Status of D2 field quality and of D2 corrector field quality

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WP2 - 26 January 2021

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- D2 status
- D2 corrector news

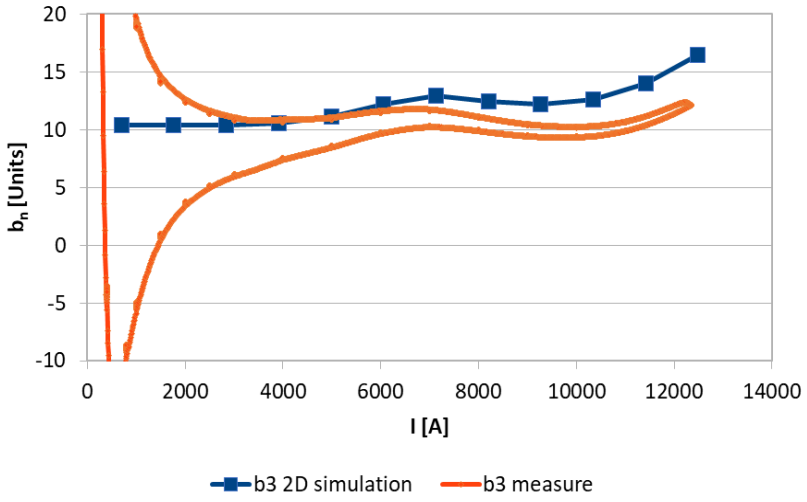
SHORT MODEL MEASUREMENTS

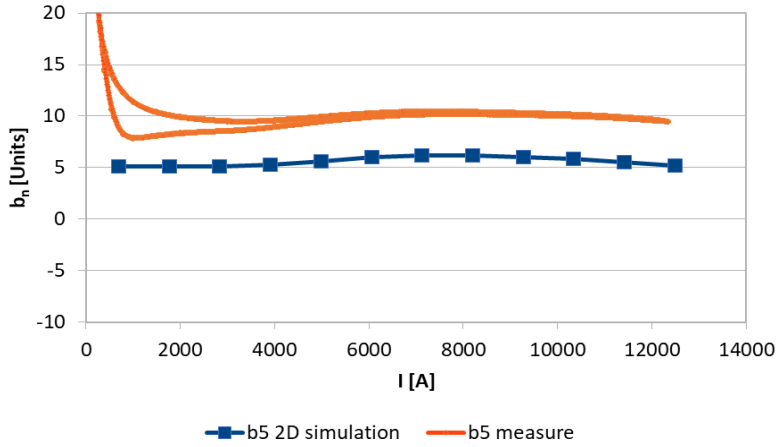
- Where are we with the model (1 aperture measured at 1.9 K)

	NCS	CTR	CS		NCS	CTR	CS		NCS	CTR	CS
	Injection				Geometric				Nominal		
n	bn										
2	-49.85	**-5.76**	-11.12		-50.10	**-5.38**	-9.95		-70.86	**-8.65**	-19.89
3	0.31	**-8.12**	12.65		16.36	**8.48**	29.86		24.19	**12.12**	38.89
4	1.57	**-0.89**	5.31		2.68	**0.08**	6.49		3.92	**0.35**	8.11
5	2.22	**8.39**	15.25		3.30	**9.04**	16.15		2.84	**9.48**	17.15
6	2.01	**1.68**	2.55		2.22	**1.84**	2.91		2.46	**2.02**	3.31
7	-7.88	**-0.07**	0.41		-6.96	**0.69**	1.31		-7.59	**1.03**	1.74
8	0.30	**0.47**	0.52		0.35	**0.50**	0.55		0.39	**0.60**	0.65
9	-2.78	**0.83**	0.34		-2.88	**0.64**	0.18		-3.25	**0.72**	0.23
10	-0.34	**-0.66**	-0.50		-0.36	**-0.67**	-0.48		-0.46	**-0.81**	-0.57
11	-2.08	**-1.02**	-1.31		-2.00	**-0.92**	-1.19		-2.19	**-0.96**	-1.23
12	0.82	**0.82**	0.40		0.77	**0.76**	0.35		0.83	**0.82**	0.34
13	-1.34	**-1.25**	-1.35		-1.34	**-1.23**	-1.35		-1.48	**-1.36**	-1.48
14	0.32	**0.31**	0.21		0.33	**0.32**	0.21		0.38	**0.36**	0.24
15	-0.65	**-0.79**	-0.71		-0.64	**-0.76**	-0.69		-0.73	**-0.87**	-0.77
n	an										
2	5.09	**-2.88**	-5.98		5.39	**-1.94**	-5.28		4.71	**-2.44**	-5.22
3	-2.35	**2.23**	6.17		-2.54	**1.50**	4.44		-2.14	**1.95**	5.23
4	-1.26	**-0.99**	0.98		-0.57	**-0.38**	1.30		-0.99	**-0.73**	1.03
5	-0.13	**-0.62**	1.54		-0.01	**-0.51**	1.36		-0.01	**-0.46**	1.49
6	0.20	**-0.91**	-0.75		0.49	**-0.63**	-0.60		0.27	**-0.73**	-0.59
7	-0.49	**-0.79**	-0.62		-0.50	**-0.82**	-0.63		-0.46	**-0.71**	-0.55
8	0.21	**-0.54**	0.34		0.34	**-0.37**	0.46		0.25	**-0.44**	0.35
9	-0.29	**-0.20**	0.29		-0.29	**-0.16**	0.26		-0.26	**-0.17**	0.25
10	0.18	**-0.33**	-0.57		0.18	**-0.25**	-0.50		0.18	**-0.26**	-0.49
11	-0.31	**-0.26**	-0.46		-0.35	**-0.29**	-0.43		-0.30	**-0.25**	-0.41
12	0.37	**0.09**	-0.17		0.35	**0.13**	-0.11		0.34	**0.10**	-0.13
13	-0.34	**-0.27**	-0.25		-0.32	**-0.25**	-0.24		-0.31	**-0.24**	-0.23
14	0.17	**0.06**	-0.08		0.17	**0.07**	-0.06		0.17	**0.07**	-0.06
15	-0.14	**-0.17**	-0.30		-0.13	**-0.16**	-0.27		-0.12	**-0.15**	-0.25

SHORT MODEL MEASUREMENTS

- Focus on b3 and b5
  - Values at nominal:
  - b_3: 12.1 units
  - b_5: 9.5 units
  - b_7: 1.0 units
  - b_9: 0.7 units
  - Geometric:
  - b_3: 8.5 units
  - b_5: 9.0 units
  - b_7: 0.7 units
  - b_9: 0.6 units





FROM SHORT MODEL TO PROTOTYPE

- Short model had a non nominal shimming on the midplane
  - 0.15 mm missing
  - Giving + 8 units of b_3, + 4 units of b_5, +1.5 units of b_7
  - (the sensitivity matrix of multipoles on shim is given in slide 7)
- Measured values at 12 kA
  - b_3: 12.1 units
  - b_5: 9.5 units
  - b_7: 1.0 units
- Expected values at 12 kA with nominal shimming
  - b_3: 4.1 units
  - b_5: 5.5 units
  - b_7: -0.5 units

FROM SHORT MODEL TO PROTOTYPE

- Prototype variation of cross section (via copper wedges)
  - b_3: -4 units
  - b_5: -4 units
  - b_7: 1 units
- Expected values prototype at 12 kA with nominal shimming
  - b_3: 4.1-4= ~0.0 units
  - b_5: 5.5-4= ~1.5 units
  - b_7: -0.5+1= ~0.5 units

PROTOTYPE SHIMMING

- Coil is 0.4 mm too large, so we have to reduce either on the pole or on the midplane
  - Series coils are likely to be the same coil size
- Sensitivity matrix calculation

	0.1 mm more on midplane			0.1 mm more on pole		
	Ansys	Roxie	Bio	Ansys	Roxie	Bio
Δb_3	-5.2/6.9	-6.40	-5.42	5.00/3.89	4.80	4.49
Δb_5	-2.35/2.95	-2.85	-2.81	-0.08/0.63	-0.63	0.13
Δb_7	-0.94/0.97	-1.02	-1.00	0.20/-0.21	0.10	-0.18
Δb_9	-0.39/0.39	-0.42	-0.39	-0.04/-0.04	-0.05	-0.03
Δb_{11}			-0.16			0.10

- Pole shimming is less sensitive on high orders
- b5 dependence on pole shimming looks difficult to compute, sign of a possible sensitivity on hypothesis on how the deformation is done

PROTOTYPE SHIMMING

- The excess of 0.4 mm in the coil size will be compensated in the prototype via 0.125 mm less on midplane and 0.25 mm less on the pole
  - It is a comprimise on getting not too far from zero for both b3 and b5, and it is expected to give
  - Δb_3: -4 units
  - Δb_5: 3 to 5 units
  - Δb_7: 1 units

- Therefore for the prototype we should land on
  - b_3: -4 units
  - b_5: 5 to 7 units
  - b_7: 2 units

TUNING POSSIBILITIES

- Actions on prototype were limited by the availability of polyimide thicknesses lower than 0.125 mm
  - We are ordering different thicknesses (0.075 mm) to be able to better tune in the future
  - Moving 0.05 mm from midplane to pole gives a +5 units displacement of b_3, and 1.0 to 1.5 more units of b_5
  - If b_3 in the prototype is within 10 units it should be not difficult to move it towards zero
    - But to reduce b5 we have to push further down b3

	0.1 mm more on midplane	**0.1 mm more on pole**	**0.1 mm less on midplane and more on pole**
	Best estimate	Best estimate	Best estimate
Δb_3	-6.0 (-5.5 to -7.0)	4.5 (4.0 to 5.0)	10.5
Δb_5	-2.8	-0.6 or 0.1 ?	-2.2 or -2.9
Δb_7	-1.0	Less than 0.2	1.0

TUNING POSSIBILITIES

- If b_5 confirms to be much larger than 3 units, coupled with a b_3 of about -5 units, we could be in a corner
  - We could recover b_3 around zero at the price of further increasing b_5
- The alternative would be to fine tune again the copper wedges in the series magnet
  - This operation is possible but non trivial since it does not work in differential, but it establishes a new baseline
  - Since the modification is order of the tolerances, it can happen that you get twice the effect or no effect
  - Moreover it should be decided very soon, on the basis of incomplete data
- If the coil size goes back to nominal, the problem disappears

TUNING POSSIBILITIES

- Last week we asked WP2 (M. Giovannozzi) exploring cases with systematic b_3 at ±3, ±6 units, and with systematic b_5 at ±3, ±6 units to see where dynamic aperture starts being affected

- A further possibility could also be to use the b_5 corrector in the corrector package to correct the b_5 of D2

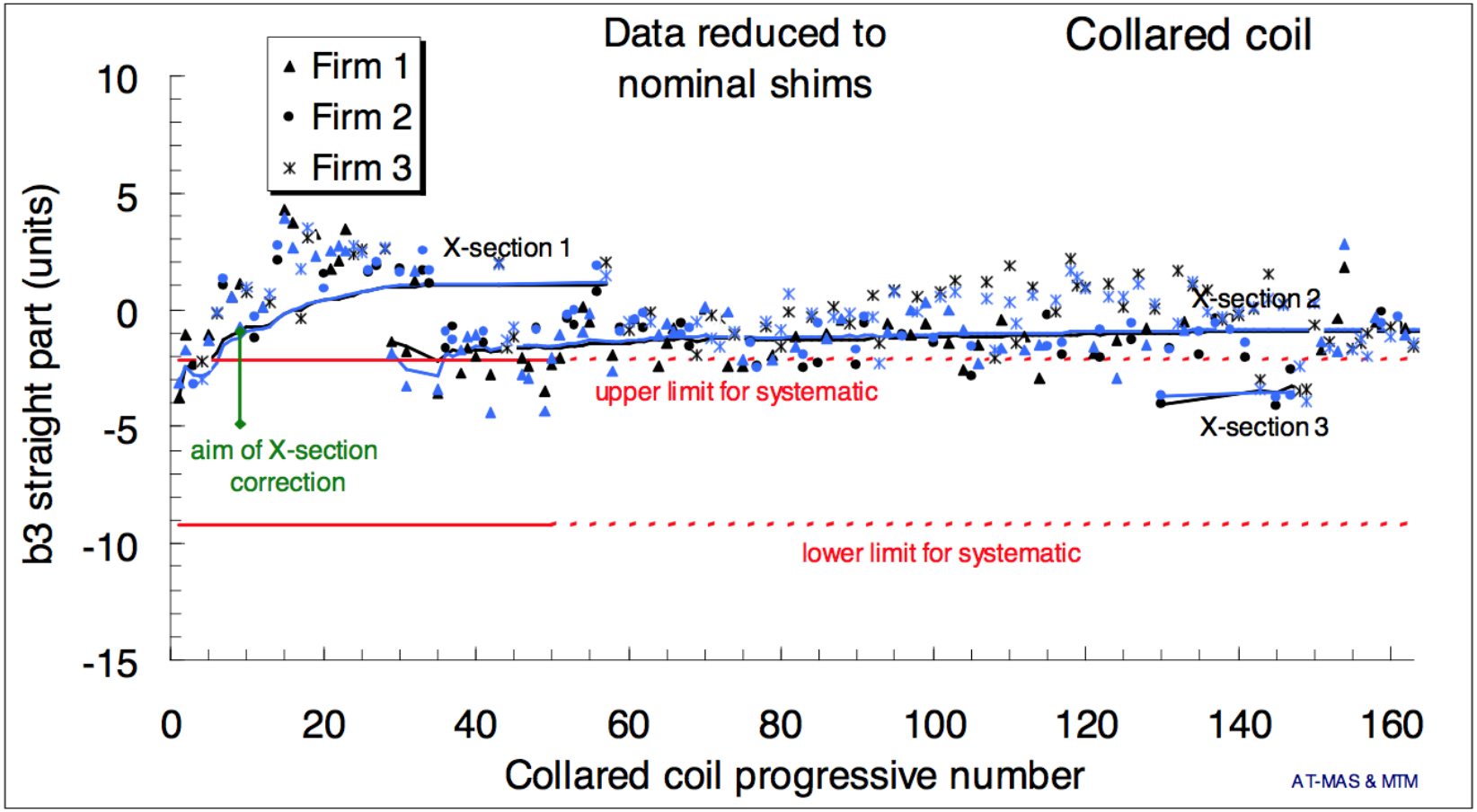
- 6 units of b_5 in D2 are equivalent to 1 unit of b_5 in the triplet
  - D2 integrated force is about 35 T m
  - Triplet integrated force is 132 T/m * 30 m * 0.050 = 200 T m

TUNING POSSIBILITIES

- The room temperature measurement of the single aperture should give an indication on b_3 and b_5
  - We are analysing the previous data to understand if the indications are with enough precision
- We have to order the wedges for the series in February/March, otherwise we will be late for the winding of the first series magnet
  - The results of simulations (especially the sensitivity on b_5) are relevant to launch the production
- To show all difficulties of matching b_3, b_5 and b_7 witihin few units I recall the LHC experience
  - You will judge yourself on our challenges, and on the possiblity of steering over a production of 6 dipoles only …
  - Do not get discouraged

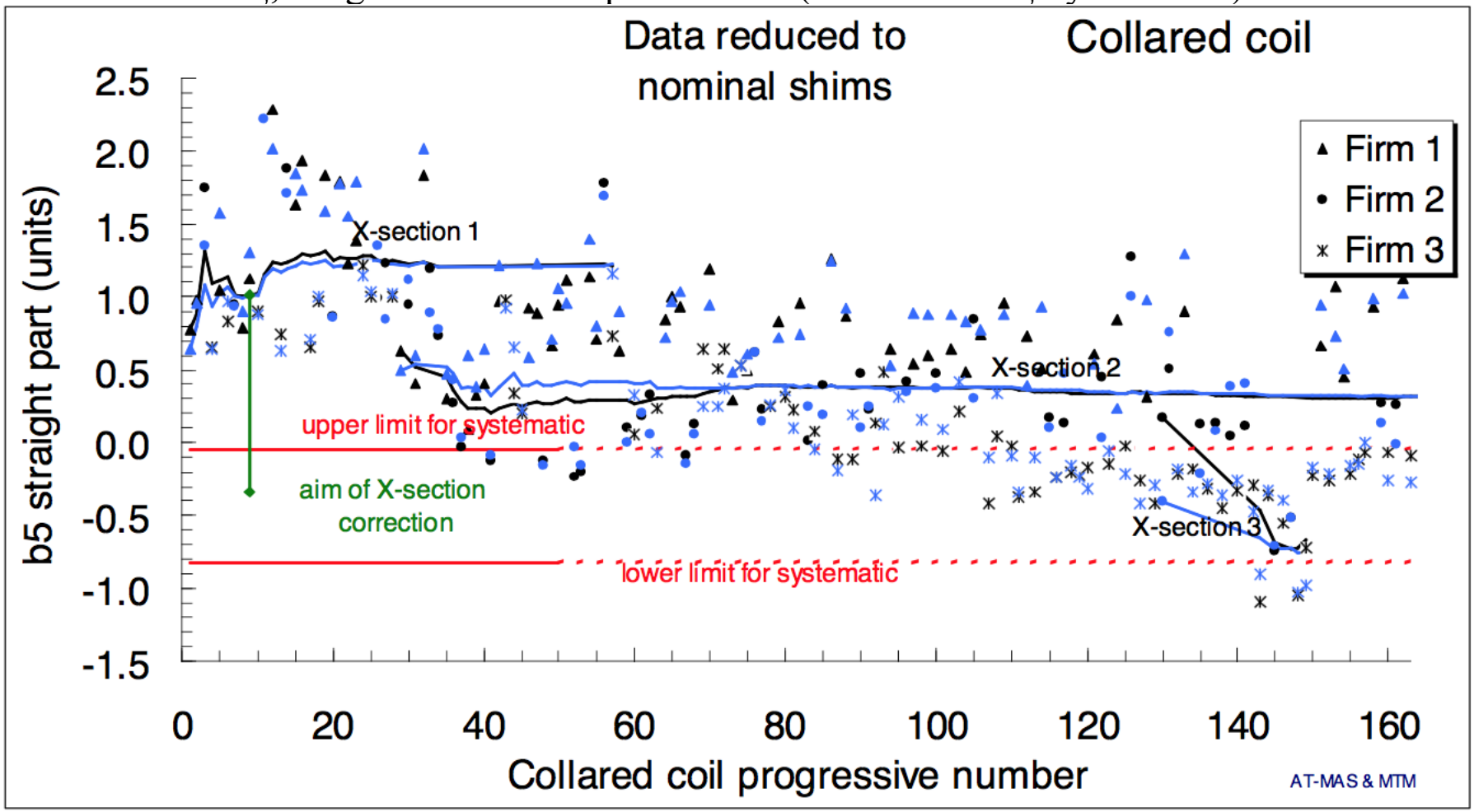
THE CASE OF LHC DIPOLE

- First intervention (after 8 dipoles, active after 35 dipoles)
  - Change of wedges to have Δb_3=-3, Δb_5=-1.2
  - It worked for b_3, but we had a trend in the first 20 coils (unexplained)



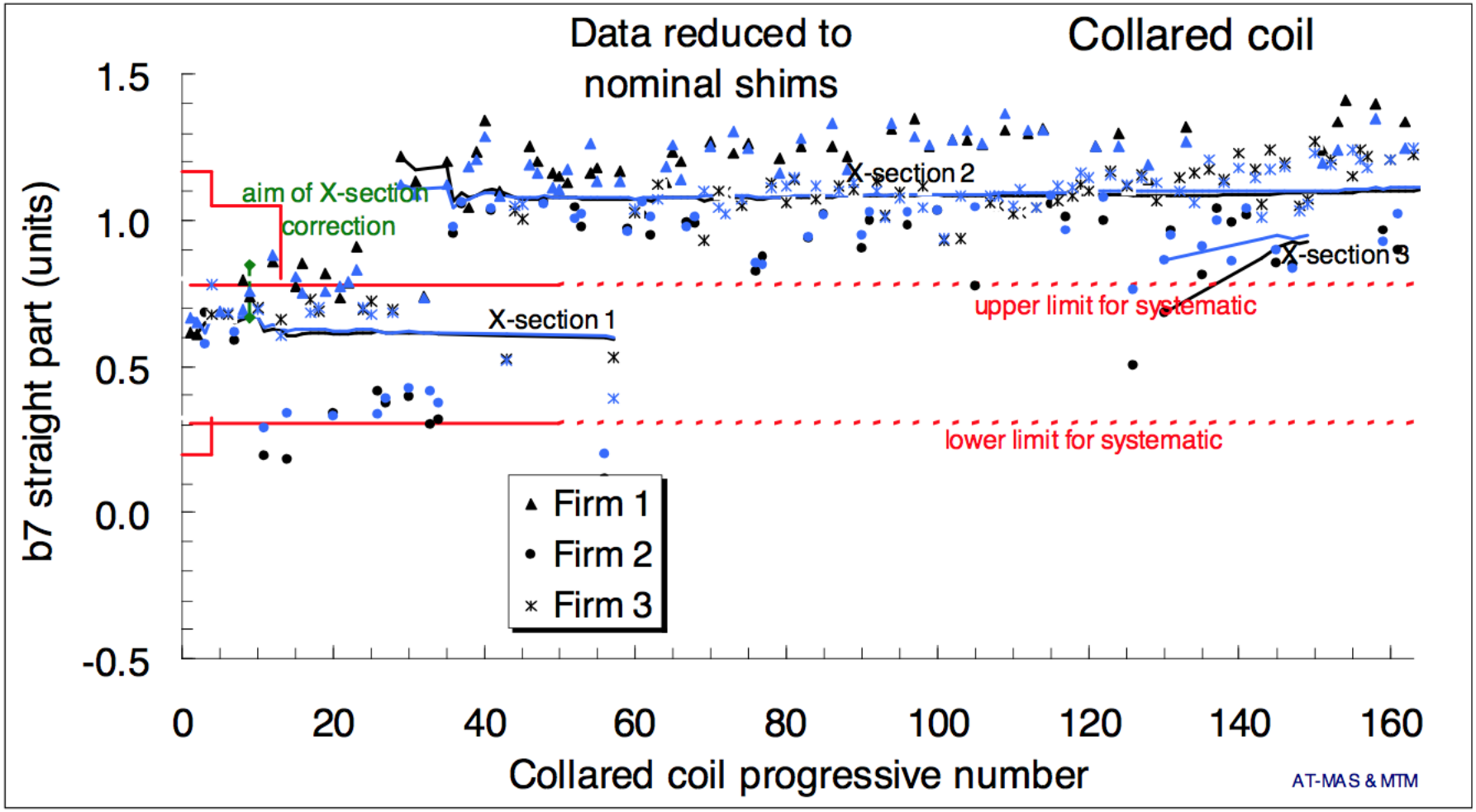
THE CASE OF LHC DIPOLE

- First intervention (after 8 dipoles, active after 35 dipoles)
  - Change of wedges to have Δb_3=-3, Δb_5=-1.2
  - For b_5, we got 2/3 of the expected shift (we reduced b_5 by 0.8 units)



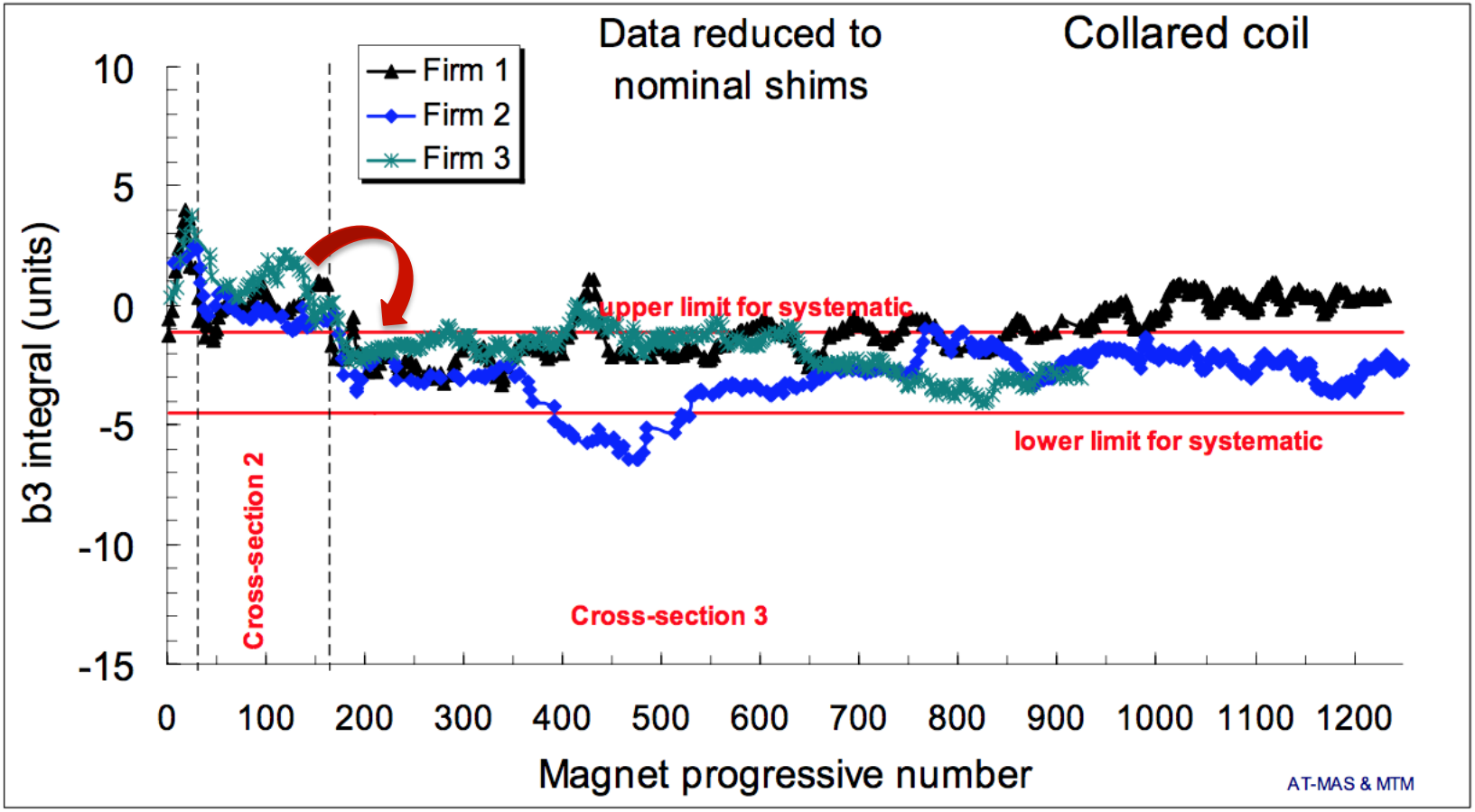
THE CASE OF LHC DIPOLE

- First intervention (after 8 dipoles, active after 35 dipoles)
  - Change of wedges to have Δb_3=-3, Δb_5=-1
  - b7 was expected not to change, but it jumped up 0.5 units



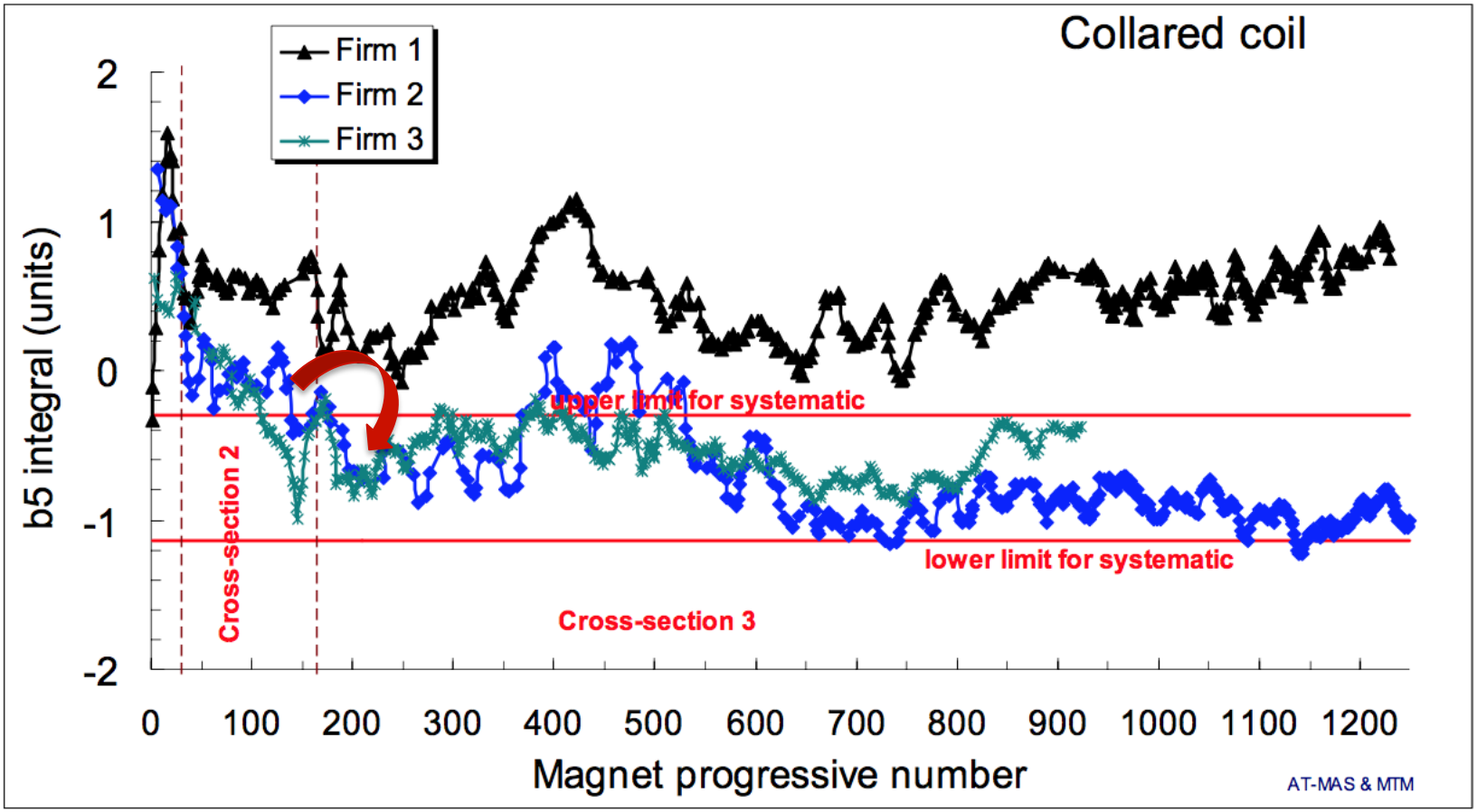
THE CASE OF LHC DIPOLE

- Second intervention (after 154 dipoles)
  - Increase of midplane shim of 0.125 mm to have Δb3=-3, Δb5=-1.0, Δb7=-0.3,
  - Worked for b_3, but note the trends along the production …



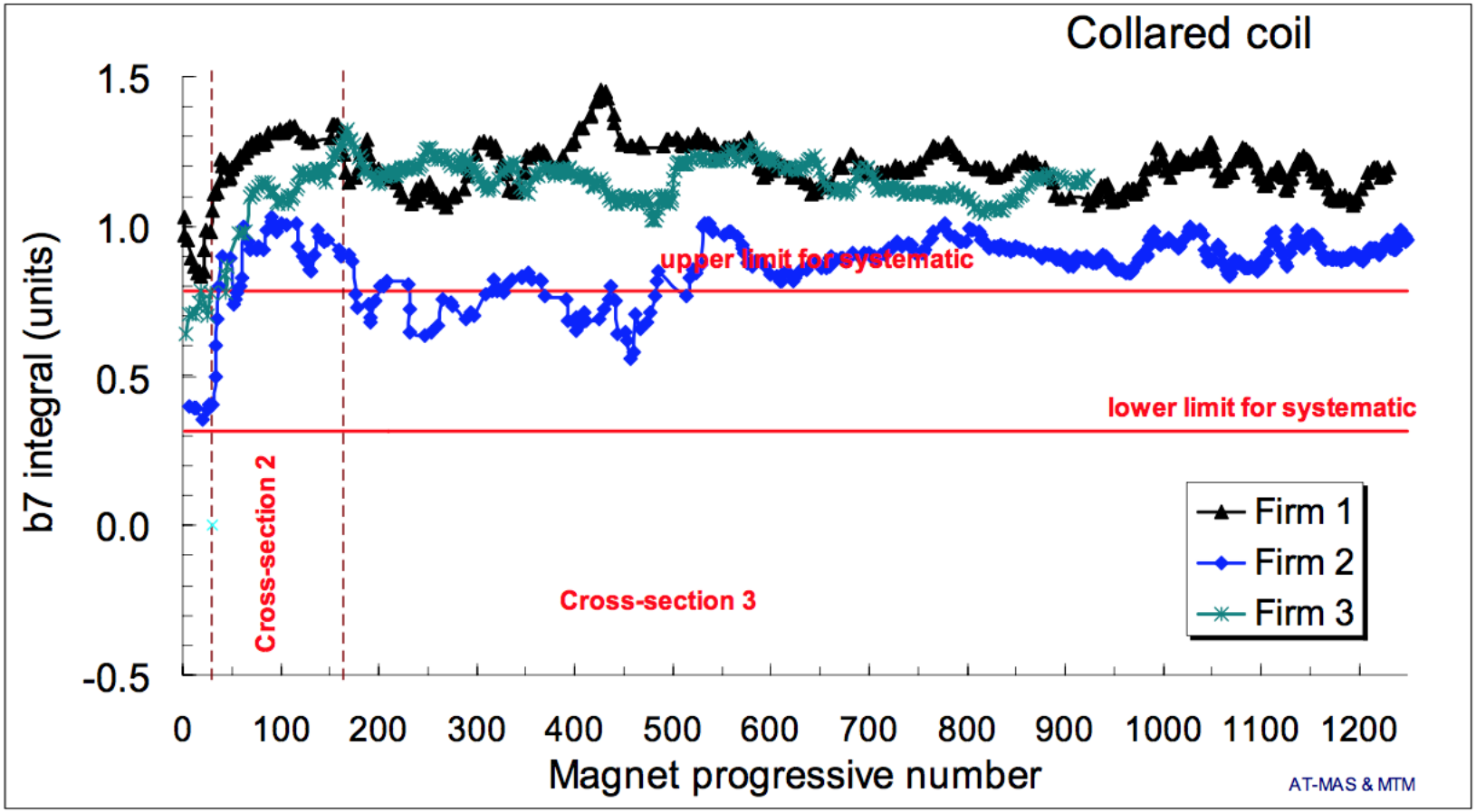
THE CASE OF LHC DIPOLE

- Second intervention (after 154 dipoles)
  - Increase of midplane shim of 0.125 mm to have Δb3=-3, Δb5=-1.0, Δb7=-0.3
  - It worked for 2 Firms out of 3 …



THE CASE OF LHC DIPOLE

- Second intervention (after 154 dipoles)
  - Increase of midplane shim of 0.125 mm to have Δb3=-3, Δb5=-1.0, Δb7=-0.3
  - Not clear if it worked, but at least it did not got worse



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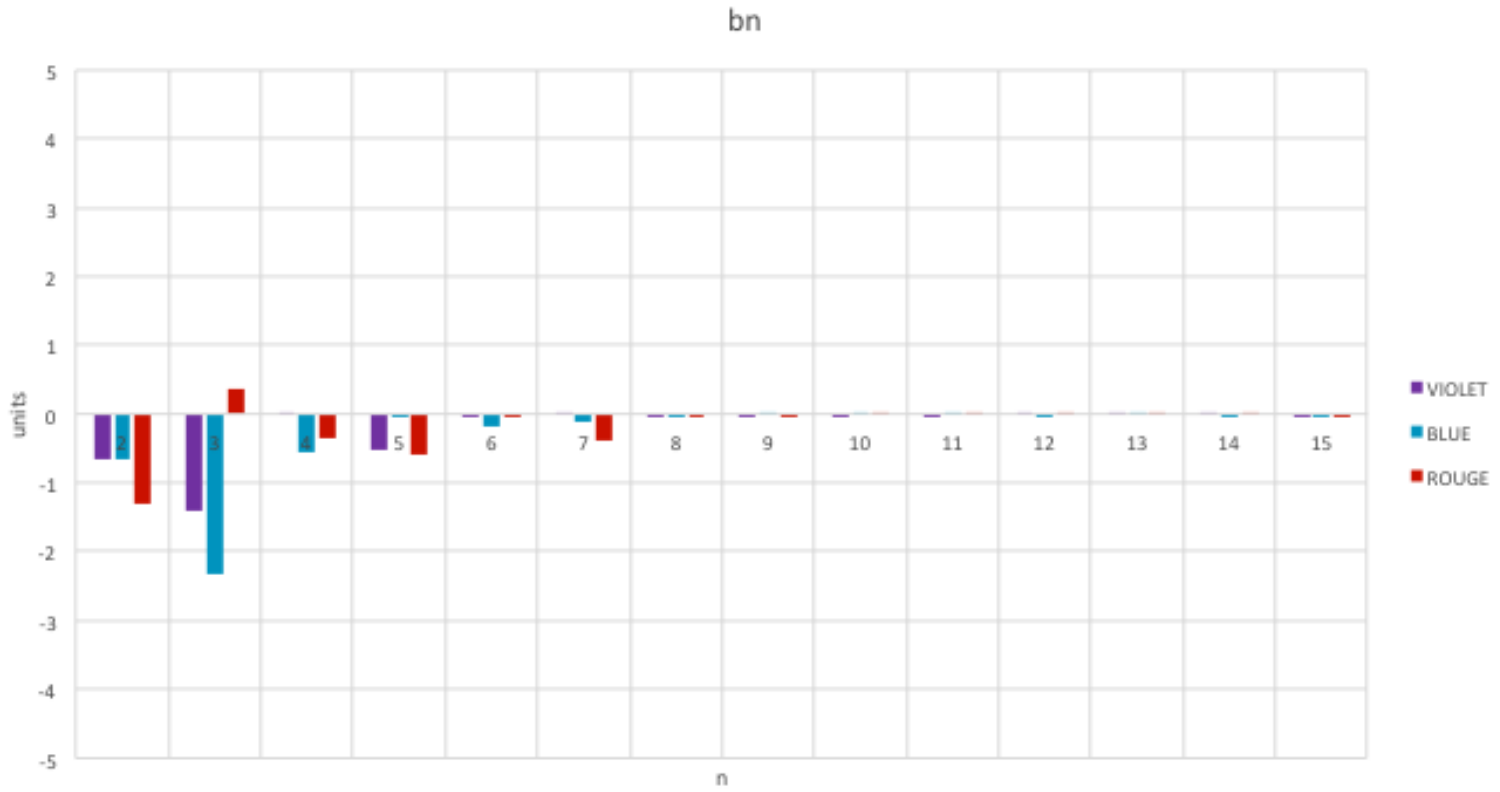
- D2 status
- D2 corrector news

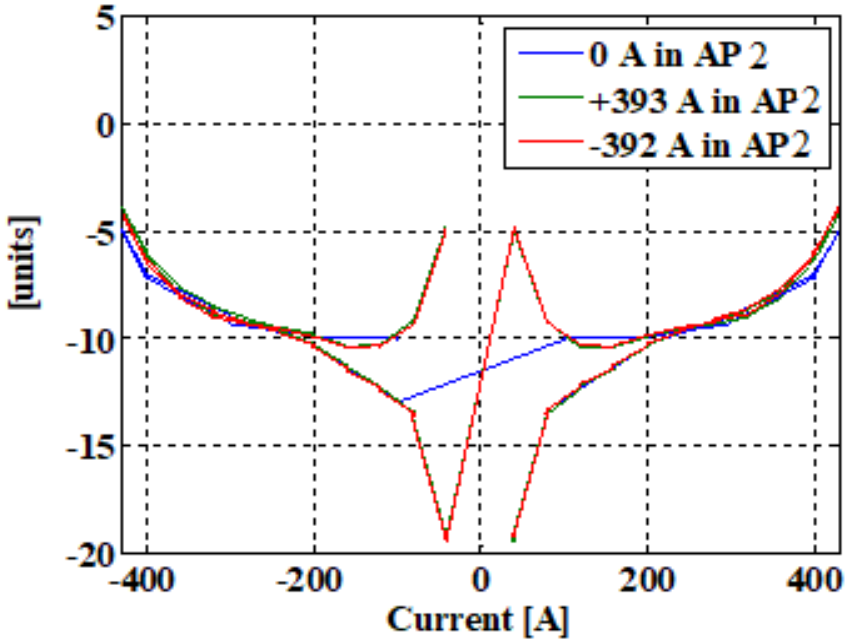
D2 CORRECTOR

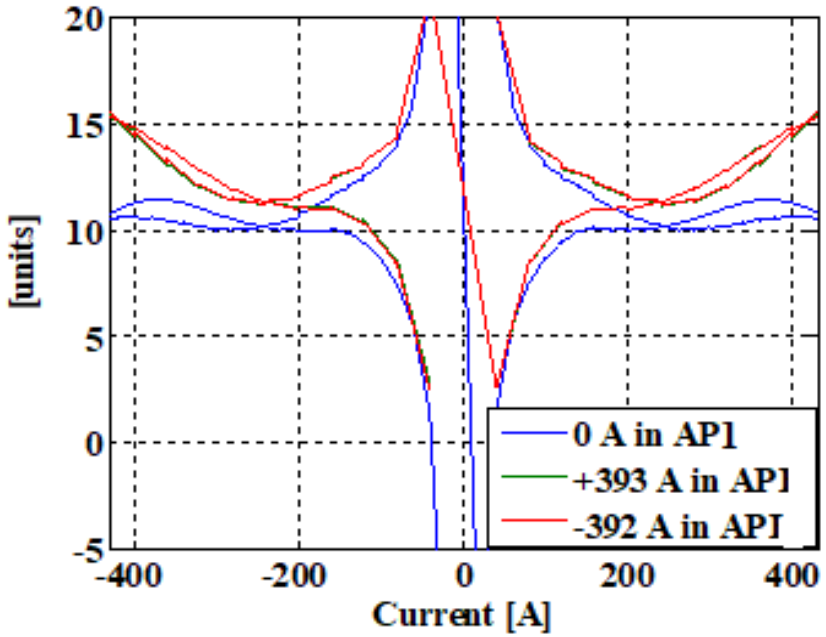
- Three apertures made at CERN measured without yoke had b_3 within 2.5 units



D2 CORRECTOR

- All apertures with yoke had b_3/a_3 of -/+10 units
  - Saturation is pushing b_3 towards -5 units, but a_3 towards 15 units





D2 CORRECTOR

- Analysis by A. Musso showed that the source of these multipoles is at the edge of the yoke
  - Suggestion of chaning the material of the yoke keys
- The blue aperture was assembled with stainless steel keys and measured
  - b_3 is smaller than 5 units (but the change from coil to yoked coil is order of 5 units)
  - It is a first indication that with SS keys the b_3/a_3 could stay within the 10 units acceptance range

	no iron		iron non mag keys		iron hybrid keys	
n	bn	an	bn	an	bn	an
2	-0.61	-1.92	1.45	0.25	-0.90	-0.49
3	-2.47	-0.10	2.82	-0.22	-9.26	-0.21
4	-0.64	0.16	-0.39	0.47	0.22	0.00
5	-0.01	-0.36	-1.21	-0.23	2.73	-0.21
6	-0.20	0.24	-0.13	0.12	0.05	-0.04
7	-0.12	-0.09	0.13	-0.06	-0.84	-0.10

D2 CORRECTOR

- Decisions:
  - We are going to give instruction to the Chinese collaboration to be ready to assemble the magnet with SS keys
  - The MCBRDP3 will be assembled with SS keys
  - We do not plan to reassemble MCBRDP1 and MCBRDP2 to remove the 15 units of a_3 that are present in case of combined powering (at full field in both apertures)
    - This operation is complex and risky if not planned before (J. C. Perez)
  - We will decide which one of the three prototypes P1, P2 or P3 will be included in the prototype cold mass of D2

SUMMARY

- D2 prototype
  - Short model had b3 b5 within 20 units
  - With the prototype we target being within 10 units, and possibly within 5 units
  - The sensitivity on b5 is problematic, so if we are out it could be impossible to change without a wedge change
    - … and I showed you how risky is such intervention
  - We ask to have simulations to have a more clear line for the relevance of b5
- D2 corrector
  - The source of the 10 units of b3/a3 has been touched by changing the material of the keys
  - We will see on the coming magnets the impact at 1.9 K