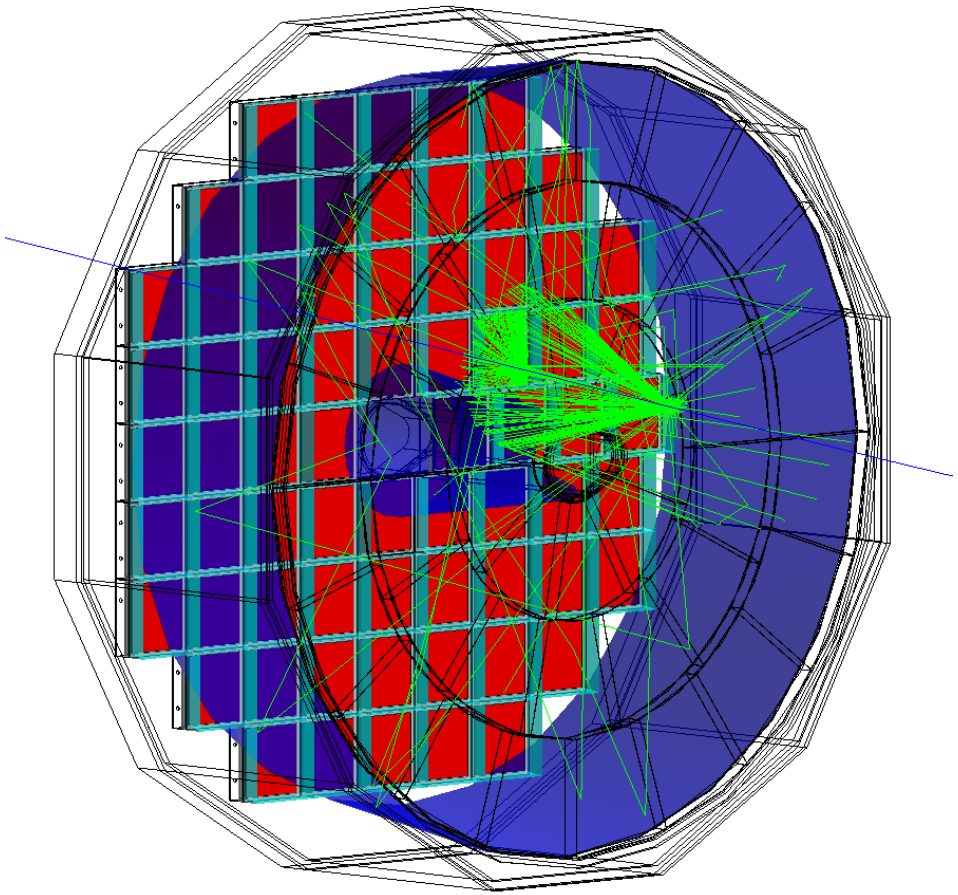


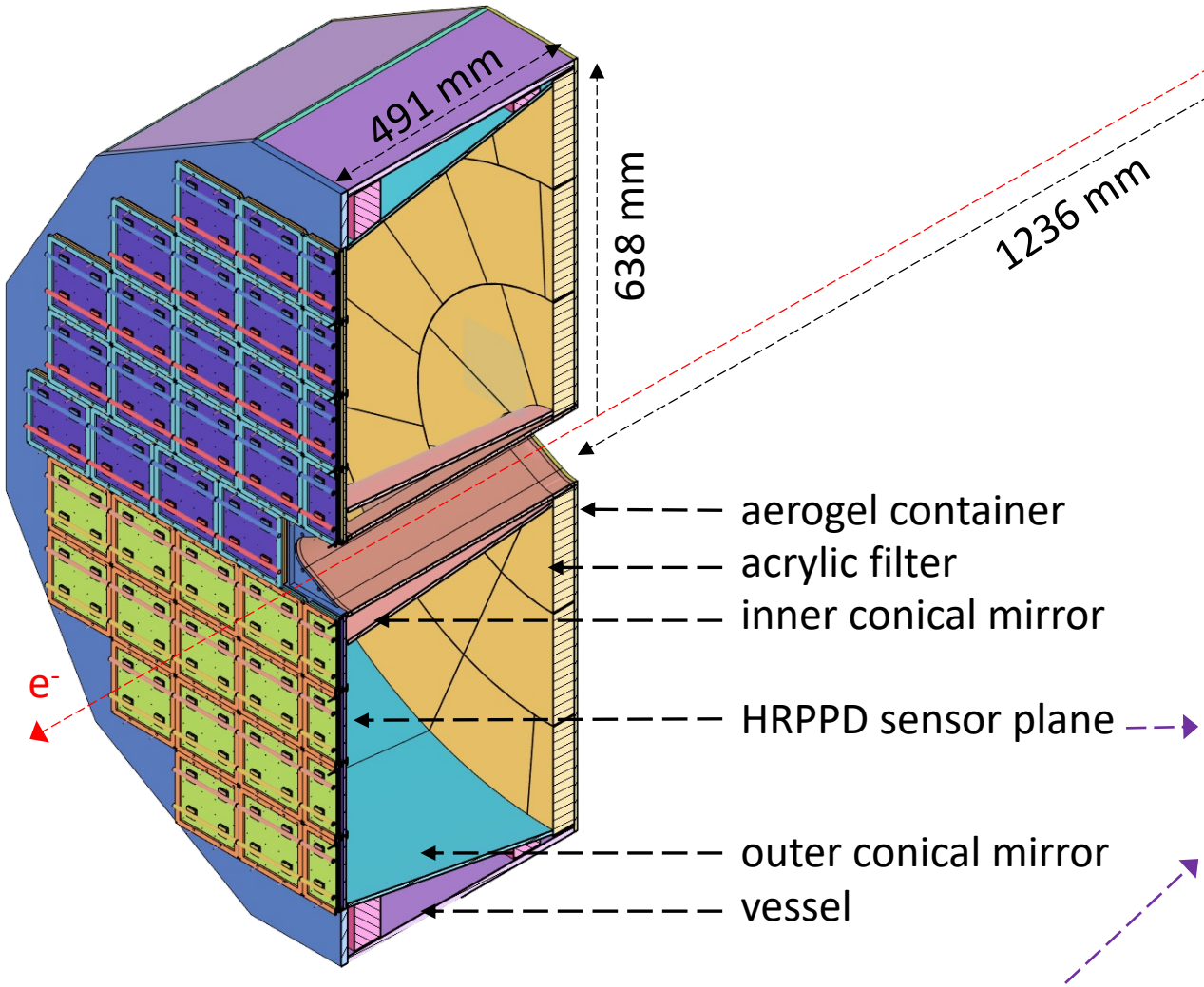
eRD114: pfRICH

EIC Project R&D Detector Advisory Committee meeting, August 31, 2023

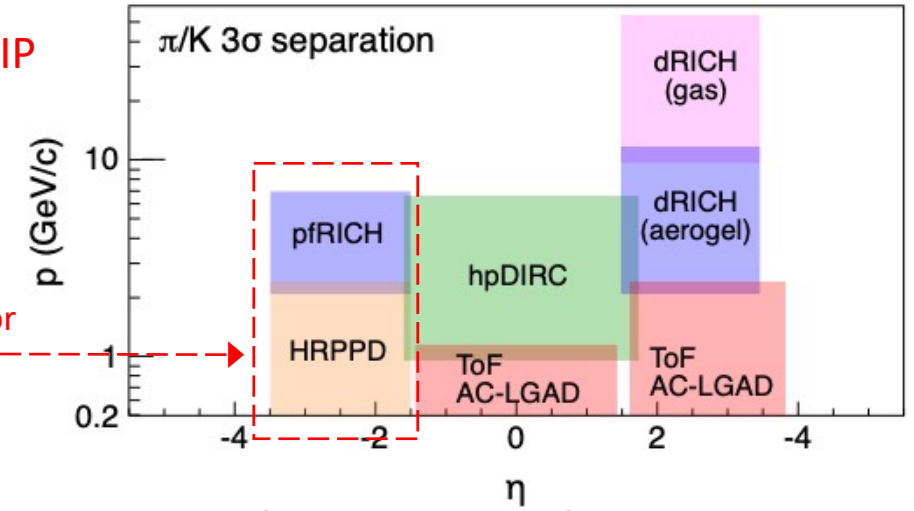
Alexander Kiselev (BNL)

e-endcap RICH for ePIC detector

pfRICH became an official baseline ePIC subsystem few weeks ago



A single RICH detector



- A classical proximity focusing RICH
  - with a high resolution timing capability
- Pseudorapidity coverage: $-3.5 < \eta < -1.5$
- Uniform performance in this $\{\eta,\phi\}$ range
- <20ps t_0 reference for the ToF subsystems
  - With a ~100% geometric efficiency
- >3σ π/K separation up to ~9.0 GeV/c

EIC Yellow Report requirement: better than 3σ π/K separation up to 7 GeV/c

Motivation for an R&D proposal

This proposal is NOT about testing of various engineering solutions essential for pfRICH implementation

R&D Milestones & Timeline

February 26, 2023

Particle ID

- Validate production readiness of a Ring-Imaging Cherenkov Detector as matched with photosensors and readout electronics on the electron-side end cap of the EIC detector, including validation by prototypes that the EIC requirements can be met. [March 2025]

We propose to build a functional pfRICH prototype and test its performance at the Fermilab Test Beam Facility (FTBF) in early Summer 2024. This R&D effort will address a technical risk to the project, evaluating the convoluted effect of specific parameters of the main components of an ePIC Backward RICH detector on its performance:

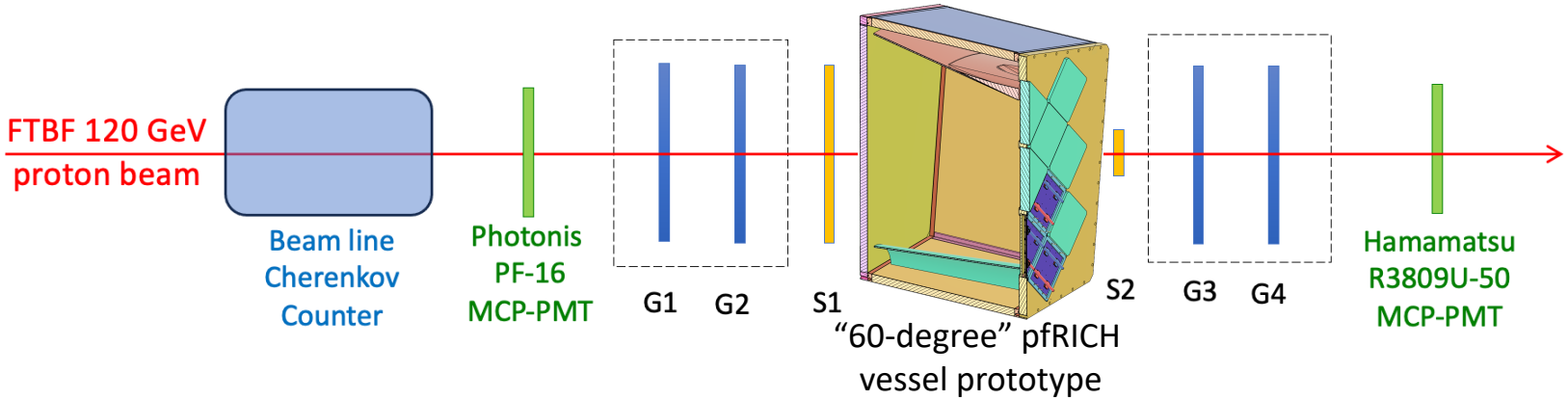
- HRPPD photosensors by Incom Inc (quantum efficiency as a function of wave length, collection efficiency, gain, transit time spread, window transparency as a function of wave length, detector capacitance seen by the front end electronics);
- Aerogel tiles by Chiba Aerogel Factory (transparency, especially in a near UV wave-length range, homogeneity);
- Time-of-Arrival(ToA)/ADC based electronics of the EICROC family by OMEGA group (intrinsic noise, dynamic range, various sources of timing jitter).

It will however make use of several ongoing or planned FY24 activities / efforts (next slide)

Pre-requisites & other essential ingredients

- Vessel with mirrors
  - Development & construction expected to be funded by the EIC project
    - PED request to be formulated in September 2023
- Five new EIC HRPPD tiles
  - Ordered by EIC project as part of the EIC-Incom contract
    - Expected by March 2024
  - QA by several groups as part of the eRD110 FY24 R&D proposal
- HGCROC3 ASIC interface
  - Development is part of the eRD110 FY24 R&D proposal
    - A functional design expected by March 2024 (yet need to equip all five HRPPDs)
- Aerogel tiles with <n> ~ 1.040 … 1.045
  - Being ordered by EIC project now
    - Expected by the end of 2023
  - QA to be performed on a new test station at Temple University

Beam test at Fermilab in summer 2024

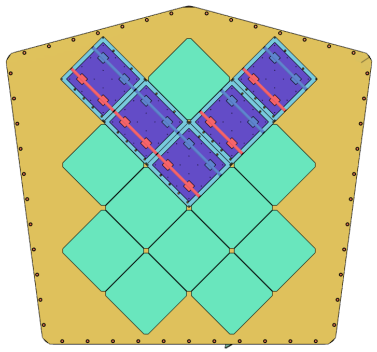


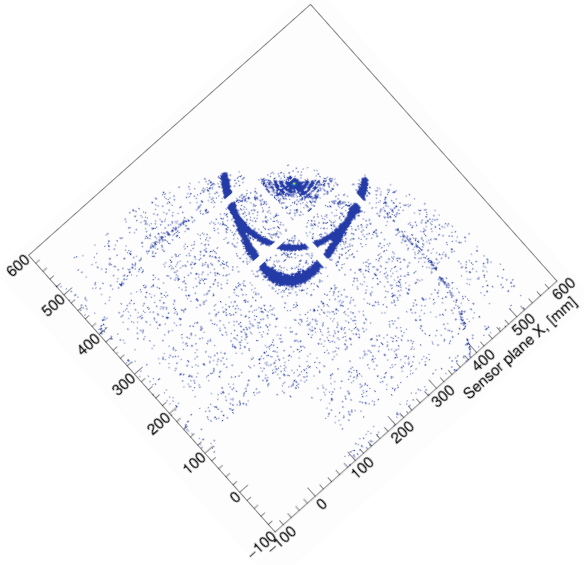
- A similar setup as presented in the eRD110 talk, except for
  - Make use of a low momentum MT6 hadron beam (and beam line Cherenkov counter)
  - Install a fully fledged 60-degree pfRICH sector prototype (aerogel, mirrors, HRPPD “sensor plane”)
  - Make use of ~5k channels of newly built HGCROC3 ASIC electronics

- **Main deliverable** is a direct simultaneous demonstration of
  - >3σ π/K separation reach up to ~ 7 GeV/c via aerogel Cherenkov photon imaging
  - HRPPD performance as a t_0 reference sensor for ePIC ToF subsystems
    - <50 ps timing resolution using aerogel Cherenkov photons
    - O(10ps) timing resolution using sapphire window Cherenkov photon flashes

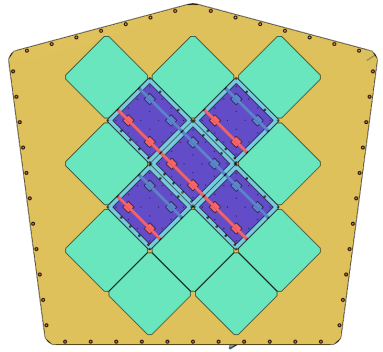
Beam test at Fermilab in summer 2024

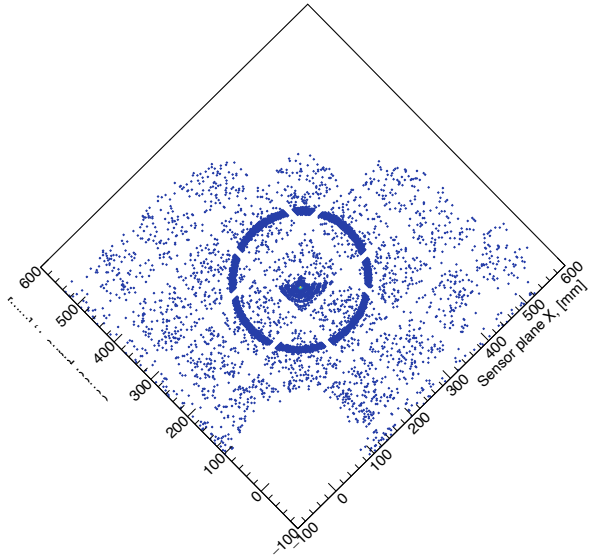
- Will consider few different HRPPD configurations within the same "60-degree sector" pfRICH vessel prototype



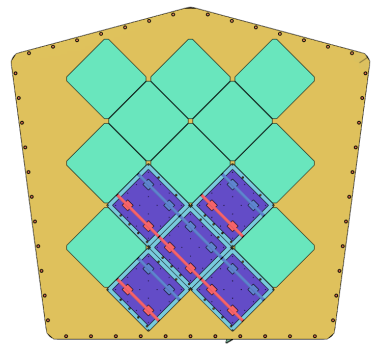


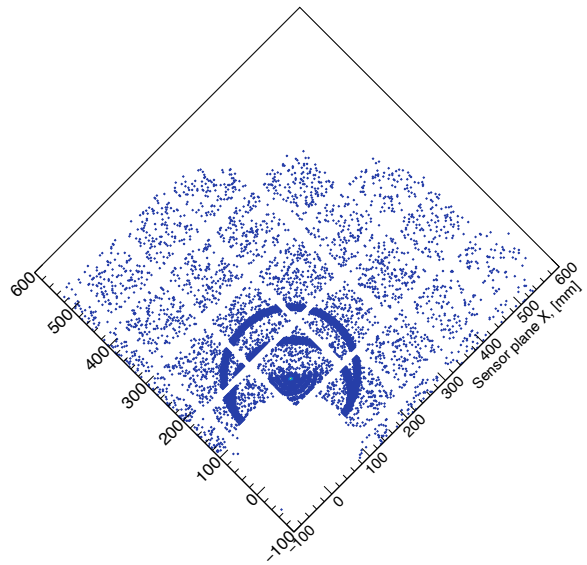
~Full ring coverage,
outer mirror performance





Partial ring coverage +
a central "timing" spot

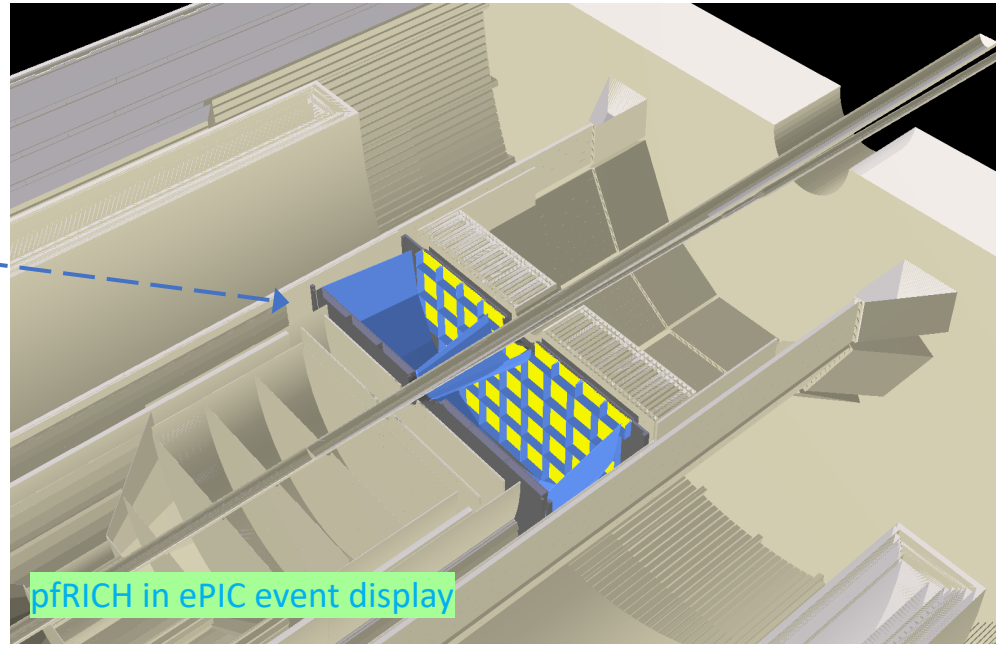


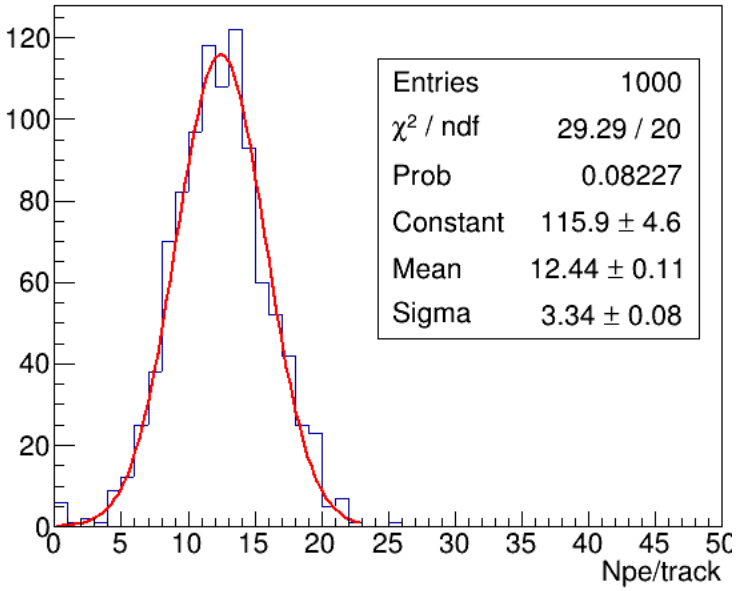


Optional: inner mirror
performance

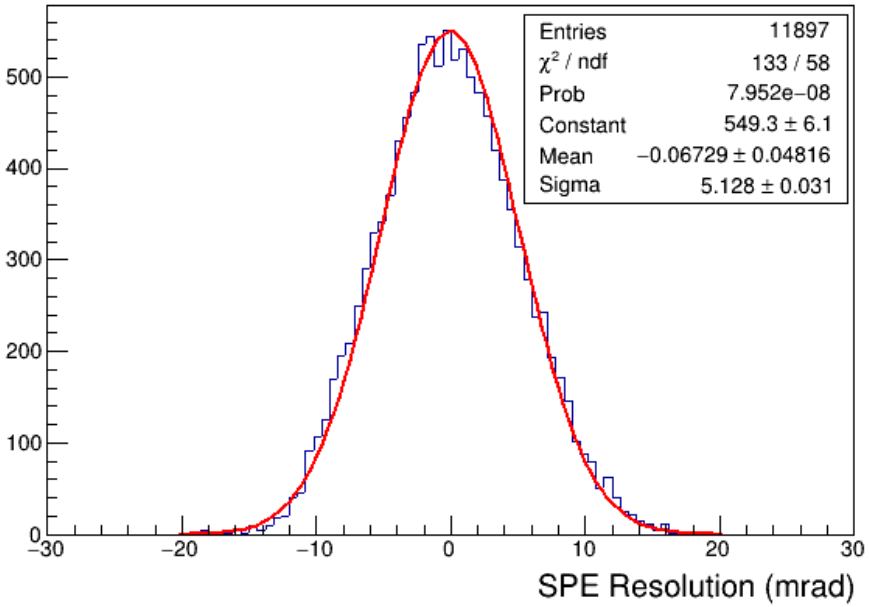
Expected performance

- Standalone GEANT4 code
  - Porting to dd4hep ePIC software framework (re)started recently
- Simulation with (almost) all known optical effects included
- Event-level digitization / reconstruction chain
  - χ^2 based algorithm with a full hit-to-track ambiguity resolution

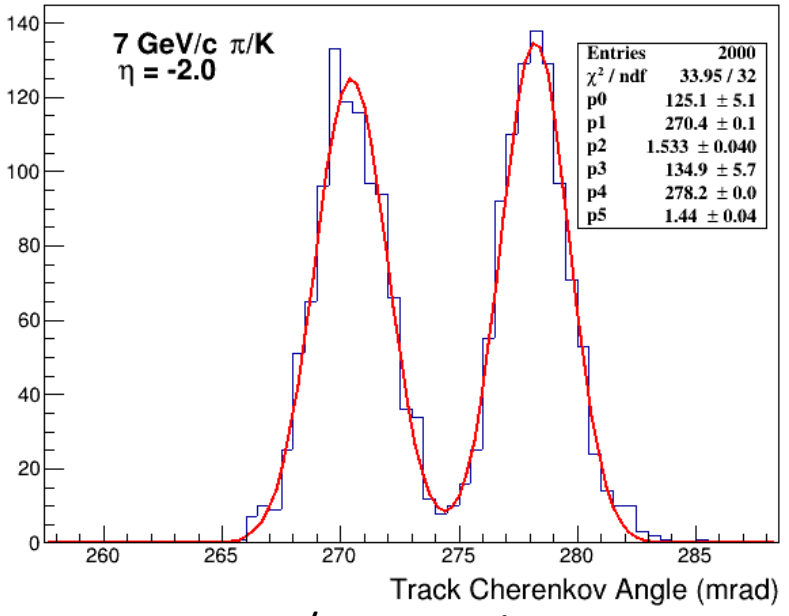




<N_{pe}> @ saturation ~ 12



σ_{SPE} ~ 5 mrad



π/K separation > 5σ

Participating institutions, budget, milestones

Full list of participating institutions

Argonne National Laboratory
Brookhaven National Laboratory
Chiba University
Debrecen University
Duke University
Istituto Nazionale di Fisica Nucleare, Genova
Istituto Nazionale di Fisica Nucleare, Trieste
Ljubljana University and J. Stefan Institute
Oak Ridge National Laboratory
Purdue University
Stony Brook University
Temple University
Thomas Jefferson National Accelerator Facility
University of Glasgow
Yale University

Budget proposal

Four 3D printed HRPPD enclosures	$2k
80 HGCROC3 chips	$10k
Four readout backplane assemblies	$8k
Two KCU105 evaluation kits	$8k
Beam test travel	$35k
Total	**$63k**

Milestones

ASIC backplane procurement & tests	March 2024
pfRICH prototype assembly @ Stony Brook	May 2024
Beam test @ Fermilab	June 2024
Data analysis & final report	By September 2024

Summary

- Monte-Carlo modeling shows that pfRICH meets EIC Yellow Report requirements

- We propose to provide a direct experimental proof of its π/K separation reach (ring imaging) and high resolution timing performance at once

- This proposal will make use of several other efforts, which are either funded by the EIC project already or are proposed for funding in FY24