Report of the FDR Absorber and Casing Steel ePIC Forward Hadron Calorimeter Review

Performed Remotely at Brookhaven National Laboratory

Upton, NY

Sept 25, 2023

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1. Executive Summary

Final Design Review of the steel and tungsten absorber and casing steel for the ePIC Forward Hadronic Calorimeter

The Electron-Ion Collider (EIC) is a major facility, fully international in character, being designed and built at the U.S. Department of Energy's (DOE) Brookhaven National Laboratory (BNL) in partnership with the Thomas Jefferson National Accelerator Facility (Jefferson Lab). The accelerator and one general purpose detector will be constructed over the next decade as a DOE construction project augmented with non-DOE in-kind contributions. The ePIC Collaboration in cooperation with the EIC Project is designing the detector systems to meet the goals as outlined in the 2015 NSAC Long Range Plan. The detector design work is currently in full swing.

The ePIC Forward Hadronic Calorimeter (LFHCAL) will provide detection of charged and neutral hadrons and jets in the EIC hadron-going endcap, in a wide energy range up to the incoming hadron beam energy. It is a transversely and longitudinally segmented sampling Fe(W)/Sc calorimeter, placed on a pair of moveable platforms behind a compensated sampling electromagnetic calorimeter, on the left and on the right side with respect to the beam line. LFHCAL occupies a nominal space between 3.6m and 5.0m from the interaction point in the hadron endcap. It consists of a small high granularity part around the beam pipe (the "insert") and a "main" part mostly built from ~10cm x 20cm x 140cm modules, with alternating layers of absorber (tungsten and steel) and scintillating plastic material, segmented into ~5cm x 5cm x 20cm logical cells. Each cell has ten scintillator plates with a single SiPM placed in a dimple in its center. These SiPM signals are summed up to provide a measure of a hadronic shower energy deposit in a given cell.

The LFHCAL steel absorber and module casing steel will serve as part of the EIC solenoid flux return. As such, the whole assembly needs to be in place early enough, in order to perform the magnet tests.

We are ready to proceed with the Final Design Review of the LFHCAL steel and tungsten absorber parts as well as the module casing steel for this ePIC detector subsystem, in order to initiate the Long Lead Procurement of these items.

2. Reponses to Charge Questions

Responses to Questions

1. Are the LFHCAL technical performance requirements complete, documented, and understood?

- The technical performance requirements are understood in terms of simulations and sufficiently consolidated for the procurements.
- Recommendations:
  - Use the power of the now existing full simulation for the further understanding of detailed requirements
    - Uniformity within segments
    - Tungsten vs stainless steel
    - Dynamic range
    - Cast and molded scintillator, small and large SiPMs.
  - Use LFHCAL simulation as integrated in overall ePIC simulation and study physics sensitivity to technical performance.

2. Are the plans for achieving detector performance and construction sufficiently developed and documented for the present phase of the project? Specifically, are they commensurate with the initiation of the LFHCAL absorber and casing steel procurement?

- FB: Yes, advanced detector performance simulations have been shown taking into account the realistic detector geometries. Moreover, detailed construction plans have been presented.
- The baseline questions are well understood but an optimization study should be done.
- Recommendation:
  - Implement software compensation as soon as possible and re-assess the benefits of the tungsten section.

3. **Do the present LFHCAL design and the resulting absorber and casing steel specifications meet the abovementioned performance requirements with a low risk of cost increases, schedule delays, and technical problems?**

The team should be commended on contacting and working with multiple vendors. Given the volatility of both material costs and labor, it is prudent to try find 5-6 potential vendors if possible. If this is not possible, a detailed bottoms-up cost estimate should be done in case there is only one or two bids submitted. This will prevent any significant delays in this procurement and reduce the risk of having to enter into a re-bid cycle.

There is some risk associated with this procurement concerning the integration gaps identified at today's review. It is important that these gaps between EMCal support plate, flux return steel, and base be closed even if just conceptually. It is recommended that this effort proceed in parallel with the procurement and closed prior to contract award.

See also points raised on question number 5.

4. Are the fabrication and assembly plans for the LFHCAL consistent with the overall project and detector schedule and appropriately developed to initiate the procurement?

Within the bounds of the information presented today, the fabrication package for steel and tungsten is very close to being ready for release for bid and subsequent fabrication. The project team has done an excellent job in preparing this package. Further development of the accompanying Specification and Statement of Work should be drafted and circulated for review as soon as possible.

It is recommended that the team perform a pre-series exercise in order to validate their production schedules.

5. Are the plans for LFHCAL integration in the EIC detector appropriately developed to initiate the procurement? In particular, is the design consistent with a requirement that LFHCAL iron components should serve as part of the EIC detector solenoid flux return?

Further clarification of magnet forces should be made along with an estimate for quench forces. Similarly seismic forces should be folded into the overall design and coupled to the integration question raised in an earlier slide.

6. Have the December 2022 EIC Calorimetry Review recommendations been adequately addressed to initiate the procurement?

Yes, with the exception of the integration components related to EMCal support plates, magnet flux return, and support structure. These integration issues should be resolved in parallel with the procurement cycle so that any changes are captured before final contract award. It is suggested that in the future the project team hold an engineering design review prior to the final design review for all additional subsystems.

7. Have ES&H and QA considerations been adequately incorporated in the procurement planning? (This includes a quality assurance plan for receipt of material, in particular verification of the required permeability of the steel components.)

ES&H and QA offices should be contacted and recommendations should be added to the Statement of Work and Specification prior to the issue for bids.

8. Is the procurement approach sound and the procurement schedule credible?

For the steel and tungsten component of this subsystem a firm-fixed-price procurement with first article requirements should be straightforward. SIPM procurement may be slightly riskier given the limited number of acceptable suppliers. It is recommended that this procurement should be followed in parallel with the steel and tungsten procurement.

Comments

General Observations

- We appreciate the well prepared and very clear presentations, and the competent replies to our questions.
- The progress in simulations is well noted. With this the technical performance expectations are on solid grounds.
  - Tools at hand to study further optimisation questions.
- Long lead procurements unavoidably come with a risk of fixing parts of the design while others are still in progress.
  - This is well understood and minimised as much as possible.

Recommendations

- The committee recommends that the project expeditiously move to procure the LFHCAL absorber and casing steel as detailed in the Final Design Review held on Monday, September 25, 2023.

- Along with this there are a number of recommendations listed in the slides below. These concern integration and technical information gaps which should be addressed during and in parallel with the procurement phase of the absorber and casing steel. Having a good understanding of these gaps is essential for project leadership, and in several cases their potential effect on the procurement should be well known prior to contract award.

3. Appendices

3.1 Appendix A: Charge to the Review Committee

Charge to the Committee:

The scope of this review is an assessment of the readiness to proceed to the procurement phase. The committee is asked to respond to the following charge questions:

1. Are the LFHCAL technical performance requirements complete, documented, and understood?

2. Are the plans for achieving detector performance and construction sufficiently developed and documented for the present phase of the project? Specifically, are they commensurate with the initiation of the LFHCAL absorber and casing steel procurement (also hereafter referred to as the "procurement")?

3. Do the present LFHCAL design and the resulting absorber and casing steel specifications meet the abovementioned performance requirements with a low risk of cost increases, schedule delays, and technical problems?

4. Are the fabrication and assembly plans for the LFHCAL consistent with the overall project and detector schedule and appropriately developed to initiate the procurement?

5. Are the plans for LFHCAL integration in the EIC detector appropriately developed to initiate the procurement? In particular, is the design consistent with a requirement that LFHCAL iron components should serve as part of the EIC detector solenoid flux return?

6. Have the December 2022 EIC Calorimetry Review recommendations been adequately addressed to initiate the procurement?

7. Have ES&H and QA considerations been adequately incorporated in the procurement planning? (This includes a quality assurance plan for receipt of material, in particular verification of the required permeability of the steel components.)

8. Is the procurement approach sound and the procurement schedule credible?

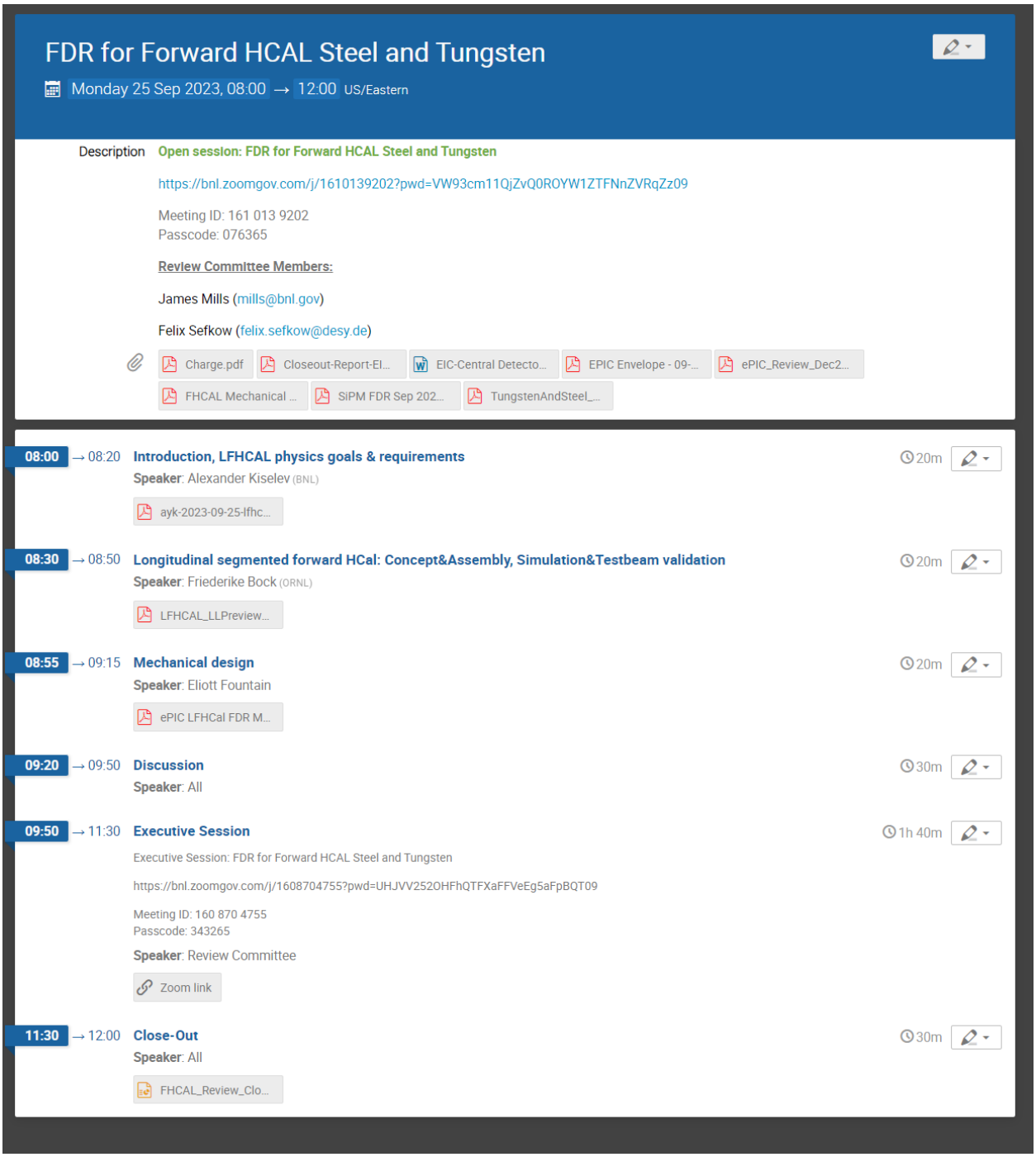
We would appreciate receiving the committee's report within 14 days of the review's conclusion.

You will be supplied as part of the pre-brief material with the report from the earlier ePIC Calorimetry technical review held in December 2022, and with a set of LFHCAL technical drawings.

3.2 Appendix B: Review Committee

Committee: James Mills (BNL), Felix Sefkow (DESY)

3.3 Appendix E: Agenda



FDR for Forward HCAL Steel and Tungsten

Monday 25 Sep 2023, 08:00 → 12:00 US/Eastern

Description **Open session: FDR for Forward HCAL Steel and Tungsten**

https://bnl.zoomgov.com/j/1610139202?pwd=VW93cm11QjZvQ0ROYW1ZTFNnZVRqZz09

Meeting ID: 161 013 9202
Passcode: 076365

Review Committee Members:

James Mills (mills@bnl.gov)

Felix Sefkow (felix.sefkow@desy.de)

Charge.pdf | Closeout-Report-EI... | EIC-Central Detecto... | EPIC Envelope - 09-... | ePIC_Review_Dec2... | FHCAL Mechanical ... | SiPM FDR Sep 202... | TungstenAndSteel_...

08:00 → 08:20 **Introduction, LFHCAL physics goals & requirements** 20m
Speaker: Alexander Kiselev (BNL)
ayk-2023-09-25-lfhc...

08:30 → 08:50 **Longitudinal segmented forward HCal: Concept&Assembly, Simulation&Testbeam validation** 20m
Speaker: Friederike Bock (ORNL)
LFHCAL_LLPreview...

08:55 → 09:15 **Mechanical design** 20m
Speaker: Eliott Fountain
ePIC LFHCal FDR M...

09:20 → 09:50 **Discussion** 30m
Speaker: All

09:50 → 11:30 **Executive Session** 1h 40m
Executive Session: FDR for Forward HCAL Steel and Tungsten

https://bnl.zoomgov.com/j/1608704755?pwd=UHJVV252OHFhQTFXaFFVeEg5aFpBQT09

Meeting ID: 160 870 4755
Passcode: 343265

Speaker: Review Committee
Zoom link

11:30 → 12:00 **Close-Out** 30m
Speaker: All
FHCAL_Review_Clo...