



# Report of the MQXFA04 Structure & shim review

US-HiLumi-doc-2505

Other:

Date: 12/12/2019

Page 1 of 7



## US HL-LHC Accelerator Upgrade Project

### Report of the MQXFA04 Structure and shim Review

*12/12/2019*

Peter Wanderer – BNL, chairperson  
Michael Anerella – BNL  
Susana Izquierdo Bermudez – CERN



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US-HiLumi-doc-2505

Other:

Date: 12/12/2019

Page 2 of 7

## TABLE OF CONTENTS

1. GOAL AND SCOPE .....	3
2. TECHNICAL DETAILS .....	3
3. REVIEW CHARGES RESPONSE.....	4
4. COMMENTS .....	6
5. RECOMMENDATIONS .....	7
6. REFERENCES .....	7



## 1. Goal and scope

The HL-LHC AUP project is starting the assembly of MQXFA04 magnet. MQXFA04 is the second pre-series of the MQXFA low beta quadrupoles to be used in Q1 and Q3 for the High Luminosity LHC. If MQXFA04 meets MQXFA requirements [1] it will be used in the first Q1/Q3 cryo-assembly to be installed in the HL-LHC.

MQXFA04 coils were reviewed on October 30, 2019 [2].

MQXFA pre-load targets and pre-loading sequence for MQXFA03 and following magnets were approved by AUP Technical Board on July 5, 2019 [3].

The goal of this review is to evaluate the MQXFA04 structure and shim plan. The reviewers are requested to assess that the MQXFA04 structure meets the MQXFA Structural Design Criteria [4], that non-conformities have been adequately processed, and that structure and shims will allow MQXFA04 to meet MQXFA requirements [1].

## 2. Technical details

### Committee

Peter Wanderer – BNL, chairperson

Michael Anerella – BNL

Susana Izquierdo Bermudez – CERN

### Date and Time

Dec 12, 2019. Start time is 7:00 am (Pacific time)

### Location/Connection

Video-link by Zoom, info by email.

### Link to agenda with talks and other documents

<https://indico.fnal.gov/event/22682/>



# Report of the MQXFA04 Structure & shim review

US-HiLumi-doc-2505

Other:

Date: 12/12/2019

Page 4 of 7

## 3. Review Charges response

The committee is requested to answer the following questions:

1. Does the MQXFA04 structure meet the MQXFA Structural Design Criteria [4]?

Yes, for the material presented.

Findings. The MQXFA04 structure has the same design as the MQXFA03 structure, which was found to meet the Structural Design Criteria after carrying out the two recommendations of the MQXFA03 review committee: (1) to extend the analysis of fillet radii of 0.5 mm and (2) extend analysis of bladder operations to two and four bladders at full pressure.

Comment: Load keys were inspected by lot when purchased and are not formally inspected for each magnet. Load keys thickness is a critical assembly parameter.

Recommendation. 100% inspect load key thicknesses to required tolerance starting with magnet MQXFA04.

2. Are there major non-conformities? If answer is yes, have they been adequately documented and processed?

No.

Findings. A total of 8 conformities have been reported. It is not explicitly stated how critical they are. However, the committee considers that they have been adequately documented and processed to the L2 level. Non conformances are tracked and communicated to Fermilab on a monthly basis.

Recommendation.

Report overall status and non-conformances to CERN using a similar scheme to the one followed for the coils (monthly excel spreadsheet AUP\_coil\_status) and verify that MTF steps are fully accepted. In the case of MQXFA03, all operations after coil pack magnetic measurements are still pending (see screenshot below).



# Report of the MQXFA04 Structure & shim review

US-HiLumi-doc-2505

Other:

Date: 12/12/2019

Page 5 of 7

**Equipment Identifier:** HCMQXFAS001-LB000001  
**Other Identifier:** MQXFA03  
**Description:** 150mm Single Aperture Nb3Sn Magnet Series (Q1,Q3)

Main Made of Equipment data **Manufacturing** Operation Non-conformities Documents History Map

Actions: Add extra step

Workflow Diagram  
No workflow diagram is defined for this equipment

Workflow Steps

Step ID	R/E	Other name	Description	Status	Last Repeat	NC
5		()	Coil Selection and Shimming Plan Review (*)	Accepted	Ok	
7		()	Hold Point by CERN (*)	Accepted	Ok	
10		()	Half-Yoke Stacks Assembly (*)	Accepted	Ok	
15		()	Shell Instrumentation (*)	Accepted	Ok	
20		()	Shell-Yoke Assembly (*)	Accepted	Ok	
25		()	Load Pad Pre-Stack (*)	Accepted	Ok	
30		()	Dressed Coil (*)	Accepted	Ok	
35		()	Pad Collar Assembly (*)	Accepted	Ok	
40		()	Coil Pack Subassembly (*)	Accepted	Ok	
45		()	Coil Pack Electrical Tests (*)	Done	Not Ok	
45.1	R	()	Coil Selection and Shimming Plan Review	Accepted	Ok	
45.2	R	()	Hold Point by CERN (*)	Accepted	Ok	
45.3	R	()	Dressed Coil (*)	Accepted	Ok	
45.4	R	()	Coil Pack Subassembly (*)	Accepted	Ok	
45.5	R	()	Coil Pack Electrical Tests (*)	Accepted	Ok	
50		()	Coil Pack Magnetic Measurements (*)	Accepted	Ok	
53		()	Hold Point by CERN (*)	Accepted	Ok	
55		()	MQXFA Magnet Fiducial Structure (*)	Pending		
60		()	Post Azimuthal Electrical Tests (*)	Pending		
65		()	Axial Rods Instrumentation (*)	Pending		
70		()	Axial Loading (*)	Pending		
75		()	Post Axial Electrical Tests (*)	Pending		
80		()	Magnetic Measurements (*)	Pending		
85		()	Splice Box Assembly (*)	Pending		
90		()	Post Splice Electrical Tests (*)	Pending		
95		()	Final Electrical Tests (*)	Pending		

3. Are the proposed shims adequate for allowing MQXFA04 to meet MQXFA requirements [1]?

Yes, assuming that the CMM measurements made at LBNL are the correct values.

Findings. The proposed shims are designed to achieve the azimuthal and axial preloads achieved by MQXFA03 and MQXFS4. MQXFA03 has achieved the present requirements for MQXFA training.

However:

- In coils 112, 113, 115 a large shift of the pole key slot is measured in the last pole piece close to the LE. This was not presented during the review, but the reviewers understand that the keys are going to be machined to account for the shift.



# Report of the MQXFA04 Structure & shim review

US-HiLumi-doc-2505

Other:

Date: 12/12/2019

Page 6 of 7

## Recommendation.

- Measure and machine accordingly the key such the key accounts for the large shift on the pole key slot. In case the final decision is not to machine the key, finite element analysis is needed to justify the decision. Machining the key should correct for shift without adversely impacting prestress, i.e., the expectation is for offset keys, not undersized keys.
  - Further understand the source of differences on CMM measurements among labs and agree on the method that is most relevant for coil assembly.
  - If the Fuji assembly reveals not uniform load distribution, the committee recommends to base the definition of the shimming on the coil azimuthal size, meaning that coils azimuthally similar have to be shimmed in a similar way.
4. Is MQXFA04 going to meet the MQXFA Interface Specification [5]? Most probably, yes. The LBNL group provided a list of the specific items in the Specification and the means by which each will be measured. Thus, the information needed to evaluate whether the magnet meets the specification will be available when the magnet is completed. At present, no item on this list is known or expected to be out of tolerance.
5. Have all recommendations from previous relevant reviews [6] been adequately addressed? Yes. Prestemon summarized the status of recommendations from the six reviews which have taken place in the period August 2017 – June 2019. Nine recommendations have been completed (closed). Two are open: (1) Work instructions for the magnetic field measurements will be available in draft form for measurements of MQXFA04. (2) Reevaluation of the risk matrix in light of events that have occurred since it was initially prepared. This is ongoing.
6. Do you have any other comment or recommendation to assure MQXFA04 is going to meet requirements?

No.

## **4. Comments**



# Report of the MQXFA04 Structure & shim review

US-HiLumi-doc-2505

Other:

Date: 12/12/2019

Page 7 of 7

## 5. Recommendations

## 6. References

- 1) *MQXFA Functional Requirements Specification*, US-HiLumi-doc-36.
- 2) *Report of the MQXFA04 Coils Acceptance Review*, US-HiLumi-doc-2432.
- 3) *MQXFA03 pre-load targets and pre-loading sequence*, US-HiLumi-doc-2496.
- 4) *MQXFA Structural Design Criteria*, US-HiLumi-doc-909.
- 5) *MQXFA Magnet Interface Specification*, US-HiLumi-doc-1674.
- 6) - *Report of the Review of the MQXFAP2 Al-Shell Issue and Lessons Learned*, US-HiLumi-doc-2192;  
- *MQXFA03 Structure & Loading Review*, US-HiLumi-doc-2260.