Magnetic measurements on the D2 prototype

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Outline

- Measurement setup
- Performed tests
- Results
- Conclusions

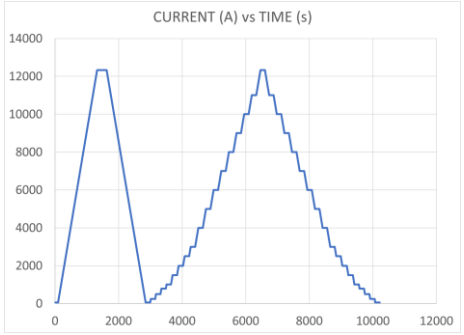
Analysis and comparison to simulations:
https://indico.cern.ch/event/1224228/

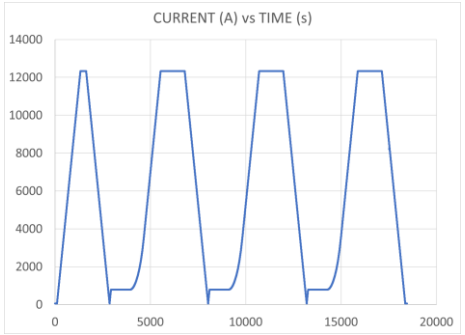
Measurement setup

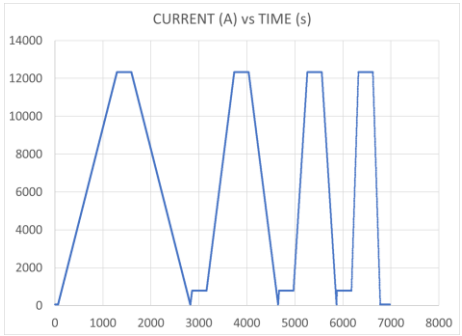
- Rotating coils
  - Same rotating shafts as LHC MB's (radius 17 mm)
  - 7 segments x (1150 mm +110 mm)
    for a total of 8710 mm
  - Acquired in 3 blocks:
    - CS (2 seg. ~ 2410 mm)
    - CTR (3 seg. ~ 3890 mm)
    - NCS (2 seg. ~ 2410 mm)
  - Both aperture measured at the same time
- Single stretched wire

Performed tests

- MBRDP1
  - Rotating coils
    - Stair-step cycle
    - Machine cycles (3x)
    - Ramp rate (20, 40, 80 A/s)
  - Stretched wire
    - Nominal 12.330 kA







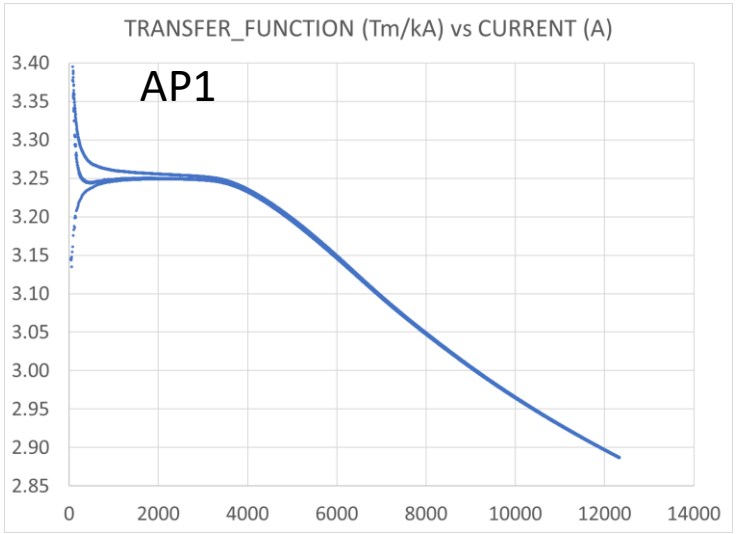
- MBRDP1 and MCBRDP1
  - Stretched wire
    - Cross-talk at injection and nominal

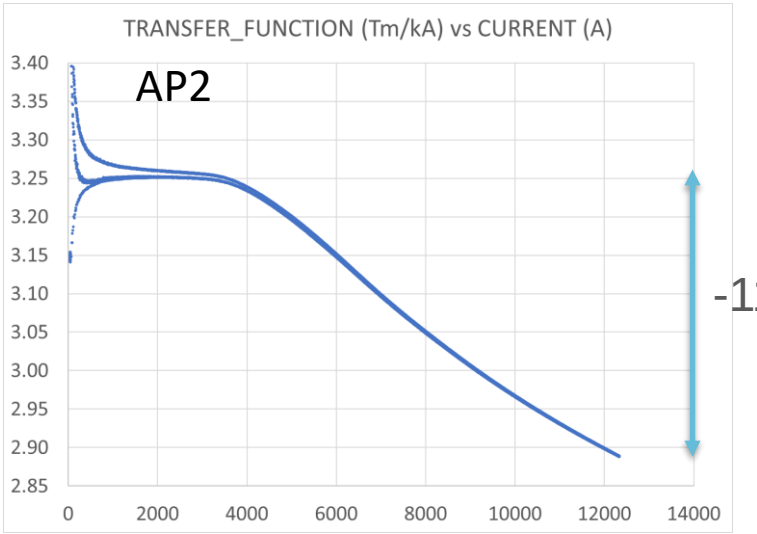
MBRDP1 – Integral transfer function

Stretched wire

Magnet aperture	Current	Bx	By	Roll angle
	A	Tm	Tm	mrad
A1	12330	-0.005	**35.770**	0.1
A2	12330	0.050	**35.769**	-1.4

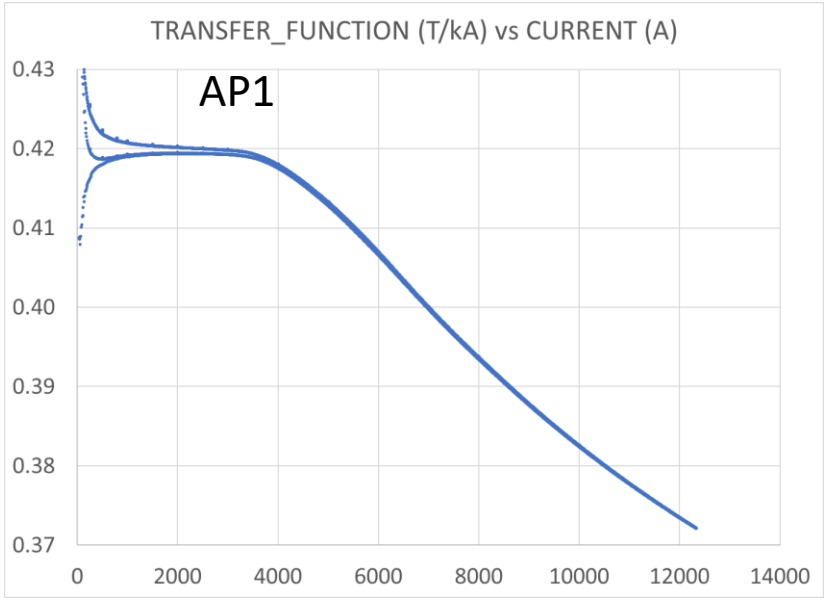
+2.2% wrt 35.00 Tm

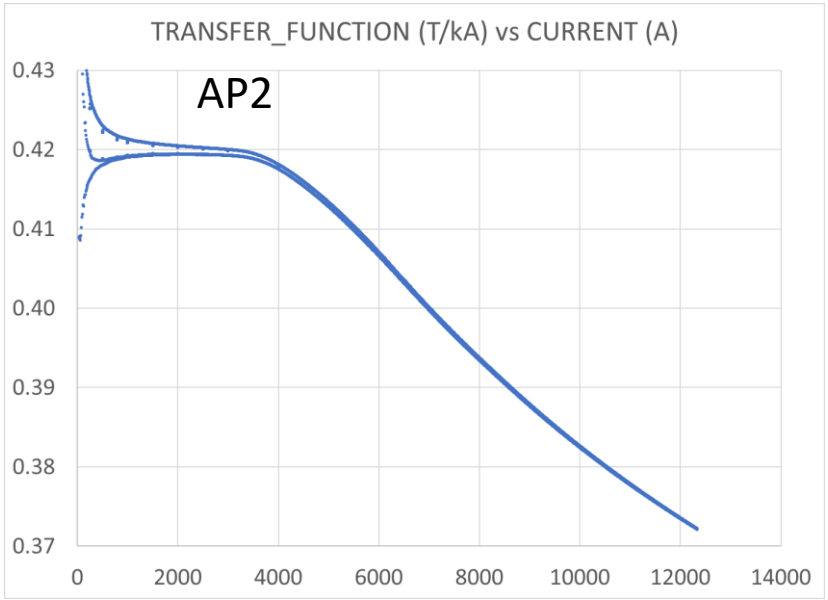




-11%

MBRDP1 – Central transfer function



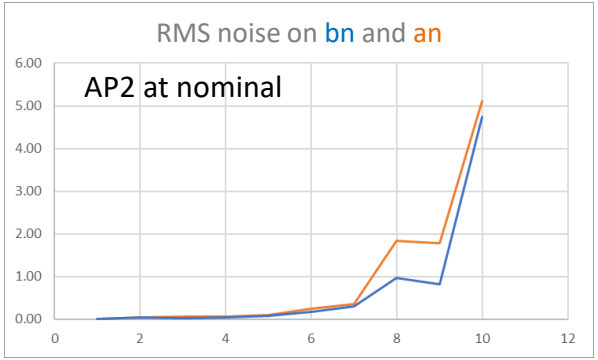


At nominal level +2.1% wrt 4.50 T

MBRDP1 – Integral field quality

	AP1				AP2		
Injection (790 A)	n	bn	an		n	bn	an
	2	-5.46	4.92		2	2.77	-0.44
	3	-10.63	3.52		3	-9.48	2.06
	4	1.52	-0.44		4	-2.27	-0.39
	5	5.83	2.10		5	6.54	0.87
	6	-1.64	-0.64		6	1.16	-0.59
	7	3.95	1.78		7	4.56	0.05
	8	-	-		8	-	-
	9	-	-		9	-	-
	10	-	-		10	-	-
Nominal (12330 A)	n	bn	an		n	bn	an
	2	-0.29	5.69		2	-2.65	0.93
	3	9.75	4.57		3	11.76	1.55
	4	-0.09	-0.82		4	-1.98	-0.66
	5	9.63	2.32		5	9.75	0.93
	6	-1.50	-0.50		6	3.13	-0.24
	7	1.56	1.73		7	0.41	0.04
	8	-	-		8	-	-
	9	-	-		9	-	-
	10	-	-		10	-	-

Due to the small measurement radius (17 mm), the measurements are not accurate for multipoles with order n>7



Feed-down not applied

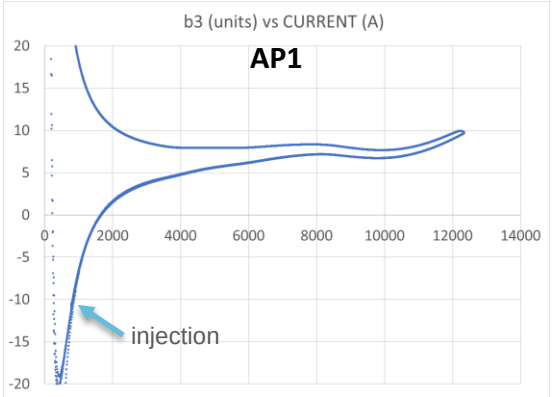
R_{ref} = 35 mm

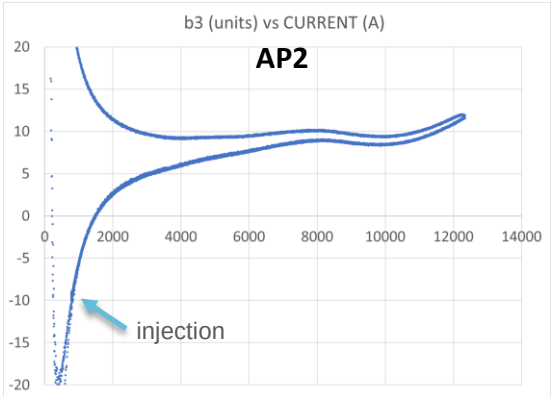
MBRDP1 – Local field quality

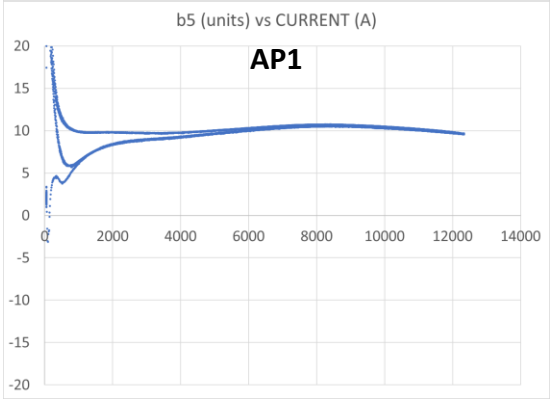
	CS (2410 mm)			CTR (3890 mm)			NCS (2410 mm)		
AP1 (12330 A)	n	bn	an	n	bn	an	n	bn	an
	2	6.27	4.05	2	-7.49	7.46	2	7.70	3.76
	3	10.23	7.02	3	10.07	4.25	3	8.58	2.71
	4	-1.06	-1.97	4	0.39	-0.67	4	-0.03	-0.11
	5	9.67	3.44	5	10.43	2.61	5	7.97	0.63
	6	-2.10	-1.13	6	-1.27	-0.35	6	-1.26	0.05
	7	1.12	1.56	7	2.28	2.17	7	0.36	1.30
	8	-	-	8	-	-	8	-	-
	9	-	-	9	-	-	9	-	-
	10	-	-	10	-	-	10	-	-
AP2 (12330 A)	n	bn	an	n	bn	an	n	bn	an
	2	-8.63	0.74	2	4.38	0.51	2	-9.59	2.54
	3	10.93	3.82	3	10.94	1.02	3	11.51	0.21
	4	-0.58	-0.21	4	-1.43	-0.98	4	0.21	-0.35
	5	10.07	2.11	5	11.05	0.74	5	8.31	0.36
	6	1.90	-0.08	6	1.06	-0.50	6	1.61	-0.29
	7	1.92	0.68	7	3.03	-0.28	7	0.93	0.13
	8	-	-	8	-	-	8	-	-
	9	-	-	9	-	-	9	-	-
	10	-	-	10	-	-	10	-	-

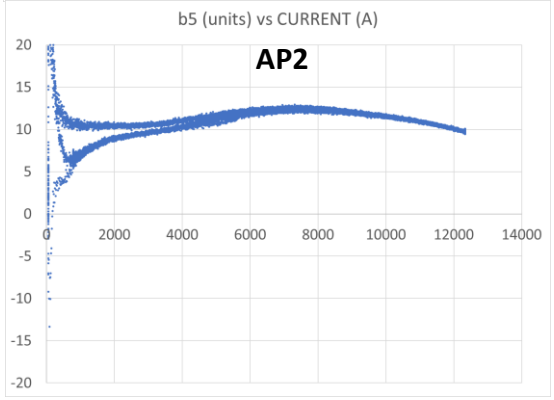
R_{ref} = 35 mm

MBRDP1 – Multipoles as function of current









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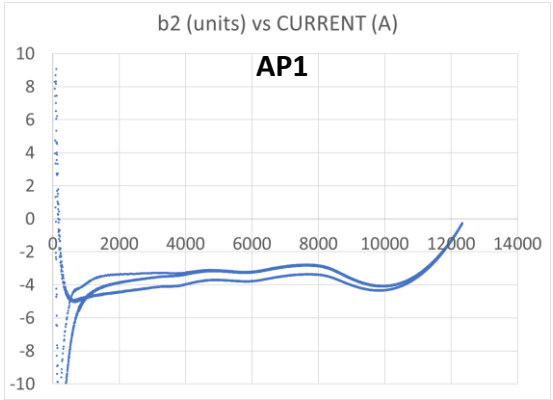

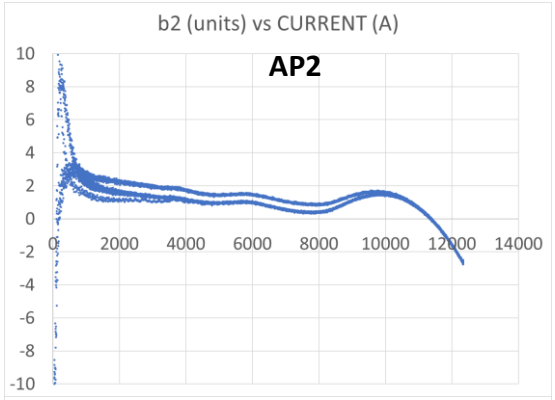

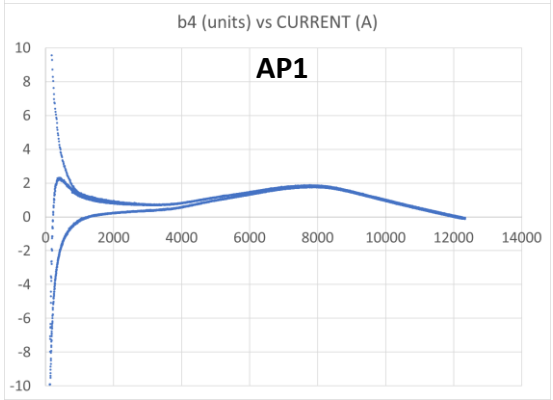

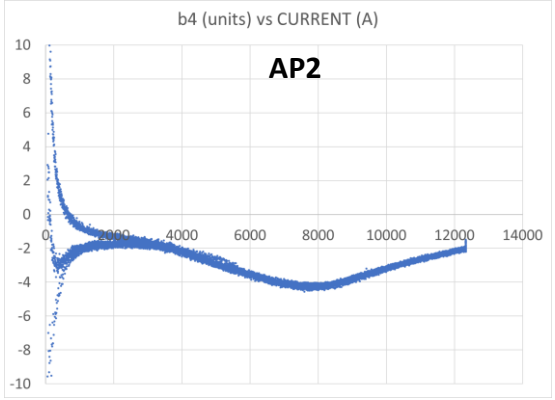

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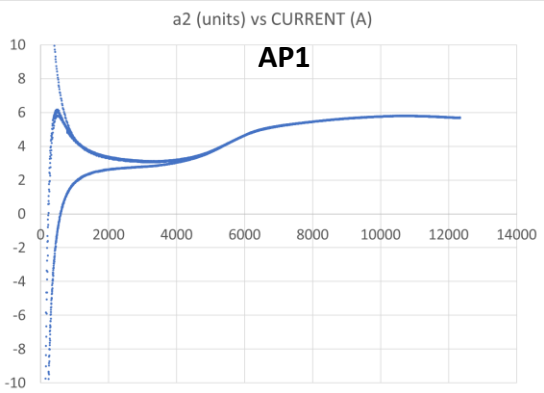

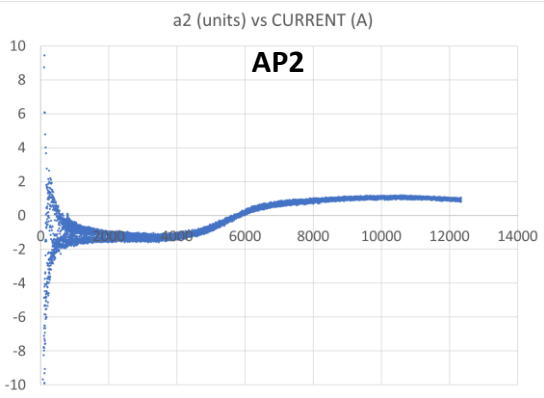

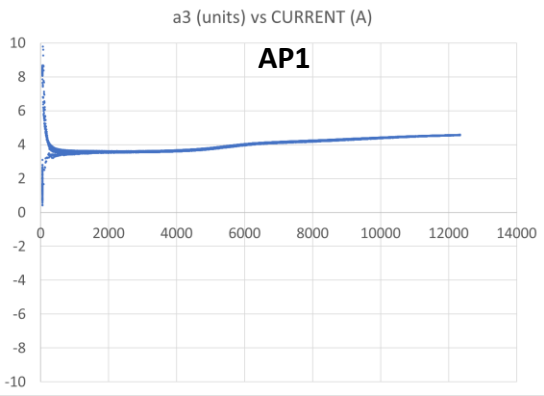

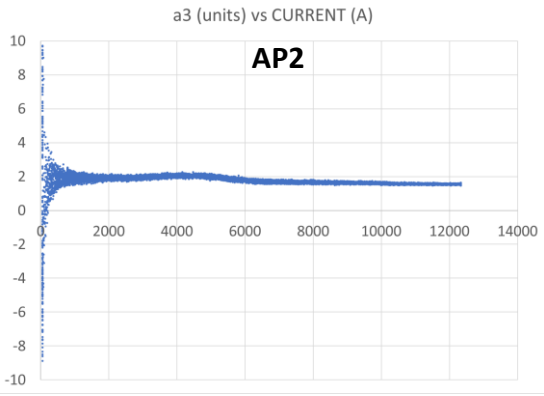

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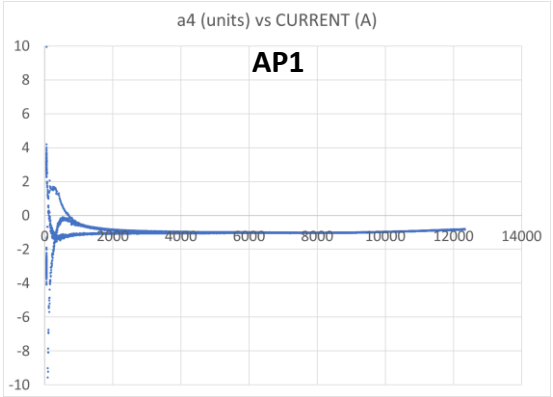

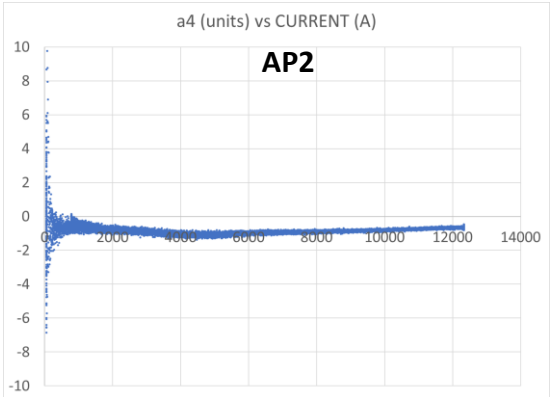

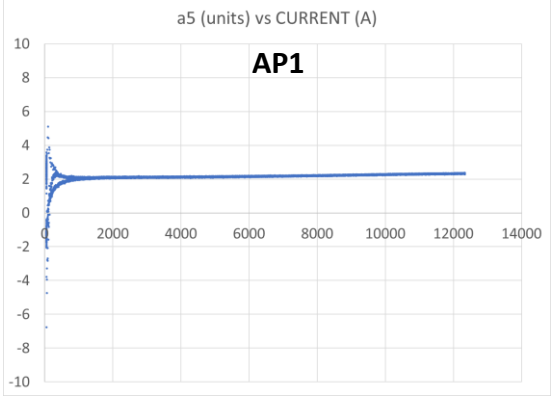

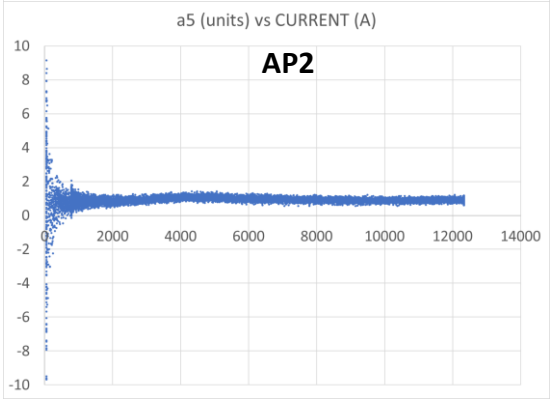

MBRDP1 and MCBRDP1 – Cross talk AP1

MBRD A	MCBRD A	By meas Tm	By corrected Tm
0	0	0.008	0.014
0	26	0.341	0.348
0	394	5.030	**5.037**
0	26	0.347	0.353
0	0	0.016	0.023
0	-26	-0.318	-0.311
0	-394	-5.006	**-4.999**
0	-26	-0.323	-0.316
0	0	0.007	0.014

MBRD A	MCBRD A	By meas Tm	By expected Tm	diff units
790	0	2.574	2.553	**0**
790	26	2.907	2.552	**-2**
790	394	7.595	2.552	**-4**
790	26	2.912	2.552	**-3**
790	0	2.582	2.552	**-2**
790	-26	2.248	2.553	**1**
790	-394	-2.441	2.552	**-3**
790	-26	2.243	2.553	**0**
790	0	2.573	2.552	**-1**

MBRD A	MCBRD A	By meas Tm	By expected Tm	diff units
12330	0	35.769	35.747	**0**
12330	26	36.103	35.748	**0**
12330	394	40.769	35.726	**-6**
12330	26	36.107	35.747	**0**
12330	0	35.778	35.748	**0**
12330	-26	35.444	35.748	**0**
12330	-394	30.736	35.728	**-5**
12330	-26	35.439	35.748	**0**
12330	0	35.769	35.748	**0**

MBRD A	MCBRD A	By meas Tm	By expected Tm	diff units
790	0	2.587	2.580	**0**
790	26	2.921	2.579	**-2**
790	394	7.609	2.579	**-4**
790	26	2.926	2.579	**-3**
790	0	2.596	2.580	**-2**
790	-26	2.262	2.580	**0**
790	-394	-2.427	2.579	**-2**
790	-26	2.257	2.580	**0**
790	0	2.587	2.580	**-1**

MBRDP1 and MCBRDP1 – Cross talk AP2

MBRD	MCBRD	Bx	By			MBRD	MCBRD	Bx	By	diff
A	A	Tm	Tm			A	A	Tm	Tm	units
0	0	-0.004	0.012			790	0	-0.006	2.578	**0**
0	26	0.330	0.012			790	26	0.327	2.578	**0**
0	394	**5.013**	0.010			790	394	5.011	2.576	**-7**
0	26	0.334	0.013			790	26	0.332	2.579	**5**
0	0	0.004	0.013			790	0	0.002	2.579	**4**
0	-26	-0.330	0.013			790	-26	-0.332	2.579	**3**
0	-394	**-5.013**	0.015			790	-394	-5.016	2.581	**10**
0	-26	-0.335	0.011			790	-26	-0.337	2.577	**-1**
0	0	-0.004	0.012			790	0	-0.006	2.578	**-1**

MBRD	MCBRD	Bx	By	diff		MBRD	MCBRD	Bx	By	diff
A	A	Tm	Tm	units		A	A	Tm	Tm	units
12330	0	-0.054	35.763	**0**		790	0	-0.006	2.591	**0**
12330	26	0.280	35.762	**0**		790	26	0.328	2.591	**0**
12330	394	4.963	35.762	**0**		790	394	5.011	2.589	**-8**
12330	26	0.284	35.764	**0**		790	26	0.332	2.592	**4**
12330	0	-0.046	35.764	**0**		790	0	0.002	2.592	**4**
12330	-26	-0.380	35.764	**0**		790	-26	-0.332	2.592	**3**
12330	-394	-5.063	35.768	**1**		790	-394	-5.016	2.594	**9**
12330	-26	-0.384	35.762	**0**		790	-26	-0.337	2.591	**-2**
12330	0	-0.054	35.764	**0**		790	0	-0.006	2.591	**-1**

Conclusions

- A full set of magnetic measurement have been performed on the D2 prototype
  - Rotating coils (stair step, machine cycles, ramp rate)
  - Stretched wire (TF calibration at nominal, cross talk)

- Main results
  - MBRDP1
    - Integral TF = 35.77 Tm at 12330 A (+2.2% wrt the required 35.00 Tm)
    - Central field of 4.59 T at 12330 A (+2.1% wrt the design value of 4.50 T)
    - AP1 at nominal: b3 = 9.8 units, b5 = 9.6 units
    - AP2 at nominal: b3 = 11.8 units, b5 = 9.8 units
  - MCBRDP1
    - TF = 5.015 Tm at nominal (average of the two apertures)
    - The cross-talk between main magnet and the adjacent corrector is less than 5 units at nominal level

- The measurement results have been analyzed and compared to simulations and fine tuning of b3 and b5 are foreseen for the series https://indico.cern.ch/event/1224228/

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Thank you

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