Sensitivity of the *pp* ridge to Hard processes

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for the ATLAS Collaboration

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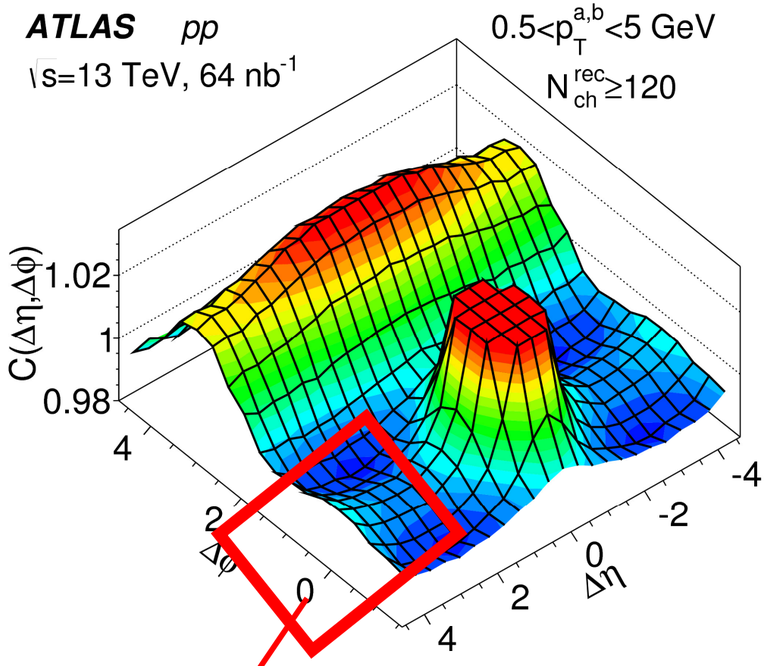
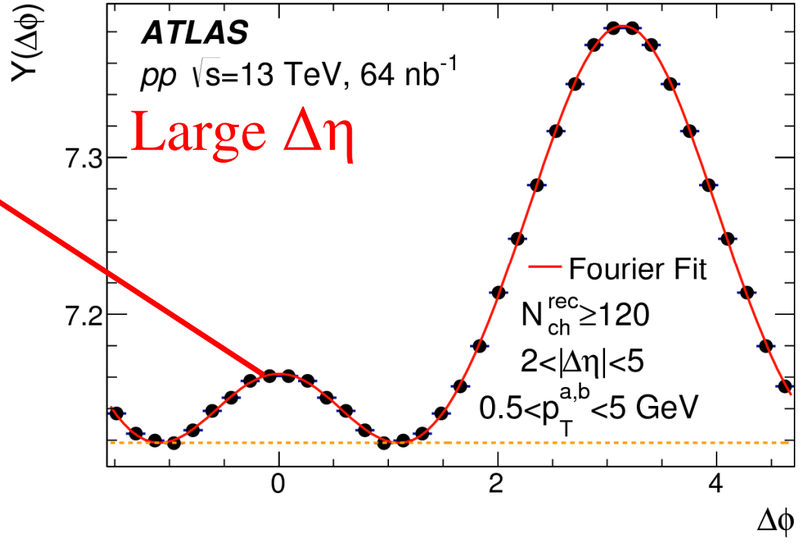
The ridge in *pp* collisions



pp ridge



- The ridge in A+A collisions is understood to be a manifestation of collective flow.
- Try to further our understanding of the origin of the *pp* ridge
  - Does it arise from collective (hydro) behavior?
  - Or is it driven by semi-hard processes? Perhaps related to gluon saturation.
- If latter, then actively selecting/rejecting events with semi-hard processes (low-p_T jets) should enhance/weaken the ridge.
- Do constituents of jets themselves exhibit such correlation with the soft Underlying Event (UE) tracks?

Define multiple correlation classes

- h : inclusive hadrons (tracks) in the event

ATLAS, arXiv:2303.17357, Accepted by PRL

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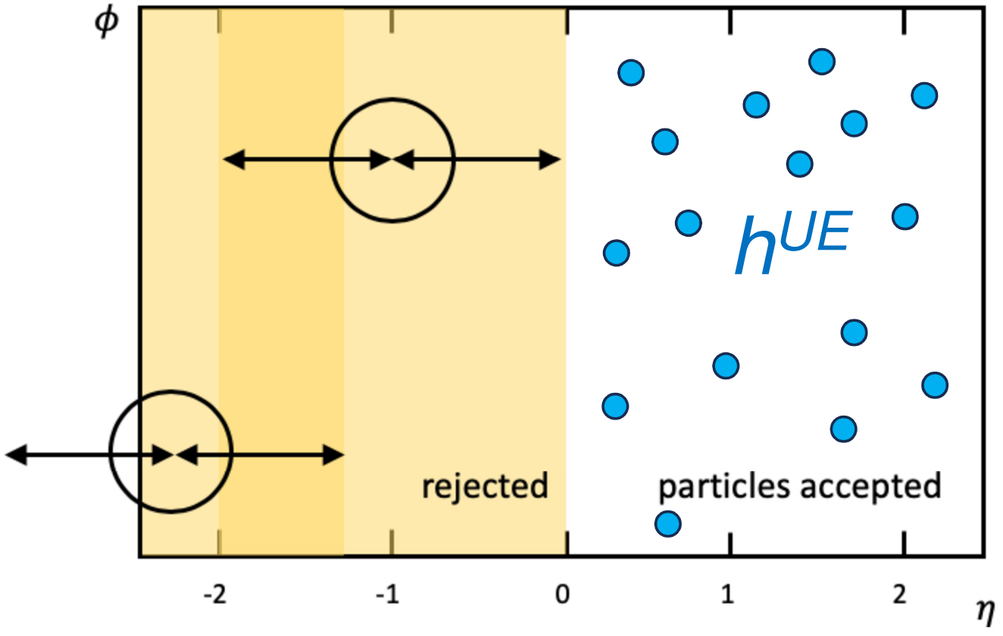
- h^{UE} : tracks from the underlying event (UE):
  - require that the track is at least one unit in $|\eta|$ from all jets with p_T >15 GeV



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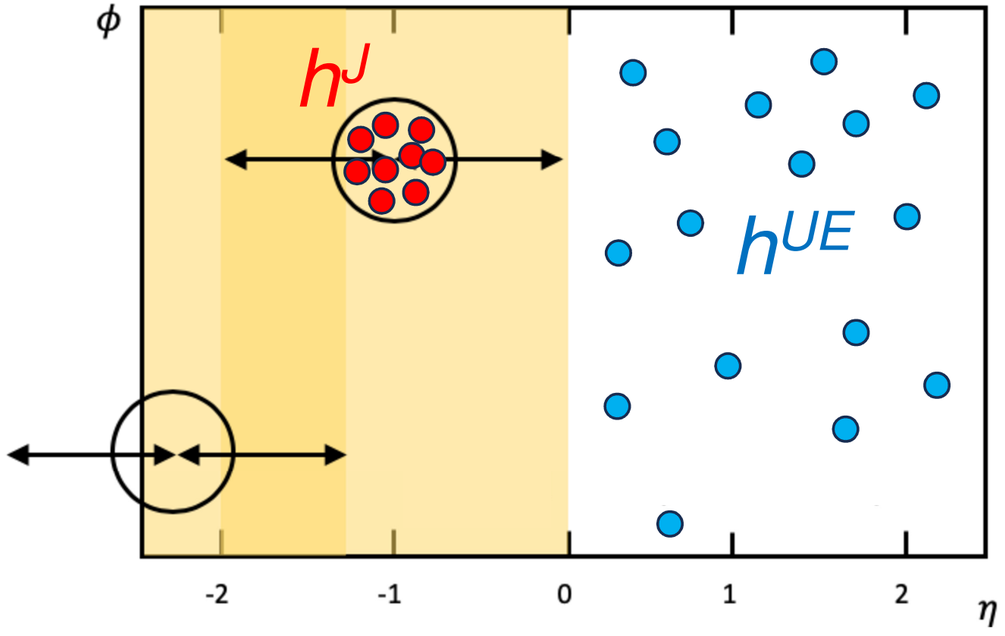
- h^{J} : track associated with a jet
  - require that the track is within a 0.4 cone of a p_T >40 GeV Jet



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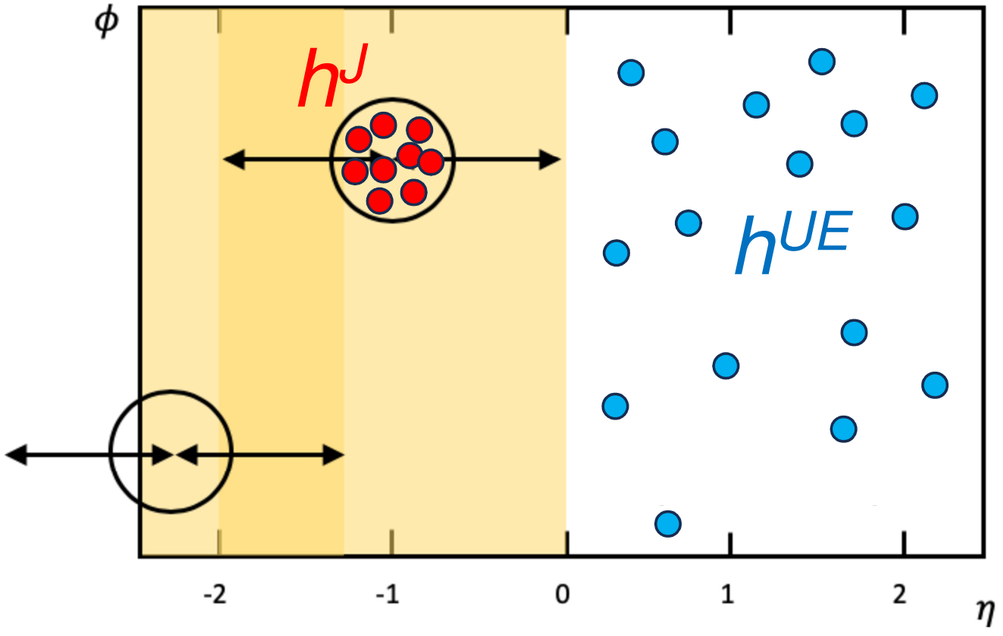

- Measure 2PCs between all tracks in all events:
  - *h-h*

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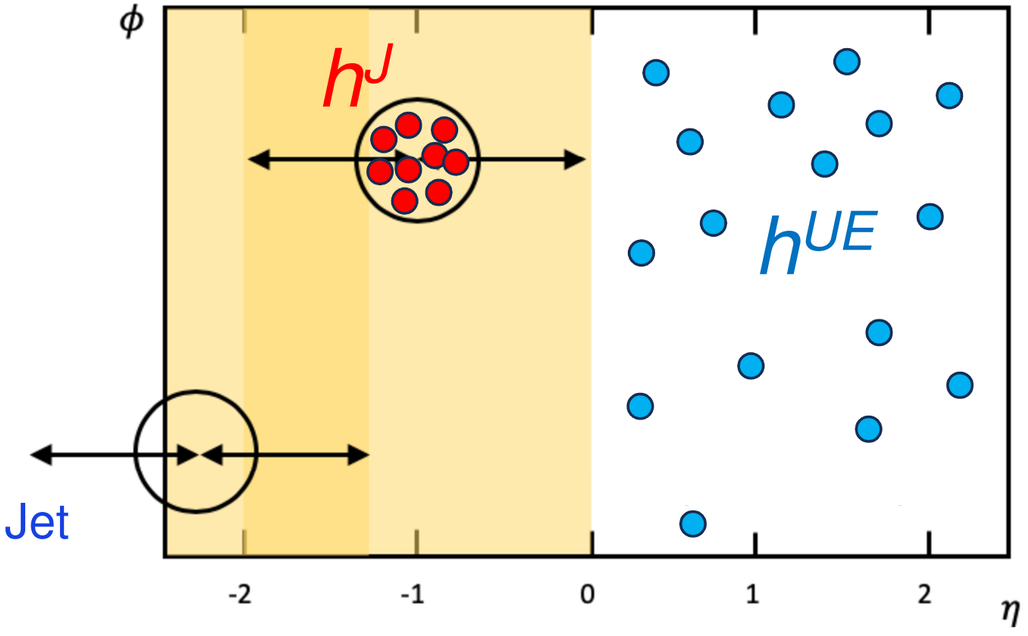

- Measure 2PCs between all tracks in all events:
  - *h-h*
- Measure 2PCs between tracks not associated with jets:
  - h^{UE}-h^{UE} *WithJets* : In events **with** at least one p_T >15 GeV Jet
  - h^{UE}-h^{UE} *NoJets* : In events **without** even a single p_T >15 GeV Jet
  - h^{UE}-h^{UE}: In inclusive events

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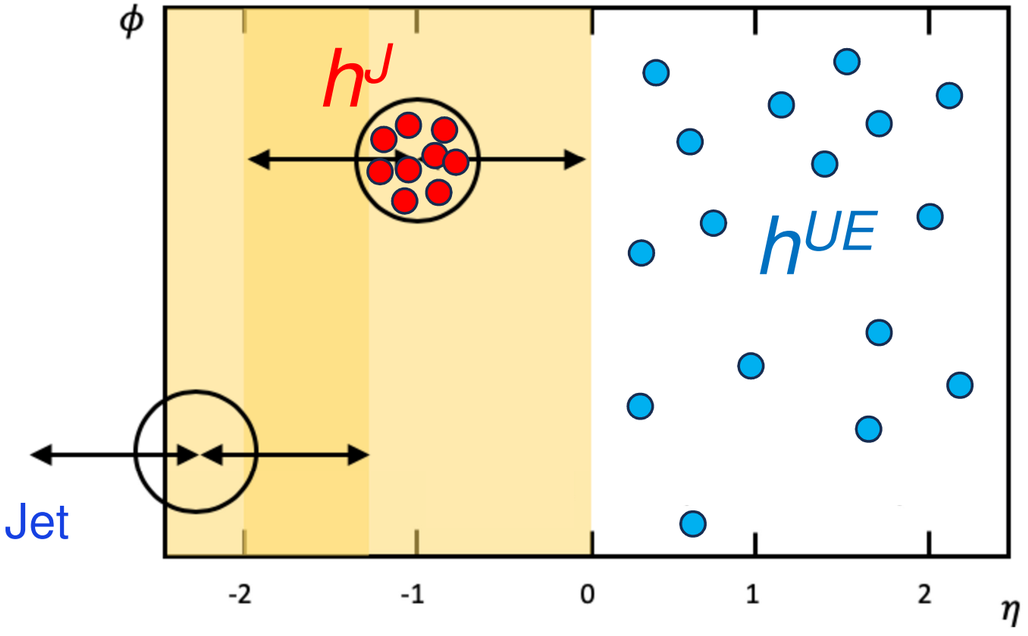

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  - h^{UE}-h^{UE}: In inclusive events
- UE-Jet 2PCs:
  - h^{UE}-h^{J}: 2PC between UE and jet constituents

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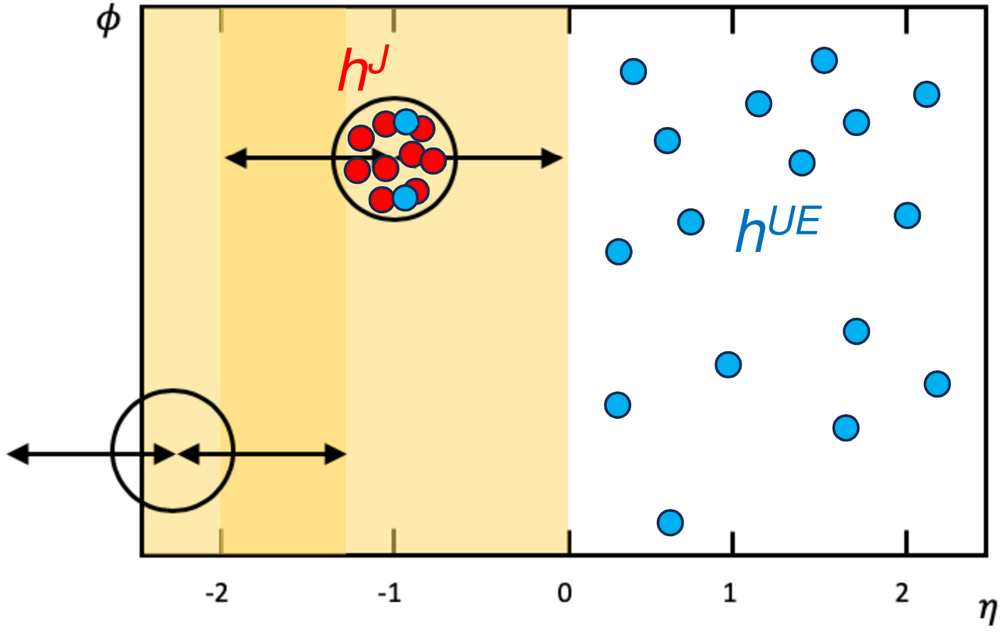
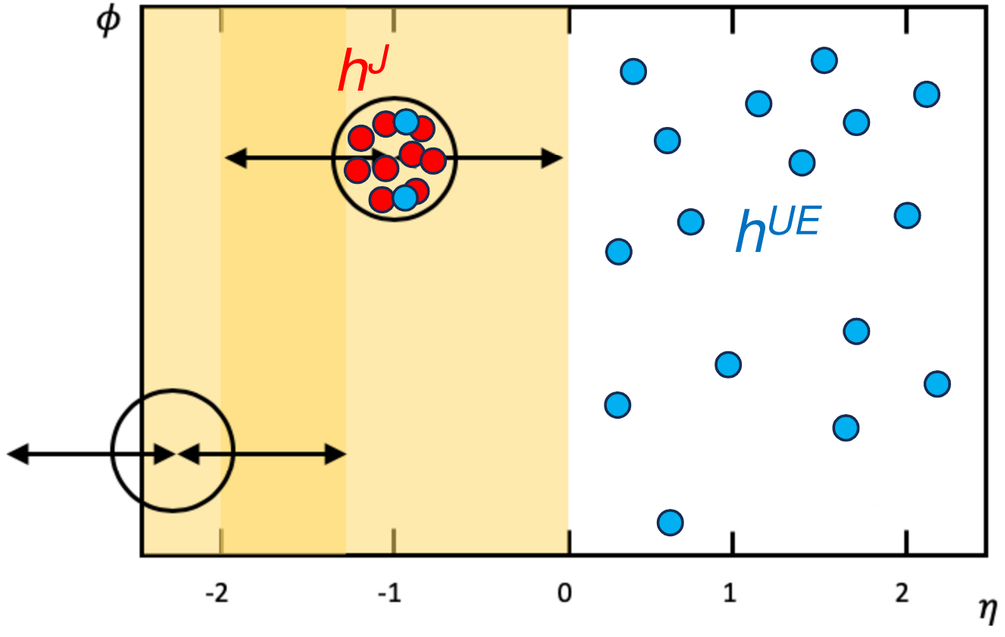
Complications in h^{UE}-h^{J} two-particle correlations

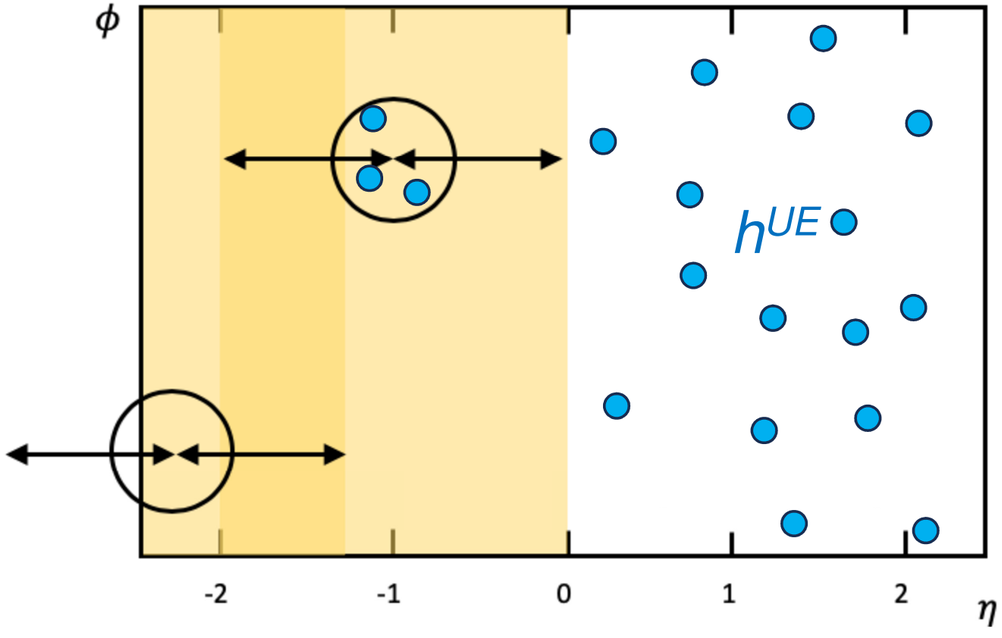
- Combinatorial pairs:
  - h^{UE} tracks that happen to be within the Jet Cone lead to h^{UE}-h^{UE} pairs



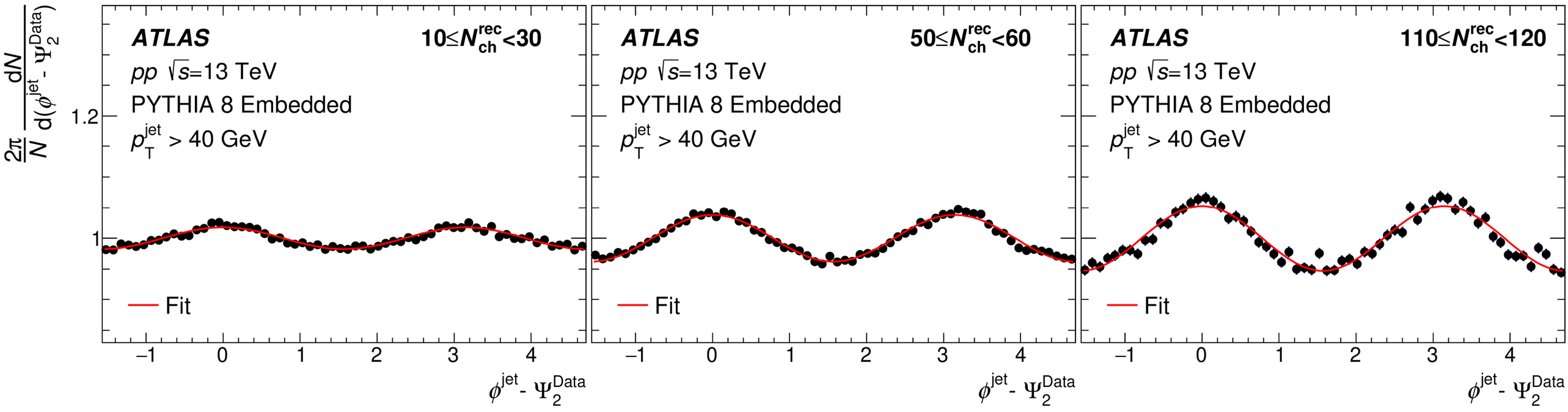
Complications in h^{UE}-h^{J} two-particle correlations

- Combinatorial pairs:
  - h^{UE} tracks that happen to be within the Jet Cone lead to h^{UE}-h^{UE} pairs
- Corrected using mixed-events
  - Take the acceptance from an h^{UE}-h^{J} event.
  - Estimate the combinatorial h^{UE}-h^{UE} pairs using an unbiased event having similar multiplicity.



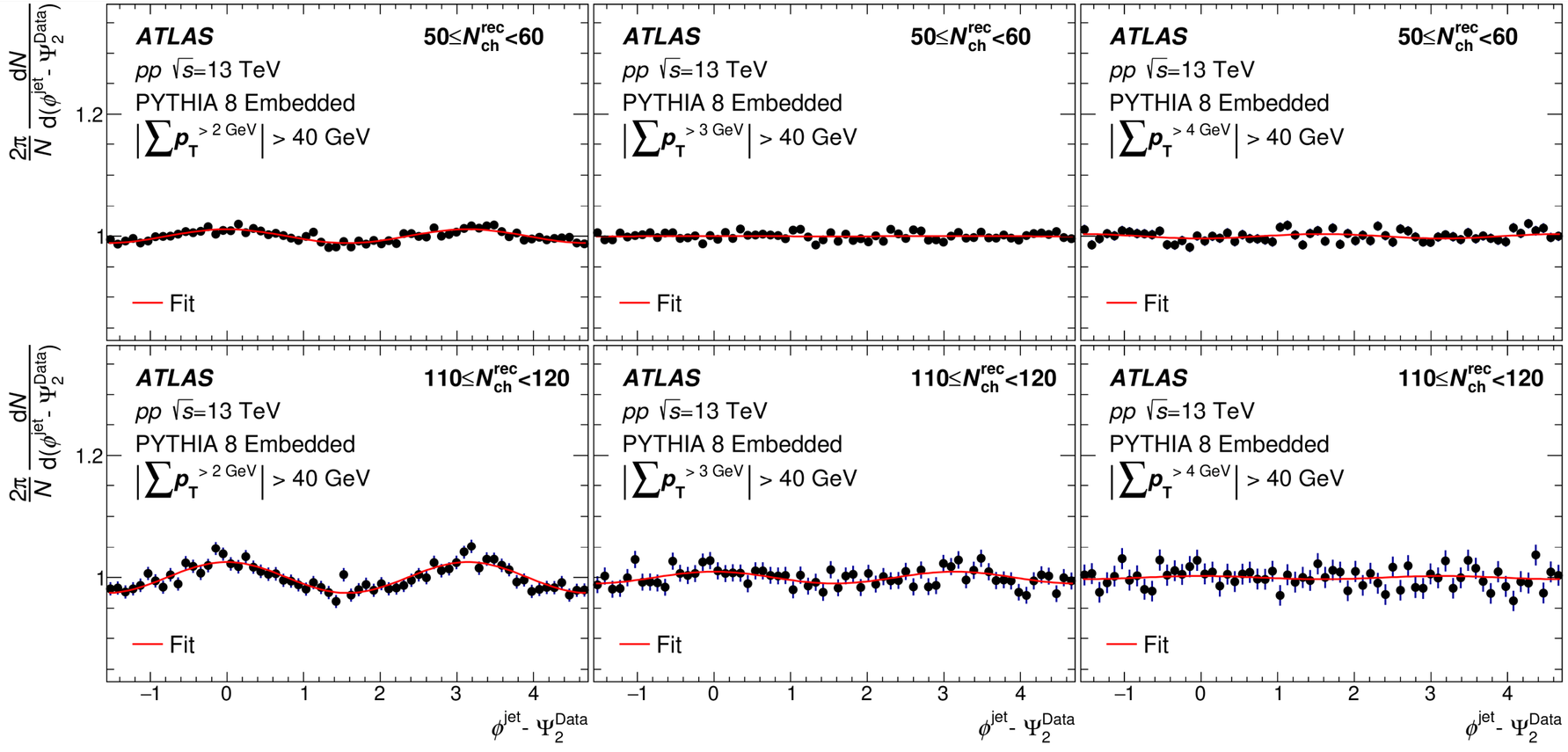


Bias due to UE modulation



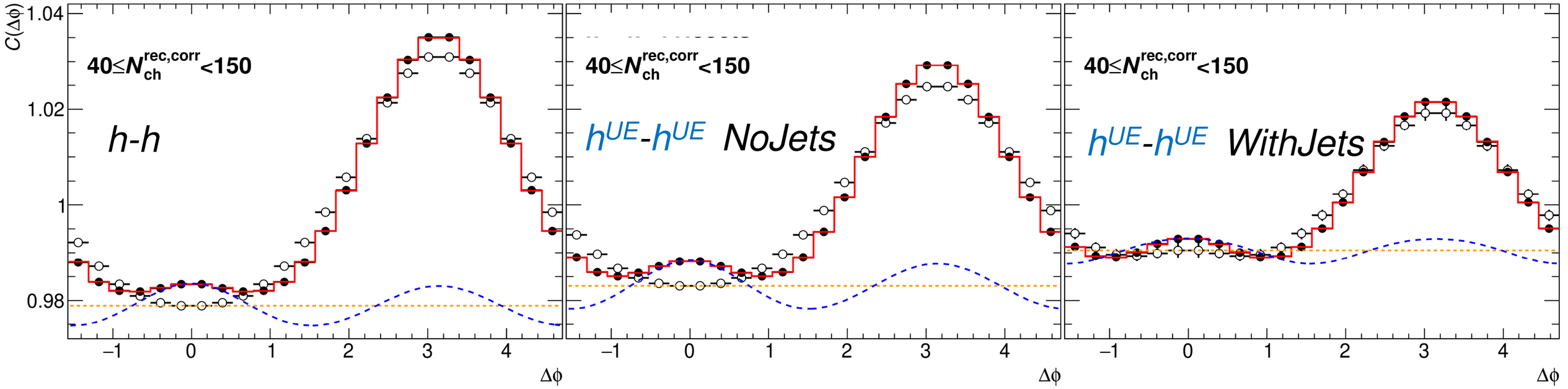
- More likely to reconstruct jets where UE is larger
- A Pythia study demonstrates this bias.
  - PYTHIA jets embedded into data events
  - PYTHIA jet more likely to be reconstructed when aligned with Ψ_2 orientation,
- Effect larger when UE multiplicity is larger!
- Cannot be removed by increasing p_T threshold on jet.
- Need alternate grooming procedure

Grooming the Jets



- Limit jet constituents to p_{T}-range where contributions from UE is negligible.
  - Tried ranges of 2-5 GeV
- Increasing p_{T}-threshold reduces bias in PYTHIA study
- p_{T}-threshold of 4 GeV removes bias even at the highest multiplicities.
- Jets in this study therefore constructed only clustering p_{T}>4 GeV constituents.

Two-particle correlations : h^{UE}-h^{UE}



- 2PC for *h-h* (left), h^{UE}-h^{UE} *NoJets* (middle), h^{UE}-h^{UE} *WithJets* (right)
- Charged particle multiplicity is measured excluding jet constituents
  - Ensure the event activity is not biased by the presence of jets
  - Only reflects the soft multiplicity in the event
- Template-fit is used to extract v_2
- Near-side ridges are observed in h^{UE}-h^{UE}

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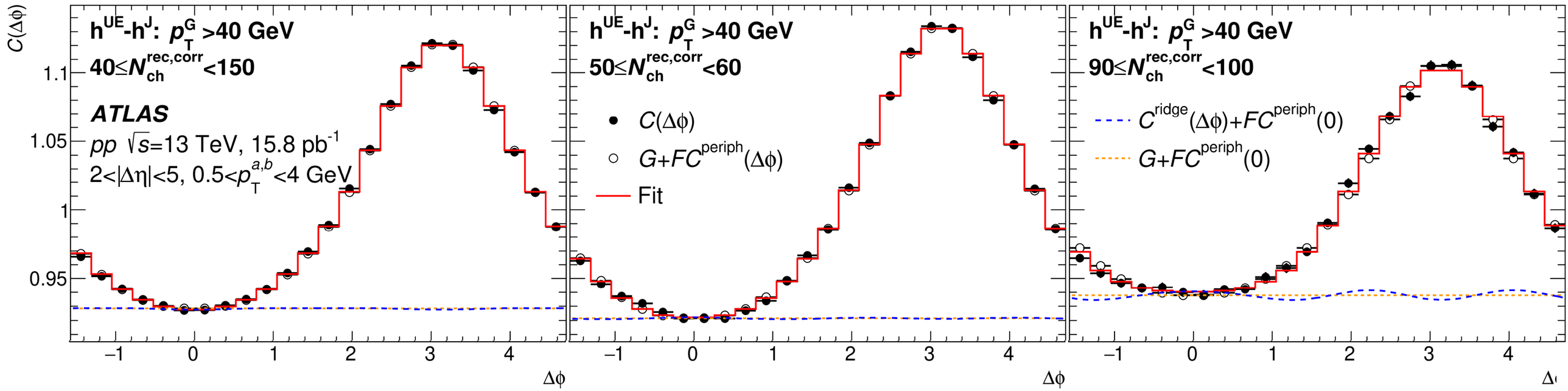
Two-particle correlations : h^{UE}-h^{J}



- h^{UE}-h^{J} 2PC for different multiplicity bins
- No ridge is observed in for any multiplicity interval!
- At face value indicates the ridge is not related to Jets/hard processes

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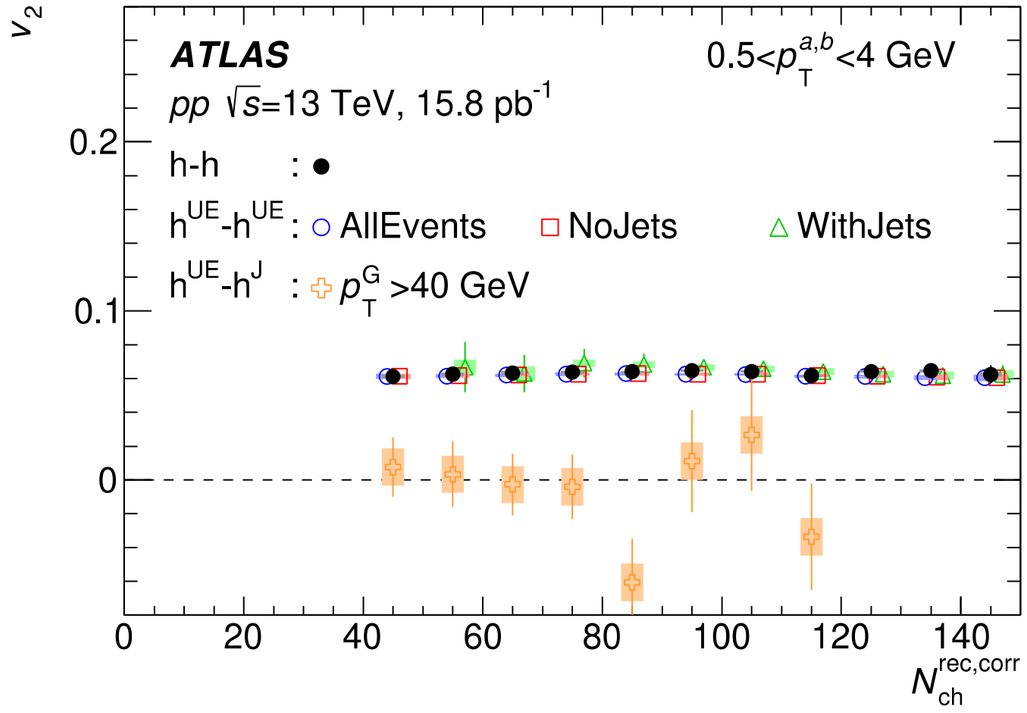
v_2 : comparison between cases



- The v_2 values are observed to vary weakly with multiplicity,
  - v_2 values for the h^{UE}-h^{UE} correlations: *NoJets*, *WithJets* and *All Events* are identical
  - Removing particles associated with jet has negligible impact on v_2
  - Presence/absence of Jets in events does not impact the v_2
- h^{UE}-h^{J} v_2 consistent with zero within uncertainties
  - Ridge is not related to jets!

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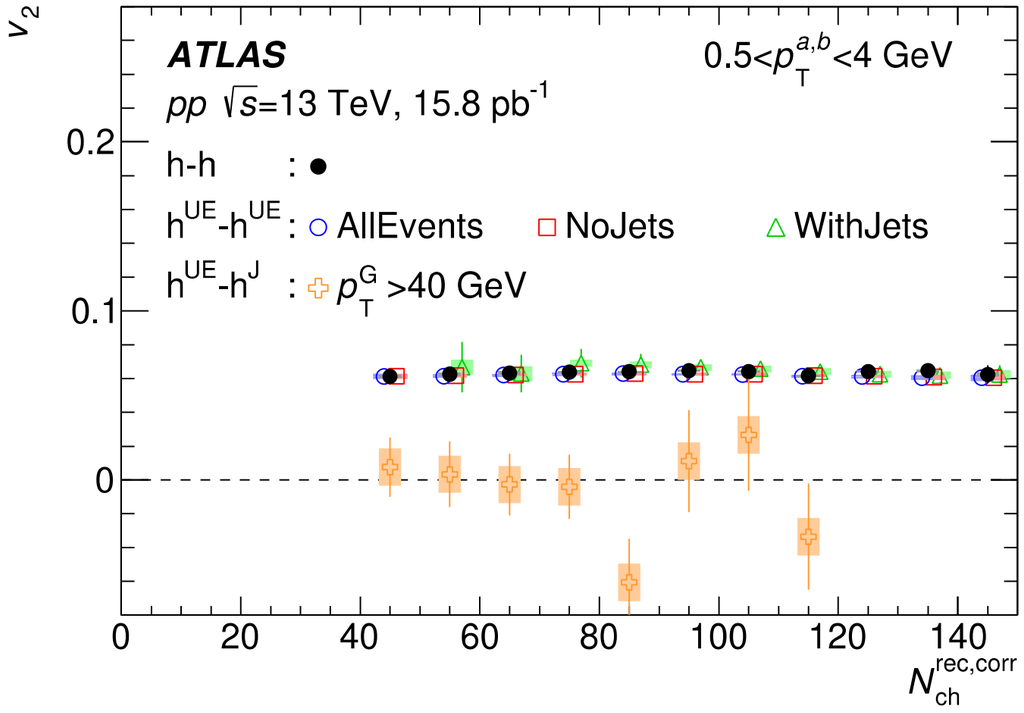

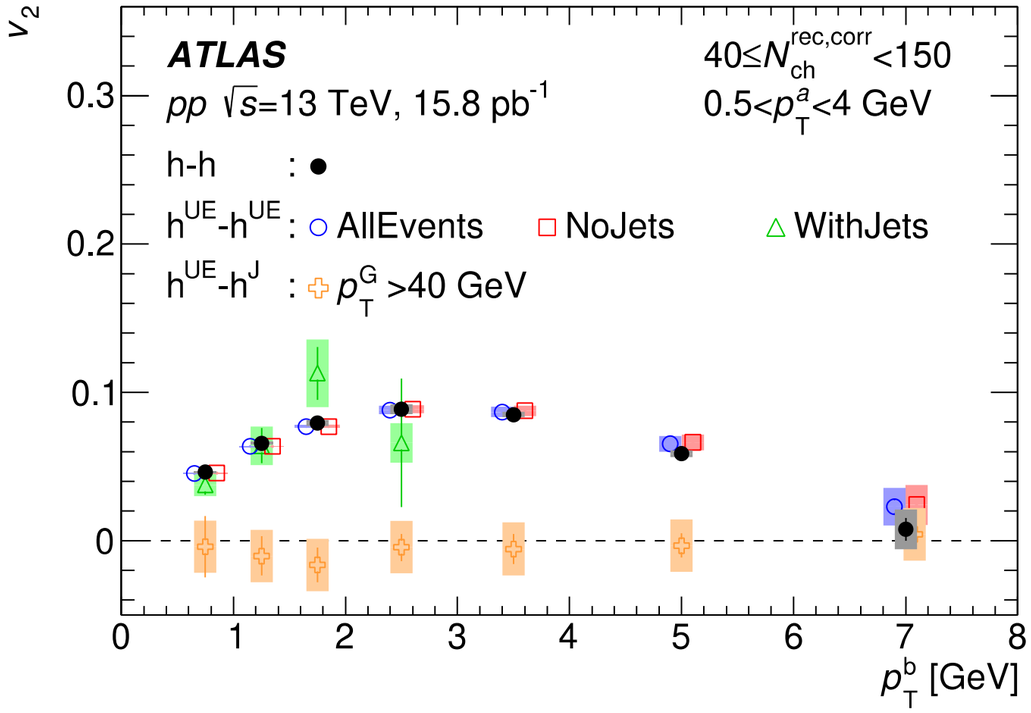

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  - Removing particles associated with jet has negligible impact on v_2
  - Presence/absence of Jets does in events not impact the v_2
- *h^{UE}-h^{J}* v_2 consistent with zero within uncertainties
  - Ridge is not related to jets!
  - Both as function of multiplicity and p_T

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Summary

- Absence or presence of jets in *pp* collision does not impact v_2
  - h^{UE}-h^{UE} Correlations are identical in events with/without Jets
- UE modulation affects jet energy even in *pp* collisions
  - Used a groomed p_T to account for this effect
- Jet fragments do not exhibit correlations with UE particles
  - h^{UE}-h^{J} v_2 consistent with zero
  - Hard scattering and soft collectivity unrelated in *pp* collisions
- Effect in contrast with that in A+A and *p*+A collisions
  - A+A collisions: Jet-UE correlations from path-length dependent quenching

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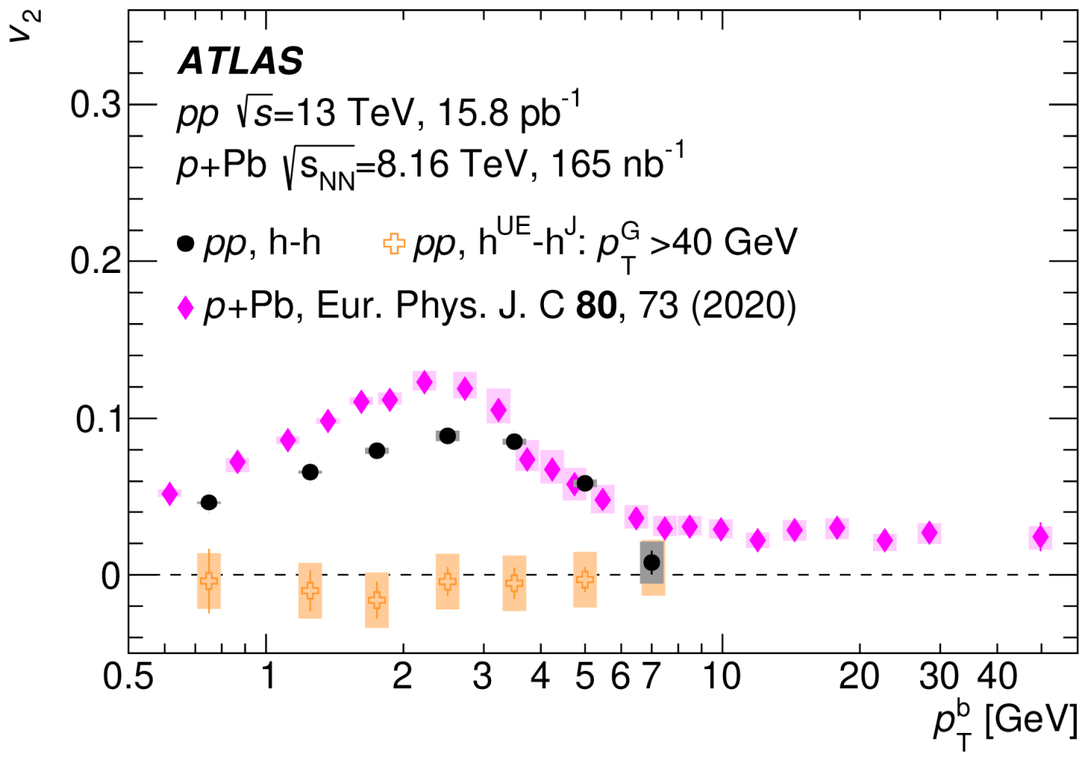
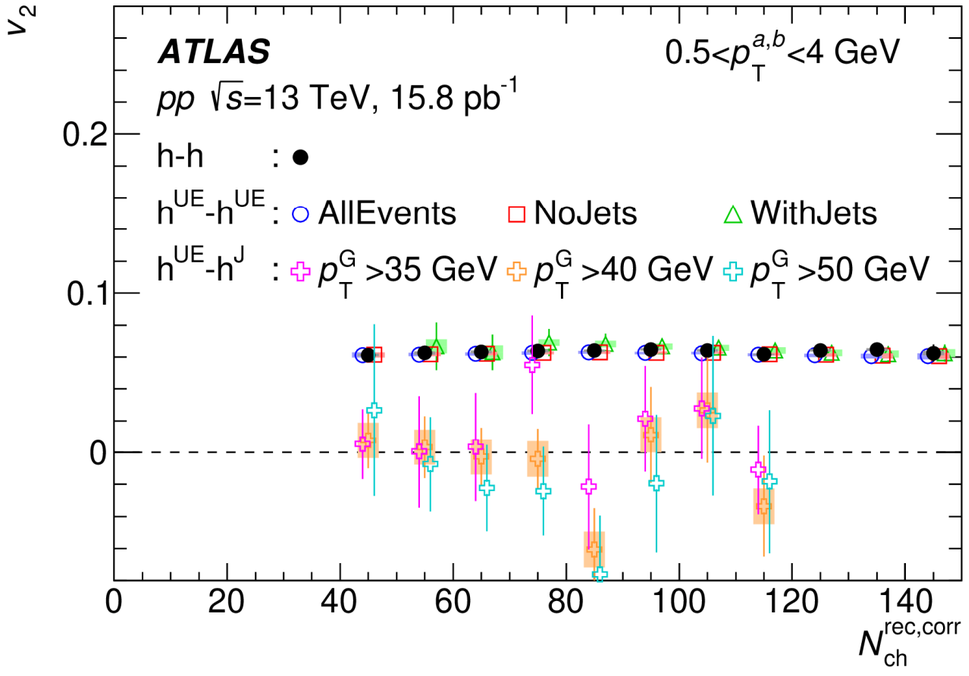
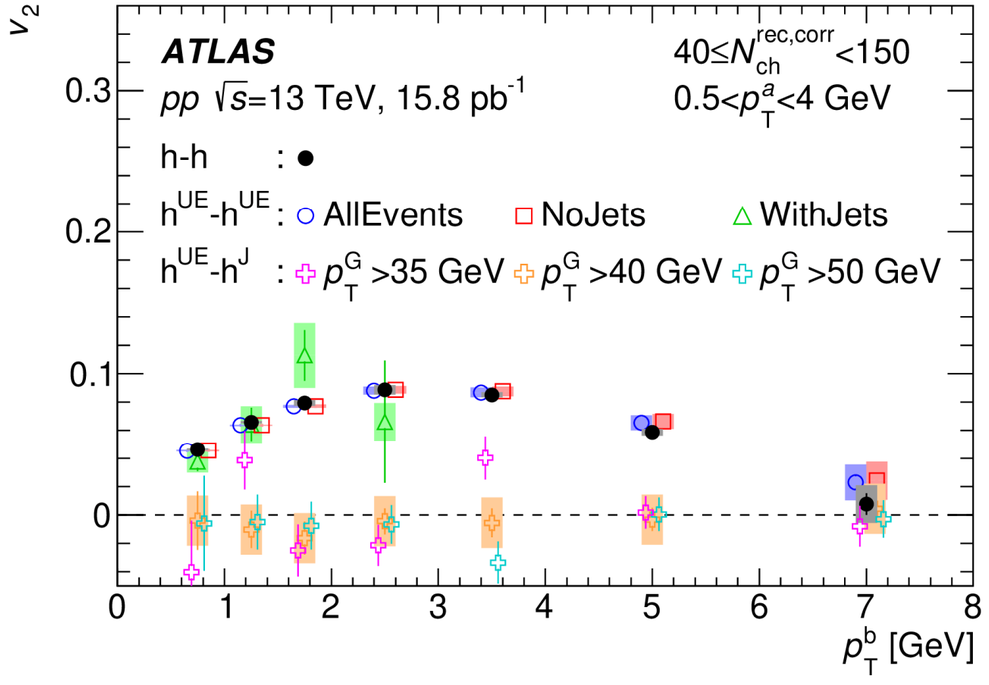


- Effect in contrast with that in A+A and *p*+A collisions
  - A+A collisions: Jet-UE correlations from path-length dependent quenching
  - *p*+A collisions: see ~2% v_2 at high- p_T

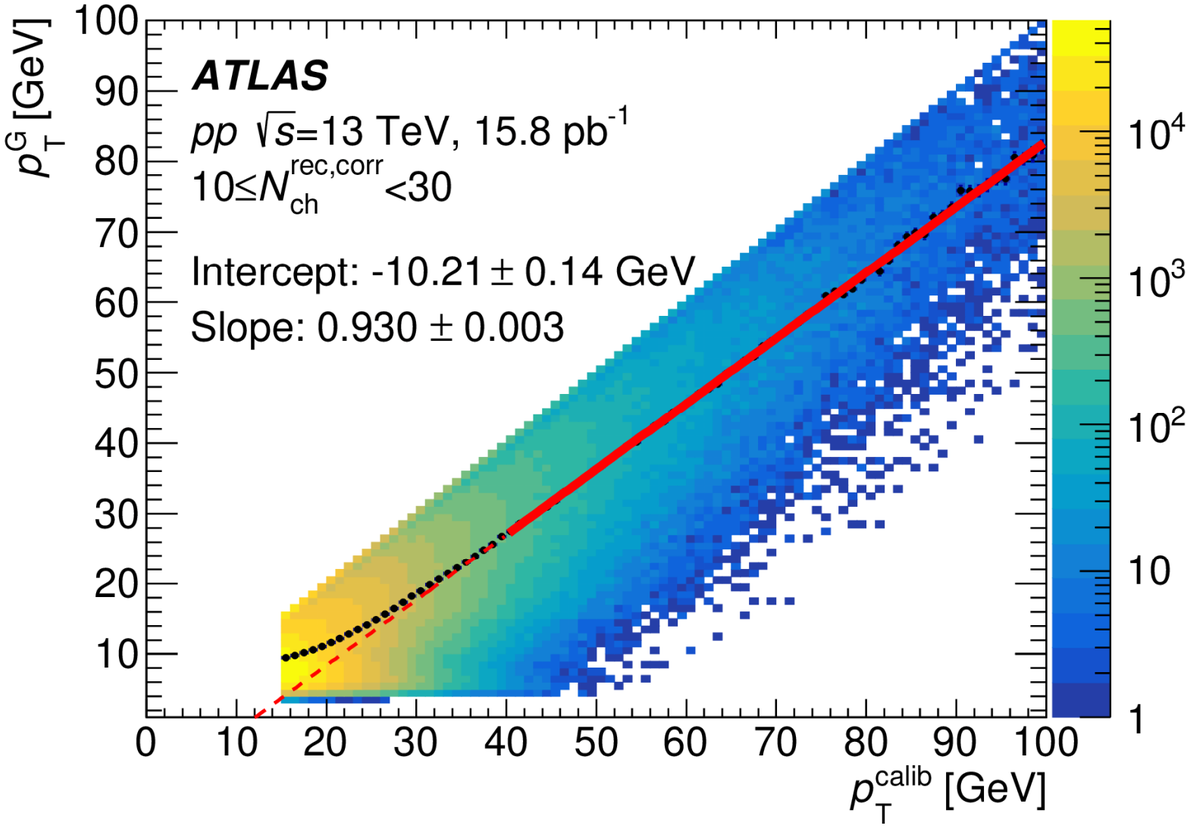
Backups

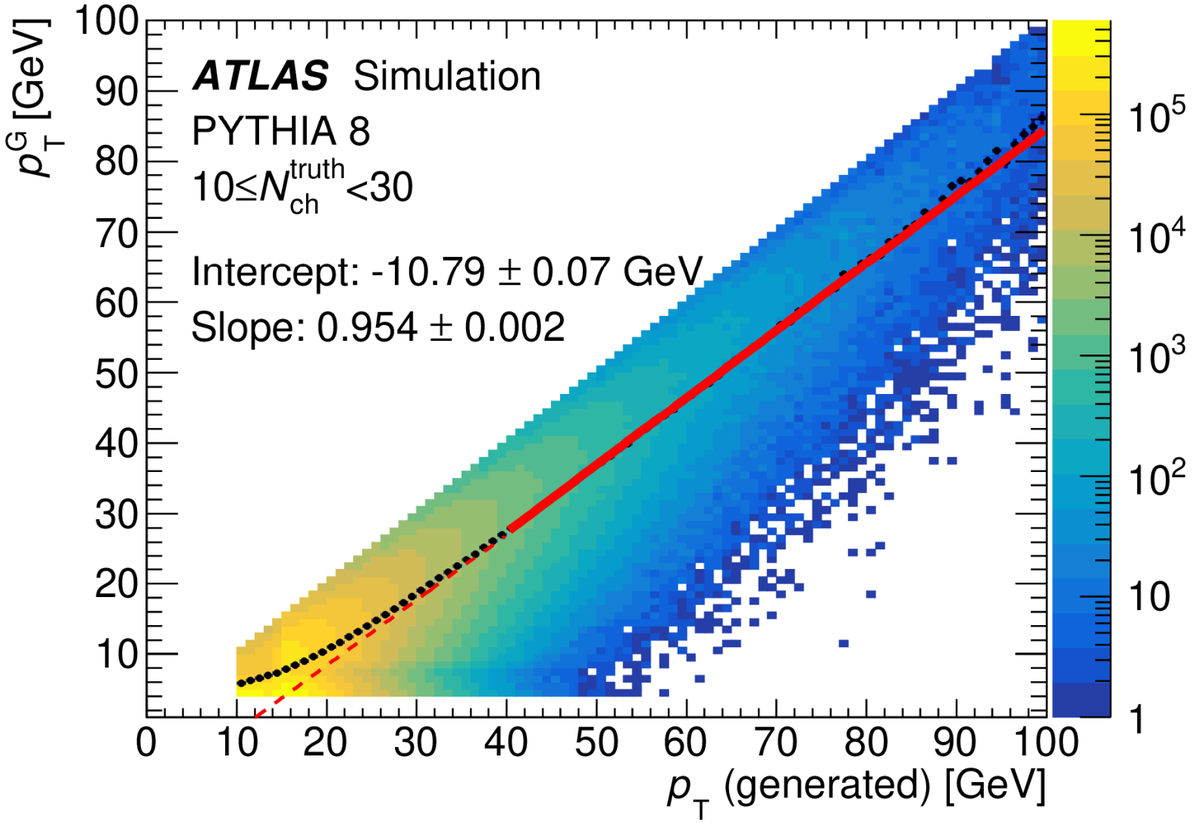
v_2 : Dependence on jet-p_T cut





Relationship between groomed and calibrated p_T





- Comparison of $p_{\mathrm{T}}^{\mathrm{G}}$ to original jet p_{T} in data (left) and PYTHIA 8 (right)
- Low multiplicity events are used as UE bias is negligible
- Fit coefficients are similar between data and MC

Multiplicity distributions