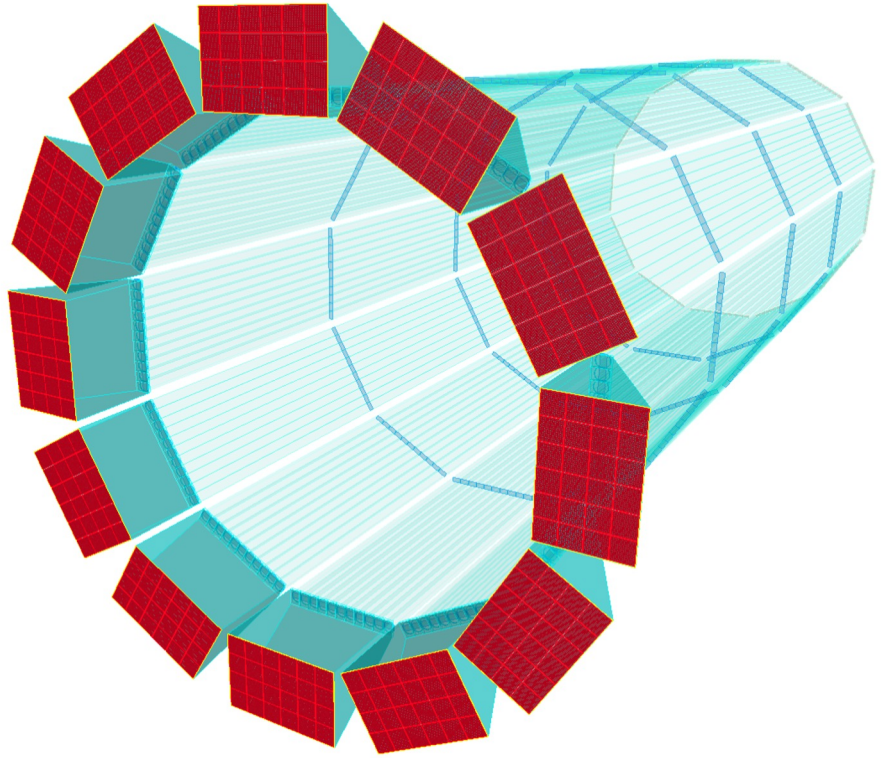
# The hpDIRC Simulation Status



Greg Kalicy

CUA

ePIC Collaboration Meeting

July 15th, 2025

CUA GSI Jefferson Lab Old Dominion Stony Brook University University of South Carolina Wayne State University William & Mary

# HPDIRC SIMULATION

## Stand-alone Geant4 Simulation

- Realistic optics, geometry, and material properties – based on prototypes and experimental data, wavelength-dependent material properties and processes
- Validated with test beam data
- Used for design optimization studies and to test novel design options

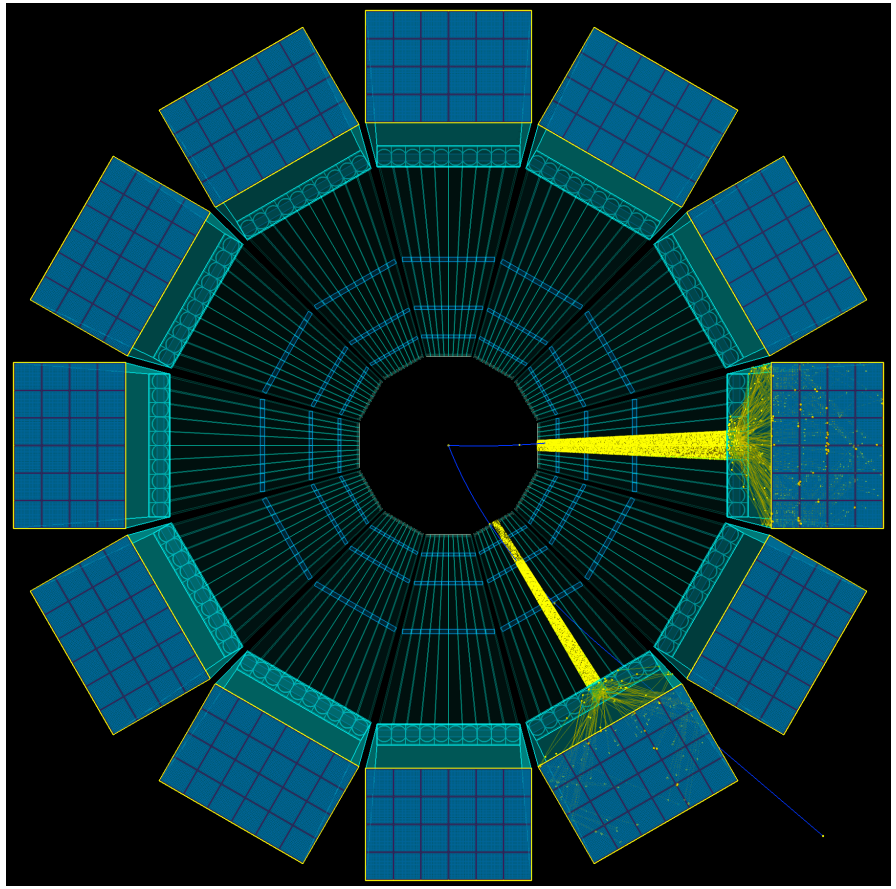
## Full ePIC Simulation:

- Functionality of Stand-alone simulation imported and integrated
- Repeat physics background and detector impact study in the full software stack

## Reconstruction and PID methods:

- Geometrical (BABAR-like), robust and fast method based on Look-Up Tables, delivers Cherenkov angle per particle and Single Photon Resolution (useful for calibration and in prototype tests), does not depend on precise time measurement
- Time Imaging (Belle II TOP-like), uses Probability Density Functions (analytical or simulation-based), makes optimum use of precision of position and time information
- Machine Learning based – in preparation, using Foundation Model

*Pythia events in hpDIRC simulation*



# HPDIRC SIMULATION

Roman Dzhygadlo (GSI)
Bill Llope (WSU)

## Recent hpDIRC related studies:

- Confirmed robust performance in magnetic field, using physics events (Pythia) to include backgrounds, multiple tracks per bar (WSU)
- Adopting hpDIRC reconstruction methods into full ePIC Simulation Stack (WSU)
- Performance with latest ePIC angular track resolution maps (GSI)
  → High-precision angular resolution crucial for reaching required hpDIRC performance.
- Verifying optimal sensor coverage (CUA, GSI)
- Study of the impact of bar imperfections on the hpDIRC performance relevant for the BaBar bar refurbishment (GSI)
- Impact of bar/lens misalignments on performance (Jazan)
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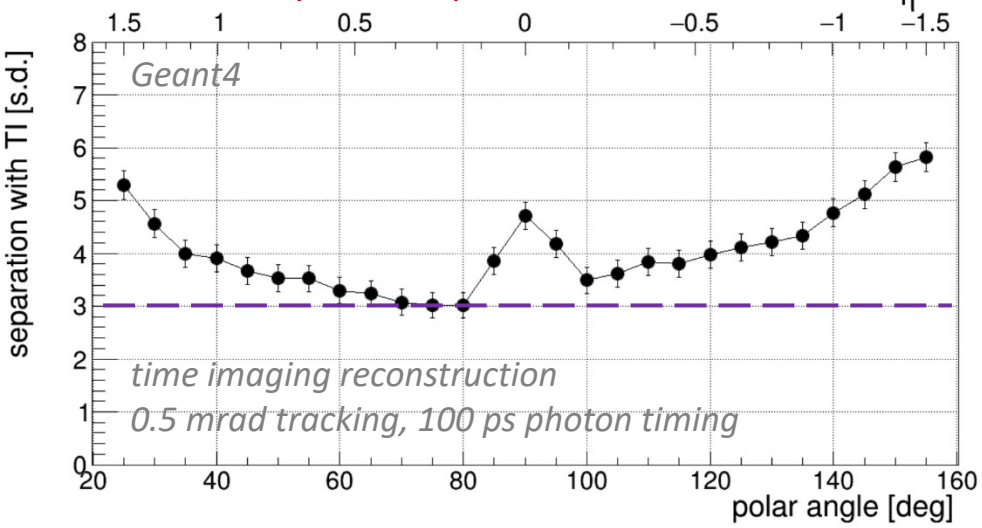
- Preparation for hpDIRC full chain test setup operation at CRT (SBU, GSI, ODU)

π/K separation power at 6 GeV/c




Simulation studies performed with

- Stand-alone Geant4 simulation
- Single particles from particle gun
- 1.7T magnetic field, no other ePIC subsystems
- 0.5 mrad tracking resolution
- 100ps time resolution

→ Performance requirements reached: ≥ 3 s.d. π/K separation at 6 GeV/c for all angles

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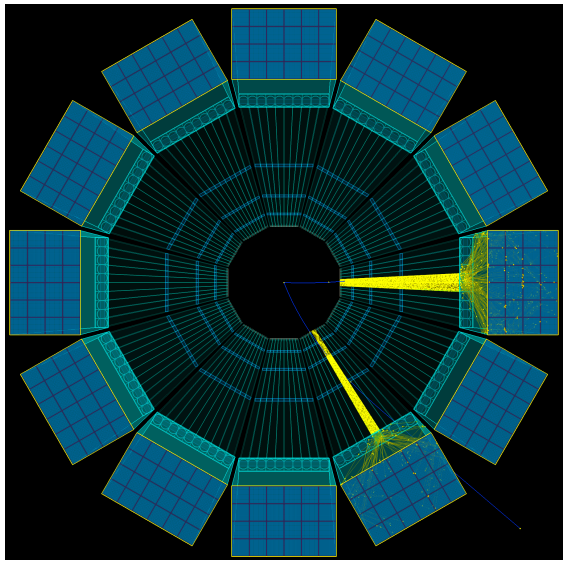
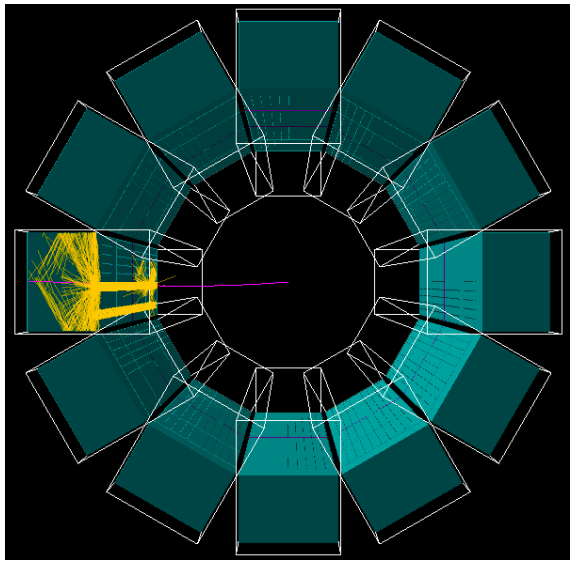
Bill Llope (WSU)

*hpDIRC in stand-alone and ePIC simulation*





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Roman Dzhygadlo (GSI)
Matt Posik (TU)

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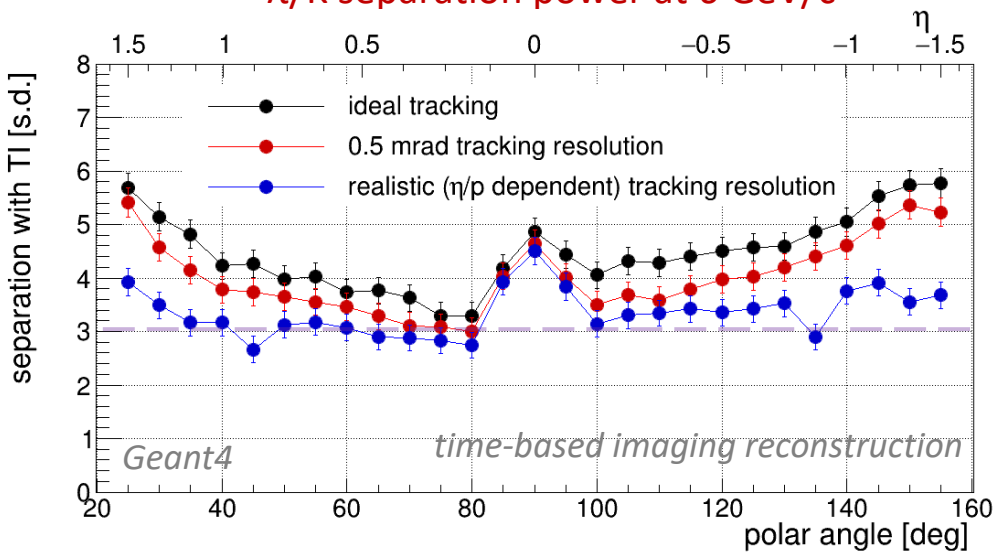

# HPDIRC SIMULATION

Roman Dzhygadlo (GSI)
Imran Hossain (CUA)
Kris Cleveland (JLab)

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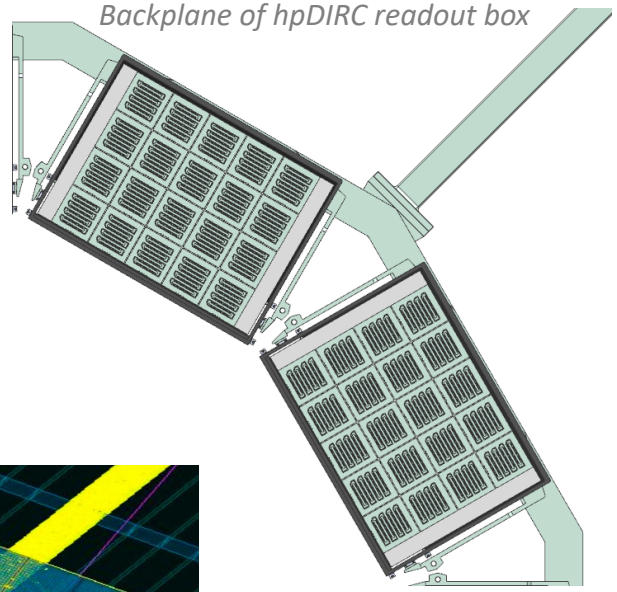
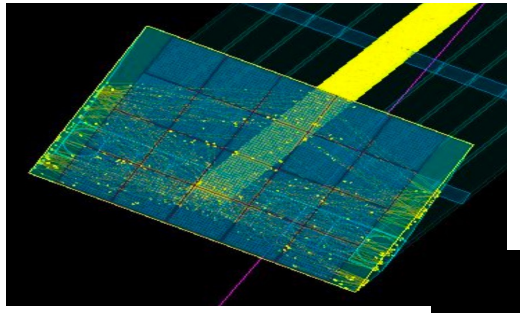
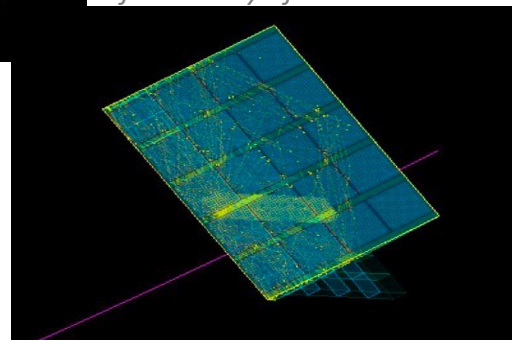


*Backplane of hpDIRC readout box*





*Two arrangements of 5x4 array of sensors*

# HPDIRC SIMULATION

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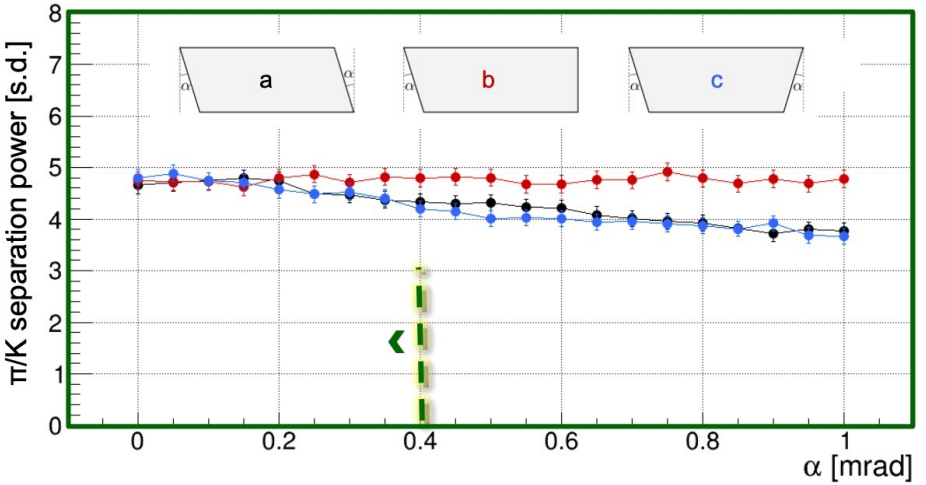
Example: π/K separation power
for 30° polar angle at 6 GeV/c momentum



# HPDIRC SIMULATION

Afaf Wasili (Jazan)

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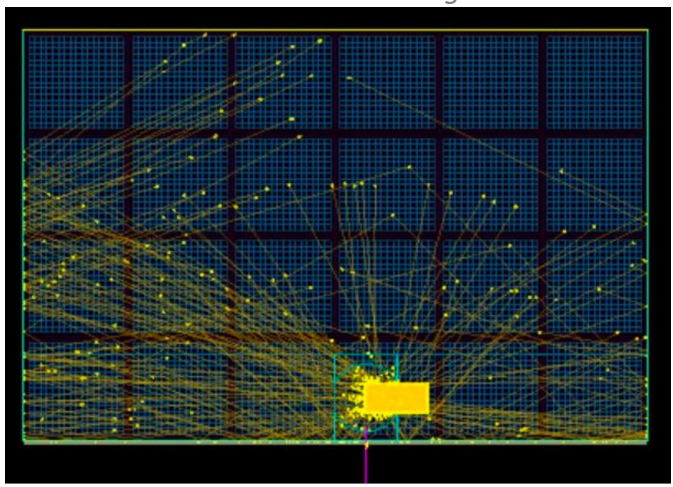
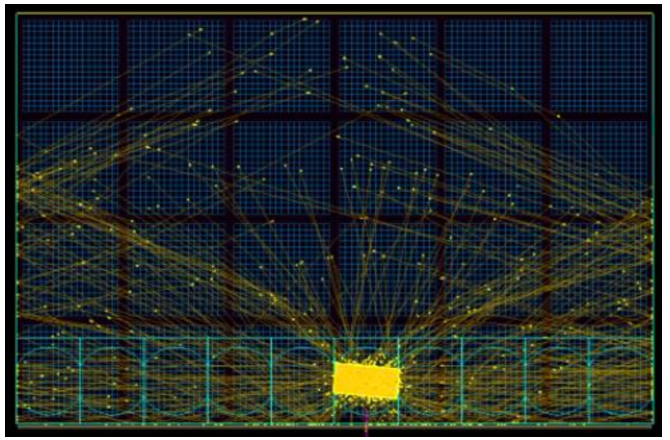
*Horizontal bar misalignment*



*Bar rotation*



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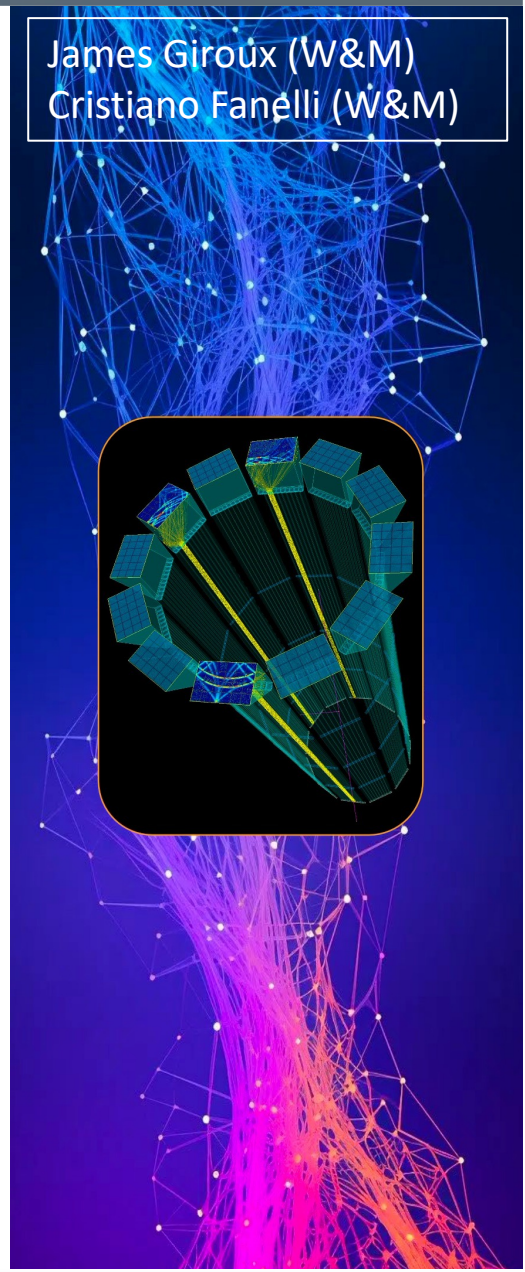
James Giroux (W&M)
Cristiano Fanelli (W&M)



# HPDIRC SIMULATION

Nathan Shankman (SBU)
Jaydeep Datta (SBU)
Carlos Ayerbe Gayoso (ODU)

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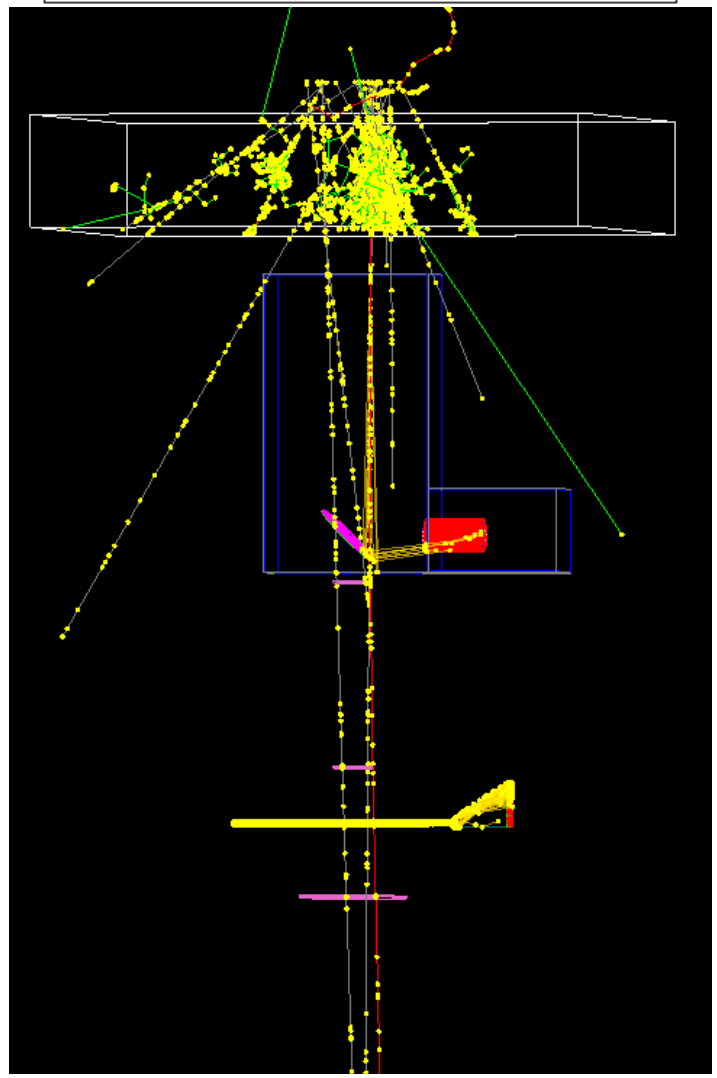
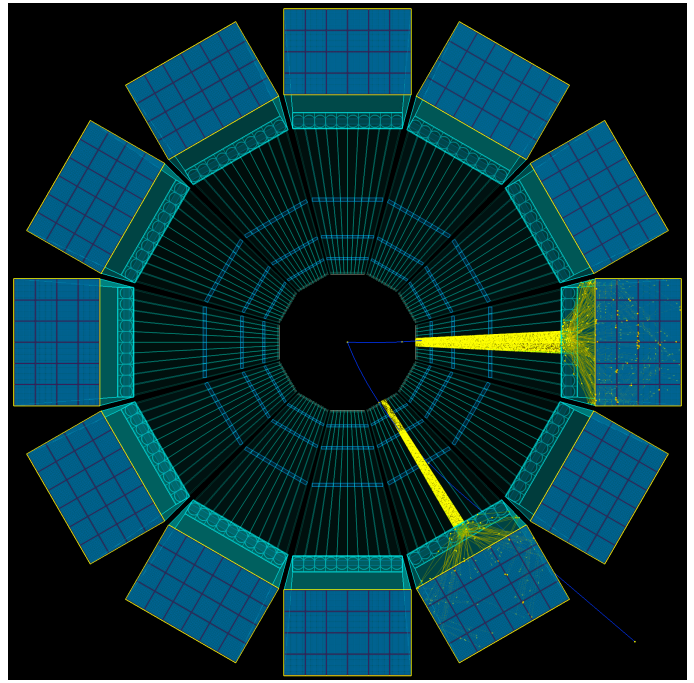
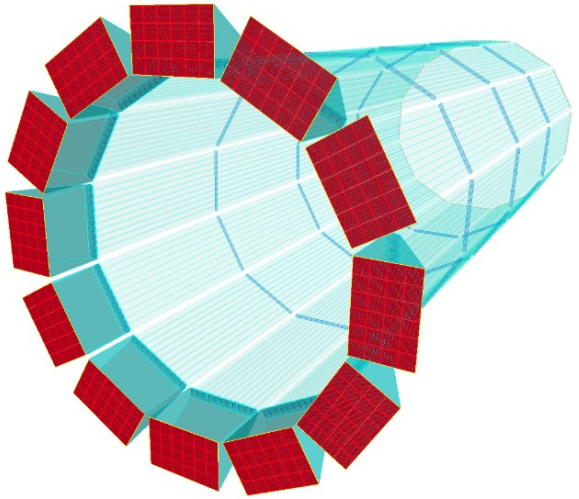


# SUMMARY

- Stand-alone hpDIRC simulation, validated in particle beams in 2018, still essential for many studies
- Important progres in understanding realistic tracking resolution and its impact on hpDIRC performnce
- Effort on finishing integrstion of hpDIRC into the ePIC simulation software restarted





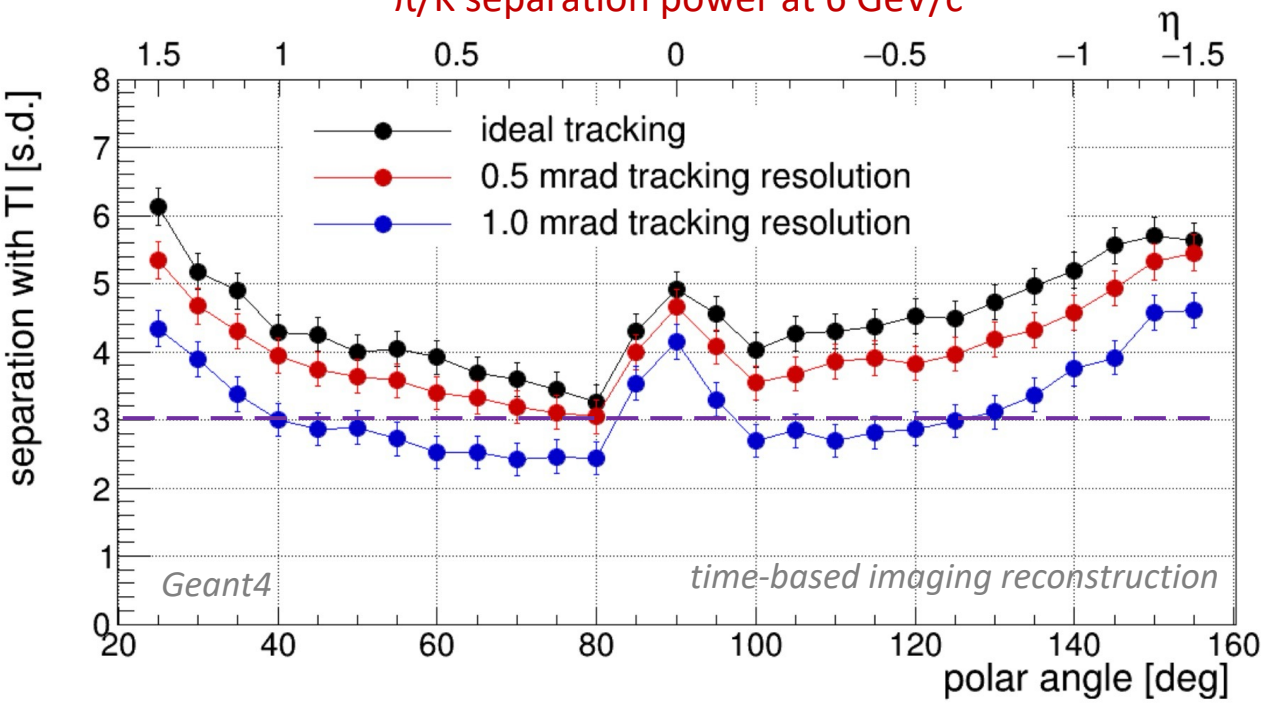
# EXPECTED HPDIRC PERFORMANCE VS. TRACKING

Impact of tracking angular resolution on hpDIRC performance

- π/K Cherenkov angle difference at 6 GeV/c: $\Delta\Theta_c \approx 3$ mrad
- Yellow Report tracking requirement: 0.5 mrad resolution at 6 GeV/c

→ High-precision angular resolution crucial for reaching required hpDIRC performance.

π/K separation power at 6 GeV/c




Simulation studies performed with

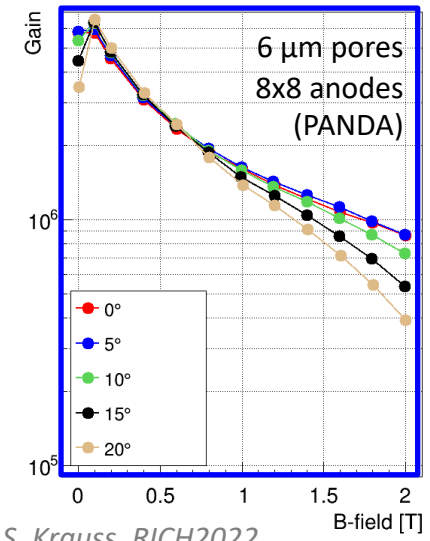
- Stand-alone Geant4 simulation
- Single particles from particle gun
- 6 GeV/c momentum
- 1.7T magnetic field, no other ePIC subsystems
- 100ps time resolution

# PHOTOSENSORS

## hpDIRC sensor requirements

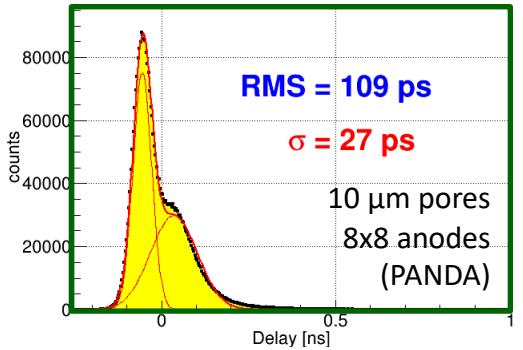
- Single photon sensitivity in ePIC magnetic field: $10^6$ gain at ~ 1T
- Fast timing for single photons: timing precision (rms) < 100 ps
- Large active area ratio for tiled sensors: goal > 75%
- High PDE in visible range: goal > 25% at 400 nm
- Small pixels: anode pixel size < 3.5 mm
- Tolerance for high photon rates: goal > 0.5 MHz/cm$^2$
- Tolerance for high occupancies: up to 200+ photoelectrons per particle, need DC-coupled anodes
- Long lifetime: goal > 10 C/cm$^2$

Photek MAPMT 253




*S. Krauss, RICH2022*

PHOTONIS XP85012-S




Expected number of photoelectrons per particle per 12 cm x 12 cm sensor