Report of the Detector Advisory Committee on EIC Detector R&D Progress and Proposals

Performed Remotely at Brookhaven National Laboratory

Upton, NY

August 28-29, 2024

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1. Executive Summary

The detector advisory committee met on August 28 and 29, 2024 to hear reports on R&D progress and proposals for the EIC project. This review precedes the future CD-2 review expected in late 2025. Overall, the committee found that the proposals focused on important remaining questions for technology choices in the detector.

The report below is organized by the individual proposals presented to the committee.

2. Reponses to Individual Projects and Proposals

2.1 Project eRD102 – Dual Radiator RICH (dRICH)

Findings:

The challenges of this project are the covering a wide momentum range (3-50 GeV/c), operating in a high magnetic field (~1T), and fitting within limited space.

Recent achievements have been: the optimization of the aerogel radiator, progress in the development of lightweight mirrors, development of compact photon detection units with advanced SiPM arrays, integration of key components like the ALCOR digitizing chip, and multiple measurements conducted with mixed hadron test beams and various radiators.

The main challenge for 2025 is the validation of a real-scale prototype with component demonstrators.

Comments:

The project is progressing well, aligning with 2024 and 2025 goals. Key areas such as the design of photon detection units show promising results.

There are pending decisions: choosing a single *vs*. two separate containment vessel design solution, definition of in-situ annealing procedures for SiPMs, and the need for windows to separate and isolate the different temperatures of the gas radiator and the photon detector.

Recommendations:

1) Provide material for the pending decision on the single vs two vessel version of the detector. The performance should be simulated since, in the case of two volumes, one expects some efficiency loss, either due to the photon loss at the separating wall or – in case the wall is covered with planar mirrors – due to ambiguity in the ring reconstruction.
2) Annealing procedures should be investigated, and defined; this will have implications for the design of the read-out board (heating).
3) Investigate whether windows are necessary to separate regions at different temperatures (gas radiator and the photon detector), and if needed, whether they impact performance significantly.
4) Present at least a vague timeline for the project at the next DAC review.

2.2 Project eRD103 – High Performance DIRC (hpDIRC)

Findings:

The objective of the targeted R&D for the high performance DIRC (hpDIRC) is to ensure that the required performance for the ePIC detector can be achieved by using a Cosmic Ray Telescope (CRT) to measure the performance of the various detector components as they become available. It will also be used to test the completed hpDIRC bar boxes.

The milestones for FY24 are:

- The completion and commissioning of the components of the CTR (Cherenkov Tagger, tracking and timing)
- Install a bar prototype
- Observe Cherenkov pattern

There has been significant progress with all the above components of the CRT, however, none of the individual components are close to the commissioning stage, with the hardware being available, but not yet fully connected to a readout system.

The quartz bars from Babar were supposed to be delivered to Jefferson Lab for examination in the autumn of 2023, while the present report now mentions that the examination will occur in autumn 2024, without any explanation for the delay.

Comments:

Having a CRT for testing the performance of the hpDIRC and later perform Quality Assurance on the hpDIRC boxes is a power tool and its commissioning an important milestone for eRD103.

The delivery of the hpDIRC prototype is also an important milestone along the path of commission the CRT.

The collaboration relies on experience and reuses techniques from the PANDA DIRC and GlueX experiments, giving them confidence and minimising risks.

The delay in the delivery and examination of the Babar quarts bars was explained and it was stated that it does not affect the hpDIRC schedule, even if new bars have to be ordered.

It is also not clear if the delays in the commissioning of the CRT will have an impact on the hpDIRC construction schedule. As an answer to the question it was stated that there is also no impact on the hpDIRC schedule for the time being.

As the CRT is supposed to be used to ensure the performance of the hpDIRC, what are the possible modifications that may come out of this R&D? The design of hpDIRC is very advanced, so it is presumably about small design tweaks and quality assurance.

Recommendations:

1) Produce a rough timeline of the construction of the hpDIRC and how it fits with the current R&D activities. Show a possible bar procurement schedule and how it fits with present the present hpDIRC schedule.

2.3 Project eRD104 – Silicon Services Reduction

Findings:

The services reduction program is working on using serial powering (SP) with Shunt LDOs to reduce the power infrastructure as well as a program to reduce the signal readout cabling. Efforts at the UK groups focused on the serial powering, designing a prototype (not using 65 nm technology) for testing, and also developing an overall scheme to power the whole detector. The ORNL group has investigated different technologies for the readout chain from detector to FELIX board. Along with MIT they are working to develop an aggregated fiber board to reduce the number of readout fibers, based on the lower occupancy of the EIC events relative to heavy ion collisions, for example.

Milestones include the production of the SP flex circuit prototype and simulation/verification of the Shunt LDO scheme. Finalization of the Shunt LDO design will allow production and testing of performance. A number of different readout components were performance tested. Design of a serialized board is ongoing , production and testing will occur later in this year.

Comments:

There has been steady progress since the review in August 2023, however much actual component fabrication and testing remains to accomplish. At the review in August 2023 it was also advised to investigate the radiation hardness of the different readout components; a decision has been made to use lpGBT and VTRx+ going forward, for which radiation hardness is known.

Recommendations:

1) Actual component fabrication and testing should proceed with high priority in order to understand if further R&D is required for both SP, serialization board and readout aggregation.

2.4 Project eRD106 – Forward EM Calorimeter

Findings:

There is significant progress toward the completion of this R&D as proven by the production of 16 blocks at UCLA and Fudan, that match the final design goal. The procedure for final production and QA is in progress (6-month timeline). In addition, mechanical tests of block installation and installation protocol were completed.

Multiple design and test iterations were carried out to improve the light guides, with the efficiency of light collection, uniformity, and industrialization driving the design. The highest performance light guide and tooling were produced at Indiana University. The light guides' uniformity, tested with light sources at UCLA, indicates an RMS spread of 10%.

Four SiPM carrying boards (SiPMboard) were produced at UCLA for the test beam run at FNAL. They were glued to light guides with the same optical RTV planned for production. Test beam of one production block was carried out at the Fermilab test beam in the middle of June. Beam conditions were not perfect but acceptable for extracting a result on uniformity and light yield. Preliminary results show that uniformity improves by a factor of two, reflecting in an energy resolution constant term improvement for increased incident beam angle. Results on light yield will be released after the summer with lab measurements. Sources of non-uniformity in this beam test include the short light guide, a mixture of different SiPMs, gluing imperfections and production block boundaries.

Proponents plan to complete the eRD106 program in the next few months.

Comments:

Albeit gluing the SiPMboard to the light guides is a simpler and more stable procedure than doing that in situ after installing the blocks, we still consider it problematic to use glue instead of optical grease. For example, if a SiPM dies, or if there is an electrical problem on the carrying boards, after installation, it will not be simple to perform a replacement. A clear procedure for dismounting the SiPMs without damaging the light guides should be envisioned. It would be nice to know if there is still space (and time) for a modified design with a holder to keep the SiPM board aligned and tight to avoid gluing.

We note that non-uniformity in light collection is a matter of concern, though minor.

A prototype has not been tested with the final front end electronics (FEE), but the SiPM readout by FEE has already been iterated to a final scheme.

Recommendations:

1) We recommend the fEmCal team take a last look at the installation (gluing) of the SiPM carrying boards and provide comments on the long-term system maintenance.
2) We recommend production of a prototype with uniform material and without gluing faults.
3) This prototype should be tested with the final front-end electronics readout.

2.5 Project eRD107 – Forward Hadron Calorimeter

Findings:

The hadronic calorimeter in the forward direction is based on the Calice design and shares work with CMS calorimeter upgrade. Good progress in producing mold scintillators of different sizes and dimples has been achieved as well as good progress in the QA/QC stations for testing light yield and uniformity of the production tiles.

A third iteration of the production of the flexible printed circuit (FPC) connecting up to 8 SiPMs to the tiles appears to be successful, reducing the stress on the pins.

Production of 30% of the FPCs needed for the August 2024 test beam have been produced and evaluated in mid-July.

Comments:

A reduction in light yield of around 30% is noticed for the tiles from injection molds vs. commercially machined tiles. Testing with MIPS, the tiles at different SiPM overvoltage values provide x2 increase of gain moving from 3.5 to 5.5 V but also a pretty consistent increase of response. So light yield looks practically saturated at something like 10 pe/MIP. What is the requirement of light yield that should be achieved to fulfill the experiment energy resolution? Is the response of injection molded tiles good enough?

So far there is no experience with the long transfer boards that connect the FPCs to the back readout connector and ROC; this is a key component of the detector. The group shows awareness of the importance of developing and testing the long boards.

Recommendations:

1) We recommend that the group proceed with test beam measurements and extract results from the assembled prototypes.

2) We recommend great attention to the development of the long transfer to readout PCB and ensure the availability of experienced engineers for this effort.

2.6 Project eRD108 – Micro-Pattern Gas Detector R&D

2.6.1 Inner Barrel Tracker - CyMBaL

Findings:

The results of the 2023 MAMI test beam, the upgrade of the cosmic stand in Saclay, and the steps toward re-establishing the production of curved micromegas in Saclay were presented.

A long list of plans was presented in the report, but the list of achievements is not as extensive. Some of these may be pushed to FY25, making the timeline tight. This should be carefully considered to understand the impact on readiness for the CD2/CD3 review.

Comments:

Due to the low-energy electron beam and multiple scattering, the results of the 2023 MAMI test beam are not conclusive. The cosmic ray test facility at Saclay will be beneficial for prototype characterization, but high energy test beams will provide simpler, faster, more accurate characterization.

Changes in materials with respect to previous cylindrical CLAS12 MM raise questions and risks. Important to demonstrate capability to produce such a detector that meets requirements.

The previous DAC review raised concern about the close interaction of services between SVT and MM and this has not been addressed.

A conceptual design for services and their impact on tracking coverage is needed as well as an updated mechanical design of the large prototype (unless already done).

Recommendations:

1) We strongly support the efforts to re-establish the production of curved micromegas in Saclay and we strongly recommend to do this as soon as possible. This is a high priority to confirm that there are no critical issues related to the baseline solution and to determine if risk mitigation measures need to be put in place in terms of production.
2) We understand the advantages of the cosmic stand; nevertheless, we strongly recommend planning several test beam campaigns in FY24 and FY25 to finalize as soon as possible the choice (on planar prototypes) of the best readout layout, the

appropriate mitigation in terms of resolution for large angle tracks (μTPC or reduced drift), and the required gas.

3) We recommend that the group define the tests (e.g. tracking capabilities, stability, operation in magnetic field...) to be performed based on the expected working conditions (magnetic field, radiation level and type, rates, and multiplicities) before the end of 2025 to conclude the R&D phase.
4) We recommend that the groups continue the studies toward full-scale prototyping (designs and prototypes), focusing on critical issues to prepare for CD2/3.

2.6.2 μRWELL Barrel Outer Tracker

Findings:

The modifications required in the prototype constructed in FY23 have been successfully made, making the detector ready for beam testing.

Although cylindrical micromegas is a more established technology, part of the studies on the cylindrical μRWELL will be relevant and beneficial for the baseline CyMBAL and the planar μRWELL- based trackers. Several risks have been raised by the CyMBAL proponents, highlighting the importance of R&D on alternative options.

Comments:

For planar μRWELL detectors (Endcap and Outer Barrel), a hybrid solution of μRWELL plus GEM is being considered. It would be beneficial to understand if the same approach would be necessary for the cylindrical detector and the impact in terms of complexity if this solution were required.

Recommendations:

1) We recommend testing the performance of the fully refurbished prototype in a beam asap to confirm gas tightness issues are resolved and the adopted solution would work for a 1mm drift gap.
2) We recommend supporting R&D studies on the readout layout with capacitive coupling and mitigation strategies for large angle spatial resolution degradation, which could also be beneficial for the CyMBAL and other planar μRWELL-based tracking detectors.
3) Impact on the material budget of the final proposed design, including the new honeycomb drift support, should be calculated.

4) Define the tests (e.g., tracking capabilities, stability, operation in magnetic field...) to be performed based on the expected working conditions (magnetic field, radiation level and type, rates, and multiplicities) before the end of 2025 to conclude the R&D phase.

2.7 Project eRD109 – ASICs and Front End Electronics

Findings:

The design of the discrete readout for Calorimeters has progressed well. Initially developed for the Forward ECAL, the design will soon be extended to the Backward ECAL.
SiPM tests were made with the H2GCROC chip, and the insights gained were incorporated into the CALOROC design. Two variations of the CALOROC chip, featuring different front-ends but sharing a common back-end, have been developed.

The design of the ALCOR for the dRICH readout has advanced well and the chip was used in beam tests.

The characterization of the small-scale EICROC has progressed and informed the design of the next prototype version. The FCFD chip, offering an alternative readout approach, was similarly characterized in the lab. Flex PCB pre-prototypes for the barrel AC-LGAD have been fabricated and their characterization is underway. Precise clock distribution was successfully demonstrated with a pre-prototype RDO and DAM.

The SALSA analog and digital blocks were fully characterized, and a chip version with the full frontend and ADC chain was submitted for production.

Comments:

We commend the progress made in all the sub-proposals of eRD109, each of which has a clear development path. We note that 3 of the 5 proposals will move to PED funding.

We also commend the efforts to expedite the design of FCFD by proposing an adaptation of the backend of the EICROC.

We are concerned about the delays in submission milestones and the resulting delays for the subsequent steps, in particular integration with the various detector technologies (EICROC1/FCFD for the AC-LGAD, HRPPD, MCP-PMT; SALSO for MPGDs; CALOROC for SiPMs). Prioritizing early detector/readout integration and maintaining active forward planning are crucial to ensuring timely progress and avoiding unnecessary delays.

Recommendations:

1) The proposed R&D activities are high priority, and we strongly recommend the approval of funding.
2) We recommend a careful analysis of the reasons for slips in submissions with a view to forward planning. Beyond the expected technical challenges, can other difficulties already be foreseen, for example missing personnel resources? Can this be helped with resources from other collaborating institutes?
3) There are 2(3) additional ASICs being custom designed for ePIC, EIC-LAS (plus ancillary chip) and ASTROPIX. So far, these have been scrutinized as parts of the sub-detectors and not included in the list of ASICs reviewed under eRD109. As the projects move towards PED, we recommend that EIC-LAS (plus ancillary chip) and ASTROPIX be scrutinized within the same framework as the other ASICs. This will help with monitoring compliance and the sharing of knowledge and experience.
4) We recommend that the proponents carefully plan the EICROC/FCFD ASIC testing with HRPPD/MCP-PMT to be ready as soon as ASIC availability permits it. For example, using EICROC1 and FCFDv2 by the second half of FY2025 would appear to be feasible. These steps are critical to ensure the specifications and performance of the ASICs are adequate for these sensors.

2.8 Project eRD110 – Photosensors

Findings:

Although R&D funds were limited, progress was made. There was careful consolidation of test infrastructure for timing and ageing studies. These systems are ready to go and test programs are well defined. This includes illumination techniques with high timing precision, well suited to this program.

LAPPD tubes were tested in magnetic field with confirmation that increased bias can recover inefficiencies. These tubes were used in ageing studies in preparation for the same study on HRPPDs. Cross-talk issues on the passive interfaces for the HRPPD were studied and an optimised design was prepared.

The majority of the FY25 request is funding for personnel.

Comments:

We commend the preparation of the testing infrastructure and the clear definition of the test program.

We heard positive news during the review on the status of the EIC-HRPPD and there are no apparent barriers to launching the program of detailed characterization in the institutes.

We also commend the continuation of studies of the MPC-PMT to prove its viability as a back-up to the HRPPD. We would like to comment, however, that there is still significant work ahead to move from small prototype quantities to production scales for both types of devices.

The timescales and necessary steps towards first integration with custom ePIC electronics (EICROC, FCFD) were not obvious to the committee, and probably require planning and coordination with the electronics teams.

The committee and proponents agree on the importance of the ageing tests following the clear observation of degradation in the older LAPPD tube after illumination to the level expected in the ePIC environment.

Recommendations:

1) Although the requested FY25 funding is modest, the test program is of high importance for ePIC. Hence, we strongly recommend the approval of funding. All effort must be made to conclude the studies and present the reports in 2025 as proposed.
2) We recommend to follow-up carefully on the potential issue of coherent oscillations and to explore mitigation techniques, maybe in the backplane design for which the team now have considerable expertise.
3) We recommend that the proponents carefully plan the route towards testing photosensors coupled to the EICROC/FCFD ASICs. These steps are critical to ensure that the specifications and performance of the ASICs are adequate for these sensors.

2.9 Project eRD111 – Silicon Vertex Tracker (SVT) Modules, Mechanics, Cooling and Integration

Findings:

Inner Barrel

The INFN institutes have pursued the design of the most inner two barrel layers, L0 and L1, by adapting the ITS3 concepts to the ePIC SVT. The first local support structure prototype, which was made of two half-rings and three connecting long support bars, was printed in 3D at Bari. A thermo-mechanical prototype using blank silicon with the dimensions of the final MOSAIX sensor with embedded heaters to mimic power consumption is planned for EOY24. Pavia is in the process of setting up a climate chamber to investigate the possible deterioration of the SVT inner layer assemblies in controlled temp/humidity conditions. Padova produced the first SVT IB global support design, including an external shell to L2, but with the cooling system under study. A mockup will be used in the fall to study the assembly procedure and possible space conflicts.

Outer Barrel

LBNL studied a disc layout using one LAS variation; 5 or 6 RSU LAS are being considered. Cooling based on a corrugated disc design improves airflow without adding mass. Thermal studies using a corrugated carbon fiber test piece are ongoing. R&D on internal air cooling using carbon foam demonstrated the importance of the foam in the cooling and thermal performance of staves and discs. Oxford is waiting for eRD111 funding but has been developing the design of OB staves and preliminary performance evaluations using an L4 stave. The OB stave design is now ready for prototyping. Purdue has not yet received funds, which has slowed the work down. Nevertheless, early studies, as part of the TOF support structure design work, considered the possibility of integrating SVT mechanical support into the larger global support structures.

Comments:

The R&D is progressing according to plan, and we congratulate the groups for the advances made in the past year. Cooling tests show manageable airflows for dissipations of heating less than 0.6W/cm^2 on the corrugated disk test piece. The optimization using carbon foam is ongoing. With approximately 4000 EIC-LAS sensors in the SVT the groups are aware that power consumption estimates might change. Even though the baseline is cooling with air internal to the mechanical structure, liquid cooling in strategic places is a wise approach.

In the 2023 review, it was recommended to (1) proceed as fast as possible to prototype bent structures using active ALPIDE parts or, even better, parts from ER1 and (2) build strong communication with the eRD104 group for flexible printed circuit (FPC) and readout concept and design. The current report shows progress on both points, in particular, having integrated the readout and FPC components into the CAD design, which is crucial for estimating the heat load and space constraints.

The main concern is the holdup with funding distribution to Oxford and Purdue. The first one is delaying the prototyping of staves, and the second has serious consequences on the integration of the SVT structures into the global detector support mechanics. This lack of funding can impact the timely contributions to ePIC TDR by the end of 2024.

Recommendations:

1) Continue performing thermal prototypes for Inner Barrel design.
2) Clarify the need for liquid cooling in "strategic places" and study the impact on the material profile
3) Continue close collaboration with the eRD104 group for FPC and readout concept and design.
4) Keep simulations on track with developments in local/global support structures.
5) Streamline the distribution of funds to collaborating institutions in a timely manner.

2.10 Project eRD112 – AC-LGADS

Findings:

This project focuses on the R&D of AC-LGADs as the chosen technology for the timing layer in the barrel and forward TOF detector, the B0 tracker, the Roman Pots, and the Off-Momentum Detectors. Various geometries and layouts have been studied, and integration with the Front End (FE) ASIC has been tested. Preliminary irradiation studies have been performed. The company FBK is being considered as a third production site to mitigate risks during the production phase.

Comments:

The R&D is progressing according to plan, and we congratulate the groups for the advances made in the past year. The results obtained with the existing basic sensors are positive; however, the margin relative to the requirements is, in some cases, small—especially when

considering potential issues or performance degradation that may arise with the final module. The involved teams appear to be aware of this, as they are consistently highlighting critical aspects that may impact the final detector.

The existing sensor studies are well-organized and well-reported, and guidelines for the future prototype have been extracted from the tested prototypes. Regarding production, mitigation of risks has been properly considered by searching for alternative vendors and investing (or planning to invest) in Technology Transfer. Initial tests with the final FE ASIC have begun, and various testing facilities have been set up across different groups. As reported in the review, potential issues related to the radiation hardness of the AC-LGAD layout must be evaluated. In particular, the effect of radiation on the time and position resolution of irradiated samples should be measured in addition to IV and other relevant metrics. Efforts on TCAD modeling and simulation have been made, with test benches on existing prototypes. Completing and validating the detailed modeling of the sensors, accurately modeling signal induction, and assessing sensor performance in terms of time and space resolution could be beneficial for the final design. Current developments may not be at that level, though.

In the 2023 review, it was recommended to (1) continue the study on sensor fabrication options with various vendors, (2) use the latest simulation framework to further check if any crucial performance requirements have changed in individual detectors to meet the goals of the EIC physics program, and (3) continue the material budget study based on the whole system, including sensor, bonding base, supporting structure, and other integration materials. The current report shows progress on (1) and (2), but there was no update on (3). Information on how the sensor will be integrated into the various sub-detectors (modules, support, services), including the impact on the material budget, is still missing. It is understood that this might be related to not having full-size sensors yet and that this part has little to do with the sensor itself. Still, it significantly impacts the proposed sub-detector and the ability to validate the proposed solution for ePIC.

The plan for 2025 includes testing a full-size AC-LGAD, beam testing a bump-bonded assembly (so far, they were wire bonded), characterizing performance under various temperature and humidity conditions, and continuing the irradiation studies.

Recommendations:

1) Clarifying the plans for testing the HPK strip sensors for the barrel ToF detector and the pixel sensors for the forward ToF and far-forward detectors would be beneficial. Details on the testing methods and the benchmarks against which the different sensors will be evaluated have not been provided.

2) To properly identify potential signal degradation, we strongly support the groups' intention to continue investigating factors that could degrade performance under final experimental conditions (e.g., radiation, environmental parameters such as temperature and humidity) by directly measuring their impact on time and spatial resolution.
3) Evaluate whether the current effort in sensor modeling should be extended towards a more detailed simulation of the detector response, allowing for time and spatial resolution predictions for various layouts. Such a tool would provide the opportunity to further optimize sensor performance and increase the margin between requirements and current performance levels.
4) Continue studying sensor fabrication options and quality with the currently selected vendors.
5) Continue research towards developing full-size sensors to identify potential issues and assess any impact on the material budget, including sensors, bonding bases, supporting structures, and other integration materials.

2.11 Project eRD113 – Silicon Sensor Development and Characterization

Findings:

Connections with the ALICE ITS3 community have been strengthened by embedding two designers from EIC institutes into the MOSAIX design team at CERN. Other institutes have contributed to the digital library for MOSAIX. In parallel, development of the specifications of an ancillary chip for the SVT has started and a target technology chosen. This chip will include circuitry for serial-power distribution and digital control interfacing. This is a collaborative effort, and a design repository framework is in preparation. EIC institutes have carried out a wide range of tests on prototype chip structures recently fabricated by TPSCo for ITS3, and there has been a large effort on preparing test infrastructure for chips from the upcoming MOSAIX submission.

Comments:

The committee is pleased to note the more direct collaboration with personnel embedded in the ALICE team.

We commend the team on the advances in specifying the serial powering requirements.

We are concerned that a collaboration agreement with ALICE is not yet in place and that access to the design technology is not yet possible.

The choice of XFAB-XT011 for the ancillary chip requires early validation of the process, and we assume a steep learning-curve requiring significant effort on both technology qualification and design-work.

The setting up of a common design repository is a vital step for the ancillary chip design and future work on the LAS. All effort must be made to finalize the agreement between institutes on its use.

Recommendations

1) The proposed R&D activities are high priority and we strongly recommend the approval of funding.
2) The qualification of the XFAB technology must be concluded quickly. This is a big effort, so we strongly recommend that this is carefully planned (including submission schedules and access to facilities for irradiation) and that the required resources (especially human) are properly understood and consolidated.
3) Similarly, we recommend that the design effort for the ancillary chip be carefully assessed and organized, especially as this is a new technology. This could become a critical issue when the ePIC community is granted access to the TPSCo design kit, and the SVT team has to support the design of both the LAS and ancillary chips.
4) We strongly recommend that the collaboration agreement with ALICE be concluded as quickly as possible.

2.12 Project eRD115 – Imaging Barrel EM Calorimeter (bECAL)

Findings:

The year 2024 has been the first year of R&D for the final technology choice adopted for the EM Barrel Calorimeter, *i.e.,* imaging Calorimetry which combines Pb/Scifi technology with a high-precision position detector (Astropix). Despite many problems encountered by the team (late funding, late and little beam delivery at the Fermilab Test Beam Facility (FTBF), and heat waves), the FY24 R&D proposal is progressing very well.

A successful integration of Astropix and BabyCal has been achieved on the readout side adding one Astropix board to the DAQ stream in the first phase, and two boards in parallel in the second phase.

Due to the problems encountered, not all program tasks have been carried out, and not all milestones were reached. In particular, the integration of BabyCal and Astropix with the short Pb/Scifi sections (SFils) was not completed. This step is fundamental to clarify/decide the needs (*e.g.*, number of position sectors, overall π/e, π^0/γ discrimination) for the final detector configuration.

Comments:

The 2024 proposed R&D program was quite ambitious and much still remains to be completed.

- First results have been obtained from the recent measurements carried out at the FTBF, but the analysis has not proceeded far enough to comment on the π/e, π^0/γ separation performance.
- No results were presented on the BabyCal energy resolution and response, although the test beam measurements were carried out last at Argonne in 2023.
- The horizontal arrangements of the AstroPix ASICs have not been presented. We understand however that this was not part of this years' R&D Program. Also, no assessment of the efficiencies of the AstroPix ASICs was given.

We believe this R&D program should continue in 2025, to complete the full set of milestones and achieve real tests with a full integration of SFils and more Astropix boards. Data-simulation comparison should still be completed. Similarly, linearity tests should be carried out to decide an eventual selection of other SiPM models.

In general we feel that the AstroPix development may need additional scrutiny.

We note that progress on the mechanical design and integration was not described, albeit this was not on the list of Milestones proposed in 2024, and indeed can be carried out independently.

Recommendations:

1) We commend the team for the work done since summer 2023, and we provide our full support for an extension of the R&D period to FY 2025. It is not clear to us if the proposal should be supported by purely R&D or PED funds.
2) We recommend completion of the analysis and simulation of the test beam data. This should be completed in time to inform the large scale procurement of the production SiPMs.
3) Extend the R&D plan to study horizontal arrangements of the AstroPix that mimic better the situation in the experiment. The reproducibility of layer production should be checked.
4) We recommend carrying out measurements to determine the efficiency of the AstroPix ASIC with the multilayer setup.
5) Early AstroPix performance should be critically compared with its promised specifications.
6) Work on the detector mechanical design, integration and cooling should continue along with the development of robust procedures for construction of the detector.

Commented [RP1]: Which Milestone 9? Did I miss something?

3. General Comments and Recommendations

1) The committee wishes to congratulate the various R&D groups on their enormous recent progress since the last review in. 2023 especially in preparation for the future CD2/3 reviews.
2) We express concern about the delays in getting funds to some groups, but it appears that work-arounds have been found to keep the R&D on track.
3) We encourage the groups to maintain focus on completion of needed R&D in FY25 in order to have no impact on the goal of being ready for CD2 review in late 2025.
4) The committee appreciates the follow-up on comments and recommendations from previous DAC reviews.

4. Appendices

4.1 Appendix A: Review Committee

C. Gerber, E. Kinney, P. Križan, A. Machado, P. Merkel, S. Miscetti, E. Oliveri A. Papanestis, R. Poeschl, B. Vachon, A. White, K. Wyllie

4.2 Appendix B: Agenda (Note the Closeout was moved to Sept 3, 2024, 10am Eastern)

Wednesday, August 28, 2024

Welcome of DAC and Discussion (Closed Session) (9:00 AM - 9:20 AM)

- **Presenter: KINNEY, Edward (University of Colorado)**
DAC CLOSED SESSION ZOOM LINK: https://bnl.zoomgov.com/j/1617950505?pwd=f5XAJKv9M1IZaa4aNfkErY14SfXxit.1 Meeting ID: 161 795 0505 Passcode: 311195

eRD106 - Forward EM Calorimeter (9:20 AM - 9:40 AM)

- **Presenter: TSAI, Oleg (ucla)**
Status Report

eRD107 Forward Hadron Calorimeter (9:50 AM - 10:10 AM)

- **Presenter: BOCK, Friederike (ORNL)**
Status Report

eRD115 - Barrel EM Calorimeter (10:20 AM - 10:40 AM)

- **Presenter: JOOSTEN, Sylvester (Argonne National Laboratory)**
Status Report

Coffee Break (10:50 AM - 11:10 AM)

eRD102 - dual RICH (11:10 AM - 11:35 AM)

- **Presenter: CONTALBRIGO, Marco (INFN Ferrara)**
Status Report & FY25 Proposal

eRD112 - Time-of-Flight & AC-LGAD (11:45 AM - 12:10 PM)

- **Presenter: JENTSCH, Alexander (Brookhaven National Laboratory)**
Status Report & FY25 Proposal

eRD103 - high performance DIRC (12:20 PM - 12:40 PM)

- **Presenter: KALICY, Grzegorz (CUA)**
Status Report

DAC Meeting (Closed Session) (12:50 PM - 2:30 PM)

- **Presenter: KINNEY, Edward (University of Colorado)**
DAC CLOSED SESSION ZOOM LINK: https://bnl.zoomgov.com/j/1617950505?pwd=f5XAJKv9M1IZaa4aNfkErY14SfXxit.1 Meeting ID: 161 795 0505 Passcode: 311195

Thursday, August 29, 2024

eRD104/eRD111/eRD113 - Silicon Tracker (9:00 AM - 9:50 AM)

- **Presenter: SICHTERMANN, Ernst (Lawrence Berkeley National Laboratory)**
Status Report & FY25 Proposal Homework attached to talk

eRD108 - MPGD Tracker (10:00 AM - 10:25 AM)

- **Presenter: BOSSU, Francesco (CEA-Saclay)**
Status Report & FY25 Proposal Homework attached to talk

Coffee Break (10:35 AM - 10:55 AM)

eRD110 - Photosensors (10:55 AM - 11:20 AM)

- **Presenter: KISELEV, Alexander (BNL)**
Status Report & FY25 Proposal

eRD109 - ASICs/FEE (11:30 AM - 11:55 AM)

- **Presenter: BARBOSA, Fernando (JLab)**
Status Report & FY25 Proposal Additional Information: August monthly update on ASIC development as part of the ePIC DAQ-Electronics working group: https://indico.bnl.gov/event/24331/ Recent DAQ - Electronics PDR: https://indico.bnl.gov/event/23355/ passwd: 2024PDRDAQ.Elec

DAC Meeting (Closed Session) (12:05 PM - 2:30 PM)

DAC CLOSED SESSION ZOOM LINK: https://bnl.zoomgov.com/j/1617950505?pwd=f5XAJKv9M1lZaa4aNfkErY14SfXxit.1 Meeting ID: 161 795 0505 Passcode: 311195