Closeout Presentation
EIC Detector Advisory Committee
R&D Review

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Closeout: September 3,2024

EIC Detector Advisory Committee
R&D Review – August 2024

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Thanks to EIC Project Team, ePIC Collaboration, and all the presenters!

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R&D Projects reviewed

eRD106 - Forward EM Calorimeter
eRD107 - Forward Hadron Calorimeter
eRD115 - Barrel EM Calorimeter

eRD102 - dual RICH
eRD112 - Time-of-Flight & AC-LGAD
eRD103 - high performance DIRC

eRD104/eRD111/eRD113 - Silicon Tracker
eRD108 - MPGD Tracker

eRD110 – Photosensors

eRD109 - ASICs/FEE

eRD106 - Forward EM Calorimeter

- Much good progress – production of final design16 blocks – UCLA and Fudan
- Mechanical tests of installation blocks and installation protocol completed.
- Iterations to improve light guides - efficiency of light collection, uniformity, and industrialization driving the design
- Test beam of one production block at FTBF in June – despite non-ideal beam conditions results show x2 improvement in uniformity
- Completion of eRD106 planned in next few months

- Gluing the SiPMboard to the light guides is a simpler and more stable procedure than doing that in situ after installing the blocks – however, difficult for replacement in case of dead SiPM or board problem
- Prototype has not yet been tested with final FEE, but SiPM readout by FEE iterated to a final scheme.

- A clear procedure for dismounting the SiPMs without damaging the light guides should be envisioned. Is a modified design still feasible with a holder to keep the SiPMboard aligned and tight to avoid gluing?
- Provide a prototype with uniform material and w/o gluing faults.
- Test prototype with final front-end electronics.

eRD107 Forward Hadron Calorimeter

- Based on CALICE AHCAL design – shares work with CMS HGCAL
- Good progress in producing mold scintillators of different sizes and dimples.
- Good progress also in the QA/QC stations for testing light yield and uniformity of the production tiles.
- Third iteration for the production of the flexible printed circuit (FPC) connecting up to 8 SiPMs to the tiles looks successful, reducing the stress on the pins.
- 30% of the FPC for August test beam has been produced.

- Molded tiles show about 30% lower LY than commercial scintillator.
- 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 LY looks practically saturated - so something like 10 pe/MIP. What is the requirement on LY that should be achieved to fulfill the experiment energy resolution?
- So far no experience with long boards, which will become the/a key component of the detector.

- Proceed with test beam and extract results from the assembled prototypes.
- Pay great attention to the development of the long r/o PCB and ensure the availability of experienced engineers.

eRD115 - Barrel EM Calorimeter

- First year of R&D which combines Pb/Scifi technology with a high-precision position detector(Astropix).
- Despite many problems (funding, test beam) FY24 R&D progressing very well.
- 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.
- Not all tasks completed - integration of BabyCal and Astropix with the short Pb/Scifi sections (SFils): fundamental to clarify needs for final detector configuration (#position sectors, π/e, π^0/γ disc.)

- First results from latest test beam at FTBF but not enough details on π/e, π^0/γ separation.
- Did not see results on BabyCal energy resolution and response from ANL 2023 test beam.
- No assessment of the efficiencies of the AstroPix ASICs shown.
- In general the AstroPix development may need further scrutiny.

- 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. (Not clear if this should be supported by R&D or PED?)
- Extend the R&D to horizontal arrangements of AstroPix to mimic better the situation in the experiment. Check reproducibility of layer production.
- Carry out tests on the efficiency of the AstroPix ASIC with the multilayer setup.
- Confront early AstroPix performance with specs.
- Data-simulation comparison should still be completed. Similarly, linearity tests should be carried out to decide an eventual selection of other SiPM models.
- Keep working on detector mechanical integration and cooling., and robust procedures for detector construction.

eRD102 - dual RICH

- Challenge: covering a wide momentum range (3-50 GeV/c), operating in a high magnetic field (~1T), and fitting within limited space.
- Recent achievements: optimization of aerogel radiator; progress in development of lightweight mirrors; compact photon detection units with advanced SiPM arrays; integration of key components like the ALCOR digitizing chip; multiple TBs conducted with mixed hadron beams and various radiators.
- Main challenge for 2025: validation of real-scale prototype with component demonstrators.

- Project progressing well, aligning with 2024, 2025 goals. Key areas like PDU design show promising results
- Pending decisions: single vs. two vessel solution, definition of in-situ annealing procedures for SiPMs, and need for windows to separate different temperatures of the gas radiator and the photon detector.

- Provide material for decision on the single vs two vessel version. The performance should be simulated since, in the case of two volumes, one expects some efficiency loss, either due to photon loss at the separating wall or – in case the wall is covered with planar mirrors – due to ambiguity in reconstruction.
- Annealing procedures should be investigated, and defined; implications for the design of the r/o board (heating).
- The necessity of windows to separate regions at different temperatures (gas radiator and the photon detector)
- Present at least a vague timeline for the project at the next DAC review.

eRD103 - high performance DIRC

- Objective of the R&D is to ensure that the required performance for ePIC can be achieved using a Cosmic Ray Telescope, which can also be used to test the completed hpDIRC bar boxes.
- Significant progress with all components of the CRT. However, none of the individual components are close to the commissioning stage, h/w available but not yet fully connected to a r/o system.
- Quartz bars from Babar, were supposed to be delivered for examination in the autumn of 2023. The report mentions arrival of the quartz bar boxes in April and examination in autumn 2024. There is no impact expected from this delay.
- CRT for testing the performance of the hpDIRC and later perform Quality Assurance on the hpDIRC boxes is a powerful tool and it's 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.

- Include a rough timeline of the construction of the hpDIRC and how it fits with the current activities. Show possible bar procurement schedule and where there is float.
- Follow the development of front-end electronics more closely.

eRD112 - Time-of-Flight & AC-LGAD

- 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 studied, and integration with the FE ASIC was tested.
- Preliminary irradiation studies have been performed.
- FBK is being considered as a third production site to mitigate risks during the production phase.

- Project is progressing according to plan – we congratulate groups for the progress in the past year.
- Positive results with basic sensors, but some cases small margin v. requirements – concern over degradation in final detector(s). Teams are aware of this.
- Alternate sensor vendor(s) considered.
- Existing sensor studies well organized.
- Initial tests with FE ASIC have begun – various testing facilities set up across groups.
- Radiation hardness esp. wrt time and position resolution should be measured.
- As flagged in previous review, still need Information on how the sensor will be integrated into the various sub-detectors (modules, support, services), including the impact on the material budget.

eRD112 - Time-of-Flight & AC-LGAD (2)

- 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.

- 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)

- 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 – optimize sensor performance.

- Continue studying sensor fabrication options and quality with the currently selected vendors.

- 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.

eRD104 - Silicon Services reduction

- Working on serial powering (SP) with Shunt LDOs to reduce the power infrastructure.
- Reduction of the signal readout cabling.
- UK groups – serial powering/prototype design, overall powering scheme for whole detector.
- ORNL – technologies for readout chain from detector to FELIX
- ORNL + MIT – aggregating fiber board to reduce number of readout fibers.

- Milestones – Production of SP flex circuit prototype
  - Simulation/verification of Shunt LDO scheme
  - Finalize Shunt LDO design will allow production and performance testing
  - Production/testing of serialized board – later in 2024

- Steady progress since August 2023 review, but much fabrication/testing remains to be done
- Radiation hardness – concern in August 2023 review – lpGBT and VTRx+ now used for which radiation hardness is known.

- 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.

eRD111 - Si-Vertex – Modules, Mechanics, Cooling, Integration

- INFN institutes have pursued design of L0, L1 of inner barrel following ITS3 experience.
- First local support structure prototype made – 3D printed in Bari.
- Thermo-mechanical prototype using blank silicon planned for EOY24
- Climate chamber being set up by Pavia to investigate temp/humidity effects
- First design of SVT IB global support developed by Padova - first mockup scheduled
- LBNL studied disc layout using LAS and cooling based on use of carbon foam
- Oxford is waiting eRD111 funding but has been developing design of OB staves
- OB stave design is ready for prototyping
- Purdue also did not yet receive funds but has studied possibility of integration of SVT local structure with larger global support structures.

- R&D is progressing according to plan – we congratulate groups on past year advances.
- Cooling tests show manageable airflows on the corrugated disk test piece.
- Optimization using carbon foam is ongoing.
- With approx 4000 EIC-LAS sensors in the SVT the groups are aware that power consumption estimates might change.
- Baseline is cooling with air internal to the mechanical structure, liquid cooling in strategic places is a wise approach.
- General concern that delays in establishing funding can lead to accumulating delays.
- Potential impact of delays to contributions to ePIC TDR at end of 2024.

eRD111 - Si-Vertex – Modules, Mechanics, Cooling, Integration (2)

- 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 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.

- Continue performing thermal prototypes for IB design.
- Clarify need for liquid cooling in "strategic places" – impact on material profile?
- Continue close collaboration with the eRD104 group for FPC and readout concept and design.
- Keep simulation on track with developments in local/global support structures.
- Streamline the distribution of funds to collaborating institutions in a timely manner.

eRD113 - Si-Sensor Development and Characterization

- 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.
- Development of the specifications of an ancillary chip for the SVT has started and a target technology chosen.
- 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.

- 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.
- Concerned that a collaboration agreement with ALICE is not yet in place and that access to the design technology is not yet possible.
- Choice of XFAB-XT011 for the ancillary chip requires early validation of the process - assume a steep learning-curve - significant effort on both technology qualification and design-work.
- 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.

eRD113 - Si-Sensor Development and Characterization (2)

- The proposed R&D activities are high priority - we strongly recommend the approval of funding.
- 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.
- 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.
- We strongly recommend that the collaboration agreement with ALICE be concluded as quickly as possible.

eRD108 - MPGD Tracker - CymBaL

- 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.
- Due to the low-energy electron beam and multiple scattering, the results of the 2023 MAMI test beam are not conclusive. CRT at Saclay will be beneficial for prototype characterization, but high energy test beams will provide simpler, faster, more accurate characterization.
- Changes in materials wrt previous cylindrical CLAS12 MM raise questions and risks. Important to demonstrate capability to produce such a detector that meets requirements.

- Previous review raised concern about close interaction of services between SVT and MM and this has not been addressed.
- Conceptual design for services and impact on tracking coverage is needed.
- An updated mechanical design of the large prototype should be prepared unless already done.

eRD108 - MPGD Tracker – CymBaL (2)

- 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.
- 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 (uTPC or reduced drift), and the required gas.
- 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.
- Continue the studies toward full-scale prototyping (designs and prototypes), focusing on critical issues to prepare for CD2/3.

eRD108 - MPGD Tracker – µRWELL Barrel

- 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 uRWELL will be relevant and beneficial for the baseline CyMBAL and the planar uRWELL-based trackers. Several risks have been raised by the CyMBAL proponents, highlighting the importance of R&D on alternative options.
- For planar uRWELL detectors (Endcap and Outer Barrel), a hybrid solution of uRWELL + 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.
- 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.
- 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 uRWELL-based tracking detectors.
- Impact on the material budget of the final proposed design, including the new honeycomb drift support, should be calculated.
- 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.

eRD110 - Photosensors

- Funds were limited but progress made with careful consolidation of test infrastructure for timing and ageing studies.
- Test systems are ready, including illumination techniques with high timing precision.
- LAPPD tubes were tested in B-field with confirmation that increased bias can recover inefficiencies.
- Cross-talk issues on the passive interfaces for the HRPPD studied and an optimised design prepared.

- We commend the preparation of the testing infrastructure and the clear definition of the test programme.
- Positive news on the status of the EIC-HRPPD - no apparent barriers to launching the programme of detailed characterisation in the institutes.
- We commend the continuation of studies of the MPC-PMT to prove its viability as a back-up to HRPPD. However, that there is still significant work ahead to move from small prototype quantities to production scales for both types of devices.
- Timescales and steps towards first integration with ePIC electronics (EICROC, FCFD) not obvious – planning and coordination with electronics teams is required.
- Agreement on importance of ageing tests after observation of degradation in older LAPPD.

- Strongly recommend approval of funding though modest to conclude studies in 2025.
- Recommend to follow up on coherent oscillations/explore mitigation techniques .
- Recommend careful planning towards testing photosensors coupled to the EICROC/FCFD ASICs - critical to ensure that the specifications and performance of the ASICs are adequate for these sensors.
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eRD109 - ASICs/FEE

- Design of the discrete readout for Calorimeters has progressed well. Design for Forward ECAL to be extended to Backward ECAL.
- Insights from SiPM tests with H2GCROC incorporated into CALOROC design.
- Design of the ALCOR for the dRICH readout has advanced well and the chip was used in beam tests.
- Characterization of the small-scale EICROC has progressed, informed the design of the next version.
- FCFD chip – alternative readout – characterized in lab.
- Flex PCB for AC-LGAD fabricated and being characterized.
- Precise clock distribution was successfully demonstrated with a pre-prototype RDO and DAM.
- SALSA analog and digital blocks fully characterized, chip version (full frontend and ADC chain) submitted for production.

- We commend progress on all sub-proposals of eRD109 – clear development paths.
- Commend efforts to expedite design of FCFD by proposing an adaptation of the EICROC backend .
- Concern over delays in submission milestones, resulting delays in integration with detector technologies (EICROC1/FCFD for the AC-LGAD; HRPPD, MCP-PMT; SALSA for MPGDs; CALOROC for SiPMs).

eRD109 - ASICs/FEE (2)

- Strongly recommend approval of proposed R&D funding – activities are high priority.
- Recommend careful analysis of reasons for slips in submissions – help with resources from collaborating institutes?
- 2(3) additional ASICs being custom designed for ePIC, EIC-LAS (plus ancillary chip) and ASTROPIX. Not so far included in list of ASICs reviewed under eRD109. We recommend that these are scrutinized in same framework as the other ASICs. This will help with monitoring compliance and the sharing of knowledge and experience.
- 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.

Overall Recommendations etc.

- Congratulations to everyone on very significant progress on R&D since the 2023 review.
- Concern over funding delays, but workarounds being found.
- Maintain focus on completion of needed R&D in FY25 so no impact on goal of CD2 late in 2025.
- Committee appreciates follow-up on comments, recommendations from previous review.