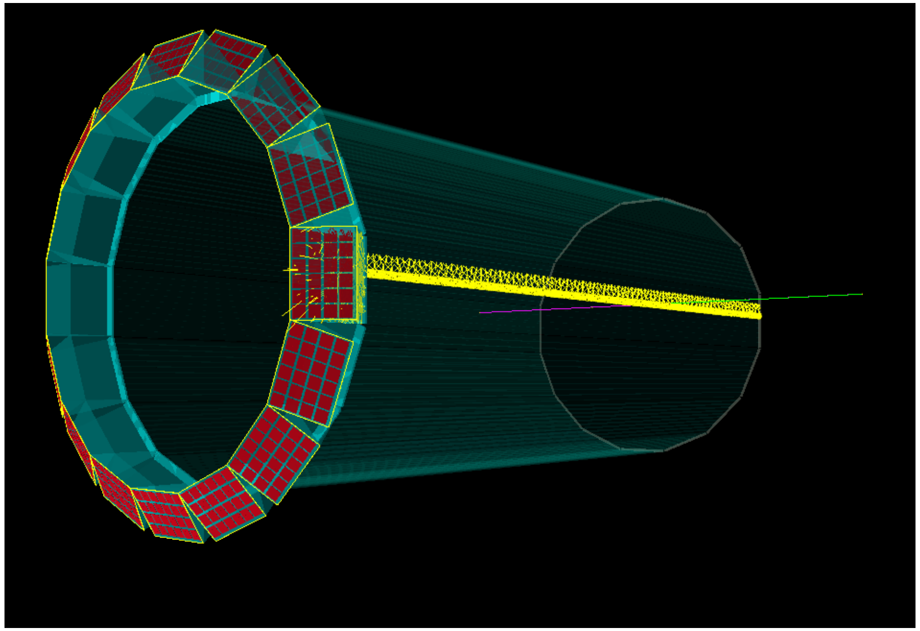
High Performance DIRC Detector for future EIC Detector

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



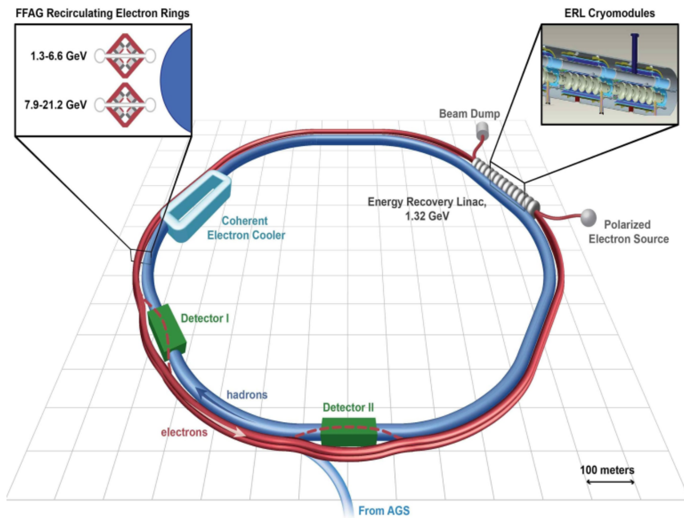
August 8th, 2017

Electron Ion Collider

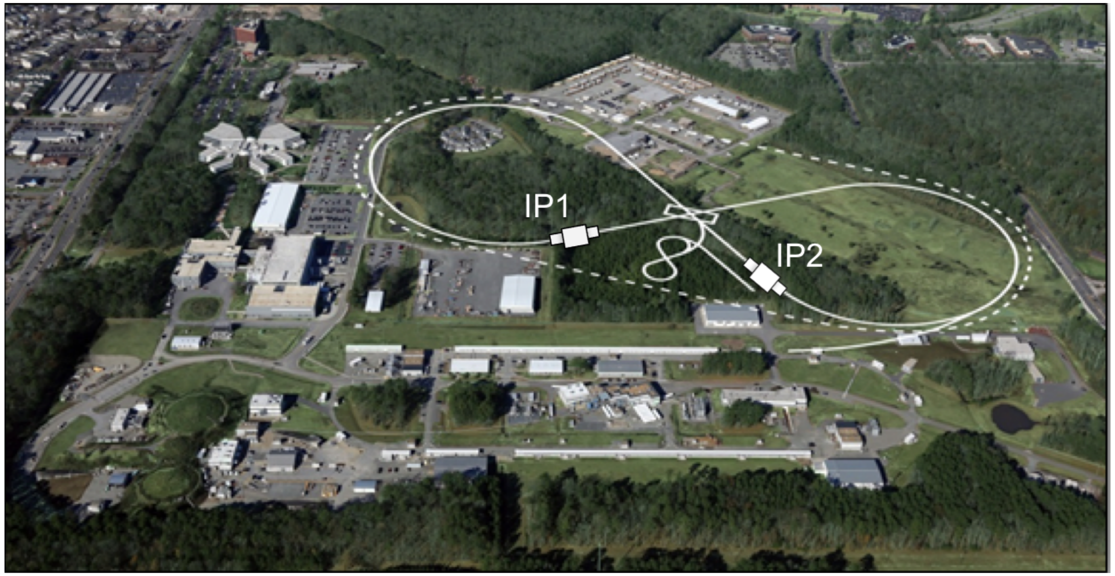
Electron ion Collider (EIC)

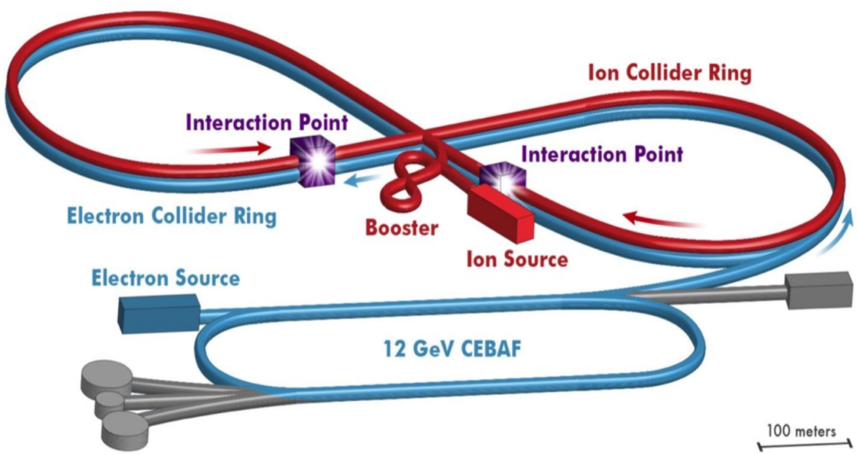
- **Two competing locations:** Jefferson Lab and Brookhaven

BNL concept o EIC accelerator ring



Jefferson Lab figure eight design of EIC accelerator





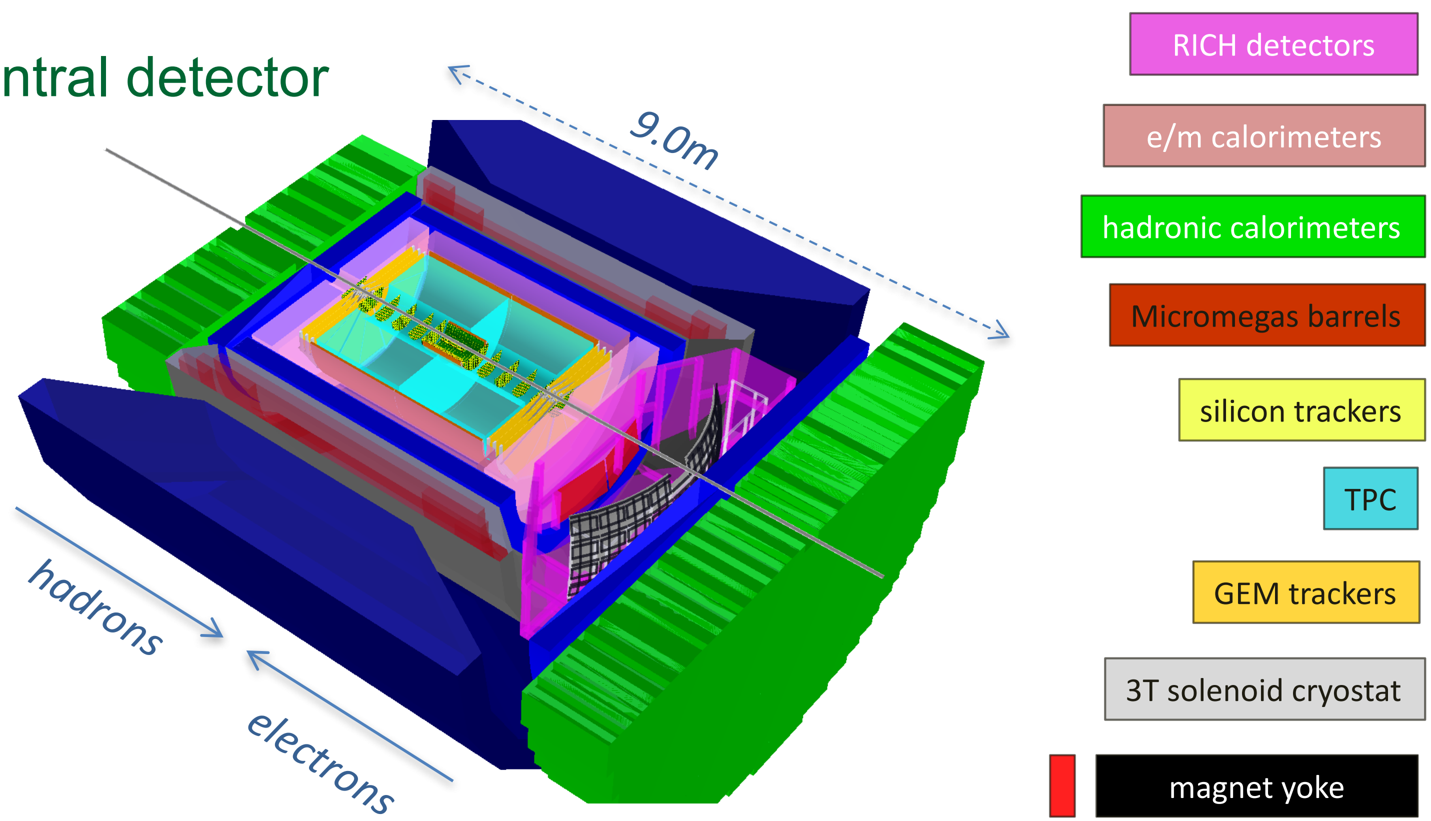
Electron Ion Collider

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
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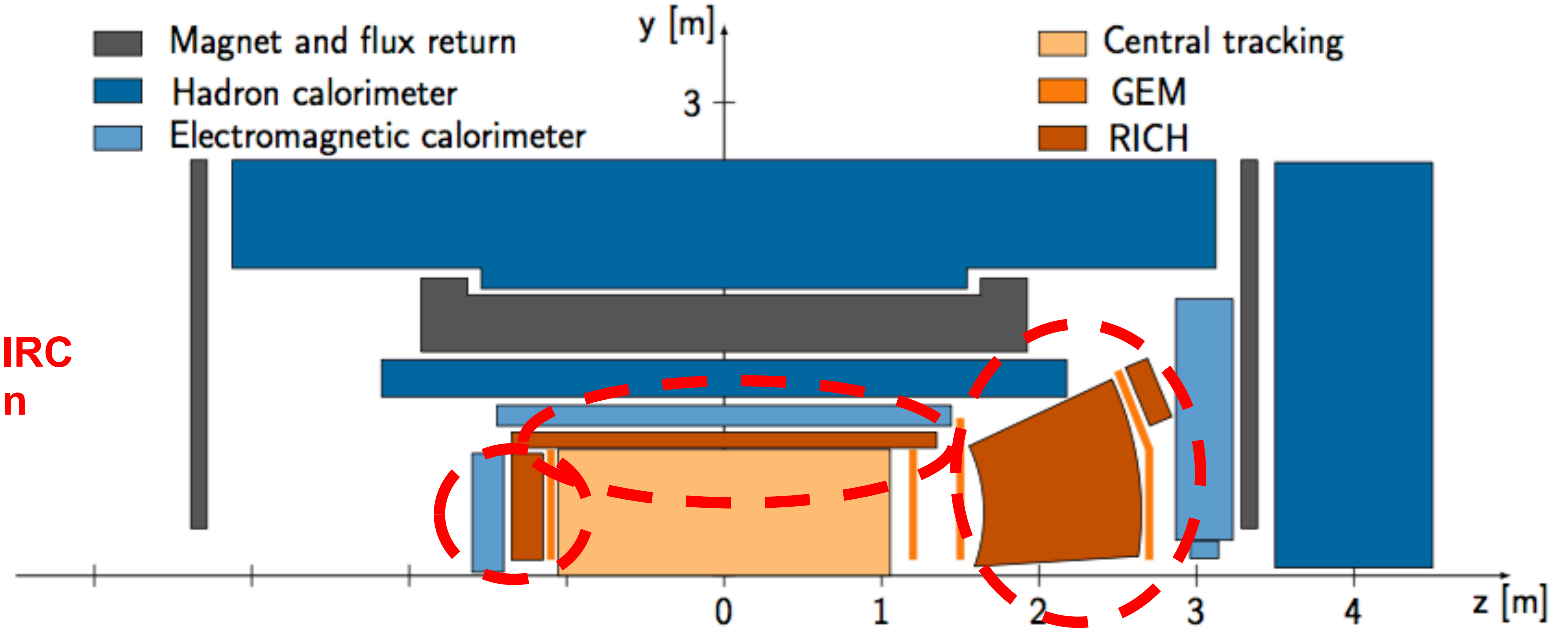
BNL ePHENIX EIC central detector

High-Performance DIRC already considered in current concept



Electron Ion Collider

Electron ion Collider (EIC)

- **Two competing locations:** Jefferson Lab and Brookhaven
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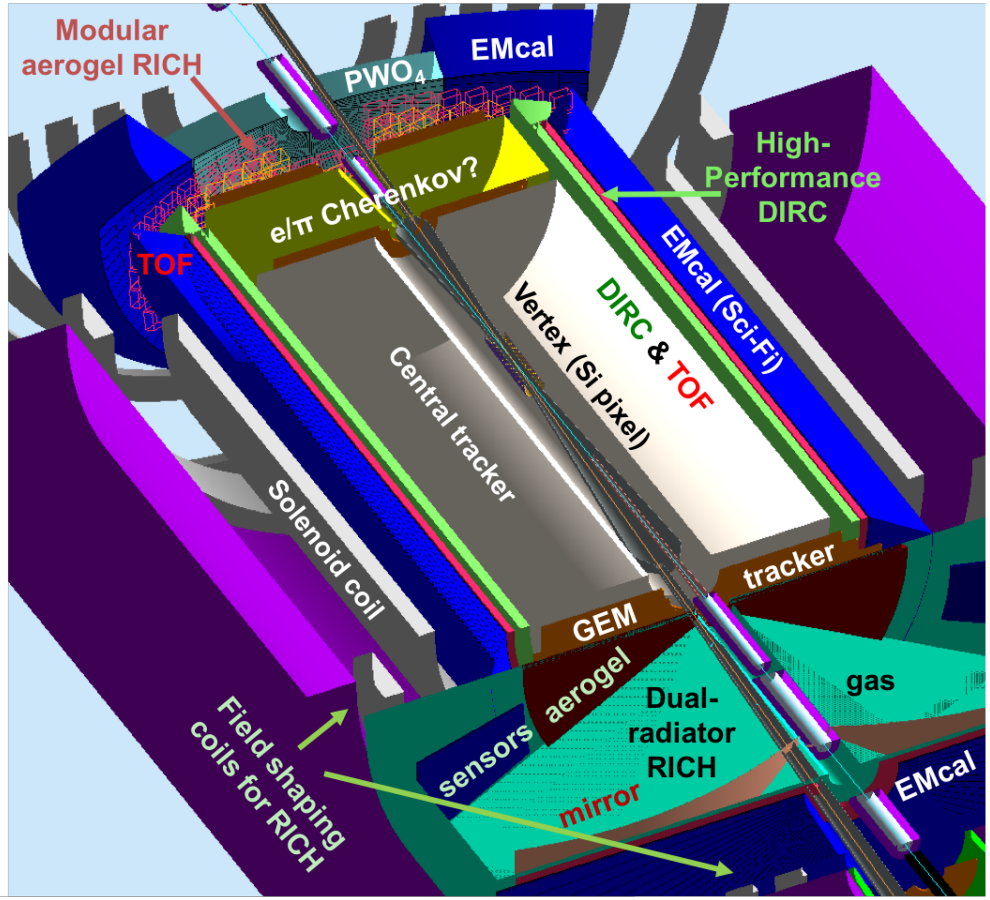
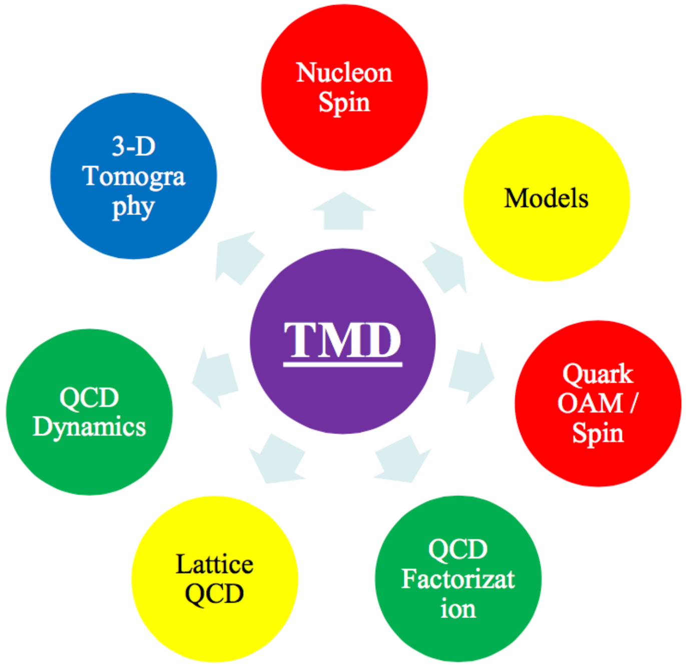
JLab EIC central detector

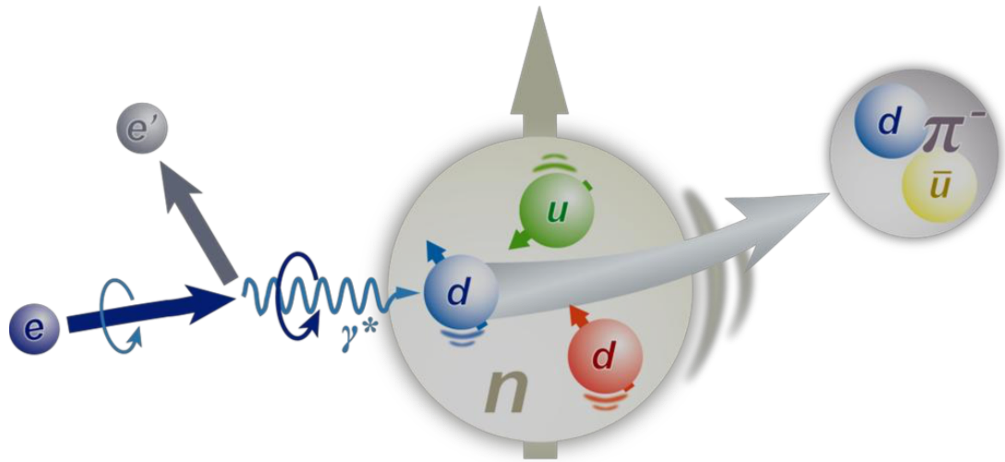
High-Performance DIRC original concept



PID Semi-Inclusive DIS (SIDIS)



Precision mapping of transverse momentum dependent parton distributions (TMD)

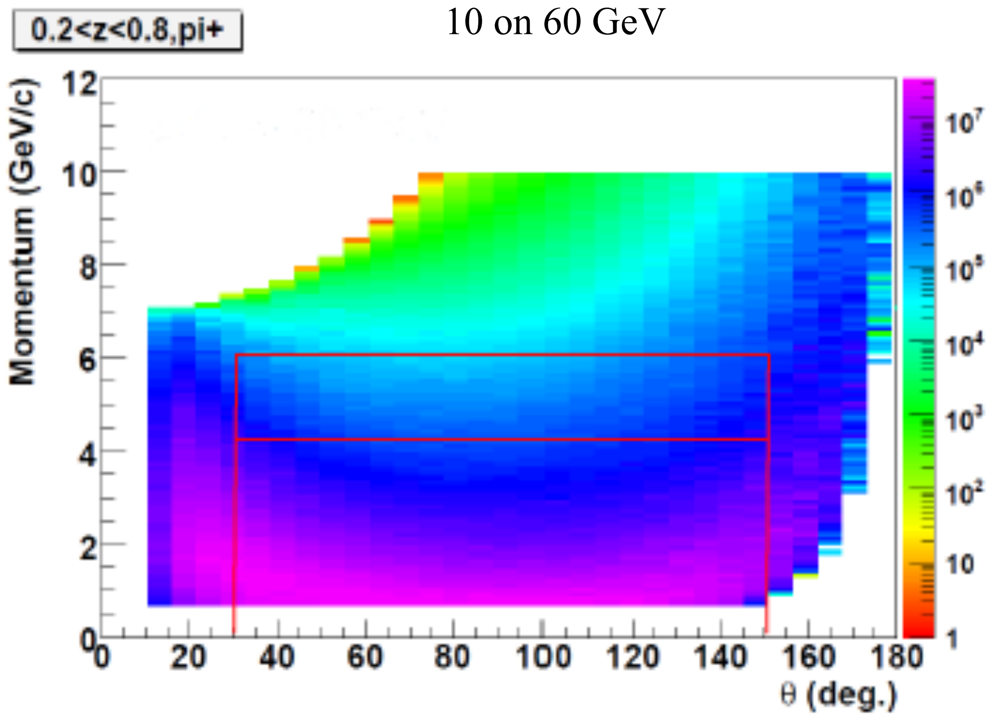


Ilustration of E06-010 Double Spin Asymmetry
Jin Huang <jinhuang@jlab.org>

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

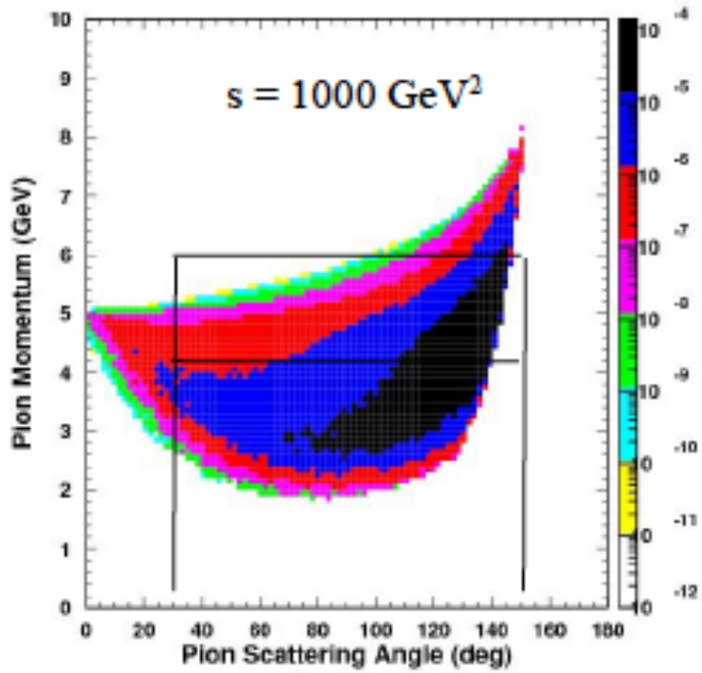
PID 3D structure of the proton

10 on 60 GeV

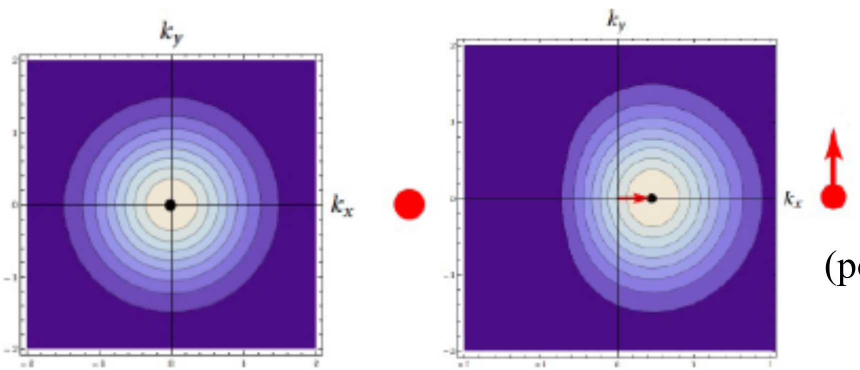


Semi-Inclusive DIS – mapping of transverse momentum distributions of (sea) quarks

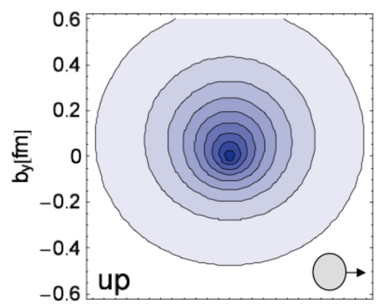
5 on 50 GeV



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

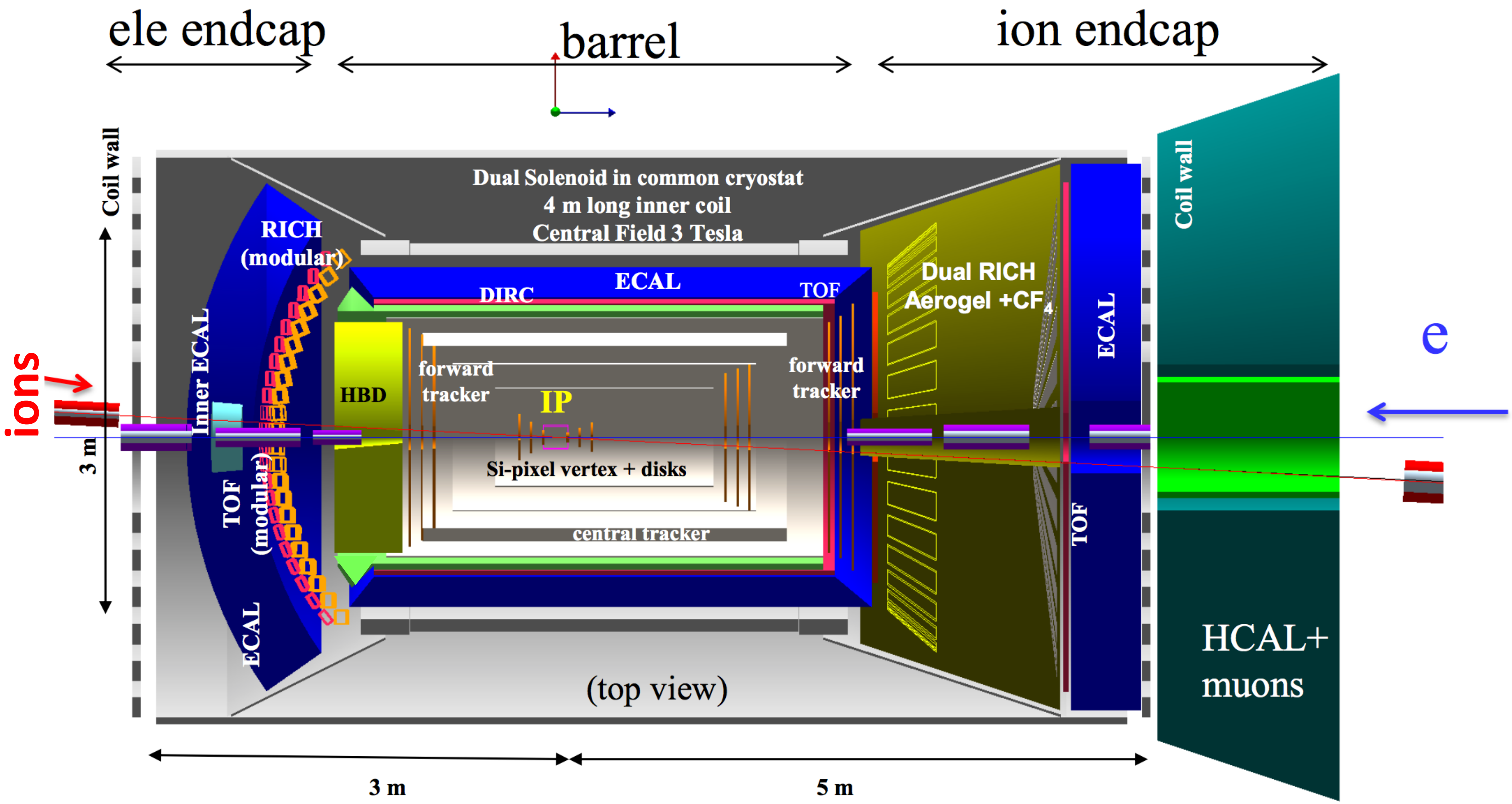


(polarized)



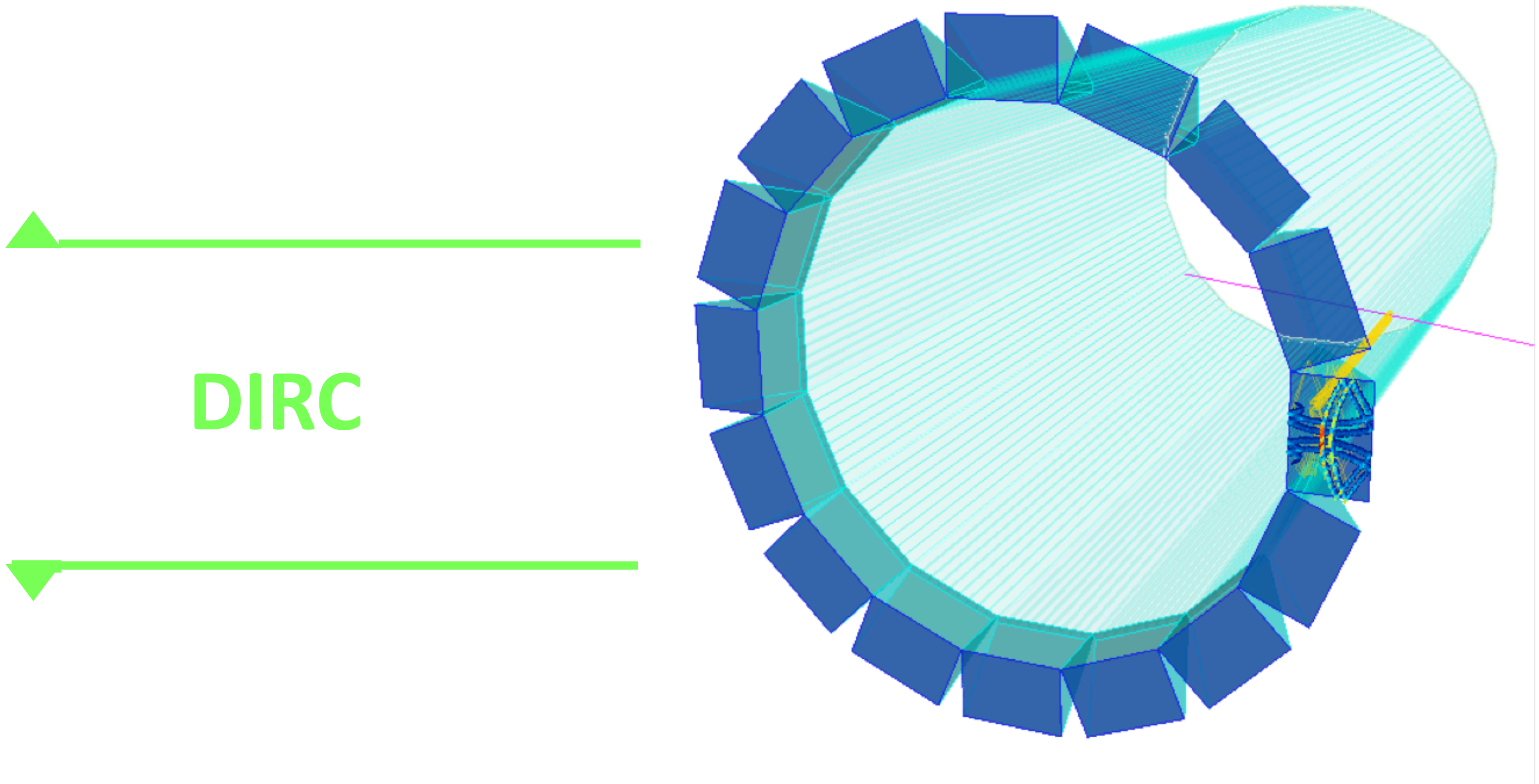
(polarized)

JLab EIC Current design



JLab EIC Current design

Geant4 simulation of High-Performance DIRC detector



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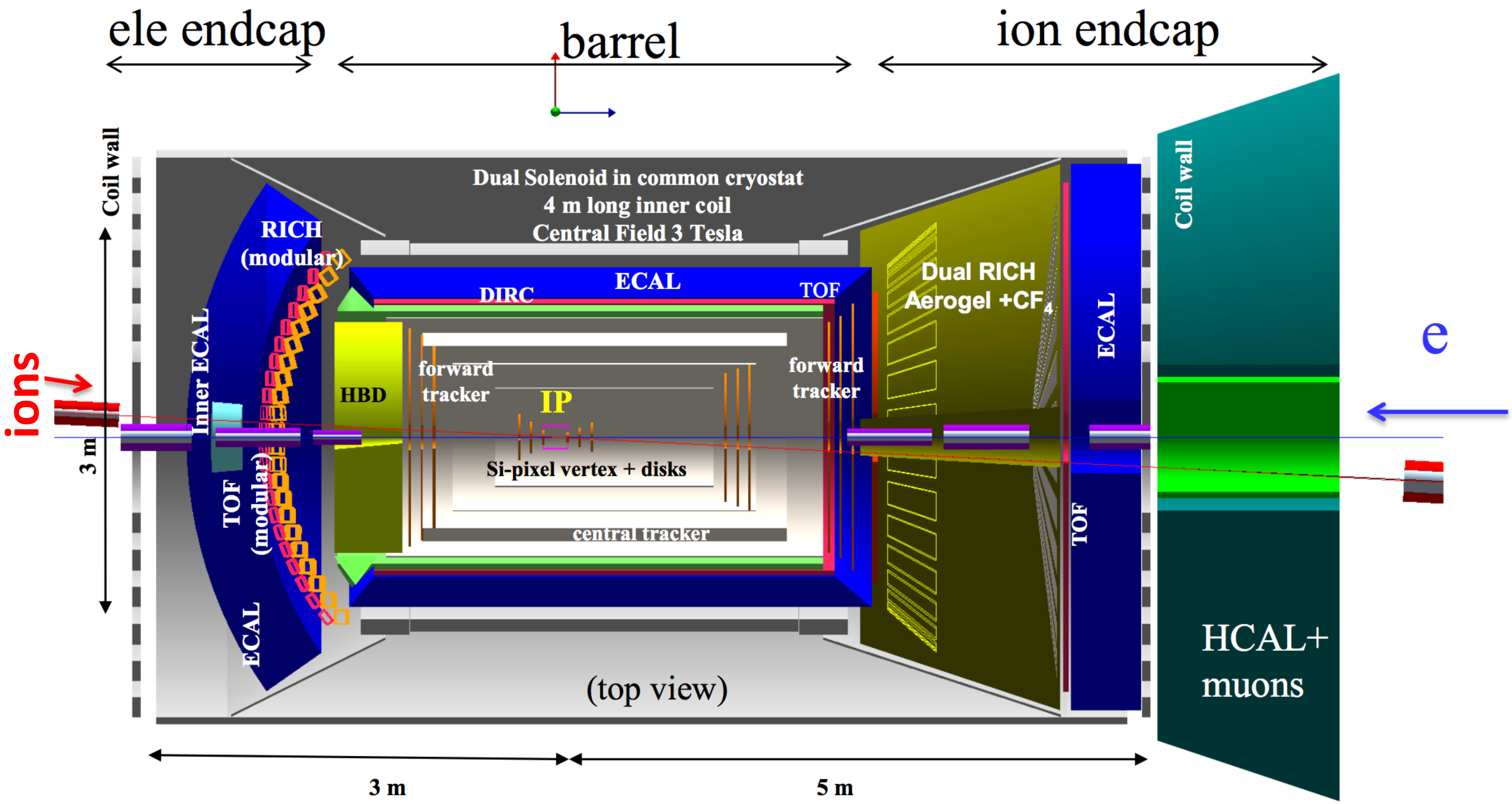
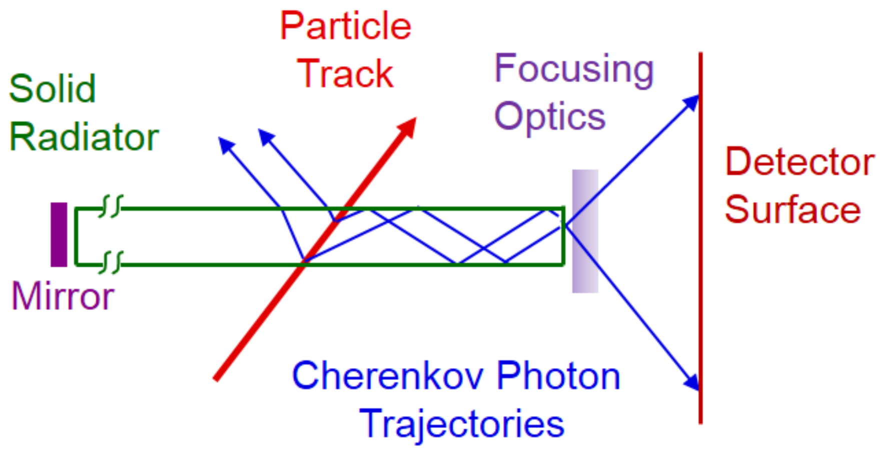
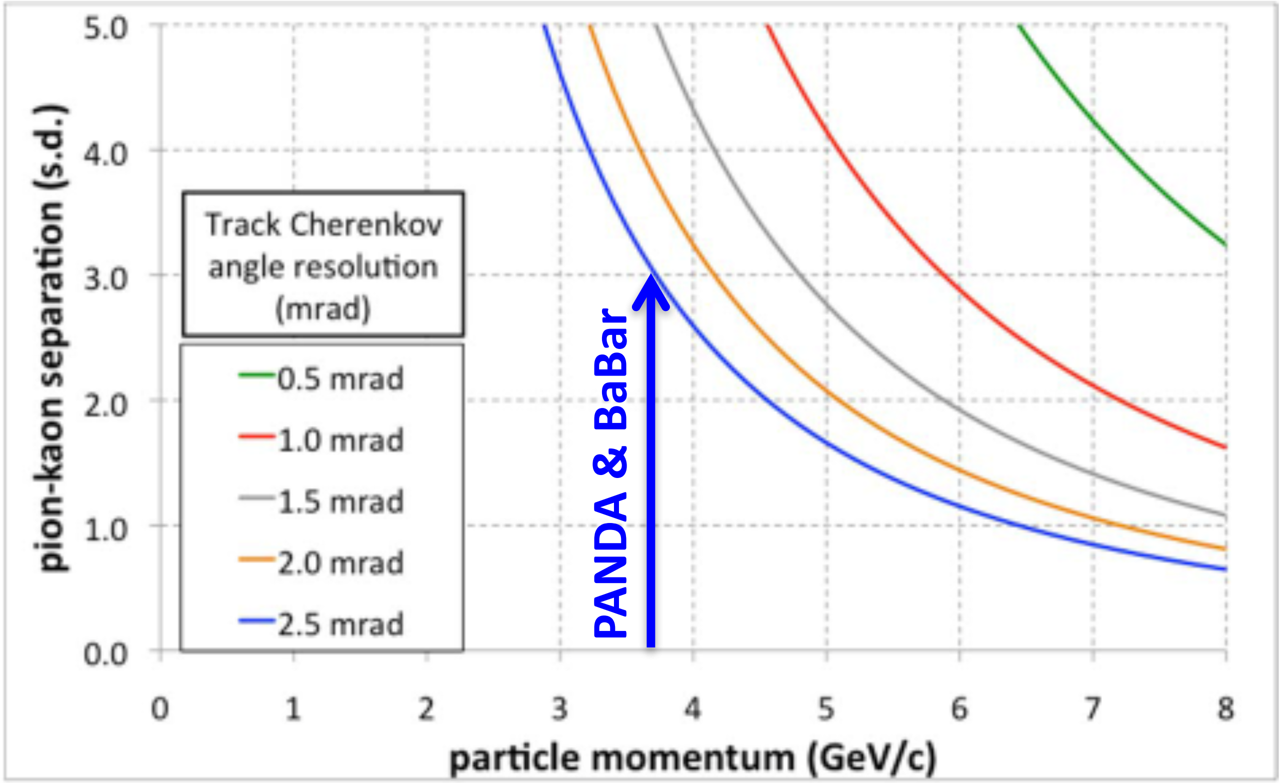


DIRC@EIC Performance goal

DIRC@EIC PID capability using geometrical reconstruction:



π/K identification as a function of the θ_c resolution



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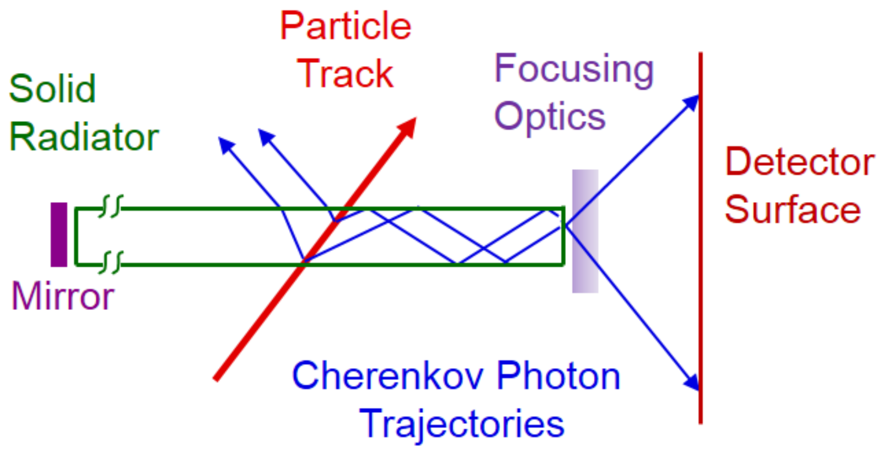
- **π/K up to 6 GeV/c**



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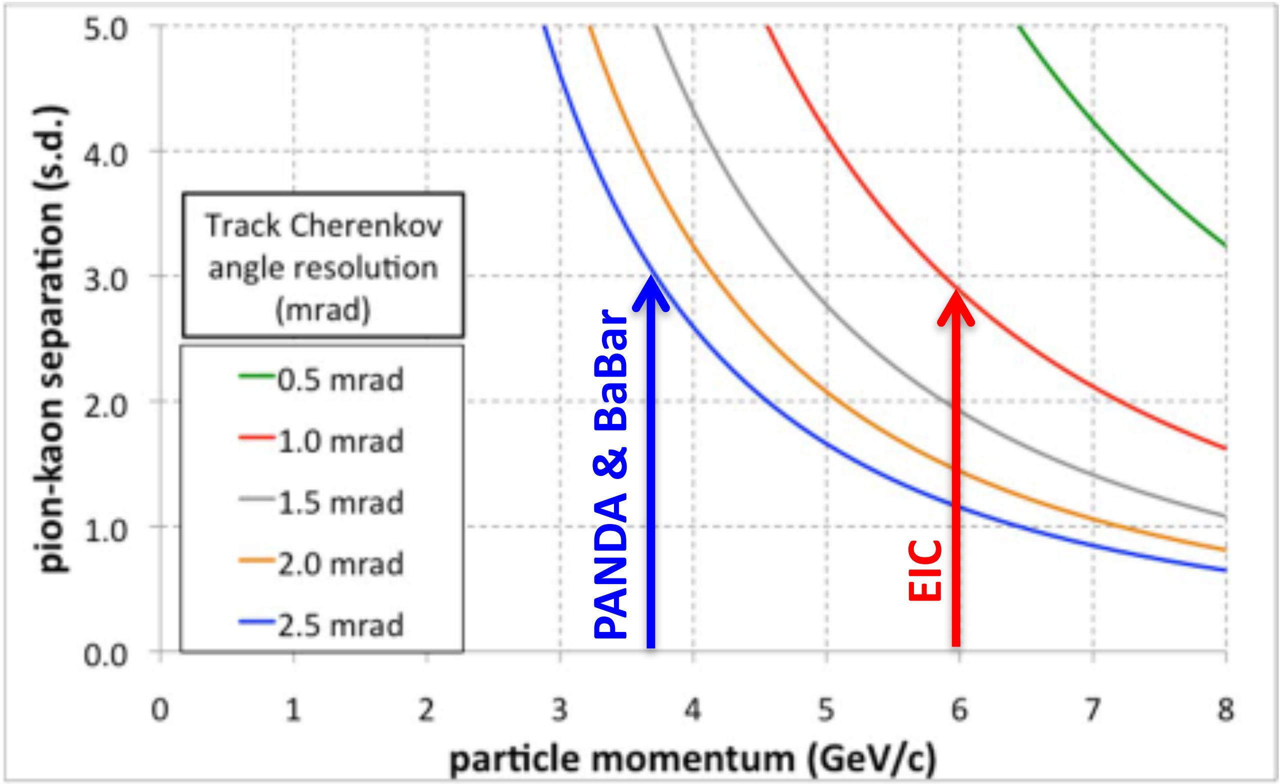
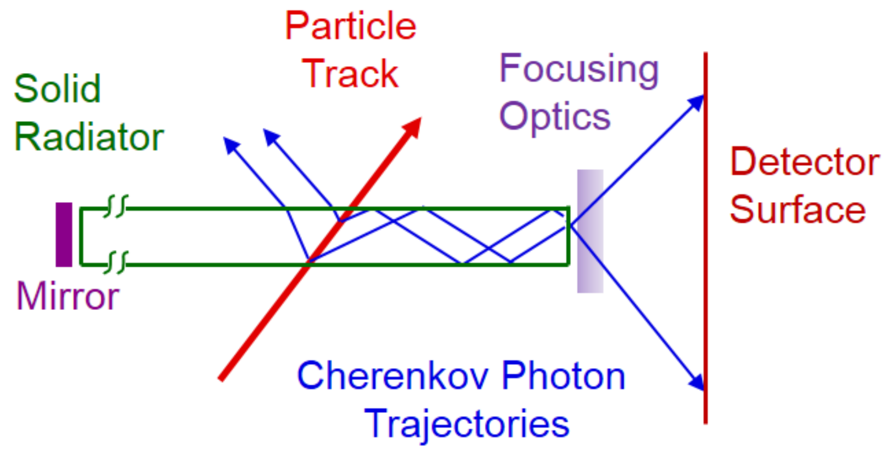


DIRC@EIC Performance goal

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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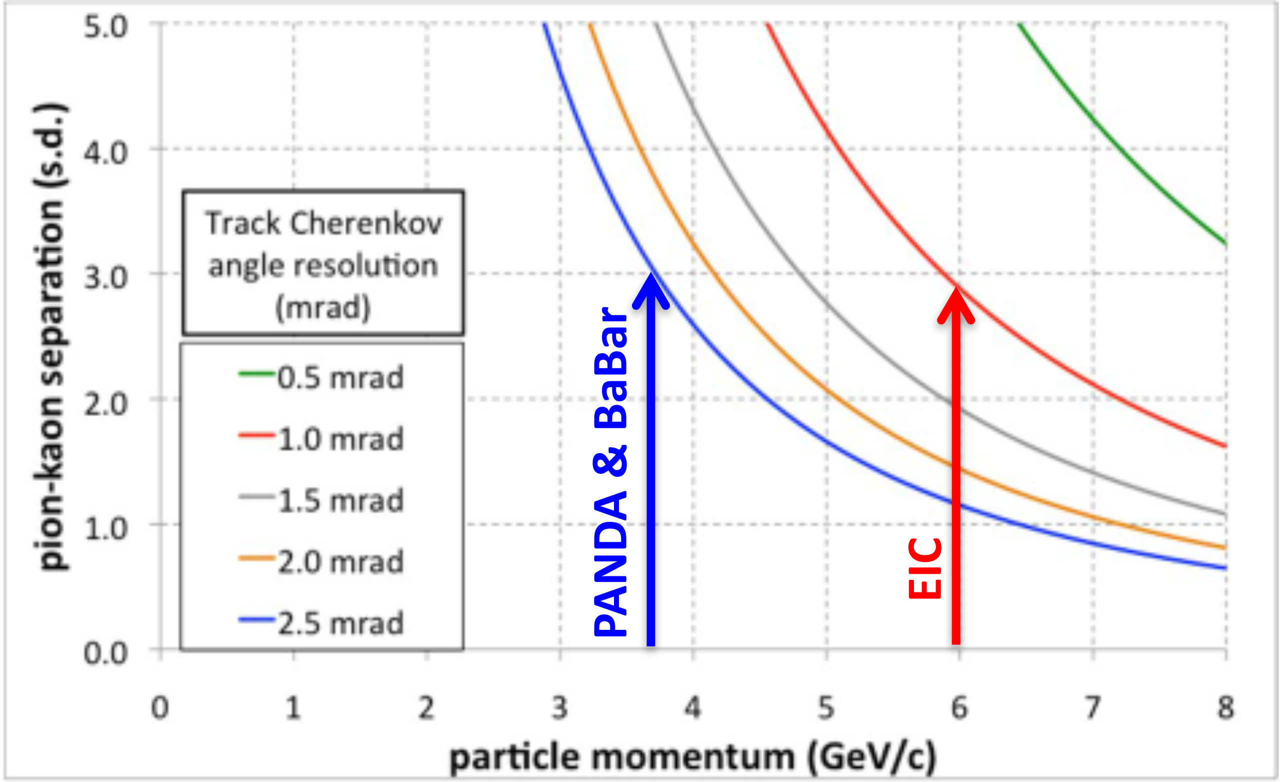


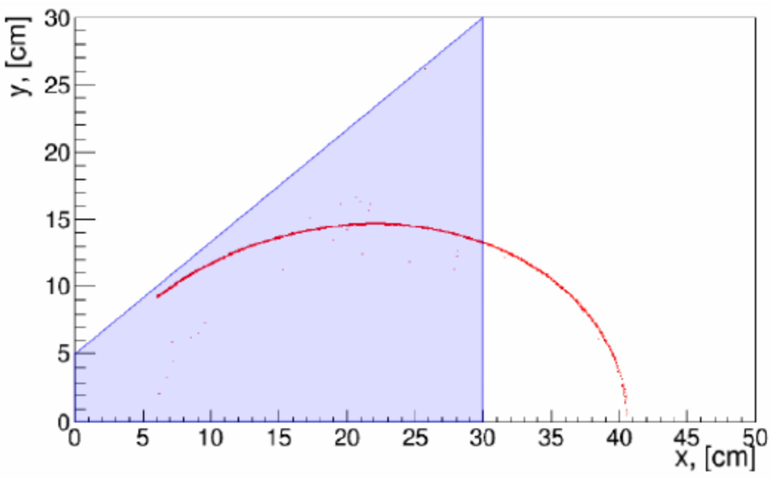
DIRC@EIC Prototype 3-component lens

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

Limitations of standard focusing lenses:

- Significant photon yield loss around 90° particle track
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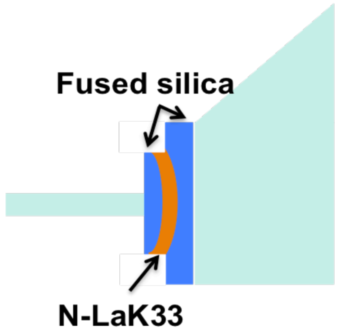
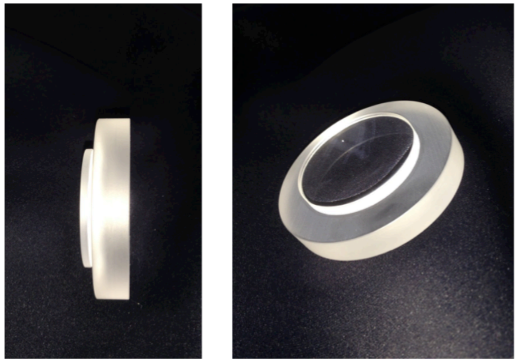
Spherical 3-layer lens prototype





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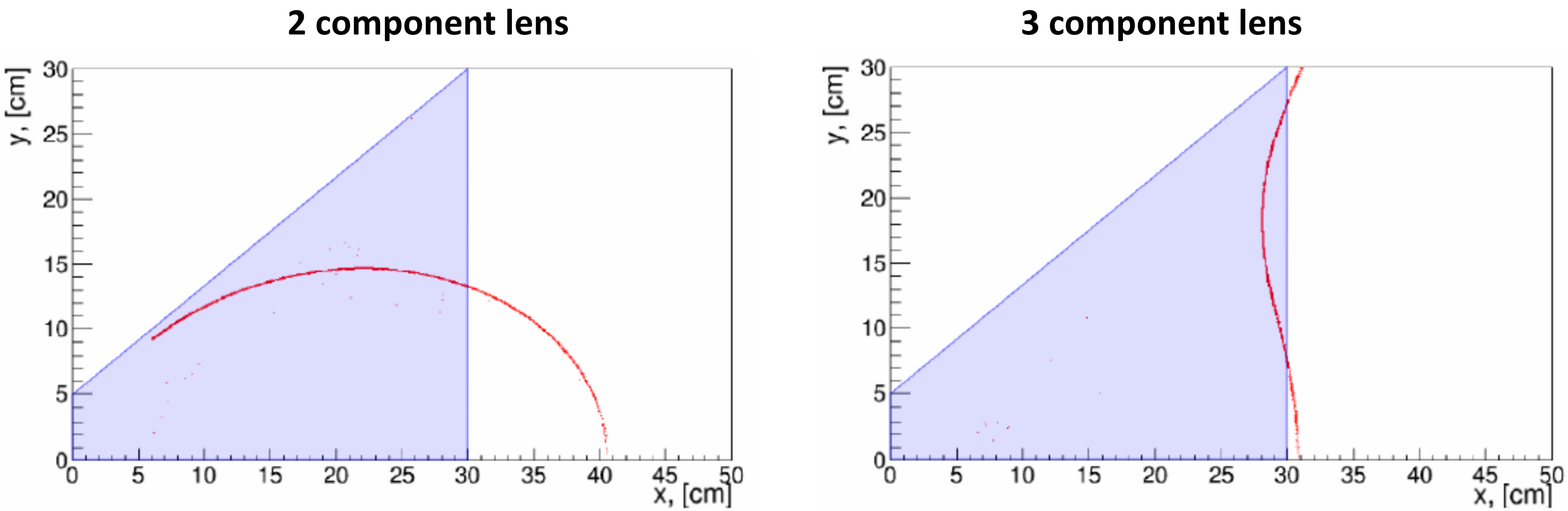


Simulated data

R. Dzhygadlo, G. Kalicy, C. Schwarz

High-performance DIRC Narrow bar design

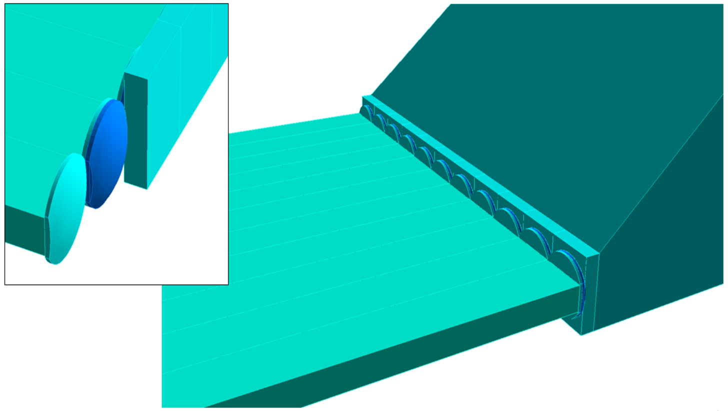
- **Radiator bars**
  - 17 x 35 x 4200 mm
  - 11 bars per box
  - 16 bar boxes, 1m from IP

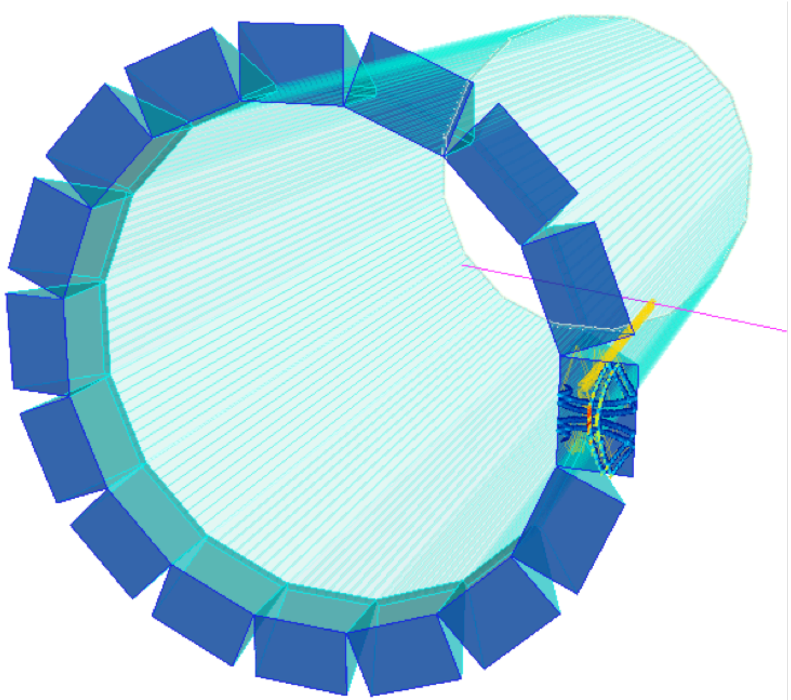
- **3 component lens**
  - 14 x 35 x 50 mm
  - radiuses: 47 mm, 29 mm

- **Expansion volume**
  - Prism with 38° opening angle
  - 285 x 390 x 300 mm

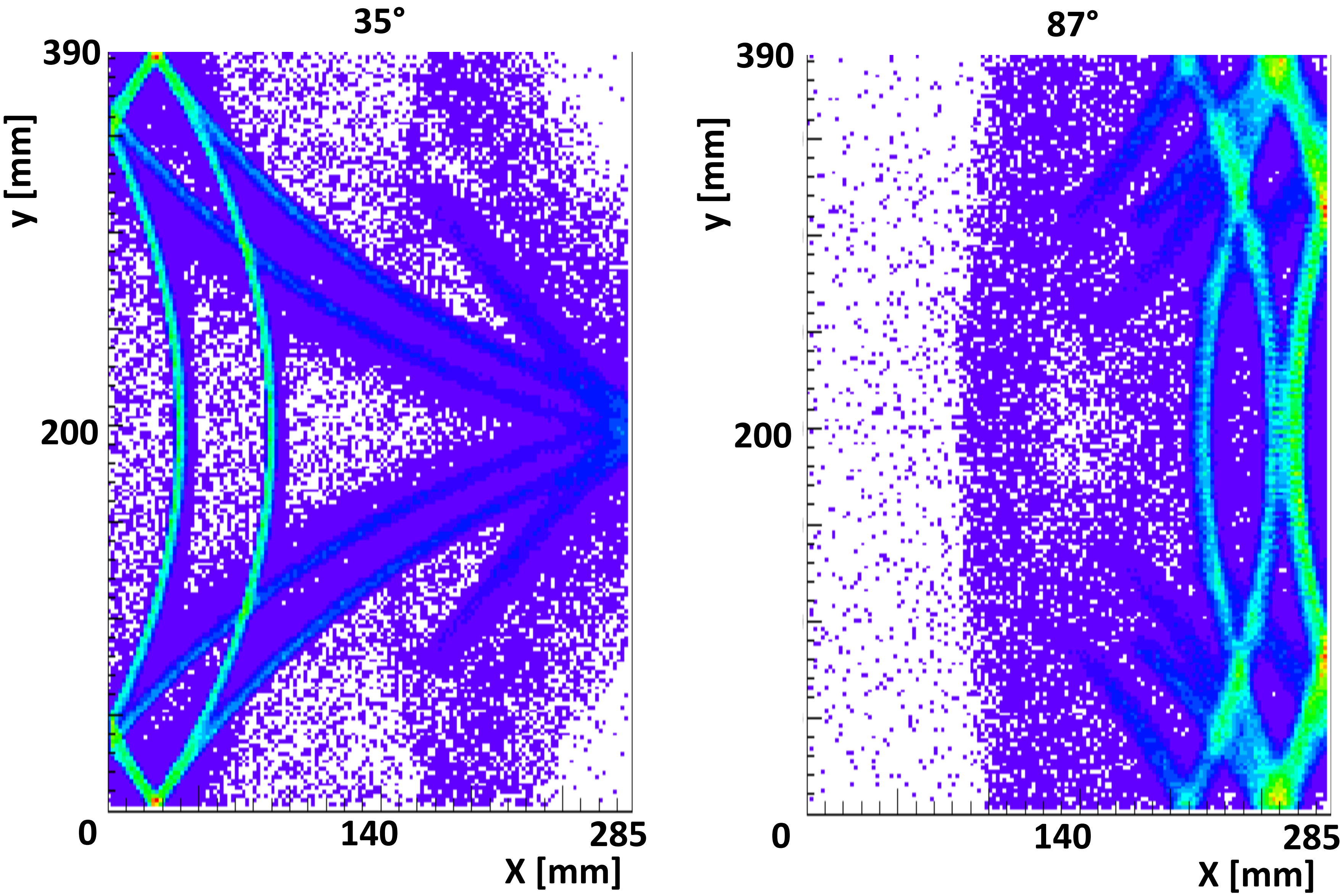
- **Sensors**
  - 208k pixels, each 3 mm^2

Geant4 simulation of High-Performance DIRC detector





High-performance DIRC Hit Patterns



Simulated data

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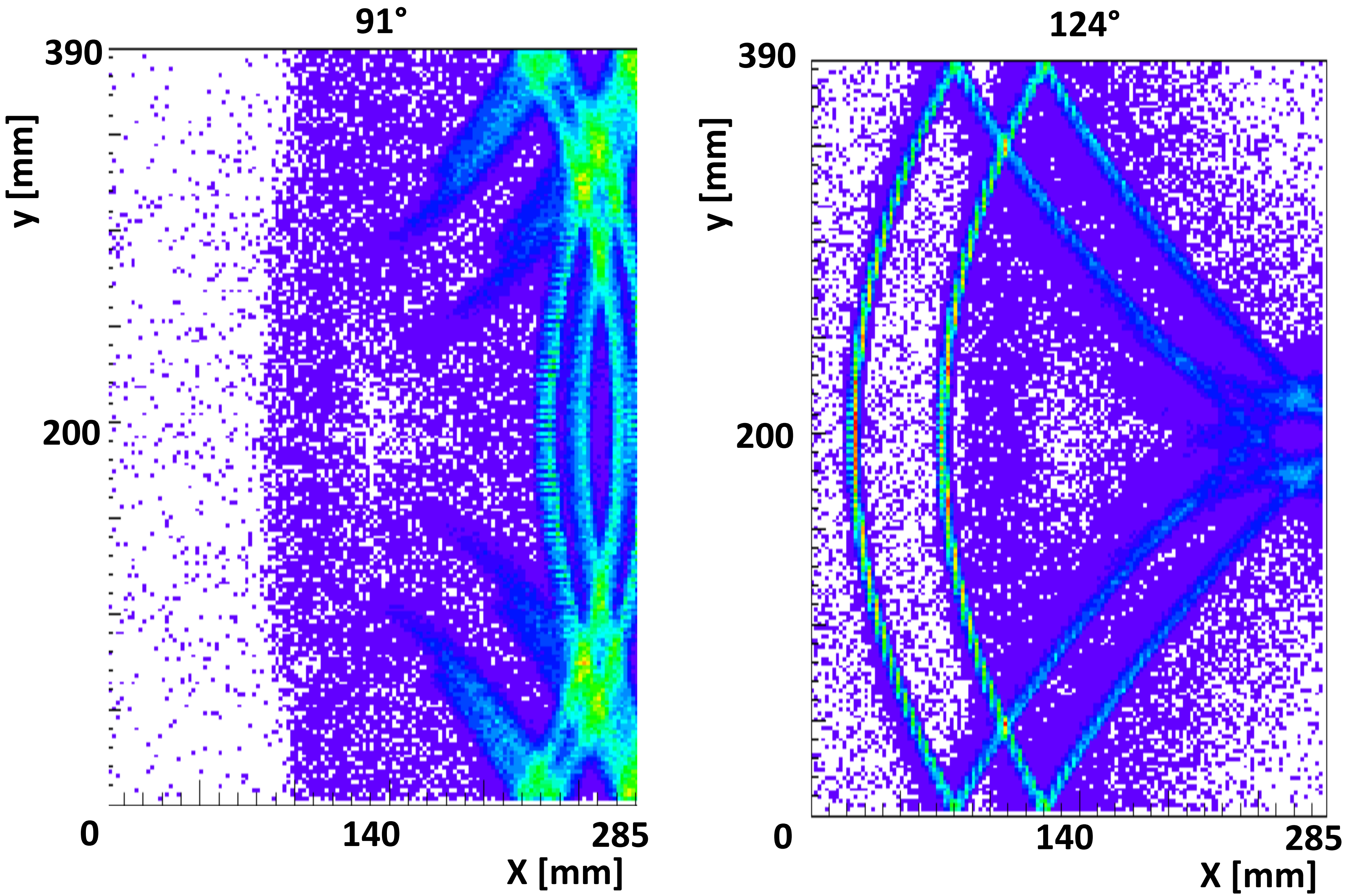
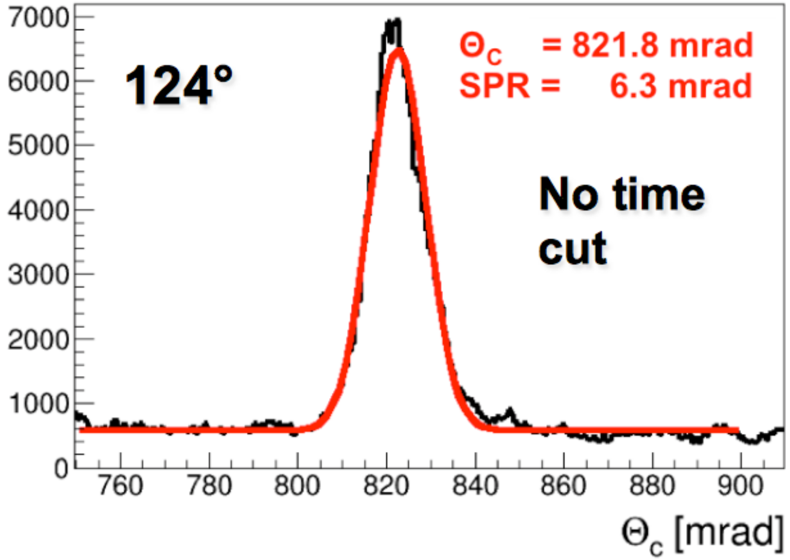
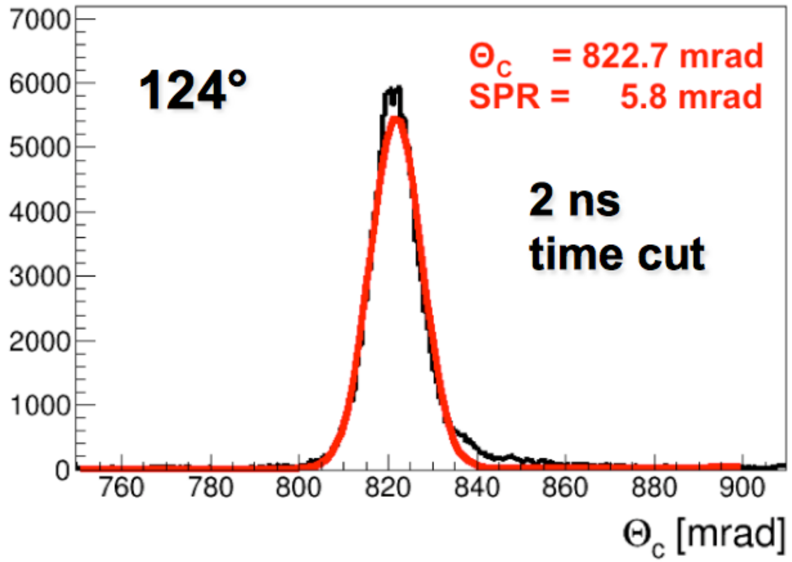
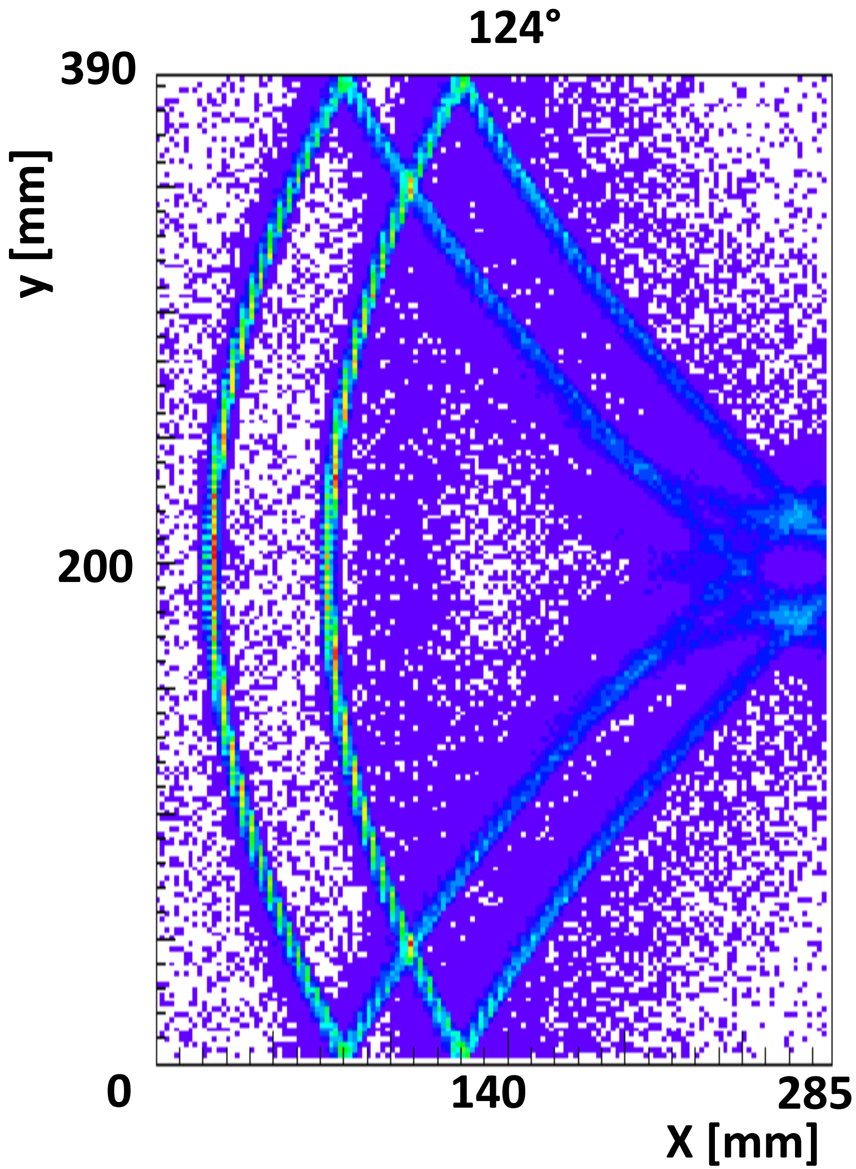


Simulated data

High-performance DIRC Single Photon Resolution (SPR)



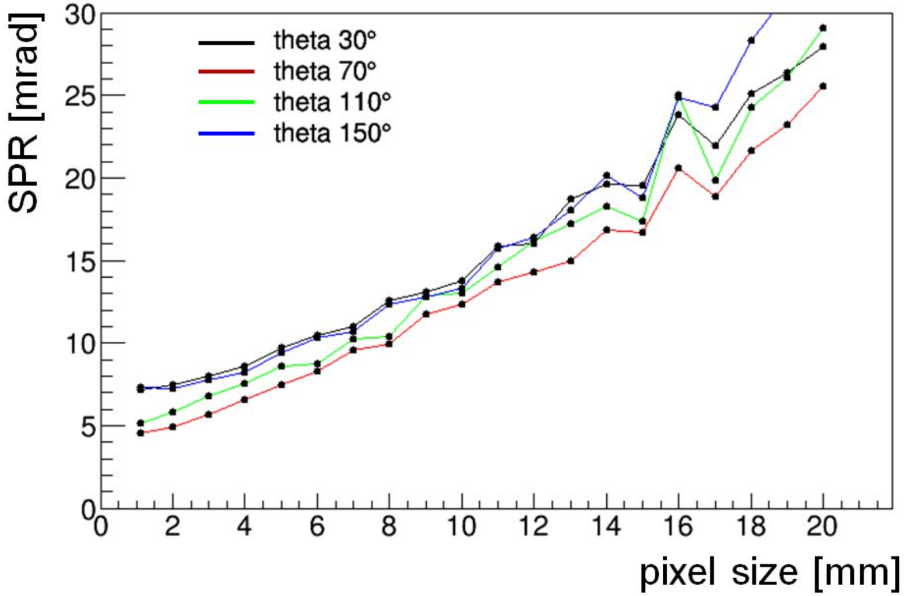


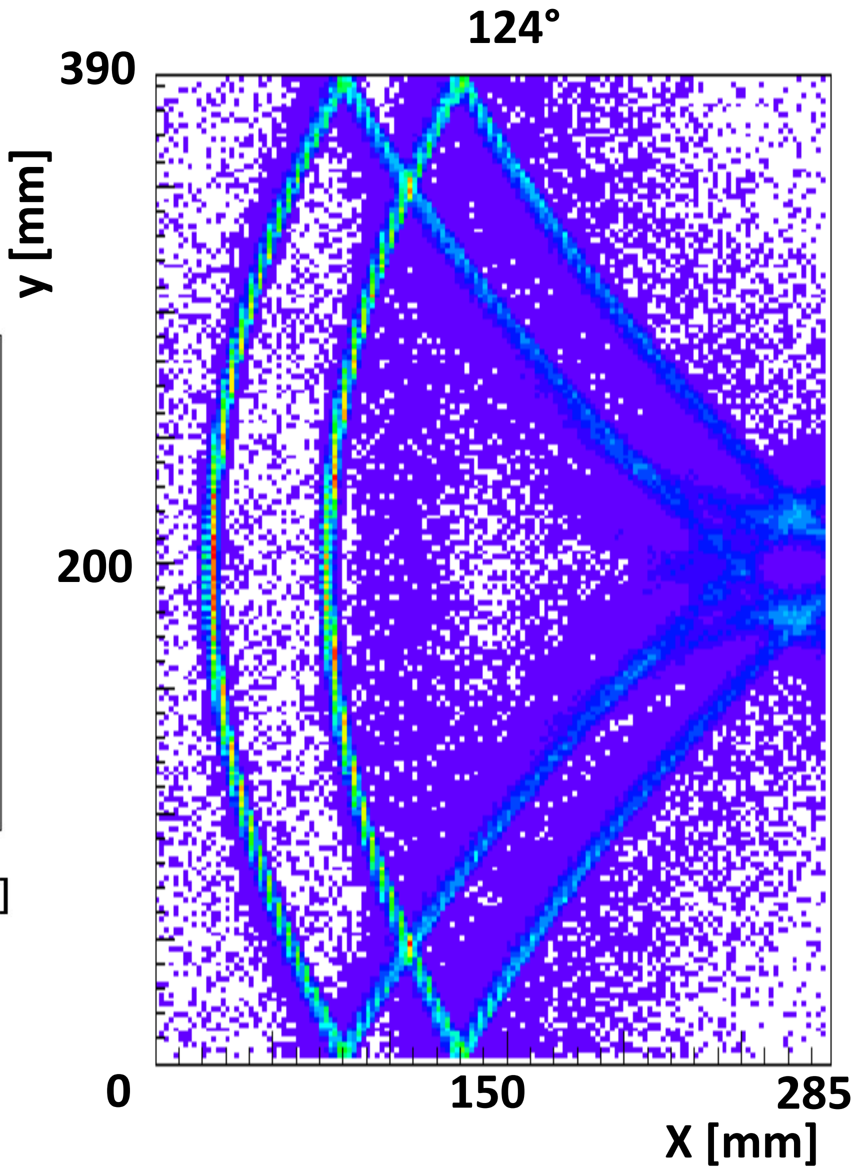


Simulated data

High-performance DIRC Single Photon Resolution (SPR)

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

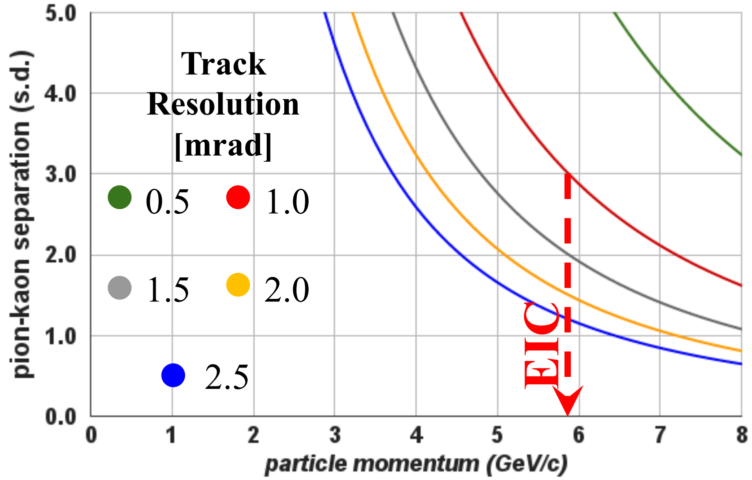




Simulated data

High-performance DIRC Performance

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



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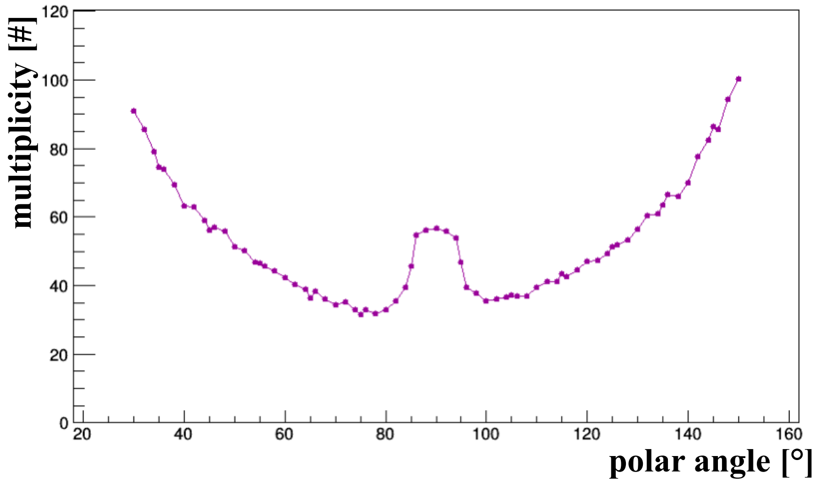

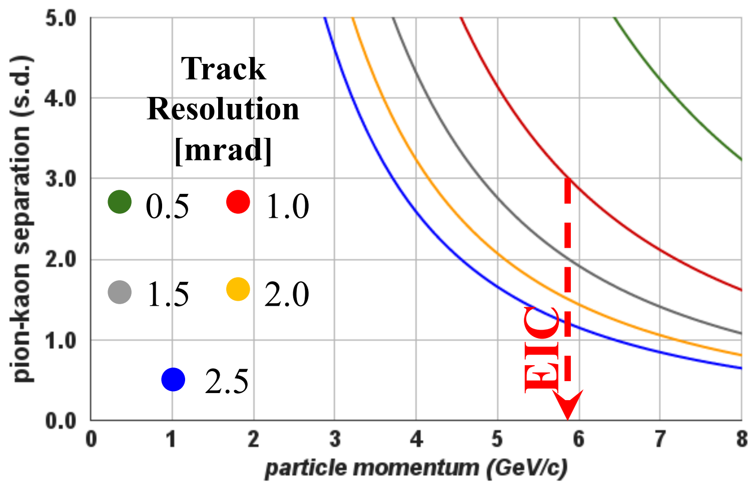

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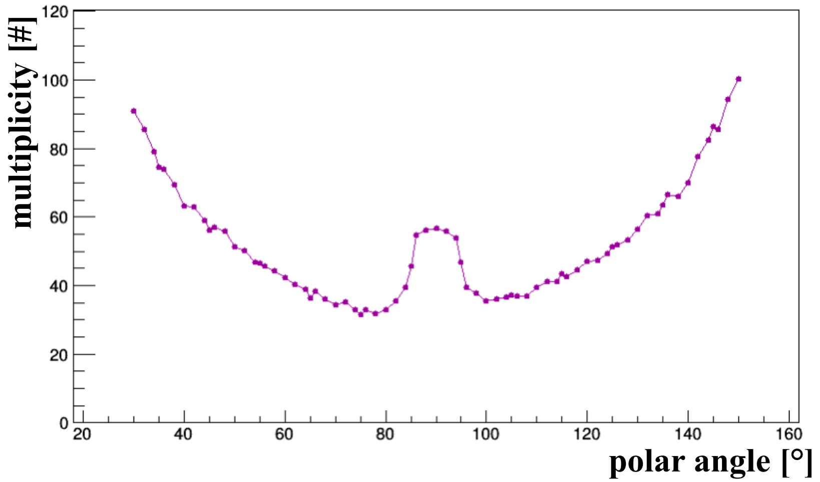
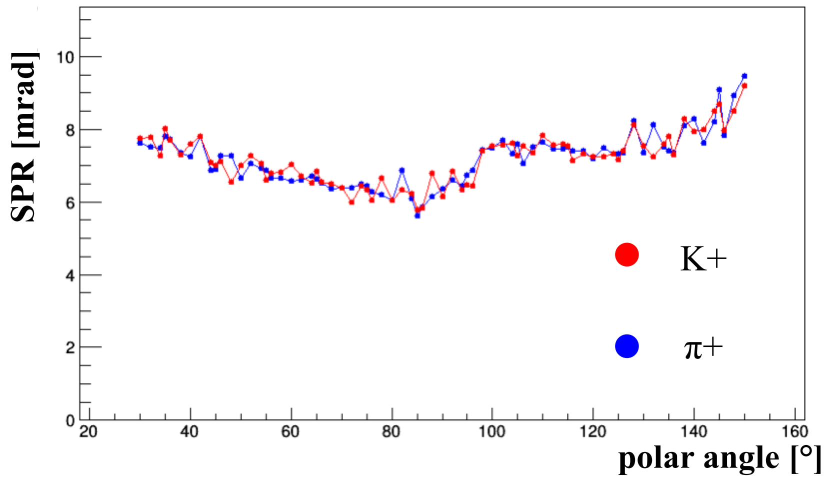


Geometric reconstruction



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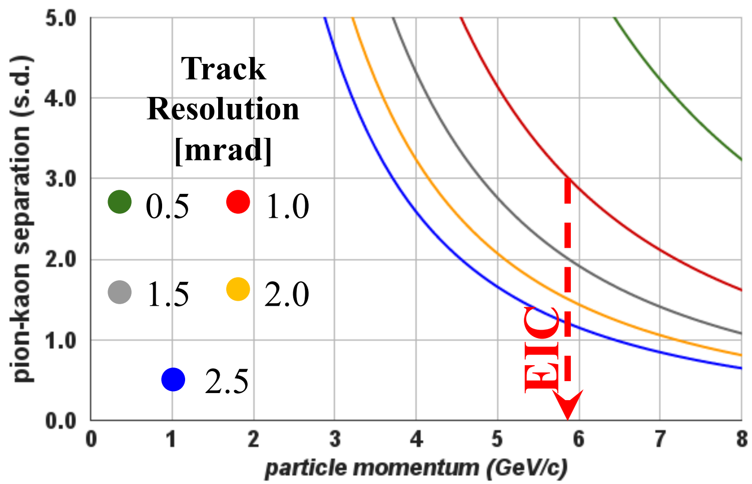

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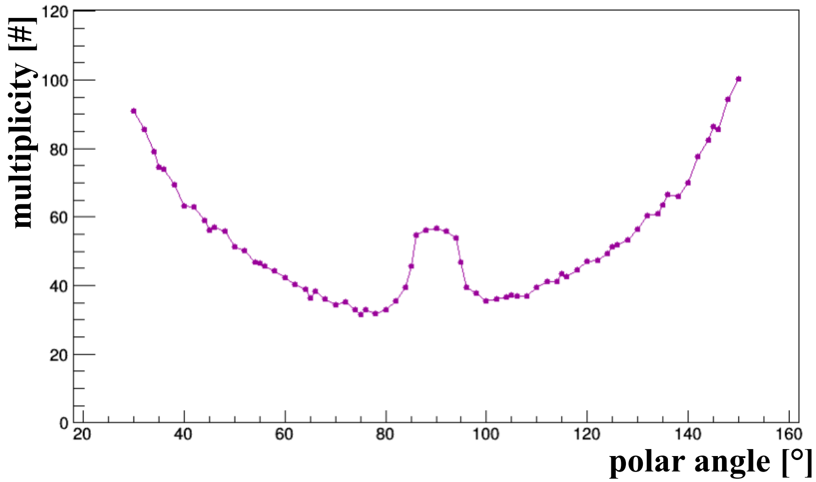

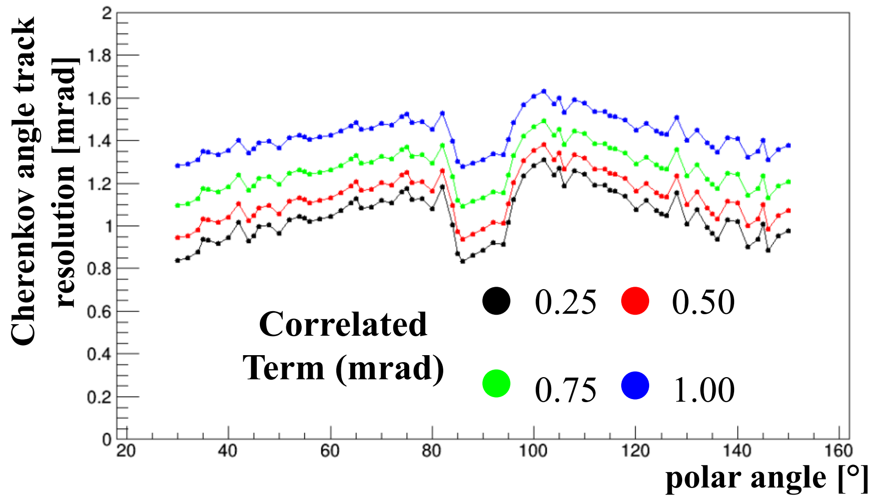

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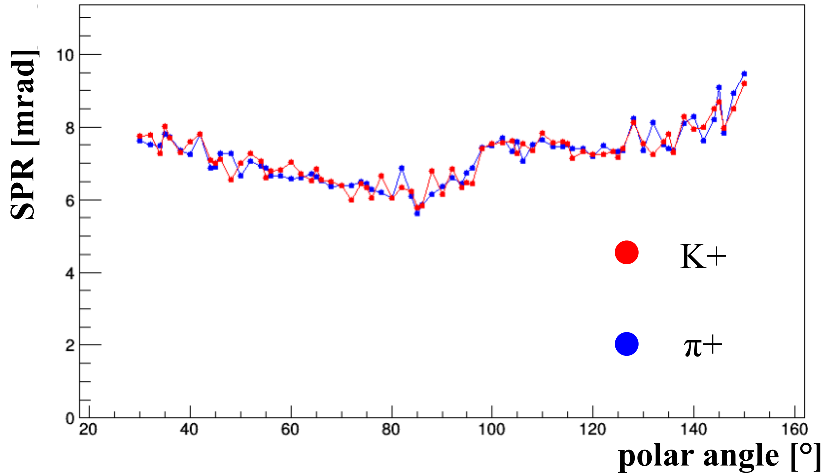

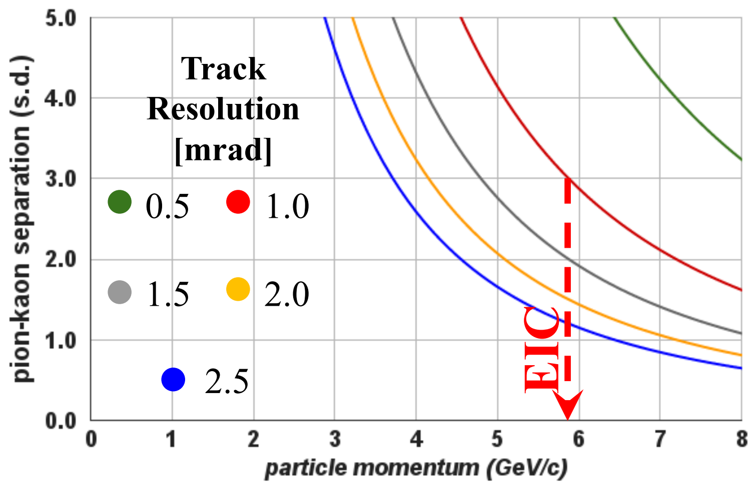

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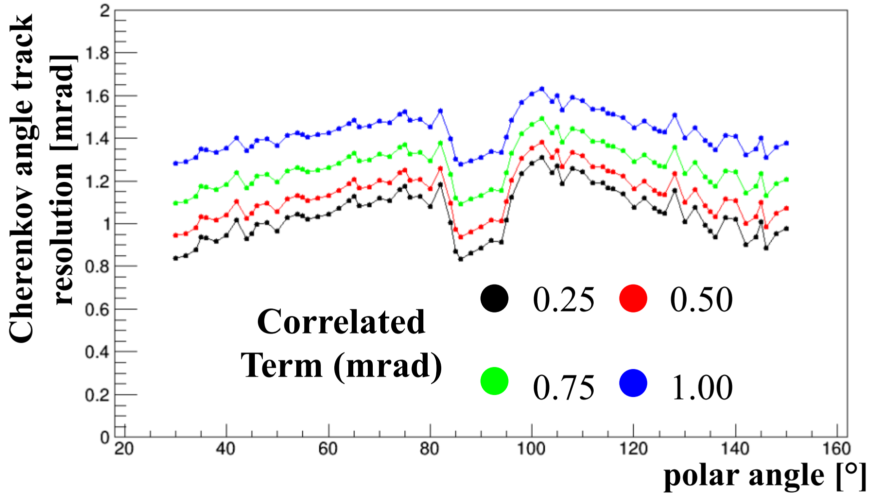
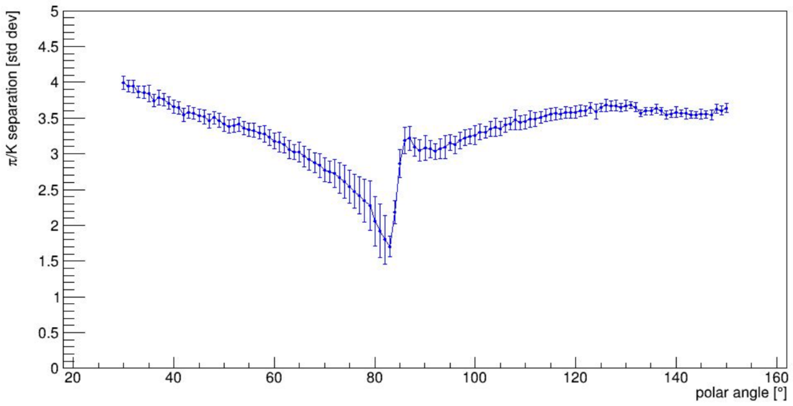


π/k separation without correlated term



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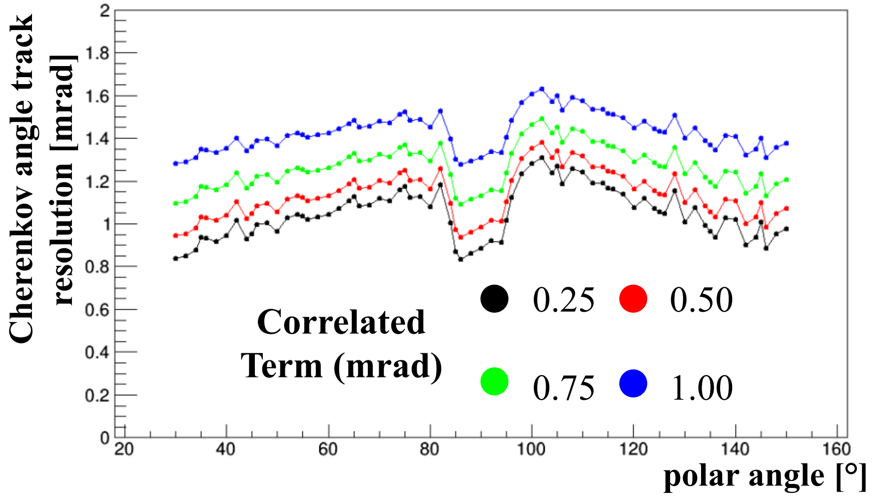

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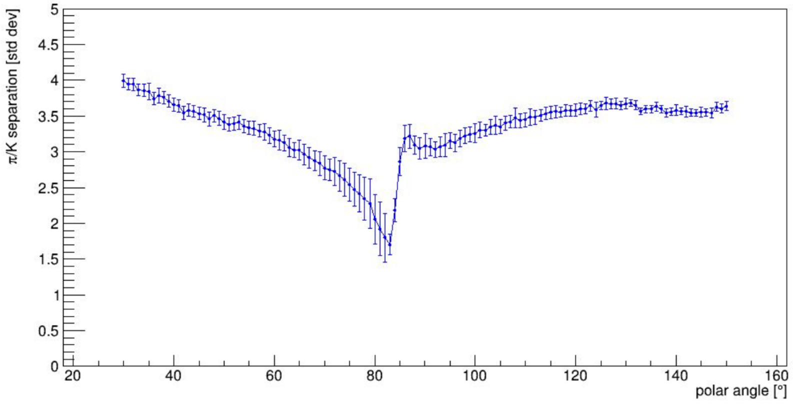
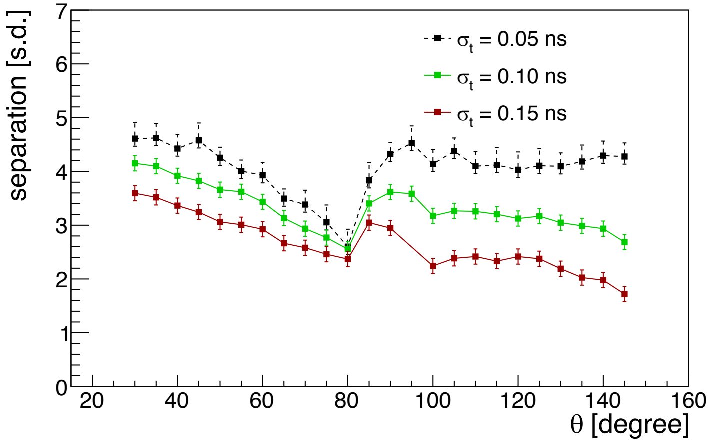


Time-based reconstruction for π/k at 6 GeV/c



CUA

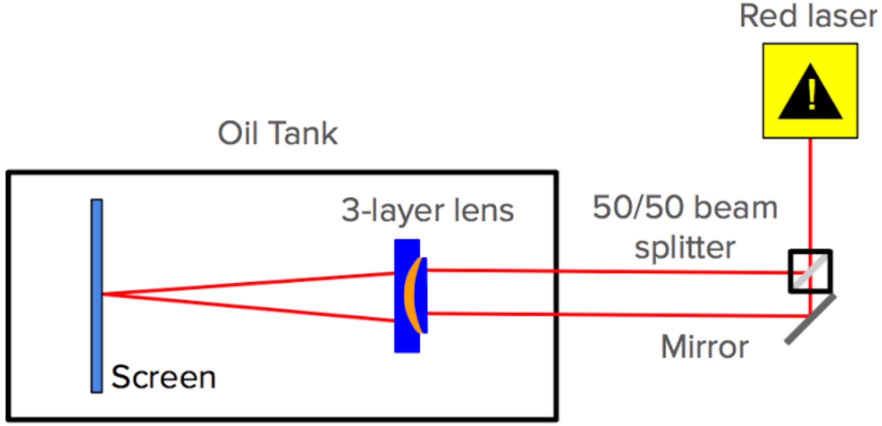
Jefferson Lab

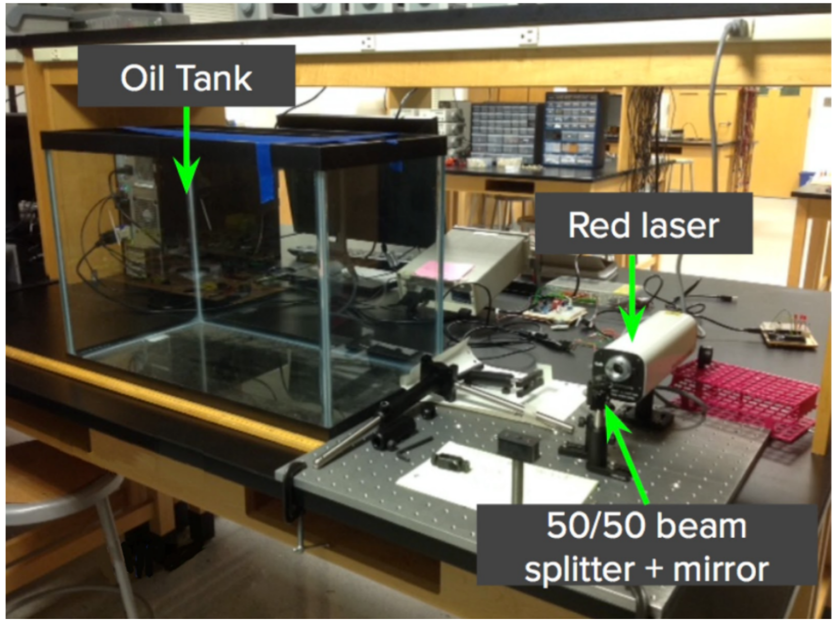
3-layer Lens Performance verification

Mapping focal plane of 3-layer lens:

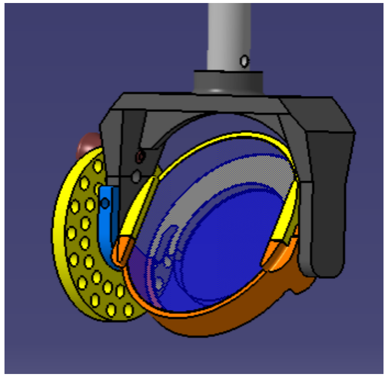
- Lens holder designed to rotate in two planes for the 3D mapping of the focal plane and shifts of lens in horizontal plane.

Laser setup to map the focal plane





3D lens holder



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

3-Component Lens Performance verification

Mapping focal plane of 3-layer lens:

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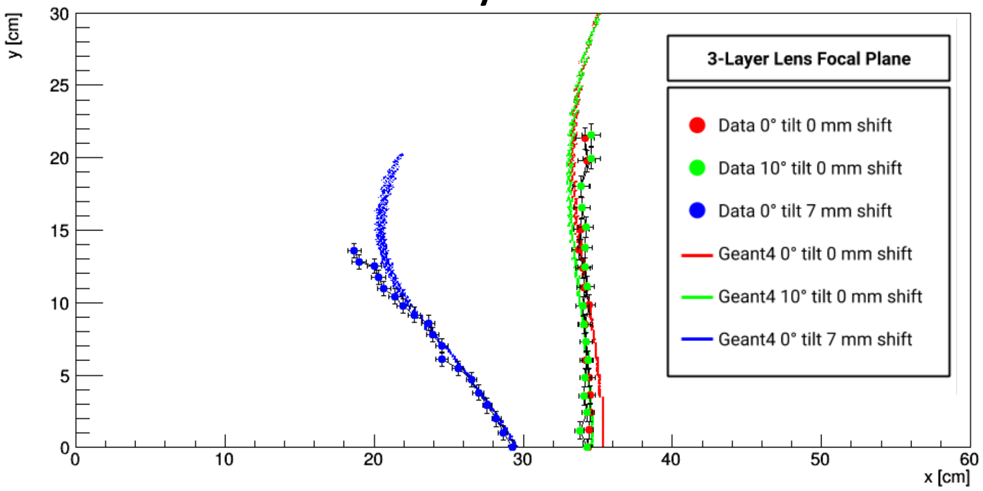
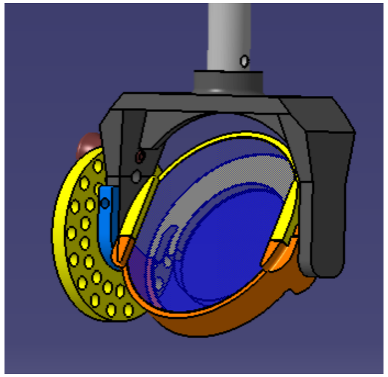
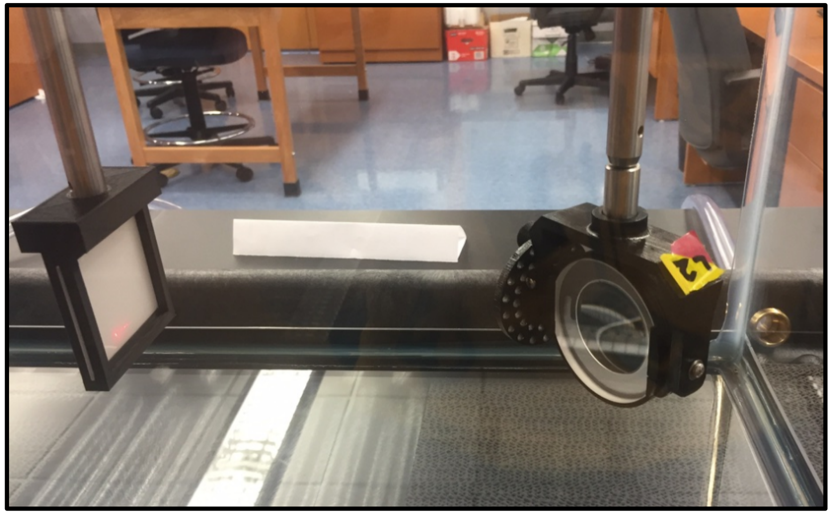
- Results of measurements confirm desired flat focal plane for centered laser beams on the lens

Measured and simulated focal plane 3-layer lens



3D lens holder





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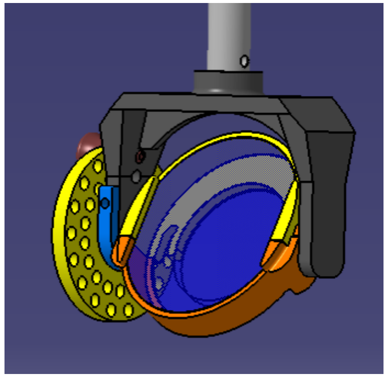
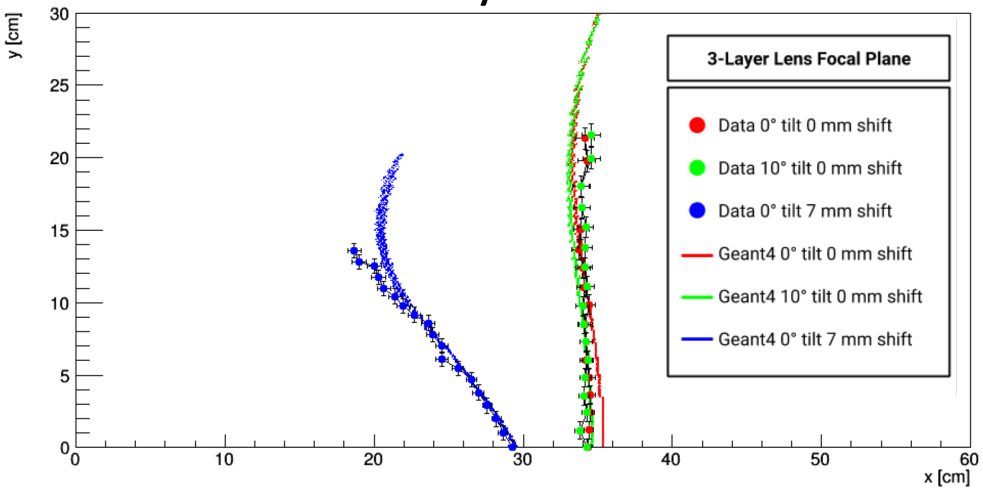
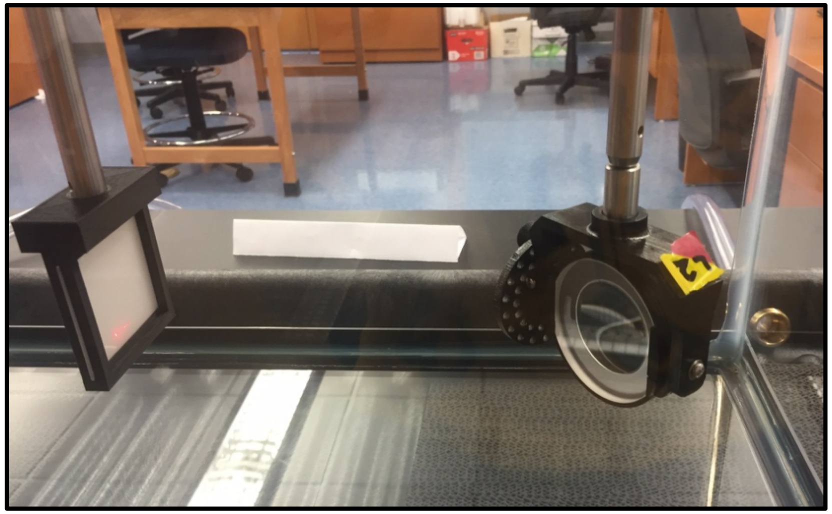
- Off-center laser beams in agreement with simulation

3D lens holder



Measured and simulated focal plane
3-layer lens





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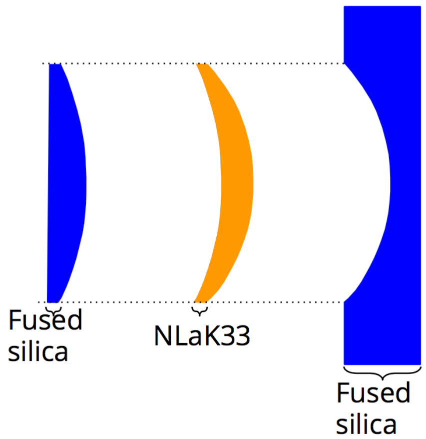
3-layer Lens Performance verification

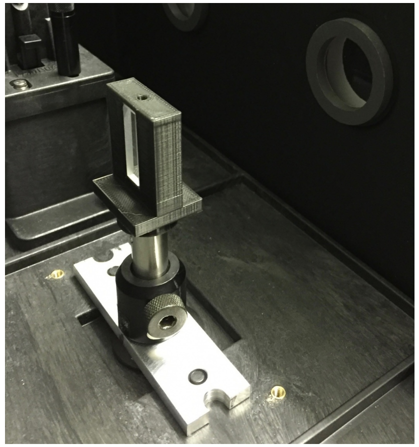
Radiation hardness tests of NLaK33 material at CUA

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

Spherical 3-layer lens



NLaK33 sample in monochromator



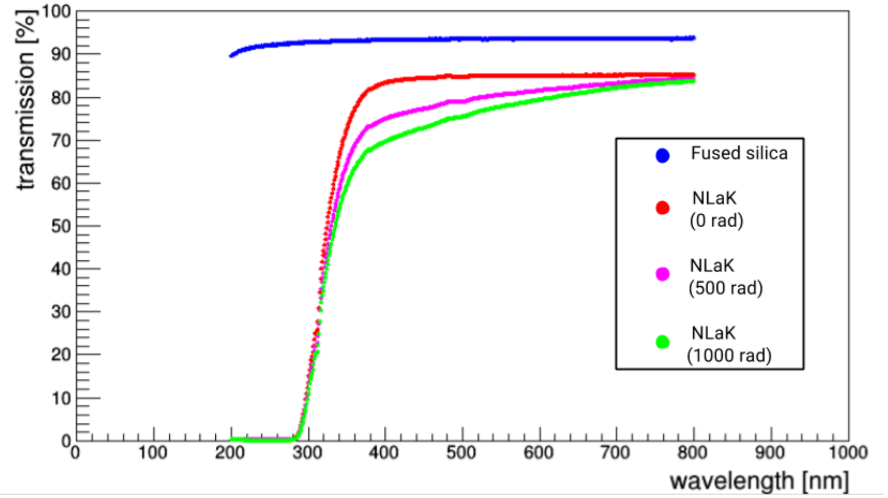
X-ray source

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

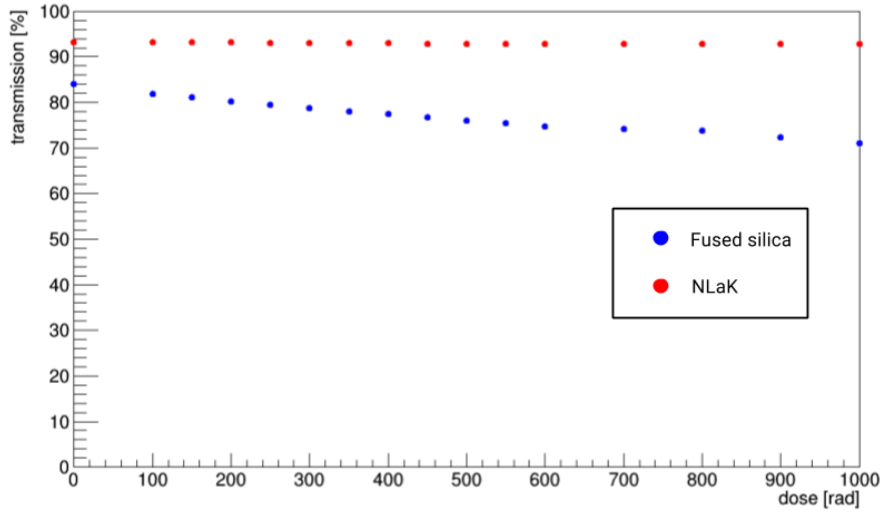
3-layer Lens Performance verification

Radiation hardness tests of NLaK33 material at CUA

- NLaK33 samples irradiated with X-Ray source, measured with monochromator.
- First results using X-Ray source show the transmission drops significantly at a rate of around 1.3% per each 100 rad at 420 nm wavelength.



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



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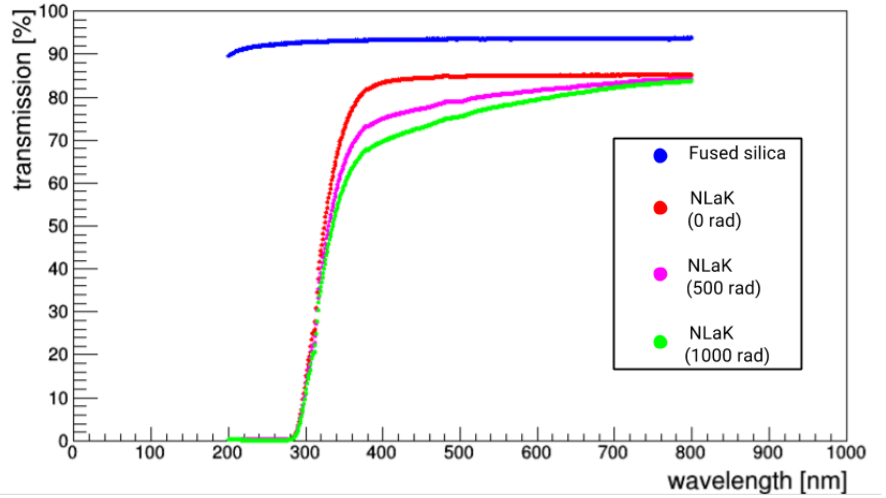

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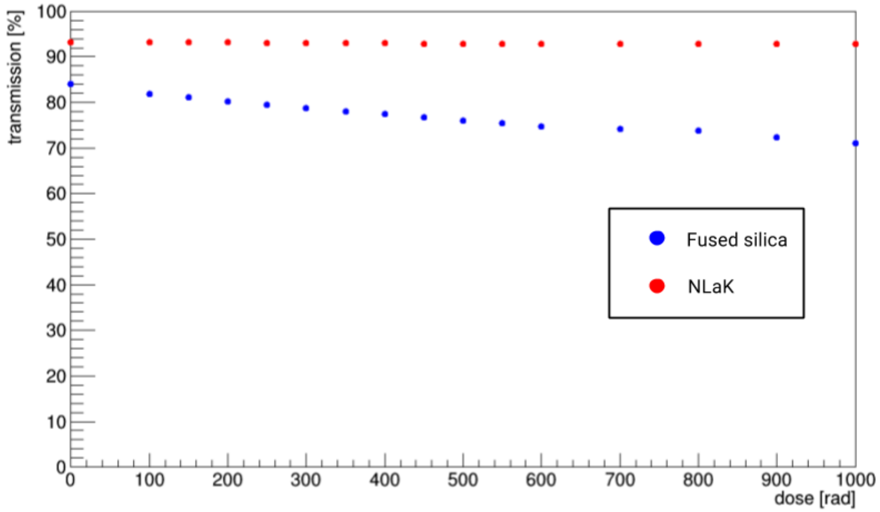

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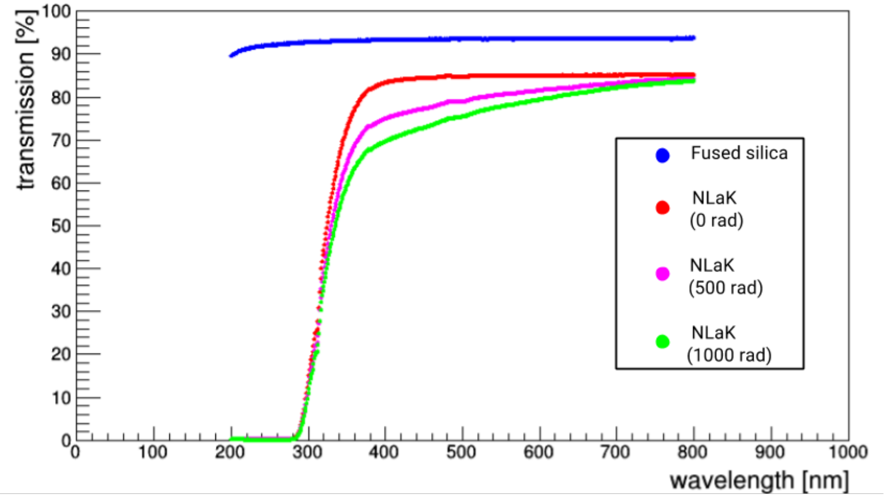
- Alternative to NLaK33 radiation hard material was found and will be validated.



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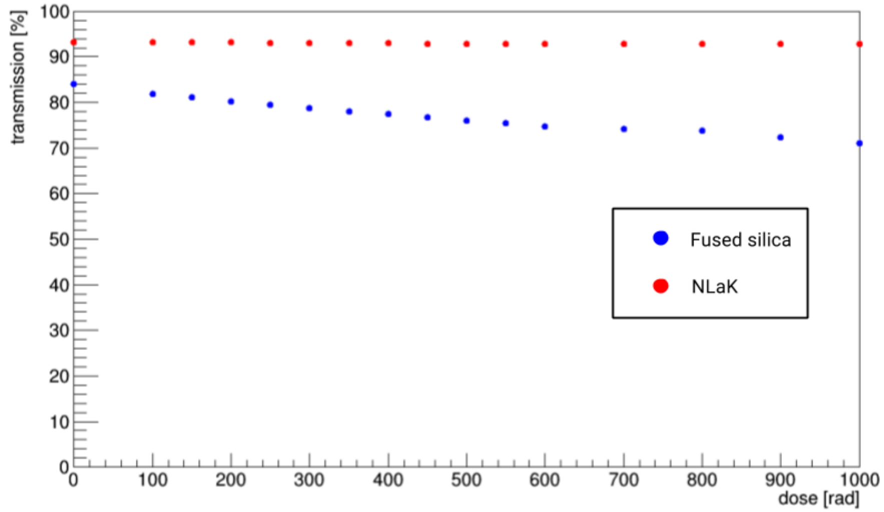
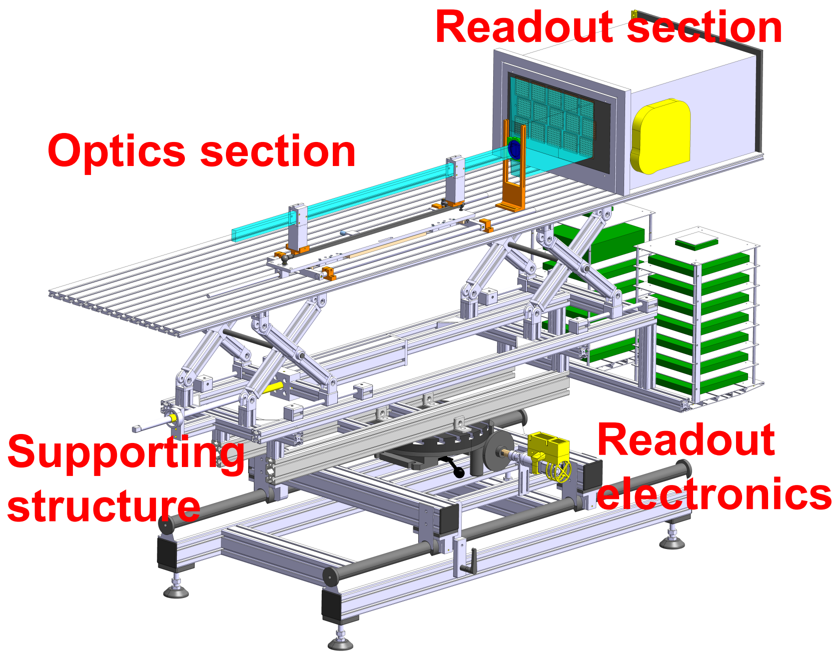
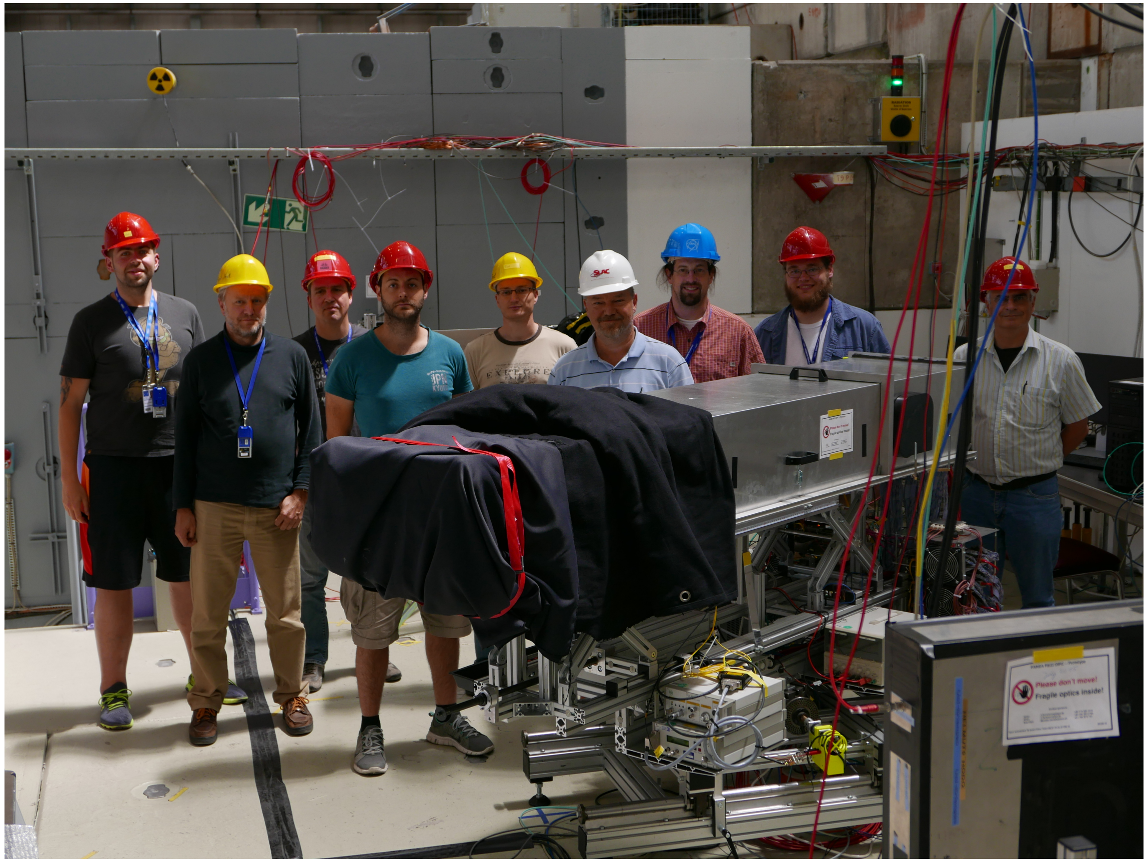


3-layer Lens Performance verification

Full system PANDA barrel DIRC prototype

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

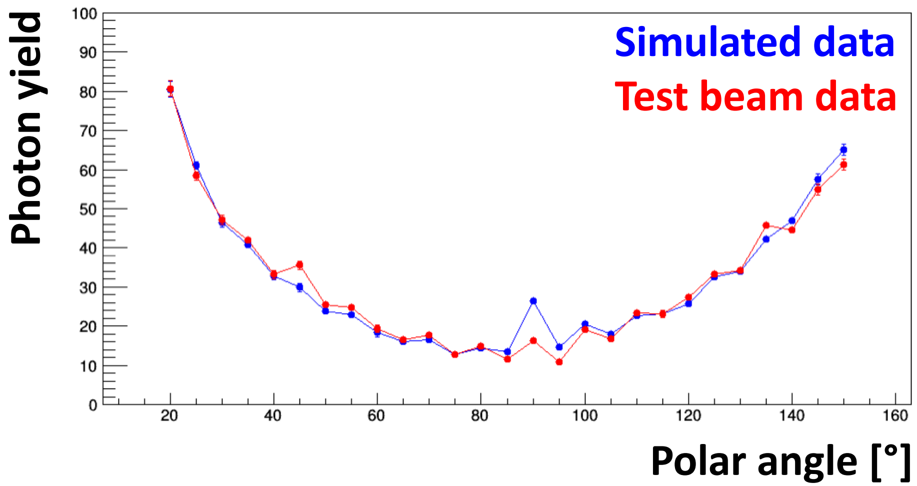


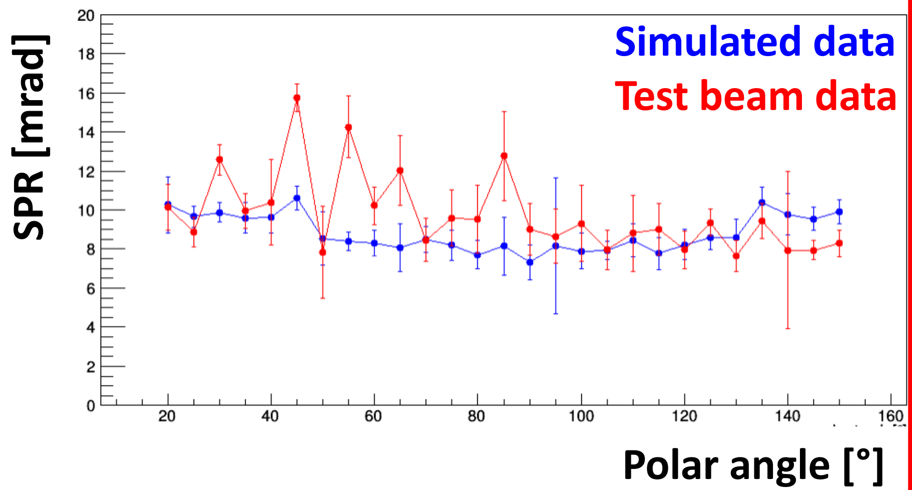


3-layer Lens Performance verification

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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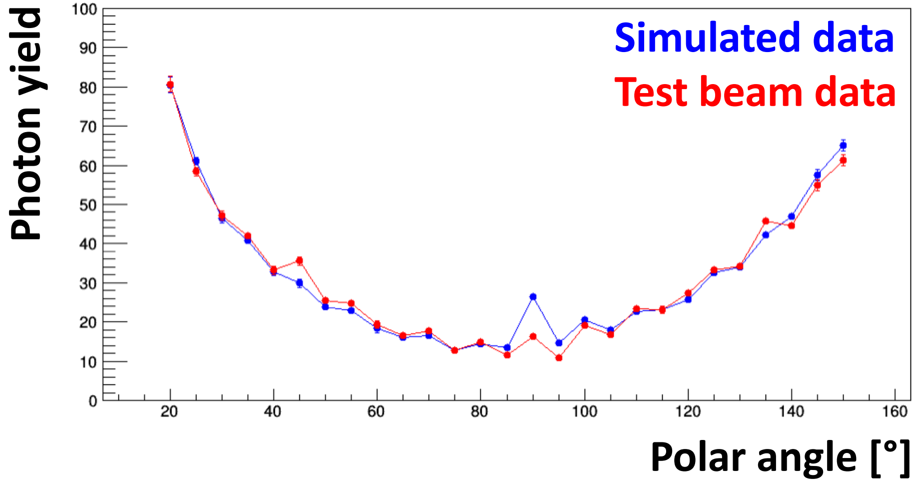

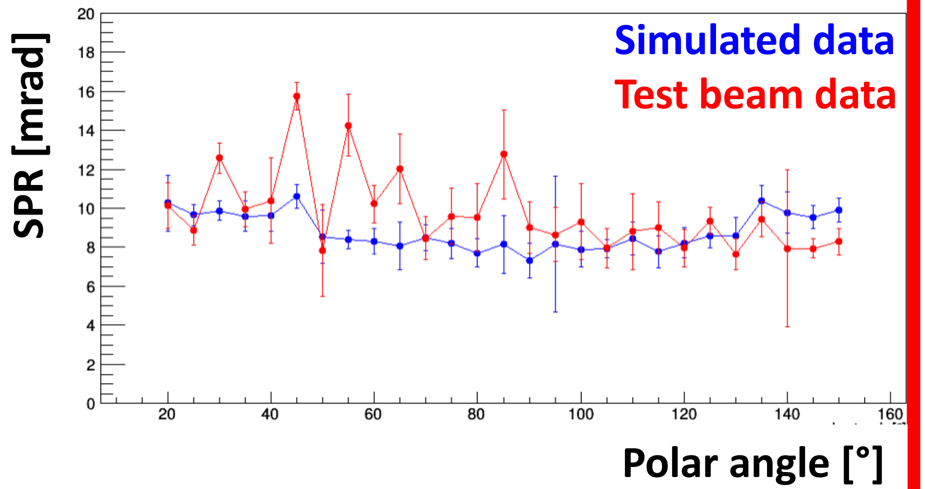

Time based imaging:

π/p separation power
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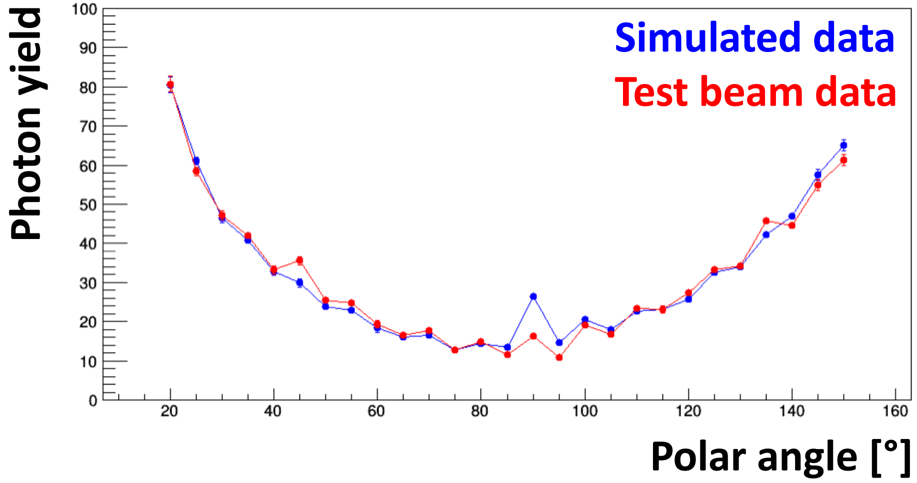

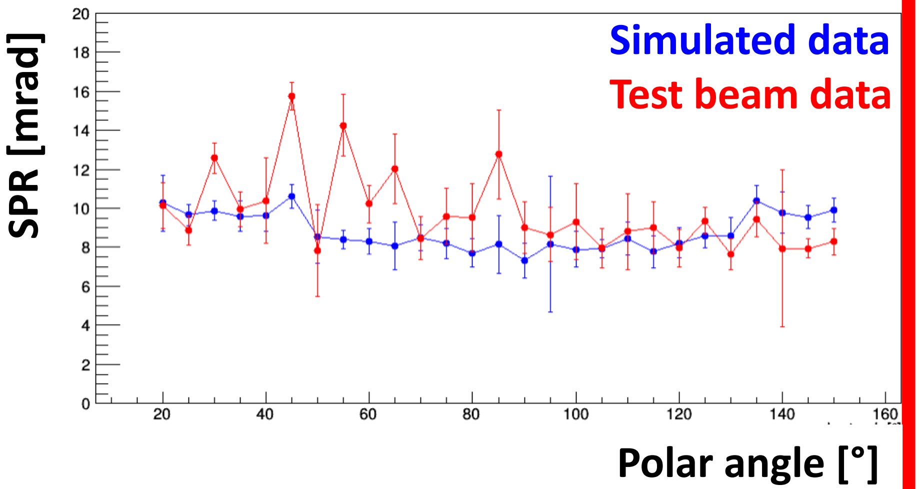

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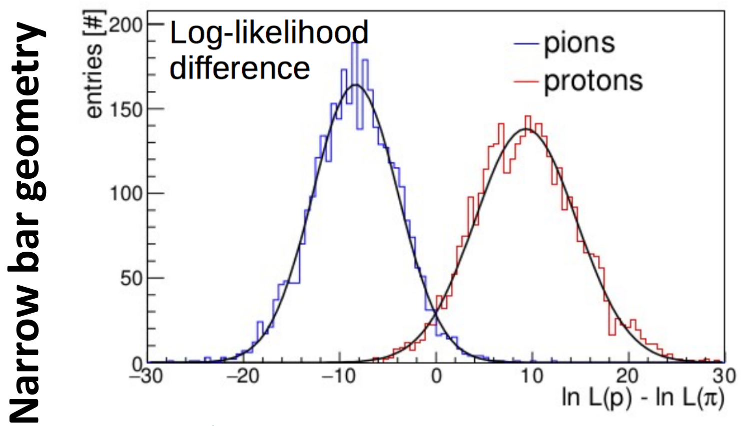

~3.6 s.d. π/K @ 3.5 GeV/c

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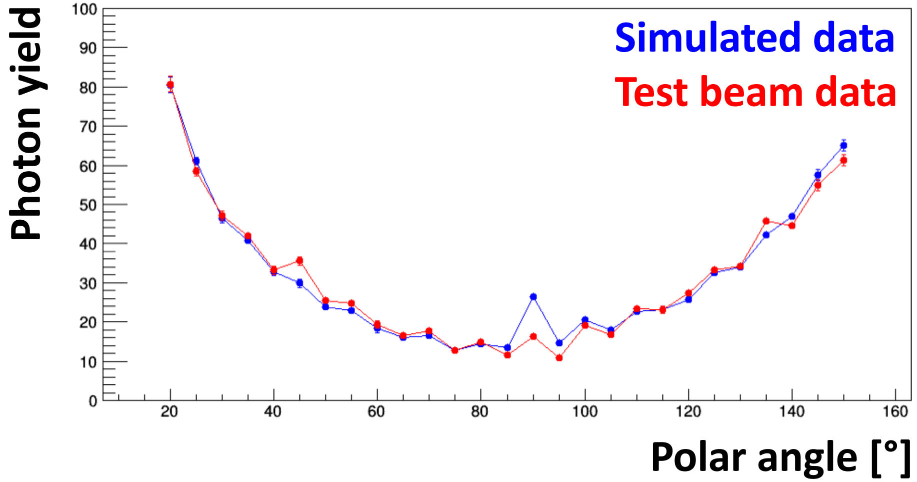

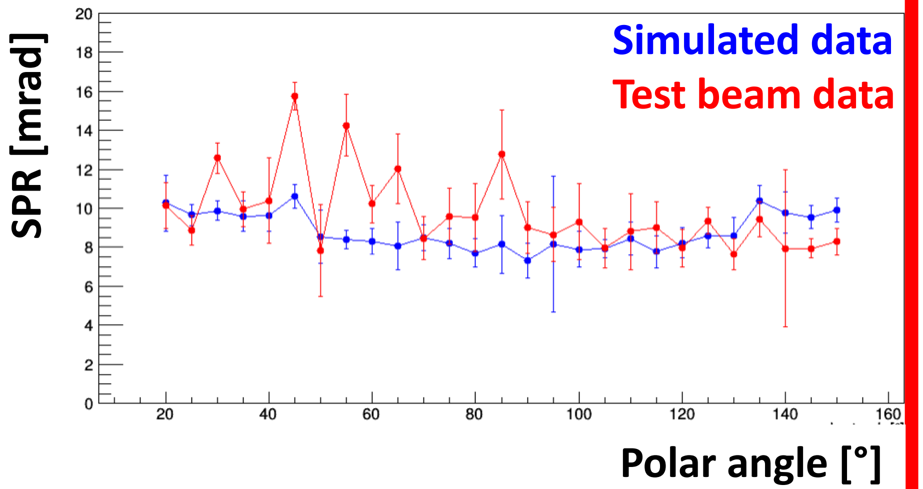

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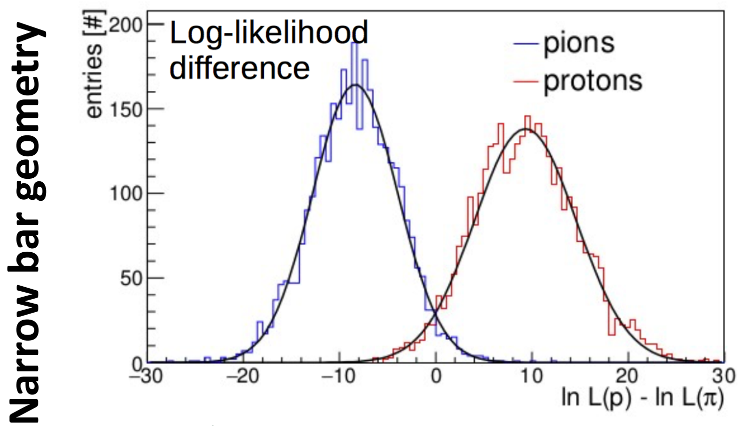

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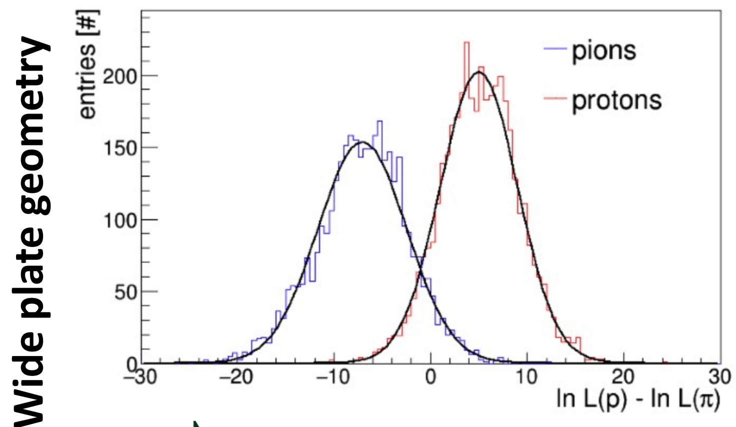
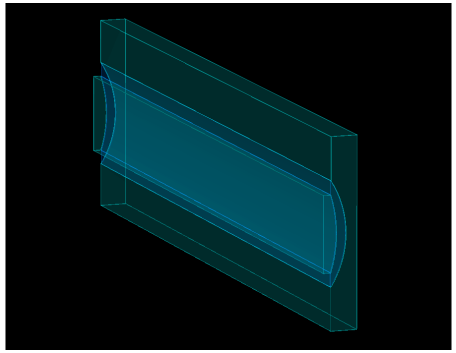


➡ ~3.2 s.d. π/K @ 3.5 GeV/c

3-layer Lens New Cylindrical Prototype

Geant4 simulation of cylindrical 3-layer lens



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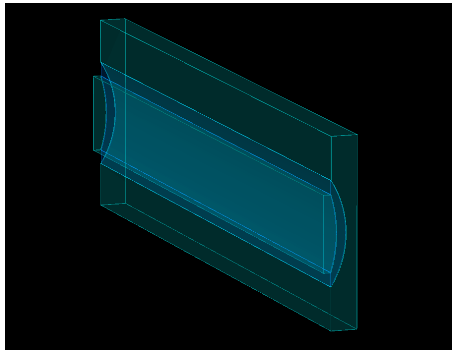
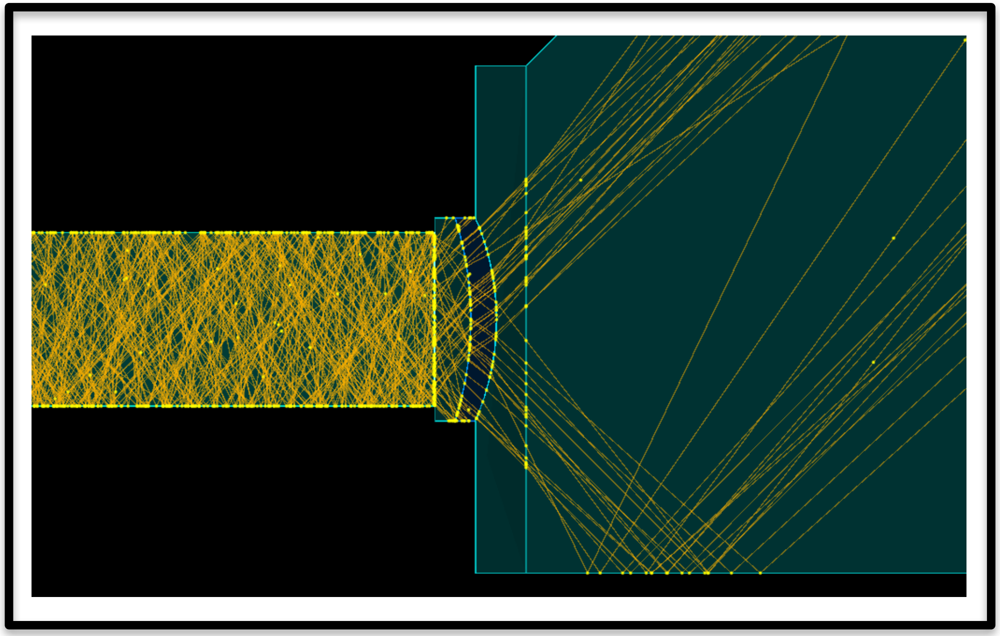
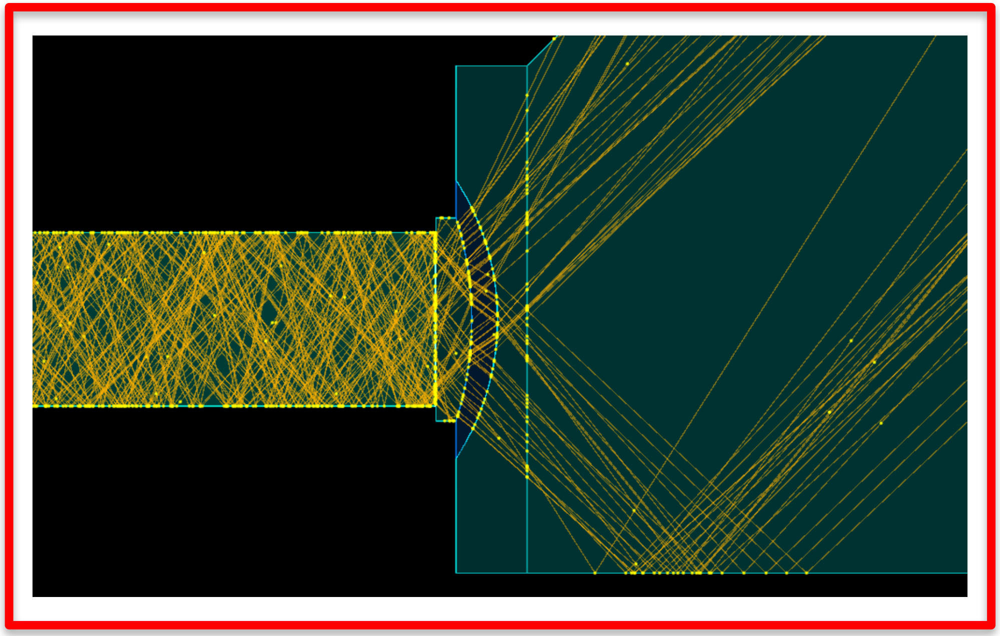
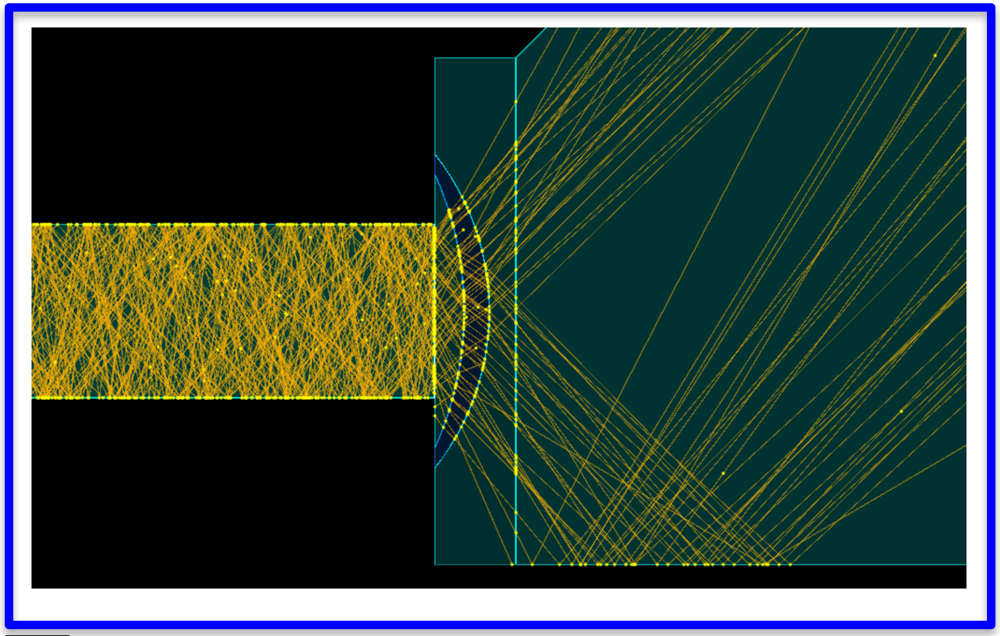
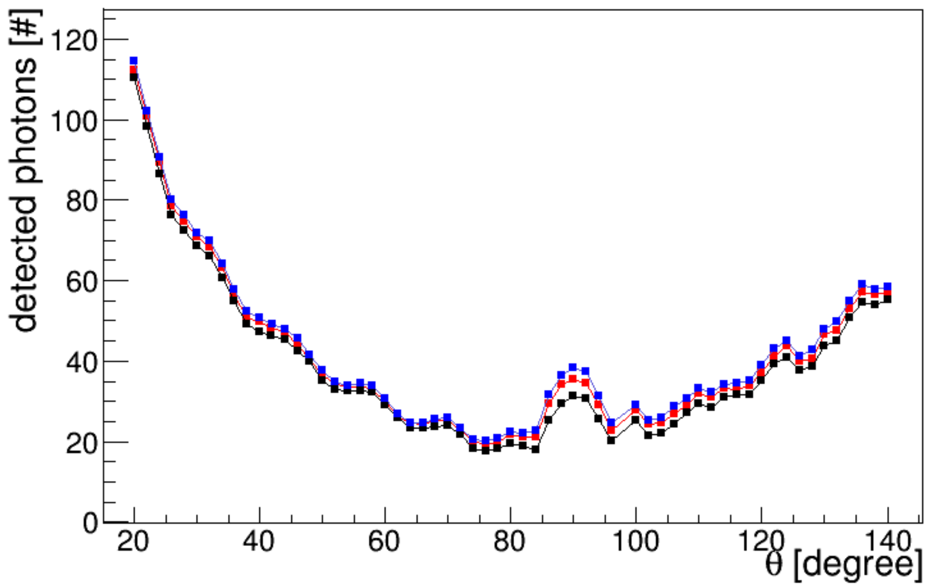


3-component Lens New Cylindrical Prototype









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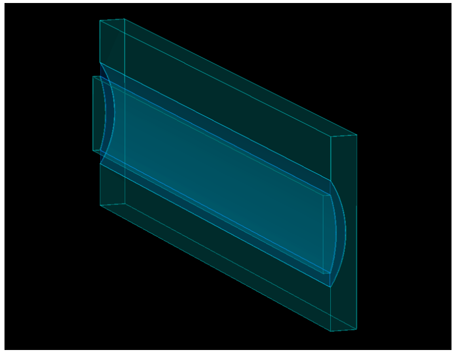
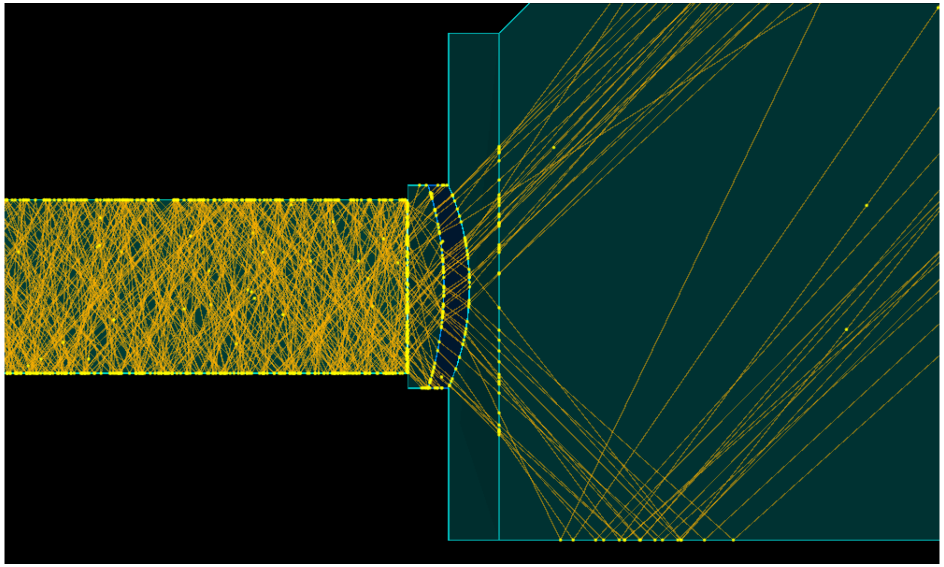
New Cylindrical 3-layer lens for wide plate geometry:

- Lens being produced by RMI from Texas
- 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

Geant4 simulation of cylindrical 3-layer lens





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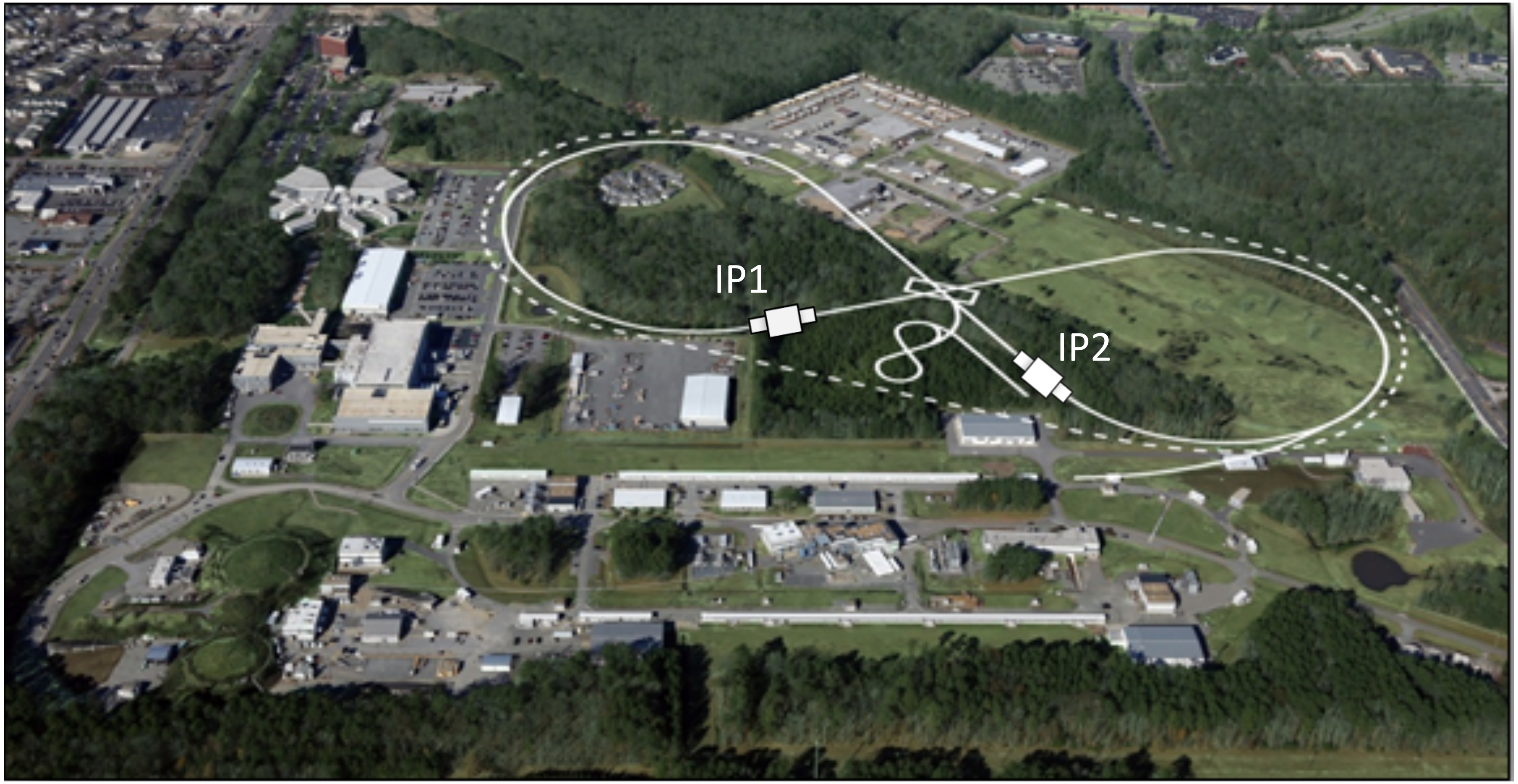
- First results of the NLaK33 material radiation hardness tests suggest need of alternative high refractive index material.
- The new cylindrical 3-layer lens prototype for wide plate geometry is being finished and will be tested in few weeks in CERN test beam.

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

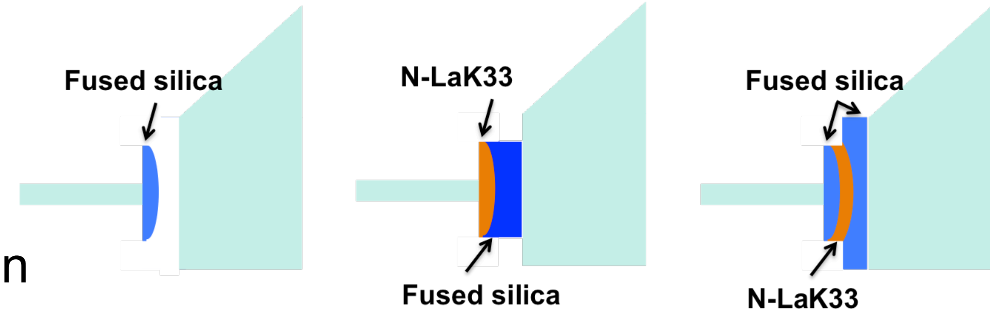
All polarizations >70%

Upgrade to higher energies and luminosity possible

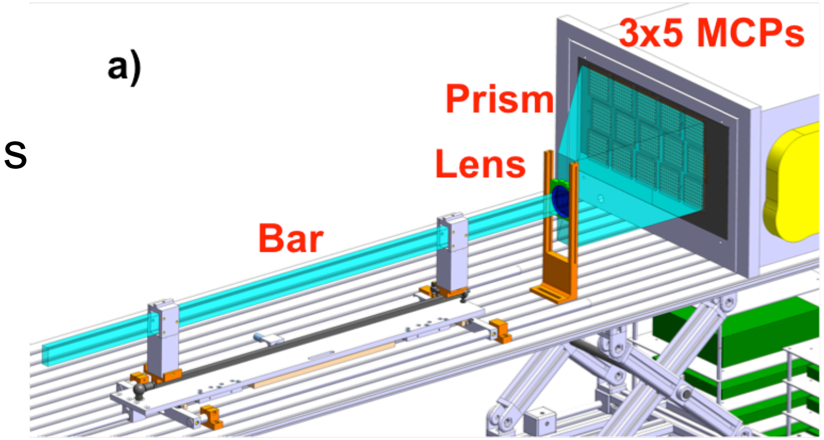
20 GeV electron, **250 GeV** proton, and **100 GeV/u** ion

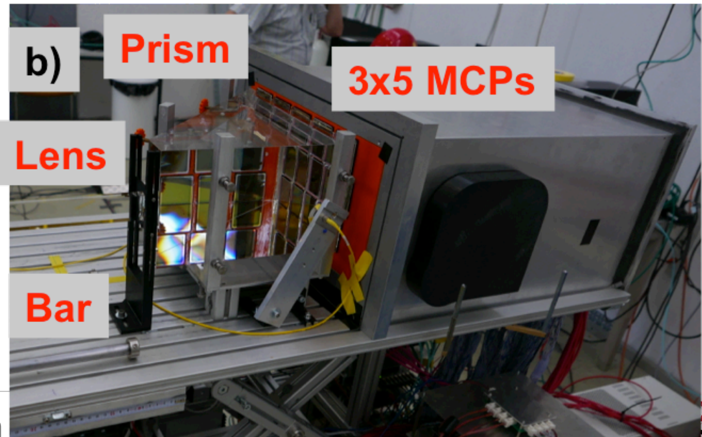
Design goals consistent with the White Paper requirements

High-performance DIRC Prototype 3-component lens

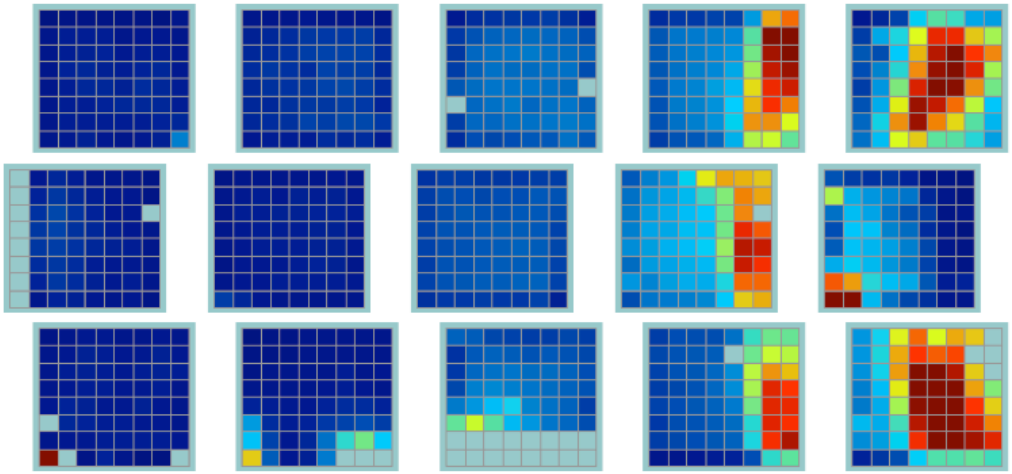


- **Polar angle of beam to bar:**
  - 20°-160° range with 5° step
  - Several fine scans for better resolution evaluation
- **Different focusing lenses:**
  - Air gap spherical and cylindrical lens
  - Spherical and cylindrical 2-component lens
  - Spherical 3-component lens
- **Different radiator:**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

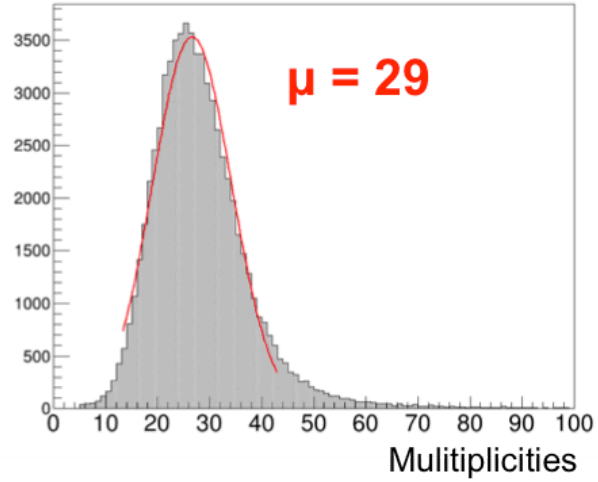


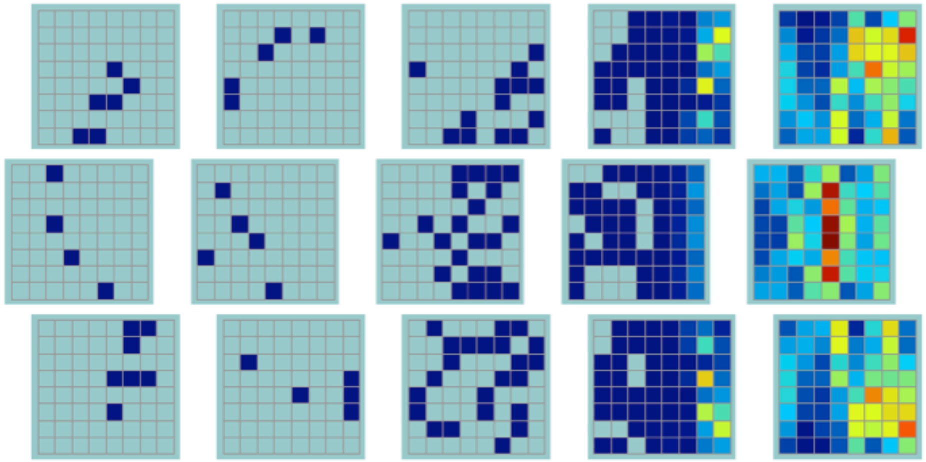


2015 Campaign: Beam polar angle: 90°

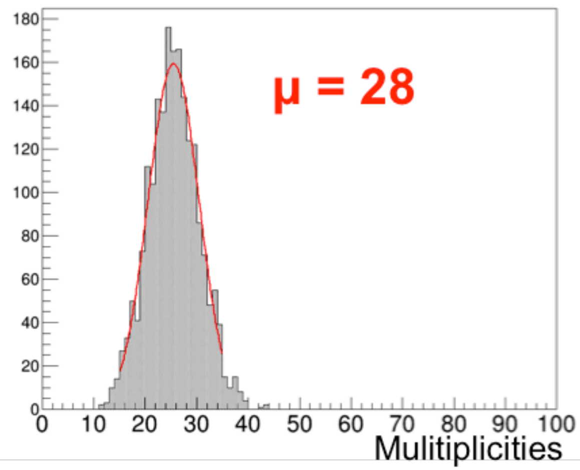


Test beam data

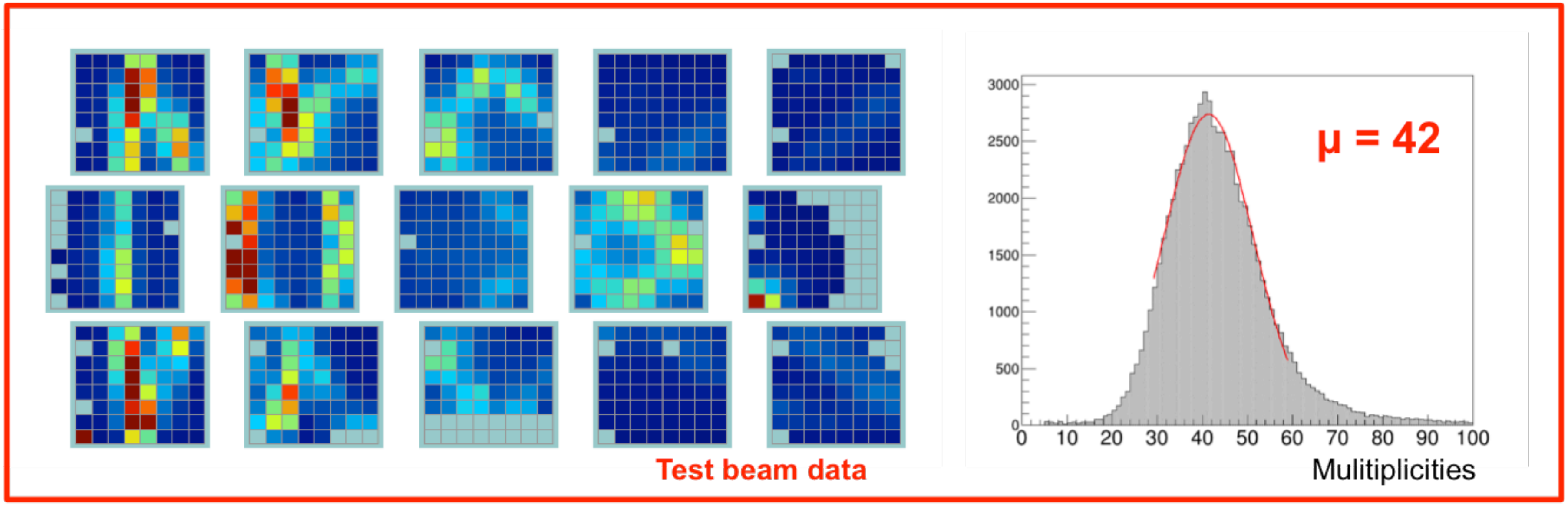


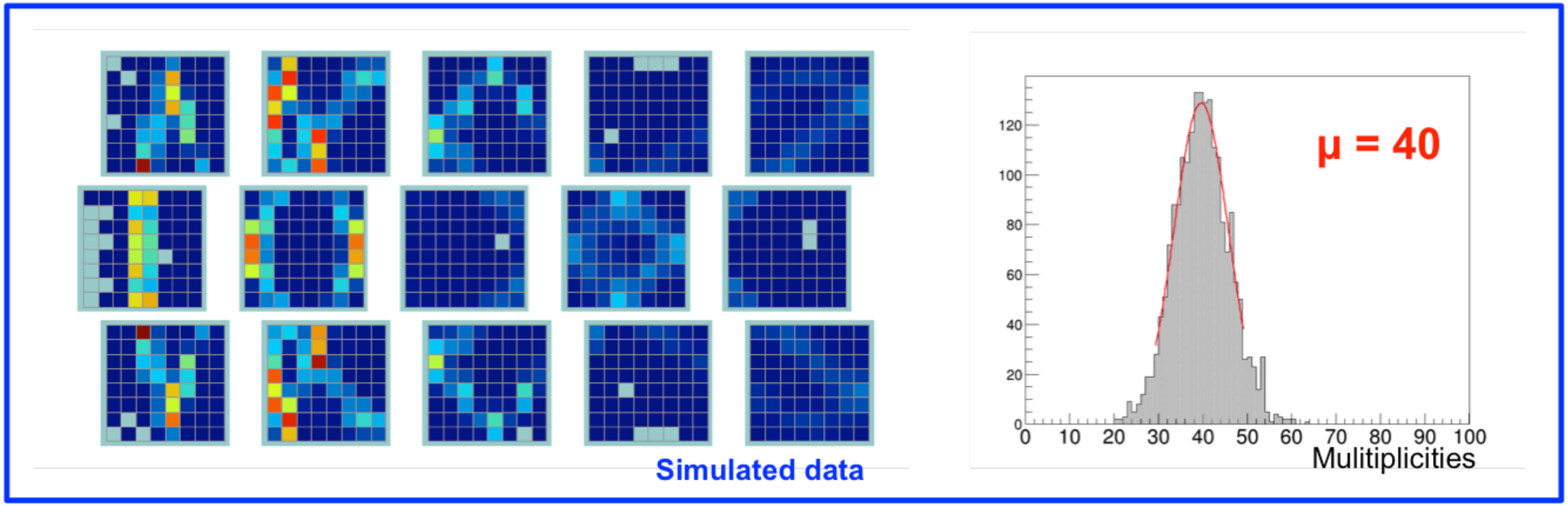


Simulated data



2015 Campaign: Beam polar angle: 125°

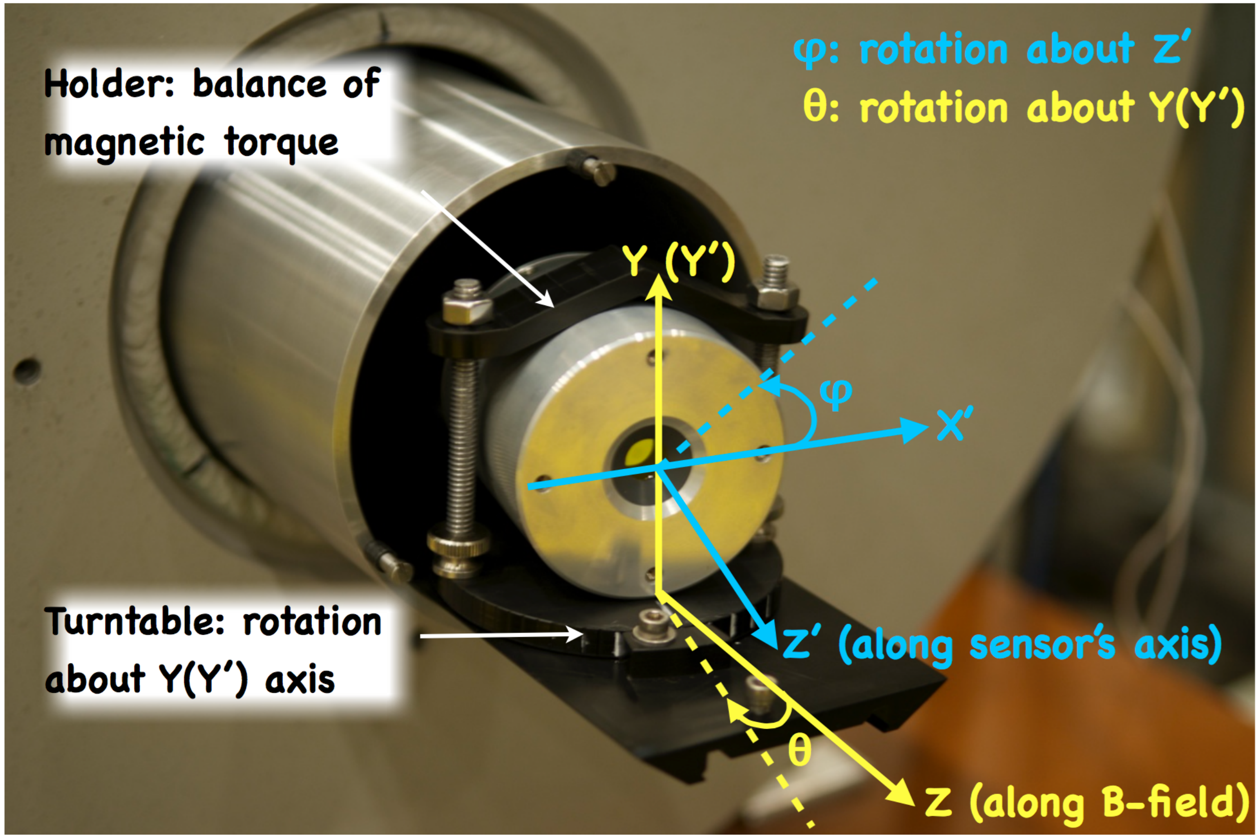




High B field test facility Measurements of photosensors

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

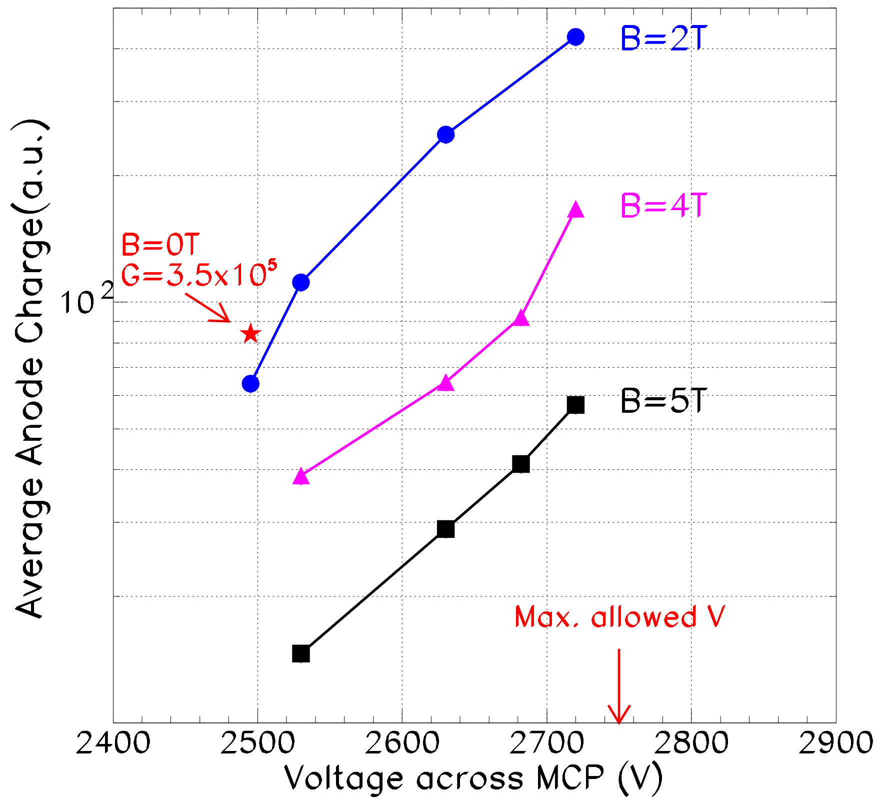
Test Box:
- non-magnetic, light-tight
- allows for rotation of sensors
- LED light source



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!