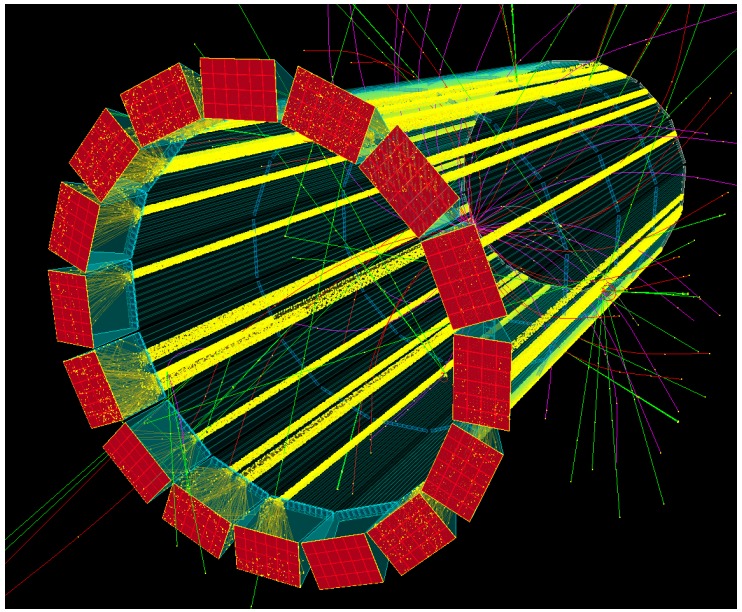
# hpDIRC Detector for EIC Detector II

Greg Kalicy

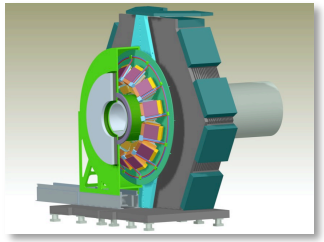
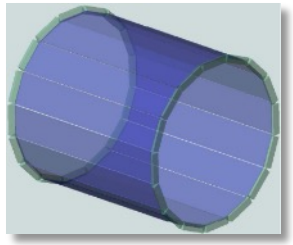
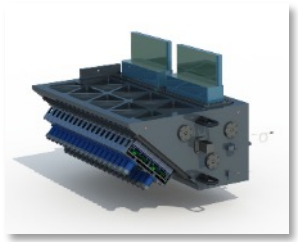
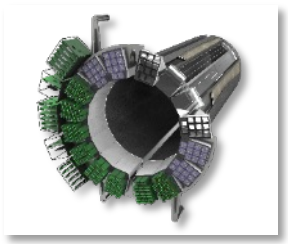
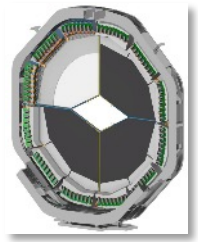
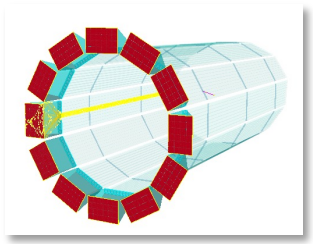
CUA



- hpDIRC concept for ePIC and its flexibility
- Design and performance
- Exploring theoretical limits
- Current and future R&D

CUA FAU GSI Jefferson Lab Old Dominion University of South Carolina Stony Brook University

# DIRC Concept

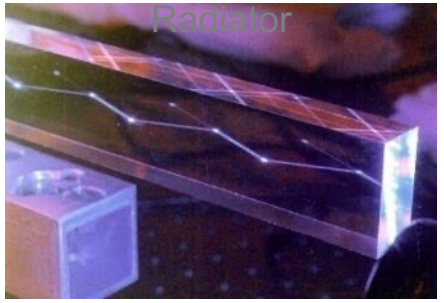








BaBar SuperB Belle II GlueX panda panda ePIC

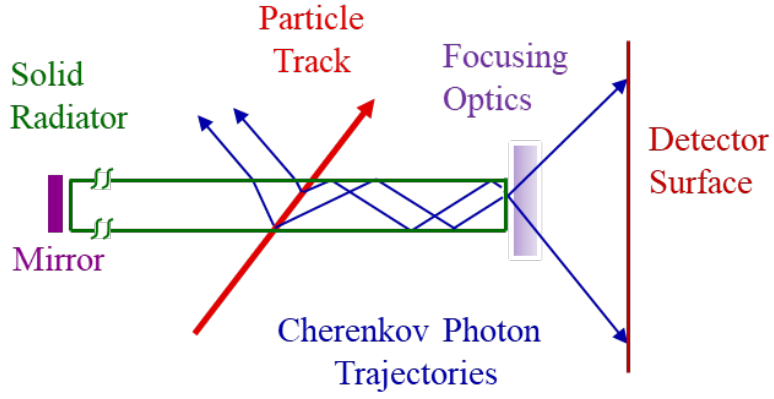
## Detection of Internally Reflected Cherenkov Light

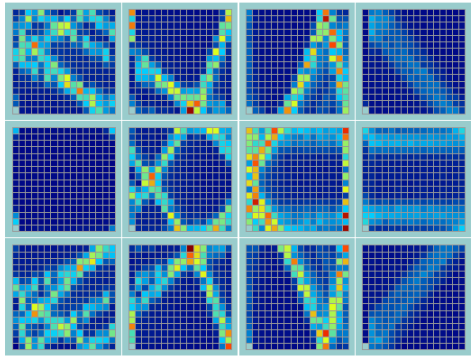
- Pioneered by the BaBar experiment at the SLAC National Accelerator Laboratory
- Fused silica radiator is used also as light guide
- Detector surface is outside active volume
- Cherenkov angle is conserved during internal reflections and reconstructed from detected photons
- Ultimate Deliverable: PID likelihoods

Synthetic Fused Silica Bar Radiator



Accumulated hit pattern (Geant4)

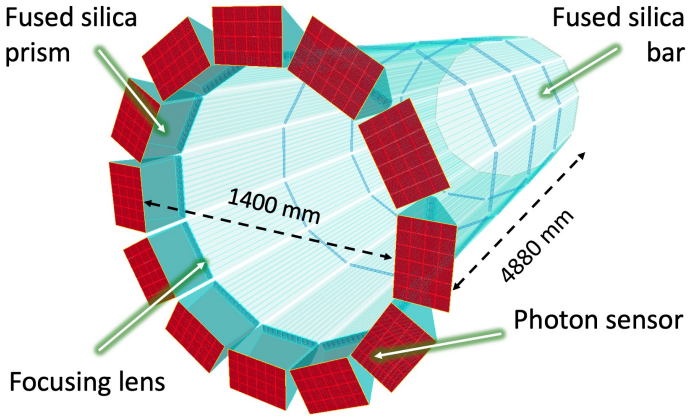


# HPDIRC CONCEPT

## High-performance DIRC Concept

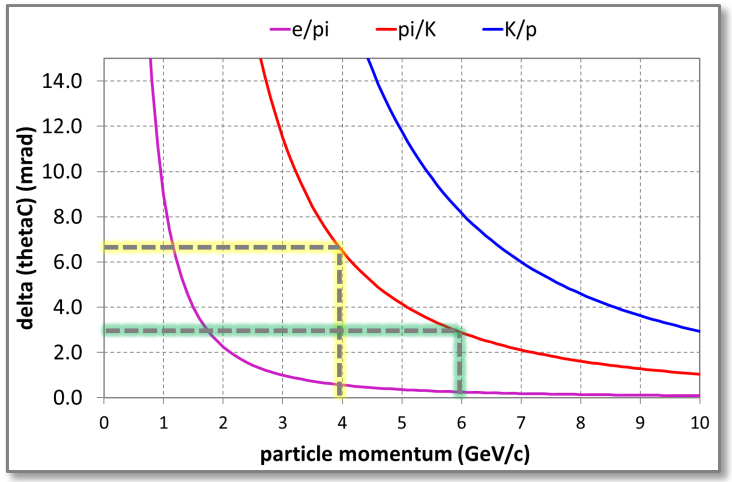
- Concept developed as part of Generic R&D program (eRD14)
- Finalizing design, risk mitigation as part of Project R&D (eRD103)
- Future DIRC R&D in new Generic R&D program (EICGENRandD12)




## Key Features:

- 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)
- 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

DIRC Cherenkov angle difference vs. momentum



# BASELINE HPDIRC DESIGN FOR EPIC

- Radiator bars:
  - Size: 4580mm x 35mm x 17mm (L x W x T)
  - Barrel: 700mm radius, 12 bar boxes, 10 long bars per bar box

    long bar: 4 bars glued end-to-end, flat mirror on far end

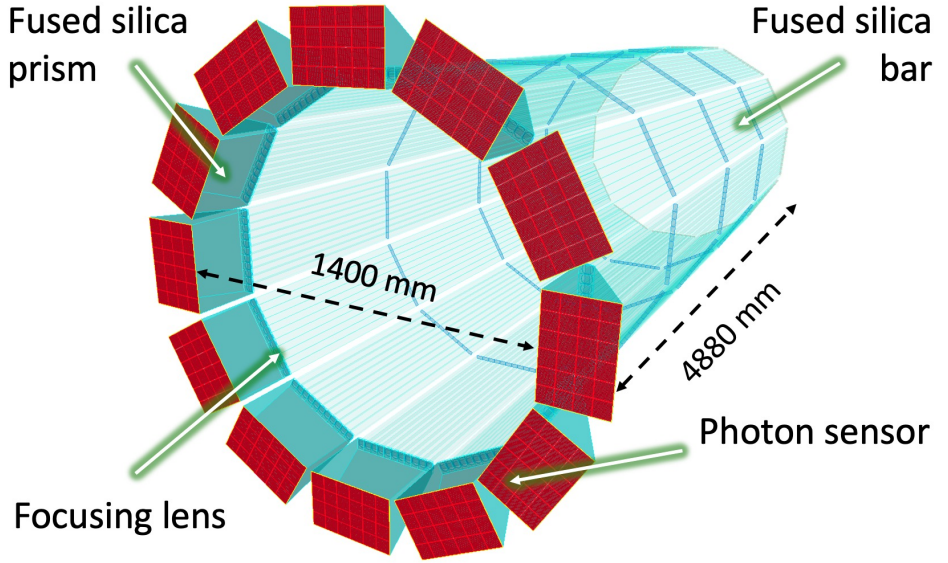
    baseline design: reuse of BaBar DIRC bars (R&D started)
- Focusing optics:

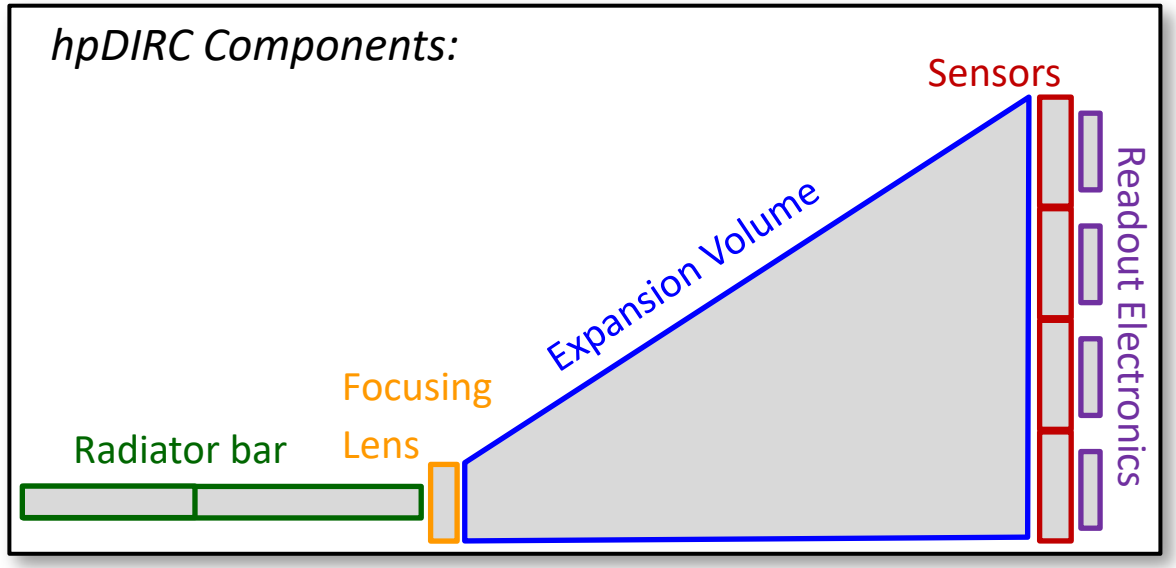
  Radiation-hard 3-layer spherical lens (sapphire or $PbF_2$)
- Expansion volume:

  Solid fused silica prism: 240 x 360 x 300 $mm^3$ (H x W x L)
- Readout system:

  MCP-PMT Sensors (e.g. Photek/Photonis/Incom)

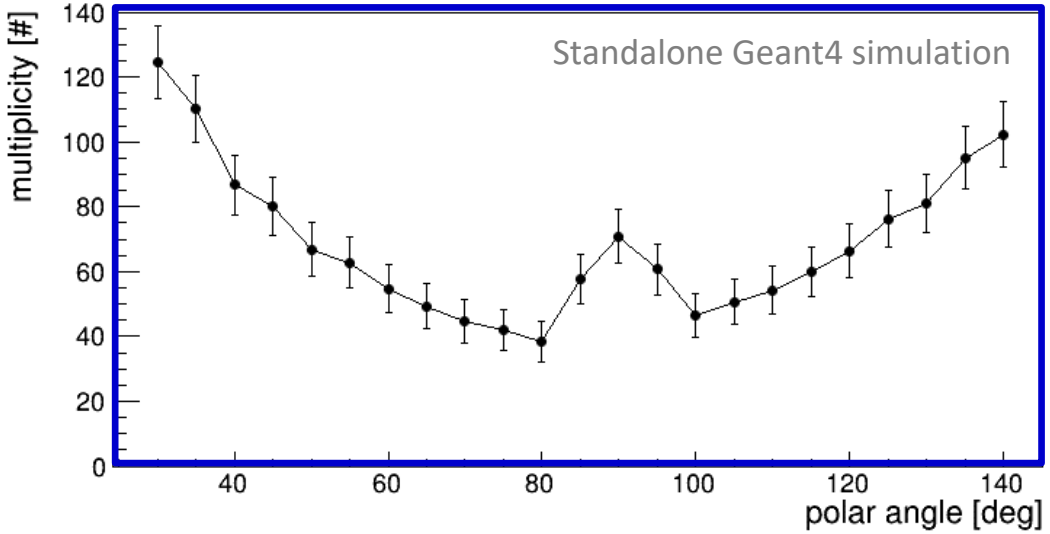
  ASIC-based Electronics (e.g UH/Nalu Scientific, EICROC)
- Several core design aspects, as well as detailed Geant simulation, validated in PANDA Barrel DIRC beam tests (prototype tests in cosmic rays and test beams in preparation)



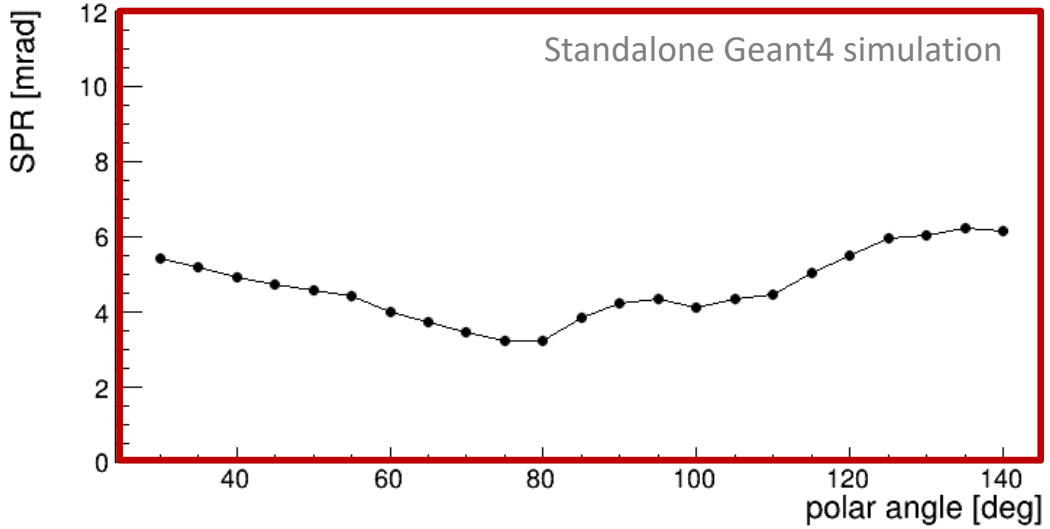



# EXPECTED EPIC HPDIRC PERFORMANCE

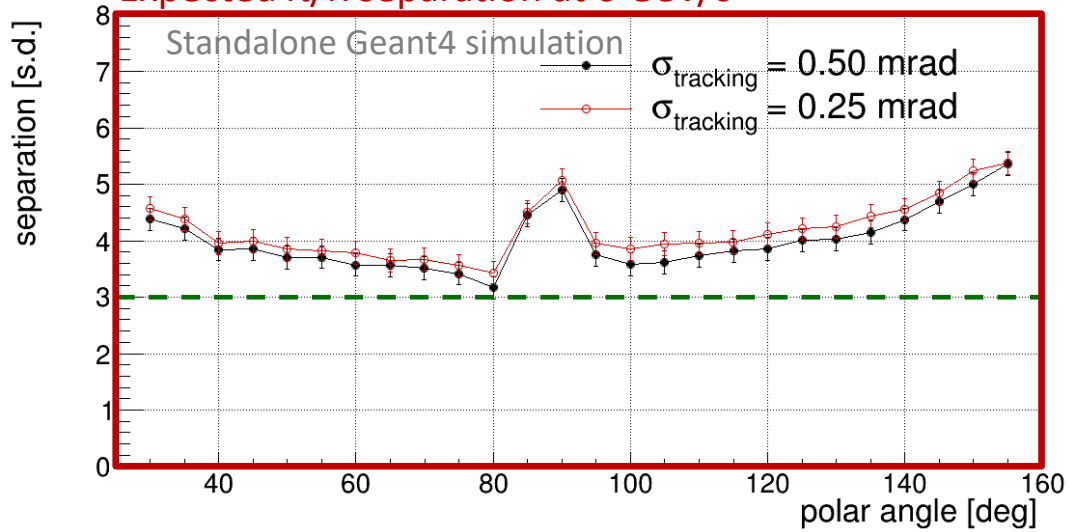
Photon yield per particle



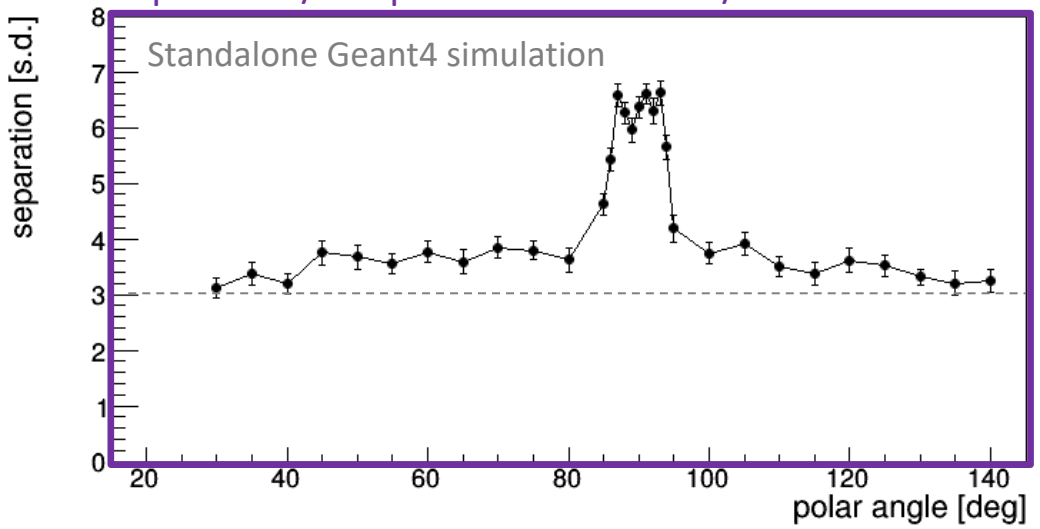

Cherenkov angle resolution per photon (SPR)




Expected π/K separation at 6 GeV/c



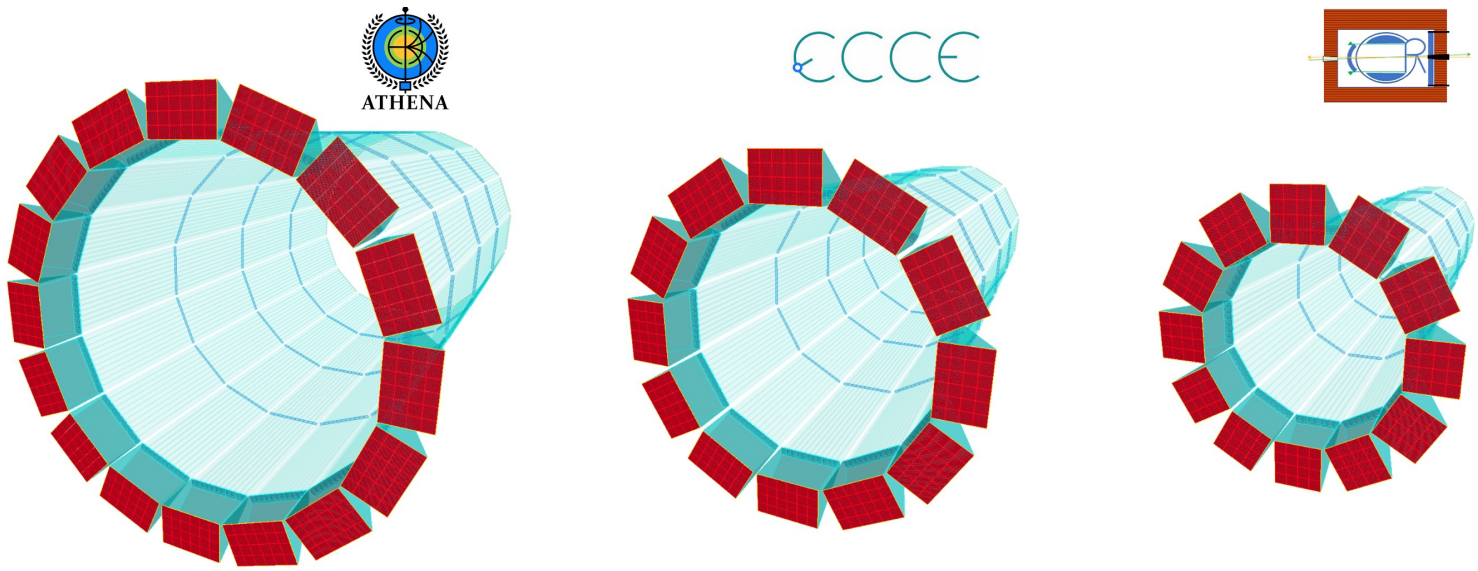

Expected e/π separation at 1.2 GeV/c



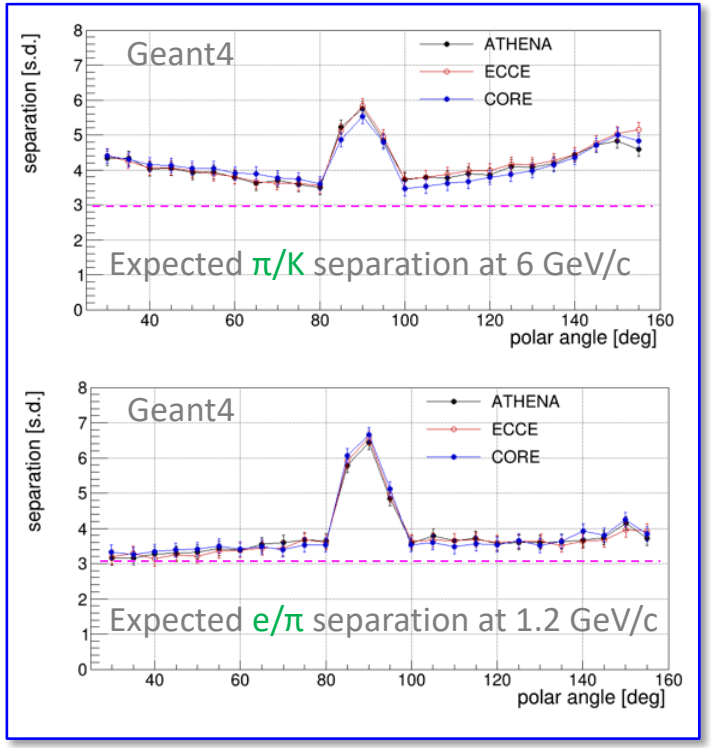

→ expect 3 s.d. separation for π/K up to at least 6 GeV/c and for e/π up to 1.2 GeV/c

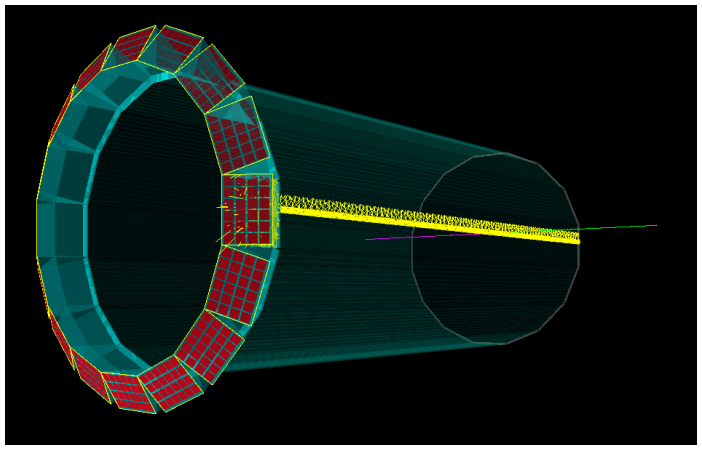
# FLEXIBILITY OF HPDIRC DESIGN

- hpDIRC PID performance largely independent of number of sectors, barrel radius, and bar length – design can be optimized for integration
- Expansion volume shape can be optimized for MCP-PMT magnetic field performance (tilted sensor plane)



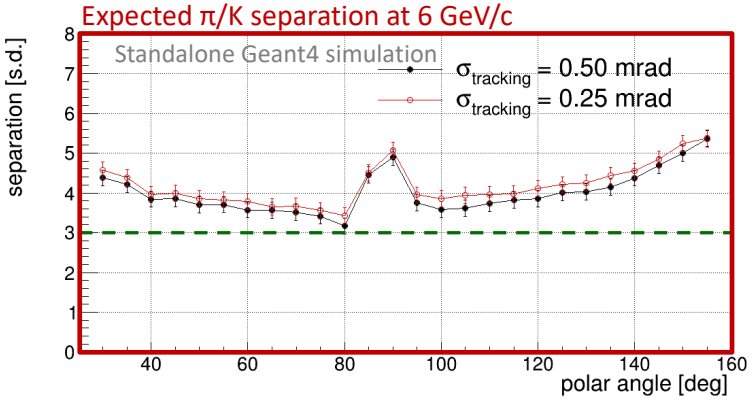

*Geant4: hpDIRC designs to scale*

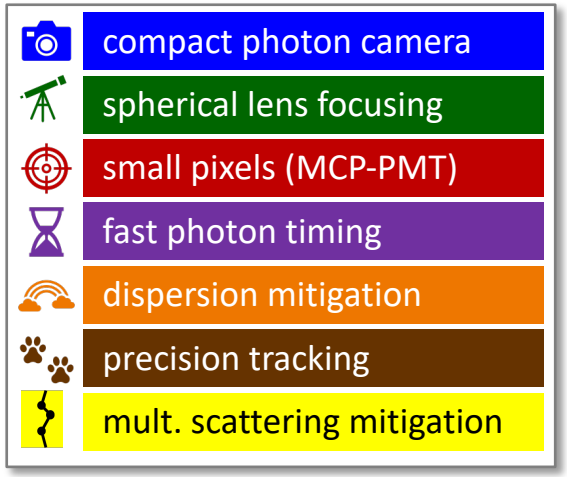


# HPDIRC BEYOND EPIC

- hpDIRC baseline design performance matches requirements for ePIC
- Reuse of BaBar DIRC bars limited some ePIC hpDIRC optics design options
- Several aspects of design and components have potential for improvement
- Performance limits and novel optical designs are explored with Geant simulation in generic R&D program (EICGENRandD12).
- Selectively disable physics processes, evaluate performance
- Isolate impact of detailed performance parameter on separation power
- Started simulation study of fundamental DIRC performance limits due to
  - multiple scattering in bar
  - chromatic dispersion of photon angle and propagation time
  - optical aberrations from focusing system
  - pixel size

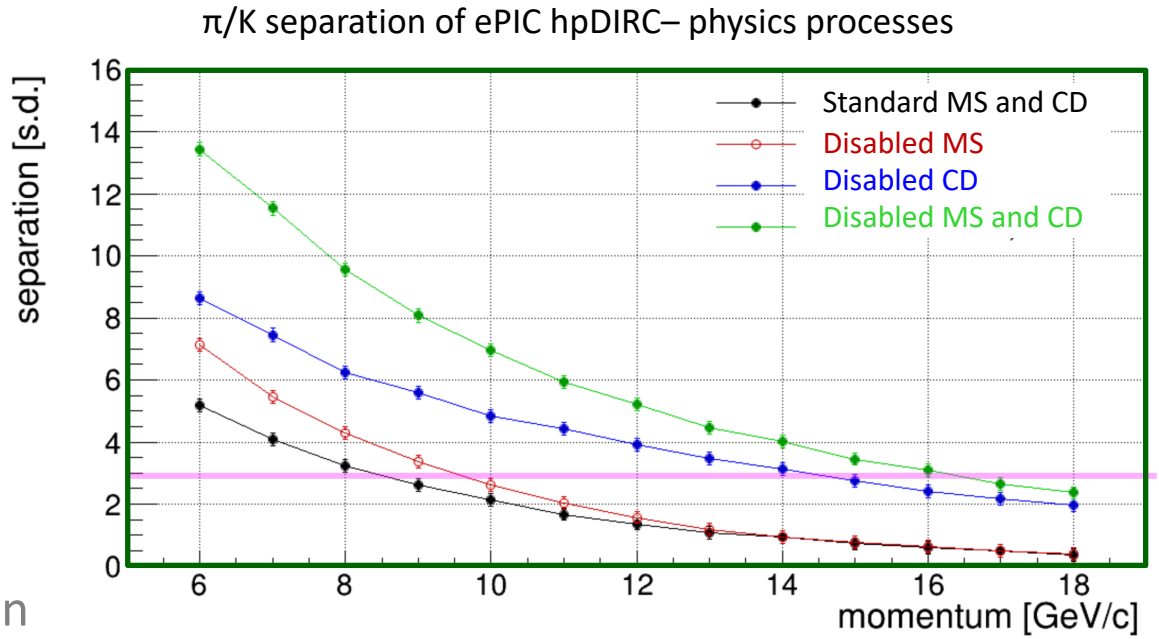


# GENERIC EIC DIRC R&D

## Main effects limiting future DIRC performance

- Loss due to multiple scattering (MS) inside the bar dominates at lower momentum
  → possible mitigation: thinner bar, post-DIRC tracking
- Loss due to chromatic dispersion (CD) of angle and time dominates at higher momentum
  → possible mitigation: limit spectral acceptance
- Significant aberrations from current focusing system design
- Some (limited) gain from decreasing pixel size



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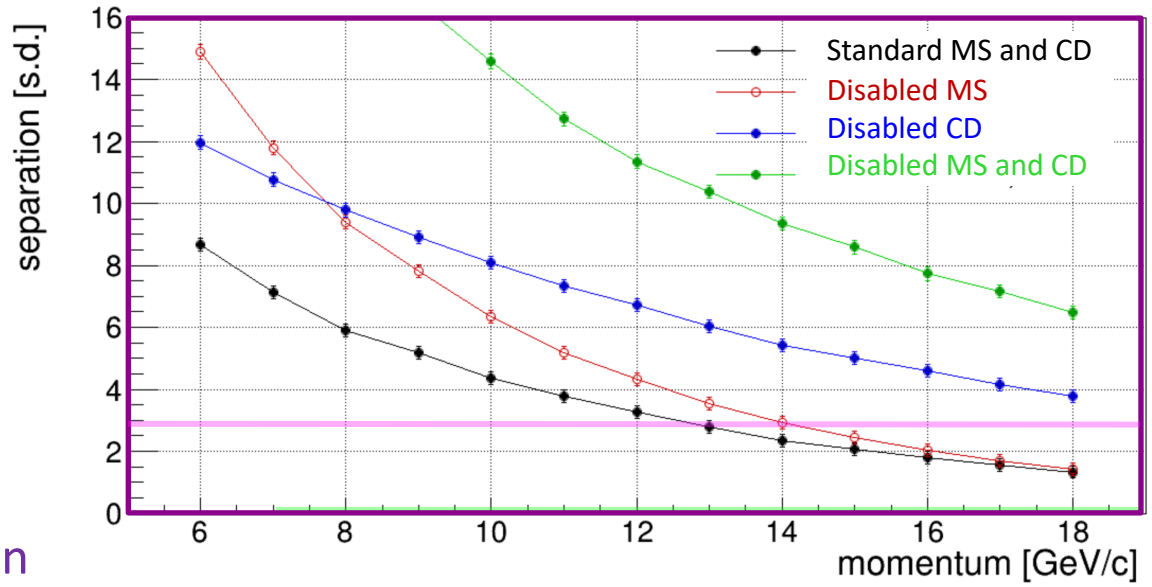
π/K separation of ePIC hpDIRC – with theoretical "ideal focussing"



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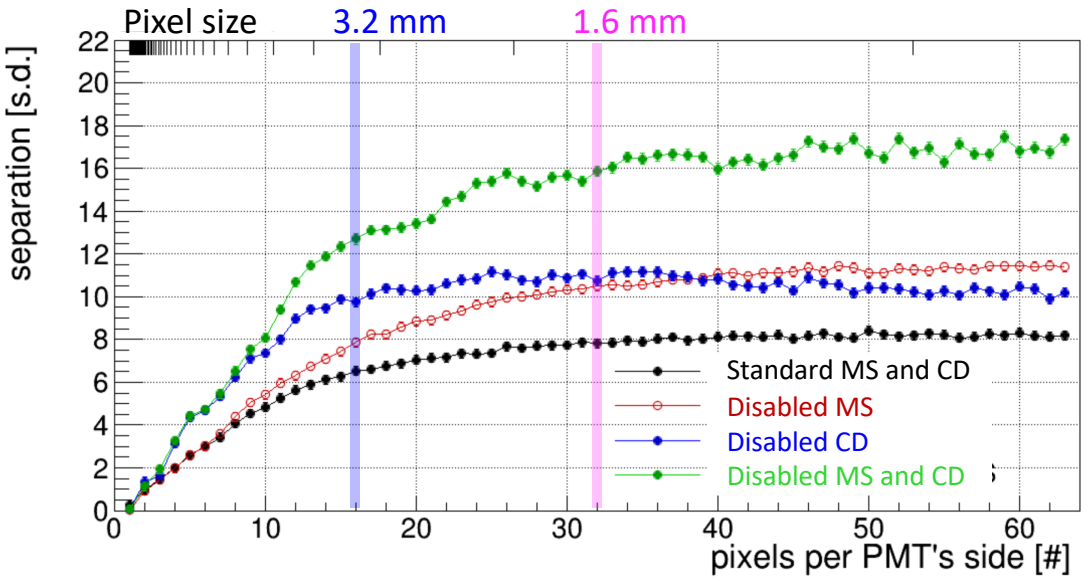
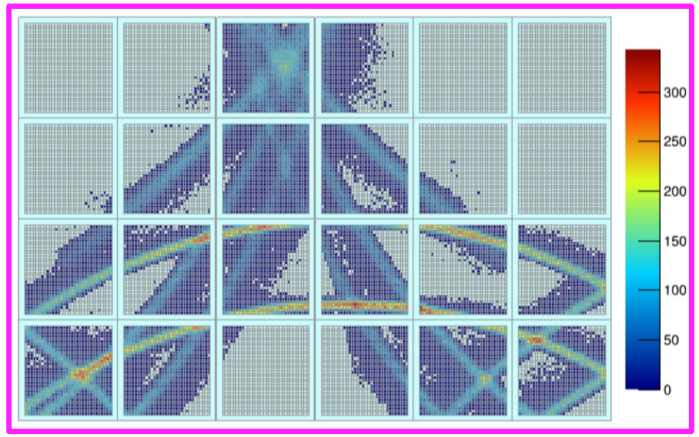
  → possible mitigation: 2-inch MCP-PMTs with 1.6 mm pixel size and small SiPM are already commercially available

π/K separation of ePIC hpDIRC – pixel size effect




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



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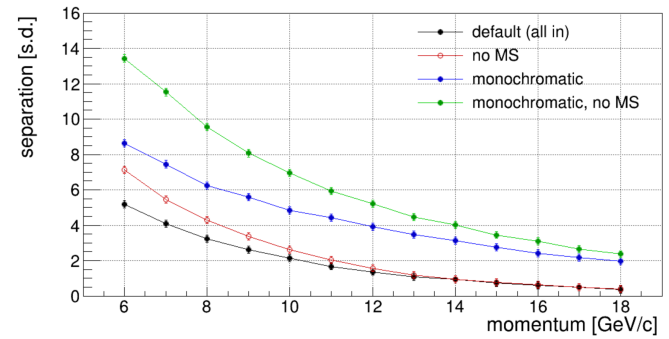
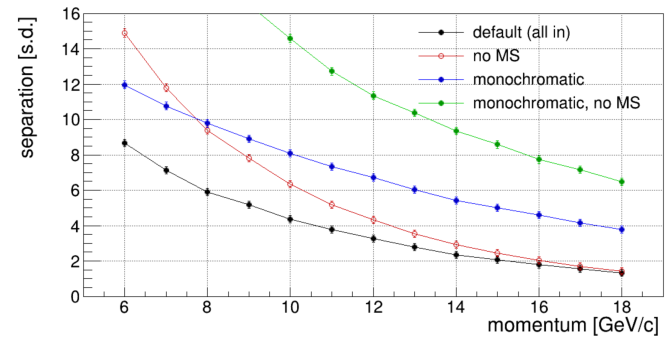
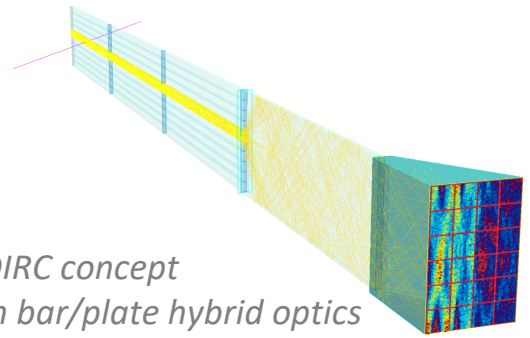


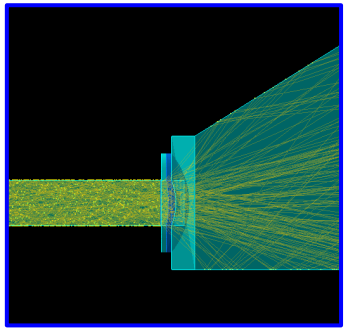



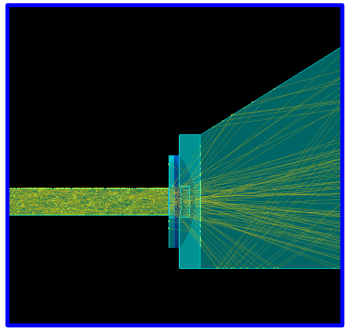
*hpDIRC concept*
*with bar/plate hybrid optics*

## EICGENRandD12 investigates ways to mitigate these performance limits

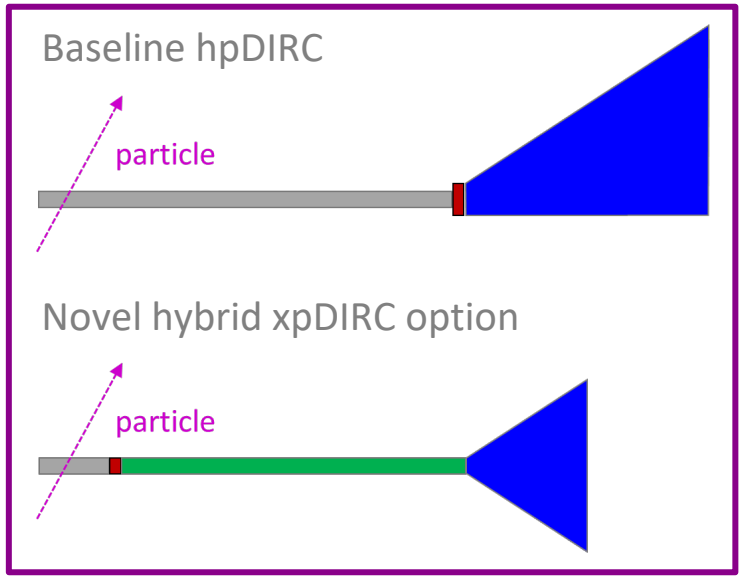
# GENERIC EIC DIRC R&D

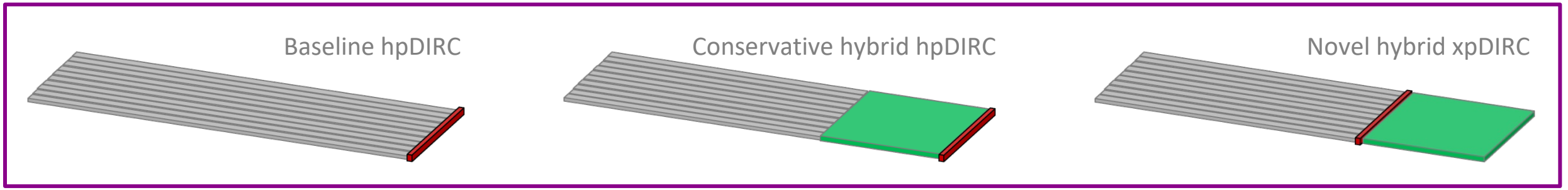
## Examples of EICGENRandD12 geometry studies





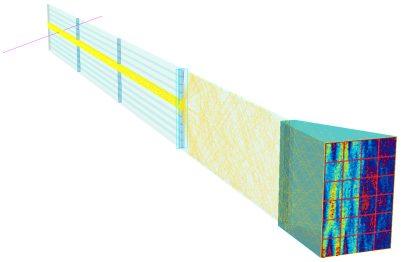
- Thinner bars could mitigate multiple scattering effects in DIRC bars
  - Improve DIRC performance at low momentum, especially for e/π
  - Reduce impact on EMCal performance
  - Make focusing less demanding
- Hybrid optics (narrow bars in active area, wide plates as light guides) could mitigate focusing errors and reduce cost
  - Expansion volume effectively starts at end of narrow bar, improving angular resolution, possible use of cylindrical lens
  - Longer expansion in plate in plate could make shorter prism possible, with smaller sensor area, possibly enabling use of SiPM



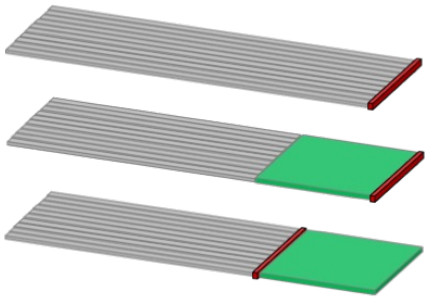



# SUMMARY AND OUTLOOK

- Performance of hpDIRC baseline design good match to ePIC PID requirements
  but planned reuse of BaBar DIRC bars limits some ePIC hpDIRC design options



- Study of effects currently limiting hpDIRC performance revealing
  potential avenues for future R&D
- New Generic DIRC R&D explores innovative optical DIRC configurations
  to create opportunities for cost reduction, performance improvement, and complementarity
  - Narrow bar/wide plate hybrid could improve the performance and save cost



  - Novel hybrid lens configurations may enable designs with more compact prisms, reducing the material budget, potentially making SiPM a viable option for the hpDIRC
  - Thinner bars reduce the DIRC material budget, lowering the impact on the EMCal;
    reduction of multiple scattering inside the bar could improve the DIRC e/$\pi$ separation