Field quality in Nb-Ti HL LHC interaction region magnets

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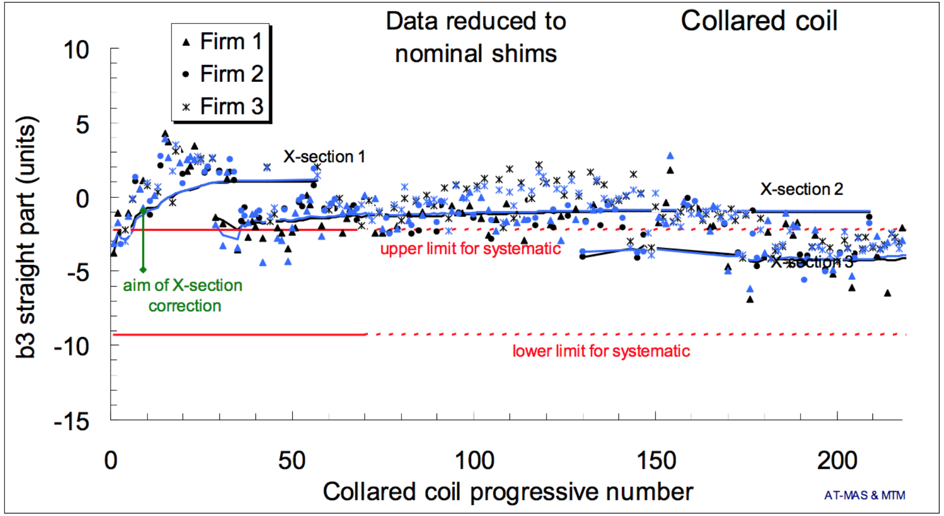
October 9th 2024

Contents

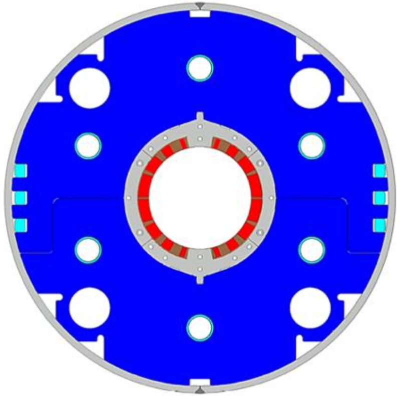
- General features
- D1
- D2

D1 and D2 features

- Field quality steering in D1 and D2 is very challenging for two different aspects:
  - The ratio coil width / aperture radius is small (1/5 in D1, ¼ in D2), and therefore normalized multipoles are much larger than in LHC dipoles (1/1 ratio between coil width and aperture radius)
  - The series is very short (6 units), and we made only one long prototype: in the LHC dipoles two actions to steer b_3 b_5 and b_7 on the right values were needed, one at dipole 35 and the second at dipole 154 …



D1

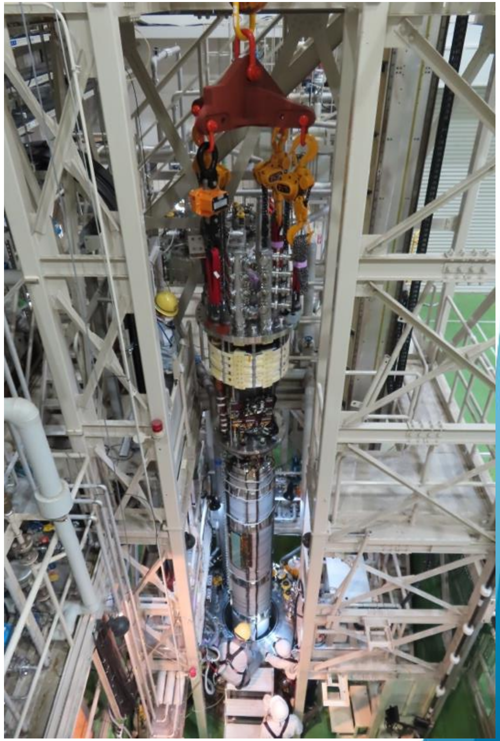


- First corrective action: from first to second short model
- Second corrective action: from third short model to prototype
- Third corrective action: from prototype to first series magnet
- All changes concerned minor modifications of the cross-section (wedges)
  - The actions were made easier and faster thanks to the use of GRP rather than copper
  - This alllowed a very fast turn around of these components

- The starting point was quite far (20 units of b3 in the first short model)

D1

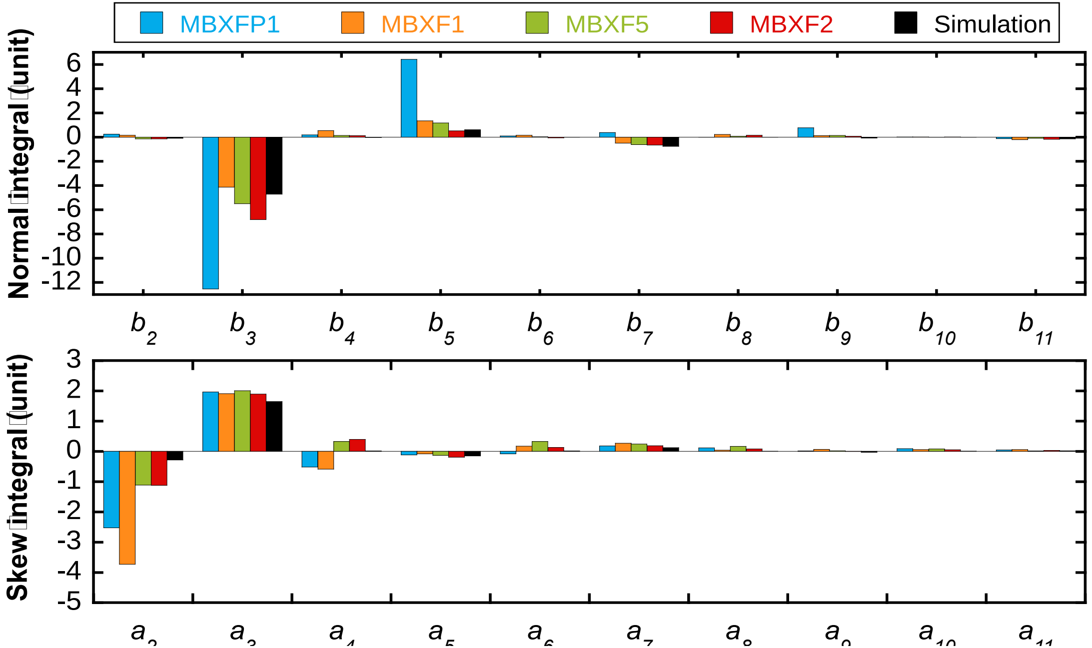
- Two additional elements of difficulty:
  - Complex interaction between heads and saturation: straight part measurements difficult to interpret
  - Presence of ferromagnetic iron in the vertical cryostat of KEK, giving about +6 units of b_3



- E. Nilsson, et al., "Influence of 3-D effects on field quality in the straight part of accelerator magnets for the high luminosity Large hadron Collider" IEEE Trans. Appl. Supercond. 28 (2018) 4003005
- K. Suzuki, et al., "Test results of the HL-LHC beam separation dipole model magnet with the new iron cross-section" IEEE Trans. Appl. Supercond. 29 (2019) 4000905
- K. Suzuki, et al., "Magnetic field design of a full-scale prototype of the HL.LHC beam separation dipole with geometrical and iron-saturation corrections" IEEE Trans. Appl. Supercond. 30 (2020) 4002706 -
- K. Suzuki, et al., "Magnetic Measurements of a Full-Scale Prototype of the HL-LHC Beam Separation Dipole" IEEE Trans. Appl. Supercond. 32 (2022) 9000407

D1

- Three series magnets were measured in vertical test station in KEK
  - B5 is now within 1 unit, and the residual b3 of -6 units is the effect of the KEK cryostat



Integrated field quality at 12. kA, measured in KEK (K. Suzuki, T. Nakamoto)

D1

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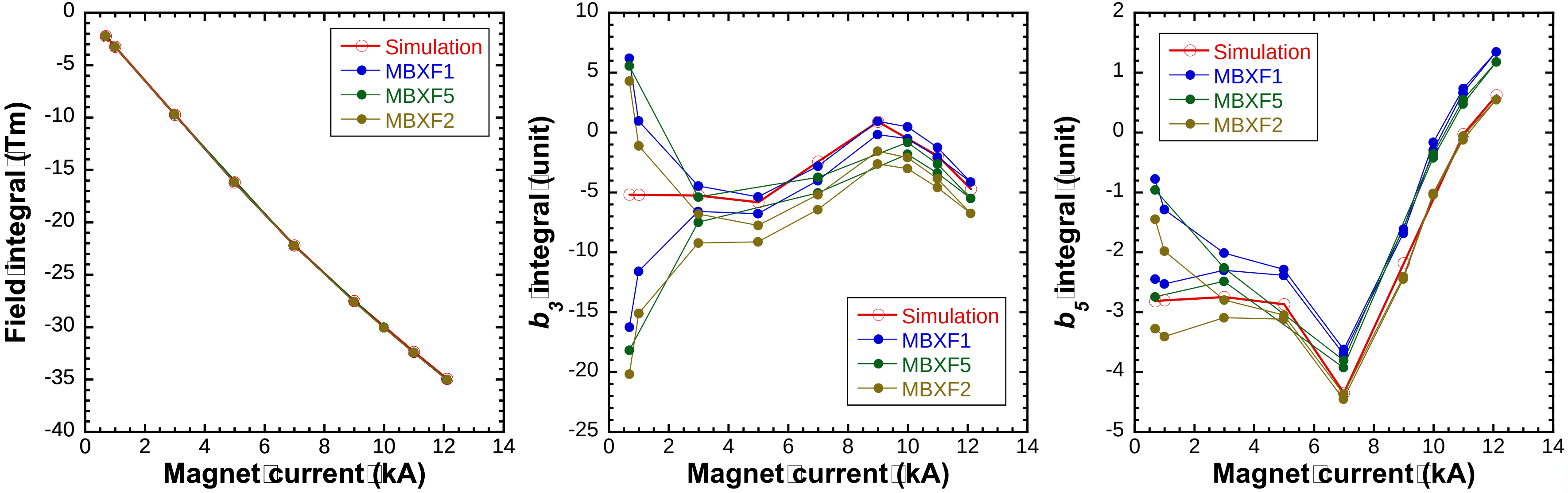
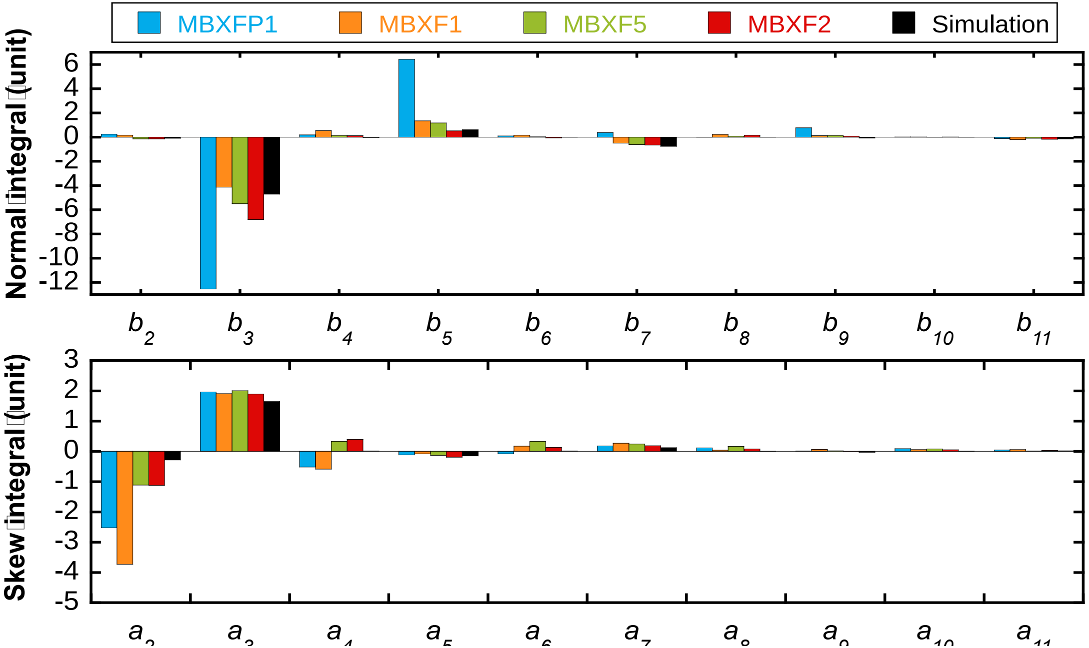


Field quality along the ramp, measured in KEK (K. Suzuki, T. Nakamoto)

D1

- Three series magnets were measured in vertical test station in KEK
  - B5 is now within 1 unit, and the residual b3 of -6 units is the effect of the KEK cryostat



Integrated field quality at 12. kA, measured in KEK (K. Suzuki, T. Nakamoto)

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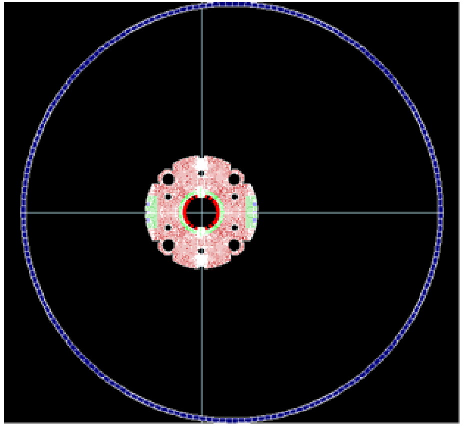
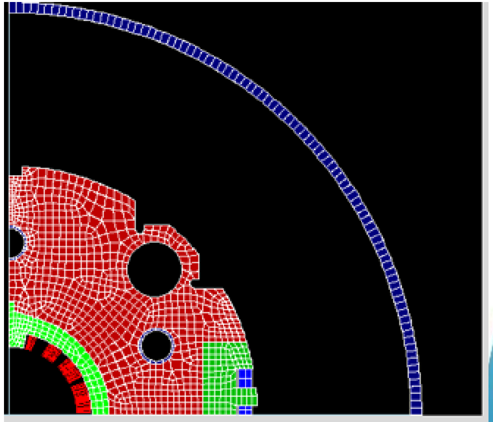
D1

- The impact of +6 units in the KEK cryostat has been verified at CERN during horizontal test of the prototype





Measurement by KEK KEK cryostat (MBXFP1)			Measurement by CERN LHC cryostat (LMBXFP1)		
Field integral (B_1)		34.935 Tm	Field integral (B_1)		35.188 Tm
n	b_n integral (unit)	a_n integral (unit)	n	b_n integral (unit)	a_n integral (unit)
2	0.25	-2.52	2	0.27	0.88
3	-12.54	1.96	3	-5.44	1.95
4	0.19	-0.52	4	0.05	0.12
5	6.43	-0.12	5	6.68	-0.19
6	0.10	-0.08	6	0.05	0.00
7	0.38	0.18	7	0.35	0.20

Integrated field quality at 12. kA, measured in KEK (L. Fiscarelli, K. Suzuki)

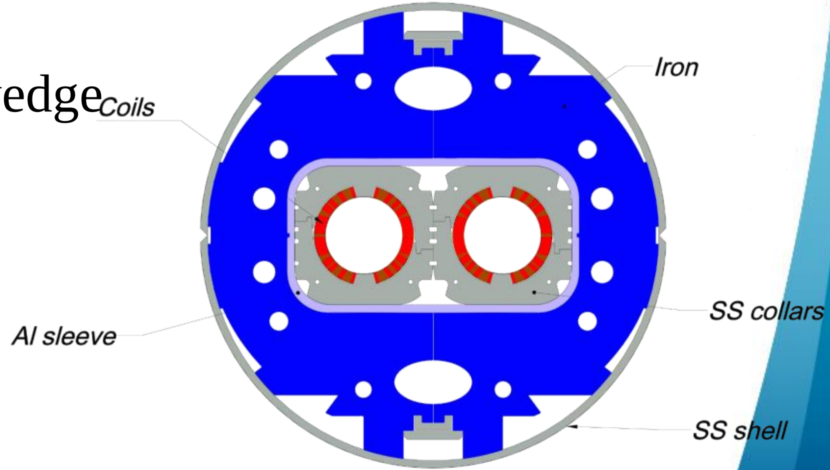
Contents

- General features
- D1
- D2

D2

- First corrective action: from short model to prototype
- Second corrective action: from prototype to first series magnet
  - With respect to D1, advantage of double aperture → double statistics
- Main reason of the correction was a coil size much larger than expected
- The change had to optimize b_3, b_5 b_7 and preload

- Second change done via iteration on one wedge and optimization of midplane and pole shims



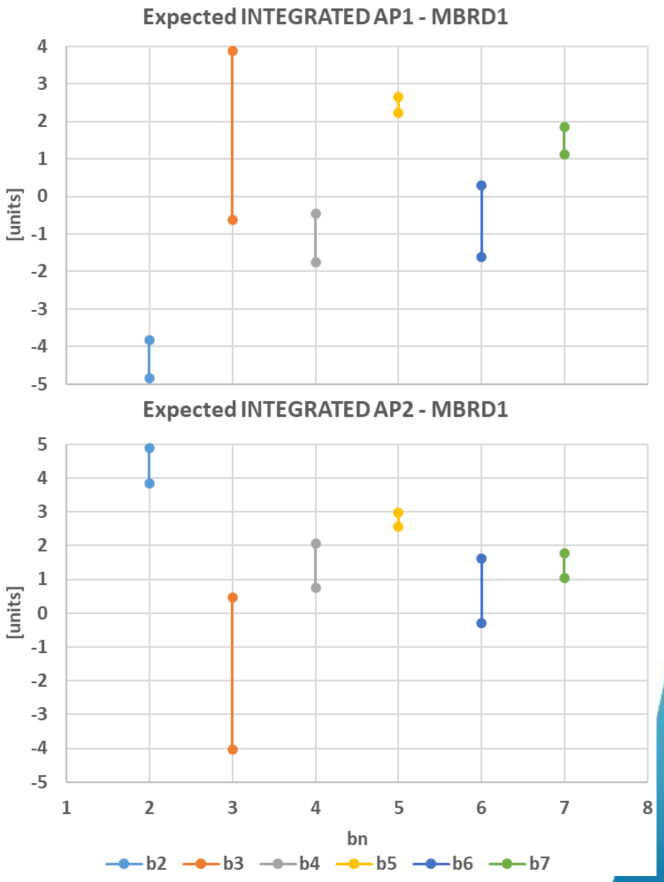
D2

- References:

  - A. Bersani, et al., "The superconducting separation dipoles MBRD for the high luminosity upgrade of LHC: from short model to prototype" IEEE Trans. Appl. Supercond. 29 (2019) 4003305
  - A. Foussat, et al., "The HL-LHC short model recombination D2 dipole: cold test results and analysis" IEEE Trans. Appl. Supercond. 30 (2020) 4003405 –
  - B. Caiffi, et al., "The Development of the Superconducting Dipoles D2 for the High Luminosity Upgrade of LHC" IEEE Trans. Appl. Supercond. 31 (2021) 4000405 -
  - F. Levi, et al., "The Separation-Recombination Dipole MBRD for the High-Luminosity LHC: From Prototype to Series" IEEE Trans. Appl. Supercond. 32 (2022) 4003905
  - S. Farinon, et al., "The MBRD Dipoles for the Luminosity Upgrade at the LHC: From Prototype Tests to the Series Production" IEEE Trans. Appl. Supercond. 33 (2023)

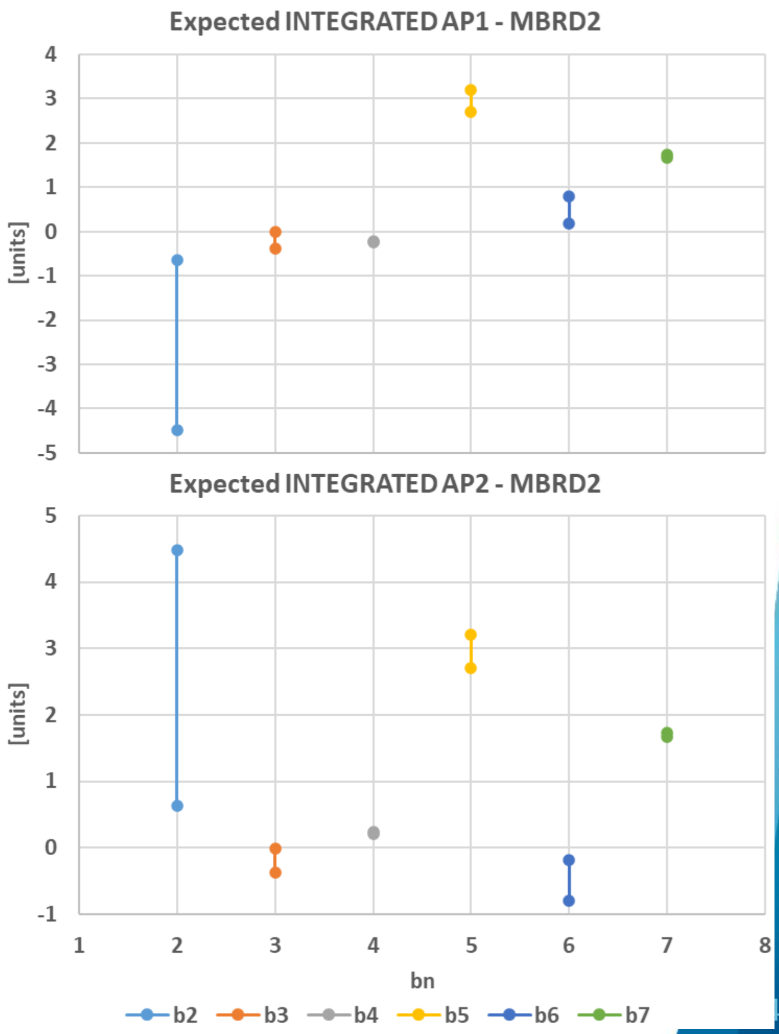
D2

- First series magnet (based on WMM)
- b_3: -1 to 4 units (Ap. 1), -4 to 1 units (Ap. 2)
- b_5: 2 to 3 units (both apertures)



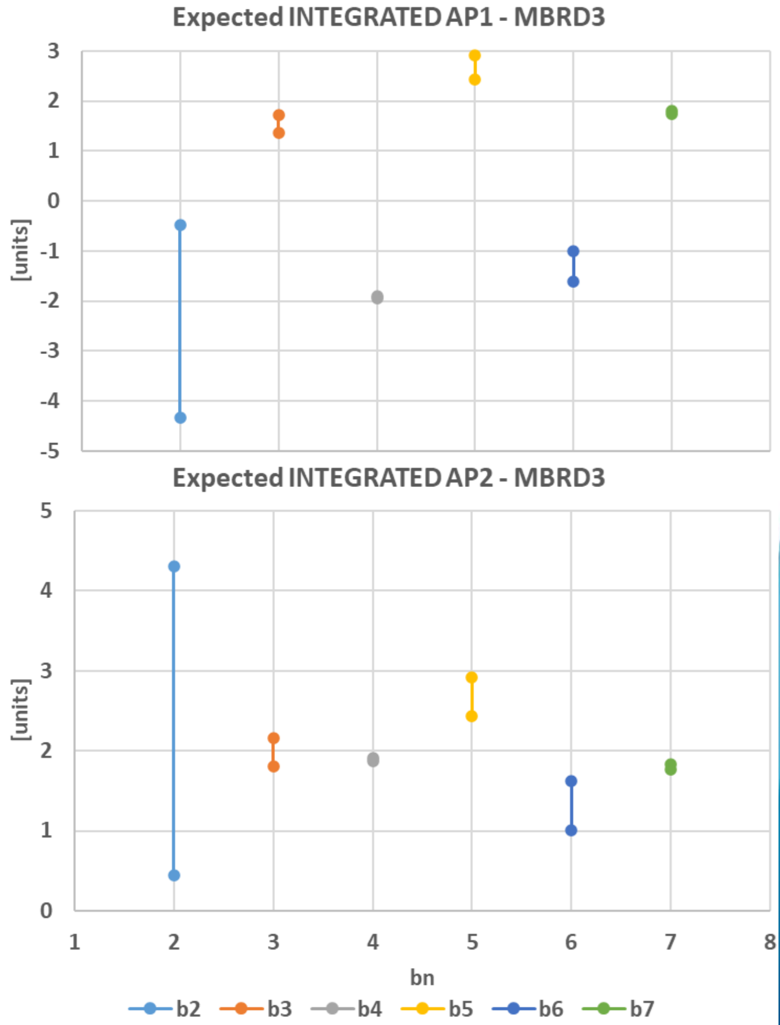
D2

- Second series magnet (based on WMM)
- b_3: 0 units both apertures
- b_5: 3 units (both apertures)



D2

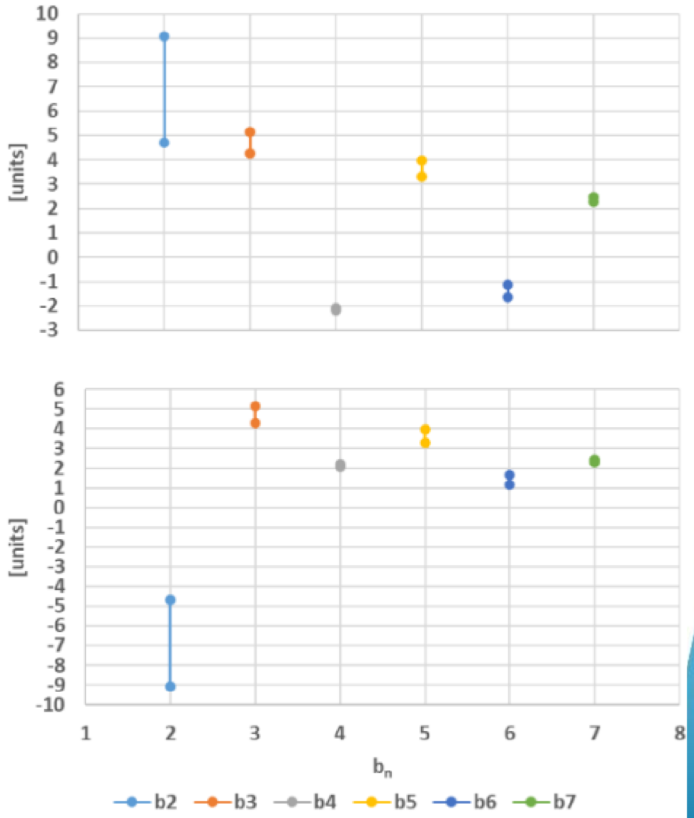
- Third series magnet (based on WMM)
- b_3: 1.5 to 2 units both apertures
- b_5: 2 to 3 units (both apertures)



D2

- Fourth series magnet (based on coil size)
  - b_3: 4 to 5 units both apertures
  - b_5: 3 to 4 units (both apertures)

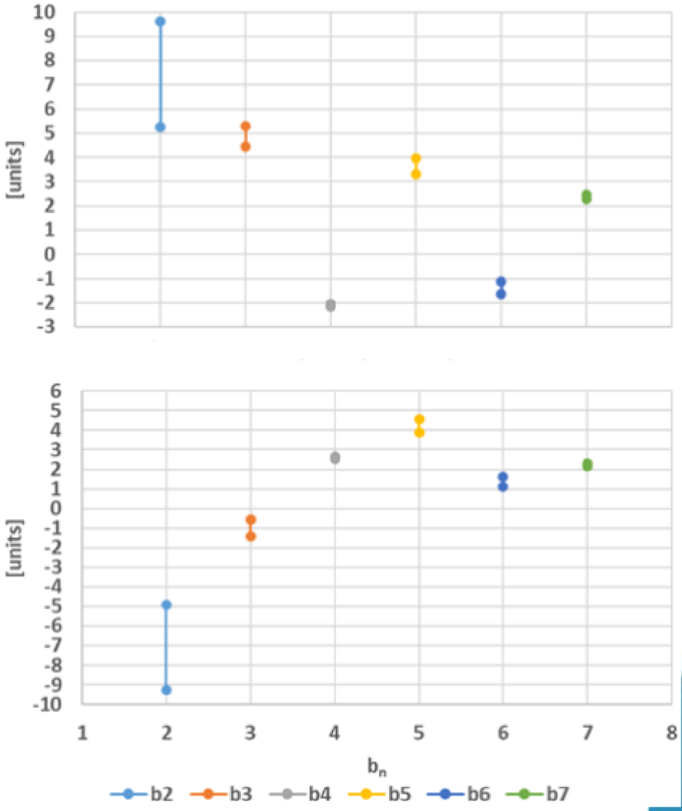
  - NB: this is central part only, heads to be added



D2

- Fifth series magnet (based on coil size)
  - b_3: 4 to 5 units (Ap. 1) and -1 units (Ap. 2)
  - b_5: 4 to 5 units (both apertures)

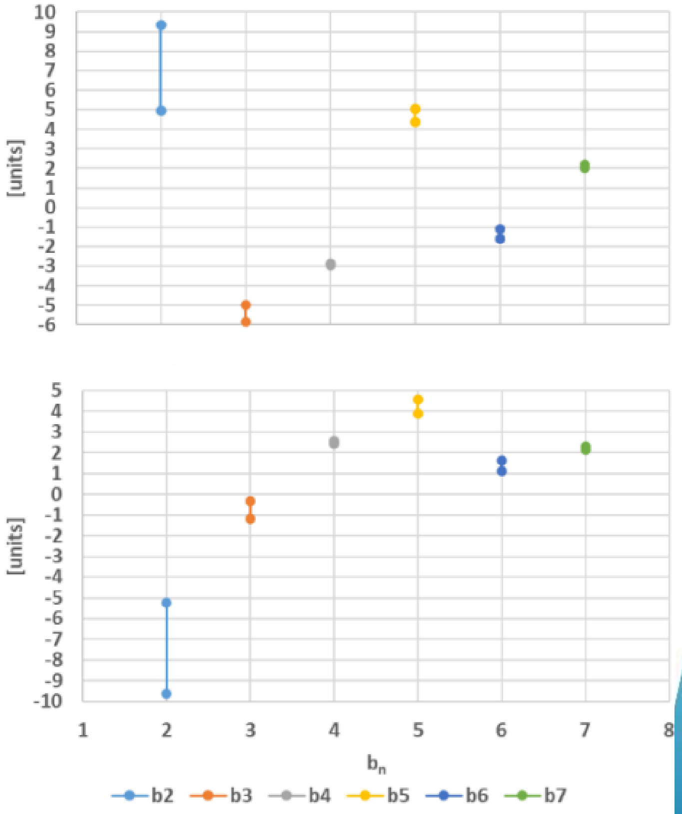
  - NB: this is central part only, heads to be added



D2

- Sixth series magnet (based on coil size)
  - b_3: -5 units (Ap. 1) and -1 unit (Ap. 2)
  - b_5: 4 to 5 units (both apertures)

  - NB: this is central part only, heads to be added



D2

- Expected values for D2 systematics (to be confirmed by measurements at 1.9 K of first series magnet)
  - Systematic value of b_5 around 4 to 5 positive units
  - Large variability in b_3, but known and within ±5 units

THANKS !