





Final Report

EIC Detector Advisory Committee 10th DAC Review

Review: June 11-13, 2025



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1 Executive Summary

The EIC Detector Advisory Committee met remotely on June 11-13, 2025 to address a series of charge questions related to the overall progress and status of the EIC Detector and its projected design maturity readiness for baselining (equivalent to CD-2) by the end of this calendar year, and for start of construction (equivalent to CD-3) roughly a year later.

Overall, the DAC found that the ePIC detector design is well established and prepared to address the broad range of the EIC physics program. The R&D phase is converging well to a conclusion and the transition to a PED phase is occurring. Naturally, with a complex detector featuring many different technologies, the various subsystems progress at different rates. Nevertheless, overall, the ePIC detector should be ready for baselining in late 2025/early 2026.

Plans for integration and installation have made good progress but work remains on details of detector services with attention to their potential impact on material profiles and consequent physics performance. Additional engineering effort may be needed to keep to the ePIC schedule.

Construction of the ePIC detector could start in late 2026 for well understood/demonstrated subsystems with other components beginning in 2027.

2 Reponses to Charge Questions

<u>Charge Question #1: Is the design of the ePIC detector and its sub-systems appropriate</u> and progressing well?

Response: YES – but with the qualifications, comments, and one major concern noted below.

Findings:

The overall ePIC detector design is well established and well studied with respect to addressing the broad range of the EIC physics program. However, the ePIC design is complex, involving a large number of subsystems many of which feature the first-time use of novel technologies, for which completion of full-scale prototypes and their testing is essential.

For the SVT the choice of serial powering is attractive but has strong implications in not only the EIC-LAS design but also the system design and the planning. The full simulation framework should be used to carry out a more quantitative comparison of the change in material versus the extra complexity of serial-powering.

The design of the AncASIC to support services that otherwise would require LAS design variations is well defined and should proceed well in parallel with the LAS development.

A significant change to the CyMBal, from eight to twelve cylindrical elements, is being considered due to servicing issues in the assembly hall. A decision is expected soon and while no major physics impact is expected this should be verified by simulation to include all services, supports and material.

uRWELL BOT and ECT are progressing well, with prototype-level results that—despite being preliminary—do not show any critical issues with respect to the requirements and highlight the advantages coming from double amplification. Some open points remain, such as the induction gap.

The gas mixture is still not defined, but there seems to be interest from all involved subsystems in moving towards mixtures that are flammable or contain flammable components.

The Far Forward detector components look challenging as does baselining by the end of 2025, while the Far Backward components appear more achievable since detector requirements seem to be less stringent. The far forward and backward design requires significant discussion and iteration between vacuum, accelerator and detector groups.

All ASICs have been prototyped at least once, and further submissions with added features are imminent. Although the designs have different levels of maturity, all are progressing successfully.

Some sub-detectors previously had alternative options for readout electronics. These have been resolved and there is a single baseline for each sub-detector.

Comments:

For the MAPS/EIC-LAS: The DAC wishes to stress the critical need for expedient completion of

the CERN/DoE agreement for access to the MOSAIX data base. This lack of agreement is a schedule risk to the entire ePIC project.

The designs for the PID system components were recently (April 2025) reviewed with a very positive outcome. All PID systems (hpDIRC, dRICH, pfRICH) are at an appropriate design stage and progressing well.

The designs of the electron and hadron polarimeters are well advanced and have no open questions requiring further design. The polarimeters are essentially ready for baselining now. Construction of the polarimeters is ready to begin when funding is available. A minor aspect that was not mentioned is the development of software to provide feedback on fast polarization measurements to the accelerator operators. This likely already exists for the hadron polarimeters.

The design of all aspects of ePIC calorimetry has seen substantial progress with the R&D phase essentially completed.

While there has been good progress in all areas of the ePIC detector, the DAC has some concerns regarding the overall design and implementation of services – installation of cables and cooling services in the limited space available, and the adequacy of cooling to prevent the transfer of a thermal load from one subsystem to another in close proximity and confined spaces.

Recommendations:

- 1) Pursue the completion of the CERN/DoE agreement for access to the MOSAIX data base with all haste.
- 2) Use the full simulation framework to carry out a more quantitative comparison of the change in material versus the extra complexity of serial-powering.
- 3) The DAC strongly recommends a wider review of the serial-powering proposal, including the system aspects and lessons learned from the ATLAS/CMS system experience.
- 4) Review the overall design and implementation of services installation of cables and cooling services in view of the limited space available, and the adequacy of cooling in confined spaces.

<u>Charge Question #2: Are the remaining work and technical, cost and schedule risks adequately understood? Are there opportunities?</u>

Response: YES – except for some areas of concern as noted below:

Findings:

For the Si-tracking there is a significant program of work remaining: ER2 testing, EIC/ITS3 design, ER3 production testing, EIC-LAS modifications (7 months), ancASIC, submission(s), testing.

Good progress has been made on mechanics/support mechanisms for the inner and outer

barrels and the disks, and a thermo-mechanical half-barrel planned soon – preparing for ER2 sensor in 2026.

Some MOSAIX/LAS features have been moved to ancASIC – with work decoupled from MOSAIX availability – a potential time saver. Progressing well but potential design sharing issues to be overcome.

For the BIC calorimeter results on BabyCal energy resolution and response at the test beam provide a first proof of concept integration and synchronization of SFils and Astropix chips done with analog signals. A full proof of concept was done at a test bench since the beam was not anymore available. The first data collected with Astropix at a beam test look OK (as commented in the April R&D review).

For the Forward EM Calorimeter there was a problem with the light yield of the Luxium scintillating fibers. The new production quality seems to be improved but the underlying cause of the poor light yield should be understood and the next production carefully monitored.

For the Backward EM Calorimeter good energy resolution has been shown for crystals from both producers, the MPPC has been selected, and there has been good progress on the mechanical design.

For the PID there was a recent 60% design review with a positive outcome. The start of the fabrication of the vessel of the pfRICH is a positive step forward, while for the dRICH the one sector prototype under construction in 2025 will allow detailed characterization. For the hpDIRC the Cosmic Ray Telescope is a valuable facility for the characterization of the detector modules.

A variant of the FCFD ASIC is now the baseline for the HRPPD/MCP readout. We commend this step to enhance commonality, but the specifications are incomplete. The community must ensure sufficient resources and communication flow to finalize specifications of the FCFD variant that will require a larger dynamic range.

Comments:

The DAC wishes to stress the critical need for expedient completion of the CERN/DoE agreement for access to the MOSAIX data base. This lack of agreement is a schedule risk to the entire ePIC project.

The proposed redesign of the CyMBal implies significant additional technical work, affecting production at Saclay (more chambers, more cost) and tests with the SALSA chip. It is noted that the cosmic ray test stand at Saclay is now ready for testing CyMBal production modules.

There is inherent risk in the use of novel MPGD technology for which large-scale prototyping is essential followed by strong focus on QA/QC in production.

Tests on the Test Article for uRWELL/GEM will be especially relevant for:

- 1) Validation of the mechanical assembly at final scale. The Test Article will help determine whether design changes are needed (e.g., spacers between GEM and uRWELL).
- 2) Validation of the powering scheme. Shorts in the GEM or malfunctioning sectors in the uRWELL should not compromise the operation of the rest of the detector. The high-voltage distribution should be capable of handling such cases.

Integration of the front-end ASIC (SALSA) is important for identifying the detector's optimal

working point.

For the ancillary detectors integration for B0 and ZDC still looks difficult and for the Roman Pots an escape mechanism should be considered when getting close to the beam, and it should be clarified what part of the detector goes in vacuum or is to be cooled in vacuum.

For the hpDIRC it will be reassuring if the test results on the second box of quartz bars from SLAC are comparable to those from the first box.

Recommendations:

Simulations using the ePIC framework should be carried out for PID that includes all sources of backgrounds – from the machine and materials.

For the ASICS the DAC recommends to start planning the procurement route as wafer production often requires advance announcement to the foundry so that they can book slots and ensure wafer availability. This is particularly true for EICROC and FCFD, which require reasonable wafer quantities. Having the procurement contacts in place will allow any early warnings of cost evolutions. The FCFD design should be properly resourced to move ahead with haste and prove the design in time for production in FY27-28. A 'production readiness' review procedure is planned for the five ASICs. We strongly recommend including Astropix and EIC-LAS/AncASIC in the review procedure.

We recommend formalizing plans within the schedule to build and operate full chain mock-up demonstrator to test all functionalities of AncASIC with EIC-LAS-like load.

Opportunities:

Can submissions (expensive Engineering Runs) be combined for ASICs implemented in the same technology?

Charge Question #3: Will the detector be technically ready for baselining by late 2025?

Response: YES – there is generally good progress towards this goal but the DAC notes the points below.

Findings:

For the SVT there is no viable alternative (ITS2, MPGDs) to ITS3 – so this must be the baseline choice.

For the CyMBal, testing of the Scale 1 module may be close in time to the expected goal for overall detector baselining. The possible change to the CyMBal layout could factor into the goal for baselining, although the underlying micromegas technology is the same and is well understood. Conversely any move to a new technology for the modules could invoke delay.

Calorimeter systems will be ready for baselining, except for the nHCAL for which design optimization and simulations are still ongoing. However, the nHCAL can be delivered later than the other calorimeter elements (e.g. it is not part of the solenoid flux return). The preparation of

QA/QC phases are well progressed and should be fully specified for all systems in advance of production of all components to ensure a correct performance of EVMS for the cost and schedule variance.

For the ancillary detectors the Far Backward elements should achieve the baselining goal while this will be challenging for the Far Forward detectors (e.g. for B0 complete integration inside the magnet and cooling system).

Comments:

For MPGD detectors, defining a list of relevant tests to performed on Test Article Detectors would be beneficial (test beams, full detector irradiation, long term irradiation, tests in magnetic field, ...) to make a timely identification of critical aspects.

For the PID there was a recent 60% design review with a positive outcome.

Some ASICs are well advanced, and prototypes have been used in many of the detector subsystems. However, all ASICs require at least one additional submission to integrate all required features and channel-counts. The ASIC availability is increasingly defining the schedule of finishing the sub-system development. The collaboration has correctly recognized this, and we commend the increased scrutiny. A strong reviewing program is mandatory.

Recommendations:

For the Calorimeter systems the DAC recommends finalizing all QA/QC procedures before the start of full component production.

For the ASICs the DAC suggests considering the assignment of engineering effort from completed designs be injected to help out with those designs that are lagging behind.

<u>Charge Question #4: Are the detector integration and planning for installation and maintenance progressing well?</u> Are there areas where further ideas should be pursued?

Response: YES – in general.

Findings:

There are many major items listed under the 3I scope. Additional engineering effort may be needed to accomplish all tasks on the schedule foreseen for ePIC completion.

While data from the ePIC detector has been shown to be able to deliver the planned EIC physics program there are final design items that could impact the quality of the physics. Examples are the location and material of the services for cables and cooling, final design of support structures, and positioning of electronics in regions of expected high radiation doses.

For the CyMBal the DAC notes that the potential new design implies 50% more detectors and revised integration, installation and maintenance plans. However, the changes should facilitate access and extraction if needed.

For the calorimeter systems integration and planning look well advanced.

Comments:

Assembly plans shown included all expected detector subsystems; however, attention is needed to the structures/planning that will be required if a delay requires the assembly without certain components, e.g. the SVT or barrel tracker.

There is a well-defined set of interfaces between subsystems. However, close attention will still be needed to potential areas of mutual interference – for services, thermal loads, emi.

The DAC is concerned by how much SVT could be delayed, and therefore GST assembly, and still keep to the overall assembly/installation schedule? Meeting the October 2031 installation deadline for the SVT requires design access by Fall 2025.

For the ancillary systems this is more challenging than for the central detector due to the more demanding integration with the beam line and requires careful monitoring.

For the Far Forward detectors particular items needed are a complete integration study inside the magnet and cooling system for B0, the vacuum situation in the Roman Pots region, and the effect of the material for the exit window for the ZDC.

For the Far Backward detectors there are less technical challenges, but work remains e,g for the low Q2 tagger for integration on the ESR lattice to finalize the beam pipe design, and to reduce synchrotron radiation levels.

Recommendations:

Include advanced planning for possible additional engineering effort to stay on schedule for ePIC completion.

Include in integration, installation planning provision for revised strategy in case some major component(s) are delayed.

If not already planned, a mockup(s) of the tighter areas for services between the barrel and endcaps would be very helpful in assurance of the final design.

Verify as soon as possible the feasibility (mechanical integration) of the new CyMBaL Micromegas proposal.

Given that the MPGD gas mixture has not yet been identified, the most conservative option—assuming the use of flammable mixtures—should be considered, imposing requirements on the detector and gas system (tightness, materials, in/out flow control, sensors, etc.).

Charge Question #5: Will the detector be ready for start of construction by late 2026?

Response: YES, for the 2026/2027 timeframe.

Findings:

By late 2026 there could be incomplete results from essential large-scale tests of subsystems

and/or demonstrations of at-scale production capability. Production of well understood/demonstrated subsystems could allow a partial construction start in late 2026.

The completion of necessary work for the Si-SVT for late 2026 construction start depends on 1) the successful sensor testing in ER2, and 2) the timely completion of the agreement with CERN for MOSAIX database access to initiate EIC-LAS design work.

CyMBaL will have a test article in 2026. Preproduction will start in 2027, with full production beginning in 2028. If the new design is adopted, 50% more detectors will need to be produced. uRWELL BOT and ECT will have a test article by late 2025. Preproduction may start in 2026, with production in 2027.

For the PID systems, the FTOF and BTOF construction readiness depend on ASIC, sensor and mechanical design staying on schedule. The dRICH final design is expected in early 2027. For the pfRICH the realization of an engineering test vessel is imminent but final design areas depend on ASIC (FCFD) development. For the hpDIRC validation of the bulk of the bars remains plus sensor and ASIC evaluation.

For the ASICs, completion of the PED phase is expected in FY26 and for most of the ASICS production is forecast for FY27 with approximately one year for the fabrication, packaging and testing cycles.

Comments:

The calorimeter subsystems are planning FDRs in 2026 and should be in a good position to start construction by later that year. However, many systems still lack finalized front-end electronics. In particular, several Front-End Boards are only now entering the design phase. We recommend to start prototyping tests for CD-2.

For the ancillary detectors there are still design/integration issues to be resolved and a start of construction in late 2026 is less clear – although these elements are decoupled from the central ePIC detector.

Recommendations:

For the MPGD detectors cross-check the up-to-date schedule with the two manufacturing sites to rule out any issues or delays in the procurement of components due to other commitments. Start prototyping tests of calorimeter Front-End Boards for CD-2.

3 Conclusion

Very significant progress has been made in many areas of the ePIC detector project. The project is successfully transitioning from the R&D phase to the PED phase. There are nonetheless several key areas to monitor closely as they can affect successful adherence to the overall schedule and delivering of ePIC on time.

There is a critical need for expedient completion of the CERN/DoE agreement for access to the MOSAIX data base.

The DAC encourages the ePIC Collaboration to keep up the momentum!

4 Appendices

4.1 Appendix A: Charge to the Review Committee

EIC Detector- 10th DAC Meeting

June 11-13, 2025

Charge

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

The EIC Critical Decision 1 (CD-1) was approved on June 29, 2021, and allowed for the release of Project Engineering and Design (PED) funding and the next phases of the design of the accelerator, detector, and infrastructure. Inflation Reduction Act funding provided at the end of 2022 allowed the EIC project to proceed to next phases. The EIC Critical Decision 3A (CD-3A) was approved on March 28, 2024 and authorized start of an initial series of long-lead procurements. The EIC Project successfully passed a DOE Independent Project Review for a next series of long lead procurements (CD-3B) in January 2025 and is waiting formal DOE authorization. In parallel, a further organization of the EIC Project in terms of subprojects is ongoing. Critical Decision 2 (CD-2), Performance Measurement Baseline Approval, is planned for 2026, shortly after the conclusion of RHIC operations. Resource Review Board meetings are now held semi-annually, see https://www.bnl.gov/eic-rrbmeeting/, with the 5th RRB meeting to be hosted in Prague, Czech on June 5-6, 2025.

The 10th DAC meeting on June 11-13, 2025, will focus on the overall progress and status of the EIC Detector and its projected design maturity readiness for baselining (equivalent to CD-2) by the end of this calendar year, and for start of construction (equivalent to CD-3) roughly a year later. The exact CD-2 and CD-3 dates depend on the overall project status and funding and might be later than these aspirational dates for the detector. The main goal would be to solicit feedback from the DAC on the maturity status of all detector sub-systems, on remaining significant technical questions, and on integration and maintenance planning and issues.

For the 10th DAC meeting, the DAC is asked to address the following charge questions:

- Is the design of the ePIC detector and its sub-systems appropriate and progressing well?
- Are the remaining work and technical, cost and schedule risks adequately understood?
 Are there opportunities?
- Will the detector be technically ready for baselining by late 2025?
- Are the detector integration and planning for installation and maintenance progressing well? Are there areas where further ideas should be pursued?
- Will the detector be ready for start of construction by late 2026?

We welcome any other suggestions you can make that will improve the success of delivering the ePIC detector. A readiness assessment of the EIC Detector subproject is planned for November 2025. This review will include cost, schedule, and technical risk and will be informed by the results of the 10th DAC meeting.

The committee is requested to organize their assessment in terms of findings, comments, and recommendations and provide a written report by July 3, 2025.

References:

7th DAC Meeting (2023): DAC Comprehensive Design Review (2023):

https://brookhavenlab.sharepoint.com/sites/EICDetectorComprehensiveDesignReview 8th DAC Meeting (2024): https://indico.bnl.gov/event/23881/ (Access Code: DAC6212024) 9th DAC Meeting on EIC Project Detector R&D (2024): https://indico.bnl.gov/event/24086/ePIC / EIC Project Detector R&D Day (April 2025): https://indico.bnl.gov/event/27200/

4.2 Appendix B: Review Committee

EIC Detector Advisory Committee Members: Edward Kinney, Ana Amelia Machado, Petra Merkel, Stefano Miscetti, Eraldo Oliveri, Antonis Papanestis, Roman Poeschl, Brigitte Vachon, Ken Wyllie, Andrew White

4.3 Appendix E: Agenda







