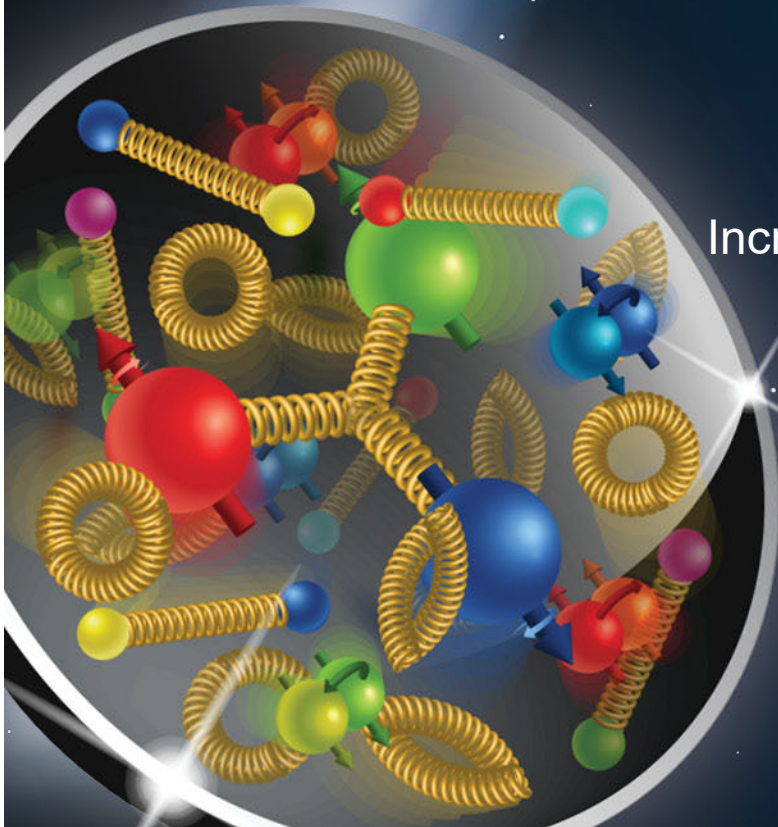


# Closeout Report

Peter Križan, Floris Keizer, Ana Amelia Machado,  
Koji Nakamura, Justin Stevens

Incremental Design and Safety Review of the Electron-  
Ion Collider (EIC) Particle Identification Detectors

July 5-6, 2023



Electron-Ion Collider

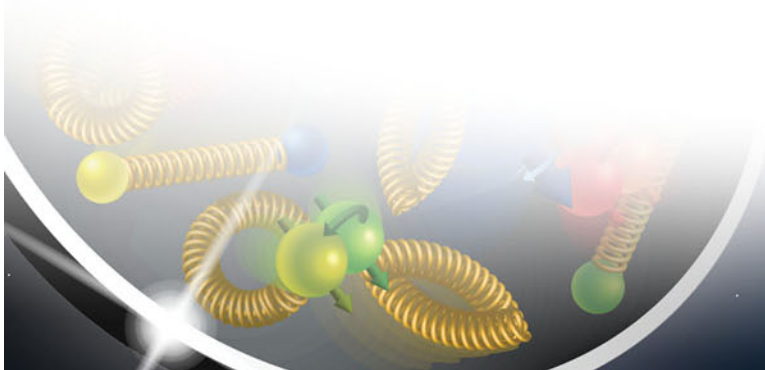
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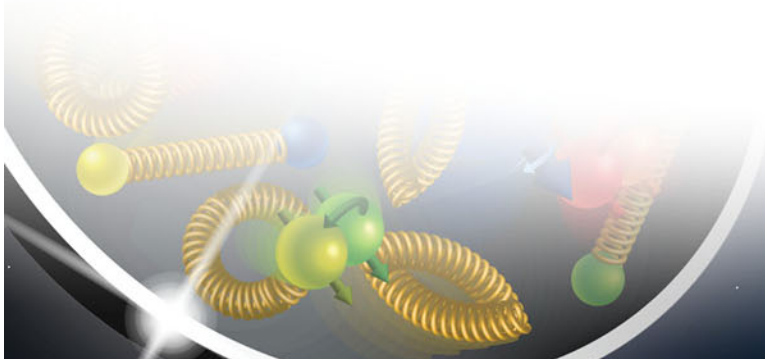
# Outline

- Review Panel
- Charge Questions
- Committee Report
  - Findings
  - Comments
  - Recommendations
- Conclusion



# Review Panel

- Peter Križan – Chair      U. Ljubljana
- Floris Keizer              CERN
- Ana Amelia Machado      UniCamp
- Koji Nakamura              KEK
- Justin Stevens              W&M



# Charge Question and Response

1. Are the technical performance requirements appropriately defined and complete for this stage of the project?
  - Yes. Detailed assessment in the comments.



# Comments

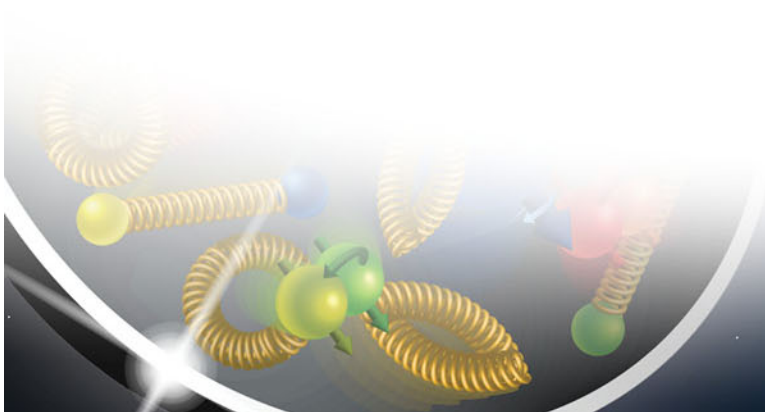
- Initial detector performance requirements were provided by the EIC Yellow Report which were translated to the JLab Requirements webpage. However, the JLab requirements page does not include all the performance requirements (or at least with the same terminology as PID detectors, e.g. tracking position and angular resolution at radiator). The Yellow Report requirements may also need to be tailored to the ePIC detector and defined for the project.
- Many studies have been done with standalone simulation and reconstruction, however additional support should be provided for integrating the latest designs and realistic PID performance into the full ePIC simulation.
- Recent progress has been made in ePIC's cross-cutting PID WG to understand tracking requirements for PID detectors. Requirements documents should capture the bi-directional interface between tracking and PID detectors: e.g. translation between extrapolated track impact point and angle resolution requirements for PID detectors. It could be evaluated where the PID subdetectors can contribute to improve the tracking performance and how in the reconstruction algorithms this could be integrated.

# Comments

- A specification on the tolerable clock drift and the robustness to phase irregularities should be defined and will help to ensure that these parameters are measured and controlled in the architecture from the beginning of the design phase. The DAQ design should include a backup solution for a directly distributed clock to the RDO boards to provide the clock precision required by each subsystem.
- It is encouraging to see the effort made to keep uniformity across the ePIC electronic readout boards in order to keep cost and firmware/software development to a minimum. The use of a single optical link technology, in this case FPGA and SFP+ at the RDO level, will also reduce the overall R&D effort that will need to go into the clock filtering and timing distribution from DAM to RDO/FEB.
- The quartz window to separate the photodetector box from the gas radiator was identified as a point of attention. A thermal simulation is required with the SiPM array at the foreseen operating temperature of -30 C and the approach to avoid condensation or convection of the C<sub>2</sub>F<sub>6</sub> gas radiator should be described. The reviewers fully recognise the importance of the foreseen small-scale system tests in the SPS testbeam facility later this year.

# Recommendations

- We recommend to capture the bi-directional interface between tracking and PID detectors: e.g. translation between position and angular resolution requirements for PID detectors.
- We recommend to perform a thermal simulation of the dRICH SiPM array considering different operating temperatures and impact on the quartz window and gas radiator.



# Charge Question and Response

2. Are the plans for achieving detector performance and construction sufficiently developed and documented for the present phase of the project?

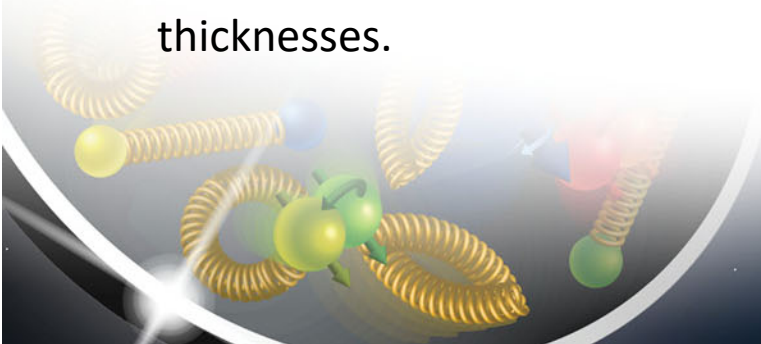
- Yes. Detailed assessment in the comments.





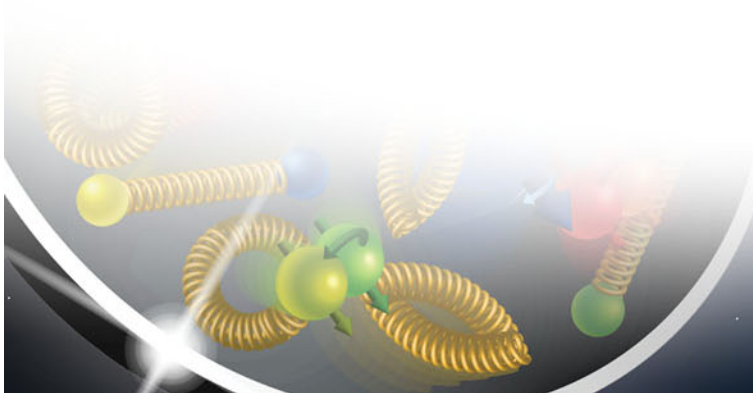
# Comments

- (AC-LGAD) 35ps Barrel/ 25ps FW timing resolution seems to be almost the best performance without safety margin. Under these circumstances, a bias voltage scheme should be more flexible than only one pair of cables for each board, because the temperature gradient and the position dependent radiation fluence require different operation voltages.
- The initial requirements for the EICROC were specified mostly for the Roman Pot detector and not for all detectors which use EICROC. We advise summarizing the requirements for all detectors and making a single EICROC specification before submitting further prototype chips.
- Following the discussion, the integrated anode charge for the HRPPD over the experiment lifetime is understood to be only a few  $C/cm^2$  in a worst-case estimate at 10M gain. Operating at lower gain can increase the lifetime but should be balanced with reduced PDE. It would be good to have the integrated charge numbers available from simulation, also for different quartz HRPPD window thicknesses.



# Comments

- A charged particle timestamp with a resolution of  $\sim 20$  ps is required. It was stated that an SPTR of  $\sim 50$  ps is required to achieve this track resolution, based on the minimum of 6 photons per track and the requirement of  $\sim 100\%$  geometric efficiency. However, it was also presented that the mean number of photoelectrons lies around 12 (in the aerogel) and  $>80$  (in the entrance window). It therefore appears that for the majority of tracks a significantly lower SPTR can be required. It would be good to see the results from simulation on how the overall pfRICH and ePIC performance behaves as a function of this SPTR.
- It would be good to evaluate the effect of the different photon angles of incidence on the quartz window across the detector plane on the number of detected photons and Cherenkov-angle resolution.



# Charge Question and Response

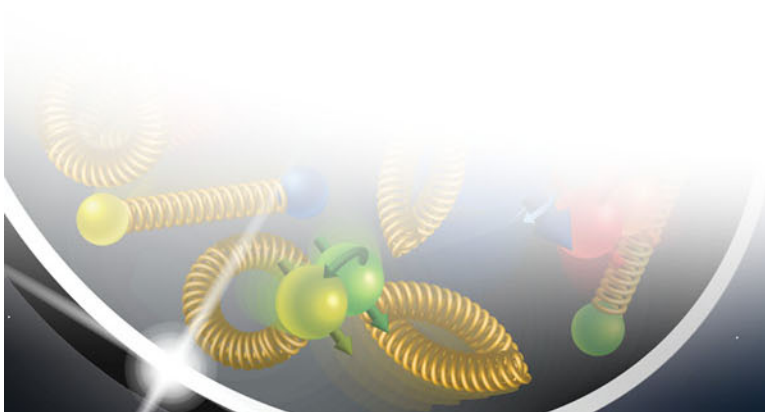
3. Are the current designs and plans for detector and electronics readout likely to achieve the performance requirements with a low risk of cost increases, schedule delays, and technical problems?

- Yes. Detailed assessment in the comments.
- Regarding the evaluation of the risk of cost increases and schedule delays, we have not received sufficient information.



# Comments

- The reviewers suggest to consider also the option of replacing the SiPM array once during the experiment lifetime as an alternative to the “oven” annealing process.
- To reduce dark current, heavy annealing is planned. It is required to check that the charge collection efficiency is not reduced due to over-annealing. The reviewers understand that this is part of the ongoing R&D campaign and that encouraging first results have been obtained.
- For online self-annealing, all materials including glue, PCB etc have to be checked to see if these are tolerant to the high temperature and if the thermal cycling does not affect the components due to CTE mismatch.
- We advise exploring the operation of SiPMs at a lower temperature (for example -40C) to guarantee a low level of DCR.



# Comments

- The online annealing procedure requires forward biasing of the sensors creating local heat generation and large current flows close to the front-end electronics. Precautions will have to be taken to avoid damage to the ASIC. It was understood that this is a part of the R&D effort, for example through the use of MOSFETs to protect the readout.
- The reviewers acknowledge that the EICROC will not be available before the design is finalized; thus evaluation of the HRPPD performance will take place with the existing HGCROC under the assumption that similar performance will be achieved with the EICROC.



# Charge Question and Response

4. Are the fabrication and assembly plans for the various particle identification detector systems consistent with the overall project and detector schedule?
- Yes. Detailed assessment in the comments.



# Comments

- In the worst-case scenario that unexpectedly the reused BaBar bars do not meet the quality requirements, an alternative production can be started up, albeit with a penalty in production time and costs. It is encouraging to see that the first tests of the BaBar bars are planned in the near future, in order to leave sufficient time for this fallback scenario of a new bar production.
- In the worst-case scenario that HRPPDs are not able to meet performance specifications or production schedule, a backup solution of MCP-PMTs is being considered and should be evaluated in parallel to the HRPPDs.
- (AC-LGAD) The type of interconnection to the sensors (like wire bonding or bump bonding) needs to be clearly specified. If a detector uses a bump bonding connection, we would advice to start testing the flip-chipping process since it takes longer to develop a stable procedure.



# Charge Question and Response

5. Are the plans for detector integration in the EIC detector appropriately developed for the present phase of the project?

- Yes. Detailed assessment in the comments.





# Comments

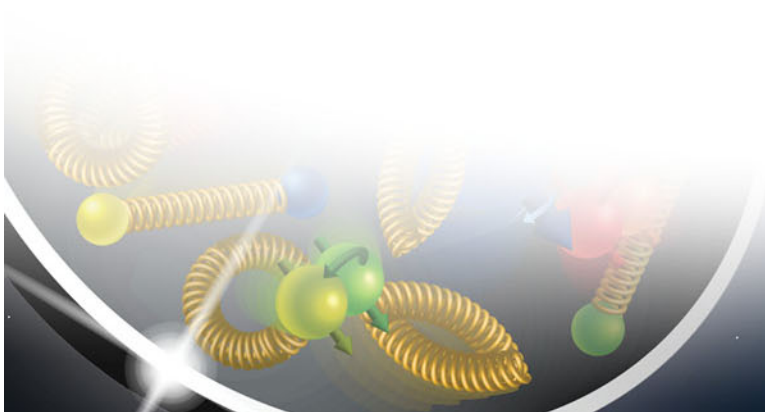
- Encouraging track momentum resolution improvement was achieved by including the AC-LGAD in reconstruction. The reviewers suggest extending this study to understand the impact on the extrapolated track impact point and angle at the radius of the DIRC.
- It was mentioned that the 3.375 mm (or potentially smaller) pitch at the HRPPD backplane is dominated by requirements of the hpDIRC using the same photodetector, and the pFRICH could operate at larger pixel areas. It should be investigated whether a small change in layout would allow multiple pixels to be grouped into a single readout channel, in order to reduce the overall channel count and cost.



# Charge Question and Response

6. Have ES&H and QA considerations been adequately incorporated into the designs at their present stage?

- All presented projects discussed at a sufficient depth possible ES&H issues and their mitigation.
- We were missing detailed QA plans, including the fraction of devices to be tested.



# Conclusion

We thank the PID detector proponents for the excellent presentations and discussions during the PID Review.

We are very happy to see the state of the project and the very interesting R&D for the PID community.

We encourage a continuation of R&D and beam tests to complete the designs.

The PID detectors are fully on track for the CD2/3 review on the current project timeline.

