Hard Probes, PWG

Event activity correlations and jet measurements in p+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV at STAR

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General Information

- Paper title: Event activity correlations and jet measurements in p+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV at STAR
- PAs: Helen Caines, Joern Putschke, David Stewart, Veronica Verkest
- Targeted Journal: Physics Review C
- Webpage: https://drupal.star.bnl.gov/STAR/blog/djs232/Paper-EA-and-UE-Corrs-High-Q2-Events-pAu-sNN200-GeV-Collisions-STAR
- Analysis Note:
  - Work in progress

Abstract

This letter reports event activities (EA) of $\sqrt{s_{\mathrm{NN}}} = 200\ \mathrm{GeV}$ p+Au collisions selected by high-$\mathrm{E_T}$ triggers measured in the STAR detector at RHIC. The EAs are measured both at high-rapidity in the Au-going direction by experimental luminosity and at mid-rapidity by the track multiplicity of the underlying event. The two regions of EA are mutually positively correlated and are each individually anti-correlated with the $\mathrm{E_T}$ scale of the trigger. This EA-bias predicts EA-dependence of the semi-inclusive jet spectra. Correspondingly, the first semi-inclusive small system jet measurements at RHIC energies are reported; they show significant suppression at high-EA. Finally, measurements of jet acoplanarity and dijet-p_{T} balance are presented. They show no EA dependence and therefore indicate that, within measurement precision, jet-quenching is not observed and does not cause the EA to trigger-p_{T} correlations, or correspondingly the EA to jet spectra correlations.

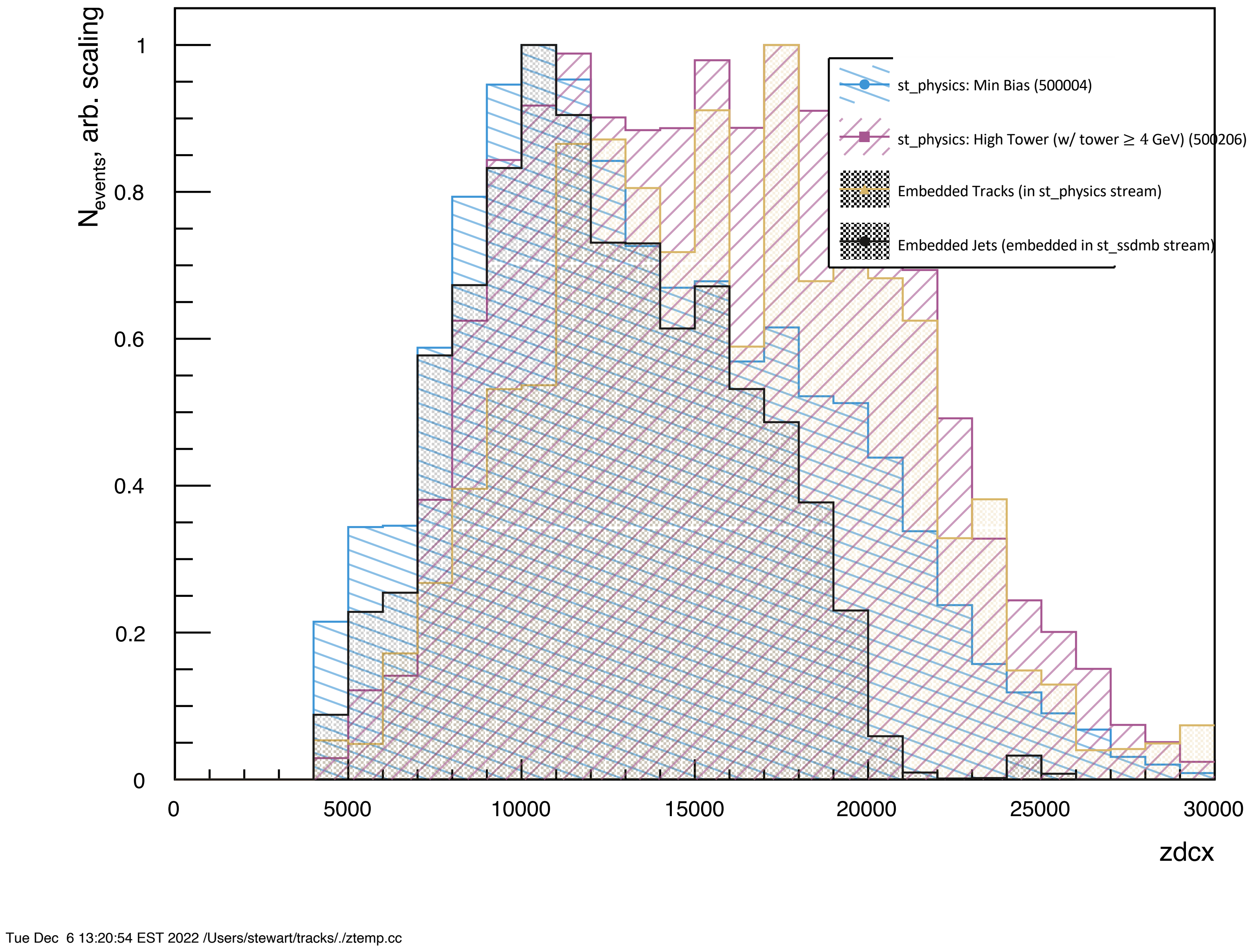
What happened intermediary months:

- GPC Convenors meeting asked about pile-up (PU) correction and ZDCx dependencies

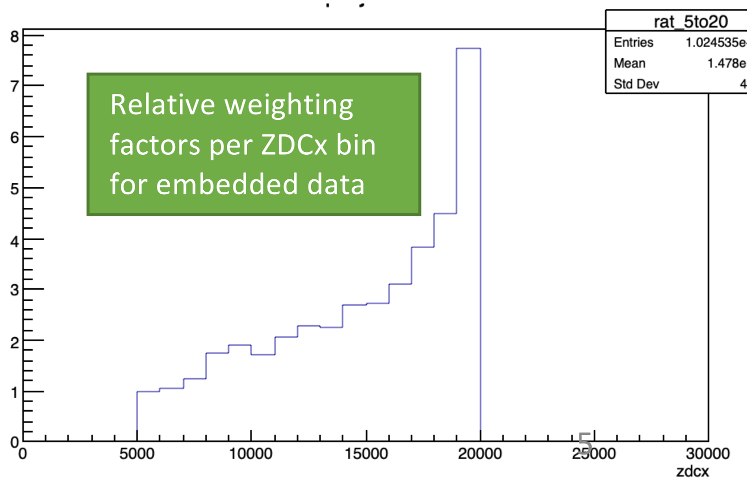
  Consequently we:
  - Found that there is non-insignificant PU, even at the track cut of DCA at 1 cm
  - Have adjusted our calculations to properly account for PU corrections
  - Updated final plots

- The physics conclusions of the final plots have not changed. Pending some work on the UE(lead jet pT) (not shown in this presentation), we will request to proceed with already authorized GPC formation

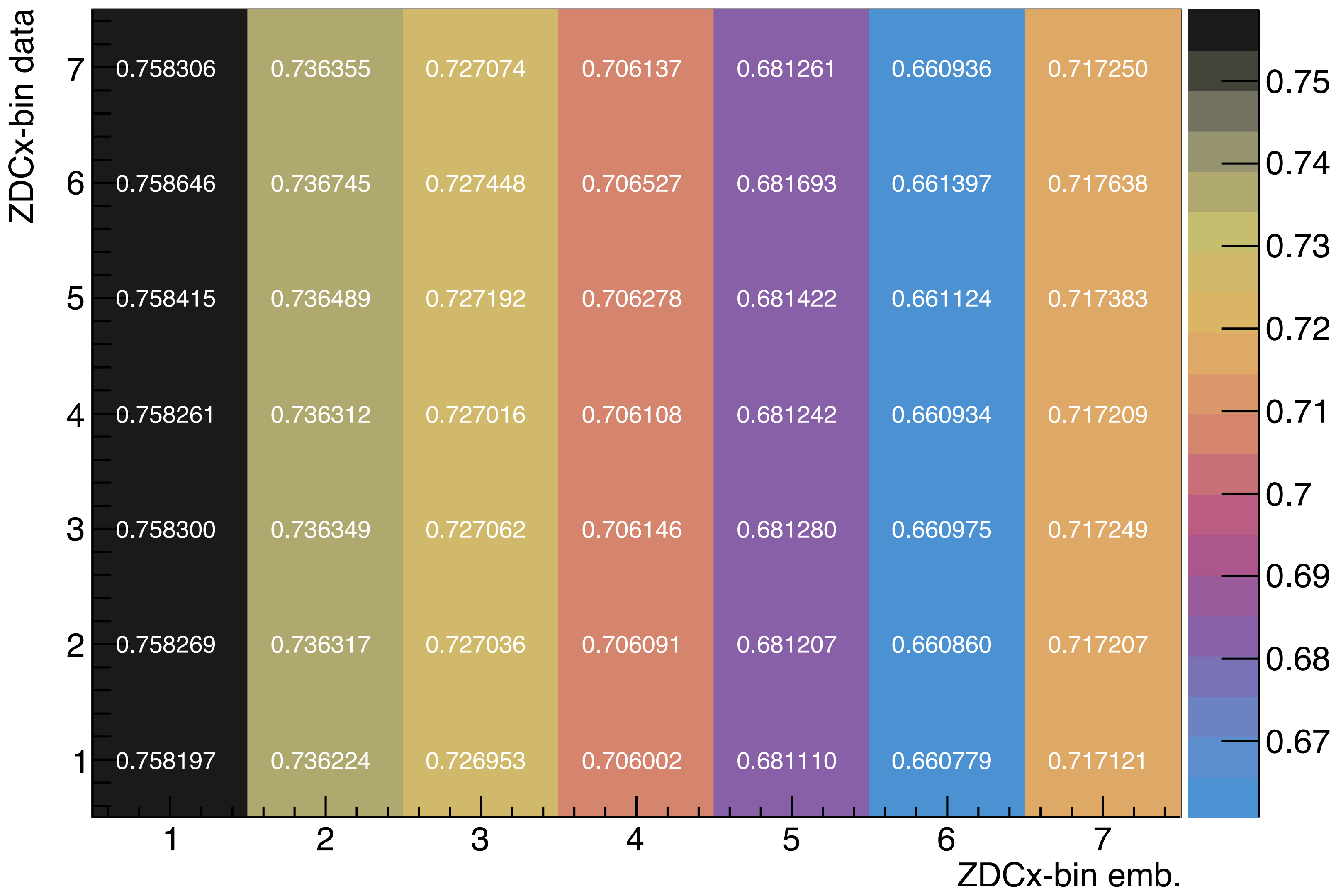
Embedding ZDCx range limited to 500001 triggers



- The track embedding (make into 50004 triggered, st_physics stream events) goes out to about ZDCx=30 kHz
- The jet embedding (make into the st_ssdmb stream) effectively goes out to ZDCx=20 kHz
- As such, we limit our analysis to the currently available ZDCx embedding range of ZDCx≤ 20 kHz. This cuts off the top 20% of ZDCx in the data, but we can show all our physics results with this limitation.
  - Therefore we are proceeding with our GPC process, but would like to have the jet embedding made into st_physics (trigger=500004) events
- When using the embedded jets, the events are re-weighted to match the data ZDCx distribution.



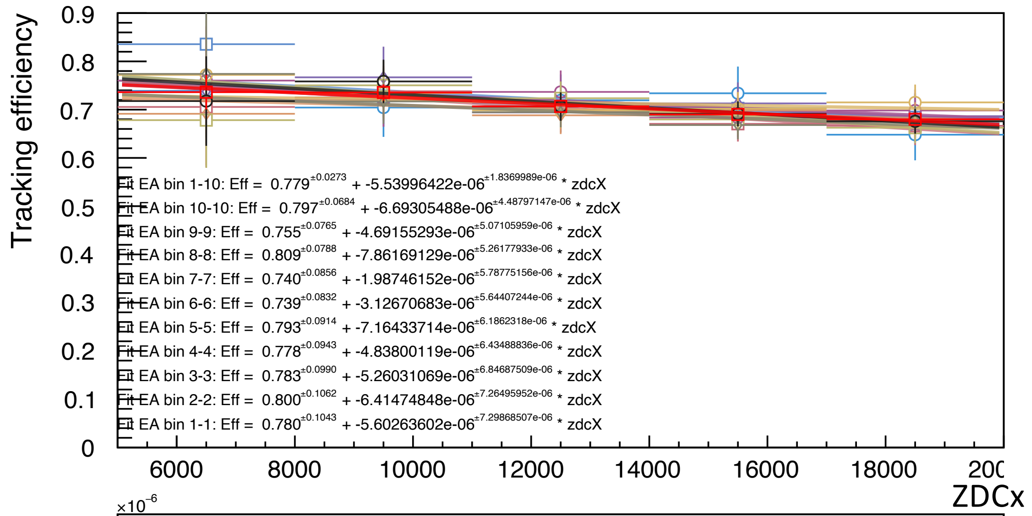
Individual Track Efficiency

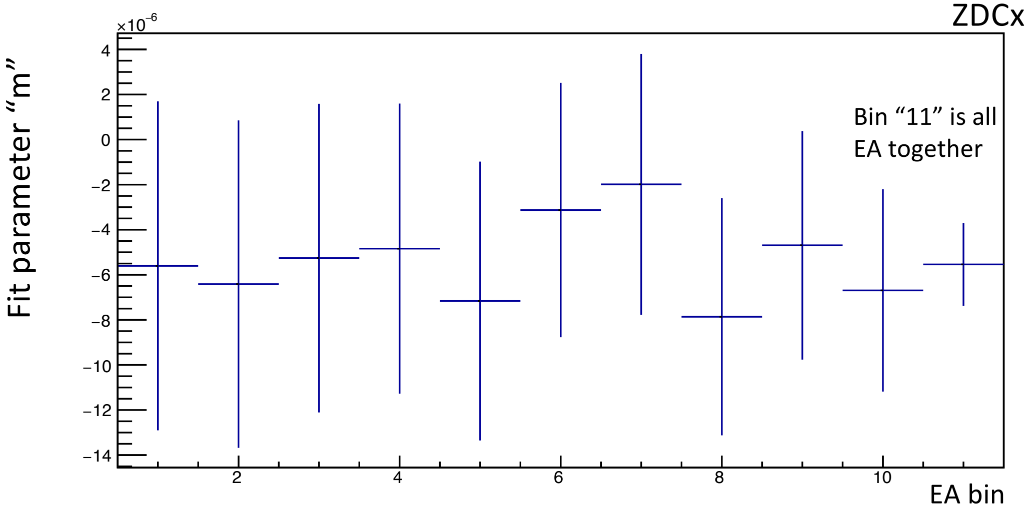


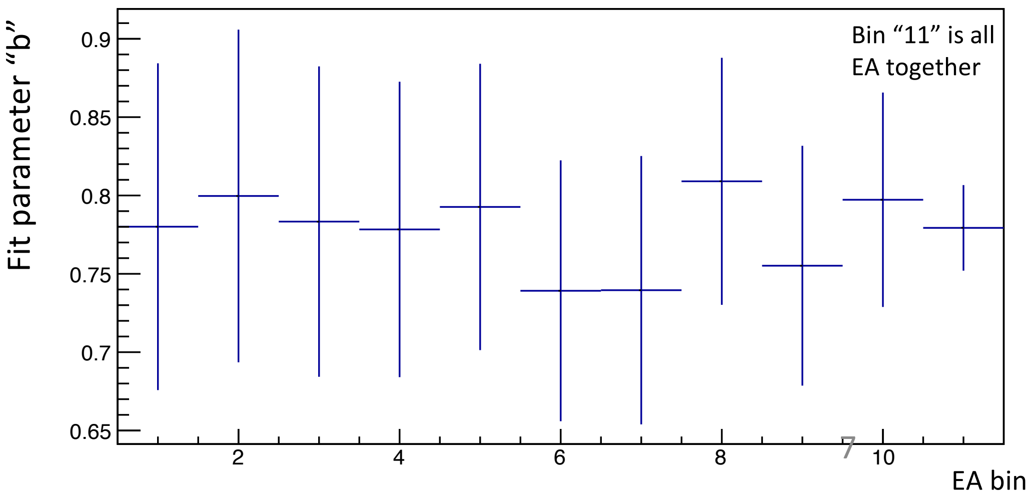
- Track reconstruction efficiency *is* dependent on ZDCx
- Tracks lost from decreasing efficiency are offset by the presence of increasing pile-up (PU) tracks
- Figure to left shows overall MB tracking efficiencies in correction as calculated using different ZDCx of data (y-axis) and ZDCx of embedding (x-axis).
  - ZDCx bins are 4-6kHz, 6-9kHZ … 22-24 kHz
- Only the ZDCx of the embedding matters; this is indicative that the pT distribution of PU closely parallels the pT distribution of primary events

Tracking Efficiency(ZDCx) is EA independent

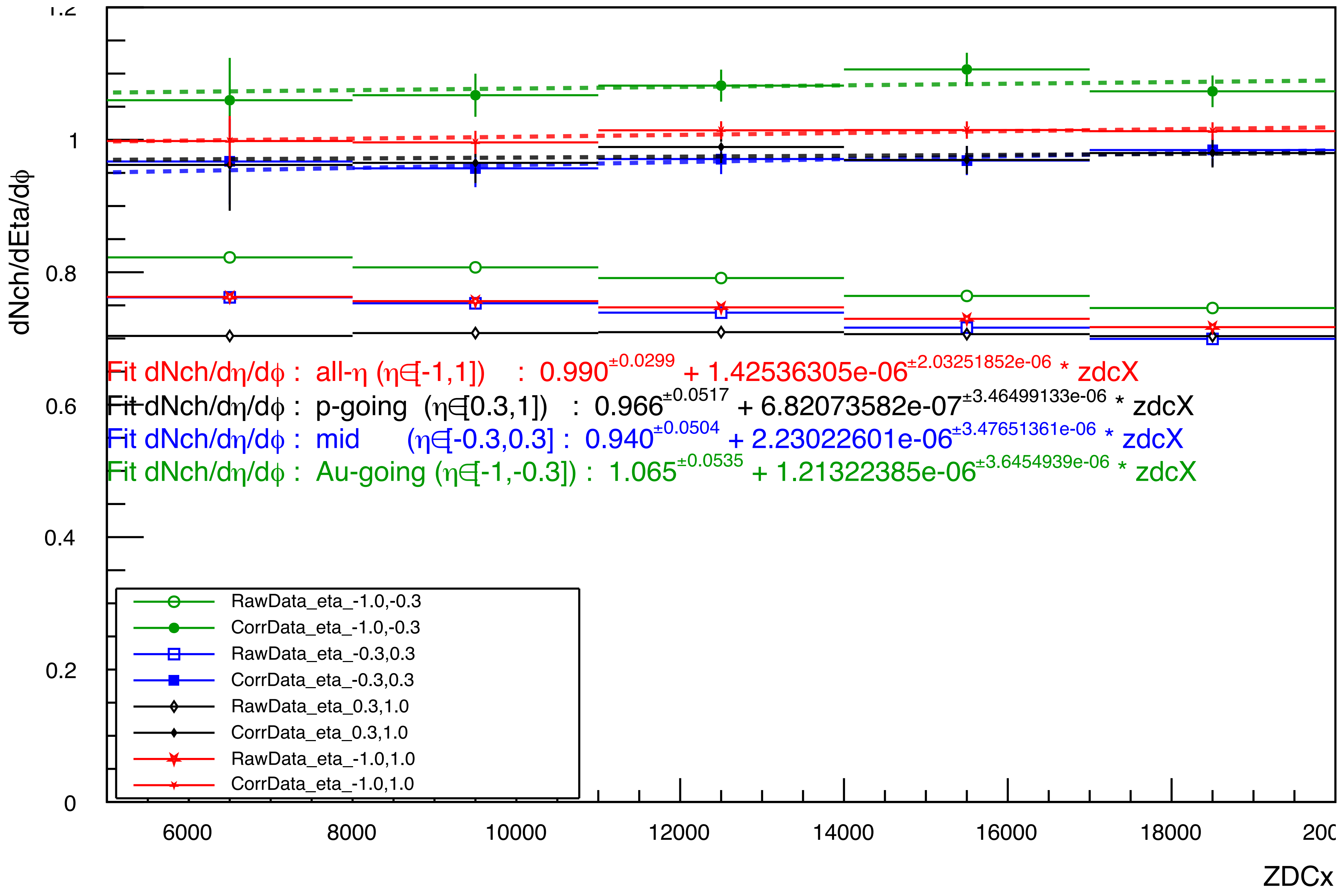
- Fit parameters for ρ_{PU} are independent of $\mathrm{EA_{BBC}}$ bin







PU(ZDCx) parameterization has eta dependence



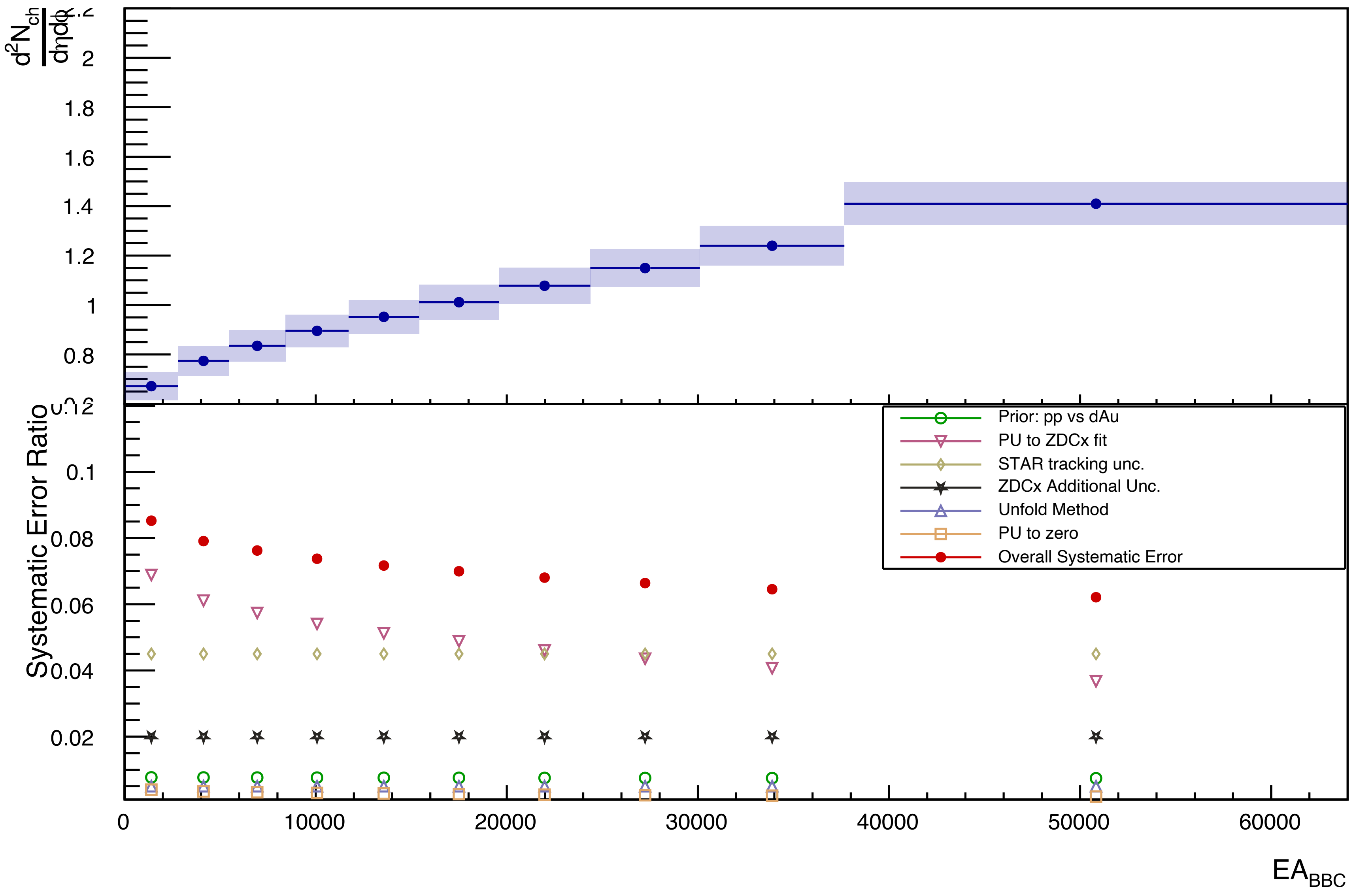
- Calculate the fit

$$\rho_{\mathrm{PU}} = m \, \mathrm{ZDCx}$$

using efficiency corrected tracks (which are a mix of primaries and PU tracks)

Errors on m end up being a principal uncertainty on overall track density measurement

Systematic Errors for MB:



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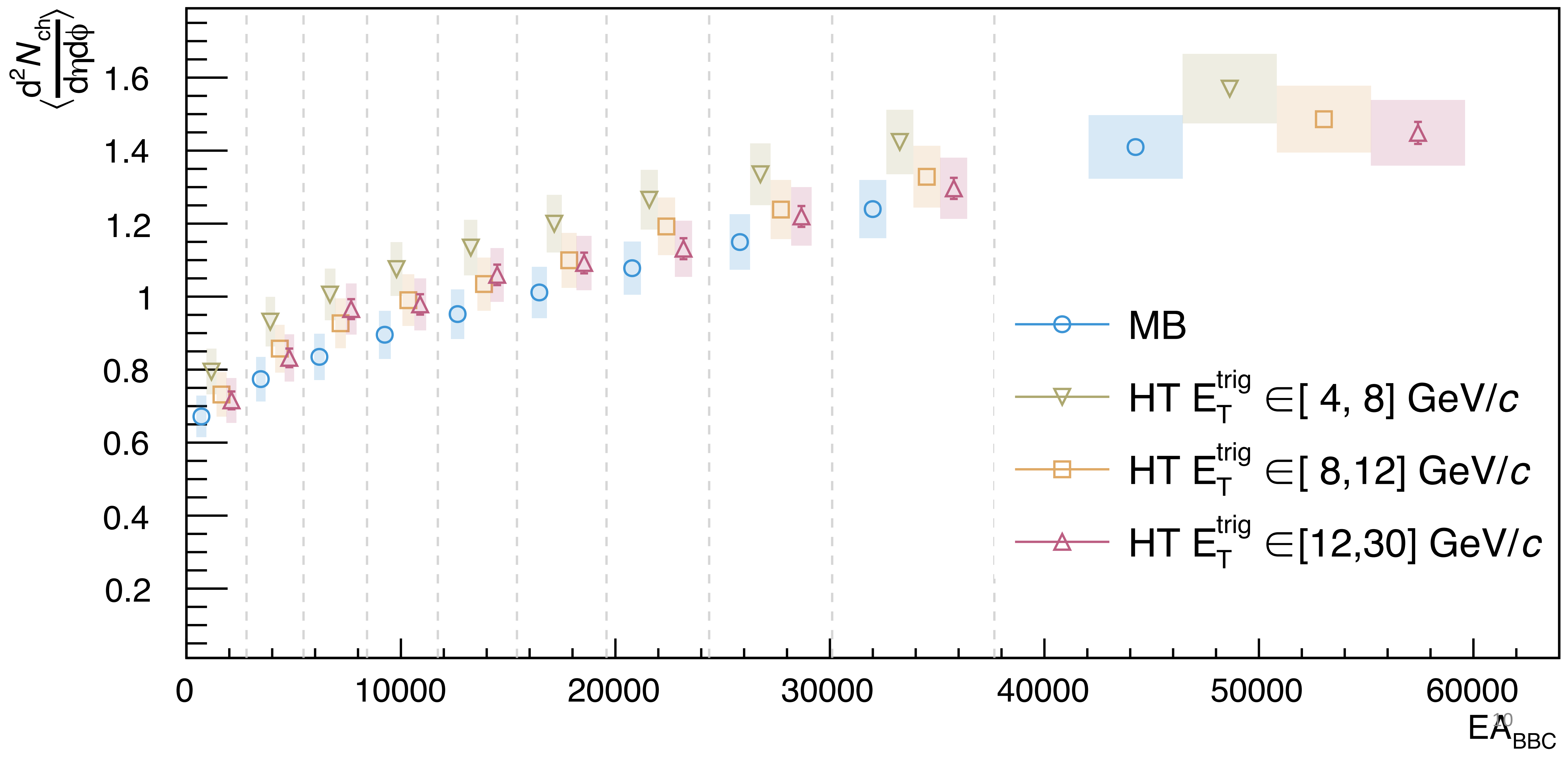
Fully corrected track densities in 10 deciles of EA-BBC



Prior version

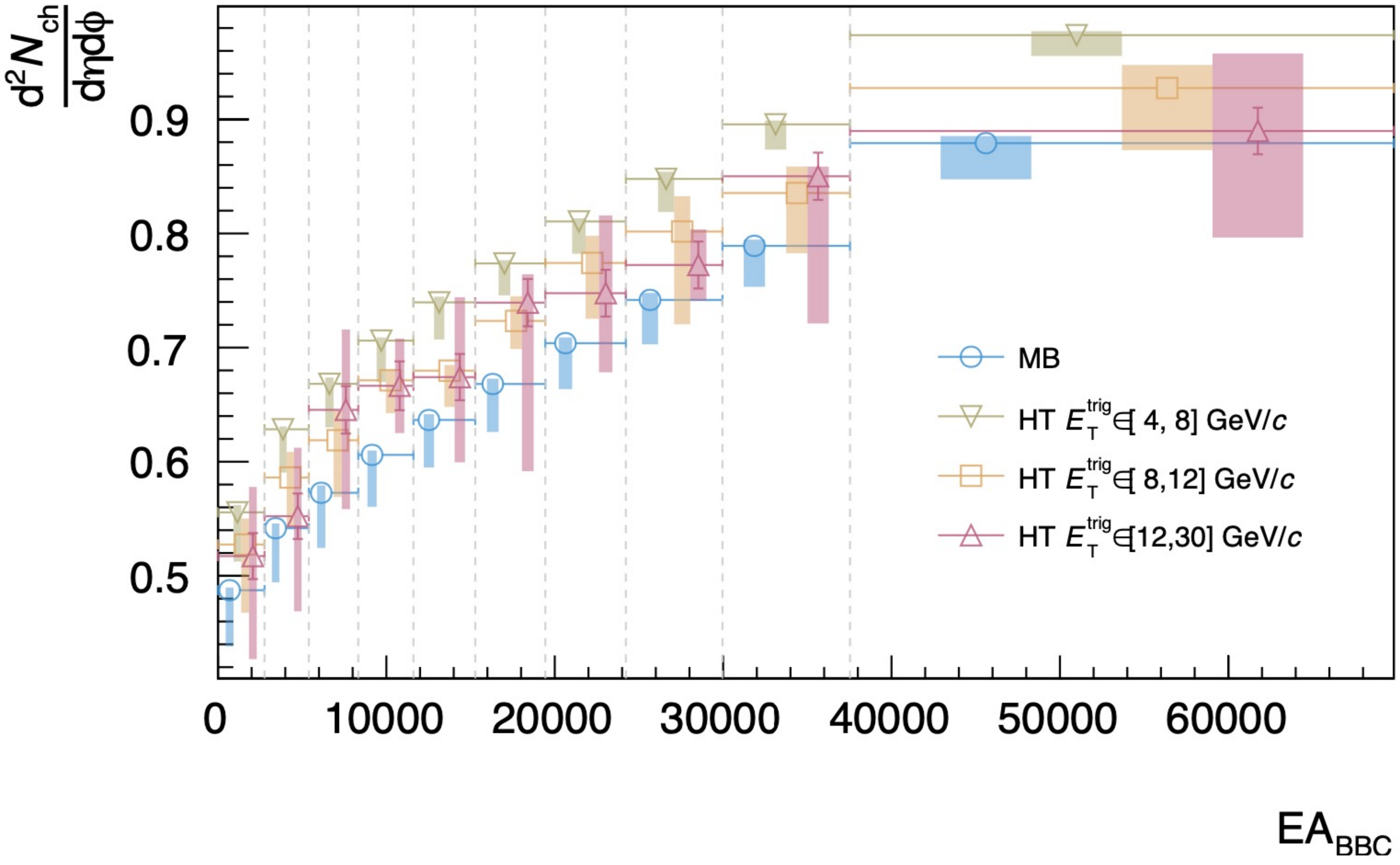
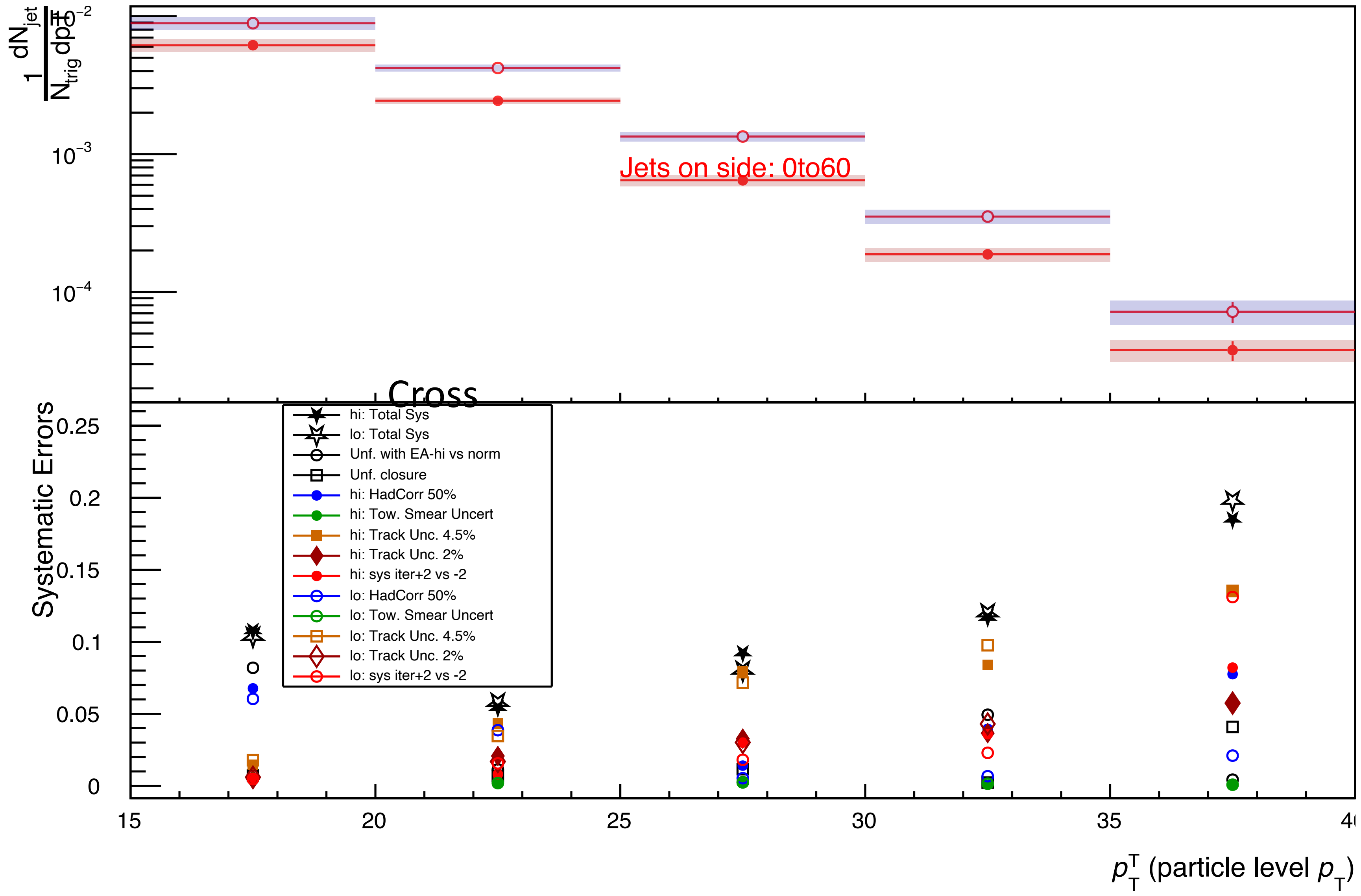


FIG. 2. $\left\langle \frac{d^2N_{ch}}{d\eta d\phi} \right\rangle$ per decile of EA_{BBC}. Bin boundaries of EA_{BBC} selected so that, by construction, 10% of all MB events are contained in each bin. Markers are horizontally offset within each bin for visual convenience.

Systematic Uncertainties 0to60 Spectra



The unfolding is done using response with all EA embedding.

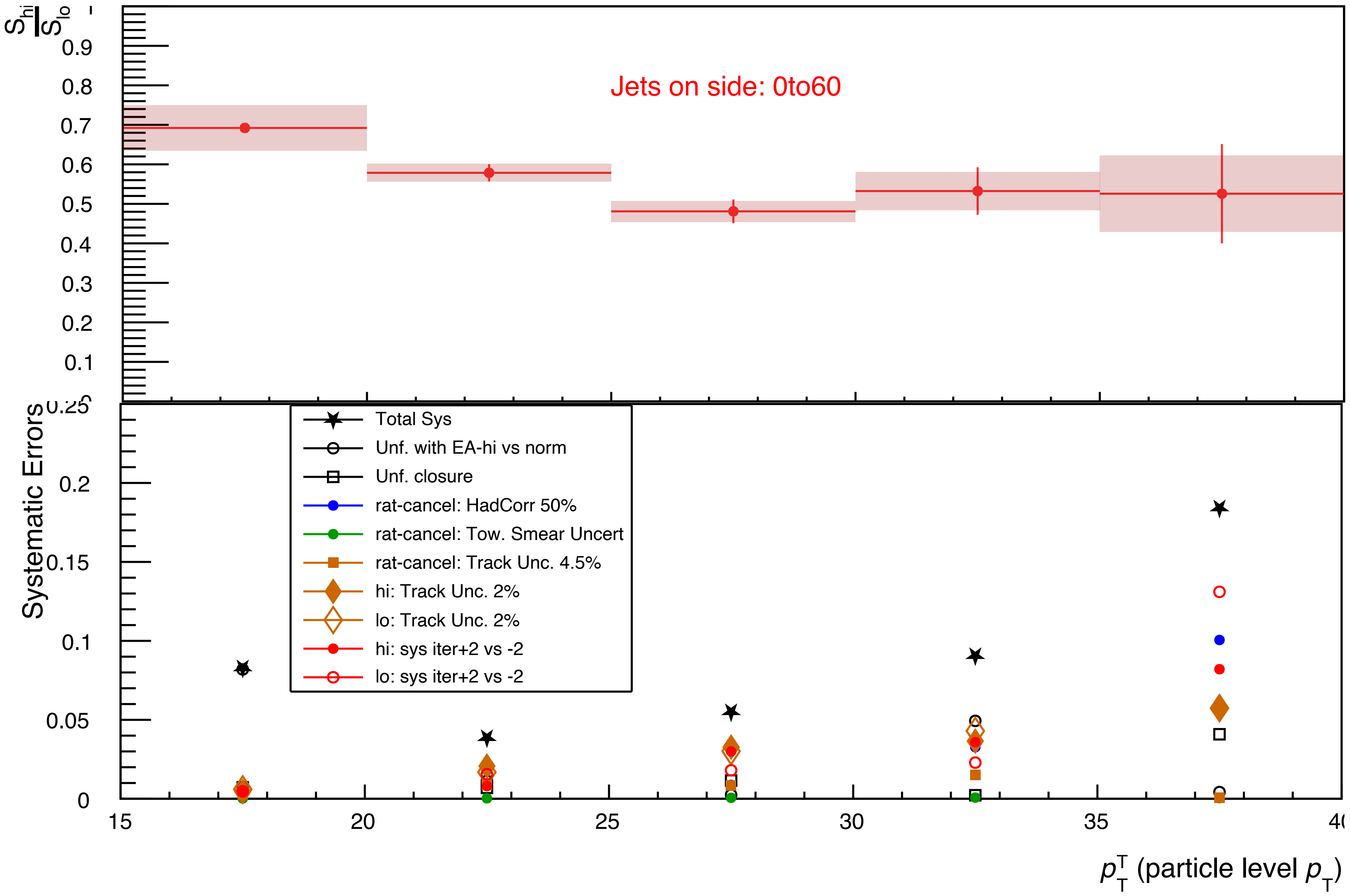
List of systematic unc. used:

- Unfolding high-EA data with high-EA emb vs unfolding high-EA data with all-EA emb
- 50% vs 100% hadronic correction
- Max difference (bin-by-bin) between unfolding with 6 iterations, and unfolding with either 4 or 8 iterations
- Tower Et smearing (3.8% Gaussian smearing)
- 4.5% Track pT unc.
- 2% additional track pT unc.

Closure is shown in bottom but not included in the total sys. error

Fri Jan 13 12:08:31 EST 2023 /Users/stewart/pAu_AN/semijets_semitrig/./draw_semispec.cc 0to60

Systematic Uncertainties Ratio: 0to60 spectra



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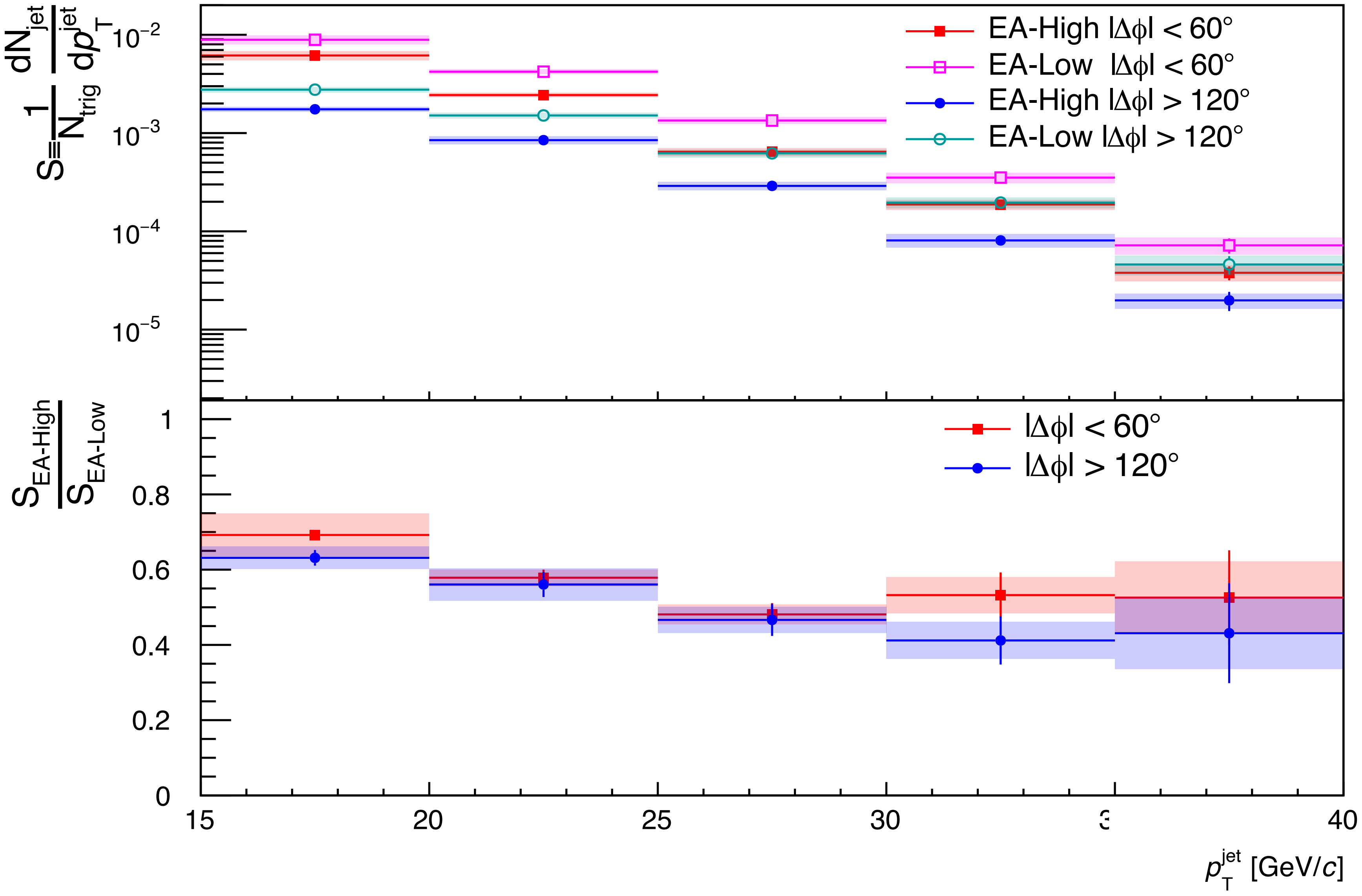
- Not ratio canceling (added directly into RSS):
  - Unfolding high-EA data with high-EA emb vs unfolding high-EA data with all-EA emb (carried directly into RSS)
  - 2% tracking error on high-EA
  - 2% tracking error on low-EA
  - Bin max of sys. iterations on high-EA and sys. Iterations on low-EA
- ”Ratio canceling” (the ratio spectra using the alternative inputs are generated and *then* the difference from the nominal ratio is added in RSS)
  - H.C. 50% -- difference in H.C. Ratio to nominal ratio
  - Tow Smearing
  - Track Unc. 4.5%

Paper figure, semi inclusive jet EA ratio figure



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Prior version

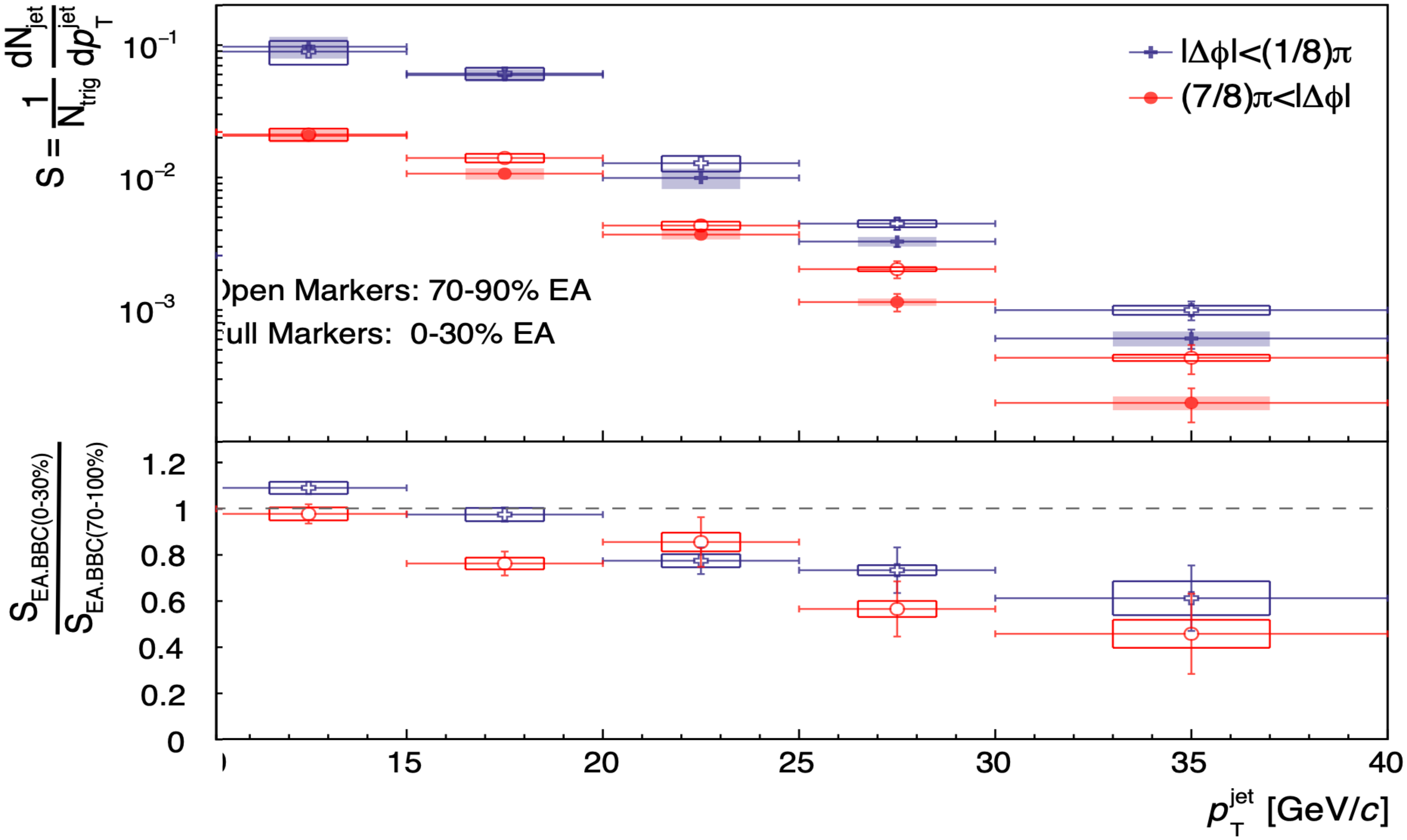


FIG. 5. Top panel: Semi-inclusive jet spectra (S) for $R = 0.4$ full jets per BEMC trigger at $E_T^{trig} \geq 8\,\mathrm{GeV}$ for trigger- and recoil-side bins. Spectra shown binned at high and low $\mathrm{EA_{BBC}}$. Bottom panel: ratio of semi-inclusive jet spectra at $\mathrm{EA_{BBC}^{High}}$ to $\mathrm{EA_{BBC}^{Low}}$.

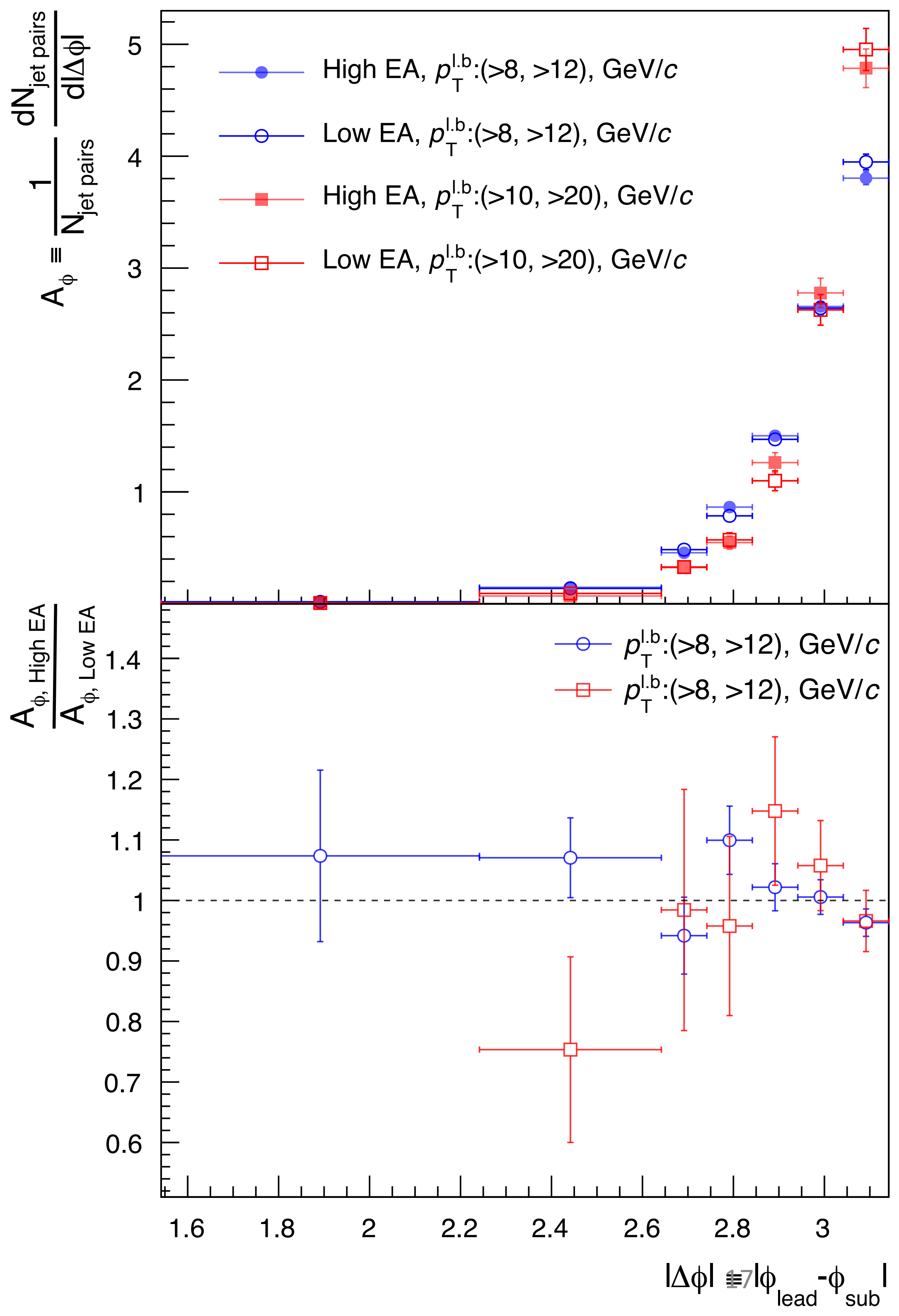
Comparison of dijet $\mathrm{A_J}$ and A_ϕ in ratio

- Measurements: Dijet pairs with highest two p_T jets with minimum p_T values of (a) 8 and 12 GeV/*c* and (b) 10 and 12 GeV/*c*. See if there is a difference in high and low EA events.
  - Measure the distribution of azimuth between them: $|\phi_\mathrm{lead} - \phi\_\mathrm{sub}|$
  - Measure the dijet p_T balance: $\frac{p_\mathrm{T,lead} - p_\mathrm{T,sub}}{p_\mathrm{T,lead} + p_\mathrm{T,sub}}$
- Although the JES and JER are not distinguishably different in high and low EA events, the increased background in high-EA events could have a change in the triggering effect of the dijet selection criteria [(a) and (b) above)
- Therefore, increase the detector-level particle background in low-EA events to match high-EA events prior to clustering jets in order to compare A_J and $\Delta\phi$ in EA ratios

$|\phi_{\text{lead}} - \phi_{\text{sub}}|$ (A_ϕ)

Opening angle distribution between dijets, binned (in smallest bin) by 0.4 radians. The limit of directly recoiling is π, as shown.

There is not a notable modification of A_ϕ when binned by EA



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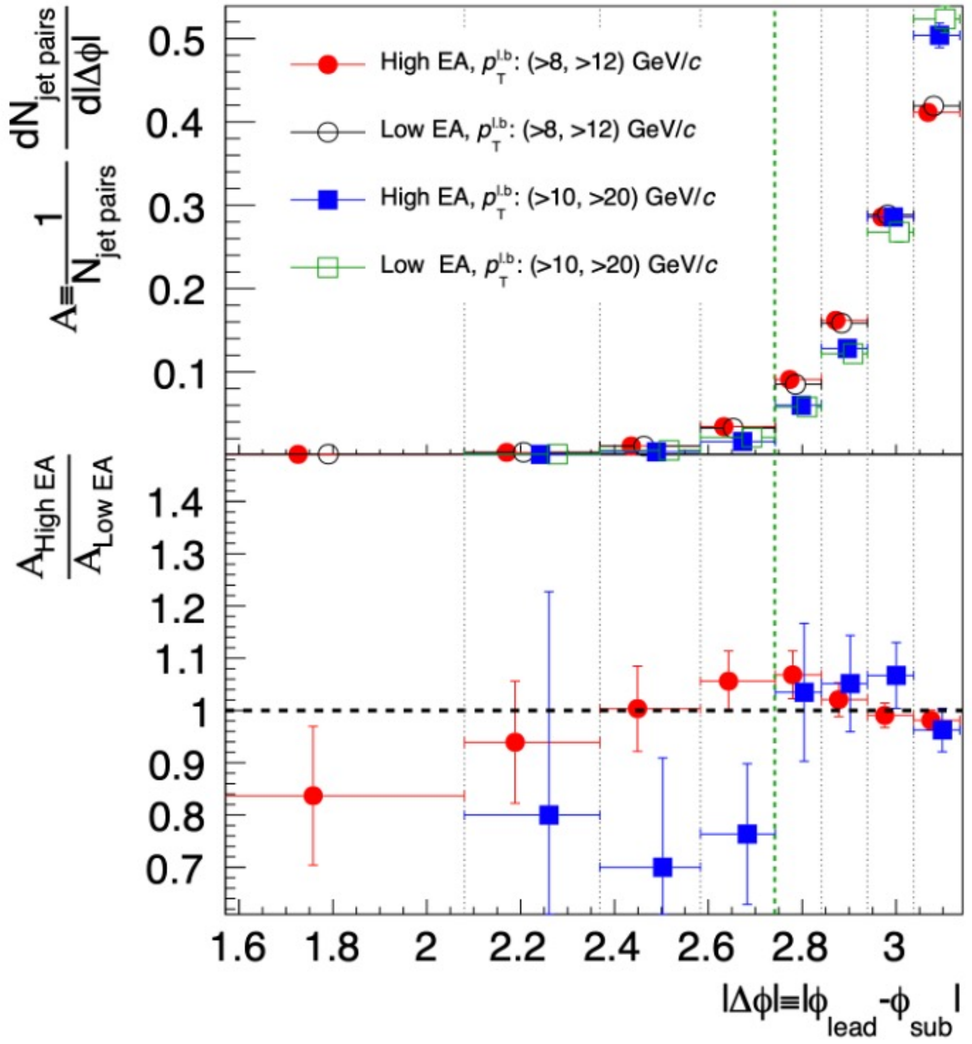
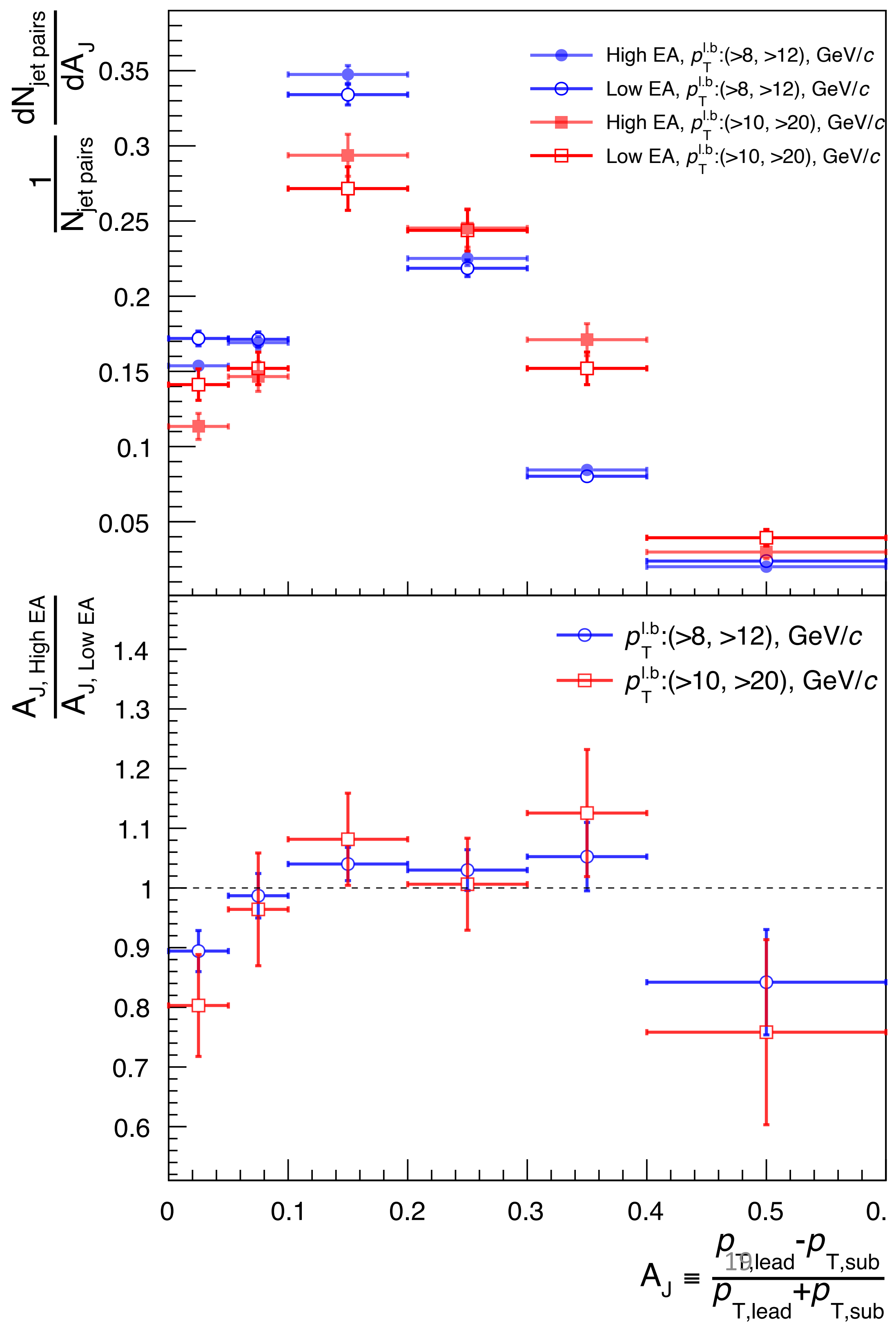


FIG. 6. Top panel: the distribution of the relative absolute azimuthal angle between the two highest p_T jets for high and low EA_{BBC} events. Cuts on the lower bounds of $p_{T,jet}^{lead}$ and $p_{T,jet}^{sub}$ are indicated in captions. EA_{BBC}^{Low} jets have been clustered with additional particles to match the UE with the UE in EA_{BBC}^{High} events. Bottom panel: Ratios of shapes at EA_{BBC}^{High} to EA_{BBC}^{Low}. In both top and bottom panels, markers are offset along the horizontal axis within each bin for convenience of viewing. All jets are detector-level jets.

$$\frac{p_{\mathrm{T,lead}} - p_{\mathrm{T,sub}}}{p_{\mathrm{T,lead}} + p_{\mathrm{T,sub}}} \qquad (\mathrm{A_J})$$

Dijet p_{T} balance in dijets.

There is not a notable modification of $\mathrm{A_J}$ when binned by EA.



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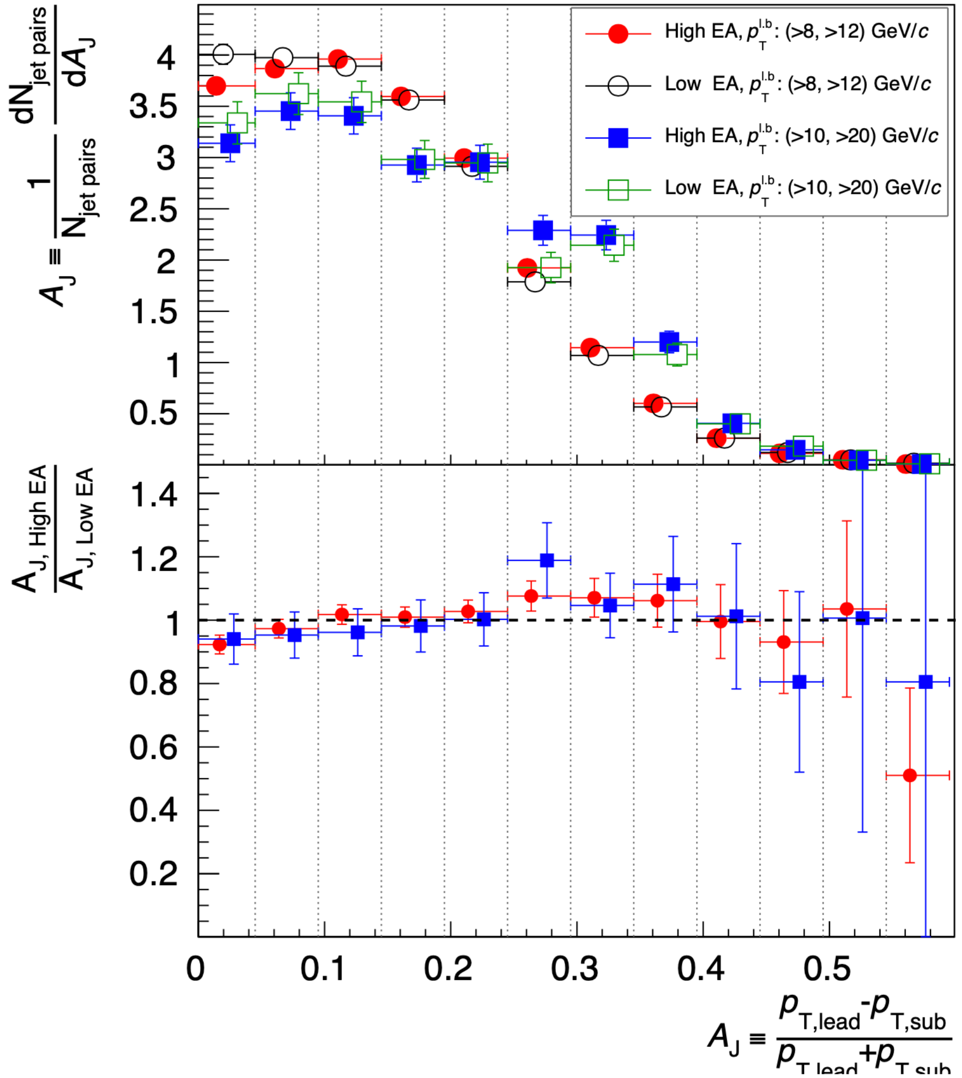


FIG. 7. Top panel: the distribution of dijet p_T balance A_J for high and low EA_{BBC} events. Cuts on the lower bounds of $p_{T,jet}^{lead}$ and $p_{T,jet}^{sub}$ are indicated in captions. EA_{BBC}^{Low} jets have been clustered with additional particles to match the UE with the UE in EA_{BBC}^{High} events. Bottom panel: Ratios of shapes at EA_{BBC}^{High} to EA_{BBC}^{Low}. In both top and bottom panels, markers are offset along the horizontal axis within each bin for convenience of viewing. All jets are detector-level jets.

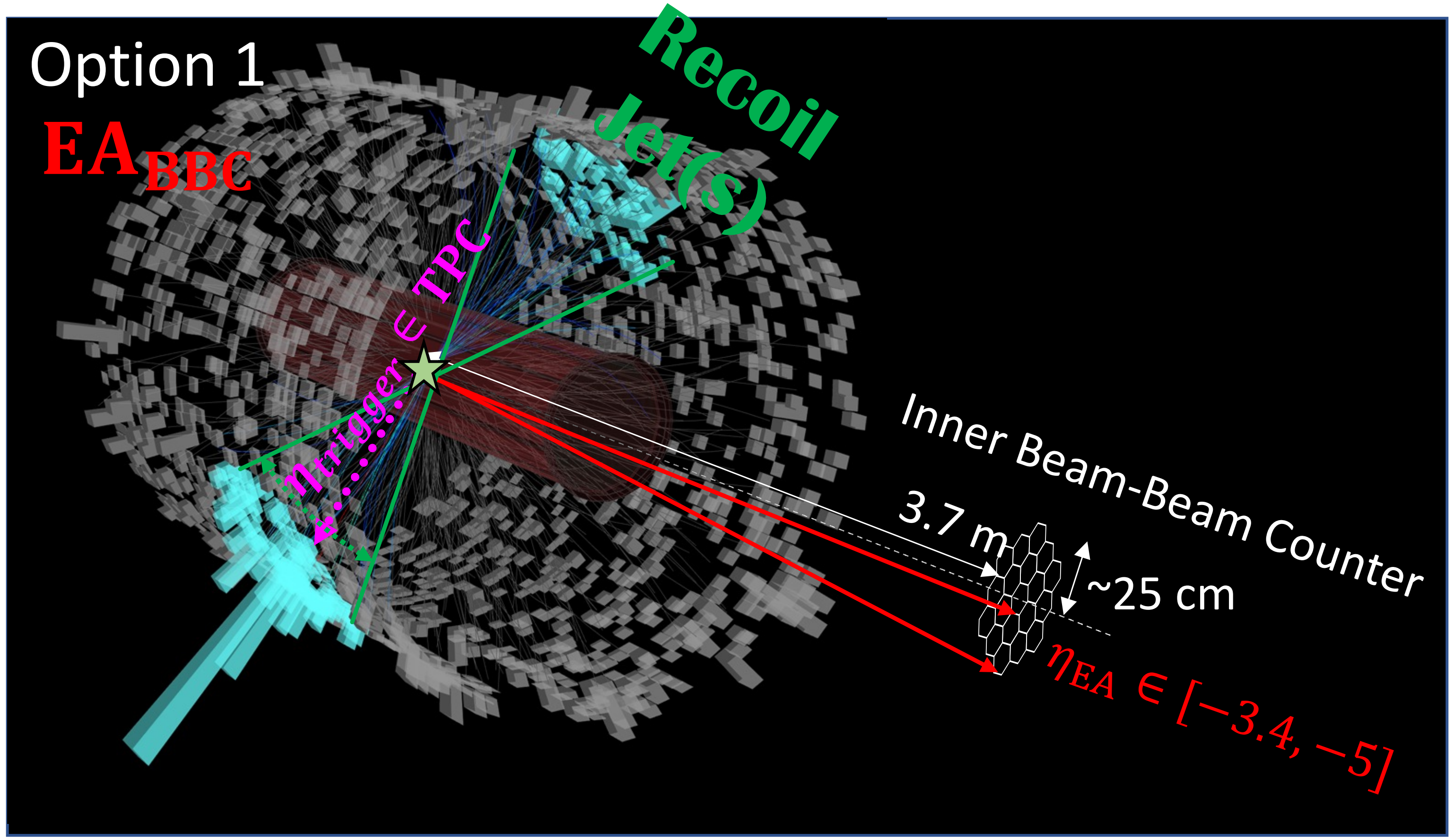
Conclusions

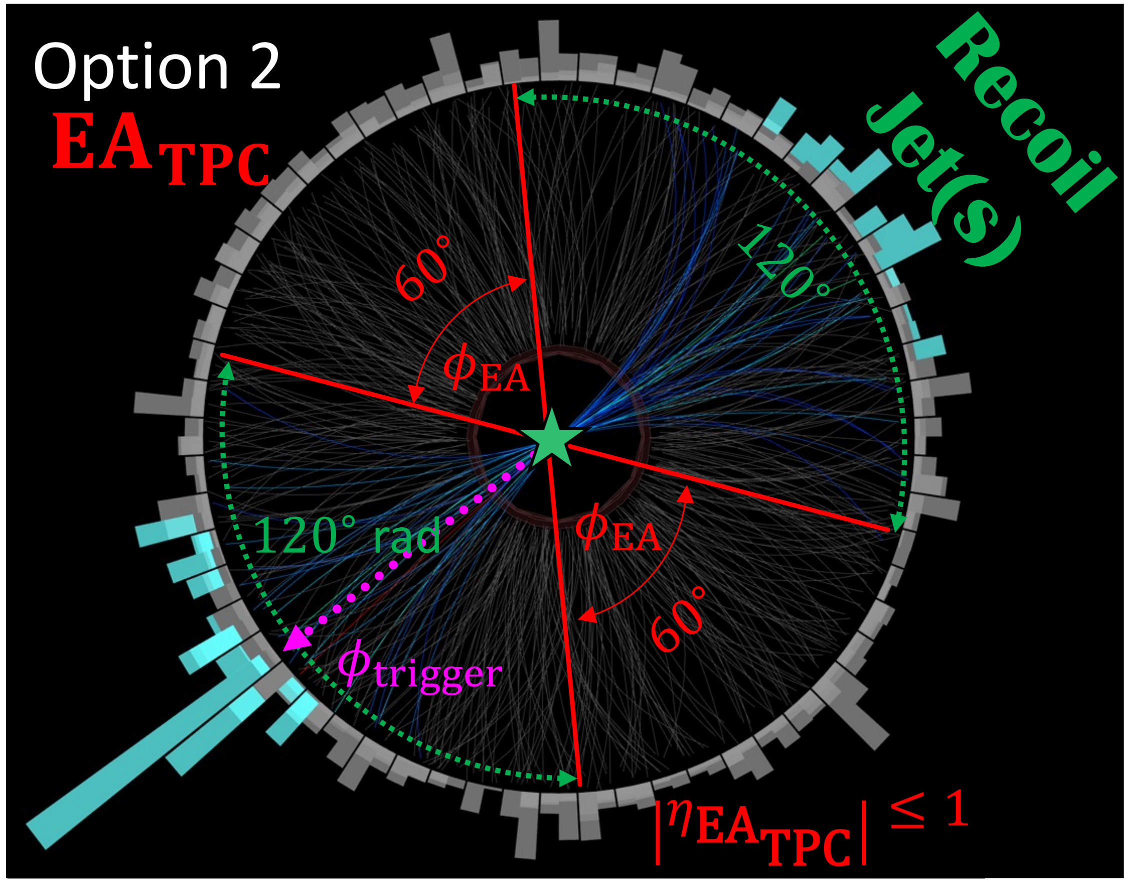
- No change in physics message
- Finalizing paper draft (ASAP)
- Will ask for GPC formation

Backup Slides

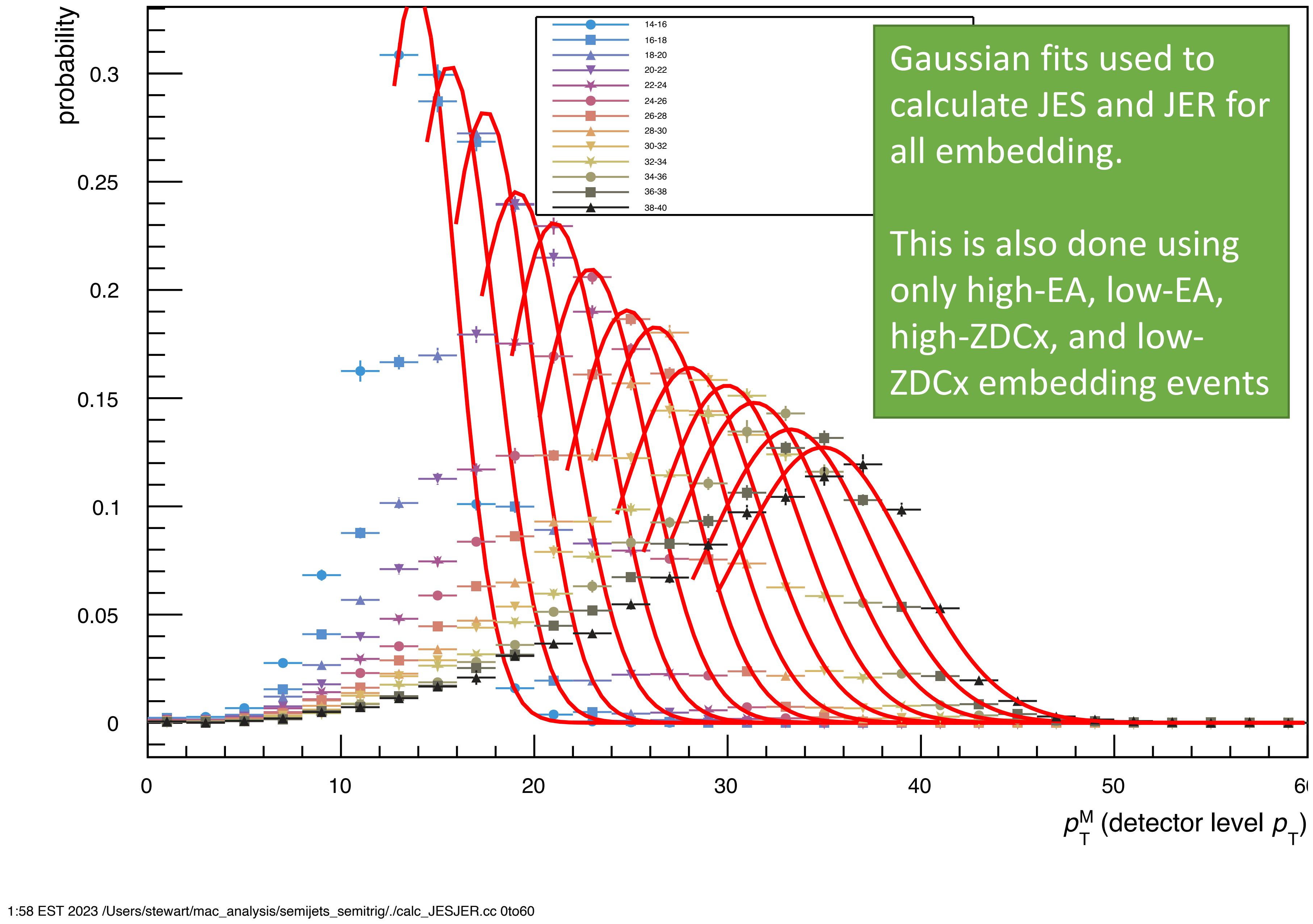
Composition of measurements:

- Triggers (BEMC towers)
- Jets from TPC tracks and BEMC towers
- **EA** separated from jets in η-ϕ phase space to avoid autocorrelation



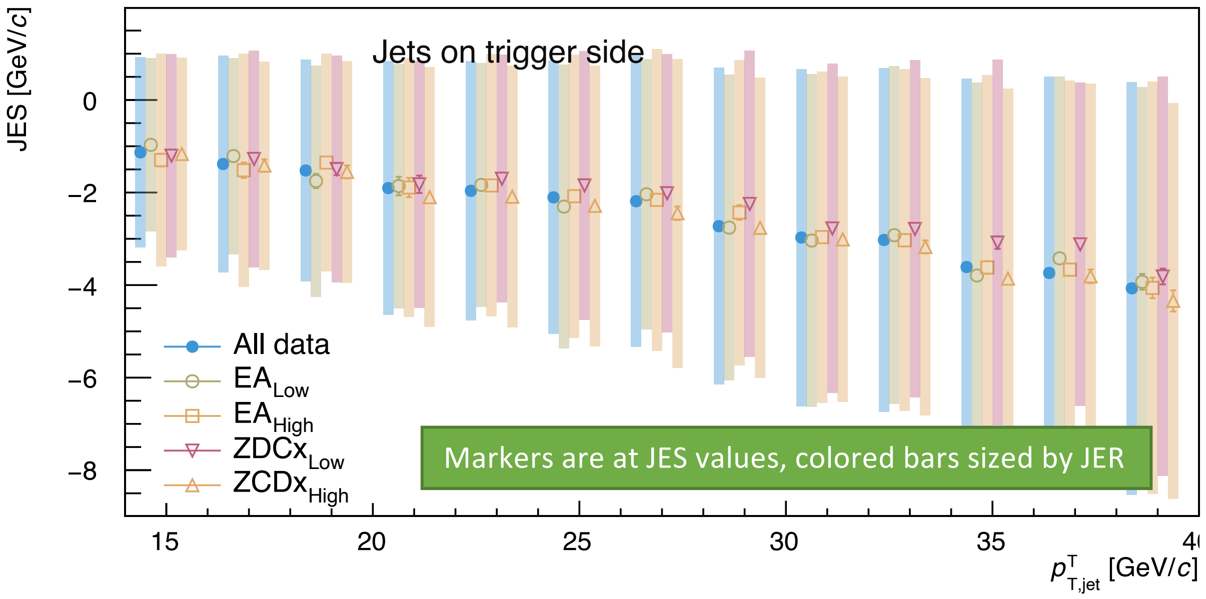


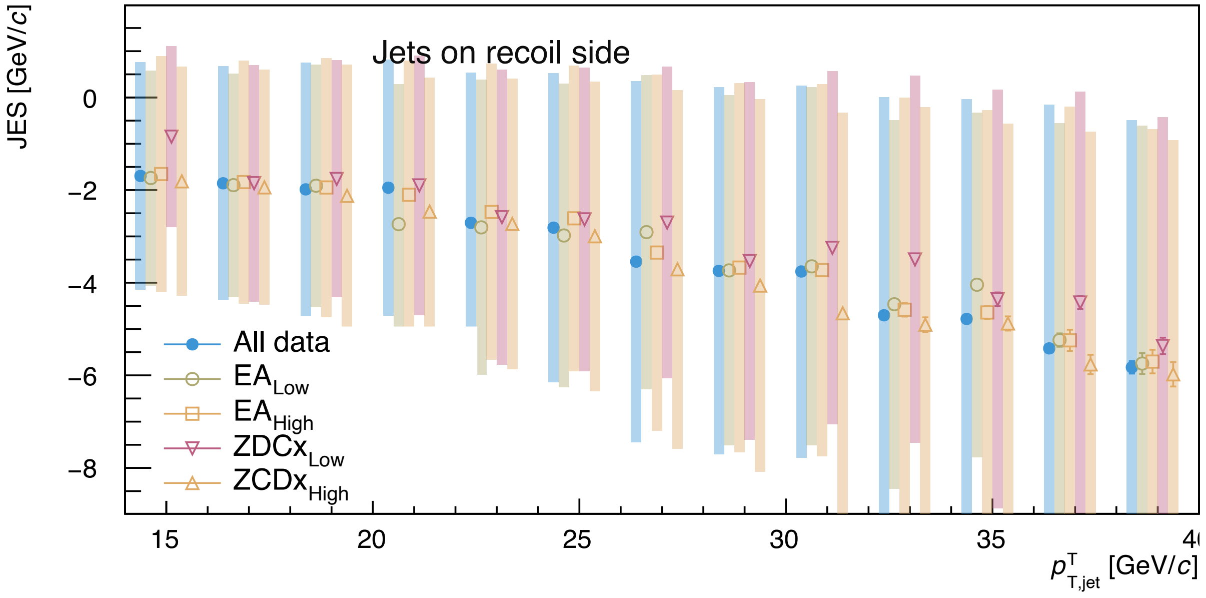
Jet Energy Scale (JES) and Jet Energy Resolution (JER):



- Per $p_{\mathrm{T,jet}}^{\mathrm{particle}}$ embedded jet, find the relative spectra of matched jets
- Look at the top 65% of the data, and fit a Gaussian (shown to the left, with 2 GeV bins of $p_{\mathrm{T,jet}}^{\mathrm{particle}}$)
- The Gaussian mean provides the JES ($GausMean - p_{\mathrm{T,jet}}^{\mathrm{particle}}$ bin) and the Gaussian width the JER

JES and JER are not distinguishably different for high/low EA and high/low

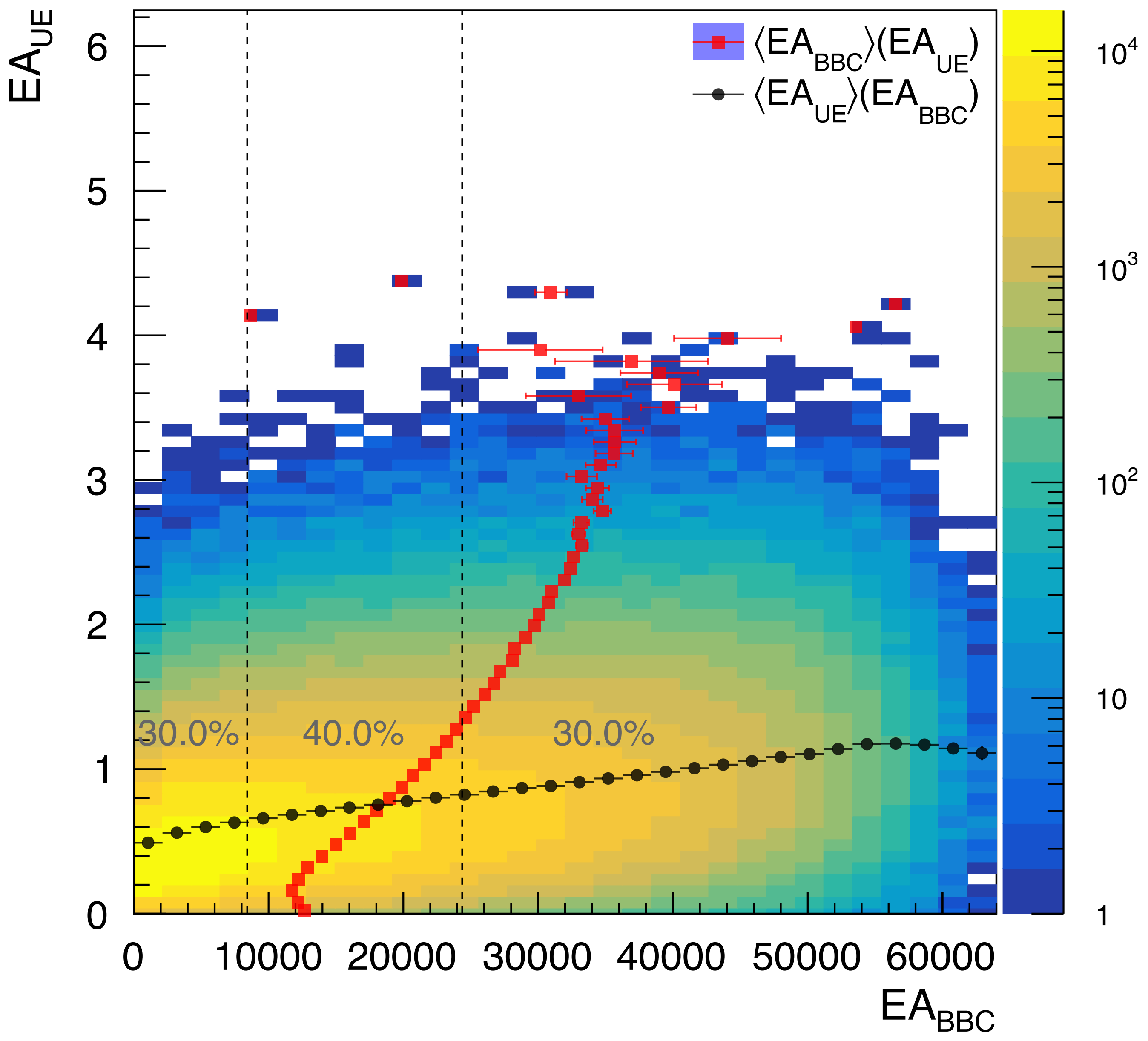




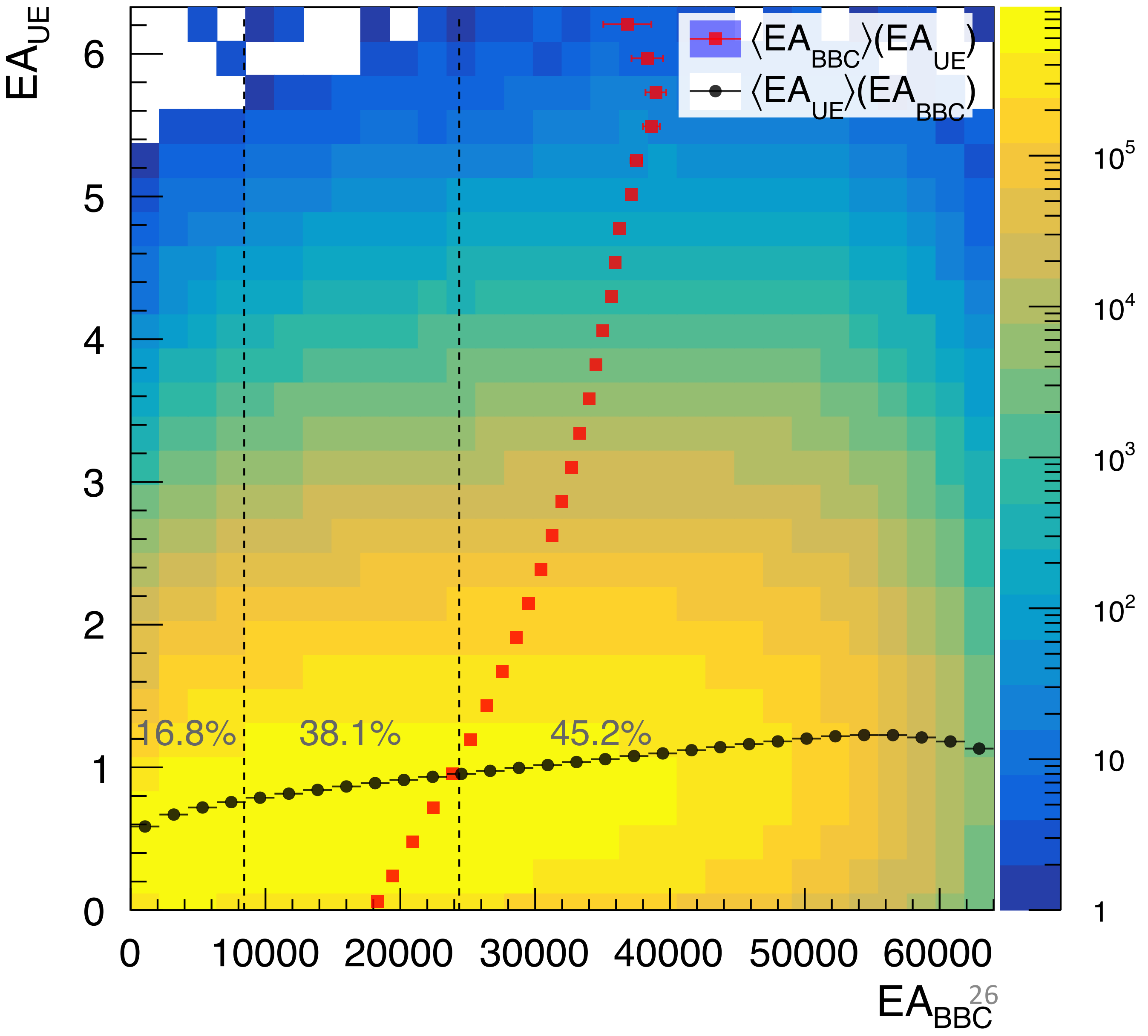
- The markers and statistical error bars are the JES and its uncertainty
- The colored bars are the JER in magnitude

Raw track density (y-axis) vs EA-BBC (x-axis)

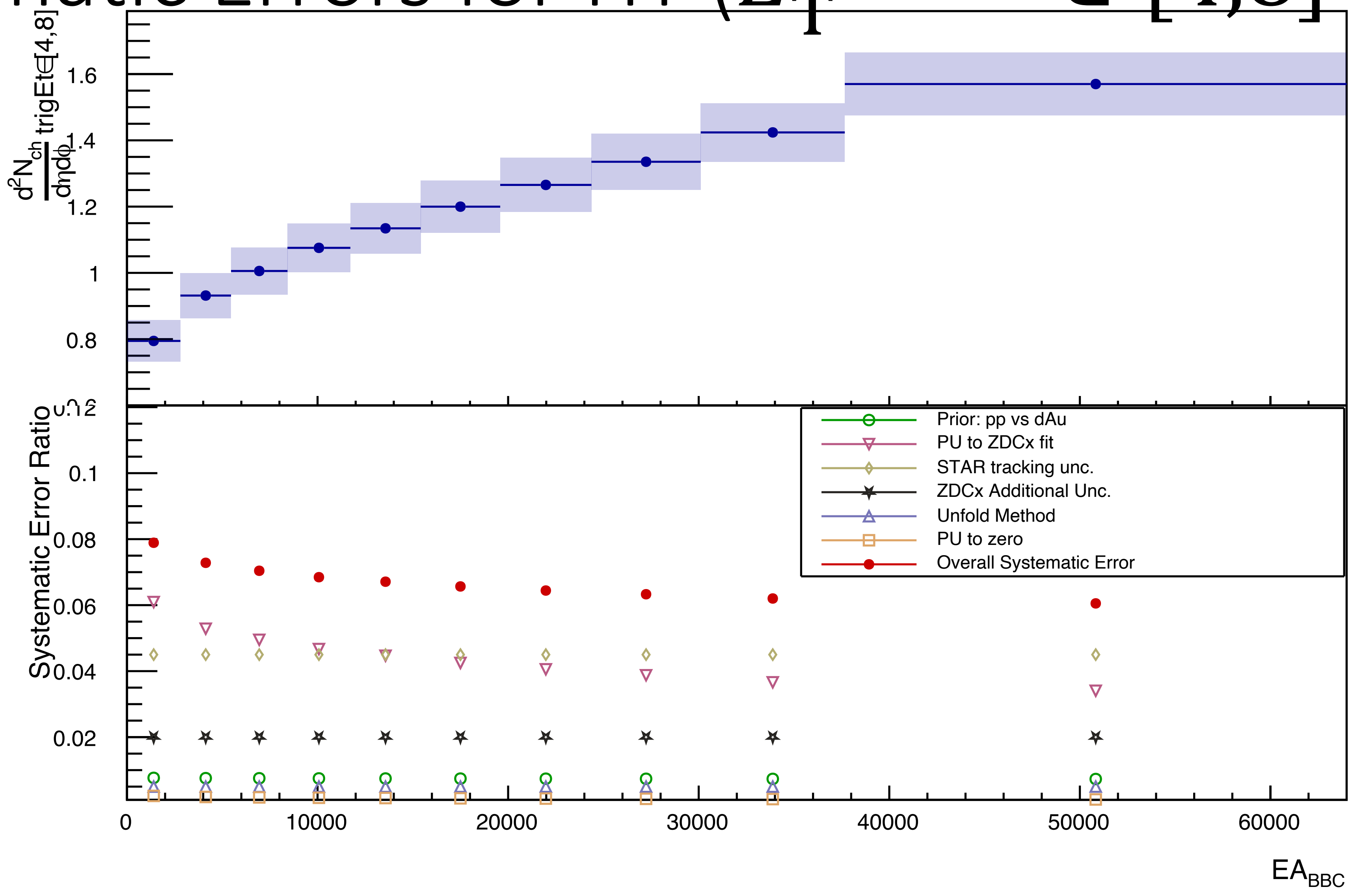
Left: MB, whole TPC



Right: HT, ϕ transverse to trigger



Systematic Errors for HT ($E_{\mathrm{T}}^{\mathrm{trigger}} \in [4,8]$ GeV/c)



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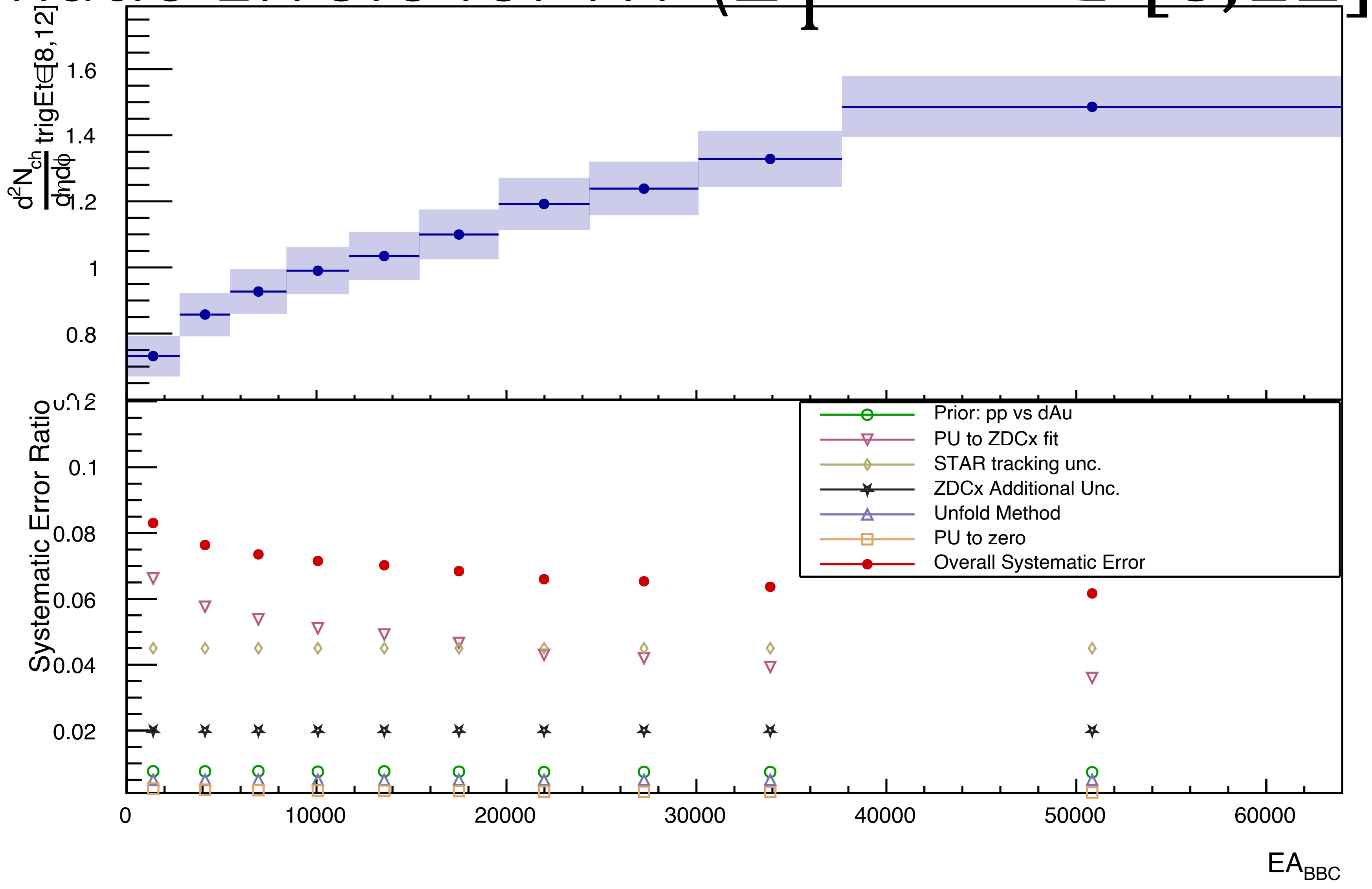
Systematic Errors for HT ($E_T^{\mathrm{trigger}} \in [8,12]$ GeV/c)



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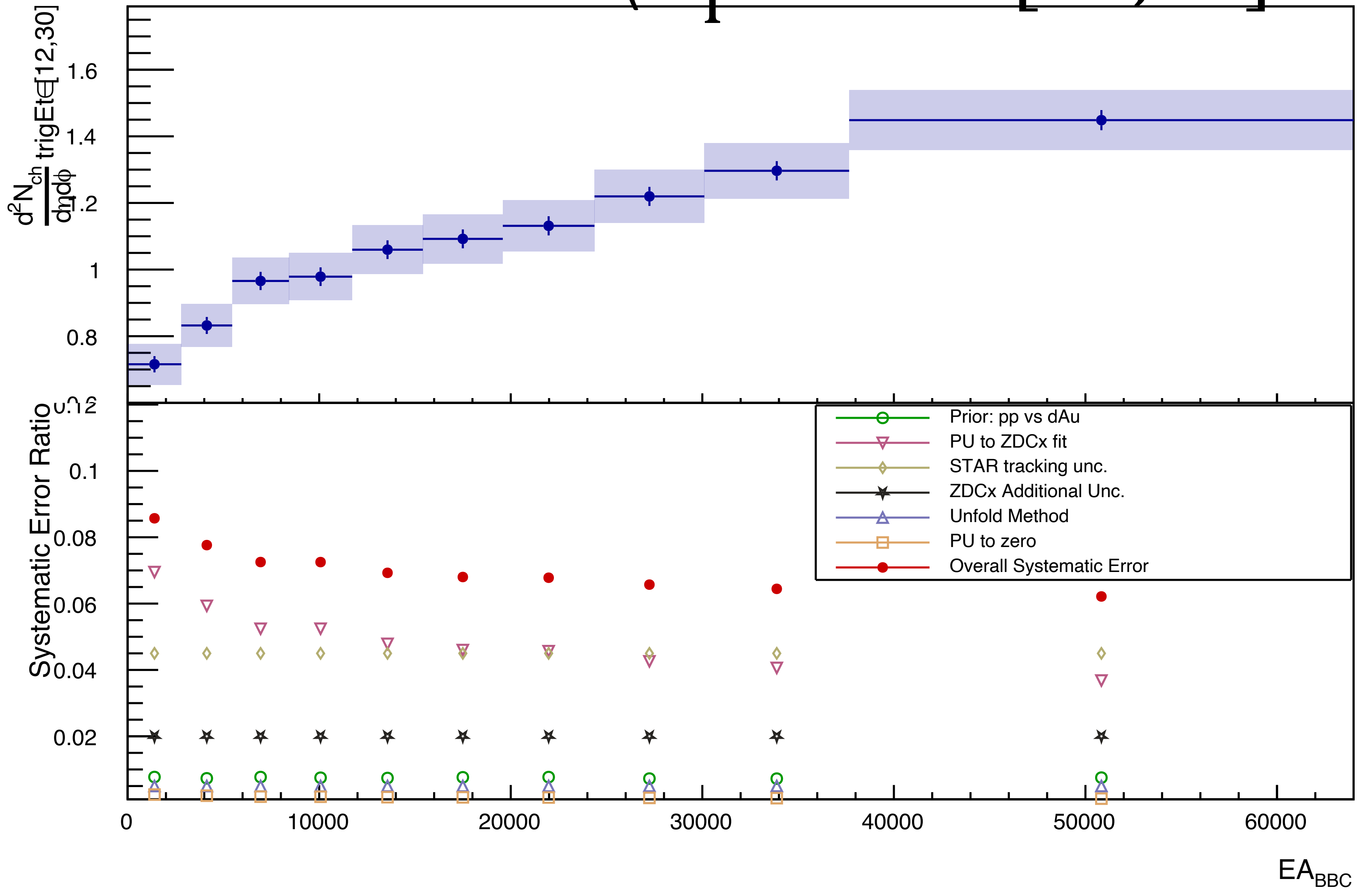
Systematic Errors for HT ($E_{\mathrm{T}}^{\mathrm{trigger}} \in [12,30]$ GeV/c)



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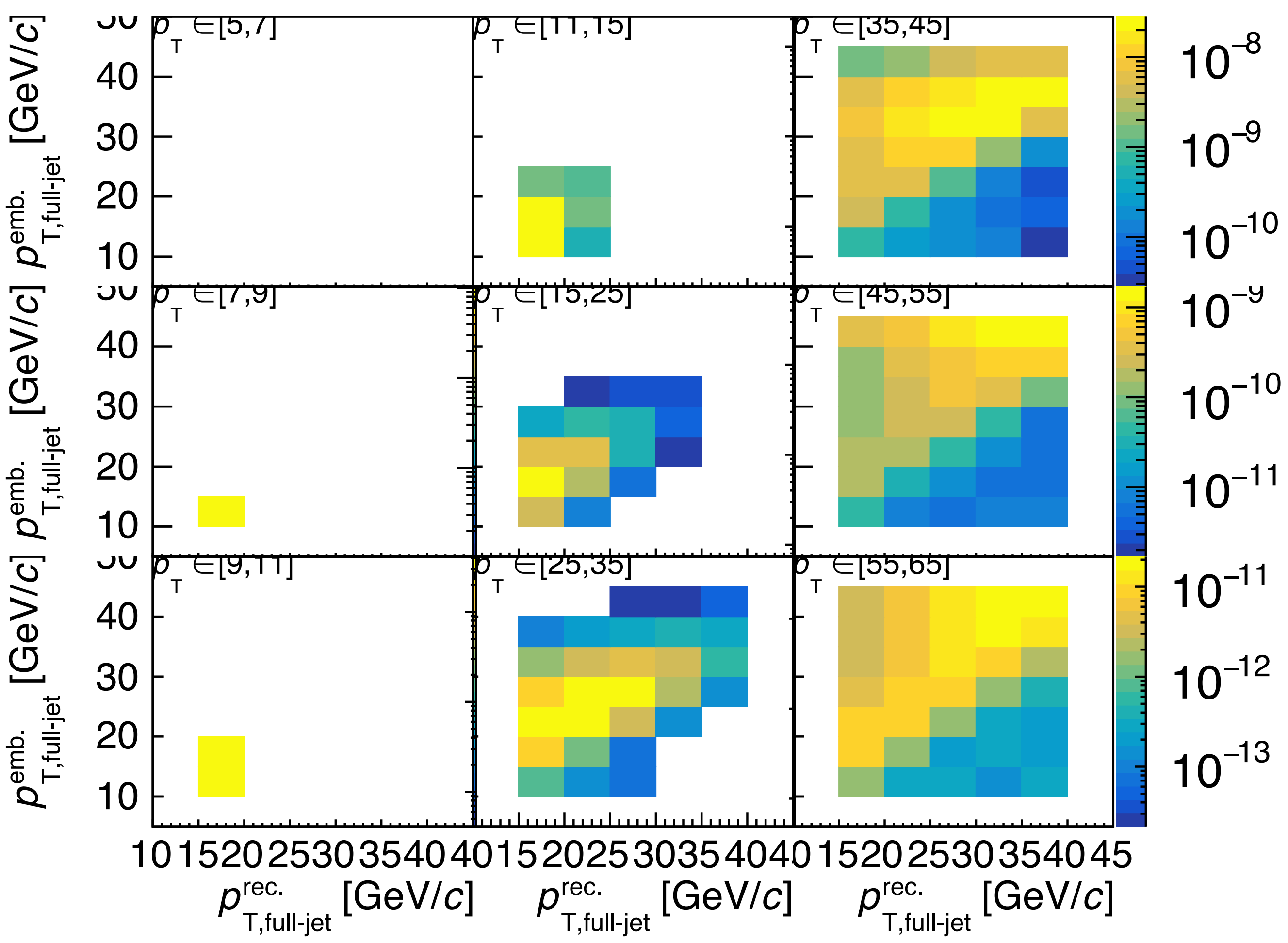
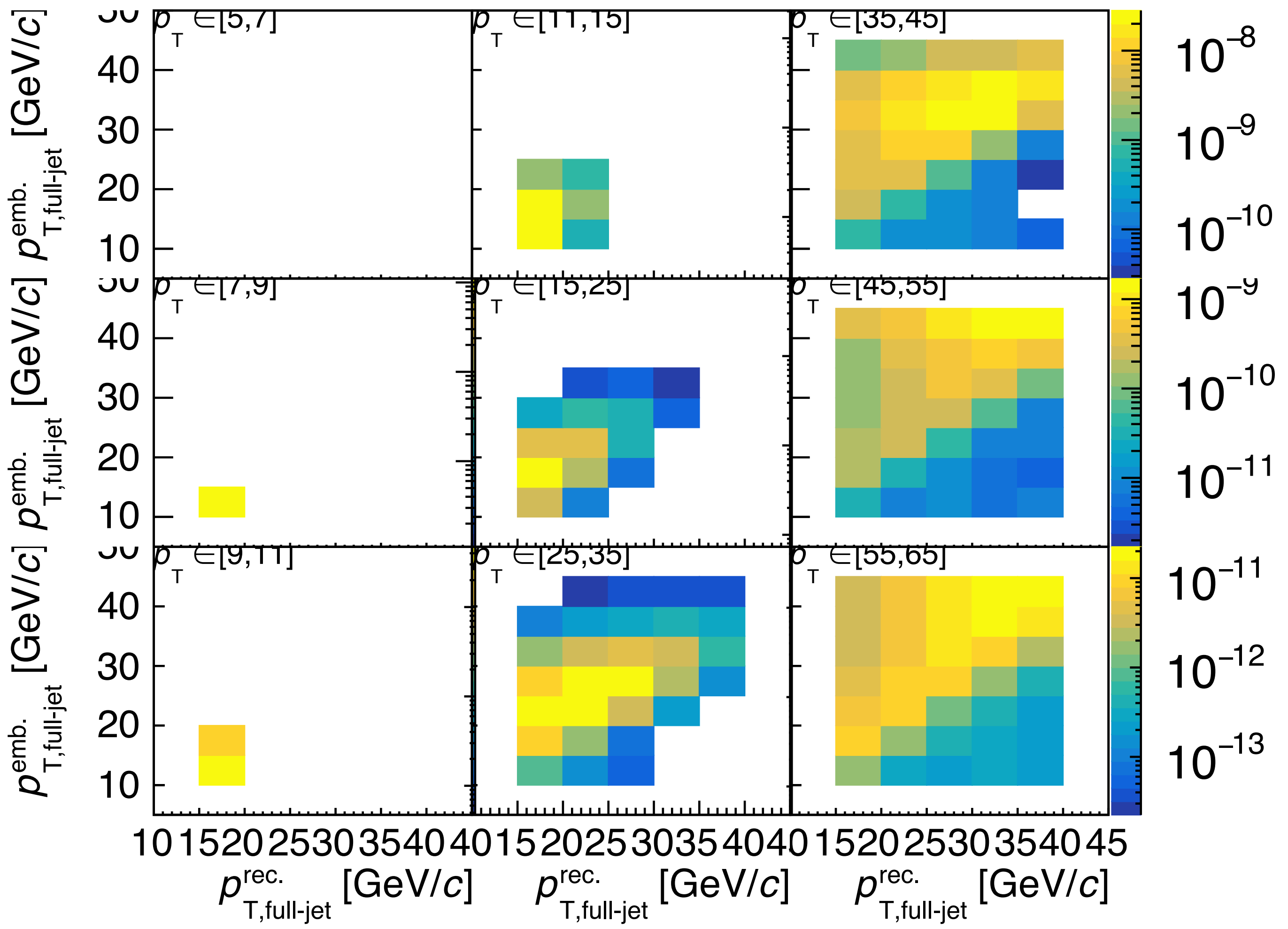
Trigger-side response matrices per $\hat{p}_{\mathrm{T}}$ embedding bin

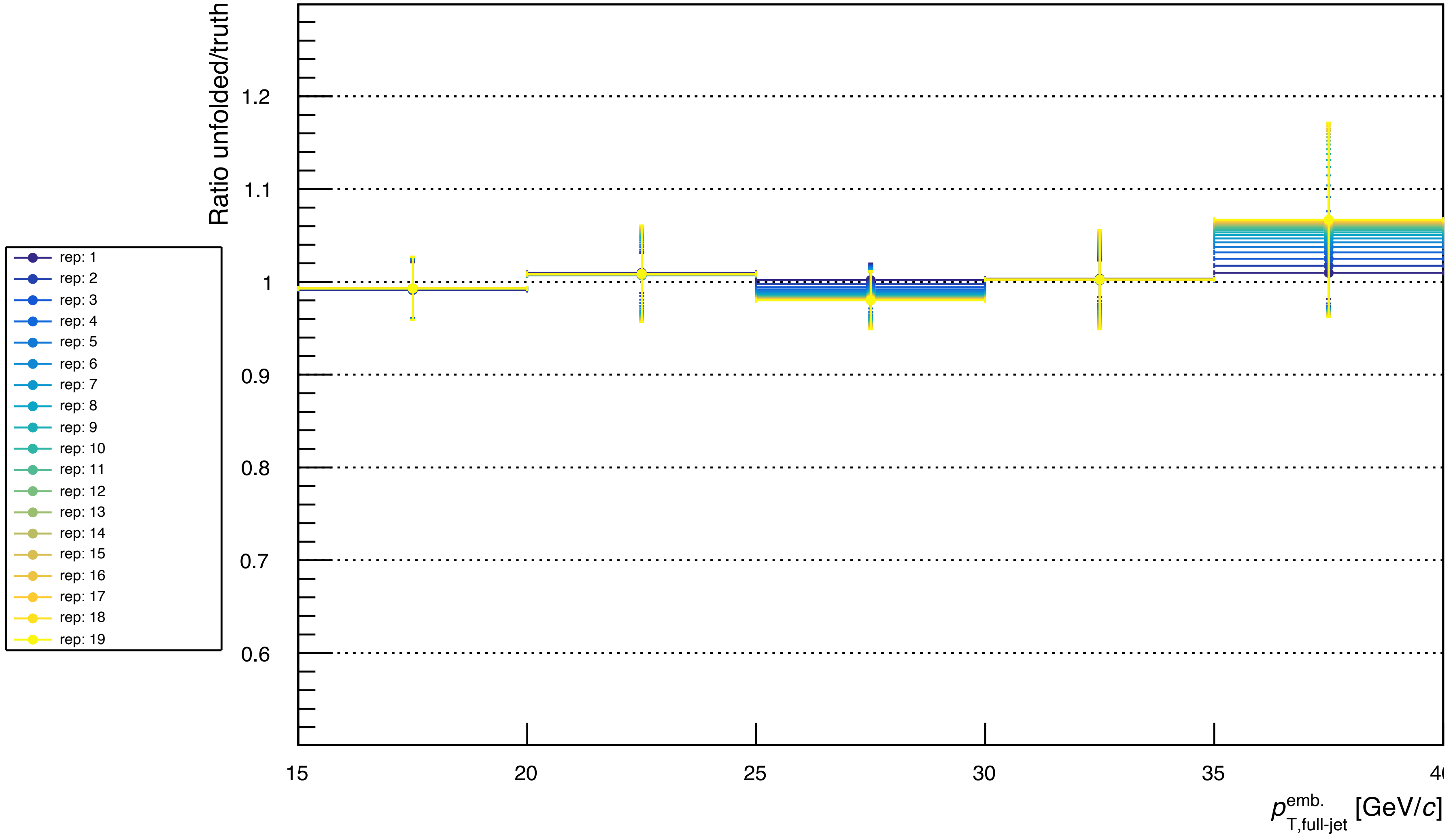
Sub-sample A



Sub-sample B



Jet spectra closure: Trigger-side



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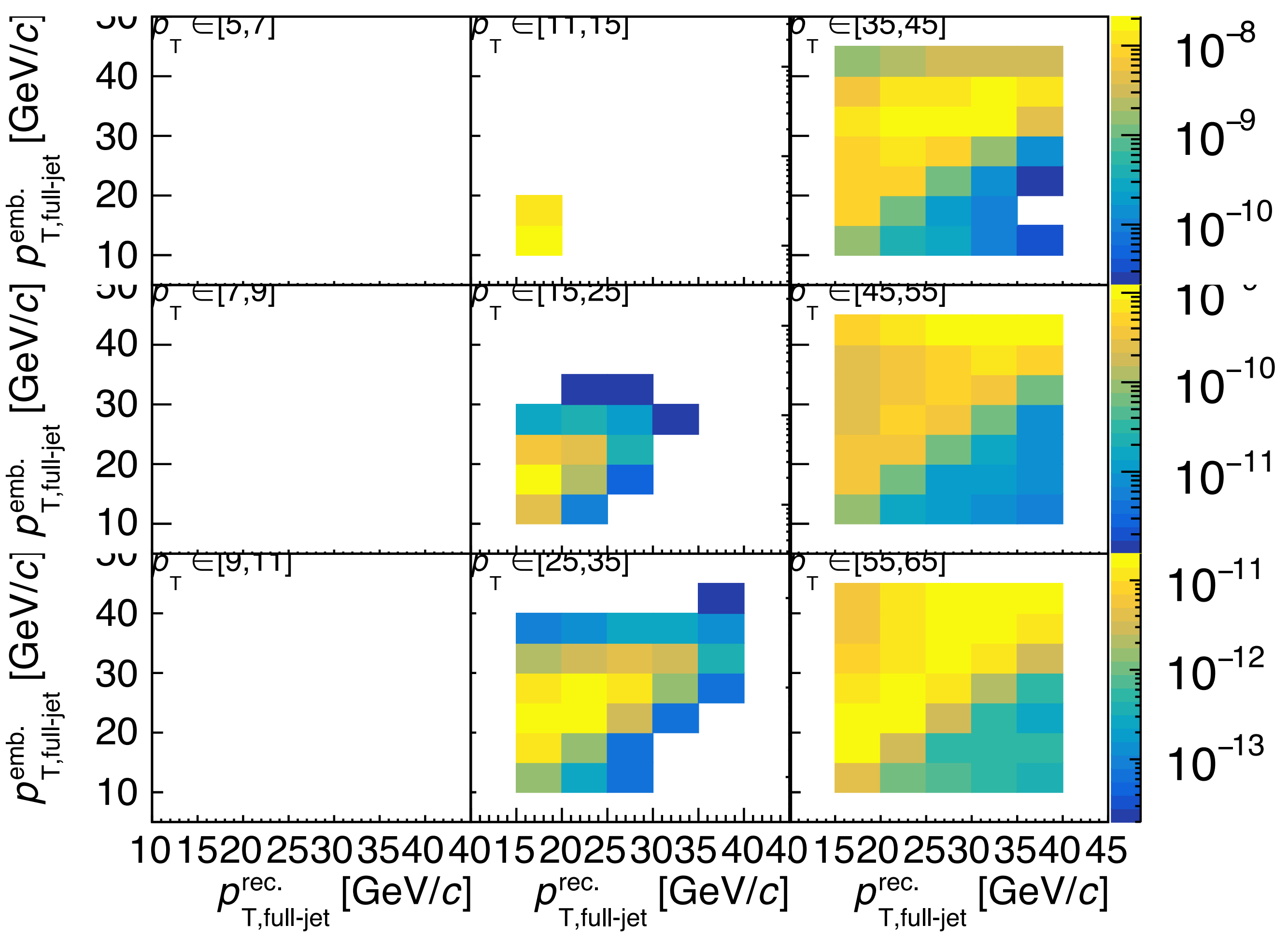
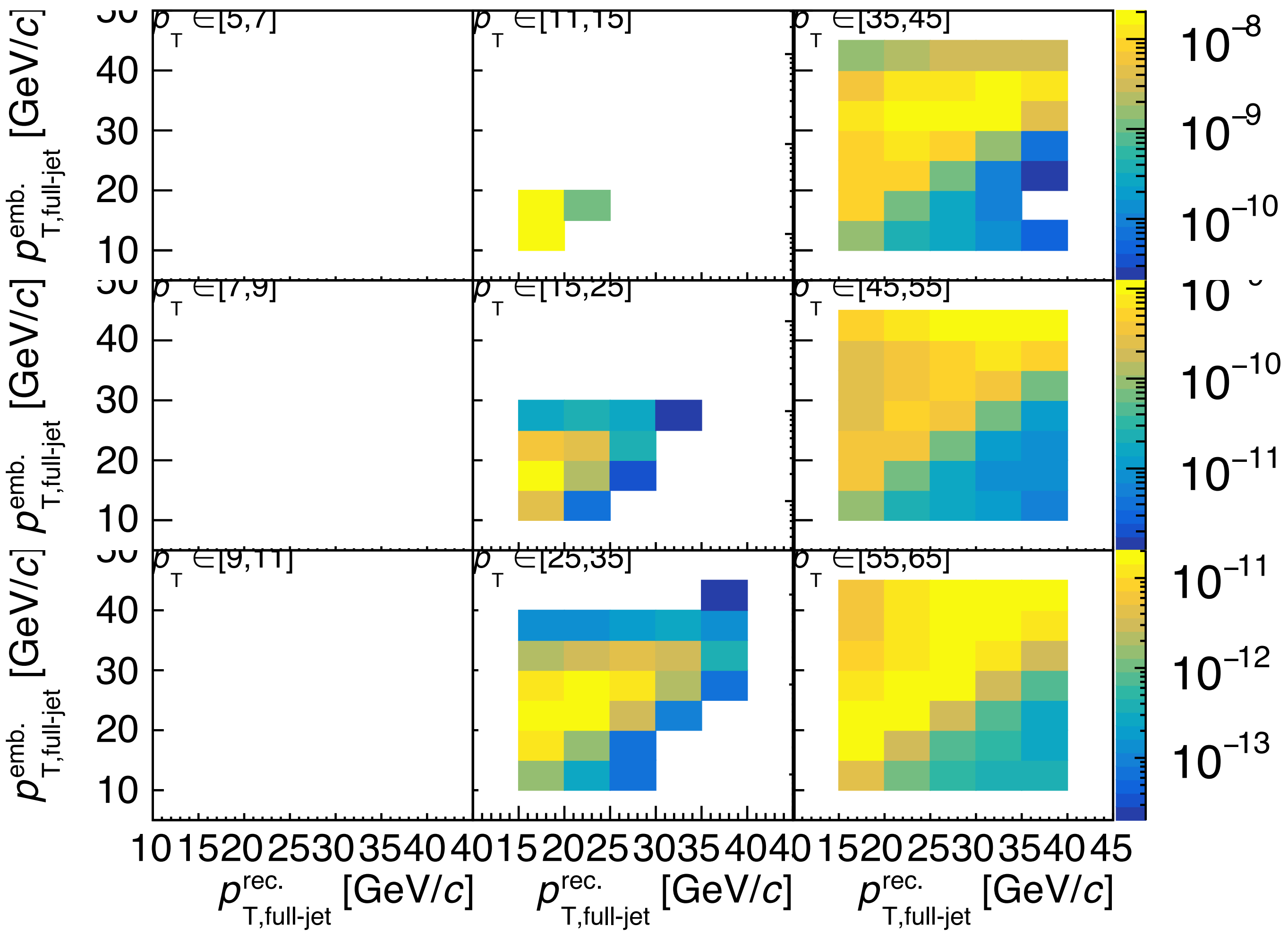
- Look at the jet spectra per triggered event both on the azimuthal trigger-size and recoil side.
- Make response matrices weighted for ZDCx bin and $\hat{p}_{\mathrm{T}}$ embedding cross sections.
- Do closure tests

Recoil-side response matrices per $\hat{p}_{\mathrm{T}}$ embedding bin

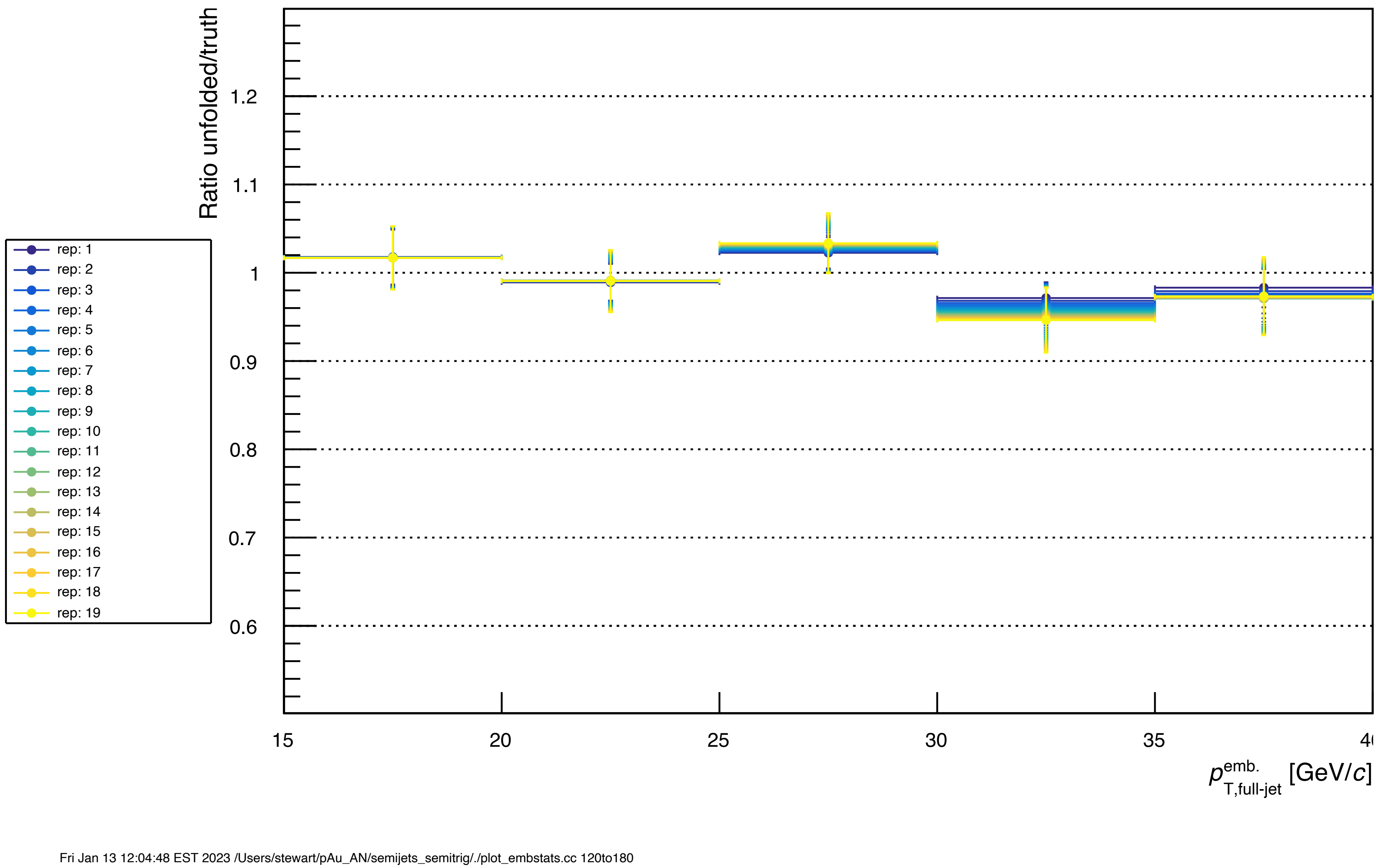
Sub-sample A



Sub-sample B

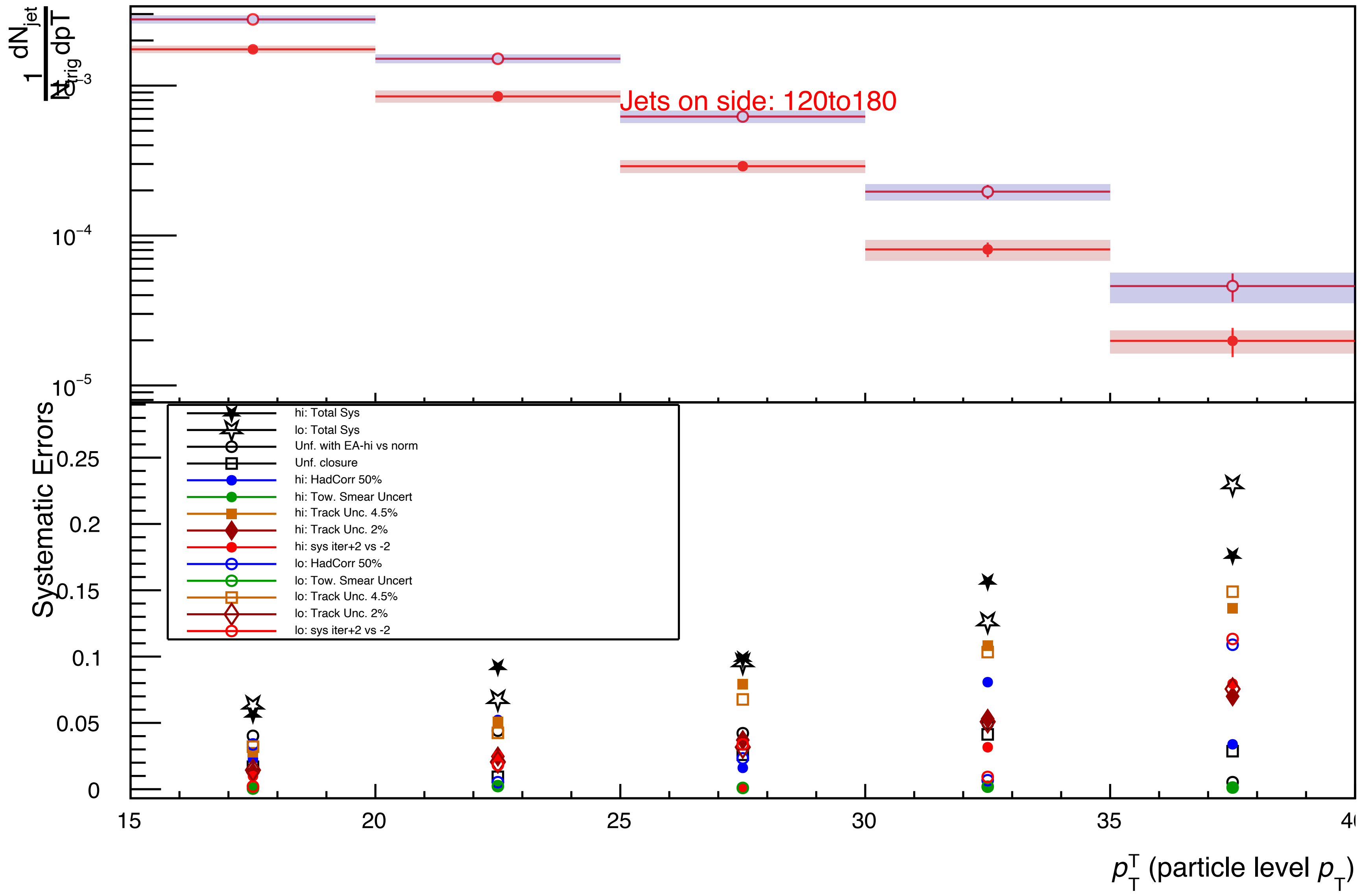


Jet spectra closure: Recoil-side



- Look at the jet spectra per triggered event both on the azimuthal trigger-size and recoil side.
- Make response matrices weighted for ZDCx bin and $\hat{p}_{\mathrm{T}}$ embedding cross sections.
- Do closure tests

Systematic Uncertainties 180to120 Spectra



The unfolding is done using response with all EA embedding.

List of systematic unc. used:

- Unfolding high-EA data with high-EA emb vs unfolding high-EA data with all-EA emb
- 50% vs 100% hadronic correction
- Max difference (bin-by-bin) between unfolding with 6 iterations, and unfolding with either 4 or 8 iterations
- Tower Et smearing (3.8% Gaussian smearing)
- 4.5% Track pT unc.
- 2% additional track pT unc.

Closure is shown in bottom but not included in the total sys. error

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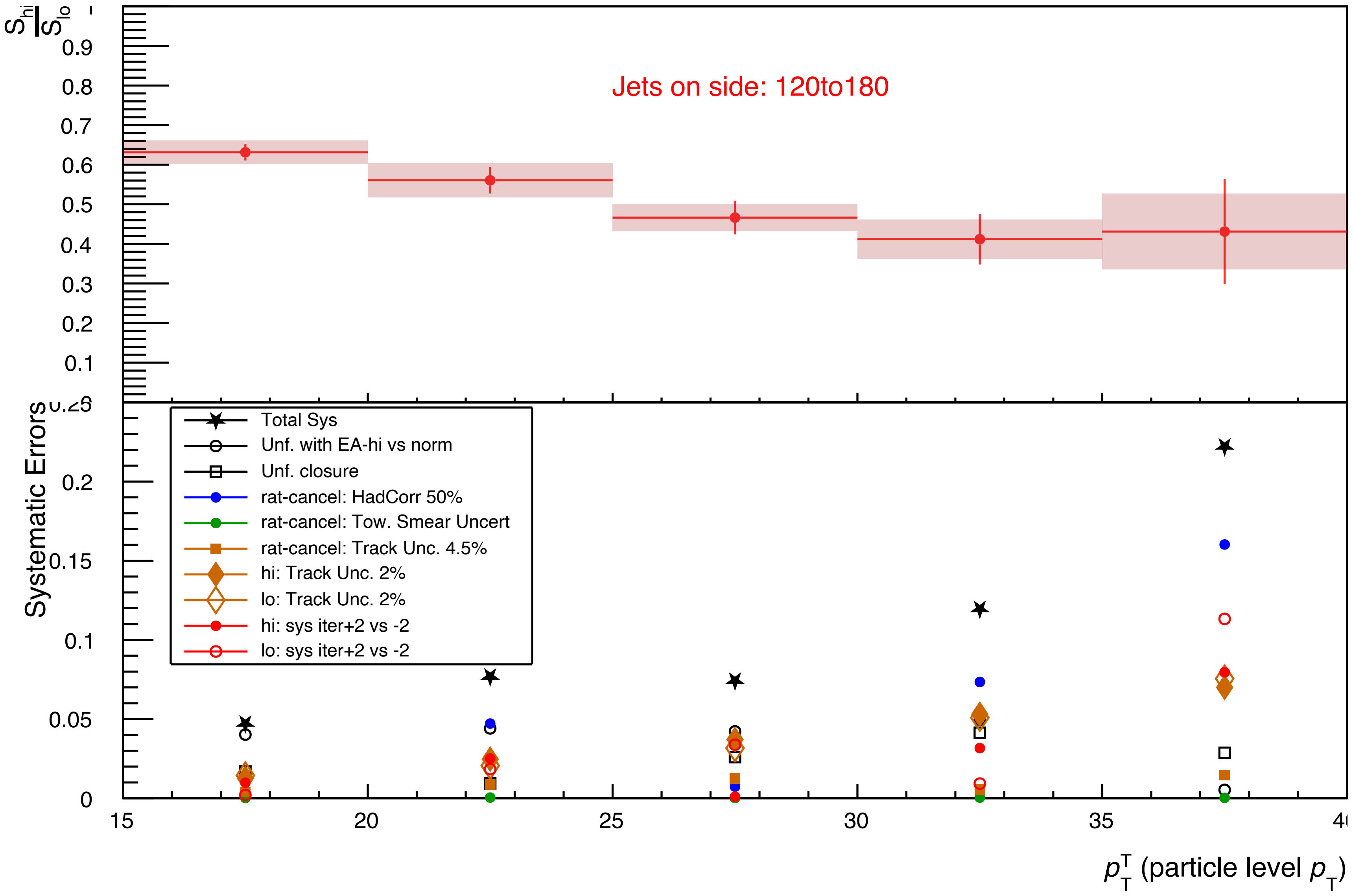
Systematic Uncertainties 180to120 Spectra



- Not ratio canceling (added directly into RSS):
  - Unfolding high-EA data with high-EA emb vs unfolding high-EA data with all-EA emb (carried directly into RSS)
  - 2% tracking error on high-EA
  - 2% tracking error on low-EA
  - Sys. iterations on high-EA
  - Sys. Iterations on low-EA
- ”Ratio canceling” (the ratio spectra using the alternative inputs are generated and *then* the difference from the nominal ratio is added in RSS)
  - H.C. 50% -- difference in H.C. Ratio to nominal ratio
  - Tow Smearing
  - Track Unc. 4.5%

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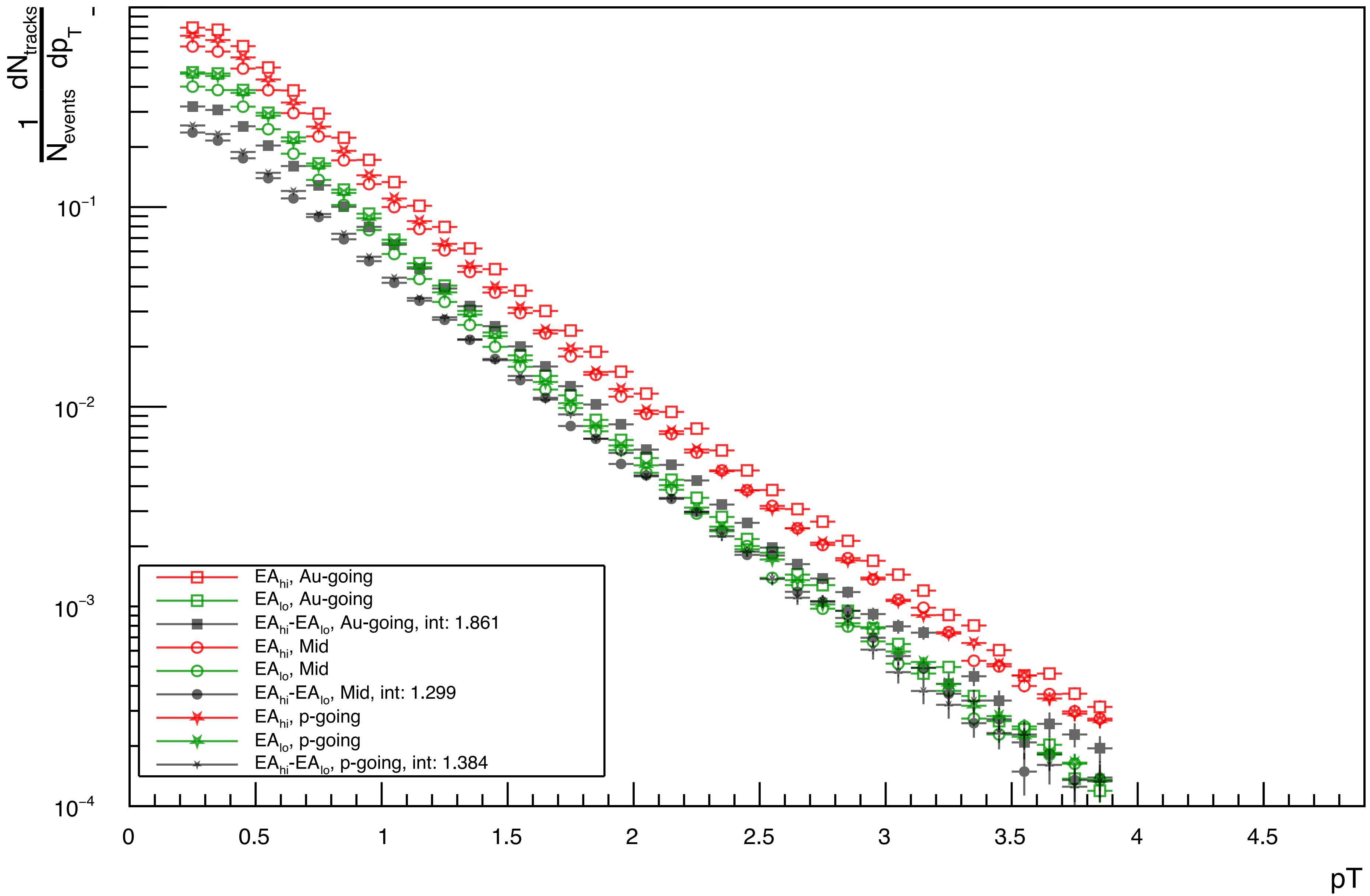
Therefore, manually increase background in low-EA events to match background in high-EA events

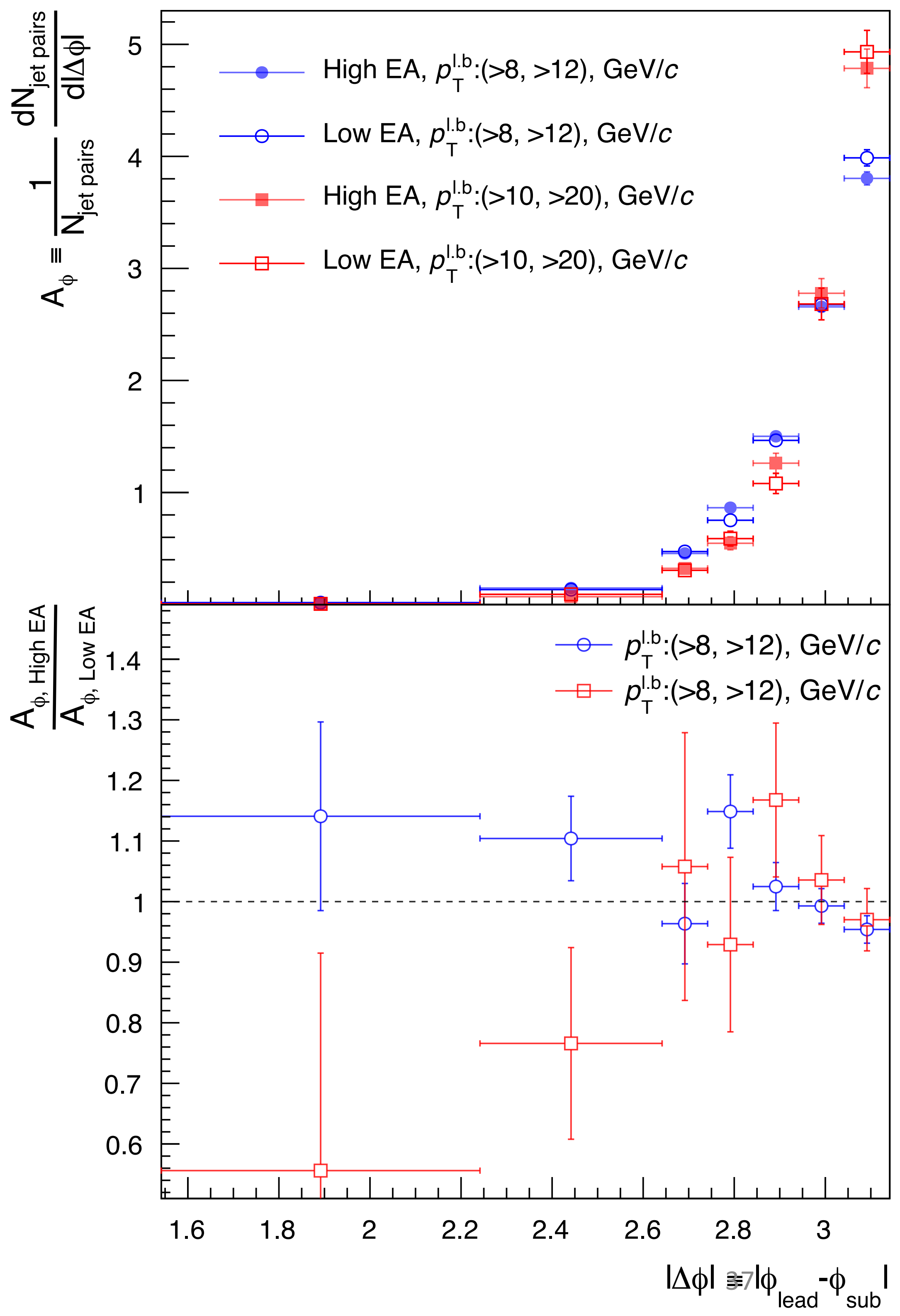


Add particles in the Au-, mid-, and p-going η ranges:

- Add the number of particles based on the Poisson distribution of the integrated difference ("int:" in the plot)
- Add from the pT distribution as plotted
- Angle the background isotropicaly distributed in rapidity and azimuth

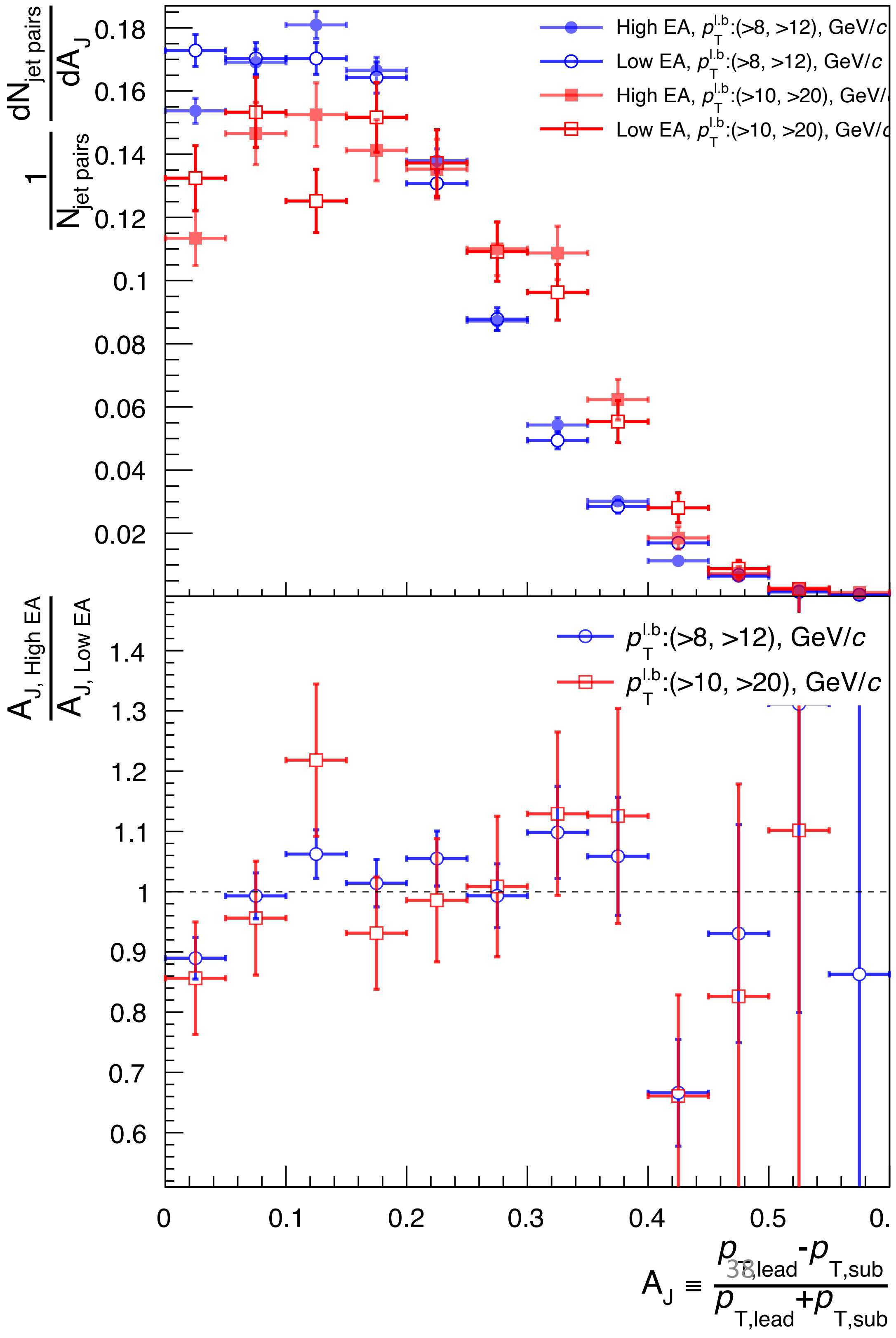
$$|\phi_{\rm lead} - \phi_{\rm sub}| \qquad (A_\phi)$$

Same but without modifying low-EA background to match high-EA background



$$\frac{p_{\mathrm{T,lead}} - p_{\mathrm{T,sub}}}{p_{\mathrm{T,lead}} + p_{\mathrm{T,sub}}} \qquad (A_J)$$

Same but without modifying low-EA background to match high-EA background



Conclusions

- Clear correlation between lead jet p_{T} and event activity (EA) measured either by:
  - Underlying event ($\mathrm{EA}_{\mathrm{UE}}$: $\left|\phi_{\mathrm{track}} - \phi_{\mathrm{lead\ jet}}\right| \in [60°, 120°]$)
  - High-η in the Au-going BBC ($\mathrm{EA}_{\mathrm{BBC}}$: $\eta \in [-5, -3.4]$)
- Both $\mathrm{EA}_{\mathrm{BBC}}$ and $\mathrm{EA}_{\mathrm{UE}}$ broadly correlated
  - When cut on both, select out obvious correlation with $p_{\mathrm{T,lead}}$
- Measurements of dijets pairs' $|\phi_{\mathrm{lead}} - \phi_{\mathrm{sub}}|$ and $\frac{p_{\mathrm{T,lead}} - p_{\mathrm{T,sub}}}{p_{\mathrm{T,lead}} + p_{\mathrm{T,sub}}}$ do not show dependence on EA
  - Therefore, no jet quenching in $p + \mathrm{Au}$ collisions
  - Long range correlations must be from early/initial stages of collisions

Tracking Efficiency(ZDCx) is EA independent

- Fit parameters for ρ_{PU} are independent of $\mathrm{EA}_{\mathrm{BBC}}$ bin
- Top bin is