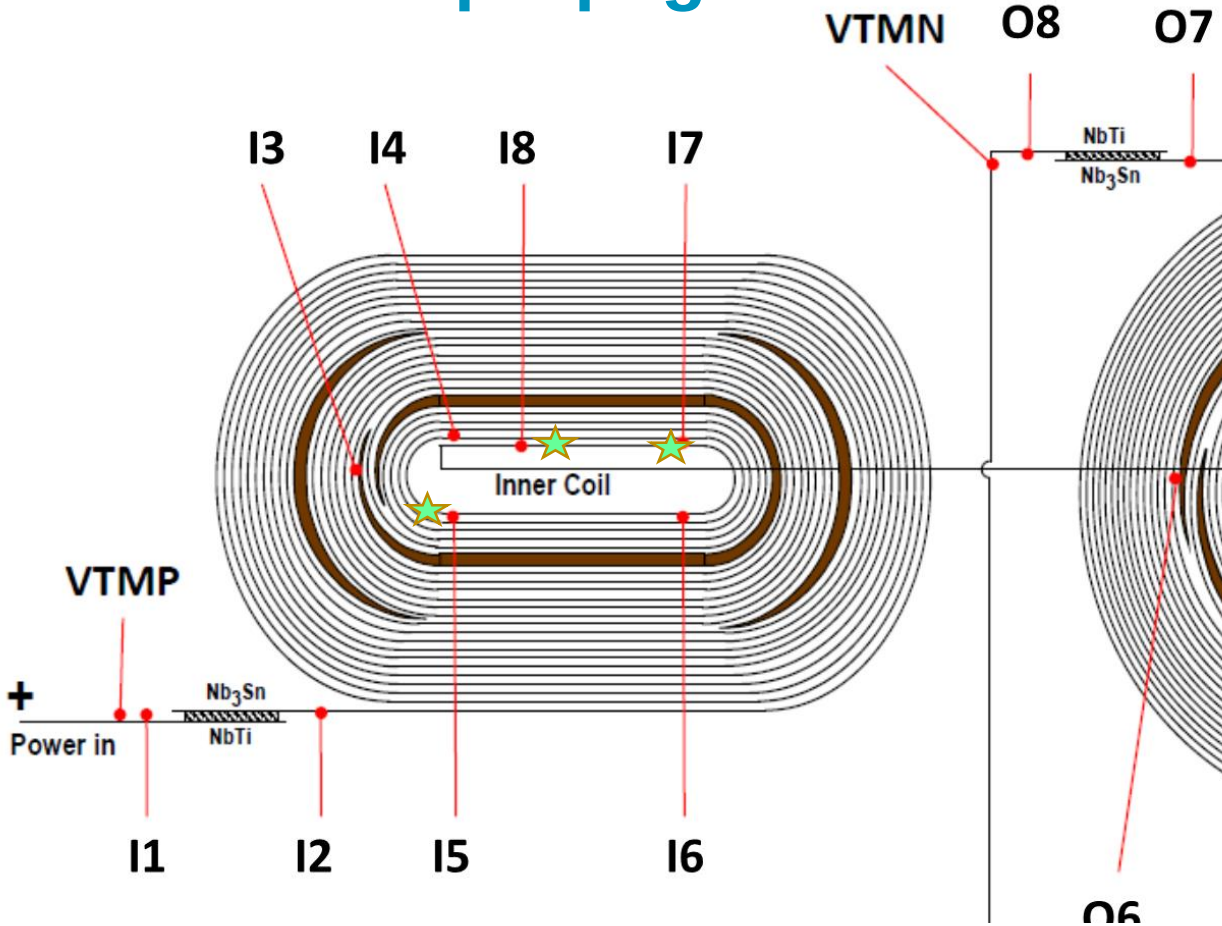


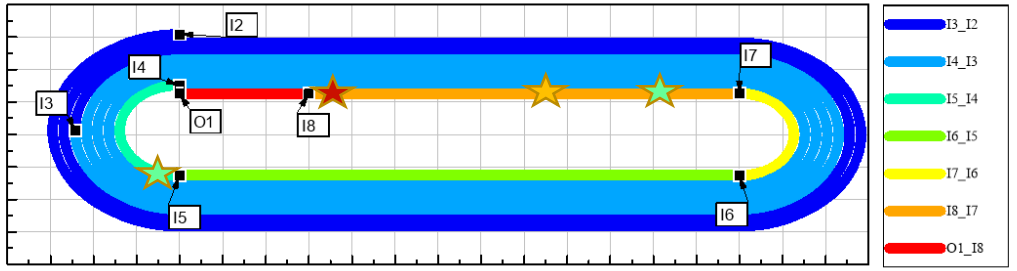




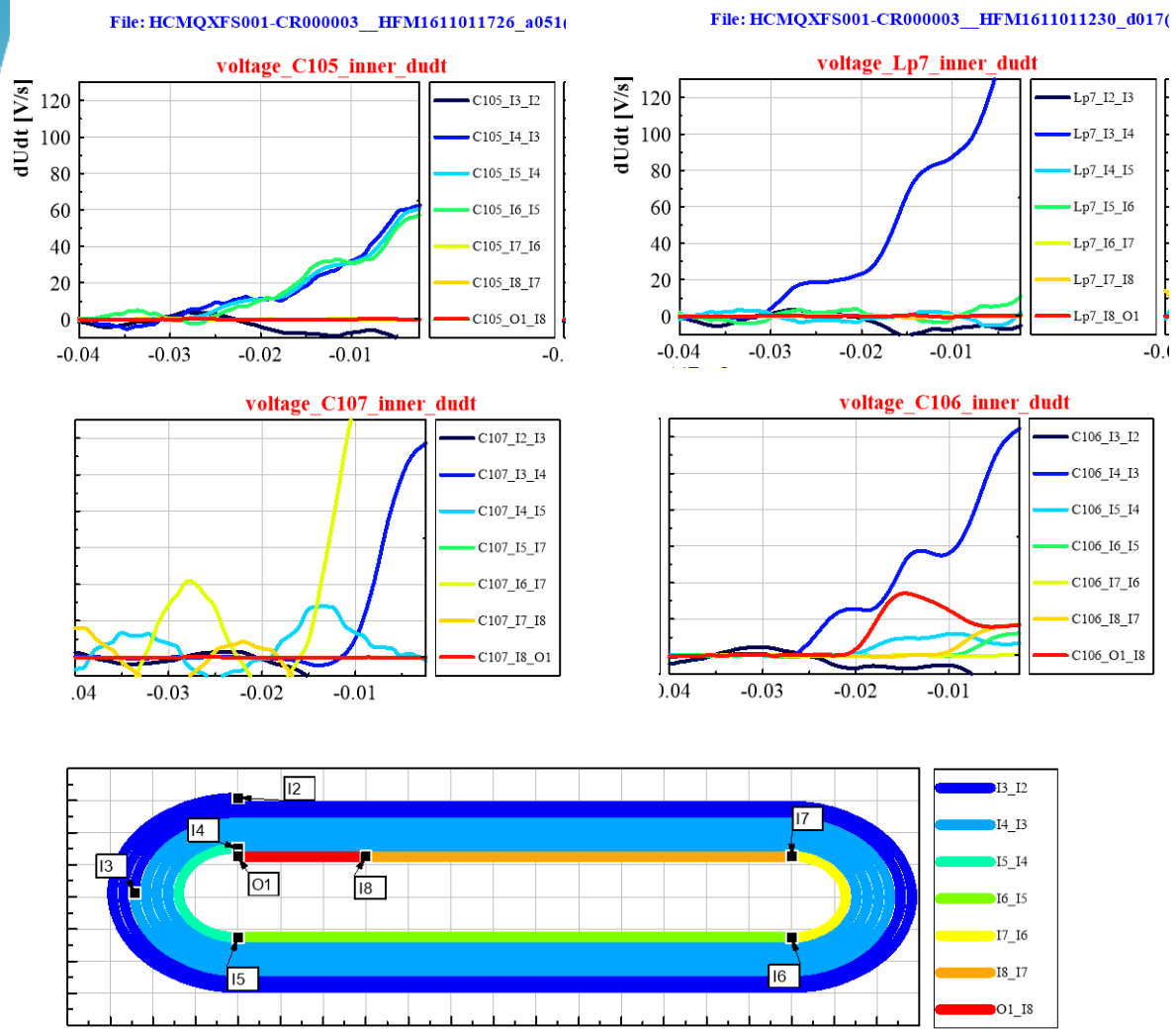
Multiple quenches in the 1st turn straight part and heads with longitudinal and transverse propagation

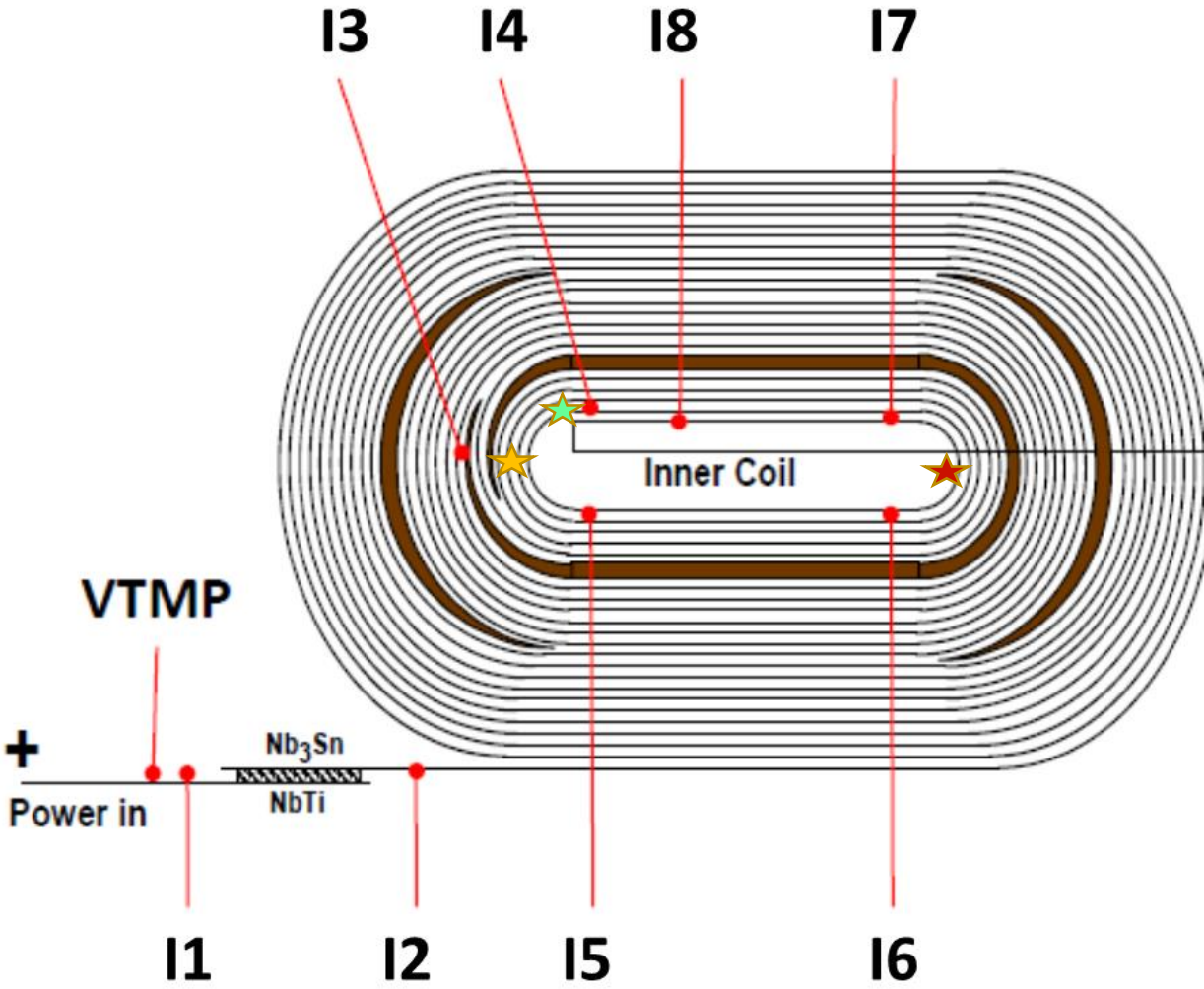






Quenches in pole head (1st turn or 1st block)

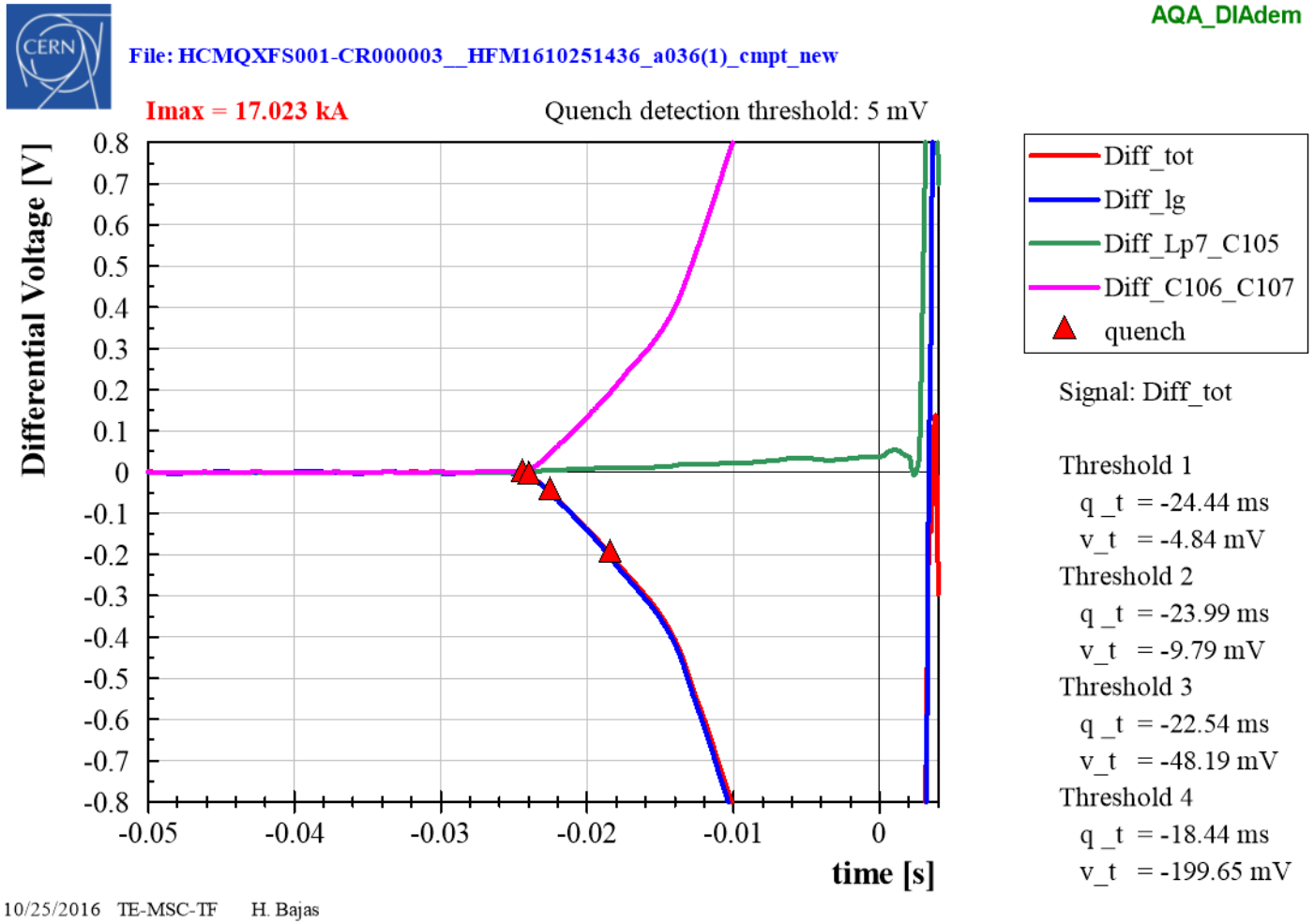




Magnet Protection main outcome

Magnet Protection main outcome

Detection time on differential signal

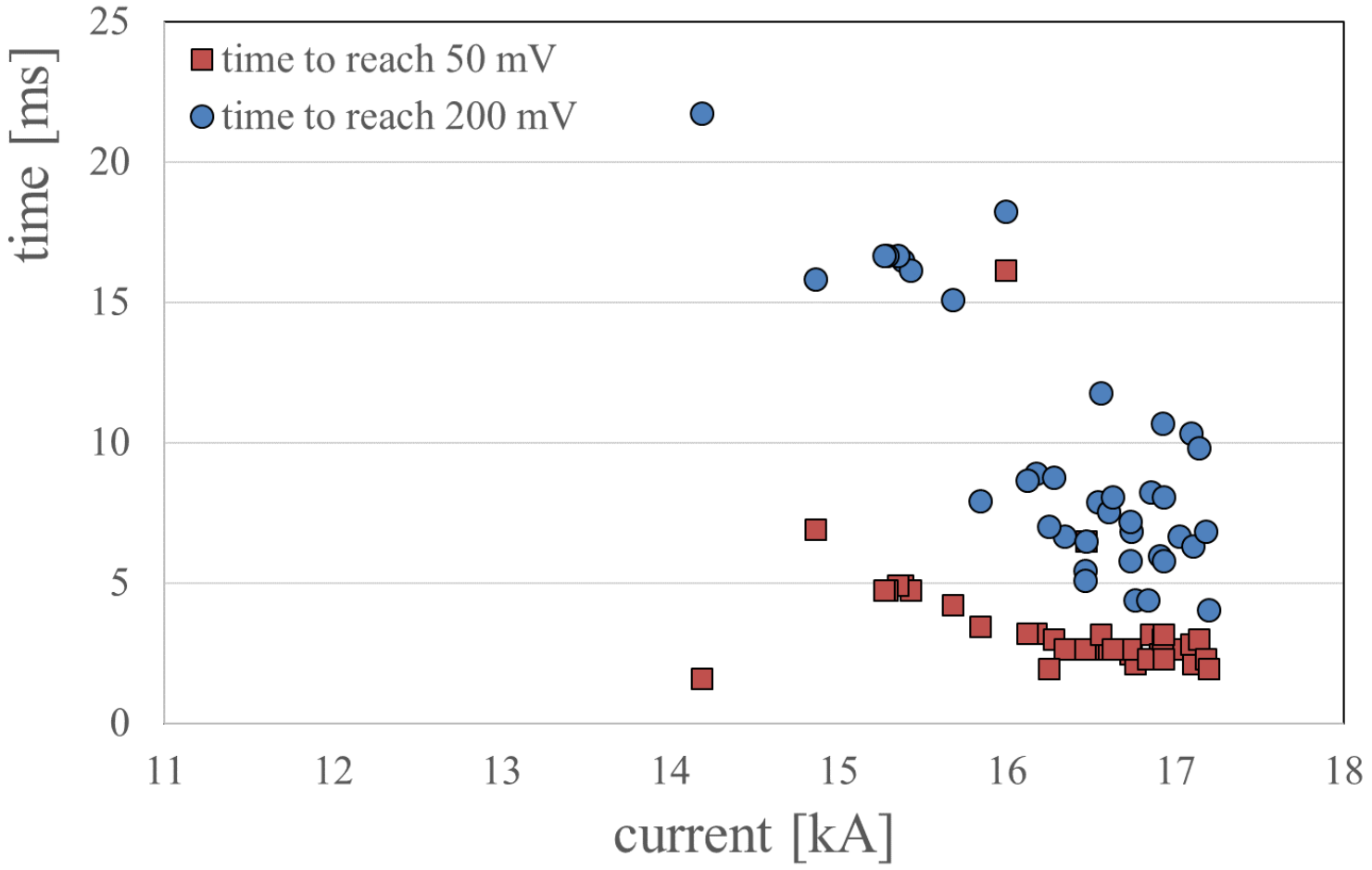


Protection parameters:

200 mV
20 ms

Magnet Protection main outcome

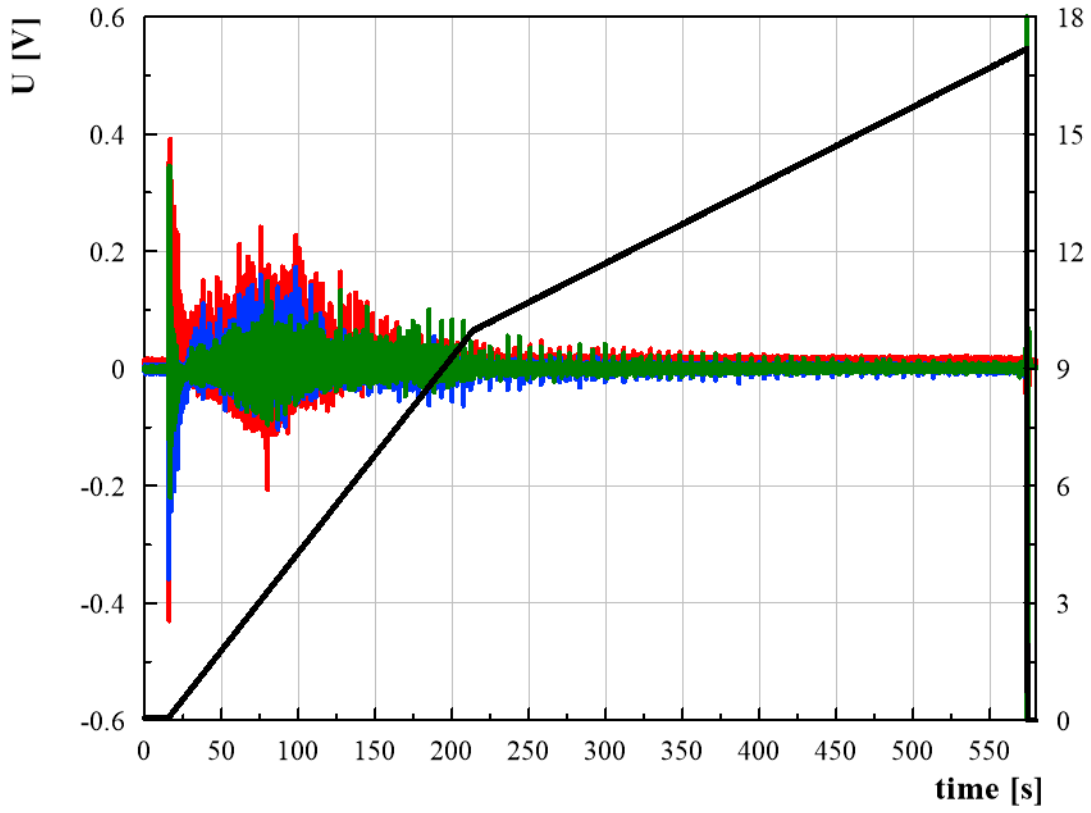
Detection time on differential signal



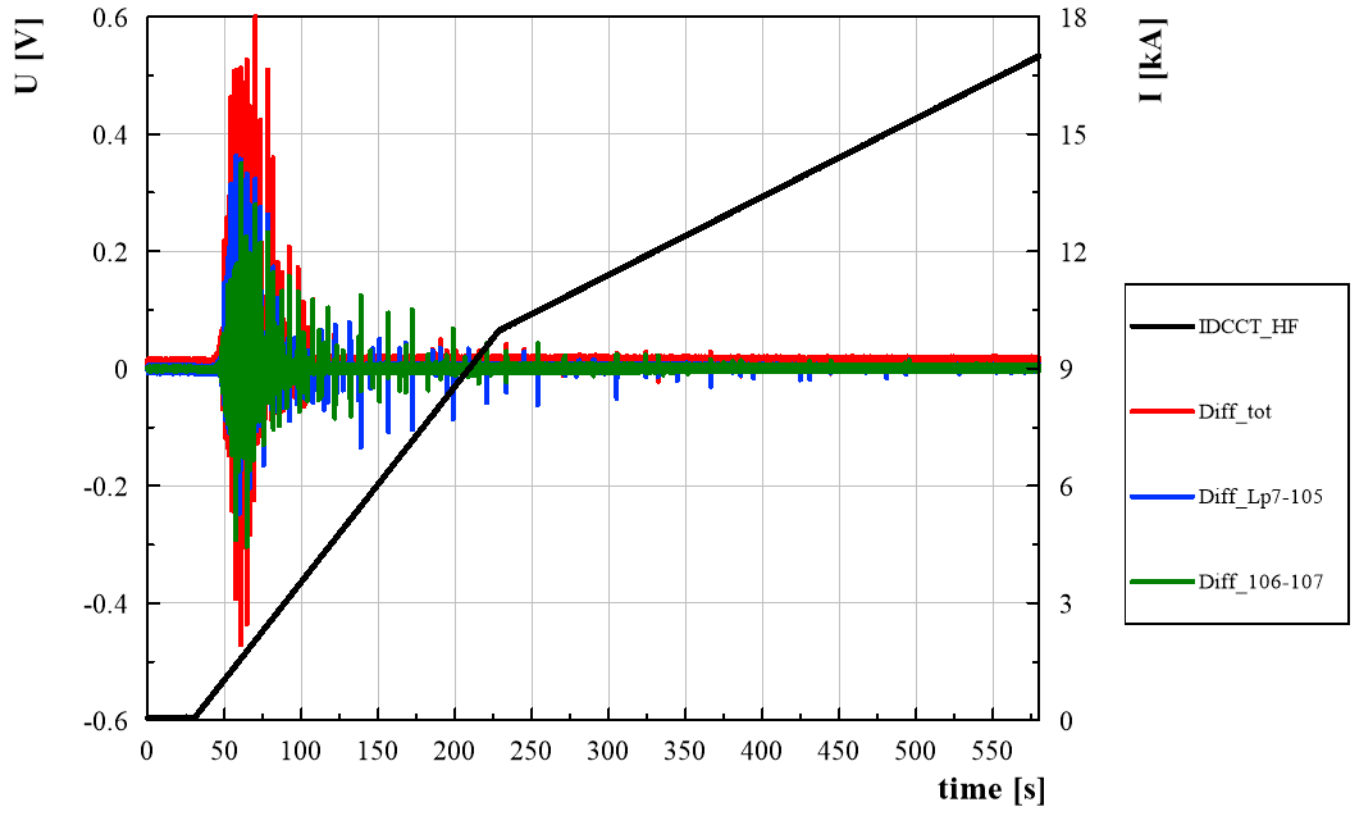
Magnet Protection main outcome

Flux Jumps (higher amplitude @ 4.3 K but less frequent

@ 2.1 K



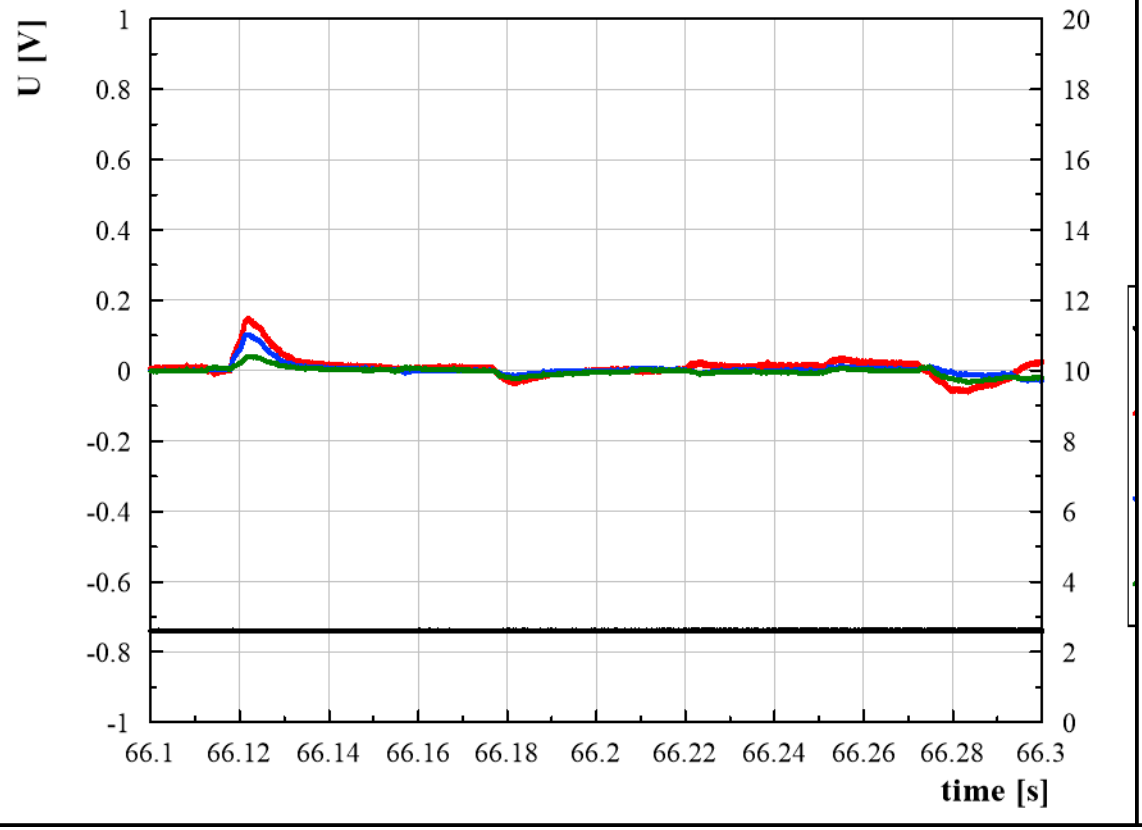
@ 4.3 K



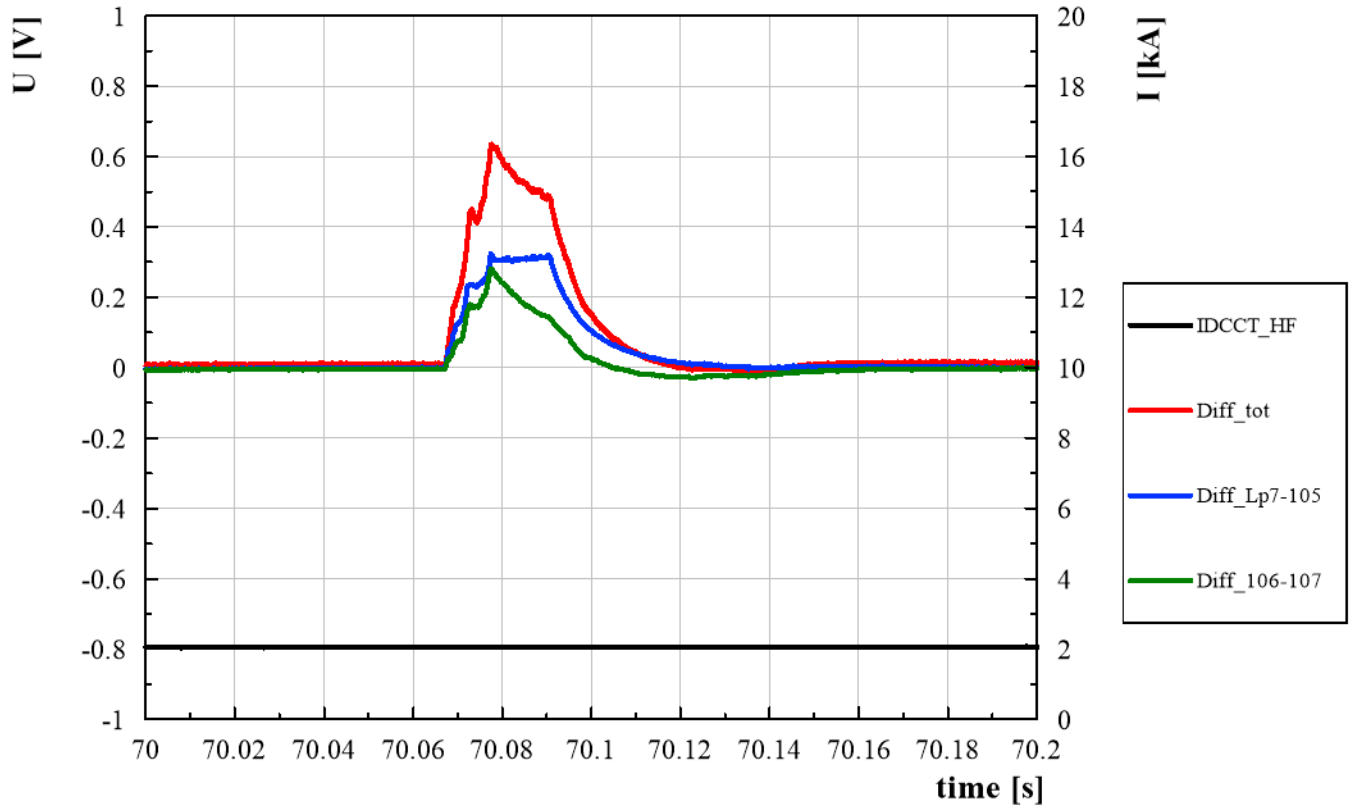
Magnet Protection main outcome

Zoom on the jump (~5-20 ms, 100-600 mV)

@ 2.1 K

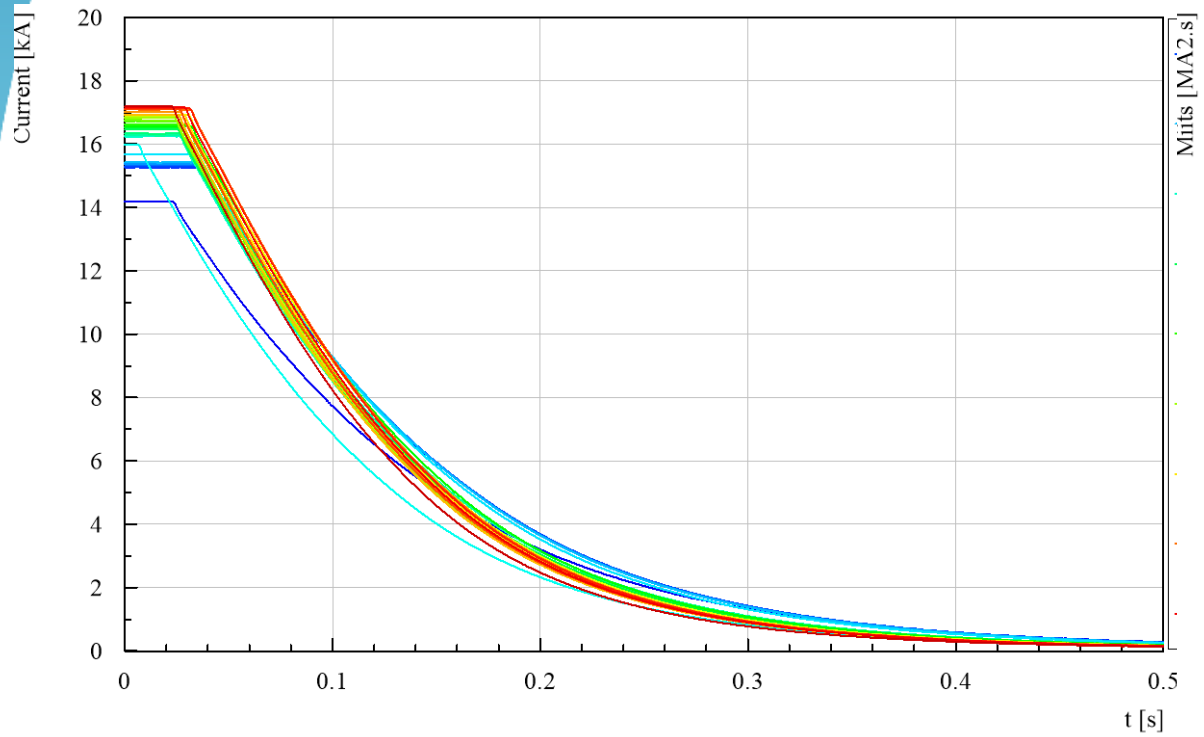


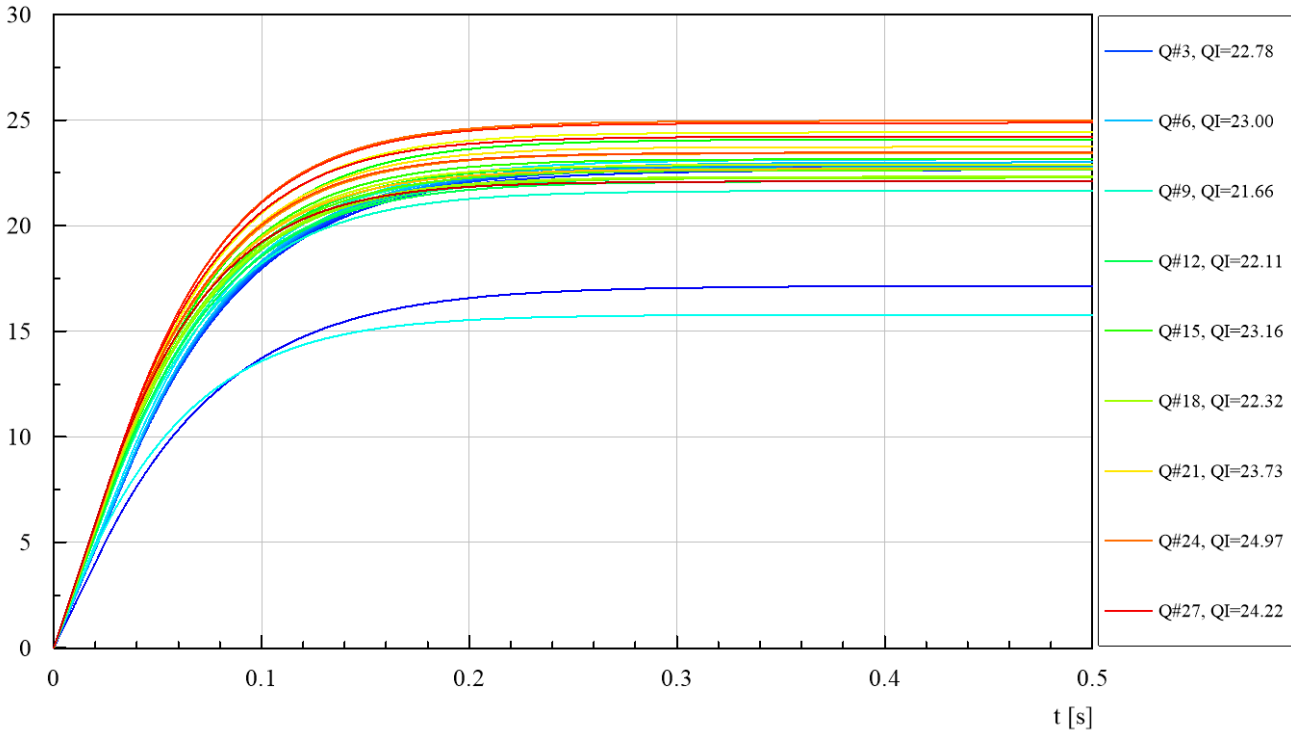
@ 4.3 K



Magnet Protection main outcome

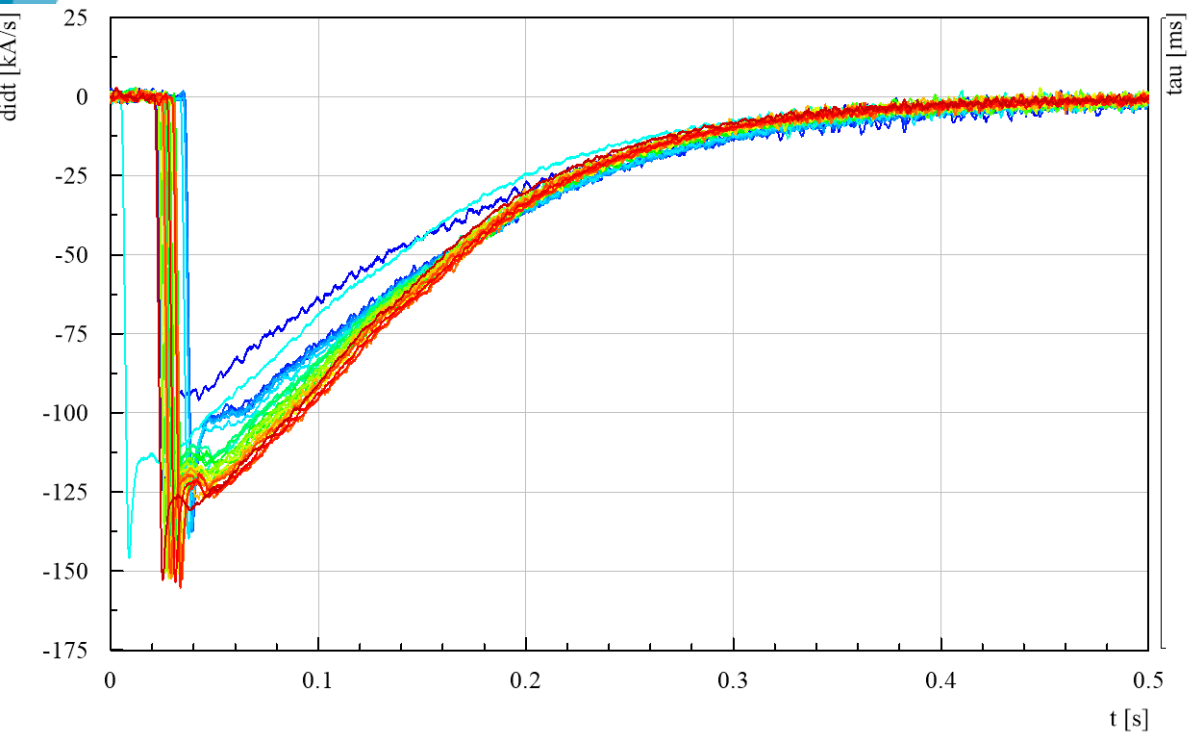
Current decay and Miits with the 60 mΩ dump

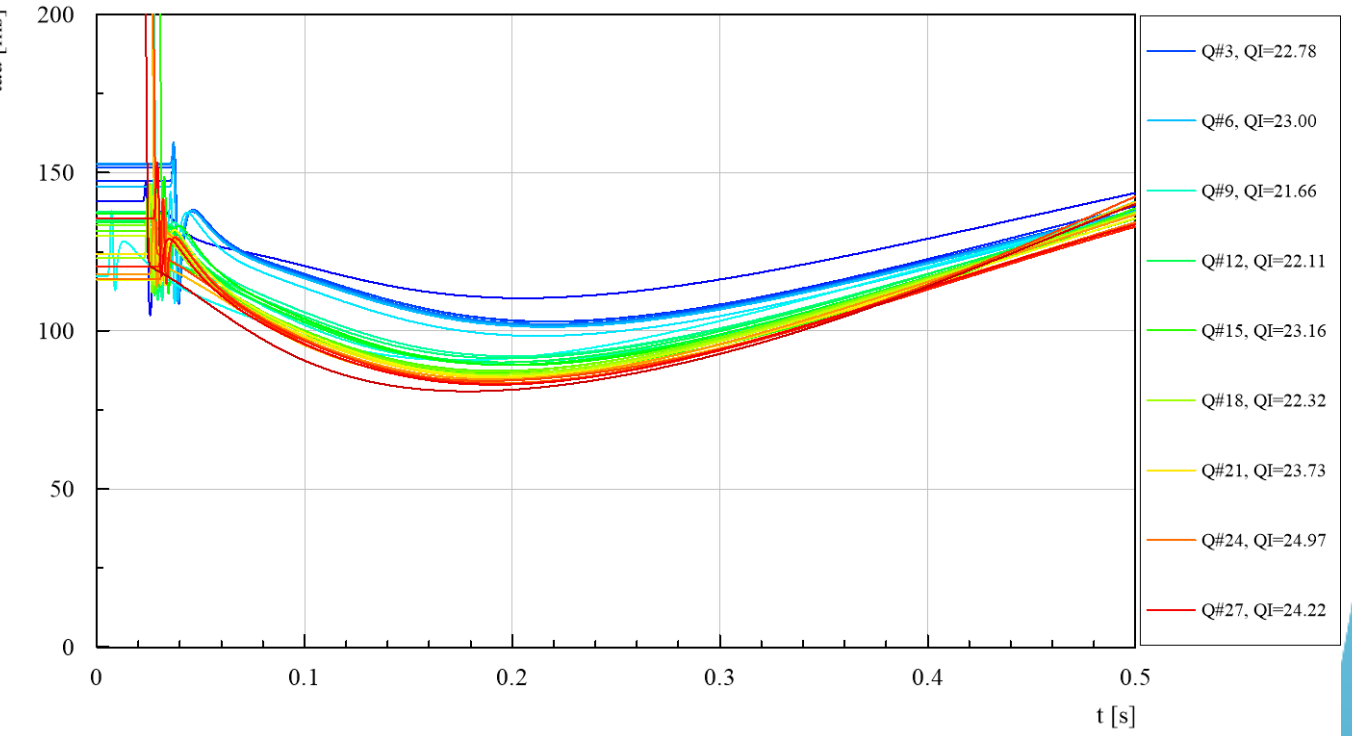




Magnet Protection main outcome

Didt and decay time constant with the 60 mΩ dump



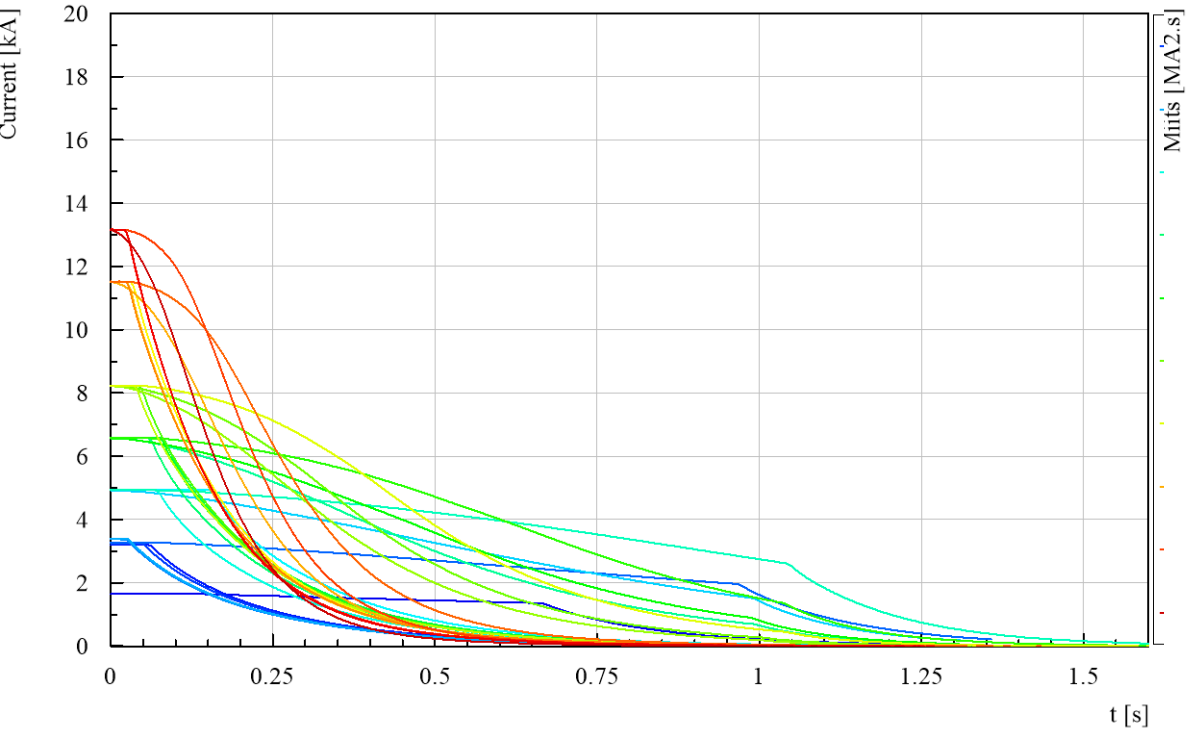


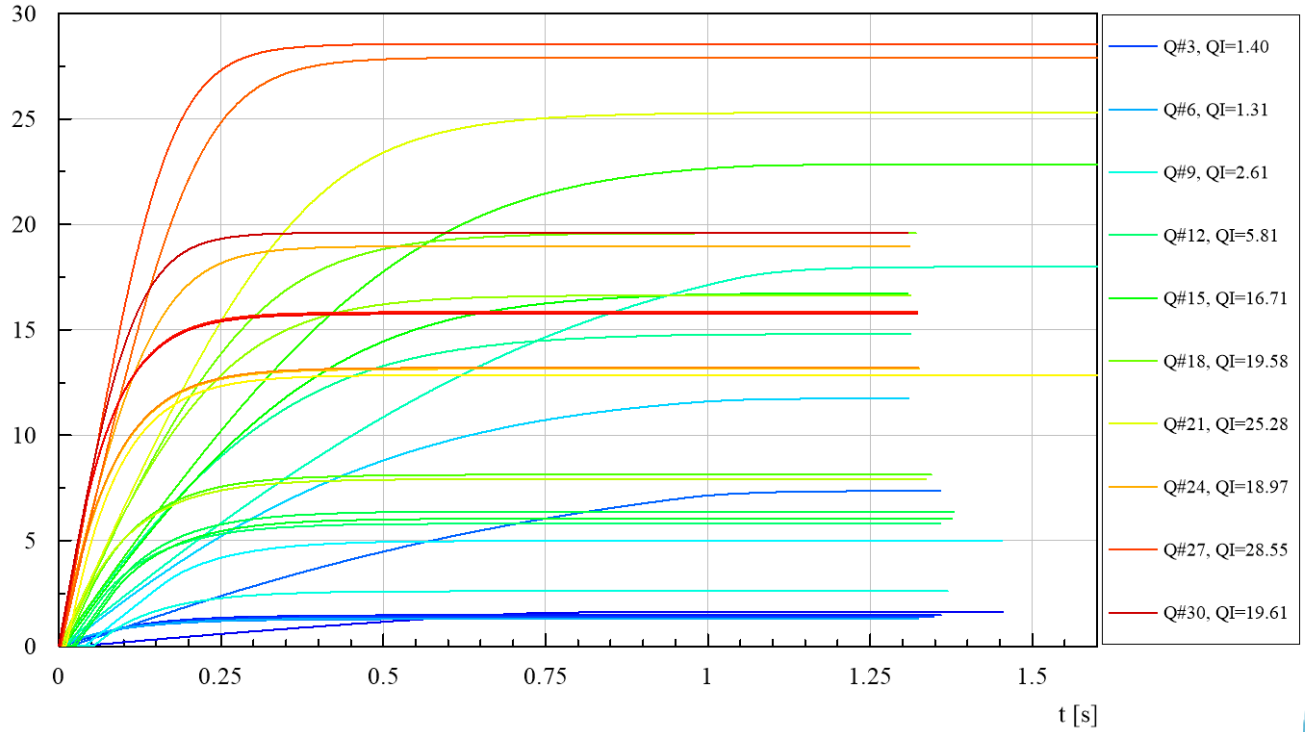
didt max = 150 kA/s

Tau non linear due to quenched magnet and non-linar inductance

Magnet Protection main outcome

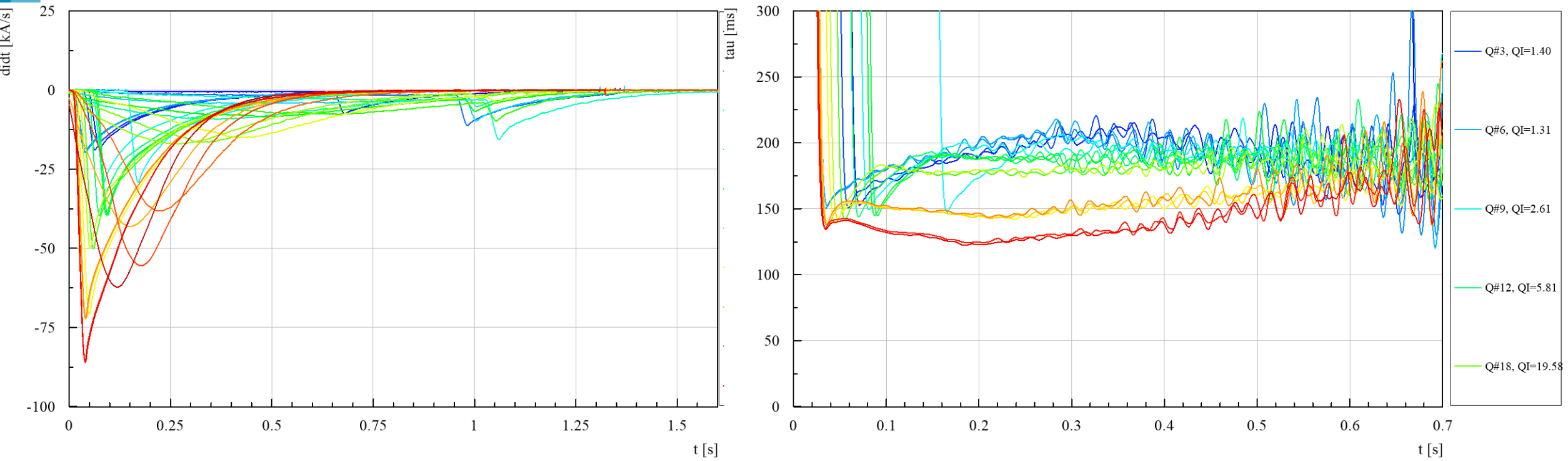
Current decay and Miits without dump





Magnet Protection main outcome

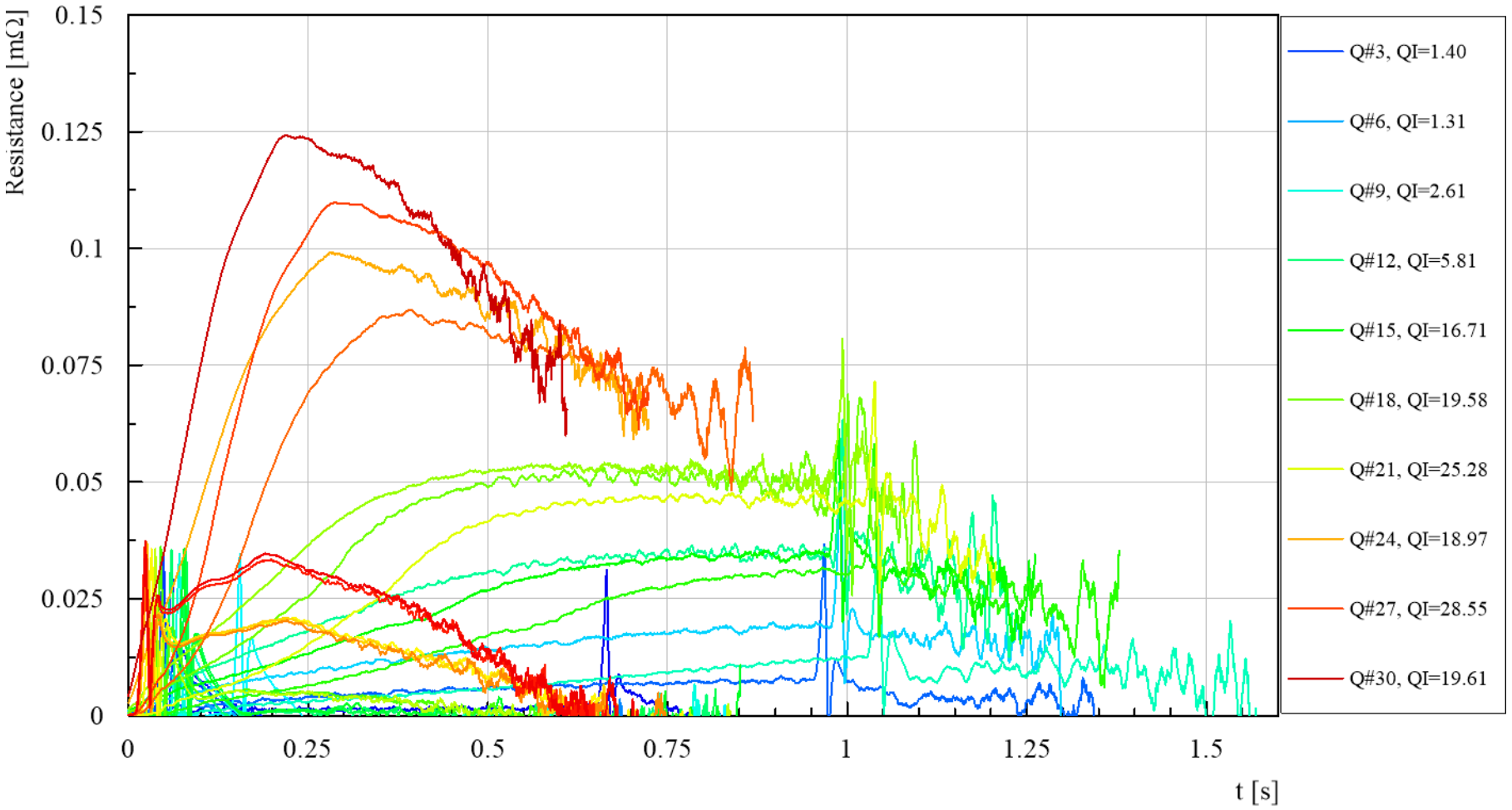
Didt and decay time constant with the 60 mΩ dump



didt max = 75 kA/s

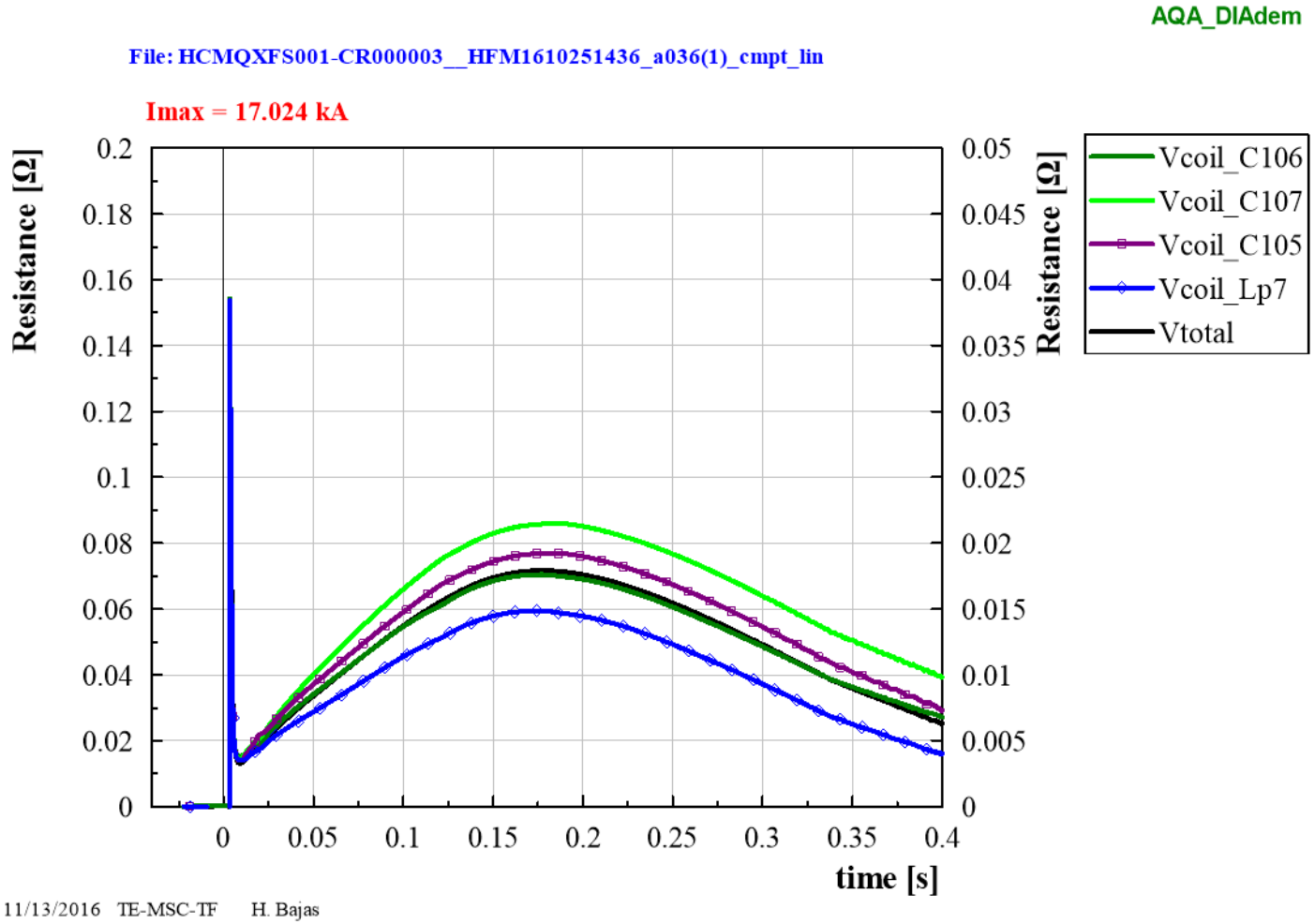
Magnet Protection main outcome

Magnet resistance growth



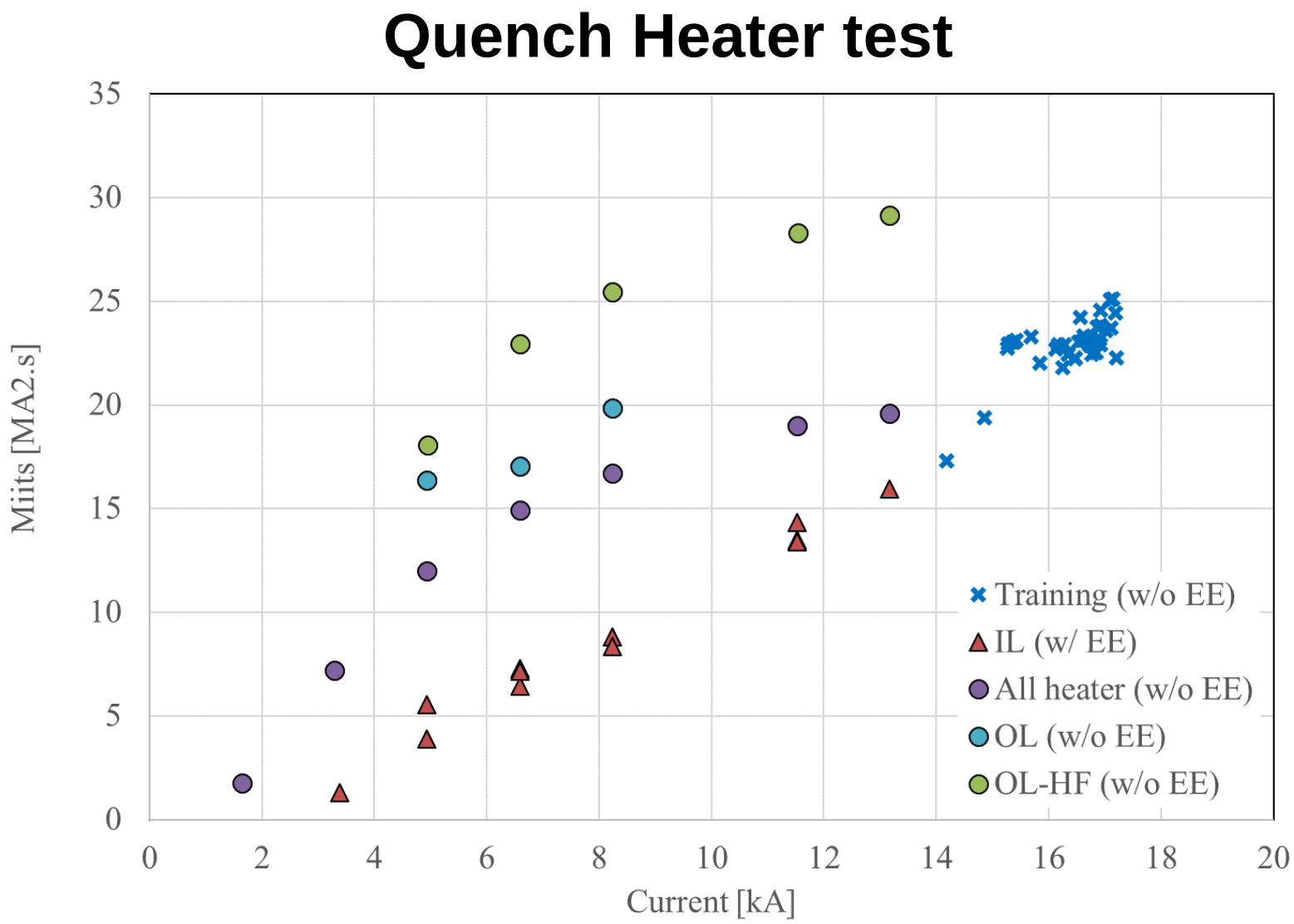
Magnet Protection main outcome

Coil resistance comparison



With higher RRR Lp7 is the least resistive

Magnet Protection main outcome



Conclusive remarks

- Temperature of the He bath limited to 2.1 K instead of 1.9 K due to issue with the new test facility (HFM). It will be tried to be fixed for Run 2.
- Most of the training quenches are located in coil 105 in the heads of the inner layer coil with independent quenches, seen from the dvdt and the multiple quench fronts
- The quenches in Coil Lp7 after the «incident» are all located in the first block multiturn, on the fourth turn.
- The different ramp rate has allowed to by pass the issue in Coil Lp7. After these quenches, Coil 105 was again the limiting coil. Also at 4.2 K.
- The standard magnetic measurement have been performed according to the test plan.
- The quench heater tests have been performed with provoked quench in the inner or outer layer (LF and/or HF).
- The occurrence of flux jumps requires to adapt the threshold at 4.2 K wrt. 1.9 K.

Set-Up in the SM-18 HFM test bench