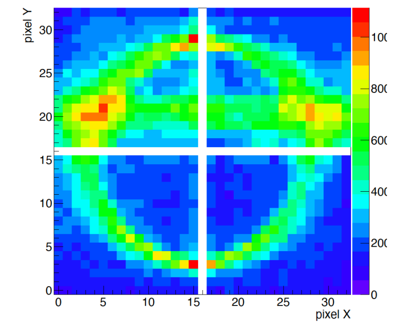
Backwards RICH Review: JLab Beam Test

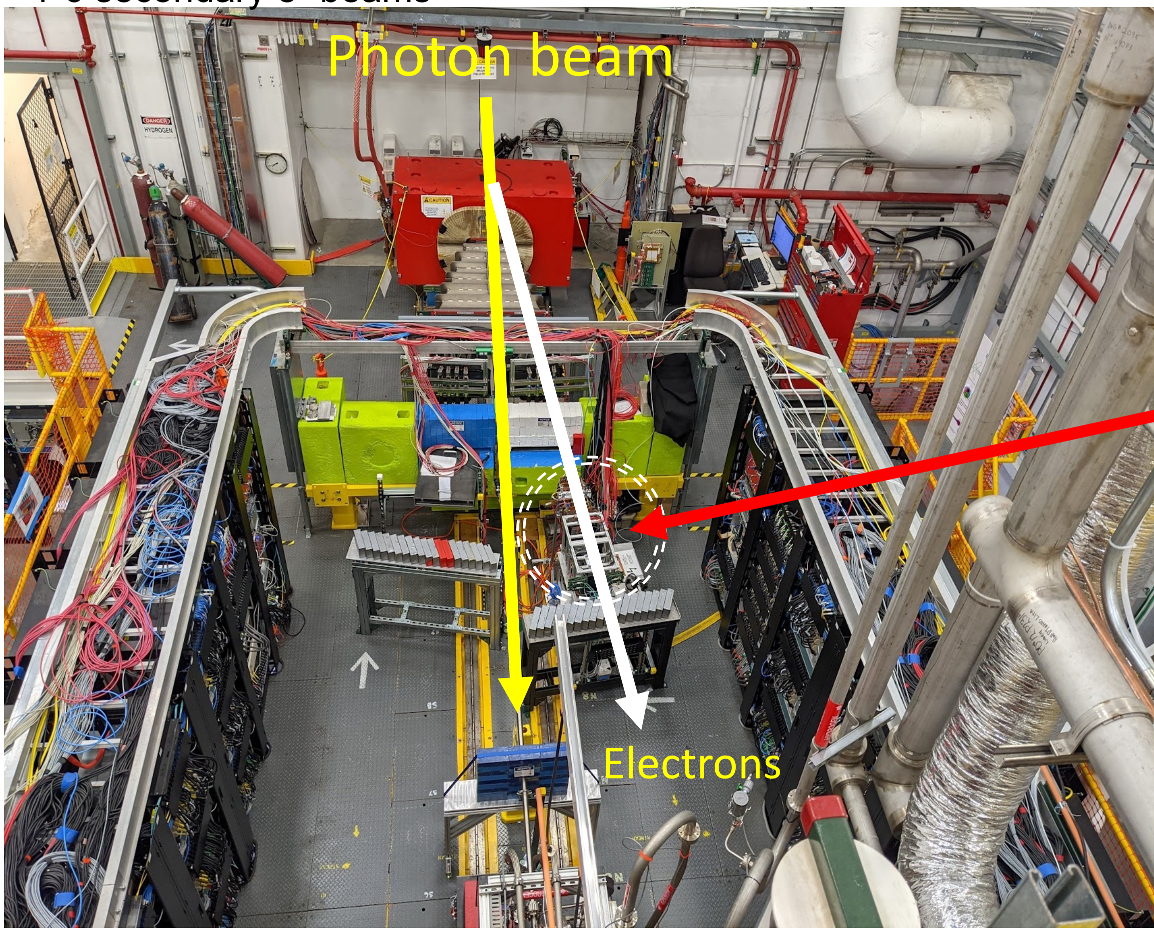
M. Sarsour (GSU)

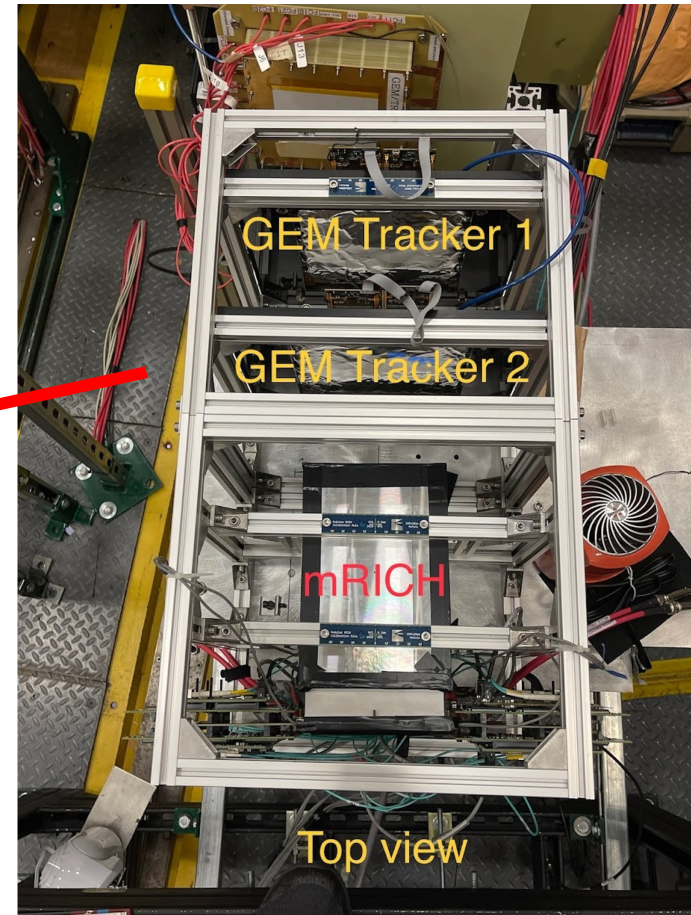


2. **Input information:**

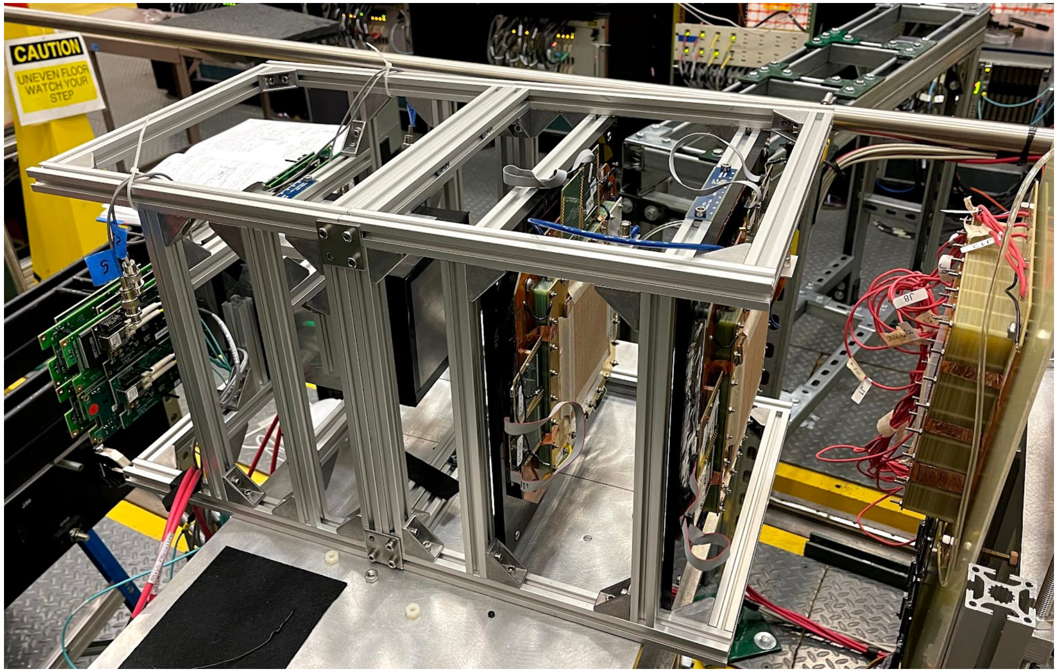
   b. Prototypes and their tests: done so far, ongoing effort, future planning (with timelines); results from prototypes and their tests

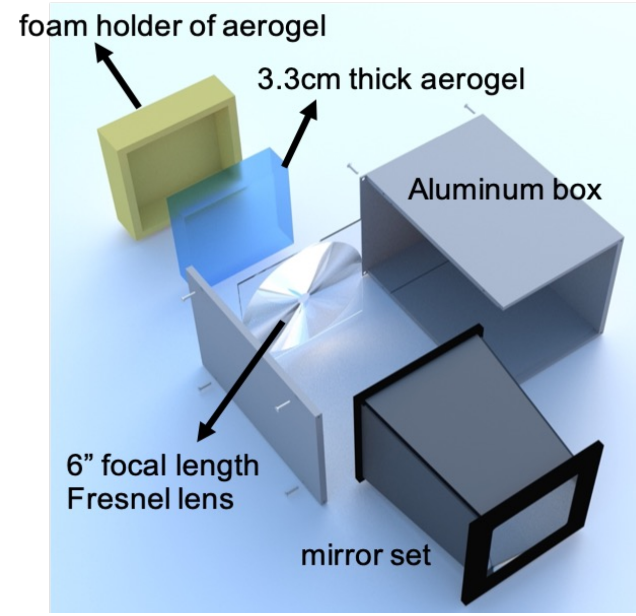
1-6 secondary e- beams





JLab Beam Test: mRICH Prototype & GEM Trackers



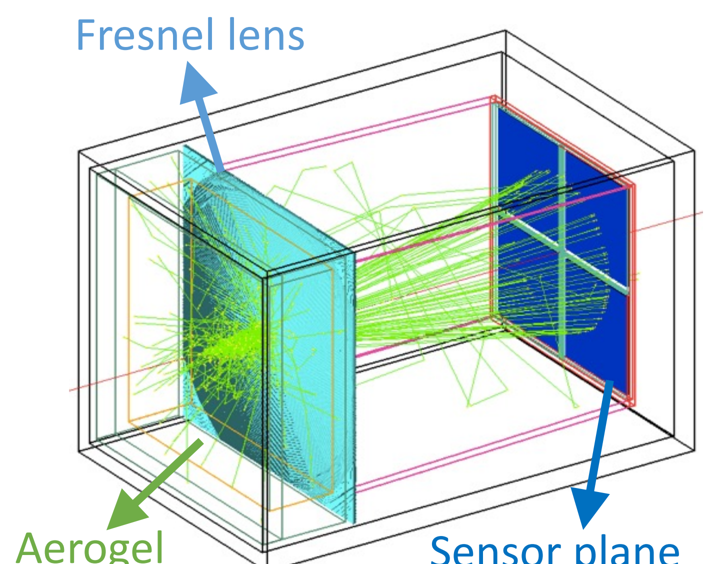


mRICH:

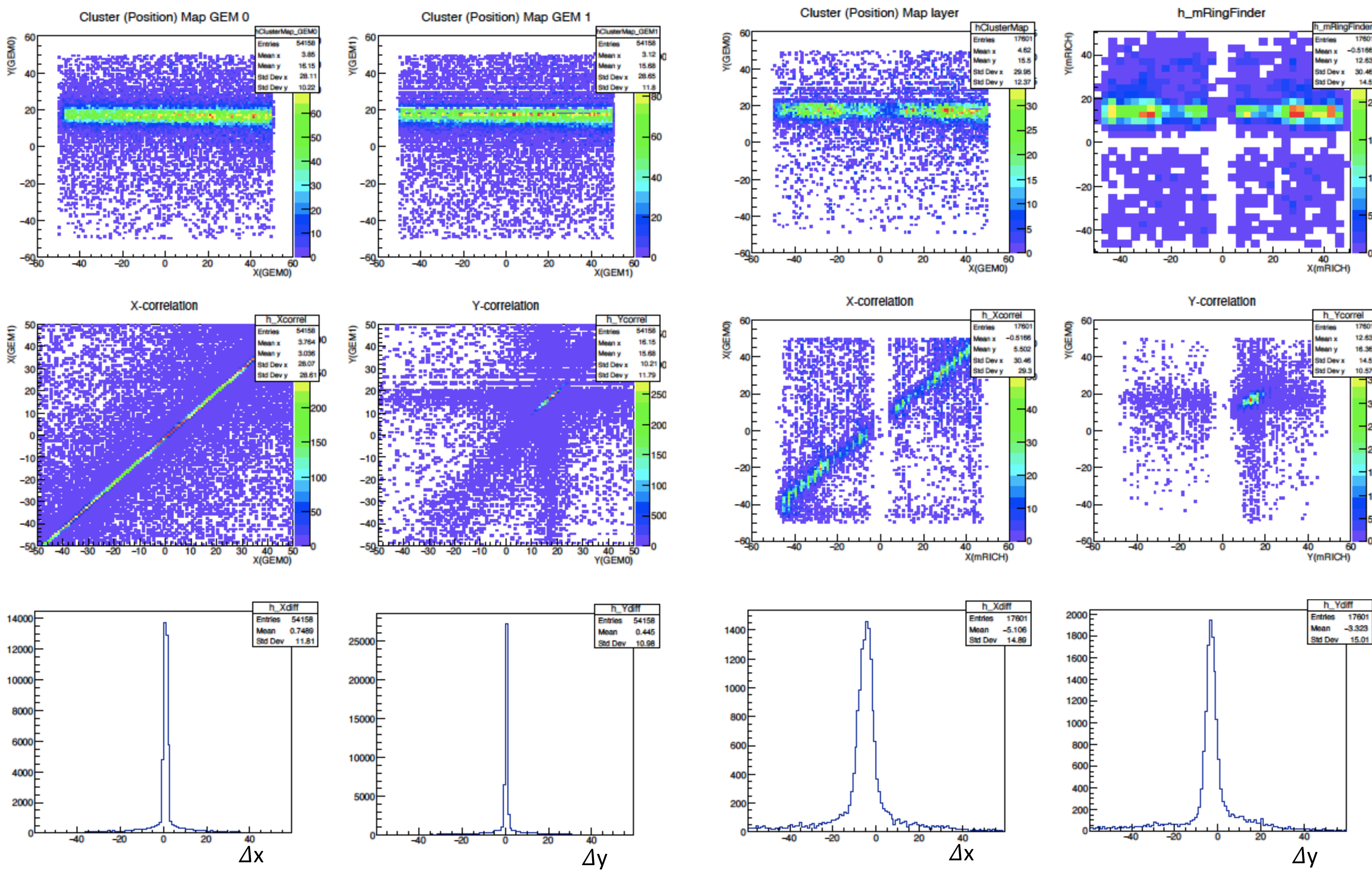
- 3 cm (3 1cm blocks) aerogel @ n=1.03
- 6” Fresnel lens
- 3mm pixel / Hamamatsu H13700 PMT

Tracking:

- 2 GEMs @ 50 µm resolution!

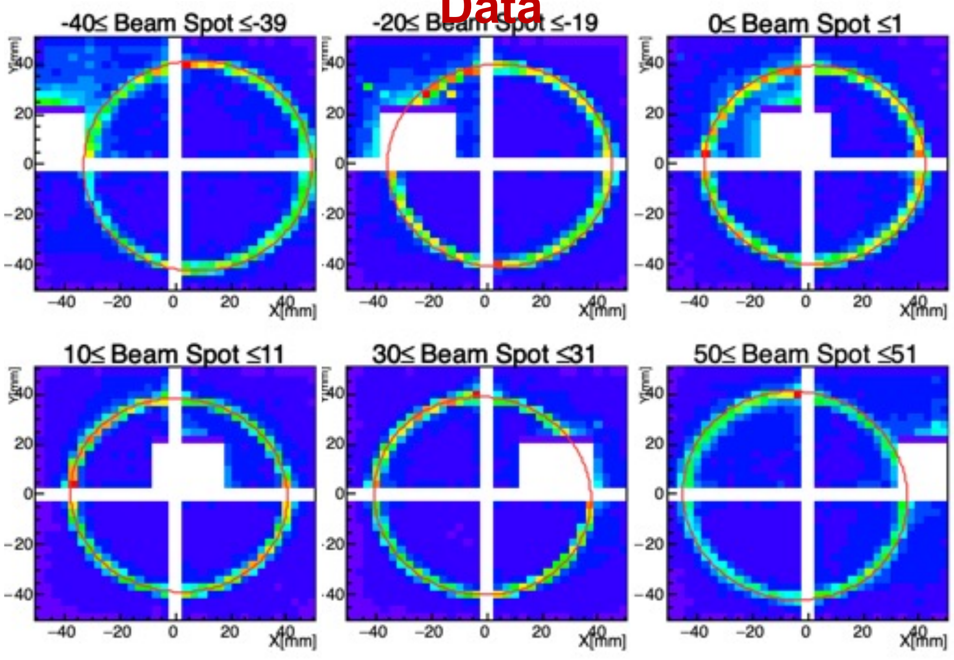


JLab Beam Test: Data Analysis

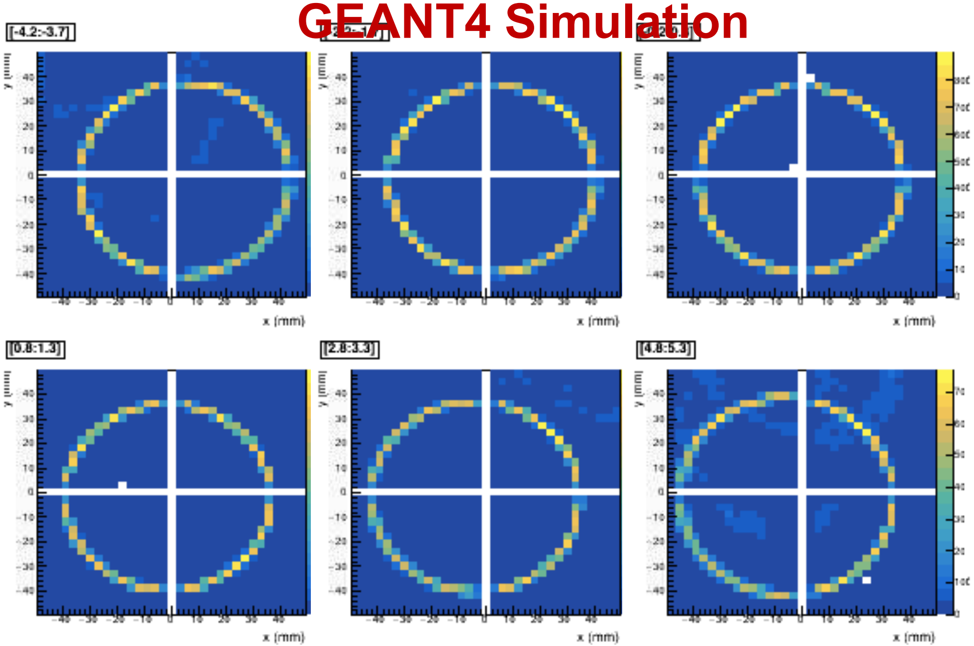


JLab Beam Test: Rings as a Function of Incident Beam Position

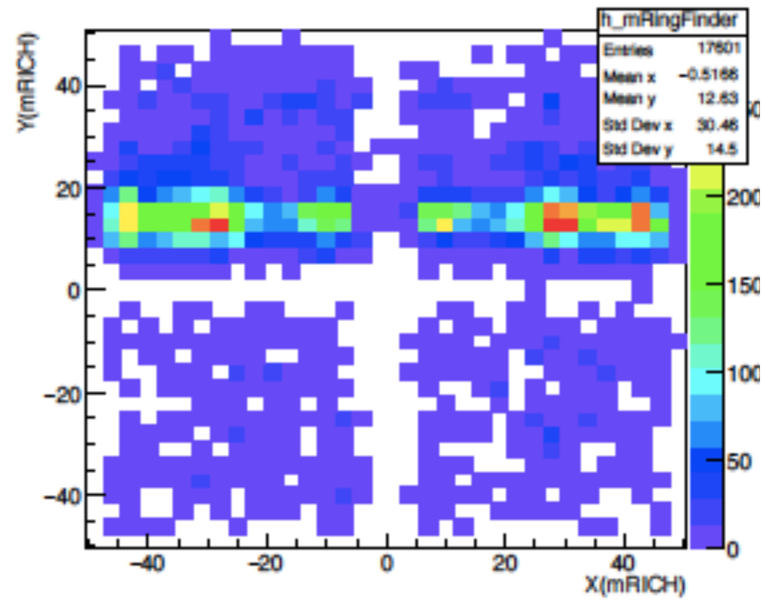
Data



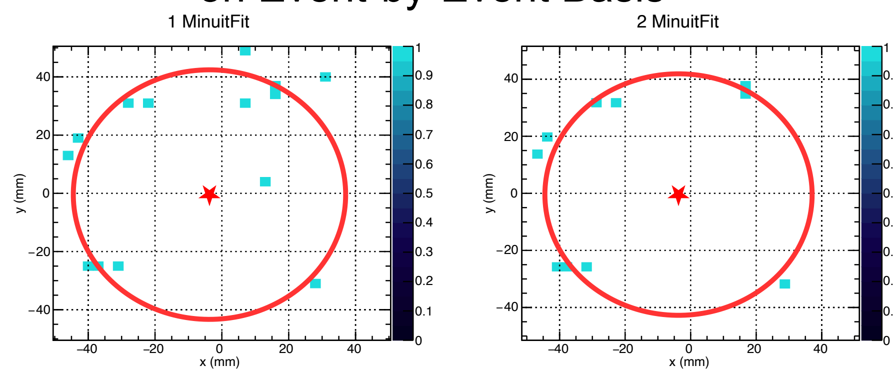
GEANT4 Simulation



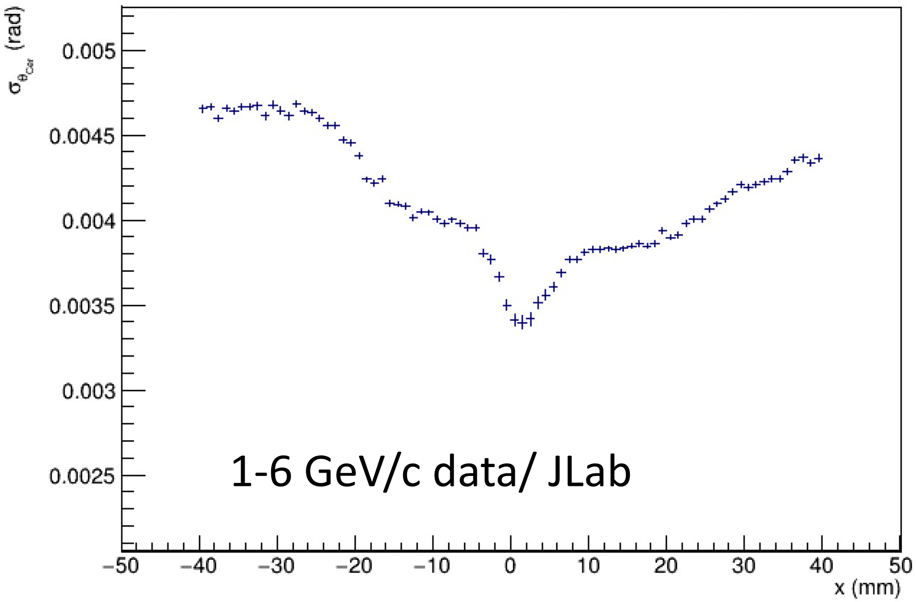
Electron Beam Profile on mRICH

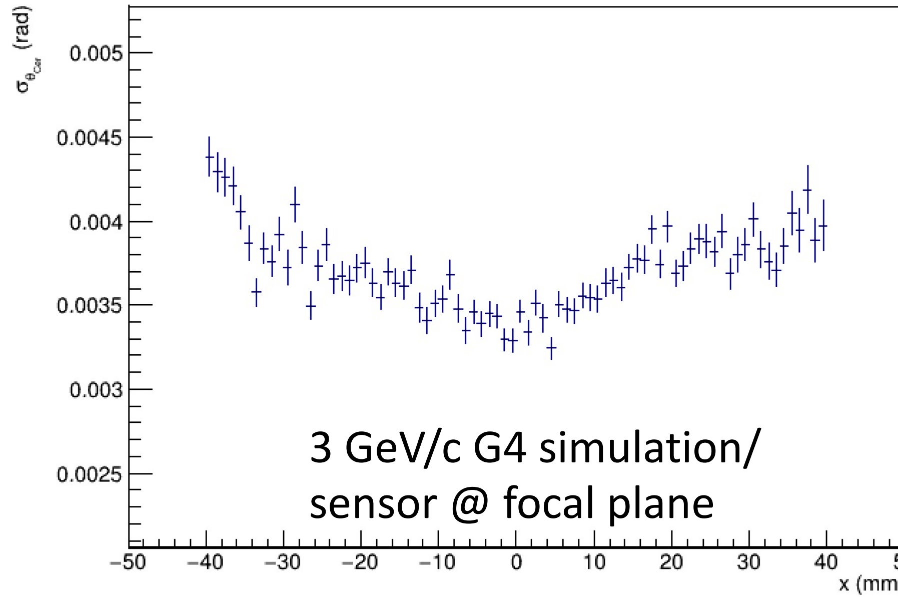


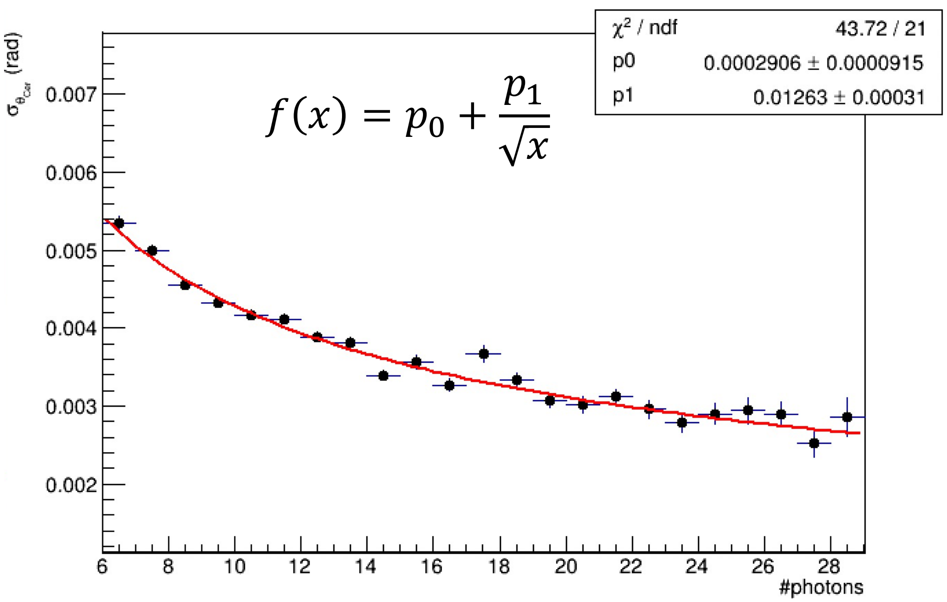
Fitting Ring Image Pattern
on Event-by-Event Basis

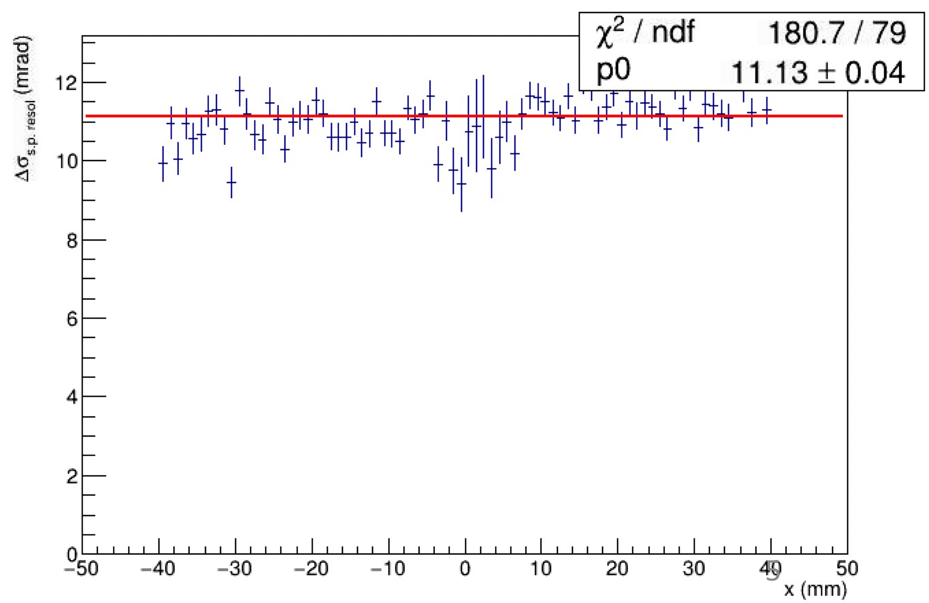


JLab Beam Test: Results

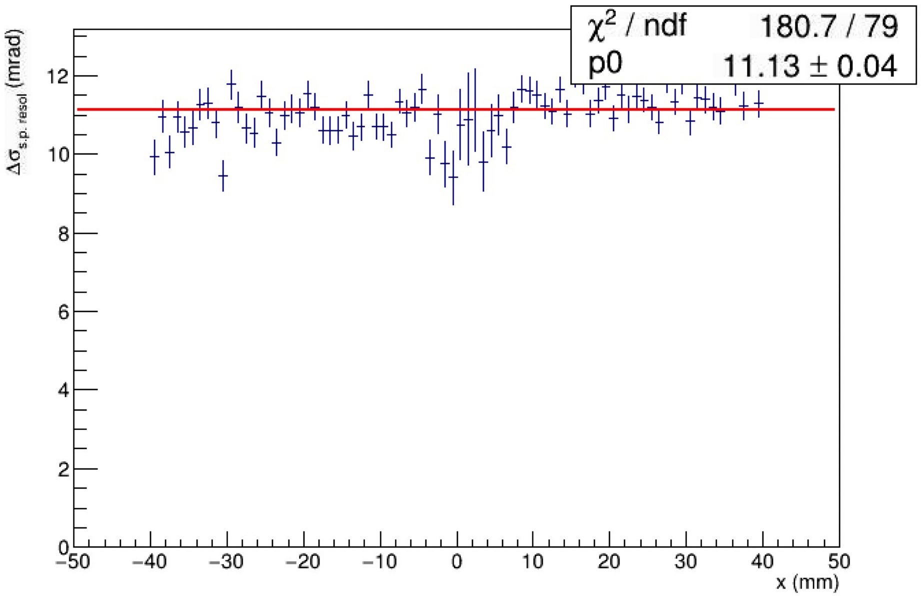




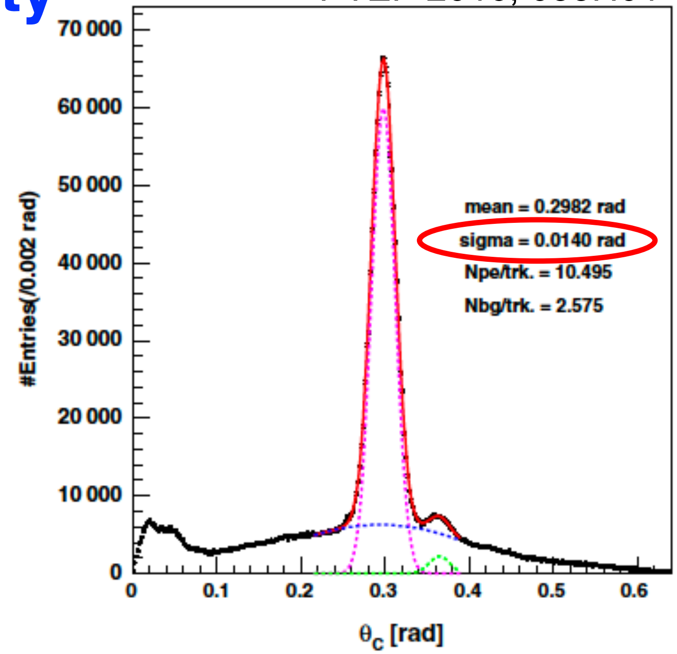




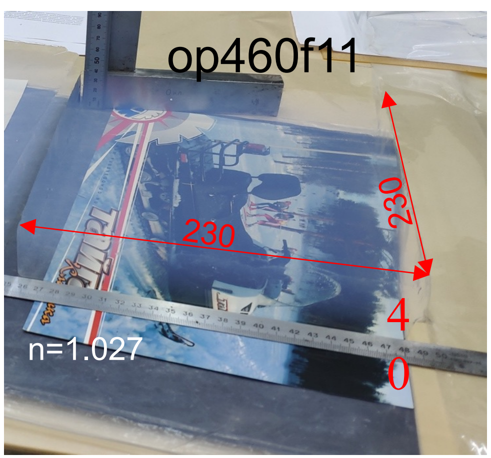
JLab Beam Test: mRICH vs Proximity

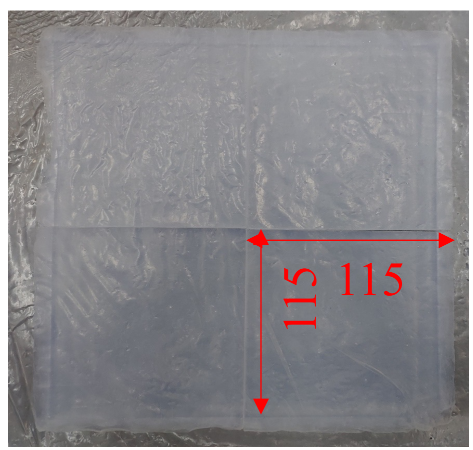


Belle II PTEP 2016, 033H01

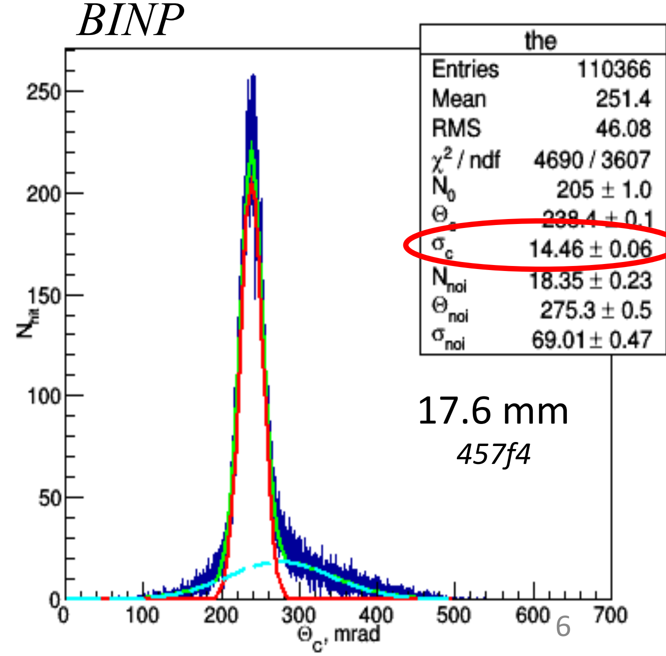


BINP Beam Test



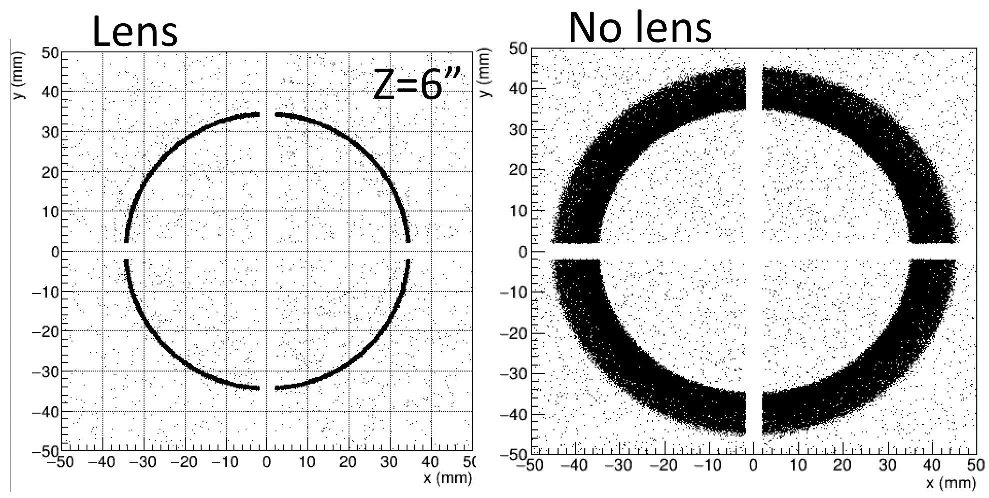


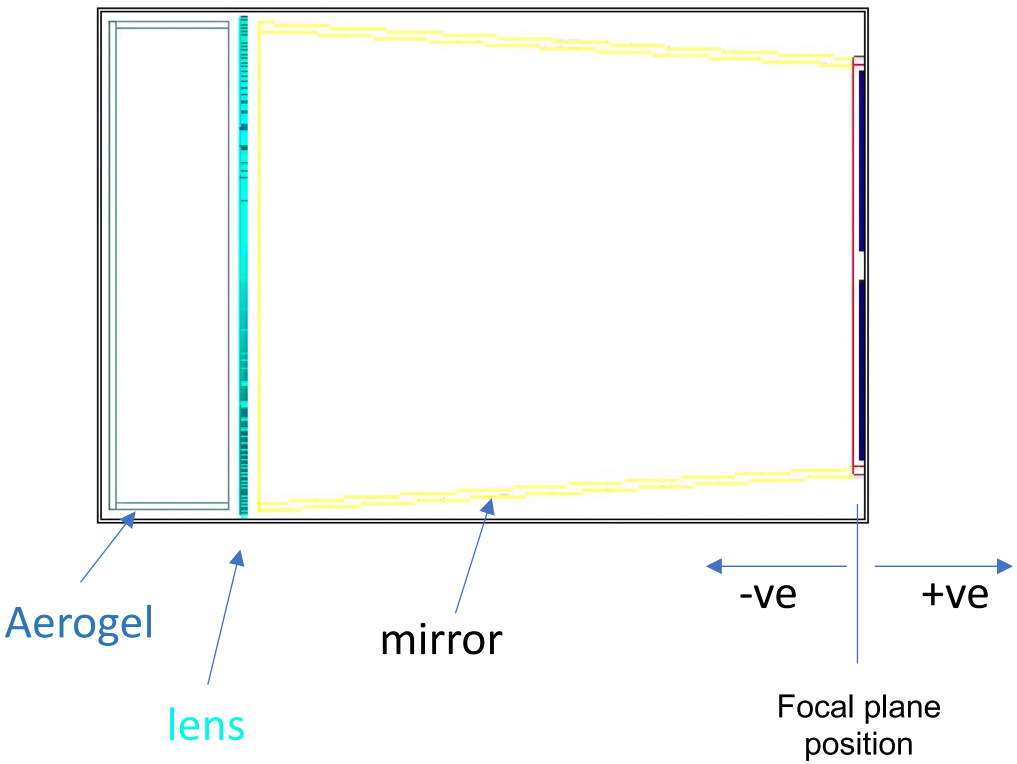
BINP

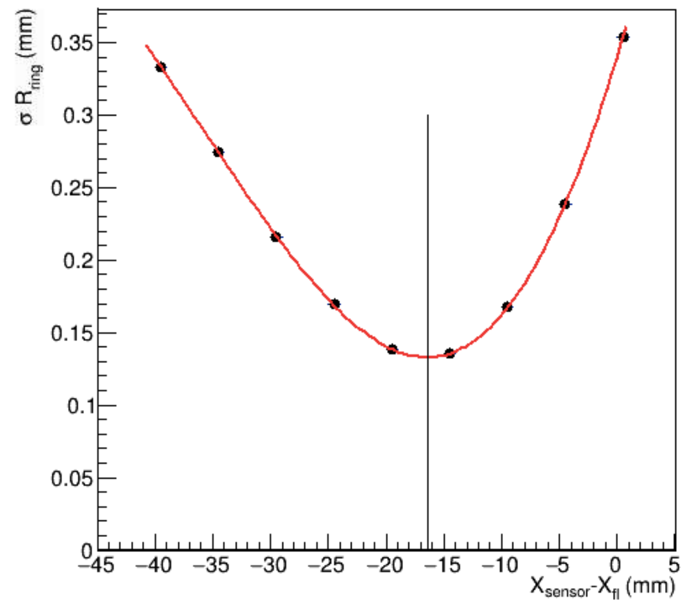


JLab Beam Test: SPR

- 11 mrad single photon angular resolution?
  - Pixel resolution (3 mm)
  - Sensors are not located at the lens's focal plane but slightly further
  - The optimal focusing position is not at the focal plane but 1.6 cm closer to the lens

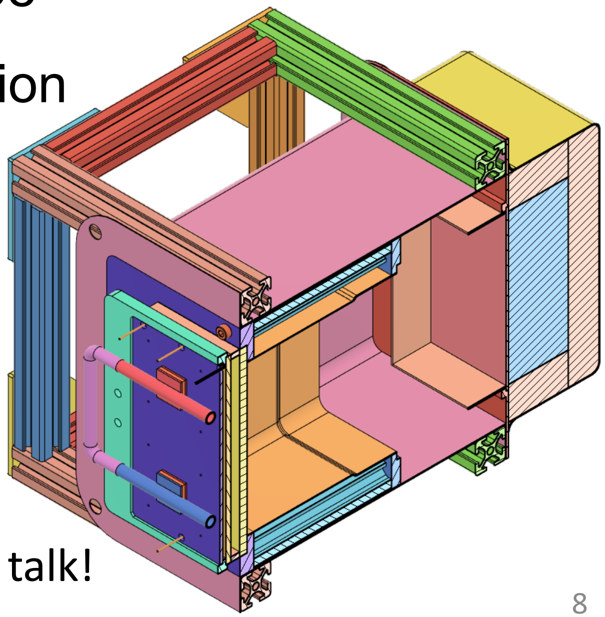






Summary and Conclusions

- Successful beam test at Jlab with 1-6 GeV/c secondary electron beam including 2 GEMs for tracking
- Completed the data analysis and obtained ~4 mrad Cherenkov angle resolution, which is translated into ~11 mrad single photon angular resolution
- GEANT4 simulation agrees very well with data
  - Good understanding of mRICH prototype
  - Confidence in mRICH GEANT4 simulation
- Next beam test:
  - Optimal focusing position studies



See Alex Eslinger's talk!

GSU (Xiaochun He, Murad Sarsour, Deepali Sharma), Jlab (Kondo Gnanvo, Duke (Bishnu Karki, Zhiwen Zhao), USC (Yordanka Ilieva), INFN (Marco Contalbrigo)

EIC PID Consortium (eRD14 Collaboration)

Thank You

mRICH Simulation & Performance

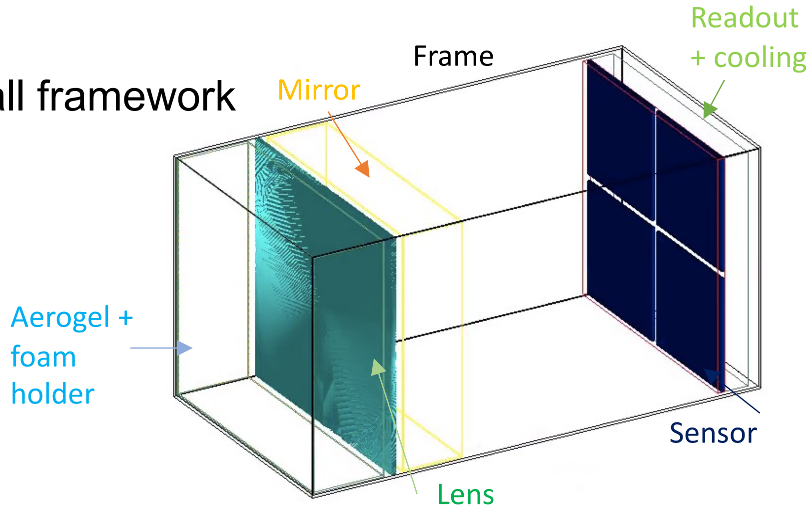
2. **Input information:**
   c. **Simulation studies**: already performed, ongoing and planned (with timelines); results from the simulations; particular care in (i) showing how realistic the parameters used in simulations are and (ii) reporting what is missing for a fully realistic simulation (backgrounds, specific event categories, …) (iii) Does the simulation take into account the **realistic response of the selected photosensors and related FEE**?

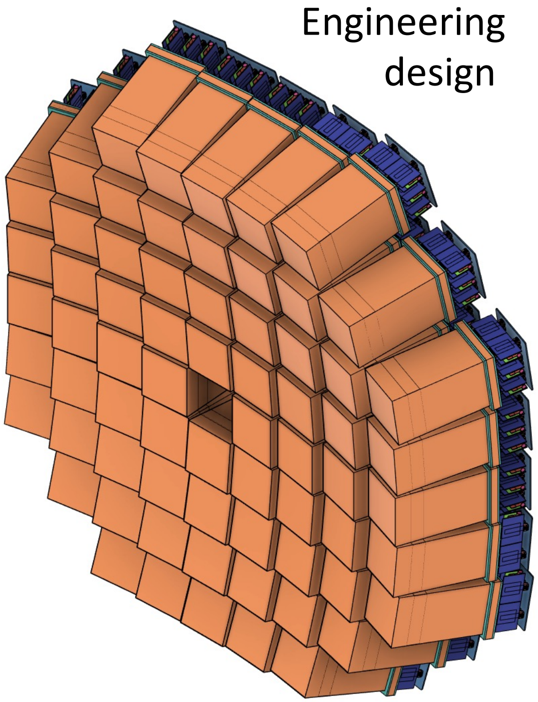
3. **Performance:**
   a. Comparison of the **present assessment of the Cherenkov PID detector performance compared with the YR requirements**?
   b. Performance perspectives **beyond the YR requirements (if any)** ?
   c. **Efficiency** figures: single particle Pi/Kaon/Proton identified as Pi/Kaon/ Proton as a function of the truth momentum in a 3x3-panel figure?
   d. Please quantify the performance for electron/hadron separation
   e. **Active area** or /dead area as 2D function of eta and phi; and comment on the edge effects?
   f. Performance or potential as timing detector, providing both timing resolution and acceptance coverage in eta and phi.
   g. Under the coordination of the SIDIS working group, provide Kaon Purity in the kinematic region of (x. .. Q^2…) via parameterized hadron PID performance.

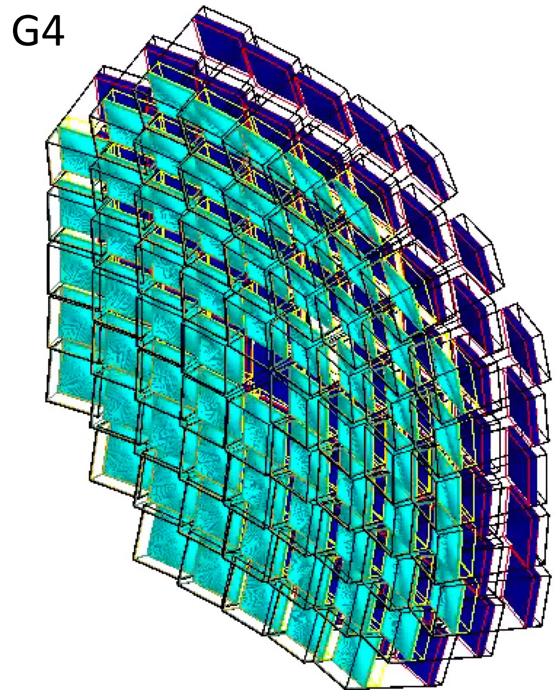
6. Integration:
   a. **Status of the proposed detector integration** into the current baseline detector?
      ii. Material effect to backward EMCal: in coordination with the calorimeter DWG, produces electron line-shape in the backward EMCal with the proposed RICH detector in front.

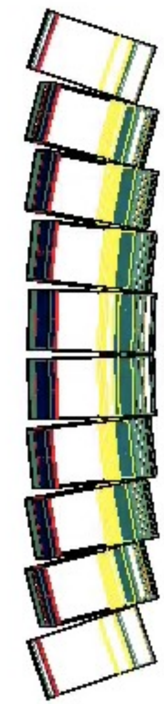
Simulation Studies / #2.c: Setup

- Full GEANT4+reconstruction implementation in Fun4all framework
  - Fun4all is simulation framework adopted by PHENIX and sPHENIX collaborations as well as EIC/ECCE proto-collaboration
  - Beam tests + current PID performance
  - Module design- 68 identical modules are stacked in a wall and projected towards the IP







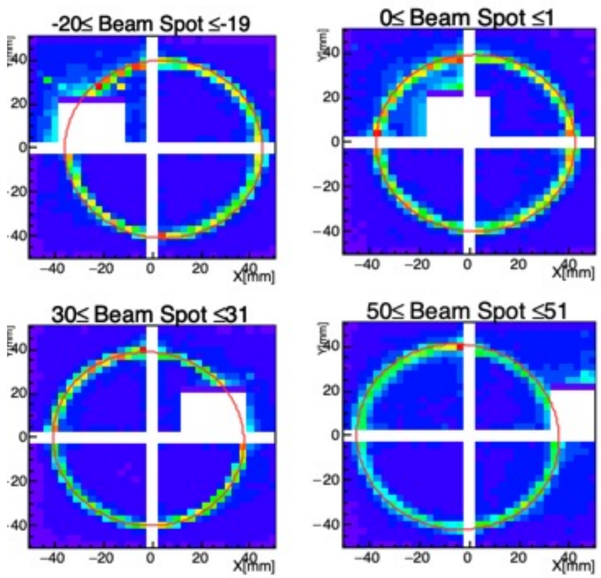


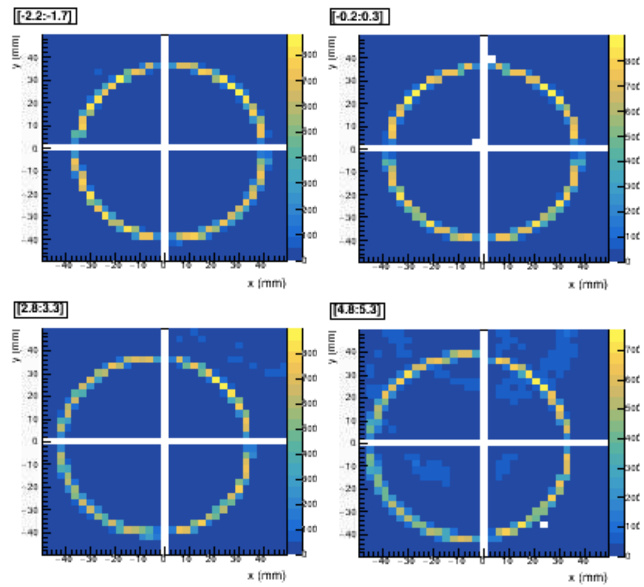
See Alex Eslinger's talk!

Simulation Studies / #2.c: Validation

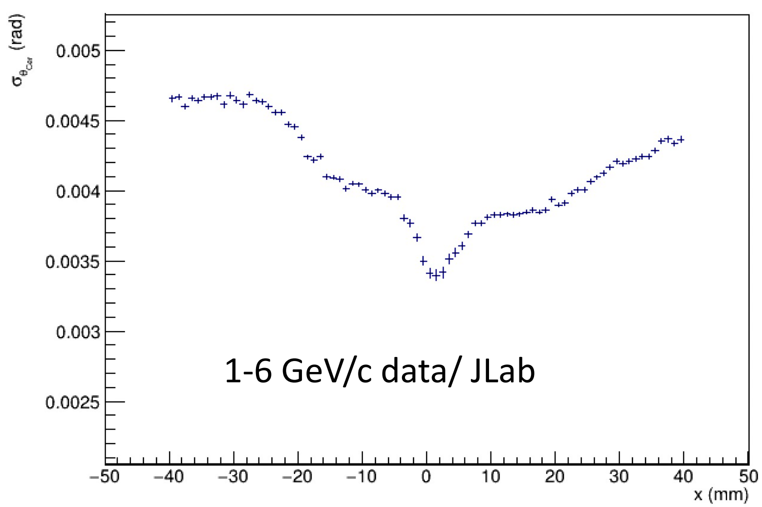
- Comparison to data from three beam tests. C.P. Wong et al., NIM A **871,** 13–19 (2017)

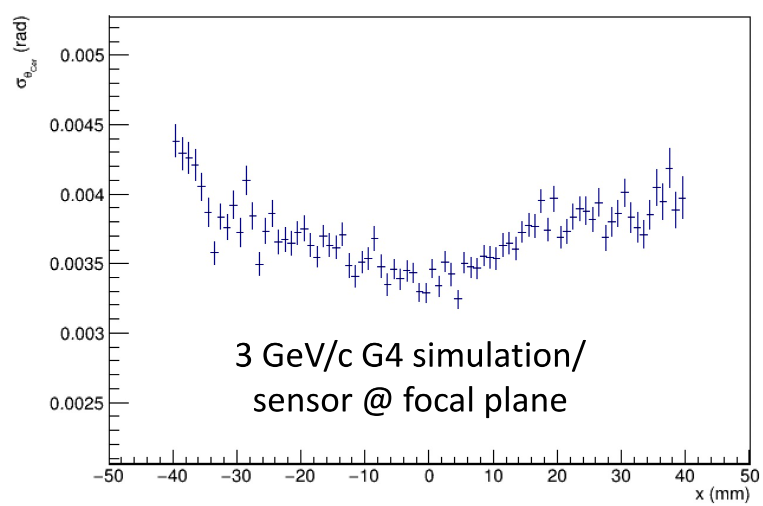
Data





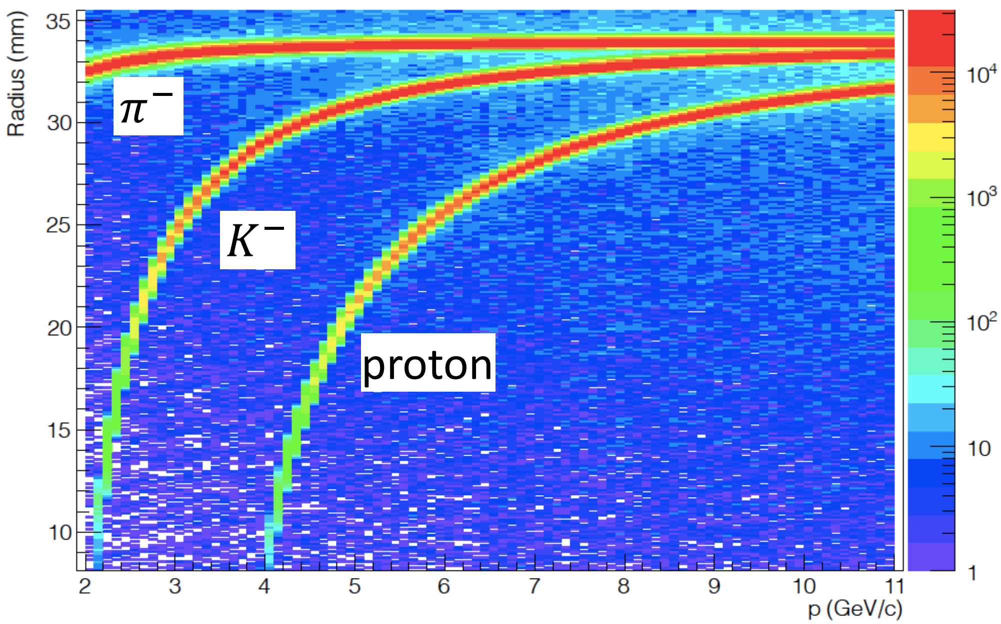
GEANT4
Simulation





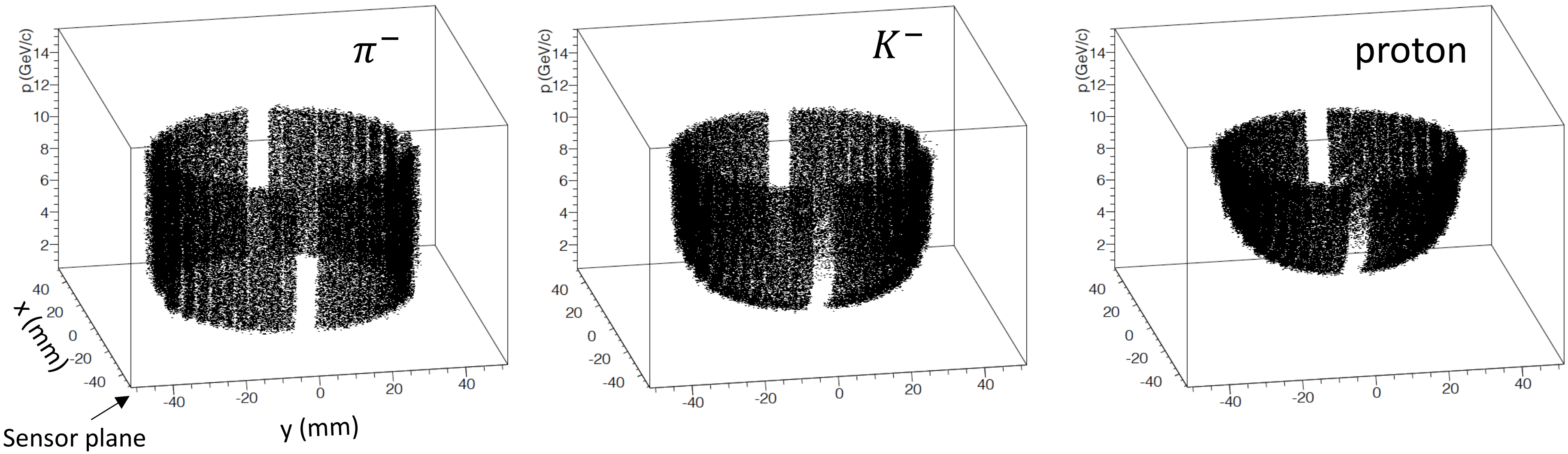
Simulation Studies / #2.c: Parameters Used

- Full GEANT4+reconstruction implementation in Fun4all framework
  - Using Babar magnet map scaled at 1.7/1.5
  - Full tracking reconstruction + projection to mRICH
  - Use 3 mm pixel size to simulate digitization + 2 photons for noise
  - No backgrounds included
  - Beyond the review: move to dd4hep (import GDML file)+JANA2 reconstruction.



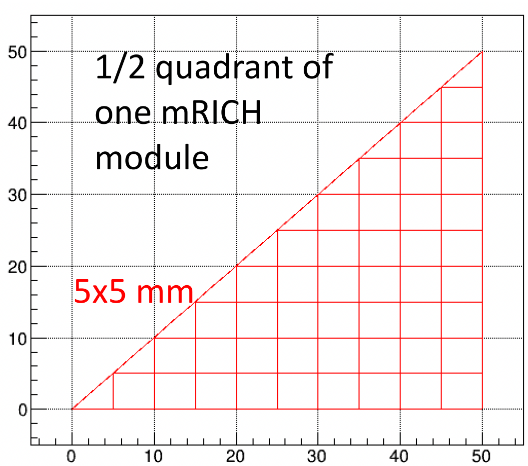
Simulation Studies / #2.c: Reconstruction Code

❖ **Log-Likelihood** method: build a DB and match patterns based on Log-Likelihood!



❖ # of unique scenarios for DB

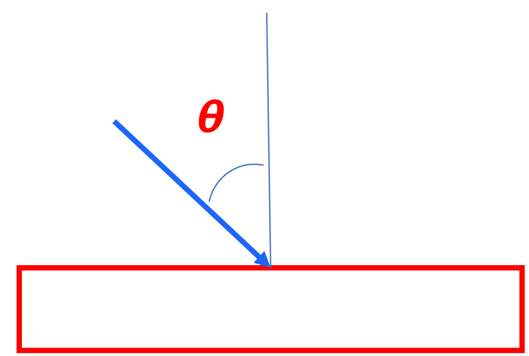
Position on Aerogel



Angle w.r.t normal on Aerogel

$-2° < \Delta\theta < 4°$

0.1° steps



Performance – #3.a&b

a. Comparison of the **present assessment of the Cherenkov PID detector performance compared with the YR requirements**?
b. Performance perspectives **beyond the YR requirements (if any)** ?

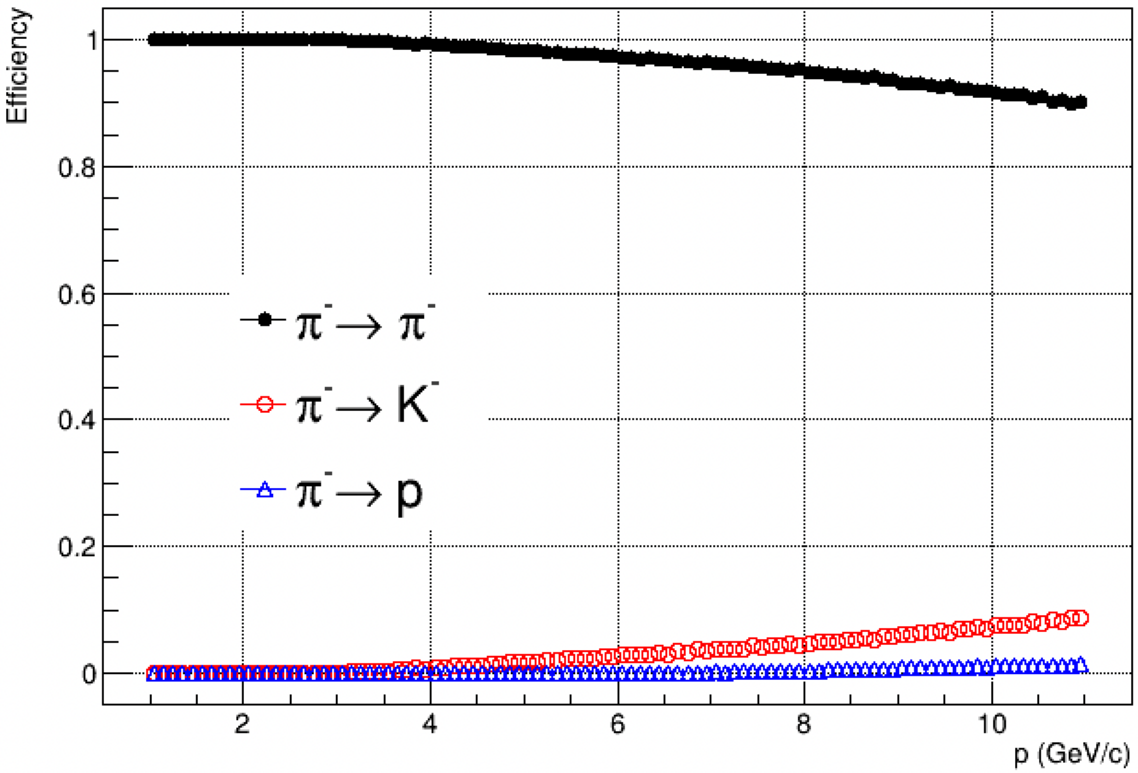
YR, Nucl.Phys.A **1026**, 122447 (2022), Table 10.6

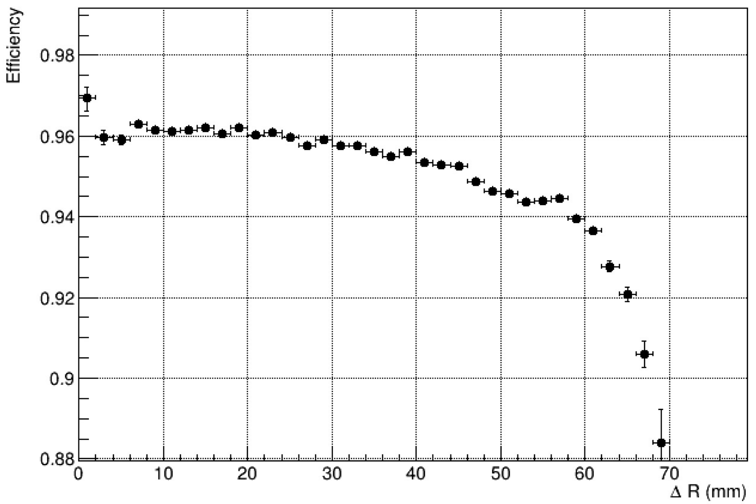
η	Nomenclature			π/K/p p-Range	π/K/p Separati
-3.5 to -3.0		Central Detector	Backward Detector	? ≤ 7 GeV/c	≥ 3 σ
-3.0 to -2.5					
-2.5 to -2.0					
-2.0 to -1.5					
-1.5 to -1.0					
-1.0 to -0.5			Barrel	≤ 10 GeV/c	
-0.5 to 0.0					
0.0 to 0.5					
0.5 to 1.0				≤ 15 GeV/c	
1.0 to 1.5			Forward Detectors	≤ 30 GeV/c	
1.5 to 2.0				≤ 50 GeV/c	
2.0 to 2.5					
2.5 to 3.0				≤ 30 GeV/c	
3.0 to 3.5				≤ 45 GeV/c	

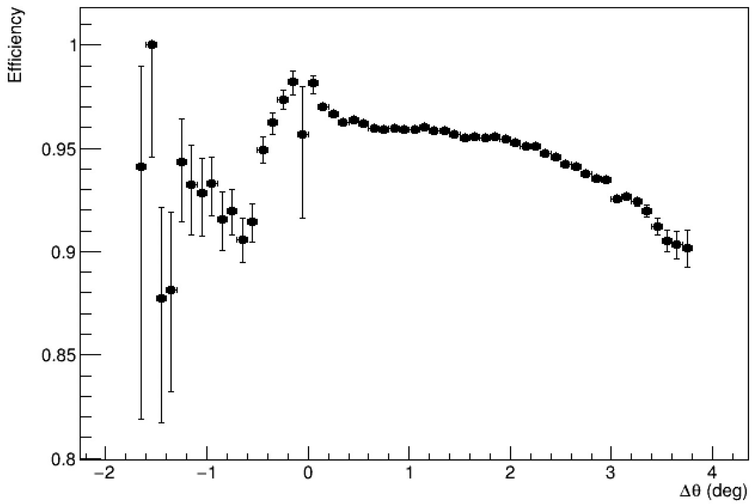
- For backward detector: $\geq 3\sigma\ \pi/K/p$ separation for $p \leq$ 8-10 GeV/c
- Beyond YR requirements:
  - K veto for p<2
  - e/π separation for p~2 GeV/c

Performance – #3.c

Efficiency figures: single particle Pi/Kaon/Proton identified as Pi/Kaon/Proton as a function of the truth momentum in a 3x3-panel figure?

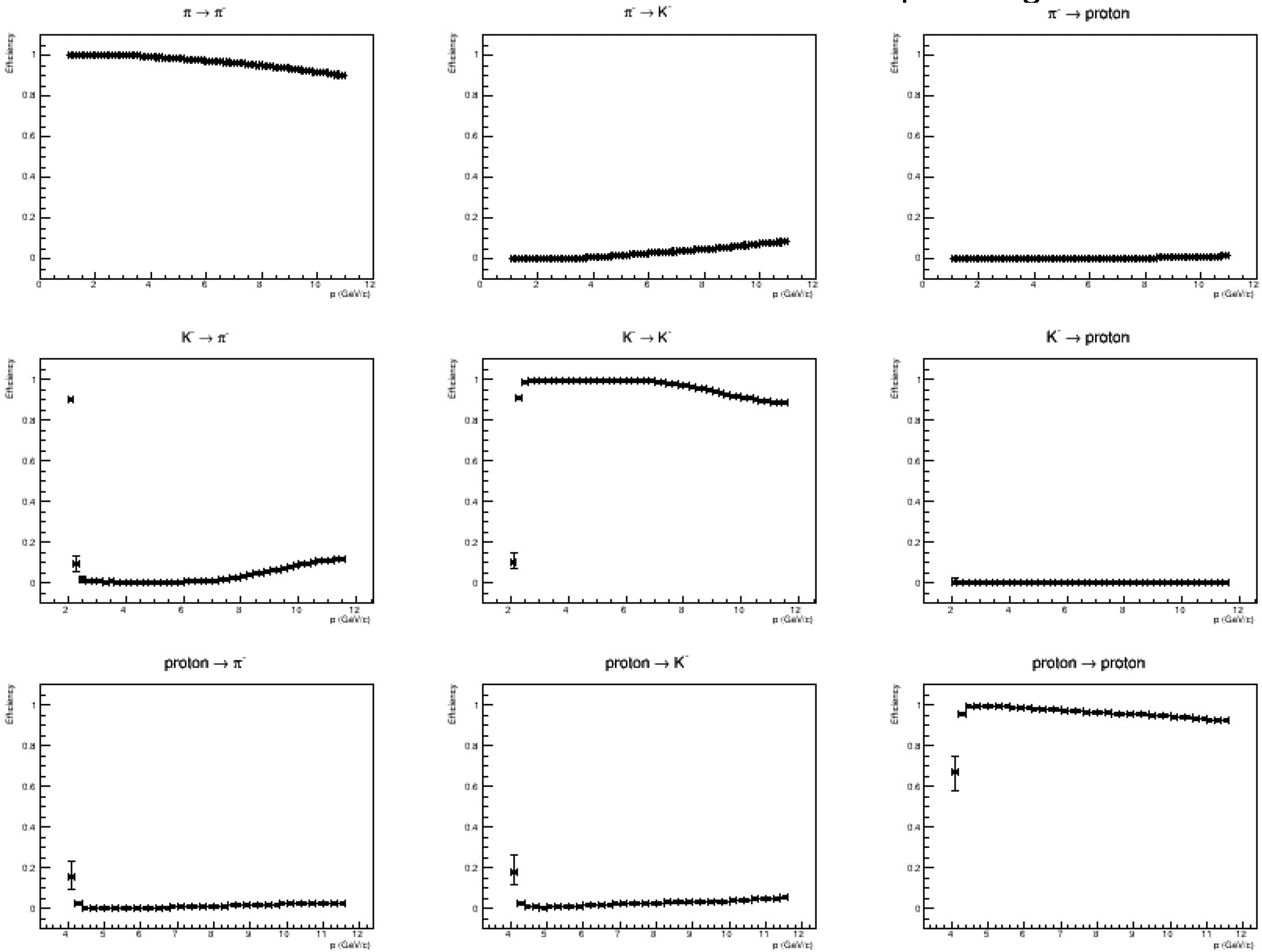






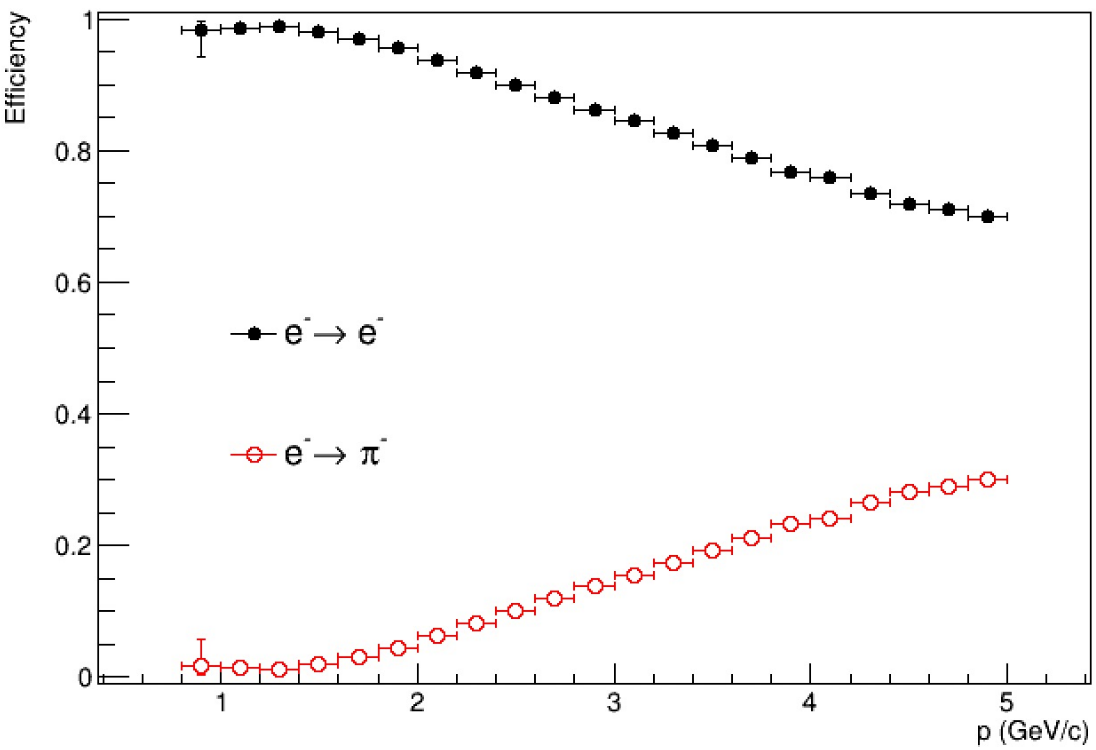
Performance – #3.c

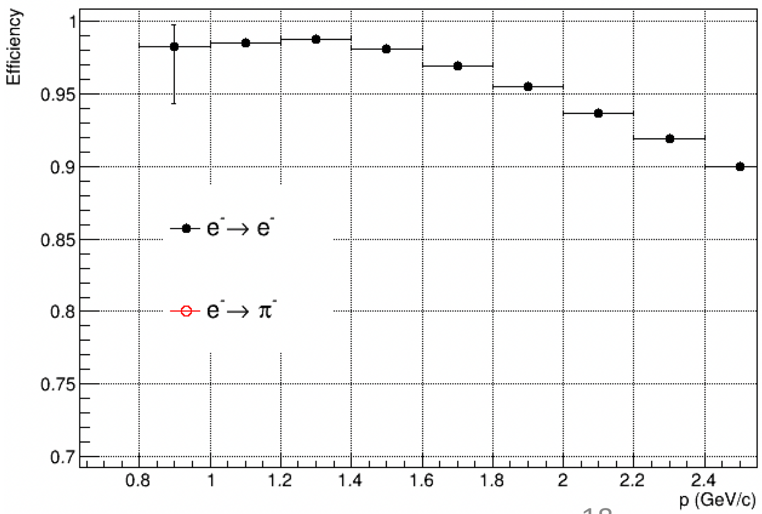
Efficiency figures: single particle Pi/Kaon/Proton identified as Pi/Kaon/Proton as a function of the truth momentum in a 3x3-panel figure?



Performance – #3.d

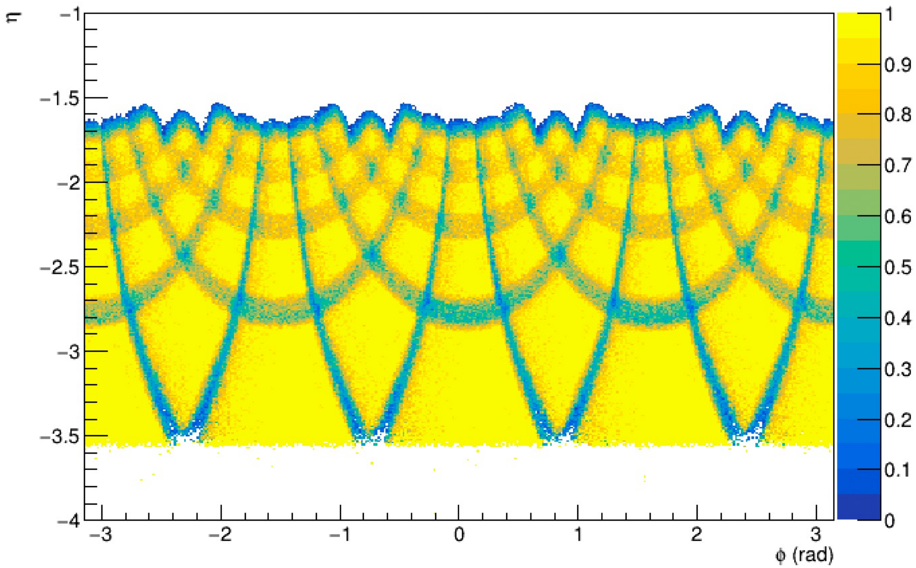
Please quantify the performance for electron/hadron separation

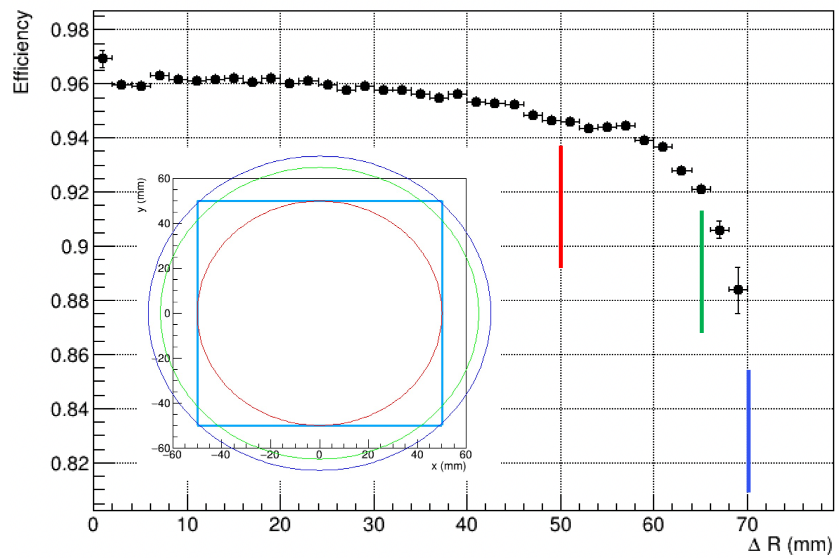


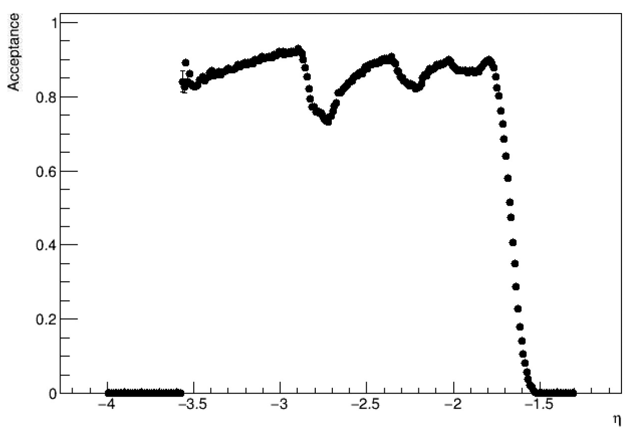


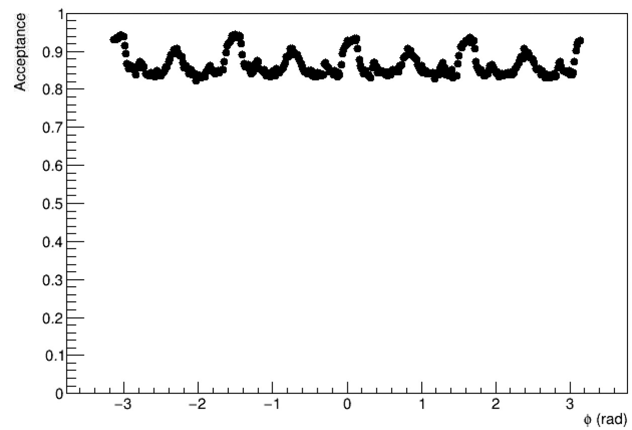
Performance – #3.e

Active area or /dead area as 2D function of eta and phi; and comment on the edge effects?



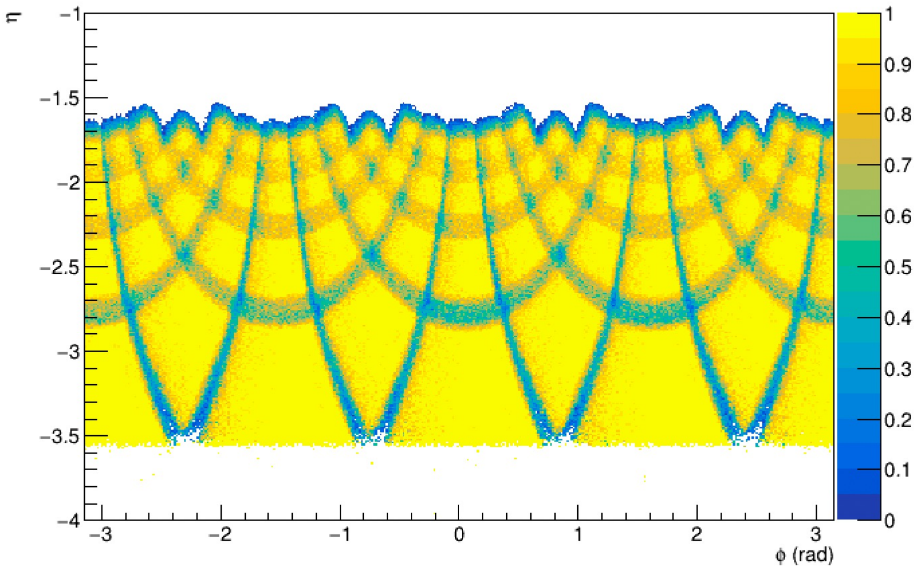


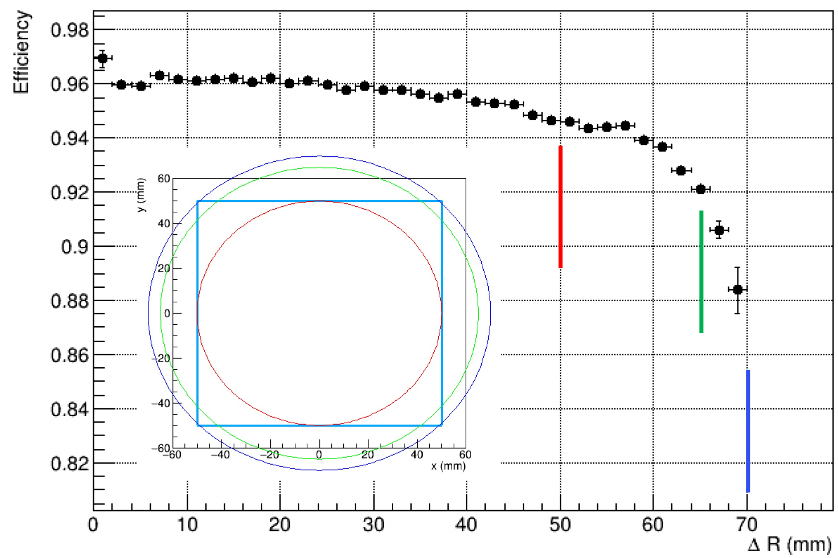


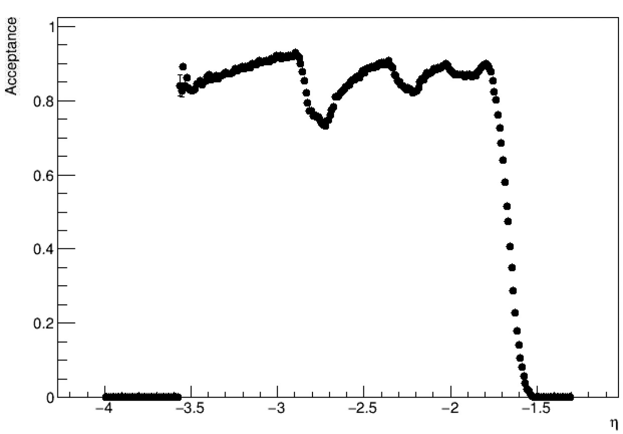


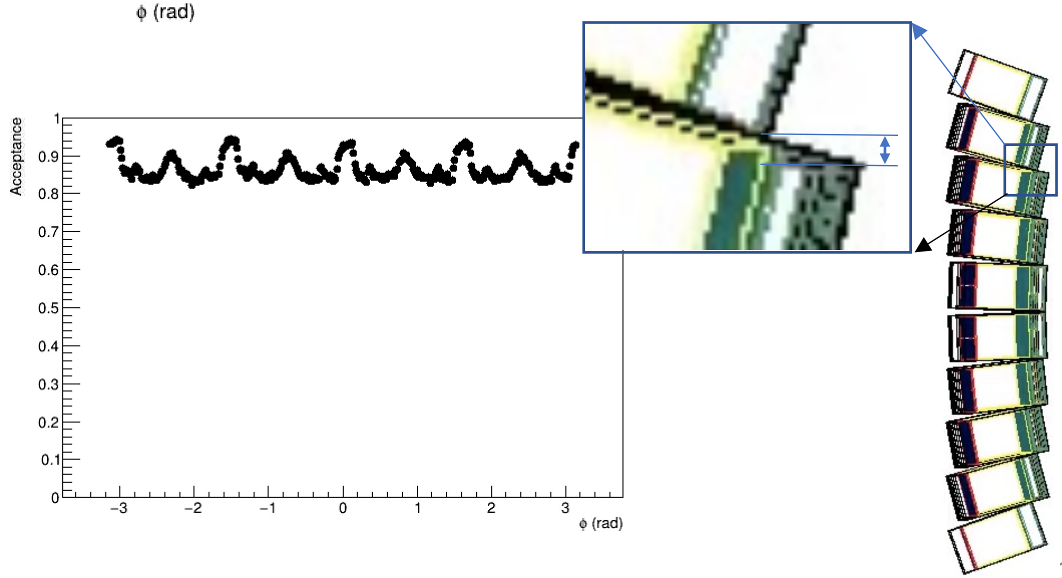
Performance – #3.e

Active area or /dead area as 2D function of eta and phi; and comment on the edge effects?



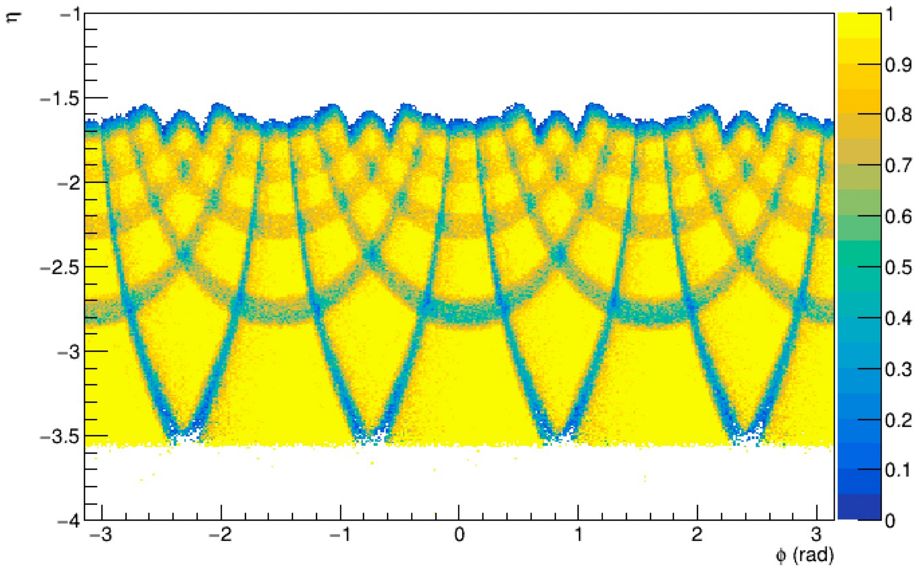


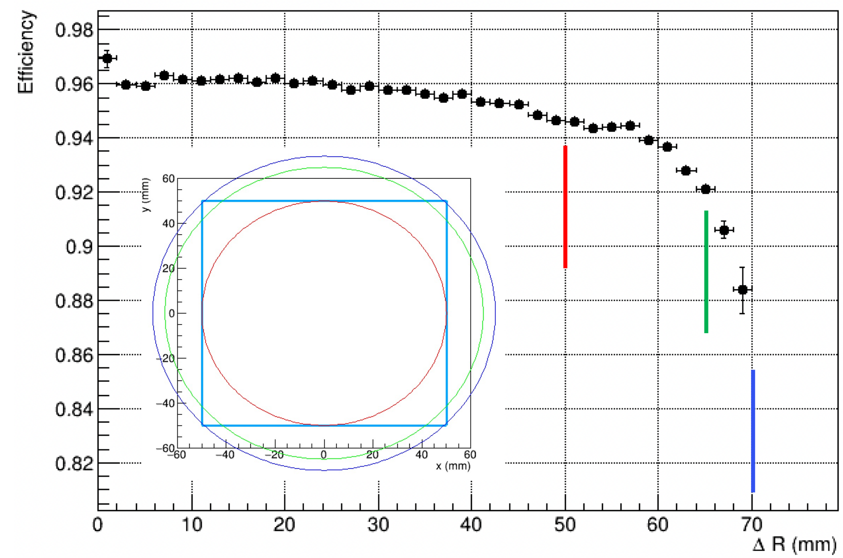


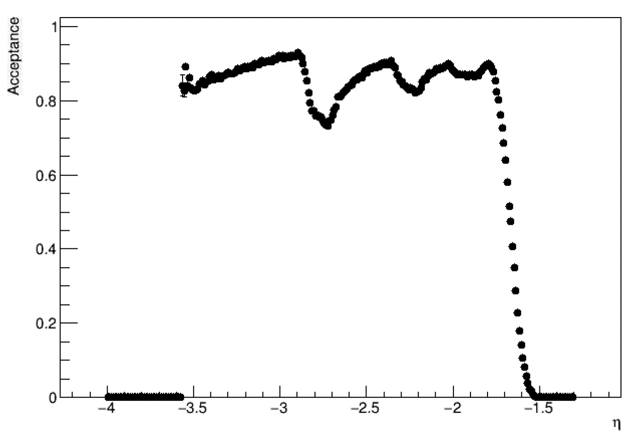


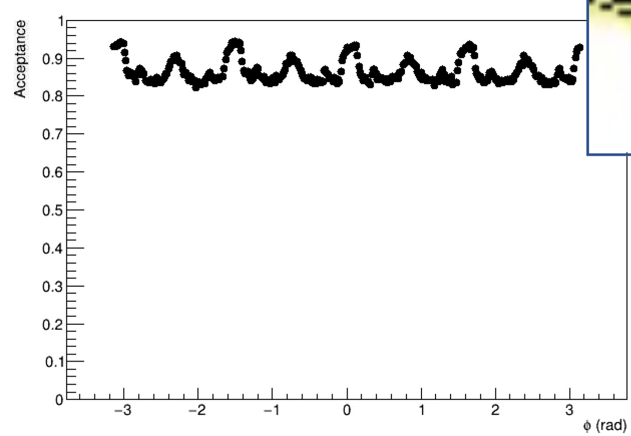
Performance – #3.e

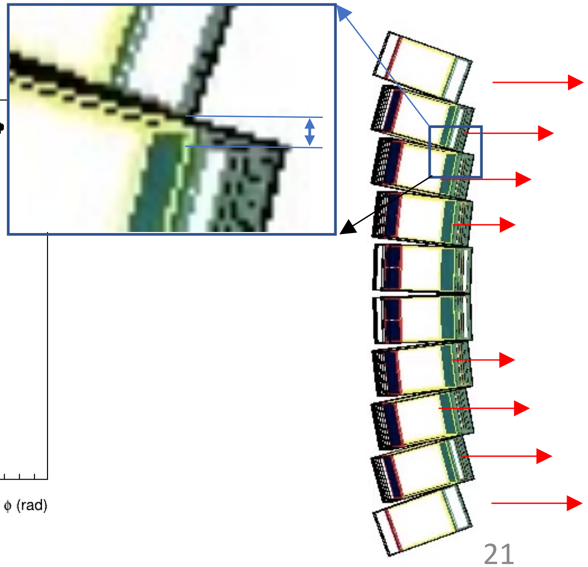
Active area or /dead area as 2D function of eta and phi; and comment on the edge effects?







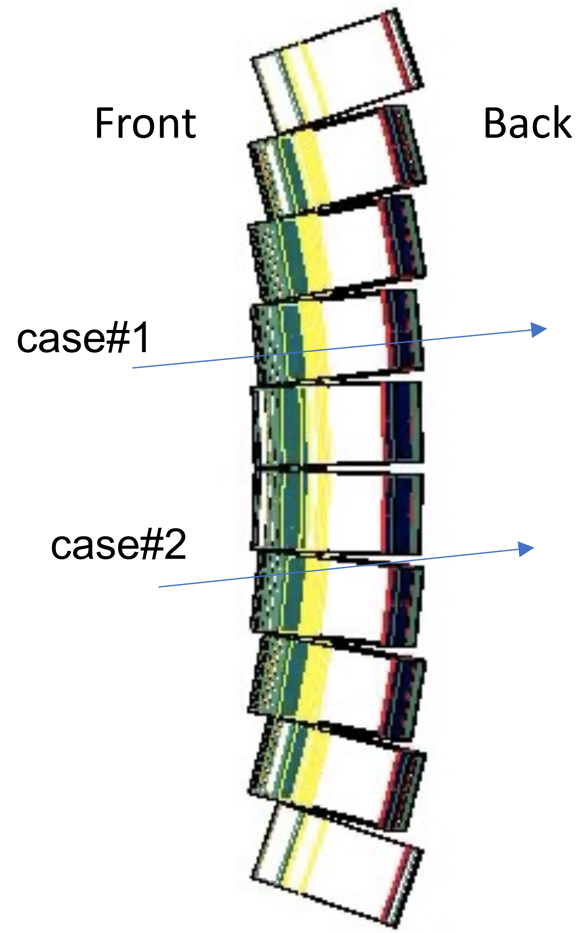




Performance – #3.f

Performance or potential as timing detector, providing both timing resolution and acceptance coverage in eta and phi.

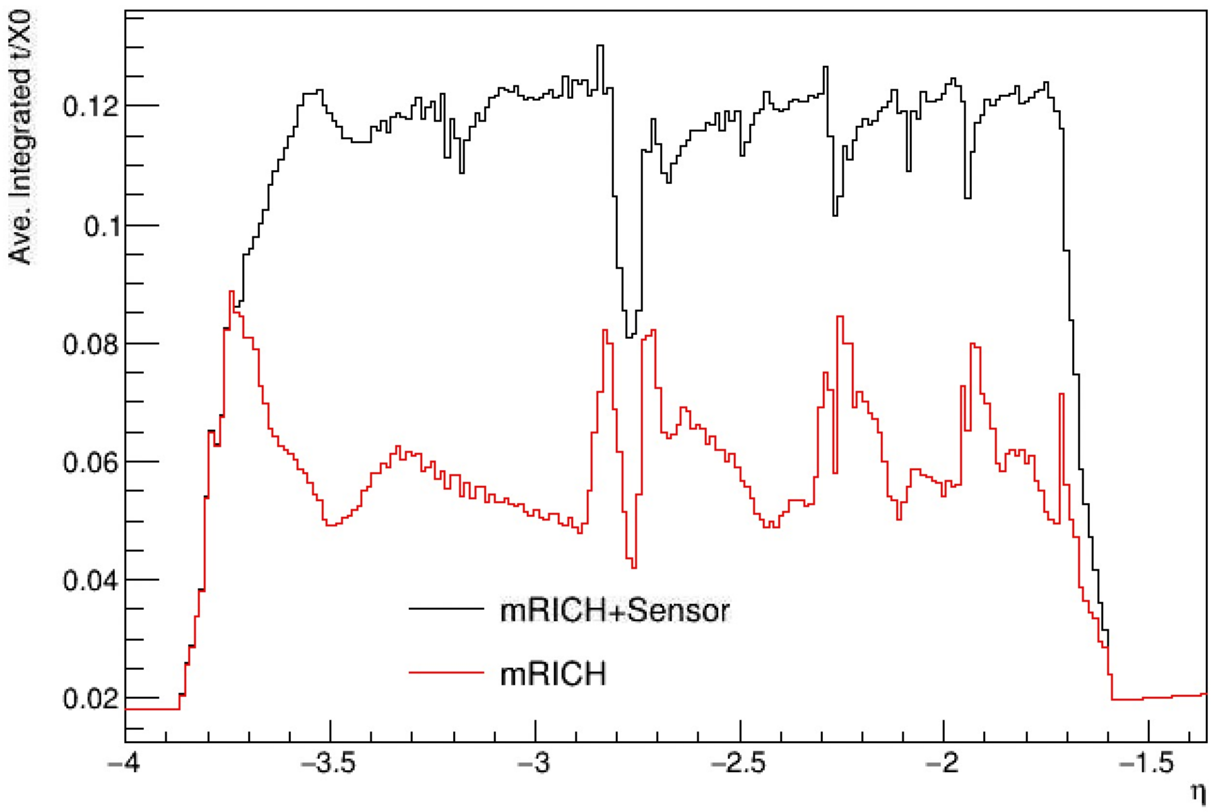
- Assuming HRPPD sensors, the active area will be the acceptance of mRICH discussed in 3#e.
- While the HRPPDs don't form a full coverage in the back plan, each e- will produce photons on the sensor – giving a timing signal.
- Have 2 classes of events:
  - Case#1: electrons that produce Cherenkov photon and hit the HRPPD
  - Case#2: electrons that produce Cherenkov photon
  - The first group is used to calibrate the second one



Integration – #6.a-ii

Material effect to backward EMCal: in coordination with the calorimeter DWG, produces electron line-shape in the backward EMCal with the proposed RICH detector in front.

Assuming 5 mm Quartz window and 9 mm ceramic.



Summary & Outlook

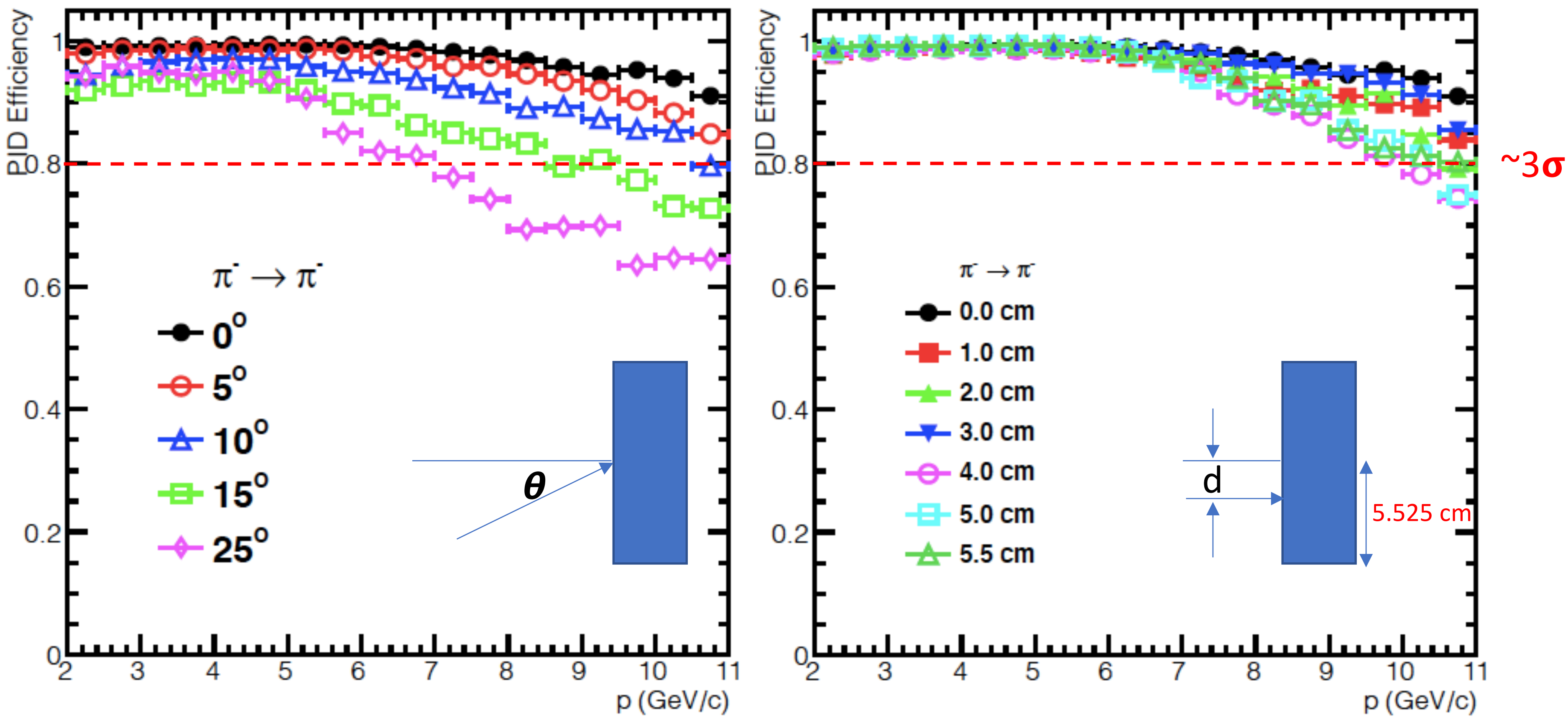
- mRICH fulfils YR Pi/Kaon/Proton PID requirement and exceeds that by providing veto for Kaons below 2 GeV/c and e/pi separation up to 2 GeV/c.
- The performance was demonstrated with simple pattern matching algorithm that can be further developed to enhance the performance – involve machine learning!

- Future:
  - Create a GDML file of mRICH for dd4hep and import the current PID reconstruction algorithm to JANA2.
  - Involve more students & postdocs in the simulation and software

Thank You

mRICH PID Performance: $^{\pi^-}/_{K^-}$

- Construction code output: $\mathcal{L}_\pi, \mathcal{L}_K, \mathcal{L}_p$
- $\pi^- \to \pi^-: \mathcal{L}_\pi - \mathcal{L}_K > 0 \&\& \mathcal{L}_\pi - \mathcal{L}_p > 0$



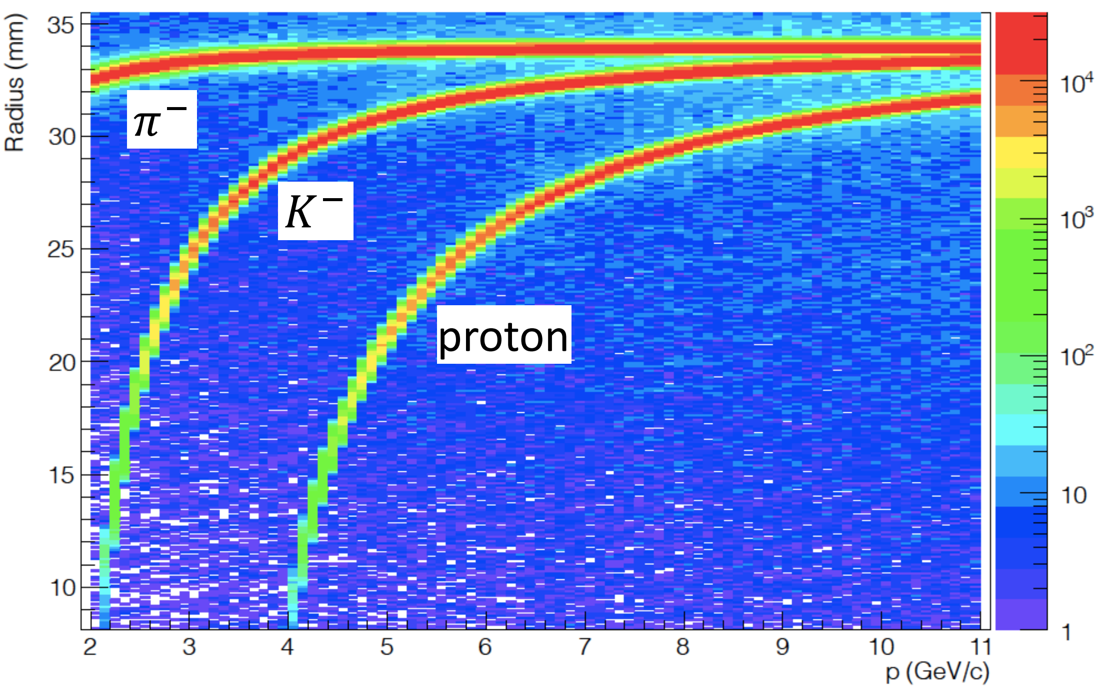
- Efficiency drops beyond 15°
- When incident perpendicular no impact even at the edge of the Aerogel

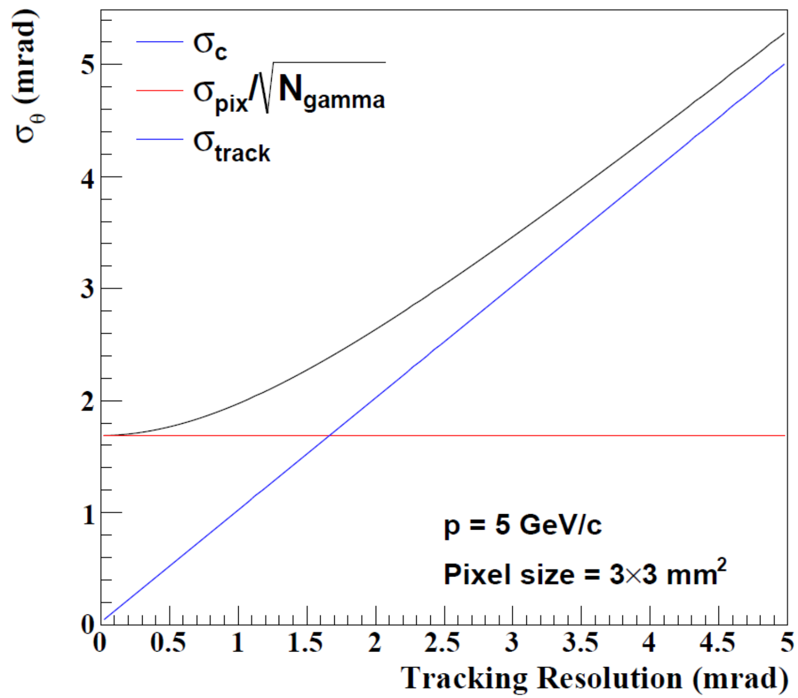
➡ Projective setup is preferable!

Reconstruction/ PID

Focusing on a single module for performance studies!

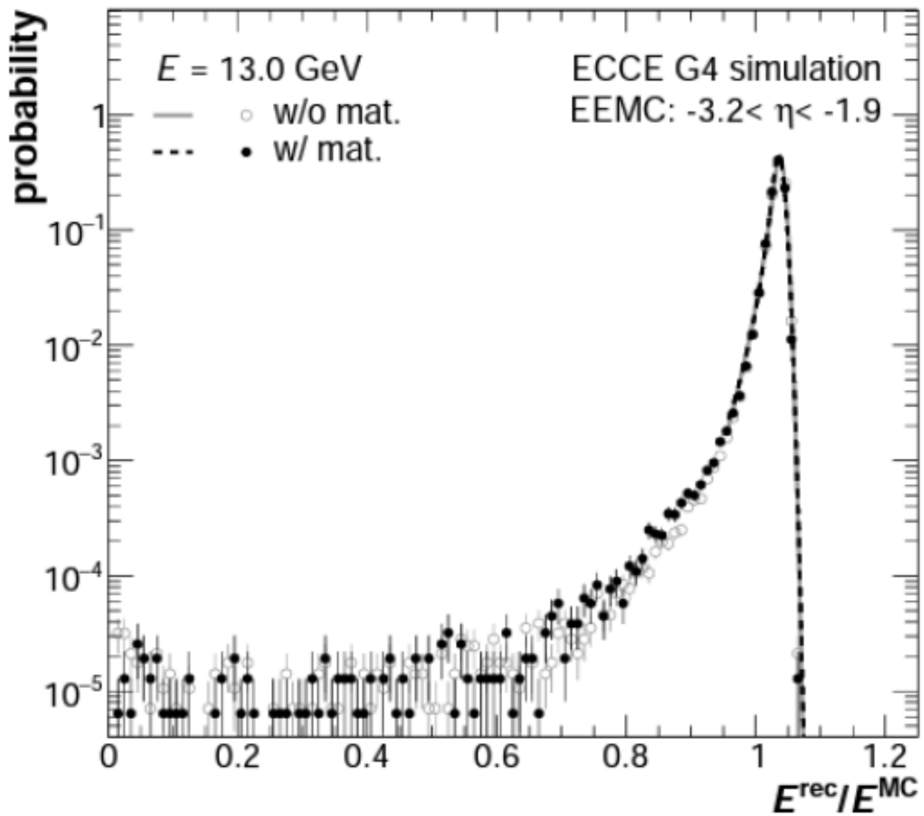
❖ Ring radius without considering the sensor pixelization!

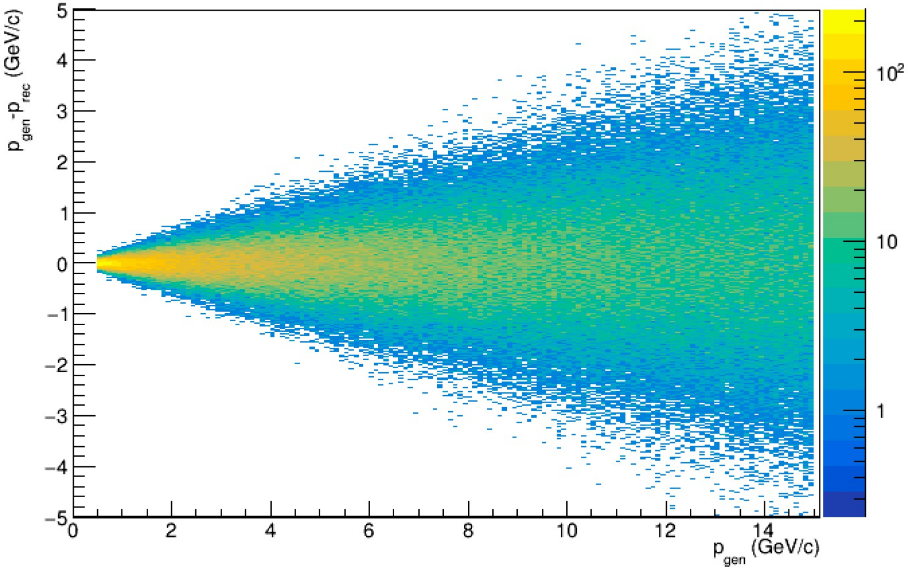




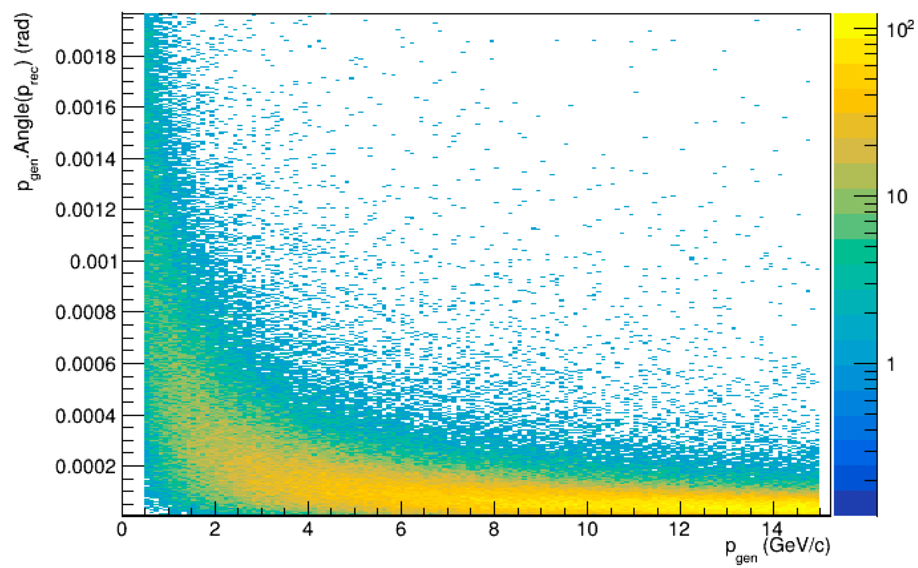
Integration – #a.i

Material effect to backward EMCal: in coordination with the calorimeter DWG, produces electron line-shape in the backward EMCal with the proposed RICH detector in front.





$p_{gen}-p_{rec}$ (GeV/c)
p_{gen} (GeV/c)



p_{gen}.Angle(p_{rec}) (rad)
p_{gen} (GeV/c)