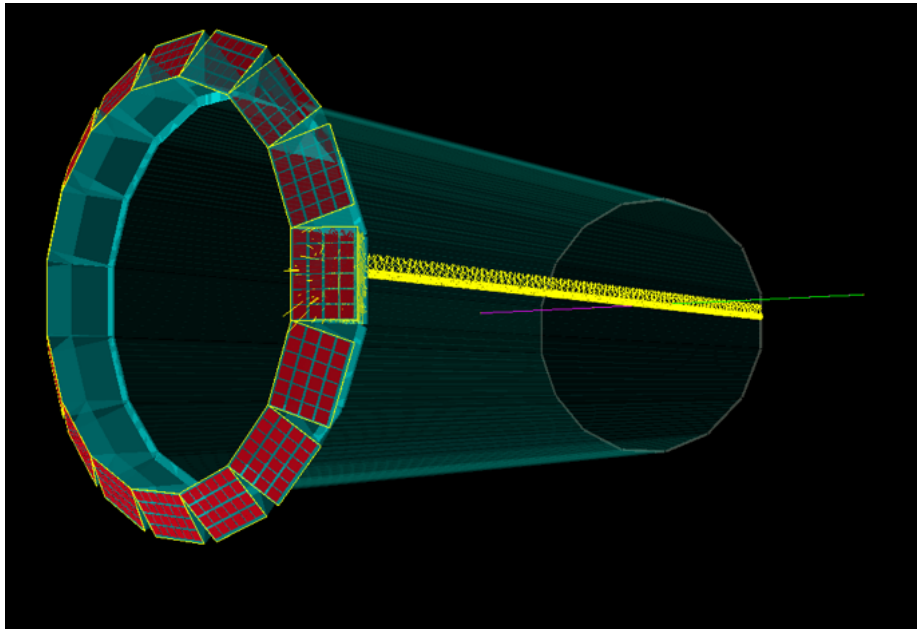
# High Performance DIRC Detector for future EIC Detector

**Greg Kalicy** on behalf of PID@EIC Consortium

**Outline:**

- **Electron ion Collider**
  Three detector options
- **High-Performance DIRC**
  Design and performance
- **3-layer lens**
  Validated in particle beam and lab



CUA

August 8th, 2017

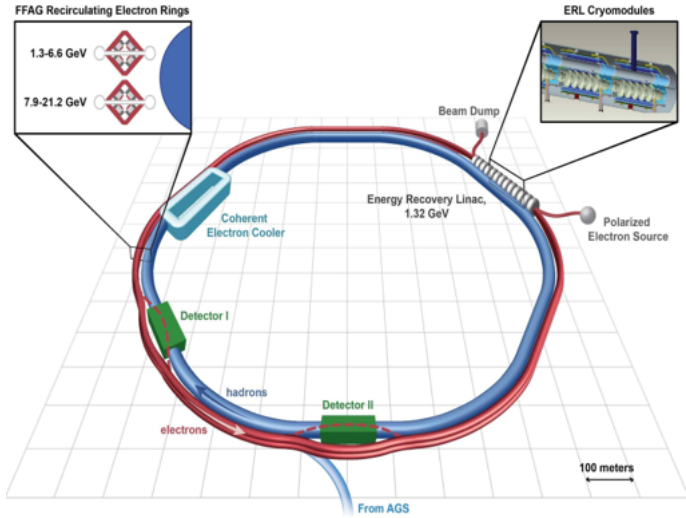
Jefferson Lab

# Electron Ion Collider

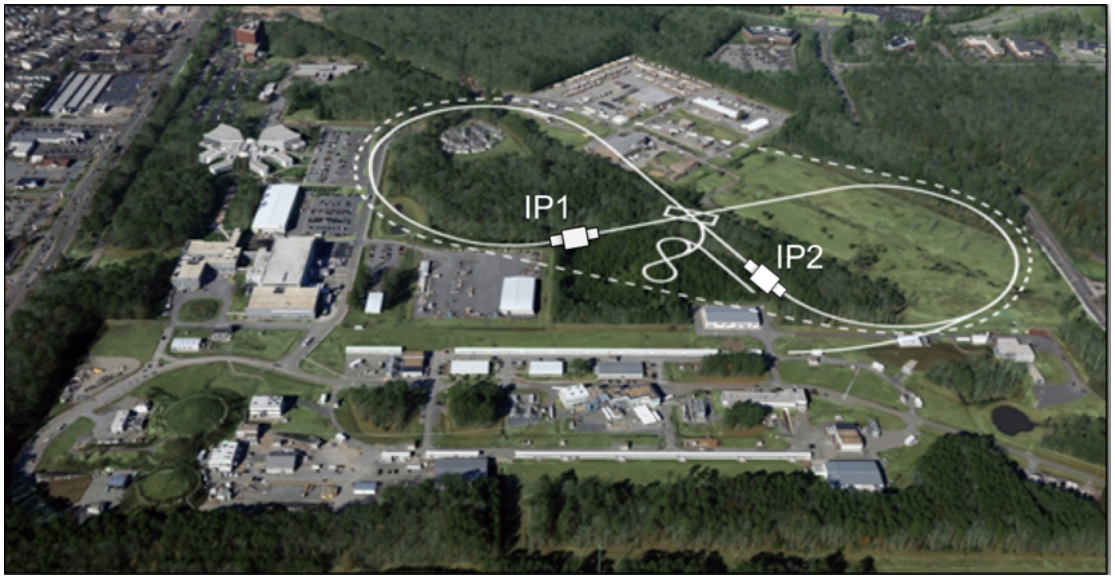
## Electron ion Collider (EIC)

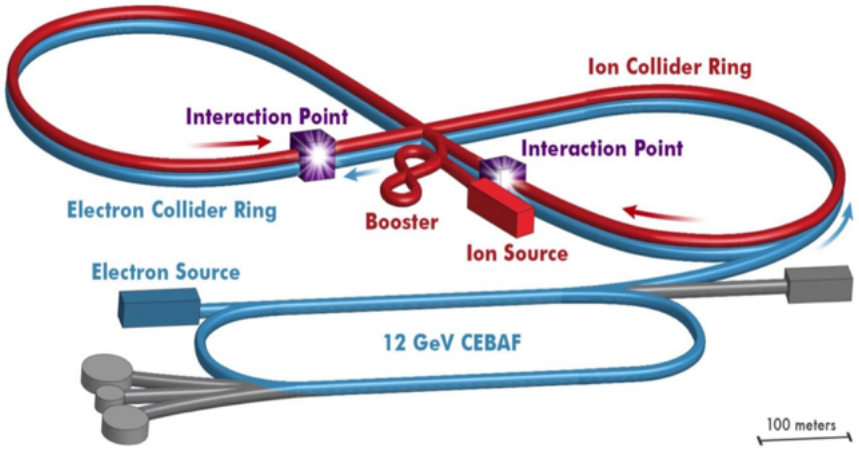
- **Two competing locations:** Jefferson Lab and Brookhaven

**BNL concept o EIC accelerator ring**




**Jefferson Lab figure eight design of EIC accelerator**



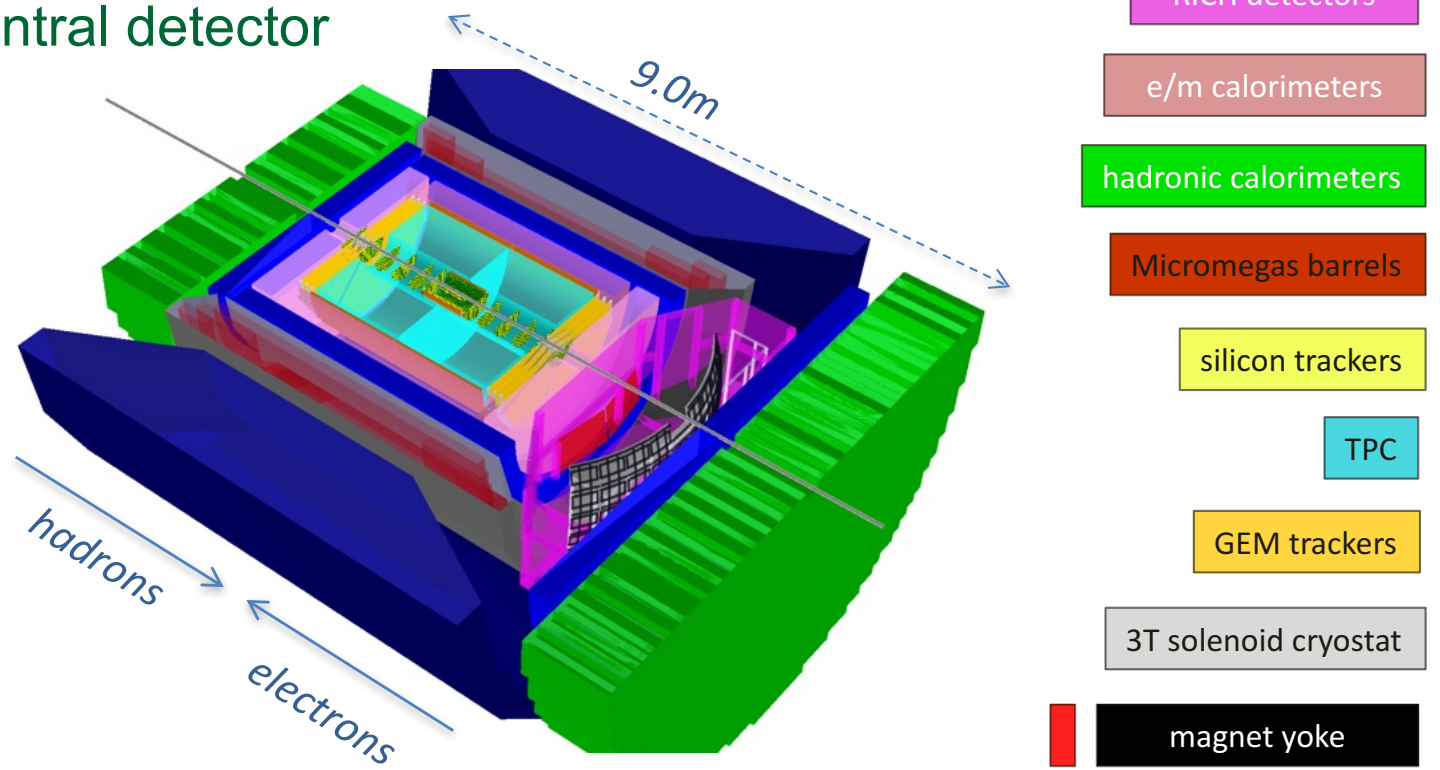
# Electron Ion Collider

**Electron ion Collider (EIC)**

- **Two competing locations:** Jefferson Lab and Brookhaven
- **Three central detector concepts:** BeAST, ePHENIX, JLab central detector

BNL BeAST EIC central detector

**High-Performance DIRC will be integrated in barrel**



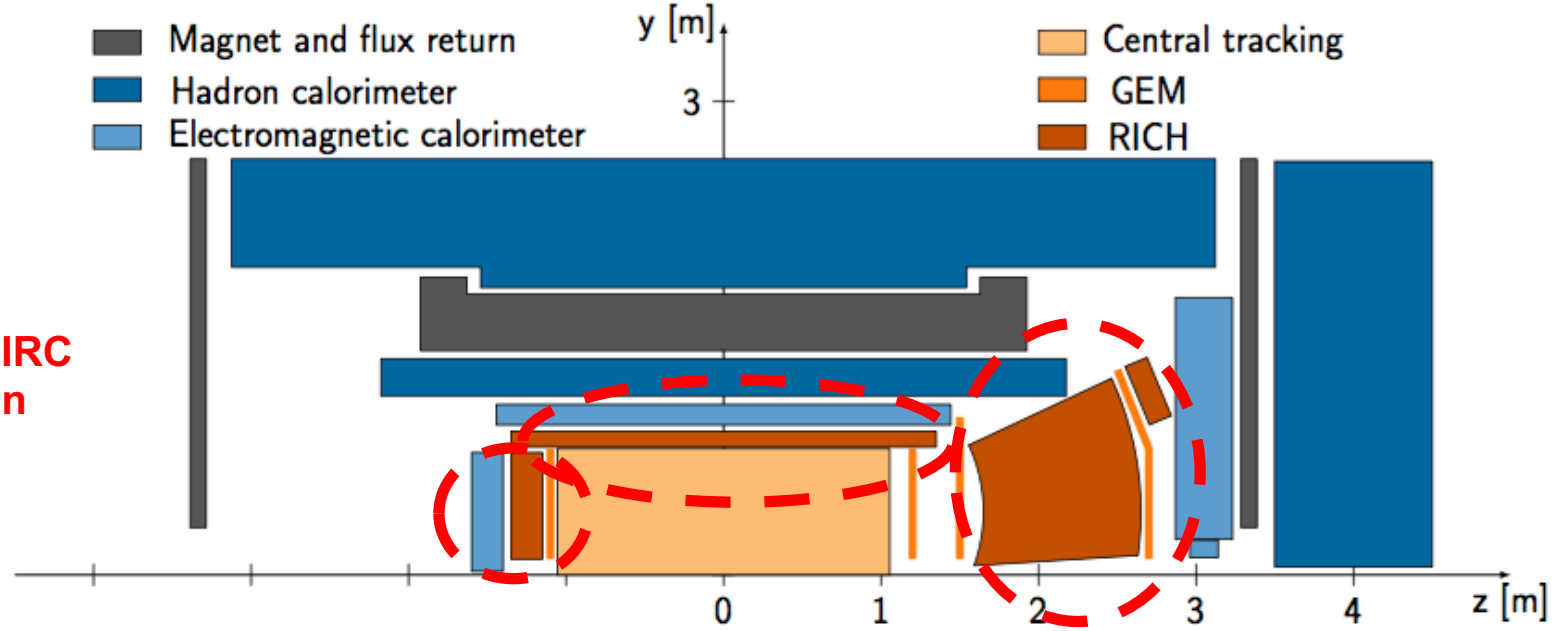
# Electron Ion Collider

**Electron ion Collider (EIC)**

- **Two competing locations:** Jefferson Lab and Brookhaven
- **Three central detector concepts:** BeAST, ePHENIX, JLab central detector

BNL ePHENIX EIC central detector

**High-Performance DIRC already considered in current concept**



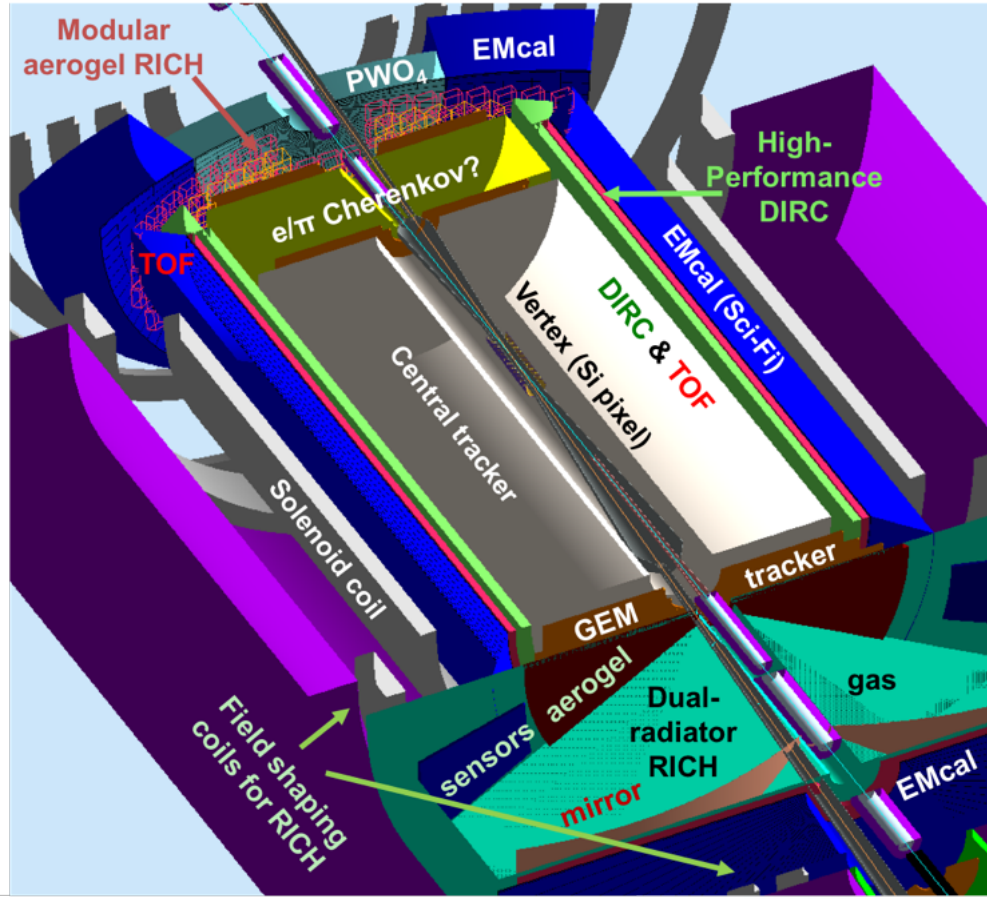
# Electron Ion Collider

**Electron ion Collider (EIC)**

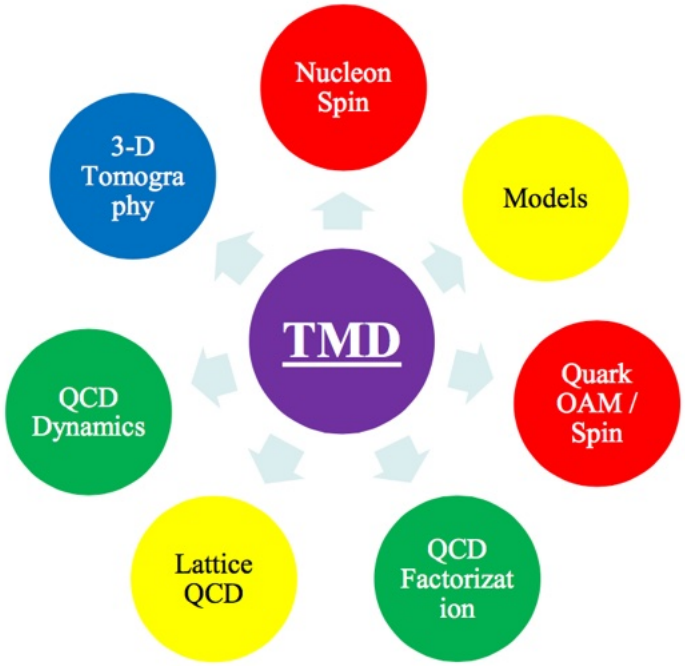
- **Two competing locations:** Jefferson Lab and Brookhaven
- **Three central detector concepts:** BeAST, ePHENIX, JLab central detector

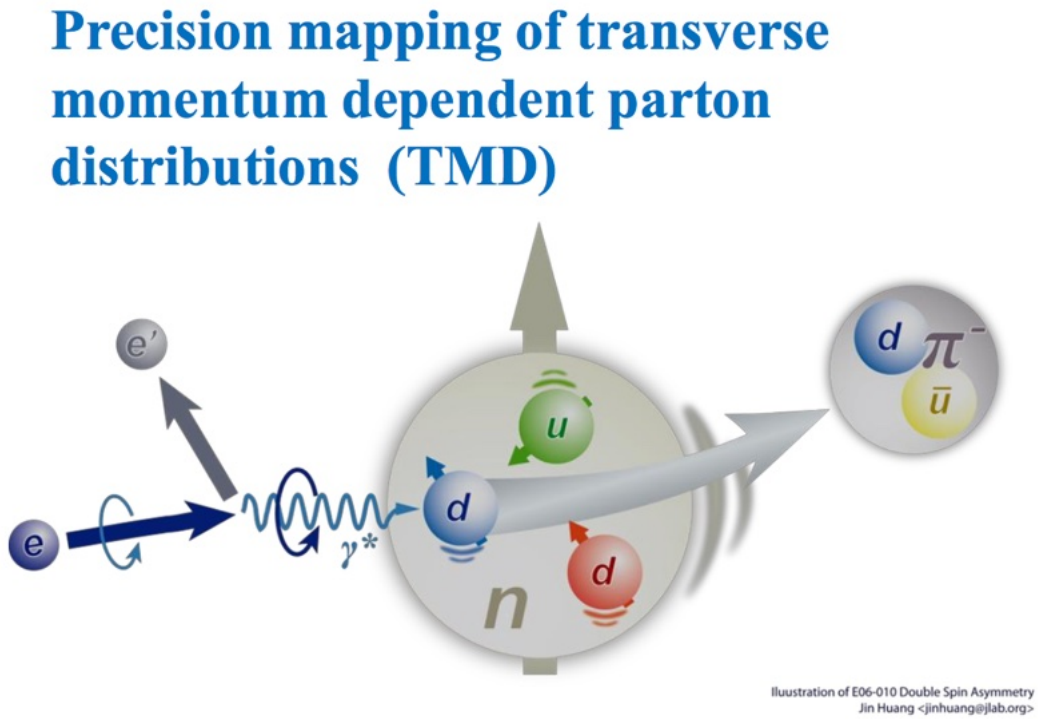
JLab EIC central detector

**High-Performance DIRC original concept**



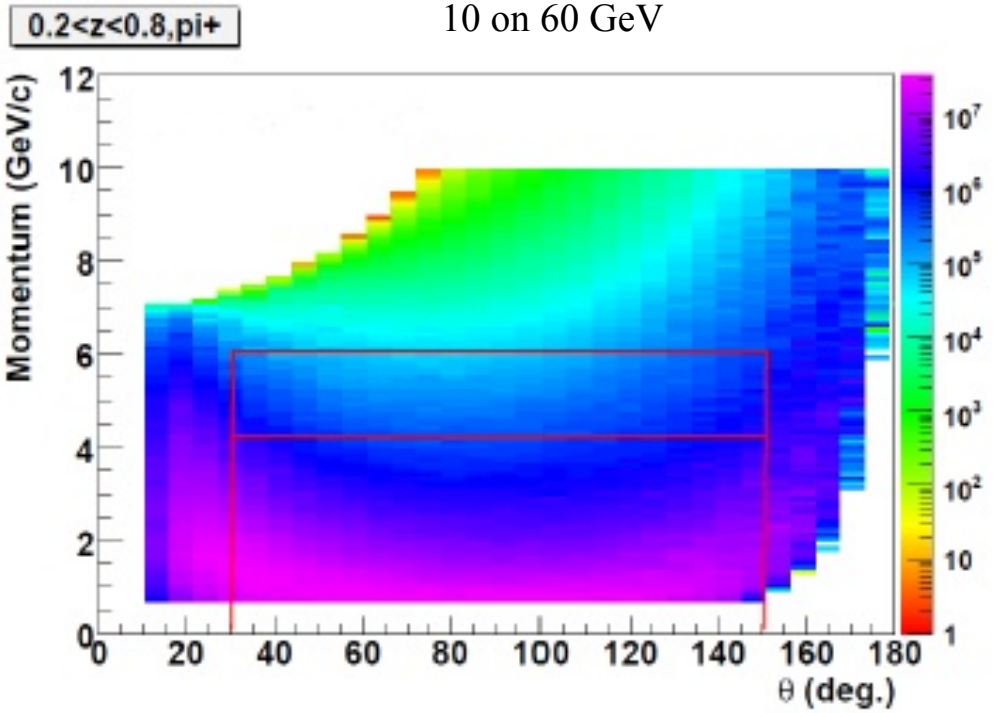
# PID Semi-Inclusive DIS (SIDIS)



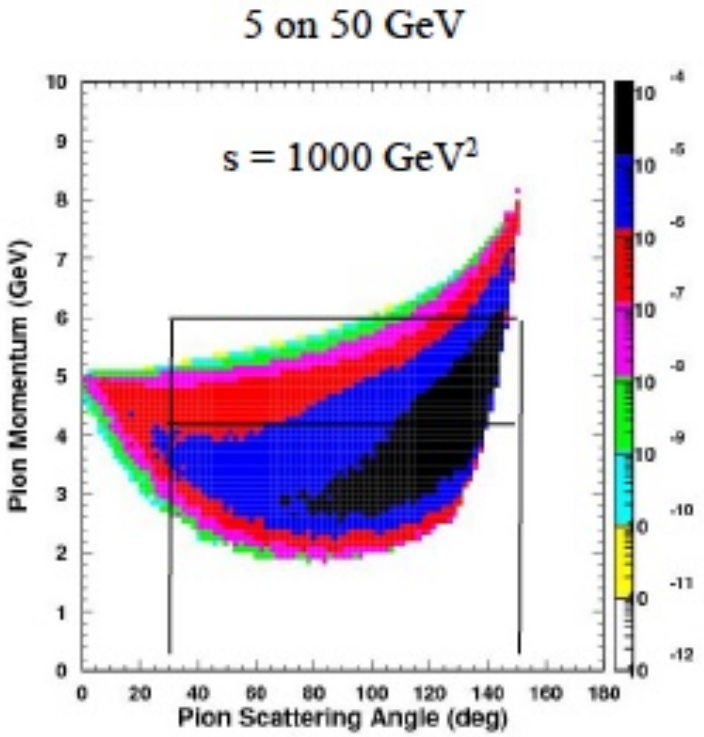




- **Highly polarized electron collide with highly polarized nuclei (proton, deuteron, 3He ,etc)**
- **Detect scattered electron and pion at full angle and full momentum range**

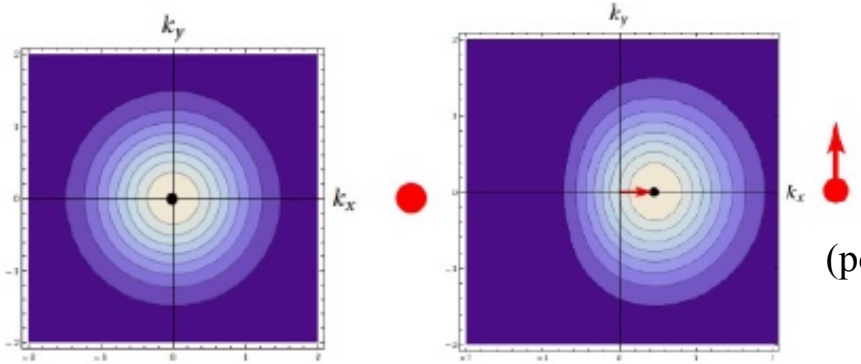
# PID 3D structure of the proton



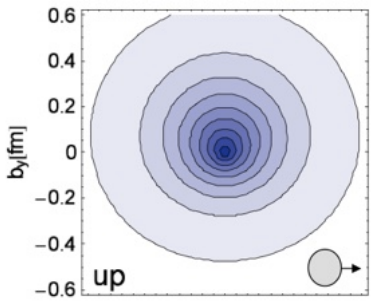

Semi-Inclusive DIS – mapping of transverse momentum distributions of (sea) quarks




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

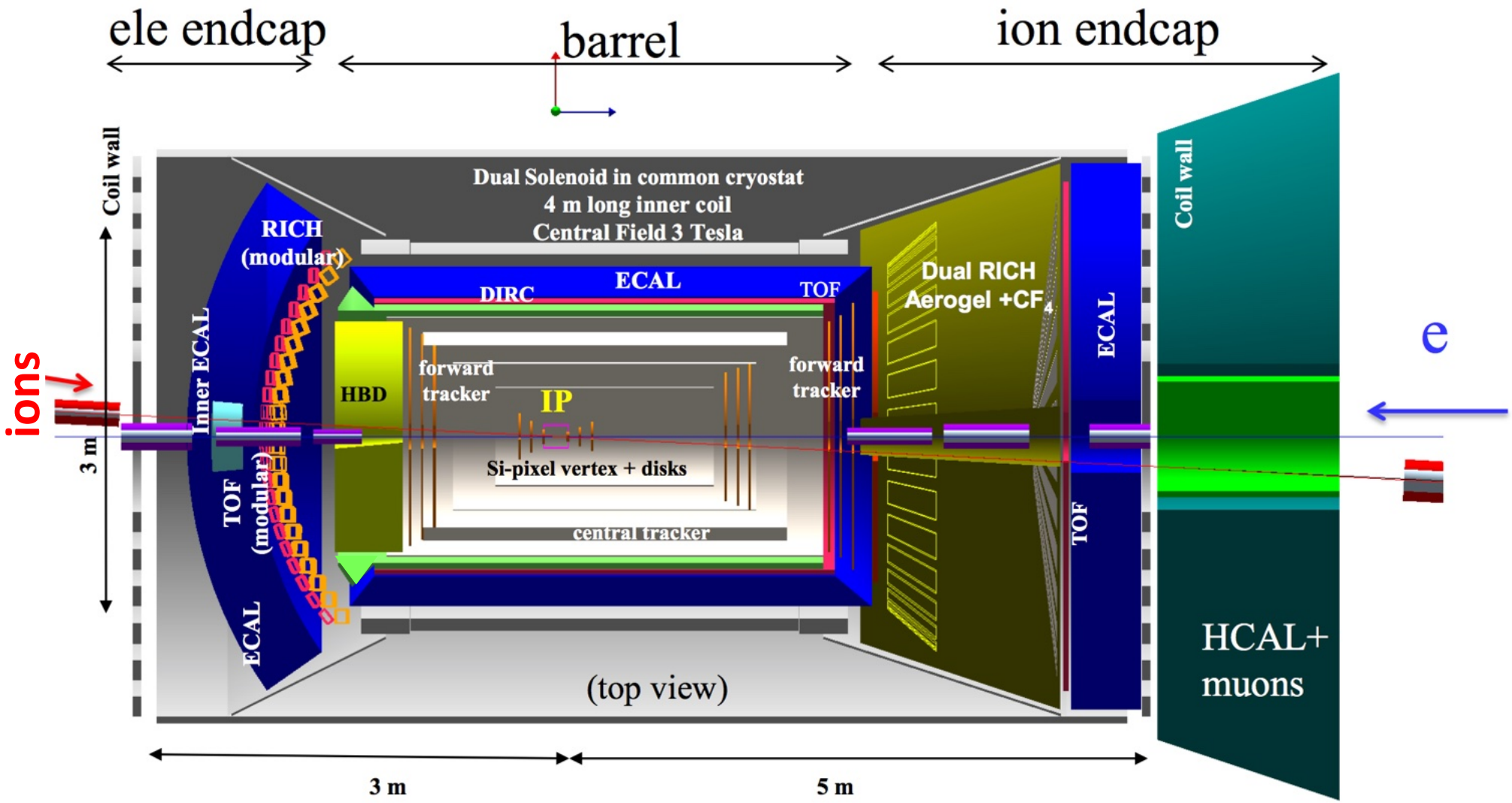



(polarized)




(polarized)

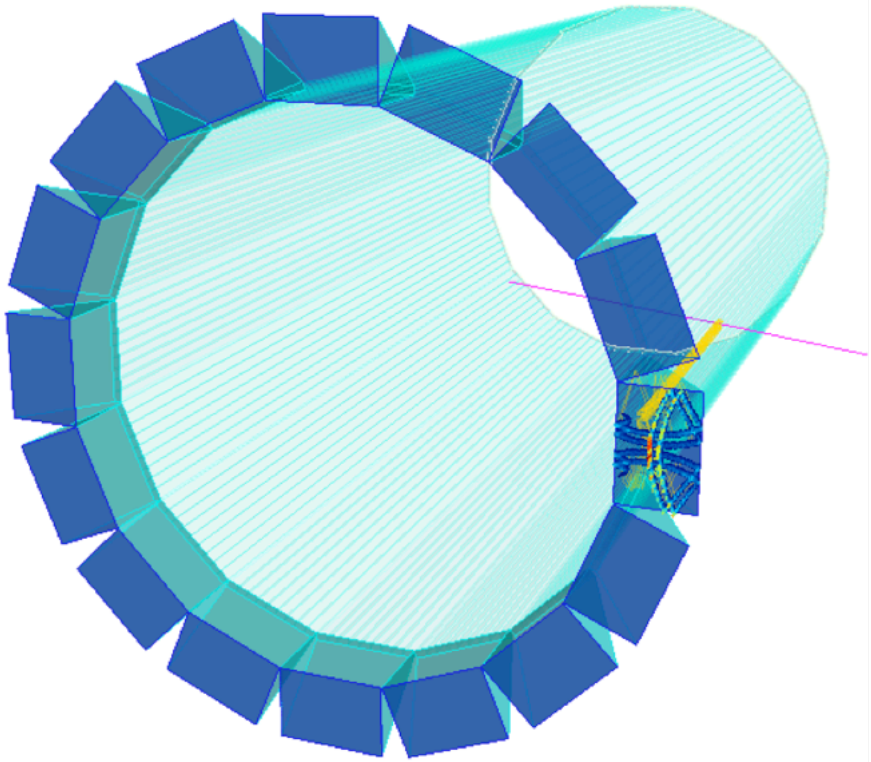
# JLab EIC Current design



# JLab EIC Current design

DIRC

**Geant4 simulation of High-Performance DIRC detector**



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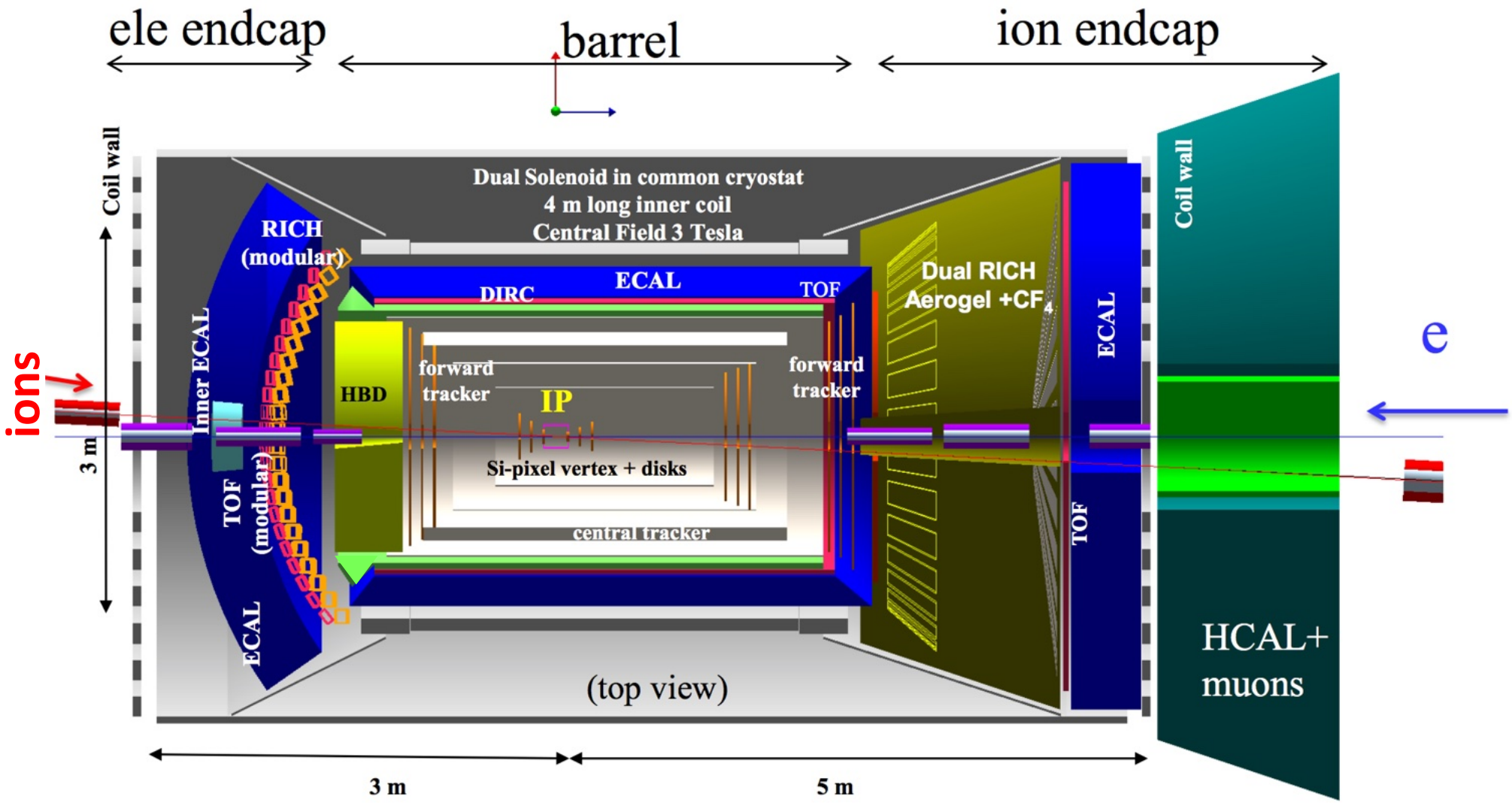
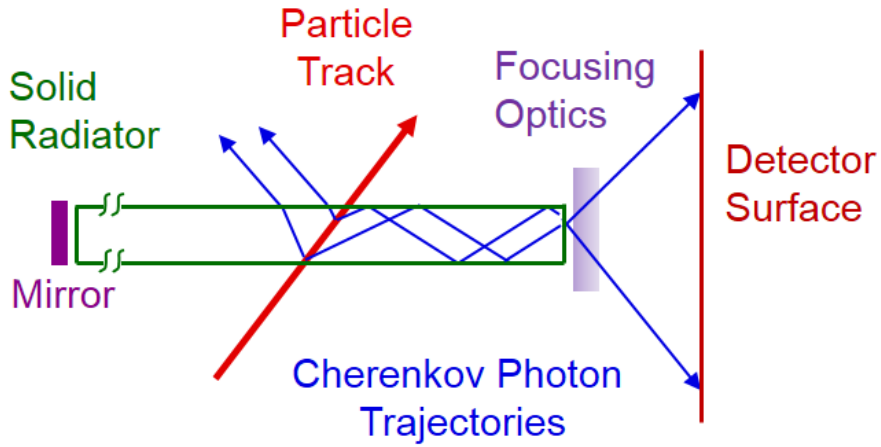
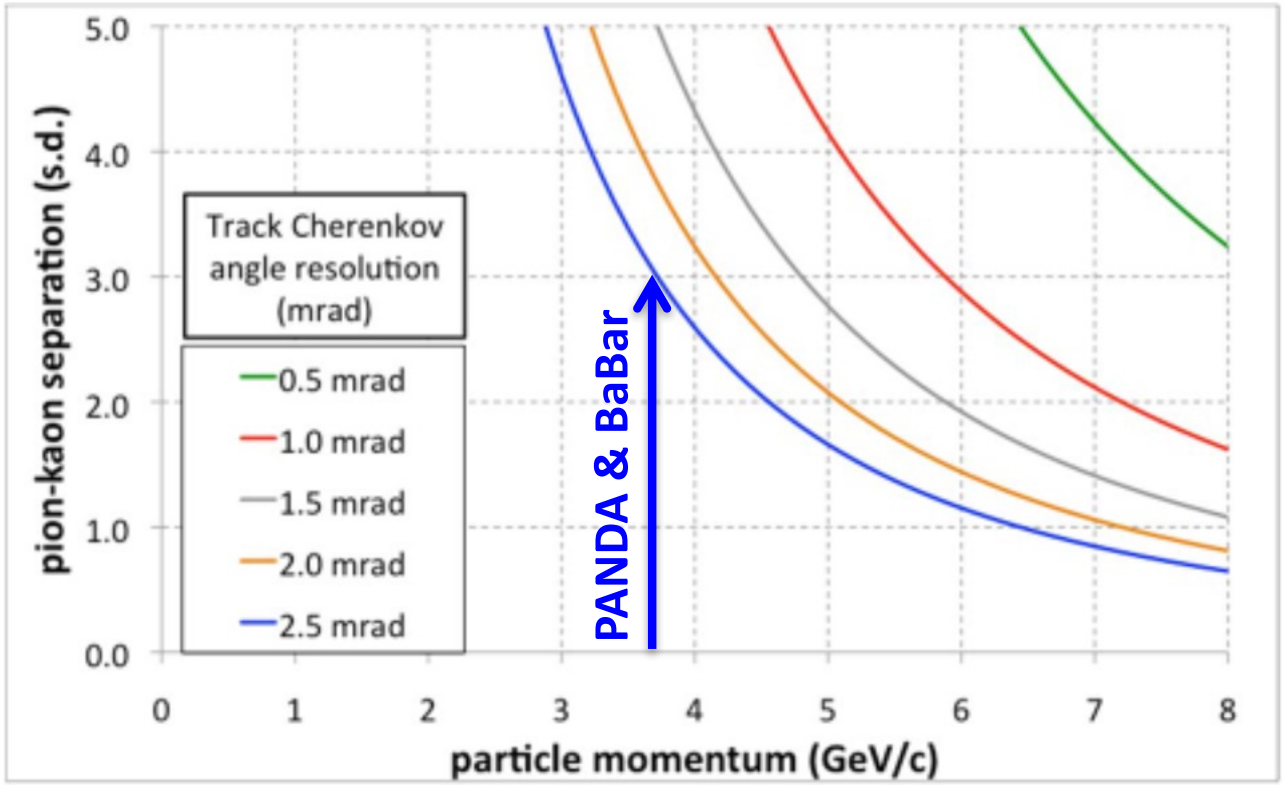


# DIRC@EIC Performance goal

**DIRC@EIC PID capability using geometrical reconstruction:**




**π/K identification as a function of the $\theta_c$ resolution**



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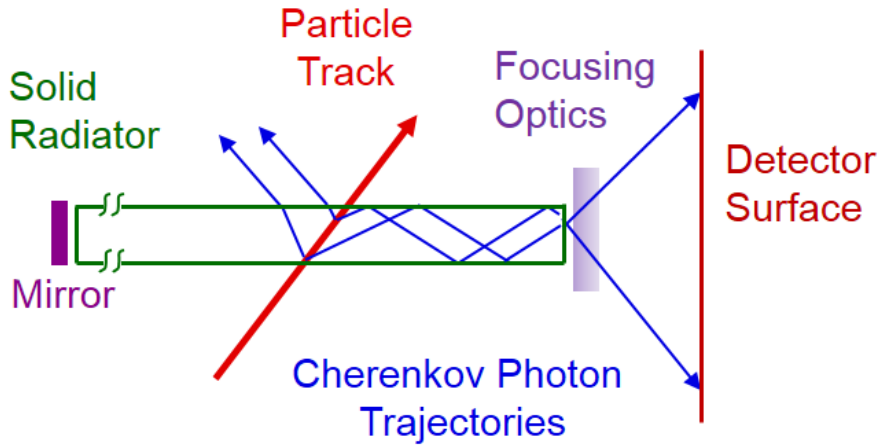
**DIRC@EIC PID capability using geometrical reconstruction:**

- **π/K up to 6 GeV/c**

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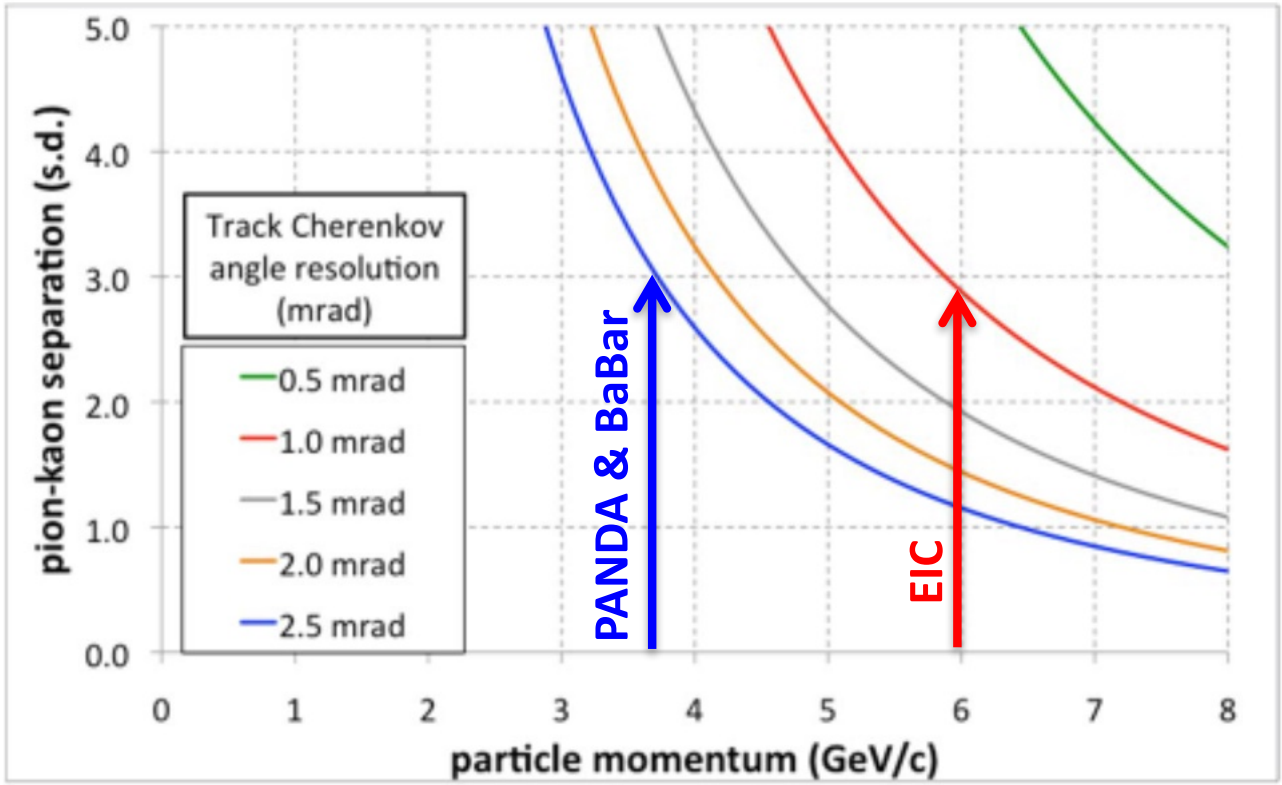
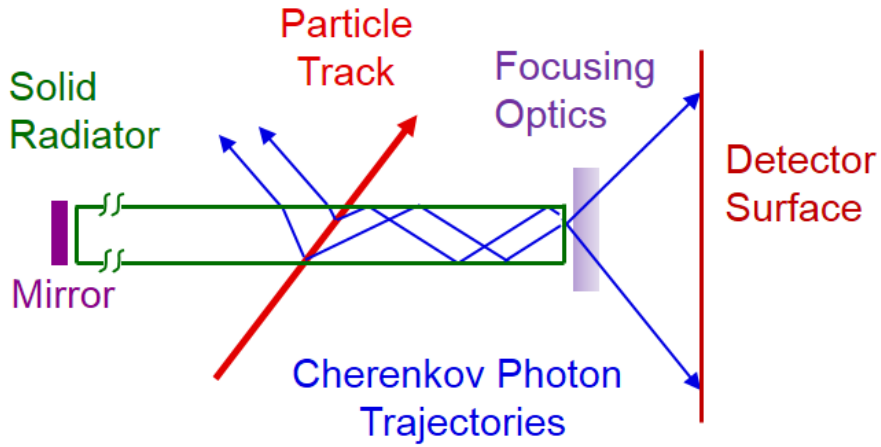


# DIRC@EIC Performance goal

**DIRC@EIC PID capability using geometrical reconstruction:**

- **π/K up to 6 GeV/c**
- **e/π up to 1.8 GeV/c**
- **p/K up to 10 GeV/c**

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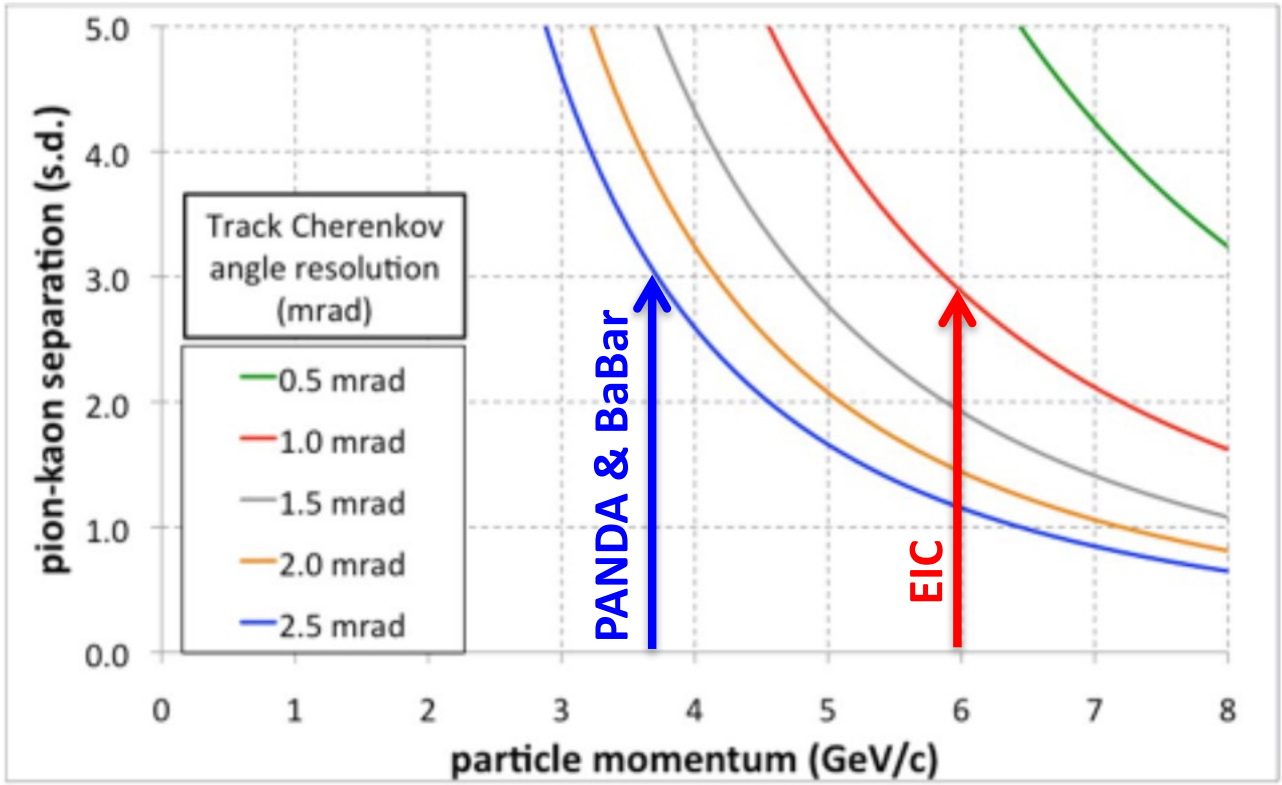


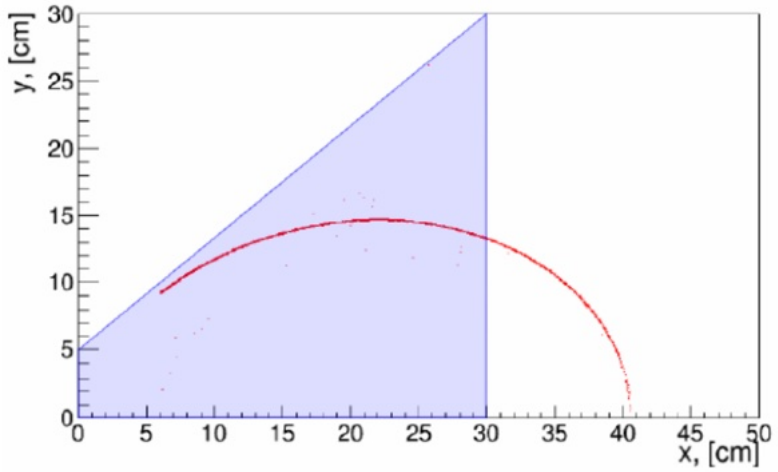
# DIRC@EIC Prototype 3-component lens

**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**

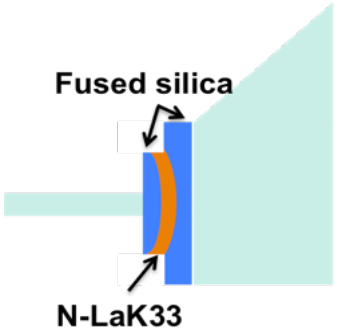
**R. Dzhygadlo, G. Kalicy, C. Schwarz**

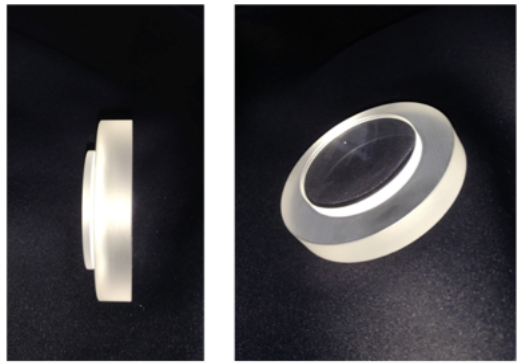
# DIRC@EIC Prototype 3-component lens

**Spherical 3-layer lens prototype**

**Limitations of standard focusing lenses:**

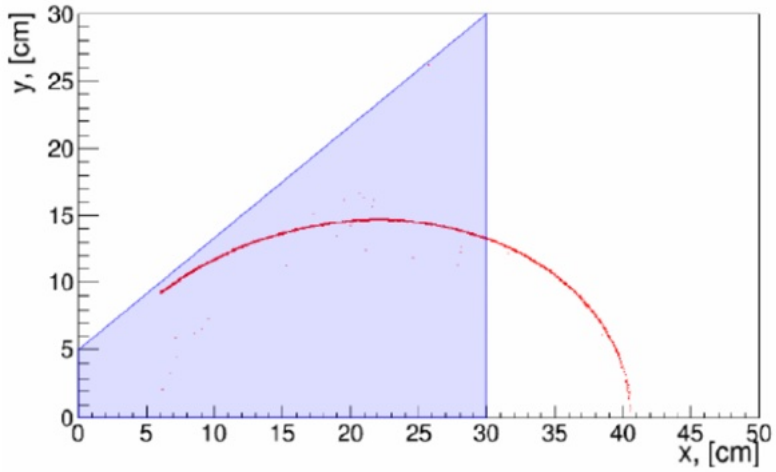
- Significant photon yield loss around 90° particle track
- Aberration for photons with steeper angles



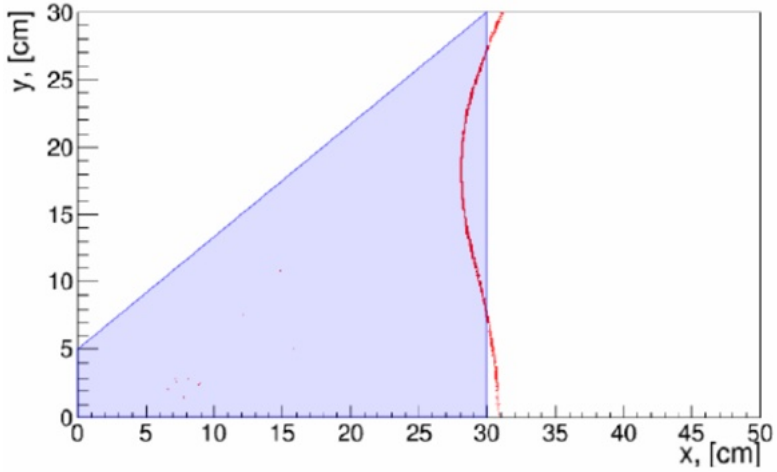



**Geant4 simulation of focal plane:**

**2 component lens**




**3 component lens**



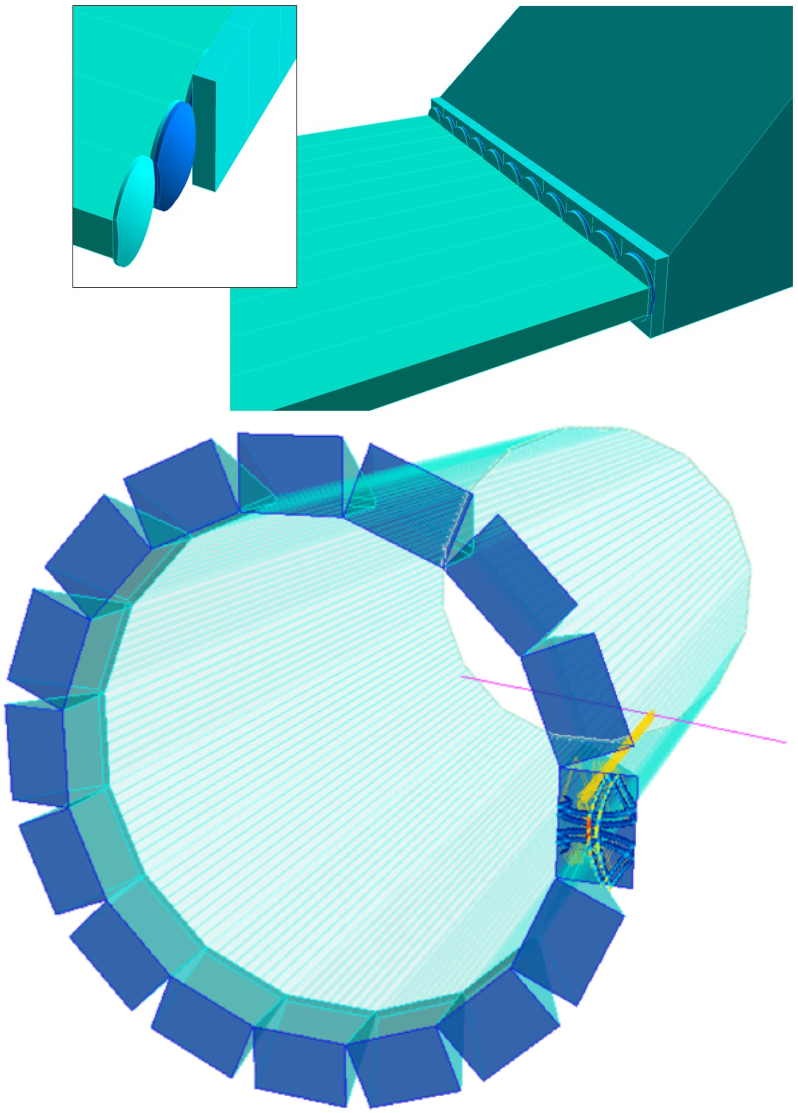

**Simulated data**

**R. Dzhygadlo, G. Kalicy, C. Schwarz**

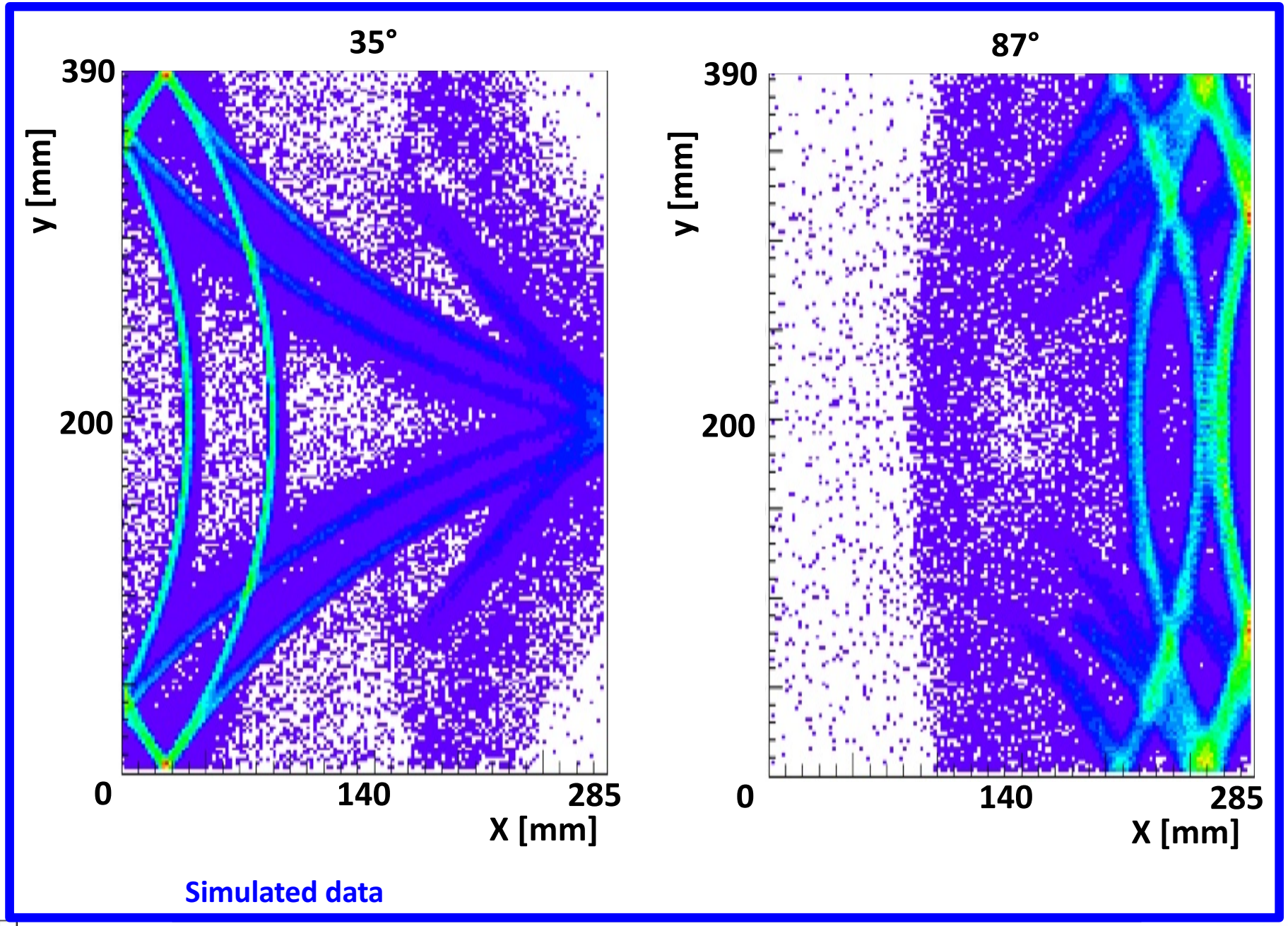
# High-performance DIRC Narrow bar design

- **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 $mm^2$

**Geant4 simulation of High-Performance DIRC detector**



# High-performance DIRC Hit Patterns



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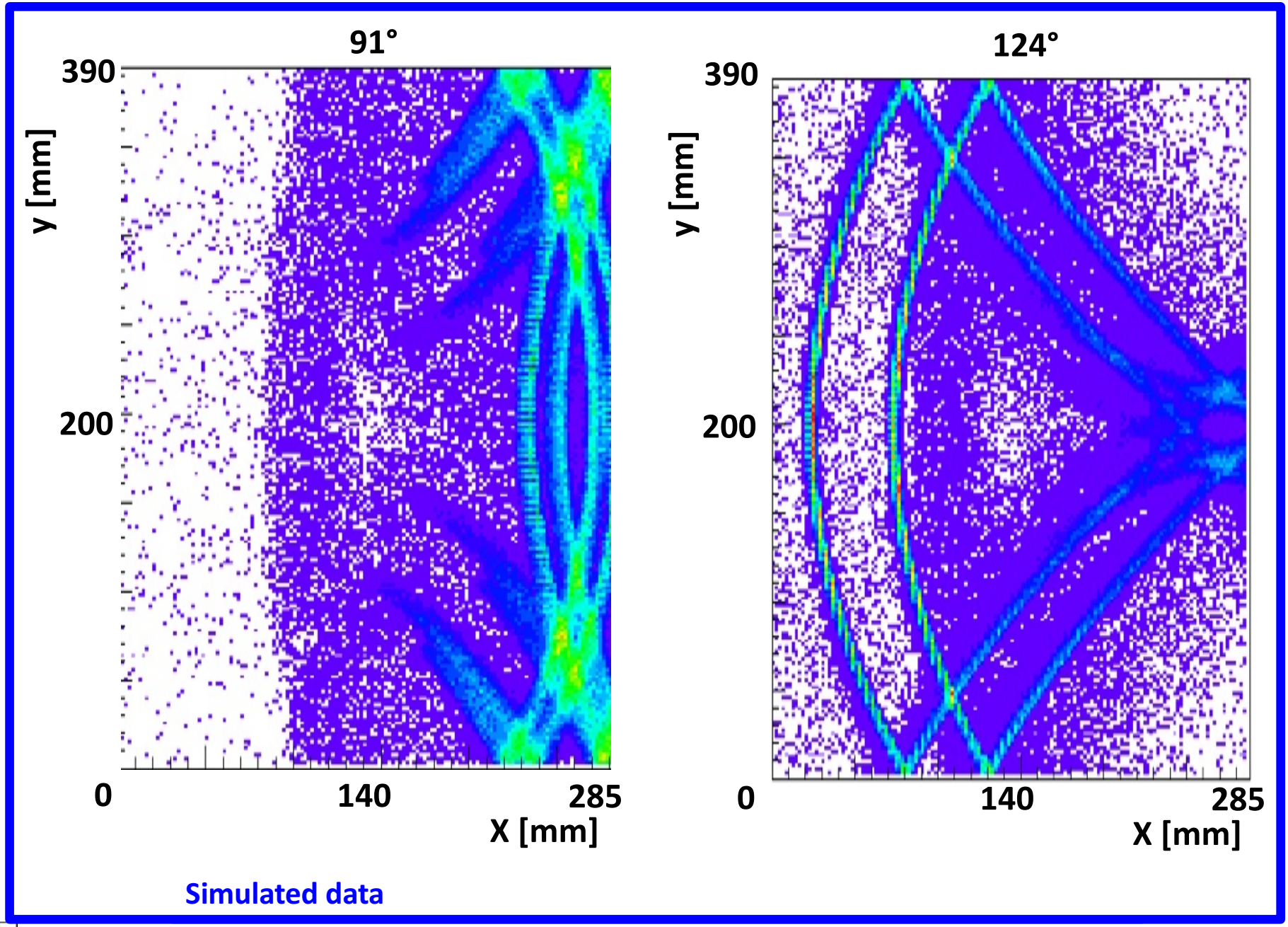
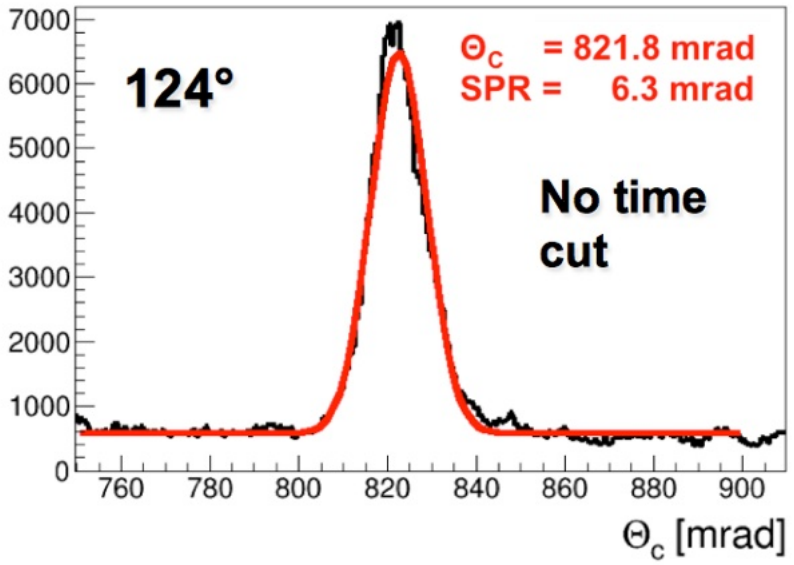
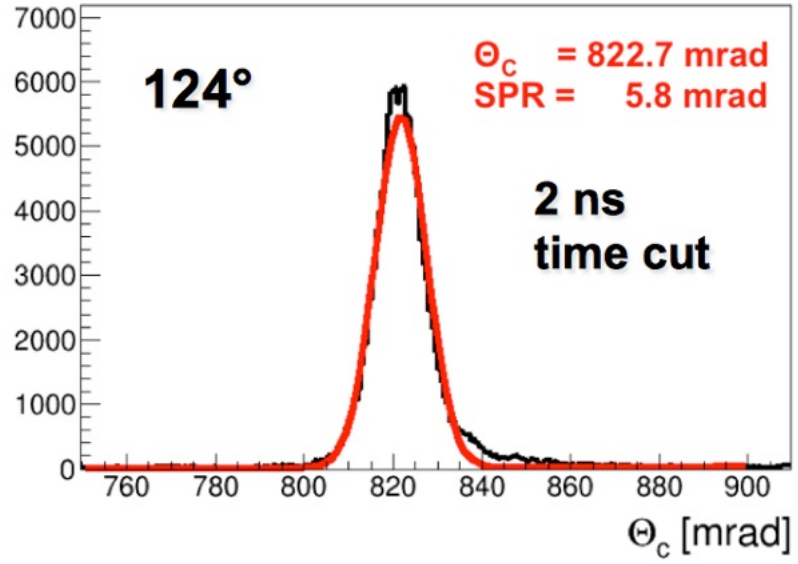
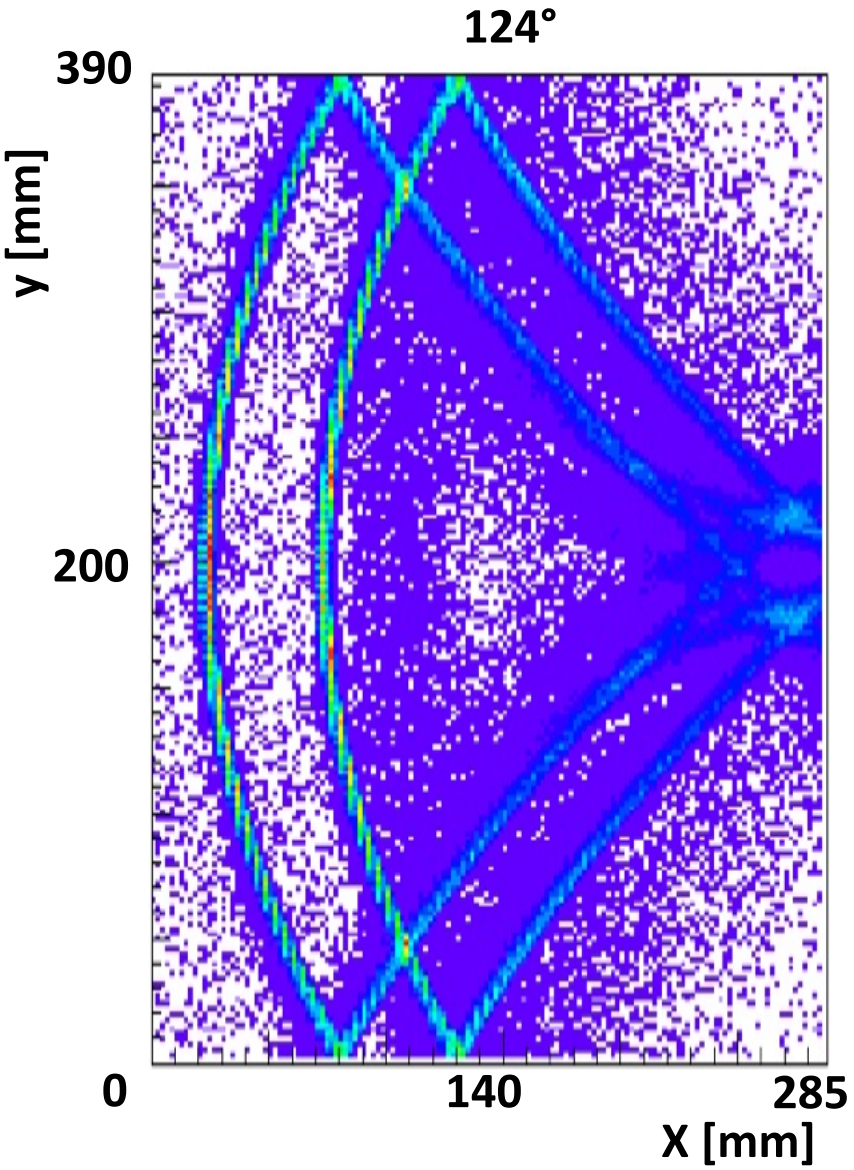


# High-performance DIRC Single Photon Resolution (SPR)



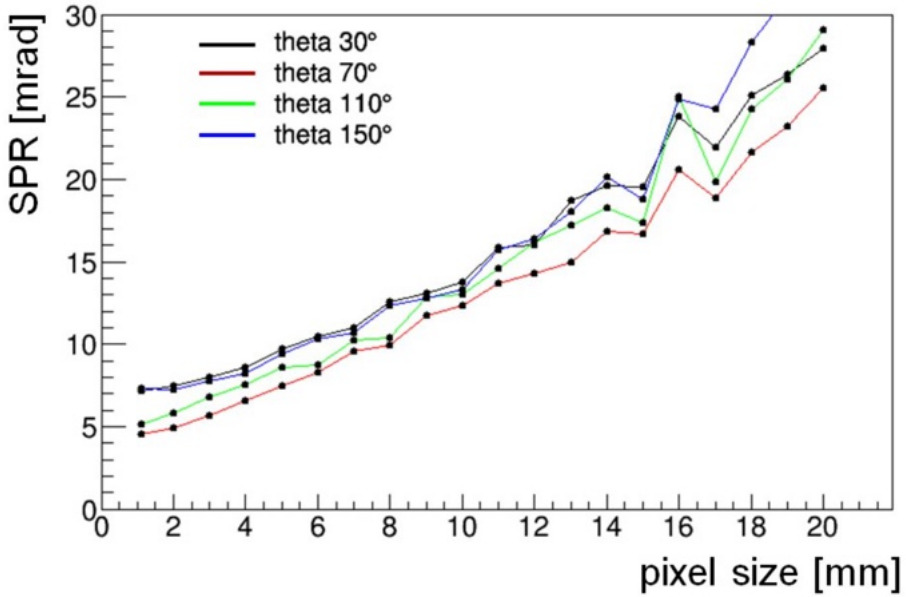



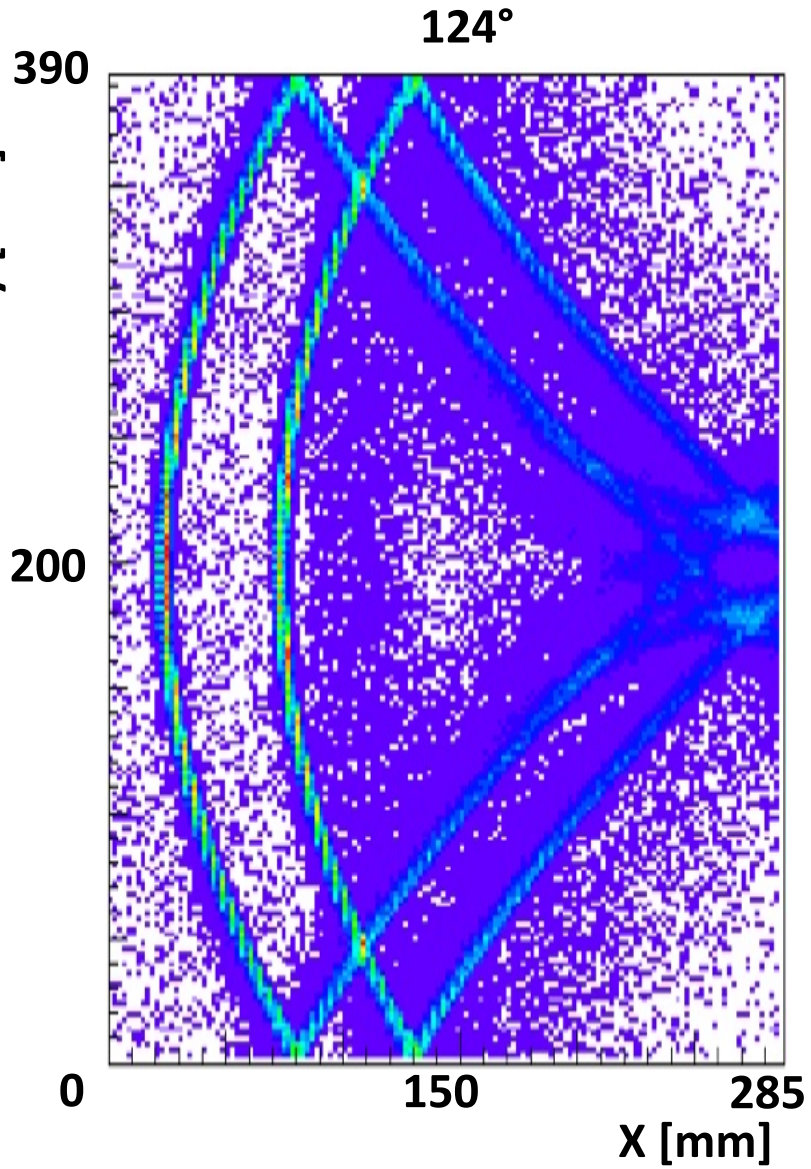




Simulated data

# High-performance DIRC Single Photon Resolution (SPR)

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

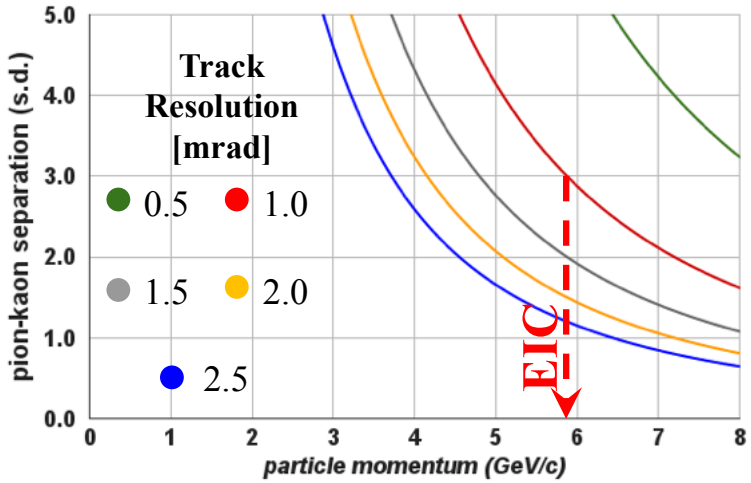



**Simulated data**

# High-performance DIRC Performance

$$\sigma^2_{track} = \sigma^2_{\theta c}/N_\gamma + \sigma^2_{correlated}$$

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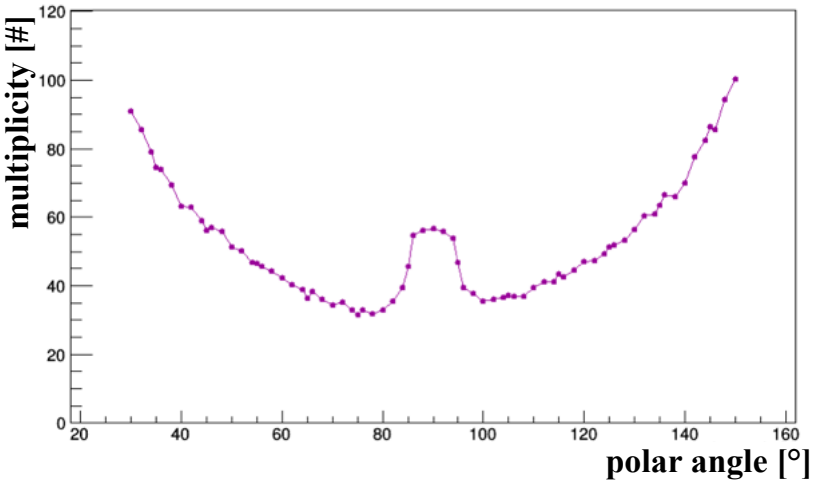


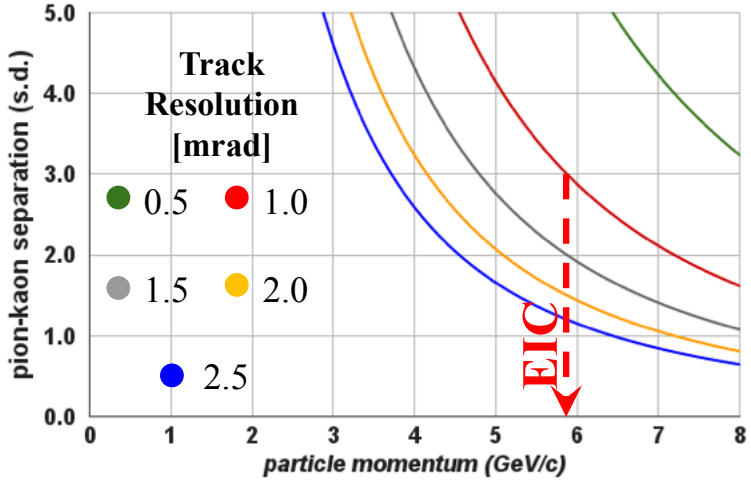


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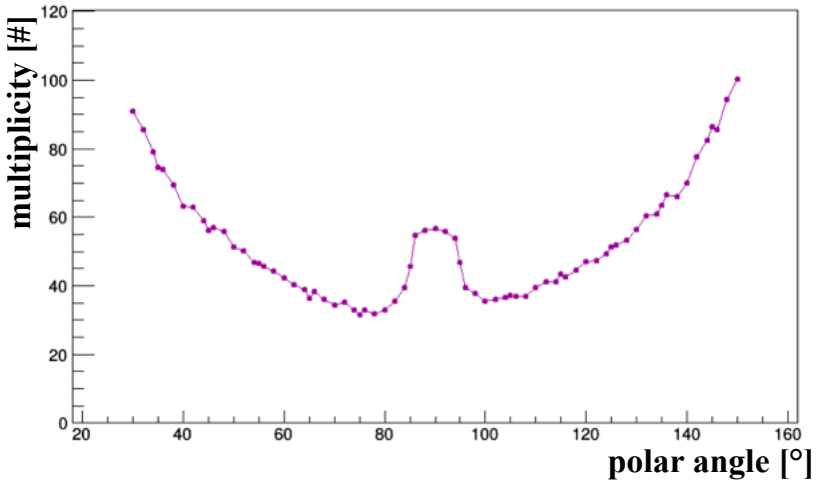
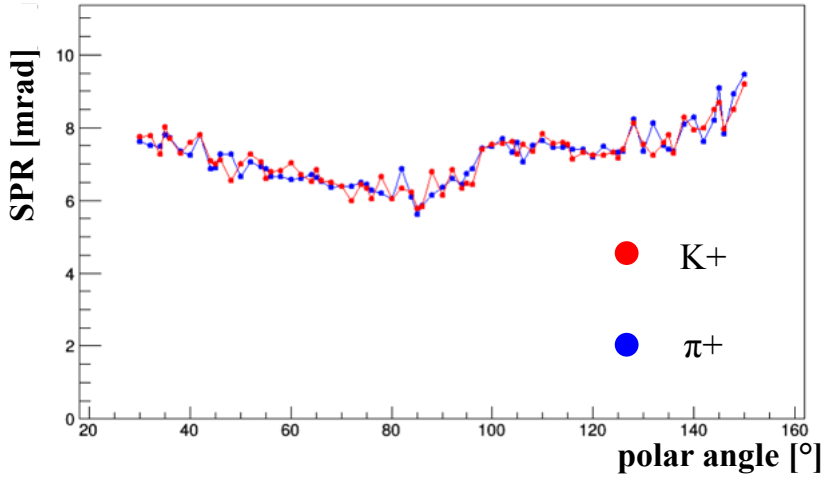



Geometric reconstruction

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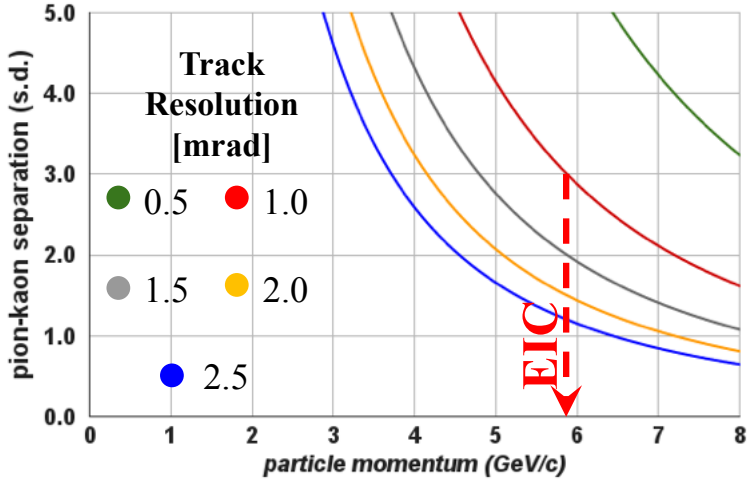

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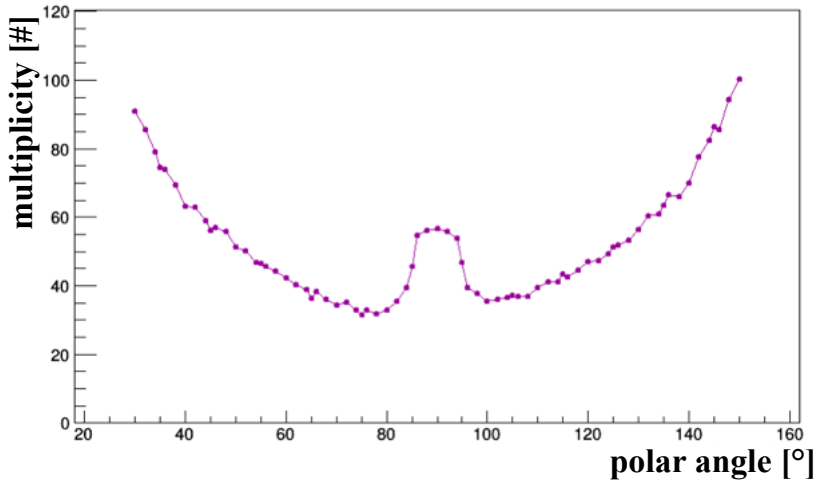
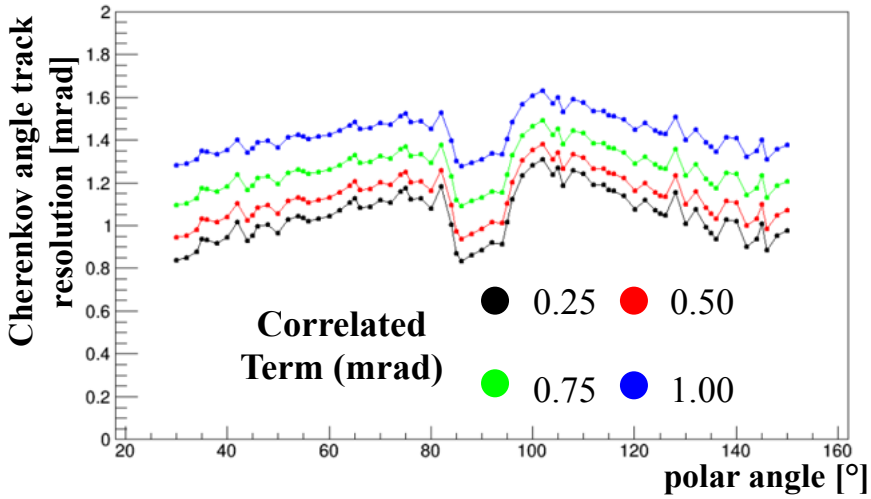
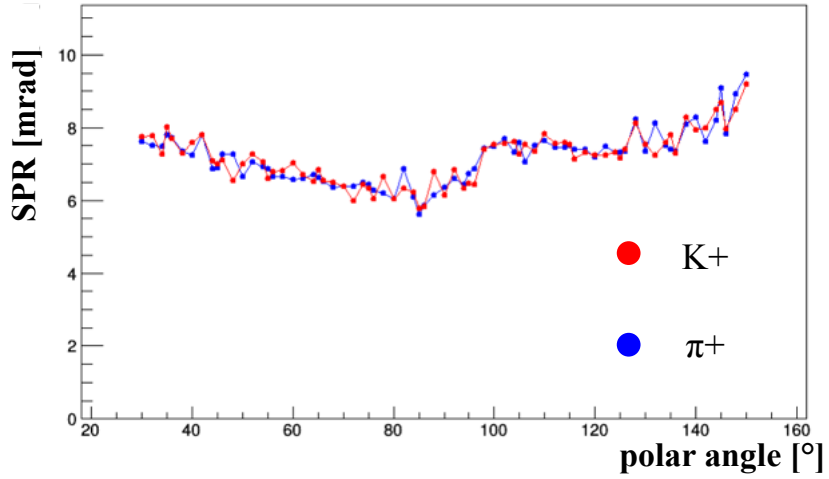
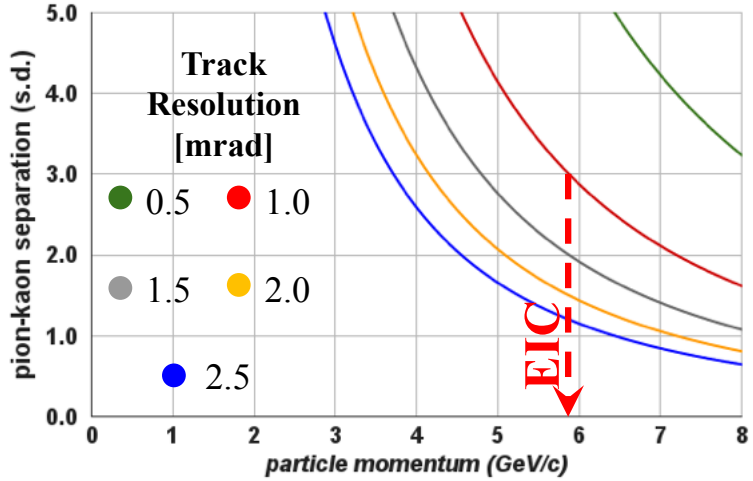


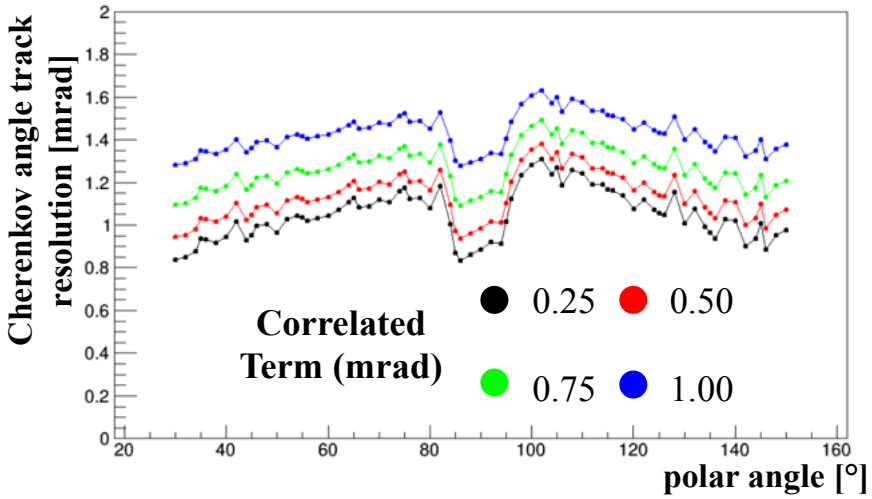

Geometric reconstruction



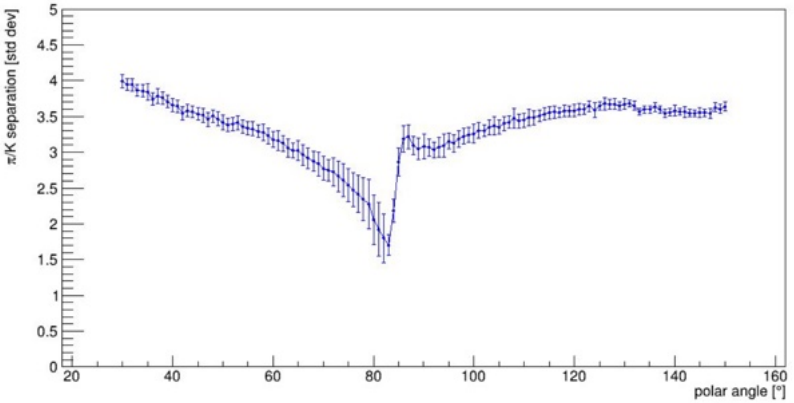




Simulated data

# High-performance DIRC Performance




π/k separation without correlated term



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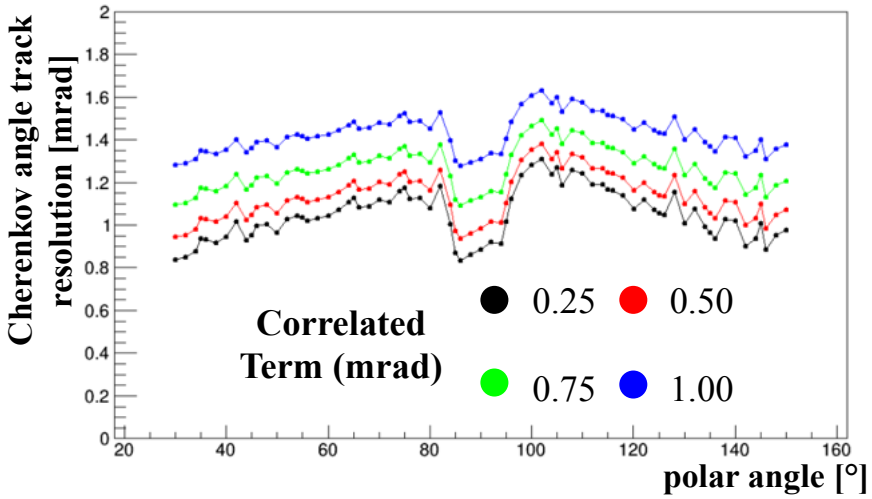


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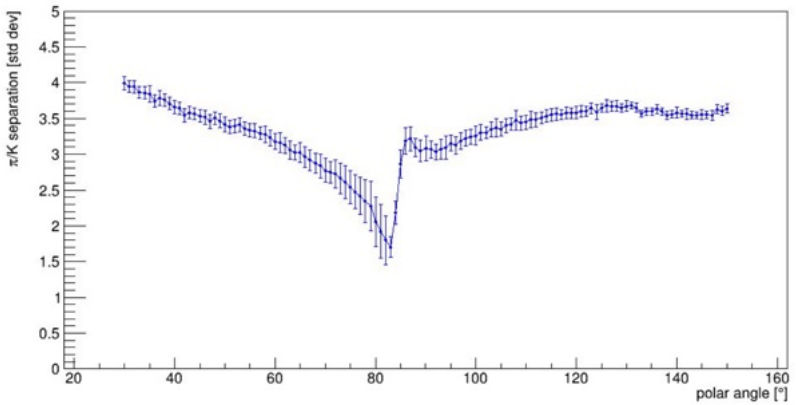
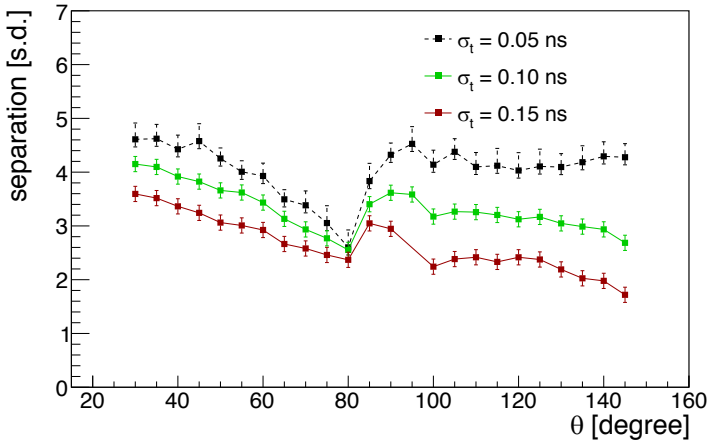
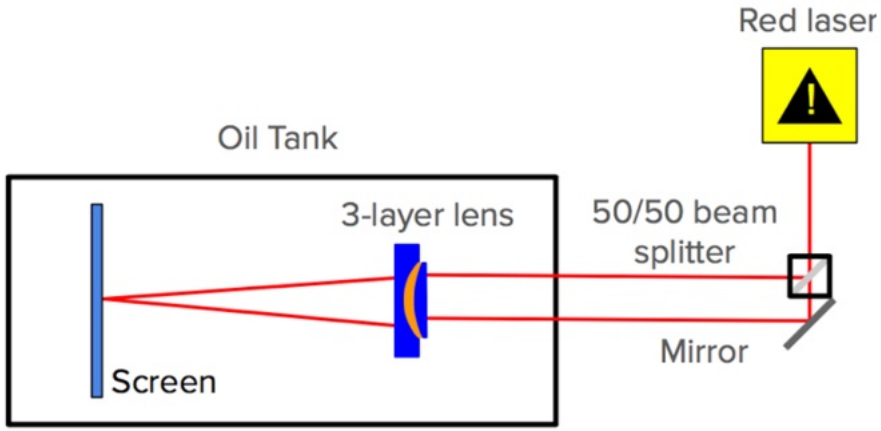



**Time-based reconstruction for π/k at 6 GeV/c**



# 3-layer Lens Performance verification

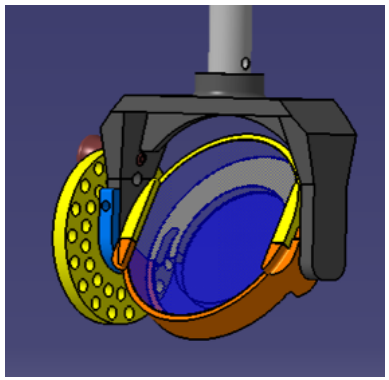
**Laser setup to map the focal plane**

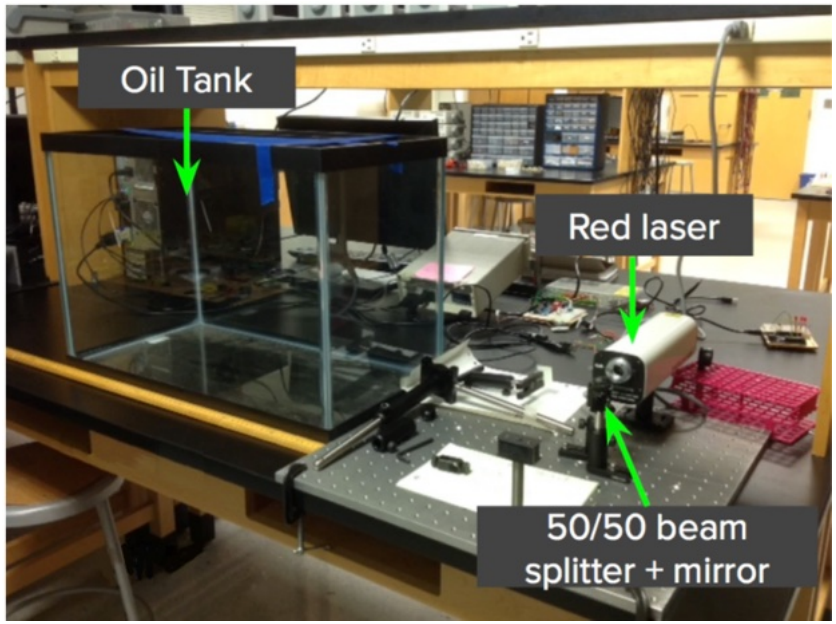



## Mapping focal plane of 3-layer lens:

- Lens holder designed to rotate in two planes for the 3D mapping of the focal plane and shifts of lens in horizontal plane.

**3D lens holder**






L. Allison, R. Dzhygadlo, G. Kalicy, C. Schwarz

# 3-Component Lens Performance verification

**Mapping focal plane of 3-layer lens:**

- Lens holder designed to rotate in two planes for the 3D mapping of the focal plane and shifts of lens in horizontal plane.
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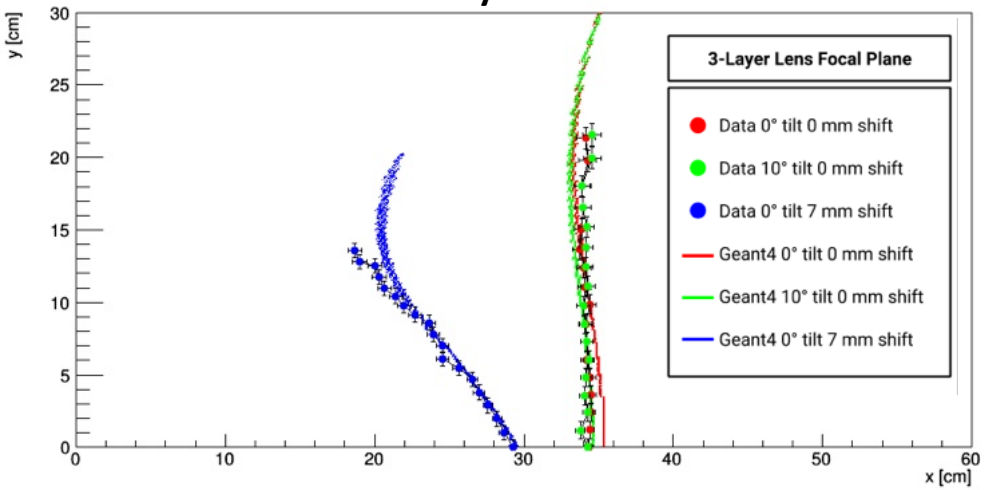
**Measured and simulated focal plane**
**3-layer lens**

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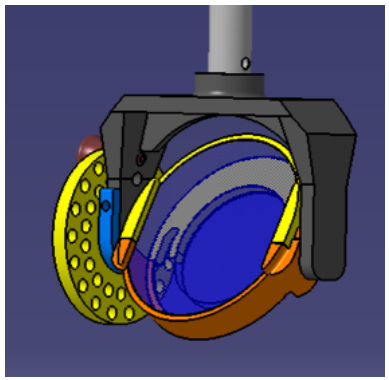

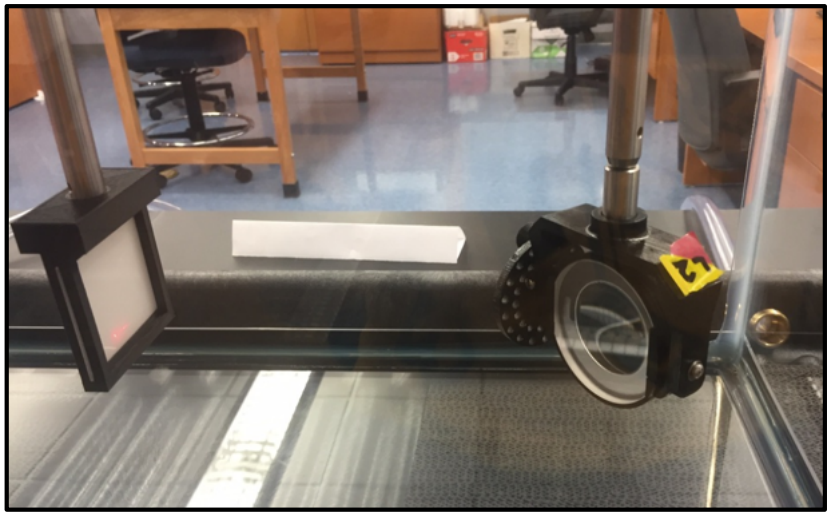

L. Allison, R. Dzhygadlo, G. Kalicy, C. Schwarz

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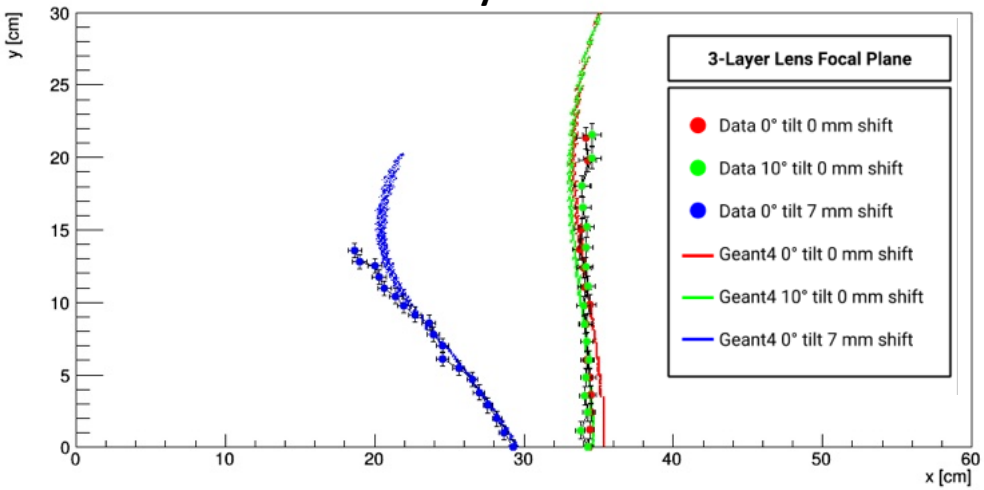


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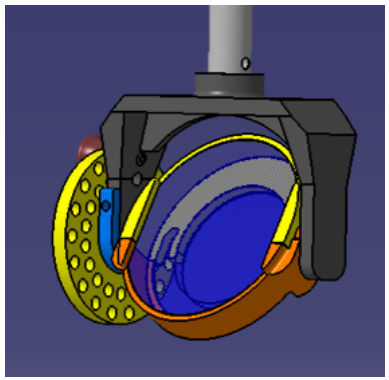

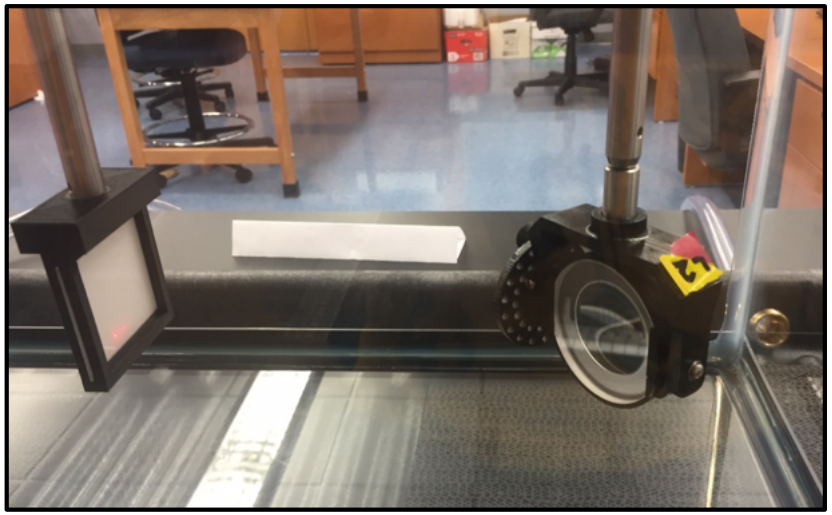

L. Allison, R. Dzhygadlo, G. Kalicy, C. Schwarz

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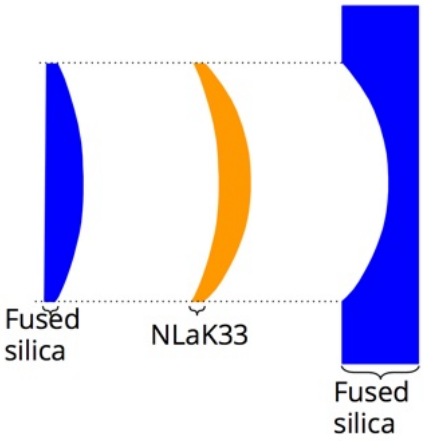
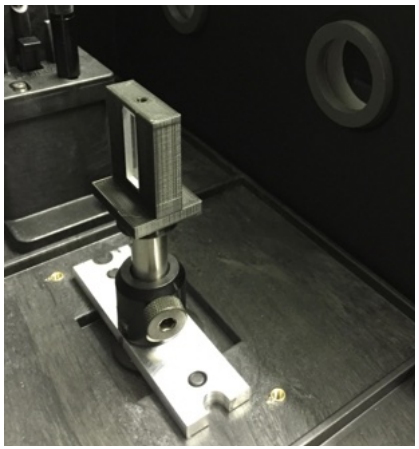
**Radiation hardness tests of NLaK33 material at CUA**

- NLaK33 samples irradiated with X-Ray source, measured with monochromator.

**Spherical 3-layer lens**




**NLaK33 sample in monochromator**



**X-ray source**

G. Kalicy, L. Allison and PANDA Barrel DIRC group

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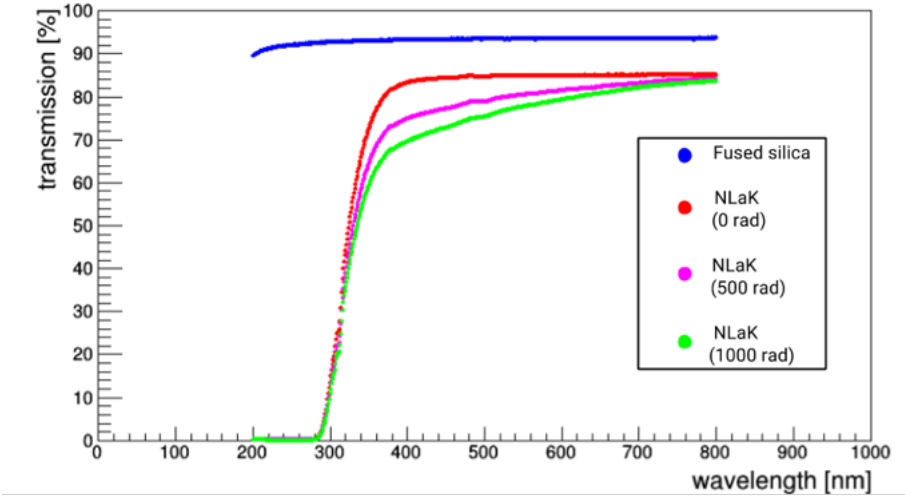
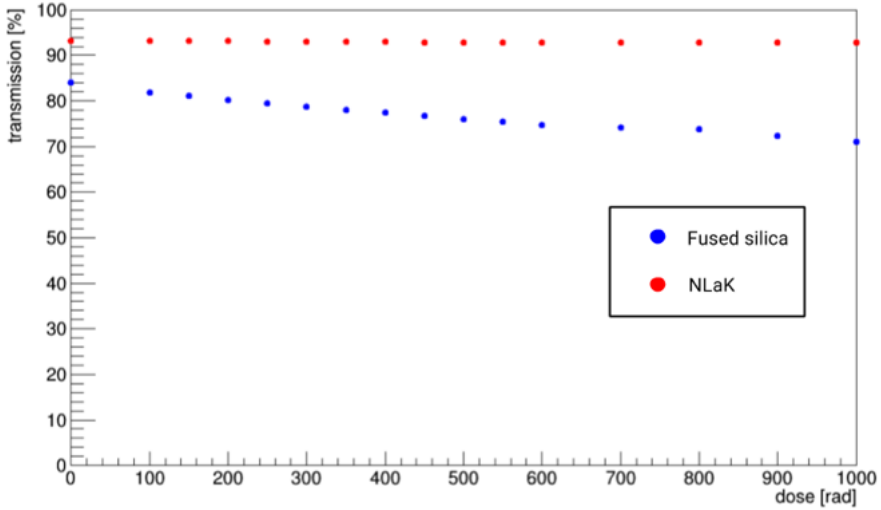



**Measured transmission (not Fresnel corrected ) through the NLaK33 irradiation dose for 420 nm.**



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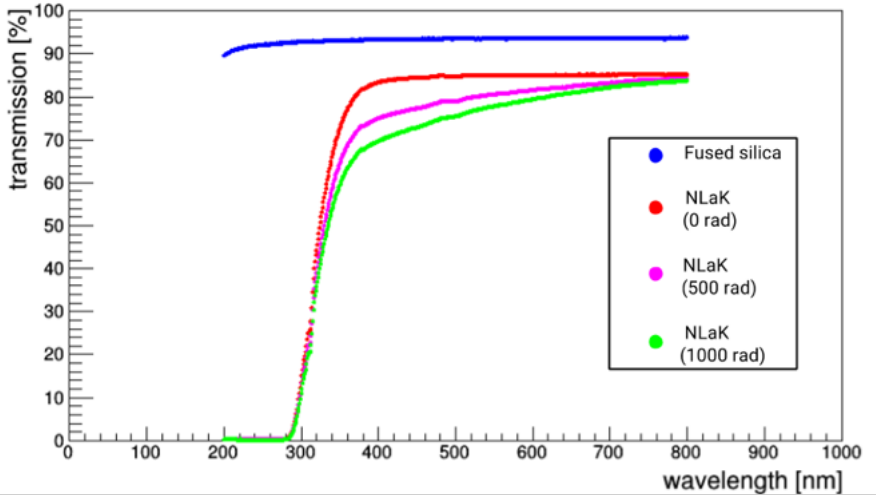


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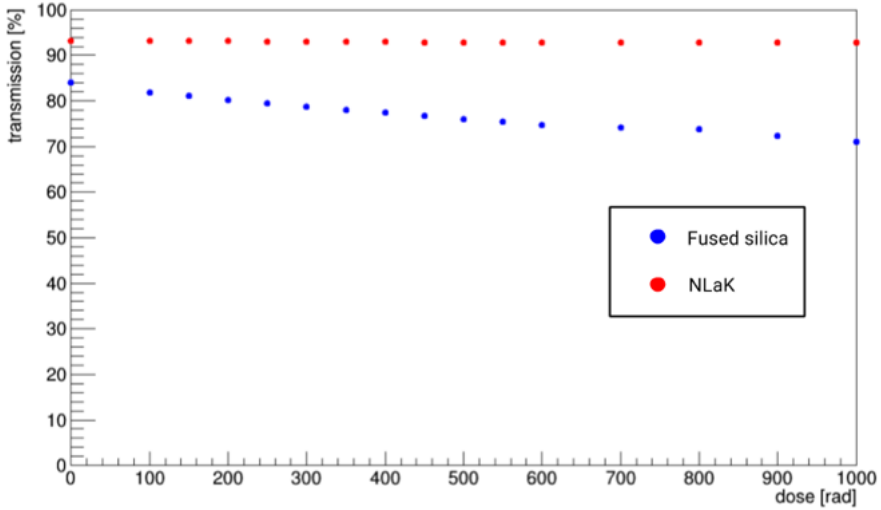

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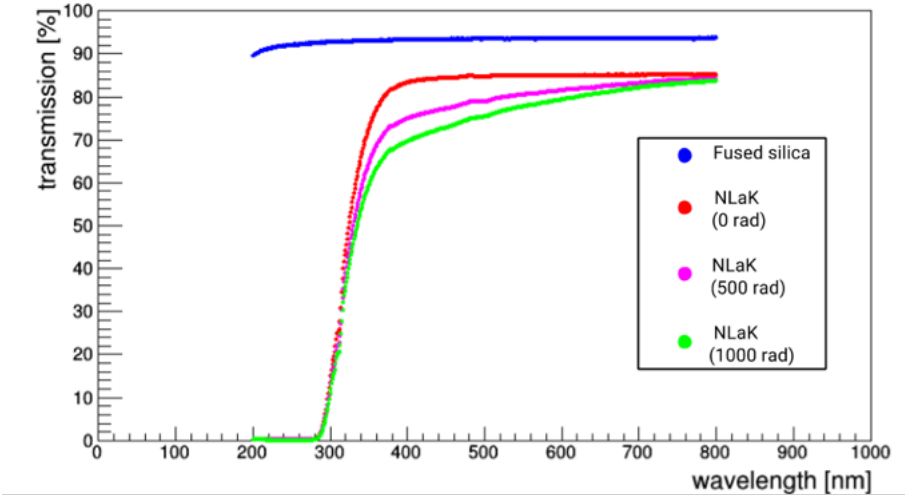
- Alternative to NLaK33 radiation hard material was found and will be validated.

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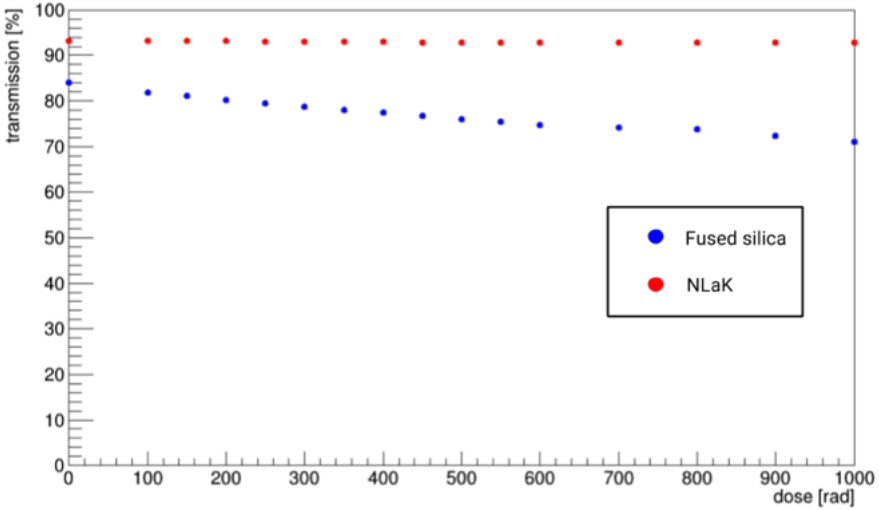
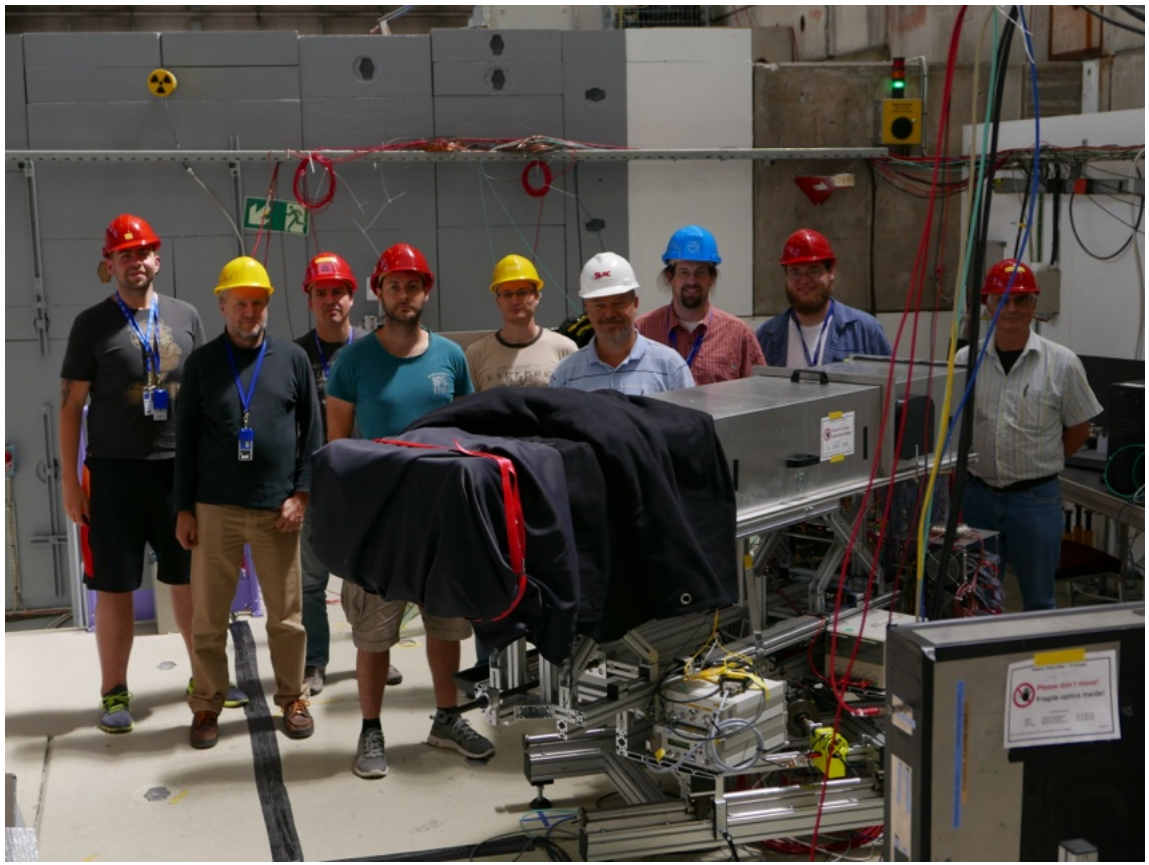
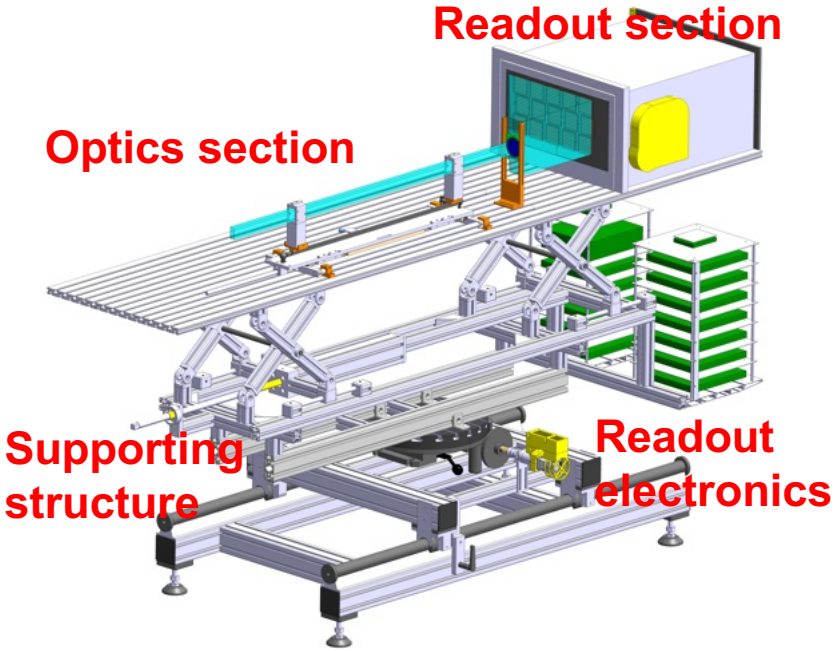


# 3-layer Lens Performance verification

**Full system PANDA barrel DIRC prototype**

- Wide range measurements performed in CERN
- Several different focusing lenses were tested





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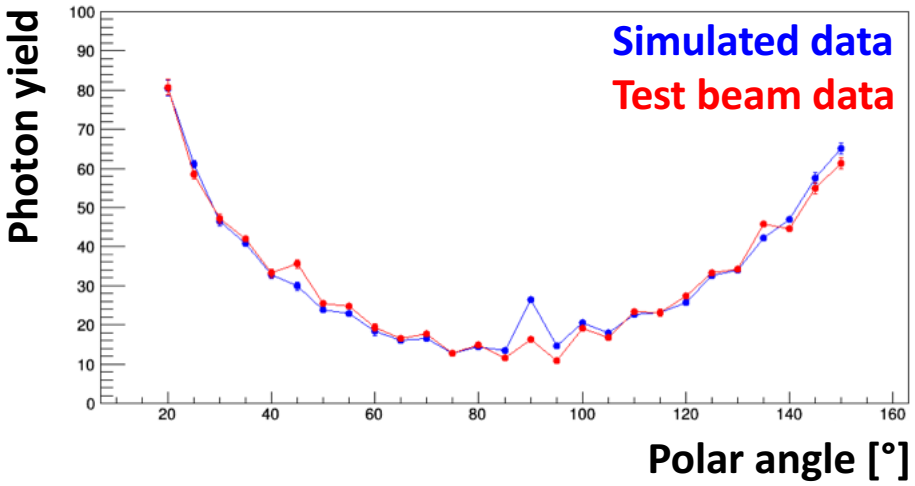
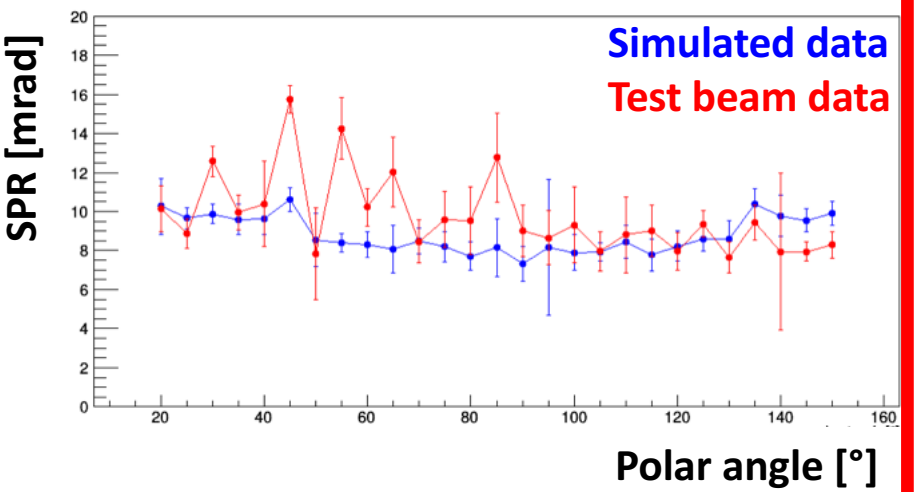
## PANDA Barrel DIRC Prototype with 3-layer lens in CERN particle beam

Performance parameters obtained with geometrical reconstruction for narrow bar geometry:



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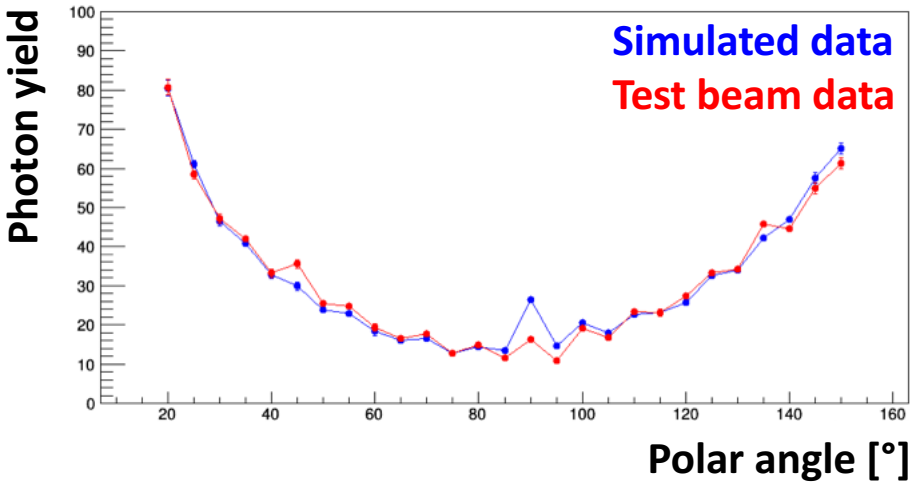


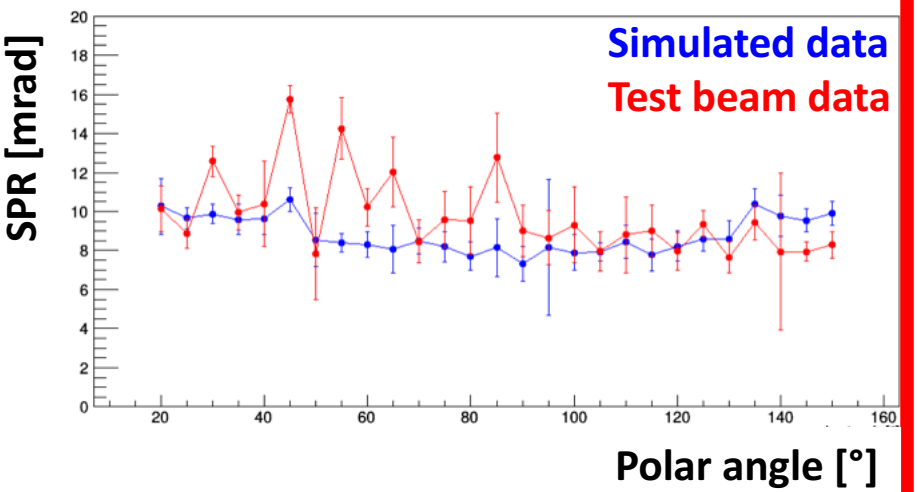


**Time based imaging:**

**π/p separation power at a momentum of 7 GeV/*c* and a polar angle of 25°**

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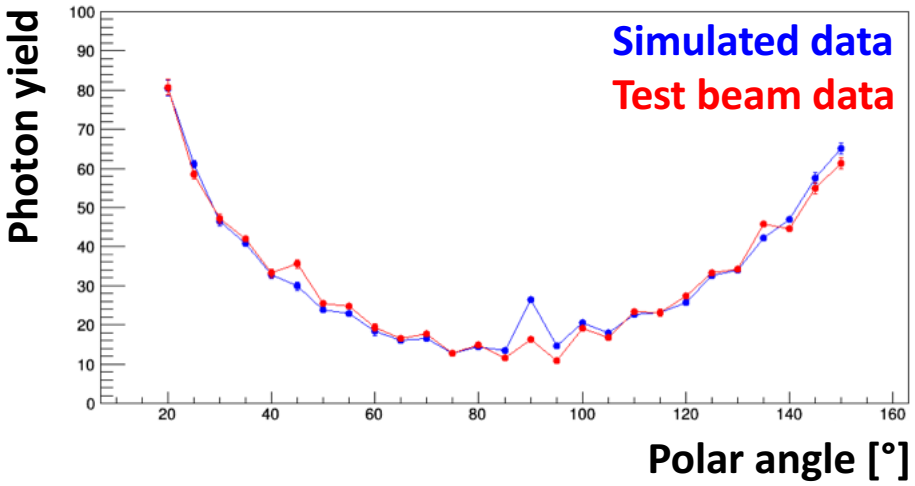


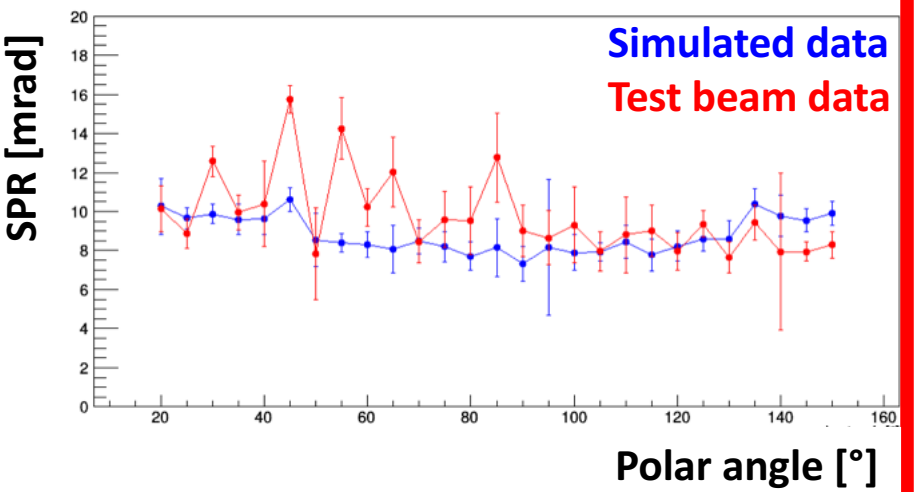


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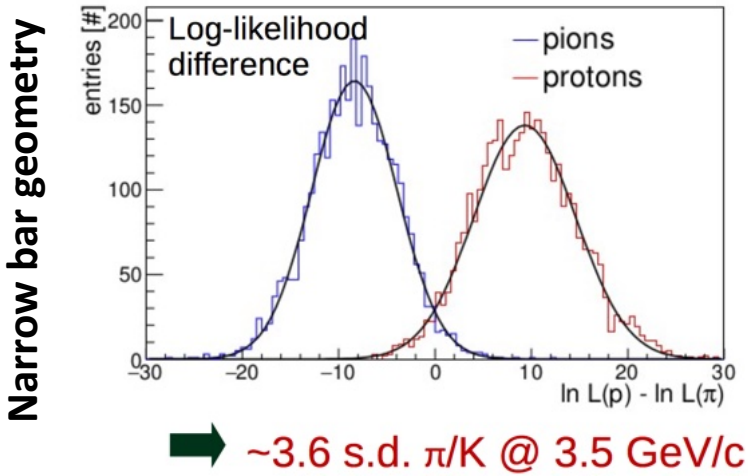


➡ ~3.6 s.d. π/K @ 3.5 GeV/c

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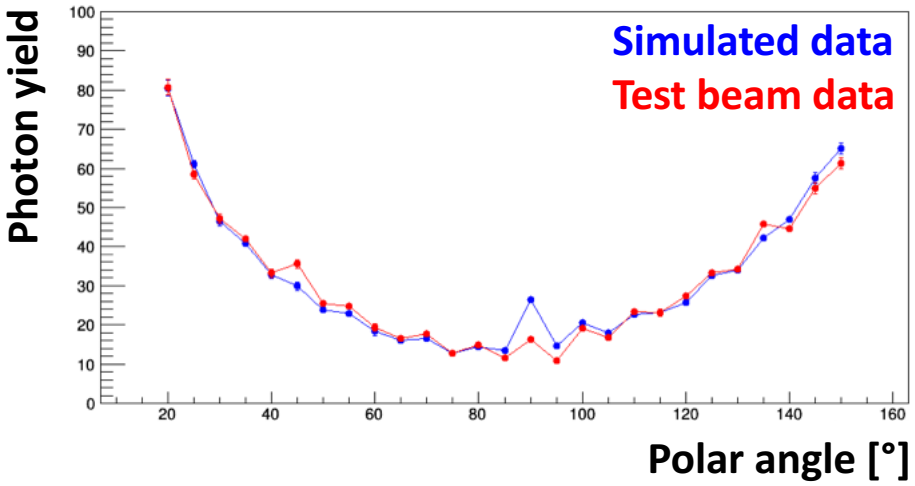


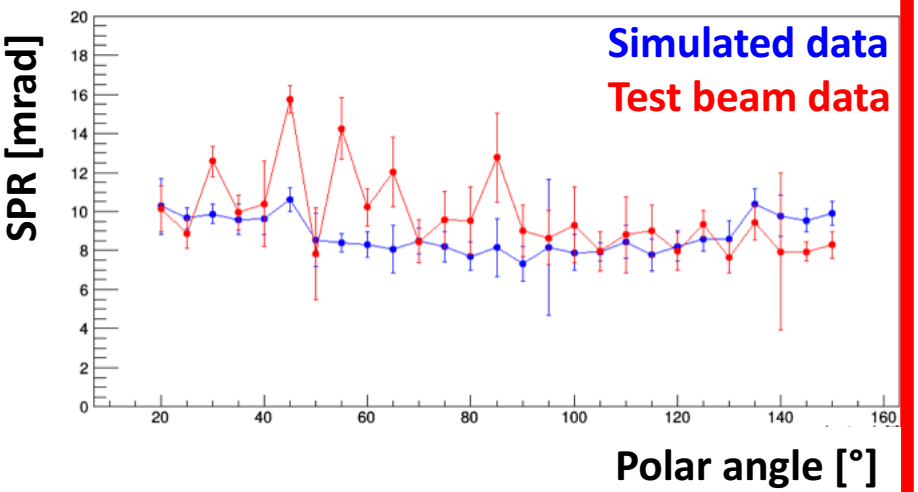


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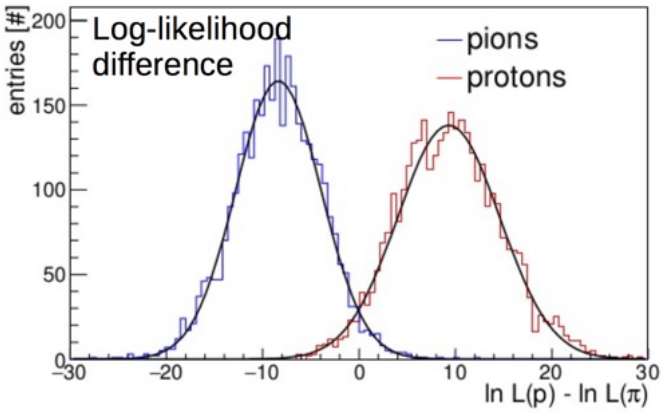
Narrow bar geometry

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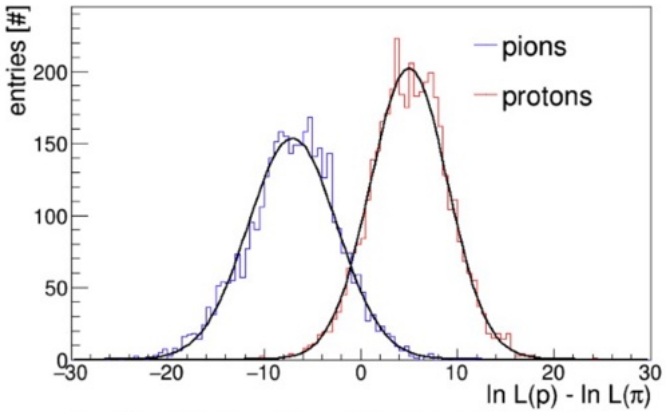
Wide plate geometry




➡ ~3.2 s.d. π/K @ 3.5 GeV/c

# 3-layer Lens New Cylindrical Prototype

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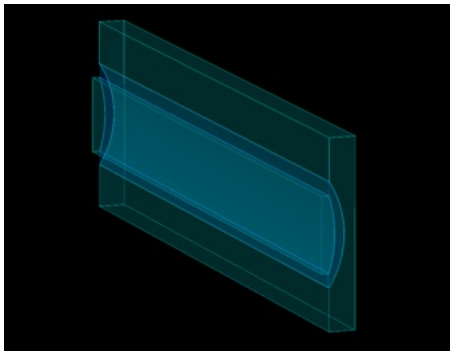
**Geant4 simulation of cylindrical 3-layer lens**



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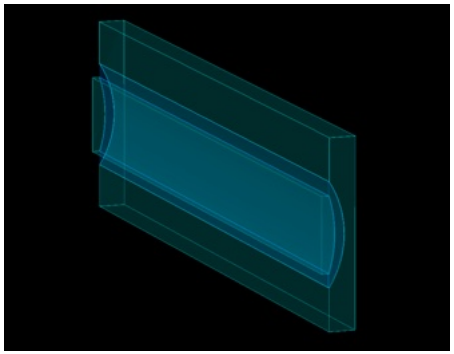
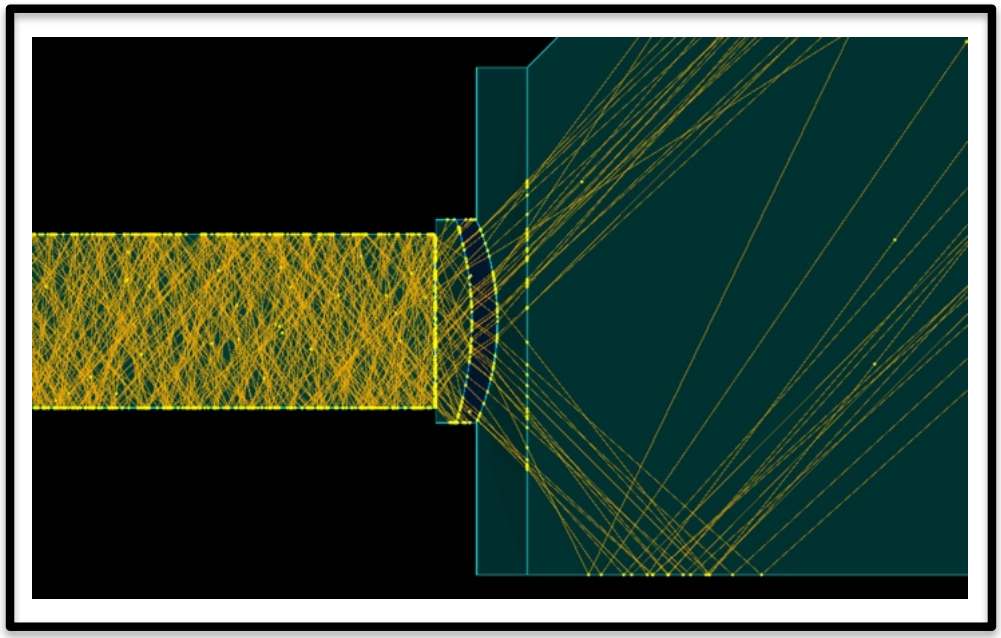
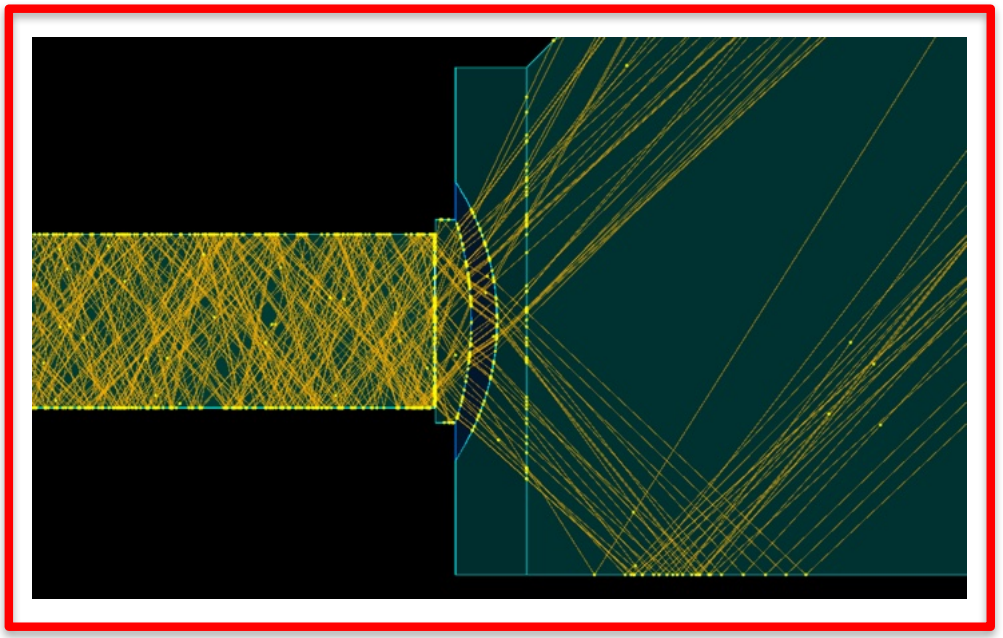
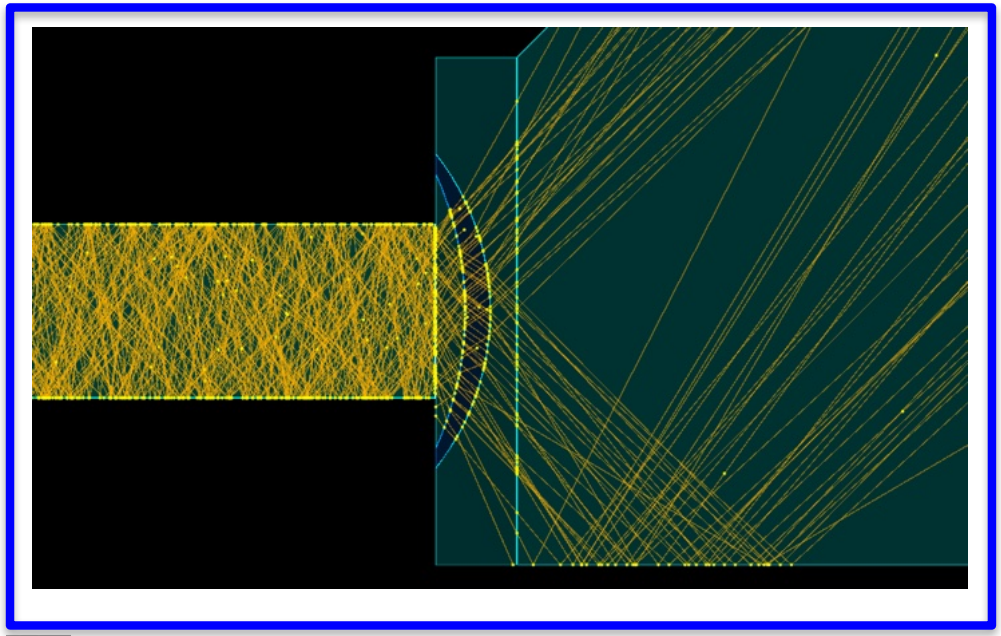


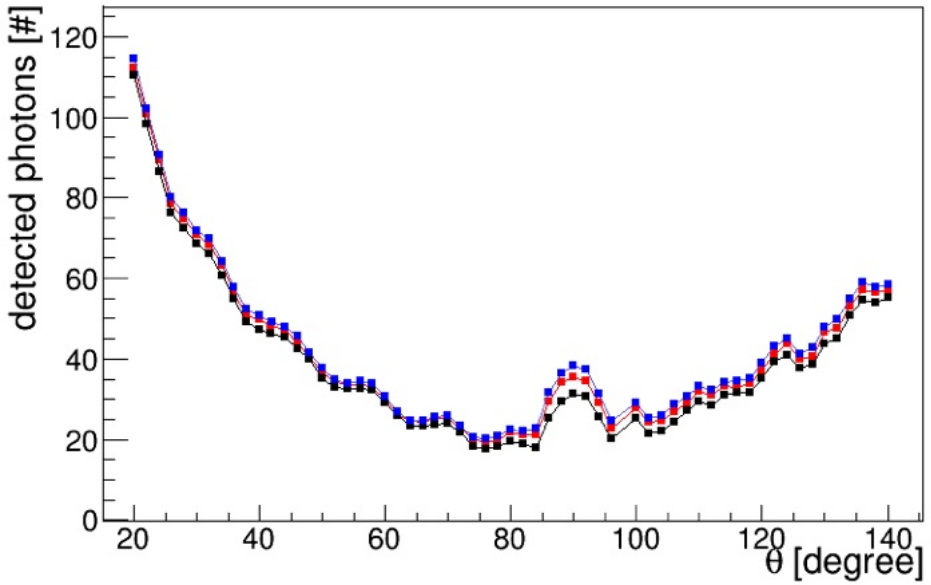
# 3-component Lens

## New Cylindrical Prototype









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- This week assembling of the lens started
- Problems with polishing edges to fit parts forced modifications to design
- Opportunity to test lens in August CERN test beam forced time efficient approach of using NLaK33 instead of alternative material

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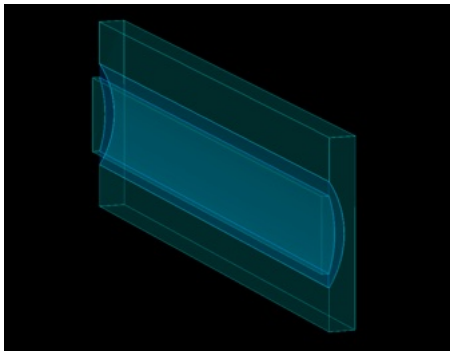

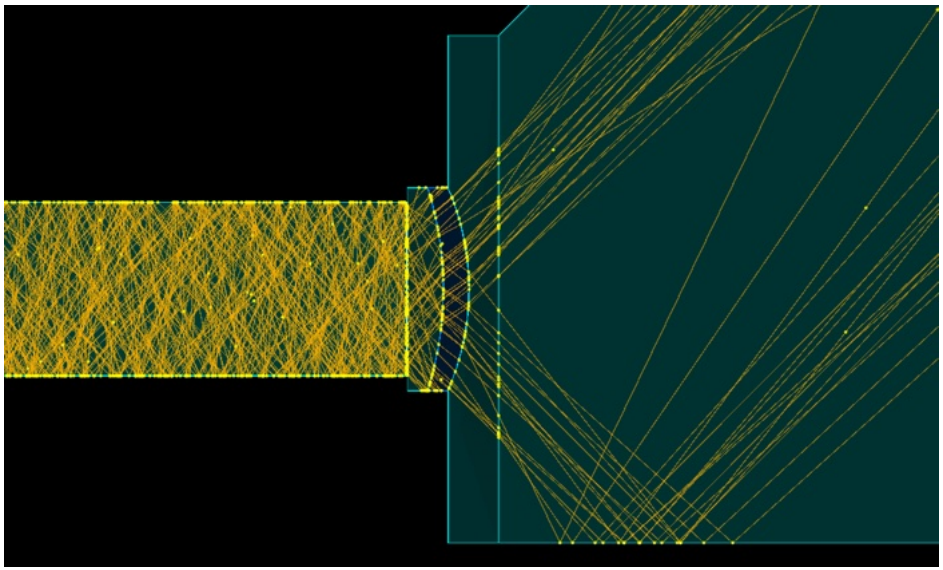

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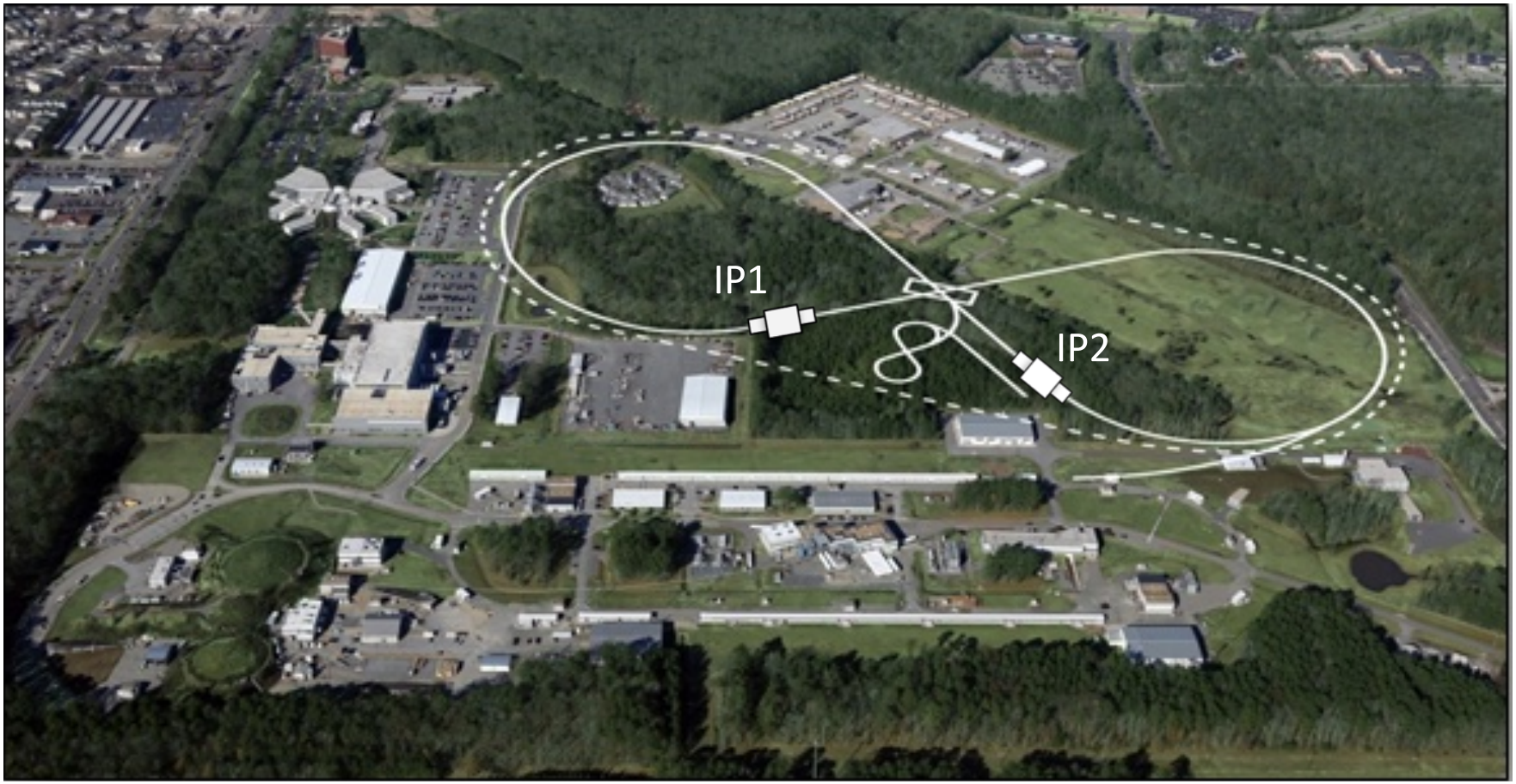
- **First results of the NLaK33 material radiation hardness tests suggest need of alternative high refractive index material.**
- **The new cylindrical 3-layer lens prototype for wide plate geometry is being finished and will be tested in few weeks in CERN test beam.**

# Backup

# 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%**

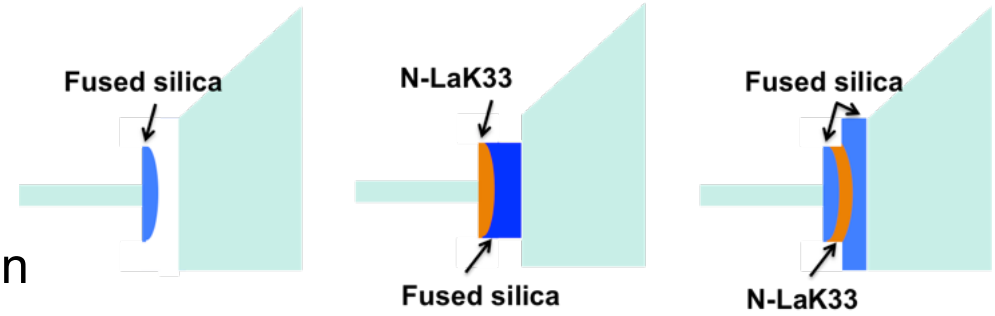
## Upgrade to higher energies and luminosity possible

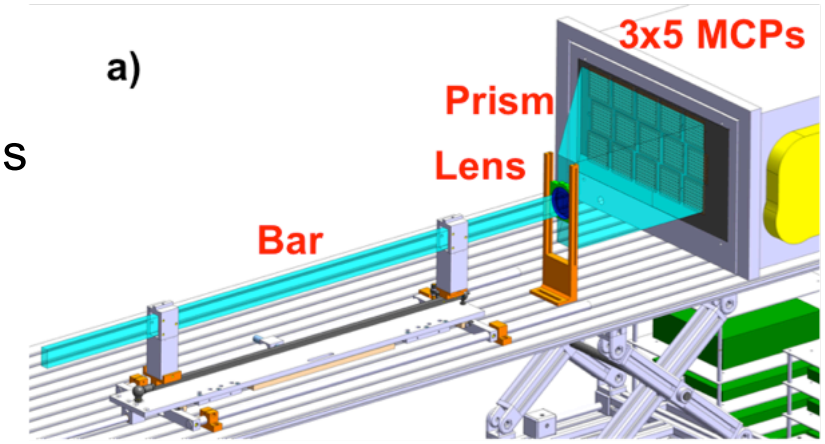
**20 GeV** electron, **250 GeV** proton, and **100 GeV/u** ion

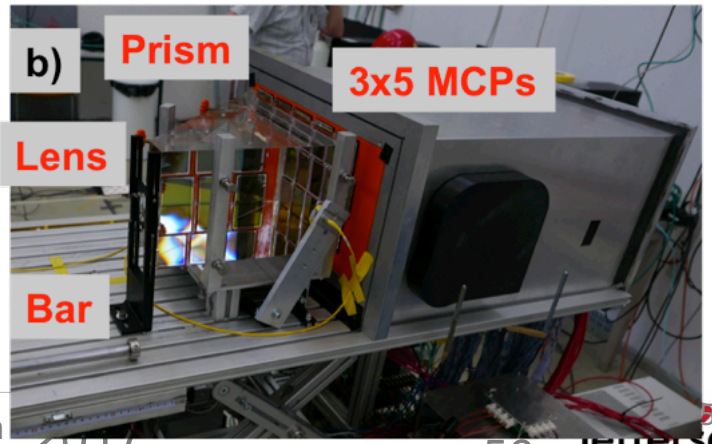
**Design goals consistent with the White Paper requirements**

# High-performance DIRC Prototype 3-component lens

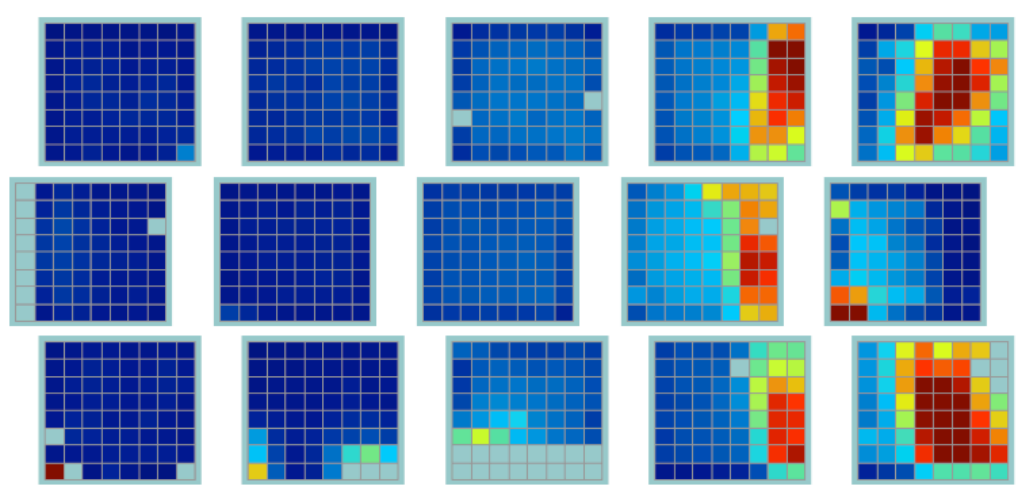
- **Polar angle of beam to bar:**
  - 20°-160° range with 5° step
  - Several fine scans for better resolution evaluation
- **Different focusing lenses:**
  - Air gap spherical and cylindrical lens
  - Spherical and cylindrical 2-component lens
  - Spherical 3-component lens
- **Different radiator:**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



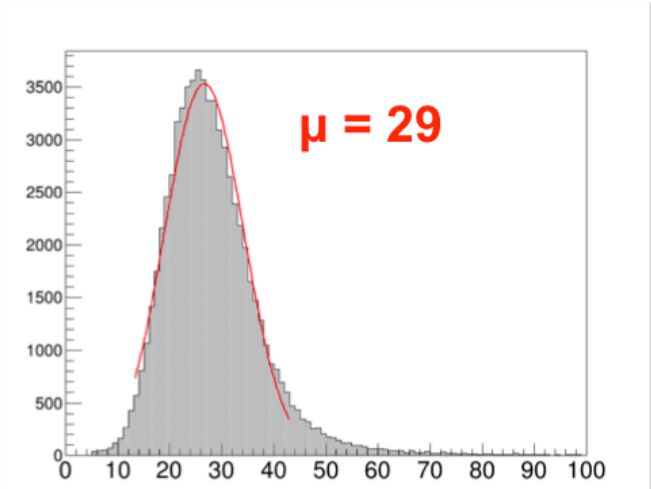



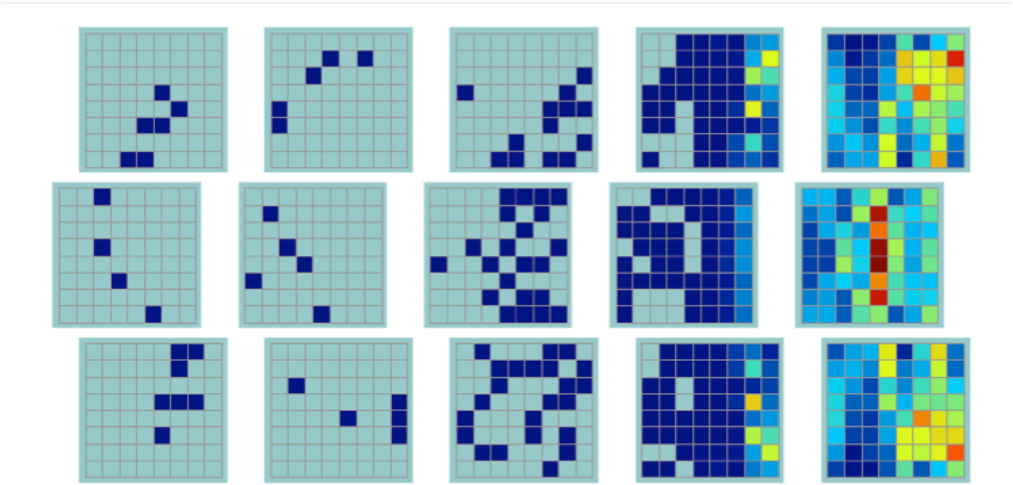



# 2015 Campaign: Beam polar angle: 90°

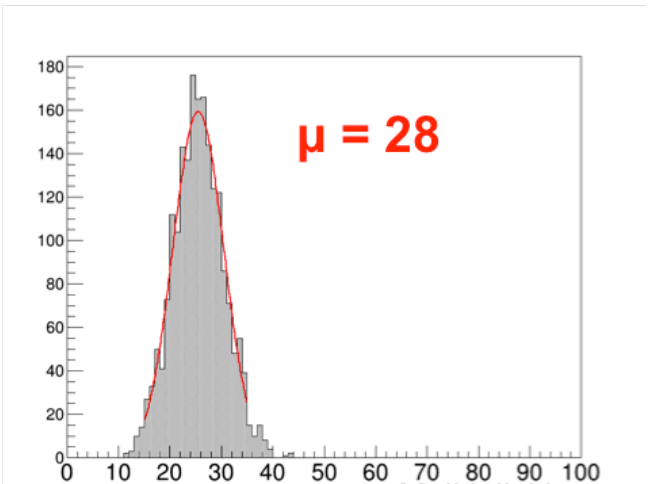


Test beam data

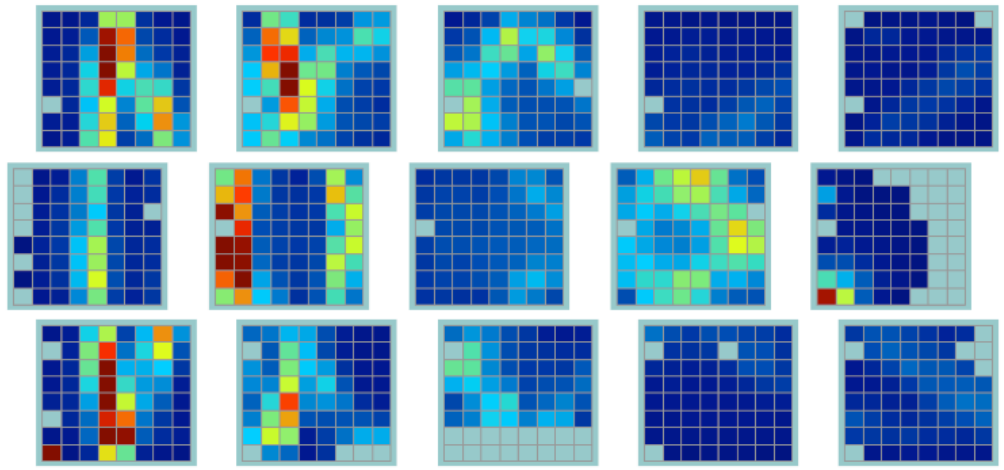


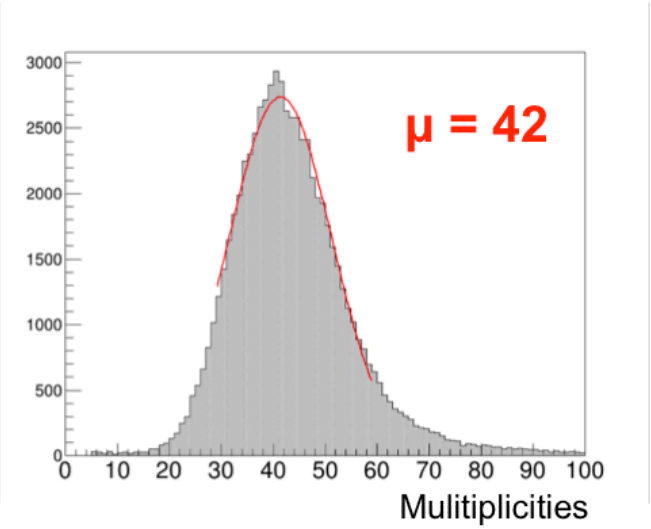
Simulated data

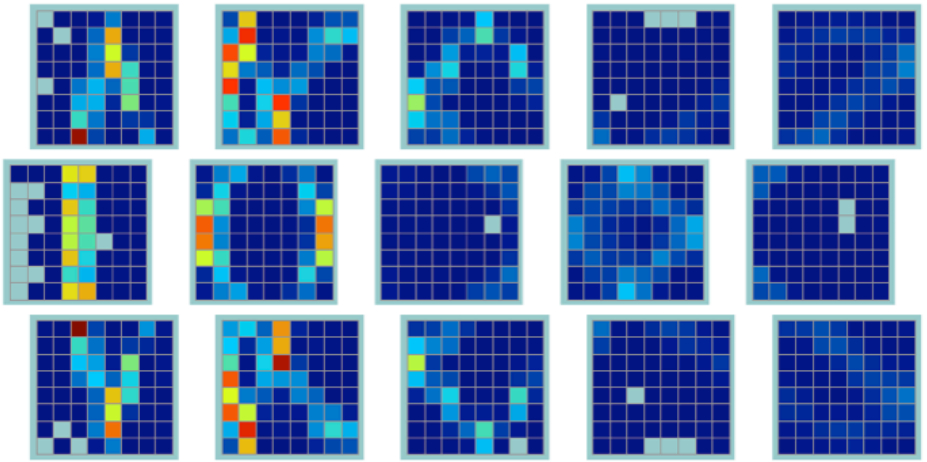


# 2015 Campaign: Beam polar angle: 125°

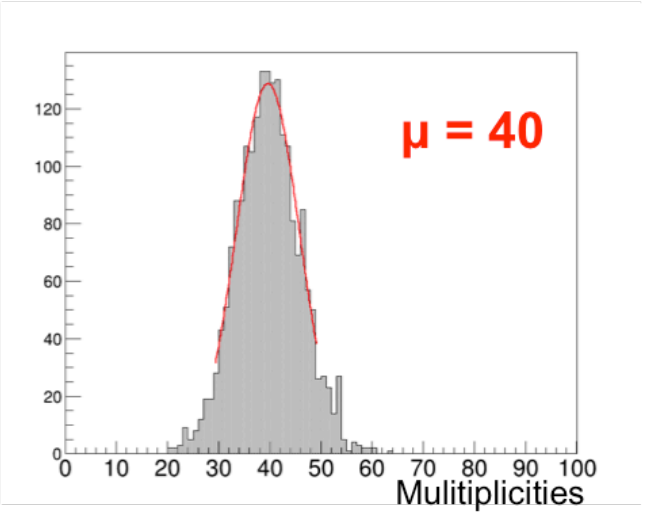


Test beam data



Simulated data



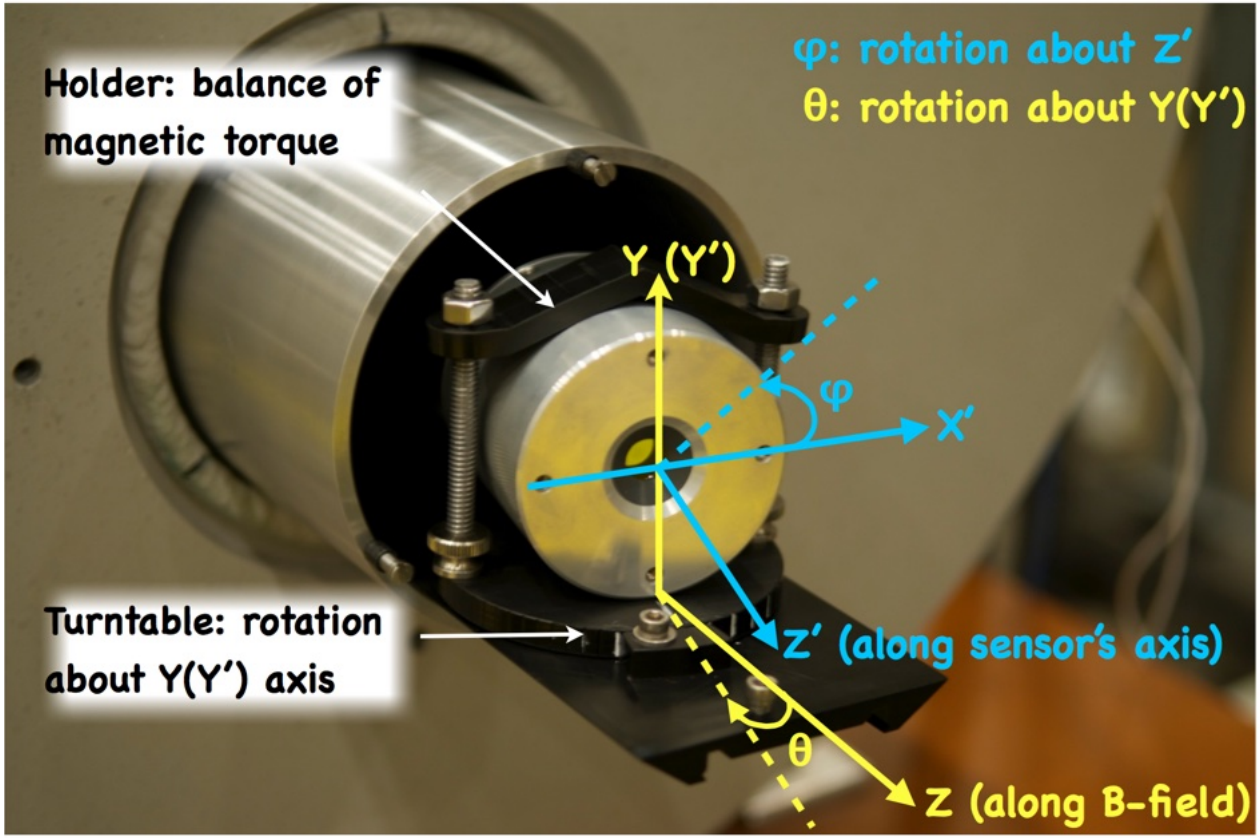
# High B field test facility Measurements of photosensors

**Magnet**:

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

**Test Box:**

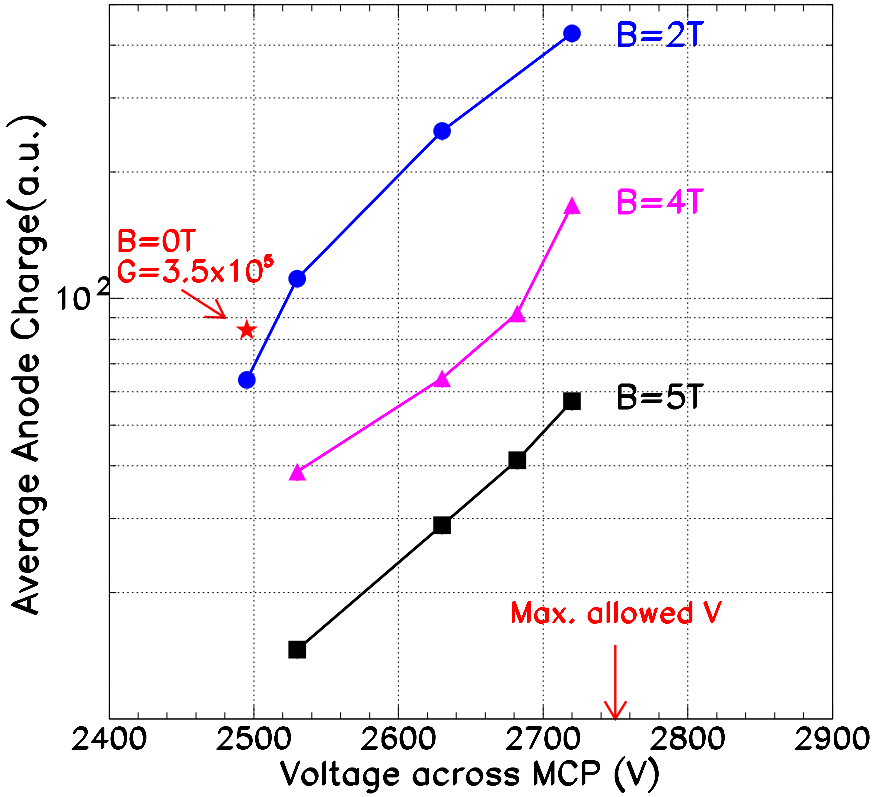
- non-magnetic, light-tight
- allows for rotation of sensors
- LED light source



# 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




Please don't move!
Fragile optics inside!