Report of the

Detector Advisory Committee

Comprehensive Review

Performed Remotely at Brookhaven National Laboratory

Upton, NY

August 29-30, 2023

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1. Executive Summary

The detector advisory committee met during August 29-30 , 2023 to hear reports on the various components of the EIC detector and review progress in all the areas of design including detector components as well as the infrastructure to support and supply services to the detectors. Particular attention was focused on preparation for the review of the project at CD 2/3a when the overall project design needs to be ready for determination of realistic costs and long lead items needs to have complete enough specification to allow the placing of purchase orders without engendering risk to the project.

The committee finds that enormous and satisfactory progress has been made in the developing of the design and specification of the detector infrastructure and components that will allow the science program of the EIC to be carried out at the desired accuracy. As expected, some components are further along in this process than others and the committee has tried to identify items needing more resources to bring them to the necessary level of specification, especially those which need to be procured in the near future.

The report below is organized by the individual charges given to the committee.

2. Reponses to Charge Questions

Charge 1: Given the detector progress over the last two years and the status of the ePIC detector, are the projected timelines of the Electron-Ion Collider detector feasible? Do there remain significant open detector technology questions?

Findings:

Tremendous progress has been made by the ePIC collaboration and the BNL and JLab project teams in the last two years, and the committee wishes to congratulate all working on the EIC for this enormous achievement. At the time of the review, all central detector technologies have been chosen and appear appropriate. Several technologies still require significant further R&D in order to confirm that they will provide the required performance. These include the Silicon Vertex Tracker (SVT), the μRWELL tracker, the Imaging Sci/Fi tracking calorimeter, the HRPPD sensors and the AC-LGAD tracker. The primary acknowledged risks to the project are delays in the production of the spectrometer magnet and the silicon tracker elements. A less prominent risk is related to the unknown status and useability of the fused silica bars proposed to be re-used in the hpDIRC. The committee notes that the far-forward detectors are at a less advanced stage of design, with open technology choices still under investigation. No major issues remain between the highly integrated accelerator and detector components, but we support continued discussion of this integration.

Comments:

The committee feels that the projected timelines are aggressive but do appear feasible. The final magnet review should be carried out expeditiously to mitigate any delay. The progress of the magnet from procurement to delivery should be closely monitored. In the event of delay, what is planned to occur or how will the present plan change?

The silicon tracker development will also require close attention. Again, in the event of serious issues with the 65nm yields what will be the consequences and planning for the SVT?

Finally, ASIC development should be closely monitored as it has often taken significantly more time and effort than originally planned. As these efforts continue well past CD 2/3a review, delays can have significant impact.

Recommendations:

1) We recommend the development of back-up plans in case of delays or other problems with the magnet and SVT production.
2) We recommend the inspection and testing of a sample of the fused silica bars from SLAC as soon as possible.

Charge 2: Are the requirements for the detector and their flow down sufficiently comprehensive for this stage of the project to complete the design of the various detector technologies?

Findings:

The committee was very impressed with the organization of the detector development facilitated by a formal system engineering approach. Its use seems critical in keeping control on the myriad requirements needed for engineering design as well as detector performance. The interaction of project engineering staff with detector groups appeared excellent.

Comments:

Overall the committee felt that the design of the detector integration and installation are developing well. There remains concern that radiation hardness and background rate issues may still affect detector performance (and design), with time-dependent rate and noise dependences. An overall plan describing the plans for survey and alignment of the detector and its components as well as the monitoring and calibration would be of interest as it can affect the full design.

It was recognized that the Yellow Report (YR) requirements at large rapidities were not feasible with available technology. We suggest that the detector requirements be modified to better match the associated physics program obtainable.

Recommendations:

1) We urge incorporating the machine background expectations into the individual detector simulations as well as attempting to provide conservatively large safety margins in performance. Likewise, we encourage the continued evaluation of the radiation hardness of the exposed components.
2) We also recommend that estimates of the expected component failure rates should be incorporated into evaluation of the individual detector's technology performance, especially where component repair is difficult and/or expensive.
3) A comprehensive description of the survey/alignment/monitoring and calibration strategy for the hardware components of all detector systems is needed.

Charge 3: Are the interfaces between the elements of the design adequately defined for this stage of the project and to proceed with the detector long-lead procurement items?

Findings:

The identified long-lead items were the superconducting solenoid magnet, a large number of SiPMs for use in the PID/CAL detectors, the PbWO4 crystals for the electron endcap calorimeter, the scintillating fibers for the calorimeters, and the absorber for the forward HCAL/insert. Once again, the demonstrated systems engineering approach gave confidence that the interfaces are sufficiently well defined that the long-lead items can be procured with small risk to the project.

Comments:

The cooling and annealing infrastructure for the SiPM needs some further study, as unforeseen issues could impact the interface to nearby detector systems; for example, high background currents could require significant cooling of normal SiPM operation. SiPM gains may therefore need to be monitored to provide the best performance. The annealing parameters (time and temperature) were not presented. The effects need to be studied as for cooling requirements.

A summary of the different types of SiPM being planned for long procurement would be useful for evaluating whether they are optimal in pixel size and environmental sensitivity.

Recommendations:

1) If not already available, a scheme for monitoring the SiPM temperature environment needed for gain corrections should be developed.
2) Likewise, the parameters and plans for SiPM cooling and annealing should be developed, if not already available.

Charge 4: Is the design of these long-lead procurement items sufficiently advanced and mature to start procurement in 2024? Are the technical specifications complete?

Findings:

The cryogenic solenoid magnet capable of proving up to 2T field must be available early to allow the timely installation of the detector components. Details of the design were presented as well as a timeline for procurement, construction and testing. The large number of SiPMs needed requires long lead procurement for vendor fabrication, testing and installation. The fabrication of the large number of individual pieces in the backward/forward HCAL also requires long-lead procurement for the same reason as the SiPMs. The recent choice of the imaging calorimeter technology made this design less mature, with some specification uncertainty. The significant amount of scintillating fiber required also demands a long-lead procurement.

Comments:

The magnet specifications are clear and the design appears quite mature and nearly completed. We note that good cooling system redundancy has been included in the design. Overall the magnet seems ready to go to procurement within a few months.

The committee notes that the background conditions are varied within the detector so that close attention to the SiPM specifications is needed, especially given the large number being purchased.

The long lead items for the HCALs seem sufficiently specified to advance to procurement.

The imaging calorimeter is based on the existing GLUE-X calorimeter, hence the long lead items of the scintillating fiber and SiPMs are specified sufficiently well. It was not mentioned how long it would take to procure sufficient astropix detectors and what services/conditions they require for reliable operation.

Recommendations:

1) The technical specifications and requirements for the acquisition and use of the astropix detectors should be fully developed, including discussion of risk factors and fallback solutions.

Charge 5: Is the projected design maturity of the further detector components likely to be accomplished by the end of 2024 for CD-2 and CD-3?

Findings:

The committee was impressed that many of the components are already in advanced stages of design, nearly ready for a CD2/3 review. In addition, the infrastructure, integration and installation effort is advanced and well supported.

Comments:

Several detector systems are still requiring prototype/production cycles. The silicon tracker development is tied to the ITS3/ALICE development, and continues past CD2/3, as does the development of the various ASICs. The μRWELL endcap/barrel tracker prototype needs validation with beam test as does the imaging calorimeter, the AC-LGAD and the pfRICH prototype. This leads to some risk for being ready in time, especially given difficulties in obtaining test beam time. The HRPPDs are not mentioned as long lead items, but as R&D is ongoing, it was not clear what production/testing times would be required.

In particular, it was not clear to the committee how the choice of μRWELL technology will be made in time for CD 2/3 review given foil production times (not only at the prototype stage but also potentially in full production). As mentioned above, the committee would like clarification about the production/acquisition strategy for the Astropix, especially relative to design finalization/development and foundry availability. Some less advanced systems, which we nonetheless feel can be ready for CD2/3 are the electron polarimeters, the dual RICH, the far forward and backward detectors, and the TOF detectors.

Recommendations:

1) The SVT sensor design will require significant effort to reach maturity by the end of 2024. The EIC community must strive to help the ITS3 project advance to their mutual benefit, but also push for the transfer of knowledge to EIC engineers. This is vital to allow progress in the independent design for the LAS.
2) Given the approximate one year production time for μRWELL foils, convergence on a preferred μRWELL implementation as soon as possible.

Charge 6: Is the overall schedule for completion of the design, production, and installation of detector components realistic?

Findings:

The overall schedule was present to the committee; it was explained that the schedule does not have added contingency, and in many cases is based on actual experience at RHIC and Jlab.

Comments:

The committee again congratulated the project on the careful planning evident in the detailed schedule. The overall schedule is quite aggressive and ambitious, and will require careful monitoring of critical milestones. The development of contingency plans would be useful for understanding the effects of delays which occur in the schedule. Flexibility in the schedule should be maintained as much as possible to minimize risk to the project. As noted above, the magnet and SVT remain high risk items for the project as a whole, especially as related to the timely assembly of the entire detector.

Recommendations:

No specific recommendations.

3. General Comments and Recommendations

1) Congratulations to all involved in the EIC project on the rapid development of a nearly complete design for the EIC detector. This was extremely impressive to the committee, especially in the organization of the many different project components and tasks. This inspired confidence in the successful completion of this incredibly complex facility.
2) Enormous progress has been made in developing a coherent design for detector to carry out EIC research goals, with minimal open technology choices at present.
3) The committee recommends continued study of the detector readout and DAQ strategy. In particular, significant resources will be necessary to support all aspects of the R&D, production and commissioning, throughout the period between CD2/3 and CD4. The committee applauds the adoption of common solutions (RDO, DAM etc), but their development and support must be properly resourced to guarantee the success of this approach.
4) ASIC development has historically been on the critical path in many projects, often due to a lack of personnel resources. In some cases, this was only resolved by the injection of centralized engineering support. We encourage the EIC community to carefully monitor the progress of the various ASIC projects and ensure these are properly resourced.

4. Appendices

4.1 Appendix A: Charge to the Review Committee

EIC Detector Comprehensive Design Review – 6th DAC meeting

August 29-30, 2023

Charge

The EIC Detector Advisory Committee (DAC) provides advice to the EIC project managed by BNL in partnership with Thomas Jefferson National Accelerator Facility (TJNAF) on the experimental equipment and on overall matters with respect to the scientific collaboration, ePIC. This includes advice on the suitability of the experimental equipment for the EIC science, on cost, schedule and technical risk of detector components and design choices, and relative importance of technical tasks, on evaluation of complementary EIC detector technologies and the sub-detector integration, detector-interaction region integration, and detector commissioning, and on the EIC-related detector R&D.

Critical Decision-One (CD-1) for the EIC was awarded on June 29 2021 and allowed for release of Project Engineering and Design (PED) funds. This initiated the next phases of design of accelerator and detector. The 2022 EIC funding from the Inflation Reduction Act allowed the EIC project to stay on pace, with the EIC project aiming to receive CD-3A (start of long-lead procurements) early 2024 and CD-2/CD-3 (baseline approval and start of construction) roughly one year later.

The 6th and 7th DAC meeting will occur in the same week, where two days will be dedicated to a comprehensive design review of the ePIC detector where you will also hear the overall progress and status of the EIC Project, and two days dedicated to the review of the ongoing EIC project detector R&D and possible continuations.

For the 6th DAC meeting that serves as comprehensive EIC detector design review, the DAC is asked to answer the following charge questions:

- Given the detector progress over the last two years and the status of the ePIC detector, are the projected timelines of the Electron-Ion Collider detector feasible? Do there remain significant open detector technology questions?
- Are the requirements for the detector and their flow down sufficiently comprehensive for this stage of the project to complete the design of the various detector technologies?
- Are the interfaces between the elements of the design adequately defined for this stage of the project and to proceed with the detector long-lead procurement items?
- Is the design of these long-lead procurement items sufficiently advanced and mature to start procurement in 2024? Are the technical specifications complete?
- Is the projected design maturity of the further detector components likely to be accomplished by the end of 2024 for CD-2 and CD-3?
- Is the overall schedule for completion of the design, production, and installation of detector components realistic?

We welcome any other suggestions you can make for additions and changes that will improve the quality of the EIC detector design. Note that there is no dedicated charge element related to detector R&D and their risk mitigation as the DAC will separately review and advice on this.

The committee is requested to organize their assessment in terms of findings, comments, and recommendations and provide a written report by September 30, 2023.

4.2 Appendix B: Review Committee

E. Auffray, E. Kinney, P. Križan, A. Machado, P. Merkel, S. Miscetti, A. Papanestis, B. Vachon, A. White, K. Wyllie, C. Yang

4.3 Appendix E: Agenda

EIC Detector Comprehensive Design Review
August 29-30, 2023 via Zoom

Tuesday, August 29, 2023
CLOSED SESSION

ET	WBS	Topic	Presenter	Duration (Min)
9:00-9:30		Executive Session	DAC members	30

PLENARY SESSION

ET	WBS	Topic	Presenter	Duration (Min)
9:30-10:00		Project Overview	Jim Yeck	30
10:00-10:45	6.10.01	Detector Overview and Requirements	Elke Aschenauer/ Rolf Ent	45
10:45-11:00	6.10.01	Requirements and Interfaces Flow	Walt Akers	15
11:00-11:45	6.10.01/6.10.10	CAD status & Infrastructure, Integration and Installation	Roland Wimmer/ Rahul Sharma	45
11:45-12:00	6.10.02	Detector R&D Status and Milestones	Thomas Ullrich	15
12:00-12:30		Vacuum, Backgrounds, Machine-Detector Interface	Elke Aschenauer	30
12:00 – 13:00		*Break*		30
13:00-13:30	6.10.07	Magnet	Renuka Rajput-Ghoshal	30
13:30-14:00	6.10.03	Tracking Detectors	Brian Eng	30
14:00-14:30	6.10.04	Particle Identification Detectors	Benedikt Zihlmann	30
14:30-15:30		Executive Session	DAC members	60
15:30		*Adjourn*		

CLOSED SESSION

ET	WBS	Topic	Presenter	Duration (Min)
14:30-15:30		Executive Session	DAC members	30

Wednesday August 30, 2023

PLENARY SESSION

ET	WBS	Topic	Presenter	Duration (Min)
9:00-9:30	6.10.05	Electromagnetic Calorimetry	Alexander Bazilevsky	30
9:30-10:00	6.10.06	Hadronic Calorimetry	Alexander Kiselev	30
10:00-10:30	6.10.11	Interaction Region integration and Ancillary Detectors	Yulia Furletova	30
10:30-11:00	6.10.14	Polarimetry	Oleg Eyser/ Dave Gaskell	30
11:00-11:30	6.10.08	Electronics	Fernando Barbosa	30
11:30-12:00	6.10.09	DAQ and Scientific Computing	David Abbott/ Jeff Landgraf	30
12:00-12:15	6.10.12	Pre-Ops planning	Elke Aschenauer/ Rolf Ent	15
12:15-12:45		*Break*		30
12:45-15:00		Executive Session		135
15:00-15:30		Closeout		30
15:30		*Adjourn*		

CLOSED SESSION

ET	WBS	Topic	Presenter	Duration (Min)
12:45-15:00		Executive Session	DAC members	30