Magnetic measurements on the LMQXFA01 at 1.9 K

Lucio Fiscarelli, Guy Deferne, Mariano Pentella, Piotr Rogacki, and all TM colleagues

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Outline

- Measurement setups: Stretched Wire and Rotating Coil
- Performed tests and results: Nominal current, Machine cycles, Stair-step cycles
- Additional results: voltage spikes
- Conclusions

Results of alignment tests are nor reported here since test are still ongoing.

Stretched wire

Standard system used for Q2 and other magnets

- PI X-Y tables
- FDI integrators
- FFMM control software
- Copper beryllium wire ⌀ 0.125 mm
- Wire length ~21 m

A careful sag correction is required

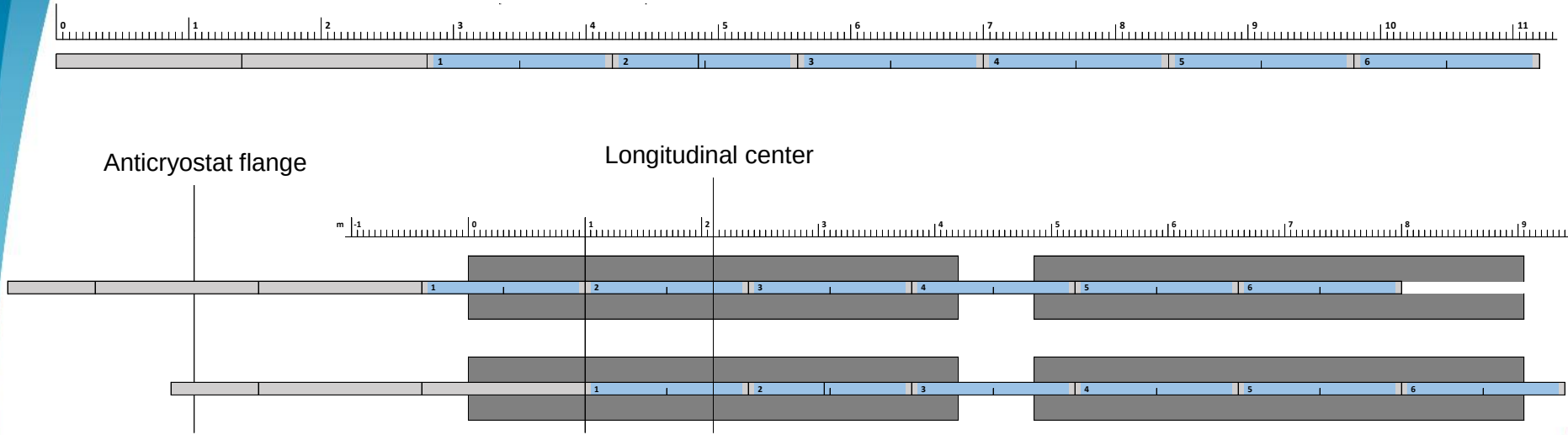
Rotating coils

Same system used on the Q2

- 6-segment rotating shaft
- Each segment is 1.3 m + 0.1 m gap
- 12 FDI integrators
- FFMM software for control and online processing
- Continuous measurement at 1 turn/s

Not optimal for Q3

Rotating coils



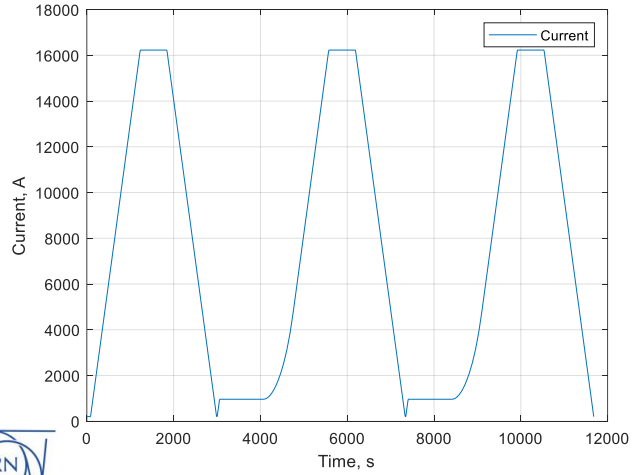
Shaft too short to cover at the same time both magnets

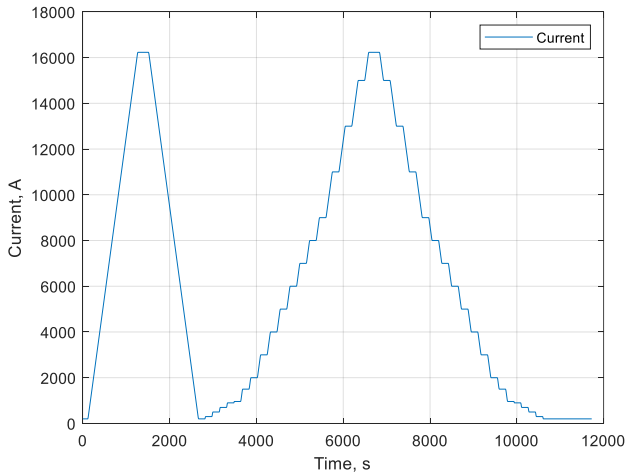
- Two measurement positions
- Cycles repeated twice

Performed tests

Performed tests

- Integrated gradient with Stretched wire
  - Nominal current
- Field quality with Rotating Coils
  - Machine cycles and Stair-step cycles

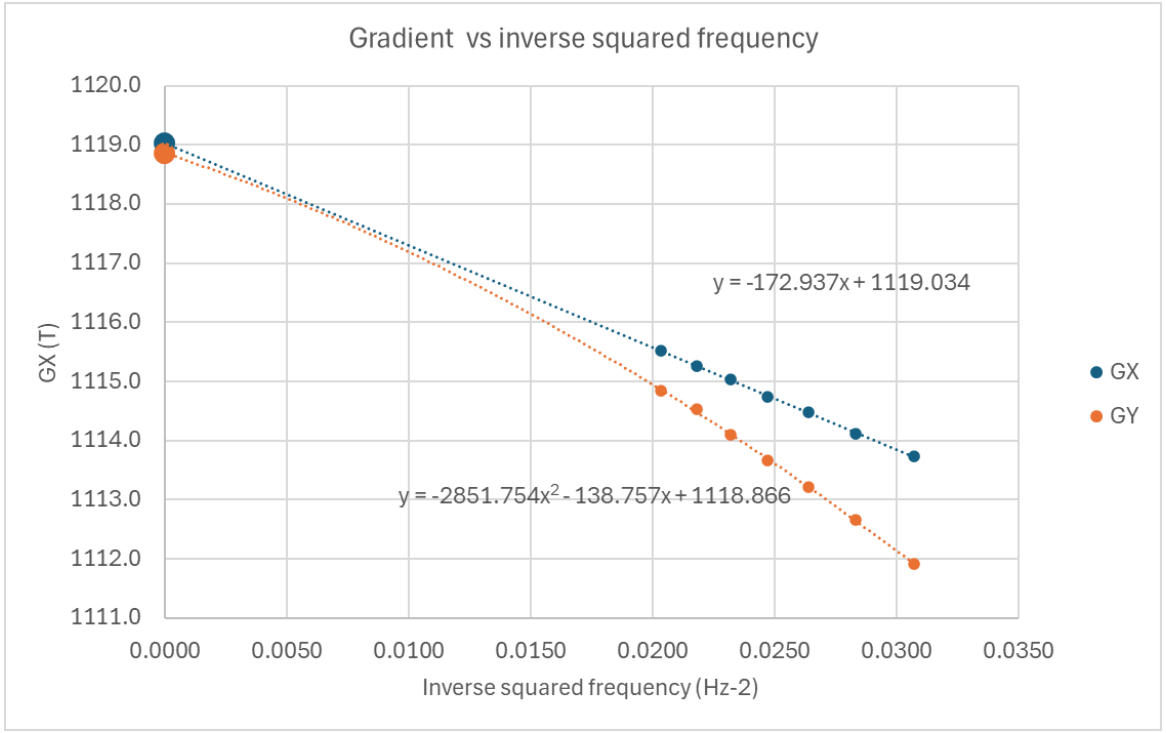




Main field and magnetic length

Current	A	16230				
		A03	**A04**	**Integral**		
CERN						
Integrated gradient	T	559.53	559.62	1119.15	SSW	1119.03
Central gradient TF	T/m/kA	8.1790	8.1828			
Lm	m	4.215	4.214			
Nodal distance	m	4.770				
FNAL						
Integrated gradient	T	559.70	559.95	1119.60		
Difference	units	8	1	4		
Nodal distance	m	4.772				
Difference	mm	-2				

Sag correction on stretched wire



- The gradient measured with a vertical displacement (GY) is affected both by gravity and wire diamagnetism: correction is more difficult
- The gradient measured with a horizontal displacement (GX) is affected mainly by the wire diamagnetism: more effective extrapolation

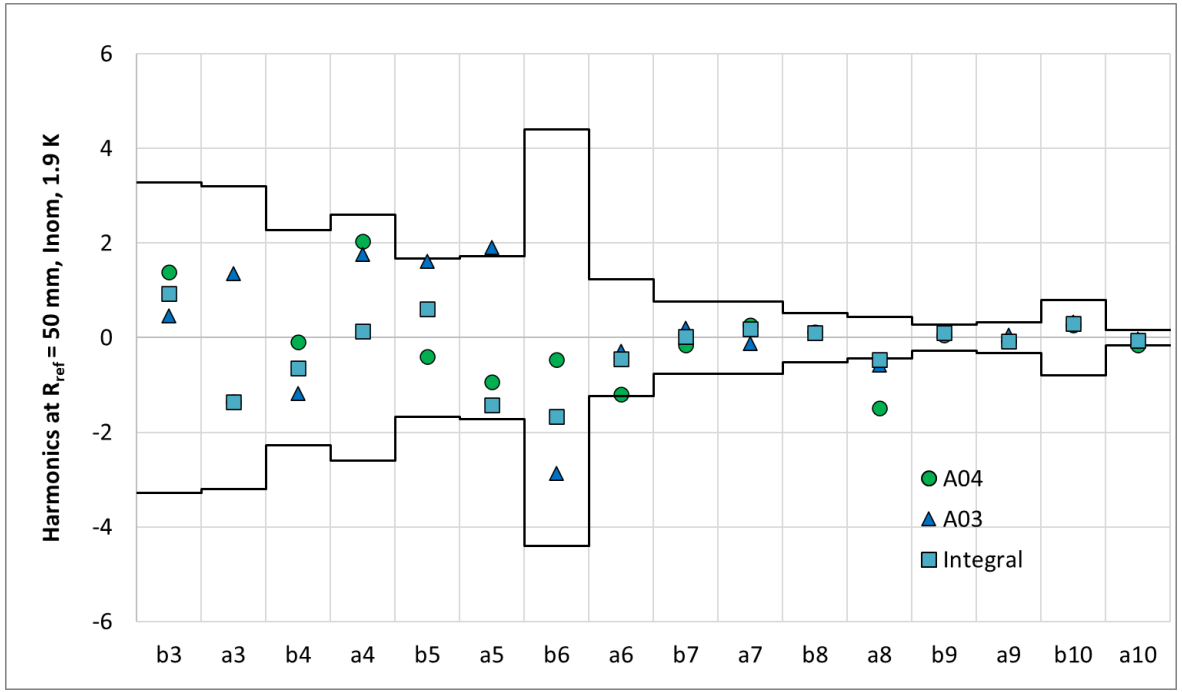
Field quality at nominal 16230 A

Current 16230 A							
	A04	A03	Integral*		A04	A03	Integral*
b3	1.39	0.46	0.93	a3	-1.36	1.35	-1.36
b4	-0.09	-1.18	-0.64	a4	2.03	1.76	0.13
b5	-0.40	1.62	0.61	a5	-0.93	1.90	-1.42
b6	-0.47	-2.87	-1.67	a6	-1.19	-0.28	-0.45
b7	-0.15	0.20	0.03	a7	0.27	-0.12	0.19
b8	0.12	0.09	0.10	a8	-1.49	-0.57	-0.46
b9	0.06	0.13	0.10	a9	-0.08	0.05	-0.07
b10	0.27	0.33	0.30	a10	-0.15	-0.03	-0.06
b11	0.09	0.14	0.11	a11	-0.01	0.05	-0.03
b12	-0.02	-0.01	-0.01	a12	0.07	0.03	0.02
b13	0.17	0.14	0.15	a13	-0.11	0.19	-0.15
b14	-0.95	-0.97	-0.96	a14	0.15	0.02	0.07
b15	0.00	0.00	0.00	a15	0.00	0.01	-0.01

Harmonics are given in units at the reference radius of 50 mm

* reference frame of A04

Field quality at nominal



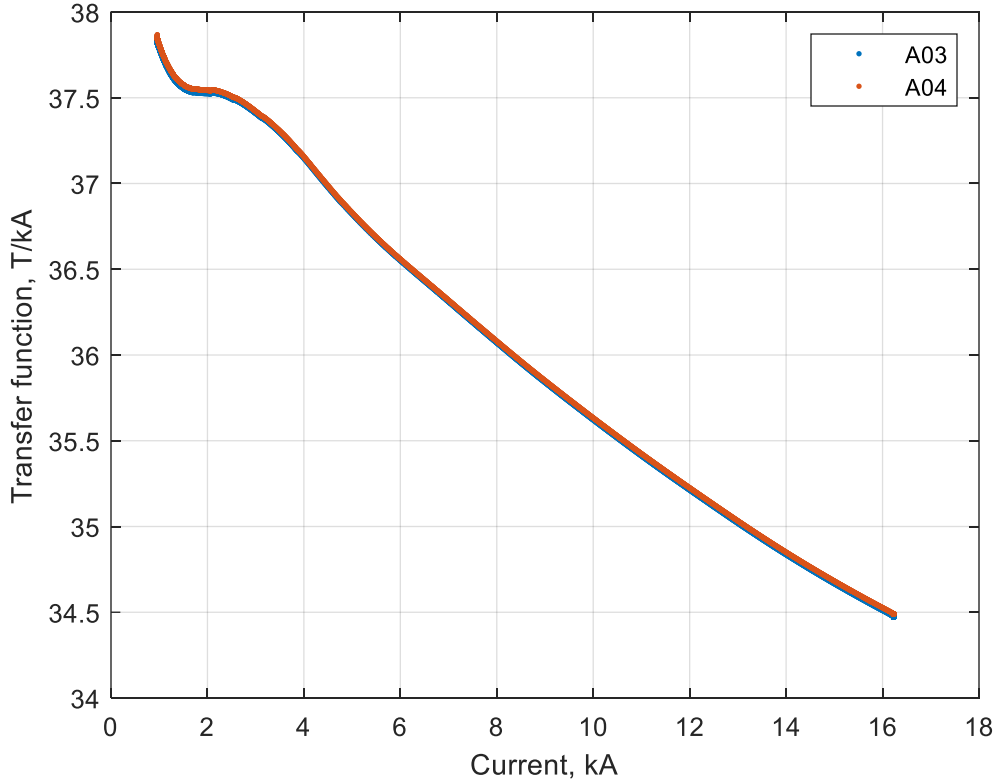
Lines show the expected range at ±(3+1) σ

Field quality at injection current (960 A)

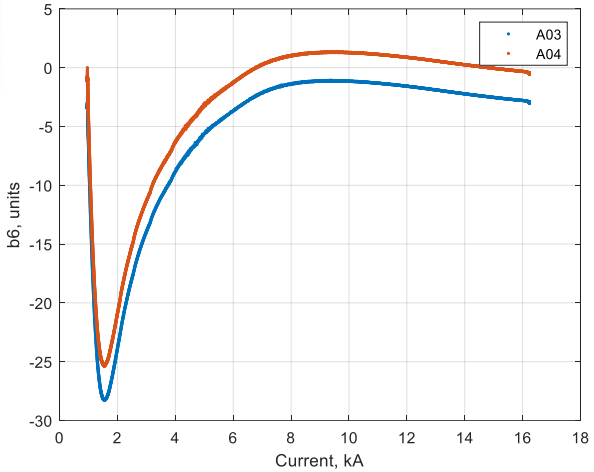
Current 960 A (precycle at 16230 A and reset at 200 A)						
	A04	A03			A04	A03
b3	-1.08	1.32		a3	-0.18	-2.38
b4	-0.58	-1.08		a4	-1.85	0.26
b5	1.11	1.26		a5	-0.07	1.16
b6	-1.00	-3.38		a6	-1.17	-0.22
b7	0.19	-0.22		a7	0.24	-0.52
b8	0.20	0.14		a8	-1.54	-0.99
b9	-0.41	-0.12		a9	0.18	-0.51
b10	2.60	2.90		a10	-0.22	0.01
b11	0.00	0.09		a11	-0.01	0.04
b12	0.00	0.00		a12	0.06	0.03
b13	0.15	0.08		a13	-0.07	0.08
b14	-0.56	-0.57		a14	0.05	0.01
b15	0.01	0.00		a15	0.00	0.02

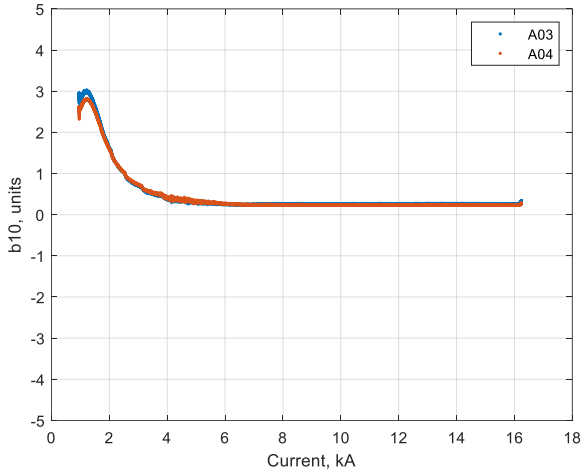
Harmonics are given in units at the reference radius of 50 mm

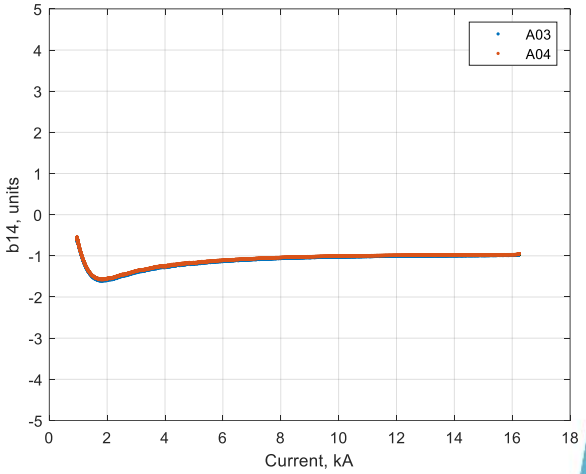
TF vs current - ramp-up of machine cycle



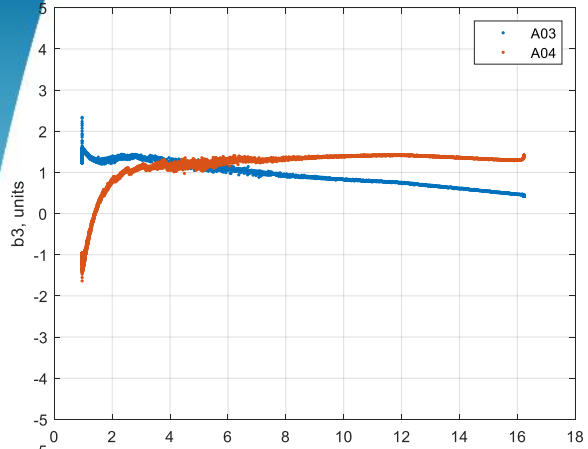
Harmonics vs current - ramp-up of machine cycle

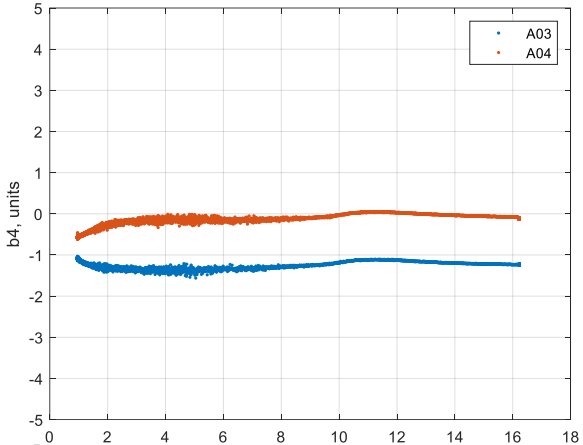


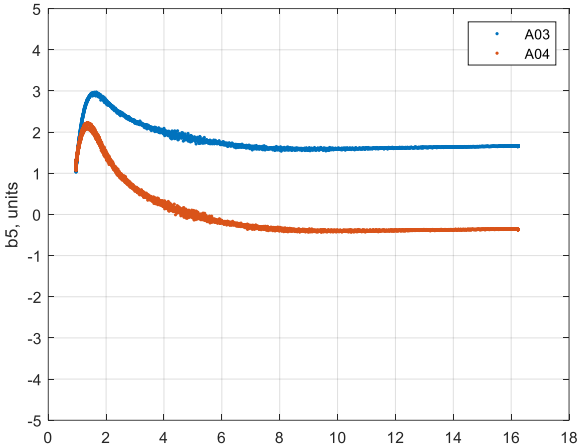


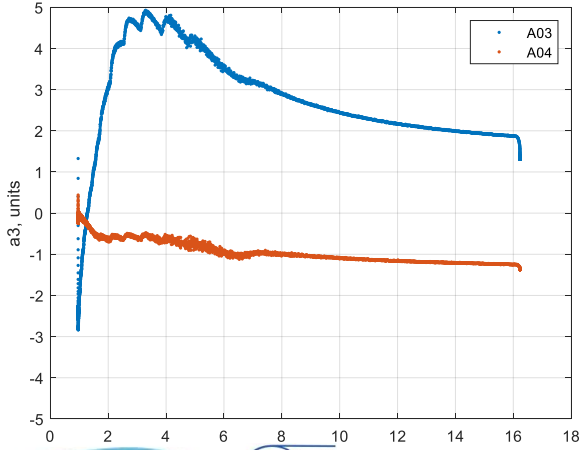


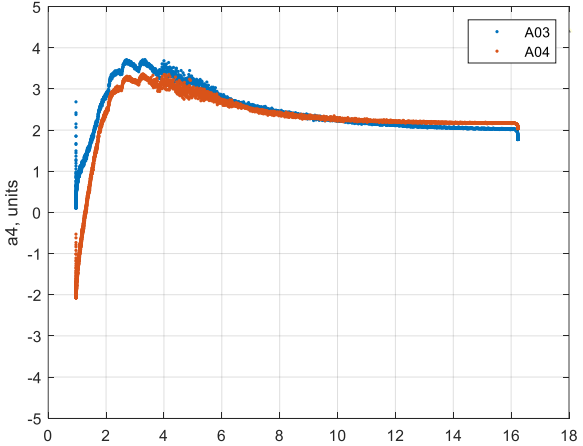
Harmonics vs current - ramp-up of machine cycle

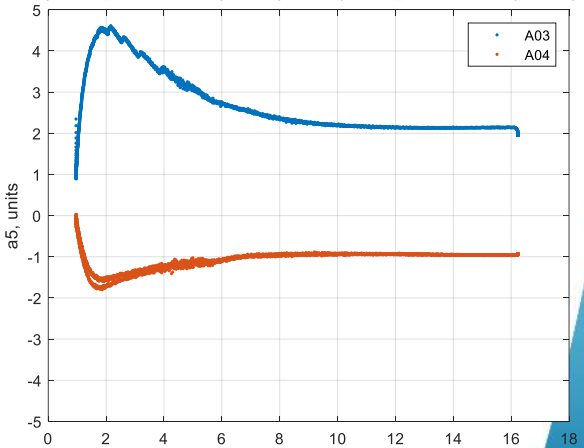




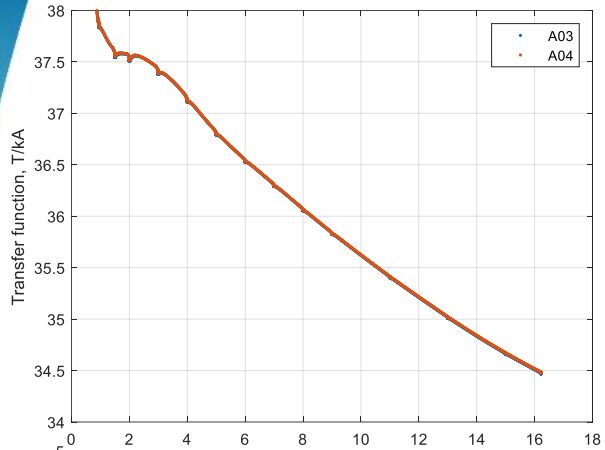


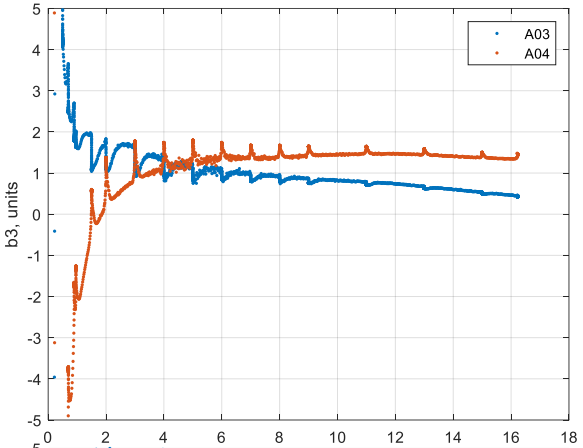


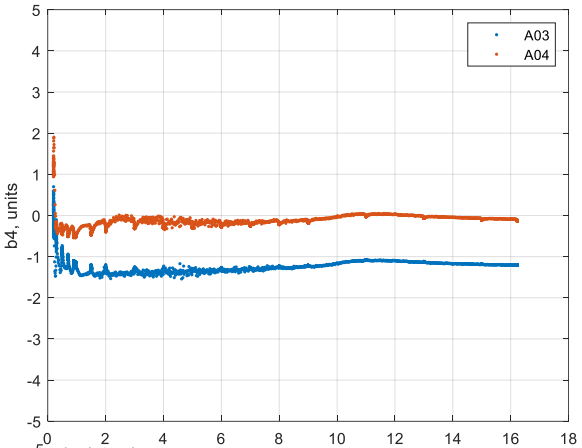


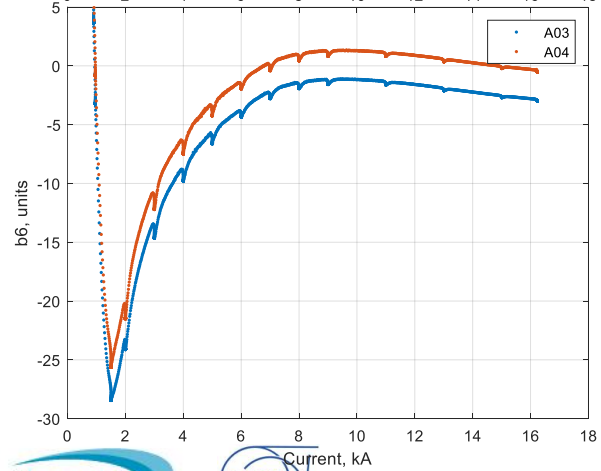


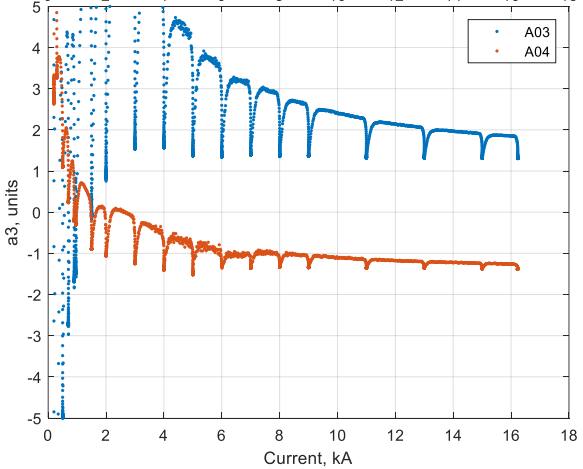
Decays after ramping – ramp up of stair-step cycle - integral

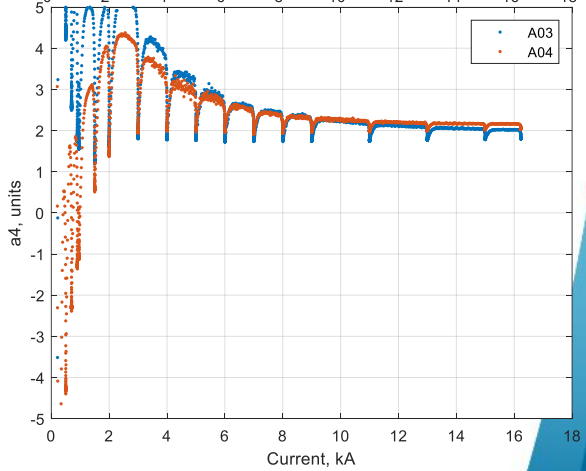




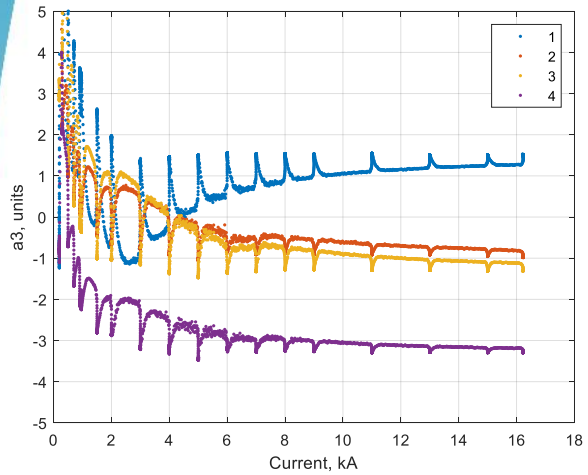


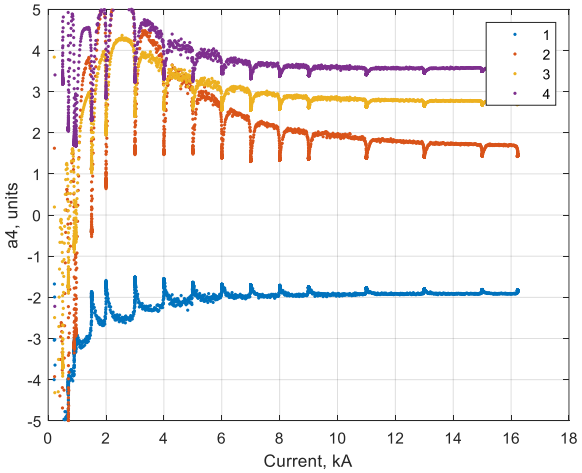


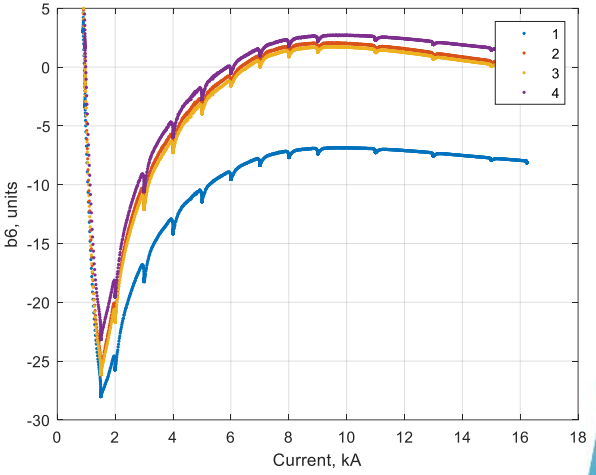




Decays after ramping - individual segments on magnet A04

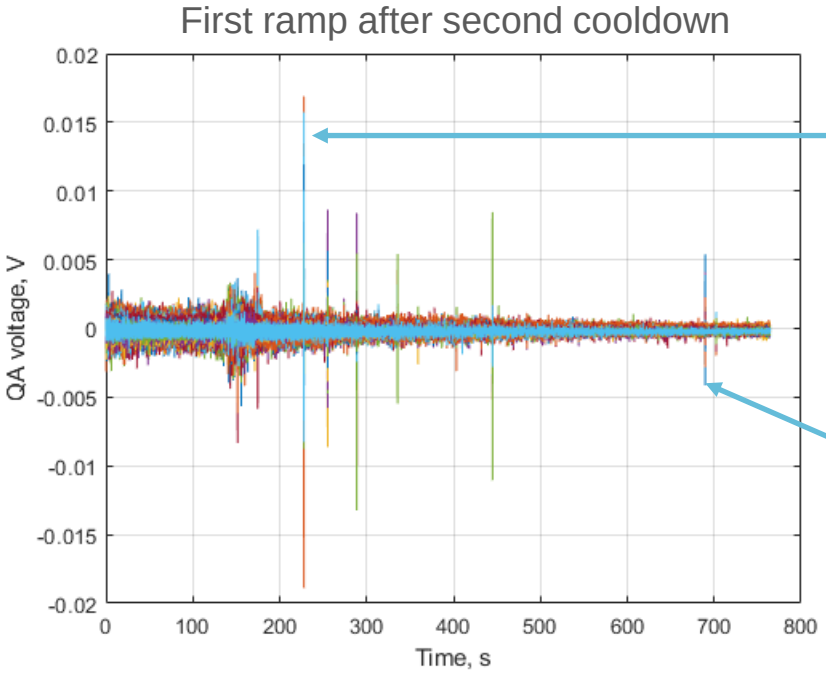


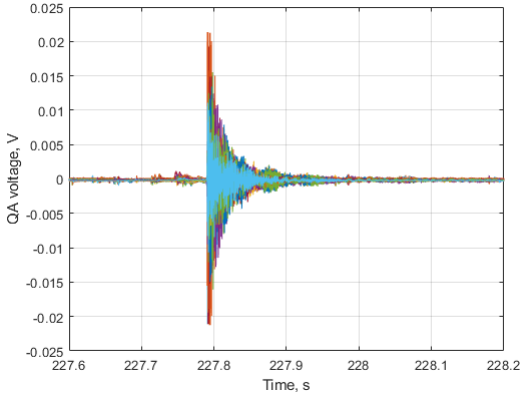


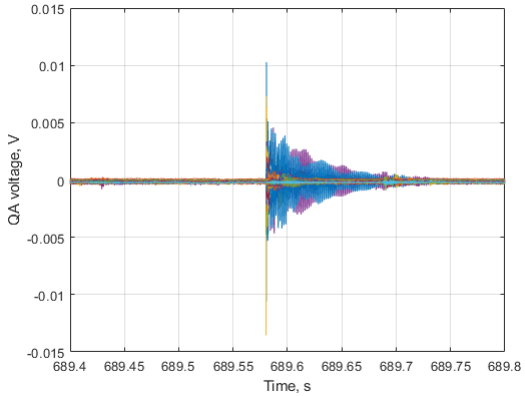


The decays look uniform along the magnet length.

Quench antenna signals and voltage spikes







Conclusions

- Measurements of integral gradient and field quality performed during the first campaign at CERN
- Main results:
  - Integral gradient and nodal distance in agreement with results from AUP
  - Field quality within the expected range
  - On plateaus after ramping, some harmonics show a decay up to 2/3 units. Similar effect already seen on MQXFB magnets.
  - Quench antenna signals don’t show events like the voltage spike seen on other MQXFA magnets. The events at intermediate and high current look of mechanical nature.
- Alignment measurements were not completed during first campaign. They are ongoing now.