MPGDs in Tracking

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Overview

- Studies

    1. Impact of MPGDs on track reconstruction

        - Tracking Working Group Meeting: May 21st , June 11th

    2. Impact of Outer Barrel MPGD on angular resolutions

        - Pre-TDR (Overleaf Version)

        - MPGD Tracking Slides (MPGD Review, December 15th , 2025)

- Ongoing/Future Work

MPGD Impact on Tracking Performance

❖ **Goal**: By scanning MPGD resolutions determine if MPGDs improve tracking through precision, geometry, or pattern recognition? **Note: simulated MPGD resolutions of $10\mu m$ and $50\mu m$ are not realistic in ePIC environment but included for studying resolution dependent trends.**

❑ Software Versions:

- epic: 26.04.1 ($10\mu m$ gold beam pipe coating)
- EICrecon: 1.34.0

❑ Simulation Files:

- 10k events
- Full background + 1 DIS (NC -- forced) signal per $2\mu s$ time window
- Energy: $10\ \text{GeV} \times 275\ \text{GeV}$
- $Q^2 \geq 1GeV^2$

❑ Detector Configuration:

- epic_Craterlake.xml

Table: Rates taken from simulation git page

Source	f [kHz]
DIS	1/event
synrad	13,277,000
e-Brems (10,000 Ahr)	3177.25
e-Coulomb (10,000 Ahr)	29.56
e-Touschek (10,000 Ahr)	233.5
Proton Beam Gas	32.60

Cuts and Definitions

Truth info from MC

All primary signal particles

Tracking surfaces >= 3

Vertex: $R < 1\text{mm}, |Z| < 100\text{mm}$

Good signal particles

Reconstructed Tracks

Tracks

nMeasurements ≥ 4

Valid tracks

>2 hits and 50% of hits from good signal particle → If not, **ghost track**

Good tracks

Is the particle of primary source of hits from DIS? → If not, **good background track**

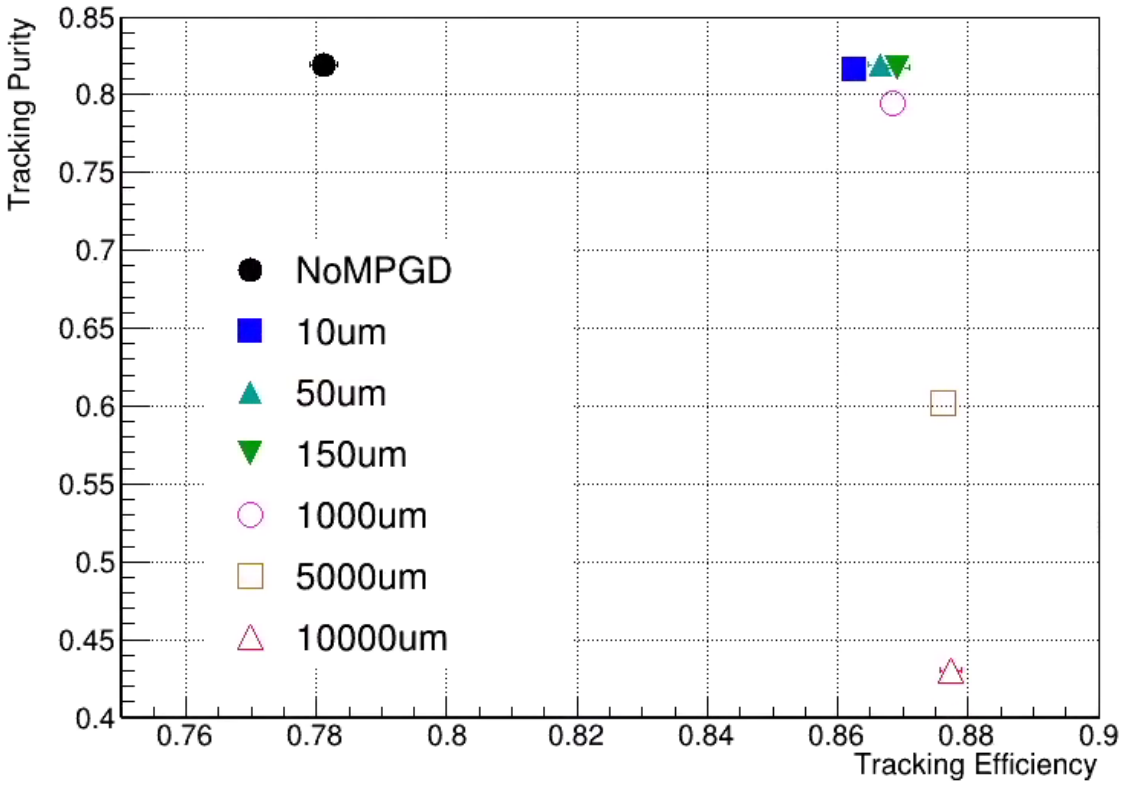
Good signal tracks

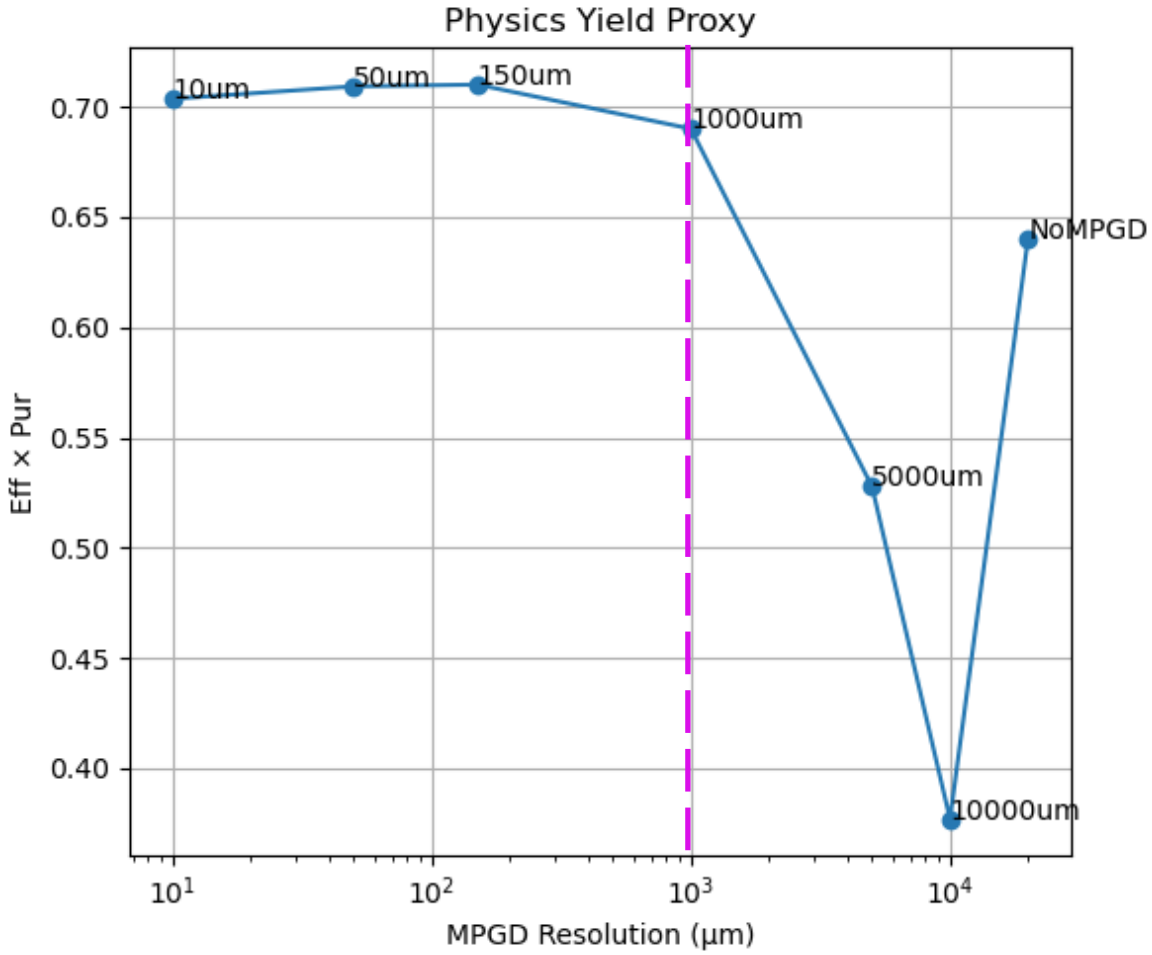
Tracking efficiency: (Good signal particles w/ good track) / (Good signal particles)

Tracking purity: (Good signal tracks) / (Valid tracks)

Efficiency and Purity

- MPGD presence with modest resolution improves efficiency
- Track-hit association quality degrades for MPGD resolutions above ~1 mm.

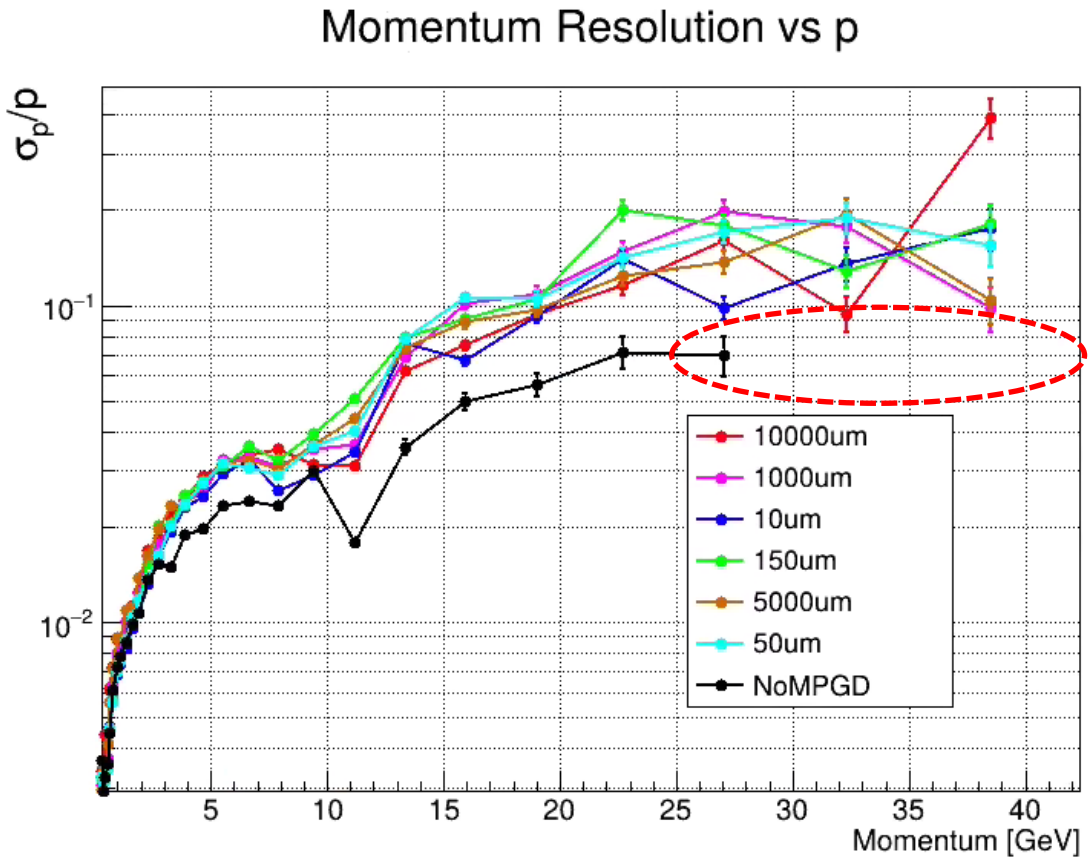


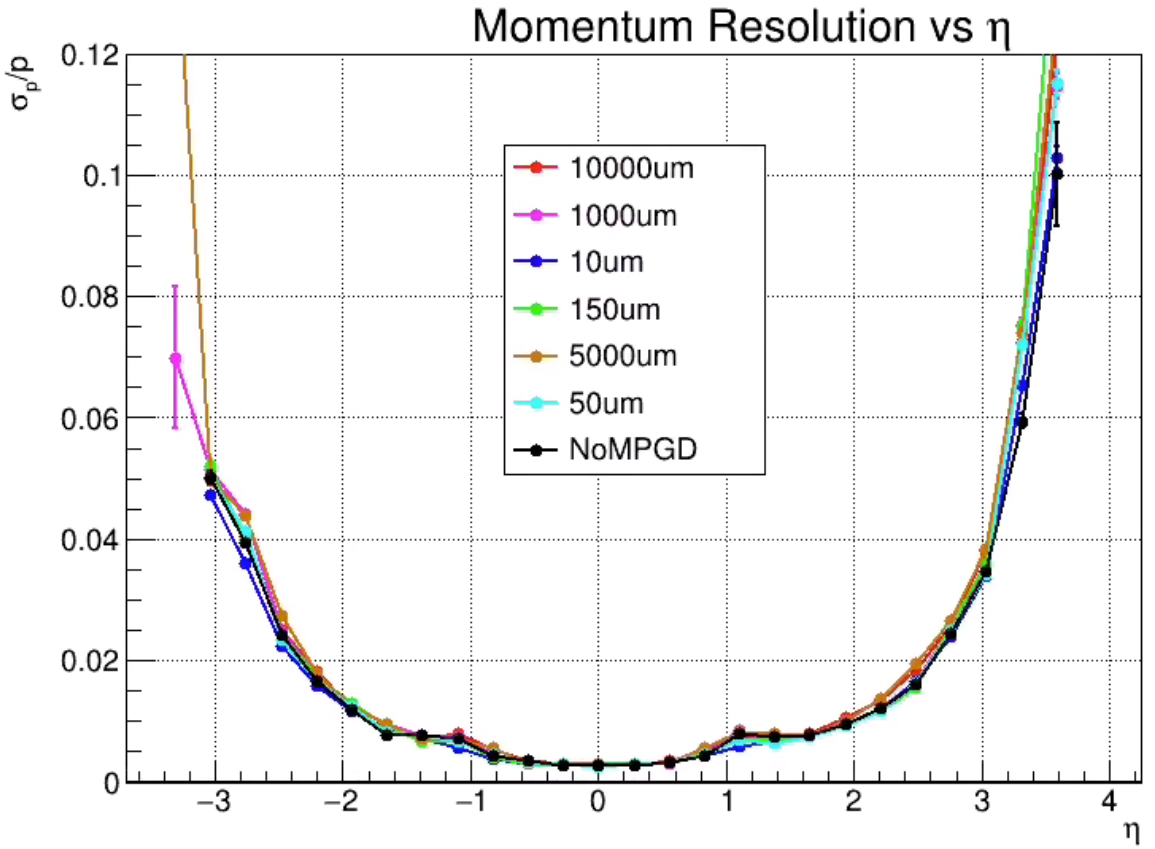


➢ Optimal performance with MPGD resolution below 1 mm

Momentum Resolution vs Momentum

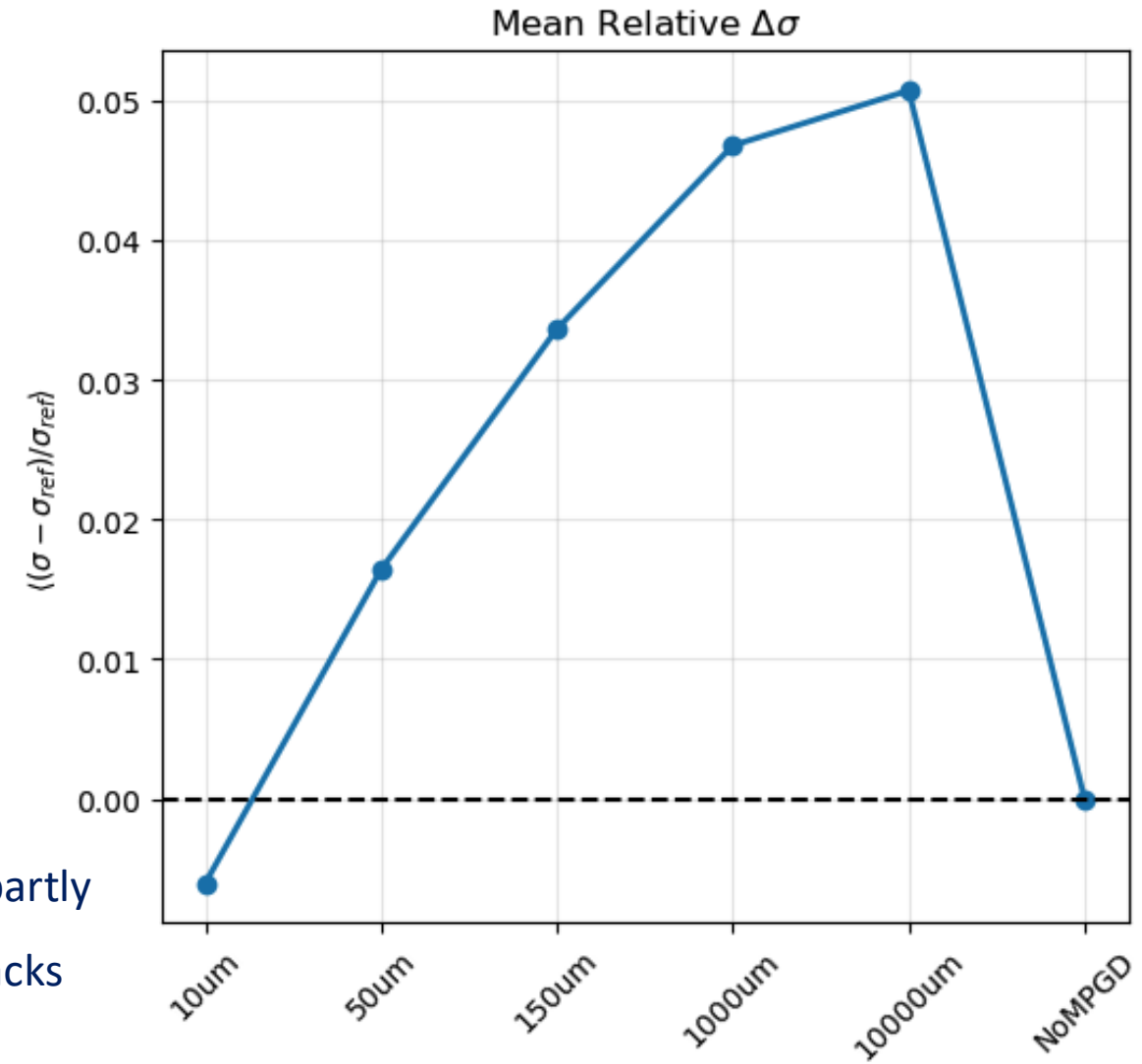
- Tracking precision is dominated by the silicon trackers ($\sigma_{Si} \approx 5\ \mu m$)
- MPGDs allow for reconstruction of higher momentum tracks
- Momentum resolution generally degrades as momentum increases wrt the No MPGD configuration





Mean Relative Momentum Resolution Difference

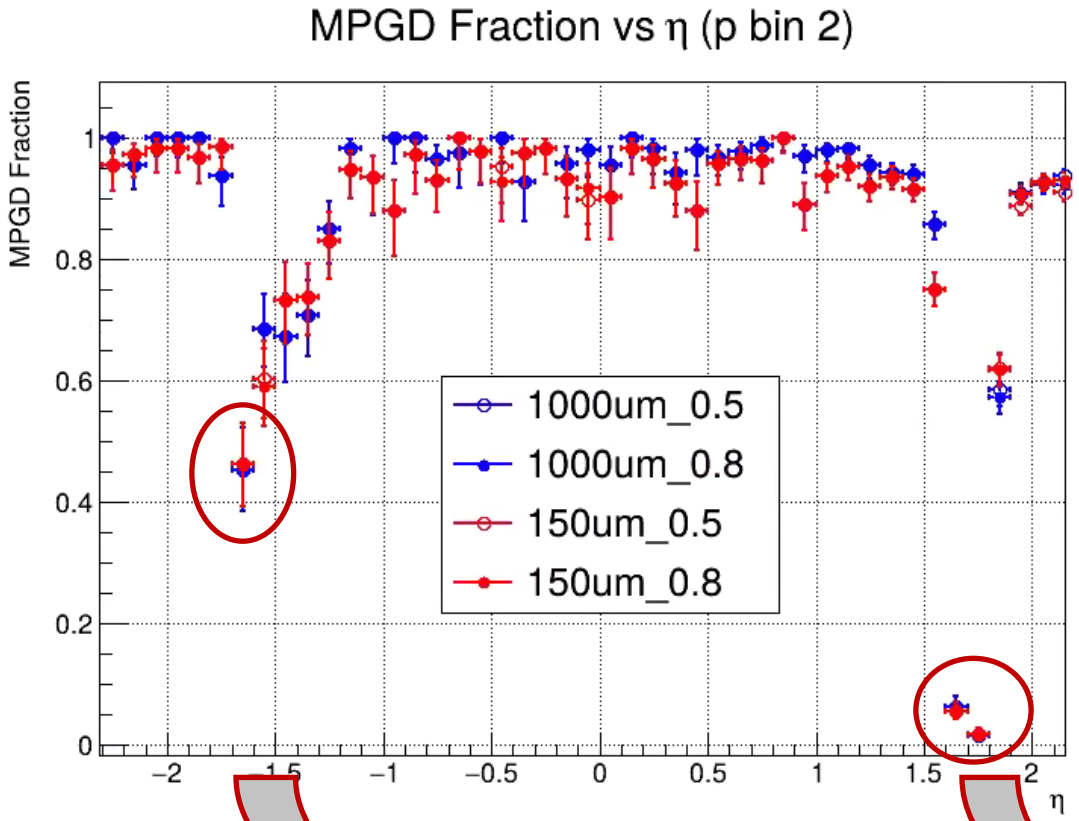
- Improved MPGD resolution reduces the impact of lower-precision MPGD hits on the fitted momentum resolution.
- Silicon tracker provides very precise hit information ($\sim 5\ \mu m$)
- MPGDs provide lower-precision measurements than silicon and therefore modestly degrade the momentum-resolution core while extending the reconstructable phase space.

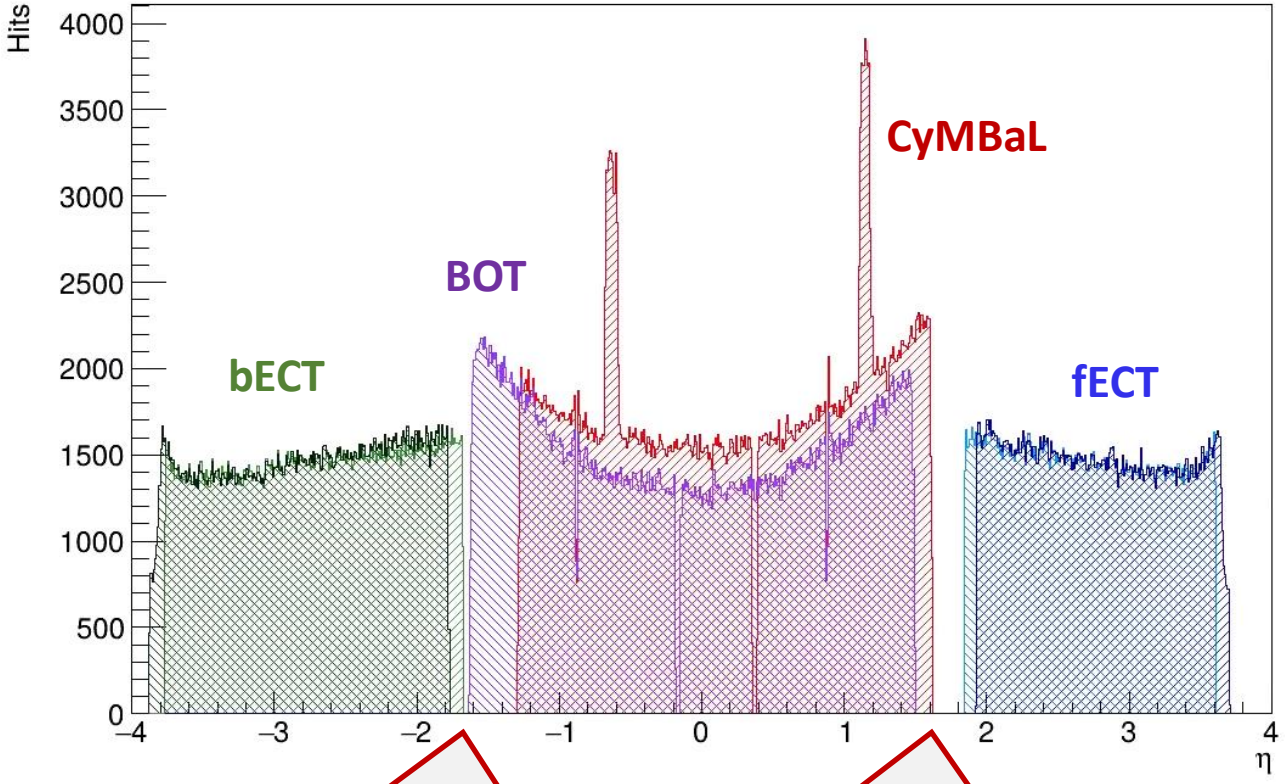


➢ The apparent degradation in average momentum resolution partly reflects the inclusion of higher-momentum and higher-|η| tracks that are not reconstructable without MPGDs.

MPGD Acceptance Holes

MPGD Fraction = #Good reconstructed tracks with MPGD hit / #Good reconstructed tracks



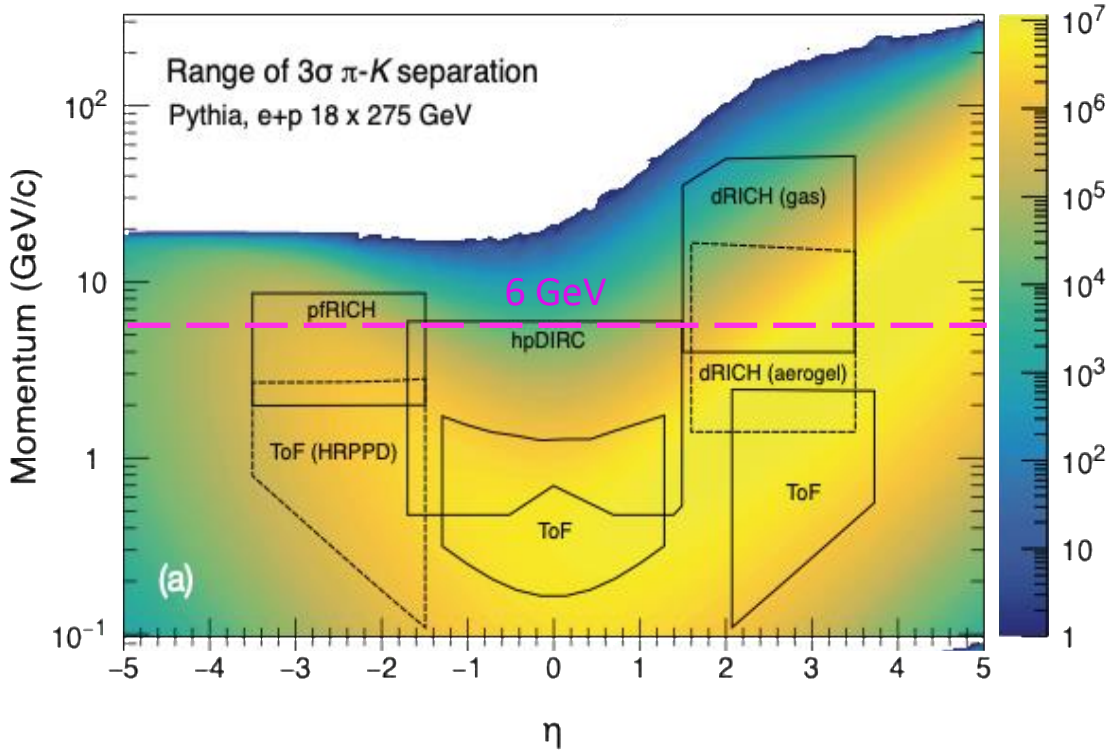


Study Summary

- Impact of MPGDs on tracking performance in background was assessed
- Large fraction of reconstructed tracks (> 90%) contain at least one MPGD hit
- MPGD performance gains are concentrated at high momentum and large pseudorapidity, where MPGDs significantly extend the reconstructable tracking phase space.
- There is a resolution threshold of ~1 mm above which MPGD hit-association quality and overall tracking performance begin to degrade.
- MPGDs primarily improve tracking through pattern recognition and acceptance extension rather than intrinsic momentum precision.
- Sharp drop in MPGD track hit efficiency is due to MPGD acceptance holes ($\sim 1.6 < |\eta| < 1.8$)

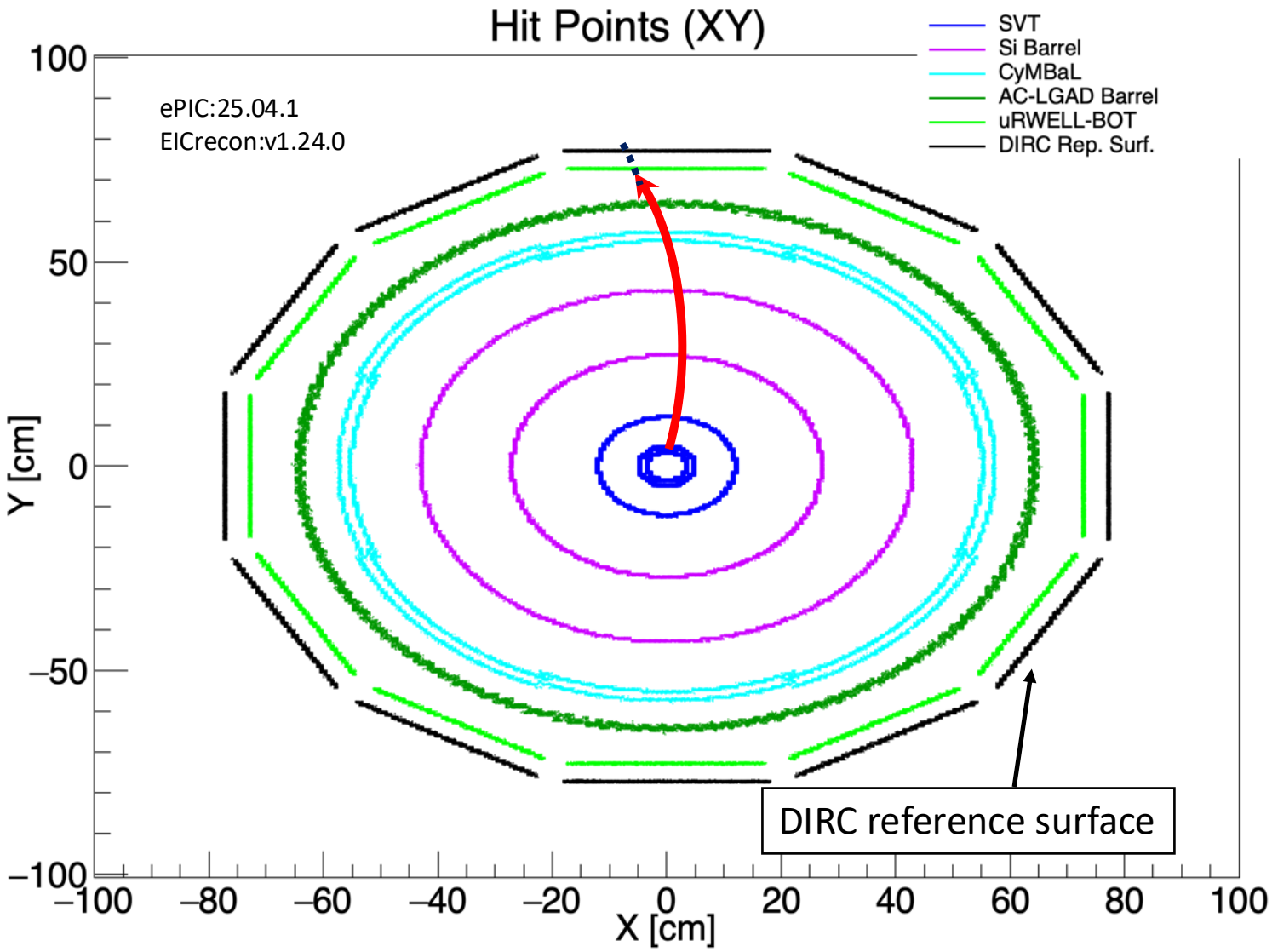
Pushing hpDIRC Performance

- Majority of hadrons in DIRC acceptance are around ~ 1GeV
  - Hadron yield drops quickly with increasing momentum
- Extending the DIRC PID performance out to a momentum of 6 GeV requires excellent angular resolution from tracking
  - ~0.5 mrad at p = 6GeV
  - The µRWell-BOT can help



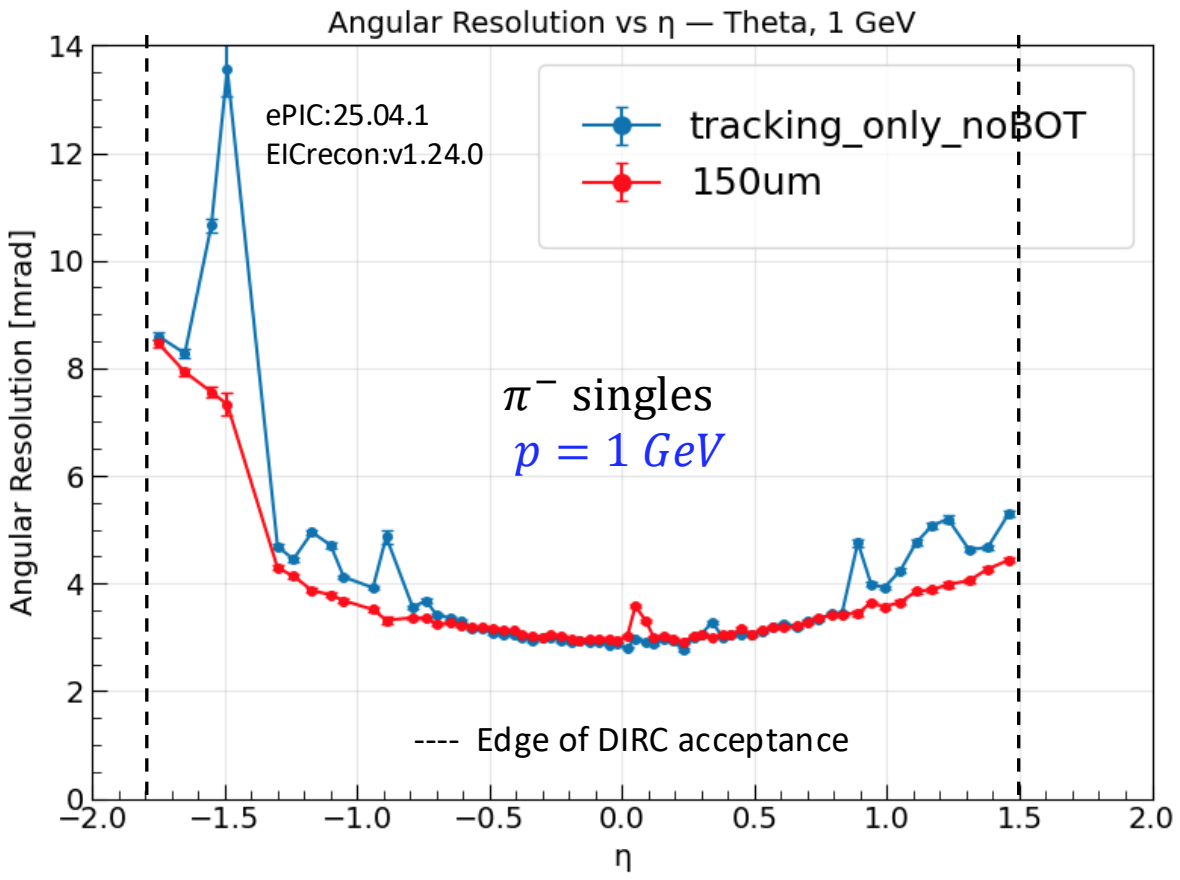
Angular Resolutions at hpDIRC

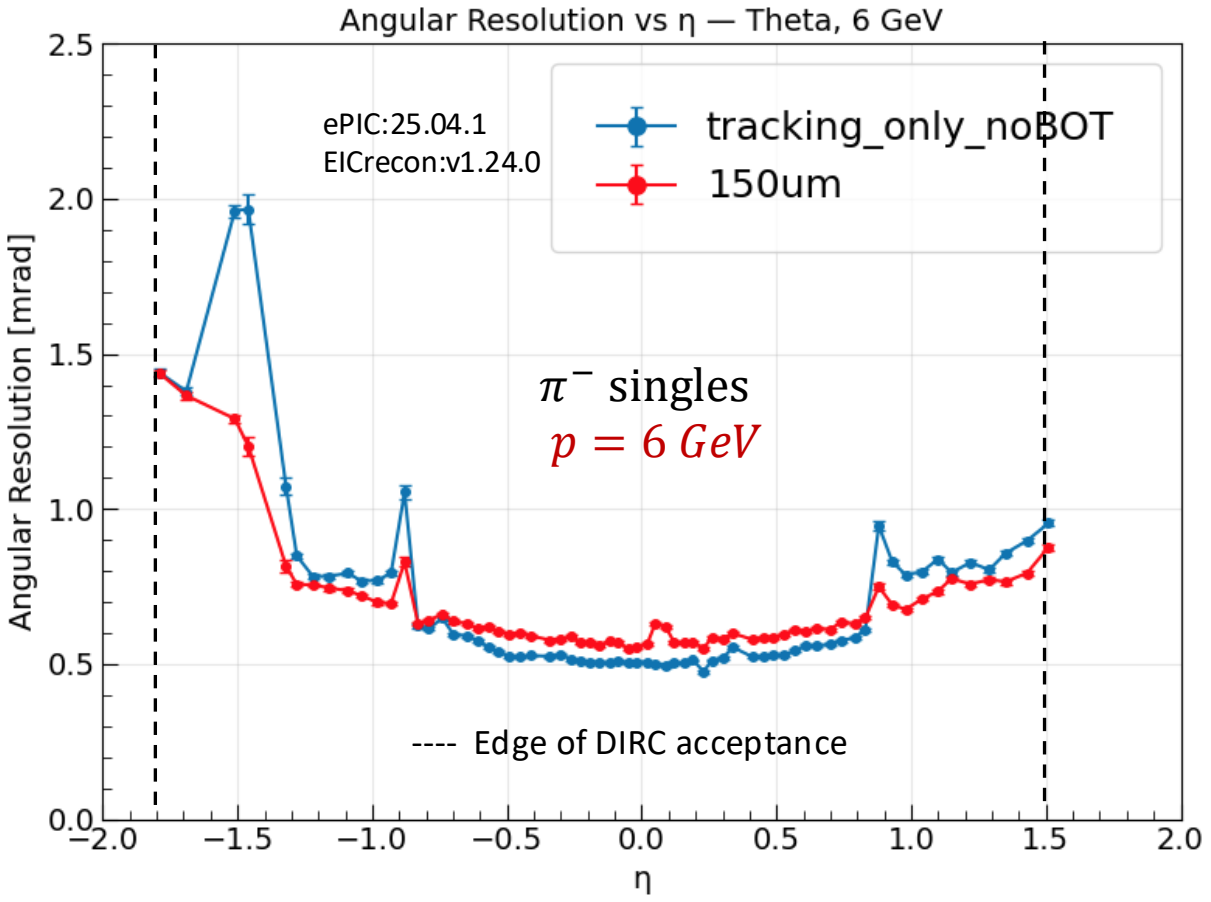
- Momentum vector information accessed via track propagation to desired target surface (e.g. hpDIRC)
  - Reference surface provides true momentum vector via SimHit
  - ACTS target surface provides reconstructed momentum vector via trajectory propagation
- Simulation Details
  - Constant MPGD spatial resolution of $150\mu m$
  - π^- singles



θ (Polar) Resolutions at hpDIRC

- Impact of μRWELL-BOT seen at $|\eta| > \approx 0.8$
  - Improvement seen particularly at areas where there is a larger amount of material and transition regions

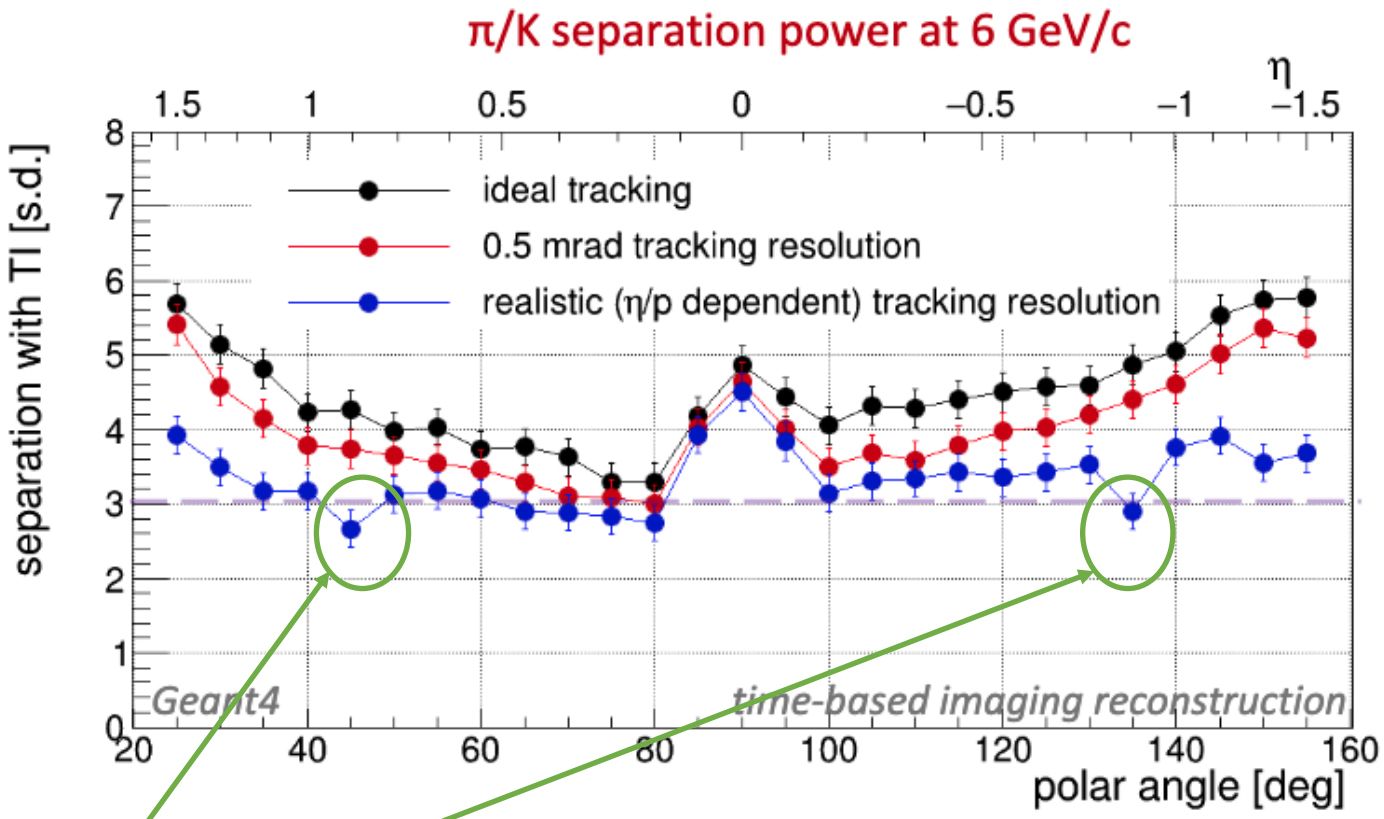




Angular Resolutions at hpDIRC: 6 GeV

ePIC Collab. Meeting June 2025

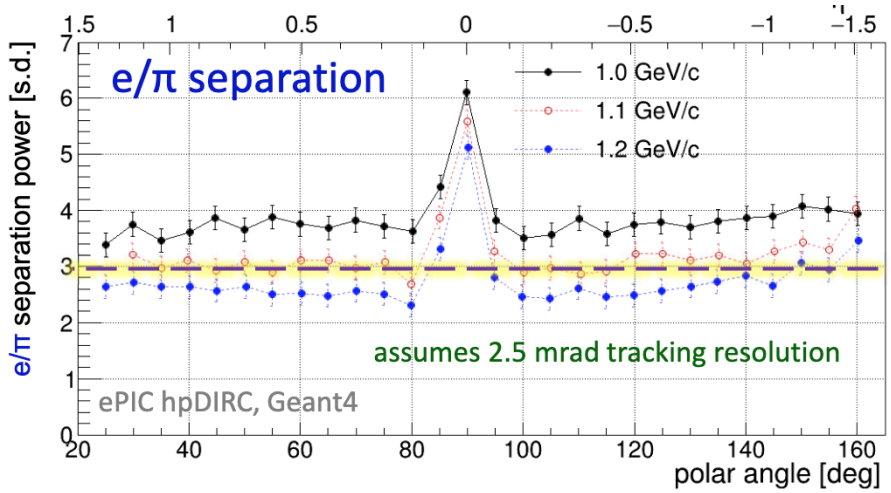
- ePIC simulation was used to map the angular resolutions as a function of momentum and η
- Resolution maps were used in stand alone hpDIRC Geant4 simulation to assess PID separation power
- π/K separation is near 3 s.d. for most polar angels at p = 6GeV

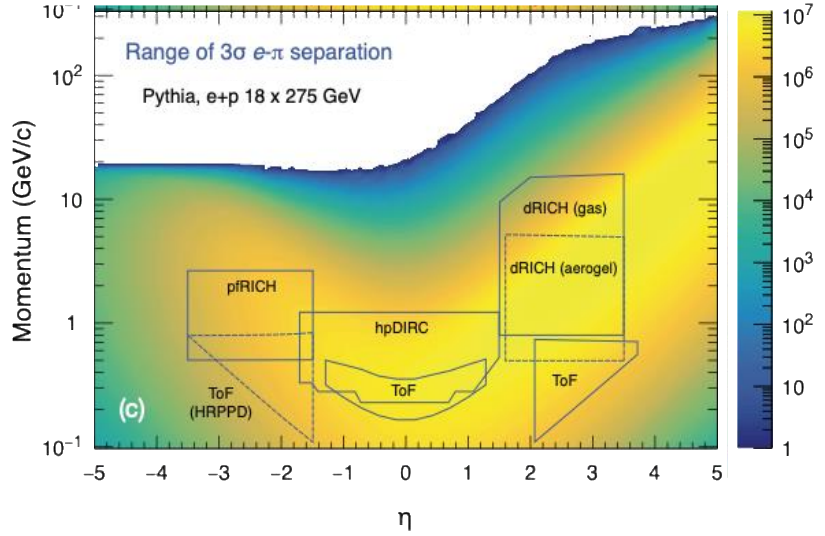


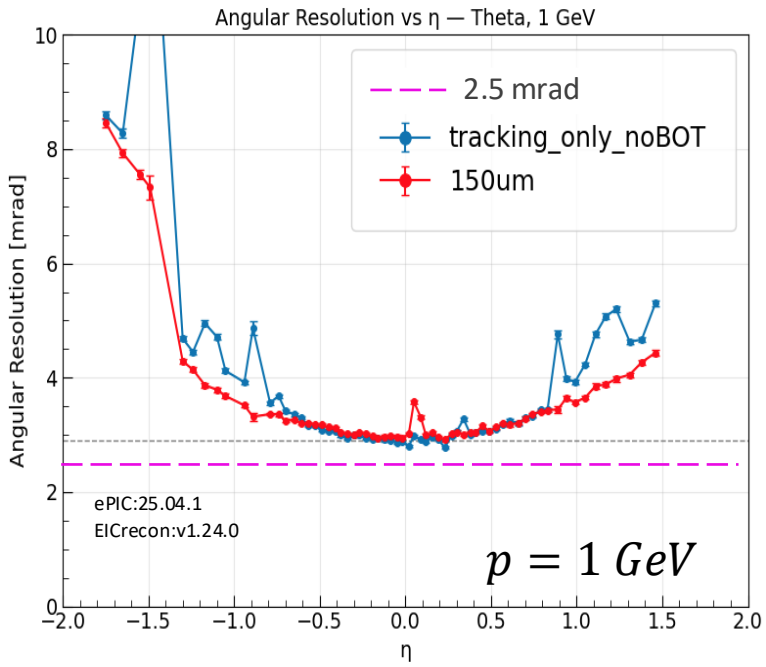
Realistic tracking resolution → ePIC resolution maps

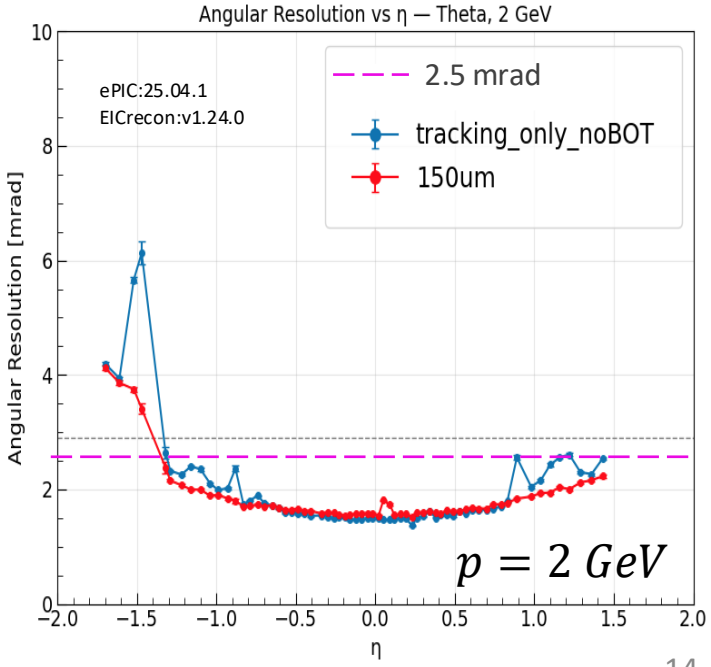
Angular Resolutions at hpDIRC: 1 GeV

- hpDIRC PID performance would like angular resolution of 2.5mrad at 1.2 GeV to push e/π performance
- ePIC tracking with μRWELL-BOT is close to this value at 1 GeV and generally better than 2.5mrad at 2GeV









Angular Resolution Summary

- Improvements seen at larger $|\eta|$, particularly in areas of larger material budgets
  - $p = 6\ GeV$
    - $|\eta| > \approx 0.2$, separation is near 3 s.d.
    - $|\eta| < \approx 0.2$ separation power is well above 3 s.d.
  - Low momentum ($p = 1 - 2\ GeV$)
    - At 1 GeV, the angular resolutions exceed 3 mrad
    - While at 2 GeV the angular resolutions are better than 2.5 mrad

Ongoing and Future Work

❑ Ongoing Work

- MPGD Endcap geometry -- INFN
- MPGD Strip Readouts – Yann Bedfer

❑ Needed Work

- Optimize acceptance (not only MPGD specific)
- Impact of BIC on angular resolution (not MPGD specific)
- Assessment on impact of timing