# US HL-LHC Accelerator Upgrade Project

# Report of the MQXFA13b Structure & Shim Review

*January 10th 2024*

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– Mike Anerella, (BNL)
– Susana Izquierdo Bermudez (CERN)

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## 1. Goal and scope

The HL-LHC AUP project is starting the assembly of MQXFA13b quadrupole magnet. This is the re-assembly of MQXFA13 that showed some issues during vertical testing (slow training and quenches after down-ramp at 100 A/s) even if it was able to reach and hold acceptance current. If MQXFA13b meets MQXFA requirements [1] it will be used in a Q1/Q3 cryo-assembly to be installed in the HL-LHC.

All issues during MQXFA13 test occurred in a single coil (227). This coil has been removed and is being replaced by coil 241 that was reviewed on November 8, 2023 [2]. In order to avoid reoccurrence of the MQXFA13 issue, analysis of CMM data in coil ends [3] and assessment of minimum loading-key shim size were added to the assembly plan.

MQFA13b used an entirely new structure, not the one from MQXFB13. The MQXFB13 structure was used in MQXFA16.

MQXFA Series magnet specifications are presented in [4]. Discrepancy or Non-Conformity Reports are generated whenever a component does not meet specifications [5].

The goal of this review is to evaluate MQXFA13b structure and shim plan. Reviewers should also assess that discrepancies and non-conformities of the magnet structure have been adequately processed, and that the shims will allow MQXFA13b to meet MQXFA requirements [1].

**Committee**

– Rodger Bossert (chairperson), FNAL
– Mike Anerella, (BNL)
– Susana Izquierdo Bermudez (CERN)

**Date and Time**

January 10, 2023. Start time is 7:30/9:30/10:30/16:30 (LBNL/FNAL/BNL/CERN)

**Location/Connection**

Video-link by Zoom, info by email.

**Link to agenda with talks and other documents**

https://indico.fnal.gov/event/62598/

## 2. Review Charges responses

The committee is requested to answer the following questions:

1. Have all recommendations from previous reviews [6] been adequately addressed?
Yes.

2. Have discrepancies and non-conformities been adequately documented and processed?
Yes.

3. If there are major/critical non-conformities [5], have they been adequately documented and processed?
There were several nicked and damaged quench protection heaters described in a presentation. This issue is critical, as this damage can easily result in a Quench heater to ground short and cannot be corrected after cold mass assembly. See recommendations.

4. Are the proposed shims adequate for allowing MQXFA13b to meet MQXFA requirements [1]?
Yes, but resolution of comments regarding addressing the coil radius and writing up the requirements for assembly (peak/average stress shim size) is still required.

5. Do you have any other comment or recommendation to assure MQXFA13b is going to meet requirements?
Yes. (see below)

## 3. Comments

- There appears to be uncertainty as to which control parameter during loading – namely 41 mil load shim or 120MPa maximum coil strain gauge reading would be the primary limit at assembly, and that no formal requirement had yet to be documented. It seems clear that the 120 MPa requirement as it already exists should be considered the most important requirement.
- One comment from the previous review indicated that since a new, more precise target for the preload was being established, the radially undersized condition of the coils and its effect on the shim system should be revisited. The same comment requested that the precision of the coil geometrical measurements should be revisited.
    - With respect to the radial shim, there remains an apparent misunderstanding of and application to assembly shim sizes of the CMM data, whereby coil radius variations are uncorrected; in this case

leading to possible undersized assembled coil packages. A further review of "TE-MSC-LMF INVESTIGATION OF MQXFB COIL GEOMETERY ALIGNMNET may prove informative.

- With respect to the precision of the coil geometrical measurements, consider the report from CERN, EDMS No. 2360408 "Investigation of MQXFB Coil Geometry Alignment" where two different coil measuring methods are compared with different results. A logical conclusion from this is that a smaller sized radius used with the OR + Midplane fit, as LBNL does, would result in a systematically smaller midplane size. If radially all the coils are very similar, this is not critical for assembly. But if there are significant differences among different coils, or among different magnet assemblies, it has an impact on the assembly and differences among magnets.
- Since the review, an attempt was made to assess the effects of the outer radius deviations that are introduced by fitting with the OR + midplane profile, by Paolo Ferracin. His conclusions are shown in HiLumi doc 4969. Small coils have a systematic negative deviation on the outer radius, and looking at the lead end (where MQXFA07/08/13 were limited), the magnet-to-magnet difference is up to 0.05 mm. This is not a negligible effect for the target key size which is now in a range of 0.075 mm (3 to 4 mils). Specific data from MQXFA13b is not included here and should be used instead of averages when assessing the preload.

## Summary
## Coil radial (shimmed) deviation and key/shim size

| | Ave ss | OR_Ave ss | LE min | OR_LE_min | RE min | OR_RE_min | Key | Shim | Shim | Ave ss + shim | LE + shim | RE + shim |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm | mm | mm | mm | mm | mm | mm | mils | mm | mm | mm | mm |
| A13b | -0.002 | | -0.147 | | -0.107 | | ? | ? | ? | ? | ? | ? |
| A17 | -0.004 | -0.041 | -0.134 | -0.051 | -0.125 | -0.061 | 13.74 | 39 | 0.9906 | 0.987 | 0.857 | 0.865 |
| A07b | -0.015 | -0.022 | -0.115 | -0.046 | -0.080 | -0.044 | 13.84 | 43 | 1.092 | 1.077 | 0.977 | 1.012 |
| A16 | 0.023 | -0.044 | -0.089 | -0.065 | -0.080 | -0.072 | 13.77 | 40 | 1.016 | 1.039 | 0.927 | 0.936 |
| A15 | 0.000 | -0.028 | -0.099 | -0.049 | -0.045 | -0.036 | 13.82 | 42 | 1.0668 | 1.067 | 0.968 | 1.022 |
| A14b | -0.007 | -0.029 | -0.129 | -0.055 | -0.107 | -0.050 | 13.84 | 43 | 1.092 | 1.085 | 0.963 | 0.985 |
| A13 | -0.004 | -0.054 | -0.146 | -0.079 | -0.094 | -0.070 | 13.72 | 38 | 0.965 | 0.961 | 0.819 | 0.871 |
| A8b | 0.000 | -0.025 | -0.181 | -0.067 | -0.136 | -0.061 | 13.77 | 40 | 1.016 | 1.016 | 0.835 | 0.880 |
| A11 | 0.004 | -0.043 | -0.124 | -0.070 | -0.047 | -0.051 | 13.74 | 39 | 0.991 | 0.995 | 0.867 | 0.944 |
| A10 | -0.092 | -0.053 | -0.221 | -0.078 | -0.199 | -0.074 | 13.82 | 42 | 1.067 | 0.975 | 0.846 | 0.868 |
| A8 | -0.029 | | -0.216 | | -0.172 | | 13.72 | 38 | 0.965 | 0.936 | 0.749 | 0.793 |
| A7 | -0.035 | | -0.139 | | -0.114 | | 13.77 | 40 | 1.016 | 0.981 | 0.877 | 0.902 |
| A6 | -0.034 | -0.020 | -0.138 | -0.024 | -0.178 | -0.051 | 13.72 | 38 | 0.965 | 0.931 | 0.827 | 0.787 |
| A5 | -0.025 | NA | -0.154 | NA | -0.105 | NA | 13.79 | 41 | 1.041 | 1.016 | 0.887 | 0.936 |

P. Ferracin

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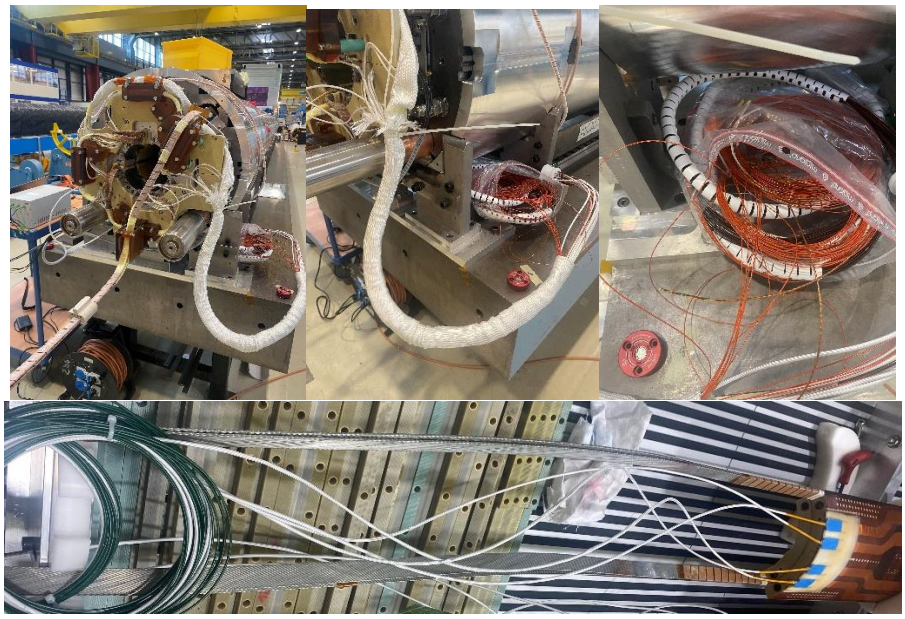
## 4. Recommendations

- There were several cases of nicked and damaged quench protection heaters shown. Protecting these wires is a critical issue. At CERN, MQXFBP3 had a quench heater to ground short at cold, see NCR **(**EDMS 2773498**).** Details were shared with the cold mass team, but the measures to protect wires need to be implemented from the installation of the quench heater wires to avoid any damage in the entire coil life cycle. At CERN, if a wire is damaged it is replaced (or cut and spliced) and not repaired. Wires are always handled adequately and protected in plastic bags when possible. Additional checks were also implemented to verify the integrity of the wires before the routing on the IFS (submerging wires in water), to be sure this defect does not reproduce in the future. These checks do not need to be implemented at the magnet assembly stage, it is part of the cold mass assembly work, but it is shared for information, to emphasize how critical a correct protection of the wires is. Shown below are some pictures from MQXFB, and more details on the specific measures in EDMS 2773498.



## 5. References

1) *MQXFA Functional Requirements Specification,* US-HiLumi-doc-36.
2) *MQXFA13b Coils Acceptance Review*, US-HiLumi-doc-4956.
3) *MQXFA Series Coil Production Specification*, US-HiLumi-doc-2986.
4) *MQXFA Series Magnet Production Specification*, US-HiLumi-doc-4009.
5) *Handling of Discrepancies and Nonconformances*, US-HiLumi-doc-2484.
6) *MQXFA17 Structure and Shims Review*, US-HiLumi-doc-4939.