Recent ATLAS measurements of correlations in small systems

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ATLAS-CONF-2020-018
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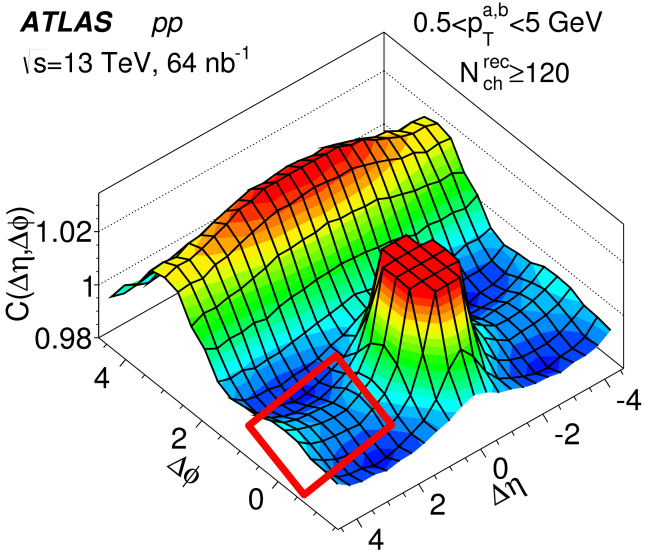
The ridge in *pp* collisions



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 an artifact of semi-hard processes?
- If latter then actively selecting/rejecting events with semi-hard processes (low-p_T jets) should enhance/weaken the ridge.

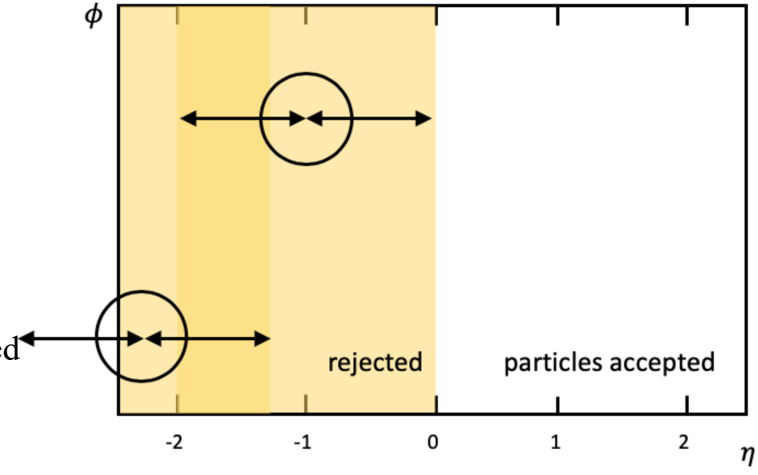
Event classes

- *WithJet*: Analysis performed on events that have a jet with p_T>10 GeV, but with tracks within $|\eta| \leq 1$ of the jet axis removed. This sample is dominated by events having a hard process

- *NoJet*: Analysis performed on events that do not have a p_T >10 GeV jet. This event sample is dominated by soft processes

- *AllEvents*: Reject tracks within $|\eta| \leq 1$ of any reconstructed jet with p_T >10 GeV. Combination of the *WithJet* and *NoJet* classes.

- *Inclusive*: Standard *pp* ridge analysis: no jet-based selection of events and no rejection of jet-associated tracks



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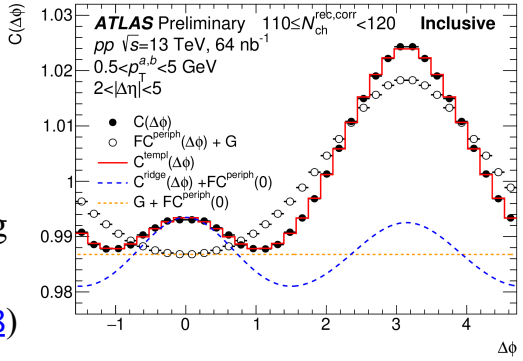
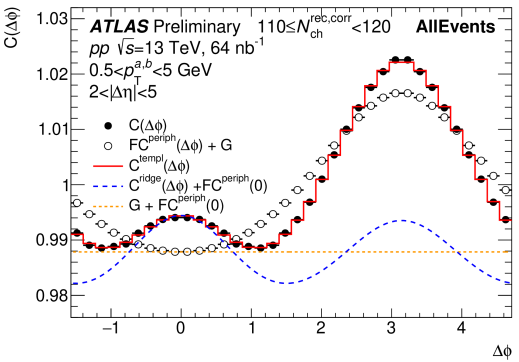
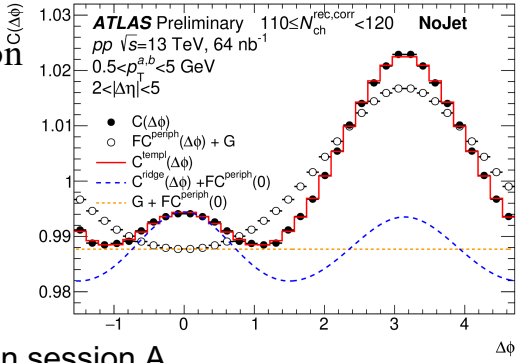
2PCs in different event classes

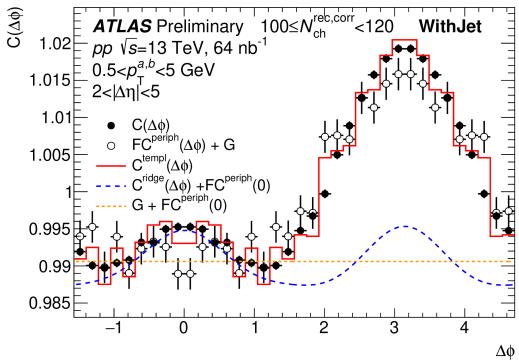
Ridge visible in all event – classes.

The strength of the ridge correlation is extracted using the “Template-fit” method, (Phys. Rev. C 96 (2017) 024908) that yields the Fourier components of the correlation



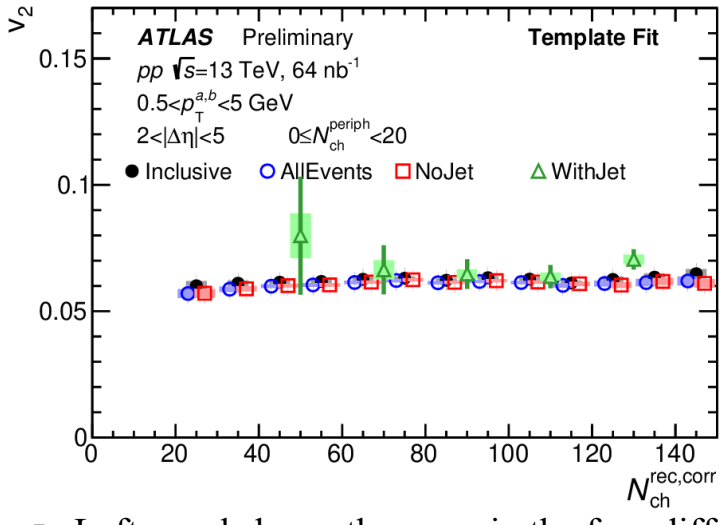


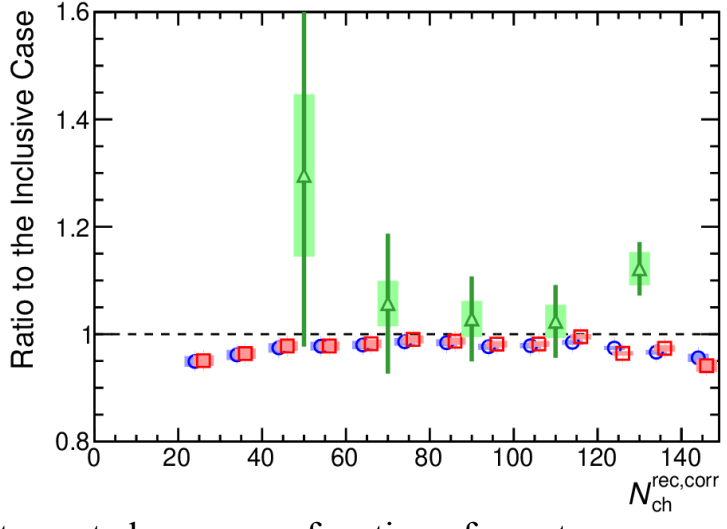




Also see poster by Pengqi Yin in session A

v_2 in different event classes: multiplicity dependence





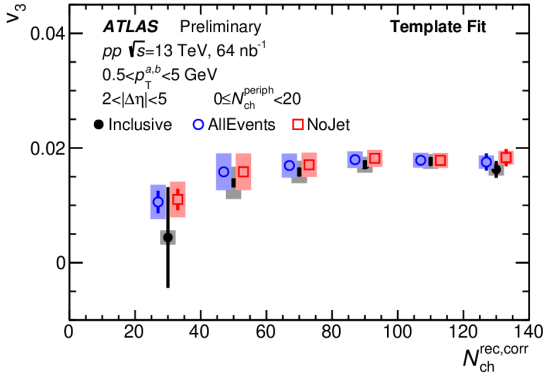
- Left panel shows the *pp* v_2 in the four different event classes, as a function of event multiplicity for the 0.5-5 GeV p_T range.
- The right panel shows the ratio to the *Inclusive* case
- There is only a marginal reduction in the v_2 for the *AllEvents* and *NoJet* cases

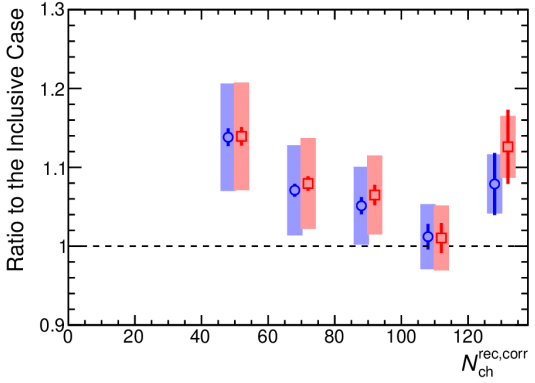
v_3 and v_4 : multiplicity dependence

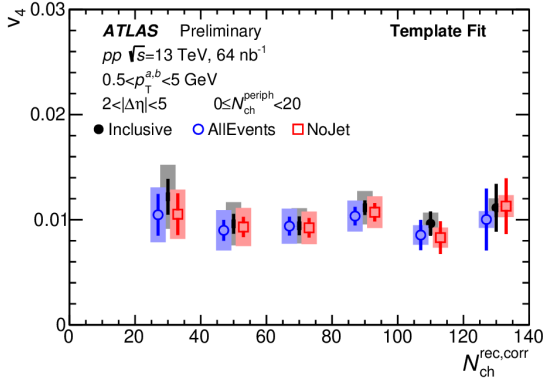
Plots for higher order harmonics v_3 and v_4

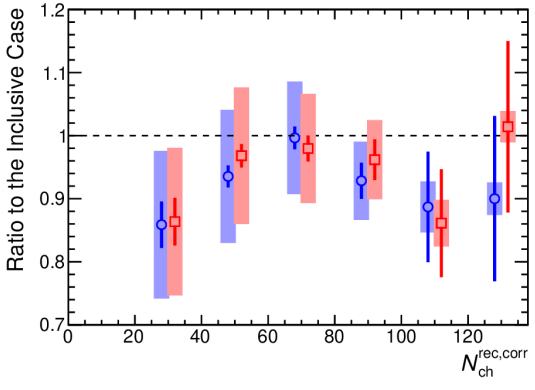
The values for the *NoJet* and *AllEvents* cases are similar to the *inclusive* case as well. ~10% difference (except at low multiplicity), but with significant uncertainties

The *WithJet* case is not shown here due to large statistical uncertainties

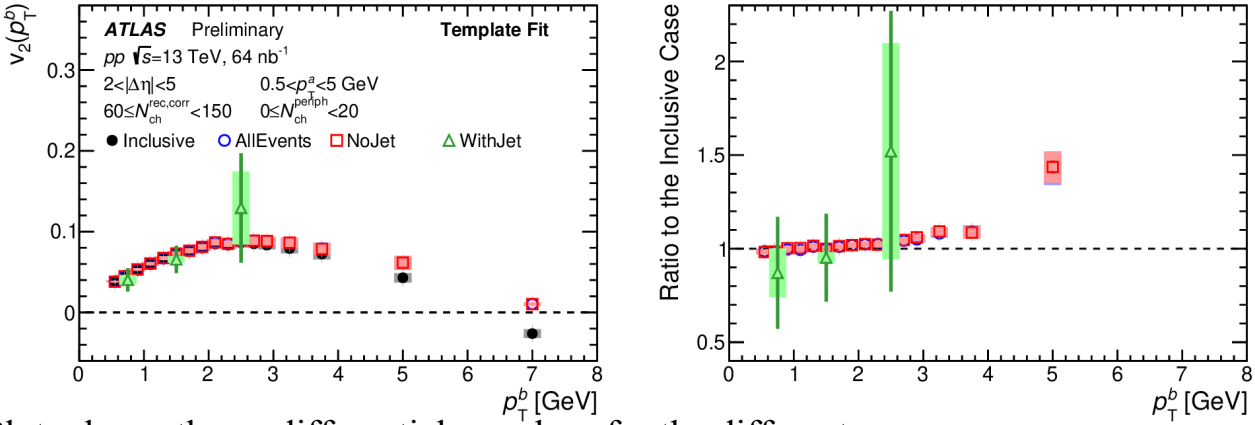








v_2 in different event classes: p_T dependence



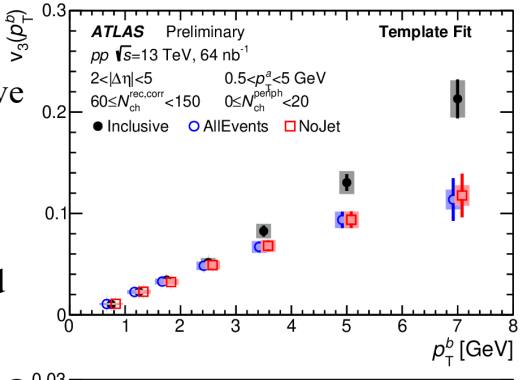
- Plots shows the p_T differential v_2 values for the different cases.
- Up to p_T=3 GeV all the *AllEvents* and *NoJet* cases have values similar to the *inclusive* case.
- The *WithJet* case is also consistent but with much larger statistical uncertainties.
- At higher p_T some significant differences are seen, but the *AllEvents* and *NoJet* cases are consistent with each other.
- Indicates that the *Inclusive* case has some bias at higher p_T, which is reduced when removing tracks associated with jets.

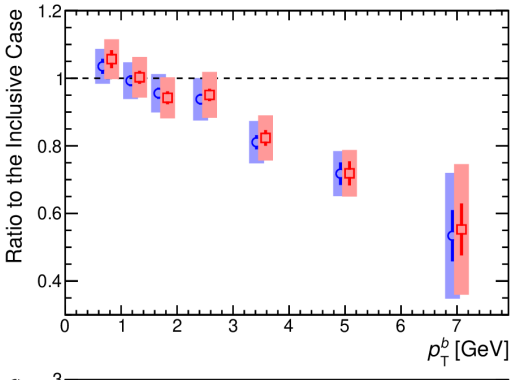
v_3 and v_4 : p_T dependence

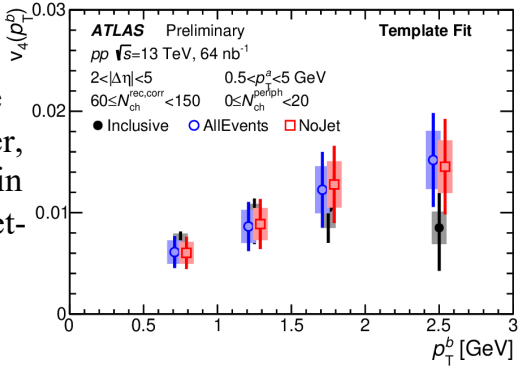
Up to p_T=3 GeV all the *AllEvents* and *NoJet* cases have values similar to the *inclusive* case for v_3 and v_4 as well.

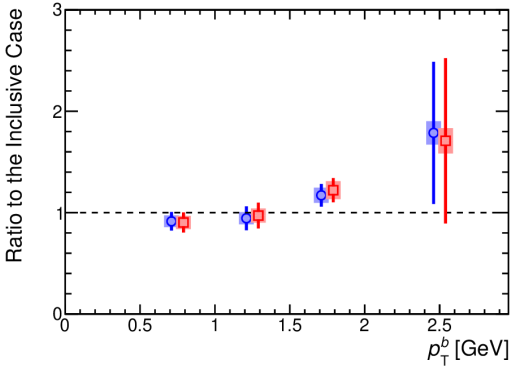
The low-p_T v_n are not affected by presence/absence of jets!

At higher p_T large deviations seen for v_3. The values for the inclusive case are much higher, indicating that the high-p_T v_3 in *inclusive* events arises from jet-bias effects









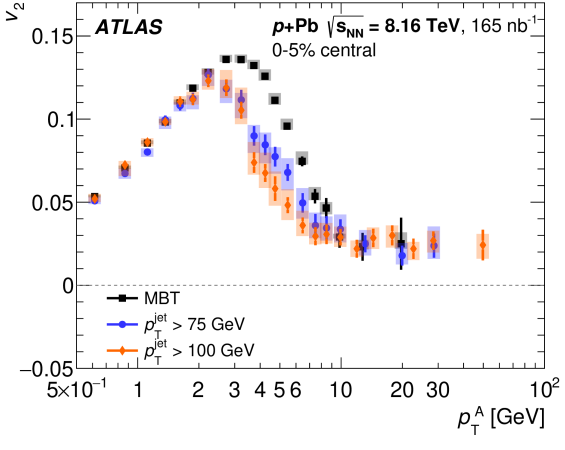
High-p_T v_n in p+Pb

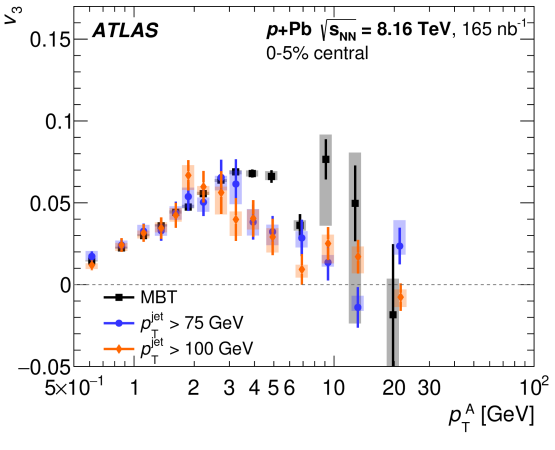
- No suppression of High p_T particles observed in p+Pb collisions

- Three classes of events used:
  - Minimum-bias,
  - Events triggered by 75 GeV jets
  - Events triggered by 100 GeV jets

- For studying the high-p_T v_n in the jet-triggered events, the associated particle in the 2PC is required to be separated $|\eta| > 1$ from any reconstructed jet with p_T>15 GeV.
  - As opposed to the previous slides, where both particles in the 2PC were required to have $|\eta| > 1$ from jets.
  - Requirement ensures that the jets contribute to the *reference* particles but not to the *associated* particles in the 2PC
  - Reduces biases in the correlation measurements from back-to-back jets

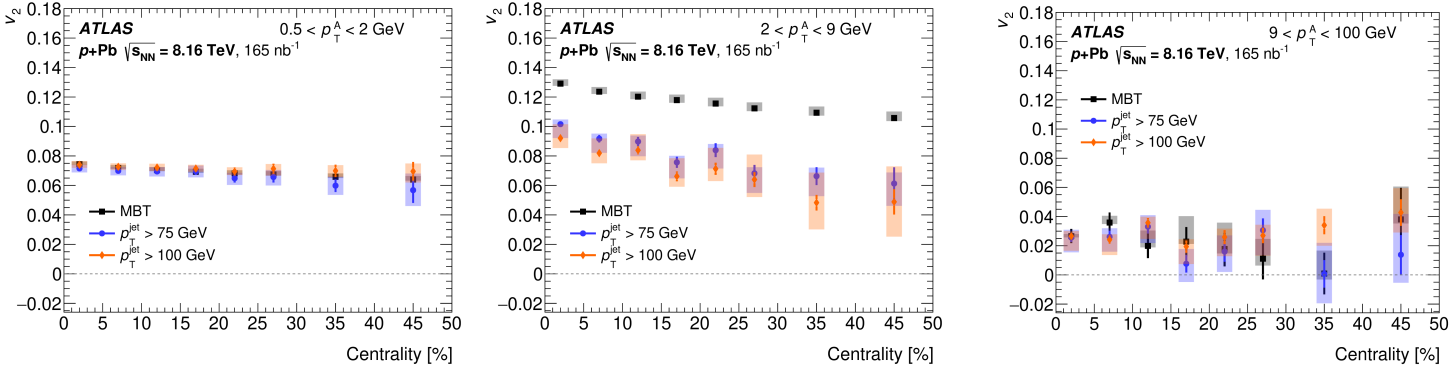
High-p_T v_n in p+Pb





- Plots shows the p_T differential v_2 and v_3 values for the different cases and for 0-5% central events.
- Up to p_T=2 GeV the minimum-bias as well as the jet-triggered events yield consistent v_n
- Between 2-9 GeV, the v_n in jet-triggered events are systematically smaller than the minimum-bias v_n.
- For p_T> 9 GeV v_n from the jet-triggered and minimum-bias events are consistent again.
- Significant v_n observed at high-p_T!

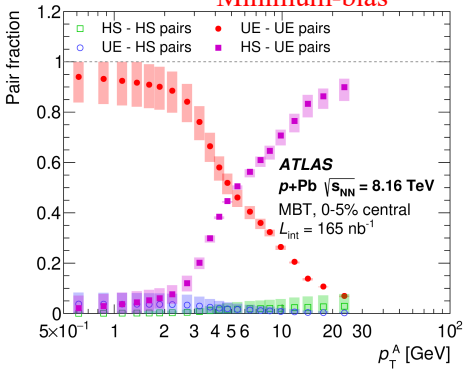
High-p_T v_n in p+Pb : centrality dependence



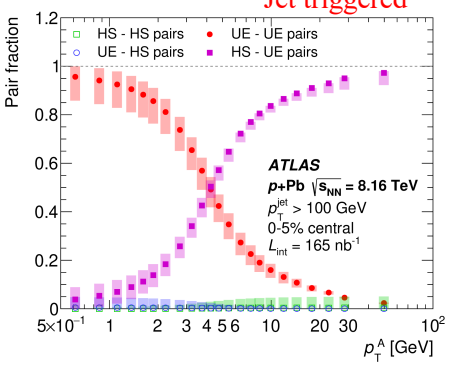
- Plots shows the v_2 as a function of centrality for three p_T intervals:
  - $0.5<p_T<2$ GeV : the minimum-bias as well as the jet triggered events yield identical v_2.
  - $2<p_T<9$ GeV : the jet triggered v_n values are systematically smaller than the minimum-bias v_2.
  - $p_T>9$ GeV v_n : from the jet-triggered and minimum-bias events are again consistent (and non-zero)
- Same trends that were seen in the p_T dependence
- The v_2 values in each event-class decrease slightly from central to peripheral events.

Understanding the difference

Minimum-bias

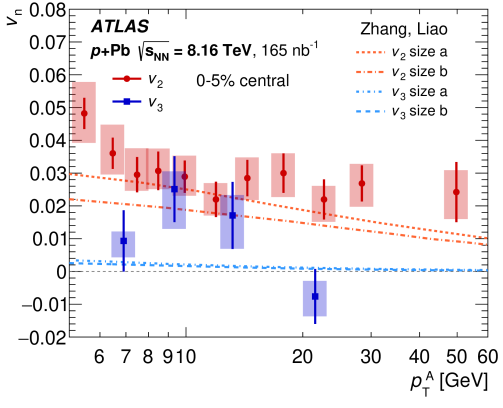


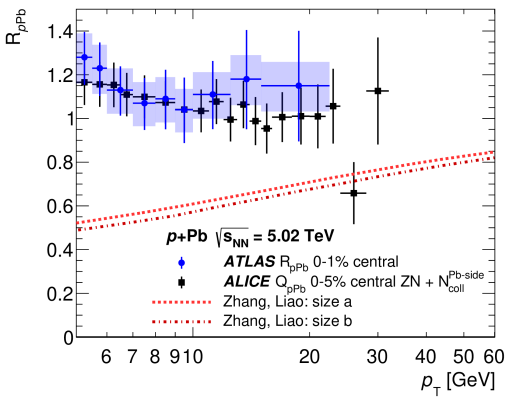
Jet triggered



- Pairs in the 2PC can arise from many combinations
  - UnderlyingEvent-UnderlyingEvent (UE-UE)
  - HardScattering-UnderlyingEvent (HS-UE)
  - HardScattering-HardScattering (HS-HS)
- Low-p_T pairs in both minimum-bias and jet triggered cases are dominated by UE-UE pairs, leading to similar v_2.
- At high p_T the pairs are dominated by pairs HS-UE pairs, again leading to similar v_2.
- But in the transition region, the jet triggered and minimum-bias samples have a different contribution from the various types of pairs.
  - Minimum-bias events have a larger fraction of UE-UE pairs over this range

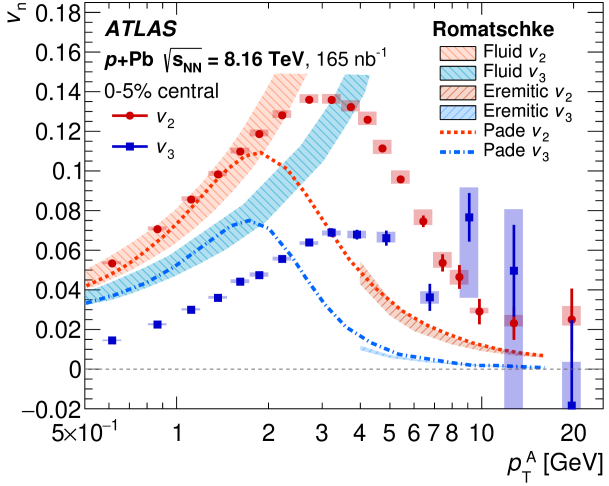
High-p_T v_n in p+Pb





- Quenching based models have trouble simultaneously reproducing the high-p_T v_n and the R_{pPb}
- Shown here are calculations from Zhang & Liao (arXiv:1311.5463)
- They reproduce the $v_n(p_T)$ reasonably well but show significant disagreement for the R_{pPb}

High-p_T v_n in p+Pb



- A kinetic theory based calculation (Romatschke & Romatschke arXiv:1712.05815) qualitatively reproduces the low-p_T v_2.
- But significantly over predicts the v_3
- It qualitatively reproduces the high-p_T trends as well,
  - But is expected to contradict the measured $R_{p\mathrm{Pb}}$

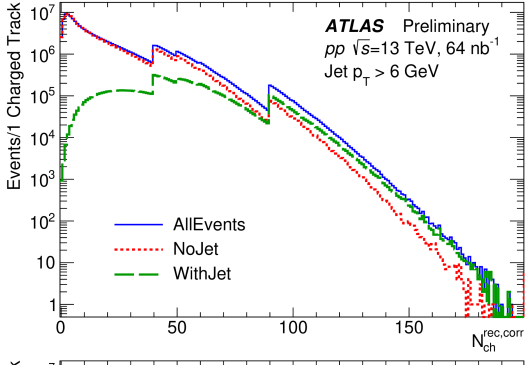
Summary

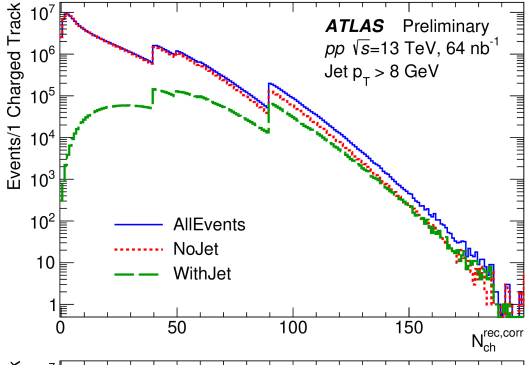
- Measured v_2-v_4 in *pp* collisions when rejecting tracks in the vicinity of jets
  - The p_T-integrated v_2 only decreases marginally (2-5%) when rejecting the jet associated tracks
  - Some of this change comes from softening of the p_T spectra when rejecting jets
  - Some comes from improvement in the template-fit procedure
- For the p_T differential measurements :
  - No significant change for p_T<3 GeV: low-p_T v_n not affected by presence/absence of jets.
  - Larger differences seen at higher p_T: difference quite large for v_3.

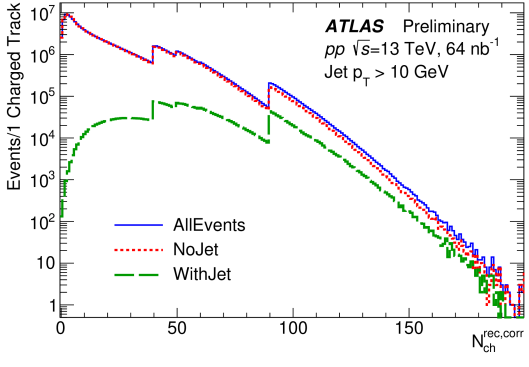
- Measured the v_n in *p*+Pb events up to p_T of 50 GeV
  - significant v_n is observed up to 50 GeV
- Measurements performed in minimum-bias events, as well as events triggered by high-p_T jets.
- The v_n for the jet-triggered and minimum-bias events are
  - Consistent over 0.5-2 GeV
  - Smaller for the jet-triggered events over 2-9 GeV
  - Consistent again for p_T>9 GeV
- Trends in R_{pPb} and $v_n(p_T)$ not simultaneously reproduced by model calculations

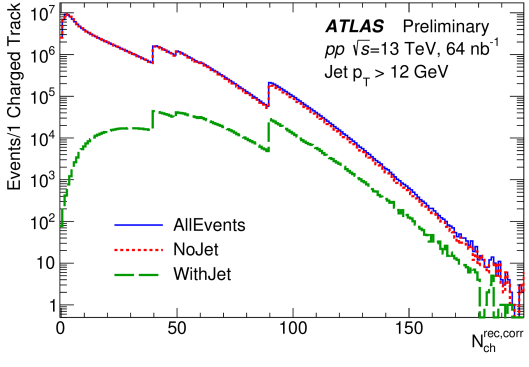
Backups

Events in each class

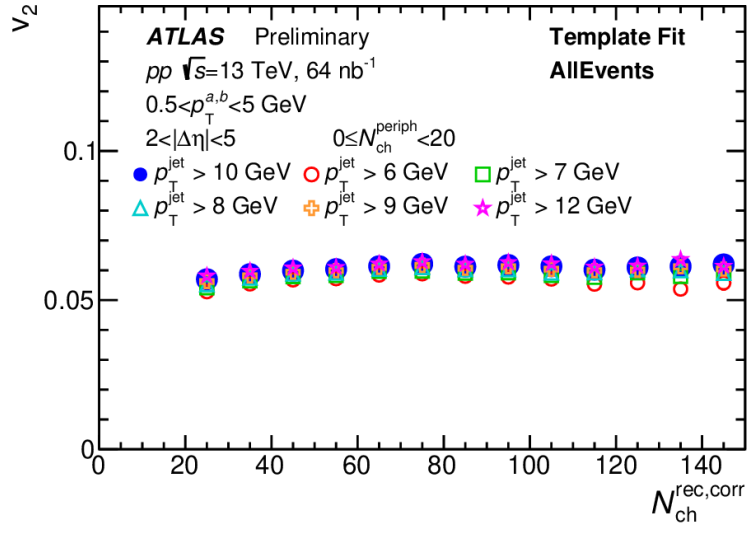


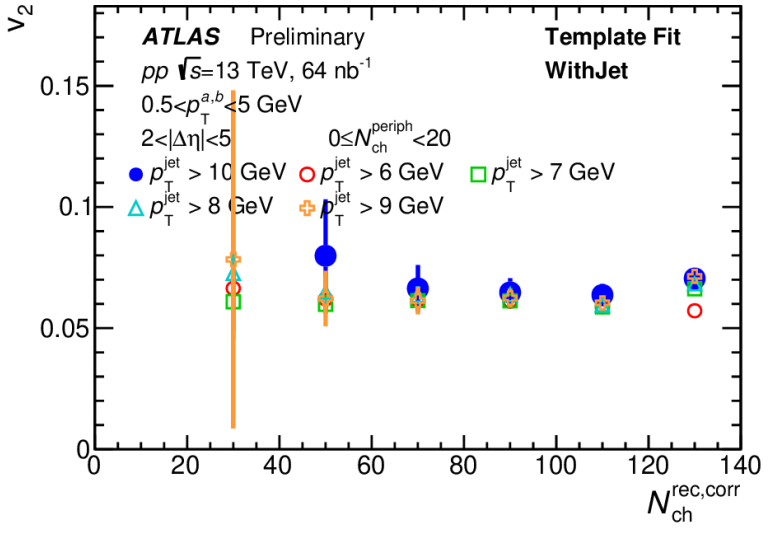






Dependence on the jet p_T Threshold





High-p_T v_n in p+Pb

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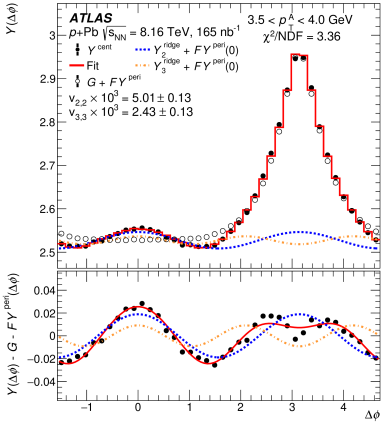
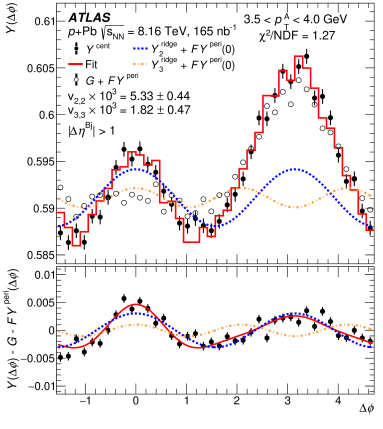


Large away-side peak when not requiring the separation of *associated* particles from jets



Much smaller away-side peak when requiring the separation

Understanding the difference

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- At high p_T the pairs are dominated by pairs HS-UE pairs, again leading to similar v_2.
- But in the transition region, the jet triggered and minimum-bias samples have a different contribution from the various types of pairs.
  - Minimum-bias events have a larger fraction of UE-UE pairs over this range