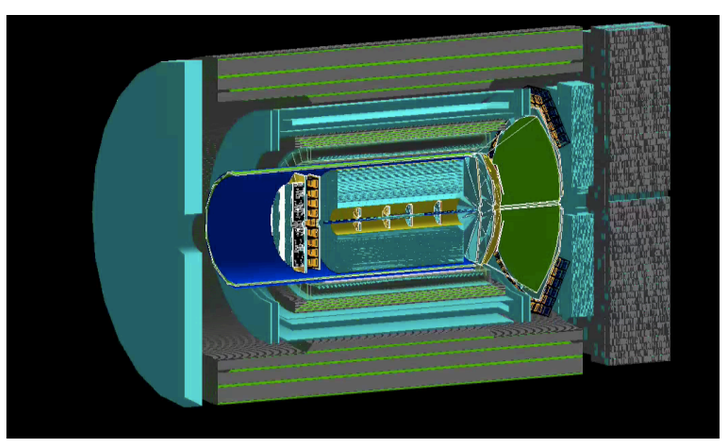
Modular Ring Imaging Cherenkov Detector for Particle Identification in the Electron-Ion Collider (EIC) Experiments

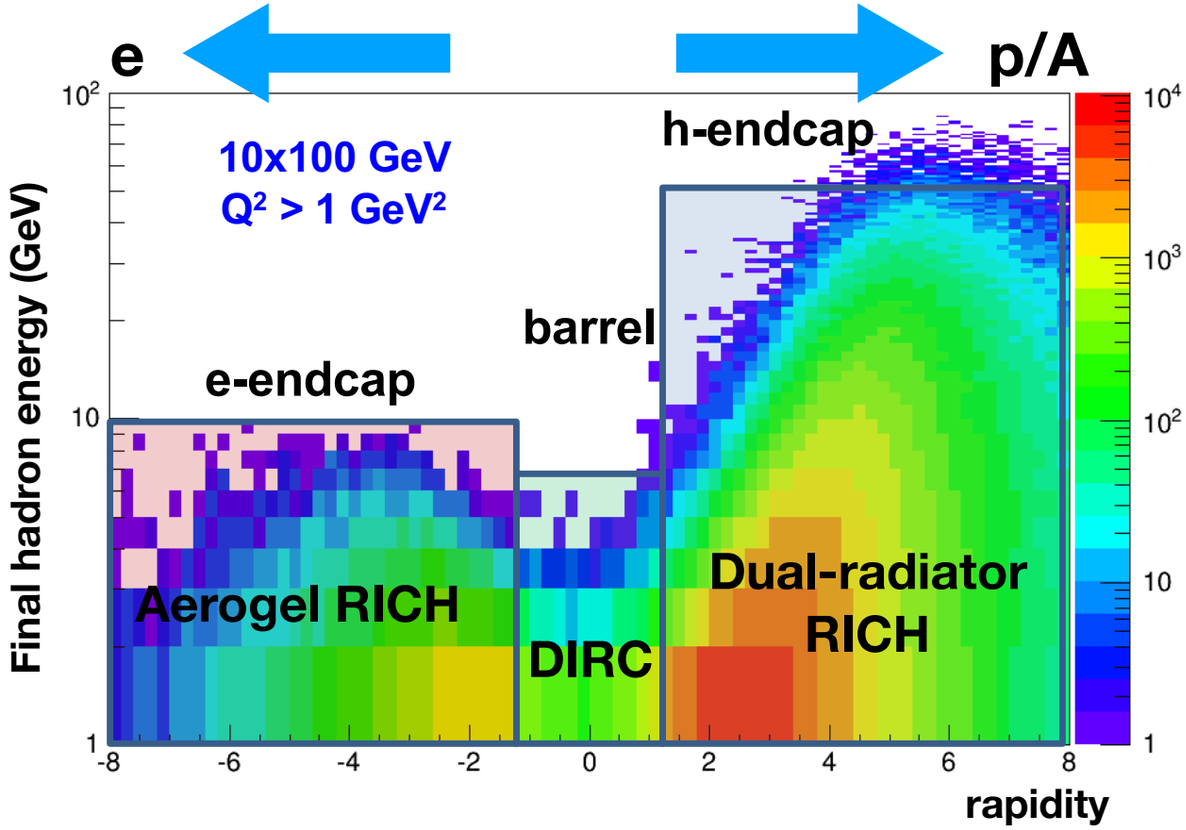
Xu Sun
Georgia State University

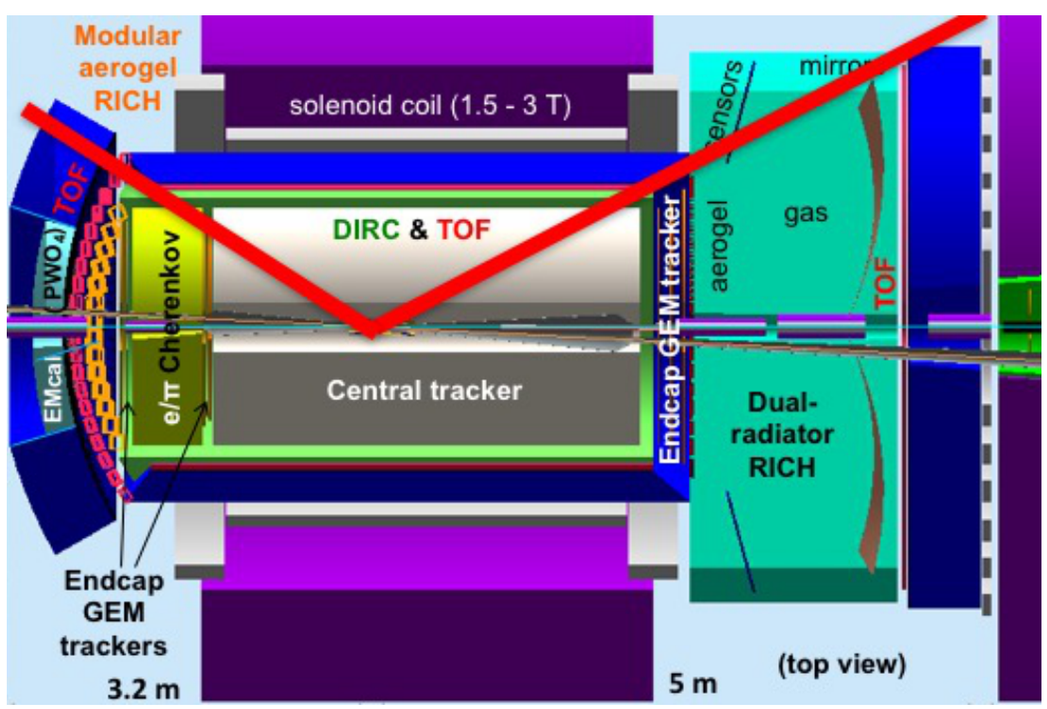


Outline

- Motivation
- Modular Ring Imaging Cherenkov (mRICH) Detector Design
- mRICH in EIC
- Summary and Outlook

A PID solution for the EIC - implementation

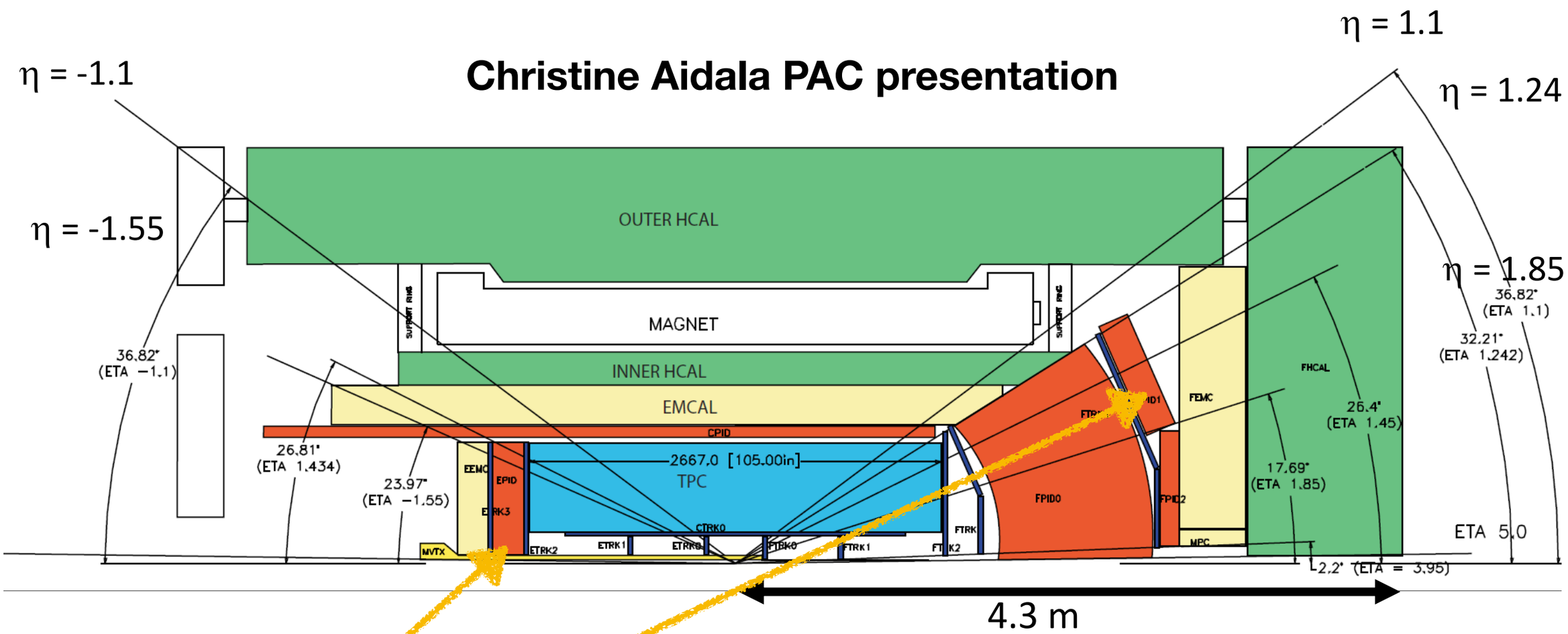


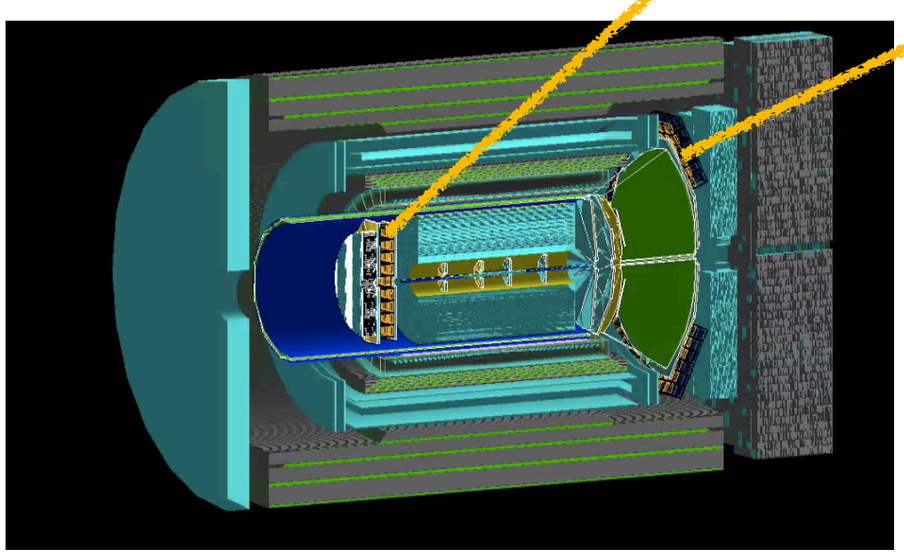


- A suite of detector systems covering the full angular and momentum range required for an EIC detector
- **h-endcap:** A RICH with two radiators (gas + aerogel) is needed for pi/K/p separation up to ~50 GeV/c
- **barrel:** A high-performance DIRC provides a compact and cost-effective way to cover the area. pi/K/p separation up to ~6-7 GeV/c
- **e-endcap:** A compact aerogel RICH which can be **projective** pi/K/p separation up to ~10 GeV/c and e/pi separation up to ~ 2 GeV/c

Detector components: sPHENIX and EIC detector

Christine Aidala PAC presentation





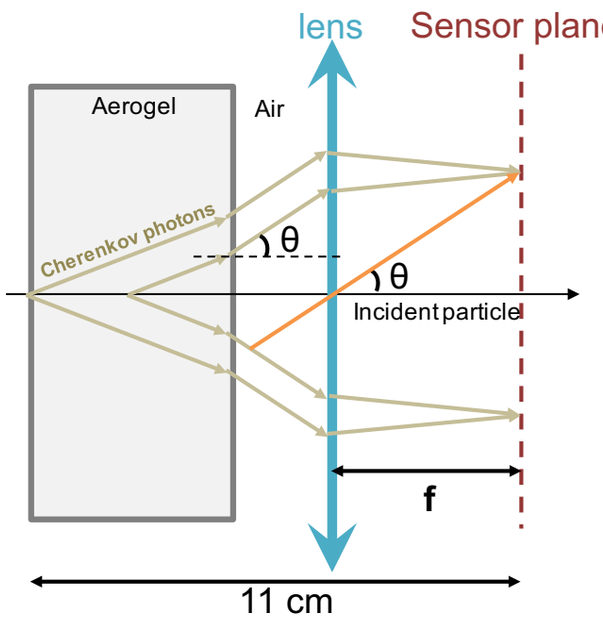
sPHENIX/ePHENIX Detector

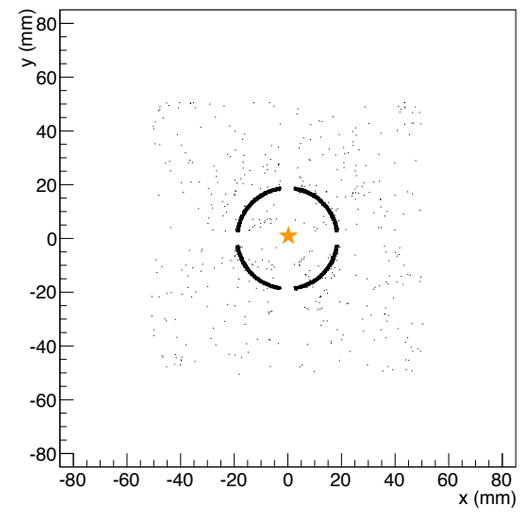
- **Enhance of the physics capabilities of sPHENIX experiment**
- **Make sPHENIX detector system a realist eRICH detector for future EIC experiment**
- **Validate the mRICH detector PID performance in real experiment before EIC coming online**

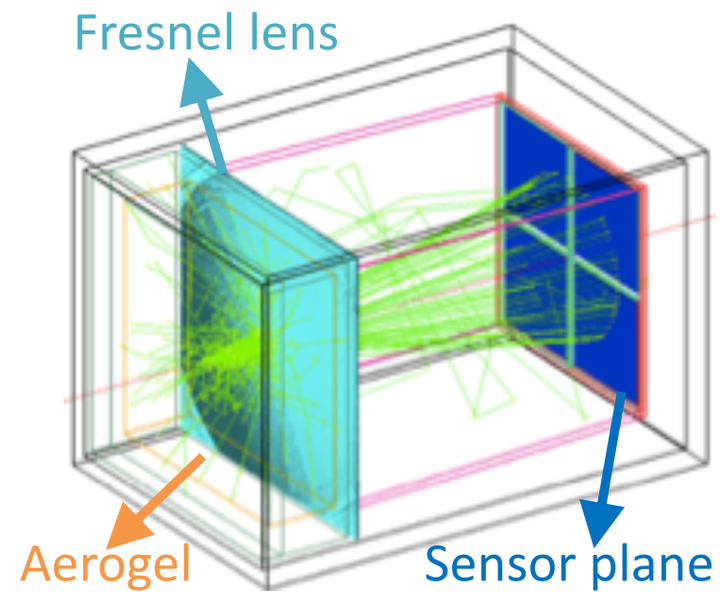
Lens-based Focusing Aerogel Detector Design

Smaller, but thinner ring improves PID performance and reduces length

Lens-Based mRICH Design

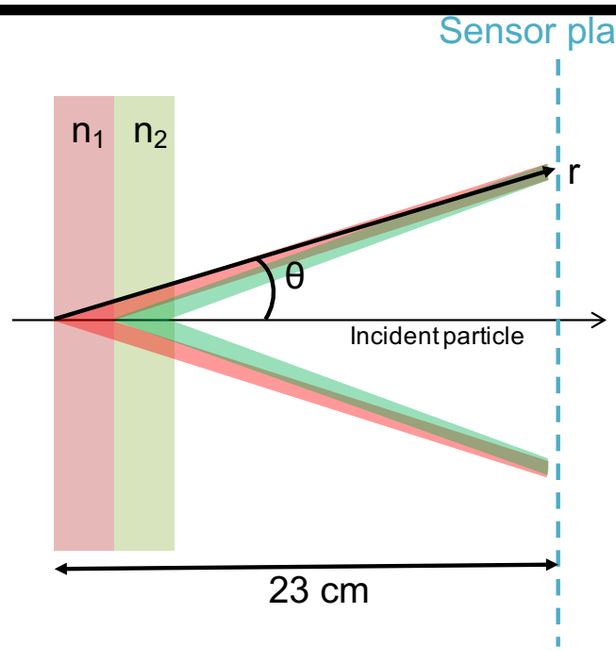


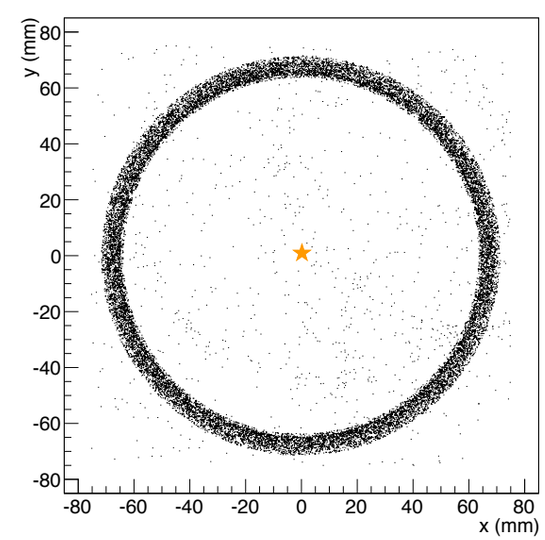




9 GeV/c pion beam launched at the center of xy plane in simulation

Two-Layer Proximity Focusing Design (BELLE-2 ARICH)



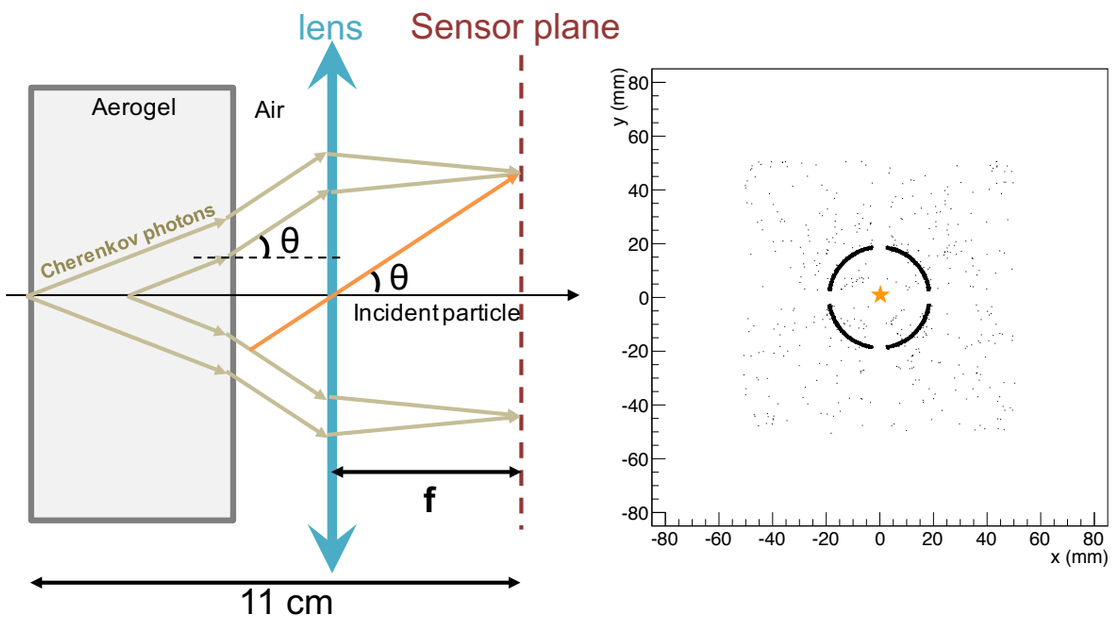


- **EIC mRICH designed for K/pi ID up to 10 GeV/c**
- **BELLE-2 ARICH aims to separate pion and kaon up to 4 GeV/c**

Lens-based Focusing Aerogel Detector Design

Smaller, but thinner ring improves PID performance and reduces length

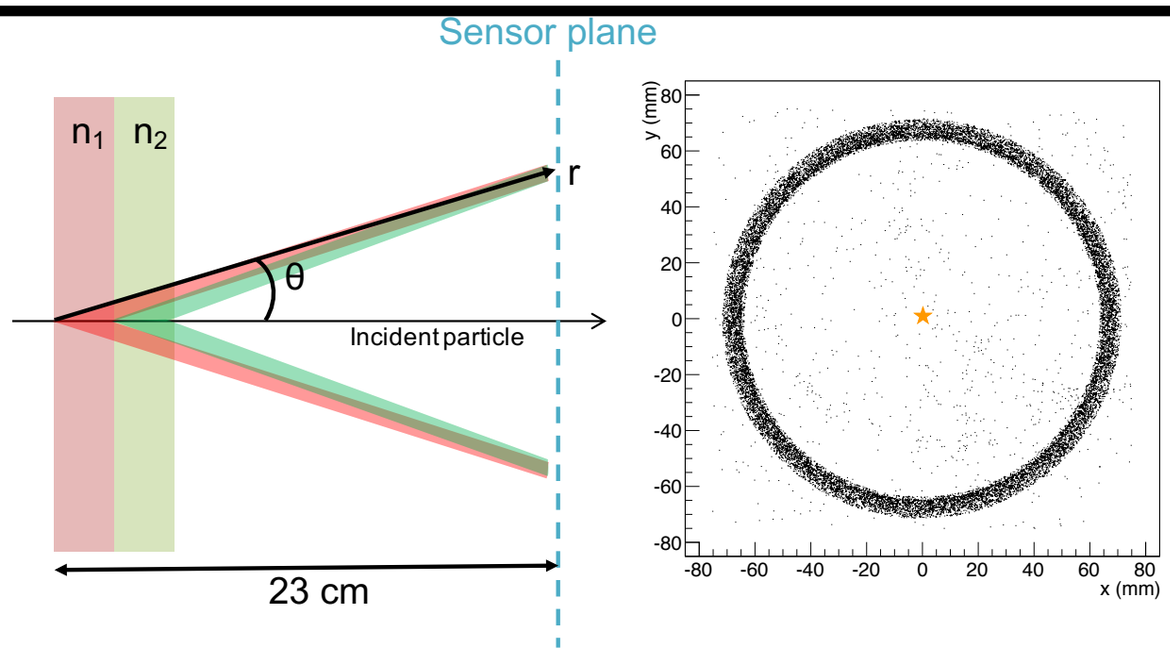
Lens-Based mRICH Design



- **9GeV/c pion beam launched at the center of xy plane in simulation**
- **Smaller and thinner ring image**

9 GeV/c pion beam launched at the center of xy plane in simulation

Two-Layer Proximity Focusing Design (BELLE-2 ARICH)



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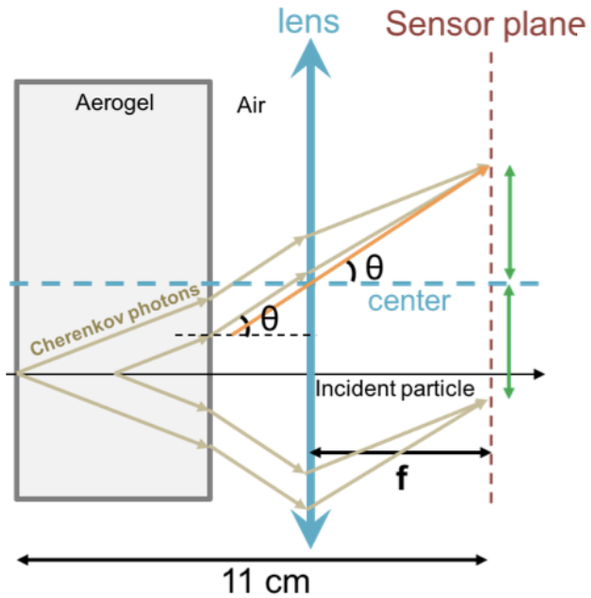
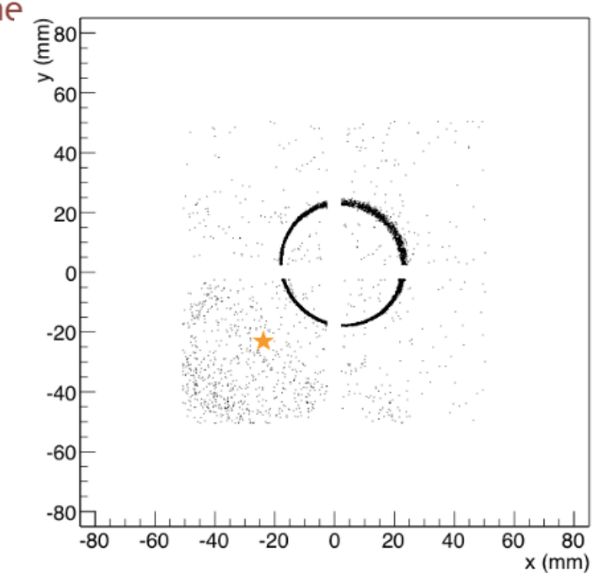
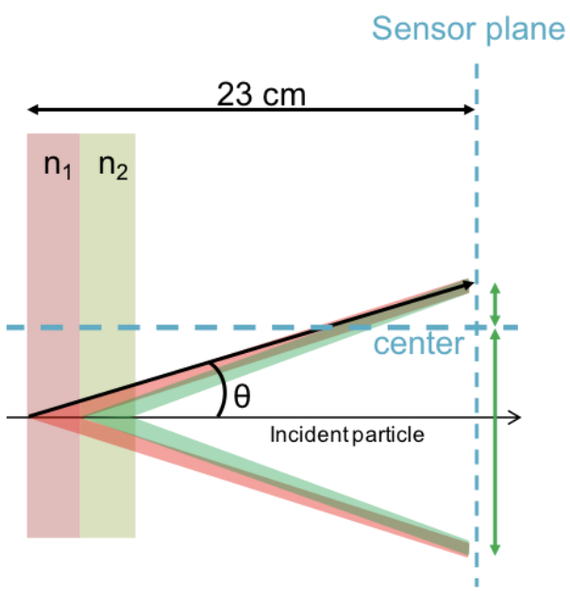
Lens-Based mRICH Design

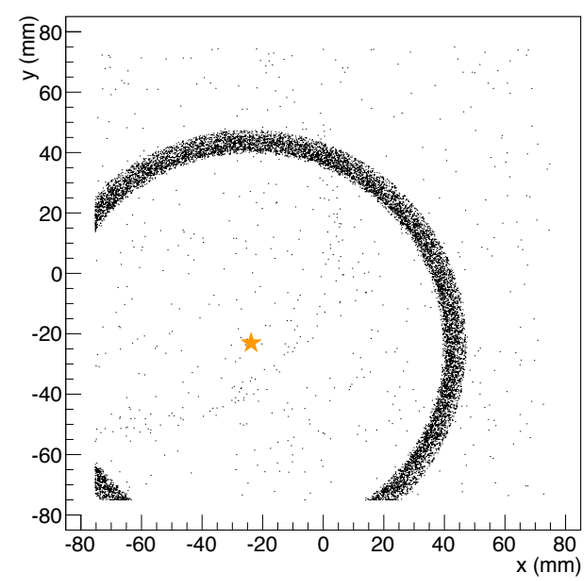




- **9 GeV/c pion beam incident at third quadrant (star) in simulation**
- **Ring image is center on the middle of the sensor plane**

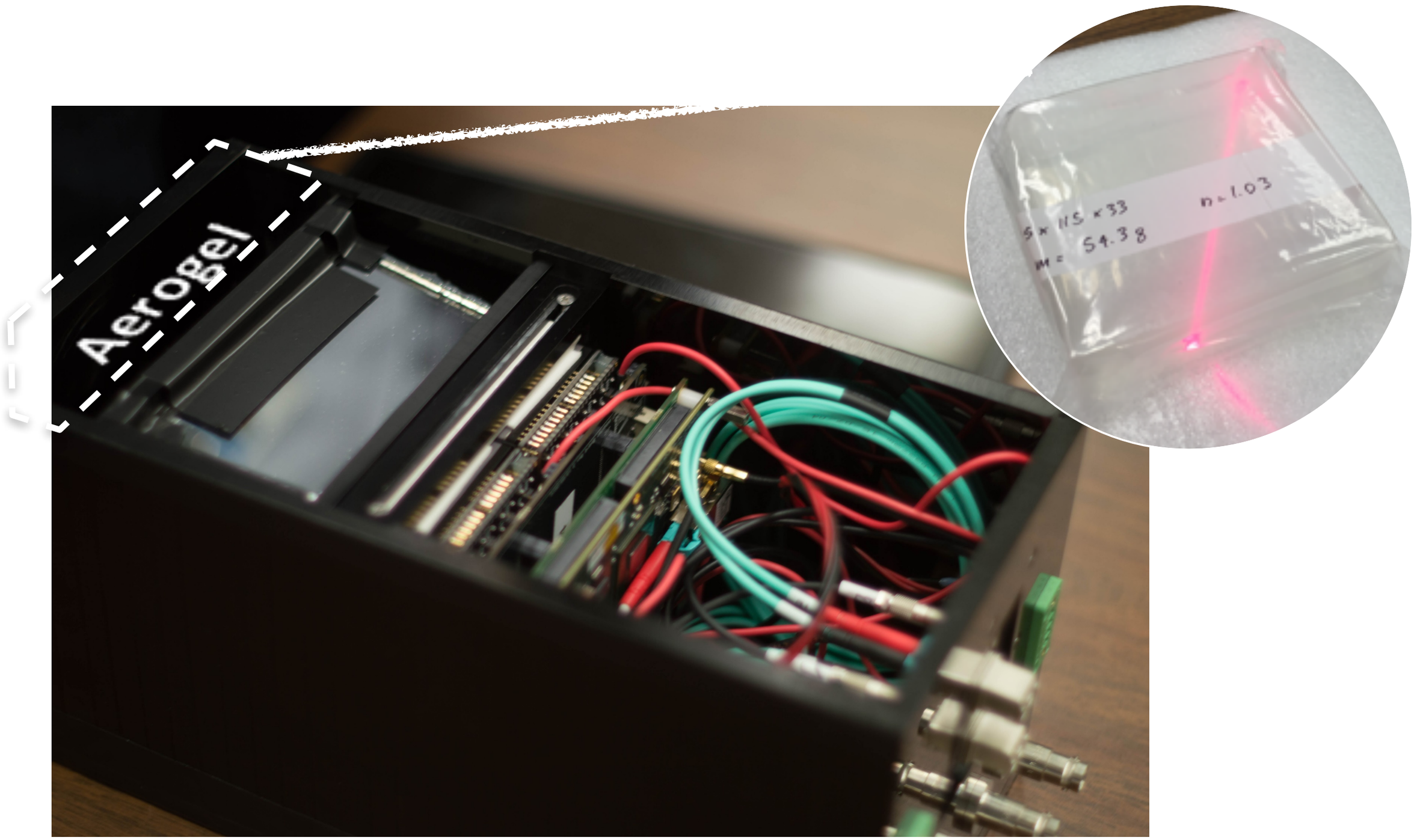
Two-Layer Proximity Focusing Design (BELLE-2 ARICH)



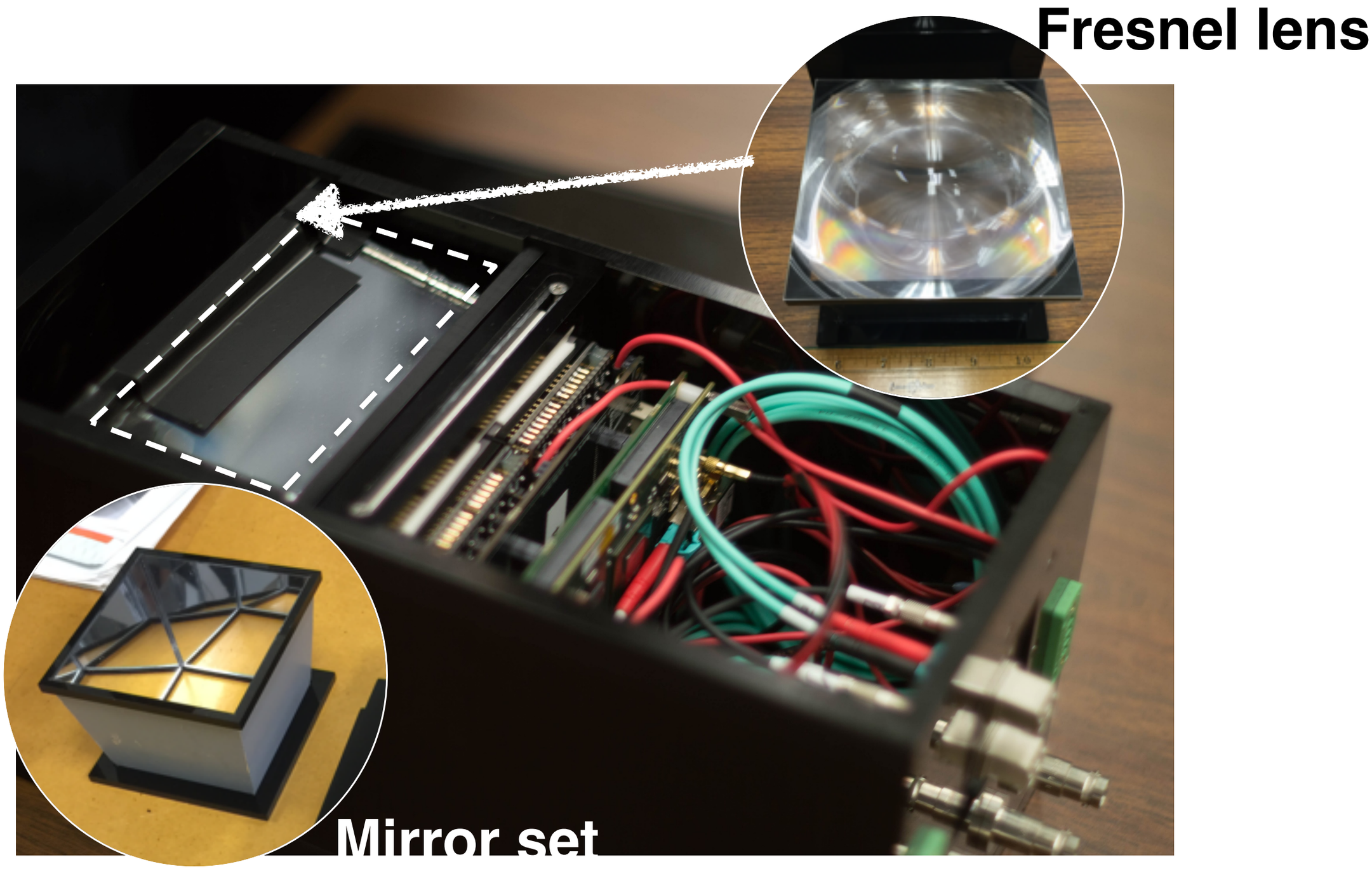


- **9 GeV/c pion beam incident at third quadrant (star) in simulation**
- **Ring is centered at point of incidence**

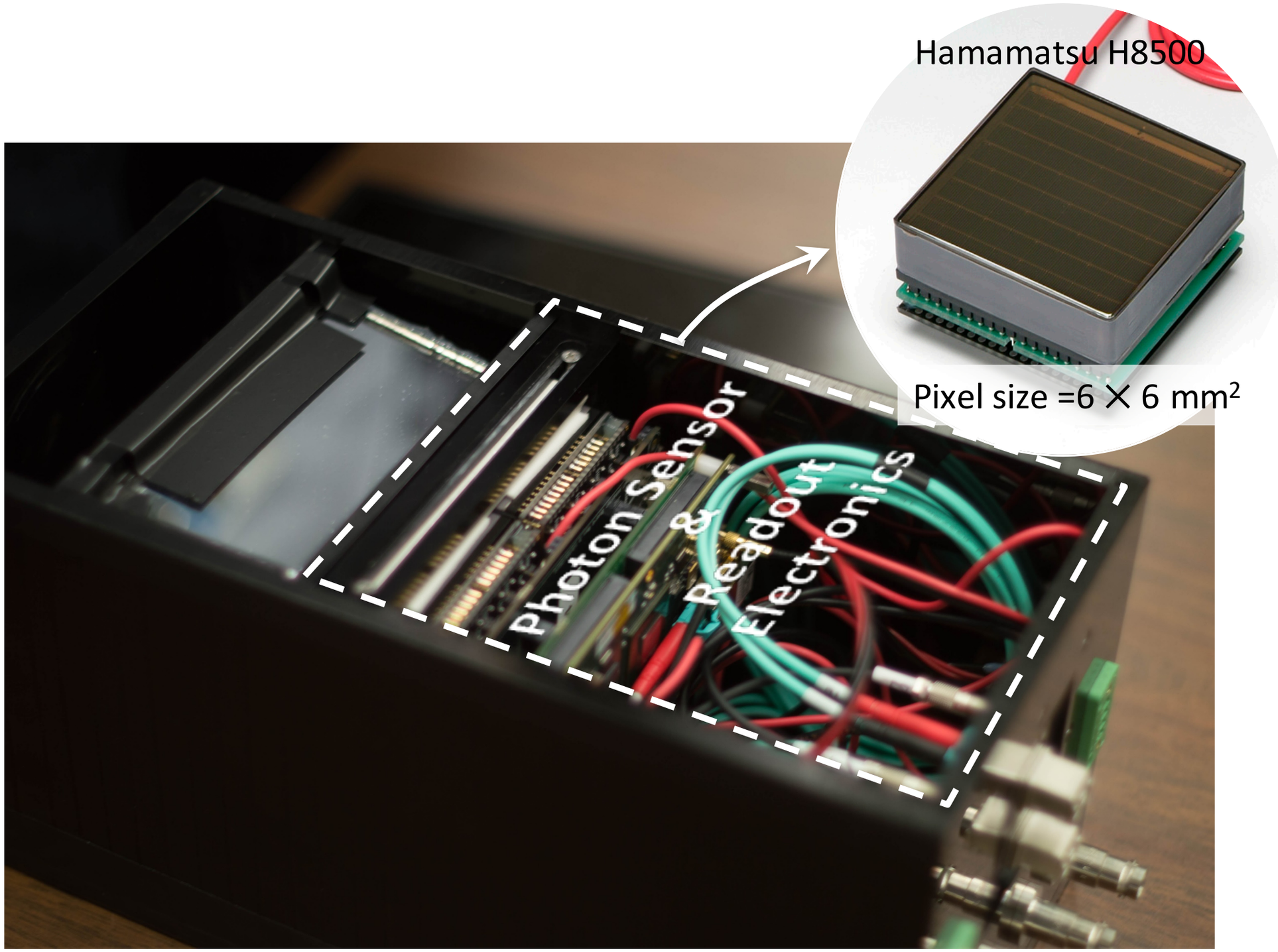
First mRICH Prototype



First mRICH Prototype



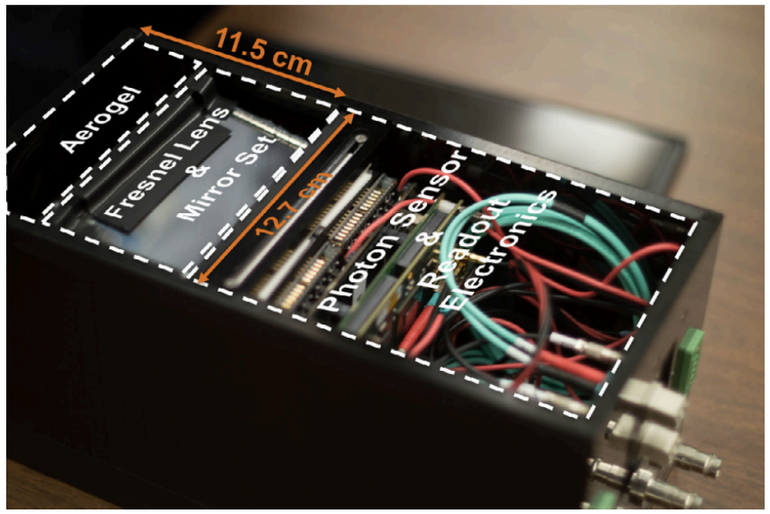
First mRICH Prototype

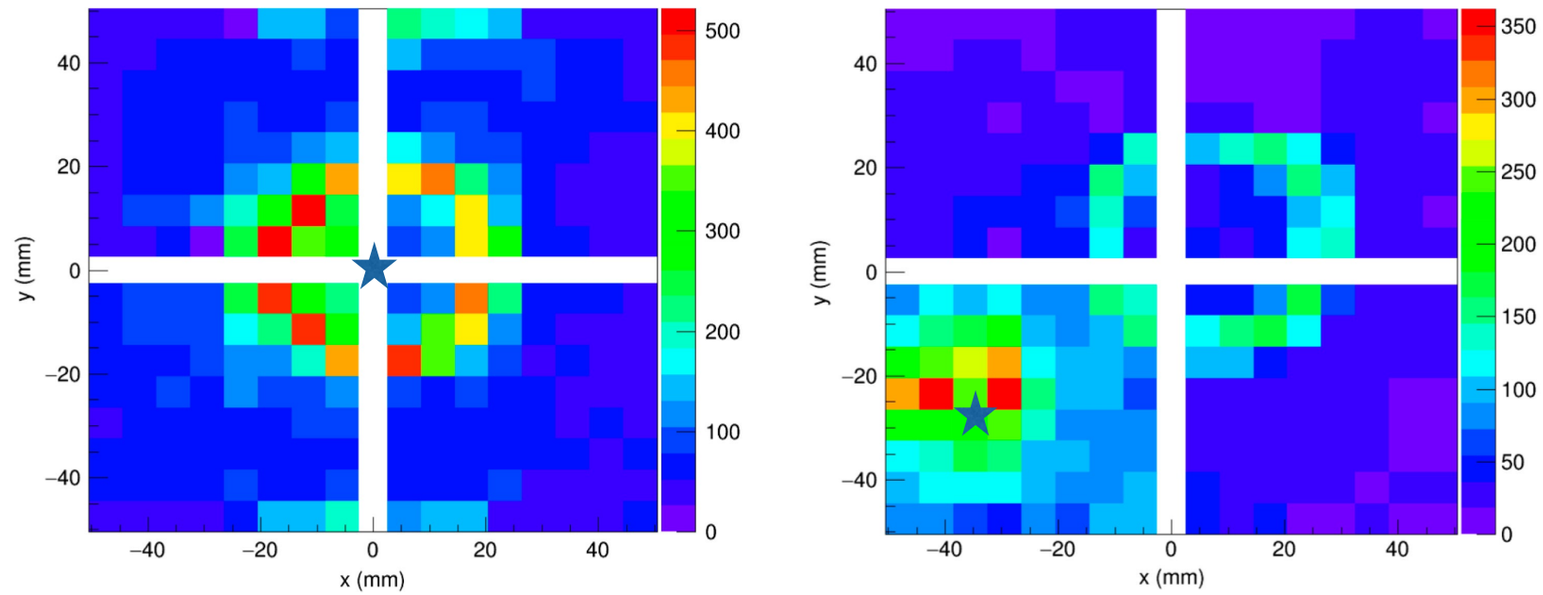


Beam Test of 1st Prototype

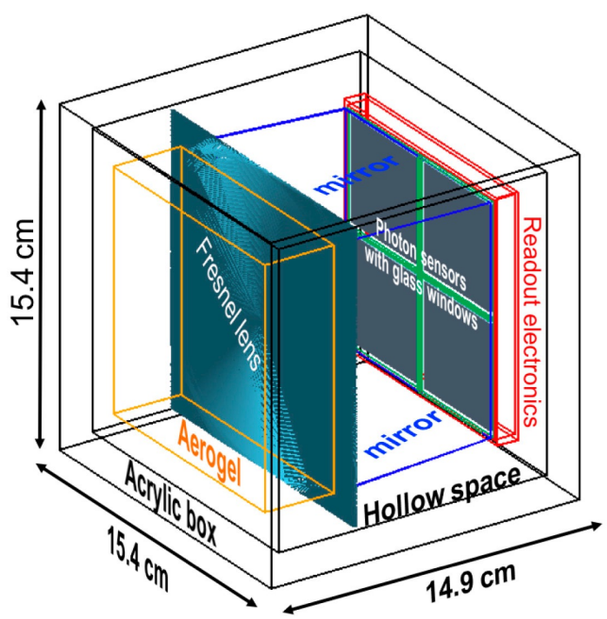
The 1st test beam result verified mRICH working principle and validated simulation

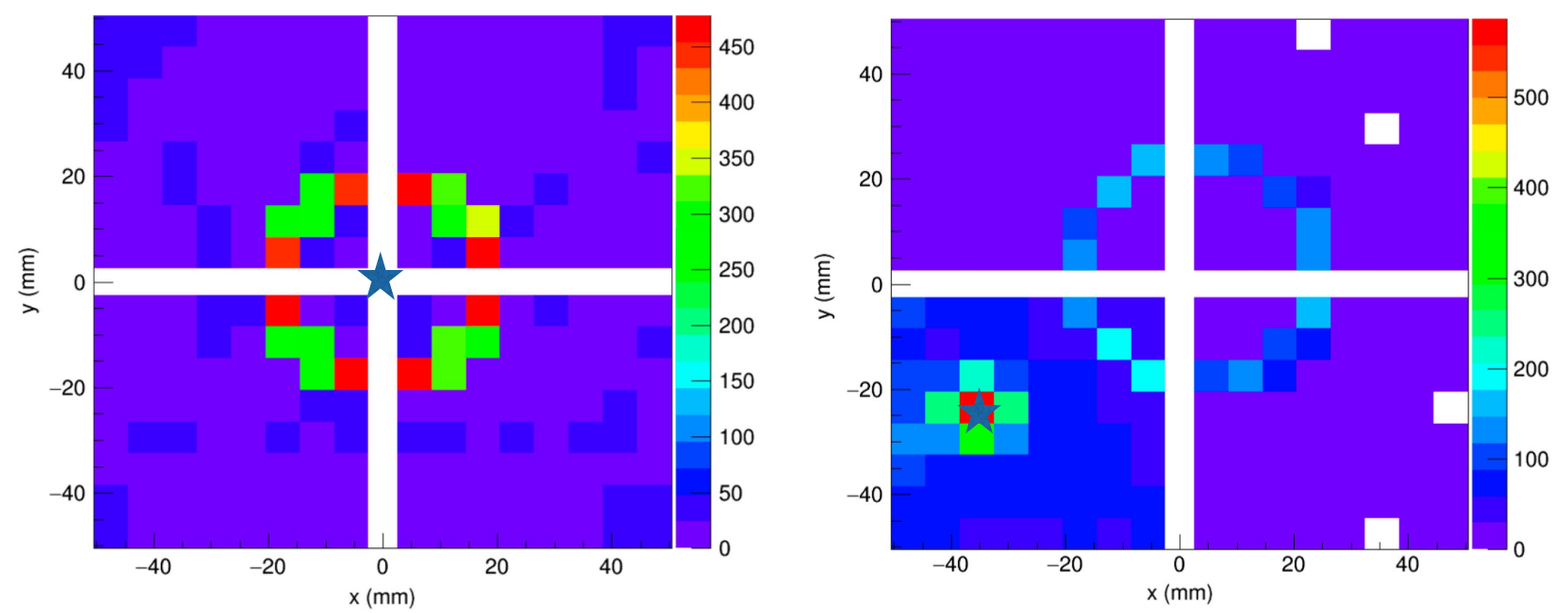
real data





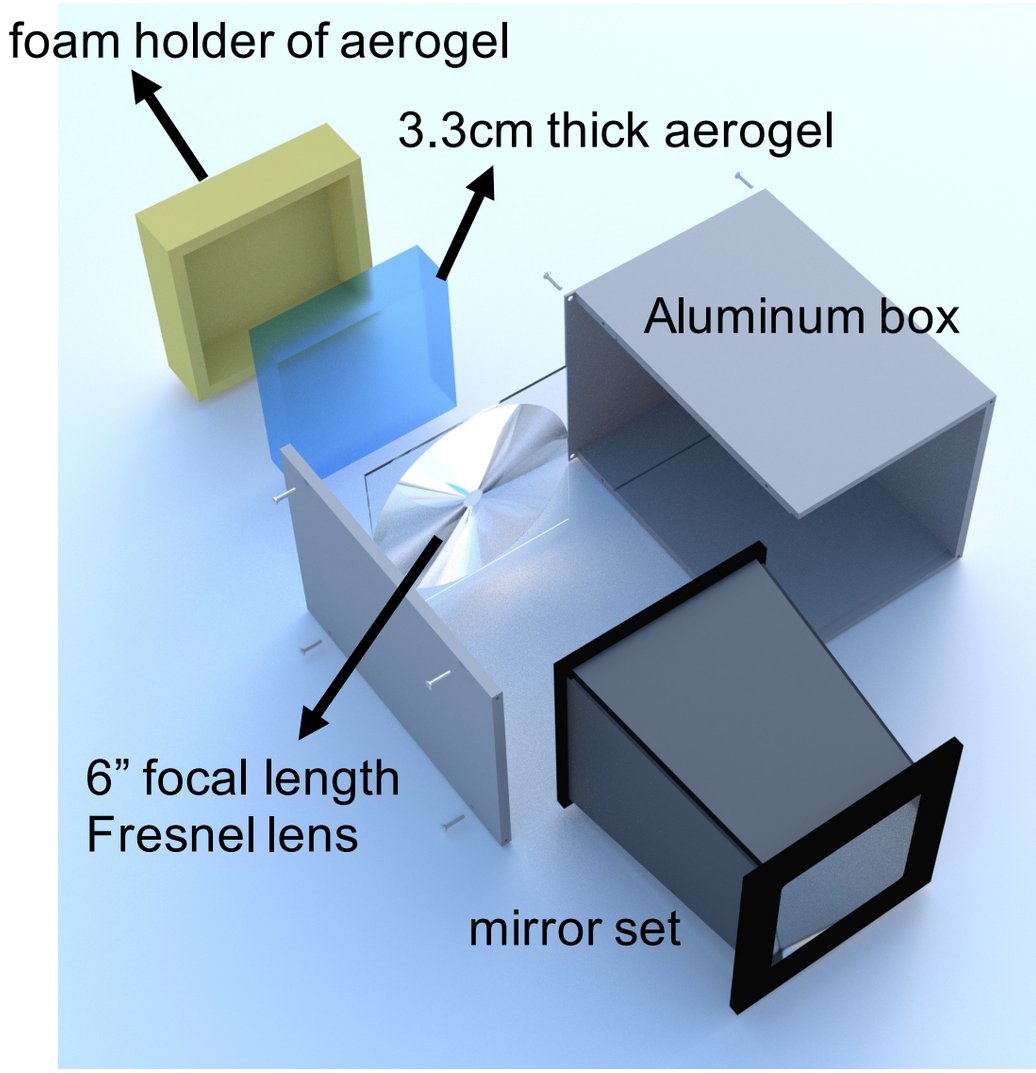
simulation

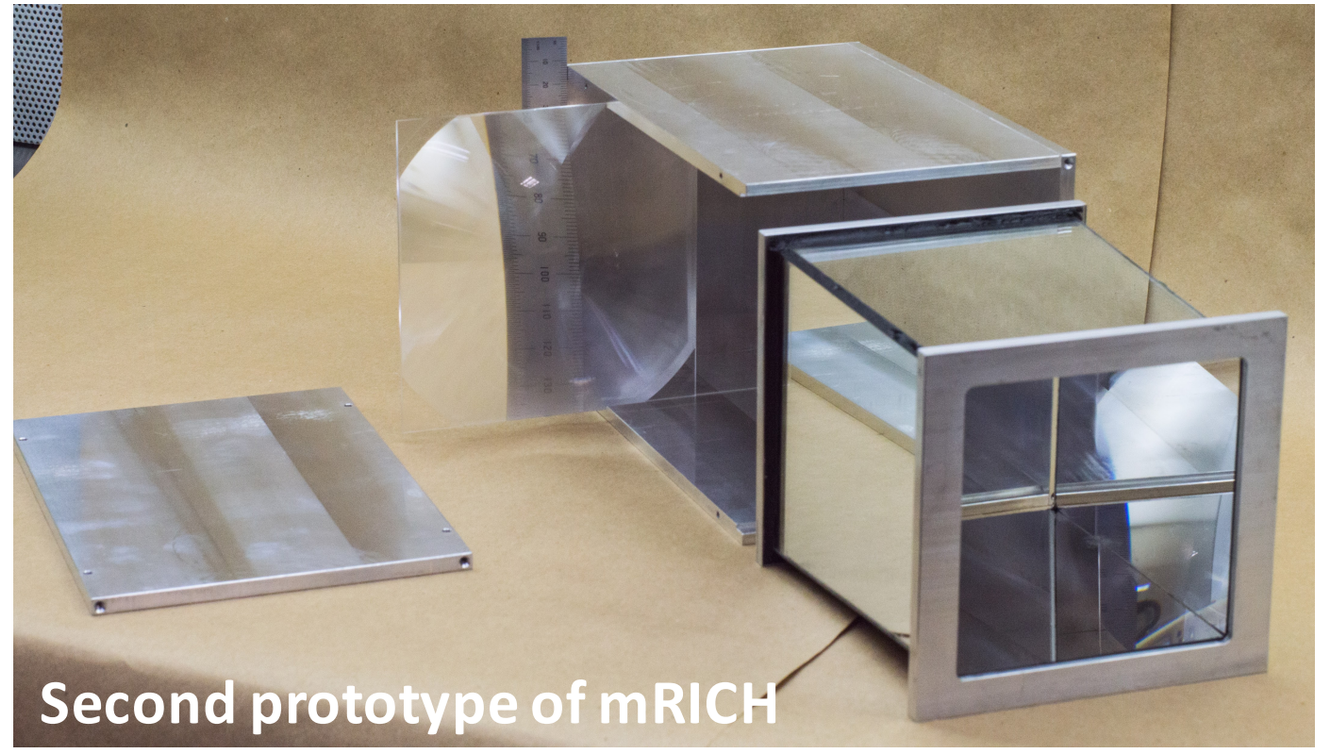




- **120 GeV proton beam test simulation matched with data perfectly**
- **Ring finder algorithm & 3” focal length**
- **Cheuk-Ping Wong et al., NIM A871 (2017) 13-19**

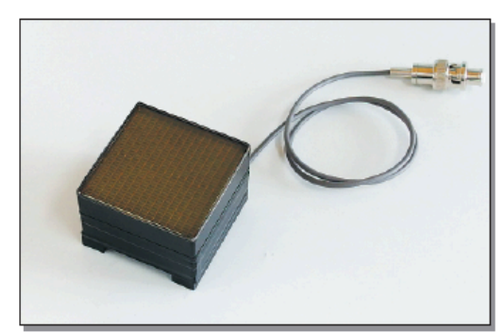
2nd mRICH Prototype





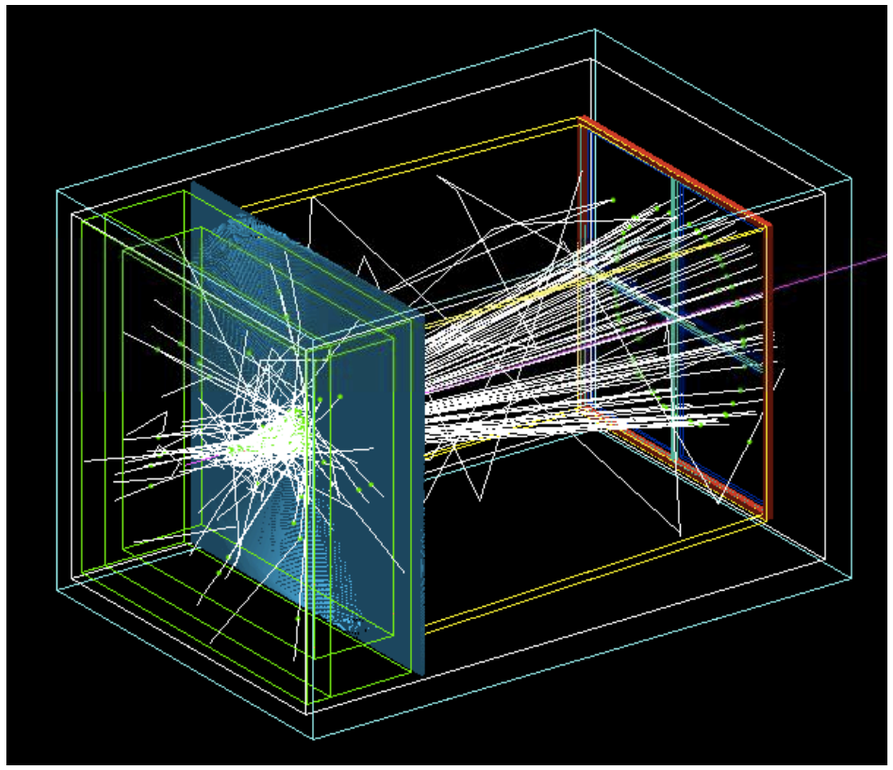
FEATURES

- High quantum efficiency: 33 % typ.
- High collection efficiency: 80 % typ.
- Single photon peaks detectable at every anode (pixel)
- Wide effective area: 48.5 mm × 48.5 mm
- 16 × 16 multianode, pixel size: 3 mm × 3 mm / anode

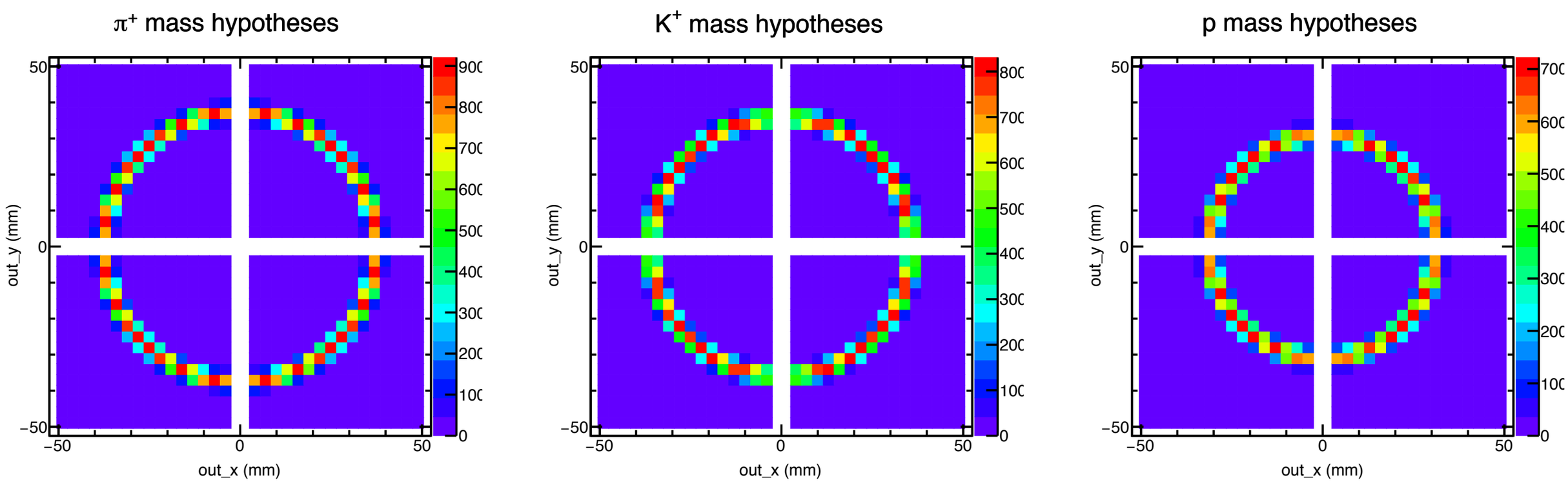


- **Longer focal length (6” Fresnel lens)**
- **Smaller pixel size sensors**
- **Test PID capability**

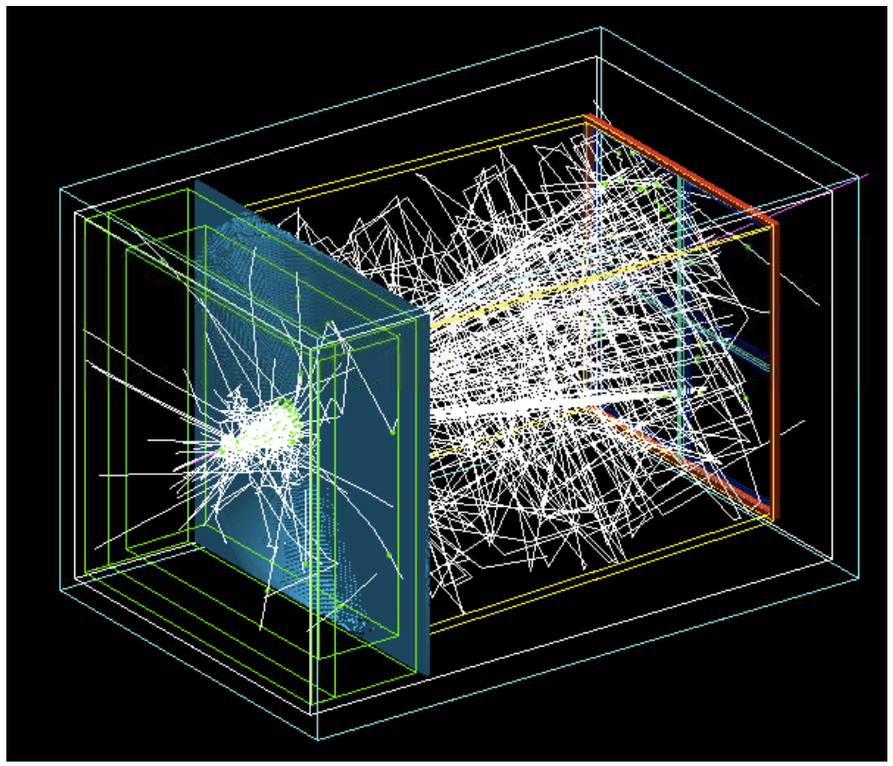
Ring Image



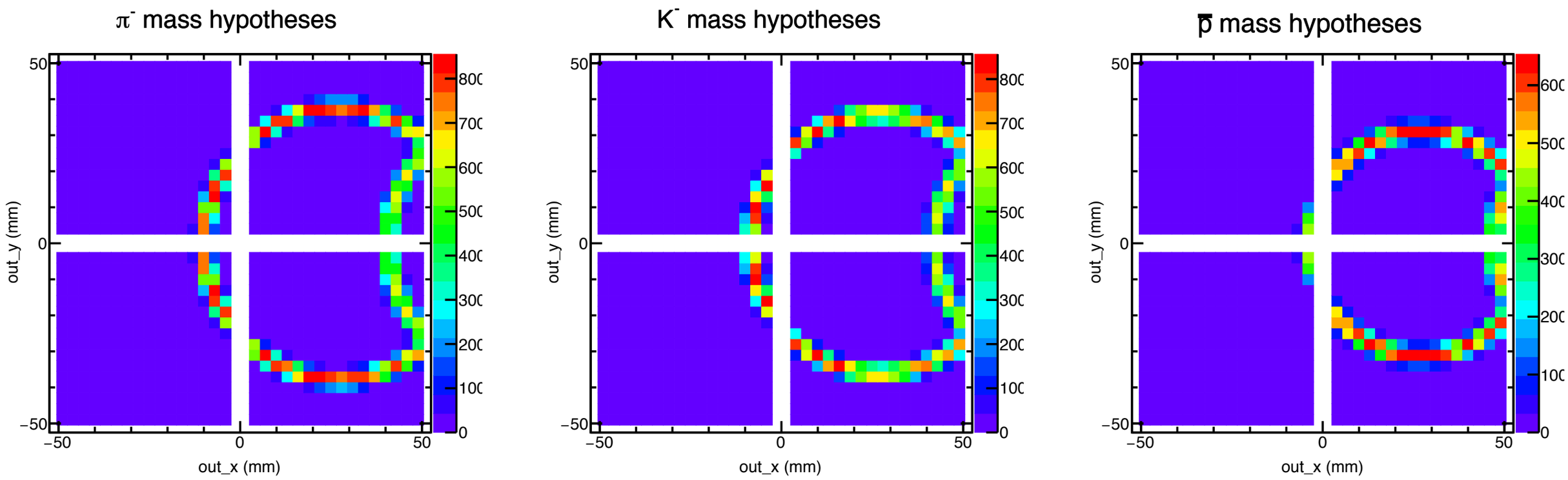
- 5 GeV/c particles launched perpendicular to the mRICH
- 3mm*3mm pixel size photon sensor
- perfect ring image
- could use ring finder algorithm



Ring Image

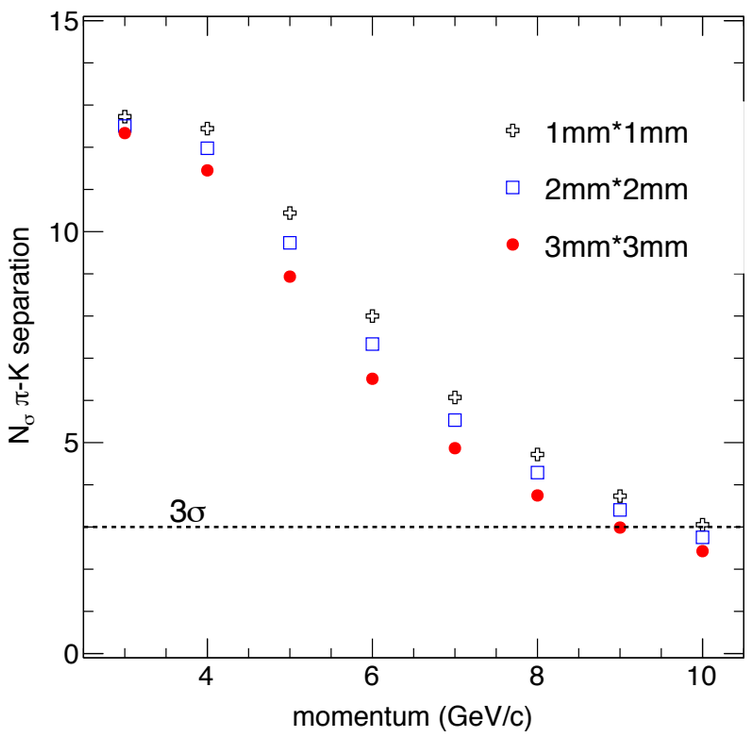


- 5 GeV/c particles launched with 10 degrees polar angle to the mRICH
- 3mm*3mm pixel size photon sensor
- moon shape ring image
- could not use ring finder algorithm
- developed likelihood method

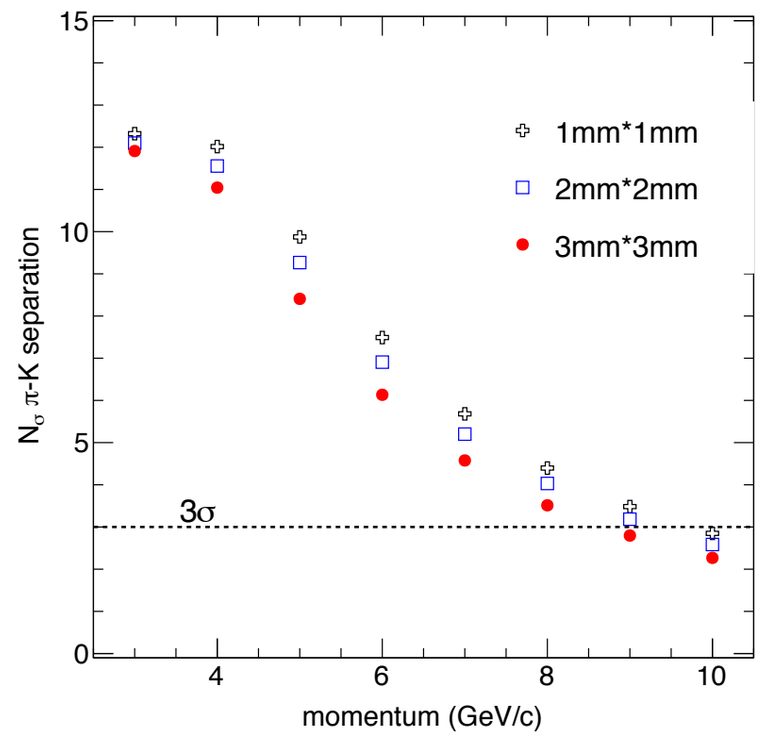


Separation Power

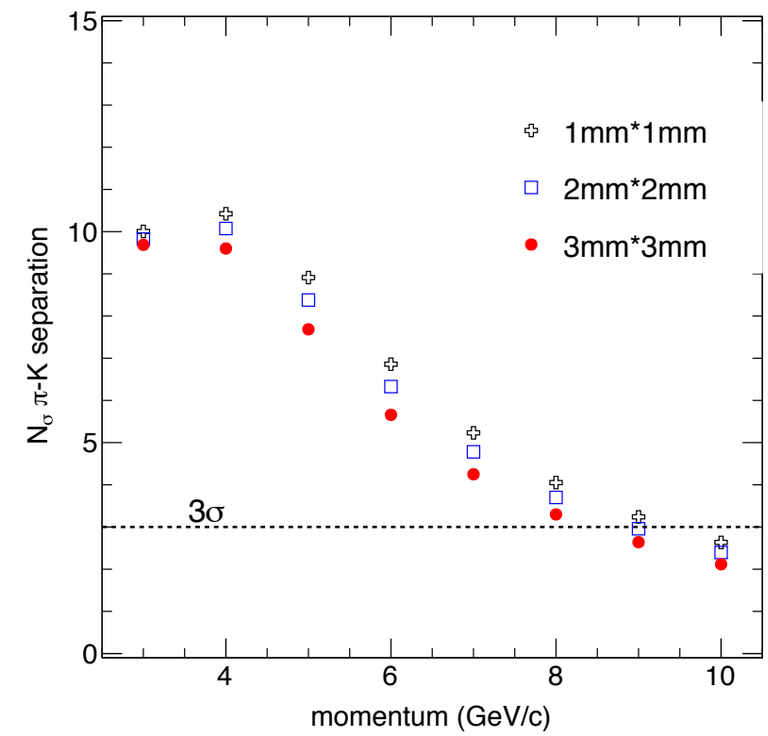
$\theta = 0°$



$\theta = 5°$

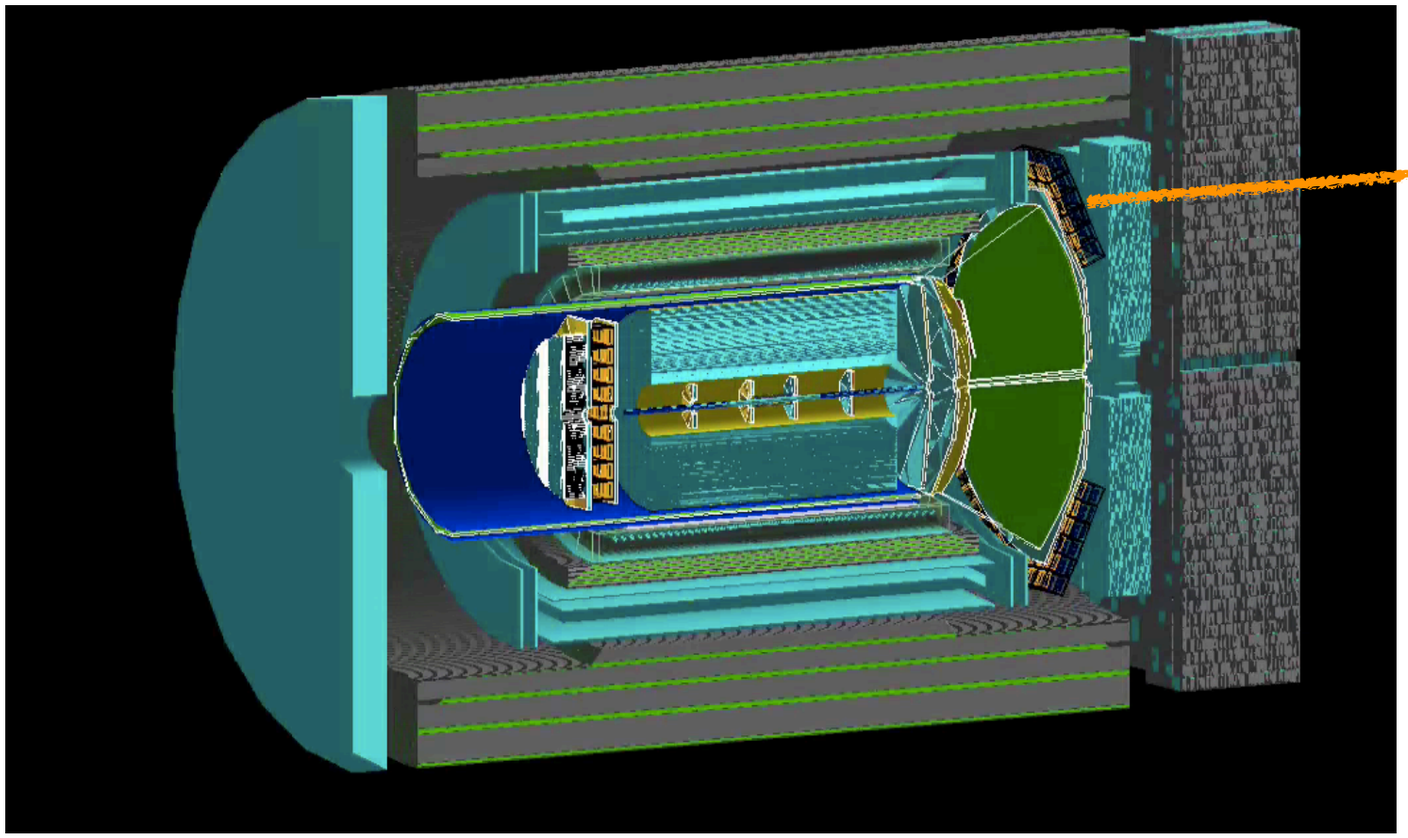


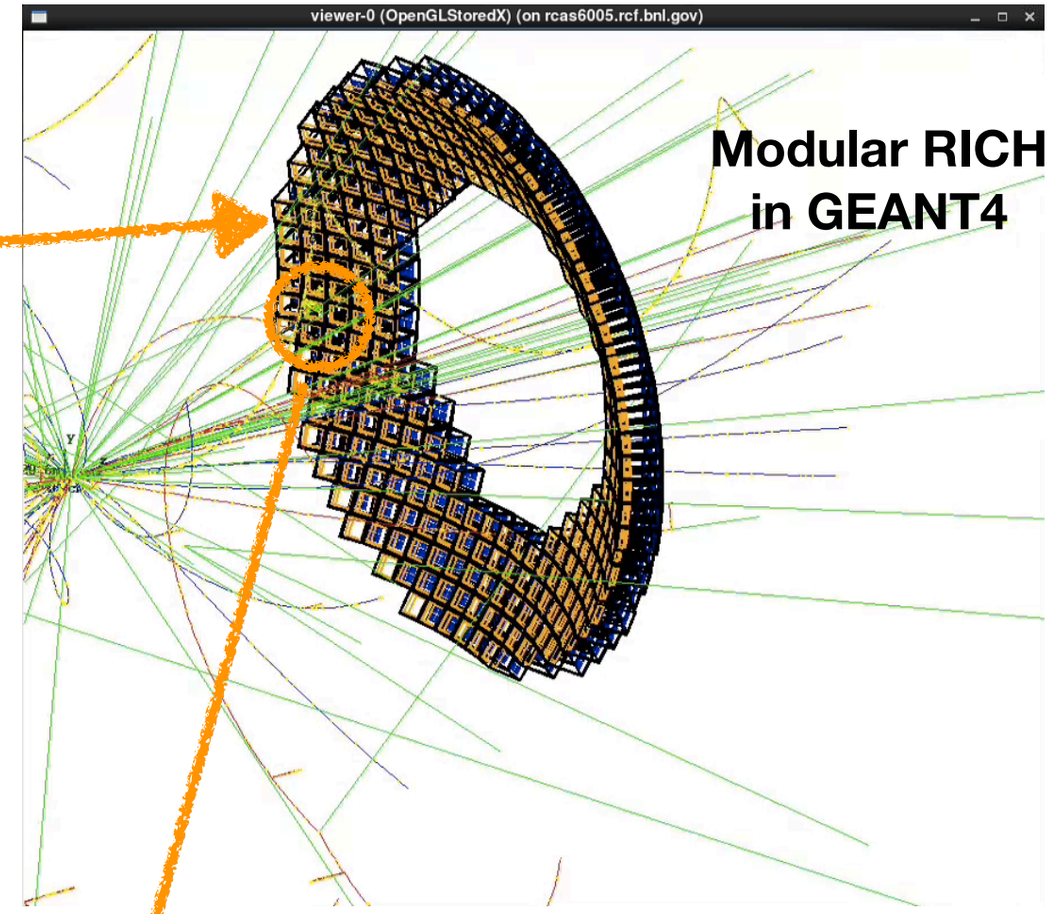
$\theta = 10°$



- **Separation power decrease with increasing polar angle**
- **3 sigma separation up to 9 GeV/c when particle launched at the center of aerogel**
- **3 sigma separation up to 8 GeV/c when particle launched at 10 degrees**
- **simulation will cover full phase space and use for future particle identification**

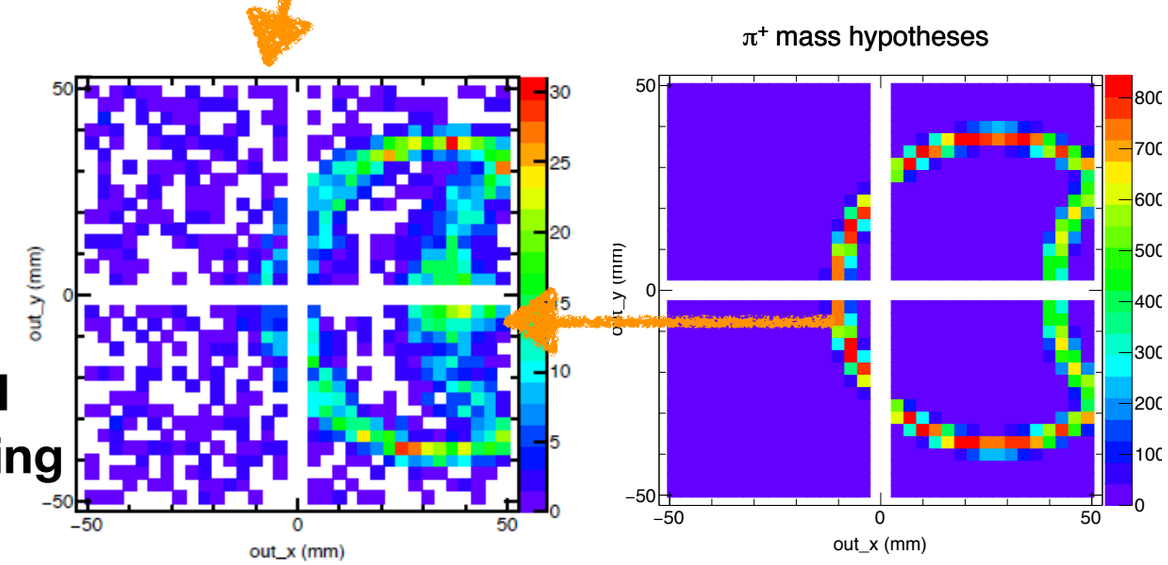
mRICH in EIC





- **validate in PYTHIA simulation**
- **likelihood method is available for PID**

Modular RICH reconstructed ring



Summary and Outlook

- 1st Beam Test Success
- 2nd prototype has been constructed at GSU
- simulation shows 3σ K/pi separation power up to 8 GeV/c
- 2nd Beam Test: June 20th—July 4th

EIC PID Consortium (eRD14)

An integrated program for particle identification (PID) for the Electron-Ion Collider Experiments

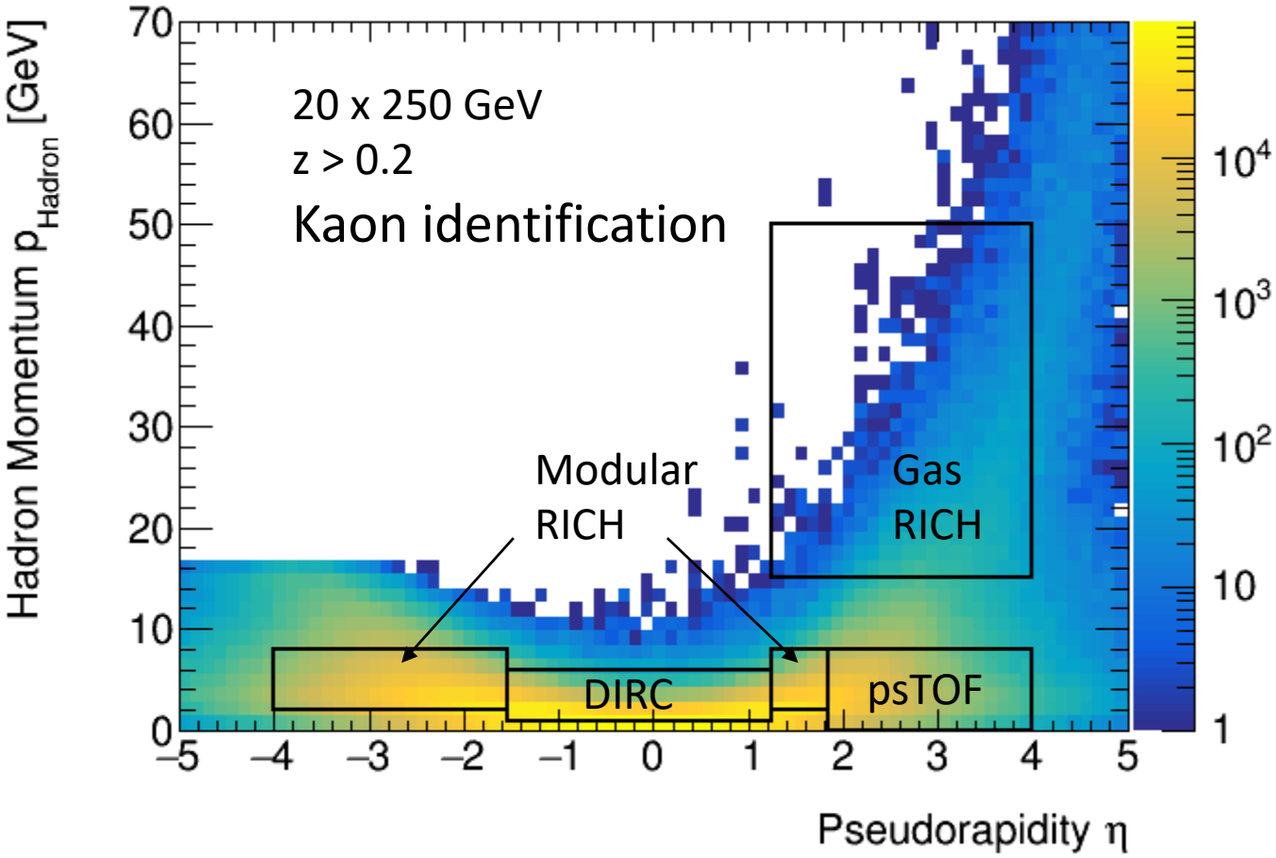
Abilene Christian University
Argonne National Lab
Brookhaven National Lab
Catholic University of America
College of William & Mary
Duke University
Georgia State University
GSI
Howard University
Hawaii University

INFN, Sezione di Ferrara
INFN, Sezione di Roma
Istituto Superiore di Sanità
Jefferson Lab
Los Alamos National Lab
Old Dominion University
Universidad Técnica Federico Santa María
University of Illinois
University of New Mexico
University of South Carolina
Yale University

Thanks for your attention!!!

Backup

A PID solution for the EIC - implementation



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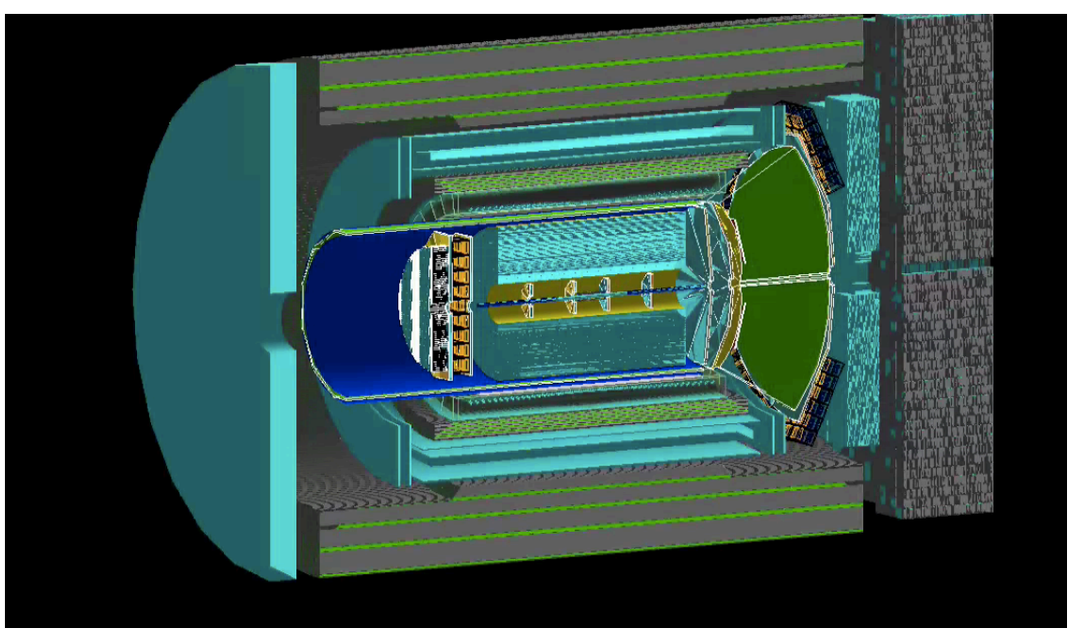
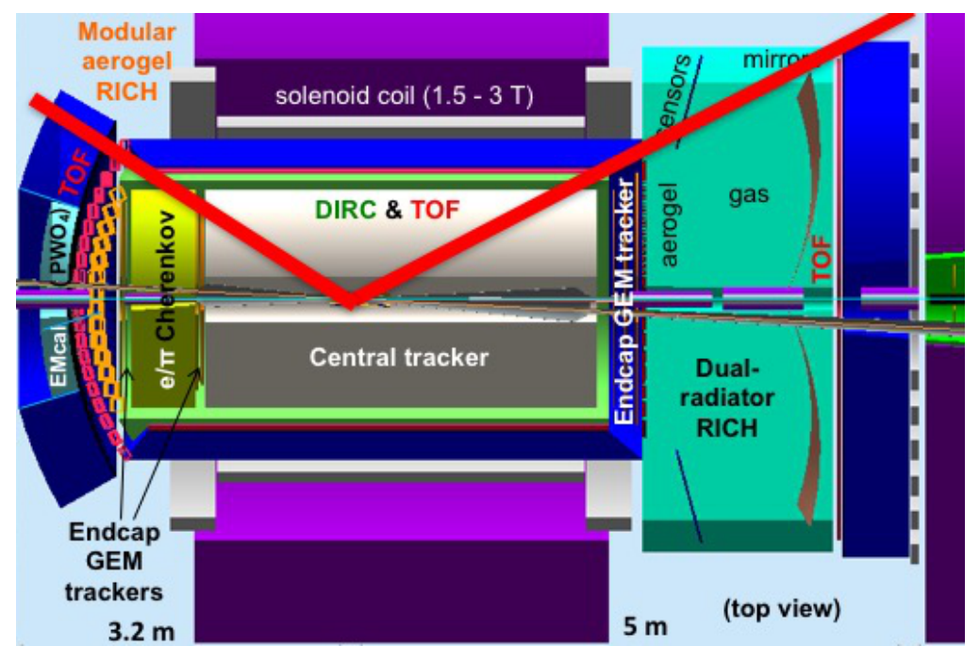
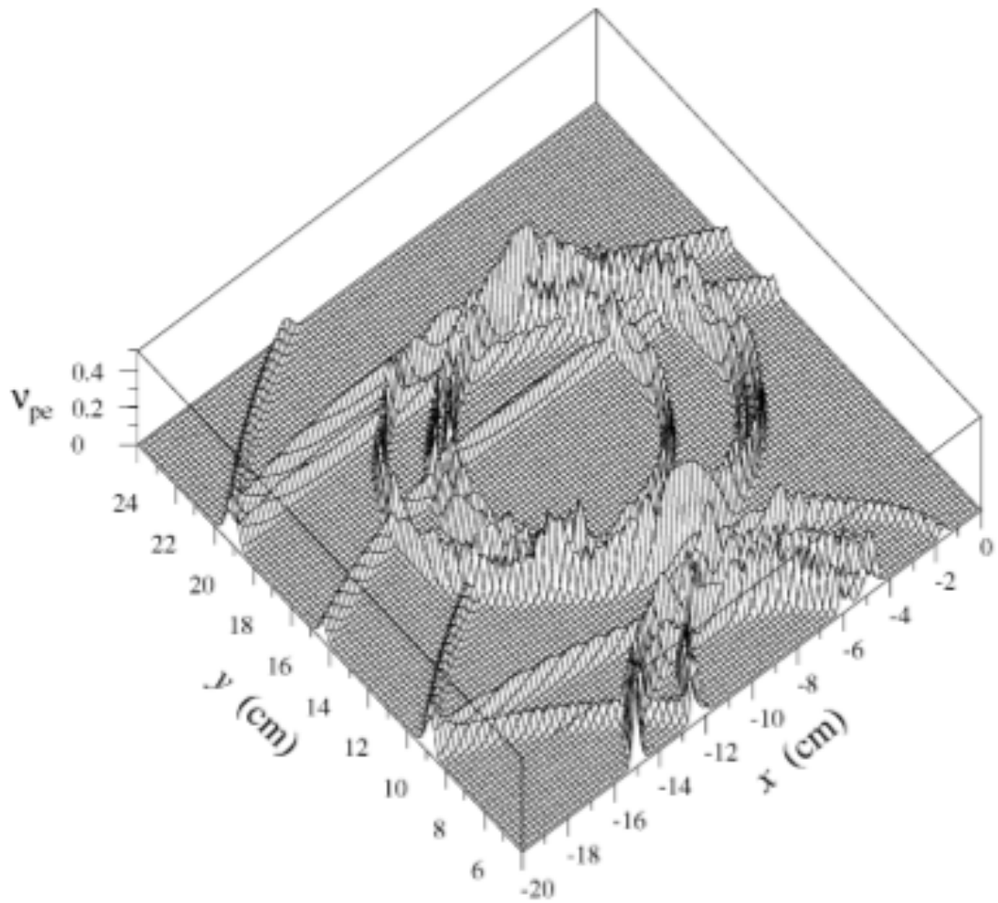
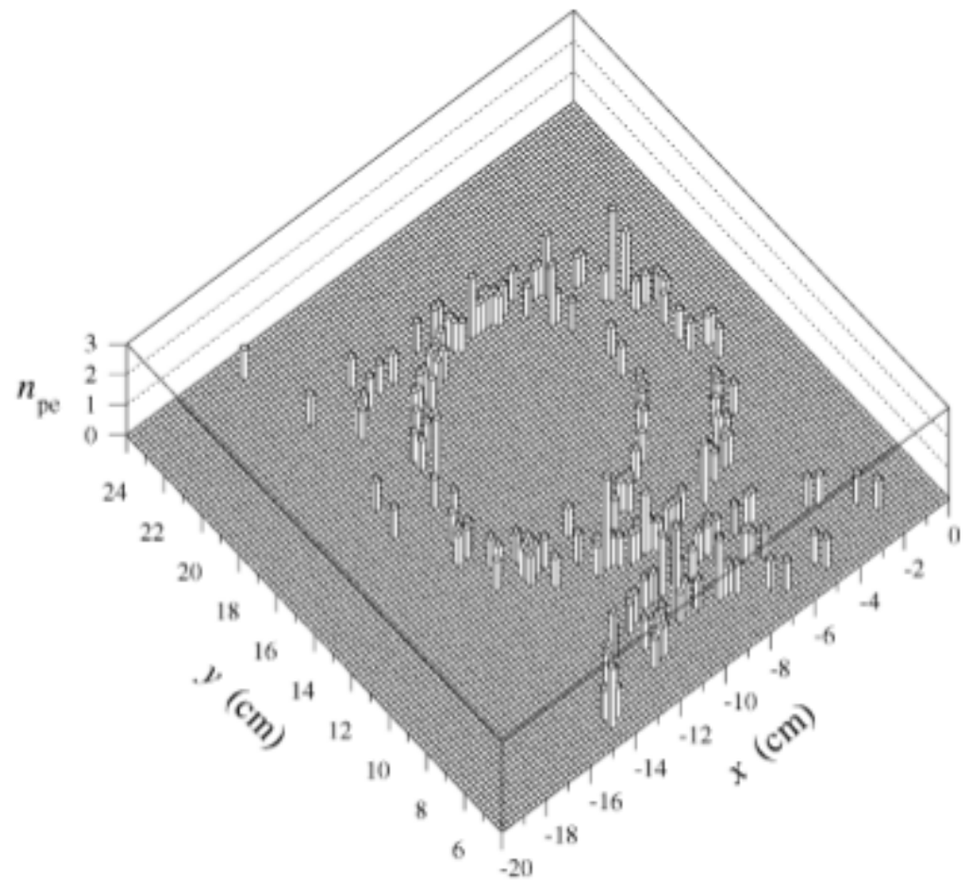




sPHENIX/ePHENIX Detector **JLEIC Detector**

Particle Identification:Maximum Likelihood Method

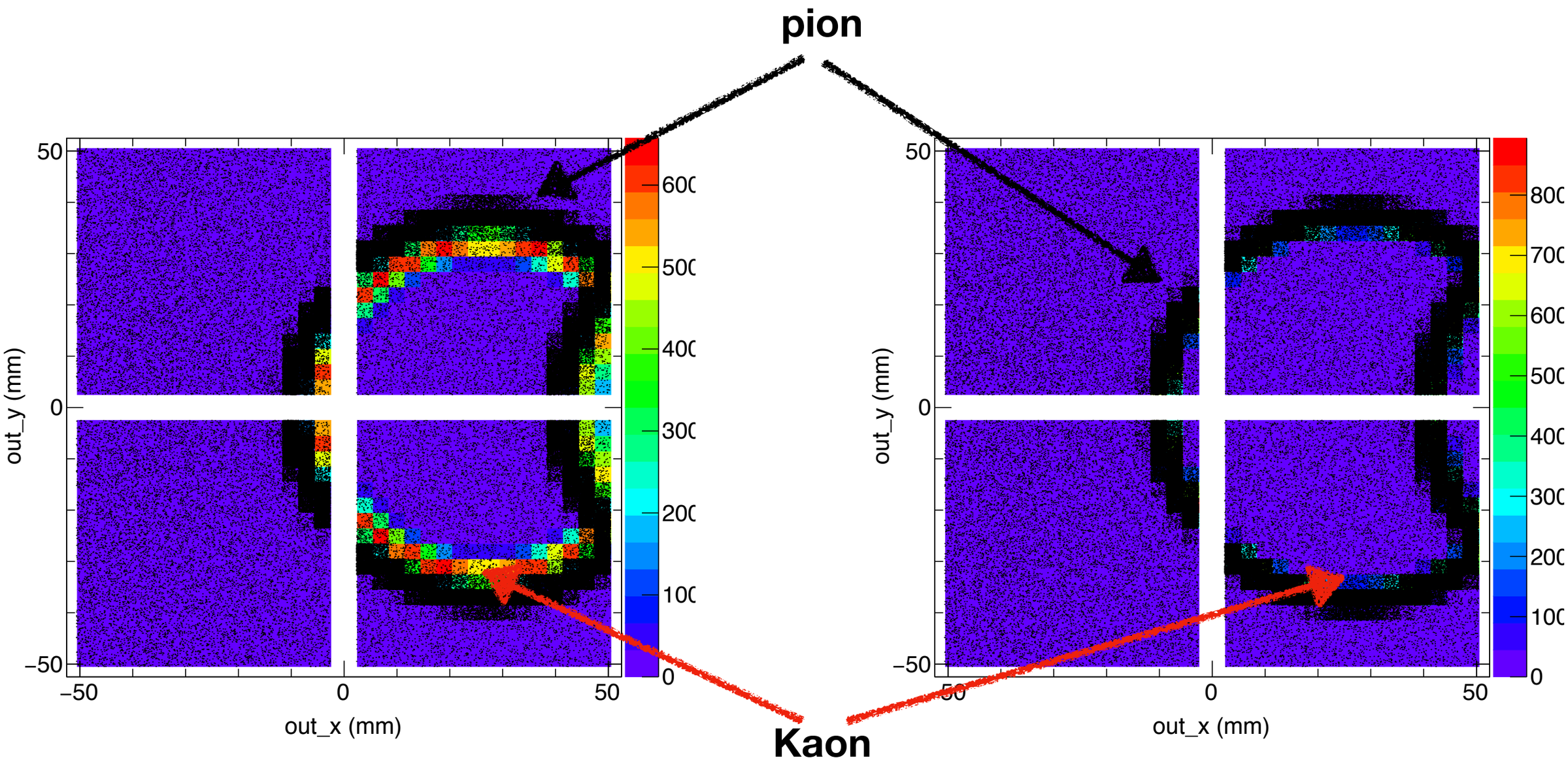




NIM A433 (1999) 257-261

- **simulate photoelectron distribution in sensor plane with different PID for certain momentum => PDF**
- **compare with measured photoelectron distribution**
- **calculate poisson likelihood** $\mathscr{L} = \prod_{\text{pixels } i} \frac{e^{-\nu_i}\nu_i^{n_i}}{n_i!}$
- **select set-of PID maximum the likelihood**

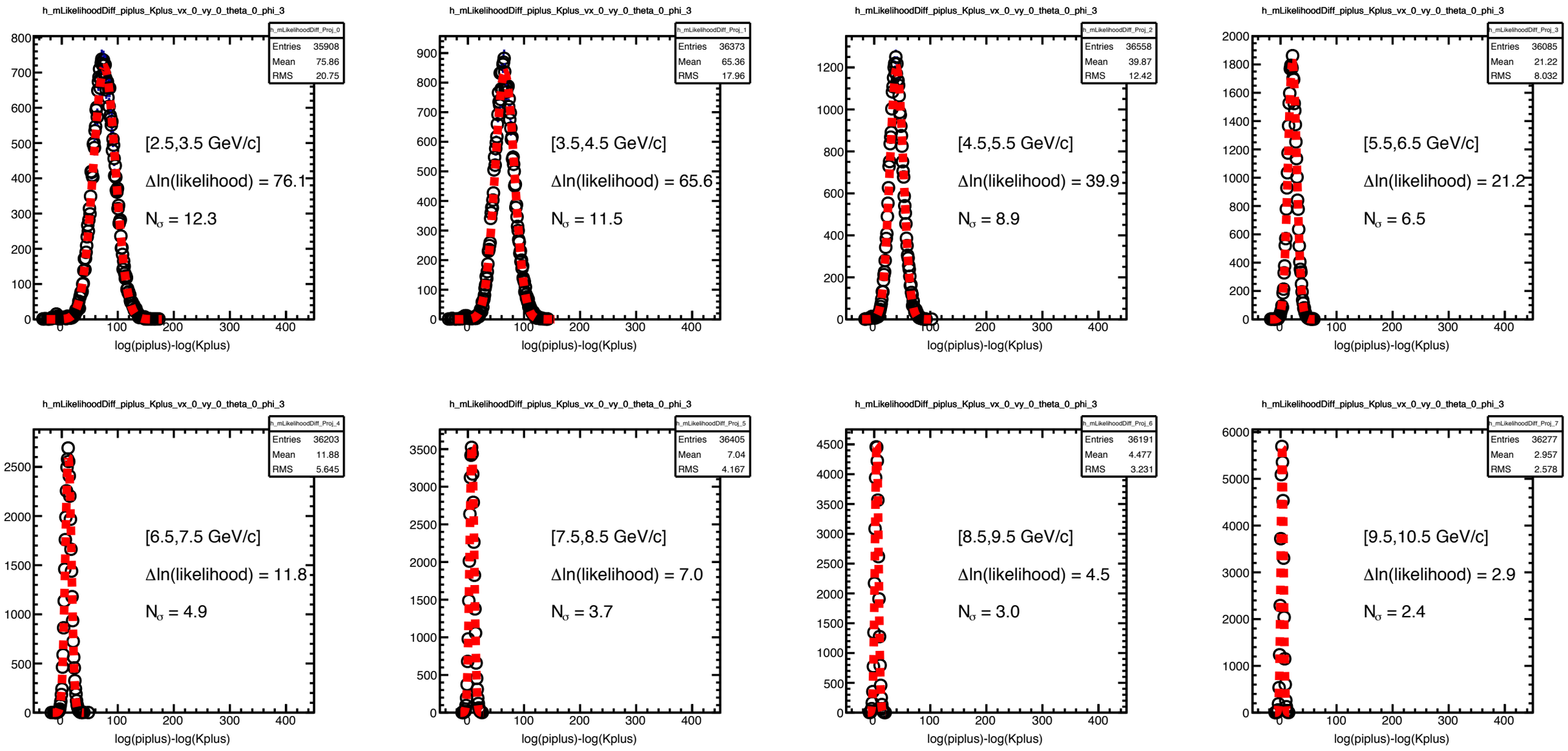
Database



- momentum: 3.5-4.5 GeV/c
- theta: 10°
- k/pi can be separated easily

- momentum: 9.5-10.5 GeV/c
- theta: 10°
- hard to separate K/pi

Log Likelihood Method



- **project each momentum bin to log likelihood axis**
- **use a gaussian fit to extract mean difference log likelihood**

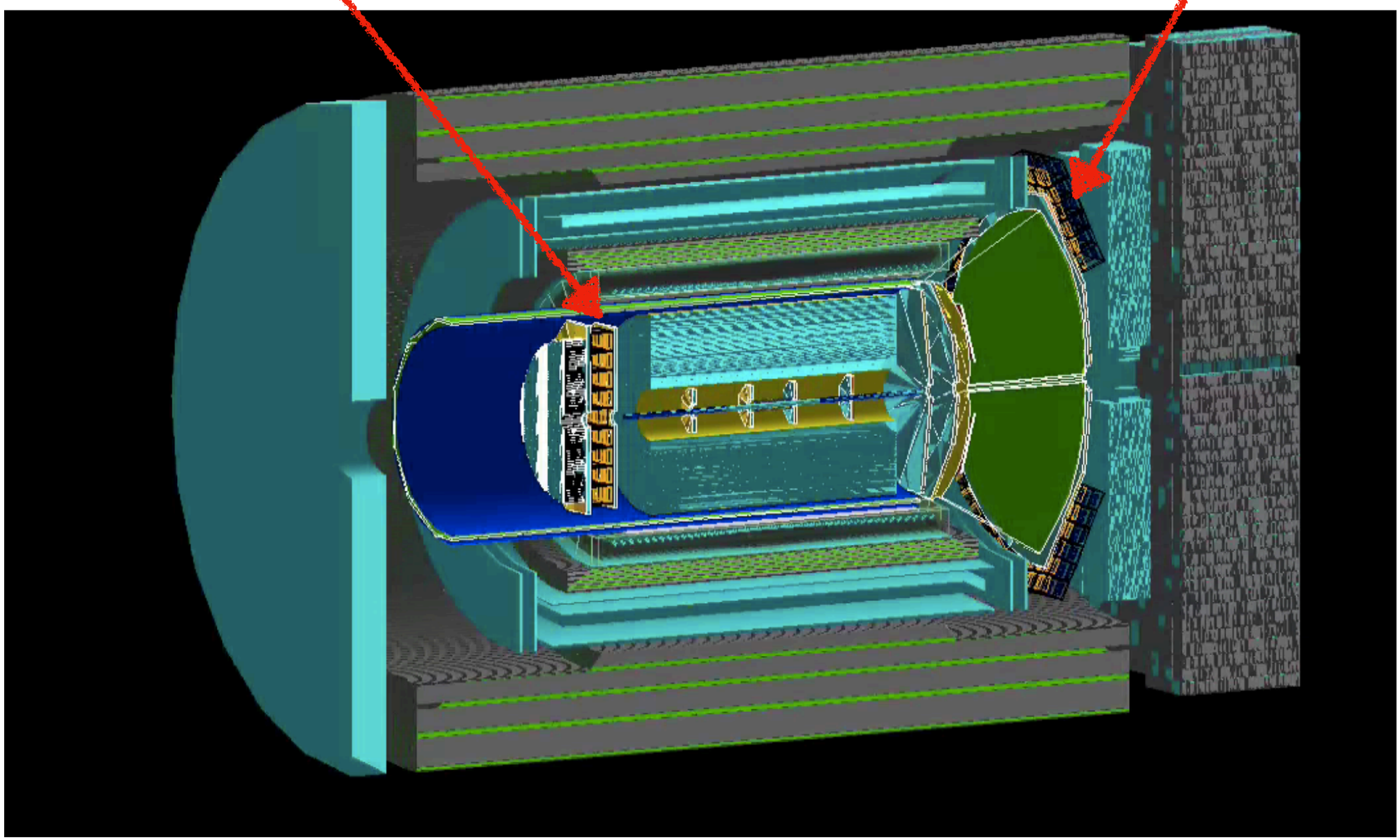
$$N_\sigma = \sqrt{2.0 * \Delta ln(likelihood)}$$

NIM A433 (1999) 257-261

mRICH Implementation in sPHENIX

5-inch mRICH
eta: -3.9 ~ -1.4

5-inch mRICH
eta: 1.1 ~ 1.85



- **https://github.com/sPHENIX-Collaboration/coresoftware.git**
- **https://github.com/sPHENIX-Collaboration/macros.git**