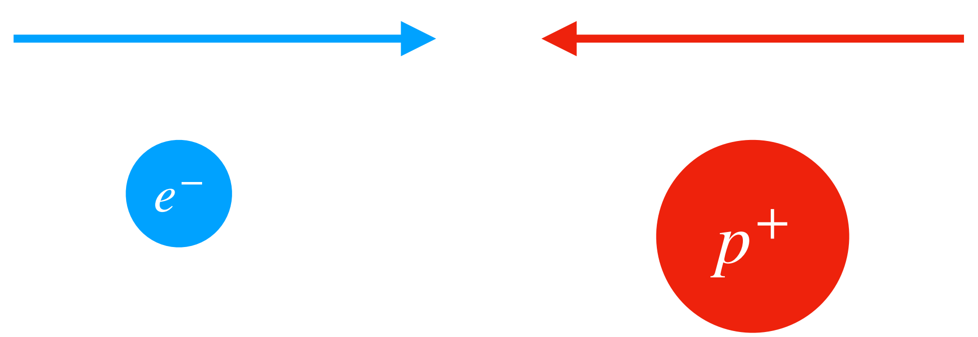
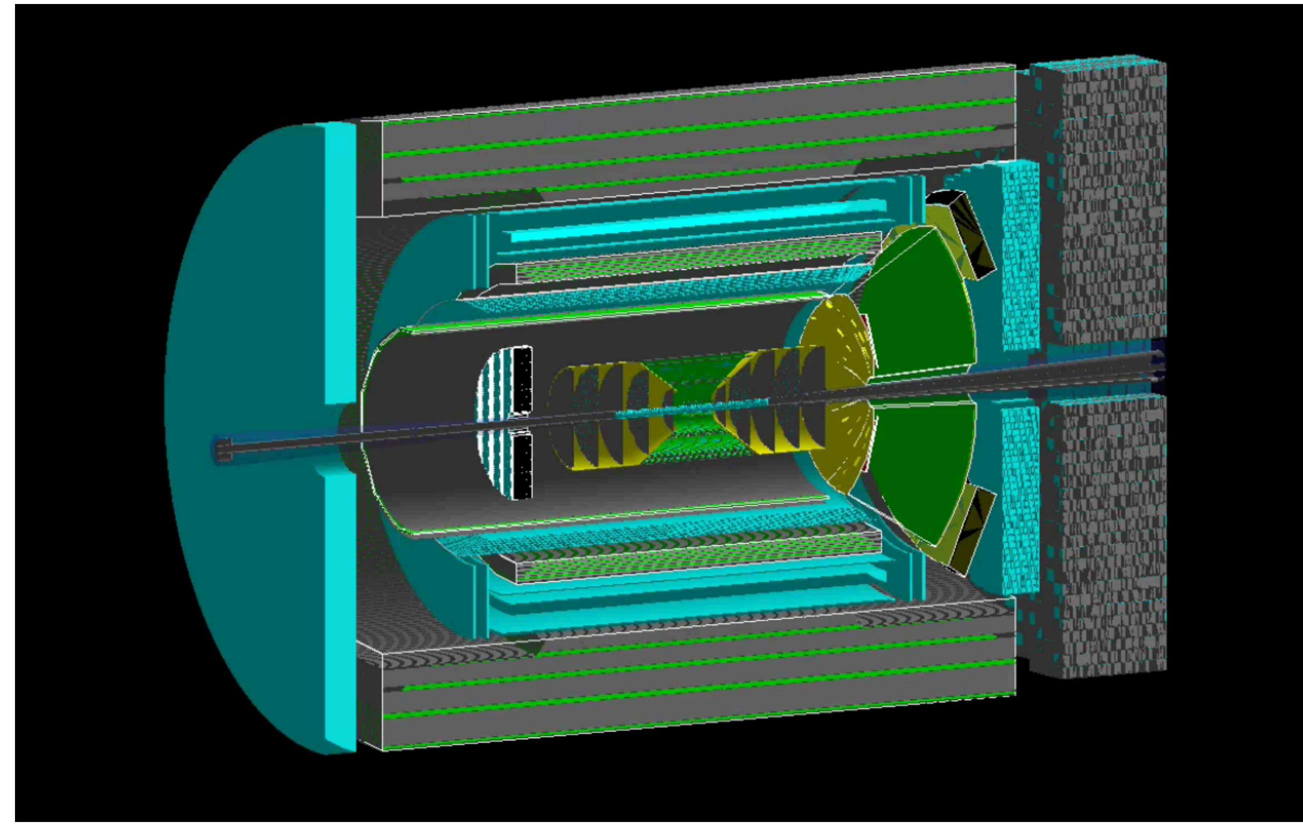
EIC All-Silicon Jet Performance

Jets in e+P PYTHIA Simulation

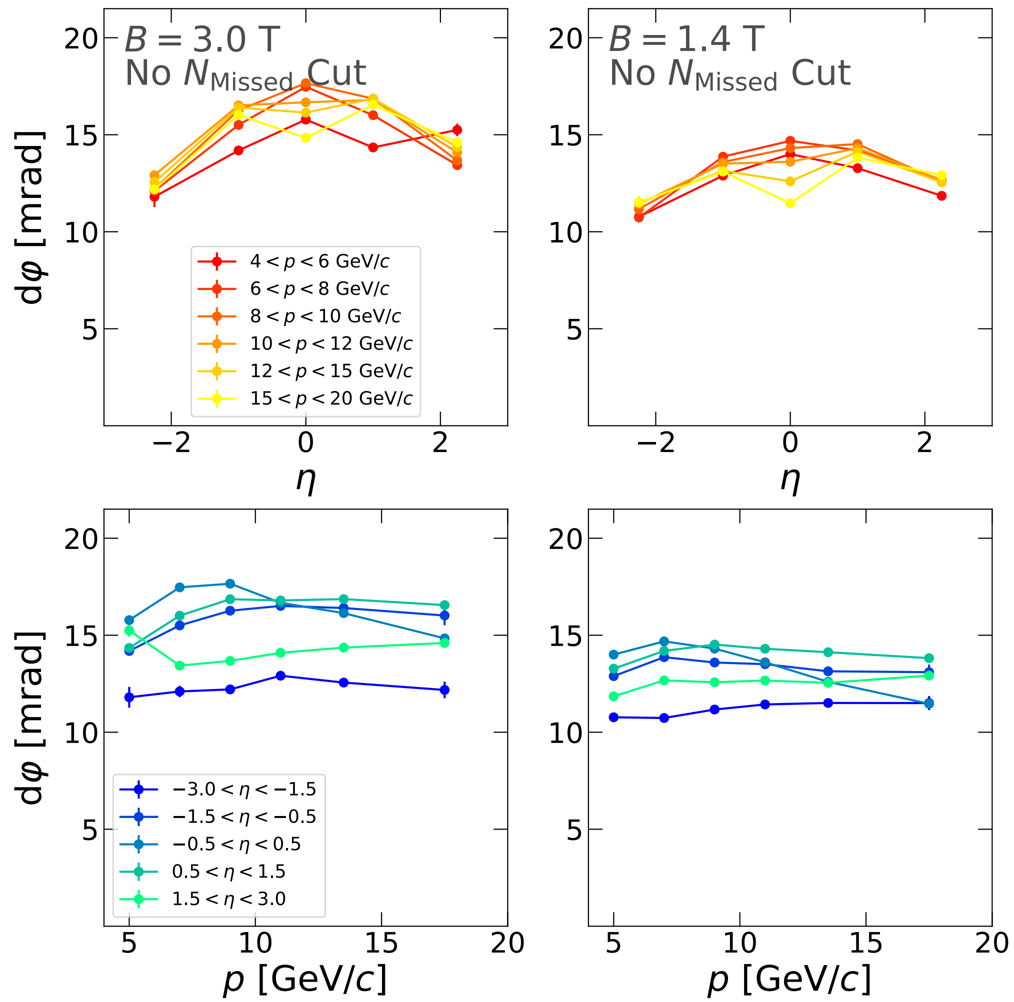




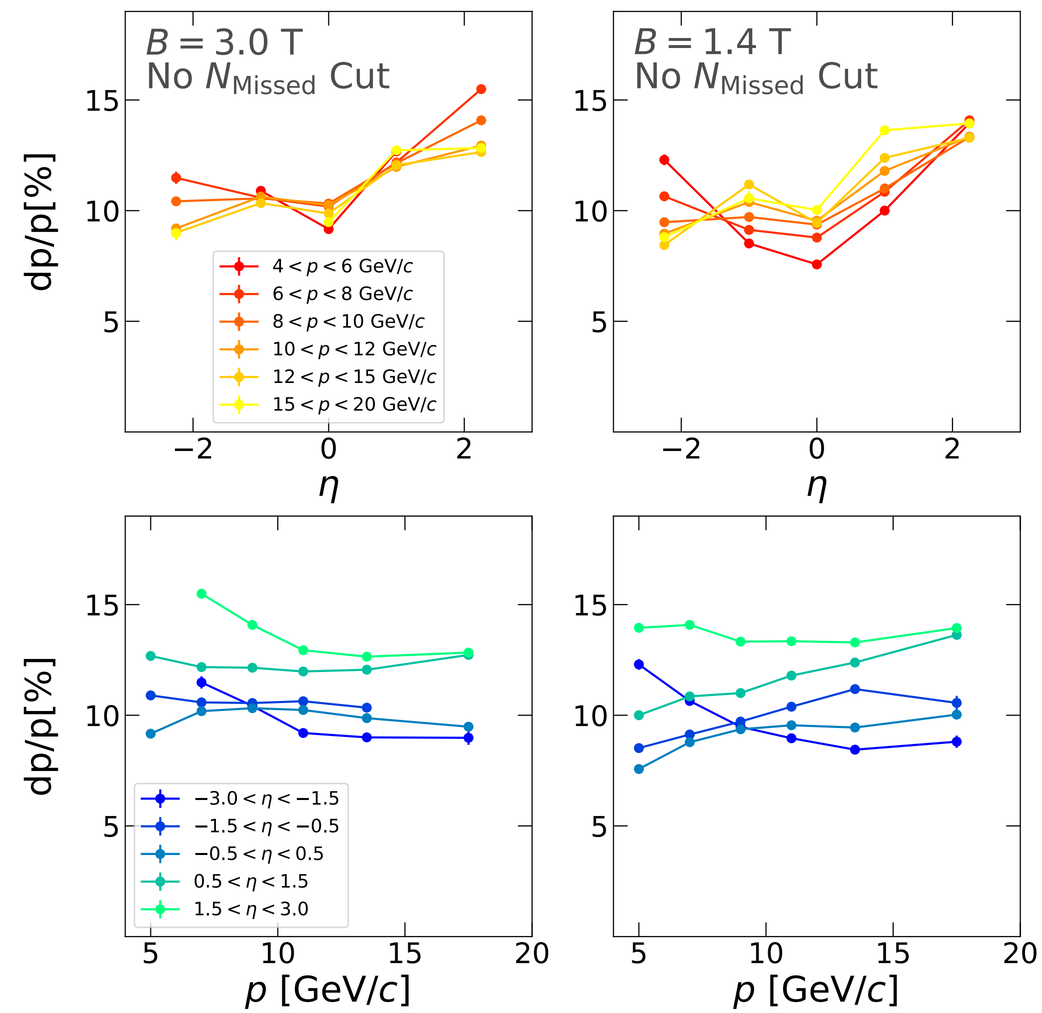
- PYTHIA 8
  - $Q^2_{\text{min}} \geq 16$ (GeV/c^2)^2
  - $\sqrt{s} = 89$ GeV
  - Electron beam: 20 GeV
  - Proton beam: 100 GeV
- Jets
  - Charged Jets
  - $E^{\text{Jet}}_{\text{Reco}} > 4.0$ GeV
  - Anti-k_{T} $R = 1.0$
  - ΔR (jet-electron) > 0.5
    - "Electron Veto"
- Jet Constituents
  - $N_{\text{constituents}}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

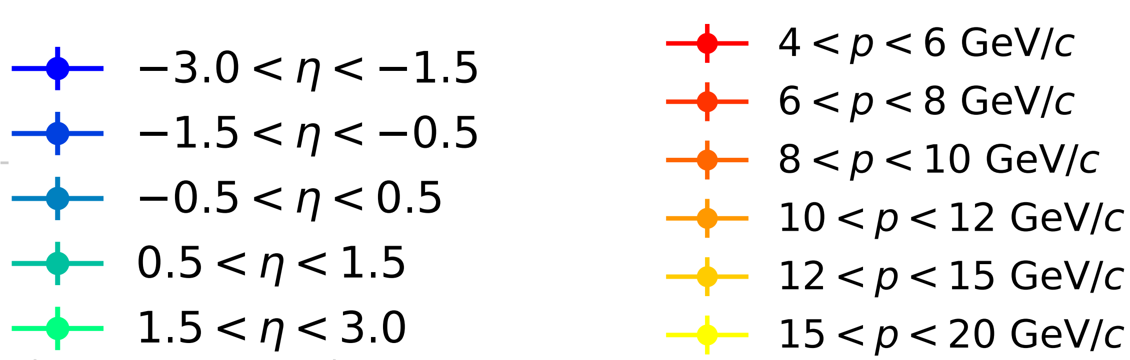
Charged Jet Resolutions

φ



$\mathrm{d}P/P$



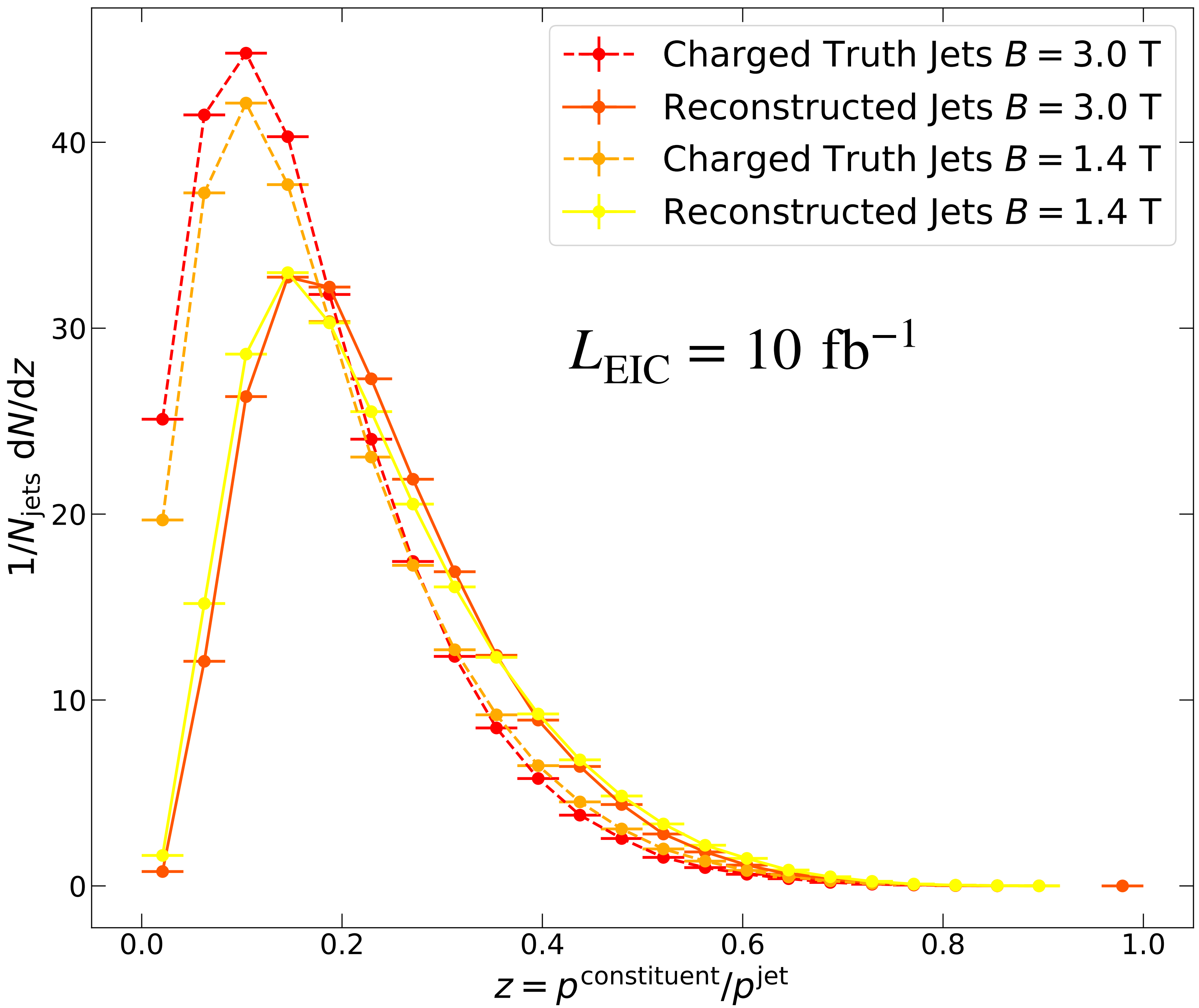


Charged Jet EIC Observables

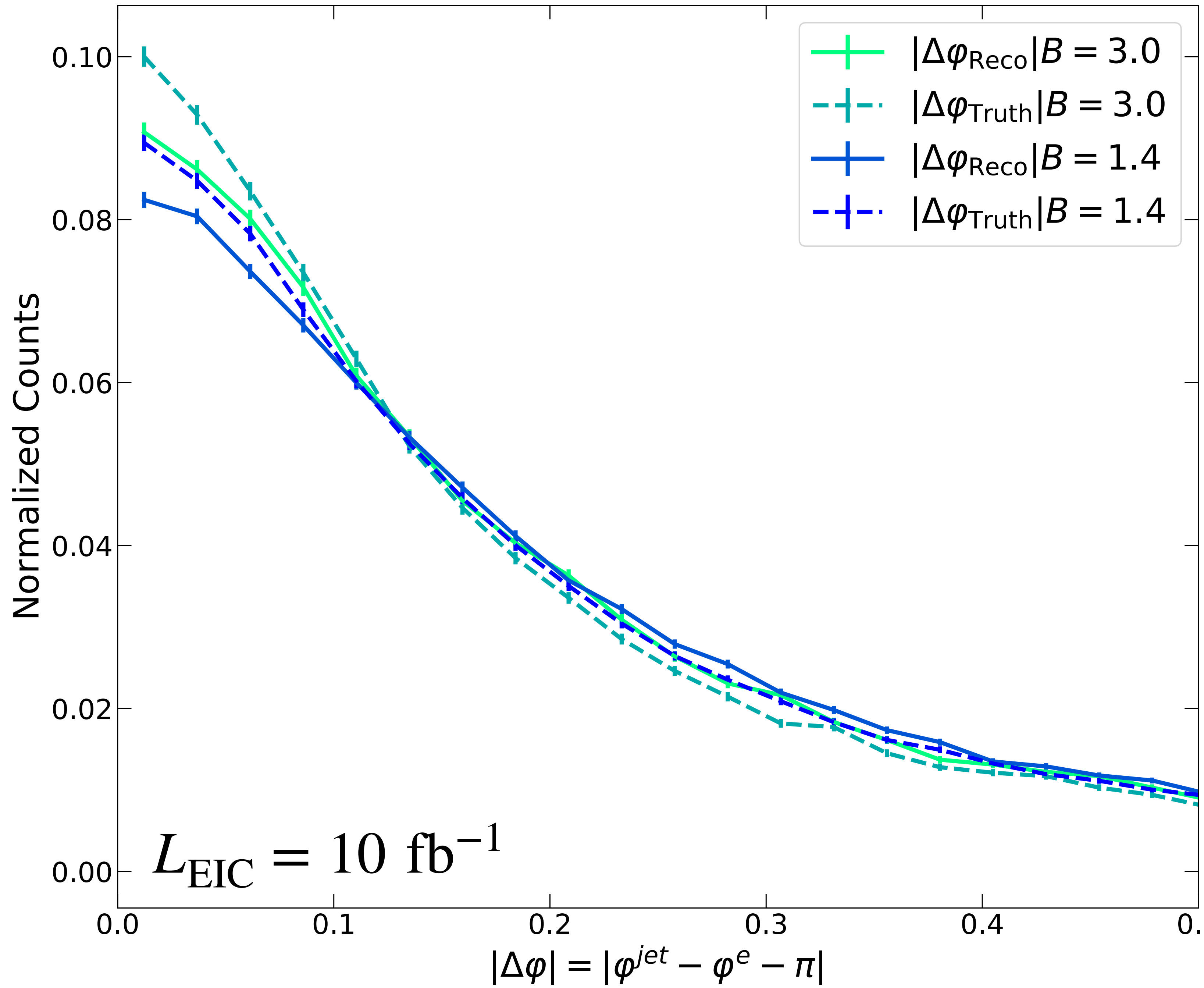
1. Charged Jet Fragmentation Function

2. Electron-Jet Correlations
   - Sensitive to p_{T} broadening effects in e+A
   - Can constrain $\hat{q}L$, and TMD of nucleus

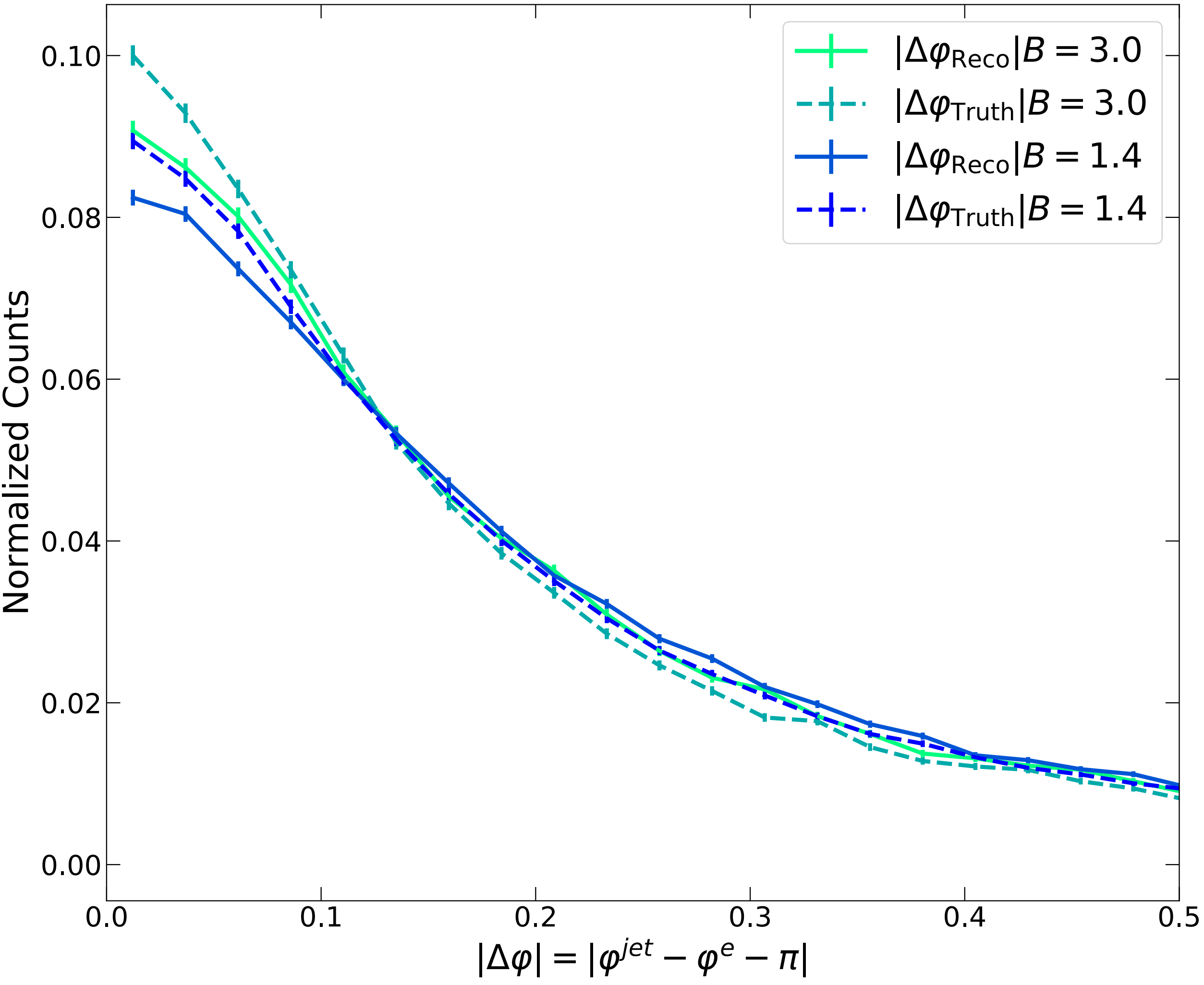
Charged Jet Fragmentation



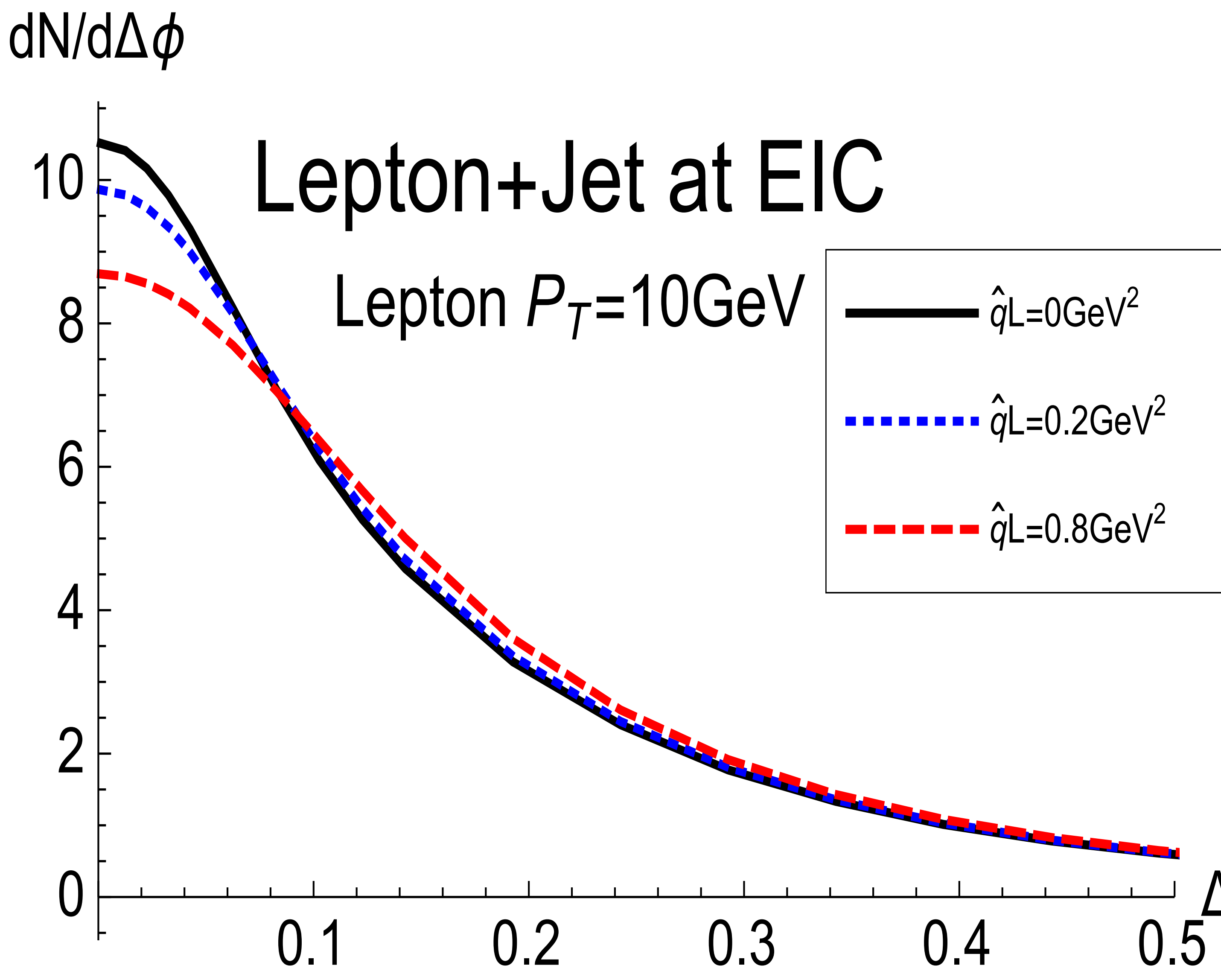
Electron-Jet Correlation



Theory Comparison



Full Simulation in 3.0 and 1.4 T Field



https://arxiv.org/pdf/1812.08077.pdf

Breakdown of Uncertainty

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

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

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

3. Unfolding Uncertainty
   - ~1-2%

1 & 2: Following similar procedure for extracting σ_φ, but for $\Delta\varphi$ (e.g. $\sigma_{\Delta\varphi}$)

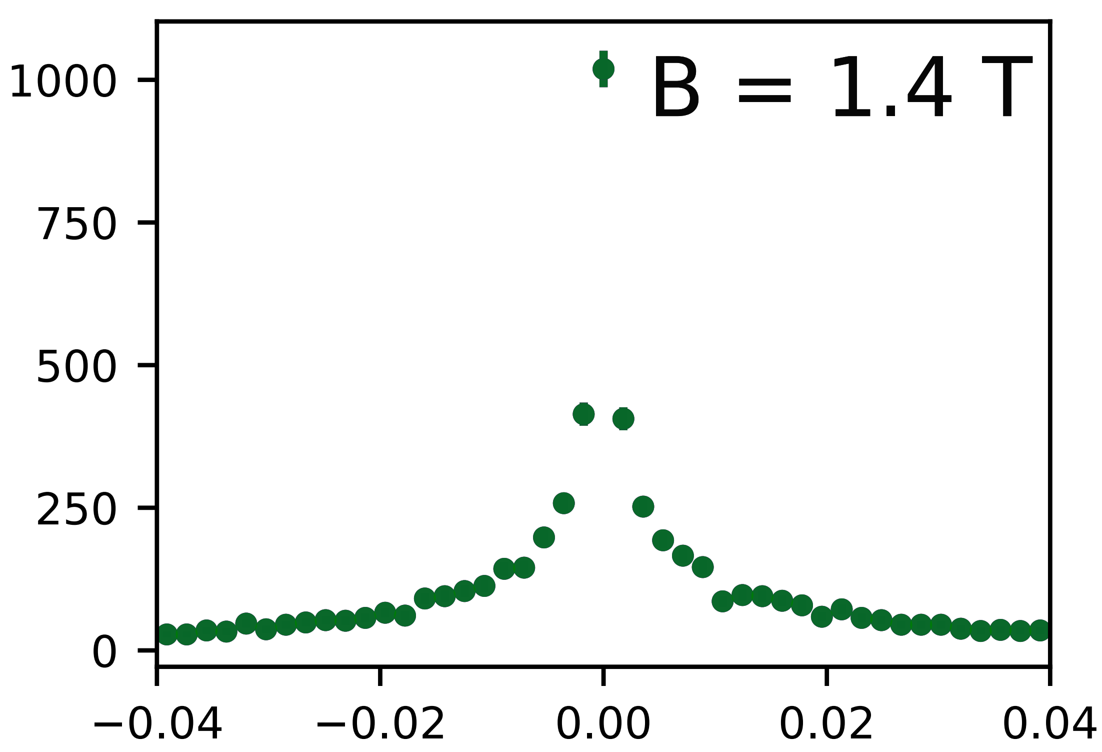
*** I also have the previously reported $\mathrm{d}\varphi^{\text{jet}}$ Distributions**

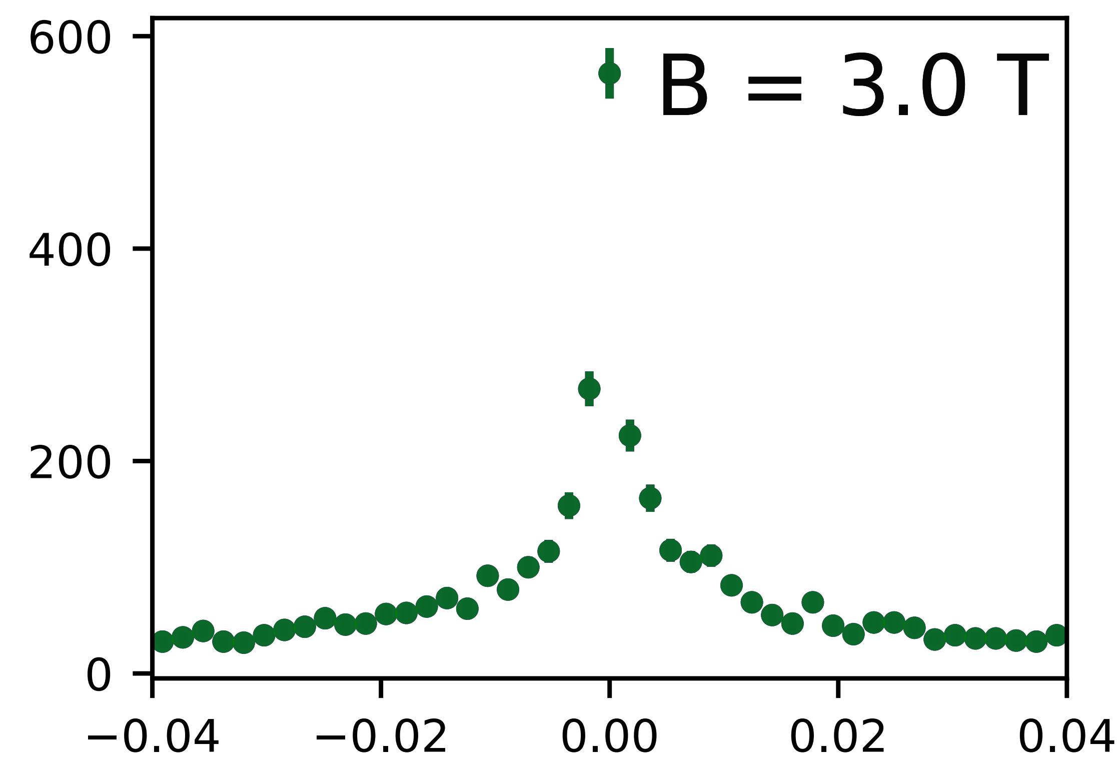
1. Truth and Reco Jet $\Delta\varphi$ Distributions

- $(\Delta\varphi^{\text{charged}}_{\text{truth}} - \Delta\varphi_{\text{reco}})/\Delta\varphi^{\text{charged}}_{\text{truth}}$

Potting $(\Delta\varphi_{\mathrm{truth}} - \Delta\varphi_{\mathrm{reco}})/\Delta\varphi_{\mathrm{truth}}$

Bin: $-0.5 < \eta^{\mathrm{jet}} < 0.5,\ 10.0 < p^{\mathrm{jet}} < 12\ \mathrm{GeV}/c$

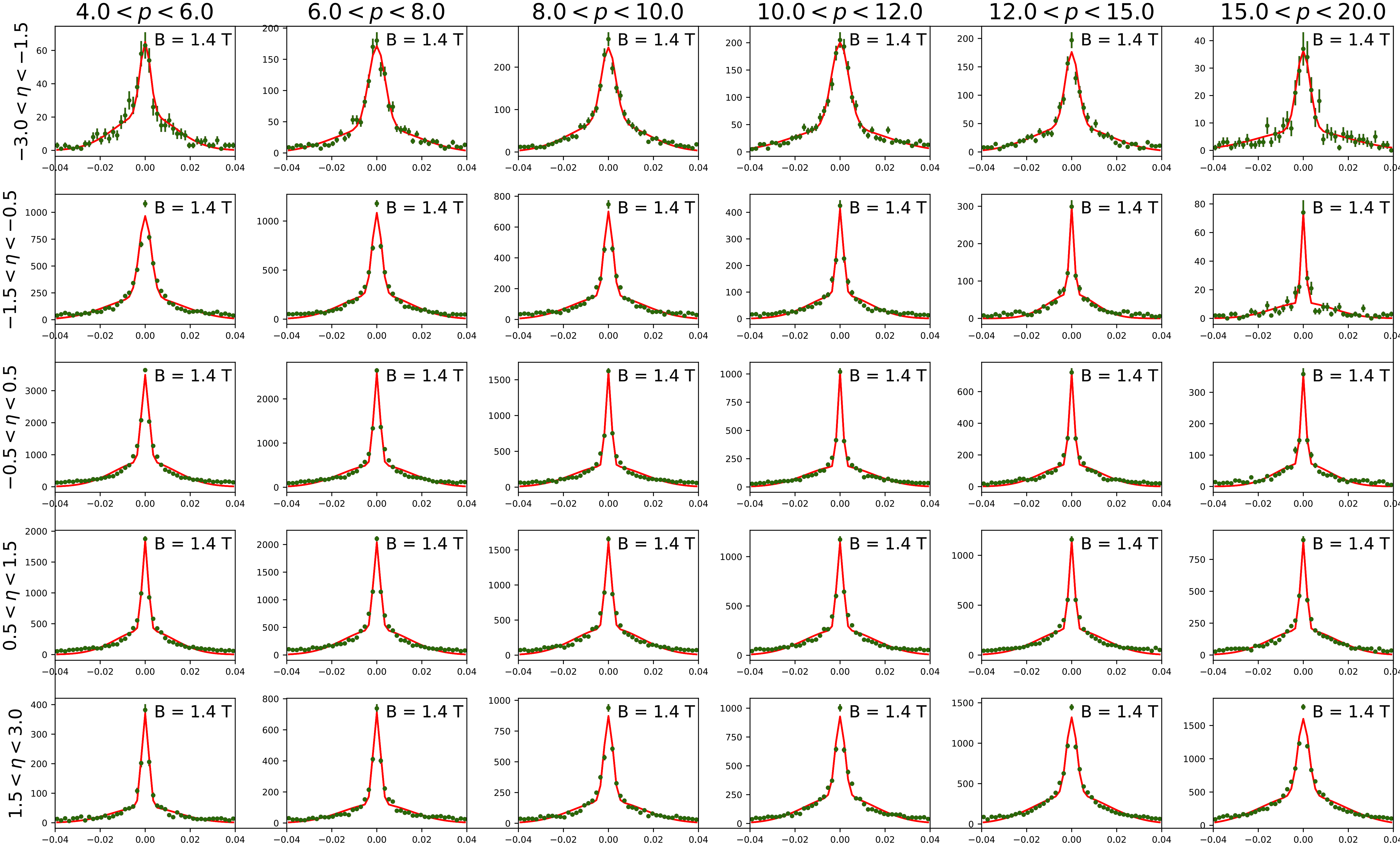




Next: double gauss Fits

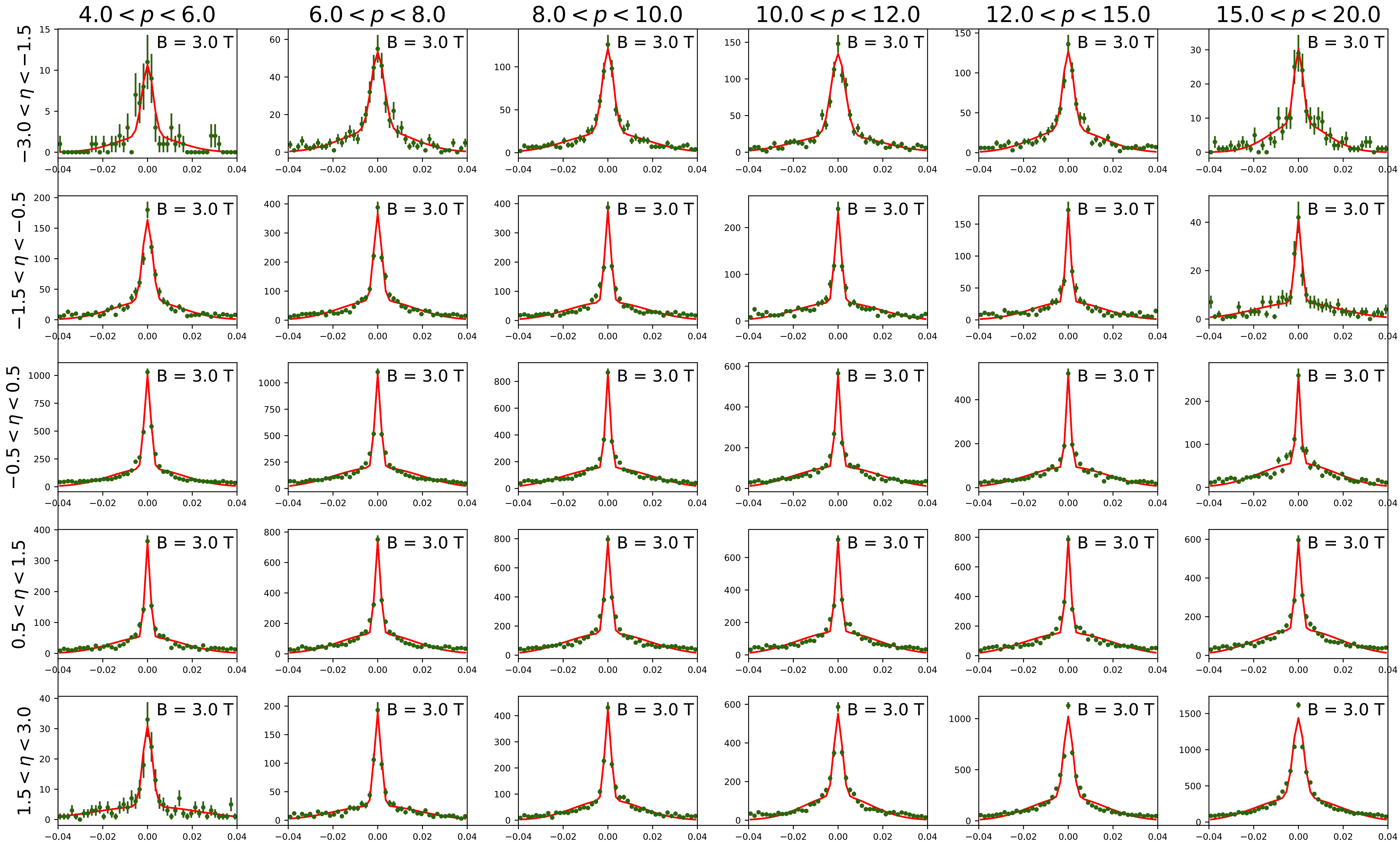
to extract $\sigma_{\Delta\varphi}$ from narrow gauss

Potting $(\Delta\varphi_{\text{truth}} - \Delta\varphi_{\text{reco}})/\Delta\varphi_{\text{truth}}$ (B = 1.4 T)



Double Gaussian Fits data well

Potting $(\Delta\varphi_{truth} - \Delta\varphi_{reco})/\Delta\varphi_{truth}$ (B = 3T)



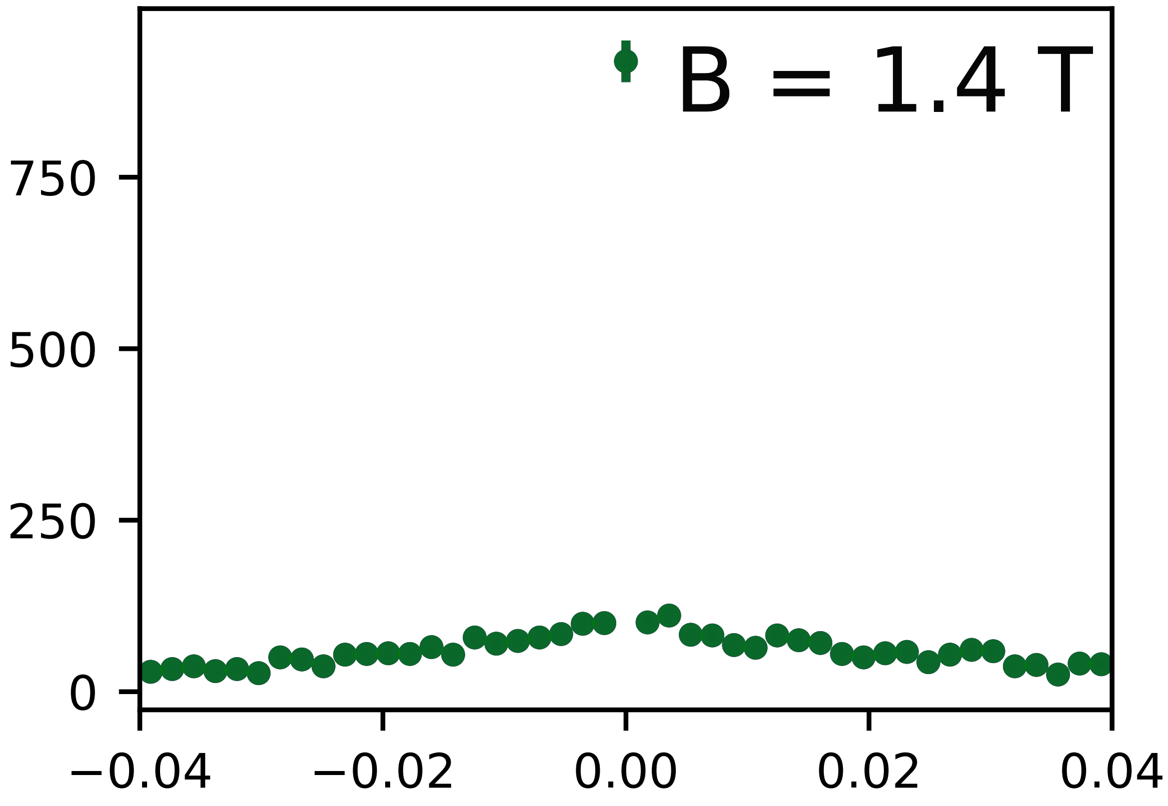
Fits also work well for 3.0 T Field

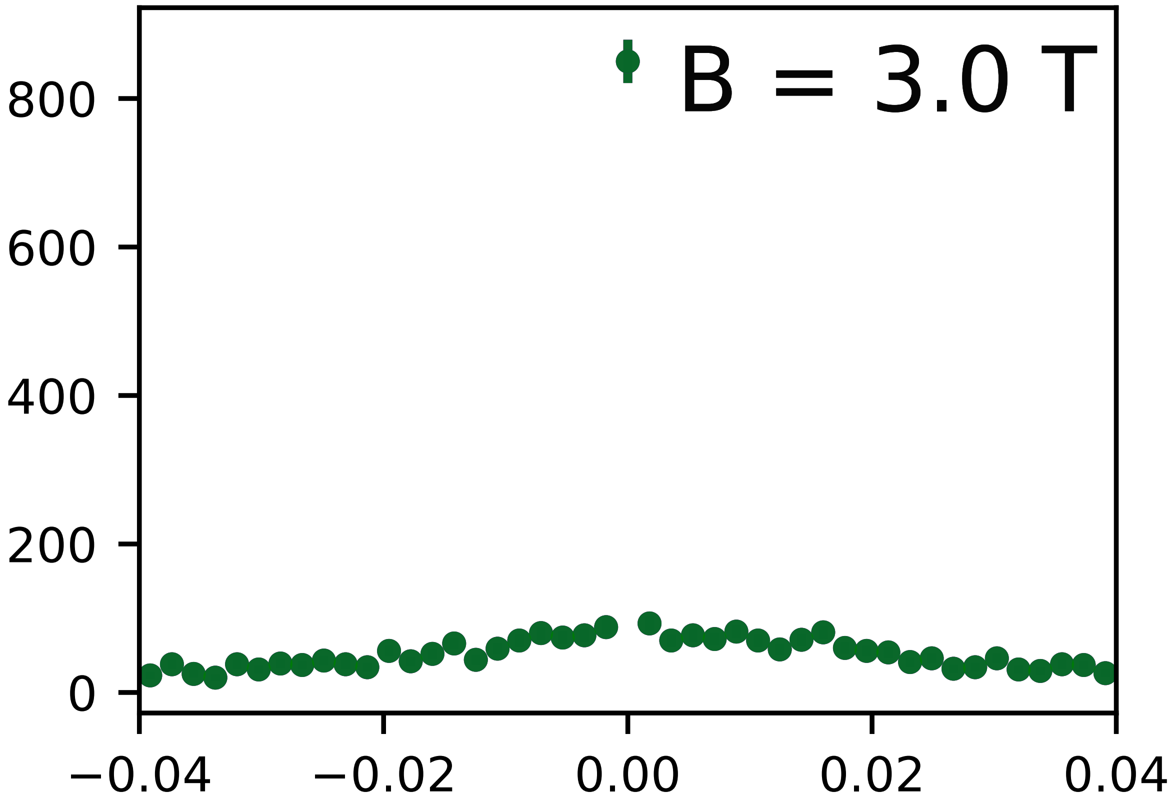
2. Full and Charged Jet $\Delta\varphi$ Distributions

- $(\Delta\varphi^{\mathrm{charged}}_{\mathrm{truth}} - \Delta\varphi^{\mathrm{full}}_{\mathrm{truth}})/\Delta\varphi^{\mathrm{charged}}_{\mathrm{truth}}$

Potting $(\Delta\varphi_{\rm truth}^{\rm charged} - \Delta\varphi_{\rm truth}^{\rm full})/\Delta\varphi_{\rm truth}^{\rm charged}$

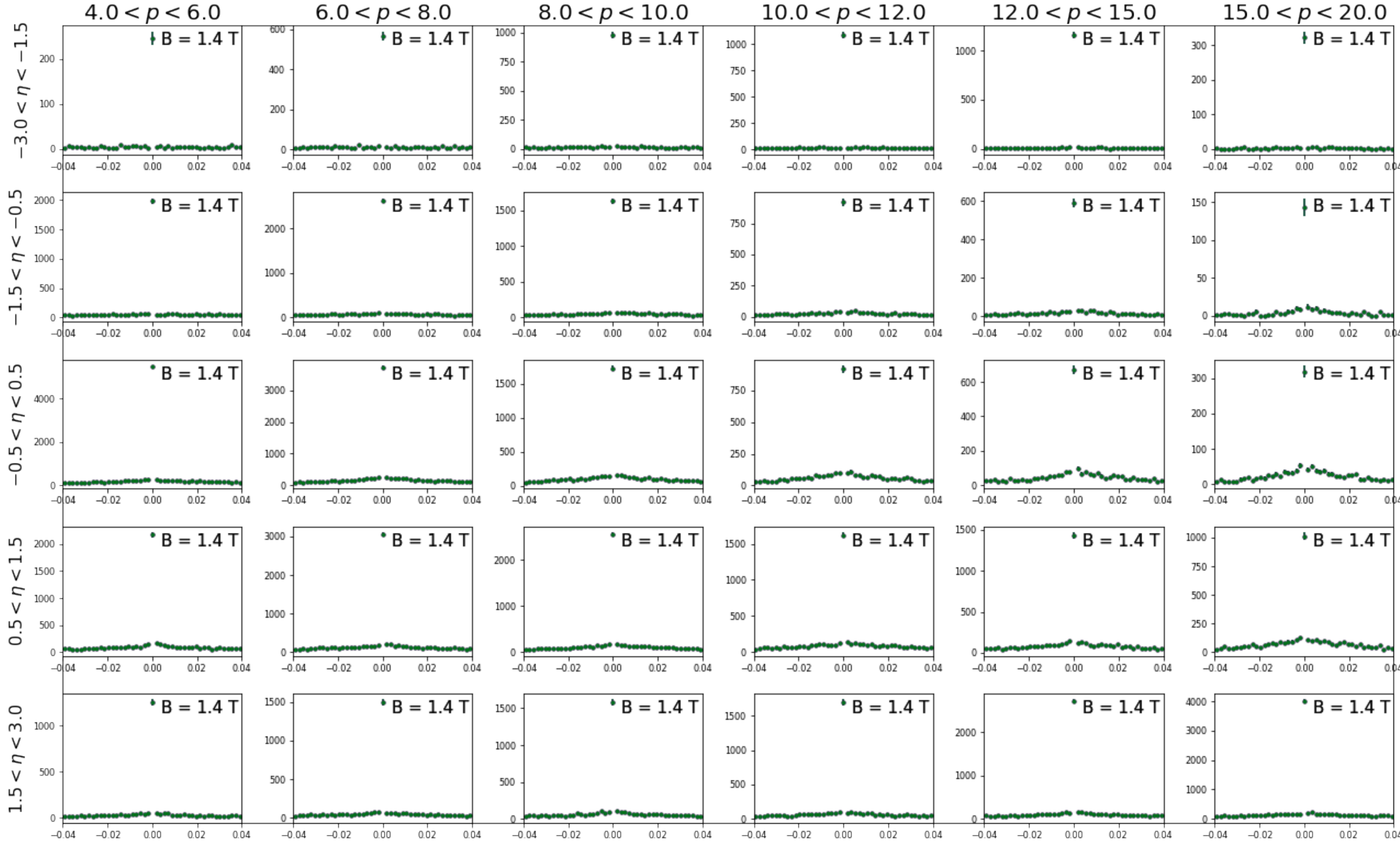
Bin: $-0.5 < \eta^{\rm jet} < 0.5$, $10.0 < p^{\rm jet} < 12$ GeV/c





Very narrow peak at 0: Charged/Neutral jets seems to have small impact

Potting $(\Delta\varphi_{\text{truth}}^{\text{charged}} - \Delta\varphi_{\text{truth}}^{\text{full}})/\Delta\varphi_{\text{truth}}^{\text{charged}}$ (B = 1.4 T)



Difference between $\Delta\varphi_{\text{truth}}^{\text{charged}}$ and $\Delta\varphi_{\text{truth}}^{\text{full}}$ not very large

Theory Curves Uncertainty

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

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

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

2. ~~Full and Charged Jet $\Delta\varphi$ Distributions~~
   - $(\Delta\varphi^{\rm charged}_{\rm truth} - \Delta\varphi^{\rm full}_{\rm truth})/\Delta\varphi^{\rm charged}_{\rm truth}$

3. Unfolding Uncertainty
   - ~1-2%

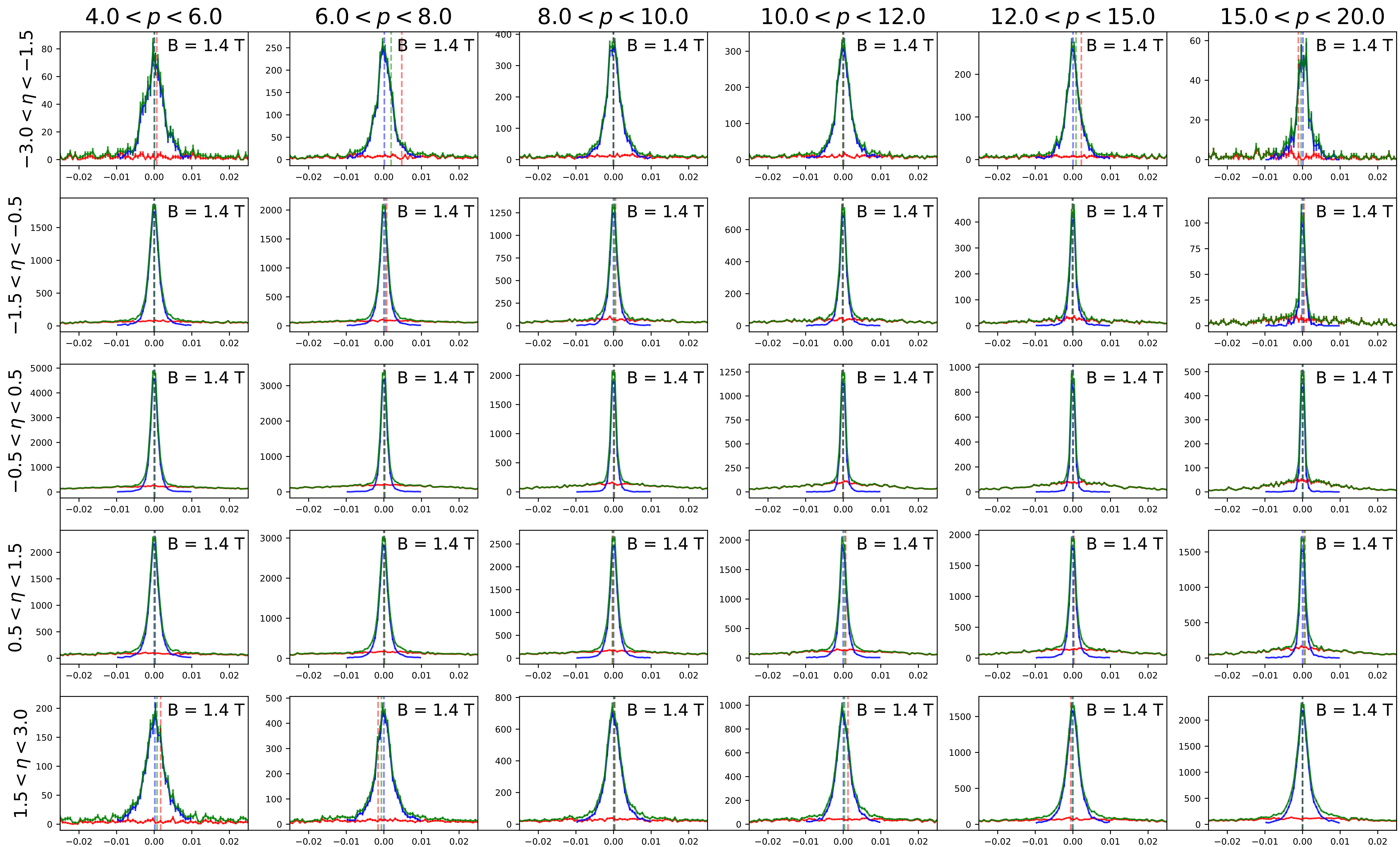
→ **Sum in quadrature with $\sigma\Delta\varphi$**

Next Step: Report lepton-jet correlations in backward, central, and forward regions

End.

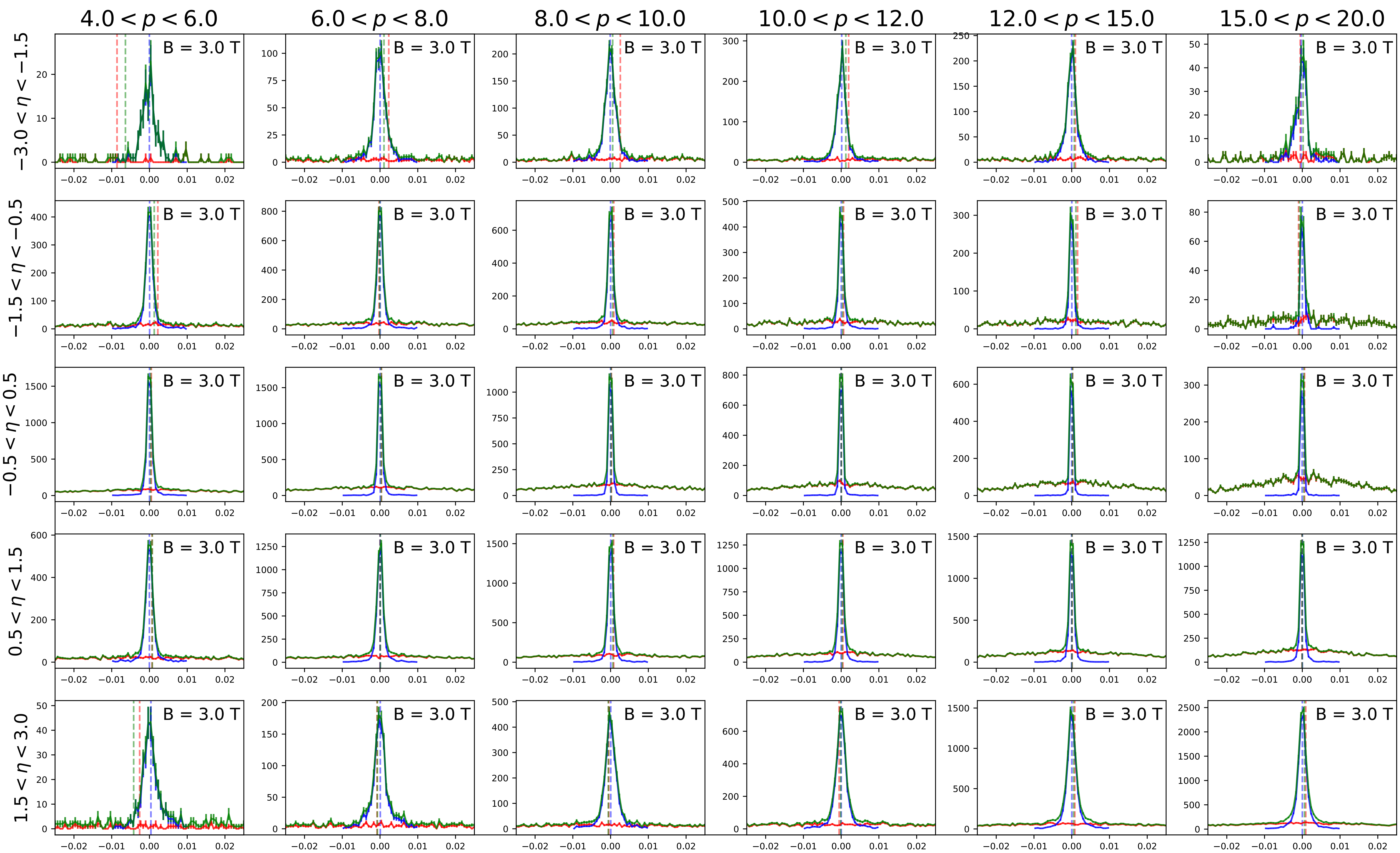
$N_{\text{Missed}} < 1$ $N_{\text{Missed}} \geq 1$ No N_{Missed} Cut

dφ [mrad]



$N_{\mathrm{Missed}} < 1$ $N_{\mathrm{Missed}} \geq 1$ No N_{Missed} Cut

dφ [mrad]



Luminosity Scaling

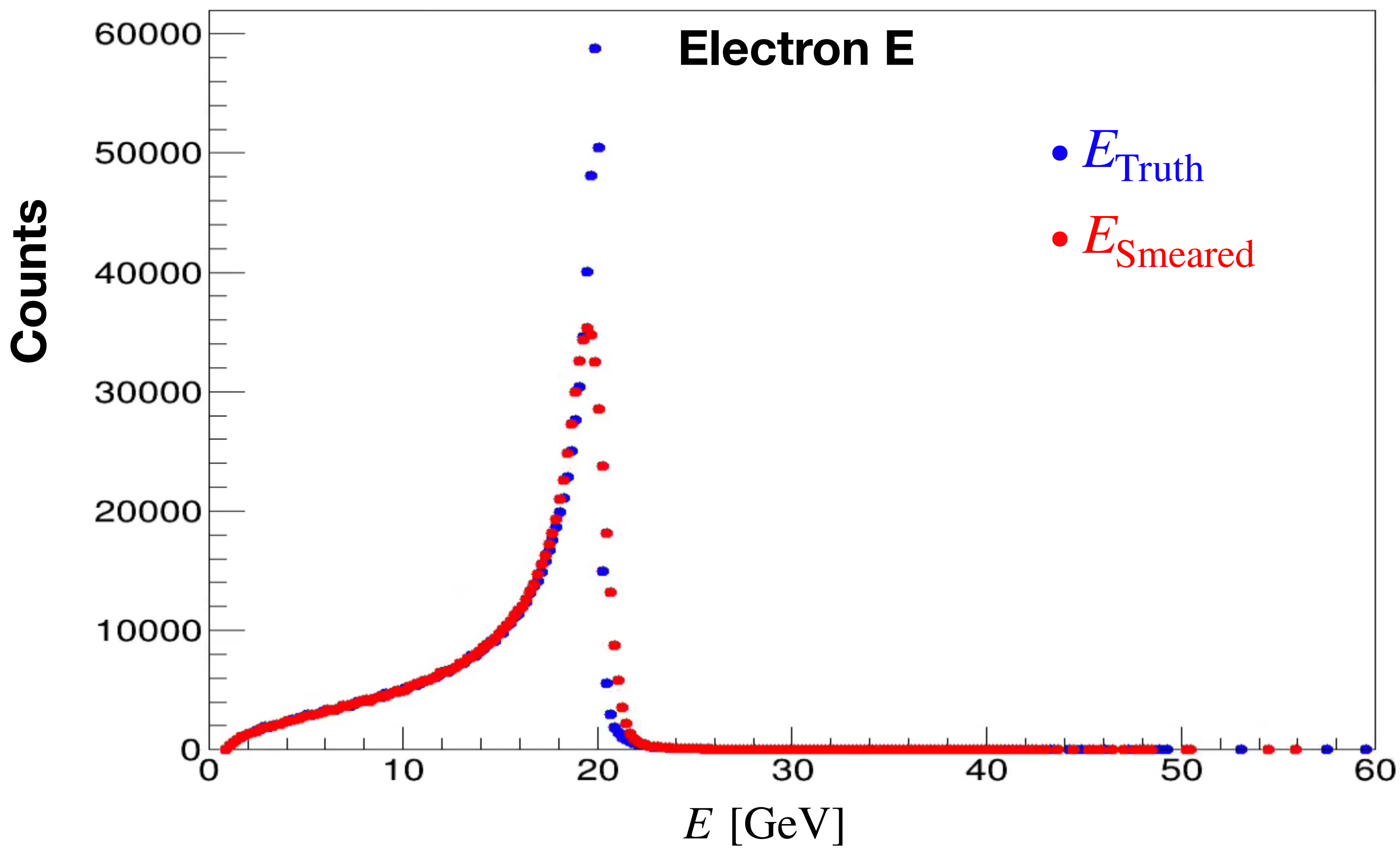
- $L_{\text{EIC}} = 10\ \text{fb}^{-1}$
- $L_{\text{gen}} = N_{\text{events}}/\sigma_{e+p}$ ⟶
- Scale = $L_{\text{EIC}}/L_{\text{gen}}$

- $\sigma_{e+p} = 9.27 \times 10^{-5}\text{mb}$
- $N_{\text{events}} \approx 2{,}000{,}000$
- $L_{\text{gen}} = 2.49\ \text{fb}^{-1}$

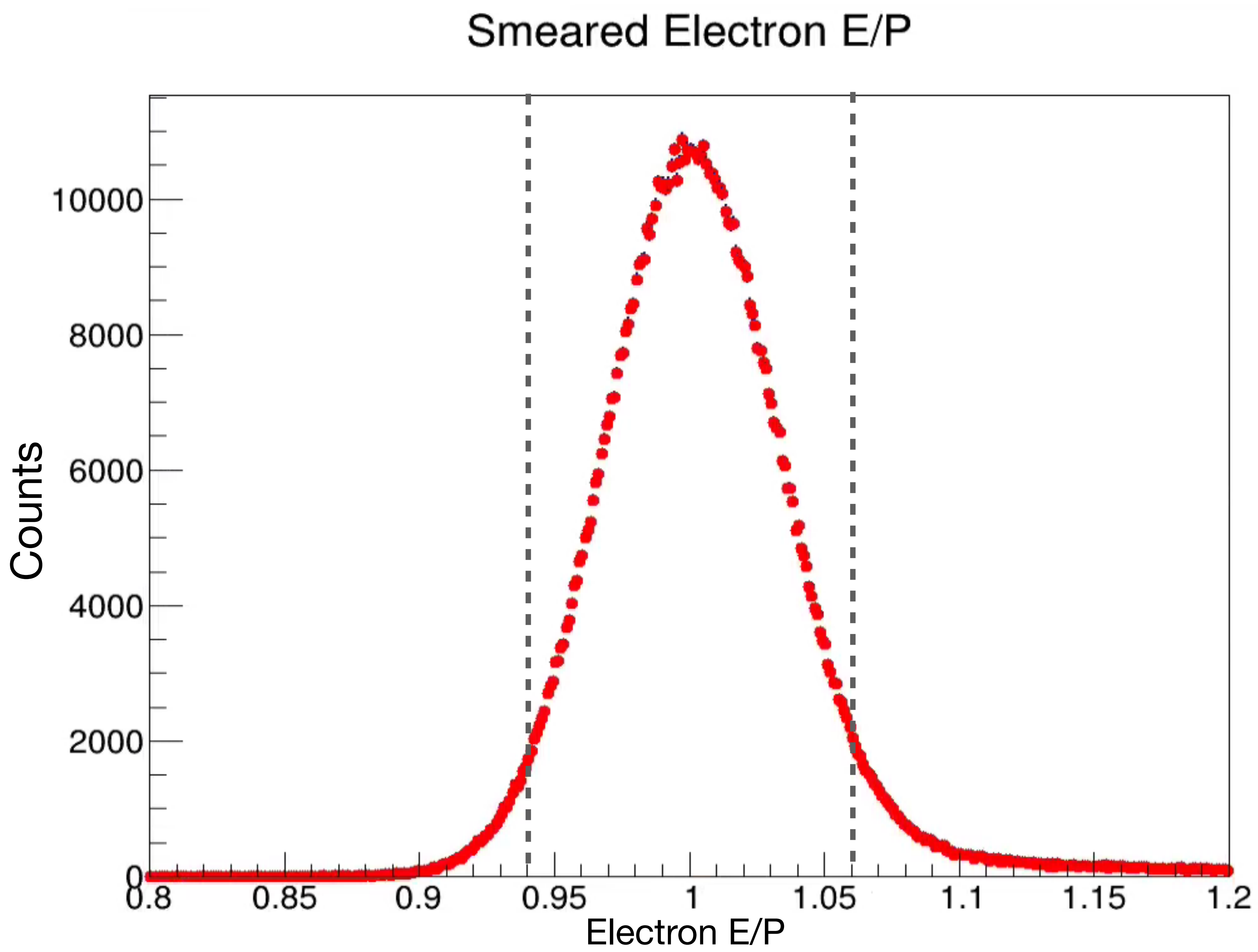
Scale = 0.401

Electron Smearing + E/P cut

- Smear electron energy in order to simulate an E/P selection
- From YR, backwards EMCal requirement:
  - $\sigma(E)/E \approx 2\,\%/\sqrt{E} \oplus (1-3)\,\%$
  - Obtain σ_E, and smear E according to Gaussian distribution ($\mu = E$, $\sigma = \sigma_E$)
  - Example: $E = 20.4$, $\sigma_E = 0.62$, $E_{\text{smeared}} = 20.6$



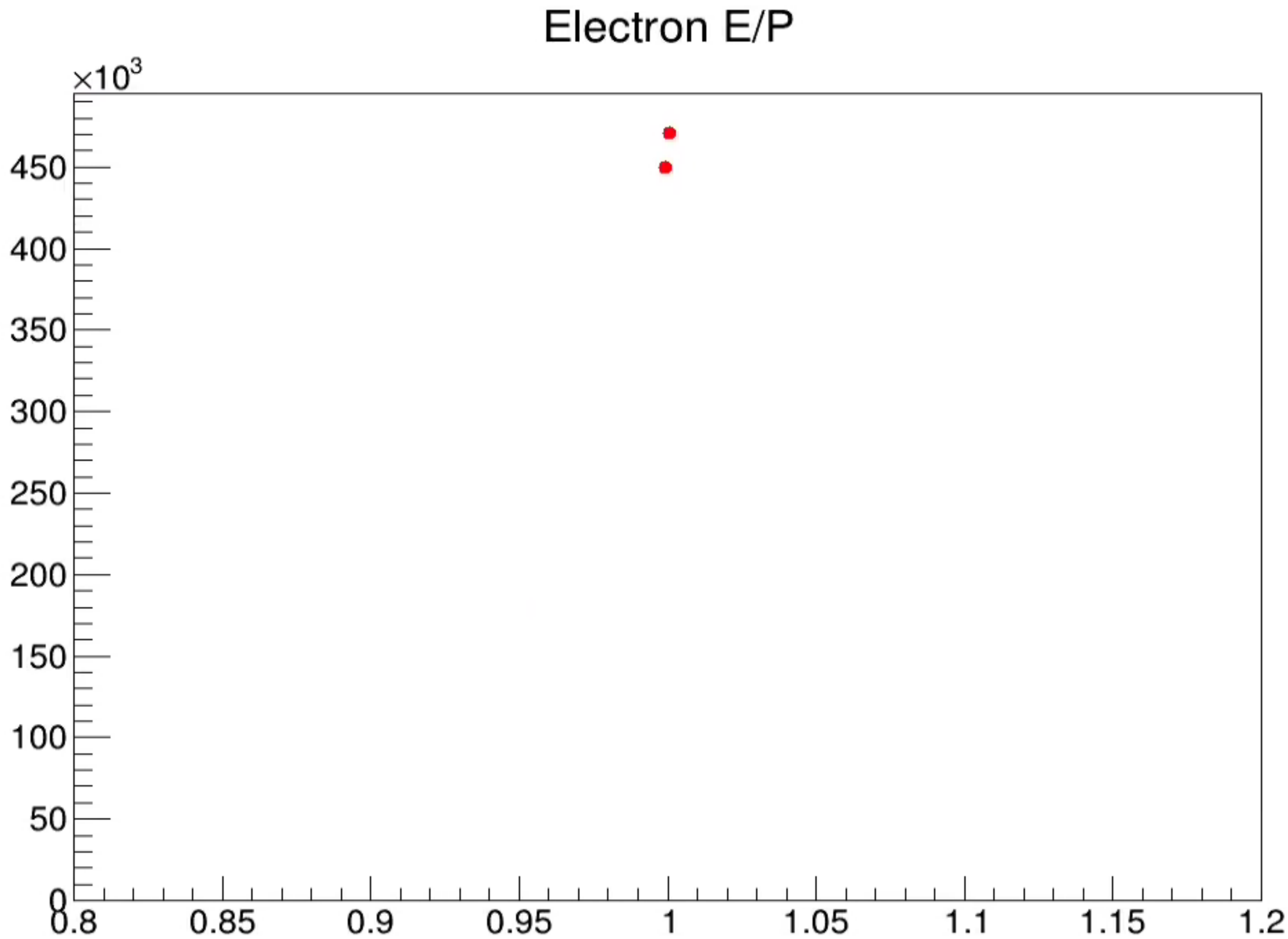
E/P Selection



Indicates smearing working as intended (clear gaus distribution)

Applying a 2σ cut, $\sigma_{\mathrm{E/P}} = 0.03$

E/P Without Smearing



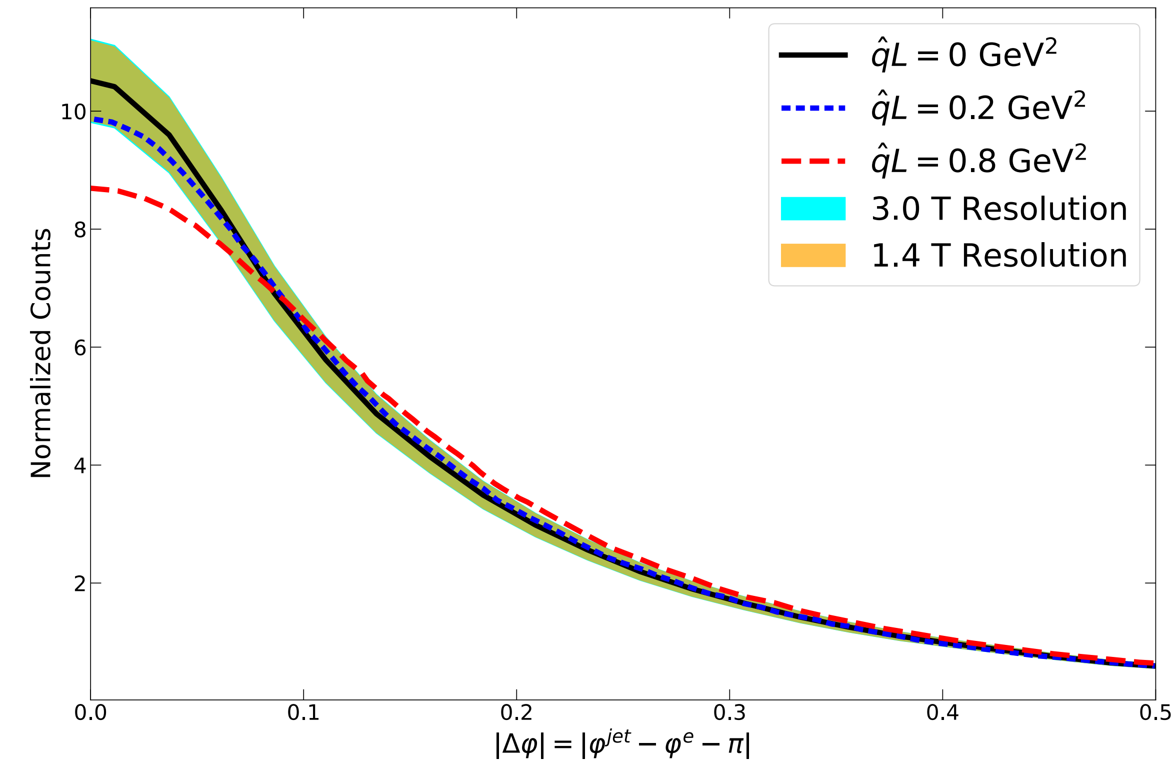
Uncertainty Exploration

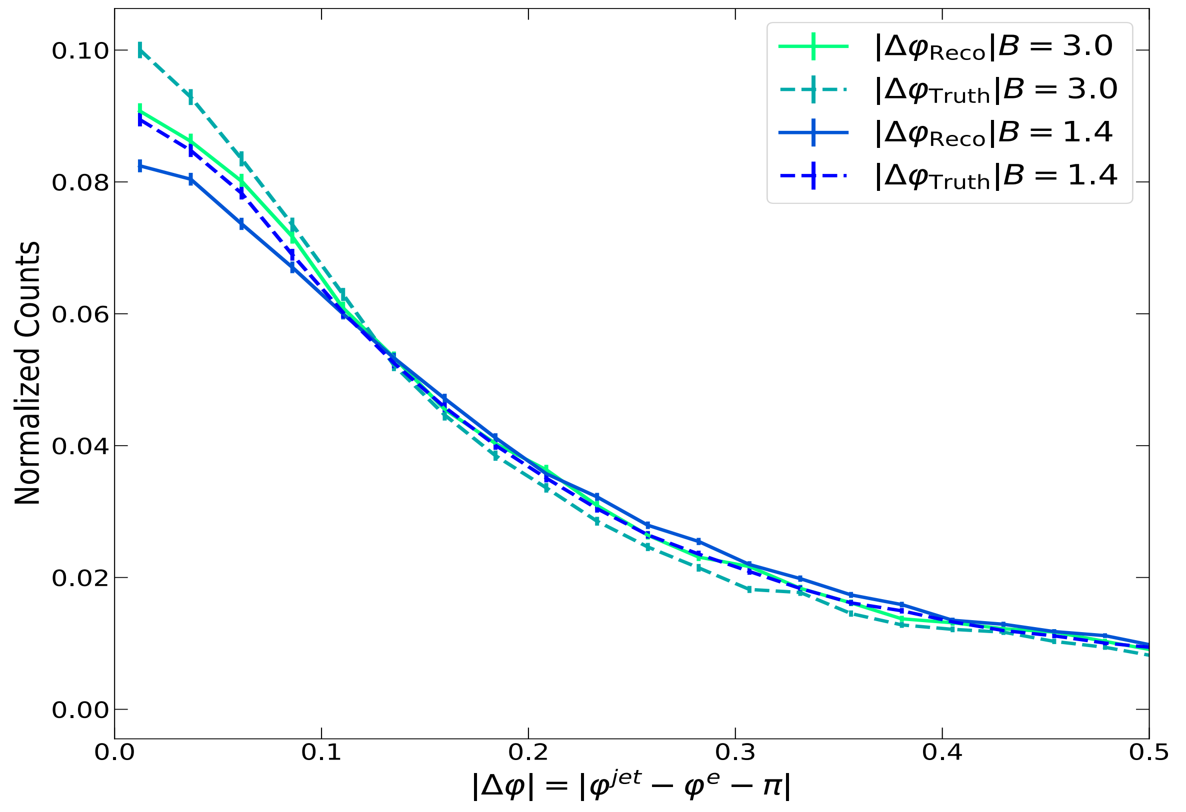
Error Propagation

- Fit+Toy MC (in progress)
  - 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?



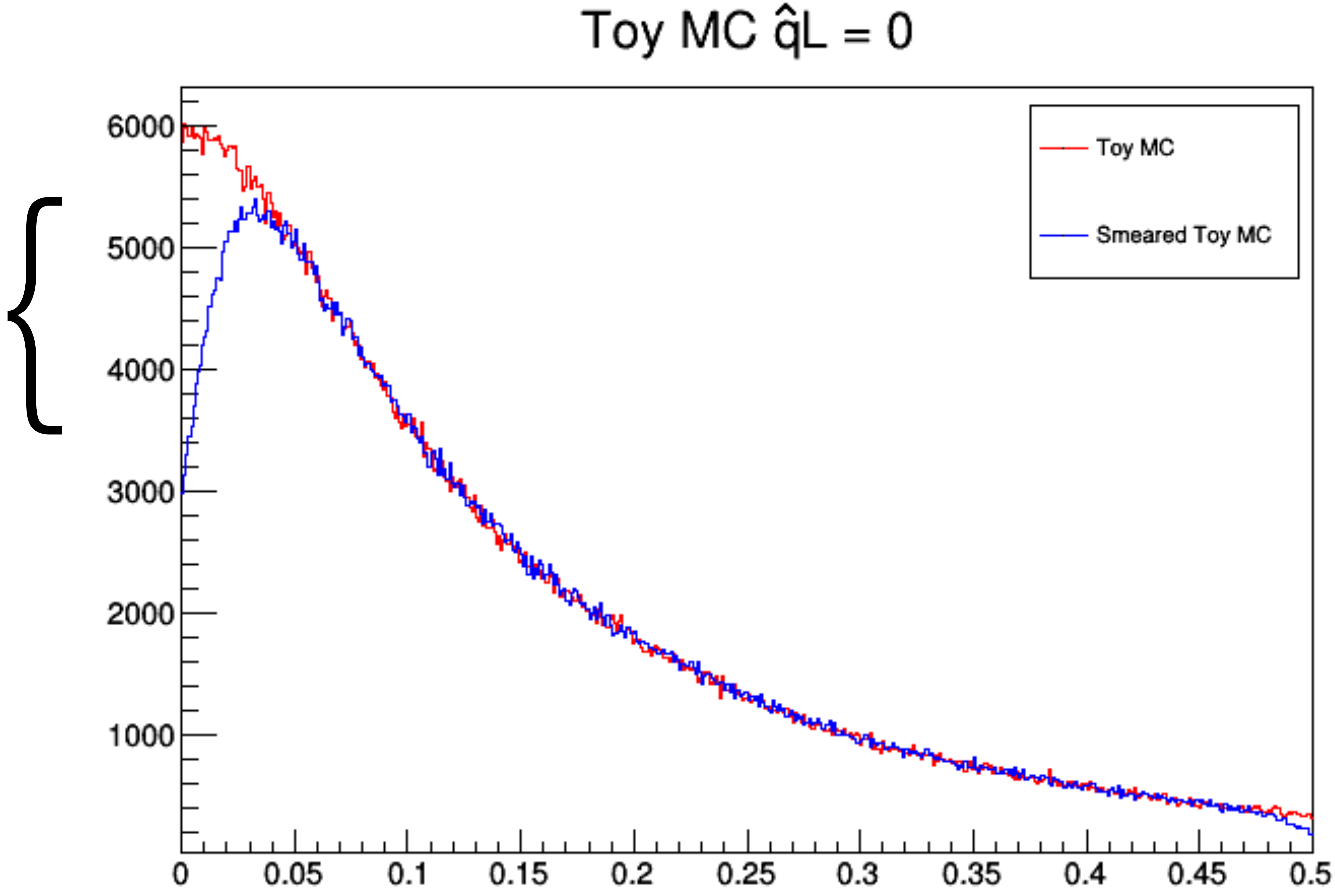


Toy MC

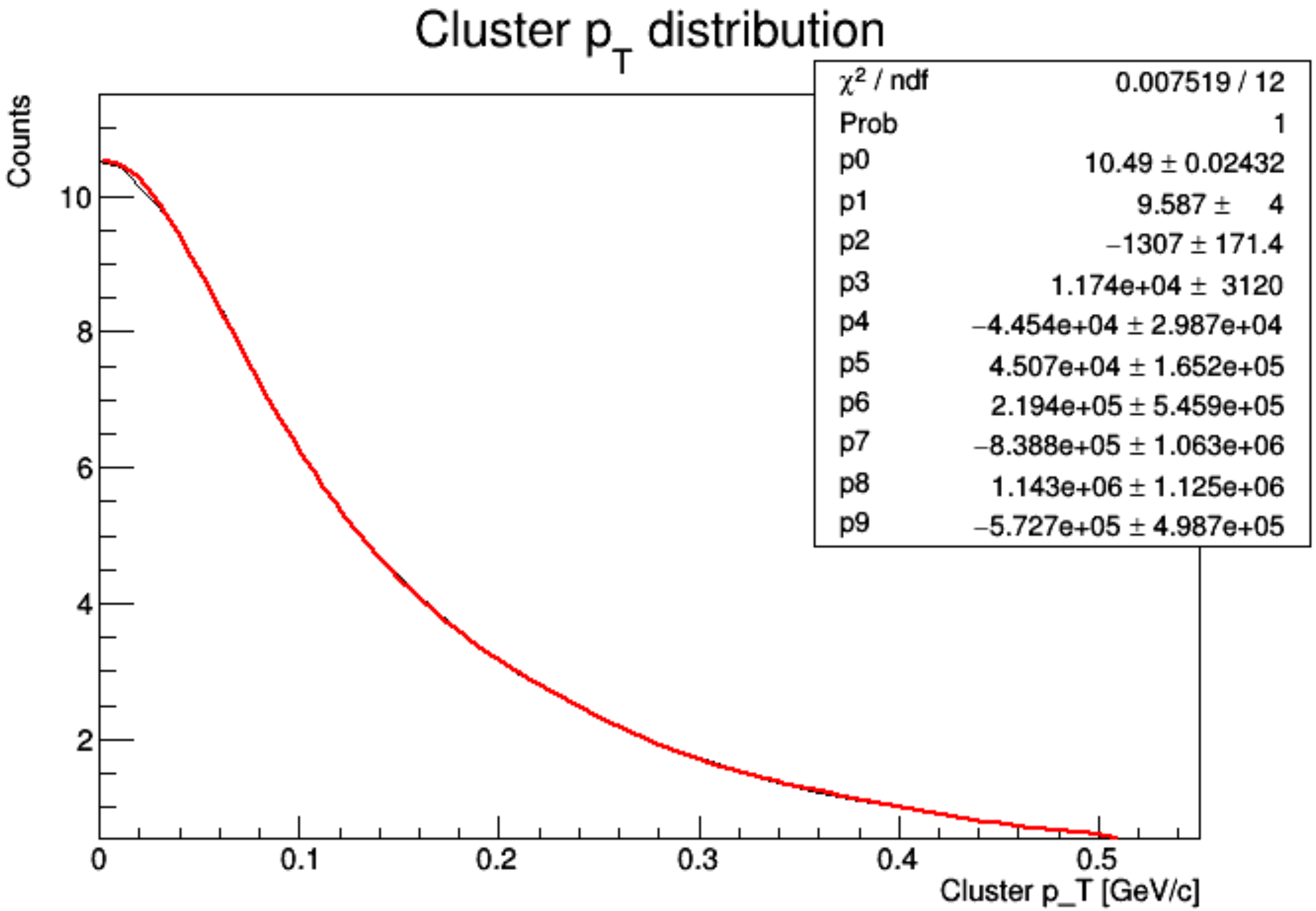
Toy MC smearing with

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

Need to implement 0-π wrap



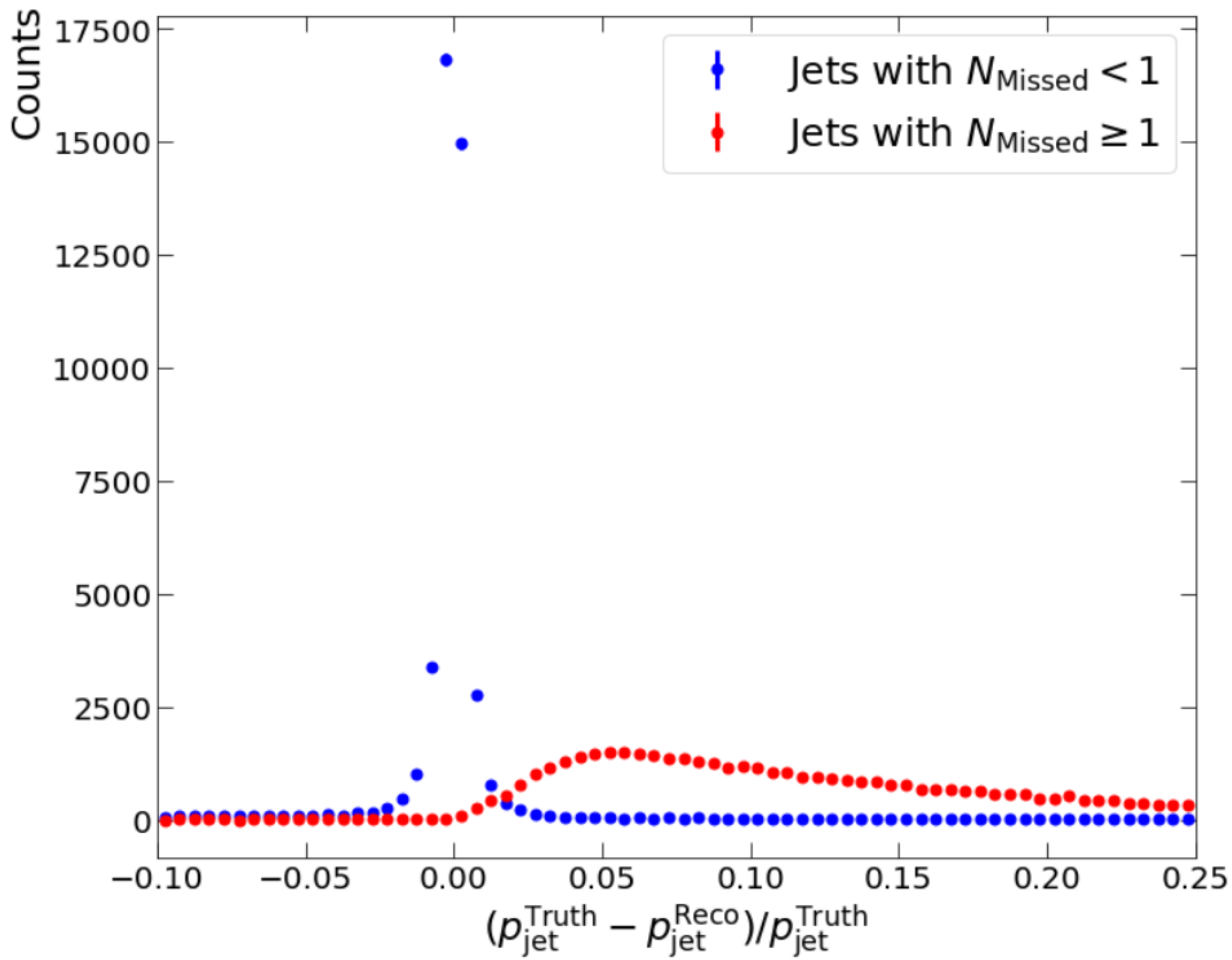
Pol9



Cluster p_T distribution
Counts
Cluster p_T [GeV/c]
χ^2 / ndf 0.007519 / 12
Prob 1
p0 10.49 ± 0.02432
p1 9.587 ± 4
p2 −1307 ± 171.4
p3 1.174e+04 ± 3120
p4 −4.454e+04 ± 2.987e+04
p5 4.507e+04 ± 1.652e+05
p6 2.194e+05 ± 5.459e+05
p7 −8.388e+05 ± 1.063e+06
p8 1.143e+06 ± 1.125e+06
p9 −5.727e+05 ± 4.987e+05

Older Distribution Studies

Two Populations of Jets

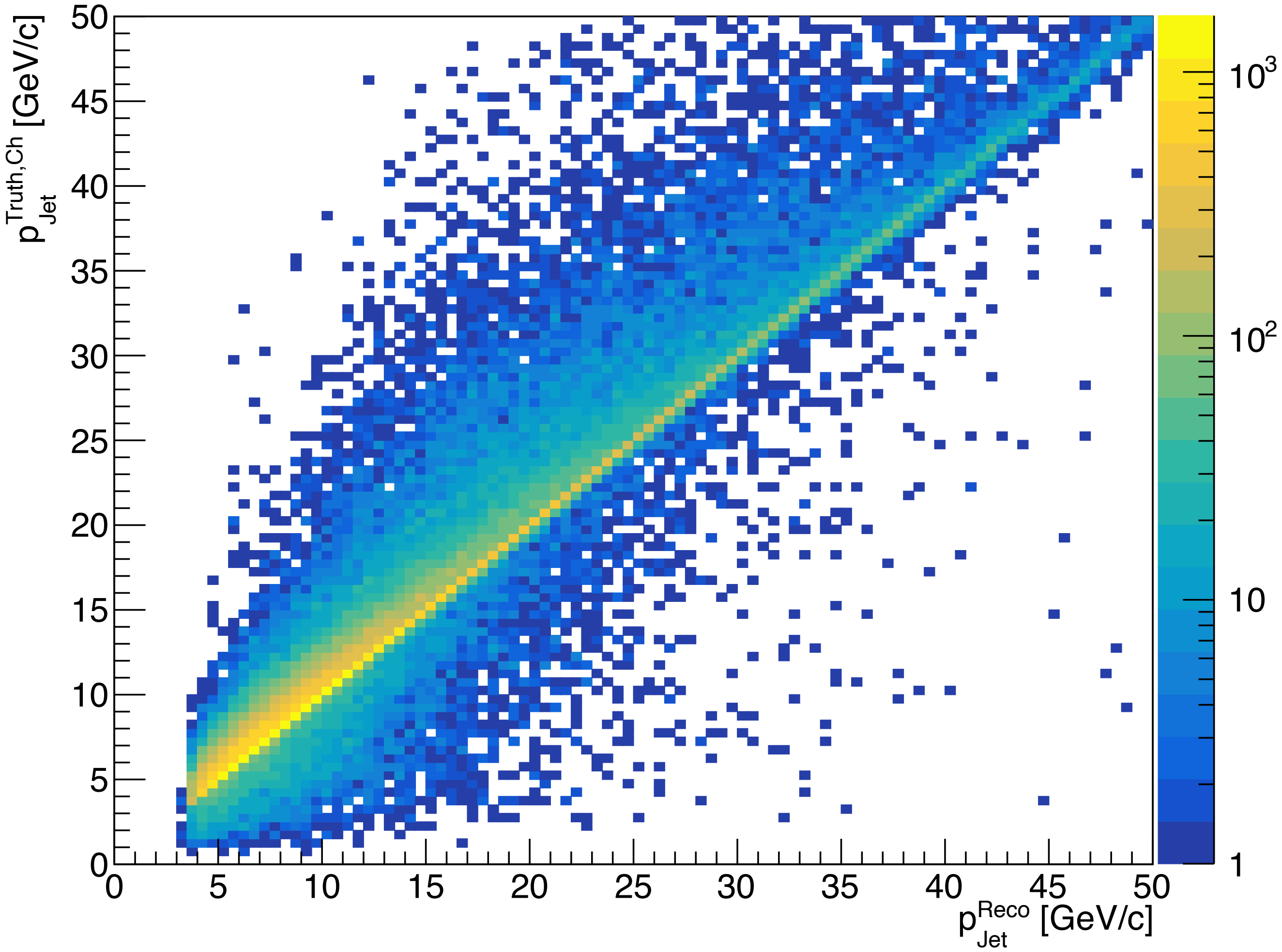


Number of Missed Charged Constituents:

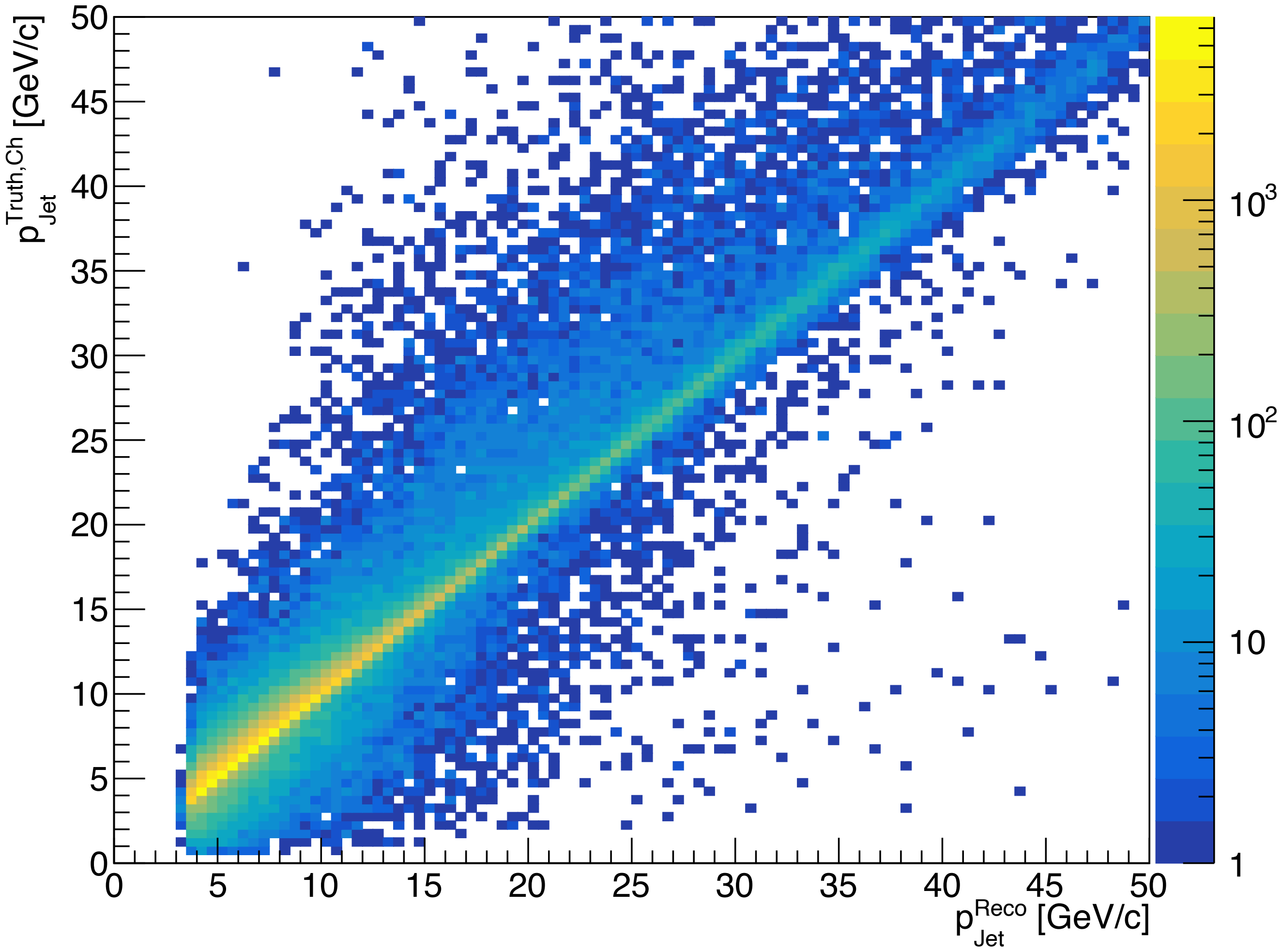
$$N_{\mathrm{missed}} = N^{\mathrm{truth}}_{\mathrm{constituents}} - N^{\mathrm{reco}}_{\mathrm{constituents}} - N^{\mathrm{truth}}_{\mathrm{neutral}}$$

Charged Jet Momentum Response

$B = 3.0$ T

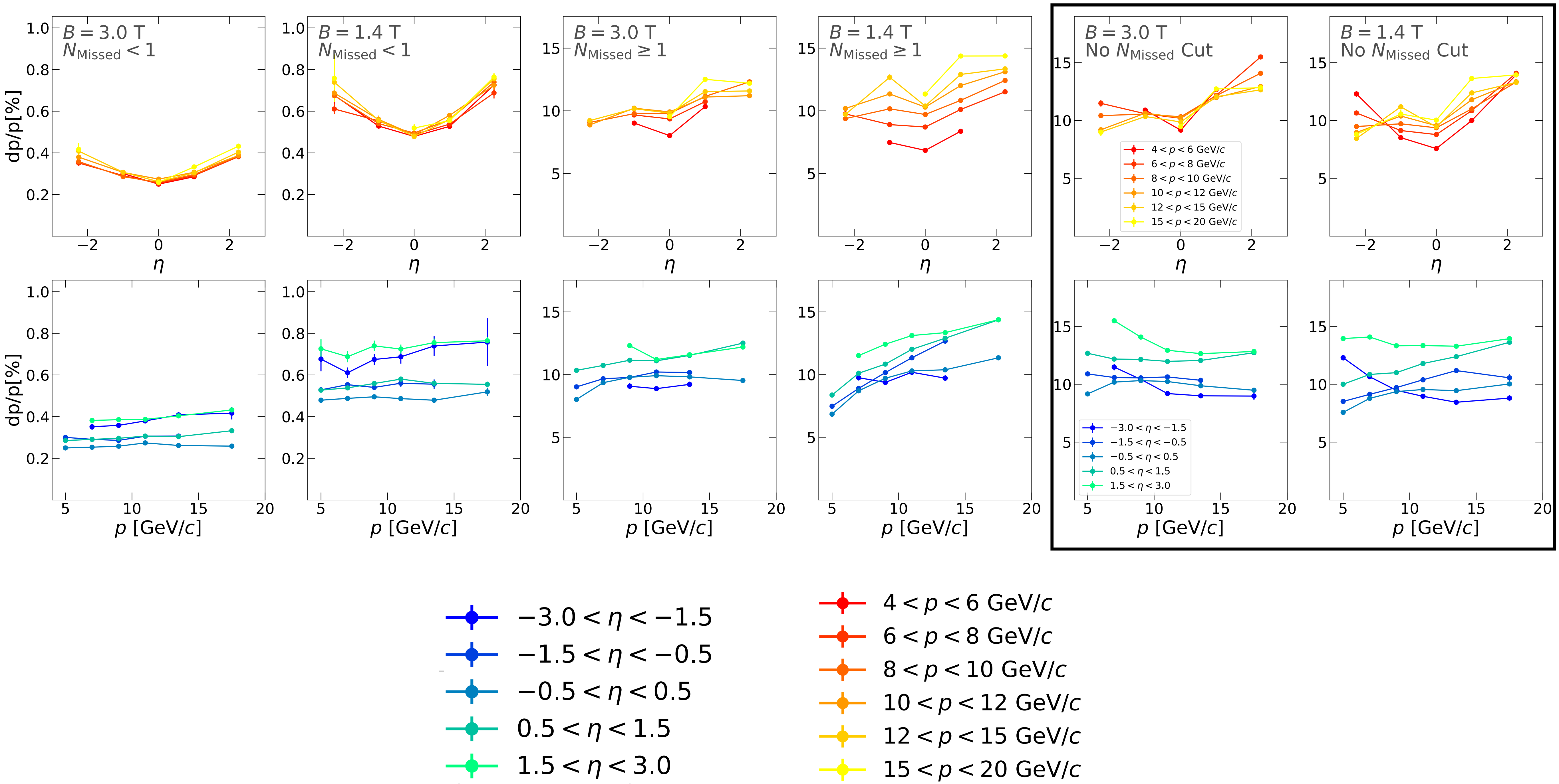


$B = 1.4$ T

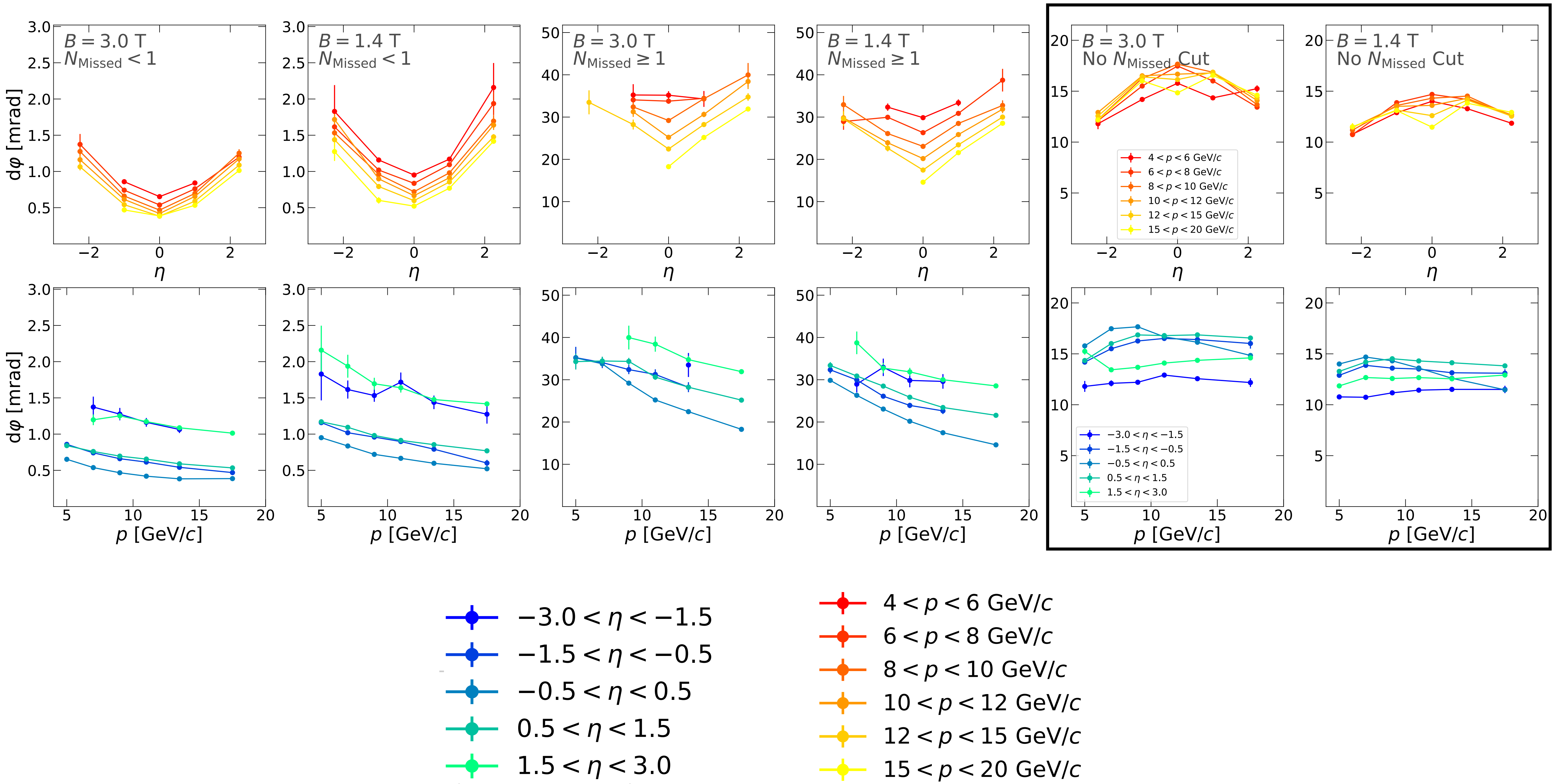


Clear truth-reco correlation, but with significant number of off-diagonal hits

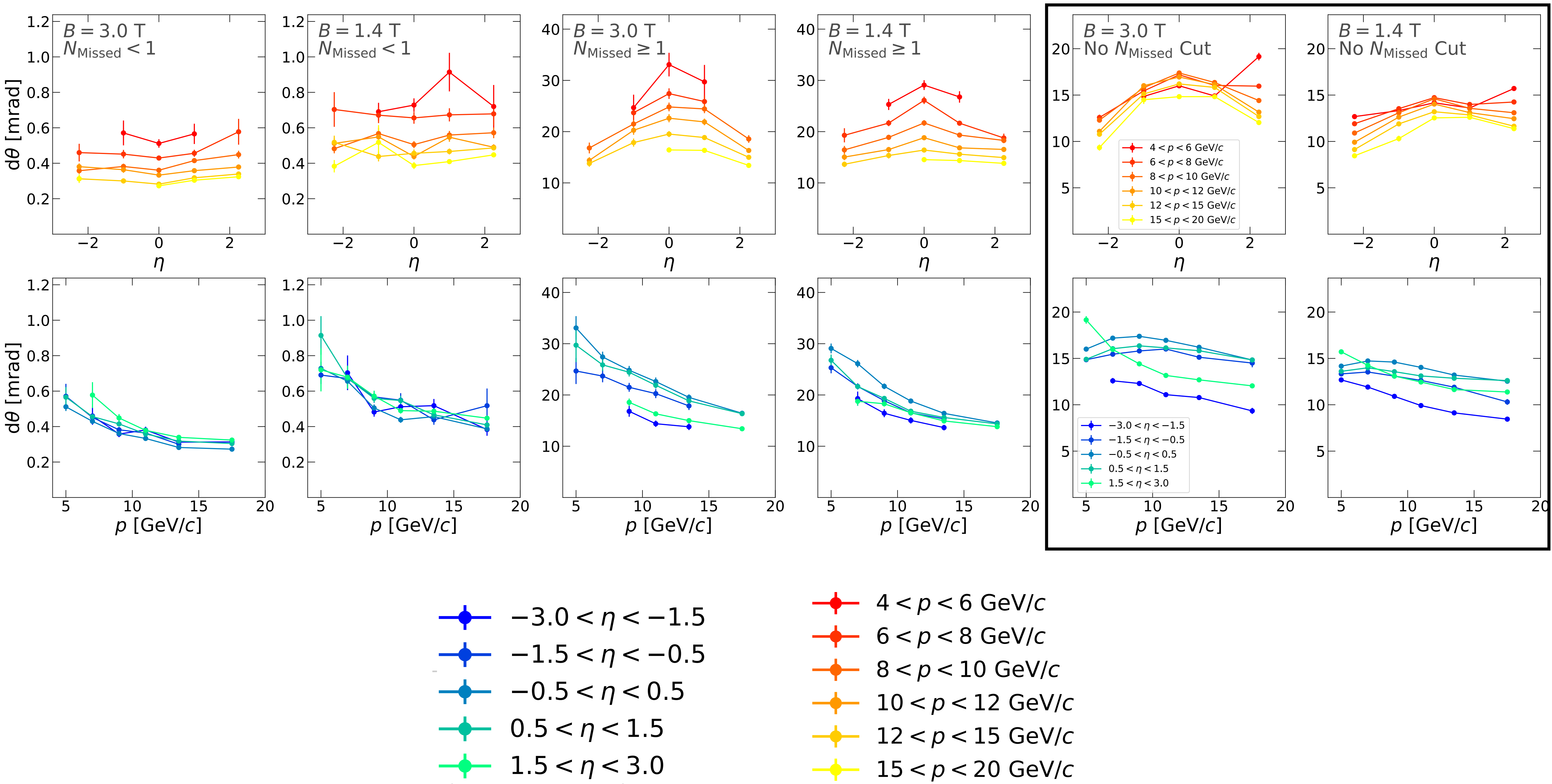
dP/P


$B = 3.0$ T
$N_{Missed} < 1$
$B = 1.4$ T
$N_{Missed} < 1$
$B = 3.0$ T
$N_{Missed} \geq 1$
$B = 1.4$ T
$N_{Missed} \geq 1$
$B = 3.0$ T
No N_{Missed} Cut
$B = 1.4$ T
No N_{Missed} Cut
dp/p[%]
η
p [GeV/c]
$-3.0 < \eta < -1.5$
$-1.5 < \eta < -0.5$
$-0.5 < \eta < 0.5$
$0.5 < \eta < 1.5$
$1.5 < \eta < 3.0$
$4 < p < 6$ GeV/c
$6 < p < 8$ GeV/c
$8 < p < 10$ GeV/c
$10 < p < 12$ GeV/c
$12 < p < 15$ GeV/c
$15 < p < 20$ GeV/c

φ Resolution

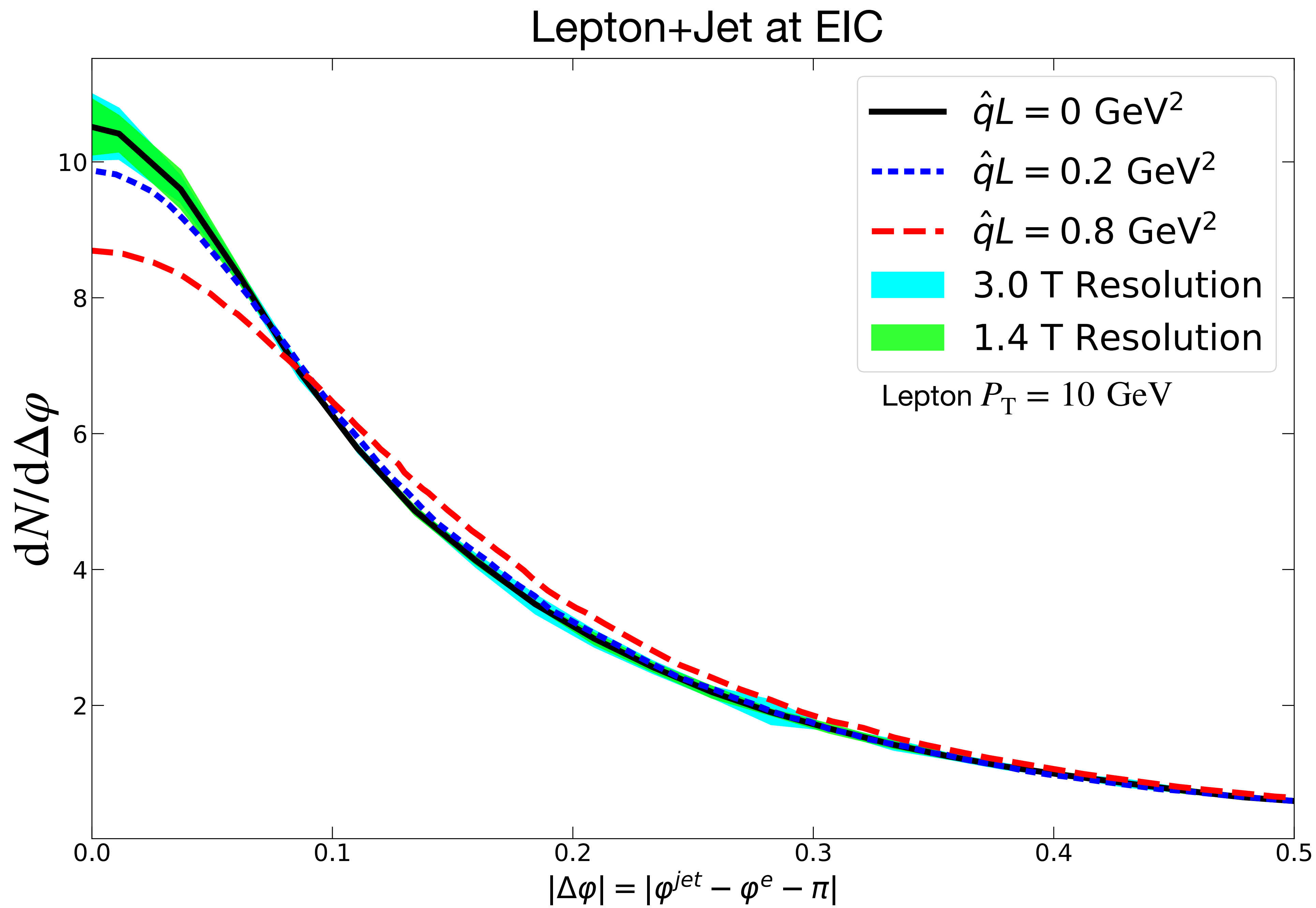


θ Resolutions

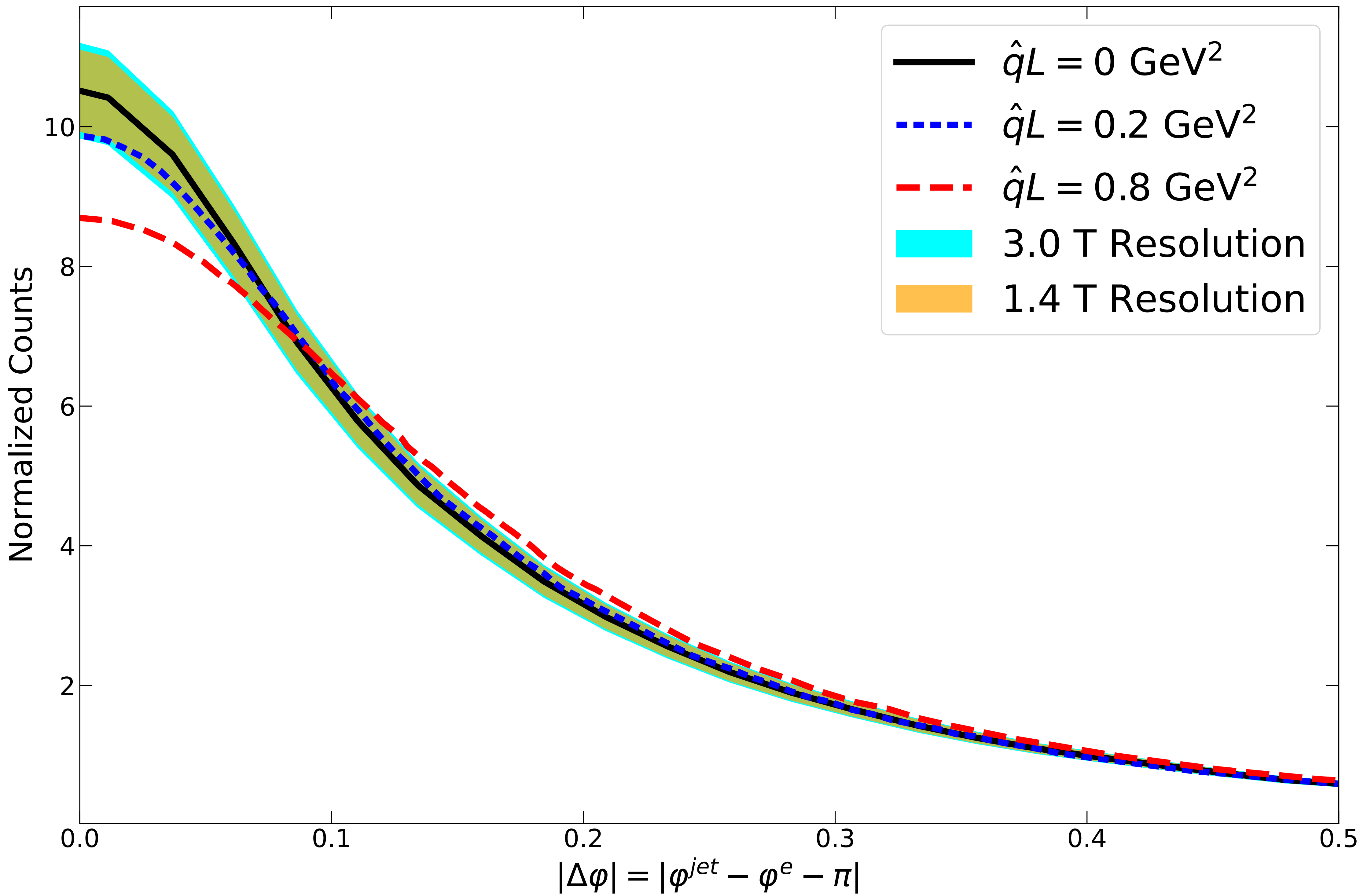


Lepton+Jet Theory

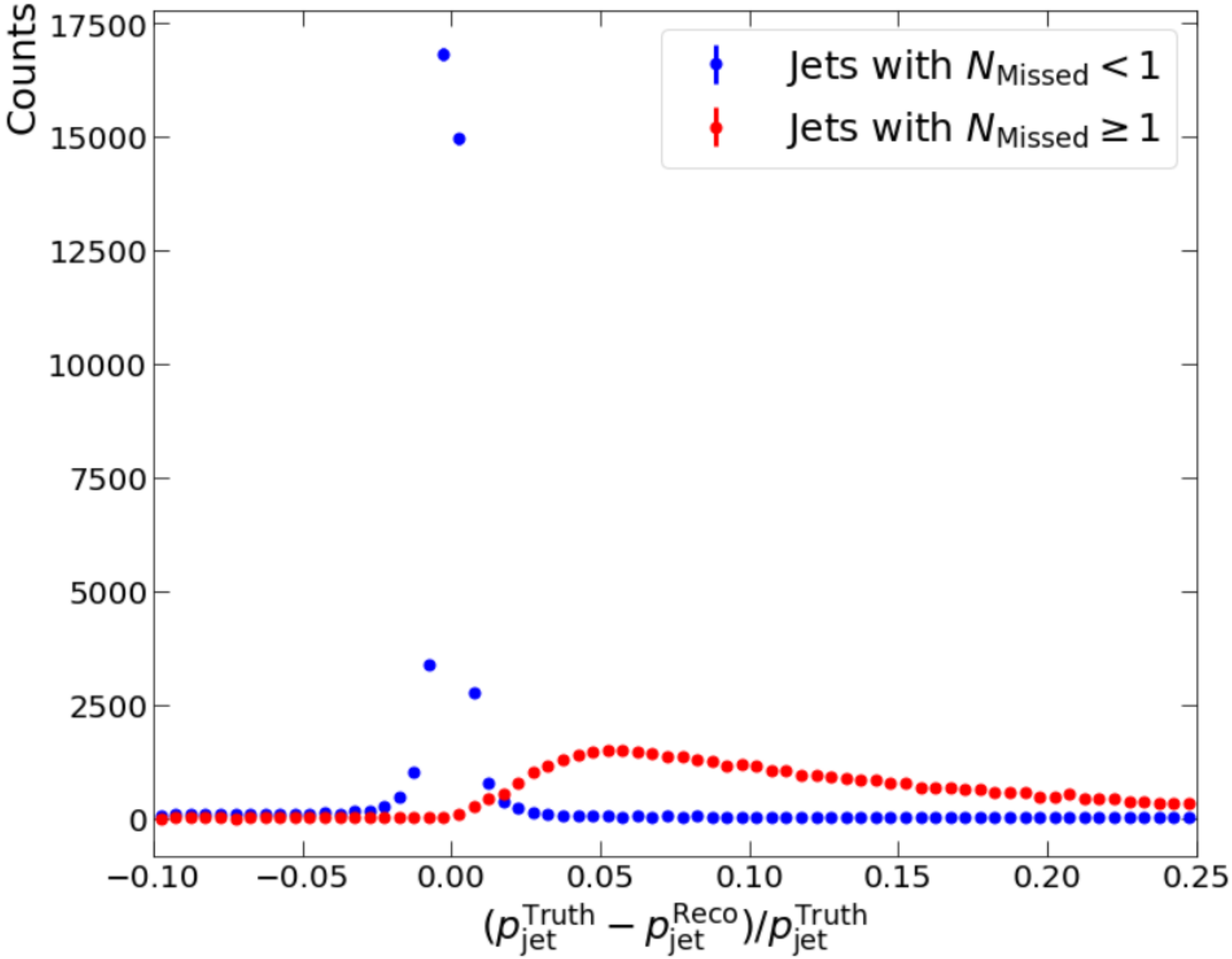
Resolution (%) = (Truth-Reco) / Truth



$|\eta| < 3.0$ (All Regions)



Two Populations of Jets



- Truth Seeded Tracking
- 100% *hit* efficiency
- Kalman filter in Fun4All
- Low p_{T} Threshold (3-hits)

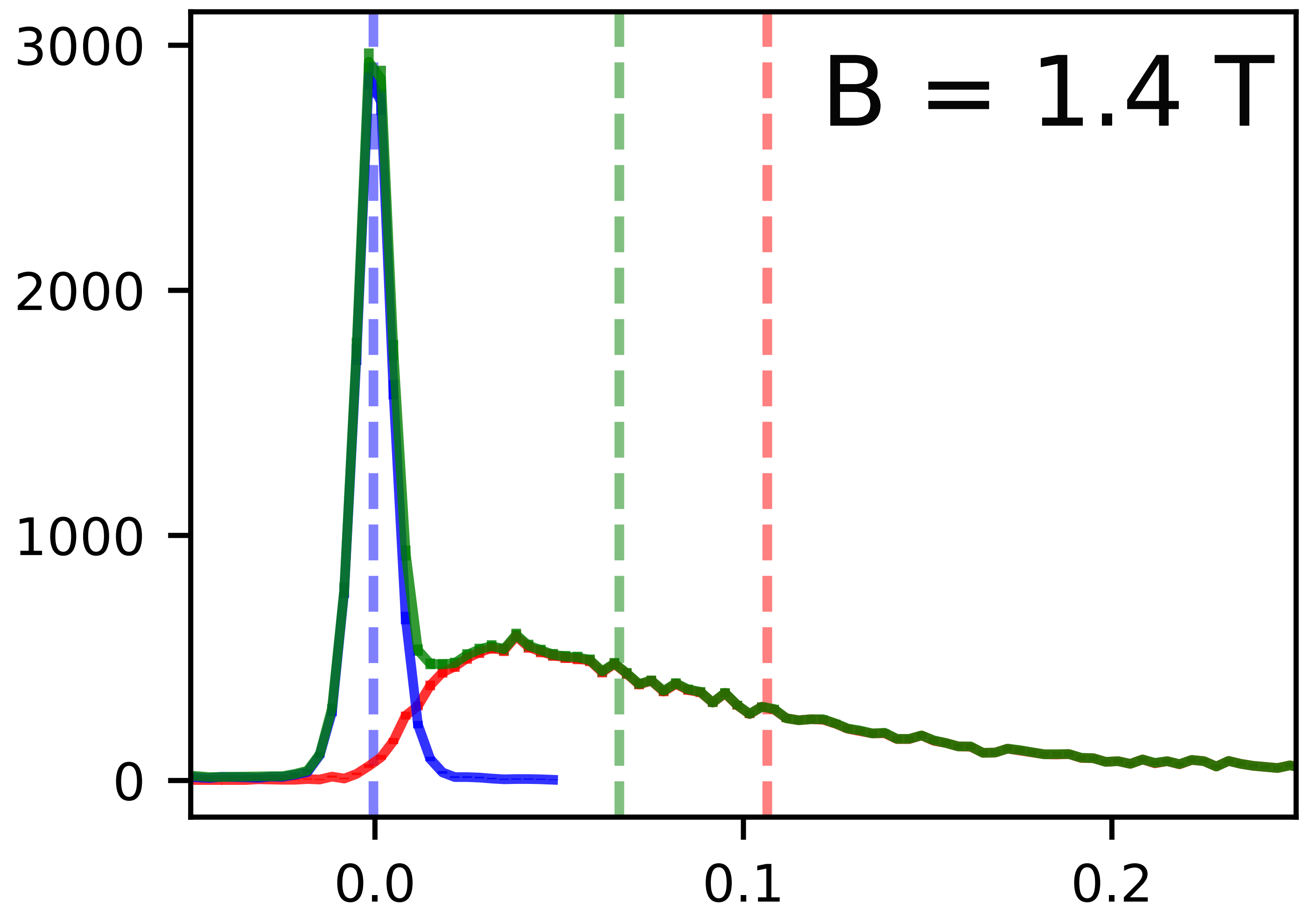
Number of Missed Charged Constituents:

$$N_{\mathrm{missed}} = N_{\mathrm{constituents}}^{\mathrm{truth}} - N_{\mathrm{constituents}}^{\mathrm{reco}} - N_{\mathrm{neutral}}^{\mathrm{truth}}$$

Example of Distribution

$6 < p < 8$ GeV/c **(← Momentum Label)**

(η Label →) $0.5 < \eta < 0.5$



$N_{\text{Missed}} < 1$

$N_{\text{Missed}} \geq 1$

No N_{Missed} Cut

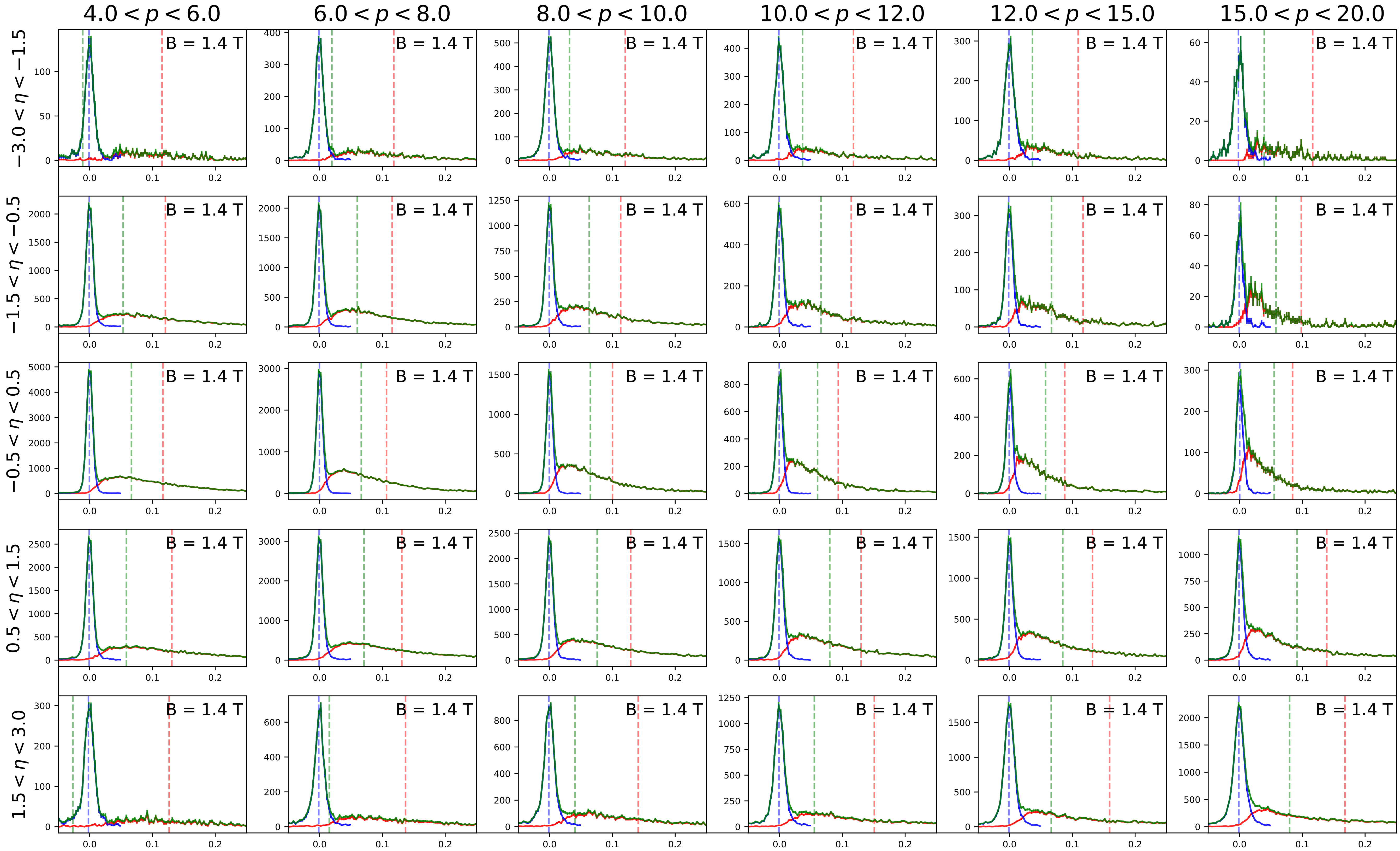
$$\sigma = \sqrt{\frac{\sum (X - \mu)^2}{N}}$$

- **Y-Axis: Simply the counts (histogram)**
- **X-axis: dp/p (%), given in title**
- **Dashed Lines: Mean of distribution**

$N_{\text{Missed}} < 1$ $N_{\text{Missed}} \geq 1$ No N_{Missed} Cut

B = 1.4 T

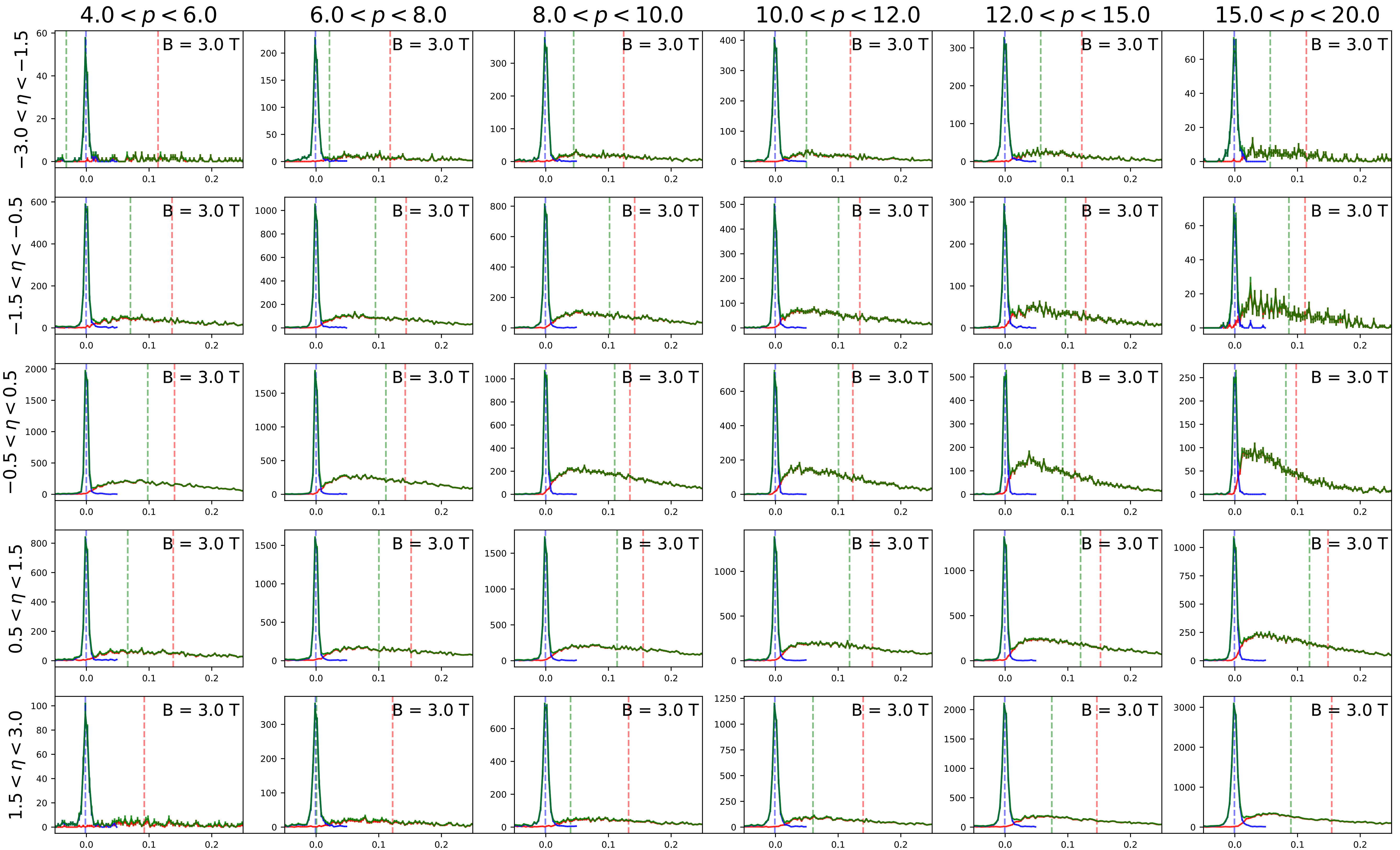
dp/p[%]



$N_{Missed} < 1$ $N_{Missed} \geq 1$ No N_{Missed} Cut

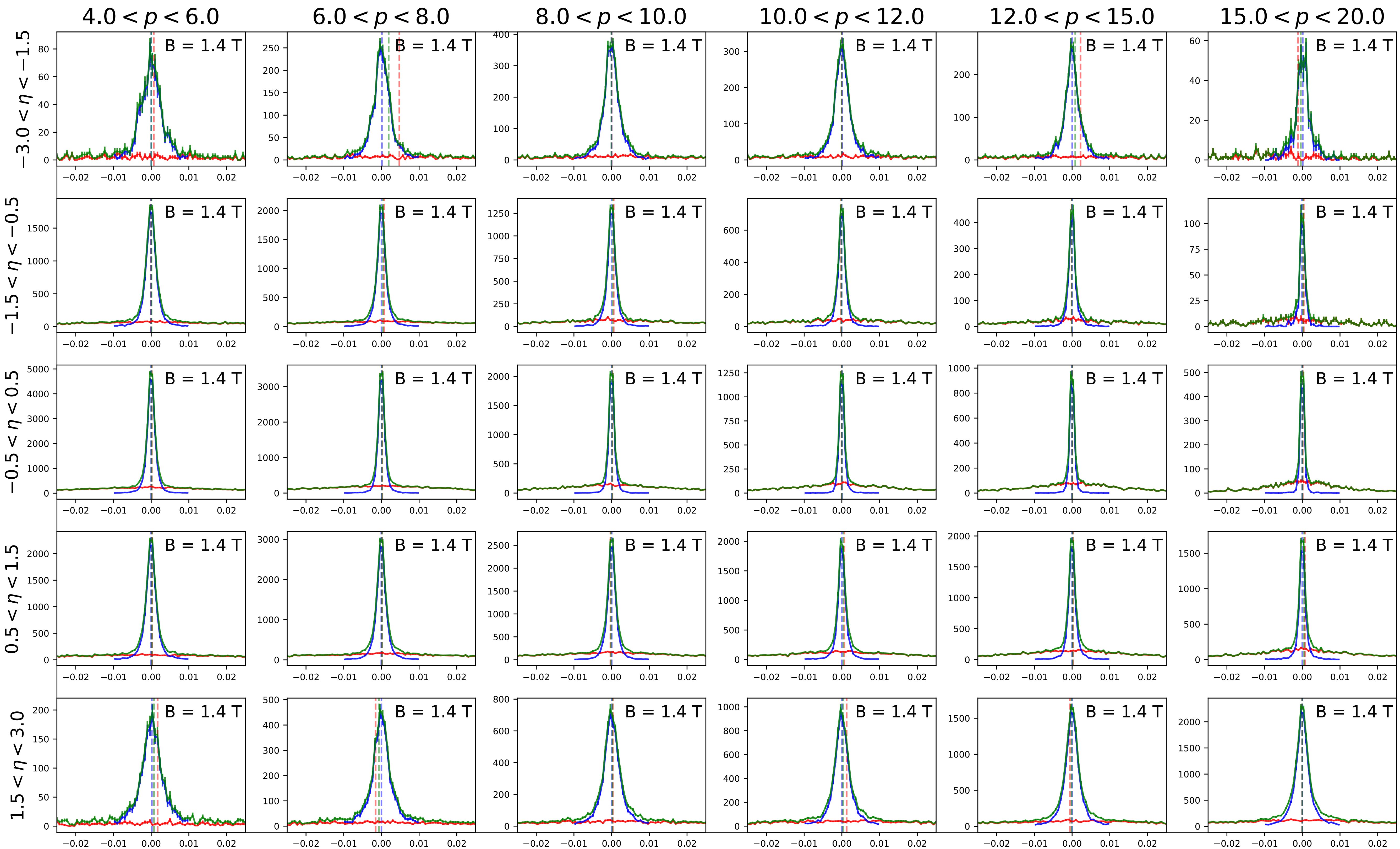
B = 3.0 T

dp/p[%]



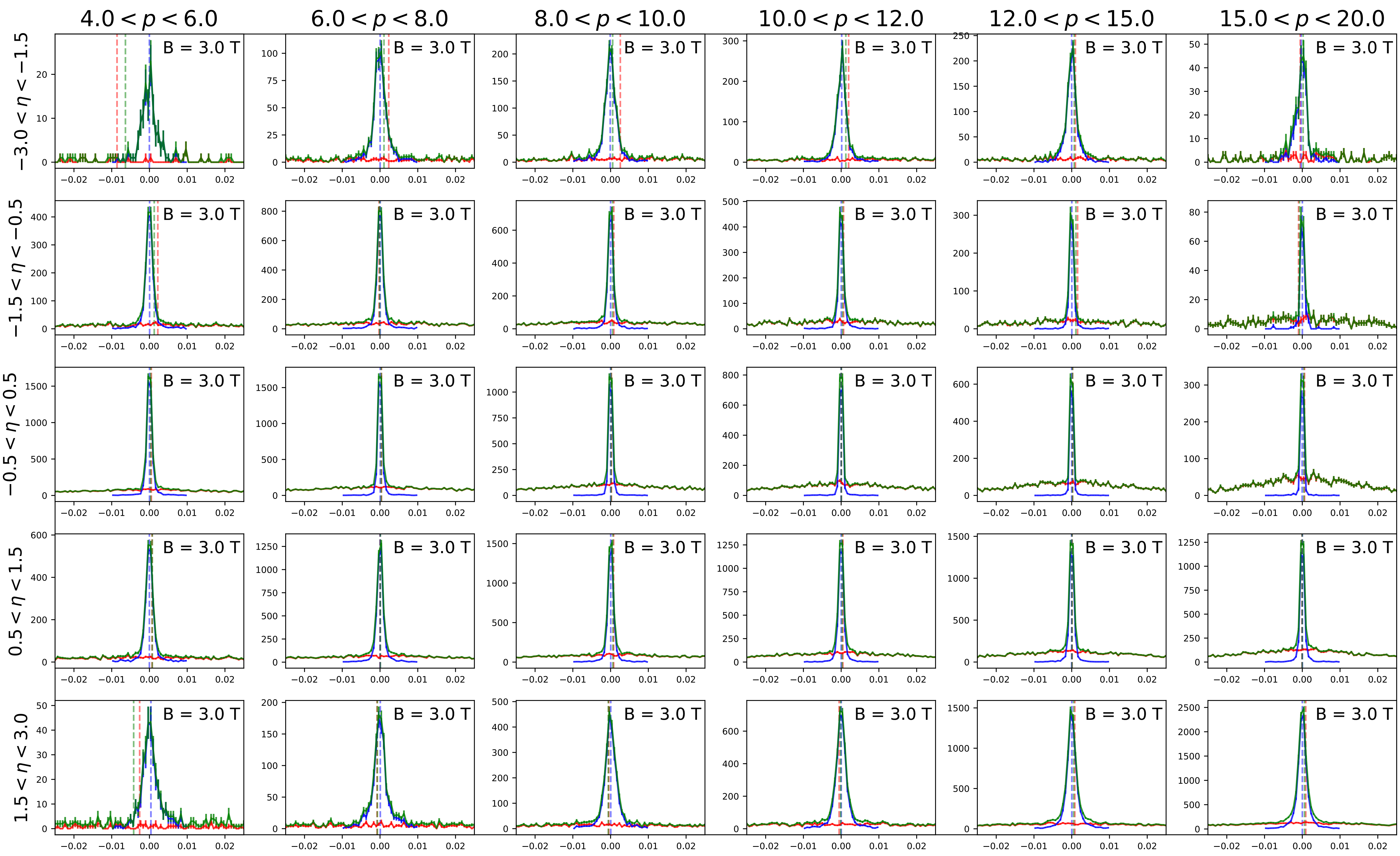
$N_{\text{Missed}} < 1$ $N_{\text{Missed}} \geq 1$ No N_{Missed} Cut

dφ [mrad]

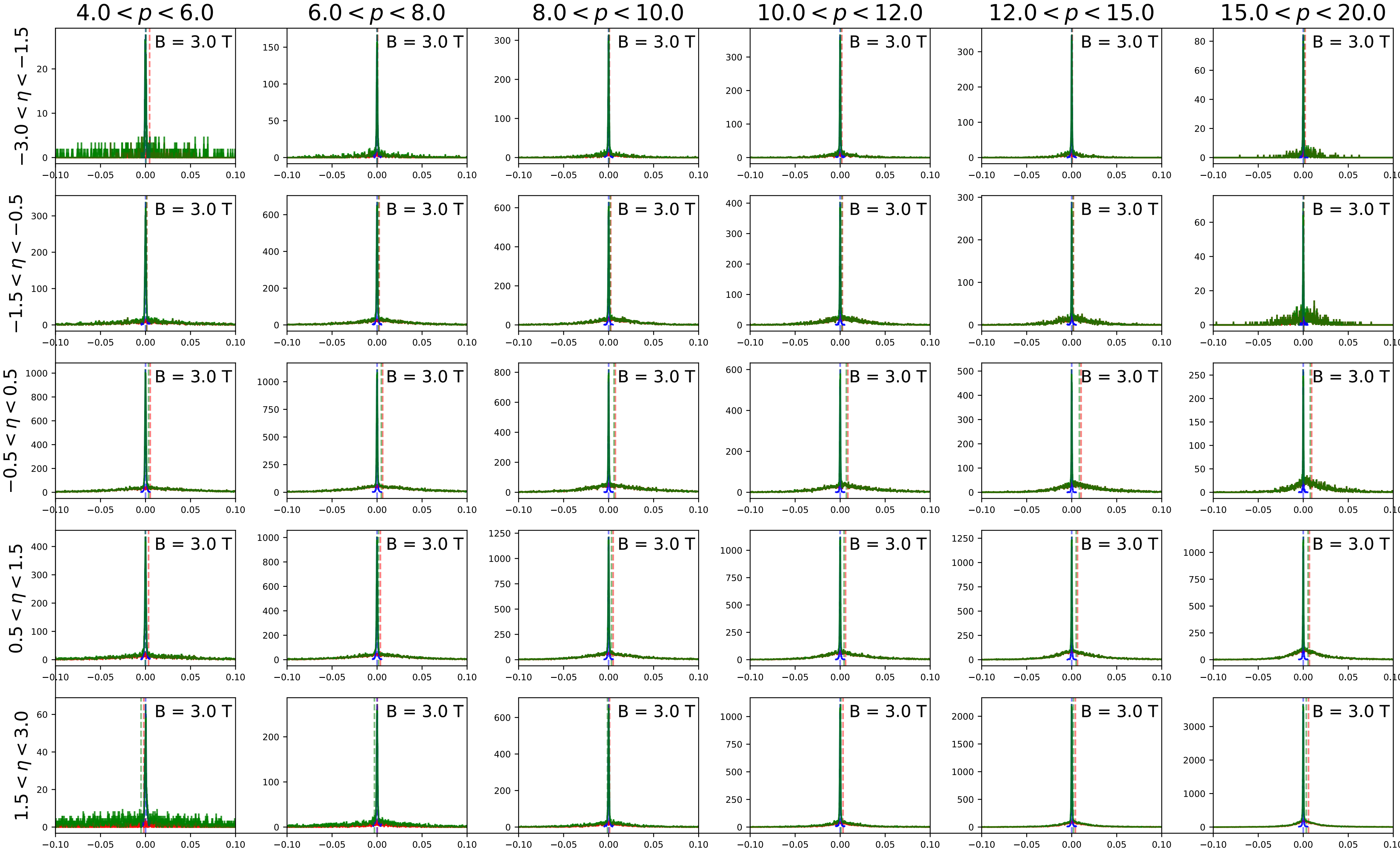


$N_{\mathrm{Missed}} < 1$ $N_{\mathrm{Missed}} \geq 1$ No N_{Missed} Cut

dφ [mrad]

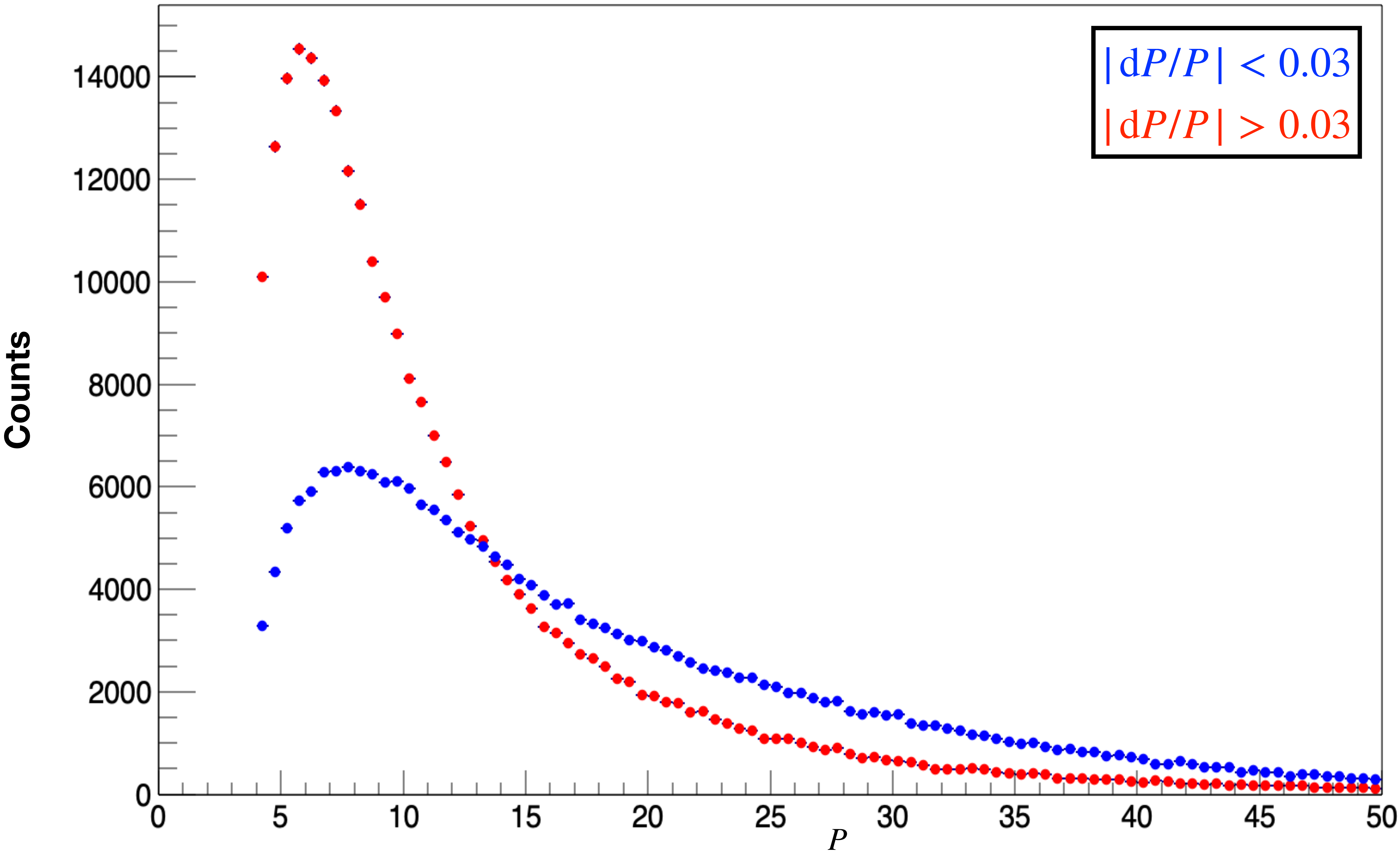


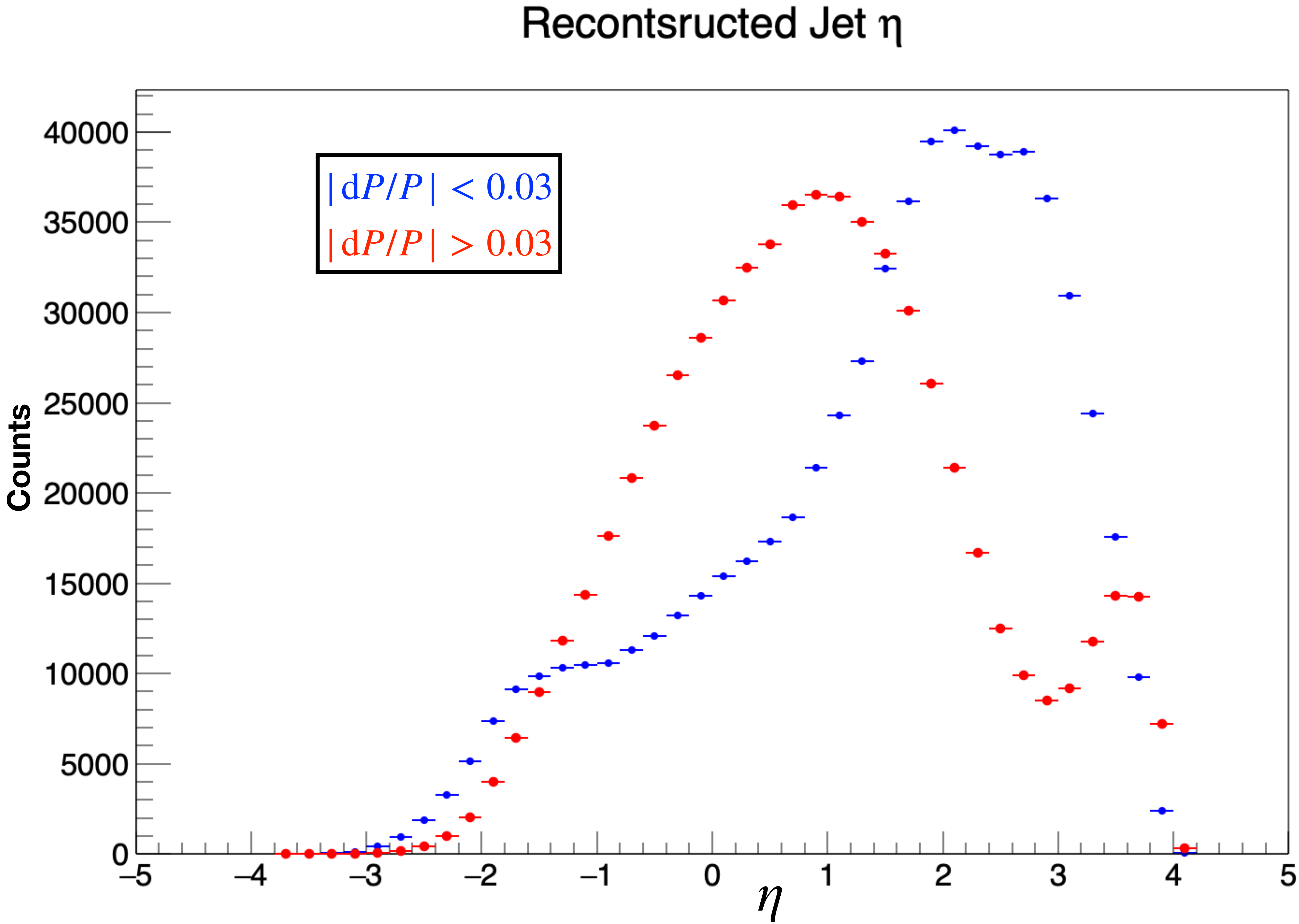
dθ [mrad]



4.0 < p < 6.0
6.0 < p < 8.0
8.0 < p < 10.0
10.0 < p < 12.0
12.0 < p < 15.0
15.0 < p < 20.0
−3.0 < η < −1.5
−1.5 < η < −0.5
−0.5 < η < 0.5
0.5 < η < 1.5
1.5 < η < 3.0
B = 3.0 T

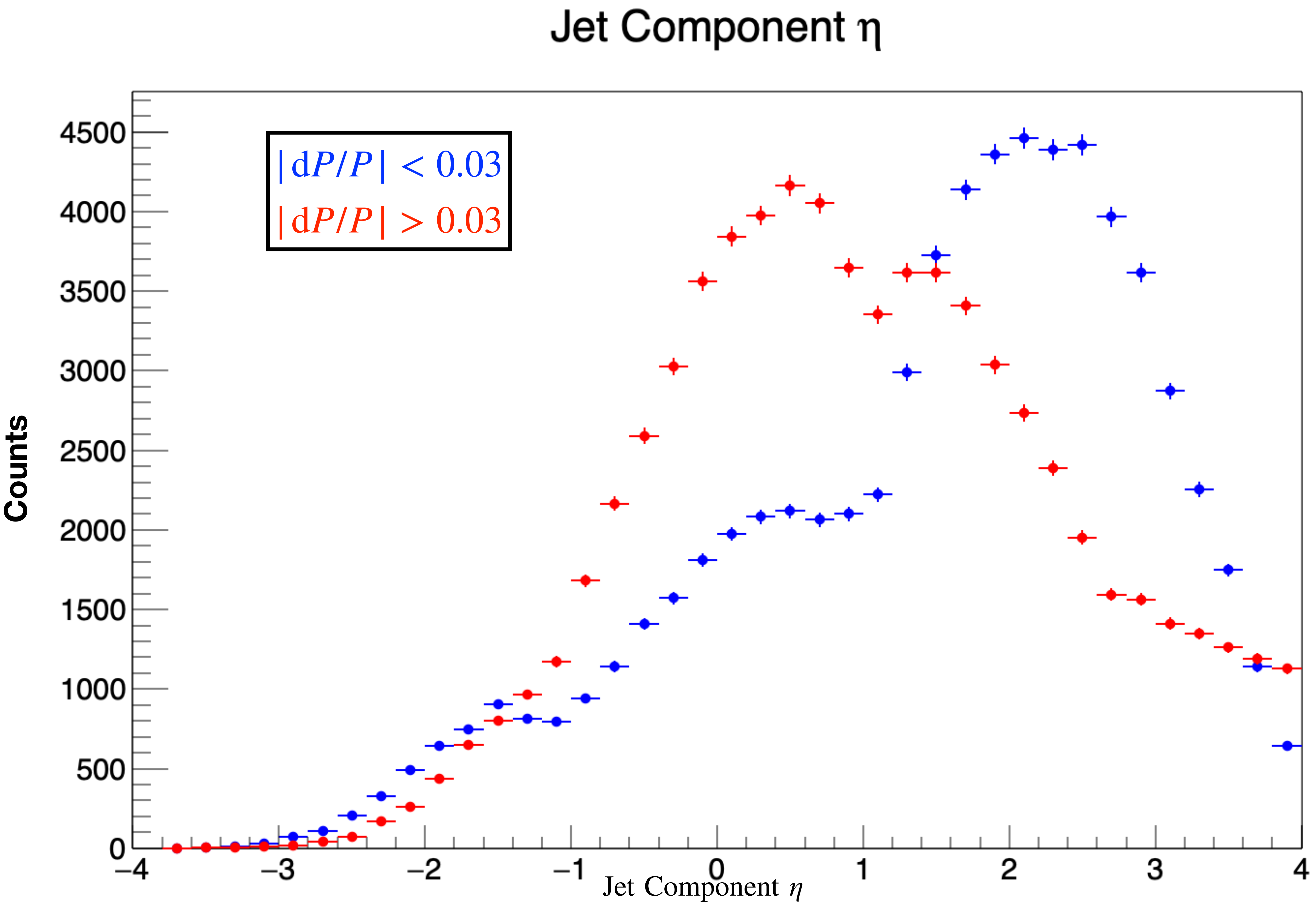
Jet Momentum distributions (two populations)





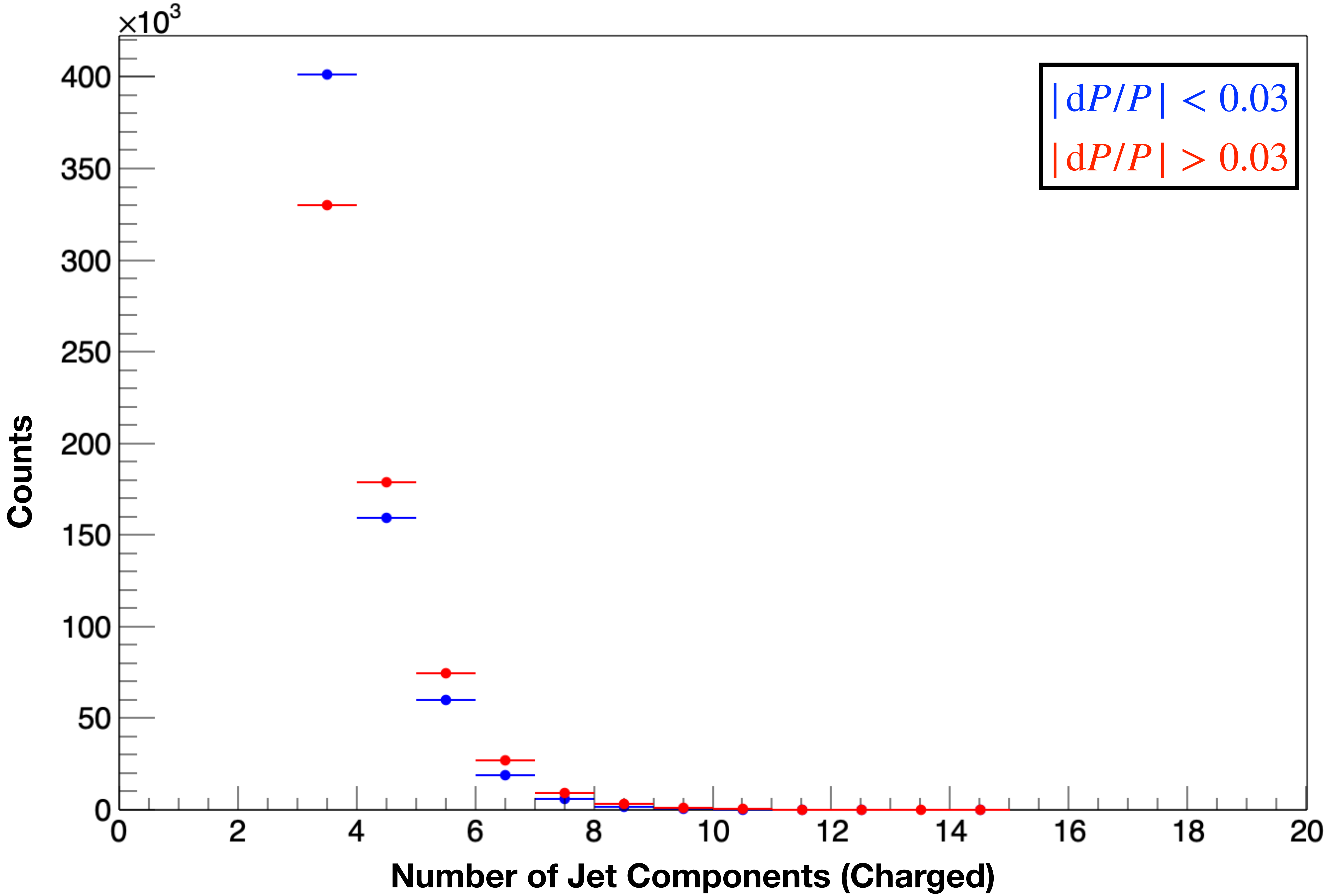
Recontsructed Jet η
Counts
η
|dP/P| < 0.03
|dP/P| > 0.03
40000
35000
30000
25000
20000
15000
10000
5000
0
−5
−4
−3
−2
−1
0
1
2
3
4
5

Jet Component Distributions

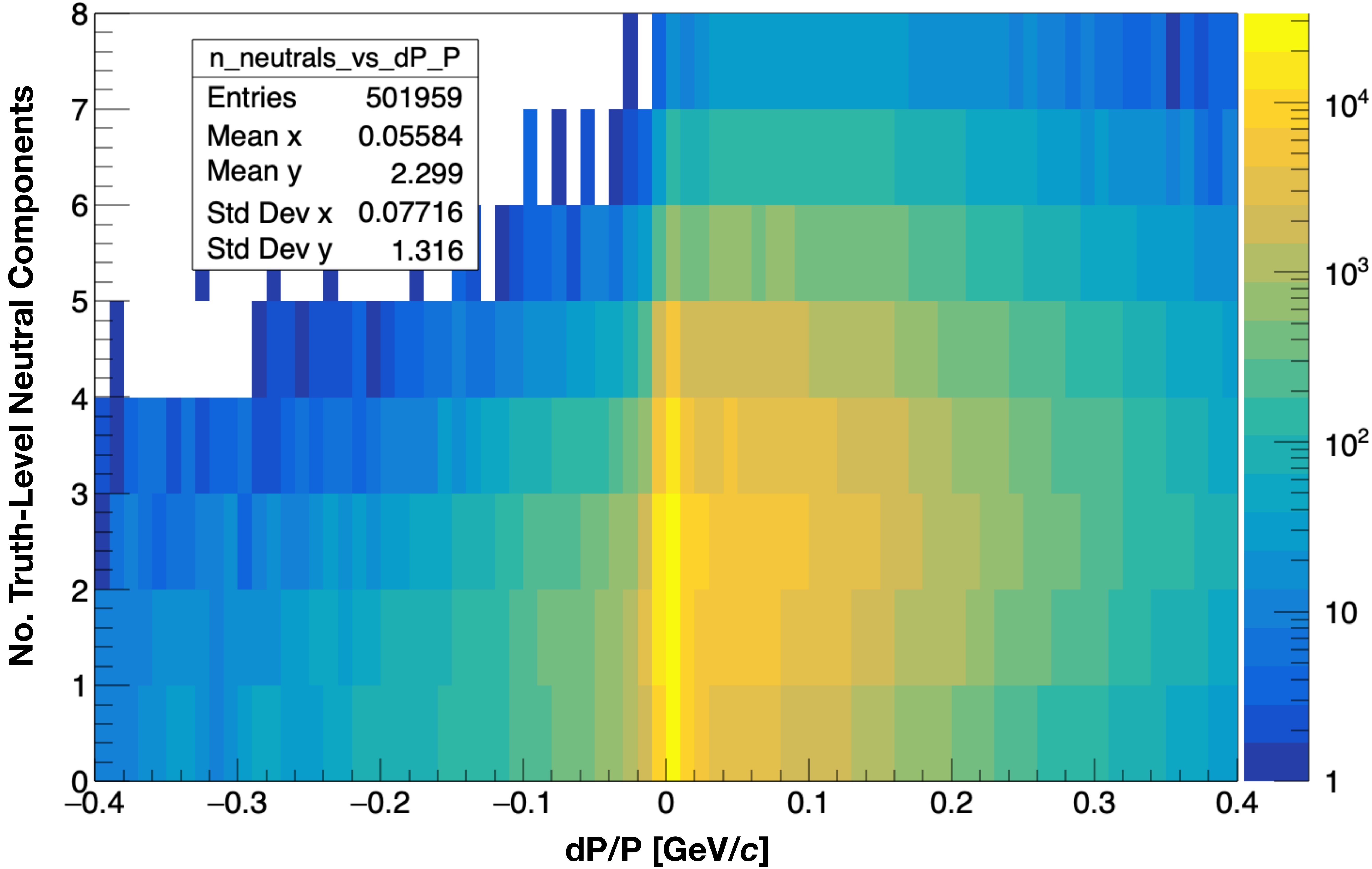


The central barrel layers meet the endcap of the all-sillicon tracker at $\eta \approx 1.1$, jets near this region are omitted in the resolution calculation

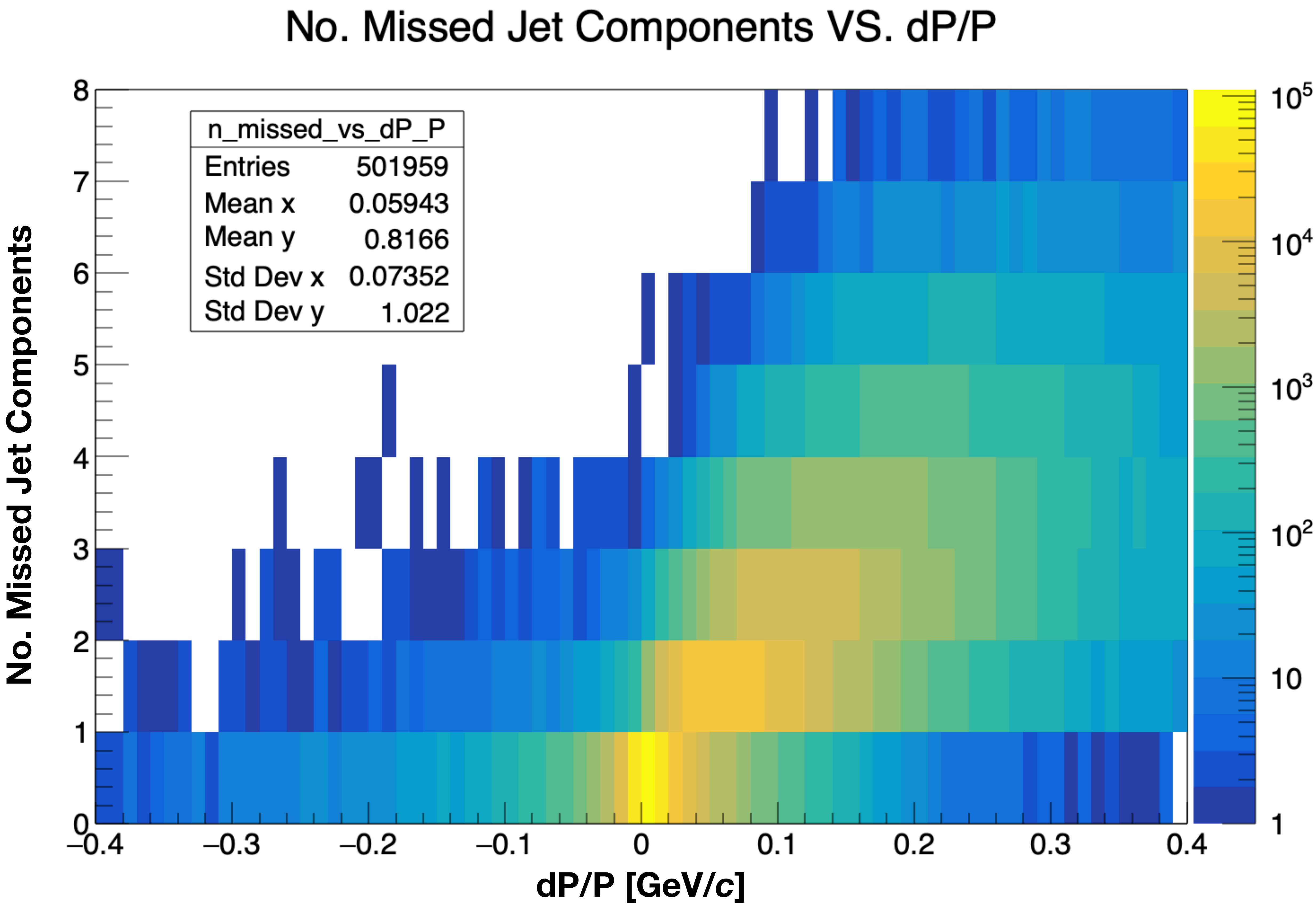
Reconstructed Jet N Component



No. Neutral Components in Original Truth Jet VS. dP/P



$$N_{\text{missed}} = N^{\text{truth}}_{\text{constituents}} - N^{\text{reco}}_{\text{constituents}}$$

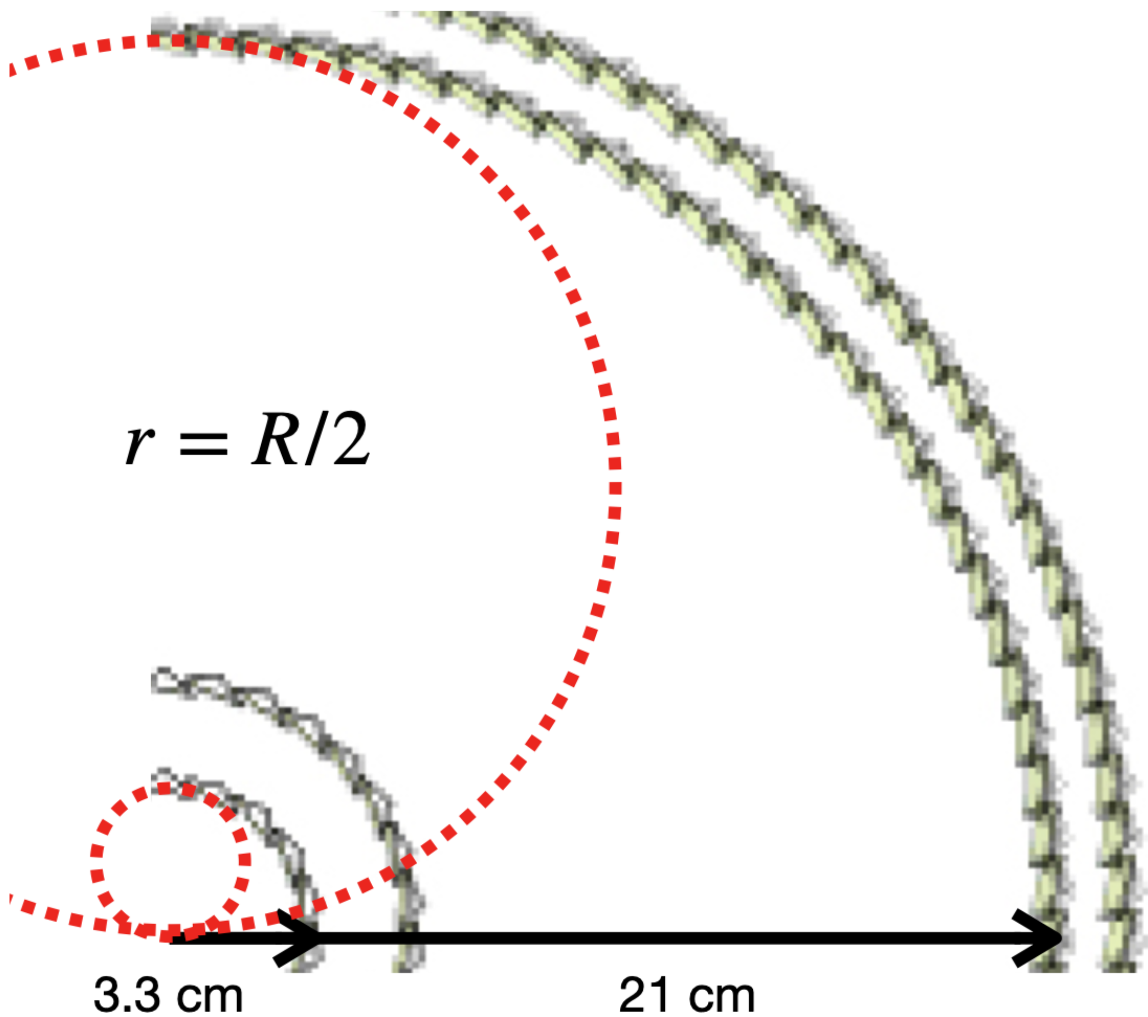


Are lost constituents and poor dP/P due to low pT constituents?

$$m\frac{v^2}{r} = qvB$$

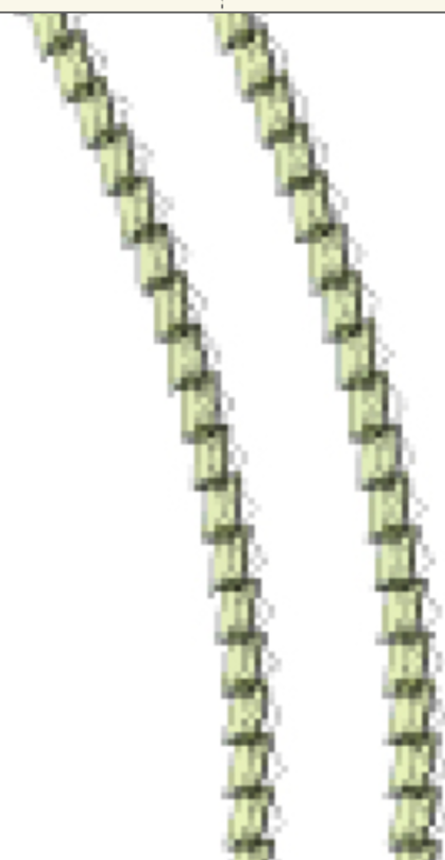
*** Need at least three points for a momentum measurement**

$$p\ [\mathrm{GeV}/c] = 0.3B\ [\mathrm{T}] \cdot r\ [\mathrm{m}]$$



p_T thresholds

	R = 3.3 cm	R = 21 cm
B = 1.4 T	7 MeV	44 MeV
B = 3.0 T	15 MeV	95 MeV



Credit: Rey Cruz Torres 6

Details for 70-150 MeV/c (B=1.5 T)

Abstract:

latest tracking performance numbers as provided recently to DWG conveners
(also circulated directly to the PWG conveners).

Referenced Files

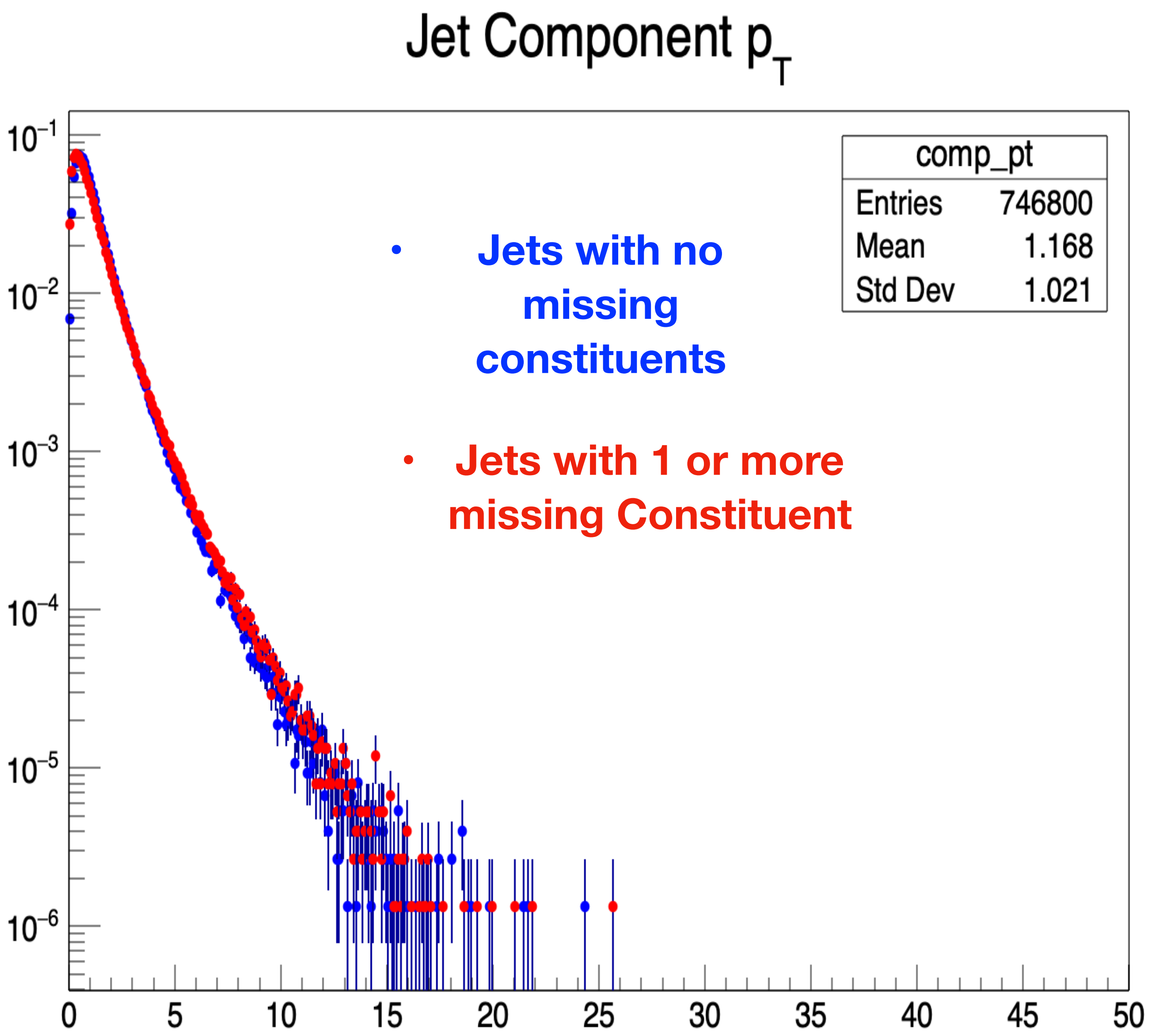
1 Tracking characteristics
Latest version of tracking from EICUG YR Tracking WG Wiki

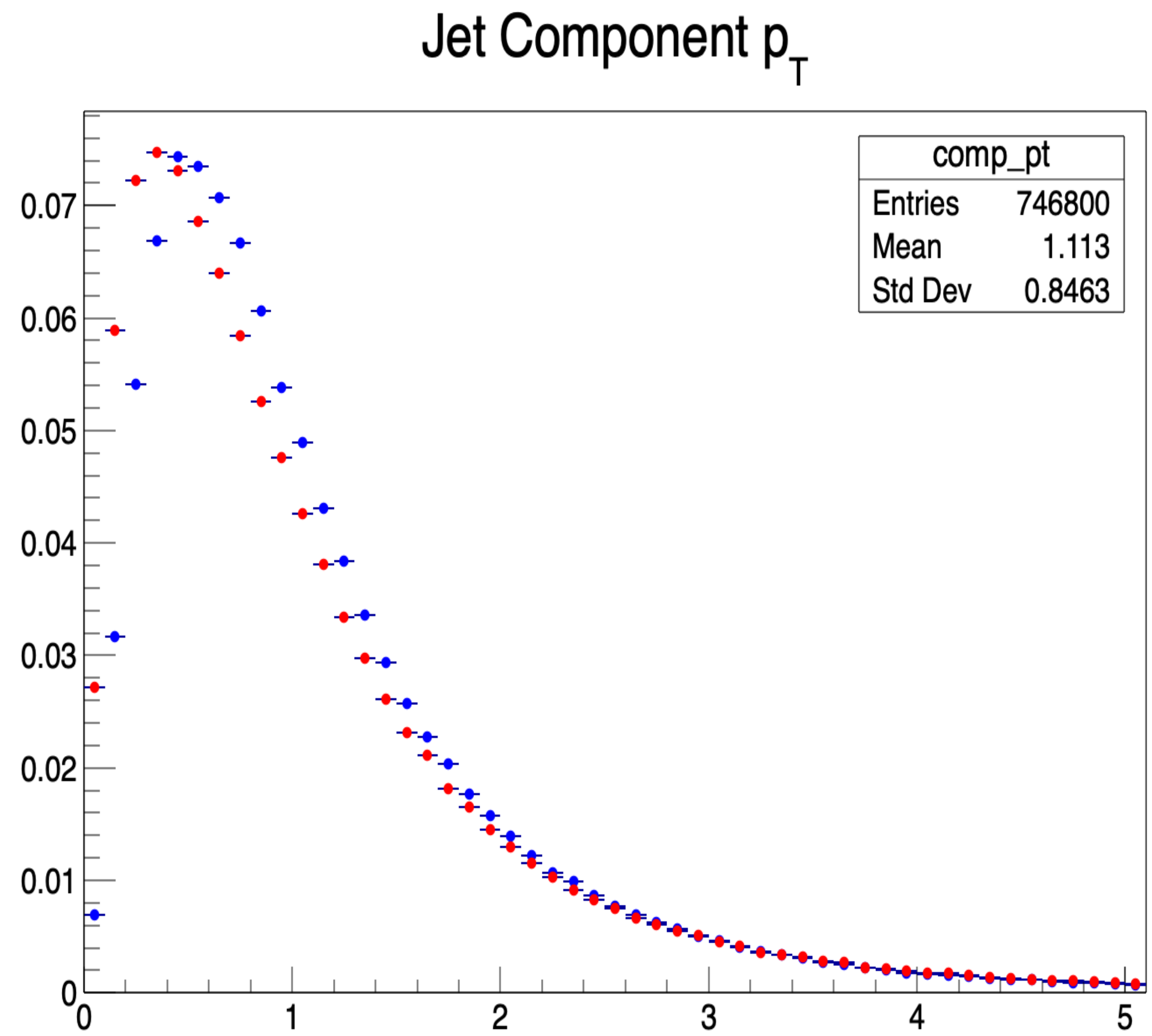
Notes:

Minimum pT for B = 1.5 T:
100 MeV/c for -3.0 < eta < -2.5
130 MeV/c for -2.5 < eta < -2.0
70 MeV/c for -2.0 < eta < -1.5
150 MeV/c for -1.5 < eta < -1.0

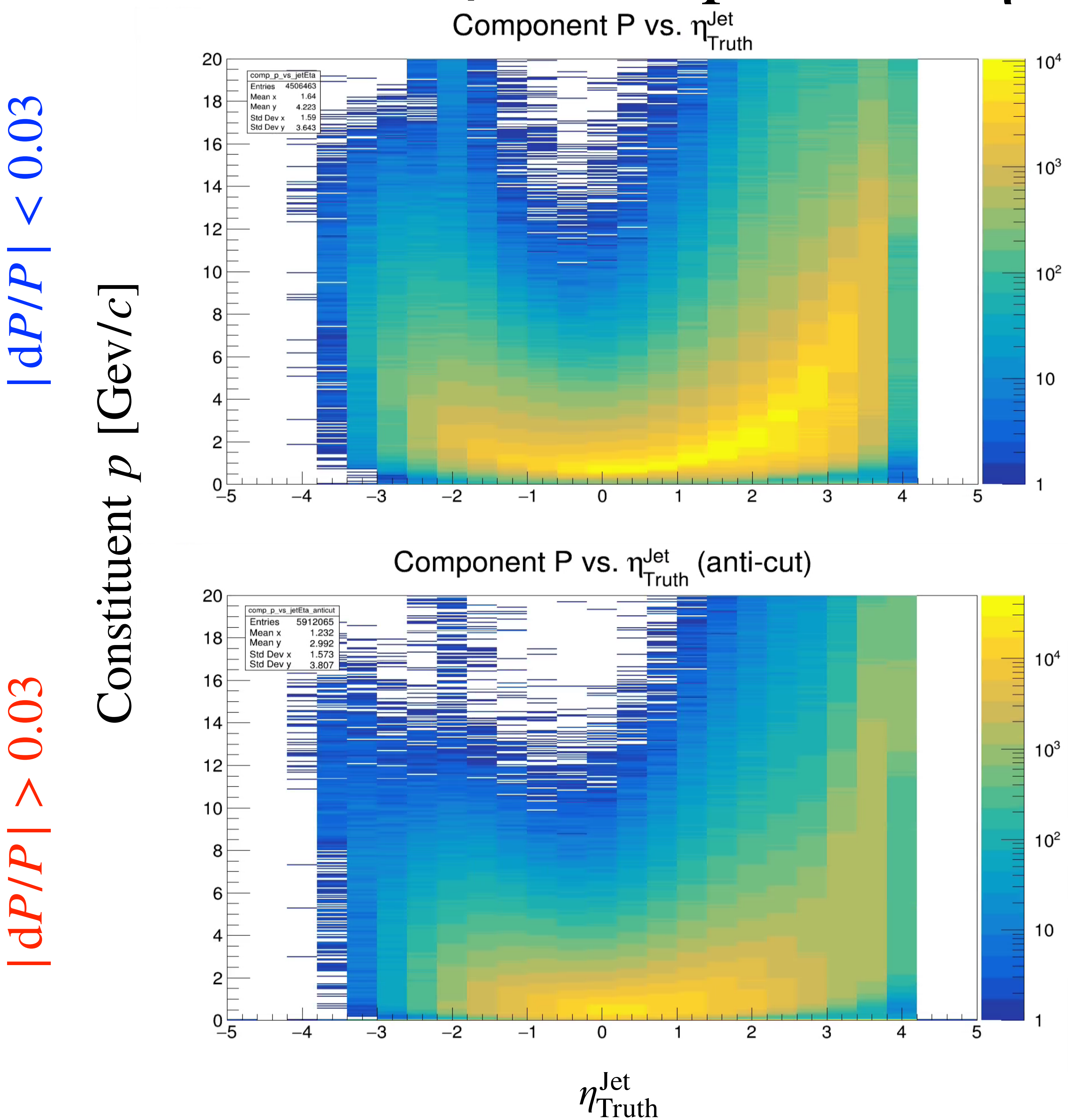
Minimum pT for B = 3 T:
150 MeV/c for -3.0 < eta < -2.5
220 MeV/c for -2.5 < eta < -2.0
160 MeV/c for -2.0 < eta < -1.5
300 MeV/c for -1.5 < eta < -1.0

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


Jet Component p_T
comp_pt
Entries 746800
Mean 1.168
Std Dev 1.021
• Jets with no missing constituents
• Jets with 1 or more missing Constituent
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0 5 10 15 20 25 30 35 40 45 50

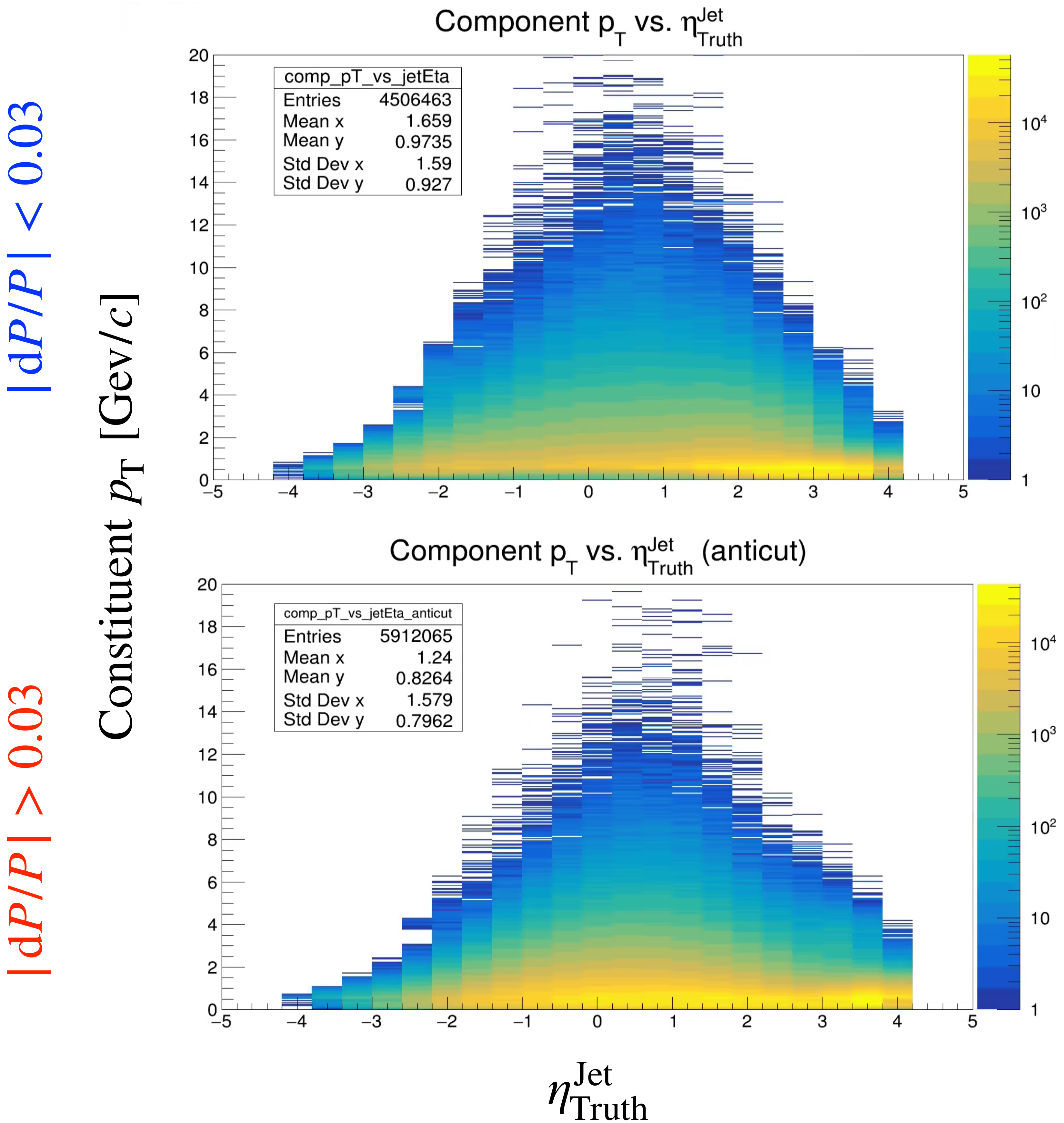

Jet Component p_T
comp_pt
Entries 746800
Mean 1.113
Std Dev 0.8463
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0 1 2 3 4 5

Jet Component p vs Jet η



An η dependent p cut does not seem to be a likely solution

Jet Component p_{T} vs Jet η



An η dependent p_{T} cut does not seem to be a likely solution either