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**HiLumi LHC**

FP7 High Luminosity Large Hadron Collider Design Study

**Milestone Report**

# Study of the Minimal Distance Between Two Coils in a Cold-Mass

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# HILUMI LHC

FP7 High Luminosity Large Hadron Collider Design Study

Seventh Framework Programme, Capacities Specific Programme, Research Infrastructures, Collaborative Project, Design Study

## MILESTONE REPORT

# STUDY OF THE MINIMAL DISTANCE BETWEEN TWO COILS IN A COLD-MASS

## MILESTONE: MS39

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**Abstract:**

In this report we present the results.

The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404. HiLumi LHC began in November 2011 and will run for 4 years.



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Executive summary

*In this report we present the minimum distance between magnets in the cold-masses of the inner triplet. At this stage, we will focus only on the Q1 assemblies assuming that the Q1 and Q3 cryo-assemblies are identical. The minimum distance between the magnetic lengths is 618 mm at warm, in the hypothesis of contact between the magnets. Therefore the 646 mm of distance between magnetic lengths at cold temperature, currently considered in the baseline of the lay-out, is feasible and consistent with the current MQXF design.*

# 1. INTRODUCTION

Each of the Q1 and Q3 quadrupoles of the interaction region triplet will be made out of two magnets assembled in the same cold mass. Here, we focus only on the Q1 cold mass and magnets assuming that the Q1 and Q3 assemblies are identical. The distance between the two magnets inside the cold mass is critical for the accelerator layout and performance, and for the magnet to magnet splices design. We will summarize here the key longitudinal dimensions and provide the minimum distance between the magnetic lengths of the two magnets in the Q1 cold mass (see Fig. 1).

# 2. Q1 AND Q3 DESCRIPTION

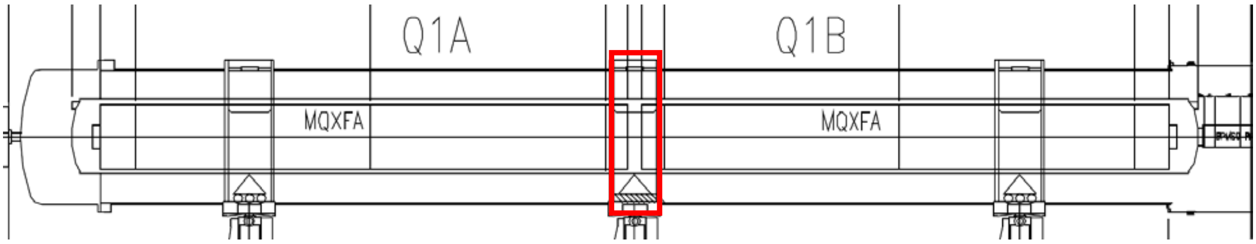


*Fig. 1 Overview of the Q1 cryostat including the Q1 cold mass composed of the two magnets MQXFA. The area of interest for this study is captured in the red box and corresponds to the distance between the two magnetic lengths.*

The MQXFA magnet is a 150 mm aperture $Nb_3Sn$ quadrupole using a shell-based support structure. Fig. 2 shows a cross-section of the MQXF short model, called MQXFS [1], [2]. MQXFA cross-section is expected to be identical to the one of MQXFS. In this report, this cross-section will be taken as a reference.

The magnetic length is 4200 mm at 1.9 K for each magnet in the Q1 and Q3 cryo-assemblies. Fig. 3 summarizes the main longitudinal dimensions of the MQXFA magnet. From left to right, i.e. from connection or lead-end side to non-connection or return-end side, the main dimensions (at room temperature):

- 77 mm of connection box;
- 15 mm of distance between connection box and lead-end axial endplate;
- 110 mm of connection-side axial endplate and loading bullets;

- 223 mm of distance between the end of the magnetic iron yoke on the connection side and the magnetic length;
- 4564.6 mm of iron yoke length;
- 129 mm of distance between the end of the magnetic iron yoke on the non-connection side and the magnetic length;
- 180 mm of non-connection-side axial endplate, loading bullets, and axial rod nuts.

By adding the contribution of all these components, one obtains that the minimum distance between the two magnetic lengths of MQXFA is 618 mm (at room temperature).

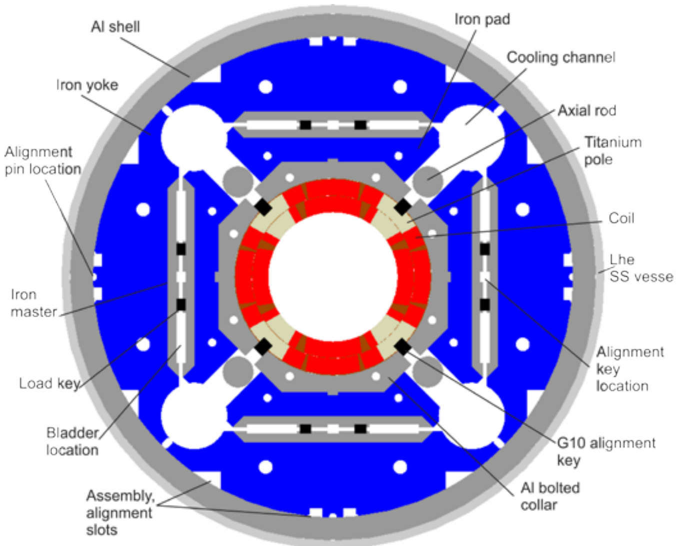


*Fig. 2 Cross-section of the MQXF magnet.*

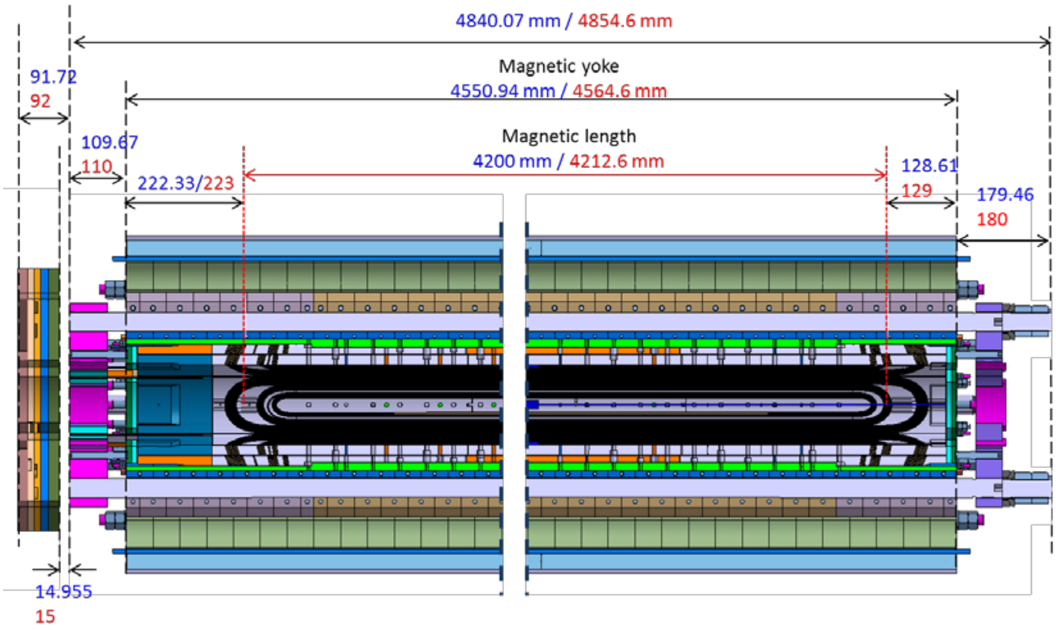


*Fig. 3 Longitudinal cross section of the MQXFA magnet (150 mm aperture). The magnetic length is not in scale with the model. Ends only are shown. Dimensions in red are at room temperature, dimension in blue are at 1.9 K.*

## 3. ANALYSIS OF DIFFERENT COMPONENTS

The driving components of the connection side are (see Fig. 3):

- The coil end and coil end-shoe length;
- The G10 and stainless steel pushers;
- The axial endplate thickness;
- The axial spacing between the end of the yoke and the endplate;
- The nuts of the end-plate.

As seen in Fig. 2, the magnetic length ends approximately at the second block of the inner layer on the connection side. From there to the edge of the last end spacer, 109 mm are used for the optimization of the coil ends (minimization of the field error and of the peak field in the end region [3]) and for the last end spacer (mechanical robustness and protection heater soldering pads). At the extremity of the end-shoes, some pushers are attached for ground plane insulation (G10) and axial preload (stainless steel). Both pusher thicknesses add up to 20 mm. On the connection side, the distance between the end of the magnetic length and the end of the yoke (outer edge of the pushers) is 129 mm.

The endplate has been optimized for compactness and is 50 mm thick. The axial tie rods are bolted through nuts that protrude beyond the plate.

The total axial build-up beyond the magnetic length on the return side adds up to 309 mm.

In the present layout of the Q1/Q3 (see Fig. 4), the distance between the magnetic lengths of the two magnets is 646 mm at 1.9 K, and 618 mm at room temperature.

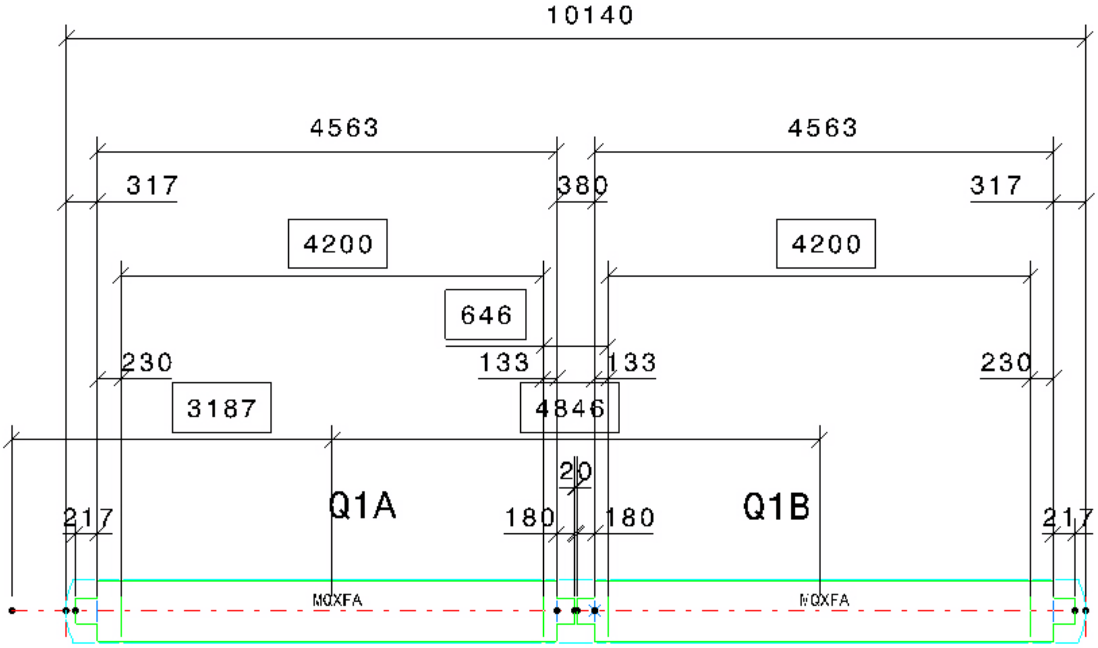


*Fig. 4 Dimensions and distances for Q1A and Q1B. Number within square are at 1.9 K.*

# 4. CONCLUSIONS

In this report we provided a detailed description of the different components in the end region of the MQXF magnet, and we determined the minimum distance between the magnetic lengths of the MQXFA magnets (Q1A-Q1B and Q3A-Q3B). This distance was originally set to 500 mm, assuming that the axial pre-load system, and in particular the nuts to tie the axial rods, were located on the connection side. As a result of a field quality analysis, which pointed out a significant effect on the integrated harmonics of the Nb-Ti leads, which links the coil to the connection box on the lead-side (connection-side), it was decided to move the nuts of the axial pre-load system to the non-connection side. This design change increased the minimum distance between the MQXFA magnetic lengths to 618 mm at room temperature, in the hypothesis of contact between the magnets. Therefore the 646 mm of distance between magnetic lengths at 1.9 K, currently considered in the baseline of the lay-out, is feasible and consistent with the current MQXF design.

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# ANNEX: GLOSSARY

| **Acronym** | **Definition** |
|---|---|
| LHC | Large Hadron Collider |
| HL-LHC | High Luminosity LHC |
| QXF | Generic name for triplet magnet |
| MQXFA | Q1 and Q3 |