R&D of a Compact DIRC Detector for EIC

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ICHEP - August 6th, 2016

OLD DOMINION UNIVERSITY
IDEA FUSION

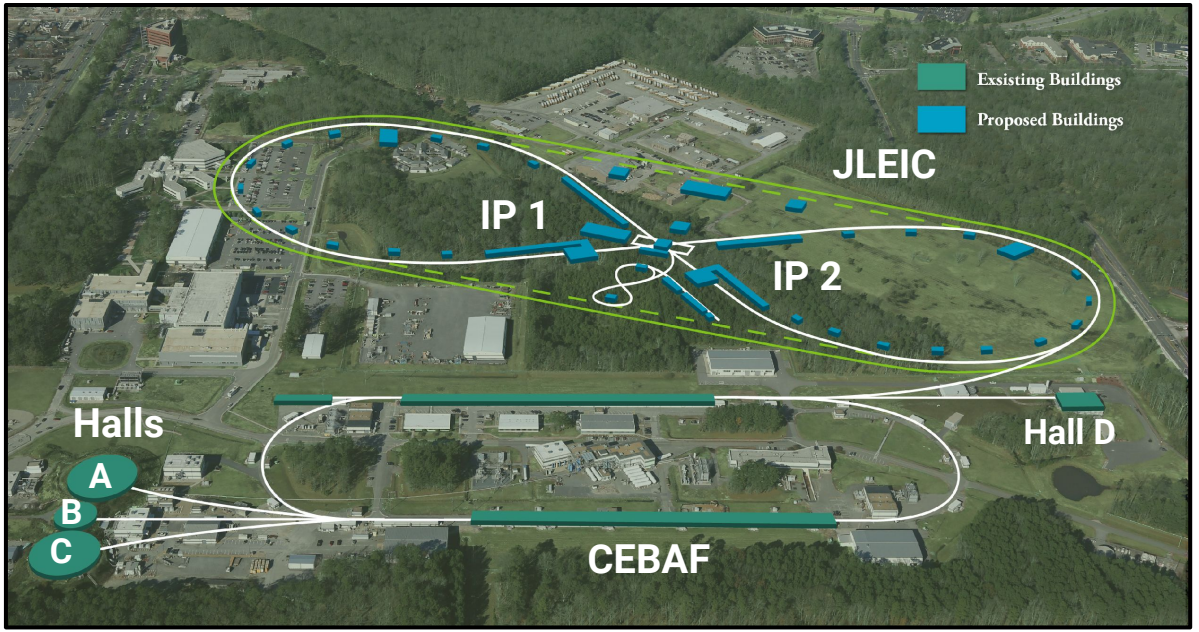
Jefferson Lab

Jefferson Lab Electron-Ion Collider Design

- Goal: understand the internal structure of hadrons and nuclei on the basis of the fundamental theory of strong interactions

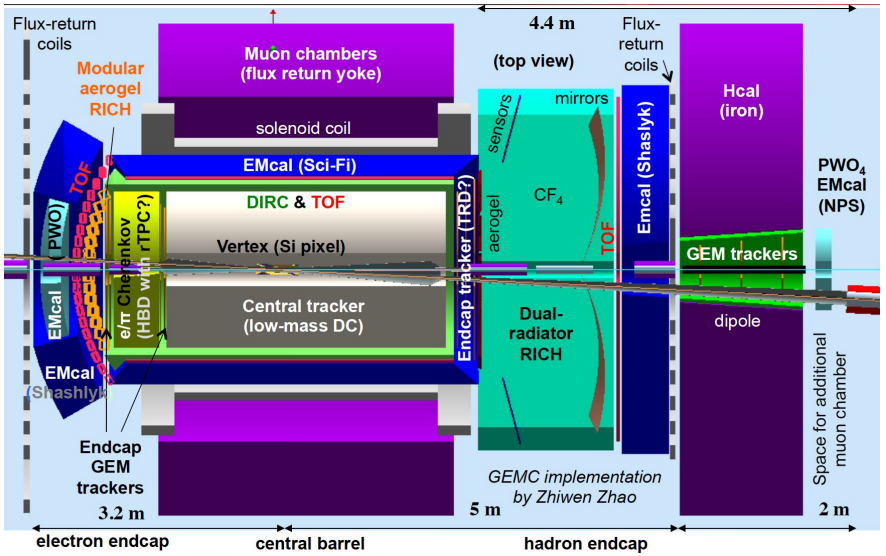
- ~ 2.4 km figure-8 accelerator design

- 12 GeV electrons on 20 - 100 GeV protons or up to 40 GeV/nucleon ions



JLEIC Detector Design

- Require high-momentum particle ID around interaction point
- 3 Cherenkov-based PID systems used:
  - Hadron endcap - Dual-radiator RICH
    - 3σ pi/K up to **50 GeV/c**
  - Electron endcap - Modular RICH
    - 3σ pi/K up to **10 GeV/c**
  - Barrel region - DIRC detector
    - 3σ pi/K up to **6 GeV/c**
- See Greg Kalicy's poster on Monday for more info!



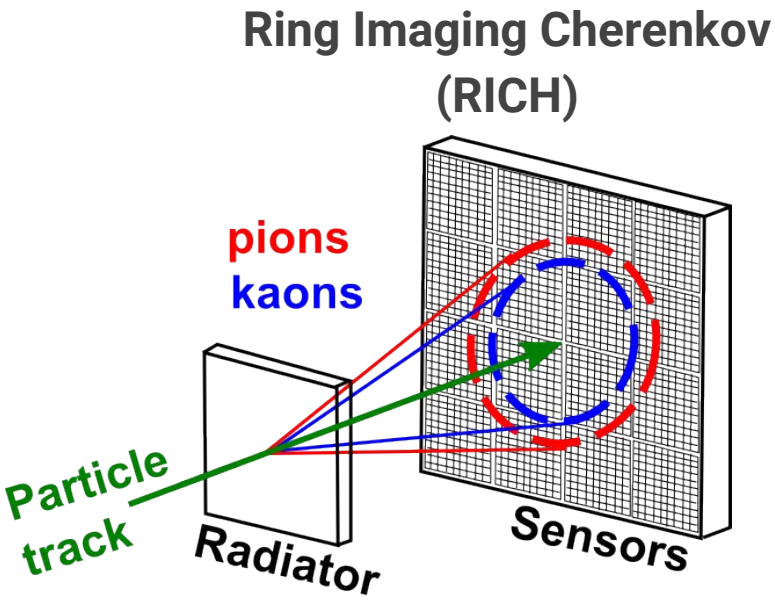
Cherenkov-based PID

- Charged particles moving through medium with refractive index *n* will emit Cherenkov photons at an angle θ_C when moving at velocities $v > c/n$

- Cherenkov angle is related to particle velocity

$$\cos(\theta_C) = \beta^{-1} n^{-1}$$

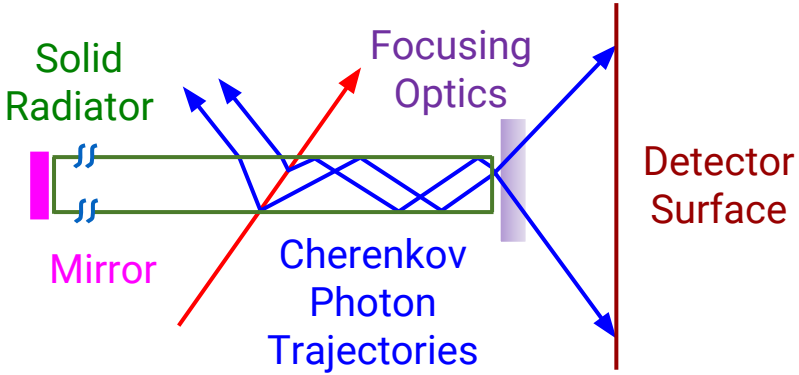
- With additional information from tracking systems, mass can be reconstructed → particle ID!

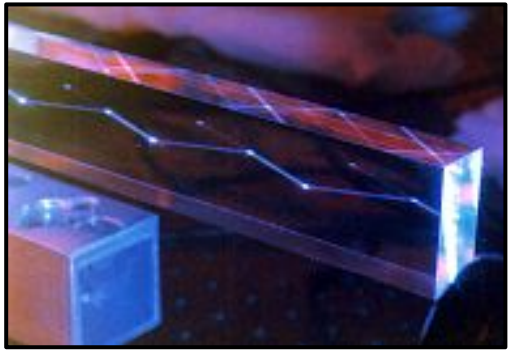


Cherenkov-based PID

Detection of Internally Reflected Cherenkov light (DIRC)

- Radially compact RICH with readout on one end of solid radiators
- Fused silica bars are used as both Cherenkov radiators and light guides
- Magnitude of Cherenkov angle preserved during internal reflections
- Position and arrival time at detector plane for each photon is used to determine Cherenkov angle





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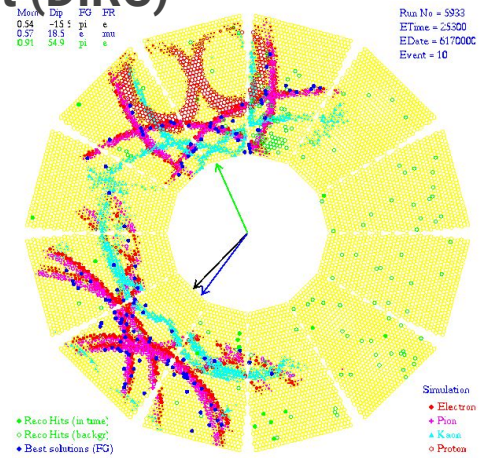
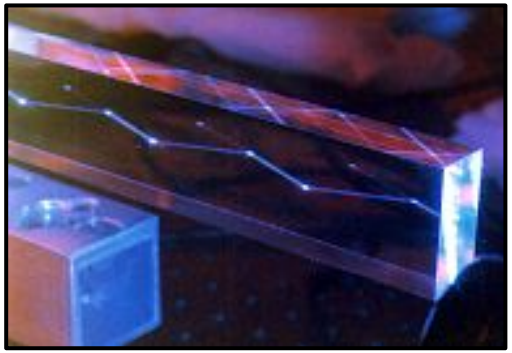


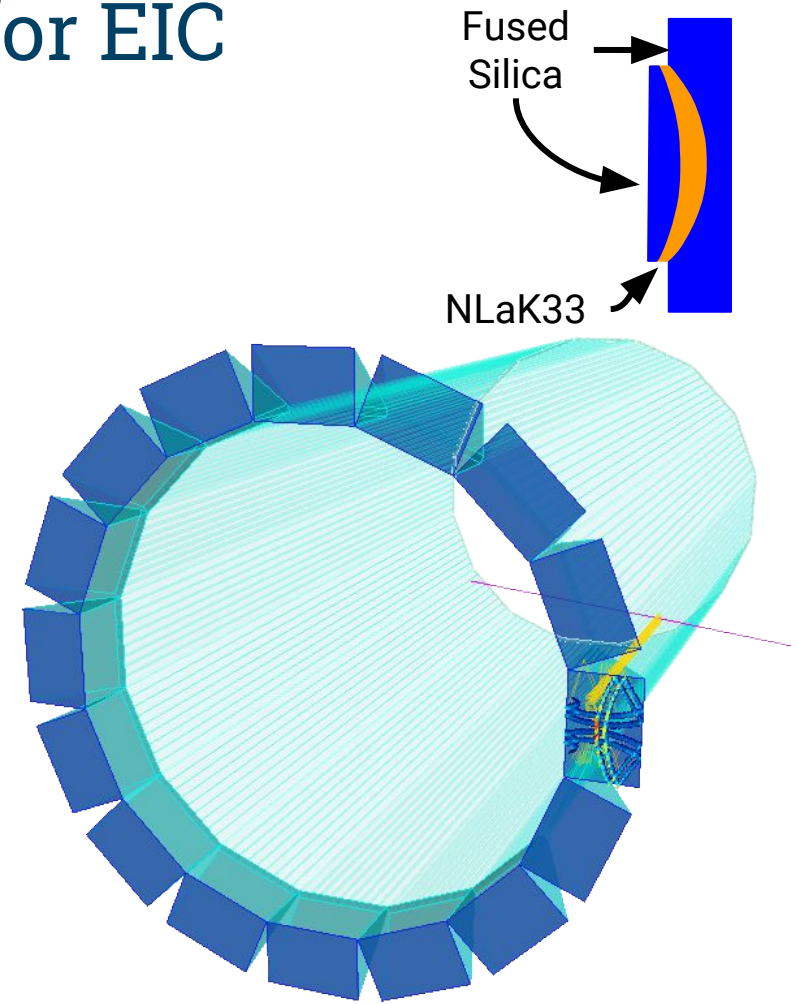
BaBar DIRC hit pattern Data + Simulation



High Performance DIRC for EIC

Current Design

- 16 bar boxes, 1m from IP
- 11 bars (each 17 x 35 x 4200 mm) per box
- **3-layer lens based baseline design**
- Fused silica prism expansion volume (30 x 39 cm with 38° tilt)
- 208k pixels, each 2 mm^2
- Experimental validation of key components are in progress



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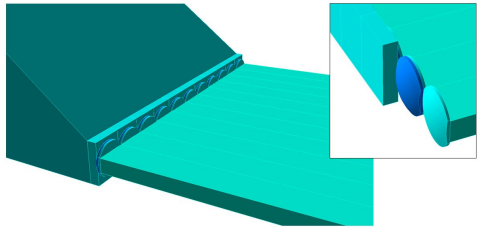
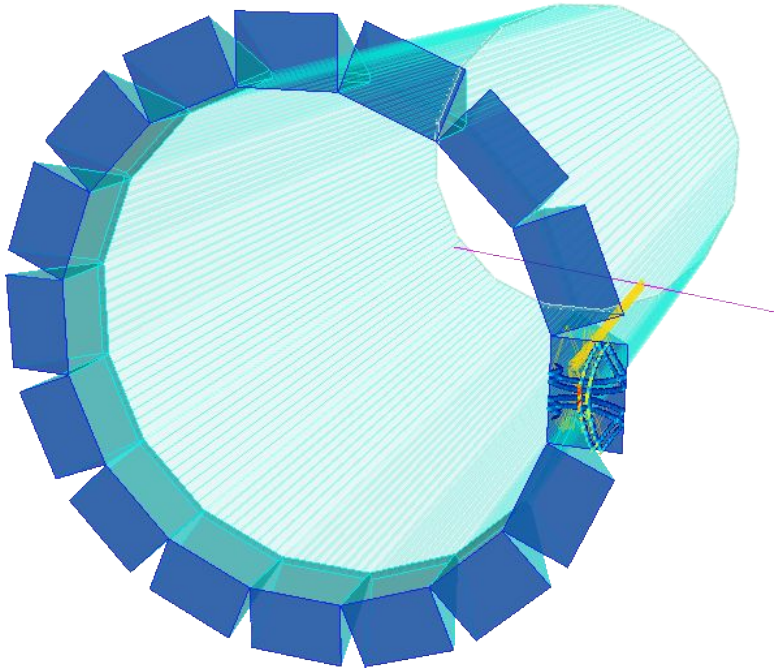
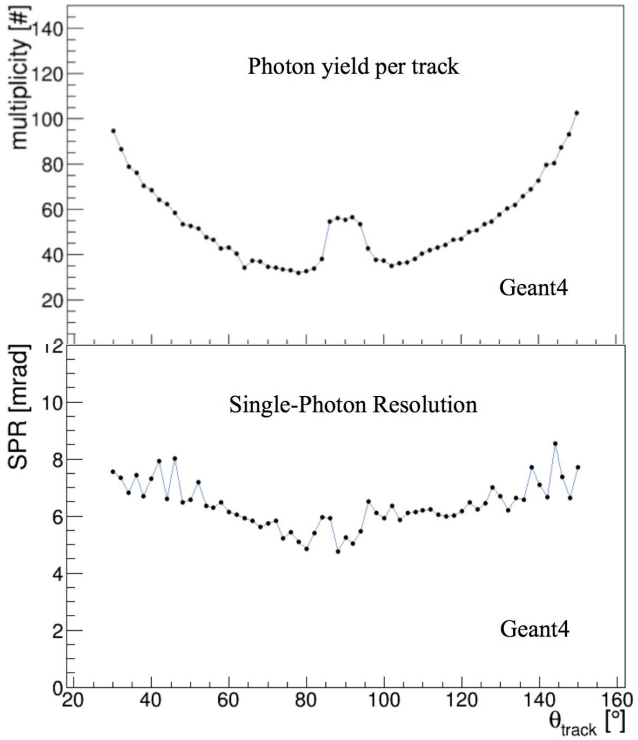
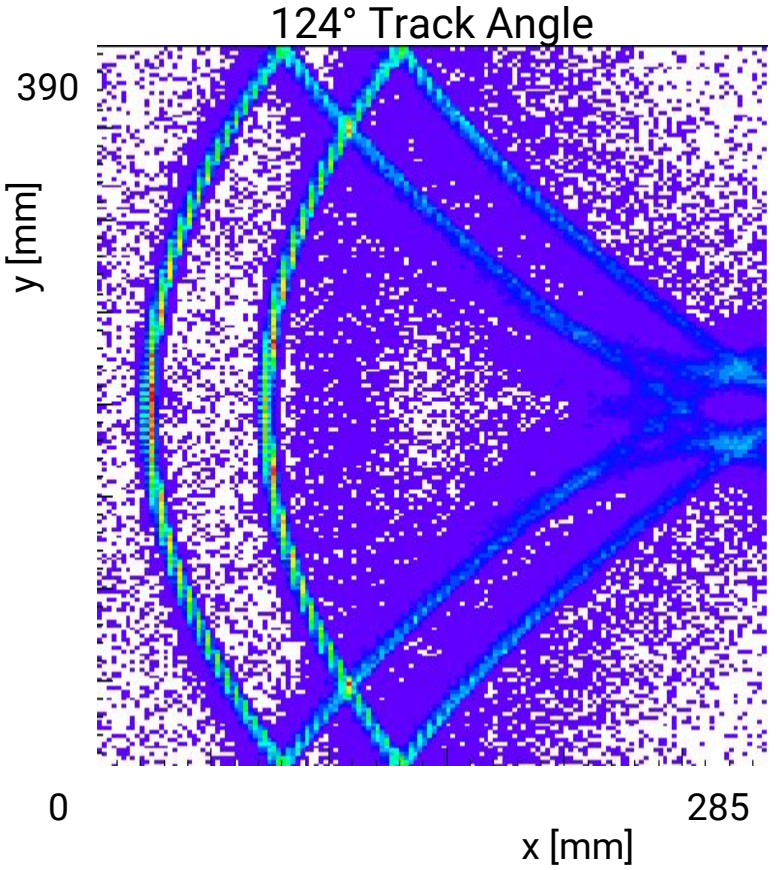




High Performance DIRC for EIC

Simulated Performance



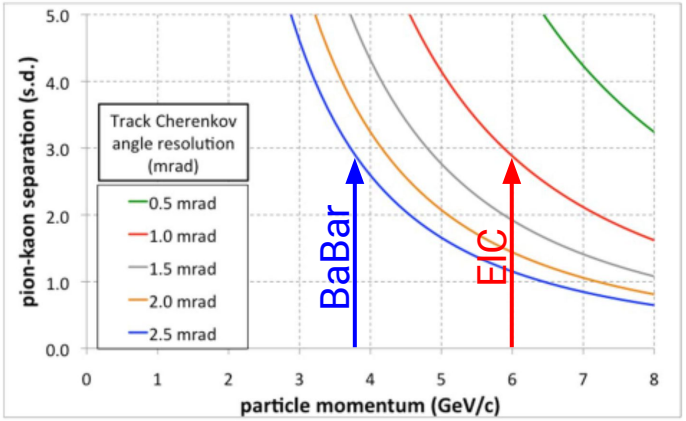


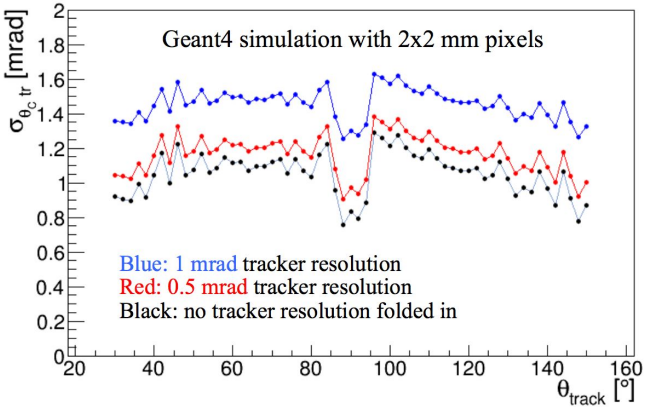
High Performance DIRC for EIC

Simulated Performance

- EIC desired pi/K separation:
  3σ at ~6 GeV/c momentum
  - BaBar DIRC reached ~4 GeV/c separation
  - Need state-of-the-art focusing to achieve such high separating power → 3-layer lens

- PID resolution dependant on
  - Tracking resolution
  - Single photon resolution
  - Photon yield

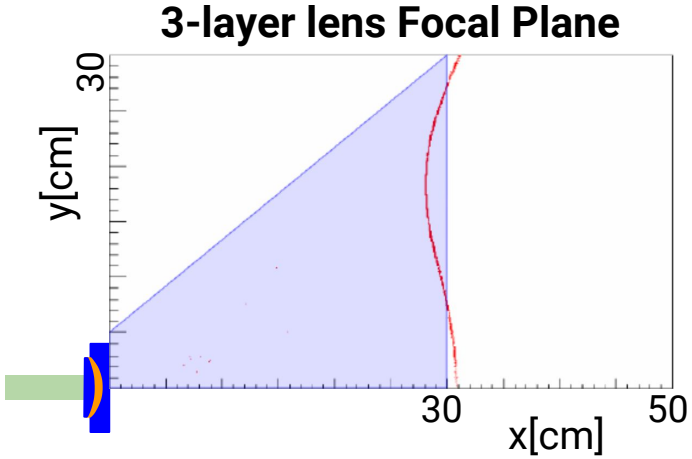




Test Bench Studies of 3-Layer Lens

Focal Plane

- Simulated focal plane follows flat detector plane, needs to be verified



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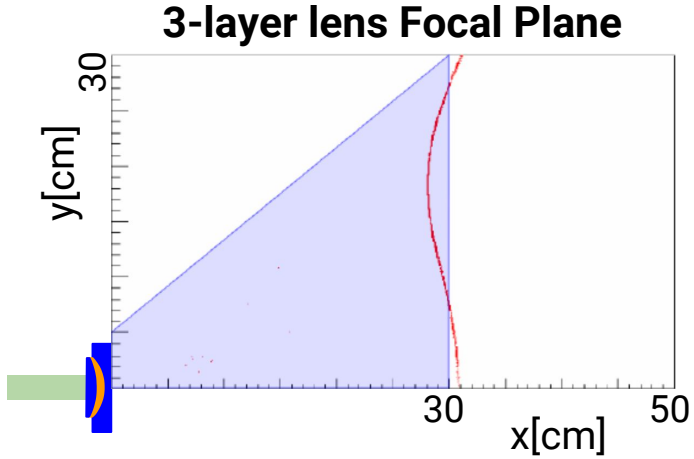

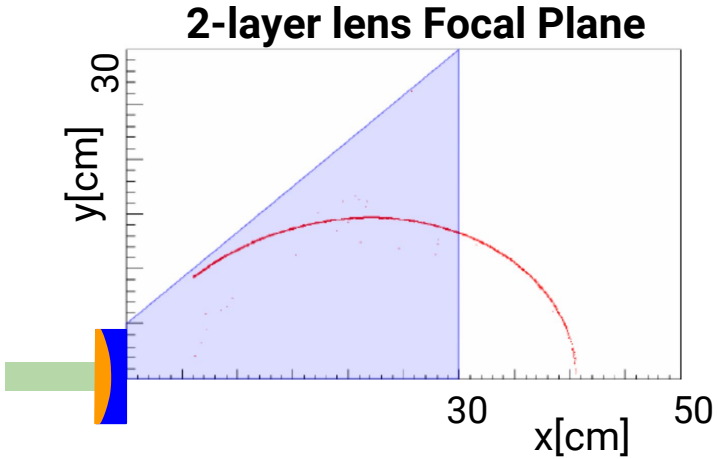

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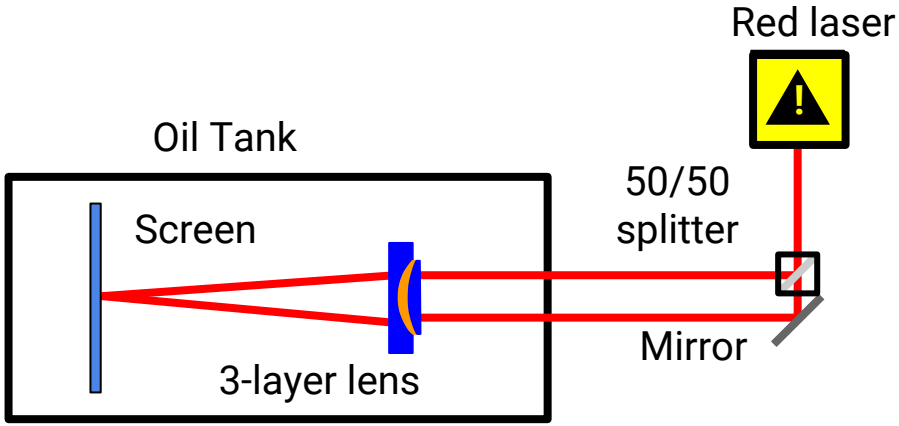

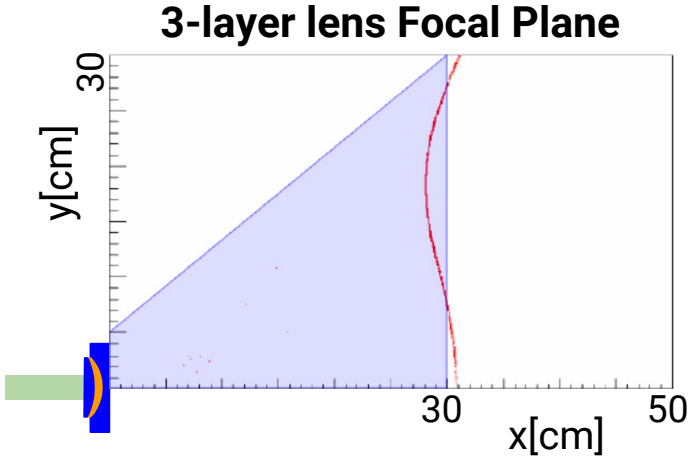

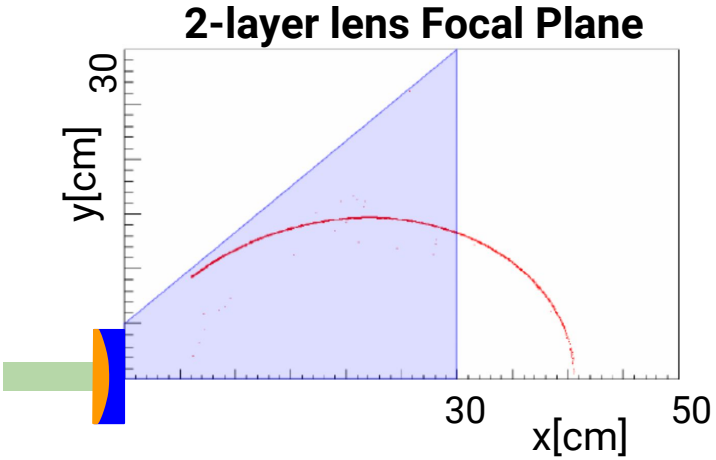

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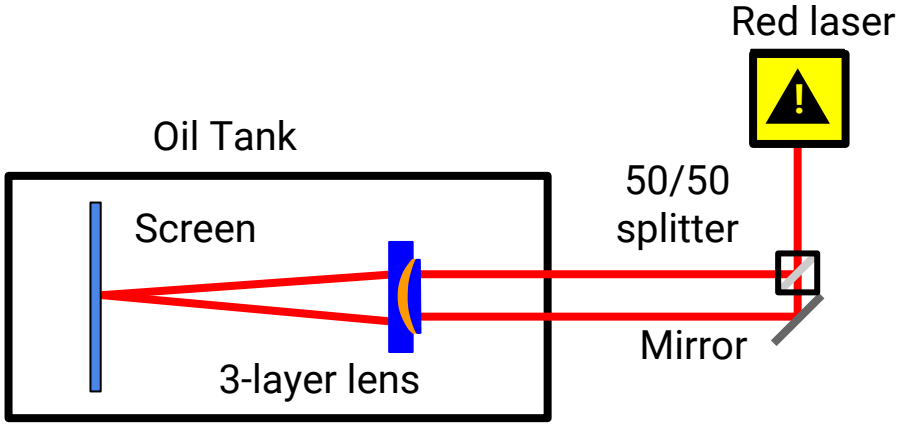
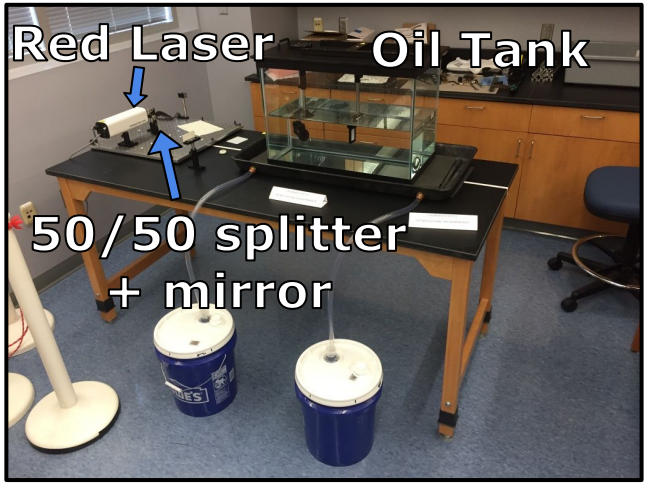
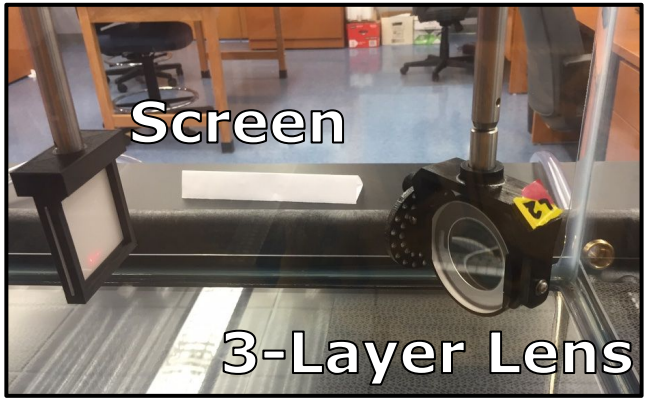




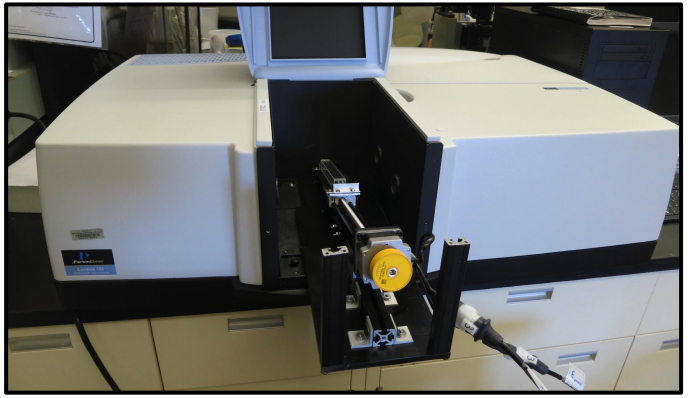


Test Bench Studies of 3-Layer Lens

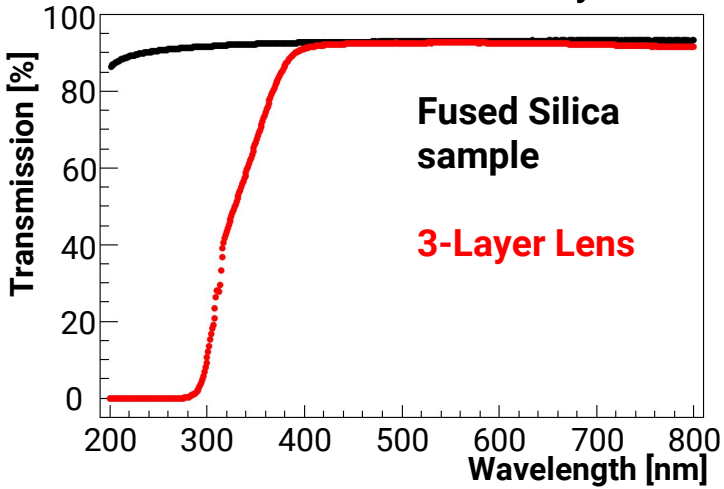
Radiation Hardness

- Irradiation using 160 keV X-ray source at CUA
- Testing prototype lens and sample of NLaK33 material
  - Also investigating other materials (e.g. PbF_2)

Monochromator



Measured transmission of 3-layer lens



X-ray source

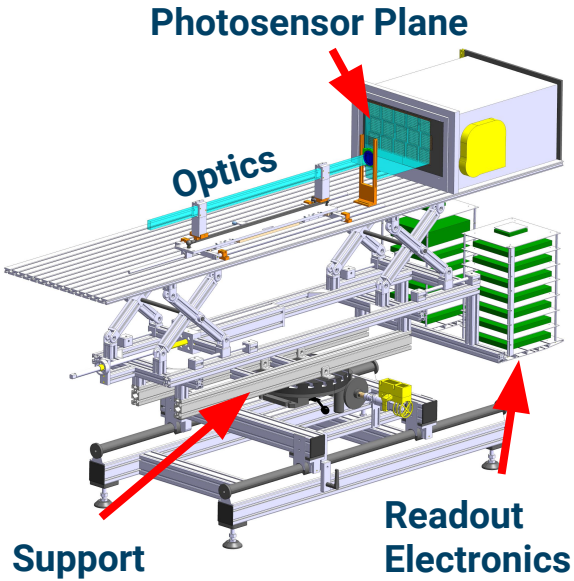
High Performance DIRC for EIC

CERN Test Beam Performance

- Testing new 3-layer lens design in fixed 1 - 7 GeV/c momentum hadron beam

- Two crucial parameters: photon yield and single photon angle resolution
  - Photon yield - number of hits per event
  - Reconstruction of Cherenkov angle and resolution per photon are more complex

- **NB:** This study is not reflective of the performance of a DIRC at EIC. It was used to verify performance of new 3-layer lens design



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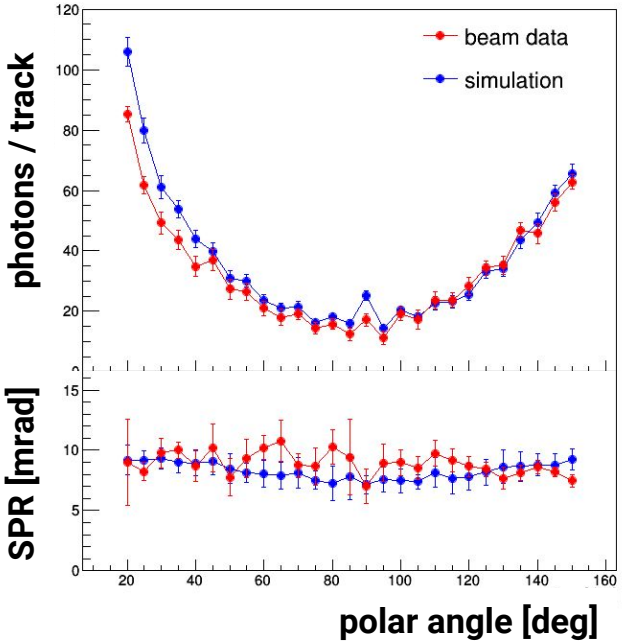


* Error evaluation not yet finalized

Summary

- DIRC is a promising solution to PID in the barrel region of an EIC
- Results of simulation and test beam data of new 3-layer lens optical focusing are in good agreement
- Focal plane and radiation hardness tests of 3-layer lens are in progress
- Other design options are also being considered

Thank you for your attention

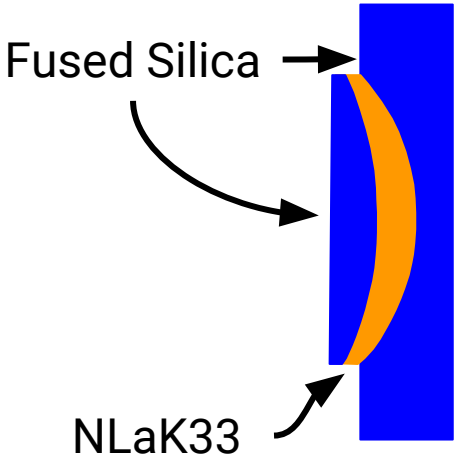
Questions?

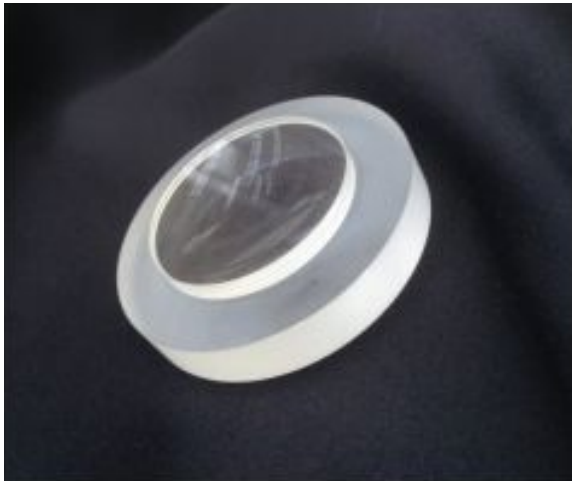
Backup

Slides

3-Layer Lens

- 2 layers of fused silica around a layer of NLaK33
  - Different radii of curvature produce a combination of defocusing and focussing
  - Effects combine to give a “flat” focal plane





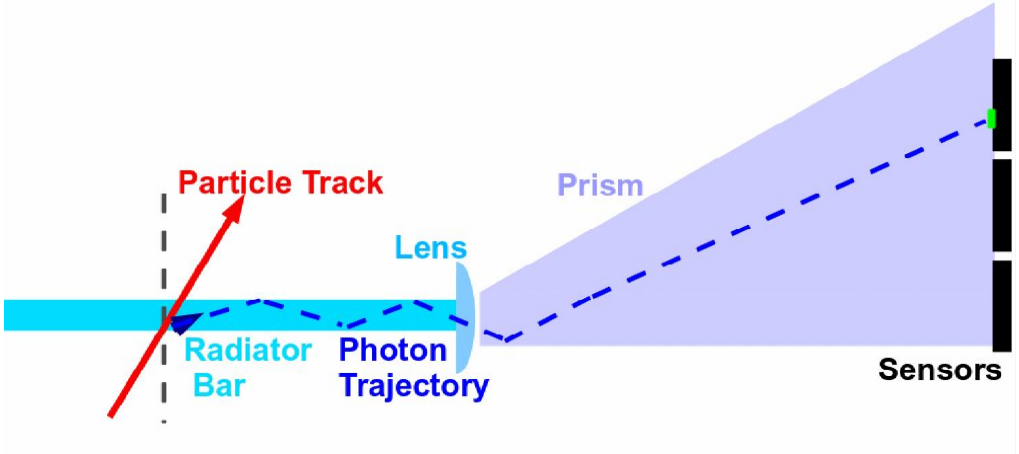
Contributions to Performance

- Expected PID performance defined by **Cherenkov angle resolution** $\sigma_{\Theta_c}^{track}$.

- $$\sigma_{\Theta_c}^{track} = \sqrt{\left(\frac{\sigma_{\Theta_c}^{photon}}{\sqrt{N_{pe}}}\right)^2 + (\sigma^{correlated})^2} \approx 3\ mrad$$

  - $\sigma^{correlated} \approx 1\ mrad$ (**Correlated term:** tracking detectors, multiple scattering)
  - $\sigma_{\Theta_c}^{photon} \approx 8 - 9\ mrad$ (**Single photon Cherenkov angle resolution:** bar size, pixel size, chromatic, bar imperfections)
  - $N_{pe} > 20$ **(Number of photons:** bar size, bar imperfections, Photon Detection Efficiency of the detector.

Geometric Reconstruction



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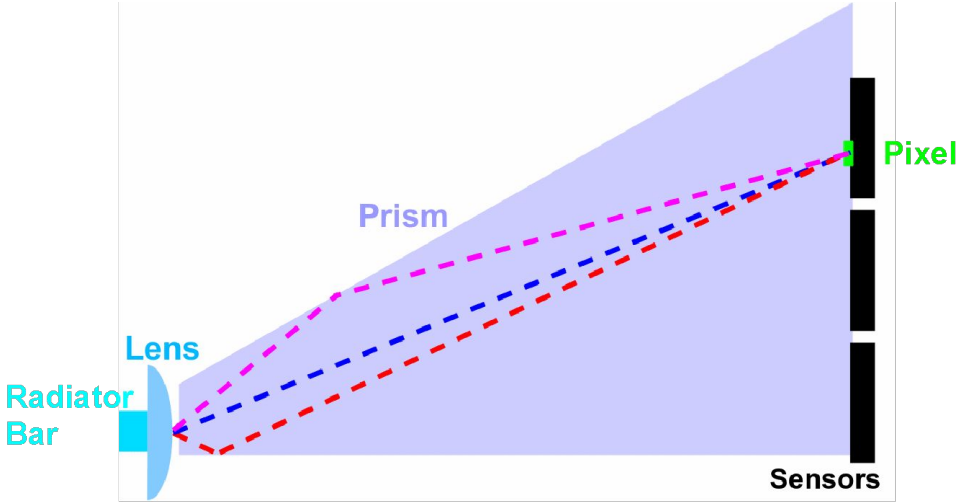

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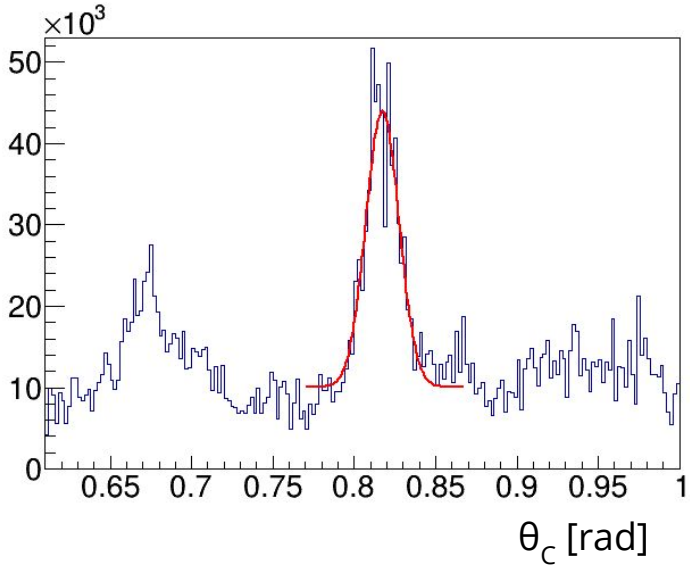

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