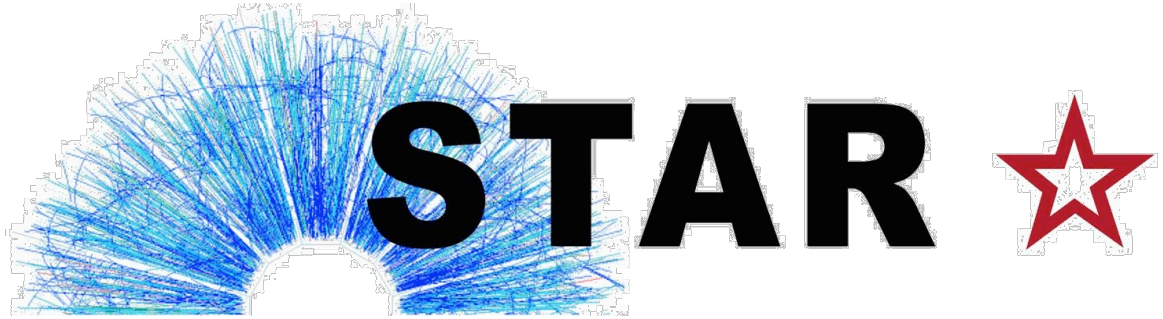

Charm Quark Jets in Au+Au Collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV

STAR Collaboration Meeting
February 28, 2023

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Rutgers University
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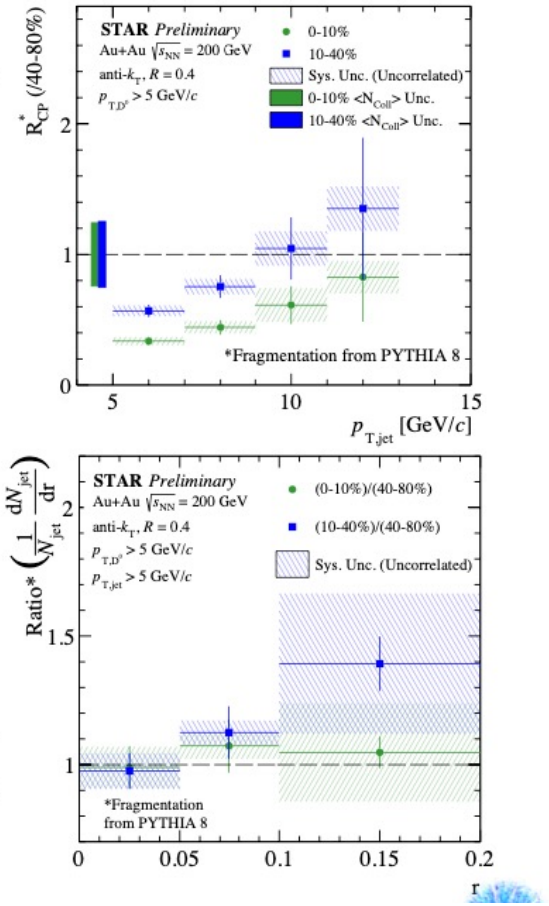
Recap

Summary

- First D^0-tagged measurement at RHIC energies
- Fragmentation from PYTHIA 8 used for correcting jet momenta and substructure
  - ✓ Spectra for D^0-tagged jets in central and mid-central events consistent with being suppressed with respect to peripheral events
  - ✓ Radial profile of D^0 mesons in jets consistent with unity within uncertainties.

Outlook

- Measure fragmentation function for D^0-tagged jets in Au+Au collisions
- Extend kinematic reach to low D^0 p_T to get closer to charm quark mass



ISSUES

1. Fragmentation function for PYTHIA is ‘too’ hard for the full range of D0 pT
2. For low D^0 p_T in jets, unfolding is dependent on the fragmentation function

Details here: https://drupal.star.bnl.gov/STAR/system/files/Kelsey_JetCorr_17Mar2022.pdf

Issues with simulation

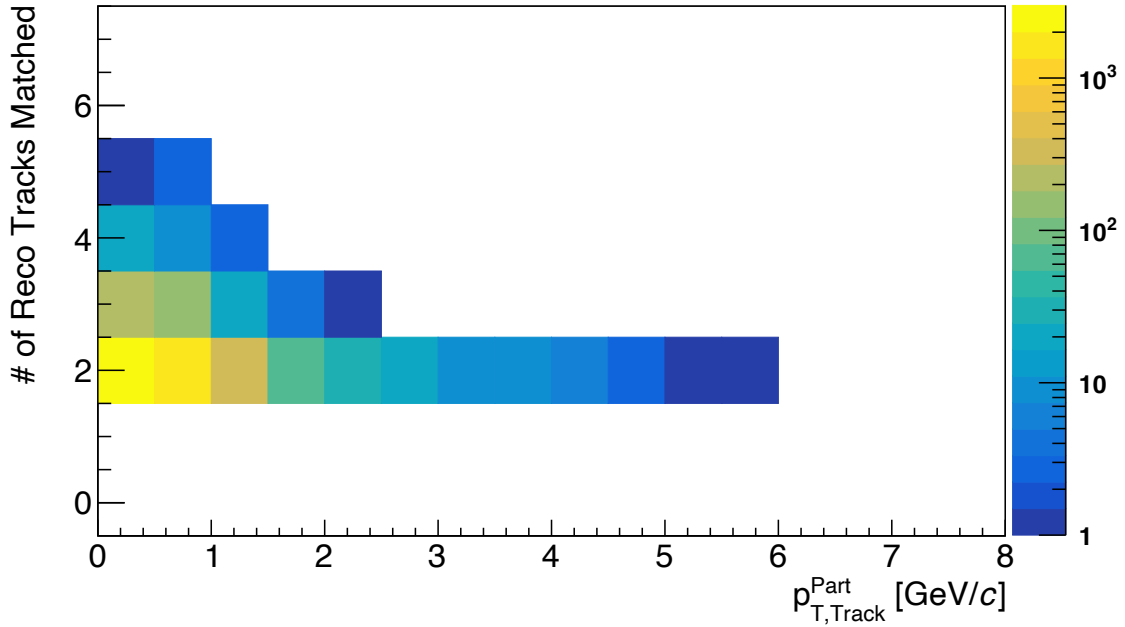
- DCA cuts were not applied to the detector level tracks

DCA < 3.0 cm
nHitsFit > 15
nHitsRatio > 0.52

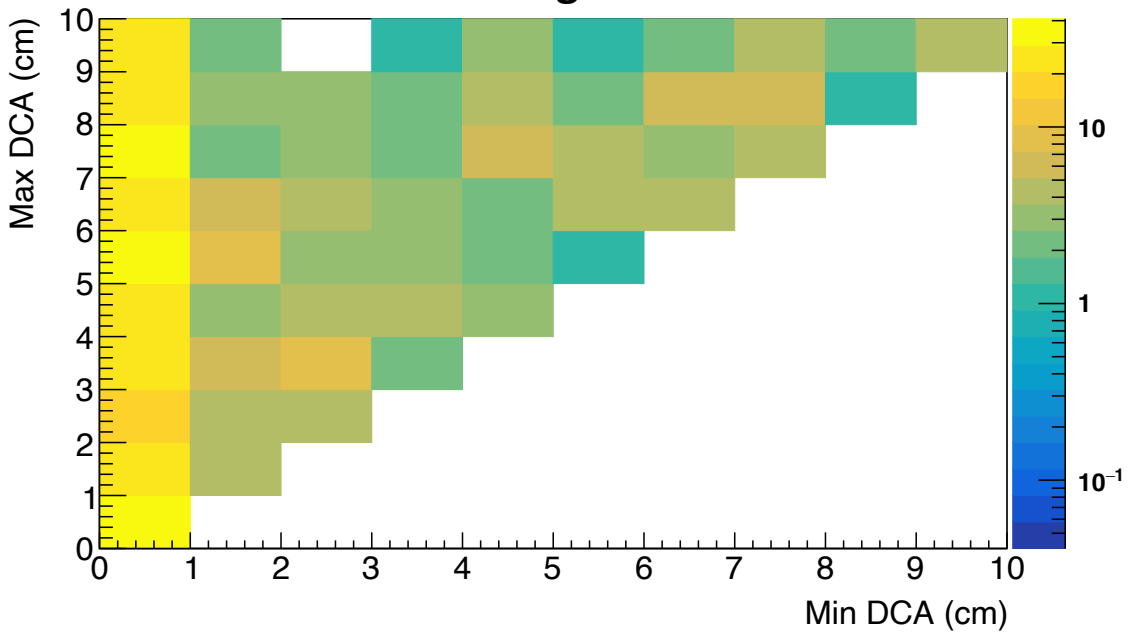
- Multiple detector level tracks → Matched to 1 generated track

Not accounted for earlier

Gen Tracks with > 1 reco track matched



Min DCA vs Max DCA for gen tracks with > 1 matches



Reco Track with lowest DCA is chosen as the matched track

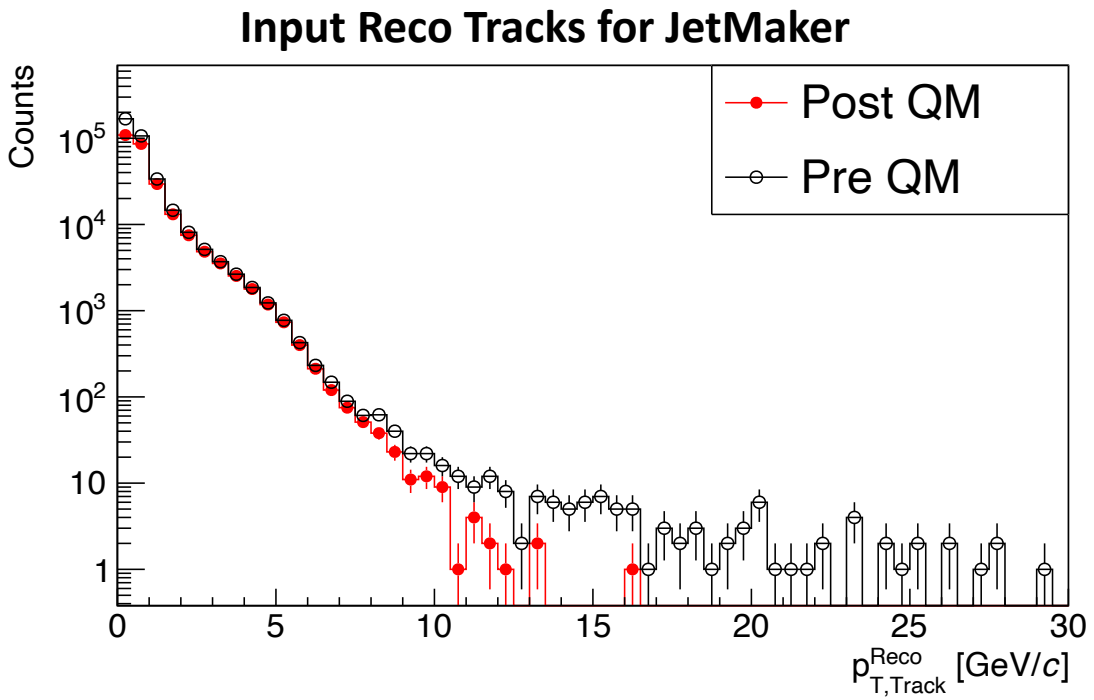
Issues with simulation

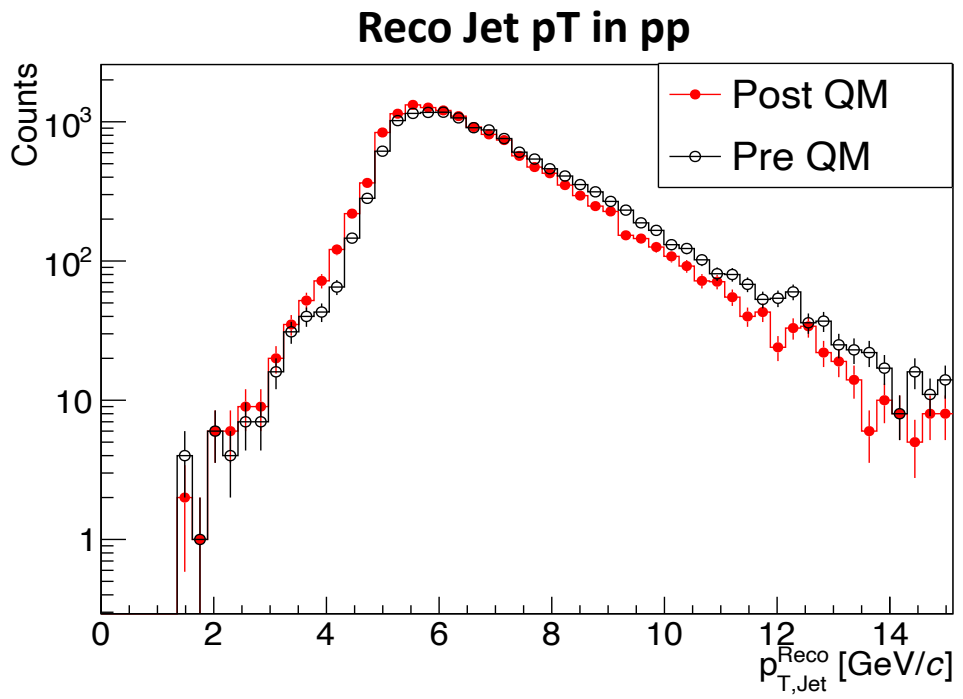
- DCA cuts were not applied to the detector level tracks

DCA < 3.0 cm
nHitsFit > 15
nHitsRatio > 0.52

- Multiple detector level tracks → Matched to 1 generated track

Not accounted for earlier





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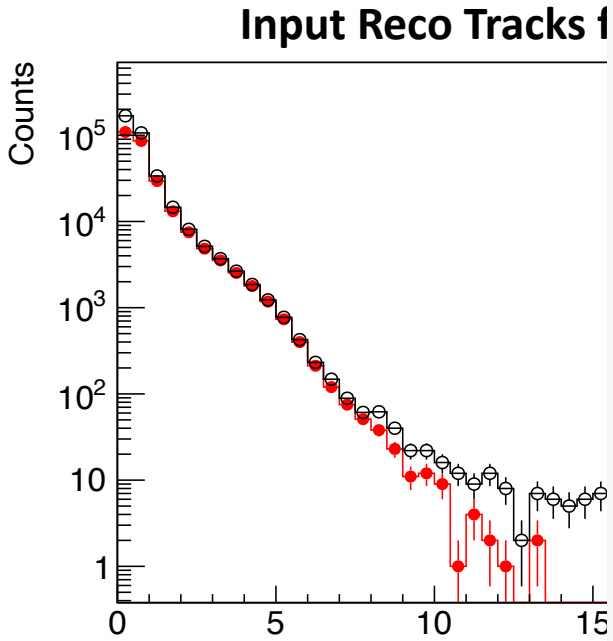
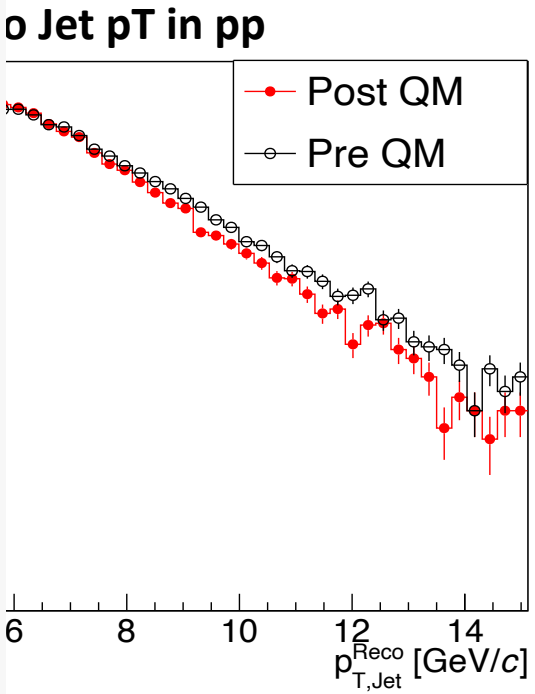


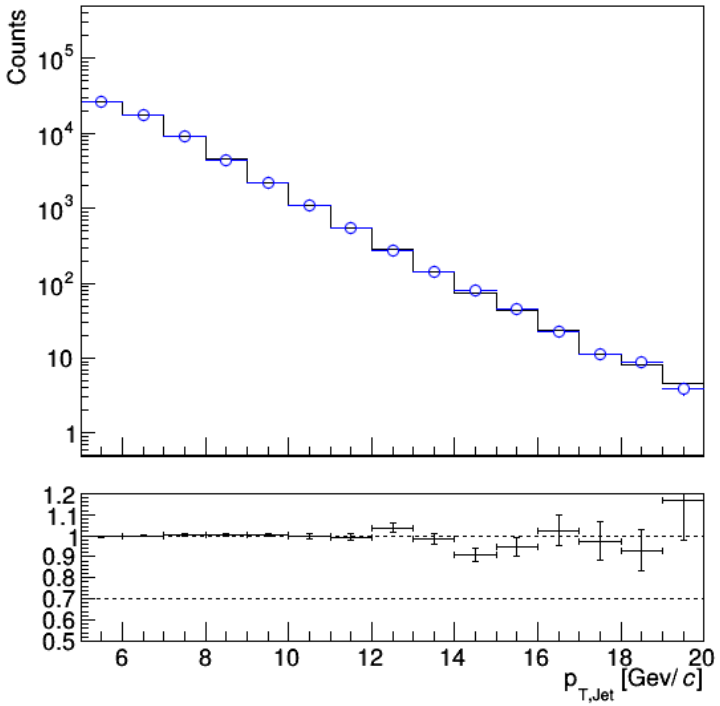


Different Jet pT distributions → Changes in response matrix

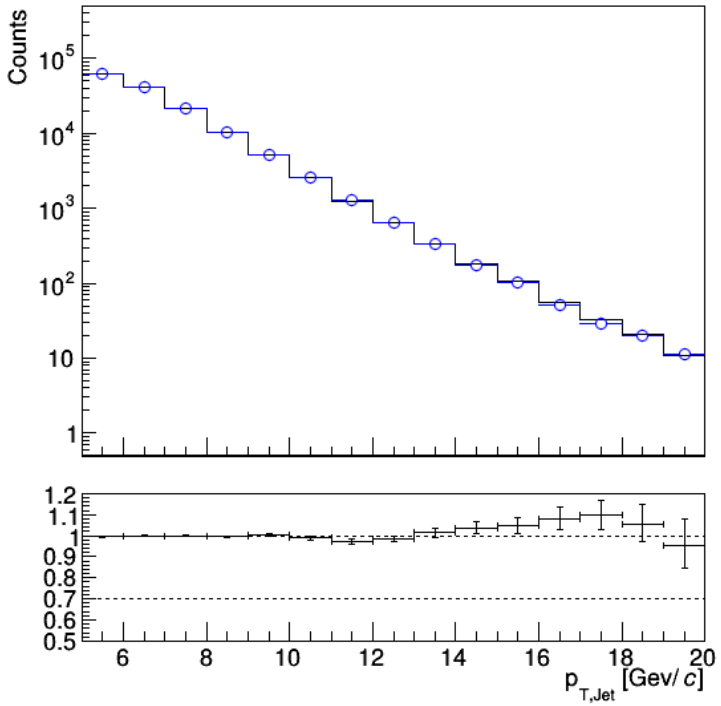
Revisiting 1D Unfolding Closure

- **PYTHIA 8 Detroit Tune**
- **5 < p_{T,D^0} < 10 GeV/*c***
- 5 < $p_{T,Jet}^{Gen}$ < 20 GeV/c
- 3 < $p_{T,Jet}^{Reco}$ < 30 GeV/c
- $|\eta_{Jet}^{Gen,Reco}| < 0.6$
- **Misses**: Everything outside the acceptance in p_T and η
- Background estimated with single particle embedding

Central



Peripheral



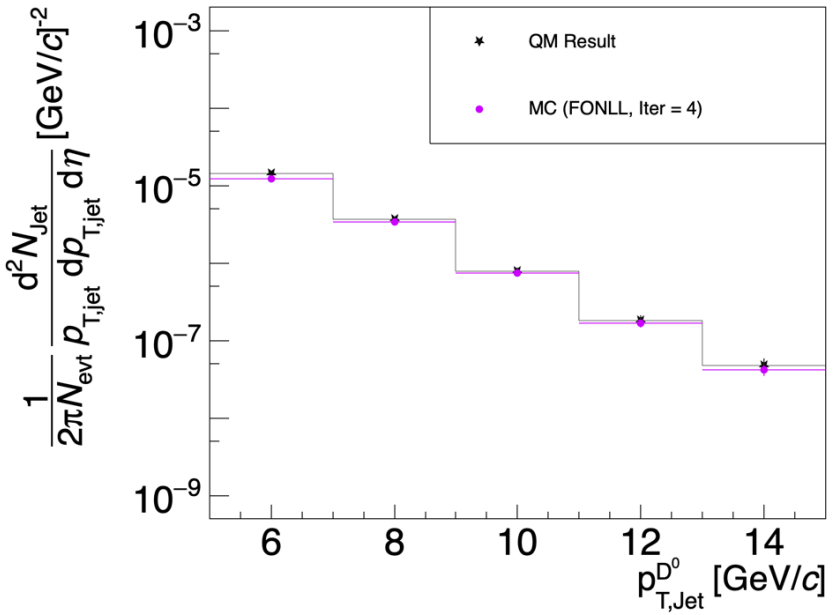
All centralities close well with new response matrices

Revisiting Data

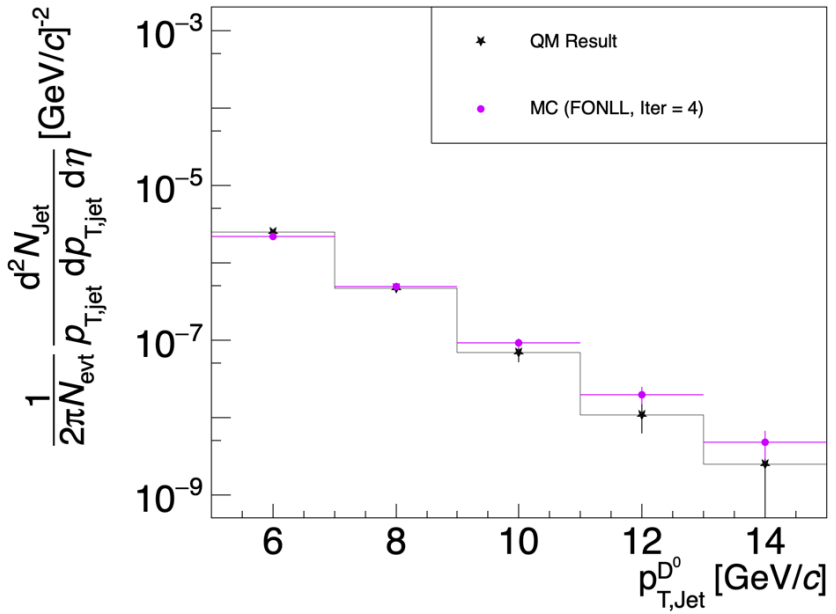
- $3 < p_{T,Jet}^{Uncorrected} < 30$ GeV/c → $5 < p_{T,Jet}^{Corrected} < 20$ GeV/c
- $5 < p_{T,D^0} < 10$ GeV/c

STAR, Au + Au $\sqrt{s_{NN}}$ = 200 GeV

Central



Peripheral



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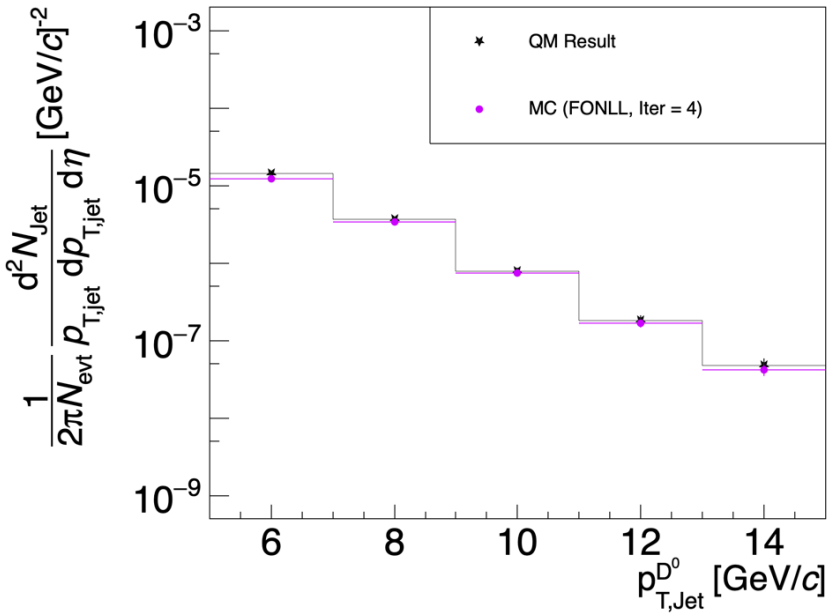
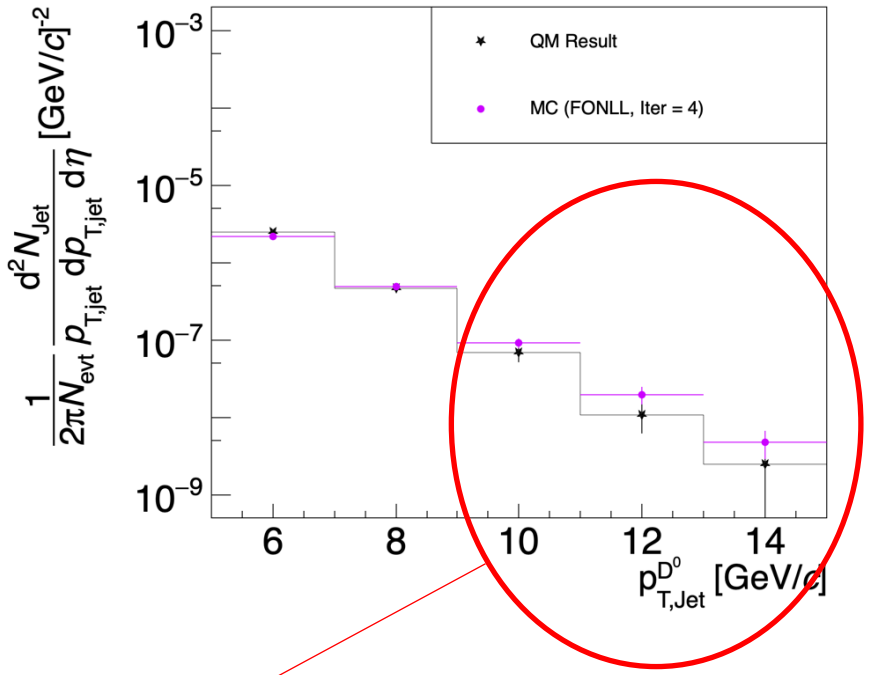


Peripheral



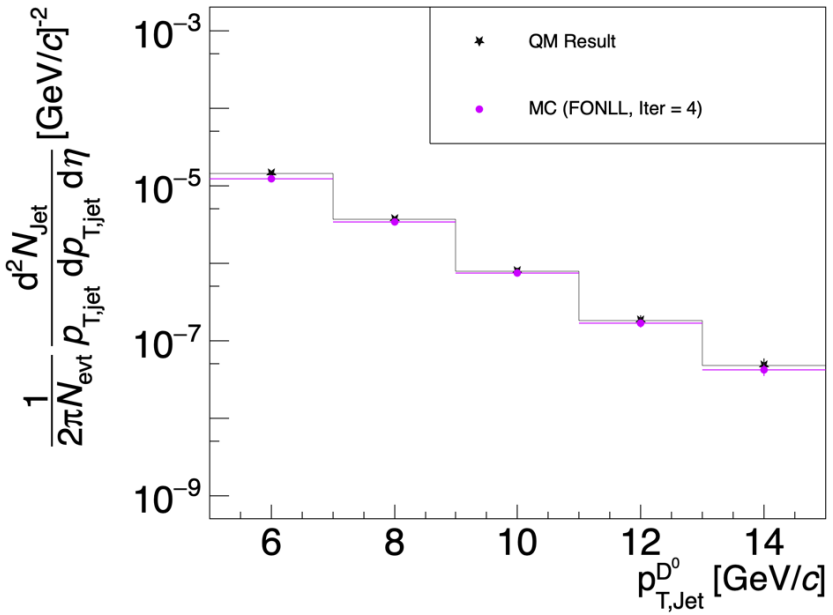
Peripheral spectra shifts significantly from QM

Revisiting Data

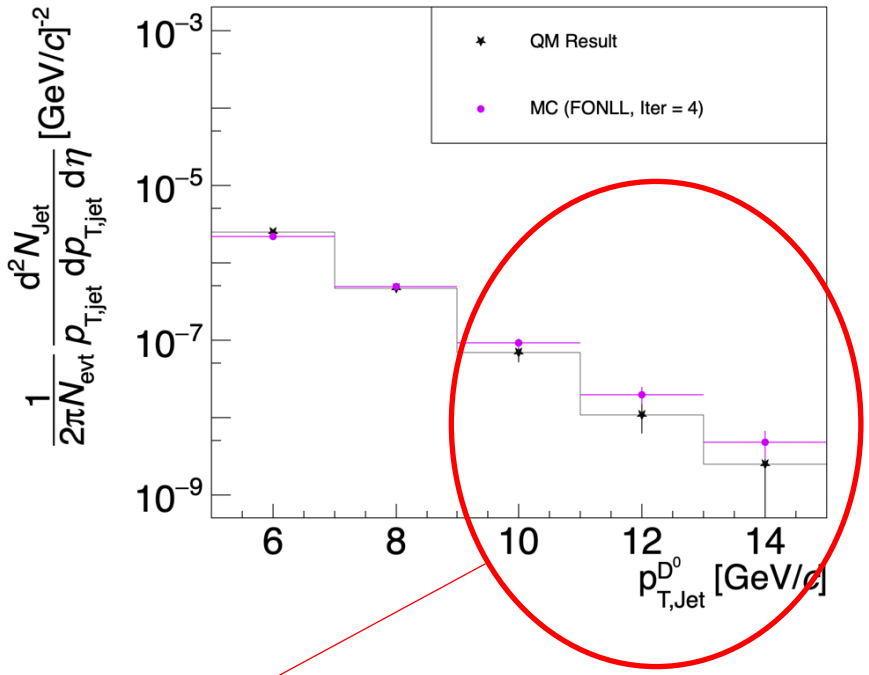
- $3 < p_{T,Jet}^{Uncorrected} < 30$ GeV/c → $5 < p_{T,Jet}^{Corrected} < 20$ GeV/c
- $5 < p_{T,D^0} < 10$ GeV/c

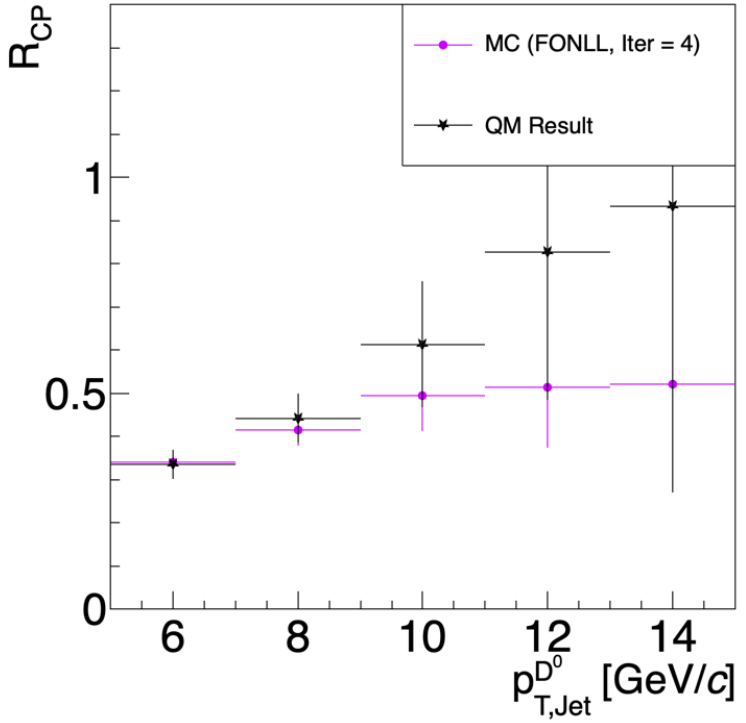
STAR, Au + Au $\sqrt{s_{NN}}$ = 200 GeV

Central



Peripheral



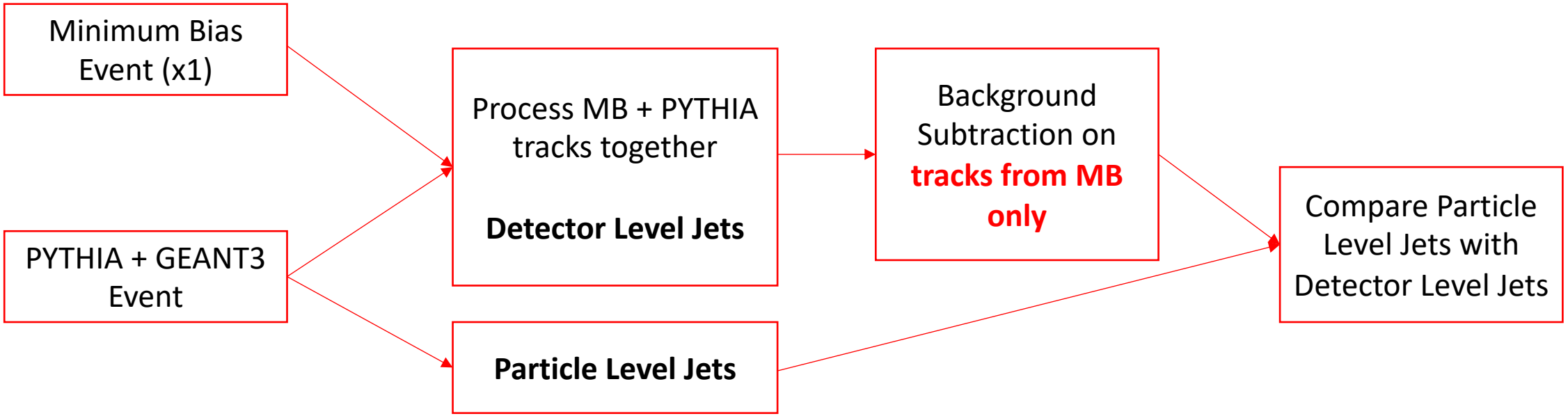


Peripheral spectra shifts significantly from QM

Rise of RCP with Jet pT less steep after corrections

Updating the simulation

Earlier, single particle embedded in minimum bias event to determine background fluctuation

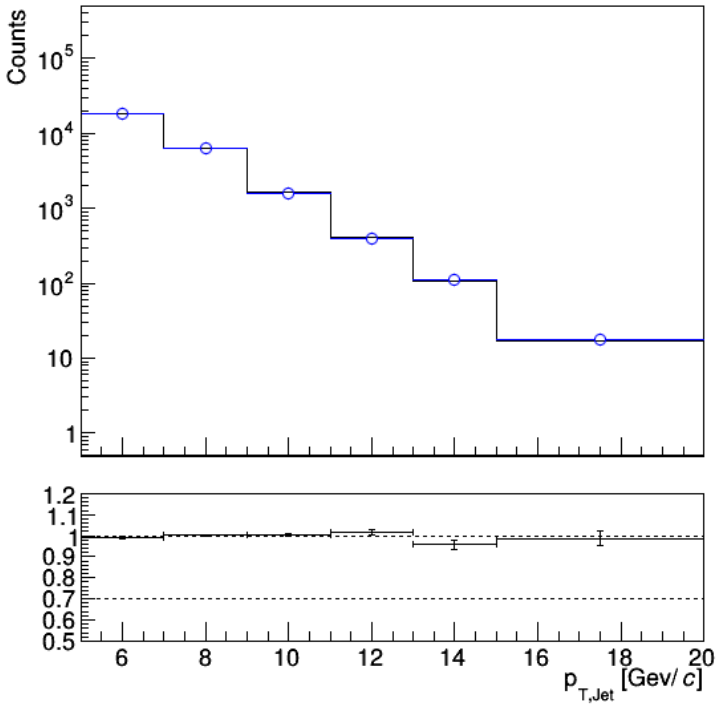


- Get a minimum bias event
- Sample a PYTHIA event for each minimum bias event
- Run jet maker on the PYTHIA events '**embedded**' in the minimum bias event -> This is **PARTICLE** level
- Run jet maker on the combined PYTHIA + Minbias event -> This is **DETECTOR** level
- Each PYTHIA event is sampled ~10 times on average

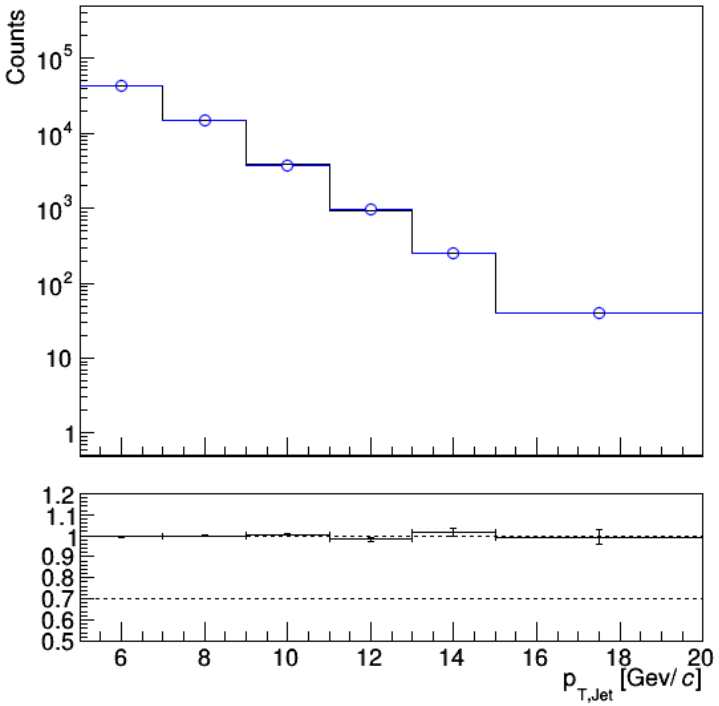
Closure with Heavy Ion Overlay for 1D Unfolding

- **PYTHIA 8 Detroit Tune**
- **5 < p_{T,D^0} < 10 GeV/c**
- 5 < $p_{T,Jet}^{Gen}$ < 20 GeV/c
- 3 < $p_{T,Jet}^{Reco}$ < 30 GeV/c
- $\left|\eta_{Jet}^{Gen,Reco}\right|$ < 0.6
- **Misses**: Everything outside the acceptance in p_T and η

Central



Peripheral



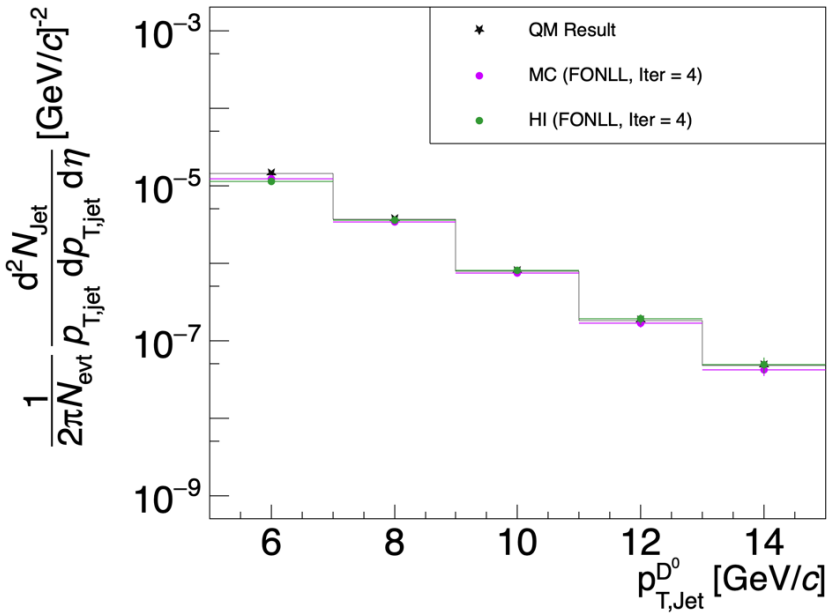
All centralities close well with the HI Overlay Method

Unfolding Data With HI Overlay

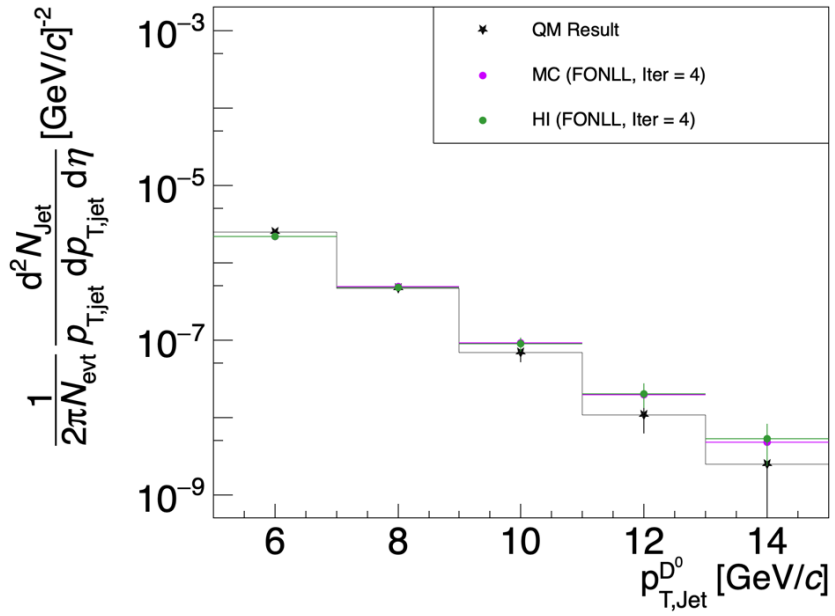
- $3 < p_{T,Jet}^{Uncorrected} < 30$ GeV/c → $5 < p_{T,Jet}^{Corrected} < 20$ GeV/c
- $5 < p_{T,D^0} < 10$ GeV/c

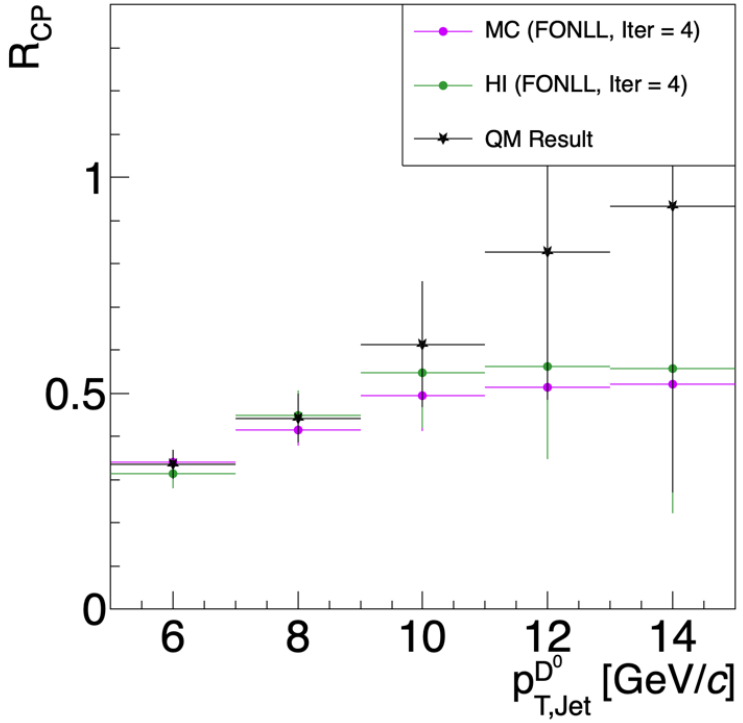
STAR, Au + Au $\sqrt{s_{NN}}$ = 200 GeV

Central



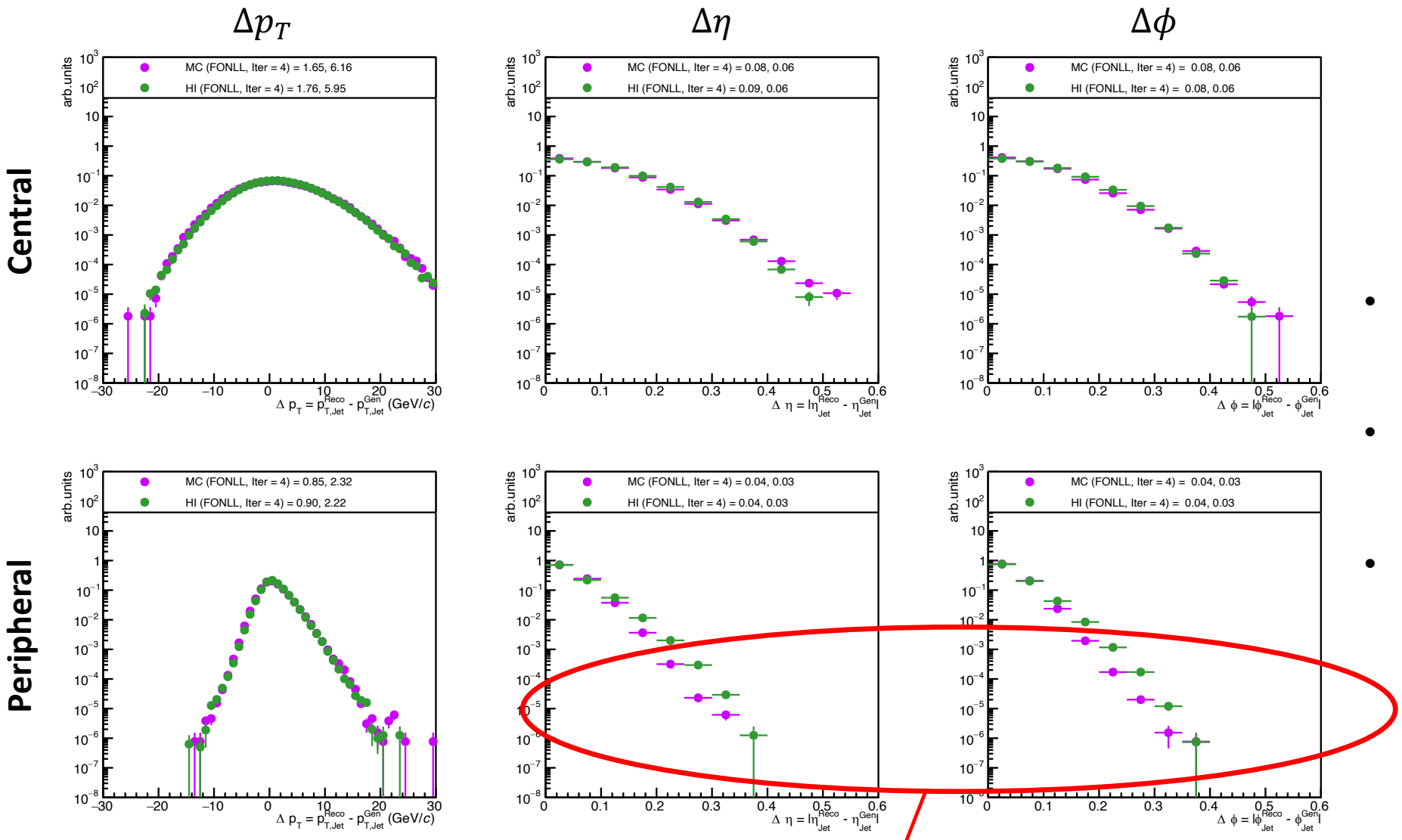
Peripheral





Slight differences in spectra – Good overall agreement

Unpacking the differences between HI Overlay and Single Particle Embedding



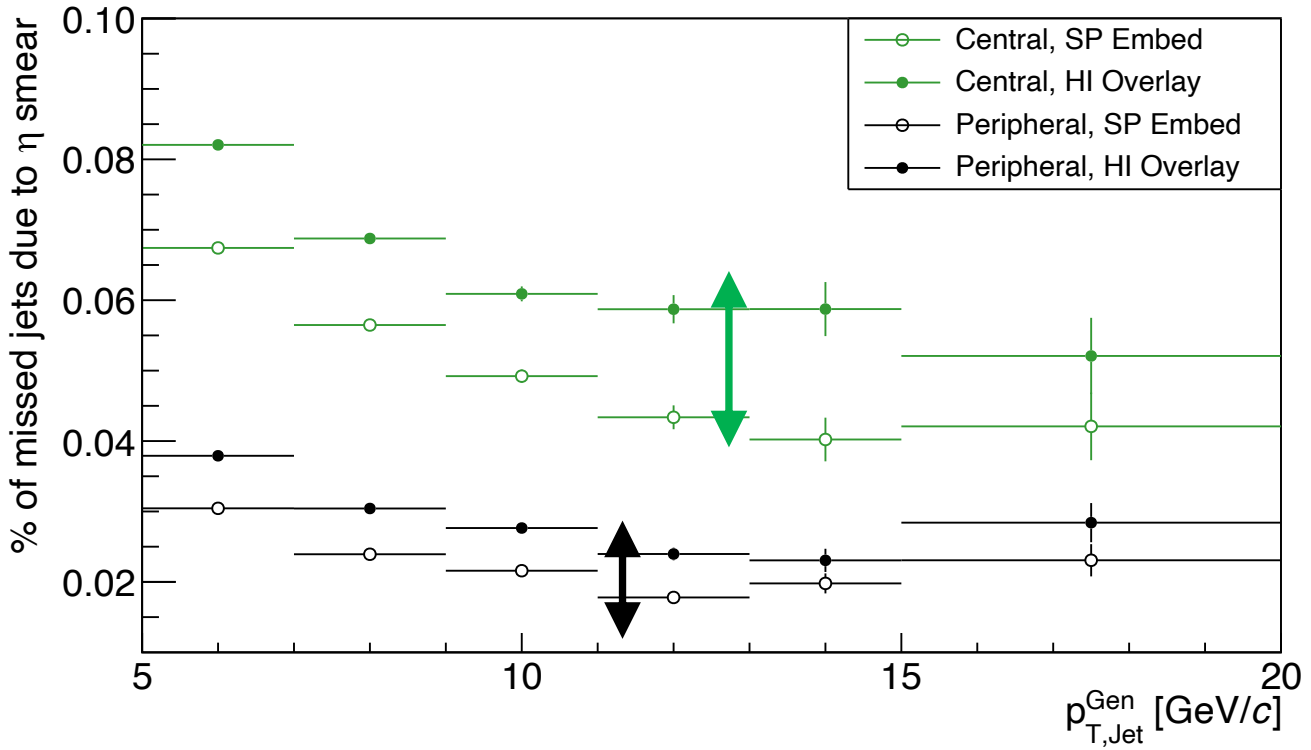
- Detector Level Jets – Particle Level Jets
- p_T smearing captured well by single particle embedding
- For central events, η & ϕ smearing are comparable

Reco Jets in HI Overlay for peripheral events have larger smearing in η, ϕ

Unpacking the differences between HI Overlay and Single Particle Embedding

Example of effect of different η smearing

$$\% \text{ of missed jets due to } \eta = \frac{\text{Gen Jets with Reco } |\eta|>0.6}{\text{Total Gen Jets}}$$



- **~2% difference in central events**
- ~1% difference in peripheral events

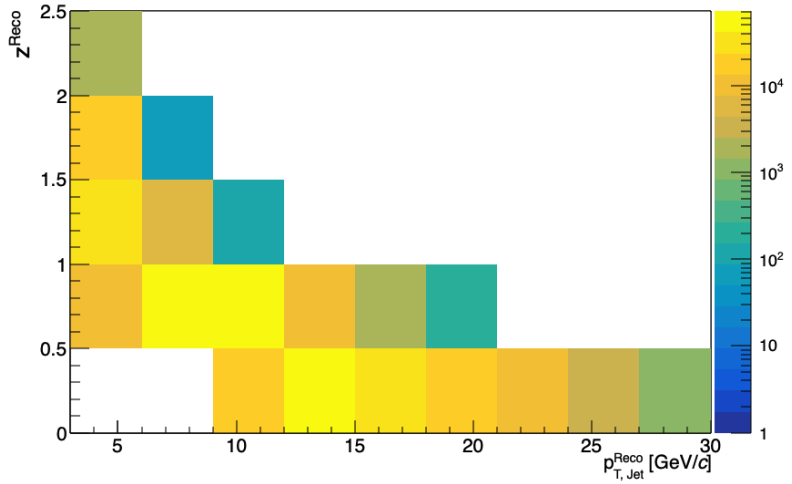
Small differences between HI and Single Particle Embedding can be attributed to the η smear.

HI is more reliable (?)

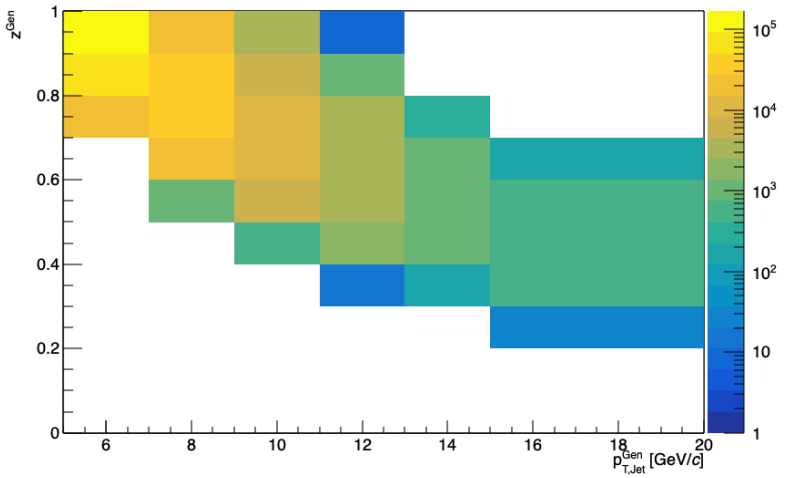
Closure For 2D Unfolding Using HI Overlay

- **PYTHIA 8 Detroit Tune**
- **5 < p_{T,D^0} < 10 GeV/*c***
- 5 < $p_{T,Jet}^{Gen}$ < 20 GeV/c
- 3 < $p_{T,Jet}^{Reco}$ < 30 GeV/c
- $|\eta_{Jet}^{Gen,Reco}| < 0.6$
- **Misses**: Everything outside the acceptance in p_T and η

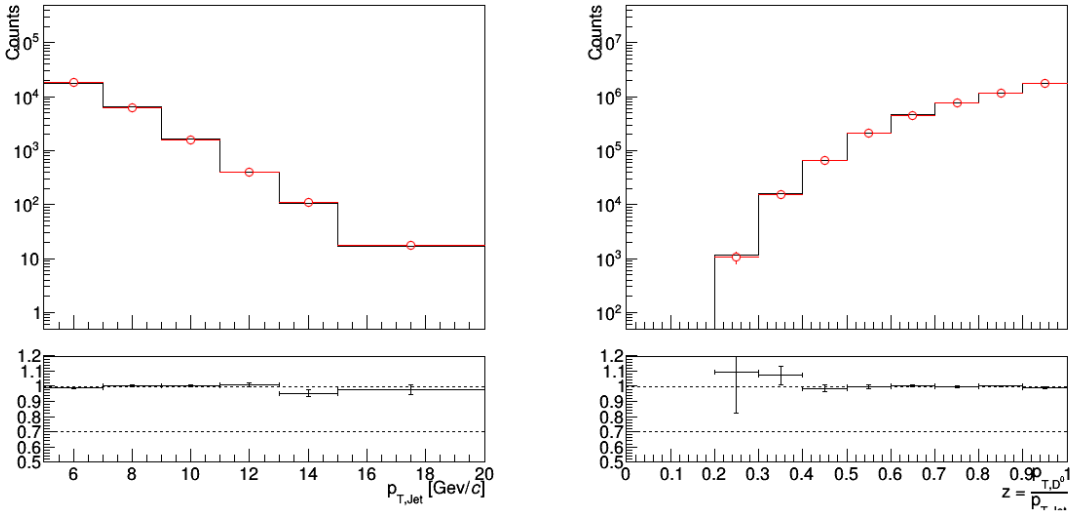
Detector Level



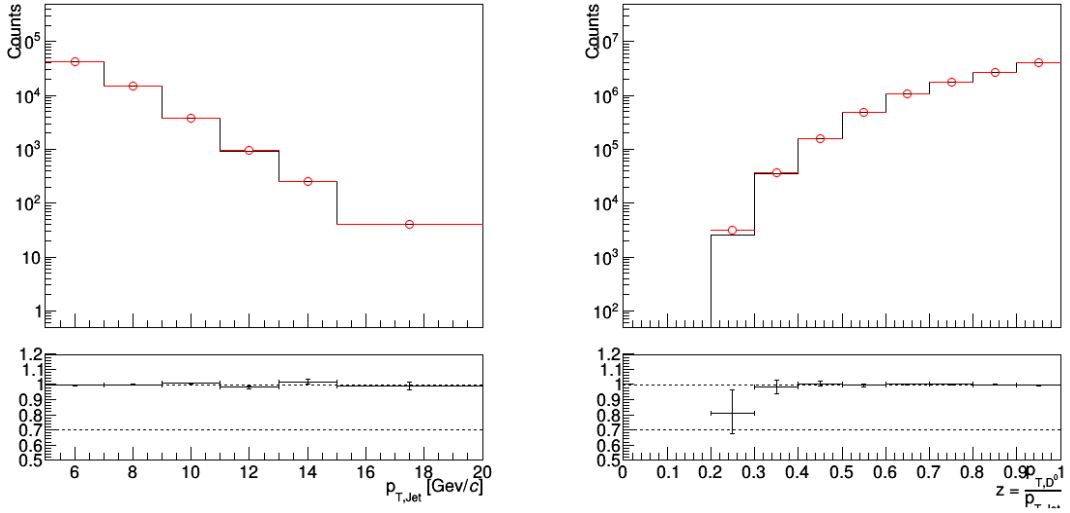
Particle Level



Central



Peripheral



Jet pT and Fragmentation function close simultaneously using HI Overlay

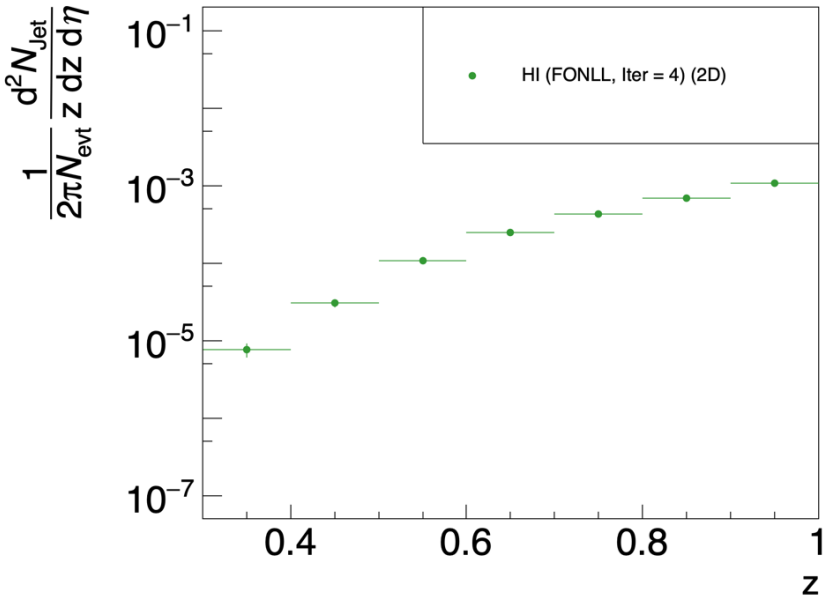
Fragmentation Function From Data – Unfolding using HI

FIRST LOOK

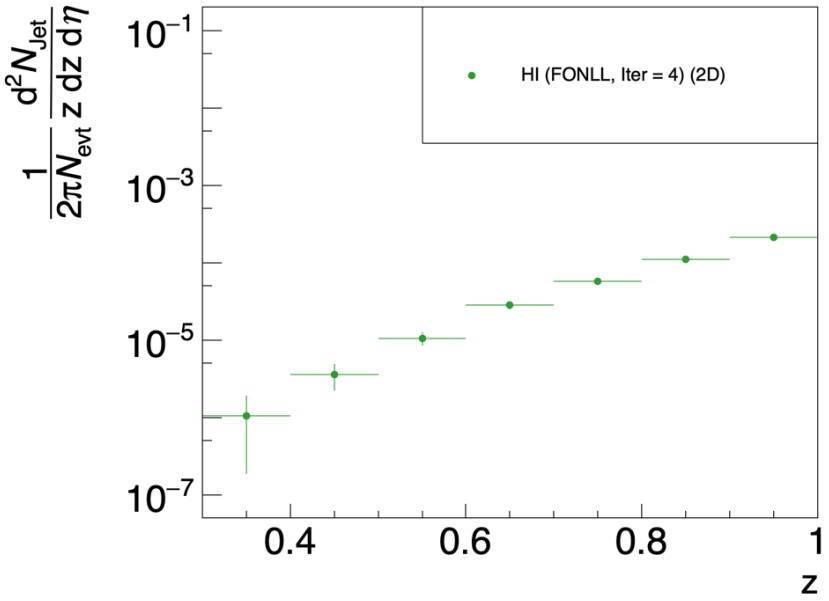
- $3 < p_{T,Jet}^{Uncorrected} < 30$ GeV/c → $5 < p_{T,Jet}^{Corrected} < 20$ GeV/c
- $5 < p_{T,D^0} < 10$ GeV/c

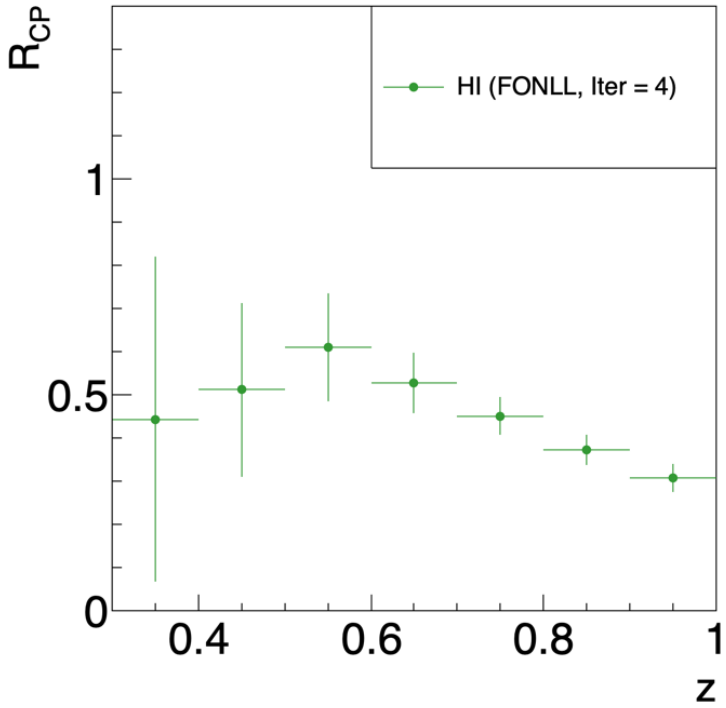
STAR, Au + Au $\sqrt{s_{NN}}$ = 200 GeV

Central



Peripheral





Unfolded Fragmentation With PYTHIA (FONLL) Prior for high pT D^0 in Jets.

Theory suggestions for comparison are welcome.

Summary

- Changed preliminary spectra due to missed track QA cuts in QM results.
- Heavy-Ion Overlay is a viable alternative for unfolding.
- Results from HI and SP Embedding have pretty good agreement.
- HI gives us enough stats to attempt 2D unfolding in Jet pT and z axis.
- First look at the unfolded z spectra and RCP.

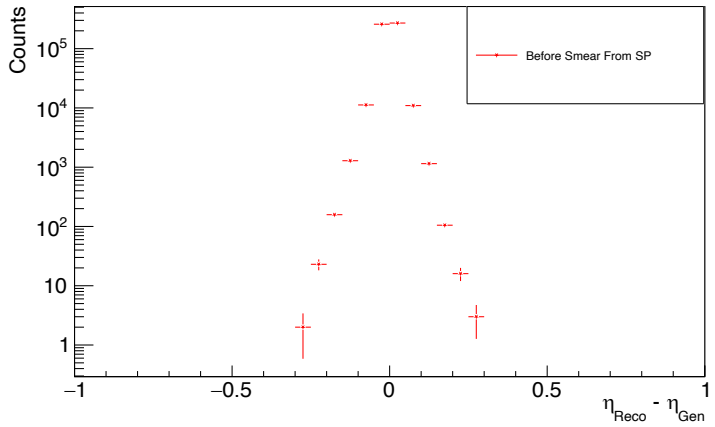
Outlook

- Extending to D0 pT > 1 GeV/c, where PYTHIA prior is possibly incorrect.
- Theory expectations for RCP of fragmentation functions (?)

BACKUP

η smearing steps in simulation

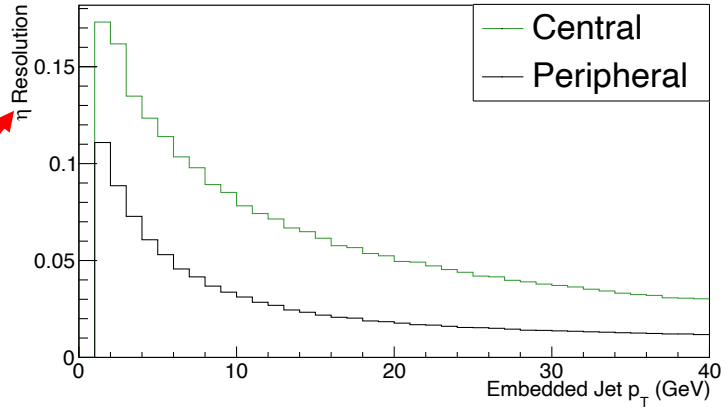
pp Simulation

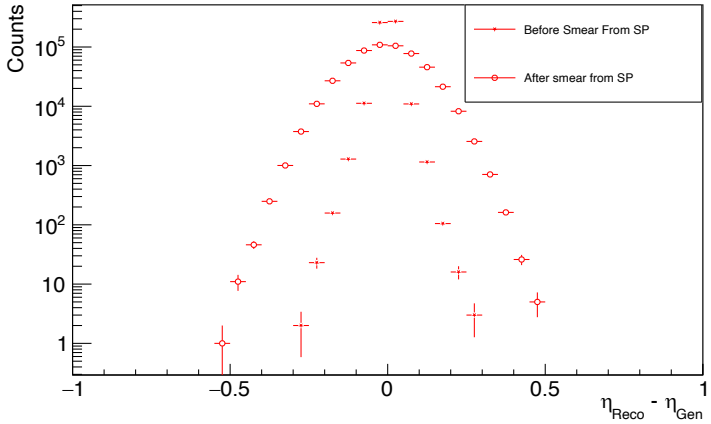


X

Single Particle Embed in AuAu

Width of $\Delta\eta$





Final $\Delta\eta$ in AuAu

Unfolding Data With HI Overlay (Includes the plot from 2D Unfolding of Jet pT)

- $3 < p_{T,Jet}^{Uncorrected} < 30$ GeV/c → $5 < p_{T,Jet}^{Corrected} < 20$ GeV/c
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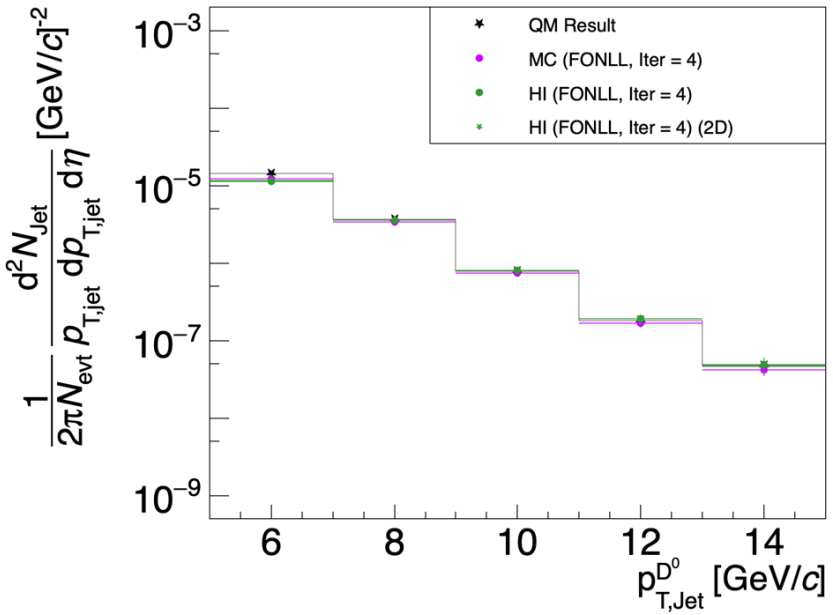
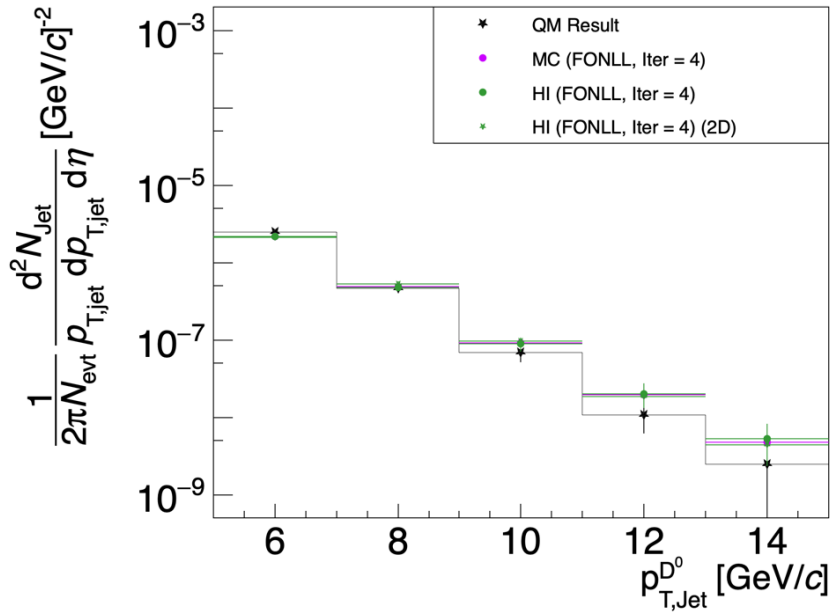
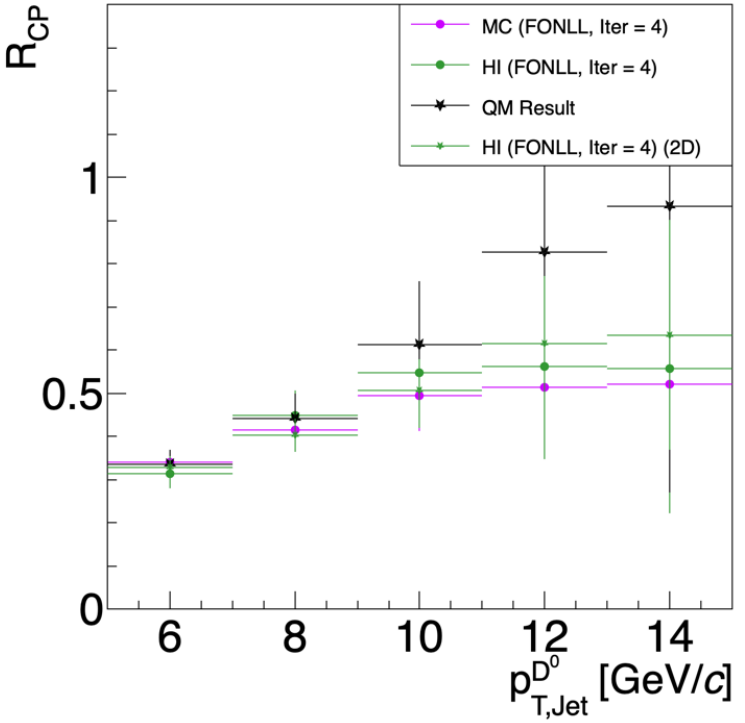
STAR, Au + Au $\sqrt{s_{NN}}$ = 200 GeV

Central



Peripheral





Slight differences in spectra – Good overall agreement

Fragmentation Function From Data – Unfolding using HI (z ∈ [0, 1])

FIRST LOOK

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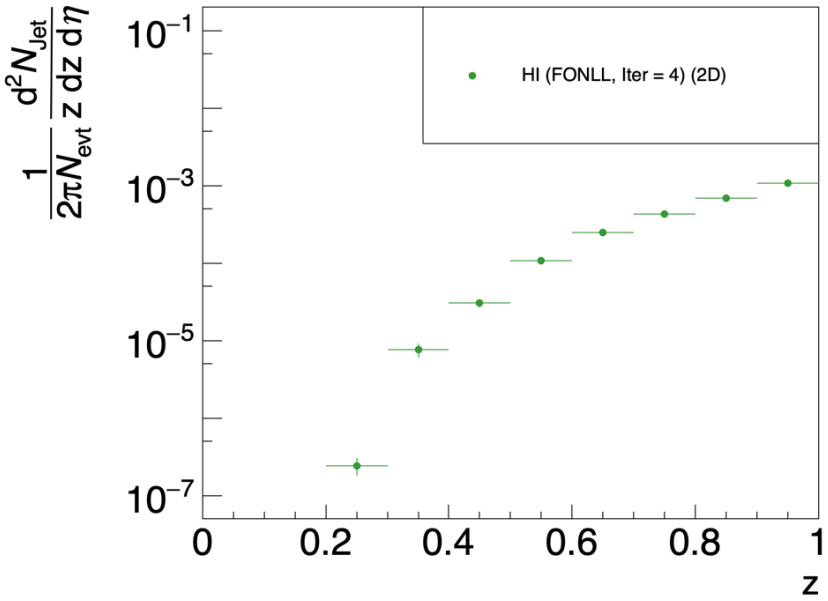
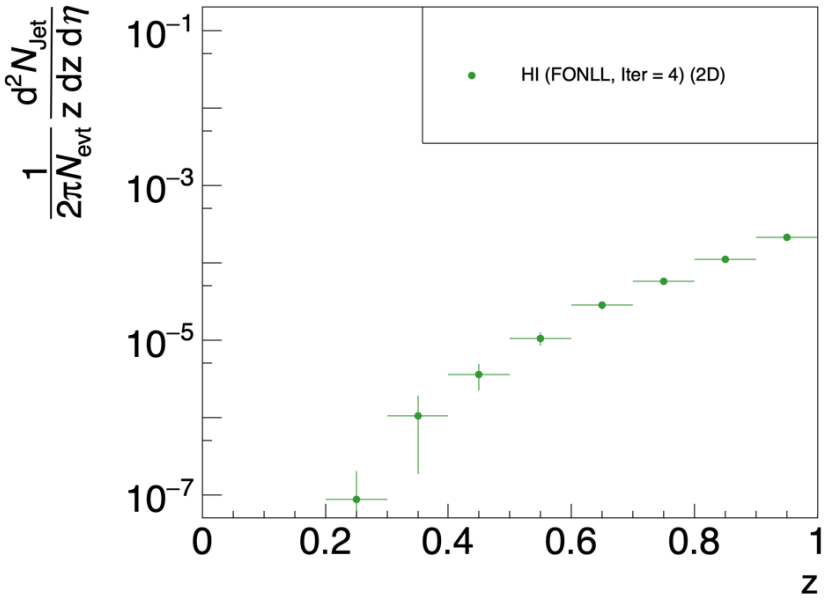
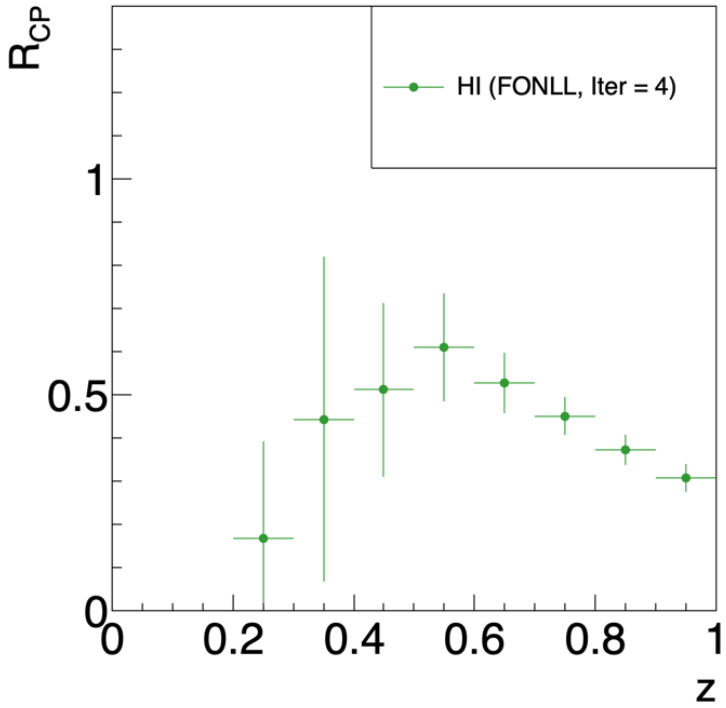


Peripheral





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