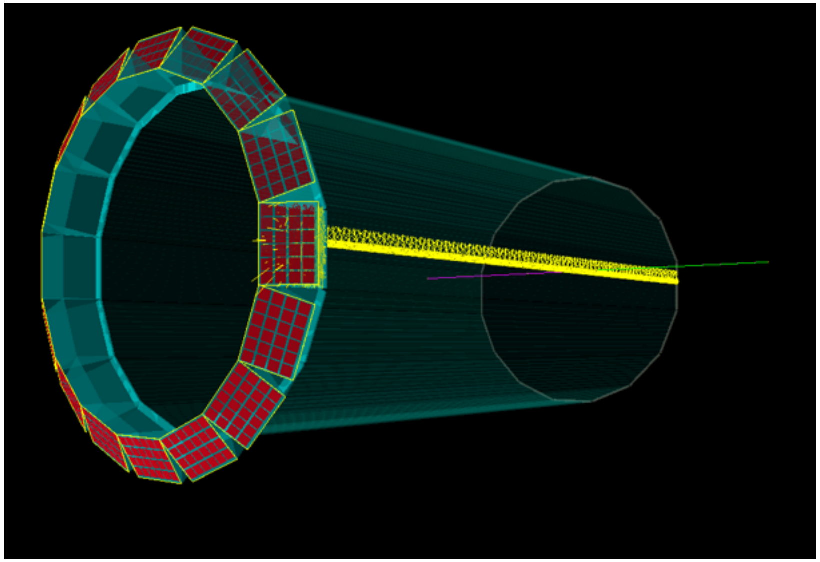
DIRC@EIC

Greg Kalicy



L. Allison[1], T. Cao[2], R. Dzhygadlo[3], T. Horn[4], C. Hyde[1], Y. Ilieva[2], G. Kalicy[1], P. Nadel-Turonski[5], K. Park[1], K. Peters[3], C. Schwarz[3], J. Schwiening[3], J. Stevens[5], W. Xi[5], and C. Zorn[5].

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2) University of South Carolina, Columbia, SC 29208
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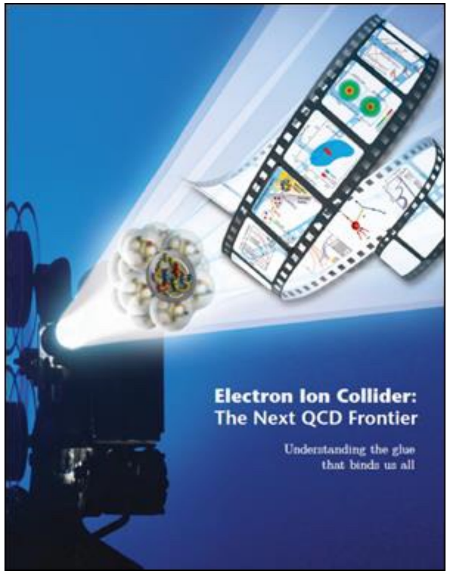
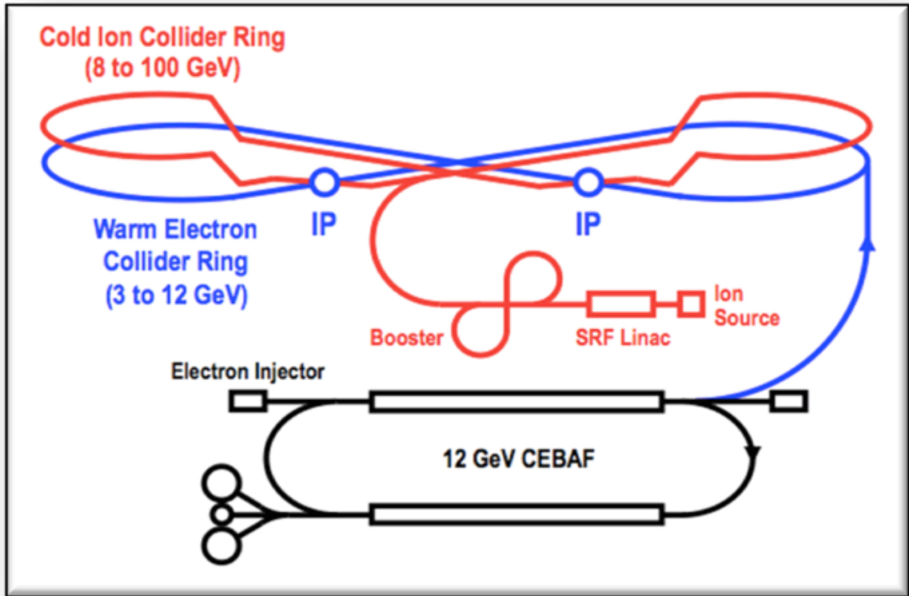
4) The Catholic University of America, Washington, DC 20064
5) Thomas Jefferson National Accelerator Facility, Newport News, VA 23606

Outline

- **Electron ion Collider**
  - High priority in Nuclear Science Advisory Committee long range plan
- **DIRC@EIC**
  - Generic R&D
- **High performance DIRC**
  - High refractive 3 component lens (3CL)
- **Components tests**
  - Performance of 3CL
  - Sensors tests in B field





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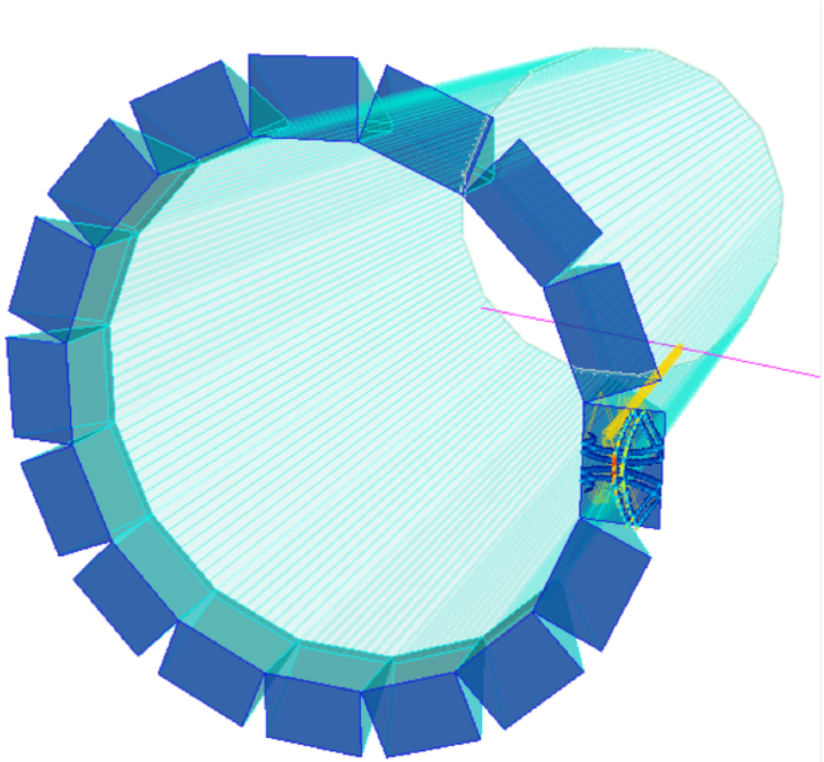

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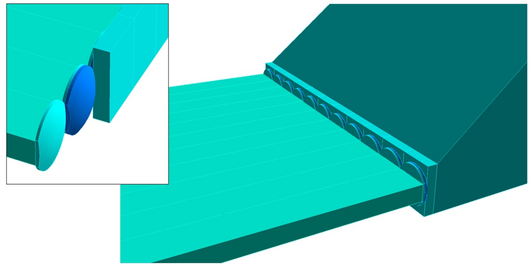

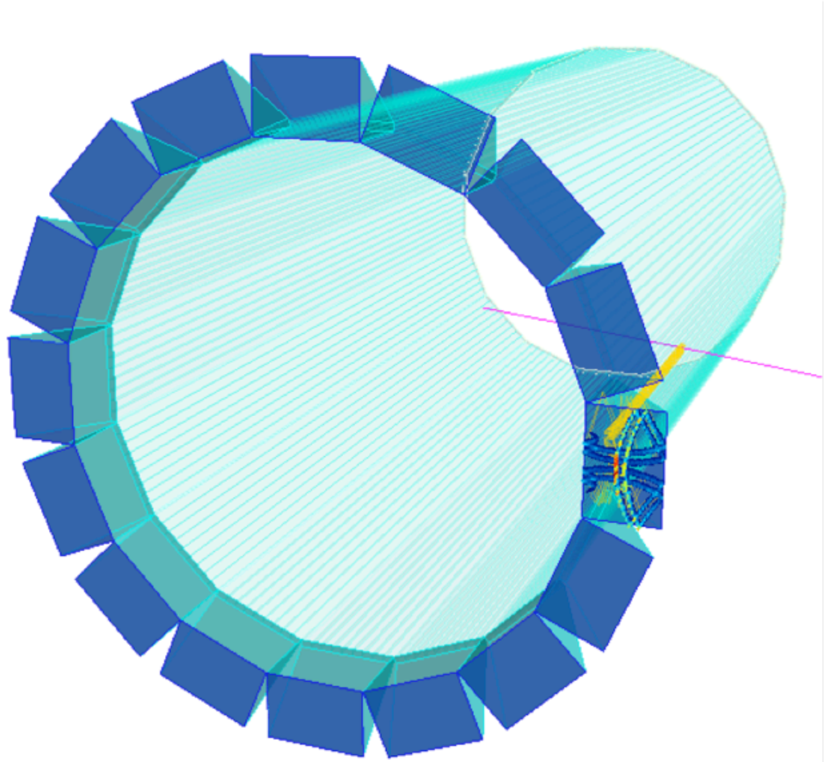

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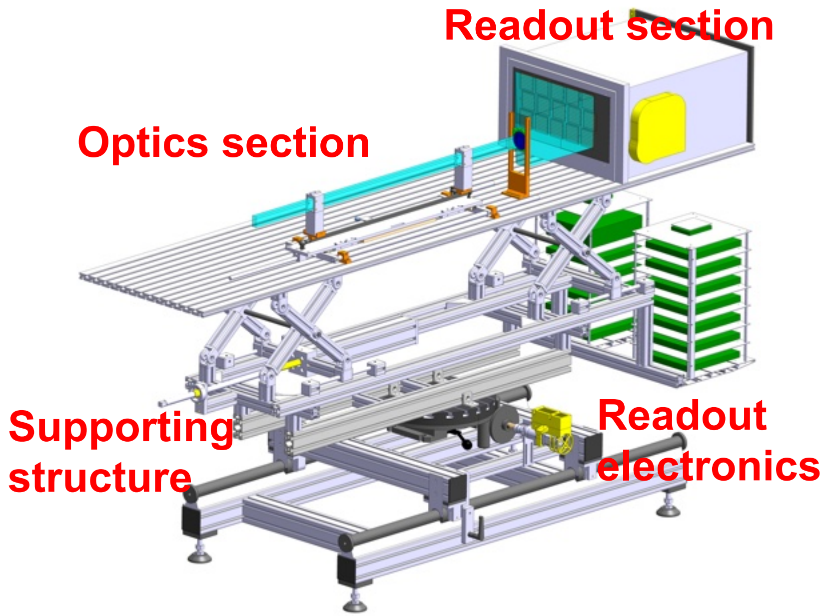

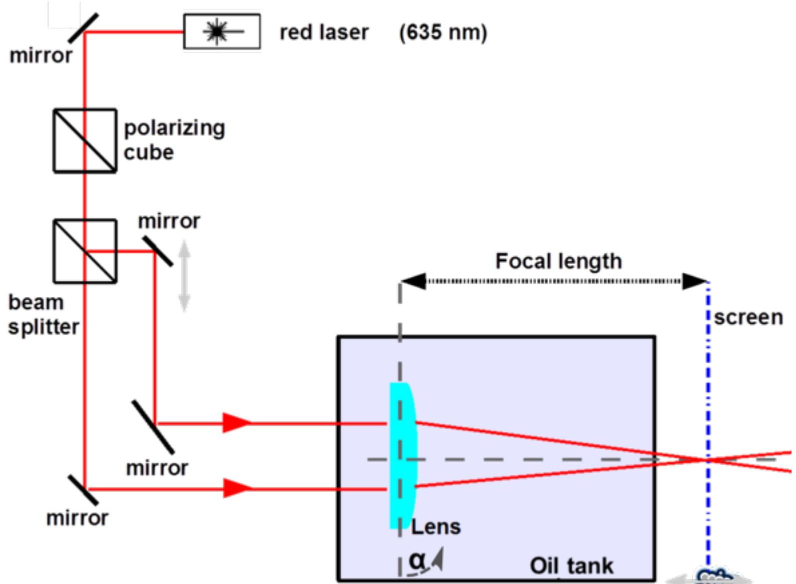

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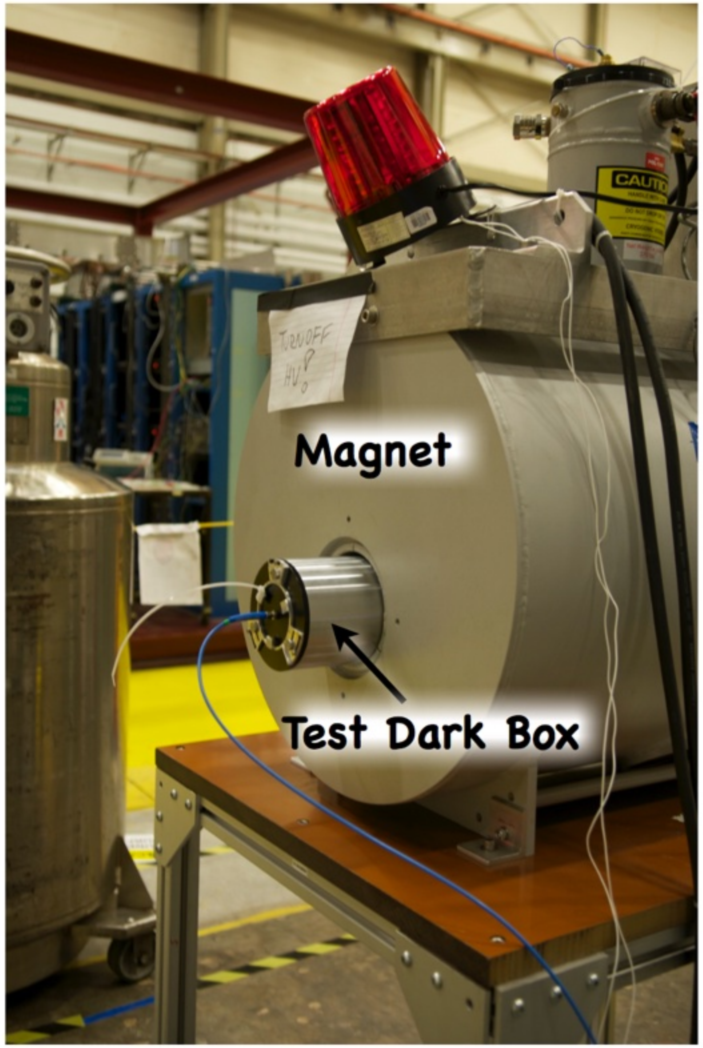
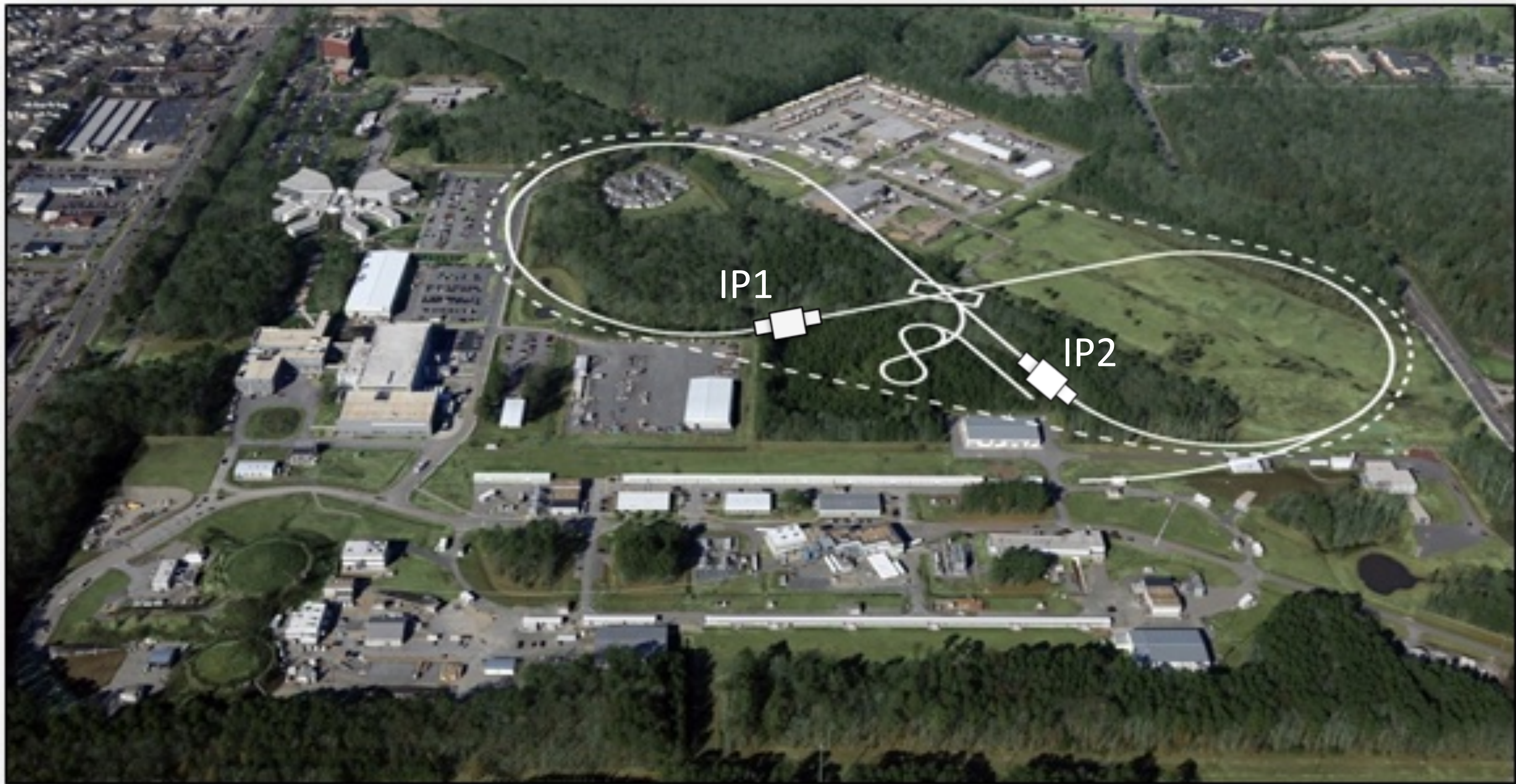


EIC@Jlab Siteplan



JLEIC Performance goals

Energy

$\sqrt{s}$ from **15** to **65** GeV

Electrons **3-10** GeV, protons **20-100** GeV, ions **12-40** GeV/u

Ion species

Polarized light ions: **p**, **d**, **^{3}He**, and possibly **Li**

Un-polarized light to heavy ions up to A above 200 (Au, Pb)

Space for at least 2 detectors

Full acceptance is critical for the primary detector

High luminosity for the second detector

Luminosity

10^{33} to 10^{34}cm^{-2}s^{-1} per IP in a *broad* CM energy range

Polarization

At IP: longitudinal for both beams, transverse for ions only

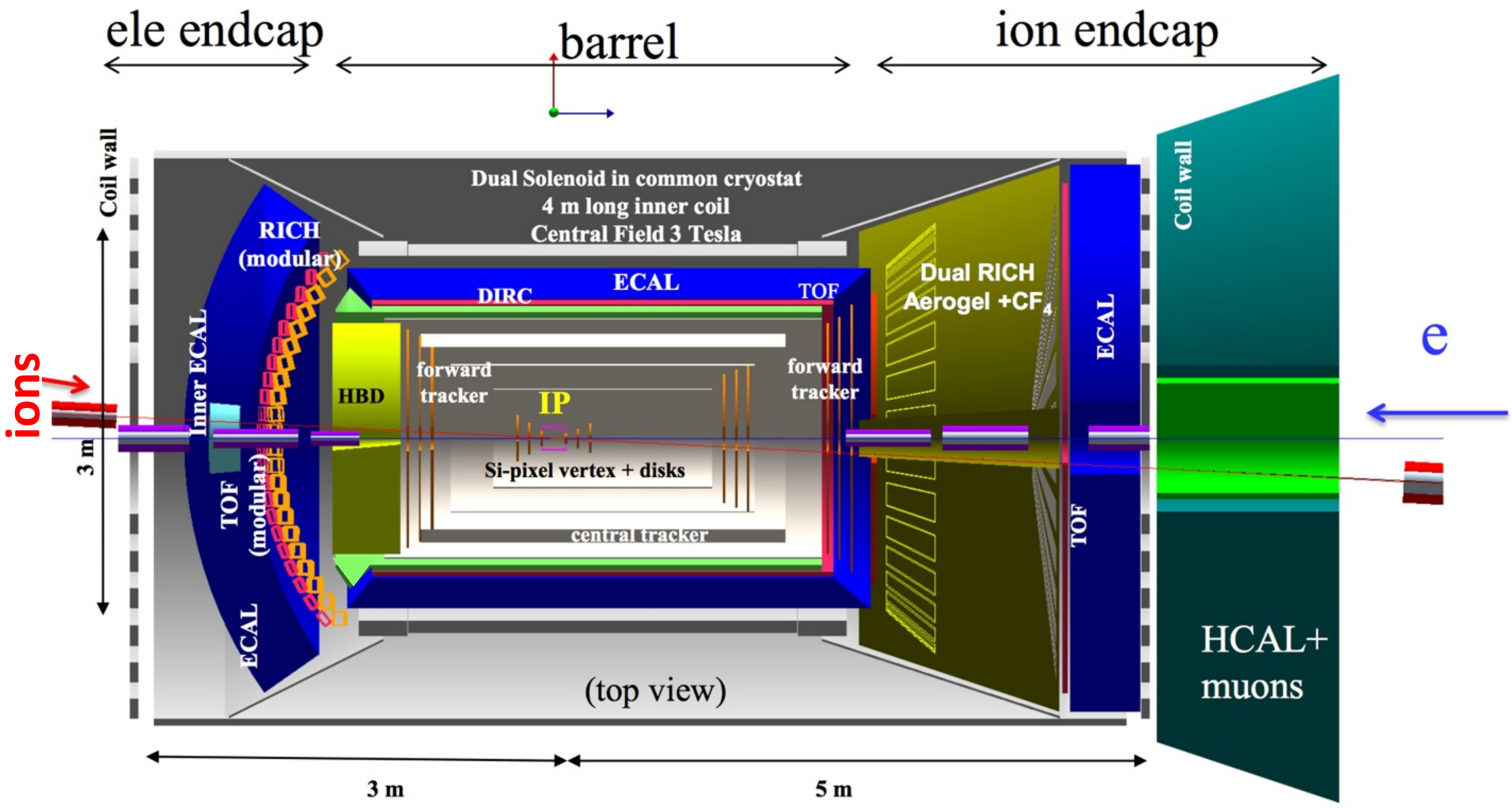
All polarizations >70%

Upgrade to higher energies and luminosity possible

20 GeV electron, **250 GeV** proton, and **100 GeV/u** ion

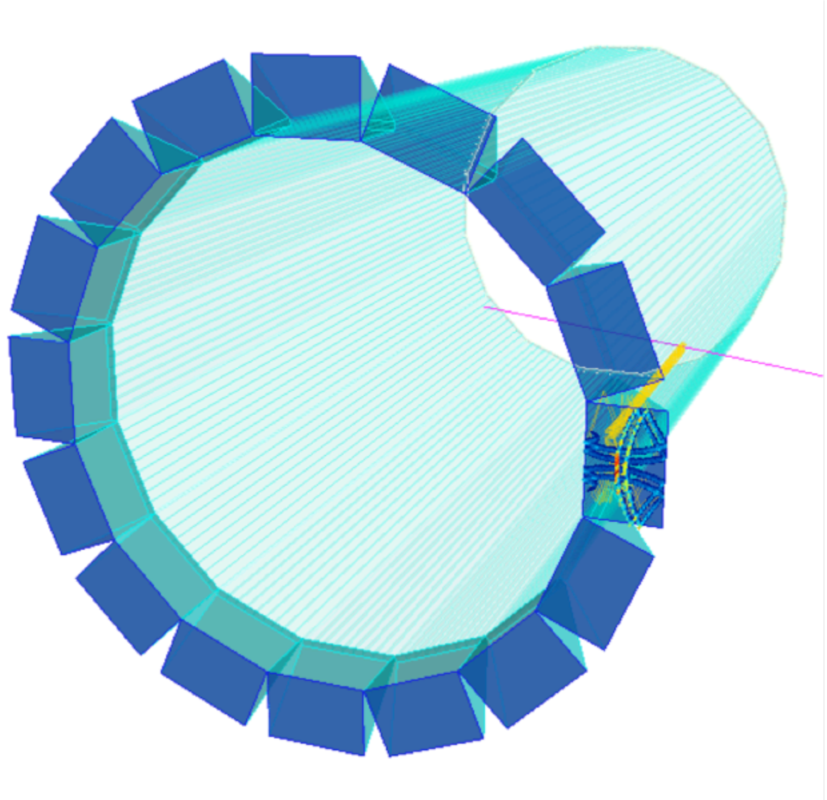
Design goals consistent with the White Paper requirements

JLEIC Current design

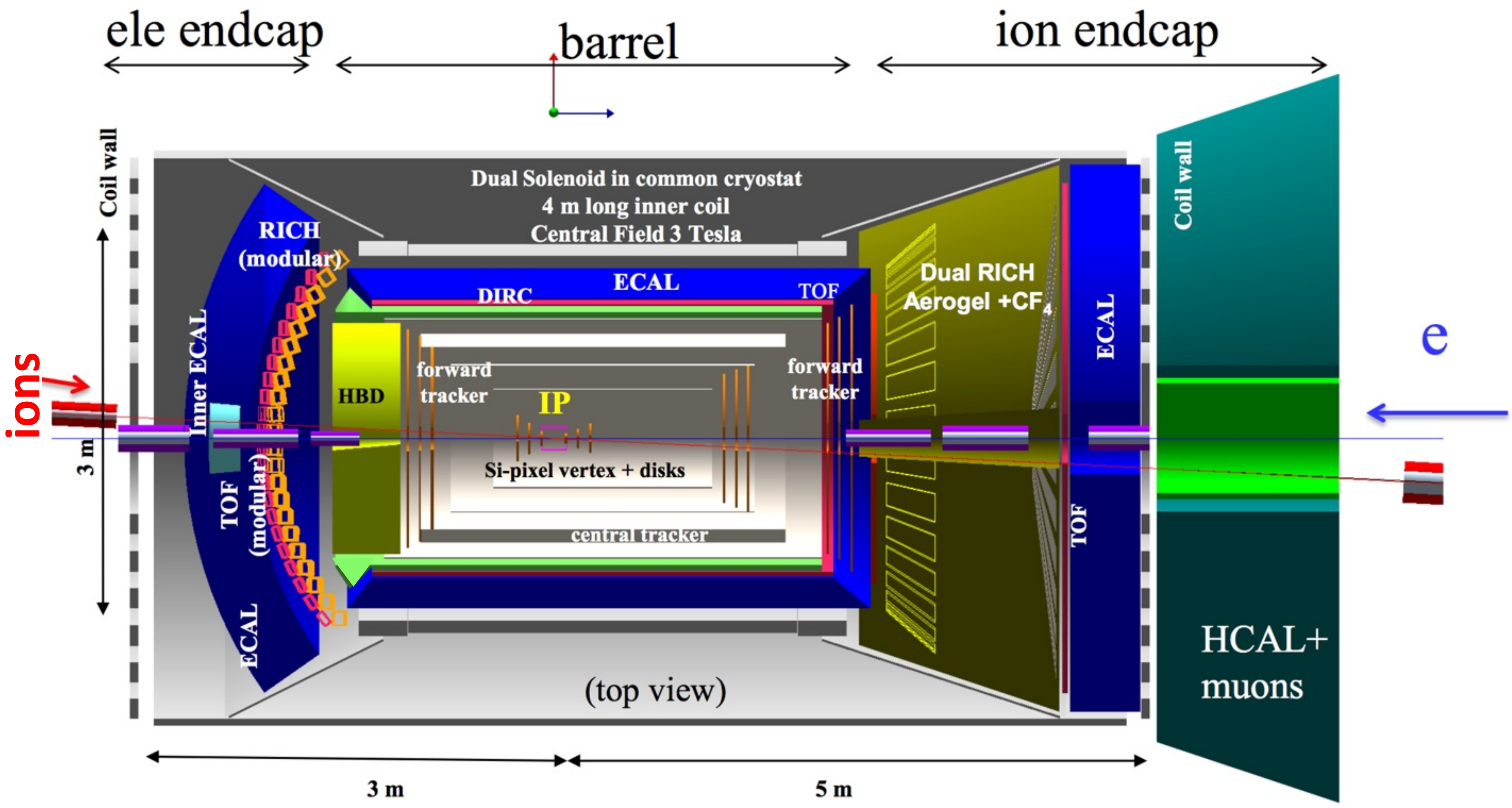


JLEIC Current design

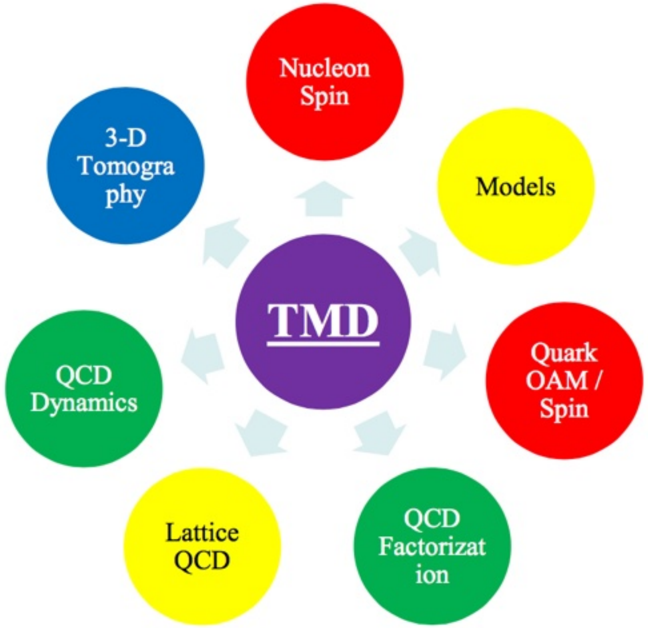
DIRC



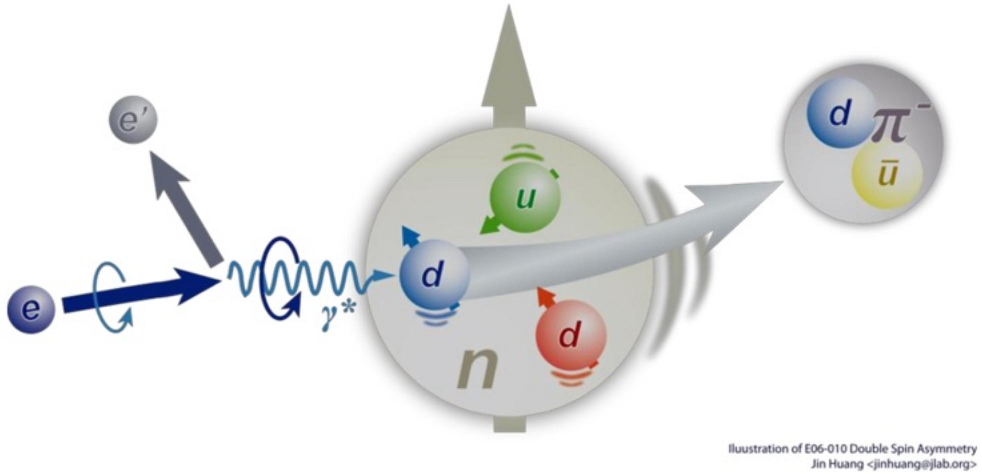
JLEIC Current design



PID Semi-Inclusive DIS (SIDIS)

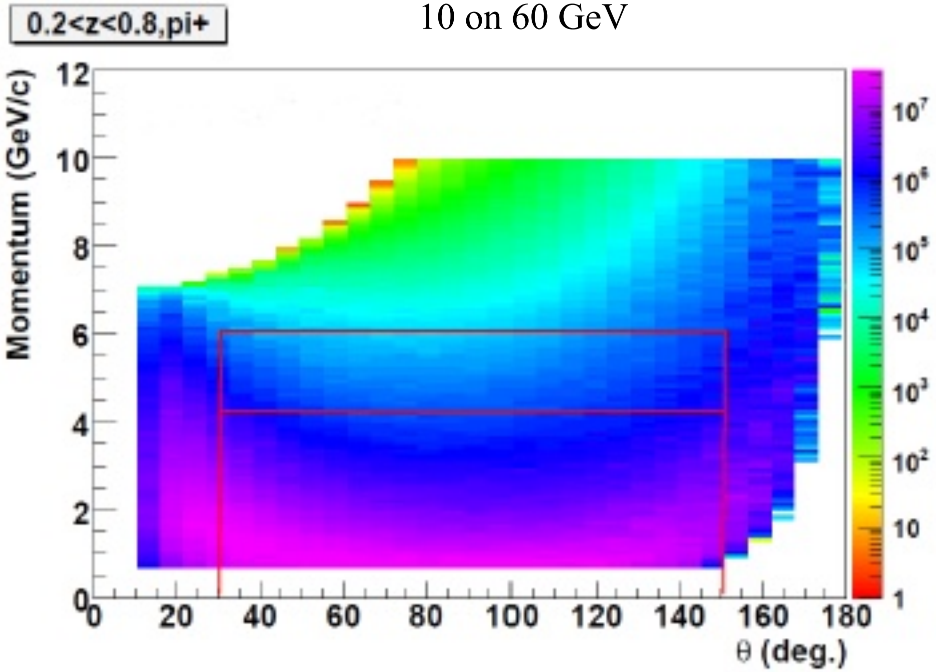


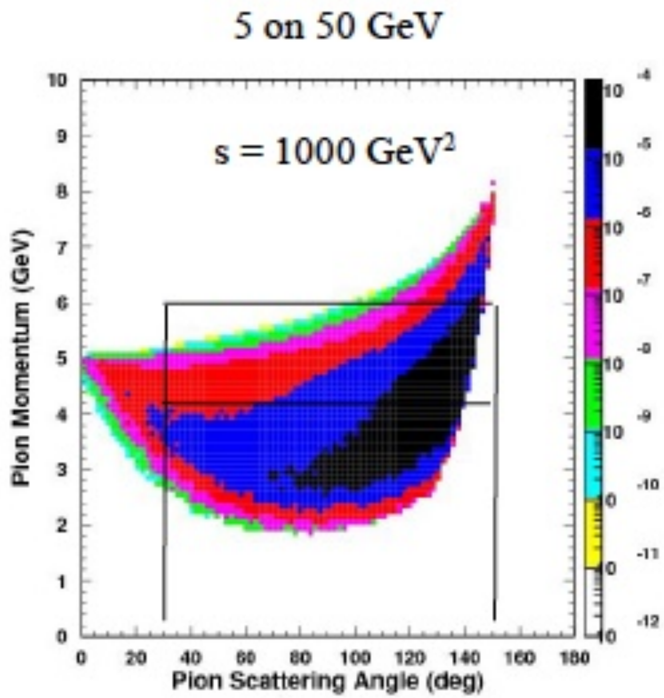
Precision mapping of transverse momentum dependent parton distributions (TMD)



- **Highly polarized electron collide with highly polarized nuclei (proton, deuteron, 3He ,etc)**
- **Detect scattered electron and pion at full angle and full momentum range**

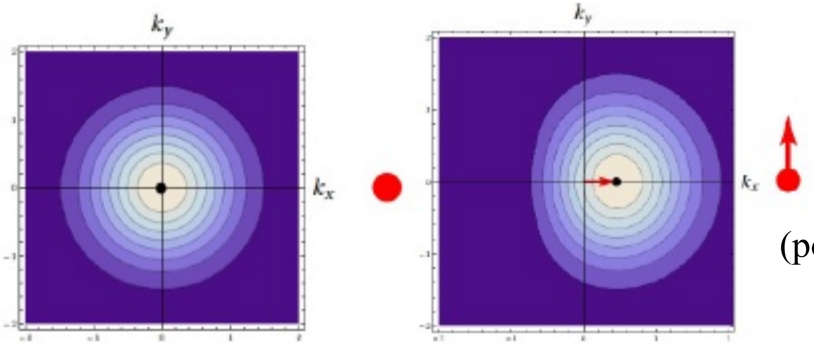
PID 3D structure of the proton



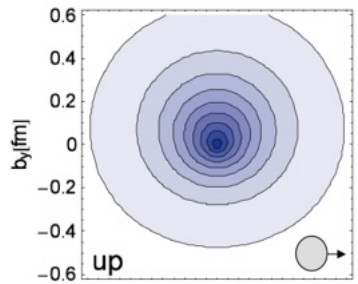


Semi-Inclusive DIS – mapping of transverse momentum distributions of (sea) quarks

Exclusive meson production – mapping of transverse spatial distribution of light and strange quarks



(polarized)

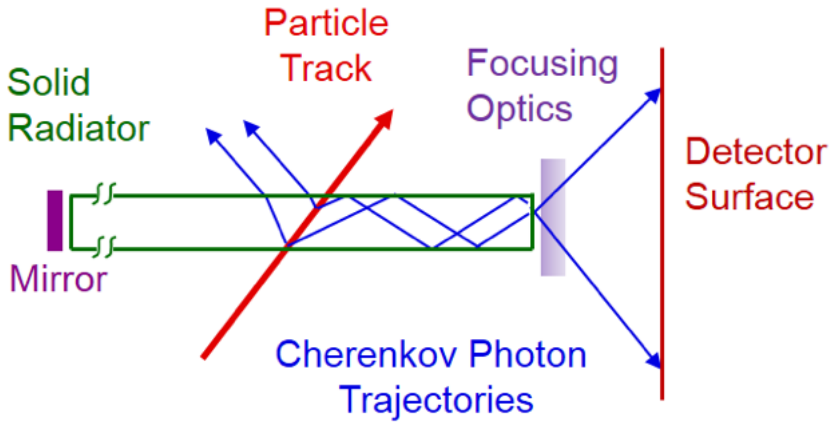


(polarized)

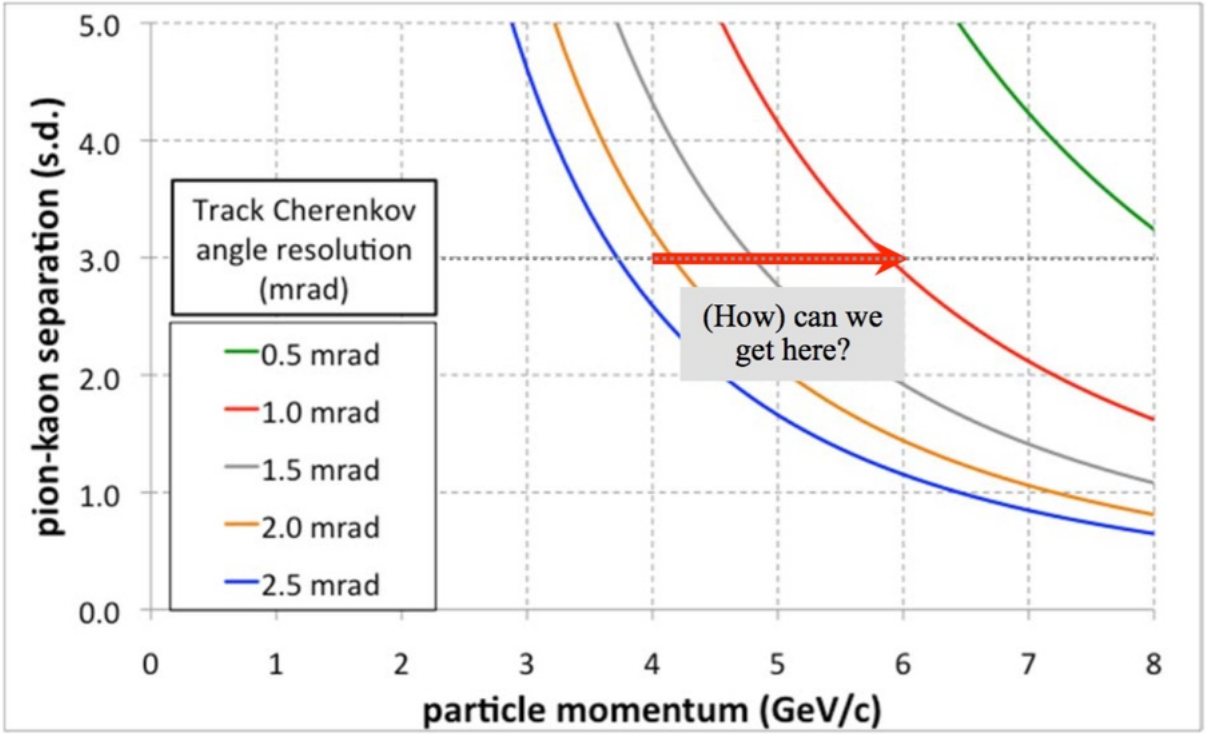
DIRC@EIC Performance goal

Contributions to performance:

- Correlated term
- Photon Yield
- Single photon Cherenkov angle resolution



π/K identification as a function of the θ_c resolution



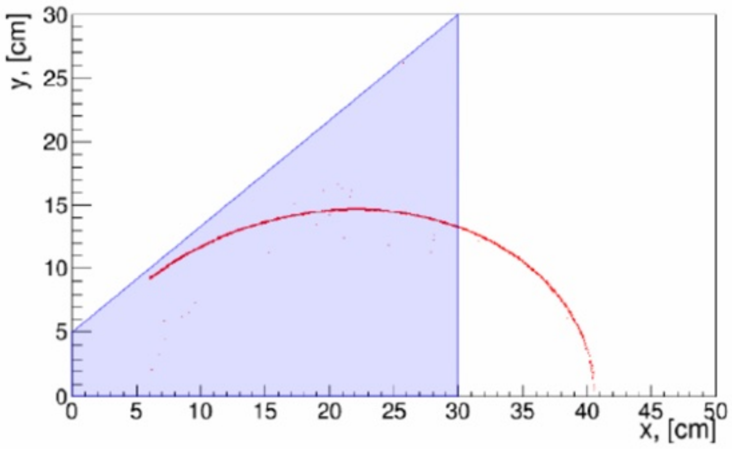
DIRC@EIC Prototype 3-component lens

Limitations of standard focusing lenses:

- Significant photon yield loss around 90° particle track
- Aberration for photons with steeper angles

Geant4 simulation of focal plane:

2 component lens



Simulated data

R. Dzhygadlo, G. Kalicy, C. Schwarz

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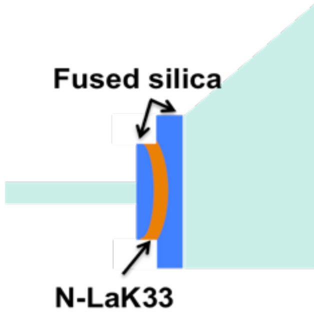

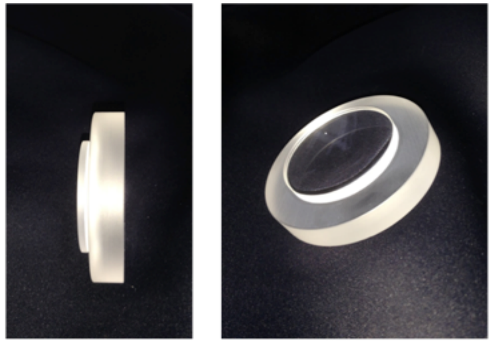

Geant4 simulation of focal plane:

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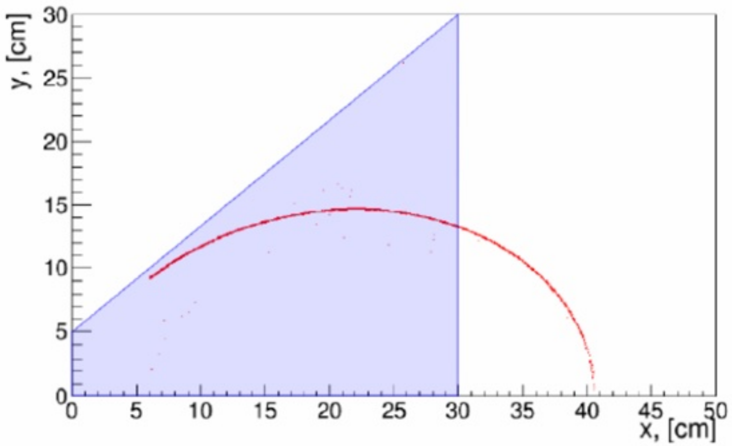
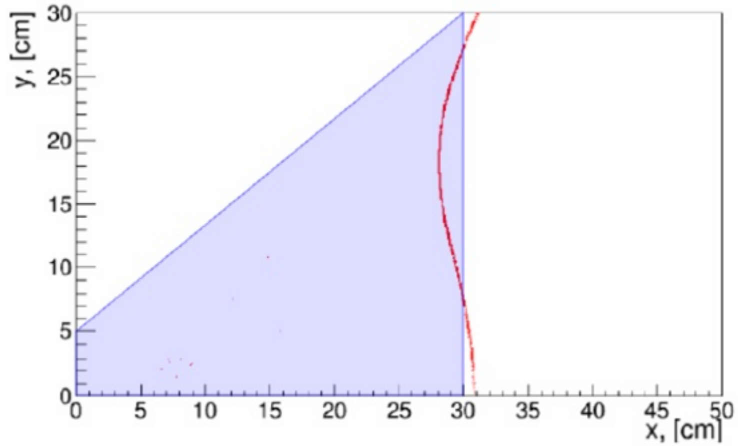


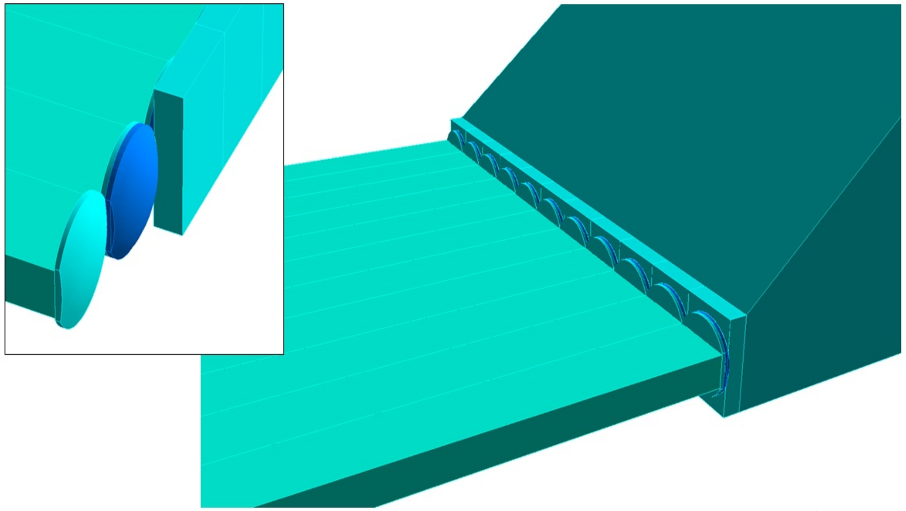
3 component lens

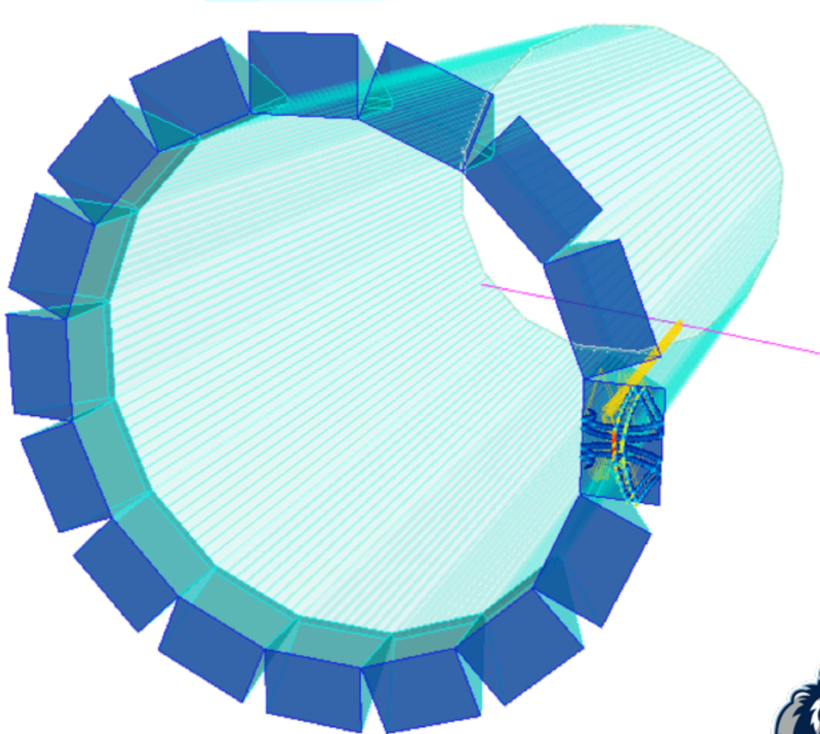


Simulated data

R. Dzhygadlo, G. Kalicy, C. Schwarz

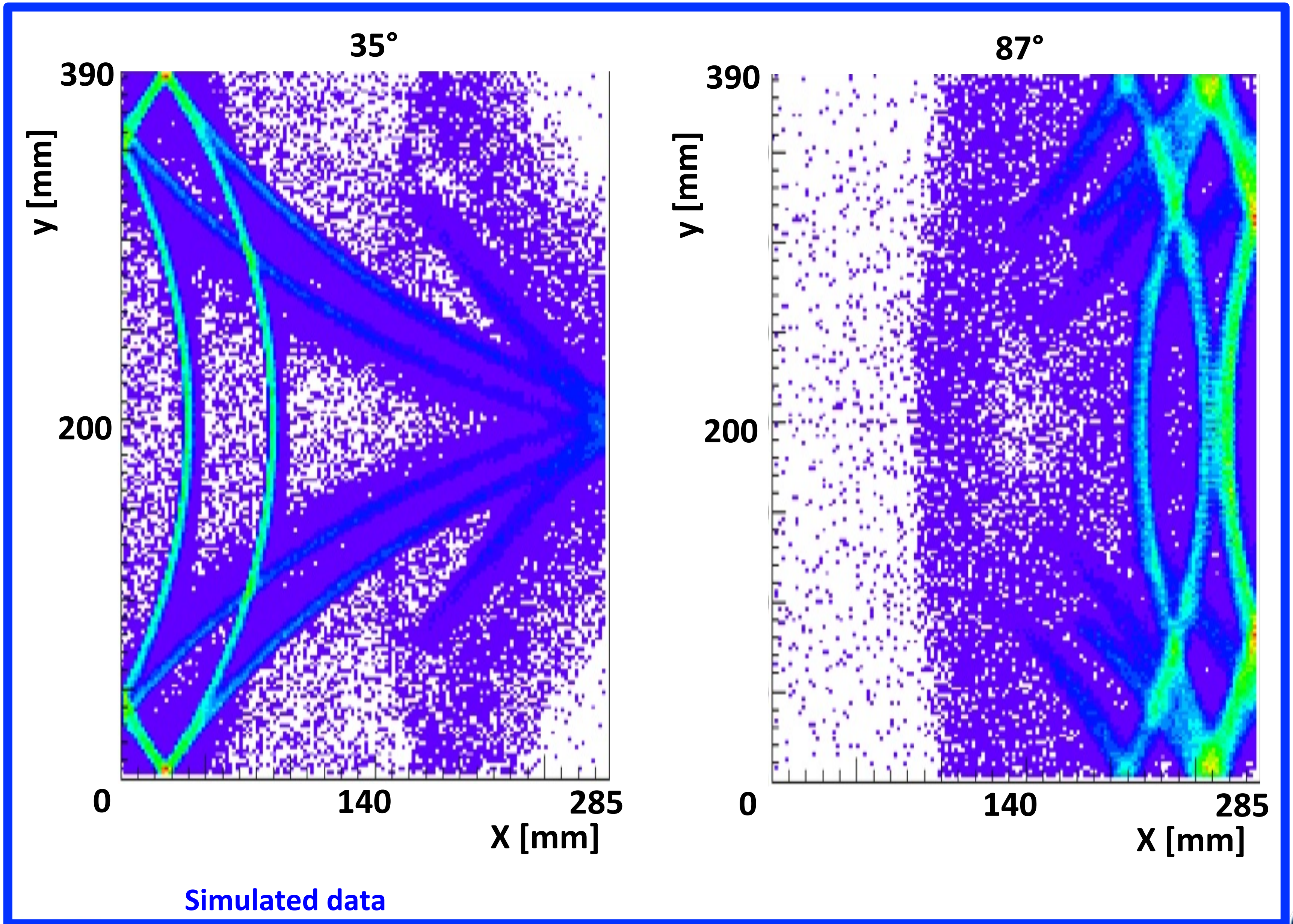
High-performance DIRC **Baseline design**





- **Radiator bars**
  - 17 x 35 x 4200 mm
  - 11 bars per box
  - 16 bar boxes, 1m from IP
- **3 component lens**
  - 14 x 35 x 50 mm
  - radiuses: 47 mm, 29 mm
- **Expansion volume**
  - Prism with 38° opening angle
  - 285 x 390 x 300 mm
- **Sensors**
  - 208k pixels, each 3 mm^2

High-performance DIRC Hit Patterns



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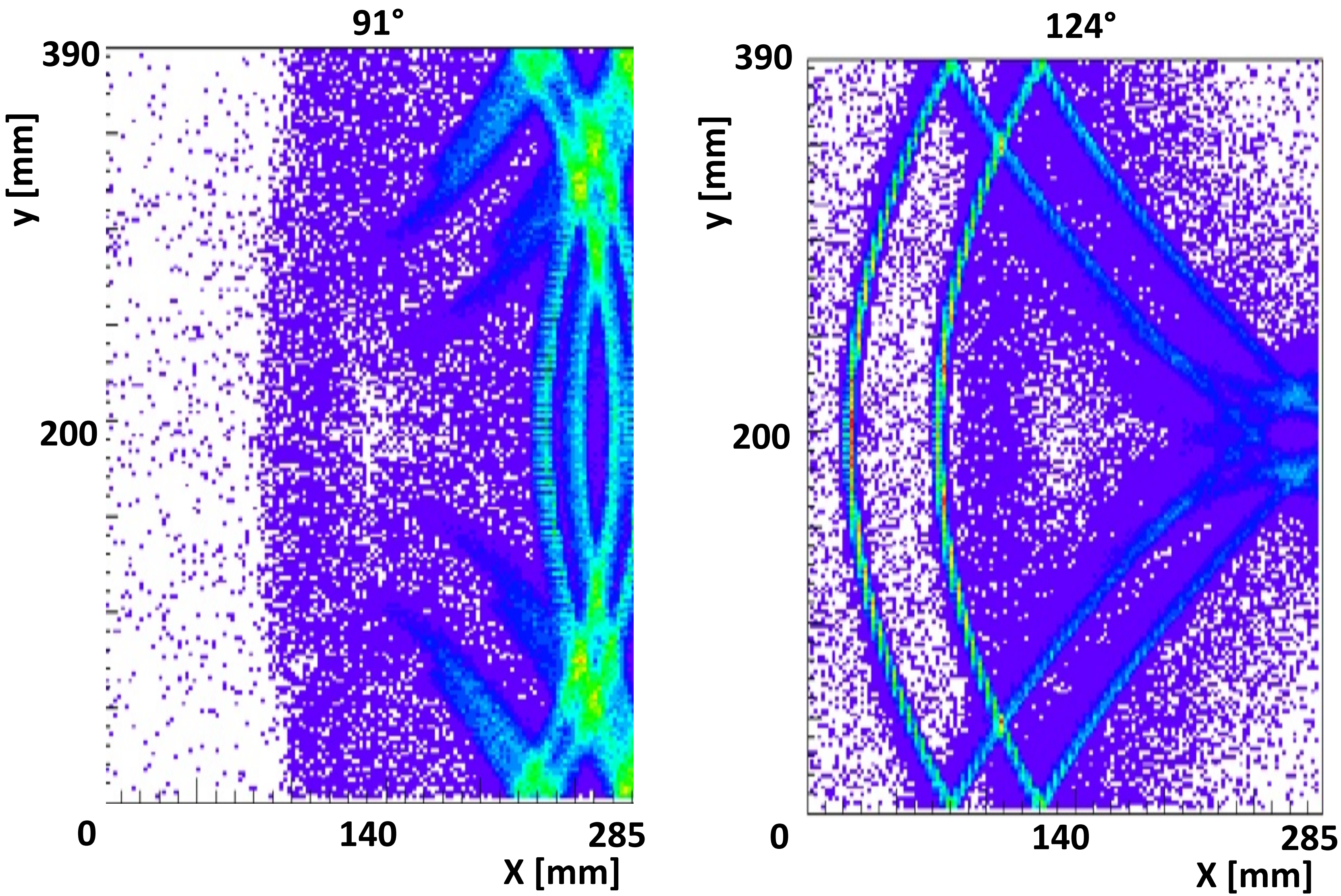
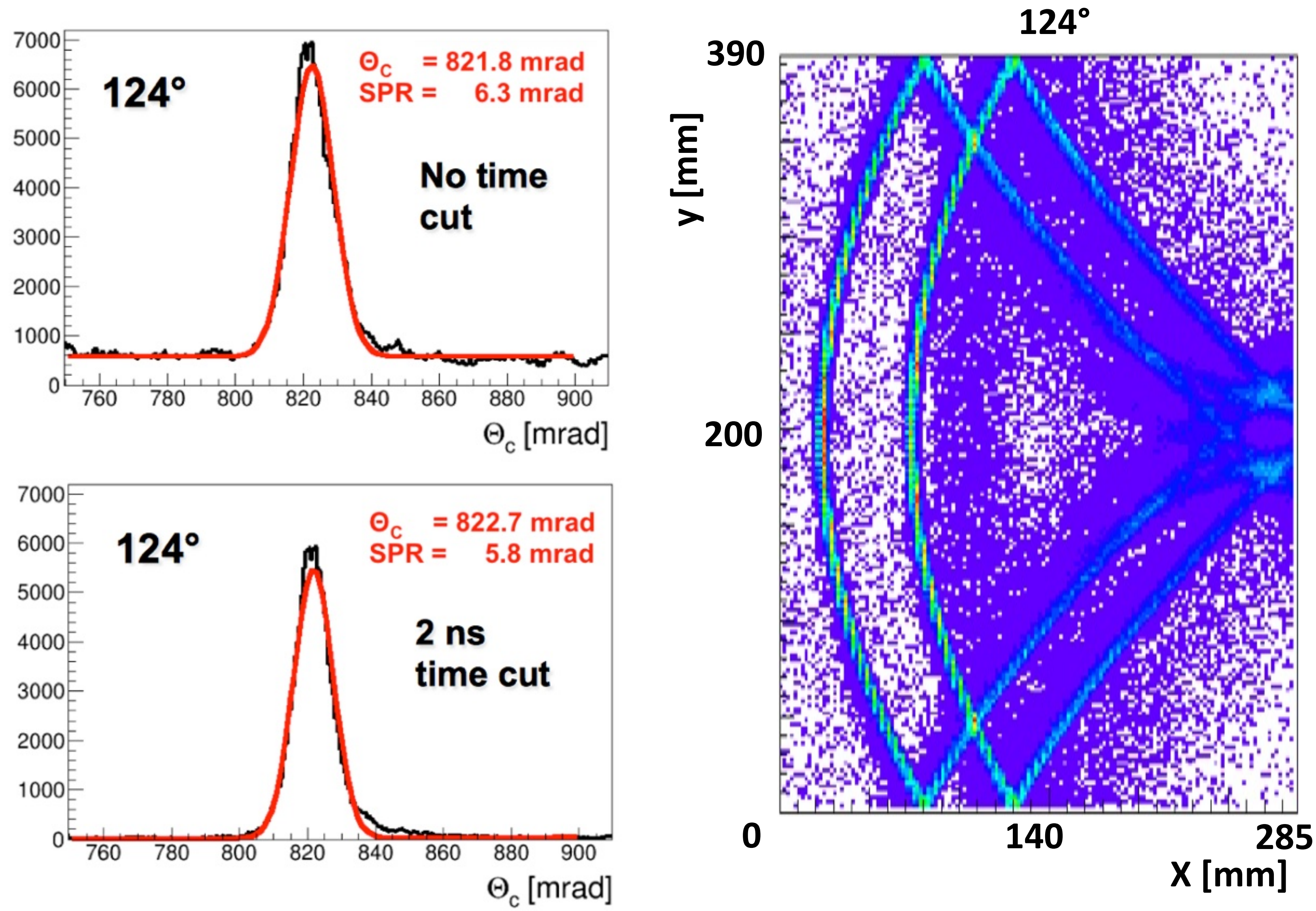


Simulated data

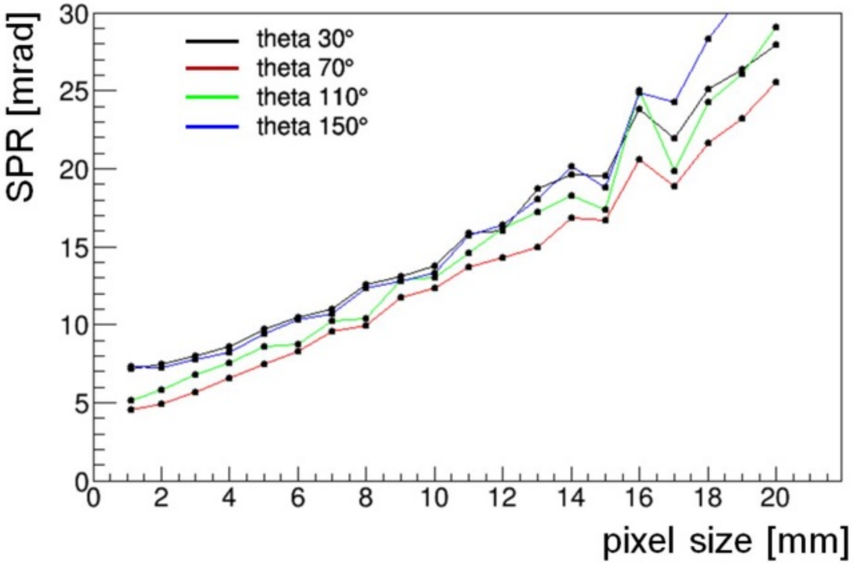
High-performance DIRC Single Photon Resolution (SPR)

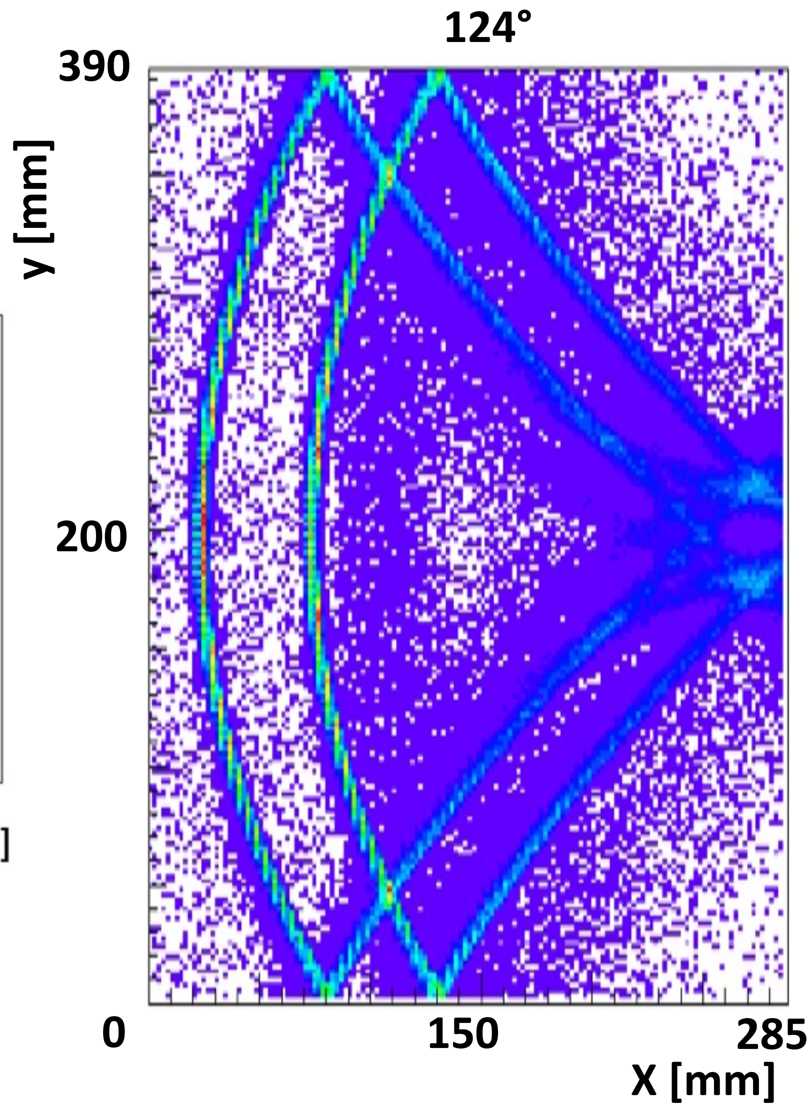


Simulated data

High-performance DIRC Single Photon Resolution (SPR)

Influence of the pixel size on SPR for selected track polar angles

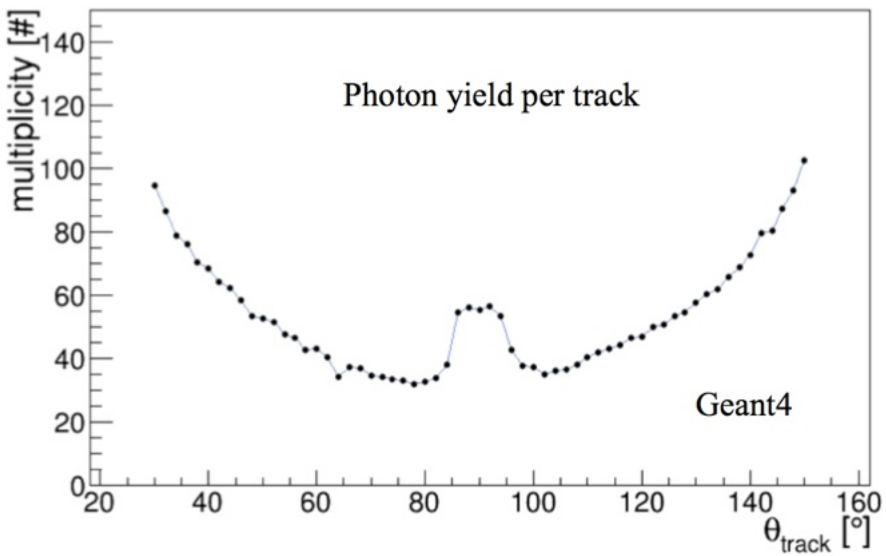


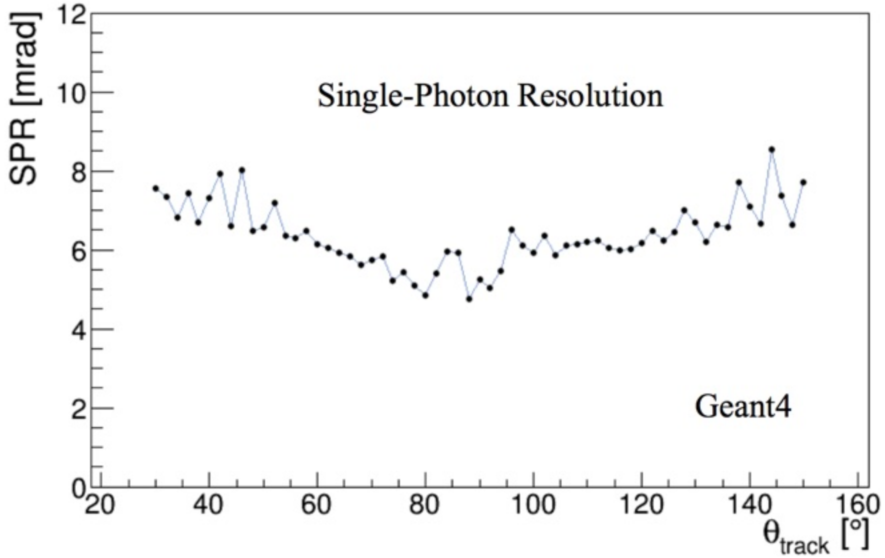


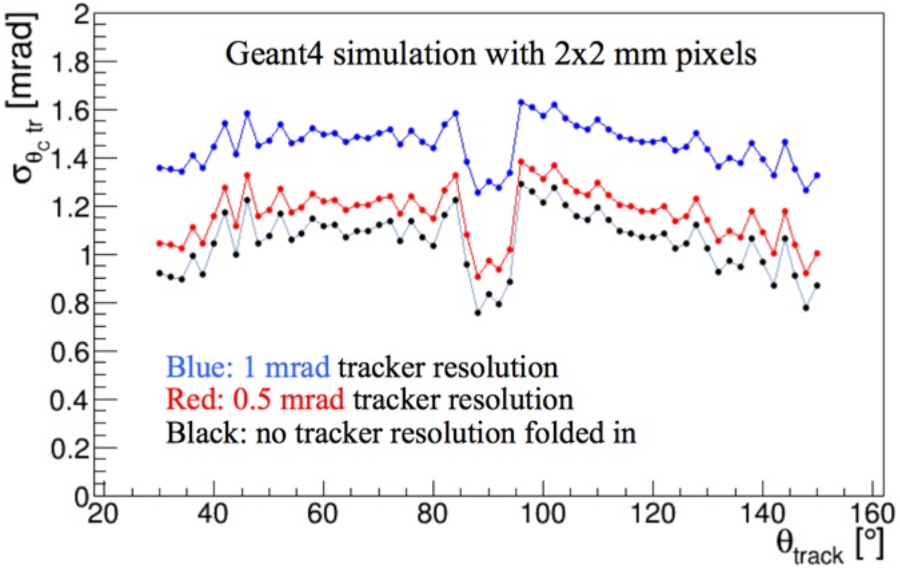
Simulated data

High-performance DIRC Track Resolution

Simulated data







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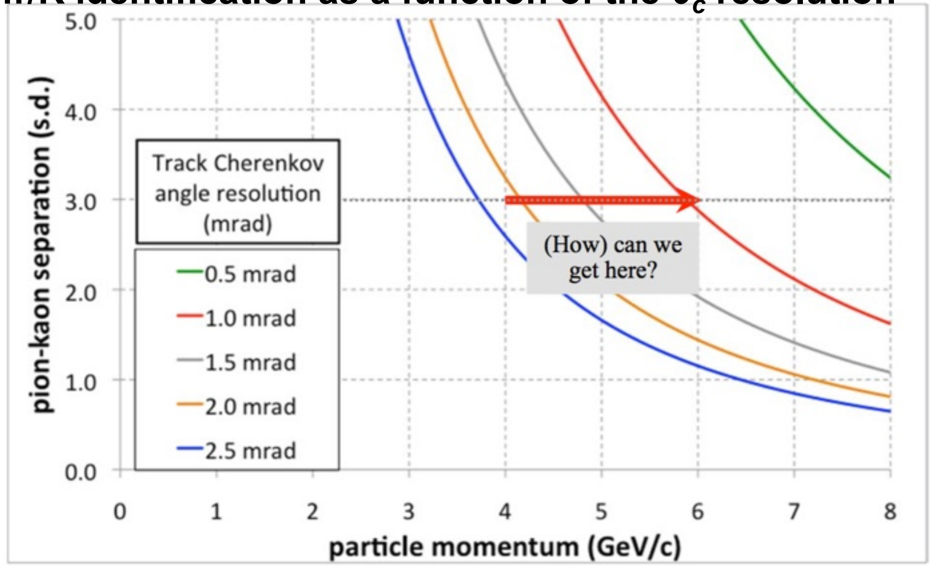
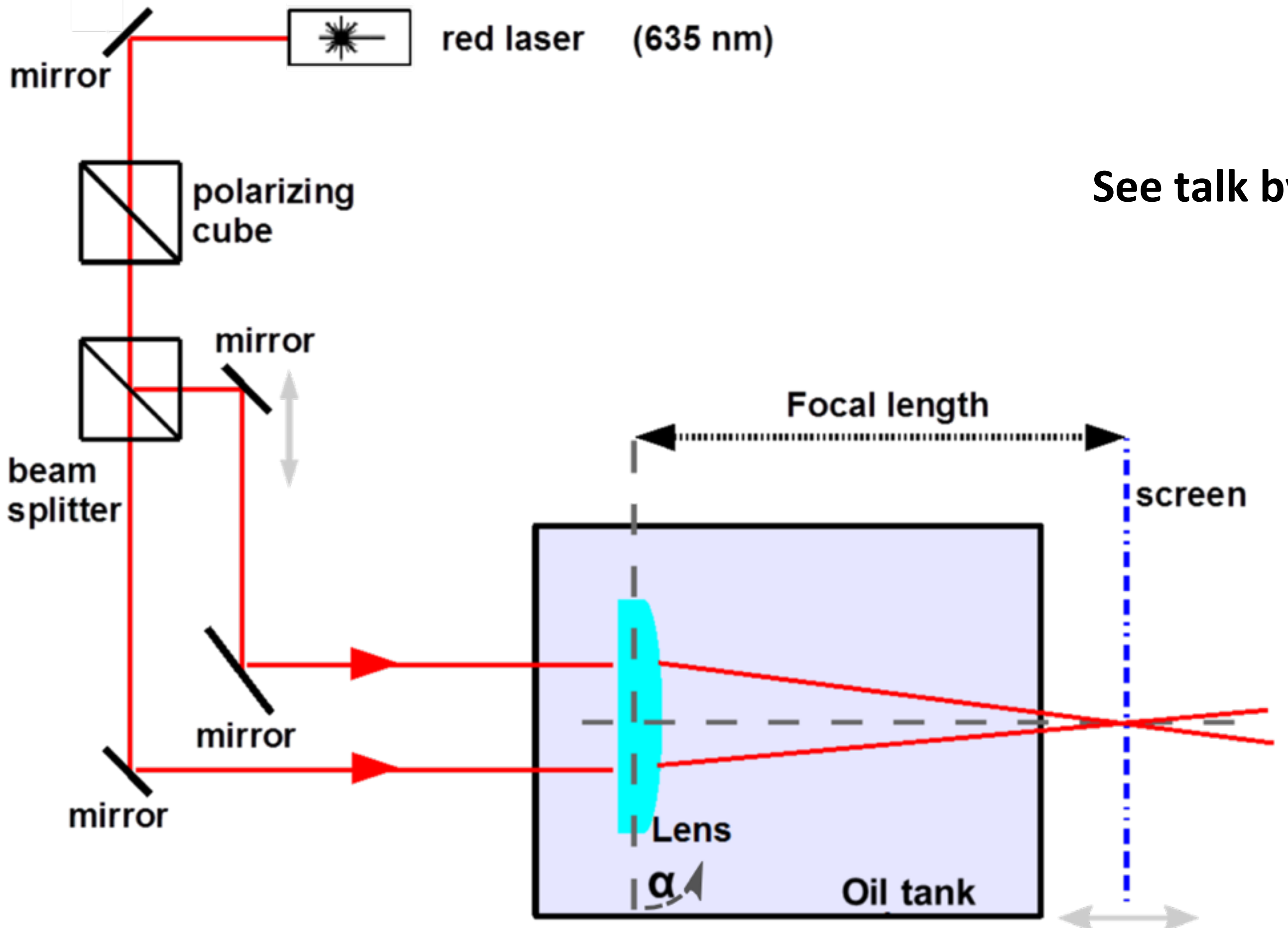


3-Component Lens **Performance verification**

Measurements on test benches

- Shape of focal plane measurement at ODU
- Radiation hardness test at Jlab

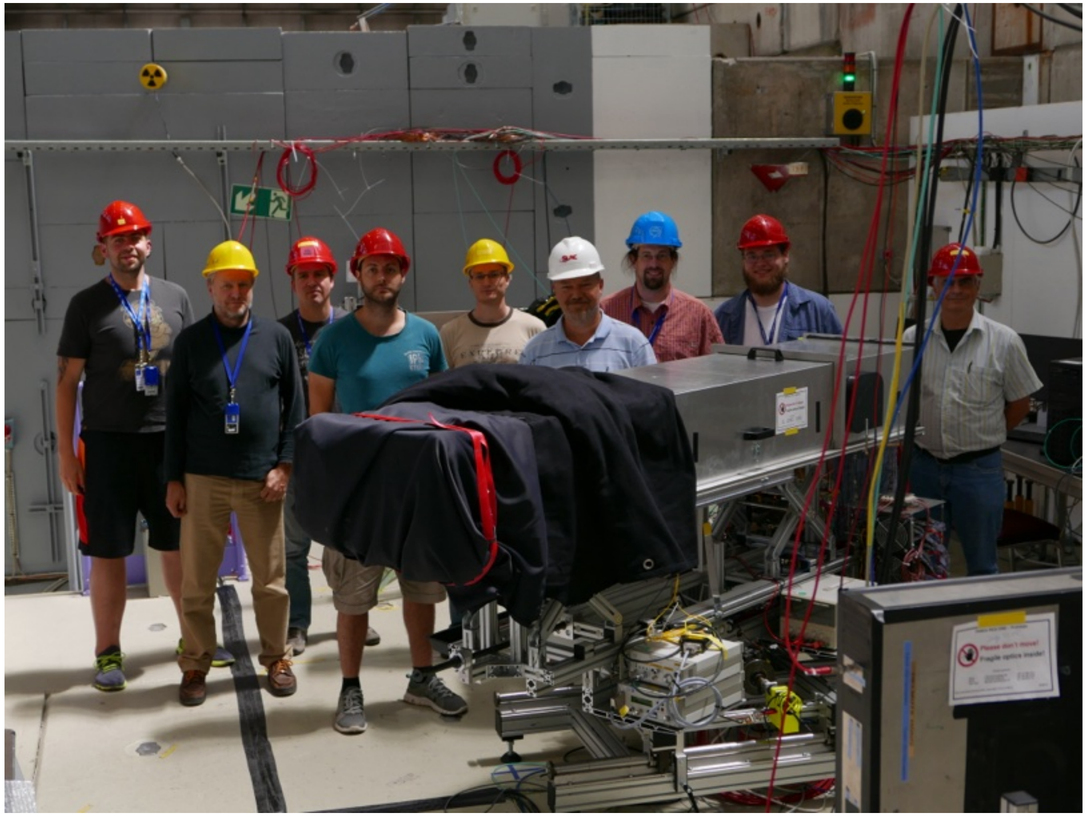


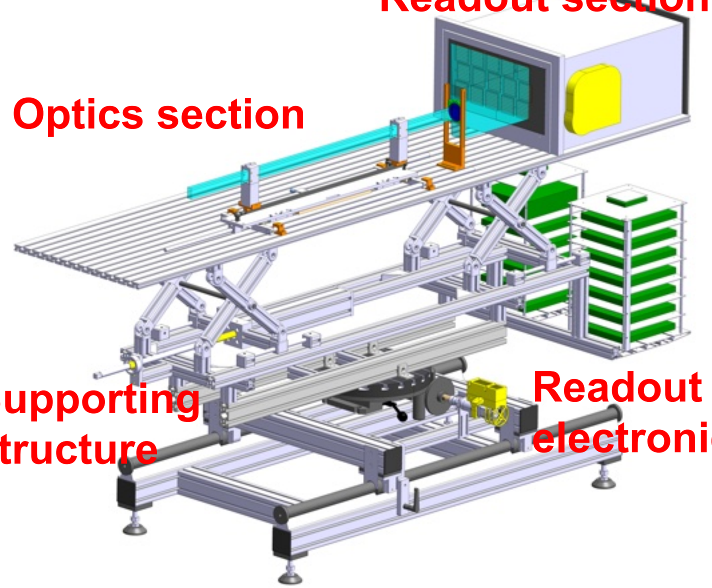
See talk by L. Allison

3-Component Lens **Performance verification**

Full system PANDA barrel DIRC prototype

- 6 weeks of measurements performed in CERN
- Several different focusing lenses were tested



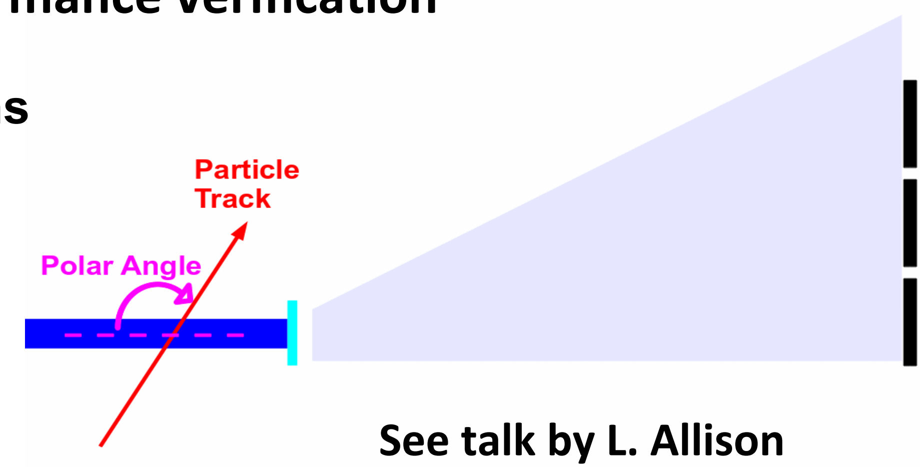


See talk by L. Allison

3-component Lens Performance verification

Comparison between standard air gap lens and 3 component lens

- 3CL improves both photon yield and resolution.



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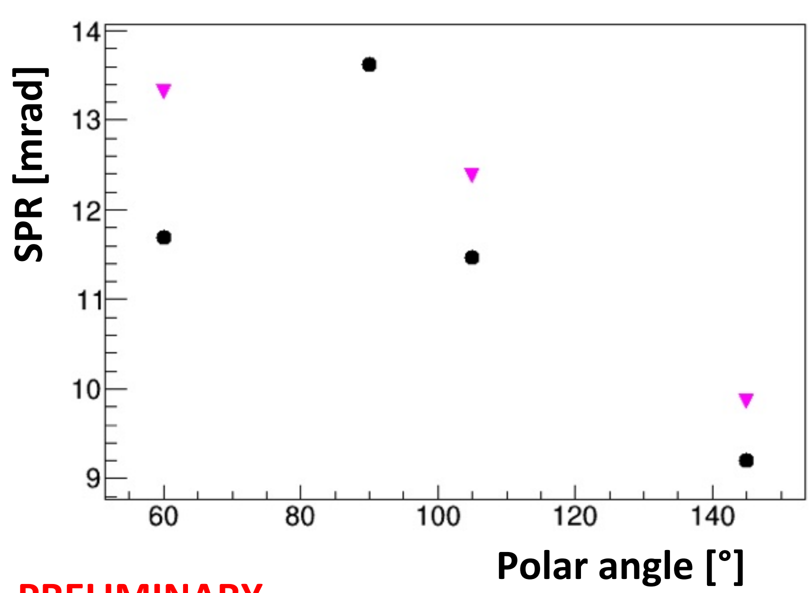
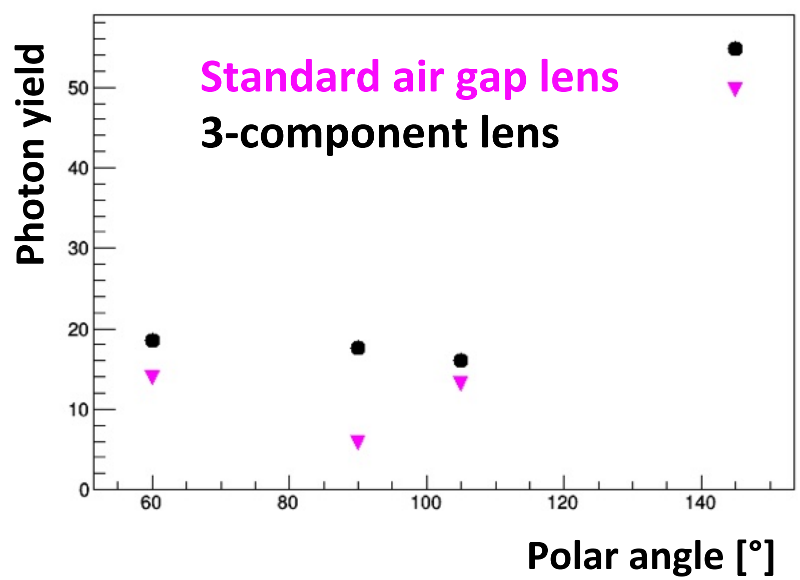




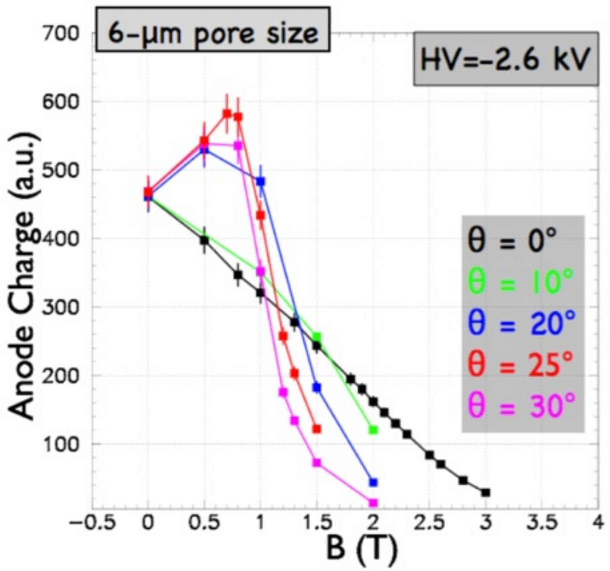
PRELIMINARY

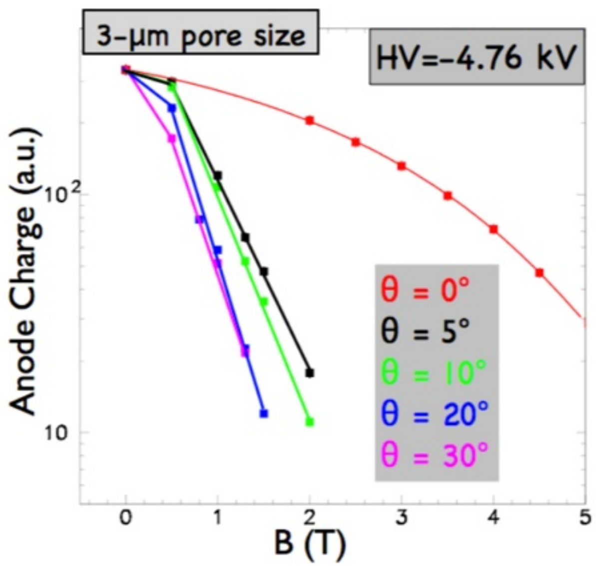
Test beam data

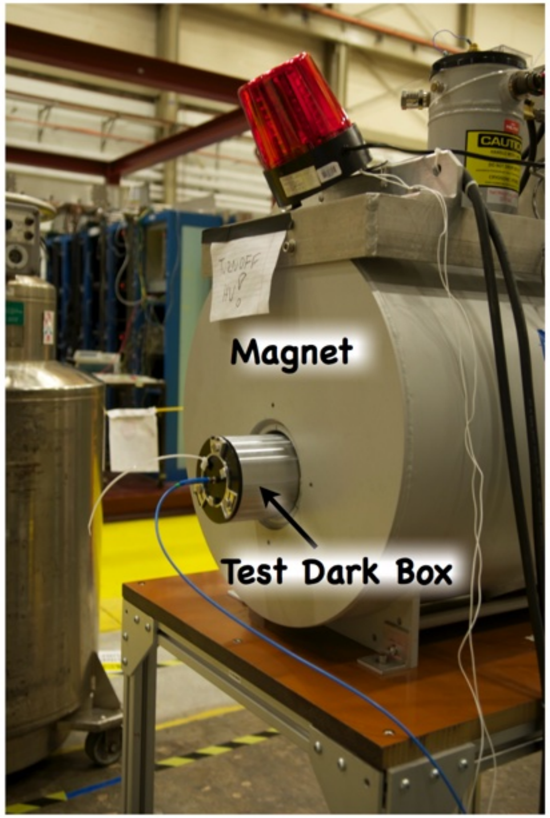
High B field test facility Measurements of photosensors

Measurements in 2014 and 2015 with several sensors at multiple positions in B field up to 5T

- Smaller Pore size - better performance
- Above 0.5 T the signal amplitude continuously decreases
- Very strong correlation between sensor orientation (both θ and φ) and averaged charge collected on anode
- Change of the voltages across allows to recover part of the signal



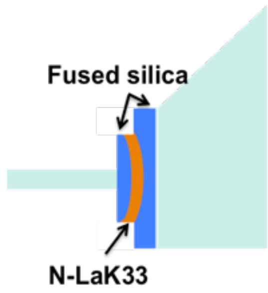


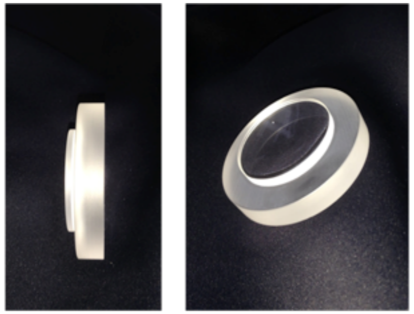


See talk by Y. Ilieva

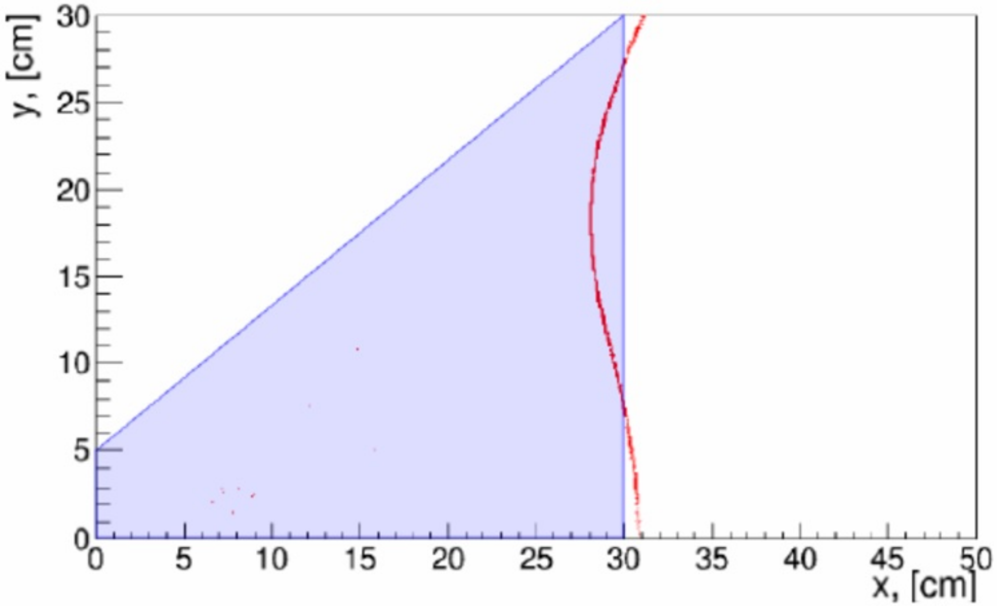
High-performance DIRC Tilted detector plane

Modification of 3-component lens





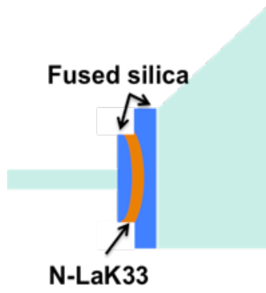
Geant4 simulation of 3-component lens

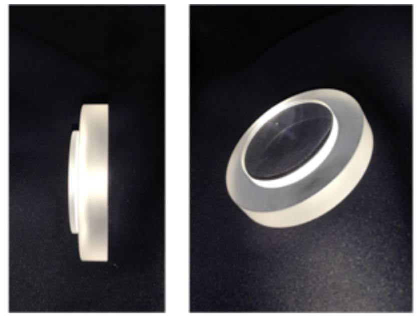


High-performance DIRC Tilted detector plane

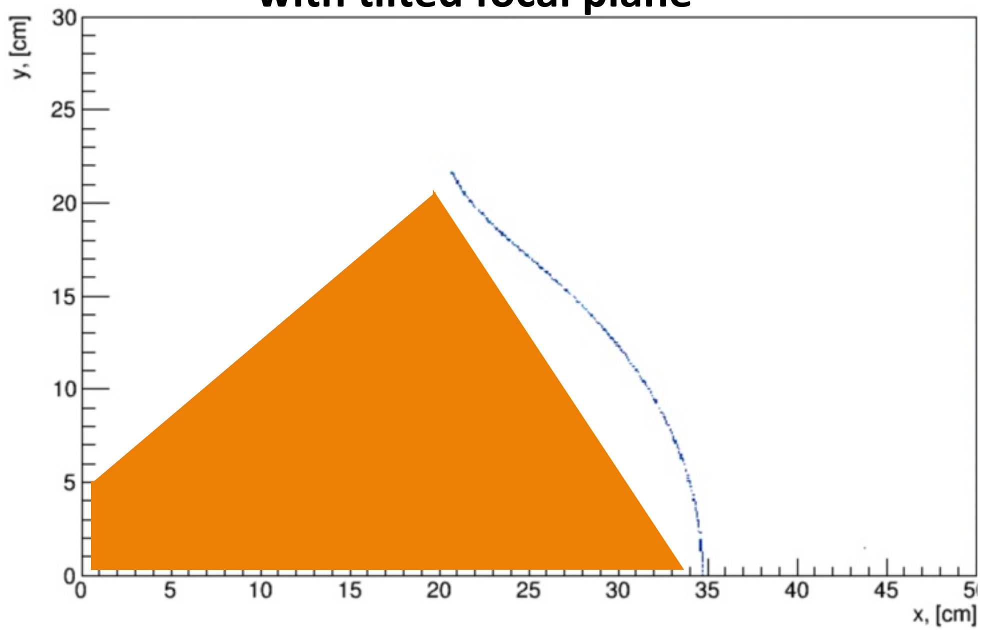
Modification of 3-component lens

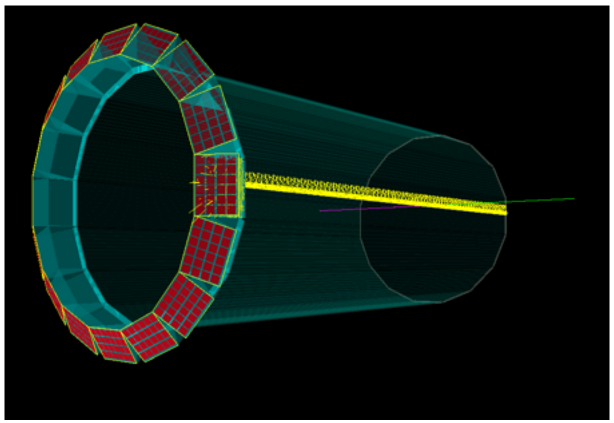
- Selecting different (larger) radiuses of lens layers allows to tilt the focal plane
- Tilted detector plane allows to locate sensors perpendicular to the B field lines
- Larger radiuses means smaller curvatures and allows to produce thinner lens what will improve photon yield.





Geant4 simulation of 3-component lens with tilted focal plane





Summary

Fundamental milestone achieved:
Simulation shows that 1 mrad Cherenkov angular resolution is reachable.

High Performance DIRC

- 3-component lens mitigates two crucial issues: photon yield loss and aberration
- Properties of 3-component lens evaluated in simulation
- Experimental tests of 3-component lens in beam and on test benches (ongoing)

High B test facility

- Tested several sensors from different vendors
- Observed strong dependence on sensor orientation in the field and pore size

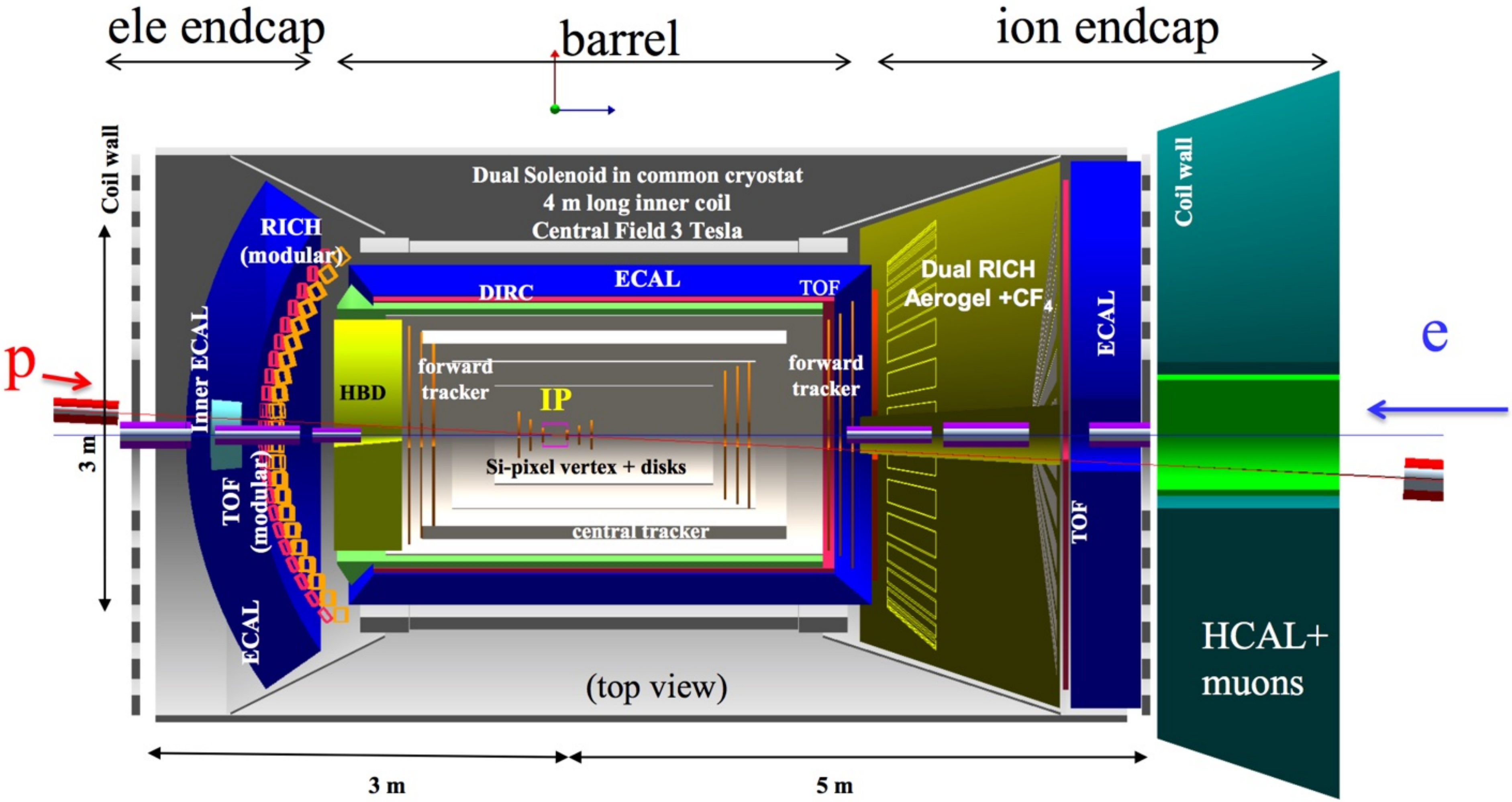
Tilted Detector Plane

- Optimized lens design allows to tilt the focal plane and place sensors perpendicular to the B field

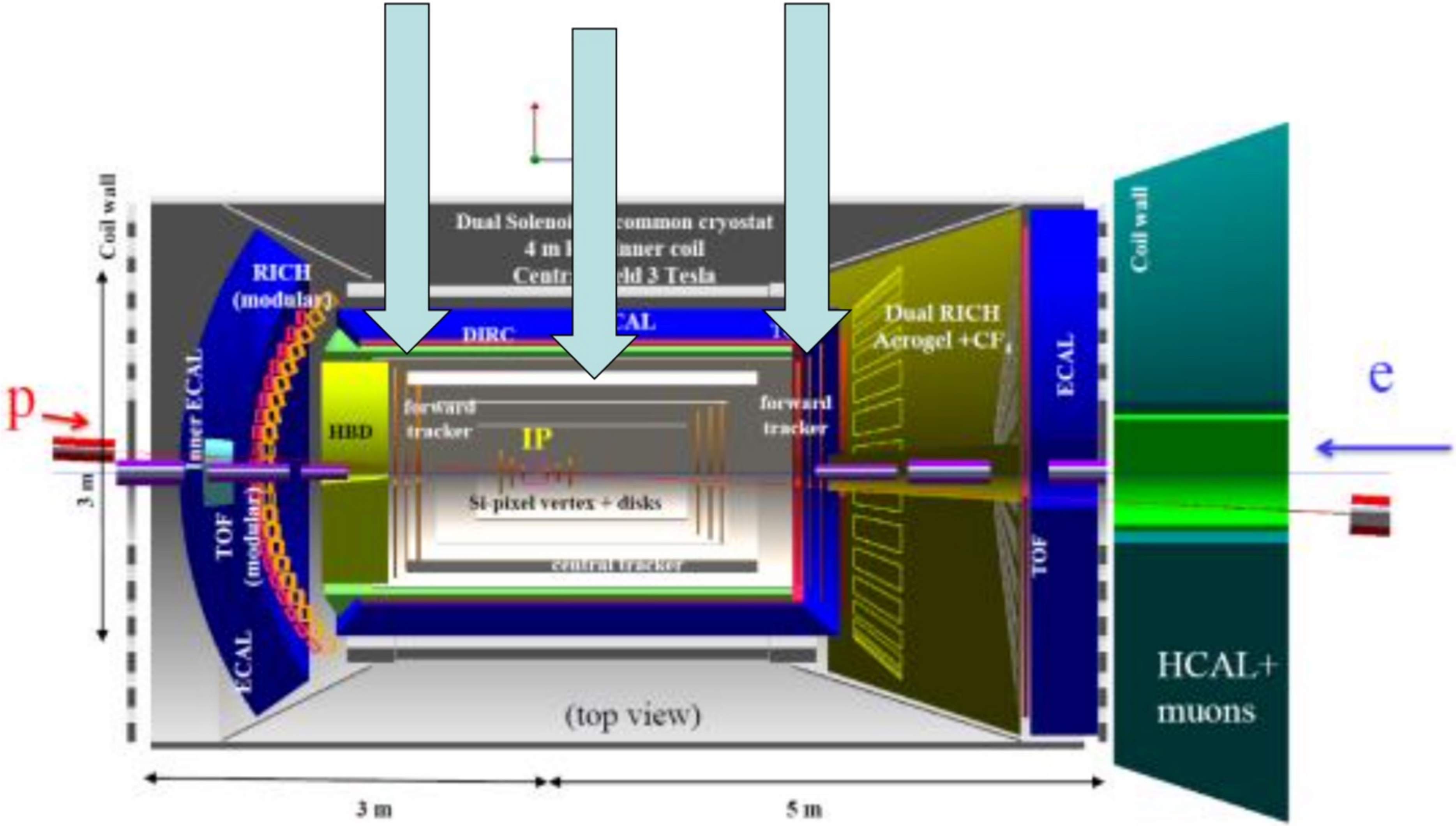
Backup

MEIC IP1 Central Detector

- Dual Solenoid Magnet, inner size similar to CLEO/BaBar magnet



Tracking (Gas Electron Multiplier)



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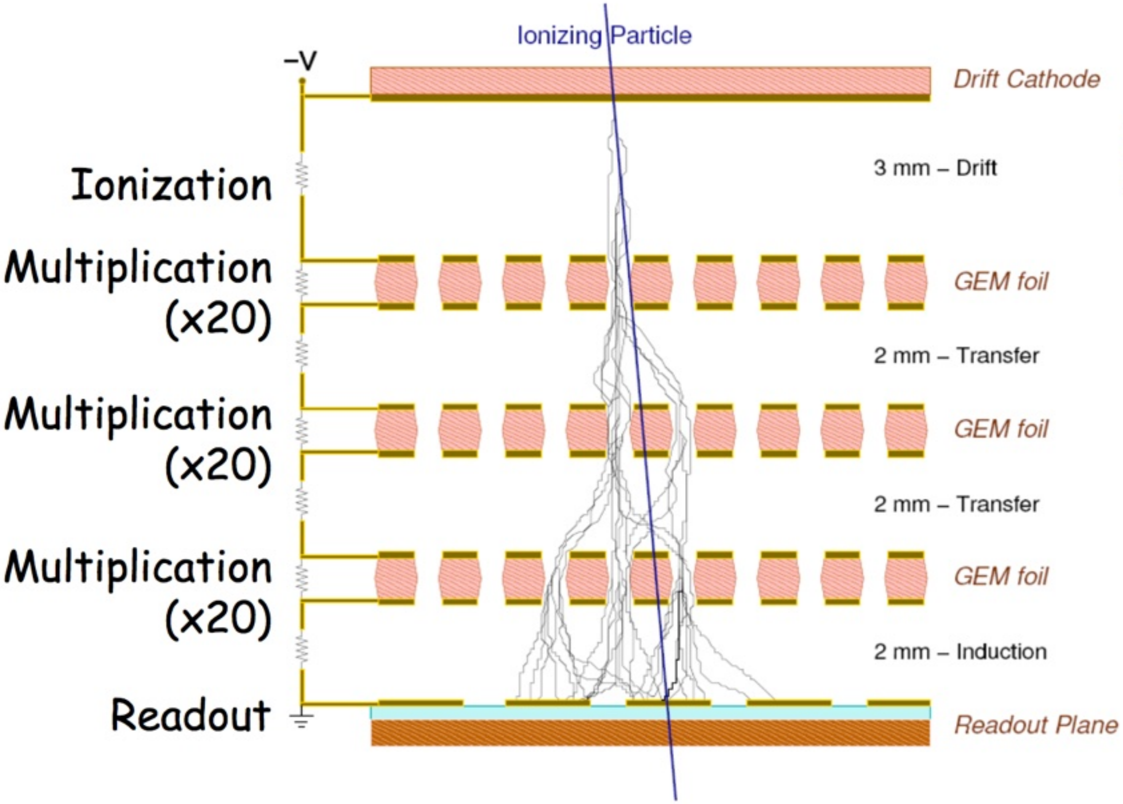
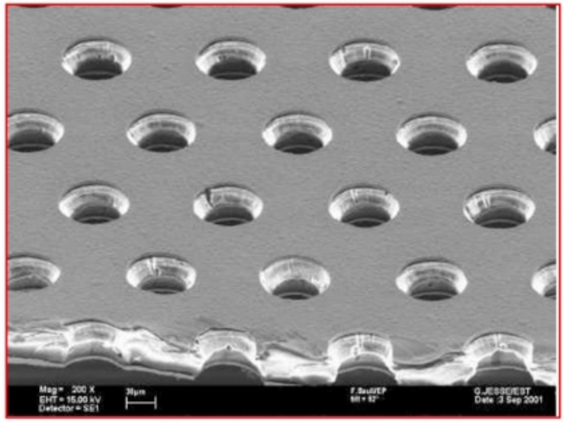
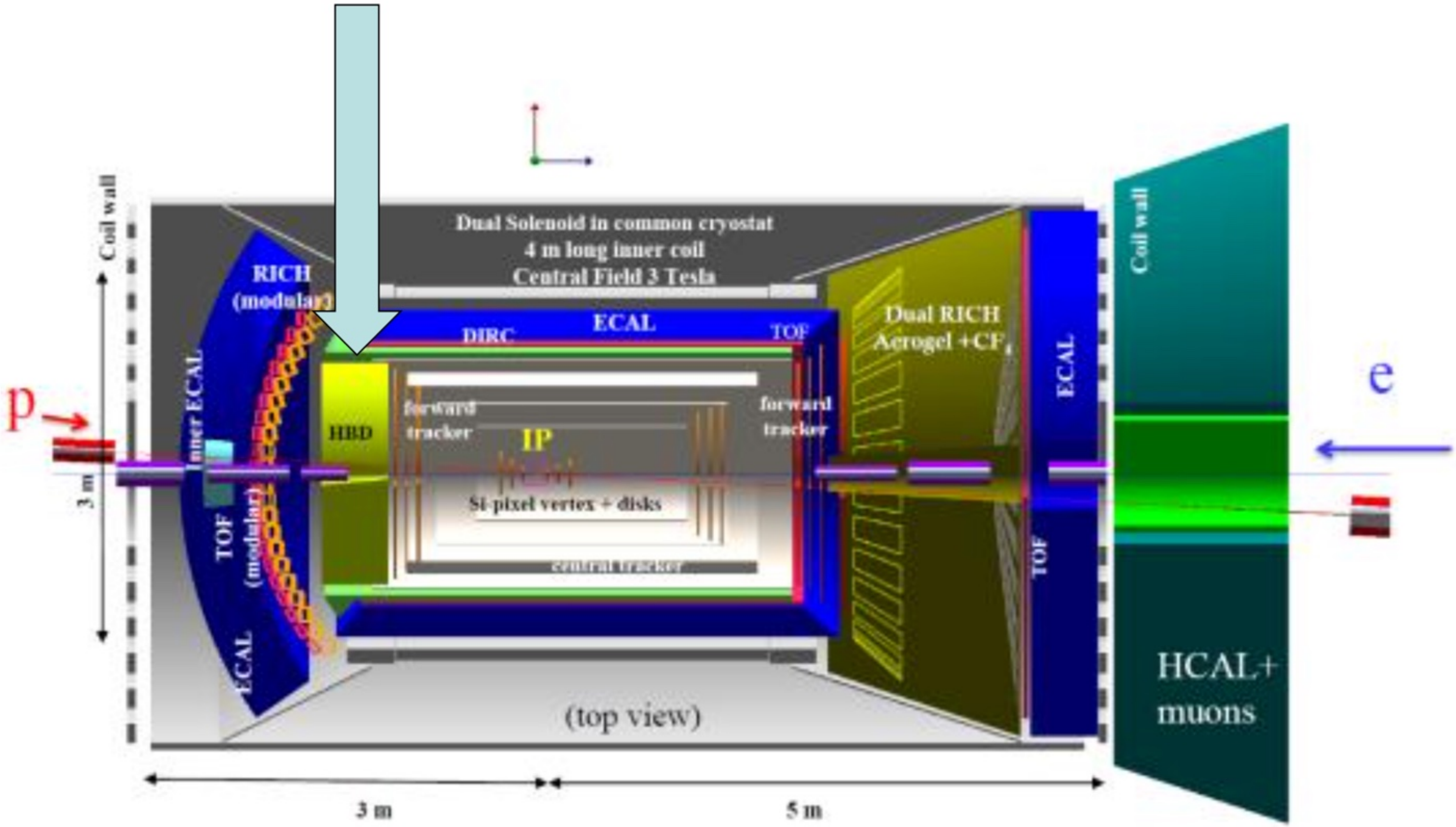


GEM foil: 50 μm Kapton + few μm copper on both sides with 70 μm holes, 140 μm pitch

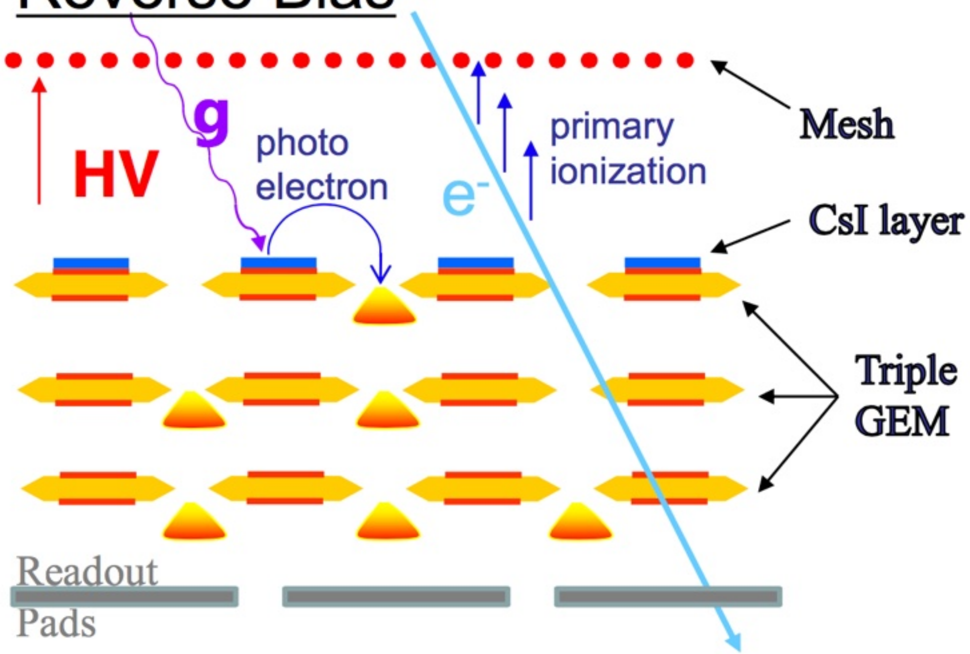


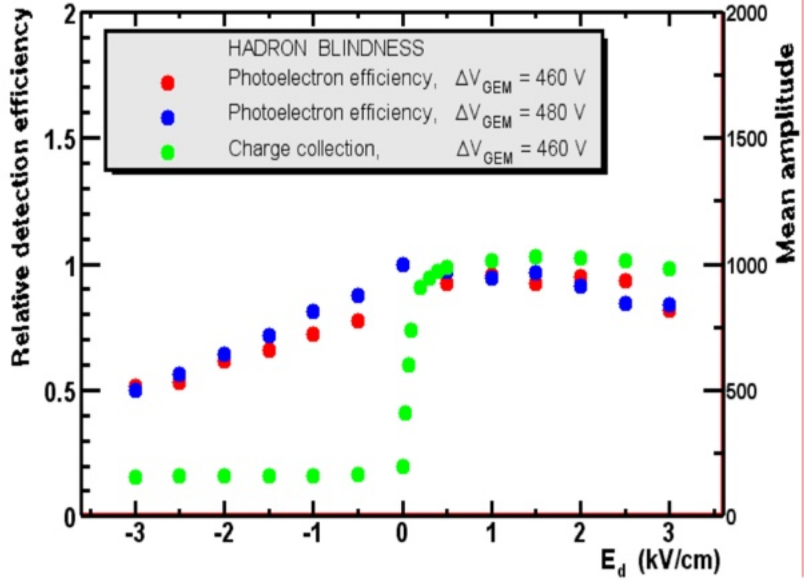
- Find particle tracks and measure momentum
- Work in high rate environment

Particle Identification Detector (Hadron Blind Detector)



Particle Identification Detector (Hadron Blind Detector)



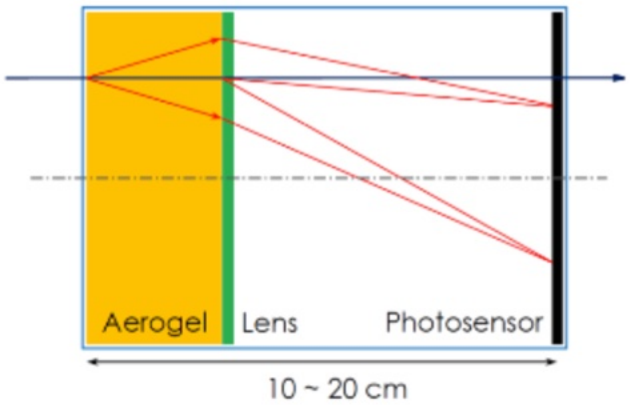


- Compact e/π PID detector
- Blind to hadron < 4GeV with CF_4 gas at PHENIX

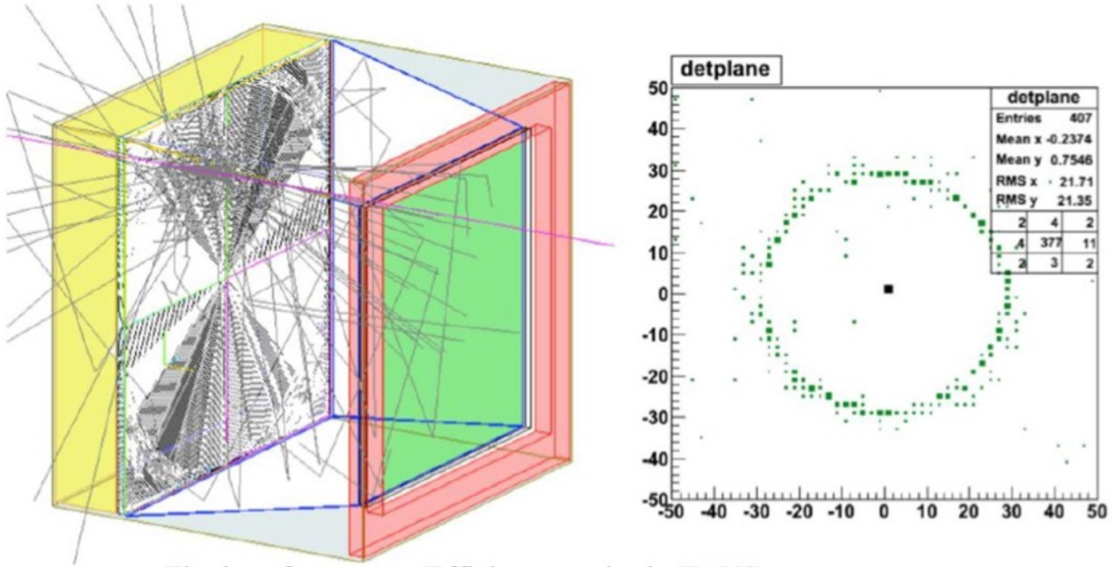
Tom Hemmick @ StonyBrook

Particle Identification Detector (Modular RICH)

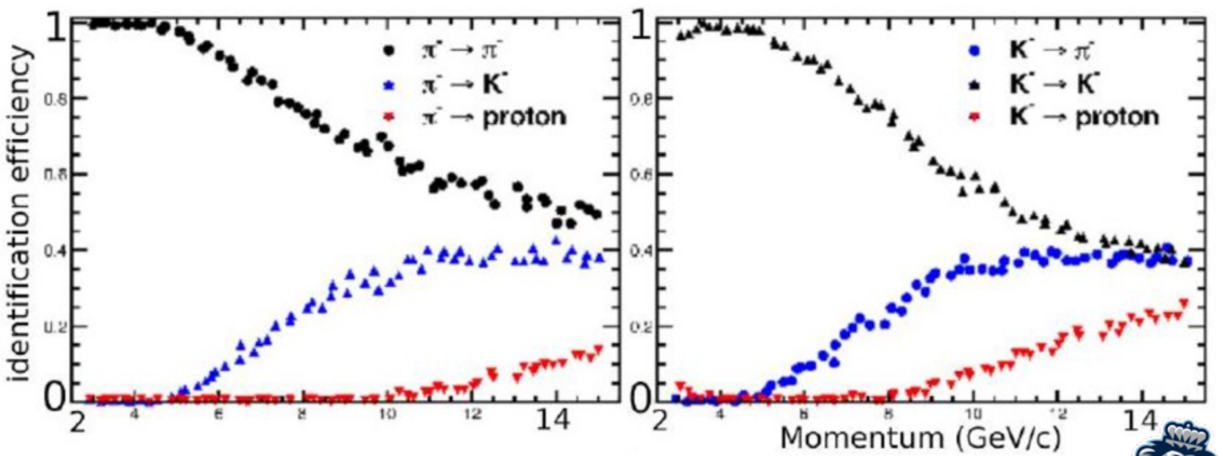
Concept



Simulation in **GEMC**



Final performance : Efficiency and mis-ID VS momentum

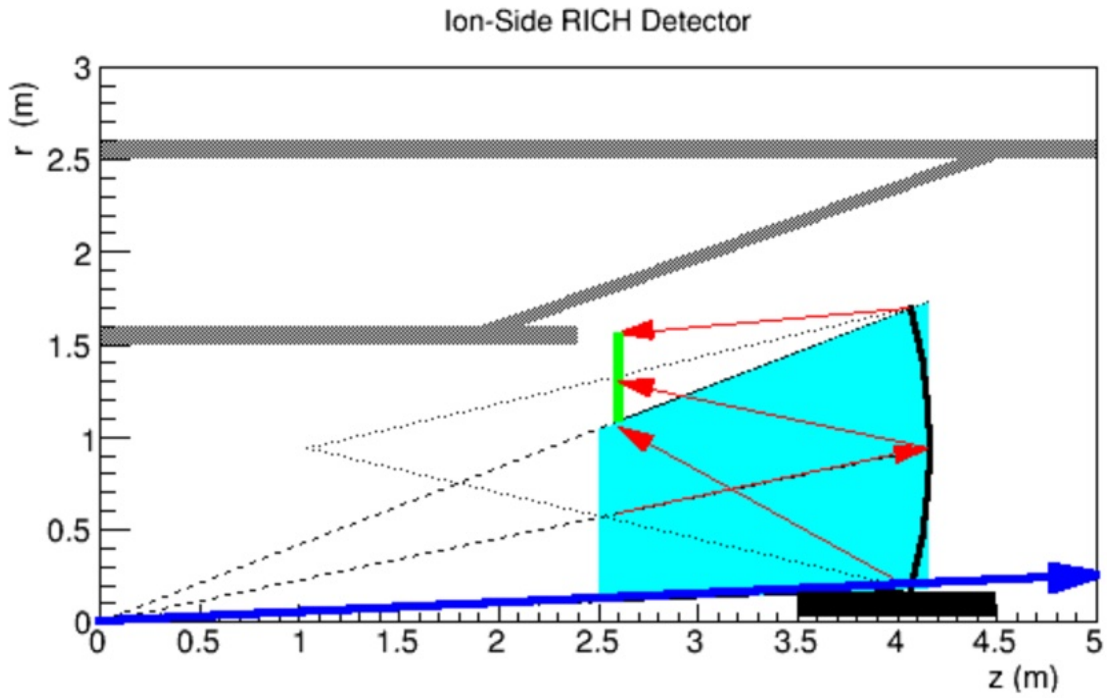


- Compact π/K PID detector at ele endcap
- Flexible arrangement, can be projective to IP at ele endcap

EIC R&D PID (RICH)

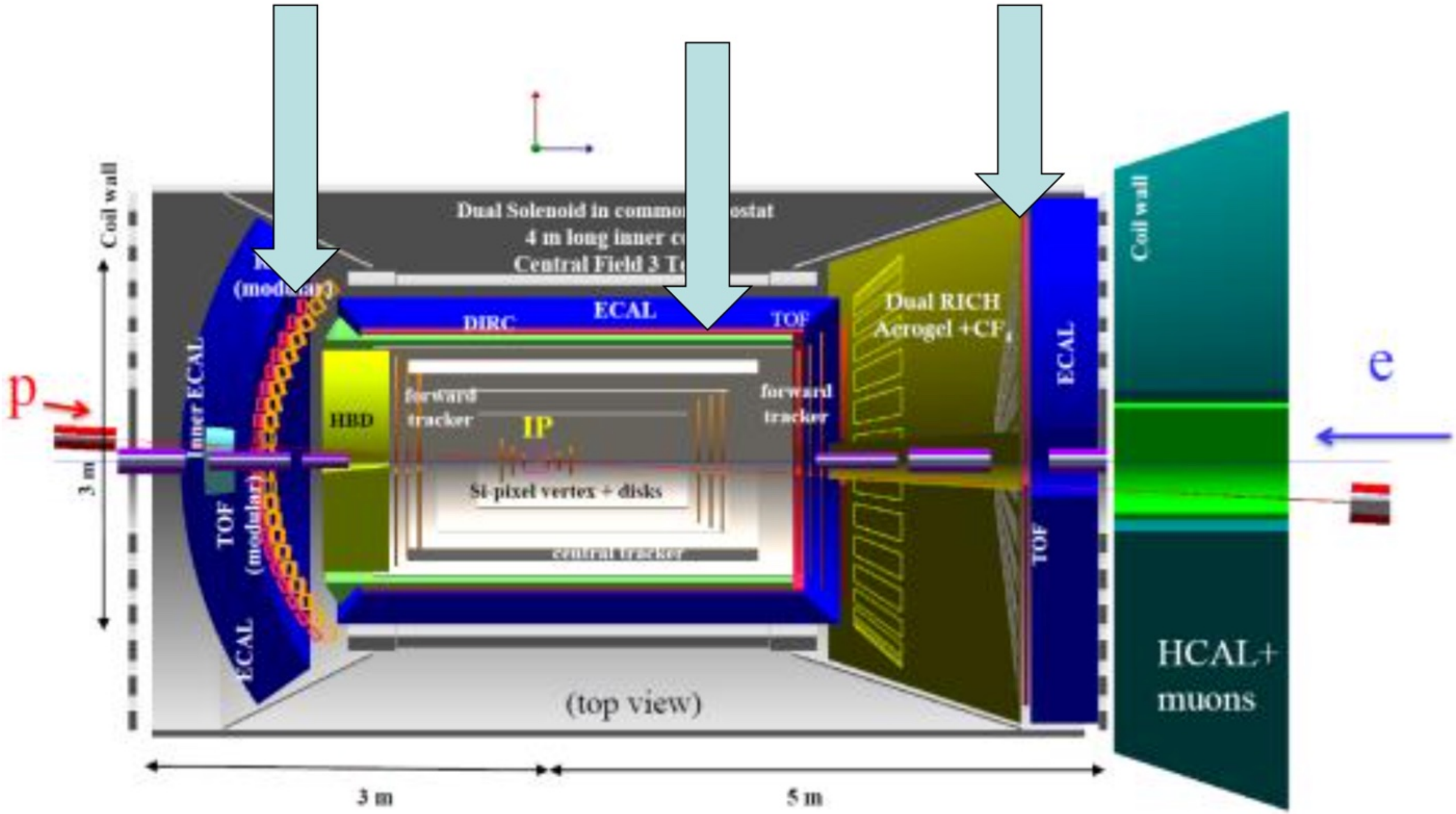
Particle Identification Detector (Dual Radiator RICH)

- π/K PID detector at ion endcap
- Aerogel with Fresnel lens ~75 cm focal length: image at focal point of mirror (also filter UV)
- CF_4 gas (visible + UV)
- 2nd mirror to place photo sensors in weaker field?

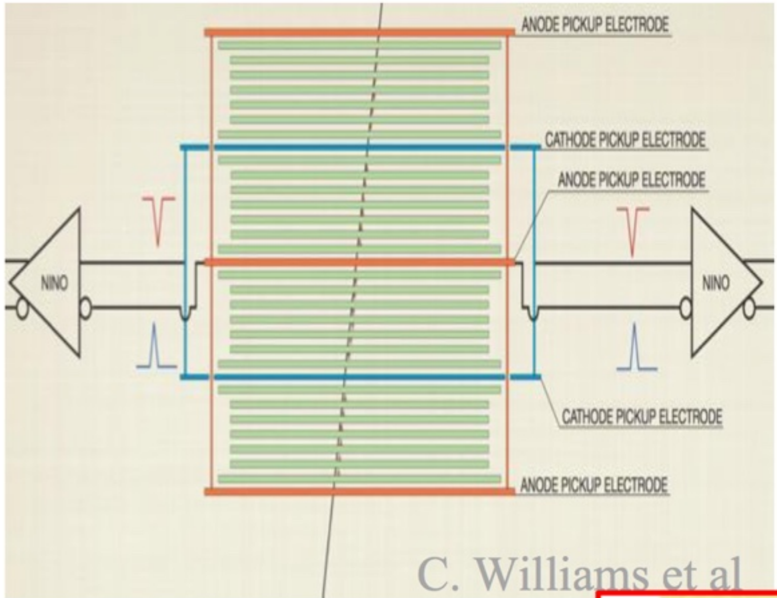


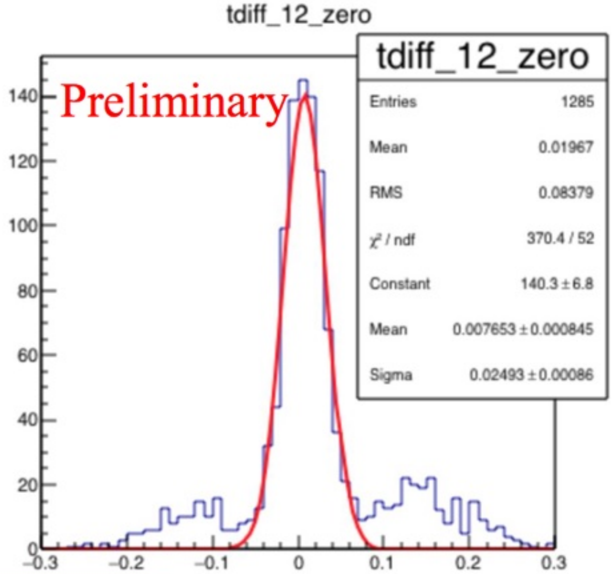
EIC R&D PID (RICH)

Particle Identification Detector (Time of Flight)



Particle Identification Detector (Time of Flight)

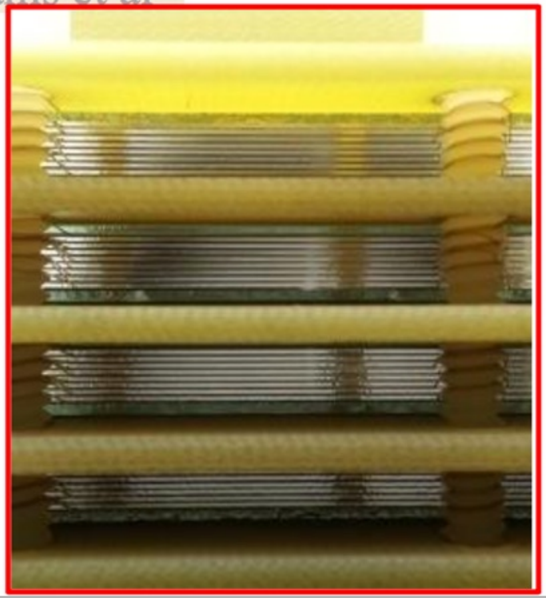


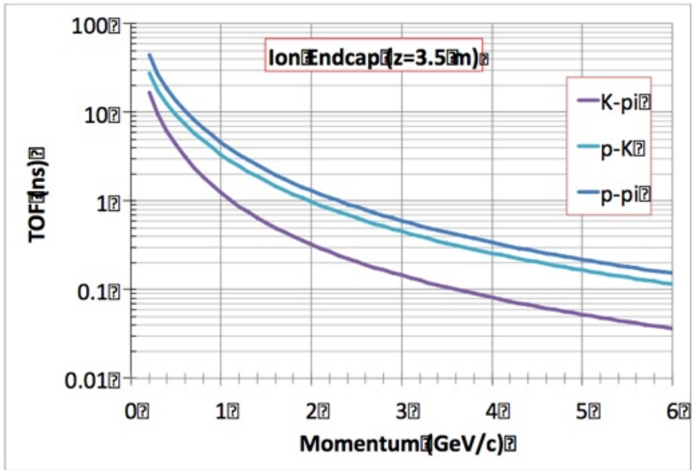


$\Delta t = t_2 - t_1$
$= 25$ ps

$\sigma_t = \Delta t/\sqrt{2}$
$= 18$ ps

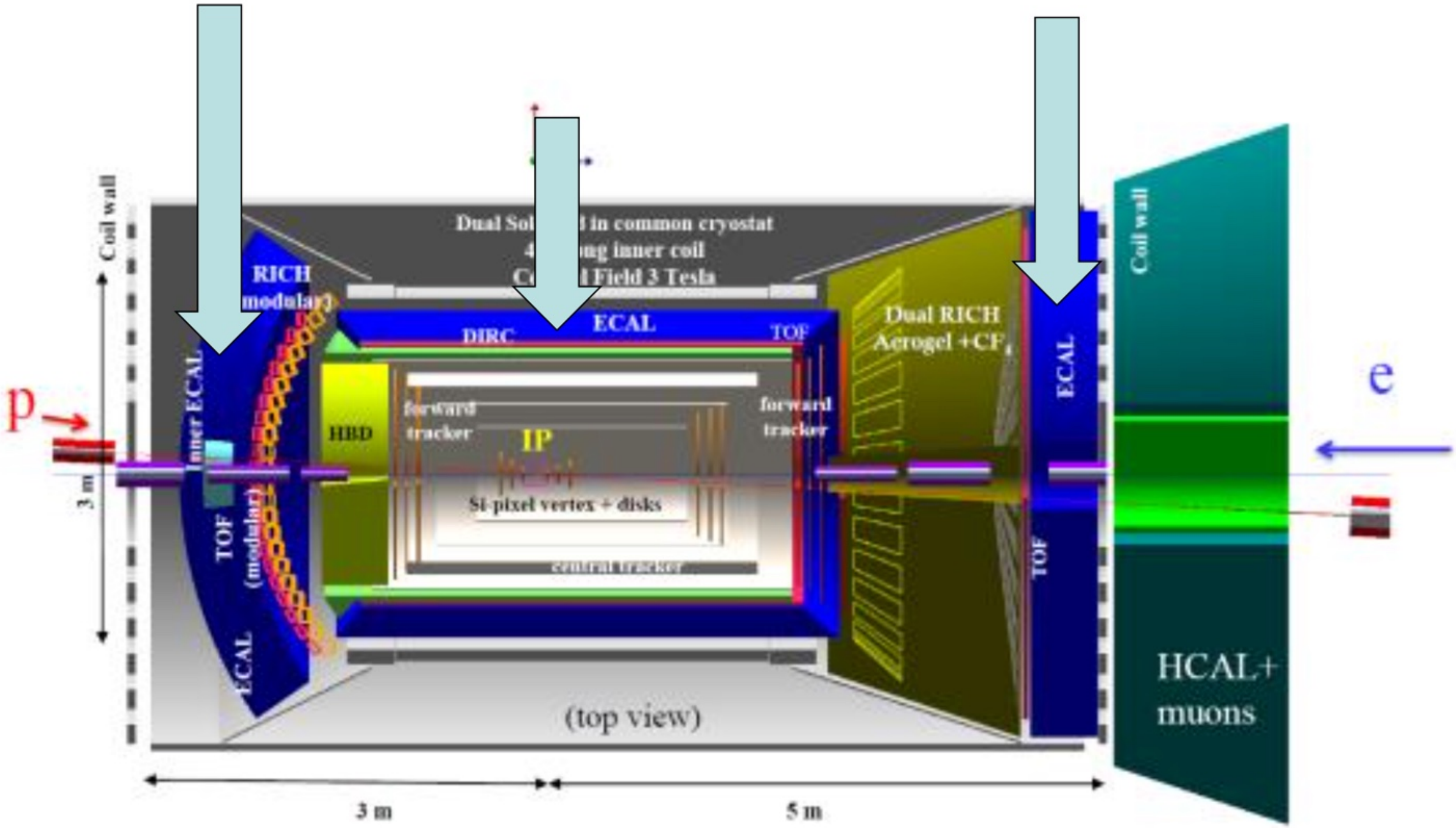
- Compact PID detector
- Flexible arrangement, can be modular, can be at both endcaps and barrel



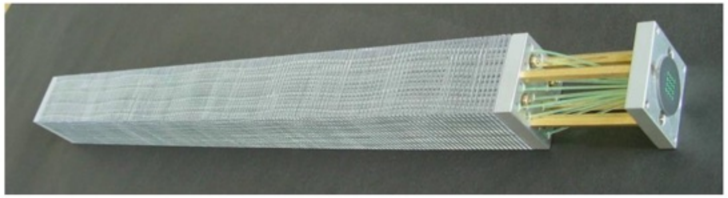


EIC R&D PID (TOF)

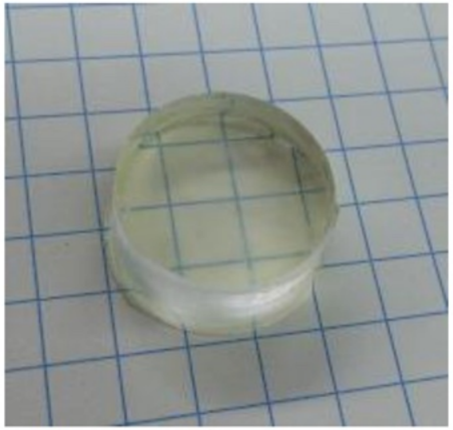
Particle Identification Detector (EMCal)



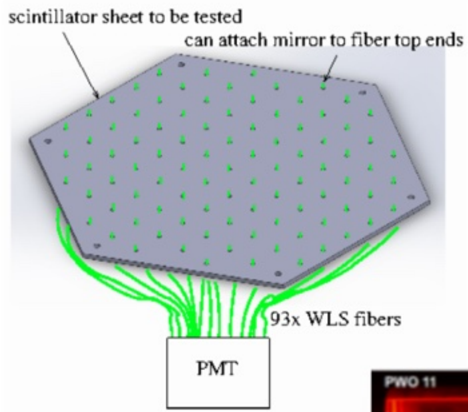
Particle Identification Detector (EMCal)



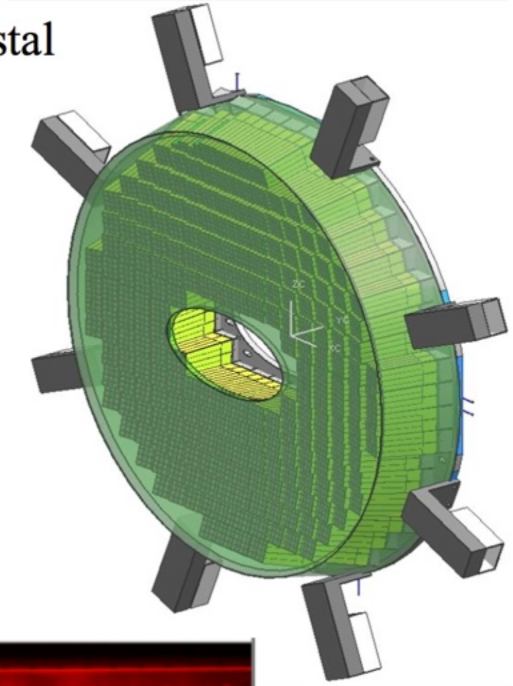
IHEP, COMPASS Shashlik, 2010

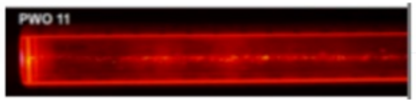


3D-printed scintillator at W&M

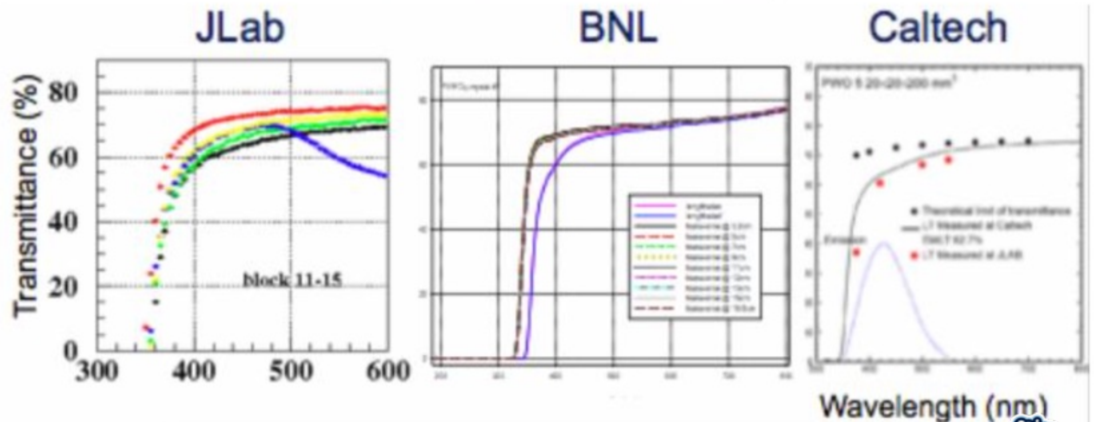


Panda Crystal endcap





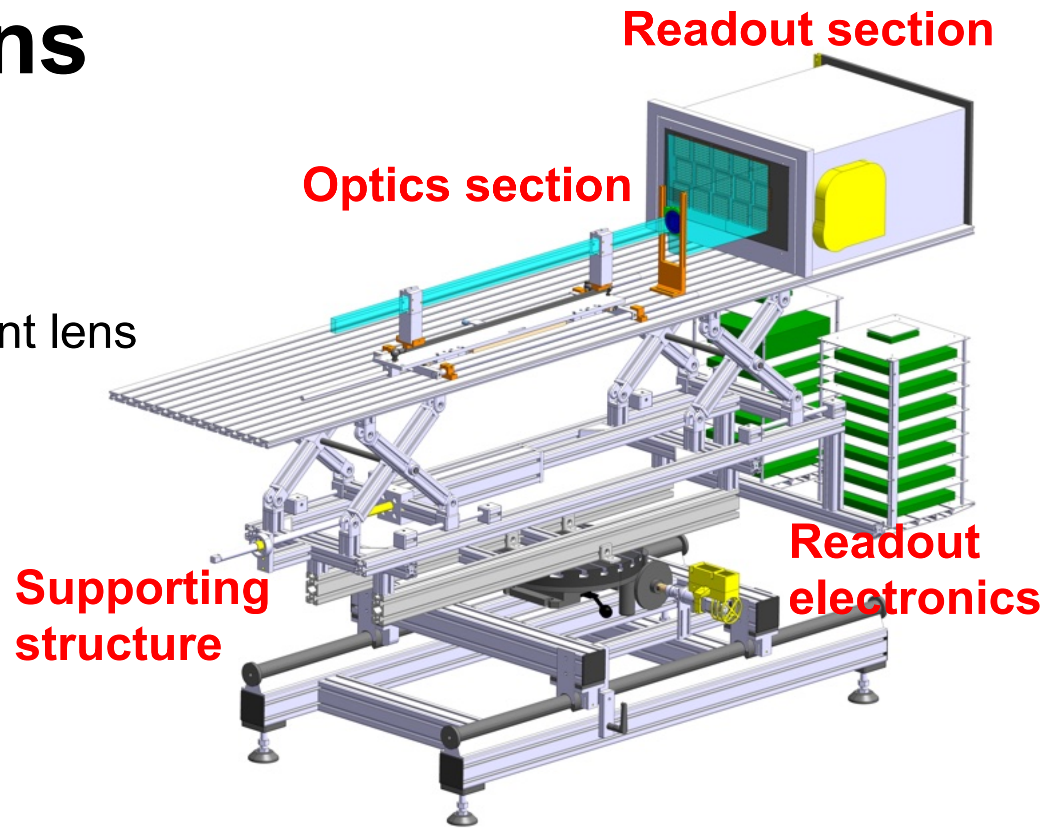
- Shashlik type at large angle with balanced performance and cost
- Crystal type at small angle compensate for tracking resolution
- Pb/SciFi type at barrel

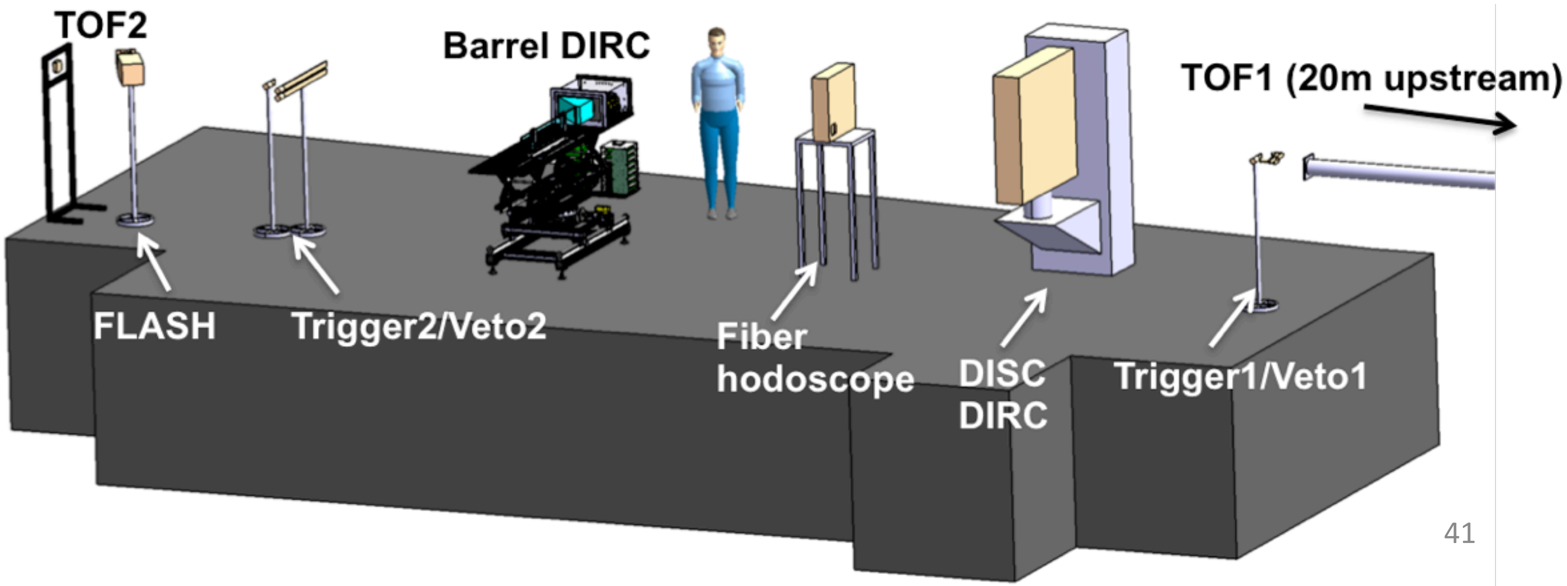


EIC R&D Calorimeter

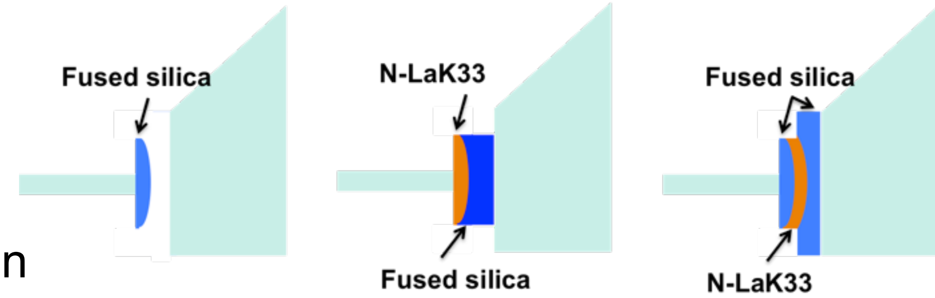
Test beam campaigns

- **2014 campaign in GSI:**
  - First experience with 3-component lens
- **2015 campaign in CERN:**
  - Around 6 weeks of beam
  - Participation of Postdoc and PhD student from ODU

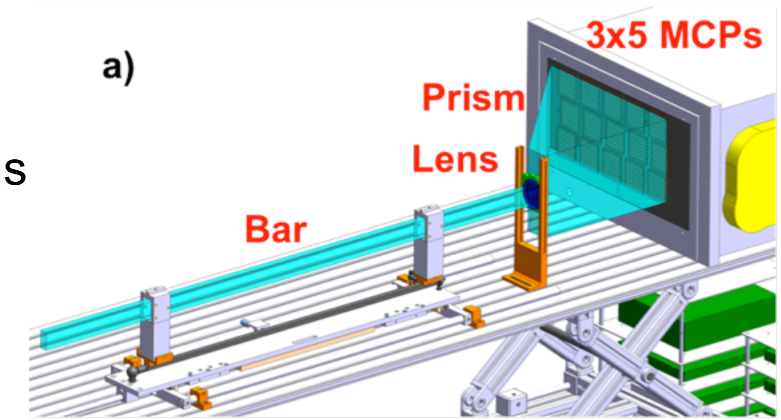


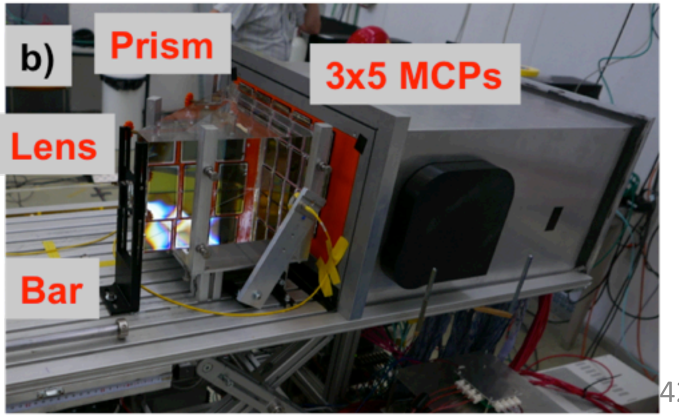


High-performance DIRC Prototype 3-component lens

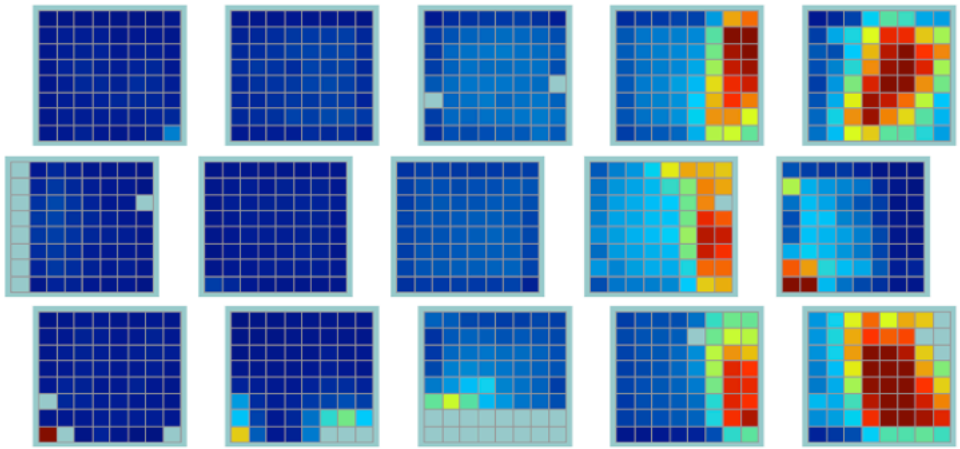


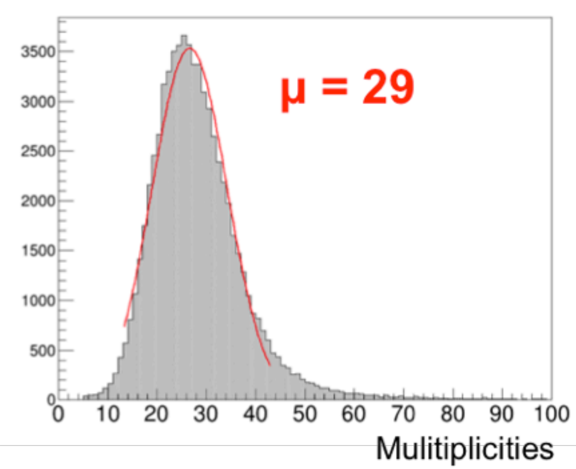
- **Polar angle of beam to bar:**
  - ➢ 20°-160° range with 5° step
  - ➢ Several fine scans for better resolution evaluation
- **Different focusing lenses:**
  - ➢ Air gap spherical and cylindrical lens
  - ➢ Spherical and cylindrical 2-component lens
  - ➢ Spherical 3-component lens
- **Different radiator:**
  - ➢ Narrow bar
  - ➢ Wide plate
- **Momentum scans**
  - ➢ 2-10 GeV/c scans.



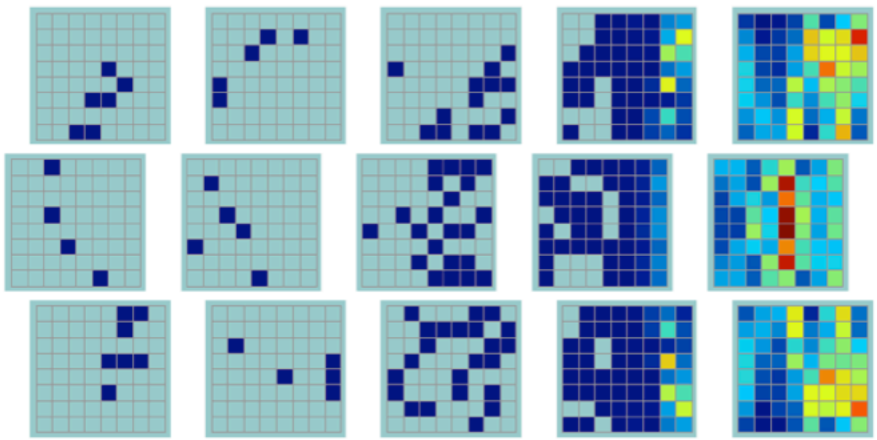


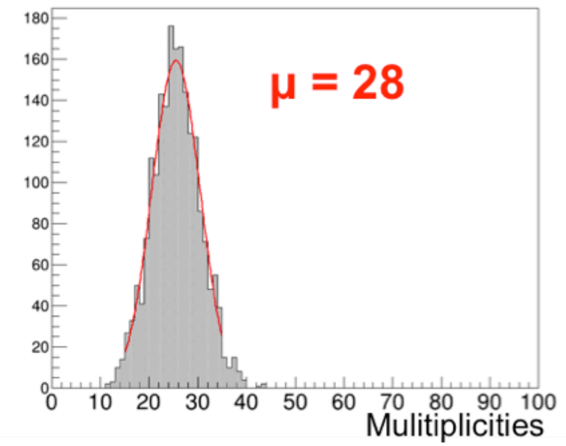
2015 Campaign: Beam polar angle: 90°





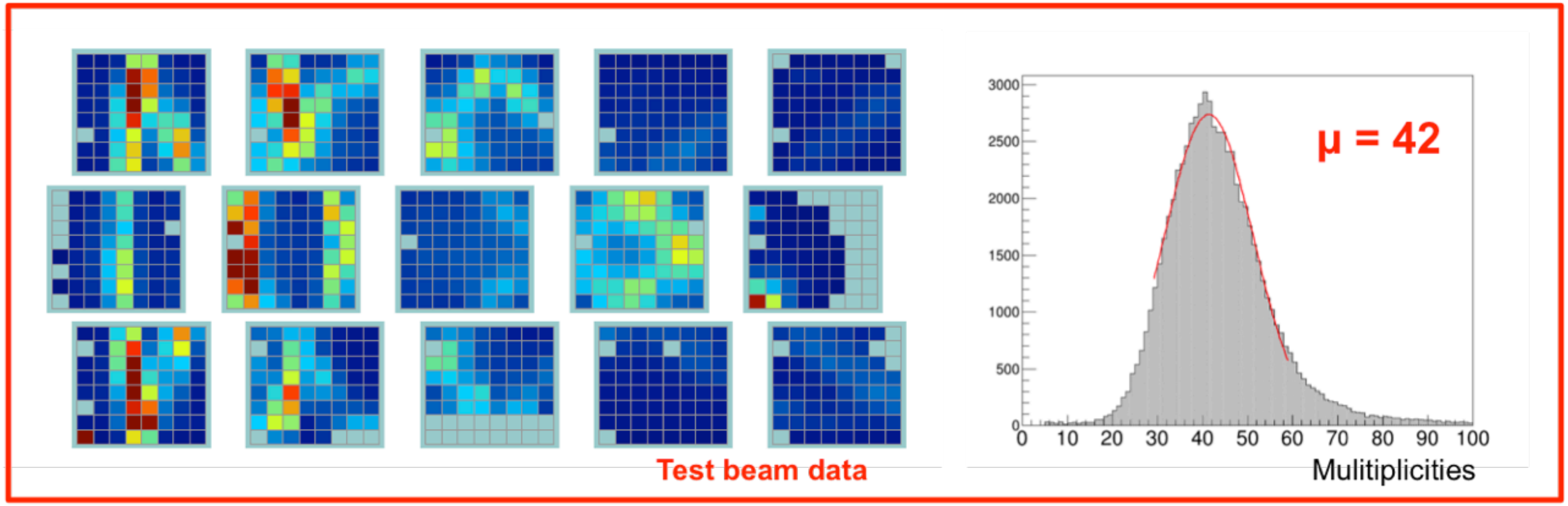
Test beam data

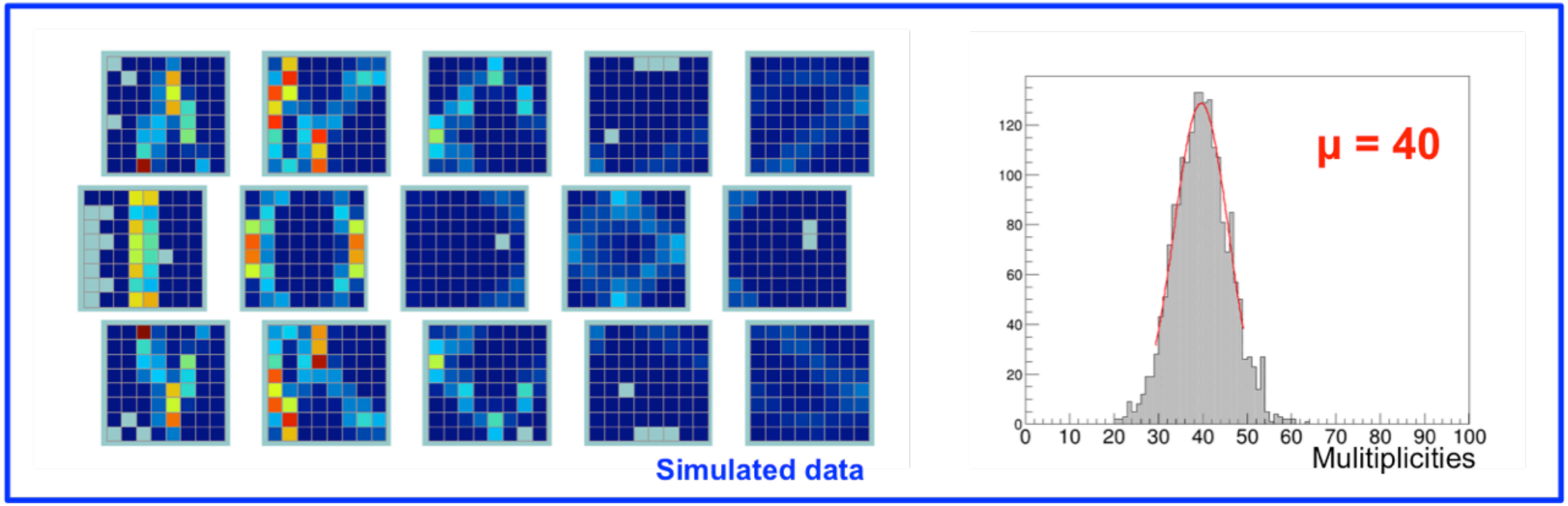




Simulated data

2015 Campaign: Beam polar angle: 125°

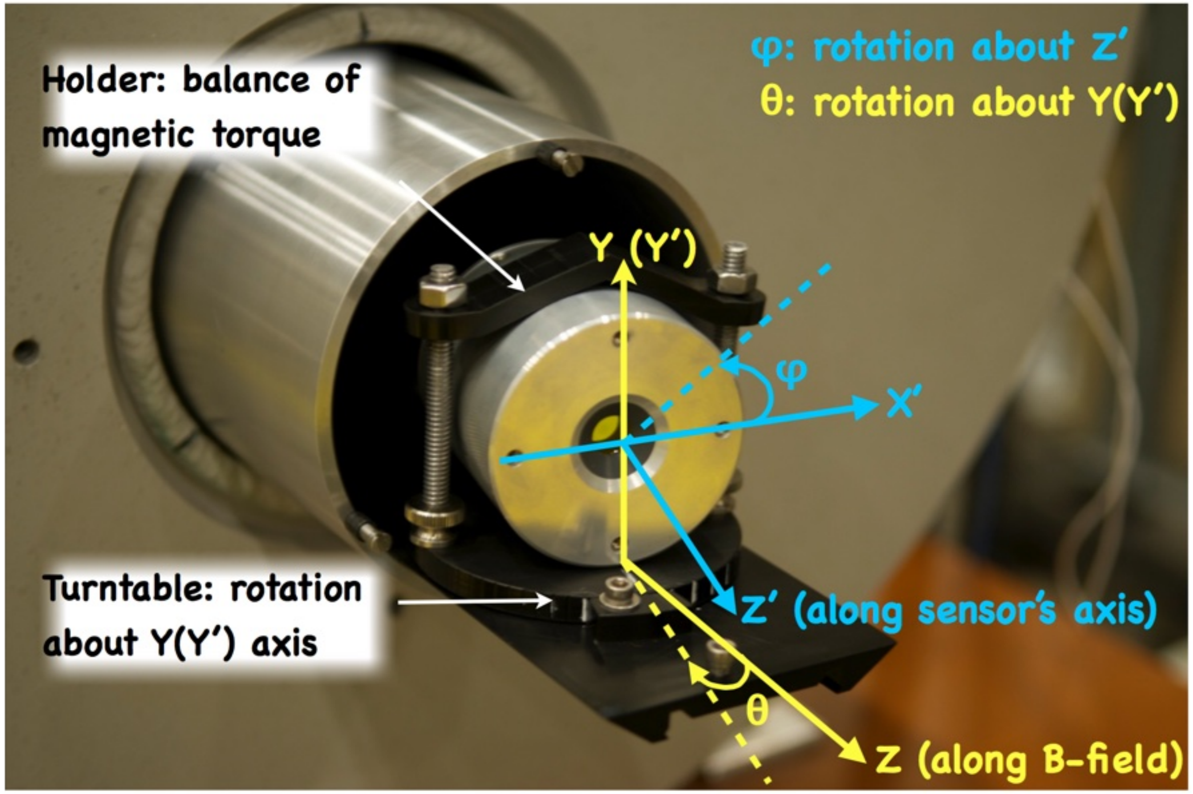




High B field test facility Measurements of photosensors

Magnet:
- superconducting solenoid
- max. field: 5.1 T at 82.8 A
- 12.7cm (5inch) diameter 76.2cm (30inch) length bore:

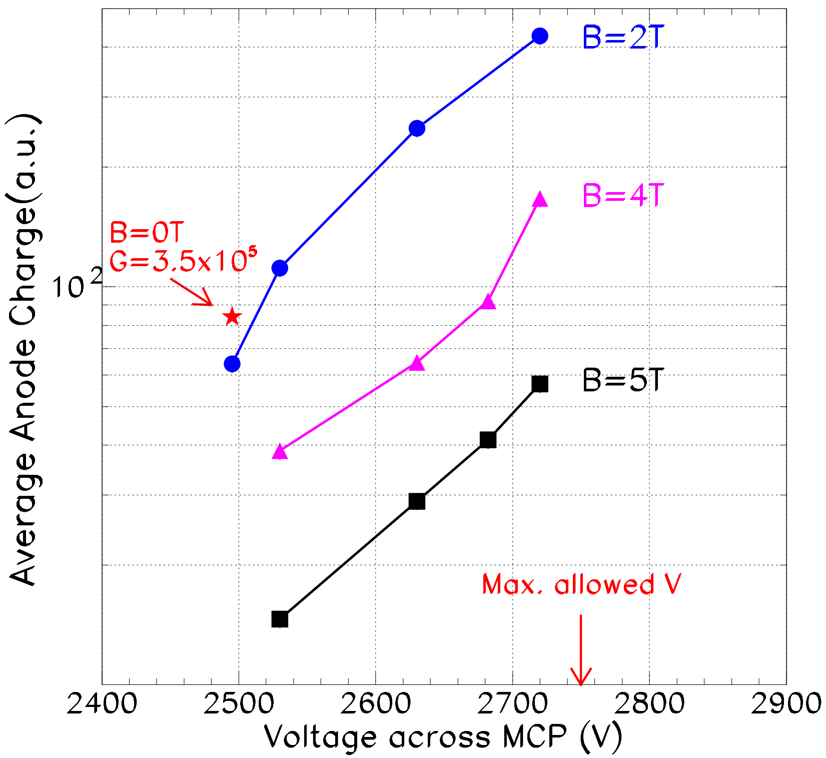
Test Box:
- non-magnetic, light-tight
- allows for rotation of sensors
- LED light source



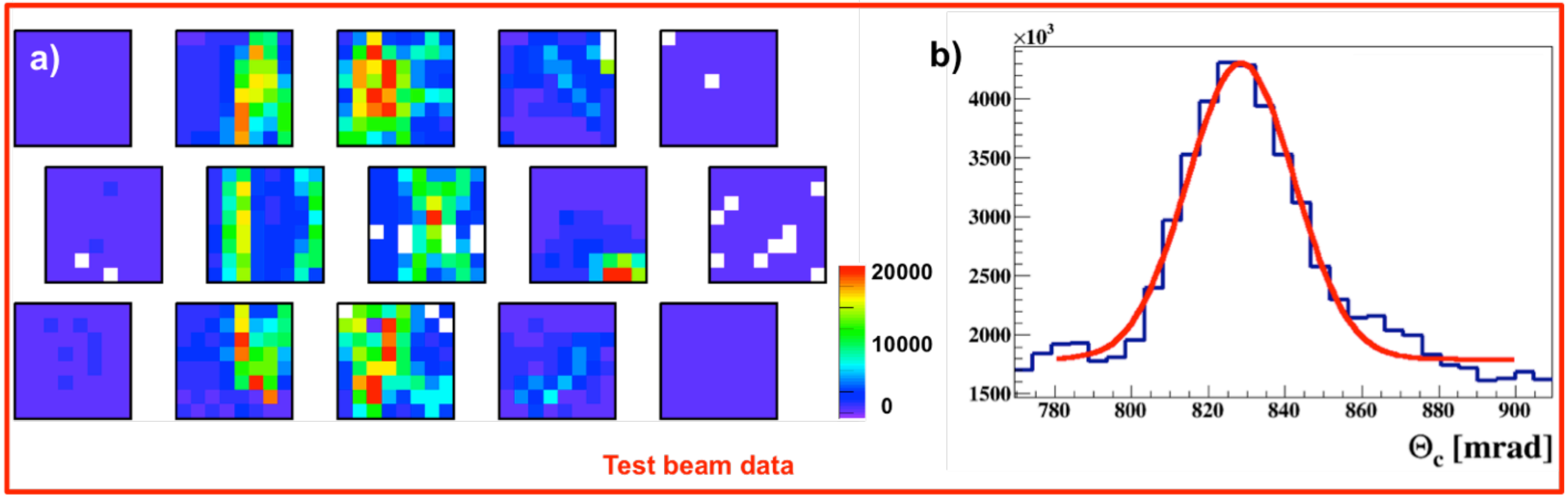
High B field tests Gain measurements of photosensors

Measurement in 2015 of Photek sensor with special voltage divider:

- Independently change the voltages cathode-MCP, across MCPs, and MCP-anode and study gain dependence
- Confirmed that voltage across the MCPs affects the gain the most
- Data at other angles are under analysis



2014 Campaign: Beam polar angle: 124°




Please don't move!
Fragile optics inside!