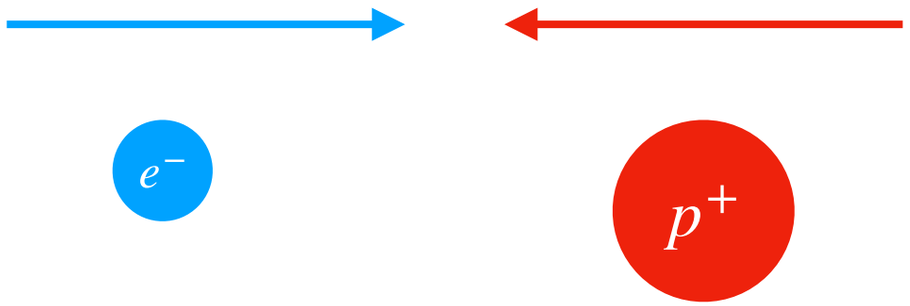
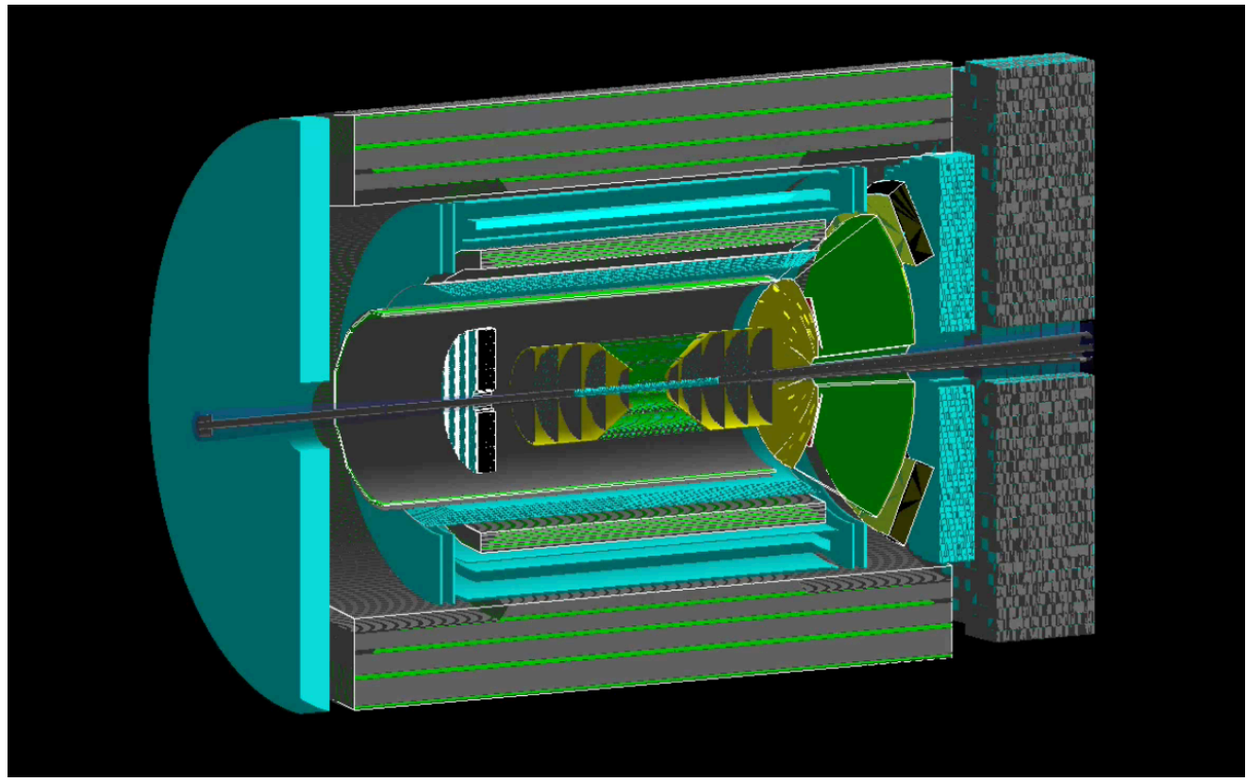
Jets in e+P PYTHIA Simulation in Fun4All



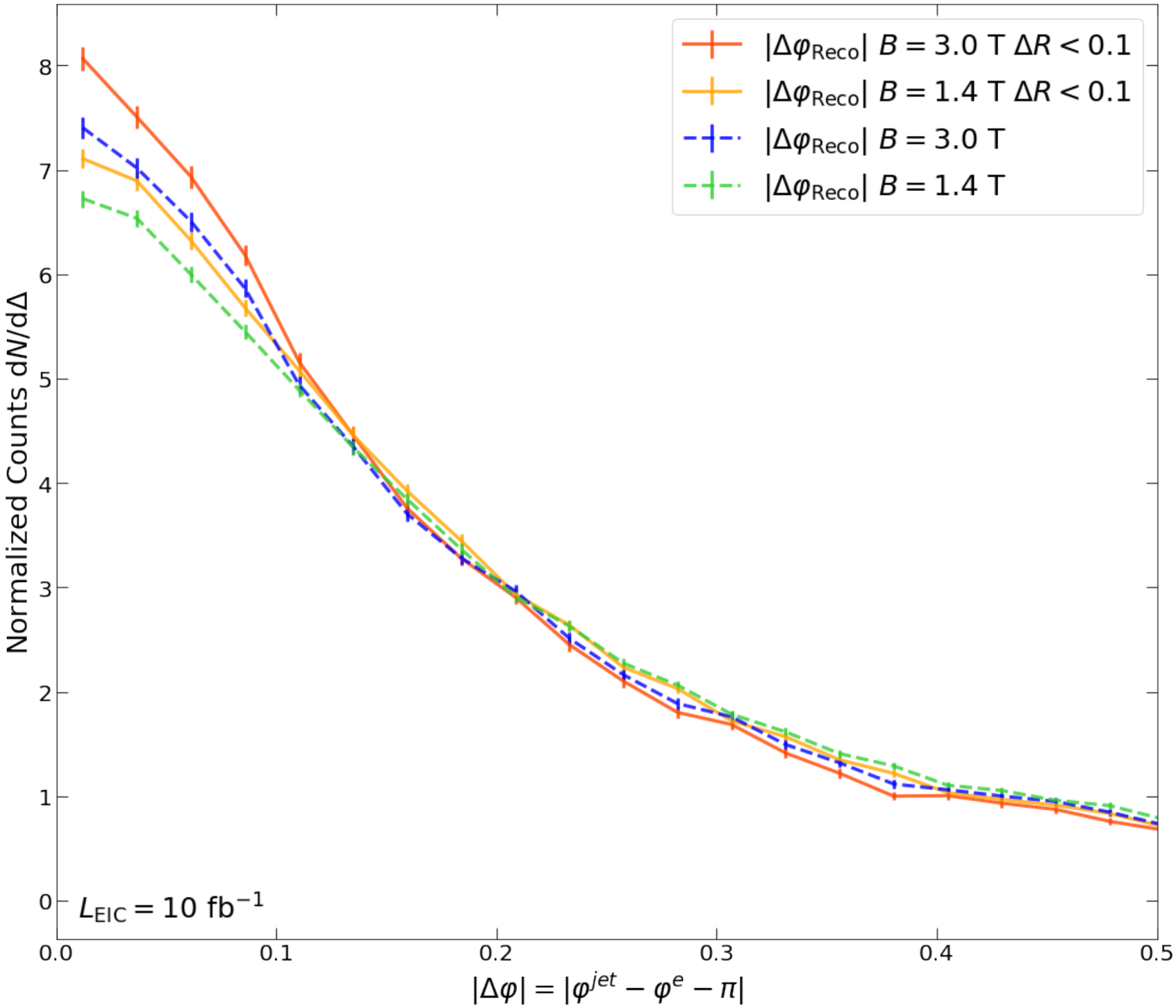


- PYTHIA 8
  - $Q^2_{\min} \geq 16$ (GeV/c^2)^2
  - $\sqrt{s} = 89$ GeV
  - Electron beam: 20 GeV
  - Proton beam: 100 GeV
- Jets
  - Charged Jets
  - $E^{\text{Jet}}_{\text{Reco}} > 4.0$ GeV
  - “Truth” = Particle Level
  - Anti-k_{T} $R = 1.0$
  - ΔR (jet-electron) > 0.5
    - “Electron Veto”
- Jet Constituents
  - $N_{\text{constituents}} \geq 4$
  - $p^{\text{constituent}} \geq 60$ MeV/c
  - η-dependent $p_{\text{T}}^{\text{constituent}}$ cut
  - Cut $1.06 < |\eta| < 1.13$
    - Central barrel meets forward layers

What's New

- Changing Reco-Truth Jet matching criteria from Fun4All to geometric matching (ΔR)
- Resolved bug in neutral jet constituent subtraction (previously reported)
  - Subtract 4-vector of neutral constituent from particle-level truth jets
  - Required for comparisons to *Charged Truth Jets*

Reco-Truth Jet Matching

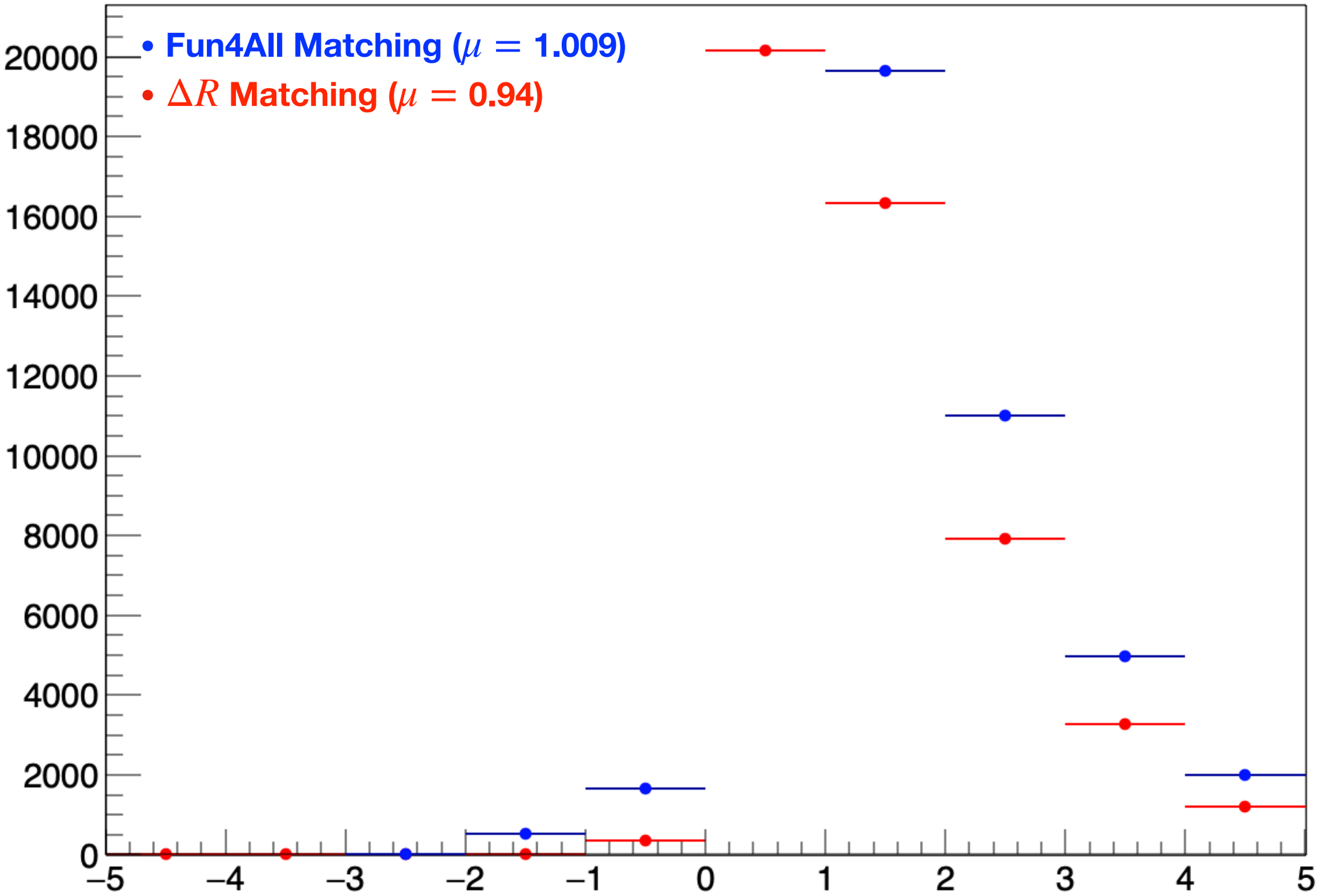


- Fun4All:
  1. Loop through reco constituents (tracks)
  2. Find truth particle associated with track
  3. If particle makes up a truth jet, matched
  4. Omit non-unique matches

- $\Delta R < 0.1$
  - Check to see if there is a change to the final observable
  - “Standard”: at least is easier to interpret

***Note: Reco Jets without a match are skipped**

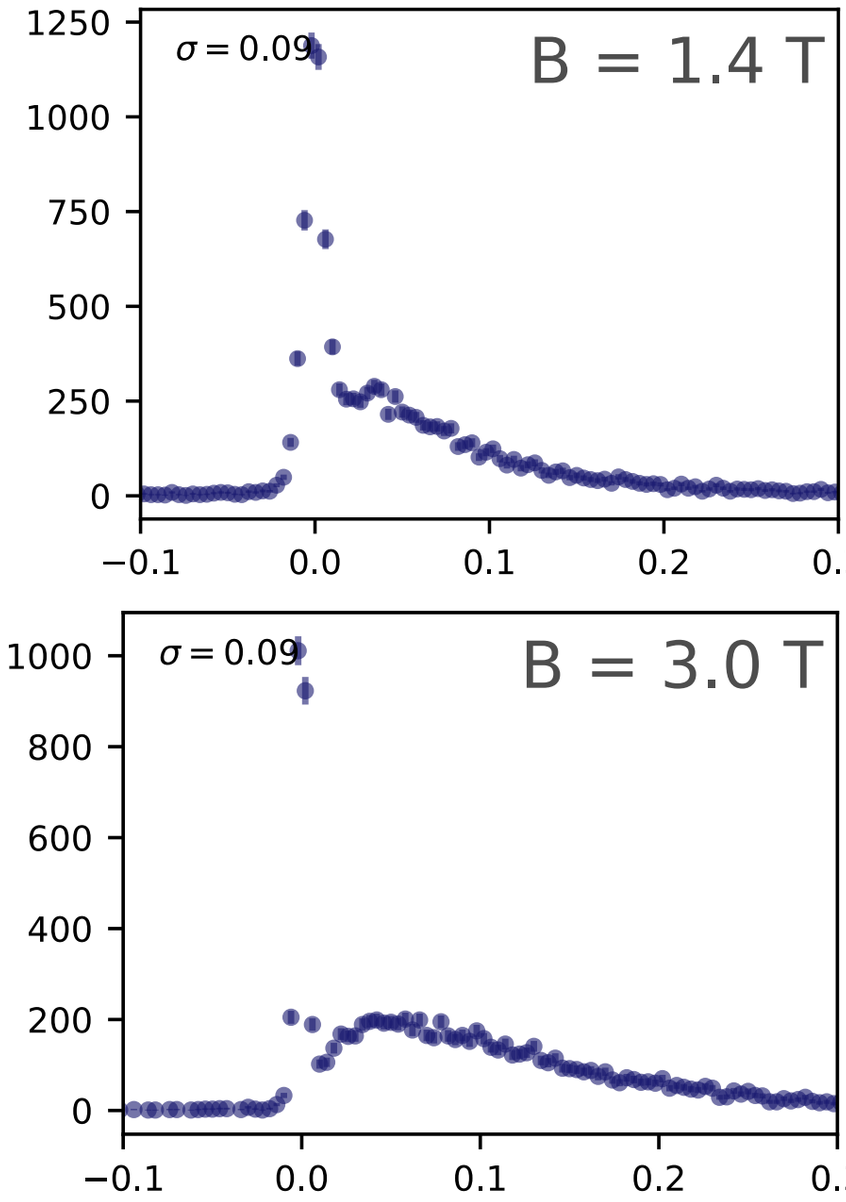
Number of Missed Constituents ($N_{\text{Truth}} - N_{\text{Reco}} - N_{\text{Neutral}}$)



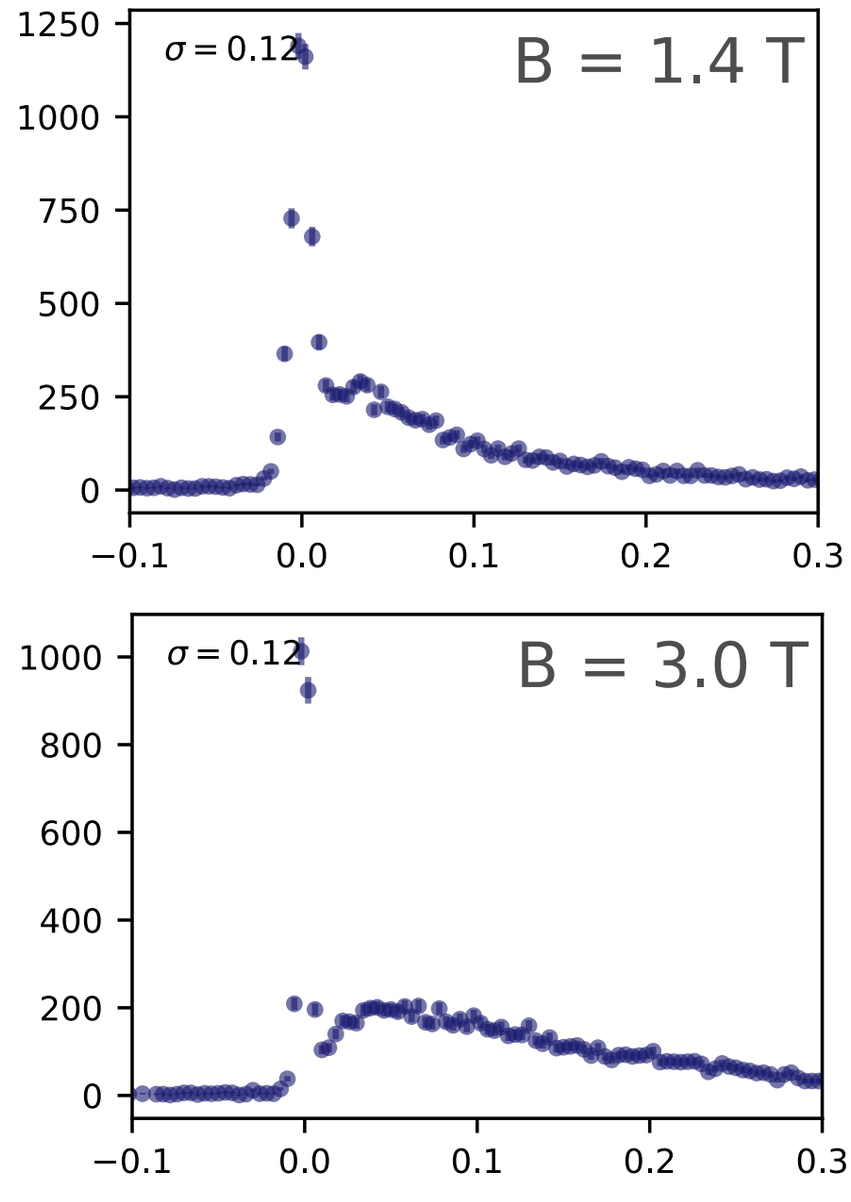
Slightly lower number of missed constituents

Momentum Resolution Example

$\Delta R < 0.1$



Fun4All Matching

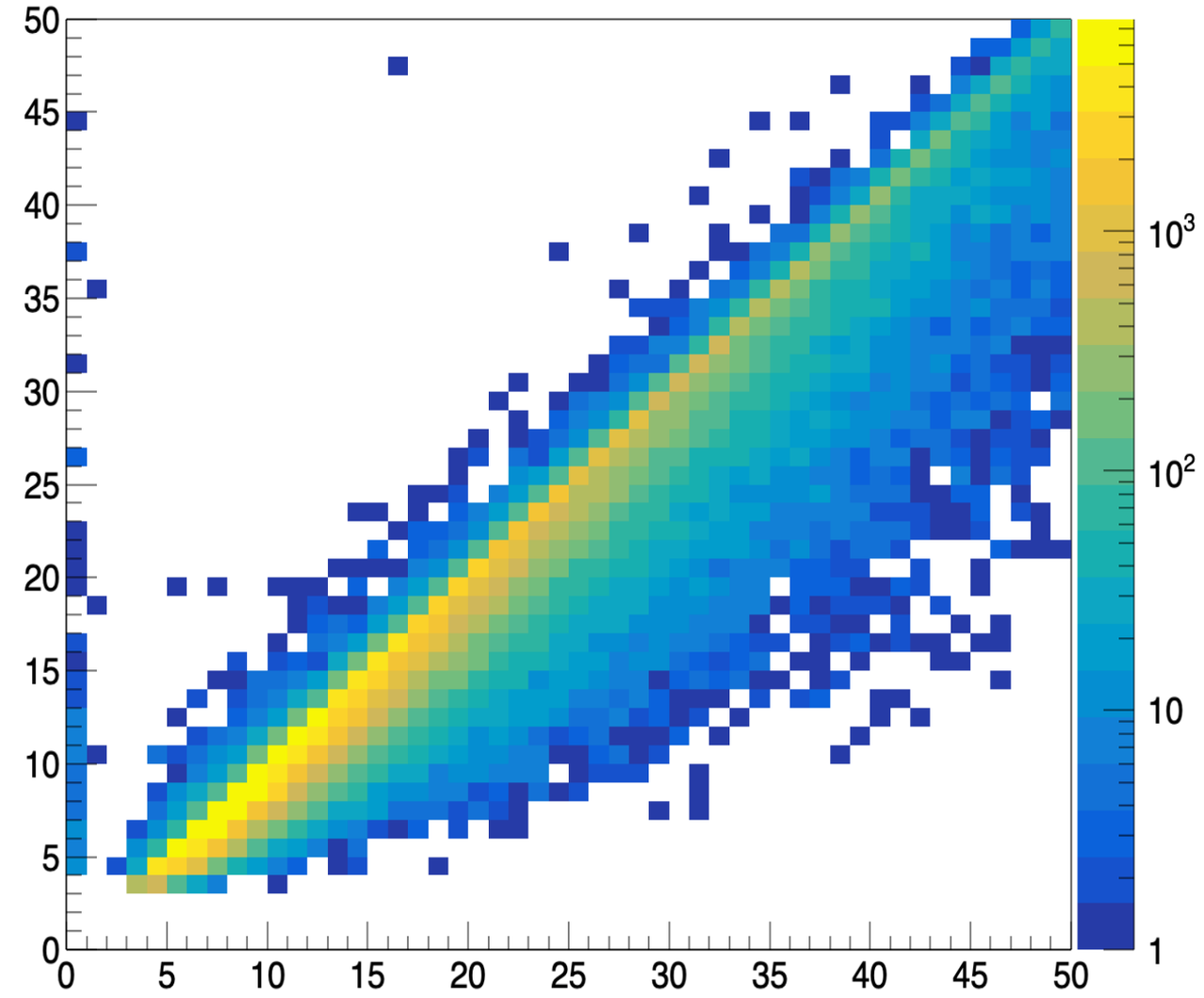


- **Standard deviation changes**
- **Narrow peak is unaffected**

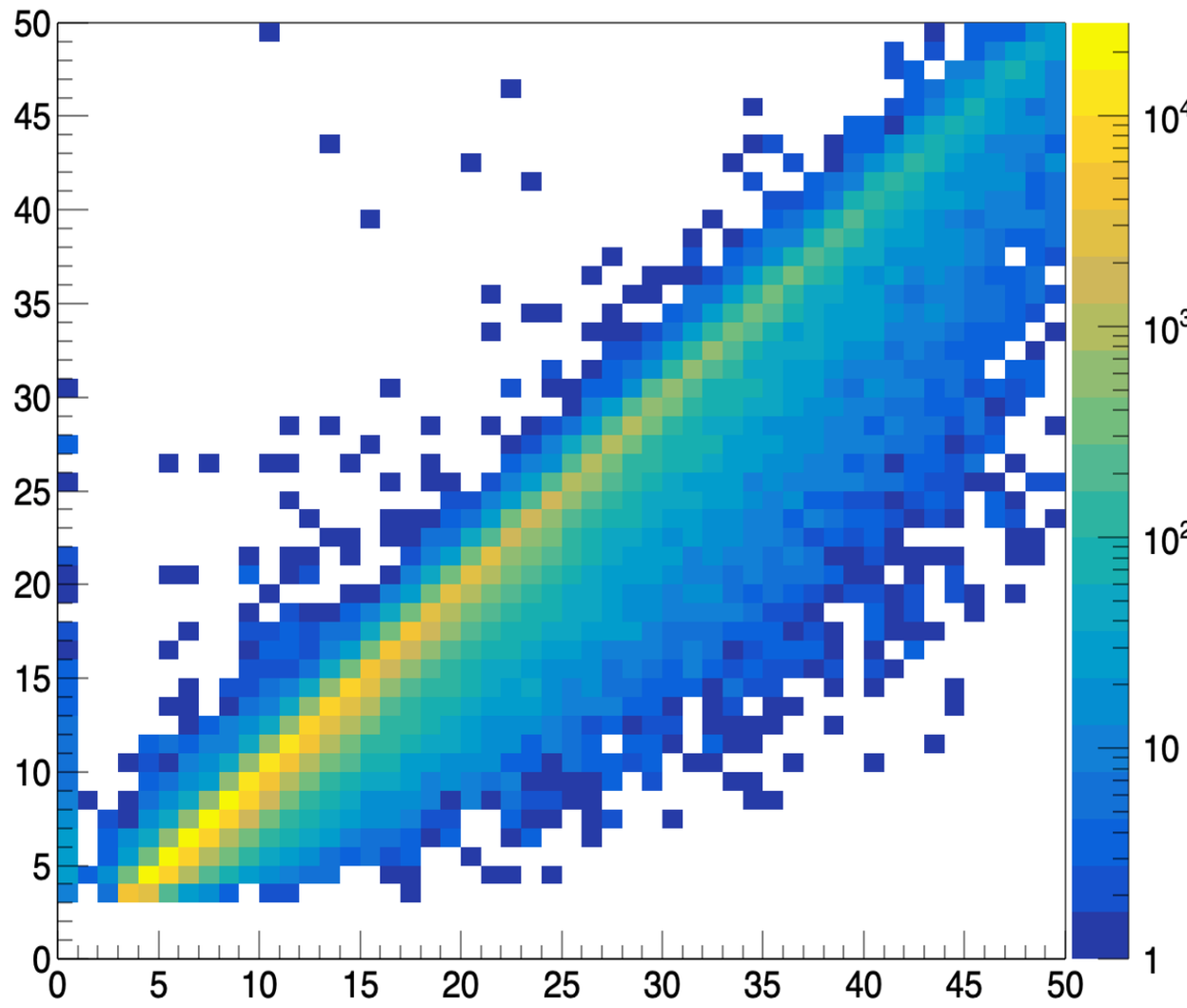
Updating Performance Plots

Charged Jet Momentum Response

$B = 3.0$ T



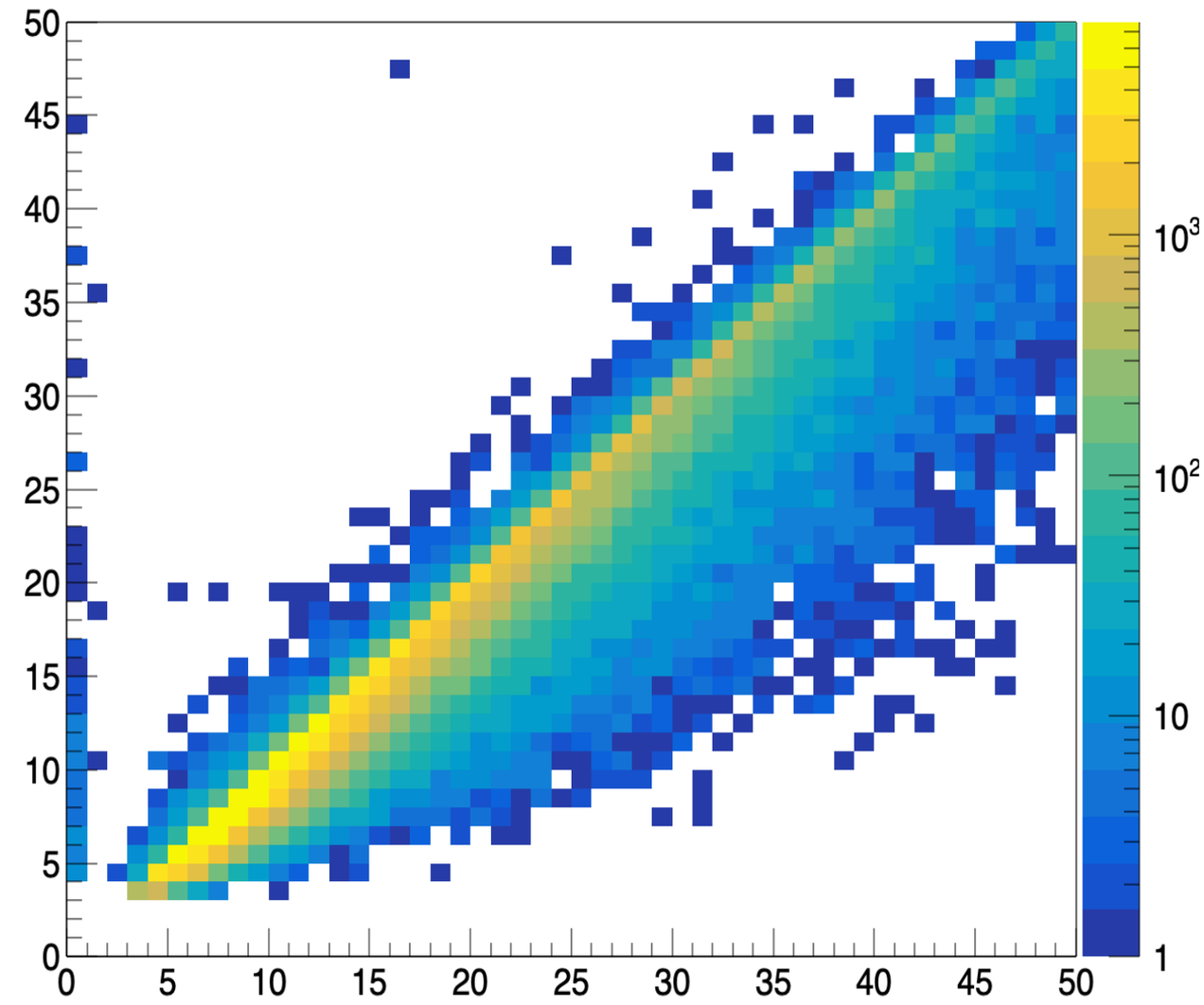
$B = 1.4$ T



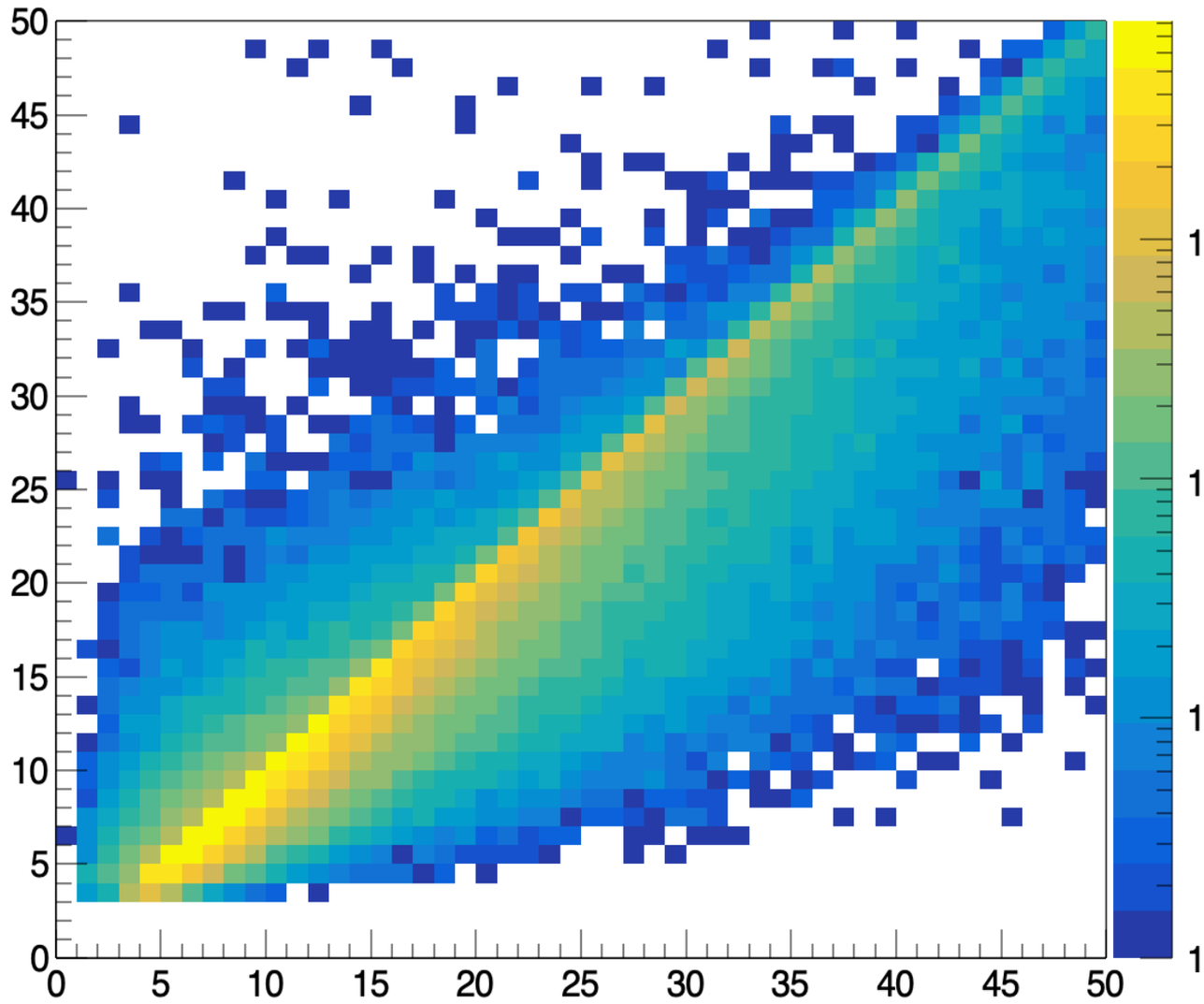
Clear Truth-Reco correlation, but with significant number of off-diagonal hits
See momentum resolution example for small differences

Comparing Momentum Response (B=3.0 T)

$\Delta R < 0.1$

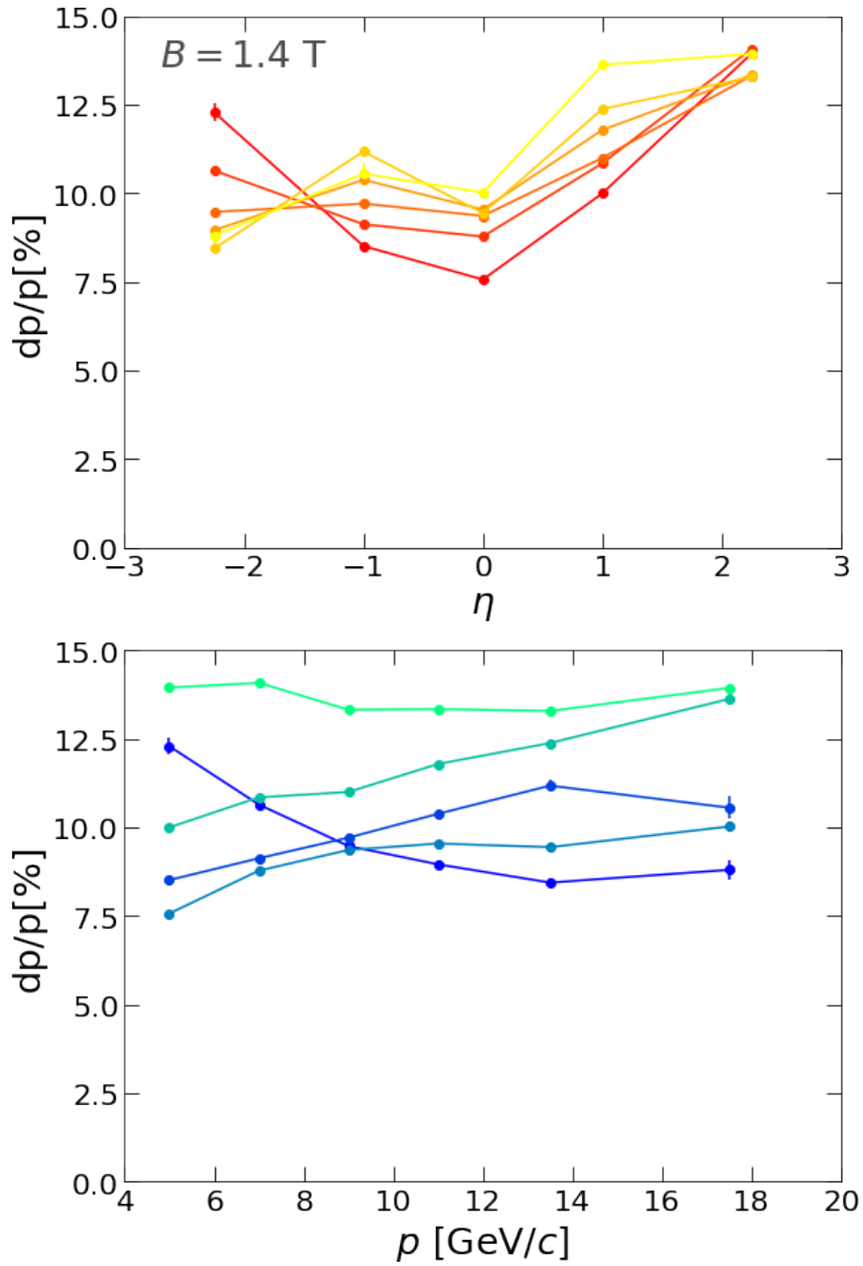


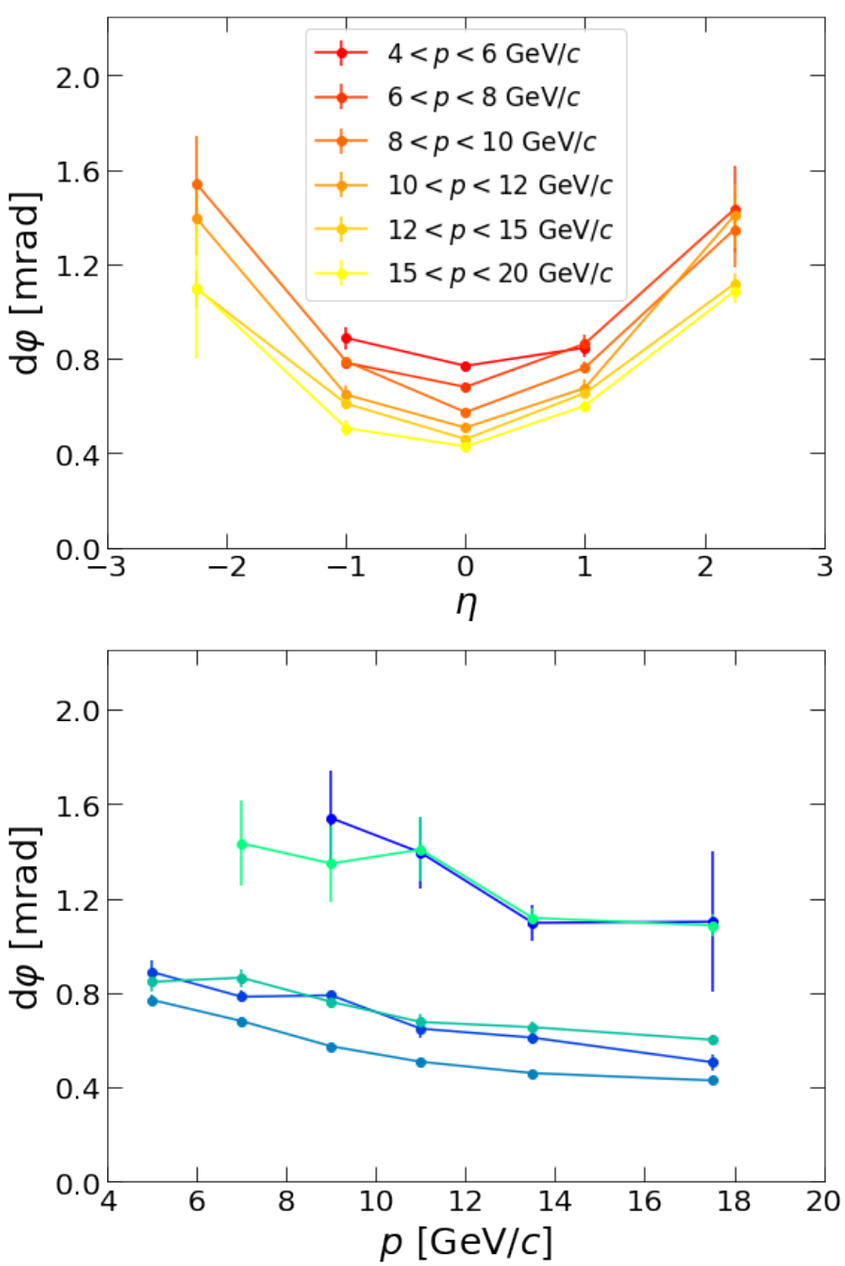
Fun4All Matching

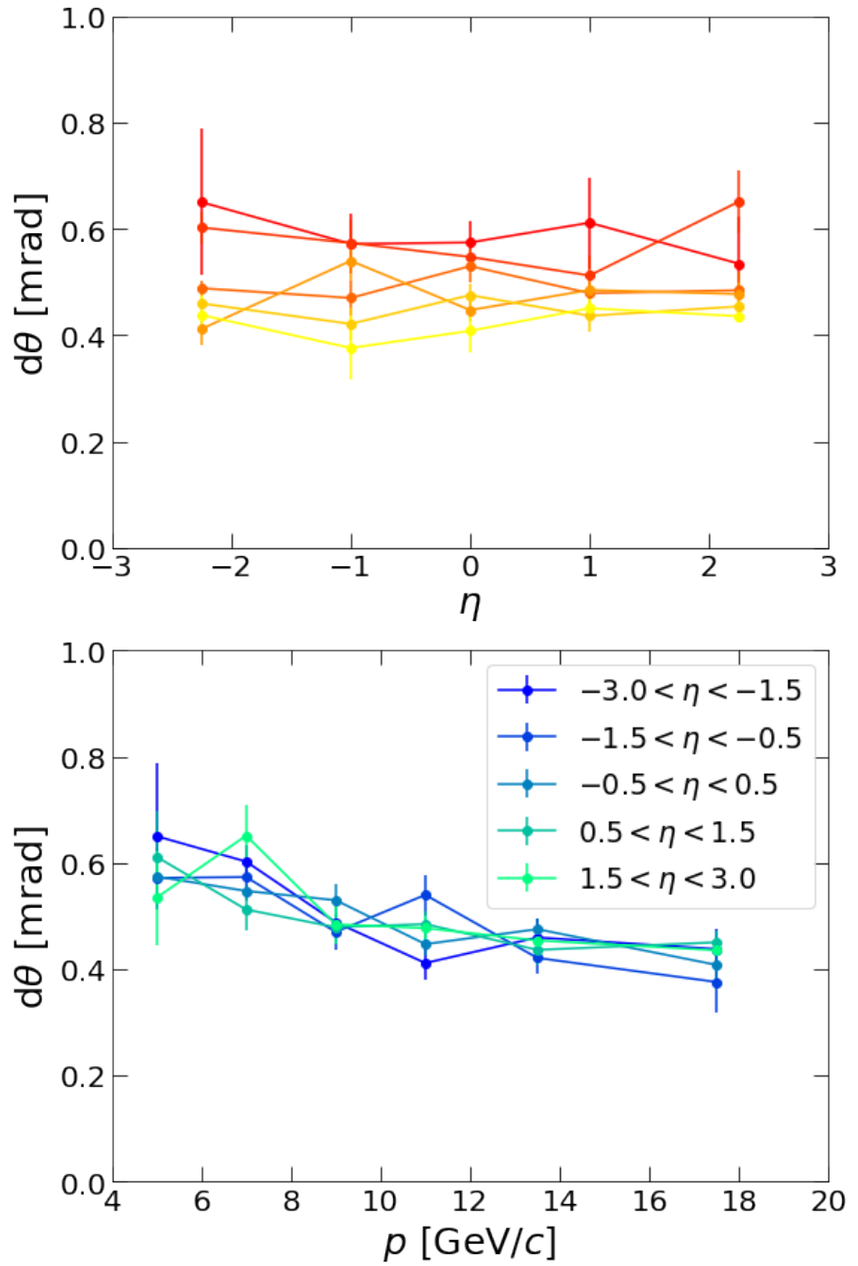


Reduced off diagonal component with new matching
See momentum resolution example for smaller differences

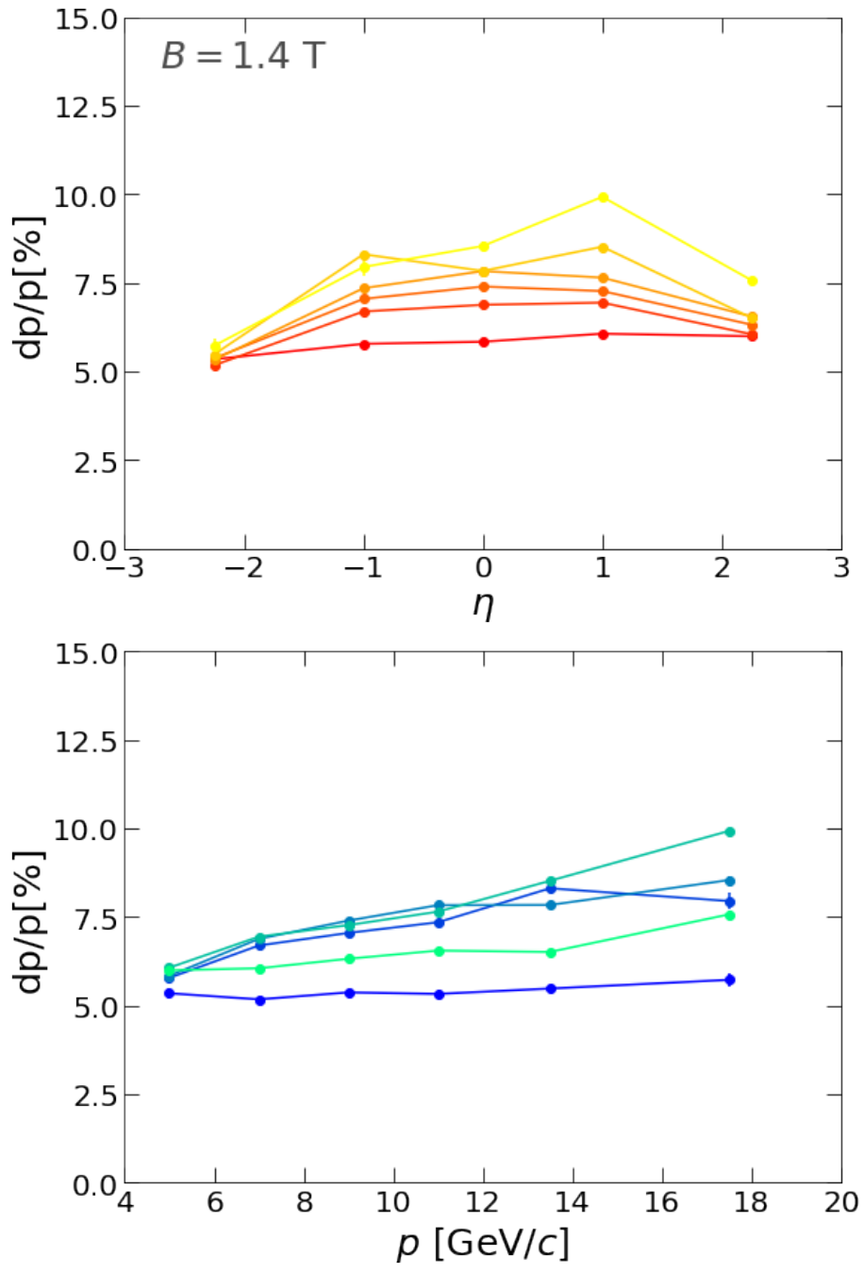
Fun4All Matching B = 1.4 T

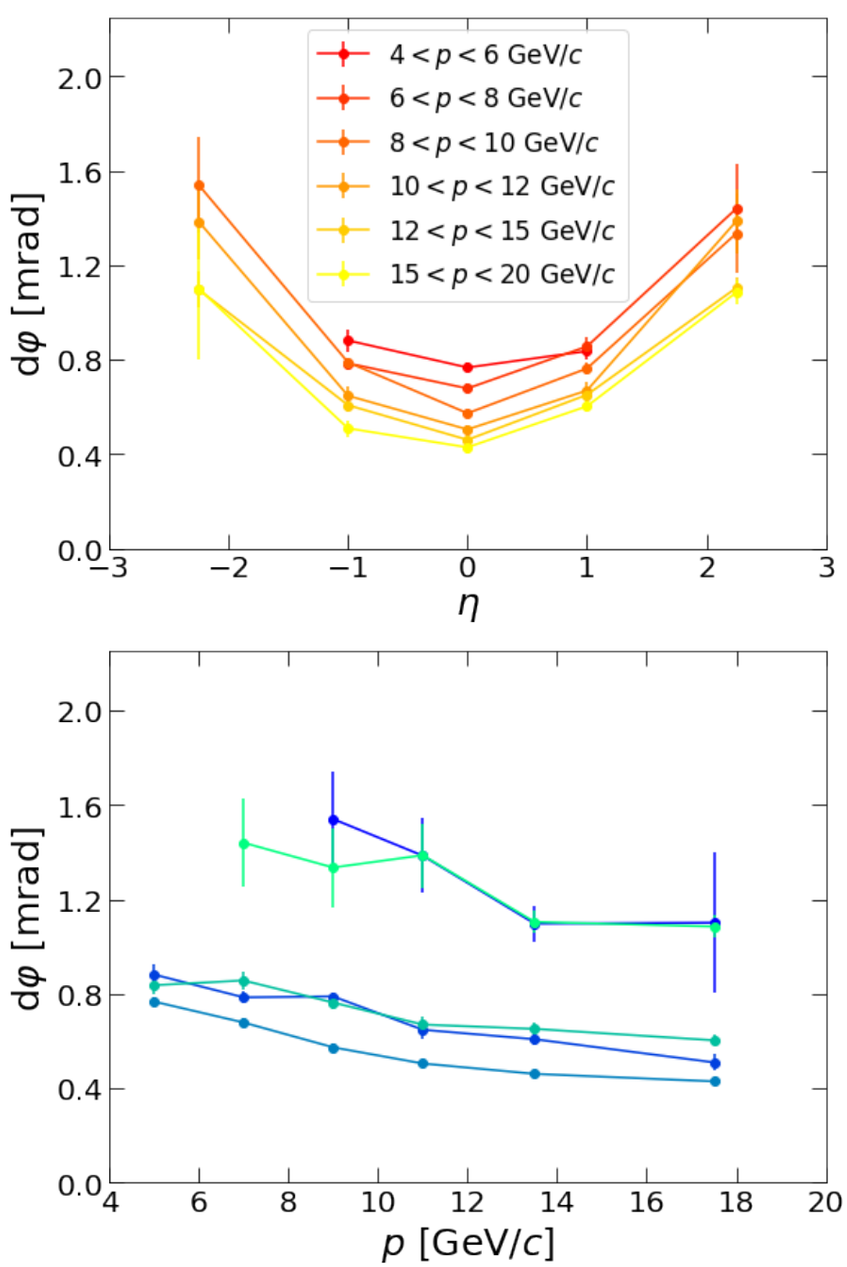


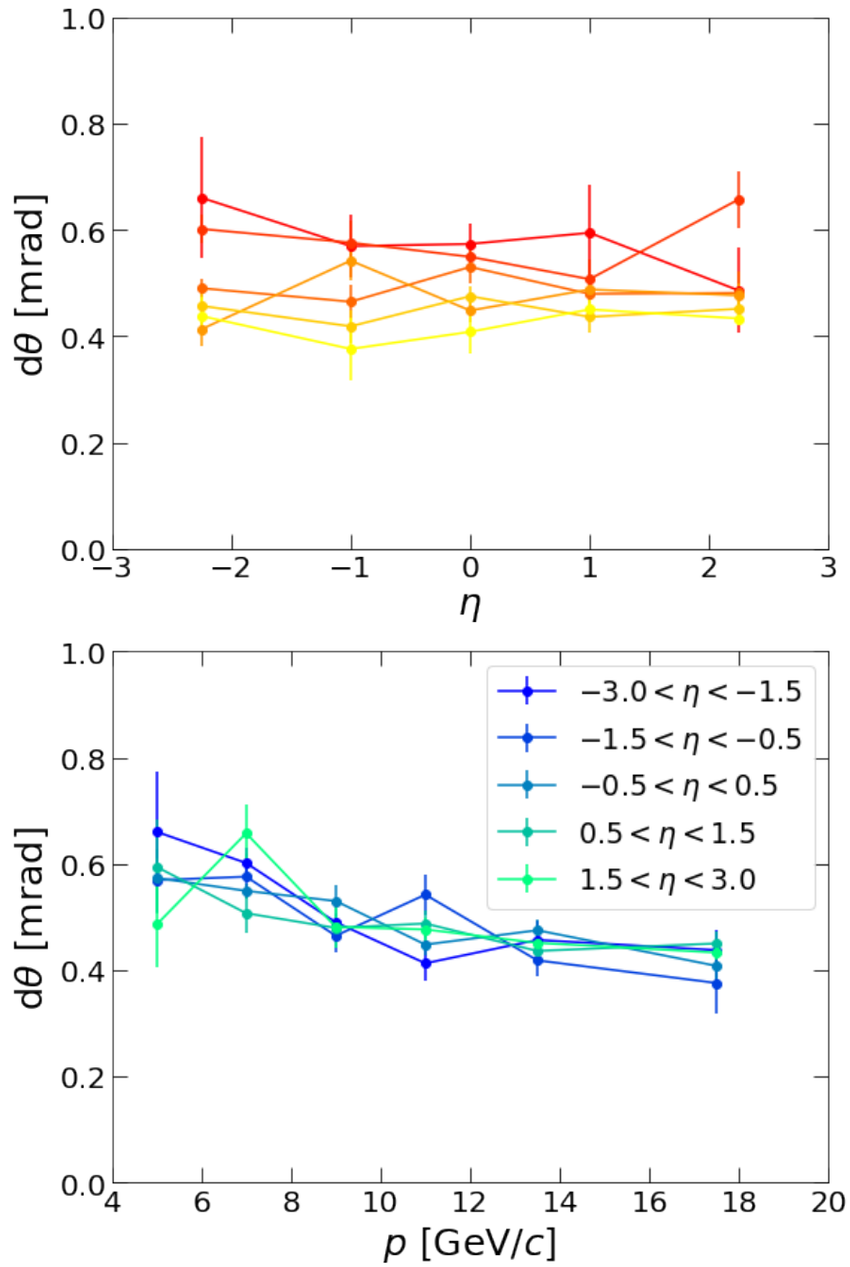




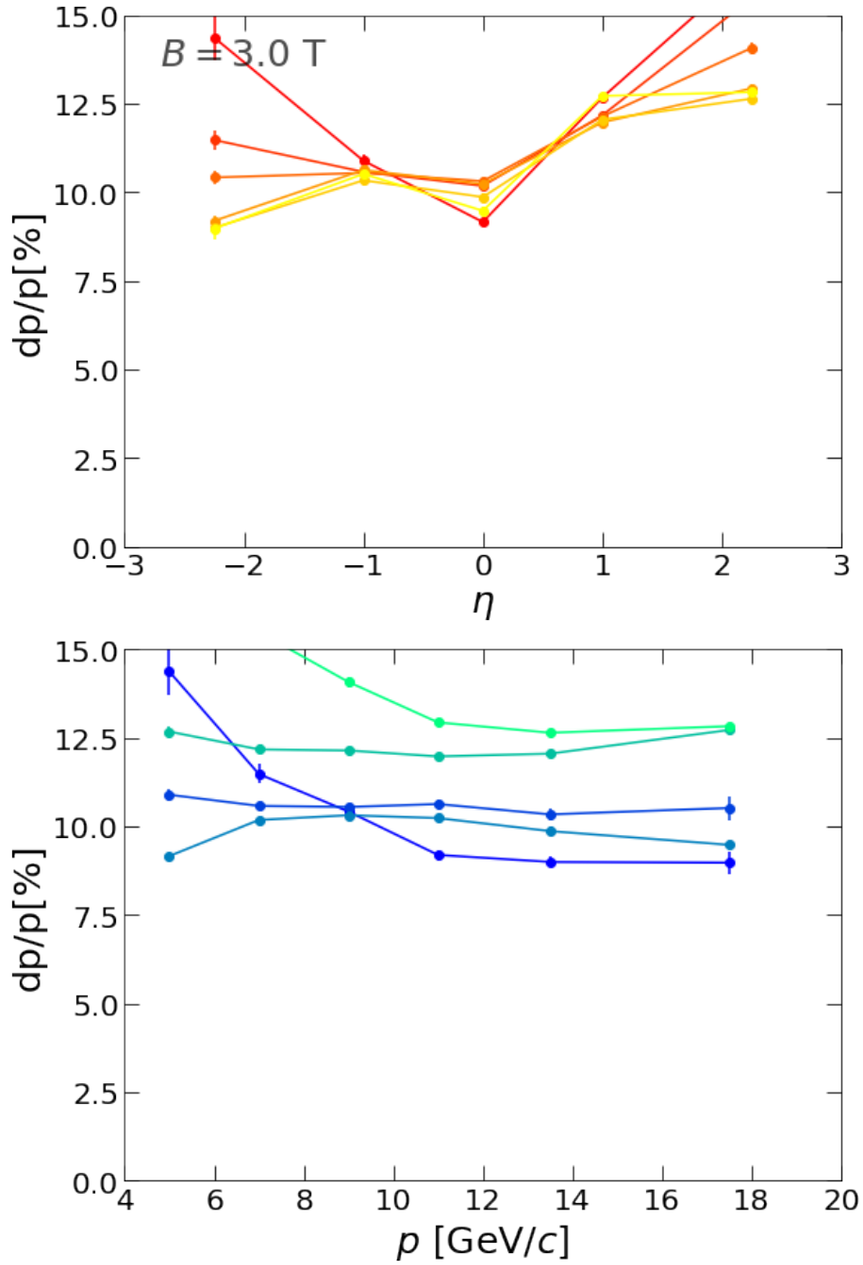
$\Delta R < 0.1$ Matching B =1.4 T

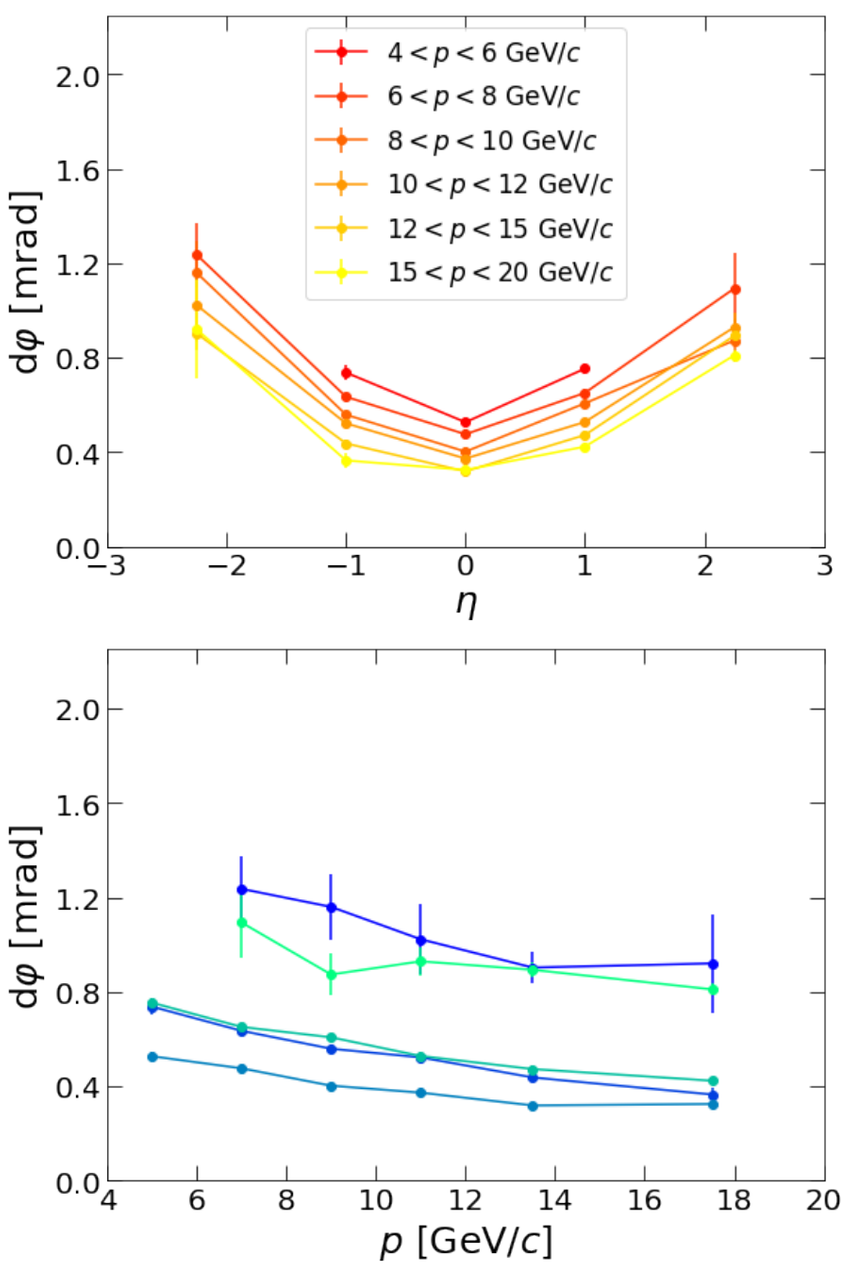


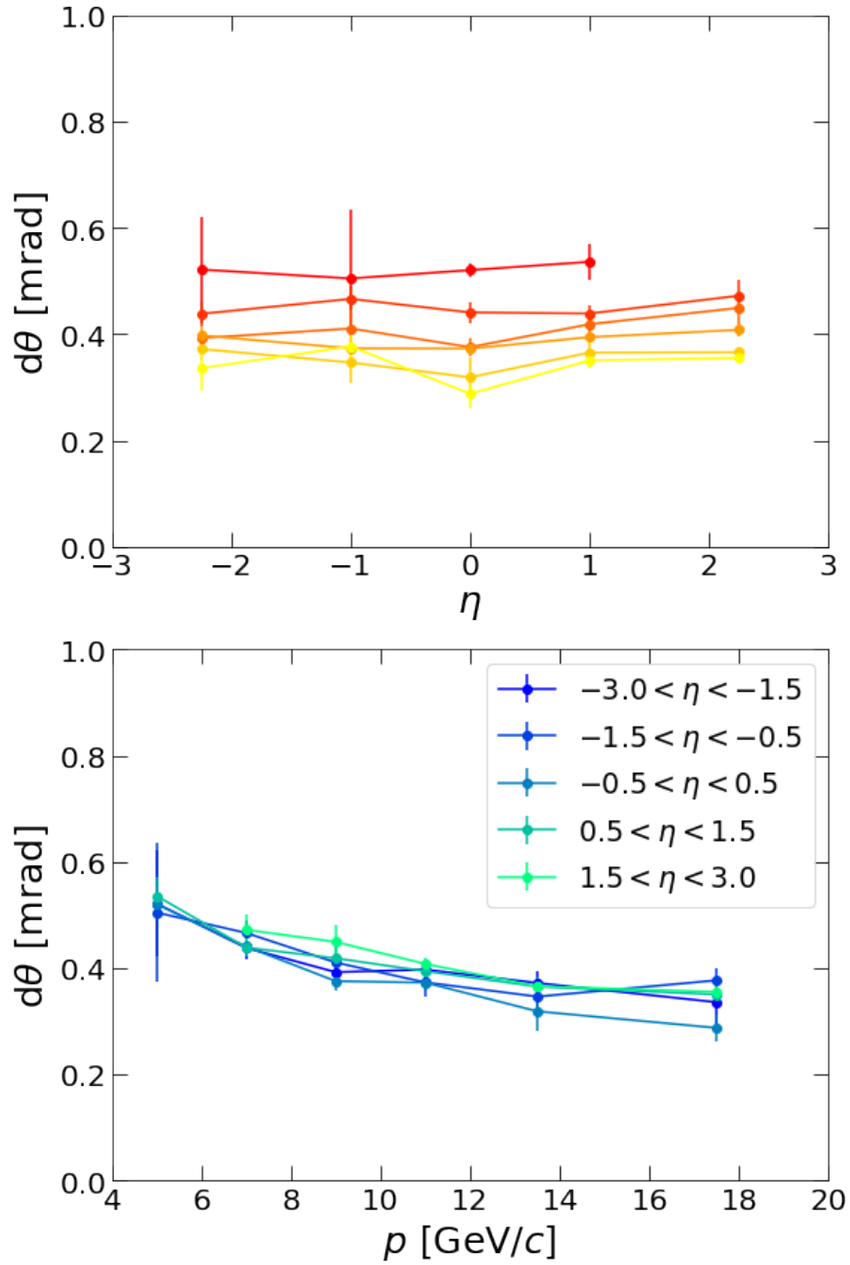




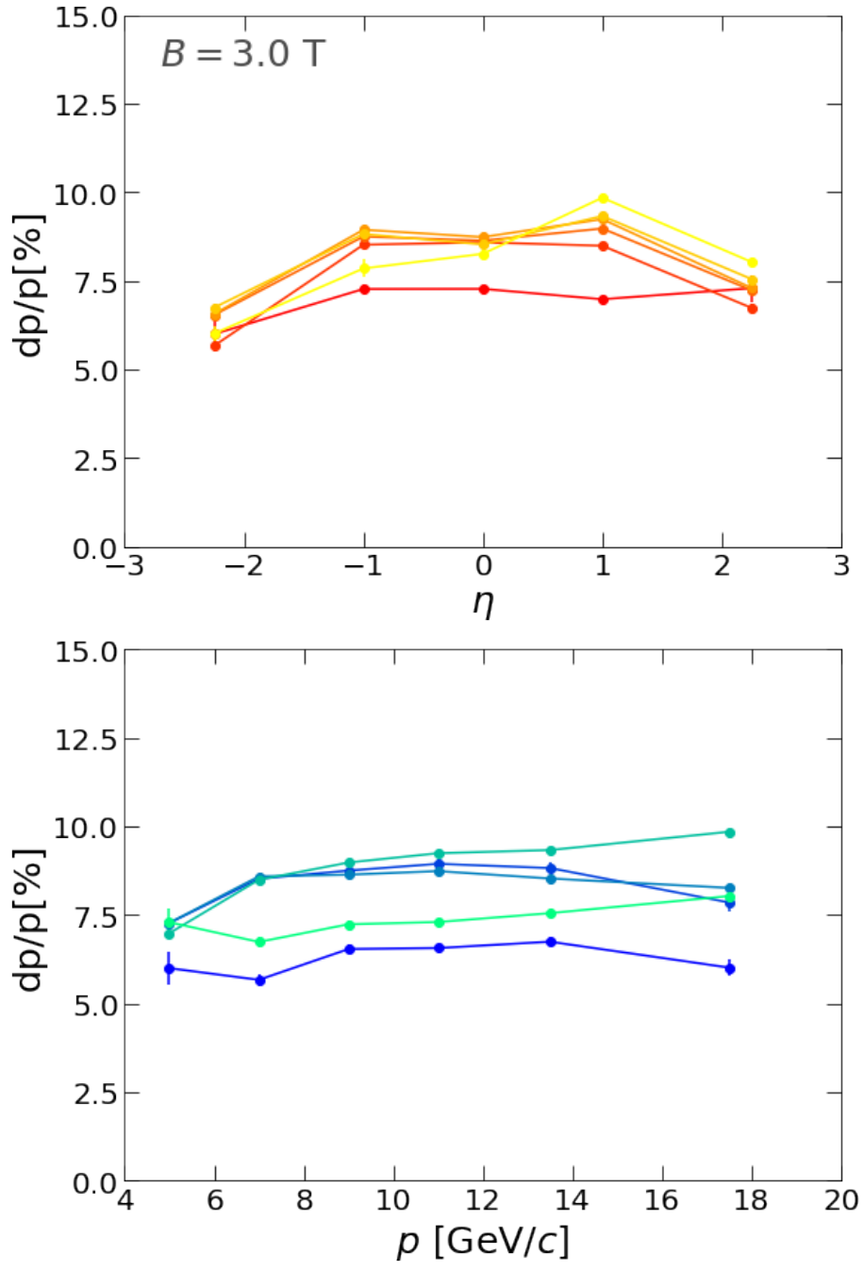
Fun4All Matching B = 3.0 T

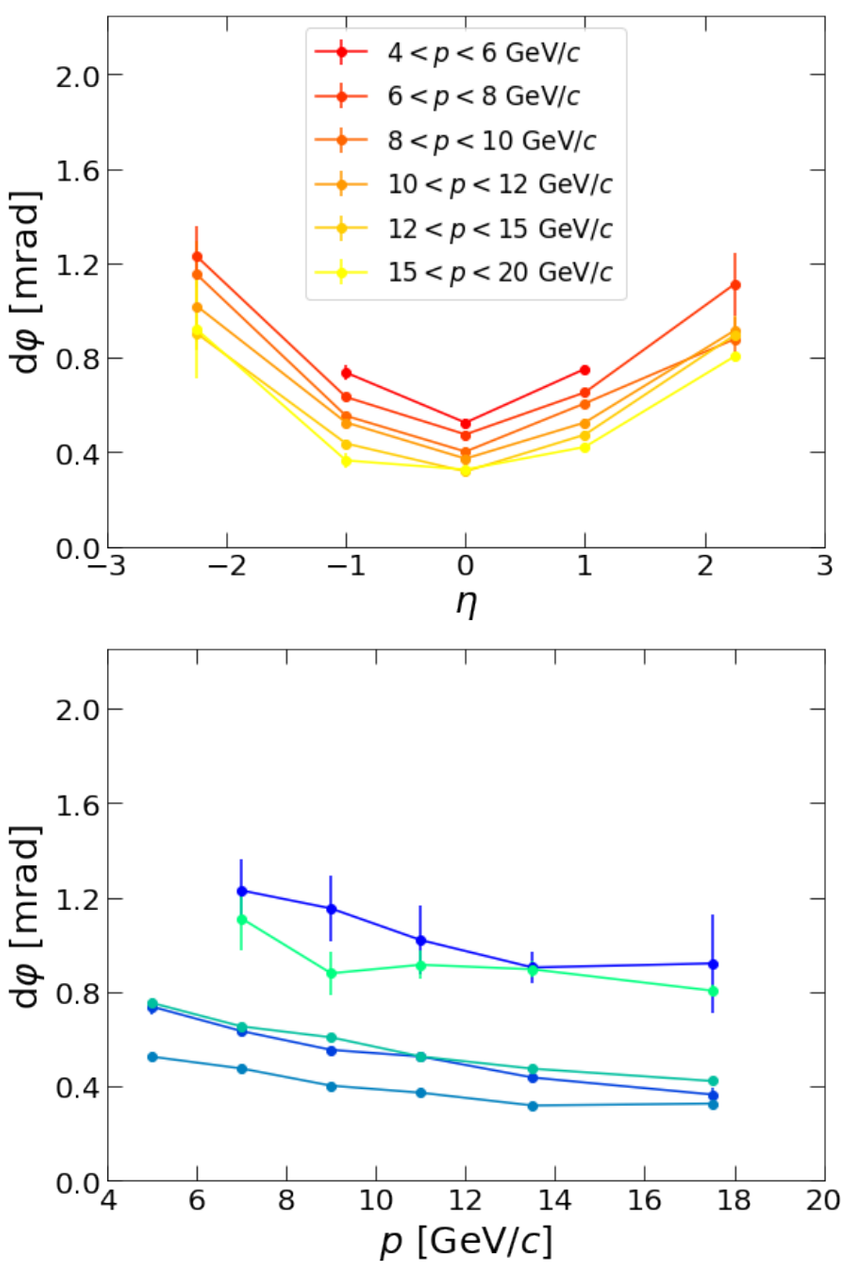


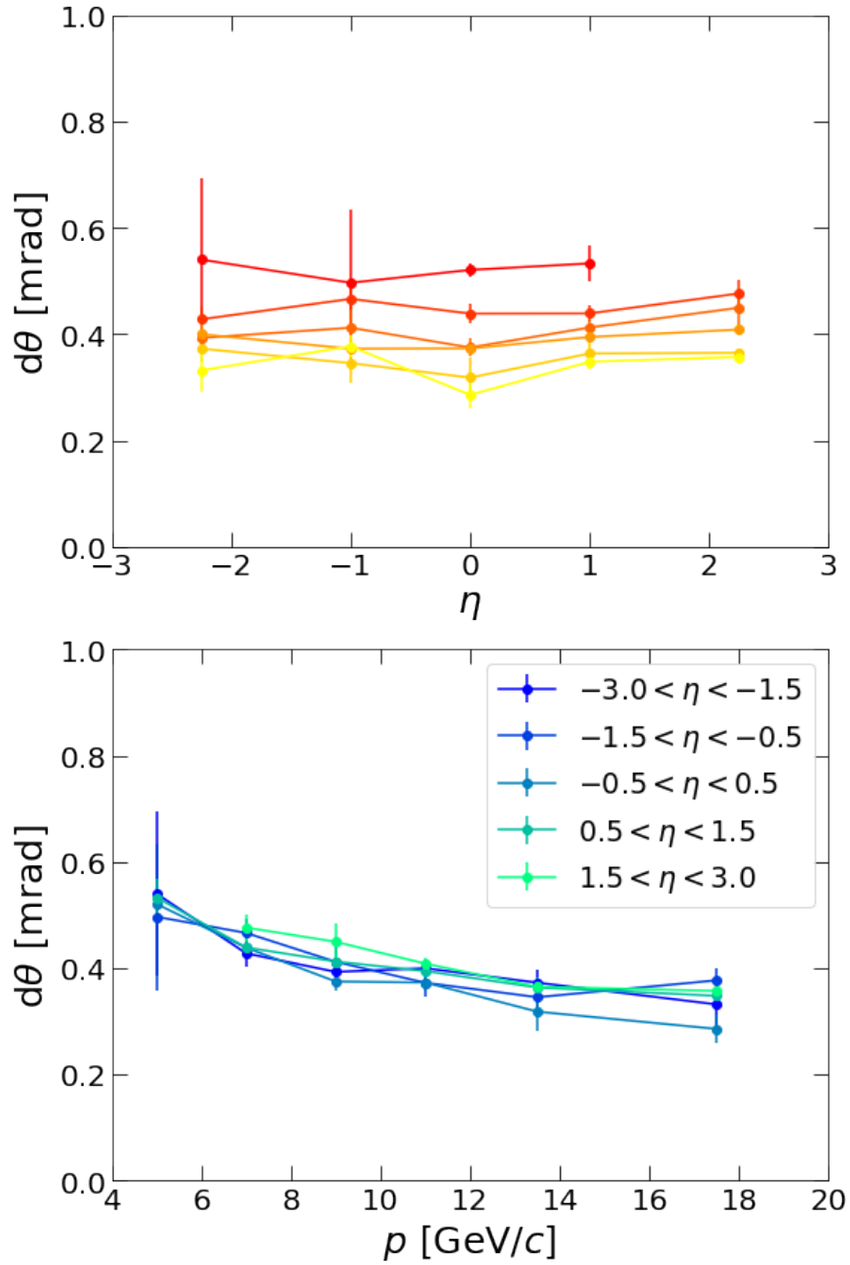




$\Delta R < 0.1$ Matching B =3.0 T







Lepton-Jet Correlations

Correlation Uncertainty

$$\Delta\varphi \equiv \varphi_e - \varphi_{\text{jet}} - \pi$$

1. **Truth and Reco Jet $\Delta\varphi$ Distributions**
   - $(\Delta\varphi_{\text{truth}}^{\text{charged}} - \Delta\varphi_{\text{reco}})/\Delta\varphi_{\text{truth}}^{\text{charged}}$

→ **Obtain $\sigma\Delta\varphi$ from double gauss fits**

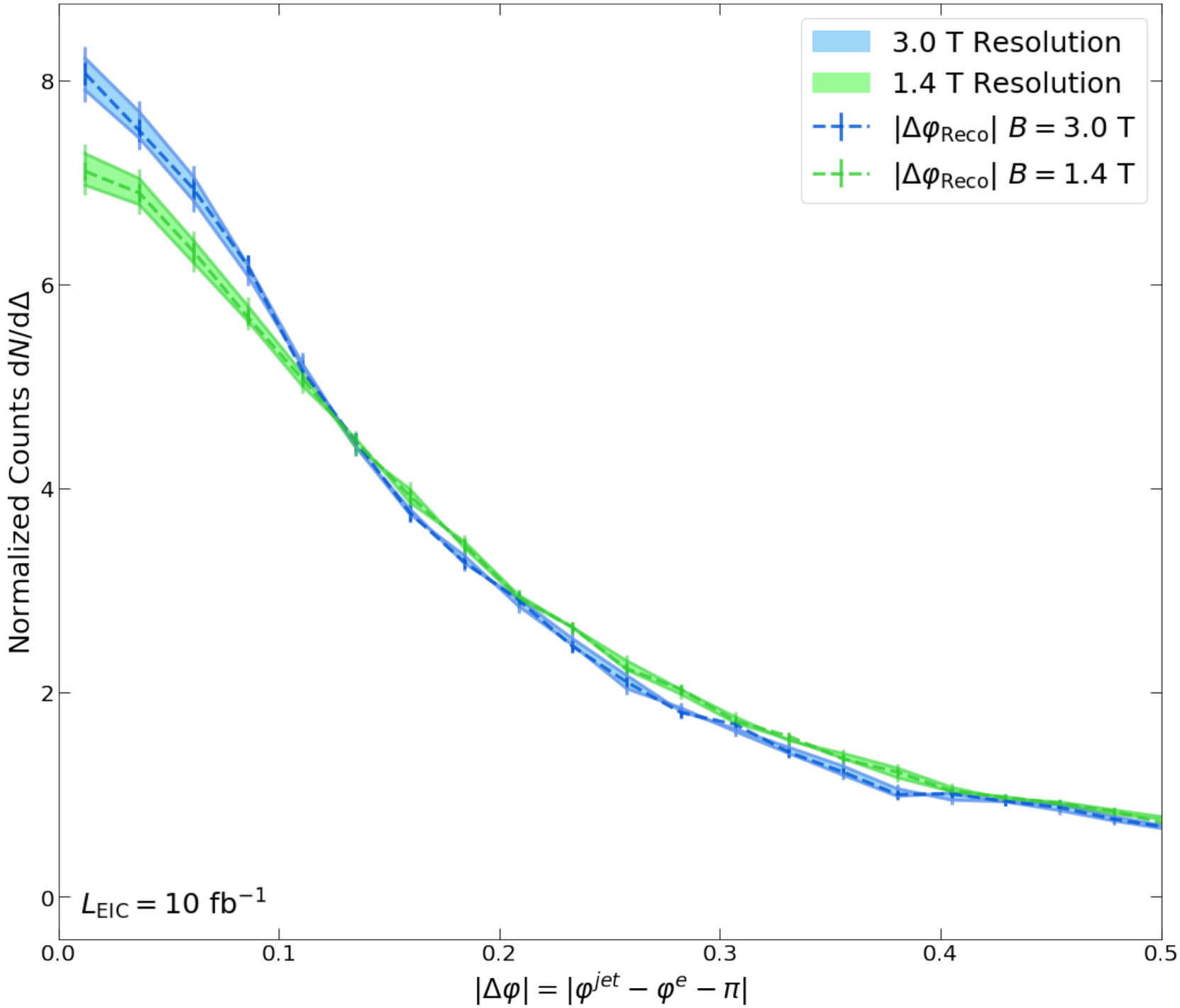
2. **Full and Charged Jet $\Delta\varphi$ Distributions**
   - $(\Delta\varphi_{\text{truth}}^{\text{charged}} - \Delta\varphi_{\text{truth}}^{\text{full}})/\Delta\varphi_{\text{truth}}^{\text{charged}}$

→ **Negligible for now**

3. **Unfolding Uncertainty**
   - ~1-2%

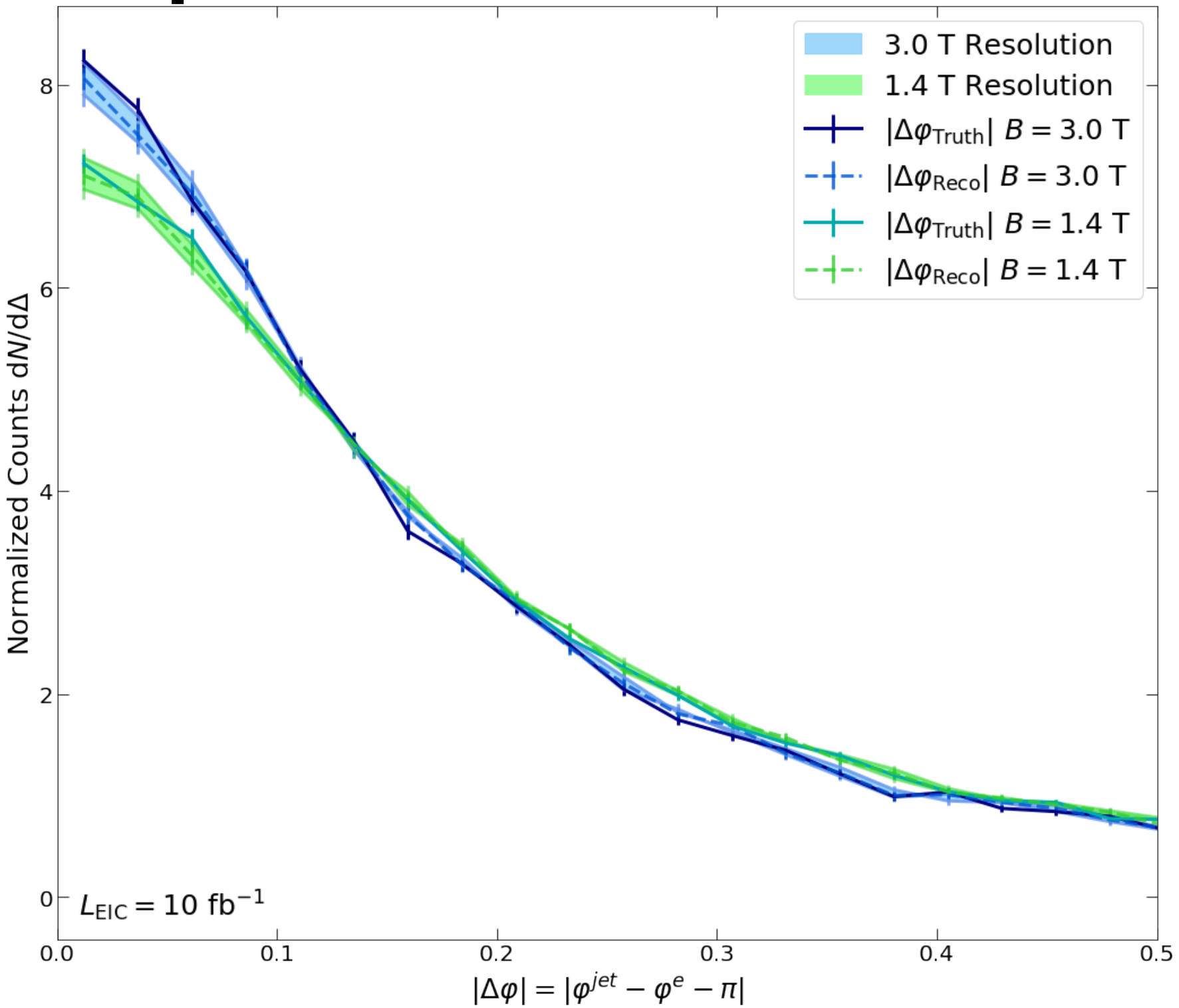
→ **Sum in quadrature with $\sigma\Delta\varphi$**

Electron-Jet Correlations ($\Delta\varphi$)



Smearing $\Delta\varphi$ by $\sigma_{\Delta\varphi}$ at fill time. Includes Estimated Unfolding

Comparison To Truth-Level

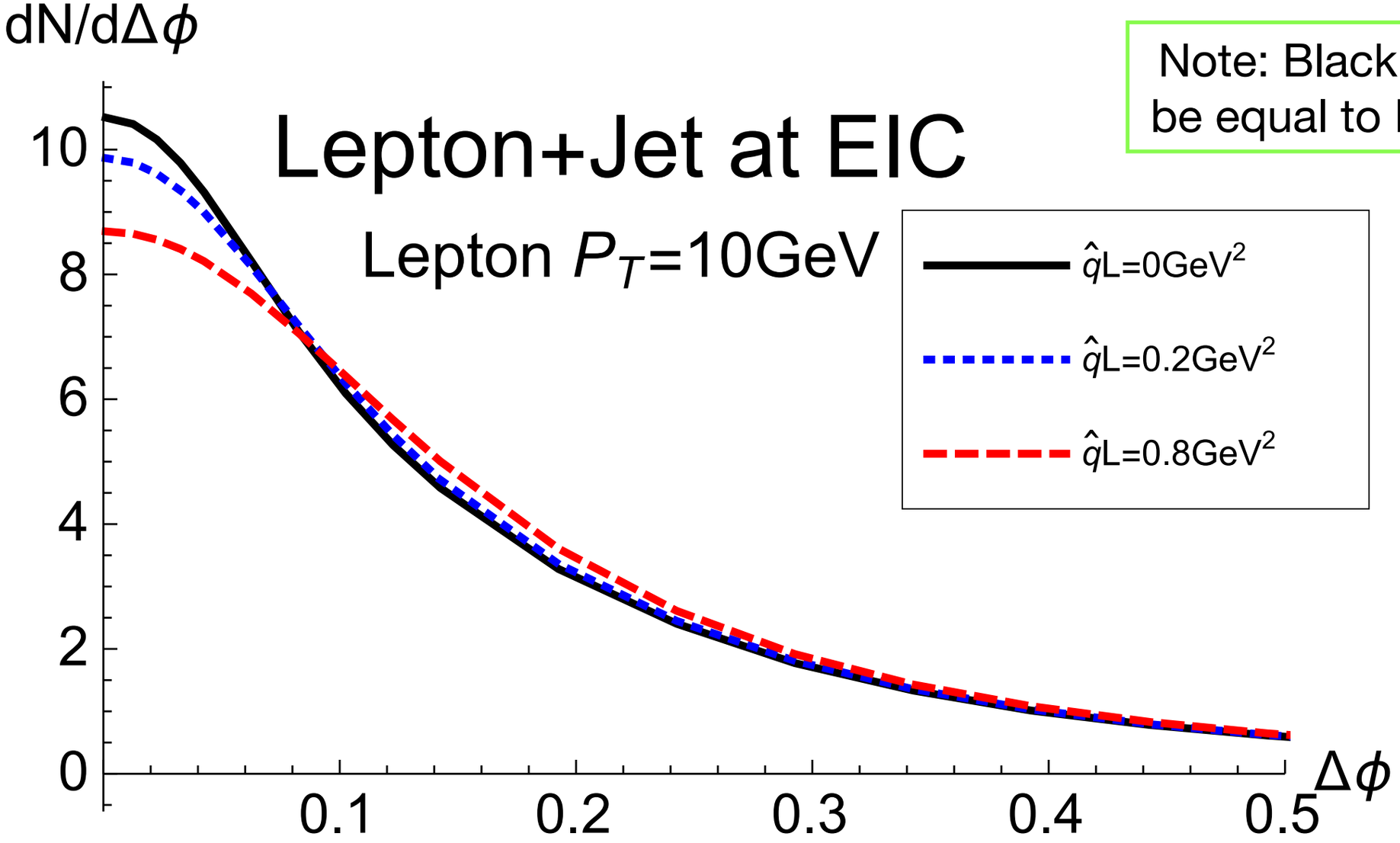


Truth and Reco Correlation agree within uncertainties

Memory Refresh: Lepton+Jet Theory

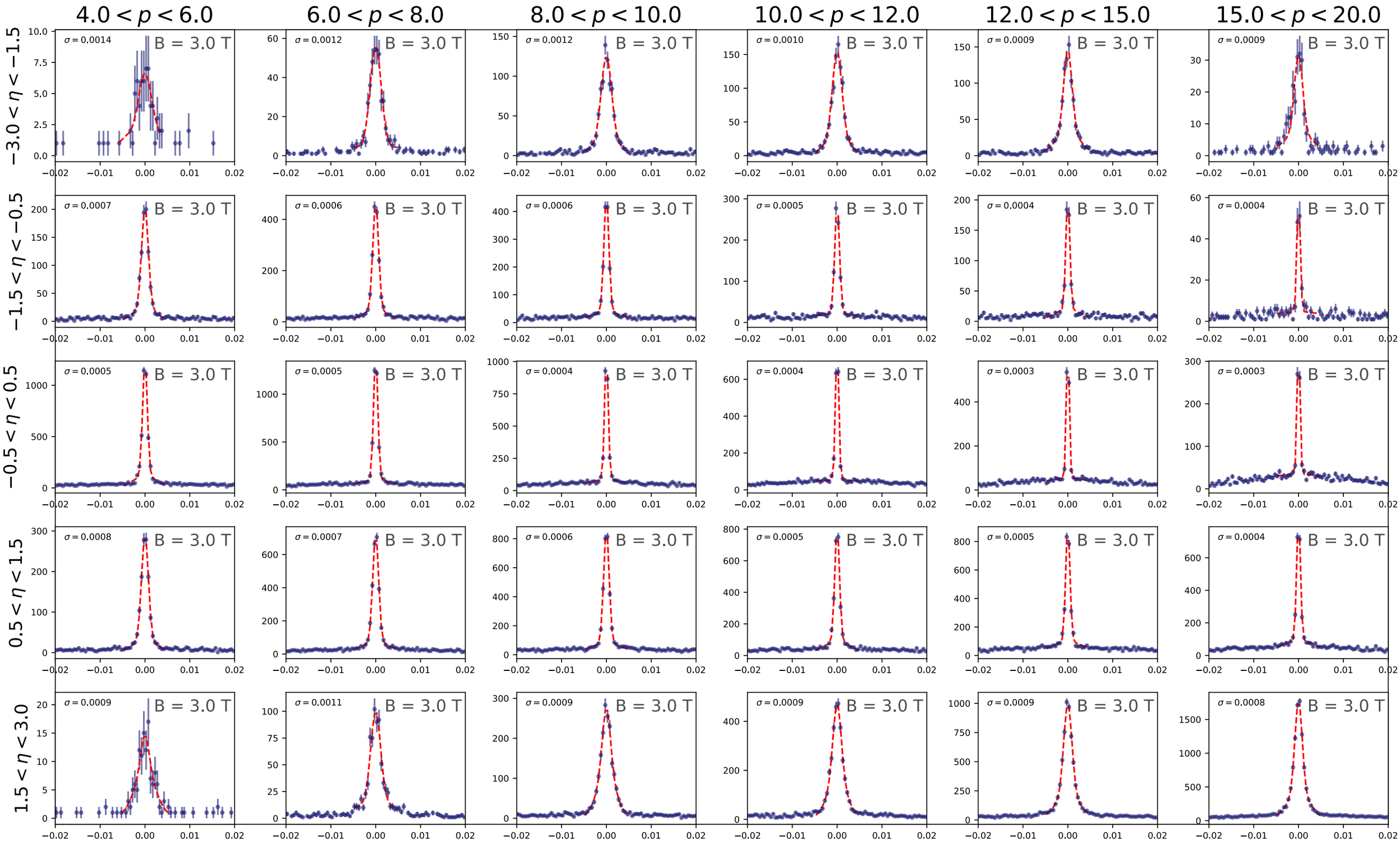
- Lepton+Jet Correlations for different $\hat{q}L$
  - https://arxiv.org/pdf/1812.08077.pdf

Note: Black *should* be equal to PYTHIA



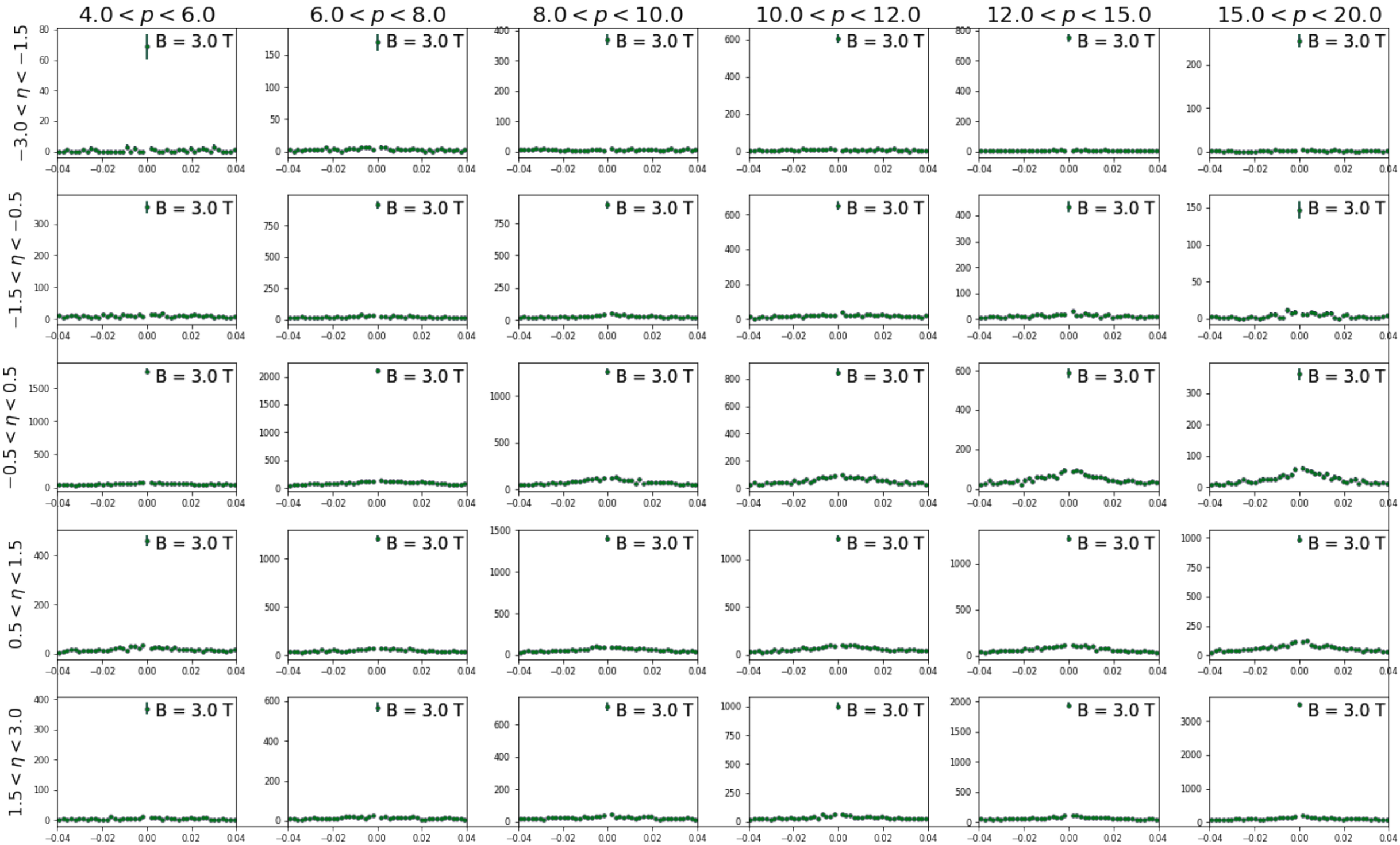
End

1. Potting $(\Delta\varphi_{\text{truth}} - \Delta\varphi_{\text{reco}})/\Delta\varphi_{\text{truth}}$ (B = 3.0 T)



Double Gaussian Fits data well → well defined $\sigma_{\Delta\varphi}$

2. Potting $(\Delta\varphi^{\text{charged}}_{\text{truth}} - \Delta\varphi^{\text{full}}_{\text{truth}})/\Delta\varphi^{\text{charged}}_{\text{truth}}$ (B = 3.0 T)



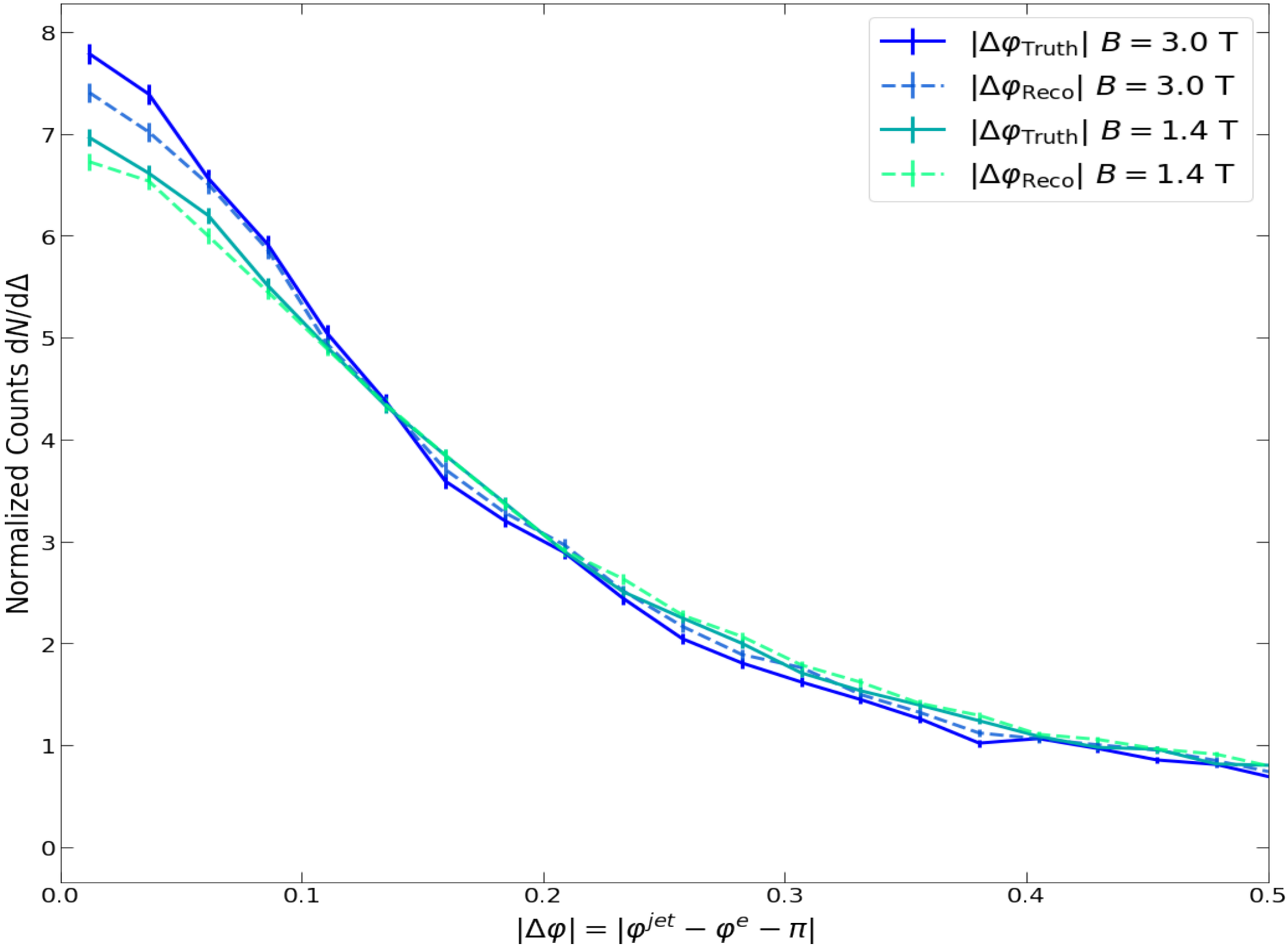
Looks to be negligible for current jet population

η-dependant pT thresholds

η	θ	Nomenclature			Tracking						Electrons and Photons			π/K/p		HCAL		Muons
					Resolution	Relative Momentum	Allowed X/X_0	Minimum-pT	Transverse Pointing Res.	Longitudinal Pointing Res.	Resolution σ_E/E	PID	Min E Photon	p-Range (GeV/c)	Separation	Resolution σ_E/E	Energy	
< -4.6		↓ p/A	Far Backward Detectors	low-Q2 tagger														
-4.6 to -4.0					Not Accessible													
-4.0 to -3.5						Reduced Performance												Muons useful for bkg, improve resolution
-3.5 to -3.0			Central Detector	Backward Detector		σ_p/p ~0.2%×p⊕5%	~5% or less X	70-150 MeV/c (B=1.5 T)			1%/E ⊕ 2.5%/√E ⊕ 1%	π suppression up to 1:1E-4	20 MeV	≤ 10 GeV/c	≥ 3 σ	50%/ √E⊕10%	~500MeV	
-3.0 to -2.5																		
-2.5 to -2.0						σ_p/p~ 0.04%×p⊕2%												
-2.0 to -1.5									dca(xy) ~ 40/pT µm ⊕ 10 µm	dca(z) ~ 100/pT µm ⊕ 20 µm	2%/E ⊕(4-8)%/√E ⊕ 2%	π suppression up to 1:(1E-3 - 1E-2)	50 MeV					
-1.5 to -1.0																		
-1.0 to -0.5				Barrel		σ_p/p ~0.04%×p⊕1%		200 MeV/c	dca(xy) ~ 30/pT µm ⊕ 5 µm	dca(z) ~ 30/pT µm ⊕ 5 µm	2%/E ⊕(12-14)%/ √E ⊕ (2-3)%	π suppression up to 1:1E-2	100 MeV	≤ 6 GeV/c		100%/ √E⊕10%		
-0.5 to 0.0																		
0.0 to 0.5																		
0.5 to 1.0																		
1.0 to 1.5				Forward Detectors		σ_p/p ~0.04%×p⊕2%		70 - 150 MeV/c (B = 1.5 T)	dca(xy) ~ 40/pT µm ⊕ 10 µm	dca(z) ~ 100/pT µm ⊕ 20 µm	2%/E ⊕ (4*-12)%/ √E ⊕ 2%	3σ e/π up to 15 GeV/c	50 MeV	≤ 50 GeV/c		50%/ √E⊕10%		
1.5 to 2.0																		
2.0 to 2.5																		
2.5 to 3.0						σ_p/p ~0.2%×p⊕5%												
3.0 to 3.5																		
3.5 to 4.0		↑ e		Instrumentation to separate charged particles from photons		Reduced Performance												
4.0 to 4.5					Not Accessible													
> 4.6			Far Forward Detectors	Proton Spectrometer														
				Zero Degree Neutral Detection														

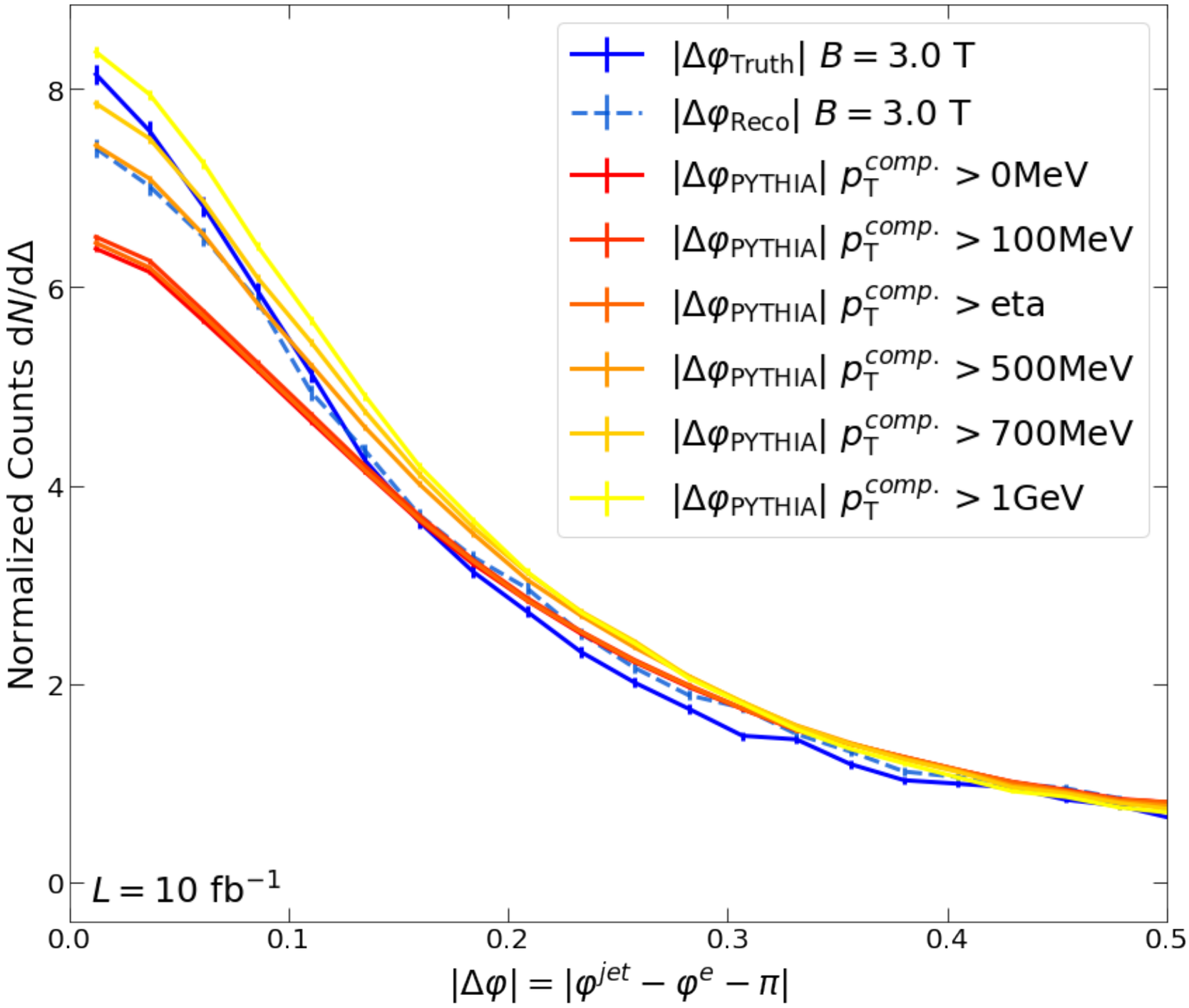
https://physdiv.jlab.org/DetectorMatrix/

Previous Correlations



Comparing *Truth* to PYTHIA

For Various Jet Component Thresholds



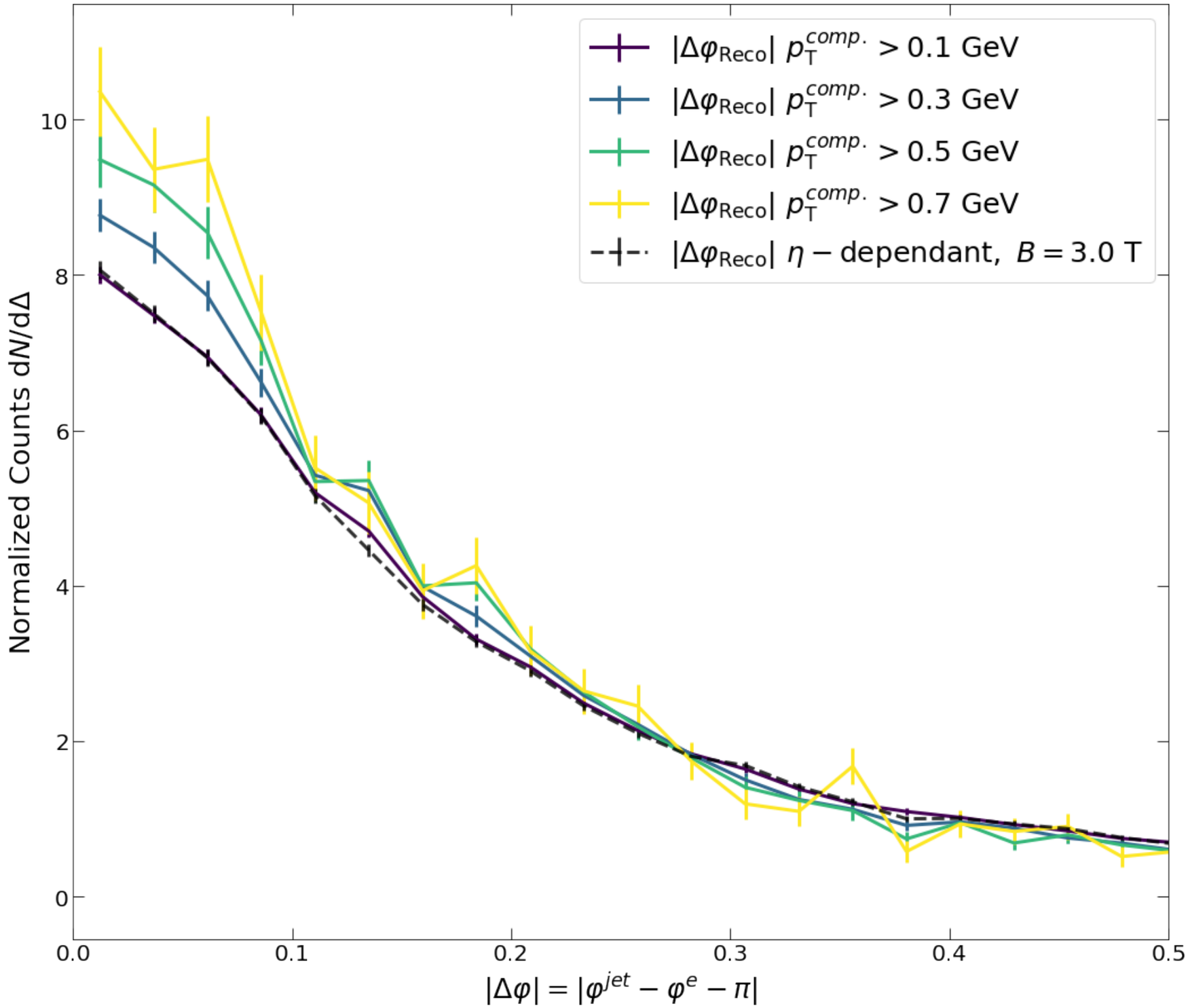
Truth: Truth-Level Jet associated with successfully reconstructed jet (reco-level).

pT threshold applied to reco directly, but not directly to “Truth” here.

PYTHIA: Particle-Level full jet, (*not necessarily associated with reco). pT* Threshold applied directly

Reconstructed Correlation

For Various Jet Component Thresholds

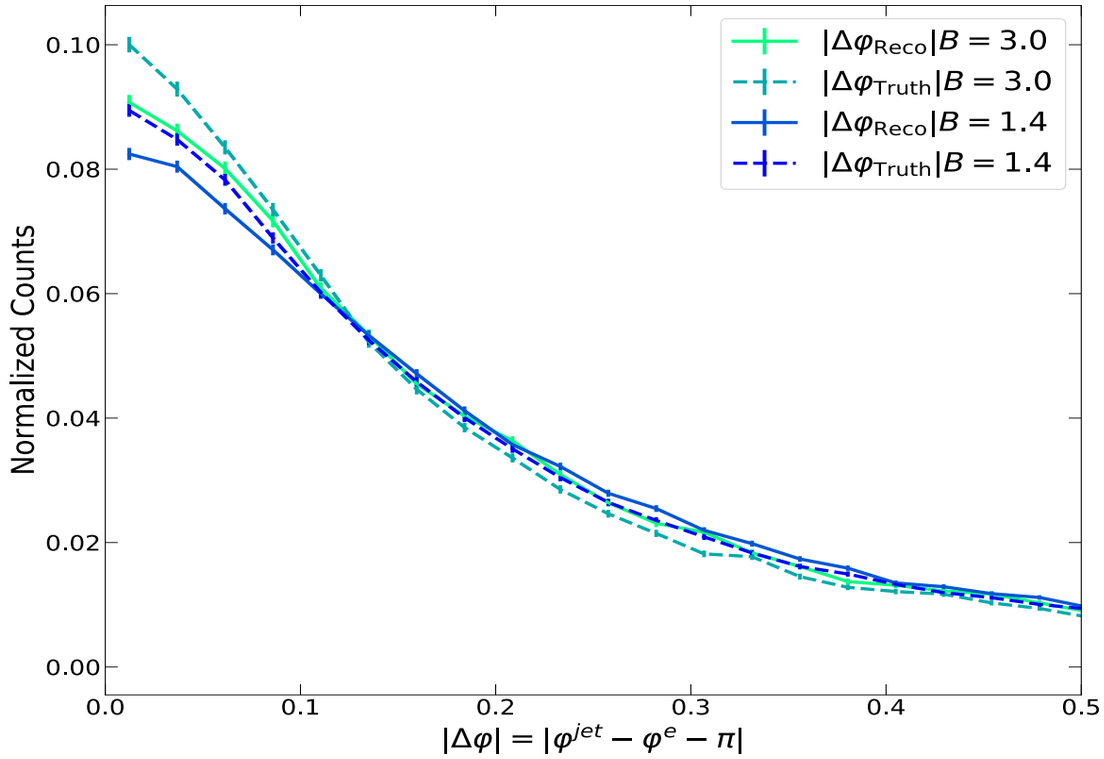


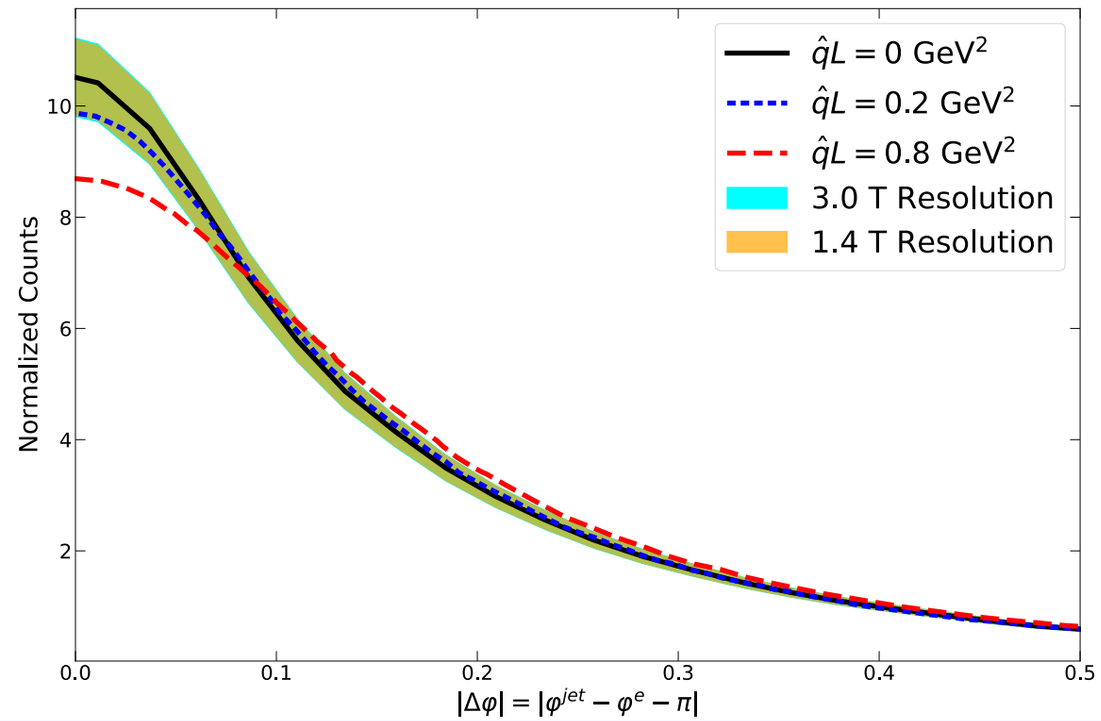
Error Propagation

- Fit+Toy MC
  - Fit black to TF1
  - Run toy MC $\Delta\varphi$, with $\sigma_e \oplus \sigma_{\text{jet}}$
  - Smears theory $\Delta\varphi$ distribution
    - Not the same as smearing σ_e, σ_{jet} separately
    - Trouble accounting for bin migration effects
  - Theory curve can only be smeared in some form of this method

- ~~Smear Pythia~~
  - Apply σ_e, σ_{jet} separately to electron+jet
  - Obtains “smeared truth”
  - $\approx$ reco?

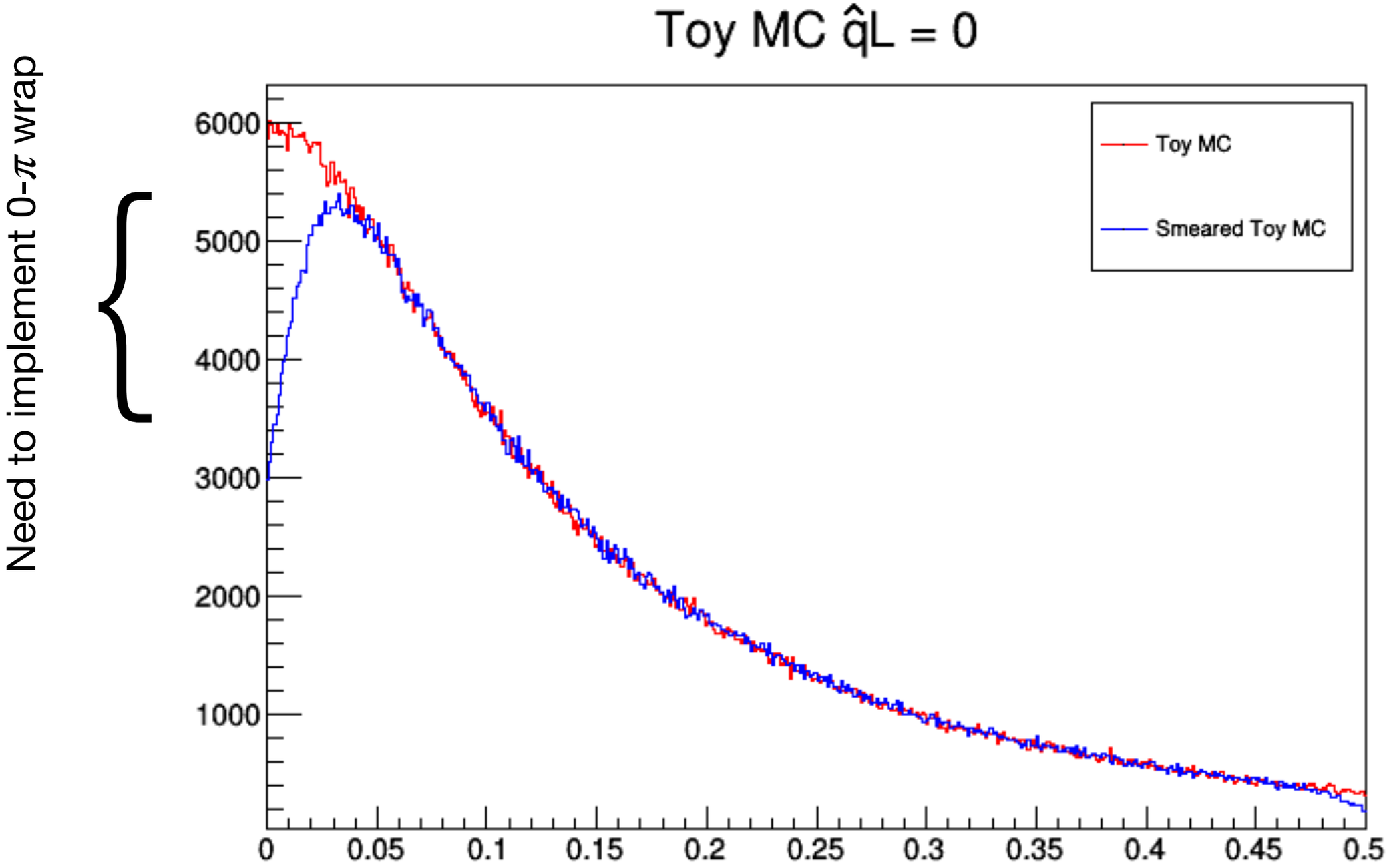
- Apply relative difference between reco and truth $\Delta\varphi$
  - Should account for bin-migration effect
  - Resolutions are primarily what cause reco and truth different





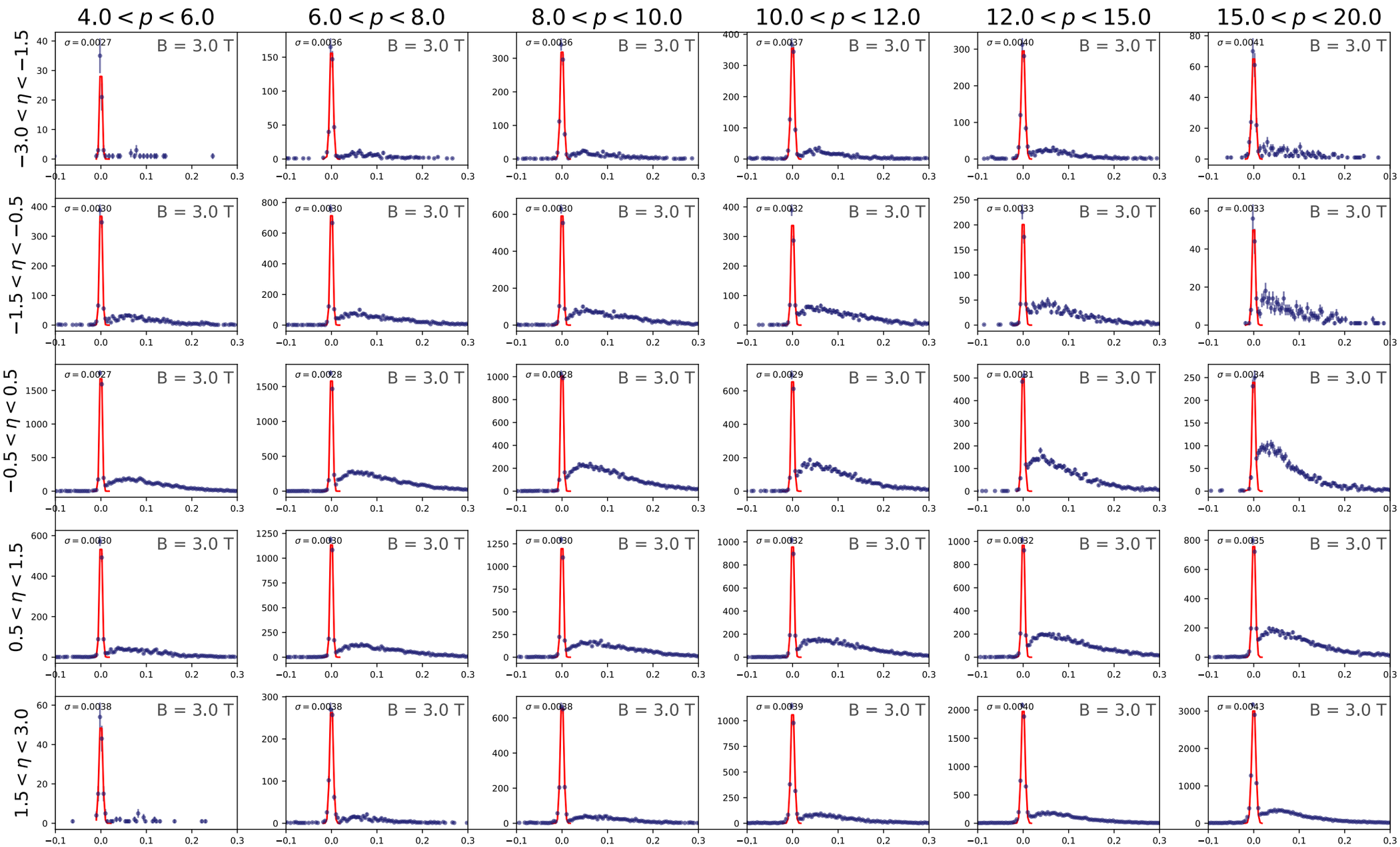
Toy MC smearing with

$$\sigma_{\Delta\varphi} = \sigma_J \oplus \sigma_e$$



Delta Phi Plots

Momentum Resulution ΔR



ΔR Matching