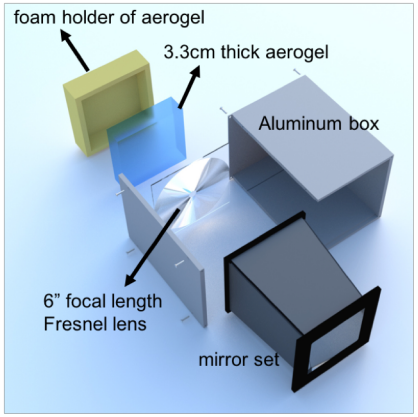
Modular aerogel RICH (mRICH)



Goal:

- Compact PID device with momentum coverage up to 10 GeV/c for π/K and e/π up to 2 GeV/c.
- First aerogel RICH with lens-based focusing (for performance and cost)

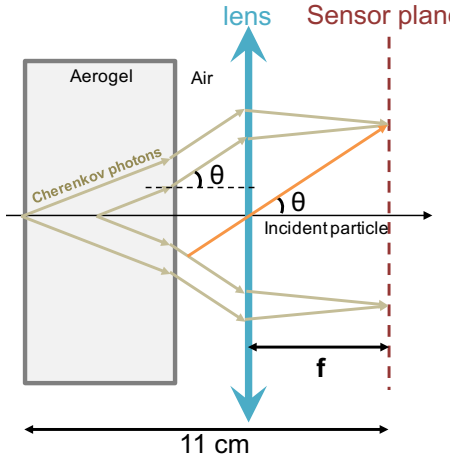
FY 19:

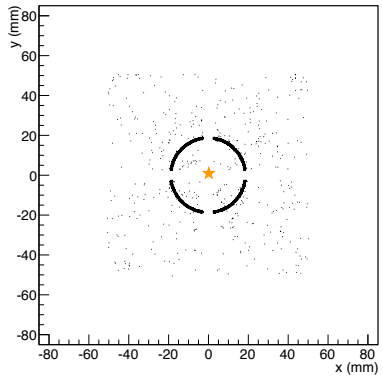
- Analyze and publish the mRICH test beam data taken in June/July 2018.
- Use the mRICH to develop an integrated readout sensor electronics solution for all Cherenkov systems (mRICH, dRICH, DIRC).
- Plan for a 3rd (final?) mRICH test beam in FY20.
- Search for best, radiation hard materials for Fresnel lens.
- Optical characterization of Fresnel lens and aerogel.

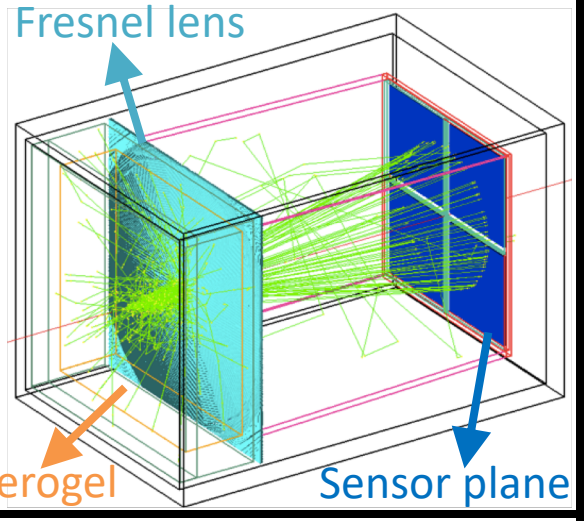
mRICH – lens-based focusing aerogel detector design

Smaller, but thinner ring improves PID performance and reduces length

Lens-Based mRICH Design

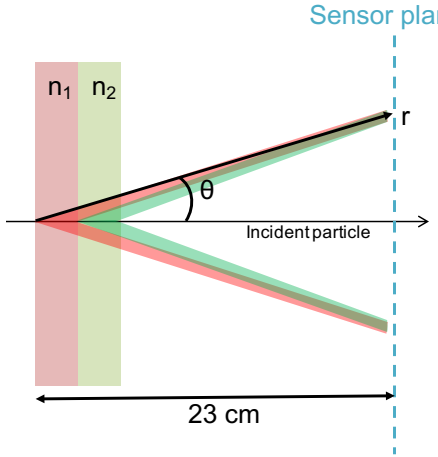


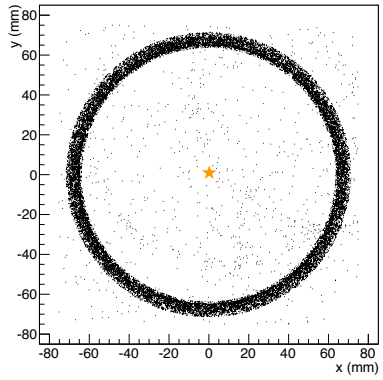




9 GeV/c pion beam launched at the center of xy plane in simulation

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



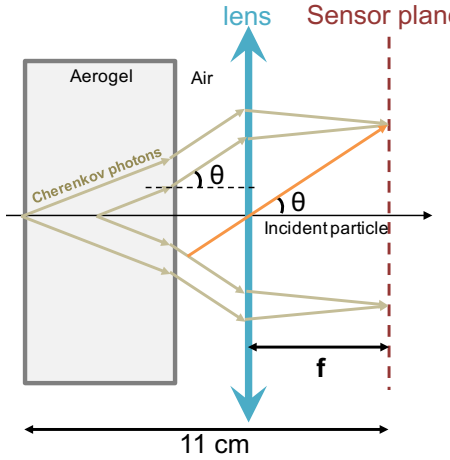


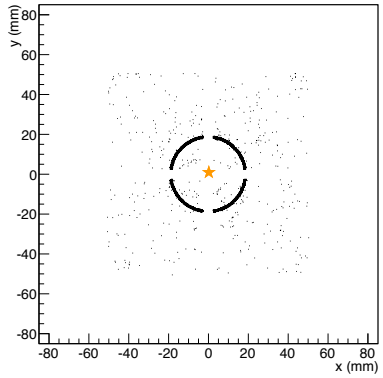
- EIC mRICH designed for K/pi ID up to 10 GeV/c
- BELLE-2 ARICH aims to separate pion and kaon up to 4 GeV/c

mRICH – lens-based focusing aerogel detector design

Smaller, but thinner ring improves PID performance and reduces length

Lens-Based mRICH Design

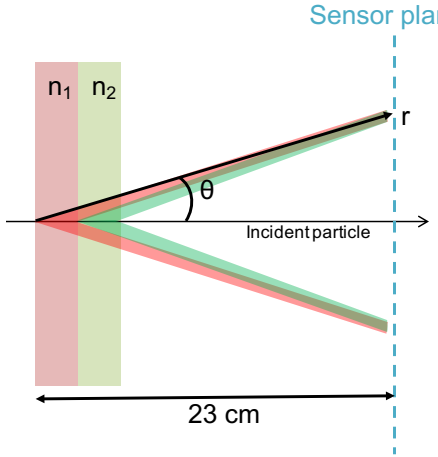


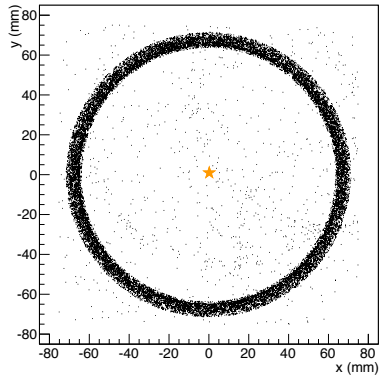


- 9 GeV/c pion beam launched at the center of xy plane in simulation
- **Smaller and thinner** ring image

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

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



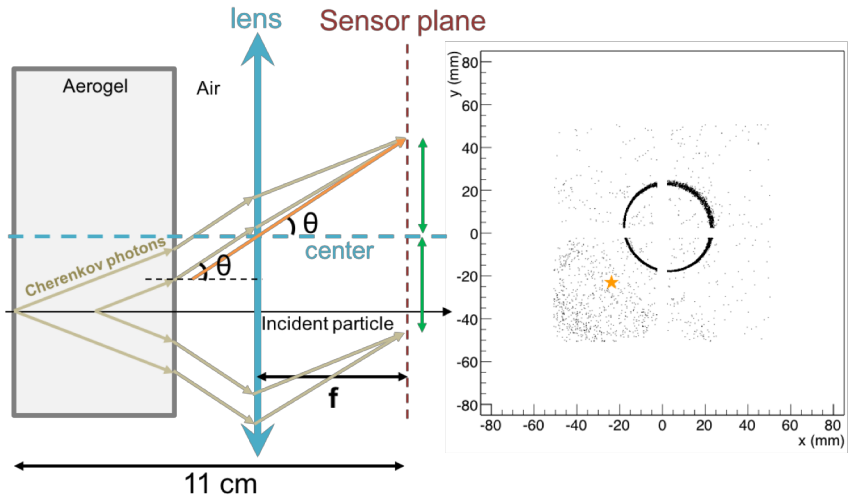


- EIC mRICH designed for K/pi ID up to 10 GeV/c
- BELLE-2 ARICH aims to separate pion and kaon up to 4 GeV/c

mRICH – lens-based focusing shifts image to center

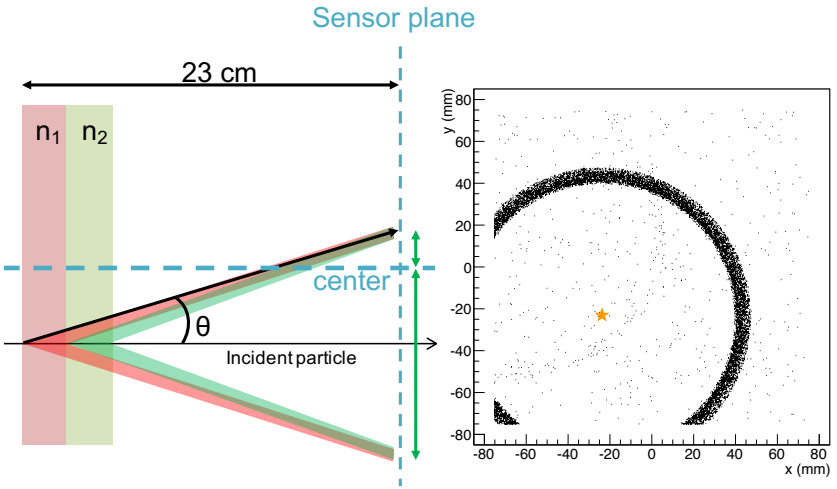
Ring centering of lens-based optics reduces sensor area (main cost driver)

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)

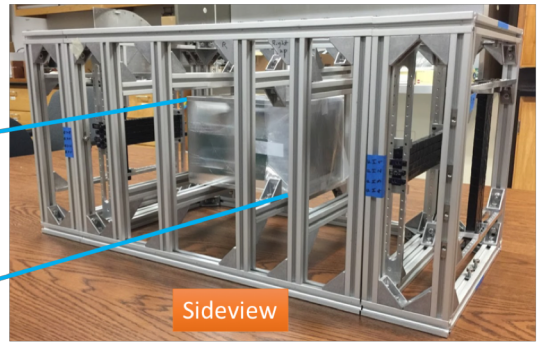


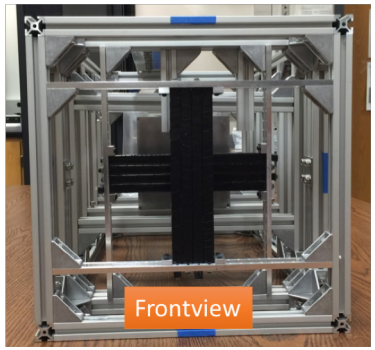
- 9 GeV/c pion beam incident at third quadrant (star) in simulation
- Ring is centered at point of incidence

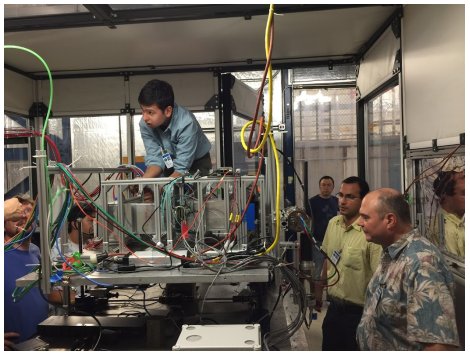
2nd mRICH Beam Test

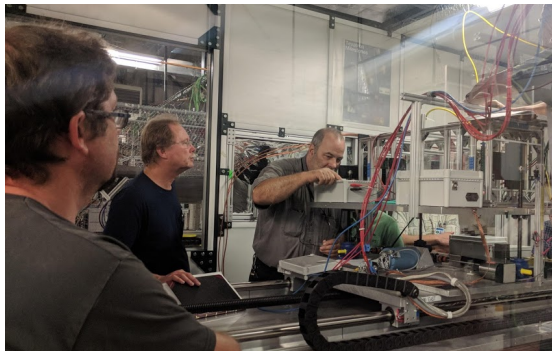
Another very successful mRICH prototype beam test at Fermilab (6/25 to 7/6/2018)

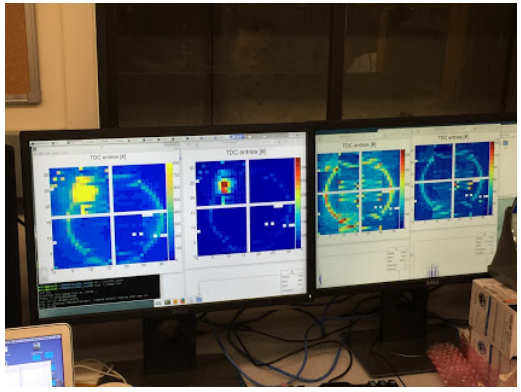
Two completed mRICH prototypes

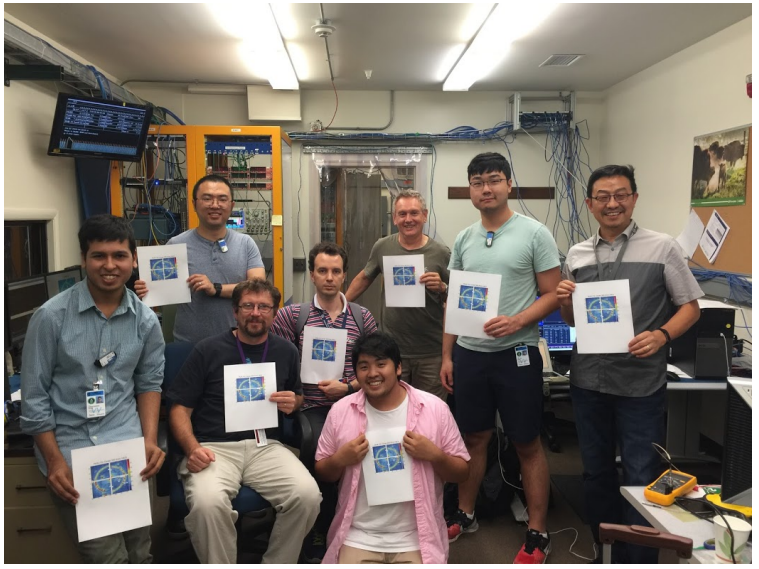








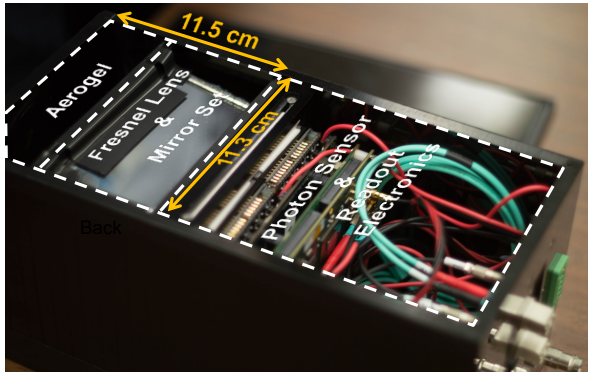




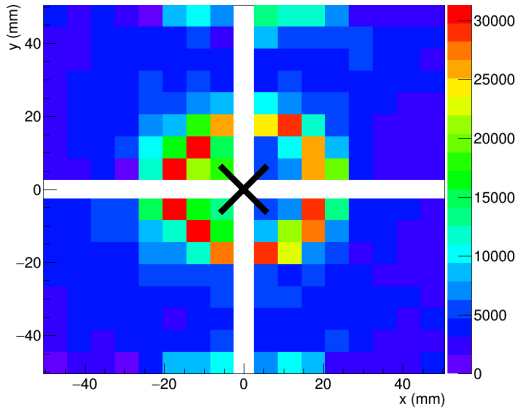
Group photo (missing two members) – the first confirmed ring image

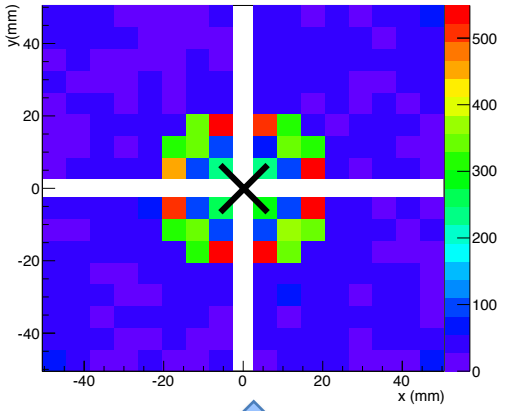
1st and 2nd Beam Test Comparison (120 GeV Proton Beam)

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



1st mRICH prototype was tested at Fermilab Test Beam Facility in April 2016

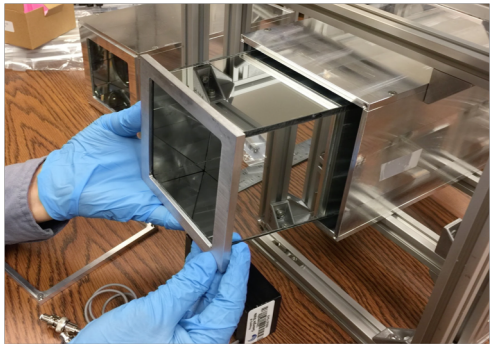




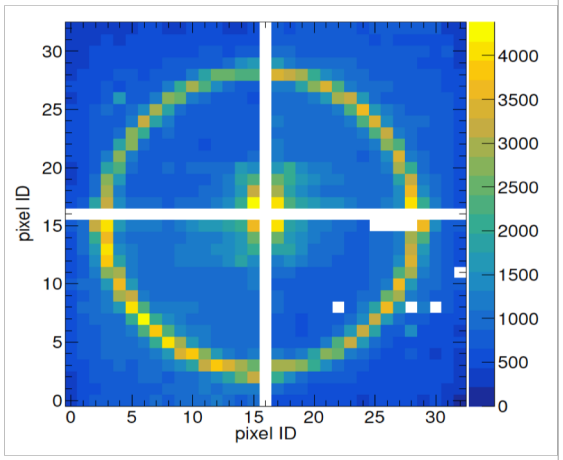
Images from 120 GeV Proton beam

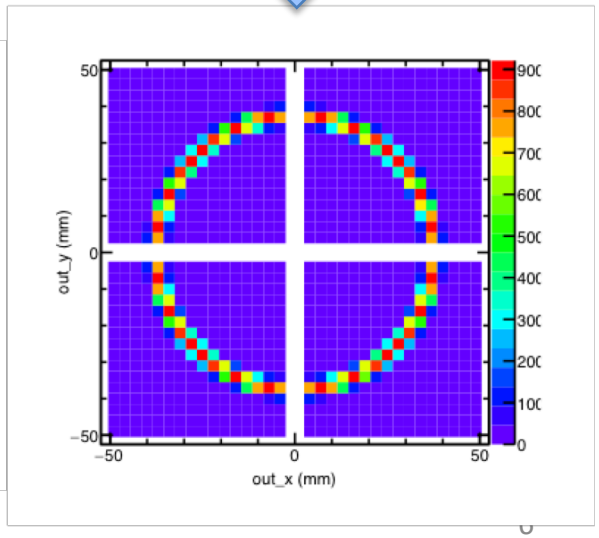
Simulated Images Using GEANT4

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



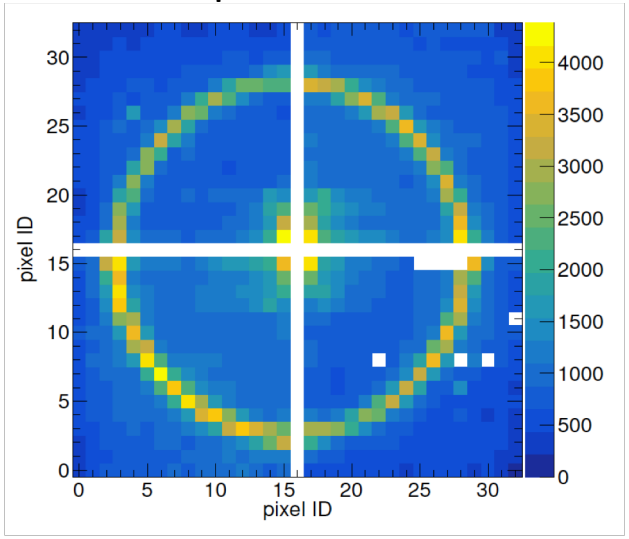
2nd mRICH prototype was tested at Fermilab Test Beam Facility in June/July 2018

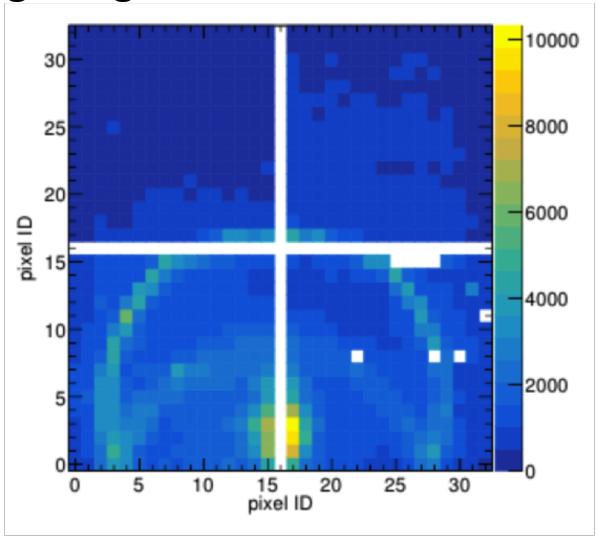


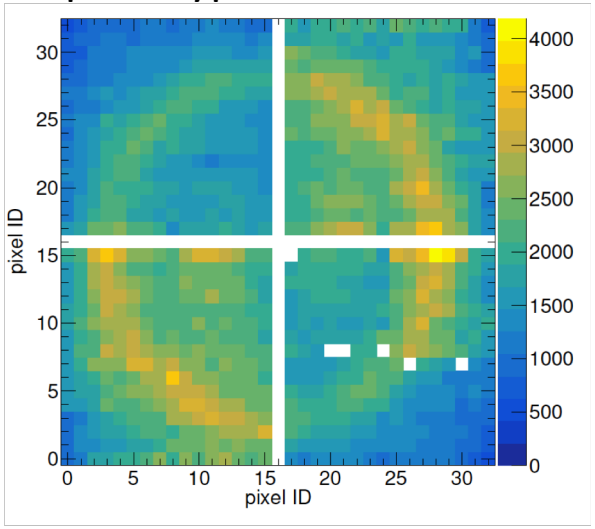


Completed Data QA Analysis for the 2nd Beam Test

Examples of cumulative ring images from the second mRICH prototype beam test







Left: ring images formed by 120-GeV primary proton beam incident on the center of mRICH. White gaps are the PMT frames.

Middle: ring images from 120-GeV primary proton beam incident at an angle of 11° toward the lower section of mRICH.

Right: images from an 8-GeV meson run. The challenge of this analysis is to determine the beam position since the beam hodoscope readout was not ready for this test.

Four Hamamatsu H13700 PMTs (3mm x 3mm pixel size; 16x16 channels) were used in these test runs. Each costs ~$5k. These sensors will NOT work in high magnetic field!!!

mRICH Ring Images from SiPM Sensors (a FIRST!)

To meet the requirement of operating photosensors in high magnetic field in EIC experiment, we successfully demonstrated ring imaging construction using mRICH in the 2nd beam test. There were only three Hamamatsu SiPM matrices available at the time of this test. Given the limited beam time, we only took data with the primary proton beam at 120 GeV with cooling temperature settings at -30°C, -20°C, -10°C, 0°C and room temperature.

SiPM matrix: 16 x 16 channels, 3mm x 3mm pixel size

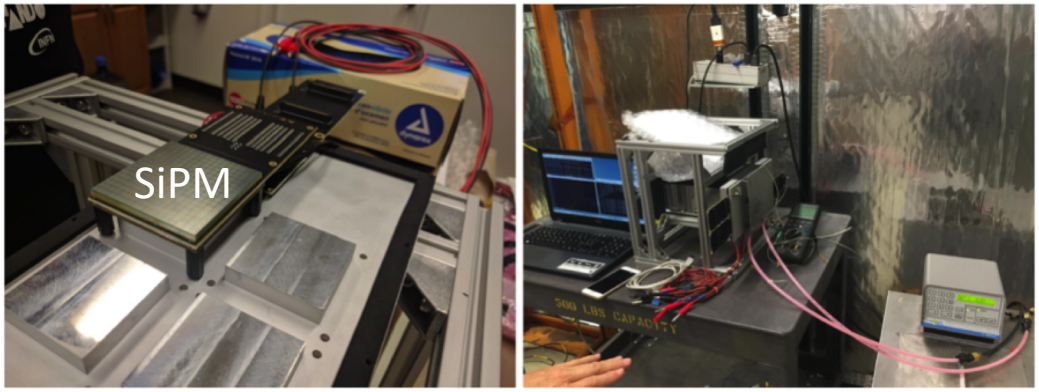


Figure 2.3.2: SiPM matrices setup (left picture) and the cooling system, liquid cooling (right picture). Only three matrices were available for this test.

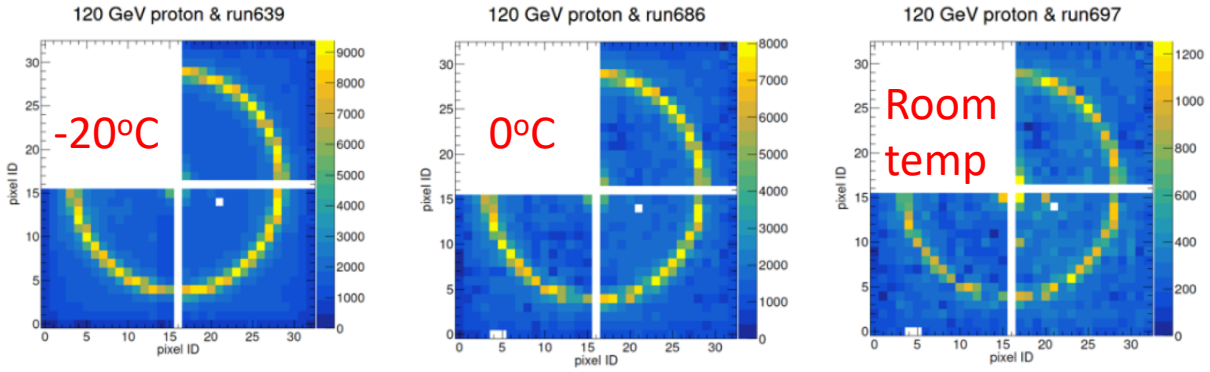
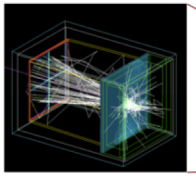


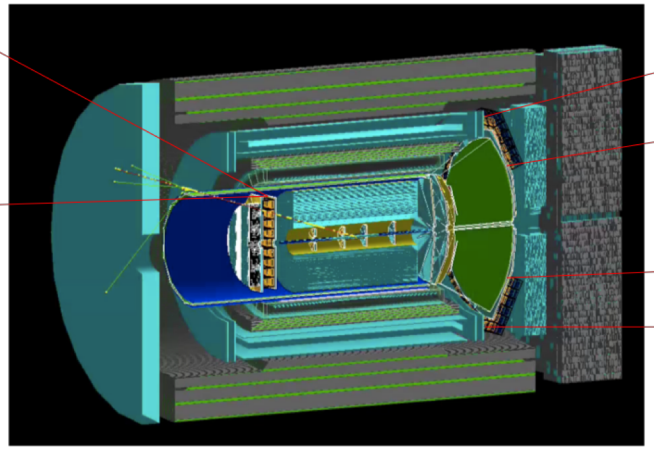
Figure 2.3.3: Examples of cumulative ring images from the second mRICH prototype beam test using three SiPM matrices. **Left:** at a cooling temperature of −20° C. **Middle:** at a cooling temperature of 0° C. **Right:** at room temperature.

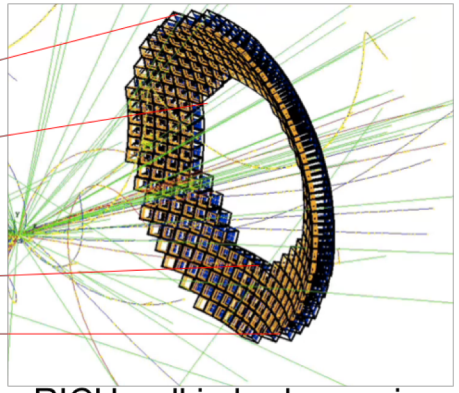
See details in the progress report

mRICH in an EIC Detector Built Around the sPHENIX Solenoid

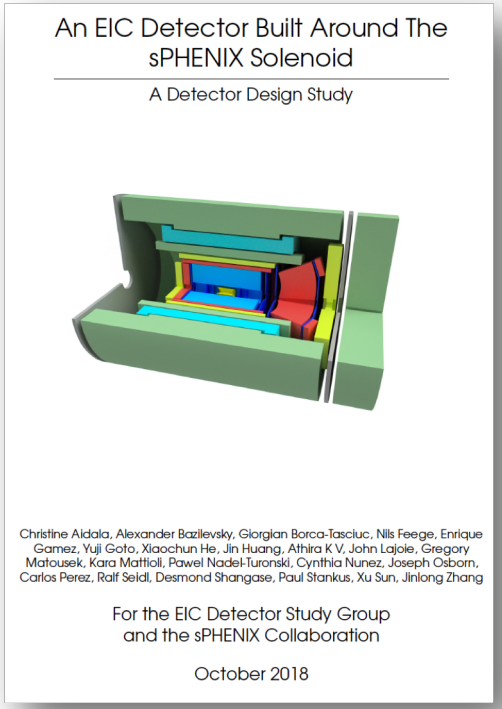


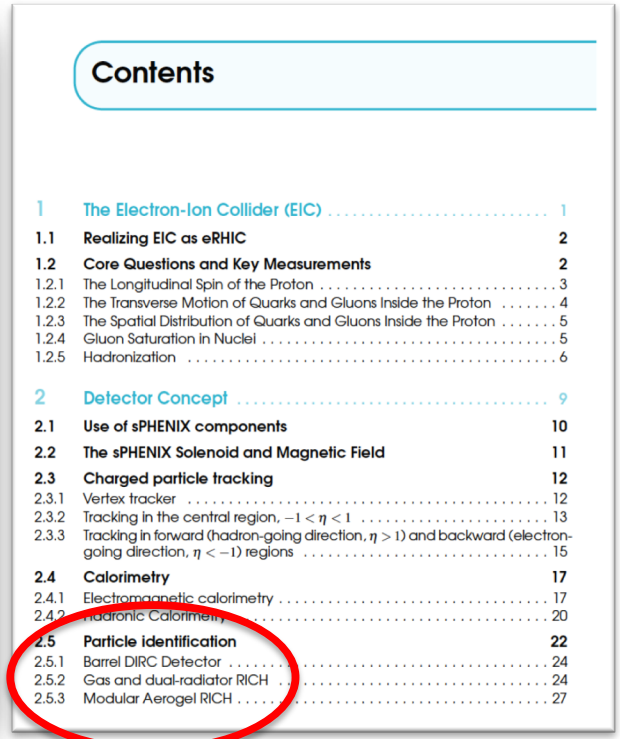
mRICH wall
e/π separation

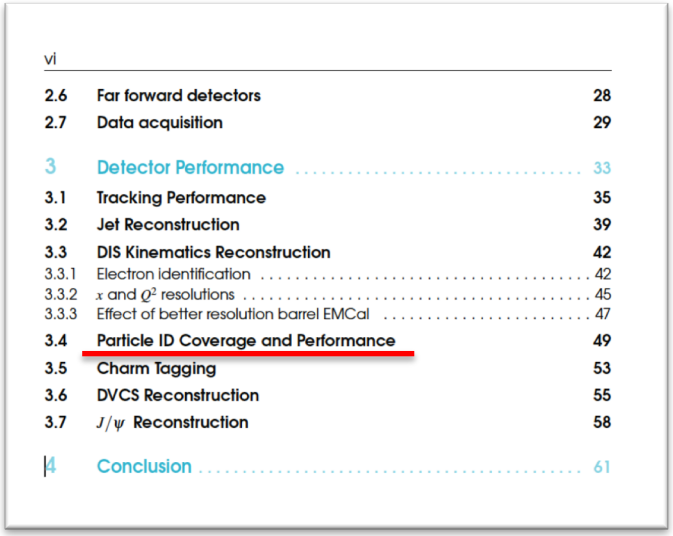




mRICH wall in hadron-going direction for hadron PID

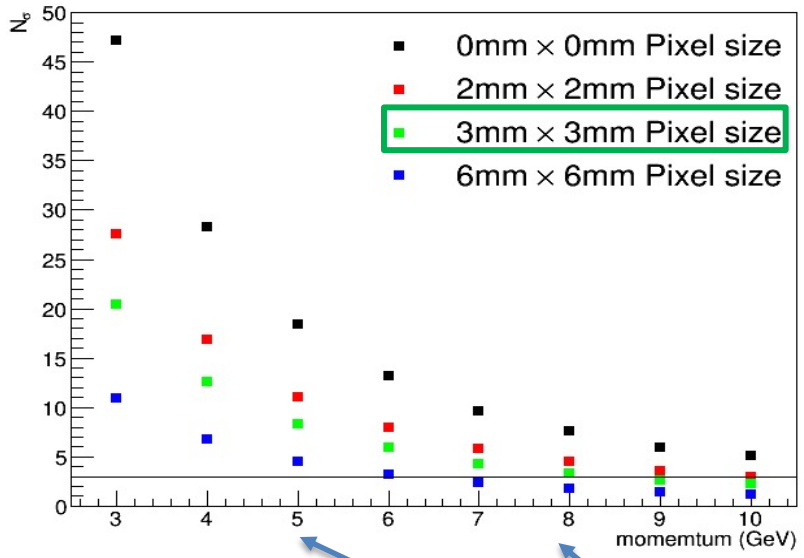




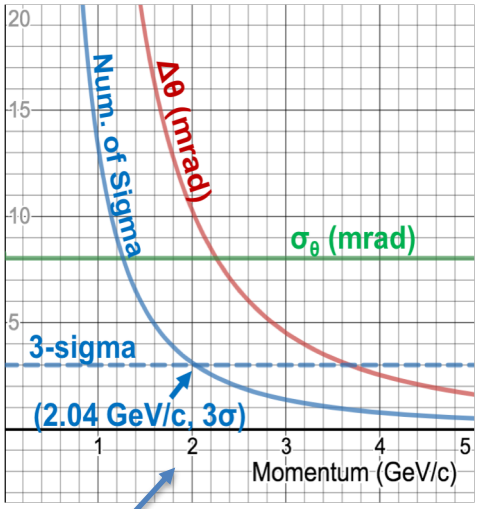


mRICH – FY19 activity (part one)

- Data analysis of the 2nd mRICH beam test and publish the new results – **verify the PID performance at 2, 5 and 8 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

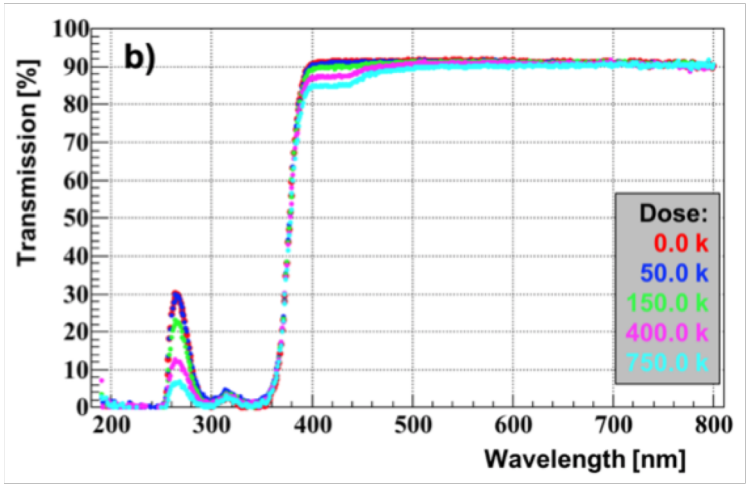


- Projected e/pi separation of mRICH 2nd prototype detector (**blue solid line**)
- 2nd prototype detector can achieve 3-sigma e/pi separation up to 2 GeV/c

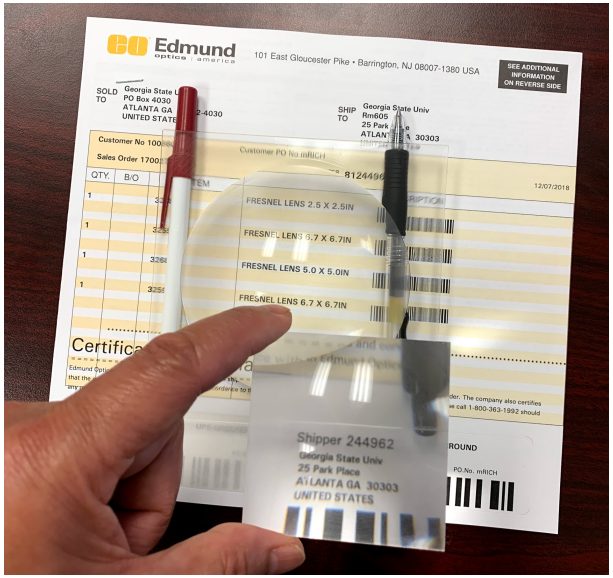
Data sets taken during the second mRICH beam test at Fermilab in June/July 2018

mRICH – FY19 activity (part two)

- Study of the radiation hardness of Fresnel lens (i.e., address the committee concern!) in spring 2019 at BNL using ^{60}Co source together with DIRC team to confirm the earlier test result shown below. Have purchased more lens samples from Edmund for this test.



Tested by Greg Kalicy. 2 mm-thick acylic mRICH lens sample. A small drop of transmission was observed below 500 nm. This material seems surprisingly radiation hard even after a dose of 750 krad.



- Simulation study of mRICH performance in the Forward sPHENIX experiment at BNL (ongoing effort).
- Simulation study of mRICH performance in the electron endcap in JLEIC (ongoing effort).
- Work with dRICH group to develop a plan for a join dRICH/mRICH beam test.