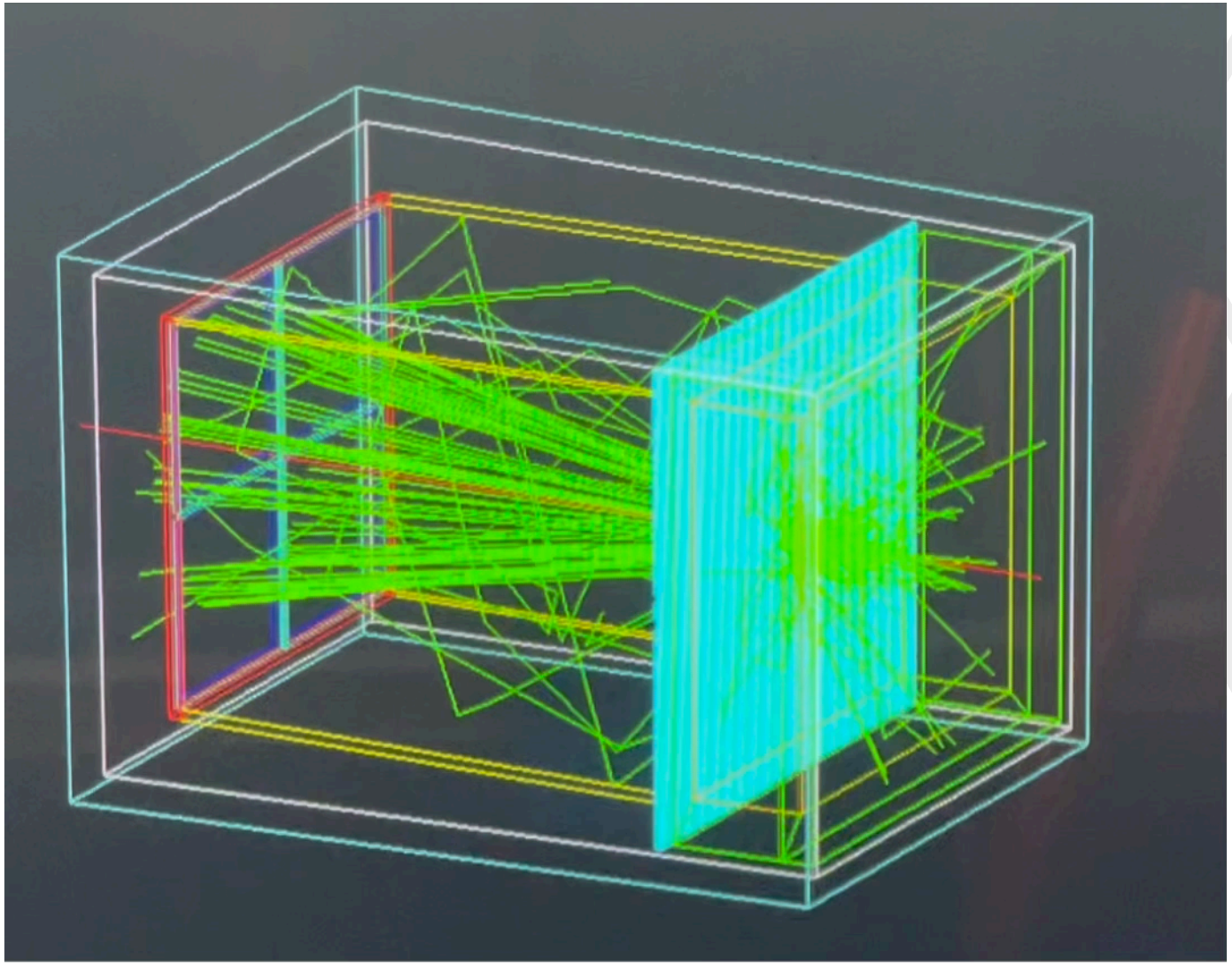
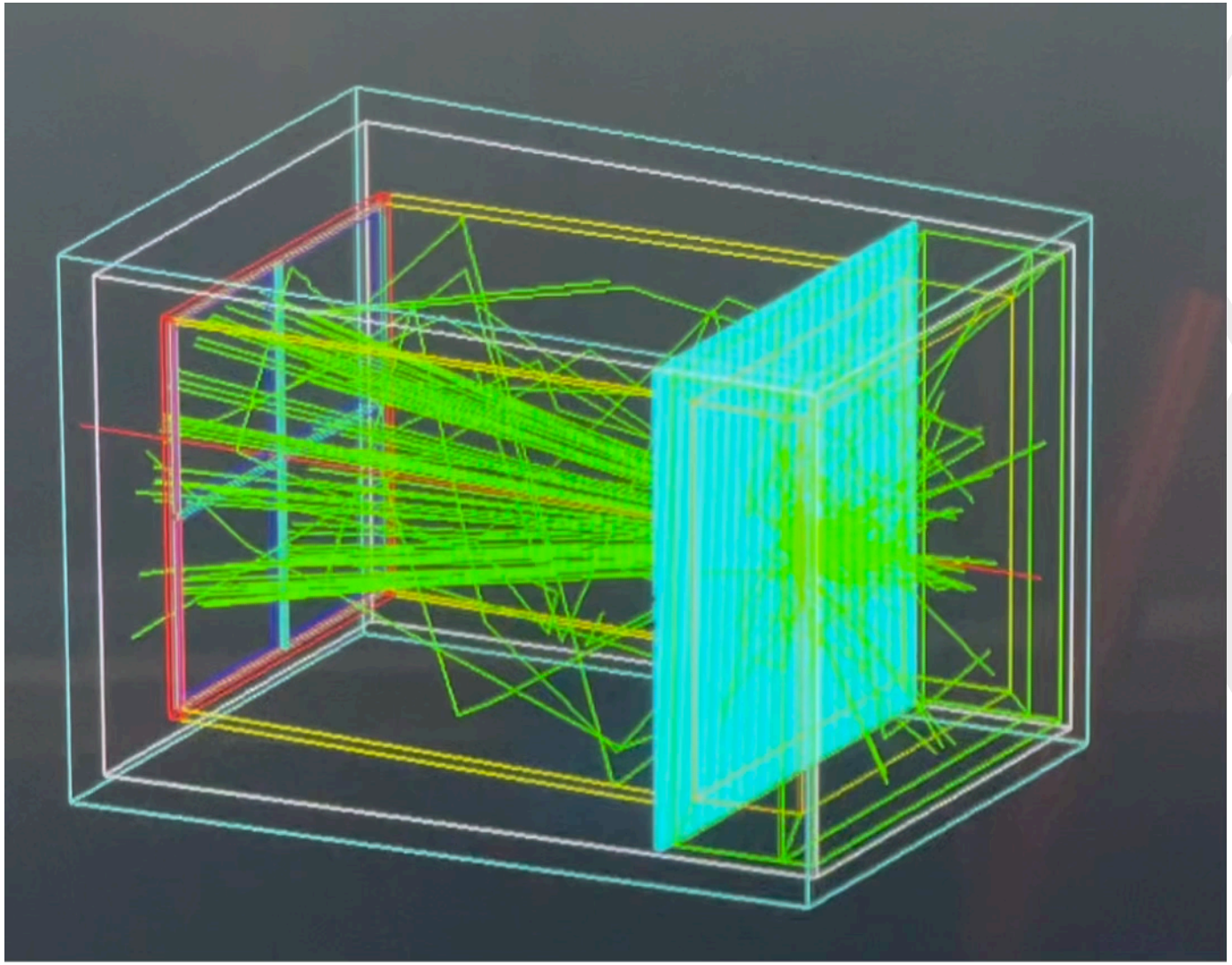


mRICH

for

Xiaochun He

Georgia State University



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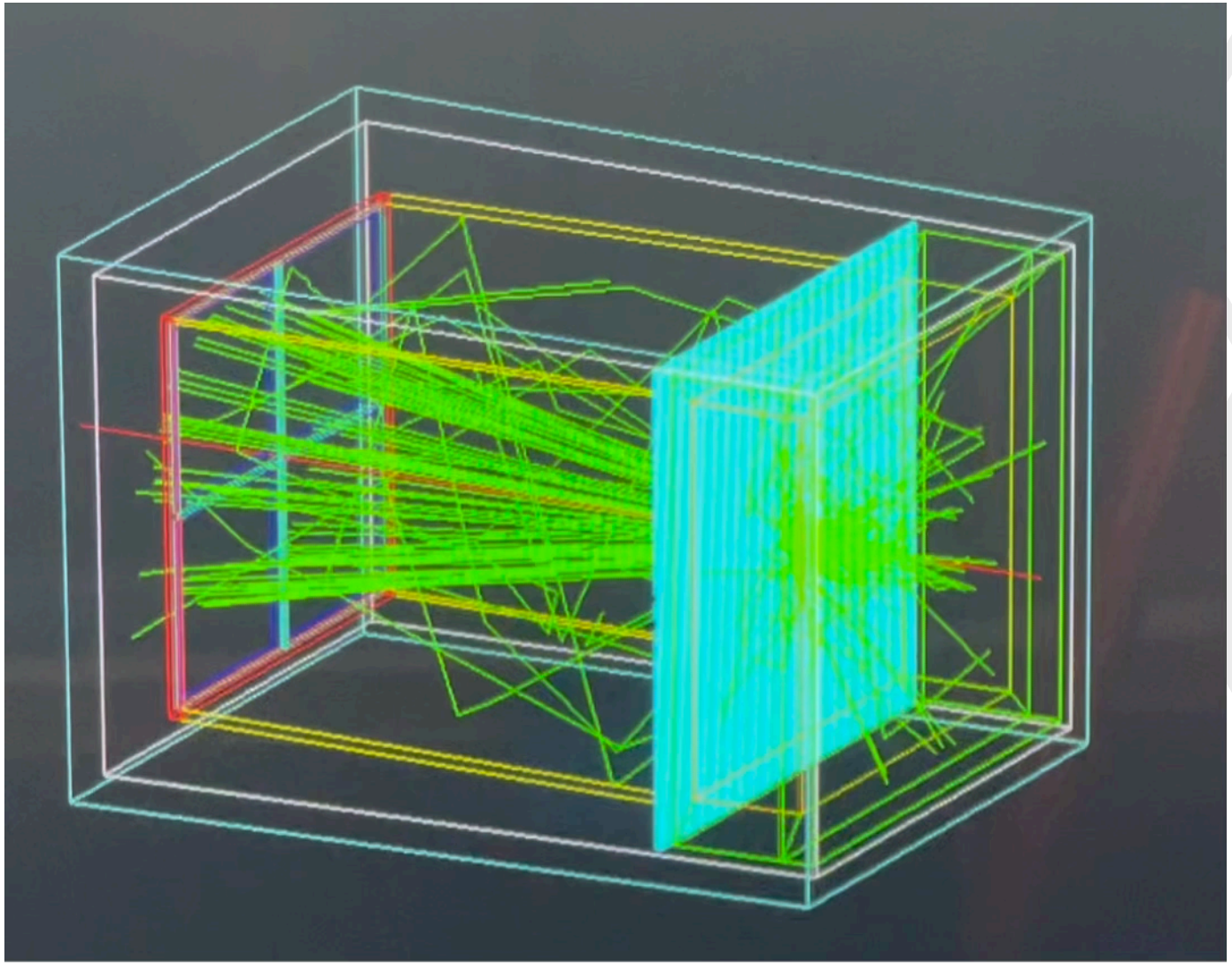


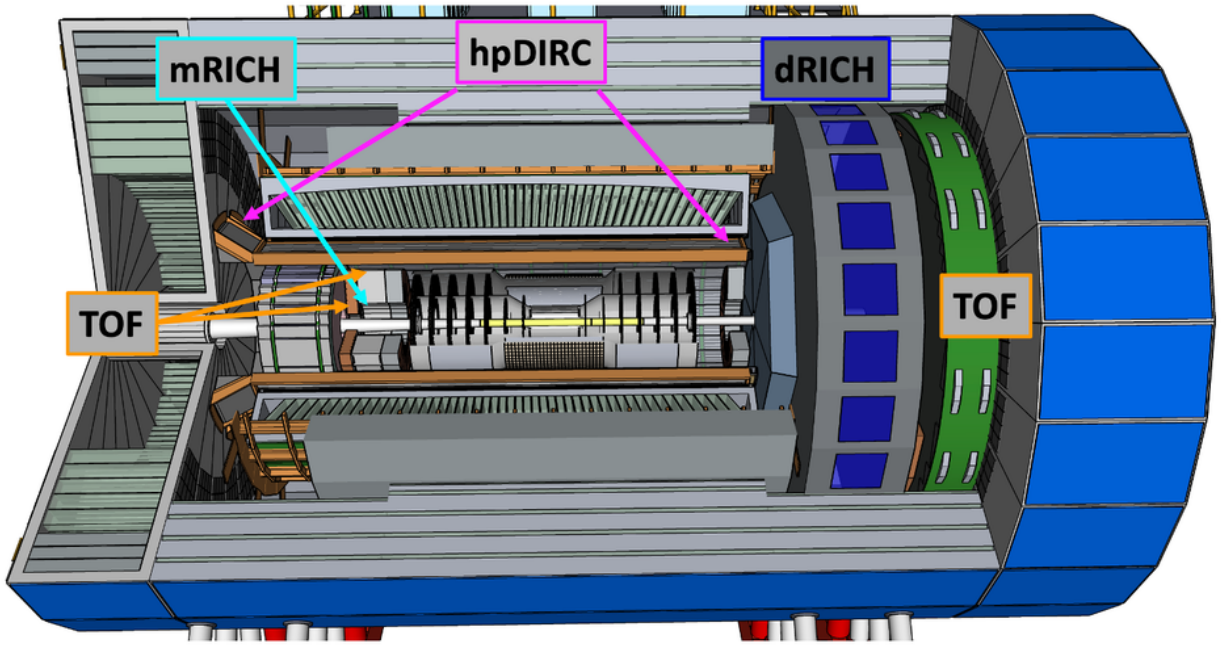
mRICH

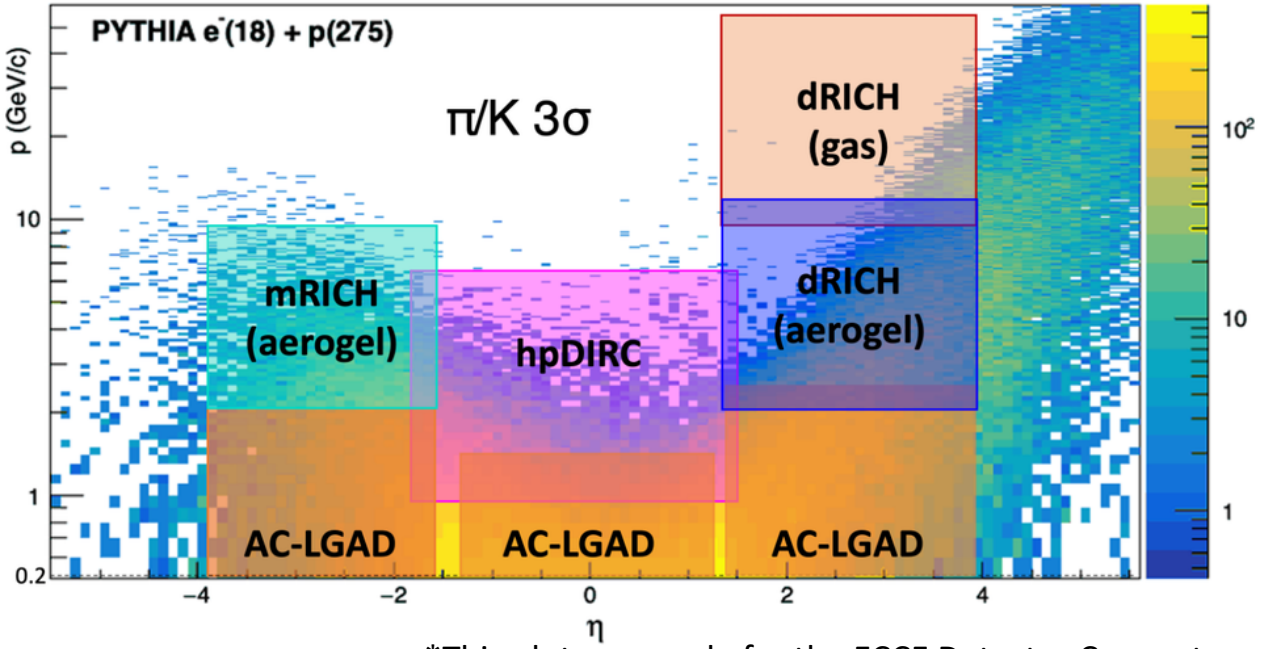
for

Xiaochun He

Georgia State University

Physics Drives RICH Technology Choices

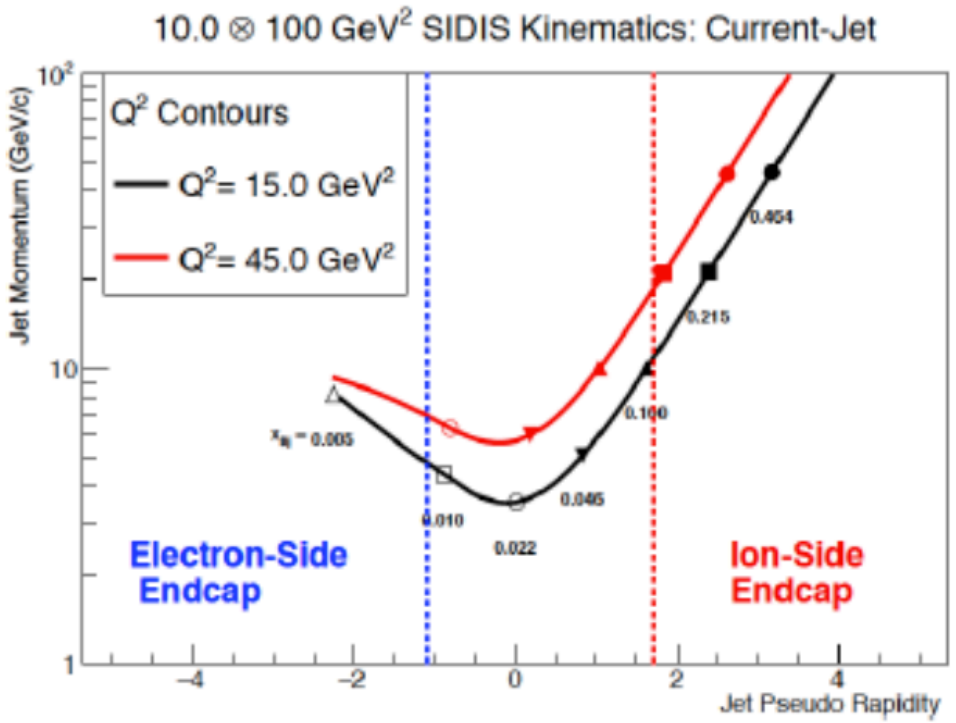


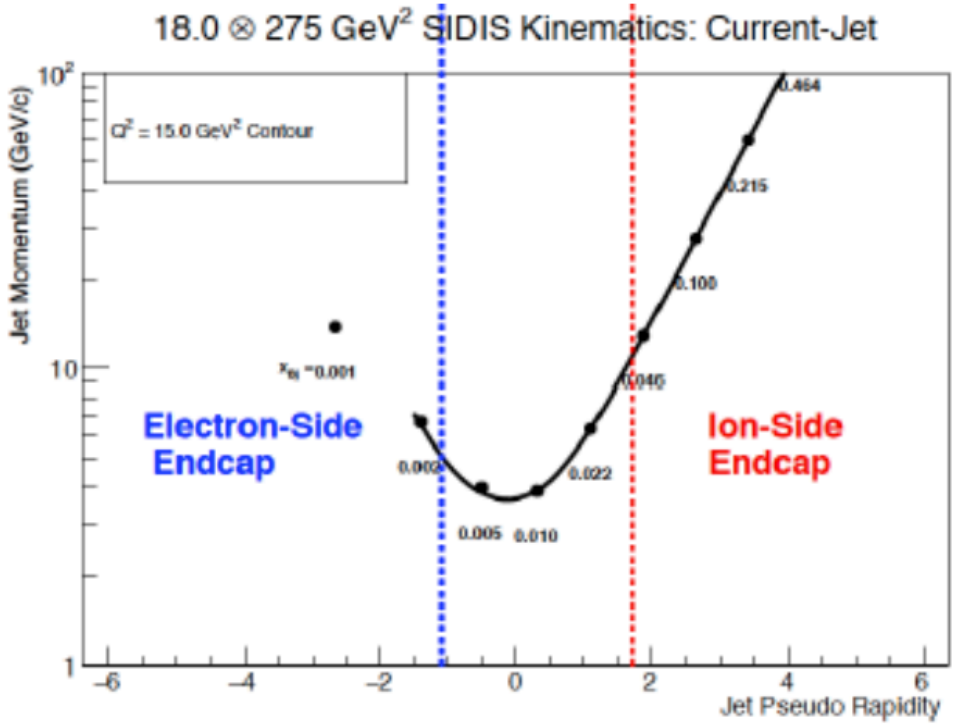


*This plot was made for the ECCE Detector Concept

- ✓ K/pi separation up to 10 GeV/c
- ✓ Limited available space in electron-going direction in EIC experiment

Hadron Kinematics at EIC (example)



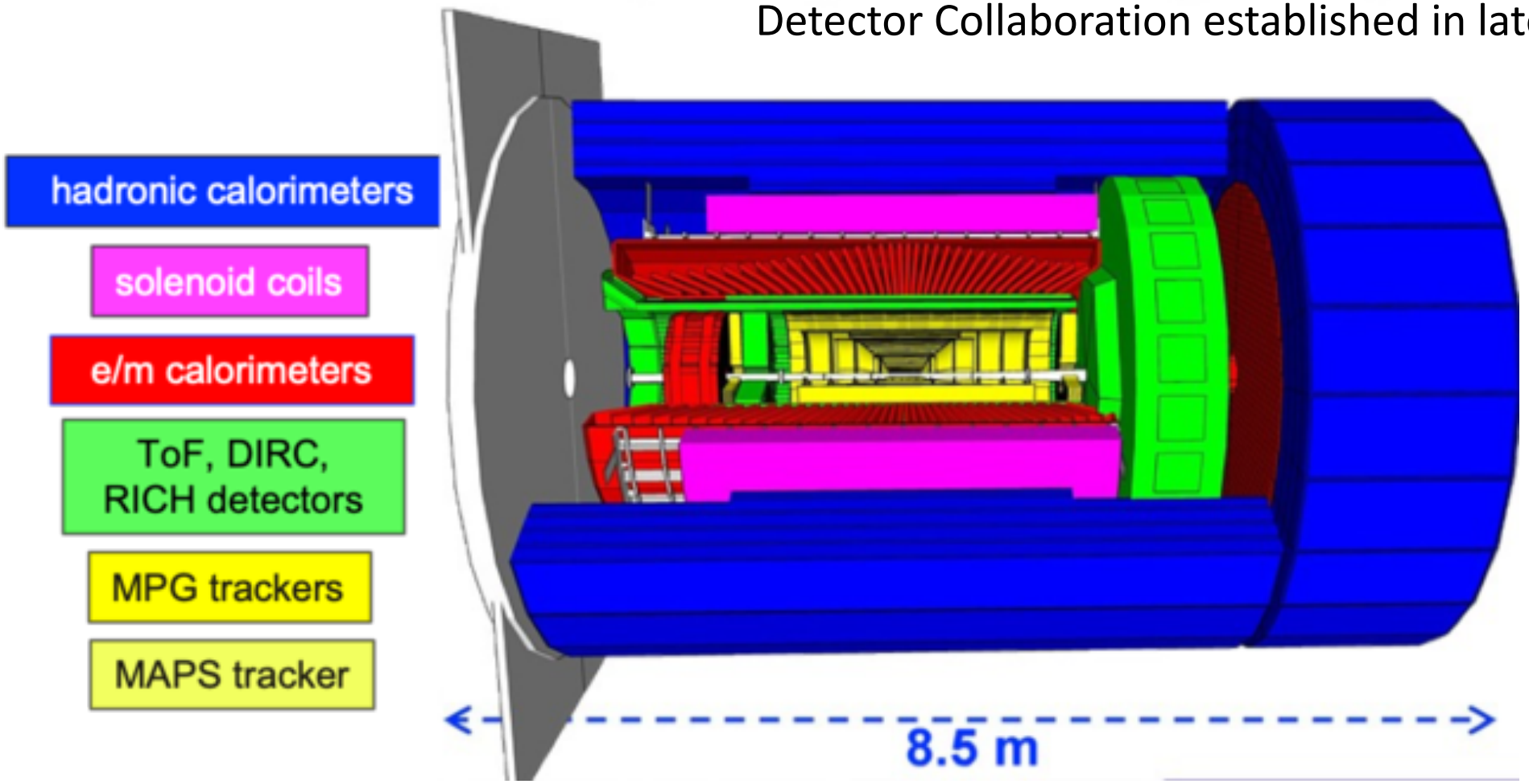


- The maximum hadron momentum in the endcaps is close to the electron and ion beam energies, respectively.
- The momentum coverage need in the central barrel depends on the desired kinematic reach, in particular in Q^2 – important for QCD evolution, etc.
  - Weak dependence on beam energies

From eRD14 2018 Report by Pawel Nadel-Turonski

mRICH in ePIC

ePIC is the brand-new name of the EIC Project Detector Collaboration established in late July of 2022



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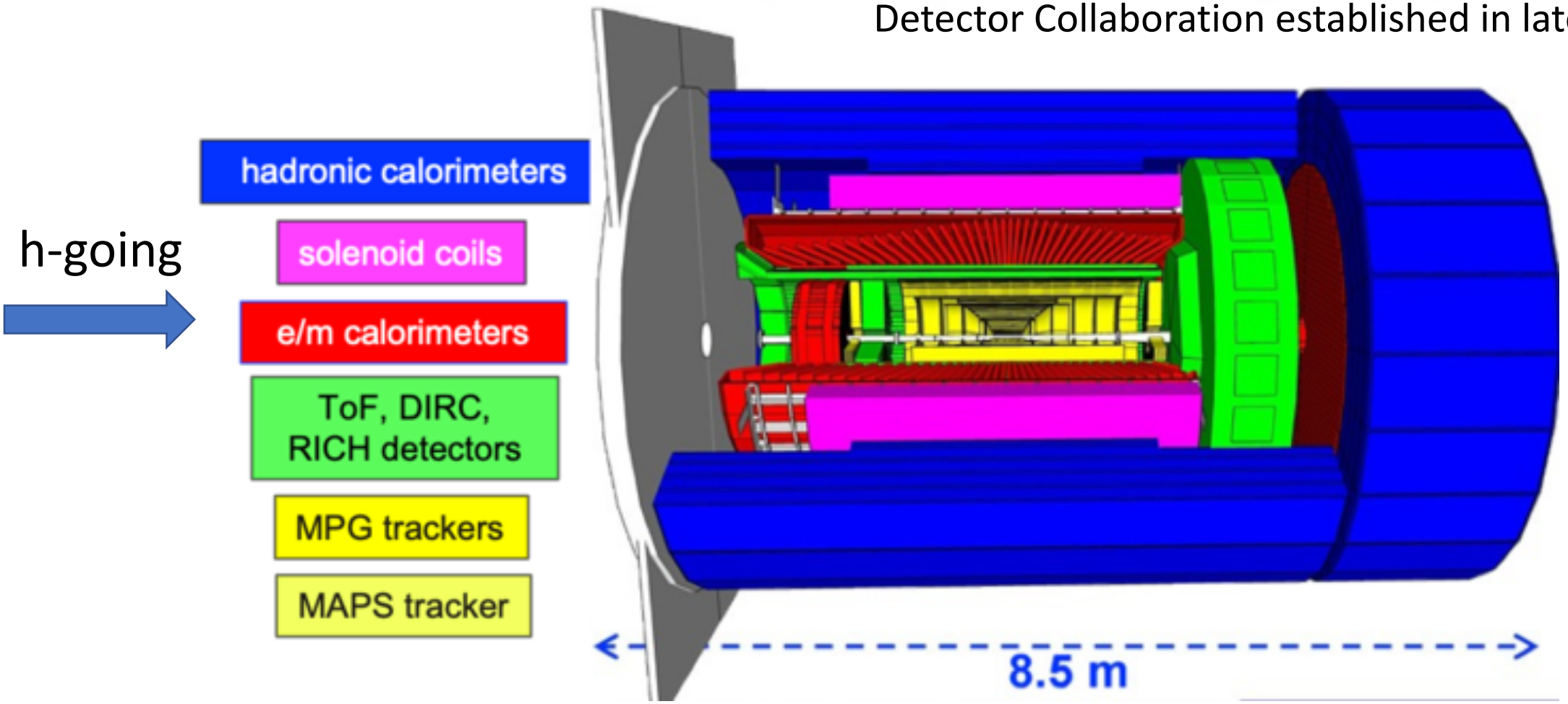

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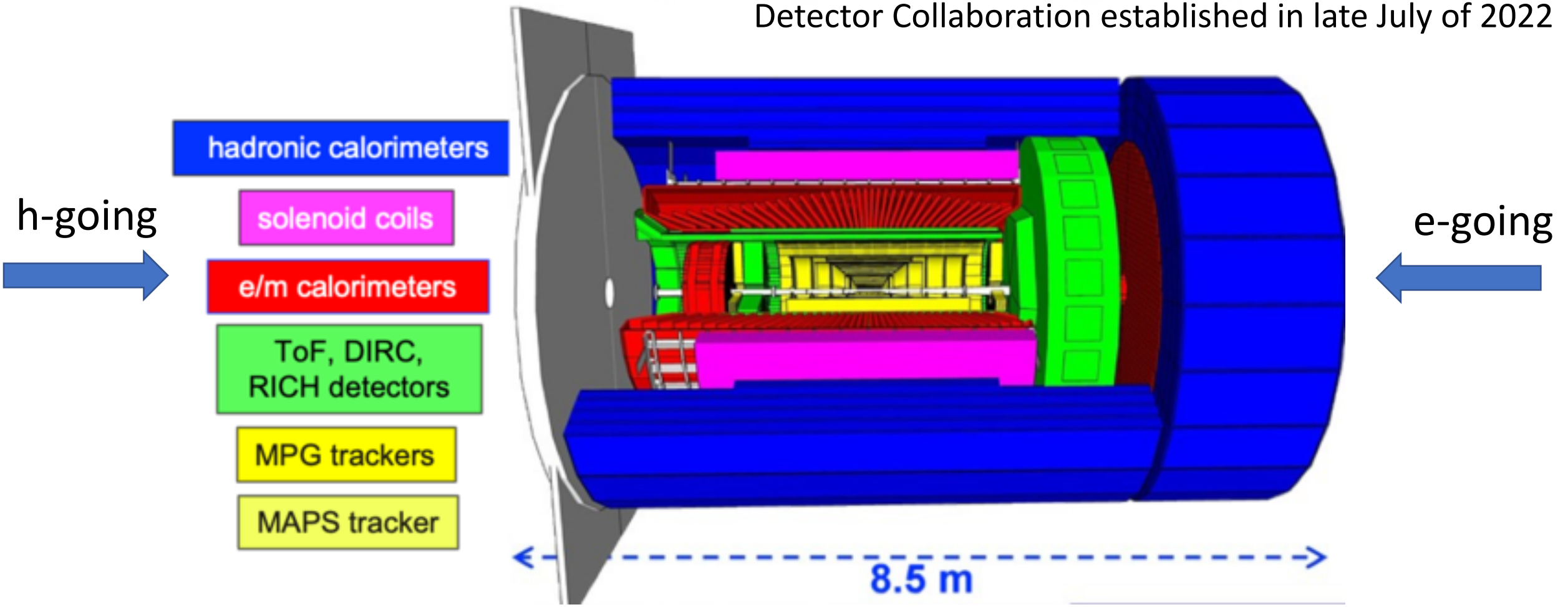

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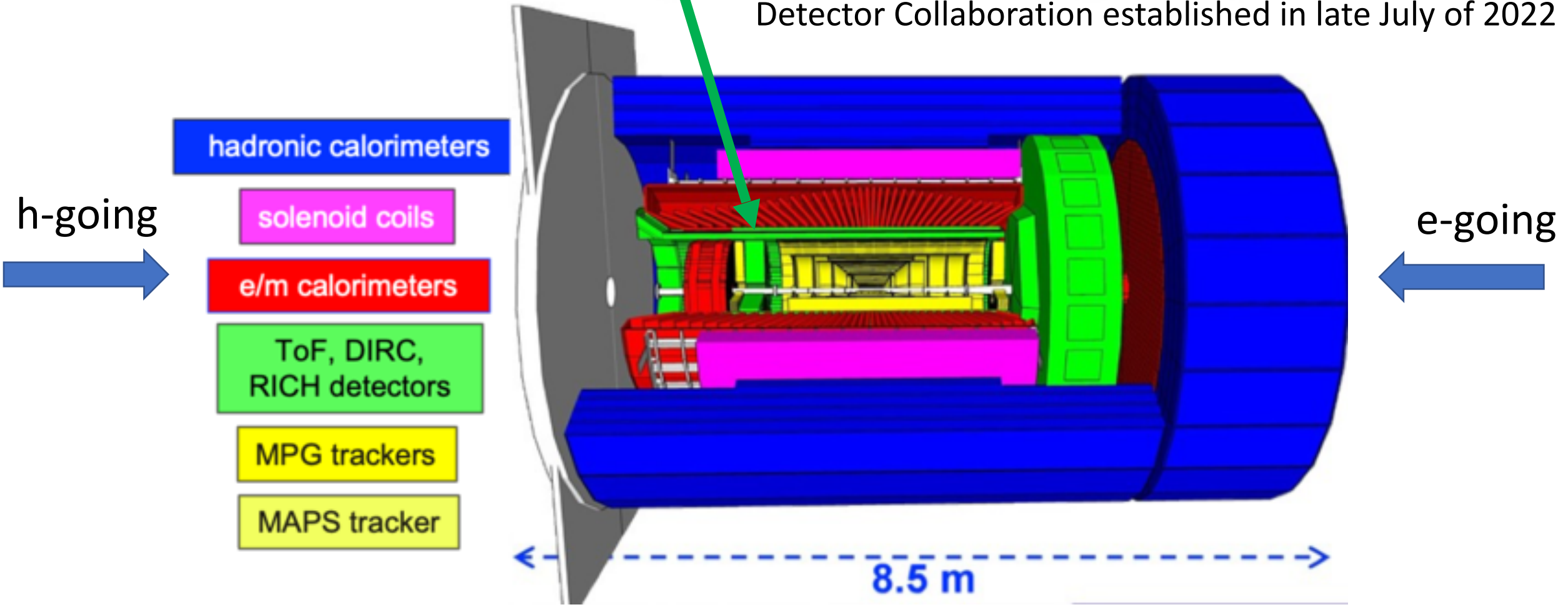
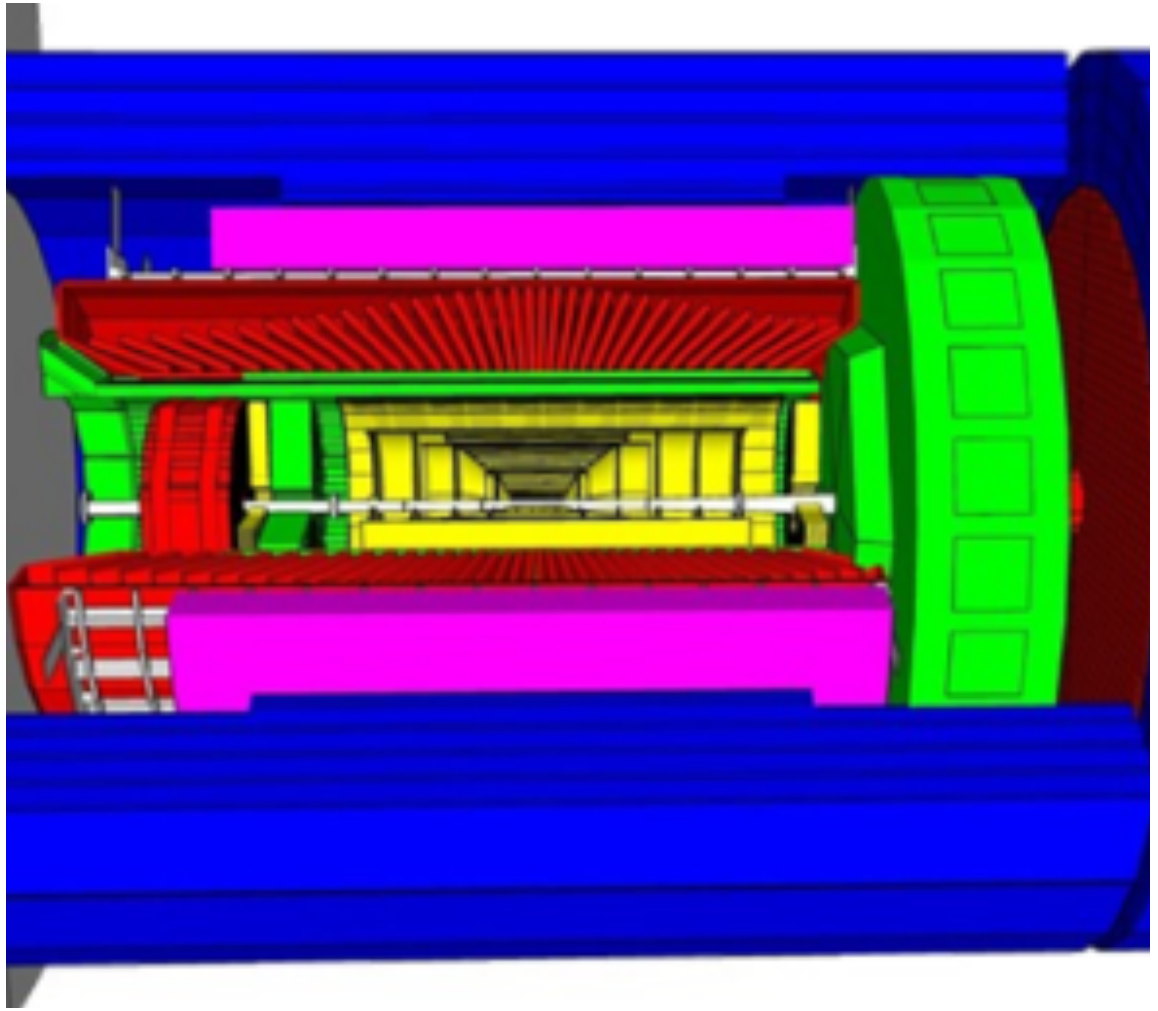
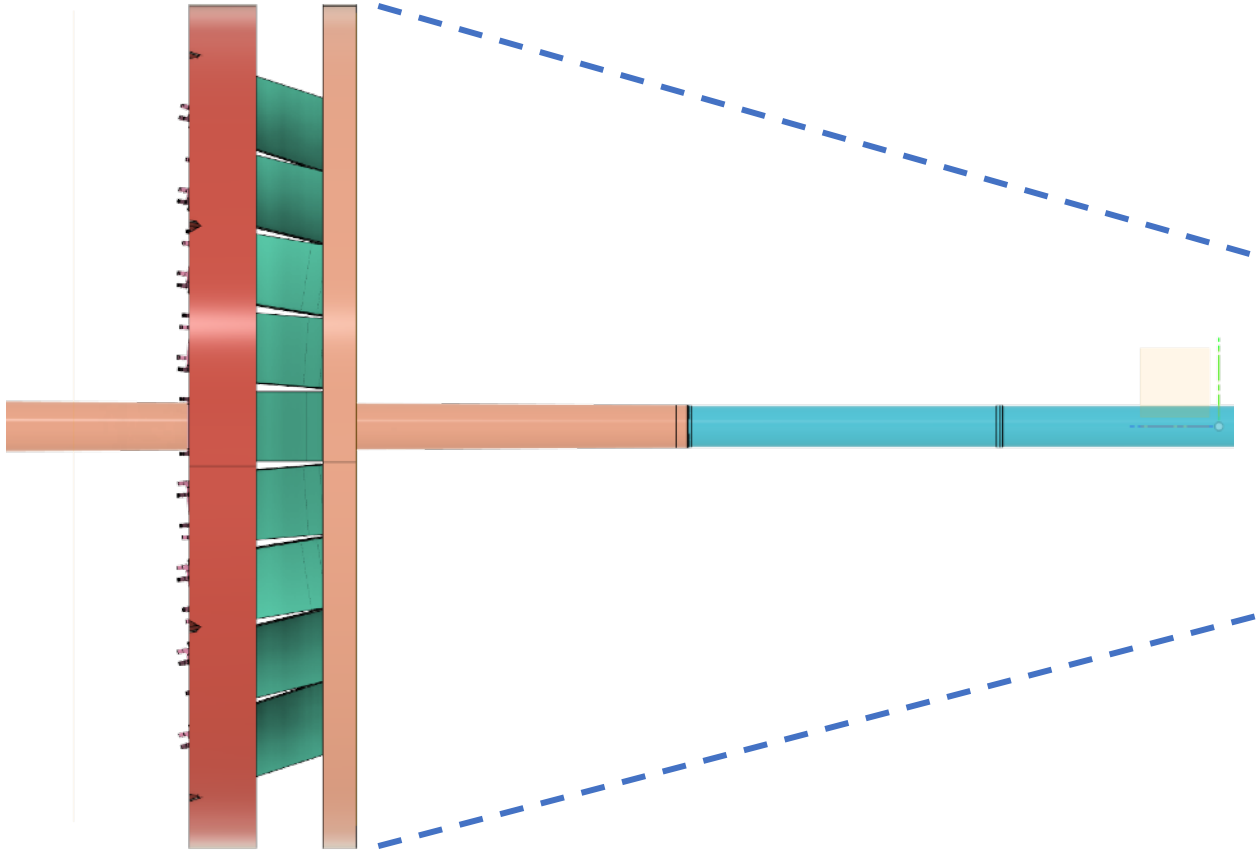
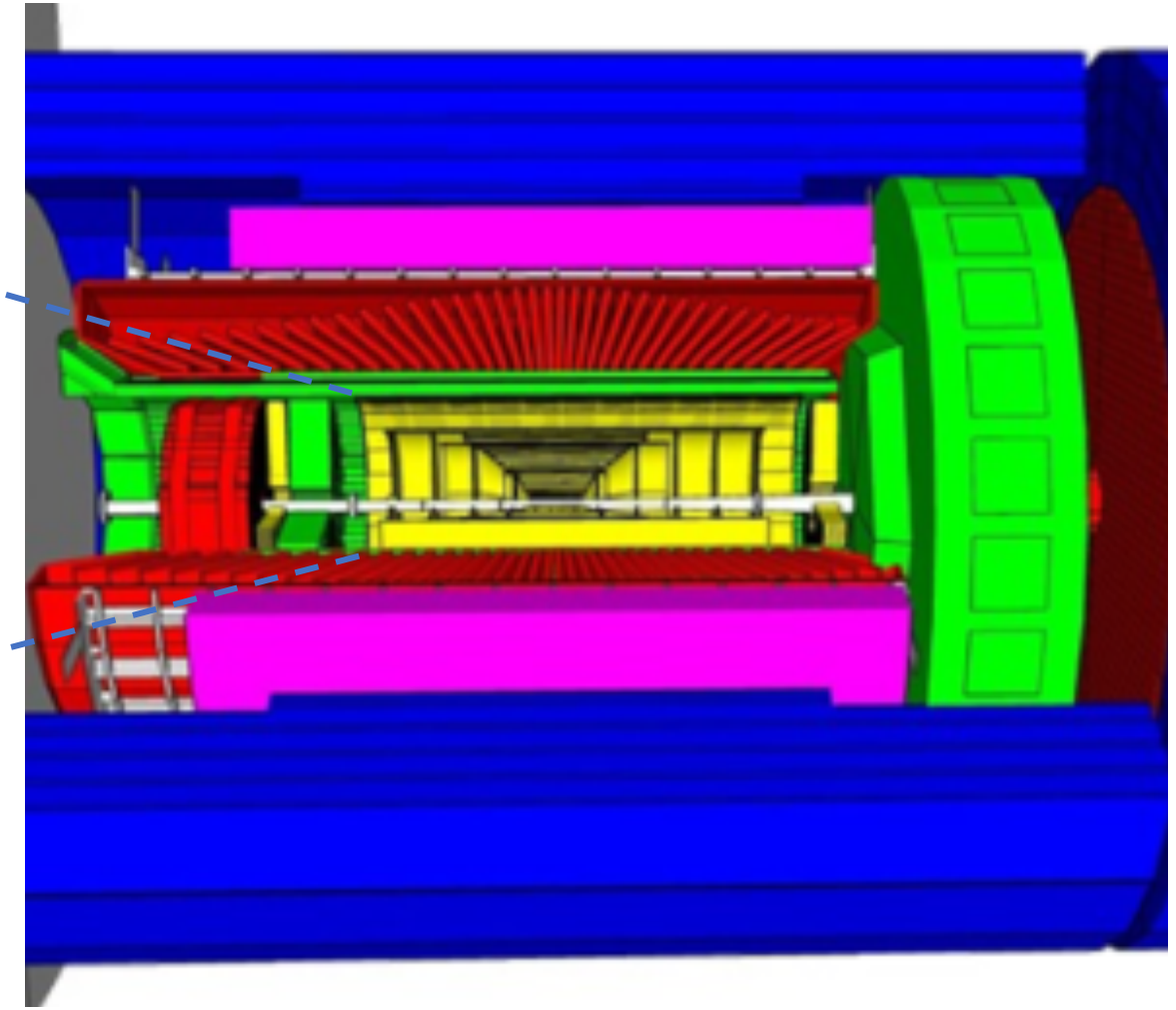


mRICH in ePIC (zoomed in)



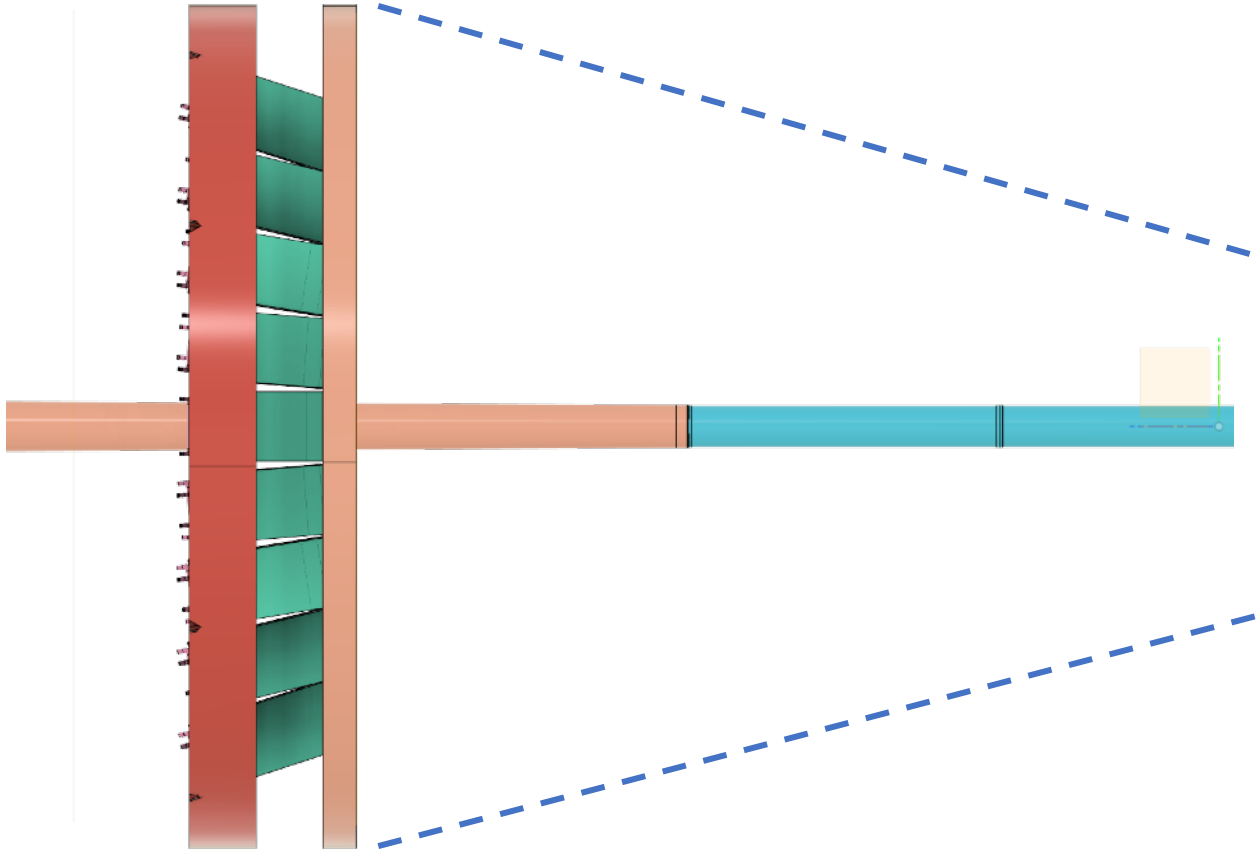
mRICH in ePIC (zoomed in)





See Alex Eslinger's presentation for details

mRICH in ePIC (zoomed in)



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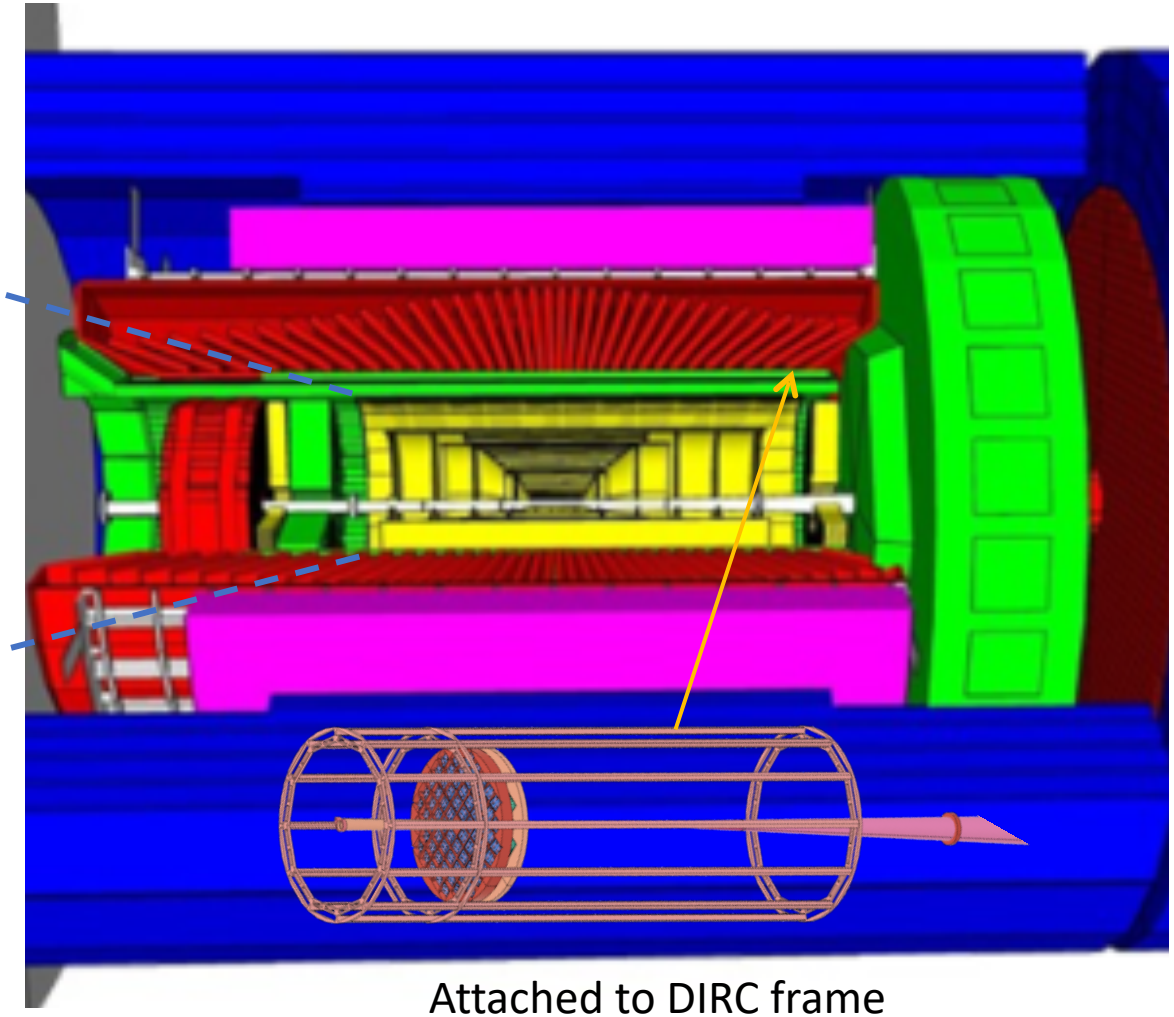


Attached to DIRC frame

To be addressed in details

To be addressed with large uncertainties

Not included in this review X

2. **Input information**:
   a. Pertinent **information on similar technology/design** that is used by other experiments or R&D efforts (example references could be literature or conference talks).
   b. **Prototypes and their tests**: done so far, ongoing effort, future planning (with timelines); results from prototypes and their tests
   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. **Performances**:
   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 ToF 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. .. Q2…) via parameterized hadron PID performance.**

4. **Radiator**
   a. Status of **radiator selection**
   b. **Status of the radiator** development and related potential issues?
   c. **Perspectives of radiator mass production** and timelines for the production period?
5. **Sensors and FEE**:
   a. Status of **photosensor selection** (a single consolidated option, more options under consideration); please provide photo sensor and pixel segmentation characteristics?
   b. **Status of the sensor** development and related potential issues?
   c. **Perspectives of sensor mass production** and timelines for the production period?
   d. Status of **FEE selection** (a single consolidated option, more options under consideration)?
   e. **Characteristics of the ASIC and FEEs** considered?

6. **Integration**:
   a. **Status of the proposed detector integration** into the current baseline detector?
      i. z-space and effect to tracking: in coordination with the tracking DWG, produce backward momentum resolution for the tracker that fit into the z-spaced allowed by the proposed RICH detector
      ii. Material effect to backward EMCal: in coordination with the calorimeter DWG, produces electron lineshape in the backward EMCal with the proposed RICH detector in front.
   b. Status of the **design of the electrical/electronic infrastructure** (channels, power supplies, heat rate)?
   c. **Cooling** strategies?
7. **Workforce:**
   a. **List of groups** engaged in the proposed detectors and of other groups potentially interested;
   b. **Workforce needed with timelines and qualification of the required professional profiles;** please, include also physicists needed for dedicated simulation studies;
   c. **Available workforce** (specifying: granted, expected, possible) by the groups proposing the detector;
8. **Cost and scheduling**:
   a. up-to-date cost estimate for the different components and expenditure categories;
   b. In-kind contributions (specifying: granted, expected, possible).
   c. Envisioned schedule for full scale production
9. **Envisioned risk and risk mitigation strategy**

Presentation Plan

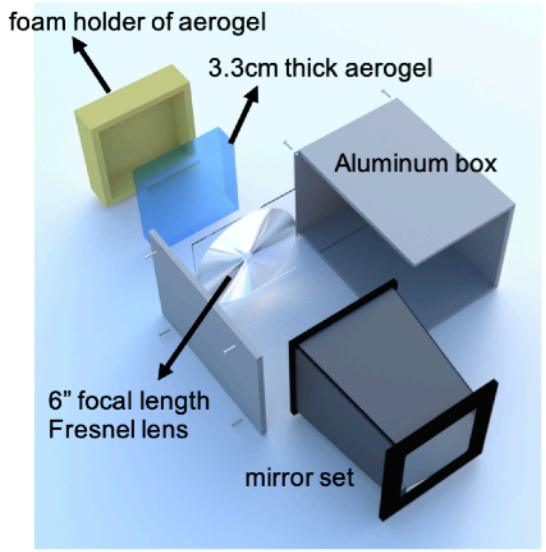
Day-1 (March 20, 2023)

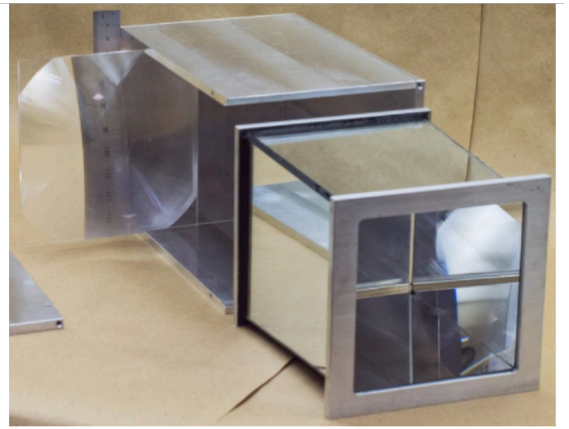
- Introduction (#2a, 2b, 2c) – Xiaochun He
- Recent R&D results (#2b, 2c) – Murad Sarsour
- Sensors and readout (#5)– Rachel Montgomery

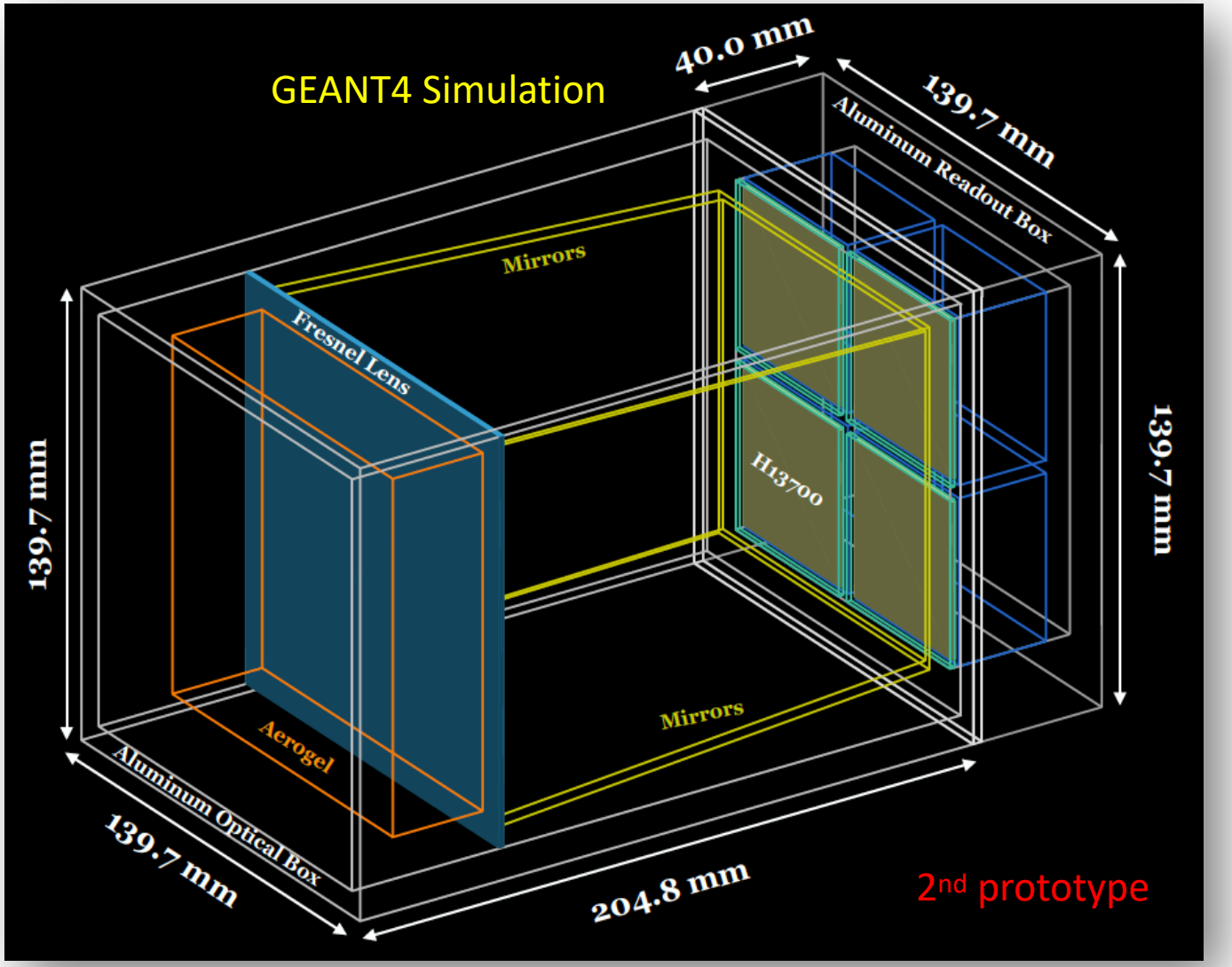
Day-2 (March 21, 2023)

- Engineering design and integration (#6) – Alex Eslinger
- New prototype design (#6) – Alex Eslinger
- Workforce, cost & schedule, and risk mitigation (#7, 8, 9) – Xiaochun He

mRICH Design

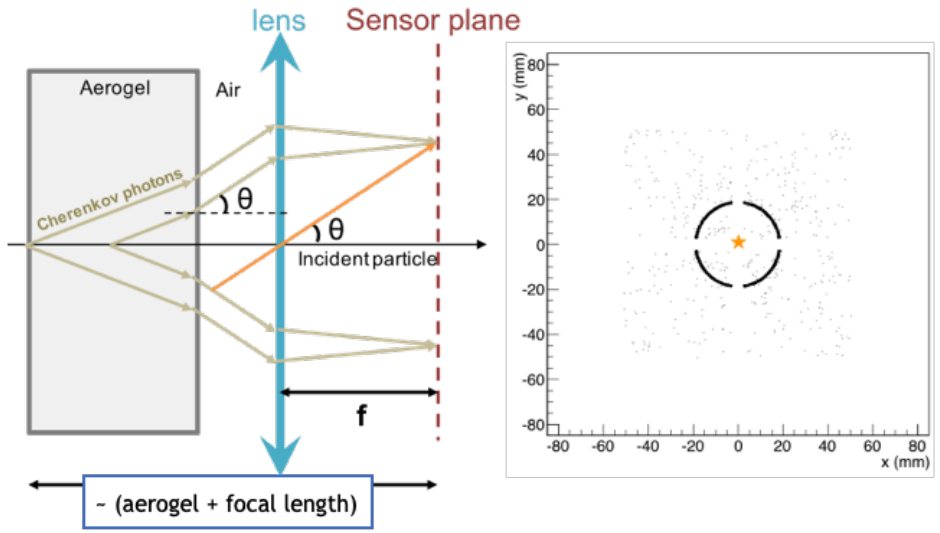






mRICH – Working Principle I (#2a)

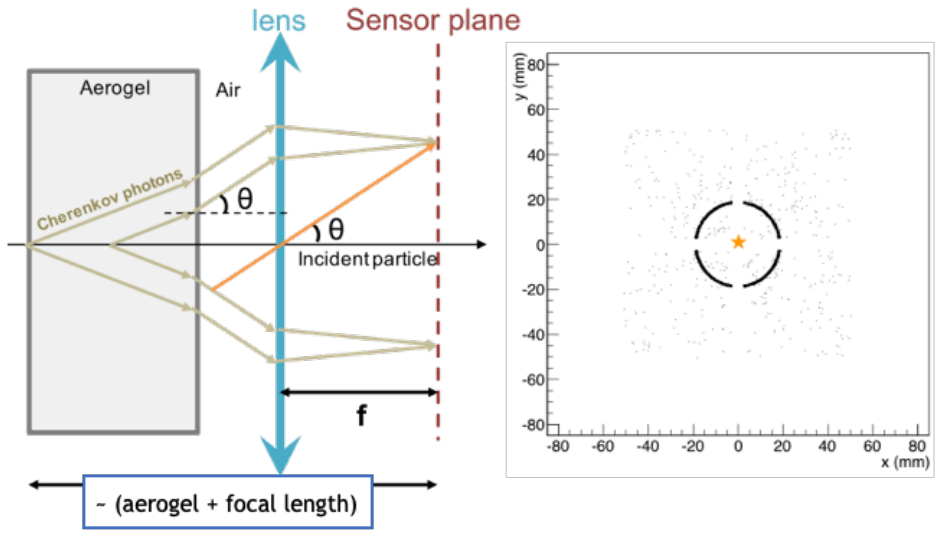
Lens-Based mRICH Design



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

mRICH – Working Principle I (#2a)

Lens-Based mRICH Design



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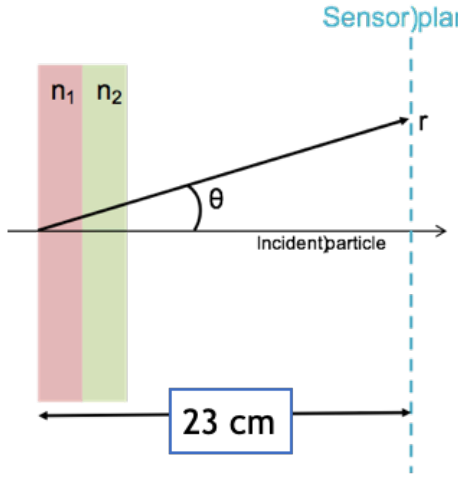
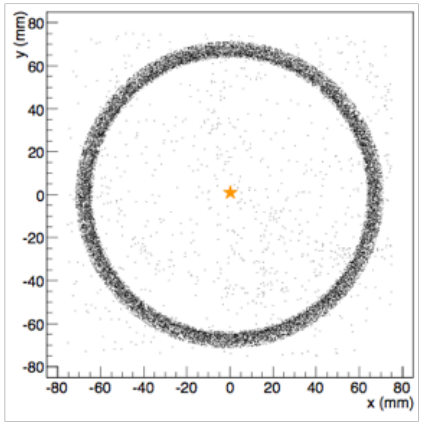
- **Smaller and thinner ring image**

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

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

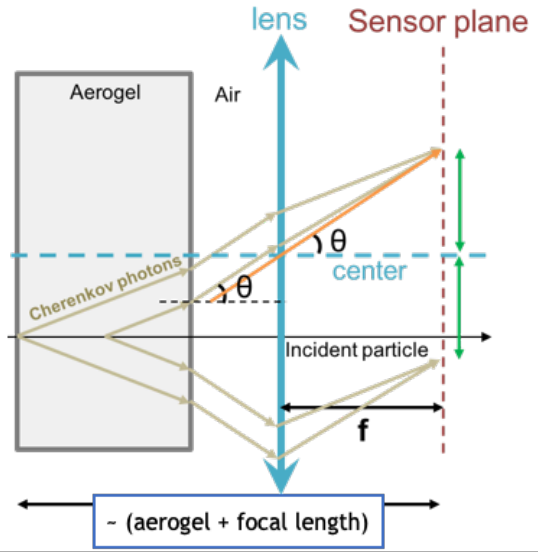


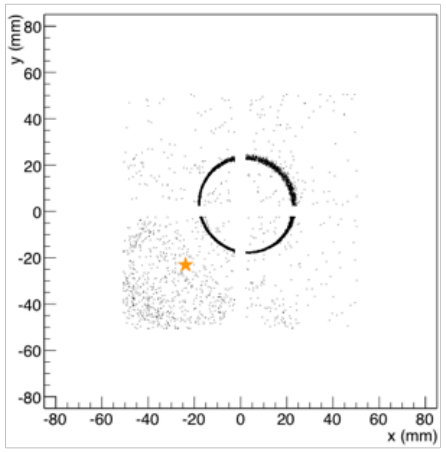


- EIC mRICH designed for K/pi ID up to 9 GeV/c
- BELLE-2 ARICH aims to separate pion and kaon up to 4 GeV/c

mRICH – Working Principle II (#2a)

Lens-Based mRICH Design

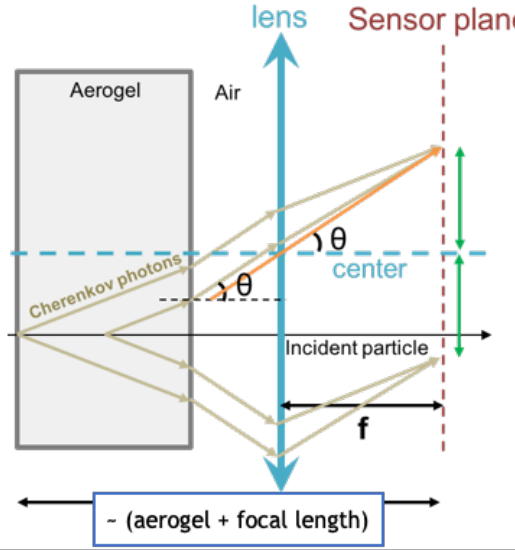


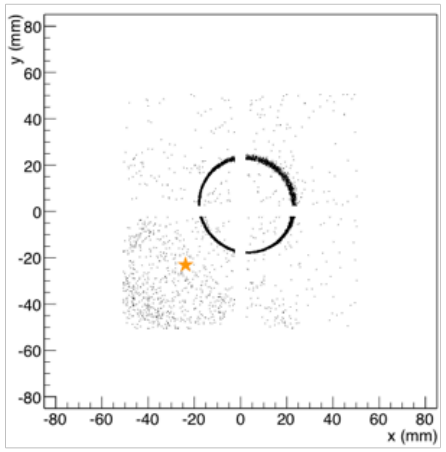


- 9 GeV/c pion beam incident at third quadrant (star) in simulation
- Ring image is shifted toward the central region on the sensor plane

mRICH – Working Principle II (#2a)

Lens-Based mRICH Design





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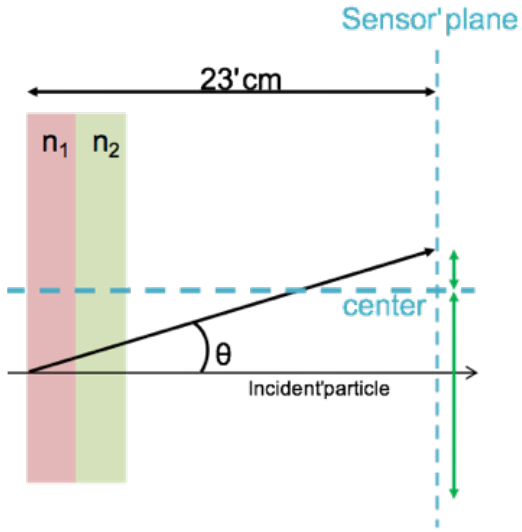
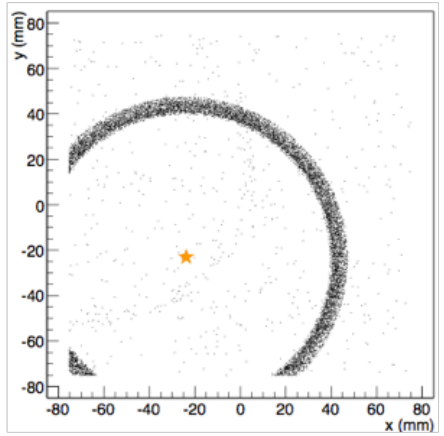




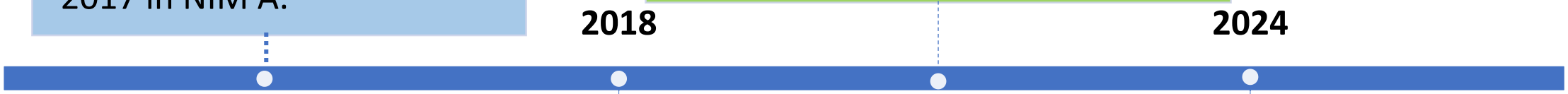
- 9 GeV/c pion beam incident at third quadrant (star) in simulation
- Ring is centered at point of incidence

mRICH Prototyping Studies (#2b)

Objectives of Prototyping Studies

The first mRICH prototype was developed in 2015 and tested at Fermilab in 2016. The goal was to verify its working principle. The results were published in 2017 in NIM A.

The third test was performed at Jlab in 2021 with the 2nd prototype together with a pair of GEM trackers. The focus of this test is to determine mRICH single photon angle resolution.



The second mRICH prototype was designed with improvement of optical components and its integration with photosensor readout. The test was performed in 2018 at Fermilab.

3rd prototype beam test is planned. The focuses include optimizing focal plane location and Aerogel choice (thickness and the index of refraction)

Objectives of Prototyping Studies

Technology evolution

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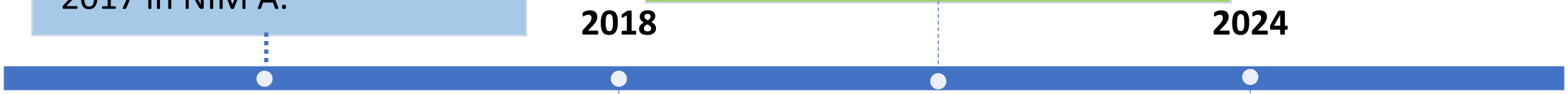

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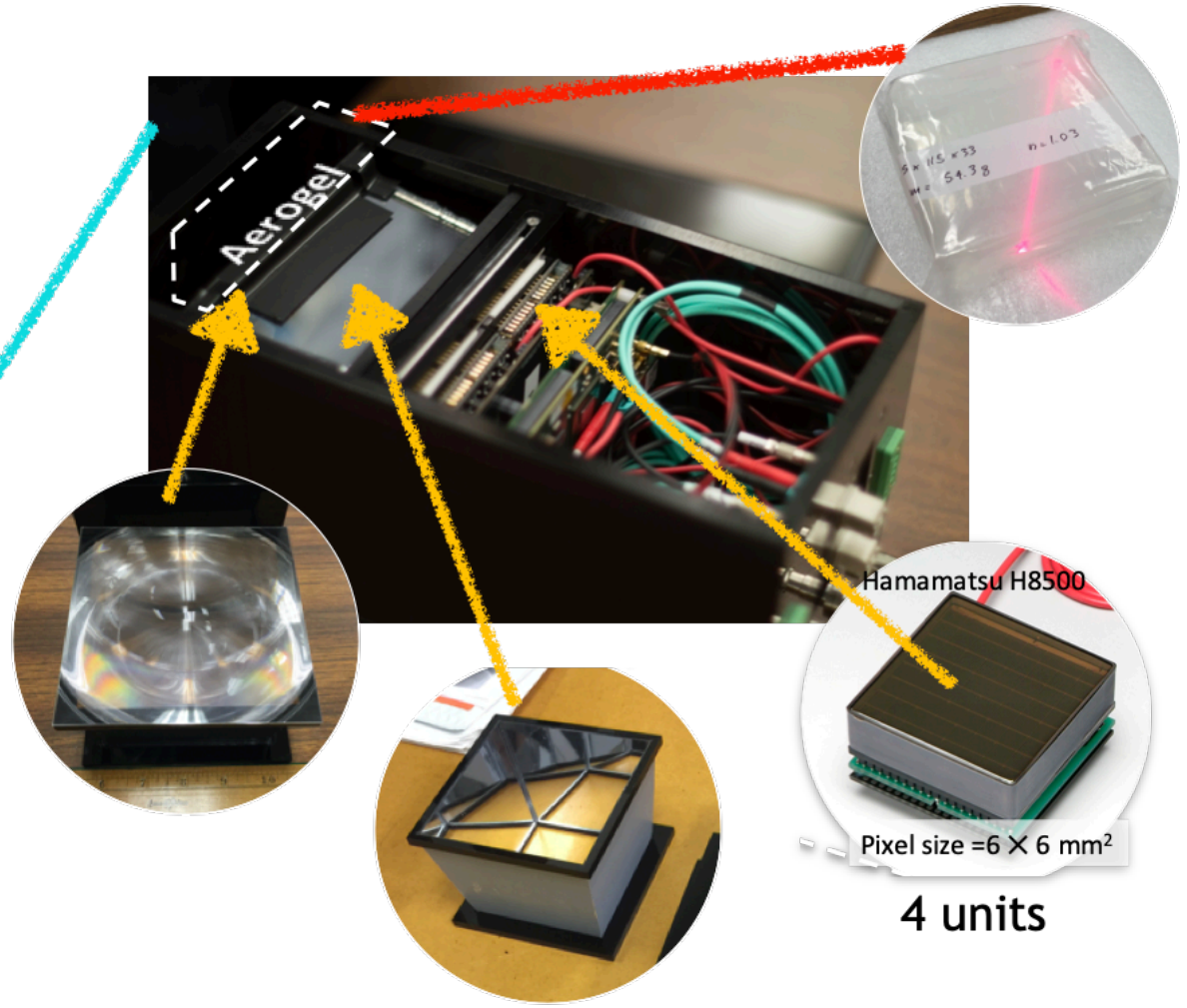
1st mRICH Prototype Beam Test – Proof of Working Principle

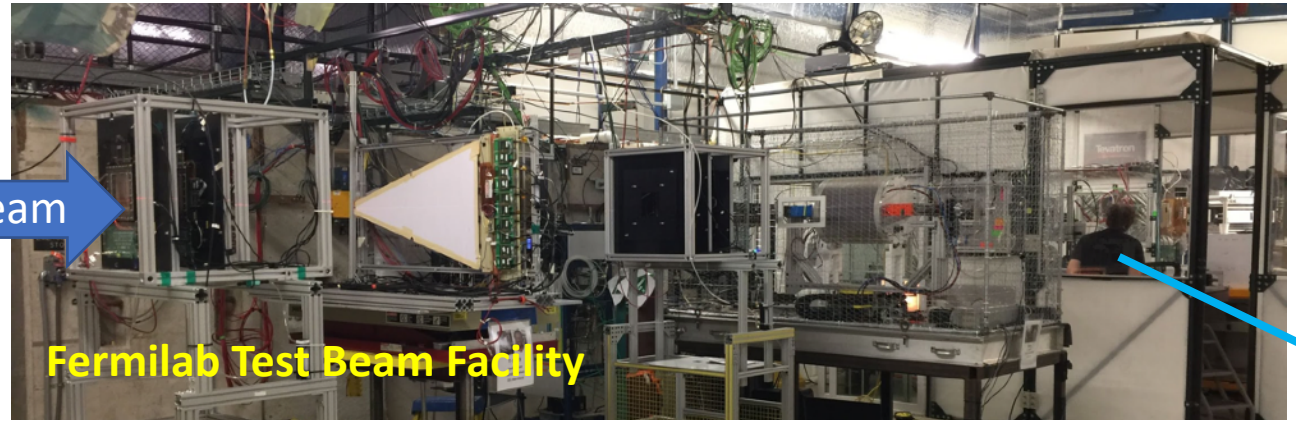
Fermilab Beam Test Facility, April 2016

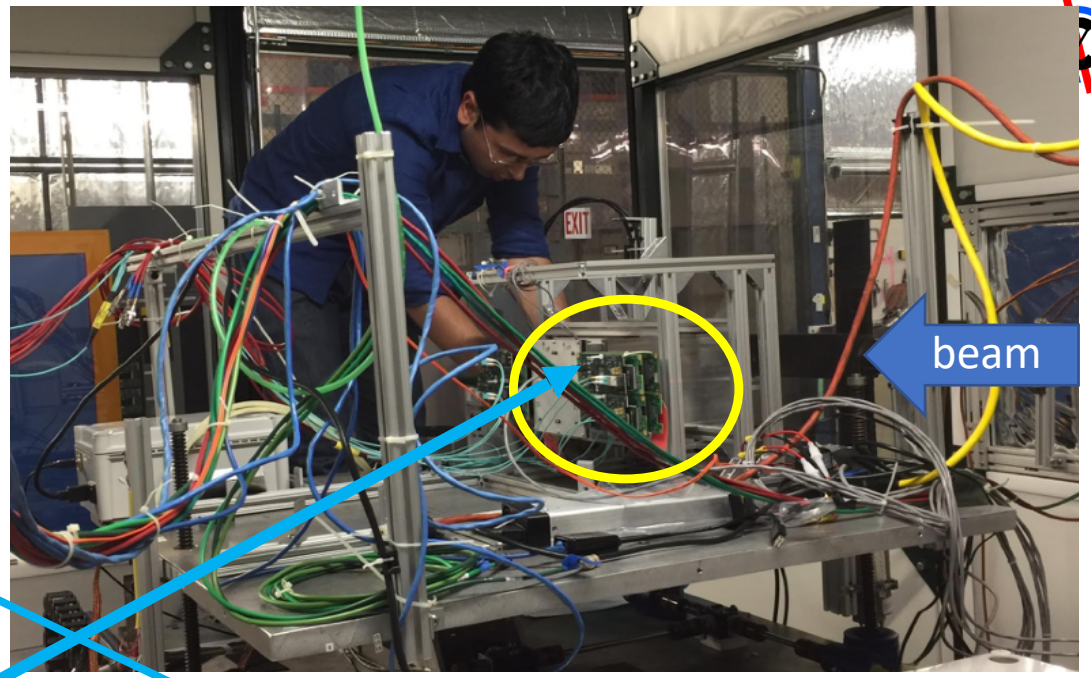


C.P. Wong et. al. NIM A871 (2017) 13-19

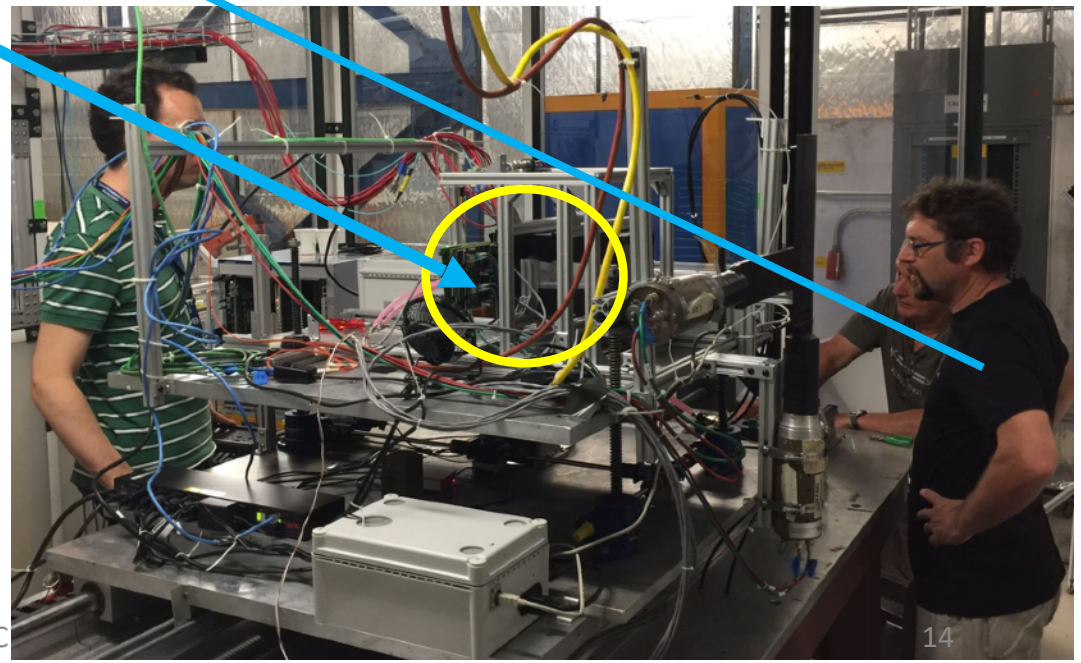
2nd mRICH Prototype Beam Test

(lens focusing and SiPM sensor)





INFN Group provided readout



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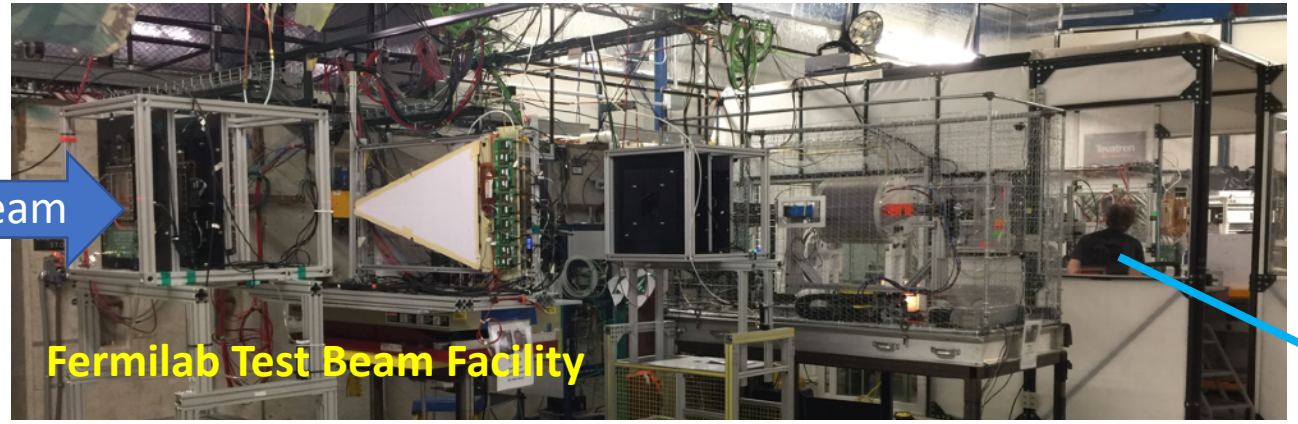

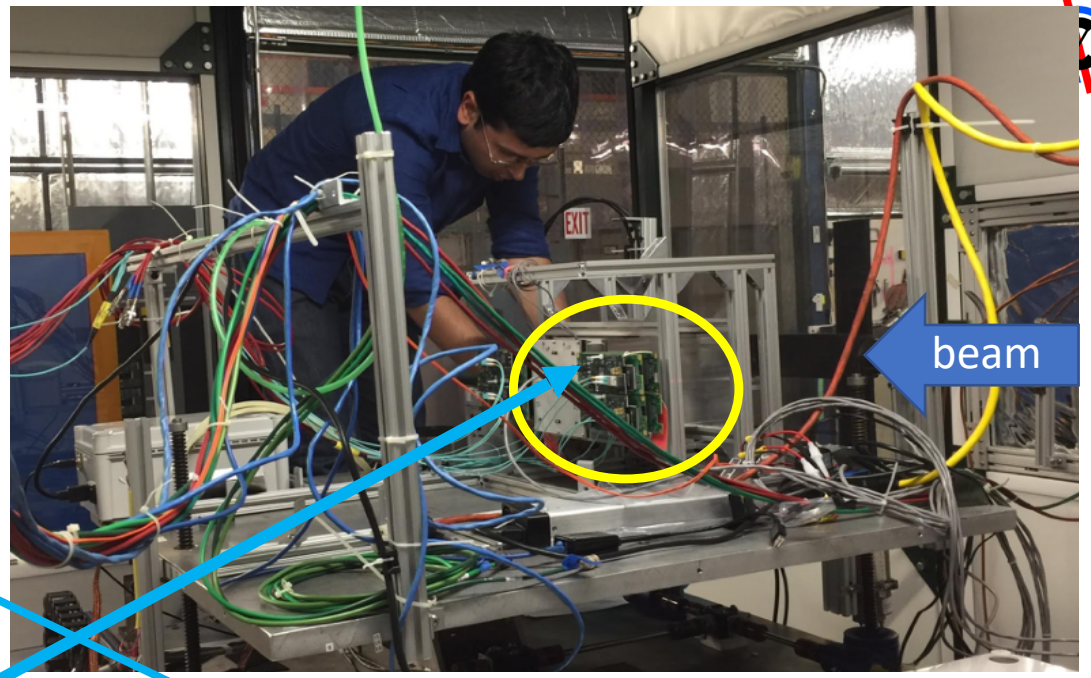

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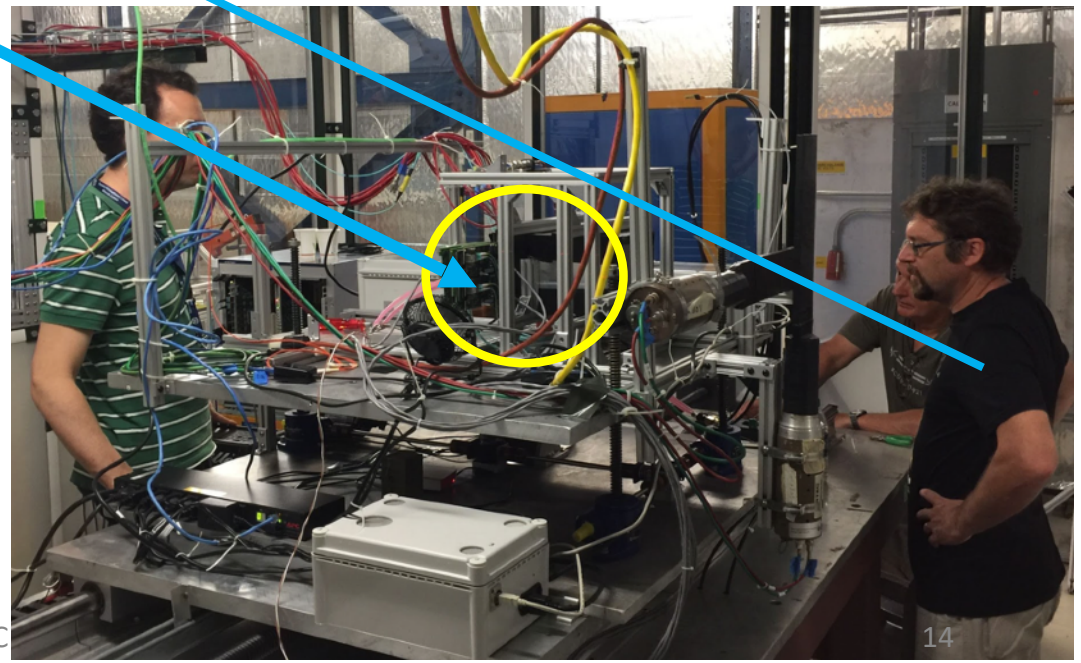
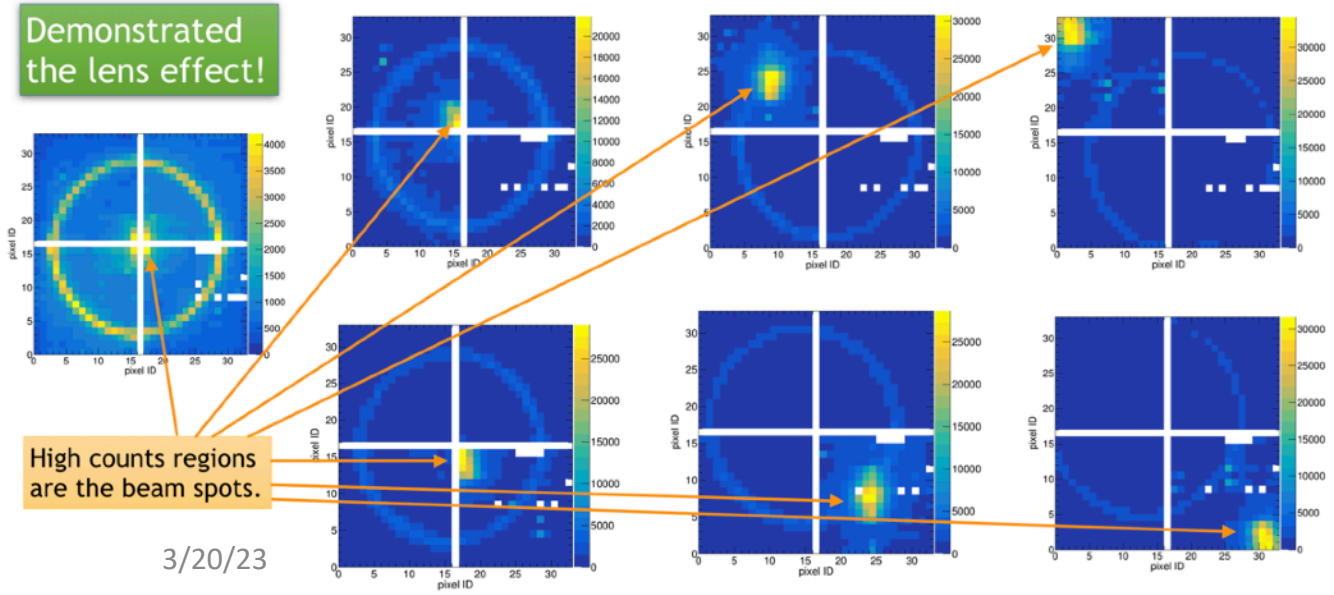


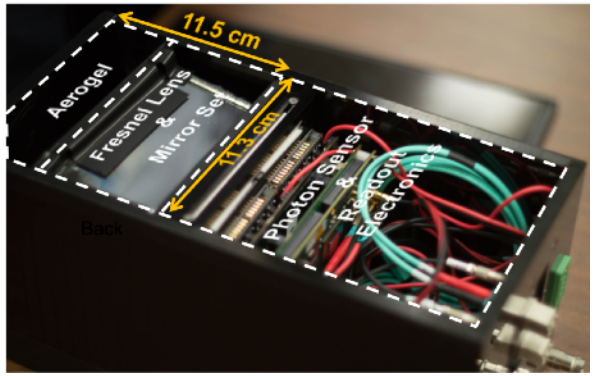
Demonstrated the lens effect!



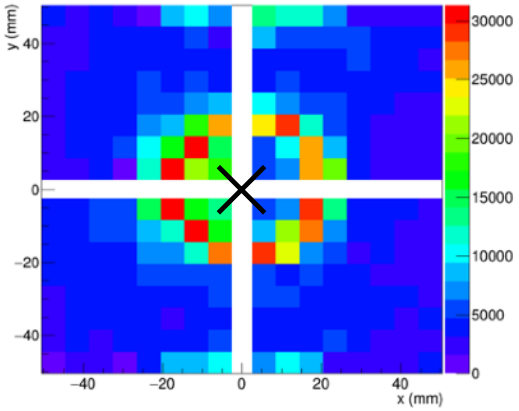
High counts regions are the beam spots.

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

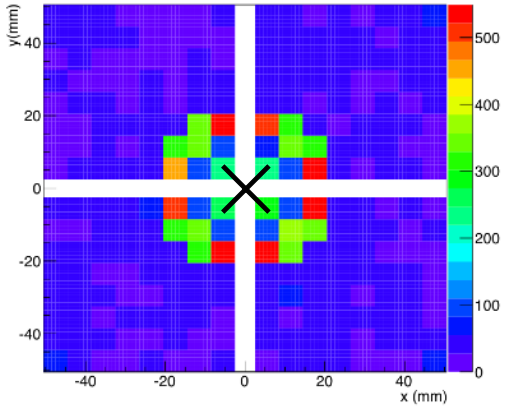
The 1st test beam result verified mRICH working principle and validated simulation



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



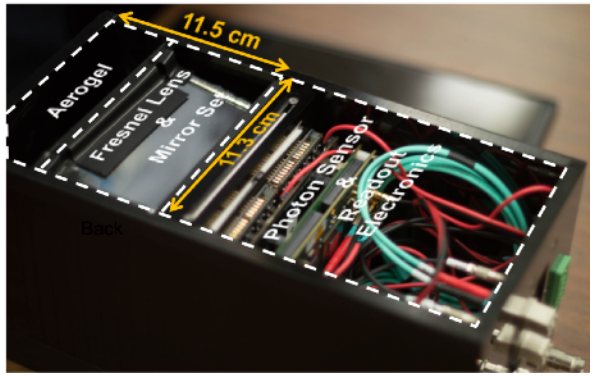
Images from 120 GeV Proton beam



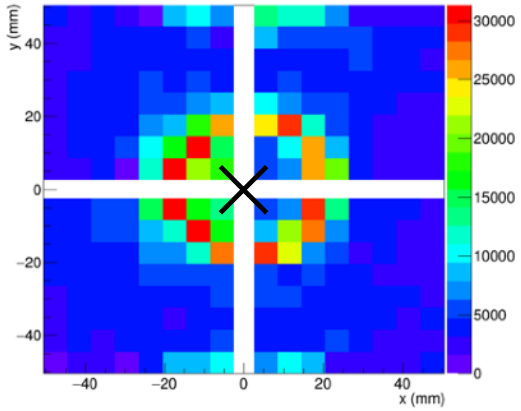
Simulated Images Using GEANT4

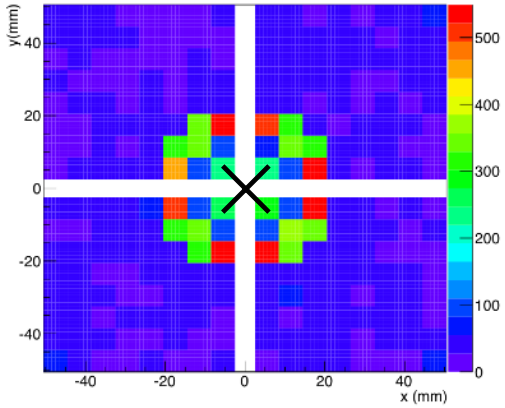
1st & 2nd Beam Test Comparison (120 GeV Proton Beam)

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

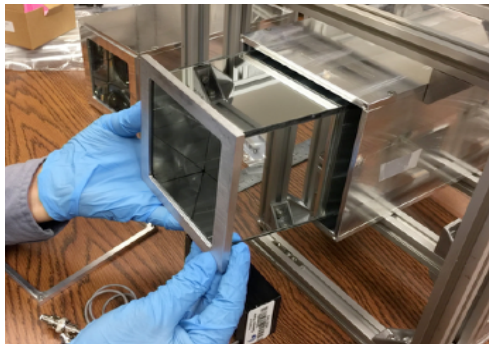




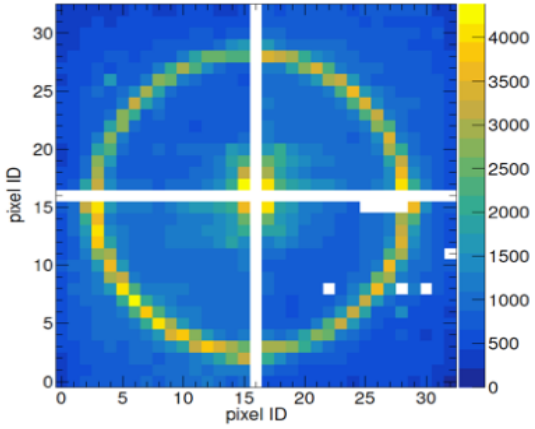
Images from 120 GeV Proton beam

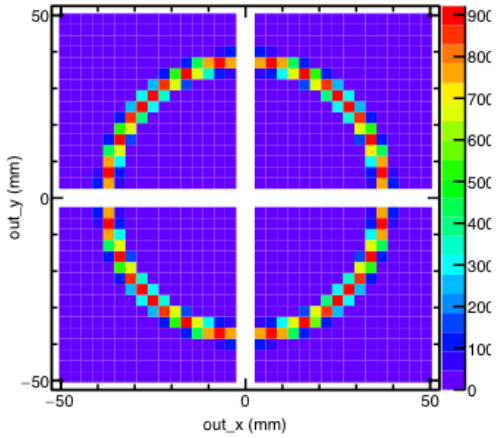
Simulated Images Using GEANT4

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



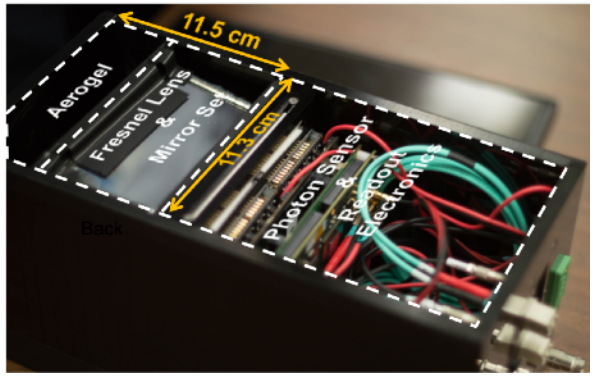
2nd mRICH prototype was tested at Fermilab Test Beam Facility in June/July 2018



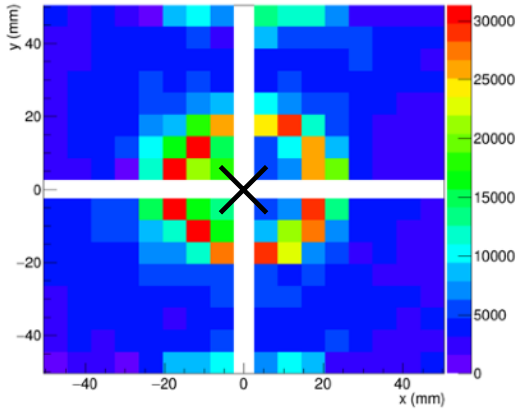


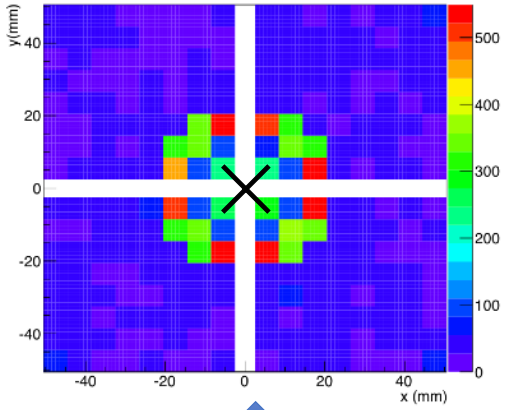
1st & 2nd Beam Test Comparison (120 GeV Proton Beam)

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

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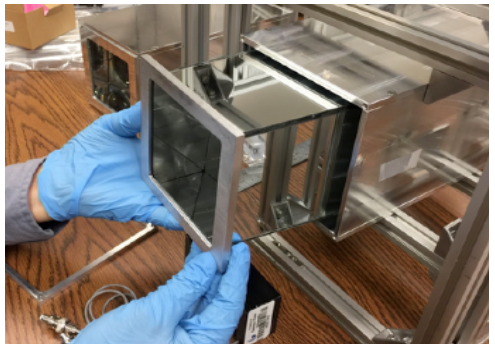

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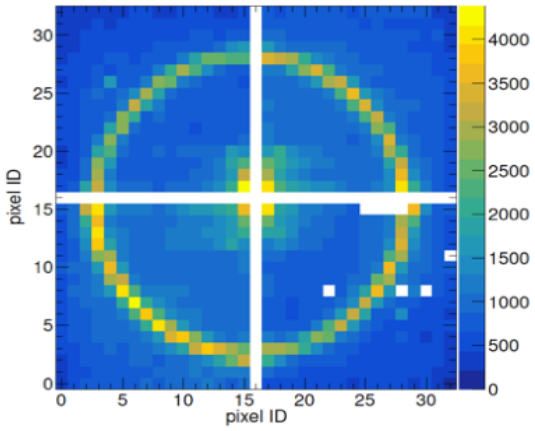
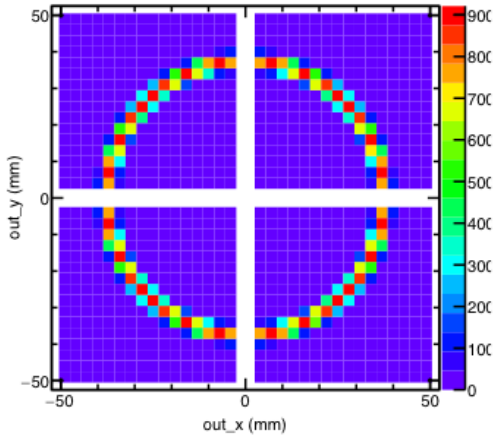
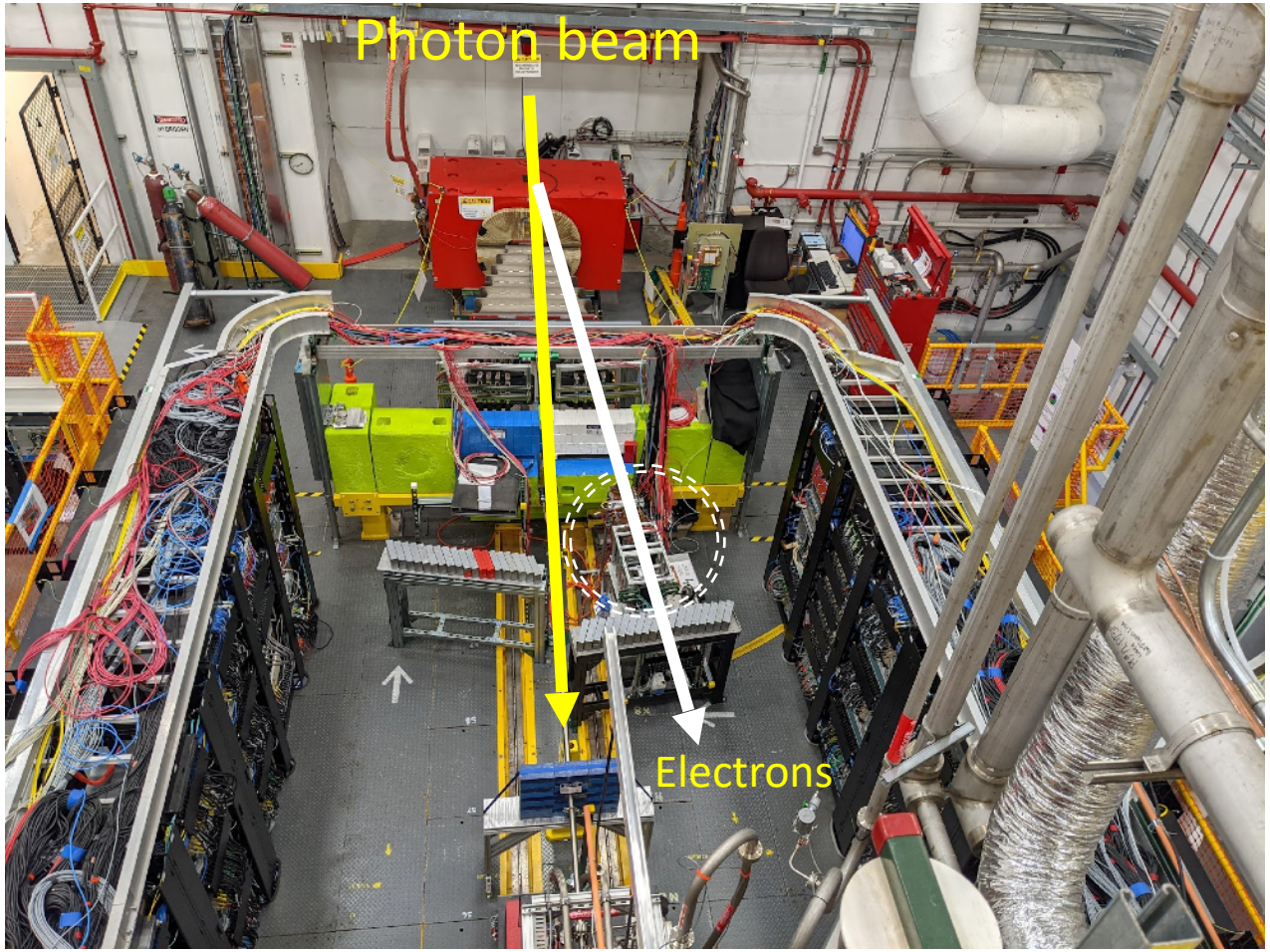




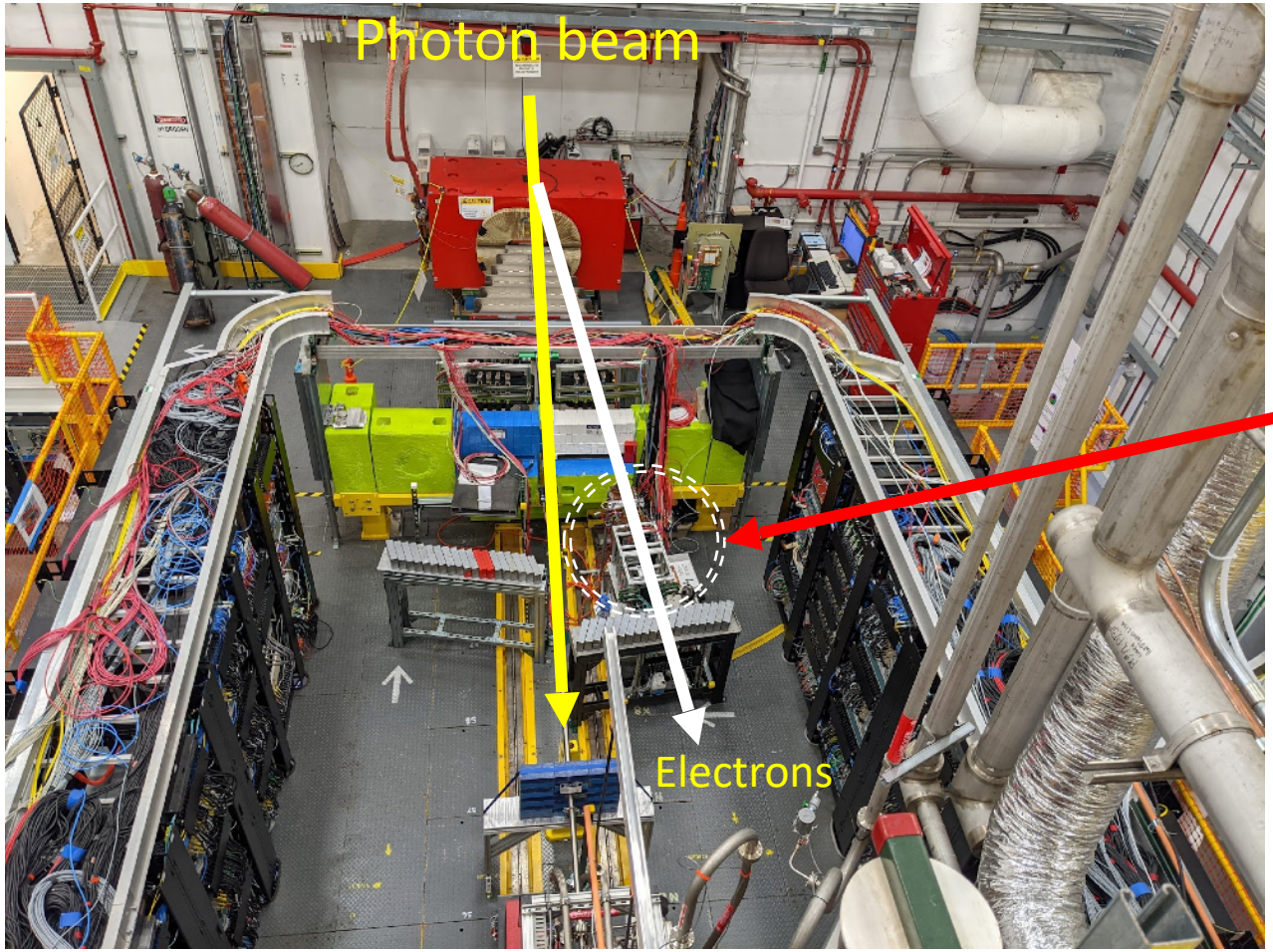
mRICH Test at JLab

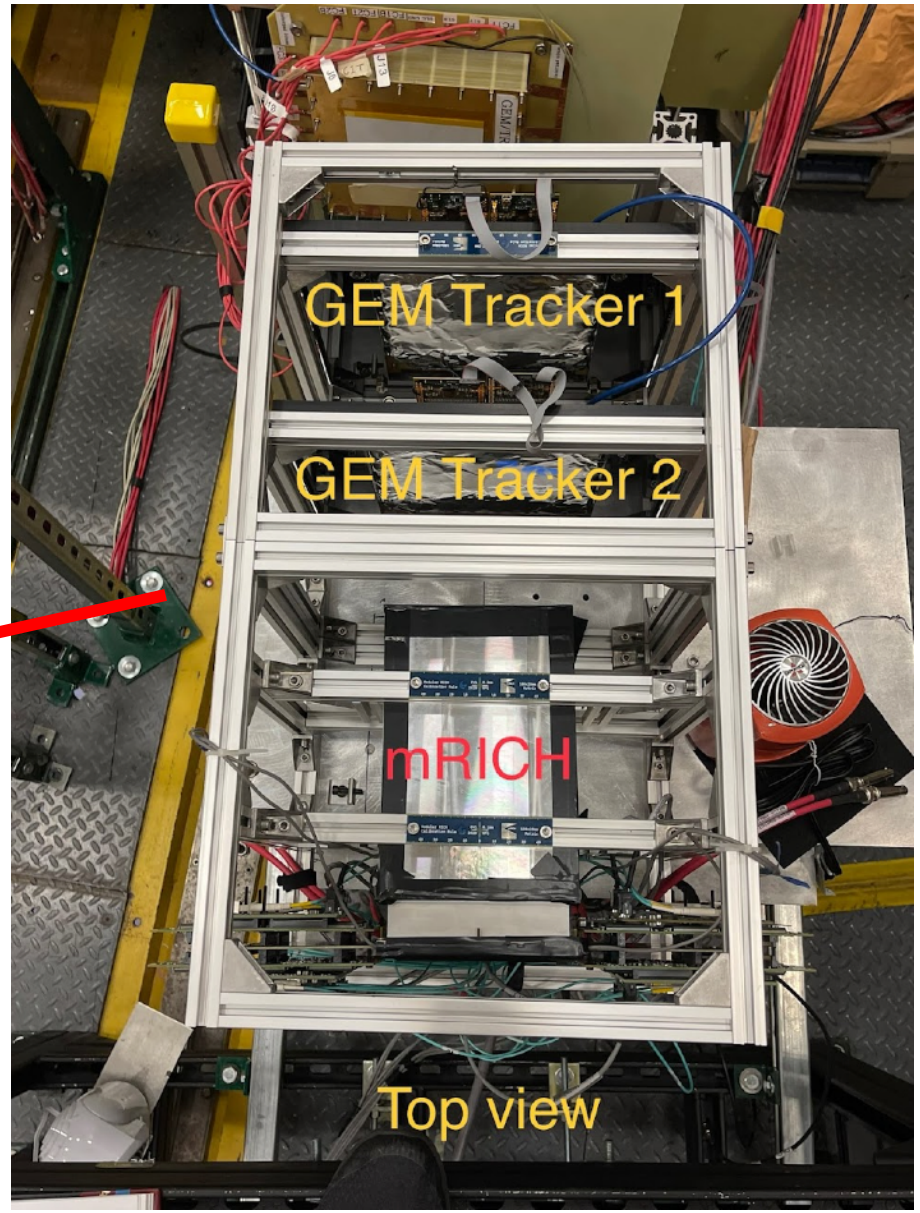
To quantify single photon angle resolution and Aerogel edge effects. This is one of the milestones achieved for the eRD101 Project R&D (FY22).

mRICH Test Setup in Hall D at JLab

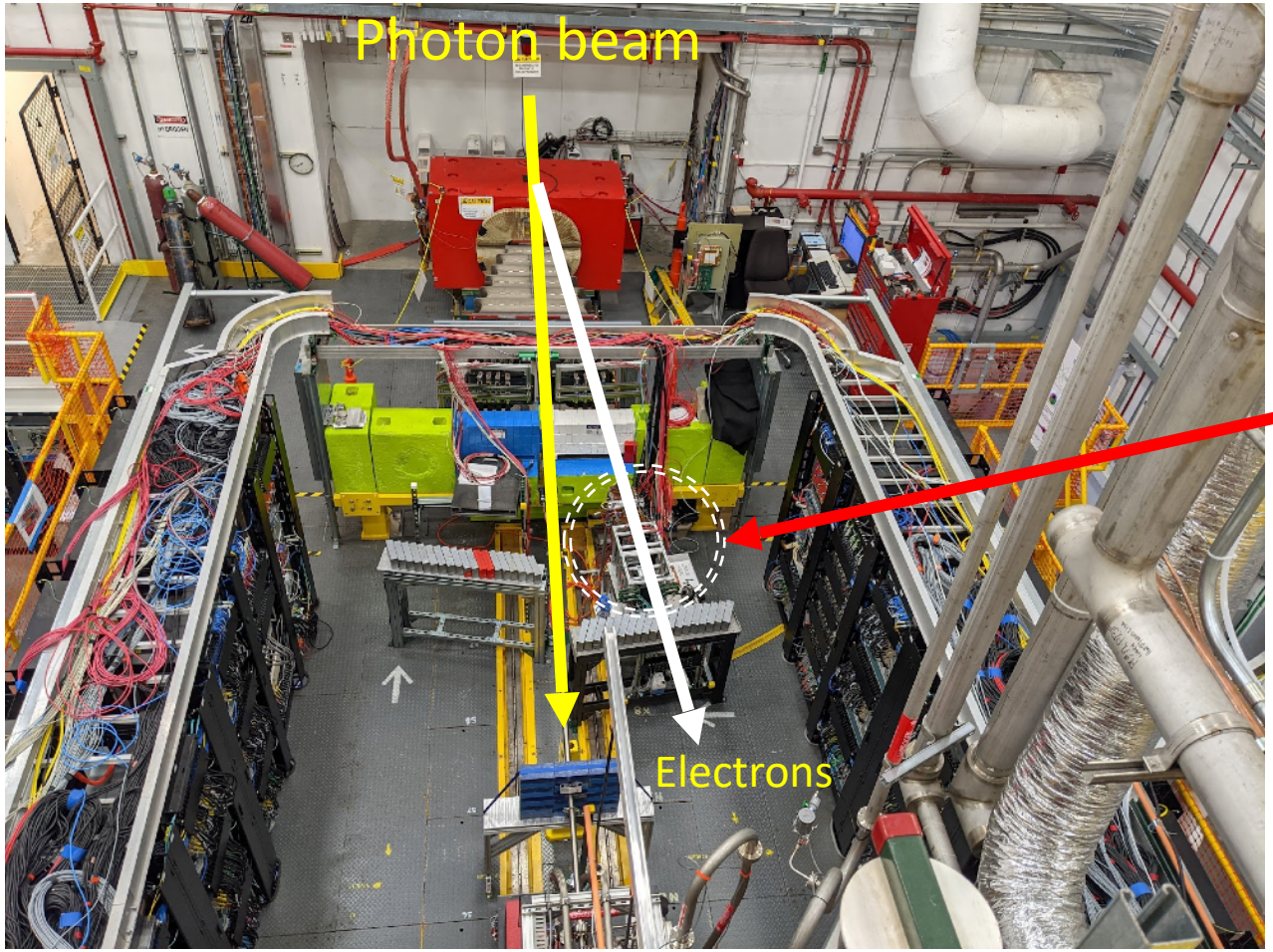


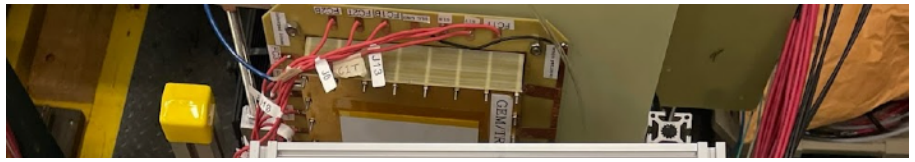
mRICH Test Setup in Hall D at JLab

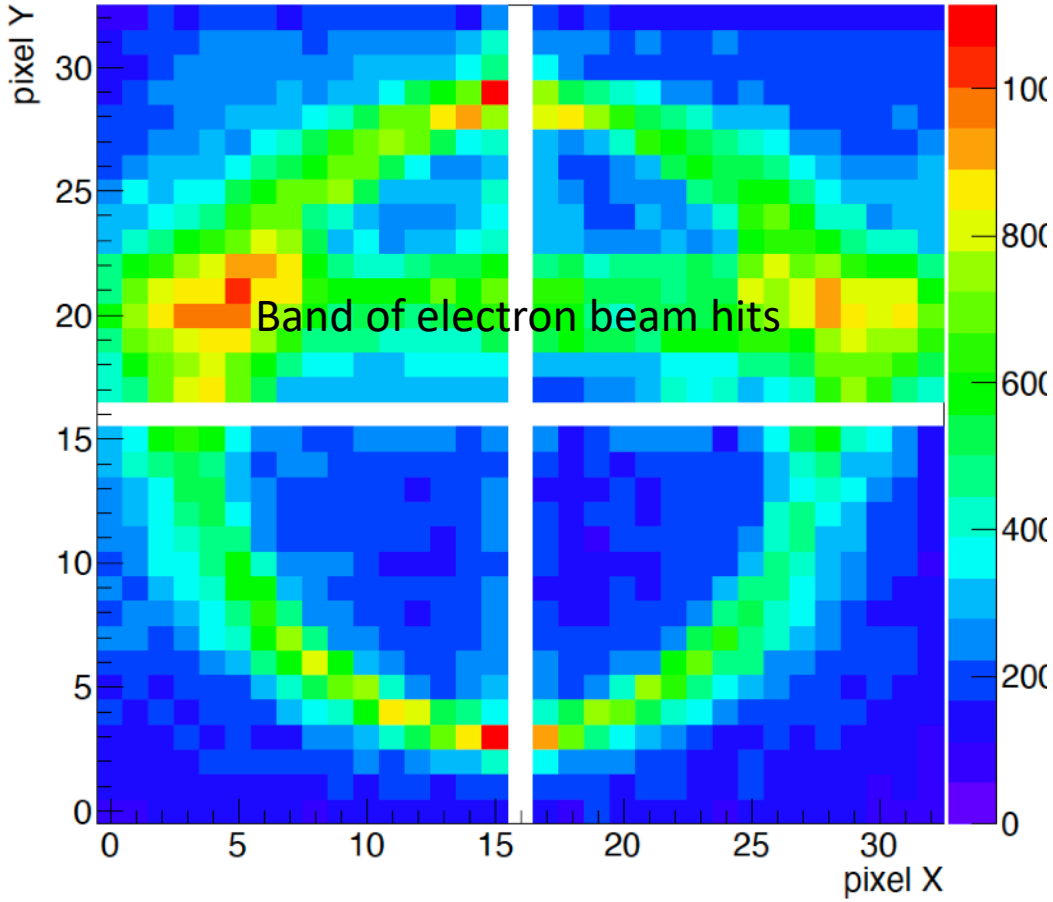


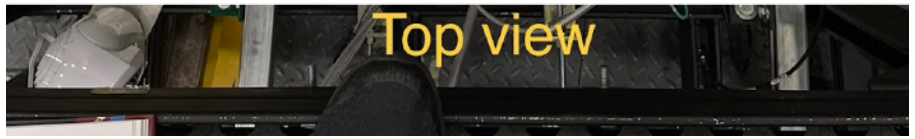


mRICH Test Setup in Hall D at JLab









Single photon angle resolution (JLab test results)

Murad Sarsour
Georgia State University

The end of the 1st presentation

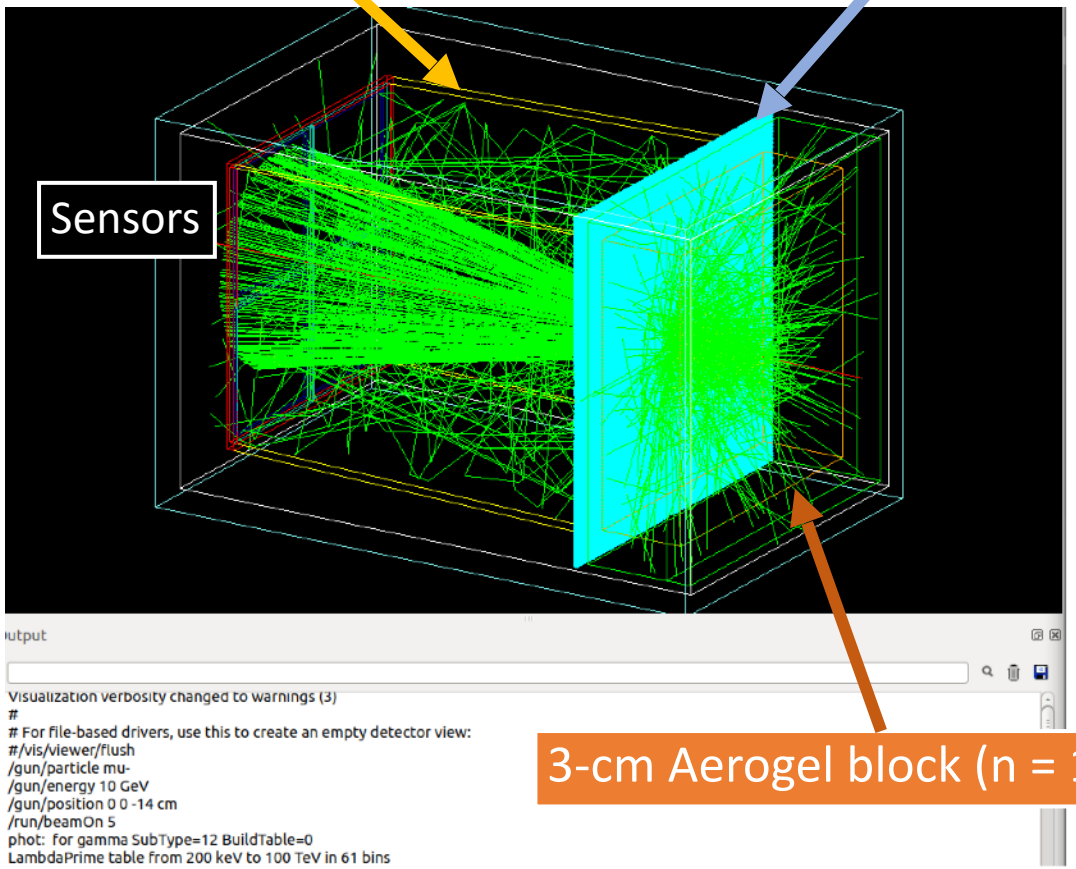
Backups

mRICH Key Features

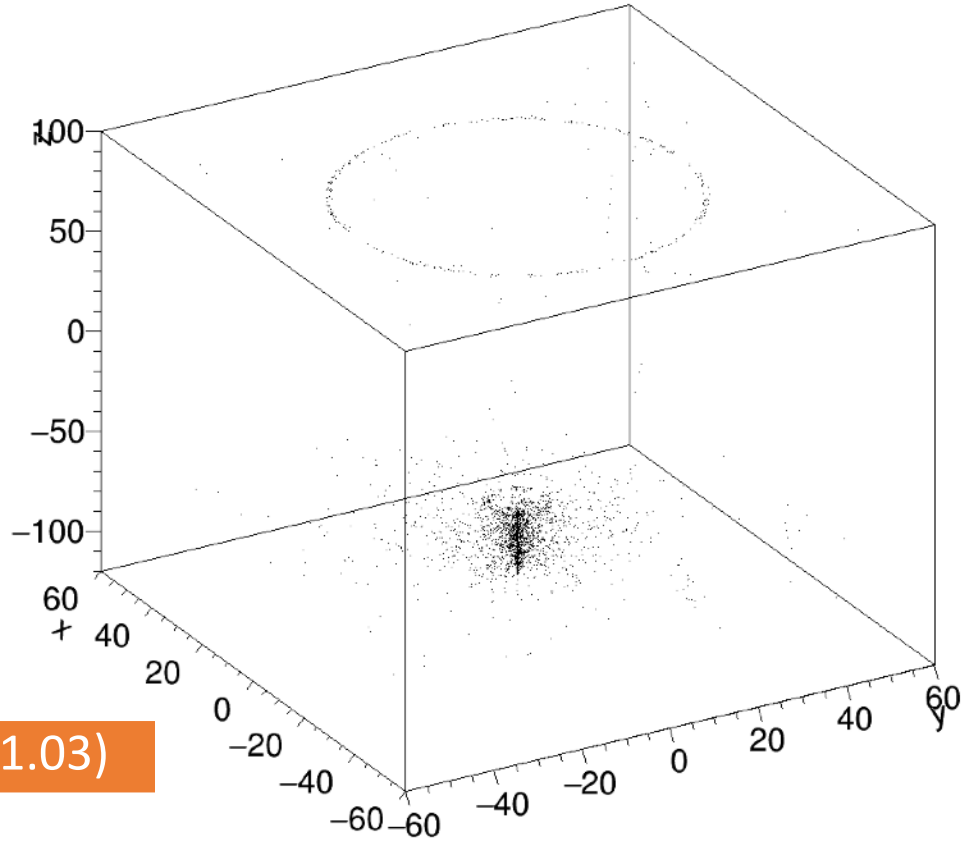
Mirror wall

6” acrylic Fresnel lens

Sensors



3-cm Aerogel block (n = 1.03)



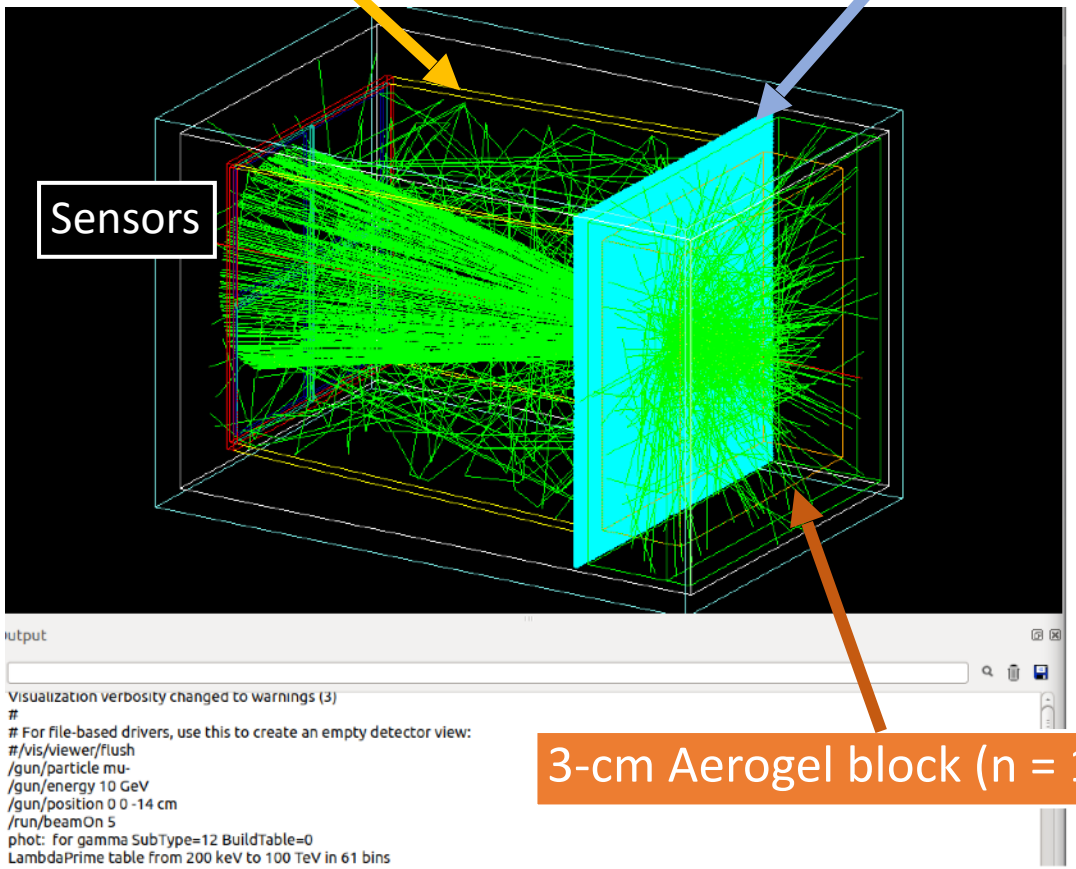
mRICH Key Features

- **Sharper & small ring image in comparison to proximity focusing**
- **Compact, projective, and modular (confining signal photons within one module)**

Mirror wall

6” acrylic Fresnel lens

Sensors



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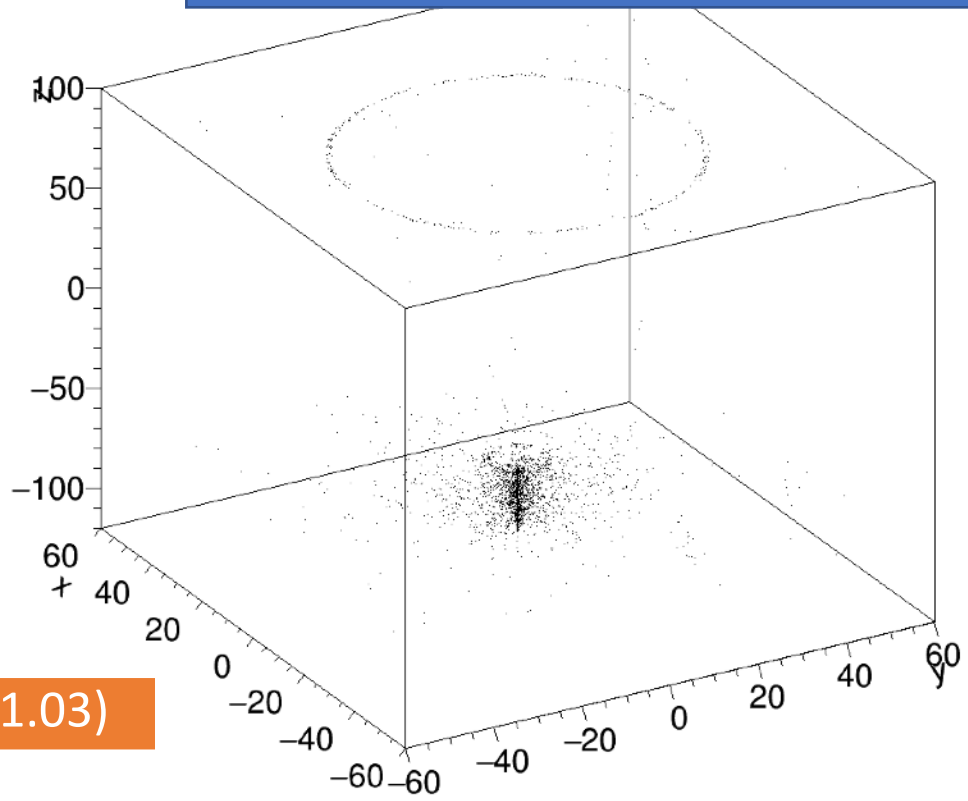
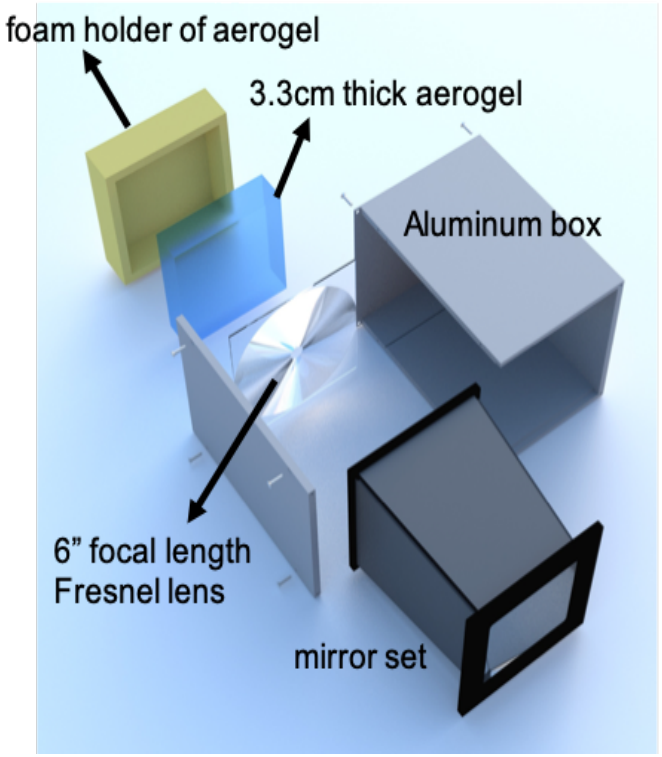
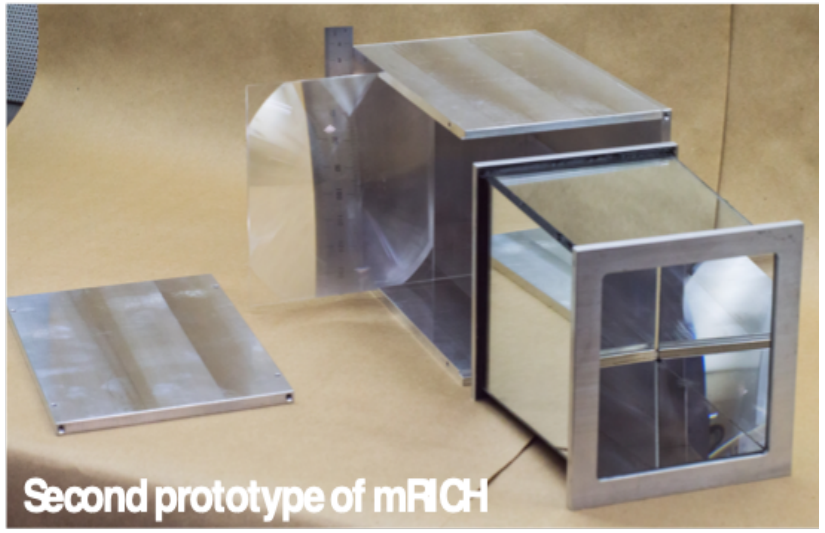


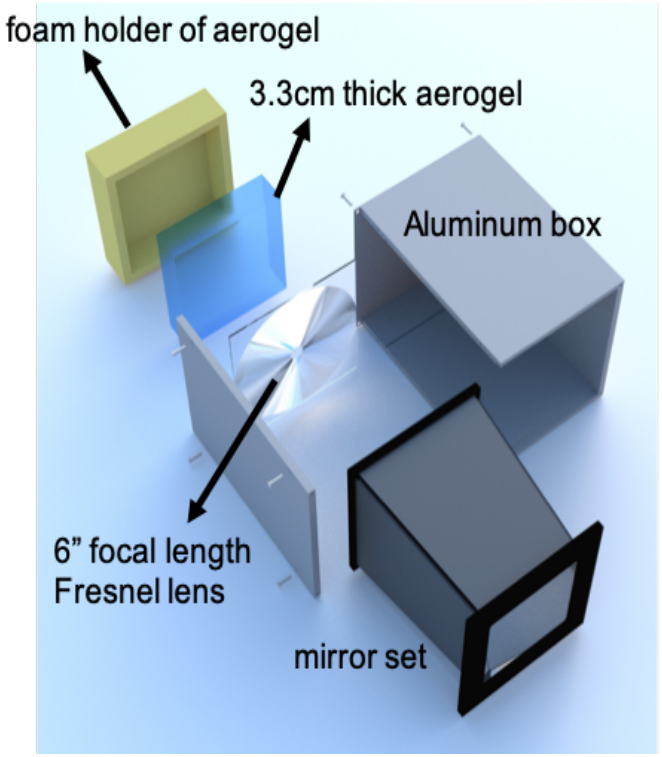
2nd mRICH Prototype
New Optical Component Design

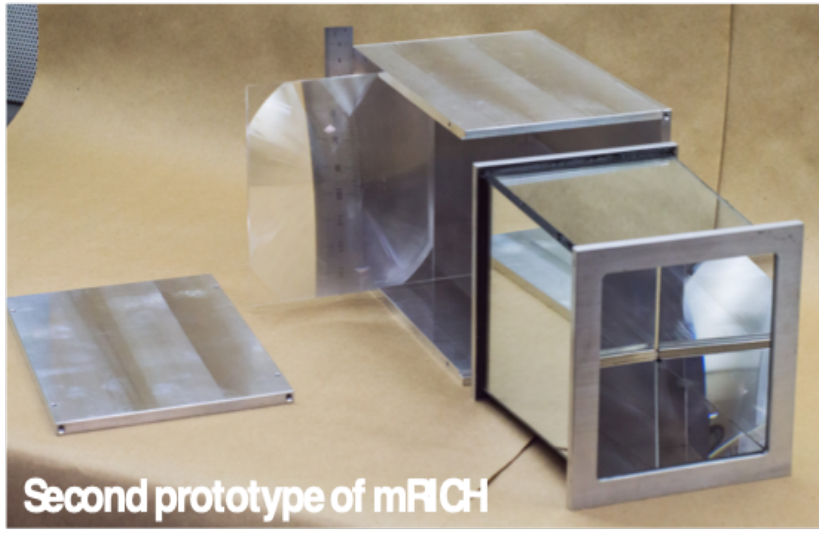




- ✓ Longer Fresnel focal length
- ✓ Photosensors with smaller pixel size

2nd mRICH Prototype
New Optical Component Design





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