EIC PID (eRD14) - mRICH

mRICH stands for compact and modular Ring Imaging CHerenkov detector, which is designed for K/pi separation in a momentum range of 3 to 10 GeV/c and e/pi separation below 2 GeV/c for the future EIC experiments.

Outline

- mRICH design principles and GEANT4 simulation
- mRICH prototyping studies
- Ongoing mRICH data analysis and preliminary results
- mRICH array implementation in EIC-like experiments
- Continued mRICH R&D toward a TDR/CDR in 4 years
- Summary and outlook

mRICH Technical Note: https://www.overleaf.com/read/vxmpgmhdpmtq

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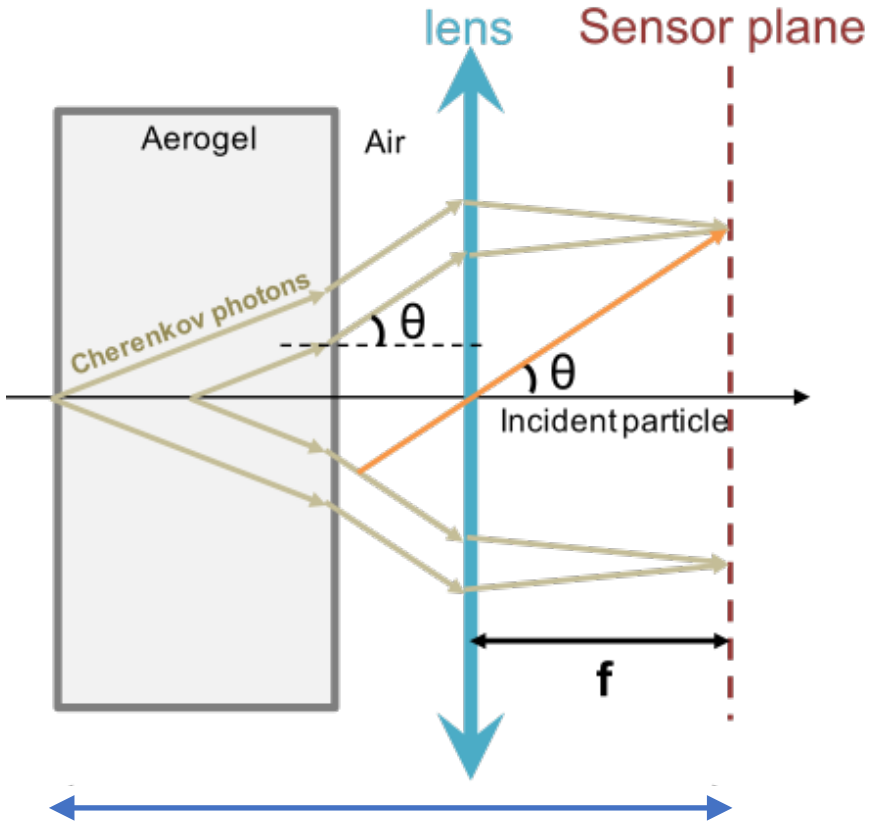
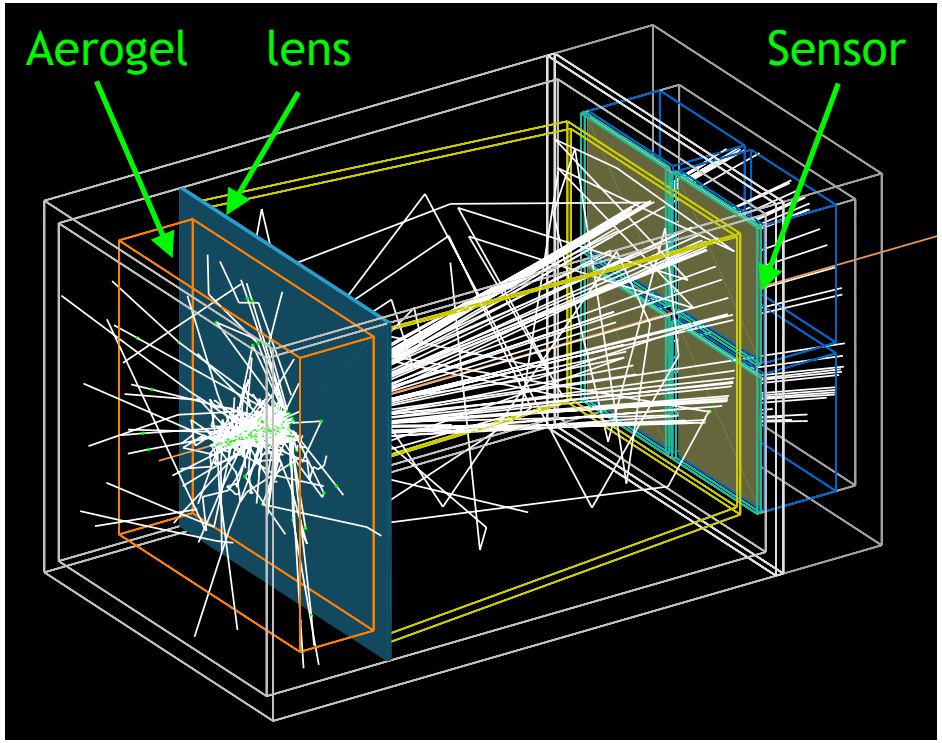
Current team members:

- **X. He**, X. Sun, S. Syed & M. Sarsour (GSU)
- M. Contalbrigo & L. Barion (INFN @ Ferrara)
- M. Mirazita, & V. Lucherini (INFN @ LNF)
- Z. Zhao (Duke)
- G. Varner & I. Mostafanezhad (UH)

EIC mRICH – Working Principle



~ (aerogel thickness + lens focal length)

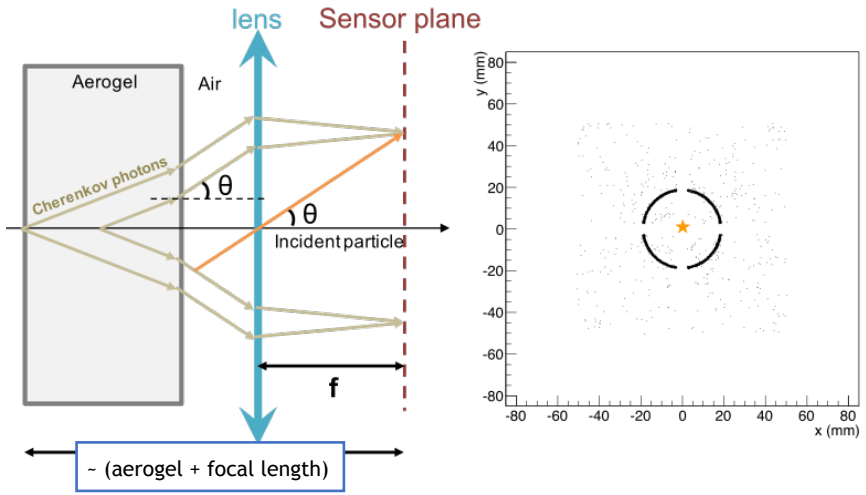


Geant4 Simulation

mRICH – lens-based focusing aerogel detector design

Smaller, but thinner ring improves PID performance and reduces length

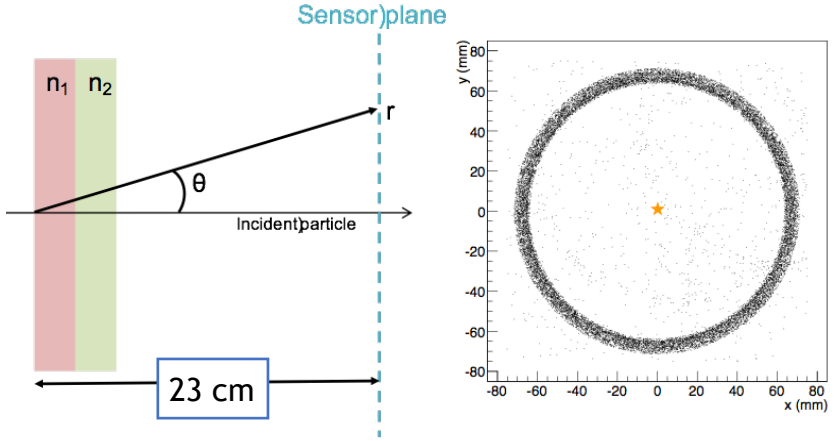
Lens-Based mRICH Design



- 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)

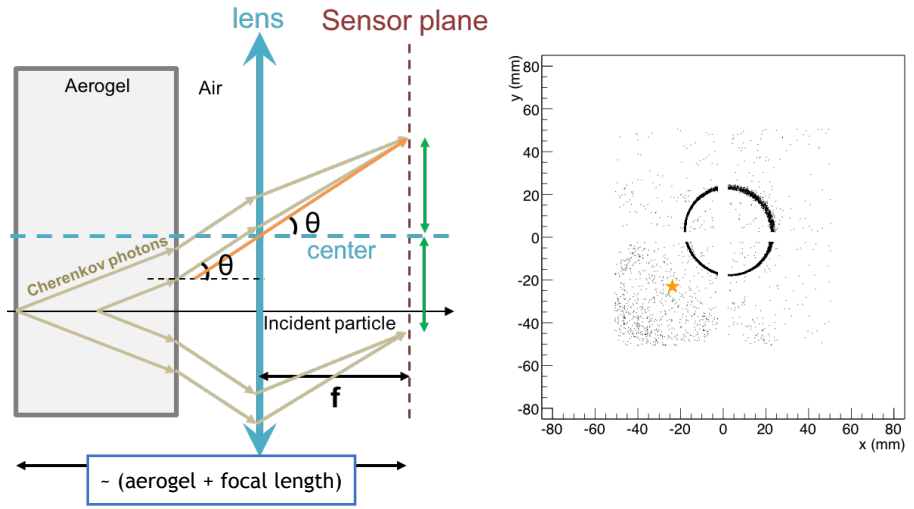


- EIC mRICH designed for K/pi ID up to 9 GeV/c
- BELLE-2 ARICH aims to separate pion and kaon up to 4 GeV/c

mRICH – lens-based focusing aerogel detector design

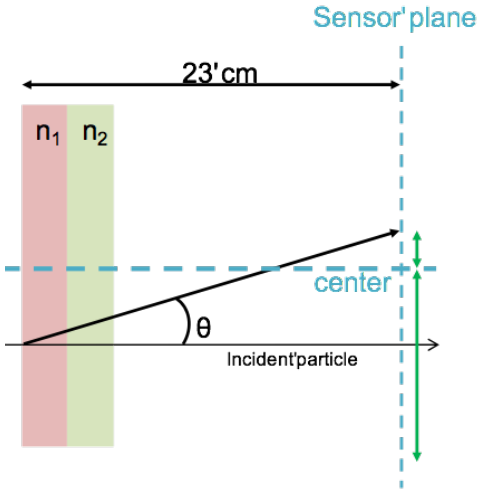
Smaller, but thinner ring improves PID performance and reduces length

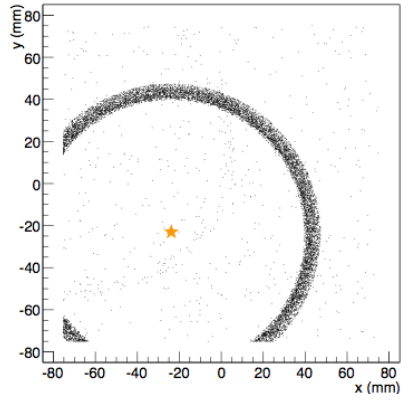
Lens-Based mRICH Design



- 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)

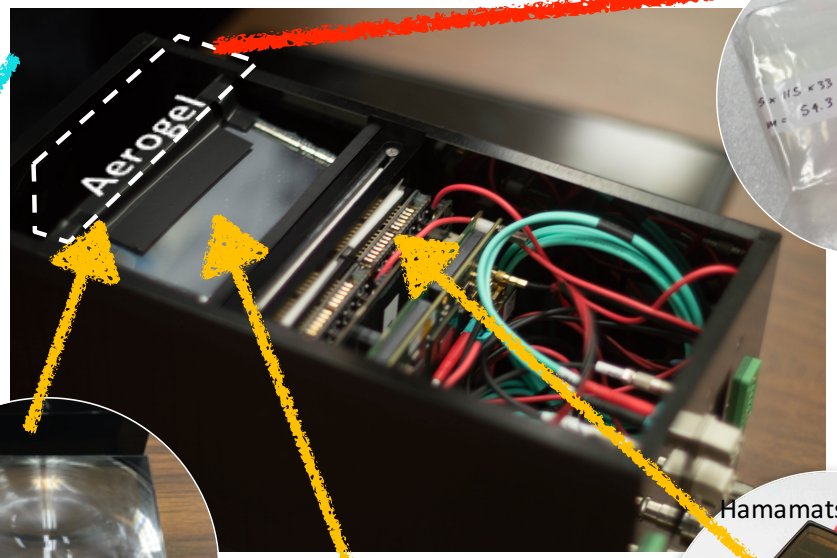


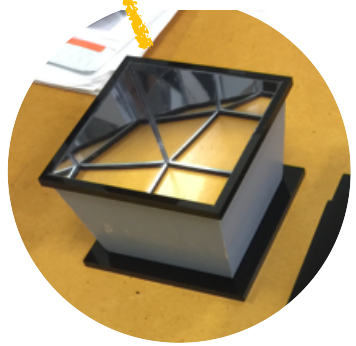


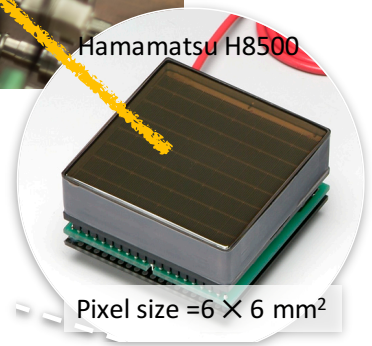
- 9 GeV/c pion beam incident at third quadrant (star) in simulation
- Ring is centered at point of incidence

1st mRICH Prototype Beam Test - Proof of Working Principle

Fermilab Beam Test Facility, April 2016



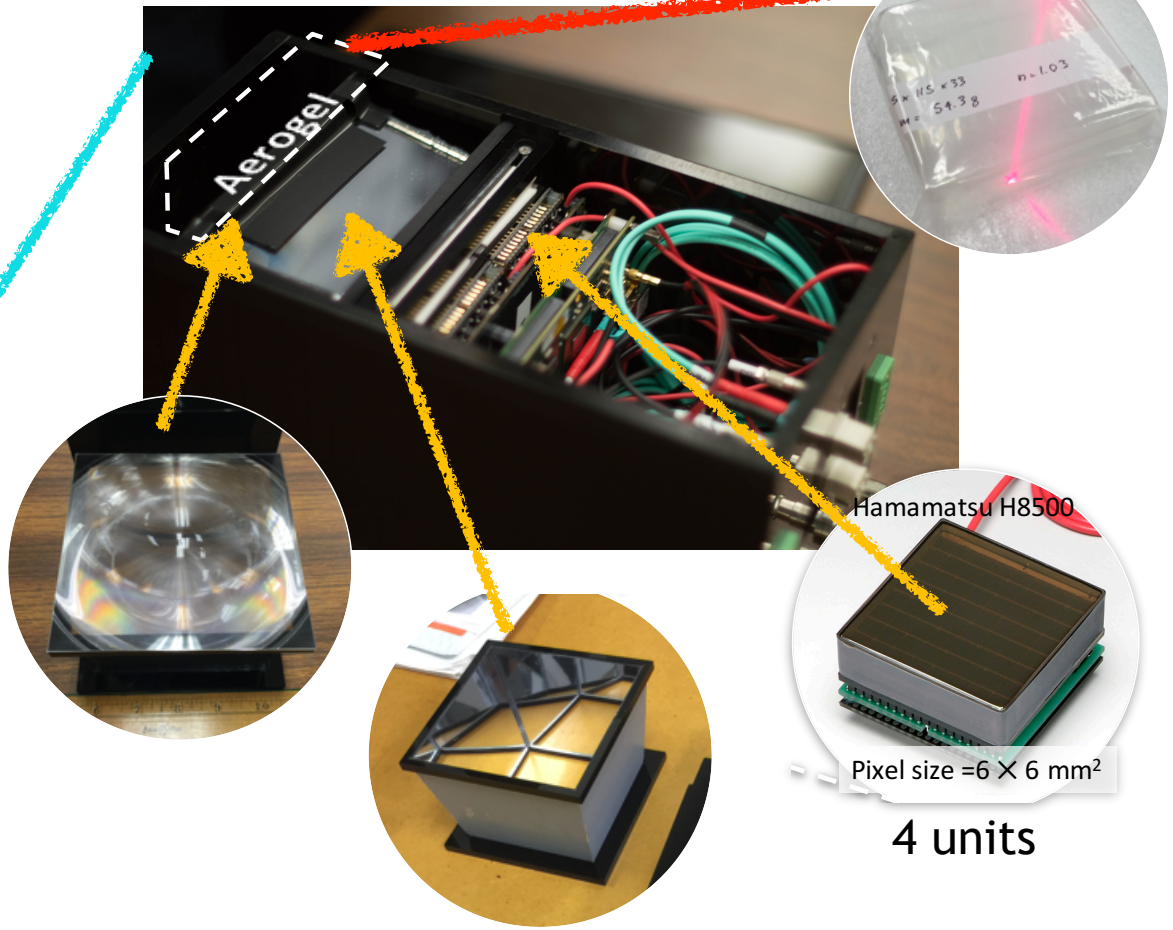




4 units

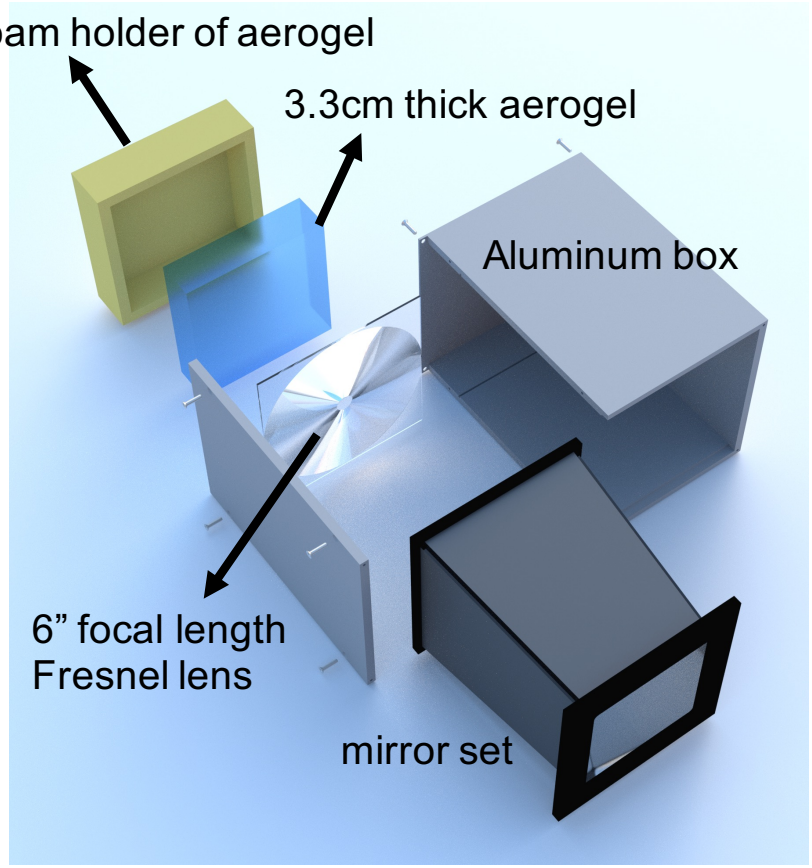
1st mRICH Prototype Beam Test - Proof of Working Principle

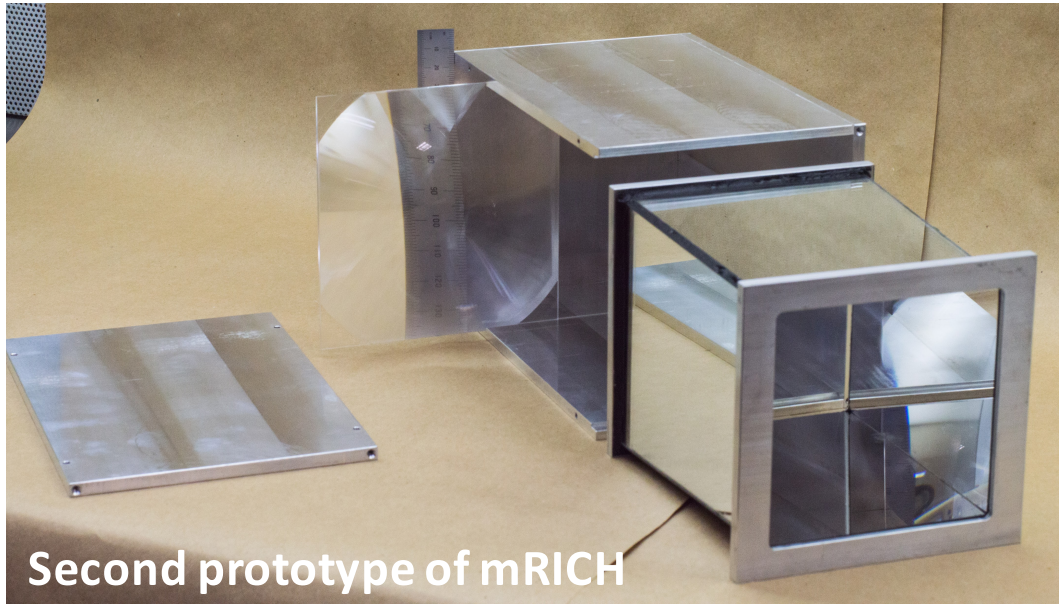
Fermilab Beam Test Facility, April 2016

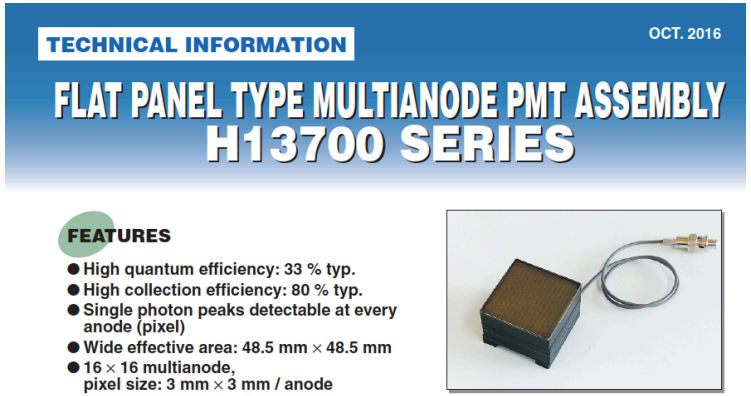


C.P. Wong et. al. NIM A871 (2017) 13-19

2nd mRICH Prototype - Improved Optical Component Design





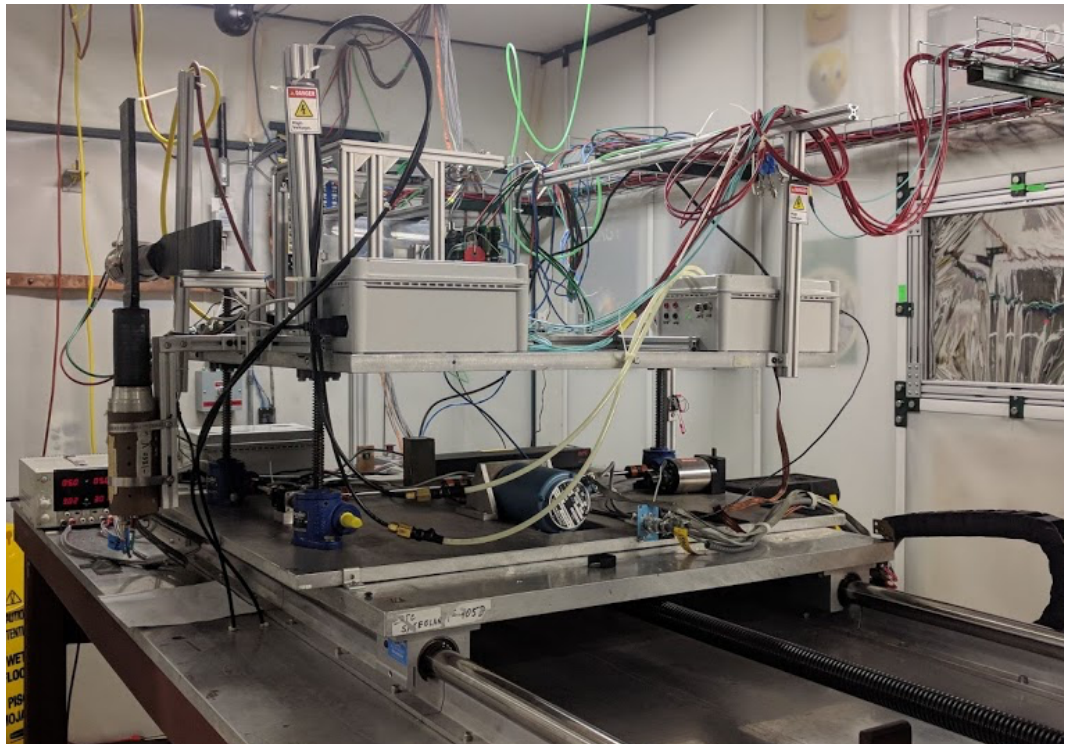


1. Longer focal length (Fresnel lens)
2. Smaller pixel size sensors

2nd mRICH Beam Test - Verify the PID Capability

Fermilab Beam Test Facility, from July 25 to August 6, 2019

120 GeV/c proton



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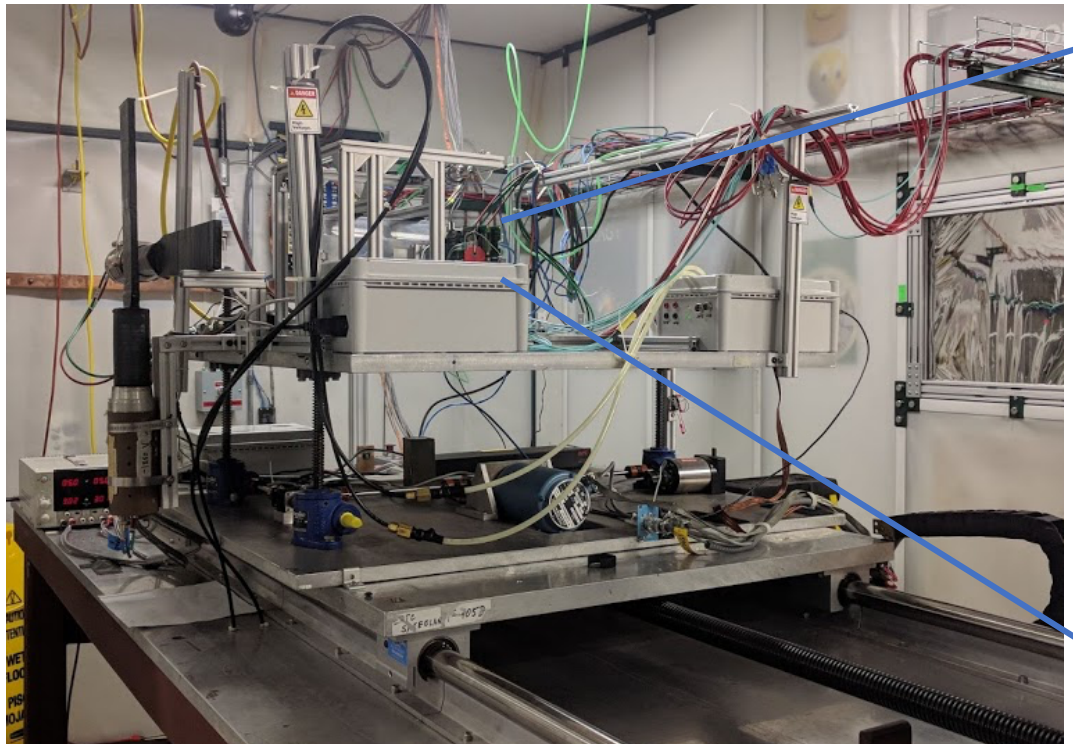
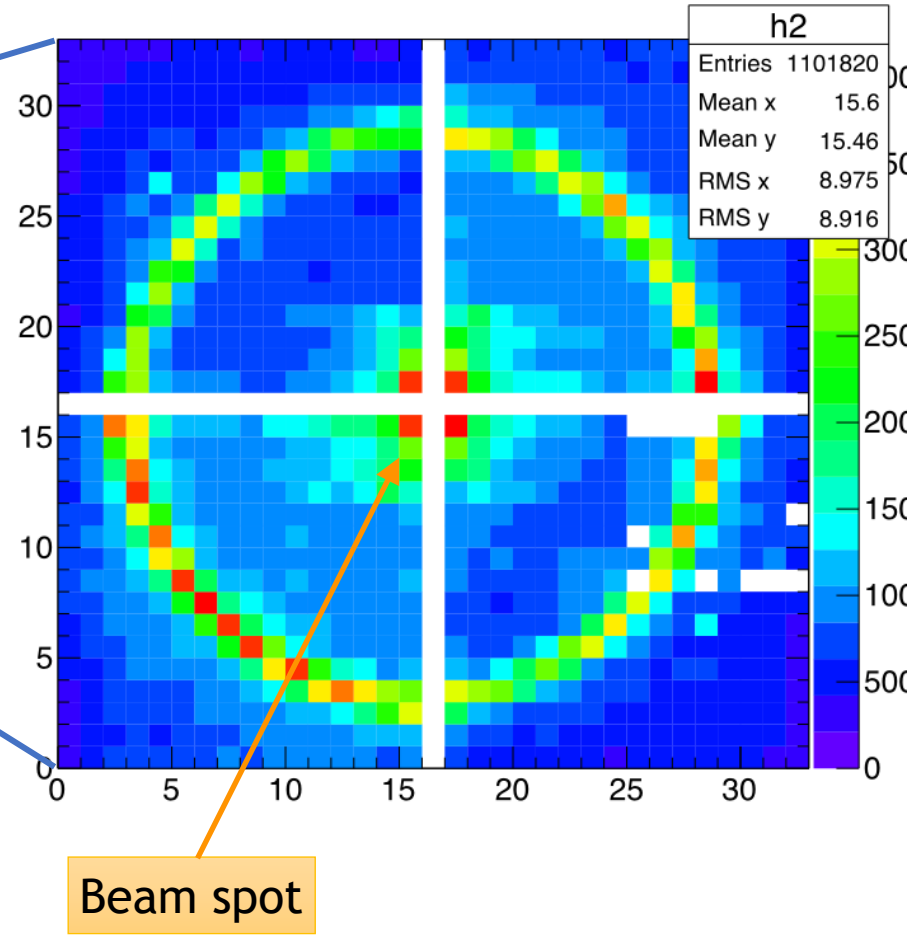
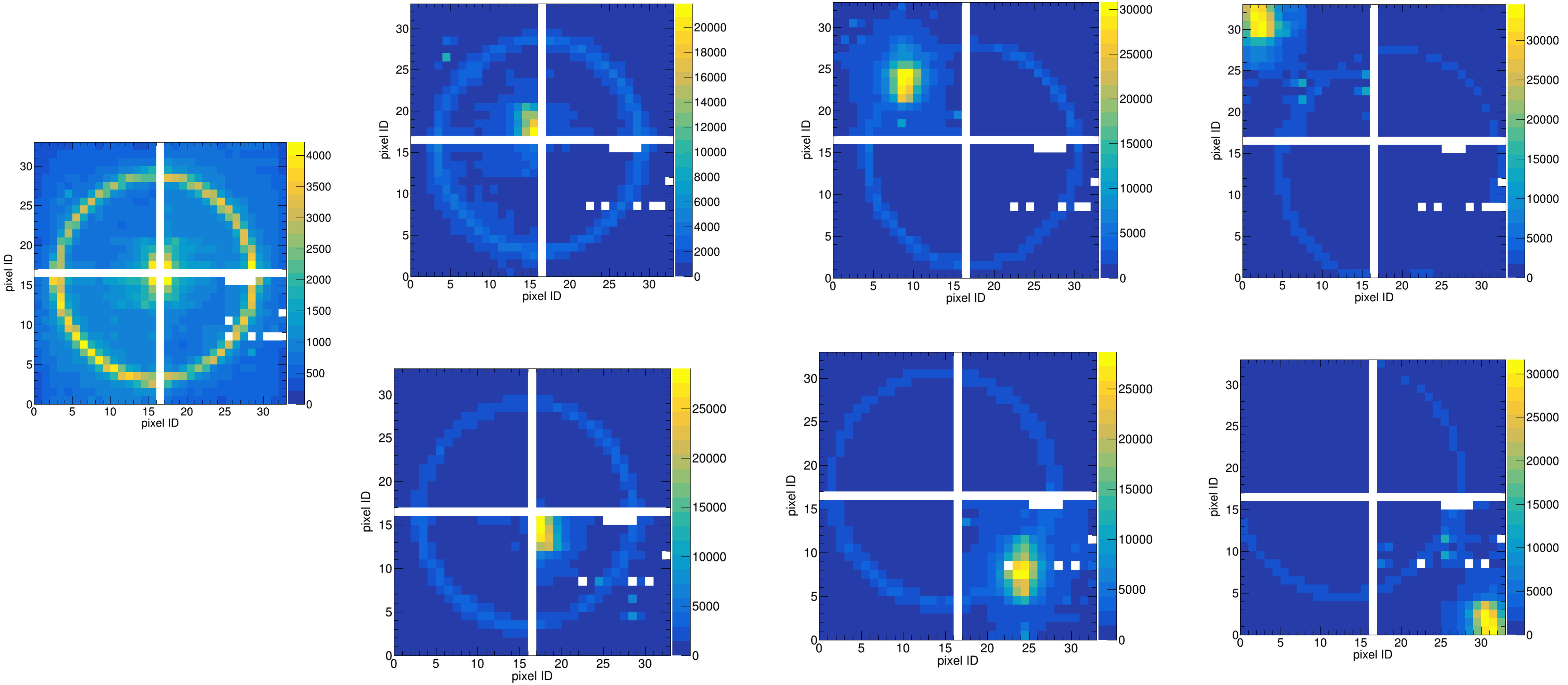
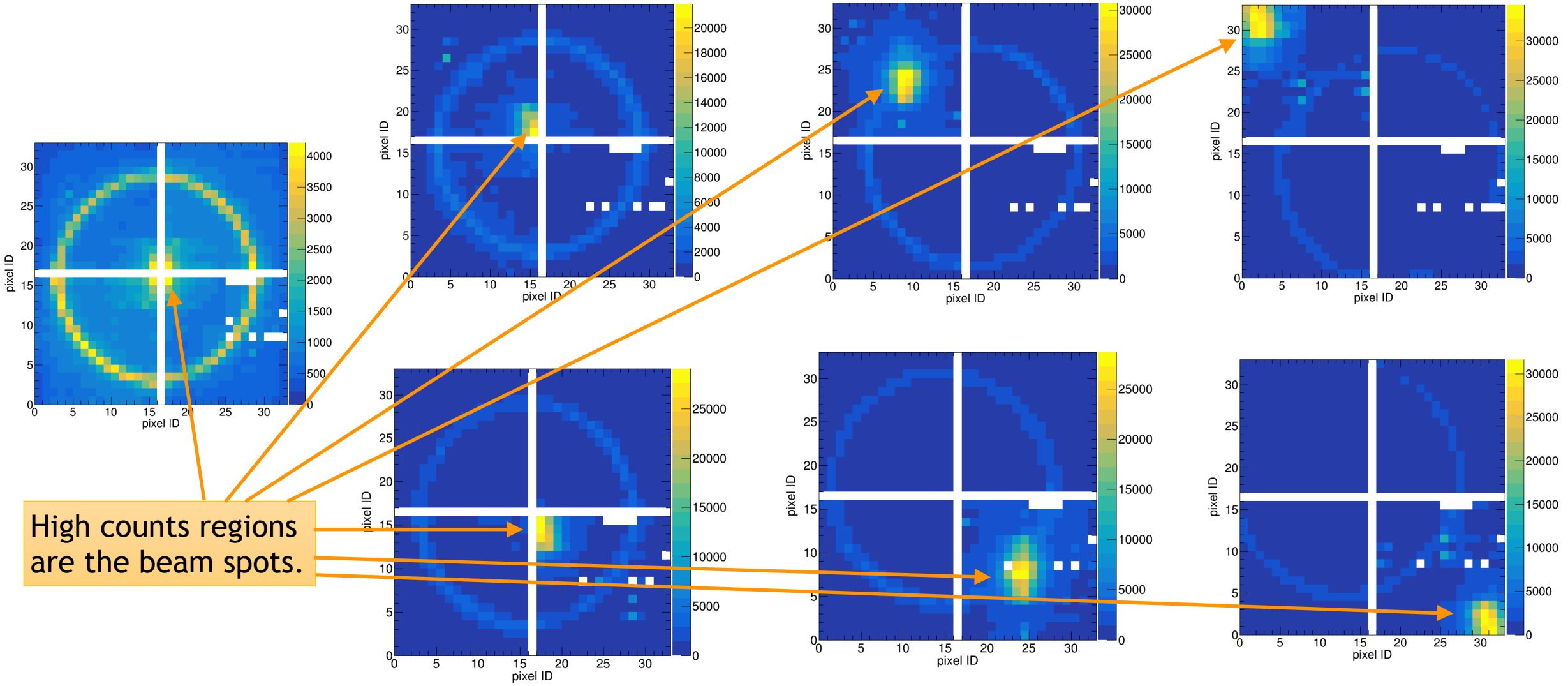




Position scans with 120 GeV/c proton beam

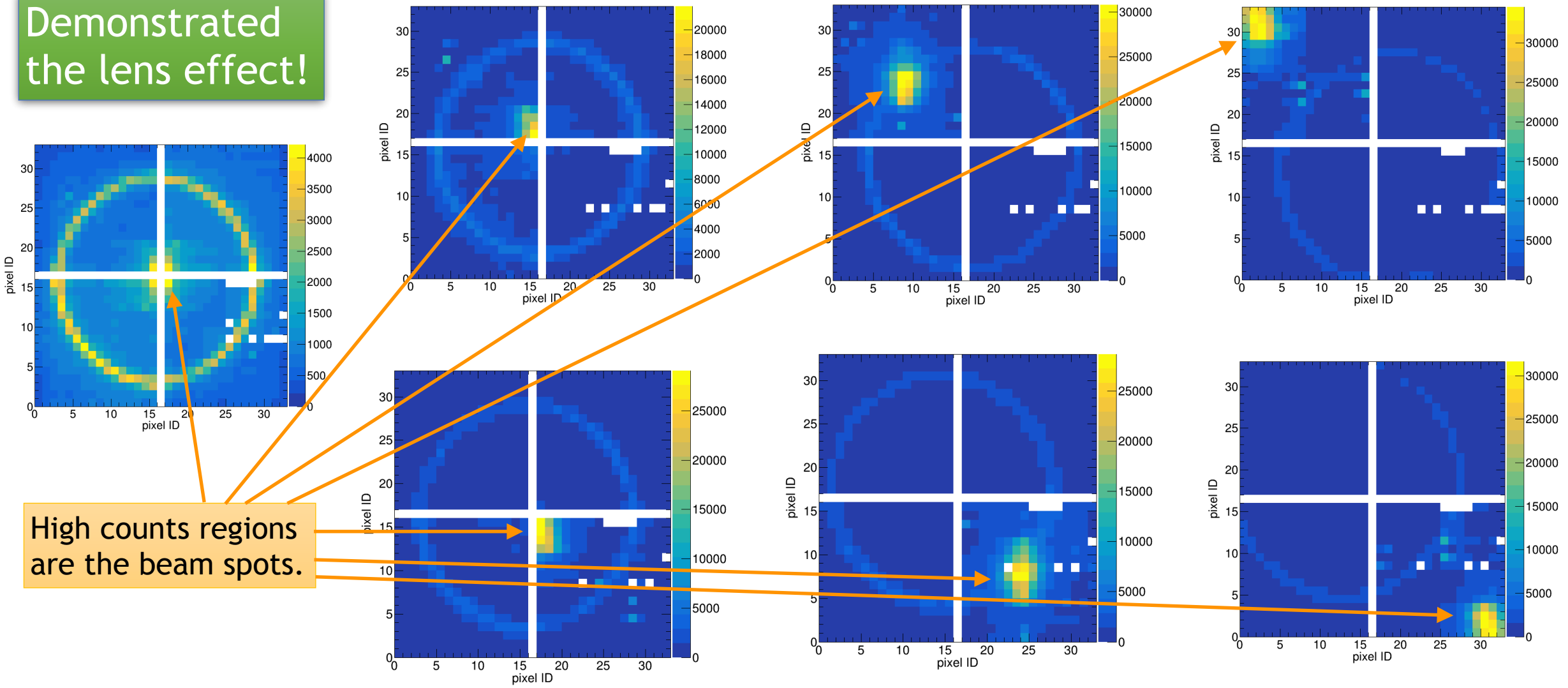


Position scans with 120 GeV/c proton beam



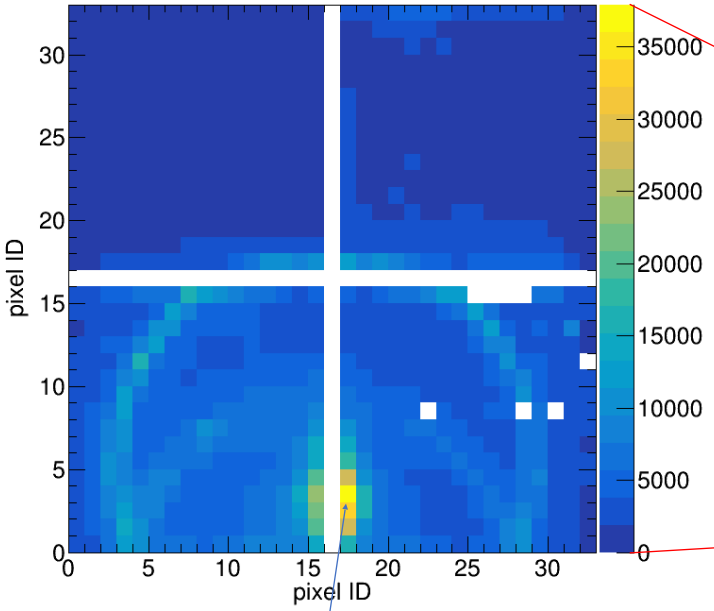
Position scans with 120 GeV/c proton beam

Demonstrated the lens effect!

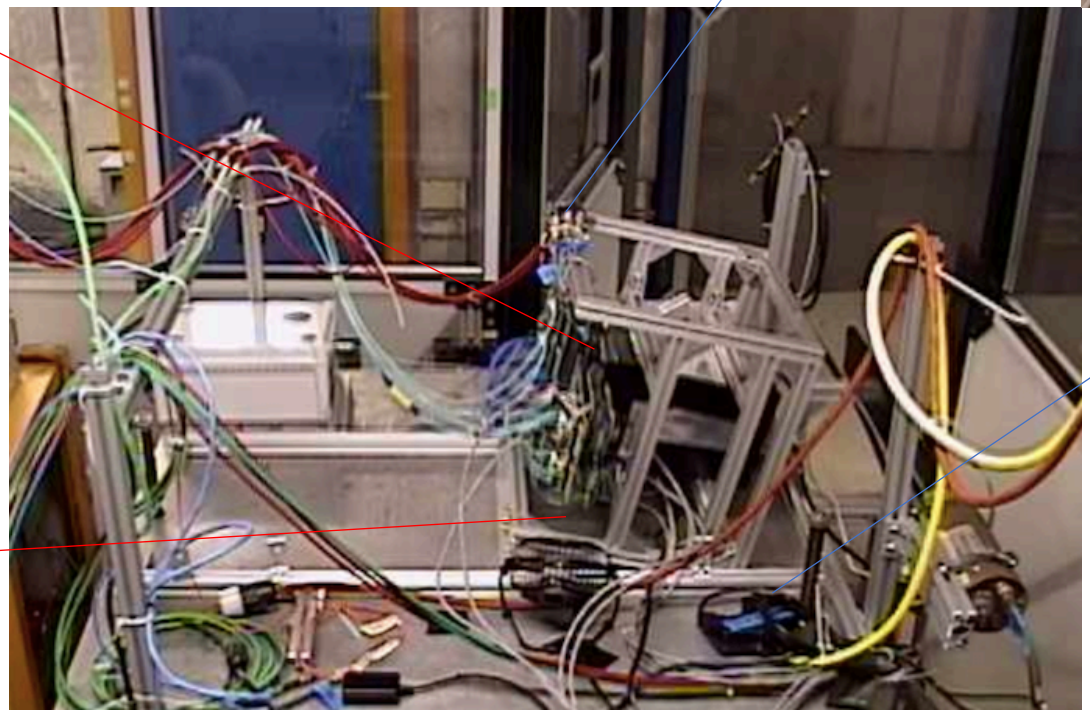


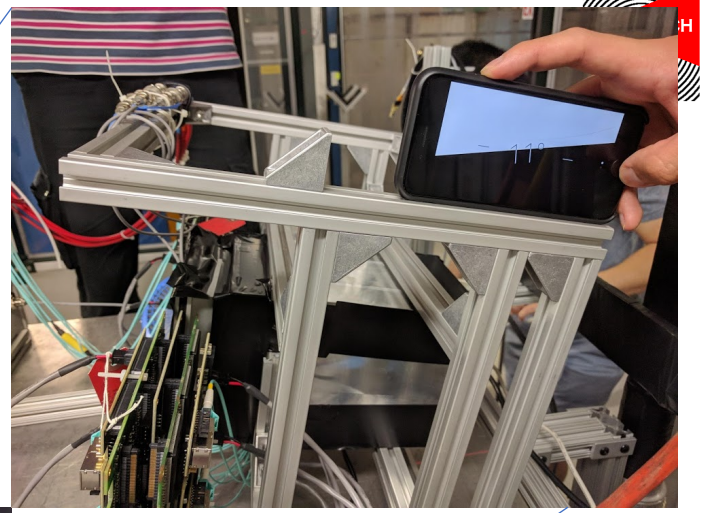
High counts regions are the beam spots.

Ring image from proton beam at an angle (11º)



Beam spot

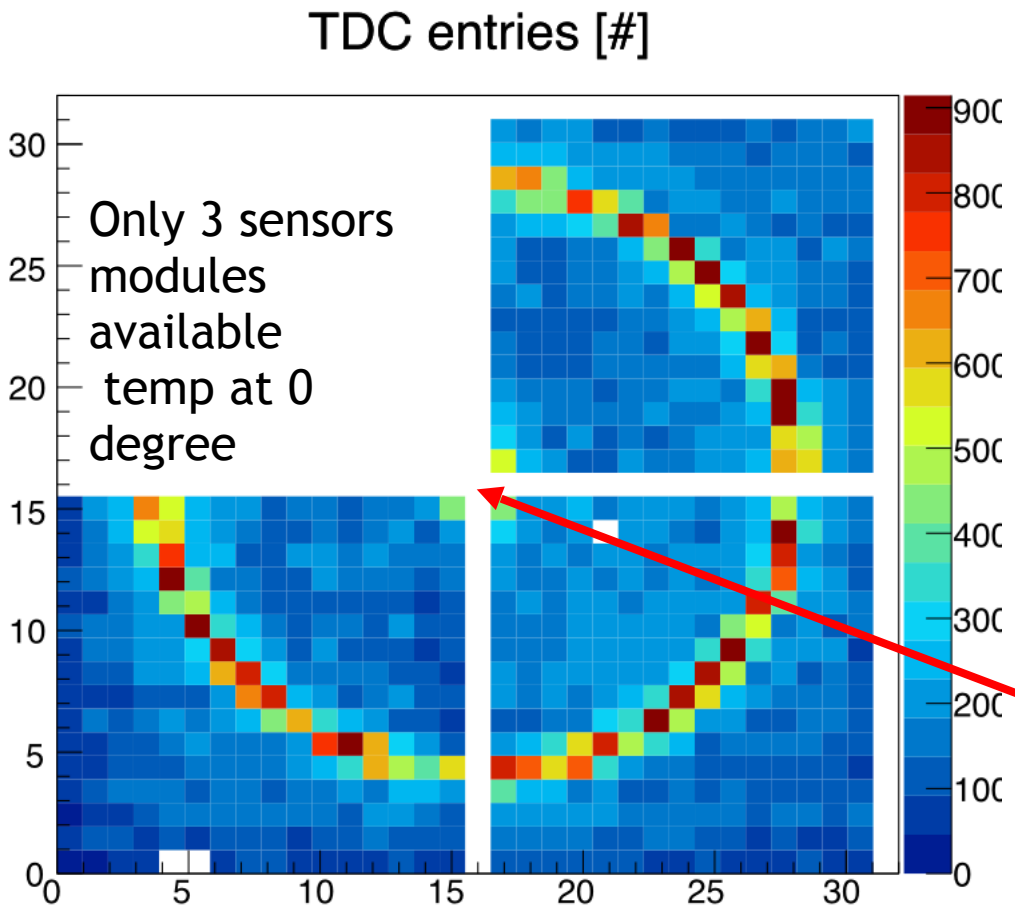


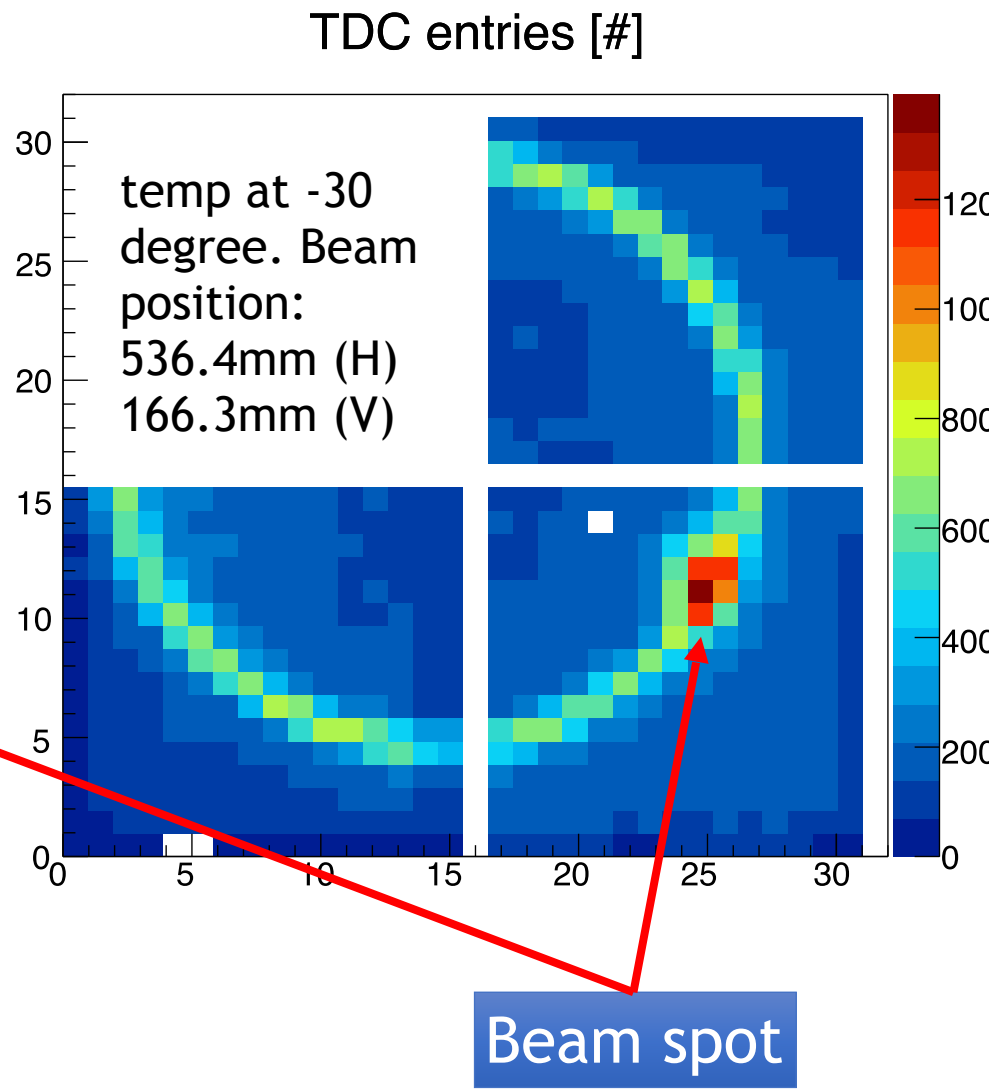


11 degree tilt downward

120 GeV/c proton beam

mRICH readout with SiPM matrix sensors

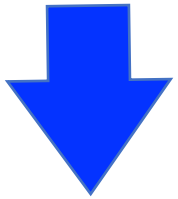




120 GeV/c proton Incident at center

Ongoing mRICH Performance Data Analysis

Data analysis is a joint effort between GSU and INFN group. The current analysis is focused on identifying clean primary beam (120 GeV protons) events (i.e., incident at the center) and determining the ring radius, number of Cherenkov photons on ring, noise level, angular resolution.

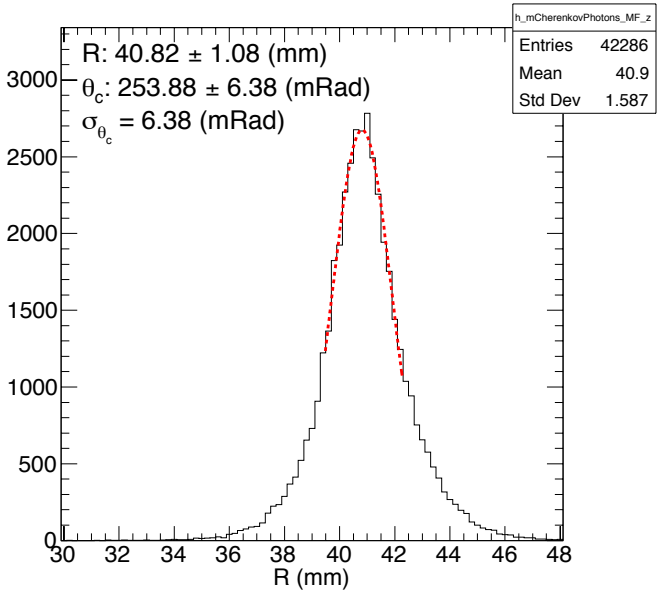


- **Fine tune the GEANT4 simulation to match with the data.**
- **Quantitative understanding the mRICH performance**

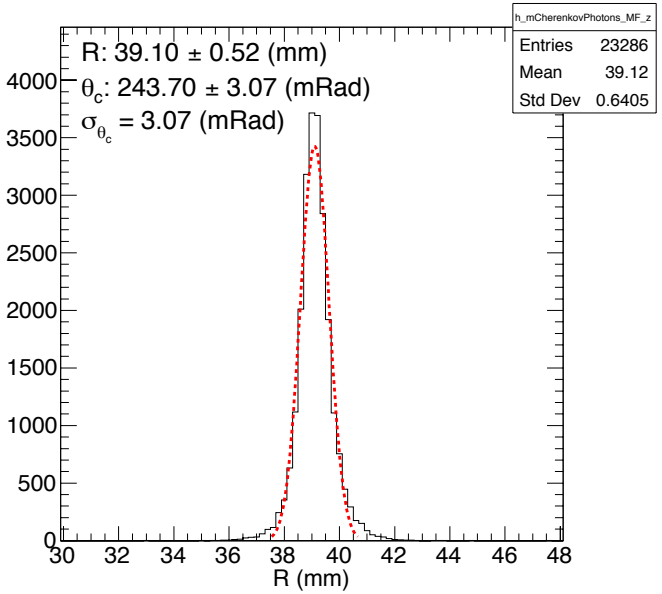
Ring Radius and Number of Cherenkov Photons

Data

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



Simulation



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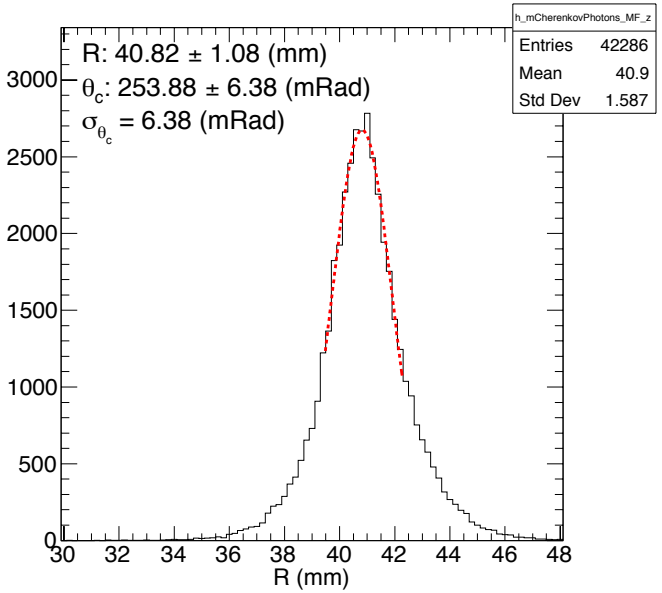
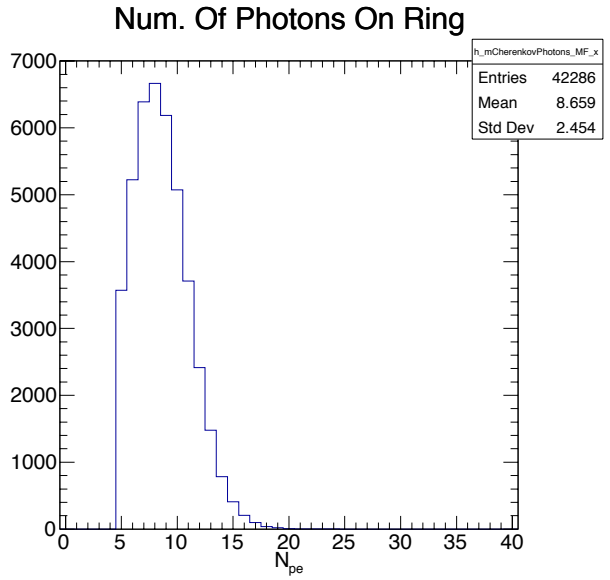
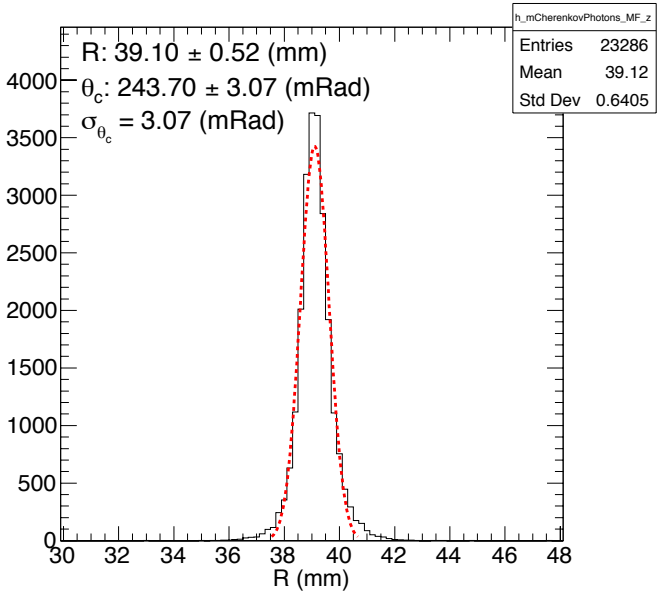
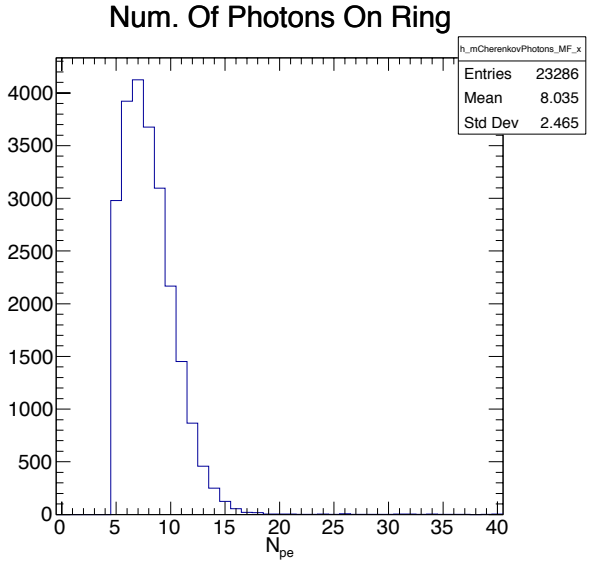




Simulation





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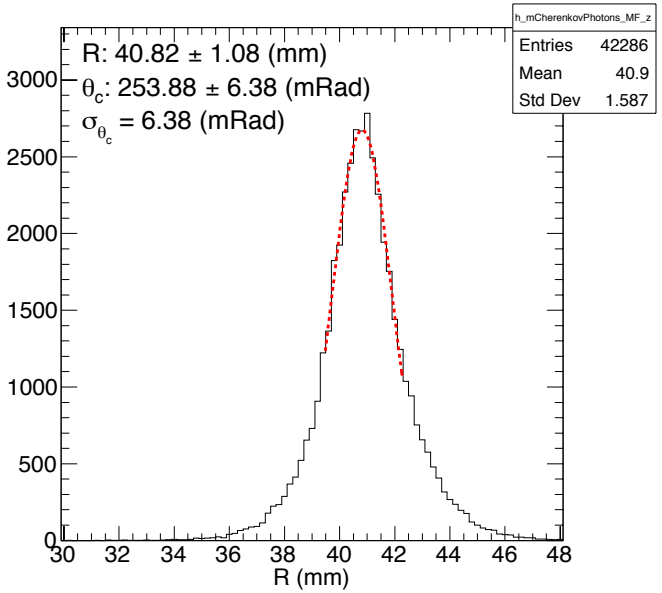
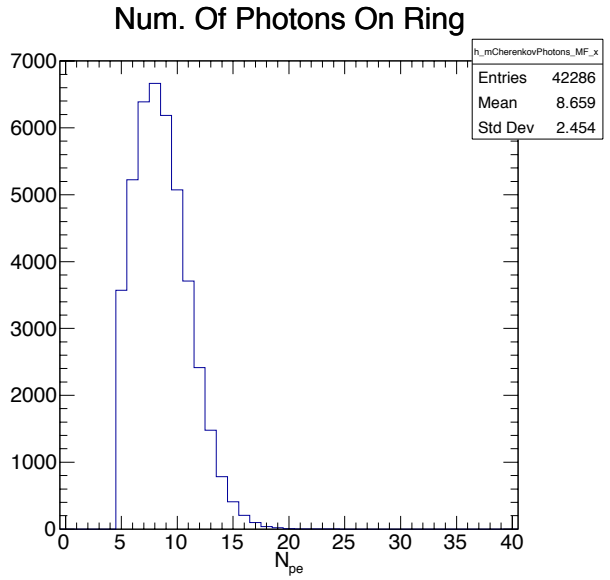
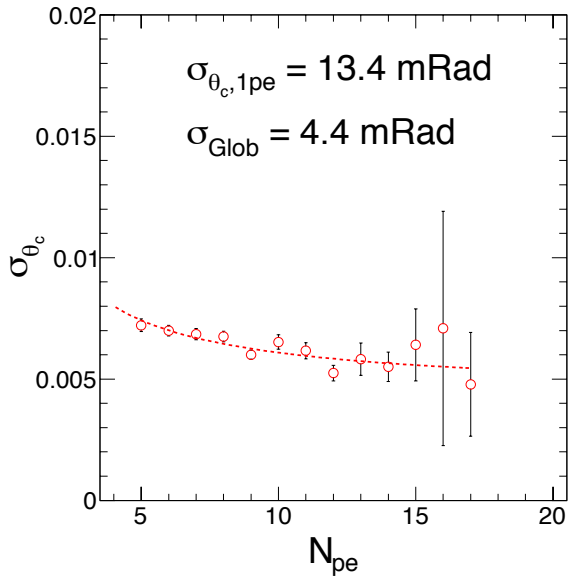
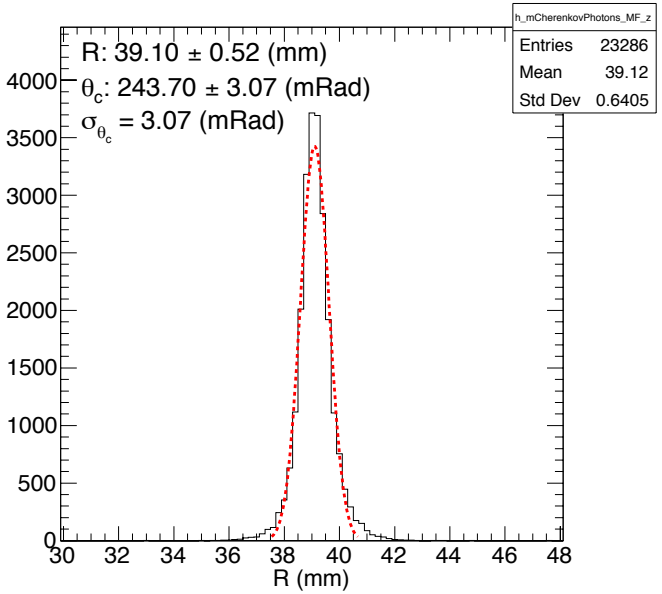
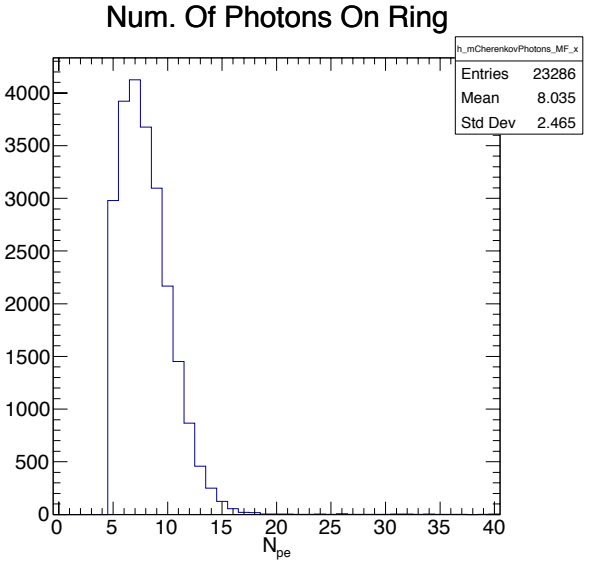


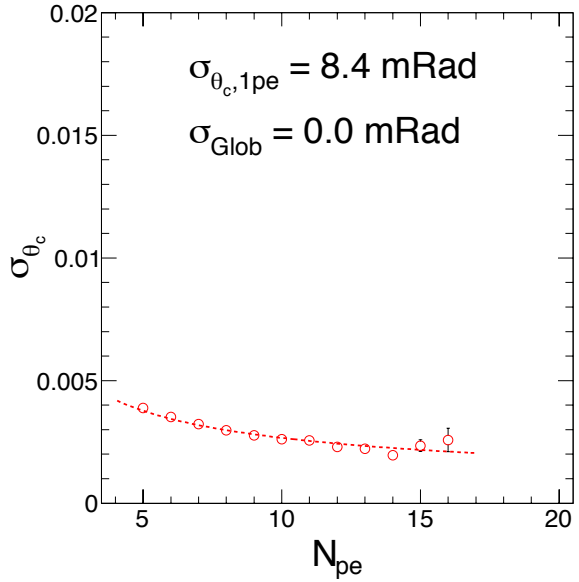




Simulation







mRICH R&D toward TDR readiness in four years

mRICH baseline design and its general property is well understood. A realistic GEANT4 simulation has been developed. However, further R&D effort is needed in order to quantify mRICH performance with precision tracking capabilities.

FY20 Activities

- Continue the mRICH data analysis and fine tune simulation (based the 2nd mRICH beam test data):
  - ✦ Quantitatively assess the effects of optical alignment on mRICH performance, which include focal plane location, sensor plane orientation, etc.
  - ✦ Quantify the temperature-dependent noise levels in the data set taken with three SiPM matrices.
- Prepare for the third mRICH beam test
  - ✦ Set up an optical characterization system at GSU for measuring the optical properties of Aerogel, lens and mirrors.

FY21 and FY22 Activities

- Plan a dedicated mRICH beam test to verify its performance parameters. Require the following key components:
  - Well characterized aerogel tiles, Fresnel lens and mirror sets
  - **mRICH holder frame box (with rotation capabilities)**
  - **Particle tracking (beyond using beam hodoscope)**
  - **Optical alignment study**
  - Dedicated readout
  - Photosensors: SiPM matrices and/or MCP-PMTs
  - Online reconstruction for assessing data quality in real time

FY23 Activities

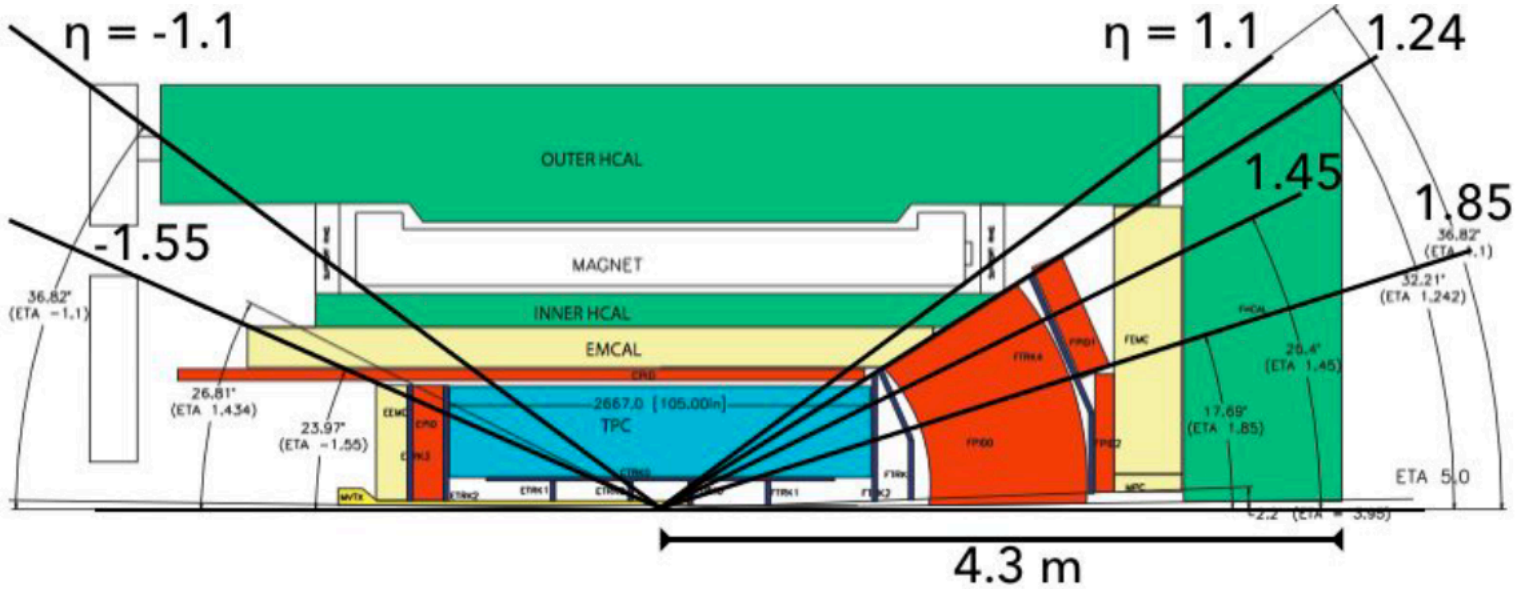
- System integration studies
  - Engineering design of mounting mRICH array
  - Optical alignment
  - Cooling system (for the case of SiPM matrix readout)
- mRICH array simulation studies in EIC experiments
- PID algorithm development

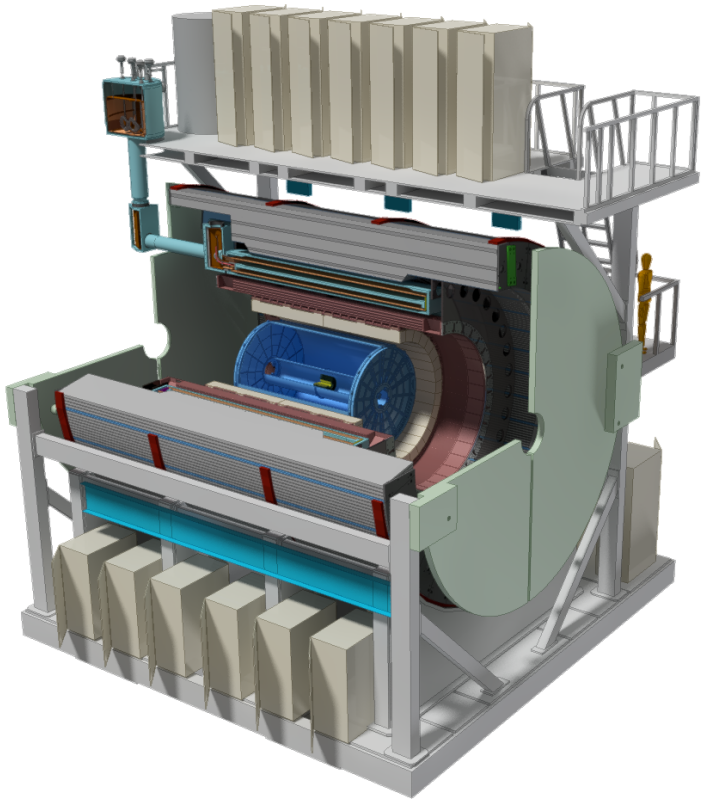
mRICH R&D Package

R&D package	FTE (cost)	Cost (material, etc)	FY Period
Aerogel (acquiring and optical test)	0.1 ($8k)	$10k	FY21 - FY22
Fresnel lens and mirror (acquiring and optical test)	0.1 ($8k)	$2k	FY21 - FY22
Engineering design of mRICH holder frame box with optical alignment	0.2 ($16k)	$5k	FY21 - FY22
Photosensors (SiPM matrices or MCP-PMT)	0.1 ($8k)	shared with dRICH	FI21 - FY22
Sensor readout (front-end sensor readout chip, back-end user interface)	0.5 ($40k)	shared with dRICH	FY21 - FY22
Tracking system	0.2 ($16k)	shared with dRICH	FY21 - FY22
Simulation/data analysis	1 ($80k)		Each year from FY20 - FY23
Travel support		$10k	Each year from FY20 - FY23
PhD student	$30k		Each year from FY20 - FY23

Outlook

Near-term PID Detector Realization – BNL ePHENIX



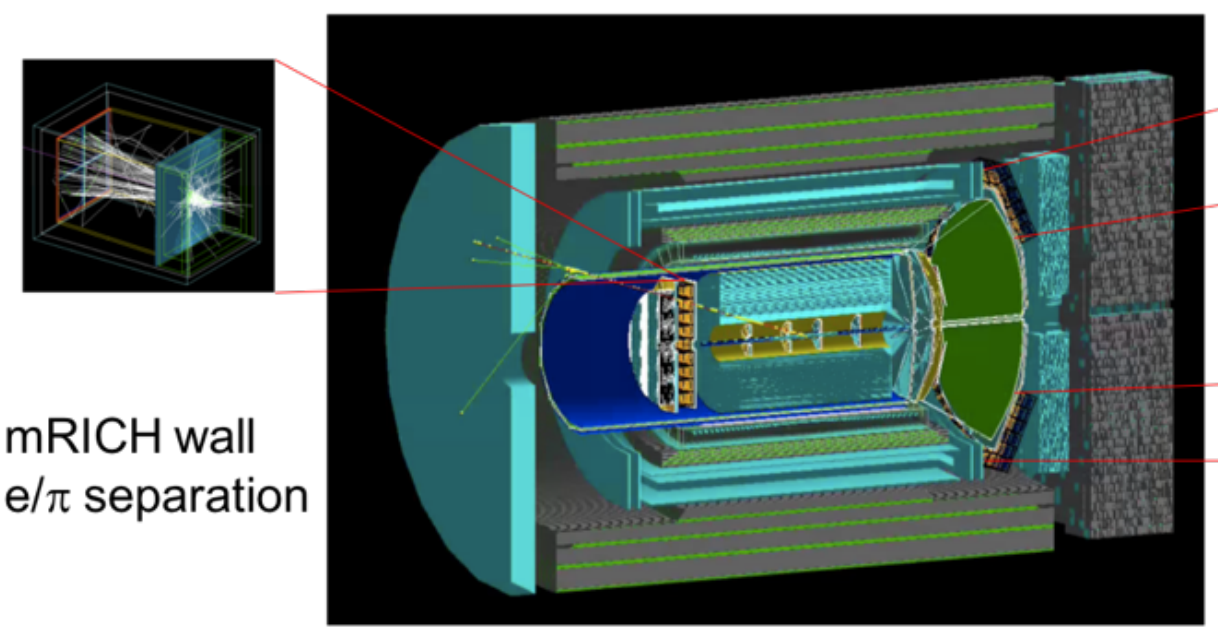


- The DIRC, mRICH, and TOF systems already part of the current concept. An implementation in Geant4 (Fun4All) is ongoing.
- In addition, either the eRD14 dRICH and eRD6 gas RICH could be used. The two options have been compared in a collaborative effort.

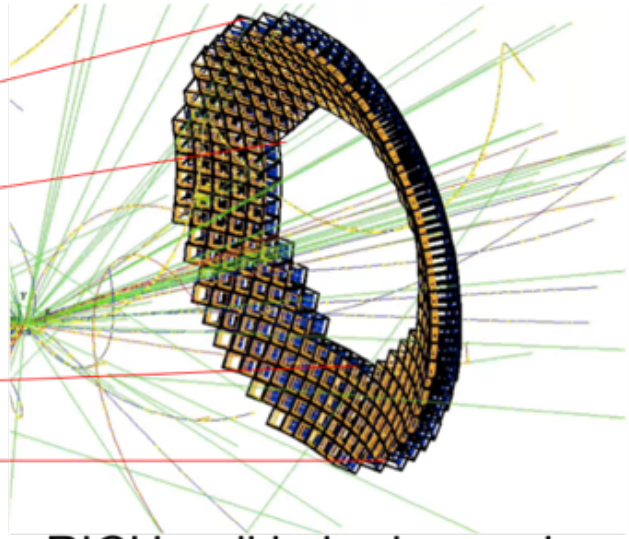
sPHENIX

mRICH in ePHENIX

mRICH array implementation in Forward sPHENIX and JLab EIC detector concept in Geant4 simulation studies. Developed mRICH-based PID algorithms using a loglikelihood method.



mRICH wall
e/π separation



mRICH wall in hadron-going direction for hadron PID

THANK YOU