Ring Imaging Cherenkov Detector for Particle Identification in the Electron-Ion Collider (EIC) Experiments

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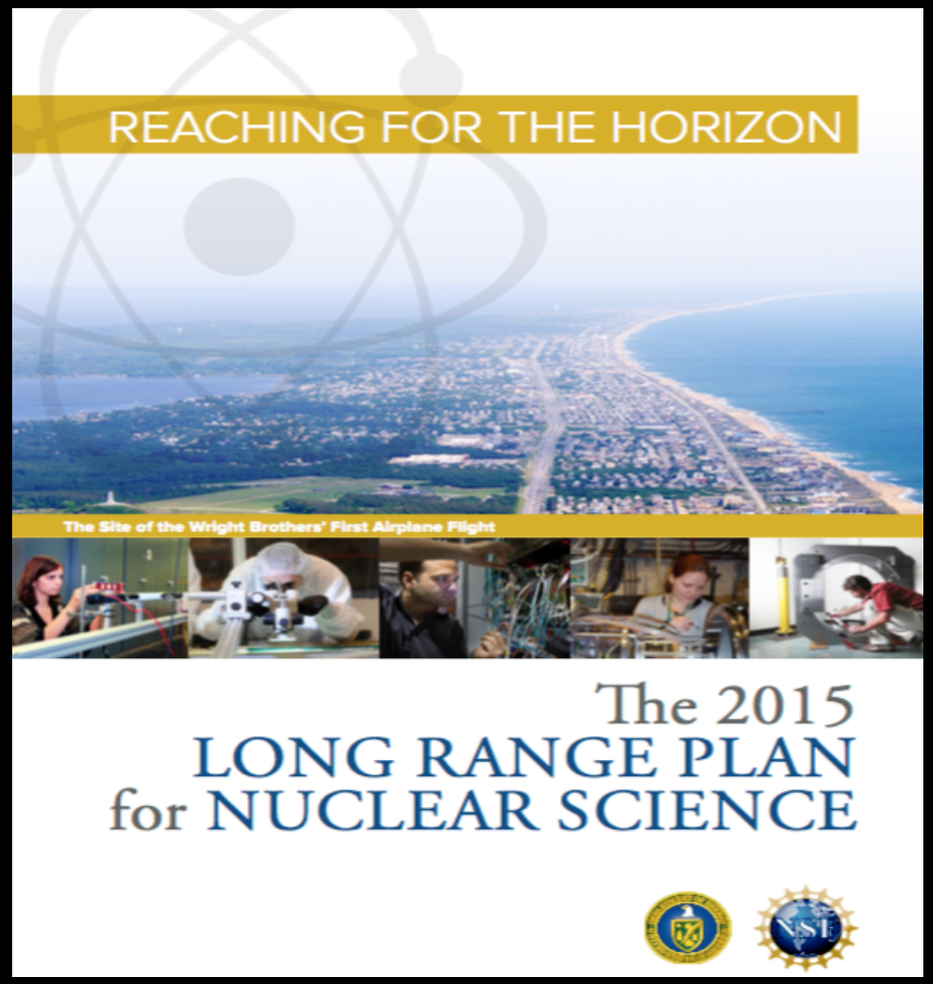
Georgia State University

for the EIC PID Consortium (eRD14)

EIC Physics

EIC Physics

- One of the three top priorities of the US DOE long range plan for nuclear science recommended by the 2015 Nuclear Science Advisory Committee.



EIC Physics

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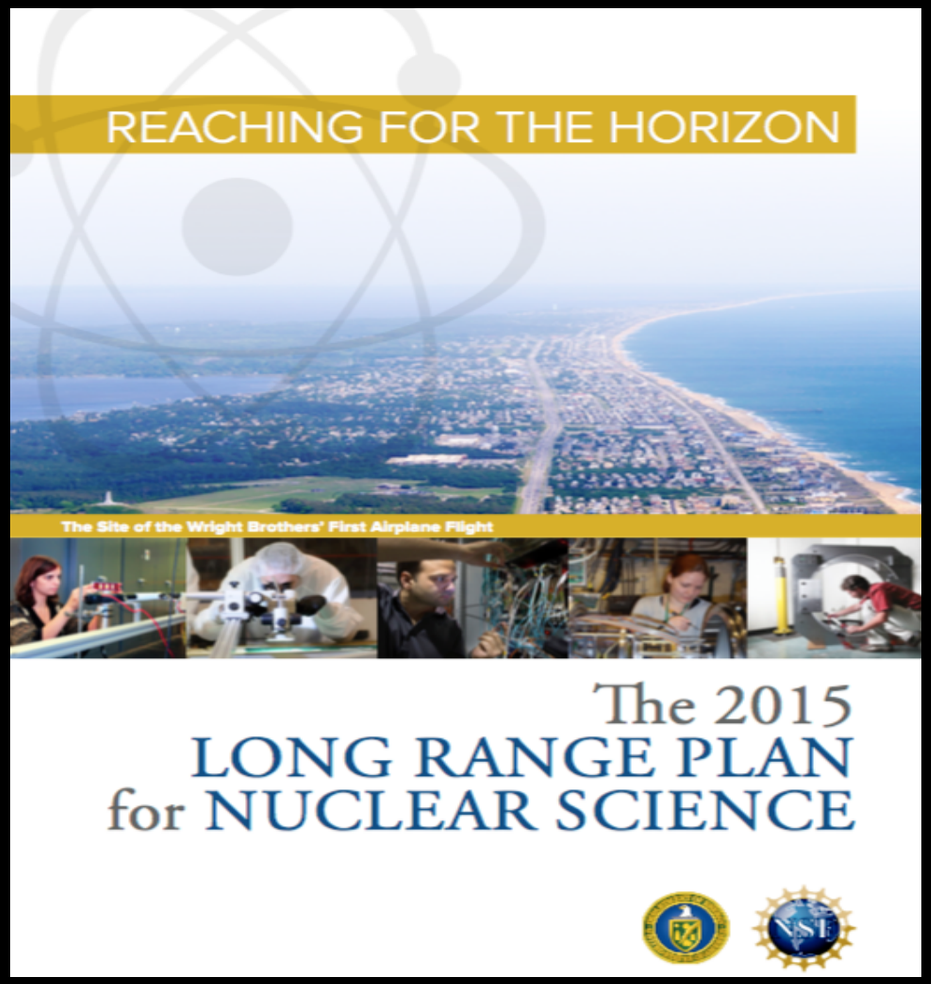
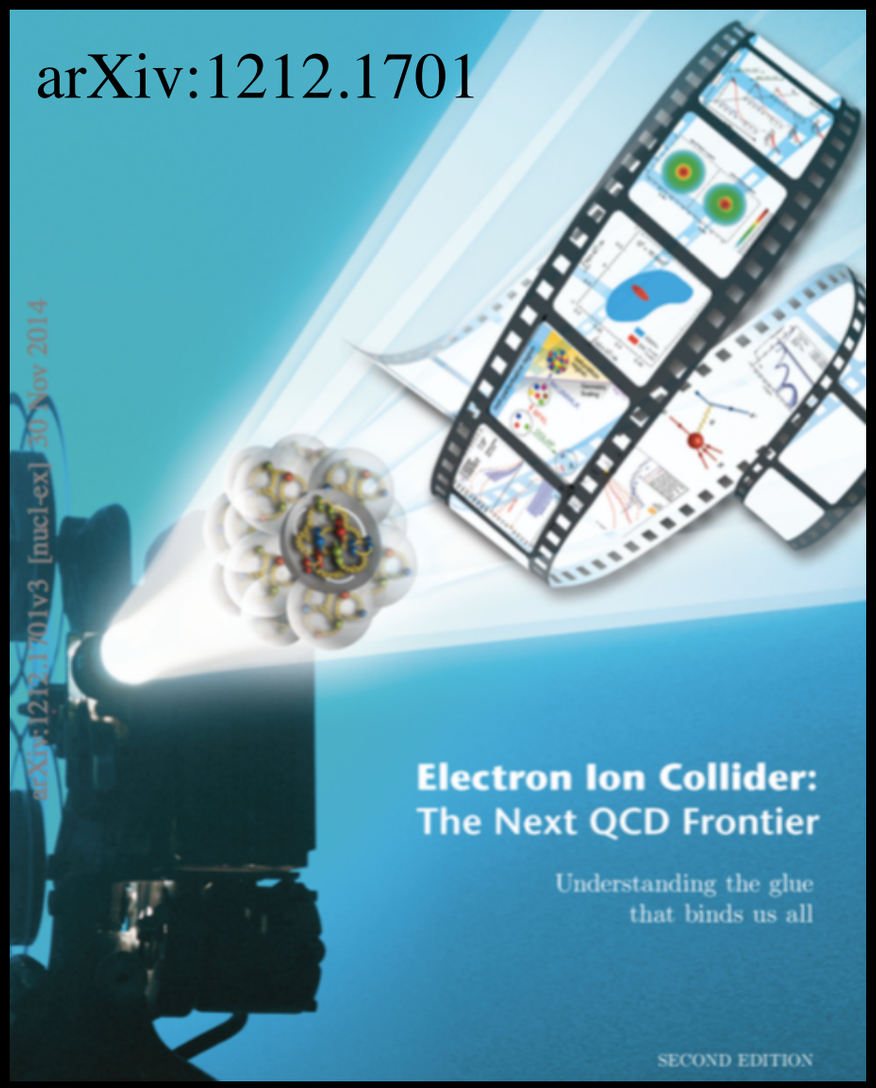


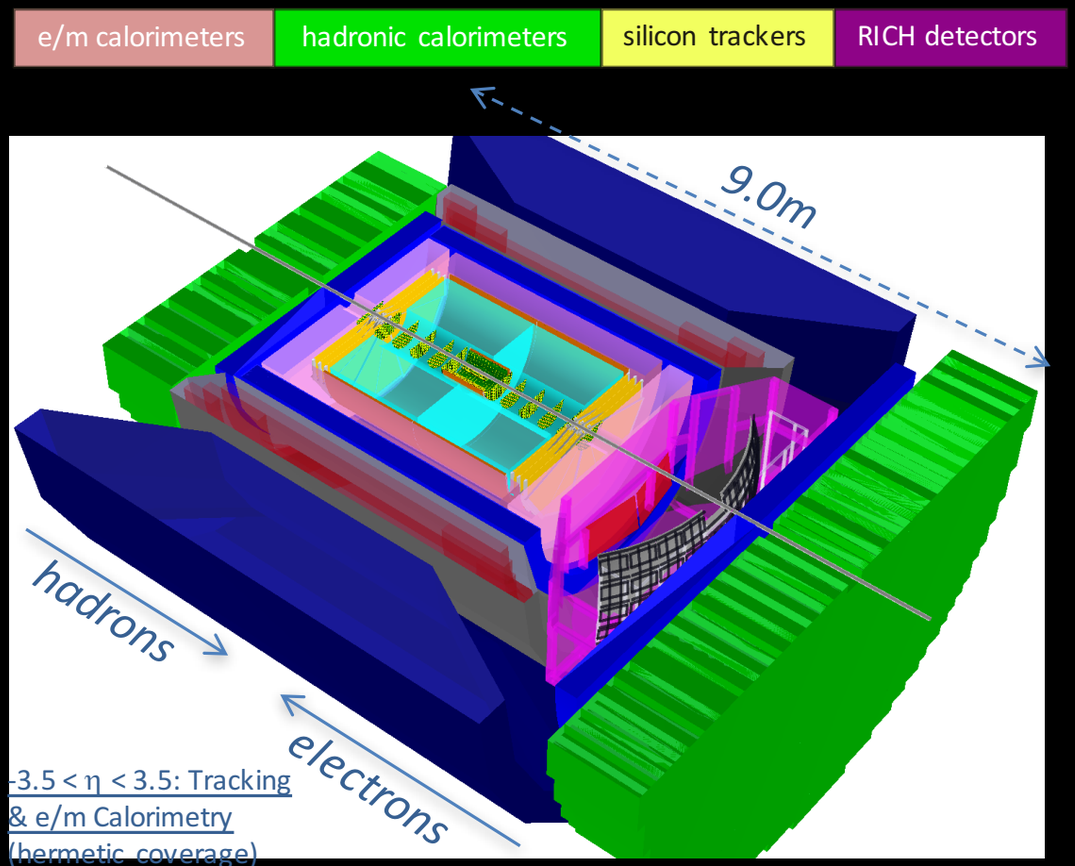


- Answer fundamental questions about the role of gluons in nucleons and nuclei. The outcome of EIC will provide the unprecedented precision about the initial state properties in relativistic heavy ion collisions at RHIC and LHC and the knowledge about the proton spin puzzle.

Proposed EIC Detector Designs

Proposed EIC Detector Designs

BNL version



Proposed EIC Detector Designs

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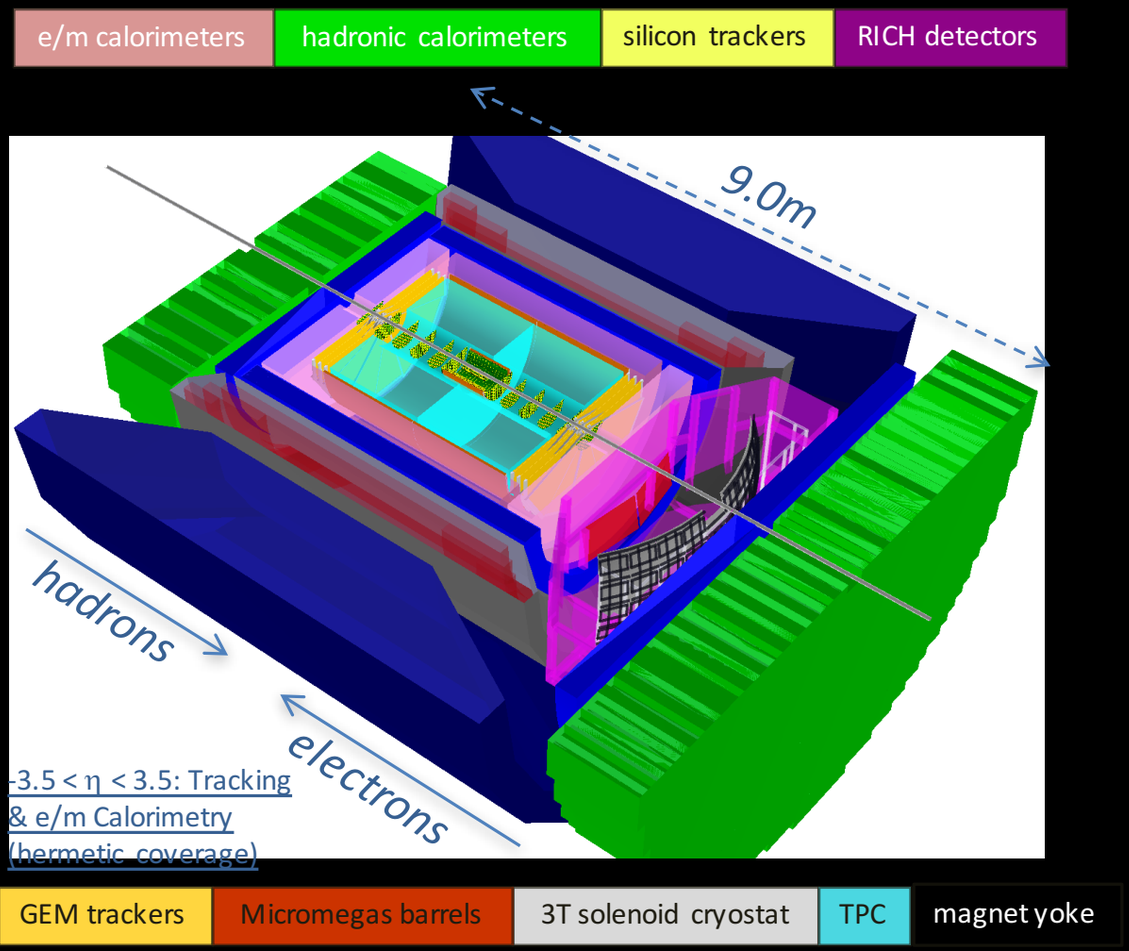
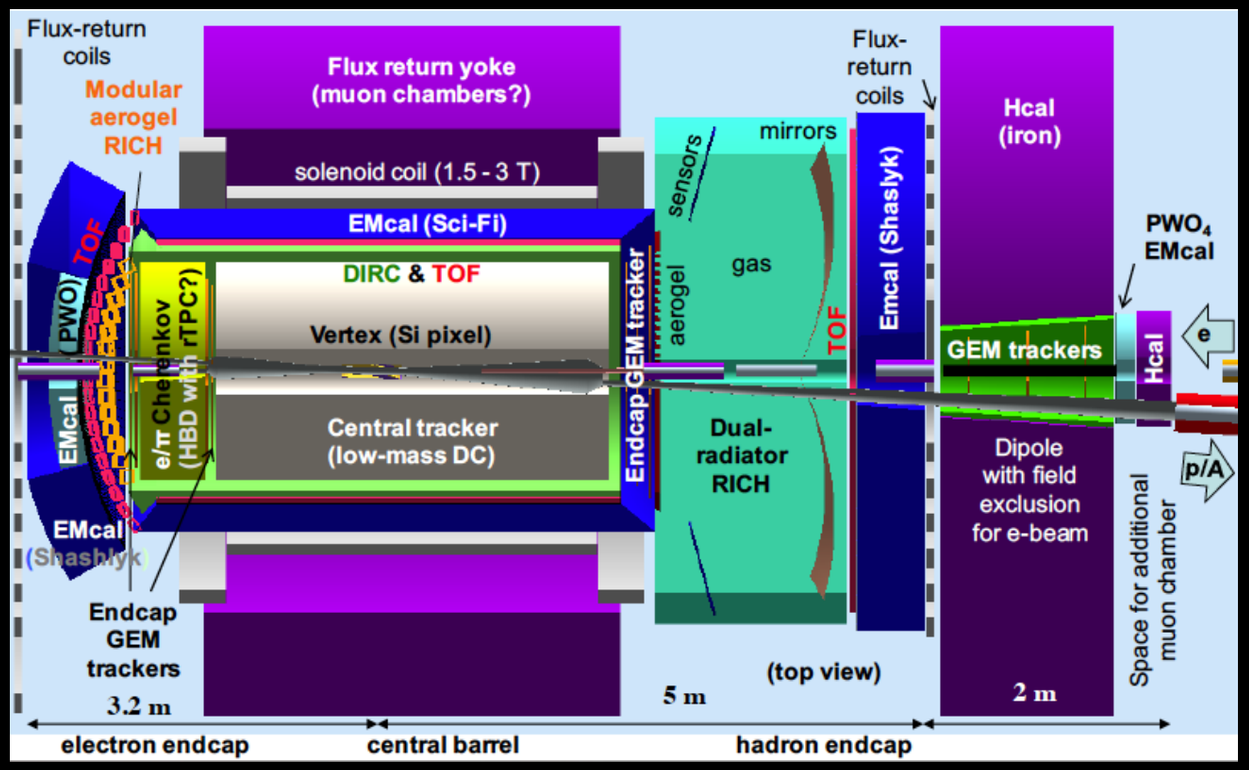
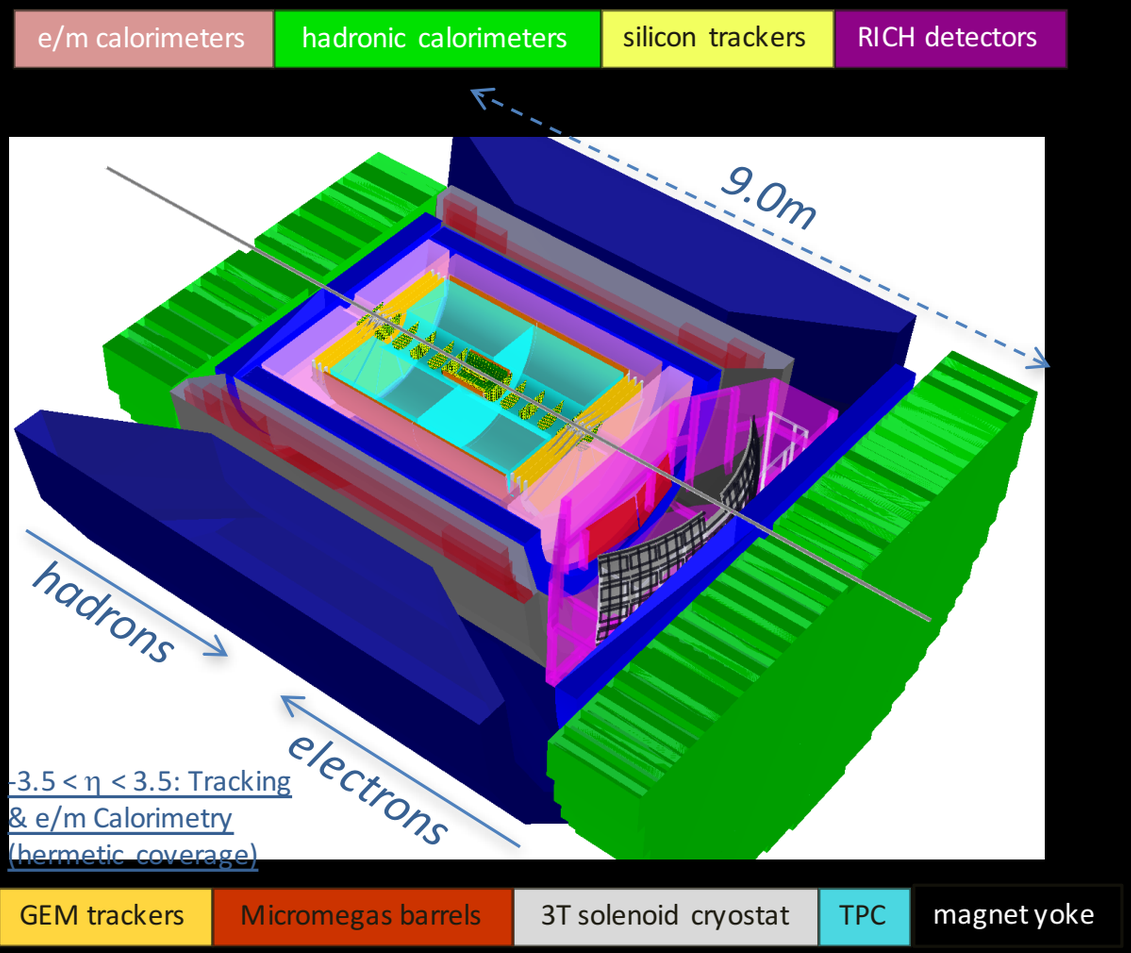


JLab version



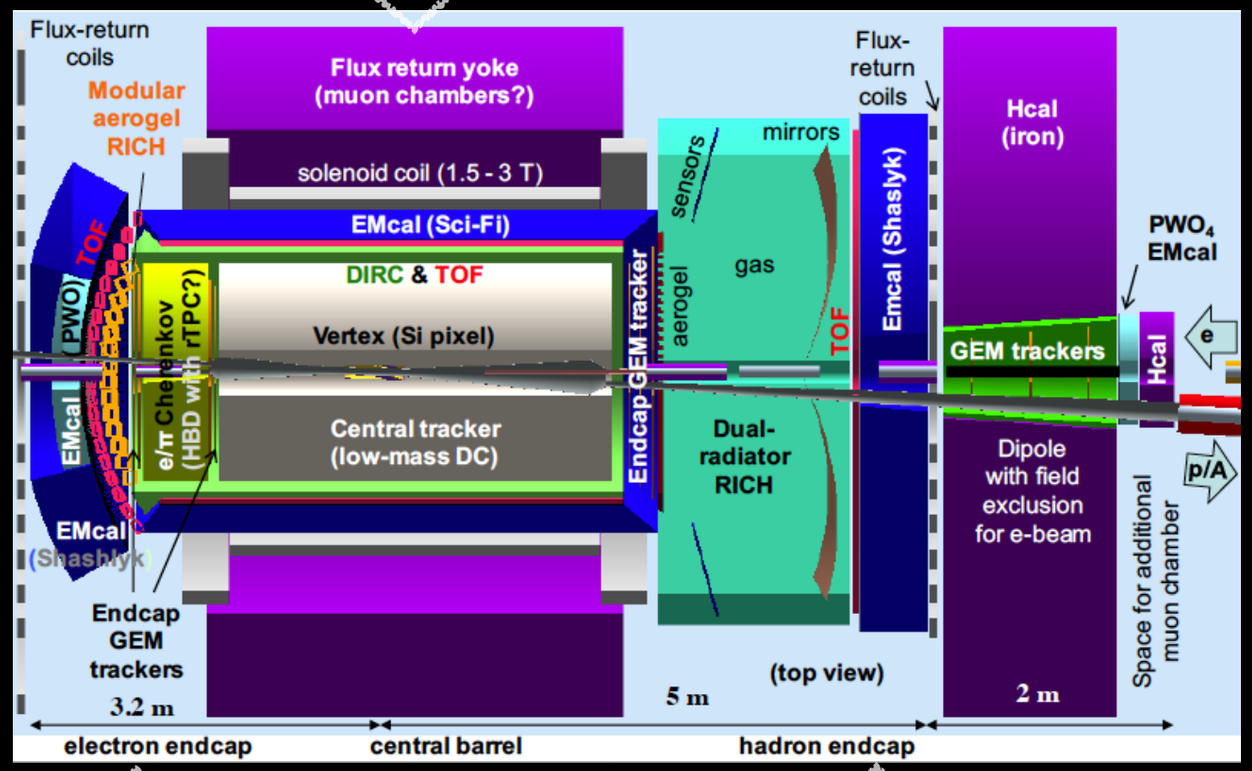
Proposed EIC Detector Designs

BNL version



JLab version

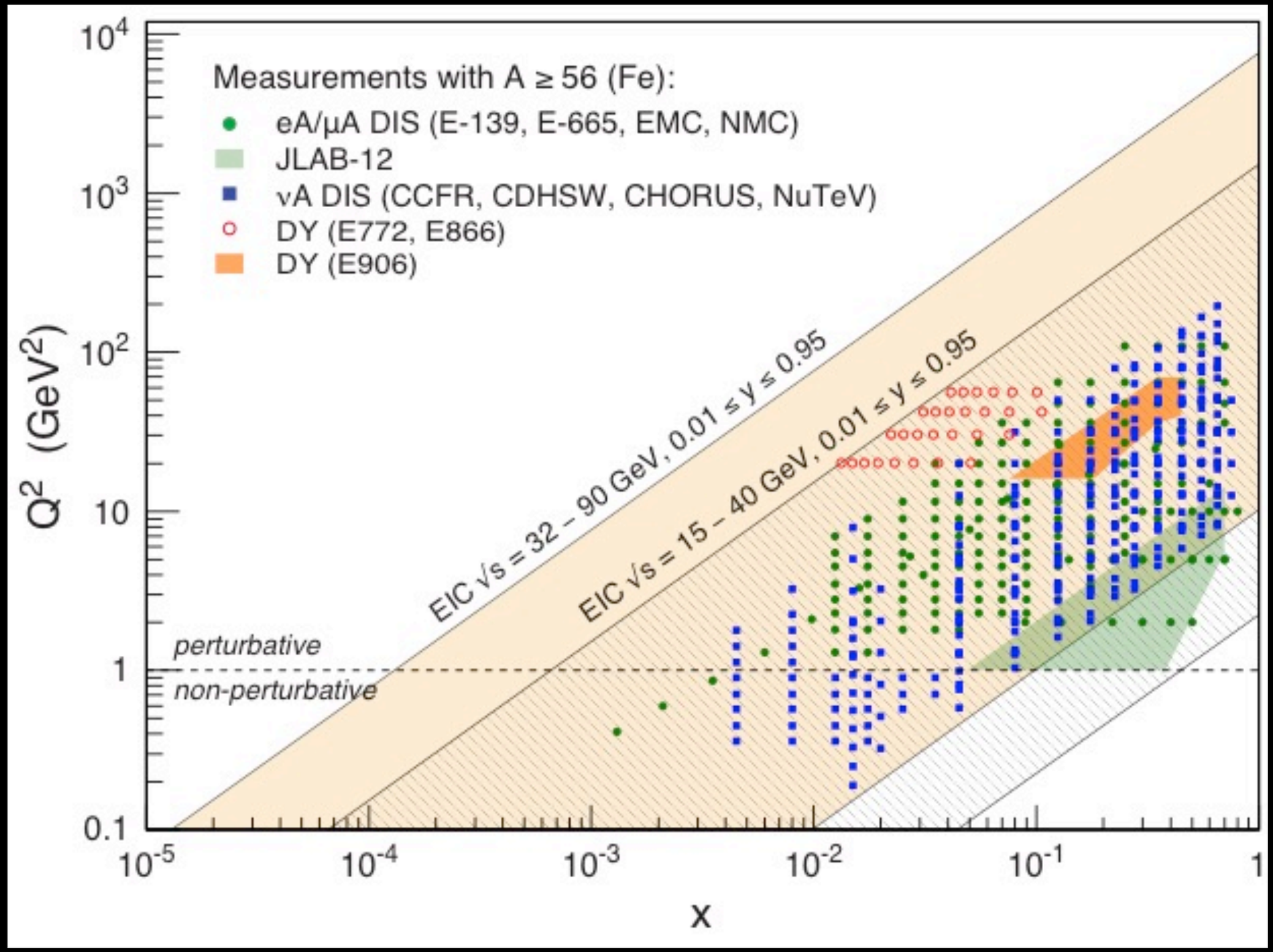
Central barrel



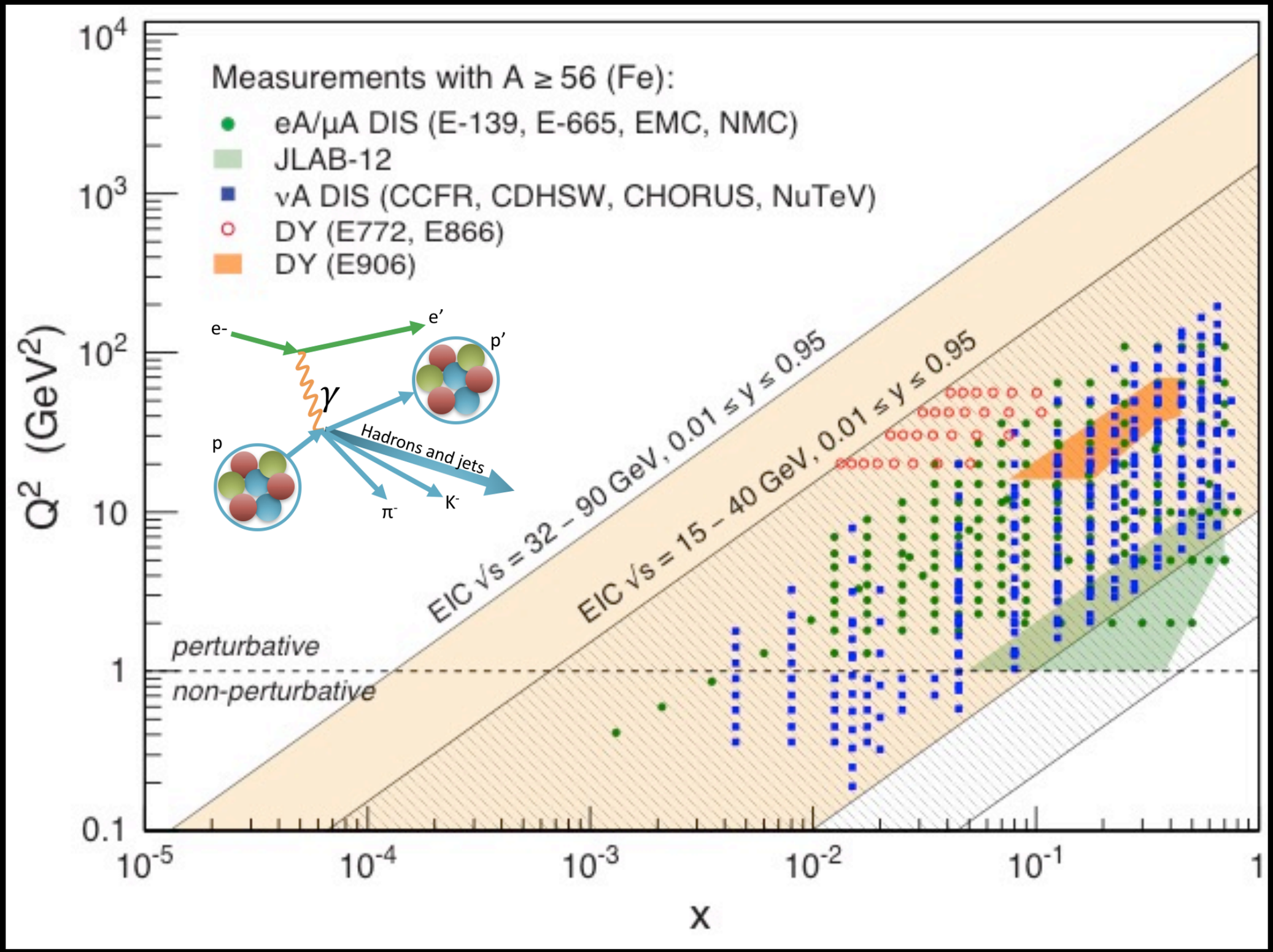
e-endcap

h-endcap

Unprecedented Reach of Phase Space at EIC



Unprecedented Reach of Phase Space at EIC



Recent EIC Users Group Meeing in Trieste, Italy

July 18 - 22, 2017

https://agenda.infn.it/conferenceDisplay.py?confId=13037

Outline

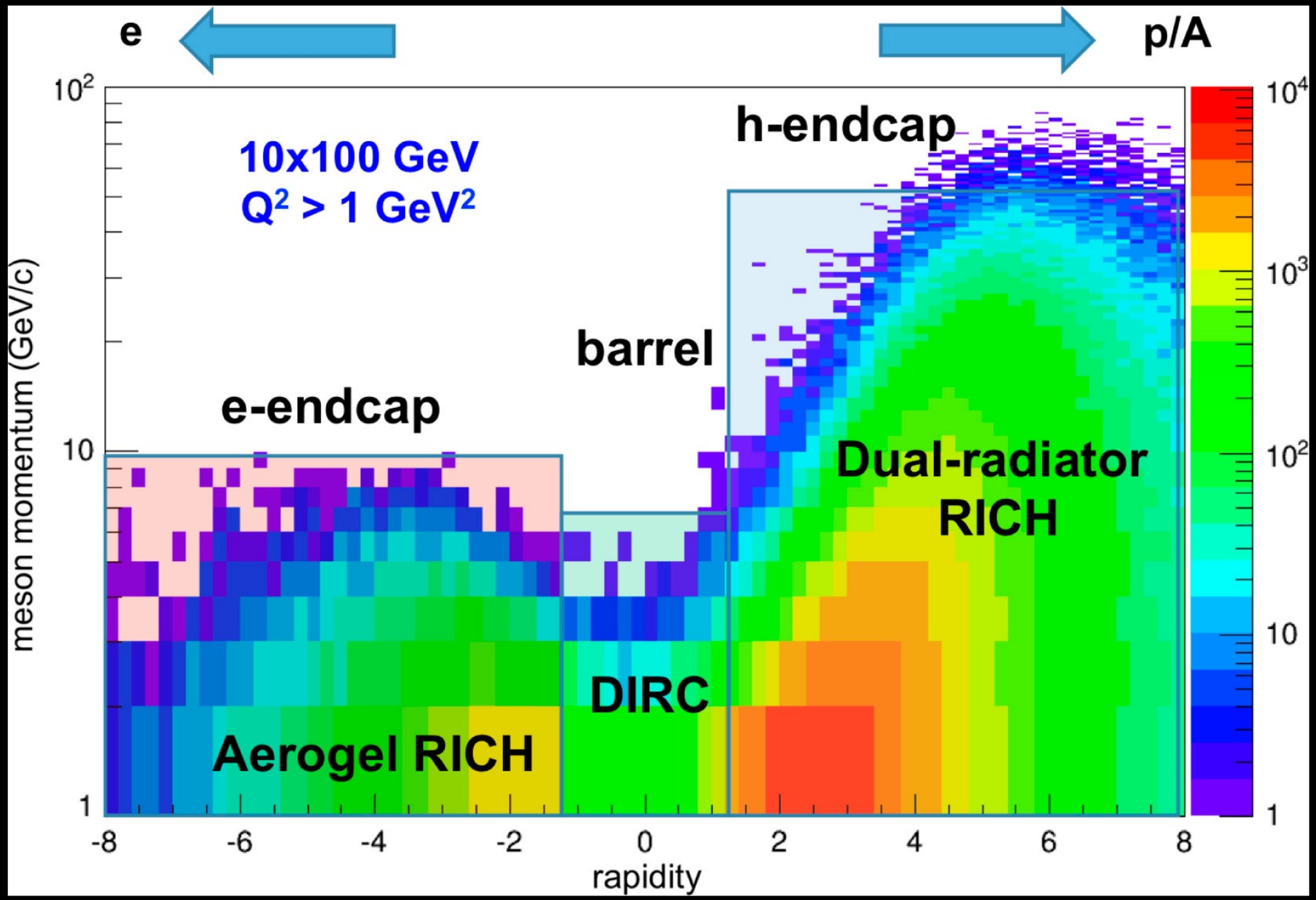
- PID Detectors for EIC Experiments
- Modular Ring Imaging Cherenkov Detector (mRICH)
- Summary and Outlook

EIC PID Consortium (eRD14)

An integrated program for particle identification (PID) for the Electron-Ion Collider Experiments

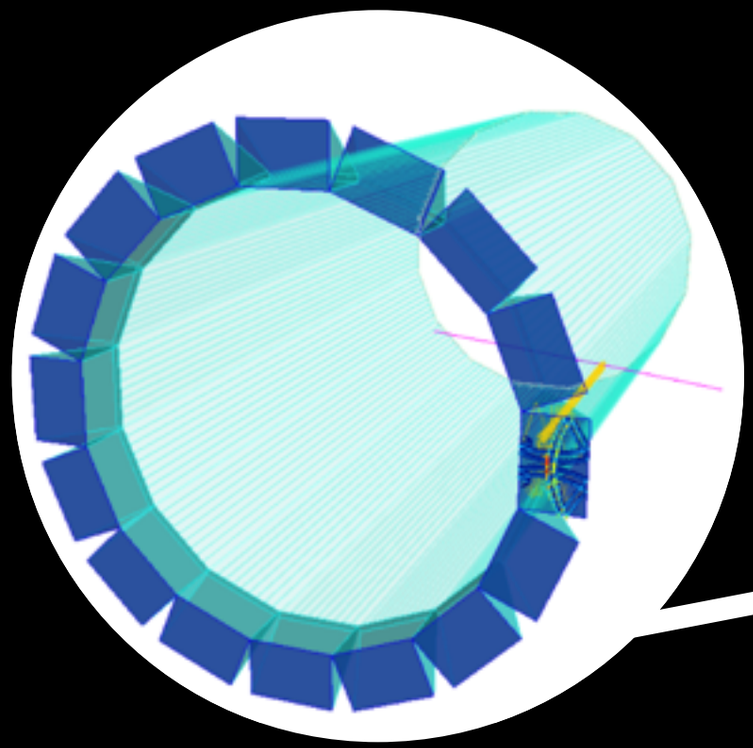
Abilene Christian University
Argonne National Lab
Brookhaven National Lab
Catholic University of America
College of William & Mary
Duke University
Georgia State University
GSI
Howard University
Hawaii University
INFN, Sezione di Ferrara
INFN, Sezione di Roma
Istituto Superiore di Sanità
Jefferson Lab
Los Alamos National Lab
Old Dominion University
Universidad Técnica Federico Santa María
University of Illinois
University of New Mexico
University of South Carolina
Yale University

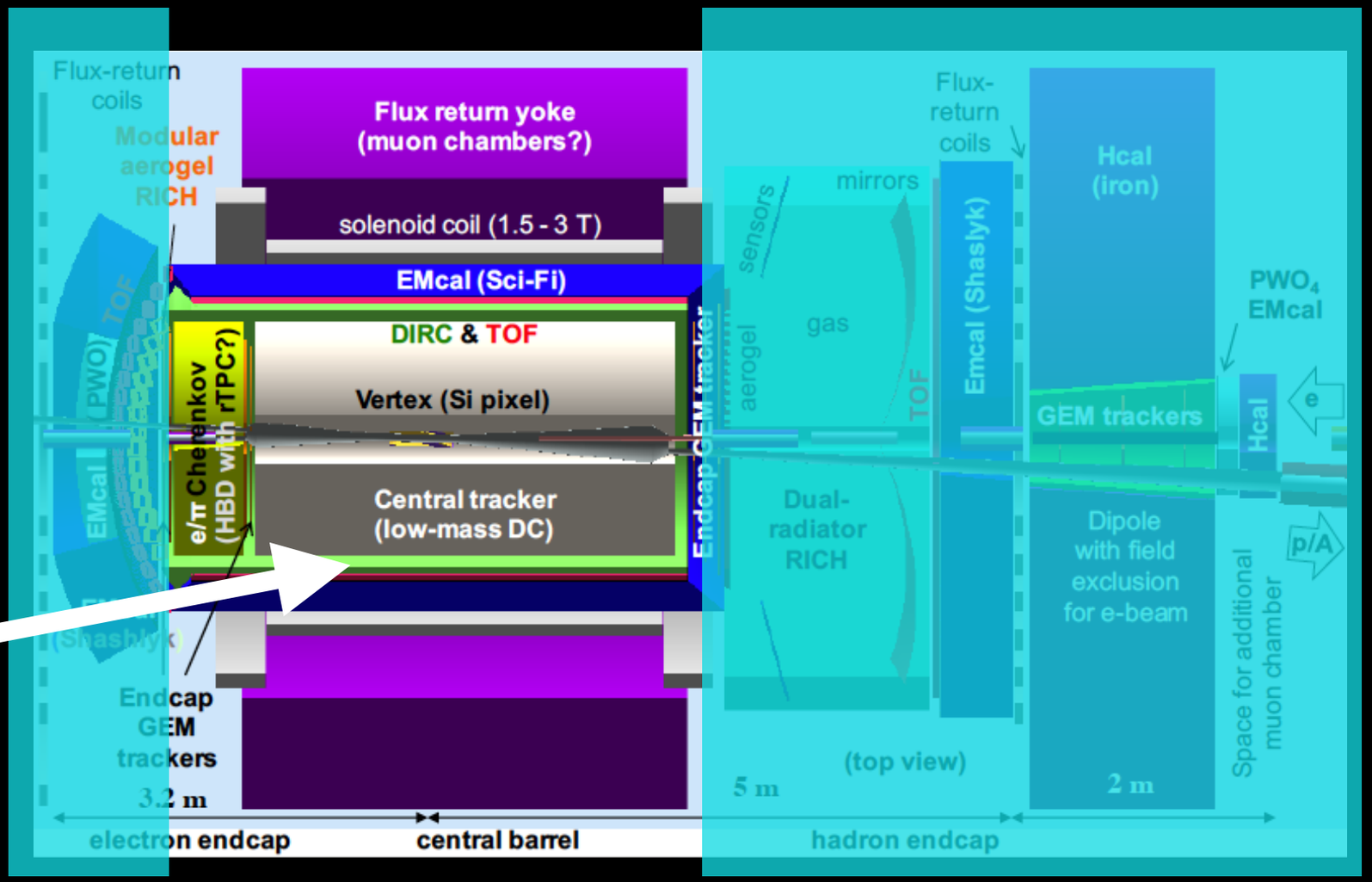
Particle Momentum Distributions



PID in Central Region

DIRC

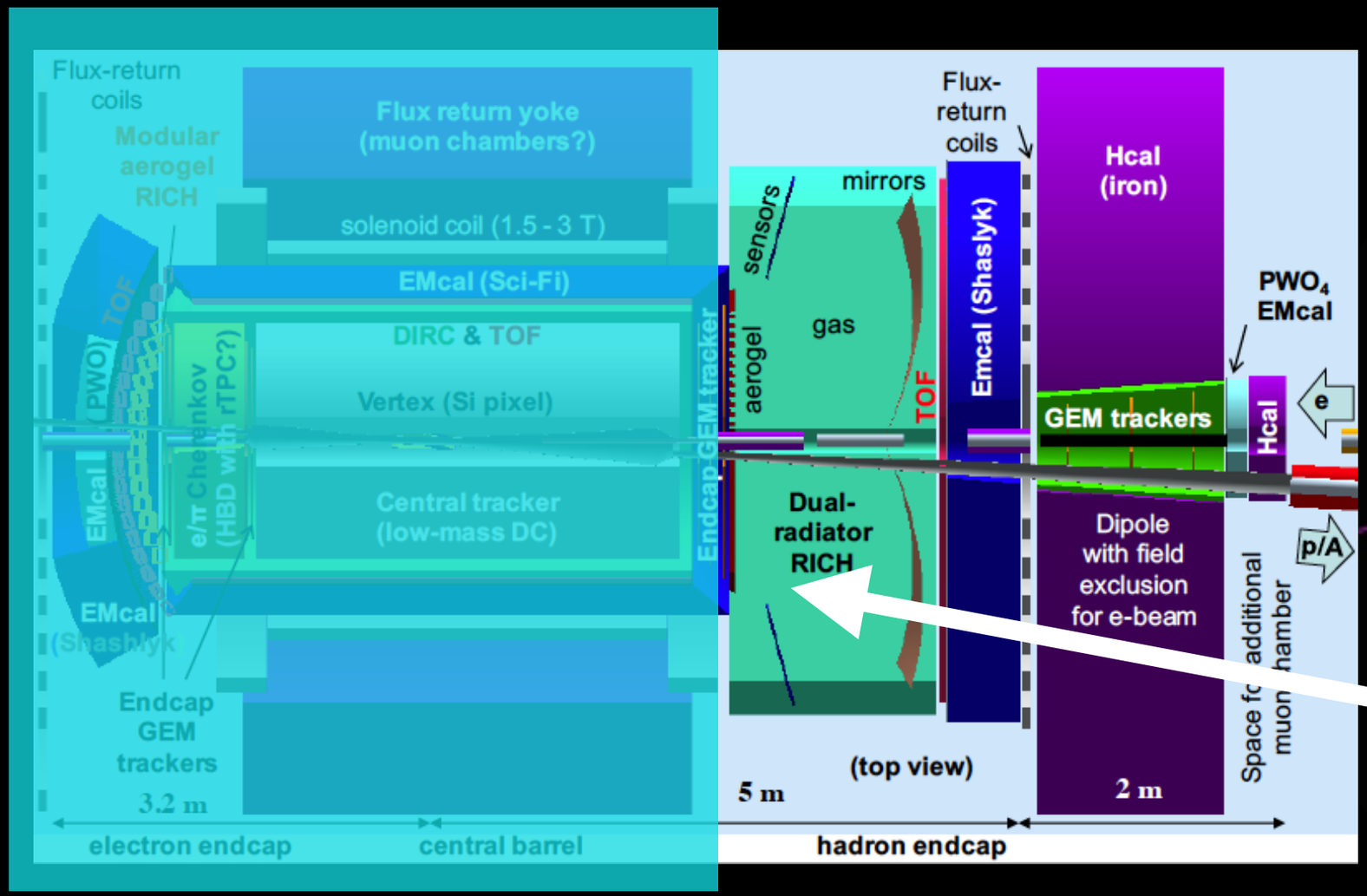




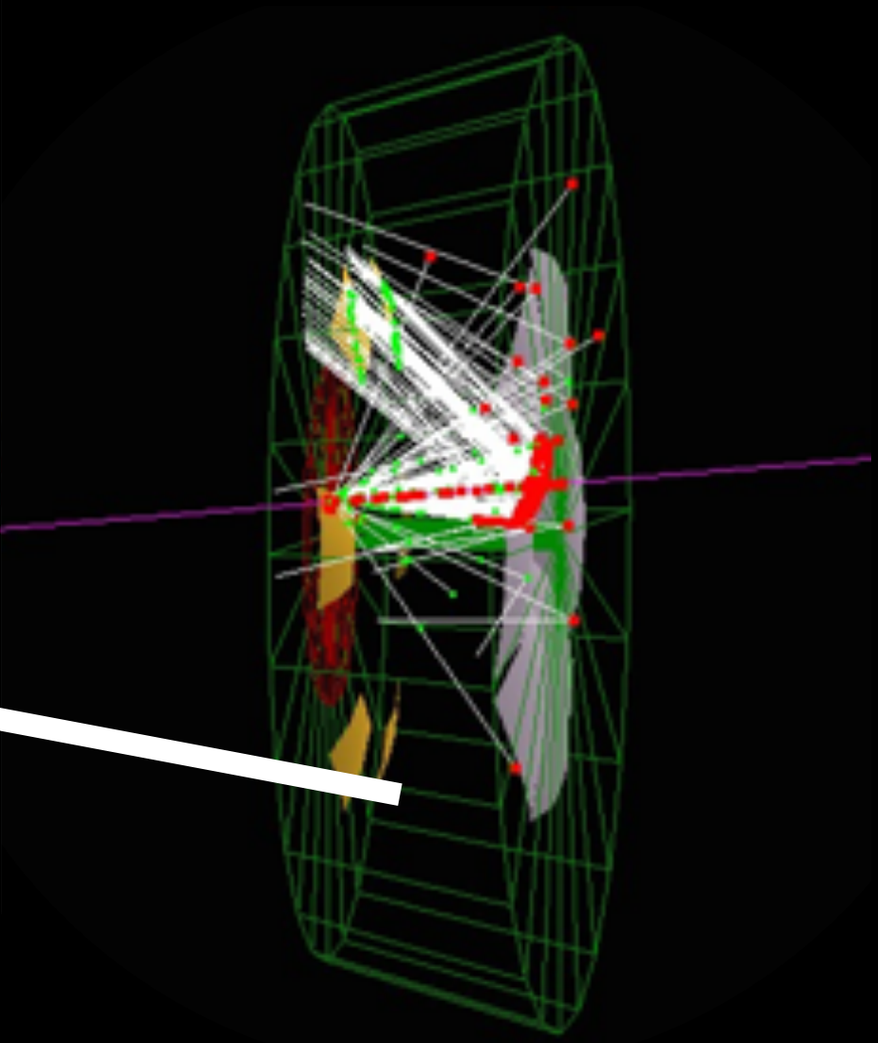
High Performance Detection of internally reflected Cherenkov light (DIRC) Detector

k/pi separation up to 6 GeV/c
e/pi separation up to 1.7 GeV/c

PID in Hadron-Going Region



Dual RICH

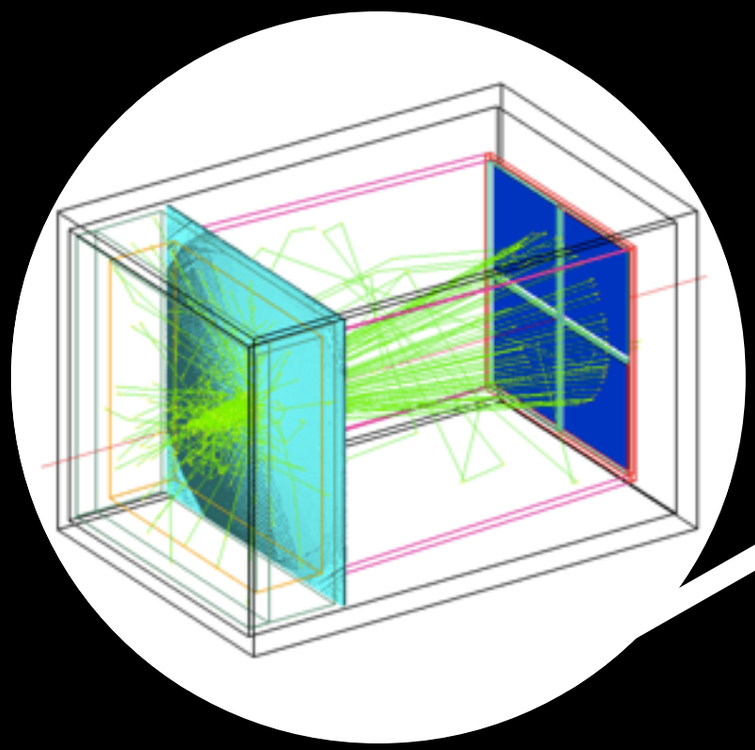


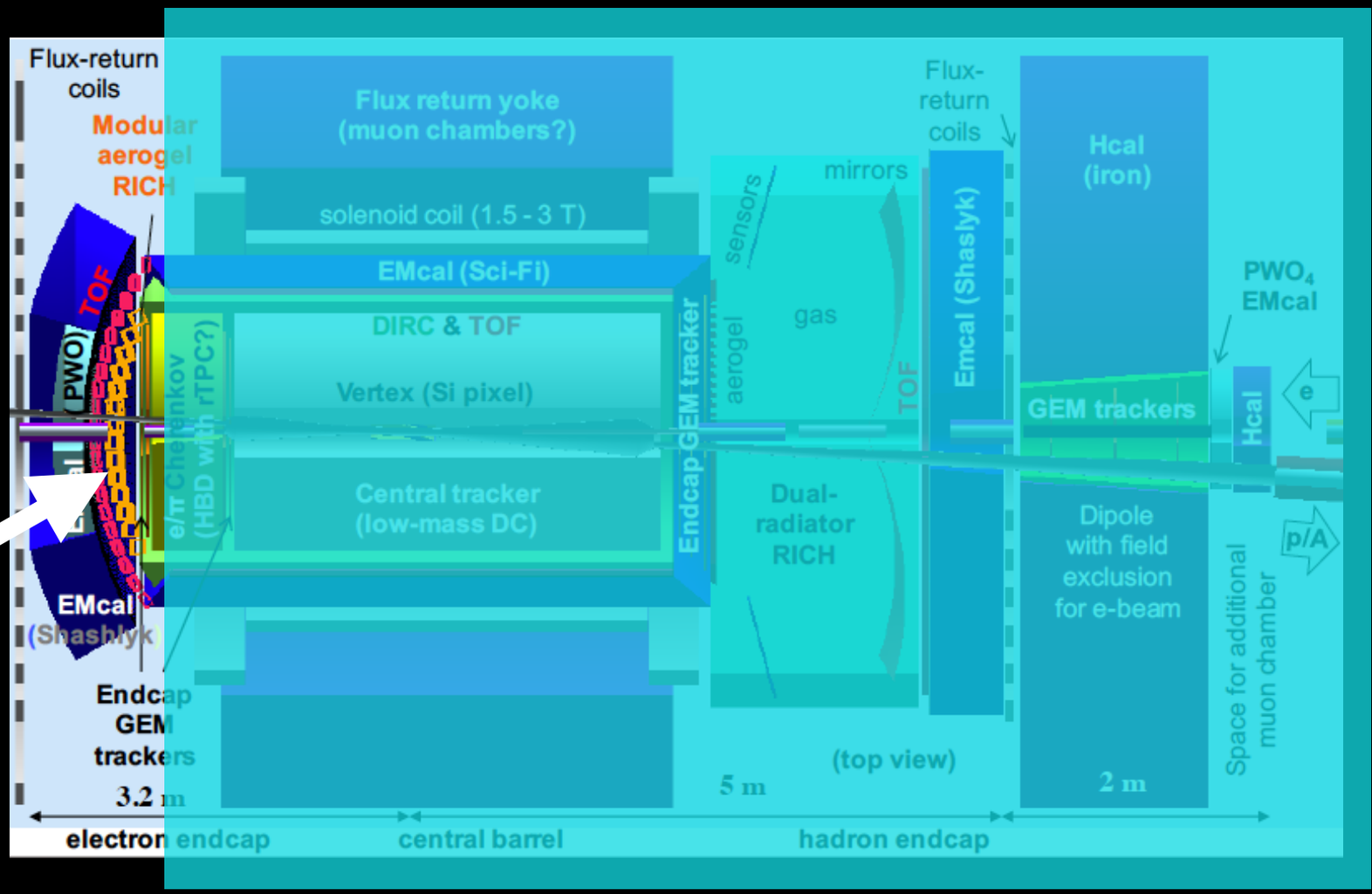
k/pi/p separation up to 50 GeV/c

Dual Radiator RICH (dRICH) Detector

PID in e-Going Region

mRICH



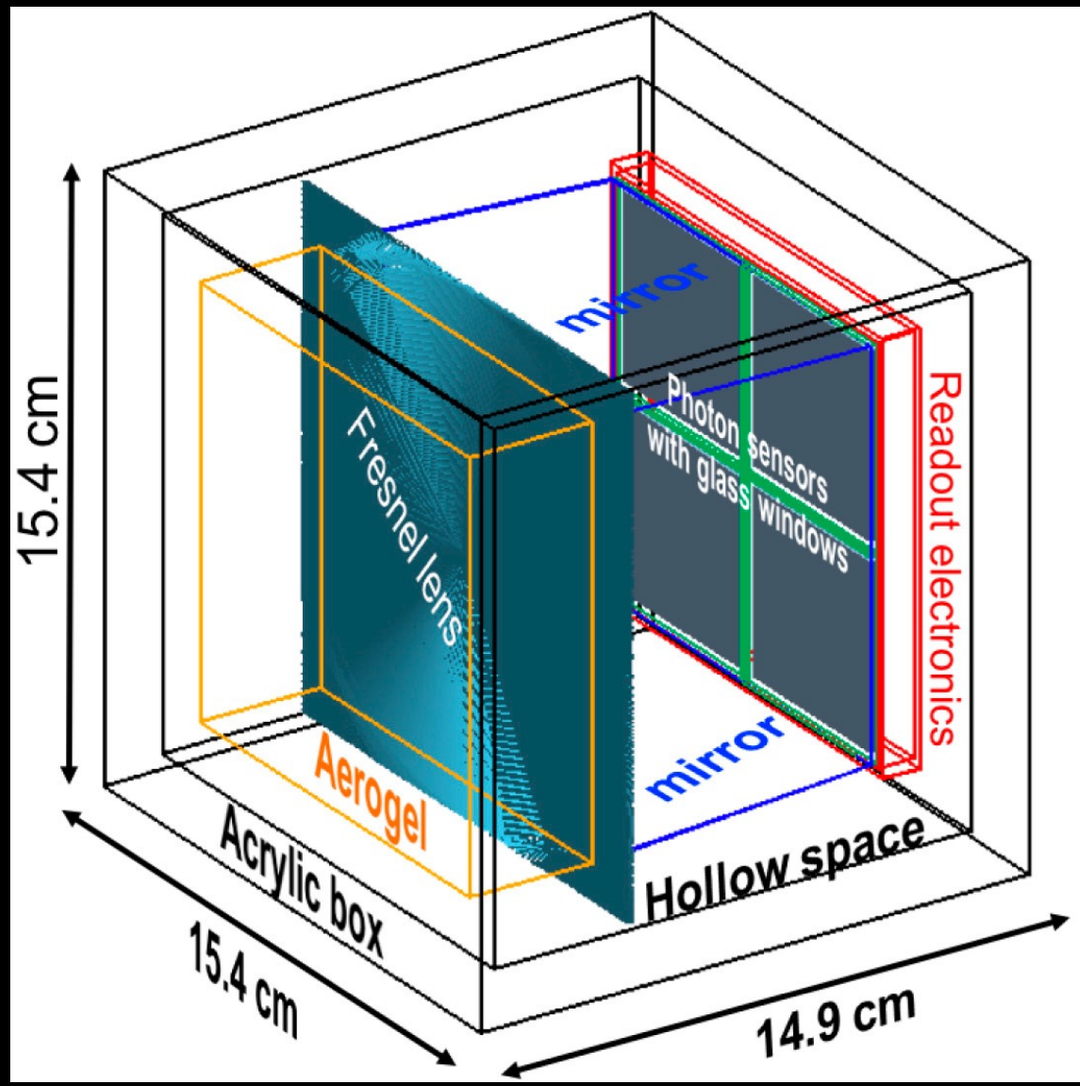


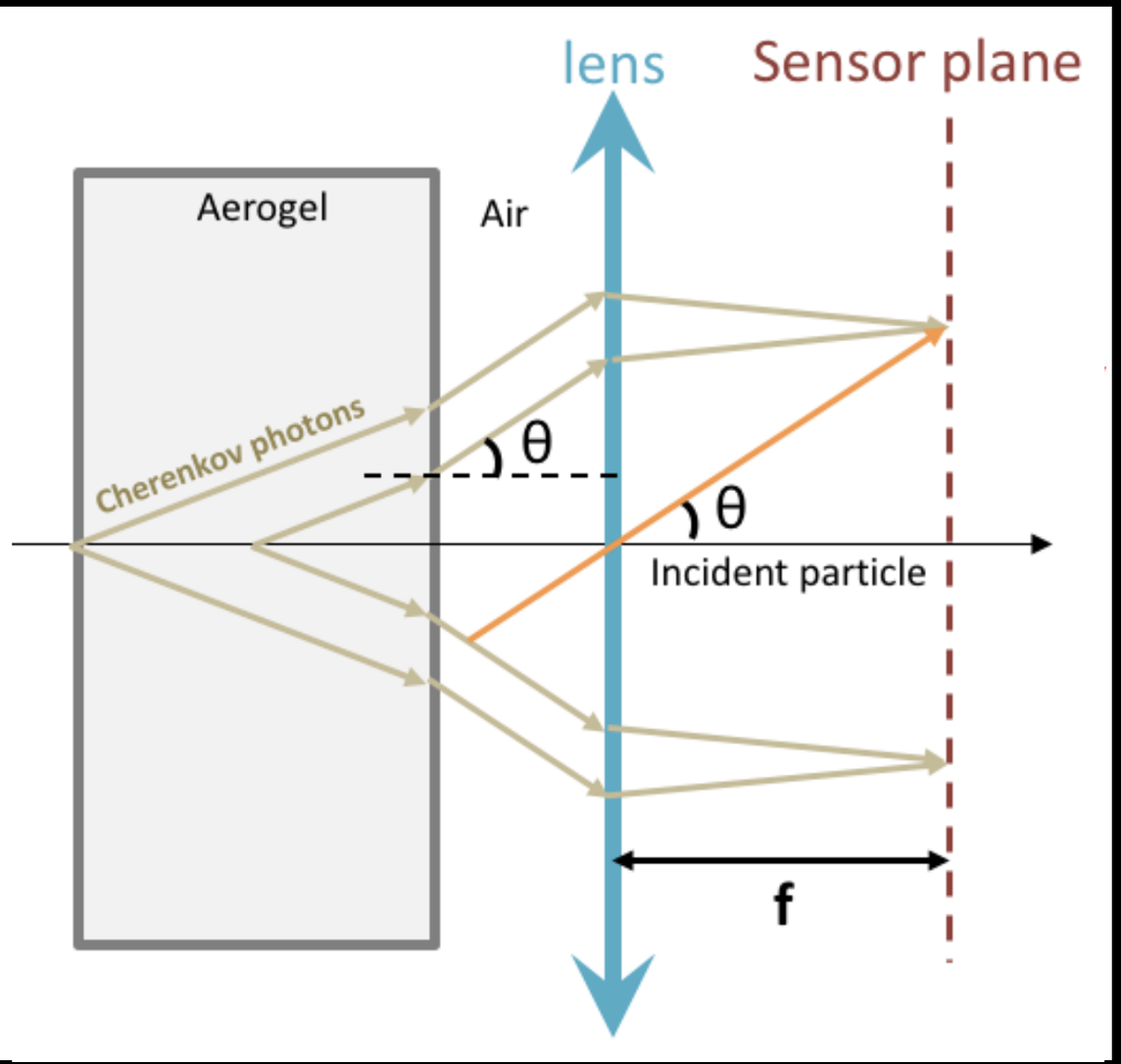
Modular RICH (mRICH)

k/pi separation up to 10 GeV/c
e/pi separation up to 1.7 GeV/c

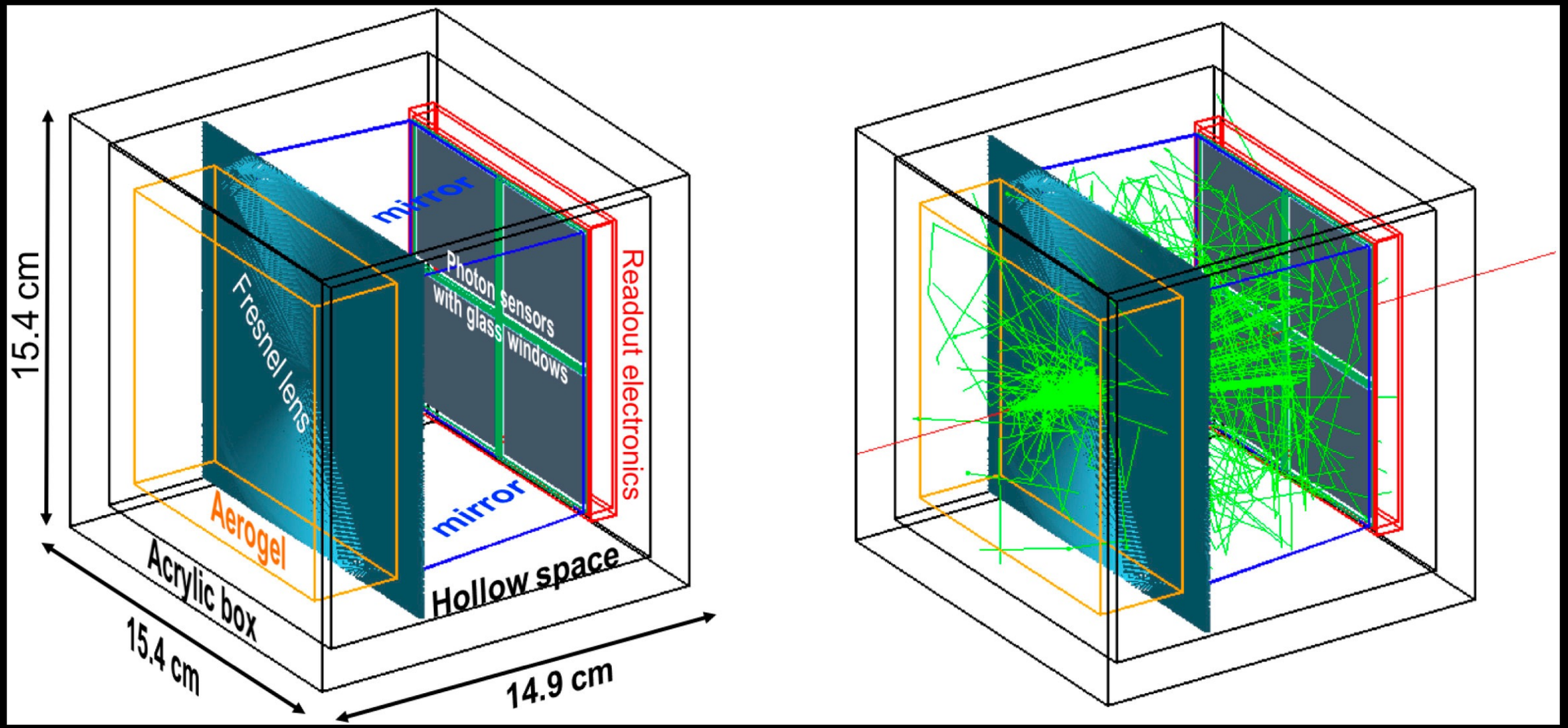
Modular RICH (mRICH) Detector Development

mRICH Design Concept





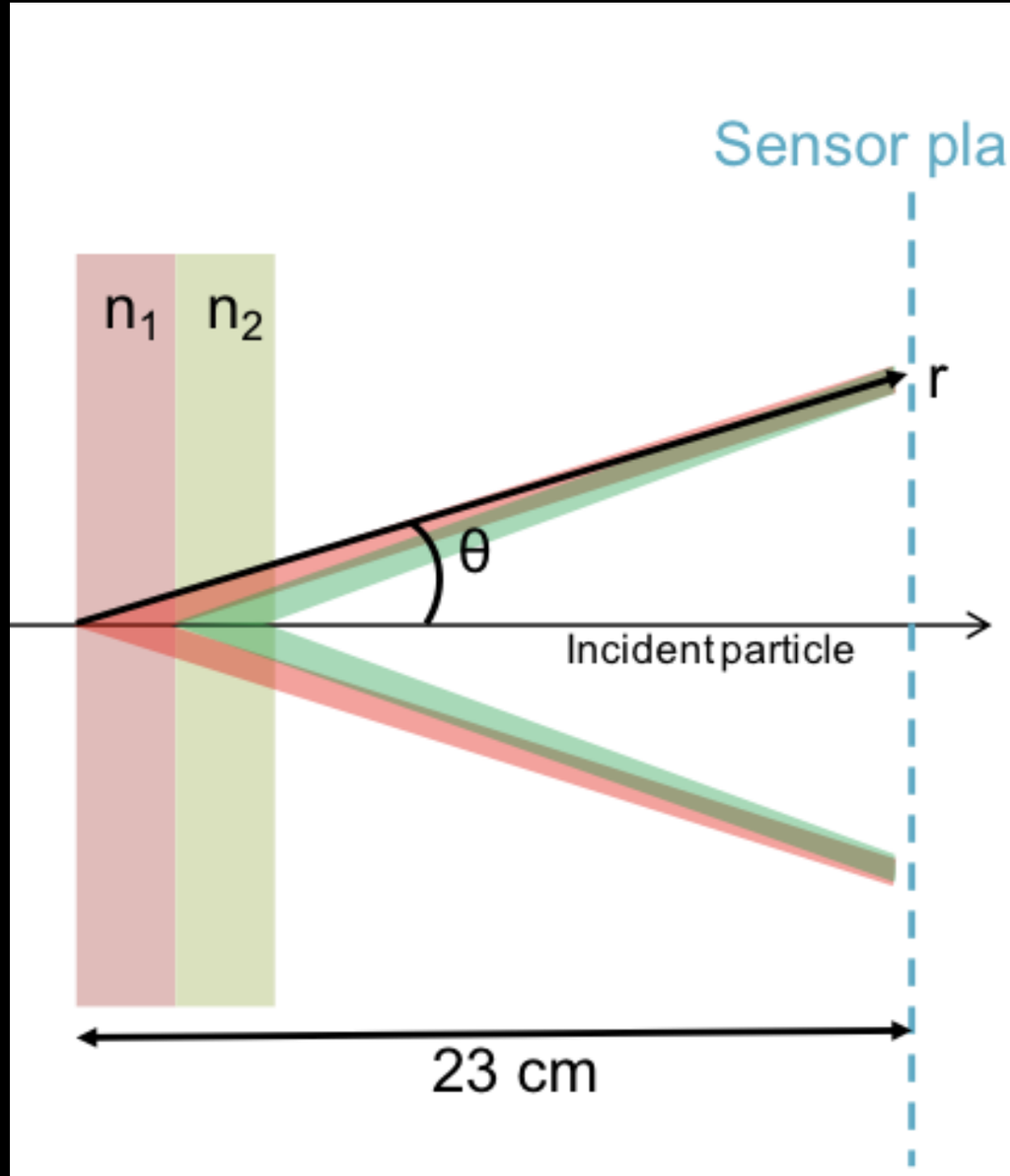
mRICH Design Concept

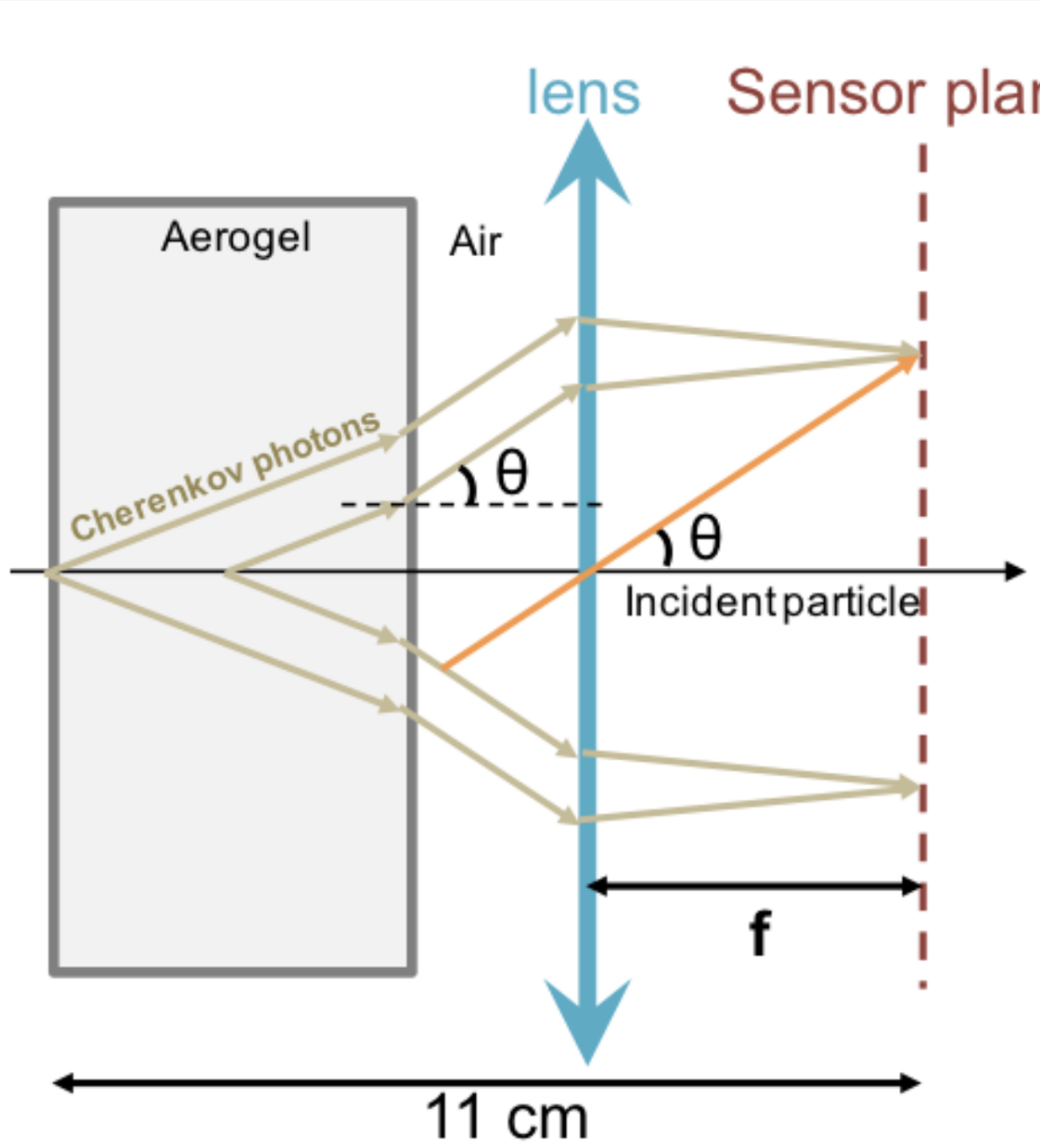


Working Principle - Focusing

Proximity RICH

mRICH





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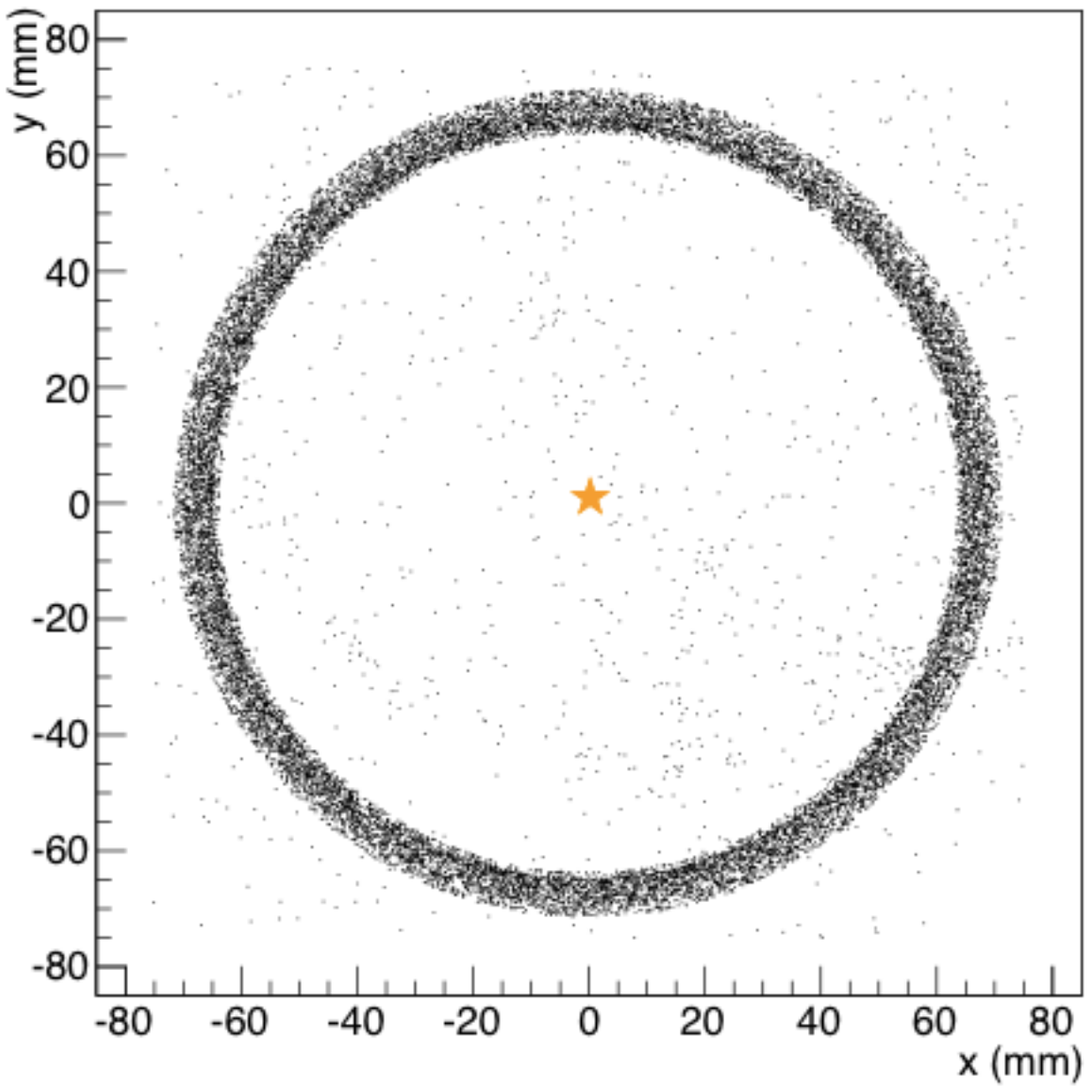
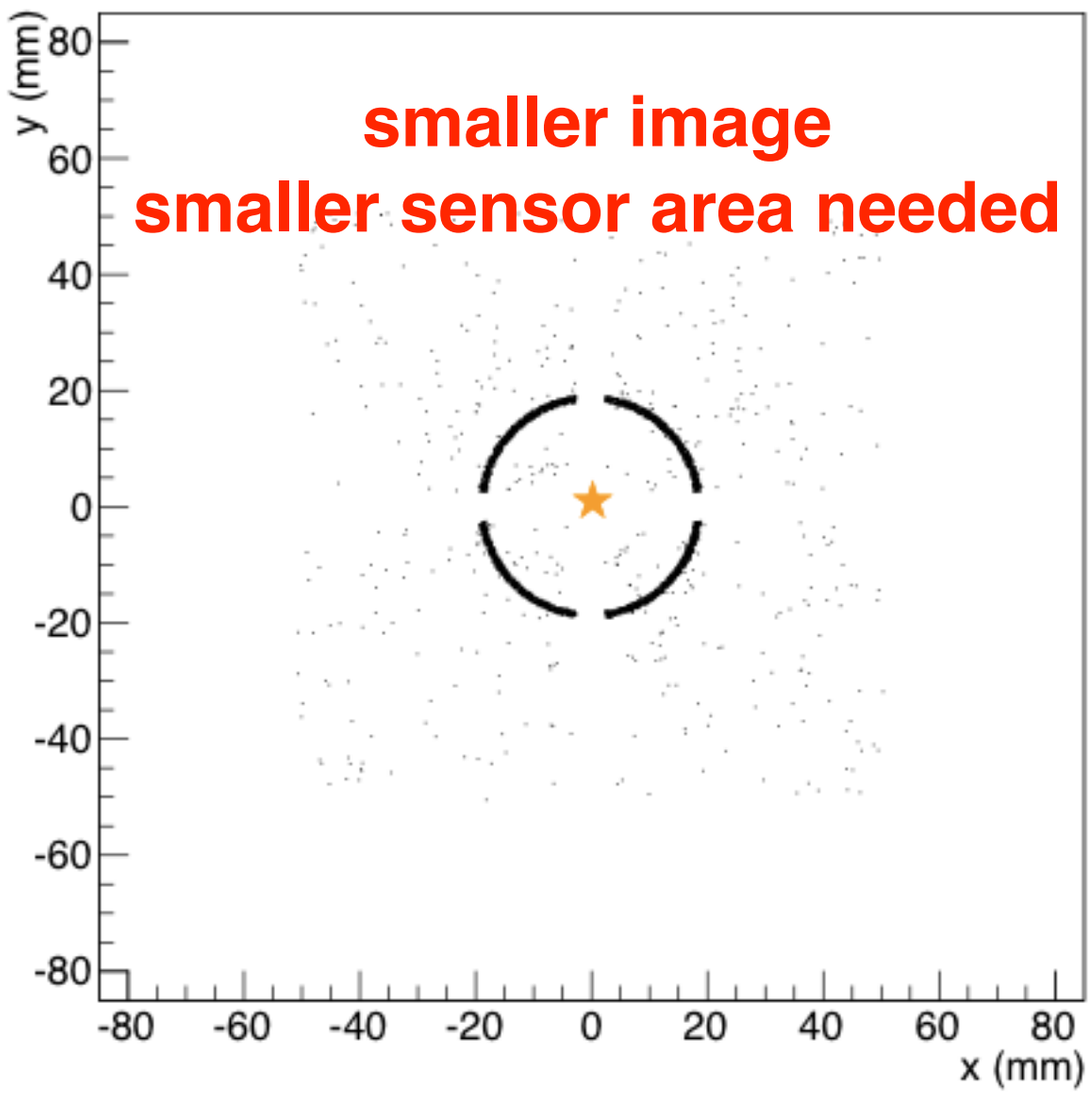


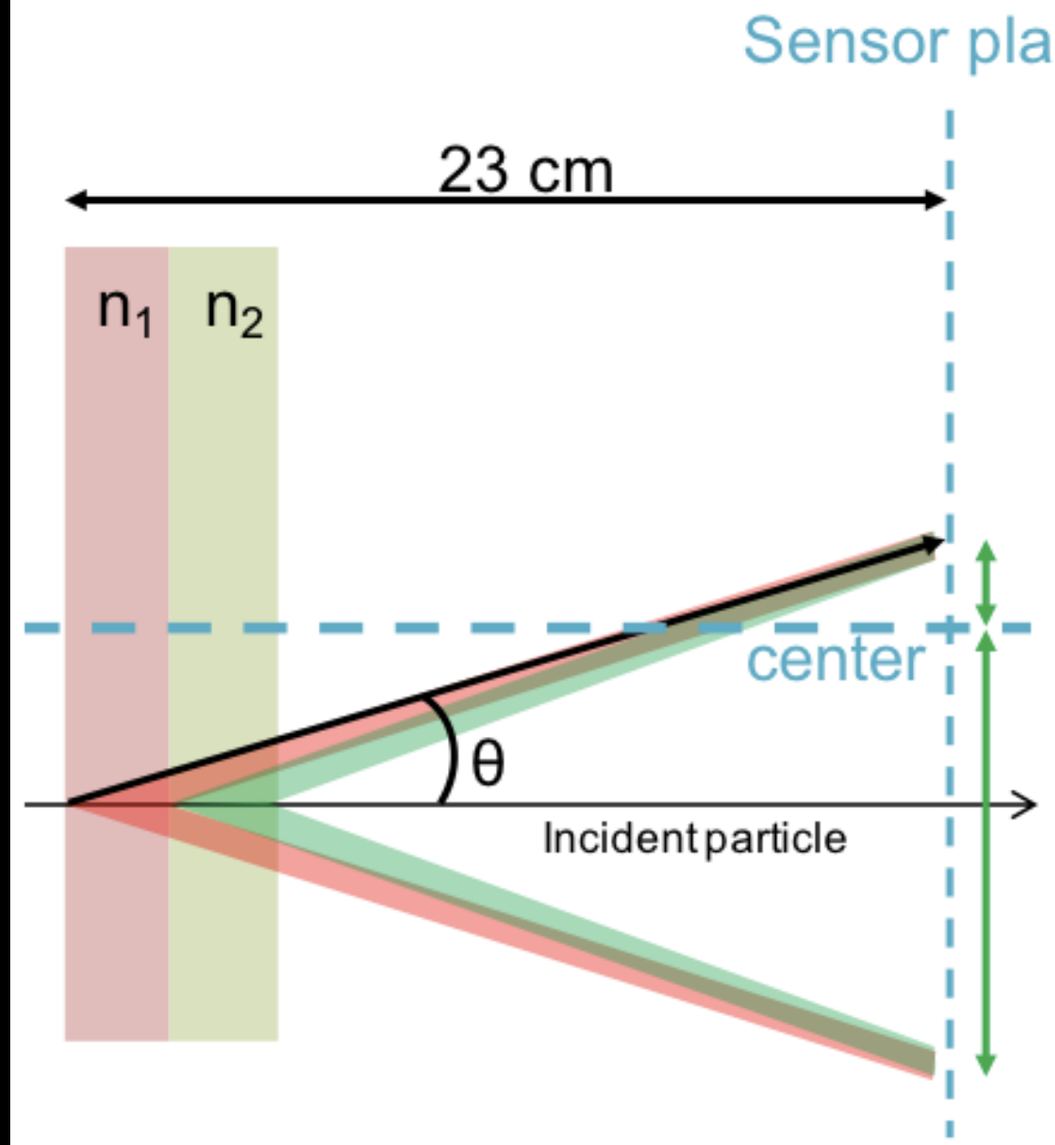
mRICH

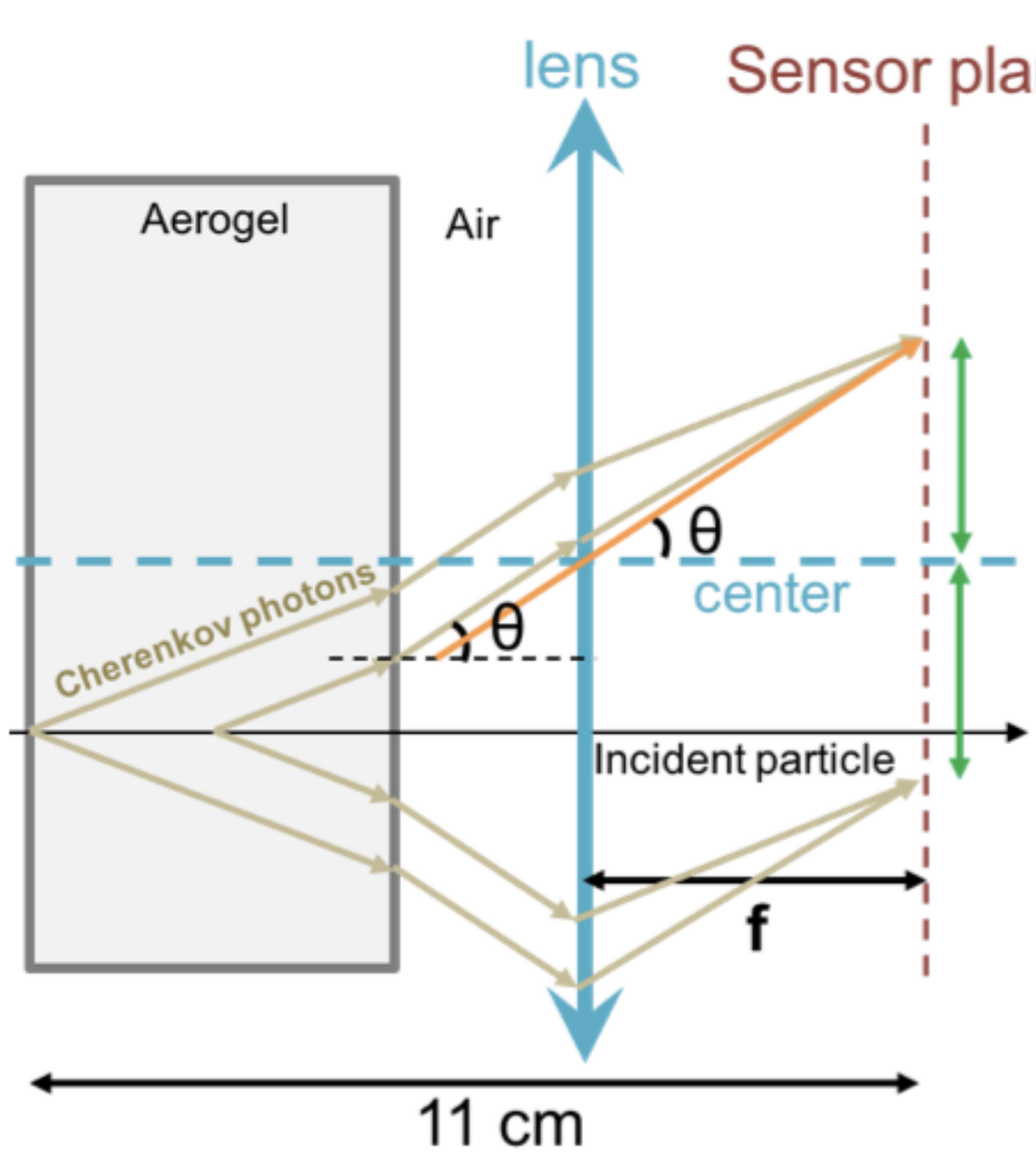


Working Principle - Centering

Proximity RICH

mRICH





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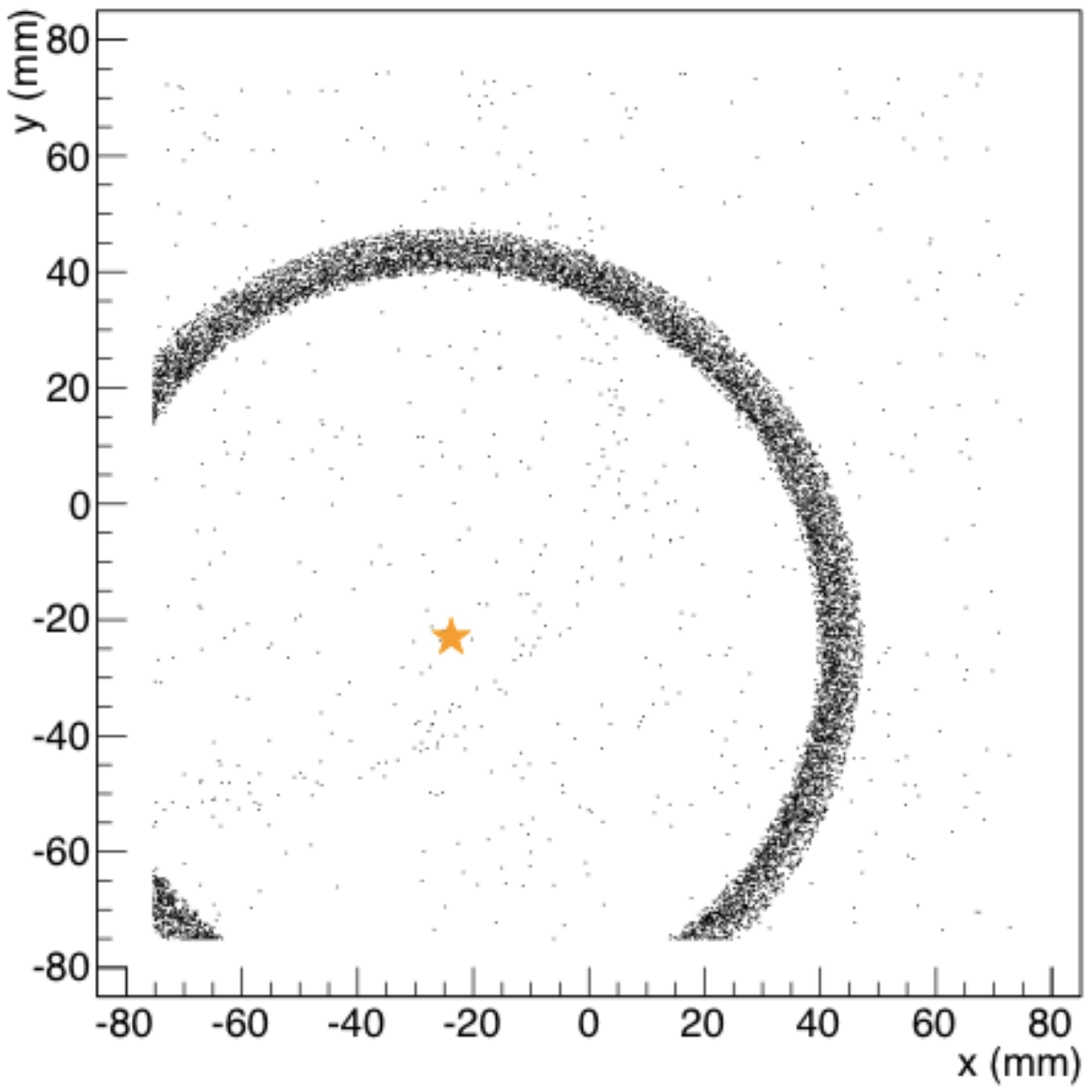
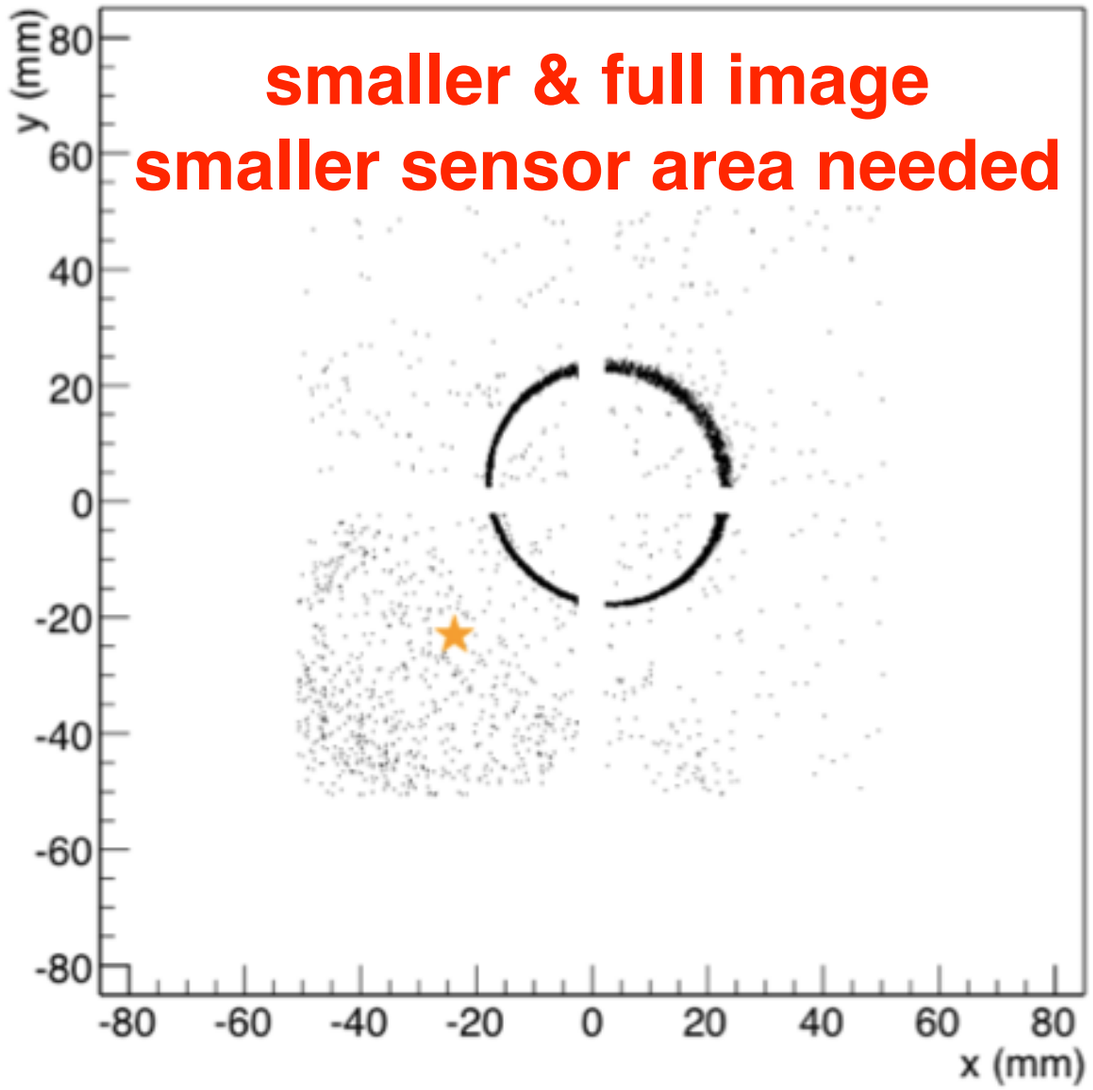


mRICH



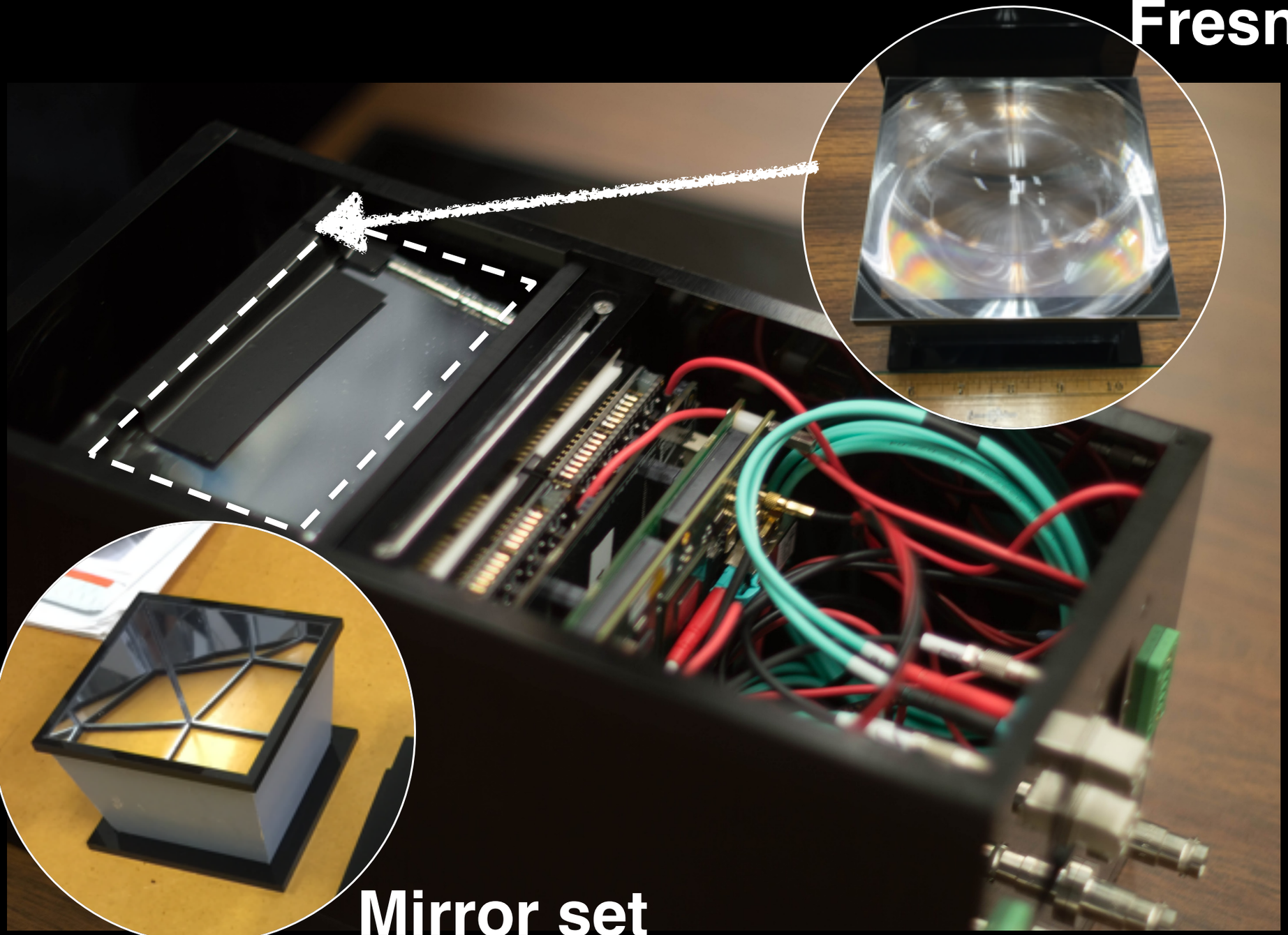
Beam Test of the 1st Prototype at Fermilab

1st mRICH Prototype

1st mRICH Prototype

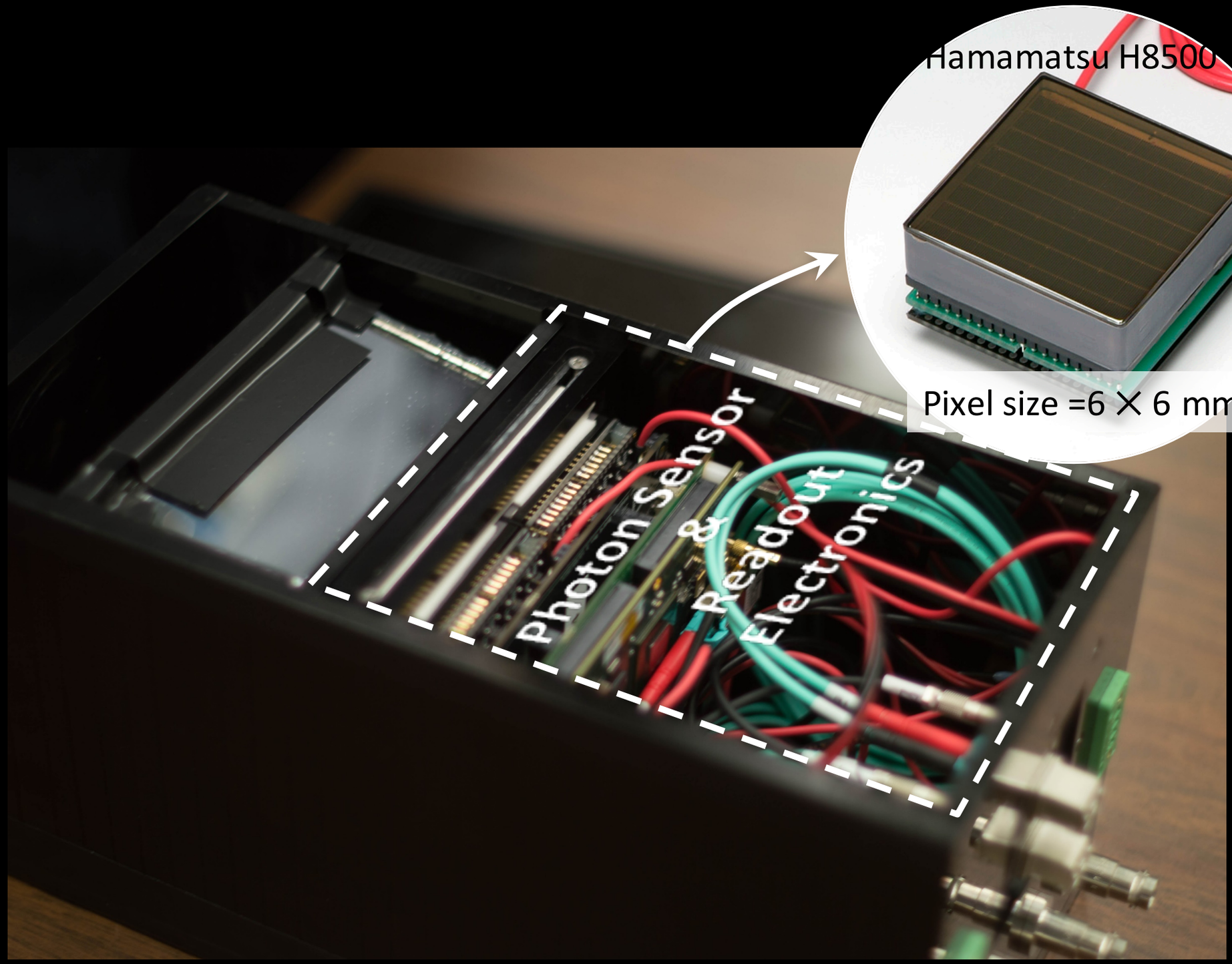
First mRICH Prototype

Fresnel lens

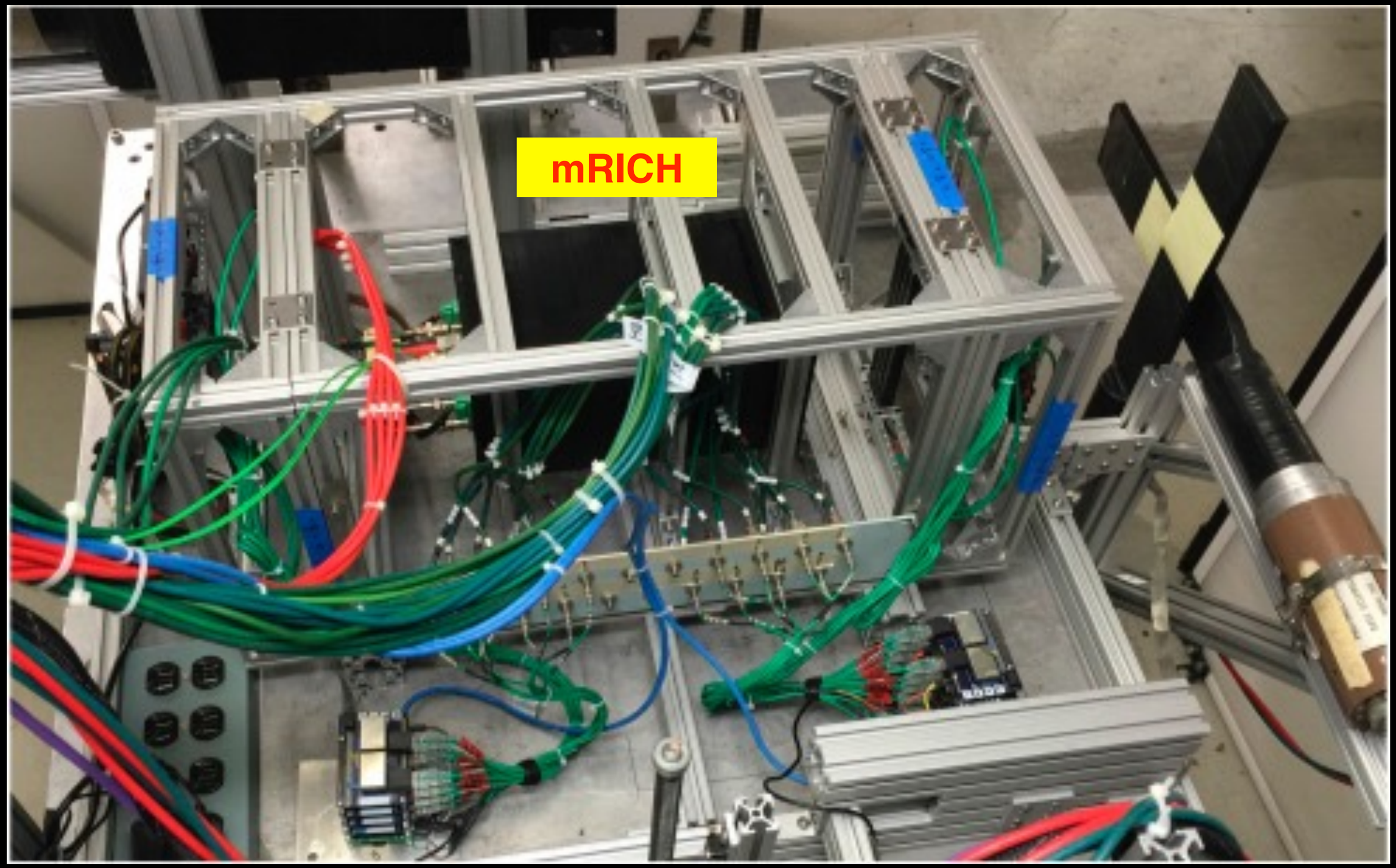


Mirror set

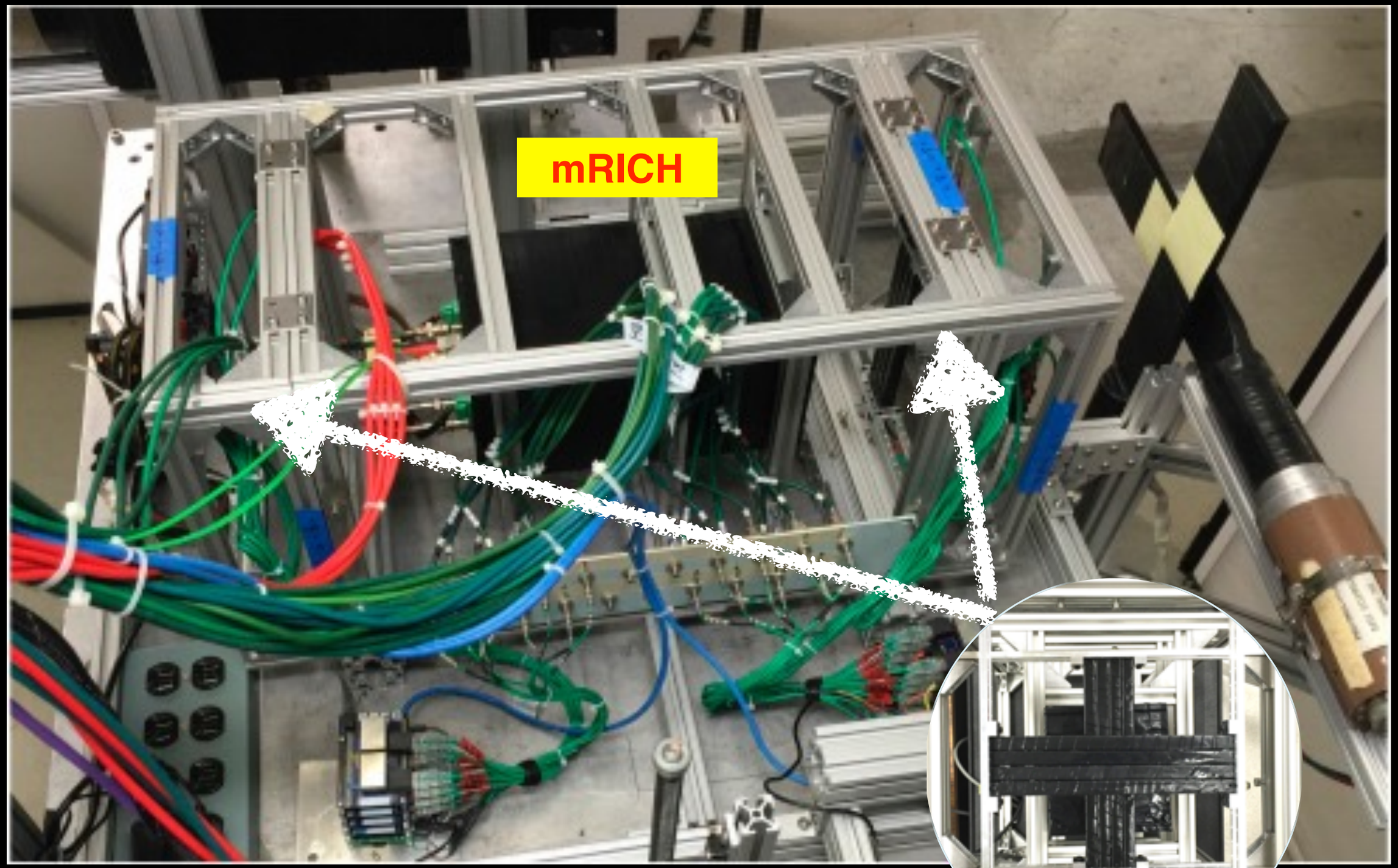
1st mRICH Prototype



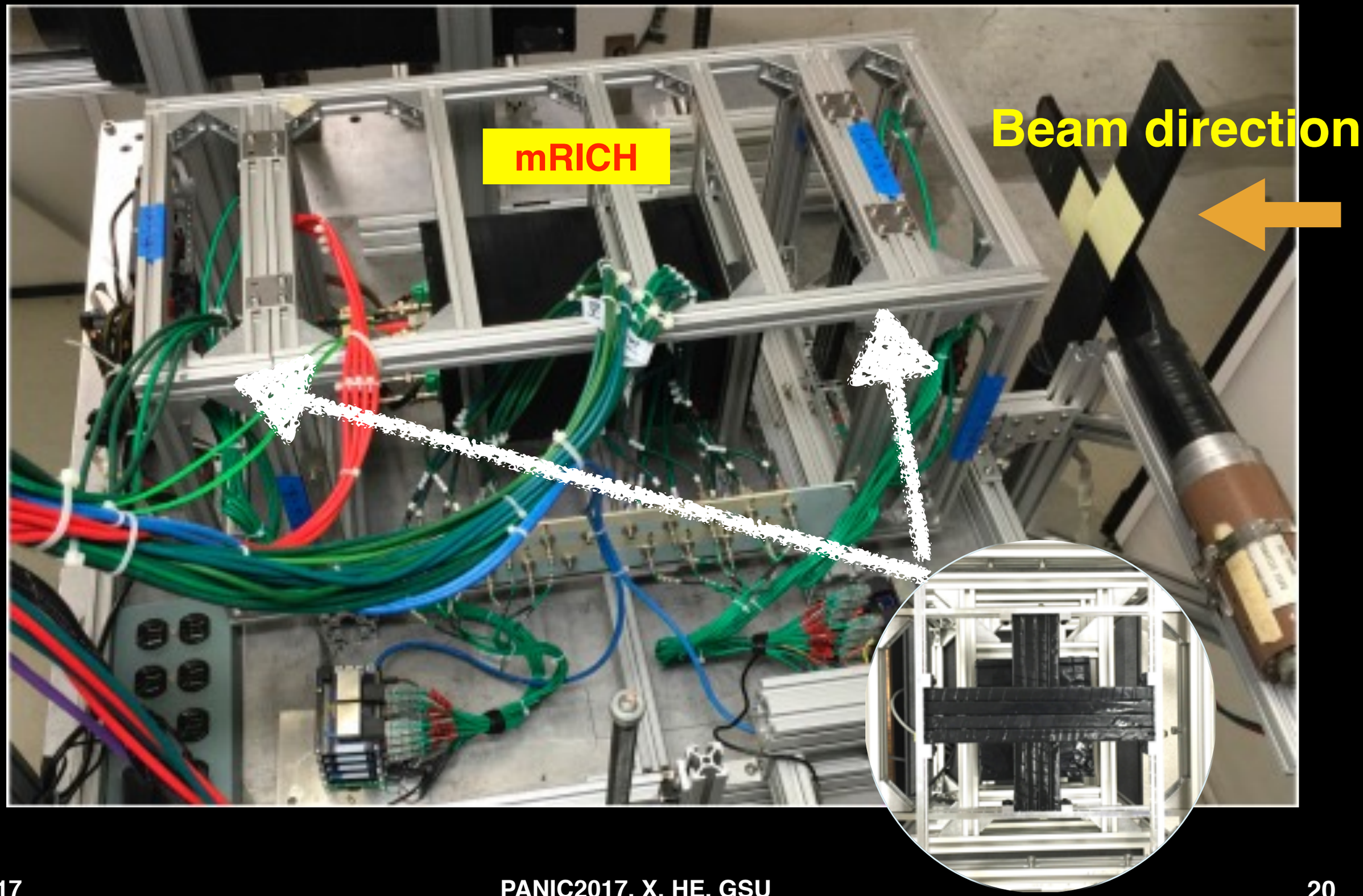
Beam Test Setup at Fermilab



Beam Test Setup at Fermilab



Beam Test Setup at Fermilab



Beam Test Setup at Fermilab

Test Beam Selection

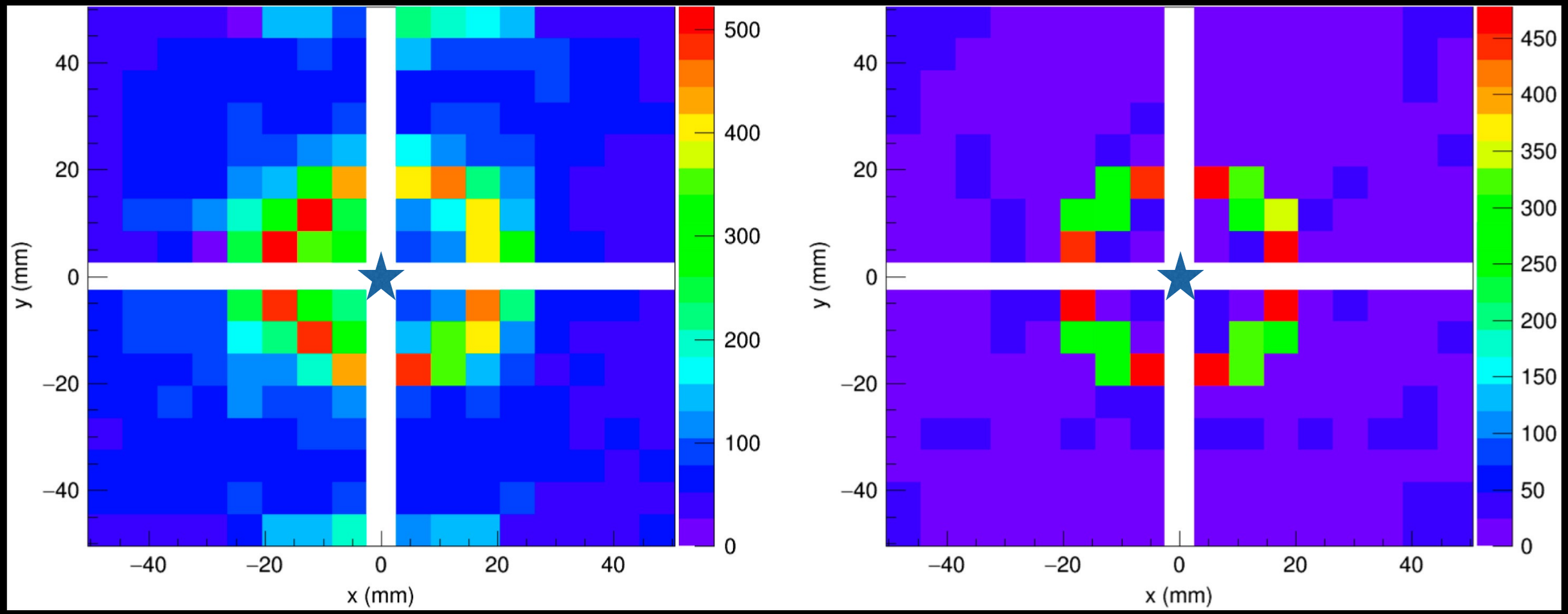
	120 GeV Proton	8 GeV pion	4 GeV pion
Full Setup with n=1.03 Aerogel	✓	✓	✓
Full Setup with n=1.02 Aerogel	✓		
Without Mirror	✓		

- Primary beam
- Small beam size → quick tool for detector alignment
- High momentum → saturated ring image, i.e. clearer ring image

Test the 1st Working Principle

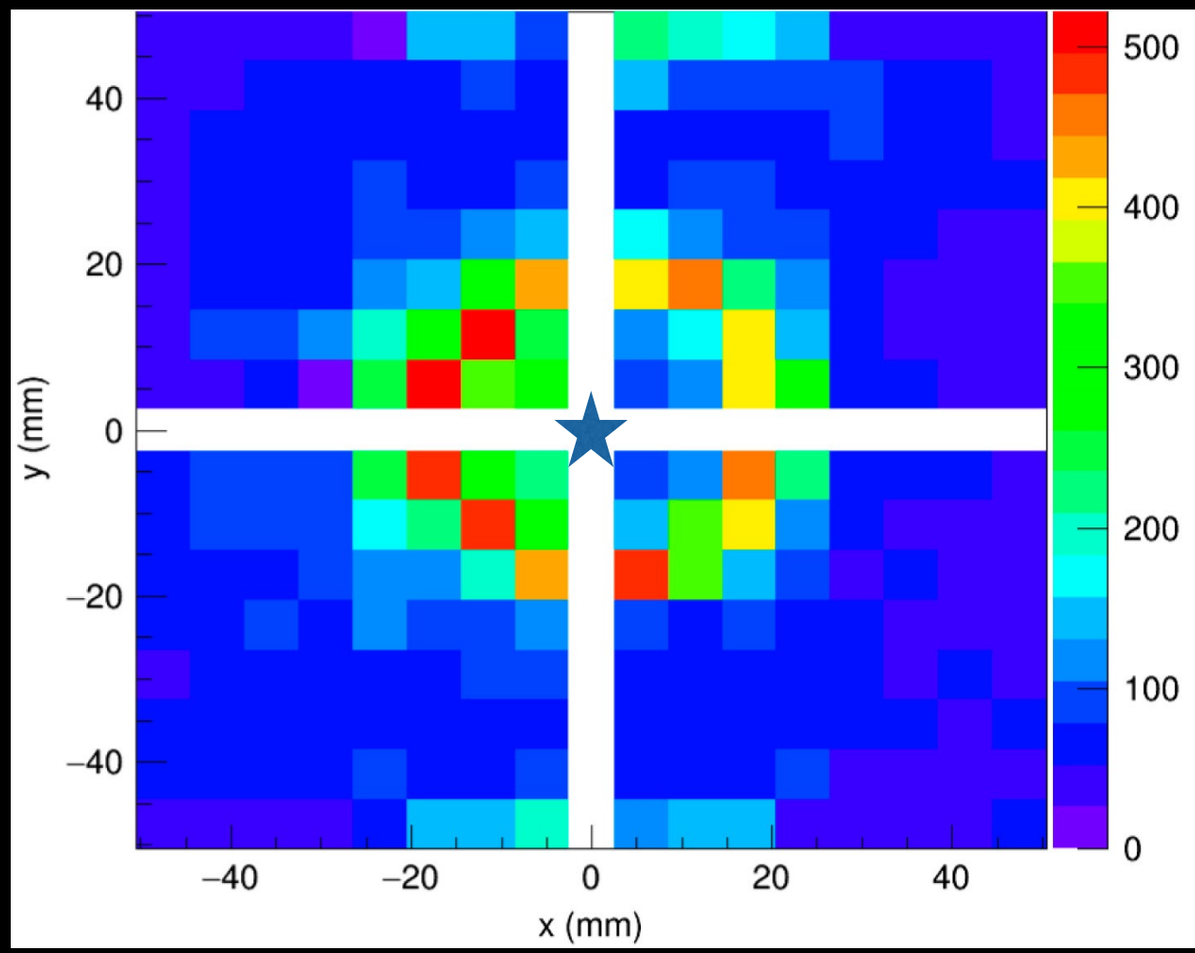
Test Beam

Geant4 Simulation

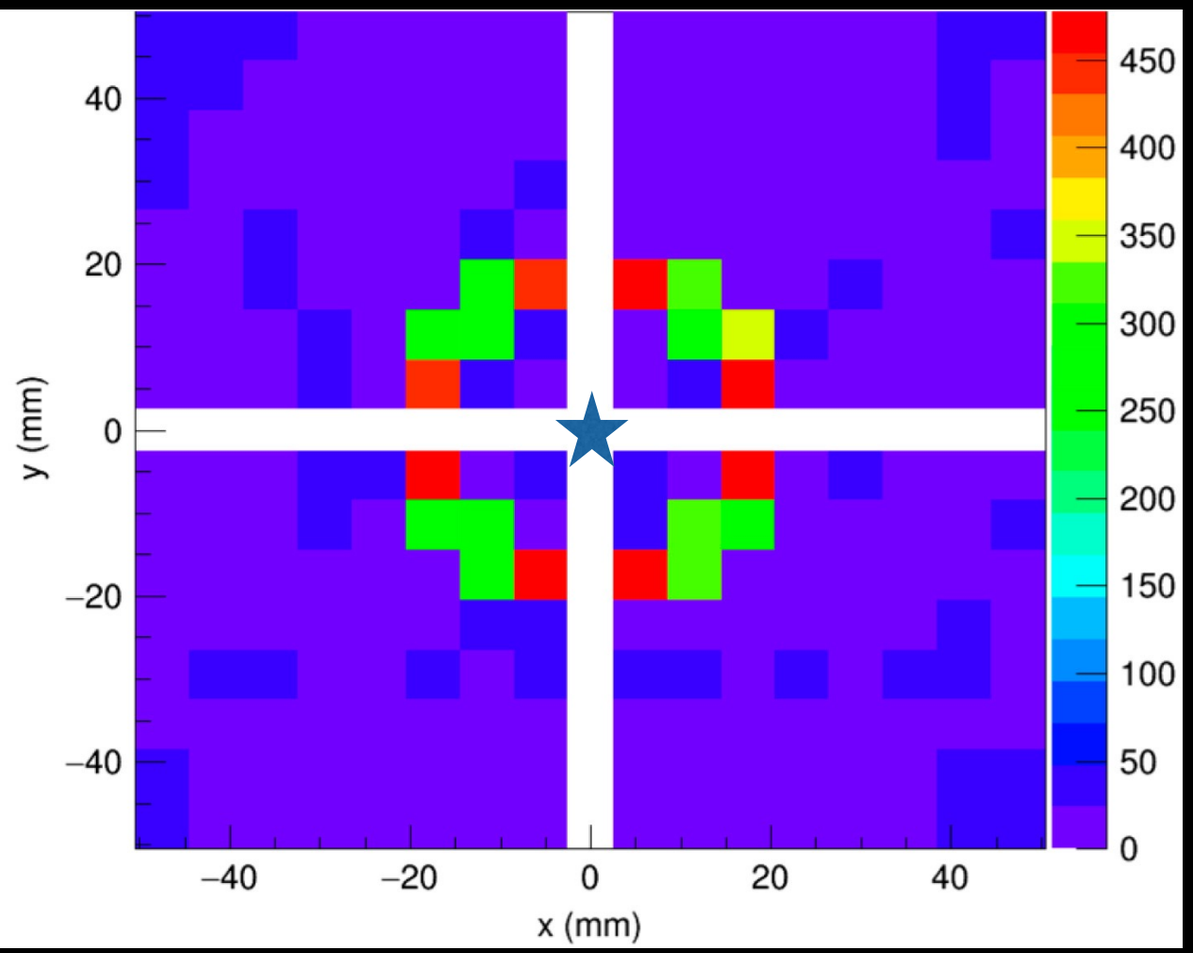


Test the 1st Working Principle

Test Beam



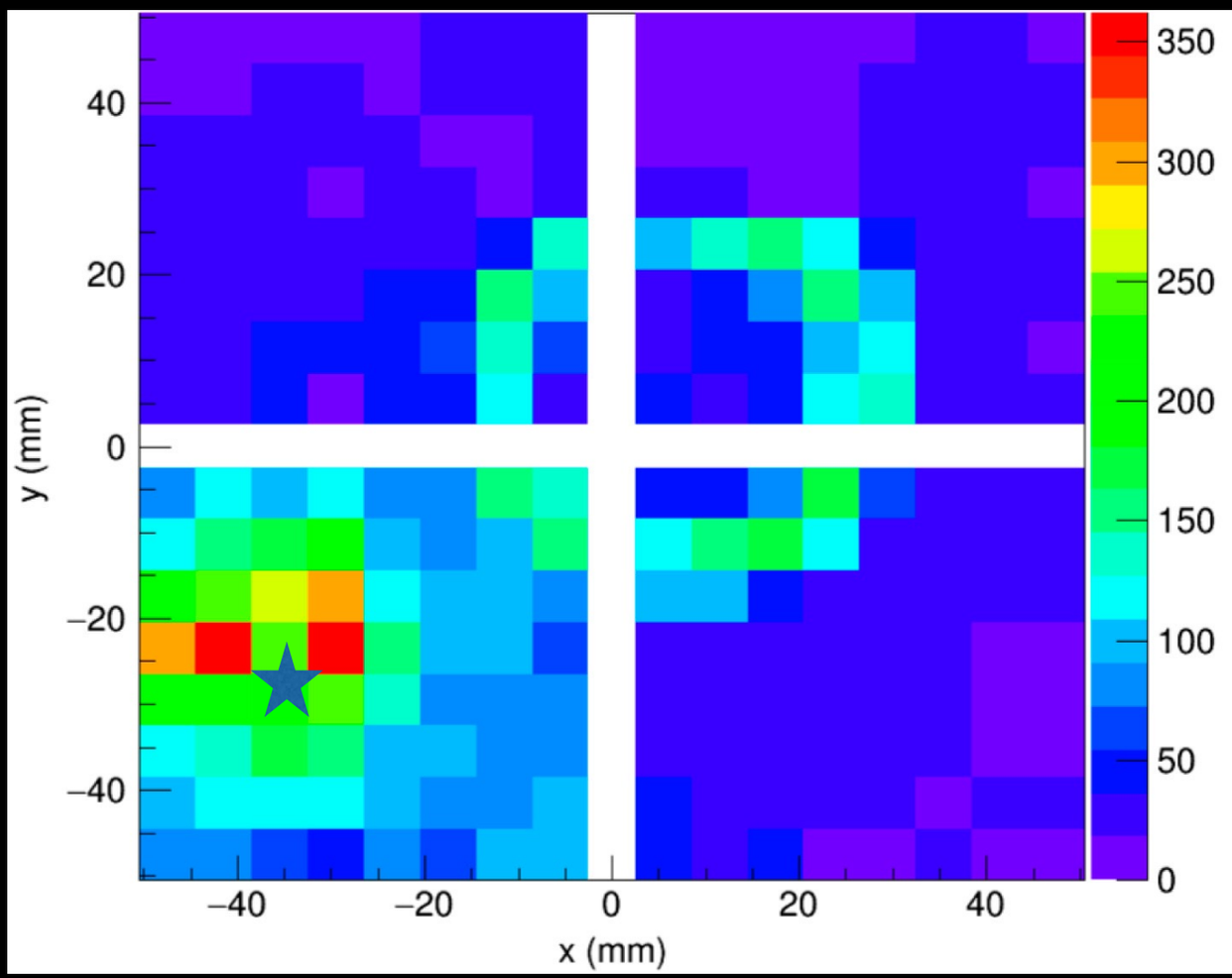
Geant4 Simulation



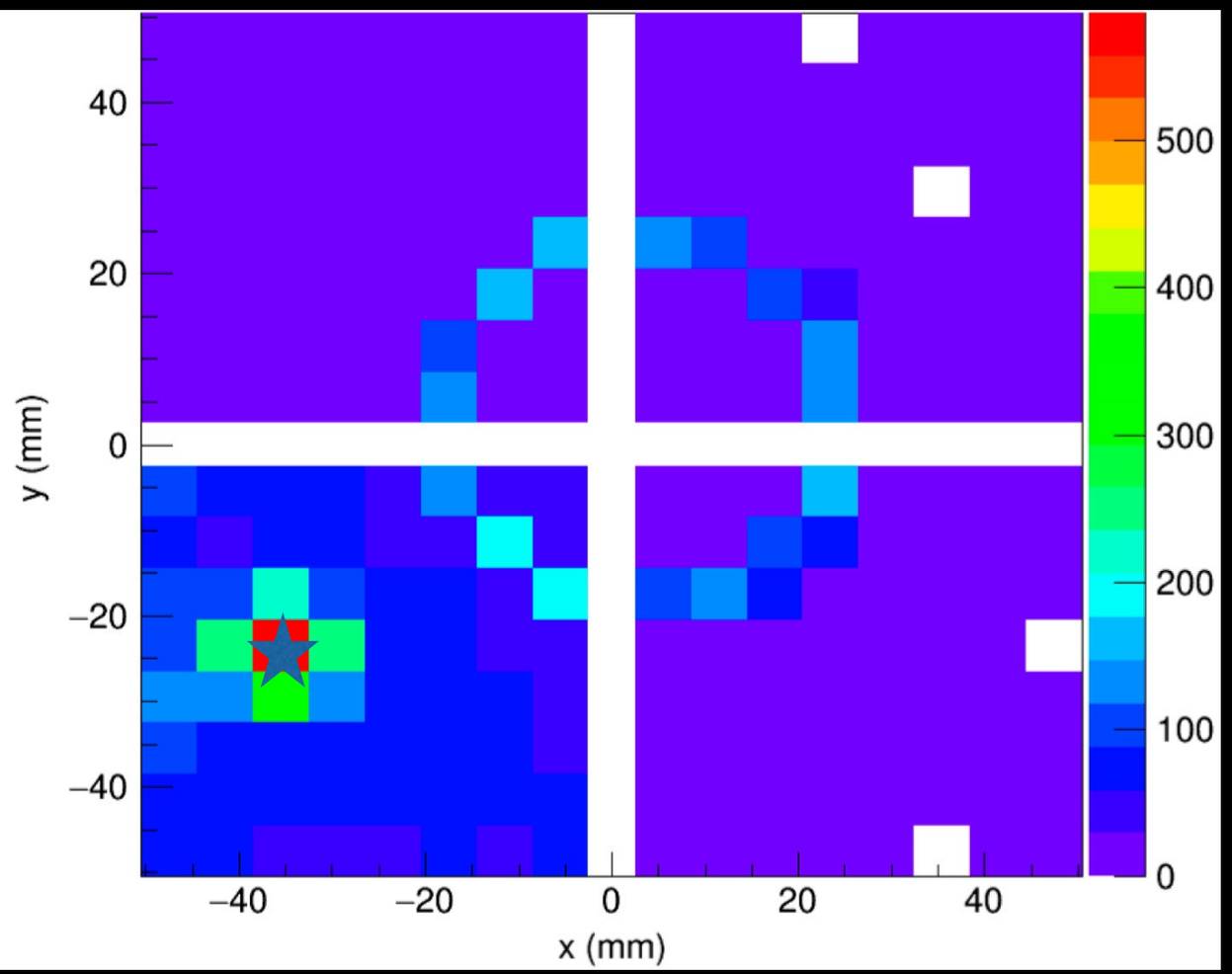
	Analytical Calculation	Test Beam Data	Simulation
Radius (mm)	19.4	19.0 ± 1.3	18.9 ± 1.0
Number of detected photons per event	10.4	11.0 ± 2.9	11.1 ± 2.9

Test the 2nd Working Principle

Test Beam



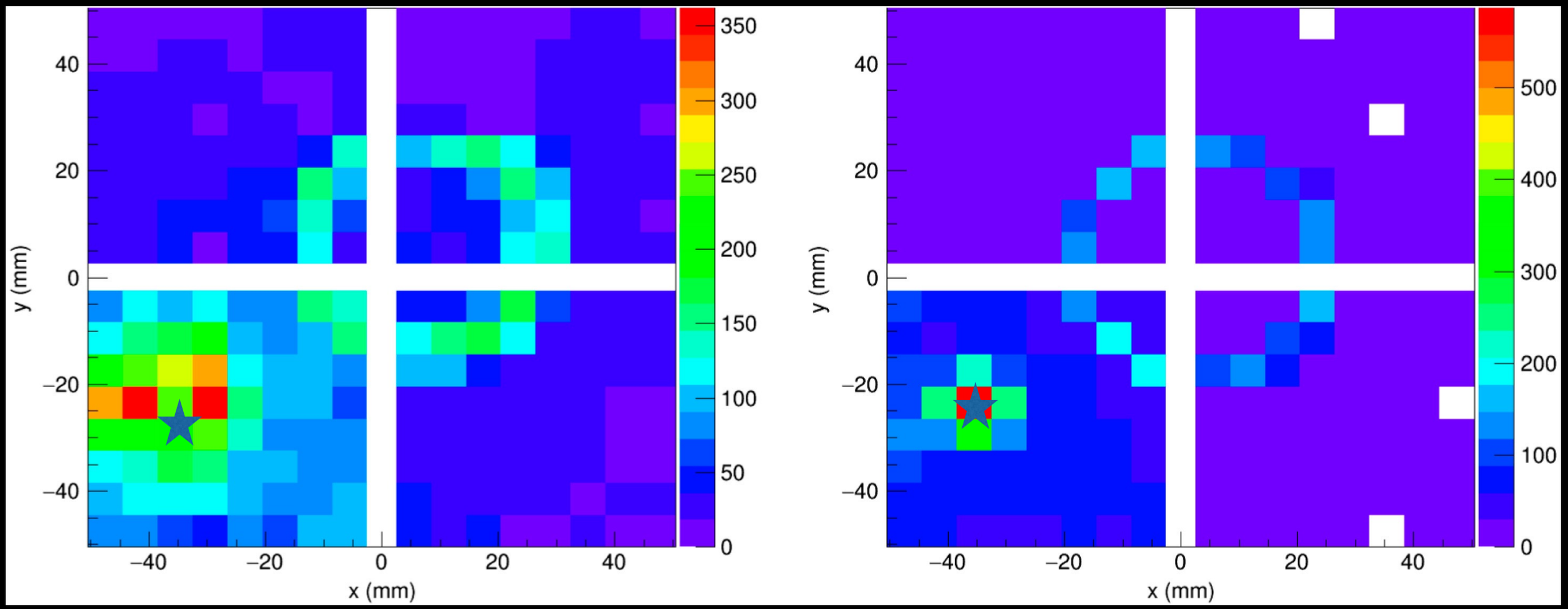
Geant4 Simulation



Test the 2nd Working Principle

Test Beam

Geant4 Simulation

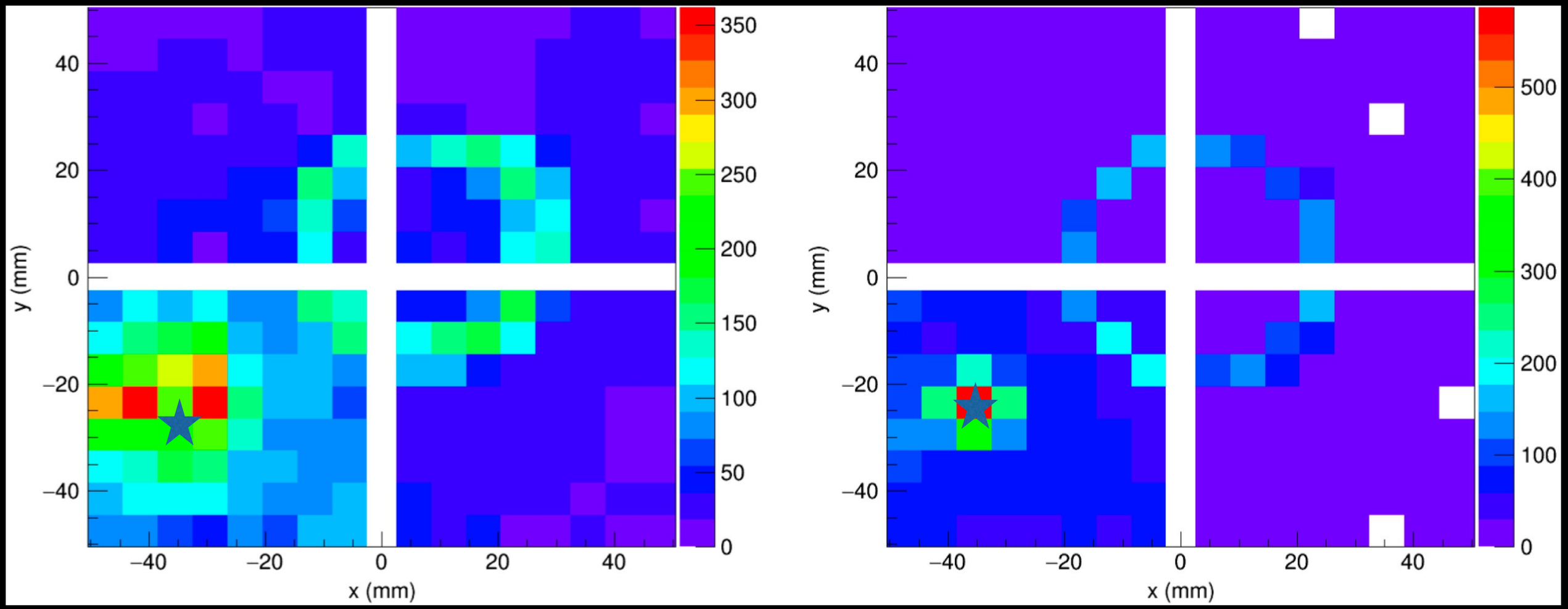


1. Beam incident in the lower quadrant

Test the 2nd Working Principle

Test Beam

Geant4 Simulation



1. Beam incident in the lower quadrant
2. Ring image from Cherenkov radiation is shifted toward central region on the sensor plane.

Test Beam Results Just Published

NIM A871 (2017) 13-19

Nuclear Inst. and Methods in Physics Research, A 871 (2017) 13–19

Contents lists available at ScienceDirect

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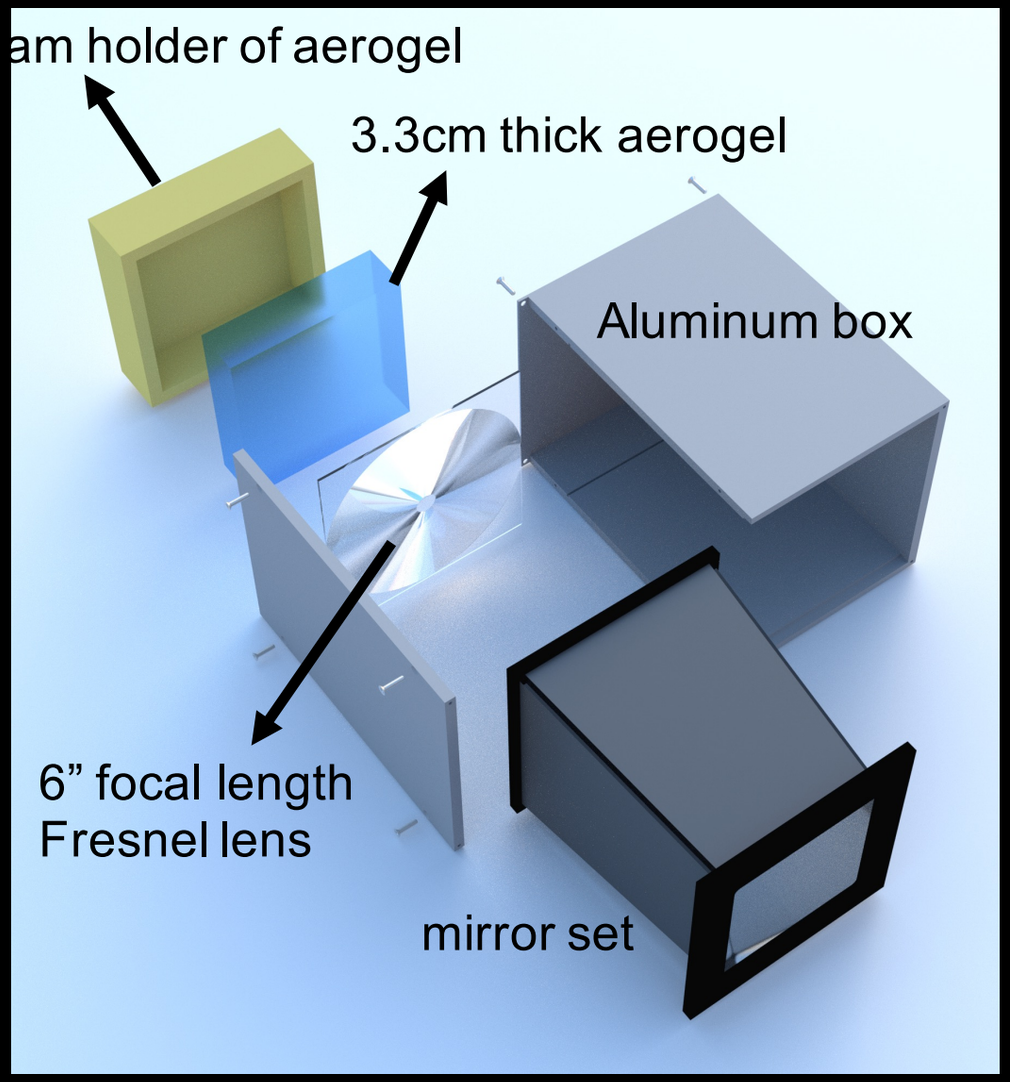
journal homepage: www.elsevier.com/locate/nima

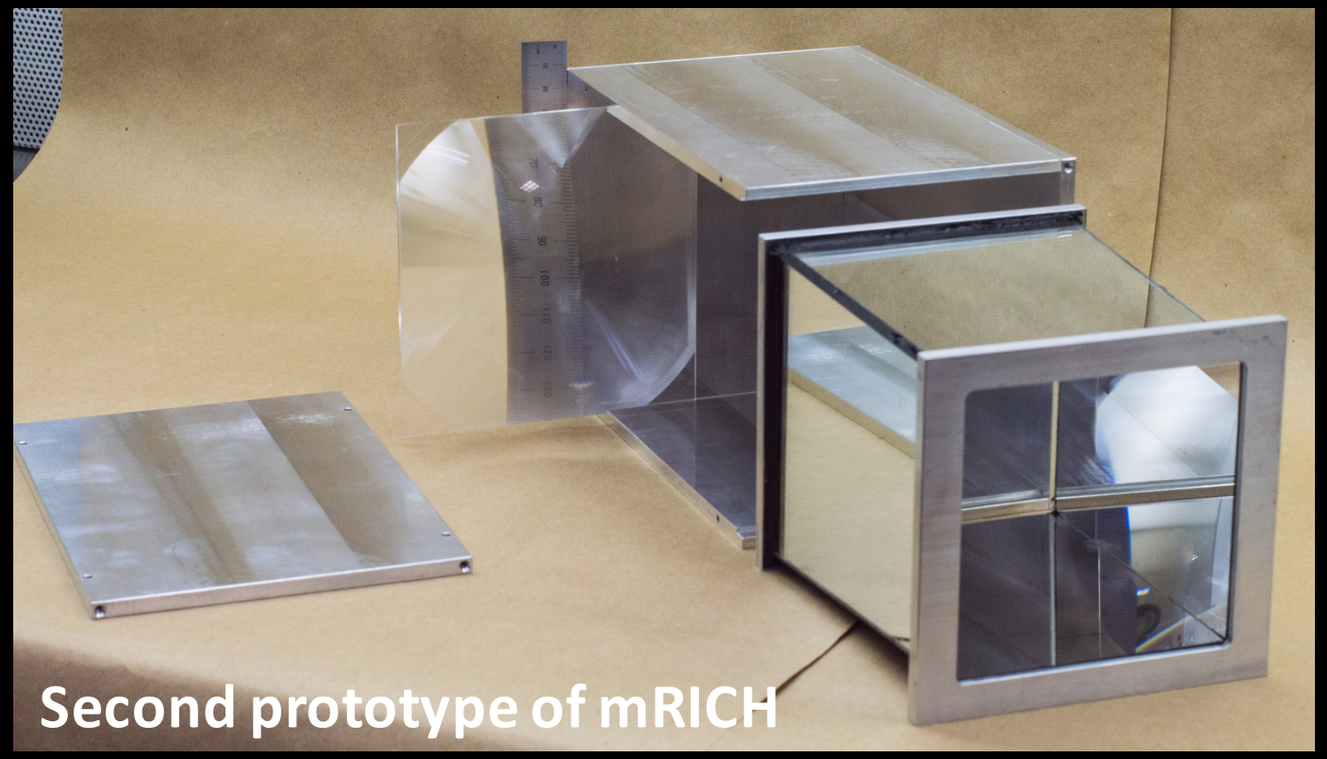
Modular focusing ring imaging Cherenkov detector for electron–ion collider experiments☆

C.P. Wong [g,*], M. Alfred [i], L. Allison [o], M. Awadi [i], B. Azmoun [c], F. Barbosa [m], L. Barion [j,r], J. Bennett [g], W. Brooks [q], C. Butler [g], T. Cao [h], M. Chiu [c], E. Cisbani [k,l], M. Contalbrigo [j], A. Datta [t], A. Del Dotto [k,u], M. Demarteau [b], J.M. Durham [n], R. Dzhygadlo [h], T. Elder [g], D. Fields [t], Y. Furletova [m], C. Gleason [u], M. Grosse-Perdekamp [s], J. Harris [f], T.O.S. Haseler [g], X. He [g], H. van Hecke [n], T. Horn [d], A. Hruschka [g], J. Huang [c], C. Hyde [o], Y. Ilieva [u], G. Kalicy [d], M. Kimball [a], E. Kistenev [c], Y. Kulinich [s], M. Liu [n], R. Majka [f], J. McKisson [m], R. Mendez [n], P. Nadel-Turonski [p], K. Park [m], K. Peters [h], T. Rao [c], R. Pisani [c], Y. Qiang [m], S. Rescia [c], P. Rossi [m], O. Sarajlic [g], M. Sarsour [g], C. Schwarz [h], J. Schwiening [h], C.L. da Silva [n], N. Smirnov [v], H.D. Stien [a], J. Stevens [e], A. Sukhanov [c], S. Syed [g], A.C. Tate [a], J. Toh [s], C.L. Towell [a], R.S. Towell [a], T. Tsang [c], M. Turisini [j,r], R. Wagner [b], J. Wang [b], C. Woody [c], W. Xi [m], J. Xie [b], Z.W. Zhao [f], B. Zihlmann [m], C. Zorn [m]

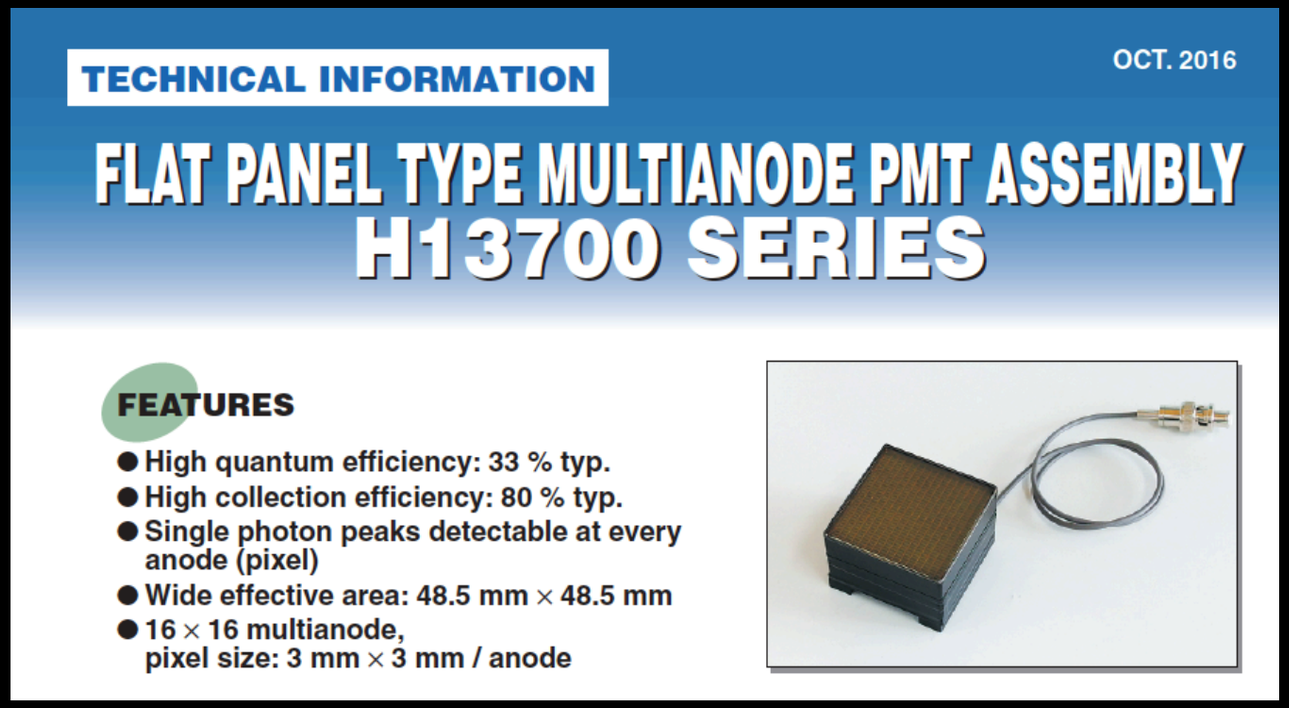
What’s Next?

2nd mRICH Prototype





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



TECHNICAL INFORMATION

OCT. 2016

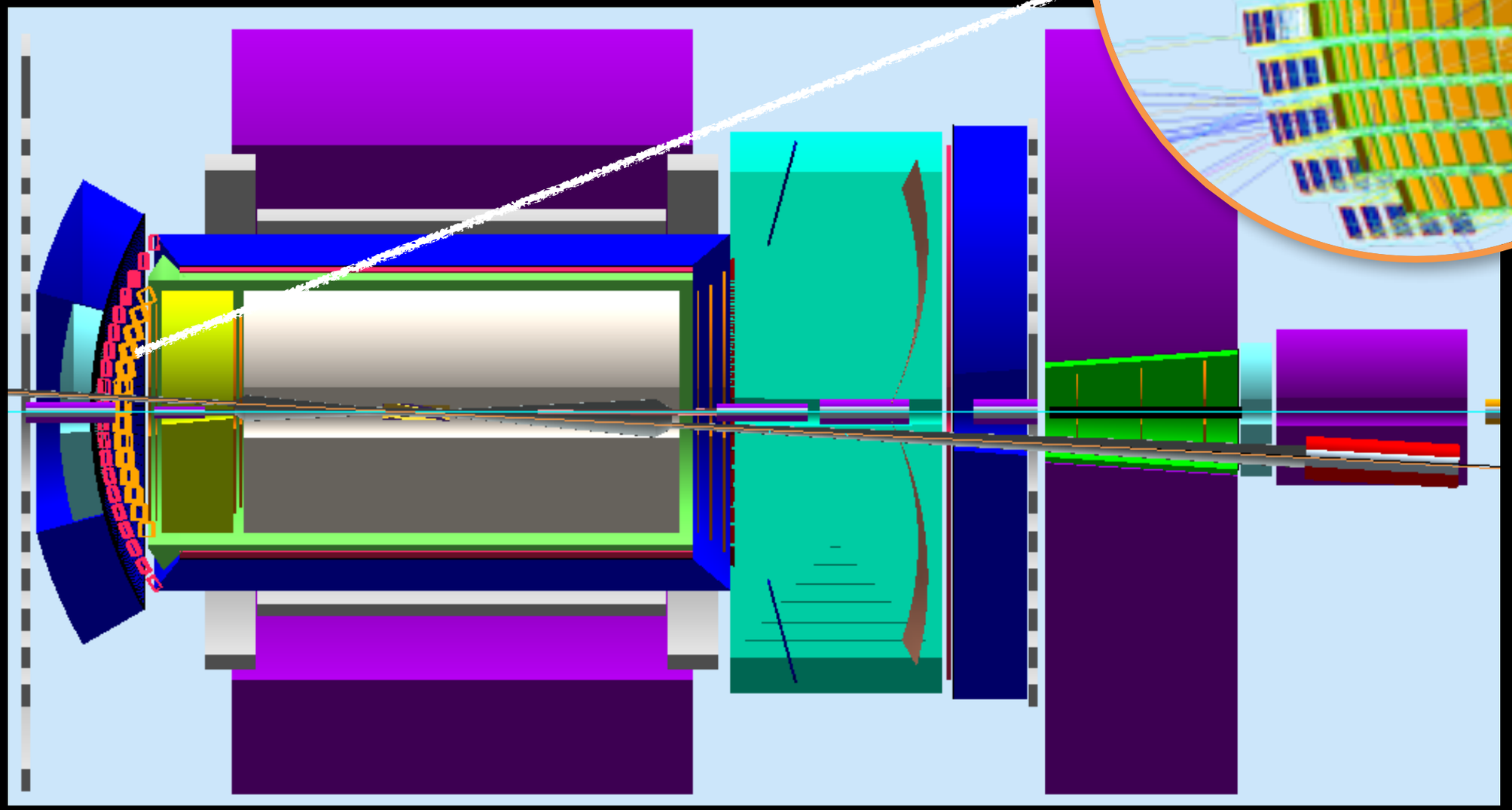
FLAT PANEL TYPE MULTIANODE PMT ASSEMBLY
H13700 SERIES

FEATURES

- High quantum efficiency: 33 % typ.
- High collection efficiency: 80 % typ.
- Single photon peaks detectable at every anode (pixel)
- Wide effective area: 48.5 mm × 48.5 mm
- 16 × 16 multianode, pixel size: 3 mm × 3 mm / anode

mRICH in JLEIC

Projective mRICH Wall



mRICH in sPHENIX

An implementation of the mRICH detector concept in the Forward sPHENIX has been proposed in a Letter of Intent to BNL.

- Enhance of the physics capabilities of the sPHENIX experiment.
- Make the sPHENIX detector system a realist eRHIC detector for the future EIC experiments.
- Validate the mRICH detector PID performance in real experiments before EIC coming online.

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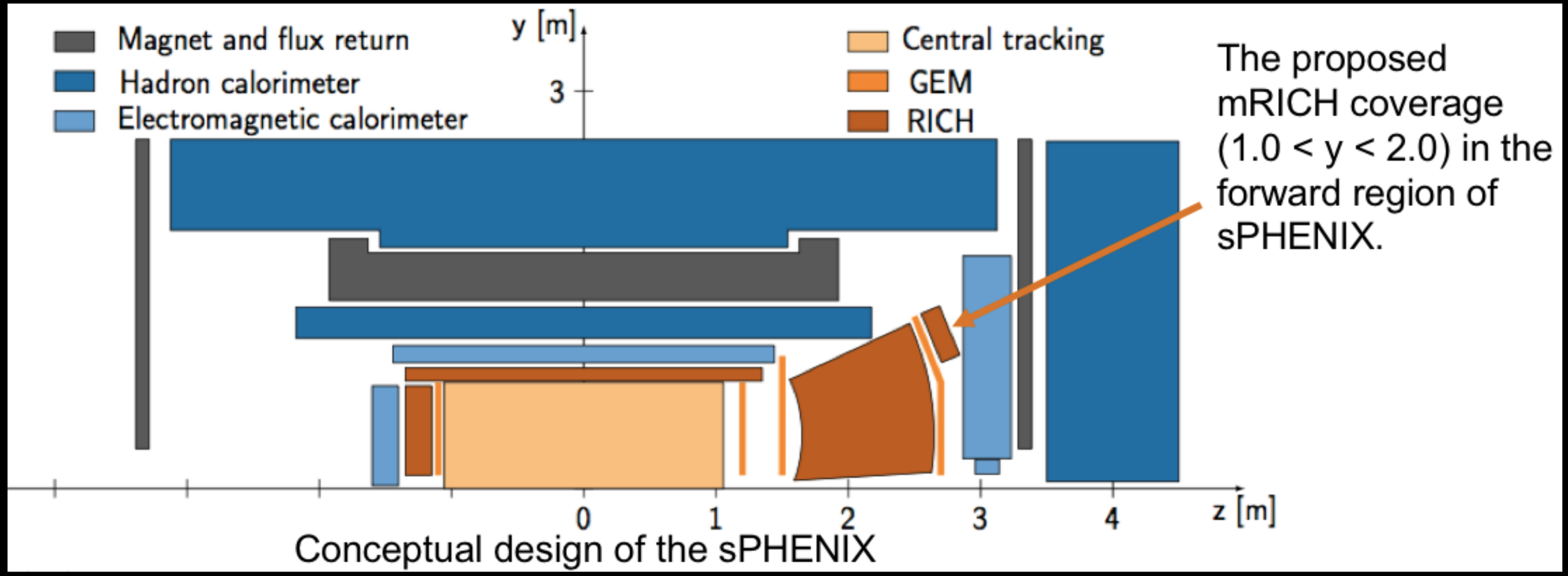
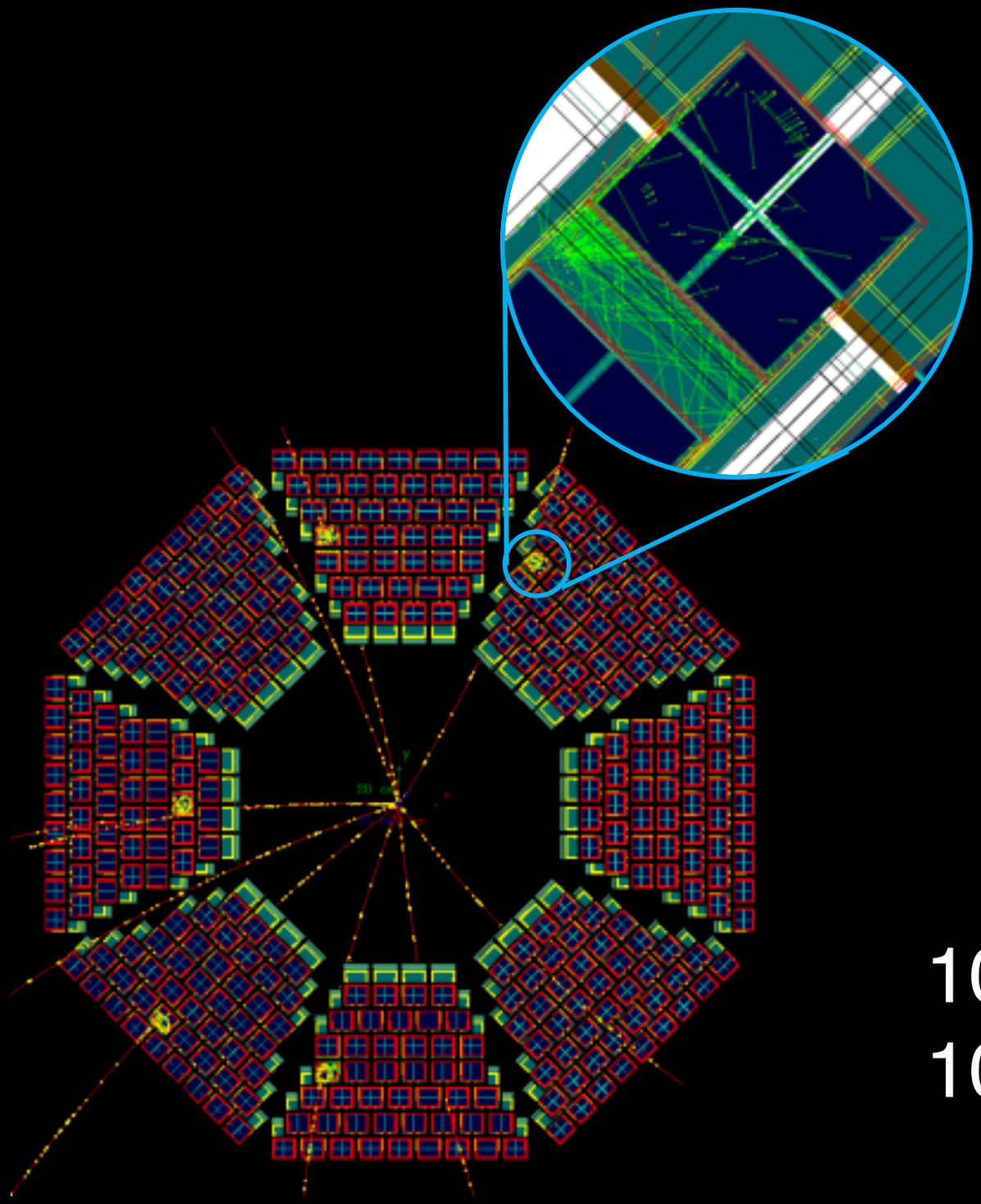
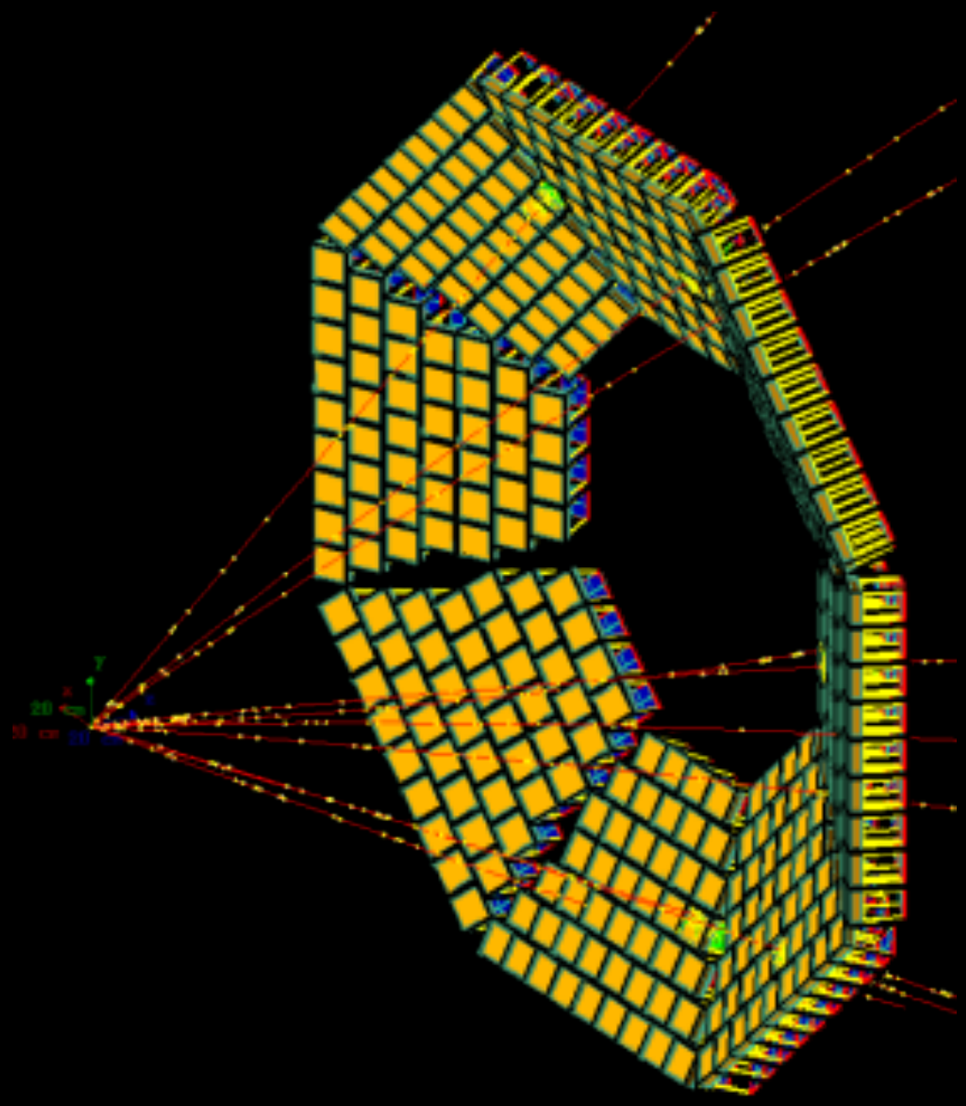


Conceptual design of the sPHENIX

mRICH Wall Optimization





10 event tracks of
10 GeV/c pions

Summary & Outlook

- The realization of EIC is at horizon to address the fundamental QCD questions, which are extremely important both for solving the proton spin puzzle and providing the unprecedented precision of the initial state properties in relativistic heavy ion collisions.

- A truly international EIC community is growing for the development of EIC accelerators and detectors.

- A consortia of PID at EIC has existed for three years to develop and optimize the particle identification technologies using ring imaging of Cherenkov radiation in full kinematics coverage.

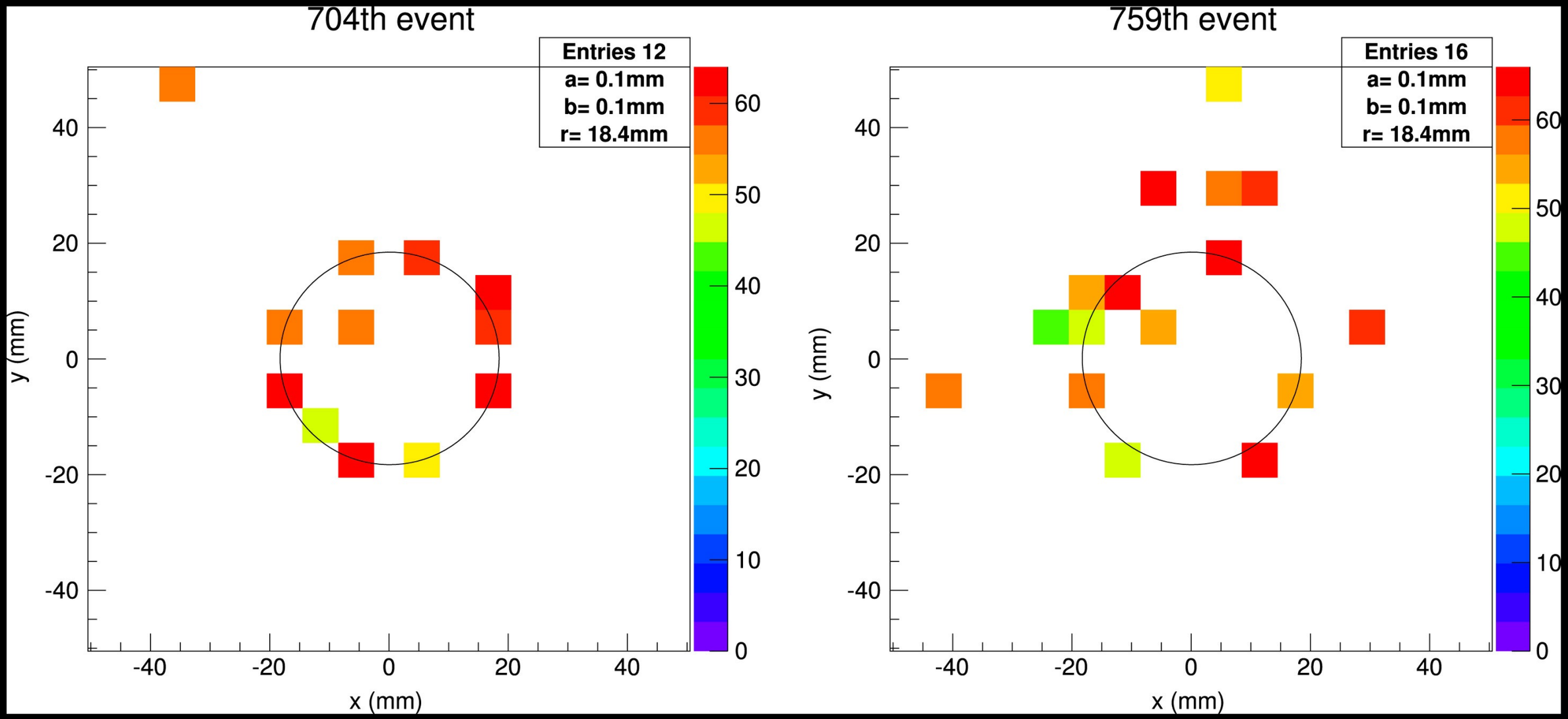
- This talk focuses on the successful demonstration of the first mRICH prototype.

- We are currently preparing for the next beam test at Fermilab in spring of 2018 and continuing the implementation of the mRICH detector in EIC experiments through simulation.

Thank you :)

Backup

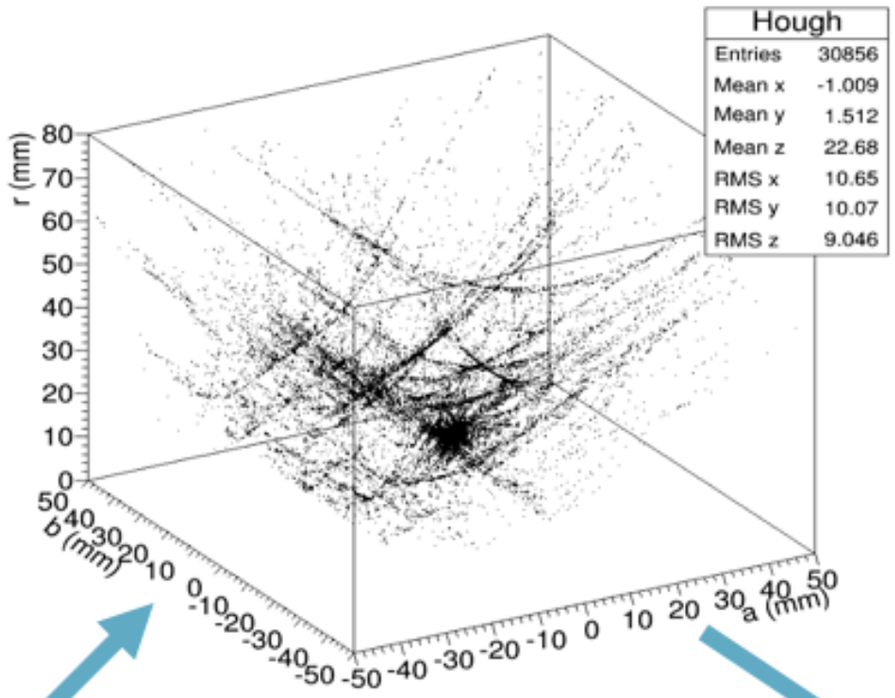
Ring Finding Algorithm



Ring Finding Algorithm

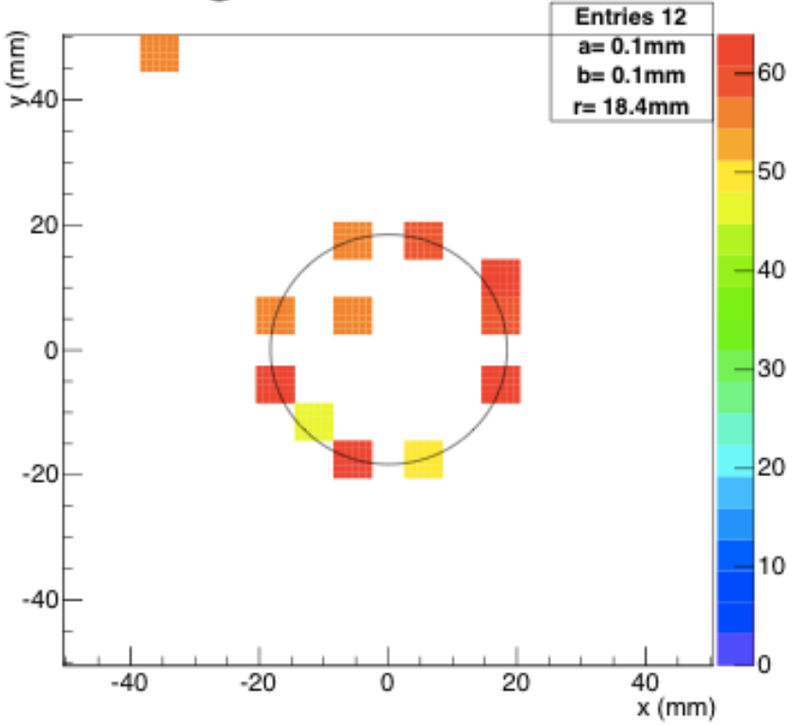
Hough Transform Algorithm

Find all possible rings in an event



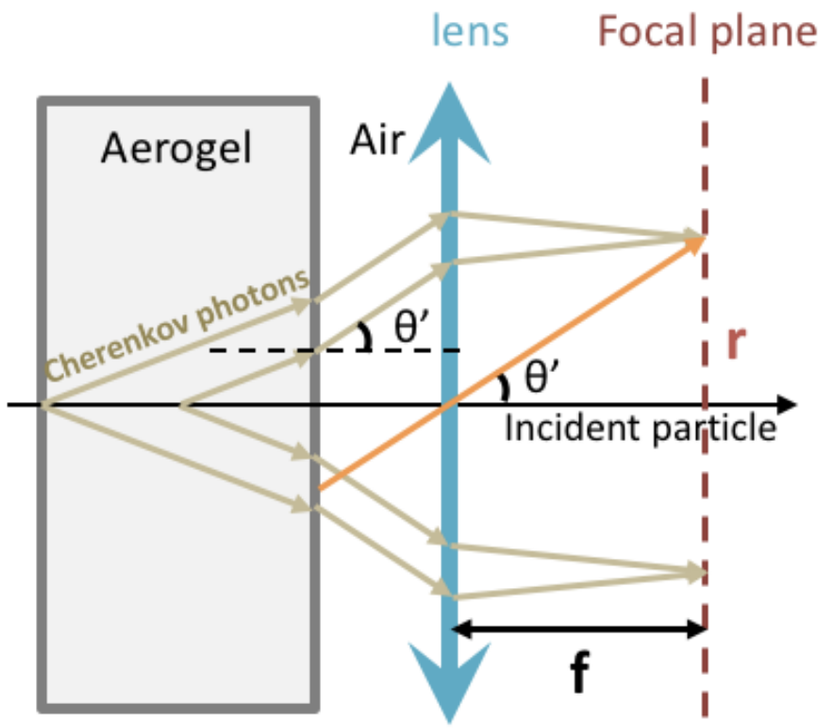
Fill possible rings' r, (a,b) in a probability density histogram

The most possible ring is the densest bin in the probability density histogram



Analytical Calculations

Estimated value of Cherenkov ring radius in modular RICH detector:



Proportional to focal length

$$r = f \cdot \tan\theta'$$

$$= f \cdot \sqrt{\frac{(n^2-1)p^2-m_0^2}{(2-n^2)p^2+m_0^2}}$$

$$= 76.2 \cdot \sqrt{\frac{(1.03^2-1)p^2-m_0^2}{(2-1.03^2)p^2+m_0^2}}$$

$$r_{120\ GeV\ proton} = 19.4\ \text{mm}$$

Estimated number of Cherenkov photons in modular RICH detector:

Fresnel lens transmission

Sensor quantum efficiency

$$N = 2\pi\alpha d\left(1-\frac{1}{\beta^2 n^2}\right)\cdot 0.92 \cdot 0.92 \int_{\lambda_1}^{\lambda_2} 0.34e^{-\frac{(\lambda-345\times10^{-7})^2}{2\times(119\times10^{-7})^2}} \cdot 0.83e^{-\frac{d\times56.29\times10^{-20}}{\lambda^4}} \frac{d\lambda}{\lambda^2}$$

$N = 10.4$ (with n=1.03)

Glass window transmission

Aerogel transmission