The Metrology of LHC components prior to their installation in the tunnel

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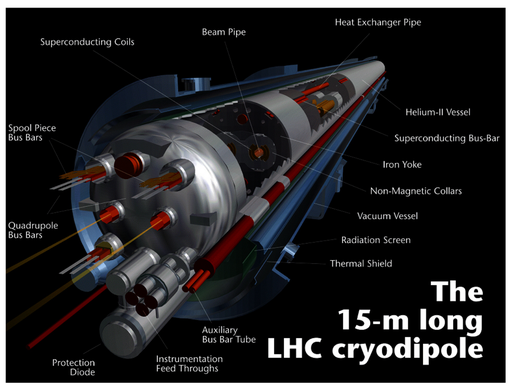
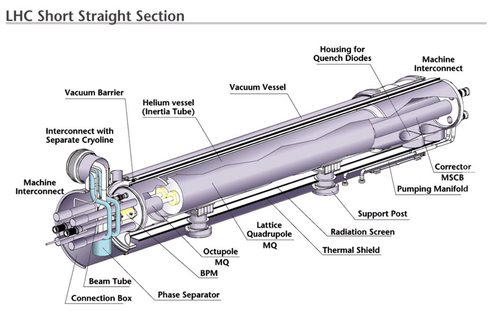
Why do the LHC magnets need geometrical checks ?

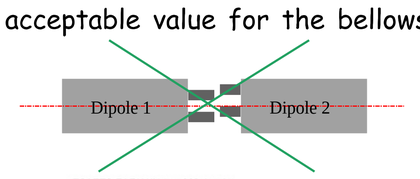




Dipole

SSS

1. Mechanical reasons : to avoid inadmissible offsets in the interconnections between adjacent magnets.
The table of alignment errors for the dipole shows that a misalignment of the cold bore tubes of 0.1 mm r.m.s combined with other errors leads to a max offset of 4mm which is the maximum acceptable value for the bellows in the interconnections.



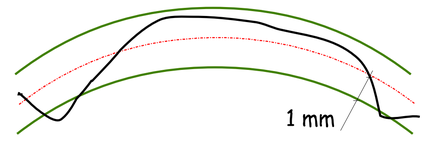
ECARTS RADIAUX (sur 360 degrés)

toutes les valeurs sont des valeurs r.m.s. (en mm)		(i) Moyenne (mm) (plan des mires)		(ii) Extrémités (mm)	(ii) %	(iii) Correcteur (mm)
Construction Masse froide	Axe magnétique moyen / axe géométrique idéal	0.1	(1)			
	Référence intermédiaire / axe géométrique idéal	0.2	(1) (2)	0.2	6.2%	
	Axe magn. / réf. d'alignement d'un correcteur					0.1
	Pos. axe magn. correcteur / axe géom. idéal du dipole					0.2
	Pos. des tubes froids / axe géom. Idéal du dipole	0.33	(2)	0.1	1.9%	
Ecran Faisc.	Pos. de l'écran faisceau / axe tube froid	0.3	(2)	0.3		
Masse froide dans son cryostat	Thermo-mécanique du pied froid	0.1	(1) (2)	0.2	6.2%	0.2
	Ovalisation et rectitude du cryostat	0.2	(1) (2)	0.4	24.9%	0.4
	Mesure des mires / à l'axe géométrique moyen	0.1	(1) (2)	0.2	6.2%	0.2
	Positionement du pied central	0.2	(1) (2)	0.2	6.2%	0.2
Positionnement dans le tunnel	Pos. radiale des mires / orbite théorique	0.28	(1) (2)	0.56	48.7%	0.56

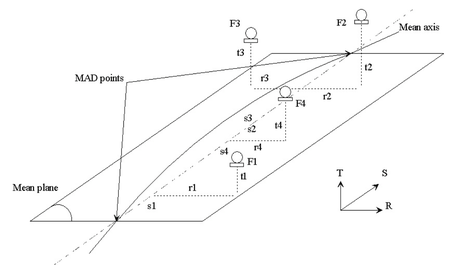
		r.m.s.
(i) (1)	Axe magnétique moyen du dipole / orbite théorique	0.48
(i) (2)	Perte d'ouverture dans le dipole	0.65
(ii)	Perte d'ouverture aux extrémités sans écran faisceau	0.80
(ii)	Perte d'ouverture aux extrémités avec écran faisceau	0.86
(iii)	Axe magn. correcteur / orbite théo.	0.80
Nota :	Souplesse dans les compensateurs RF des lignes V : 0.80*1.414*3 + 1 = 4.4 mm	

Dipole alignment errors table

2. Beam Aperture : axis of cold bore tubes has to be included inside a toroid of 1 mm radius.

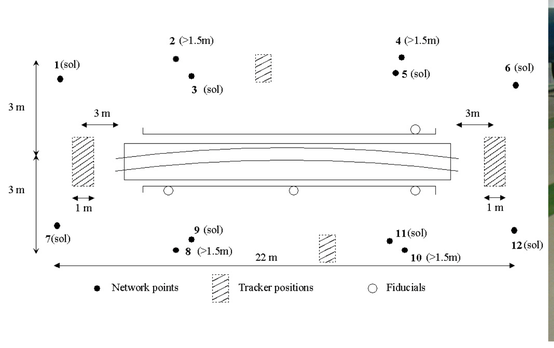


3. Alignment in the tunnel : The position of the fiducials of the dipoles have to be knowm w.r.t mechanical magnet axis. These positions combined with the co-ordinates of the points of the beam trajectory coming from MAD will give the alignment co-ordinates for the fiducials in the CERN Co-ordinates System



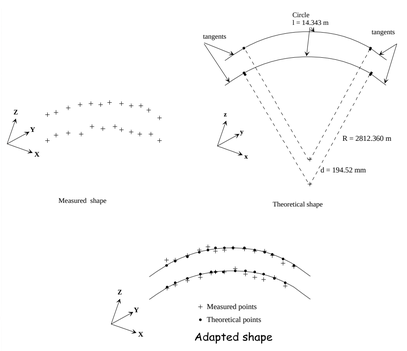
Laser Tracker technology

Dipole fiducialisation



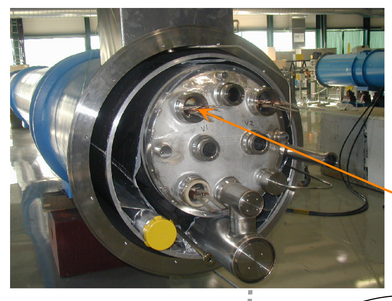
The geometrical axis of the dipole is determined by measuring the position of the axis of the two cold bore tubes from each extremity of the dipole. This measurement is done automatically by a Laser Tracker. Network points are used to link the measurements taken from different positions of the laser tracker.

Mole used to materialise the center of the cold bore tube

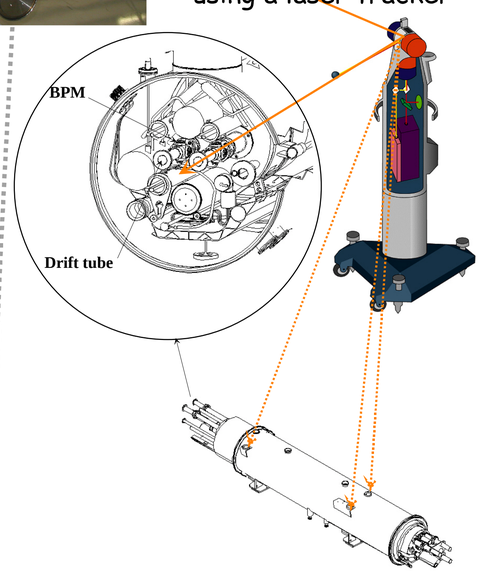


Then, the theoretical shape of the dipole is adapted on the measured shape using a 3D transformation program. The deviations between the measured shape and the theoretical shape are also computed. The positions of the fiducials are calculated with respect to the theoretical adapted shape

Cartography of the positions of the tubes at the extremities of dipoles

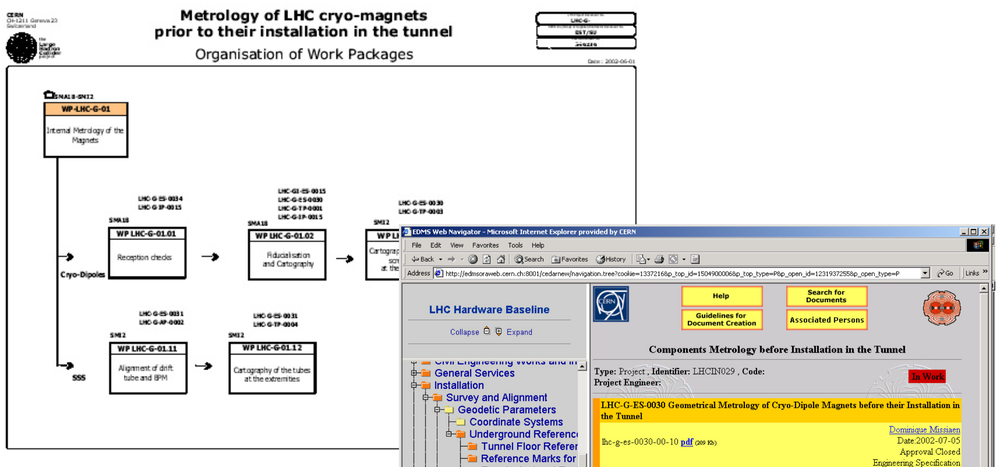


W.r.t the theoretical adapted shape, the position of a set of tubes at each extremity of the dipoles is measured using a laser tracker



For the SSS, the laser tracker is also used to : - align the Beam Position Monitor (BPM) and its drift tube with respect to the magnetic axis known through the "fiducials" - measure the position of the tubes at the extremities

Results and Quality Assurance



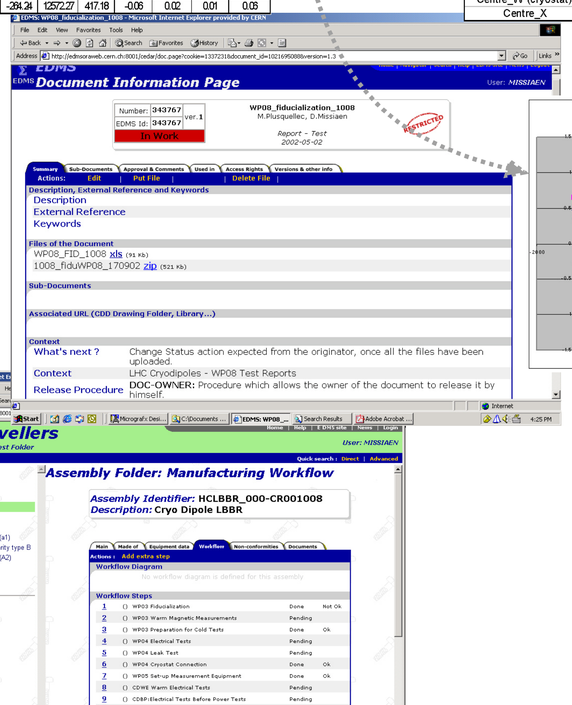
The work has been decomposed into work packages, described inside Engineering Specifications and Technical Procedures to explain how it has to be done.

These documents are stored in an Electronic Data Management System (EDMS) so that other systems Holders know what will be done, what is neeed for doing the work and what results will be kept. All the versions of the documents are saved.

Then, using this decomposition, the work will be done in the frame of a result oriented contract.

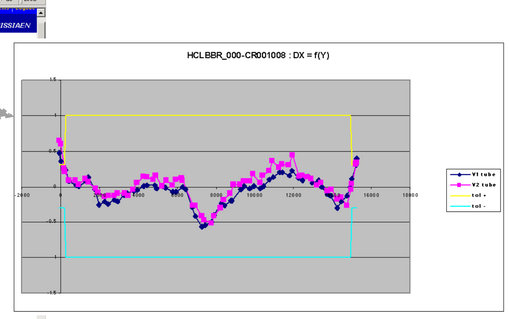
Position of the fiducials w.r.t the magnet axis

Point	R	S	T	RMSR	RMSS	RMST	Total RMS
mire_E	287.86	1772.45	418.39	-0.07	0.02	0.01	0.07
mire_M	286.88	7172.5	415.1	-0.02	0.03	0.01	0.04
mire_S	285.41	12572	417.21	-0.05	0.02	0	0.05
mire_T	-284.24	12572.27	417.18	-0.05	0.02	0.01	0.05



Position of the tubes at the "Connection" extremity of the dipole

CONNECTION SIDE	X (mm)				Z (mm)			
Point	Measured	Theo	Delta	Tolerance	Measured	Theo	Delta	Tolerance
Centre_E	-270.32	-270.00	-0.32	+/- 2	-286.57	-290.00	3.43	+/- 2
Centre_M1	-139.70	-140.00	0.30	+/- 0.5	145.62	145.00	0.62	+/- 0.5
Centre_M2	140.28	140.00	0.28	+/- 0.5	145.29	145.00	0.29	+/- 0.5
Centre_M3	-144.73	-145.00	0.27	+/- 0.5	-144.55	-145.00	0.45	+/- 0.5
Centre_N	313.31	310.00	3.31	+/- 1	-67.54	-70.00	2.46	+/- 1
Centre_V1	-96.79	-97.26	0.47	+/- 1	0.55	0.00	0.55	+/- 1
centre_V2	97.91	97.26	0.65	+/- 1	0.73	0.00	0.73	+/- 1
Centre_W (cryostat)	2.97	0.75	2.22	+/- 2	-78.39	-80.00	1.61	+/- 2
Centre_X	-0.17	0.00	-0.17	+/- 0.5	180.67	180.00	0.67	+/- 0.5



Deviations to the theoretical shape in the horizontal plane

At the present time, 20 magnets have been measured, and their results are available immediately on the WEB using the Magnet Test Folder (MTF) interface

ALL the results are also stored in EDMS