Electron-Ion Collider

SiPM Applications in ePIC Detector Sub-systems

Final Design Review

September 14, 2023

Performed Remotely at Jefferson Lab
Newport News, Virginia

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1. Executive Summary

The ePIC collaboration at EIC is preparing for long-lead procurements. Photo sensors, specifically SiPMs, for calorimeters and PID detectors fall into this category. The purpose of this review is to evaluate the preparedness of the detector groups to commence procurement. The whole project requires more than 1,000,000 SiPMs of various types, and initiating procurement in a timely manner is imperative for the project's success. The vendor pool capable of meeting the required specifications is limited, and the construction of some detectors necessitates a substantial amount of time.

We would like to emphasize three general considerations related to the selection of SiPMs:

1. The insensitivity of modern SiPMs to magnetic fields and their compact size makes them an excellent choice for many of the ePIC detectors.
2. The specifications of individual SiPMs are well-matched to the detector requirements presented at this review.
3. The choice of specific SiPMs is not strongly affected by final design of infrastructure and electronics, and therefore is compatible with early procurement.

Based on the above observations, *we strongly recommend commencing the procurement process for the SiPM light sensors as soon as possible*, considering funding and other constraints.

The reviewers extend their gratitude to the ePIC collaboration for their efforts in preparing presentations, providing supplementary information, and patiently addressing our inquiries during the review. Below, we provide our responses to the review charge questions along with some comments that we believe could prove beneficial to the project.

2. Responses to Charge Questions

Charge Question 1:

Are the technical performance requirements complete for all detector systems that employ SiPMs, documented, and understood?

Yes. The technical performance requirements are complete.

Charge Question 2:

Are the plans for achieving detector performance and construction sufficiently developed and documented for the present phase of the project? (i.e., are they commensurate with the initiation of the SiPM procurement?)

Yes. The plans for construction and for achieving detector performance are sufficiently developed.

Charge Question 3:

Do the present detector system designs and the resulting SiPM specifications meet the performance requirements with a low risk of cost increases, schedule delays, and technical problems?

Most of the SiPM specifications are completed, but some detectors do not yet have final technical specifications (LFHCal and Insert, Barrel imaging Ecal).

Charge Question 4:

Are the fabrication and assembly plans for the detector systems consistent with the overall project and detector schedule and sufficiently developed to initiate the SiPM procurement?

Yes. The detector fabrication and construction plans are sufficiently developed and consistent with project schedule.

Charge Question 5:

Are the plans for detector integration in the EIC detector appropriately developed to initiate the SiPM procurement?

Yes. The SiPM procurement can start.

Charge Question 6:

Have previous review recommendations been adequately addressed to initiate the SiPM procurement?

Yes. The feedback from previous reviews have been incorporated into the current designs.

Charge Question 7:

Have ES&H and QA considerations been adequately incorporated in the SiPM procurement planning? (This includes a quality assurance plan for receipt of material meeting specifications.)

Experience with receipt, QA and testing of SiPMs is extensive and are being included in planning. However, detailed decisions about the extent of testing, how many setups are needed, and how long the tests will take is still under discussion.

Charge Question 8:

Is the procurement approach sound and the procurement schedule credible?

More than half of the one million SiPM cells are required for the Forward HCAL, which needs them before the start of detector construction because they are incorporated into the detector volume. Thus, the completion of the Forward HCAL drives the schedule. The SiPM procurement, receipt and testing, followed by detector construction must be completed by December of 2029 to be ready for solenoid mapping. About a third of the sensors are required by the dRICH, assembled into 5k arrays of 8x8 SiPMs, but they can be installed after detector contraction.

The procurement for the various SiPMs will be staged, starting with the FHCAL, which are required sooner to meet their schedule. This approach is prudent and compatible with limited vendors. The lead time for delivery needs to be incorporated into the procurement process.

3. Comments

The requirements were presented in presentations and in excel files. However, we urge the collaboration to produce documentation that could be expanded into a Technical Design Report.

We urge the collaboration to continue performing realistic simulations that verifies that all the goals are met, including PID performance. The goals were clearly stated, but detailed verification was not presented for some of these.

We recommend speedy decisions on the final details of all specifications, especially for the FHCAL, where the procurement drives the schedule. During the selection of the pixel size for the sensors, one should review and evaluate the effective number of active pixels in each cell so as to not overestimate the actual dynamic range that is achievable.

The decision of the array arrangement for the Barrel ECAL is not as urgent, but should be pursued deliberately.

Experience has shown that the choice of SiPMs has little technical risk, once final specifications are available.

Timely issuance of procurements will mitigate schedule and cost risk.

The schedule for refurbishment of the Barrel Hadronic calorimeter depends on timely decommissioning of sPHENIX, and should be watched very carefully.

The design for infrastructure, electronics and integration of detectors is still underway and was not presented at this review.

The design for the energy resolution of the electromagnetic calorimeters requires that the constant term be on the order of 1-2%. This puts stringent requirements on the temperature stabilization of the sensors, whose breakdown voltage and therefore gain depends on temperature. Therefore, special care must be taken to the final design and integration of onboard electronics to ensure that the temperature is stabilized at a level that meets those requirements. This activity can proceed in parallel with SiPM procurement.

4. Recommendations

1. None.

5. Appendices

5.1 Appendix A: Charge to the Review Committee

Jefferson Lab
Thomas Jefferson National Accelerator Facility

MEMO

Date: September 7, 2023

To: Elton Smith (JLab) and Stephan Stepanyan (JLab)

From: Elke Aschernaur (BNL) and Rolf Ent (JLab)

Subject: EIC SiPM Applications in ePIC Detector Sub-systems Final Design Review

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

1. Are the technical performance requirements complete for all detector systems that employ SiPMs, documented, and understood?
2. Are the plans for achieving detector performance and construction sufficiently developed and documented for the present phase of the project? (i.e., are they commensurate with the initiation of the SiPM procurement?)
3. Do the present detector system designs and the resulting SiPM specifications meet the performance requirements with a low risk of cost increases, schedule delays, and technical problems?
4. Are the fabrication and assembly plans for the detector systems consistent with the overall project and detector schedule and sufficiently developed to initiate the SiPM procurement?
5. Are the plans for detector integration in the EIC detector appropriately developed to initiate the SiPM procurement?
6. Have previous review recommendations been adequately addressed to initiate the SiPM procurement?
7. Have ES&H and QA considerations been adequately incorporated in the SiPM procurement planning? (This includes a quality assurance plan for receipt of material meeting specifications.)
8. Is the procurement approach sound and the procurement schedule credible?

   The list of detector sub systems that employ SiPM are given here:

   - Barrel Hadronic Calorimeter
   - Forward Hadronic Calorimeter
   - Backward Electromagnetic Calorimeter
   - Barrel Electromagnetic Calorimeter
   - Forward Electromagnetic Calorimeter
   - dual-RICH PID detectors

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

cc: J. Fast

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5.2 Appendix B: Review Committee

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Stephan Stepanyan	stepanya@jlab.org	JLab

5.3 Appendix E: Agenda

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Electron-Ion Collider
Final Design Review for SiPM Applications in ePIC Detector Sub-systems
Thursday, September 14, 2023

Open Session Zoom Link

EST	Topic	Presenter	Duration (Min)
8:00 AM	Executive Session	Review Panel	20
8:20 AM	Detector Overview and Requirements	Beni Zihlmann (JLab)	15 +5
8:40 AM	dual-RICH	Roberto Preghenella (INFN)	20 +10
9:10 AM	Forward Hadronic Calorimeters (HCAL)	Friederike Bock (CERN)	20 +10
9:40 AM	Barrel Hadronic Calorimeters (HCAL)	John Lajoie (IA State)	20 +10
10:10 AM	Break		20
10:30 AM	Backward Electromagnetic Calorimeters (ECAL)	Tanja Horn (CUA)	20 +10
11:00 AM	Barrel Electromagnetic Calorimeters (ECAL)	Sylvester Jooster (ANL)	20 +10
11:30 AM	Forward Electromagnetic Calorimeters (ECAL)	Oleg Tsai (UCLA)	20 +10
12:00 PM	Lunch/Executive Session		120
2:00PM	Closeout		

Closed Session Zoom Link

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