Magnetic measurements on MBHSP105

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Second debriefing meeting on the cold tests of the 11T dipole model MBHSP105
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CERN

Outline

- Coils, models and conductors
- Measurement list
- Measurement systems

- Measurement results
  - Ambient temperature
    - TF, field quality, and comparison with other models
  - Cryogenic temperature
    - TF and saturation, b3 and persistent currents
    - Field quality
    - Comparison with other models
    - Effects of pre-cycle RR, effects of temperature

- Conclusions

Coils, models, and conductors

	Magnet	Strand layout	Cu/SC	Coil R at 300 K	Average coil	Min Ic at 4.2 K, 12 T
				mΩ	$RRR_{293K/4K}$	A
Coil 105	SM101	RRP 108/127	1.22	426	81	
Coil 106	SP102	RRP 108/127	1.22	423	66	466
Coil 107	SP101	RRP 108/127	1.22	426	97	
Coil 108	SP102	RRP 132/169	1.22	407	185	417
Coil 109	SP103	RRP 132/169	1.27	400	131	395
Coil 111	SP103	RRP 132/169	1.27	401	124	395
Coil 112	SP104	RRP 132/169	1.27	403	125	395
Coil 113	SP104	RRP 132/169	1.27	403	115	395
Coil 114	**SP105**	**RRP 150/169**	**0.98**	**438**	**115**	**415**
Coil 115	**SP105**	**RRP 150/169**	**0.97**	**438**	**110**	**415**

Thanks to B. Bordini and G. Willering

Measurement list

- Ambient temperature, central and integral field at ±20 A
  - After collaring (CC)
  - After shell welding (CM)

- Cryogenic temperature, central and integral field up to nominal
  - Standard
    - At 1.9 K
      - Machine simulation cycle after pre-cycling at 50 As^{-1}
      - Stair-step cycle
      - Machine simulation cycle after pre-cycling at 10 As^{-1}
  - Extended
    - At 1.9 K
      - Machine simulation cycle with injection at 3 kA
      - Machine simulation cycle with injection at 4 kA
    - At 4.3 K
      - Machine simulation cycle (up to 10 kA)

Measurement system at ambient temp.

- Motor + encoder + slip-ring unit (MRU)
- Fast Digital Integrator (FDI)
- FuG low voltage power supply (40 V, 20 A)
- DCCT Hitec MACC-plus
- Search coil shafts

Number of turns	(-)	256
Inner width	(mm)	13.41
Inner length	(mm)	1195.60
Groove thickness	(mm)	1.40
Magnetic surface	(m^2)	3.37
Radius	(mm)	21.33

A measurement is an average over 1.2 m

Measurements in 3 positions:

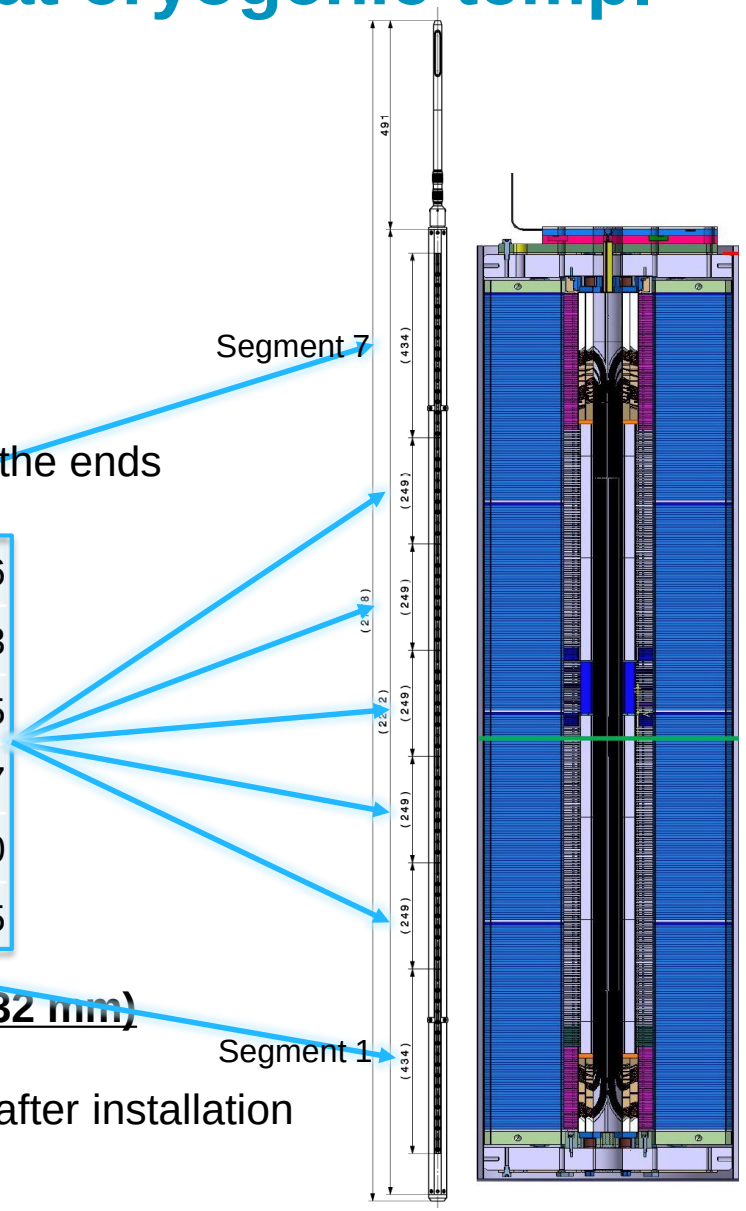
Shaft centered	->	central field
Two adjacent positions	->	integral field

Measurement system at cryogenic temp.

- **Fast Digital Integrators (FDI)**
- **Motor + encoder + slip-ring unit (MRU)**
- **Vertical shaft rotating in liquid He**

7 segments: 5 short in the middle + 2 longer on the ends

Number of turns	-	36	36
Inner width	mm	10.3	10.3
Inner length	mm	431.5	246.5
Groove thickness	mm	0.57	0.57
Magnetic surface	m^2	0.17	0.10
Radius	mm	21.5	21.5



A measurement is an average over 250 mm (432 mm)

The shaft cannot be translated along the magnet after installation

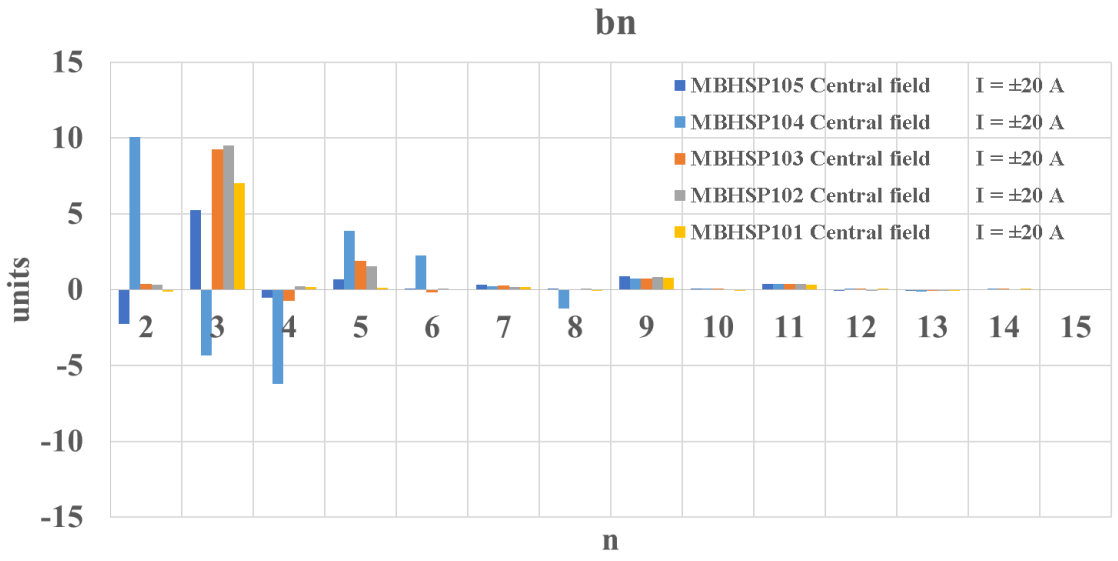
Ambient temperature: TF

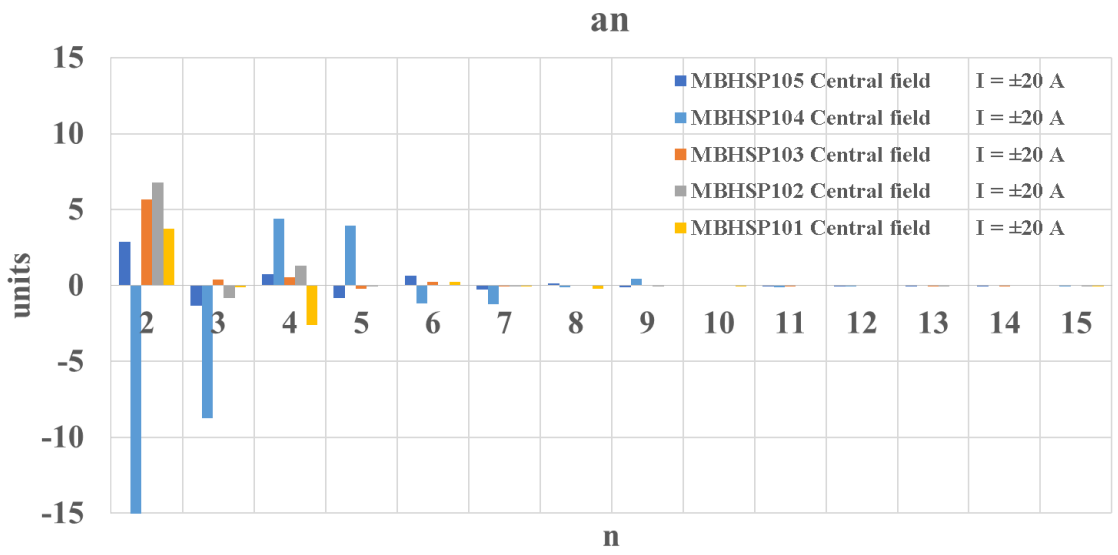
Measured transfer function		SP101*	SP102	SP103	SP104	SP105	ROXIE
CC 2D	T/kA	-	0.7971	0.7970	0.7979	0.7983	0.7980
CM 2D	T/kA	0.9987	0.9926	0.9916	0.9933	0.9939	0.9949
CM 3D	Tm/kA	1.6916	1.6833	1.6755	1.6793	1.6848	1.6747

MM - ROXIE		SP101*	SP102	SP103	SP104	SP105	ROXIE
CC 2D	units	-	-11	-12	-1	3	0
CM 2D	units	-	-23	-33	-16	-10	0
CM 3D	units	-	51	5	27	60	0

Ambient temperature: multipoles

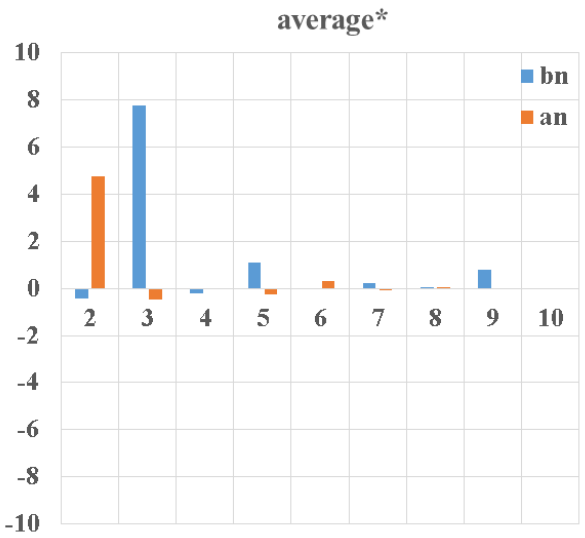
SP105 CM		
n	bn	an
2	-2.28	2.87
3	5.25	-1.34
4	-0.52	0.75
5	0.69	-0.82
6	0.06	0.65
7	0.35	-0.25
8	0.04	0.16
9	0.86	-0.14
10	0.00	0.01
11	0.39	-0.06
12	-0.05	-0.01
13	-0.10	-0.01
14	0.00	0.00
15	-0.02	0.00



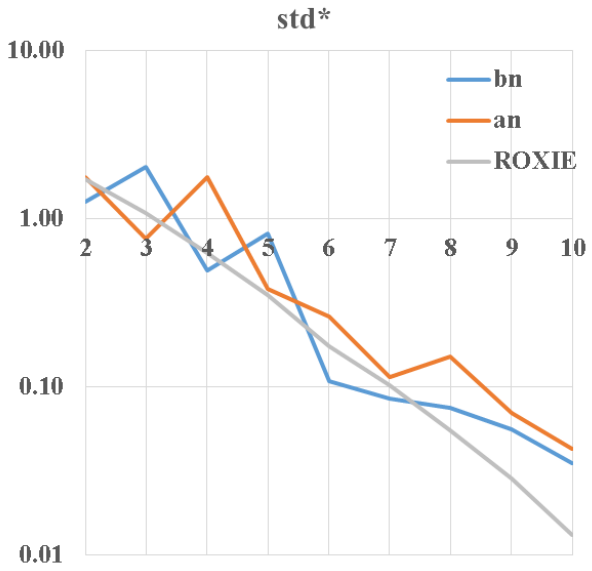


Ambient temperature: up to now…

CM 2D				
	average		std	
TF**	0.9929		12	
n	bn*	an*	bn*	an*
2	-0.43	4.75	1.26	1.77
3	7.76	-0.48	2.02	0.76
4	-0.22	-0.01	0.49	1.76
5	1.08	-0.27	0.81	0.38
6	-0.04	0.30	0.11	0.26
7	0.24	-0.08	0.09	0.11
8	0.01	0.00	0.08	0.15
9	0.80	-0.03	0.06	0.07
10	-0.01	-0.02	0.04	0.04



std from ROXIE ±60 µm		
n	bn	an
2	1.70	1.82
3	1.08	1.18
4	0.62	0.67
5	0.35	0.39
6	0.17	0.20
7	0.10	0.10
8	0.06	0.05
9	0.03	0.02
10	0.01	0.01

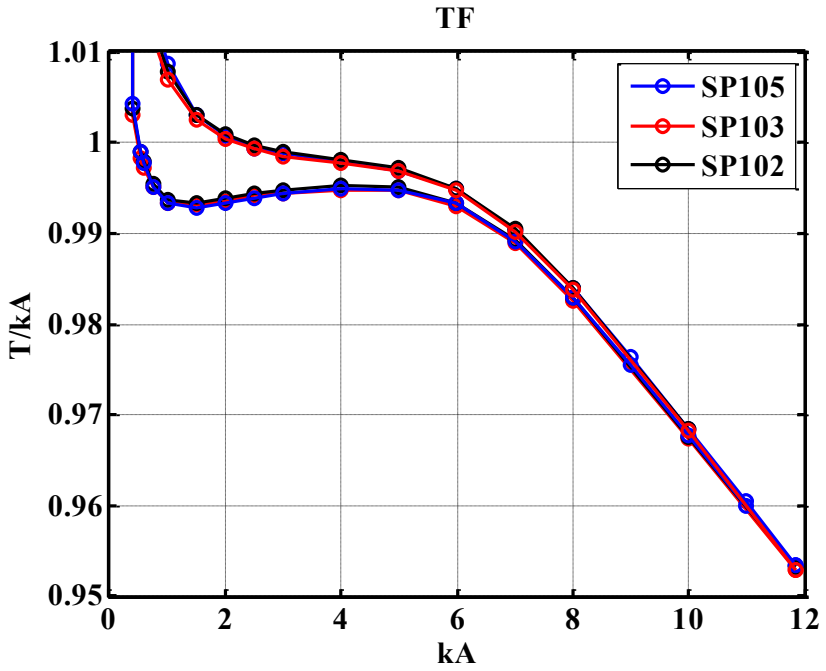


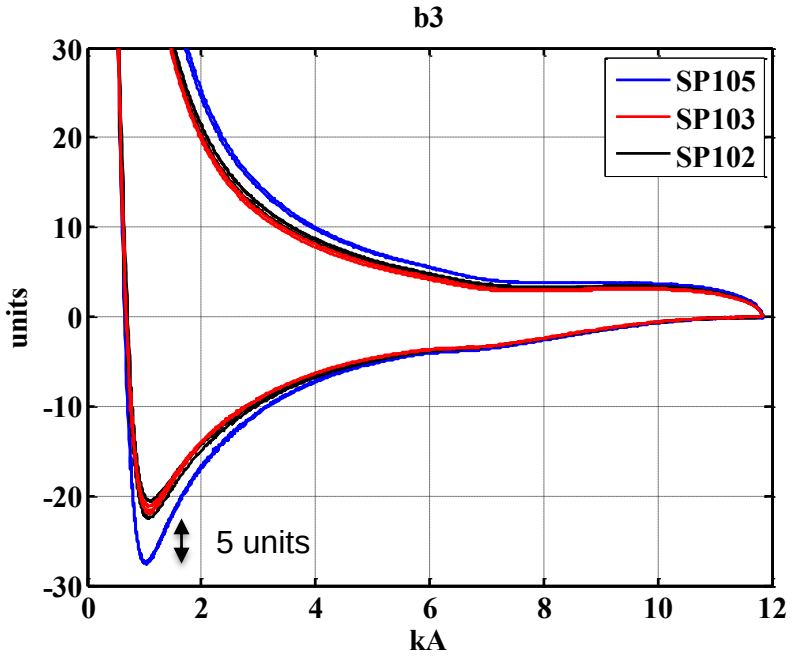
* SP104 not considered

** SP101 not considered

Cryogenic temperature: TF and b3

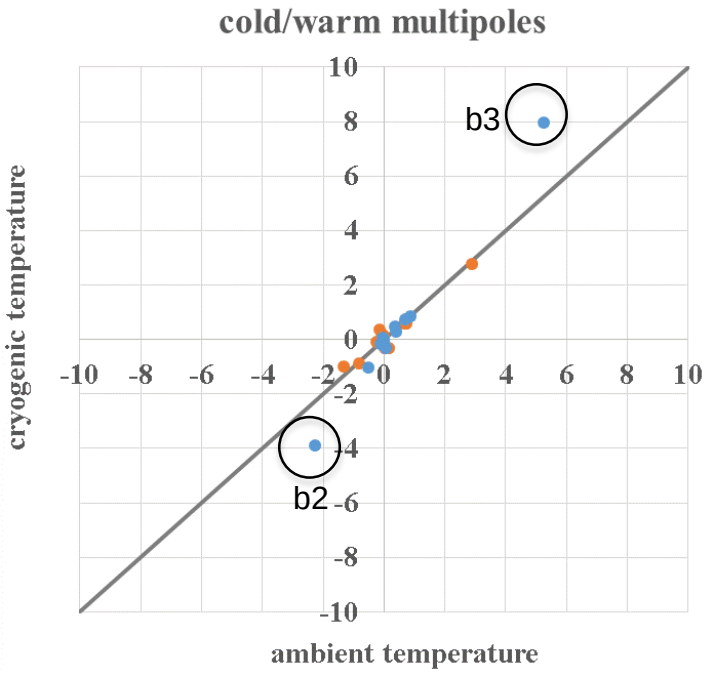
Comparison SP105 and SP103, SP102



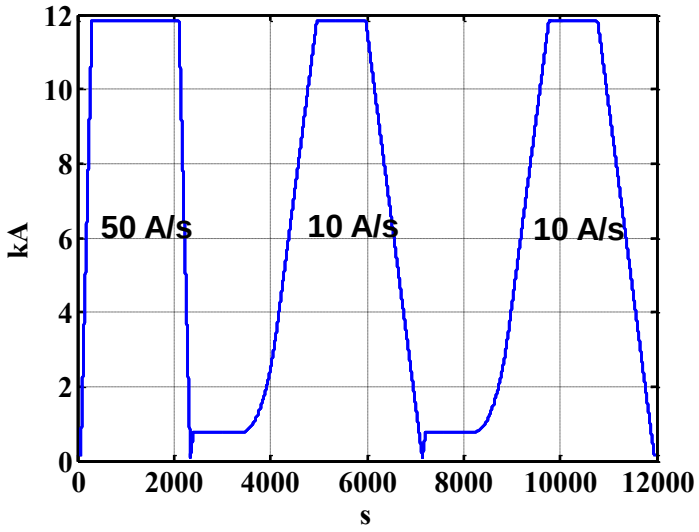


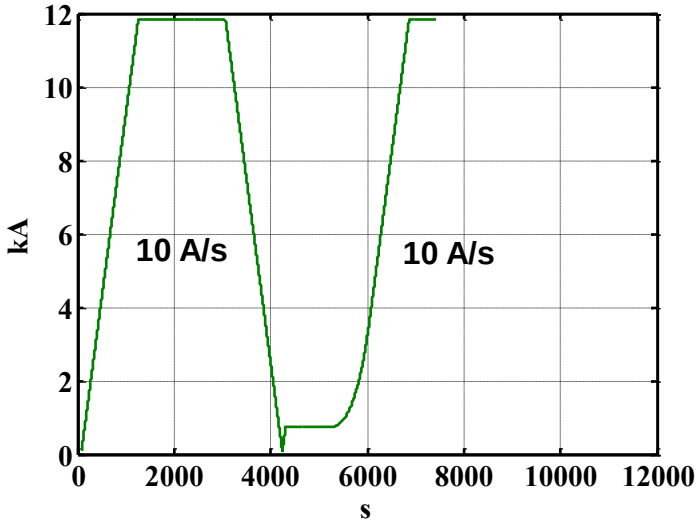
Cryogenic temperature: multipoles

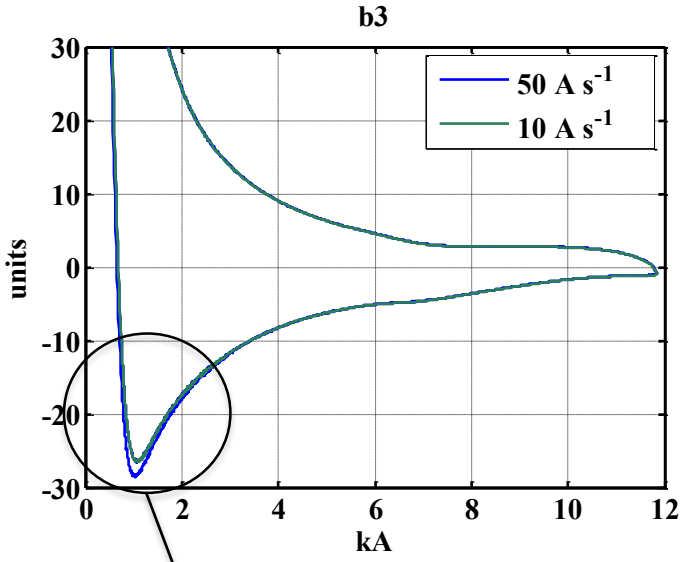
	760 A		11850 A		geometric (5 kA)	
n	bn	an	bn	an	bn	an
2	-2.28	3.99	-3.81	3.06	-3.88	2.76
3	-9.58	-2.45	6.97	-1.05	7.98	-0.98
4	-1.56	0.54	-1.05	0.62	-1.01	0.60
5	3.46	-0.85	0.82	-0.91	0.73	-0.87
6	-0.35	0.60	-0.26	0.65	-0.28	0.60
7	0.81	0.05	0.42	-0.11	0.47	-0.08
8	-0.48	-0.62	-0.32	-0.28	-0.32	-0.30
9	1.50	0.53	0.85	0.36	0.84	0.36
10	0.05	-0.30	-0.03	-0.33	-0.03	-0.32
11	0.11	0.10	0.30	0.23	0.28	0.20
12	-0.04	0.55	0.11	0.11	0.08	0.14
13	-0.37	0.10	-0.14	0.03	-0.15	0.04
14	0.04	0.00	0.03	0.02	0.04	0.01
15	-0.03	0.00	-0.03	-0.01	-0.03	-0.01

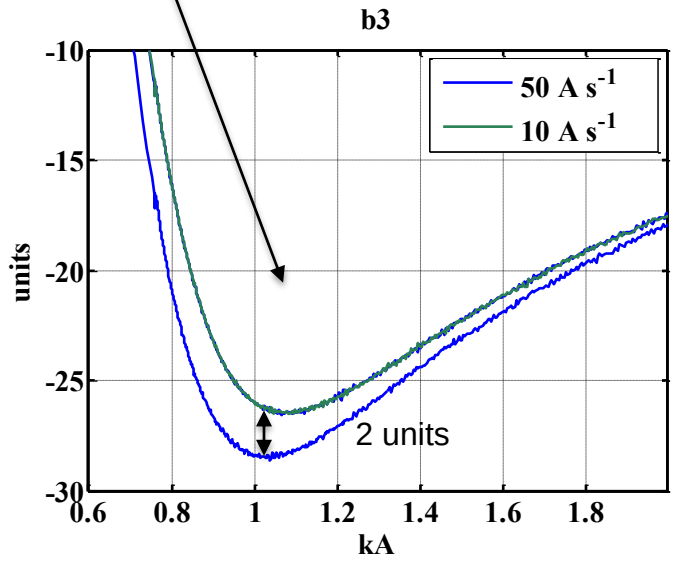


Cryogenic temperature: effect of pre-cycle RR

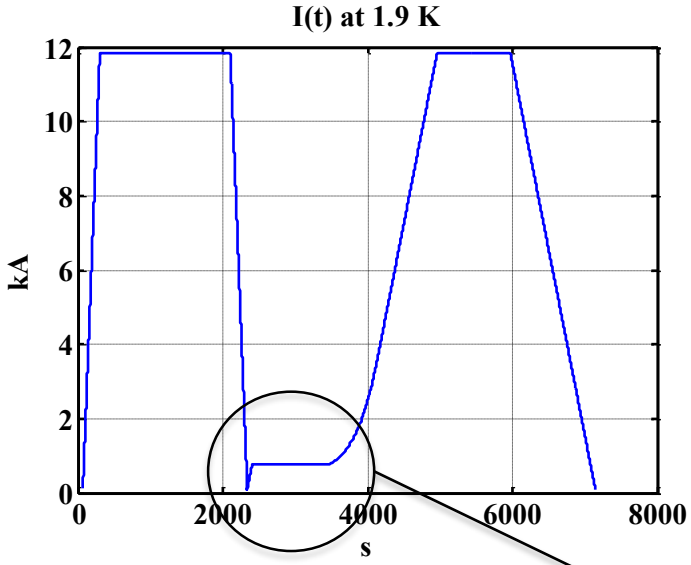


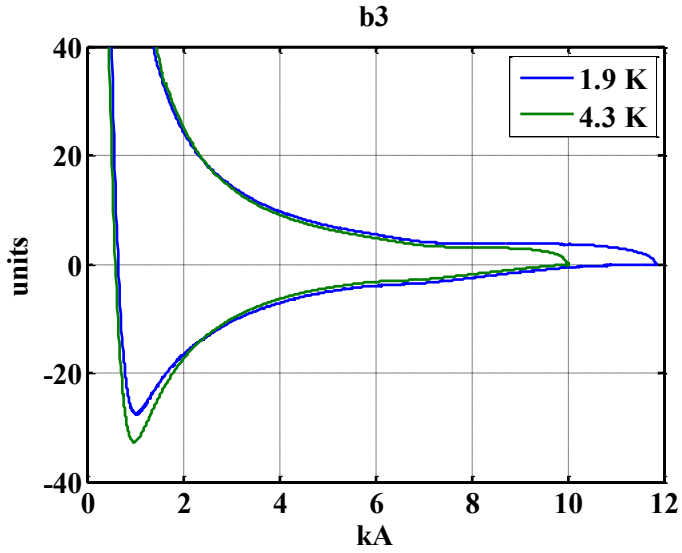


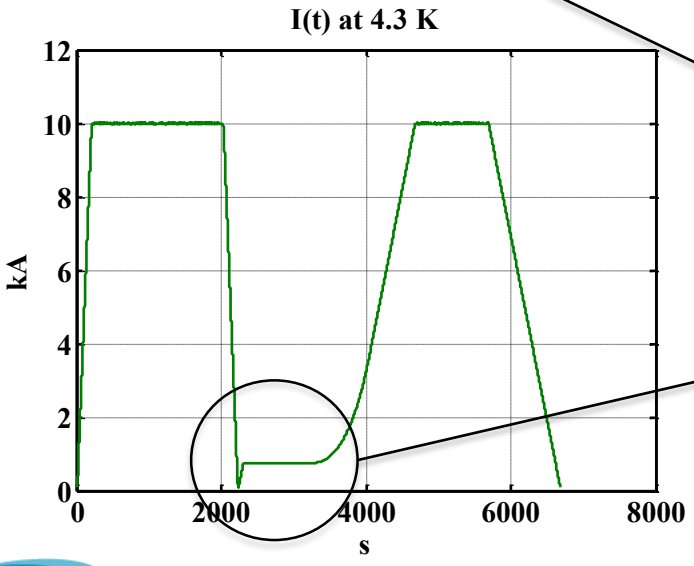


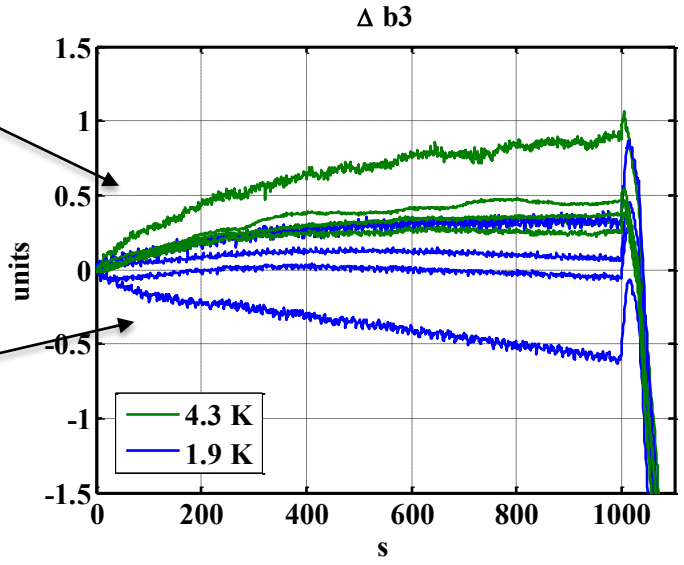


Cryogenic temperature: effect of temperature









Conclusions

MBHSP105 and comparison with other magnets tested so far:

- MM TF is -10 units on CM (+3 units on CC) wrt calculations
- Best field quality so far: b3 ~ 5 units, others < 3 units

- Saturation on TF as in previous magnets: -4.2 %
- PC effects on b3 larger (+ 5 units) than SP102, SP103: strand layout

- Effects of pre-cycle RR: 2 units on b3 at 50 A s^{-1} wrt 10 A s^{-1}
- Effect of temperature: larger b3 and different decay