CONCEPTUAL SPECIFICATION

SINGLE APERTURE DECAPOLE CORRECTOR

SUPERCONDUCTING MAGNETS

[HL-LHC MCDXF AND HL-LHC MCDXSF]

Equipment/system description

This decapole features a single aperture and it is part of the set of correctors installed on both side of the IP1 and IP5 in the final focus region. It will assembled inside the Corrector Package cold mass

Layout Versions	**LHC sectors concerned**	**CDD Drawings root names (drawing storage):**
V 1.0	S1-2,S4-5, S5-6, S8-1	Text

TRACEABILITY

Project Engineer in charge of the equipment	**WP Leader in charge of the equipment**
P. Fessia G. Volpini	E. Todesco G. Sabbi

Committee/Verification Role	**Decision**	**Date**
PLC-HLTC/ Performance and technical parameters	Rejected/Accepted	20YY-MM-DD
Configuration-Integration / Configuraration, installation and interface parameters	Rejected/Accepted	20YY-MM-DD
TC / Cost and schedule	Rejected/Accepted	20YY-MM-DD
Final decision by PL	Rejected/Accepted/Accepted pending (integration studies, …)	20YY-MM-DD

Distribution: N. Surname (DEP/GRP) *(in alphabetical order) can also include reference to committees*

Rev. No.	***Date***	***Description of Changes*** *(major changes only, minor changes in EDMS)*
X.0	20YY-MM-DD	Description of changes

1 CONCEPTUAL DESCRIPTION

1.1 Scope

The decapole installed in the final focus area is meant to compensate the decapole imperfections originated in the other IT magnets.

1.2 Benefit or objective for the HL-LHC machine performance

The objective is to guarantee suitable Dynamic Aperture despite errors and construction defects of the other magnets in the inner triplet area.

1.3 Equipment performance objectives

Each decapole shall provide a nominal integrated field of 0.025 T·m at 50 mm radius of aperture.

TECHNICAL ANNEXES

2 PRELIMINARY TECHNICAL PARAMETERS

2.1 Assumptions

- Table I lists the multipoles used in [1] for the simulation leading to the determination of the required magnet strength.
- The total absorbed dose in the most exposed point of the coil is less than 25 MGy for an integrated luminosity of 3000 fb^{-1}.
- The peak deposited power at peak luminosity of 5×10^{34} cm^{-2} s^{-1} is less than 4 mW/cm^3

- The mechanical design of the magnet and the protection design will be performed in order to guarantee full functionality at 110% of the nominal operating current.

		IT quadrupoles			D1 dipole		
	Mutipole	Mean	Unc.	Random	Mean	Unc.	Random
normal	3	0.000	0.820	0.820	-0.900	0.727	0.727
	4	0.000	0.570	0.570	0.000	0.126	0.126
	5	0.000	0.420	0.420	0.000	0.365	0.365
	6	0.800	1.100	1.100	0.800	0.060	0.060
skew	2	0.000	0.000	20.000	0.000	0.679	0.679
	3	0.000	0.800	0.800	0.000	0.282	0.282
	4	0.000	0.650	0.650	0.000	0.444	0.444
	5	0.000	0.430	0.430	0.000	0.152	0.152
	6	0.000	0.310	0.310	0.000	0.176	0.176

Table I Multipoles used for the field quality of the triplets and of the D1 separation dipole. The values are in units of 10^{-4} at R_{ref}=50 mm [1]

2.2 Equipment Technical parameters

Table 1: Equipment parameters

Characteristics	Units	Value
Aperture	mm	150
Number of apertures		1
Design		Superferric
Superconductor		Nb-Ti
Conductor type		wire
Bare wire diameter	mm	0.500
Insulation thickness	mm	0.07
Cu/ non Cu		2.3
Superconductor current density at 5 T, 4.22 K	A/mm^2	3,000
Number of turns per coil		256
Wire unit length (for 1 coil)	m	67
Coil physical length	m	0.107
Coil peak absorbed peak power [at 5 10^{34} cm^{-2} s^{-1}]	mW/cm^3	0.2
Power absorbed per magnet [at 5 10^{34} cm^{-2} s^{-1}]	W	2-3
Integrated dose in most exposed point of coils of integrated luminosity of 3000 fb^{-1}	MGy	0.2
External magnet diameter (iron yoke OD)	mm	320
Weight	kg	75
Mechanical Length end plate to end plate	mm	172
Mechanical Length including connection boxes	mm	Not foreseen in present design (connection on external magnet diameter) if needed 50 mm more to be added

The magnet shall be able to allow precise alignement of the mechanical centre of the aperture respect to the mechanical centre of the nearby magnets at +/- 0.15 mm

The magnet section shall allow at least 130 cm^2 of free passage summing the free areas in its cross section (with all piping and services installed including cold bore tube, heat exchagner, bus bars …) and the free area between the iron yoke exernal diameter and the inner diameter of the He containment shell.

2.3 Operational parameters and conditions

Table 2: Operating parameters

Characteristics	Units	Value
Operating temperature	K	1.9
Maximum Operating Current (I_{op})	A	139
Loadline margin @ I_{op}	%	60
Magnetic length @ I_{op}	m	0.095
Gradient @ I_{op}	T/m^4	50623
Integrated field @ I_{op} and @ 50 mm radius	T·m	0.025
Coil peak field @ I_{op}	T	2.34
Overall current density @ I_{op}	A/mm^2	360
Stored energy @ I_{op}	kJ	1.39
Stored energy per meter @ I_{op}	kJ/m	14.7
Differential inductance @ I_{op}	H	0.11
Differential inductance per meter @ I_{op}	H/m	1.12
Max voltage rating to ground	V	300
F_x @ I_{op} Force per unit of magnetic length per quadrant	kN/m	23
F_y @ I_{op} Force per unit of magnetic length per quadrant	kN/m	19.4
F_z @ I_{op} Total force 1 coil over half coil length	kN	0.6

Remark: force referece system at is follows:

- x: perpendicular to the coil face parallel to the yoke profile. Positive outwards.
- y: perpendicular to the coil face aligned with the iron pole. Positive upwards.
- z: along the beam axis.

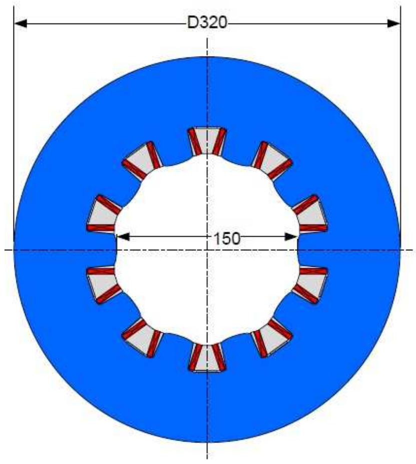

Fig 1: Sketch of the cross-section (skew case).

2.4 Technical and Installation services required

The magnets will be assembled with other magnets inside a He vessel. As part of this equipment (cold mass) it shall be capable to withstand a pressure test in the order of 25-30 bar. The cold mass will present the necessary piping for the effective cooling to 1.9 K and will allow the connection of the magnet bus bar to the electrical feeding circuit.

In the present layout, the decapole is part of the Corrector Package. For the heat load please refer to the Conceptual Specification of the whole Corrector Package assembly.

Concerning handling and alignement please refer to the Corrector Package assembly Conceptual Specification

Concerning instrumentation the magnet could be equipped with about 5-8 split Vtaps to be routed to a warm flange on the cold mass and the Corrector package shall be equipped with a Temperature sensor for the He bath temperature measurement. REMARK the protection system needs to be studied. In particular possible needs of Vtaps to measure the coils inductive voltage shall be assessed, and the inductance variation due to the iron saturation shall be taken into account.

2.5 Reliability, availability, maintainability

There will be no possibility to intervene on the magnet in the tunnel as integreted in the Corrector Package Unit. In case of failure the whole cryostated Corrector Package will be replaced unless operational scenarios, not requiring the correction provided by this magnet, will be possible.

2.6 Radiation resistance

The magnet shall be designed to withstand a total dose of 25 MGy including all instrumentation wires and bus bar insulation system.

2.7 List of units to be installed and spares policy

4 decapole units will be installed as part of the 4 Corrector Packages on both side of IP1 and IP5. 4 skew decapole units will be installed as part of the 4 Corrector Packages on both side of IP1 and IP5. Two spare units.

3 PRELIMINARY CONFIGURATION AND INSTALLATION CONSTRAINTS

3.1 Longitudinal range

Present location of the magnetic centre of the magnet from the IP (indicative): 69.525 m (normal) and 69.700 m (skew).

3.2 Installation/Dismantling

The present LHC inner triplet will be dismantled together with its DFBX. The CP will take part of the space free.

4 PRELIMINARY INTERFACE PARAMETERS

4.1 Interfaces with equipment

Mechanical interface: the Corrector Package He shell and the neighbouring magnets in the Corrector Package. IMPORTANT the magnet has a diameter smaller than the probable final diameter of the Corrector Package Shell and therefore the assembly will require radial compensation elements.

The magnet will be integrated in an ad hoc designed Quench Protection System still to be defined,

4.2 Electrical interfaces

List new circuits to be generated:

Table 2: Circuits to be generated

New circuit description	Circuit LHC code name (if known)	Approx. current rating (if known)	Approx. voltage rating (if known)
Decapole left of 1	RCDXF.L1	0.2 kA	1 kV
Decapole right of 1	RCDXF.R1	0.2 kA	1 kV
Decapole left of 5	RCDXF.L5	0.2 kA	1 kV
Decapole right of 5	RCDXF.R5	0.2 kA	1 kV
Skew Decapole left of 1	RCDSXF.L1	0.2 kA	1 kV
Skew Decapole right of 1	RCDSXF.R1	0.2 kA	1 kV
Skew Decapole left of 5	RCDSXF.L5	0.2 kA	1 kV
Skew Decapole right of 5	RCDSXF.R5	0.2 kA	1 kV

5 COST & SCHEDULE

5.1 Cost evaluation

91109, (HL-LHC IR & MS Corrector Magnets)

5.2 Approximated Schedule

Simplified schedule by years

Table 3: Schedule

Phase	2014		2015		2016		2017		2018		2019		2020	
Requirements definition	■													
Prototype development	■	■	■	■	■	■	■							
Engineering specification							■							
Acquisition Process								■	■					
First corrector magnet batch assembly & test									■	■	■	■		
Second corrector magnet batch assembly & test												■	■	■

5.3 Schedule and cost dependencies

- Optic parameter shall be fixed in order to allow final design and production
- Presently it is not foreseen to deliver components from CERN to the supplier. If the policy would change the production would be linked to the delivery of these items. Superconducting wire and iron for the yoke could be potential candidates for CERN delivery.
- The Corrector Package Assembly can start only after delivery of the decapole.

6 TECHNICAL REFERENCE DOCUMENTS

- [1] “INITIAL MODELS OF CORRECTION SYSTEMS” M. Giovannozzi, S. Fartoukh, R. De Maria (CERN) https://cds.cern.ch/record/1644776/files/CERN-ACC-2014-0010.pdf

7 APPROVAL PROCESS COMMENTS FOR VERSION X.0 OF THE CONCEPTUAL SPECIFICATION

7.1 PLC-HLTC / Performance and technical parameters Verification

Comments or references to approval notes. In case of rejection detailed reasoning

7.2 Configuration-Integration / Configuraration, installation and interface parameters Verification

Comments or references to approval notes. In case of rejection detailed reasoning

7.3 TC / Cost and schedule Verification

Comments or references to approval notes. In case of rejection detailed reasoning

7.4 Final decision by PL

Comments or references to approval notes. In case of rejection detailed reasoning