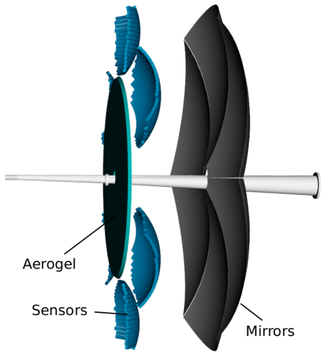
PID Systems: Status of preTDR Studies

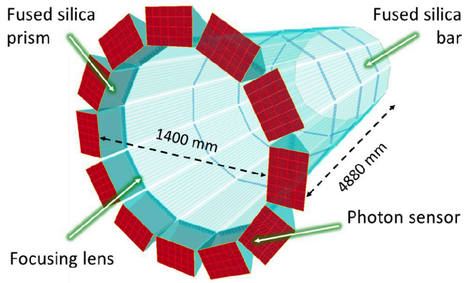
Thomas Ullrich on behalf of the PID DSCs

TIC Meeting

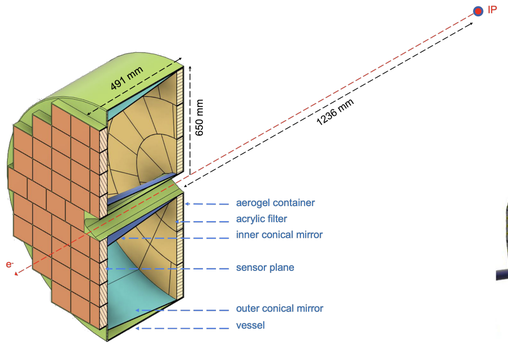
September 22, 2025



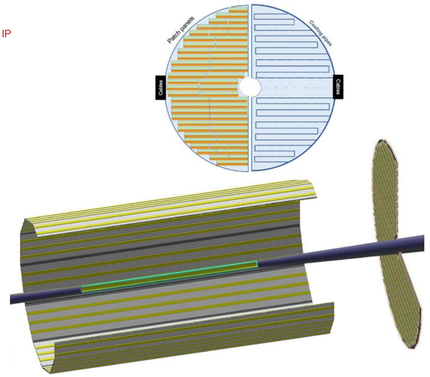
dRICH



hpDIRC



pfRICH



ToF

Brookhaven National Laboratory

Input & Acknowledgments

Thanks all DSCs to provide input for this brief summary

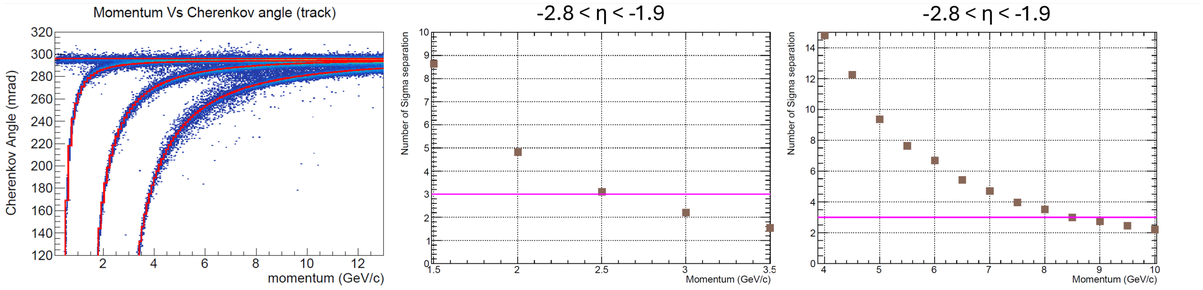
- Grzegorz Kalicy (hpDIRC)
- Brian Page (pfRICH)
- Satoshi Yano (ToF)
- Marco Contalbrigo (dRICH)

Preparations were somewhat complicated by the RICH 2025 conference last week

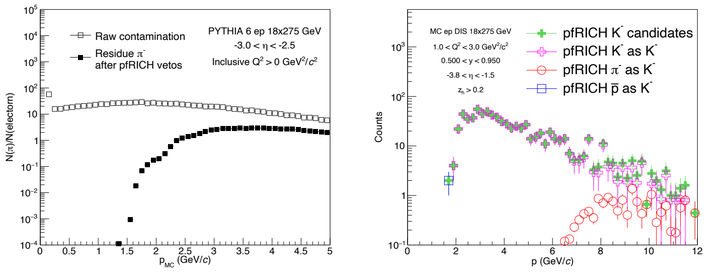
pf*RICH*

pfRICH Performance Plots for pre-TDR

- Two plots in the pfRICH section of the preTDR (v2.2) were produced using the standalone simulation
  - 8.107 (Cherenkov angle vs p and N_σ vs p for e/π and π/K)
  - 8.108 (π veto power and K id power)
- RICH geometry and reconstruction software currently on IRT-2.1a branch should be sufficient to reproduce figure 8.107
  - Code is ~ready to merge into main branch now
  - Reproduction of figure would not need a DIS production, but a set of single particle runs at discreet momenta and η – in theory, could be run privately using the official tagged software version
- Prospect for reproducing figure 8.108 less clear on preTDR timescale, but this figure can likely be moved to the supplemental materials
- Need to converge very soon on plan for including IRT-2.1a code in a way kosher for the preTDR



8.107



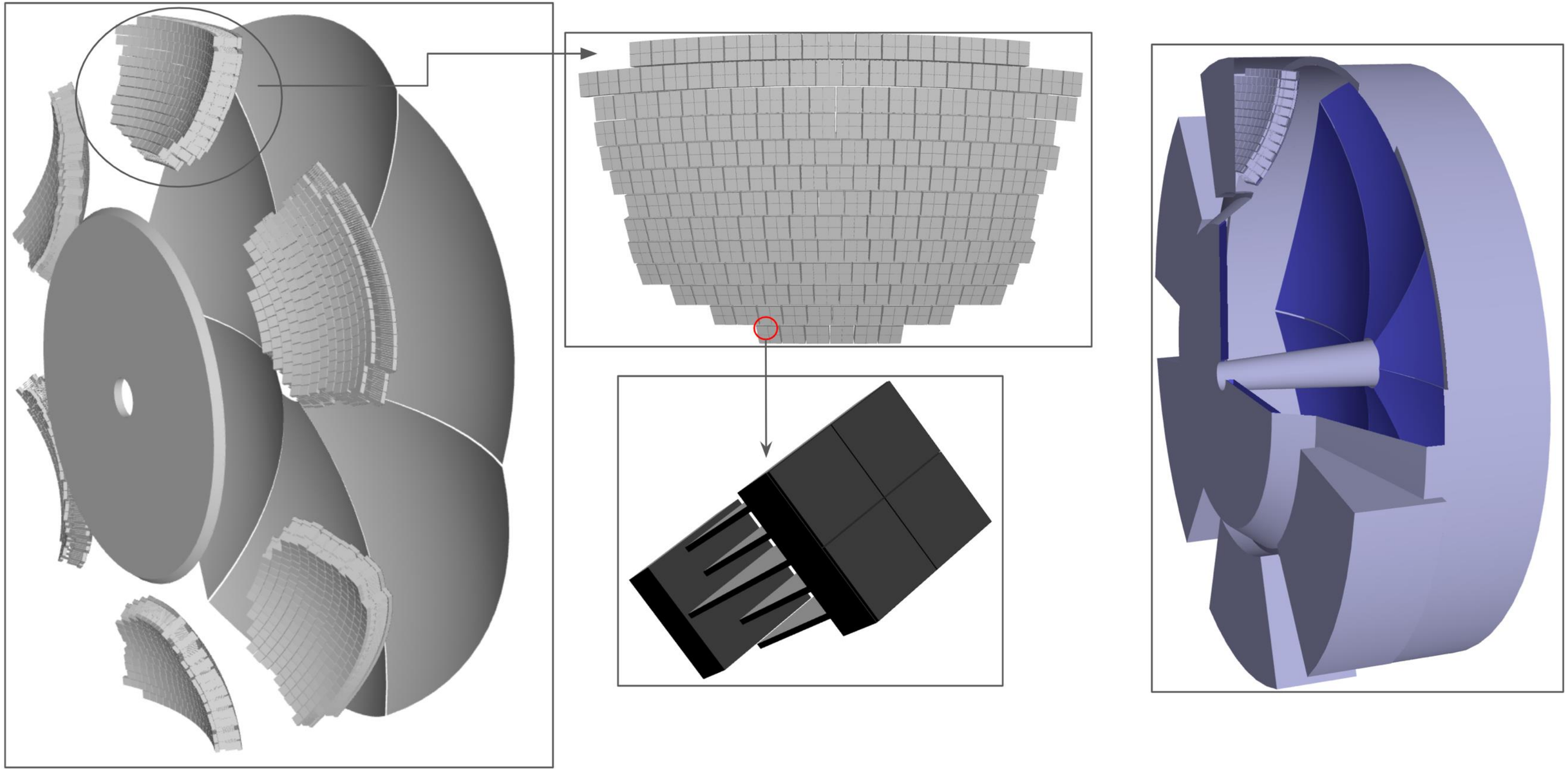
8.108

Verify Radiation Hardness Numbers

- Estimates for total accumulated charge/cm^2 on HRPPDs (aging) quoted in the "Requirements from Radiation Hardness" section need to be updated
  - Old electron beam gas background files used
  - Prior simulations did not use full ePIC geometry
  - Other simplifying assumptions made (no optical photons were simulated, etc)
- Redo estimates using *npsim* with official ePIC geometry, updated pfRICH geometry and latest background files
- Update requirements section (in coordination with editorial board) with new numbers when study is complete
- Investigation of full reconstruction in the presence of background is high on our priority list, but will likely not be done in time for preTDR
  - At a minimum, requires factoring a digitization step out of the IRT library
- Some of these studies likely can be done in ePIC software environment privately, without using official productions

d*RICH*

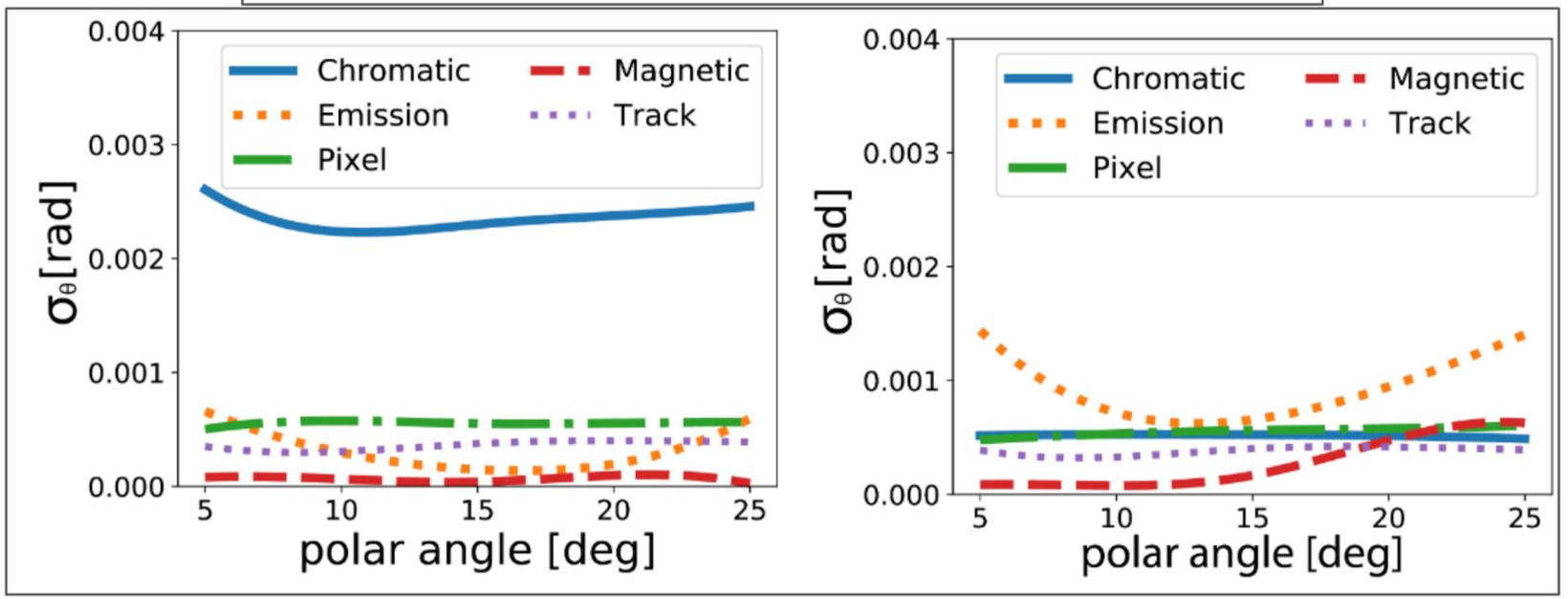
Recalling dRICH in ePIC Simulation (Geometry)

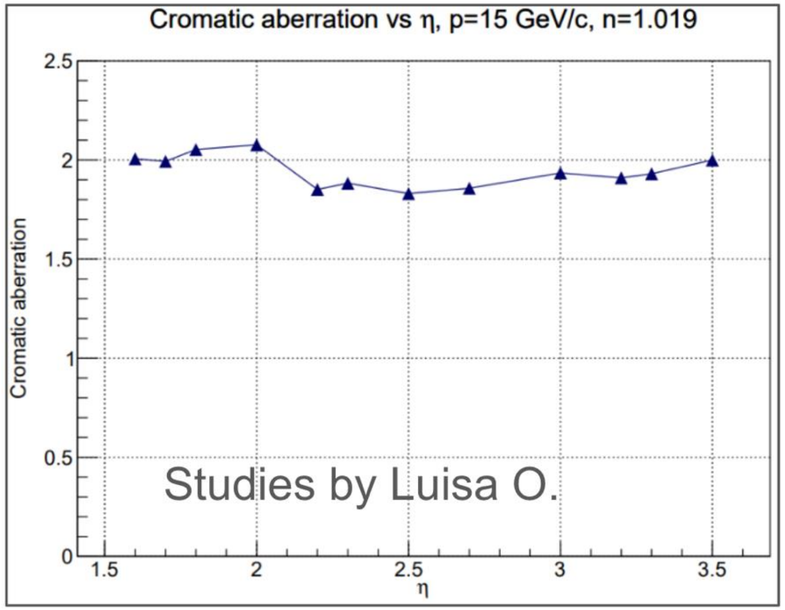


dRICH Plan

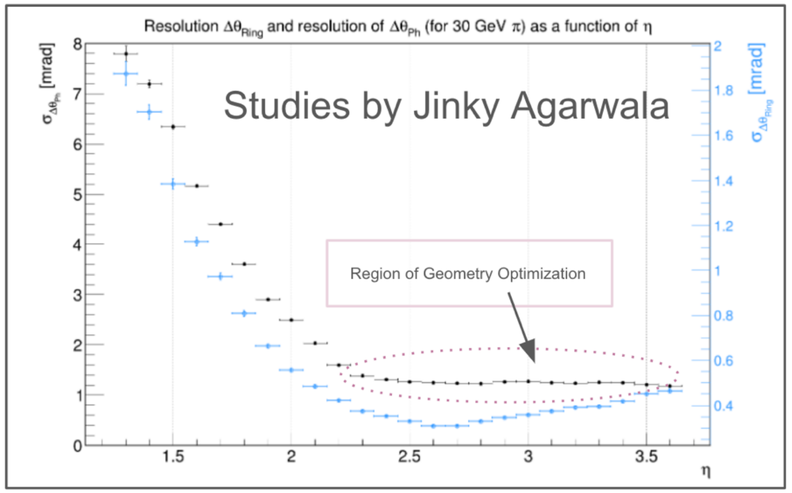
- Short-term: Perform refinements and performance checks that may impact LUTs
- Medium-term: Implement IRT-2
- Long-term: Refined geometry and PID

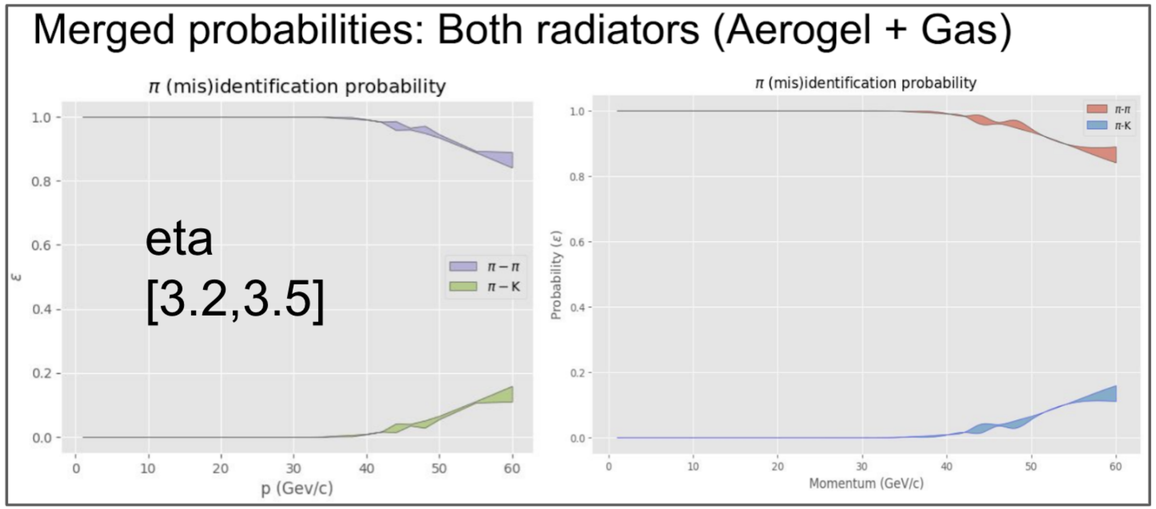
$$\sigma^2_{\theta_c} = \sigma^2_{\theta_c \text{pixel}} + \sigma^2_{\theta_c\ \text{chromatic}} + \sigma^2_{\theta_c\ \text{magnetic}} + \sigma^2_{\theta_c\ \text{track}} + \sigma^2_{\theta_c\ \text{emission}}$$

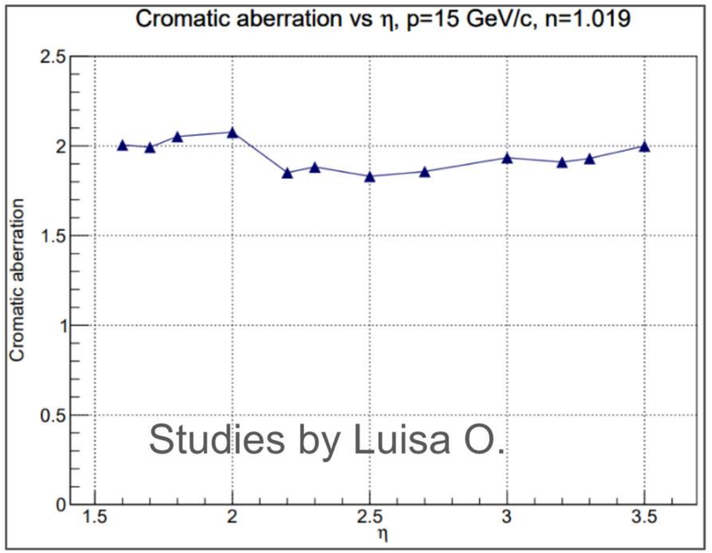




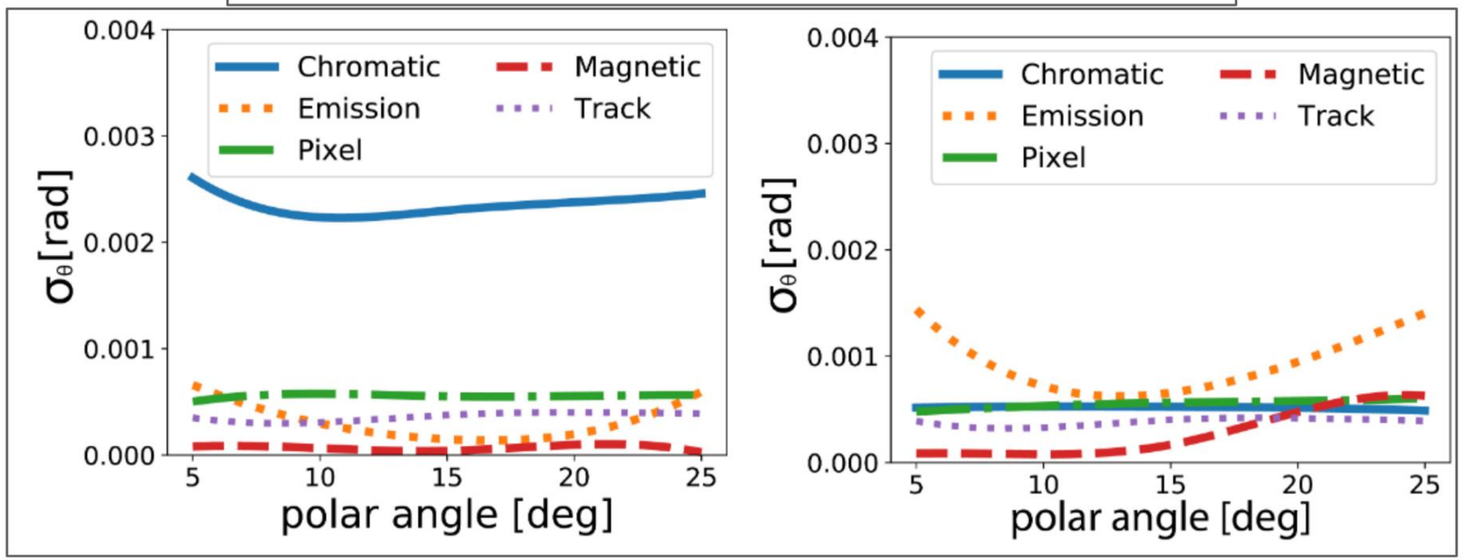
Checks





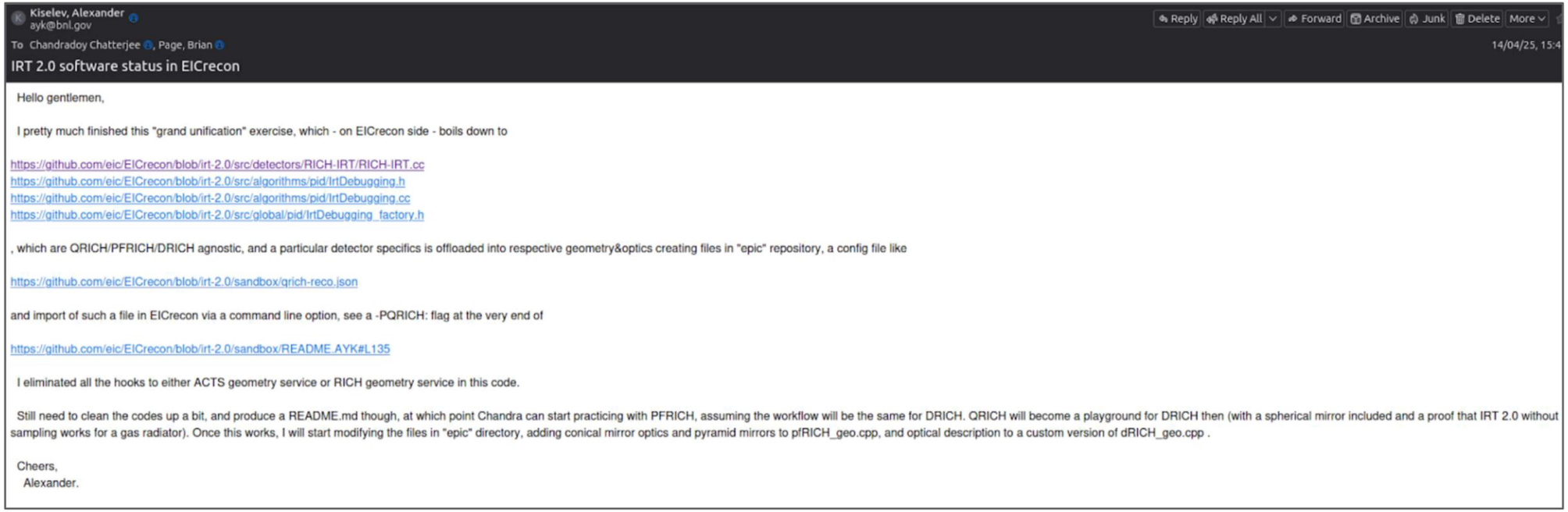


$$\sigma^2_{\theta_c} = \sigma^2_{\theta_c \text{pixel}} + \sigma^2_{\theta_c \text{ chromatic}} + \sigma^2_{\theta_c \text{ magnetic}} + \sigma^2_{\theta_c \text{ track}} + \sigma^2_{\theta_c \text{ emission}}$$



Reconstruction Algorithm (IRT v2)

- Alexander has implemented IRT version 2 in ePIC stack.
- Currently works for toy RICH.
- dRICH optics and performance features will be tested.
  - Deepak, Raman and Chandra will take care of this.
- This week is meeting on this topic
- Priority is to deal with multi-track and multi-sectors



Kiselev, Alexander
ayk@bnl.gov

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To Chandradoy Chatterjee, Page, Brian

14/04/25, 15:4

IRT 2.0 software status in EICrecon

Hello gentlemen,

I pretty much finished this "grand unification" exercise, which - on EICrecon side - boils down to

https://github.com/eic/EICrecon/blob/irt-2.0/src/detectors/RICH-IRT/RICH-IRT.cc
https://github.com/eic/EICrecon/blob/irt-2.0/src/algorithms/pid/IrtDebugging.h
https://github.com/eic/EICrecon/blob/irt-2.0/src/algorithms/pid/IrtDebugging.cc
https://github.com/eic/EICrecon/blob/irt-2.0/src/global/pid/IrtDebugging_factory.h

, which are QRICH/PFRICH/DRICH agnostic, and a particular detector specifics is offloaded into respective geometry&optics creating files in "epic" repository, a config file like

https://github.com/eic/EICrecon/blob/irt-2.0/sandbox/qrich-reco.json

and import of such a file in EICrecon via a command line option, see a -PQRICH: flag at the very end of

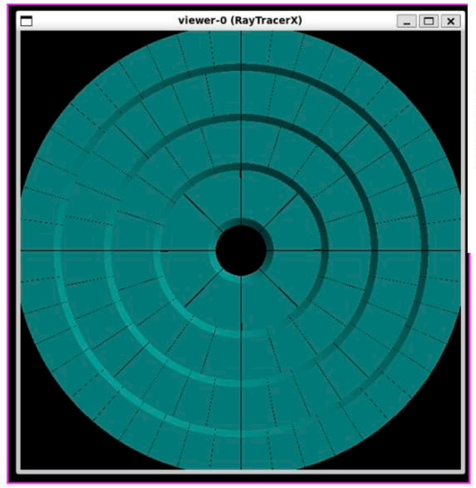
https://github.com/eic/EICrecon/blob/irt-2.0/sandbox/README.AYK#L135

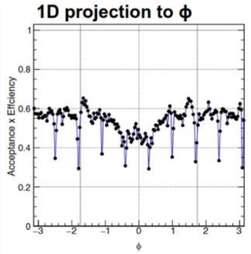
I eliminated all the hooks to either ACTS geometry service or RICH geometry service in this code.

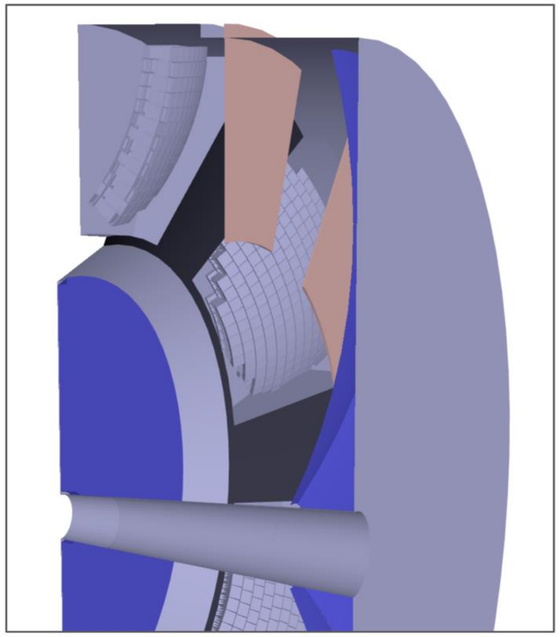
Still need to clean the codes up a bit, and produce a README.md though, at which point Chandra can start practicing with PFRICH, assuming the workflow will be the same for DRICH. QRICH will become a playground for DRICH then (with a spherical mirror included and a proof that IRT 2.0 without sampling works for a gas radiator). Once this works, I will start modifying the files in "epic" directory, adding conical mirror optics and pyramid mirrors to pfRICH_geo.cpp, and optical description to a custom version of dRICH_geo.cpp .

Cheers,
Alexander.

Geometry & PID

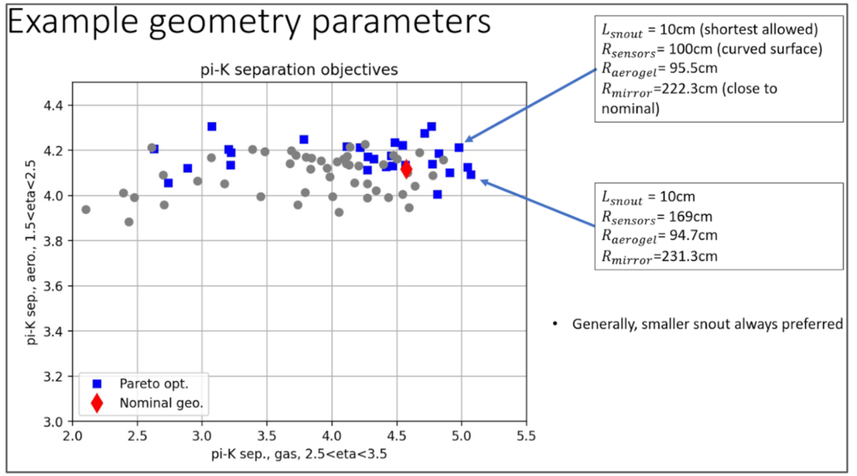


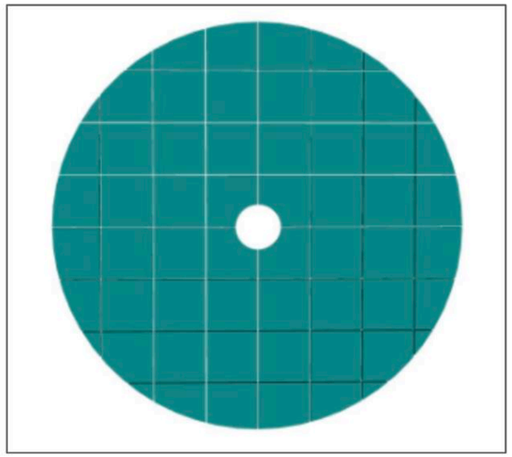




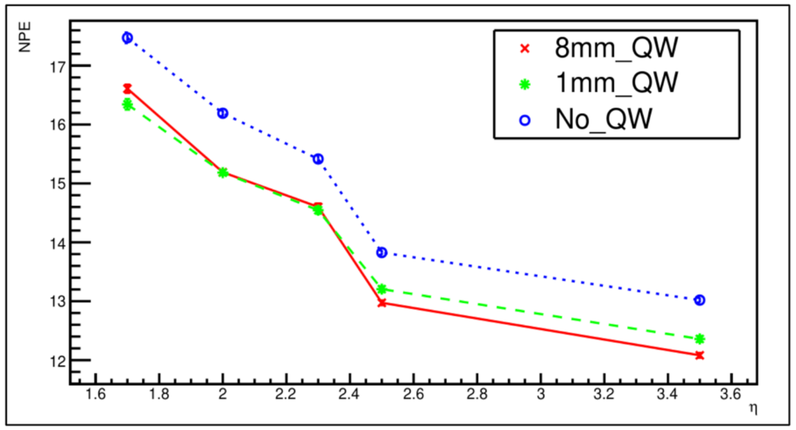
Implementation of the quartz window ongoing!

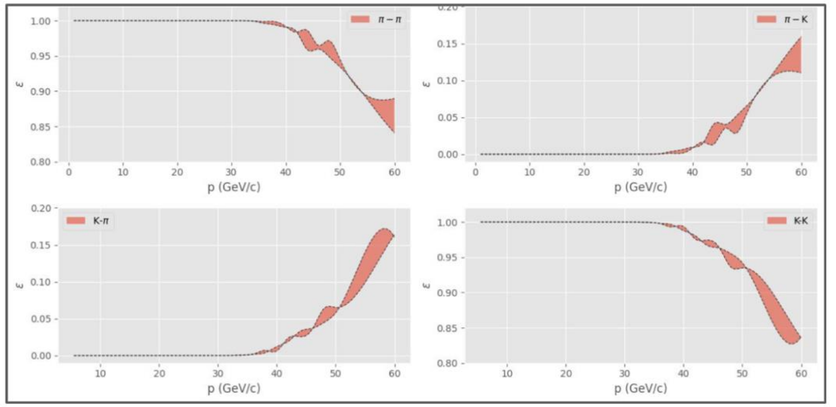
Bayesian Optimization of Optics





Quartz window





First trial of PID based on CNN by Nebin Geroge.

hp*DIRC*

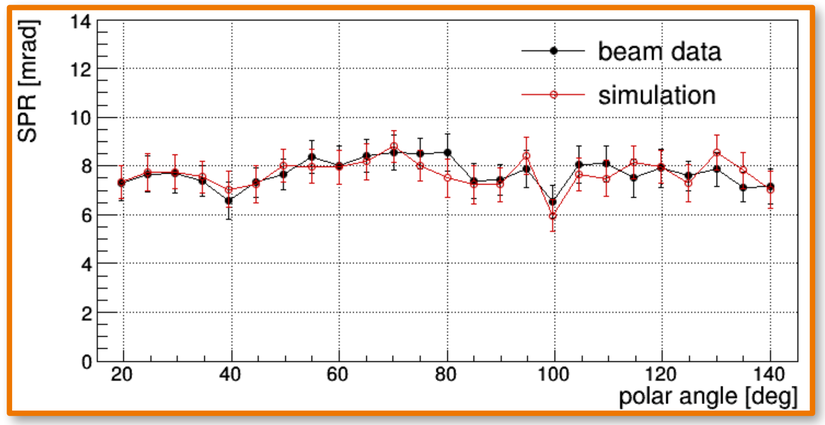
hpDIRC Simulation (i)

Geant4 DIRC Simulation Software

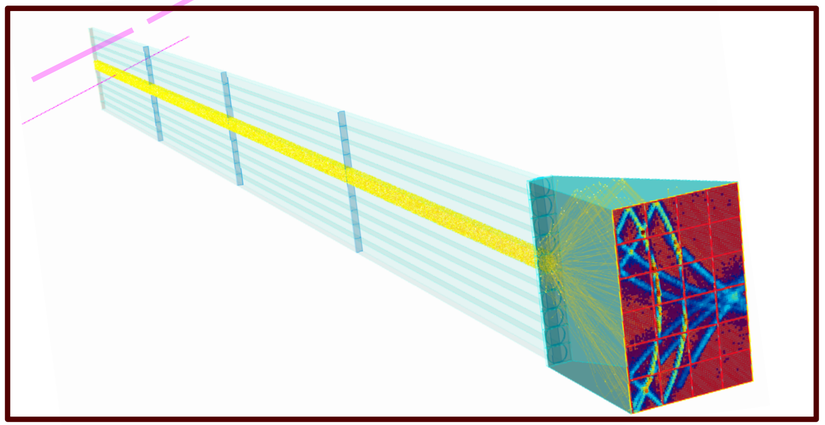
- Realistic optics, geometry, and wavelength-dependent material properties
- Single particle gun mode used to scan full polar and azimuthal angle range
- Using physics events (Pythia) to include backgrounds, multiple tracks per bar showed no impact on hpDIRC performance
- Validated with test beam data (PANDA Barrel DIRC prototype at CERN)

Test beam campaign with PANDA Barrel DIRC Group

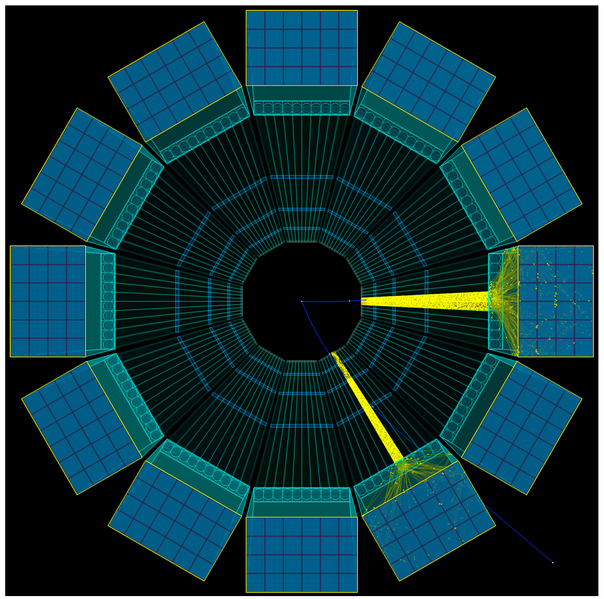
Single Photon Resolution



Single particle gun events to map hpDIRC performance

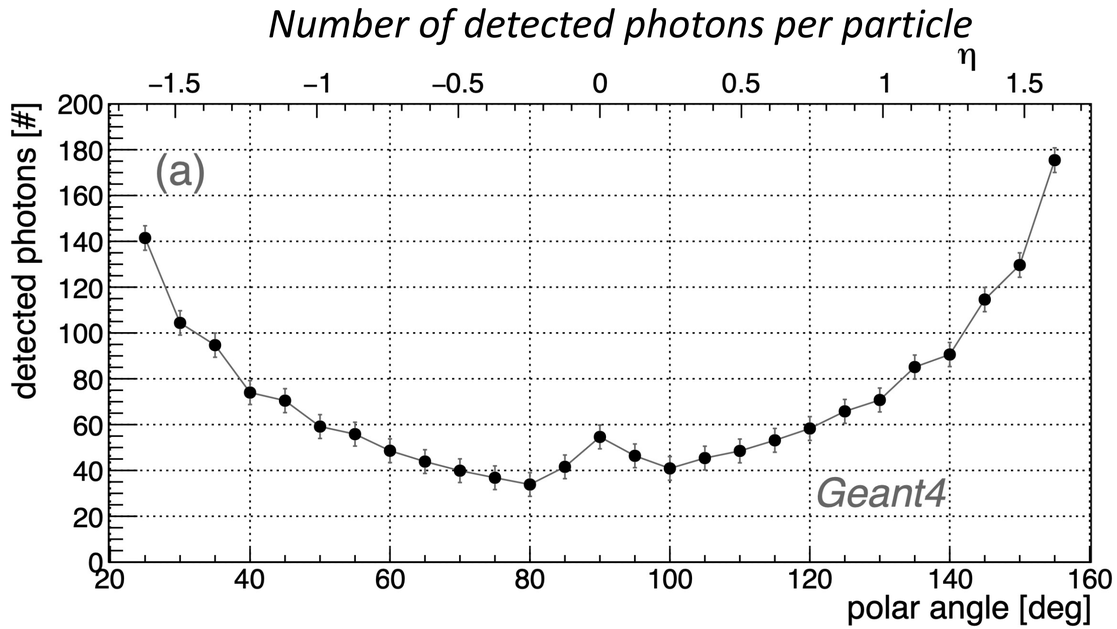


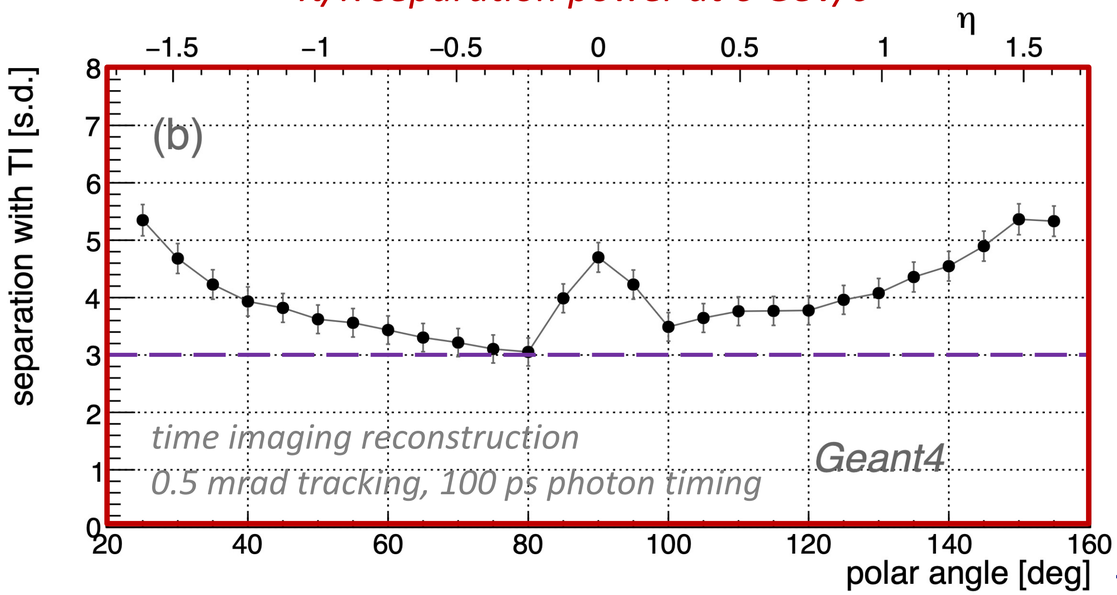
Pythia events in hpDIRC simulation



hpDIRC Simulation (ii)

- hpDIRC Performance
  - 38-180 detected photons per track, depending on the particle polar angle
  - Expected PID performance meets ePIC requirements (Yellow Report), separation: ≥ 3 s.d. π/K up to 6 GeV/c
- Simulation studies performed with
  - Stand-alone Geant4 simulation
  - Single particles from particle gun
  - 1.7T magnetic field, no other ePIC subsystems
  - 0.5 mrad tracking resolution
  - 100ps time resolution



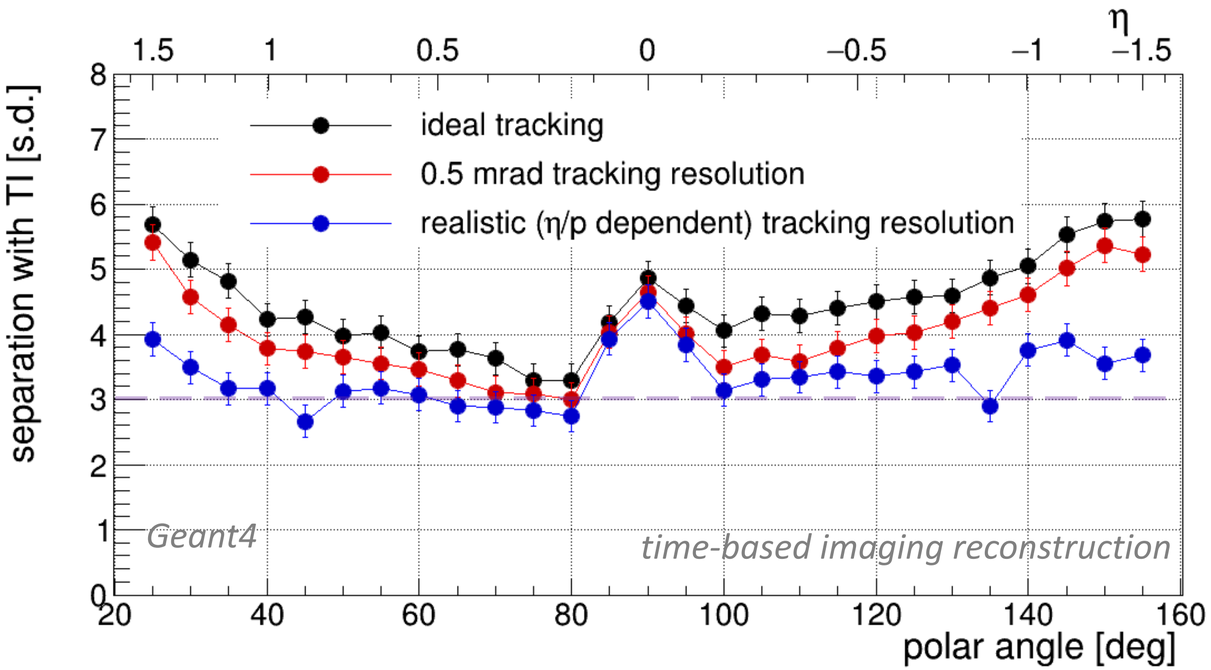


hpDIRC Simulation (iii)

- Performance plots in preTDR assume 0.5 mrad track angular resolution
- Performance with latest ePIC angular track resolution maps (June 2025) not final
- Angular track resolution map still expected to change

- Photon Detection Efficiency (PDE) = Quantum Efficiency (QE) x Collection Efficiency (CE) of MCP-PMTs in all simulations is based on measured Photonis tube properties. To be updated once sensor decision is made.

π/K separation power at 6 GeV/c



ToF

Situation of Hardware

Sensor (eRD112 FY2024 sensor + full-size “real” sensor) is available

- FY2024 sensor has been tested @ JLab in July and analysis is ongoing
- Full-size “real” sensor has been received 2 weeks ago and will be tested at DESY in December
- This update will be included in v3

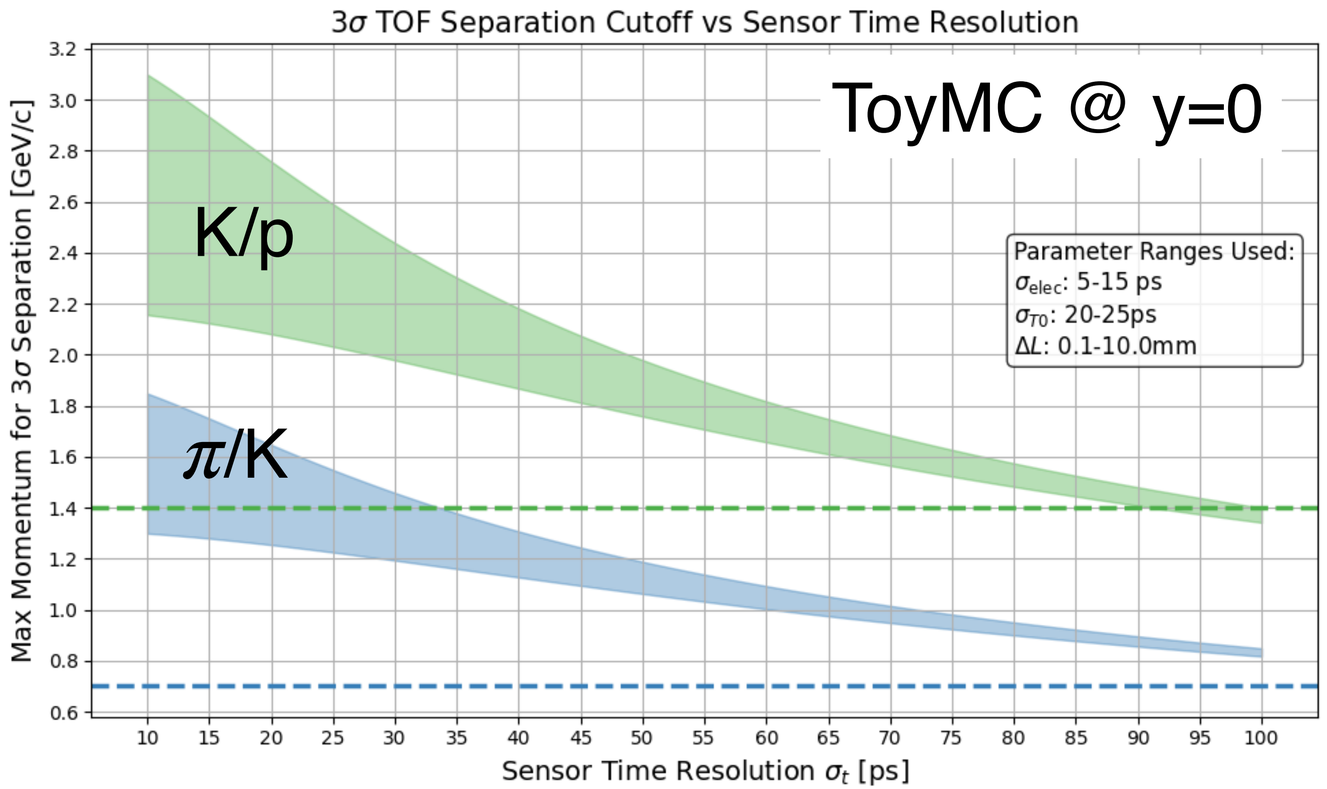
FCFDv1.1 has been received in May

- It has been tested in July @ DESY and analyzing
- This update will be included in v3

Demonstrator project has been started

- First demo of the interposer and dummy FPCs
- Dummy FPCs have been shipped to UCSC from RIKEN
- This update should be included in v3

Status of Simulations



- New performance plot has been made by Toy-MC
- Full simulation study is ongoing
- This update should be included in v3

Summary of TOF after preTDRv1

New hardware results have not been finalized yet

- New sensor and ASIC have been fabricated
  - Beam-tests in July @ Jlab and DESY

→ No additional text

PID performance has been re-evaluated

- No full simulation results yet (was computed by toy-MC)

→ No additional text


THANK
YOU