Charm-Meson Tagged Jets in AuAu 200 GeV at STAR

Preliminaries For Hard Probes 2024

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Sep 3, 2024
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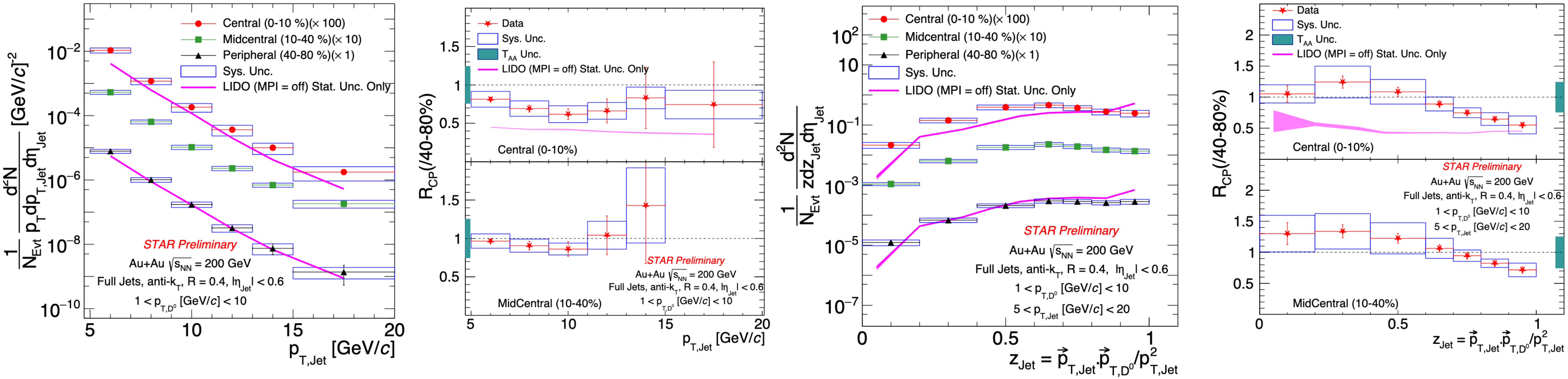
General Information

- **Paper Title**: D^0 Meson Tagged Charm Jets In AuAu collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV
- **PAs**: Diptanil Roy, Matthew Kelsey, Sevil Salur, Joern Putschke
- **Targeted Journal**: PRL + PRC
- **Webpage**: https://drupal.star.bnl.gov/STAR/blog/droy1/D0-Meson-Tagged-Jets-Au-Au-collisions-200-GeV
- **Analysis Note**: https://drupal.star.bnl.gov/STAR/system/files/D0_Tagged_Jets_Analysis_Note_v0.pdf

General Information

- Existing preliminaries on jet p_T spectra and fragmentation function

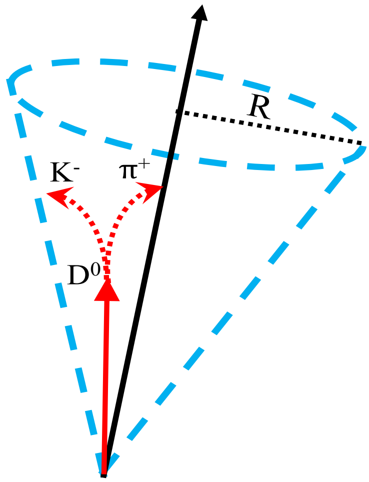


- Can we resolve a jet cone size dependence for these observables?

Dataset

- **Dataset**: AuAu 200 GeV Low and Mid Luminosity
- **Year**: 2014
- **Production Tag**: P16id
- **Triggers Used**:
    - Results available with 2 sets of triggers
    - **VPDMB-5-p-nobsmd, VPDMB-5-p-nobsmd-hlt** --> `450005, 450015, 450025, 450050, 450060`
    - **VPDMB-5-p-nobsmd, VPDMB-5-p-nobsmd-hlt, VPDMB-5-p-nobsmd-ssd-hlt, VPDMB-5-nobsmd, VPDMB-5** --> `450005, 450008, 450009, 450014, 450015, 450018, 450024, 450025, 450050, 450060`
- **Embedding Request ID**: Simulation: 20220210

Analysis Details



- **Centrality ∈ [0, 80]% (3 bins: [0-10], [10-40], [40-80])**
- $0.2 < p_{T,track}$ [GeV/c] < 30 ; $0.2 < E_{T,tower}$ [GeV] < 30
- $|\eta_{track}| < 1$; $|\eta_{tower}| < 1$
- $D^0 \rightarrow K^{\mp} + \pi^{\pm}$ [B.R. = 3.82 %]
- For D^0 reconstruction: Tracks contain at least three hits on HFT
- $1 < p_{T,D^0}$ [GeV/c] < 10
- **$K^{\mp}, \pi^{\pm}$ originating from D^0 replaced with D^0 in the event record before jet clustering**
- Anti-k_T full jets of radius R = 0.2, 0.3, 0.4, area-based background subtraction
- $|\eta_{Jet}| < 1 - R$
- 2D unfolding done for [Jet p_T, D^0 transverse momentum fraction] and [Jet p_T, radial profile]

Systematic Uncertainties

More details here:
https://drupal.star.bnl.gov/STAR/system/files/HardProbes_Aug10_Diptanil_v5.pdf

- ✓ Regularization Parameter From Unfolding **(Correlated)**
- ✓ Prior Variation (FONLL, PYTHIA, p_T vs Z Data-Weighted) **(Correlated)**
- ✓ Tracking Efficiency Uncertainty **(Correlated)**
- ✓ D^0 Signal Extraction **(Uncorrelated)**
- ✓ D^0 Reconstruction Efficiency without vertex correction **(Correlated)**
- ✓ D^0 Reconstruction Efficiency due to vertex correction **(Uncorrelated)**
- ✓ Variation of NHitsFit (**Correlated**)
- ✓ Variation of DCA (**Correlated**)
- ✓ Variation of number of leading kT jets dropped (**Uncorrelated**)
- ✓ Variation of Hadronic Correction (**Correlated**)

→ D^0 Spectra 2014 Paper Analysis Note

Range of systematic variations

Sources	Lower Value	Central Value	Upper Value
Regularization Parameter	3	4	5
Prior Variation	FONLL, PYTHIA, Data-reweighted		
Tracking Efficiency	0.95	1.	NA
Hadronic Correction	50 %	100 %	NA
NHitsFit	13	15	17
Leading k_T Jets Dropped	1	2	NA
DCA (cm)	2.8	3.0	3.2

D^0 Systematics are taken from the Run14 analyses directly.

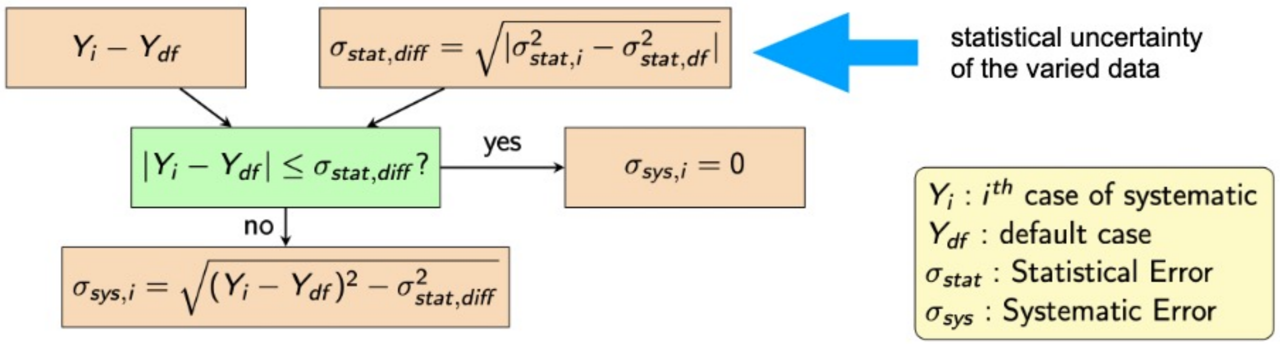
Barlow Test

Barlow Check

Often in cut variations, the difference in the results is subject to statistical fluctuation.

The following procedure has been exercised in STAR to perform the Barlow check and remove statistical fluctuation from systematic uncertainty evaluation

direct-photon paper, GPC # 214, isobar CME paper, GPC #282



Junior's Day, STAR Collaboration Meeting, 3/18/2024-3/22/2024, BNL X. Dong/LBNL 12

1. For every source, systematic error is calculated following the Barlow Check.
2. Removing the statistical fluctuation from every systematic source

https://drupal.star.bnl.gov/STAR/system/files/20240318_BNL_Syst.pdf

Central Values Reported:

Case of the data-weighted distribution:

1. The reported values depend on this variation.

2. Our solution: Quote central value as this:

With two equal variations, quote $$\frac{R_1 + R_2}{2} \pm \left| \frac{R_1 - R_2}{\sqrt{2}} \right|$$

Here, R1 refers to the default measurement, and R2 refers to the data weighted measurement

The statistical error is roughly the same for R1 and R2, so we quote the statistical error for R1. The difference is < 1%.

On top of that, there is a systematic error: This arises from the fact that the result can vary between R1 and R2, and we have no way of determining the exact value presently.

Other sources undergo the same Barlow Test

https://drupal.star.bnl.gov/STAR/system/files/20240318_BNL_Syst.pdf

Preliminary

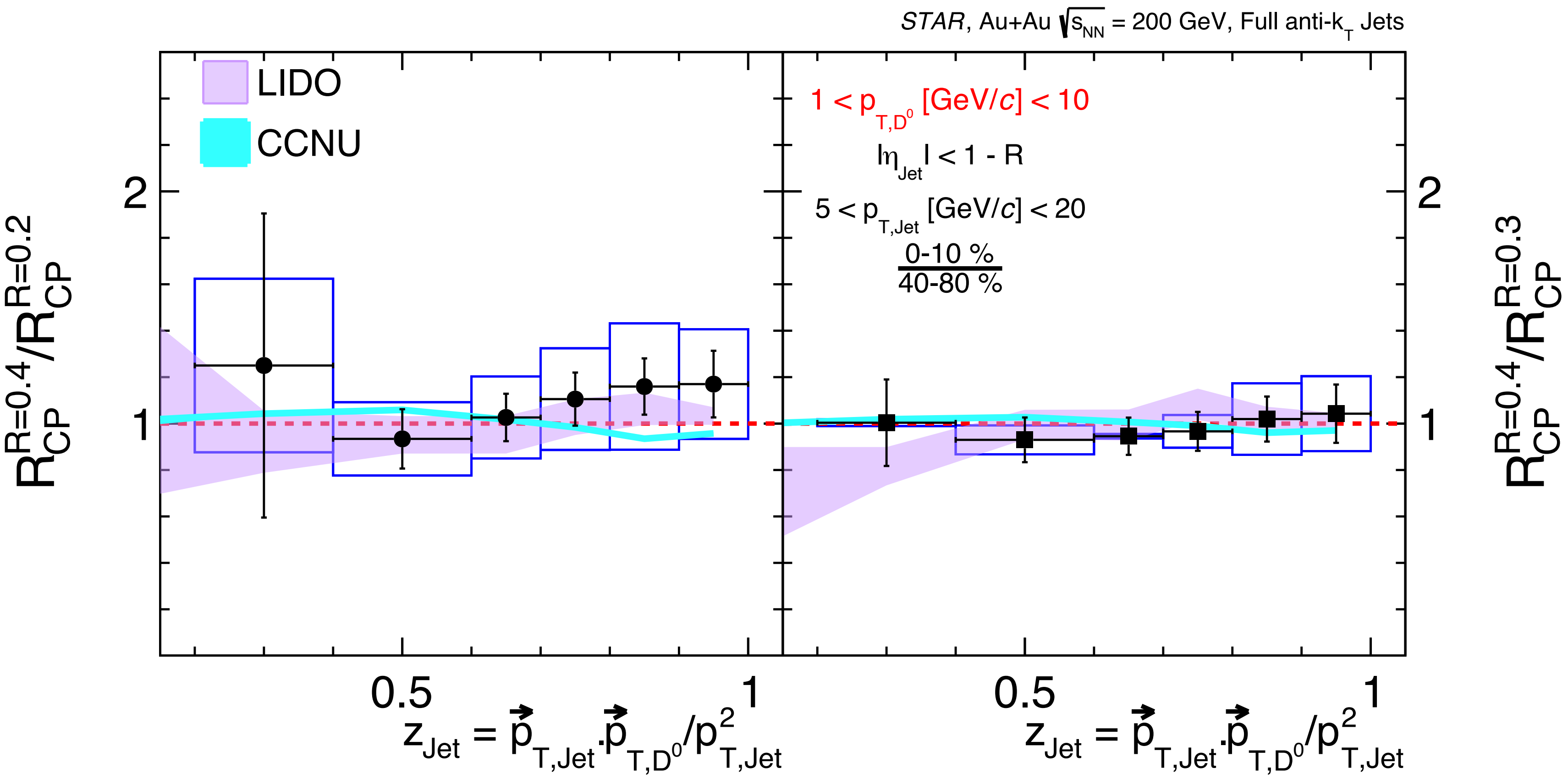
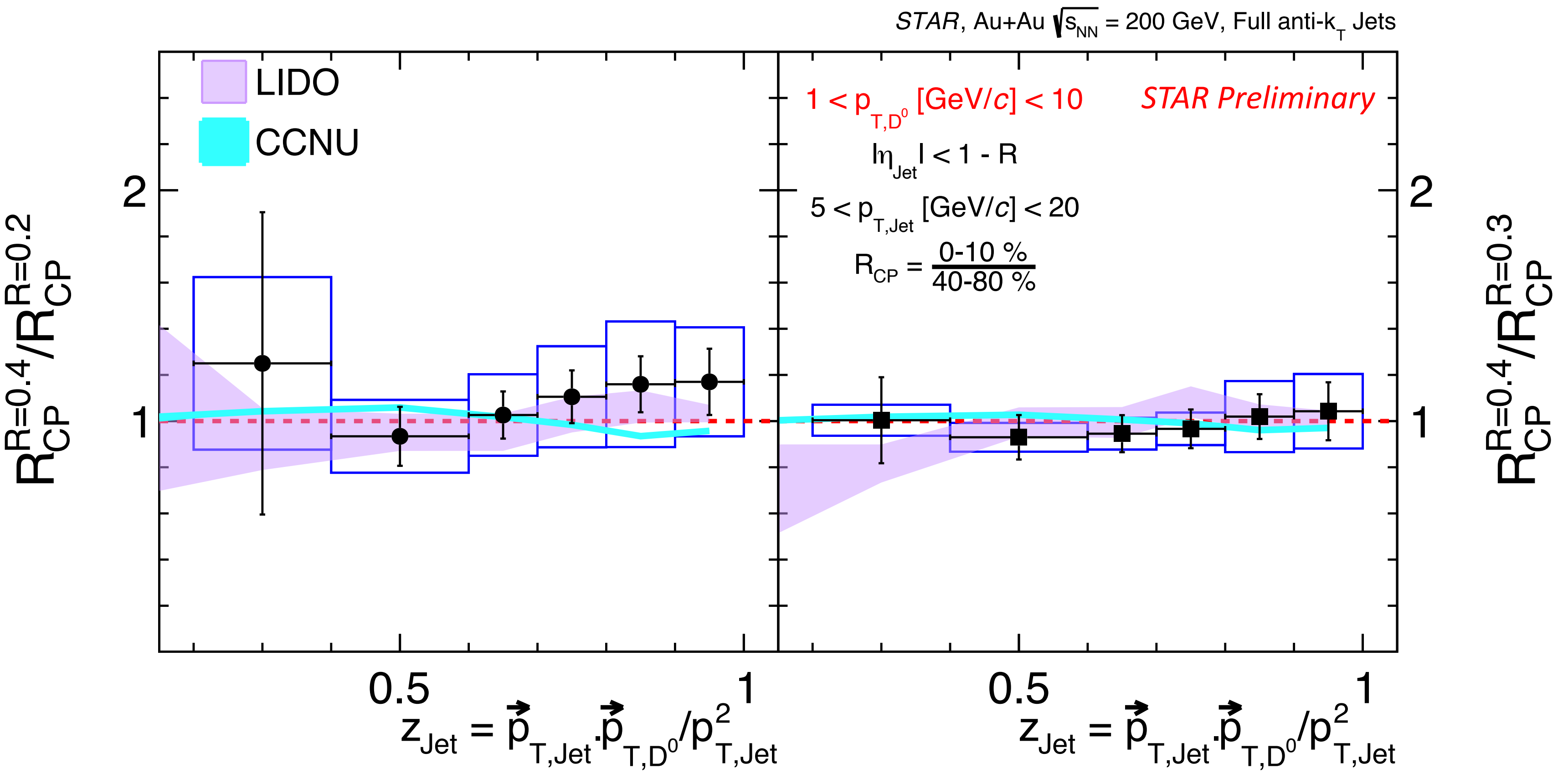


Fig: Ratio of R_{CP} as functions of $z = \frac{p_{T,D^0} \cdot \vec{p}_{T,Jet}}{|\vec{p}_{T,Jet}|^2}$ for **R = 0.4 and R = 0.2** (**left panel**) and **R = 0.4 and R = 0.3** (**right panel**) anti-k_T jets in AuAu collisions at $\sqrt{s_{NN}} = 200$ GeV.

No jet cone size dependence within current resolution. Agreement with models.

Preliminary

The bins with no systematic unc. post Barlow test have been attributed the relative systematic unc. of the next bin.



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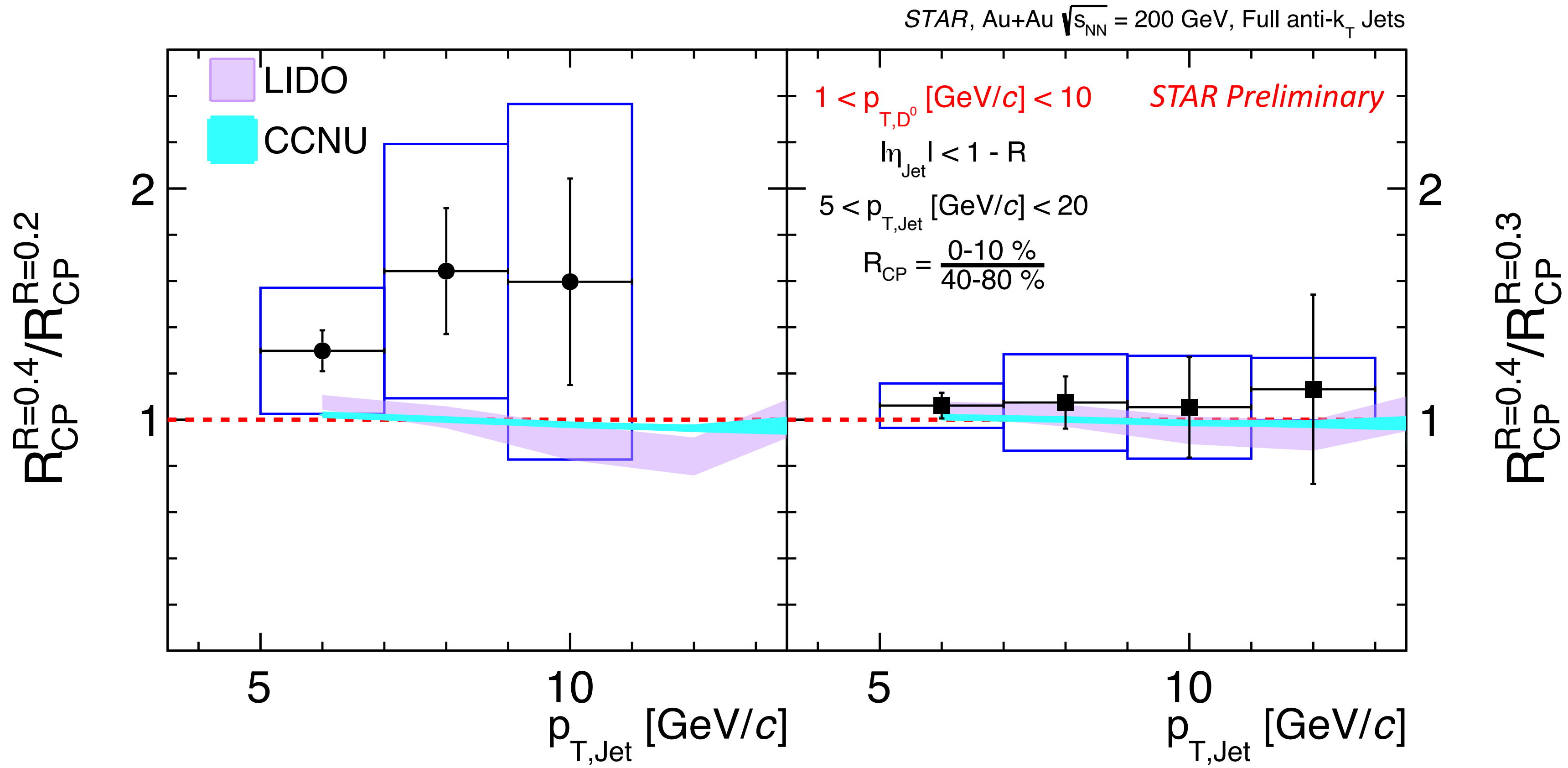
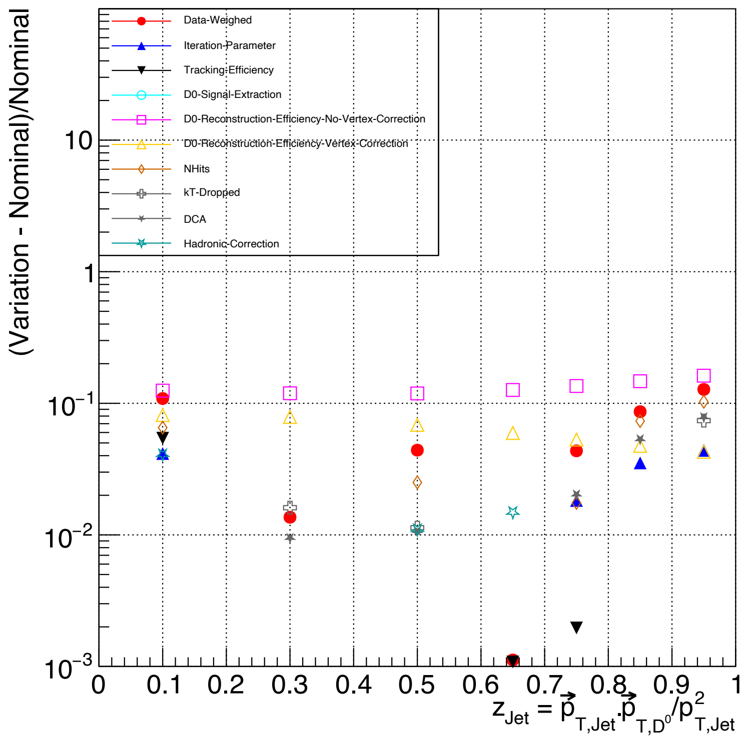


Fig: Ratio of R_{CP} as functions of $p_{T,Jet}$ for **R = 0.4 and R = 0.2** (**left panel**) and **R = 0.4 and R = 0.3** (**right panel**) anti-k_T jets in AuAu collisions at $\sqrt{s_{NN}}$ = 200 GeV.

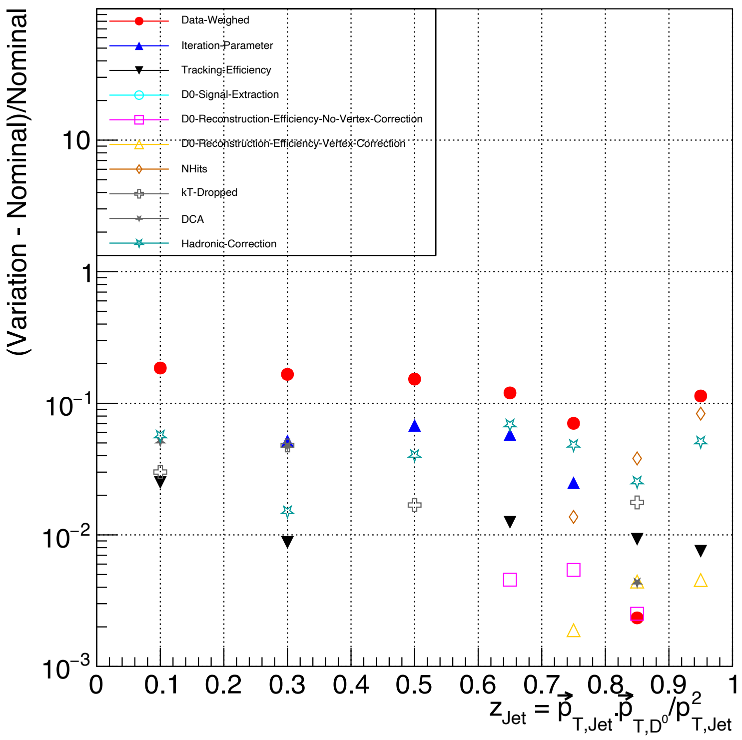
No jet cone size dependence within current resolution. Agreement with models.

Systematics for Jet Z (R = 0.4)

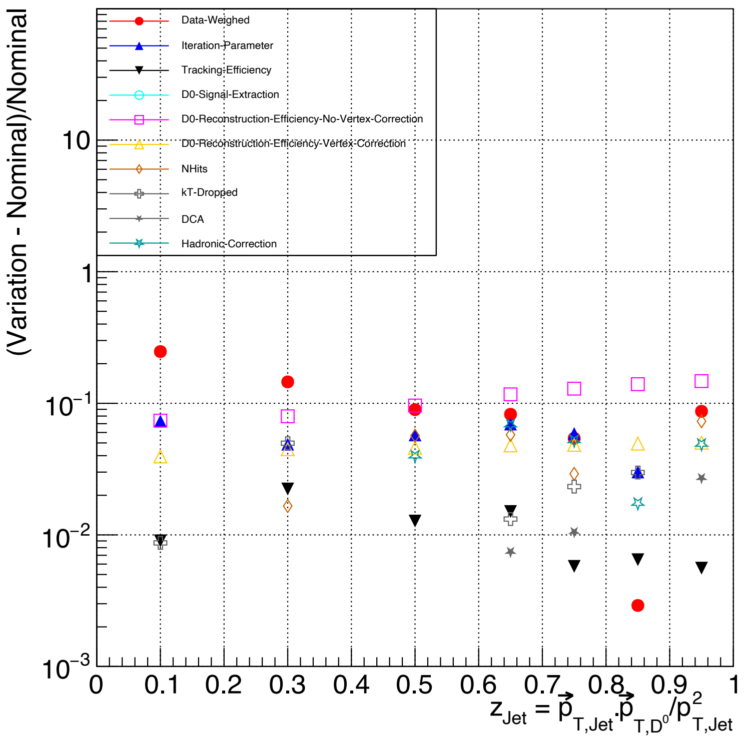
Central



MidCentral



Peripheral

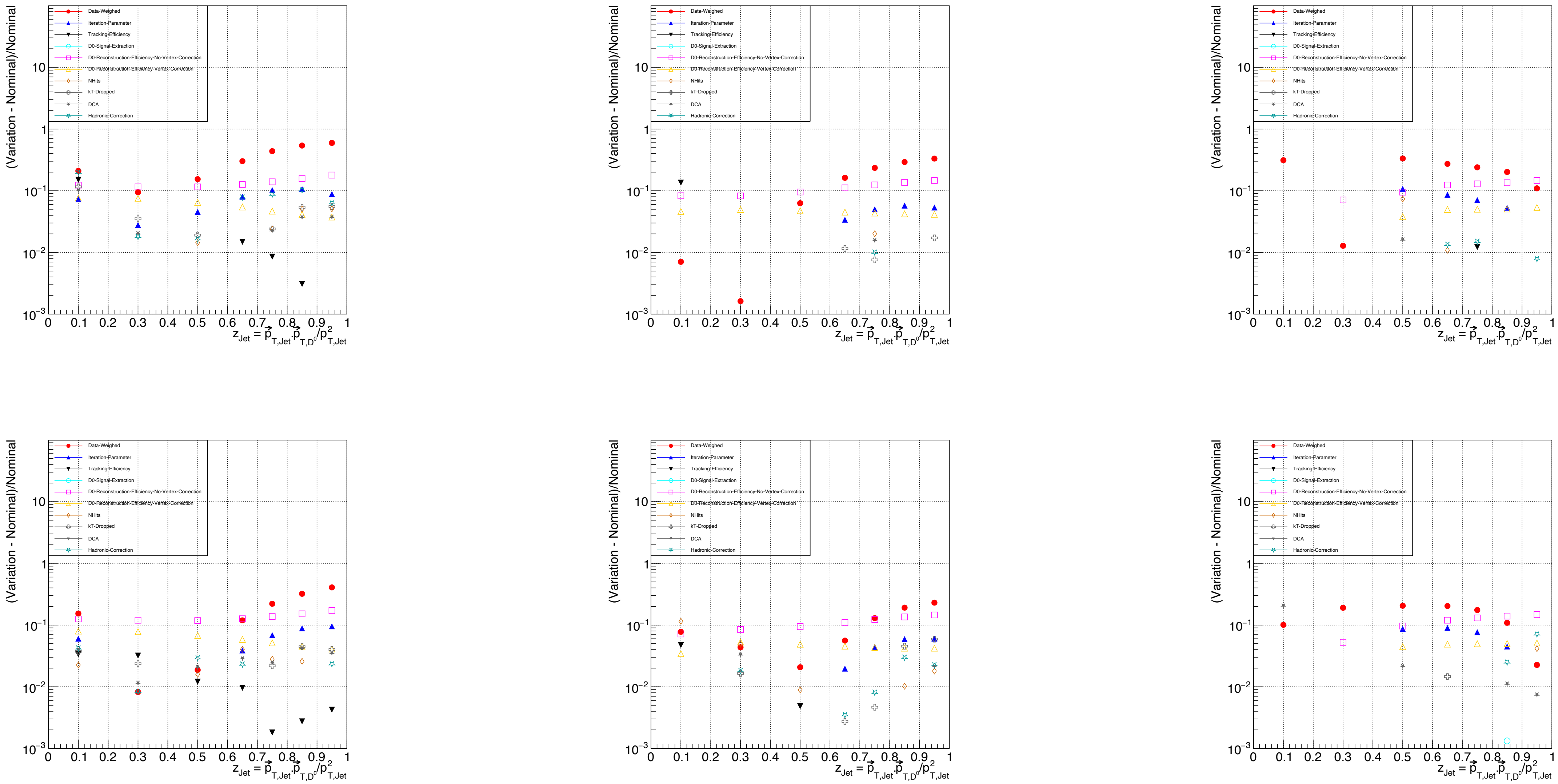


Systematics for Jet Z (R = 0.2, 0.3)

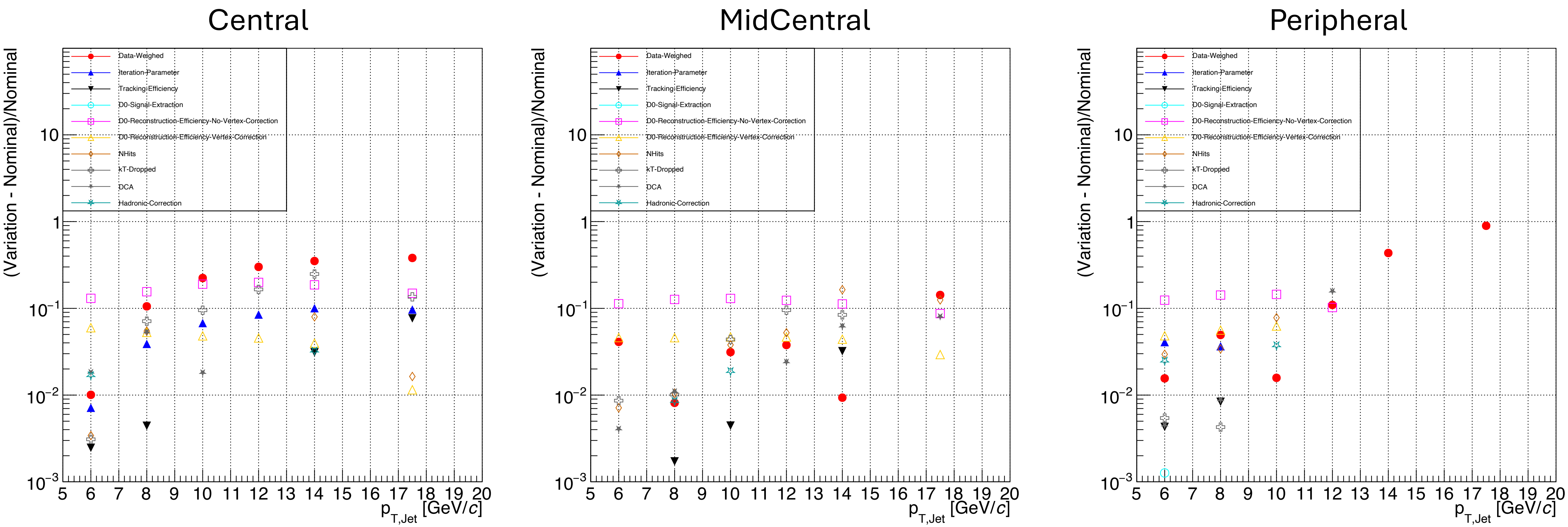
Central | MidCentral | Peripheral

$R = 0.2$

$R = 0.3$



Systematics for Jet p_T (R = 0.4)

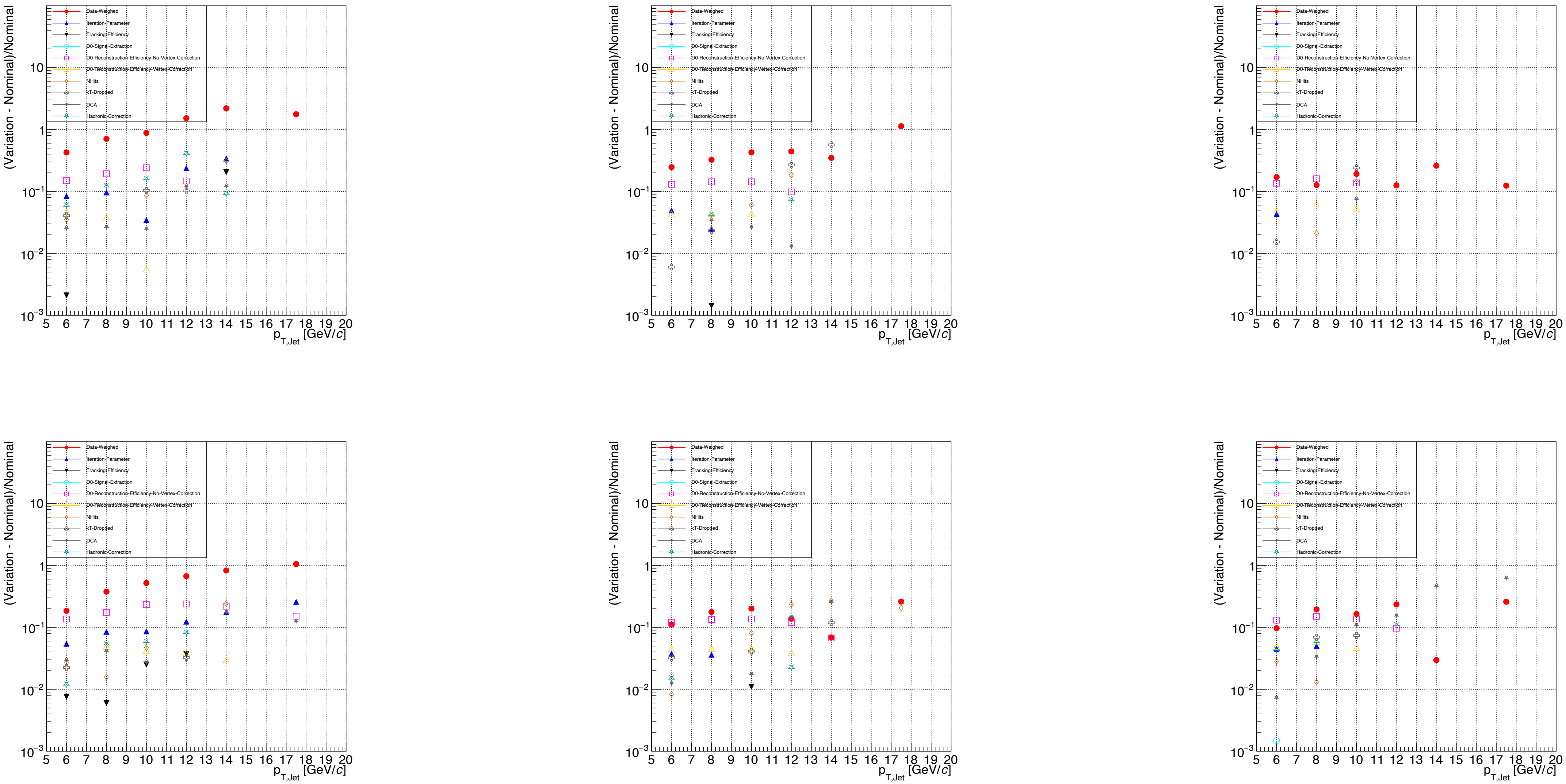


Systematics for Jet p_T (R = 0.2, 0.3)

Central | MidCentral | Peripheral

$R = 0.2$

$R = 0.3$



Backup

Preliminary

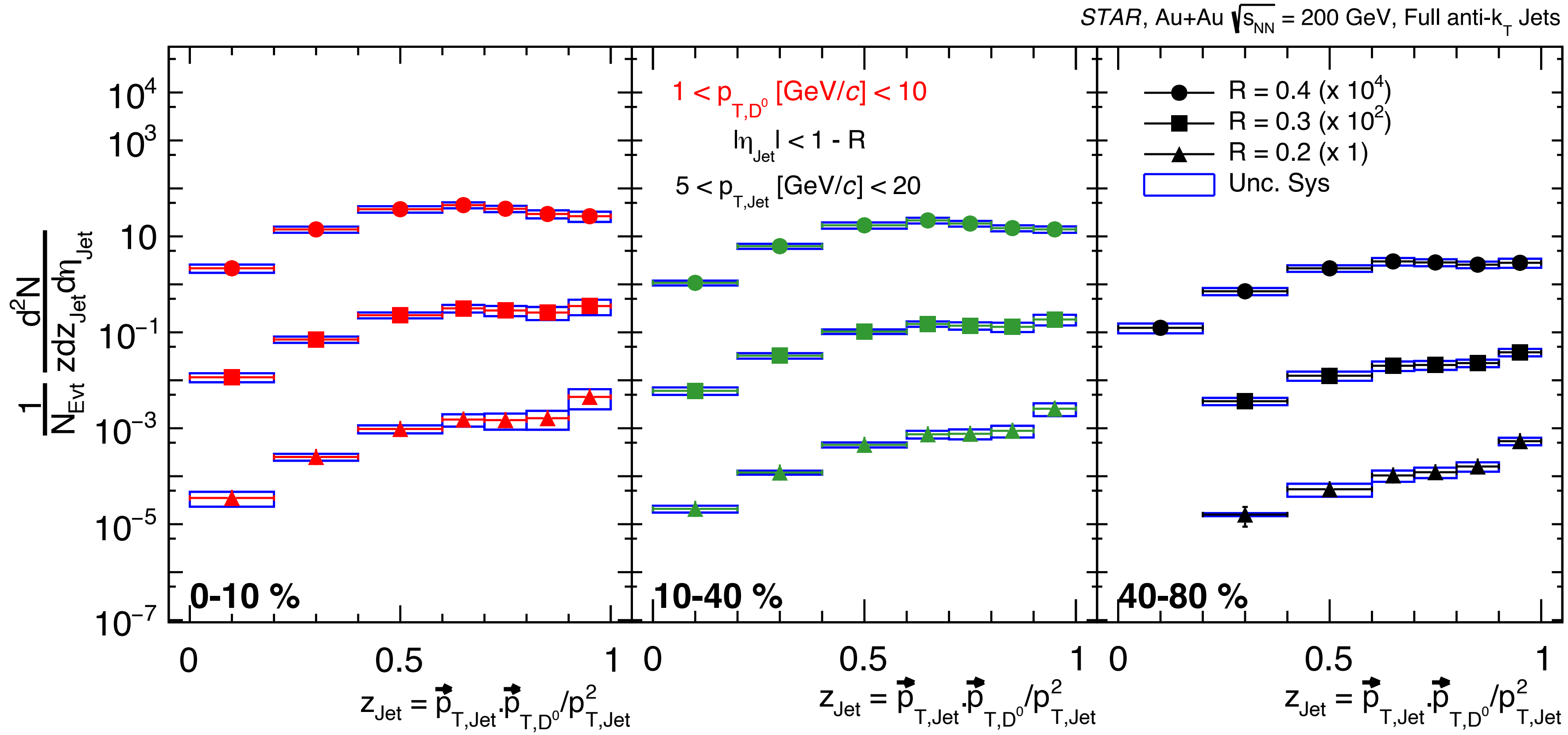
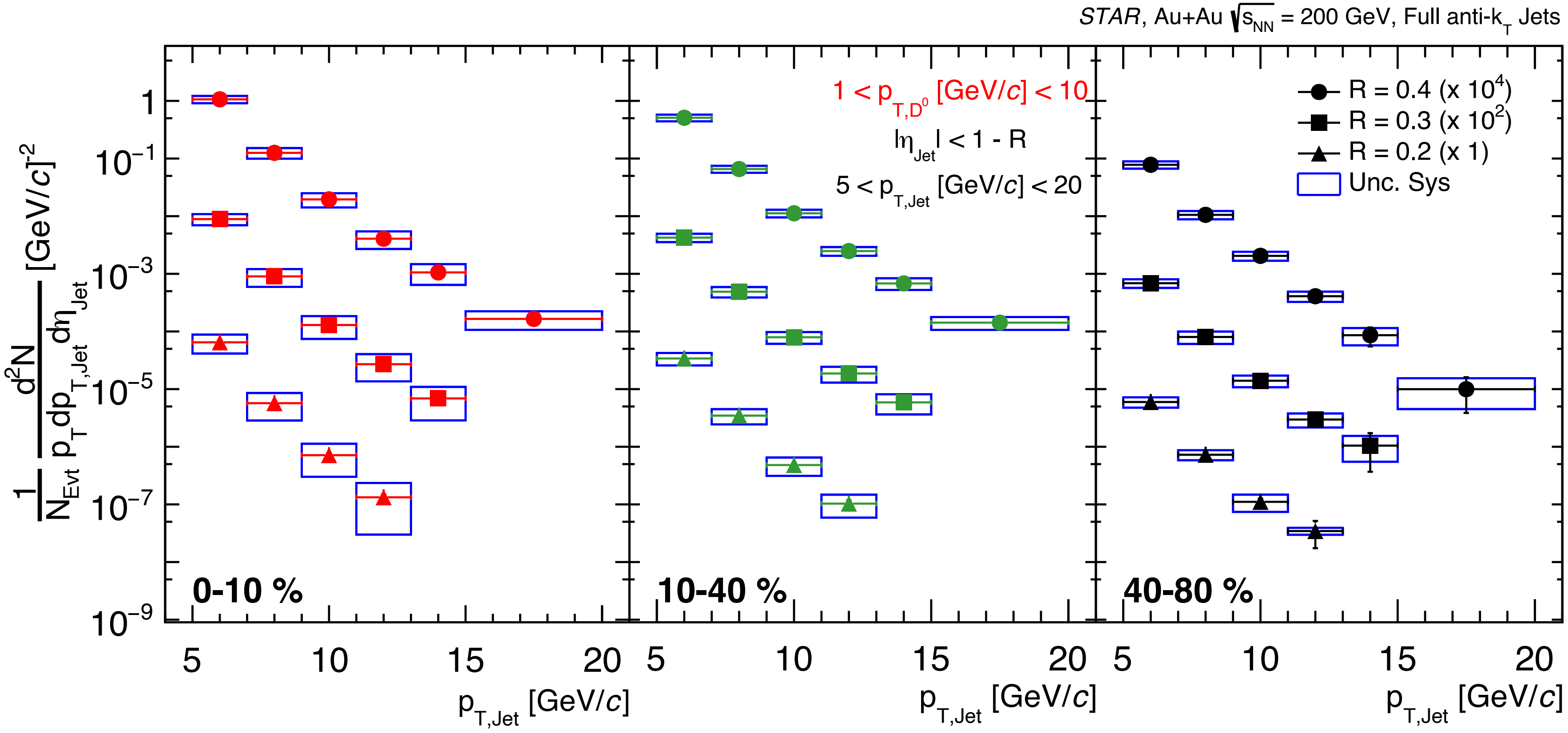


Fig: D^0 meson tagged jet yields as functions of $z = \frac{p_{T,D^0} \cdot \hat{p}_{T,Jet}}{|\vec{p}_{T,Jet}|}$ for **R = 0.2** (triangles, scaled by 10^4), **R = 0.3** (square, scaled by 10^2), and **R = 0.4** (circle, scaled by 1) anti-k_T jets in AuAu collisions at $\sqrt{s_{NN}}$ = 200 GeV for central (**left panel**), midcentral (**middle panel**), peripheral (**right panel**).

Preliminary



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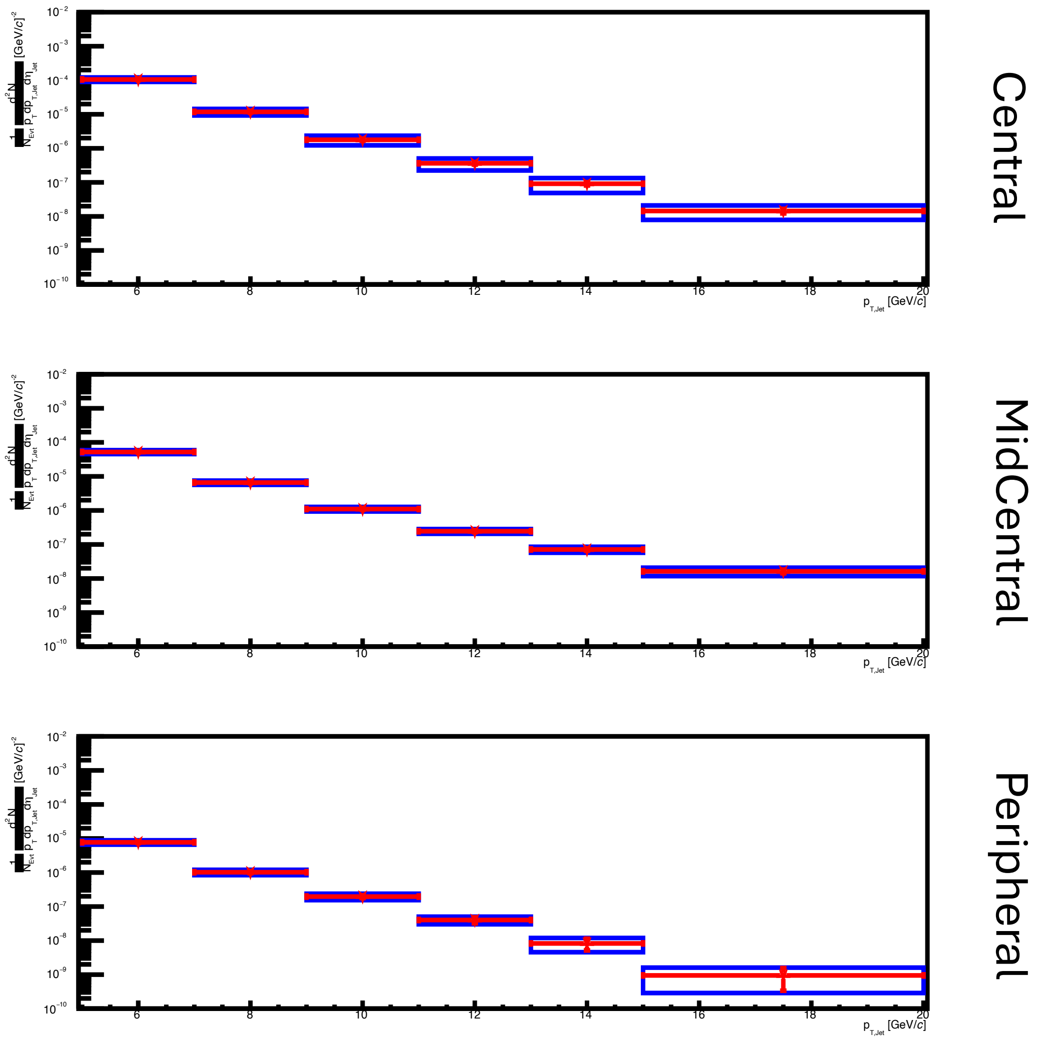
Present Preliminary For Jet pT Spectra

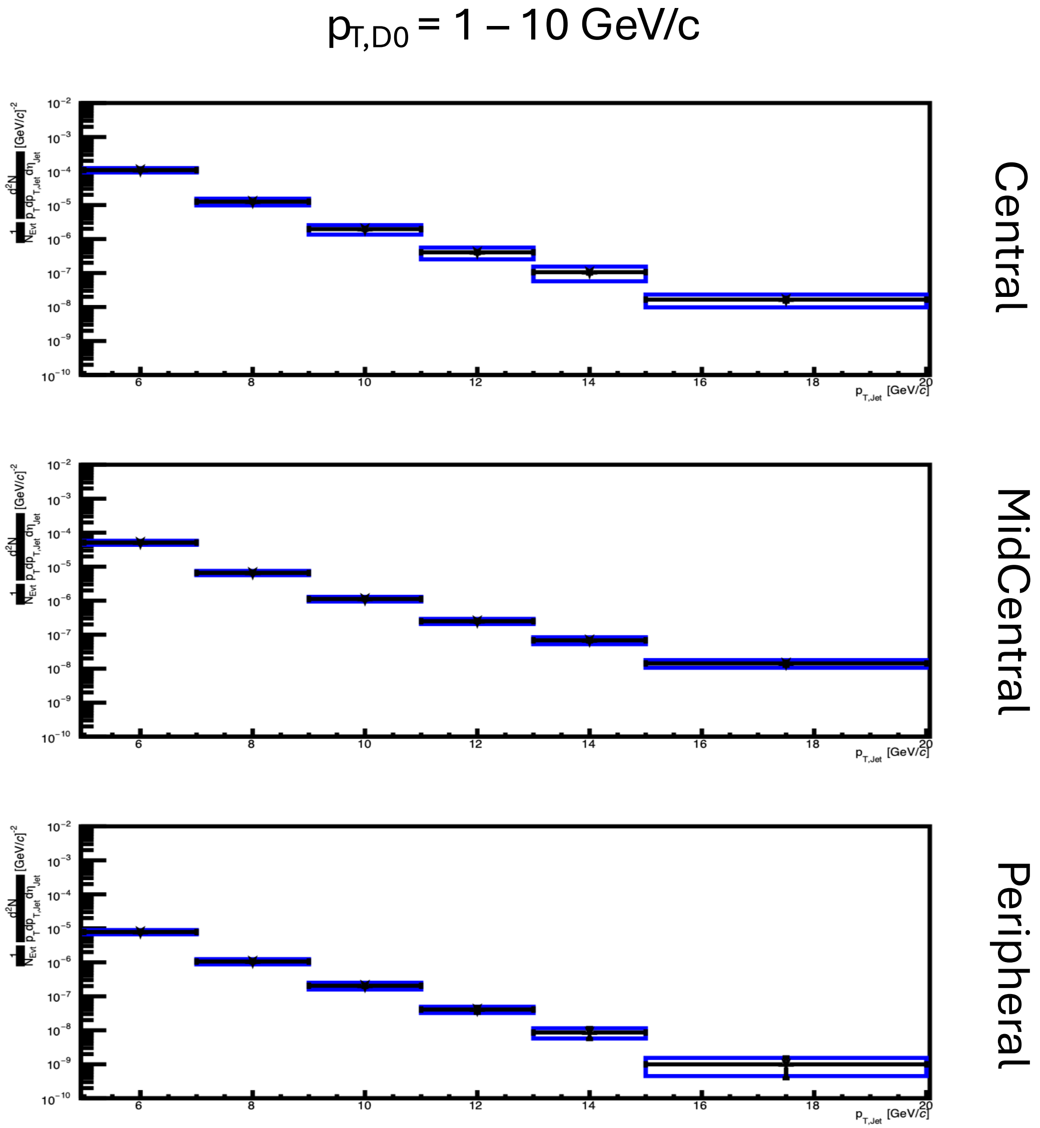
R = 0.4

$p_{T,D0} = 1 – 10$ GeV/c



Results With Barlow Testing For Jet pT Spectra

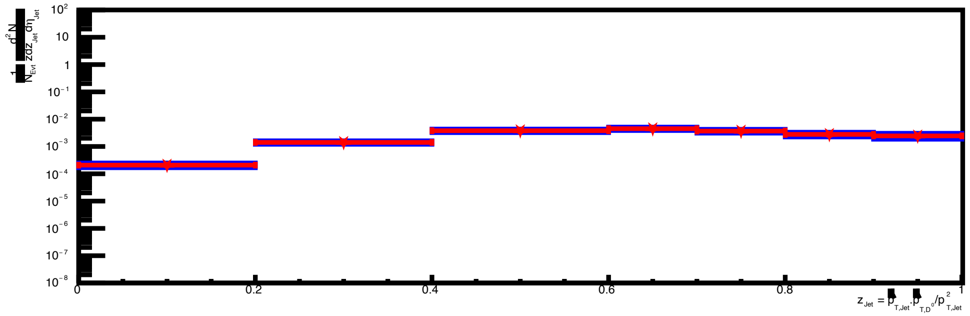
R = 0.4

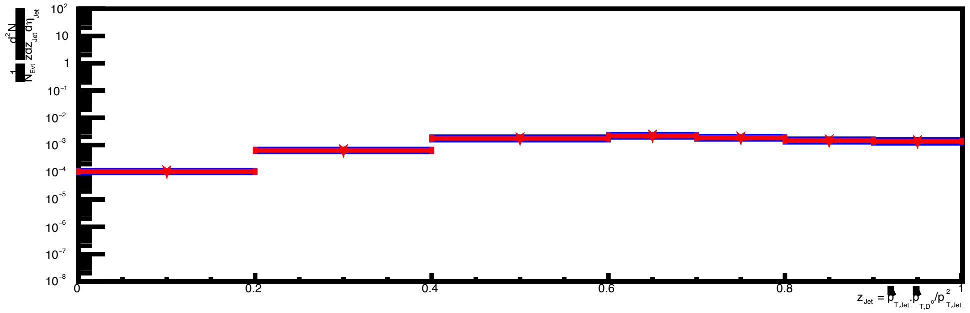


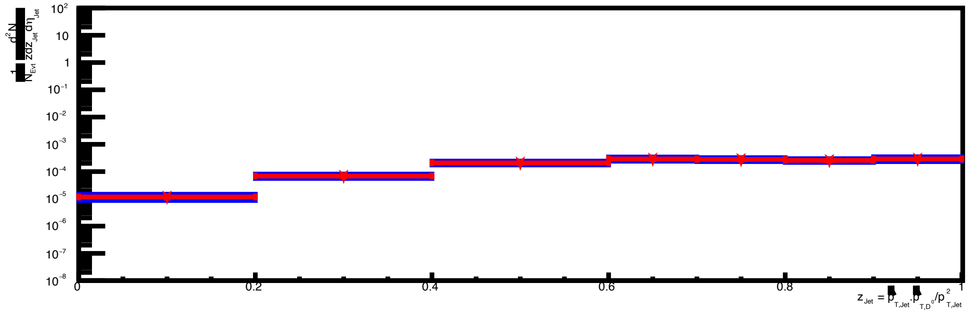
Present Preliminary For Jet Z Spectra

R = 0.4

$p_{T,D0} = 1 - 10$ GeV/c







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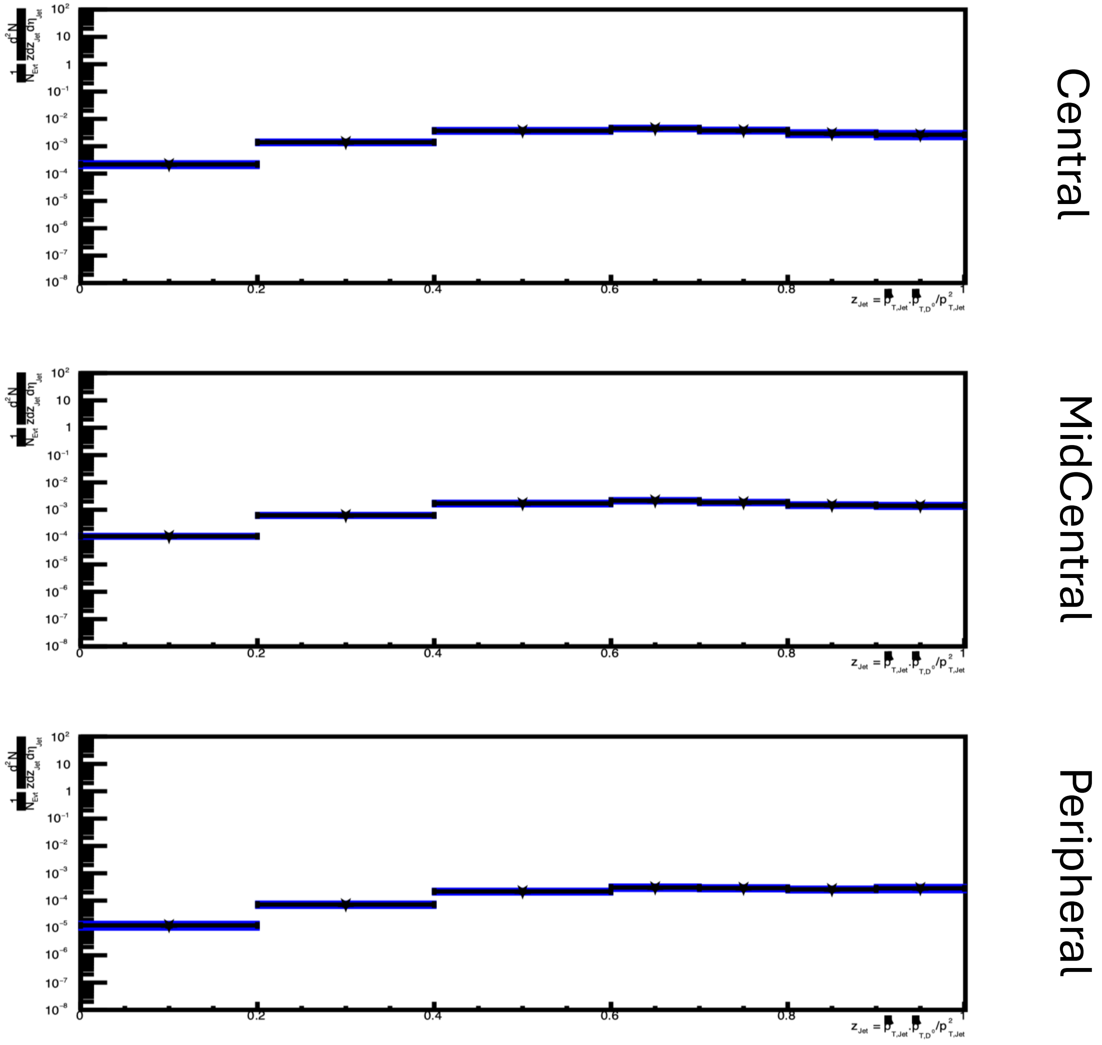
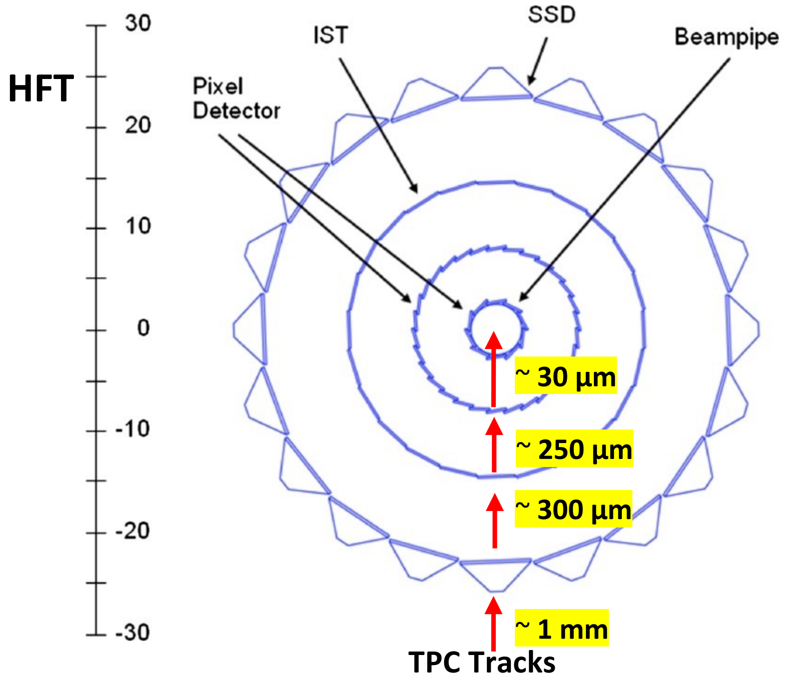
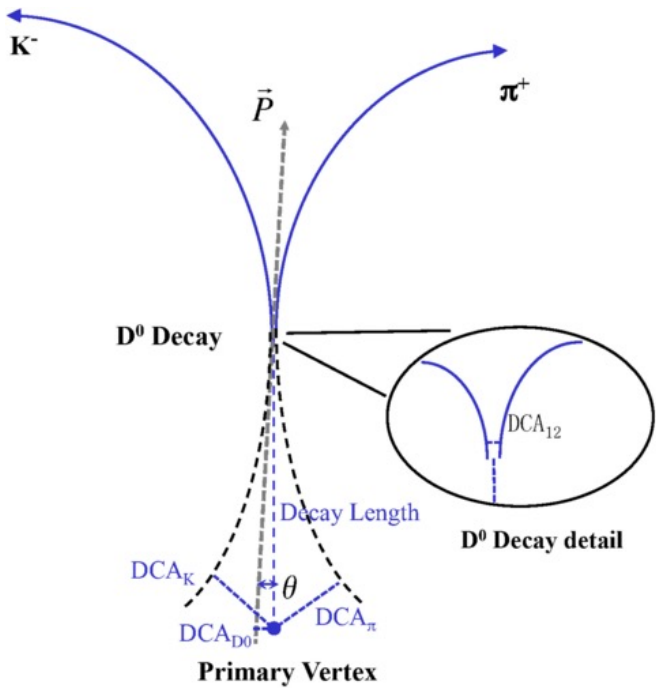
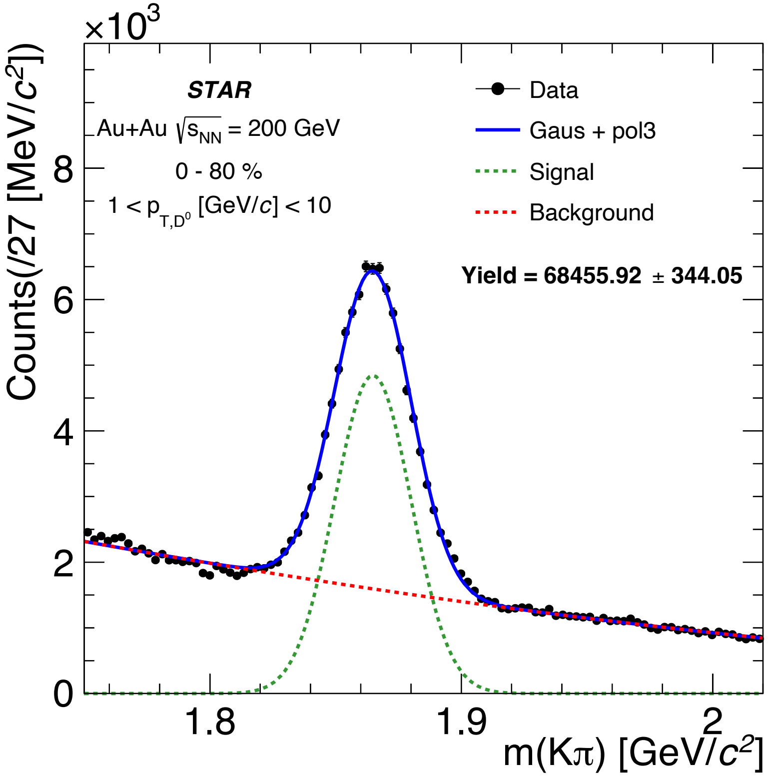


Technical Details



STAR, Phys. Rev. C 99 (2021) 034908





HFT used for better secondary vertex resolution
Topological cuts on the D^0 candidates improve signal significance

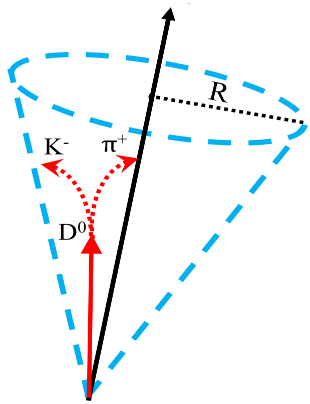
Yield is calculated using sPlot method [1]

[1] Nucl. Instrum. Methods Phys. Res., A (2005) 555

Technical Details

D^0-Jet Yield Extraction ${}_s\mathcal{P}lot$

Nucl. Instrum. Methods Phys. Res., A (2005) 555



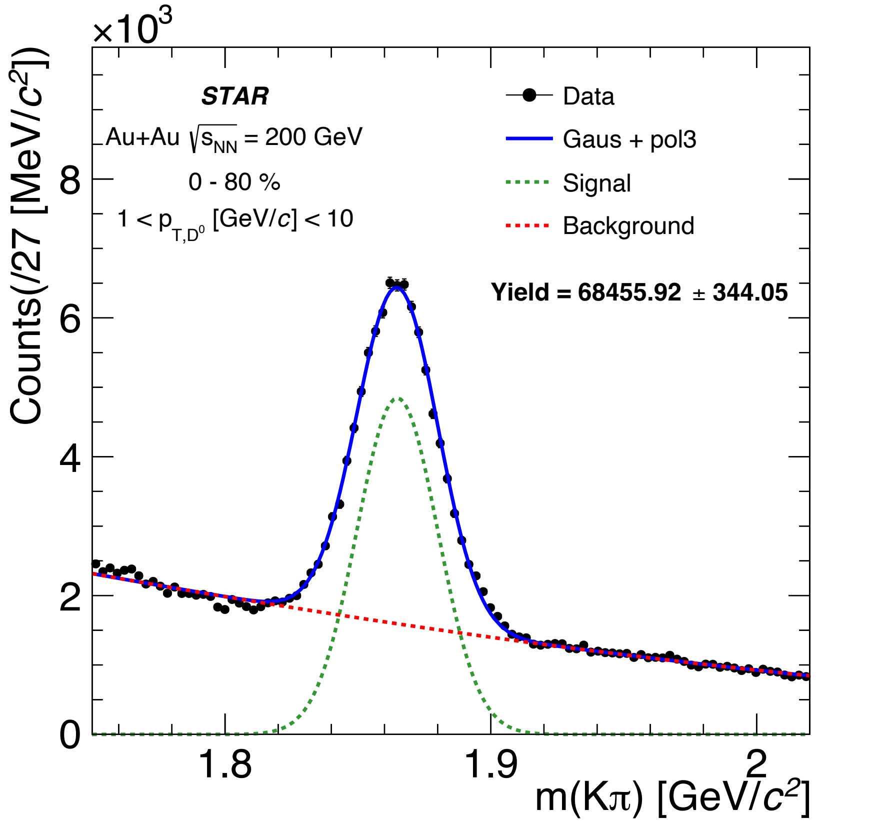
- Native class in RooStats, and widely used in HEP
- Unbinned maximum likelihood fit to invariant mass integrated over all kinematics
- $p_{\mathrm{T,jet}}$ and radial distributions with all D^0-tagged jet candidates using sWeights
- Easy to include reconstruction efficiencies versus D^0 kinematics

$$ {}_s\mathcal{P}_n(m_{K\pi,i}) = \frac{\sum_{j=1}^{N_T} V_{nj} f_j(m_{K\pi,i})}{\sum_{k=1}^{N_T} N_k f_k(m_{K\pi,i})} $$

Unbinned max. likelihood fit
n = n-th fit component(sig/bkg)
N_k = k-th yield (T=2)
$f_k(m_{K\pi,i})$ = per-event PDF value with k^{th} hypothesis
V = cov. matrix

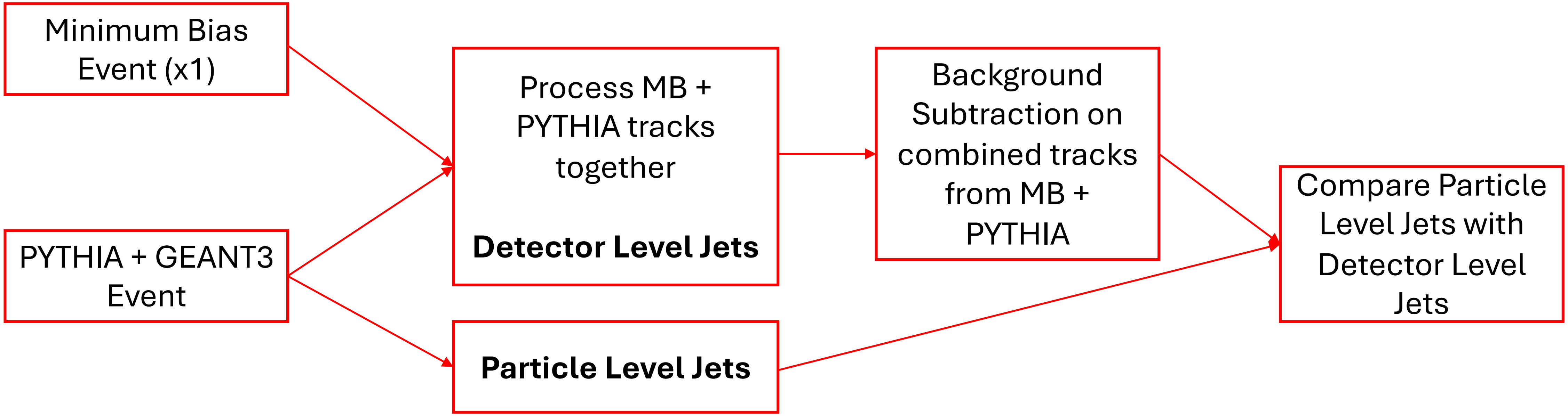
Efficiency Correction

$$ {}_s\mathcal{P}_n(m_{K\pi,i}) \rightarrow \frac{{}_s\mathcal{P}_n(m_{K\pi,i})}{\varepsilon(m_{K\pi,i})} $$



Technical Details

Creating a hybrid embedding sample

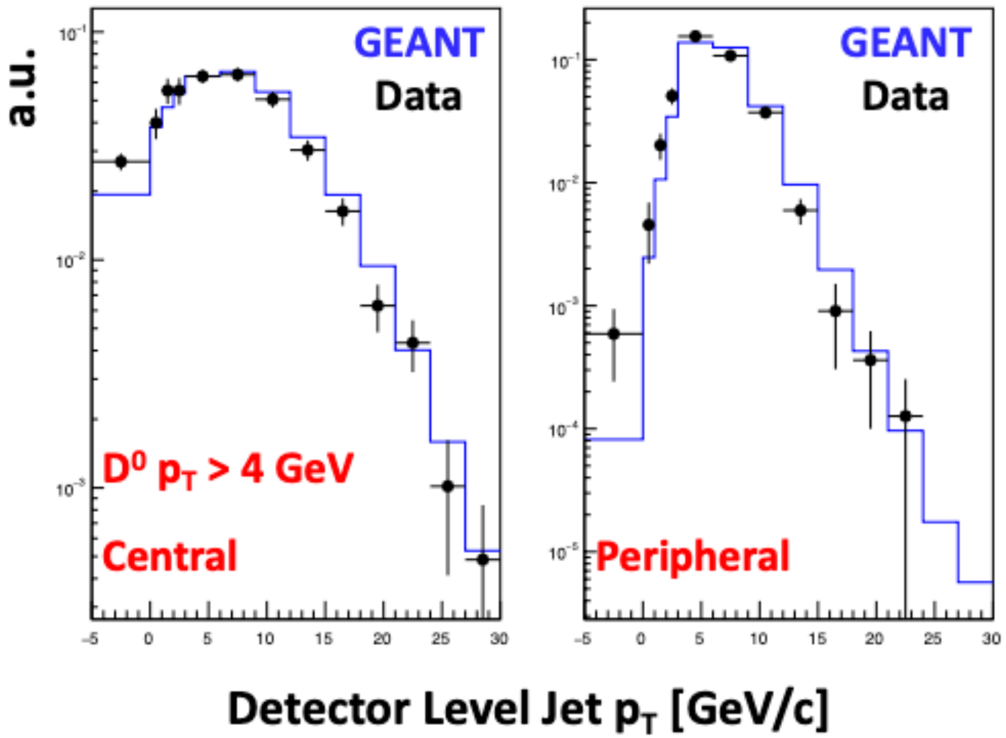


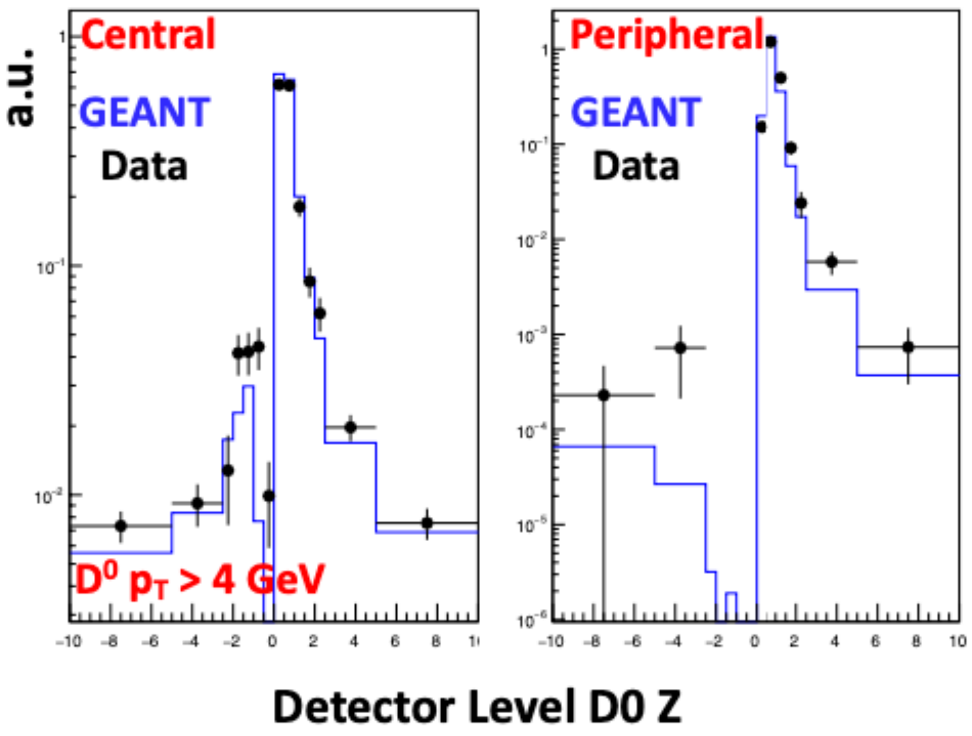
- Get a minimum bias event
- Sample ~10 random PYTHIA events for each minimum bias event
- Run jet maker on the PYTHIA events ‘**embedded**’ in the minimum bias event -> This is **PARTICLE** level
- Run jet maker on the combined PYTHIA+Minbias event -> This is **DETECTOR** level

Technical Details

Data-driven prior

Example D^0 p_T bin: [4-10] GeV/c





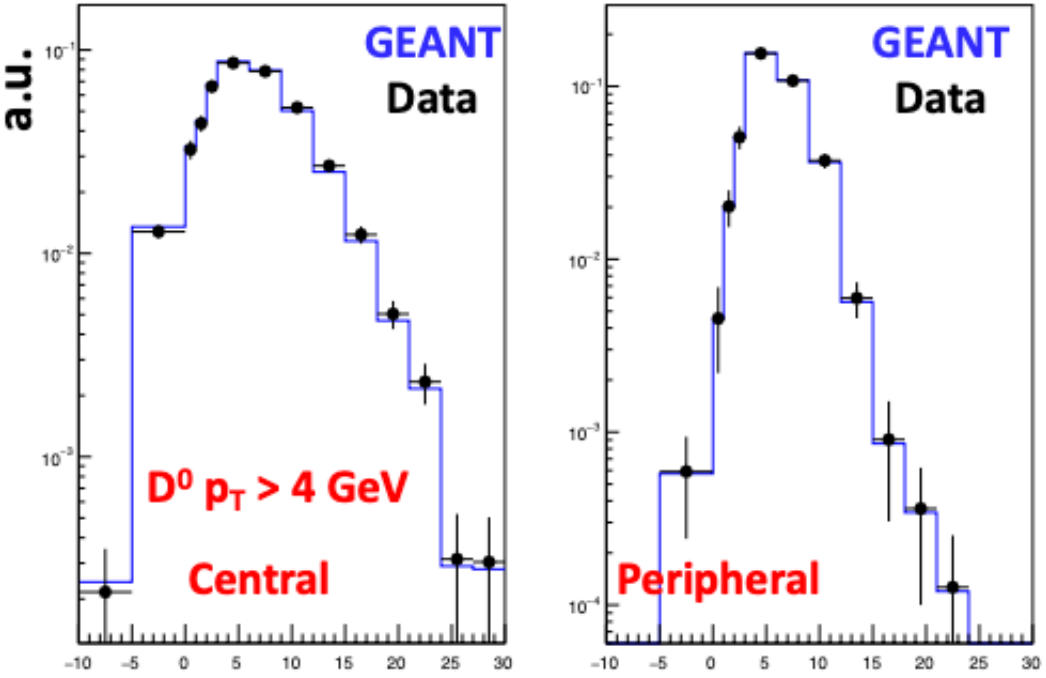
In the absence of a prior, best way to estimate effect of variation

Resolve differences between detector level observables from GEANT and DATA

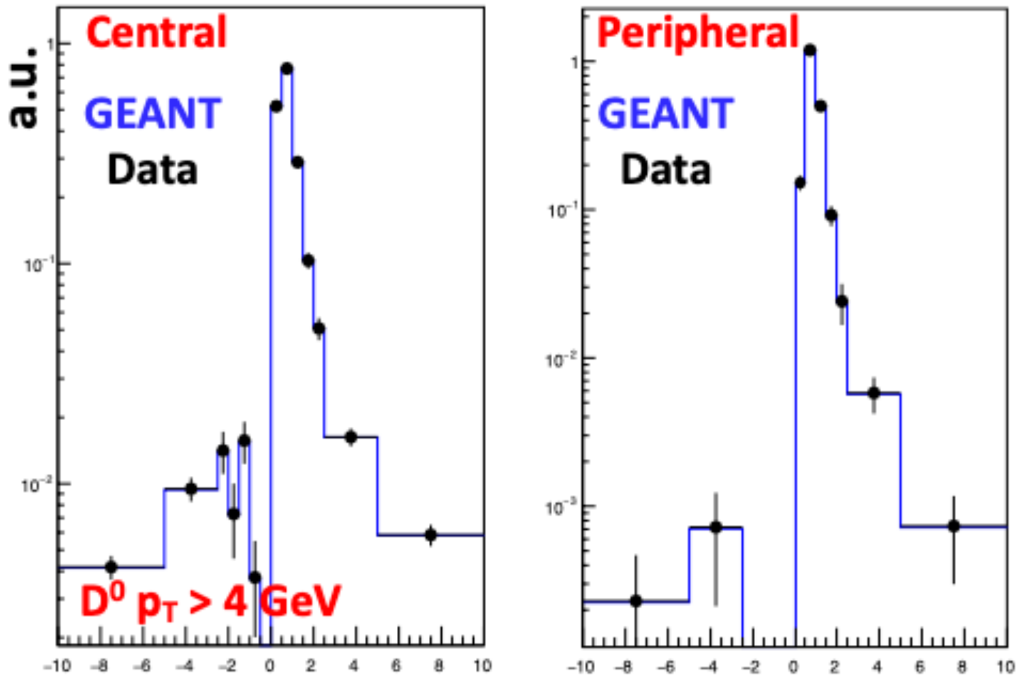
Technical Details

Corrections To Prior – After applying Data vs GEANT weights

Example D^0 p_T bin: [4-10] GeV/c



Detector Level Jet p_T [GeV/c]



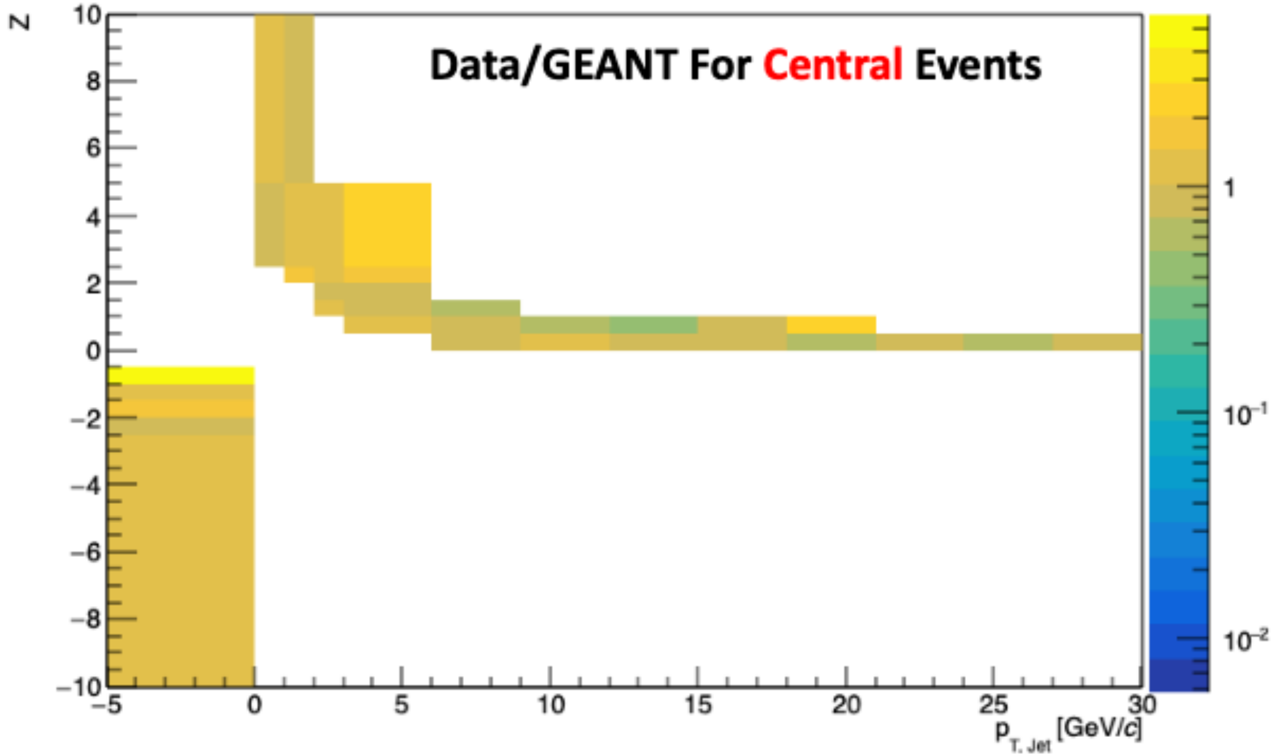
Detector Level D0 Z

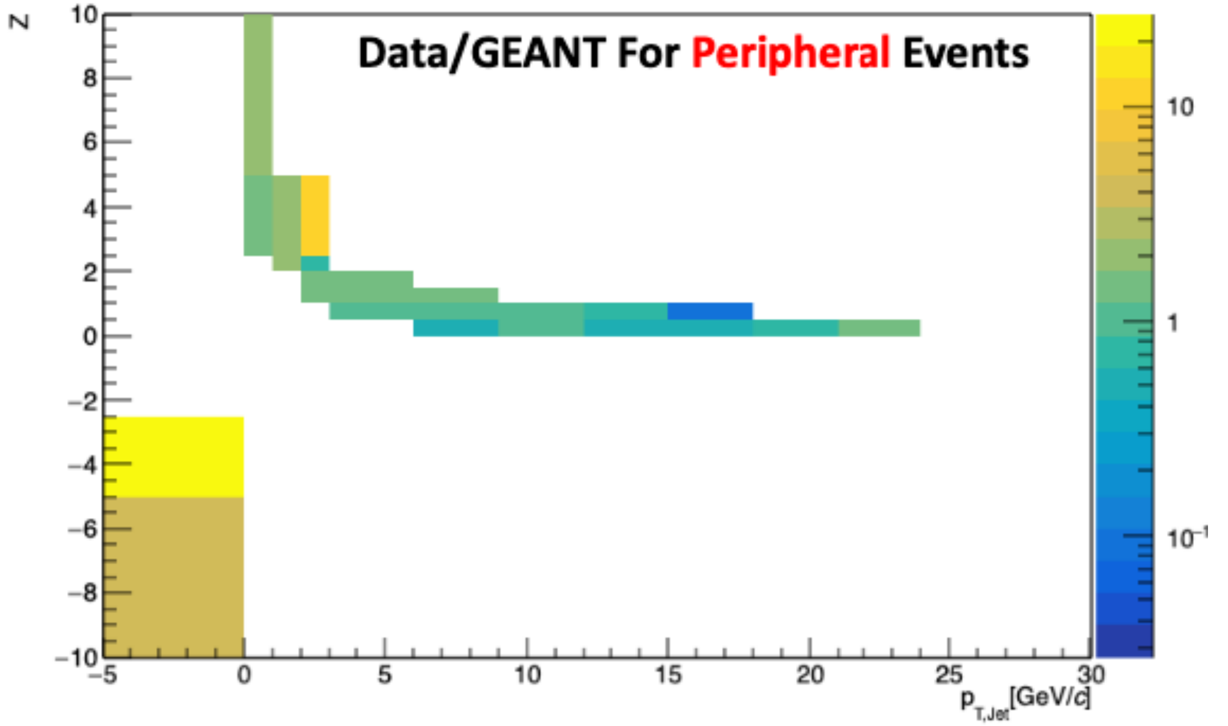
2D Weighing can resolve the differences between Data And GEANT

Technical Details

Corrections To Prior – Derive Data vs GEANT Weights

Example D^0 p_T bin: [4-10] GeV/c



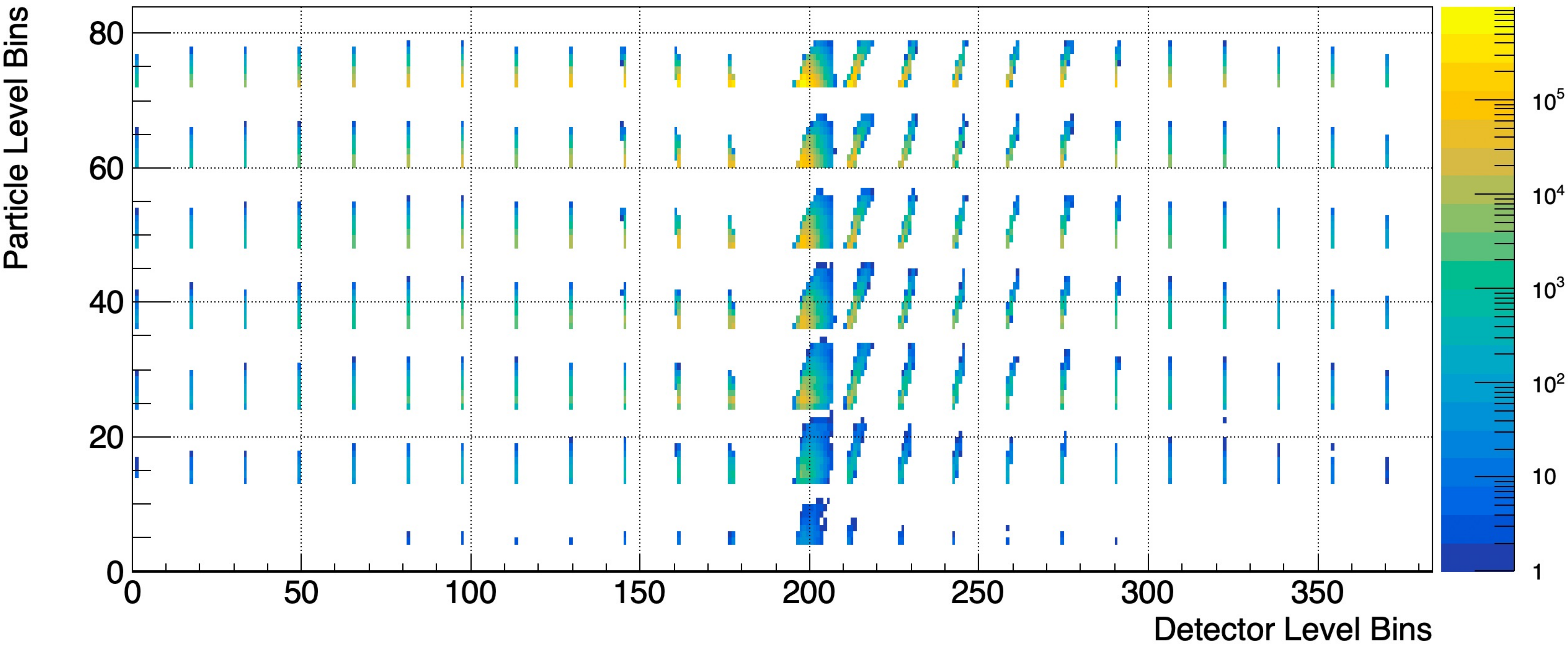


In the absence of a prior, best way to estimate effect of variation

Resolve differences between detector level observables from GEANT and DATA

Centrality Dependent Corrections

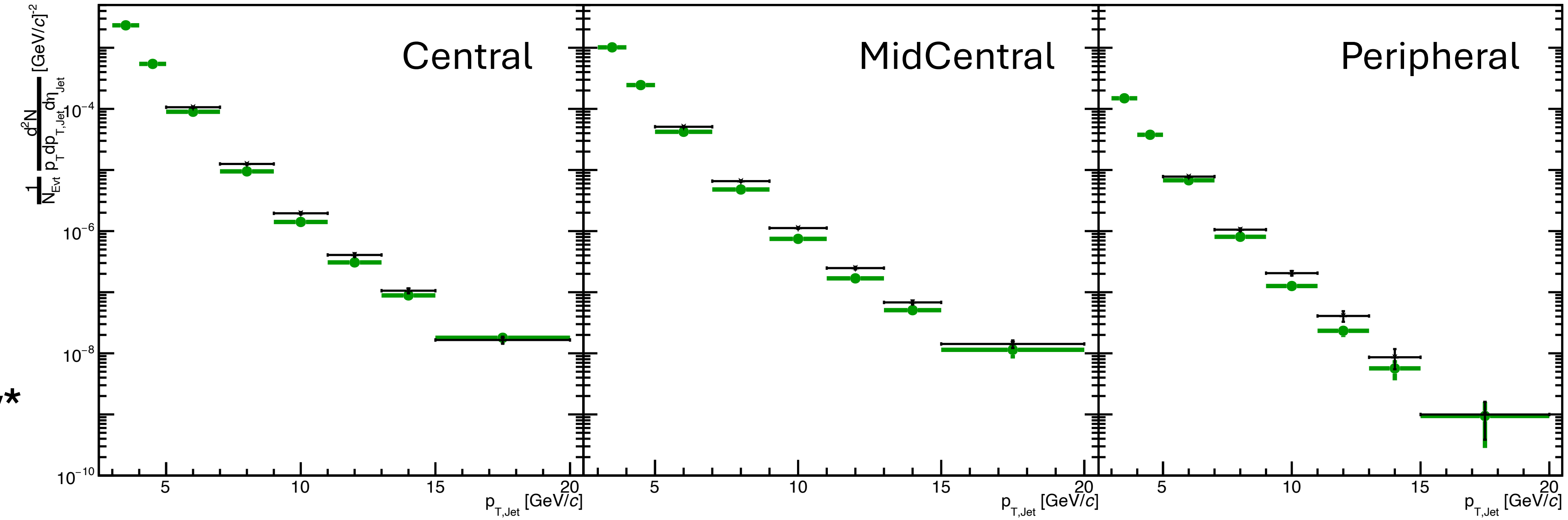
Technical Details



Flattened representation of 4D response matrix for Jet p_T and Fragmentation Function

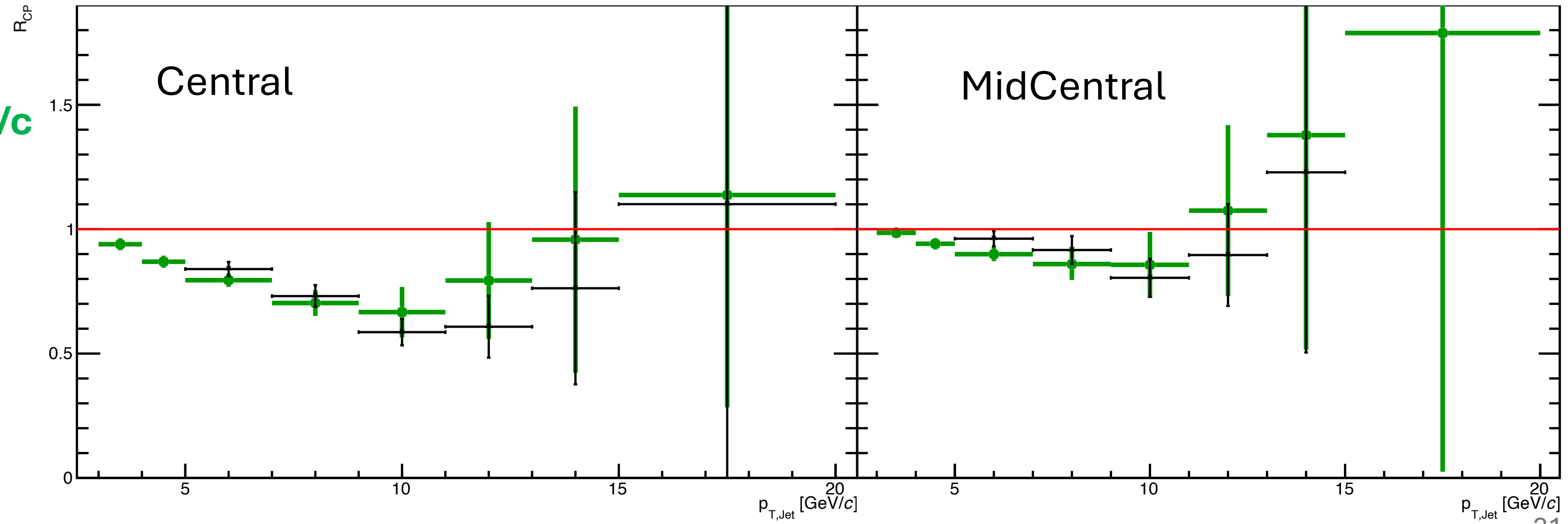
Consistency Check With Charged D0 Jets

R = 0.4



Green → Charged Jets
Black → Full Jets

Statistical Errors Only

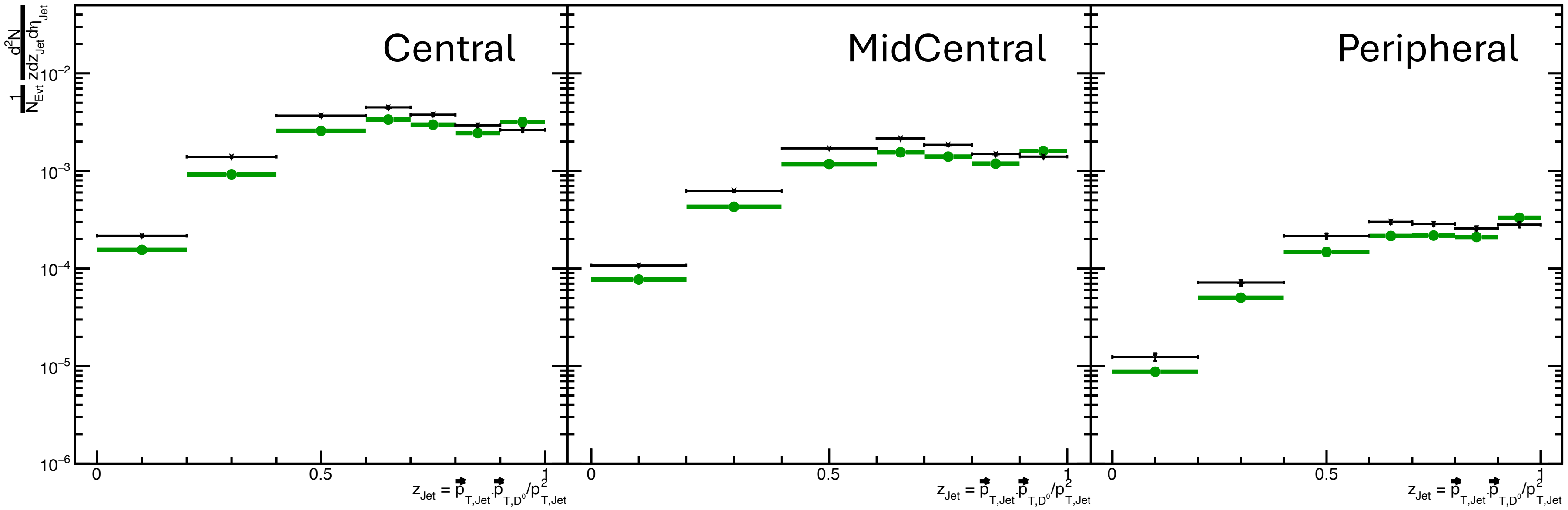


Charged Jets → [3, 20] GeV/c
Full Jets → [5,20] GeV/c

Physics message consistent across charged and full jets

Consistency Check With Charged D0 Jets

R = 0.4



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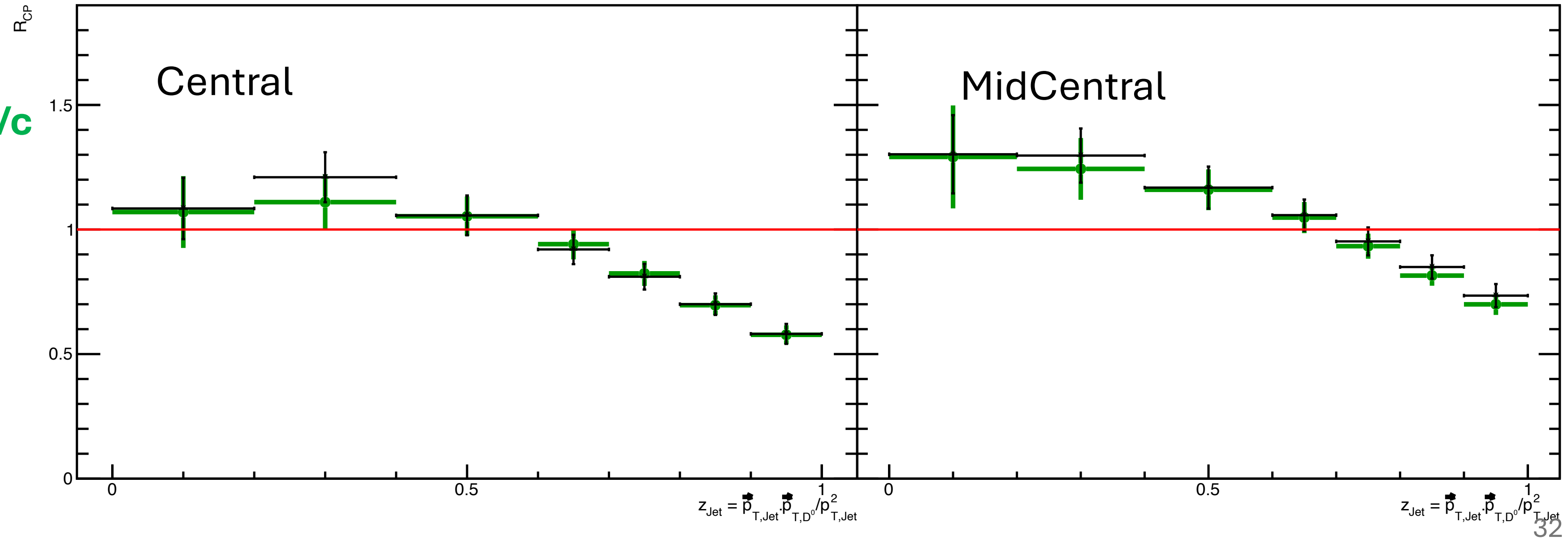

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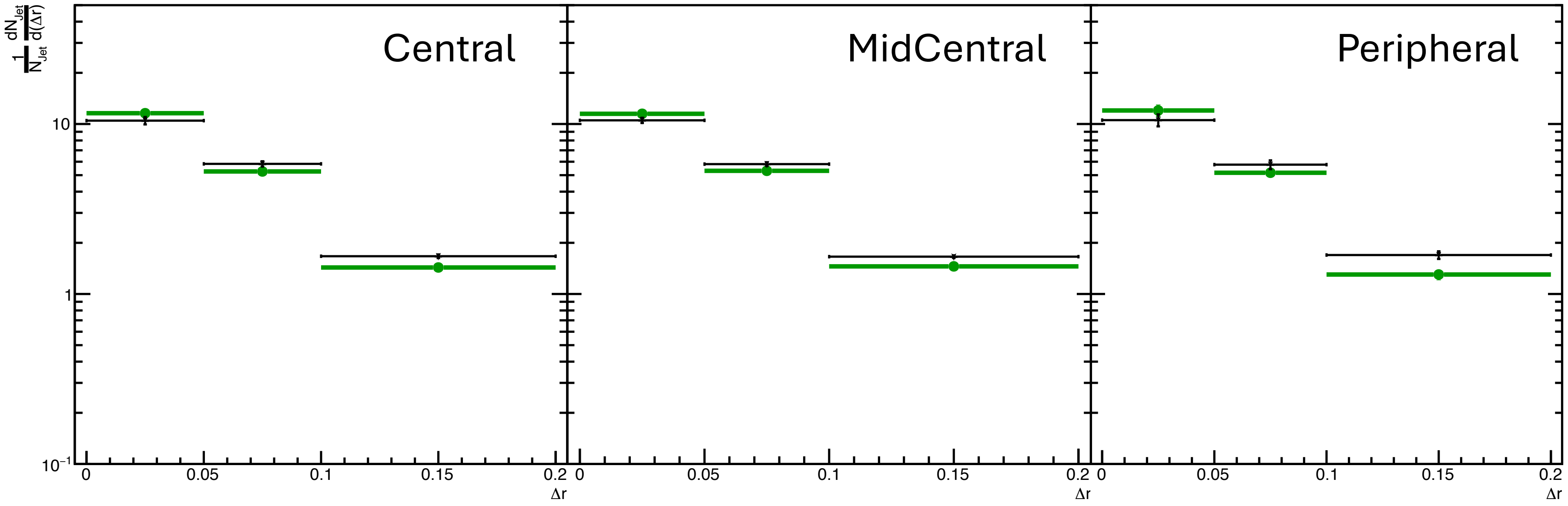

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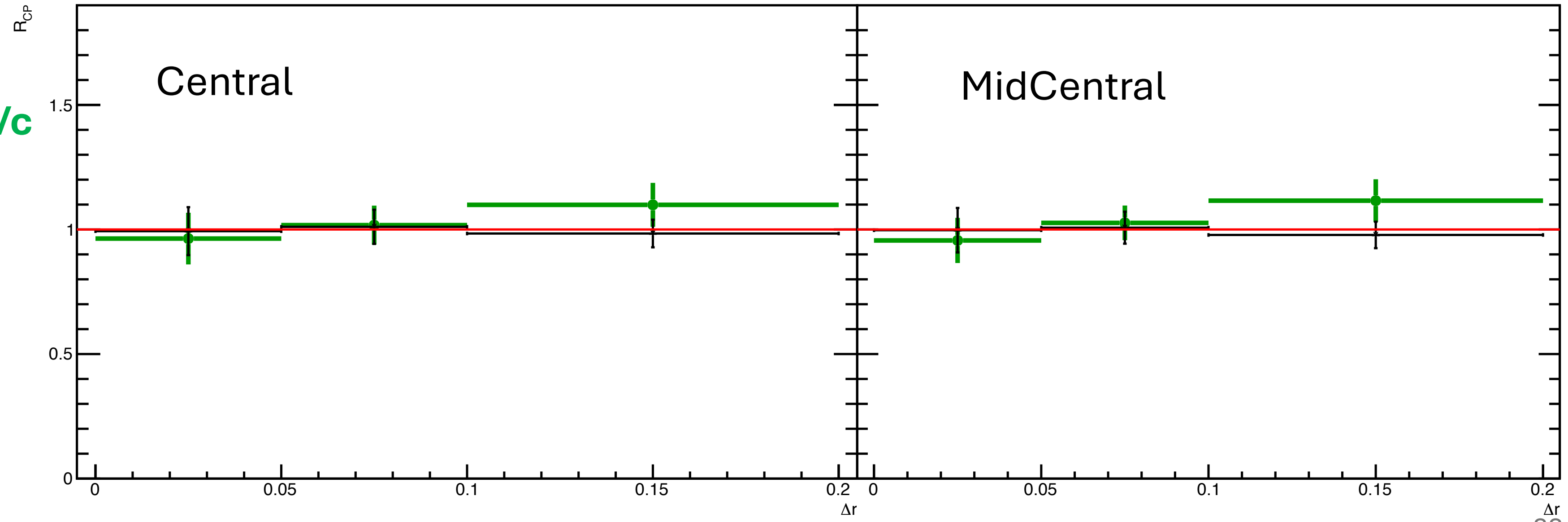

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