hpDIRC R&D for future upgrades

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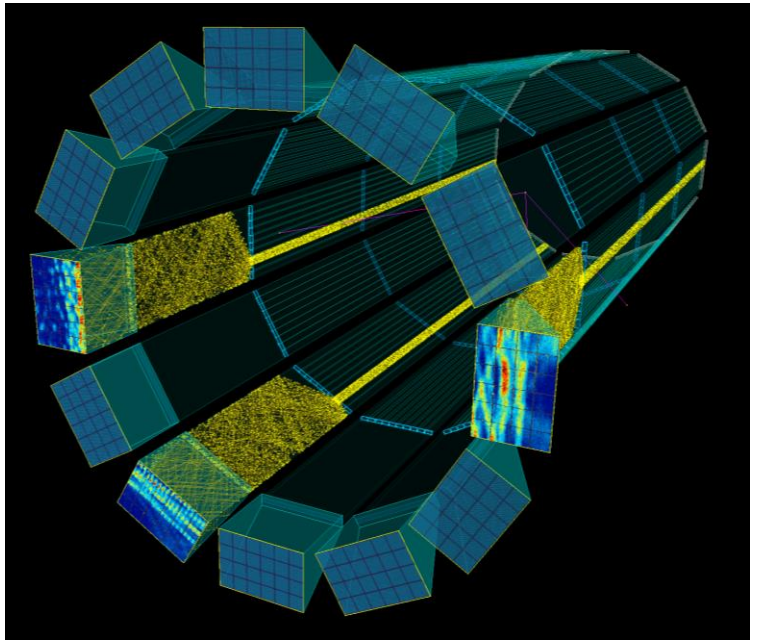
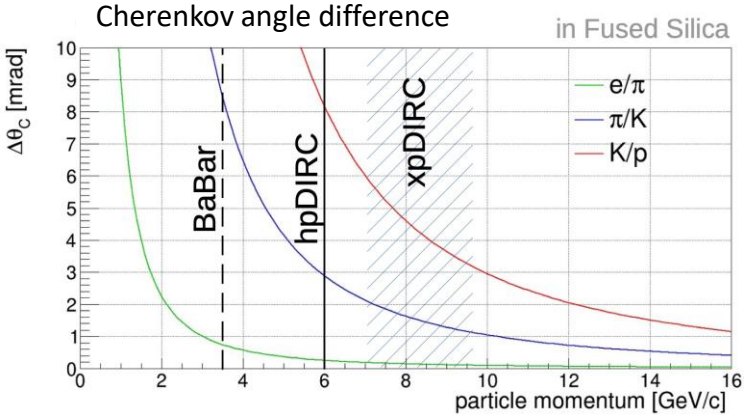
Overview of Current DIRC@EIC R&D

- DIRC R&D efforts are continuation of program initiated as part of JLab EIC Generic R&D
- hpDIRC design for ePIC serves as a reference for potential upgrades
- Study of DIRC performance limits lead to xpDIRC concept and three most promising avenues to further explore:
  - Alternative light-guide/focusing/expansion volume geometry
  - Possibility of using SiPMs
  - Low-mass thinner bar section
- SBU-CUA-ODU with support of GSI and USC submitted proposal for 3-year program to continue/expand these studies and test xpDIRC concept in prototype
- Potential xpDIRC prototype studies fit perfectly into the CRT schedule and ePIC hpDIRC studies

Hybrid xpDIRC in Geant4 Simulation



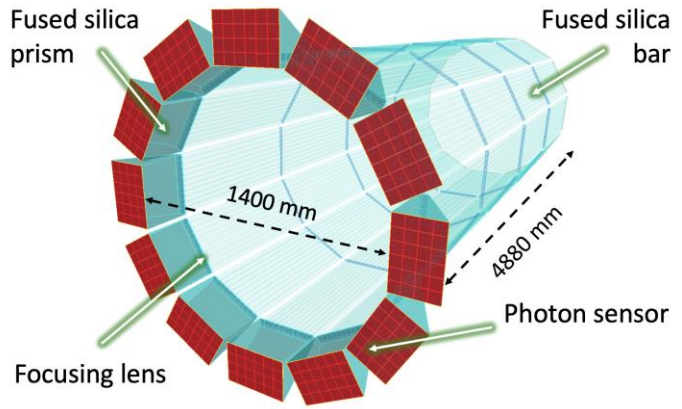
Cherenkov angle difference in Fused Silica

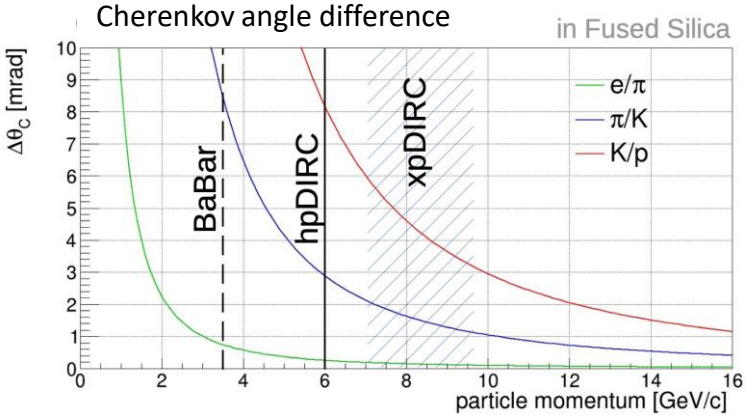


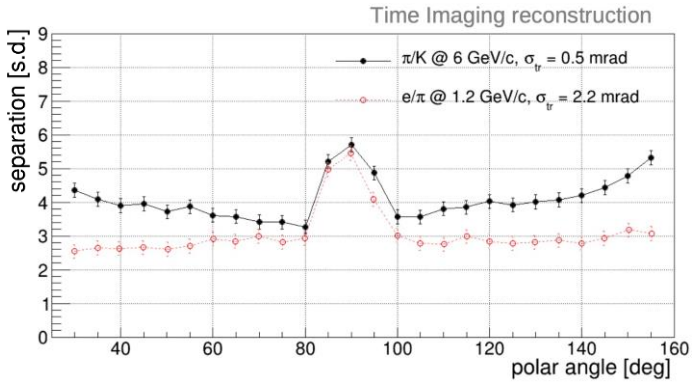
HPDIRC CONCEPT

hpDIRC Concept:

- Fast focusing DIRC, utilizing high-resolution 3D (x,y,t) reconstruction
- Design based on BaBar DIRC, R&D for SuperB FDIRC, PANDA Barrel DIRC
- Radiator/light guide: narrow fused silica bars (radius/length flexible)
- Barrel radius: 762 mm, 12 sectors, 10 long bars per sector
- Innovative 3-layer spherical lenses
- Compact fused silica prisms as expansion volumes
- Fast photon detection: small-pixel MCP-PMTs and high-density readout electronics
- Detailed Geant4 simulation: ≥ 3 s.d. π/K separation at 6 GeV/c,
  ≥ 3 s.d. e/π separation at 1.2 GeV/c







HPDIRC CONCEPT -> XPDIRC

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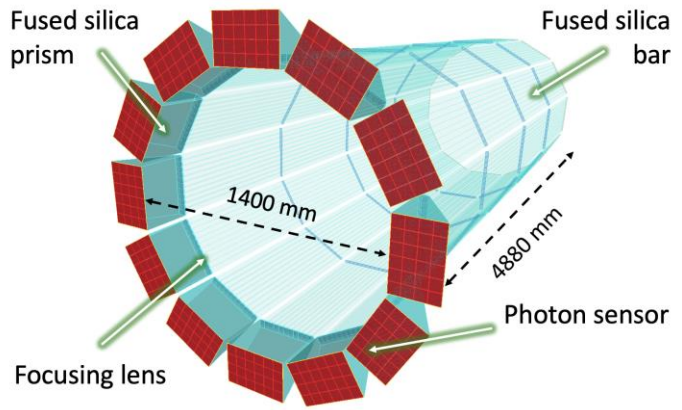
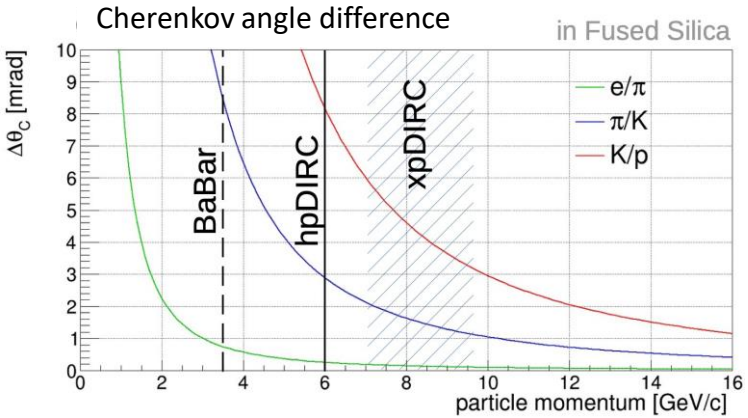
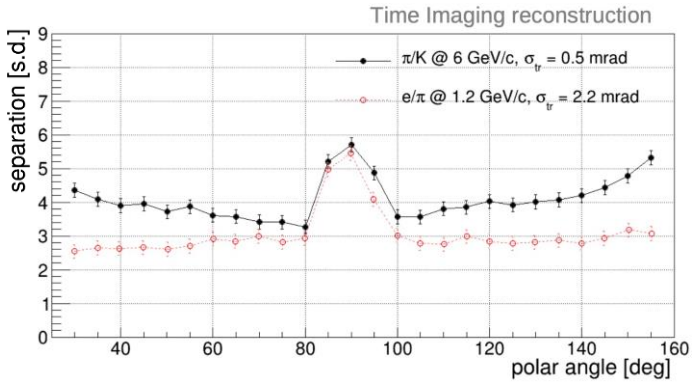


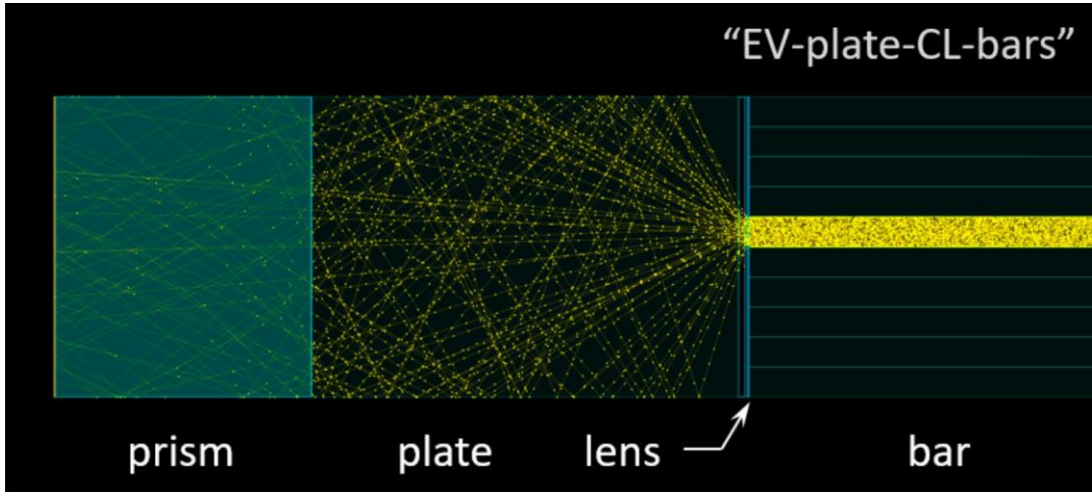




Alternative Design

- ePIC detector barrel length requires additional “light guide” section to connect BaBar DIRC bars to prism
- Alternative to baseline (narrow bars) is one single short wide plate
- Hybrid optics (narrow bars in active area, wide plates as light guides)
  could mitigate focusing errors and reduce cost
- Expansion volume effectively starts at end of narrow bar, improving angular resolution, possible use of cylindrical lens
- xpDIRC “thick plate” hybrid design with cylindrical lens placed between the narrow bars and 50 mm-thick wide plate
- Longer expansion in plate could make shorter prism possible, with smaller sensor area, possibly enabling use of SiPM

Hybrid of bars and wide plate in each



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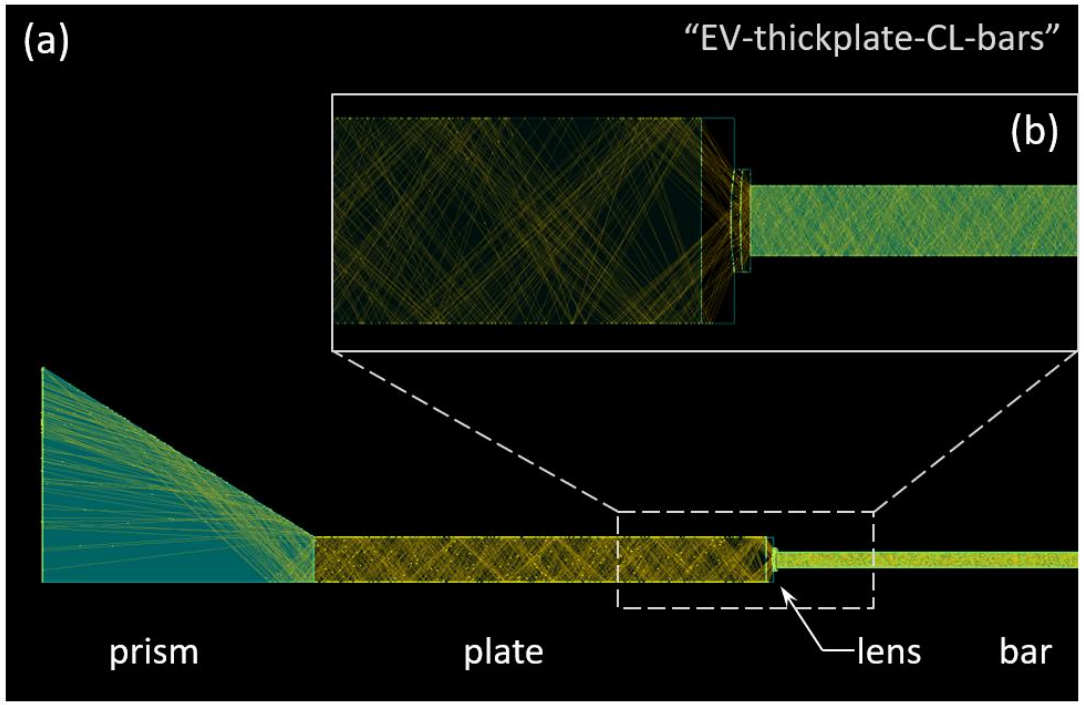
Hybrid of bars and "thick plate" in each sector



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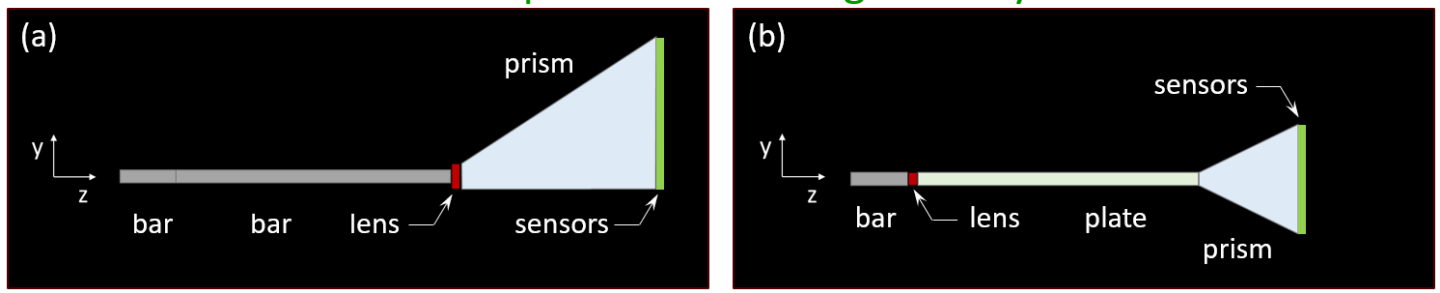
Alternative expansion volume geometry



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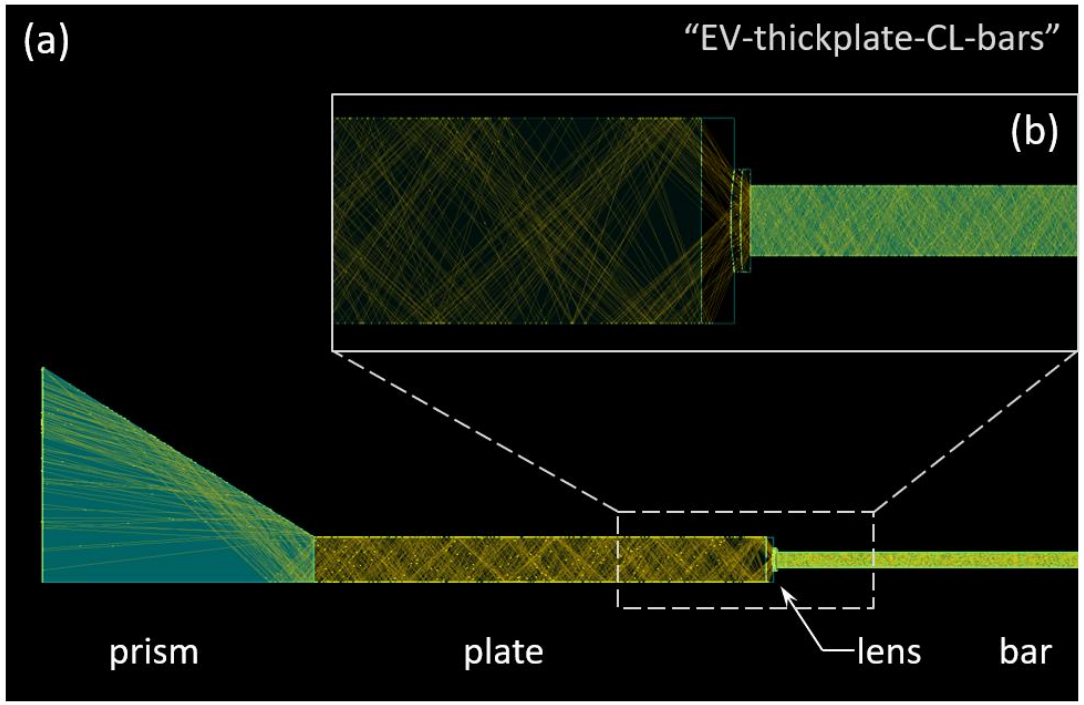
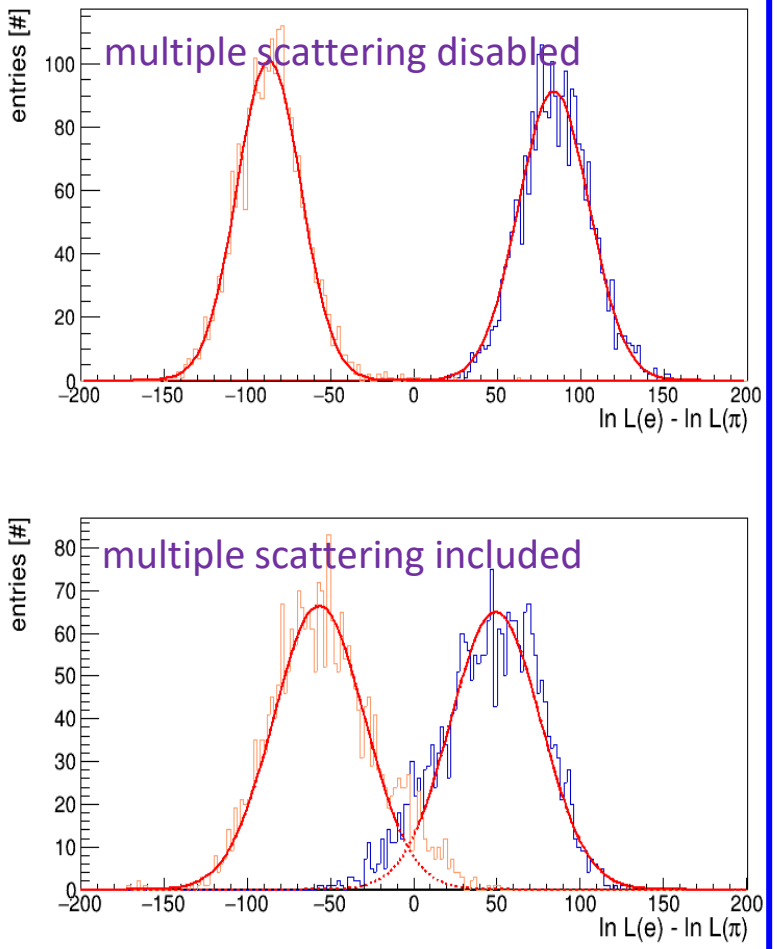


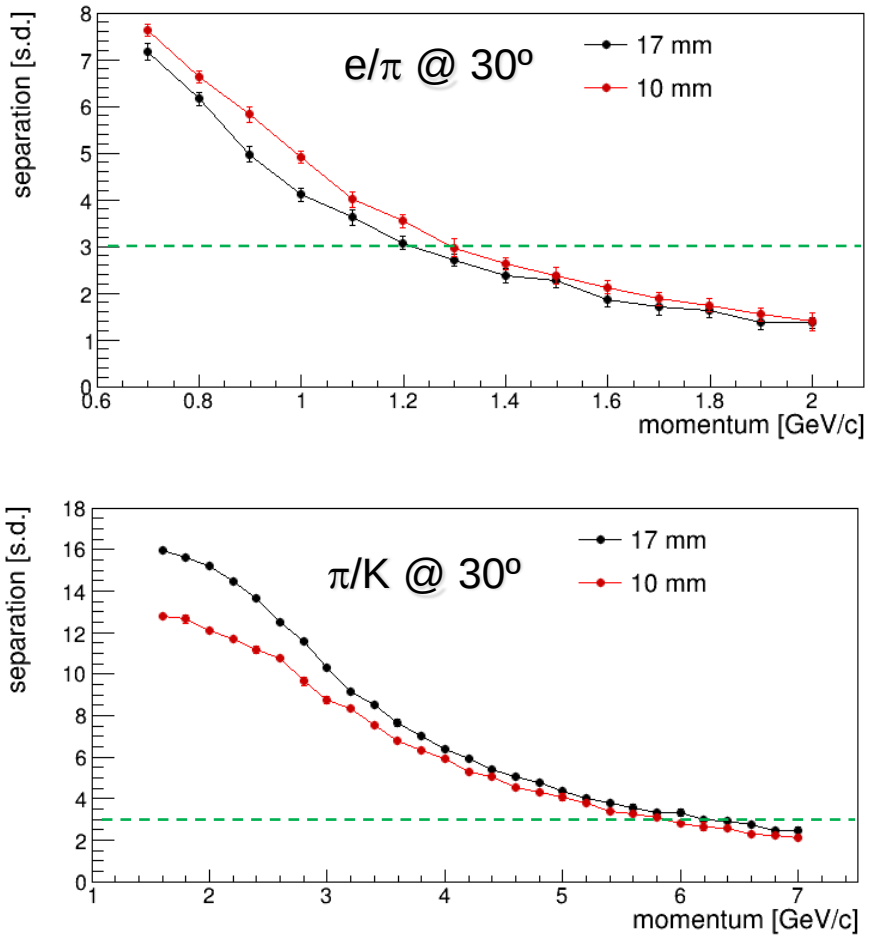
Low-Mass Thin xpDIRC

G4 simulation of e/π separation at 1.2 GeV/c
bar thickness: 17 mm

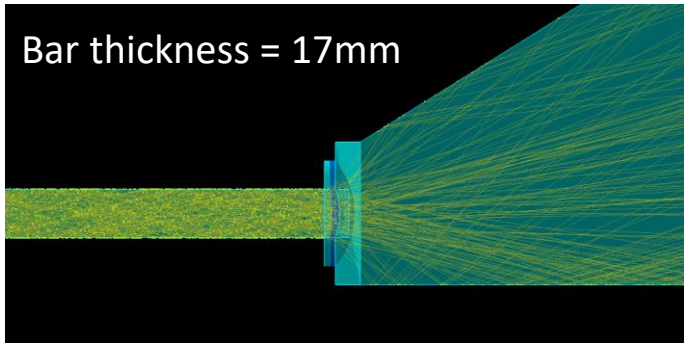


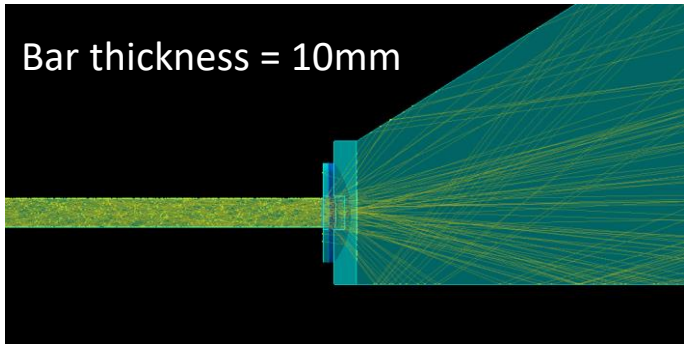
41% reduction in mass, benefits the EMCal performance and reduces Multiple scattering in the DIRC bar.

G4 simulation performance of 10mm and 17mm options of hpDIRC (CORE scenario)



Potential for significant e/π ID improvement around 1 GeV/c, without significantly affecting π/K ID above 4 GeV/c





10 mm–thick LHCb TORCH prototype

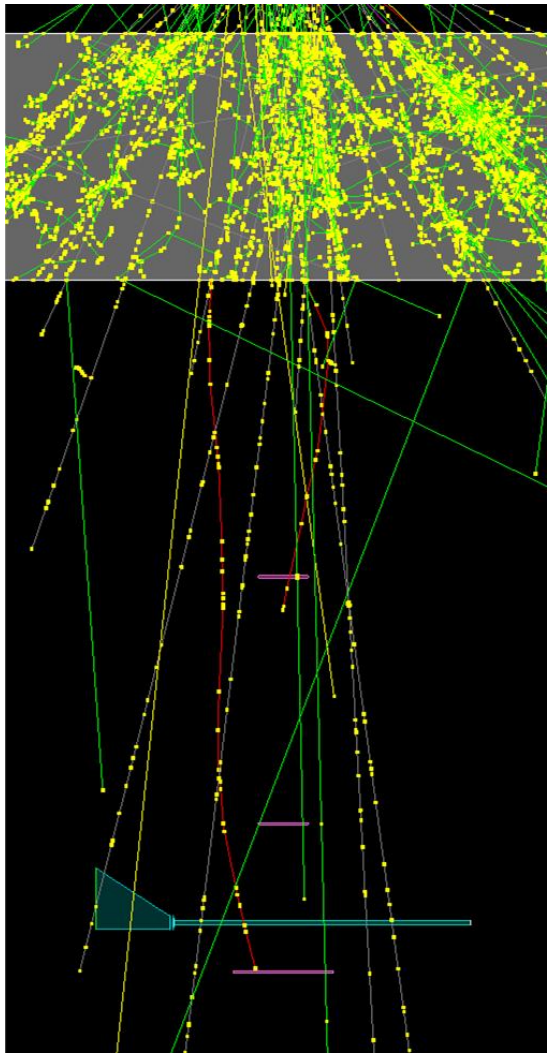
Cosmic Ray Telescope (CRT)

Cosmic Ray Telescope (CRT) at SBU

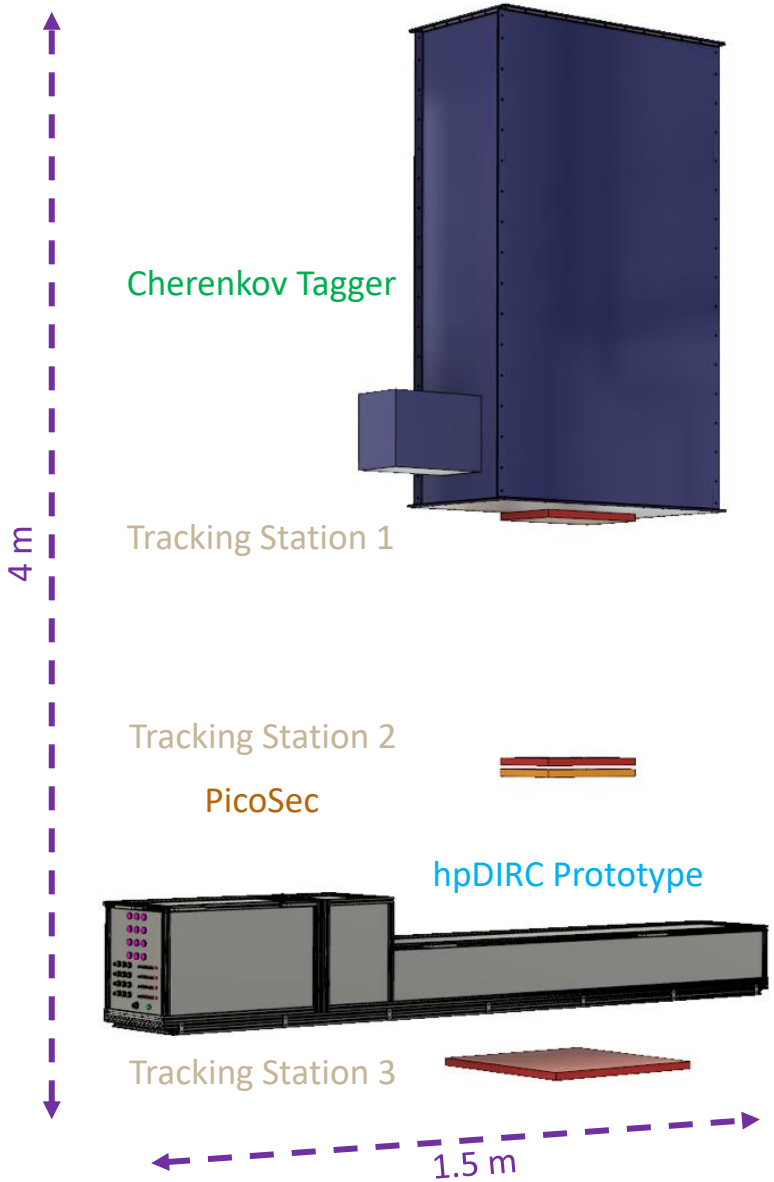
Facility to test incremental upgrades of prototype components, performance evaluation

- Initial PANDA Barrel DIRC-based prototype to commission setup
- Modular design will allow to add new ePIC hpDIRC components once they become available
- Cherenkov Tagger to select muons above 3.5 GeV/c
- Three tracking stations for high-precision 3D-track reconstruction (location optimized with simulations)
- PicoSec detector for event timing (Jlab group committed prototype and personnel to project)
- Geant4 simulation used to optimise setup arrangement

Geant4 simulation of CRT setup

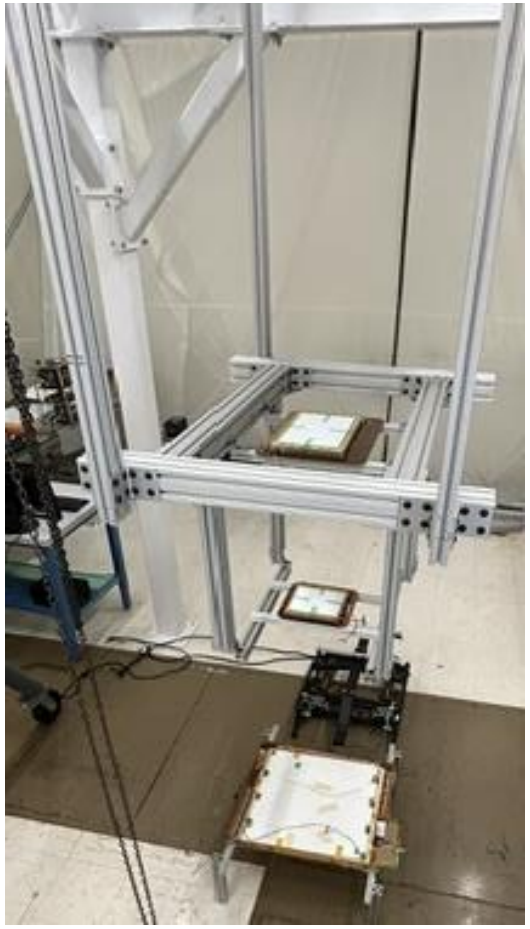


CRT setup CAD schematic

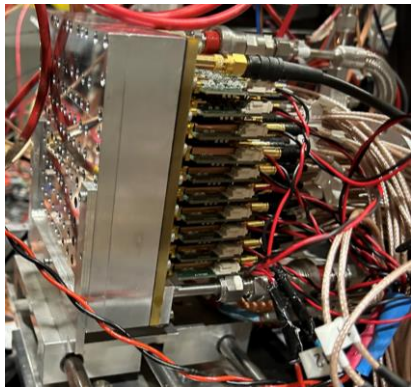


Cosmic Ray Telescope (CRT)

Momentum tagger installed and being tested with the scintillators

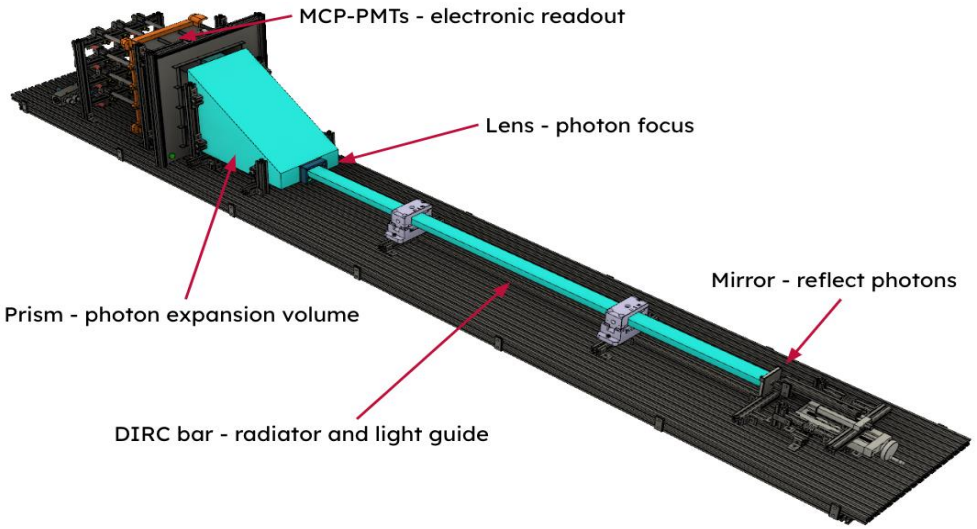


Trackers in the CRT



Large area PICOSEC at CERN test beam

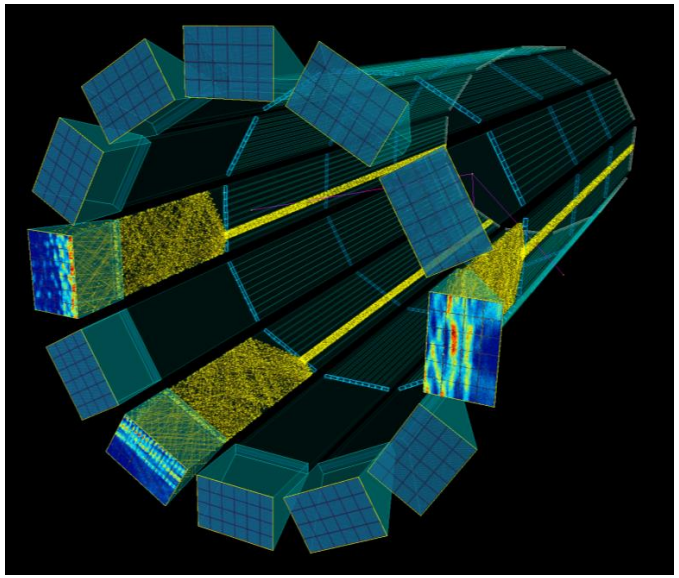
DIRC Protoype



Modular DIRC protoype at CRT

Conclusions and Outlook

- Current and future DIRC experimental studies are connected to CRT setup at SBU
- SBU-CUA-ODU with support of GSI and USC submitted proposal for 3-year program to continue/expand past studies and test new concept in prototype
- Priority and present CRT effort on hpDIRC tests for ePIC, potential future xpDIRC tests fit well into the ePIC schedule
- R&D for xpDIRC will take full advantage of the CRT setup while we wait for newly purchased components for hpDIRC (like readout)
  - Alternative light-guide/focusing/expansion volume geometry
  - Possibility of using SiPMs
  - Low-mass thinner bar section
- SBU has personnel support to lead the CRT setup that has the potential to serve as a multipurpose setup
- PicoSec experts will support integration and operation of the prototype



Thank you

Backup

HPDIRC RECENT ACTIVITIES

hpDIRC prototype in Cosmic Ray Telescope (CRT):

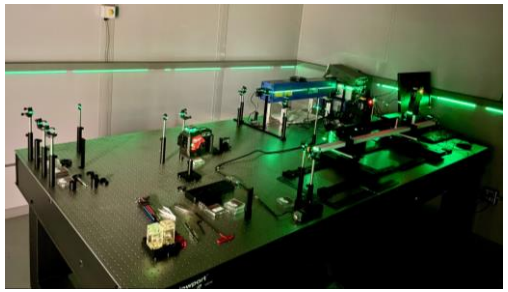
- CRT construction in final stage at SBU to become test bench for incremental upgrades of new components (bars, sensors, readout electronics, eventually full hpDIRC modules)
- Momentum tagger installed and tested
- Tracker installation and DAQ synchronization ongoing

hpDIRC prototype at SBU

Validation of the BaBar DIRC bar reuse:

- Bar boxes transferred from SLAC to JLab in April 2024
- Disassembly of the boxes have started
- Decision on reuse of bars expected by Q1-Q2/2025

QA lab at JLab

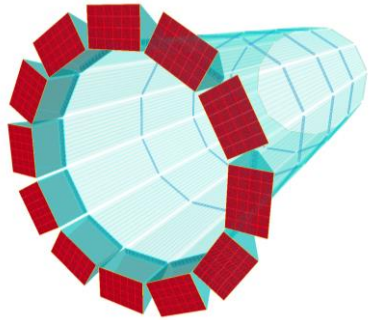


Disassembly setup at JLab

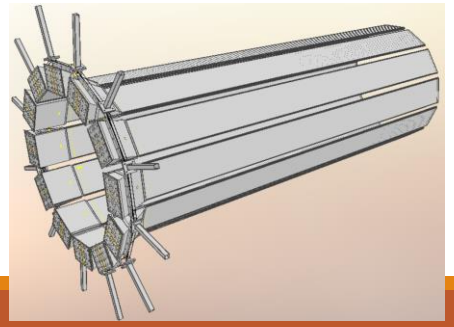
Ongoing hpDIRC studies in simulation:

- Light-guide, prism, sensor coverage design optimization

hpDIRC in Geant4



hpDIRC in CAD



Mechanical Design and Integration:

- Work with two engineers and synergies with PANDA Barrel DIRC

DIRC Performance Limits

Main effects limiting future DIRC performance

- Multiple scattering (MS) inside the bar

  dominates at lower momentum

  → possible mitigation: thinner bar, post-DIRC tracking

- Chromatic dispersion (CD) of angle and time

  dominates at higher momentum

  → possible mitigation: limit spectral acceptance

- Optical aberrations from focusing system

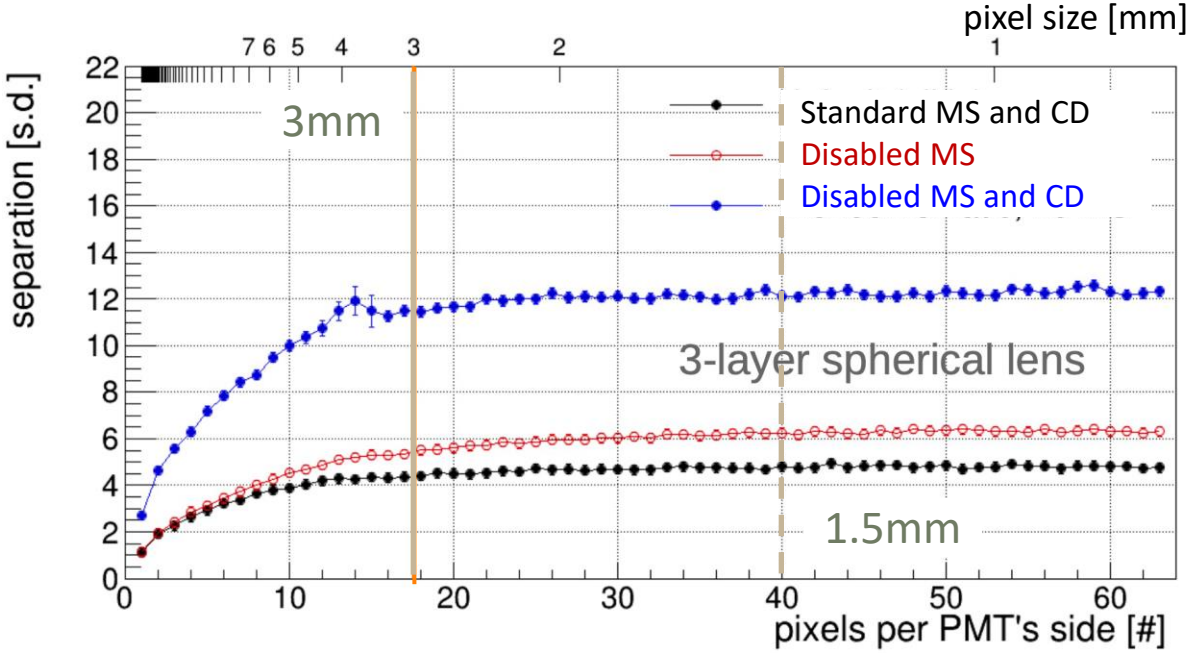
  → possible mitigation: hybrid optics, aspherical lenses

- Pixel size

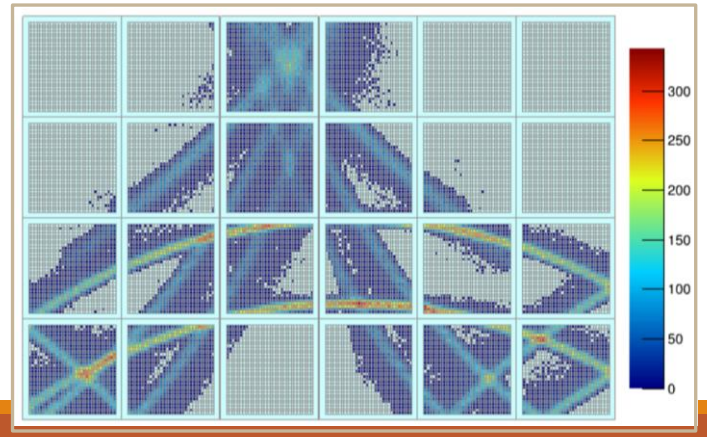
  → possible mitigation: MCP-PMTs and SiPM with small pixels (~1.5mm) commercially available, very active field

→ Optical aberrations, multiple scattering, pixel size are promising areas; start with hybrid optics, initial exploration of thin bar and small-pixel sensors.

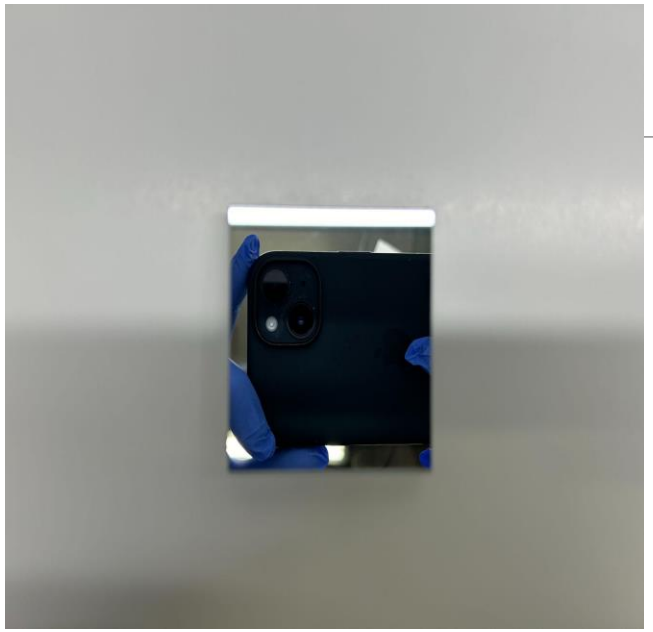
π/K separation of ePIC hpDIRC at 6 GeV/c – pixel size effect



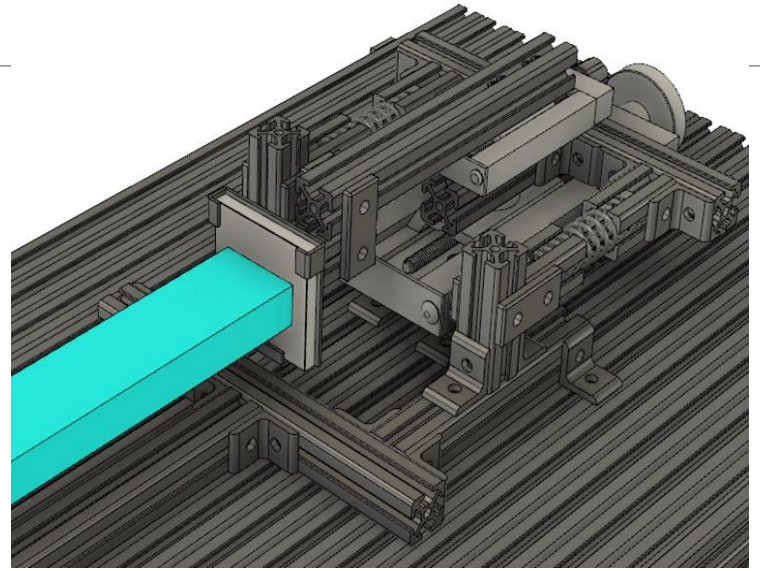
32x32 pixels (1.6 mm) per 2'' MCP-PMT

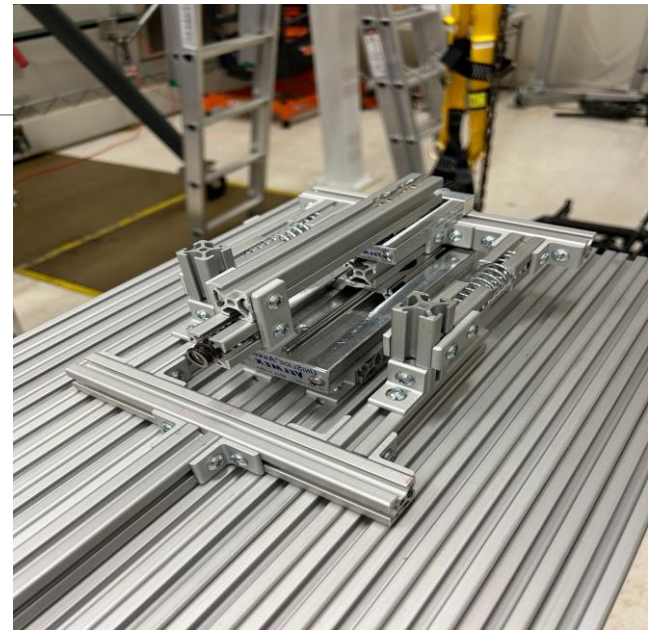


Mirror and Linear actuators



UV enhanced mirror





Linear actuator, CAD and in reality

- UV enhanced mirror to reflect the Cherenkov photons
- Linear actuators to move the mirror and the bar