

Isolation in Pb-Pb: Study of the underlying event (UE) in the isolation cone using random cones, update

1. Analysis settings and data samples
2. Clusterization and shower shape
3. Isolation and UE energy density estimators
4. Results with ABCD method (very preliminary)
5. Conclusion

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- In the photon isolation analysis we have 2 main parameters
 - ▶ Calorimeter shower shape
 - ▶ Sum of transverse momentum of particles in isolation cone $p_{\text{T}}^{\text{iso}}$
- Both quantities are strongly dependent on the event particle multiplicity (underlying event, UE)
 - ▶ Photon shower shape distribution broadened difculting the resolving power — Lower purity - efficiency
 - ▶ Photon energy shifted to higher values — Higher correction.
 - ▶ $p_{\text{T}}^{\text{iso}}$ shifted from less than 1 GeV mean value in pp collisions to several tenths of GeV — Need to estimate the underlying event contribution to the cone each event
- In the next slides study in Pb-Pb collisions
 - ▶ Shower shape for different reconstruction clusterizers and collision centralities, effect on efficiency and purity
 - ▶ UE subtraction in the calculation of with different estimators, depending cone size and centrality
 - ▶ Very preliminary attempt of isolated photon spectrum in 4 different centrality bins

- Data: Analysis of Pb-Pb 5.02 TeV LHC18q and LHC18r samples
 - ▶ MB and centrality triggers, used in embedding to MC
 - ▶ L1 EMCal+DCal trigger (~ 12 GeV for cen < 50 % and ~ 5 GeV for cen > 50 %)
- Data: Analysis of Pb-Pb 5.02 TeV LHC15o for random cone analysis MB data
- MC embedded into data: pp 5.02 TeV, PYTHIA8 anchored to LHC18qr
 - ▶ jet-jet unbiased LHC20g4
 - 20 p_T -hard bins {5,7,9,12,16,21,28,36,45,57,70,85,99,115,132,150,169,190,212,235,-1} GeV/c
 - ~ 8 M events each bin
 - ▶ jet-jet biased with decay photon $p_{T^\gamma} > 3.5$ GeV/c triggered on calorimeters acceptance
 - 6 p_T -hard bins {5, 7, 9, 12, 16, 21, -1} GeV/c
 - ~ 8 M events each bin
 - ▶ jet-jet biased with decay photon $p_{T^\gamma} > 7$ GeV/c triggered on calorimeters acceptance
 - 8 p_T -hard bins {8, 10, 14, 19, 26, 35, 48, 66, -1} GeV/c
 - ~ 8 M events each bin
 - ▶ γ -jet events triggered on calorimeters acceptance
 - 6 p_T -hard bins {5, 11, 21, 36, 57, 84, -1} GeV/c
 - ~ 8 M events each bin

1 - Introduction: Analysis settings

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- EMCal and DCal clusters, for shower shape analysis, only EMCal for first full isolation analysis
- Clusterizer: $E_{\text{cell}} > 100 \text{ MeV}$, $E_{\text{seed}} > 500 \text{ MeV}$
- LED event rejection ON (at SM and strip level)
- Exotic rejection $F_+ < 0.95$
- Cross talk default emulation on MC
- Cluster $|time| < 20 \text{ ns}$
- Non linearity:
 - data, “kTestBeamFinalShaper”;
 - MC, “kTestBeamFinalMC” with afterburner “kPCM_EMCal”
- Distance to bad channel cut not applied, 1 cell from SM border cut applied
- Same track matching residual p_T track dependent cuts as in pp analyses plus require $E/p < 1.7$ to 3, depending when the analysis was done

2 - Clusterization and shower shape in Pb-Pb environment

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- In pp collisions, isolated γ measurement relies on

- ▶ **V1 clusters**

- To be able to veto merged decay γ and use the right tail in the shower shape σ_{long}^2 to estimate purity, tail suppressed in V2 clusterizer

- ▶ Number of local maxima **$n_{\text{LM}}=1-2$** in clusters

- To avoid part of the bias of jet cluster merging in data driven purity estimation, but still have meson decay merging in the shower shape σ_{long}^2 tail

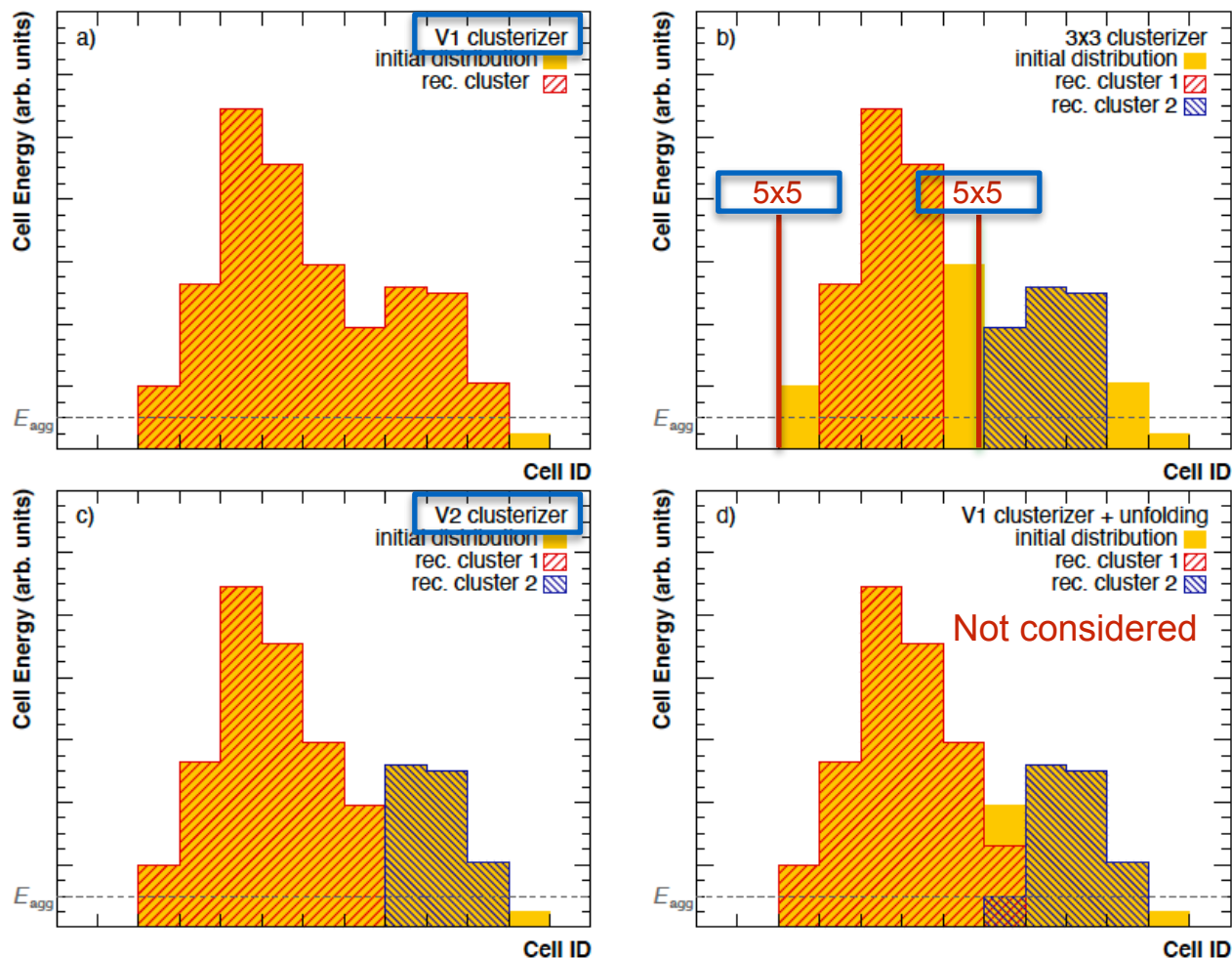
- In Pb-Pb central collisions, the same could be used but:

- ▶ Reduced efficiency of isolated γ due to random overlaps with the collision UE, adding extra n_{LM} and higher shower shape σ_{long}^2 right tail to γ clusters
- ▶ Significant energy bin shift due to collision UE, specially at low p_{T} .
- ▶ **Can we avoid these with other clusterizer?**

Study shower shape σ^2_{long} with different clusterizations: V1, 5x5, V2

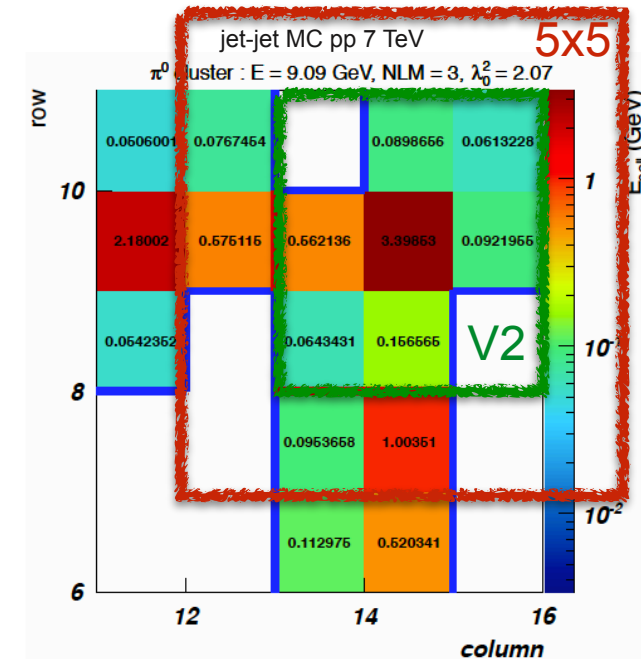
- **Why 5x5?** Limit contribution of UE to V1 cluster, still allow merged clusters

Schematic view of clusterizers working

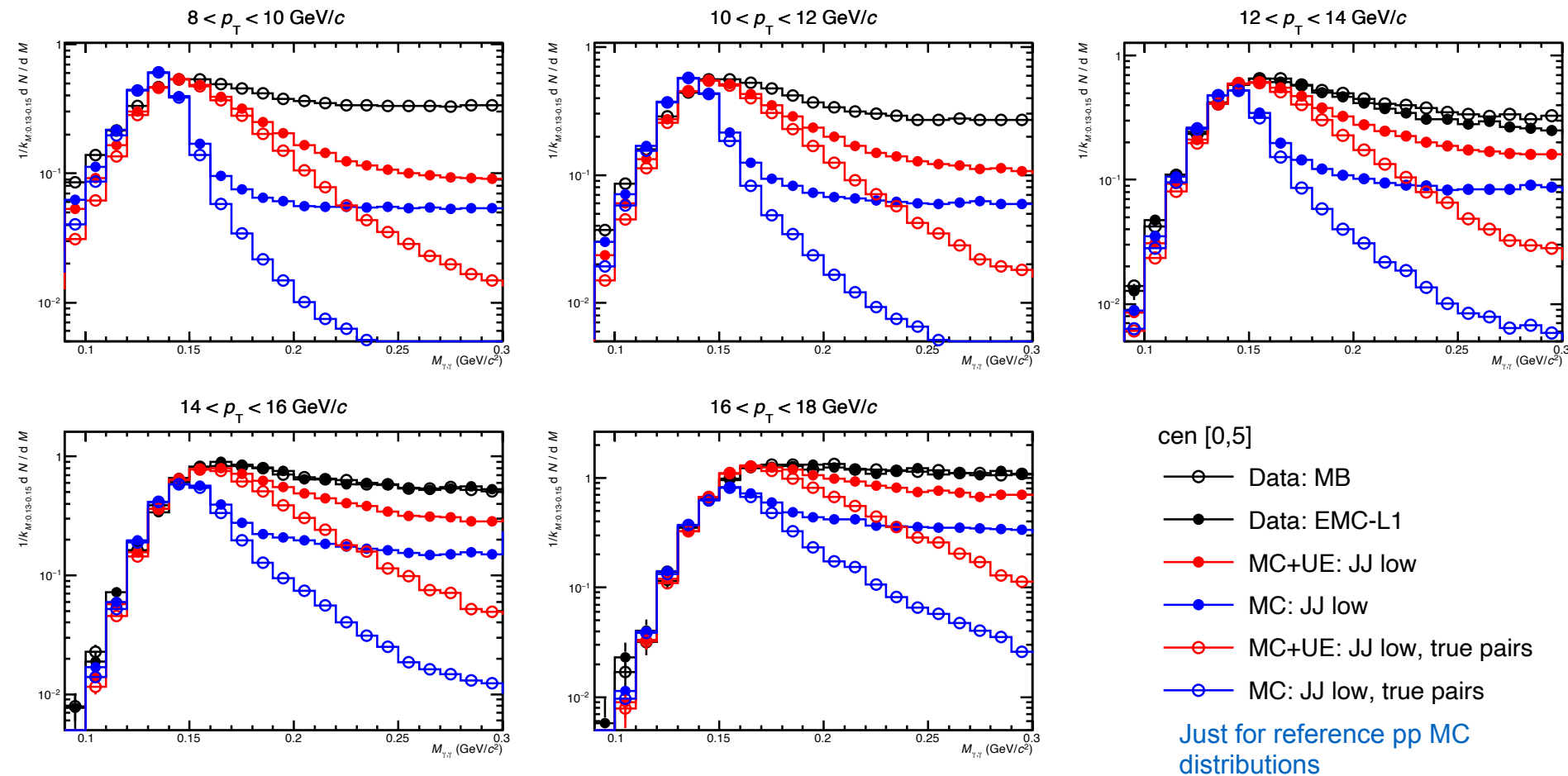


2- Shower shape with fixed size

- Additionally, for V2 clusters calculate a different σ^2_{long}
 - Consider the cells around the highest energy cell in a 5x5 fixed window in the σ^2_{long} calculation, independently if cells were assigned to the original V2 cluster
 - Those cells must be all neighbours (unlike currently in 5x5 clusterizer)
 - **The cluster energy and position remains the same as the V2 cluster**
 - A different case considered also, if 5x5 cells have
 - ◆ $n_{\text{LM}} = 1$ or > 2 maxima take the V2 standard σ^2_{long} ,
 - ◆ $n_{\text{LM}} = 2$, take the 5x5 recalculated σ^2_{long}



2 - π^0 invariant mass: centrality 0-5% - Clusterizer V2

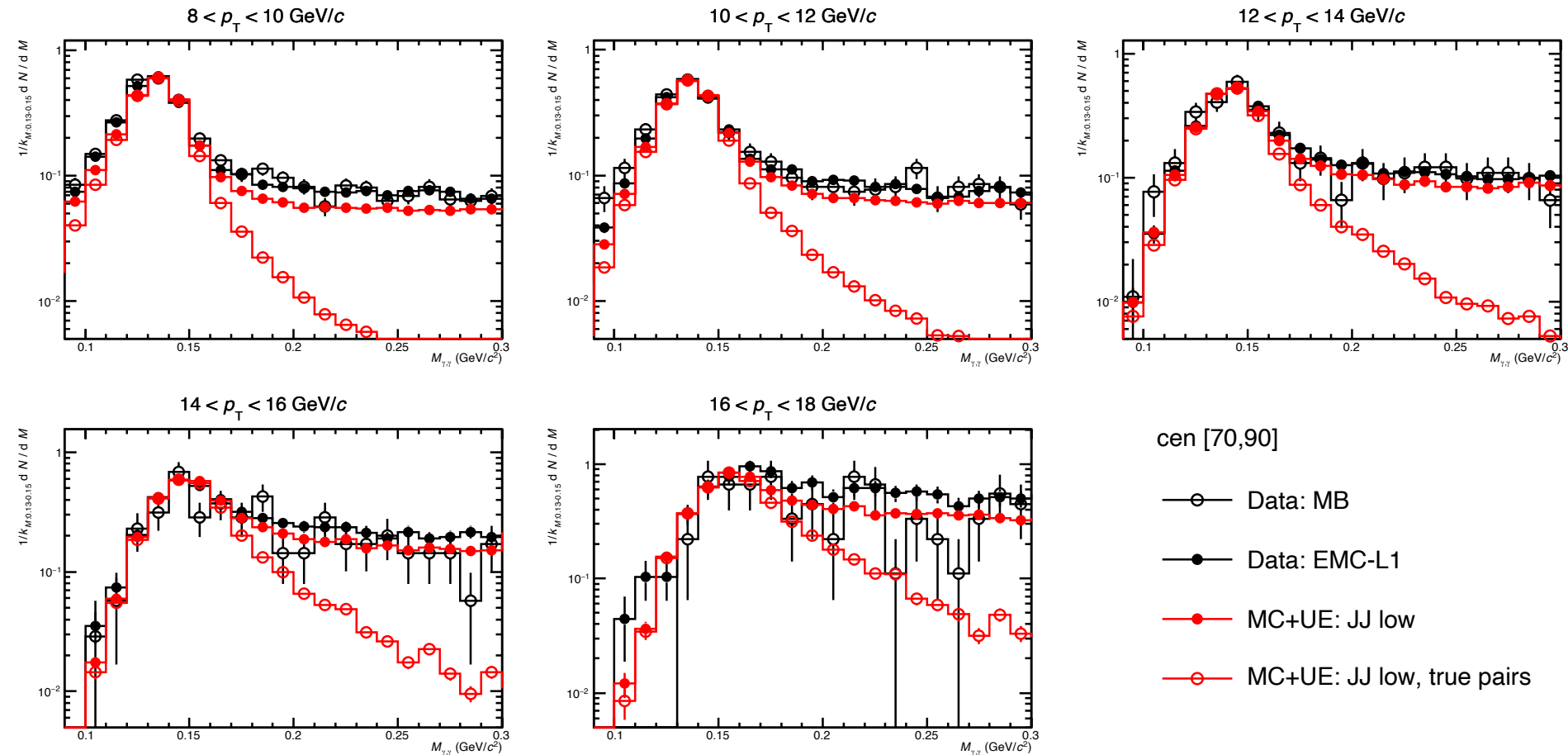


Cluster $p_T > 1.5$ GeV/c, 0.017 rad < opening angle < 80 degrees

MC+UE: **clusters from data do not enter invariant mass calculation**, that is why tails are lower, but including them, I would expect a rather perfect agreement.

Distributions normalized to the peak in range 0.12-0.14 MeV/c²

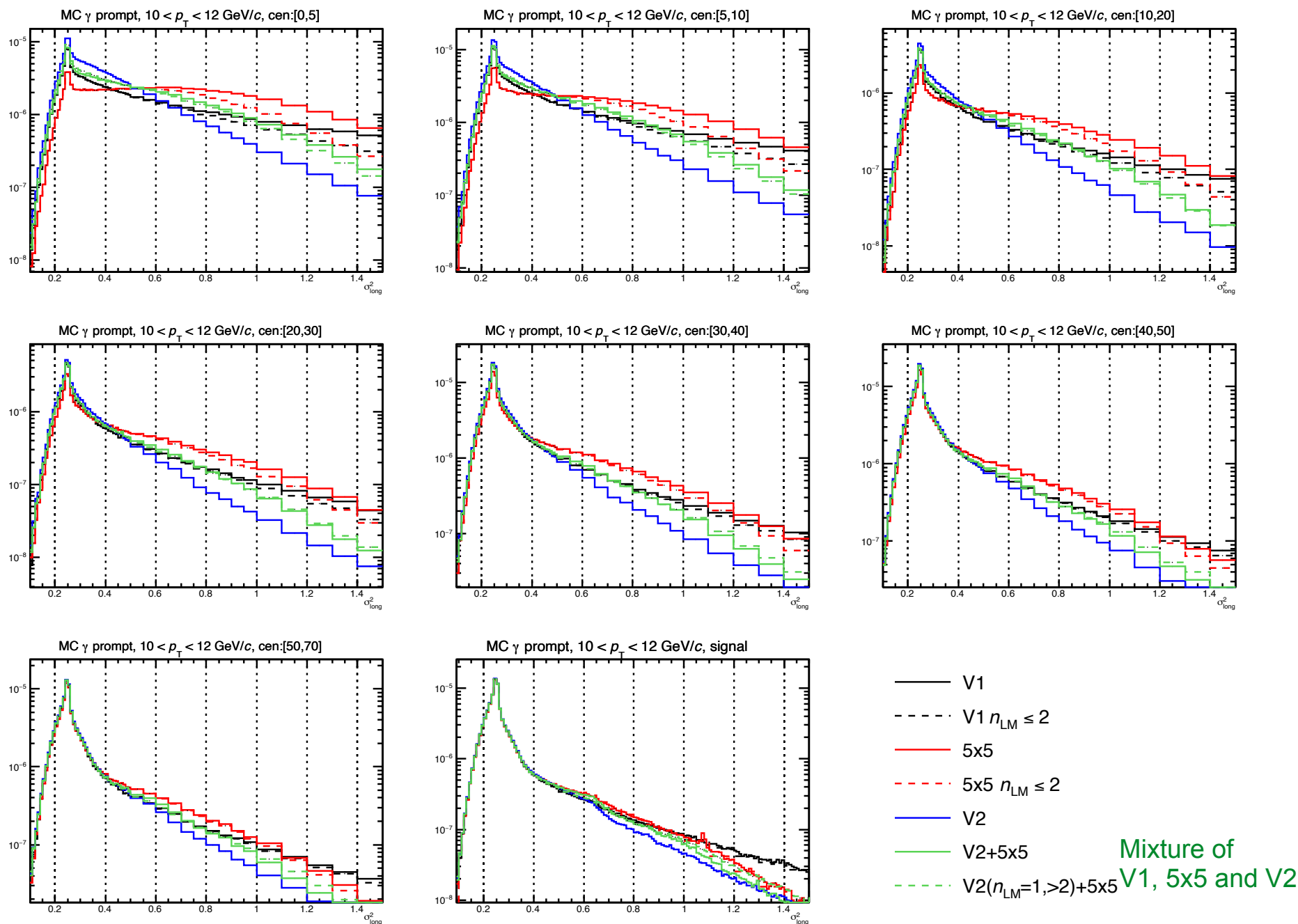
2 - π^0 invariant mass: centrality 70-90% - Clusterizer V2

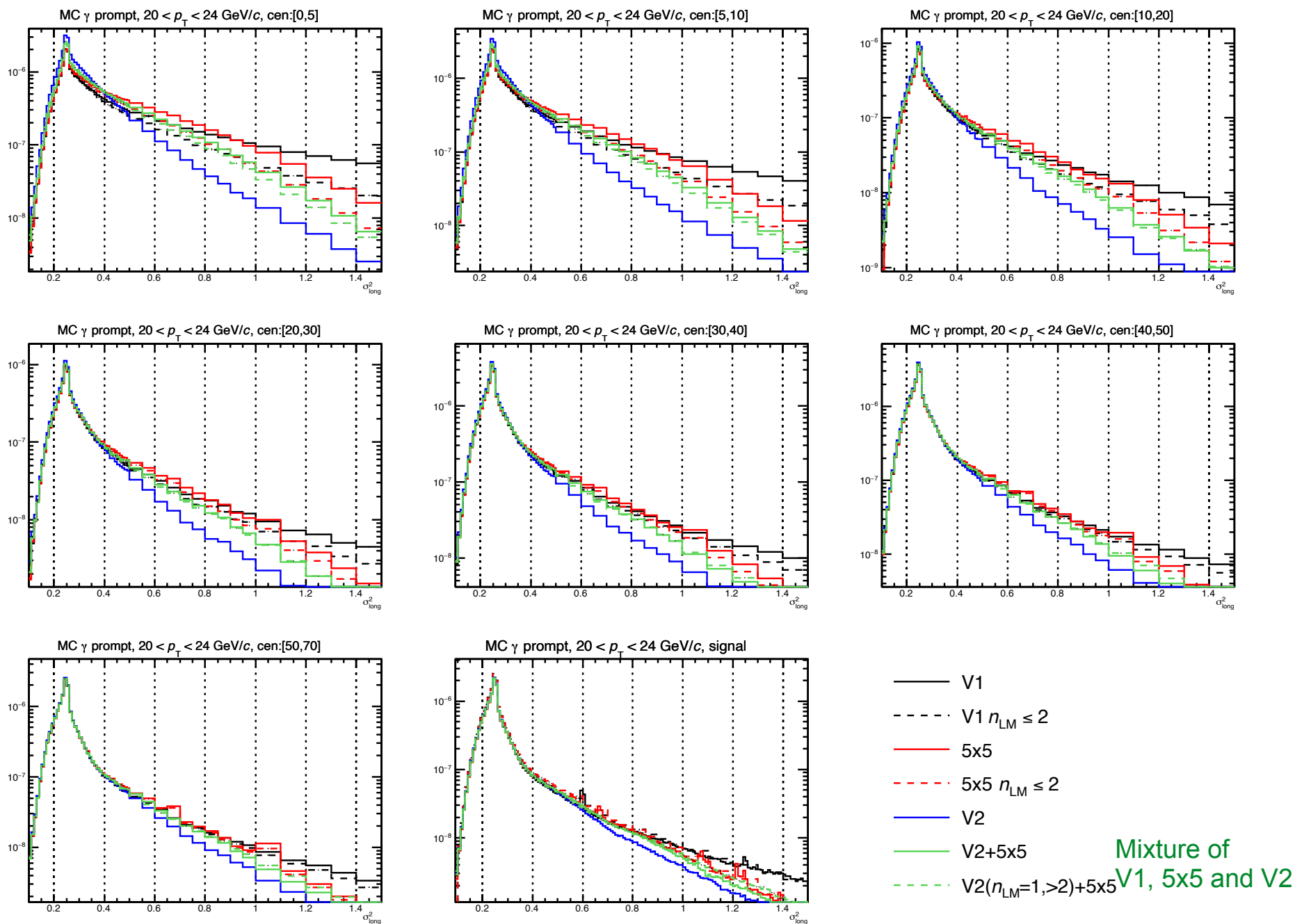


Cluster $p_T > 1.5$ GeV/c, 0.017 rad < *opening angle* < 80 degrees

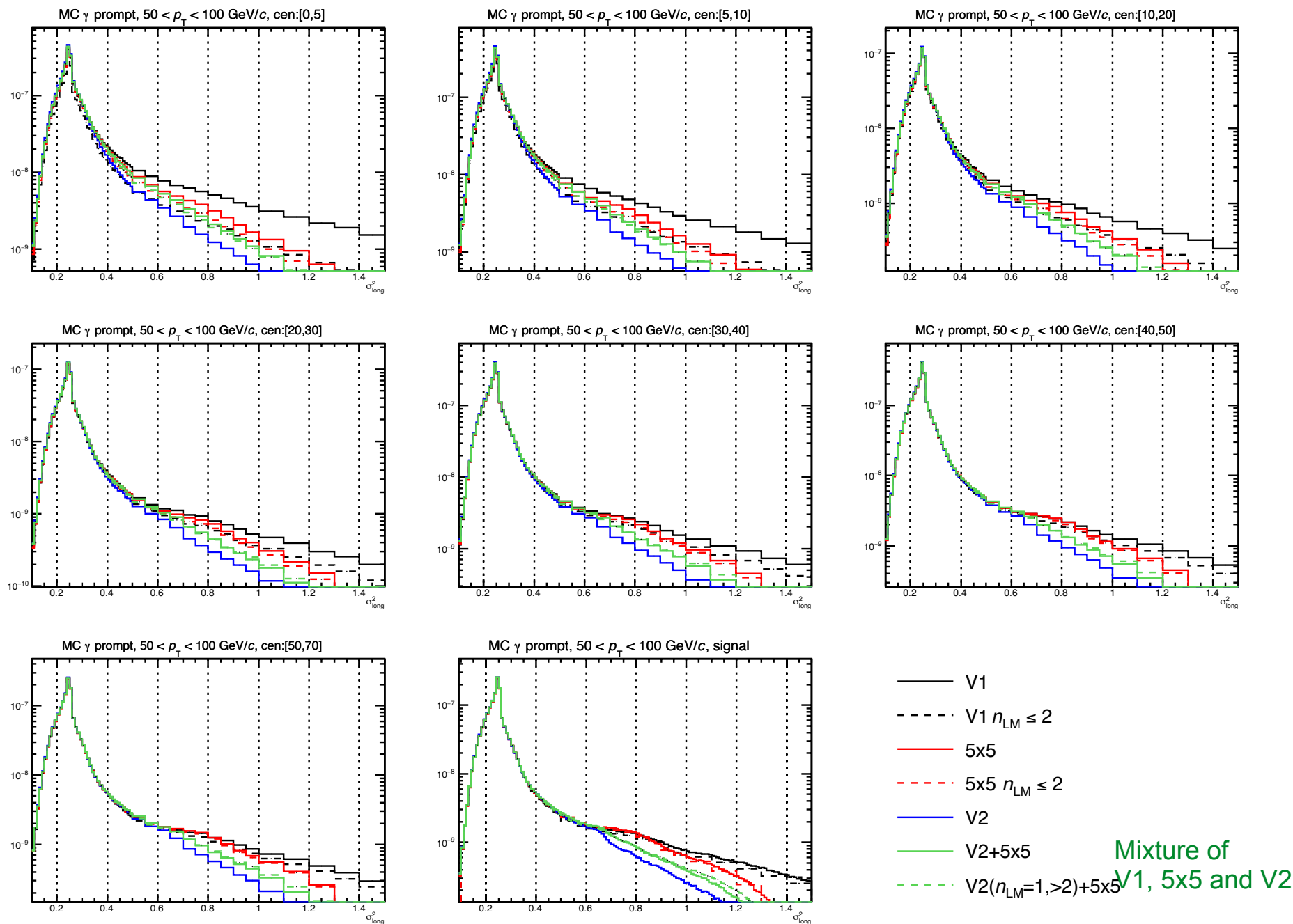
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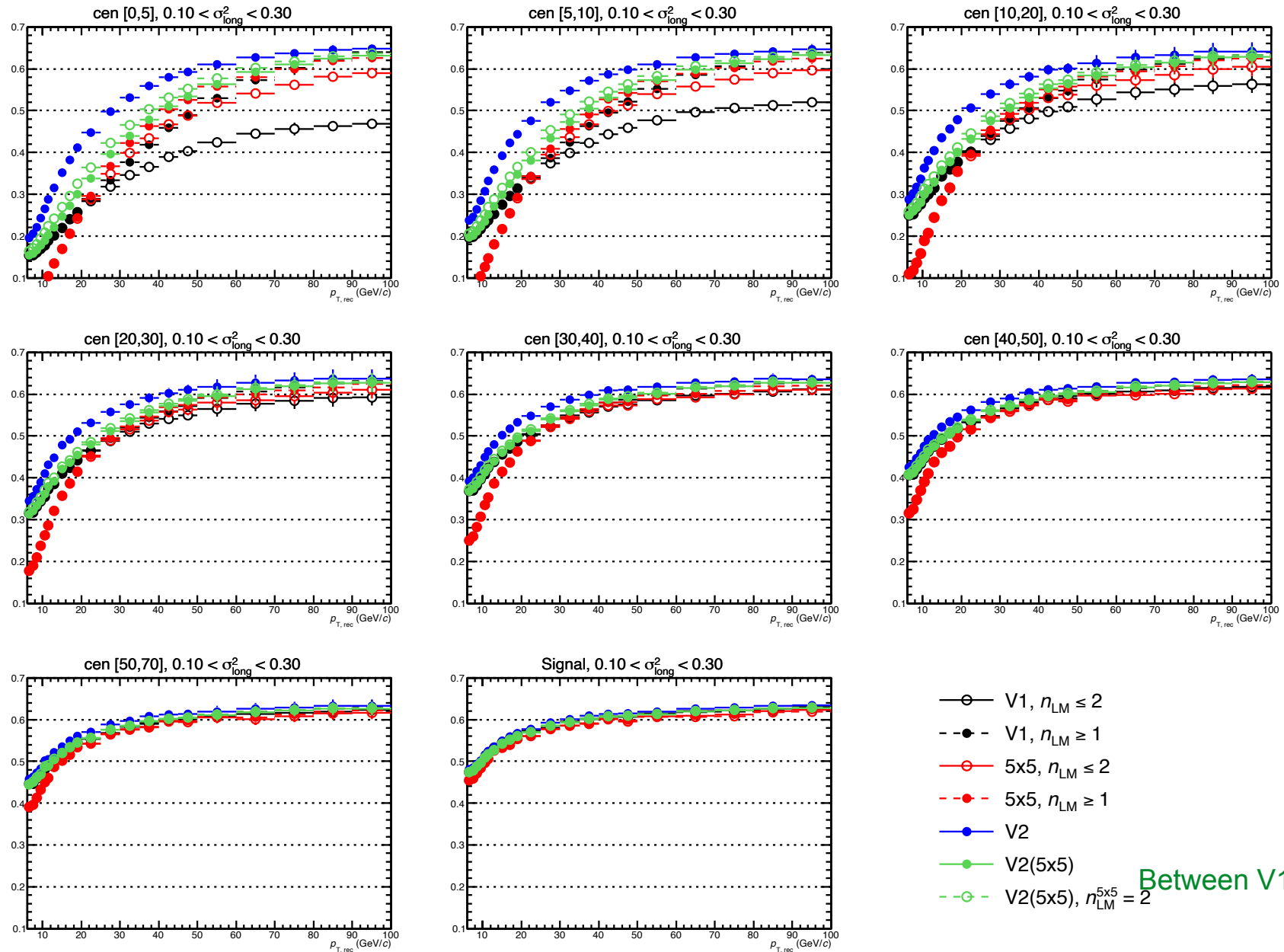
2 - σ^2_{long} of prompt γ : $50 < p_T < 100 \text{ GeV}/c$



- Distributions normalized to cross section
- UE of central events has a significant contribution to photons shape below approximately 20 GeV/c specially for 5x5 clusters
 - V2 less modified, as expected
 - V1 and V2 using 5x5 have similar performance in most centralities, less similar in central
- At high energies, for $\sigma^2_{\text{long}} < 0.4$ the distribution is basically the same for all cases in all centralities

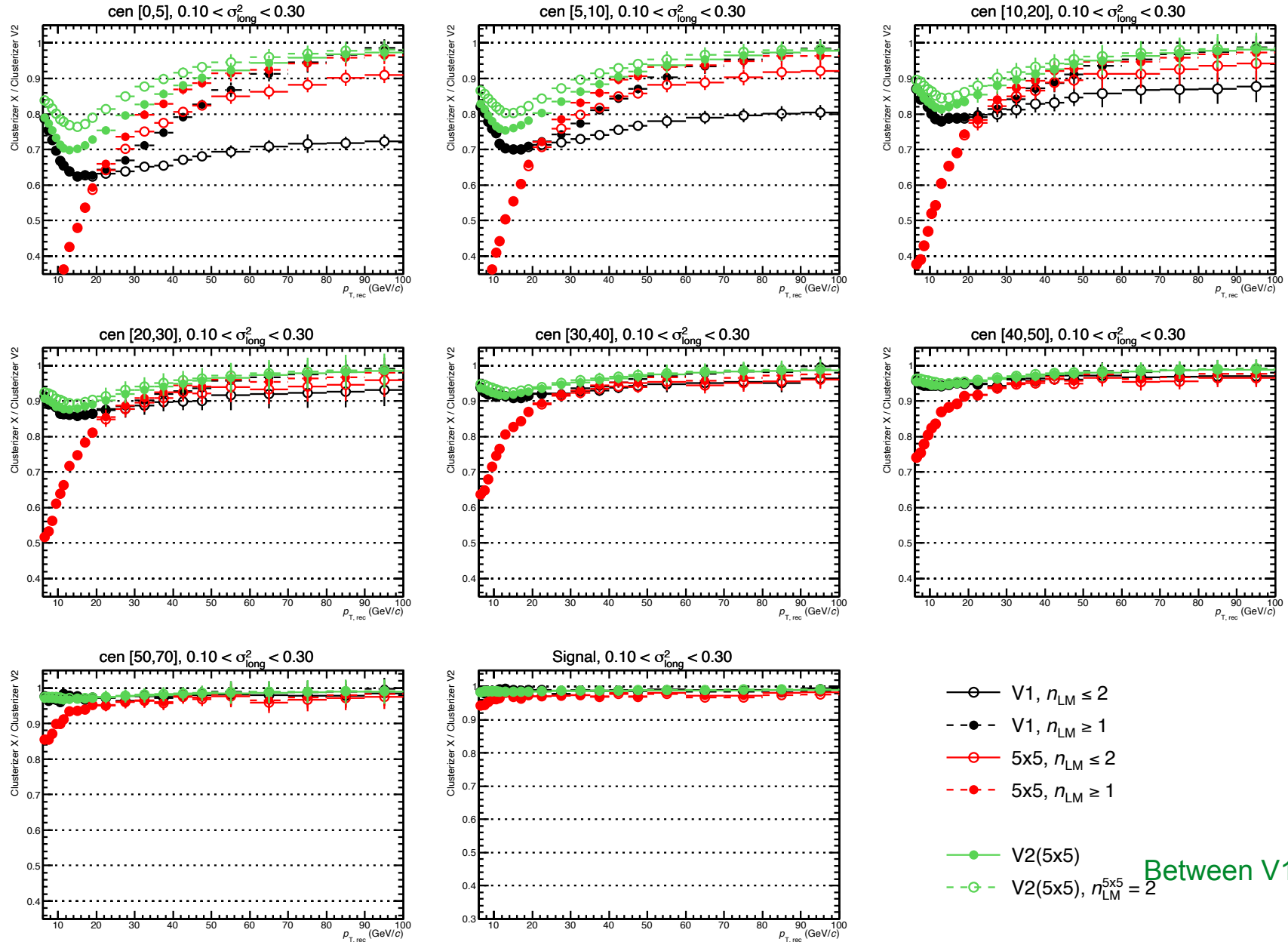
2 - Prompt γ reconstructed efficiency:

$p_{T, \text{reconstructed}} / p_{T, \text{generated}}, 0.1 < \sigma_{\text{long}}^2 < 0.3$

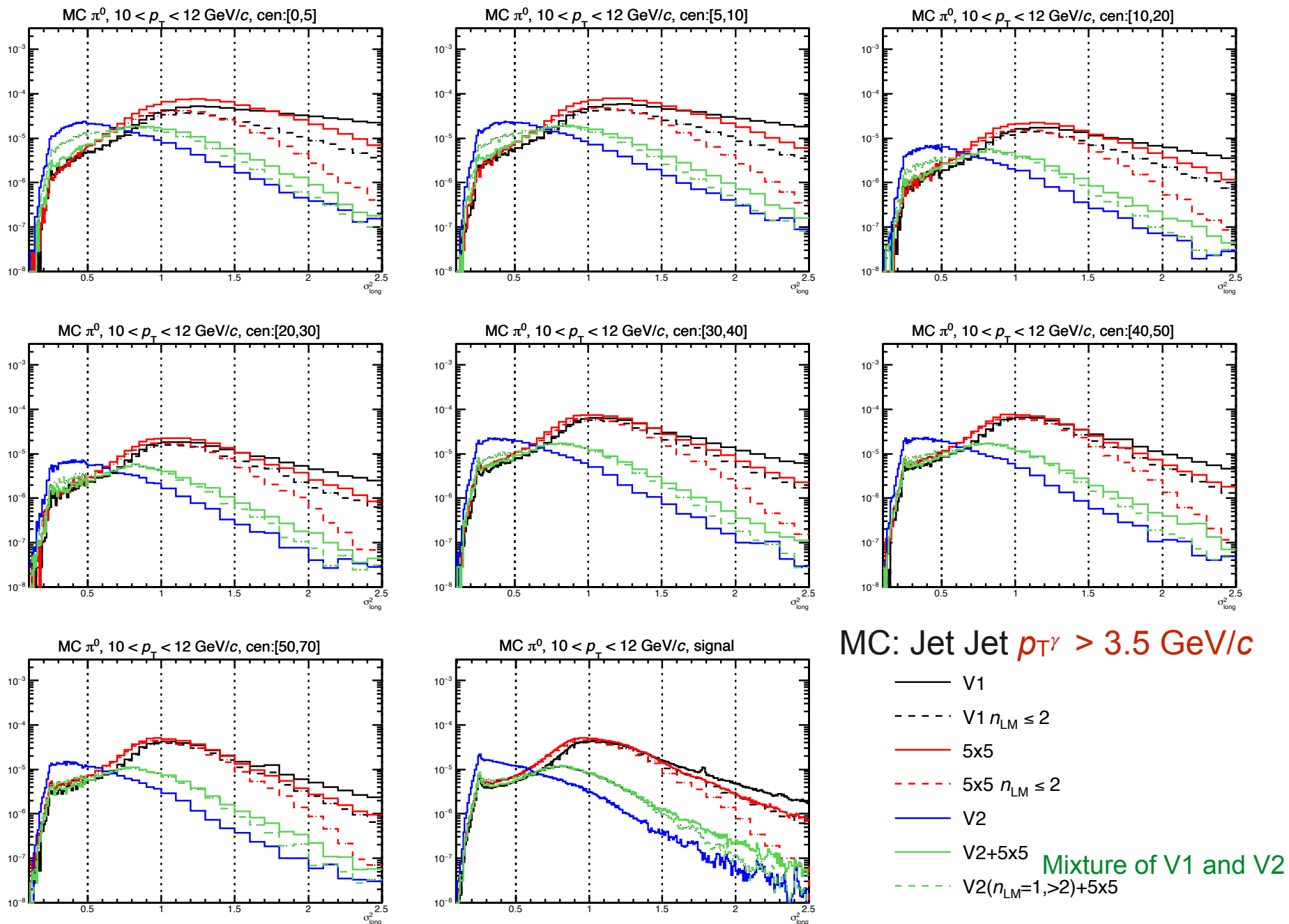


2 - Prompt γ reconstructed efficiencies ratio:

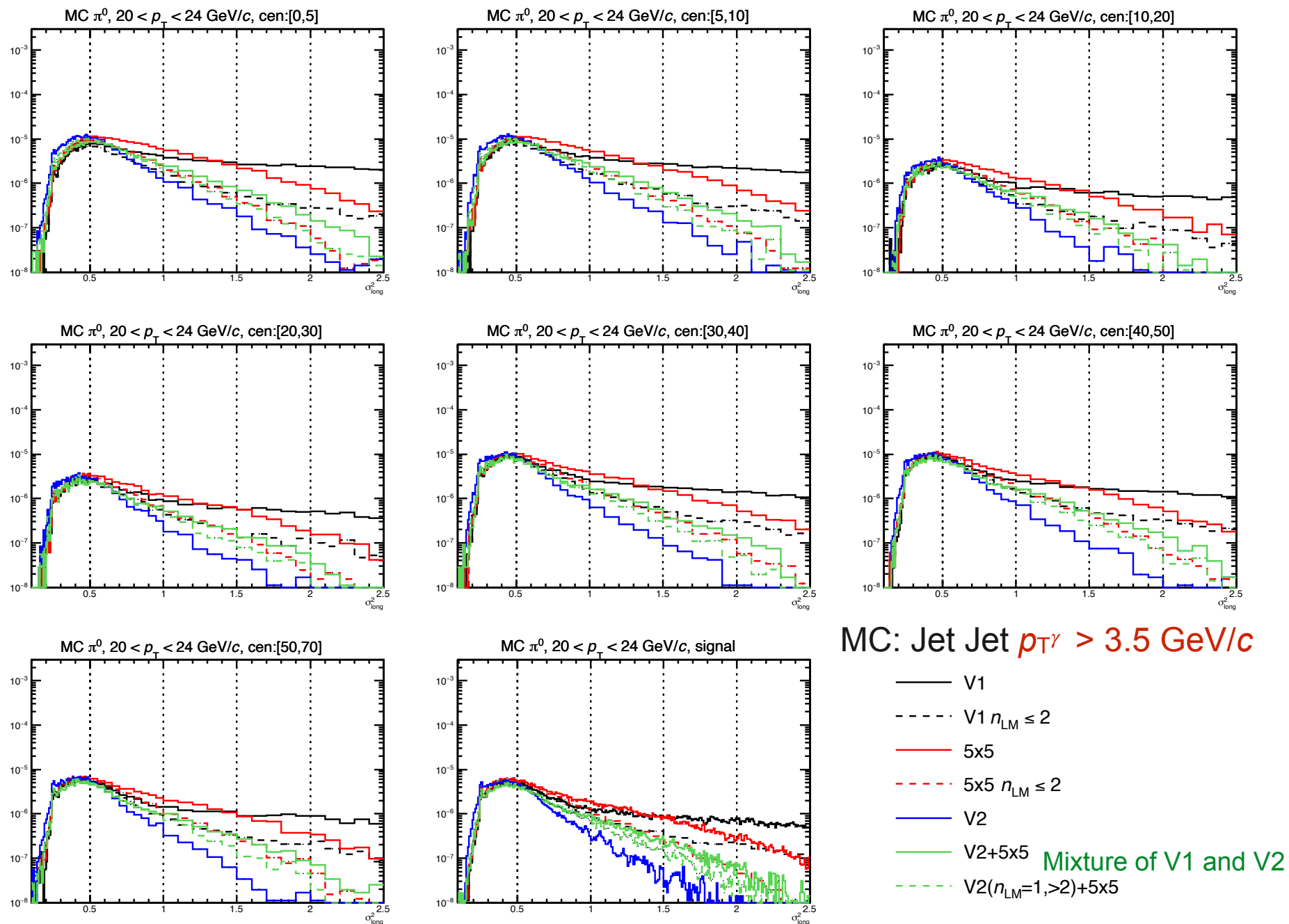
clusterizer Vx / clusterizer V2, $0.1 < \sigma_{\text{long}}^2 < 0.3$

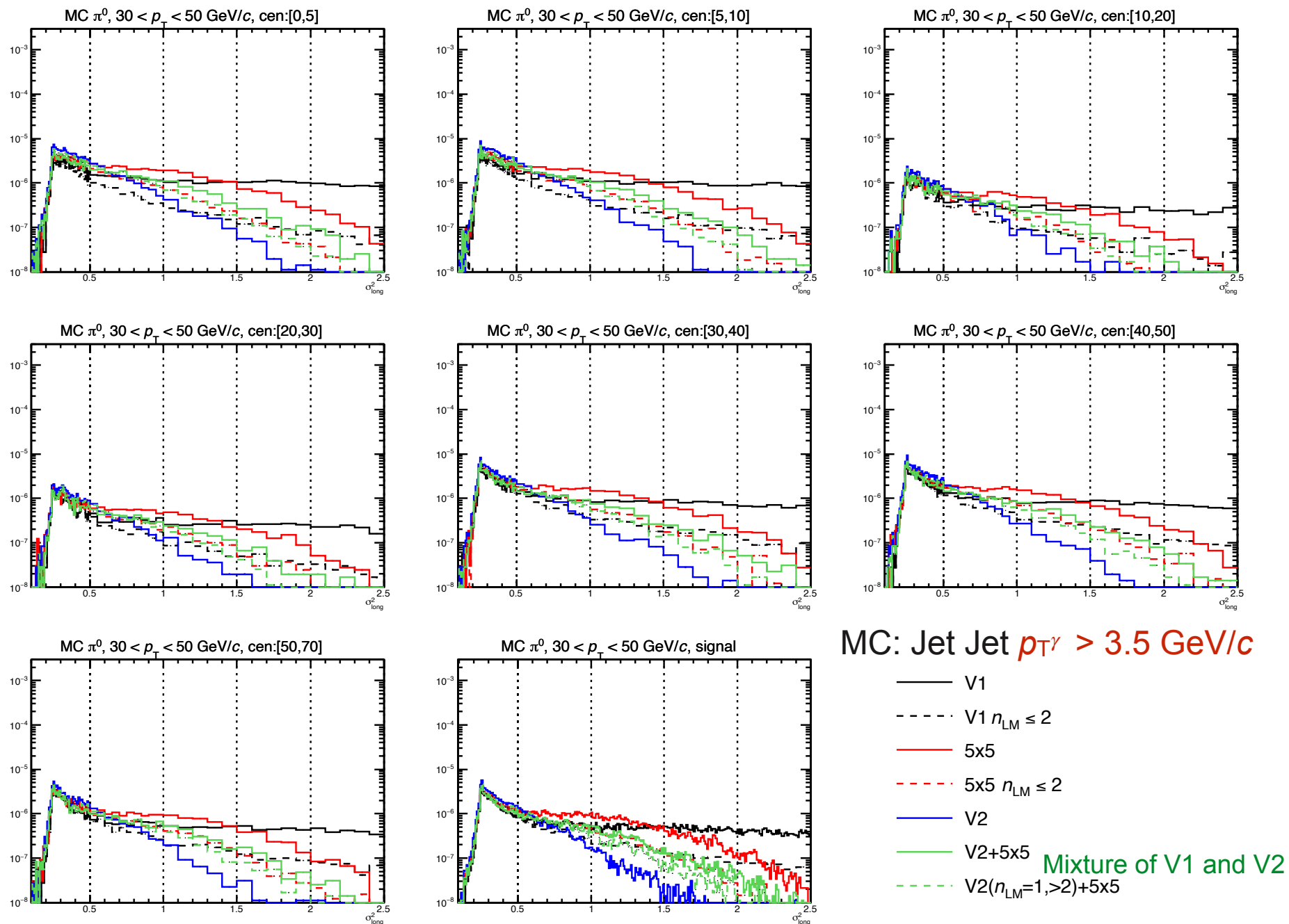


2 - σ^2_{long} of merged π^0 clusters: $10 < p_T < 12$ GeV/c



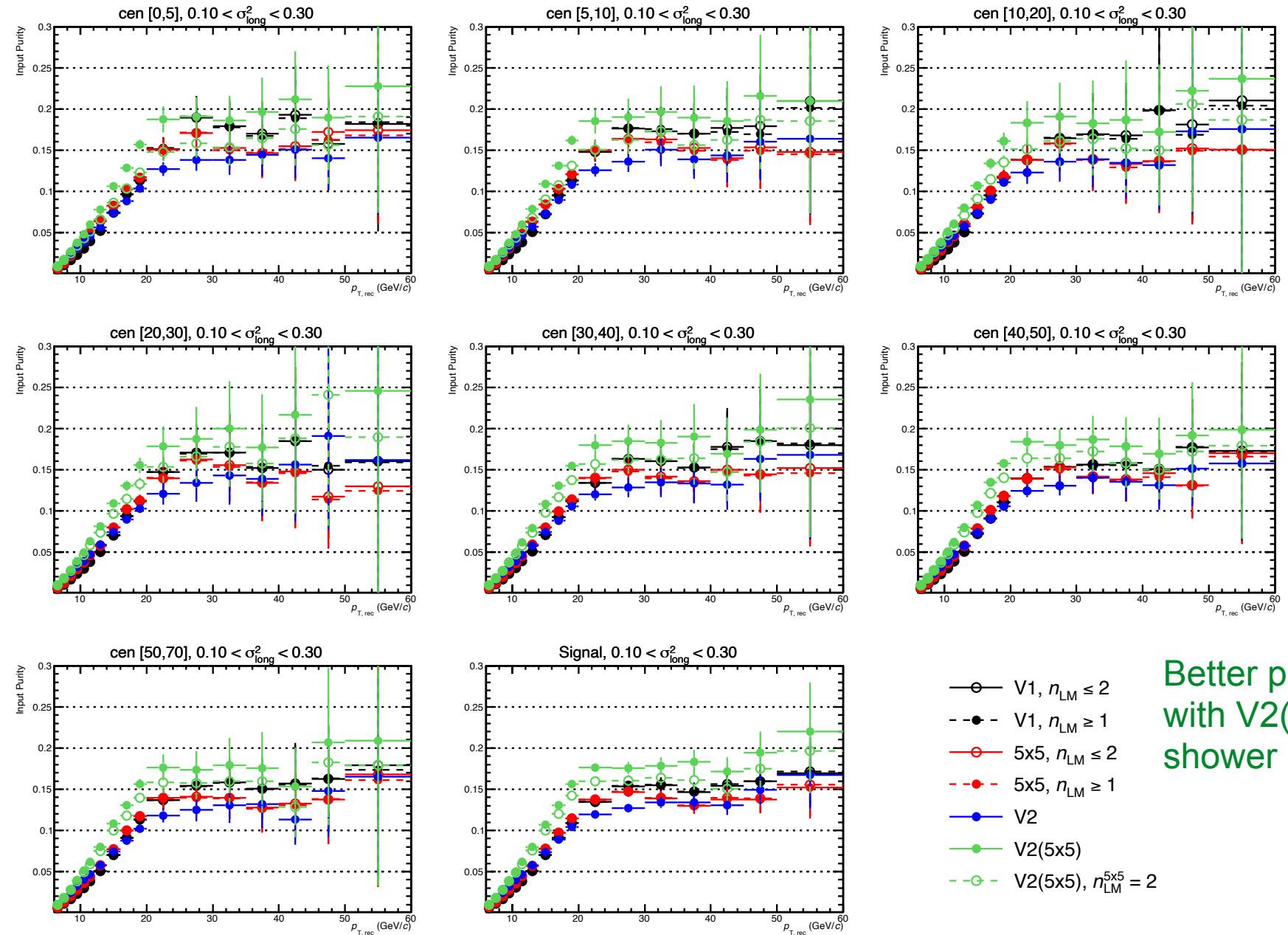
2 - σ^2_{long} of merged π^0 clusters: $20 < p_T < 24 \text{ GeV}/c$





- Distributions normalized to cross section
- UE of central events widens the π^0 merged photons clusters bump in the shower shape distribution
 - ▶ V2 and V2 using 5x5 less modified
 - ▶ V1 and 5x5 have similar performance
- Above 20 GeV, V1 and 5x5 with $n_{LM}=1,2$ similar σ^2_{long} as V2 using 5x5
- Below 20 GeV, V2 using 5x5 shows also the σ^2_{long} π^0 bump, less wide than in V1, and not present for V2
- What is the effect on the purity?
 - ▶ Next slides without isolation!

$$0.1 < \sigma_{\text{long}}^2 < 0.3$$

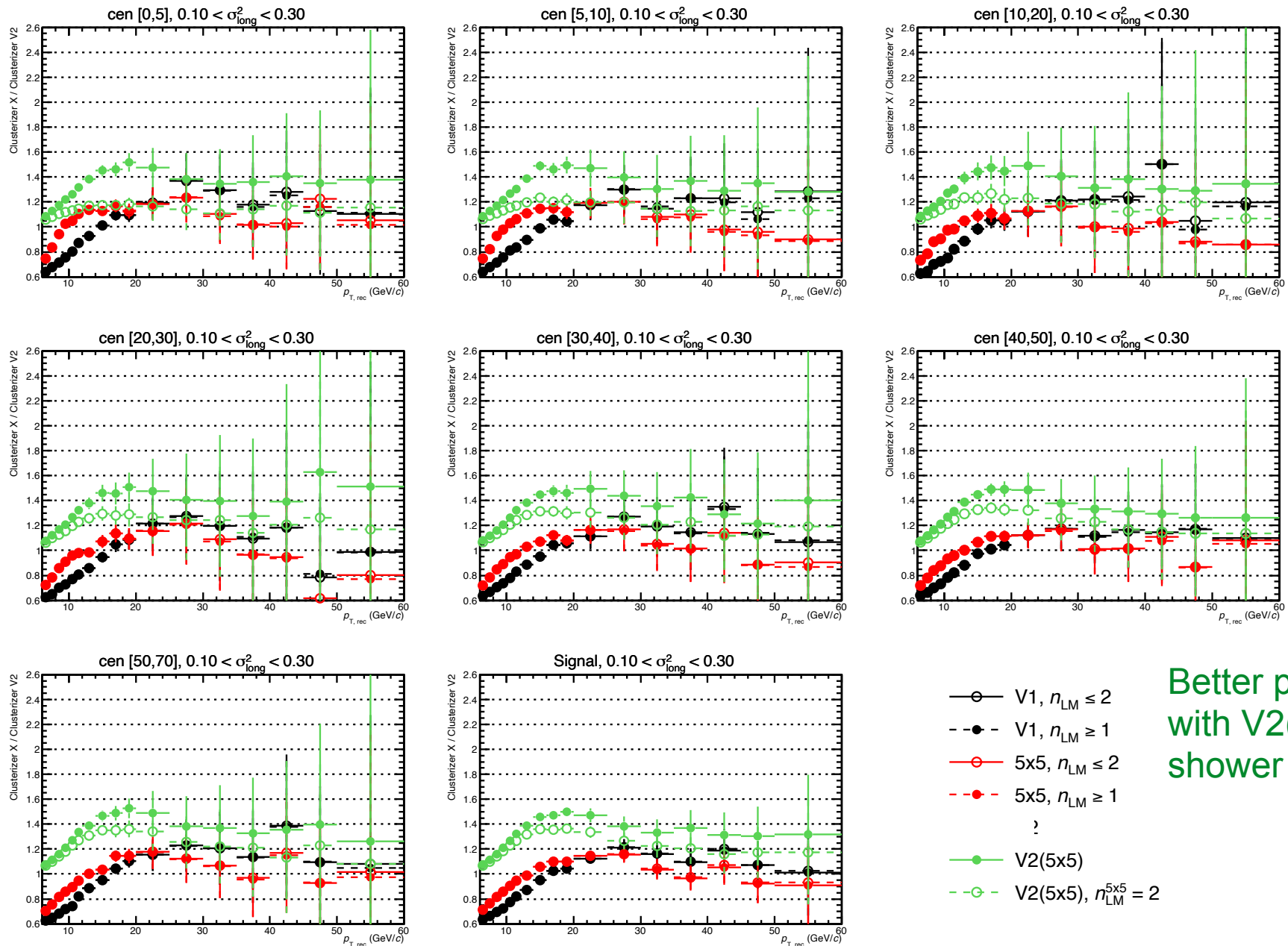


2 - MC purity ratio:

MC: Jet Jet $p_{T\gamma} > 3.5 \text{ GeV}/c$

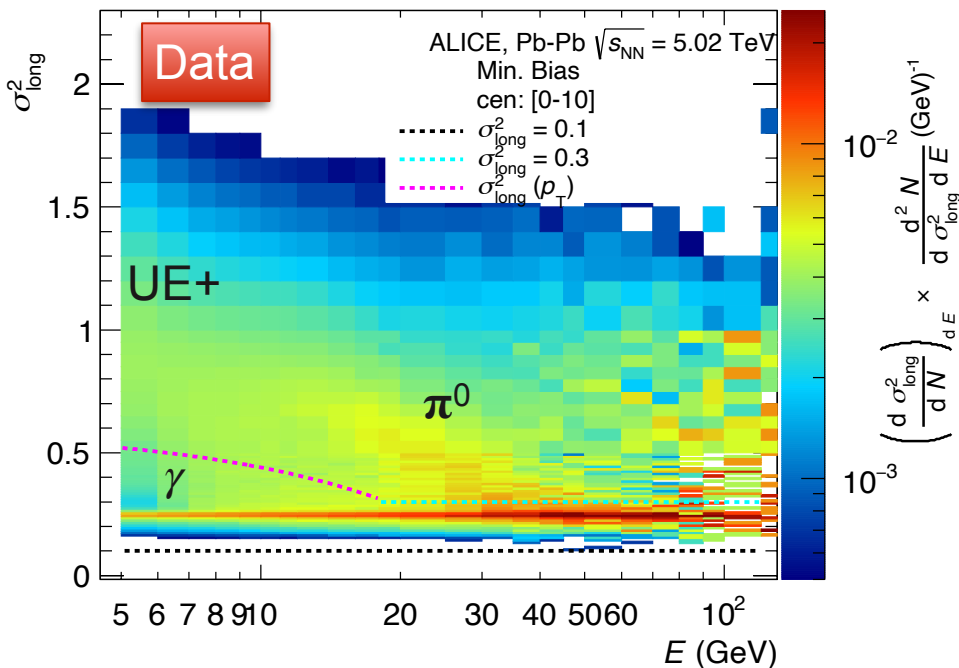
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clusterizer Vx / clusterizer V2, $0.1 < \sigma_{\text{long}}^2 < 0.3$

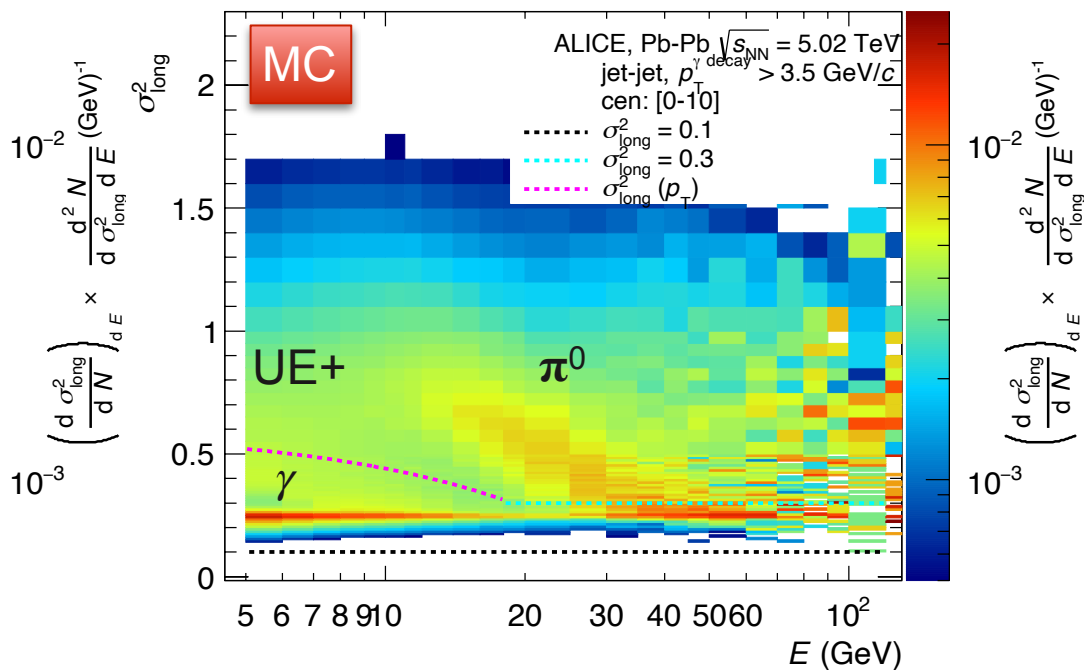
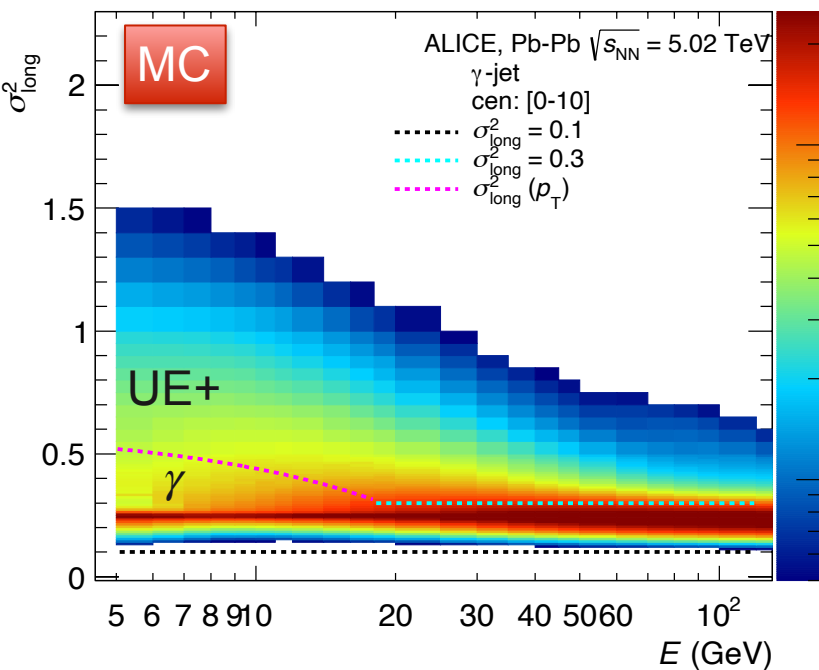


Better purity
with V2(5x5)
shower shape

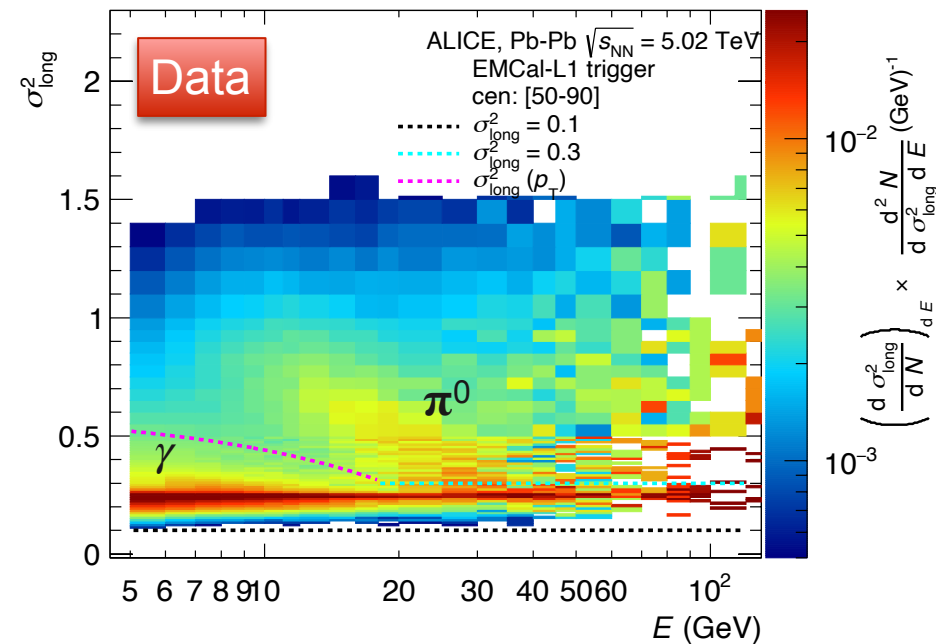
2- σ^2_{long} V2(5x5) - 0-10% (EMCal+DCal)



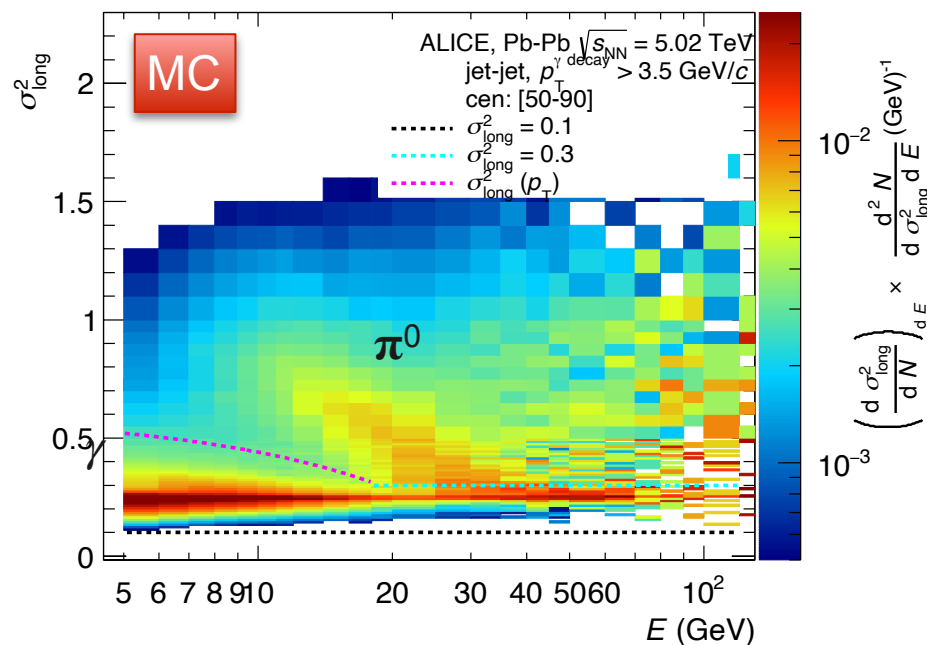
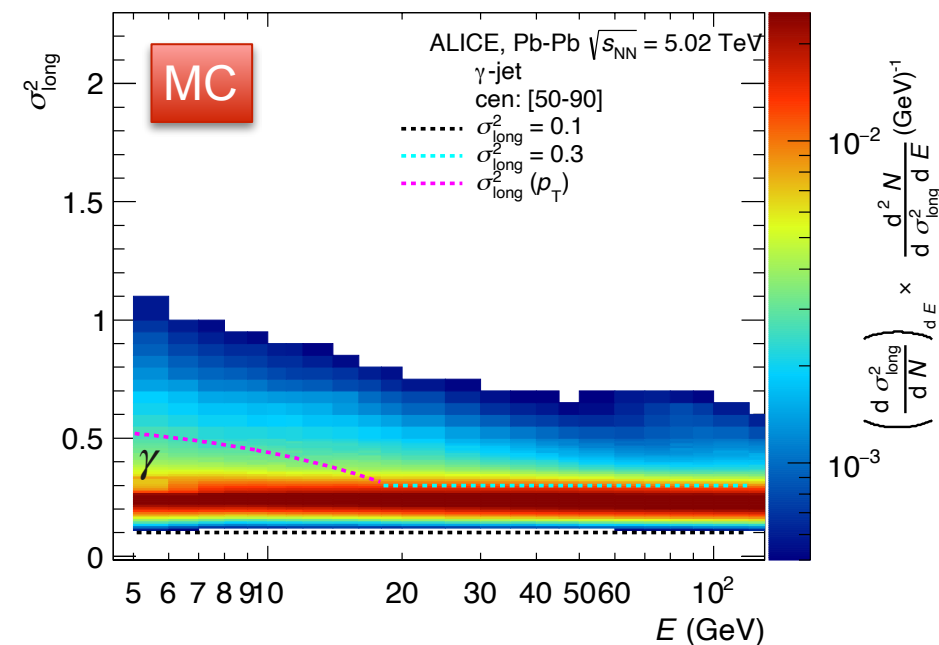
Suggest for photon selection:
Energy dependent cut below ~ 20 GeV:
 $0.1 < \sigma^2_{\text{long}} \text{ V2}(5 \times 5) < 0.6 + 0.016 p_{\text{T}}$
Above 20 GeV
 $0.1 < \sigma^2_{\text{long}} \text{ V2}(5 \times 5) < 0.3$



2- σ^2_{long} V2(5x5) - 50-90% (EMCal+DCal)

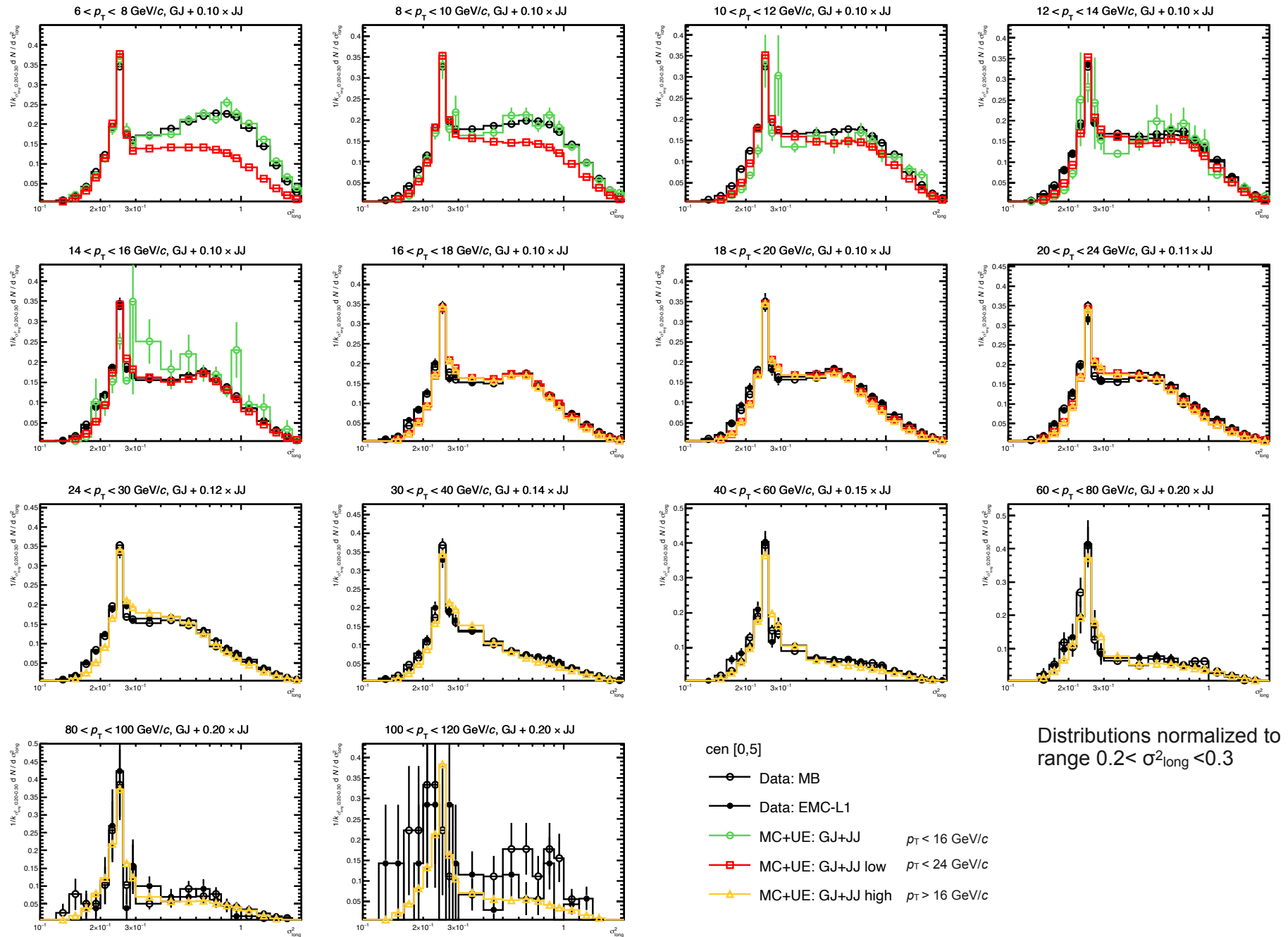


Suggest for photon selection:
Energy dependent cut below ~ 20 GeV:
 $0.1 < \sigma^2_{\text{long}} \text{ V2}(5 \times 5) < 0.6 - 0.016 p_T$
Above 20 GeV:
 $0.1 < \sigma^2_{\text{long}} \text{ V2}(5 \times 5) < 0.3$

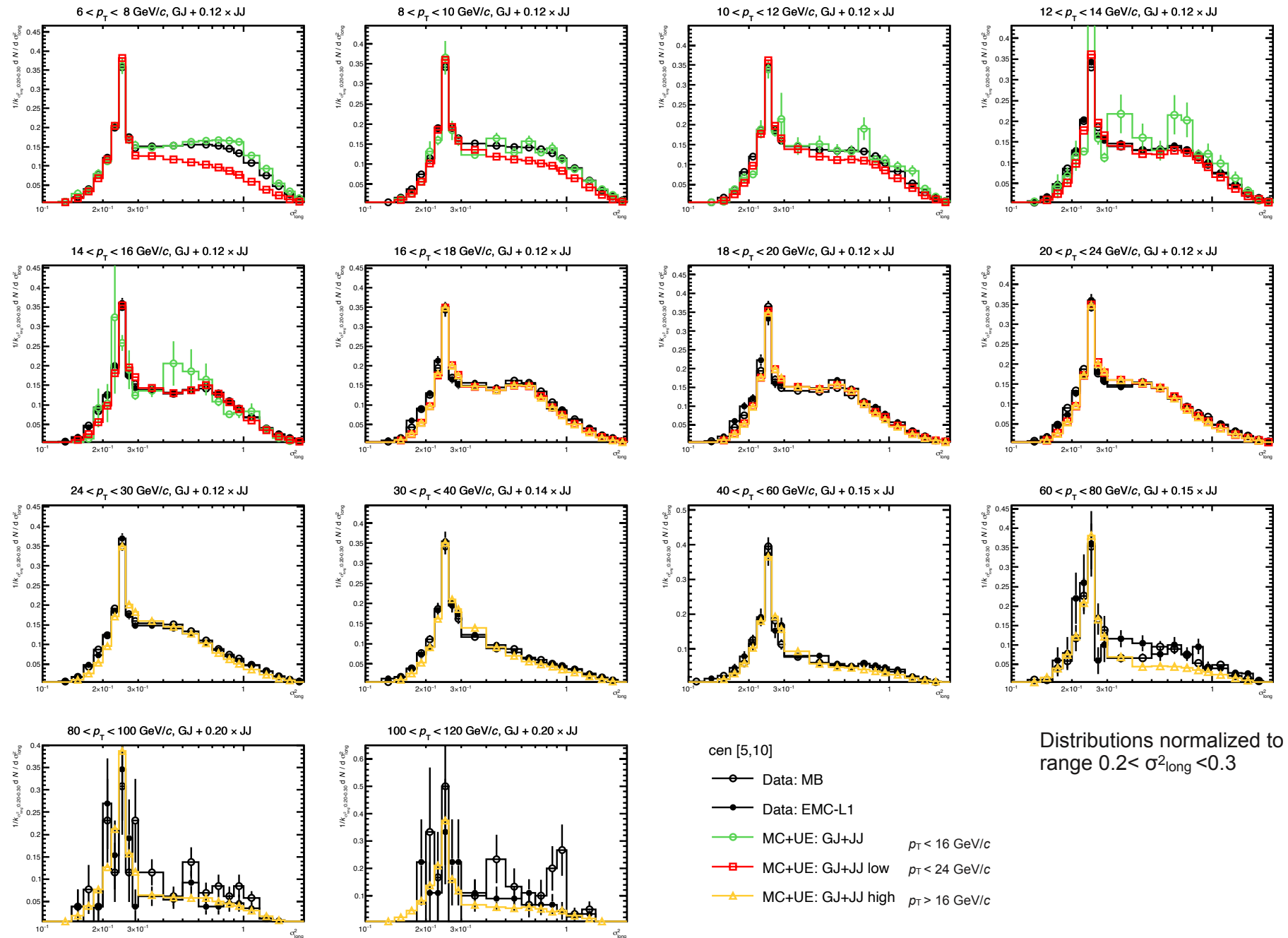


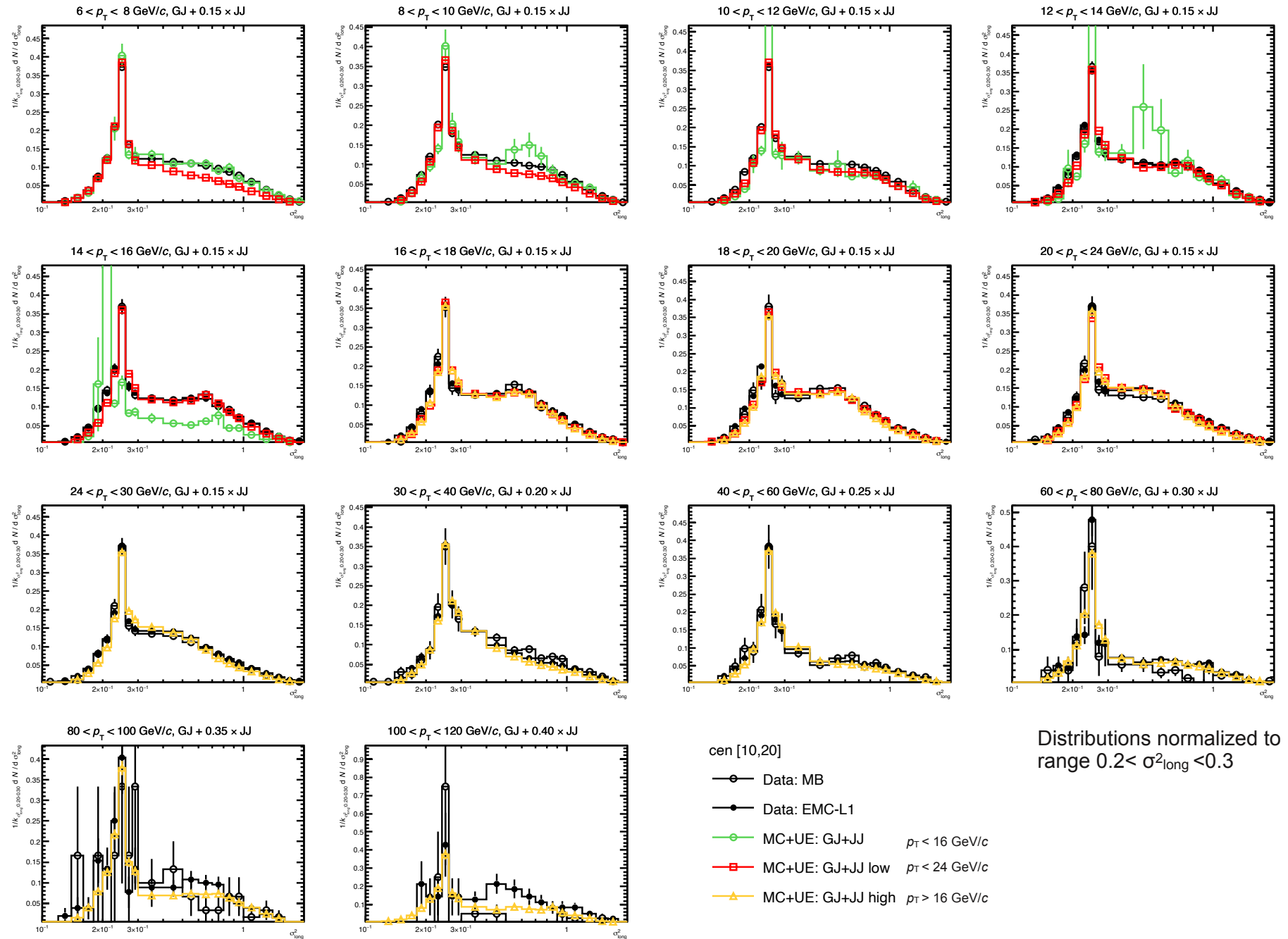
- V2 with shower shape recalculated in 5x5 window has better merged clusters rejection power than any of the clusterizers, specially in the region 10 to 20 GeV/c
- At least for Pb-Pb analysis, I would from now on use V2 clusterizer with shower shape recalculated in a 5x5 window
- Below 20 GeV, in order to improve efficiency, consider opening the cut with a simple p_T dependent function
 - ▶ Energy dependent cut below ~20 GeV: $0.1 < \sigma^2_{\text{long V2}(5 \times 5)} < 0.6 + 0.016 p_T$
 - ▶ Above 20 GeV: $0.1 < \sigma^2_{\text{long V2}(5 \times 5)} < 0.3$
- Next slides, compare data and MC with such shower shape definition to be sure it reproduces properly the data behavior
 - ▶ Need to scale down the jet-jet MC with respect the gamma-jet MC to have a better agreement

2 - σ^2_{long} v2(5x5) in Data and MC, 0-5%, MC JJ scaled down ~ 0.1 25 / 83



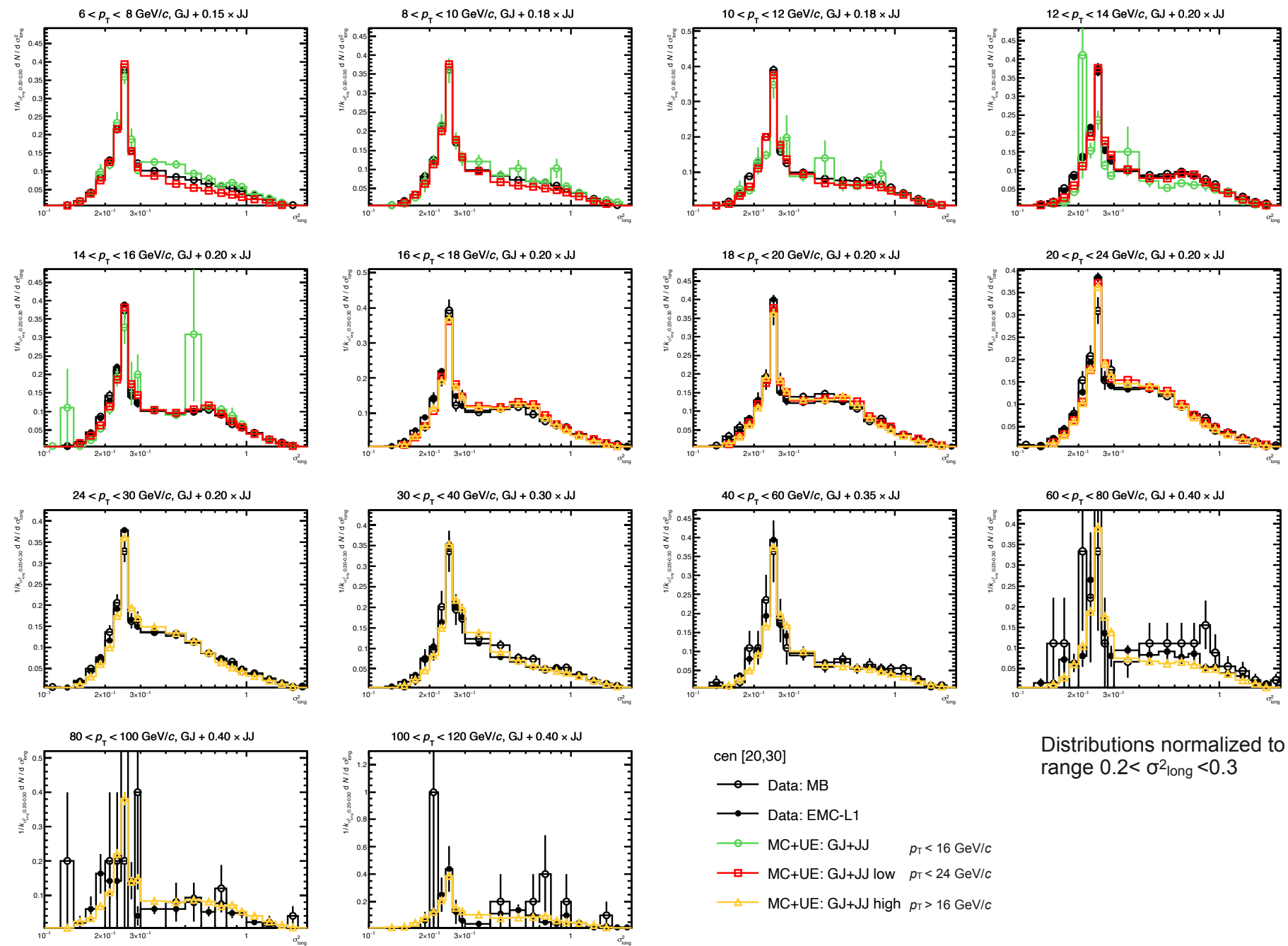
2 - σ^2_{long} v2(5x5) in Data and MC, 5-10%, MC JJ scaled down ~ 0.12 26 / 83

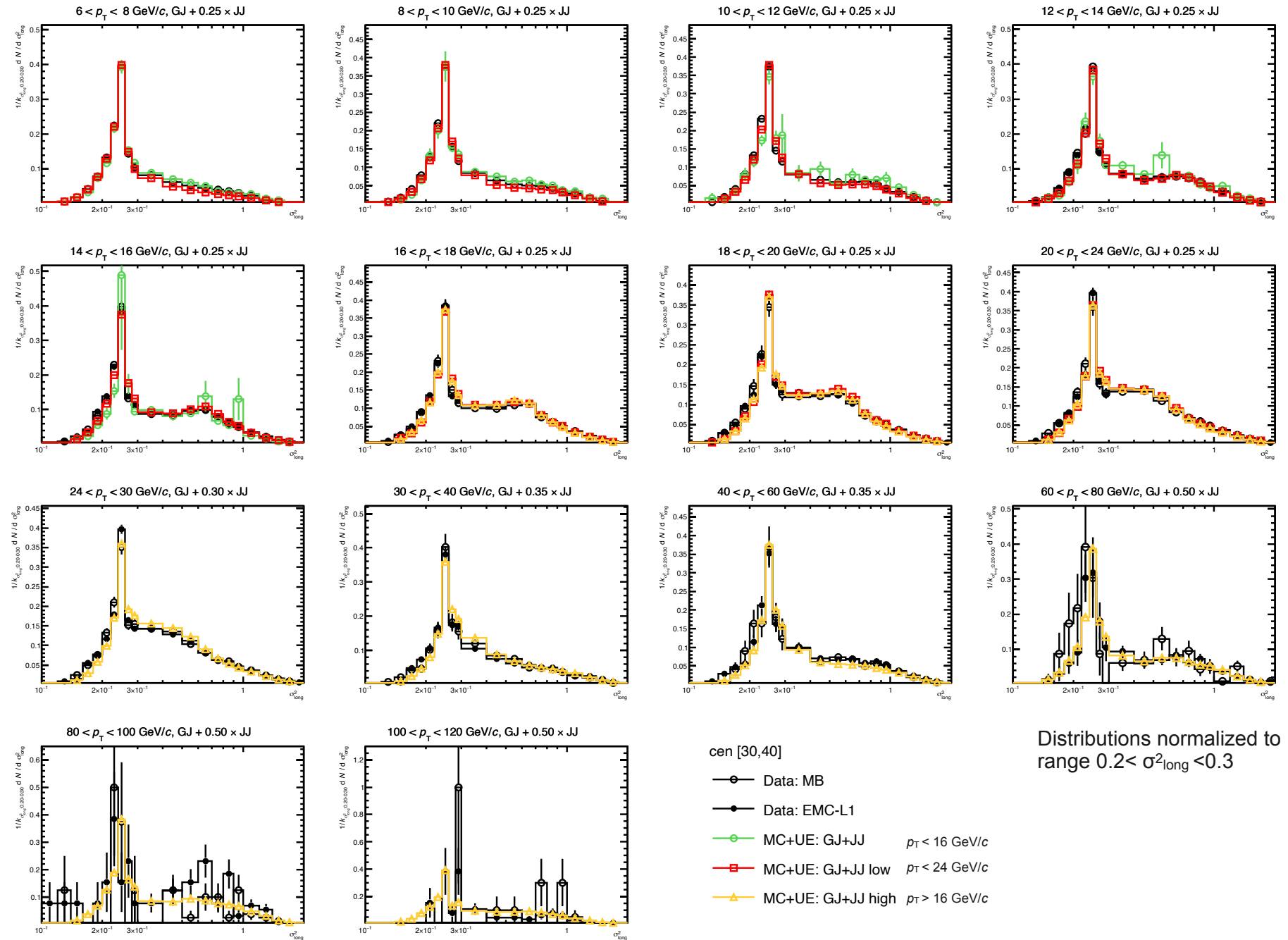




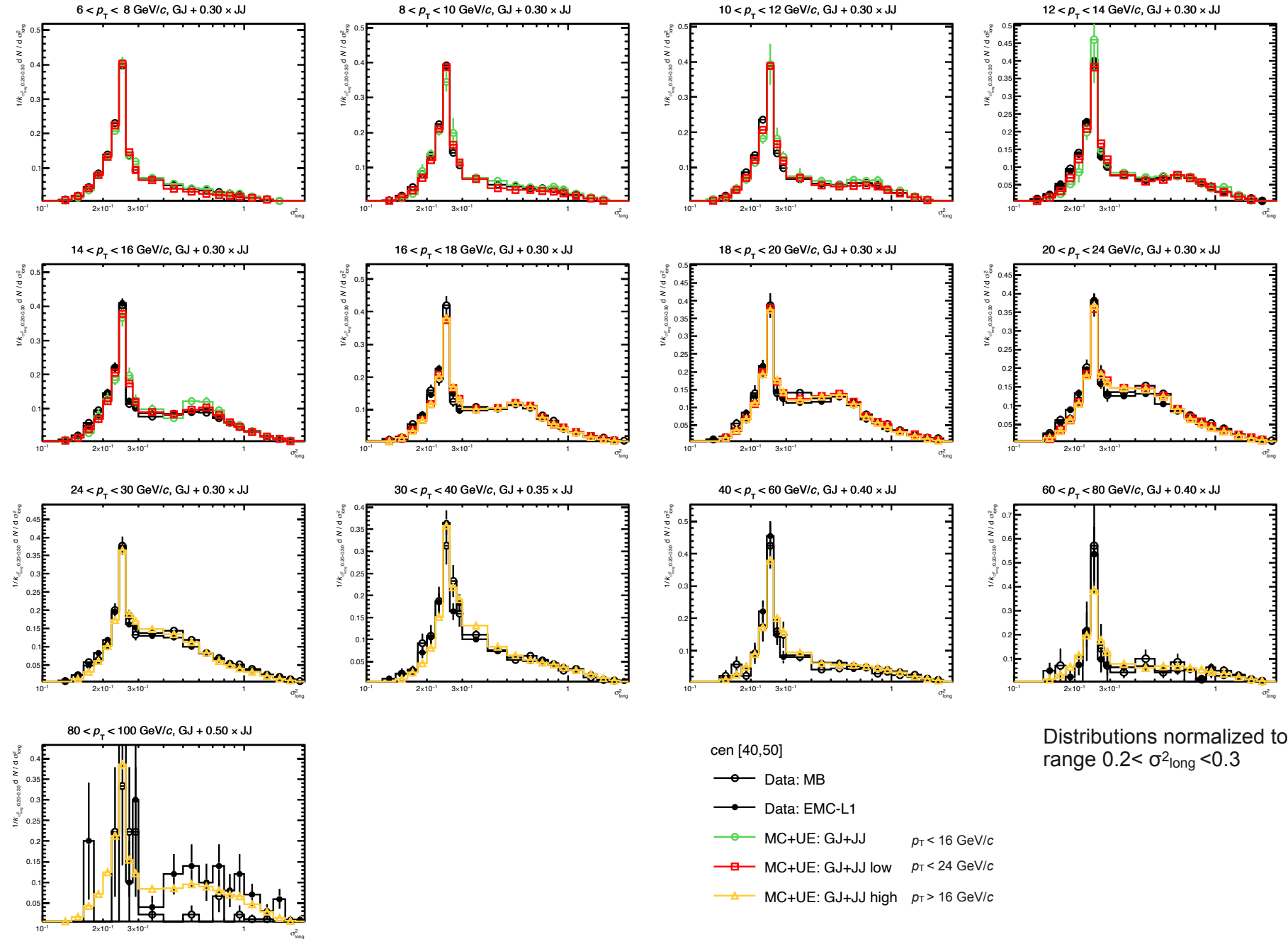
2 - σ^2_{long} v2(5x5) in Data and MC, 20-30%, MC JJ scaled down ~ 0.20

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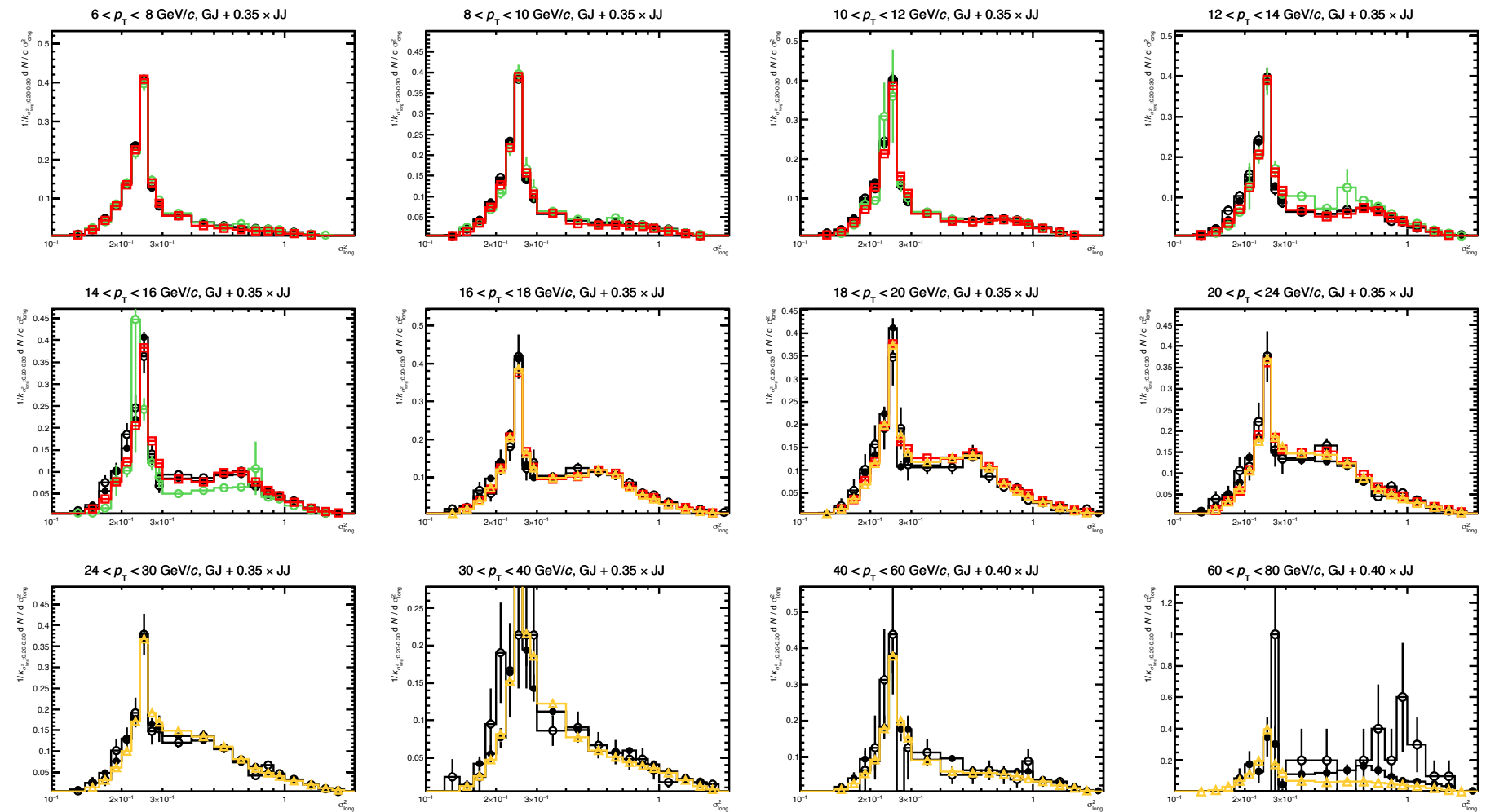


2 - σ^2_{long} v2(5x5) in Data and MC, 40-50%, MC JJ scaled down ~ 0.30



2 - σ^2_{long} v2(5x5) in Data and MC, 50-70%, MC JJ scaled down ~ 0.35

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cen [50,70]

—○— Data: MB

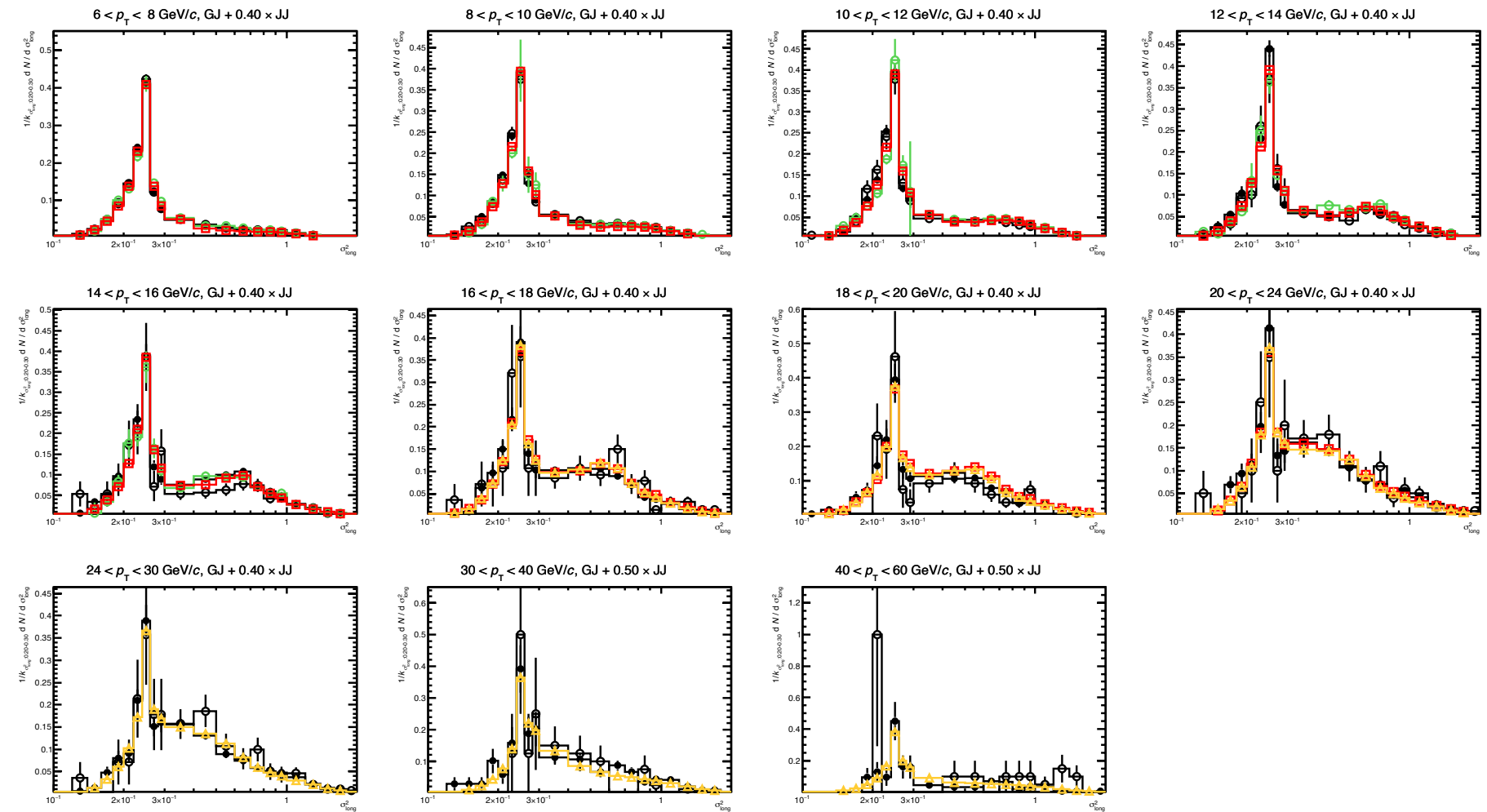
—●— Data: EMC-L1

—○— MC+UE: GJ+JJ $p_T < 16$ GeV/c

—□— MC+UE: GJ+JJ low $p_T < 24$ GeV/c

—△— MC+UE: GJ+JJ high $p_T > 16$ GeV/c

Distributions normalized to
range $0.2 < \sigma^2_{\text{long}} < 0.3$



cen [70,90]

○ Data: MB

● Data: EMC-L1

○ MC+UE: GJ+JJ $p_T < 16$ GeV/c

■ MC+UE: GJ+JJ low $p_T < 24$ GeV/c

▲ MC+UE: GJ+JJ high $p_T > 16$ GeV/c

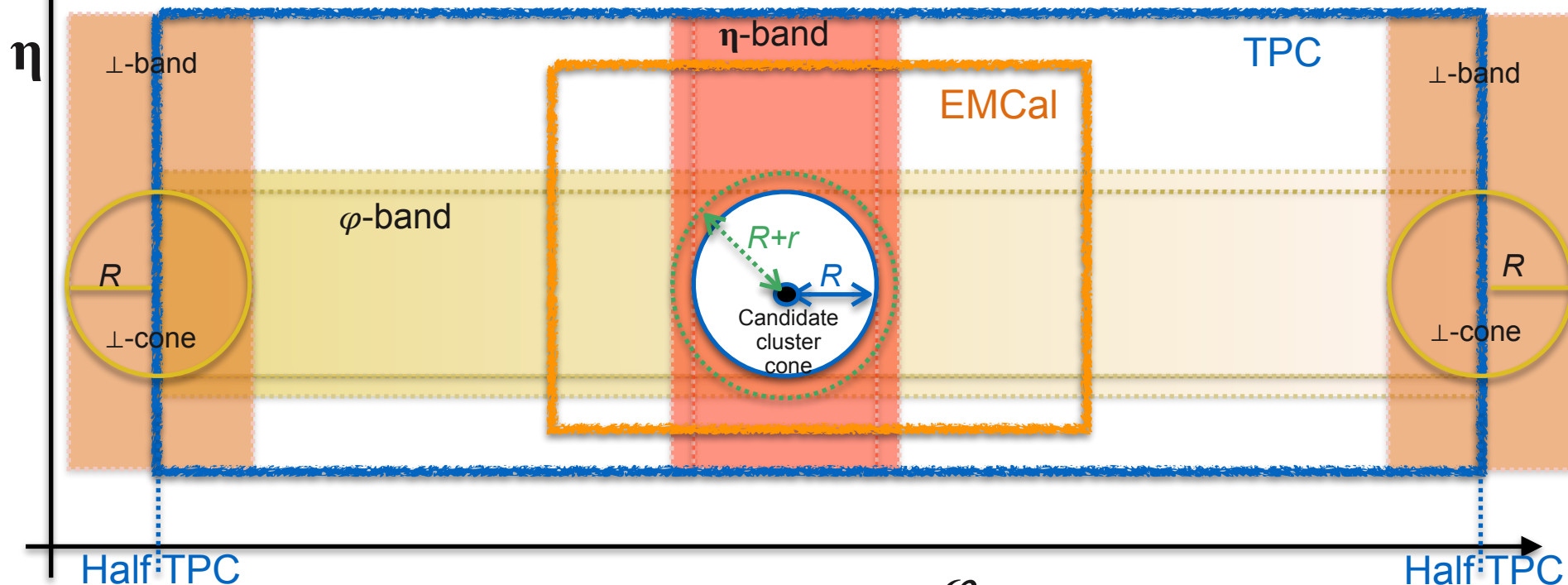
Distributions normalized to
range $0.2 < \sigma^2_{\text{long}} < 0.3$

2 - Conclusion on shower shape and clusterization

- V2 clusterizer with σ^2_{long} for 5x5 at least on Pb-Pb is selected for isolated photon analysis
- MC of pp events (jet-jet+ γ -jet) embedded on MB data reproduces reasonably the cluster shower shape behaviour in data from 6 to 100 GeV/c when properly scaling down jet-jet MC biased and unbiased samples.
 - ▶ Need to find a reasoning for the found values
 - ▶ Also reasonable agreement with other clusterizer and in more differential checks, per supermodule and per pseudorapidity window and per sector
- Biased jet-jet MC events assumed to be usable from cluster $p_T \sim 2 \times 3.5 = 7$ GeV/c but apparently still biased in central events between $8 < p_T < 12$ GeV/c, no bias observable in non central events
 - ▶ Below 12 GeV/c it is better to use unbiased jet-jet at least in central events or we need to check carefully those bins using biased productions.

3 - Isolation in Pb-Pb: p_T^{iso} and UE energy estimation methods 34 / 83

- Different cone sizes studied: $R = 0.2, 0.4$ (0.15, 0.3, also available)
- Different UE energy density (ρ) in cone estimators:



- Isolation cone energy: $p_T^{\text{iso}} = \Sigma p_T^{\text{tracks in cone}} - \rho \pi R^2$

ϕ

- Jet ρ sparse and non sparse estimator (used as black box):

- AddTaskEmcalJet("usedefault", "", AliJetContainer::kt_algorithm, 0.2, AliJetContainer::kChargedJet, 0.15, 0, 0.005, AliJetContainer::E_scheme, "Jet", 0., kFALSE, kFALSE)
- Sparse: AddTaskRhoSparse("usedefault", "usedefault", "Rho", 0.2, AliEmcalJet::kTPCfid, AliJetContainer::kChargedJet, AliJetContainer::E_scheme, kTRUE)
- Non sparse: AddTaskRhoNew("usedefault", "usedefault", "Rho", 0.2, AliEmcalJet::kTPCfid, AliJetContainer::kChargedJet, kFALSE, AliJetContainer::E_scheme, "")
- Set option to exclude 2 leading jets (tried with 4 also but nothing changes)

p_T in $R < 0.05$ not counted (UE density correction considers this hole)
It does not affect the discussion here, same thing observed without this condition.

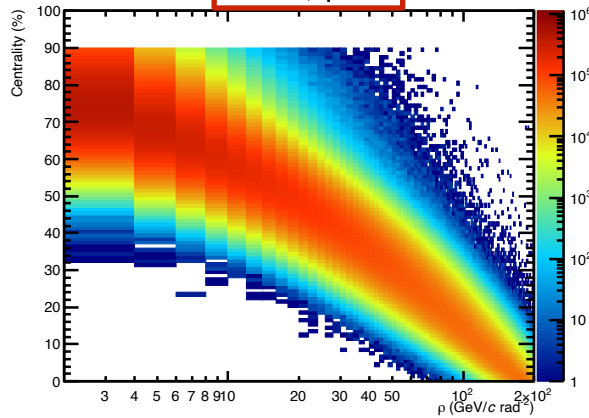
For η and ϕ -bands, an additional gap is considered so that only the region above $R+r=R+0.1$ is considered to avoid any jet constituents bias. It also does not change with or without the gap

3 - UE energy density ρ , $R = 0.2$

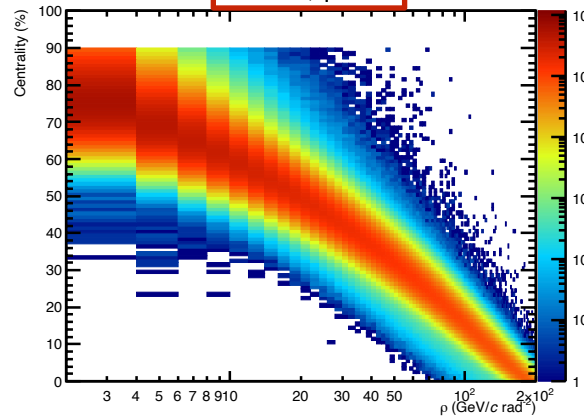
Track $p_T > 0.15$ GeV/c

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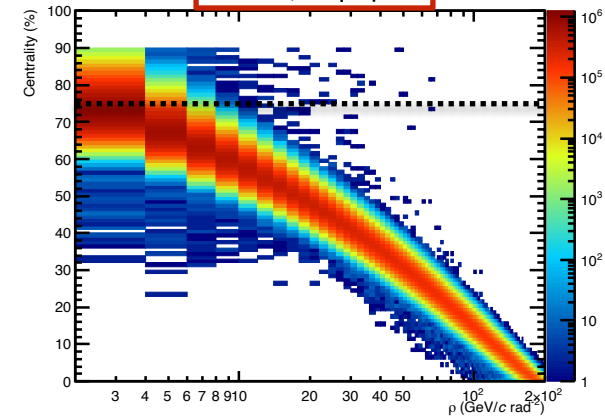
$R = 0.20$, η -Band



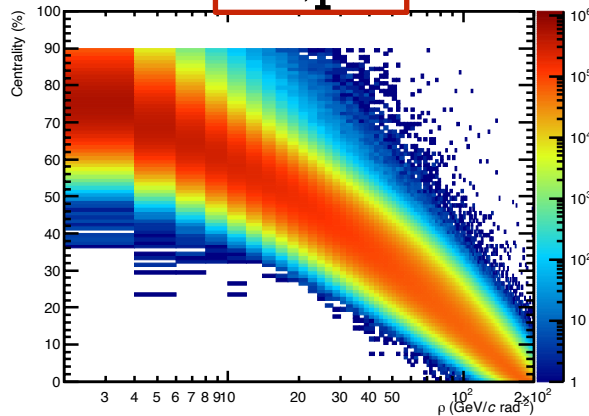
$R = 0.20$, φ -Band



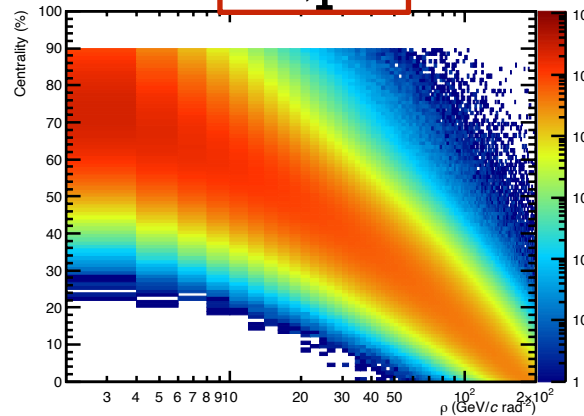
$R = 0.20$, Jet ρ Sparse



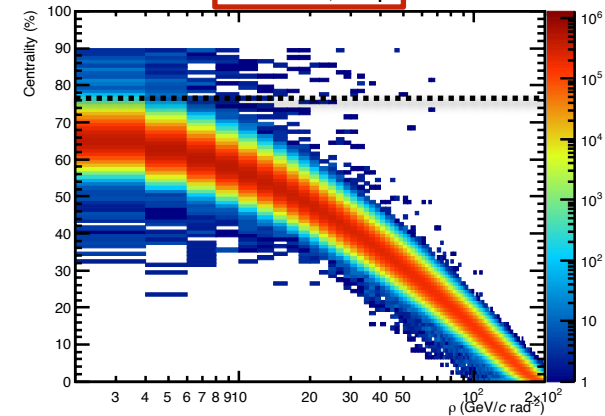
$R = 0.20$, η -Bands



$R = 0.20$, η -Cones



$R = 0.20$, Jet ρ



Less wide energy density band with the jet estimator, in part due to the more acceptance inspected.

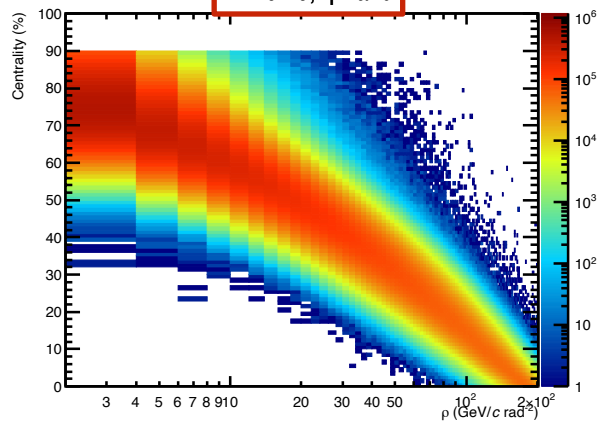
The non sparse jet estimator can be used for centrality < 70 % approx.
Performance below 70% is similar to sparse estimator so let's use this one.

3 - UE energy density ρ , $R = 0.4$

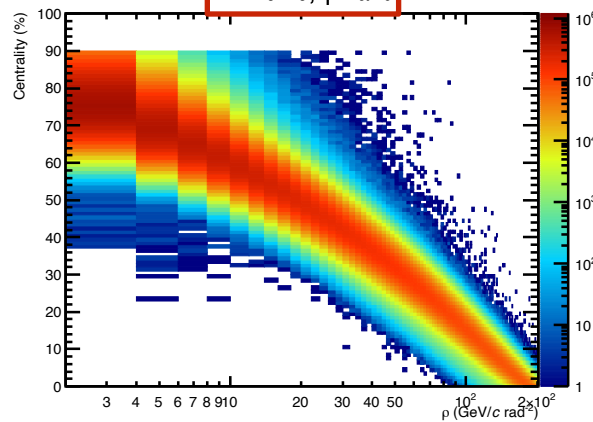
Track $p_T > 0.15$ GeV/c

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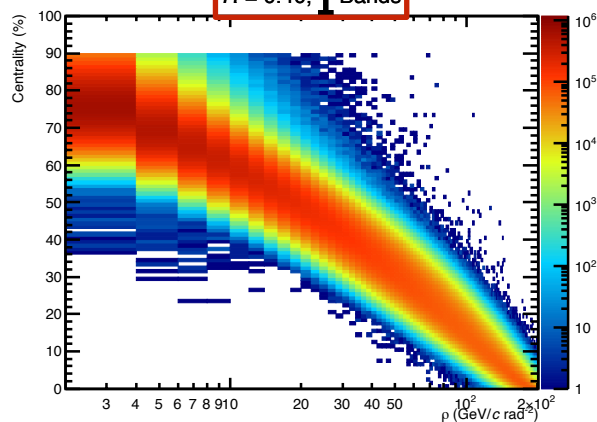
$R = 0.40$, η -Band



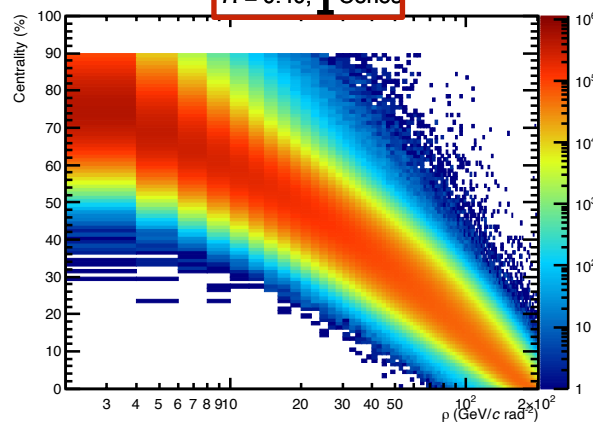
$R = 0.40$, φ -Band



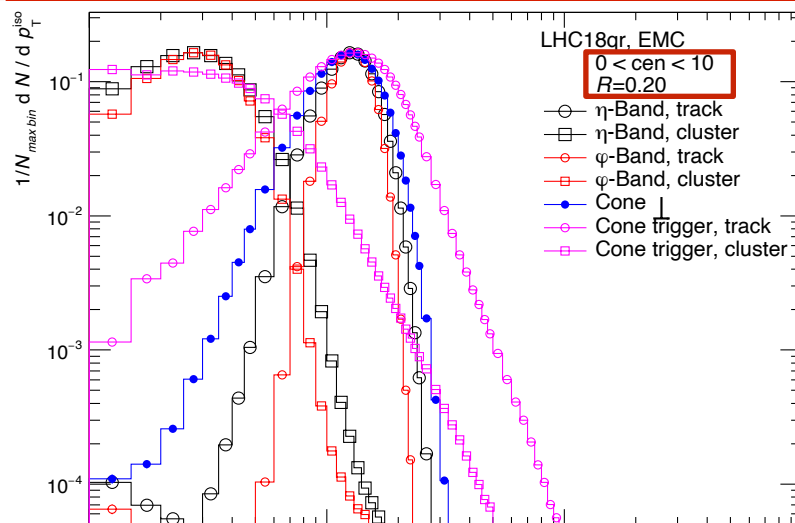
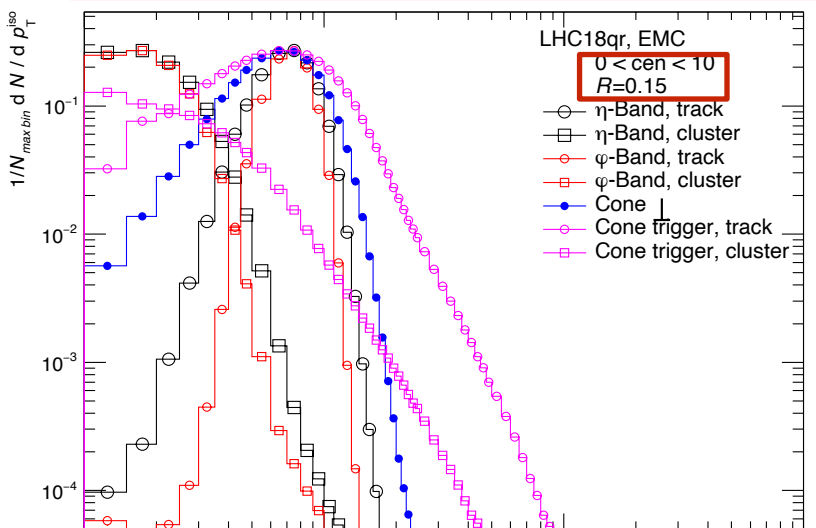
$R = 0.40$, $\perp$ -Bands



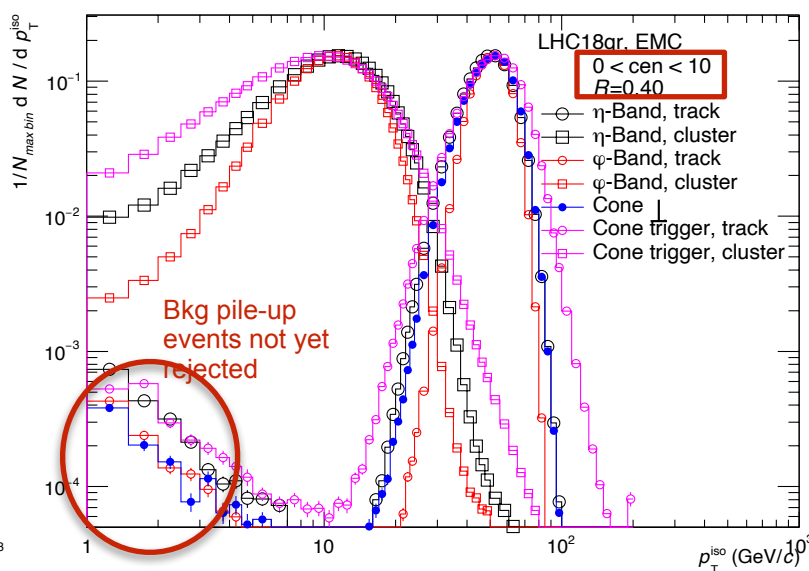
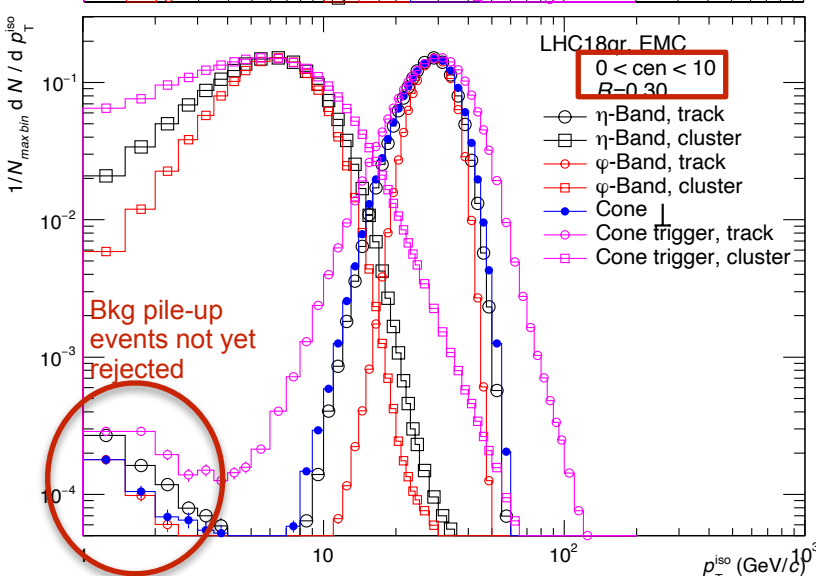
$R = 0.40$, $\perp$ -Cones



Increasing R reduces a bit the width of the distributions, more significantly for the perpendicular cones case



Distributions normalized to the maximum



UE bands energy normalized to trigger cone size

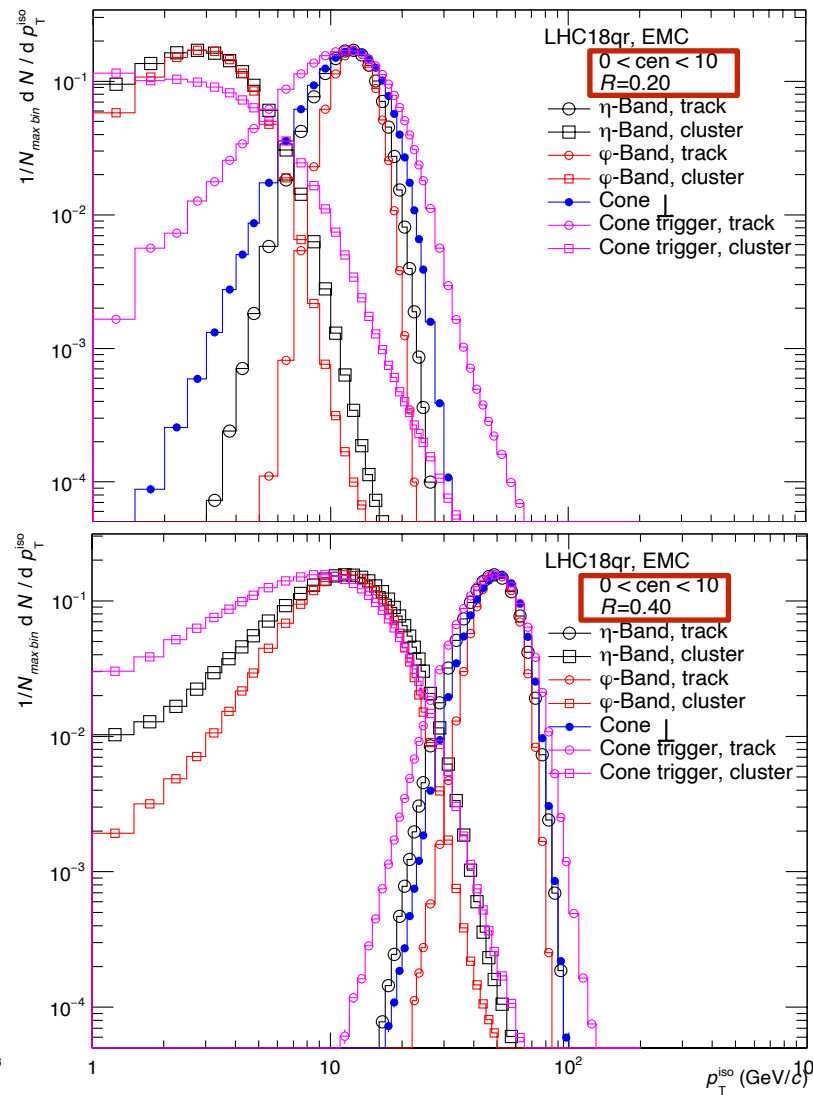
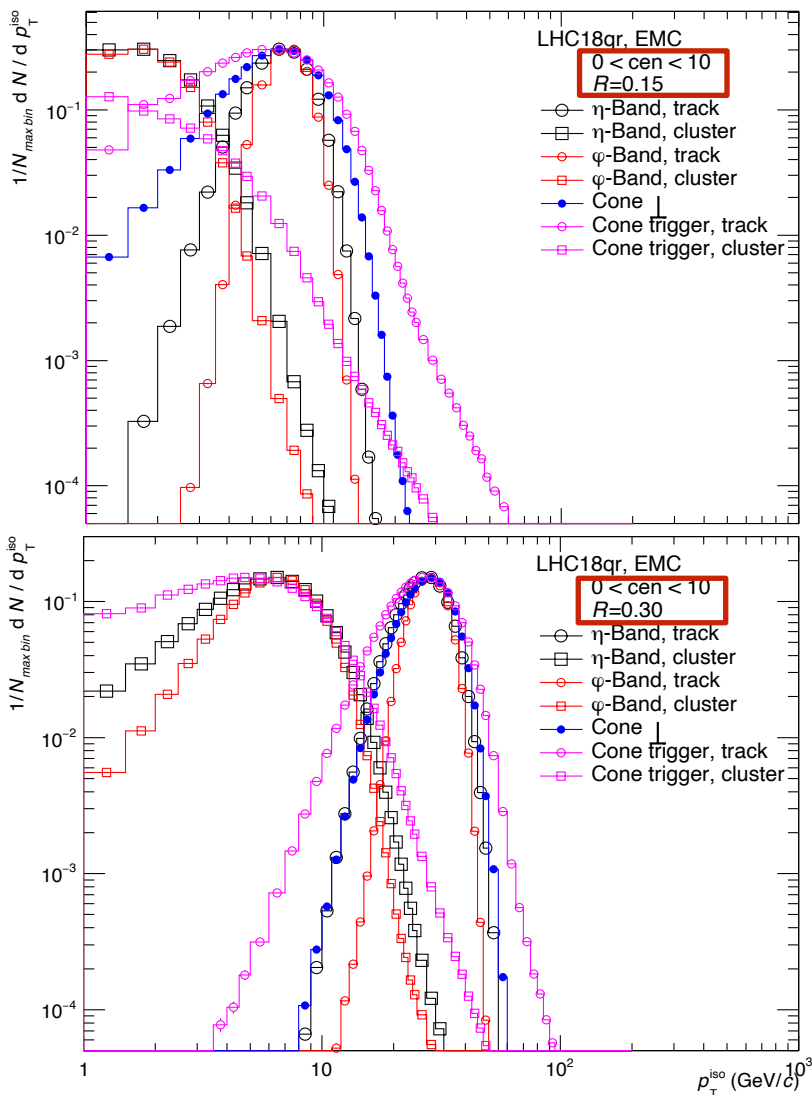
Distribution narrower, likely due to larger acceptance (less fluctuations) in this order:

ϕ -band < η -band $\approx$ $\perp$ cones < trigger cluster cone

Track $p_T > 0.7$ GeV/c

In any case mean of the UE distributions seem to match the mean of the trigger cone, no obvious mistake in UE normalization

Analysis with jet estimator and perp band not done yet



Distributions normalized to the maximum

UE bands energy normalized to trigger cone size

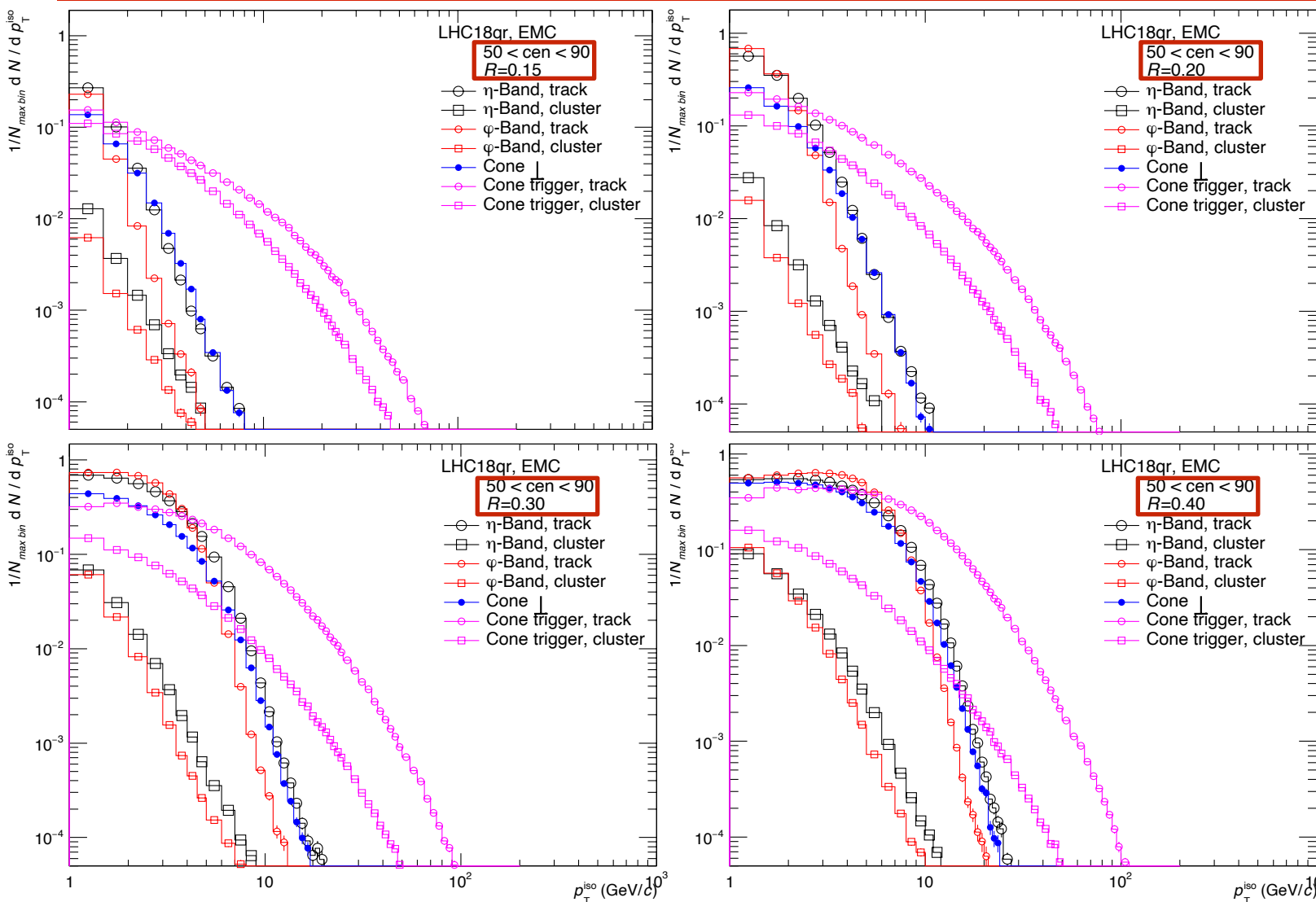
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Distributions normalized to the maximum

UE bands energy normalized to trigger cone size

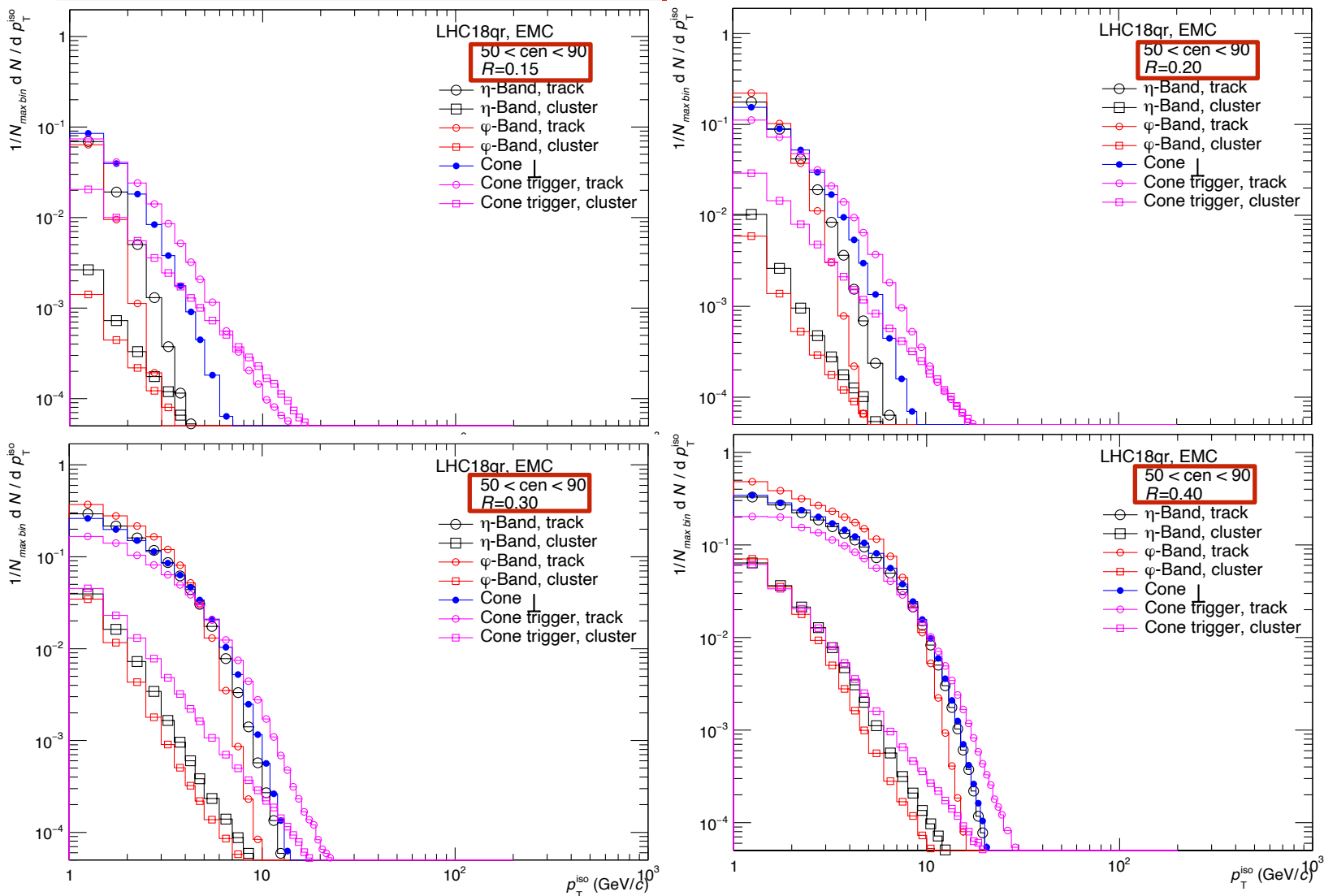
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In any case mean of the UE distributions seem to match the mean of the trigger cone, no obvious mistake in UE normalization

Analysis with jet estimator and perp band not done yet

Track $p_T > 0.7$ GeV/c



Distributions normalized to the maximum

UE bands energy normalized to trigger cone size

Distribution narrower, likely due to larger acceptance (less fluctuations) in this order:

ϕ -band < η -band $\approx$ $\perp$ cones < trigger cluster cone

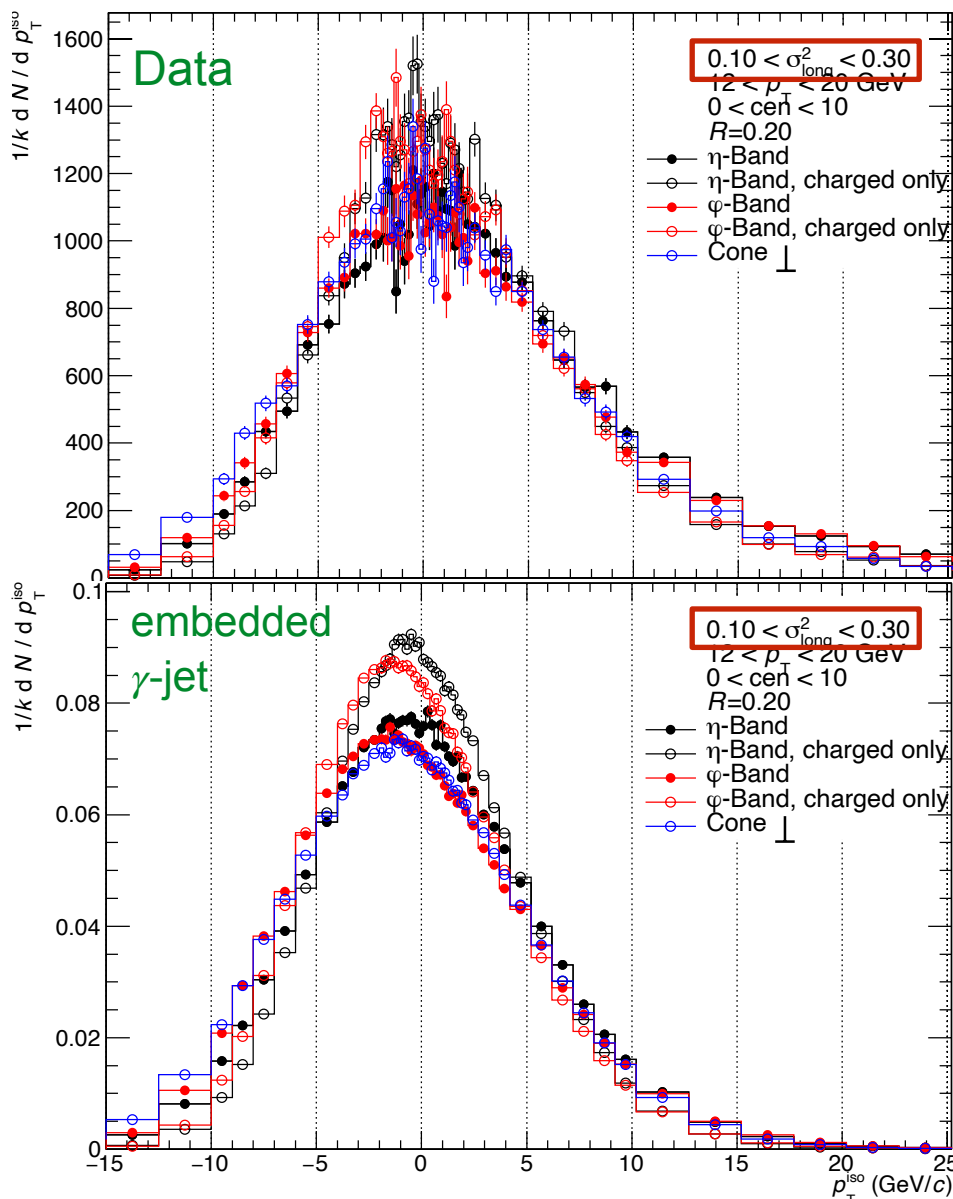
In any case mean of the UE distributions seem to match the mean of the trigger cone, no obvious mistake in UE normalization

Analysis with jet estimator and perp band not done yet

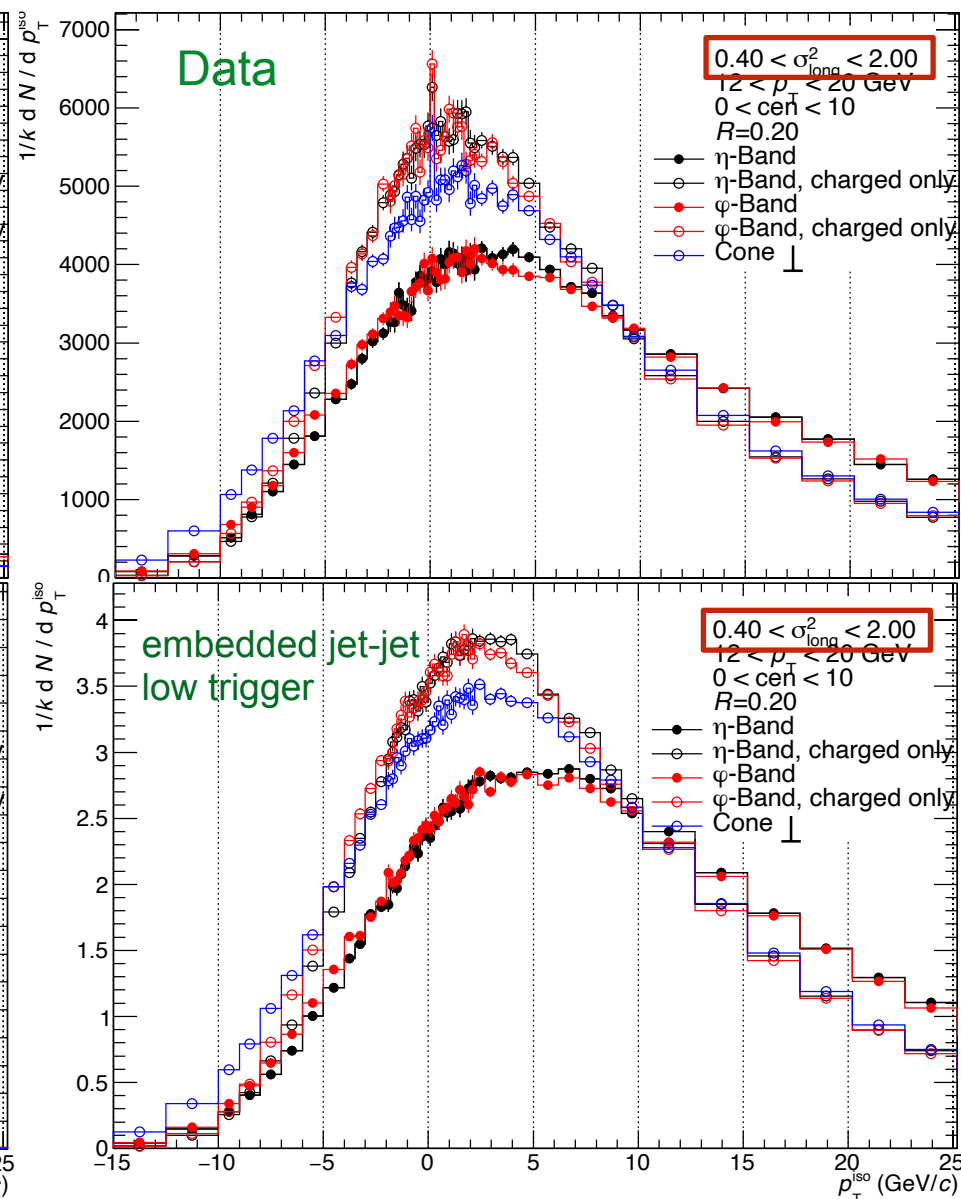
Track $p_T > 0.7 \text{ GeV/c}$

LHC18qr, EMC, MB

LHC18qr, EMC, MB



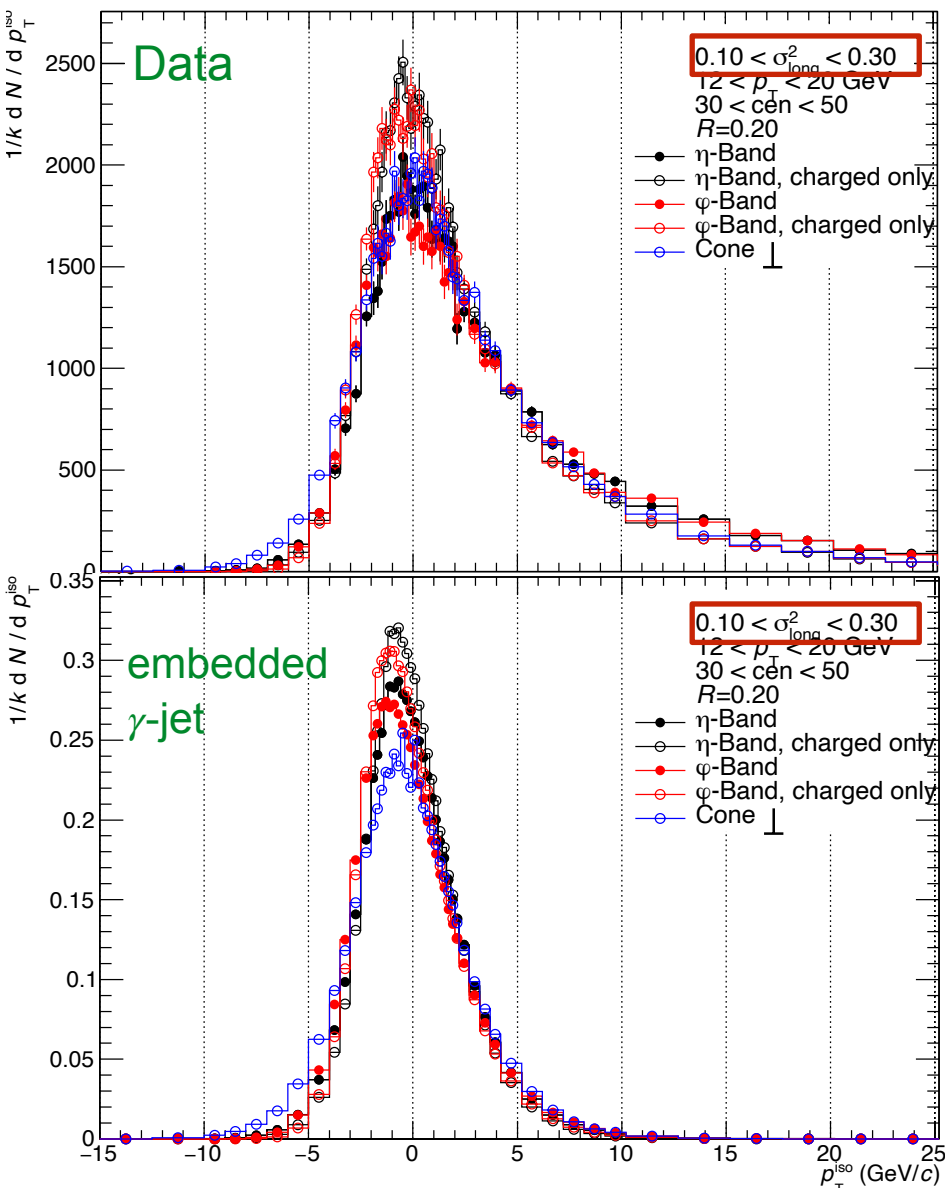
UE for ϕ -band and $\perp$ cone seem not centred at 0, few GeV below 0, also η -band but less



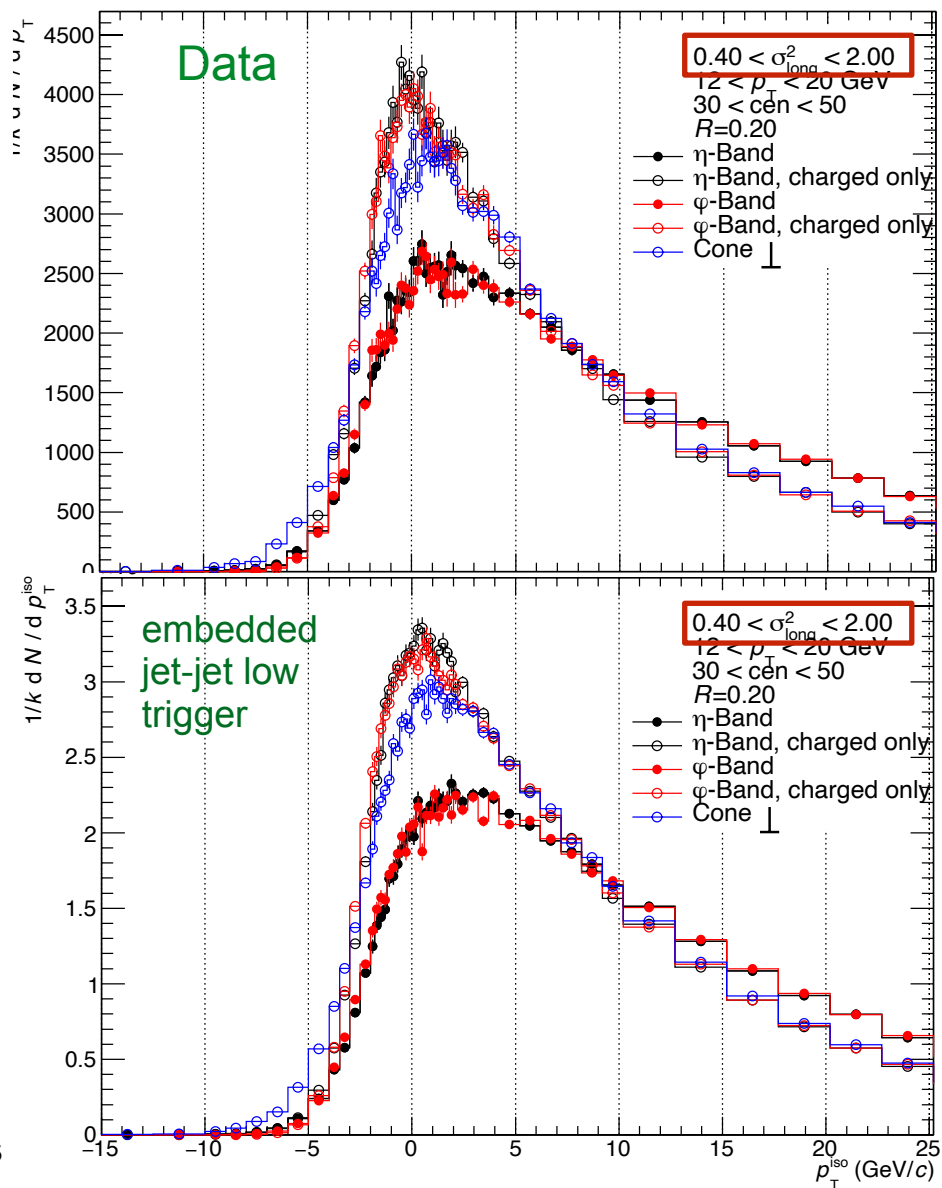
Similar right tail for all UE estimators

LHC18qr, EMC, L1

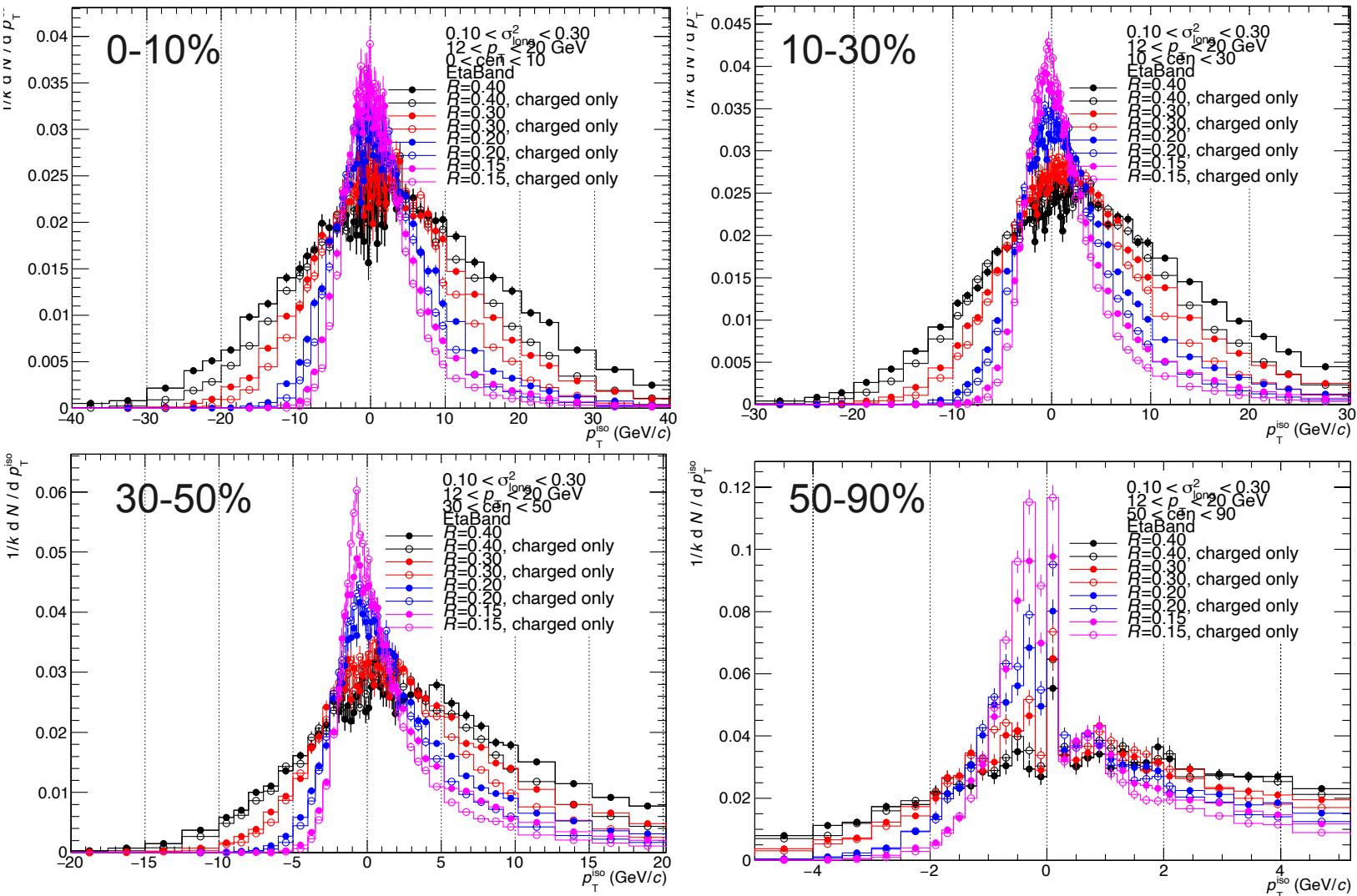
LHC18qr, EMC, L1



UE for η -band, ϕ -band and $\perp$ cone seem not centred at 0, few GeV below 0, also ϕ -band even more shifted



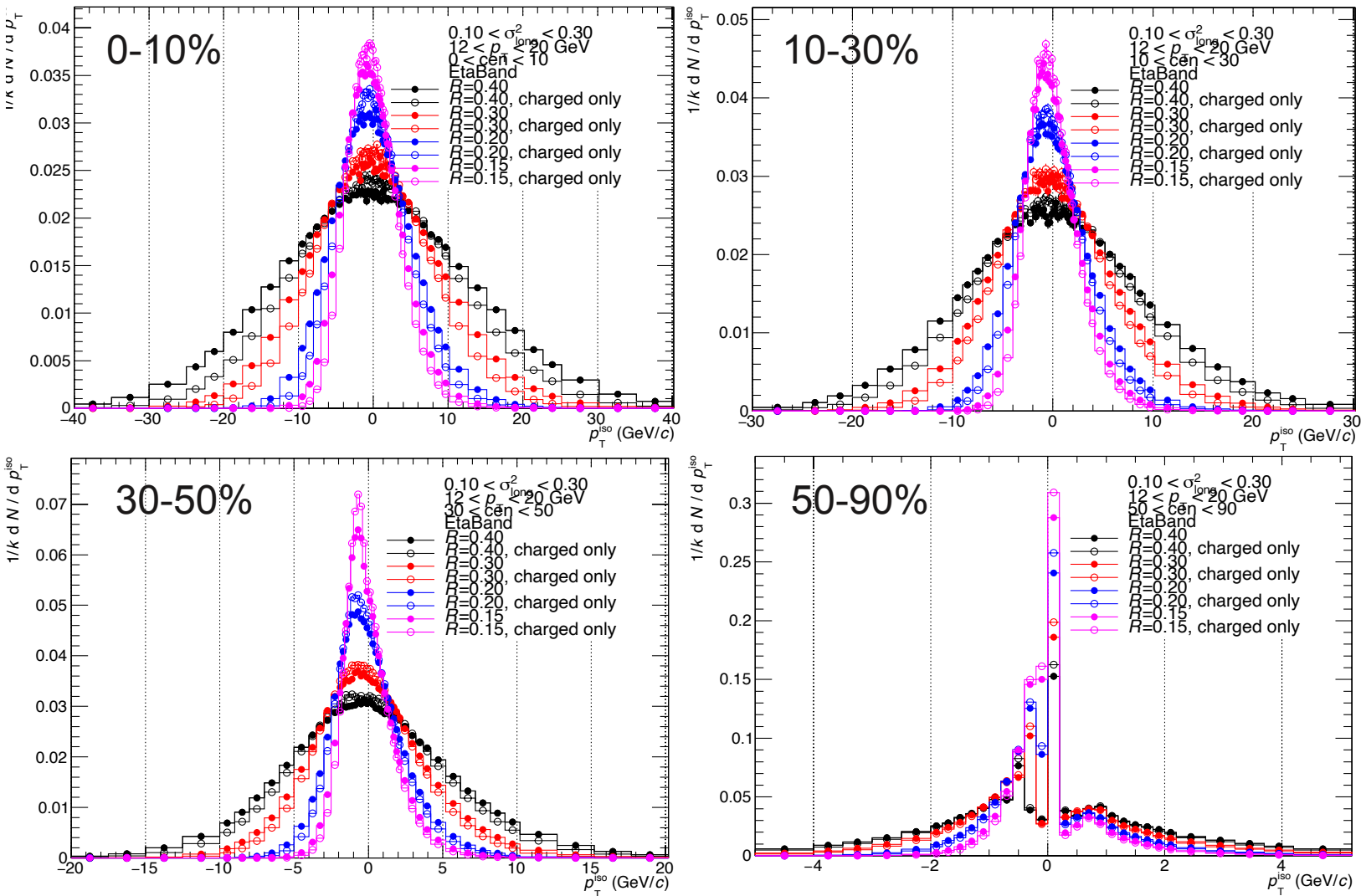
Similar right tail for all UE estimators



Distributions normalized to the maximum

Distributions mean below 0, specially in non central events and smaller cone size not clear why. Events with jets in UE region that over-subtract?
Cone size $R=0.15, 0.2$ distribution seems rather narrow even in central collisions.

Track $p_T > 0.7$ GeV/c



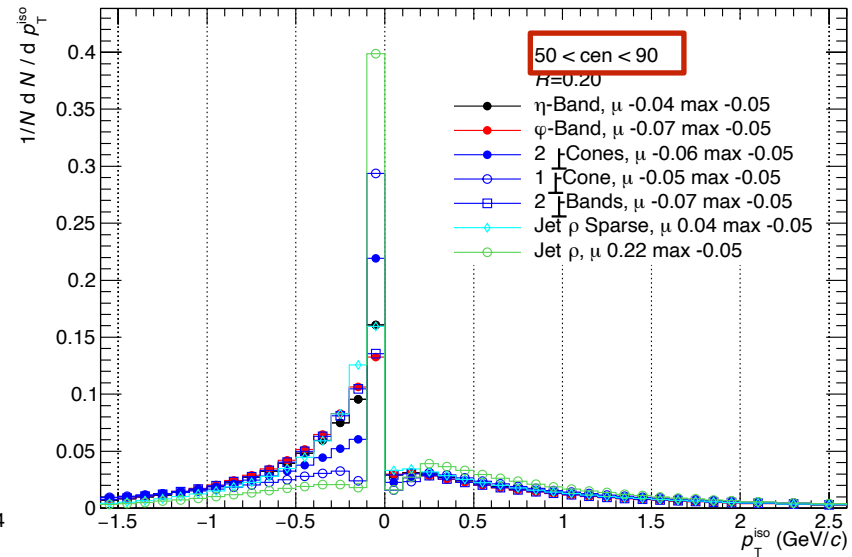
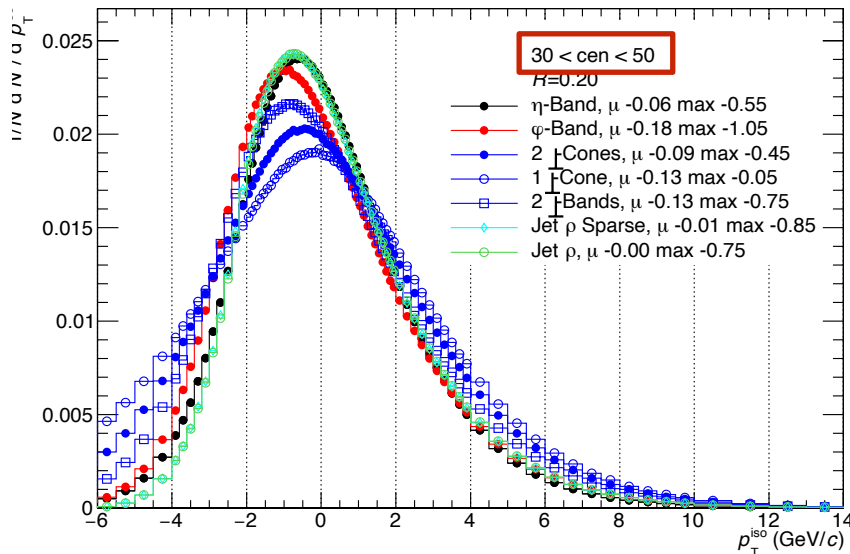
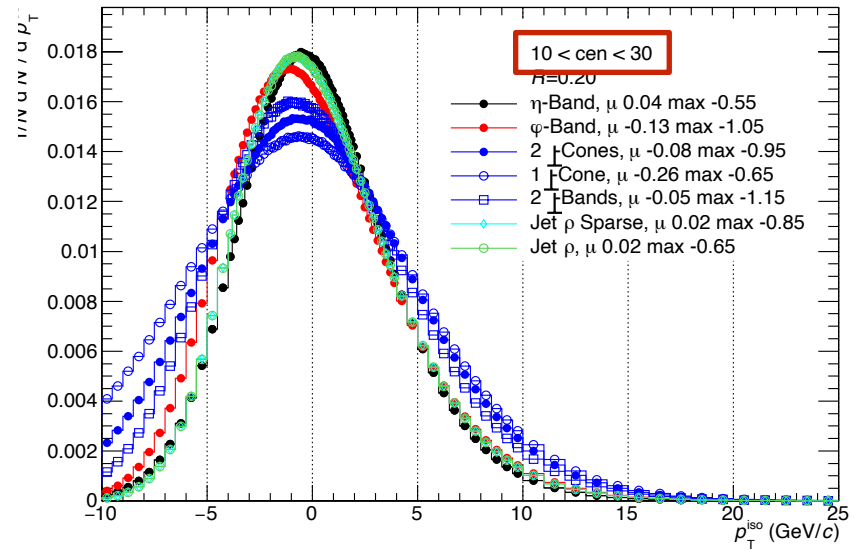
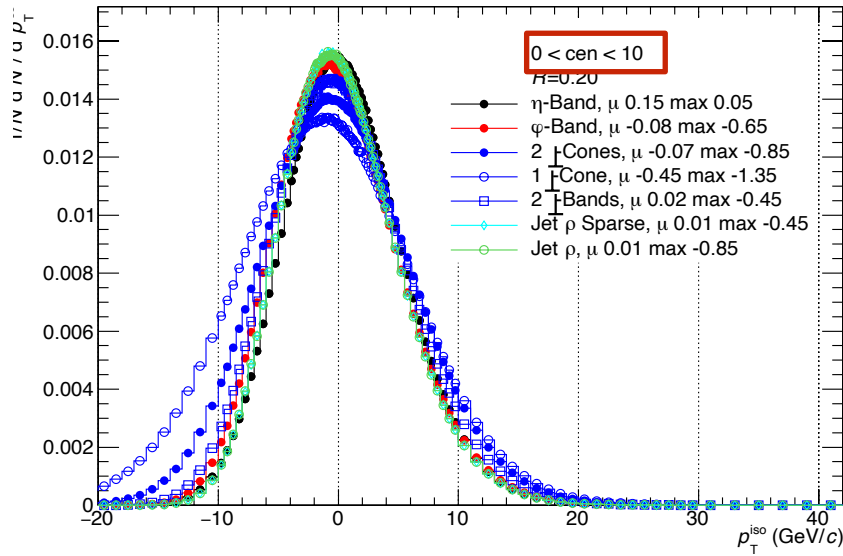
Distributions normalized to the maximum

Distributions mean below 0, specially in non central events and smaller cone size not clear why. Events with jets in UE region that over-subtract?
Cone size $R=0.15, 0.2$ distribution seems rather narrow even in central collisions.

Track $p_T > 0.7 \text{ GeV/c}$

3 - p_T^{iso} , $R=0.2$, random cones

Track $p_T > 0.15$ GeV/c 45 / 83



Maximum not centred at 0 GeV but -1 to 0 GeV in 0-50%.

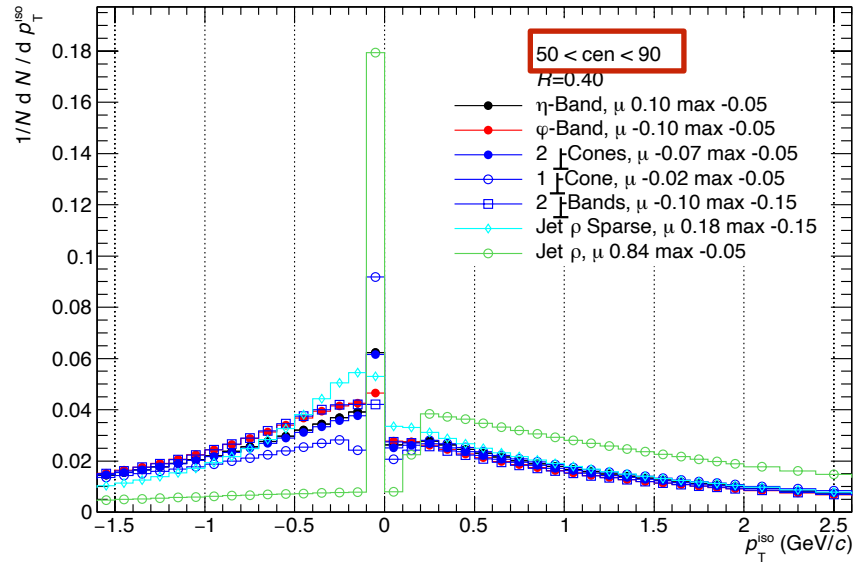
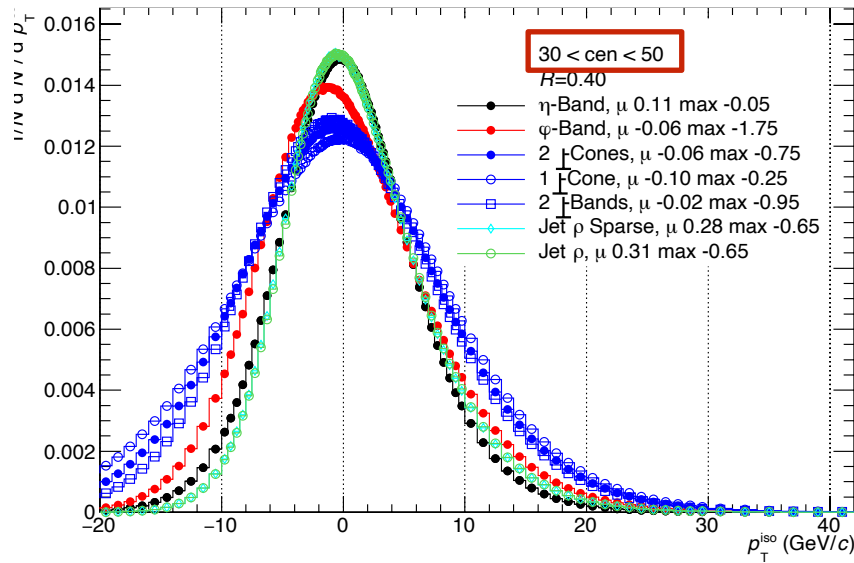
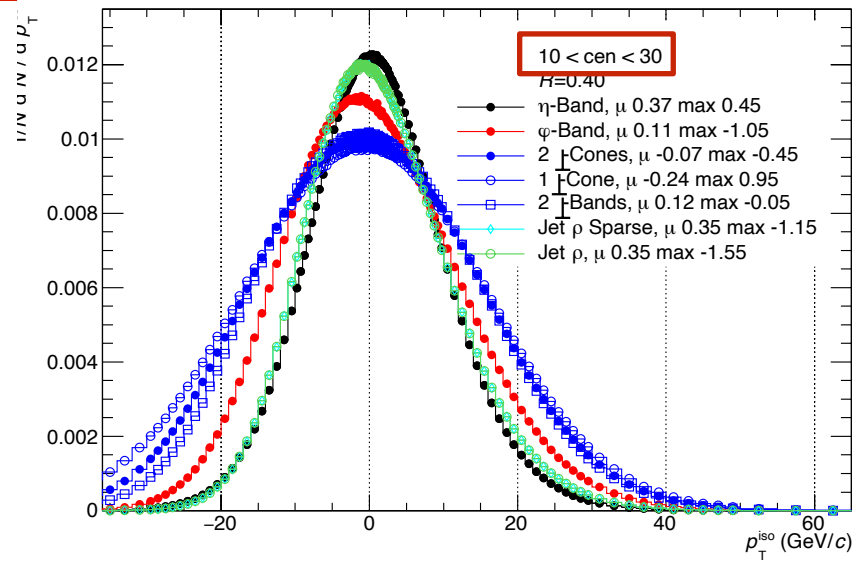
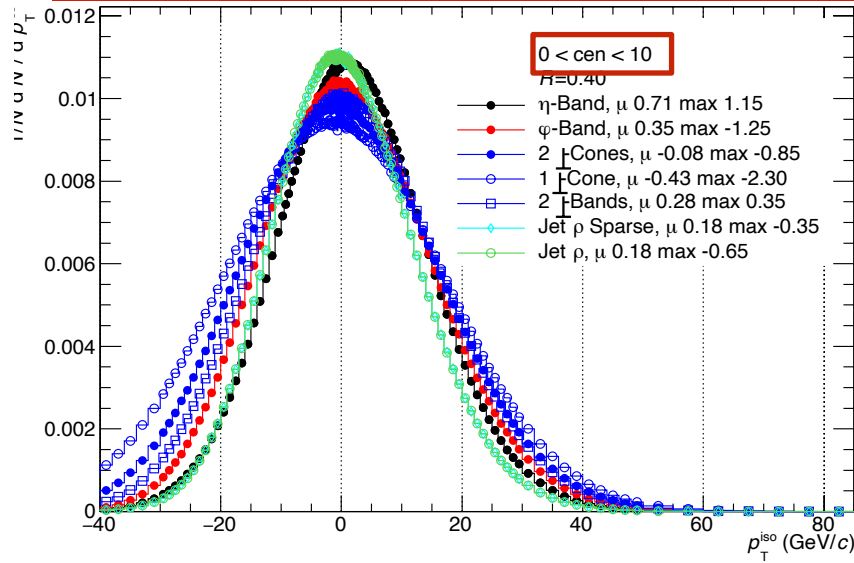
Less shifted η band and 1 $\perp$ cone, but this one with more left tail.

Jet and η bands have similar width and mean but jet a bit more shifted

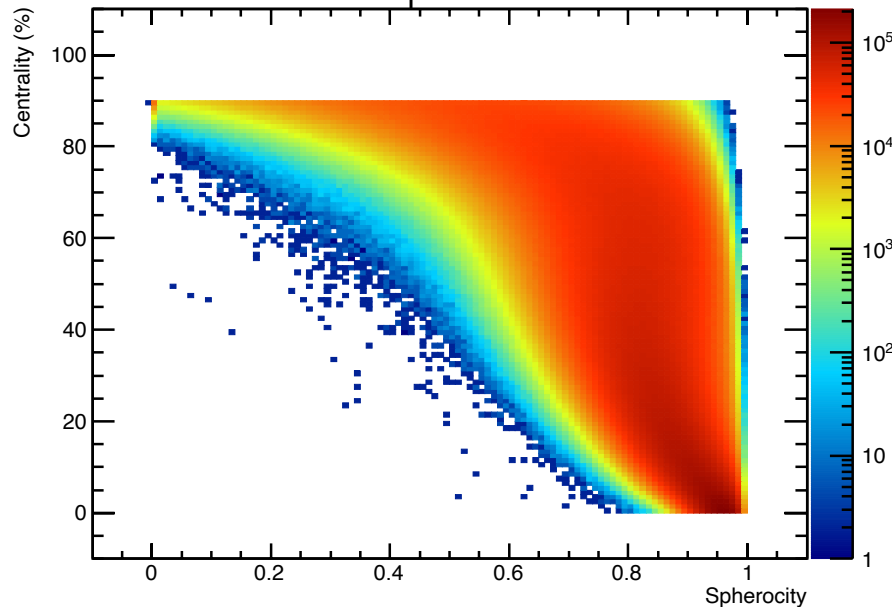
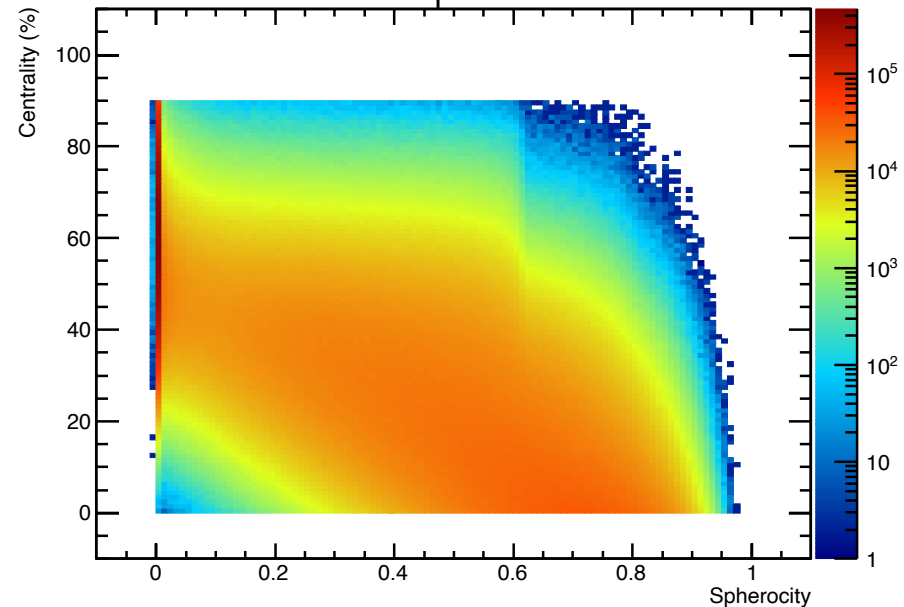
Sparse and non sparse jet UE estimators disagree for 50-90% centrality

3 - p_T^{iso} , $R=0.4$, random cones

Track $p_T > 0.15$ GeV/c 46 / 83



Similar to $R=0.2$ but less shifted, specially for η band and jet estimators

Track $p_T > 0.15 \text{ GeV}/c$ Track $p_T > 3 \text{ GeV}/c$ 

Large S_0 : Isotropic azimuthal distribution

Small S_0 : Jetty azimuthal distribution

Large UE makes S_0 to be large for small centralities, event looks isotropic.

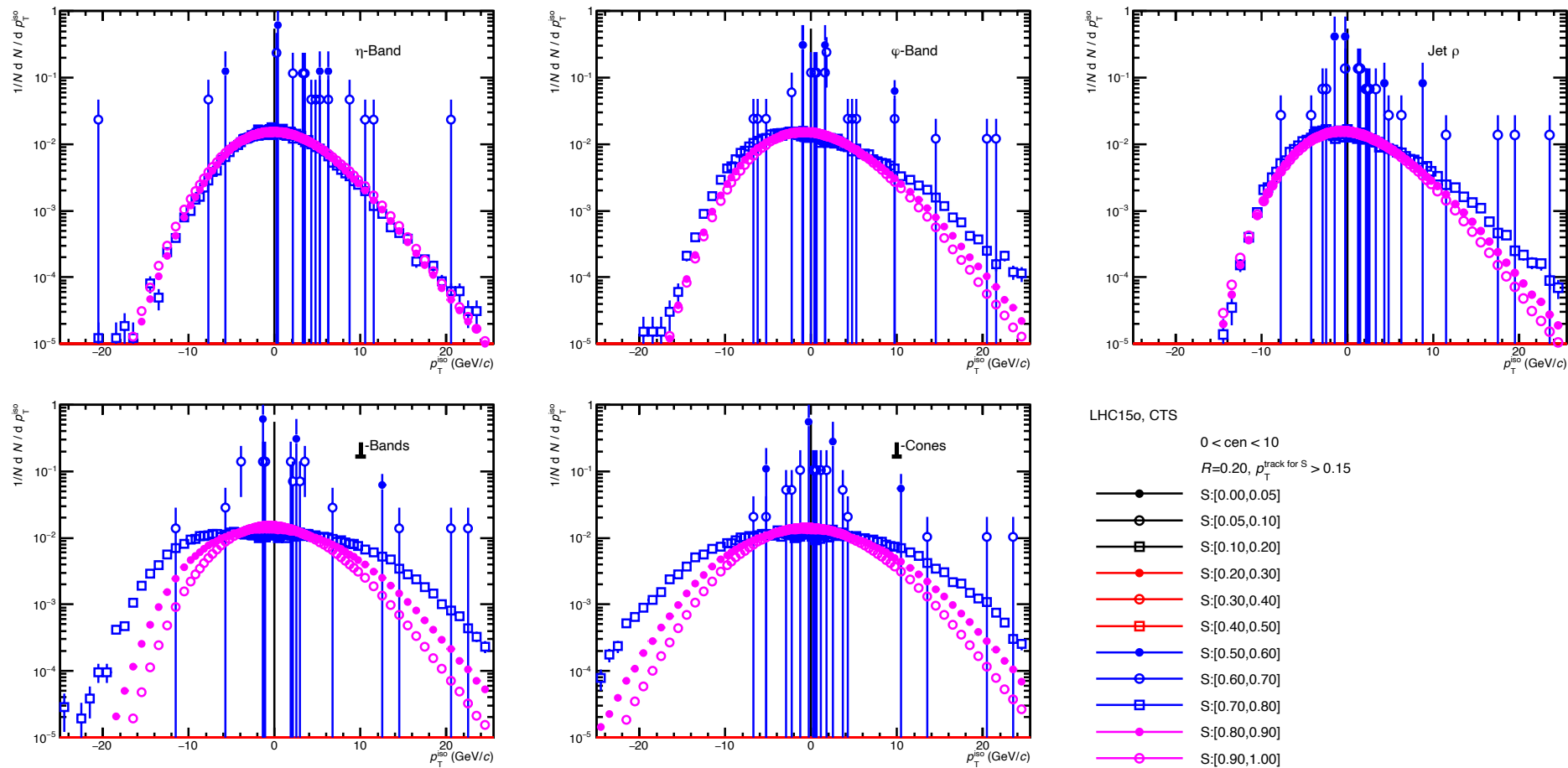
It was suggested by Antonio Ortiz to apply a $3 \text{ GeV } p_T$ cut in the S_0 calculation to avoid this and flow effects.

Sphericity papers

<https://arxiv.org/pdf/1705.02056.pdf>

<https://arxiv.org/pdf/1905.07208.pdf>

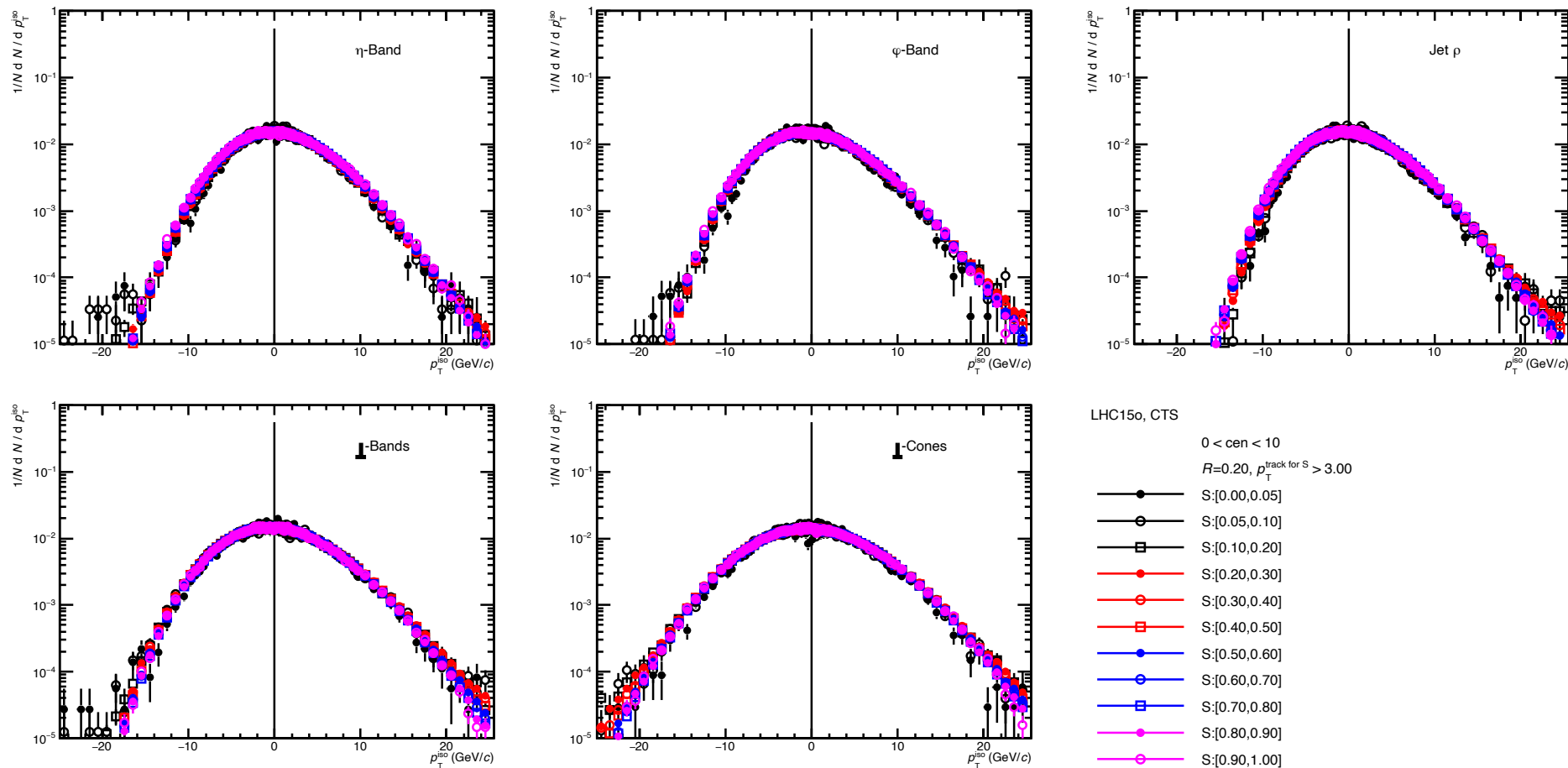
<https://arxiv.org/pdf/1205.3963.pdf>



η band is not sensitive to the S_0 bin then jet ρ is a bit sensitive.

Similar observations for $R=0.4$, larger S_0 bin by bin difference in other bands than η band (back-up)

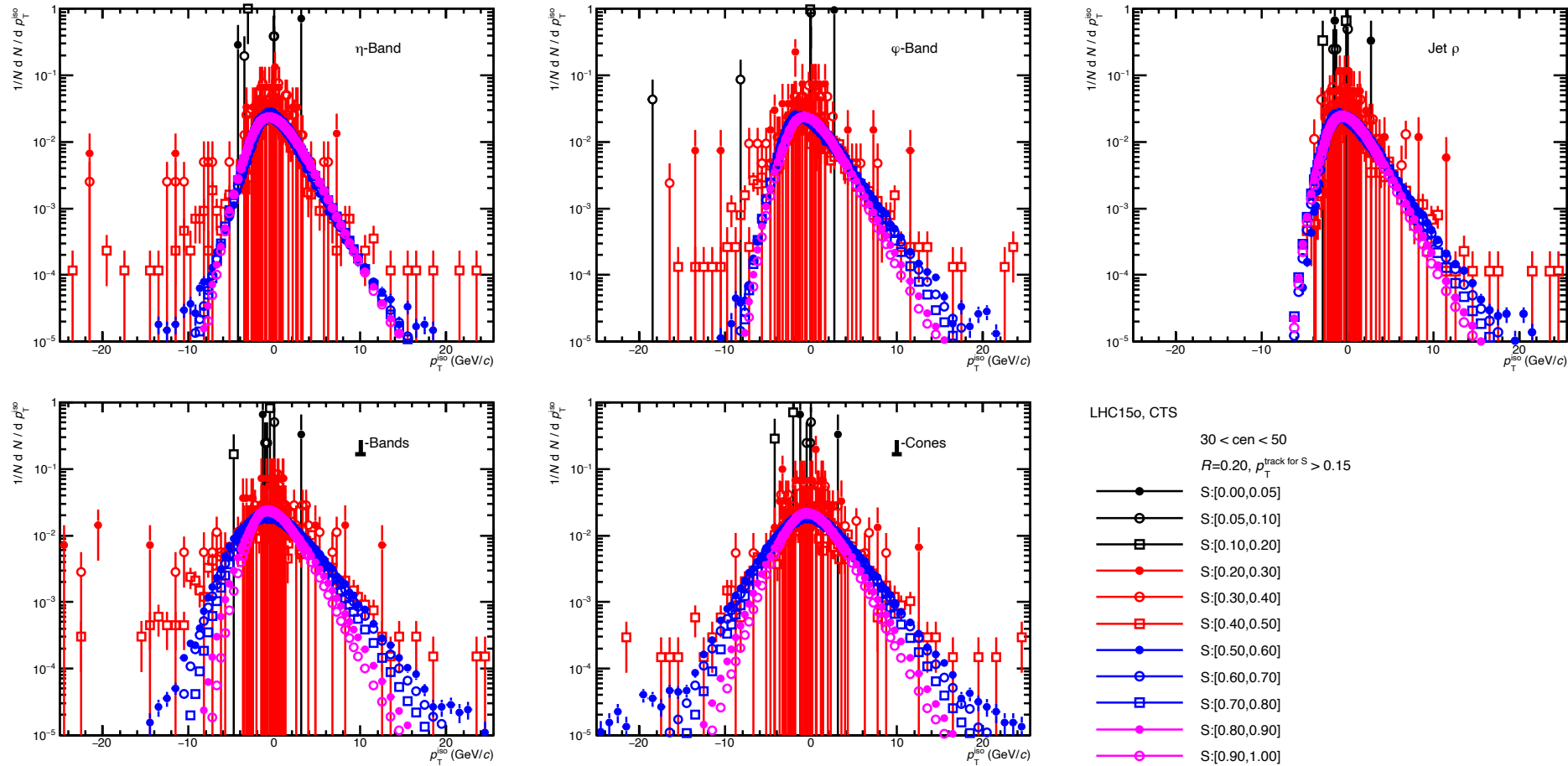
In cone track $p_T > 0.15$ GeV/c



All bands are not sensitive. The effect observed for track S_0 $p_T > 0.15 \text{ GeV/c}$ must be flow related.

Similar observations for $R = 0.4$ (back-up)

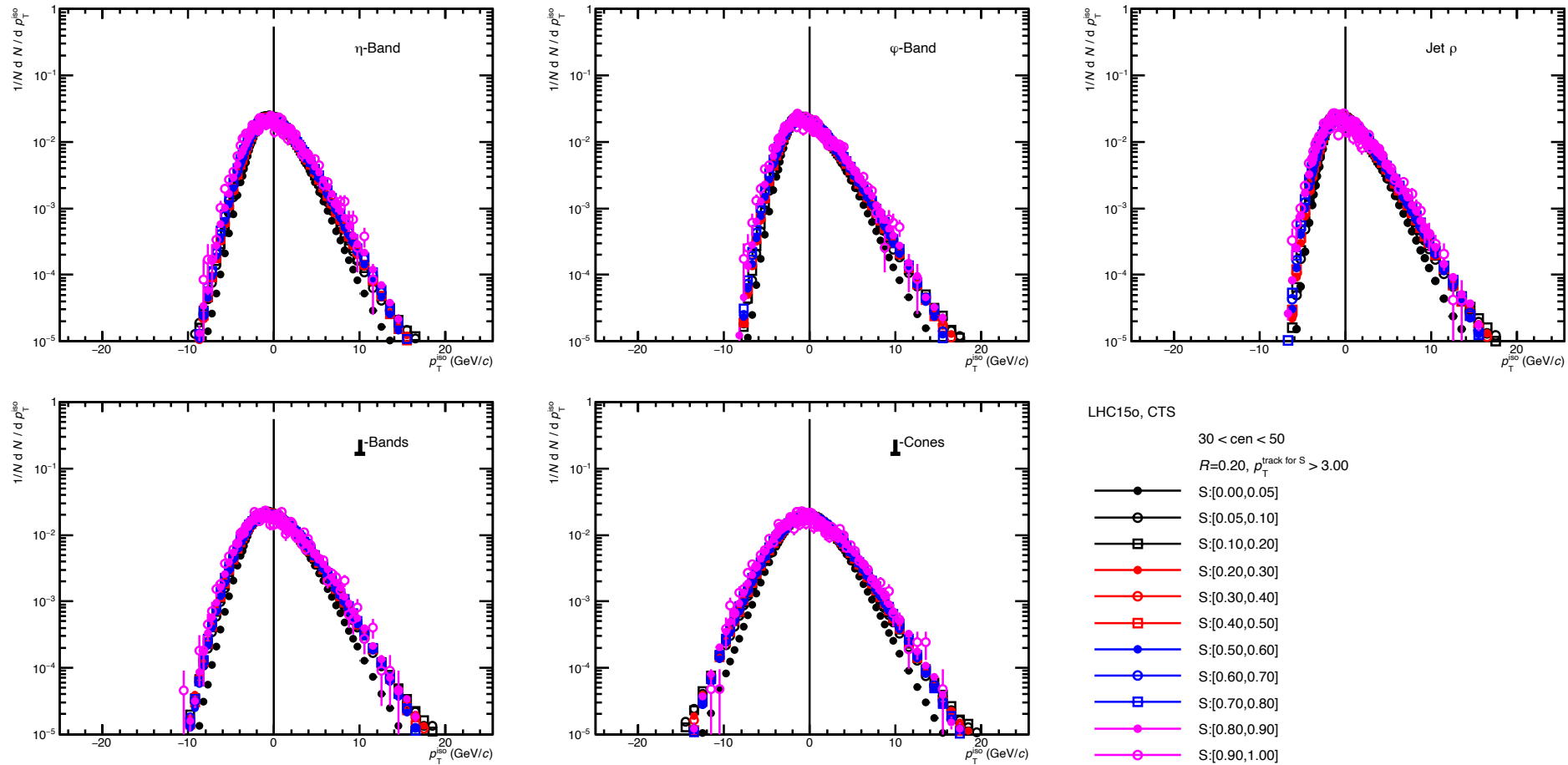
In cone track $p_T > 0.15 \text{ GeV/c}$



η band is not sensitive to the S_0 bin then jet p is a bit sensitive.

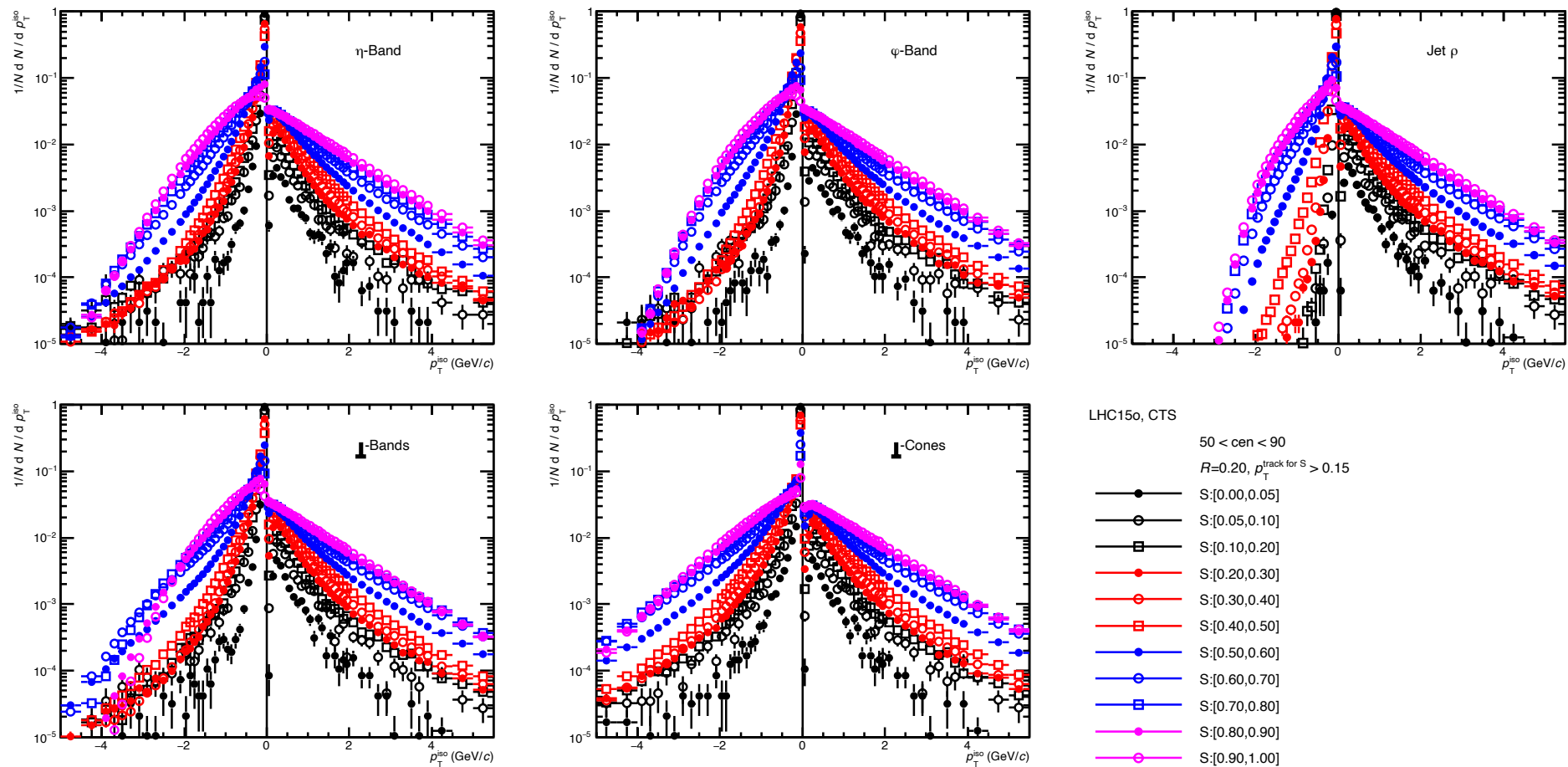
Similar observations for $R = 0.4$, larger sphericity bin by bin difference in other bands than η band (back-up)

In cone track $p_T > 0.15$ GeV/c



All bands are not sensitive. The effect observed for track S_0 $p_T > 0.15 \text{ GeV/c}$ must be flow related. Only smallest S_0 bin (less spherical) has clear smaller width. Similar observations for $R = 0.4$ (back-up)

In cone track $p_T > 0.15 \text{ GeV/c}$

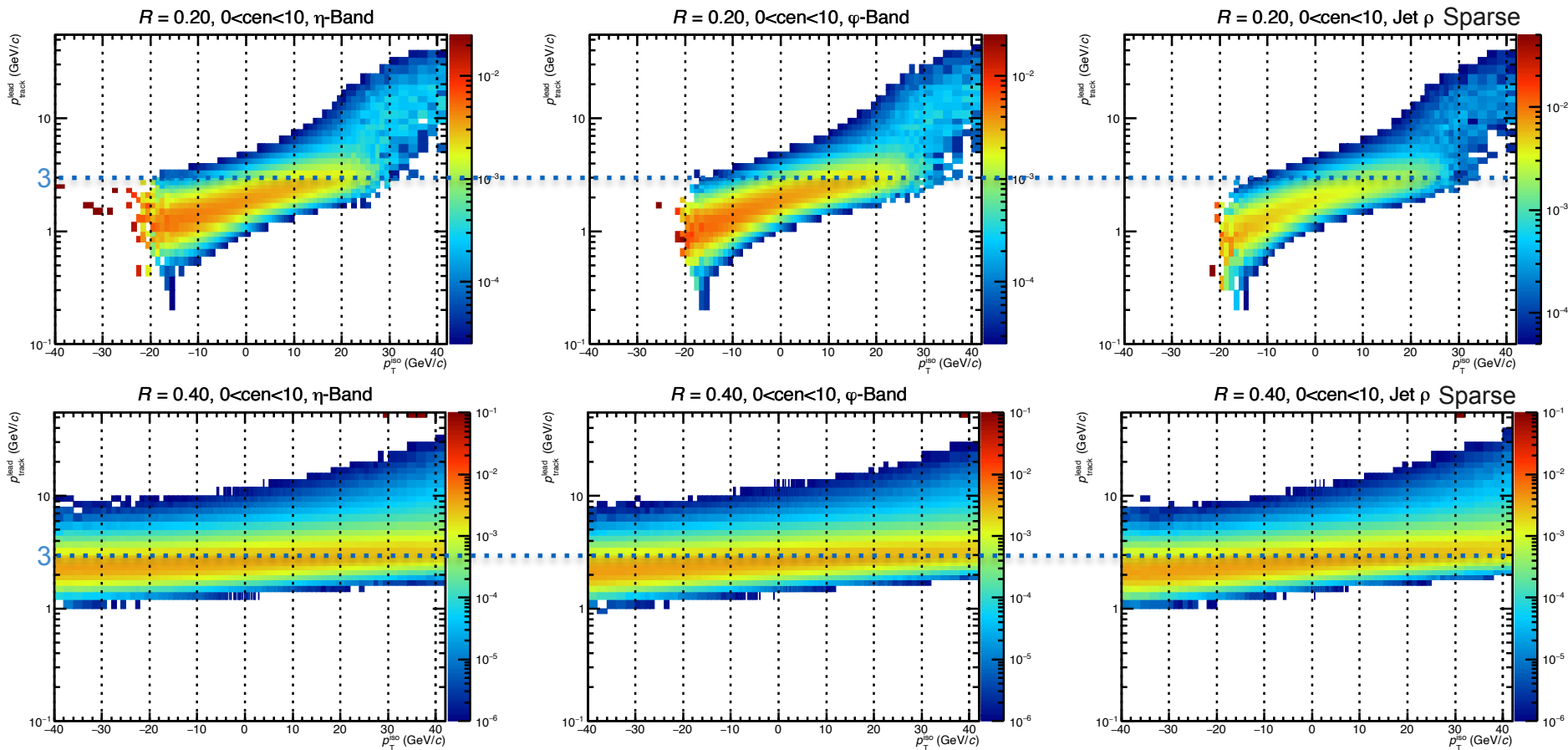


Events with smaller S_0 (less spherical) have smaller width. A reflection of particle multiplicity?

Similar observations for $R=0.4$ (back-up)

In cone track $p_T > 0.15$ GeV/c

3 - p_T^{iso} vs leading track in random cone, 0-10%, random cones 53 / 83



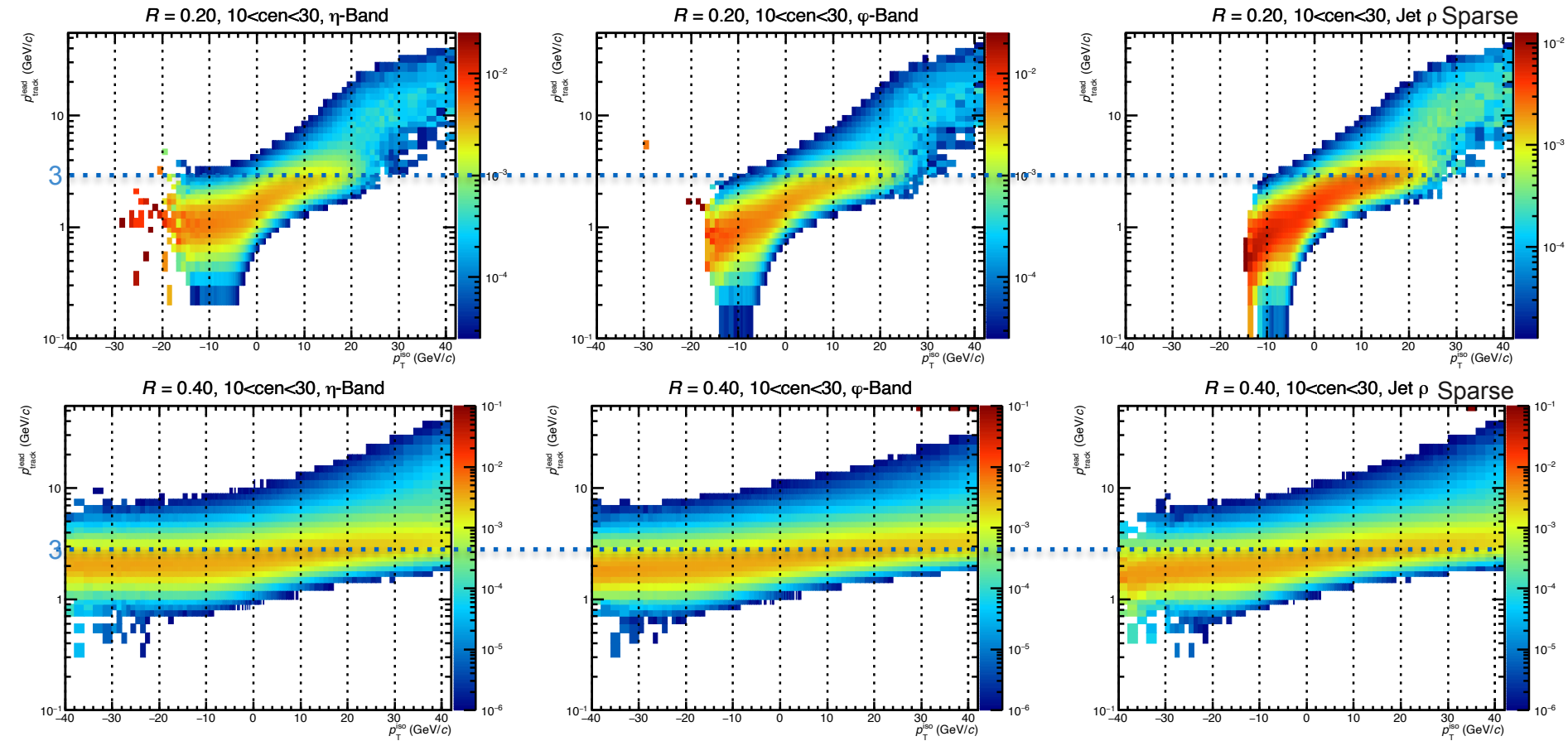
Correlation between leading track p_T in cone and p_T^{iso} , small leading track p_T populate more likely the negative p_T^{iso} , specially for smaller R .
Same behavior in all UE estimators.

When negative p_T^{iso} , cone tracks p_T are below ~ 2 GeV/c for $R=0.2$ and ~ 5 GeV/c for $R = 0.4$

In cone track $p_T > 0.15$ GeV/c

Reminder from last presentation

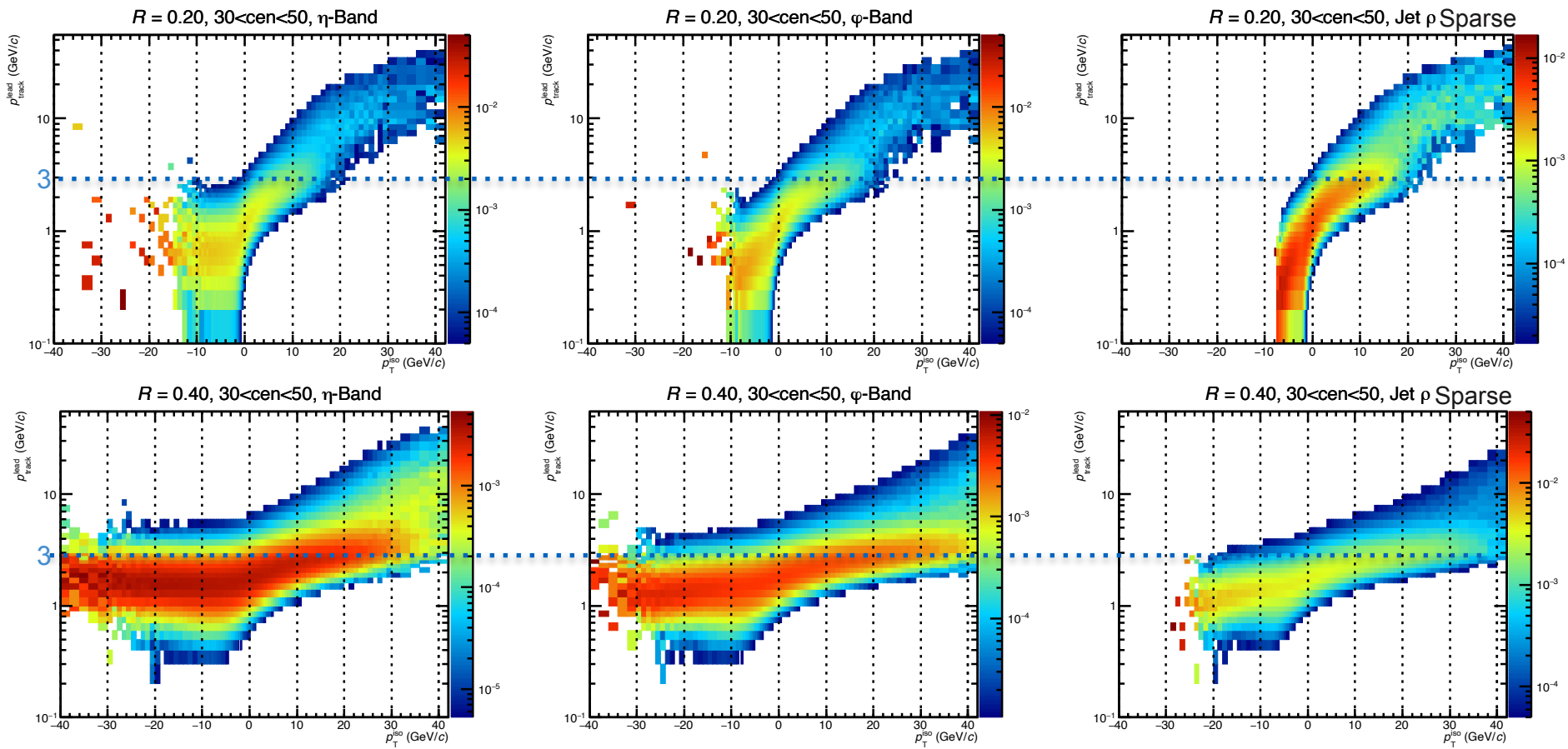
p_T^{iso} bins normalized to bin integral



Correlation between leading track p_T in cone and p_T^{iso} , small leading track p_T populate more likely the negative p_T^{iso} , specially for smaller R .
Similar behavior in all UE estimators.

When negative p_T^{iso} , cone tracks p_T are below ~ 2 GeV/c for $R=0.2$ and ~ 5 GeV/c for $R = 0.4$

In cone track $p_T > 0.15$ GeV/c



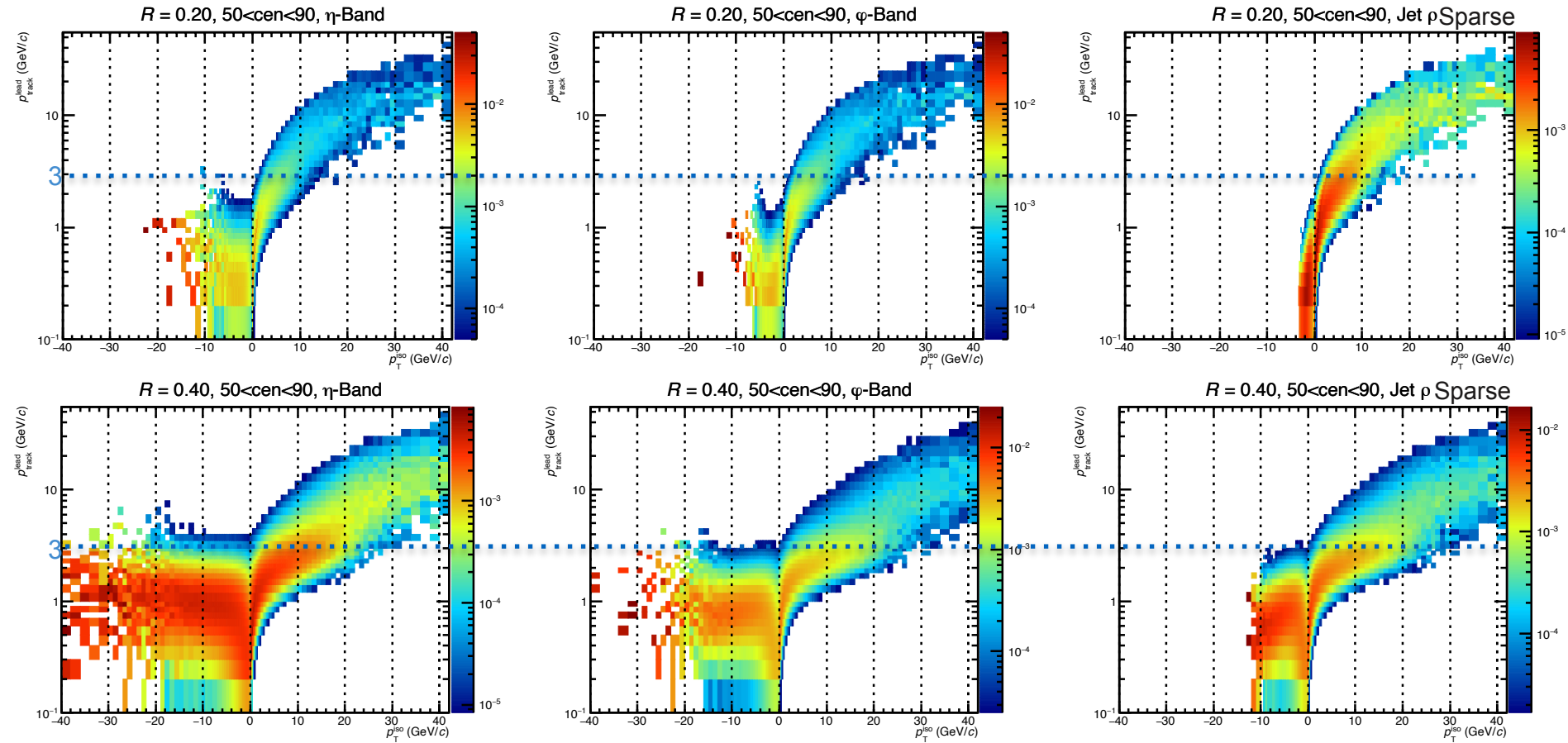
Correlation between leading track p_{T} in cone and $p_{\text{T}}^{\text{iso}}$ above ~ 1 GeV track p_{T} , smaller leading track p_{T} populate more likely the negative $p_{\text{T}}^{\text{iso}}$.
Similar behavior in all UE estimators.

When negative $p_{\text{T}}^{\text{iso}}$, cone tracks p_{T} are below ~ 2 GeV/c for $R=0.2$ and ~ 5 GeV/c for $R = 0.4$

In cone track $p_{\text{T}} > 0.15$ GeV/c

Reminder from last presentation

$p_{\text{T}}^{\text{iso}}$ bins normalized to bin integral



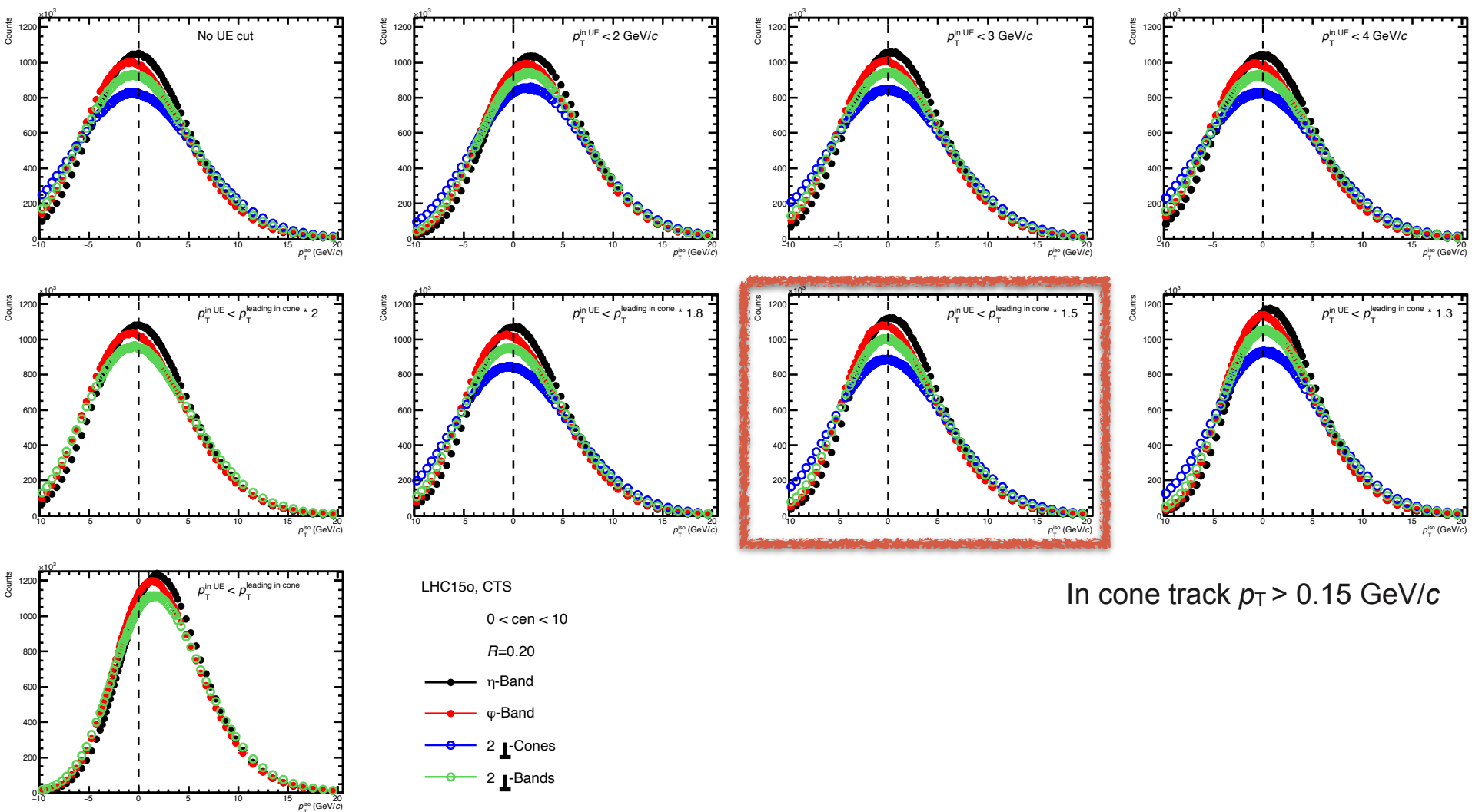
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 Similar behavior in all UE estimators.
 When negative $p_{\text{T}}^{\text{iso}}$, cone tracks p_{T} are below ~ 2 GeV/c

In cone track $p_{\text{T}} > 0.15$ GeV/c

Reminder from last presentation

$p_{\text{T}}^{\text{iso}}$ bins normalized to bin integral

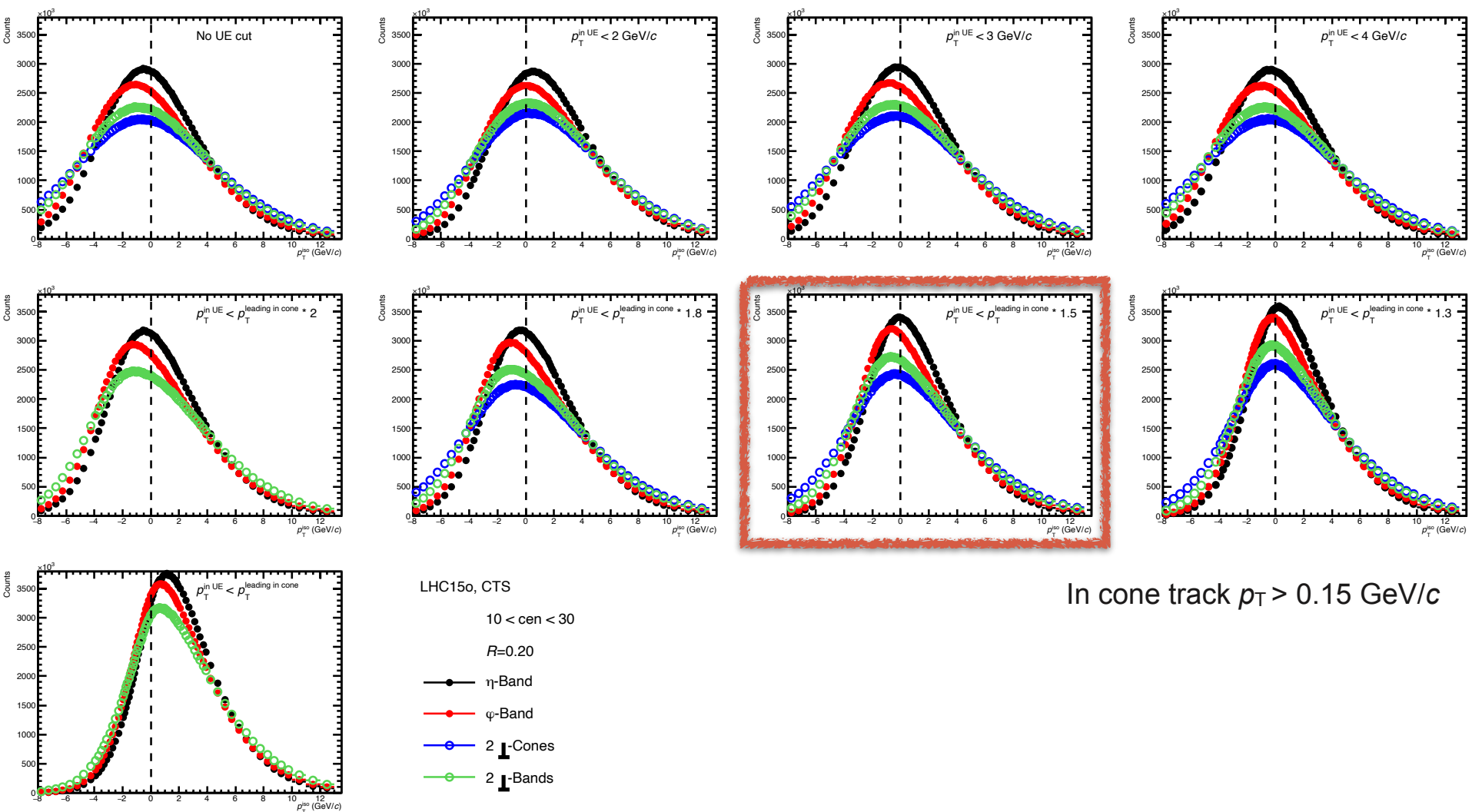
3 - p_T^{iso} , track p_T cut in UE region, $R=0.2$, 0-10%, random cones 57 / 83



In cone track $p_T > 0.15 \text{ GeV}/c$

Fix track p_T cut at 3 GeV seems reasonable.

Cutting on leading track p_T in cone $\times 1.5$ seems reasonable.

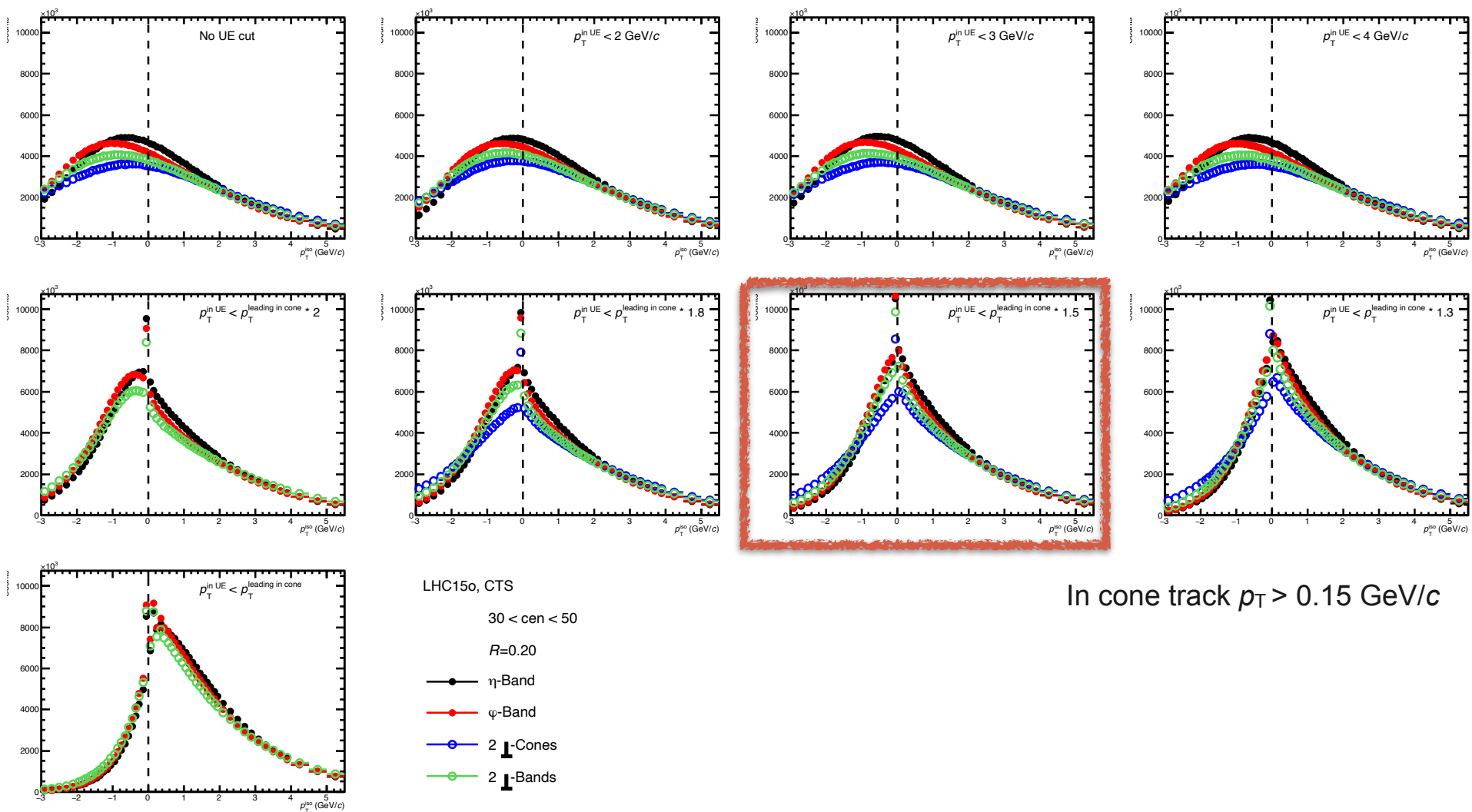


In cone track $p_T > 0.15 \text{ GeV/c}$

Fix track p_T cut does not do much unless we go to 2 GeV but too much for η -band.

Cutting on leading track p_T in cone $\times 1.5$ seems reasonable for η -band $\times 1.3$ for other bands.

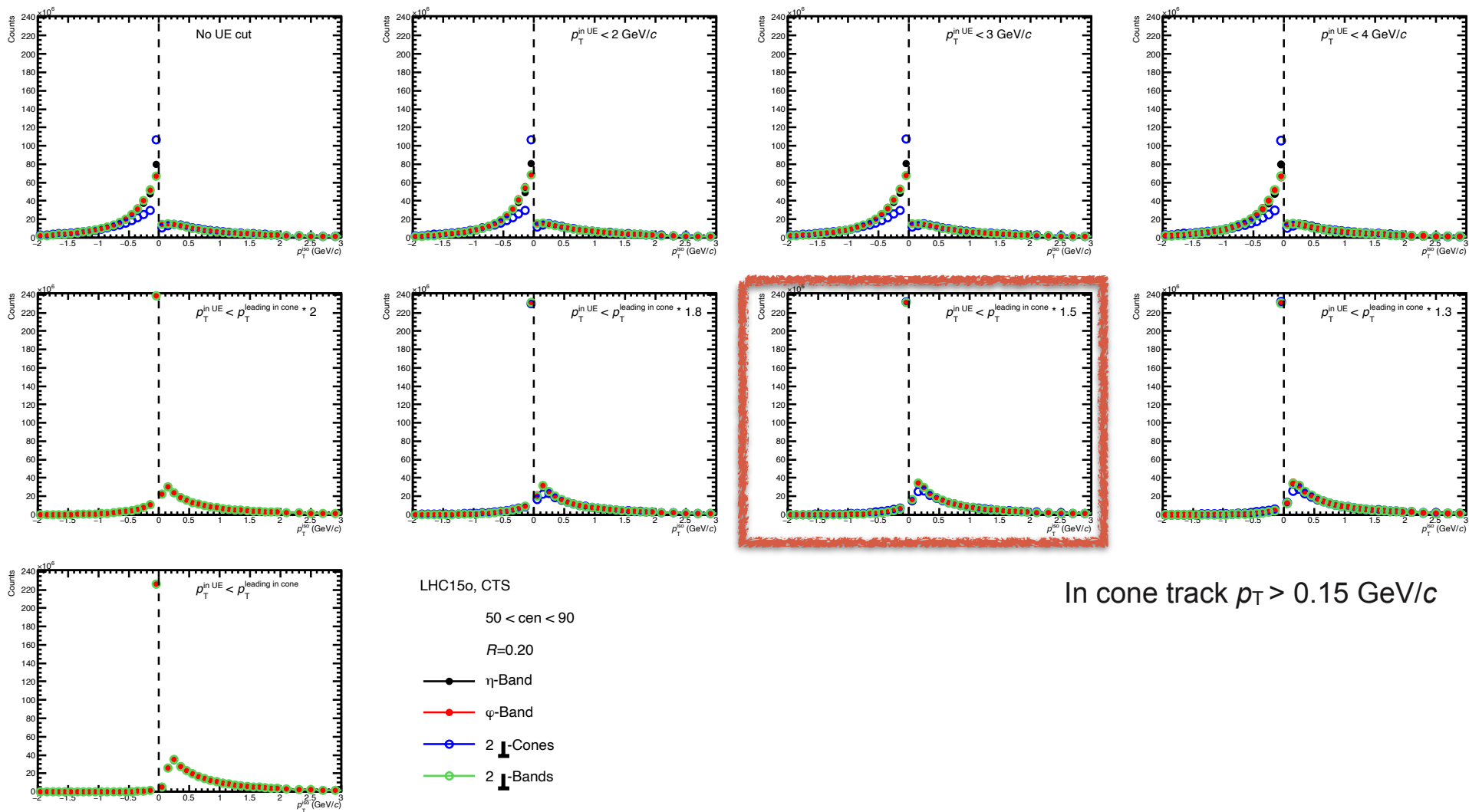
3 - $p_{\text{T}}^{\text{iso}}$, track p_{T} cut in UE region, $R=0.2$, 30-50%, random cones 59 / 83



In cone track $p_{\text{T}} > 0.15 \text{ GeV}/c$

Fix track p_{T} cut does not do much.
Cutting on leading track p_{T} in cone $\times 1.5$ seems reasonable.

3 - $p_{\text{T}}^{\text{iso}}$, track p_{T} cut in UE region, $R=0.2$, 50-90%, random cones 60 / 83

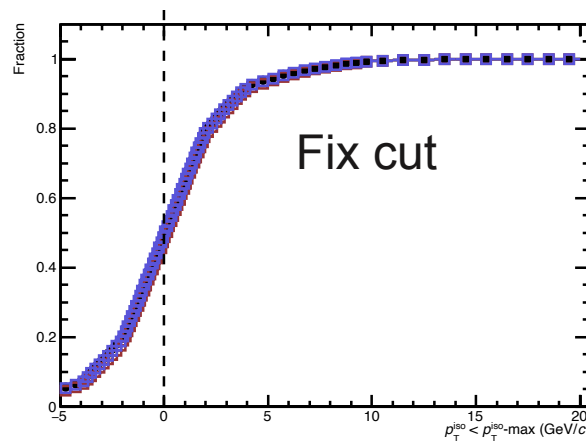
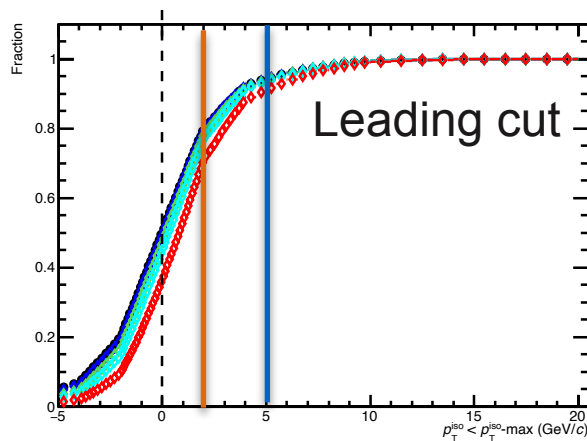


In cone track $p_{\text{T}} > 0.15 \text{ GeV}/c$

Fix track p_{T} cut does not do much.

3 - Integrated p_{T}^{iso} , track p_T cut in UE region, $R=0.2$, η -band, random cones

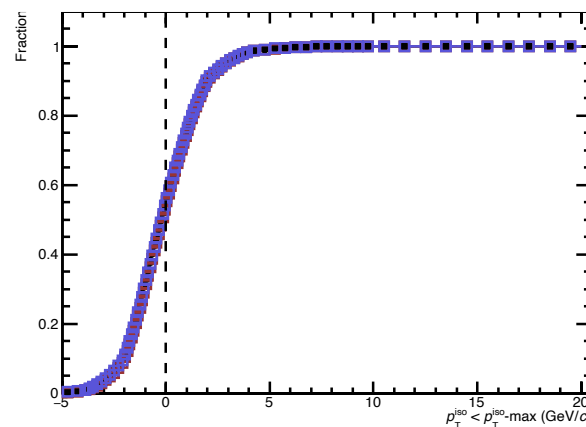
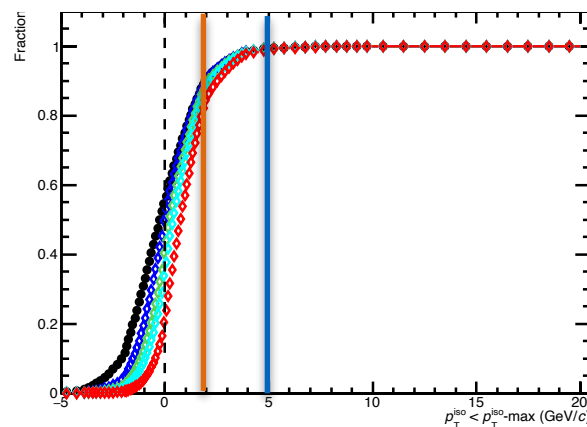
61 / 83



LHC150, CTS, η -Band

$0 < \text{cen} < 10$
 $R=0.20$

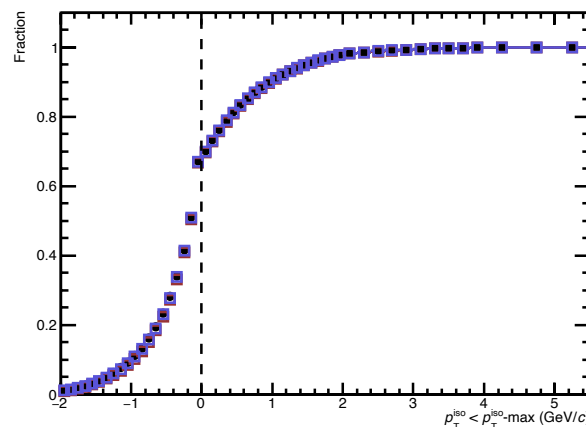
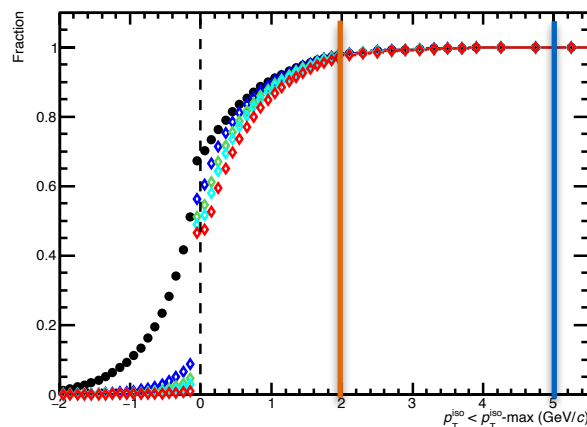
- No p_T^{iso} cut
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}} * 2$
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}} * 1.8$
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}} * 1.5$
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}} * 1.3$
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}}$
- $p_T^{\text{iso}} < 4 \text{ GeV}/c$
- $p_T^{\text{iso}} < 3 \text{ GeV}/c$
- $p_T^{\text{iso}} < 2 \text{ GeV}/c$
- No p_T^{iso} cut
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}} * 2$
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}} * 1.8$



LHC150, CTS, η -Band

$30 < \text{cen} < 50$
 $R=0.20$

- No p_T^{iso} cut
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}} * 2$
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}} * 1.8$
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}} * 1.5$
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}} * 1.3$
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}}$
- $p_T^{\text{iso}} < 4 \text{ GeV}/c$
- $p_T^{\text{iso}} < 3 \text{ GeV}/c$
- $p_T^{\text{iso}} < 2 \text{ GeV}/c$
- No p_T^{iso} cut
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}} * 2$
- ◆— $p_T^{\text{iso}} < p_T^{\text{leading in cone}} * 1.8$



LHC150, CTS, η -Band

$50 < \text{cen} < 90$
 $R=0.20$

Leading track p_T based cut can have some impact on efficiency if too tight isolation cut.

With track cut factor 1.5 seems safe to cut p_T^{iso} above 2 GeV in all centrality bins
Same fractions in other UE estimators (back-up)

In cone track $p_T > 0.15 \text{ GeV}/c$

3 - Conclusion on UE and random cones

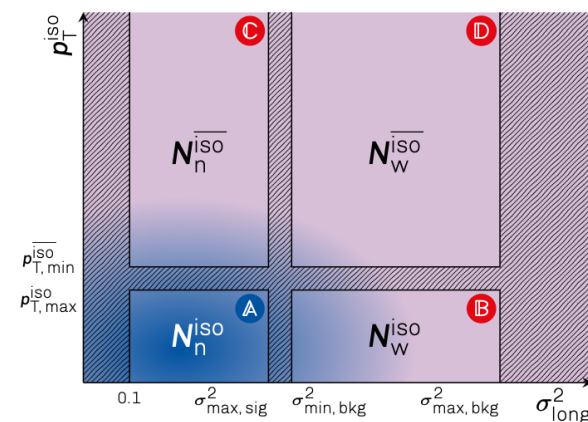
- The shift to negative values in the mean of the p_T^{iso} distribution is observed with random isolation cones
 - ▶ **It is more important for small R and semi-central collisions**
- It is present for different UE estimators,
 - ▶ Also the jet UE estimator that has similar performance as the η -band
 - ▶ **The jet energy density estimator with and without sparse calculation are equivalent for centralities smaller than 70%, below that only the sparse works**
- It is likely due to high energy tracks present in the UE estimator region more likely to be there due to the larger acceptance and presence of jets
- The shift and width of UE subtraction could potentially be reduced applying a maximum p_T cut on the tracks in the UE region, based on the p_T of the leading track in the candidate cone
 - ▶ **A factor 1.5 seems to work on all centralities for the η -band and $R=0.2$.**
 - ▶ Is it a reasonable approach?
 - ▶ η -band is the preferred UE estimator since less shifted and less affected by flow as hinted by S_0 studies shown in the (back-up)
- Action plan under consideration: Make full analysis with and without this cut for the η -band and $\perp$ or φ -bands, also the jet UE estimator as is and see how the results vary.

Phase space of calorimeter clusters divided in 4 regions

- ▶ A: Signal, $0.1 < \sigma_{\text{long}}^2 < \sigma_{\text{long-max}}^2(p_T)$, $p_T^{\text{iso}} < x \text{ GeV}/c$
- ▶ B: Background, $0.4 < \sigma_{\text{long}}^2 < 2.0$, $p_T^{\text{iso}} < x \text{ GeV}/c$
- ▶ C: Background, $0.1 < \sigma_{\text{long}}^2 < \sigma_{\text{long-max}}^2(p_T)$, $x+1 < p_T^{\text{iso}} < x+6 \text{ GeV}/c$
- ▶ D: Background, $0.4 < \sigma_{\text{long}}^2 < 2.0$, $x+2 < p_T^{\text{iso}} < x+12 \text{ GeV}/c$

Purity in A region extracted as

$$P = \underbrace{1 - \left(\frac{N_n^{\text{iso}} / N_n^{\text{iso}}}{N_w^{\text{iso}} / N_w^{\text{iso}}} \right)_{\text{data}}}_{P_{\text{dd}}} \times \underbrace{\left(\frac{B_n^{\text{iso}} / N_n^{\text{iso}}}{N_w^{\text{iso}} / N_w^{\text{iso}}} \right)_{\text{MC}}}_{\alpha_{\text{MC}}}$$



- ▶ α_{MC} : correction term needed due to the non perfect proportionality in the different regions, jet-jet MC are the main ingredient for this correction factor combined with γ -jet MC: $\mathbf{N} = \mathbf{B}$ (jet-jet) + $\mathbf{S}$ (γ -jet)

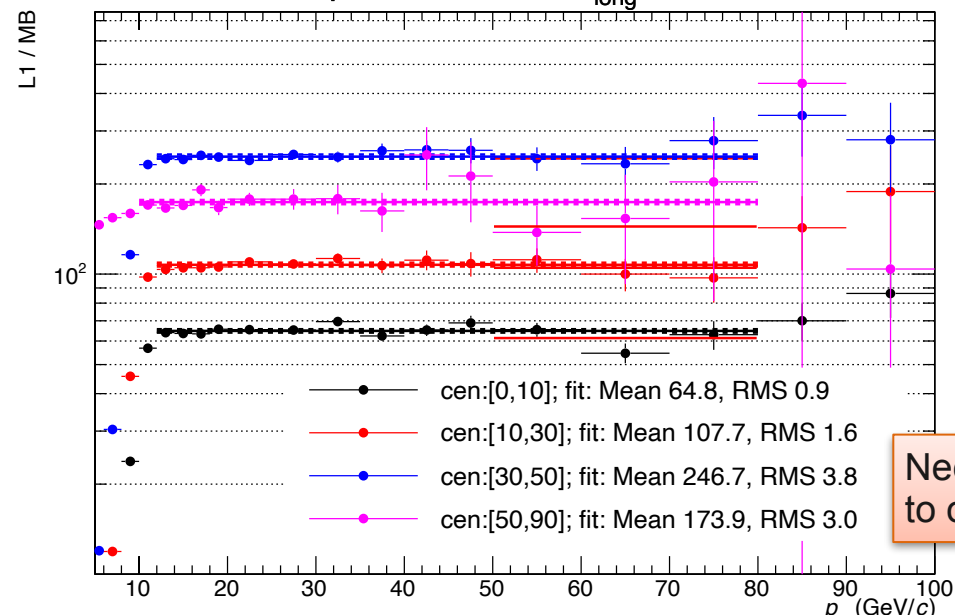
- ▶ Remark: **One has to remove in the analysis the existing generated fragmentation photons from the jet-jet sample**, removed from all distributions in the next slides. This is more important in unbiased JJ.

Next slides measurement for η -band, tracks in cone, $p_T^{\text{iso}} < x=4 \text{ GeV}/c$

In cone track $p_T > 0.7 \text{ GeV}/c$

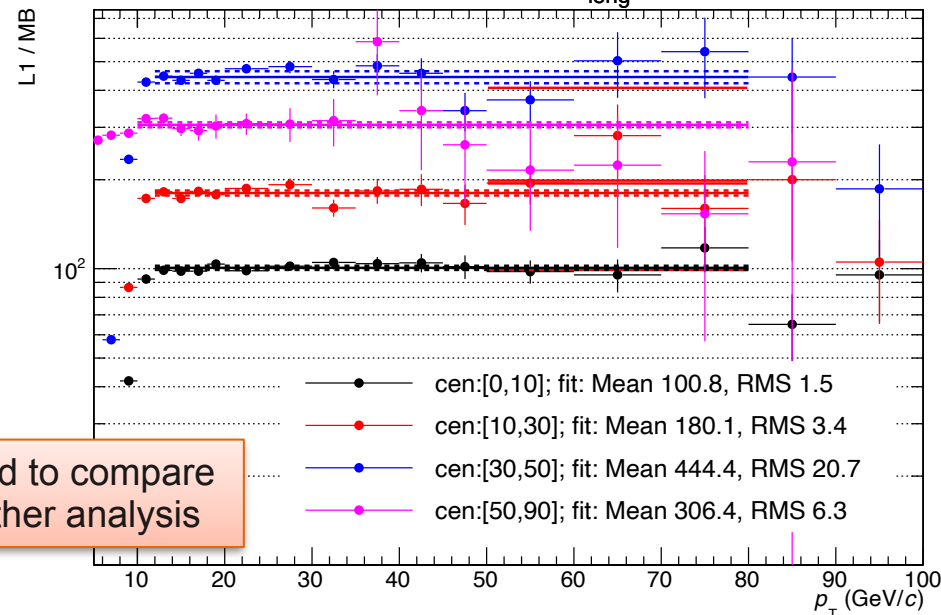
4-EMC/DMC triggers rejection factor: LHC18qr

LHC18qr, EMC, $0.10 < \sigma_{\text{long}}^2 < 2.00$

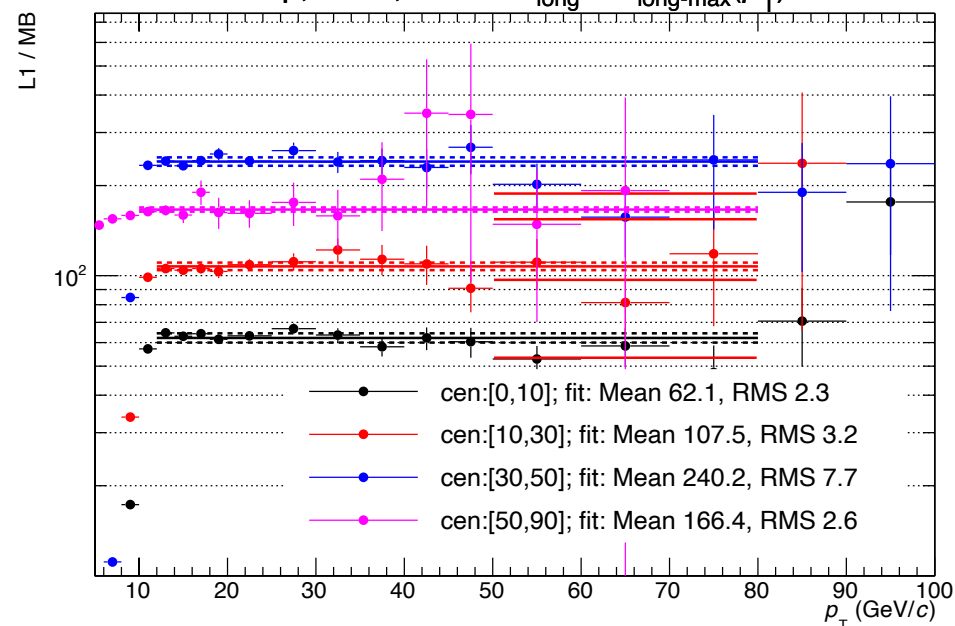


Need to compare
to other analysis

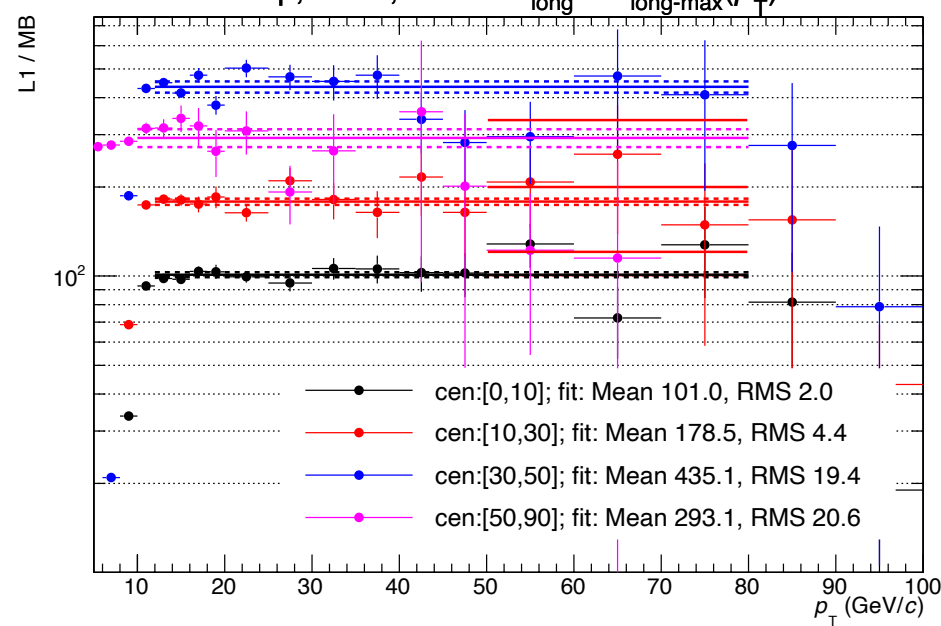
LHC18qr, DMC, $0.10 < \sigma_{\text{long}}^2 < 2.00$

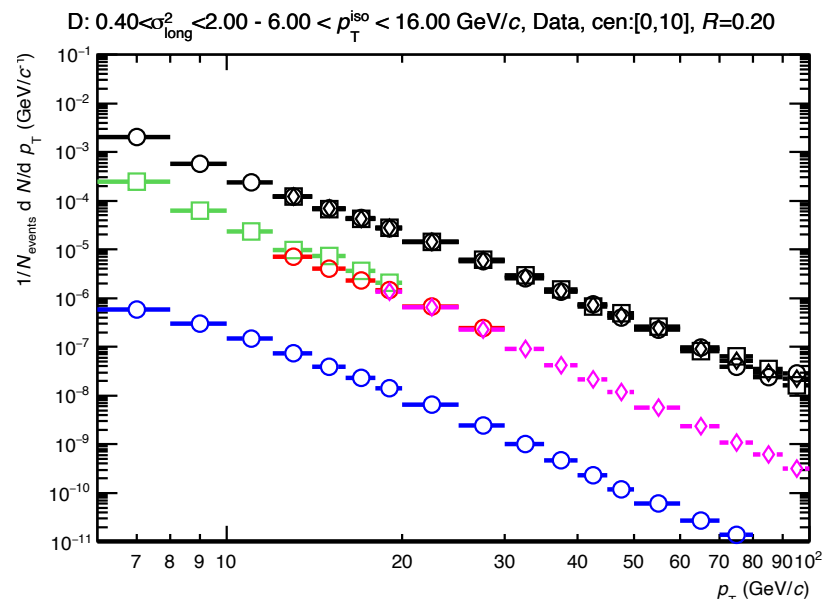
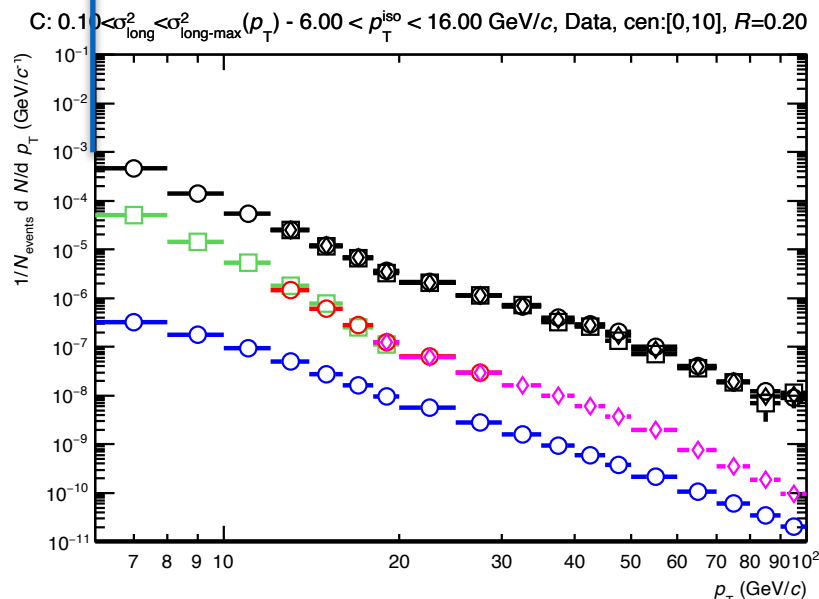
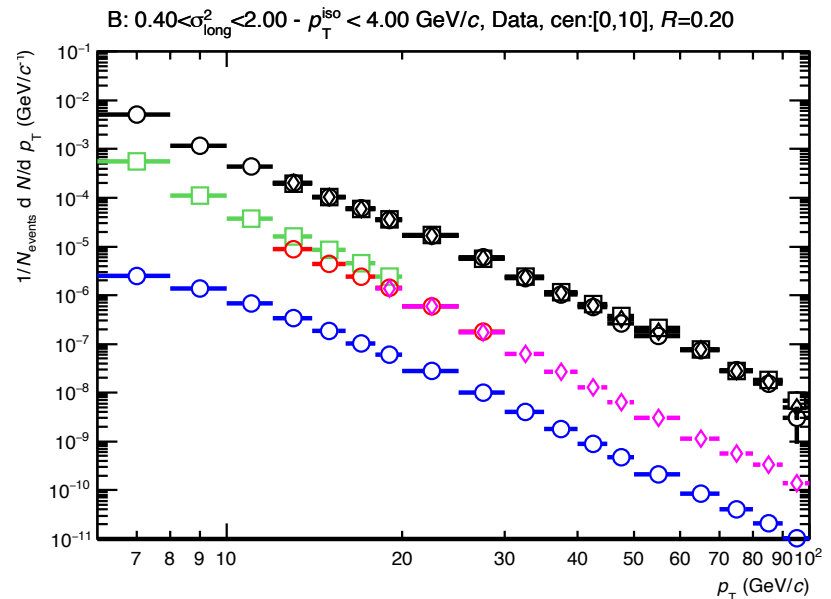
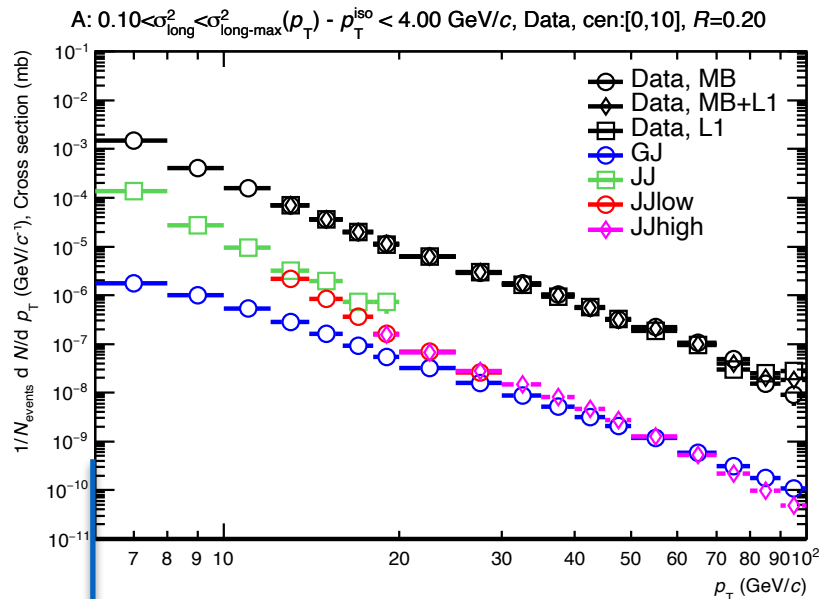


LHC18qr, EMC, $0.10 < \sigma_{\text{long}}^2 < \sigma_{\text{long-max}}^2(p_T)$



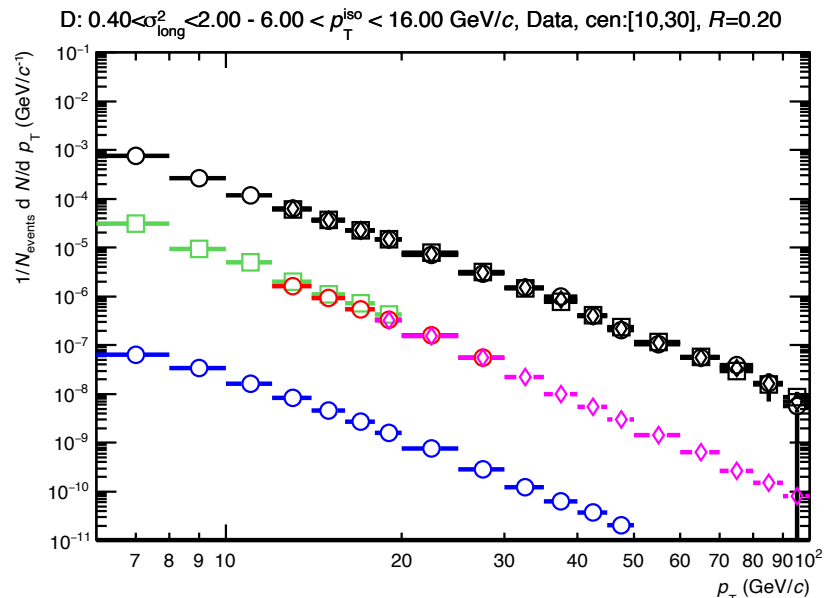
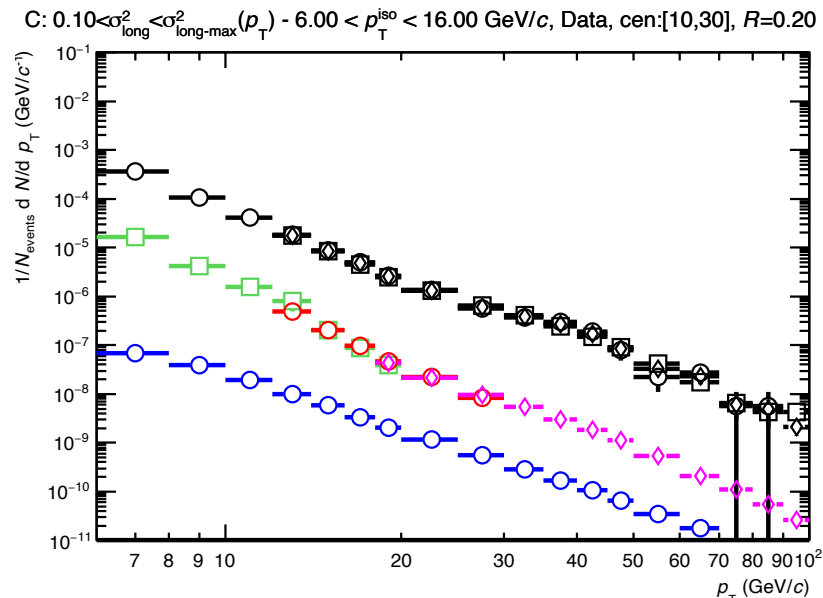
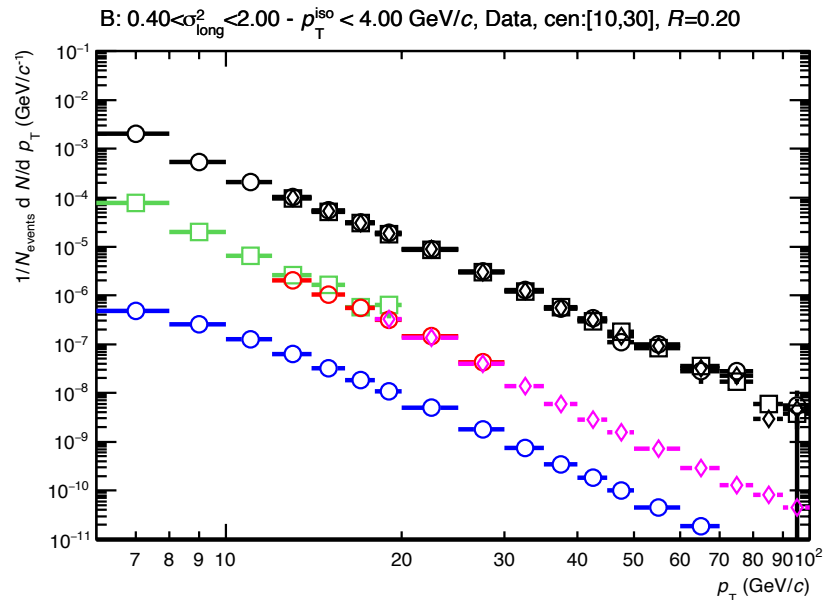
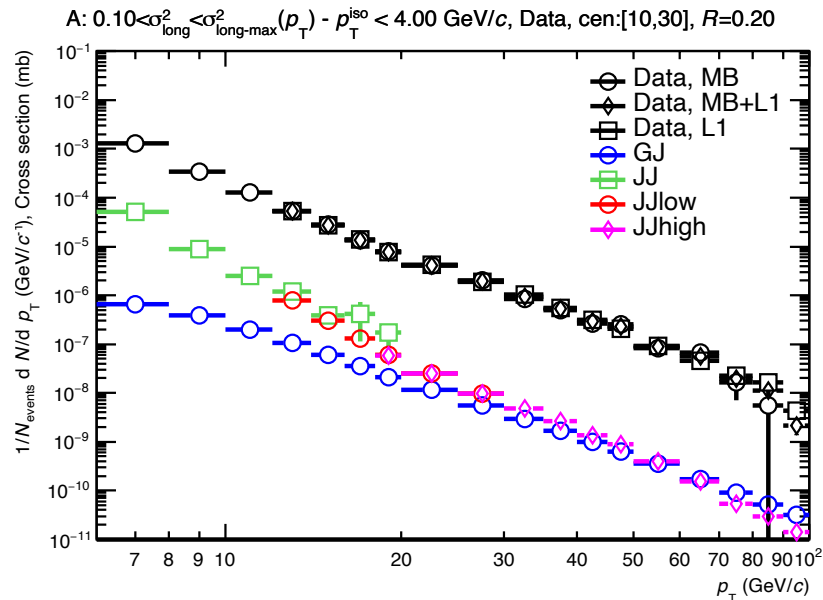
LHC18qr, DMC, $0.10 < \sigma_{\text{long}}^2 < \sigma_{\text{long-max}}^2(p_T)$



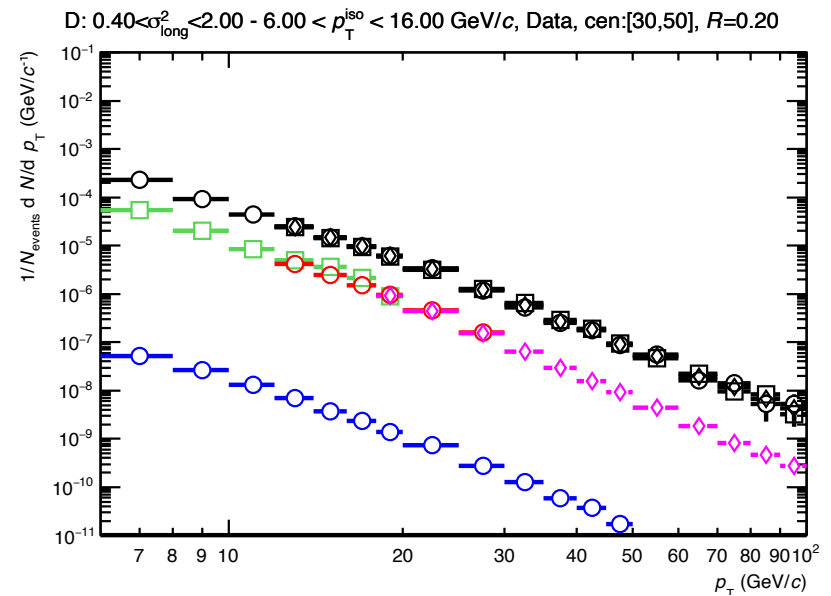
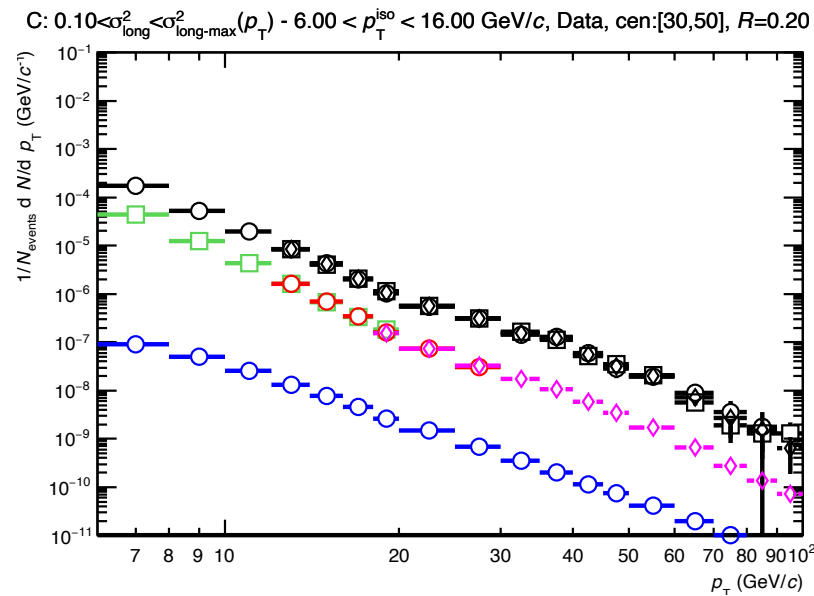
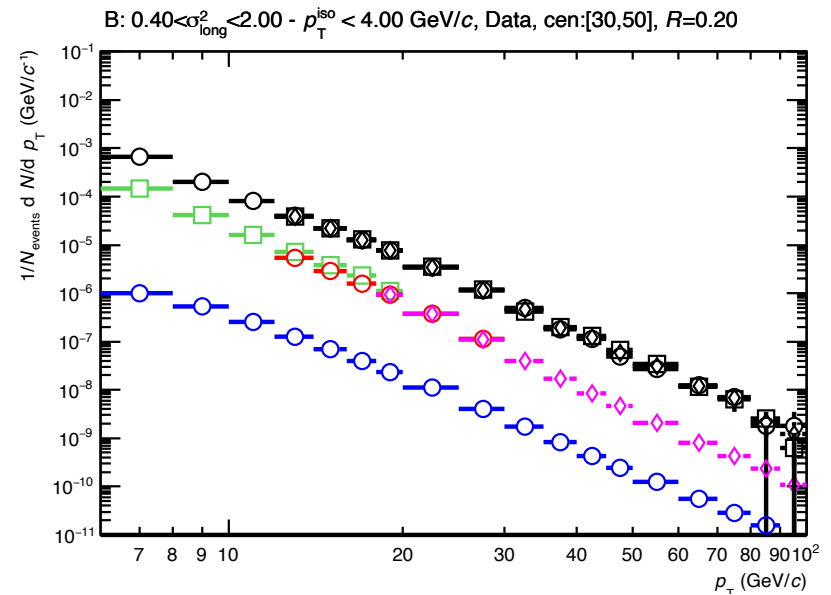
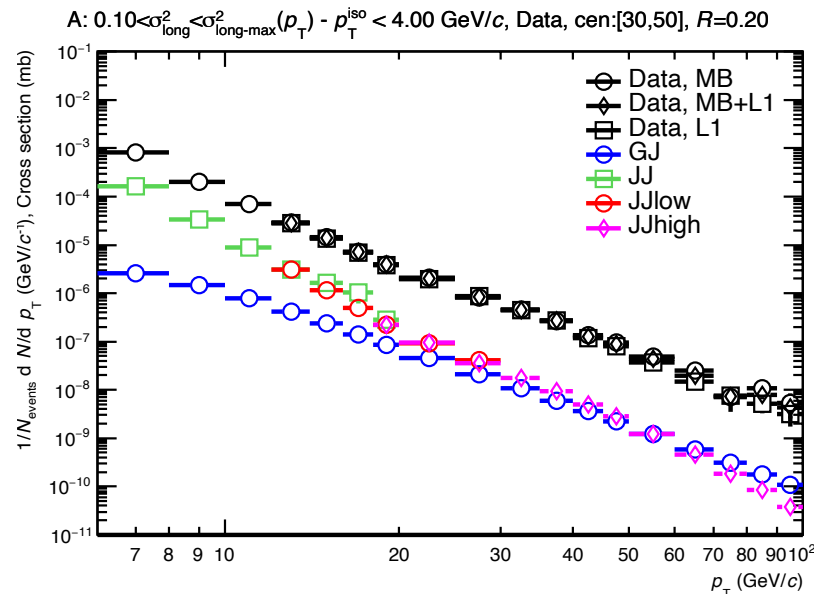


JJ unbiased and biased do not match too well

Measurement feasible till $\sim 100 \text{ GeV}/c$ possibly even a bit more

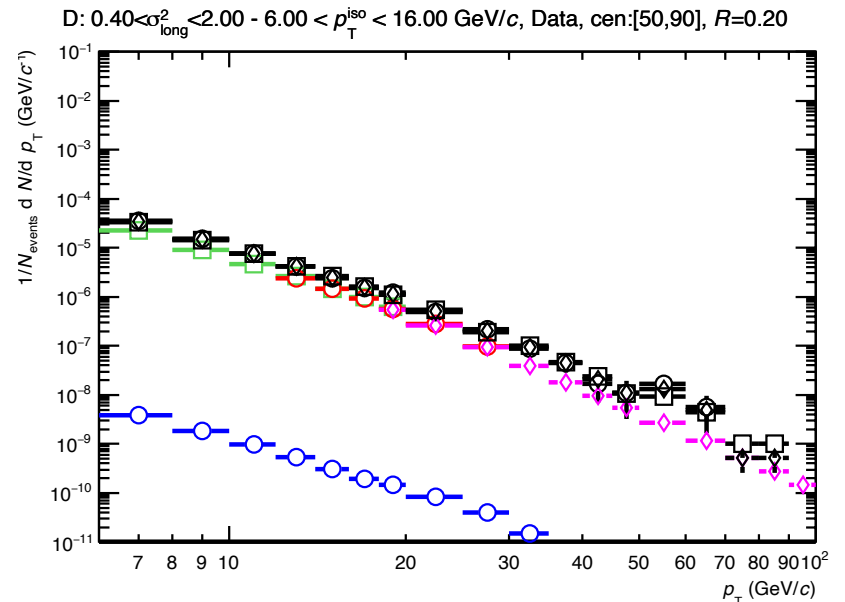
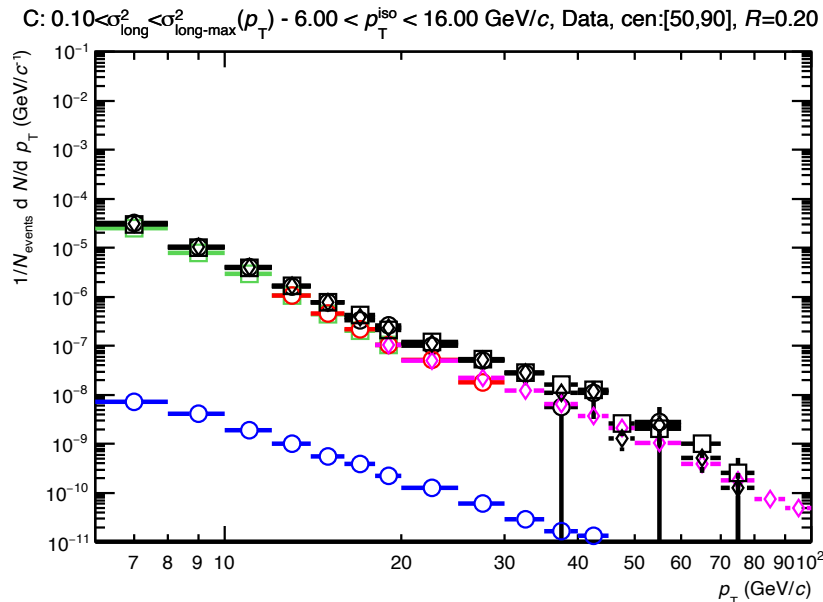
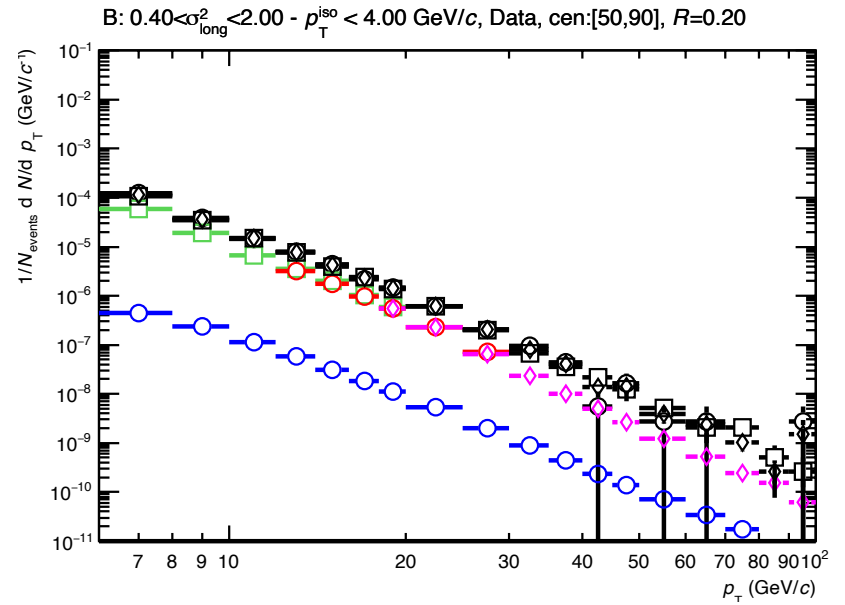
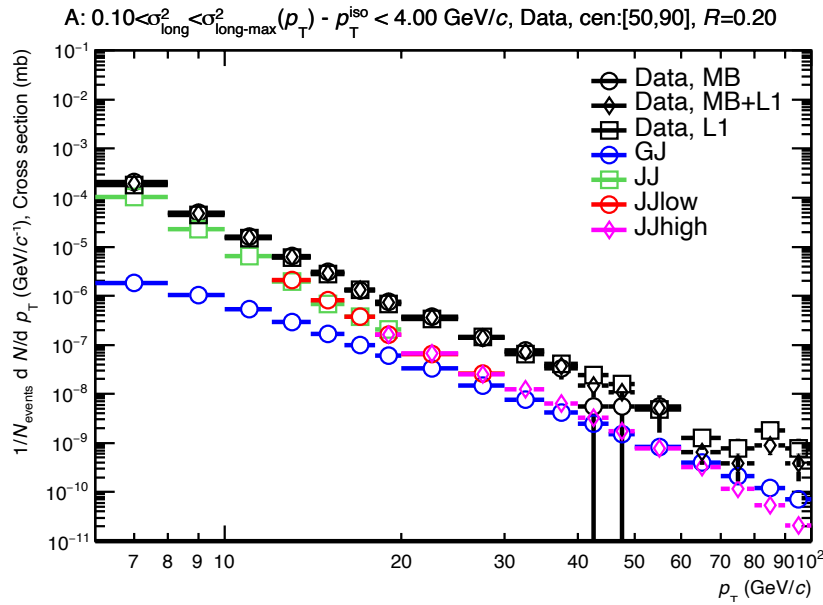


JJ unbiased and biased do not match too well
Measurement feasible till $\sim 80\text{-}100 \text{ GeV/c}$



JJ unbiased and biased do not match too well

Measurement feasible till $\sim 80\text{-}100 \text{ GeV}/c$

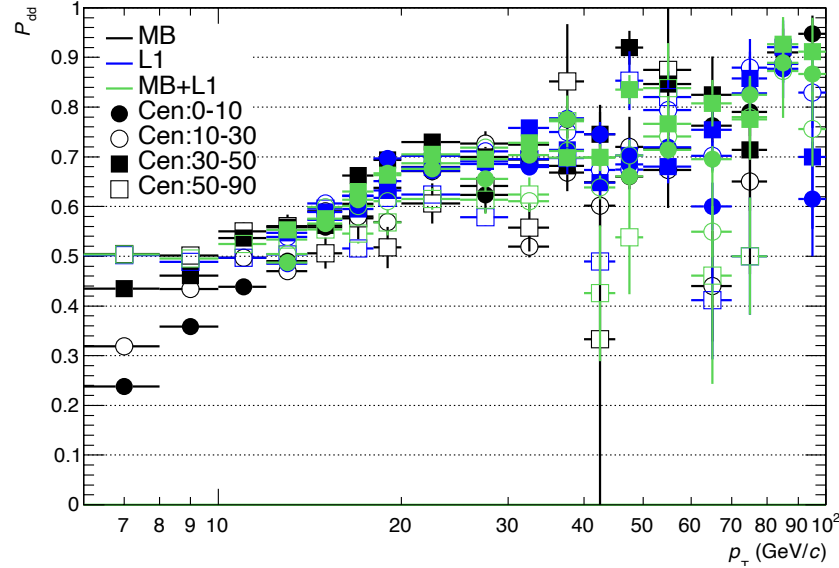


JJ unbiased and biased match
Measurement feasible till $\sim 80 \text{ GeV}/c$

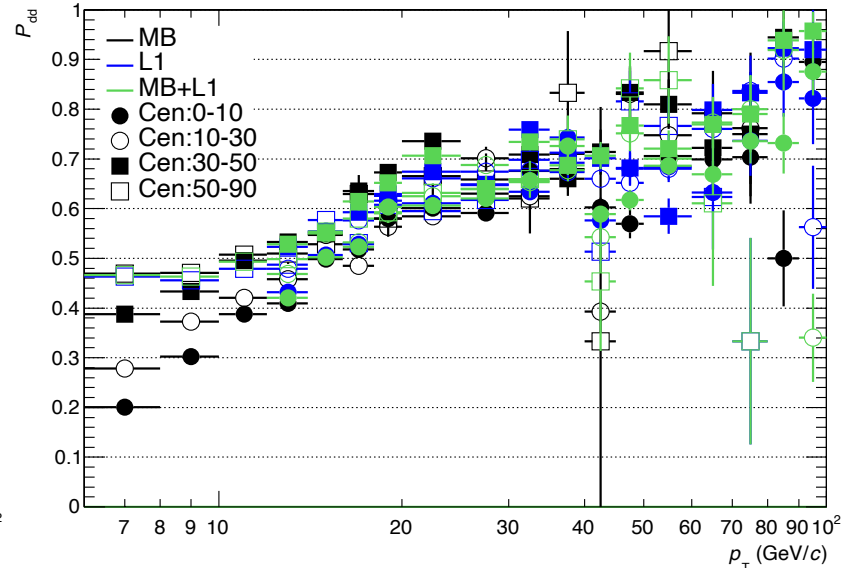
$$P = 1 - \left(\frac{N_{\text{n}}^{\text{iso}} / N_{\text{n}}^{\text{iso}}}{N_{\text{w}}^{\text{iso}} / N_{\text{w}}^{\text{iso}} \right)_{\text{data}}$$

Centrality and R dependent

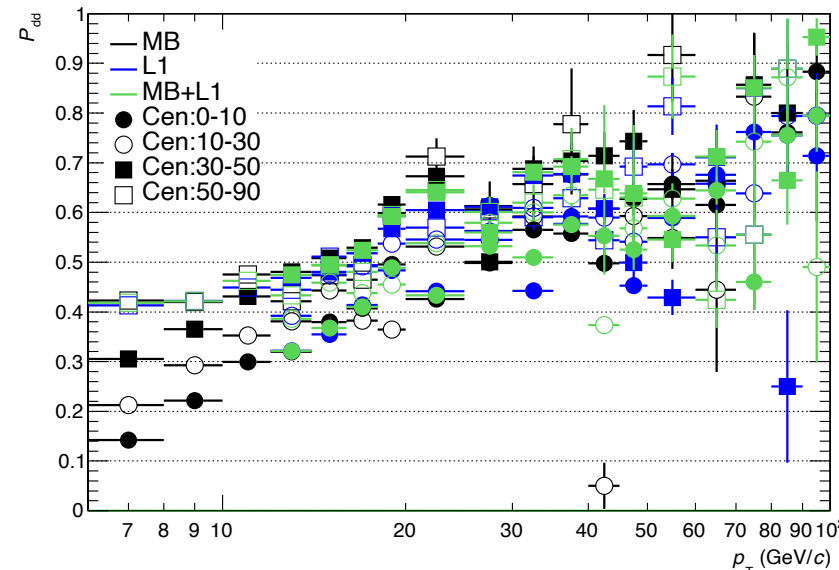
$p_{\text{T}}^{\text{iso}} < 4.0, 6.0 < p_{\text{T}}^{\text{anti-iso}} < 16.0 \text{ GeV}/c, R=0.15$



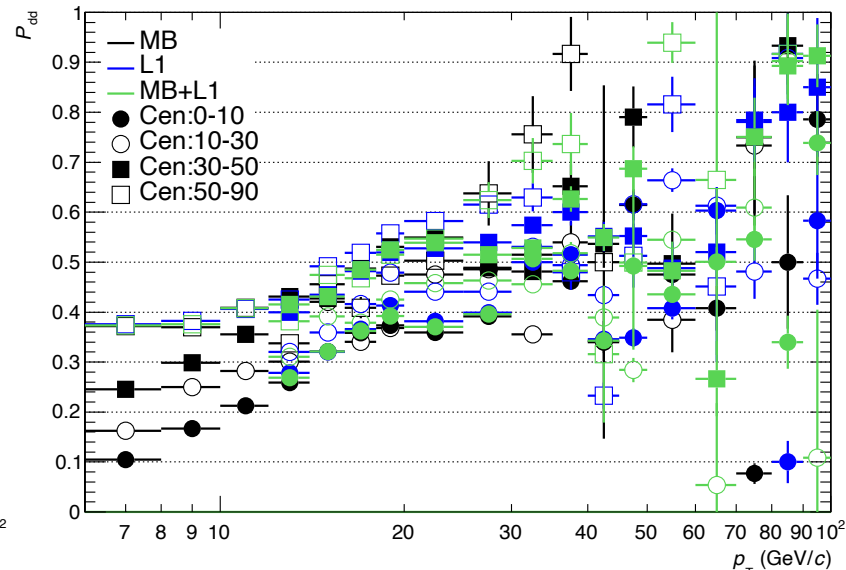
$p_{\text{T}}^{\text{iso}} < 4.0, 6.0 < p_{\text{T}}^{\text{anti-iso}} < 16.0 \text{ GeV}/c, R=0.20$



$p_{\text{T}}^{\text{iso}} < 4.0, 6.0 < p_{\text{T}}^{\text{anti-iso}} < 16.0 \text{ GeV}/c, R=0.30$



$p_{\text{T}}^{\text{iso}} < 4.0, 6.0 < p_{\text{T}}^{\text{anti-iso}} < 16.0 \text{ GeV}/c, R=0.40$

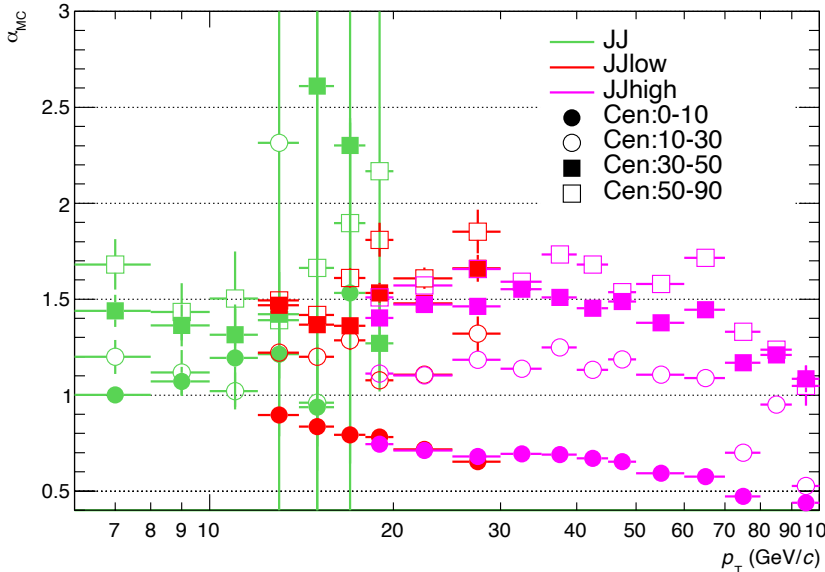


4-MC Correction factor: EMCal, η -band, tracks in cone, $p_{\text{T}}^{\text{iso}} < 4 \text{ GeV}/c$ 70 / 83

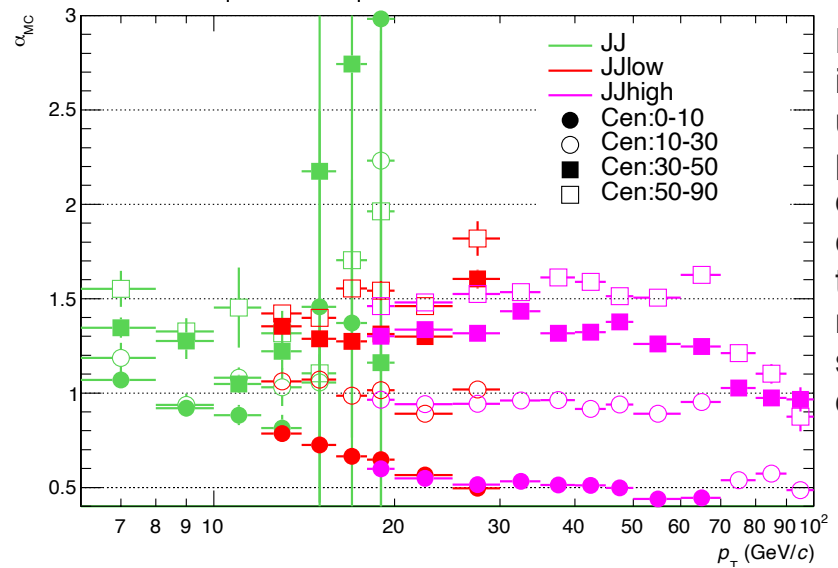
$$\alpha_{\text{MC}} = \left(\frac{B_{\text{n}}^{\text{iso}} / N_{\text{n}}^{\text{iso}}}{N_{\text{w}}^{\text{iso}} / N_{\text{w}}^{\text{iso}}} \right)_{\text{MC}}$$

Strong dependence on centrality due to GJ (N=GJ+JJ, B=JJ) and centrality dependent JJ downscaling.

$p_{\text{T}}^{\text{iso}} < 4.0, 6.0 < p_{\text{T}}^{\text{anti-iso}} < 16.0 \text{ GeV}/c, R=0.15$

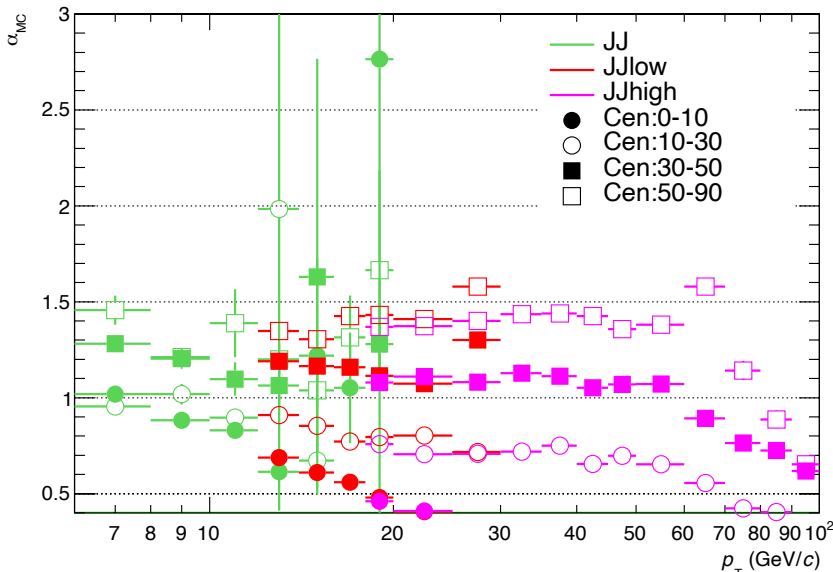


$p_{\text{T}}^{\text{iso}} < 4.0, 6.0 < p_{\text{T}}^{\text{anti-iso}} < 16.0 \text{ GeV}/c, R=0.20$

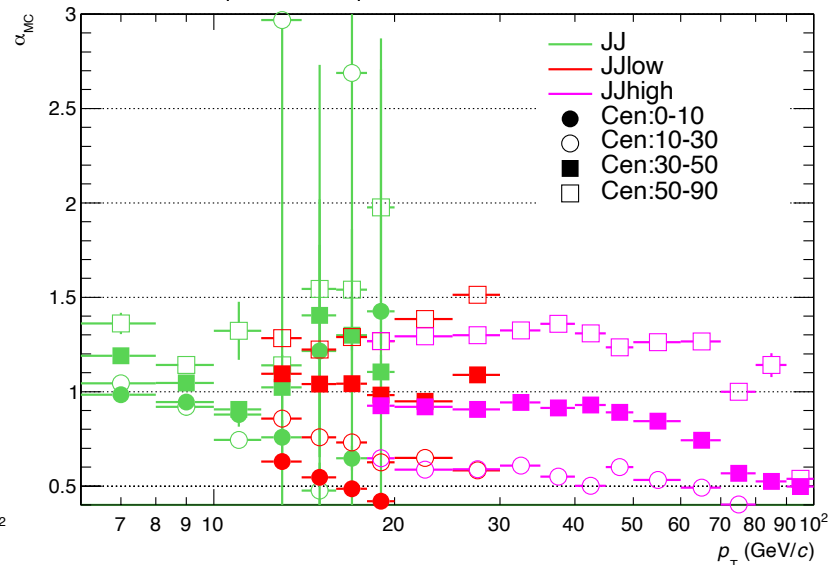


Difficult to see if JJ biased and unbiased produce different correction in the overlapping region but they seem not too different.

$p_{\text{T}}^{\text{iso}} < 4.0, 6.0 < p_{\text{T}}^{\text{anti-iso}} < 16.0 \text{ GeV}/c, R=0.30$



$p_{\text{T}}^{\text{iso}} < 4.0, 6.0 < p_{\text{T}}^{\text{anti-iso}} < 16.0 \text{ GeV}/c, R=0.40$



Quite large correction in any case, try to see in next iteration if imposing a minimum r hole in the cone could reduce this

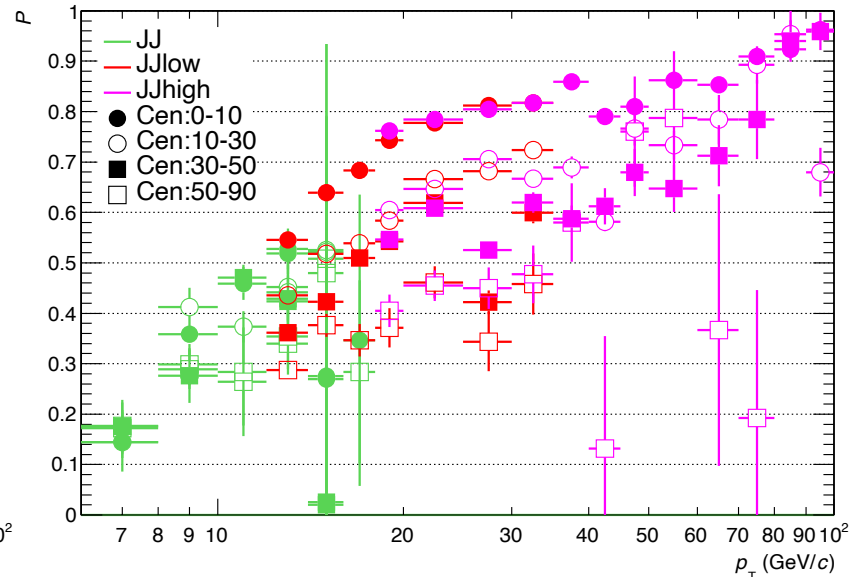
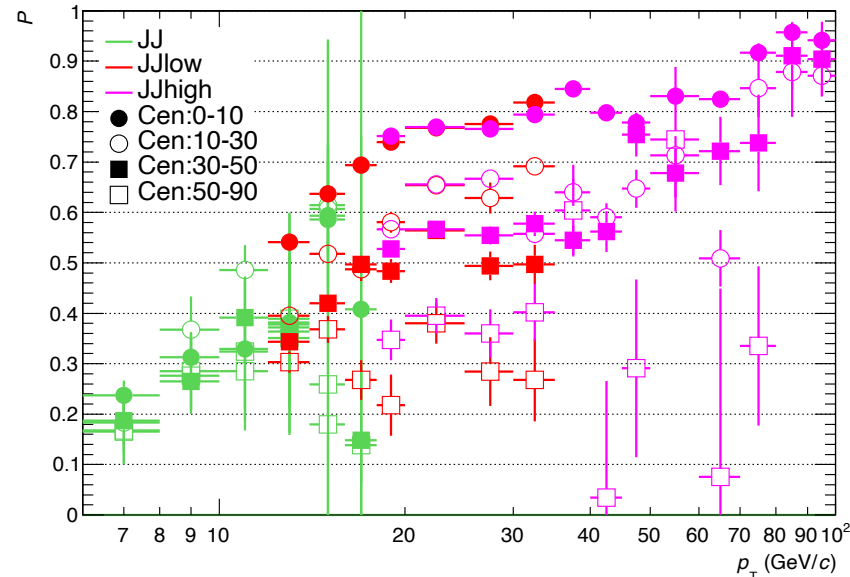
4-Purity: EMCal, η -band, tracks in cone, $p_{\text{T}}^{\text{iso}} < 4 \text{ GeV/c}$

$$P = 1 - \left(\frac{N_{\text{n}}^{\text{iso}} / N_{\text{n}}^{\text{iso}}}{N_{\text{w}}^{\text{iso}} / N_{\text{w}}^{\text{iso}} \right)_{\text{data}} \times \left(\frac{B_{\text{n}}^{\text{iso}} / N_{\text{n}}^{\text{iso}}}{N_{\text{w}}^{\text{iso}} / N_{\text{w}}^{\text{iso}} \right)_{\text{MC}}$$

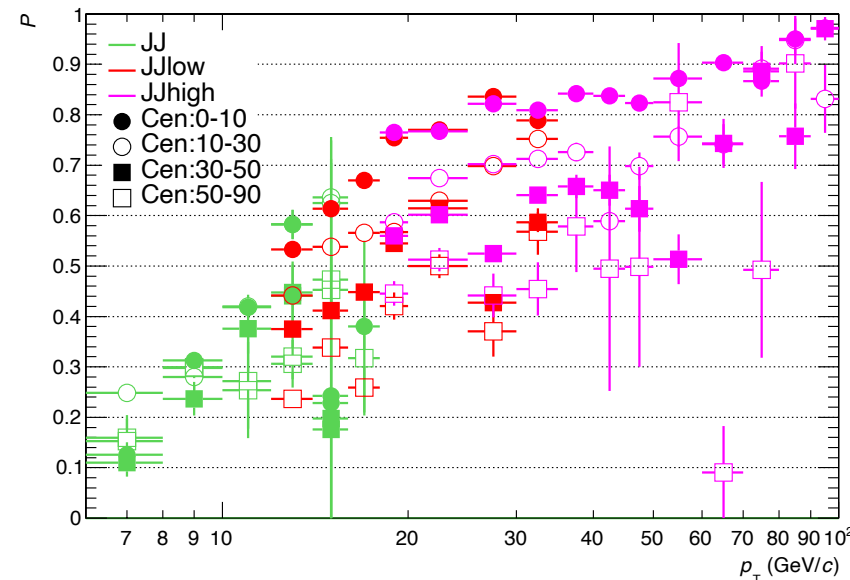
$p_{\text{T}}^{\text{iso}} < 4.0, 6.0 < p_{\text{T}}^{\text{anti-iso}} < 16.0 \text{ GeV/c}, R=0.15$

Strong dependence on centrality, not so much on R

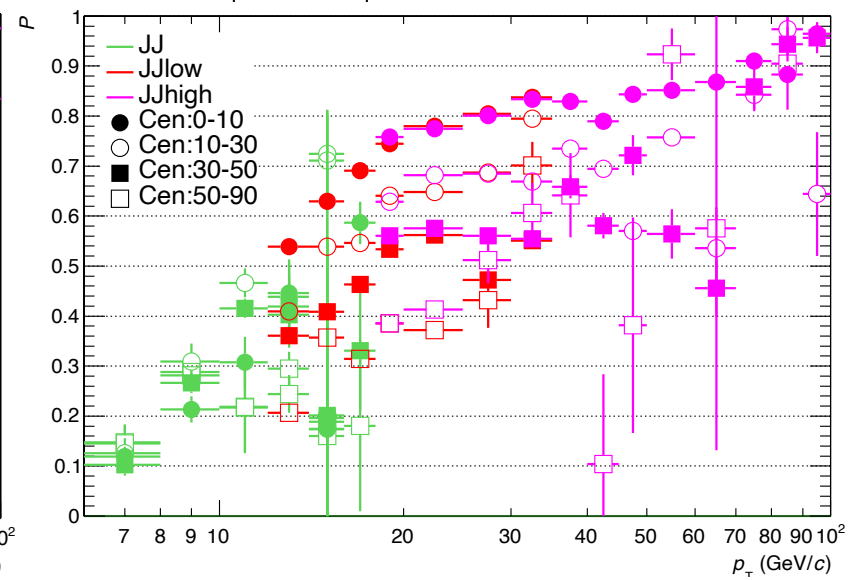
$p_{\text{T}}^{\text{iso}} < 4.0, 6.0 < p_{\text{T}}^{\text{anti-iso}} < 16.0 \text{ GeV/c}, R=0.20$



$p_{\text{T}}^{\text{iso}} < 4.0, 6.0 < p_{\text{T}}^{\text{anti-iso}} < 16.0 \text{ GeV/c}, R=0.30$



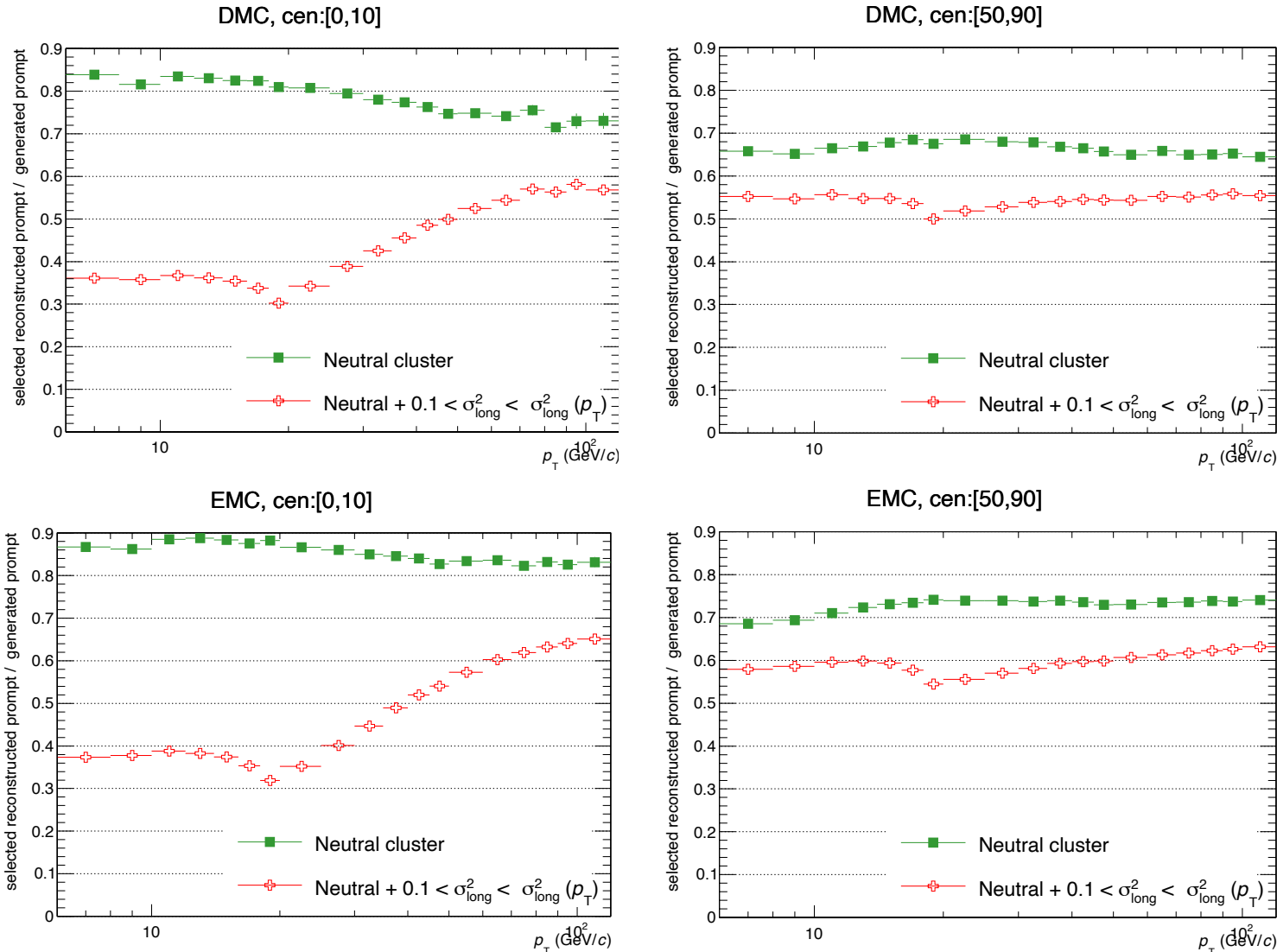
$p_{\text{T}}^{\text{iso}} < 4.0, 6.0 < p_{\text{T}}^{\text{anti-iso}} < 16.0 \text{ GeV/c}, R=0.40$

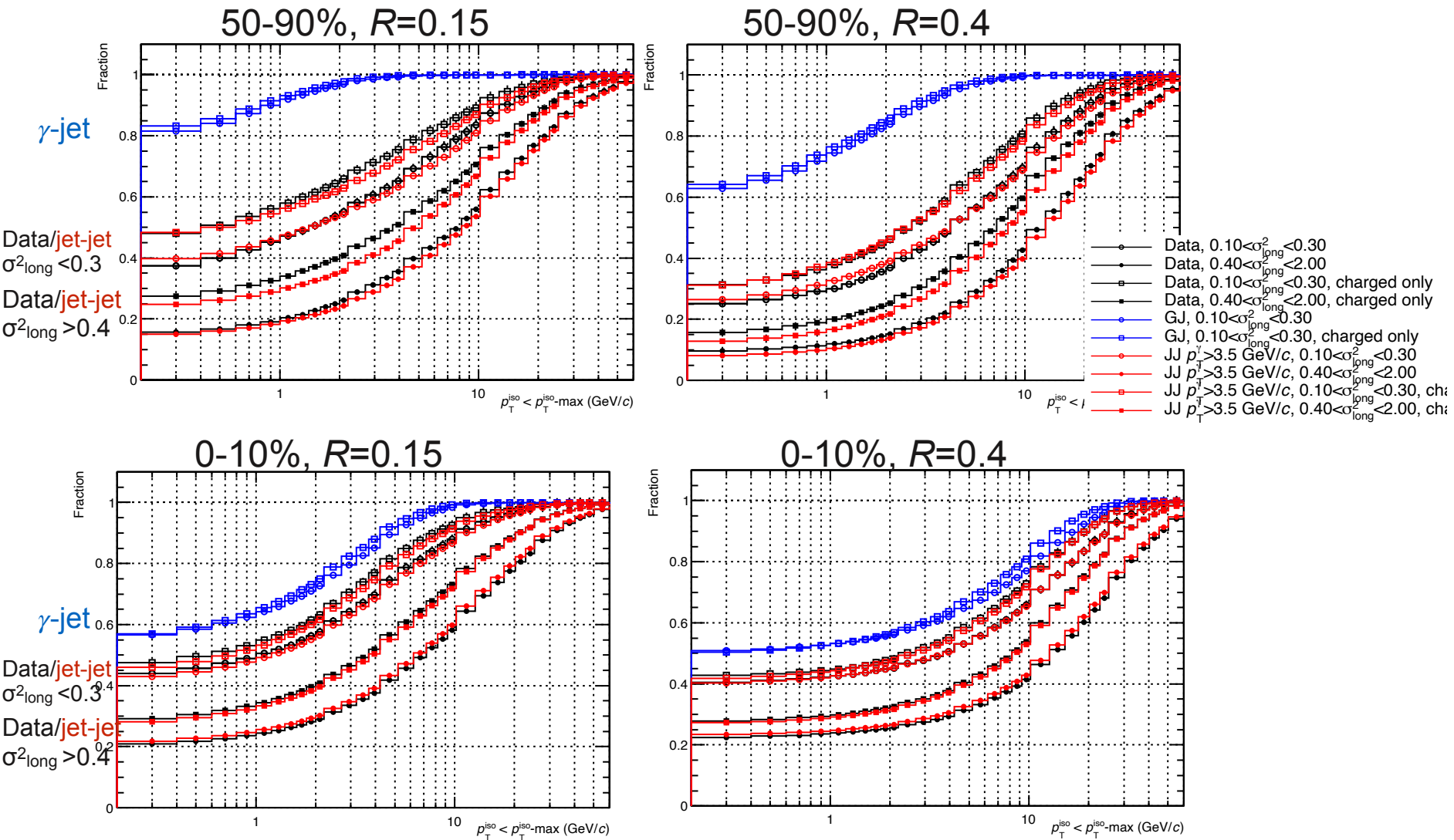


4-Reconstruction efficiency, p_T dependent maximum σ^2_{long} cut 72 / 83

- Reconstructed cluster spectra (reconstructed p_T) divided by generated photon spectra (generated p_T)

► Flatter and higher efficiency till 18 GeV/c, specially for central collisions

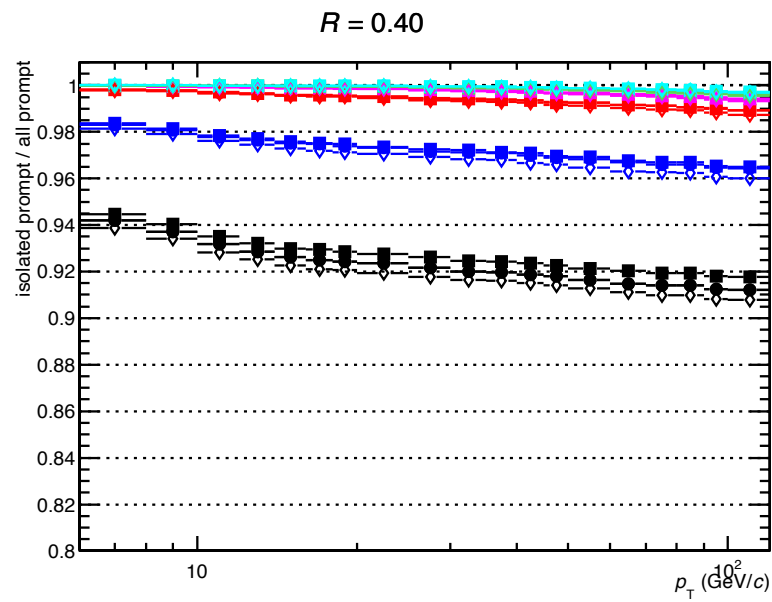
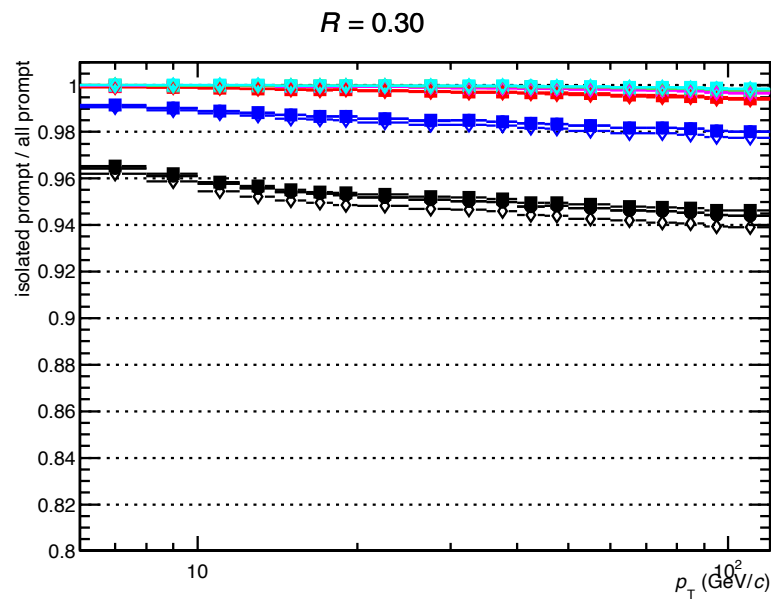
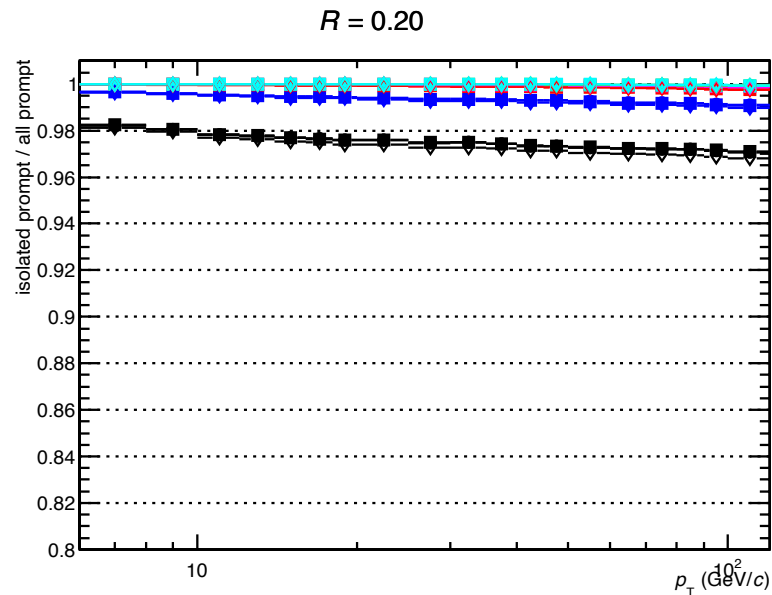
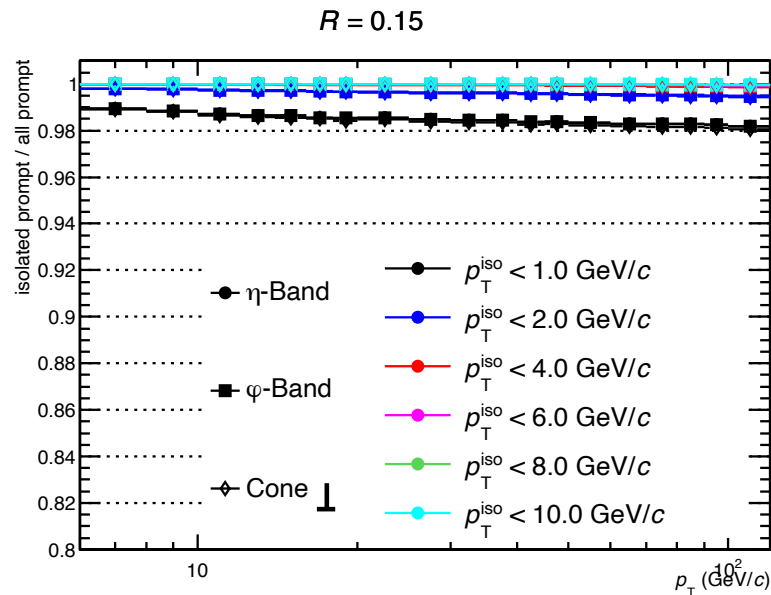




Consider similar constant cut as in pp 2 GeV or a bit higher 4-5 GeV to enhance efficiency in central. Smaller cone size has better efficiency, specially in central.

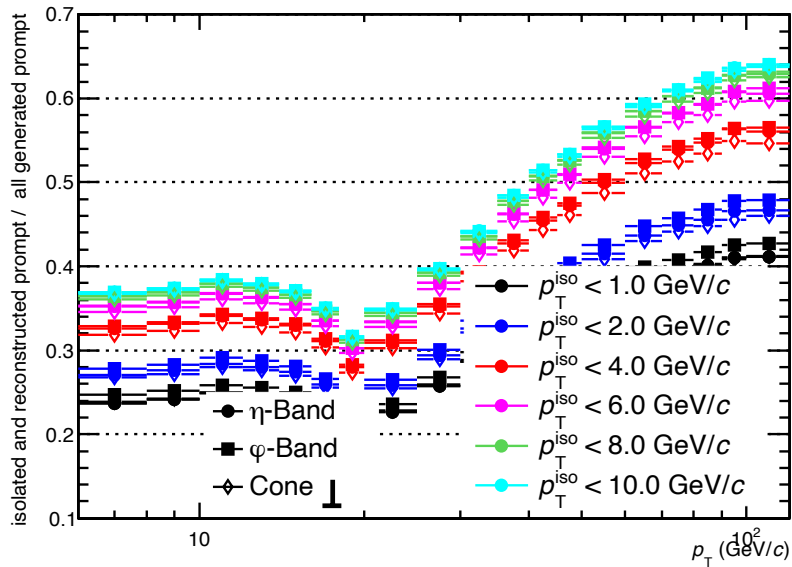
4-Isolation efficiency at generator level, no Pb-Pb UE

Charged only in cone, a bit lower with clusters also in cone. The UE method has small effect. From 4 GeV/c, fraction decreases significantly

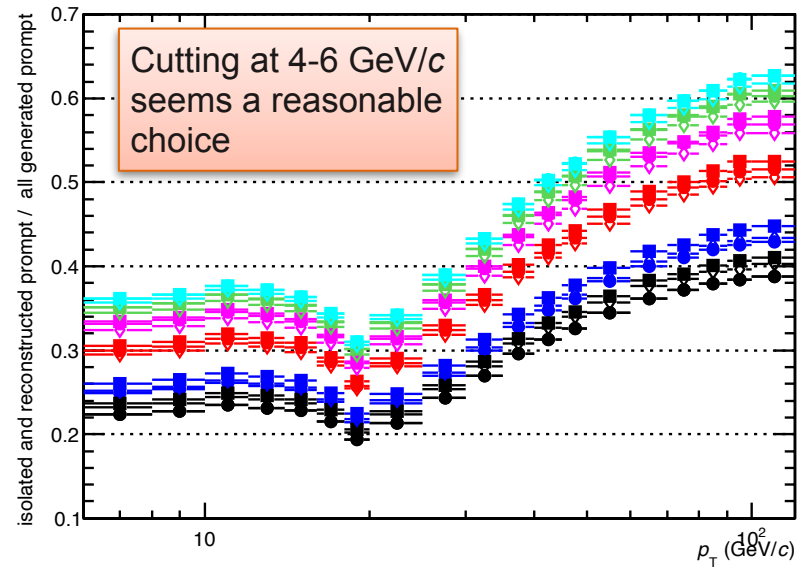


Central 0-10%, charged only in cone, a bit lower with clusters also in cone

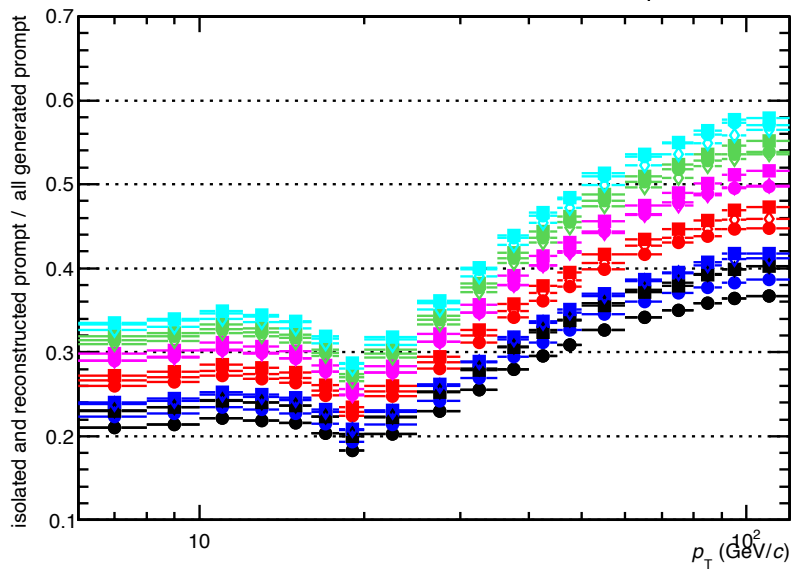
EMC, $R = 0.15$, cen:[0,10], $0.1 < \sigma_{\text{long}}^2 < \sigma_{\text{long}}^2(p_T)$



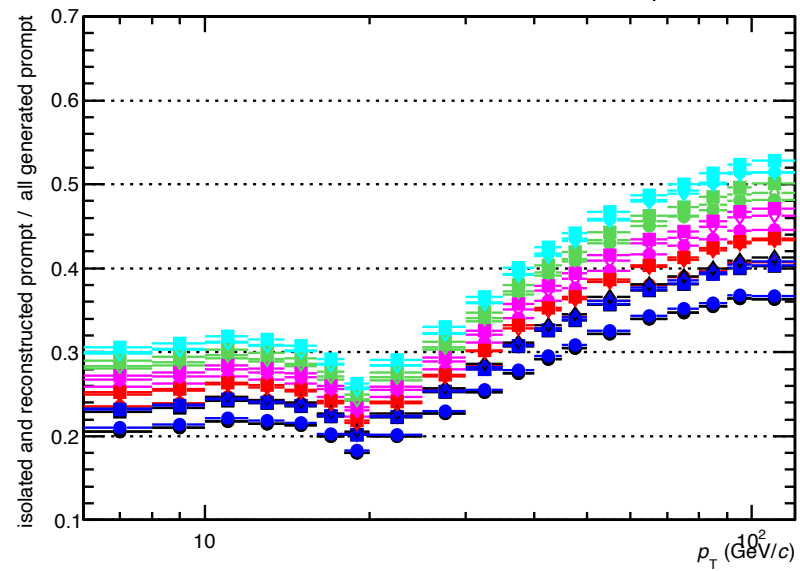
EMC, $R = 0.20$, cen:[0,10], $0.1 < \sigma_{\text{long}}^2 < \sigma_{\text{long}}^2(p_T)$



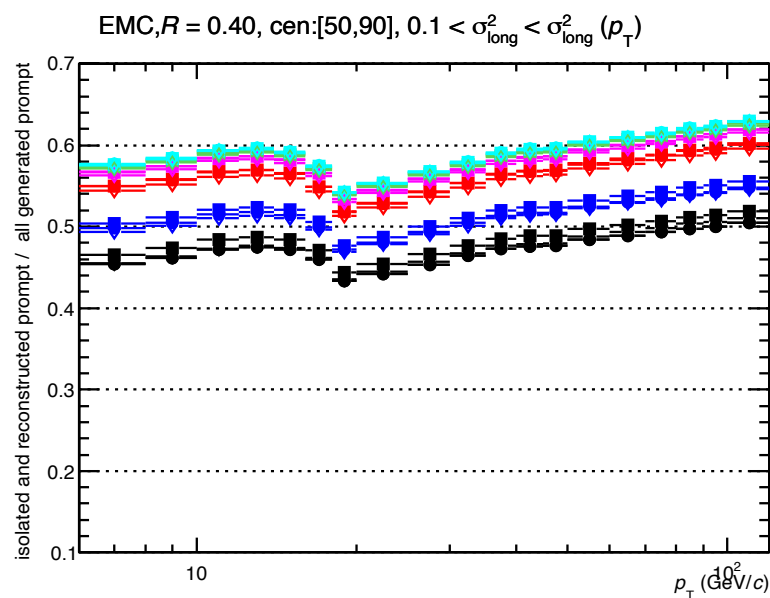
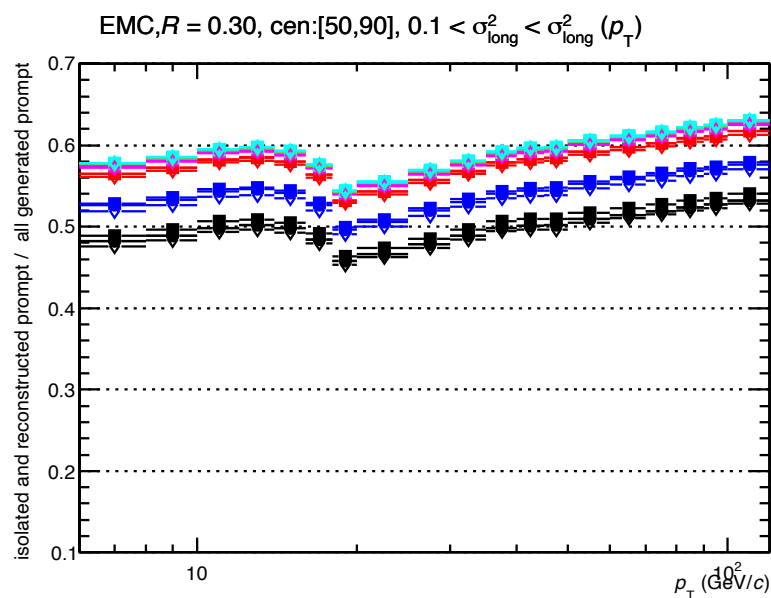
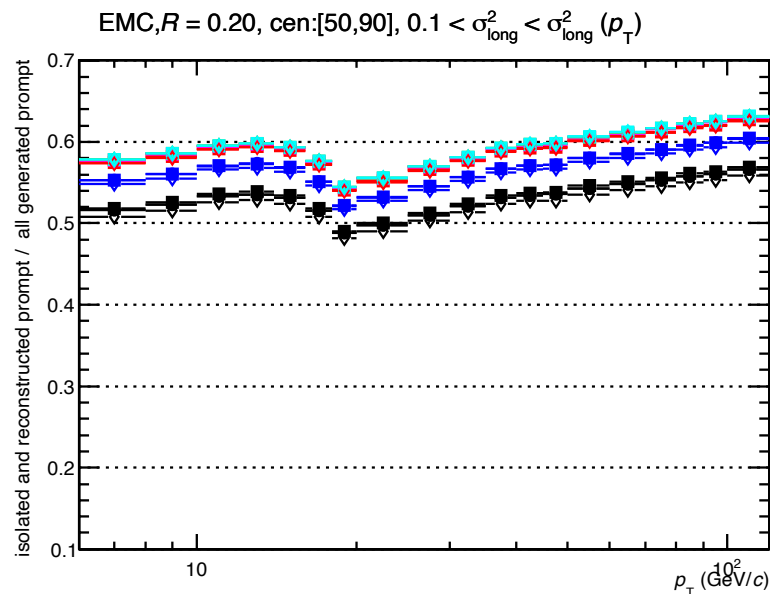
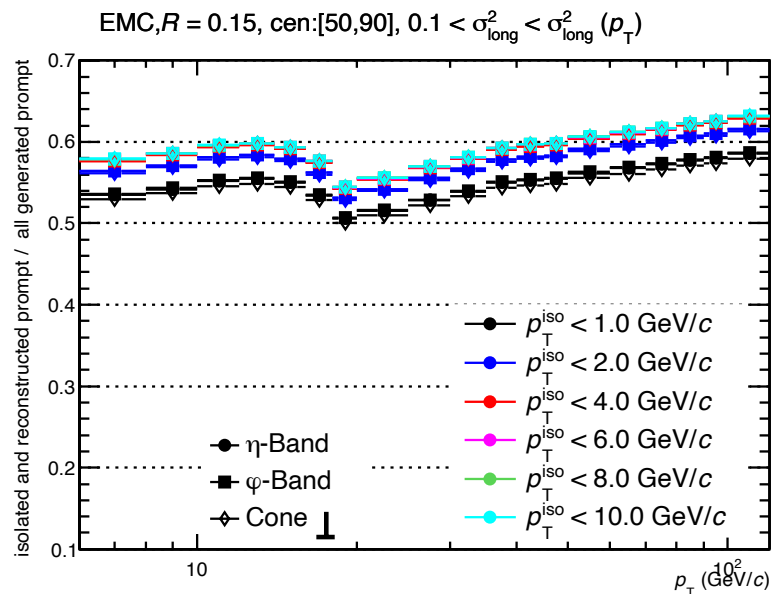
EMC, $R = 0.30$, cen:[0,10], $0.1 < \sigma_{\text{long}}^2 < \sigma_{\text{long}}^2(p_T)$



EMC, $R = 0.40$, cen:[0,10], $0.1 < \sigma_{\text{long}}^2 < \sigma_{\text{long}}^2(p_T)$

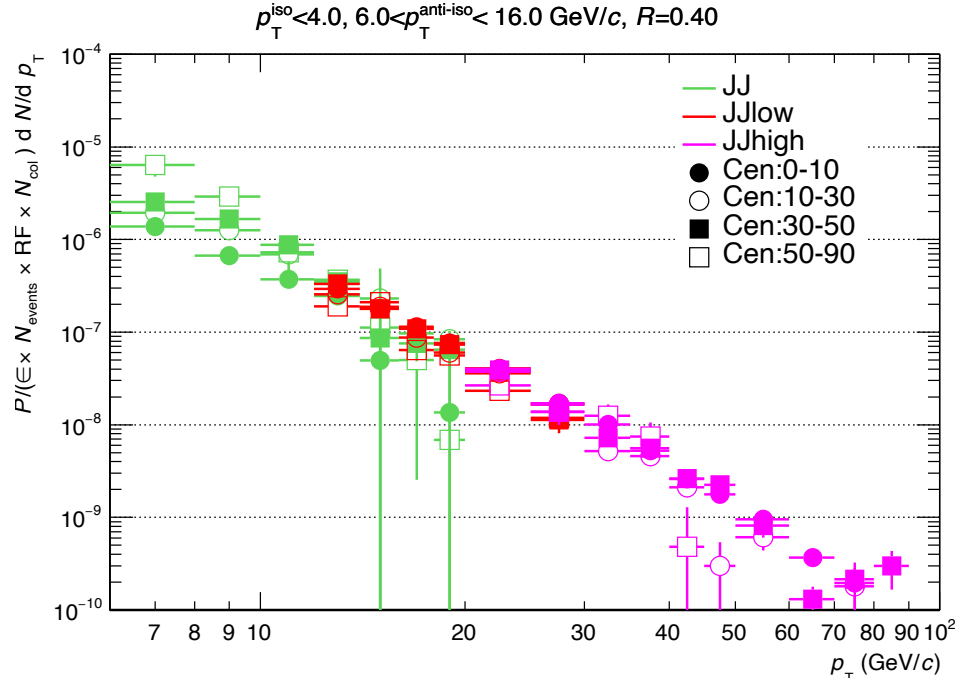
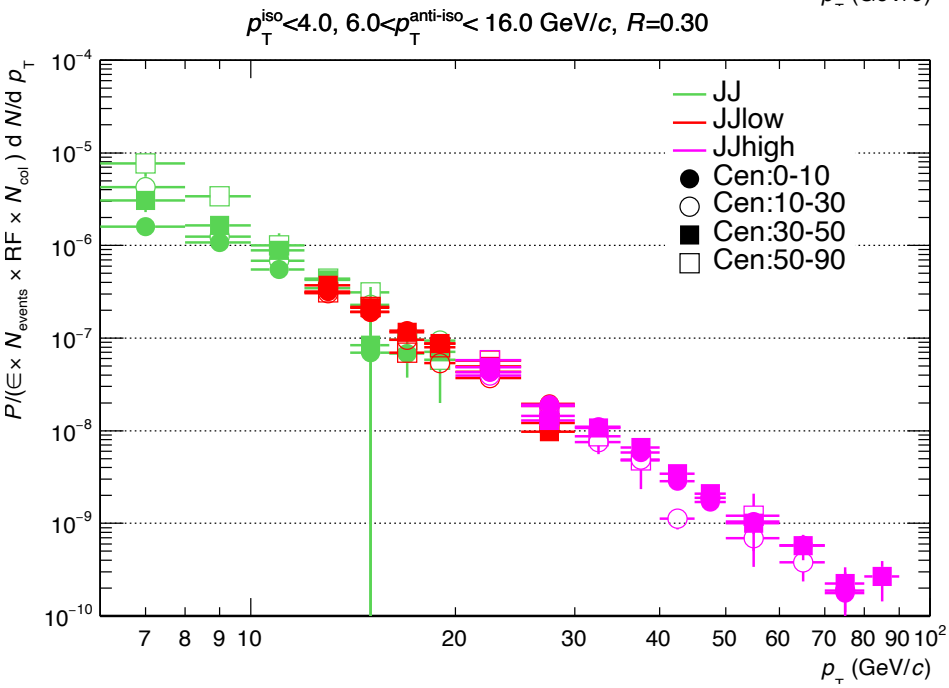
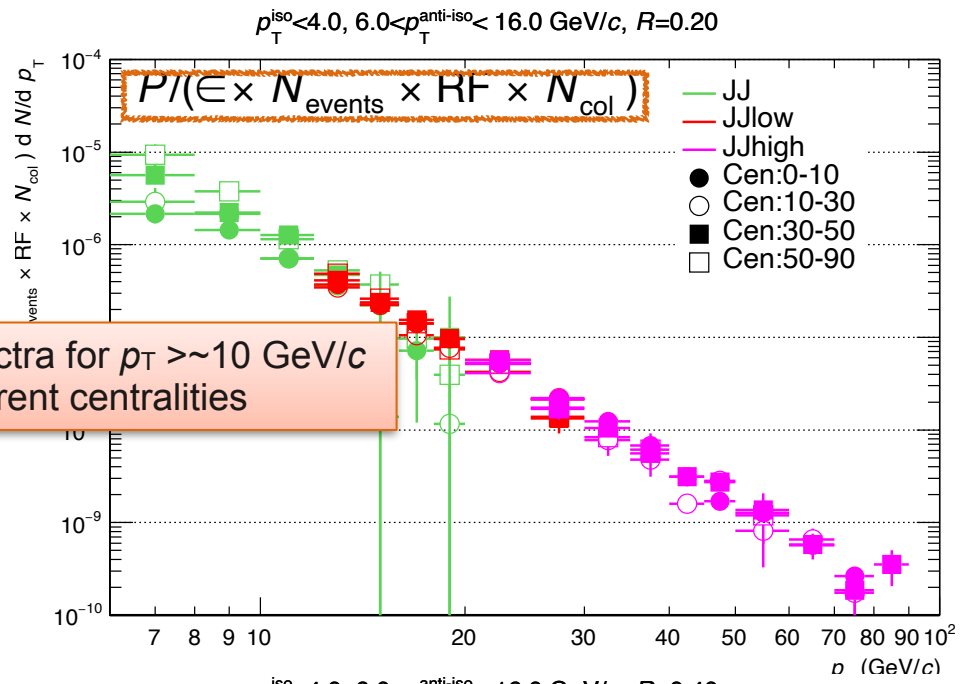
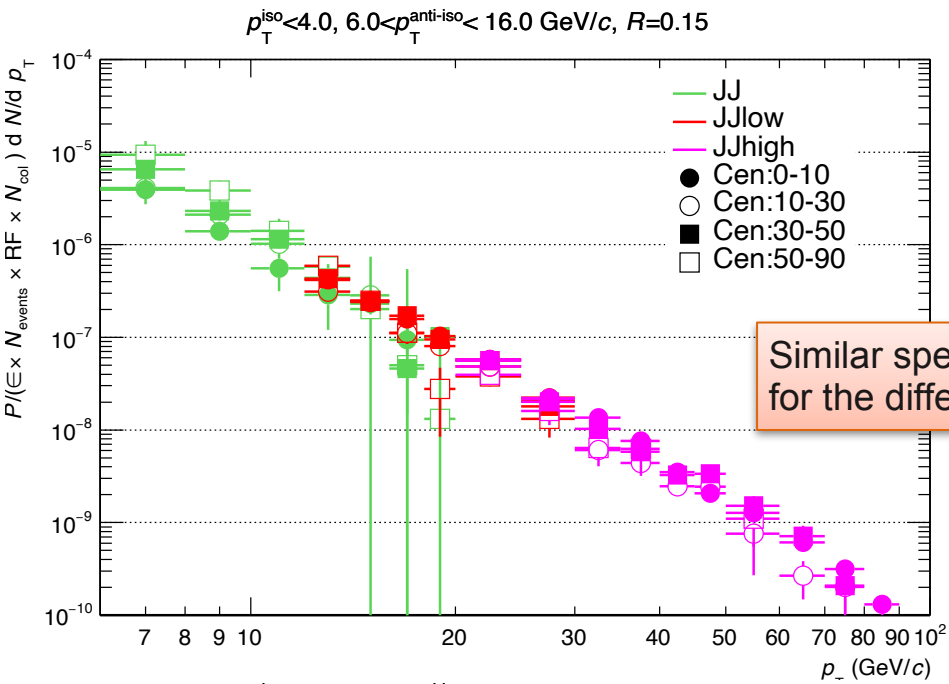


Peripheral 50-90%, charged only in cone, similar with clusters also in cone

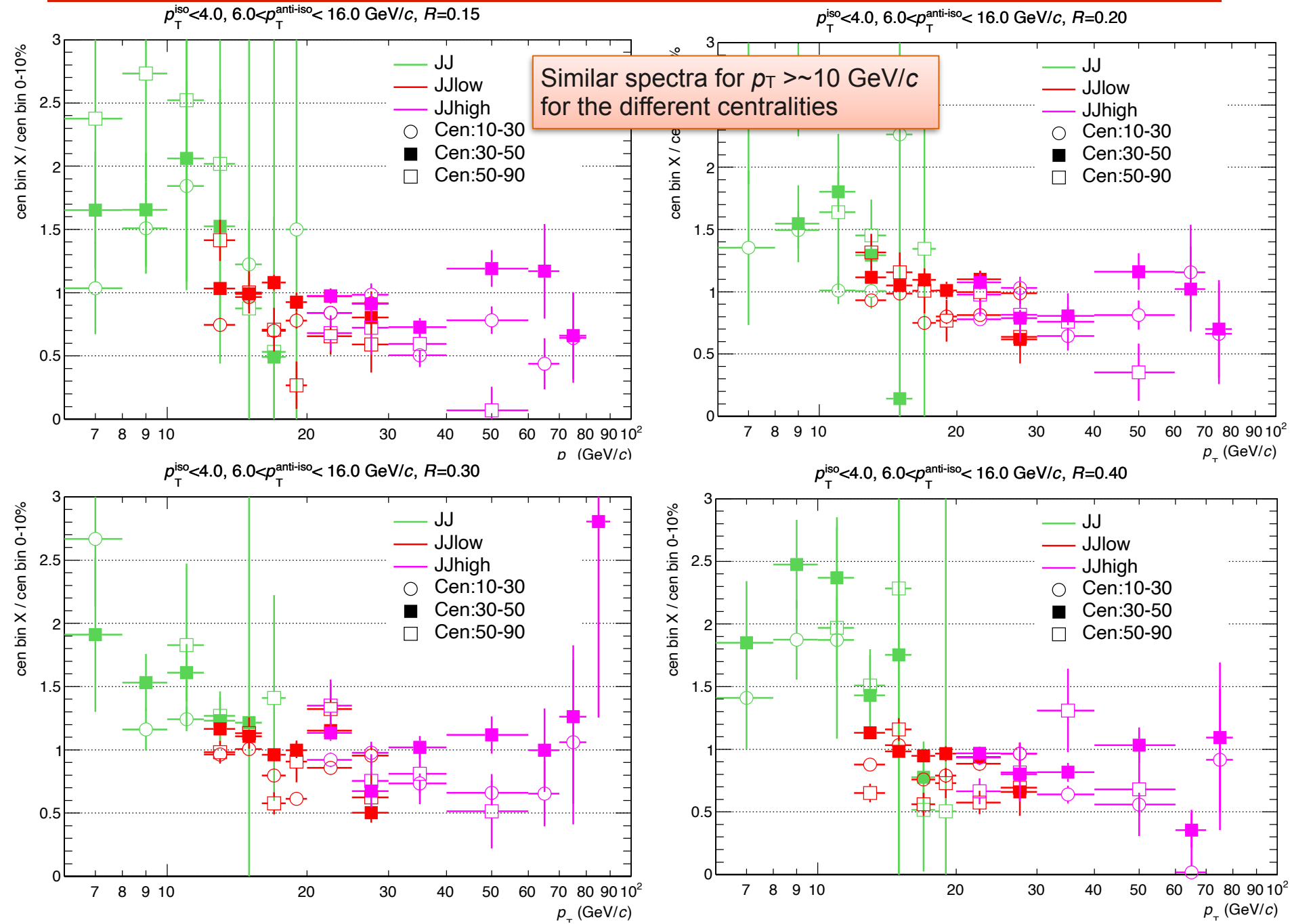


4-Corrected spectra: EMCal, η -band, tracks in cone, $p_{\text{T}}^{\text{iso}} < 4 \text{ GeV}/c$

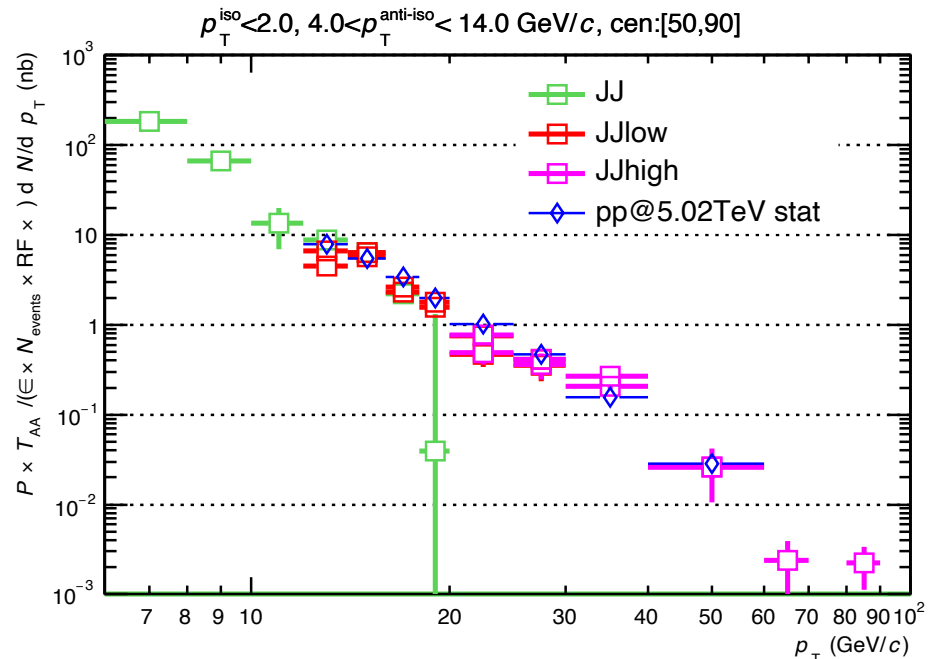
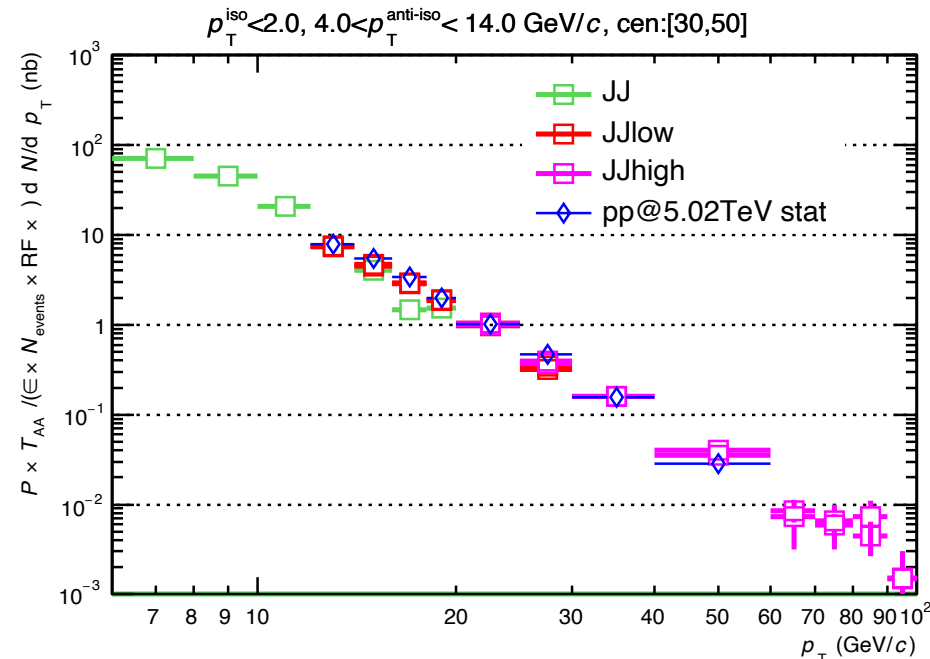
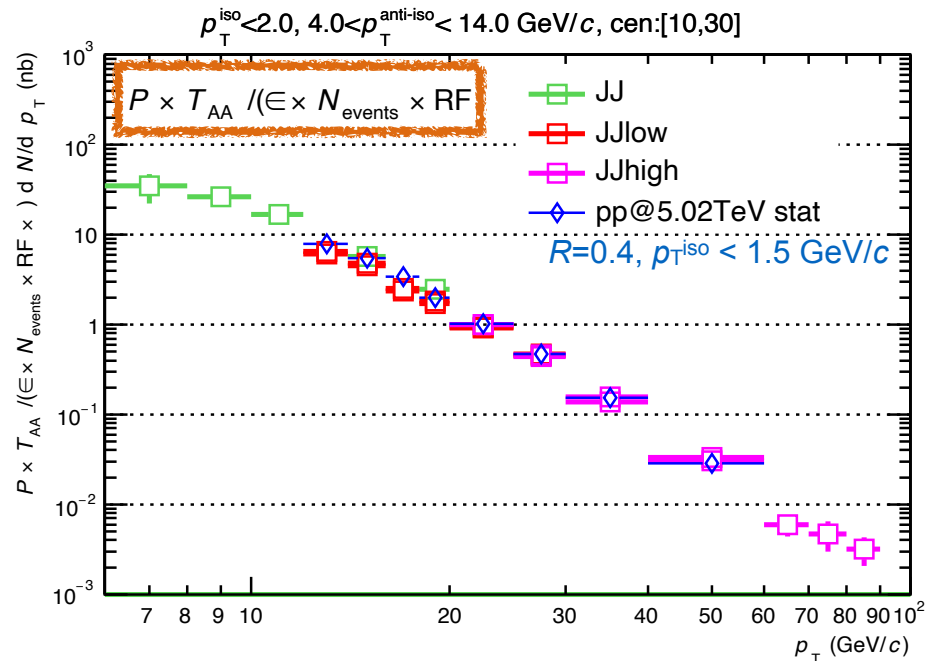
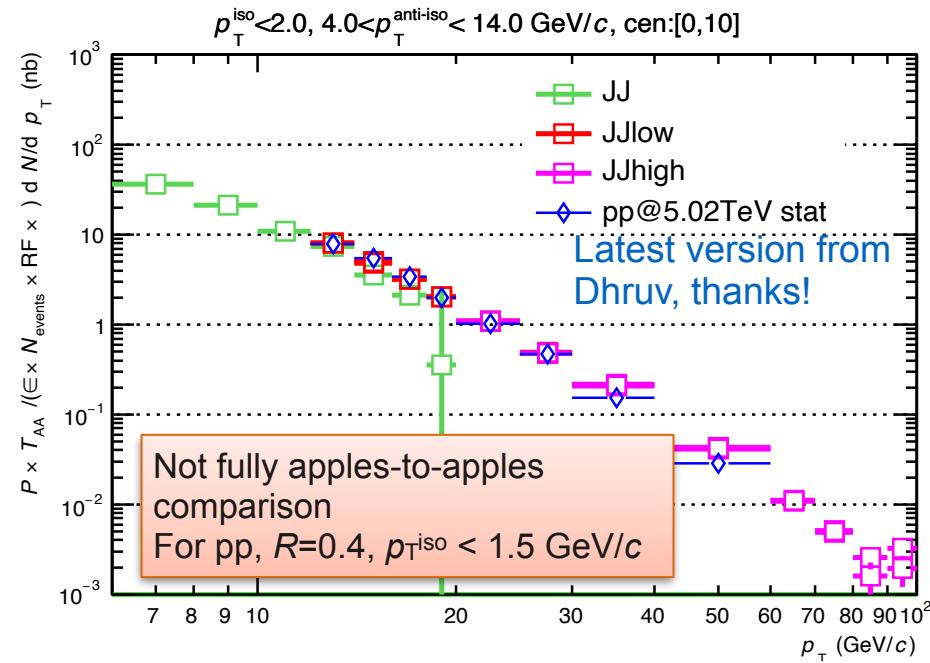
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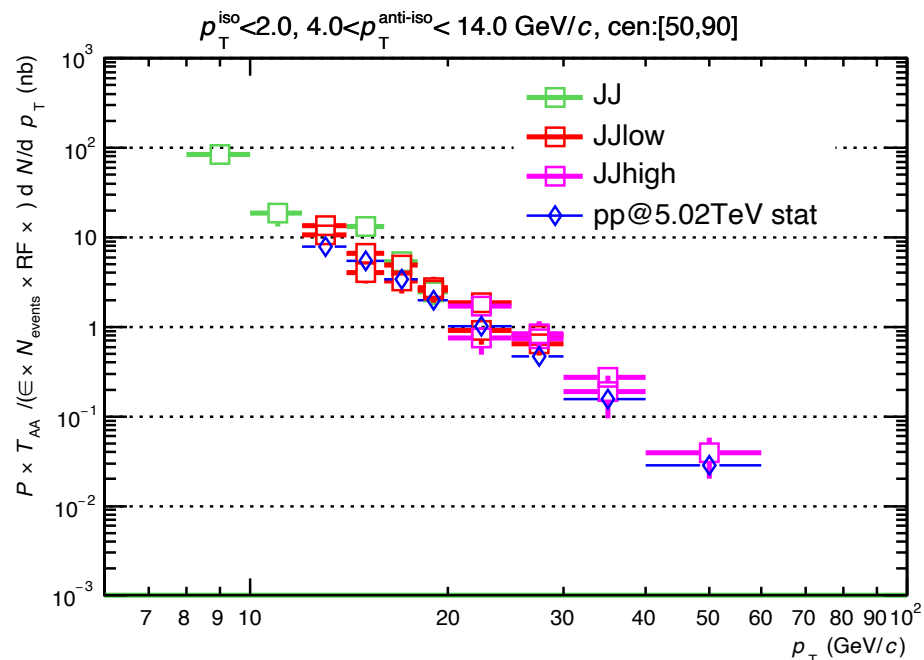
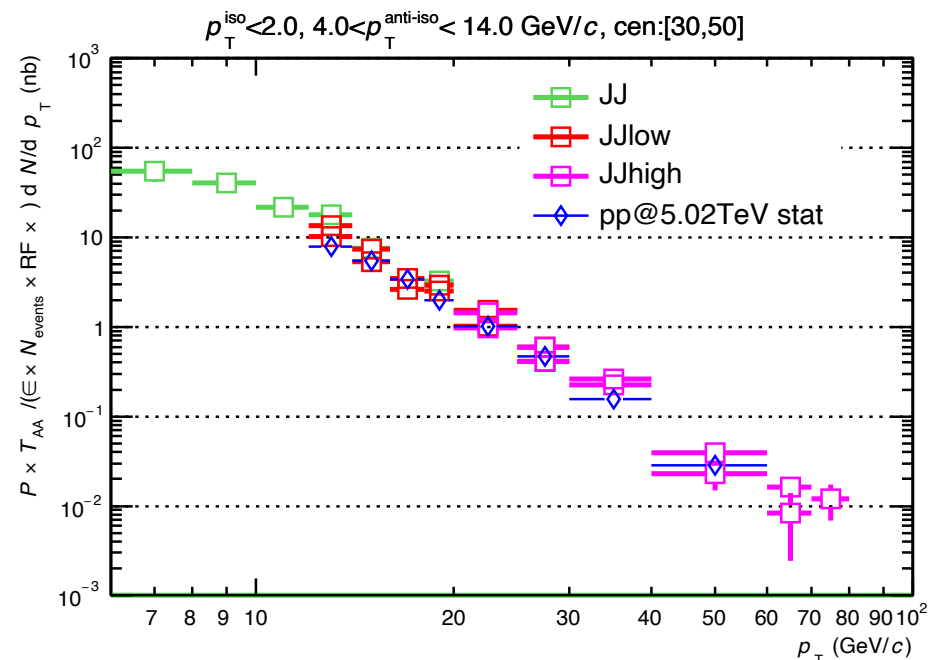
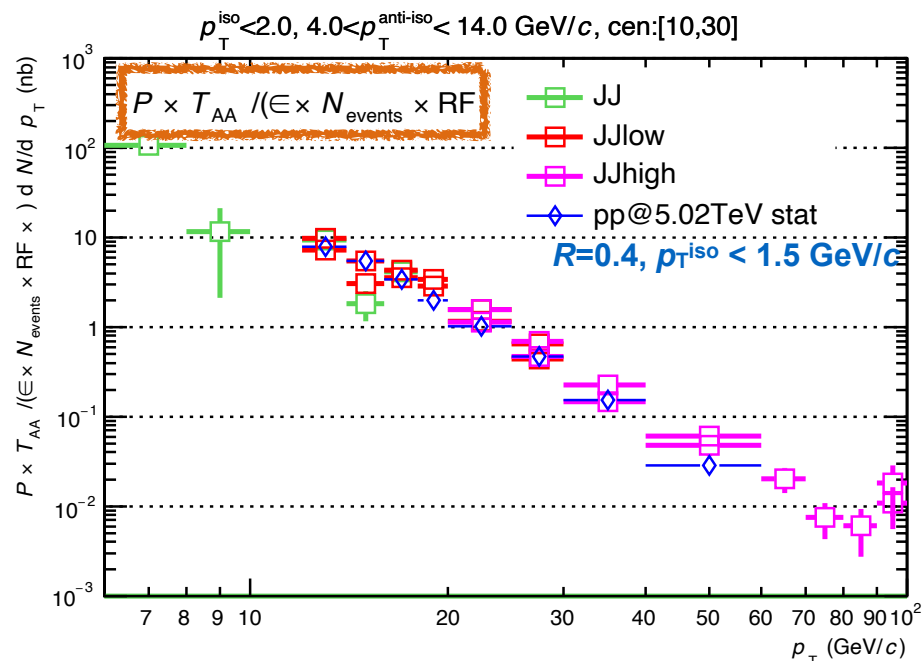
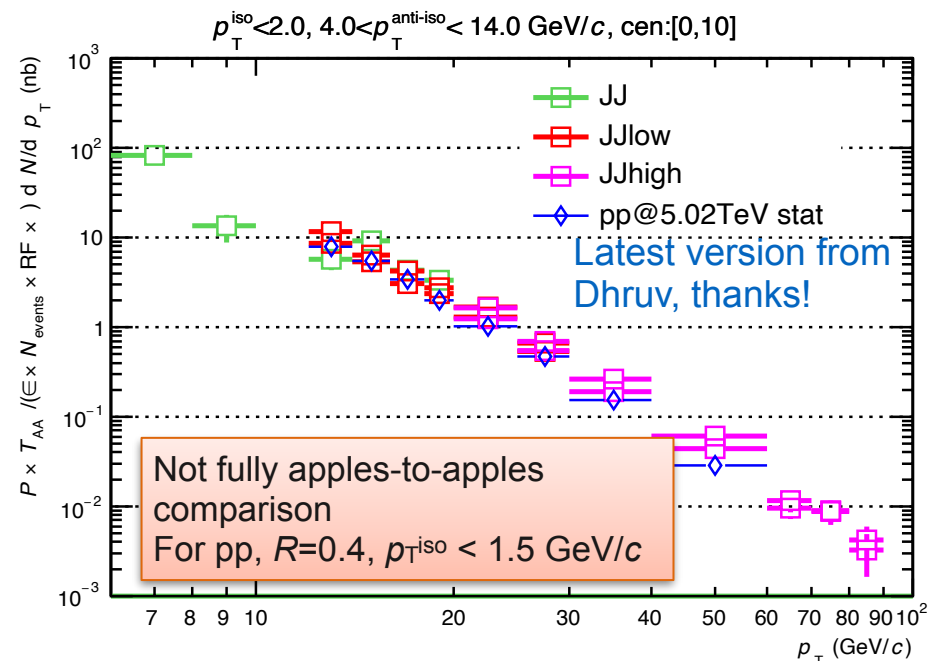
4-Ratio to central: EMCal, η -band, tracks in cone, $p_{\text{T}}^{\text{iso}} < 4 \text{ GeV}/c$



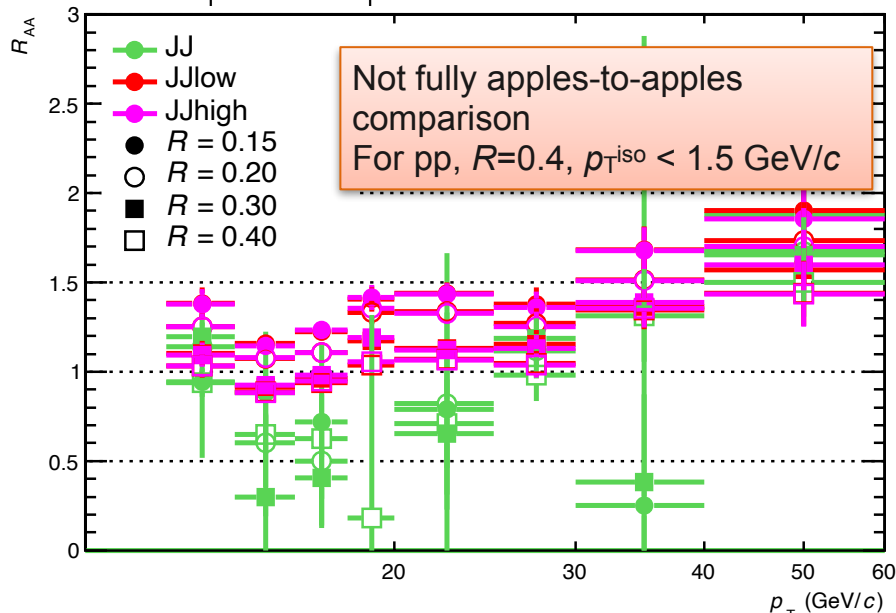
4-Corrected spectra vs pp: **EMCal**, η -band, tracks in cone, $R=0.4$, $p_{T}^{\text{iso}} < 2 \text{ GeV/c}$ 79 / 83



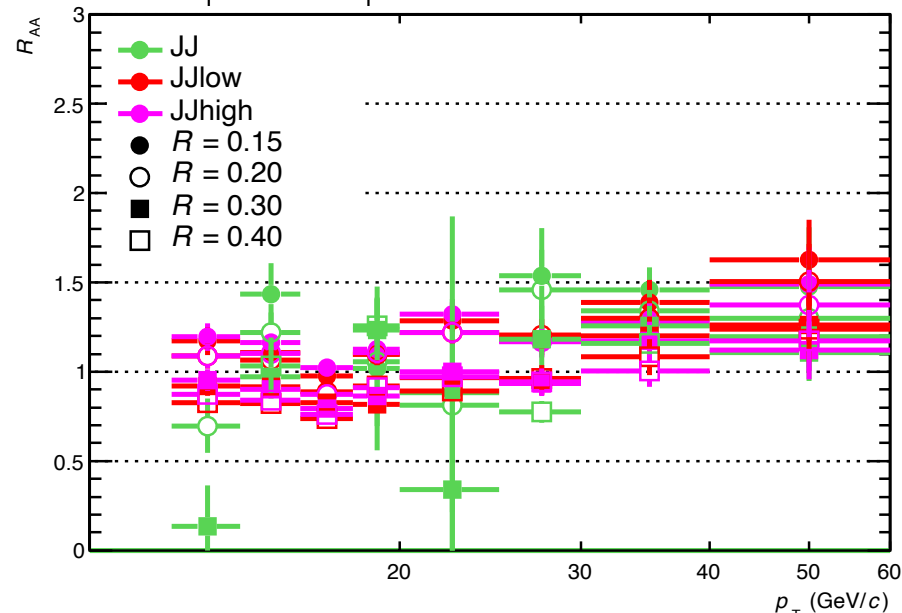
4-Corrected spectra vs pp: **DCal**, η -band, tracks in cone, $R=0.4$, $p_{\text{T}}^{\text{iso}} < 2 \text{ GeV/c}$ 80 / 83



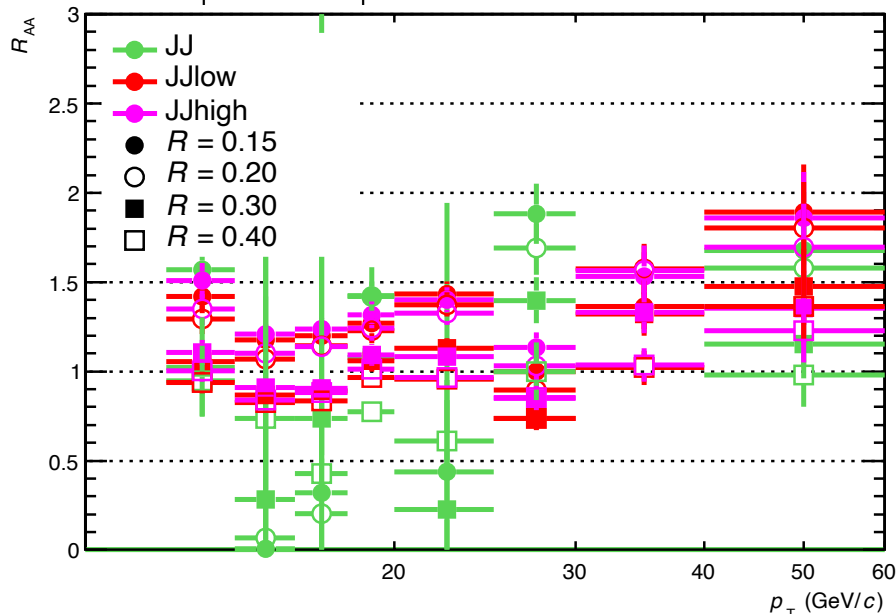
$p_{T}^{iso} < 2.0$, $4.0 < p_{T}^{anti-iso} < 14.0$ GeV/c, cen:[0,10]



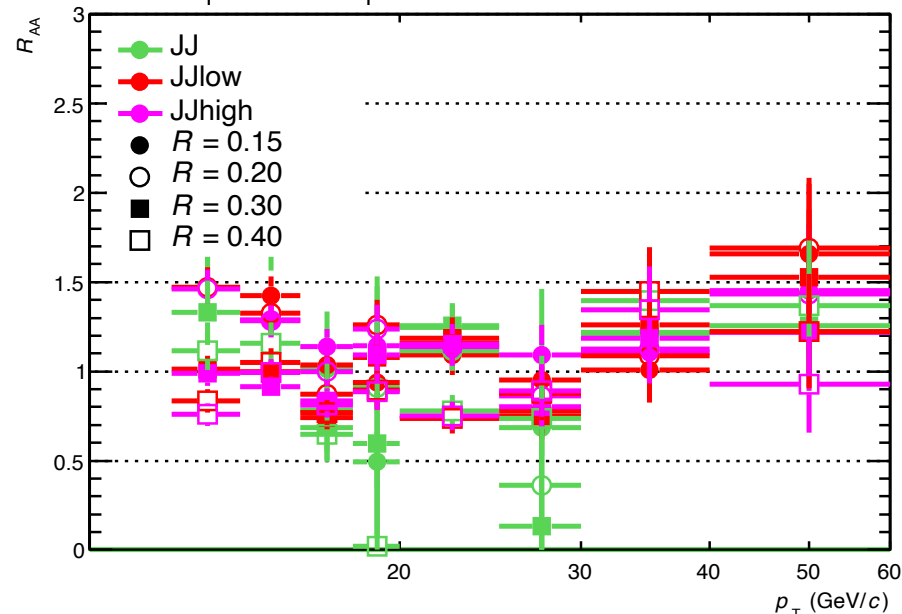
$p_{T}^{iso} < 2.0$, $4.0 < p_{T}^{anti-iso} < 14.0$ GeV/c, cen:[10,30]



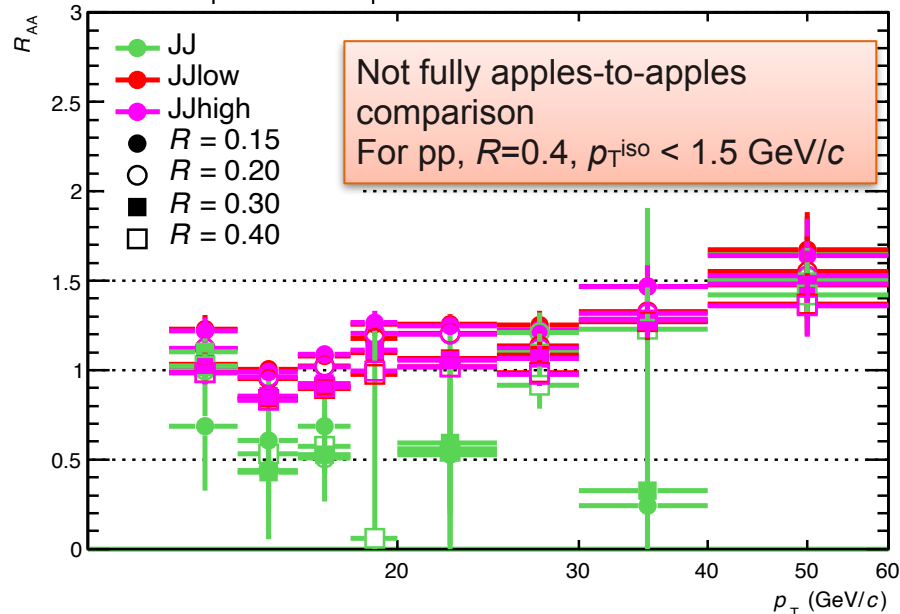
$p_{T}^{iso} < 2.0$, $4.0 < p_{T}^{anti-iso} < 14.0$ GeV/c, cen:[30,50]



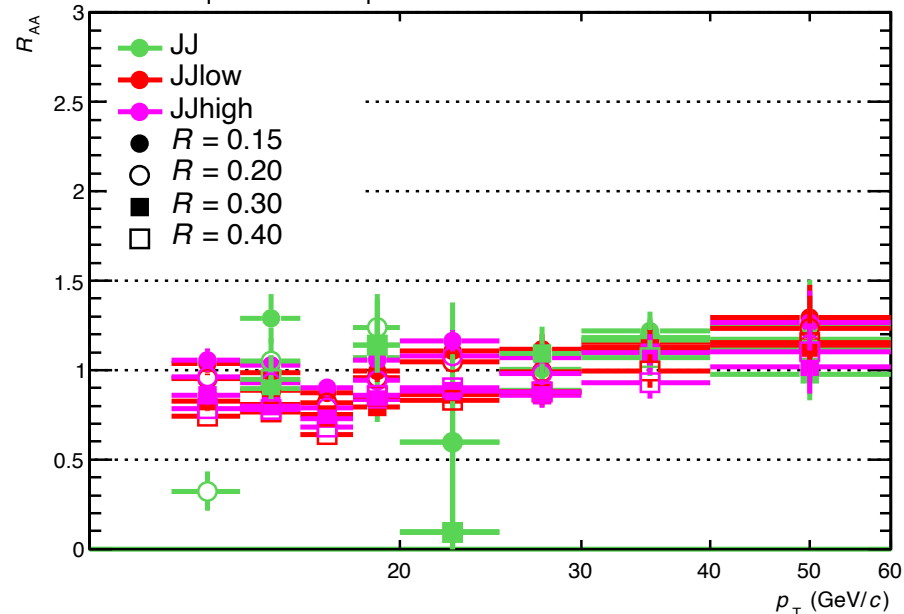
$p_{T}^{iso} < 2.0$, $4.0 < p_{T}^{anti-iso} < 14.0$ GeV/c, cen:[50,90]



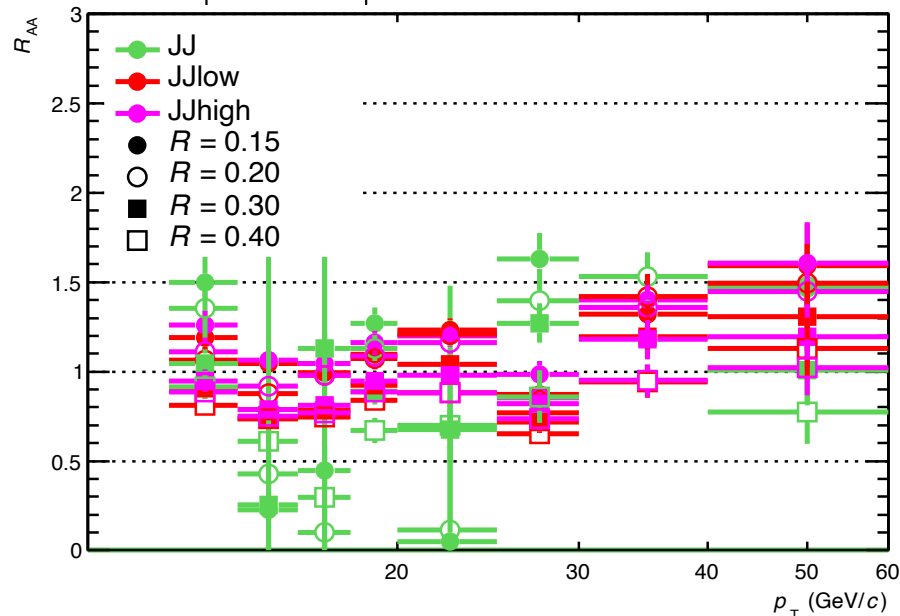
$p_{T}^{iso} < 1.0$, $3.0 < p_{T}^{anti-iso} < 13.0$ GeV/c, cen:[0,10]



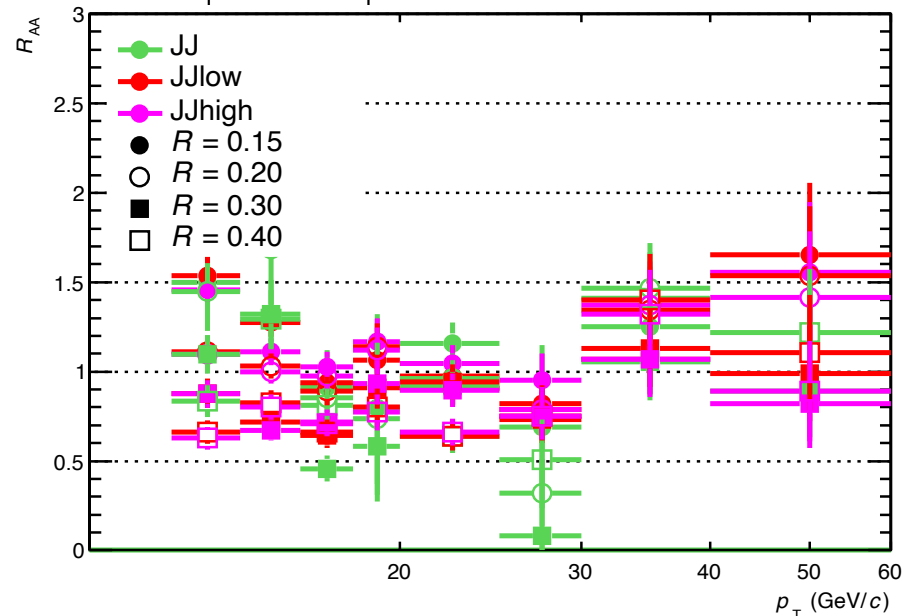
$p_{T}^{iso} < 1.0$, $3.0 < p_{T}^{anti-iso} < 13.0$ GeV/c, cen:[10,30]



$p_{T}^{iso} < 1.0$, $3.0 < p_{T}^{anti-iso} < 13.0$ GeV/c, cen:[30,50]



$p_{T}^{iso} < 1.0$, $3.0 < p_{T}^{anti-iso} < 13.0$ GeV/c, cen:[50,90]



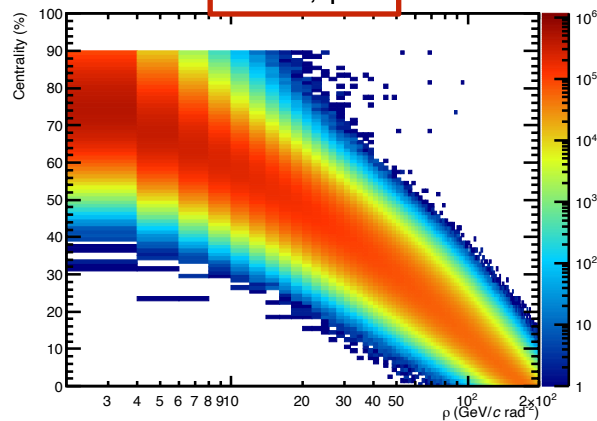
- Isolated photon spectra analysis seems feasible in Pb-Pb data using
 - ▶ V2 clusterizer with new shower shape in 5x5 window
 - ▶ UE estimated with different approaches has similar performance
- Current results are not crazy, but a lot of work still to be done.
- Currently running analysis with:
 - ▶ Clusterizer V2 with 5x5 shower shape
 - ▶ New event selection cuts
 - ▶ Only tracks in isolation cone with track $p_T > 0.15 \text{ GeV}/c$
 - ▶ Include UE from jet group, perpendicular band, and w/out UE p_T track cut.
 - ▶ $0.05 < R < 0.15, 0.2, 0.3$ and 0.4 .
 - Minimum implemented to see if MC correction is smaller
 - ▶ Aim to combine LHC15o and LHC18qr data
 - 1/3 SM of DCal not considered since not calibrated in LHC18qr
 - Problems in DCal LHC15o, try to use bad triggers (noisy) rejection but not working yet (Markus)
 - ▶ Rather open η acceptance for photons, $|\eta| < 0.65$
 - ▶ MC embedding run with less p_T hard bins per train
 - JJ unbiased, first bins one train per p_T hard bi

Back-up: Mostly slides from last presentation

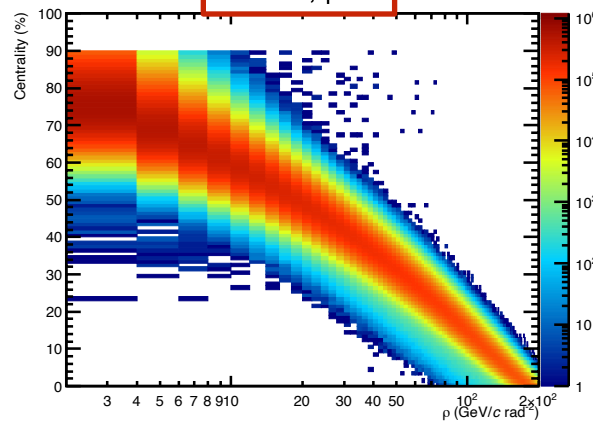
UE energy density ρ , $R = 0.2$, $p_T^{\text{in UE}} < 3 \text{ GeV}$

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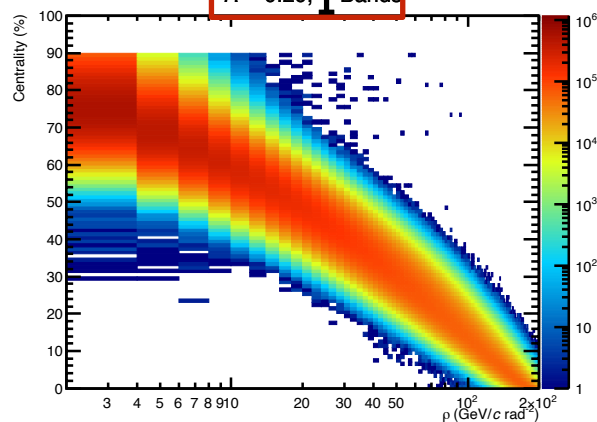
$R = 0.20$, η -Band



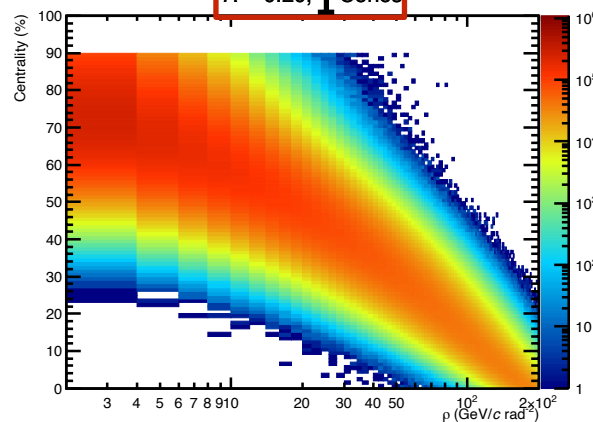
$R = 0.20$, φ -Band



$R = 0.20$, $\perp$ -Bands



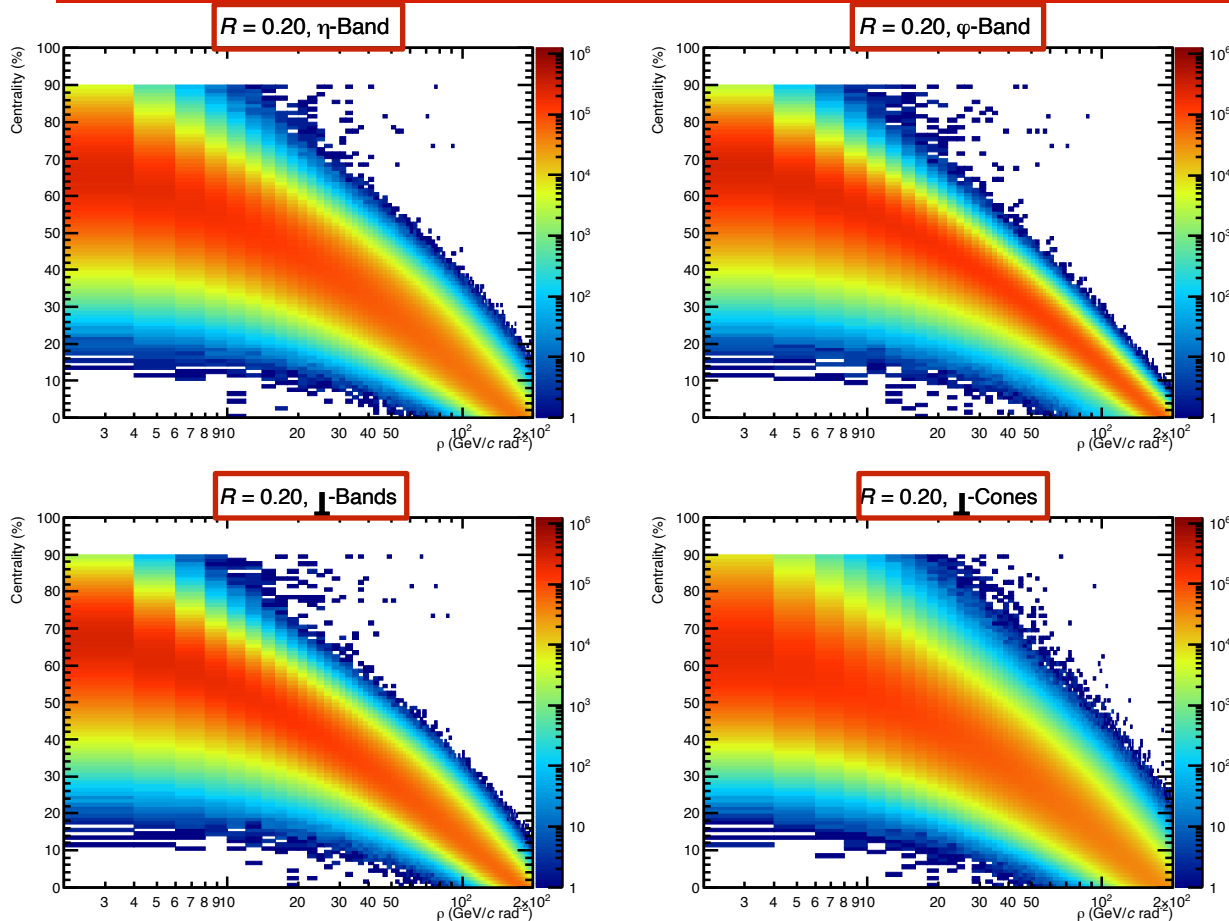
$R = 0.20$, $\perp$ -Cones



A maximum p_T cut restricts UE estimation in the upper band

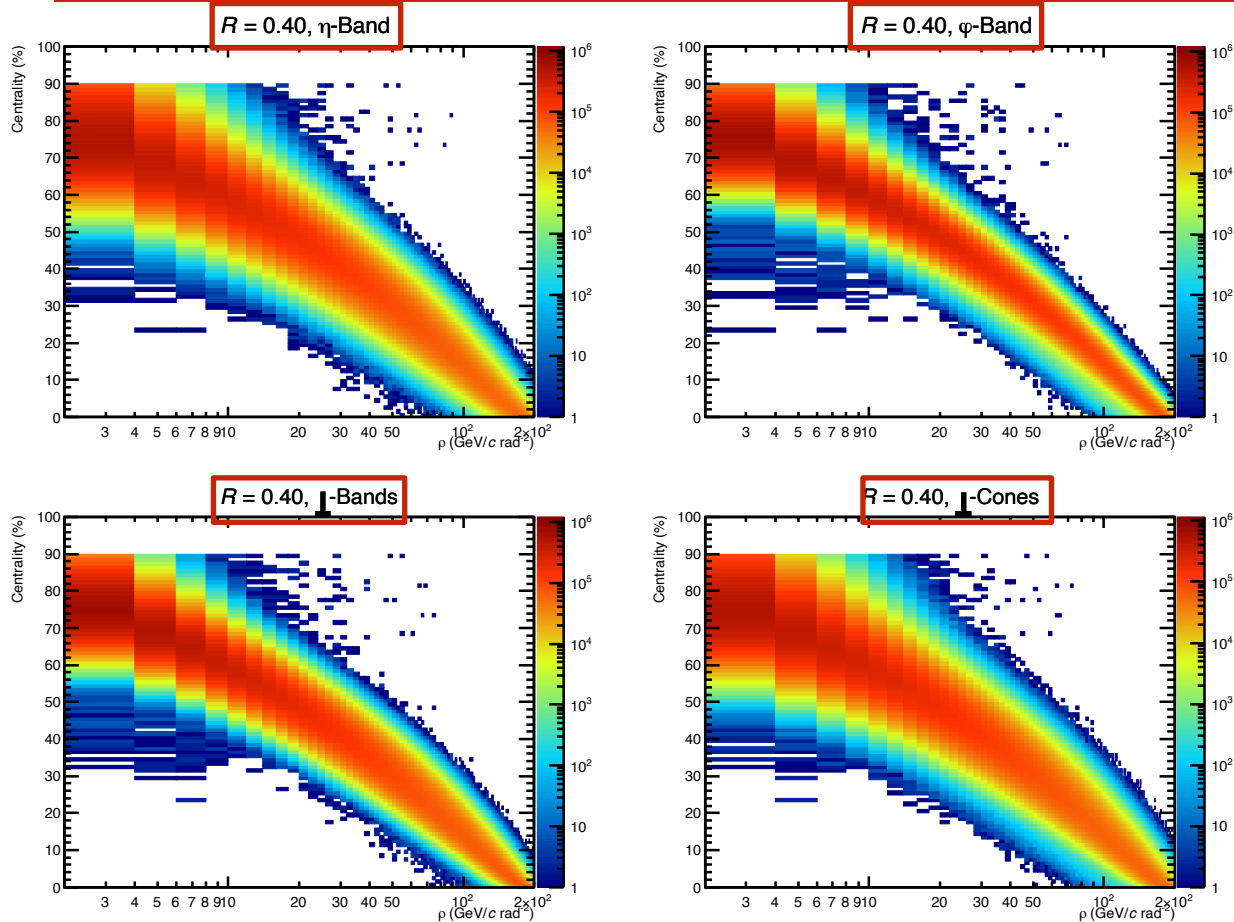
UE energy density ρ , $R = 0.2$, $p_{T}^{\text{in UE}} < p_{T}^{\text{leading in cone}} * 1.5$

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A cut depending on the leading track in cone p_T moves down the mean and seems to widen the energy density distribution

UE energy density ρ , $R = 0.4$, $p_{\text{T}}^{\text{in UE}} < 3 \text{ GeV}$

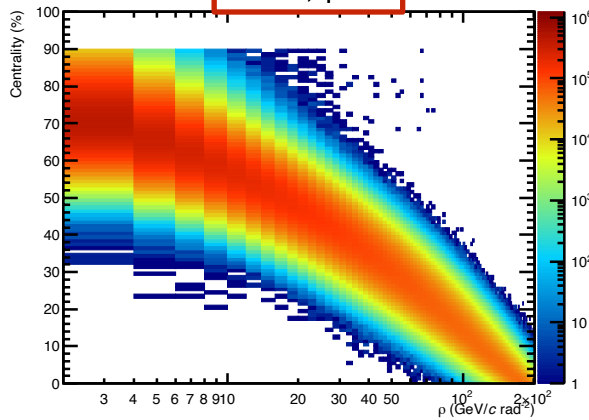


A maximum p_{T} cut restricts UE estimation in the upper band

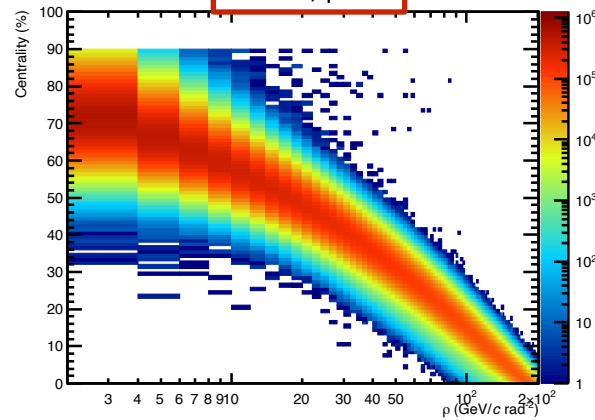
UE energy density ρ , $R = 0.4$, $p_{T}^{\text{in UE}} < p_{T}^{\text{leading in cone}} * 1.5$

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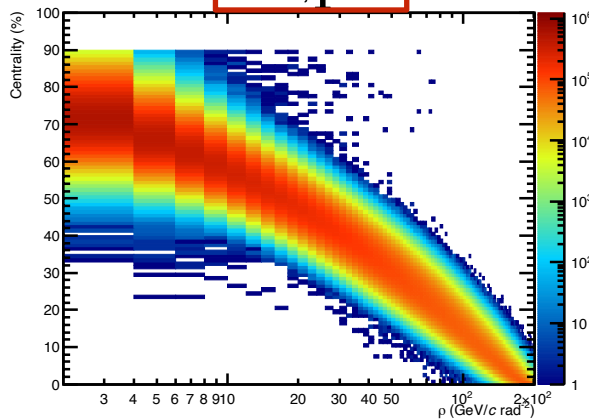
$R = 0.40$, η -Band



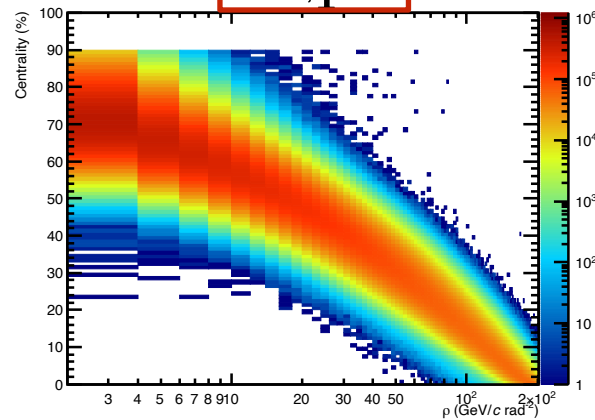
$R = 0.40$, φ -Band



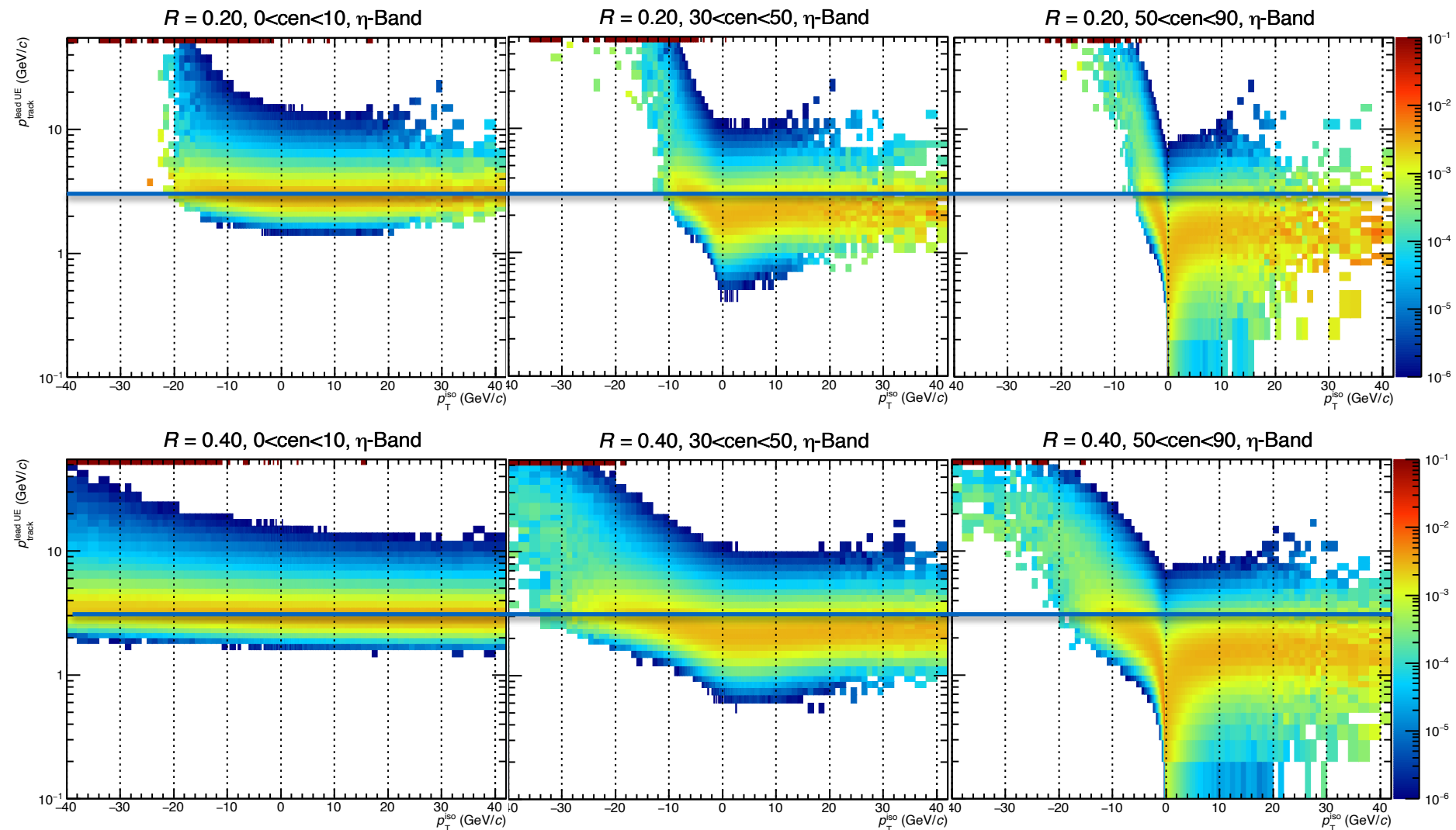
$R = 0.40$, η -Bands



$R = 0.40$, η -Cones



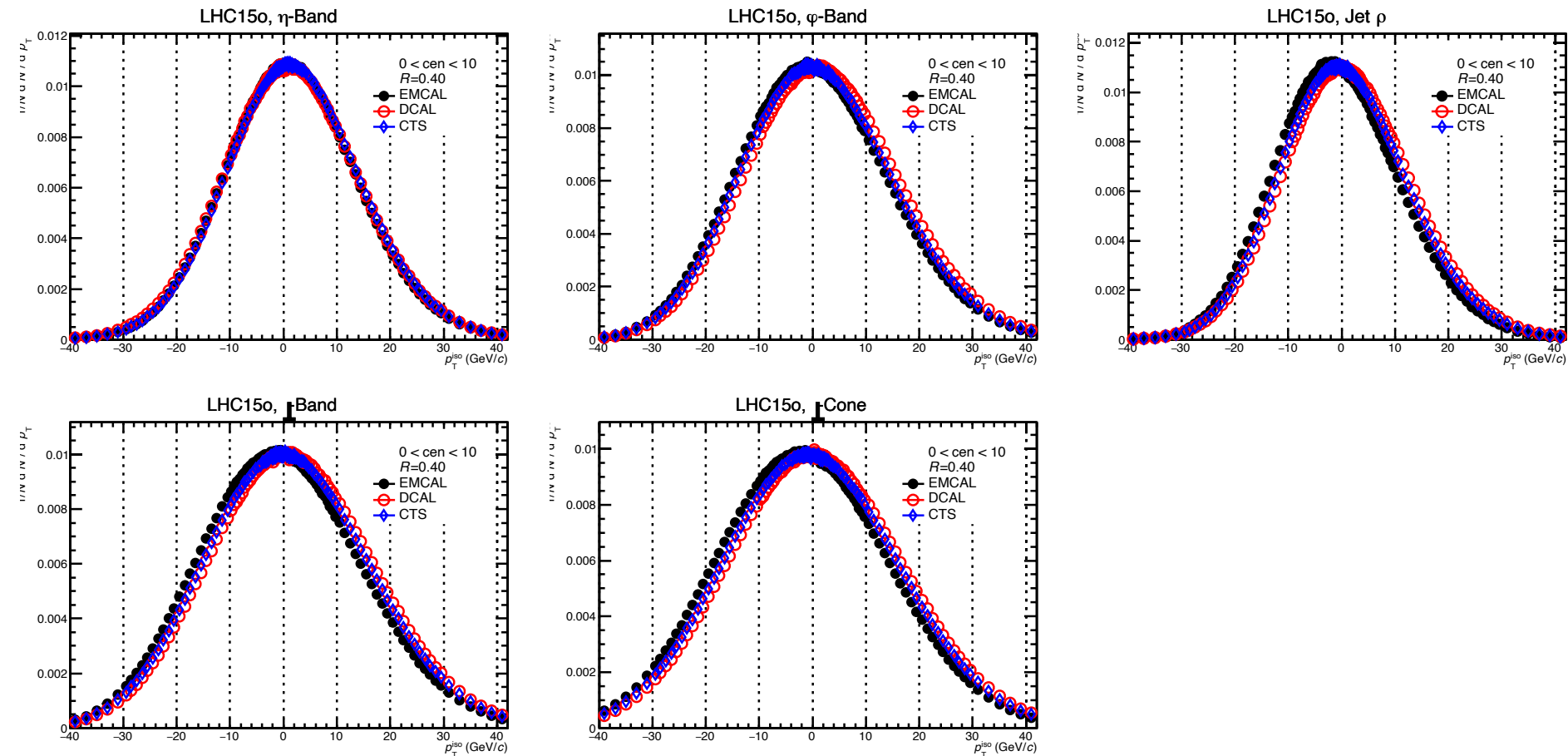
A cut depending on the leading track in cone p_T moves down the mean.



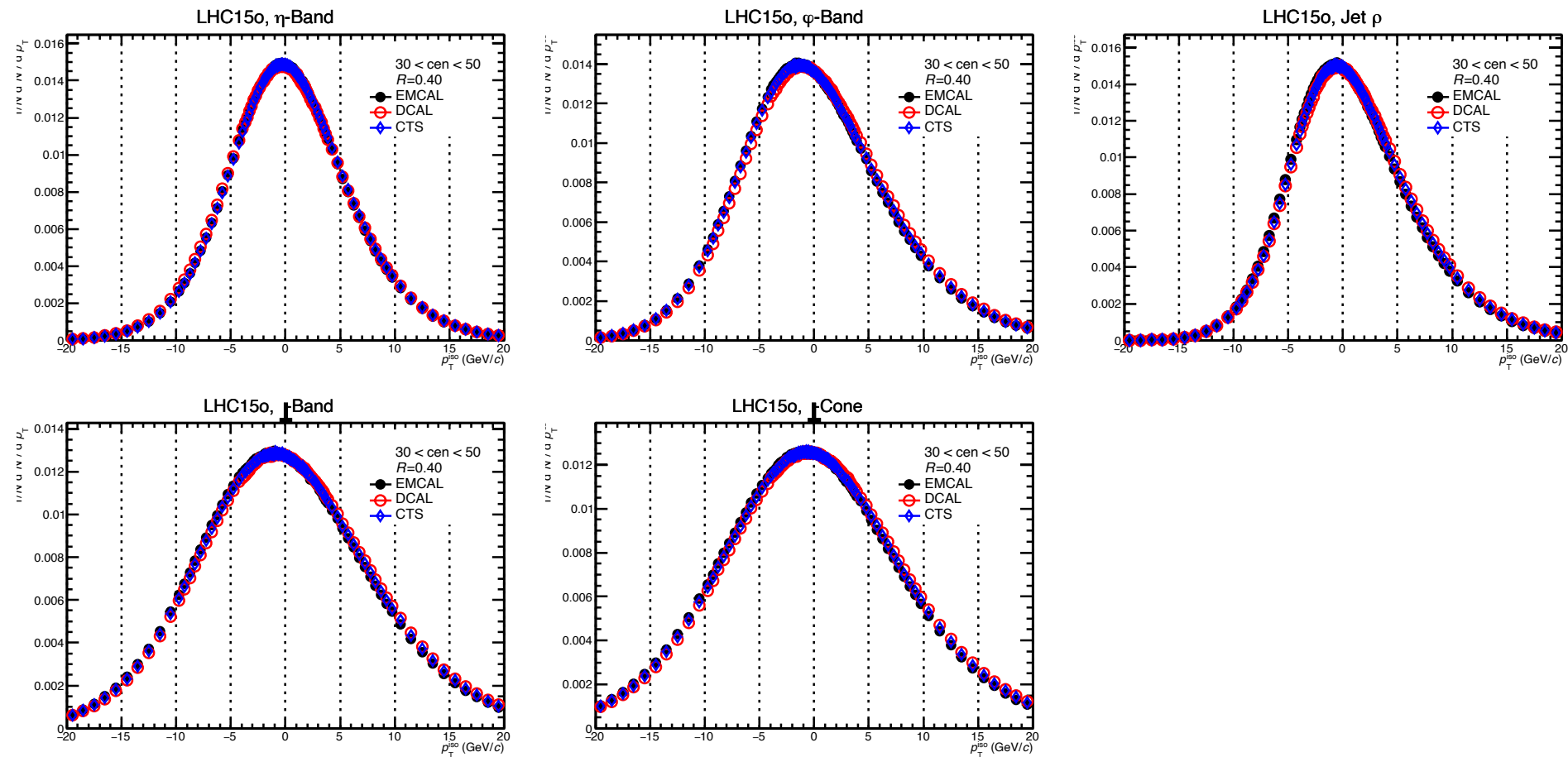
No strong correlation with leading track in UE region
 When leading track in UE is larger than ~ 3 GeV in non central collisions more chance to have p_T^{iso} below 0

Reminder from last presentation

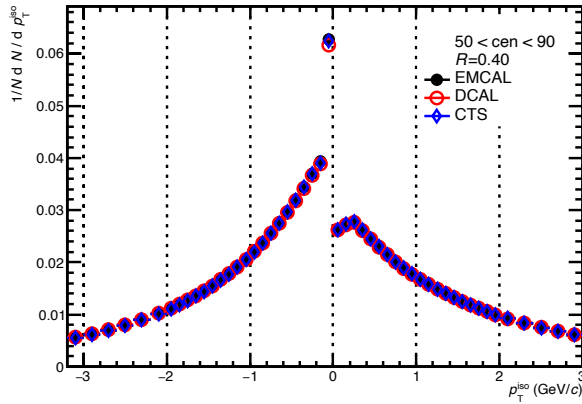
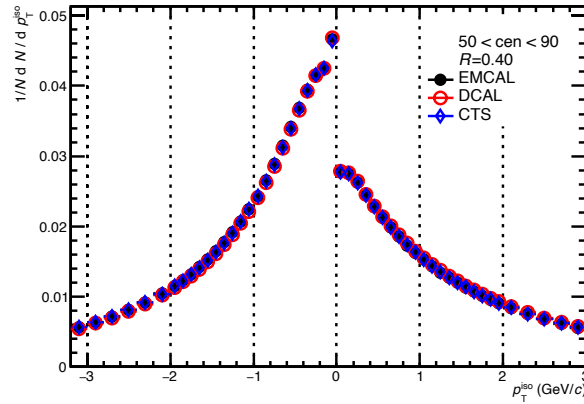
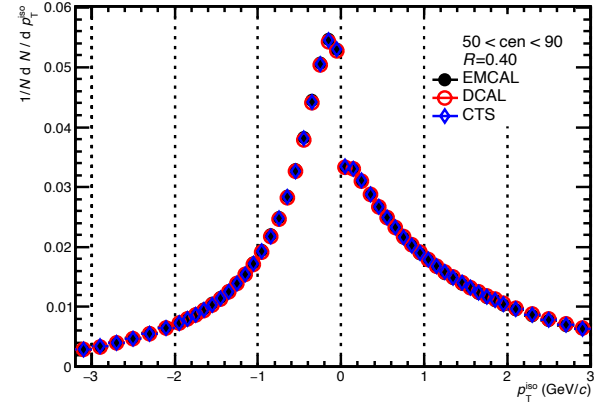
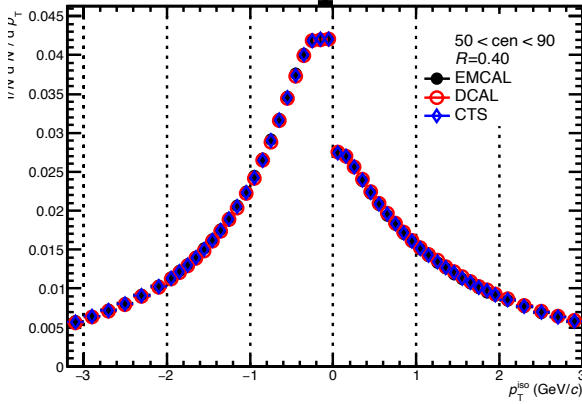
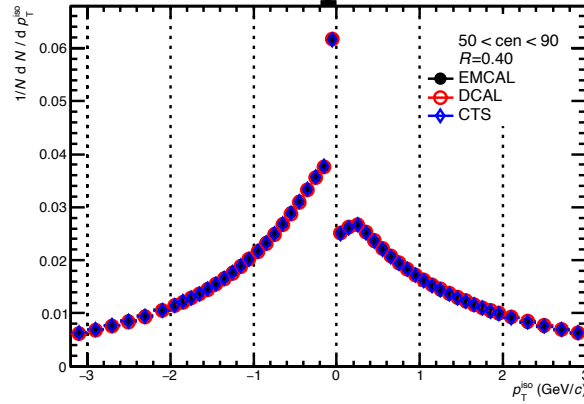
p_T^{iso} bins normalized to bin integral



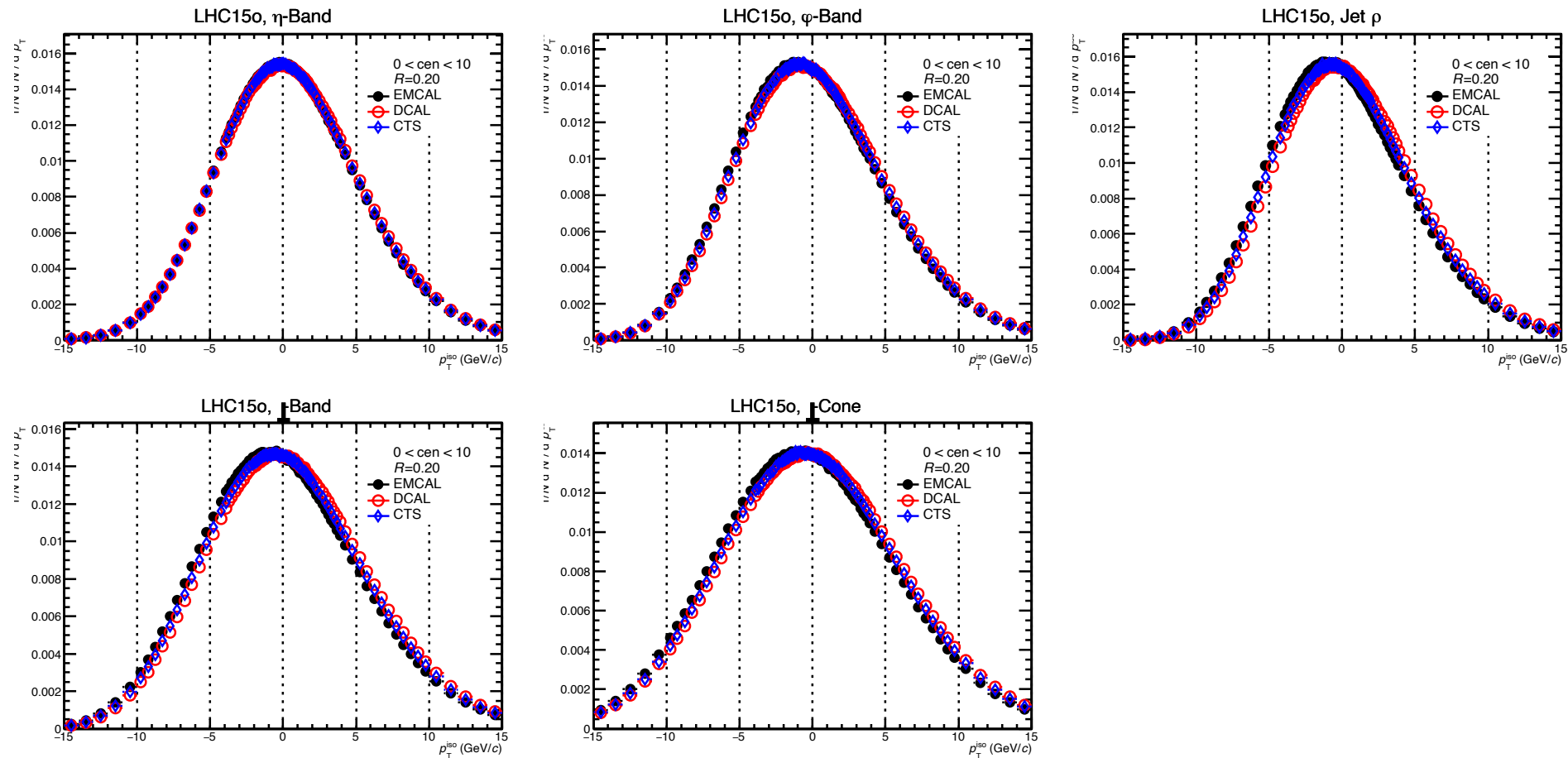
Small difference depending where the random cones are located. Finer rapidity and azimuth regions studied and differences observed due to different tracking efficiencies but still not significant. DCAL seems a bit more centred at 0



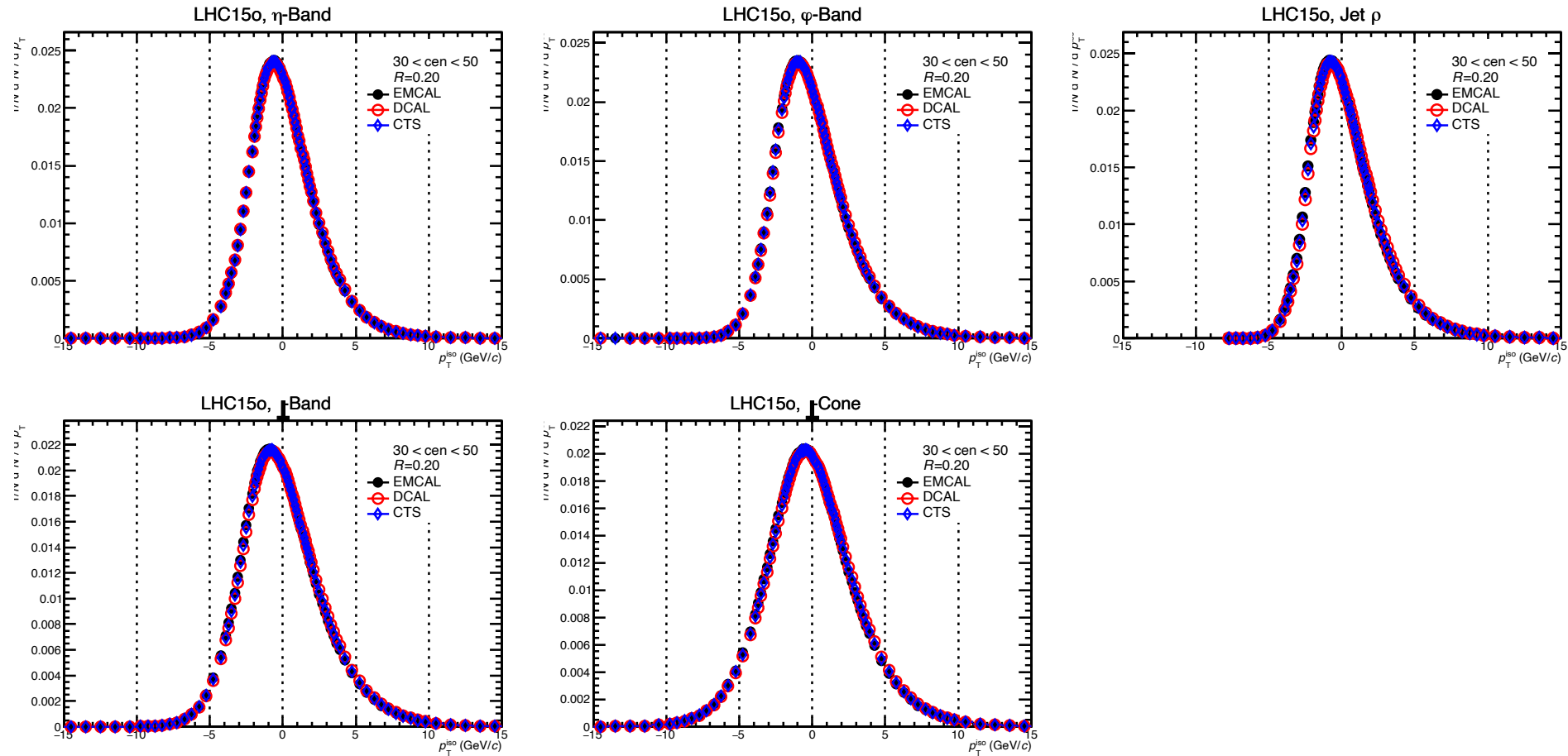
Small difference depending where the random cones are located. Finer rapidity and azimuth regions studied and differences observed due to different tracking efficiencies but still not significant.

LHC15o, η -Band

LHC15o, φ -Band

LHC15o, Jet ρ

LHC15o, η -Band

LHC15o, η -Band


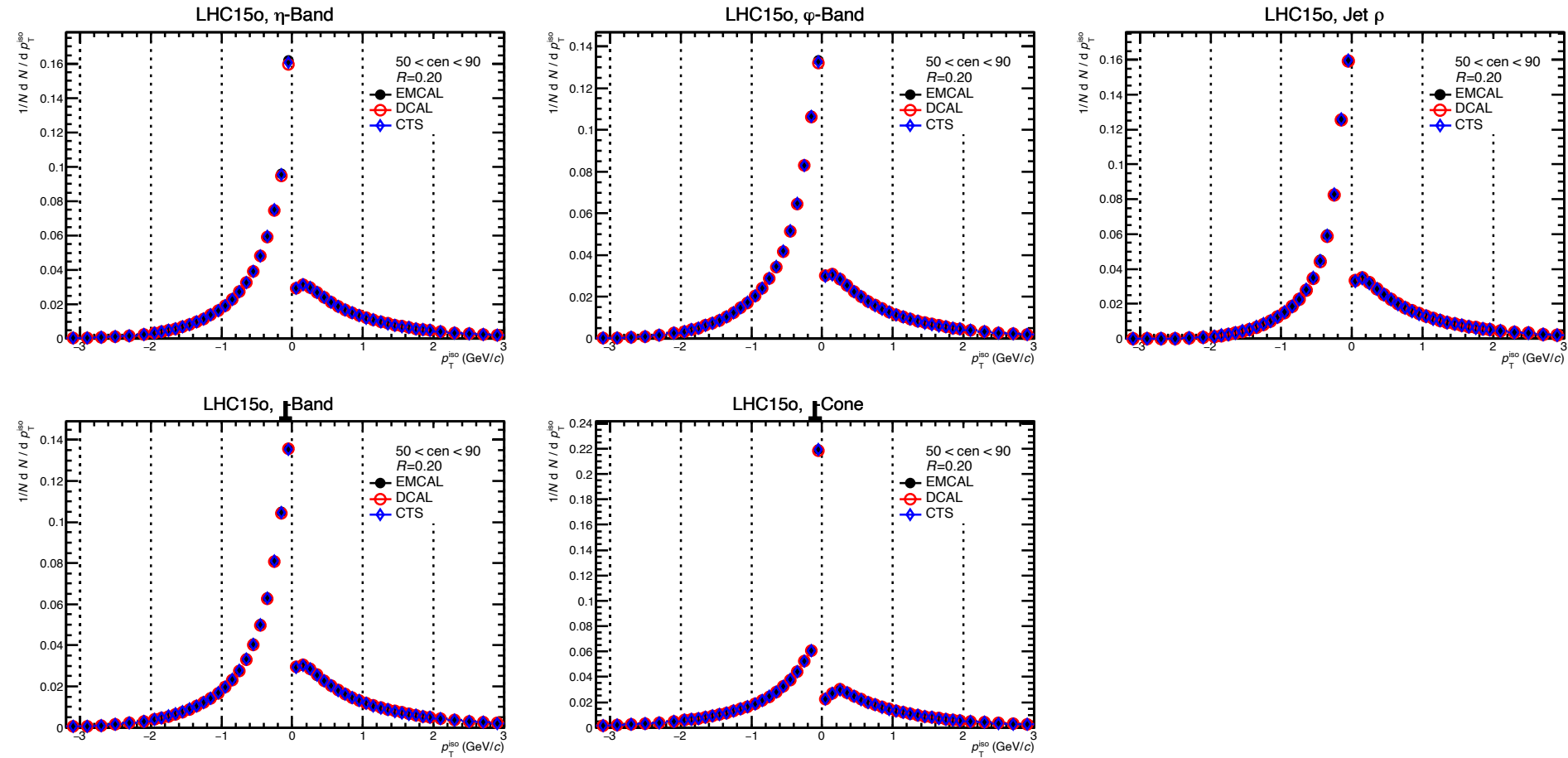
Almost no difference depending where the random cones are located. Finer rapidity and azimuth regions studied and differences observed due to different tracking efficiencies but still not significant.



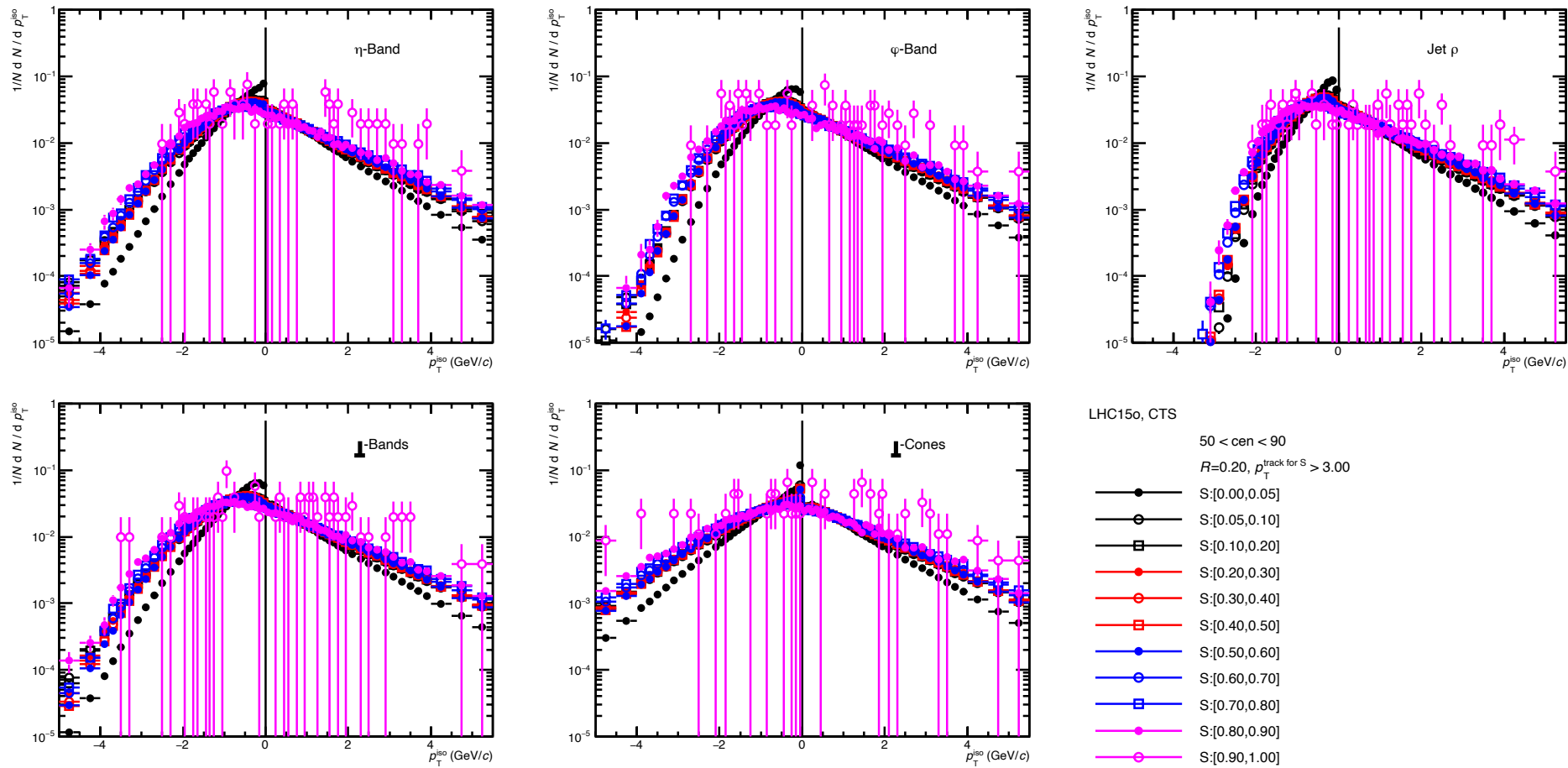
Small difference depending where the random cones are located. Finer rapidity and azimuth regions studied and differences observed due to different tracking efficiencies but still not significant.



Small difference depending where the random cones are located. Finer rapidity and azimuth regions studied and differences observed due to different tracking efficiencies but still not significant.

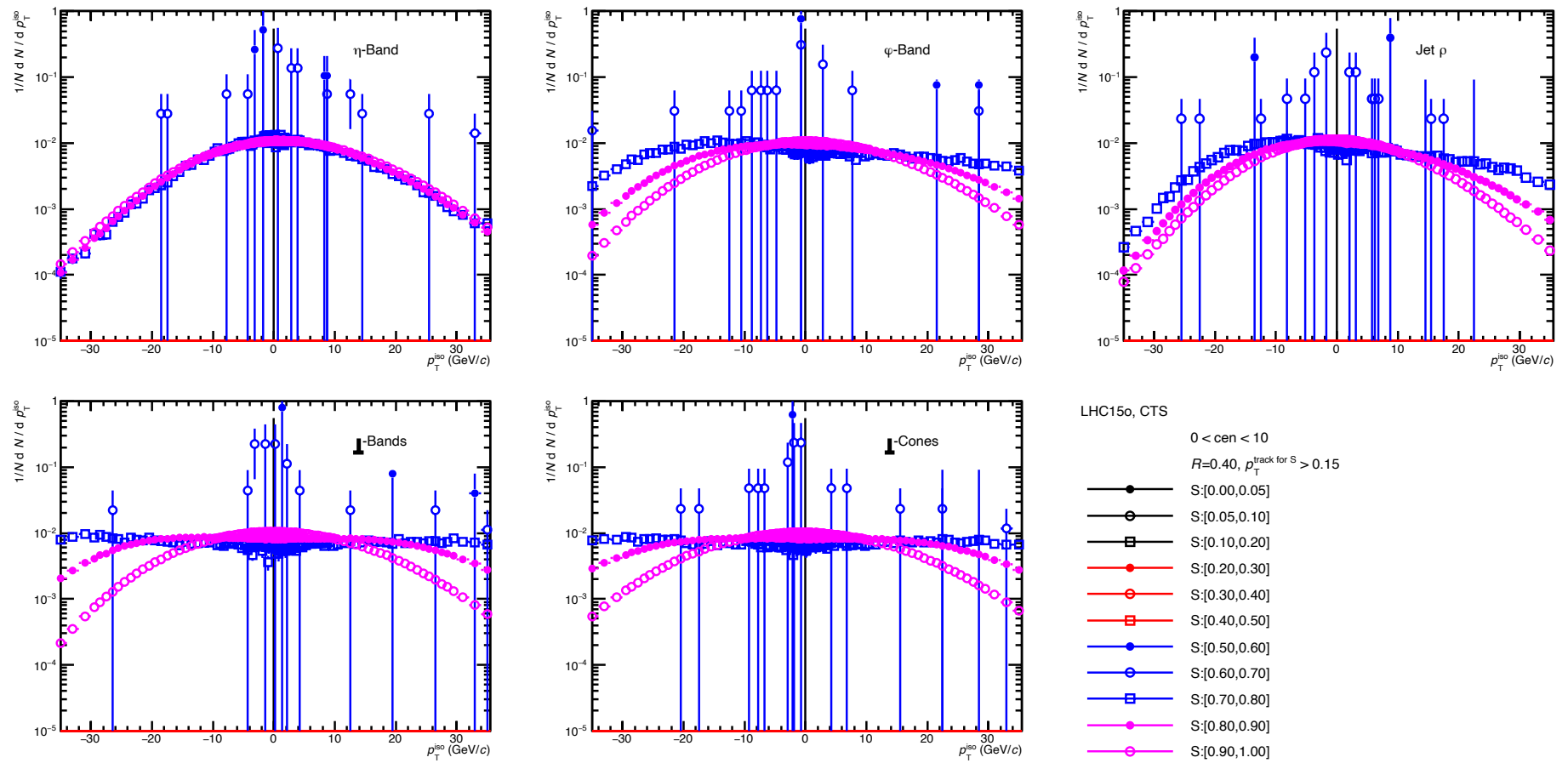


Almost no difference depending where the random cones are located. Finer rapidity and azimuth regions studied and differences observed due to different tracking efficiencies but still not significant.

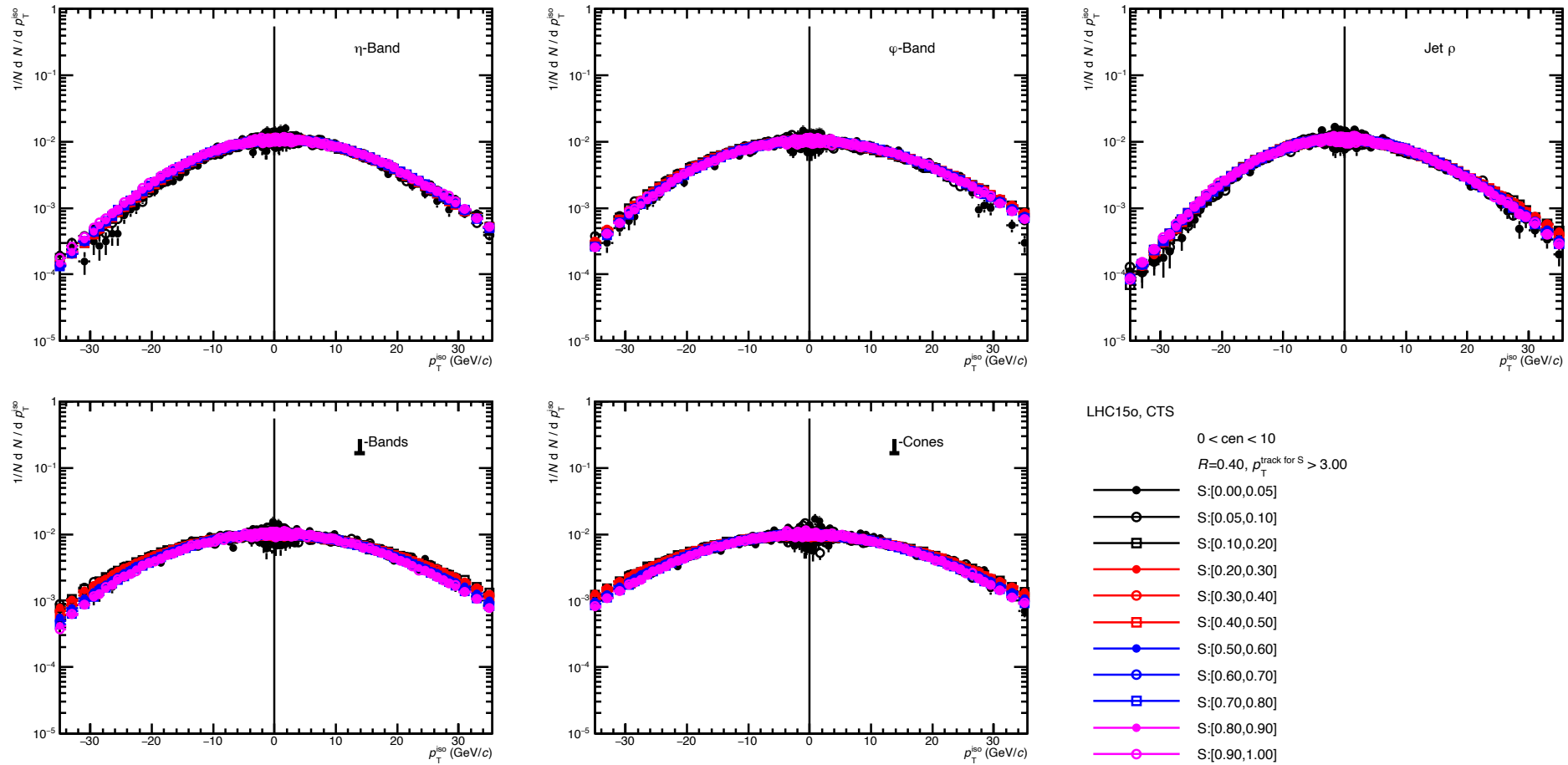


All bands are not too sensitive. Only smallest S_0 bin (less spherical) has clear different shape.

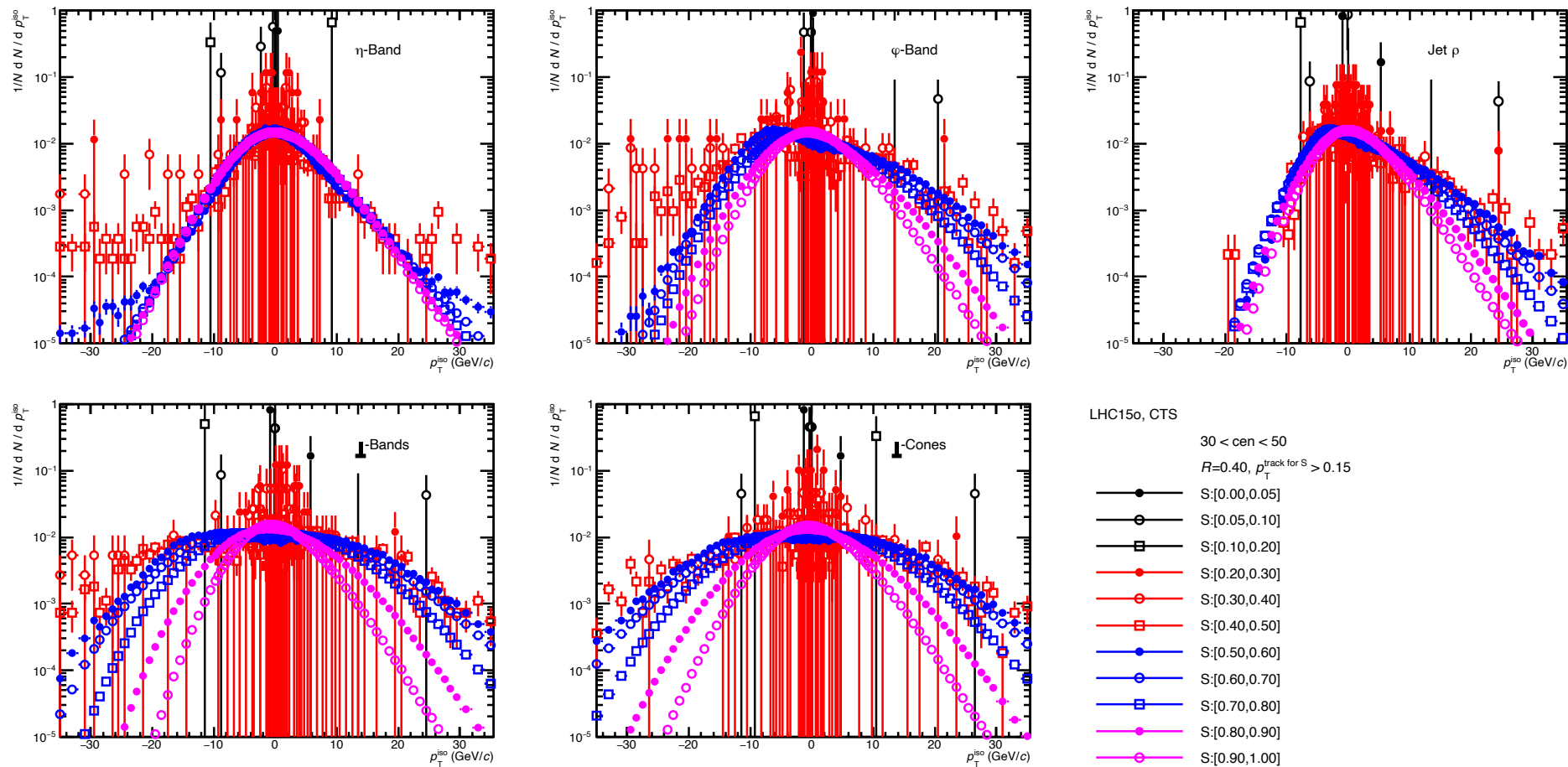
Similar observations for $R = 0.4$ (back-up)



η band is not sensitive to the S_0 bin.



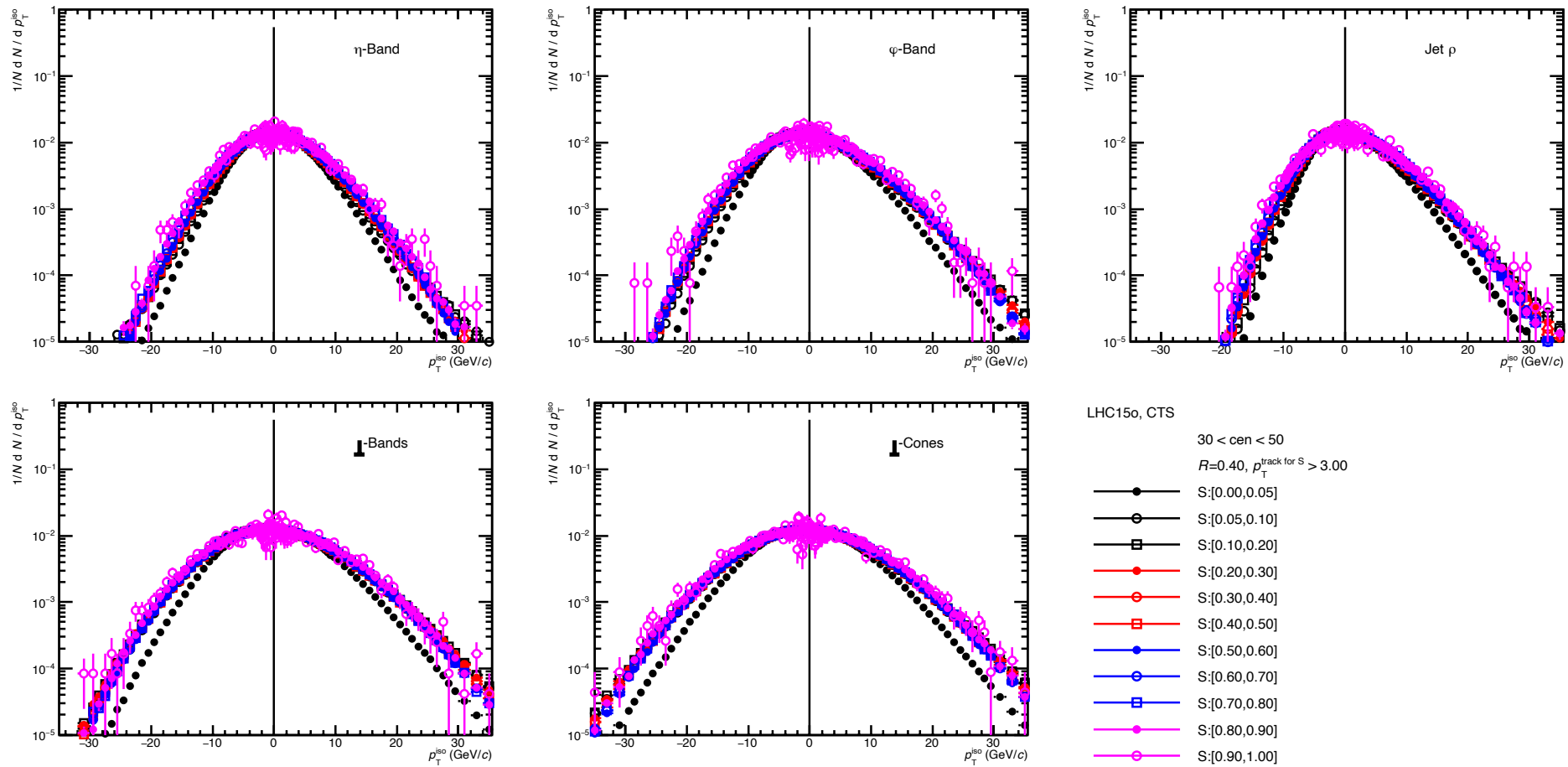
All bands are not sensitive. The effect observed for track S $p_T > 0.15 \text{ GeV/c}$ must be flow related



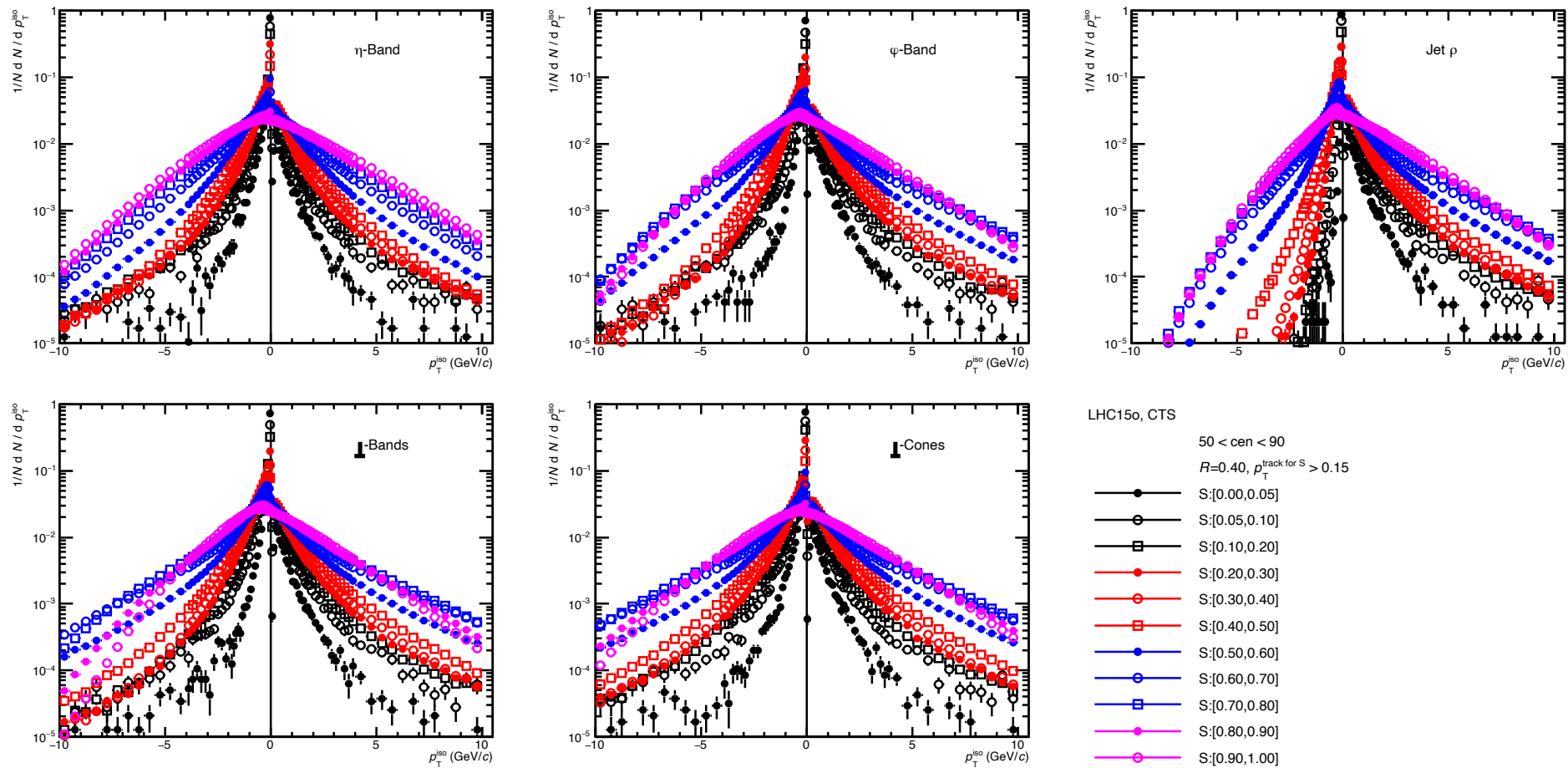
η band is not sensitive to the S_0 bin then jet ρ is a bit sensitive.

p_T^{iso} , vs sphericity bins, $R=0.4$, 30-50%, S_0 track $p_T > 3 \text{ GeV}/c$

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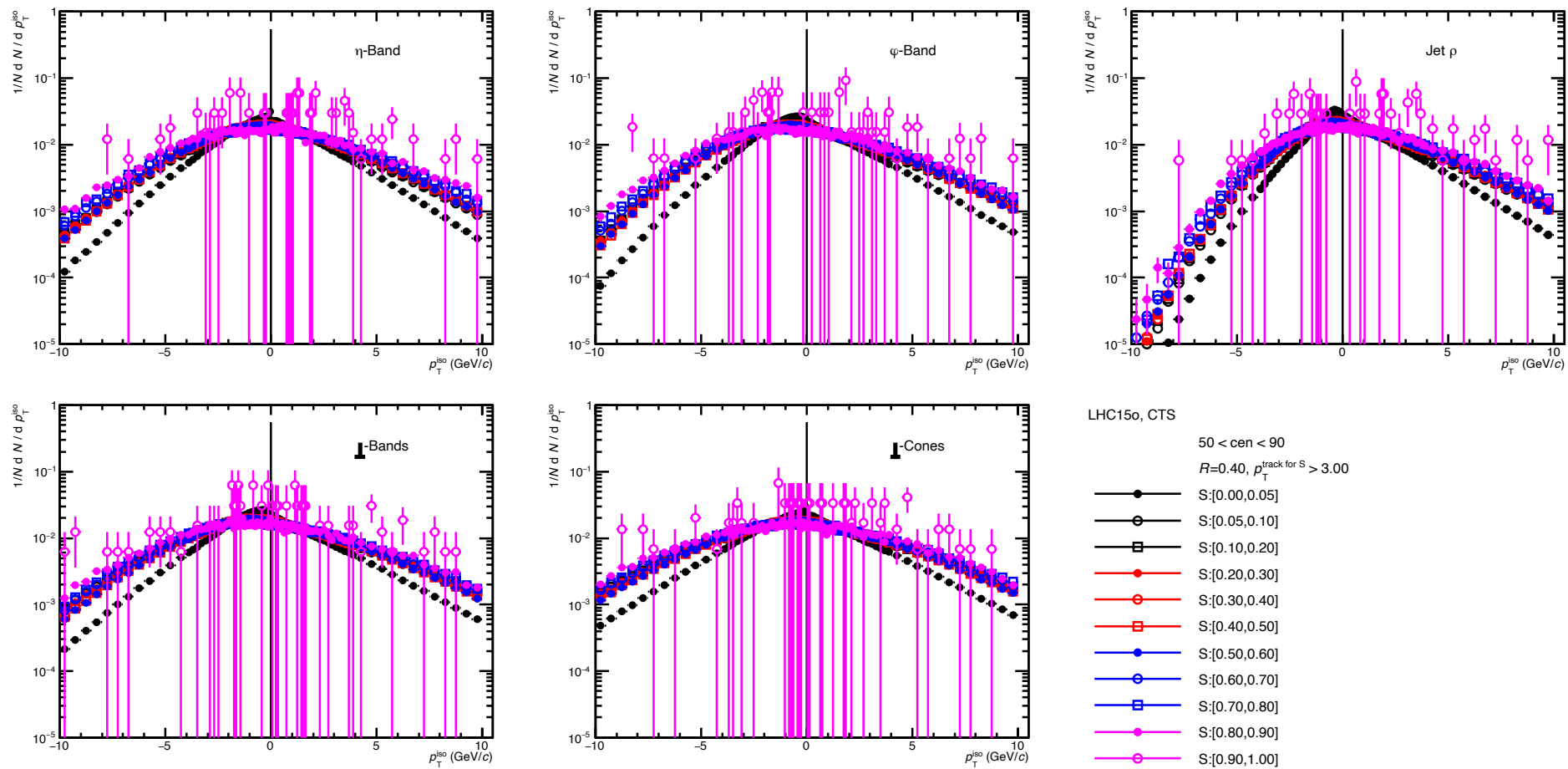
All bands are not sensitive. The effect observed for track S_0 $p_T > 0.15 \text{ GeV}/c$ must be flow related. Only smallest S_0 bin has clear smaller width.



Low S_0 bins have smaller width.

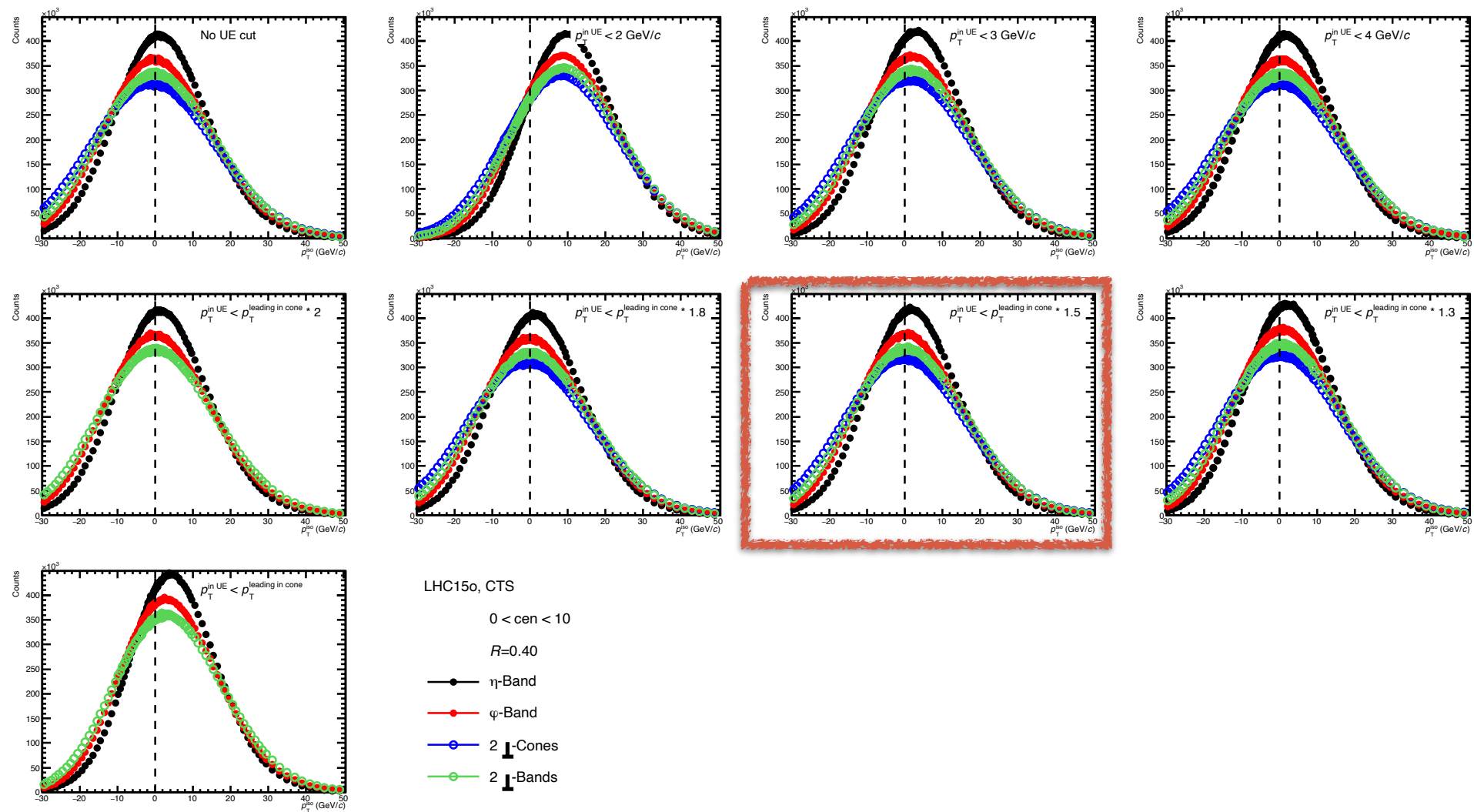
p_T^{iso} , vs sphericity bins, $R=0.4$, 50-90%, S_0 track $p_T > 3 \text{ GeV}/c$

102 / 83



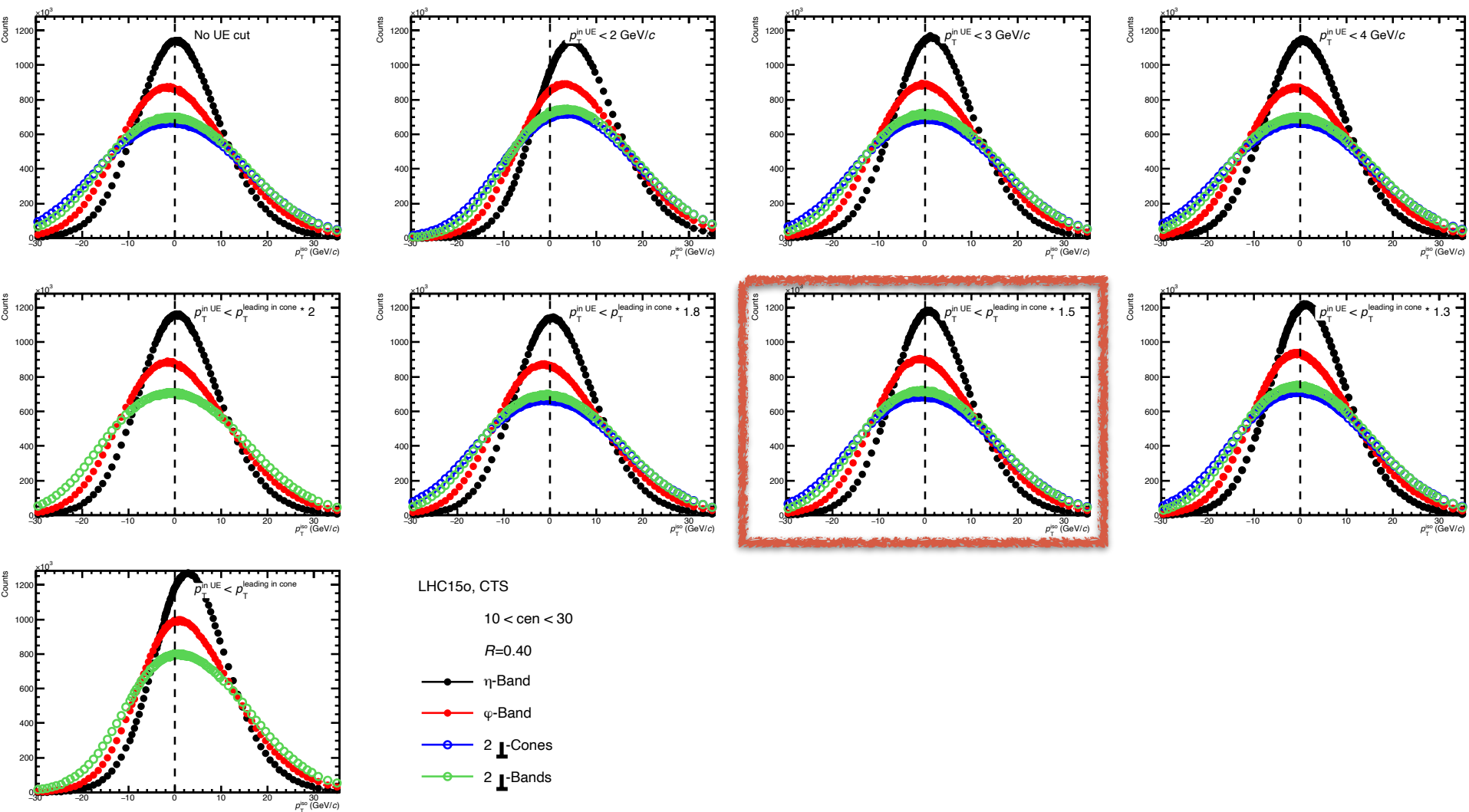
All bands are not too sensitive. Only smallest S_0 bin has clear different shape.

3 - $p_{\text{T}}^{\text{iso}}$, track p_{T} cut in UE region, $R=0.4$, 0-10%, random cones 103 / 83



Fix track p_{T} cut does not help much.
Cutting on leading track p_{T} in cone $\times 1.5$ not help much.

3 - $p_{\text{T}}^{\text{iso}}$, track p_{T} cut in UE region, $R=0.4$, 10-30%, random cones 104 / 83

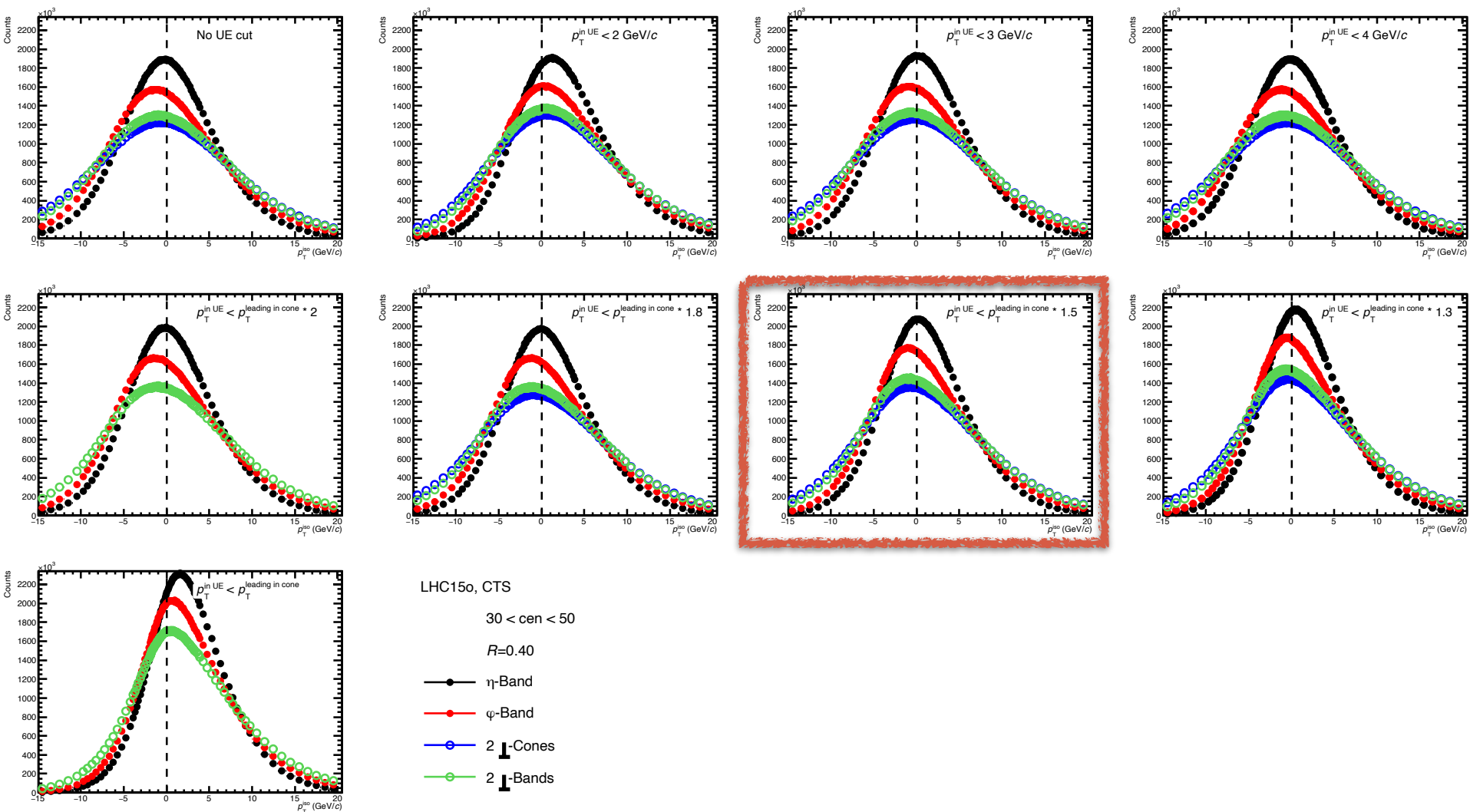


Without cut, all distributions rather centered at 0 except φ -band.

Fix track p_{T} cut does not help much.

Cutting on leading track p_{T} in cone $\times 1.5$ not help much.

3 - $p_{\text{T}}^{\text{iso}}$, track p_{T} cut in UE region, $R=0.4$, 30-50%, random cones ^{105 / 83}

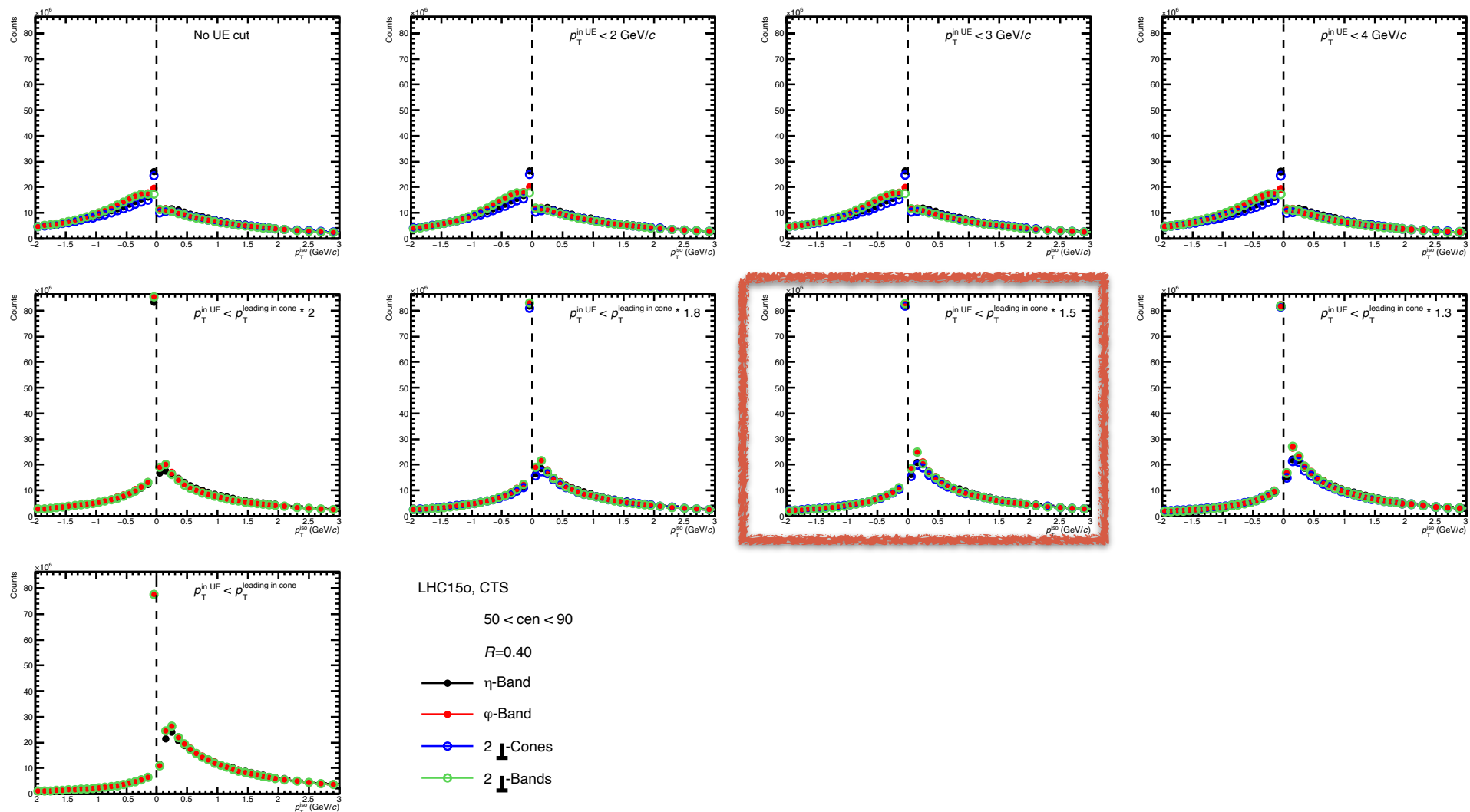


Without cut, all distributions rather centered at 0 except ϕ -band.

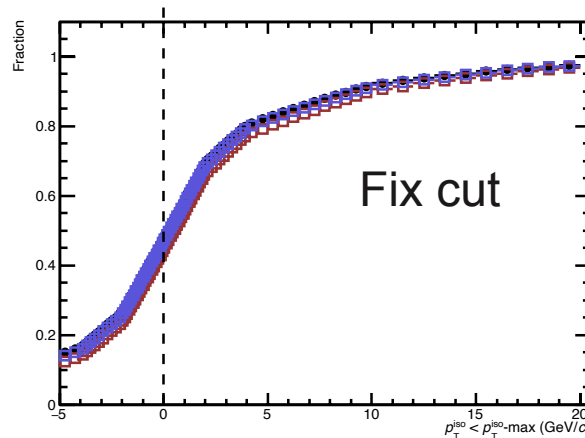
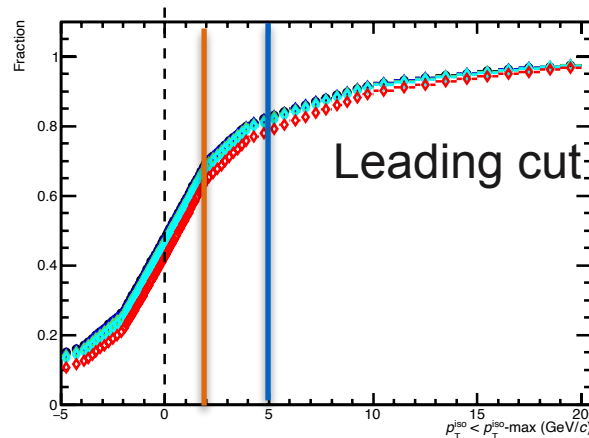
Fix track p_{T} cut does not do much

Cutting on leading track p_{T} in cone $\times 1.5$ does not do much.

3 - $p_{\text{T}}^{\text{iso}}$, track p_{T} cut in UE region, $R=0.4$, 50-90%, random cones 106 / 83



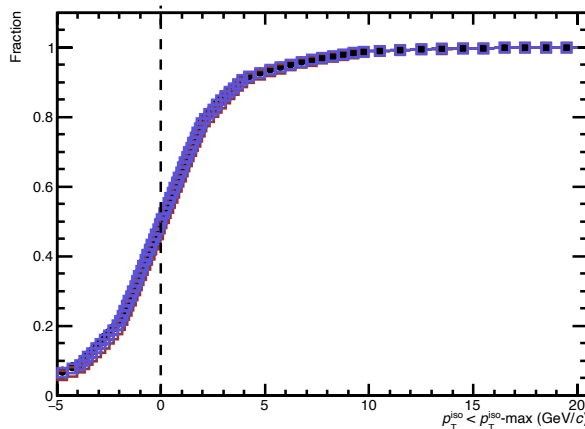
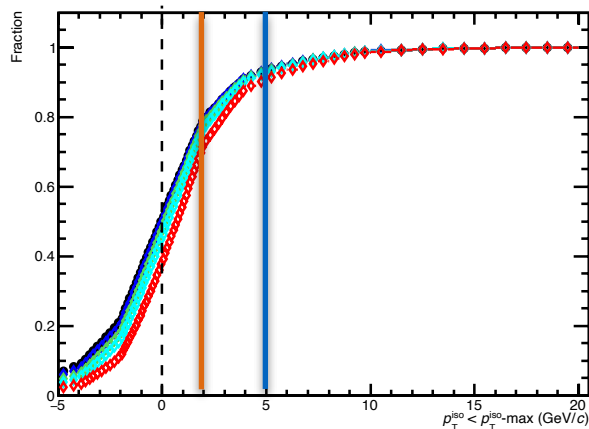
Fix track p_{T} cut does not do much.



LHC15o CTS η -Band

$0 < \text{cen} < 10$
 $R=0.40$

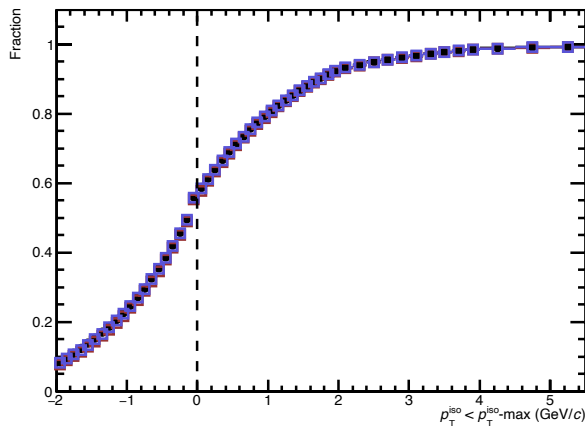
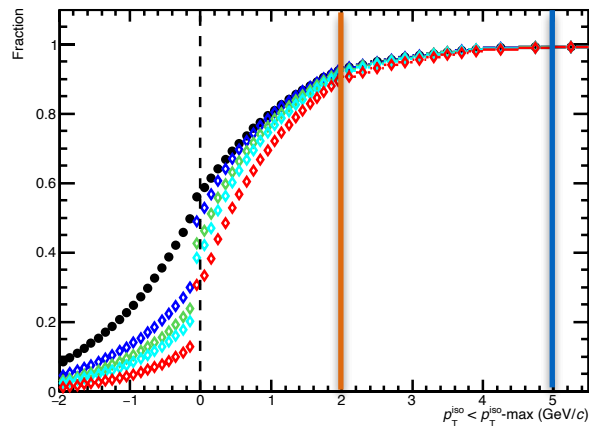
- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}}$
- ◇— $p_T^{\text{in UE}} < p_T$
- ◇— $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 2 \text{ GeV}/c$
- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$



LHC15o CTS η -Band

$30 < \text{cen} < 50$
 $R=0.40$

- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}}$
- ◇— $p_T^{\text{in UE}} < p_T$
- ◇— $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 2 \text{ GeV}/c$
- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$



LHC15o CTS η -Band

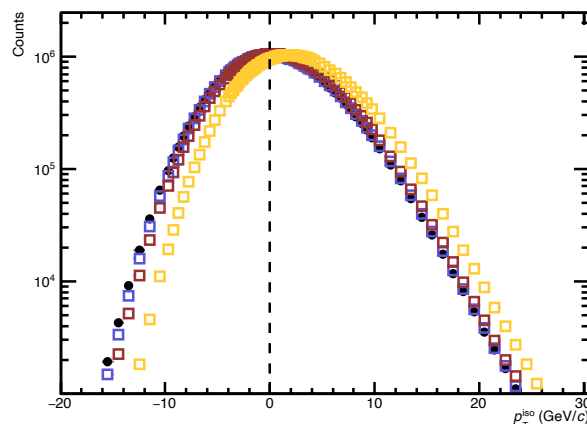
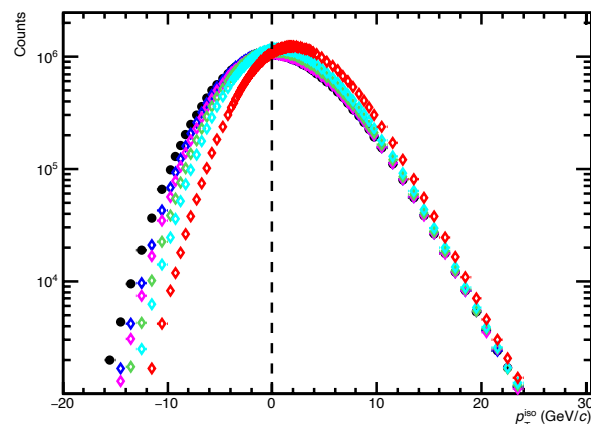
$50 < \text{cen} < 90$
 $R=0.40$

- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$

Leading track p_T based cut can have some impact on efficiency if too tight isolation cut.

With track cut factor 1.5 seems safe to cut p_T^{iso} above 2 GeV in all centrality bins

Same fractions in other UE estimators (back-up)

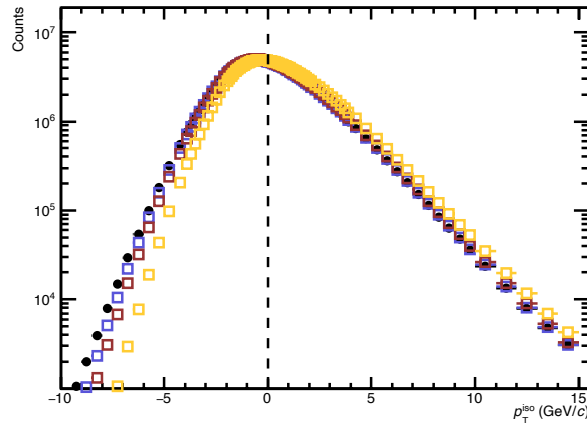
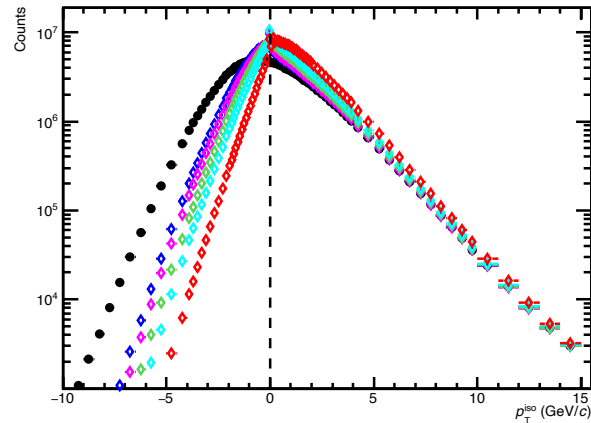


LHC150, CTS, η -Band

$0 < \text{cen} < 10$

$R=0.20$

- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 2$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}}$
- ◇— $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 2 \text{ GeV}/c$

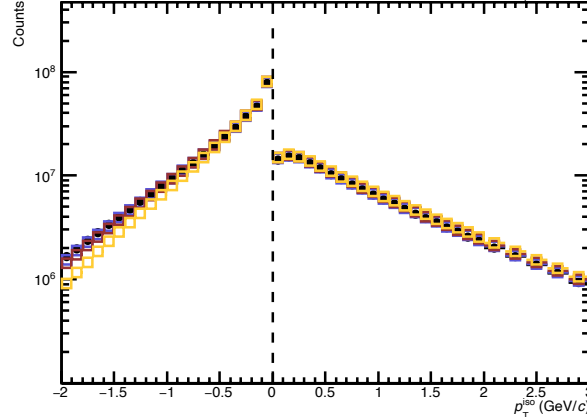
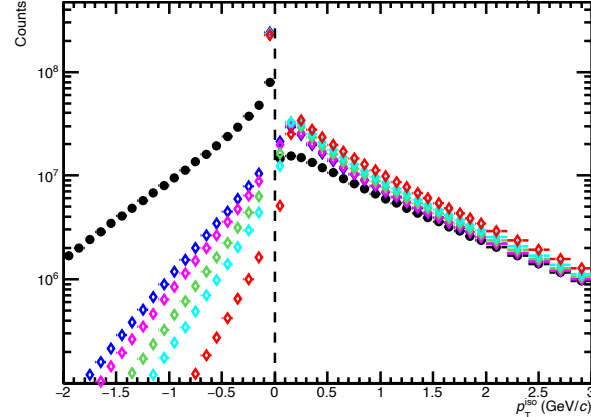


LHC150, CTS, η -Band

$30 < \text{cen} < 50$

$R=0.20$

- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 2$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}}$
- ◇— $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 2 \text{ GeV}/c$

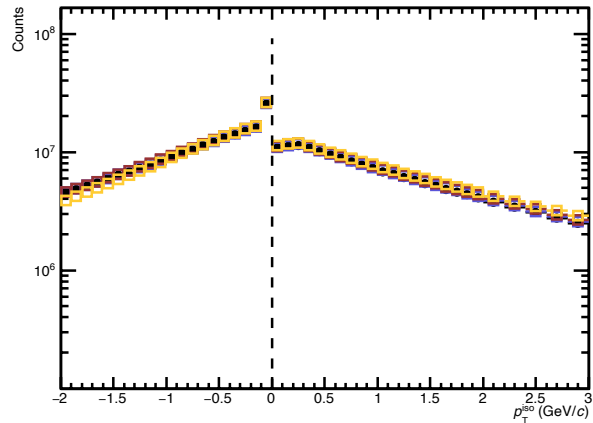
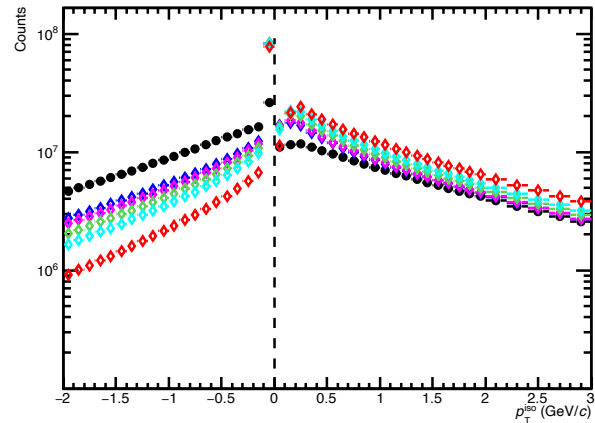
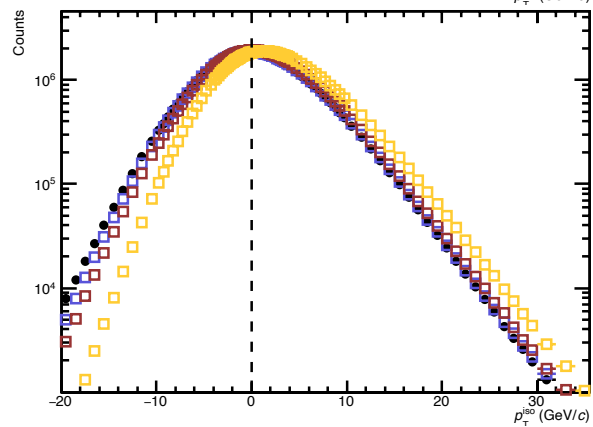
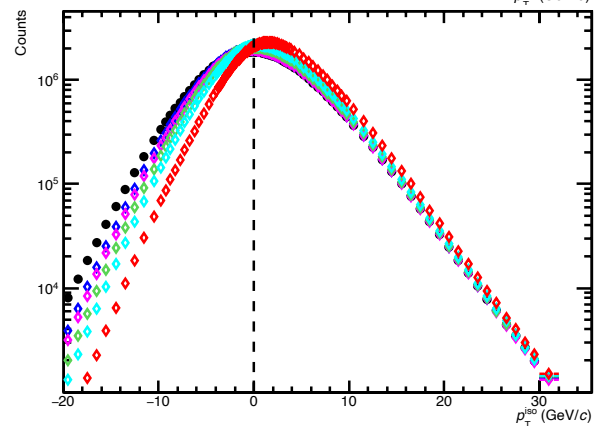
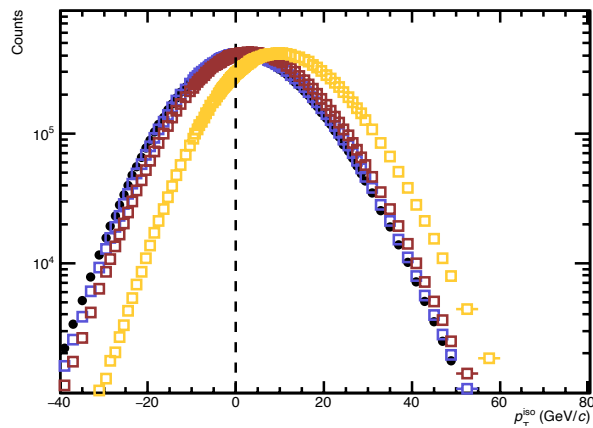
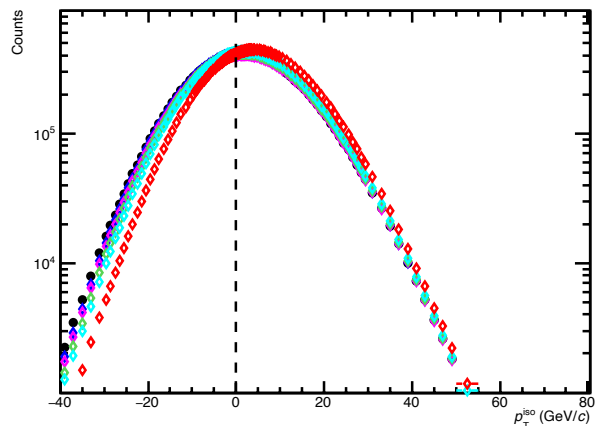


LHC150, CTS, η -Band

$50 < \text{cen} < 90$

$R=0.20$

- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 2$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}}$
- ◇— $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 2 \text{ GeV}/c$



LHC150, CTS, η -Band

$0 < \text{cen} < 10$

$R=0.40$

- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}}$
- $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- $p_T^{\text{in UE}} < 2 \text{ GeV}/c$

LHC150, CTS, η -Band

$30 < \text{cen} < 50$

$R=0.40$

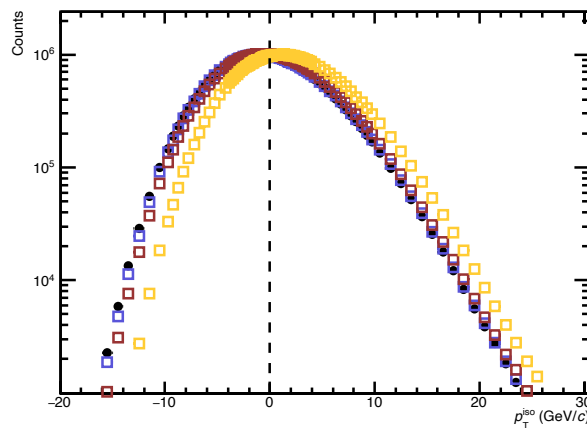
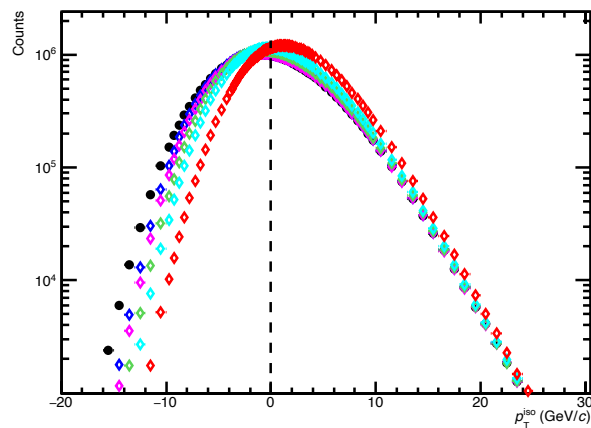
- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}}$
- $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- $p_T^{\text{in UE}} < 2 \text{ GeV}/c$

LHC150, CTS, η -Band

$50 < \text{cen} < 90$

$R=0.40$

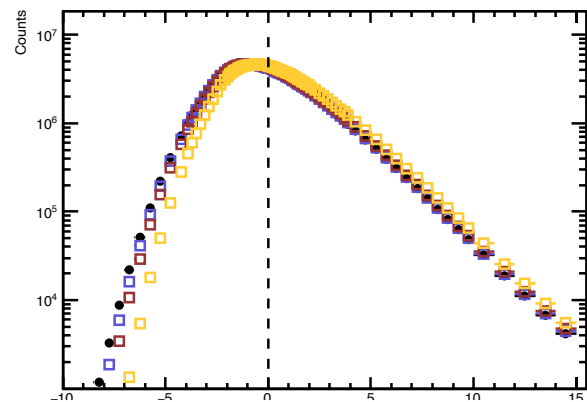
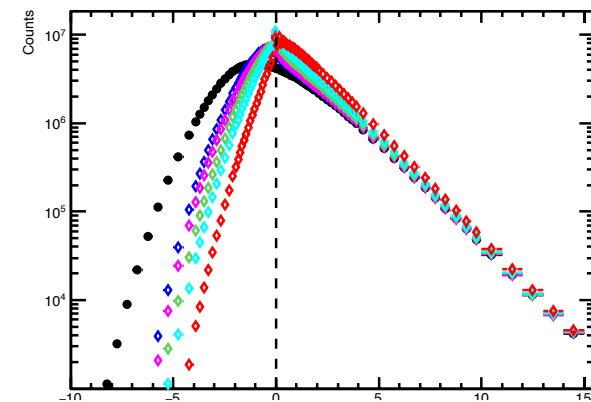
- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}}$
- $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- $p_T^{\text{in UE}} < 2 \text{ GeV}/c$



LHC15o, EMCAL, φ -Band

0 < cen < 10
 $R=0.20$

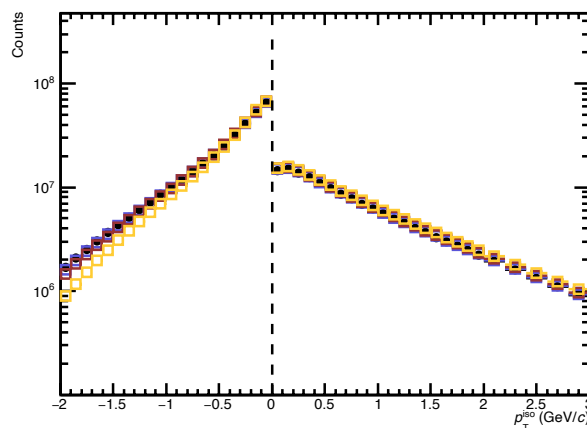
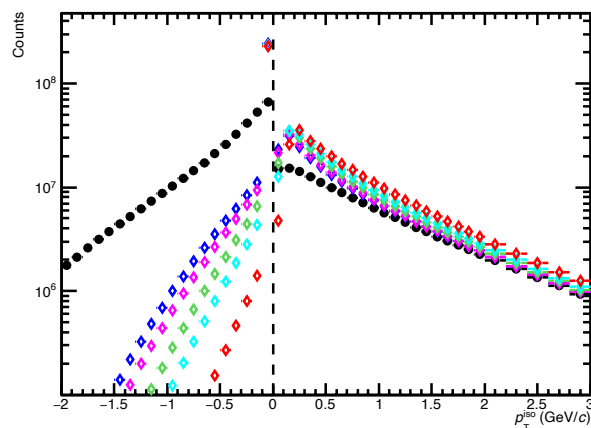
- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}}$
- $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- $p_T^{\text{in UE}} < 2 \text{ GeV}/c$



LHC15o, EMCAL, φ -Band

30 < cen < 50
 $R=0.20$

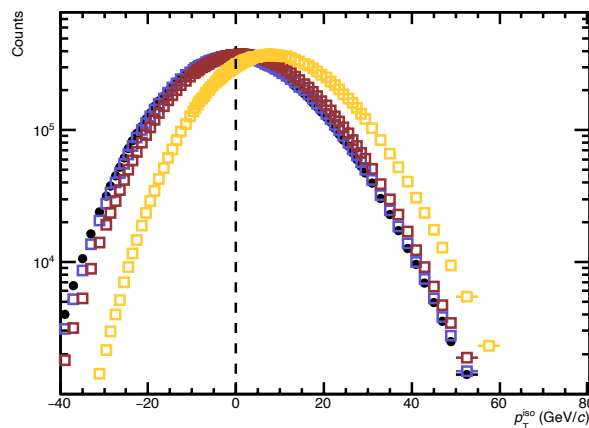
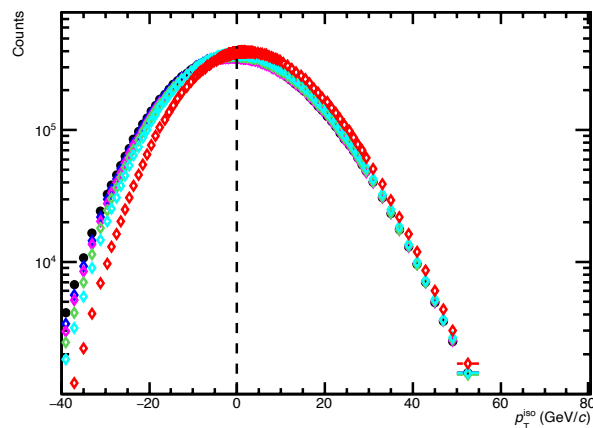
- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}}$
- $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- $p_T^{\text{in UE}} < 2 \text{ GeV}/c$



LHC15o, EMCAL, φ -Band

50 < cen < 90
 $R=0.20$

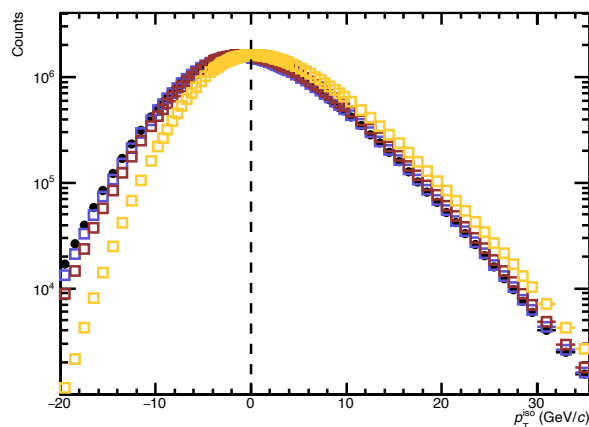
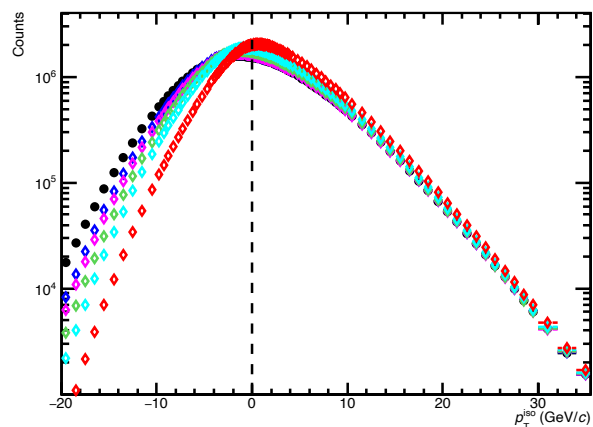
- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_T^{\text{leading in cone}}$
- $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- $p_T^{\text{in UE}} < 2 \text{ GeV}/c$


LHC15o, EMCAL, φ -Band

0 < cen < 10

 $R=0.40$

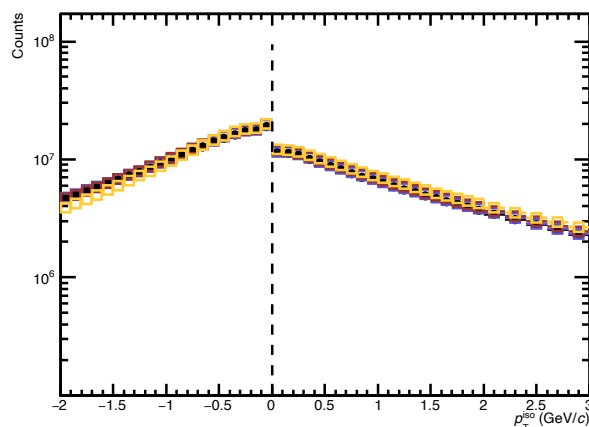
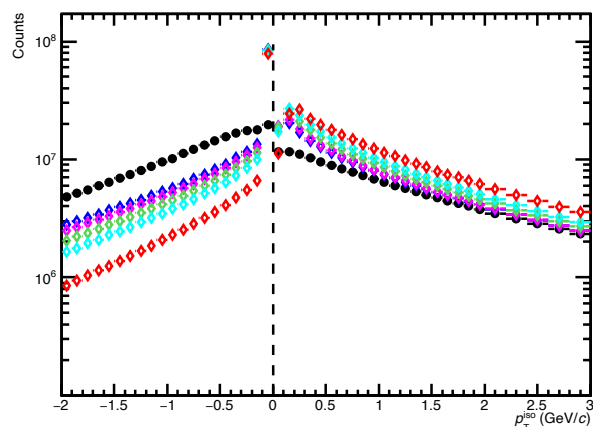
- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 2$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}}$
- ◇— $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 2 \text{ GeV}/c$


LHC15o, EMCAL, φ -Band

30 < cen < 50

 $R=0.40$

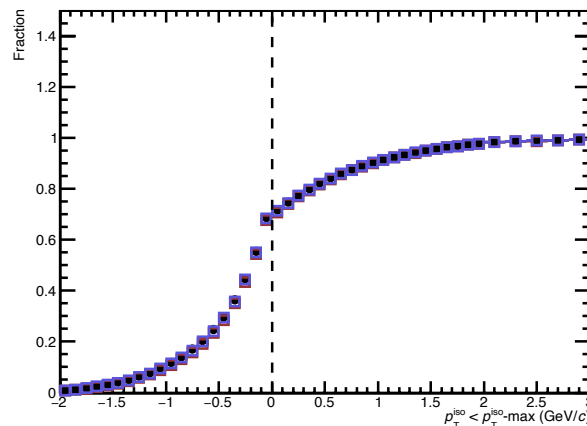
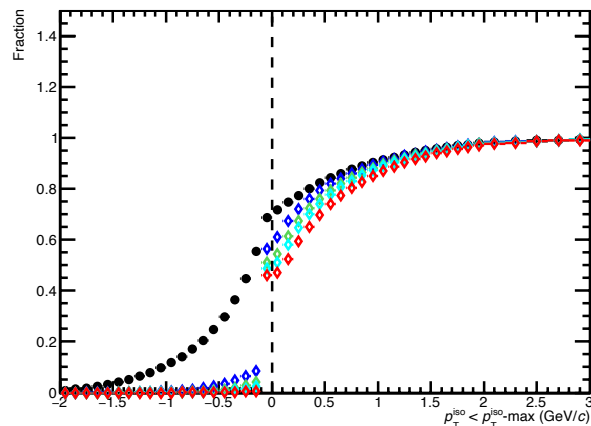
- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 2$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}}$
- ◇— $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 2 \text{ GeV}/c$


LHC15o, EMCAL, φ -Band

50 < cen < 90

 $R=0.40$

- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 2$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.8$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.5$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}} * 1.3$
- ◇— $p_T^{\text{in UE}} < p_{\text{leading in cone}}^{\text{in UE}}$
- ◇— $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- ◇— $p_T^{\text{in UE}} < 2 \text{ GeV}/c$



 No $p_T^{\text{in UE}}$ cut
 $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
 $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$
 $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.5$
 $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.3$
 $p_T^{\text{in UE}} < p_T^{\text{cut}}$
 $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
 $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
 $p_T^{\text{in UE}} < 2 \text{ GeV}/c$
 No $p_T^{\text{in UE}}$ cut
 $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
 $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$

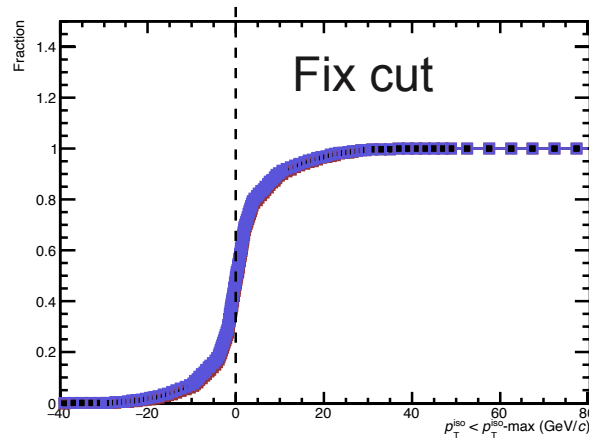
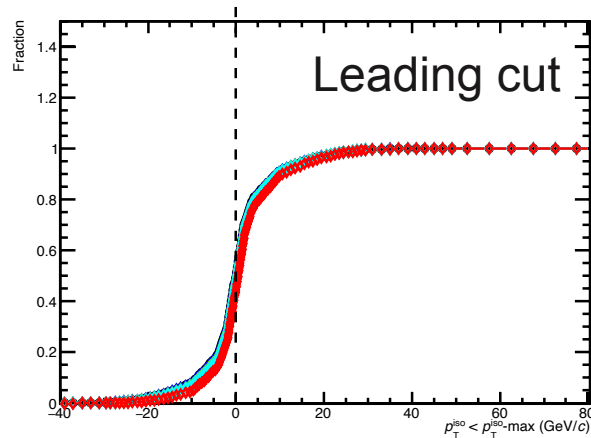
Figure 1 displays 14 particle identification (PID) criteria, each represented by a colored line with a marker and a corresponding mathematical expression. The criteria are as follows:

- Black line with a solid circle: No p in UE cut
- Blue line with a solid diamond: $p_T^h \text{ UE} < p_T^{\text{leading in cone}} * 2$
- Magenta line with a solid diamond: $p_T^h \text{ UE} < p_T^{\text{leading in cone}} * 1.8$
- Green line with a solid diamond: $p_T^h \text{ UE} < p_T^{\text{leading in cone}} * 1.5$
- Cyan line with a solid diamond: $p_T^h \text{ UE} < p_T^{\text{leading in cone}} * 1.3$
- Red line with a solid diamond: $p_T^h \text{ UE} < p_T^{\text{leading in cone}}$
- Blue line with an open square: $p_T^h \text{ UE} < 4 \text{ GeV}/c$
- Red line with an open square: $p_T^h \text{ UE} < 3 \text{ GeV}/c$
- Yellow line with an open square: $p_T^h \text{ UE} < 2 \text{ GeV}/c$
- Black line with a solid circle: No p in UE cut
- Blue line with a solid diamond: $p_T^h \text{ UE} < p_T^{\text{leading in cone}} * 2$
- Green line with a solid diamond: $p_T^h \text{ UE} < p_T^{\text{leading in cone}} * 1.8$

Figure 1 shows a list of 14 particle physics processes, each represented by a horizontal line with a specific marker and a corresponding text label. The processes are:

- Black line with a black dot: No $p_T^{\text{in UE}}$ cut
- Blue line with a blue diamond: $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
- Magenta line with a magenta diamond: $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$
- Green line with a green diamond: $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.5$
- Cyan line with a cyan diamond: $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.3$
- Red line with a red diamond: $p_T^{\text{in UE}} < p_T^{\text{leading in cone}}$
- Blue line with a blue square: $p_T^{\text{in UE}} < 4 \text{ GeV}/c$
- Red line with a red square: $p_T^{\text{in UE}} < 3 \text{ GeV}/c$
- Yellow line with a yellow square: $p_T^{\text{in UE}} < 2 \text{ GeV}/c$
- Black line with a black dot: No $p_T^{\text{in UE}}$ cut
- Blue line with a blue diamond: $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 2$
- Green line with a green diamond: $p_T^{\text{in UE}} < p_T^{\text{leading in cone}} * 1.8$

The first five processes (black dot, blue diamond, magenta diamond, green diamond, cyan diamond) are grouped under a red box labeled "No $p_T^{\text{in UE}}$ cut". The last five processes (red diamond, blue square, red square, yellow square, black dot) are grouped under a red box labeled " $p_T^{\text{in UE}} < 2 \text{ GeV}/c$ ".

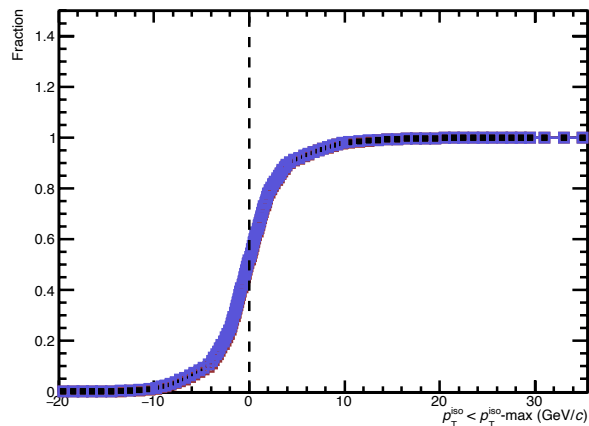
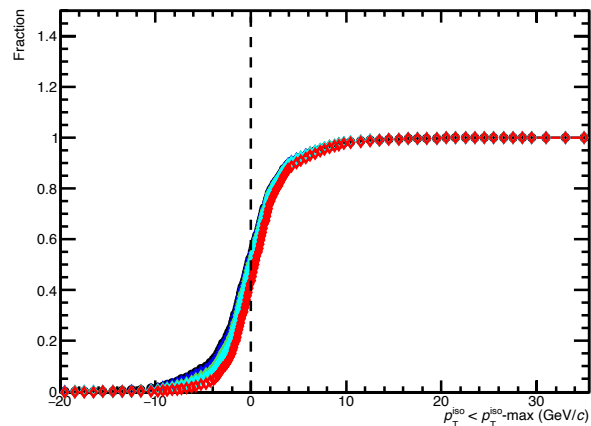


LHC150, CTS, φ -Band

$0 < \text{cen} < 10$

$R=0.40$

- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UET}} < p_T^{\text{leading in cone}} * 2$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}} * 1.8$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}} * 1.5$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}} * 1.3$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}}$
- ◆— $p_T^{\text{ih UE}} < p_T$
- $p_T^{\text{ih UE}} < 4 \text{ GeV}/c$
- $p_T^{\text{ih UE}} < 3 \text{ GeV}/c$
- $p_T^{\text{ih UE}} < 2 \text{ GeV}/c$
- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UET}} < p_T^{\text{leading in cone}} * 2$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}} * 1.8$

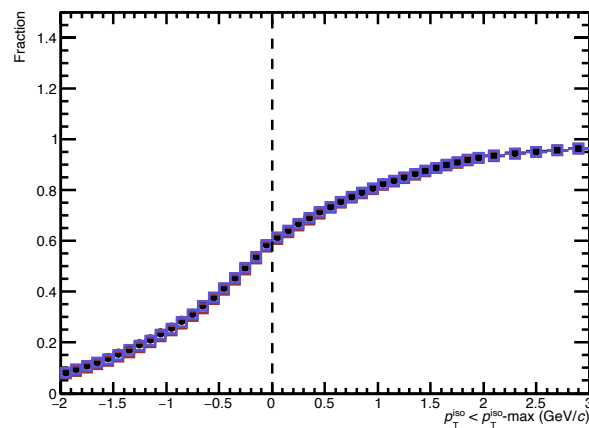
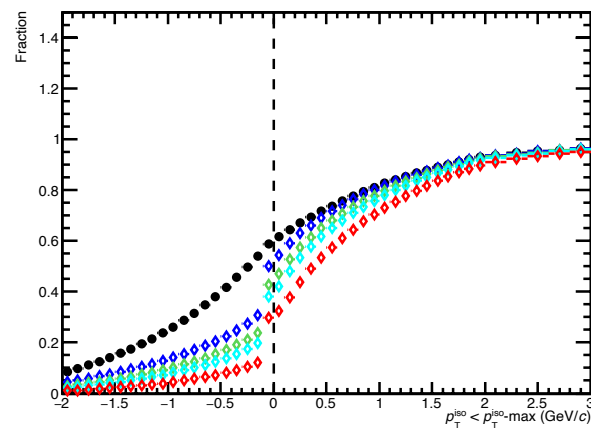


LHC150, CTS, φ -Band

$30 < \text{cen} < 50$

$R=0.40$

- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UET}} < p_T^{\text{leading in cone}} * 2$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}} * 1.8$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}} * 1.5$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}} * 1.3$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}}$
- ◆— $p_T^{\text{ih UE}} < p_T$
- $p_T^{\text{ih UE}} < 4 \text{ GeV}/c$
- $p_T^{\text{ih UE}} < 3 \text{ GeV}/c$
- $p_T^{\text{ih UE}} < 2 \text{ GeV}/c$
- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UET}} < p_T^{\text{leading in cone}} * 2$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}} * 1.8$



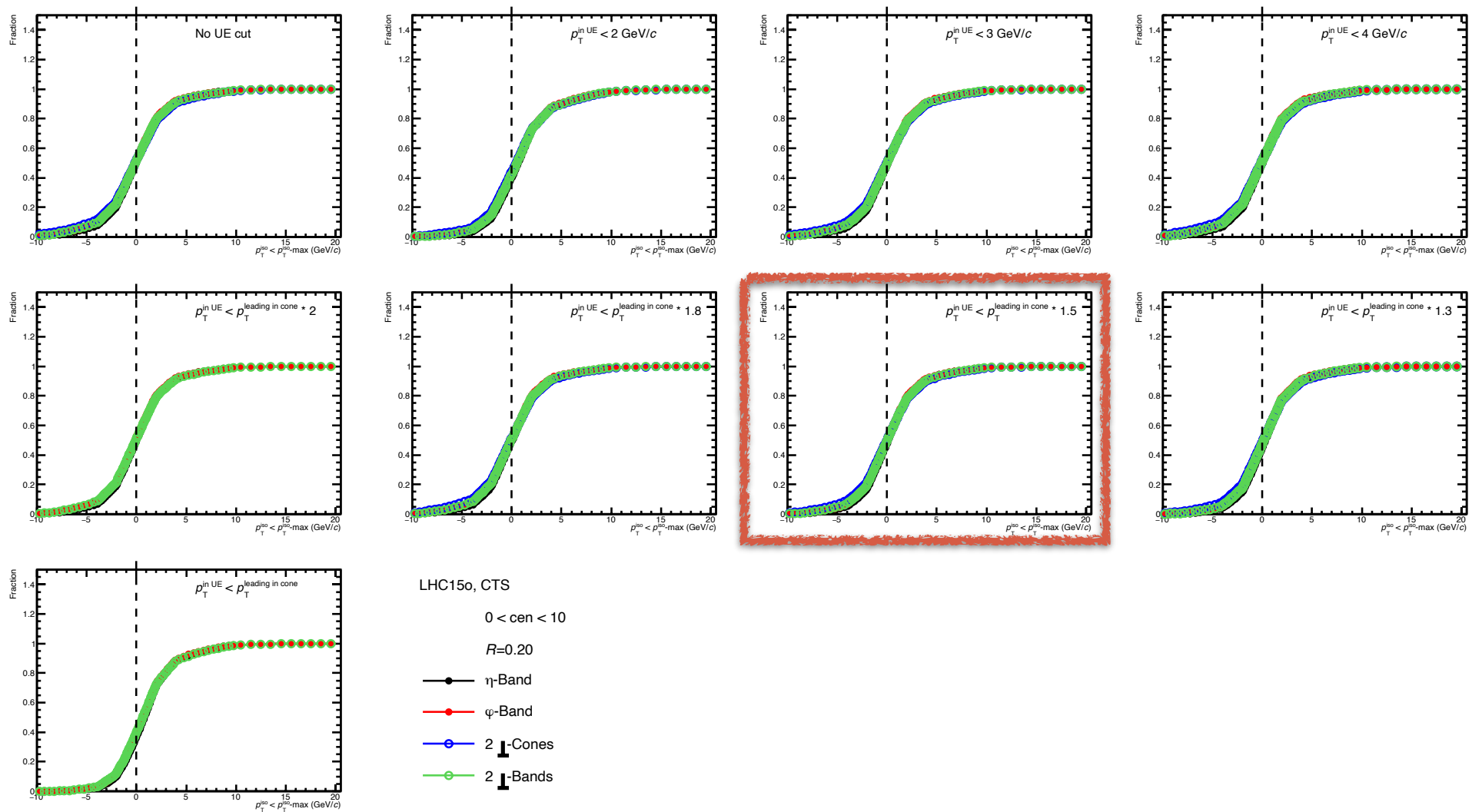
LHC150, CTS, φ -Band

$50 < \text{cen} < 90$

$R=0.40$

- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UET}} < p_T^{\text{leading in cone}} * 2$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}} * 1.8$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}} * 1.5$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}} * 1.3$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}}$
- ◆— $p_T^{\text{ih UE}} < p_T$
- $p_T^{\text{ih UE}} < 4 \text{ GeV}/c$
- $p_T^{\text{ih UE}} < 3 \text{ GeV}/c$
- $p_T^{\text{ih UE}} < 2 \text{ GeV}/c$
- No $p_T^{\text{in UE}}$ cut
- ◆— $p_T^{\text{in UET}} < p_T^{\text{leading in cone}} * 2$
- ◆— $p_T^{\text{ih UE}} < p_T^{\text{leading in cone}} * 1.8$

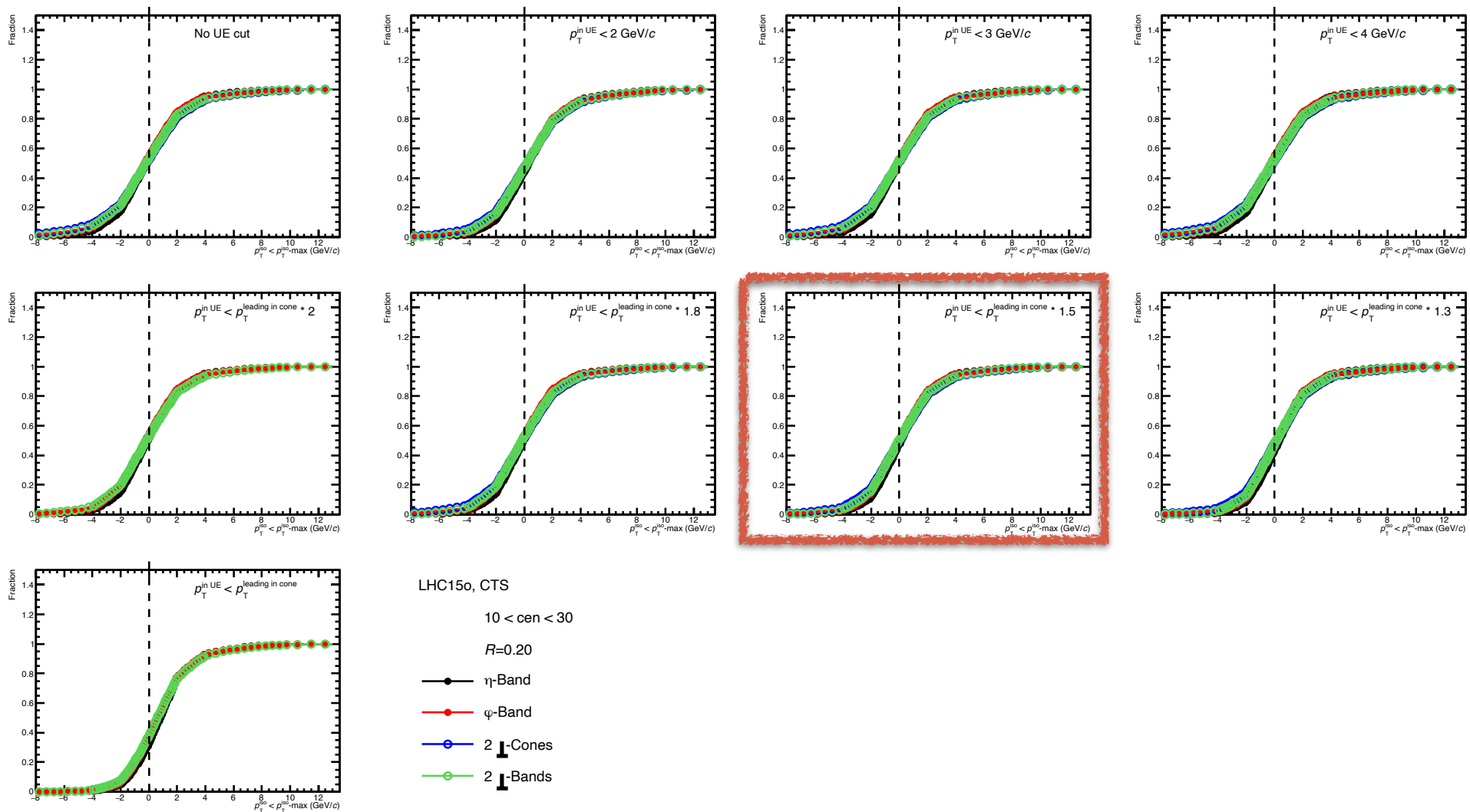
5 - Integrated p_T^{iso} , track p_T cut in UE region, $R=0.2$, 0-10% 114 / 83



Fix track p_T cut at 3 GeV seems reasonable.

Cutting on leading track p_T in cone $\times 1.5$ seems reasonable.

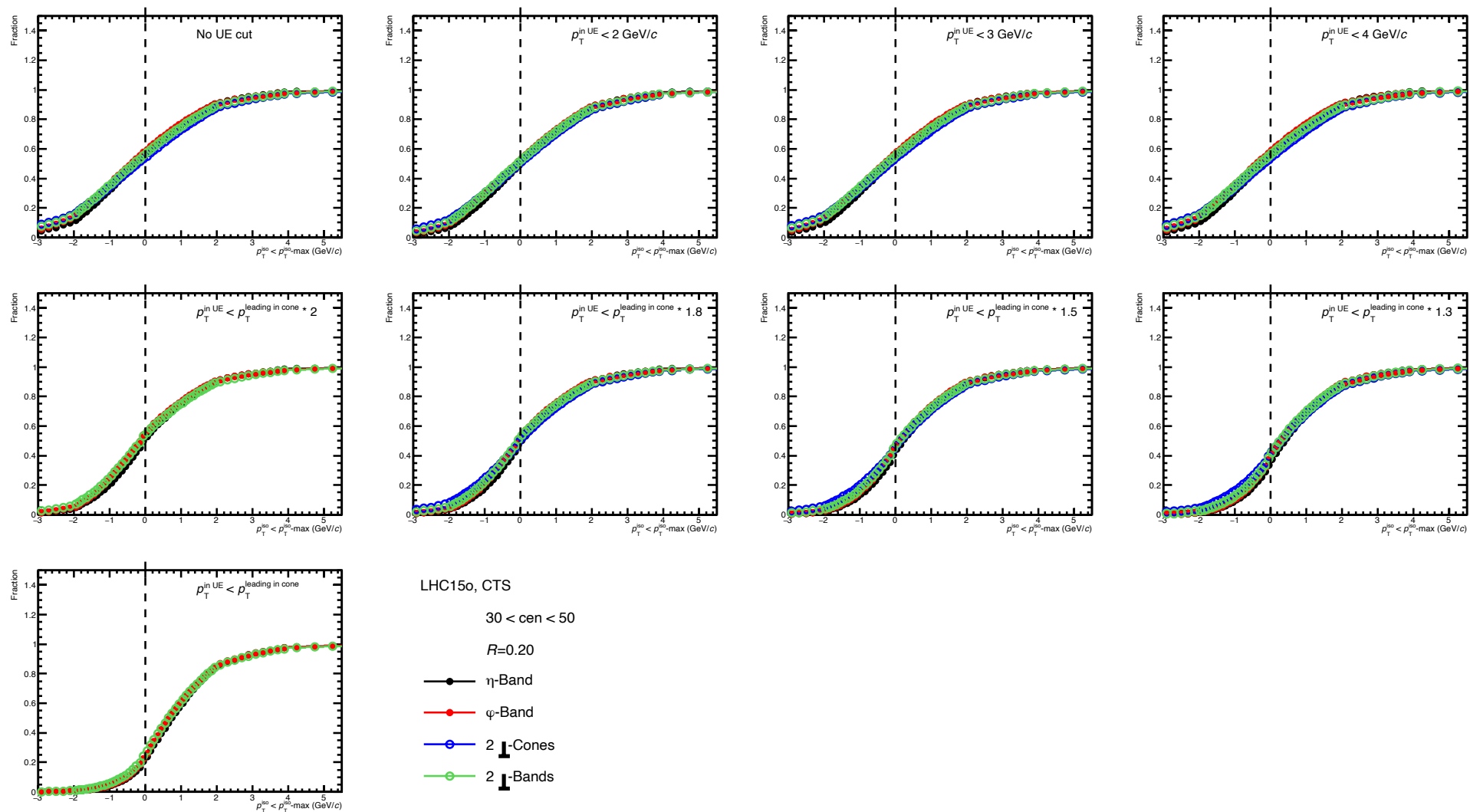
5 - Integrated p_T^{iso} , track p_T cut in UE region, $R=0.2$, 10-30% 115 / 83



Fix track p_T cut does not do much unless we go to 2 GeV but too much for η -band.

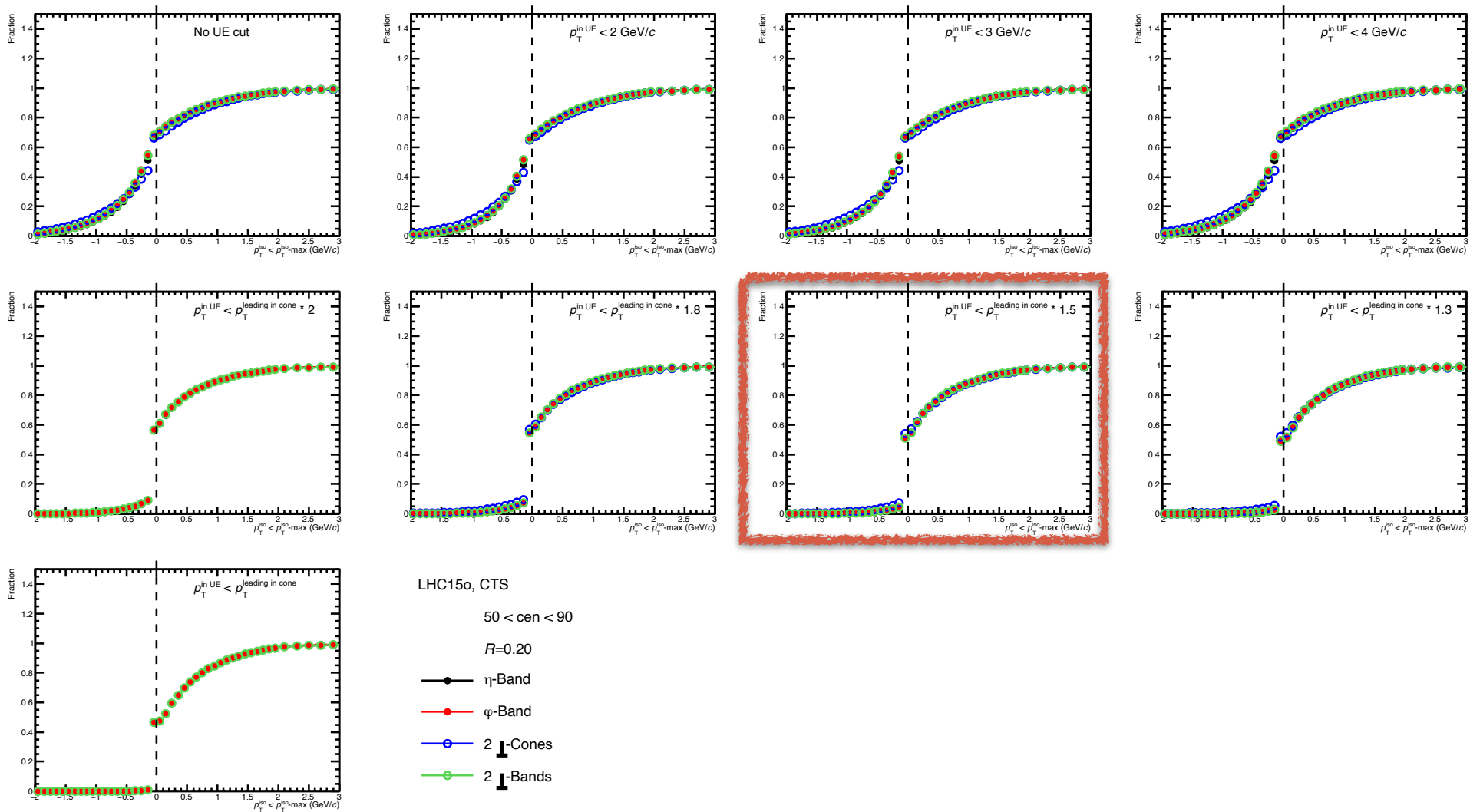
Cutting on leading track p_T in cone $\times 1.5$ seems reasonable for η -band $\times 1.3$ for other bands.

5 - Integrated p_T^{iso} , track p_T cut in UE region, $R=0.2$, 30-50% 116 / 83



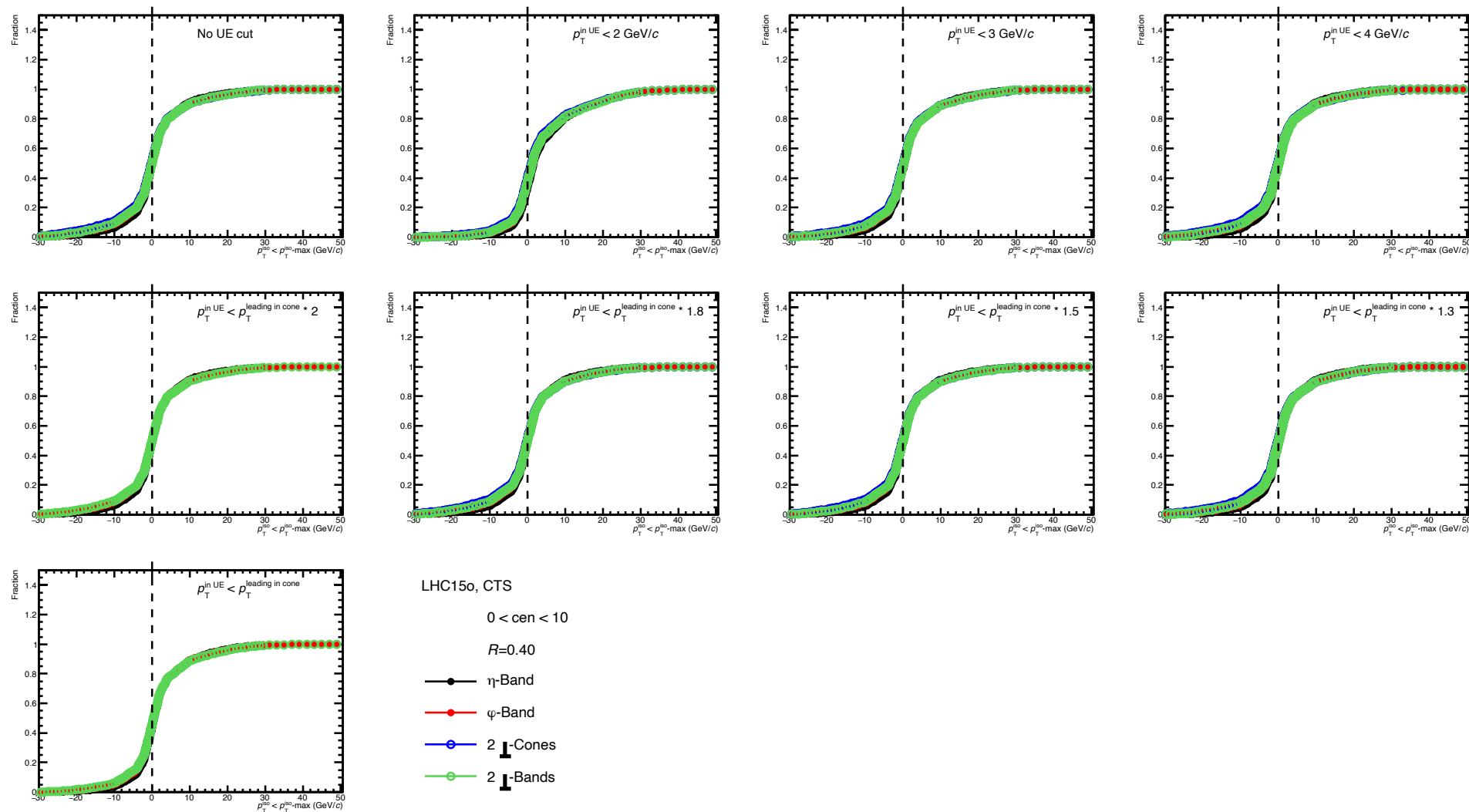
Fix track p_T cut does not do much.
Cutting on leading track p_T in cone $\times 1.5$ seems reasonable.

5 - Integrated $p_{\text{T}}^{\text{iso}}$, track p_{T} cut in UE region, $R=0.2$, 50-90% 117 / 83



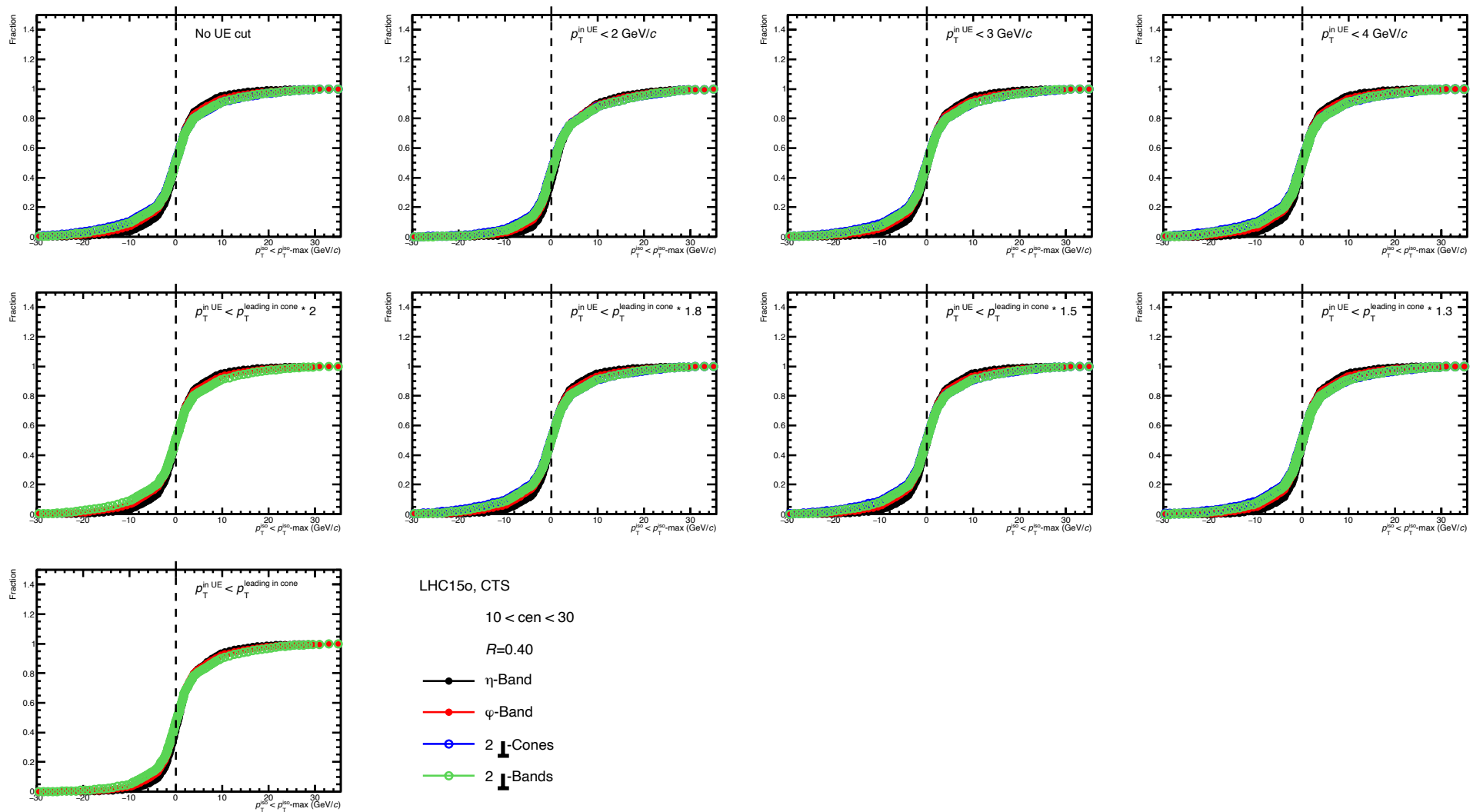
Fix track p_{T} cut does not do much.

5 - Integrated p_T^{iso} , track p_T cut in UE region, $R=0.4$, 0-10% 118 / 83



Fix track p_T cut does not help much.
Cutting on leading track p_T in cone $\times 1.5$ not help much.

5 - Integrated p_T^{iso} , track p_T cut in UE region, $R=0.4$, 10-30% 119 / 83

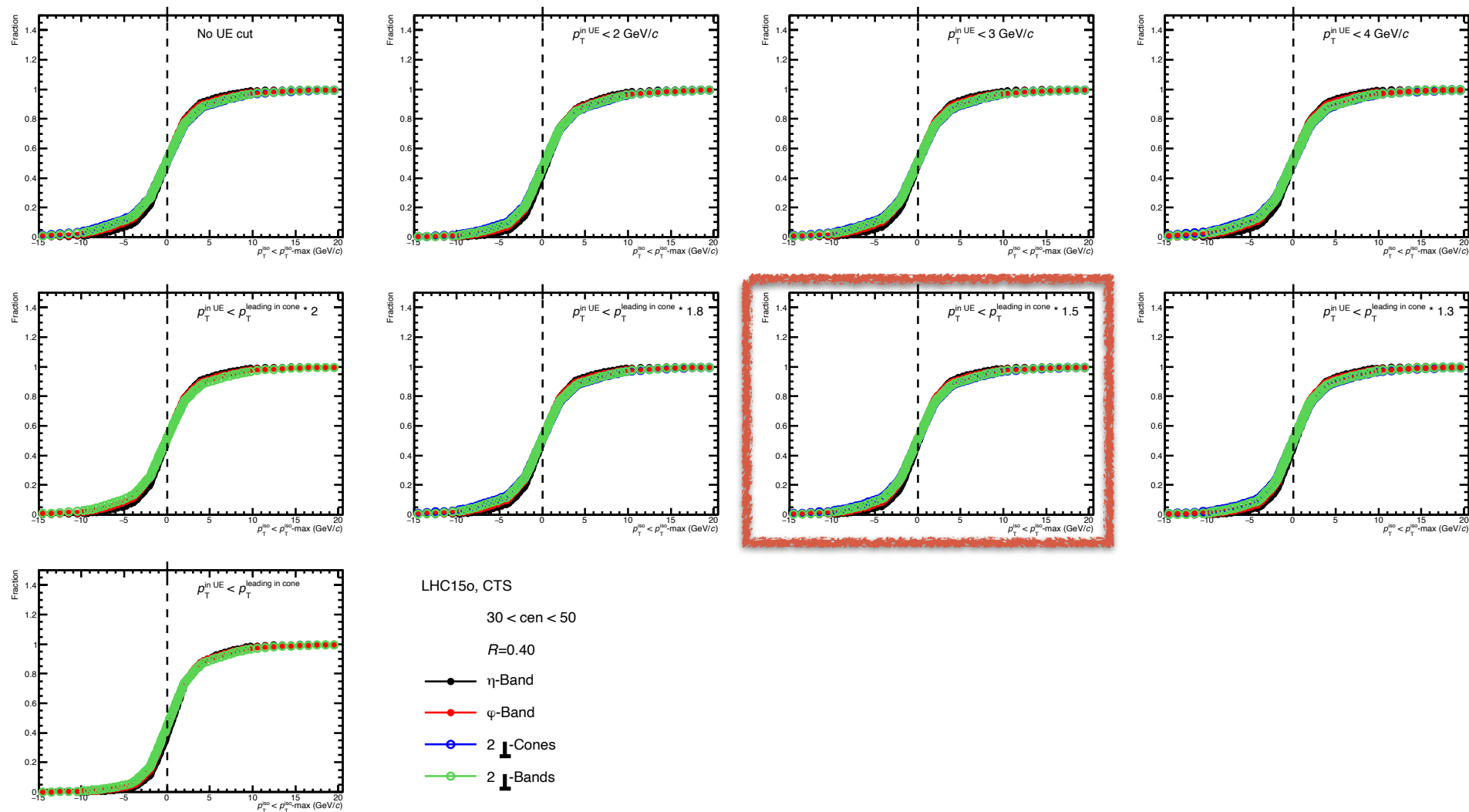


Without cut, all distributions rather centered at 0 except φ -band.

Fix track p_T cut does not help much.

Cutting on leading track p_T in cone $\times 1.5$ not help much.

5 - Integrated p_T^{iso} , track p_T cut in UE region, $R=0.4$, 30-50% 120 / 83

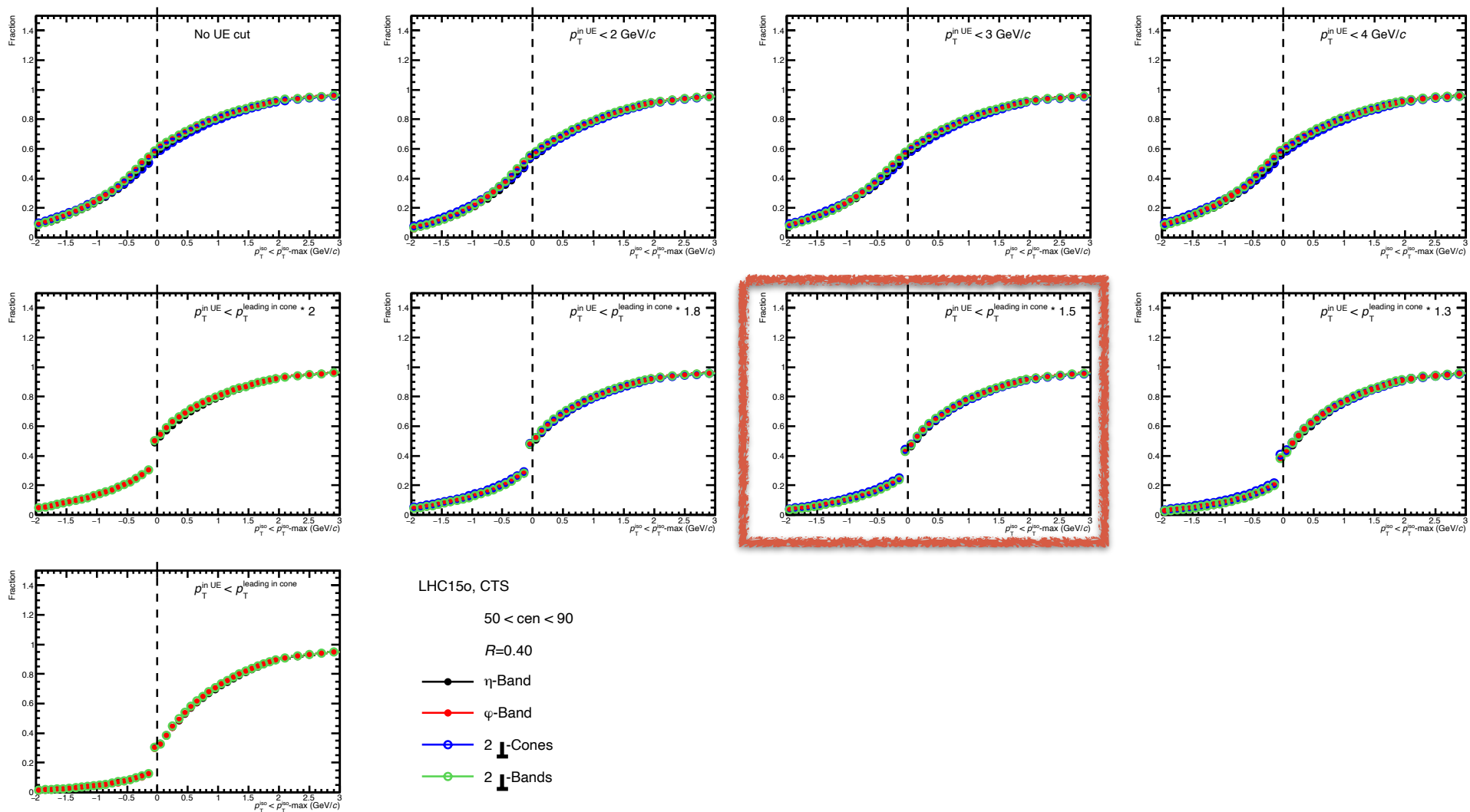


Without cut, all distributions rather centered at 0 except φ -band.

Fix track p_T cut does not do much

Cutting on leading track p_T in cone x 1.5 does not do much.

5 - Integrated $p_{\text{T}}^{\text{iso}}$, track p_{T} cut in UE region, $R=0.4$, 50-90% 121 / 83



Fix track p_{T} cut does not do much.