Report on field quality in the main LHC dipole collared coils: November-December 2003

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This report gives data relative to field quality measured in collared coils during the period November 1– December 31 2003, comparison to beam dynamics targets and status of the holding points. Updated graphs can be found in the LHC-MMS field quality observatory http://lhc-div-mms.web.cern.ch/lhc-div-mms/MMSPAGES/MA/Obs.html.

EDMS n. **439482**

The dashboard

- Available measurements: 275 collared coils, 200 cold masses, 74 cryodipoles.
- In these two months, 57 collared coils: 17 from Firm1, 8 from Firm2 and 32 from Firm3.

What's new

- **Production rate:** Notwithstanding Christmas holidays, production rate has ramped up to 28.5 collared coils per month. Firm3 is at 3.5 collared coils per week, and is producing more than Firm1 and Firm2 together. Firm1 and Firm2 are at 2.0 and 1.0 collared coils per week respectively.
- **Length of feedback loop:** The delay between collared coil magnetic measurements and cold test is stable at 12 months (in average), and at 2.5 months (minimal, obtained for 3038).
- **Cold tests:** Results of this year show that it will not be possible to measure the magnetic field of all dipoles at 1.9 K at CERN. A discussion about the size and the strategy of the sampling has been started. More information can be found in the web site of the Field Quality Working Group: http://fqwg.web.cern.ch/fqwg/hmmm/hmmm.html
- **Coil size:** Firm1 is still producing outer layers with large azimuthal coil size, which is forcing to use non-nominal shims up to 0.2 mm less with respect to nominal. This has a non-negligible effect on main field and normal sextupole. Details in Section 1 and in the report by I. Vanenkov, see also http://lhc-div-mms.web.cern.ch/lhc-div-mms/MMSPAGES/MA/obs_coil.html
- **Switch to cross-section 3:** the addition of 0.125 mm insulation (X-section 3) in the coil mid-plane is now the baseline. All manufacturers are producing X-section 3. The total number of magnets with X-section 1 and 2 is 35 and 139 respectively, i.e. the second octant will contain at most 20 magnets with X-section 2 and 134 with X-section 3.
- **Trends in main field:** collared coil data of the more recent production show that the difference between firms is disappearing. More information in Section 3 and Appendix A.
- **Integrated main field spread:** The spread of integrated main field is within targets in the collared coil. The spread is mainly due to higher values in Firm3 with respect to Firm1 and 2. Indeed, both cold mass data and measurements in operational conditions show that this difference is reduced after the assembly of the iron yoke. No corrective action on ferromagnetic lamination is necessary, but the situation should be continuously monitored.
- **Trends in odd multipoles:** we have around 100 collared coils with X-section 3. Systematic b_3 and b_5 are within the target range in optimal positions. Systematic b_7 is 0.23 units larger that the upper limit, corresponding to a value of 0.29 units at injection (beam screen included).
- **Trends in skews:** the large systematic a_4 in Firm2 observed in the previous report (0.9 units) is getting smaller in the more recent production (around 0.3 units). More information in the Crisis Unit web page http://lhc-div-mms.web.cern.ch/lhc-div-mms/MMSPAGES/MA/a4_firm2.html and in Appendix B.
- **Trends in skews:** No effect of cross-section 3 on a_2 and a_4 as expected.
- **Estimates of random errors:** We present for the first time an analysis of the random multipoles in cross-section 3. Details are given in Section 9.

1. Measured magnets and assembly data

- 57 new collared coils have been measured (collared coils 219th to 275th)
  - o 17 of Firm1 (1065, 1072, 1073, 1075-1079, 1081-1089)
  - o 8 of Firm2 (2046, 2047, 2051, 2059, 2060, 2062, 2064, 2066)
  - o 32 of Firm3 (3094-3101 and 3103-3126).

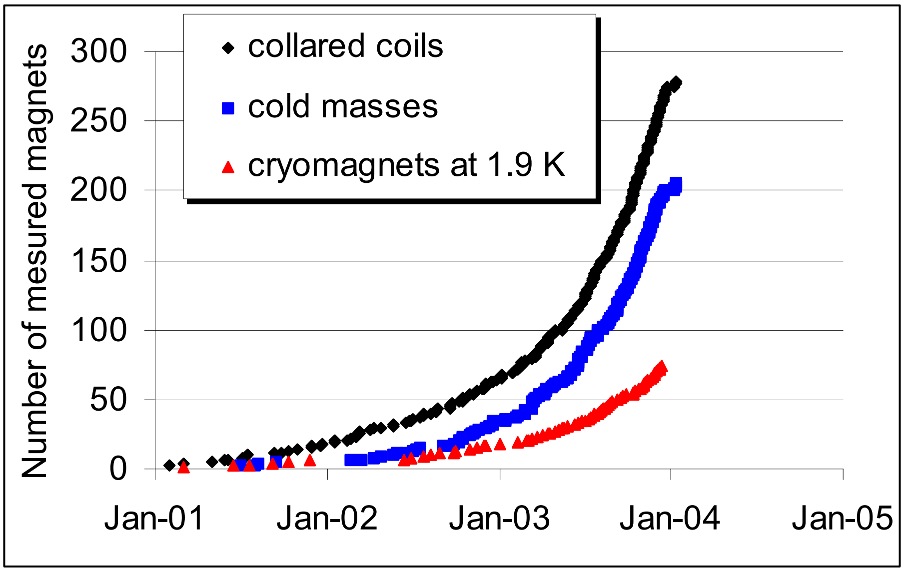


Fig. 1: Number of magnets measured at CERN at 1.9 K and at the manufacturers at room temperature at different stages of assembly procedure

- Cross-section: all magnets 57 collared coils have X-section 3. Total number of magnets with cross-section 1 and 2 is 35 and 139 respectively. We will have at most 20 magnets with cross-section 2 in the second octant. 101 magnets have been manufactured with X-section 3 up to now.
- Shims are nominal in Firm2 and in Firm3. On the other hand, in Firm1 all manufacrtured collared coils have non-nominal shims within 0.1 mm on the inner layer and within 0.2 mm for the outer. Since in both cases layers are too large, thus imposing smaller shims, this has a relevant impact on main field and normal sextupole (both lower than nominal values).

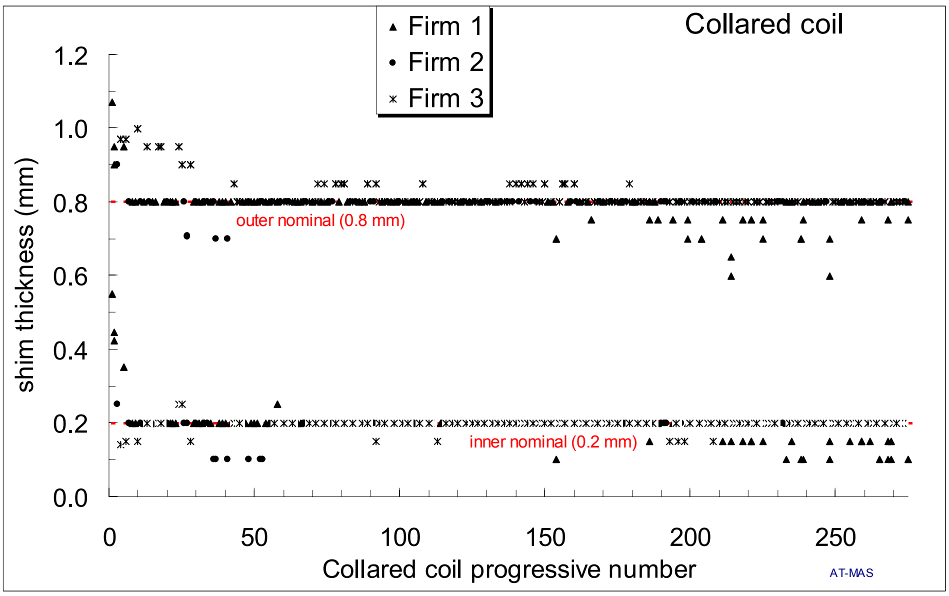


Fig. 2: Thickness of the polar shims used in the collared coils

2. Estimated coil waviness

- Coil waviness estimated from the variation of the multipoles along the axis is below 30 microns. The only exception is aperture 2 of 2046 (253th in Fig. 3). The general situation of this parameter is very good in all firms.

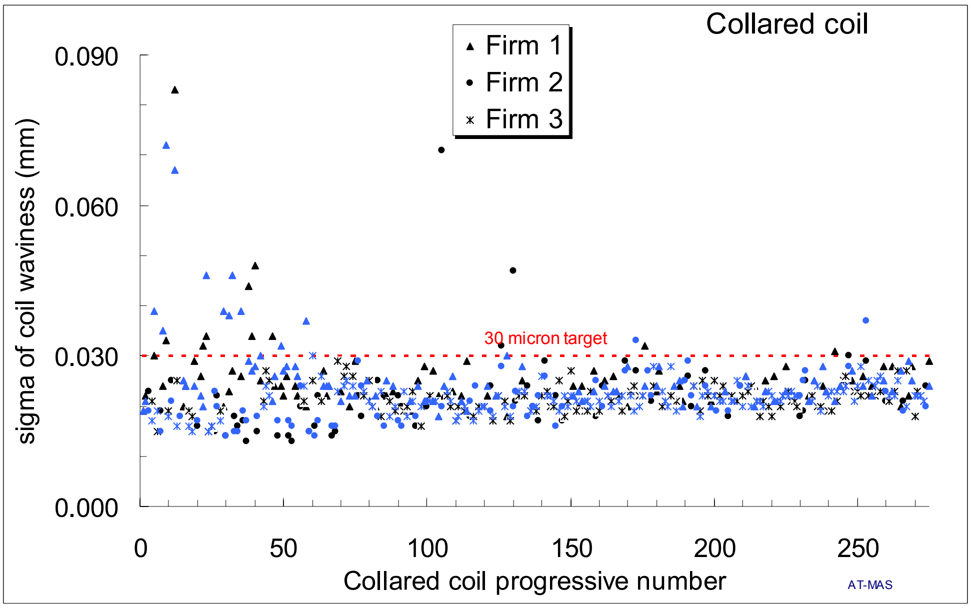


Fig. 3: Estimated coil waviness in the straight part of the measured collared coils (black dots: aperture 1, blue dots: aperture 2).

3. Magnetic length and transfer function

- Magnetic lengths of collared coils 219th to 275th are well within targets (see Fig. 4). The spread in magnetic length is very low (3 units).
- Firm3 is producing collared coils with a magnetic length 5 units smaller than Firm1. Firm2 values are in between.

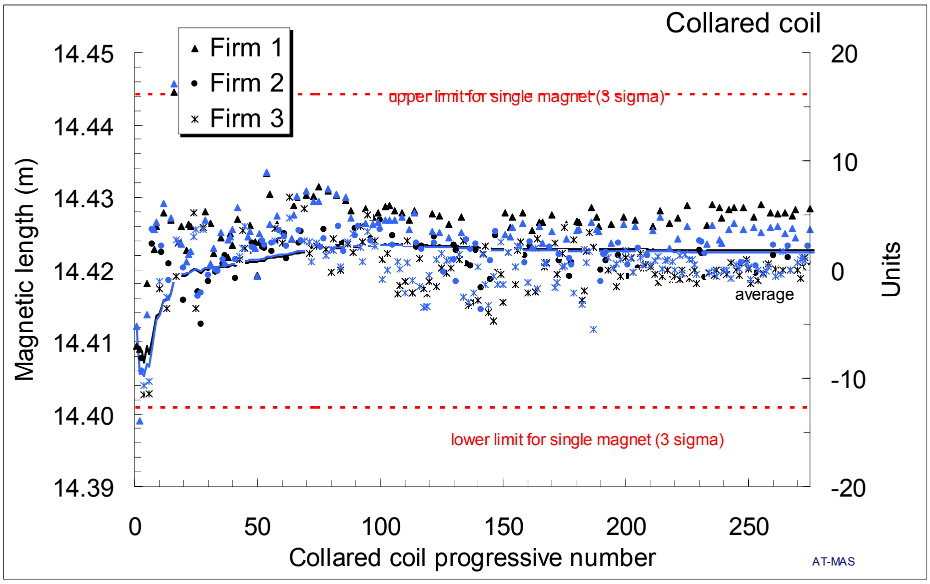


Fig. 4: Magnetic length of the measured collared coils (black dots: aperture 1, blue dots: aperture 2)

- Collared coil 1076 (248th in Figs. 5 and 6) has a very low main field, which is mainly due to non-nominal shims.
- In the more recent production, the main field is decreasing in Firm3, and increasing in Firm1. Latest values show that the difference between firms is disappearing. More information in Appendix A.
- In general, the introduction of cross-section 3 has shifted down the main field by less than 5 units.

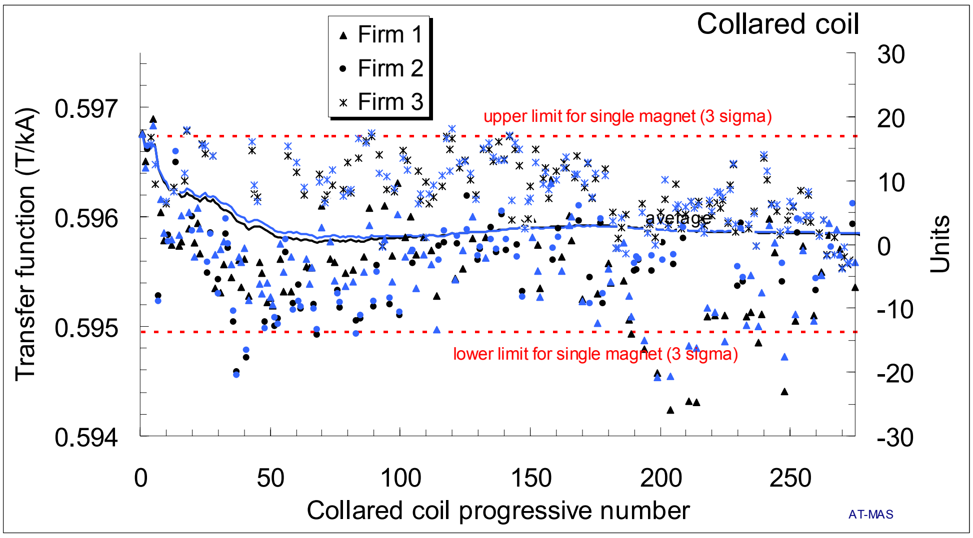


Fig. 5: Main field in the straight part of the collared coils (black dots: aperture 1, blue dots: aperture 2) and average over all collared coils (solid lines).

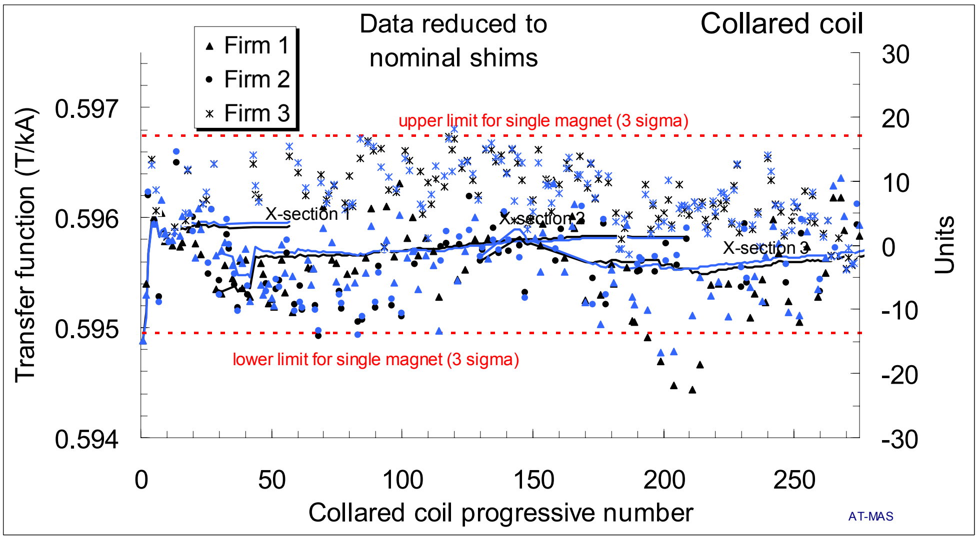


Fig. 6: Main field in the straight part of the collared coils (black dots: aperture 1, blue dots: aperture 2) and best estimate of systematic (solid lines). Data are reduced to nominal shims and separated according to different cross-sections.

- The spread of the integrated transfer function in all collared coils is 7.7 units (one sigma), i.e. within the target of 8 units.
- Cold mass data show that the systematic difference between firms is reduced by the iron yoke (see Appendix A and http://fqwg.web.cern.ch/fqwg/031111/031111.html). This is confirmed by measurements at 1.9 K. Therefore, we can expect that in operational conditions the main field spread is furtherly reduced with respect to the 7.7 units observed in collared coils. We therefore implement no corrective action, with the exception of acting on isolated magnets showing anomalous main field due to non-nominal shims.

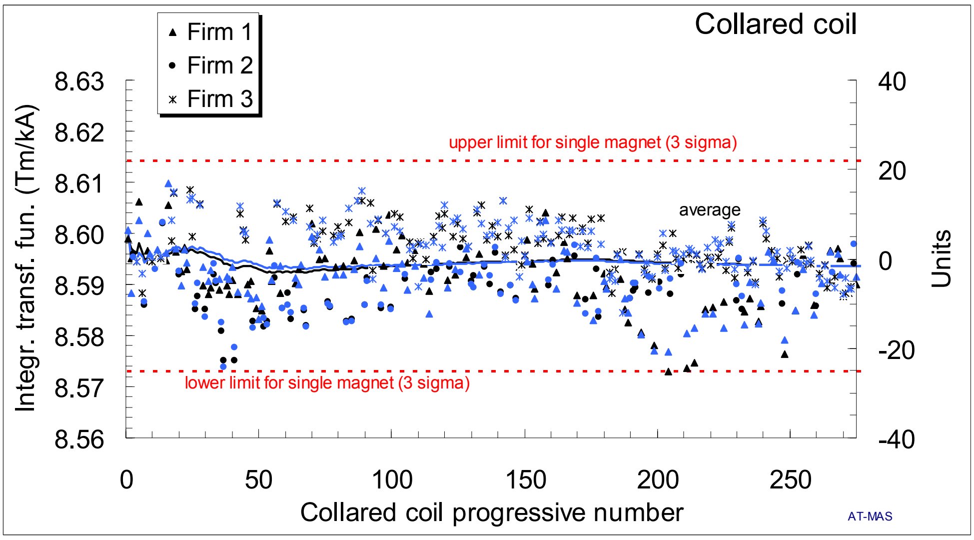


Fig. 7: Integrated transfer function (black dots: aperture 1, blue dots: aperture 2) and average over all collared coils (solid lines)

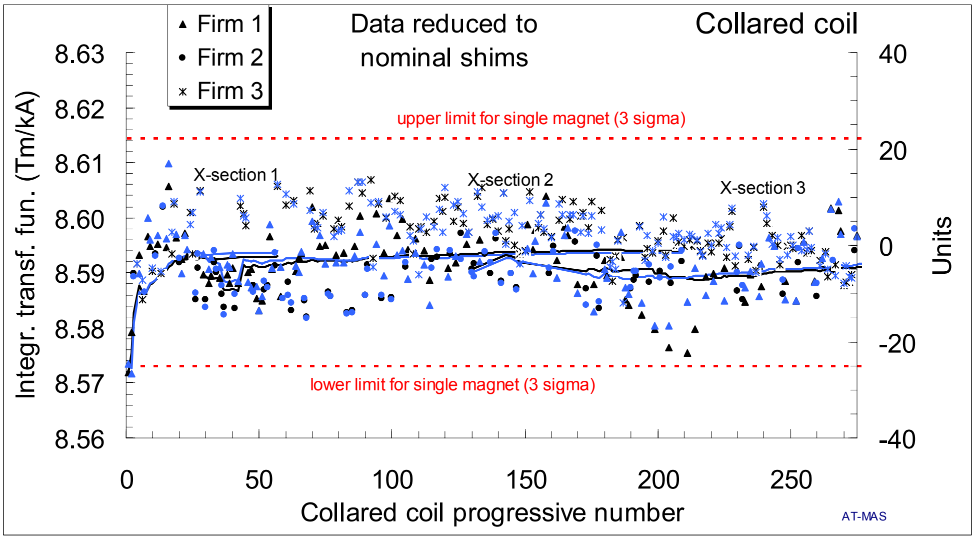


Fig. 8: Integrated transfer function (black dots: aperture 1, blue dots: aperture 2) and best estimate of systematic (solid lines). Data are reduced to nominal shims and separated according to different cross-sections.

4. Summary of systematics

- Best estimates of skew and even normal systematics are given in Fig. 9, with an error at 95% confidence limit (two sigma). All the multipoles are within specifications. Details are given in sections 6 and 7.

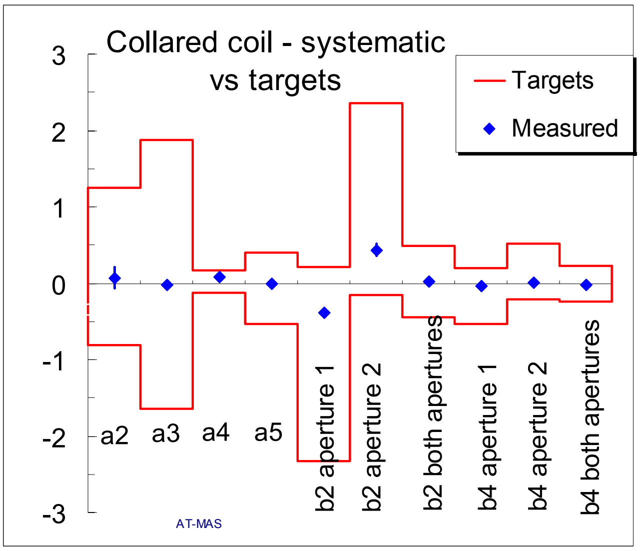


Fig. 9: Best estimate for systematic skew multipoles and even normal multipoles (markers) versus beam dynamics limits (red line). An error of two sigma (95% confidence limit) is associated to the best estimates of systematics.

- Best estimates for systematic odd normal multipoles are shown in Fig. 10. In the left part, raw data are plotted. This gives the actual situation for global values relative to all manufactured collared coils, which are slowly moving towards optimal ranges: b_3 and b_5 are larger than the upper specifications of 0.4 and 0.34 units respectively. For the first time, the systematic normal sextupole is within the hard target of 4.35 units at high field.
- In the right part of Fig. 10, data are reduced to nominal shims and separated according to the two cross-sections (35 collared coils have cross-section 1, 139 have cross-section 2, 101 have cross-section 3). With cross-section 3, b_3 is within targets, 1.6 units below the upper limit (i.e., 1.7 units at high field), and also b_5 is within targets, 0.17 units below the upper limit (i.e., 0.96 units at injection). Finally, b_7 is 0.23 units larger than the limits (i.e. 0.29 units at injection).

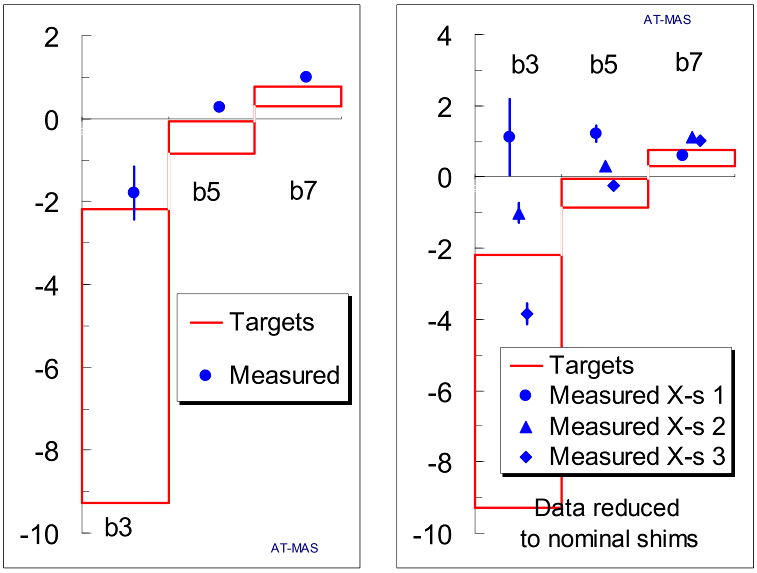


Fig. 10: Best estimate for systematic odd normal multipoles (markers) versus beam dynamics limits (red line). An error of two sigma (95% confidence limit) is associated to the best estimates of systematics. Raw data (left) and data reduced to nominal shims and separated according to different cross-sections (right).

5. Summary of systematic differences between firms

The relevant systematic difference between firms in the main field is disappearing. The more relevant signature of Firms is in b_7.

- Normal 14th pole: b_7 at Firm2 is 0.35 units lower than Firm2 and Firm1. This difference is three to four times the natural sigma within the same manufacturer measured in cross-section 3.

We observe a small systematic difference between firms (from one to two times the natural sigma within the same manufacturer) in the following cases.

- Normal decapole b_5: Firm1 has a systematic b_5 of 0.7 units larger than Firm2-3. This difference is two times the natural sigma within the same manufacturer.
- Skew sextupole a_3: Firm3 has a systematic a_3 of 0.65 units, against –0.3 units in Firm2, Firm1 being at 0.0 units. This difference is two times the natural sigma within the same manufacturer.
- Skew octupole a_4: Firm2 has a systematic a_4 of 0.4 units, against 0.0 units in Firm2 and Firm1. This difference is equal to the natural sigma within the same manufacturer.

No systematic differences between firms are visible in a_2, b_2 b_3 and b_4.

6. Systematic skew multipoles

- Systematic skew multipoles a_2, a_3 and a_4 are within beam dynamics limits (see Figs. 11-13). We have a large margin for the a_3, whereas beam dynamics limits are tighter for a_2 and a_4.
- In the production of these two months, we observe a reduction of the spread between firms in a_3 and a_4 analysed in the previous report (September-October 2003):
    - The high positive values of a_4 of 0.5 to 1.5 units observed in Firm2 between collared coils 100th and 200th are not present any more (see Fig. 13). The average a_4 in the production of these two months in Firm2 is 0.35 units. The situation is monitored and a crisis meeting to inform project engineers has been held. More information in Appendix and in the Crisis Unit web page http://lhc-div-mms.web.cern.ch/lhc-div-mms/MMSPAGES/MA/a4_firm2.html
    - Systematic a_3 in collared coils from Firm3 is decreasing from 0.9 units of previous months Fig. 12, collared coils from 150th to 220th) to around 0.5 units (see Fig. 12, from 220th to 275th). This parameter is anyway well inside the target and therefore there is no concern about this multipole.
- The introduction of cross-section 3 produced no effect on a_2 and a_4, as expected.

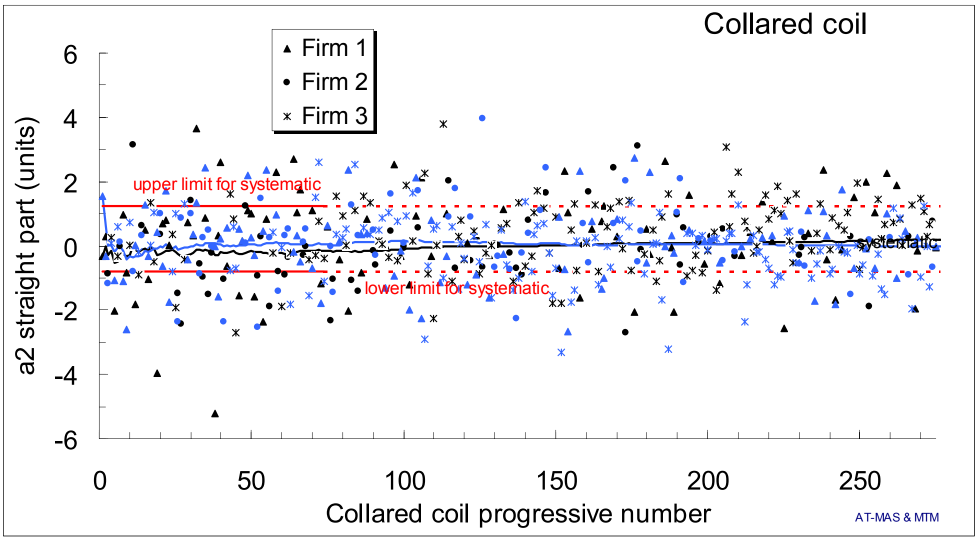


Fig. 11: Average a_2 in the straight part of the collared coils (black dots: aperture 1, blue dots: aperture 2), best estimate for systematic in each aperture (solid lines), and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles.

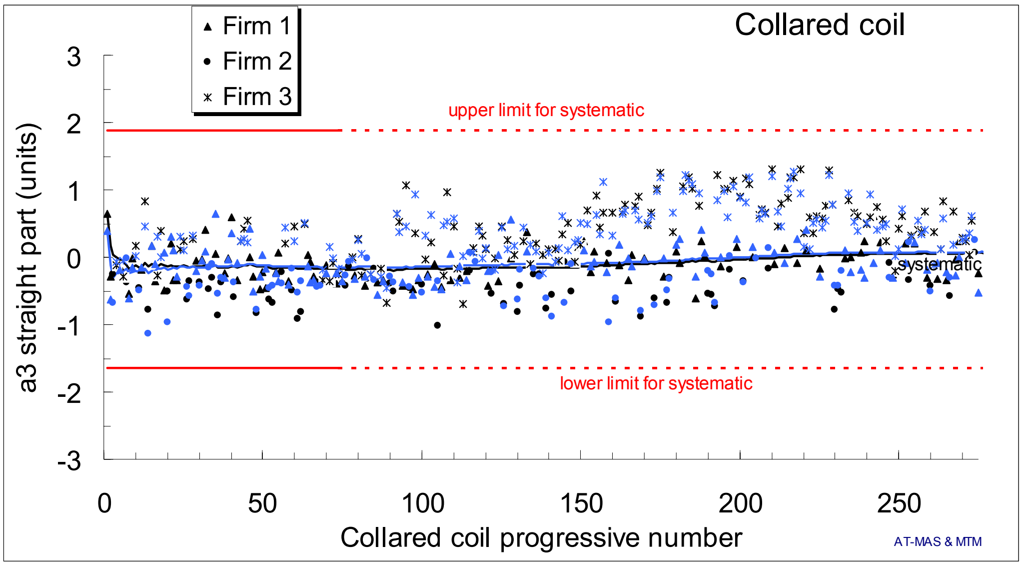


Fig. 12: Average a_3 in the straight part of the collared coils (black dots: aperture 1, blue dots: aperture 2), best estimate for systematic in each aperture (solid lines), and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles.

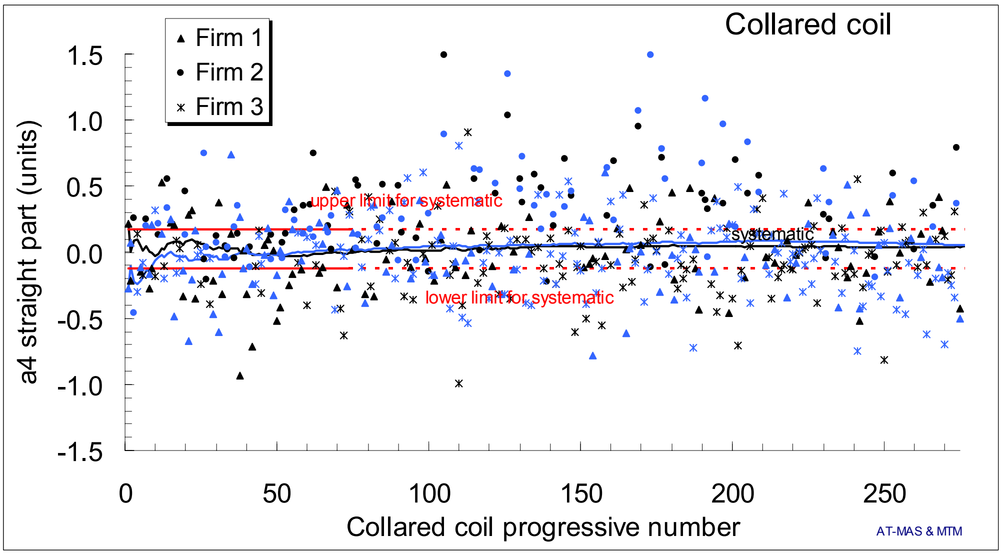


Fig. 13: Average a_4 in the straight part of the collared coils (black dots: aperture 1, blue dots: aperture 2), best estimate for systematic in each aperture (solid lines), and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles.

7. Systematic even multipoles

For each multipole being subject to beam dynamics specifications, we present two separated plots for the systematic per aperture, plus a plot of the systematic per beam, i.e. the average of both apertures (that should be zero due to two-in-one symmetry).

7.1 Normal quadrupole

- The systematic per aperture is within specifications in both apertures (see Figs. 14 and 15).

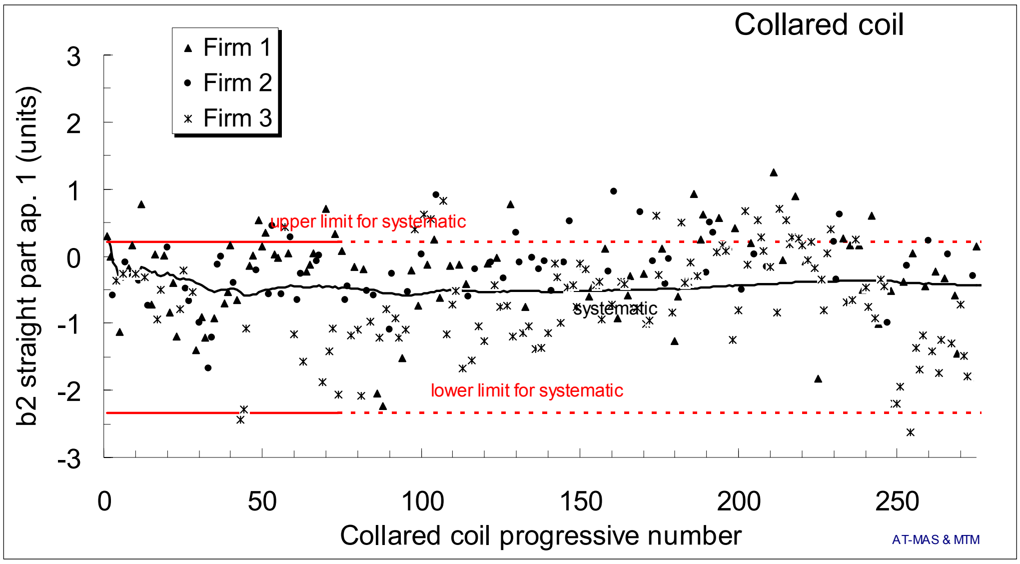


Fig. 14: Average b_2 in the straight part of the aperture 1 collared coils (black dots), best estimate for systematic per aperture (black line), and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles.

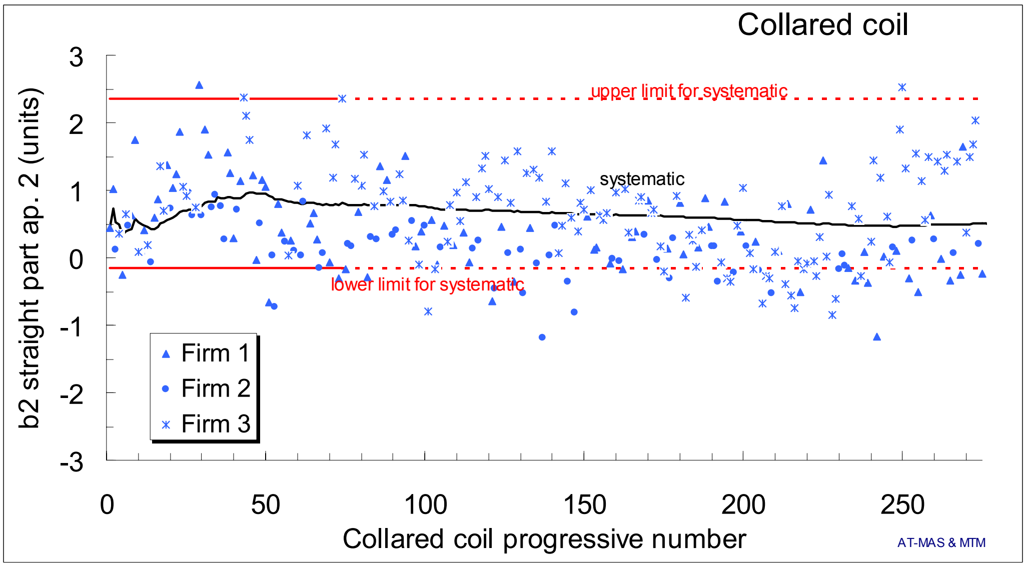


Fig. 15: Average b_2 in the straight part of the aperture 2 collared coils (blue dots), best estimate for systematic per aperture (blue line) and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles.

- The systematic normal quadrupole per beam is within specifications (see Fig. 16).

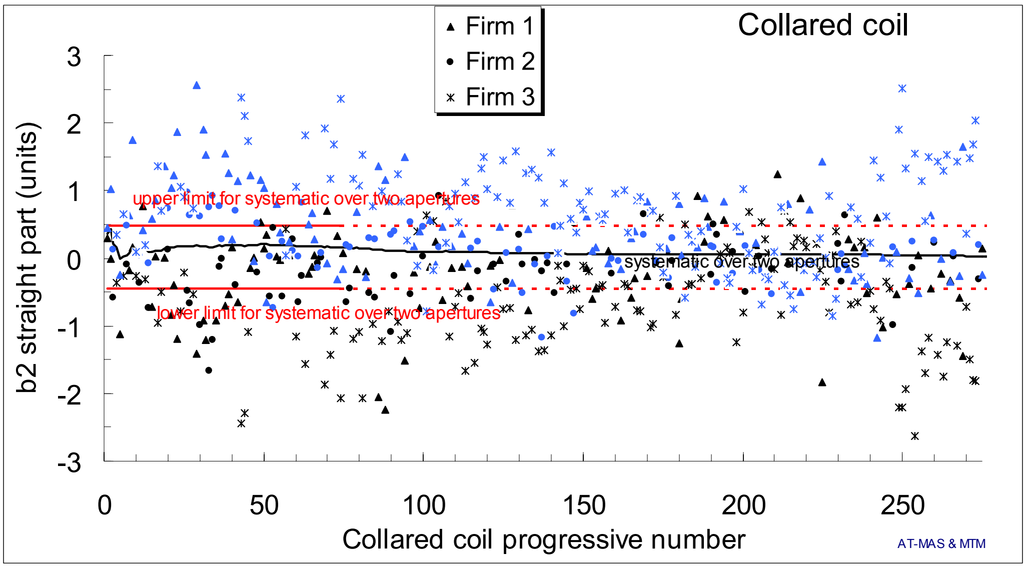


Fig. 16: Average b_2 in the straight part of collared coils ((black dots: aperture 1, blue dots: aperture 2), best estimate for systematic per beam (soild line) and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles.

7.2 Normal octupole

- The systematic per aperture is within specifications in both apertures (see Figs. 17 and 18).
- The systematic per beam is also within specifications (see Fig. 19).

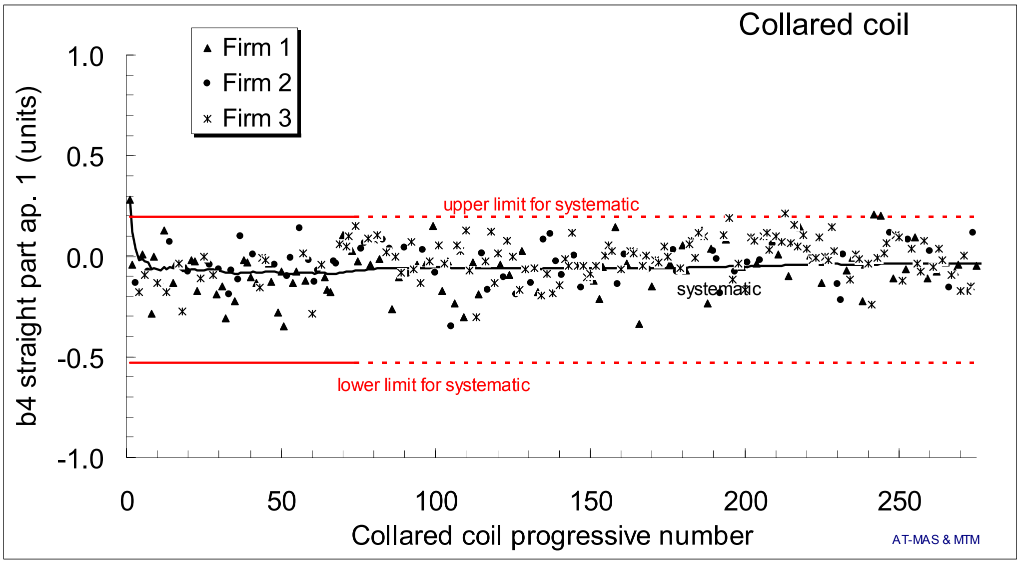


Fig. 17: Average b_4 in the straight part of the aperture 1 collared coils (black dots), best estimate for systematic per aperture (black line), and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles.

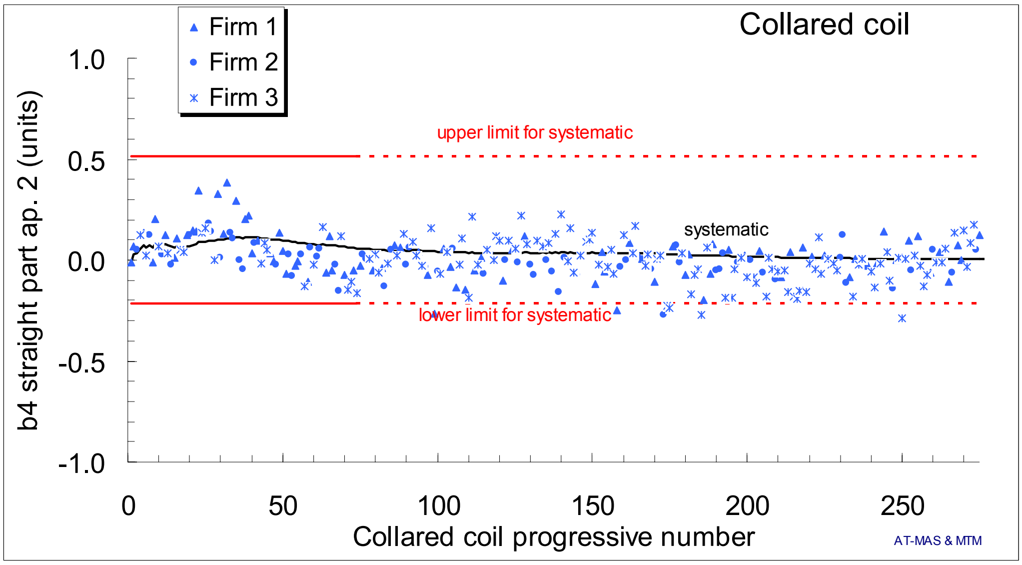


Fig. 18: Average b_4 in the straight part of the aperture 2 collared coils (blue dots), best estimate for systematic per aperture (black line) and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles.

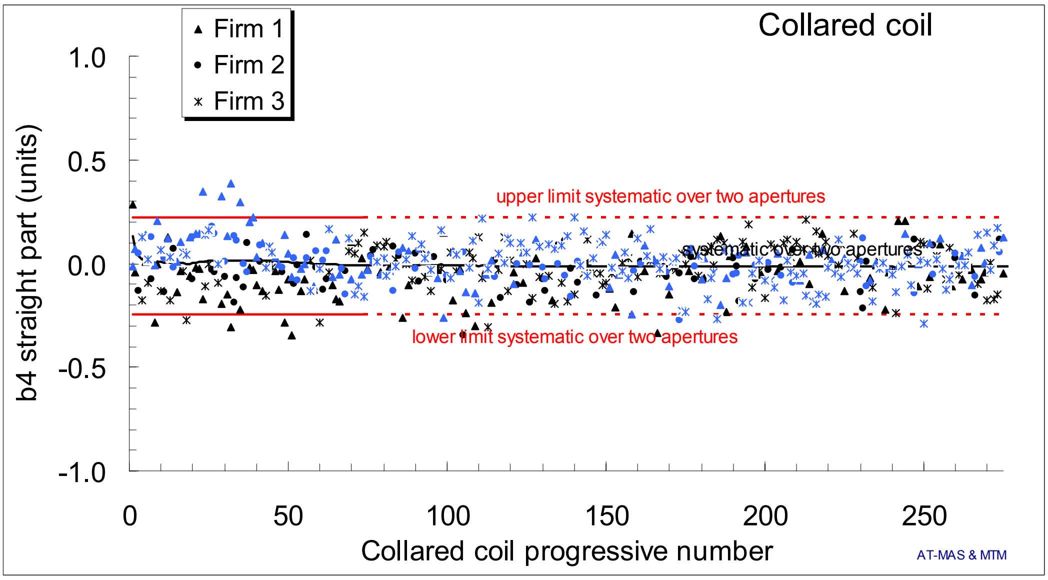


Fig. 19: Average b_4 in the straight part of collared coils (black dots: aperture 1, blue dots: aperture 2), best estimate for systematic per beam (black line) and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles.

8. Systematic odd multipoles

8.1 Normal sextupole

- Data not reduced to nominal shims and not separated according to different cross-section show a negative trend due to the introduction of cross-section 2 (at collared coil 30th) and 3 (around collared coil 140th, see Fig. 20).
- The introduction of cross-section 3 has brought b_3 in the upper half of the target range (see Fig. 21). Some collared coils of Firm1 feature a rather low b_3 due to non-nominal shims.
- In cross-section 3, b_3 values show a low spread for Firm2 and Firm3 (standard deviation of 0.5 to 0.6 units), whilst for Firm1 data have a larger spread (standard deviation of 1.5 units). The spread in Firm1 is partly due to non-nominal shims: when this effect is subtracted, the standard deviation goes to 1.1 units.
- Average b_3 in cross-section 3 is at -5.6, -4.1 and -3.2 units in Firm1, 2 and 3 respectively, showing a small difference between Firms.

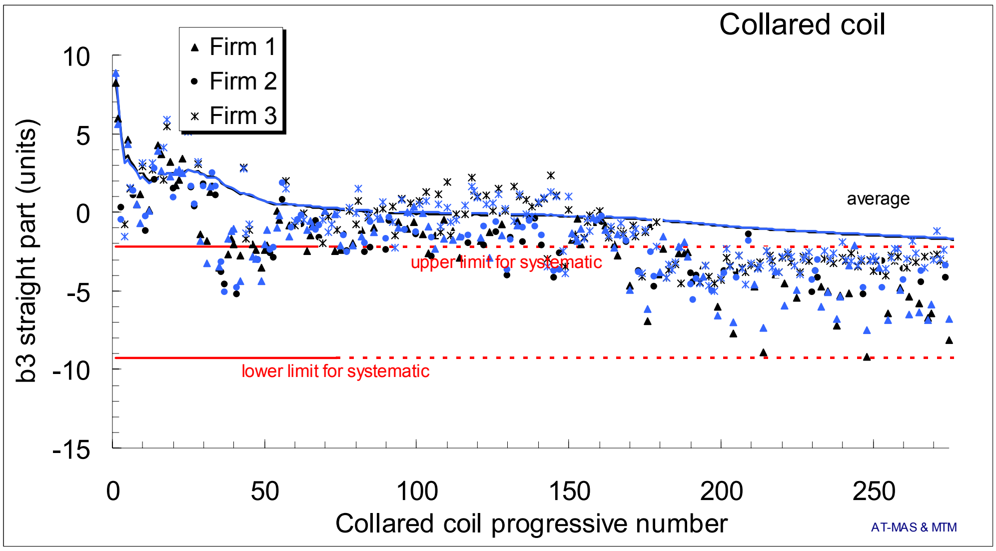


Fig. 20: Average b_3 in the straight part of the collared coils (black dots: aperture 1, blue dots: aperture 2), best estimate for systematic (solid lines), and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles.

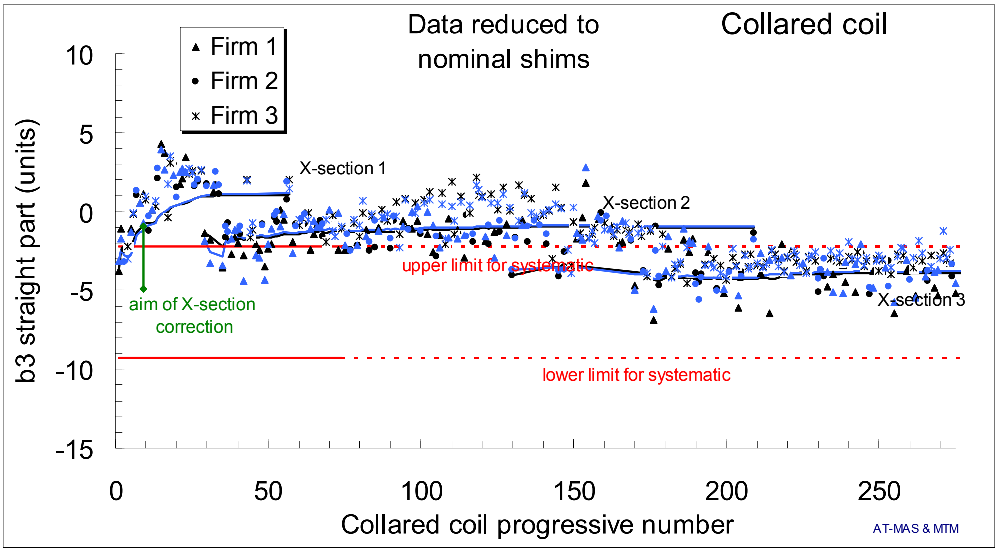


Fig. 21: Average b_3 in the straight part of the collared coils (black dots: aperture 1, blue dots: ap. 2), best estimate for systematic (solid lines), and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles. Data reduced at nominal shims and separated according to cross-section type.

8.2 Normal decapole

- Data not reduced to nominal shims and not separated according to different cross-section show a negative trend due to introduction of cross-section 2 (see Fig. 22, from 35th to 140th) and then due to the introduction of cross-section 3 (same Figure, after 140th).
- Indeed, when data are separated according to cross-sections and reduced to nominal shims, one finds that the average b_5 in all cross-sections is stable after a transient due to low statistics (see Fig. 23).
- Cryodipoles with the cross-section 3 should feature 0.96 units of b_5 at injection. This places b_5 safely within the target range, not far from the centre of the range.
- Spread of b_5 for cross-section 3 is very similar in all firms: around 0.25 units.
- Average b_5 for cross-section 3 is at 0.30, -0.42 and –0.40 units in Firm1, 2 and 3 respectively. Therefore, the high value of this multipole in Firm1 is confirmed: this feature was present already in cross-section 1 and 2.

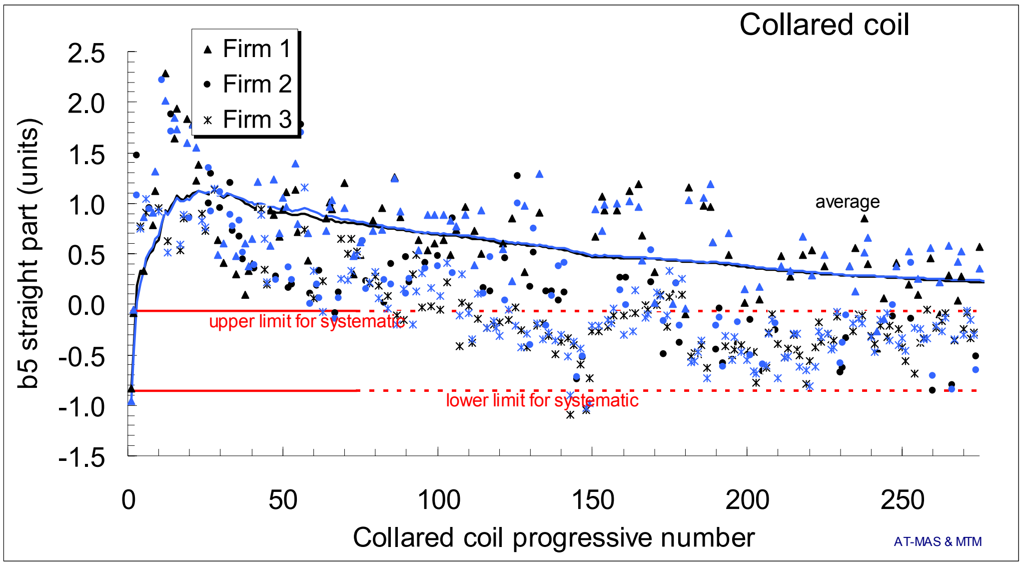


Fig. 22: Average b_5 in the straight part of the collared coils (black dots: aperture 1, blue dots: aperture 2), best estimate for systematic (solid lines), and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles.

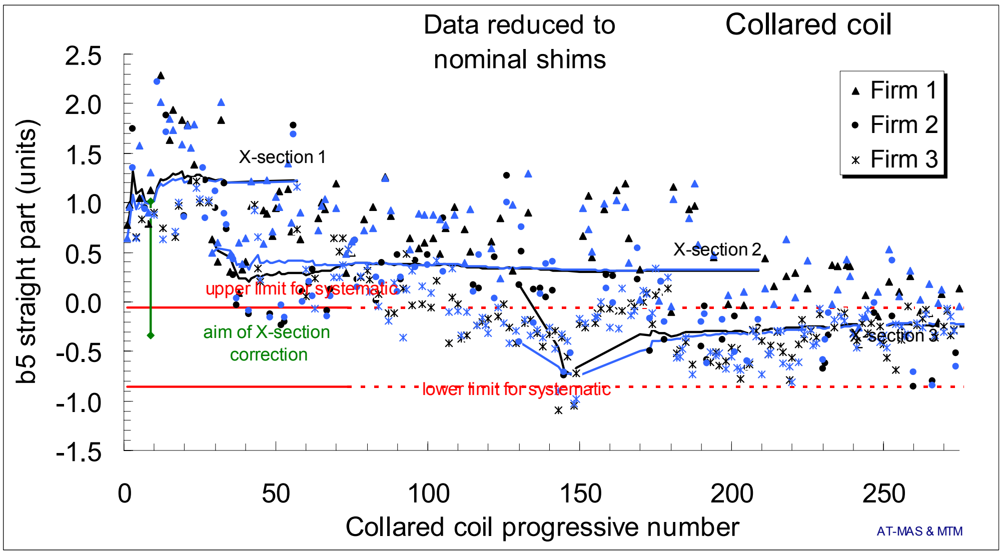


Fig. 23: Average b_5 in the straight part of the collared coil (black dots: aperture 1, blue dots: aperture 2), best estimate for systematic (solid lines), and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles. Data are reduced to nominal shims and separated according to different cross-sections.

8.3 Normal 14-th pole

- The introduction of cross-section 3 reduced b_7 of 0.22 units in Firm2, of 0.12 units in Firm1, but had no effect in Firm3. This anomaly in Firm3 is mainly due to a positive trend of b_7 in X-section 2 *see Fig. 24, from 100th to 180th) the effect of the correction is smaller than expected.
- Firm2 has a very low average b_7 (0.75 units, i.e. 0.35 units less than Firm1 and Firm3), as it is observed in cross-section 2: this is one of the few cases where a non-negligible difference between Firms is observed.
- Cryodipoles with the cross-section 3 should feature 0.29 units of b_7 at injection. This would place b_7 above the target, but within the previous target of 0.30 units (see Fig. 31).

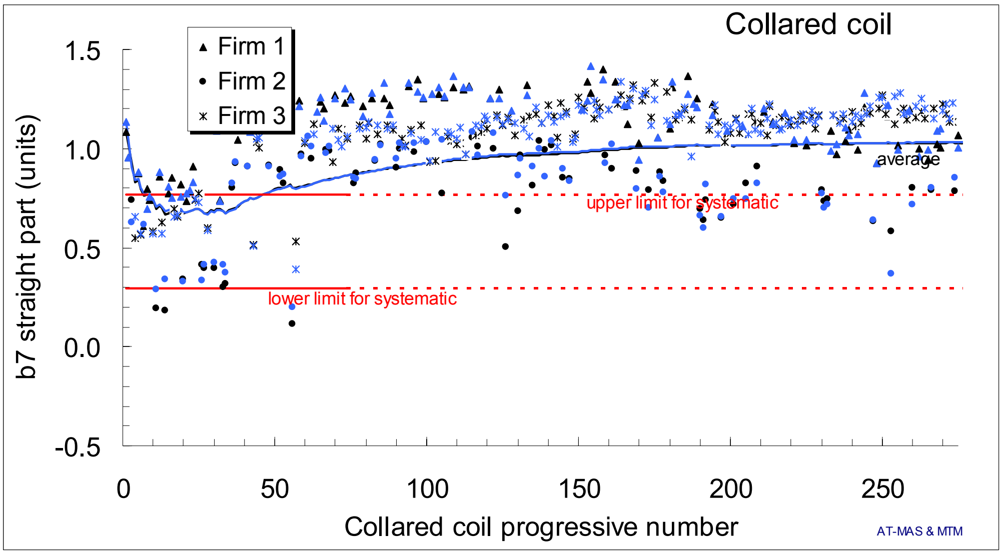


Fig. 24: Average b_7 in the straight part of the collared coils (black dots: aperture 1, blue dots: aperture 2), best estimate for systematic (solid lines), and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles.

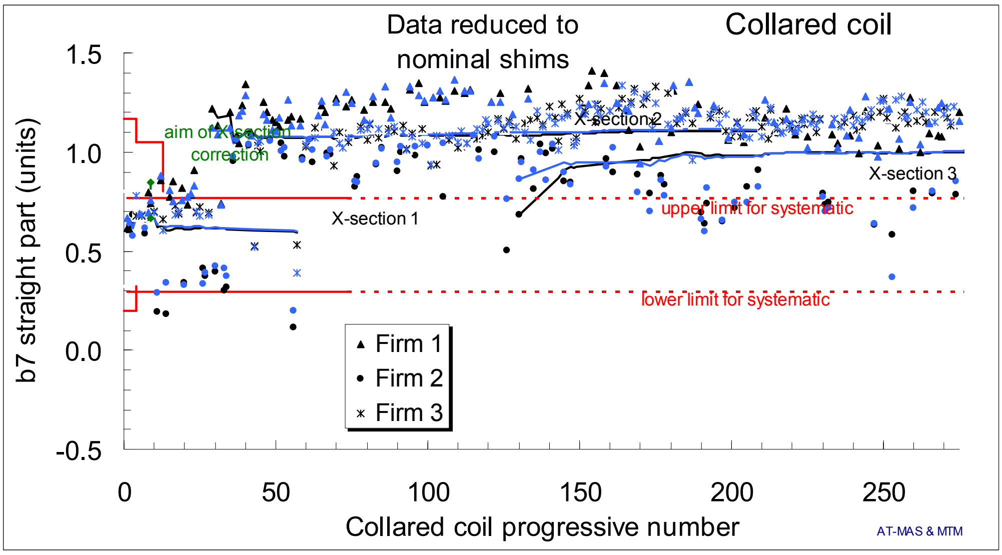


Fig. 25: Average b_7 in the straight part of the collared coils (black dots: aperture 1, blue dots: aperture 2), best estimate for systematic (solid lines), and beam dynamics limits for the systematic (red lines) based on correlations with 74 cryodipoles. Data are reduced to nominal shims and separated according to different cross-sections.

9. Random multipoles

Having 101 collared coils with X-section 3, we can assess for the first time the random component in this new baseline.

- The standard deviation of magnetic length, main field, bending strength, and multipoles are shown in Fig. 26. They are separated according to the three cross-sections. One can observe that cross-section 1 showed an important out of target in b_3 and b_5, whereas cross-section 2 and 3 are all within tolerances. Please note that these data are not reduced to nominal shims. In general, the spread in cross-section 3 is similar to the spread in cross-section 2.
- In cross-section 3, the spread in b_3 is of 1.4 units but goes down to 0.9 units when the contribution of non-nominal shims is taken out.

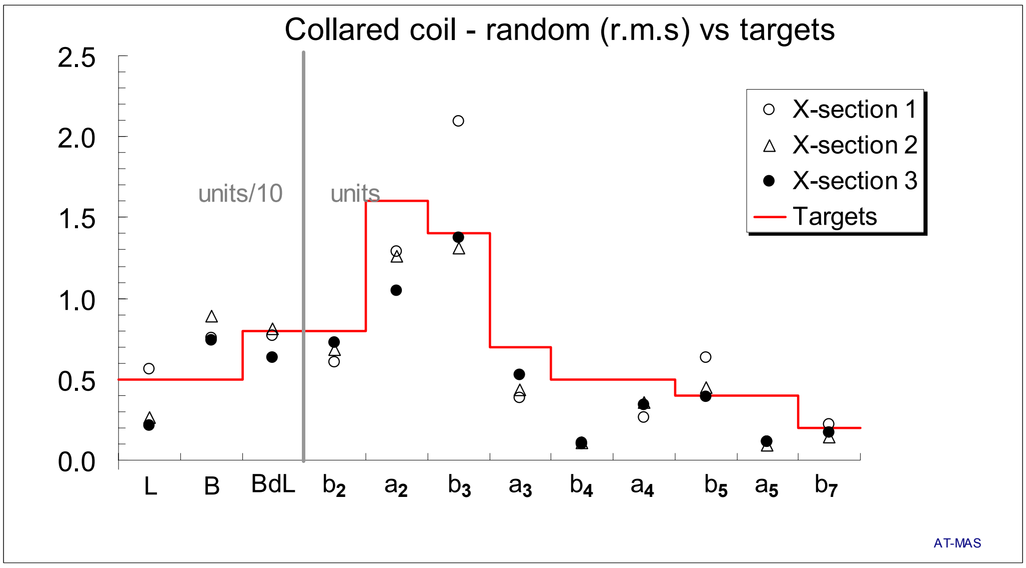


Fig. 26: Random component in the measured collared coils, separated according to different cross-sections.

- We give an estimate of the actual spread due to the geometric component in the first two arcs. We assume that the first arc is made up with X-section 1 and 2, and that the second arc is made up with cross-section 3 plus 20 magnets with X-section 2 of Firm3 (see Fig. 27). In the first arc, random b_3 is 2.1 units, and in the second arc is 1.9 units, due to the mixture of cross-sections and to non-nominal shims. These values are expected to be reduced by 18% when the yoke is assembled, and then one has to add the random components due to persistent currents (0.5 units). Summing in quadrature, one obtains 1.7 units in the second arc. This value should go down to 1 unit for the successive arcs if nominal shims are used and if no changes of cross-section are carried out, as expected.

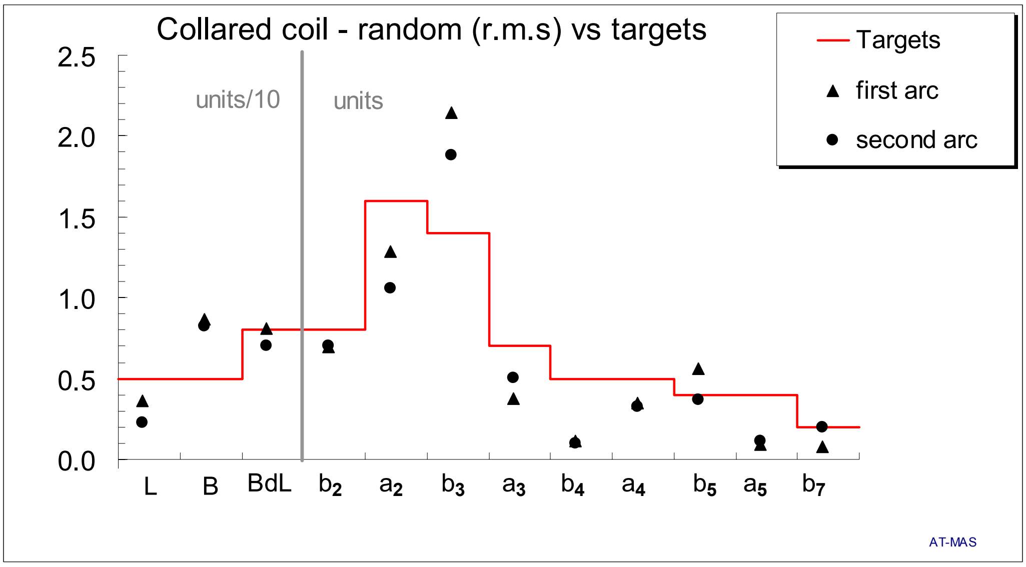


Fig. 27: Estimate of random component in the first and second arc **due to collared coils**.

10. Acknowledgements

Magnetic measurements have been taken through instrumentation of the AT-MTM-IF section, and are now performed by firm personnel. Measuring system developed by D. Cote, P. Galbraith, D. Giloteaux, V. Remondino, J. Billan. Data at 1.9 K have been taken and made available by the AT-MTM-OP and AT-MTM-AS sections. We wish to acknowledge L. Bottura, V. Chohan, L. Rossi, S. Sanfilippo, W. Scandale, for valuable help and discussions. Thanks to C. Vollinger, E. Wildner and V. Remondino for data analysis. We acknowledge P. Hagen and C. Vollinger for useful comments on the manuscript.

Appendix A: spread in bending strength

The spread in bending strength is mainly due to the spread in the transfer function, i.e., the main field in the straight part divided by the current. Indeed, the magnetic length has a very low spread (3 units) and therefore plays a less relevant role. The phenomenology of the data of collared coils and cold masses is now rather clear and is shown in Figs. 28 and 29.

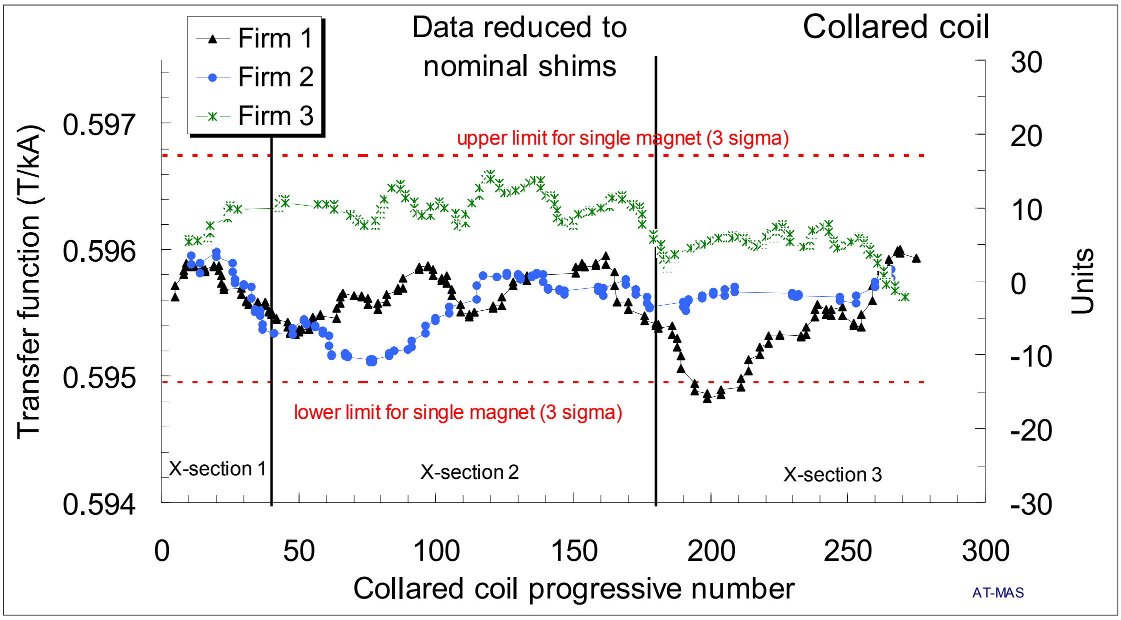


Fig. 28: Main field divided by current in the straight part of the collared coil. Moving averages of 5 collared coils are plotted for each manufacturer.

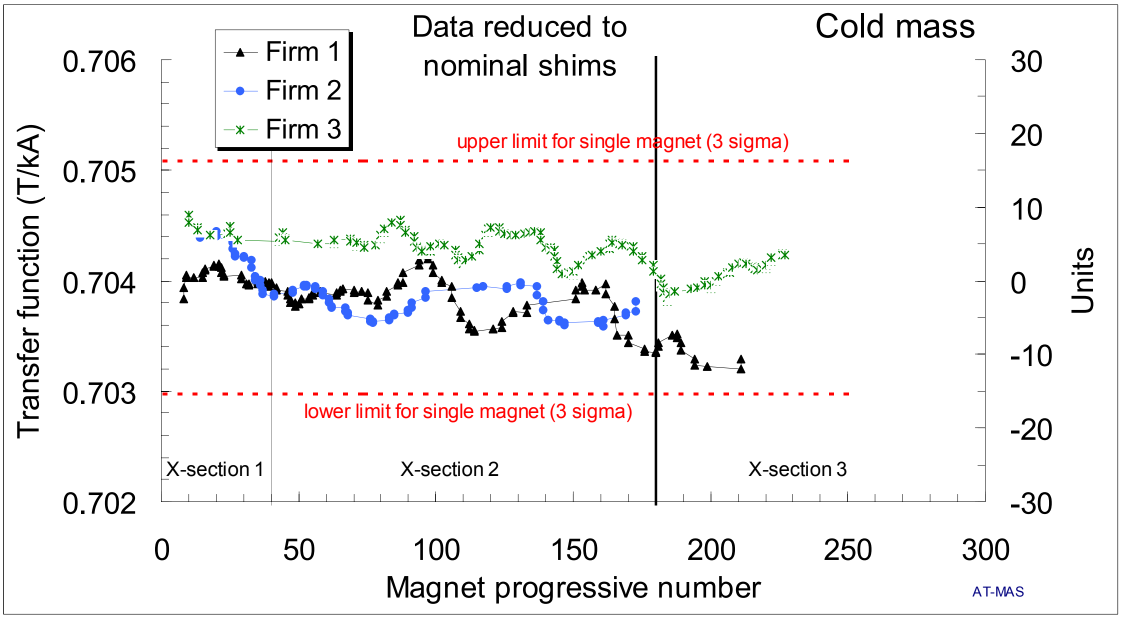
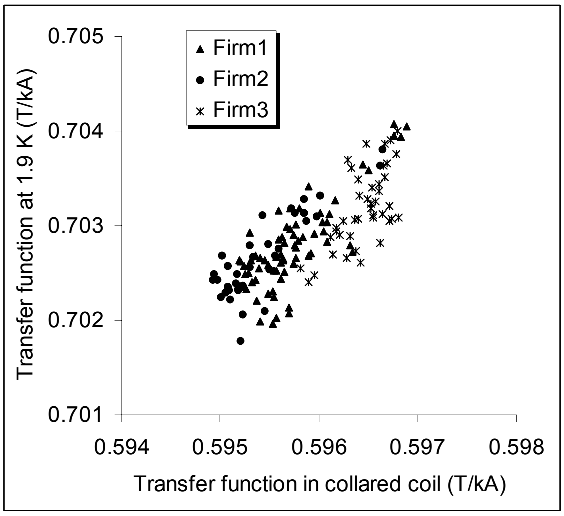


Fig. 29: Main field divided by current in the straight part of the cold mass. Moving averages of 5 cold masses are plotted for each manufacturer.

- In the collared coil (see Fig. 28), all Firms started producing very similar transfer functions, but soon after 20-30 coils a systematic difference of around 20 units between Firm3 and Firm1-2 has been observed. With the introduction of cross-section 3, the transfer function has decreased in Firm3 of around 5 units. In the more recent production, Firm3 is decreasing and Firm1 and Firm2 are increasing, so that the spread between Firms is now very low (less than 10 units).
- These patterns of trends are confirmed by the cold mass data (see Fig. 29). In particular, the fine structure of transfer function trends observed for collared coils is also seen in cold masses. This gives a very strong indication of a high precision of all measurement systems (at least 5 units), as shown during the calibration campaign in July 2003 by S. Pauletta.
- The only difference in the cold mass data is that Firm3 values are around 5 units lower than in the collared coil (see Fig. 28 and 29). This reduces the spread between firms observed in the production of collared coils 50th to 250th.
- Data at 1.9 K confirm the cold mass data: the standard deviation of the spread in the correlation with cold mass is 3 units (see Fig. 30, right). Indeed, collared coil data show as expected a worse correlation, with Firm3 values on the lower side (see Fig, 30, left).



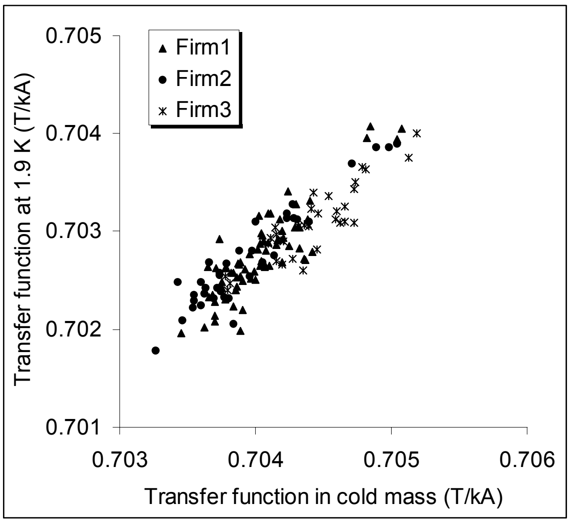


Fig. 30: Correlations between transfer function measured at 1.9 K at high field and measurements in collared coil (left) and in cold mass (right).

- Origins of these differences are not yet understood. Indeed, the order of magnitude of the errors necessary for getting these values is close to fabrication tolerances: 20 units of transfer function can be induced by a different coil radius of 60 micron only.

The conclusions are the followings:

- Our set of data is consistent, both at room temperature and at 1.9 K.
- Trends in transfer function are changing along the production and therefore have to be continuously monitored. In particular, one should verify if the lower increase of the transfer function at Firm3 is confirmed also for cross-section 3.
- The overall spread in integrated transfer function is within targets and no correction through the addition of ferromagnetic laminations is needed.

Appendix B: systematic a4 in Firm2

The measurements of a_4 in Firm2 are plotted in Fig. 31. We also plot a moving average of this multipole over 5 collared coils (i.e., 10 apertures). One can observe that a_4 has always been positive in Firm2, and that the value has drifted from an average of 0.2-0.3 units up to 0.5 units in the more recent months (collared coils 120th to 200th). The production of the last two months is showing a lower average (between 0.2 and 0.3 units). A crisis meeting has been held with Project Engineers; we summarize here the results of the discussion, that can be found in http://lhc-div-mms.web.cern.ch/lhc-div-mms/MMSPAGES/MA/a4_firm2.html

- The large a_4 values are not due to X-section 3, since they are observed also in collared coils of X-section 2. Moreover, collared coils with X-section 3 of the other Firms do not show this problem.
- The large a_4 values are also observed at 1.9 K.
- No correlation is found with a_2: therefore, the coil displacement necessary to give such a large a_4 is not a simple shift of the coil midplane.
- It seems improbable that such a multipole is due to asymmetries in the coil dimensions, since in Firm2 no rule is used for selecting upper and lower poles. The multipole should be generated during the process of coil assembly or during the collaring.

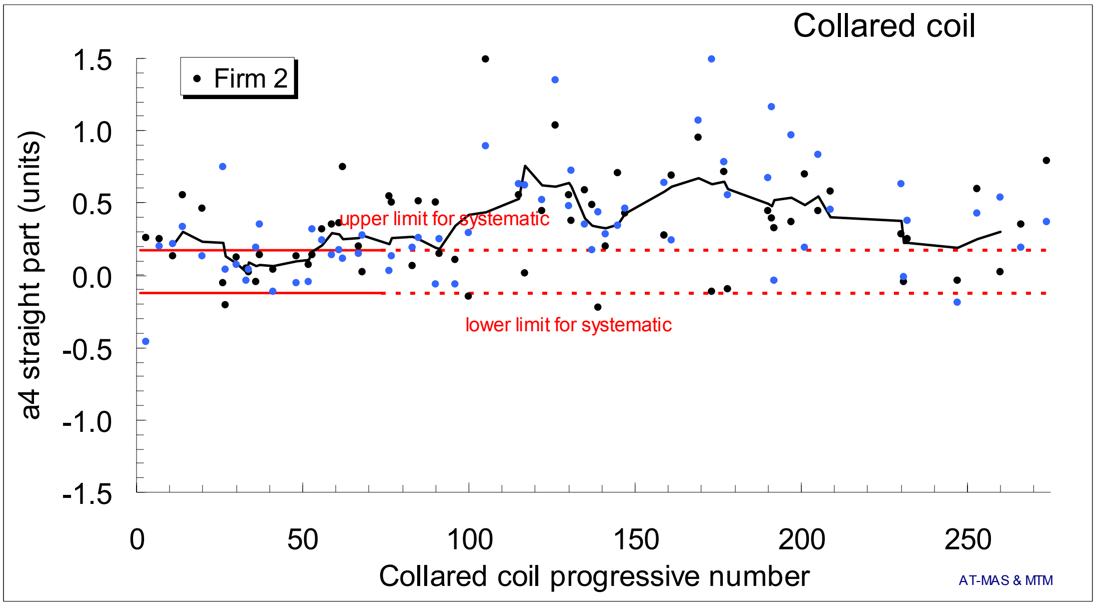


Fig. 31: Measured a_4 in the straight part of the collared coil in Firm2 (dots), and moving average over 5 collared coils (10 apertures, solid line)

Appendix C: collared coil assembly data

Table I: Magnet number, collared coil progressive number used in all figures, and cross-section type (data available on January 30 2004).

magnet	cc number	X-section
1001	1	1
1002	2	1
1003	5	1
1004	8	1
1005	9	1
1006	12	1
1007	15	1
1008	16	1
1009	19	1
1010	21	1
1011	22	1
1012	23	1
1013	29	2
1014	31	2
1015	32	1
1016	35	2
1017	38	2
1018	39	2
1019	40	2
1020	64	2
1021	42	2
1022	47	2
1023	49	2
1024	50	2
1025	51	2
1026	46	2
1027	54	2
1028	55	2
1029	58	2
1030	65	2
1031	66	2
1032	70	2
1033	73	2
1034	75	2
1035	79	2
1036	82	2
1037	86	2
1038	88	2
1039	97	2
1040	102	2
1041	99	2
1042	106	2
1043	186	2
1044	121	2
1045	94	2
1046	104	2
1047	109	2
1048	158	2
1049	112	2
1050	114	2
1051	154	2
1052	124	2
1053	153	2
1054	162	2
1055	133	2
1056	181	2
1057	128	2
1058	165	2
1059	151	2
1060	166	2
1061	170	3
1062	188	2
1063	176	3
1064	180	3
1065	242	3
1066	189	2
1067	211	3
1068	194	2
1069	204	3
1070	199	3

magnet	cc number	X-section
1071	214	3
1072	238	3
1073	239	3
1074	218	3
1075	221	3
1076	248	3
1077	225	3
1078	235	3
1079	233	3
1081	244	3
1082	252	3
1083	259	3
1084	255	3
1085	262	3
1086	265	3
1087	268	3
1088	269	3
1089	275	3
1090	277	3
1091	279	3
1092	278	3
1093	287	3
1094	290	3
1095	291	3
1096	298	3

magnet	cc number	X-section
2001	3	1
2002	11	1
2003	7	1
2004	20	1
2005	14	1
2006	30	1
2007	27	1
2008	26	1
2009	34	1
2010	33	1
2011	56	1
2012	37	2
2013	36	2
2014	41	2
2015	61	2
2016	48	2
2017	52	2
2018	53	2
2019	59	2
2020	62	2
2021	67	2
2022	68	2
2023	76	2
2024	126	2
2025	77	2
2026	83	2
2027	85	2
2028	90	2
2029	91	2
2030	96	2
2031	100	2
2032	105	2
2033	131	2
2034	117	2
2035	130	3
2036	115	2
2037	122	2
2038	137	2
2039	141	2
2040	145	3
2041	139	2
2042	135	2
2043	147	3
2044	159	2
2045	201	3
2046	253	3
2047	232	3
2048	161	2
2049	190	3
2050	177	2
2051	247	3
2052	169	2
2053	178	3
2054	173	3
2055	191	3
2056	209	2
2057	192	3
2058	197	3
2059	231	3
2060	260	3
2061	205	3
2062	230	3
2063	289	3
2064	266	3
2066	274	3
2069	293	3
2072	276	3
2073	297	3

magnet	cc number	X-section
3001	4	1
3002	6	1
3003	10	1
3004	13	1
3005	17	1
3006	18	1
3007	24	1
3008	25	1
3009	28	1
3010	57	1
3011	43	1
3012	44	2
3013	45	2
3014	60	2
3015	63	2
3016	69	2
3017	72	2
3018	71	2
3019	74	2
3020	80	2
3021	78	2
3022	81	2
3023	84	2
3024	87	2
3025	89	2
3026	108	2
3027	92	2
3028	93	2
3029	95	2
3030	98	2
3031	202	3
3032	203	3
3033	206	3
3034	101	2
3036	103	2
3037	107	2
3038	111	2
3039	113	2
3040	187	3
3041	110	2
3042	116	2
3043	119	2
3044	118	2
3045	120	2
3046	123	2
3047	125	2
3048	127	2
3049	129	2
3050	132	2
3051	134	2
3052	136	2
3053	138	2
3054	140	2
3055	142	2
3056	143	3
3057	144	2
3058	146	2
3059	148	3
3060	149	3
3061	150	2
3062	152	2
3063	155	2
3064	156	2
3065	157	2
3066	160	2
3068	163	2
3069	164	2
3070	167	2
3071	179	2
3072	168	2

magnet	cc number	X-section
3073	171	2
3074	172	2
3075	174	3
3076	175	2
3077	200	3
3078	184	3
3079	183	3
3080	182	3
3081	195	3
3082	213	3
3083	185	3
3084	193	3
3085	196	3
3086	198	3
3087	207	3
3088	208	3
3089	210	3
3090	212	3
3091	215	3
3092	216	3
3093	217	3
3094	219	3
3095	220	3
3096	222	3
3097	224	3
3098	223	3
3099	226	3
3100	227	3
3101	228	3
3103	229	3
3104	234	3
3105	236	3
3106	237	3
3107	240	3
3108	241	3
3109	243	3
3110	245	3
3111	246	3
3112	249	3
3113	250	3
3114	251	3
3115	254	3
3116	256	3
3117	257	3
3118	258	3
3119	261	3
3120	263	3
3121	264	3
3122	267	3
3123	273	3
3124	272	3
3125	270	3
3126	271	3
3127	280	3
3128	281	3
3129	282	3
3130	283	3
3131	284	3
3132	285	3
3133	286	3
3134	288	3
3135	295	3
3136	292	3
3137	296	3
3138	293	3
3140	294	3