



**Report of the
MQXFA18
Structure & Shim Review Report**

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US HL-LHC Accelerator Upgrade Project

**Report of the MQXFA18 Structure & Shim
Review**

June 14th 2024

- Peter Wanderer, chairperson (BNL)
- Mike Anerella, (BNL)
- Rodger Bossert, (FNAL)
- Susana Izquierdo Bermudez (CERN)



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1. Goal and scope

The HL-LHC AUP project is starting the assembly of MQXFA18 quadrupole magnet. This is the first MQXFA magnet to be assembled after MQXFA17 did not meet requirements during vertical test. Therefore, it will be the first new magnet to use tapered loading shims to prevent MQXFA17 issue.

If MQXFA18 meets MQXFA requirements [1] it will be used in a Q1/Q3 cryo-assembly to be installed in the HL-LHC.

MQXFA18 coils were presented and approved at the MQXFA18 Coil Acceptance Review [2].

The insertion of tapered loading keys was tested during the assembly of MQXFA12b. Comparison between FE simulations and strain gauge measurements can be found at [3]. The Off-normal work procedure used for this test is on the Indico page of this review [4].

Discrepancy or Non-Conformity Reports are generated whenever a component does not meet specifications [5, 6].

The goal of this review is to evaluate MQXFA18 structure, the proposed shim plan, and the use of tapered loading keys to prevent MQXFA17 issue. Reviewers should also assess that discrepancies and non-conformities of the magnet structure have been adequately processed to meet MQXFA requirements [1].

Committee

Peter Wanderer, chairperson (BNL)

Mike Anerella, (BNL)

Rodger Bossert, (FNAL)

Susana Izquierdo Bermudez (CERN)

Date and Time

June 14, 2024.

Start time is 7:00/9:00/10:00/16:00 (LBNL/FNAL/BNL/CERN)

Location/Connection

Video-link by Zoom, info by email.

Link to agenda with talks and other documents

[MQXFA18 Structure & Shims Review \(June 14, 2024\) · INDICO-FNAL \(Indico\)](#)



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2. Review Charges responses

The committee is requested to answer the following questions:

1. Have all recommendations from previous reviews [7] been adequately addressed?
Yes. (There were no new recommendations in [7].)
2. Have discrepancies and non-conformities of MQXFA18 structure been adequately documented and processed?
Yes.
3. If there are major/critical non-conformities, have they been adequately documented and processed?
There were no major/critical non-conformities.
4. Are the proposed shims adequate for allowing MQXFA18 to meet MQXFA requirements [1]?
Yes, meaning that they are consistent with the shimming strategy applied in previous magnets. The tapered loading keys in the lead end will bring the coil to the design preload achieved in previous successful magnets.
5. Do you have any comment or recommendation about the plan to use tapered loading keys to prevent MQXFA17 issue? **Comment:** The tapered loading keys are expected to limit the risk of the performance degradation exhibited by MQXFA17.
6. Do you have any other comment or recommendation to assure MQXFA18 is going to meet requirements? See comments below.

3. Findings

- The analysis combines the size of the load key shim and the radius of the shimmed coil pack to set the room temperature preload.
- The range of acceptable values for these parameters was calculated using data from two successful magnets (MQXFA14b and MQXFA05) and an unsuccessful magnet (MQXFA13).
- Verification that the off-normal procedure developed for installing tapered keys in the coil lead end was made by a test assembly of MQXFA12b [3,4]. MQXFA18 will be assembled with additional mechanical instrumentation in the coils and shells to have better monitoring of the stress state in the region of interest. An off-normal procedure was written for the MQXFA12b test, but a procedure for MQXFA18 was not presented. We **recommend** having this document ready before the assembly of MQXFA18. The additional instrumentation and the wiring shall be part of this procedure such that the additional cabling does not introduce any additional risk in the assembly. This is important because the coil strain gauges are disconnected after loading before the electrical tests.



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4. Comments

- The plan for MQXFA18 is to use tapered keys to increase the radial pre-load in the end and prevent coil damage during powering. There was an in-depth investigation including numerical analysis and post-mortem inspection on the previous non-performing coils. The proposal of using tapered keys in the future magnets is well justified. However, magnets with smaller equivalent size in the lead end did not show any performance degradation. Other parameters can contribute to the magnet weakness in the coil ends. For this reason, tapered keys shall be seen as a risk mitigation action, but not a full 'curative' action.
- The basic reason for using tapered load keys in the lead end, increased support of the coil, applies also to the return end. The group may wish to reconsider the decision to not use them in the return end.
- During assembly, use of load keys calculated as discussed above could lead to preloads above the conductor limit, 120 MPa. It may be advisable for the L2 leader to be made aware of this at the time the decision is made and/or set an upper limit above which a discussion is needed before proceeding with the assembly (e.g., 140-160 MPa).
- The tapered key installation causes small inward radial deflection of the coils in the shimming region. When asked about impact on pylons or other, the answer was that the shimming was beyond the last pylon. A later view of the locations indicated there was overlap.

5. Recommendations

- Write the procedure for assembling MQXFA18 with tapered shims before the magnet is assembled.
- Proceed with the assembly of MQXFA18, including the tapered load keys at the lead end.
- Consider also applying the same approach to the return end, unless there are other manufacturing features in addition to coil end size that justify the use of tapered keys only in the lead end.
- In parallel, proceed with post-mortem inspection of coils that did not show limitation during training, for a better understanding of the phenomenology.
- Study in ANSYS the impact of the AI-shell segmentation in the coil end. The transition between the short shell and first long shell is very close in the longitudinal direction with the transition wedge-end spacer. It would be interesting to study the axial strain in the regions of interest if the last aluminum shell is full length instead of half length.



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6. References

- 1) *MQXFA Functional Requirements Specification*, US-HiLumi-doc-36.
- 2) *MQXFA18 Coils Acceptance Review*, US-HiLumi-doc-5084.
- 3) *Analysis of test performed on MQXFA12b using tapered loading keys*
<https://indico.fnal.gov/event/64922/>
- 4) *Off-Normal Procedure for Tapered Key Demonstration*, Indico page of this review.
- 5) *MQXFA Series Magnet Production Specification*, US-HiLumi-doc-4009.
- 6) *Handling of Discrepancies and Nonconformances*, US-HiLumi-doc-2484.
- 7) *MQXFA12b Structure and Shims Review*, US-HiLumi-doc-4983.