MPGD Angular Resolution Study Update: Tracking layers and *Fast* Tracklets
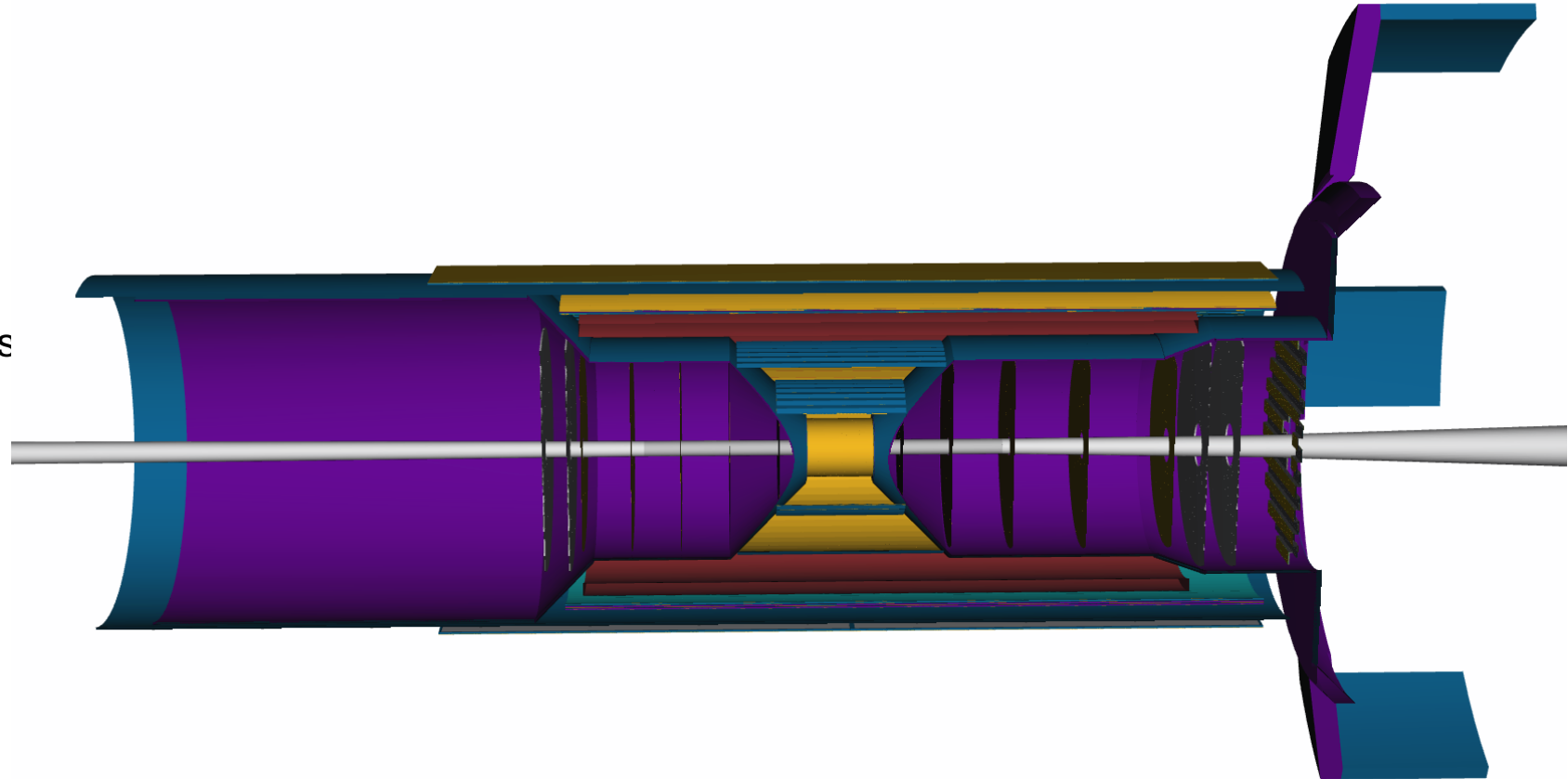
Matt Posik
Temple University

❑ Simulation details

❑ Angular resolution extractions

❑ Impact of detector layers and services on angular resolution

- Angular resolution with μRWELL-BOT and Si only tracking layers

- How angular resolution evolves with tracking layers

❑ Angular resolution via *fast* tracklets

- Spatial resolution

- μRWELL-BOT Material

Outline

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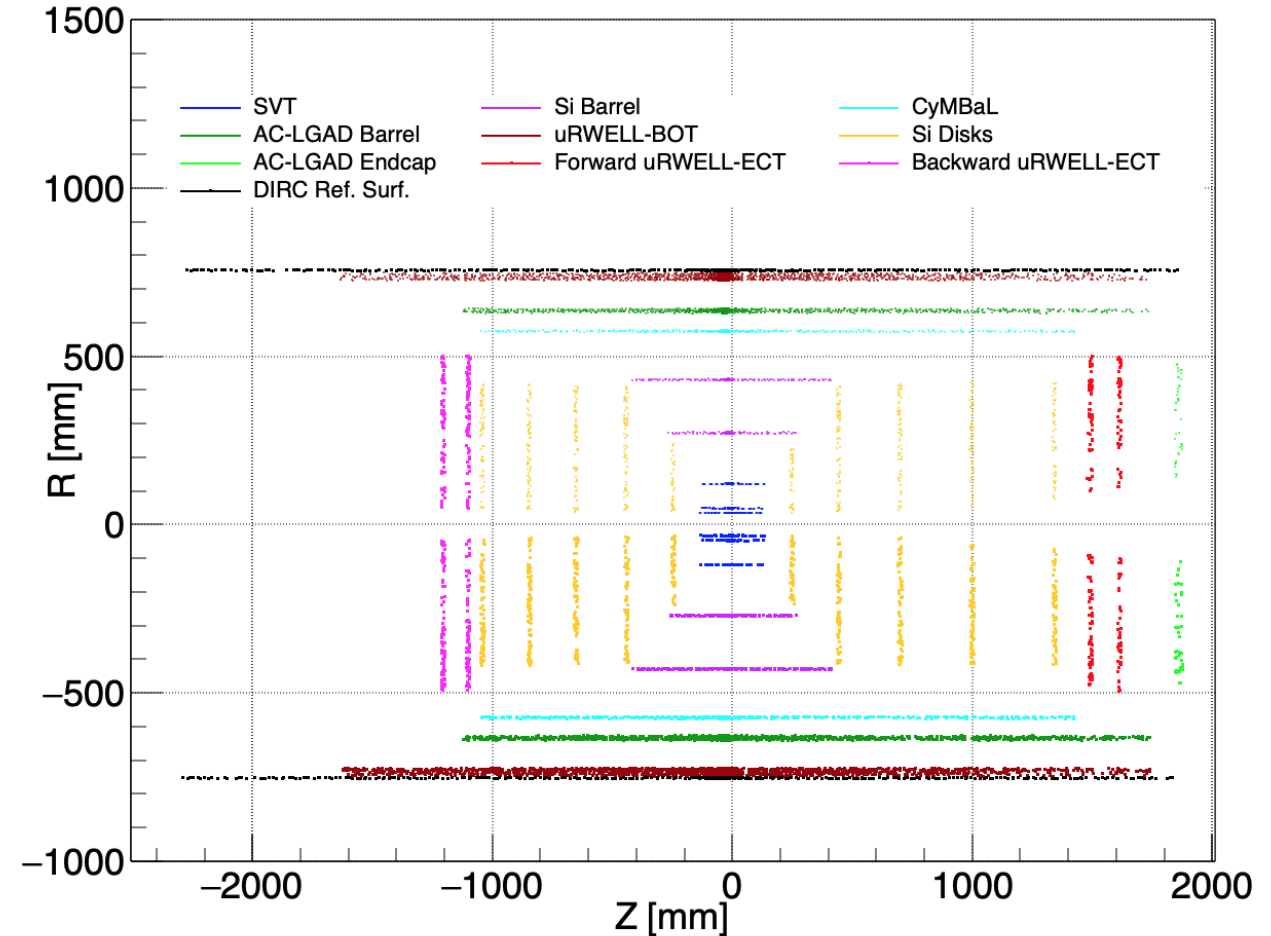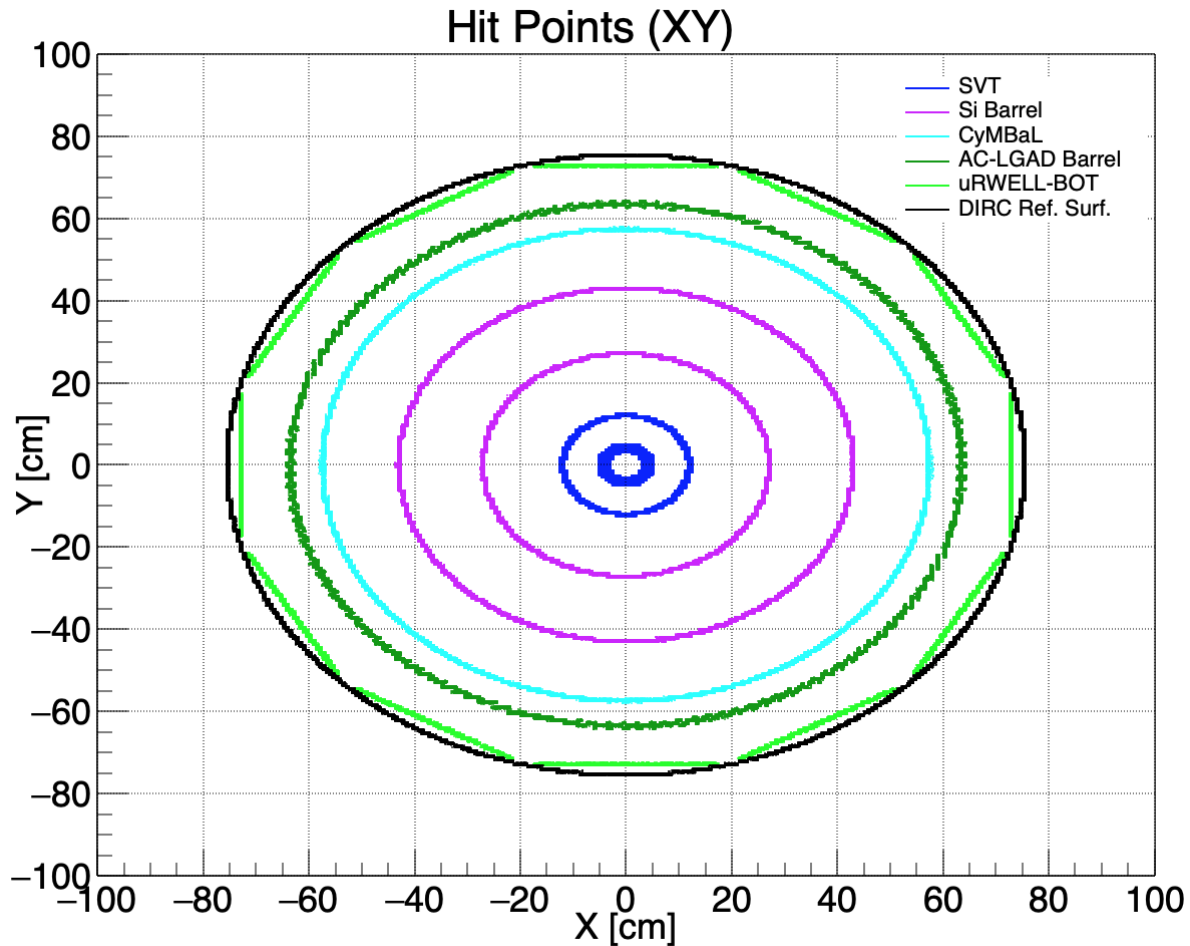
- Spatial resolution

- μRWELL-BOT Material

Simulation Details

- ❏ ePIC: 24.04.0/ 24.06.0

- ❏ EICRecon: v1.13.0/ v1.14.0

- ❏ Single particle π^-

- ❏ Two discrete momentum settings
  - ➢ 1, 2, 5, 7,10 GeV
  - ➢ 1, 2, 4, 6, 8, 10 GeV

- ❏ $92^o \leq \theta \leq 94^o$
  - ➢ $< \eta > = -0.05$

- ❏ $0^o \leq \phi \leq 360^o$

Outline

❏ Define low mass DIRC reference surface in DD4HEP to record truth hit information

DIRC Reference Surface

- ❑ Define low mass DIRC reference surface in DD4HEP to record truth hit information

- ❑ Define ACTS surface that matches D44HEP DIRC reference surface to propagate tracks to

DIRC Reference Surface

❑ Define low mass DIRC reference surface in DD4HEP to record truth hit information

❑ Define ACTS surface that matches D44HEP DIRC reference surface to propagate tracks to

❑ Take difference of truth hit and propagated track point

- Resolution is given by Gaussian sigma

DIRC: dth [mrad], 92.0 < θ [deg] < 94.0, <η> = -0.05, p = 6.00 GeV

$\Delta\theta$

$p = 6\ GeV$

$\eta = -0.05$

h_dth_th00_p03	
Entries	49927
Mean	0.005171
Std Dev	1.363
χ^2 / ndf	1186 / 101
Prob	1.109e−184
Constant	1.245e+04 ± 7.517e+01
Mean	0.001719 ± 0.002759
Sigma	0.5936 ± 0.0023

proj.theta - hit.theta [mrad]

DIRC: dphi [mrad], 92.0 < θ [deg] < 94.0, <η> = -0.05, p = 6.00 GeV

$\Delta\phi$

$p = 6\ GeV$

$\eta = -0.05$

h_dphi_th00_p03	
Entries	49927
Mean	0.01231
Std Dev	1.287
χ^2 / ndf	1038 / 90
Prob	3.833e−161
Constant	1.24e+04 ± 7.44e+01
Mean	−0.003919 ± 0.002771
Sigma	0.5965 ± 0.0023

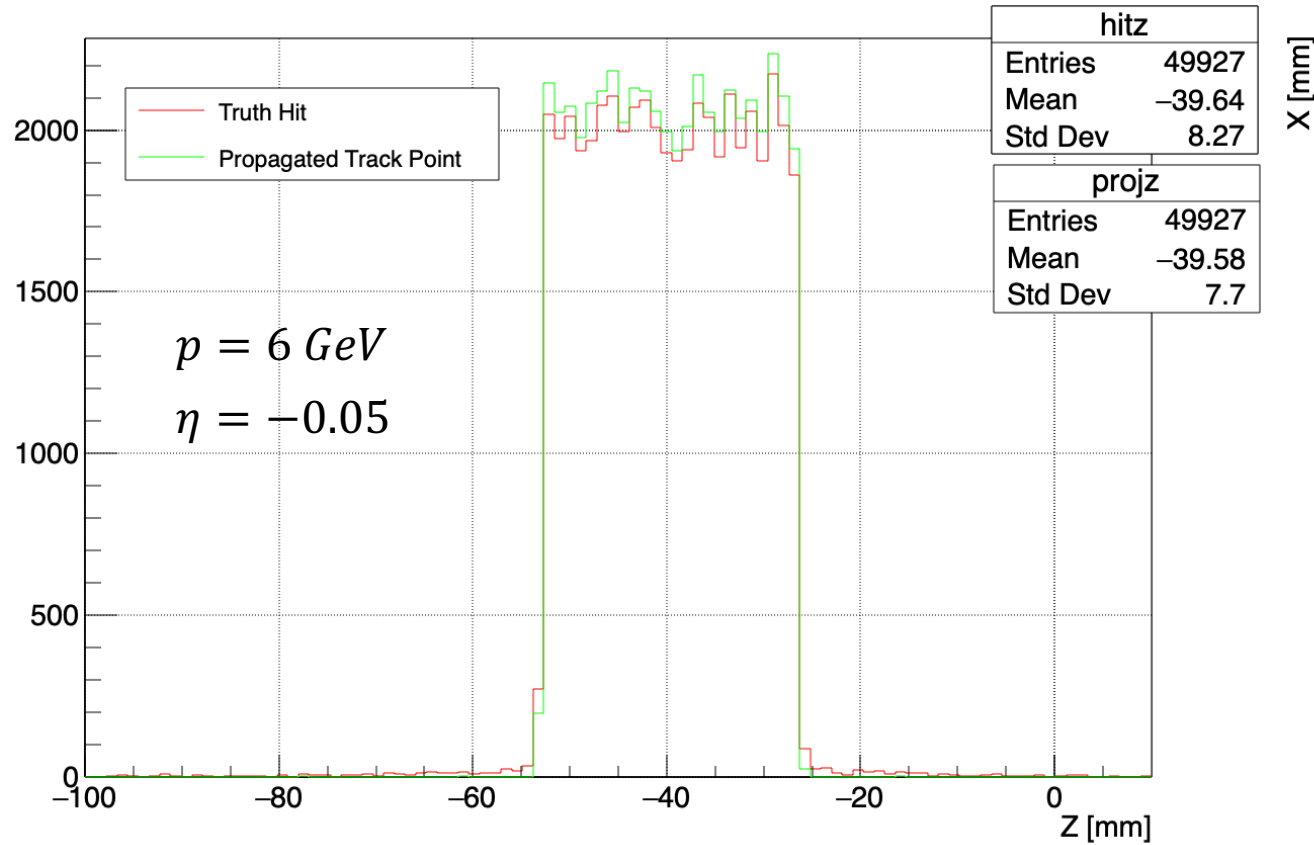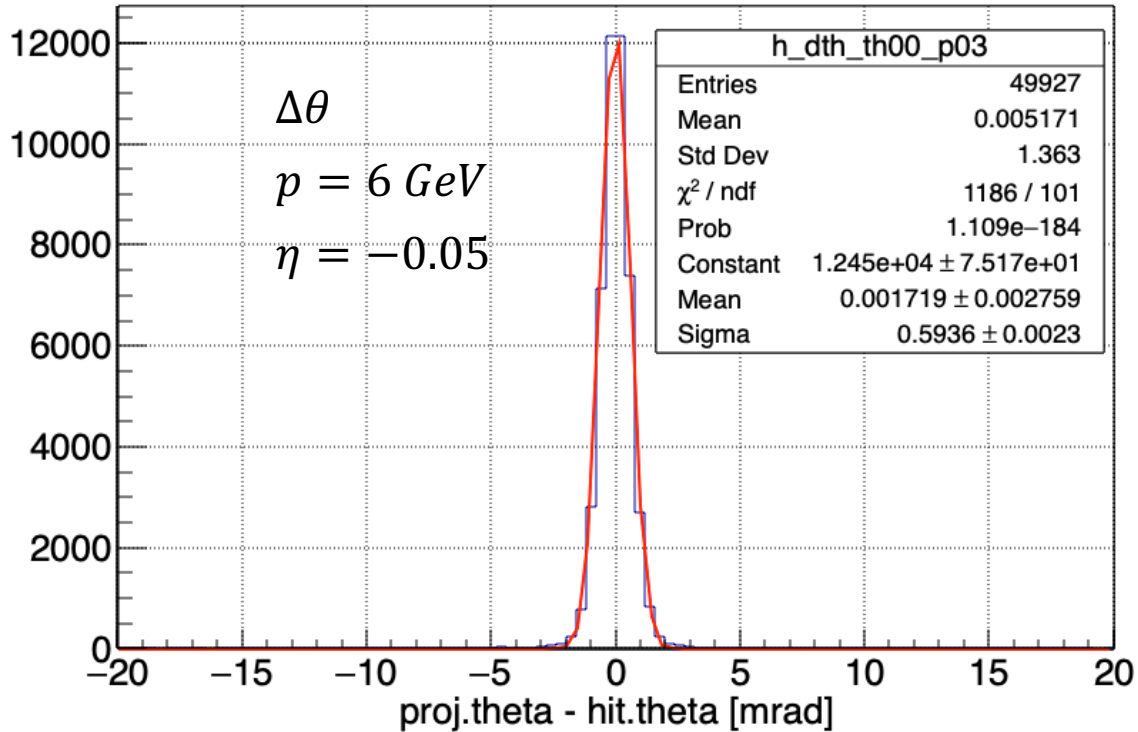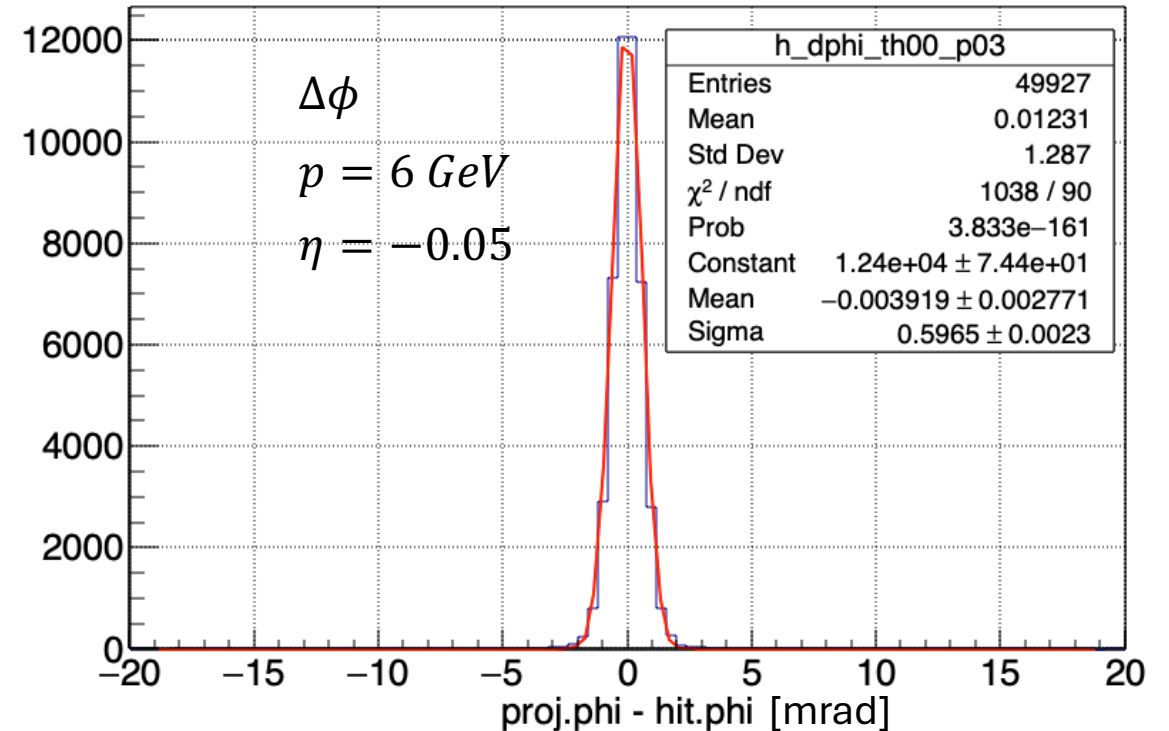proj.phi - hit.phi [mrad]

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❑**Impact of detector layers and services on angular resolution**

■ **Angular resolution with μRWELL-BOT and Si only tracking layers**

■ How angular resolution evolves with tracking layers

❑ Angular resolution via *fast* tracklets

■ Spatial resolution

■ μRWELL-BOT Material

❑ Remove all tracking layers other than Si layers

❑ Remove all services

❑ Compare μRWELL nominal material budget ($\chi_0 \sim 2\%$) to very low material budget ($\chi_0 \sim 5\times10^{-3}$ %)
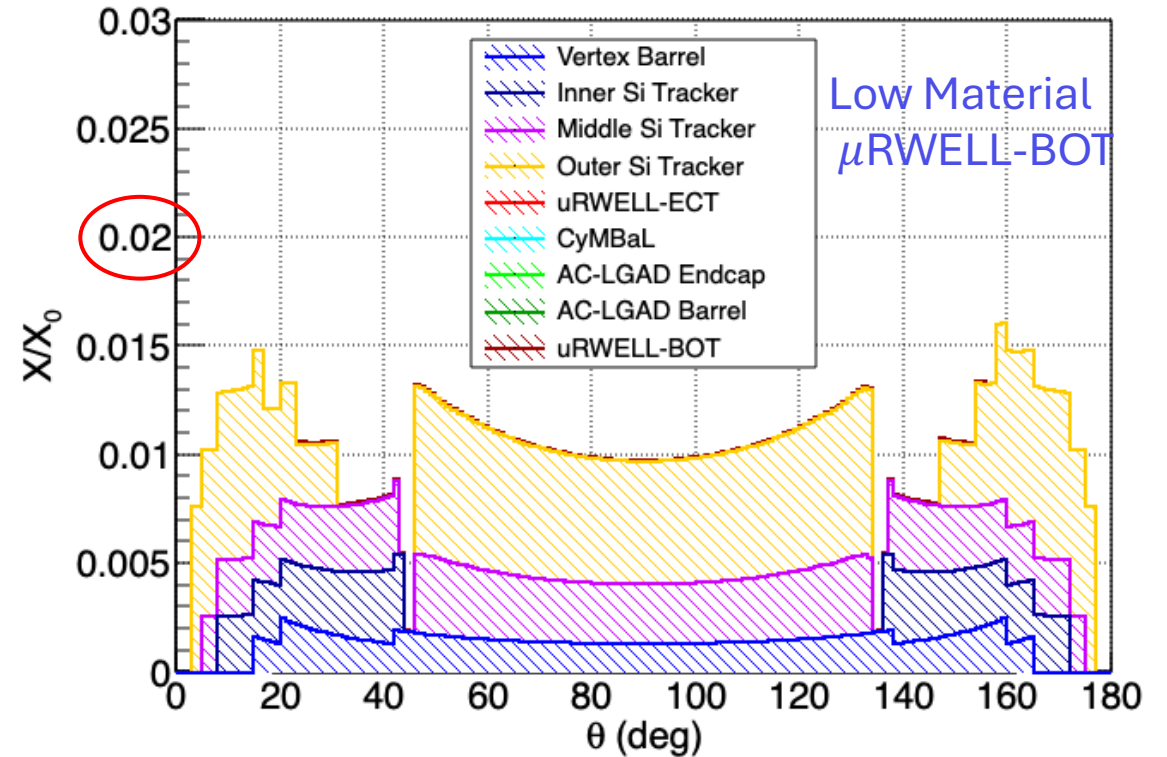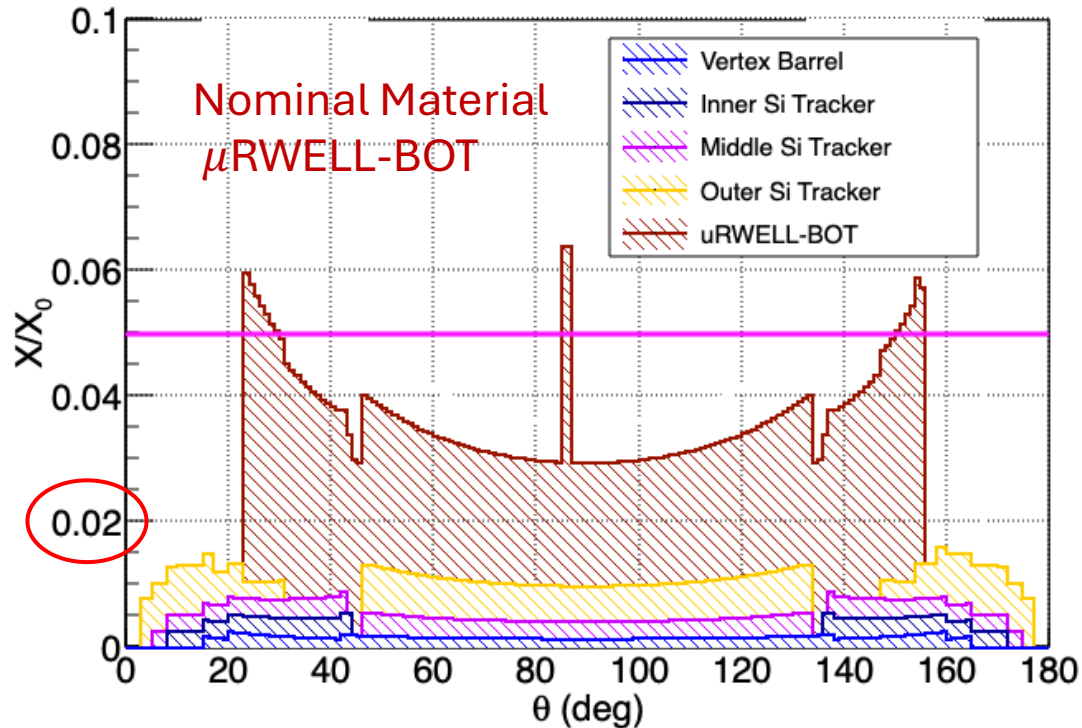
❏ As momentum increases performances become comparable

❏ Including low material μRWELL-BOT

- Similar performance as Si only tracking layers

- Negligible dependence on spatial resolution

92 < θ < 94, <η> = -0.05

24.04.0/1.13.0

Legend:
- Si+BOT Nominal (150um)
- Si Only
- Si+Bot Low Mat. (15um)
- Si+BOT Low Mat. (150um)

Axes: $\Delta\theta$ [mrad] vs p_{true} [GeV]
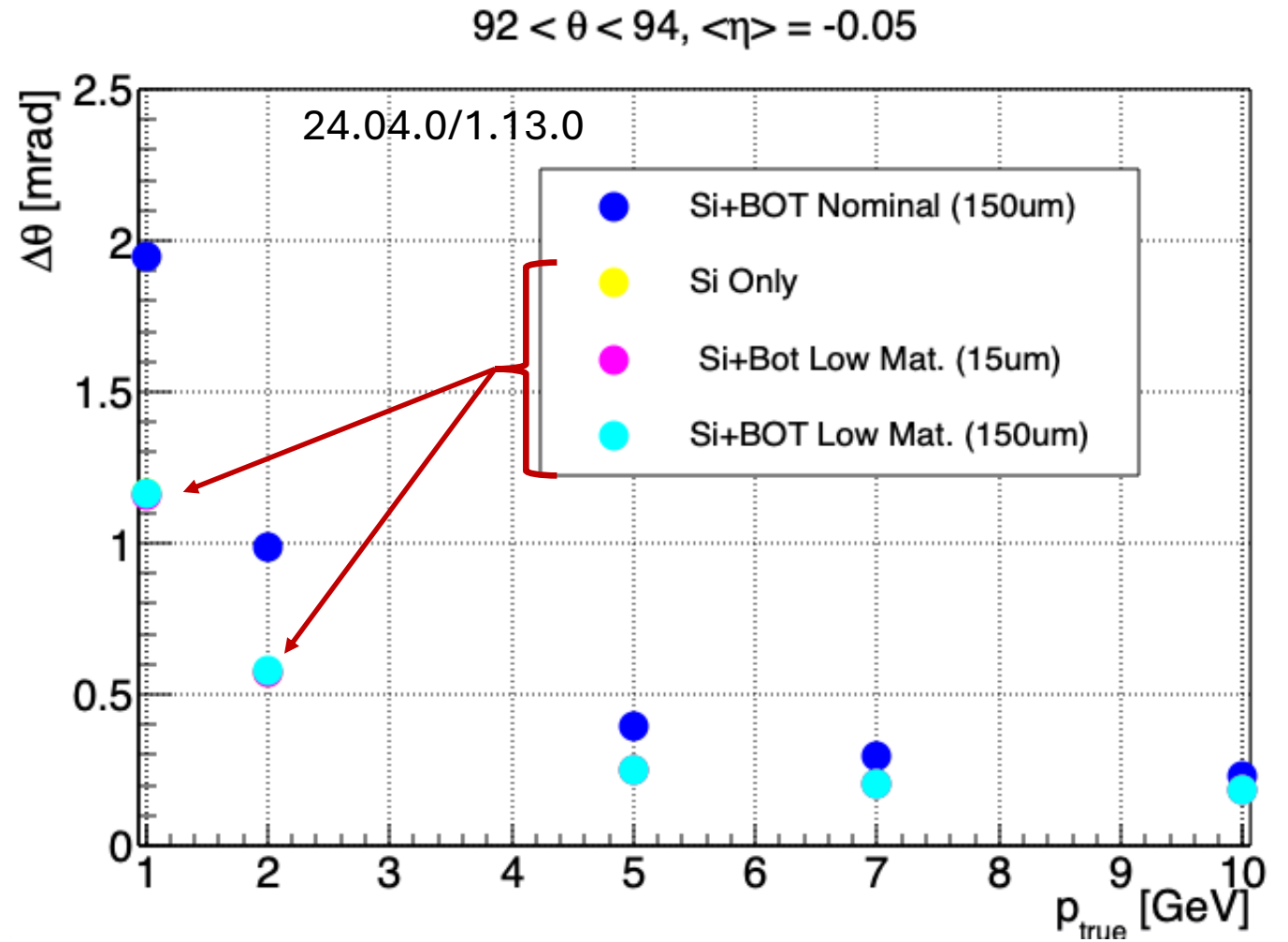
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❑**Impact of detector layers and services on angular resolution**

- ▪ Angular resolution with μRWELL-BOT and Si only tracking layers

- ▪ **How angular resolution evolves with tracking layers**

❑ Angular resolution via *fast* tracklets
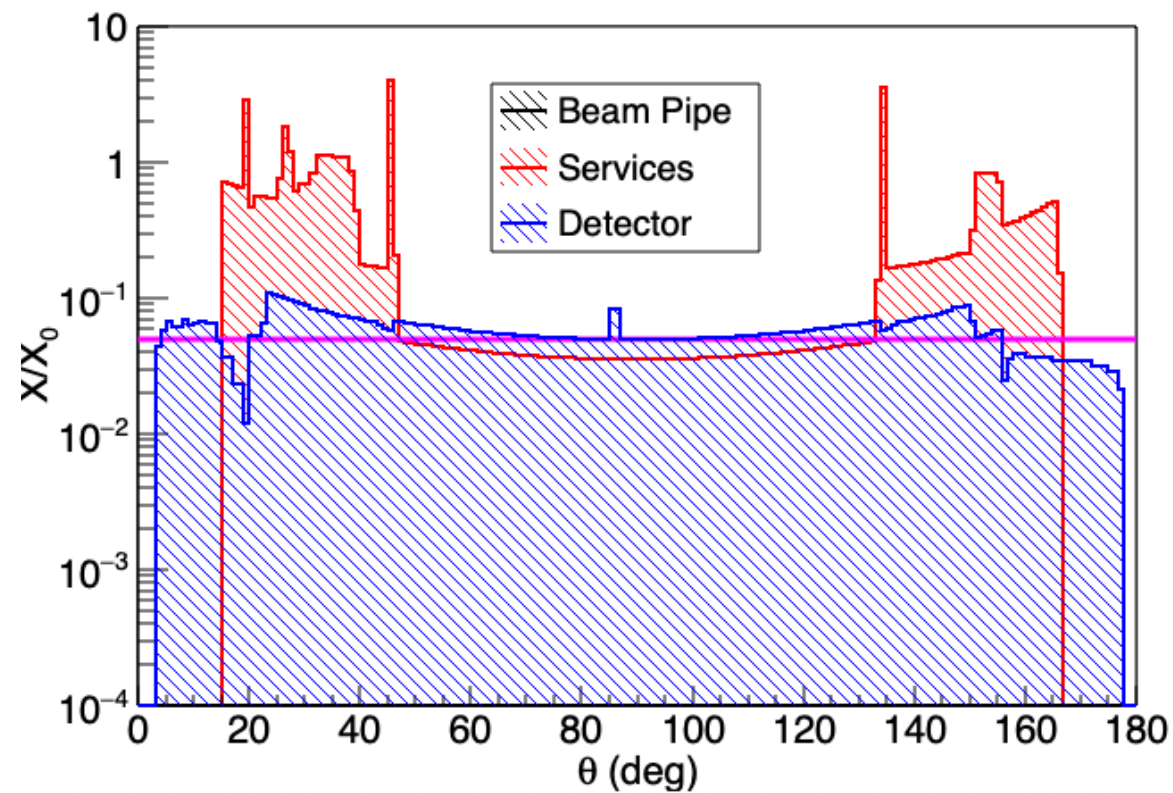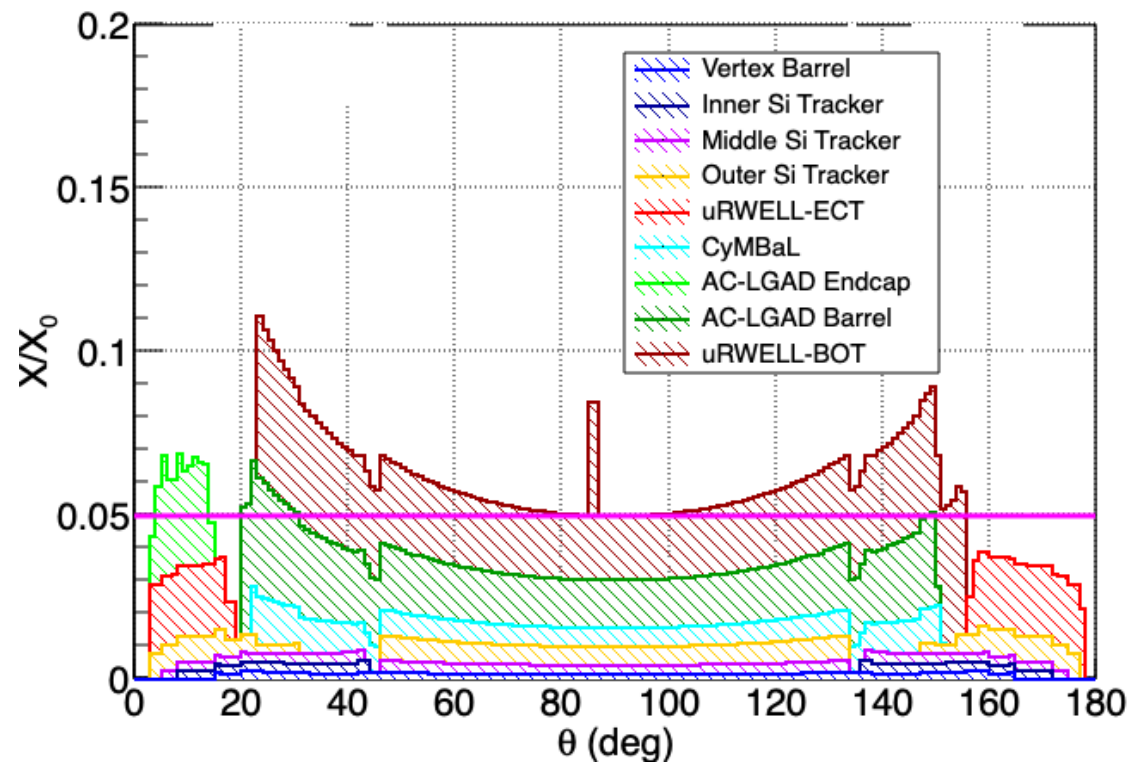
- ▪ Spatial resolution

- ▪ μRWELL-BOT Material

Nominal Material Budgets

Nominal Material Budgets

❑ As momentum increases performances

   become comparable

❑ Service material ($\chi_0 \sim$ 3.5%) introduces

   significant degradation of angular

   resolution at low momentum

$92 < \theta < 94, <\eta> = -0.05$

☐ As momentum increases performances become comparable

☐ Service material ($\chi_0 \sim 3.5\%$) introduces significant degradation of angular resolution at low momentum

$92 < \theta < 94$, $\langle \eta \rangle = -0.05$

24.04.0/1.13.0

Legend:
- Si Only
- Si + BOT
- Si + MPGDs
- All Trackers (wo/services)
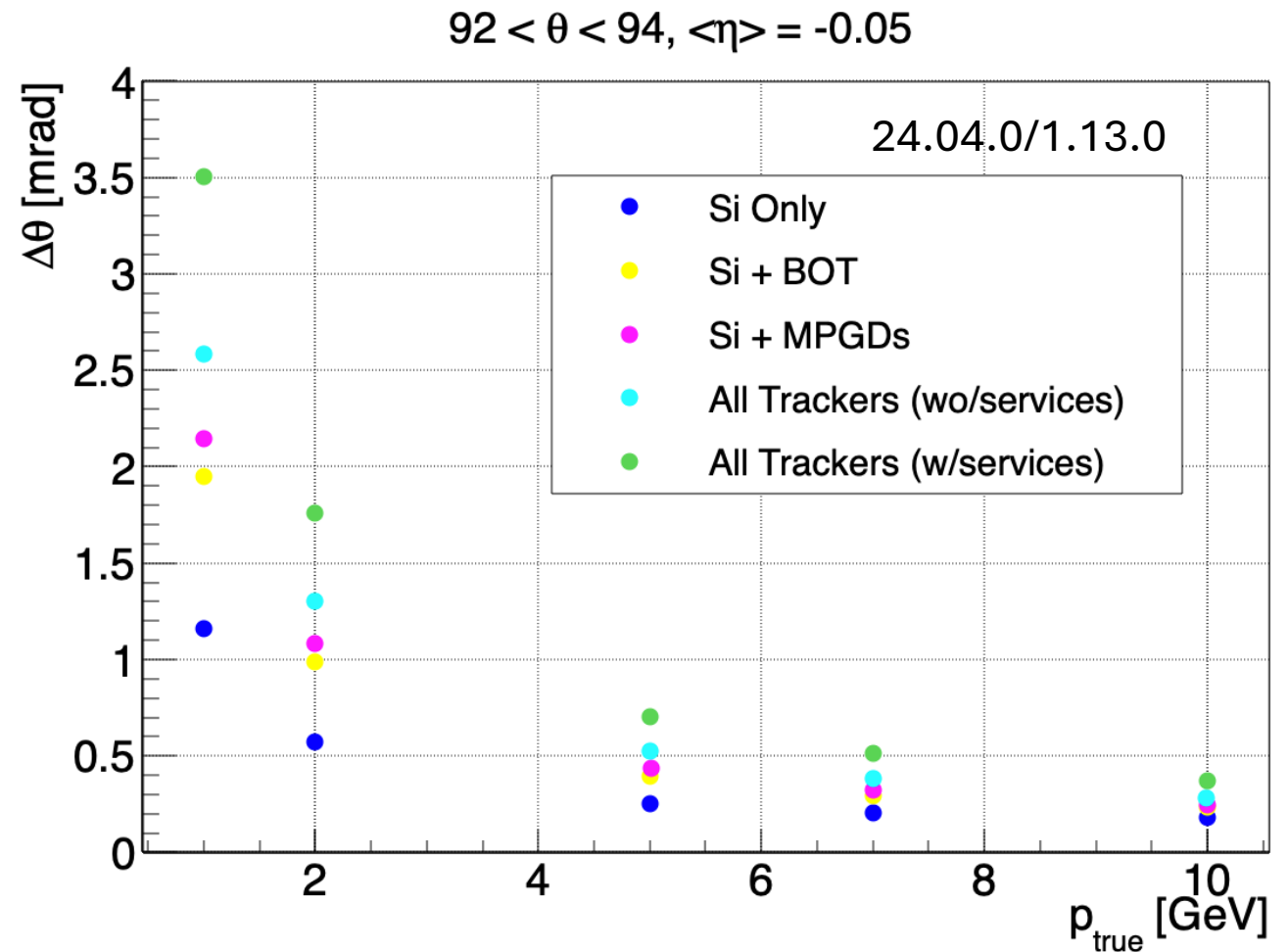- All Trackers (w/services)

$\Delta\phi$ [mrad] vs p_{true} [GeV]

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❑ **Angular resolution via _fast_ tracklets**
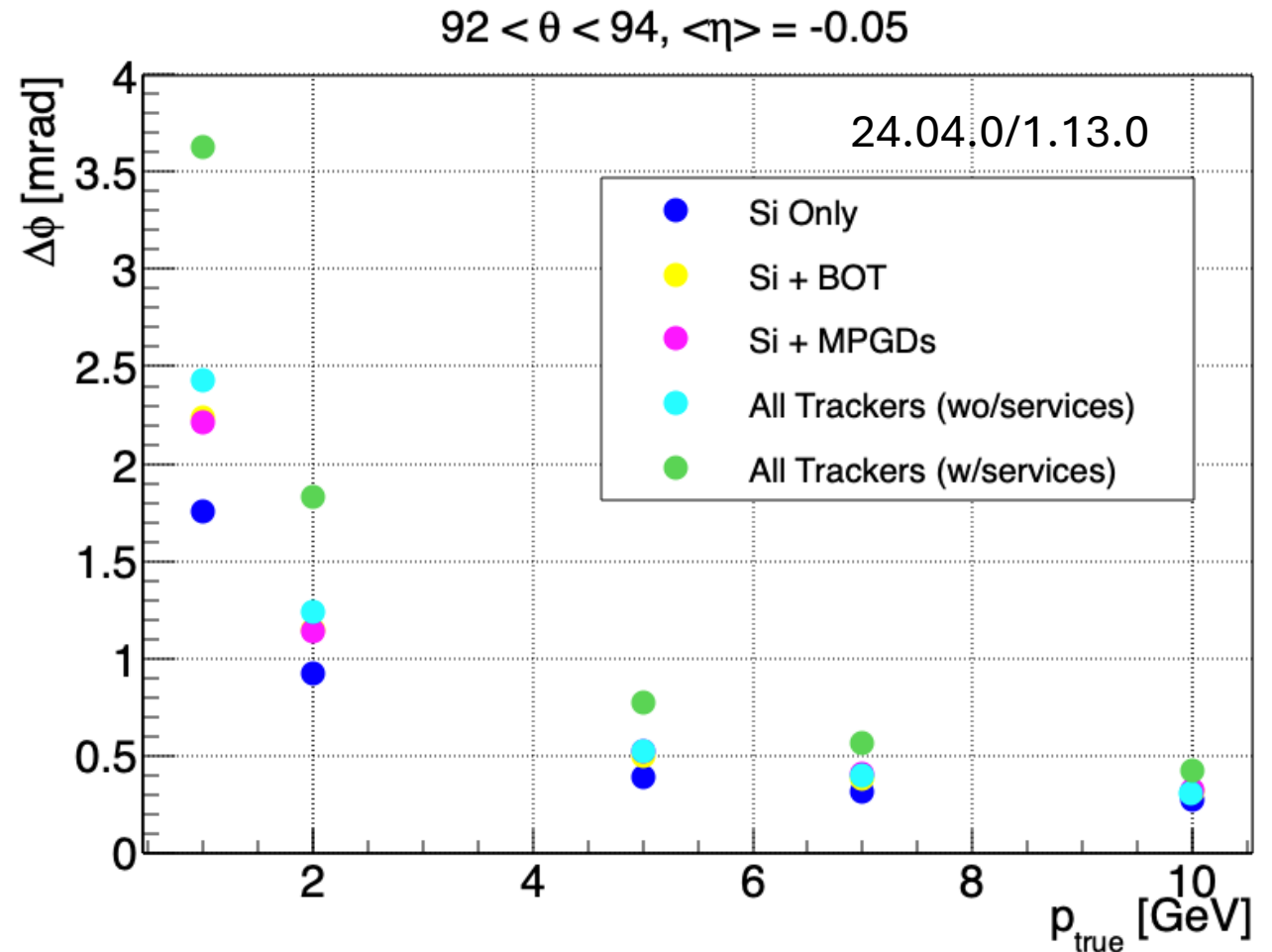
- ▪ Spatial resolution

- ▪ μRWELL-BOT Material

Evaluating Performance with *Fast* Tracklets

❏ Use only hits from MPGDs and AC-LGADs in track reconstruction

- Three *fast* layers → ~3 measurements / track

Full Track Reconstruction

htemp	
Entries	49927
Mean	7.228
Std Dev	0.7778

<nMeas> = 7.2

CentralCKFTrajectories.nMeasurements
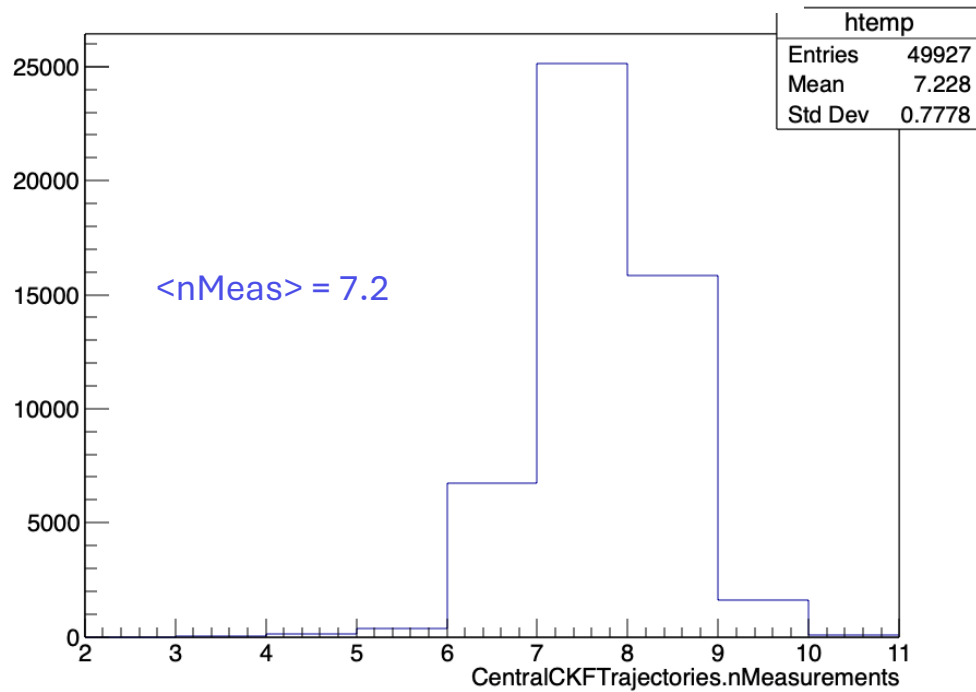
***Fast* Tracklet Reconstruction**

htemp	
Entries	16179
Mean	3.066
Std Dev	0.2474

<nMeas> = 3.1

CentralCKFTrajectories.nMeasurements
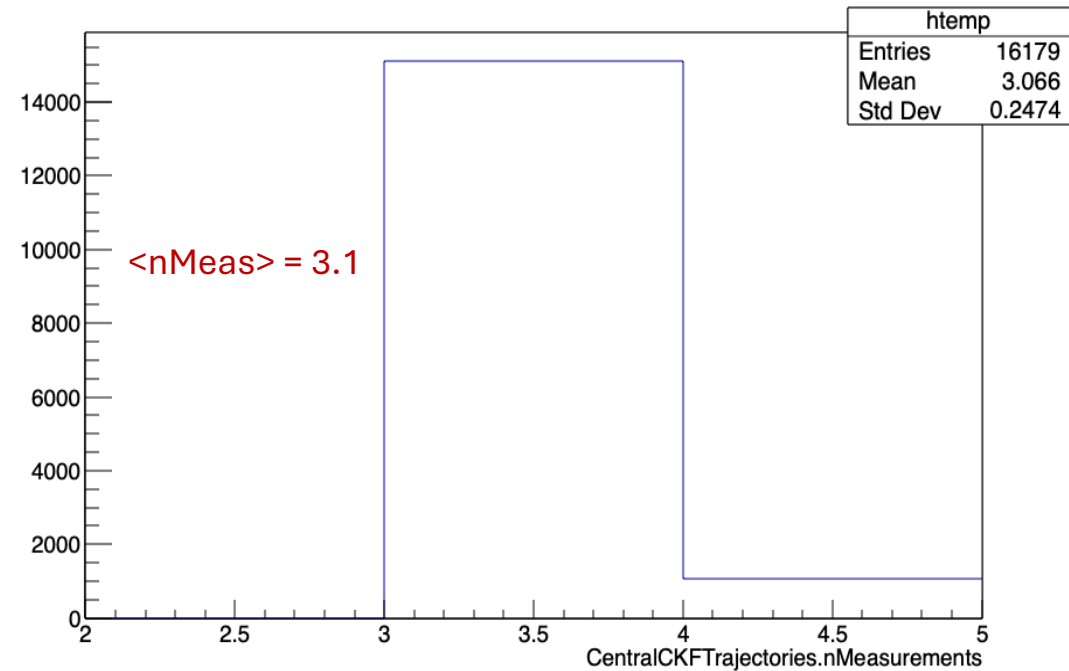
❑ Full track gives better momentum resolution at hpDIRC compared to *fast* tracklets

100*(DIRCproj.p-DIRChit.p)/DIRChit.p

Full Track
P = 1 GeV

Entries	49812
Mean	0.6285
Std Dev	0.7079
χ^2 / ndf	1379 / 90
Constant	8713 ± 53.2
Mean	0.583 ± 0.002
Sigma	0.4206 ± 0.0017

100*(DIRCproj.p-DIRChit.p)/DIRChit.p

Fast **Tracklet**
P = 1 GeV

Entries	8625
Mean	0.581
Std Dev	1.176
χ^2 / ndf	112.1 / 60
Constant	605.6 ± 8.4
Mean	0.568 ± 0.012
Sigma	1.102 ± 0.010
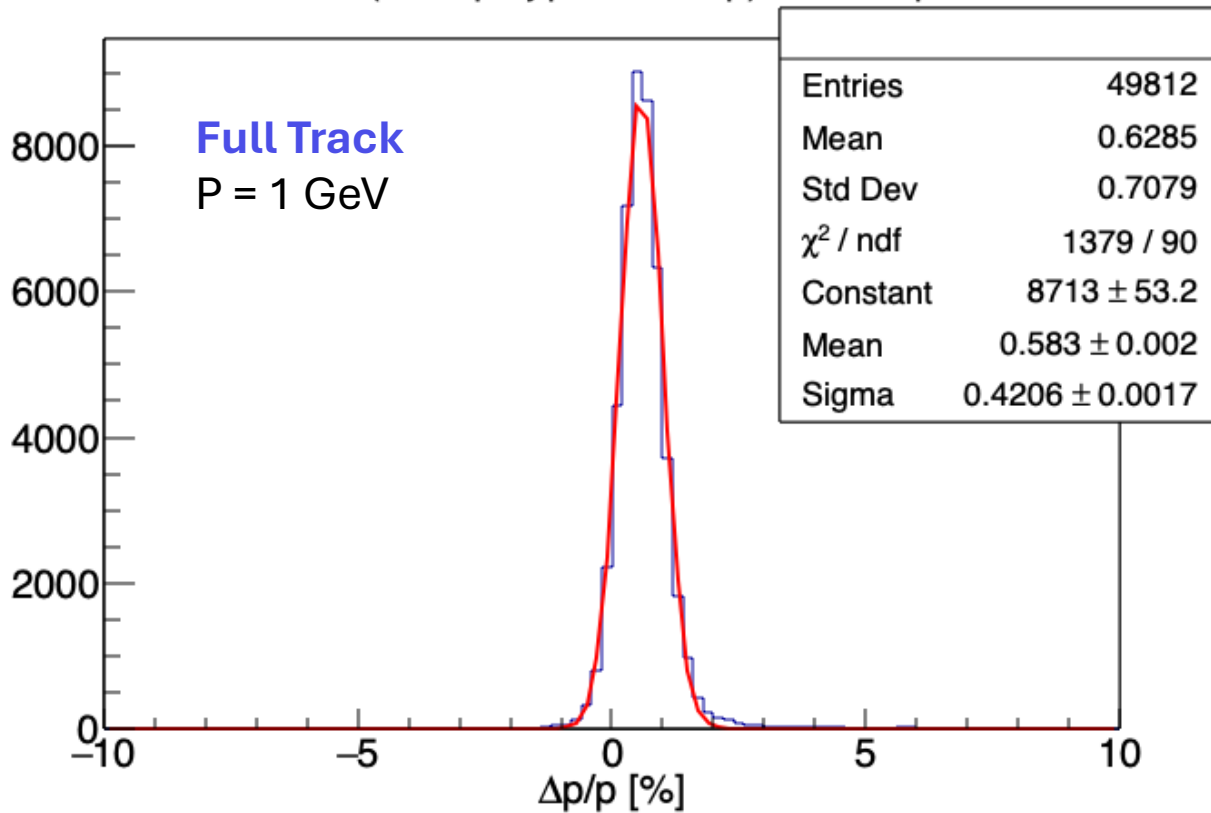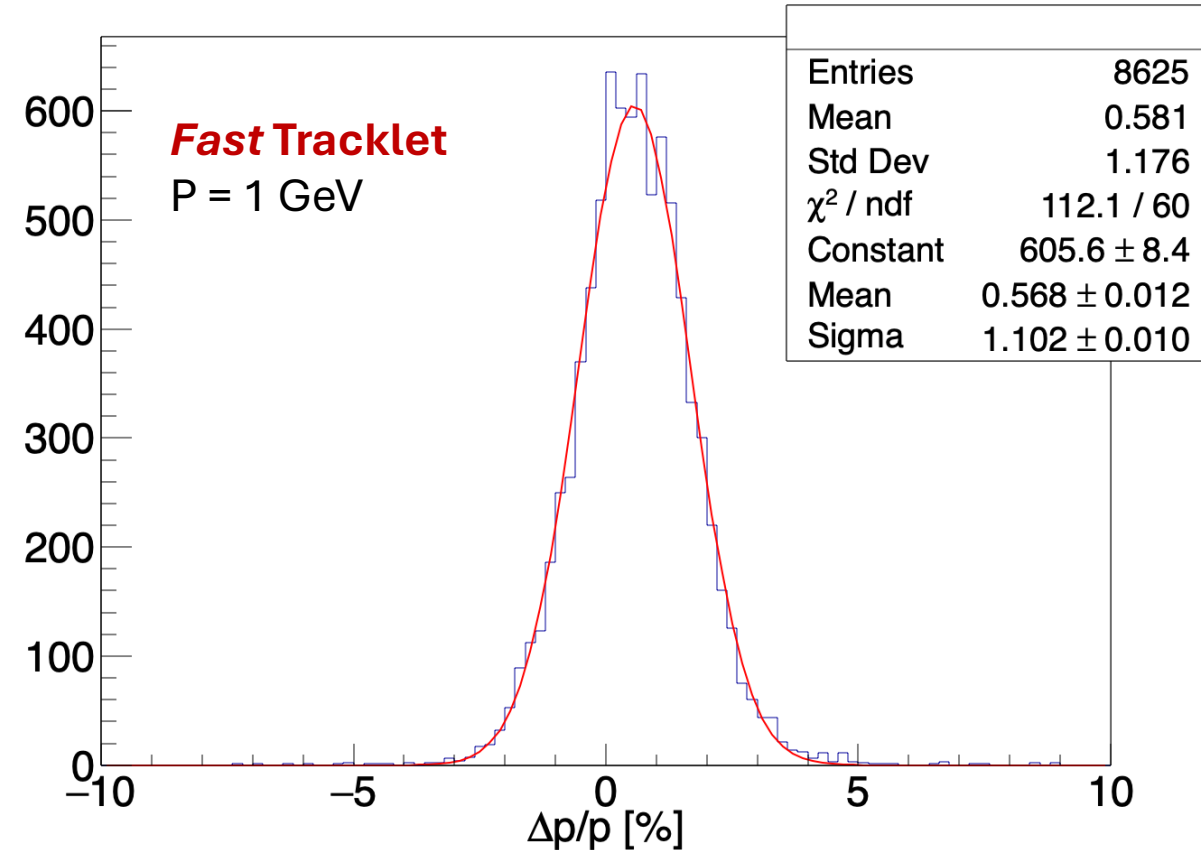
❑ Clear μRWELL-BOT spatial resolution impact seen in momentum resolution at hpDIRC seen in *fast* **tracklets**

100*(DIRCproj.p-DIRChit.p)/DIRChit.p
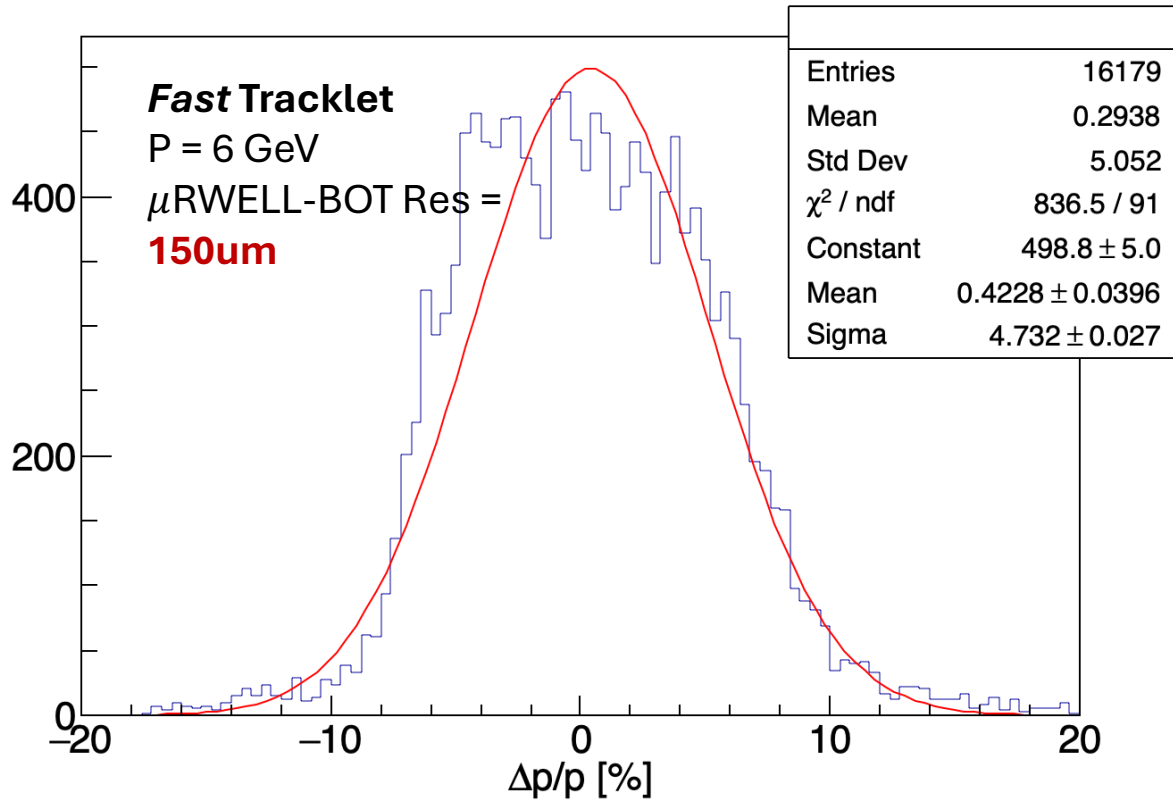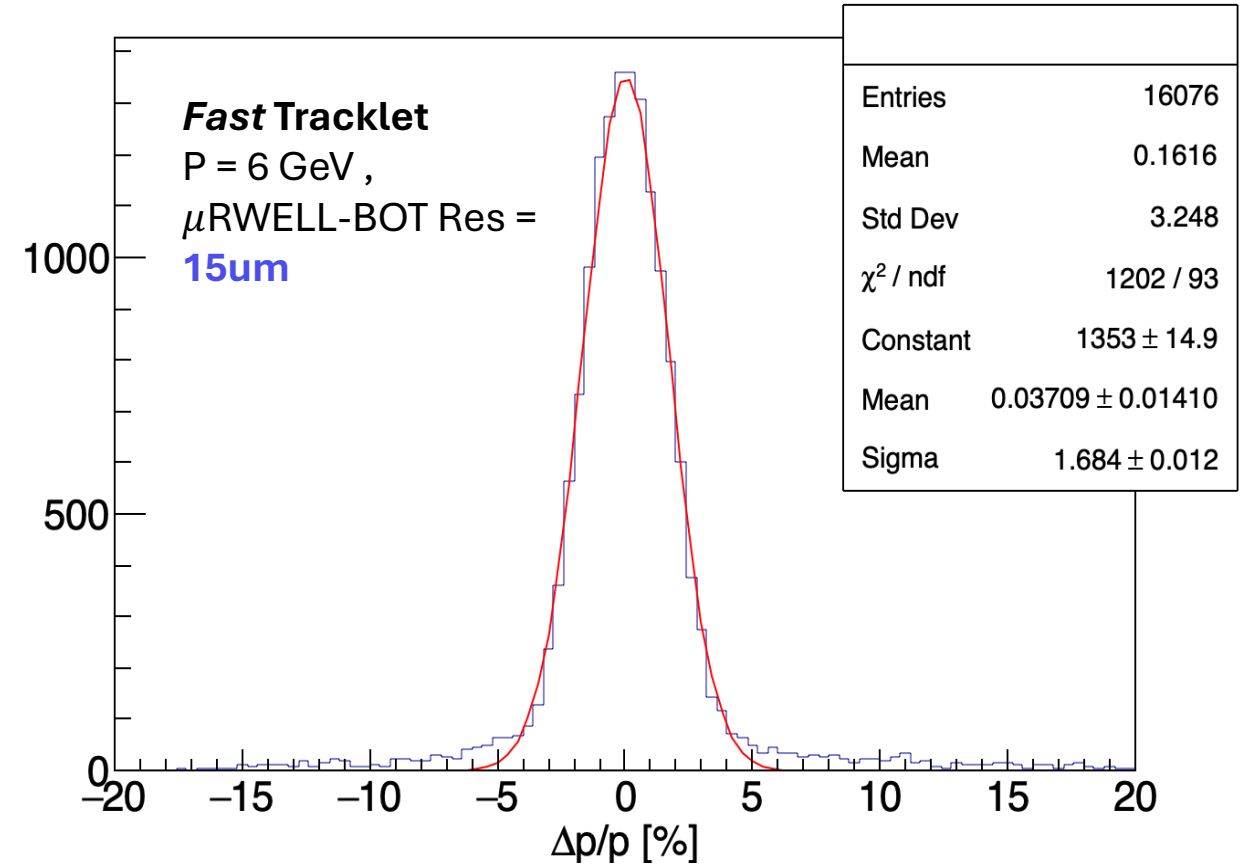
Fast Tracklet
P = 6 GeV
μRWELL-BOT Res =
150um

Entries	16179
Mean	0.2938
Std Dev	5.052
χ^2 / ndf	836.5 / 91
Constant	498.8 ± 5.0
Mean	0.4228 ± 0.0396
Sigma	4.732 ± 0.027

100*(DIRCproj.p-DIRChit.p)/DIRChit.p

Fast Tracklet
P = 6 GeV ,
μRWELL-BOT Res =
15um

Entries	16076
Mean	0.1616
Std Dev	3.248
χ^2 / ndf	1202 / 93
Constant	1353 ± 14.9
Mean	0.03709 ± 0.01410
Sigma	1.684 ± 0.012

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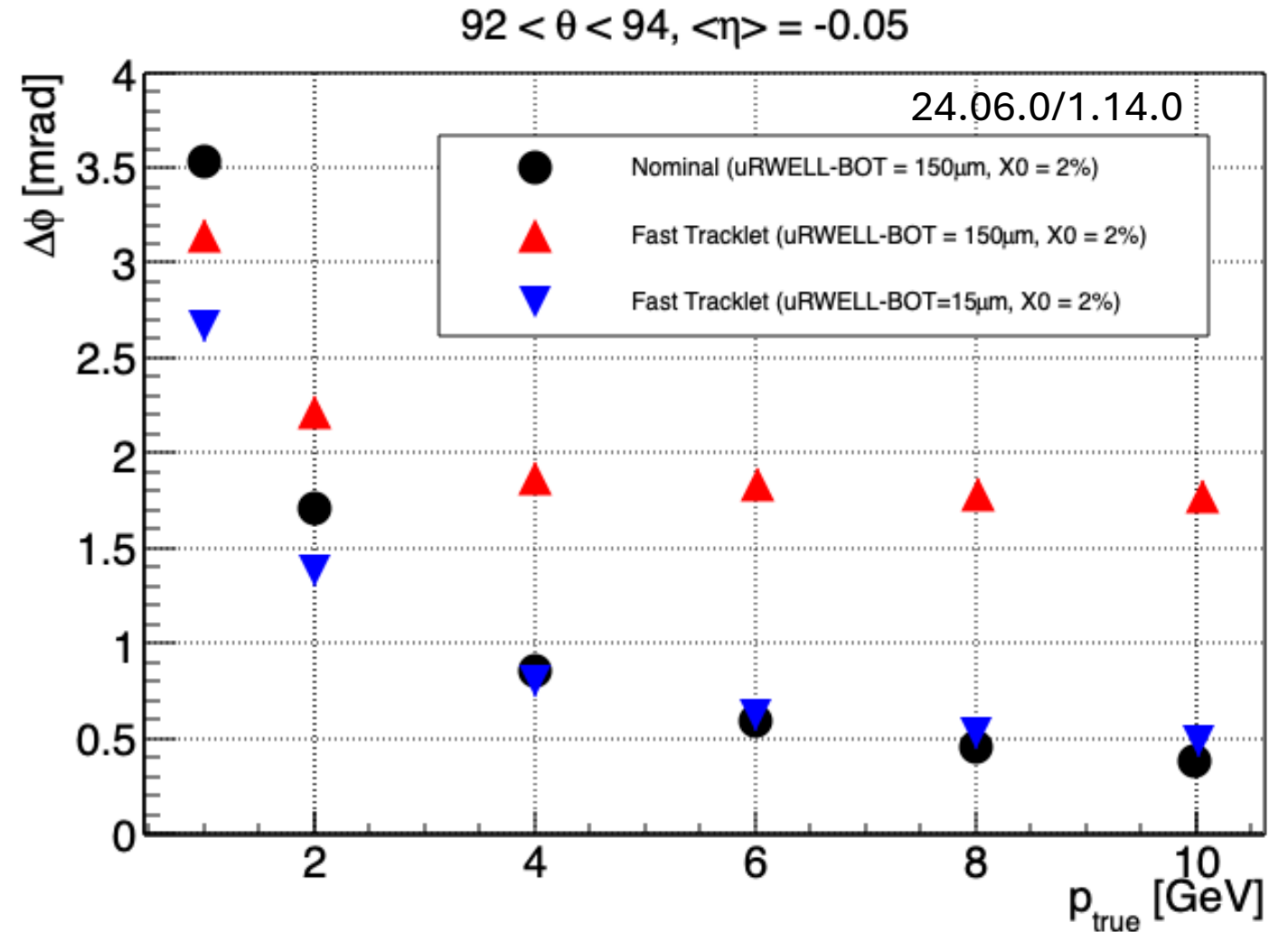
- **Spatial resolution**

- μRWELL-BOT Material

$92 < \theta < 94$, $<\eta> = -0.05$

☐ Slight sensitivity to μRWELL-BOT spatial resolution seen in *fast* tracklets

☐ Improved angular resolution in *fast* traklets at low momentum (p < ~3 GeV)

☐ Full track provides better angular resolution at p > ~3 GeV

24.06.0/1.14.0

- ● Nominal (uRWELL-BOT = 150μm, X0 = 2%)
- ▲ Fast Tracklet (uRWELL-BOT = 150μm, X0 = 2%)
- ▼ Fast Tracklet (uRWELL-BOT=15μm, X0 = 2%)

$\Delta\theta$ [mrad]

p_{true} [GeV]

- ❏ Large sensitivity to μRWELL-BOT spatial resolution seen in *fast* tracklets

- ❏ Improved angular resolution in *fast* traklets (150 μm) at low momentum (p < ~2 GeV)

- ❏ Full track (150 μm) provides better angular resolution at p > ~2 GeV

$92 < \theta < 94$, $<\eta> = -0.05$

24.06.0/1.14.0

- ● Nominal (uRWELL-BOT = 150µm, X0 = 2%)
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$\Delta\phi$ [mrad]

p_{true} [GeV]

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- ▪ Spatial resolution

- ▪ **μRWELL-BOT Material**

Angular Resolutions with *Fast* Tracklets

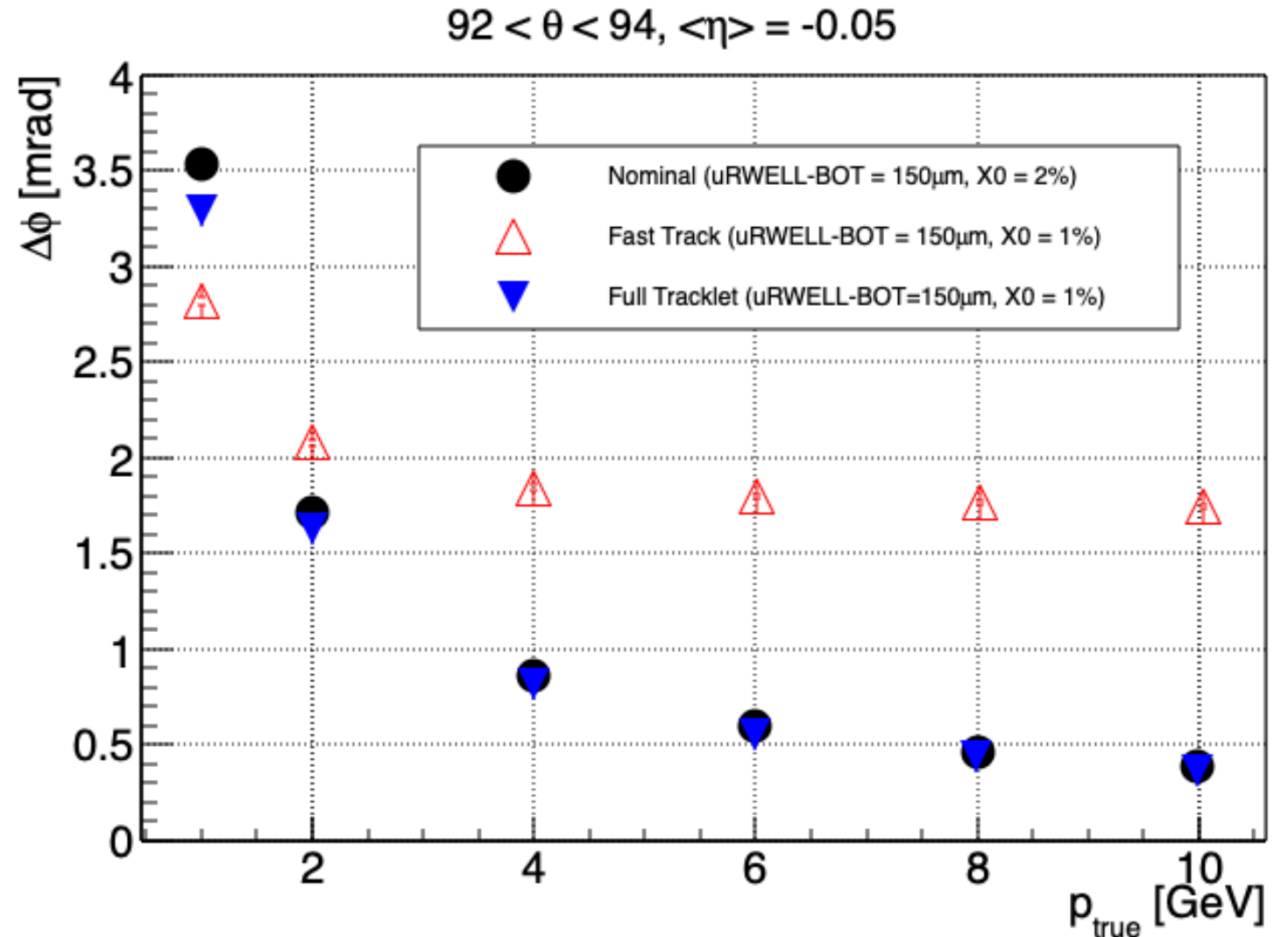□ Improved angular resolution in *fast* traklets at low momentum (p < ~3 GeV)

□ Full track provides better angular resolution at p > ~3 GeV

□ Slight improvement in angular resolution when reducing μRWELL-BOT material budget from ~2% → 1%

  ▪ Mainly at low momentum

$92 < \theta < 94, <\eta> = -0.05$

Legend:
- Nominal (uRWELL-BOT = 150μm, X0 = 2%)
- Fast Track (uRWELL-BOT = 150μm, X0 = 1%)
- Full Tracklet (uRWELL-BOT=150μm, X0 = 1%)

Angular Resolutions with *Fast* Tracklets
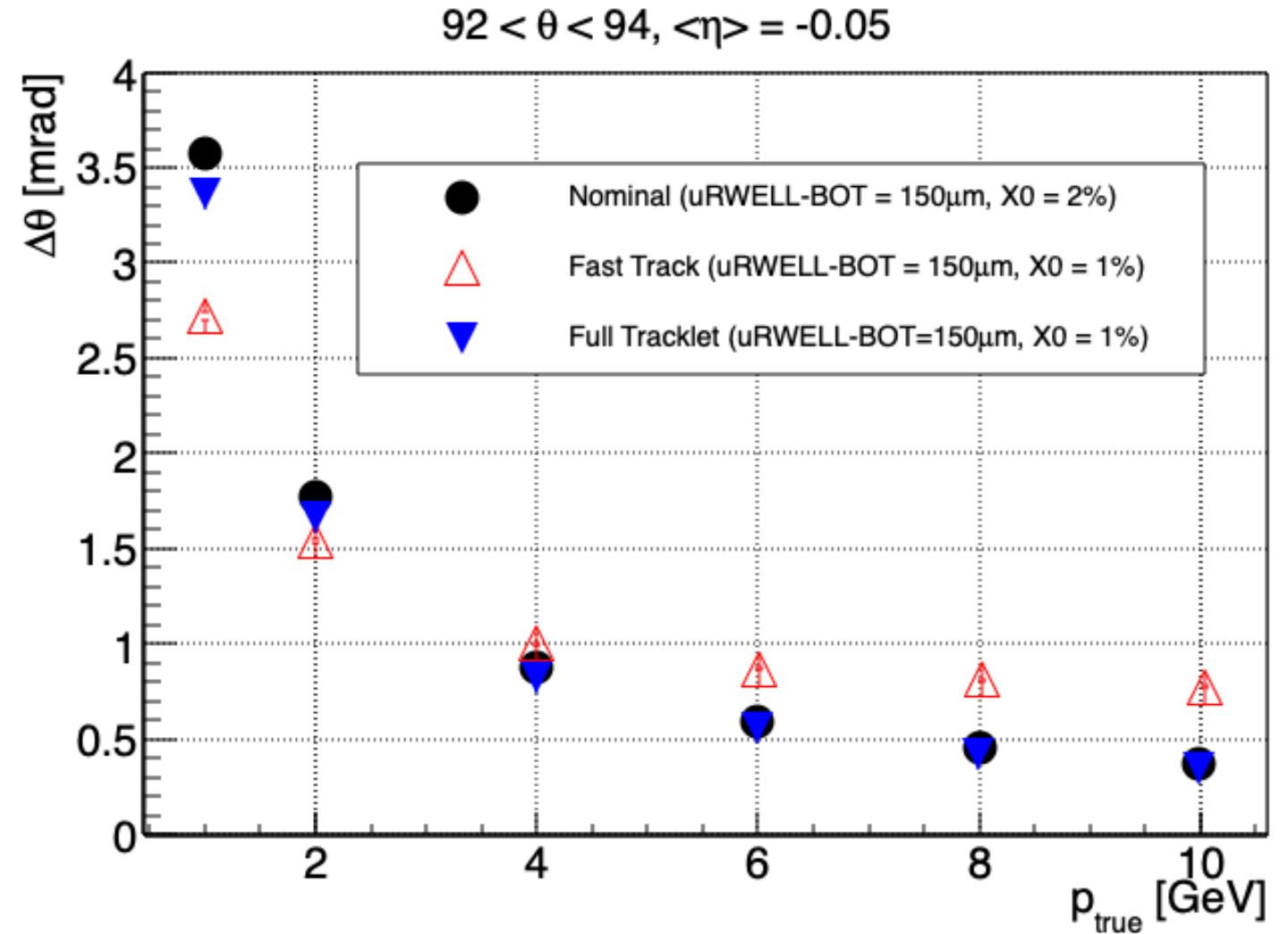
- [ ] Improved angular resolution in *fast* traklets (150 μm) at low momentum (p < ~2 GeV)
- [ ] Full track (150 μm) provides better angular resolution at p > ~2 GeV
- [ ] Slight improvement in angular resolution when reducing μRWELL-BOT material budget from ~2% → 1%
    - Mainly at low momentum

$92 < \theta < 94$, $\langle\eta\rangle = -0.05$

Legend:
- Nominal (uRWELL-BOT = 150μm, X0 = 2%)
- Fast Track (uRWELL-BOT = 150μm, X0 = 1%)
- Full Tracklet (uRWELL-BOT=150μm, X0 = 1%)

Summary

- ❑ Materials

    - ▪ Significant degradation in angular resolutions at low momentum from central barrel support cylinder

- ❑ *Fast* Tracklets

    - ▪ Sensitivity to μRWELL-BOT spatial resolution seen in angular resolutions

        - ➢ Much larger impact in ϕ than θ

    - ▪ Provide better angular performance at low momentum ($p \sim 1\ GeV$), then full track performance is better

    - ▪ Reduction of μRWELL-BOT material from $\chi_0 = 2\% \rightarrow 1\%$ leads better performance around $p \sim 1\ GeV$, then change becomes negligible