Compact, Projective and Modular Ring Imaging Cherenkov (mRICH) Detector for Particle Identification in EIC Experiments

Xiaochun He
Georgia State University

For the EIC PID Consortia
(eRD14 Collaboration)

Compact, Projective and Modular Ring Imaging Cherenkov (mRICH) Detector for Particle Identification in EIC Experiments

Outline

- What is mRICH?
- What is it used for?
- Ongoing development
- Road to Electron-Ion Collider

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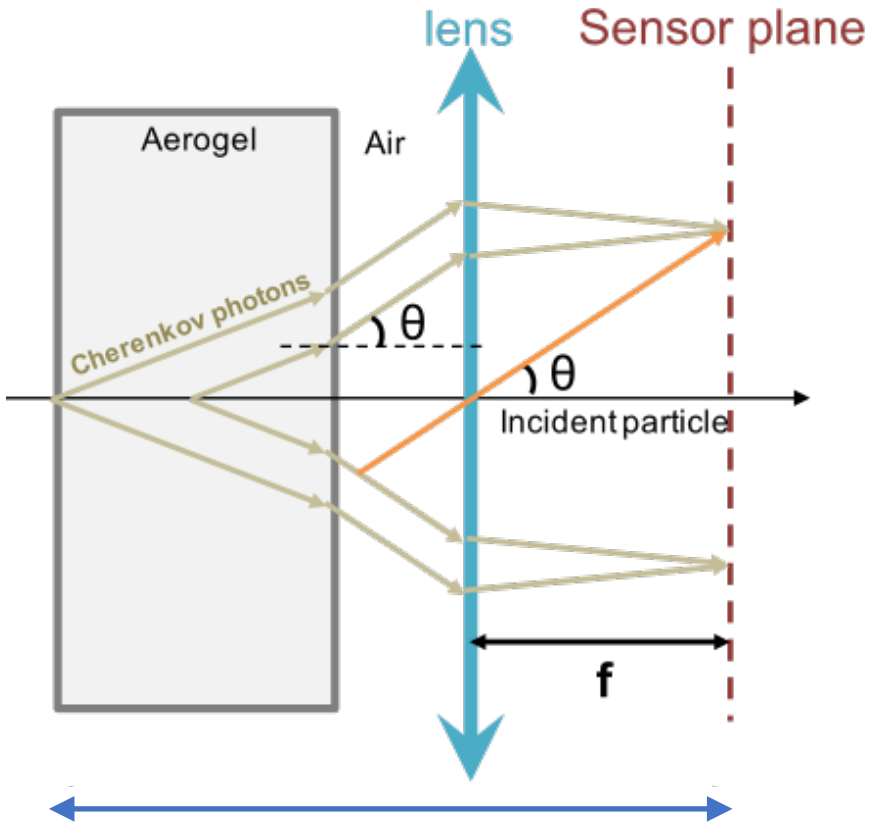
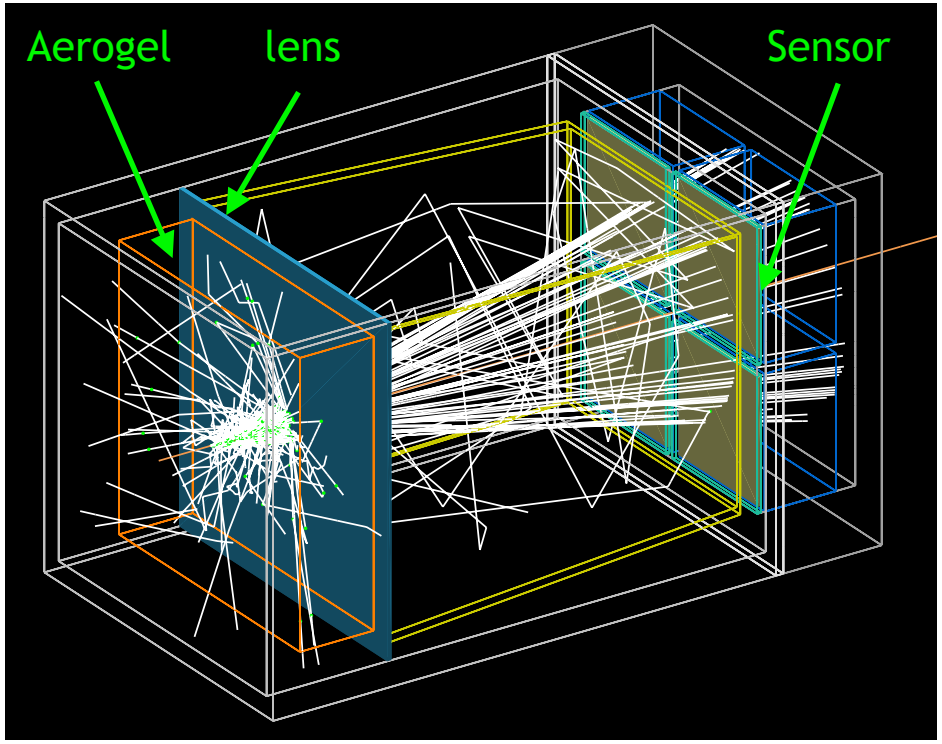
mRICH – Working Principle



~ (aerogel thickness + lens focal length)

Not to scale

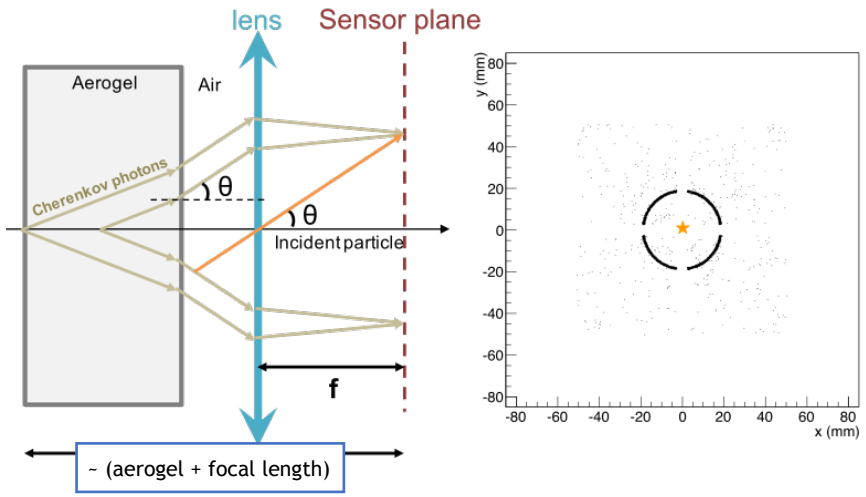


Geant4 Simulation

mRICH – lens-based focusing aerogel detector design

Smaller, but thinner ring improves PID performance and reduces length

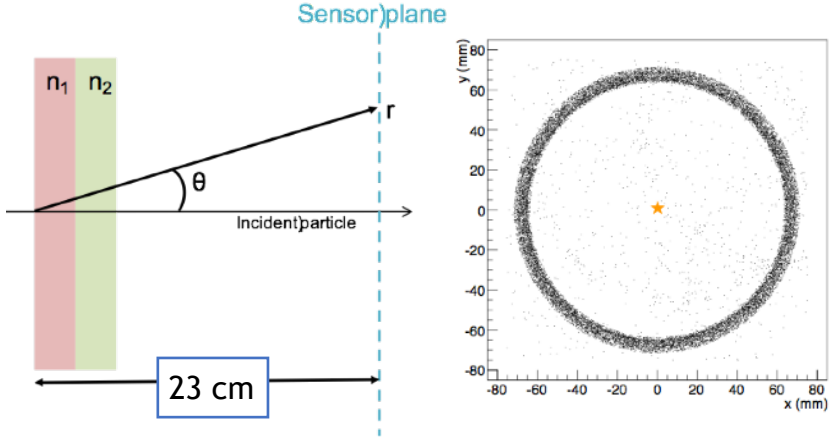
Lens-Based mRICH Design



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

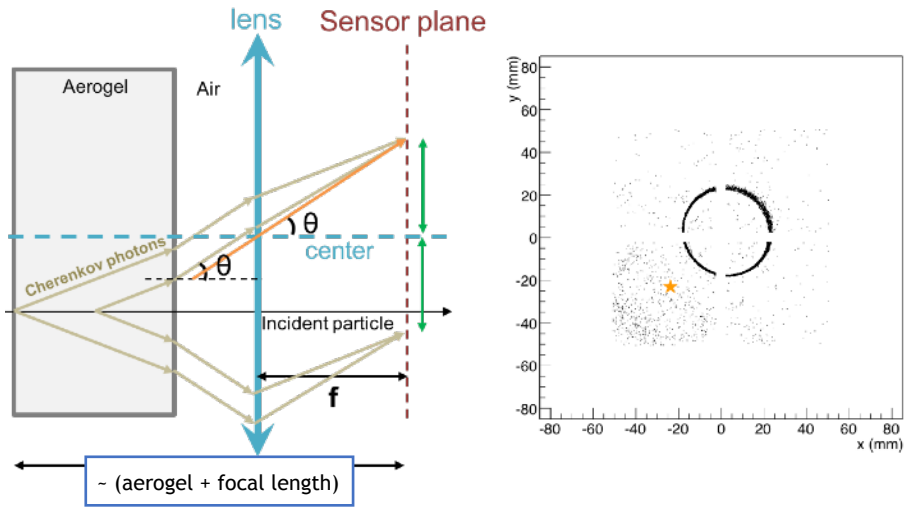


- EIC mRICH designed for K/pi ID up to 9 GeV/c
- BELLE-2 ARICH aims to separate pion and kaon up to 4 GeV/c

mRICH – lens-based focusing aerogel detector design

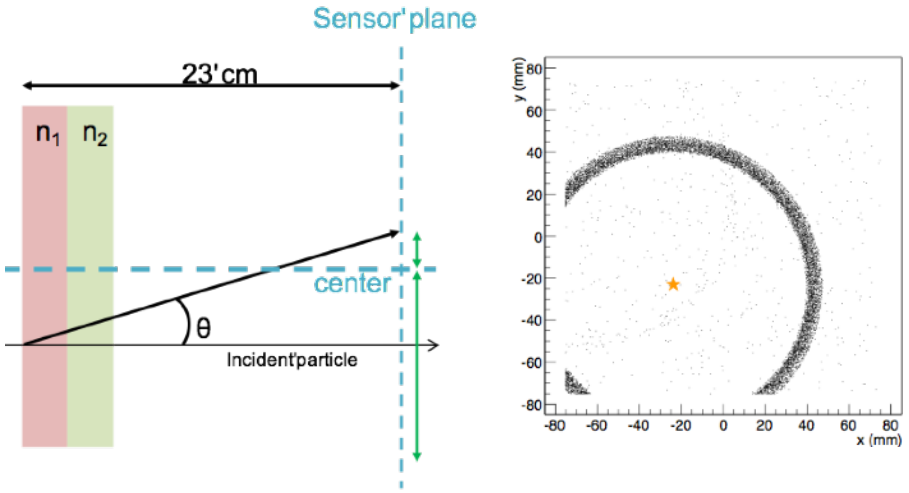
Smaller, but thinner ring improves PID performance and reduces length

Lens-Based mRICH Design



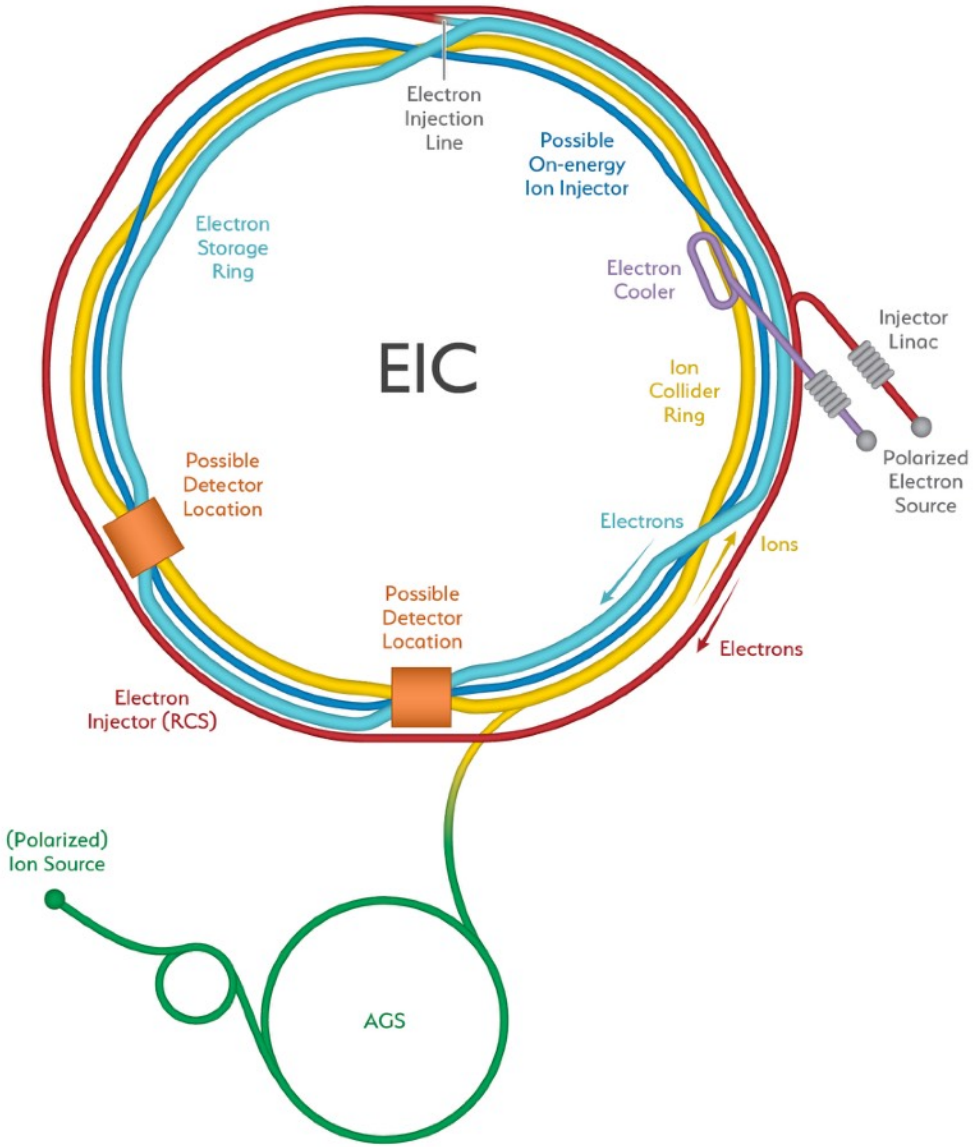
- 9 GeV/c pion beam incident at third quadrant (star) in simulation
- Ring image is **shifted toward the central region** on the sensor plane

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

Electron-Ion Collider Needs mRICH for Particle Identification



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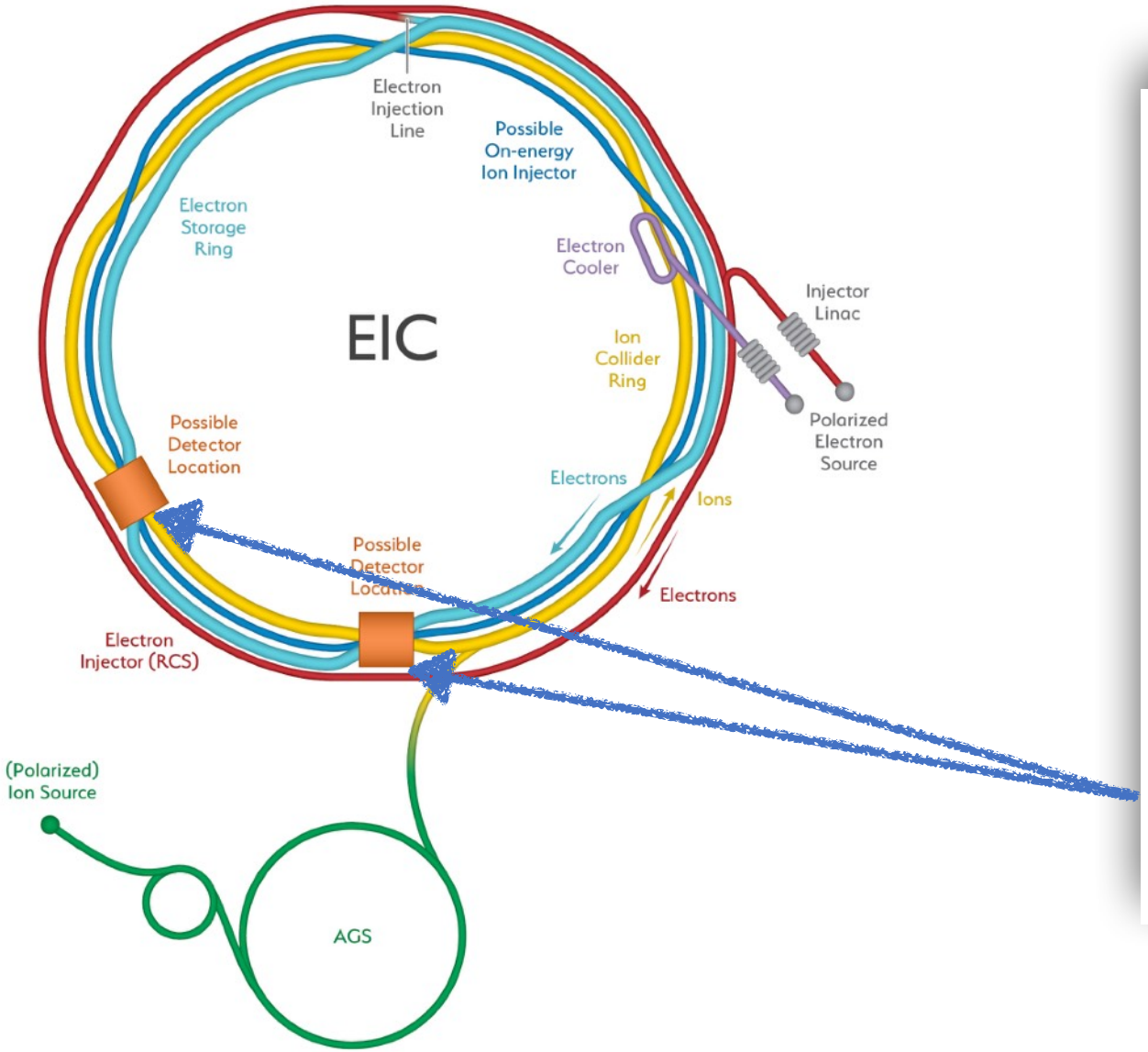

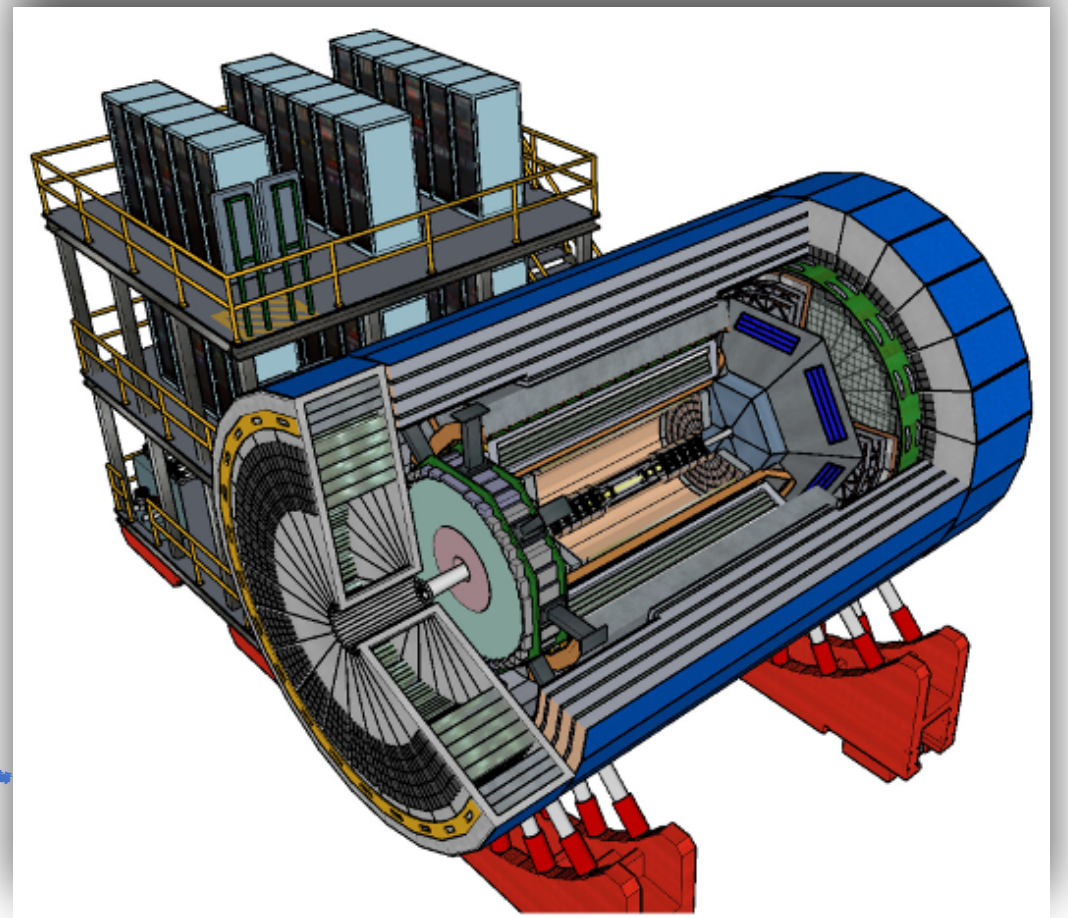

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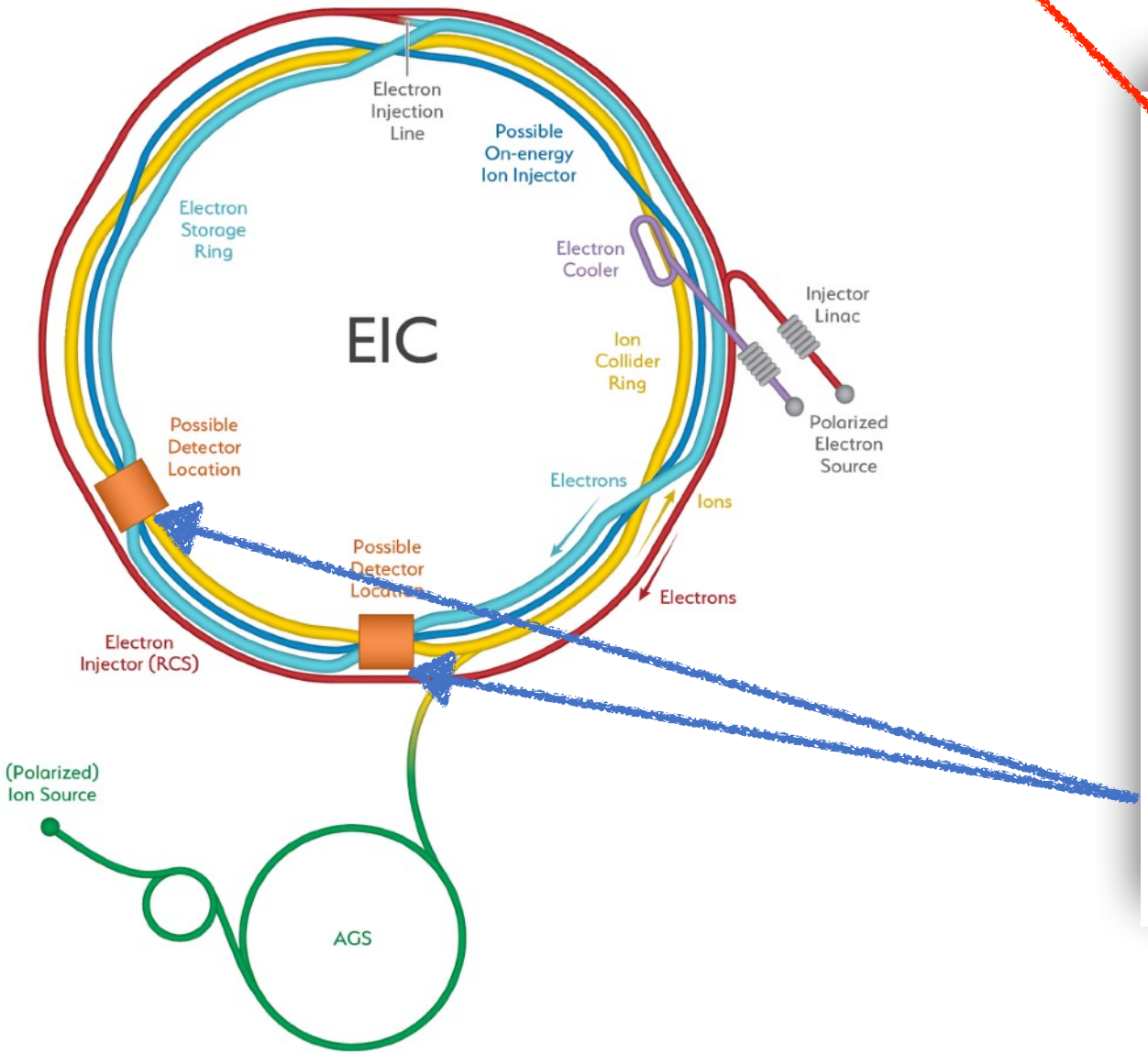

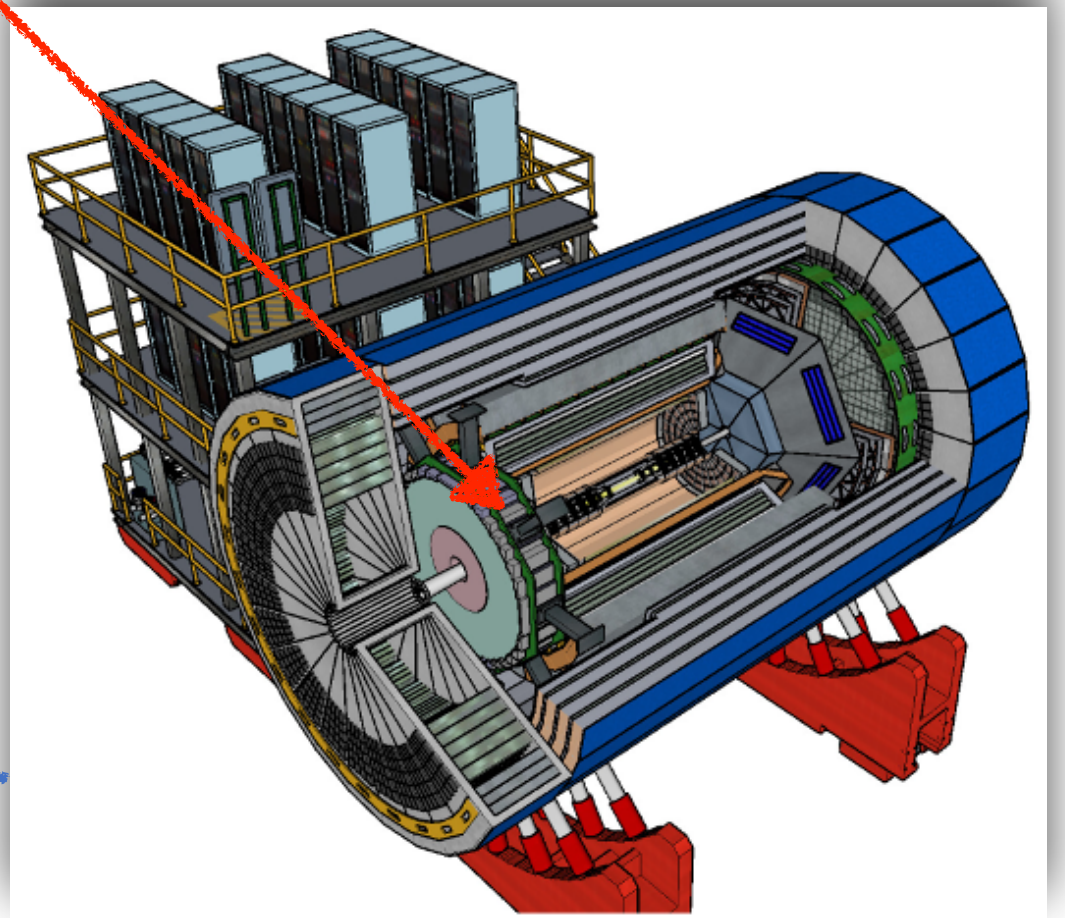

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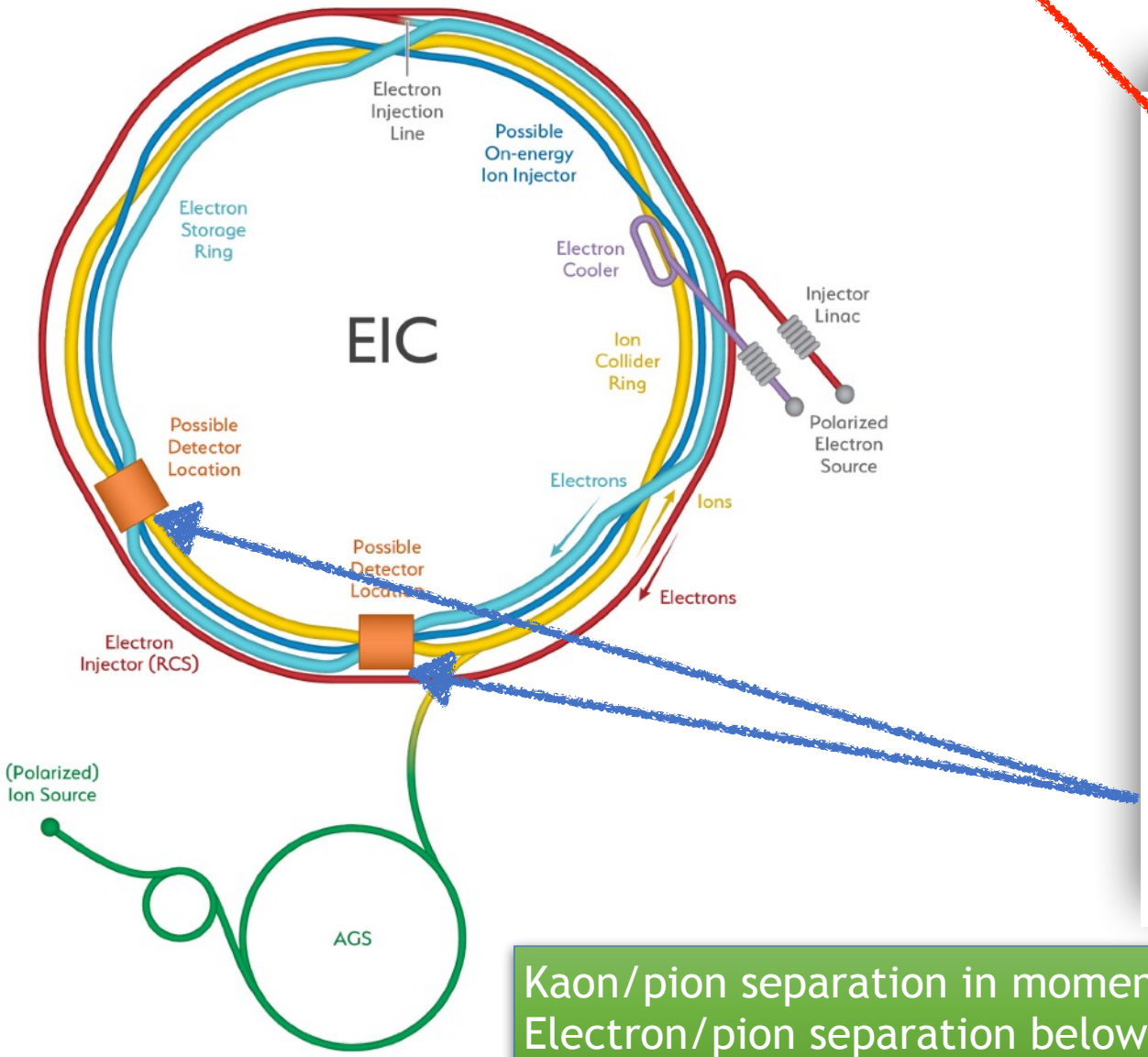
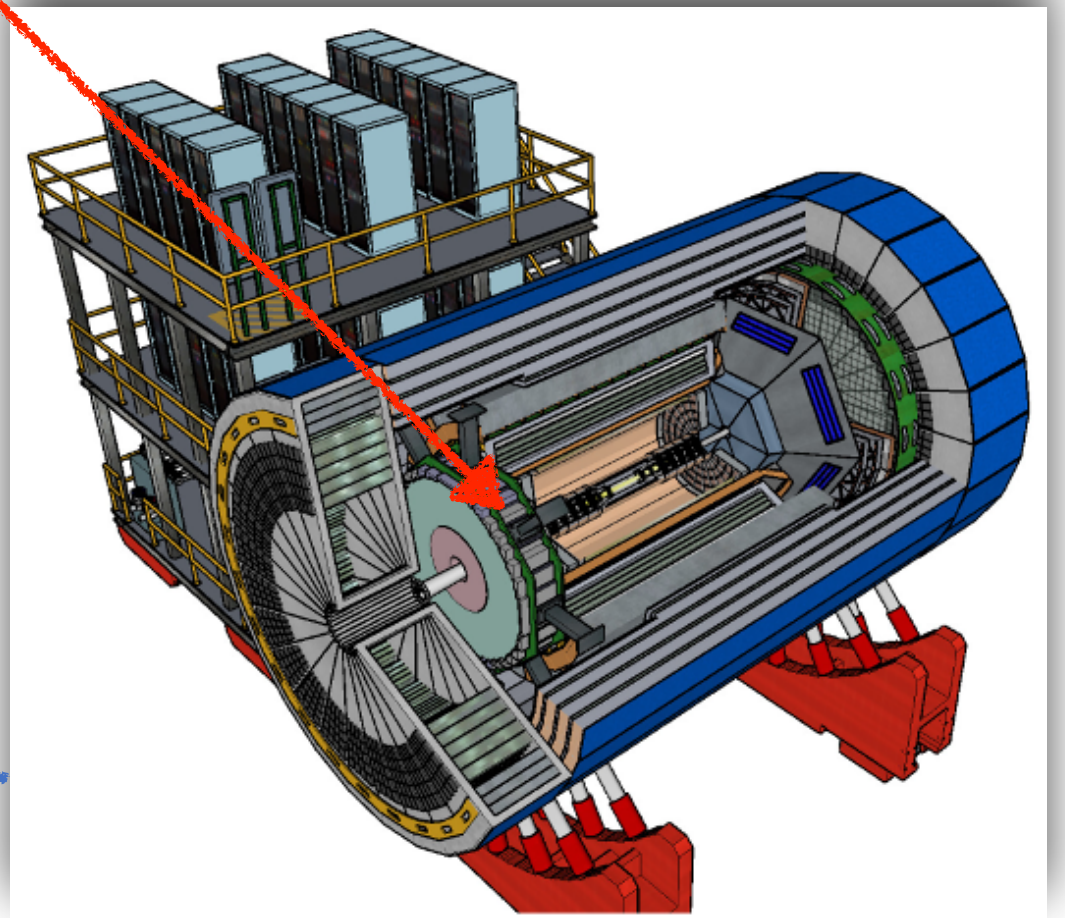
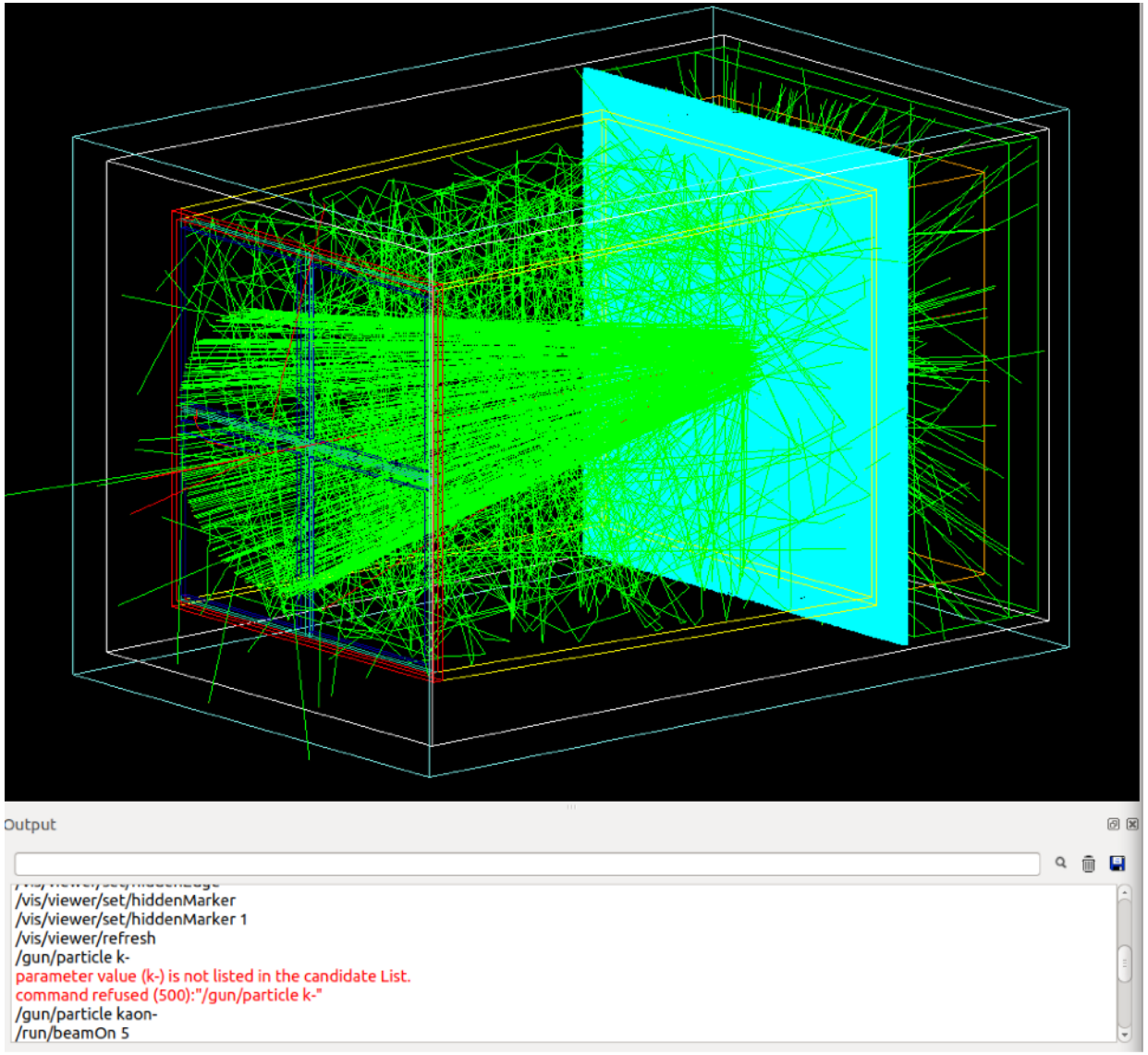


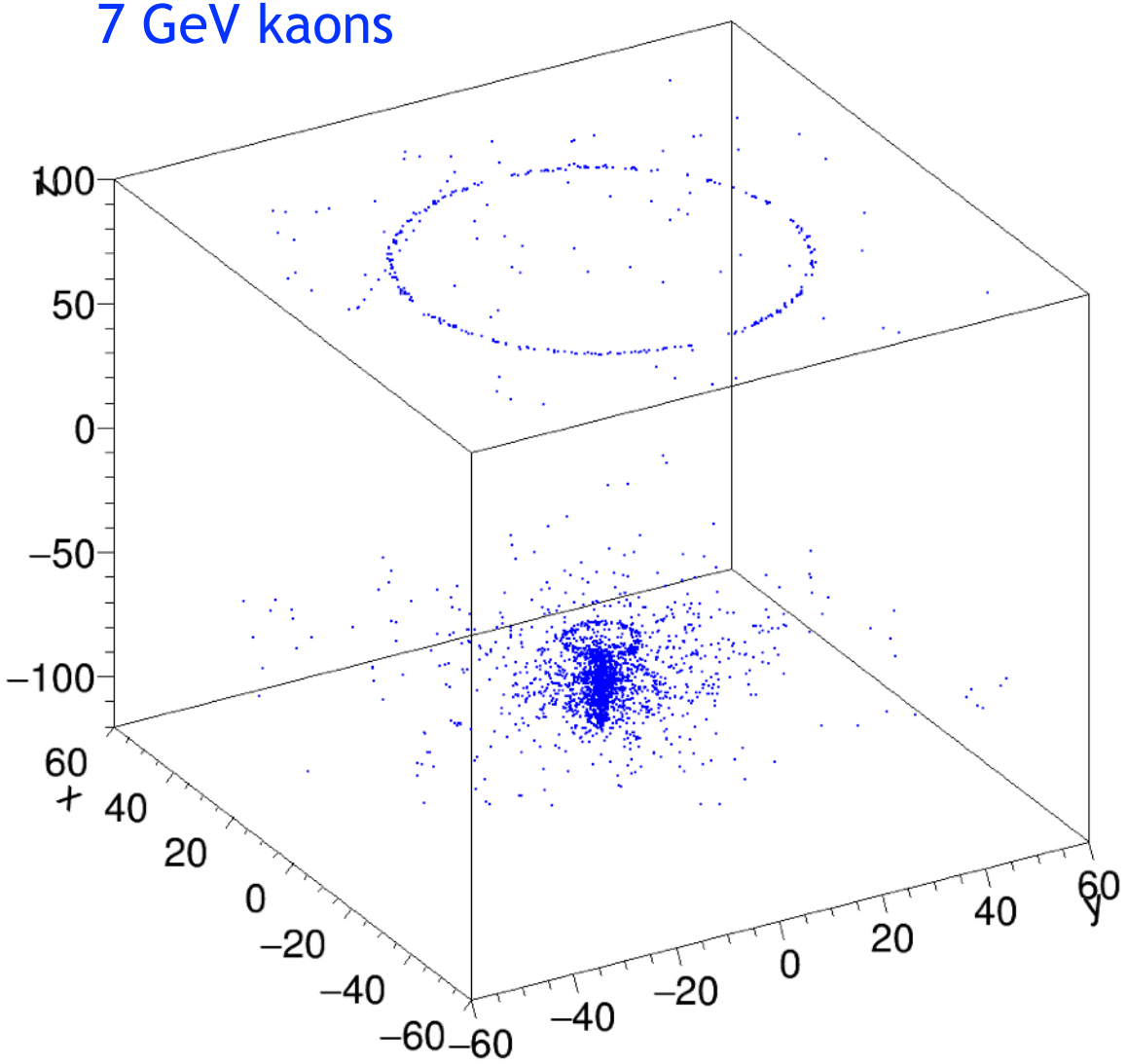


Kaon/pion separation in momentum range from 3 to 10 GeV/c
Electron/pion separation below 2 GeV/c

GEANT4-based mRICH Simulation

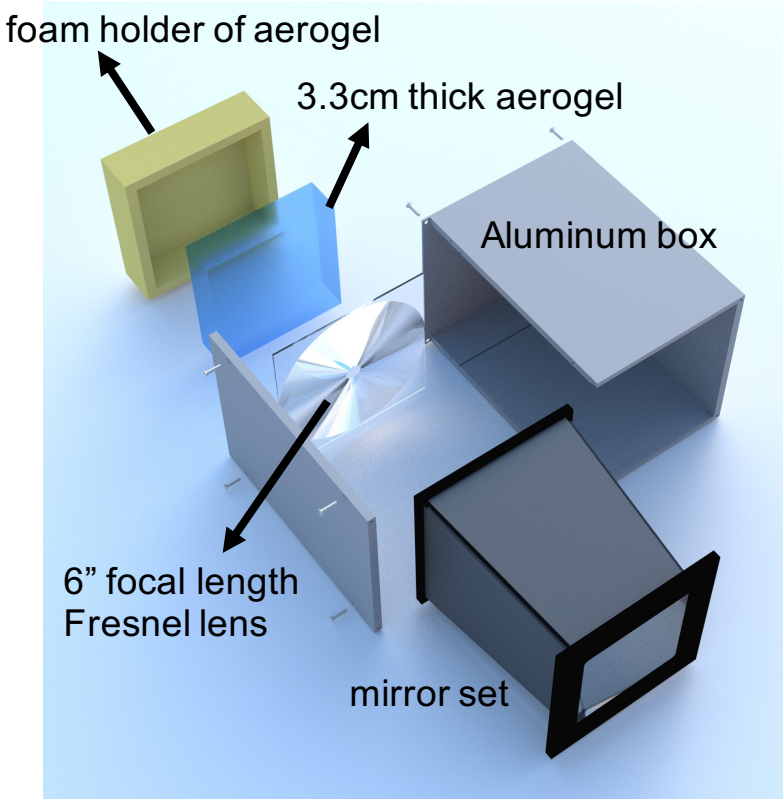


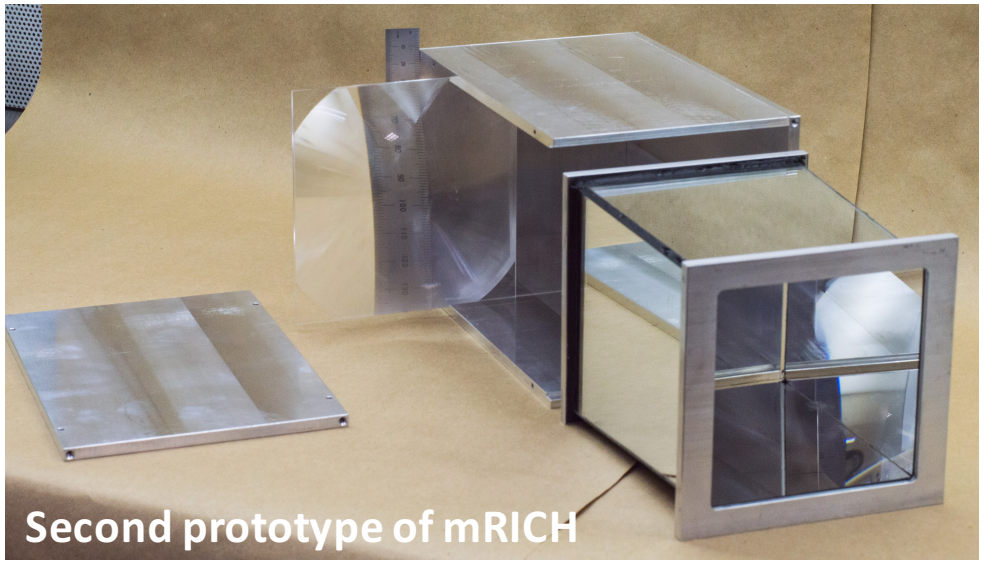
7 GeV kaons



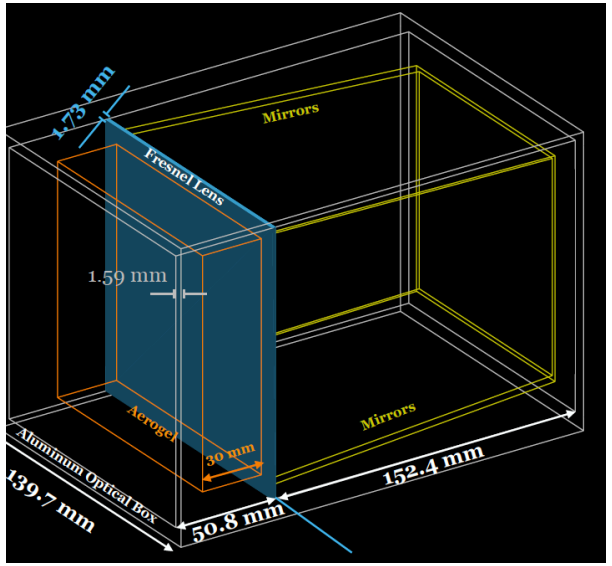
Prototyping & Beam Tests

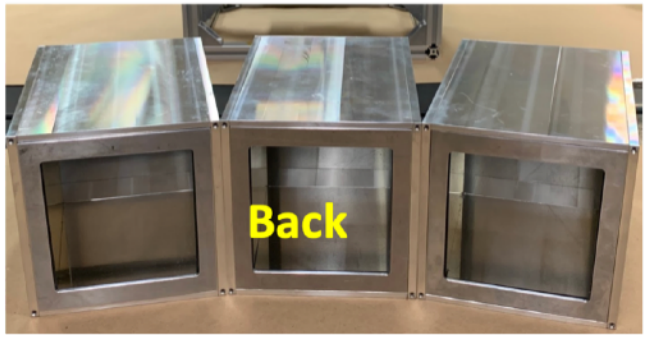
- Two beam tests: 2016 and 2018. The results from the 1st beam test have been published (C.P. Wong et. al. **NIM A871 (2017) 13-19).**
- Two more tests are planned in 2021.

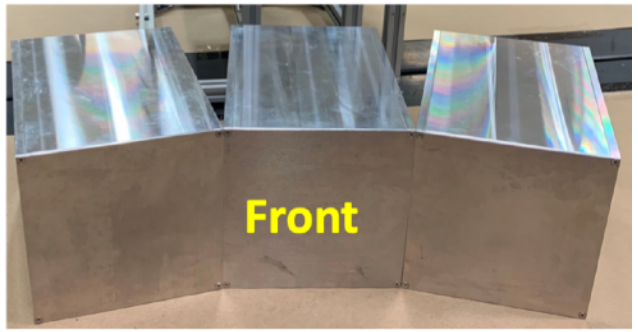




Dimension (from GEANT4 simulation)

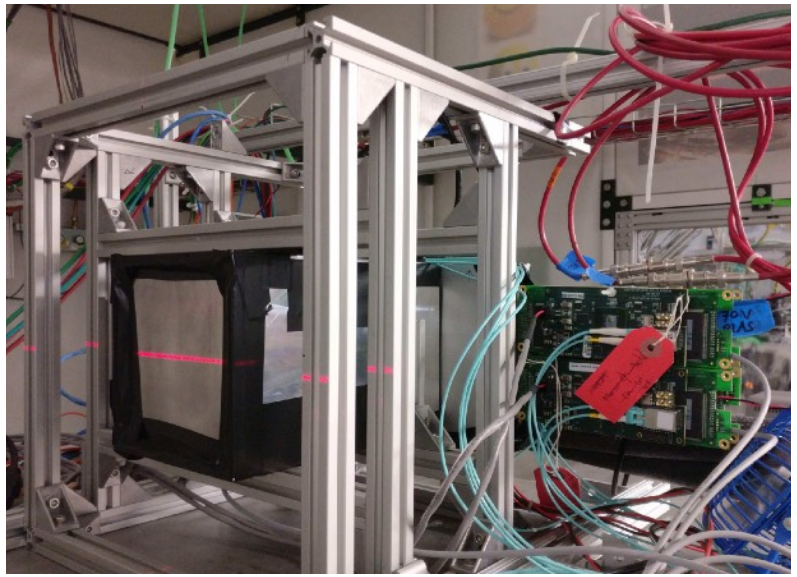


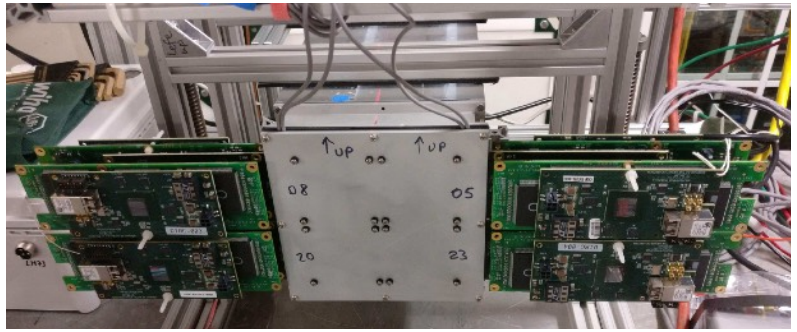




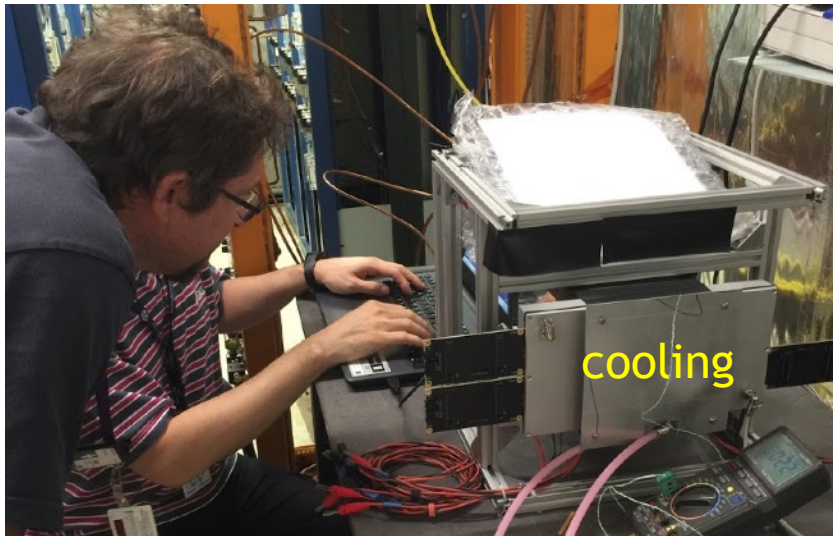
The separation of the optical and electrical components in the improved mRICH design allows us to test different photosensors

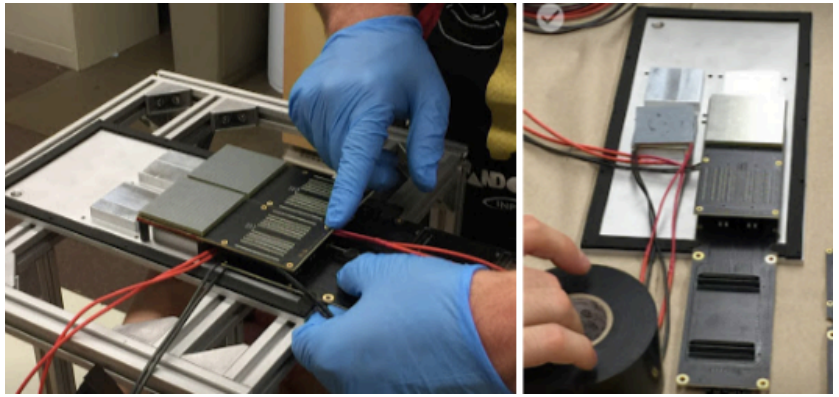
Using four H13700 Multi-anode PMTs





Using three Hamamatsu SiPM Matrices





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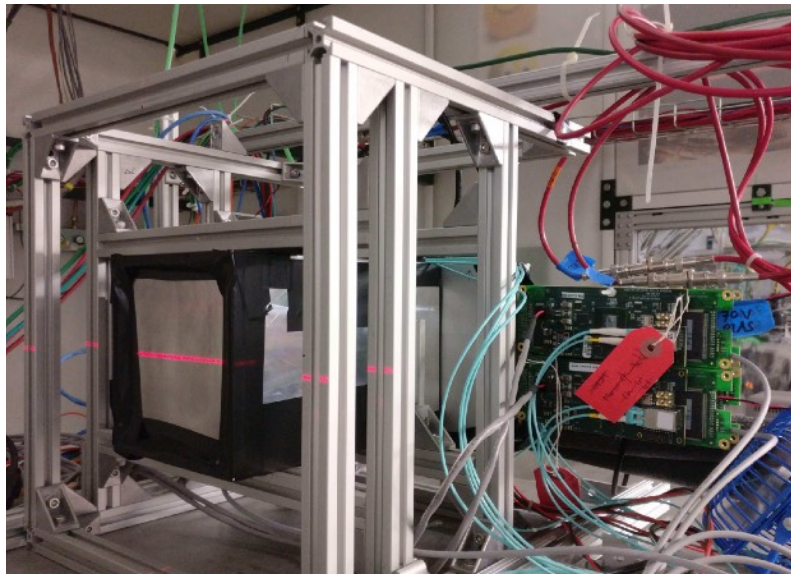
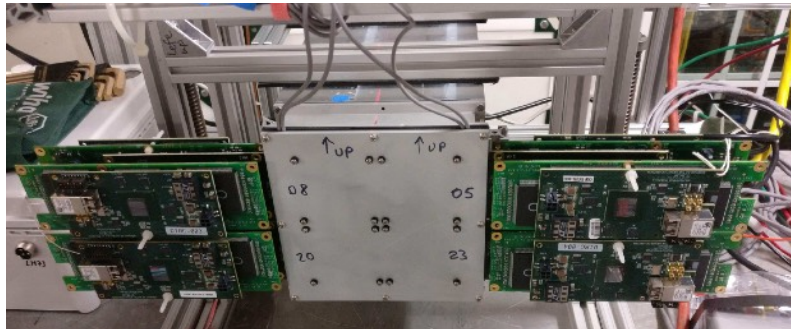
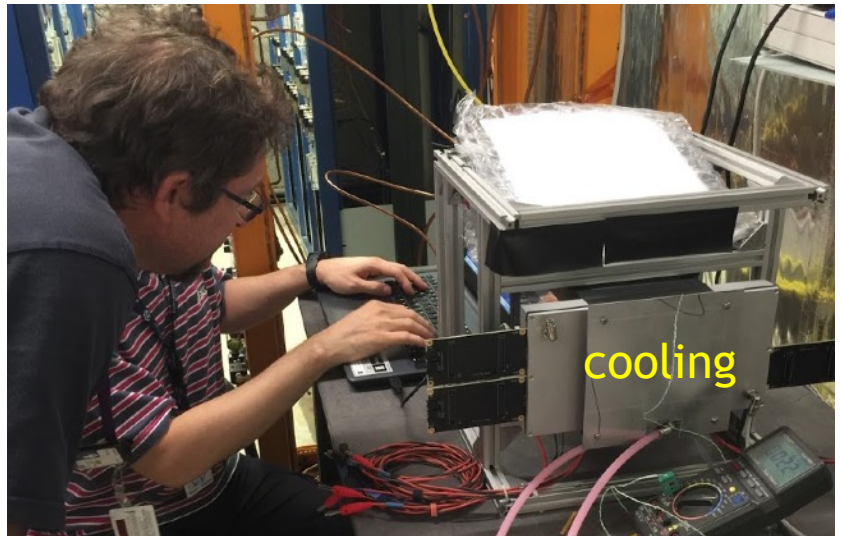


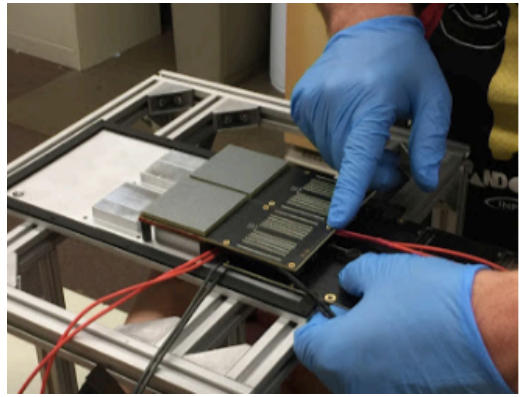


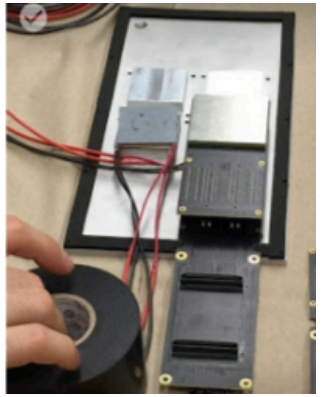
To achieve the required PID separation power, the pixel size of photosensors should be 3mm x 3mm or smaller.

Each H13700 & SiPM matrix have 16 x 16 pixels (3mm x 3mm). Four sensors are needed to cover the imaging plane of mRICH. This leads to 1024 readout channels per module.

Using three Hamamatsu SiPM Matrices



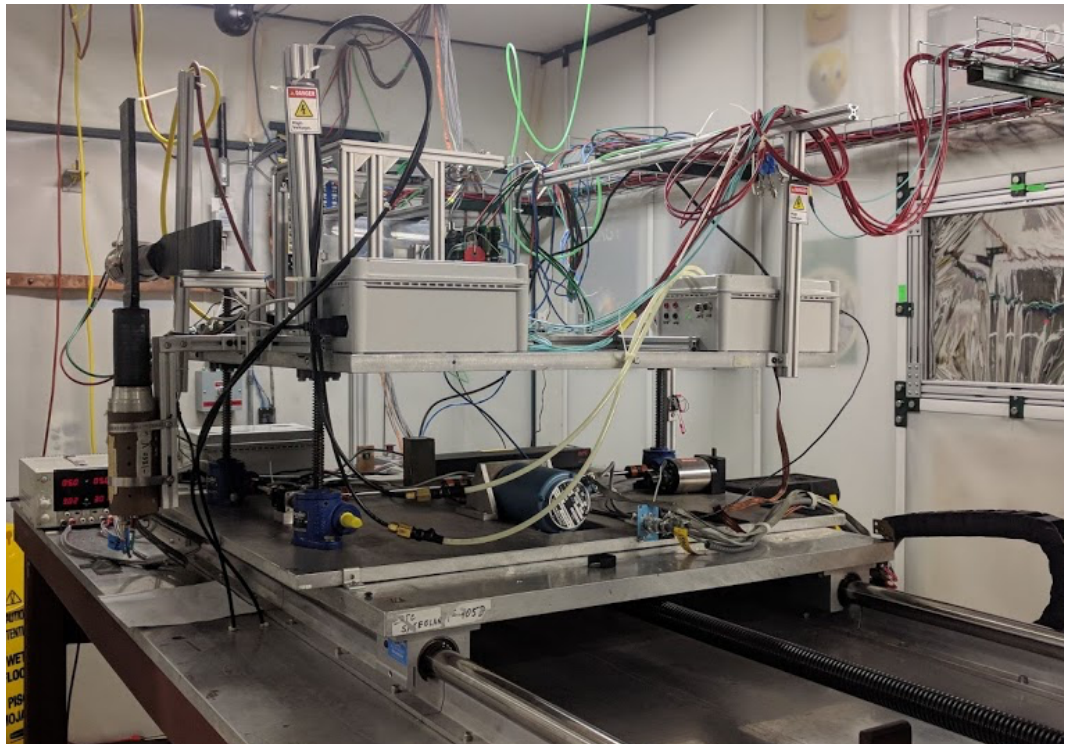




2nd mRICH Beam Test - Verify the PID Capability

Fermilab Beam Test Facility, from July 25 to August 6, 2018

120 GeV/c proton



Accumulated ring image

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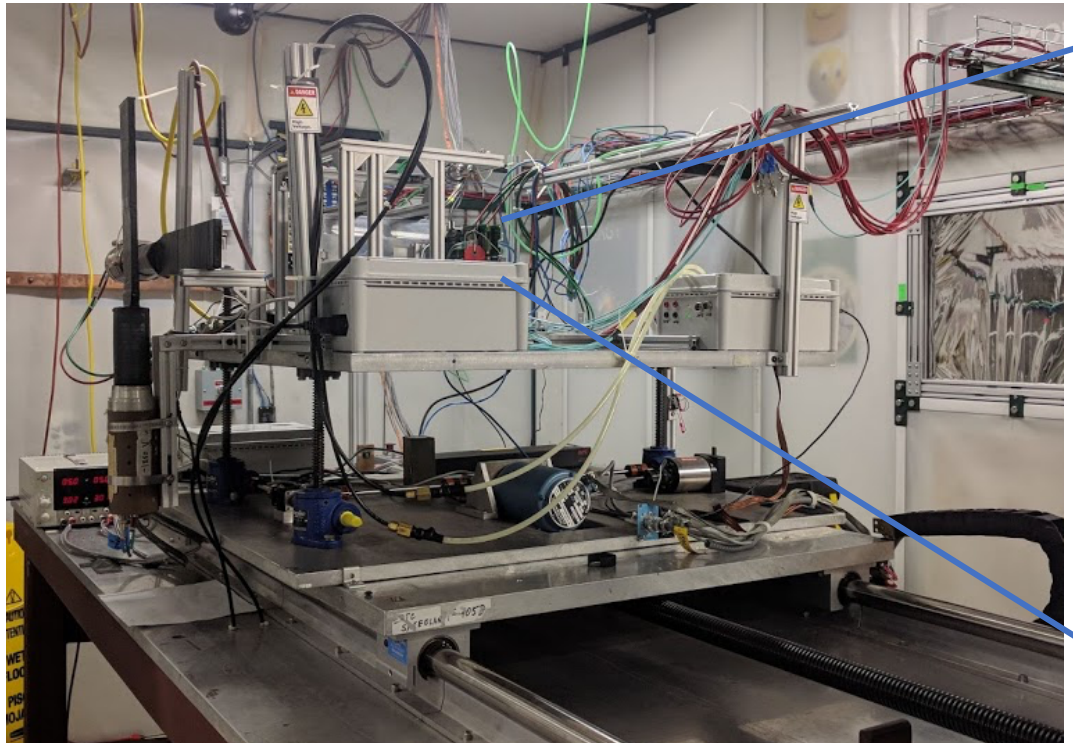

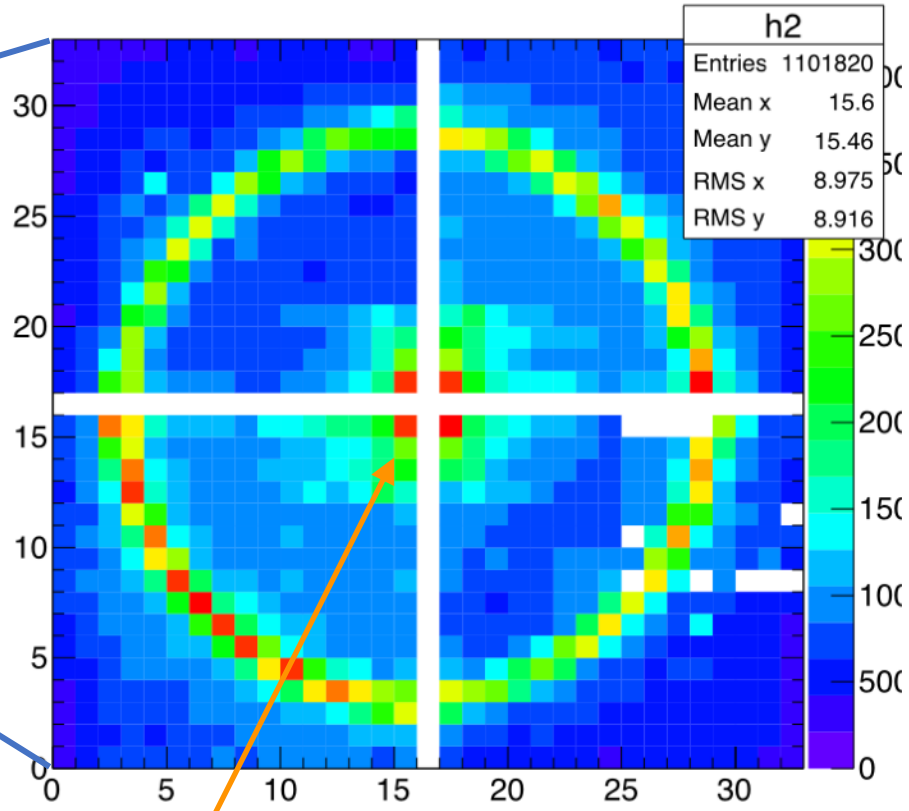

Beam spot

Accumulated ring image

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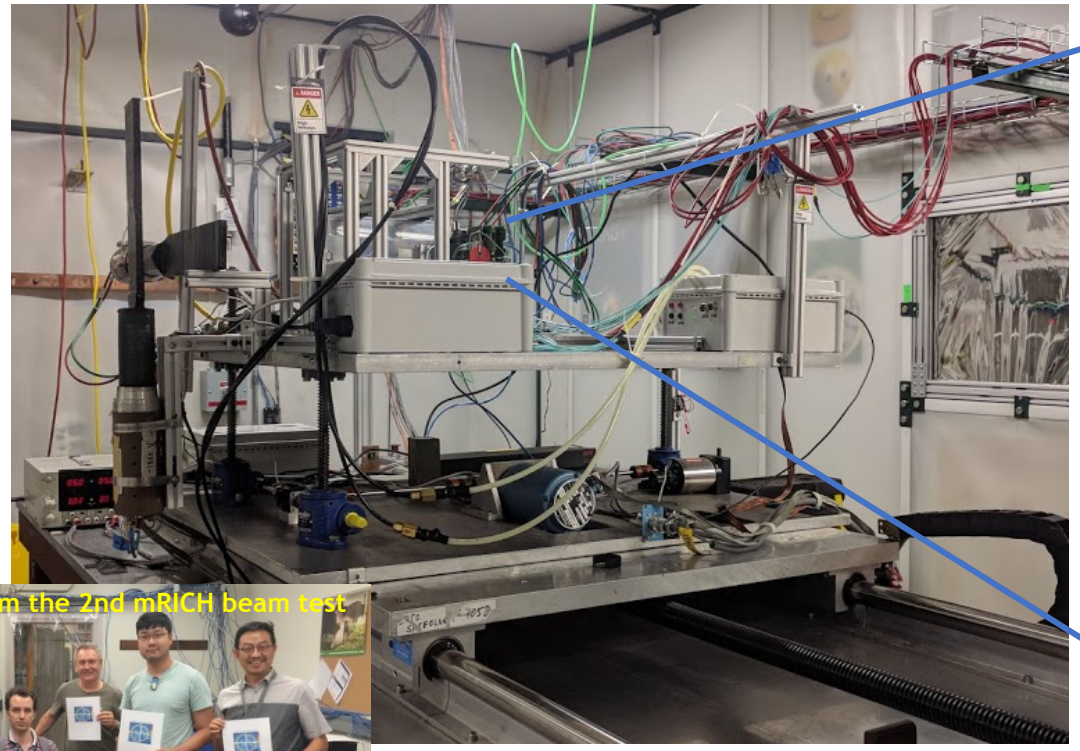
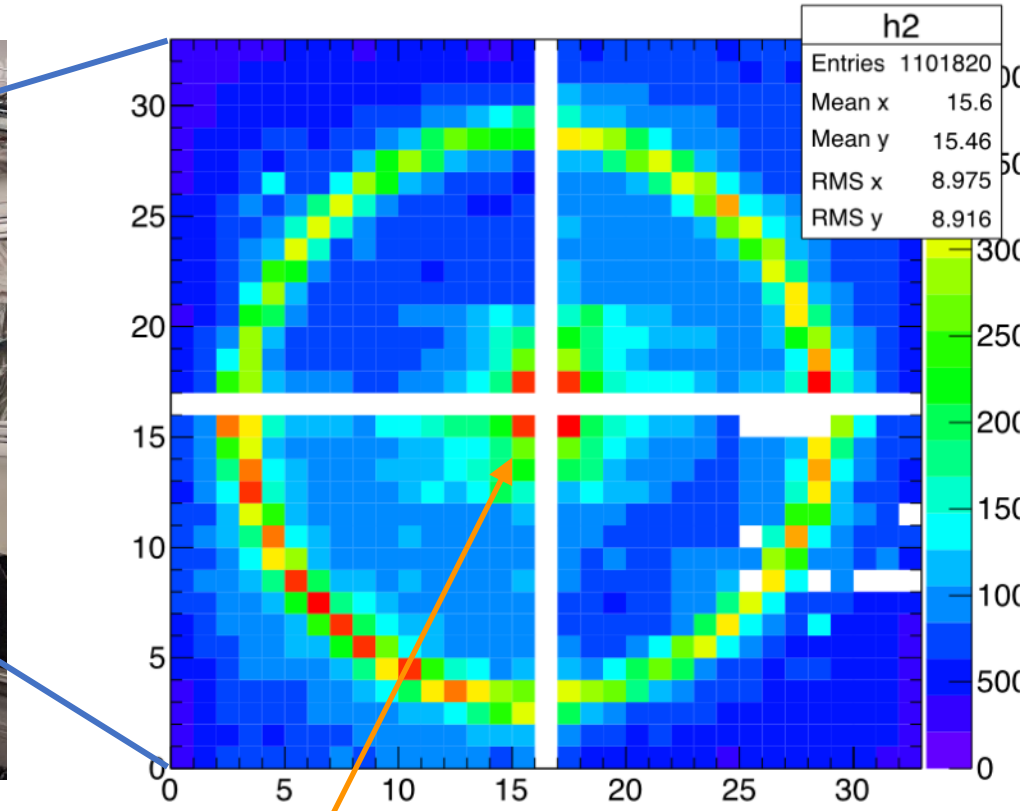
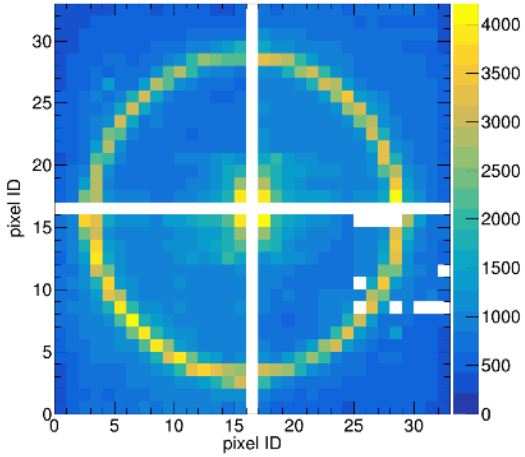
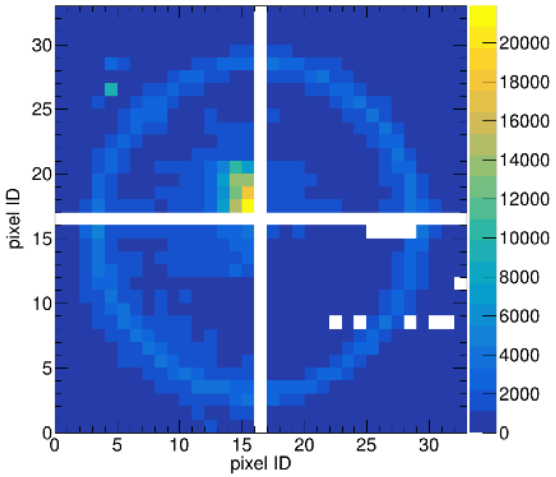


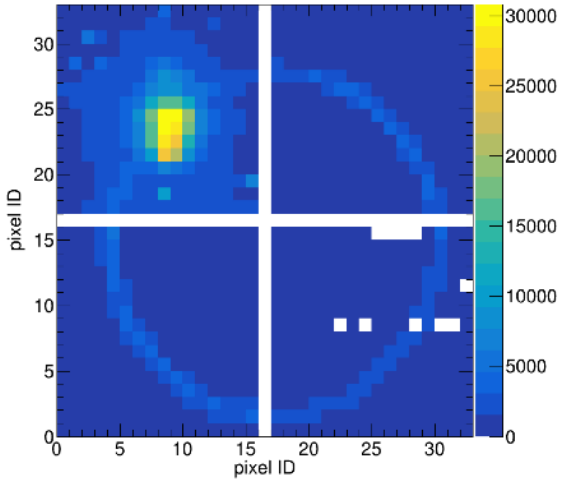


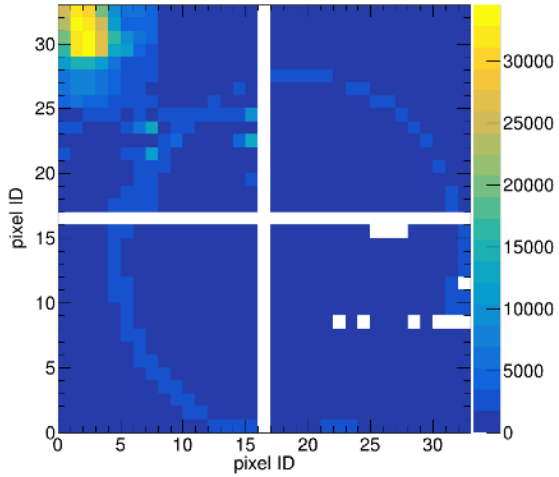
Beam spot

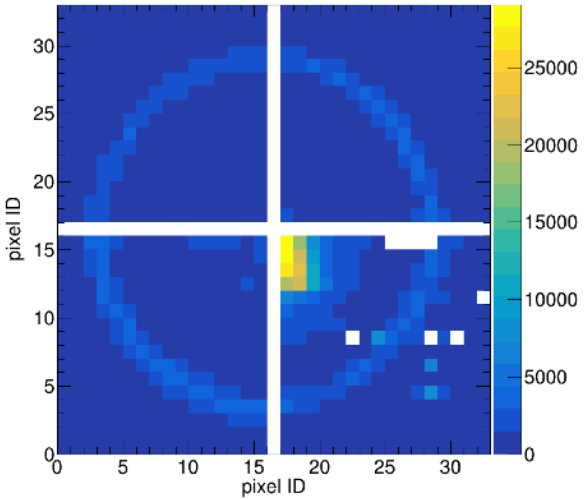
Accumulated ring image

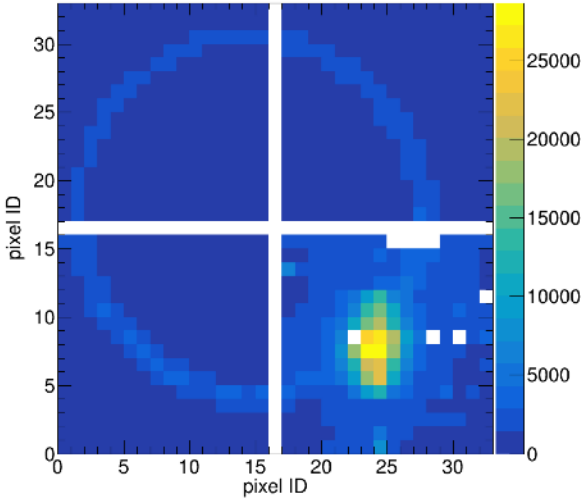


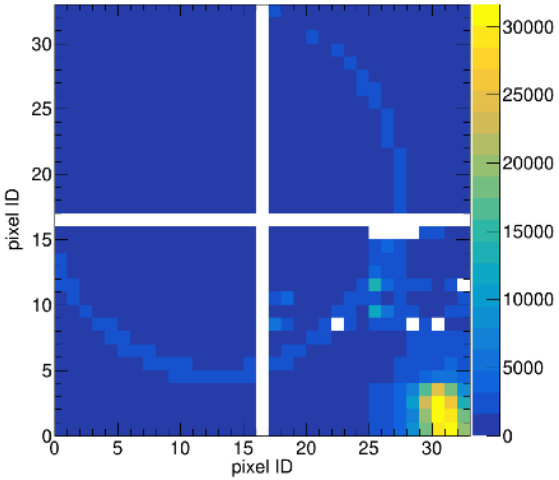






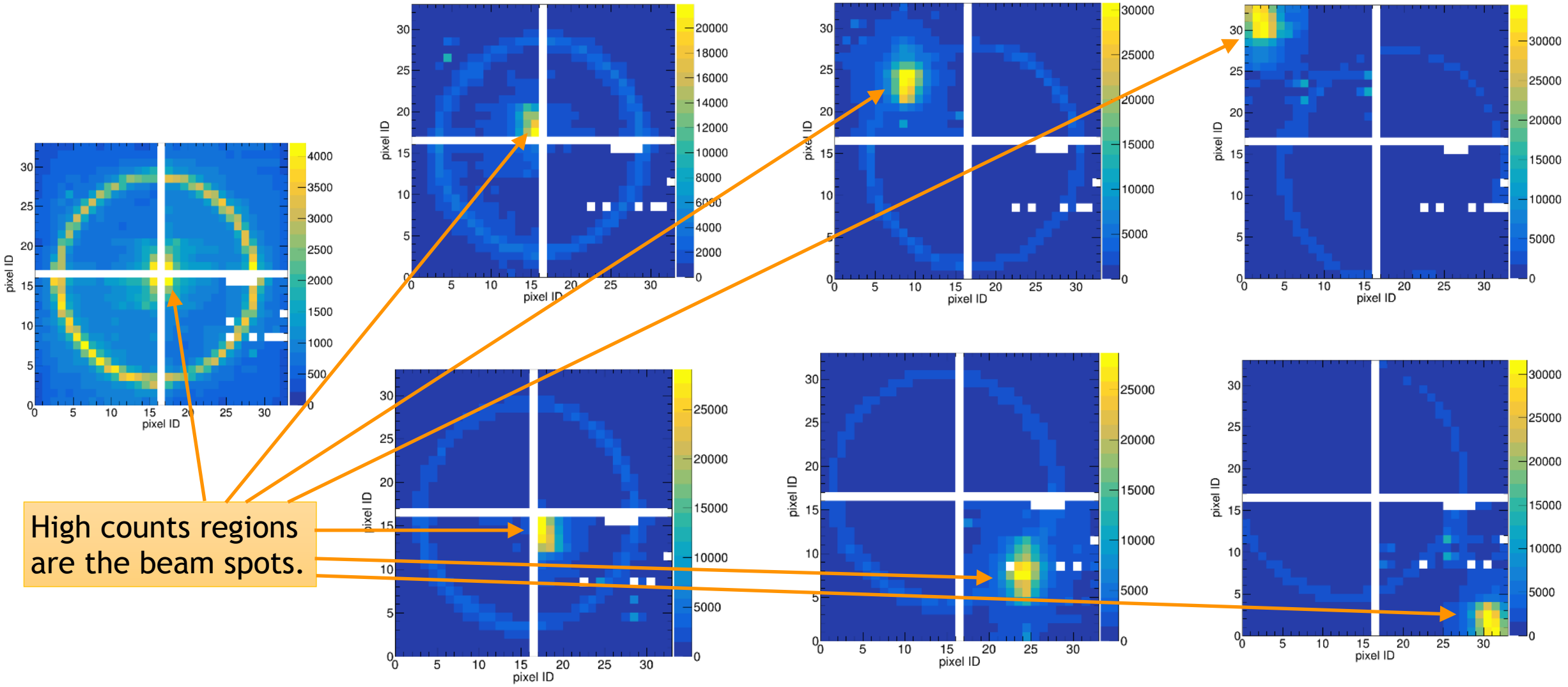






Position Scans with 120 GeV Proton Beam

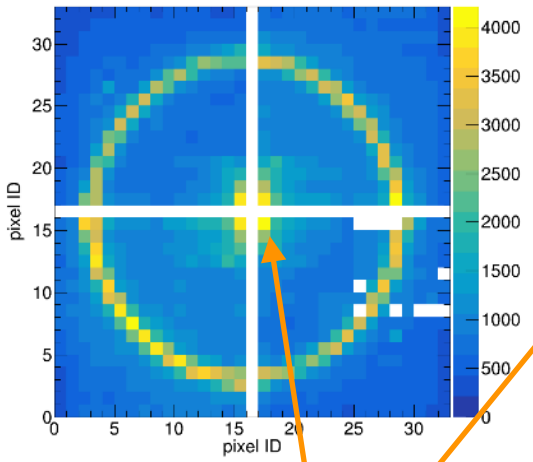
Position Scans with 120 GeV Proton Beam

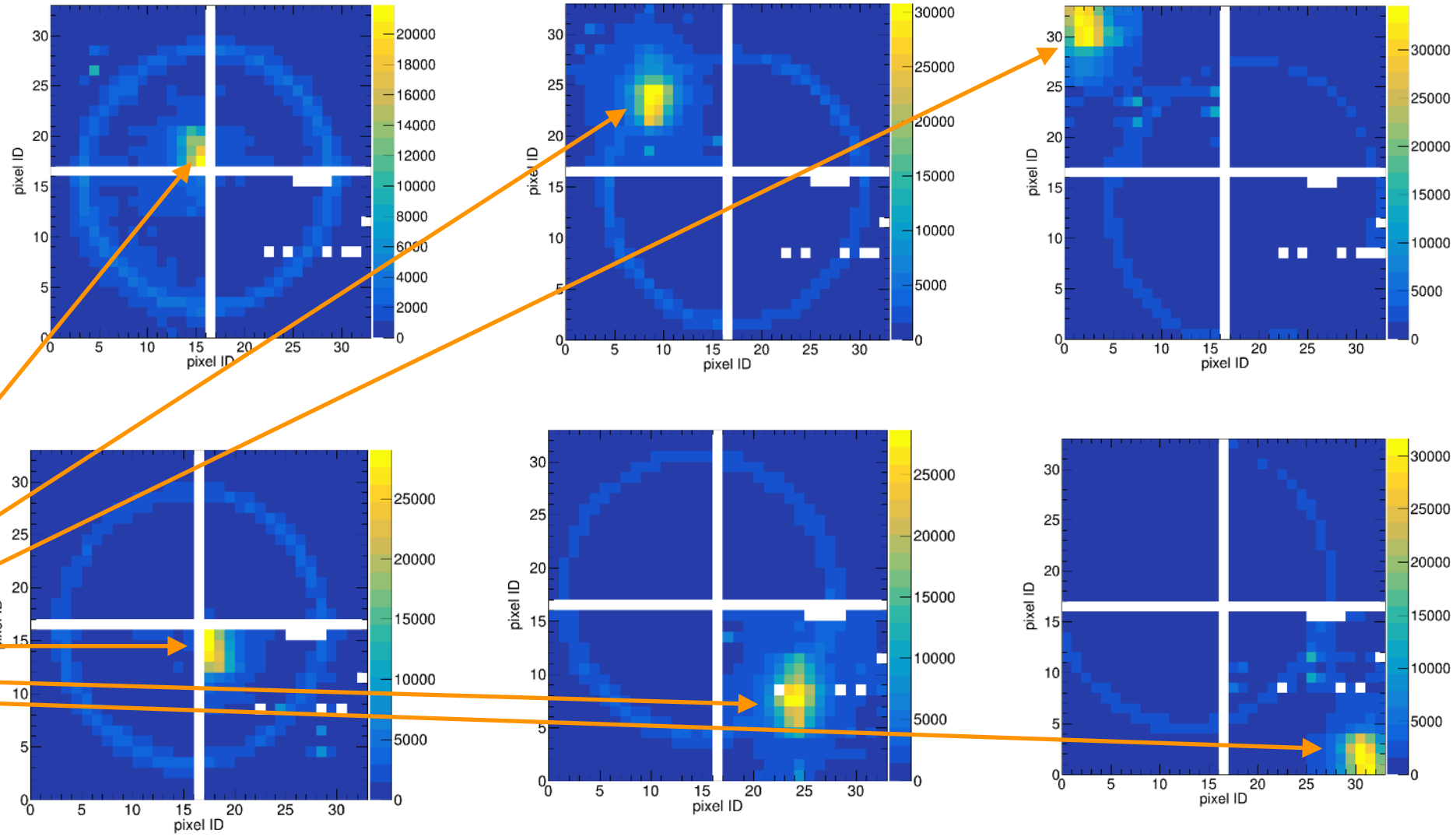


High counts regions are the beam spots.

Position Scans with 120 GeV Proton Beam

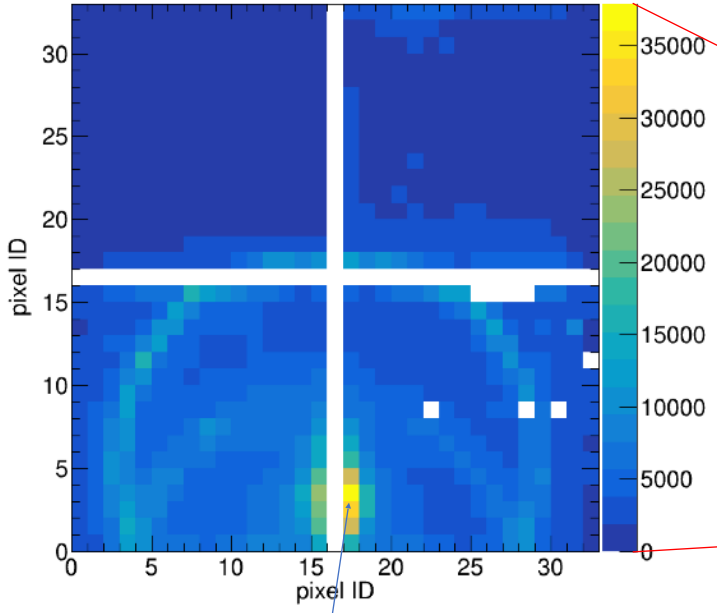
Demonstrated the lens effect!



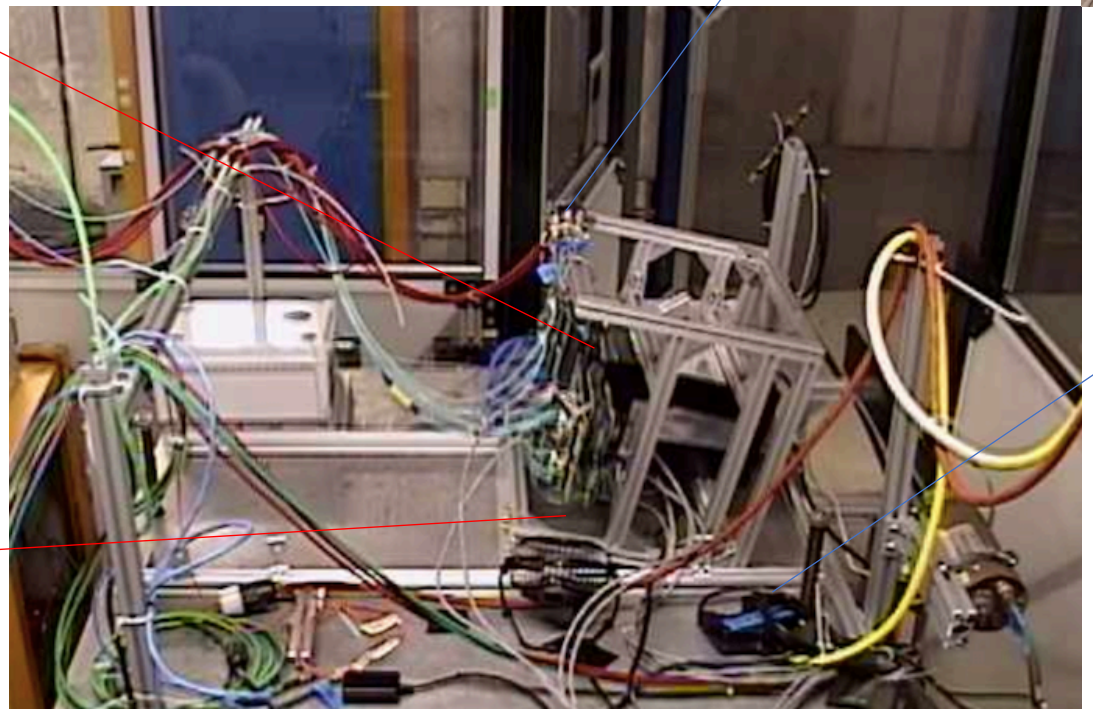


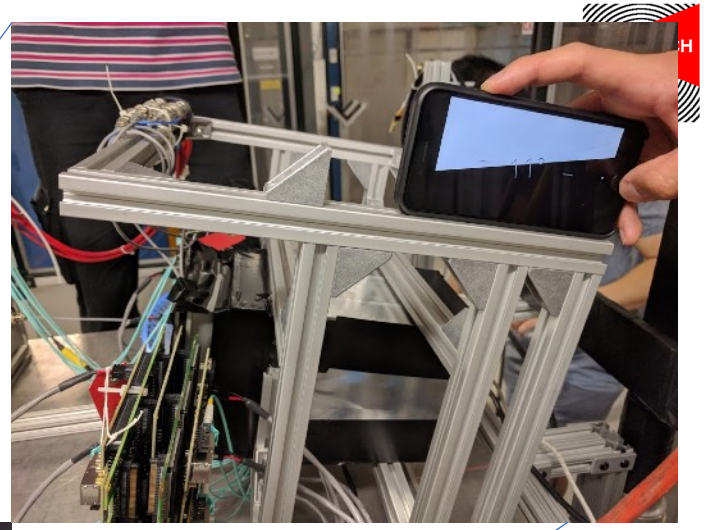
High counts regions are the beam spots.

Ring image from proton beam at an angle (11⁰)



Beam spot

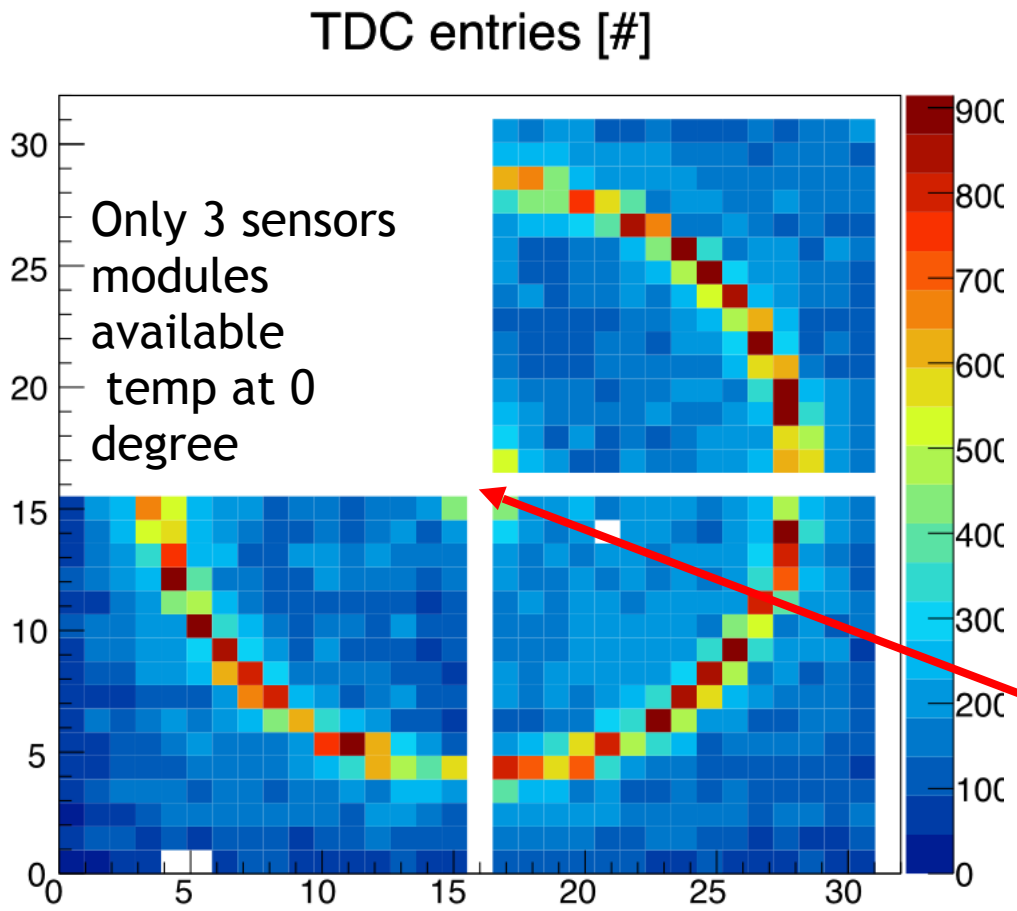


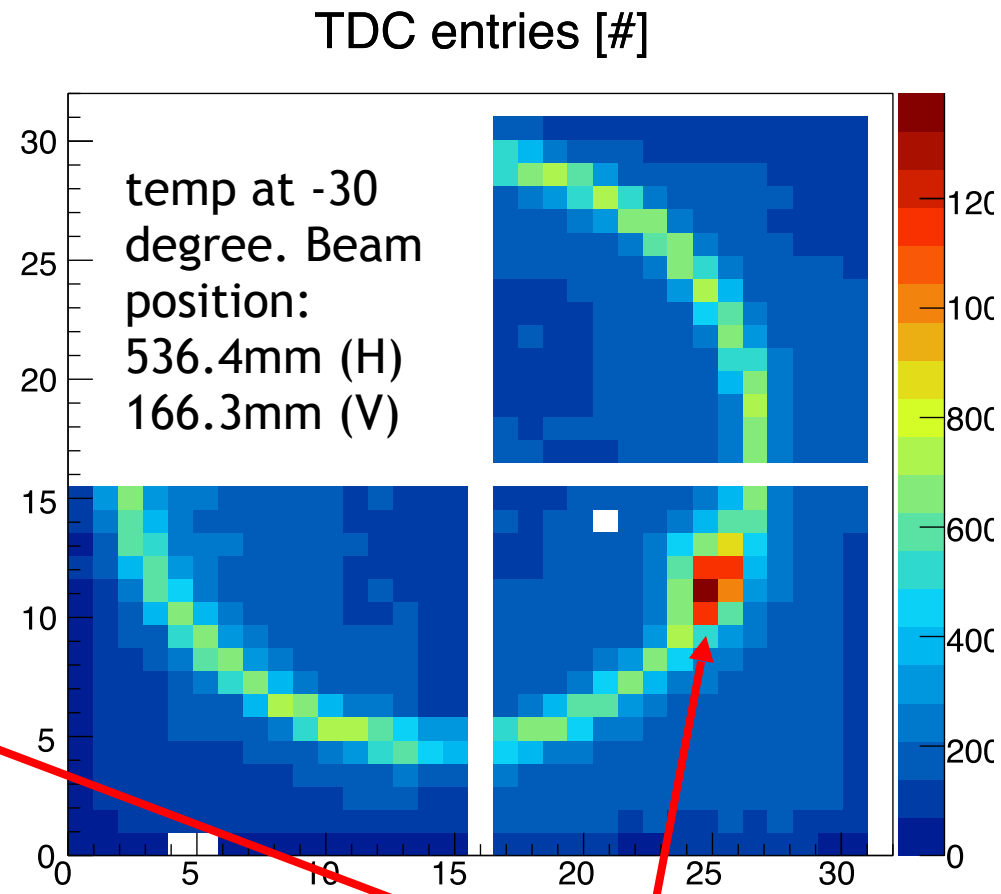


~11 degree tilt downward

120 GeV/c proton beam

mRICH readout with SiPM matrix sensors





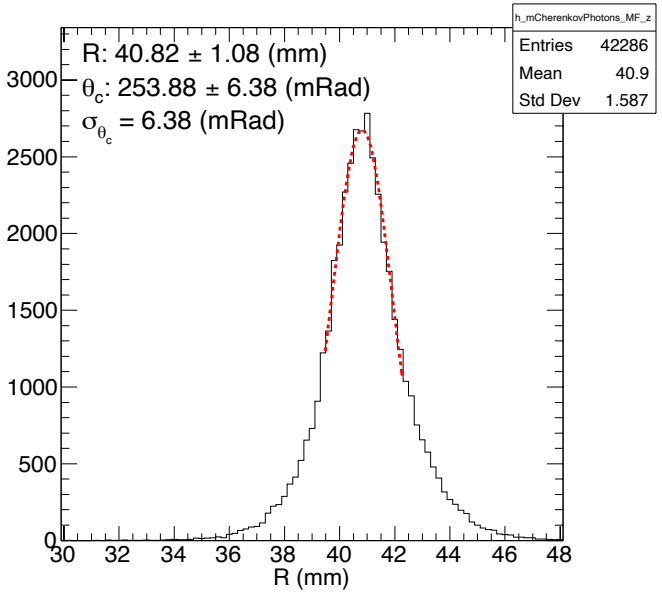
120 GeV/c proton Incident at center

Beam spot

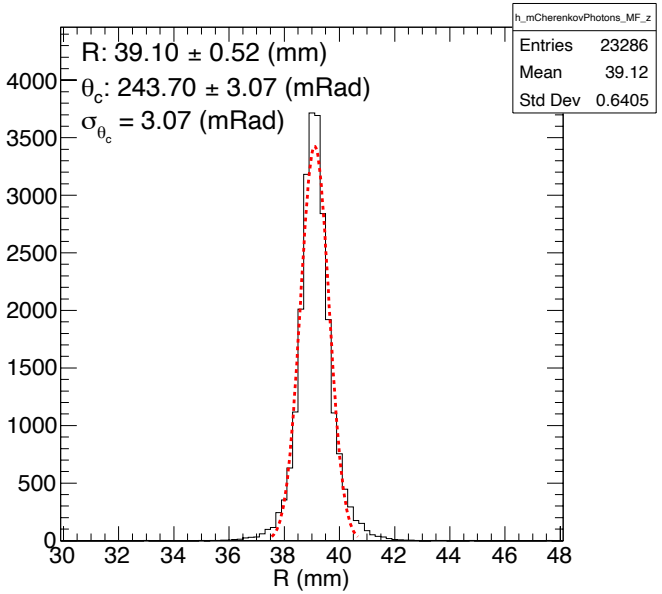
Ring Radius and Number of Cherenkov Photons

Data

No precision tracking was available. Beam size is ~6mm in radius.



Simulation



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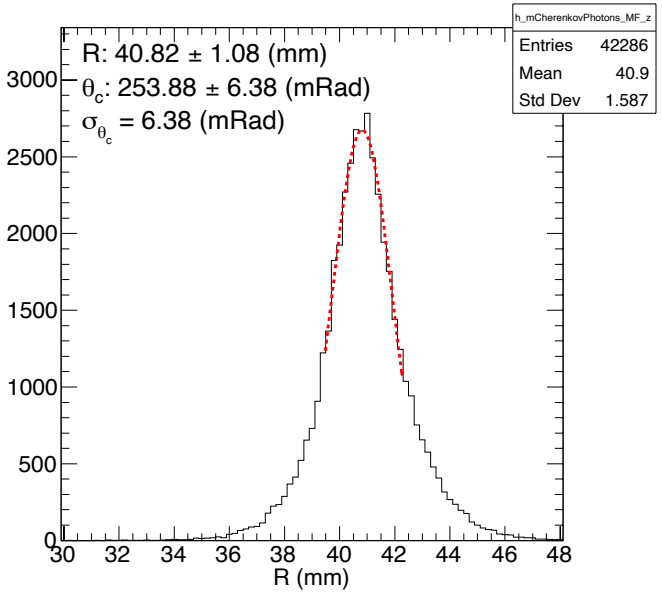
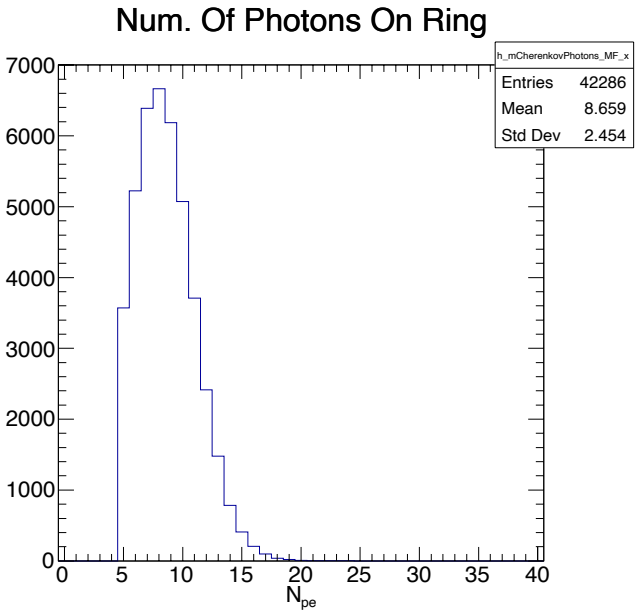
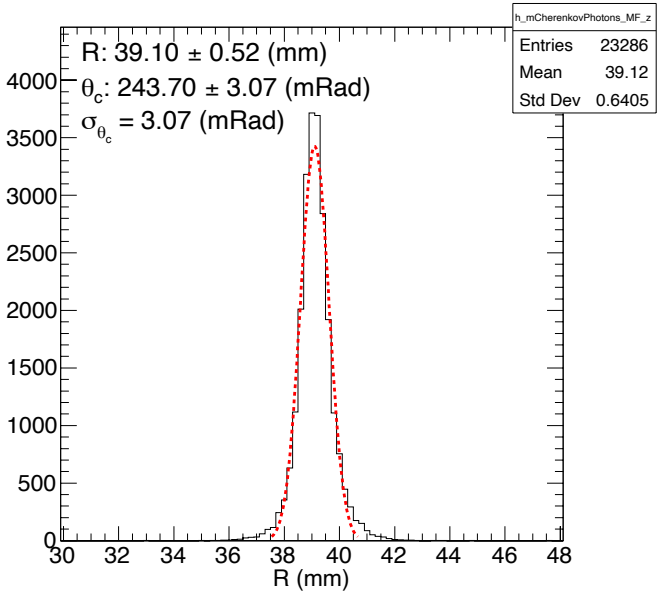
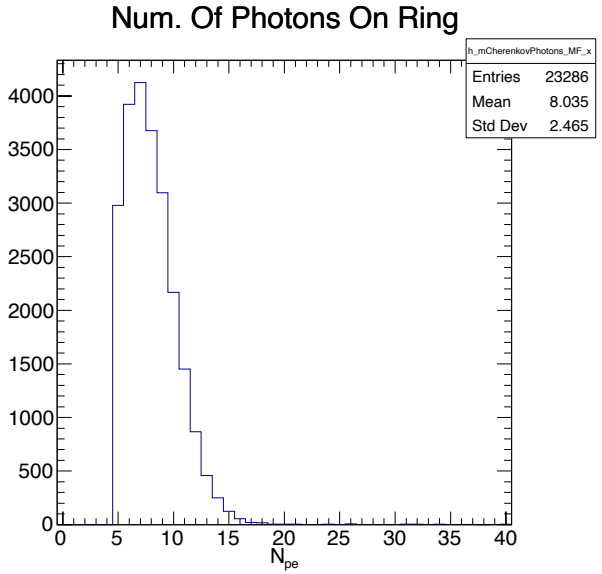




Simulation

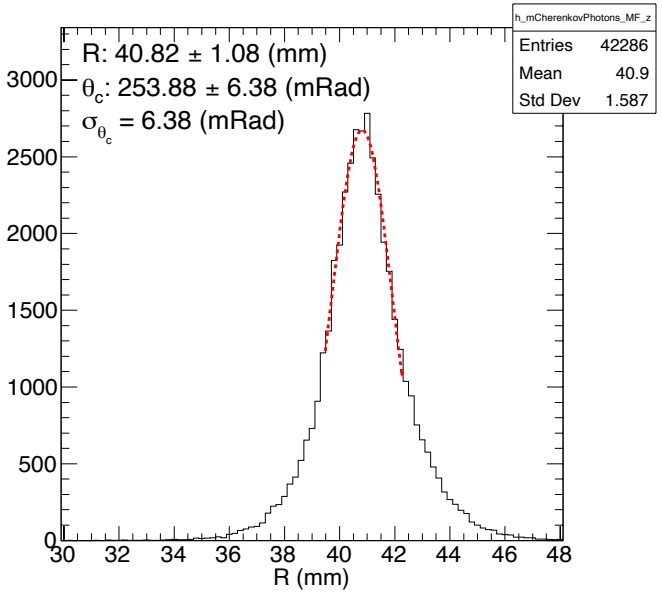


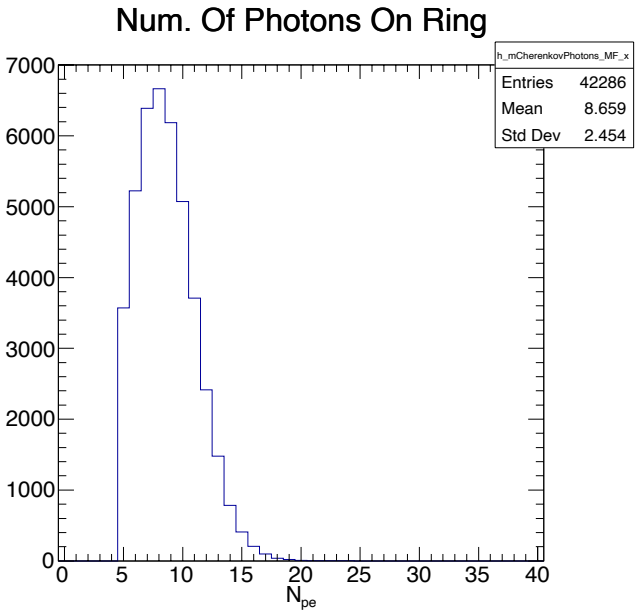


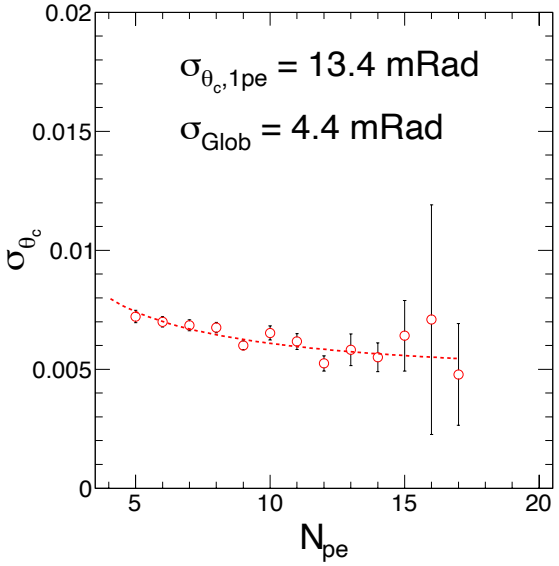
Ring Radius and Number of Cherenkov Photons

Data

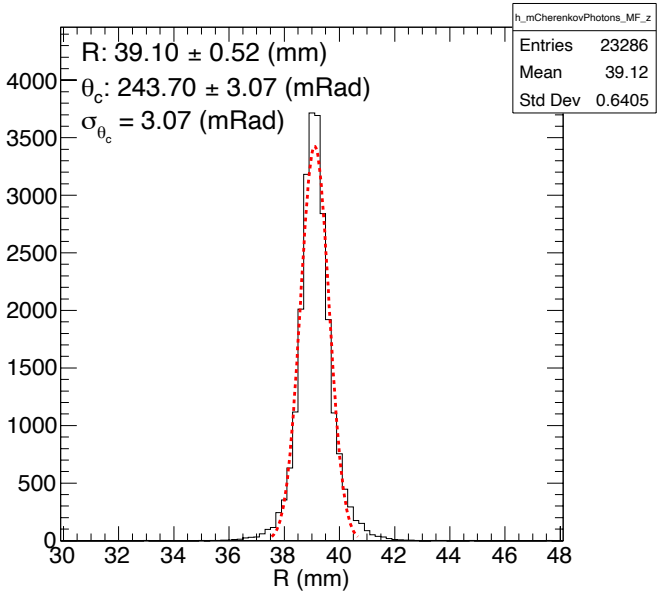
No precision tracking was available. Beam size is ~6mm in radius.

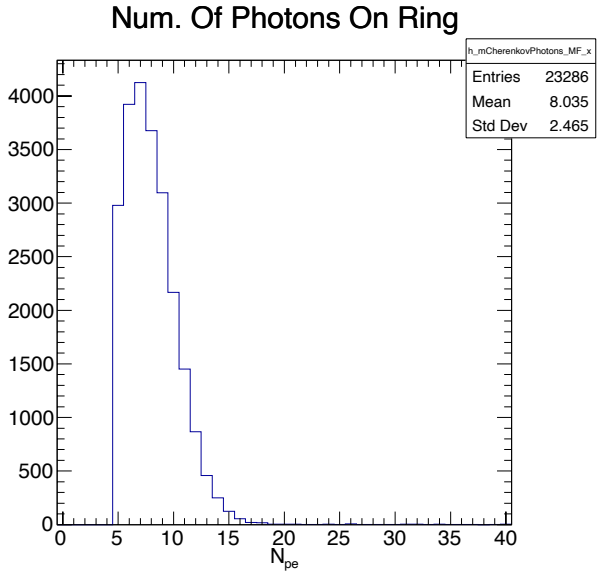


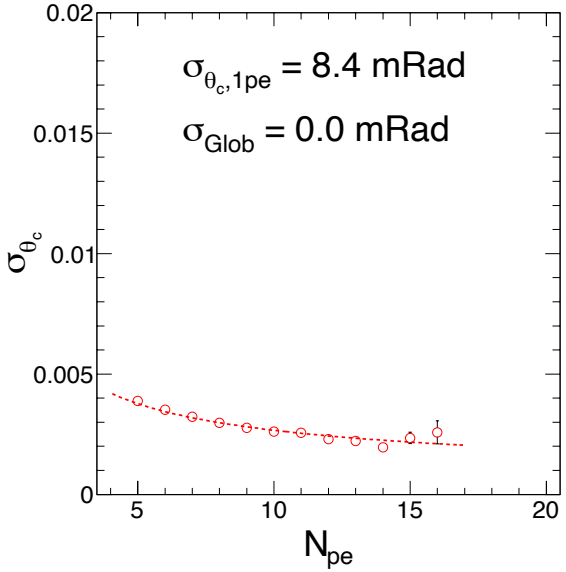




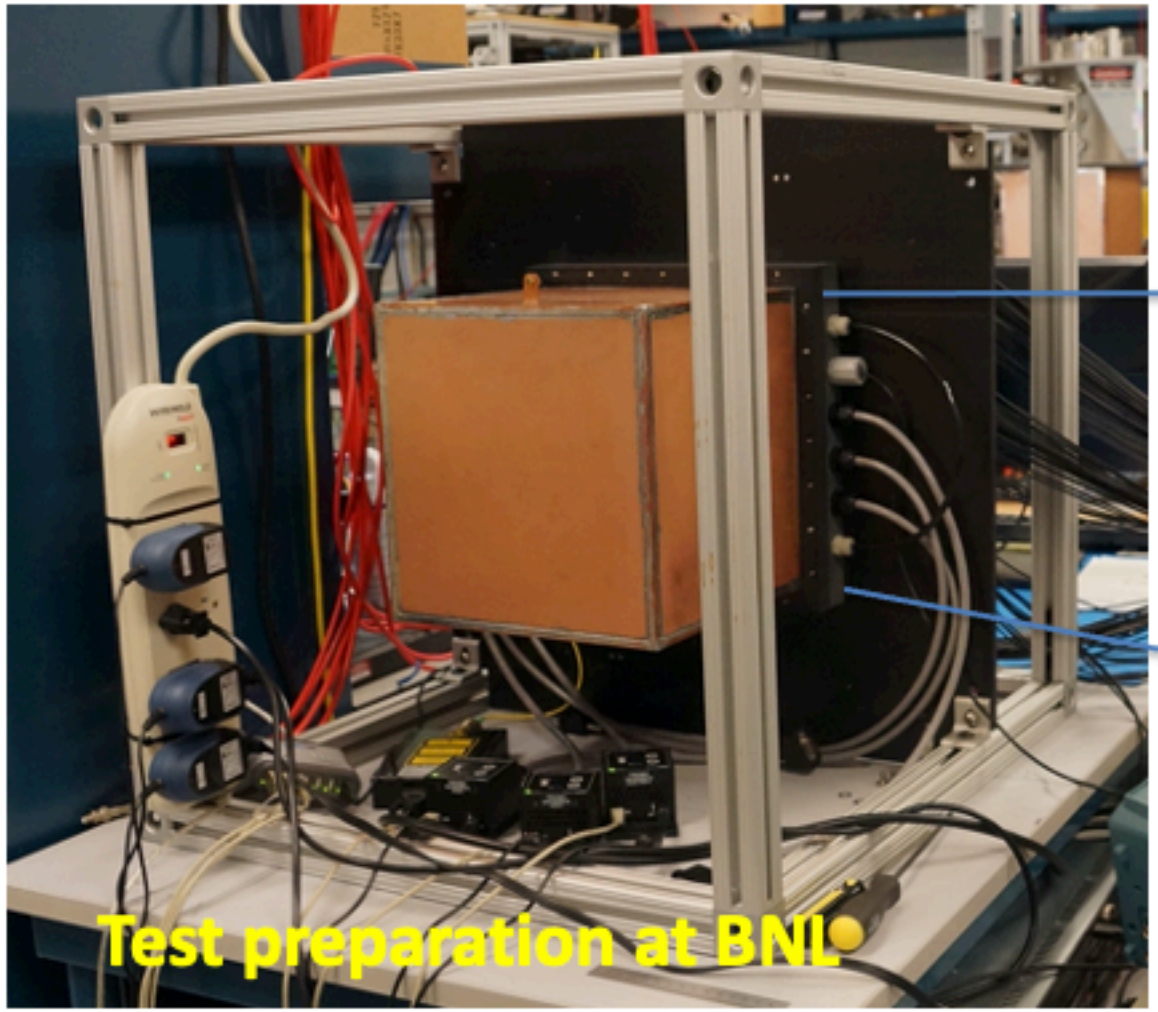
Simulation

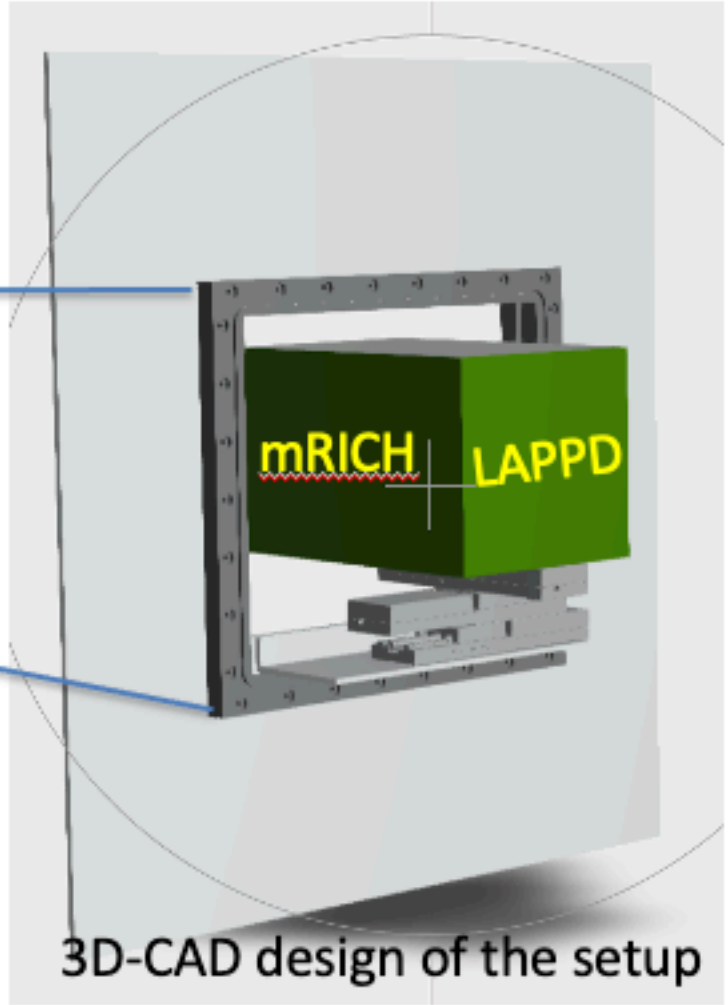




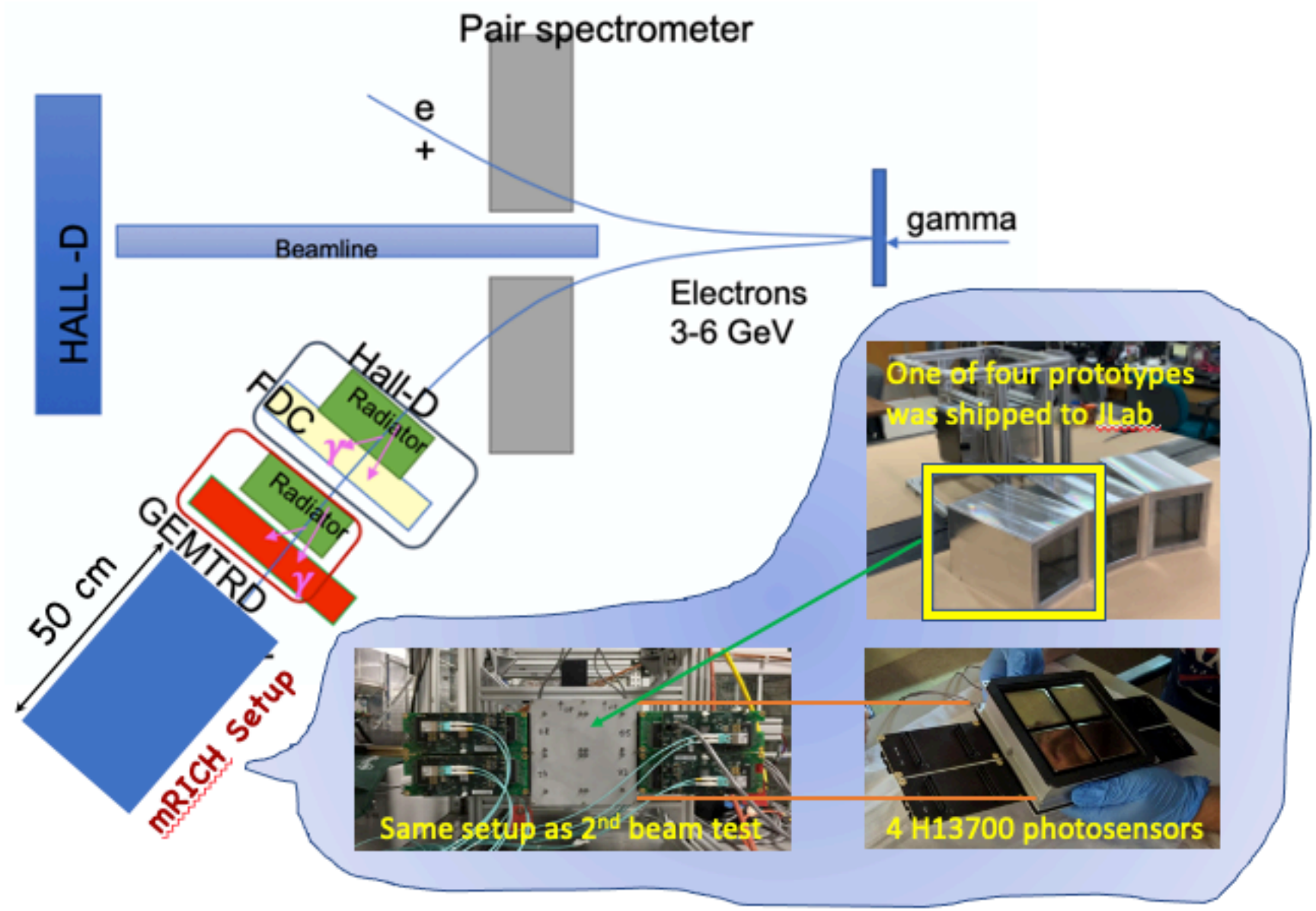


mRICH-LAPPD Fermilab Test (5/25 - 6/14/21)



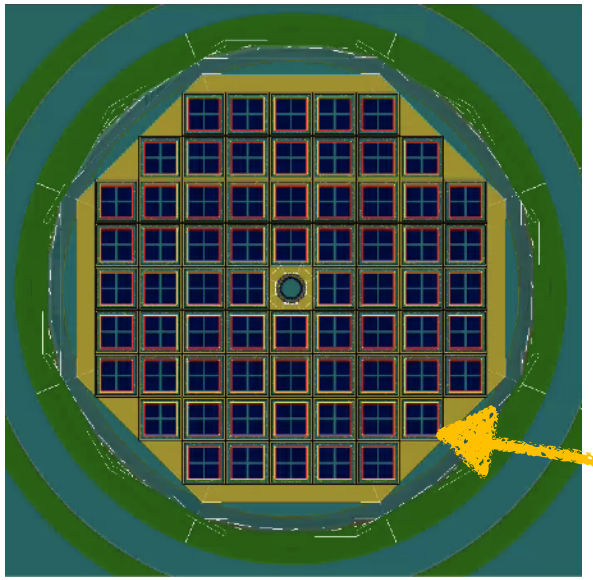


Planned mRICH Test at JLab in August 2021

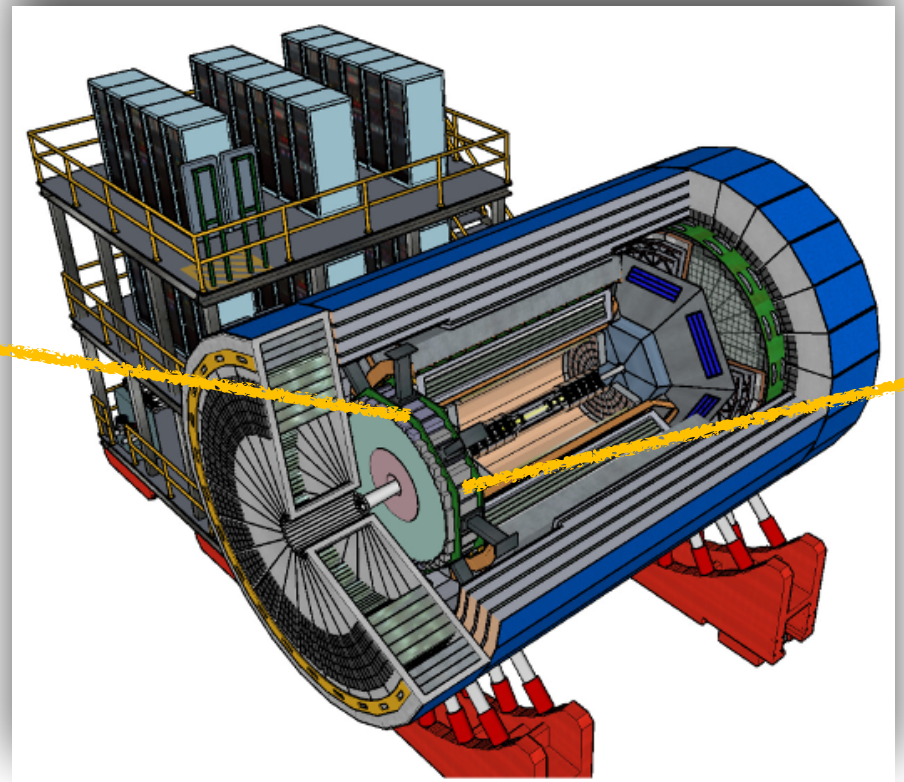


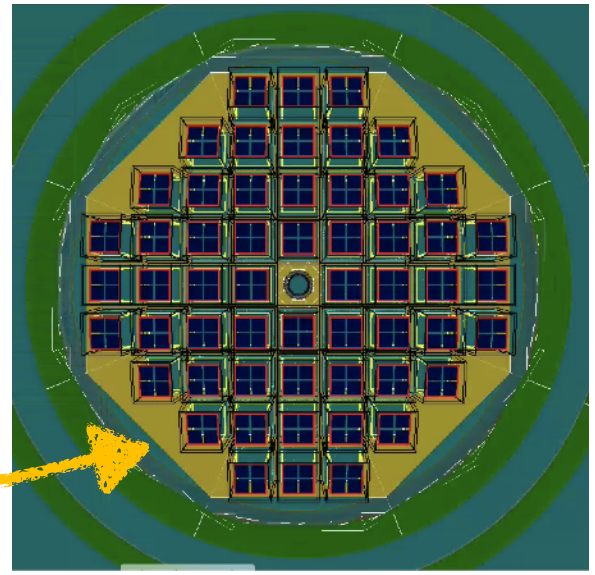
Outlook - Optimization of mRICH Array Implementation for EIC Experiments

Maximize acceptance and PID efficiency



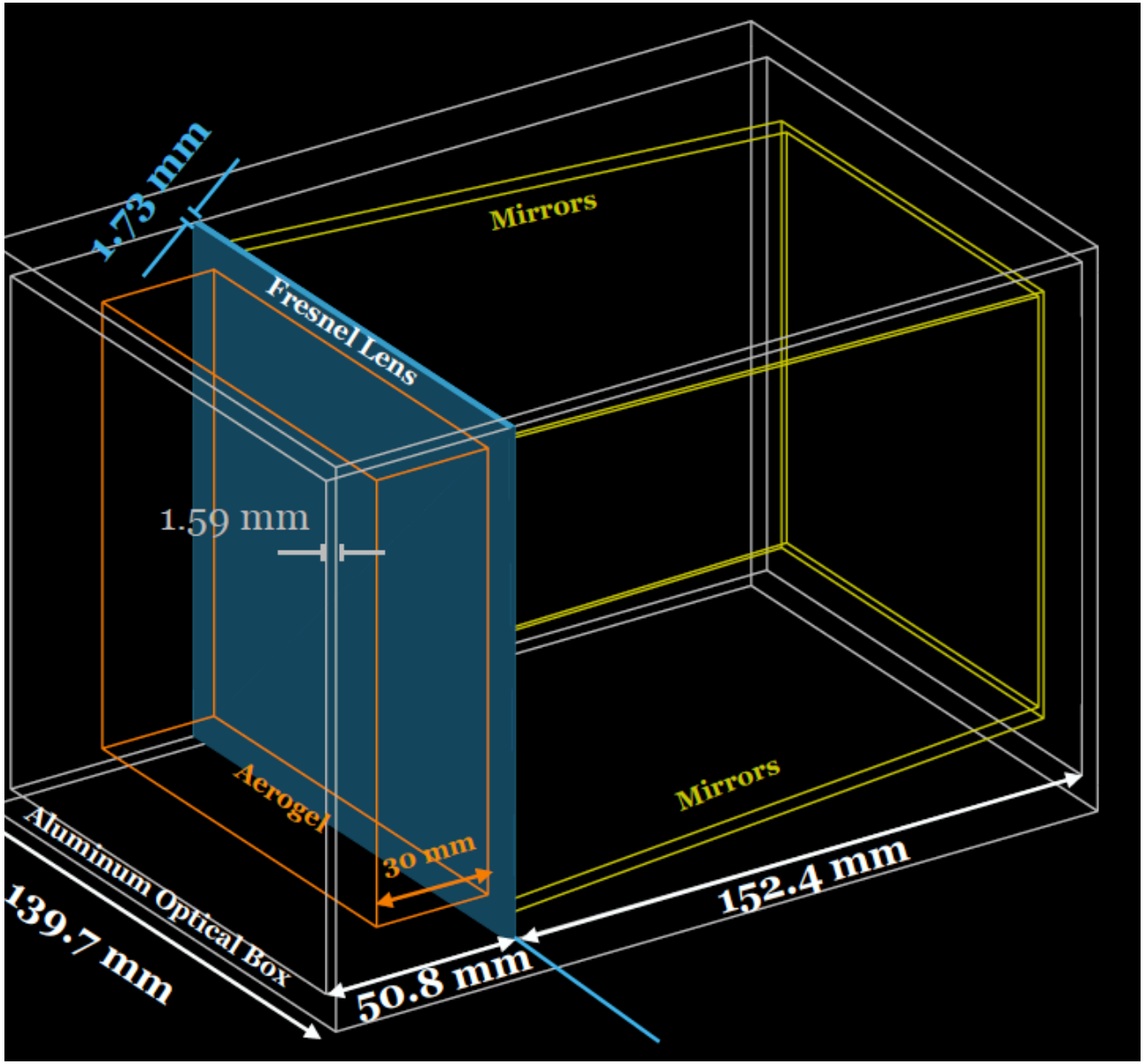
Non-projective

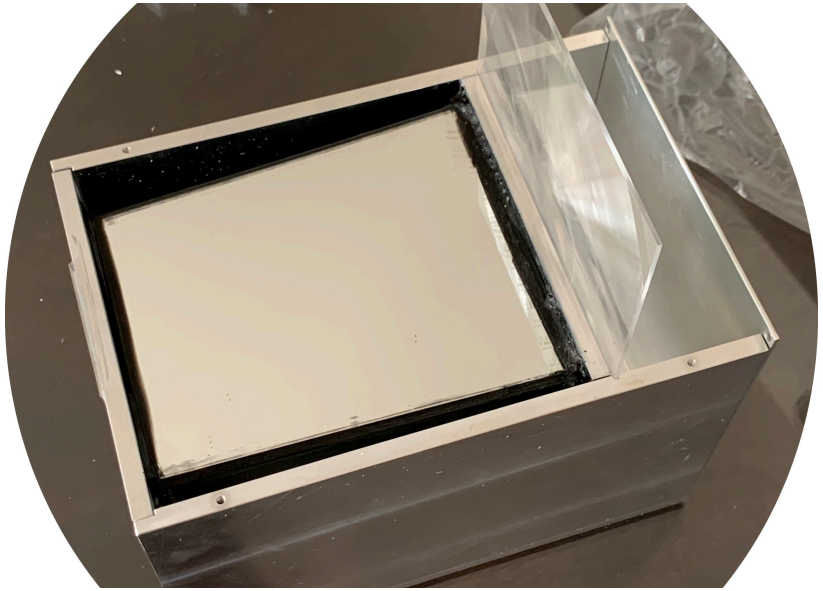


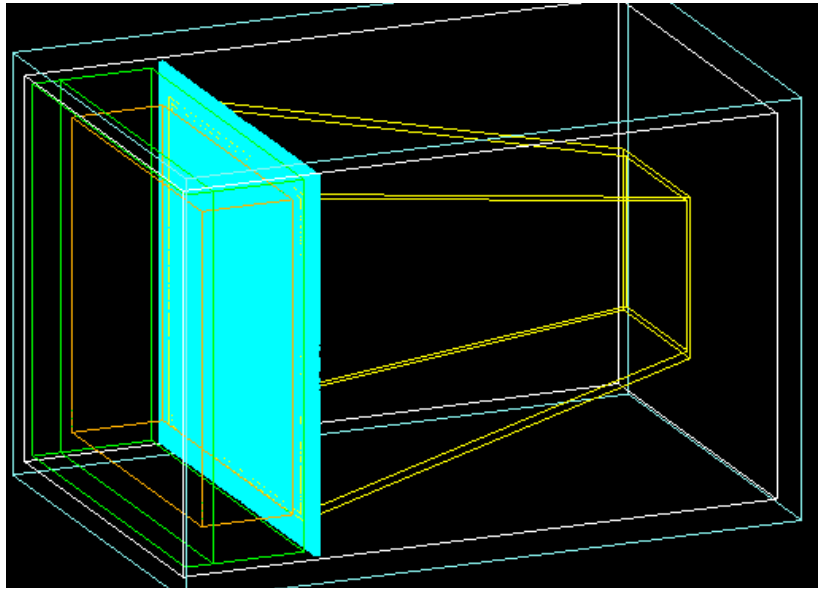


Projective

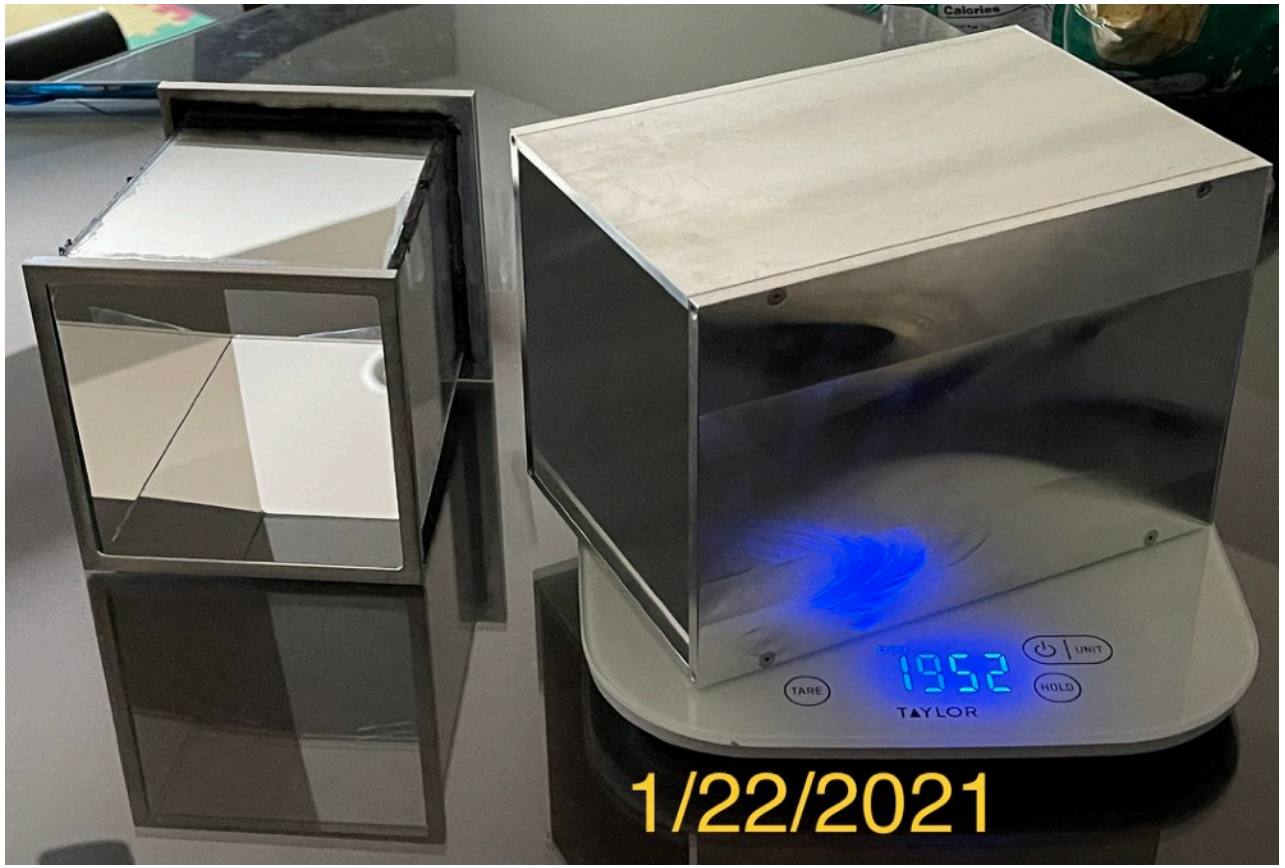
THANK YOU


1.73 mm
Mirrors
Fresnel Lens
1.59 mm
Aerogel
30 mm
Mirrors
Aluminum Optical Box
139.7 mm
50.8 mm
152.4 mm



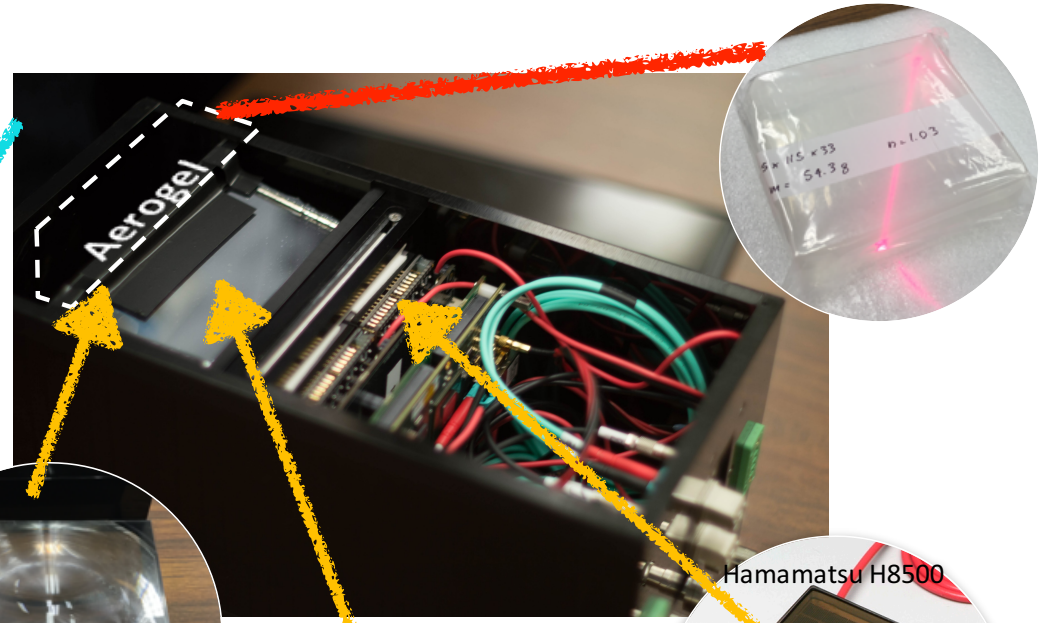


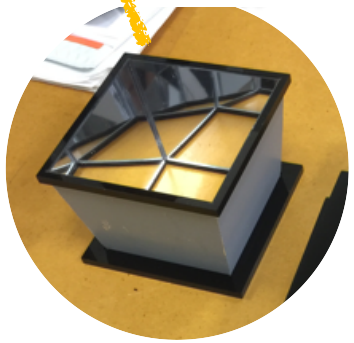

mRICH module
1/22/2021
TARE
2561
UNIT
HOLD
TAYLOR

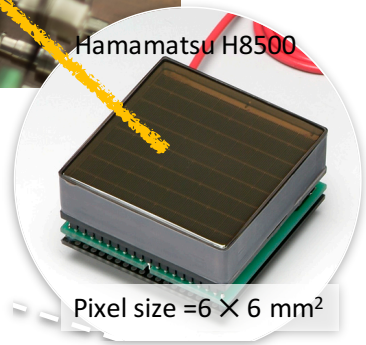

1952
TARE
UNIT
HOLD
TAYLOR
1/22/2021

1st mRICH Prototype Beam Test - Proof of Working Principle

Fermilab Beam Test Facility, April 2016







4 units

1st mRICH Prototype Beam Test - Proof of Working Principle

Fermilab Beam Test Facility, April 2016

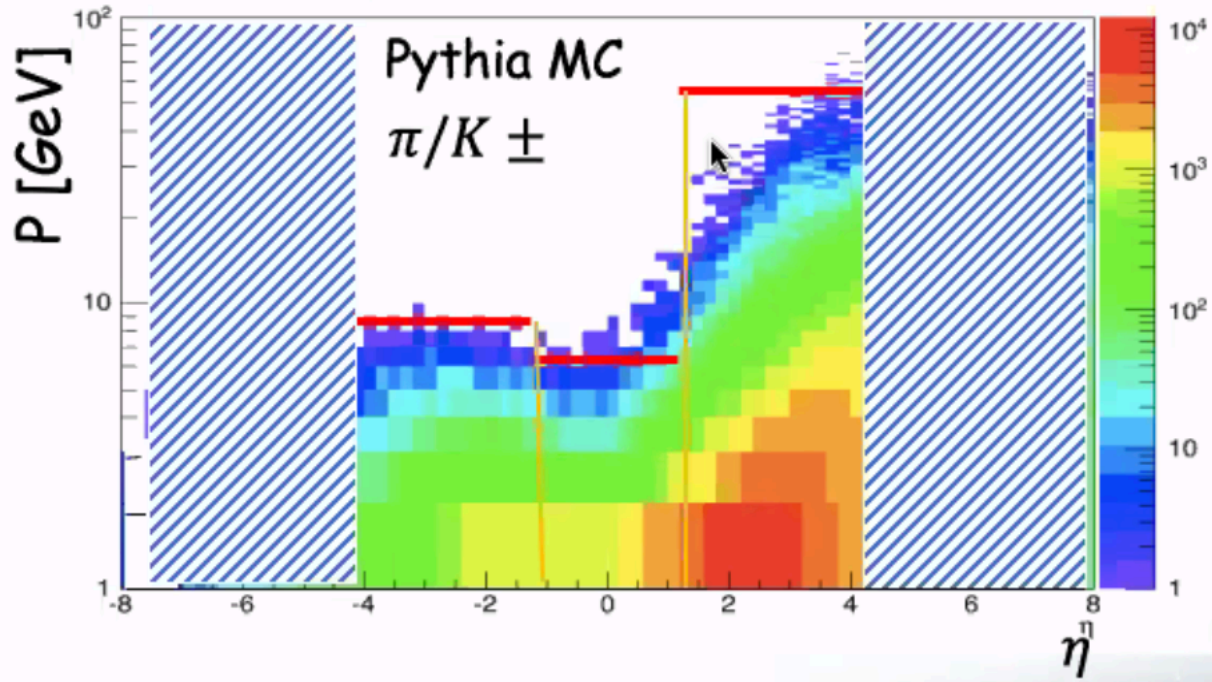
C.P. Wong et. al. NIM A871 (2017) 13-19

- In general, need to separate:
  - Electrons from photons -> 4π coverage in tracking
  - Electrons from charged hadrons -> mostly provided by calorimetry
  - Charged pions, kaons and protons from each other -> Cherenkov detectors

Physics requirements:

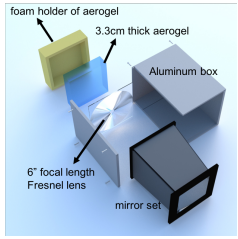
Rapidity	π/K/p and π0/γ	e/h	Min pT (E)
-3.5 – -1.0	7 GeV/c	18 GeV/c	100 MeV/c
-1.0 – 1.0	8-10 GeV/c	8 GeV/c	100 MeV/c
1.0 – 3.5	50 GeV/c	20 GeV/c	100 MeV/c

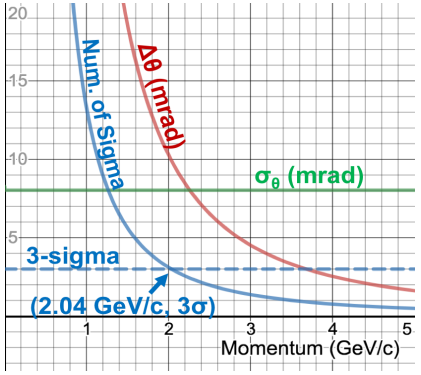
Illustration of PID detectors achievements:



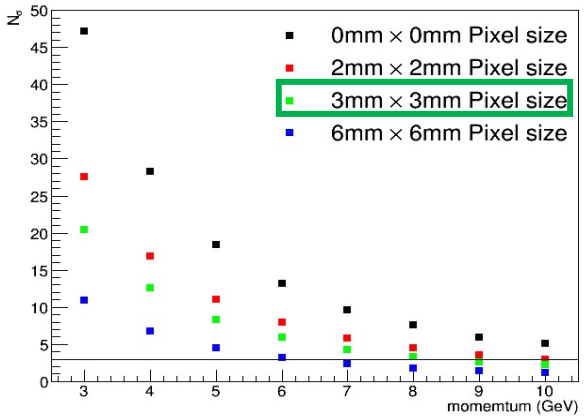
Prepared by X. He on 8/12/2019, EIC PID Consortium (eRD14 Collaboration)

Modular and compact ring imaging Cherenkov (mRICH) PID detector for EIC experiments

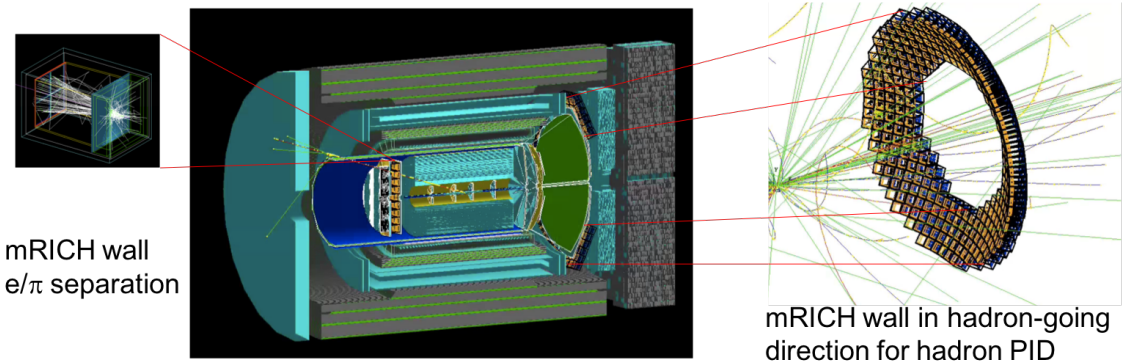




- Projected e/pi separation of mRICH 2nd prototype detector (**blue solid line**)
- 2nd prototype detector can achieve 3-sigma e/pi separation up to 2 GeV/c



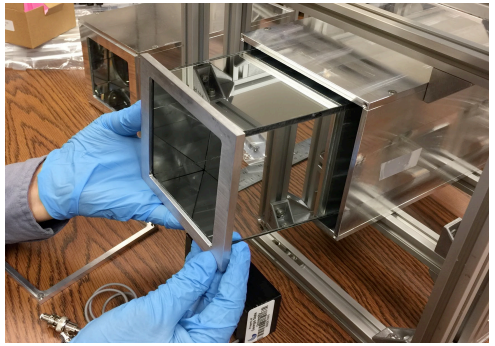
- Projected K/pi separation of mRICH 2nd prototype detector (**Green dots**)
- 2nd prototype detector can achieve 3-sigma K/pi separation up to 8 GeV/c



mRICH wall e/π separation

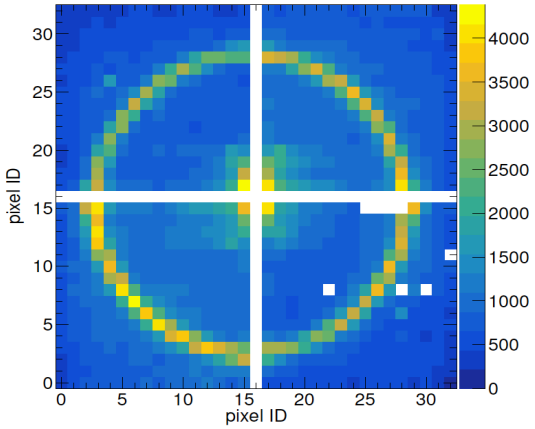
mRICH wall in hadron-going direction for hadron PID

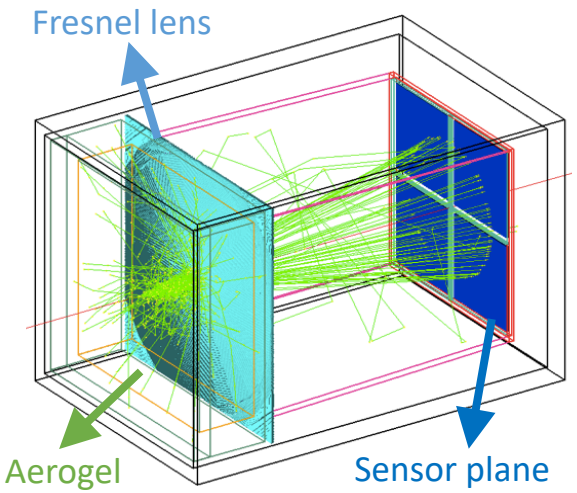
New features: a) separation of optical and electronic components; b) longer focal length (6”); c) 3mm x 3mm photosensors.



2nd mRICH prototype was tested at Fermilab Test Beam Facility in June/July 2018

Beam Test at Fermilab





GEANT4 Simulation