Magnets and Superconductors Group
AT-MAS

September 2005
Internal Note 2005-0x

Study of magnets transported using new transport restraints

Deleted: the movements of the end covers of the dipole cold mass WP08-WP09

J. Beauquis, N. Emelianenko, E. D. Fernandez Cano, F. Seyvet, E. Wildner

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Abstract

A study has been made on 19 cryodipoles equipped with a new type of transport restraints to replace the presently used large aluminium restraints. The last complete measurement of the cold mass geometry is made after blockage of the central support and after cold test and final adjustment of the support (Included in Work Package 8, WP08, in the CERN work flow). After finalization of the cryostated dipole, a final cartography of the extremities is made (WP09). Between those measurements the magnet has been transported using transport restraints. By comparing the position of the cold mass extremities in the two measurements we are able to see if the magnet is stable in the cryostat. All measurements are made by (TS/SU).

Distribution:

Lucio Rossi, Jean-Pierre Koutchouk, Alan Poncet, Ph. Lebrun, Davide Tommasini, Jerome Beauquis, Natalia Emelianenko, Elena Wildner, Walter Scandale, Fabien Seyvet, Bernard Jeanneret, Elena Delia Fernandez Cano, Marta +++…..etc

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Magnets equipped with new supports, overview of the results

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A study has been made on a set of 19 cryodipoles equipped with the new yellow restraints to be used for transports. The yellow transport restraints substitute the big aluminium transport restraints used in the past, see Fig. 1. A set of three is located at each cryodipole extremity, and they connect the cryostat to the cold mass, reducing unwanted displacements during transport which could damage the cryodipole supporting system (GFRE support posts).

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The stability of the new restraints has been compared with those from production. The results of the study will be used for validation of the use of the new transport restraints. We have studied the movement of the end-covers between the last complete fiducialization at Work Package 8 (WP08) and the end cartography at Work Package 9 (WP09). Between those measurements the magnet has been transported using restraints.

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The different acceleration values obtained from the shock-log data during transport between SMA18 and SMI2 of these 19 cryodipoles have been taken into account.

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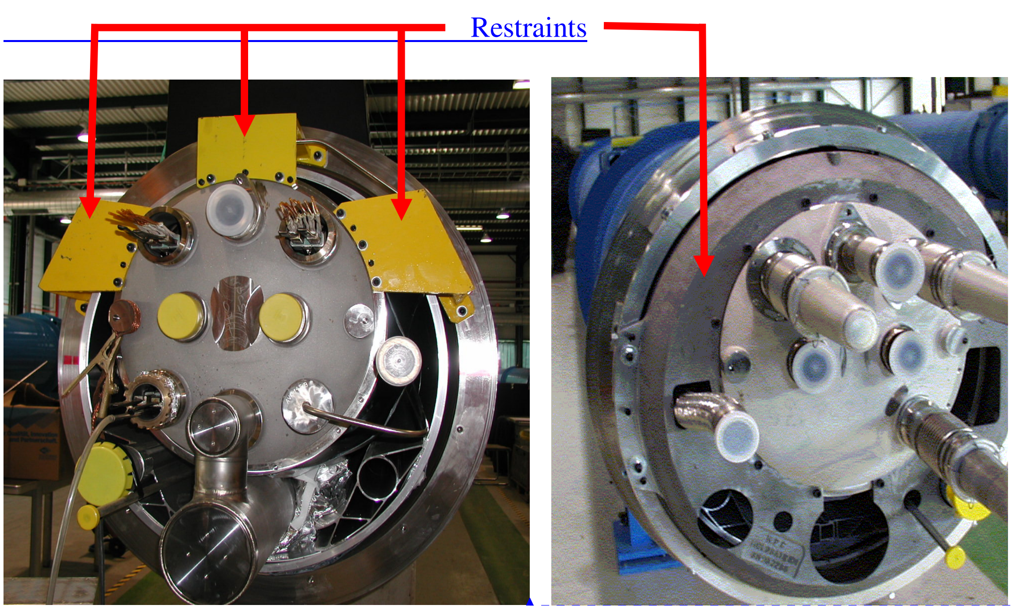

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Fig. 1: Cryodipoles equipped with the new yellow transport restraints, left, and with the former aluminium transport restraints, right.

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From the study cannot detect any statistically different behaviour for the 19 magnets with the new restraints and for the magnets transported with the old ones, neither in the transverse plane nor longitudinally. We have also looked at magnets individually.

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For all magnets, there is a small positive bias in the x-direction (outwards w.r.t. the LHC machine) and in the longitudinal direction (clockwise w.r.t. the LHC machine).

Effects from the data treatments necessary for the comparison of the measurement data from WP08 and WP09 add errors to the data. Differential contraction of the cryostat and the cold mass may explain the movement of the cold mass with respect to the cold mass ends. This is true for all cryodipoles, not only for the magnets with the new reastraints.

We could not detect any correlation between the magnets with special transport supports with large movements and the data from the shock-log.

A check that effects from storage time do not influence the results has also been made.

An overview of the movement of the end covers for the transverse plane is shown in table 1. In table 2 we show the situation for the longitudinal movement of the centre of the cold mass between the last fiducialization and the end cartography.

The set of magnets is shown in Table 3. The table contains also test dates, the way the magnet was adjusted (statistical adjustment or adjustment to the shape the magnet had in industry as measured at the Inspection and Test Plan step 20, itp20) and geometry class at CERN Work Package 8, WP08.

For details of the study see the annex.

We recommend however that all longitudinal movements larger that 0.5 mm should be signalled to F. Seyvet, B. Jeanneret and E. Wildner. The action is proposed to be made by the measurement team.

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Table 1. Summary, movement in transverse plane: Comparison between the whole production, magnets from special set excluded, and special set with new restraints

Feature	*Side*	*All production*		*Special set*	
		Average	*St.dev.*	*Average*	*St.dev.*
Number			388		19
Movement in x	Connection	0.11	0.19	0.16	0.22
	Lyre	0.06	0.16	0.02	0.17
Movement in z	Connection	-0.01	0.12	-0.08	0.11
	Lyre	0.00	0.13	-0.02	0.09
Rotation	Connection	0.05	0.18	0.16	0.17
	Lyre	0.01	0.13	0.06	0.17

Table 2. Summary, movement of the centre of the cold mass: Comparison between the whole production, magnets from special set excluded, and special set with new restraints

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Feature	*All production*		*Special set*	
	Average	*St.dev.*	*Average*	*St.dev.*
Number		388		19
Movement in y	0.11	0.22	0.18	0.21

Table 3. List of Magnets for the study

Magnet	Last step at WP08	Test date	Blockage status	Class at WP08	Passed WP09	Last step at WP09	Test date
1177	WP08-FID	28-Apr-05	itp20stat	silver right	29-Aug-05	WP09-WELD	29-Aug-05
1184	WP08-FID	29-Mar-05	itp20stat	golden	19-Jul-05	WP09-WELD	19-Jul-05
1186	WP08-FID	01-Mar-05	itp20stat	silver	25-Aug-05	WP09B-WELD	21-Sep-05
1206	WP08-FID	12-Apr-05	itp20stat	golden	31-Aug-05	WP09-WELD	31-Aug-05
1208	WP08-FID	19-Apr-05	itp20stat	silver	01-Sep-05	WP09-WELD	01-Sep-05
1210	WP08B-FID	11-Apr-05	itp20	silver	05-Sep-05	WP09-WELD	05-Sep-05
1226	WP08-FID	17-Jun-05	itp20stat	silver	25-Aug-05	WP09-WELD	25-Aug-05
2059	WP08C-FID	22-Jun-05	itp20	silver left right	28-Jun-05	WP09B-WELD	19-Jul-05
2137	WP08-FID	11-Mar-05	itp20stat	silver	19-Jul-05	WP09B-WELD	29-Jul-05
2147	WP08-FID	08-Mar-05	itp20stat	silver left right	05-Sep-05	WP09-WELD	05-Sep-05
2148	WP08-FID	07-Mar-05	itp20stat	silver	17-Aug-05	WP09D-WELD	21-Sep-05
2150	WP08-FID	09-Mar-05	itp20stat	silver	19-Jul-05	WP09B-WELD	26-Jul-05
2154	WP08-FID	21-Mar-05	itp20stat	silver	01-Sep-05	WP09-WELD	01-Sep-05
3065	WP08H-FID	04-Aug-05	itp20	golden	23-Aug-05	WP09-WELD	23-Aug-05
3177	WP08B-FID	11-Aug-05	itp20	silver	29-Aug-05	WP09-WELD	29-Aug-05
3187	WP08B-FID	08-Aug-05	itp20	golden	22-Aug-05	WP09B-WELD	20-Sep-05
3203	WP08B-FID	14-Jan-05	itp20	silver left right	25-Aug-05	WP09-WELD	25-Aug-05
3205	WP08B-FID	16-Aug-05	itp20	golden	30-Aug-05	WP09-WELD	30-Aug-05
3237	WP08B-FID	25-Nov-04	itp20	golden	29-Aug-05	WP09B-WELD	29-Aug-05
Total magnets: 19							

Acknolwedgements

We would like to thank Dominique Missiaen, Patrick Winkes and Monique Dupont (TS/SU) and their teams for the measurements on the geometry that we used for the study.

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Table 1. List of Magnets with special support checked in this study.¶
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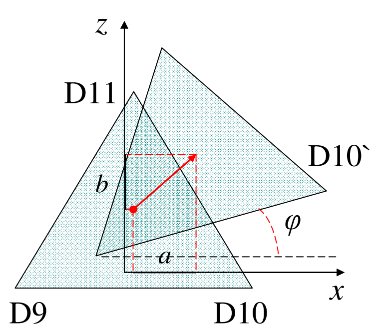
Annexe

Parameters used in the study

There are 3 reference points on the cold mass extremities, the "D-points" forming a triangle. These points are measured w.r.t. the Geometrical Axis (GA), the best fit of the measurements to the theoretical axis, in the horizontal and the vertical plane at WP08. At WP09 there is no measurement of the axis, so the calculation of the position of the D-point is made by a best fit of the fiducials of the two measurements. In this way the old GA is used to express the D-points with respect to this GA. All this treatment is done by the measurement procedures of TS/SU and the result is uploaded to the MAS database.

In this study we look at the barycentre of these 3 points. We have also looked at the longitudinal movement of the cold mass within the cryostat (movement with respect to fiducials).

In figure 1 we show the movements of the centre of the D-points and the corresponding changes in the x and z coordinates. The rotation is also defined.



Movement in the X and Z directions can be found from the equations:

$$x = a + x` \cos\varphi - z` \sin\varphi$$
$$z = b + x` \sin\varphi + z` \cos\varphi$$

Rotation:

$$\varphi = \mathrm{arctg}\,(z_{10}' - z_9') / (x_{10}' - x_9') - \mathrm{arctg}\,(z_{10} - z_9) / (x_{10} - x_9)$$

Figure 2. Definition of the movements in the x and the z directions.

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Transverse plane

Table 4. End Covers Movement Summary: Whole Production, Magnets from Special Set Excluded

Feature	*Side*	*Total*		*Firm 1*		*Firm 2*		*Firm 3*	
		Average	*St.dev.*	*Average*	*St.dev.*	*Average*	*St.dev.*	*Average*	*St.dev.*
Whole Production									
Number			388		134		86		168
Movement in x	Connection	0.11	0.19	0.11	0.21	0.08	0.19	0.12	0.18
	Lyre	0.06	0.16	0.07	0.15	0.02	0.17	0.06	0.15
Movement in z	Connection	-0.01	0.12	-0.02	0.11	-0.01	0.17	-0.01	0.11
	Lyre	0.00	0.13	0.01	0.09	0.01	0.08	-0.01	0.16
Rotation	Connection	0.05	0.18	0.06	0.16	0.03	0.21	0.05	0.18
	Lyre	0.01	0.13	0.02	0.12	0.00	0.14	0.01	0.13

Table 5. End Covers Movement Summary: Magnets from Special Set

Feature	*Side*	*Total*		*Firm 1*		*Firm 2*		*Firm 3*	
		Average	*St.dev.*	*Average*	*St.dev.*	*Average*	*St.dev.*	*Average*	*St.dev.*
Special Set									
Number			19		7		6		6
Movement in x	Connection	0.16	0.22	0.12	0.26	0.18	0.21	0.17	0.22
	Lyre	0.02	0.17	-0.01	0.17	0.08	0.15	0.01	0.19
Movement in z	Connection	-0.08	0.11	-0.11	0.08	-0.13	0.09	0.02	0.09
	Lyre	-0.02	0.09	-0.03	0.09	-0.02	0.10	0.01	0.10
Rotation	Connection	0.16	0.17	0.17	0.08	0.24	0.22	0.05	0.13
	Lyre	0.06	0.17	0.03	0.12	0.13	0.17	0.04	0.21

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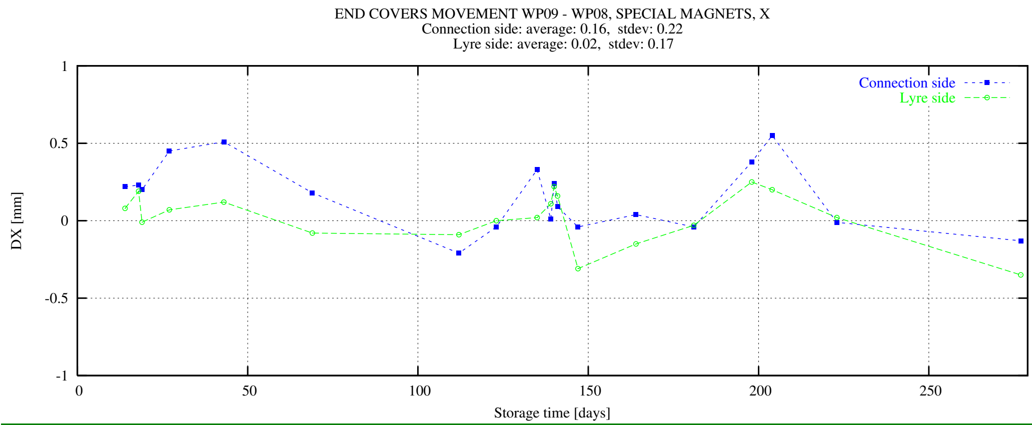

Figure 3. Check of storage time dependence, set of 19 magnets with new restraints, end cover movement x direction

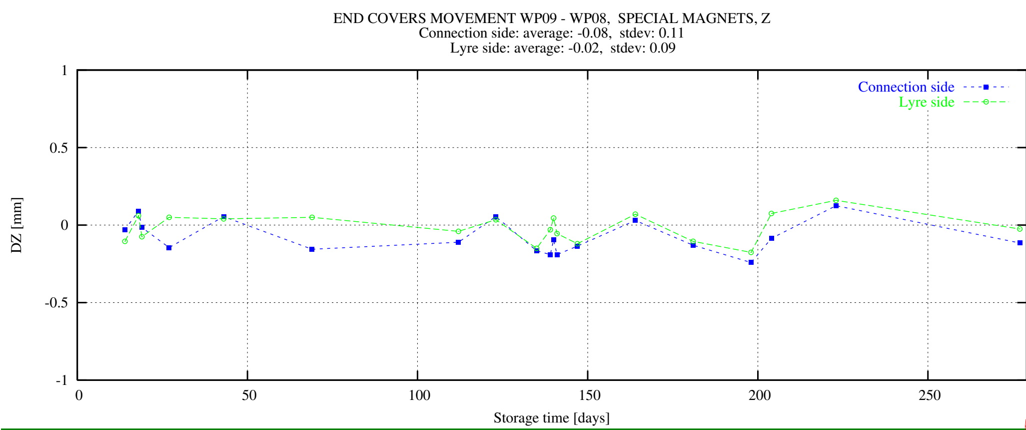

Figure 4. Check of storage time dependence, set of 19 magnets with new restraints, end cover movement z direction

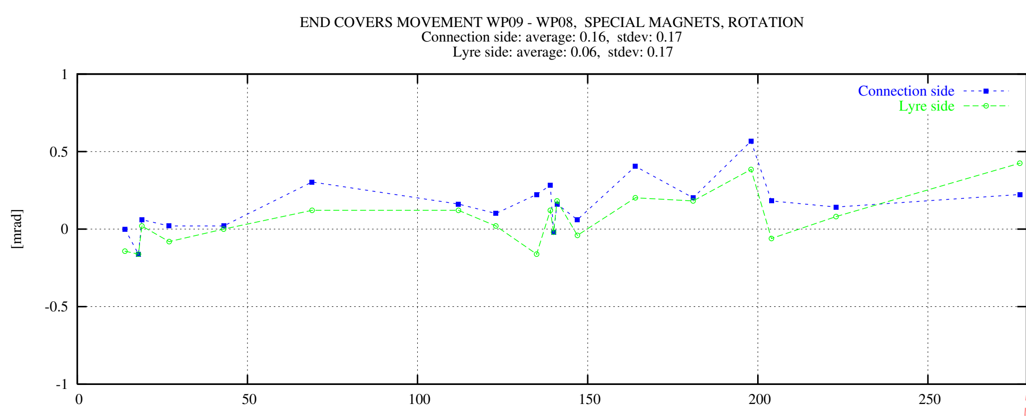

Figure 5. Check of storage time dependence, set of 19 magnets with new restraints, end cover rotation

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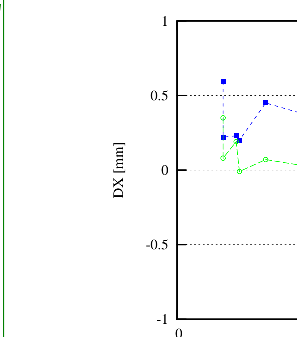

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Figure 3. Special Set Magnets. Movement in the x-direction.¶

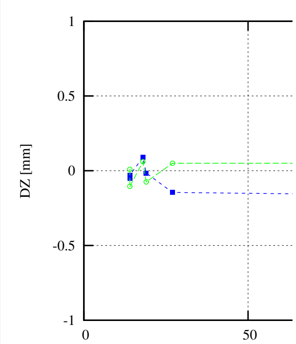

Figure 4. Special Set Magnets. Movement in the z-direc ... [17]

Figures 6 to 17 gives the summary (histograms) of the movements of the end cover centres for the special set and for the whole production excluding the special set. There is a small positive bias for the movements in the x-direction. This can maybe be the increase of sagitta continuing after blockage (cold tests and storage increases the sagitta). The special set and the whole production are very similar.

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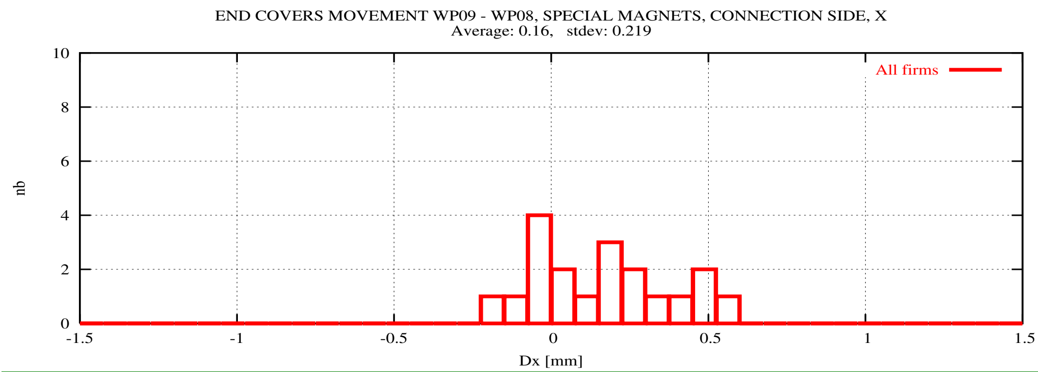

Figure 6. End Cover Movements in the x-direction for the 19 magnets : Connection Side

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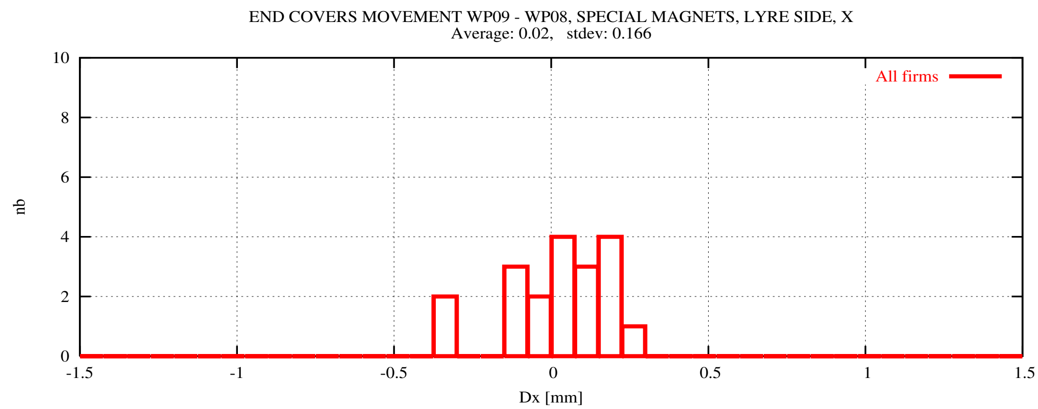

Figure 7. End Cover Movements in the x-direction for the 19 magnets : Lyra Side

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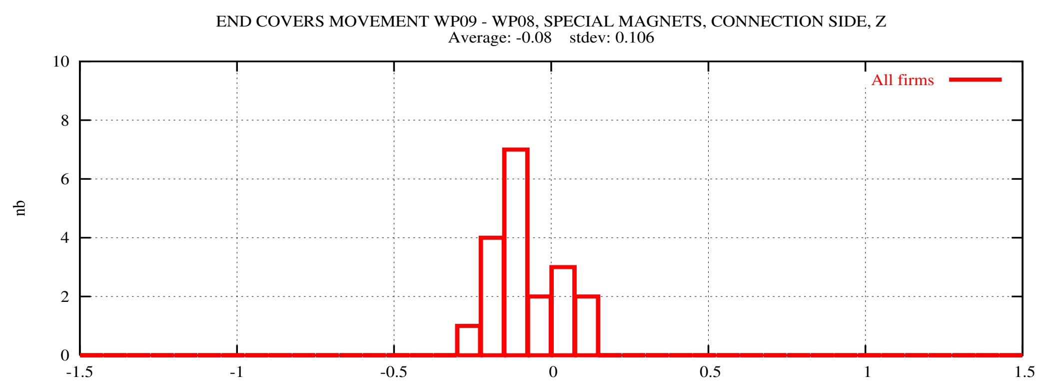

Figure 8. End Cover Movements in the z-direction for the 19 magnets:

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Connection Side

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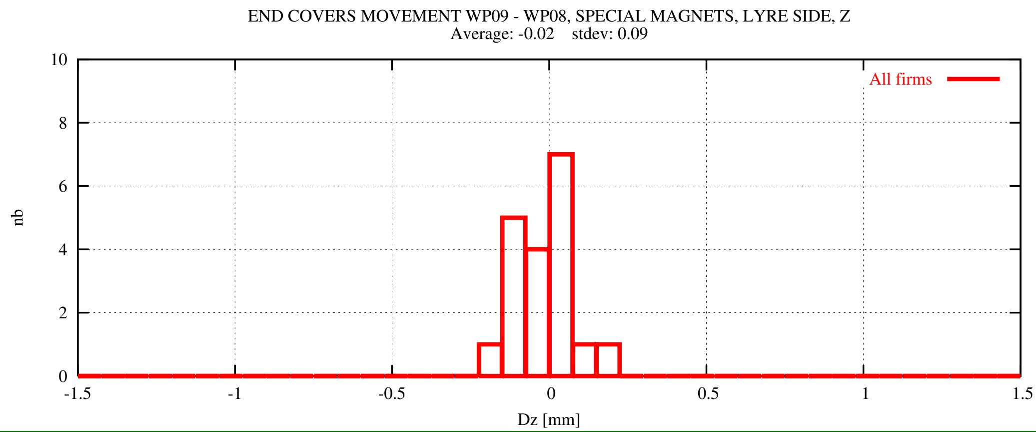

Figure 9. End Cover Movements in the z-direction for the 19 magnets : Lyra Side

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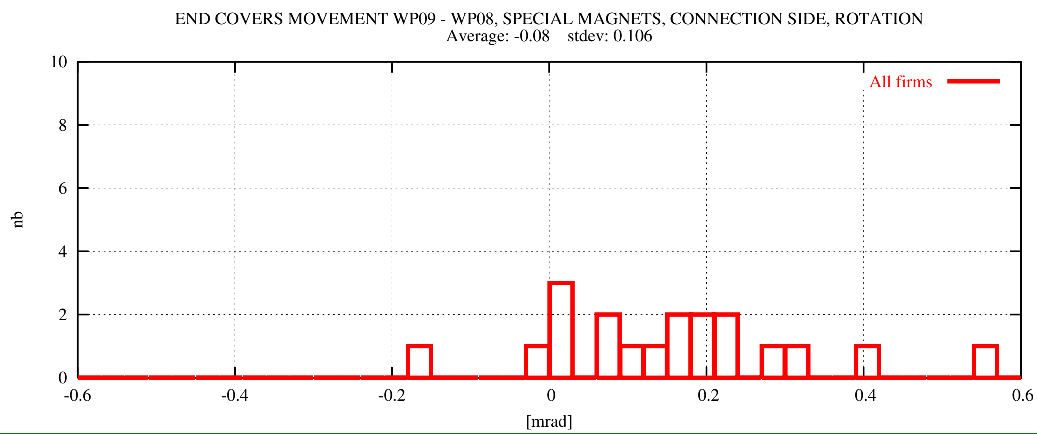

Figure 10. End Cover Rotation the 19 magnets : Connection Side

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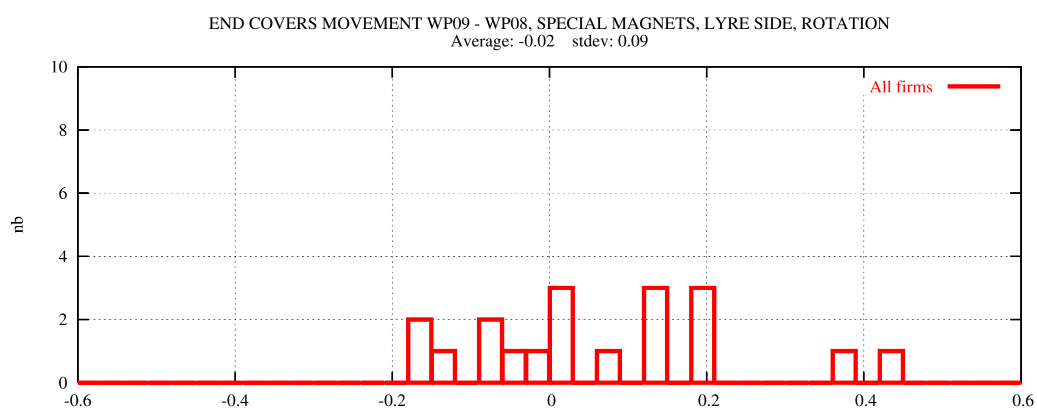

Figure 11. End Cover Rotation the 19 magnets : Lyra Side

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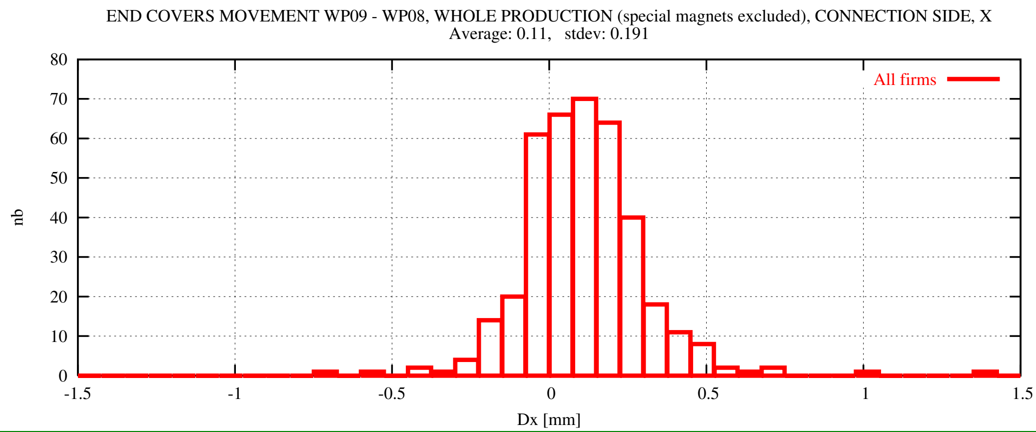

Figure 12. End Cover Movements in the x-direction for the whole production : Connection Side

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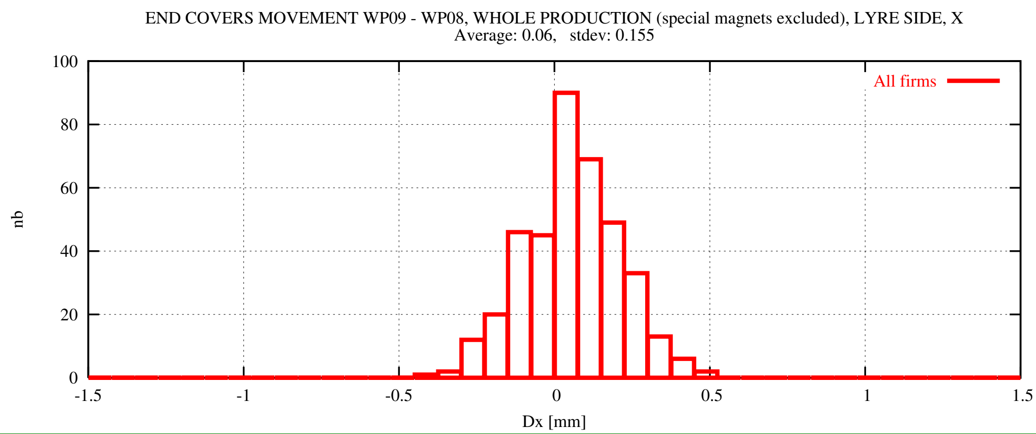

Figure 13. End Cover Movements in the x-direction for the whole production : Lyra Side

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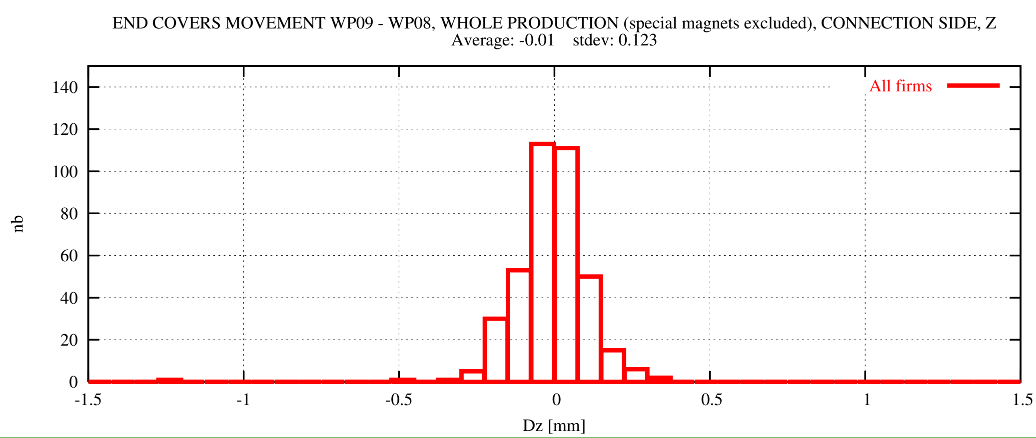

Figure 14. End Cover Movements in the z-direction for the whole production : Connection Side

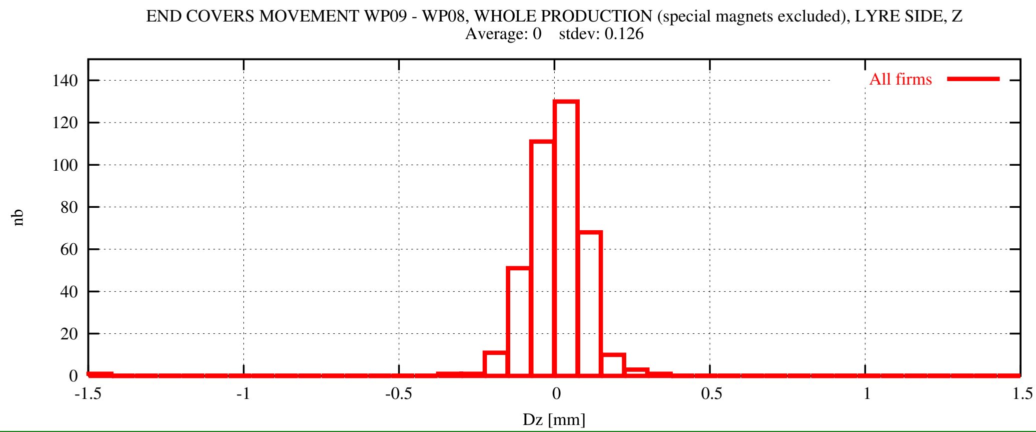

Figure 15. End Cover Movements in the z-direction for the whole production : Lyra Side

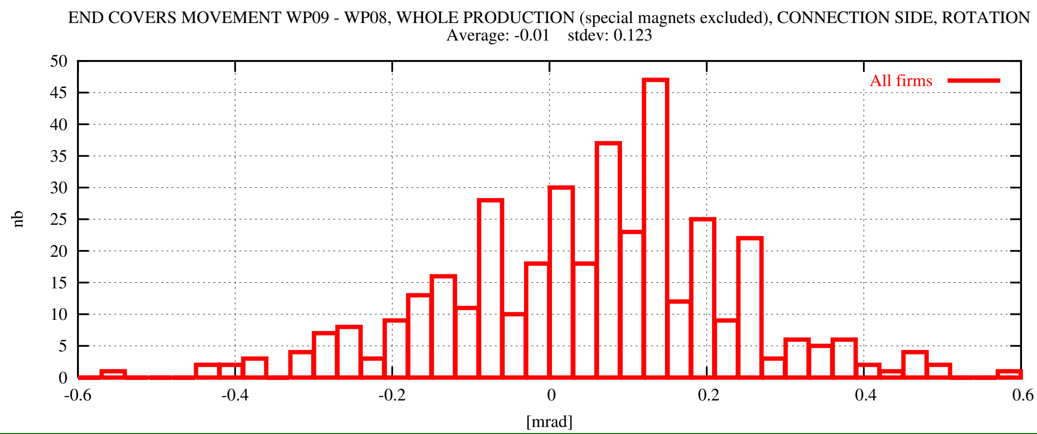

Figure 16. End Cover Rotation for the whole production : Connection Side

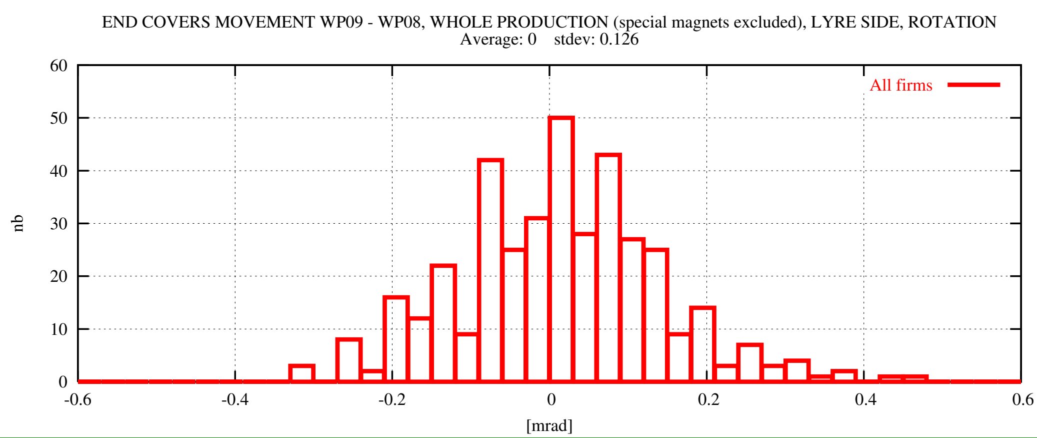

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Figure 17. End Cover Rotation for the whole production : Lyra Side

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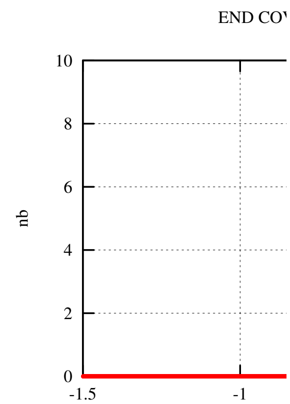

... [18]

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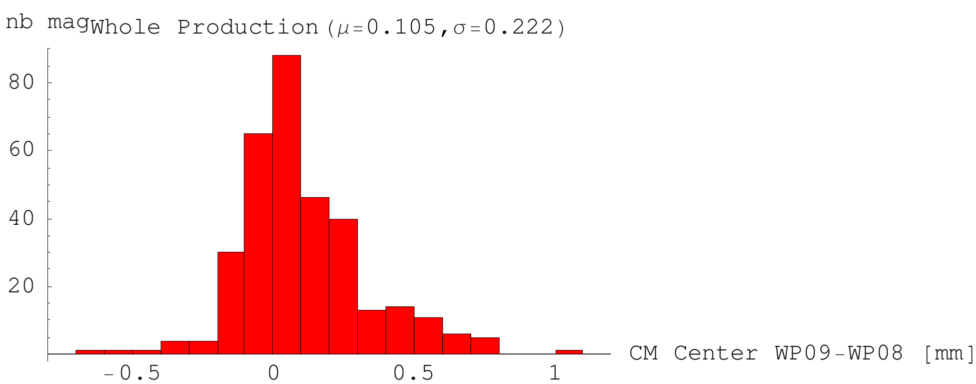
Longitudinal Plane

The longitudinal movement of the mid point of the magnet with respect to the fiducials is shown in figure 18.
The mid-point (centre) of the cold mass in the longitudinal direction is calculated by taking the mean of D-points' (D9, D10, D11) longitudinal position. We see that there is a slight movement towards the lyra side for both sets, the whole production (0.11mm) and the specially selected set with yellow supports (0.18 mm). This may be an artefact of the procedure of comparing the measurements: best fits of the fiducials favour the lyra side due to two fiducials versus one at the connection side []. We also subtract measurements and this introduces additional errors. Therefore we consider the 0.1 mm movement for the whole production and the additional movement of 0.06 mm as non significant. The spread in the longitudinal movement of the test set is smaller than for the whole production. The uncertainty of the mean is the standard deviation divided by the square root of the number of samples: for the whole production this gives 0.01 mm and for the special set 0.05 mm.



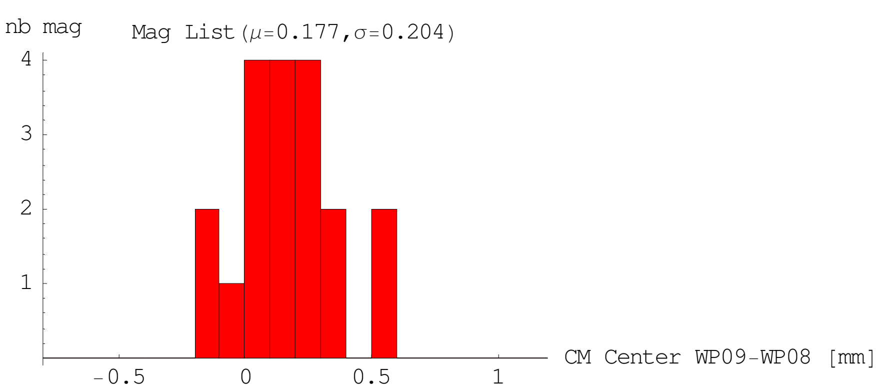


Figure 18. Displacement of the centre of the cold mass between WP08 and WP09.

A check of the cold mass length difference between the two work-packages has also been made, see figure 19. The cold mass length is expressed as the difference between end covers in the longitudinal position.

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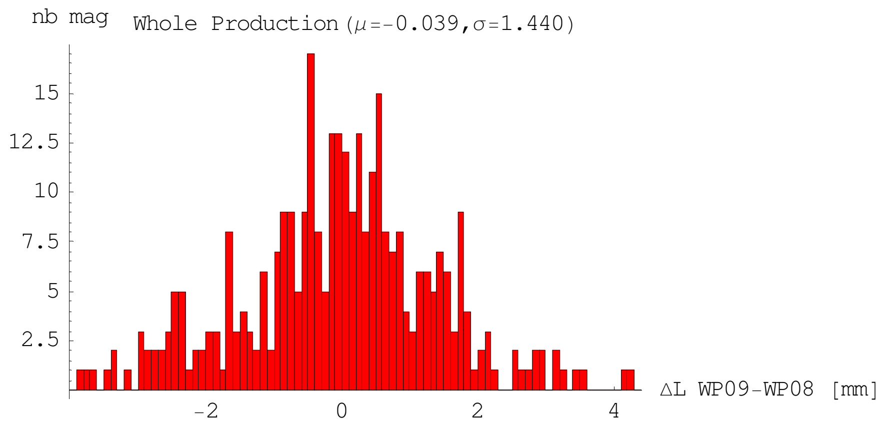

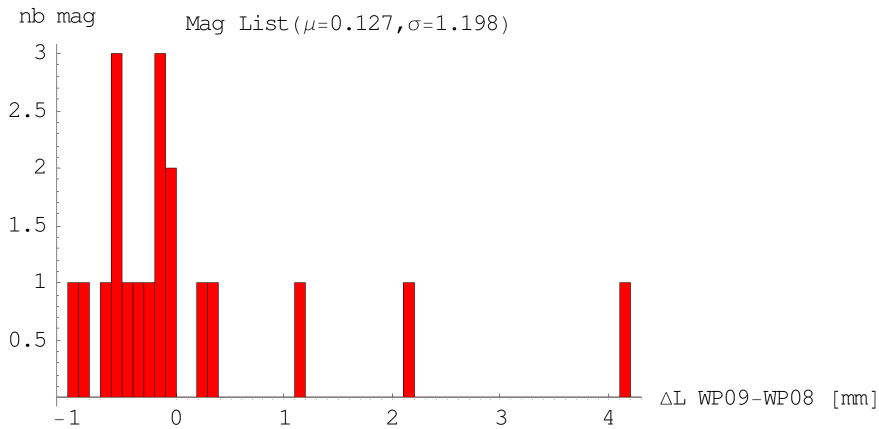

Figure 19. The change of the length of the cold mass between WP08 and WP09, whole production and special set.

For the whole production we see a distribution centred around 0.0 (the uncertainty in the mean value is 0.08 for the whole production and 0.28 for the 19 special magnets) with a spread (excursions up to ±4 mm) due to temperature effects: magnets are stored with different ambient temperature, which may explain the differences we see. The length of the magnets has been checked consistent with the length measured in industry [2]. We can compare with the tolerance for the length of the magnet in industry is ±2mm (at 20° C)

To check that there is no systematic shift of the centre of the cold mass with temperature we show the correlation between the cold mass length change and the cold mass centre movement in figures 20 and 21. The correlation is weak. This would mean that the small displacement (statistically) in the longitudinal plane is not due to a different systematic behaviour of the two sides due to a different temperature of the cold mass. We probably have temperature gradients along the magnet, so the check only means that we have not detected any dependence with temperature of the centre point.

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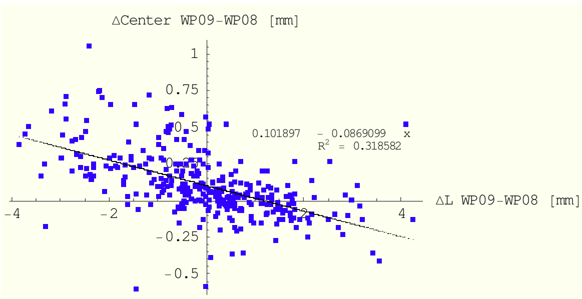

Figure 20. The correlation between the change in length and the change of the center position, whole production.

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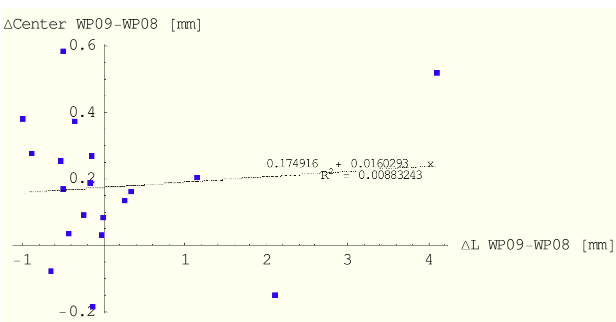

Figure 21. The correlation between the change in length and the change of the center position, special set.

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The variation of the cold mass length related to the longitudinal position of the end cover centre for the two sides is shown in figures 22 and 23. The fact that the relation is a factor 0.59 for connection side and 0.41 for lyre side is under discussion.

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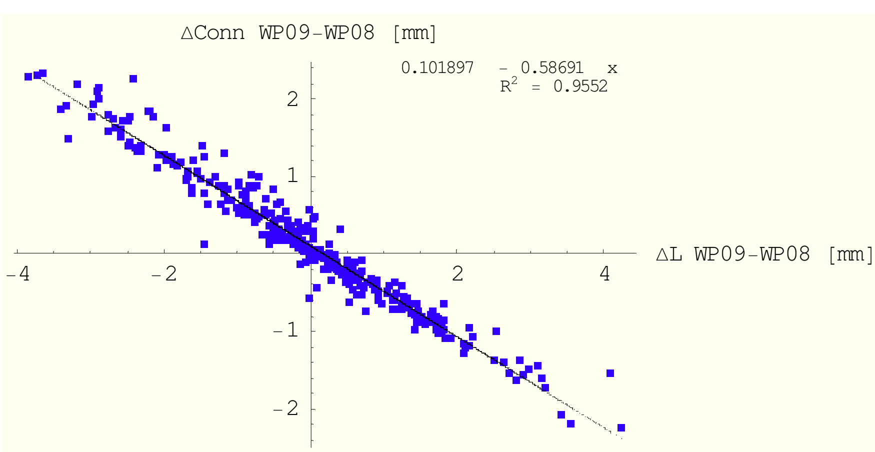

Figure 22. The correlation between the change in length and the change of the connection side position, whole production, special set excluded.

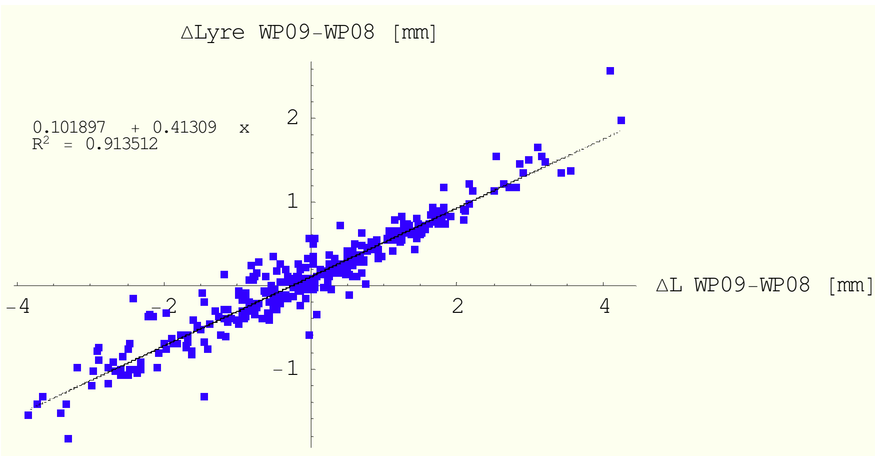

Figure 23. The correlation between the change in length and the change of the lyre side position, whole production, special set excluded.

In tables 6, 7 and 8 we give tables of the movements between WP08 and WP09 in the 3 directions, x, z (transverse) and y (longitudinal), together with the magnet numbers, the accelerometry and comments from the transport.

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Specific study of the magnets displaying significant longitudinal motion of the cold mass inside the cryostat

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A detailed study of table 6 shows that two magnets, 3203 and 3237, are identified with longitudinal displacement estimate (as defined previously) greater than 0.4 mm. This limit was arbitrarily set to perform a preliminary analysis. It should be noted that magnet 2148 displayed a longitudinal displacement of the cold mass inside the cryostat of 2.2 mm at the beginning of the study (before second WP09 measurement).

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These three cases have been studied in more detail.

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Case 1: 2148 (longitudinal movement estimated to 2.2 mm)

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This magnet was first measured on the 17^{th} of August 2005 and was re-measured on the 12^{th} Sep 2005. The first measurement led to a longitudinal motion of 2.2 mm of the cold mass inside its cryostat, which is significant and would actually be destructive for the cold mass supporting system. This disappeared at the 2^{nd} measurement (dy CM w.r.t. cryostat estimated as 0.37 mm), a measurement system error (hardware or software) or human error is expected to be the source of the surprising result of the first measurement.

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Case 2: 3203 (dy CM w.r.t. cryostat estimated as 0.5 mm)

The elongation of the cryostat was studied for this magnet. Indeed extremity fiducials on the cryostat have moved apart longitudinally by 0.65 mm between WP08 and WP09. The calculations of the cold mass flange (D points) movements between WP08 and WP09 are performed using a best fit on the four cryostat fiducials. This best fit does not take into account a half weight for the S and T fiducials; thus, such an elongation of the cryostat could lead to an artifact change of the position of the cold mass in the cryostat of 0.1 mm. From a longitudinal displacement estimate of 0.5 mm => 0.4 mm (within arbitrary limit).

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Furthermore, the dipole cold mass got significantly longer between WP08 and WP09 measurements. It can be concluded that the magnet was surely measured at WP08 when it was at a different and lower average temperature (either still a bit cold from SM18 cold test or just coming from outdoor storage during winter, on a cold day). Differential thermal contraction of the dipole cold mass (lyre vs. connection side) could explain as well the phenomenon observed.

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Case 3: 3237 (dy CM w.r.t. cryostat estimated as 0.6 mm)

There were two WP09 cartographies in the same day for this magnet. Analysis of the MTF WP09 files led to the conclusion that a horizontal screw of one transport restraint was not properly un-tightened before first measurement. In this case, the elongation of the cryostat between fiducials is 0.39 mm only; a corresponding artefact motion due to the best fit would remain around 0.05 mm.

Two phenomena could explain the observation; i) differential thermal contractions of the cold mass (lyre vs. connection sides) and ii) friction between the support posts and their centering pieces.

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A sample calculation is made below illustrating sensitivity of the result to the

differential thermal contraction effects. Assuming an average temperature on the connection side of the magnet 5 K below the average temperature on the lyra side (which is reasonable and realistic according to the standard storage conditions: cryomagnet under partial shadow, its orientation or incomplete warm-up before disconnection from cold test bench, etc.), this would lead to a longitudinal motion of the centre of mass of 0.26 mm, and a length reduction of the magnet of 0.5 mm (which is the case for this specific magnet).
=> This phenomenon would be fully sufficient to bring back this magnet within the 0.4 mm arbitrary limit.

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In conclusion to this specific sub-section,

1) There is no real worry or concern about small y-longitudinal movement of the cold mass w.r.t the cryostat (parameter estimated as defined previously to establish Table 6).
2) Out of the three magnets studied, a measurement artifact explains one case, the best fit computation and the differential thermal contraction of the cold mass (lyre vs. connection) realistically explain the other 2.
3) Sensitivity of the CM longitudinal displacement estimate to i) differential thermal contraction of the cold mass (Lyre vs. Connection) and ii) cryostat elongation have been preliminary studied.
4) We recommend to create a notification based on the CM longitudinal displacement estimate, but we should be made aware only of movements greater than 0.5 mm.

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References

[1] SU document
[2] D. Tommasini, Private communication

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Table 6. Summary: Magnet number, longitudinal displacement, accelerometry and comment

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#	Mag Nu	Center Y Mvt [mm]	Y g	Transport comment
1	1177	0.083	No Alarm	
2	1184	0.204	0.5	TBD with sheet transportation
3	1186	0.163	N/A	
4	1206	0.382	No Alarm	
5	1208	0.278	0.1	OK: Shock during transport + suspension (3HZ)
6	1210	0.255	0.2	OK
7	1226	0.033	No Alarm	
8	2059	0.133	0.2	OK
9	2137	0.189	0.1	OK
10	2147	0.17	N/A	
11	2148	0.374	0.4	OK
12	2150	0.271	0.6	TBD with sheet transportation
13	2154	-0.148	N/A	
14	3065	-0.075	No Alarm	
15	3177	0.035	N/A	
16	3187	0.093	0.6	OK
17	3203	0.52	No Alarm	
18	3205	-0.185	No Alarm	
19	3237	0.587	N/A	

Table 7. Summary: Magnet number, horizontal displacement, accelerometry and comment

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#	Mag Nu	EC conn X mvt [mm]	EC lyre X mvt [mm]	X g	Transport comment
1	1177	-0.03	0.055	No Alarm	
2	1184	-0.185	-0.11	0.9	TBD with sheet transportation
3	1186	0.28	0.065	N/A	
4	1206	0.105	-0.19	No Alarm	
5	1208	0.35	-0.165	0.3	OK: Shock during transport + suspension (3HZ)
6	1210	-0.03	-0.135	0.5	OK
7	1226	0.145	-0.155	No Alarm	
8	2059	0.425	-0.145	0.1	OK
9	2137	0.255	-0.095	0	OK
10	2147	-0.02	-0.13	N/A	
11	2148	-0.045	-0.195	0.1	OK
12	2150	0.03	-0.19	0.6	TBD with sheet transportation
13	2154	0.03	0.03	N/A	
14	3065	0.205	-0.015	No Alarm	
15	3177	0.225	0.09	N/A	
16	3187	0.575	-0.05	0.1	OK
17	3203	0.005	0.125	No Alarm	
18	3205	0.23	-0.03	No Alarm	
19	3237	-0.135	-0.115	N/A	

Table 8. Summary: Magnet number, vertical displacement, accelerometry and comment

#	Mag Nu	EC conn Z mvt [mm]	EC lyre Z mvt [mm]	Z g	Transport comment
1	1177	-0.01	0.035	No Alarm	
2	1184	-0.095	-0.04	1.1	TBD with sheet transportation
3	1186	0.195	0.02	N/A	
4	1206	0.14	-0.055	No Alarm	
5	1208	-0.02	-0.15	0.9	OK: Shock during transport + suspension (3HZ)
6	1210	-0.325	-0.12	0.2	OK
7	1226	-0.07	0.05	No Alarm	
8	2059	0.085	0.05	0.5	OK
9	2137	0.2	0.045	0.4	OK
10	2147	-0.06	-0.105	N/A	
11	2148	0.095	-0.17	0.6	OK
12	2150	0.075	-0.03	1.3	TBD with sheet transportation
13	2154	-0.175	0.07	N/A	
14	3065	-0.005	-0.075	No Alarm	
15	3177	0.185	0.06	N/A	
16	3187	0.38	0.01	0.6	OK
17	3203	0.005	0.16	No Alarm	
18	3205	0.075	-0.105	No Alarm	
19	3237	-0.385	-0.025	N/A	

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This statistical overview does not give any indication that the cold mass moves significantly with respect to the cryostat. There is a small positive bias in the x-direction (outwards w.r.t. the LHC machine) and in the longitudinal direction (clockwise w.r.t. the LHC machine).¶
Temperature effects may explain that the centre of the magnets have moved with respect to the ends. Effects from the beast fits used to compare measurements, the subtraction of measurement data add errors to the data. Differenti

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Deleted: al contraction of the cryostat and the cold mass may also influence the results. This is true for all cryodipoles, not only for the special test. The 19 selected magnets with "yellow" transport restraints behave similarly as the rest of the production. We could not detect any correlation between the magnets with special transport supports with large movements and the data from the shock-log.¶
We recommend however that all longitudinal movements larger that 0.5 mm should be signalled to F. Seyvet, B. Jeanneret and E. Wildner.

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We would like to thank Dominique Missiaen, Patrick Winkes and Monique Dupont (TS/SU) and their teams for the measurements on the geometry that we used for the study.

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Table 1. List of Magnets with special support checked in this study.

Magnet	Last step at WP08	Test date	Blockage status	Class at WP08	Passed WP09	Last step at WP09	Test date
2059	WP08C-FID	22-Jun-05	itp20	silver left right	28-Jun-05	WP09B-WELD	19-Jul-05
2137	WP08-FID	11-Mar-05	itp20stat	silver	19-Jul-05	WP09B-WELD	29-Jul-05
2150	WP08-FID	09-Mar-05	itp20stat	silver	19-Jul-05	WP09B-WELD	26-Jul-05
1184	WP08-FID	29-Mar-05	itp20stat	golden	19-Jul-05	WP09-WELD	19-Jul-05
2148	WP08-FID	07-Mar-05	itp20stat	silver	17-Aug-05	WP09B-WELD	17-Aug-05
3187	WP08B-FID	08-Aug-05	itp20	golden	22-Aug-05	WP09-WELD	22-Aug-05
3065	WP08H-FID	04-Aug-05	itp20	golden	23-Aug-05	WP09-WELD	23-Aug-05
1186	WP08-FID	01-Mar-05	itp20stat	silver	25-Aug-05	WP09-WELD	25-Aug-05
1226	WP08-FID	17-Jun-05	itp20stat	silver	25-Aug-05	WP09-WELD	25-Aug-05
3203	WP08B-FID	14-Jan-05	itp20	silver left right	25-Aug-05	WP09-WELD	25-Aug-05
1177	WP08-FID	28-Apr-05	itp20stat	silver right	29-Aug-05	WP09-WELD	29-Aug-05
3177	WP08B-FID	11-Aug-05	itp20	silver	29-Aug-05	WP09-WELD	29-Aug-05
3237	WP08B-FID	25-Nov-04	itp20	golden	29-Aug-05	WP09B-WELD	29-Aug-05
3205	WP08B-FID	16-Aug-05	itp20	golden	30-Aug-05	WP09-WELD	30-Aug-05
1206	WP08-FID	12-Apr-05	itp20stat	golden	31-Aug-05	WP09-WELD	31-Aug-05
1208	WP08-FID	19-Apr-05	itp20stat	silver	01-Sep-05	WP09-WELD	01-Sep-05
2154	WP08-FID	21-Mar-05	itp20stat	silver	01-Sep-05	WP09-WELD	01-Sep-05
2147	WP08-FID	08-Mar-05	itp20stat	silver left right	05-Sep-05	WP09-WELD	05-Sep-05
1210	WP08B-FID	11-Apr-05	itp20	silver	05-Sep-05	WP09-WELD	05-Sep-05
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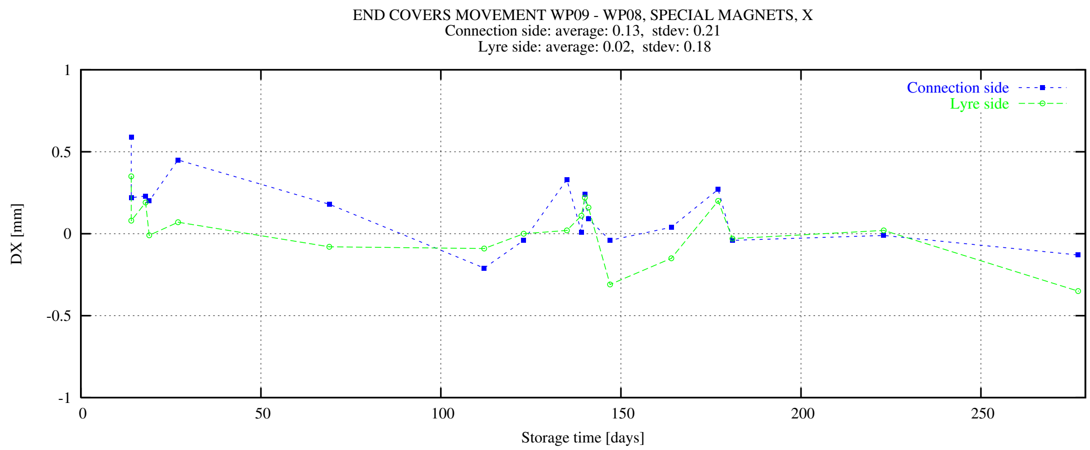

Figure 3. Special Set Magnets. Movement in the x-direction.

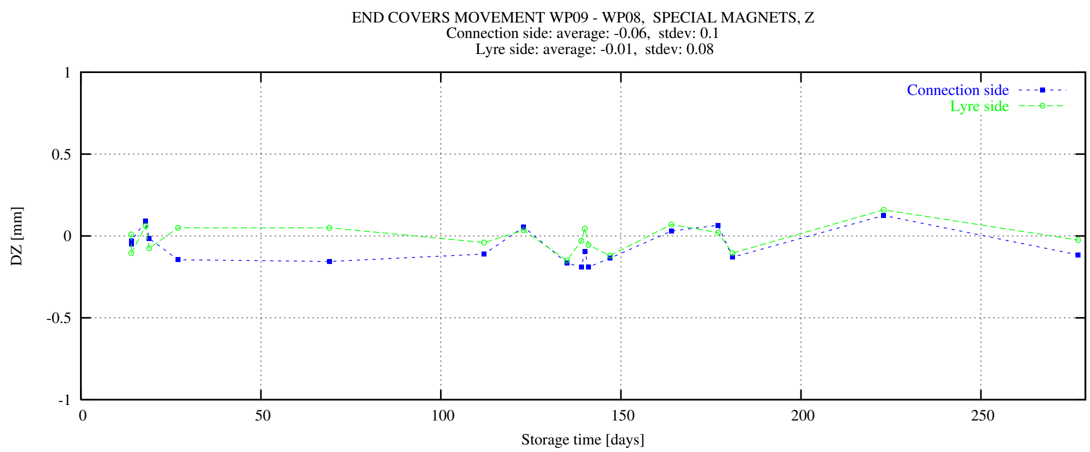

Figure 4. Special Set Magnets. Movement in the z-direction.

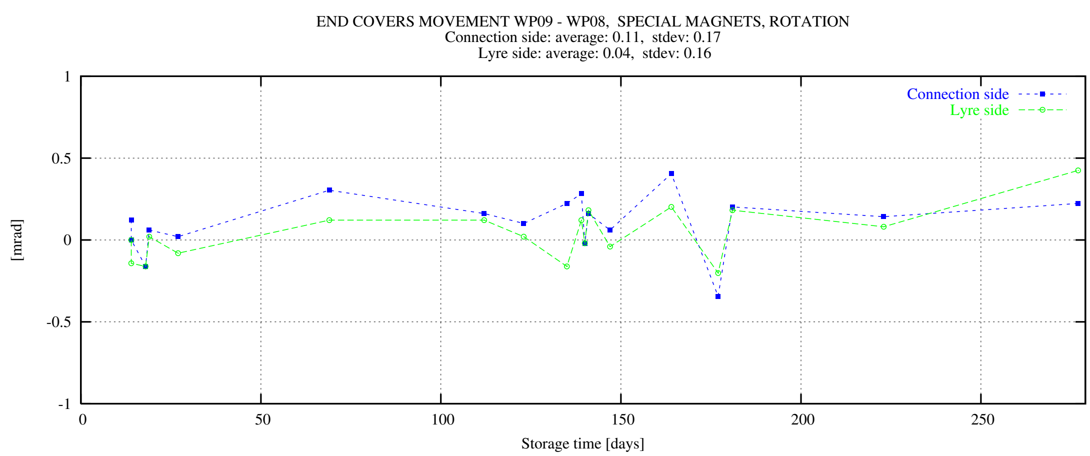

Figure 5. Special Set Magnets. Rotation

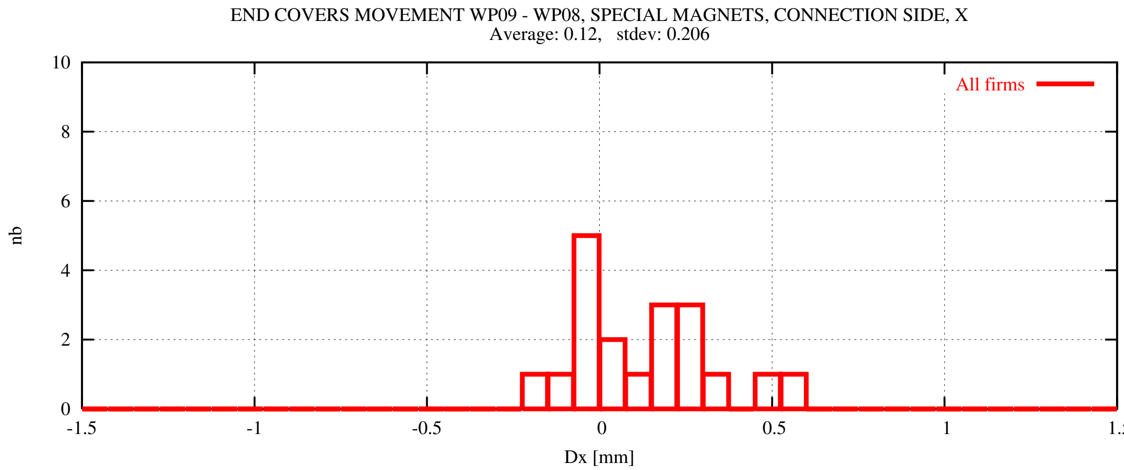

Figure 6. Special Set Magnets. Connection Side, Movement in the x-direction.

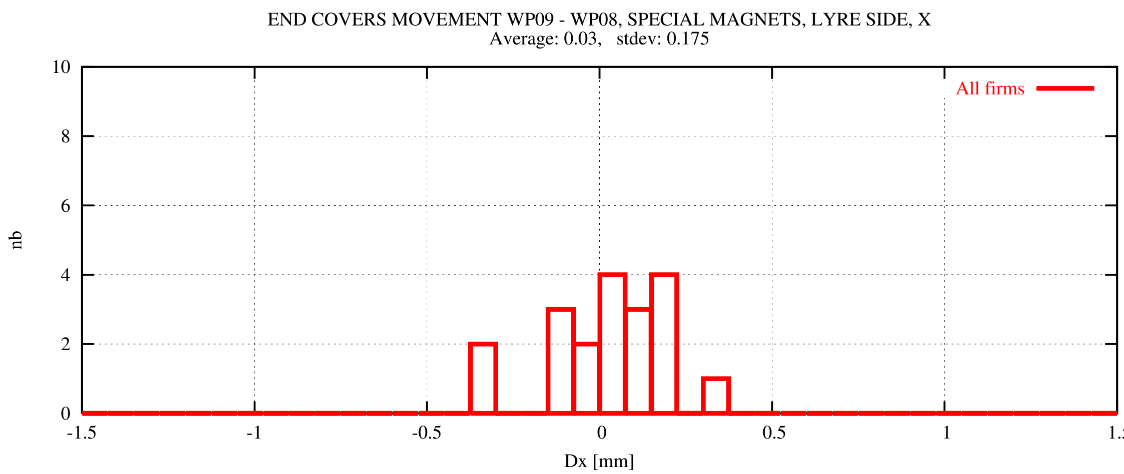

Figure 7. Special Set Magnets. Lyre Side, Movement in the x-direction.

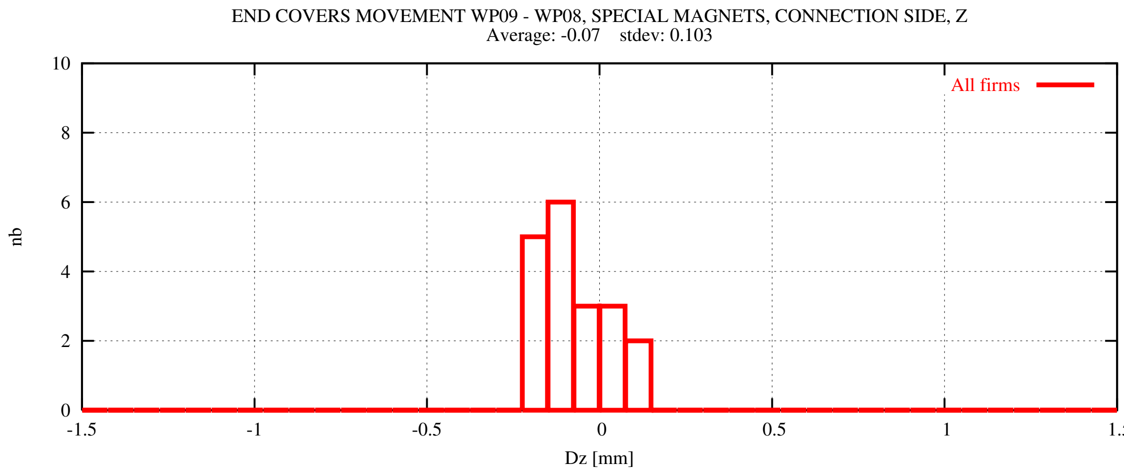

Figure 8. Special Set Magnets. Connection Side, Movement in the z-direction.

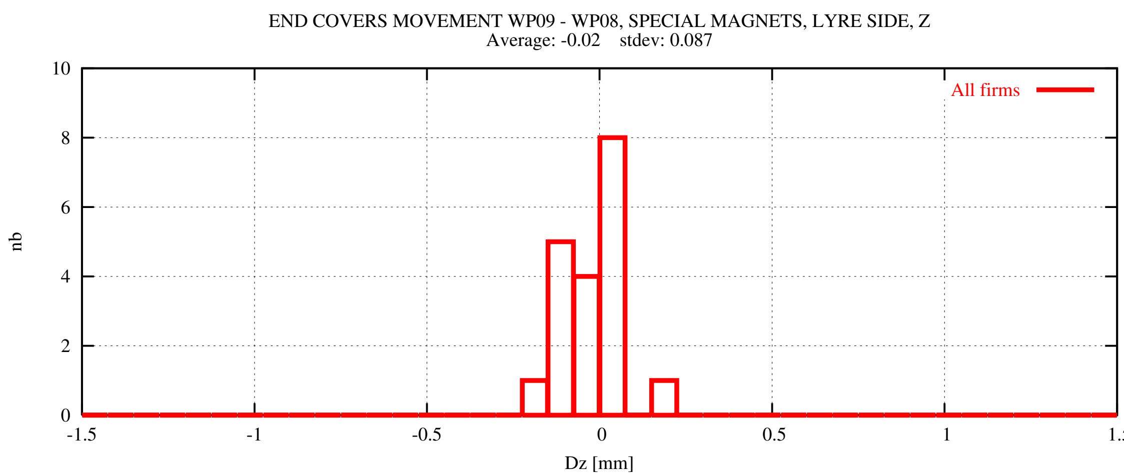

Figure 9. Special Set Magnets. Lyre Side, Movement in the z-direction.

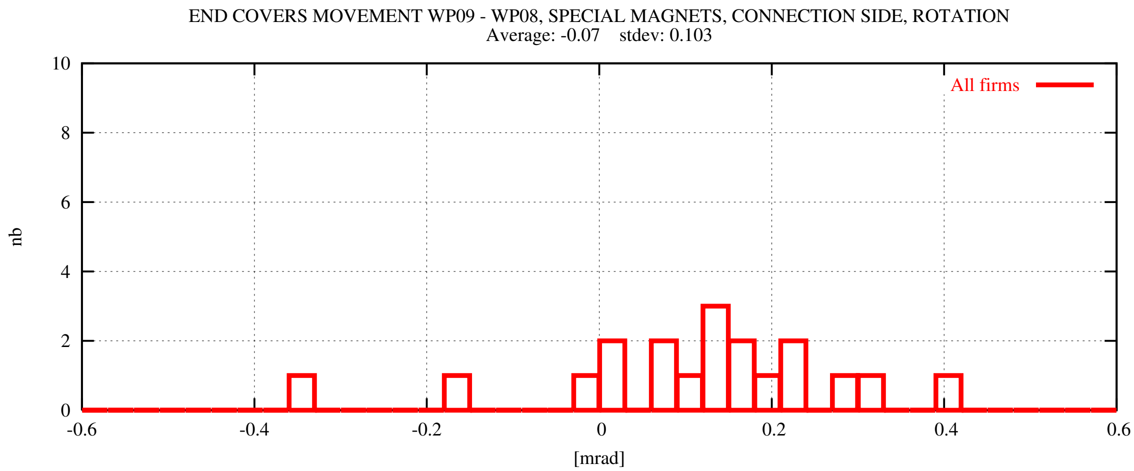

Figure 10. Special Set Magnets. Connection Side, Rotation

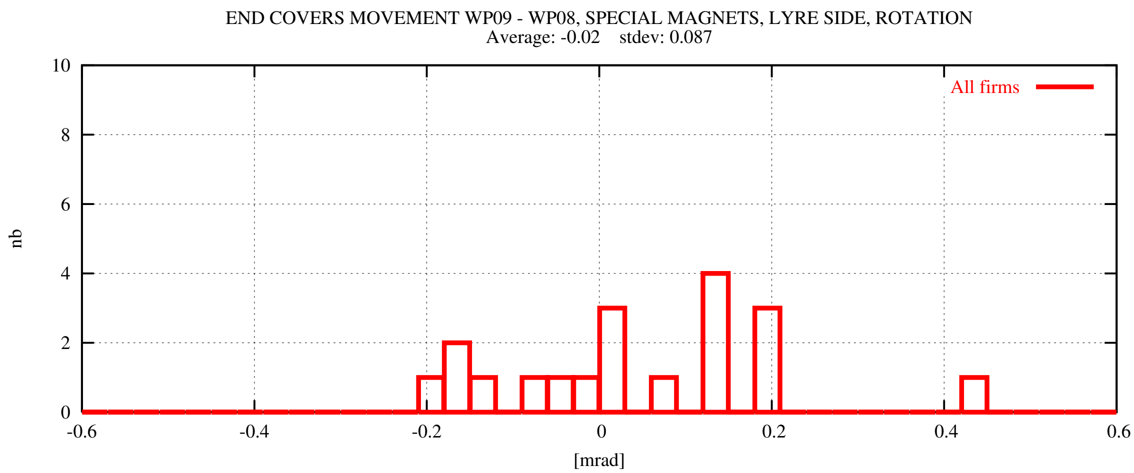

Figure 11. Special Set Magnets. Lyre Side, Rotation

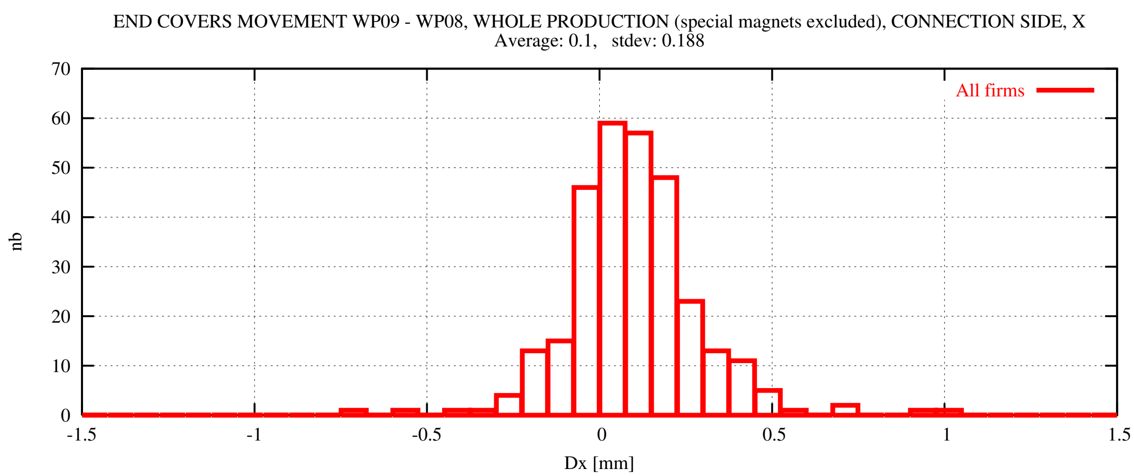

Figure 12. Special Set Magnets. Connection Side, Movement in the x-direction.

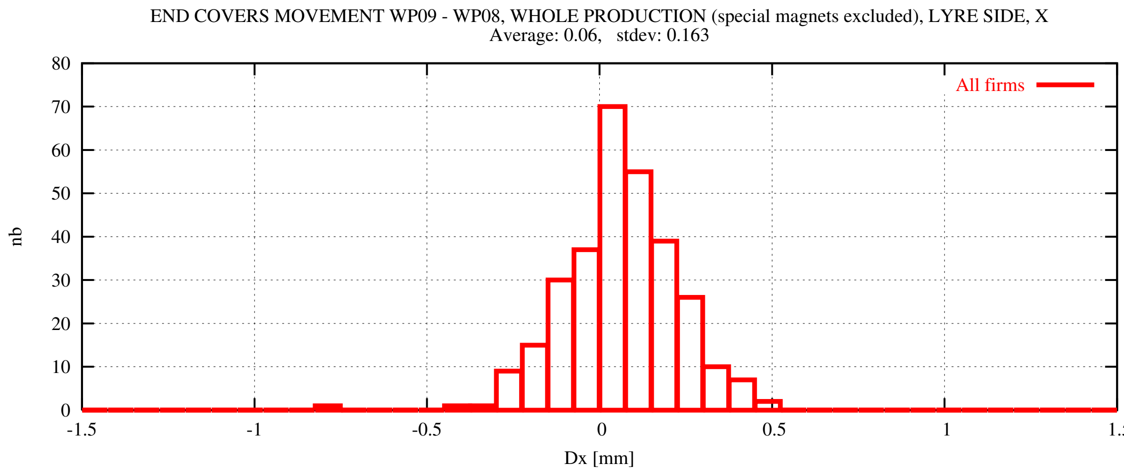

Figure 13. Special Set Magnets. Lyre Side, Movement in the x-direction.

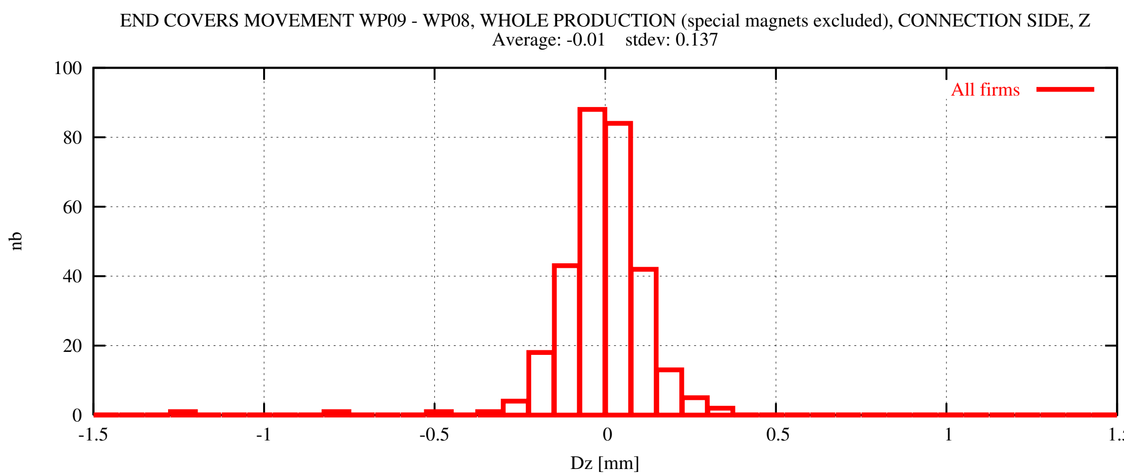

Figure 14. Special Set Magnets. Connection Side, Movement in the z-direction.

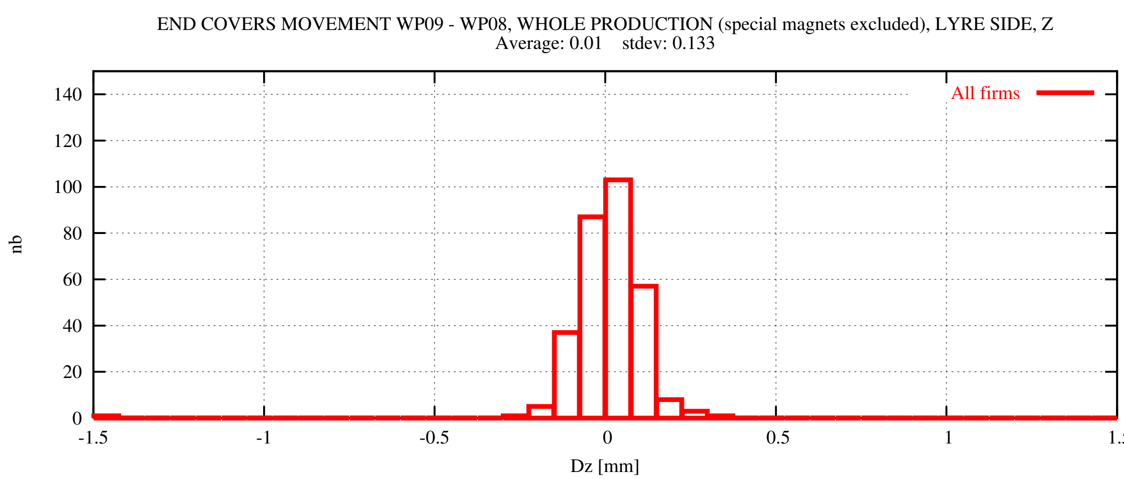

Figure 15. Special Set Magnets. Lyre Side, Movement in the z-direction.

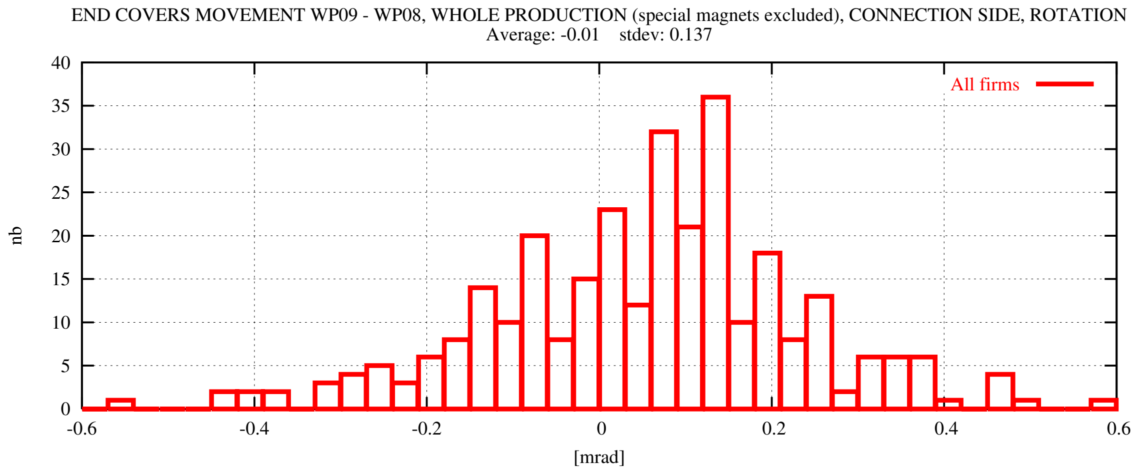

Figure 16. Special Set Magnets. Connection Side, Rotation