EDMS NO.	REV.	VALIDITY
2031177	**1.4**	**VALID**

REFERENCE : US-HiLumi-doc-1674

ENGINEERING SPECIFICATION

MQXFA MAGNET INTERFACE SPECIFICATION

Abstract

This specification defines the mechanical and electrical interfaces of the MQXFA magnets, which are relevant for the incorporation of these elements into the LMQXFA cold mass assembly, and subsequently into the cryostat which completes the LQXFA/B cryo-assembly.

TRACEABILITY

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Distribution: HL-LHC-WP

Rev. No.	***Date***	***Description of Changes*** *(major changes only, minor changes in EDMS)*
1.1	2020-06-02	Changed Figure 2: CLIQ leads and their exits Removed old reference [6], Added new references [6] and [7] Added EDMS# to references 2,3,9 and 10.
1.2	2021-04-08	Changed length of wires used for Voltage Taps, Quench Detection and Quench Heaters: wires coming from coils are 7 m long from saddle extensions, and wires coming from the splice-connection box are 6.4 m
1.3	2021-06-15	Cold Mass Welding section was re-written. See pag. 3 for full description.
1.4	2022-10-03	CLIQ leads changed from Habia Cable 700061251 to copper cable within 2 polyimide tubes, reference [6] changed accordingly

This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.

US HL-LHC Accelerator Upgrade Project

MQXFA MAGNET
INTERFACE SPECIFICATION

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Revision History

Revision	Date	Section No.	Revision Description
V0	10/2/18	All	Initial Release
V0.1	11/26/18	All	Updated magnet bore, wire length and references
V0.2	1/18/19	2.3	Current lead lengths, wires not twisted
V0.3	4/8/19	2.3	Asymmetric current leads, added sentence about splice order
V0.4	5/1/19	2.3	Added CLIQ cable info to Table 1, updated reference [6]
V0.5	5/7/19	2.3	Changed length of instrumentation wires to 4.5 m.
V1	5/31/19	2.3	Changed length of power lead A from 0.5 m to 445 mm, and of power lead B from 2.1 m to 2040 mm.
V1a	8/13/19	Header	Added EDMS#
V3	9/30/19	2.3	Changed Figure 2: CLIQ leads and their exits
V4	5/29/20	2.3 and 3	Removed reference [6] HL-LHC Triplet Electrical Scheme, US-HiLumi-doc-1097; EDMS#2002347. Added references [6] MQXFA Series VT Schematic, Whole Magnet, LBNL drawing #SU-1010-3108, and [7] MQXFA Series PH Schematic, Whole Magnet, LBNL drawing # SU-1010-7805 with note: *a copy of this drawing is available on US-HiLumi-doc-1674; updated version is on LBNL drawing system. Added EDMS# to references 2,3,9 and 10.
EDMS v 1.2	04/08/21	2	In table I: changed length of wires used for Voltage Taps, Quench Detection and Quench Heaters: wires coming from coils are 7 m long from saddle extensions, and wires coming from the splice-connection box are 6.4 m; Wire length and gauge removed from text and substituted by “Wire gauge and length are shown in Table I”.
EDMS v 1.3	06/15/21	2.2	Cold Mass Welding specification was revised from “coil pre-load increase shall not exceed 15 MPa at room temperature” to: “The circumferential interference after welding is defined as: Delta_C = Circumference (SS inner) – Circumference (Al outer). The Delta_C average along each magnet length must be ≥ - 0.2 mm, resulting in average coil pre-load increase ≤ 3.2 MPa at room temperature [4]. In short spots, for possible local repair, the local Delta_C must be ≥ - 0.5 mm, and the average along magnet length must meet the previous specification. More details are shown in [4].”
EDMS v 1.4	10/3/22	2.3 and 3	CLIQ leads changed from Habia Cable 700061251 to copper cable within 2 polyimide tubes, reference [6] changed accordingly.

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1. Introduction

MQXFA magnets [1][2] are the quadrupole magnetic components of the HL-LHC Q1 and Q3 inner triplet optical elements in front of the interactions points 1 (ATLAS) and 5 (CMS). Two MQXFA magnets are installed in each Q1 or Q3. Since these magnets are identical whether installed in Q1 or Q3, the interface specifications are identical for all MQXFA magnets.

This specification defines the mechanical and electrical interfaces of the MQXFA magnets, which are relevant for the incorporation of these elements into the LMQXFA cold mass assembly, and subsequently into the cryostat which completes the LQXFA/B cryo-assembly.

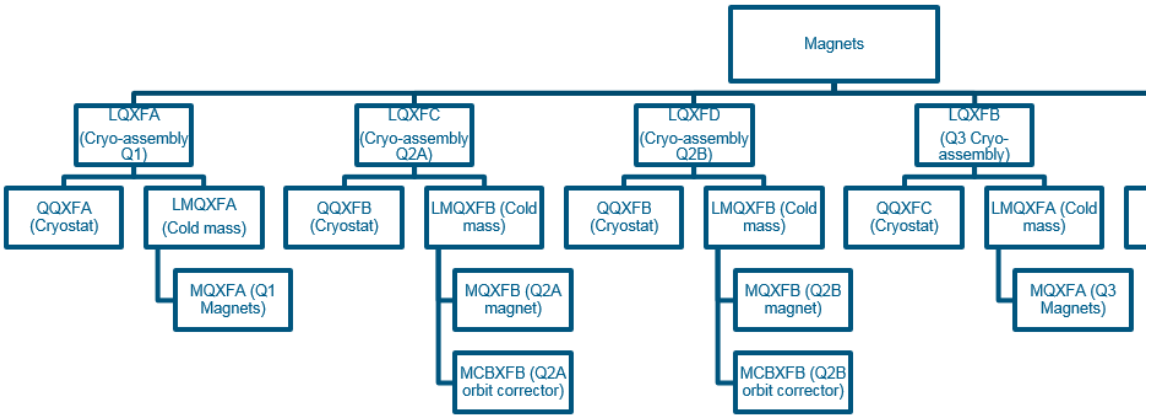

Figure 1: CERN Naming Conventions for HL-LHC Inner Triplets

2. MQXFA interfaces

2.1. Mechanical interfaces

The MQXFA Magnet mechanical interfaces are defined in [3]. This drawing defines:

- The diameter, length, and weight of the magnet.
- The longitudinal position of the magnetic center relative to the return end of the yoke.
- The position and aperture of the holes for heat exchangers.
- The position of the slots for tack blocks.
- The features of the slots where the tack blocks will be inserted.
- The positions and features of the alignment slots.
- The envelope of the lead connection block (“pizza box”).
- The orientation of the leads when magnet is in horizontal position.

The bore of the MQXFA magnet has a 146.7 mm inside diameter at room temperature after insertion of coil-bumpers and magnet pre-load, allowing for the insertion of an insulated beam tube.

The OD of the beam tube is 144.7 +0.7/-0.0 mm at room temperature. The beam tube insulation thickness is 0.2 mm.

The iron yoke of the MQXFA magnet has four cooling channels. The two upper channels (wrt. to the orientation shown in Fig 2) will be used for the heat exchangers of the LMQXFA cold mass. The minimum diameter of the MQXFA yoke cooling channels is 77 mm at room temperature.

2.2. Cold Mass Welding

When the two half shells of the LMQXFA cold mass are welded together the weld shrinkage may increase the coil pre-load. This pre-load increase may cause excessive conductor strain if the interference between magnet and cold mass is not limited. In addition, friction force may prevent sliding of the magnet structure

with respect to the SS-shell during cooldown and warm-up resulting in excessive axial loads on the brittle conductor. Therefore, this interference shall be kept under control and meet the following specification.

The circumferential interference after welding is defined as: Delta_C = Circumference (SS inner) – Circumference (Al outer).

The Delta_C average along each magnet length must be ≥ - 0.2 mm, resulting in average coil pre-load increase ≤ 3.2 MPa at room temperature [4].

In short spots, for possible local repair, the local Delta_C must be ≥ - 0.5 mm, and the average along magnet length must meet the previous specification. More details are shown in [4].

2.3 Electrical Interfaces

The MQXFA magnet has two 18 kA leads extending from the lead end of the assembly. Each lead is made of two NbTi cables [2]. The leads will be labelled A and B according with the CERN standard [5]. Looking from the lead end, the "A" lead is the lower exiting lead and the "B" lead is the upper exiting lead with the magnet oriented as shown in Figure 2. The splice order (e1i – i4e – i2e – e3i) gives a positive gradient as defined by CERN document "LHC Magnet Polarities" [5] if the current enters lead "A".

The minimum length of Current Lead "B" is 2040 mm from the splice-connection block ("pizza box"). The minimum length of Current Lead "A" is 445 mm long from the splice-connection block ("pizza box").

The MQXFA magnet has two CLIQ leads [6] extending from the lead end of the assembly. The leads will be labelled "A" and "B", based on how close they are in the electrical circuit to the A/B current leads. Looking from the lead end, with the magnet oriented as shown in Figure 2, the CLIQ "A" lead is on the left, and the CLIQ "B" lead is on the top. The CLIQ leads exiting the splice-connection block ("pizza box") are 2 m long, such that further routing and splicing can be completed.

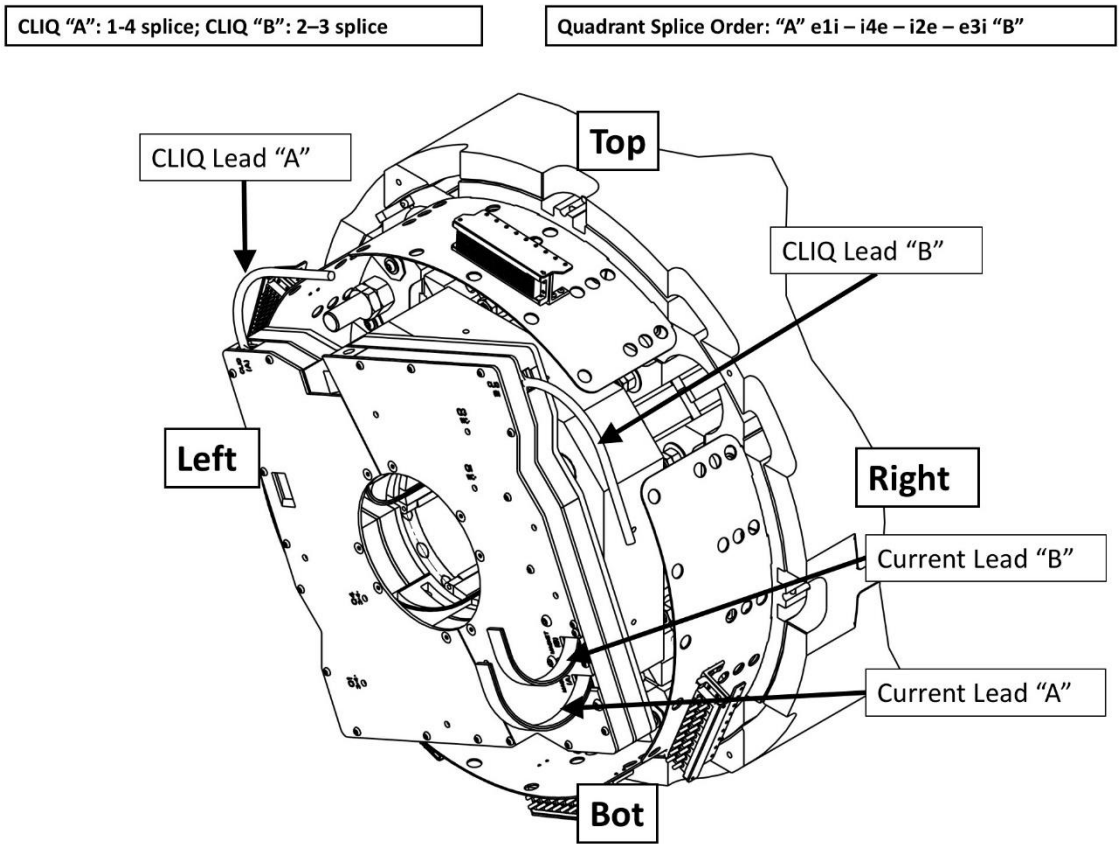

Figure 2: Power leads and CLIQ leads on a completed MQXFA magnet.

The instrumentation wires required for the MQXFA magnet are listed in Table 1. All wires shall not be twisted because they must go through a capillary tube in the cold mass. Each wire will be labelled indicating functionality and location according to [7] and [8]. All voltage tap and quench heater wires exit from the lead end of the magnet.

The MQXFA magnet has 2 voltage taps for each internal Nb_3Sn-NbTi splice resulting in 16 wires [7]. Wire gauge and length are shown in Table I.

The MQXFA magnet has three quench detection voltage taps located on each magnet lead and at the electrical midpoint of the magnet circuit. According to MQXFA Magnets Functional Requirements Specification [1] each voltage tap used for quench detection must have a redundant voltage tap. Redundancy of the voltage taps located on magnet leads is provided by the voltage taps on internal Nb_3Sn-NbTi splices to magnet leads. Therefore, the total number of wires for quench protection is 4. Wire gauge and length are shown in Table I.

The MQXFA magnet has four outer layer heater strips per coil (one high-field and one low-field strip on each coil side). Pairs of heater strips are connected in series according to [8]. The heater-heater connections are done at magnet return end. Therefore, there is a total of 16 heater wires exiting from the lead end. Wire gauge and length are shown in Table I.

MQXFA heaters and CLIQ leads are compatible with the HL-LHC Inner Triplet quench protection system [9].

Table I. Instrumentation wires, heater wires and CLIQ cables. Length is measured from coil saddle extension or from the magnet splice-connection box (“pizza box”).

Wire	Number	Gauge/OD	Length	Description	Twisted/Not
Quench detection from coil	2	26 AWG	7 m from coil saddle extension	AXON HH2619 - LH [10]	Not twisted
Quench detection from splice-connection box	2	26 AWG	6.4 m from splice-connection box	AXON HH2619 - LH [10]	Not twisted
Voltage tap	16	26 AWG	7 m from coil saddle extension	AXON HH2619 - LH [10]	Not twisted
Heater wire	16	18 AWG	7 m from coil saddle extension	AXON HH1819 - LH [11]	Not twisted
CLIQ cable	2	8.6 mm OD	2 m from splice-connection box	copper cable within 2 polyimide tubes: first one with diam 4.8 mm and 115 µm thickness, and second one with diam 5.5 mm and 85 µm thickness [6]	Not twisted

3. References

[1] MQXFA Magnets Functional Requirements Specification, US-HiLumi-doc-36, EDMS#1535430
[2] MQXFA Final Design Report, US-HiLumi-doc-948, EDMS#2031097
[3] MQXFA Structure & Mechanical Interface Specification Drawing US-HiLumi-doc-1885, EDMS#2216229
[4] LMQXFA SS shell Axial Interaction, US-HiLumi-doc-4098
[5] LHC MAGNET POLARITIES, CERN Specification LHC-DC-ES-0001 rev 3.2, EDMS# 90041

[6] Revised CLIQ LEADS, US-HiLumi-doc-4328; EDMS# 2772060
[7] MQXFA Series VT Schematic, Whole Magnet, LBNL drawing #SU-1010-3108, EDMS# 2264880
[8] MQXFA Series PH Schematic, Whole Magnet, LBNL drawing # SU-1010-7805, EDMS# 2264882
[9] HL-LHC Decision management: WP3 - Q1/Q2/Q3 protection baseline, US-HiLumi-doc-2910, EDMS# 1972818
[10] Drawing: S515769BB-ENG_DWG; US-HiLumi-doc-1603, FC0067203, EDMS#2030599
[11] Drawing: S563483AA_DWG; US-HiLumi-doc-1603, FC0067205, EDMS#2030601

* a copy of this drawing is available on US-HiLumi-doc-3268; updated version is on LBNL drawing system.