Stand-alone test of the series magnet 01 aperture 1: Red coil from Bama

IHEP, IMP, BAMA

China

Objective of the test

- Training up to 530A (plan to do)

To achieve the same stress levels as MCBRD magnets, for Bama Red coil, the current is 530A, so that's our ultimate goal.

- Electrical insulation

Checking the electrical insulation strength of Bama Red coil at room temperature and 4.5K.

- Magnetic field measurement

For the magnetic field measurement, we will measure it at warm and cold with the PCB coil. The measured position is the center of the magnet.

Table1. The equivalent stress in the aperture without yoke

	B[T]	I[A]	B*I stress factor
With yoke CERN test res.	2.59	393	1017.9
Ultimat	2.78	422	1173.6
No Yoke	1.88	450	846.0
Nominal Current stress equivelant	2.06	494	1019.5
Ultimat Current stress equivalent	2.21	530	1173.5

Fig1. The Bama Red coil

Electrical test at reception

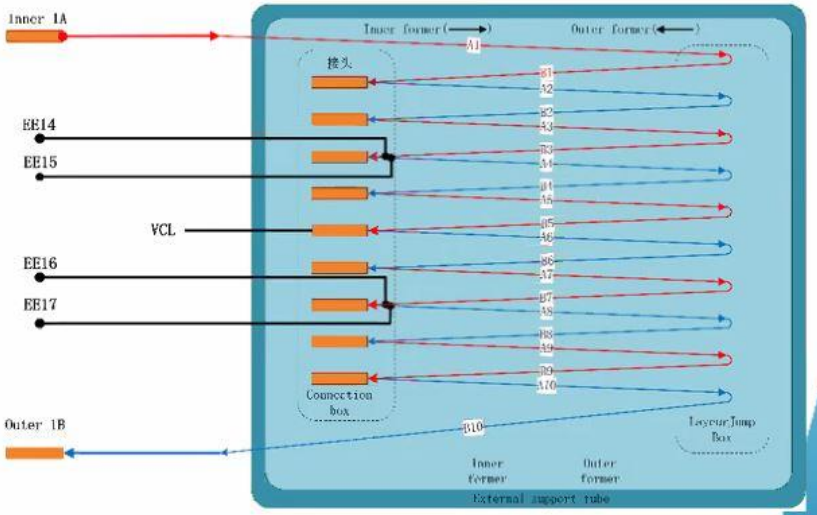
Table 2. The resistance measurement results

Equipment	Object	Function			Resistance/Ω
KEITHLEY 2002	Coil resistance	4 wires	Inner 1A -> Outer 1B		233.95
		4 wires	Inner 1A -> EE17		163.06
		4 wires	Inner 1A -> EE16		163.07
		4 wires	Inner 1A -> VCL		116.13
		4 wires	Inner 1A -> EE15		69.56
		4 wires	Inner 1A -> EE14		69.55
	CCS resistance		Serial	R calibration	
		4 wires	836	1047.47Ω@293.16K	The signal wires are sealed by the epoxy
		4 wires	837	973.17Ω@293.16K	981.03@278K

Test condition：11.7℃ & relative humidity 16.3%

Table 3. The insulation test results

Equipment	Object	Function	Voltage/Current	Test Time	Resistance/GΩ
KIKUSUI TOS9301	Coil to ext. tube	IR	499V/21nA	60s	23.4
	Coil to ext. tube	IR	999V/30nA	60s	32.4
	Coil to ext. tube	IR	1500V/32nA	60s	46.5
	Coil to ext. tube	IR	2000V/26nA	60s	74.8
	Coil to ext. tube	IR	2240V/18nA	60s	122.2
	Coil to inner former	IR	499V/161nA	30s	3.096
	Coil to inner former	IR	999V/283nA	30s	3.525
	Coil to CCS 837	IR	499V/0nA	60s	1.27TΩ
	Coil to CCS 837	IR	999V/0nA	60s	1.69TΩ



The circuit of Bama Red coil

Electrical test after completing the installation

Table 4. The insulation test results (on the assembly platform)

Equipment	Object	Function	Voltage/Current	Test Time	Resistance/GΩ
	Coil to ground	IR	499V/53nA	30s	9.363
	Coil to ground	IR	999V/88nA	30s	11.231
	Coil to ground	IR	1500V/56nA	30s	26.642

Table 5. The insulation test results (in cryostat with the helium gas)

Equipment	Object	Function	Voltage/Current	Test Time	Resistance/GΩ
KIKUSUI TOS9301	Coil to ground	IR	98V/15nA	30s	6.451
	Coil to ground	IR	247V/8nA	30s	27.54
	Coil to ground	IR	499V/10nA	30s	47.69
	Coil to ground	IR	749V/3nA	30s	217.76

Table 6. The insulation test results (at 4.5K)

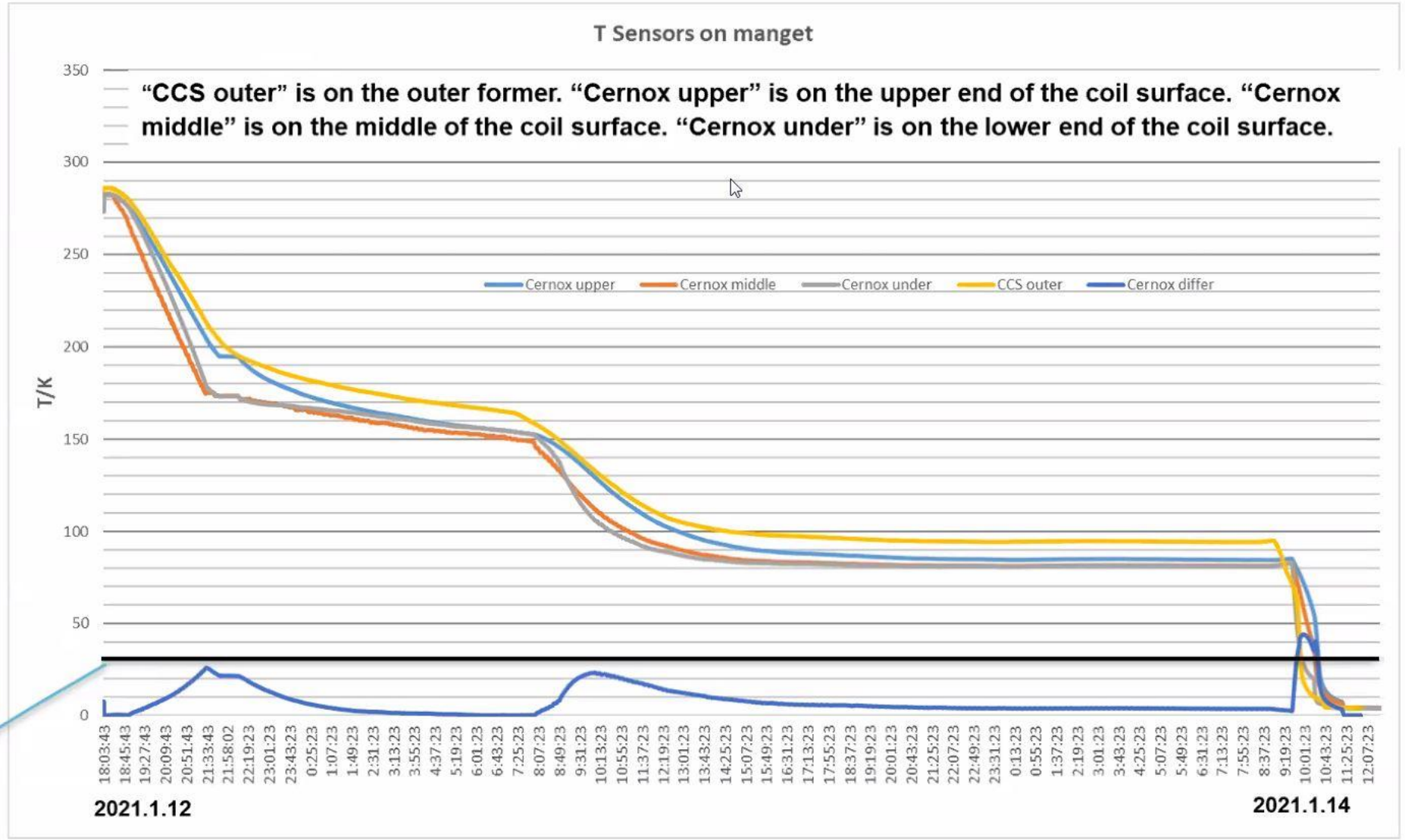
Equipment	Object	Function	Voltage/Current	Test Time	Resistance/GΩ
KIKUSUI TOS9301	Coil to ground	IR	247V/25nA	30s	9.84
	Coil to ground	IR	499V/23nA	30s	21.43
	Coil to ground	IR	749V/47nA	30s	15.76

All electrical test results show that the Bama Red coil has a good electrical performance!

Coil installation

Cool down

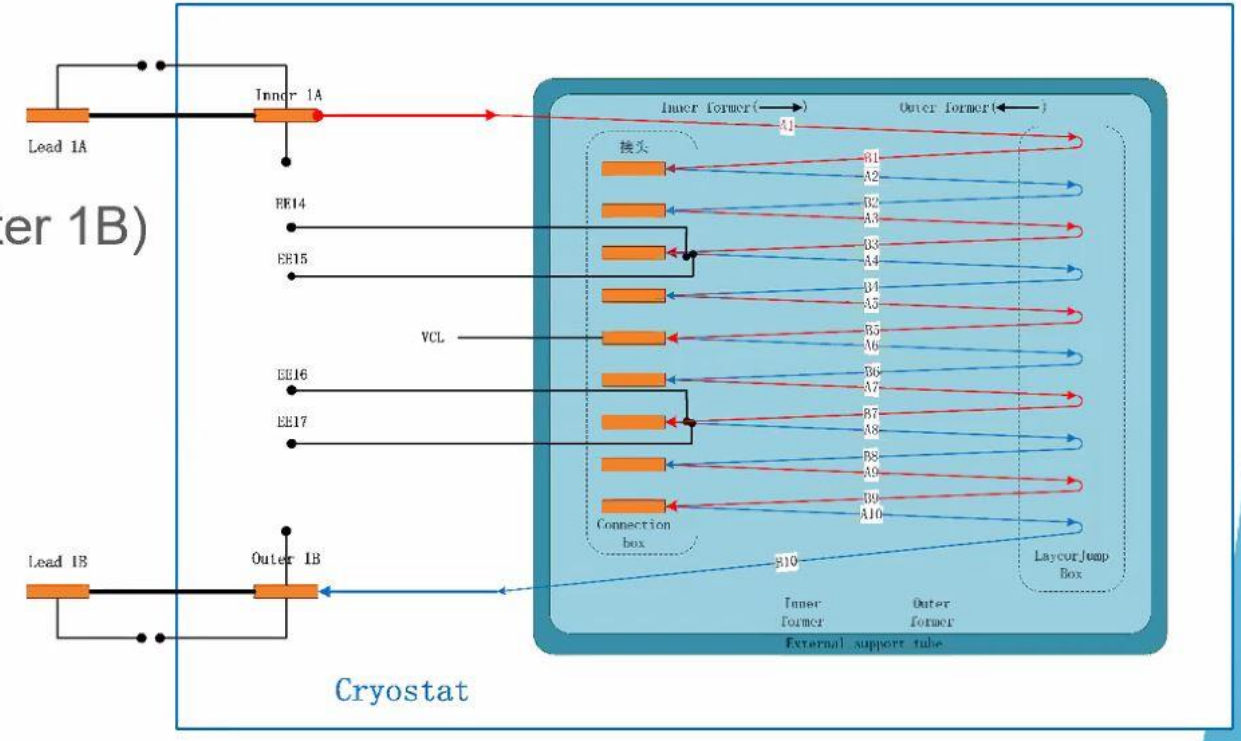
During the cooling process, the temperature difference is lower than 30 K.



30K

Quench Detection

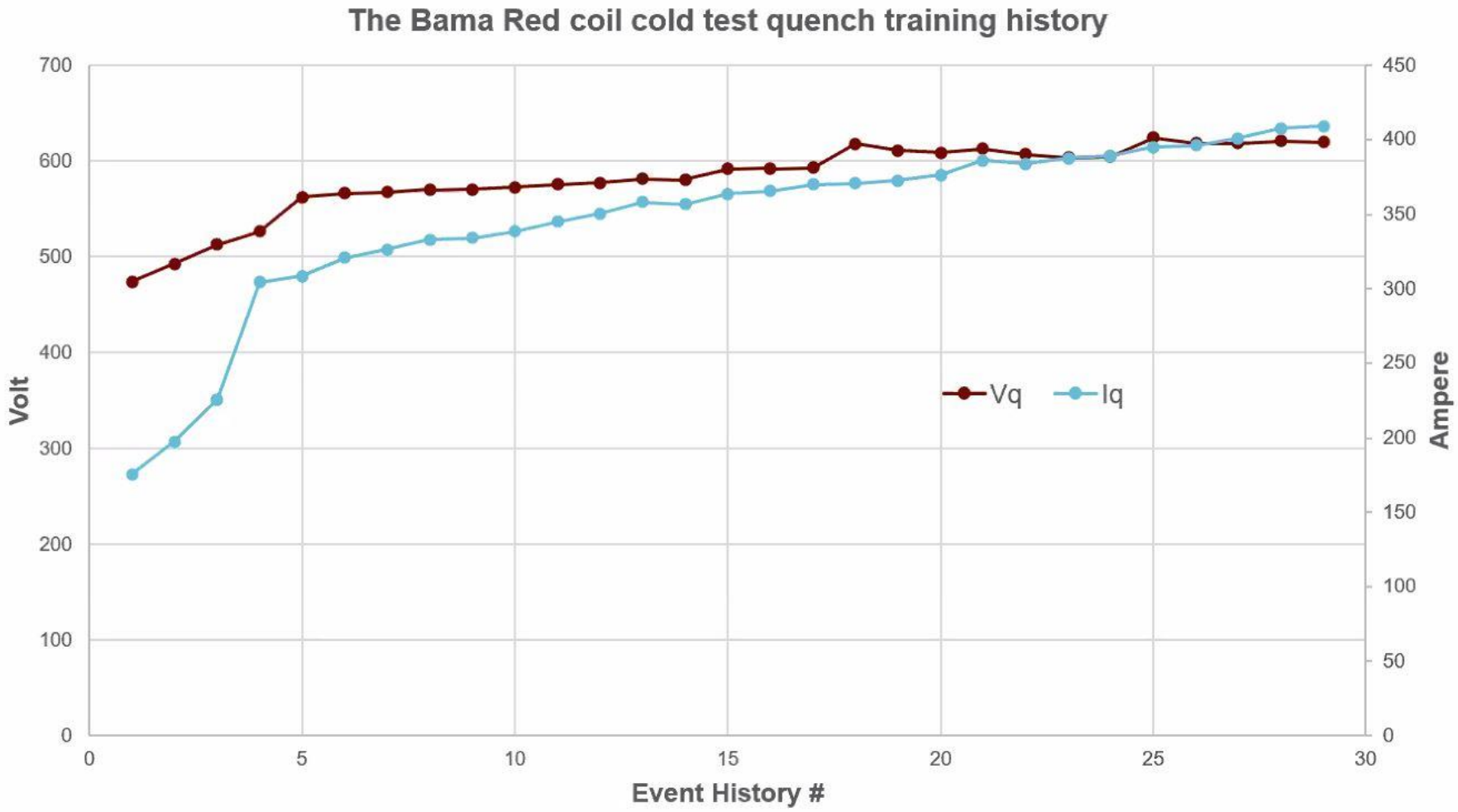
- QDS setup (bridge):
  - 2.3*(Inner1A - EE14) – (EE15 – Outer 1B)
  - （1/2.3）*(inner 1A – EE16) – (EE17 – Outer 1B)
  - **Trigger after 10 ms @ 100 mV**
- QDS setup(Current leads):
  - Lead 1A - Inner1A
  - Lead 1B - Outer 1B
  - Trigger after 10 ms @ 100 mV



Voltage taps diagram

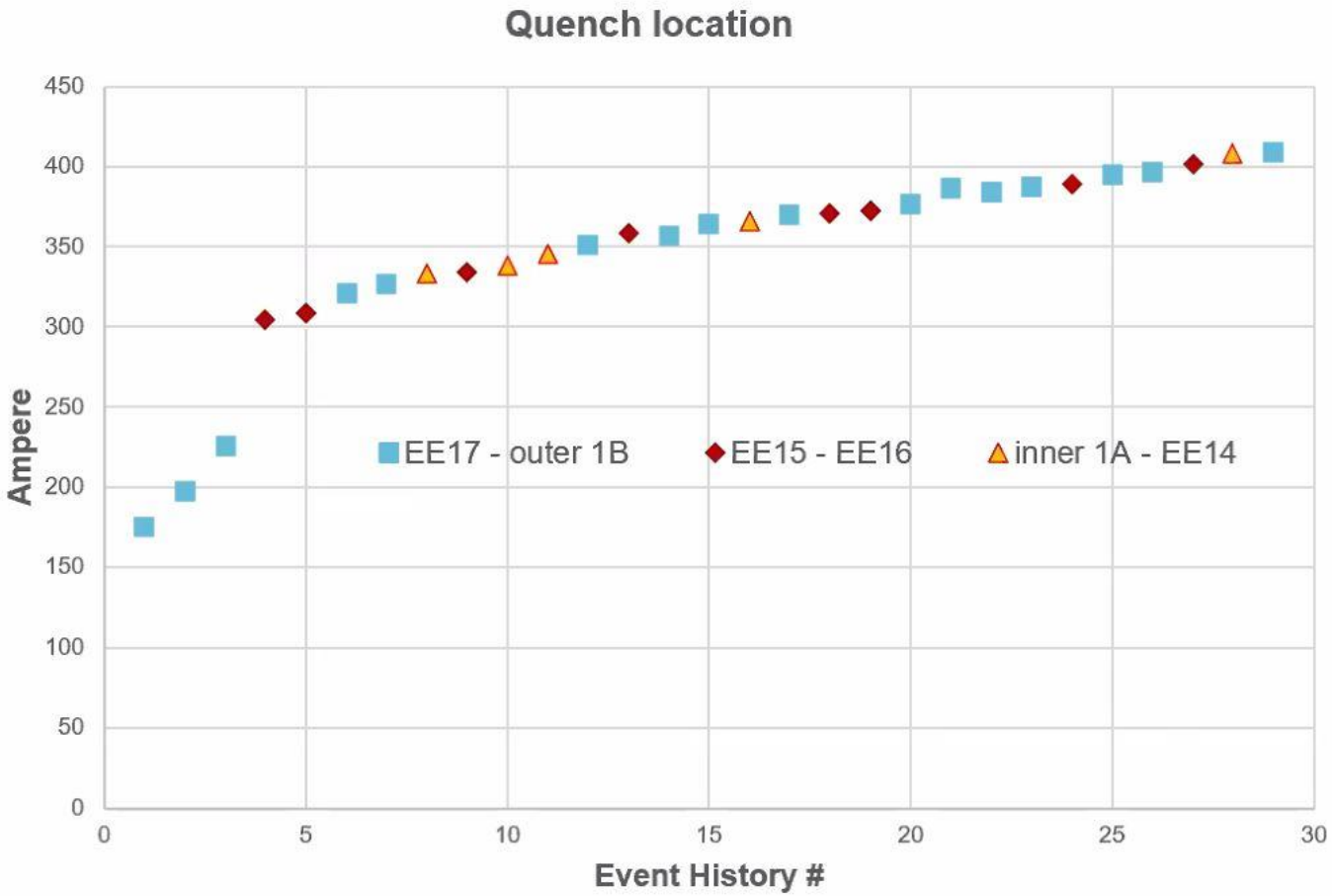
Cold test – Training history

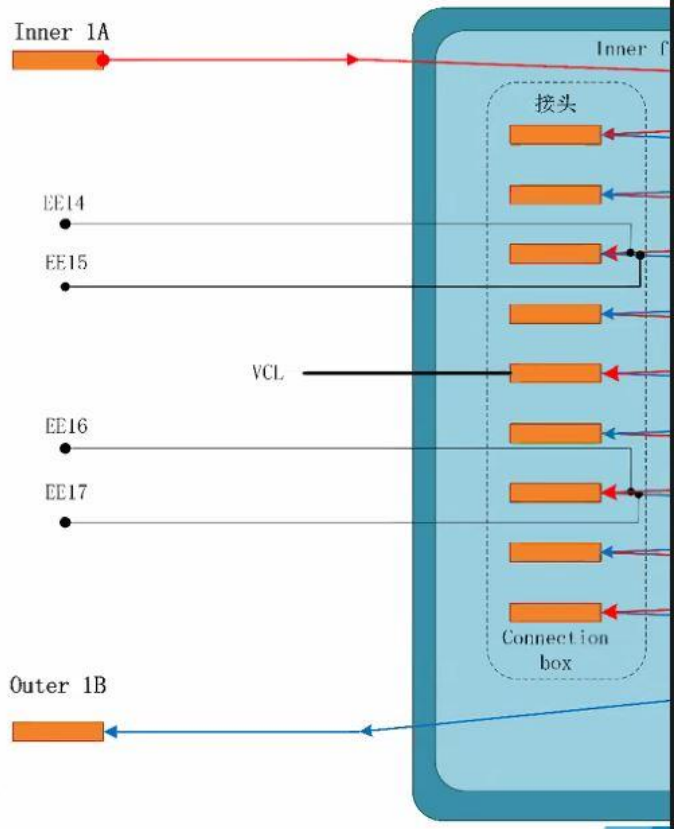
After 29 quenches, the coil was finally trained up to 409 A, that's about 77% of 530A. The current grows very slowly, just like the training process of the MCBRDP2.



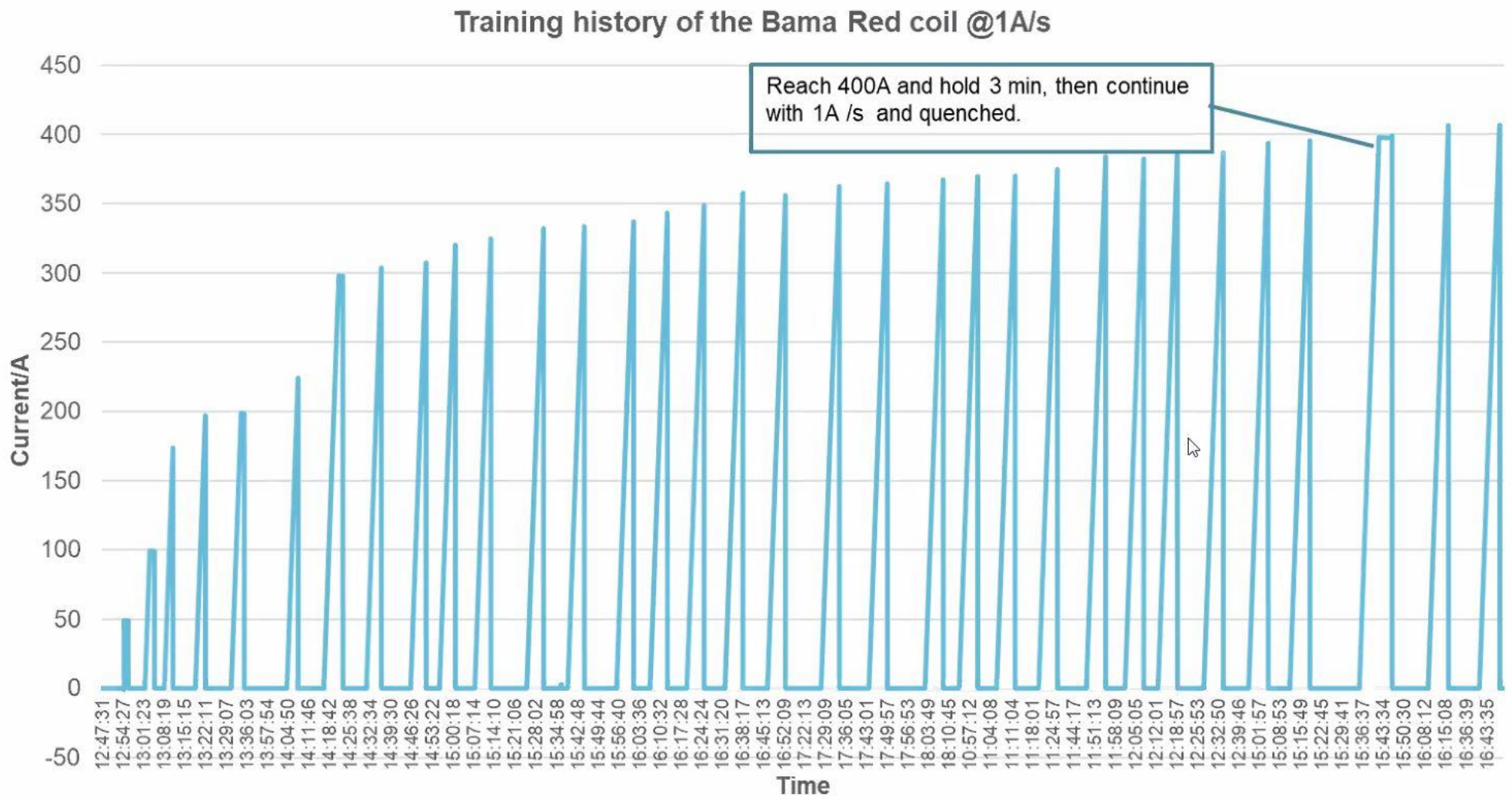
Cold test – Quench location

Most of the training of the Red coil are in the *EE17 – outer 1B*, but other segments also quenched throughout the process of training.

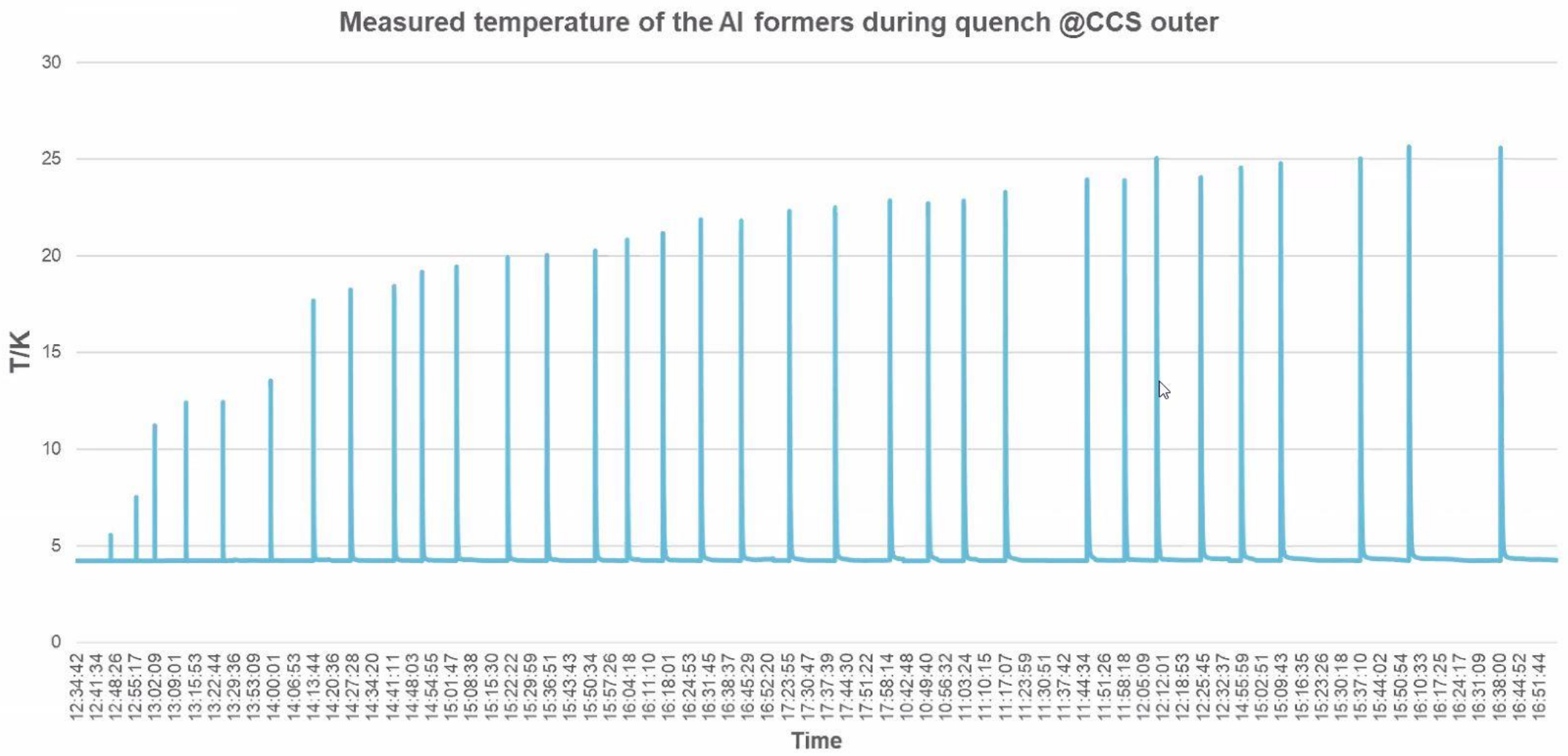




Cold test – Ramping profile



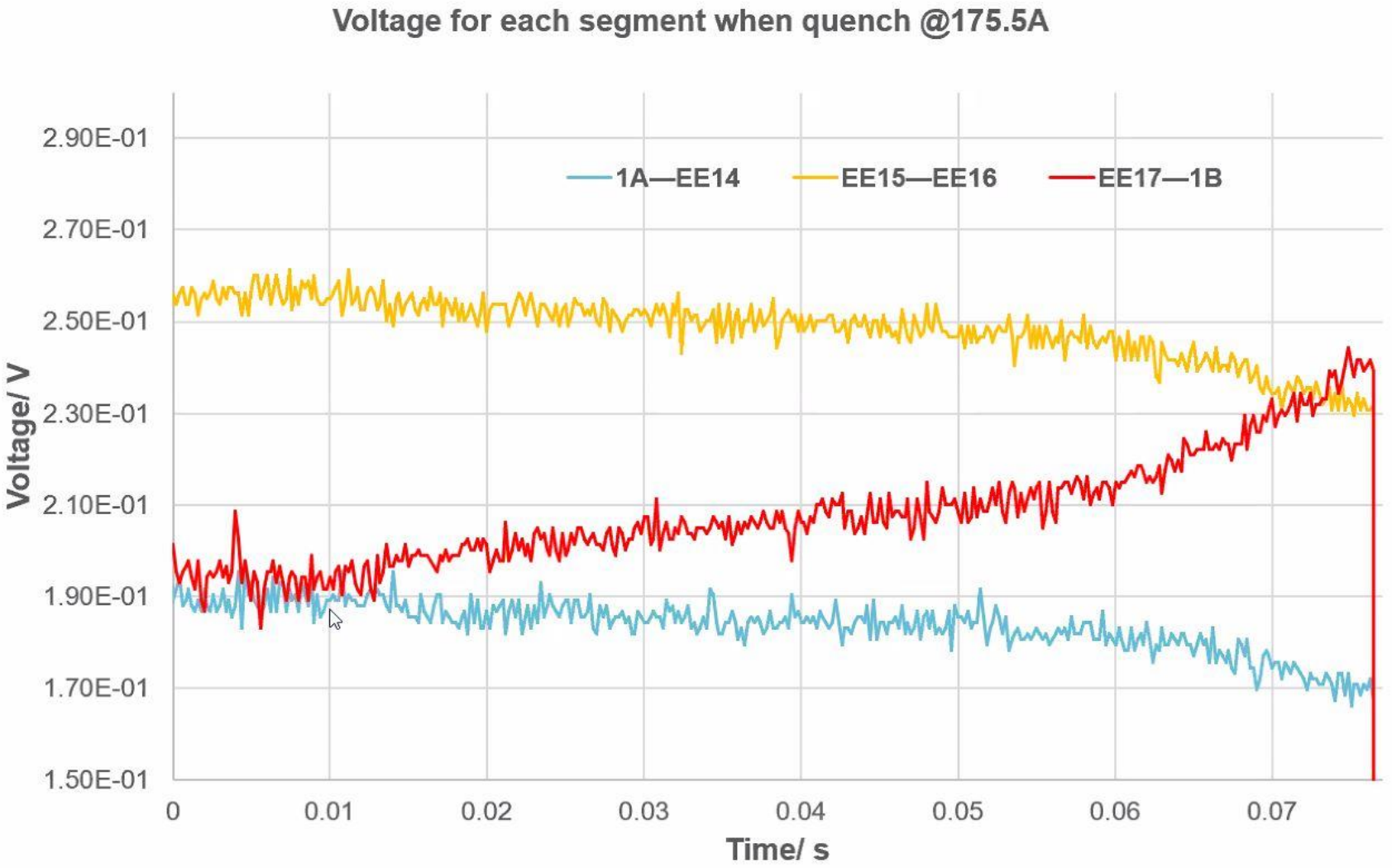
Cold test – Temperature rise



Cold test - Some quench curves

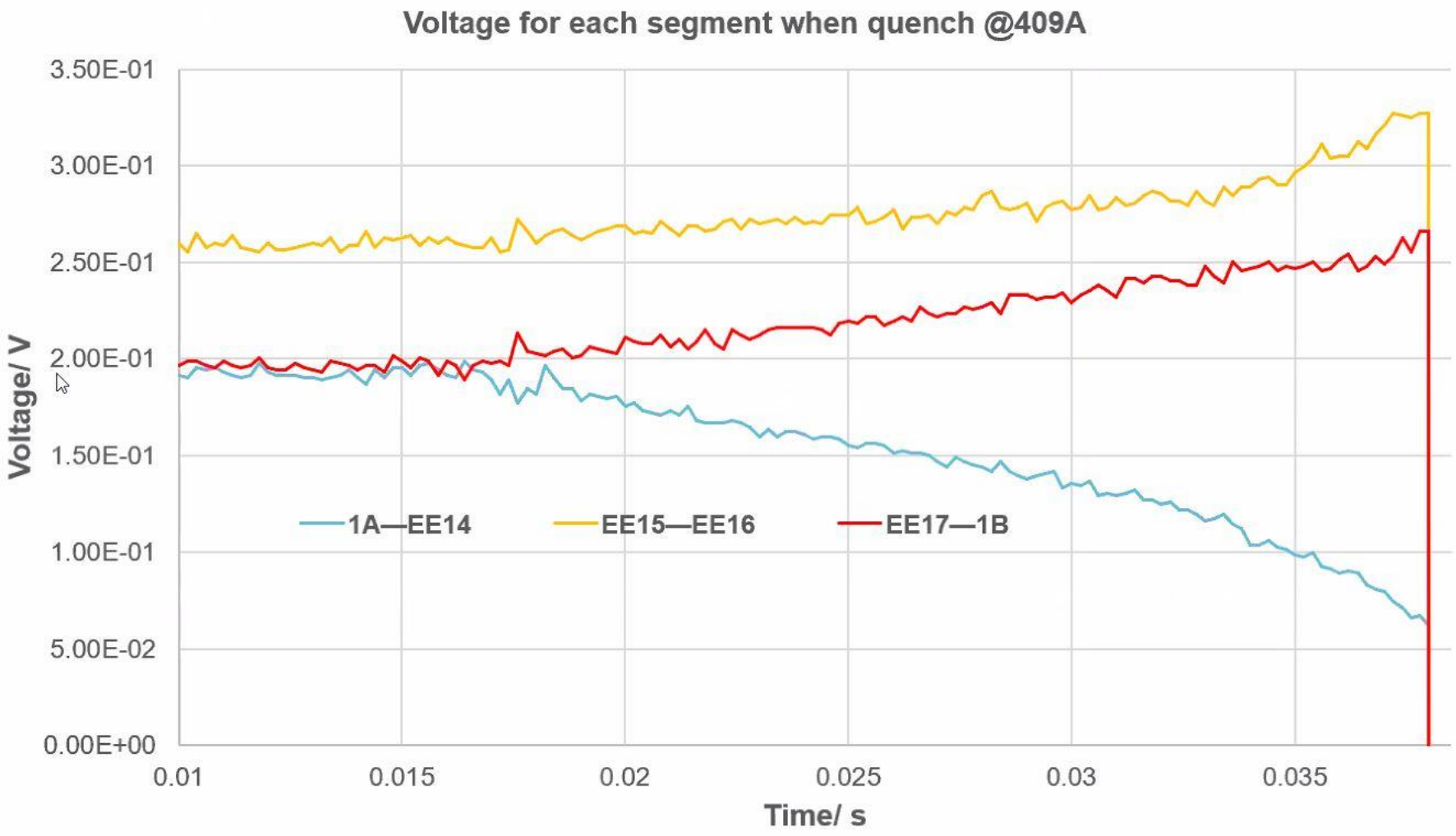
The first quench, ramping rate is 1A/s, the quench segment is:

EE17 – outer 1B

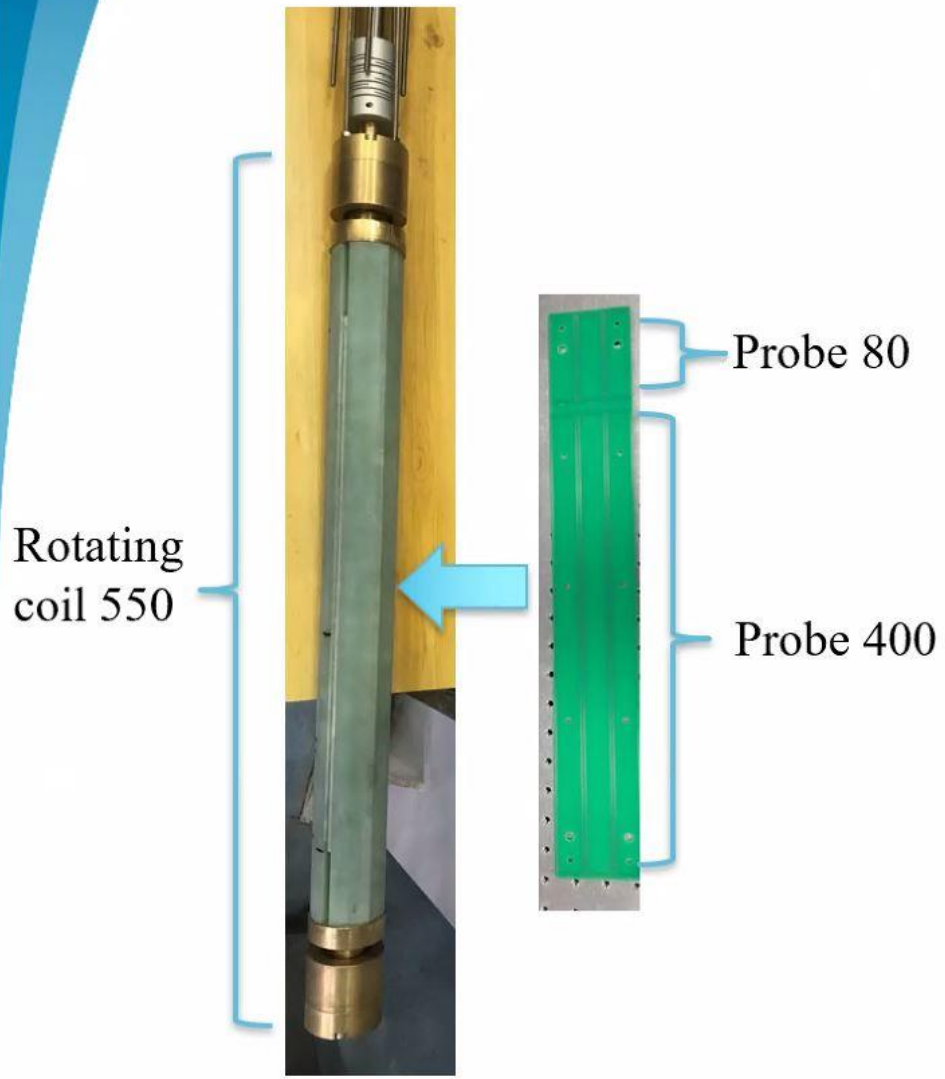


Cold test - Some quench curves

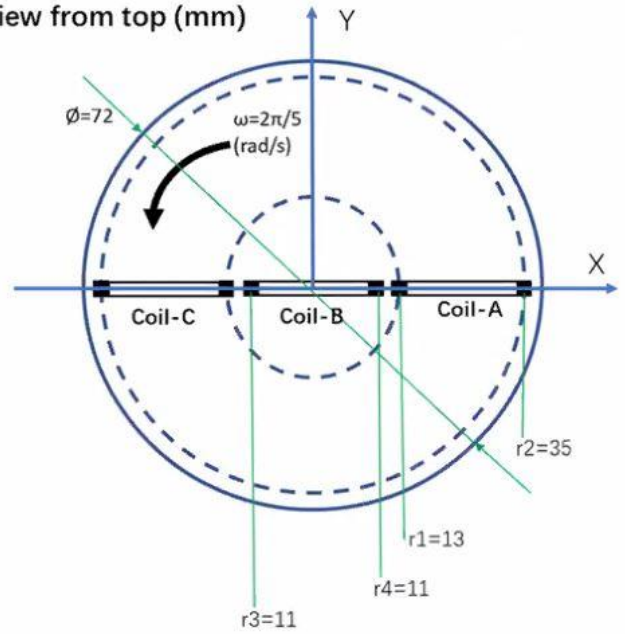
The final quench, ramping rate is 1A/s, the quench location is between the two segments of *EE17 – outer 1B* and *EE15 – EE16*

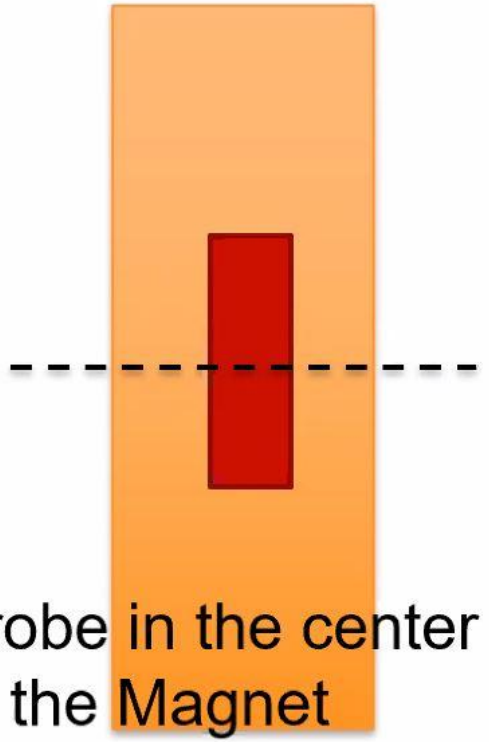


Magnetic field measurement - PCB rotating coil



- The rotating coil based on PCB coil
- Only Probe 400 was used (Length is 400mm)
- Rotate in the anti-cryostat to get local harmonic
- Not enough to cover the entire magnet for Z scan
- Choose Central Position to measured

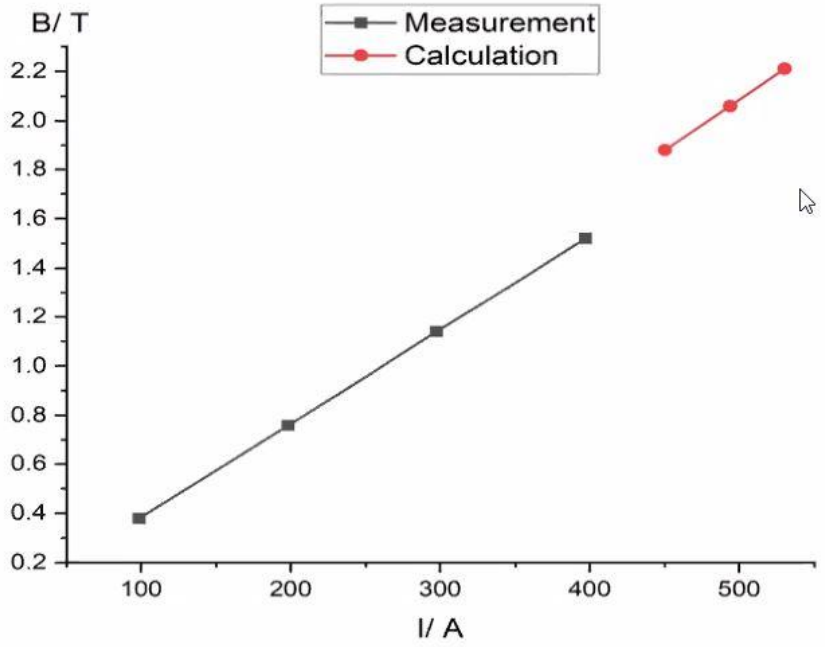




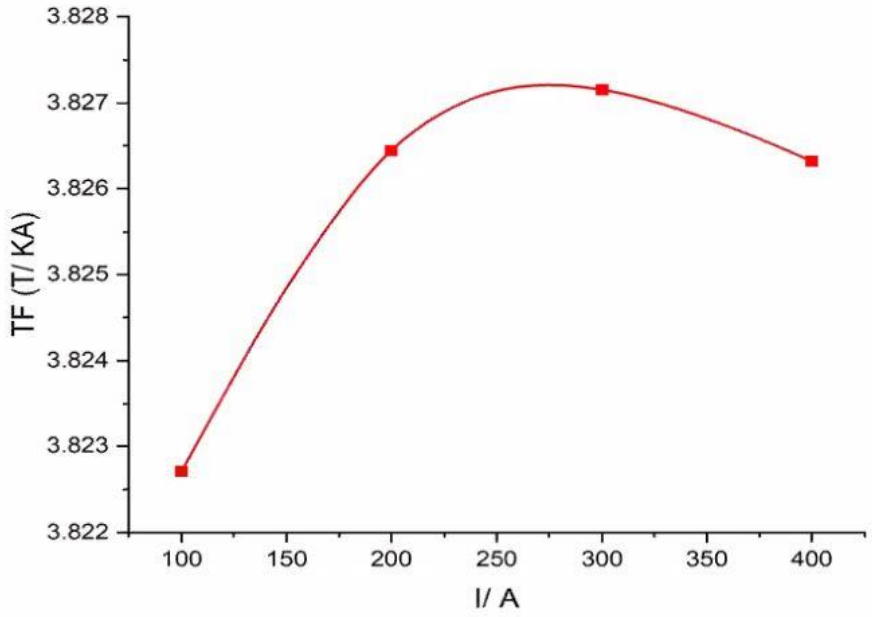
Probe in the center of the Magnet

Magnetic field measurement - Result-1

Excitation curve



Transfer function

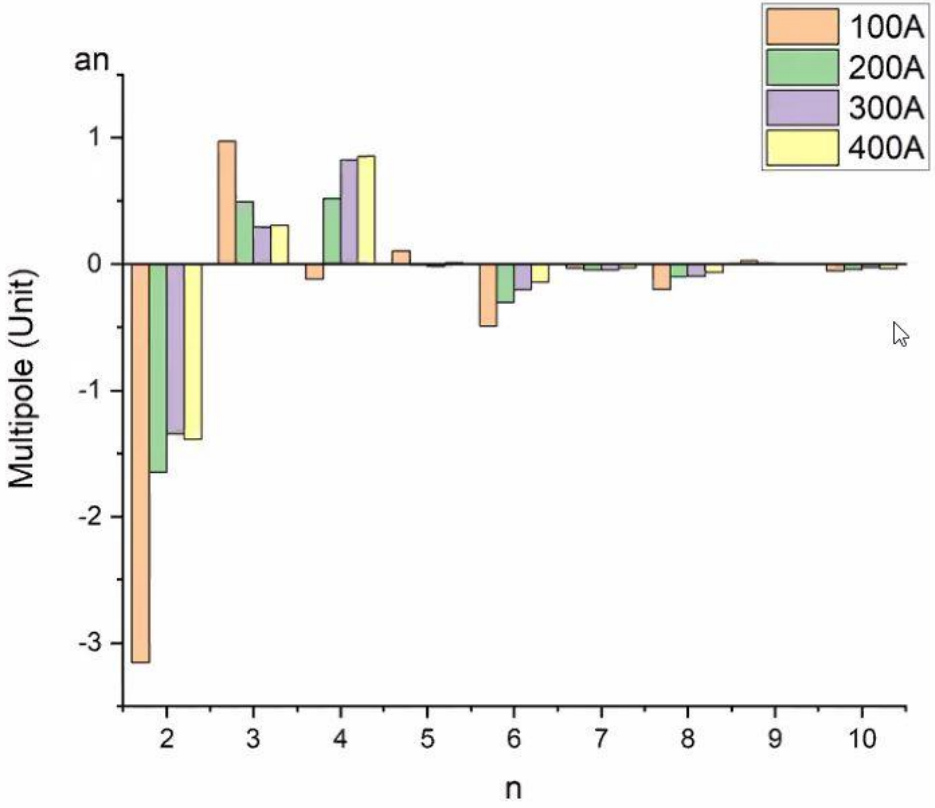


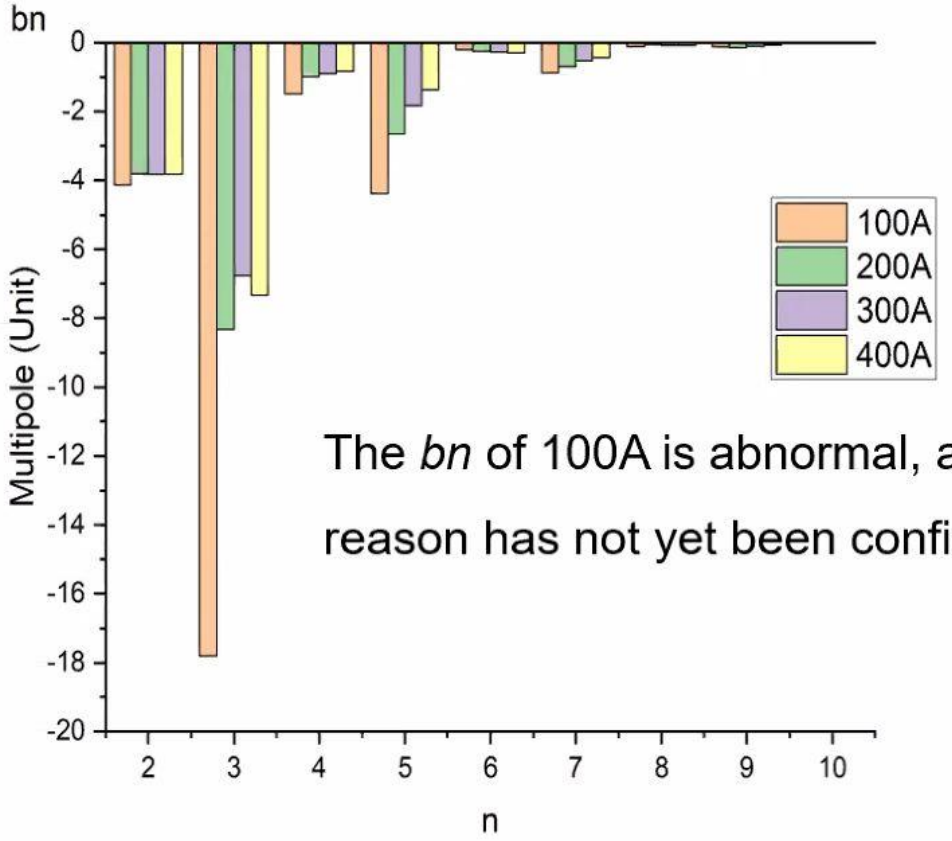
Because there's not enough liquid helium, only the positive current direction was measured.

I(A)	98.92	198.47	297.65	397.4
B(T)	0.378	0.76	1.139	1.52
TF(T/KA)	3.8227	3.8264	3.8272	3.8263

Magnetic field measurement - Result-2

Field quality (local harmonic)of center

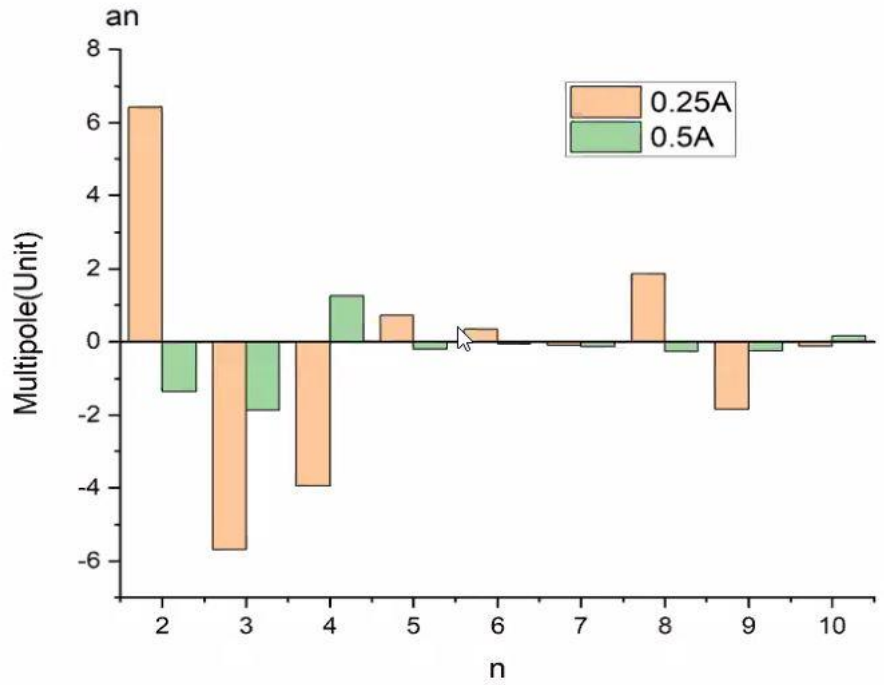


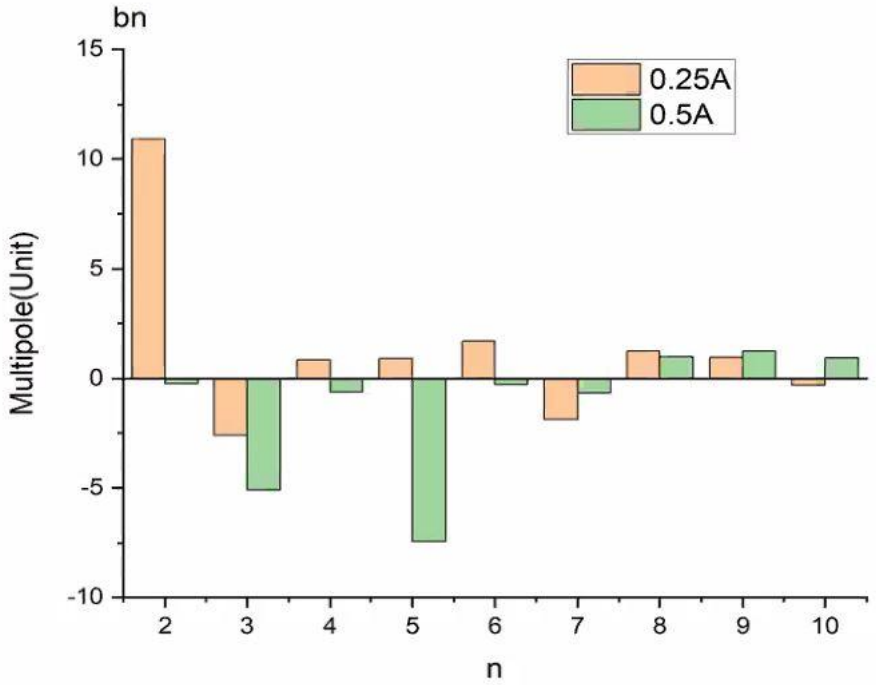


The *bn* of 100A is abnormal, and the reason has not yet been confirmed.

Magnetic field measurement - Result-3

Averaged harmonics of warm measurement at +/- 0.25A, +/-0.5A at center





I(A)	B(T)	TF(T/kA)
0.25	0.000957	3.827
0.5	0.00191	3.825

Conclusion and plan

- General feeling about the test results: very like MCBRDP2, very slow training process.
- Due to the limited availability of the test station, we stopped the training of aperture 1, start to test the aperture 2 this week.
- If the performance of aperture 2 is similar with aperture 1, we will make a decision to adapt the wet wind process for the following apertures.
- From next week assembly of the 01 magnet will be started.

Plan from now to mid 2021

Late this week	01-Aperture 2 stand-alone test
End of January 2021	Start to assemble the 01 magnet
Beginning of March 2021	The 01 magnet ready for test
April 2021	The 01 Magnet ready for delivery to CERN
June 2021	The 02 Magnet ready for delivery to CERN