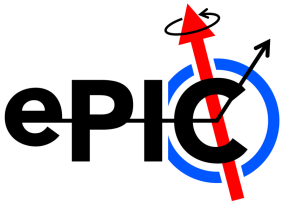


Impact of MPGDs on Tracking II

Matt Posik
Temple University

Goal and Settings

❖ **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:

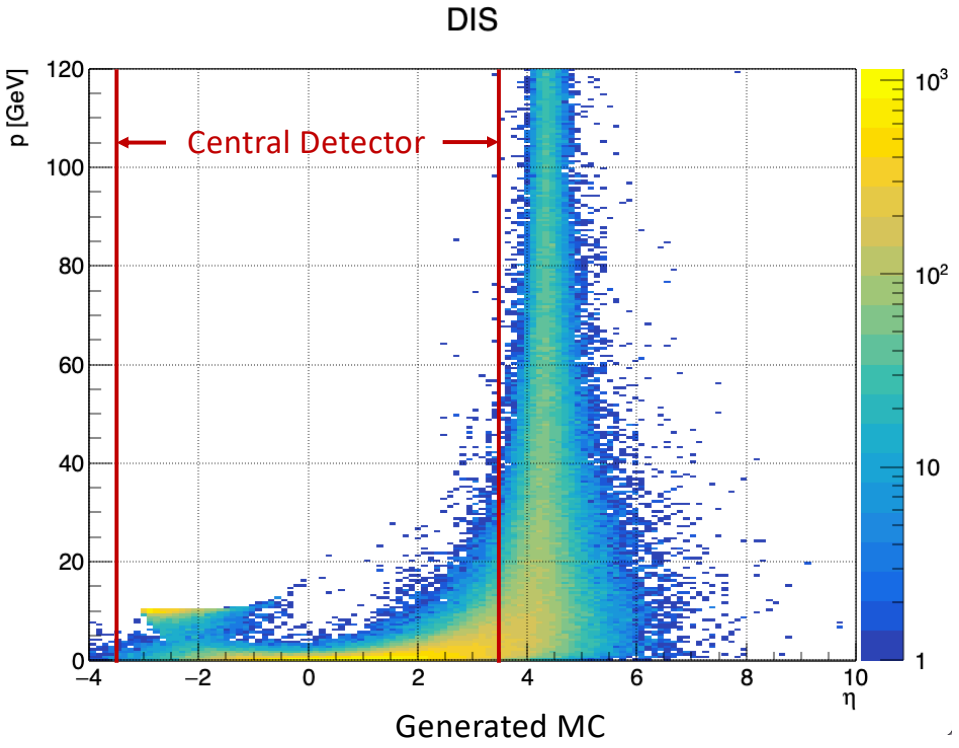
- epic: 26.04.1 ($10\mu m$ gold beam pipe coating)
- EICrecon: 1.34.0

❑ Simulation Files:

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

❑ Detector Configuration:

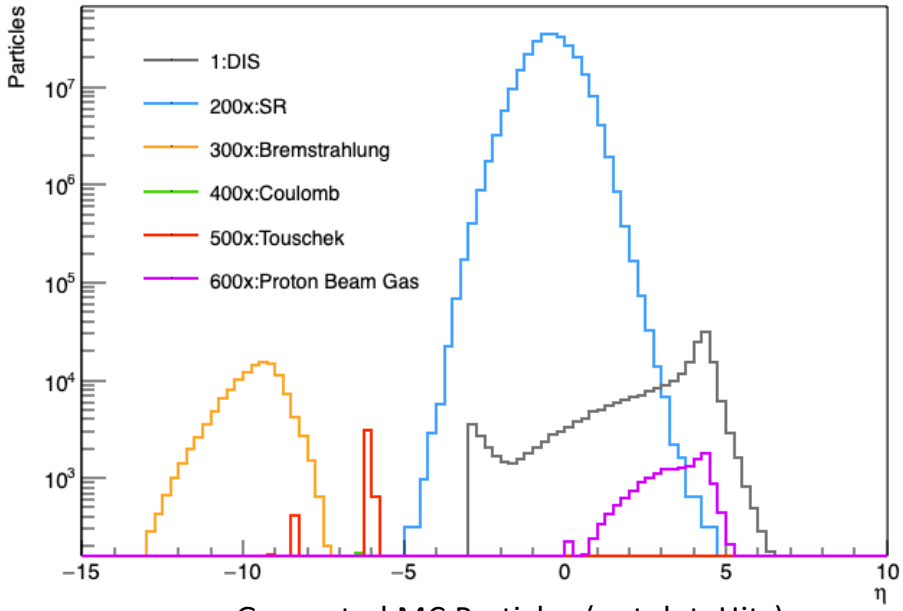
- epic_Craterlake.xml



Background Rates

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



Generated MC Particles (not det. Hits)

MPGD Geometry: 26.04.1

Detector	$Z_{\min}$ [mm]	$Z_{\max}$ [mm]	R [mm]
BOT	-1925	1675	730
CyMBaL	-1025	1450	550 - 615

Detector	$R_{\min}$ [mm]	$R_{\max}$ [mm]	$\sim Z$ [mm]
L1-ECT	50	420	-1200
L2-ECT	50	420	-1075
H1-ECT	70	420	1285
H2-ECT	70	420	1410

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

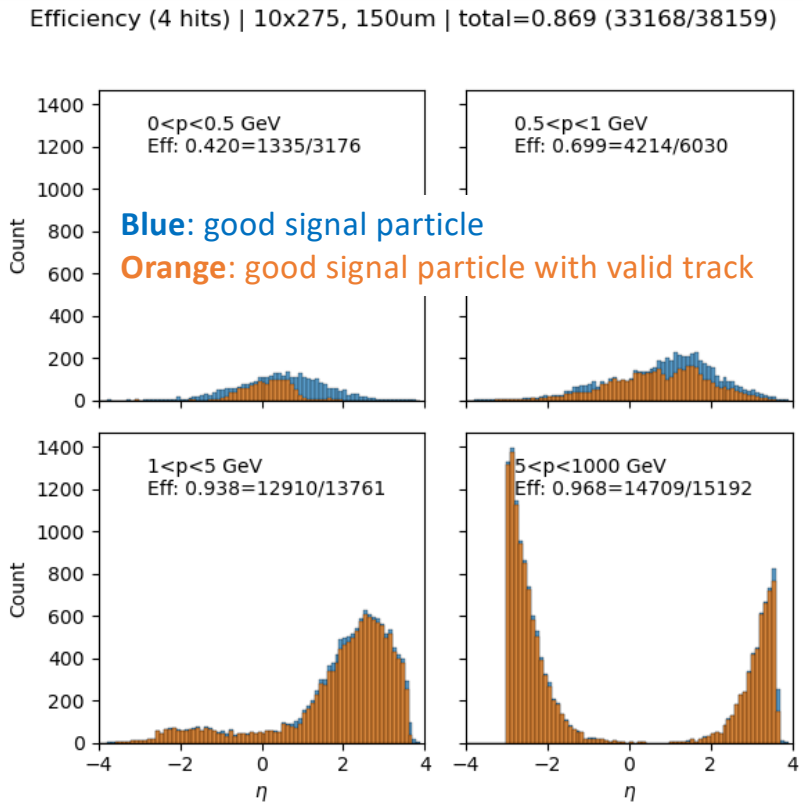
Is the particle of primary source of hits from DIS? → If not, **good background track**

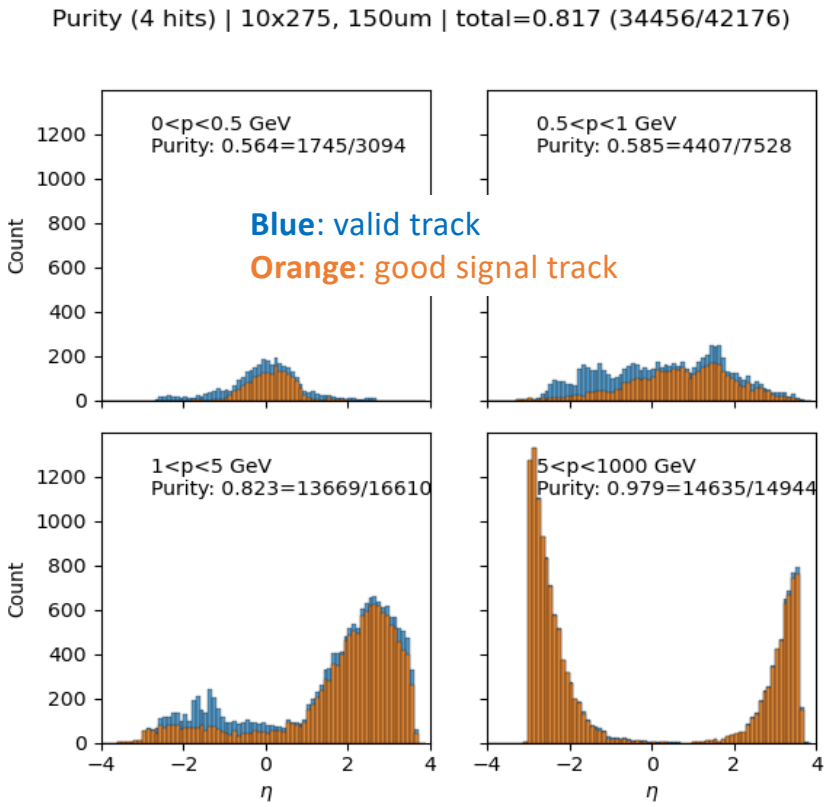
Good signal tracks

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

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

Efficiency and Purity: MPGD Resolution = 150 μm





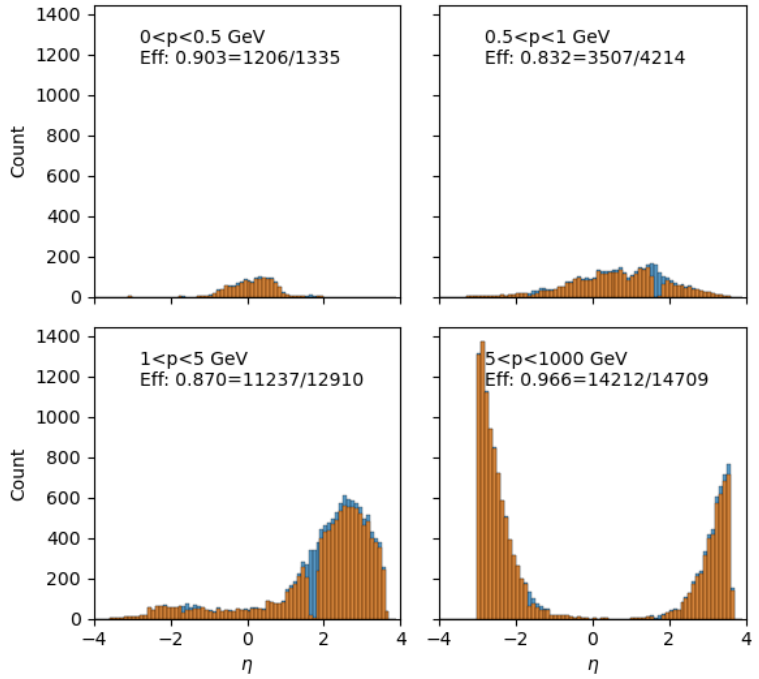
- High efficiency and purity.
- Worst tracking performance at low momentum

➢ Consistent with previous findings (Shujie Tracking Presentation)

Efficiency and Purity: MPGD Resolution = 150 μm

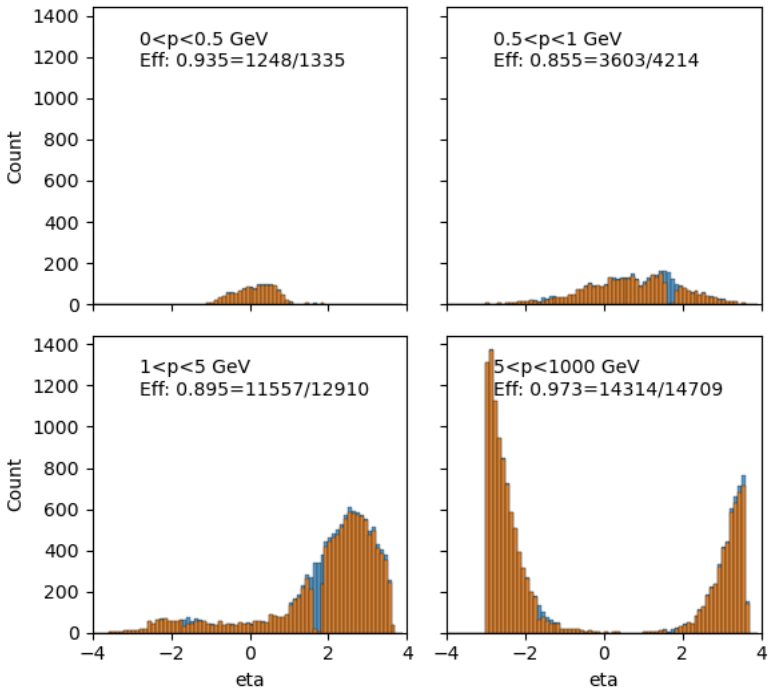
MPGD Efficiency (4 hits) | 10x275, 150um | total=0.909 (30162/33168)

MPGD Fraction



Efficiency (4 hits) | 10x275, 150um | total=0.926 (30722/331

Fast Fraction



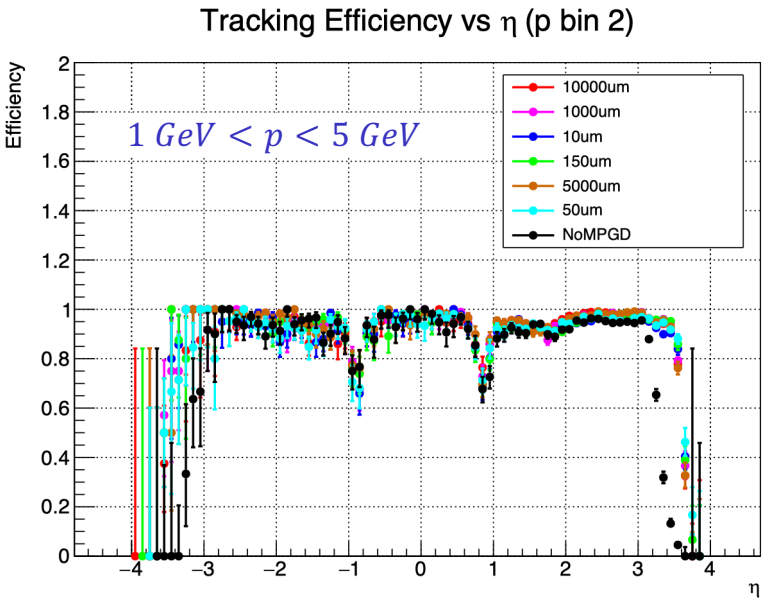
MPGD fraction: (Good signal particles w/good track + MPGD hit) / (Good signal particles w/ good track) **~91%**

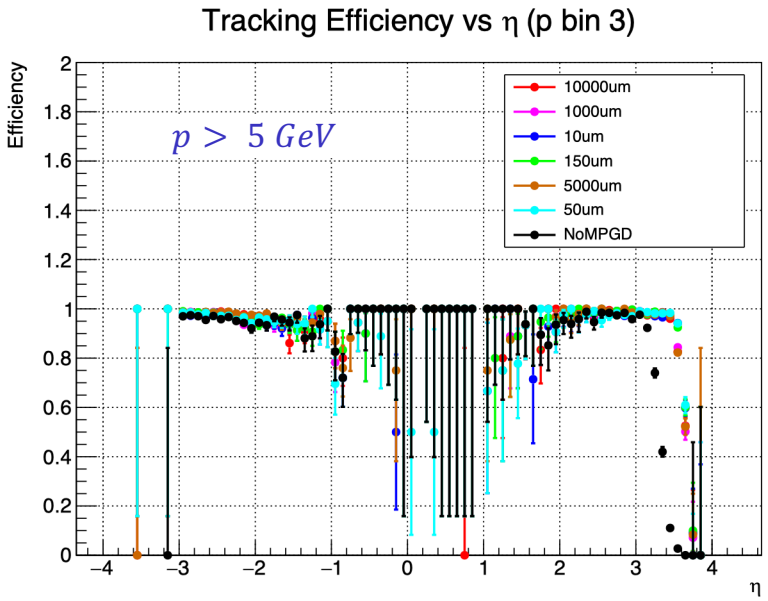
Fast fraction: (Good signal particles w/good track + (MPGD || TOF) hit) / (Good signal particles w/ good track) **~93%**

- Large fraction of tracks contain at least one "fast" tracker hit

Efficiency: Pattern Recognition

- Efficiency is comparable with MPGD resolutions spanning $10\ \mu m$ to $10\ mm$
- Significant drop (~10%) when MPGDs are removed from track reconstruction

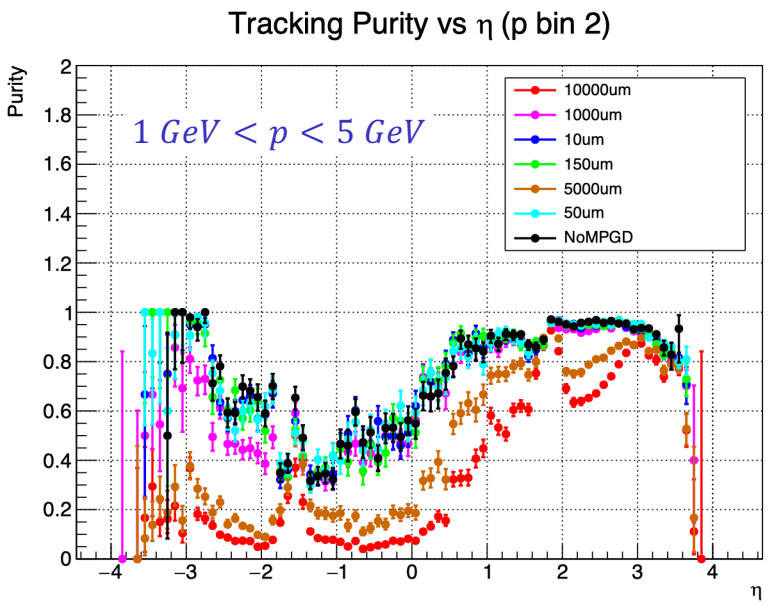


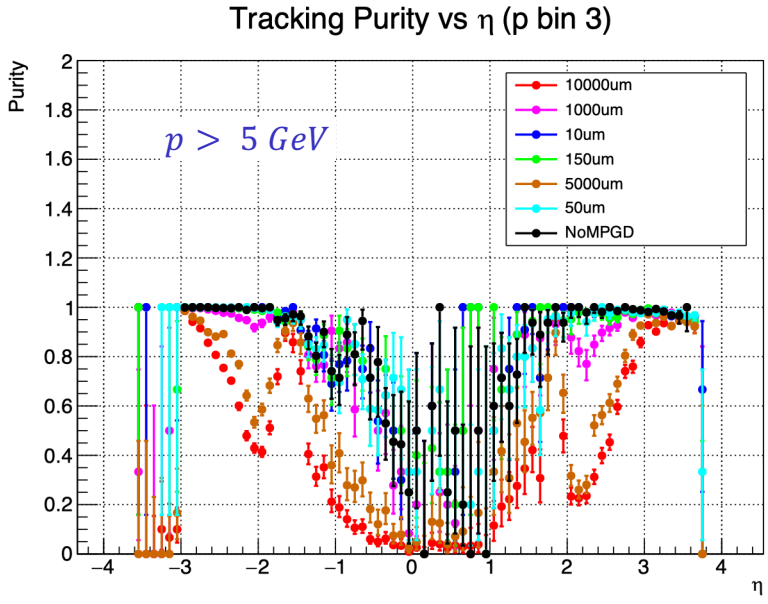


➢ MPGD presence improves reconstruction efficiency even at modest spatial resolution, although very poor resolutions degrade hit association quality.

Purity: Hit Association Quality

- Dependence on MPGD resolution is weak below 1 mm
- Clear degradation of purity with MPGD resolutions above 1 mm

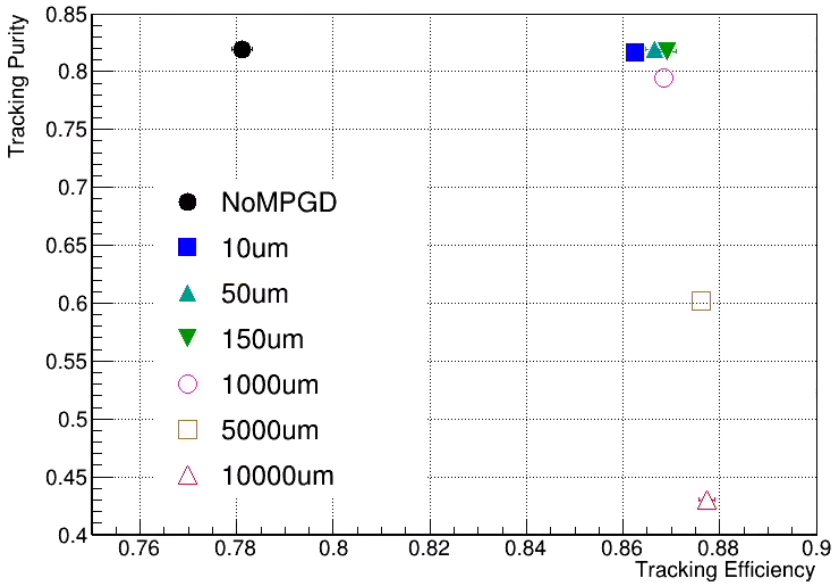


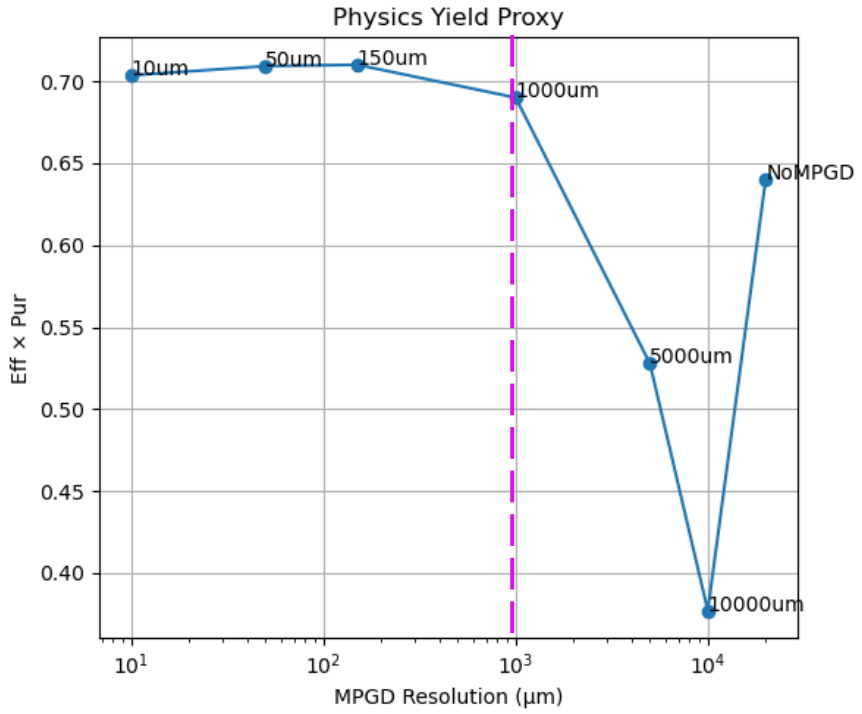


➢ There is a resolution threshold of ~1 mm above which MPGD hit-association quality and overall tracking performance begin to degrade.

Efficiency x Purity

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



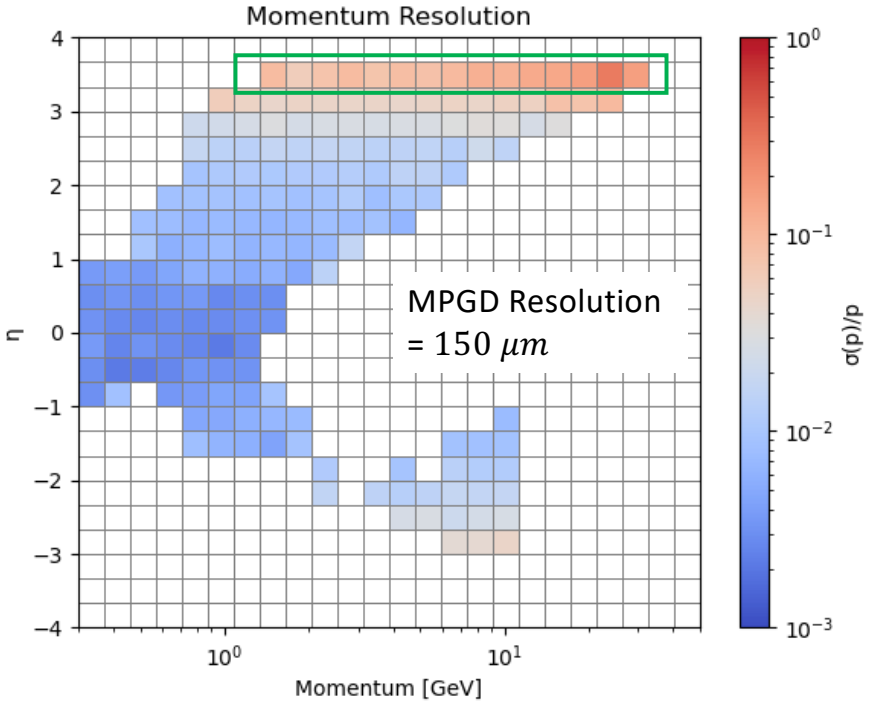


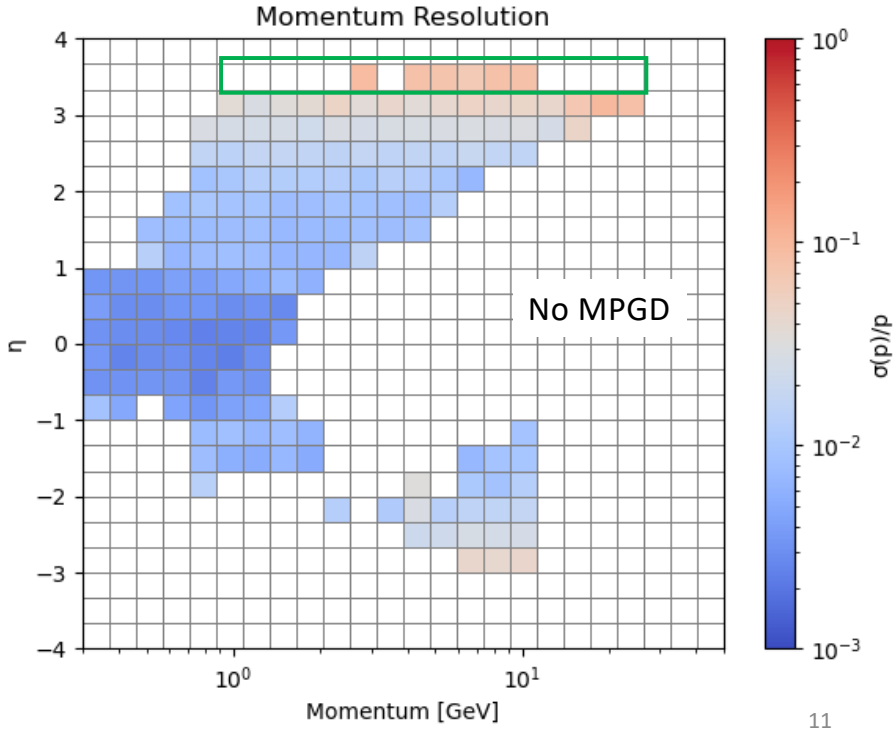
➢ Optimal performance with MPGD resolution below 1 mm

Momentum Resolution vs (p , η)

- Momentum resolution was evaluated using iterative Gaussian core fits to reduce sensitivity to non-Gaussian tails.
- Momentum-resolution maps only include bins with sufficient statistics for stable Gaussian-core fitting.

➢ MPGDs allow for reconstruction of higher momentum and pseudo rapidity tracks

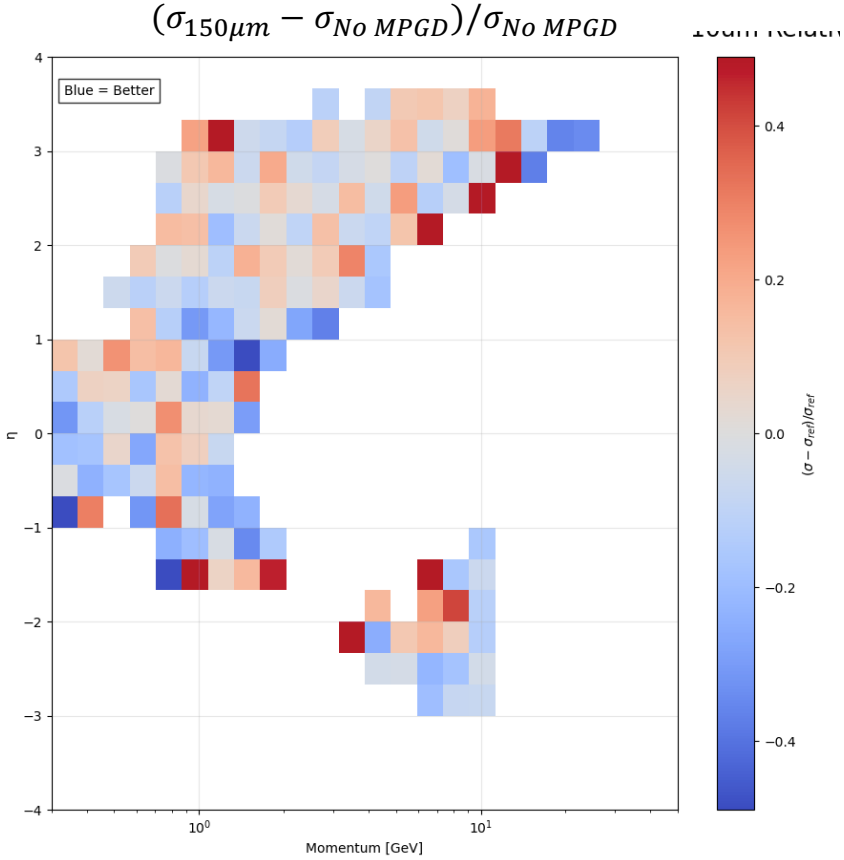




Relative Momentum Resolution Difference vs (p , η)

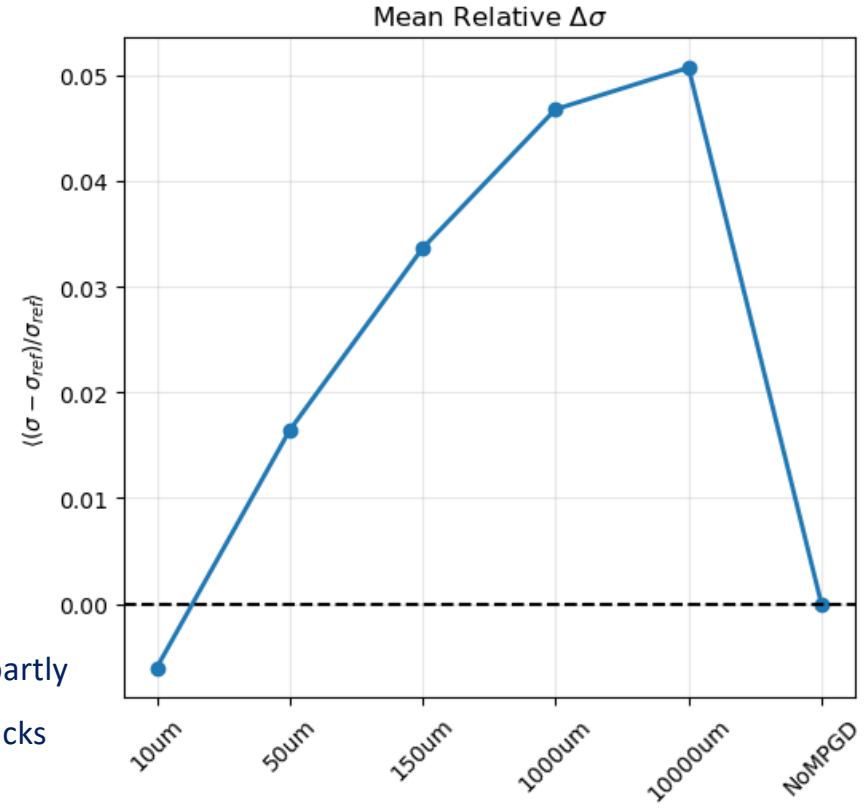
- Relative momentum resolution difference:
  - $(\sigma_{150\mu m} - \sigma_{No\ MPGD})/\sigma_{No\ MPGD}$
  - Blue shade highlights better performance

➢ The impact of MPGDs is strongly phase-space dependent, with the largest gains occurring at high momentum and forward/backward pseudorapidity.



Mean Relative Momentum Resolution Difference

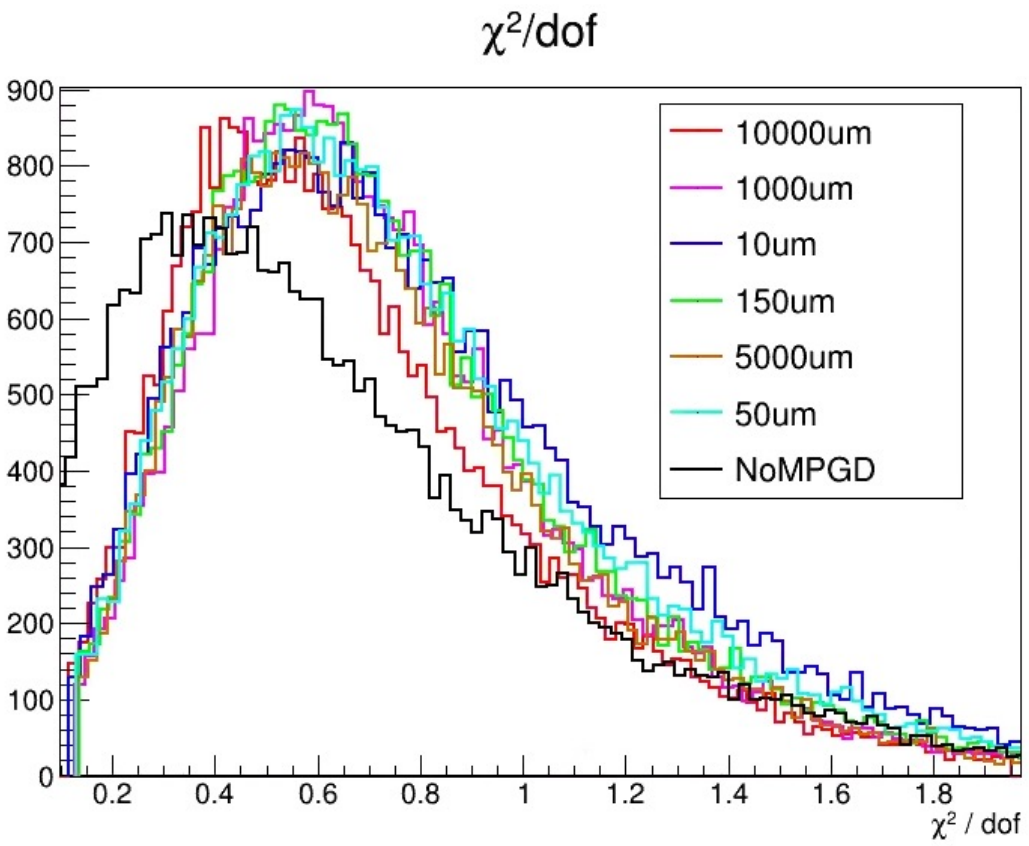
- Improved MPGD resolution reduces the impact of lower-precision MPGD hits on the fitted momentum resolution.
- Silicon tracker provides very precise hit information (~ $5\ \mu m$)
- MPGDs provide lower-precision measurements than silicon and therefore modestly degrade the momentum-resolution core while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

χ^2 and Fit Quality

- χ^2/dof < 1 (peaks near ~ 0.4-0.7)
- Adding MPGD hits increases the total χ^2 contribution while also increasing the fit degrees of freedom.
- As MPGD hit uncertainties increase, their contribution to the fit weight decreases, causing the fit behavior to approach the No-MPGD configuration.



χ^2 / ndof

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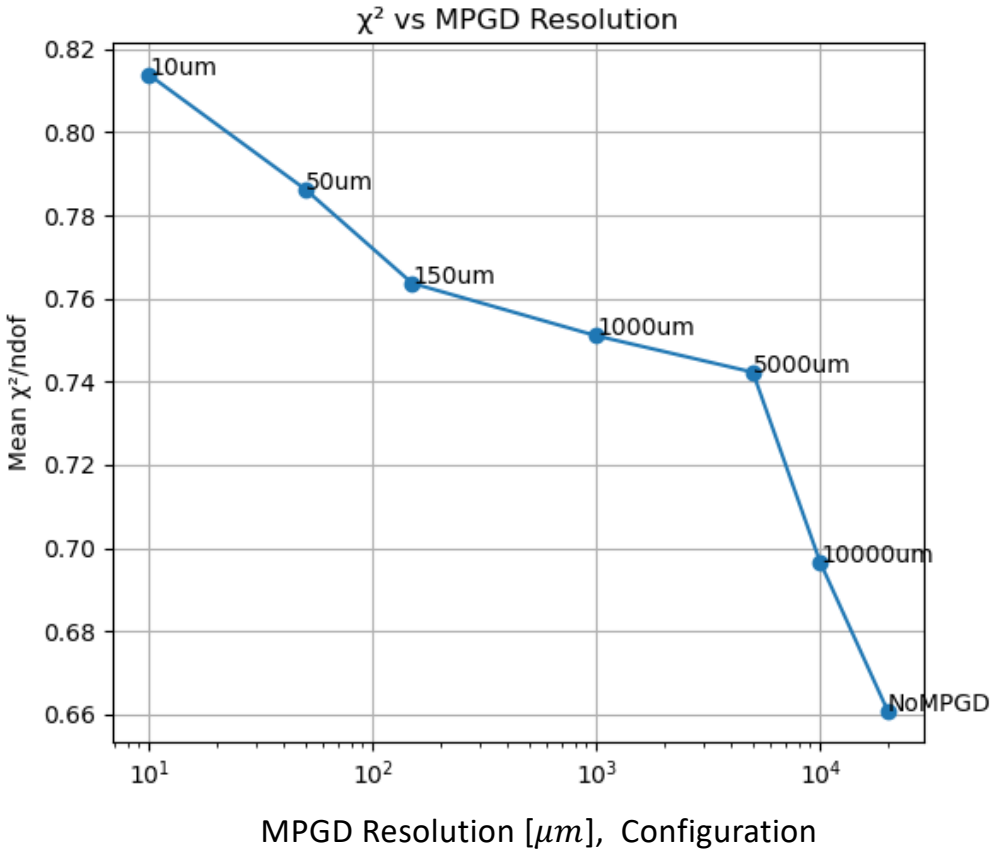
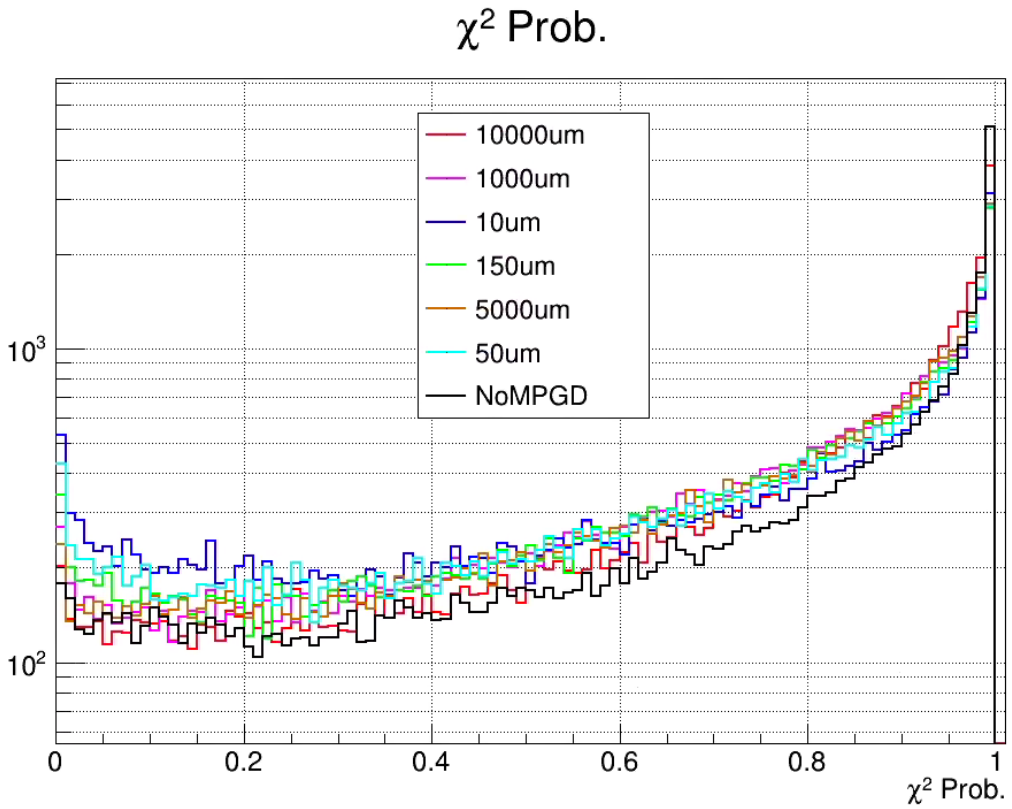


χ^2 and Fit Quality

- Peak at χ^2 prob. = 0
  - smallest for No MPGD case
  - Grows with improving MPGD resolution
- Strong peak at χ^2 prob. = 1
  - Strongest for the No MPGD config.
- The non-uniform χ^2 probability distributions suggest non-Gaussian residual behavior, the fit uncertainties and/or residual correlations are not perfectly modeled



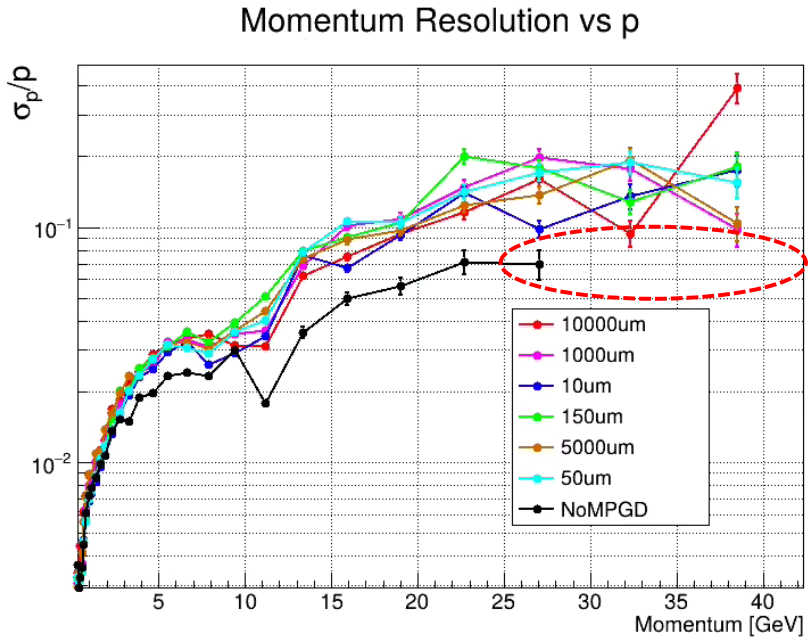
Summary

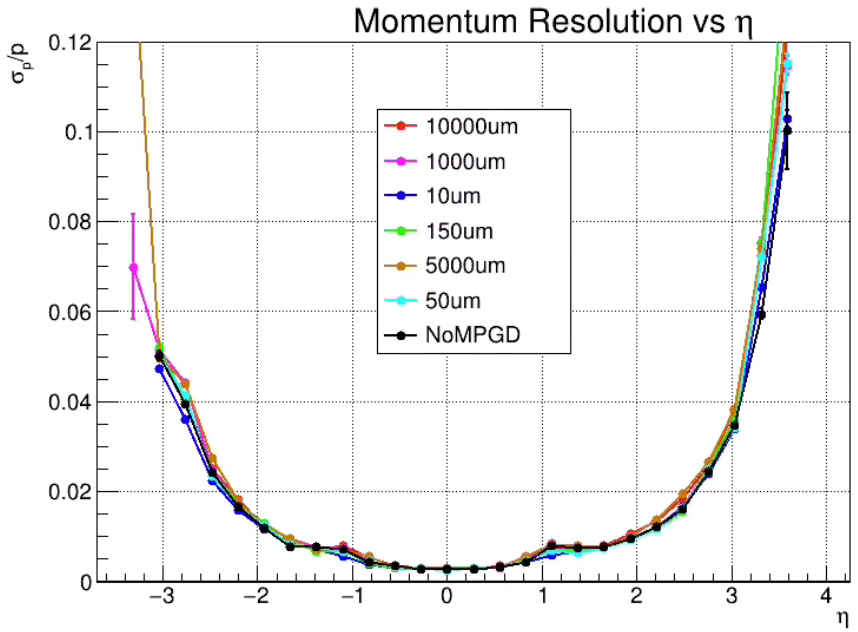
- Impact of MPGDs on tracking performance in background was assessed
- Large fraction of reconstructed tracks (> 90%) contain at least one *fast* hit
- MPGD performance gains are concentrated at high momentum and large pseudorapidity, where MPGDs significantly extend the reconstructable tracking phase space.
- There is a resolution threshold of ~1 mm above which MPGD hit-association quality and overall tracking performance begin to degrade.
- χ^2/ndof increases (tending towards 1) as MPGD resolution improves and approaches the No MPGD configuration (lower χ^2/ndof) as the MPGD resolution worsens
- MPGDs primarily improve tracking through pattern recognition and acceptance extension rather than intrinsic momentum precision.

Backup

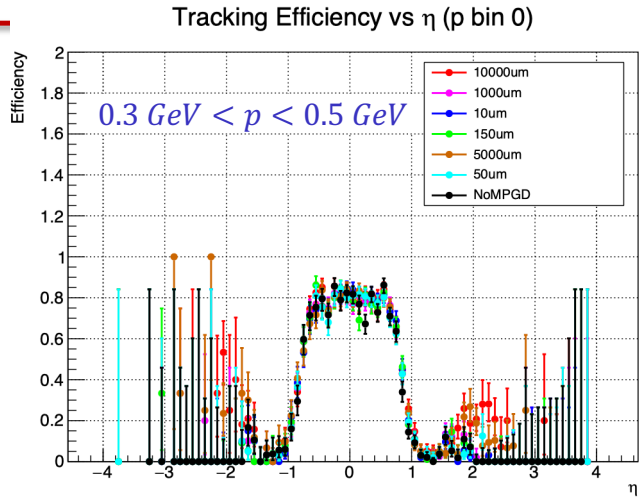
Momentum Resolution vs Momentum

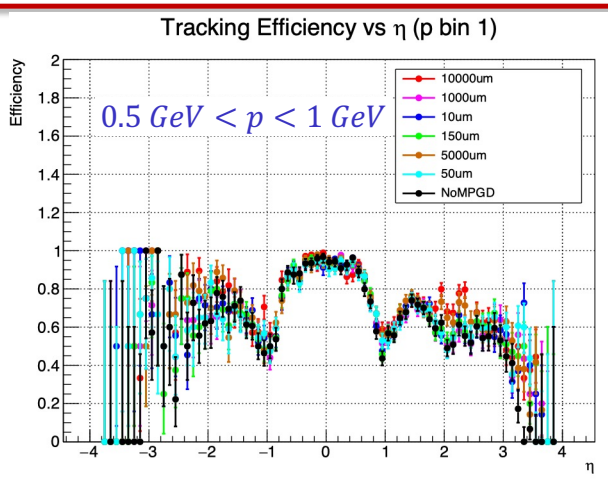
- Tracking precision is dominated by the silicon trackers ($\sigma_{Si} \approx 5\ \mu\mathrm{m}$)
- MPGDs allow for reconstruction of higher momentum tracks
- Momentum resolution generally degrades as momentum increases wrt the No MPGD configuration

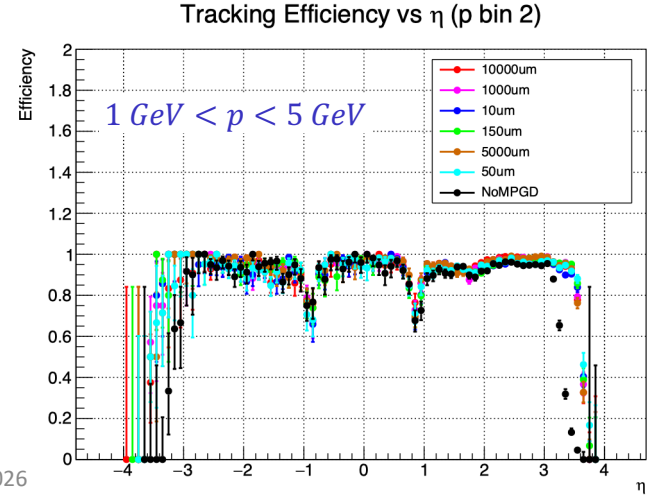


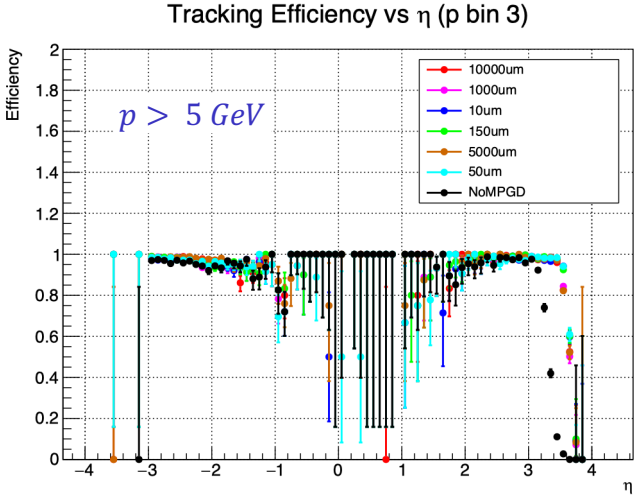


Efficiency

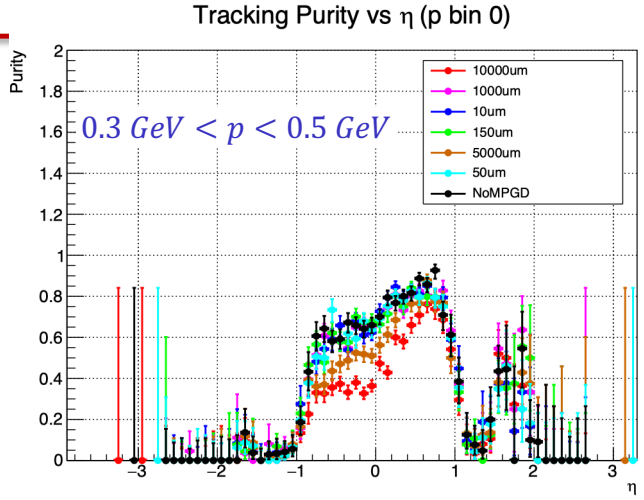

Tracking Efficiency vs η (p bin 0)
$0.3\ GeV < p < 0.5\ GeV$
10000um
1000um
10um
150um
5000um
50um
NoMPGD
Efficiency
η

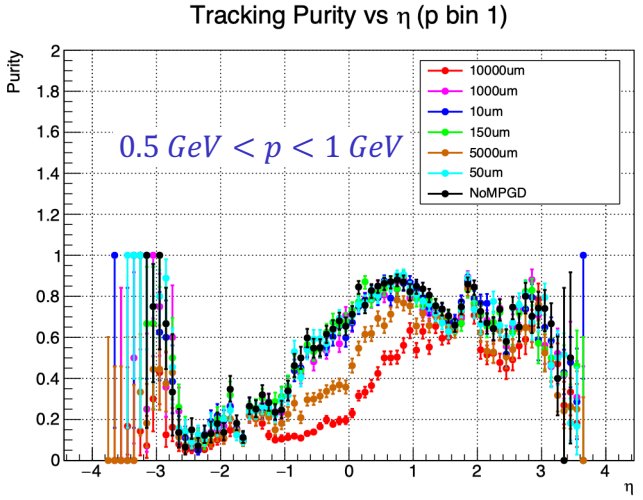

Tracking Efficiency vs η (p bin 1)
$0.5\ GeV < p < 1\ GeV$
10000um
1000um
10um
150um
5000um
50um
NoMPGD
Efficiency
η

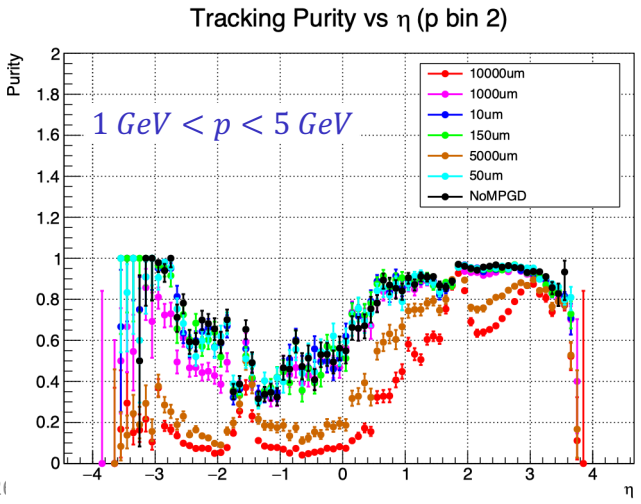

Tracking Efficiency vs η (p bin 2)
$1\ GeV < p < 5\ GeV$
10000um
1000um
10um
150um
5000um
50um
NoMPGD
Efficiency
η

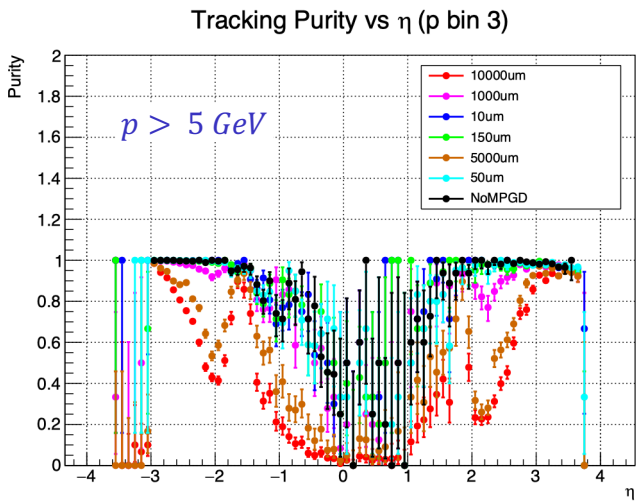

Tracking Efficiency vs η (p bin 3)
$p > 5\ GeV$
10000um
1000um
10um
150um
5000um
50um
NoMPGD
Efficiency
η

Purity


Tracking Purity vs η (p bin 0)
$0.3\ GeV < p < 0.5\ GeV$
10000um
1000um
10um
150um
5000um
50um
NoMPGD
Purity
η


Tracking Purity vs η (p bin 1)
$0.5\ GeV < p < 1\ GeV$
10000um
1000um
10um
150um
5000um
50um
NoMPGD
Purity
η


Tracking Purity vs η (p bin 2)
$1\ GeV < p < 5\ GeV$
10000um
1000um
10um
150um
5000um
50um
NoMPGD
Purity
η


Tracking Purity vs η (p bin 3)
$p > 5\ GeV$
10000um
1000um
10um
150um
5000um
50um
NoMPGD
Purity
η