

Transverse and longitudinal flow fluctuations in Xe+Xe Collisions



Soumya Mohapatra
(Columbia University)

On behalf of the ATLAS Collaboration



Posters:

Pengqi Yin (Flow in Xe+Xe, CD-05)

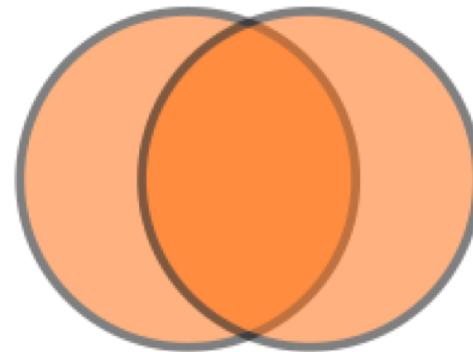
Arabinda Behera (Flow decorrelation in Xe+Xe, CD-04)

CERN-EP-2019-227
ATLAS-CONF-2019-055

Why is a smaller collision system interesting²

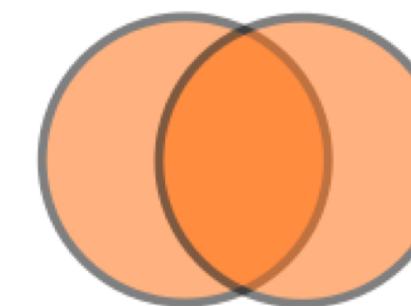
Pb+Pb

A=208, R=7.5 fm



Xe+Xe

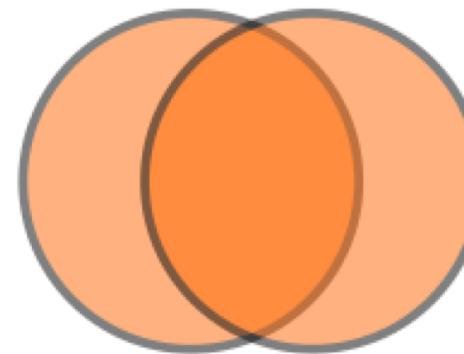
A=129, R=6.4fm



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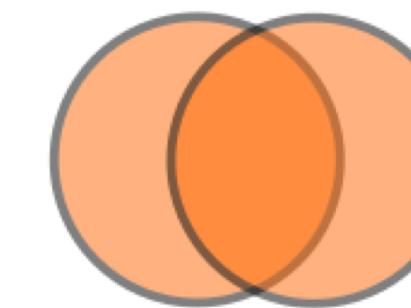
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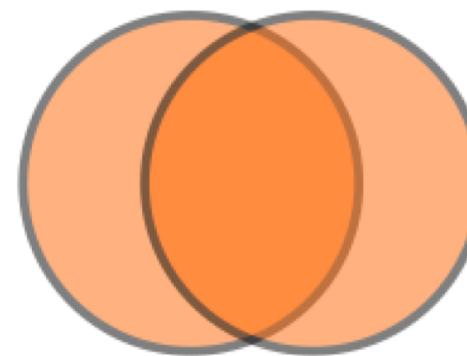
Smooth Geometry
+
Ideal hydrodynamics

Identical v_n

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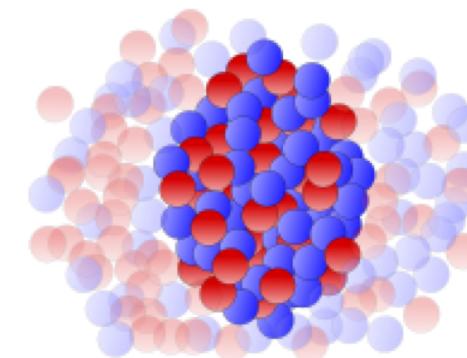
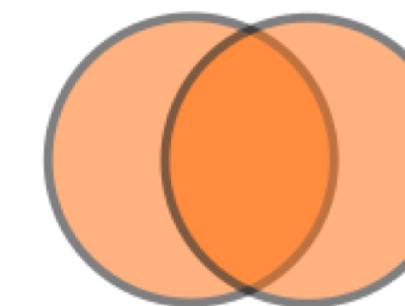
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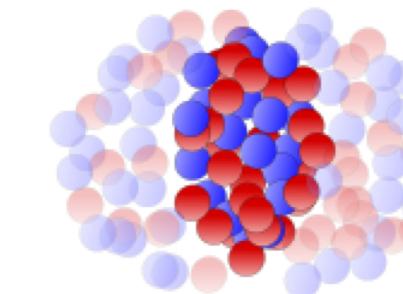


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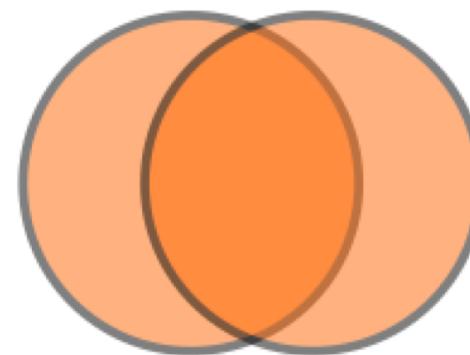
Ideal hydrodynamics

Larger v_n
in Xe+Xe

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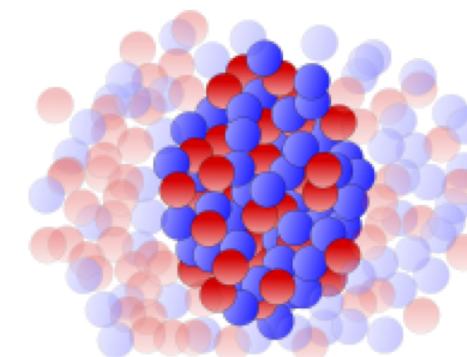
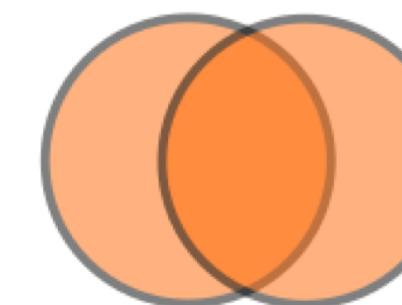
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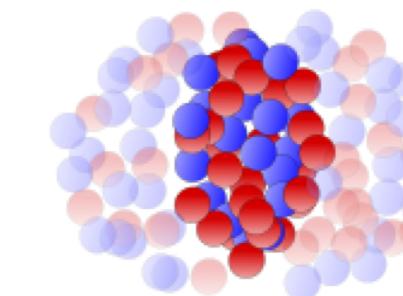


Xe+Xe

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Smooth Geometry
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Identical v_n

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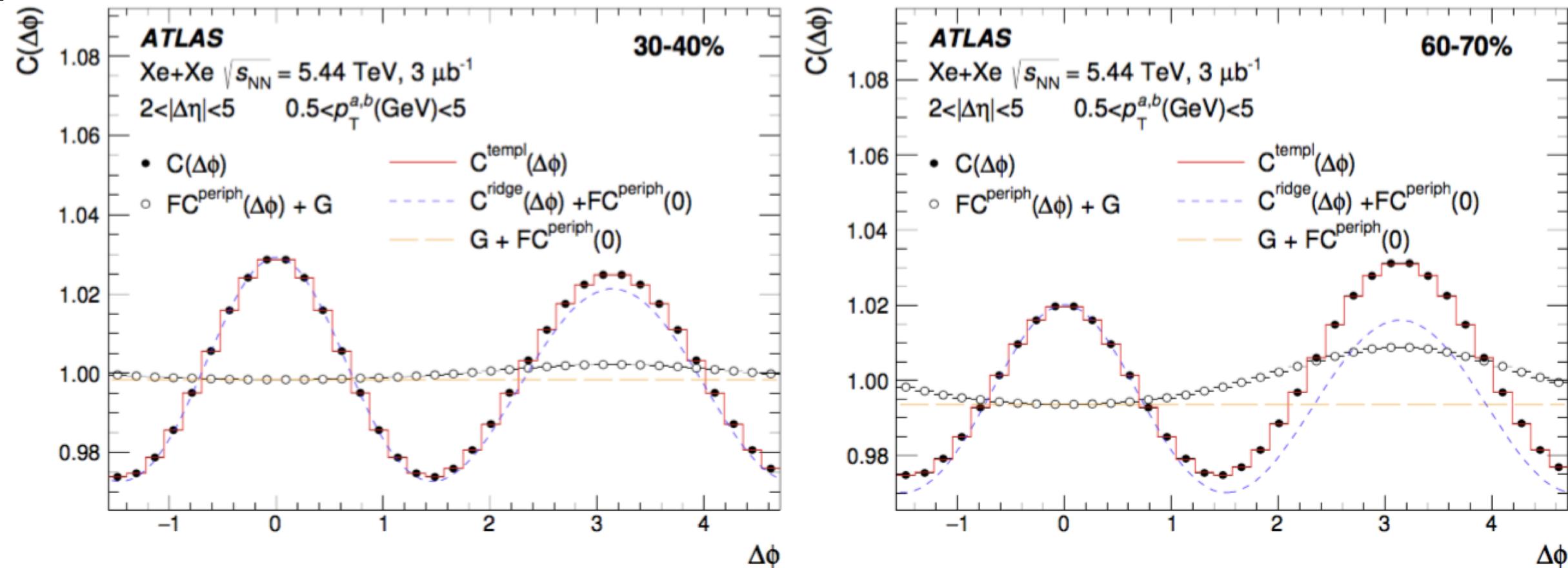
Fluctuating Geometry

+

Viscous hydrodynamics

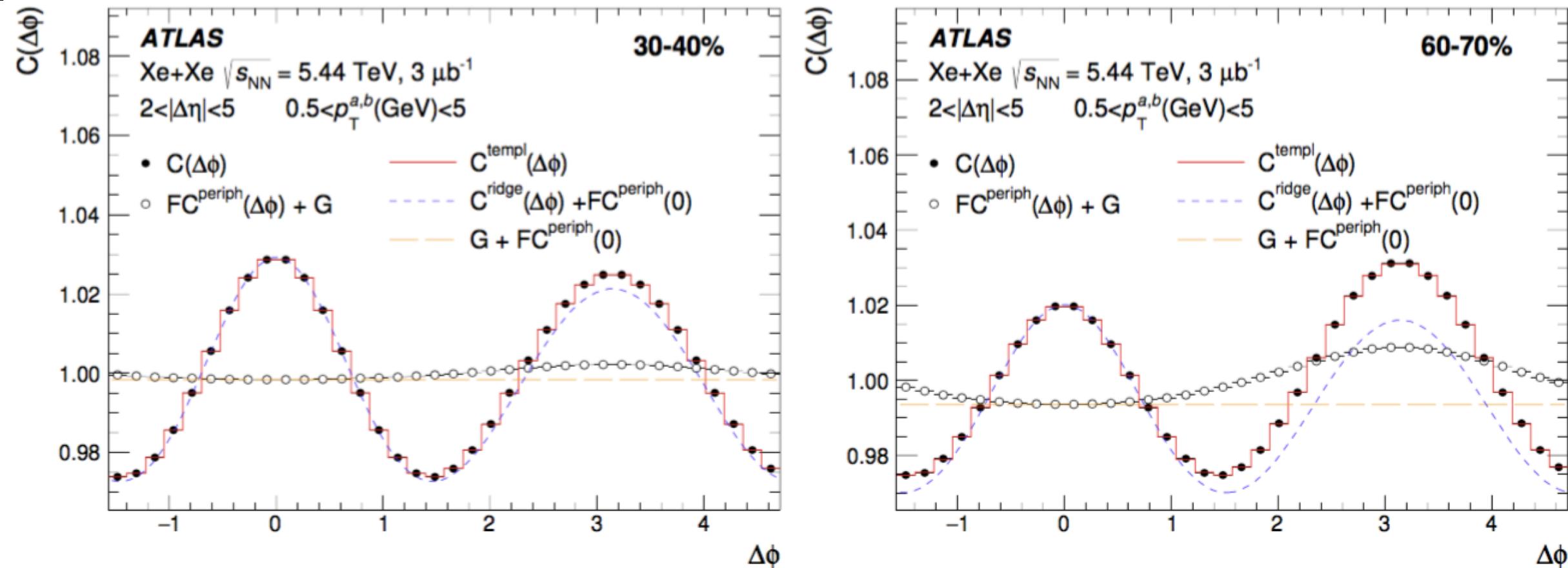


v_n measurement techniques



- v_n -measurements done via:
 - Scalar-product method
 - Two-particle correlations
- Also measured using **template-fit** method
 - Developed to measure flow-like correlations in pp collisions
 - But applicable wherever dijet correlations bias v_n measurements
 - In heavy ion collisions: peripheral collisions and/or at $p_T \gtrsim 4$ GeV
 - More important for the smaller Xe+Xe collisions.

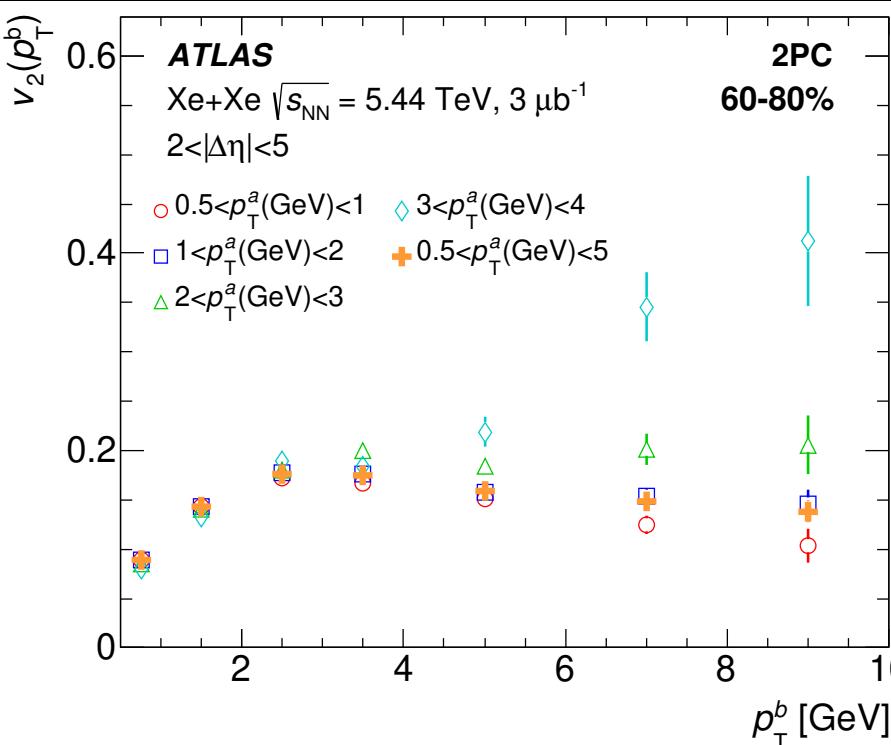
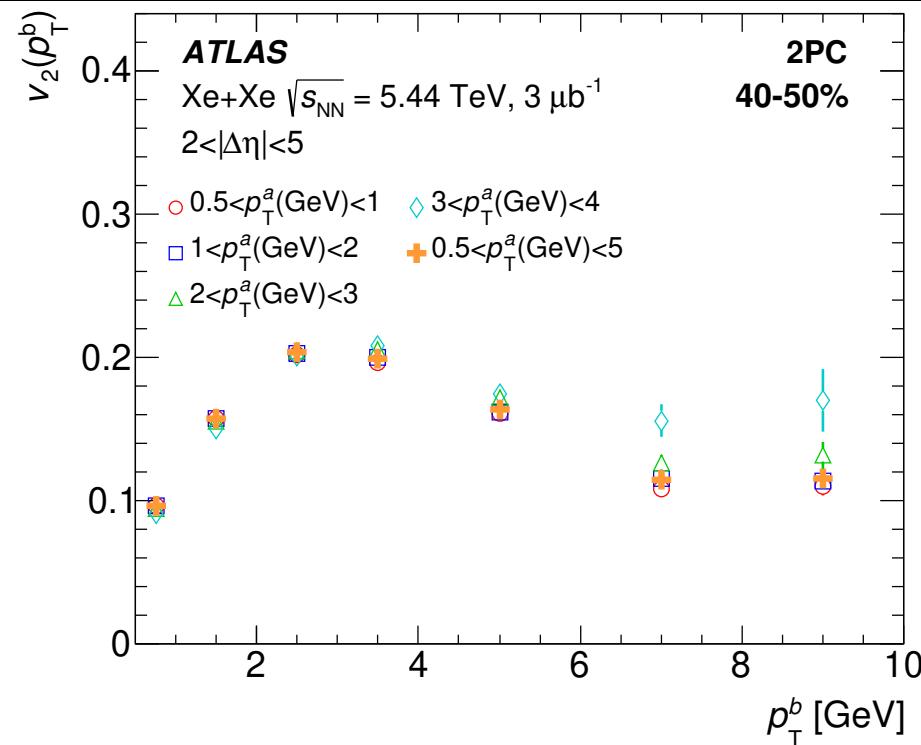
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Two Variations:
With and without ZYAM

Factorization of Fourier coefficients

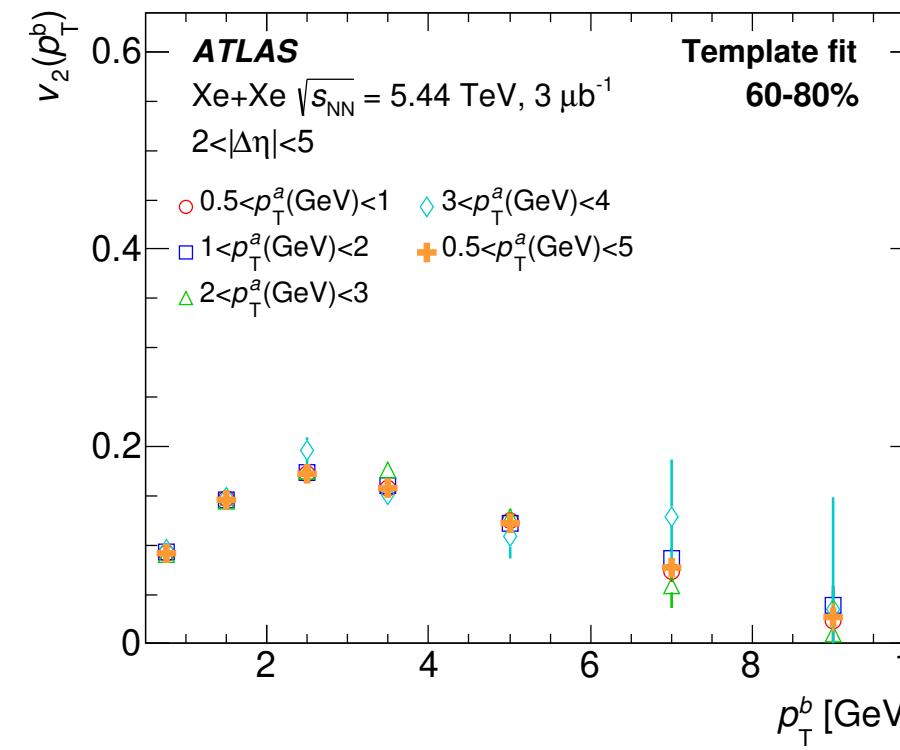
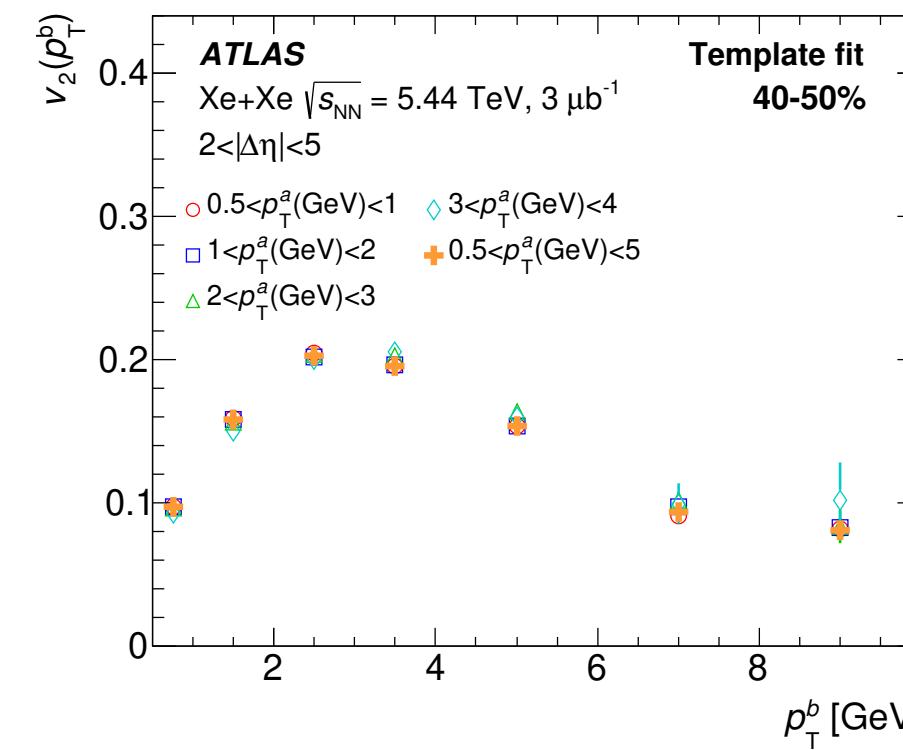
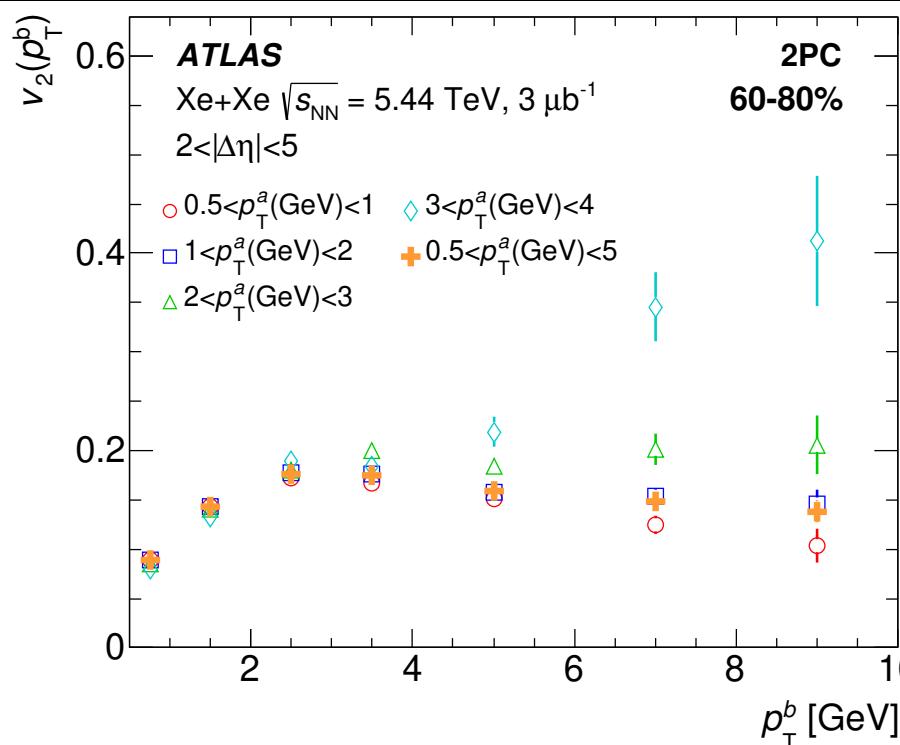
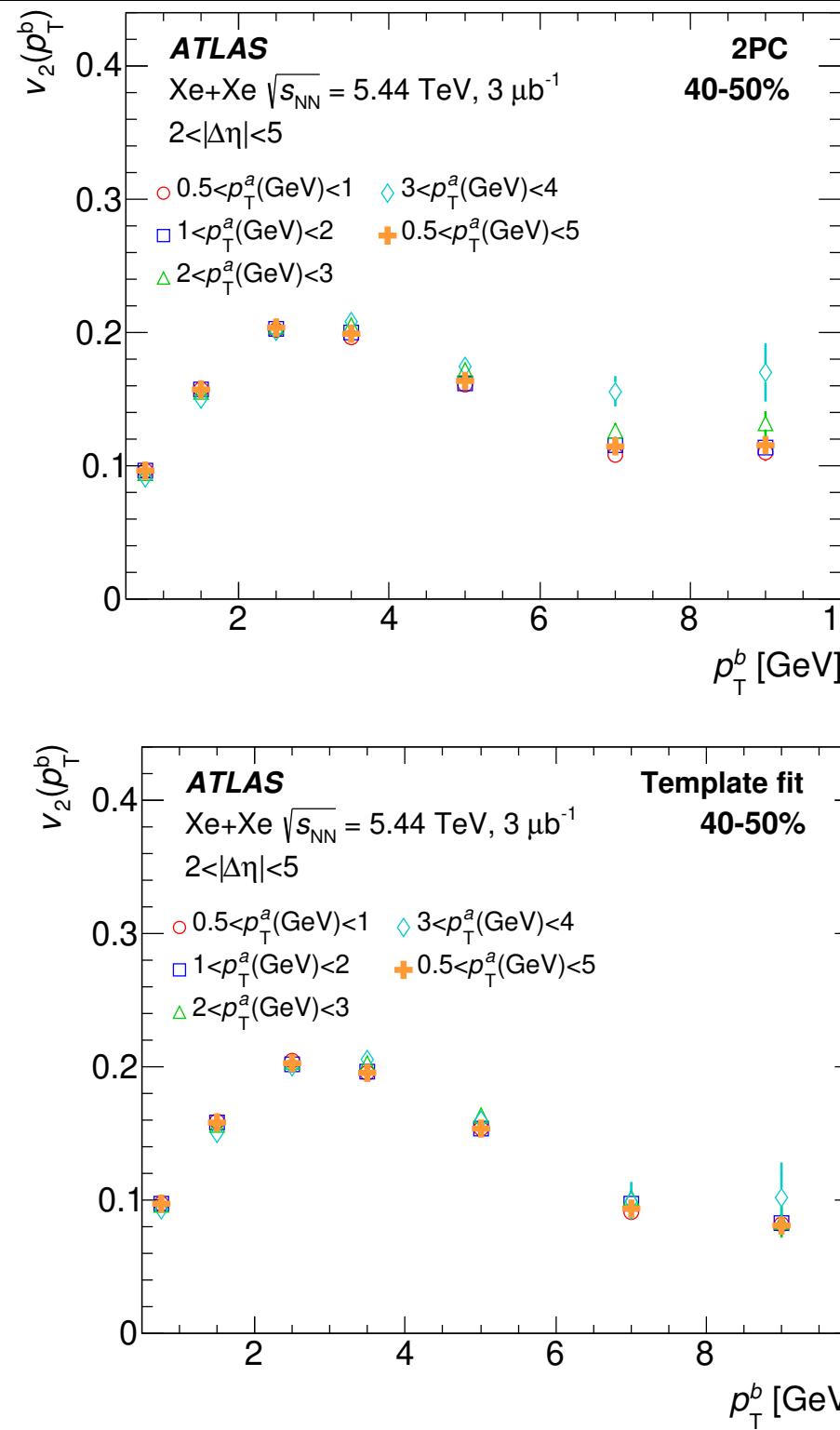


Correlations techniques measure the v_n of particle “*b*” by correlating with particle “*a*”.

The v_n obtained for “*b*” should be independent of the choice of particle “*a*”: called “Factorization”.

OK for 2PC method at low- p_T and in central, mid-central events. Breaks at high- p_T and in peripheral events.

Factorization of Fourier coefficients



Correlations techniques measure the v_n of particle “ b ” by correlating with particle “ a ”.

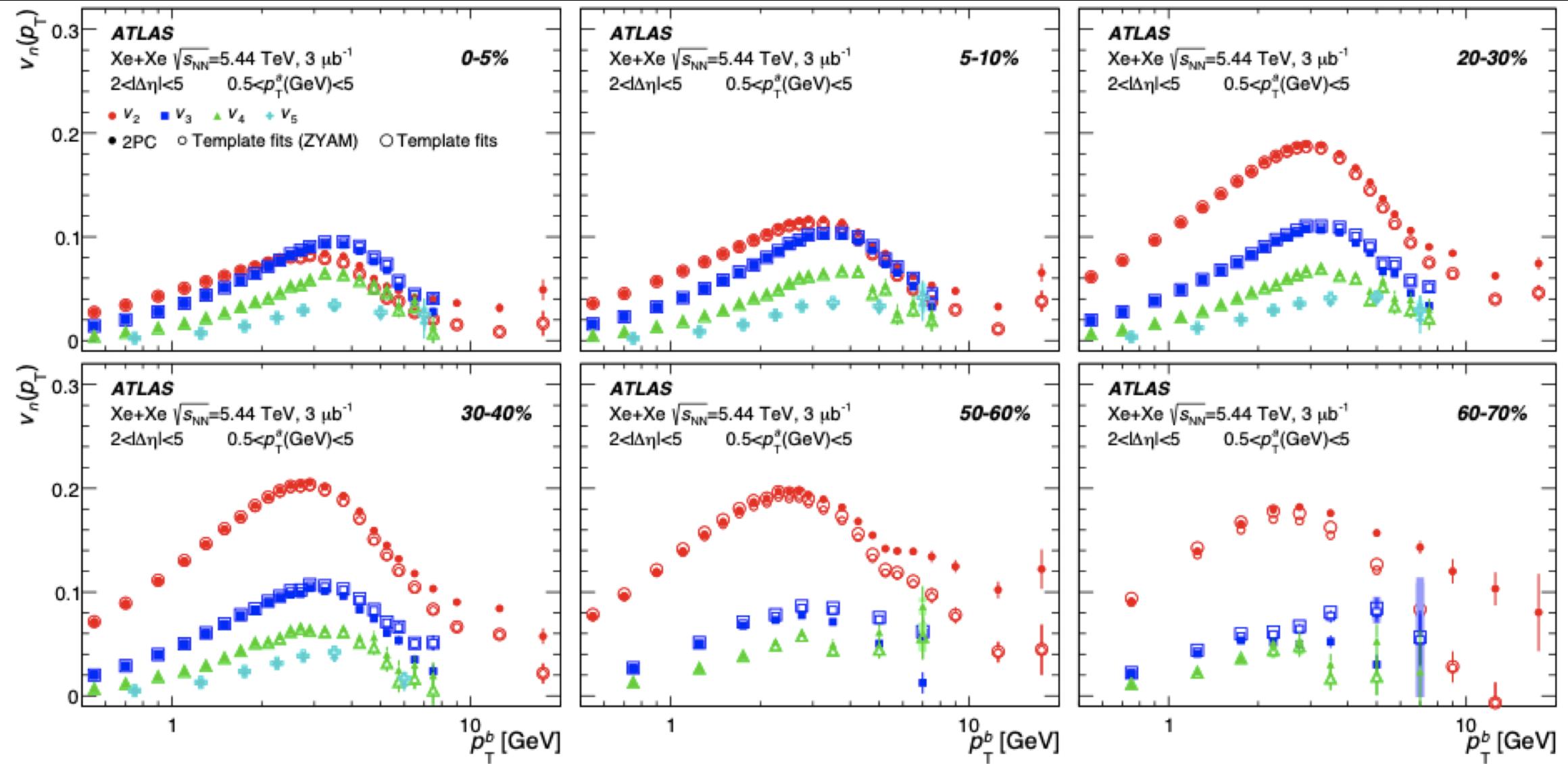
The v_n obtained for “ b ” should be independent of the choice of particle “ a ”: called “Factorization”.

OK for 2PC method at low- p_T and in central, mid-central events. Breaks at high- p_T and in peripheral events.

On the other hand Factorization works well to higher p_T and for more peripheral events.

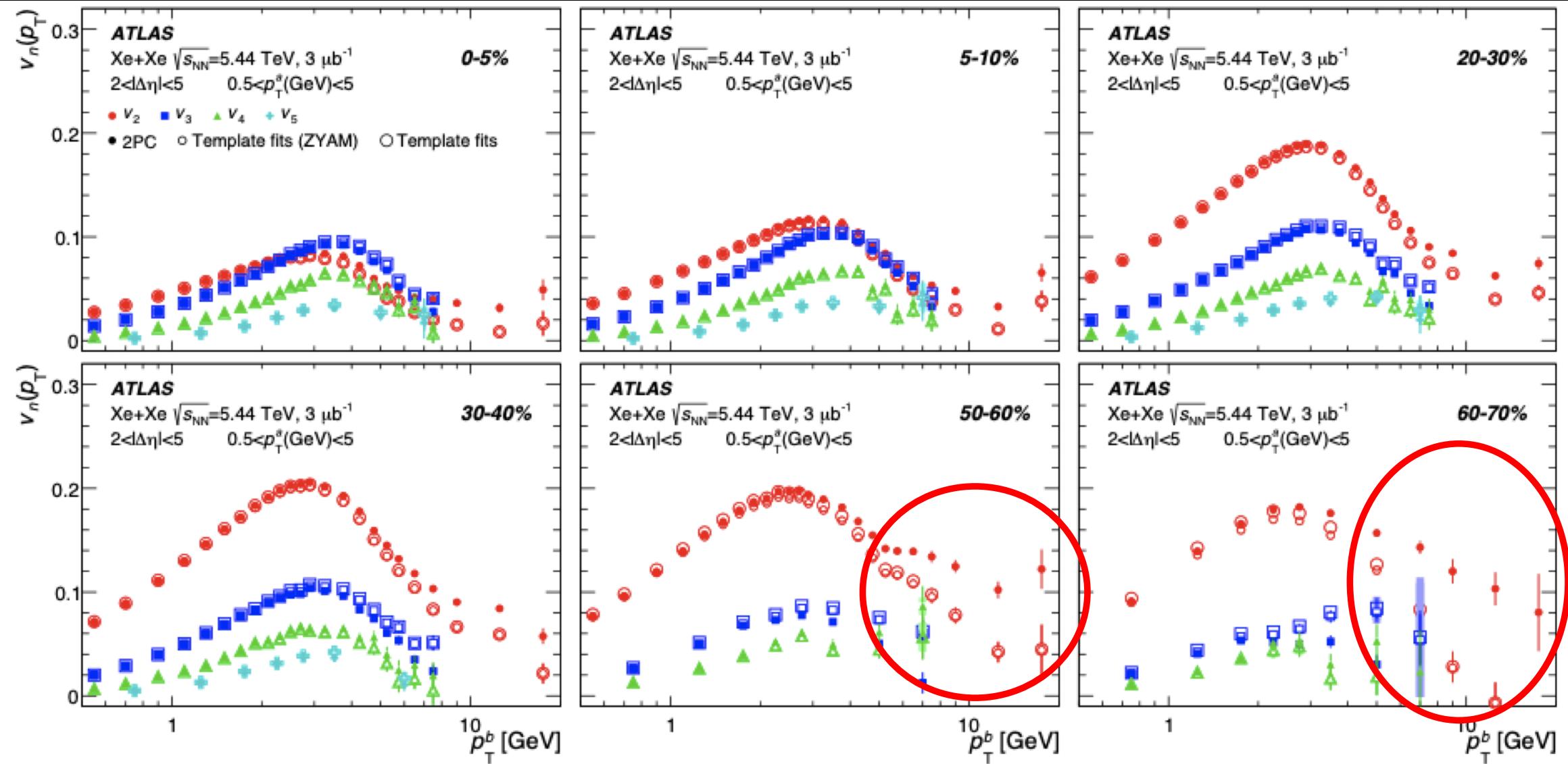
Indicated robustness of the template-fit results to bias from non-flow correlations.

v_n in Xe+Xe collisions:



- Plots show p_T dependence of the v_n from 2PC and template fitting method.

v_n in Xe+Xe collisions:



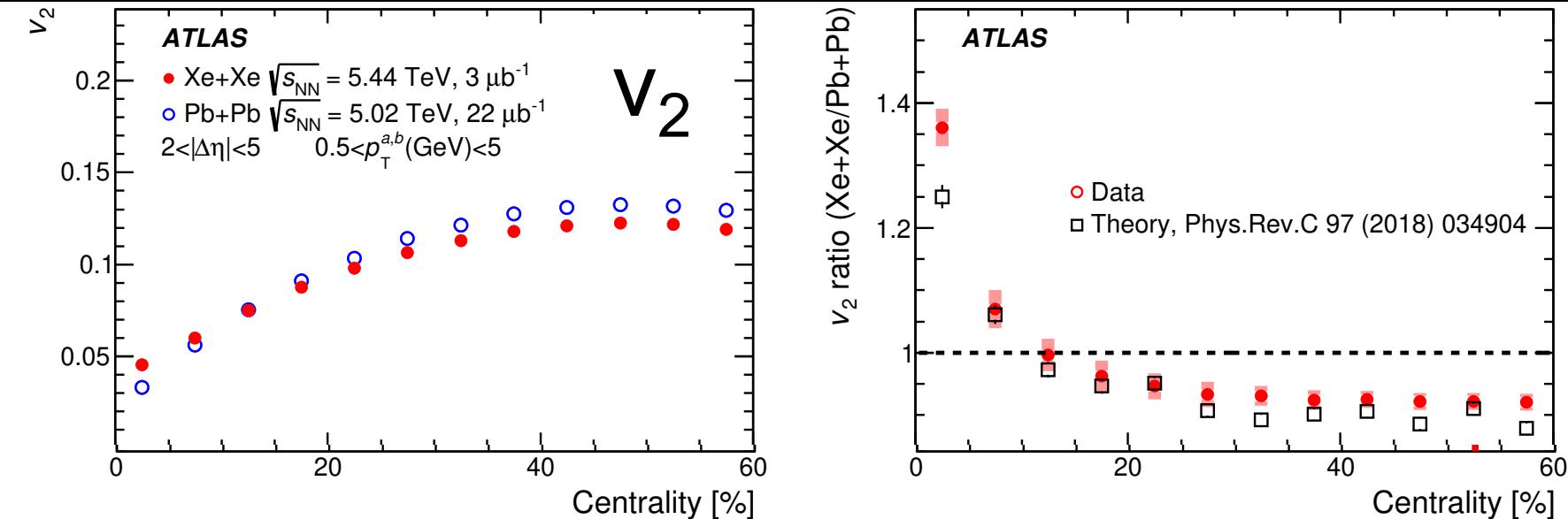
- Plots show p_T dependence of the v_n from 2PC and template fitting method.
- Large jet-bias effects are seen in peripheral events for 2PC (most clear for v_2, v_4).
- Removed by template-fit measurements

Comparison of Xe+Xe and Pb+Pb v_n

Right panels show the ratio, and the comparison to theory (blue points)
 (arXiv:1711.08499: G. Giacalone et. al.)

v_2 :

- In most central events the Xe+Xe v_2 larger than Pb+Pb v_2 .
- From central→mid-central events, the ratio for v_2 decreases, becomes smaller than 1.
- For more peripheral events the ratio seems to saturate.



Comparison of Xe+Xe and Pb+Pb v_n

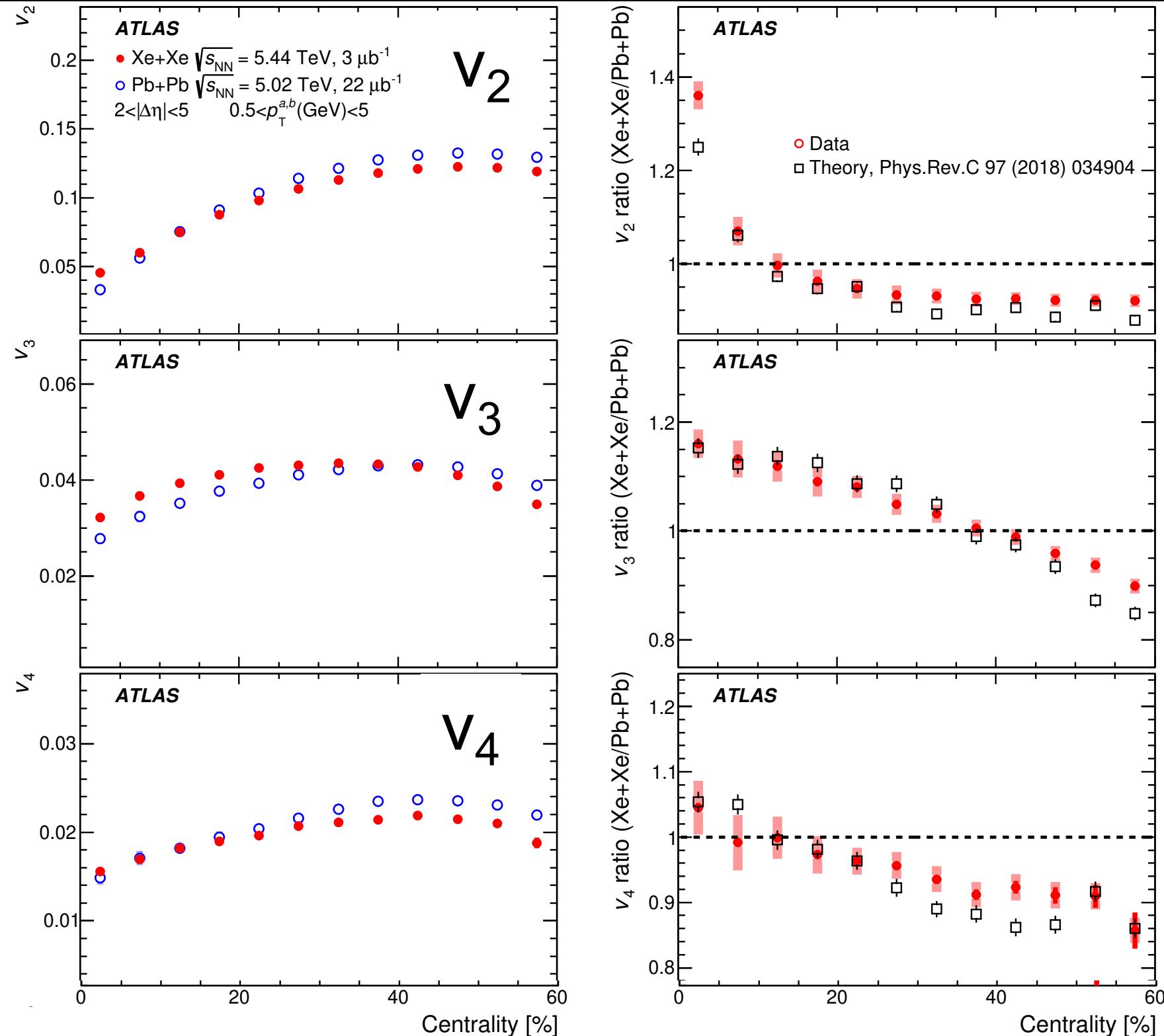
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v_3 , v_4 & v_5 :

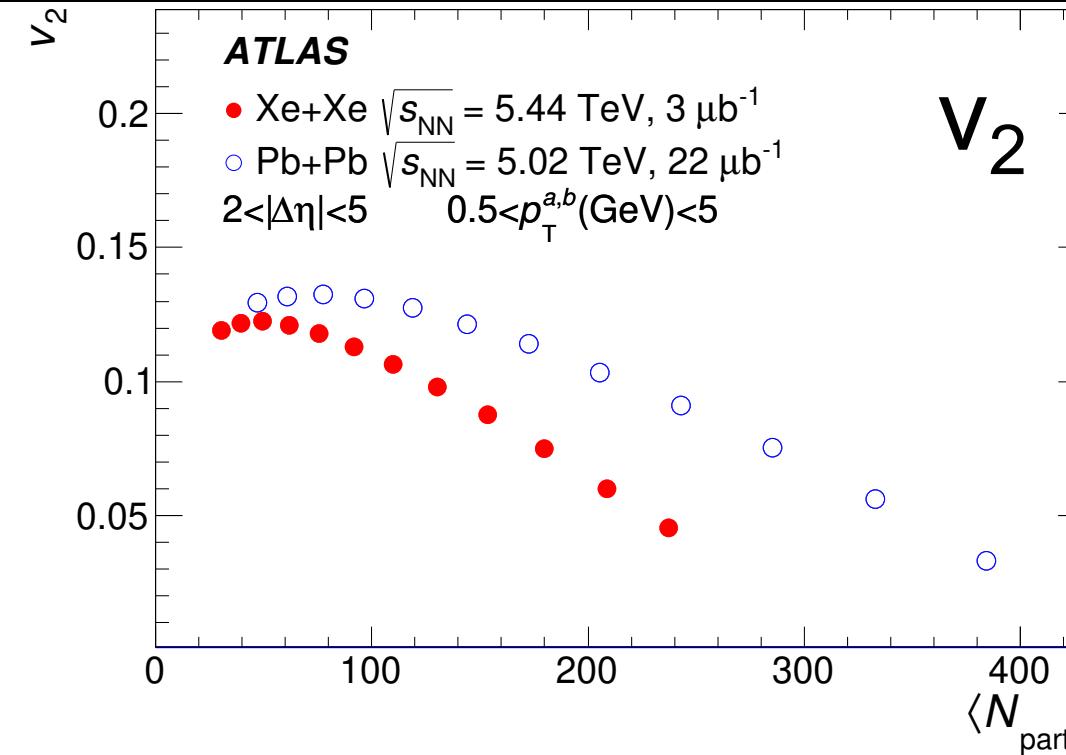
- Similar qualitative trends
- v_3 -ratio > v_4 -ratio > v_5 -ratio
- Reflects larger viscous effects in XeXe collisions.



Comparison of Xe+Xe and Pb+Pb v_n : $\langle N_{\text{part}} \rangle^{14}$

At same N_{part} v_2 , smaller in XeXe compared to PbPb.

XeXe geometry is less elliptic than Pb+Pb at the same N_{part} . Thus this difference.



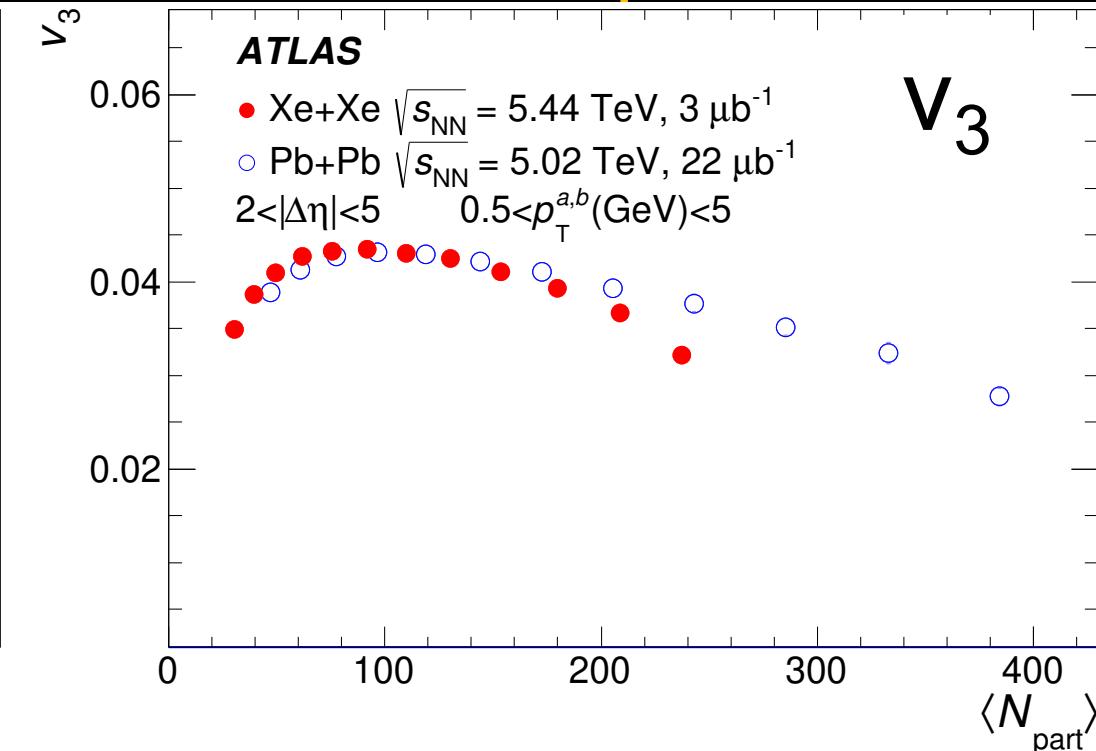
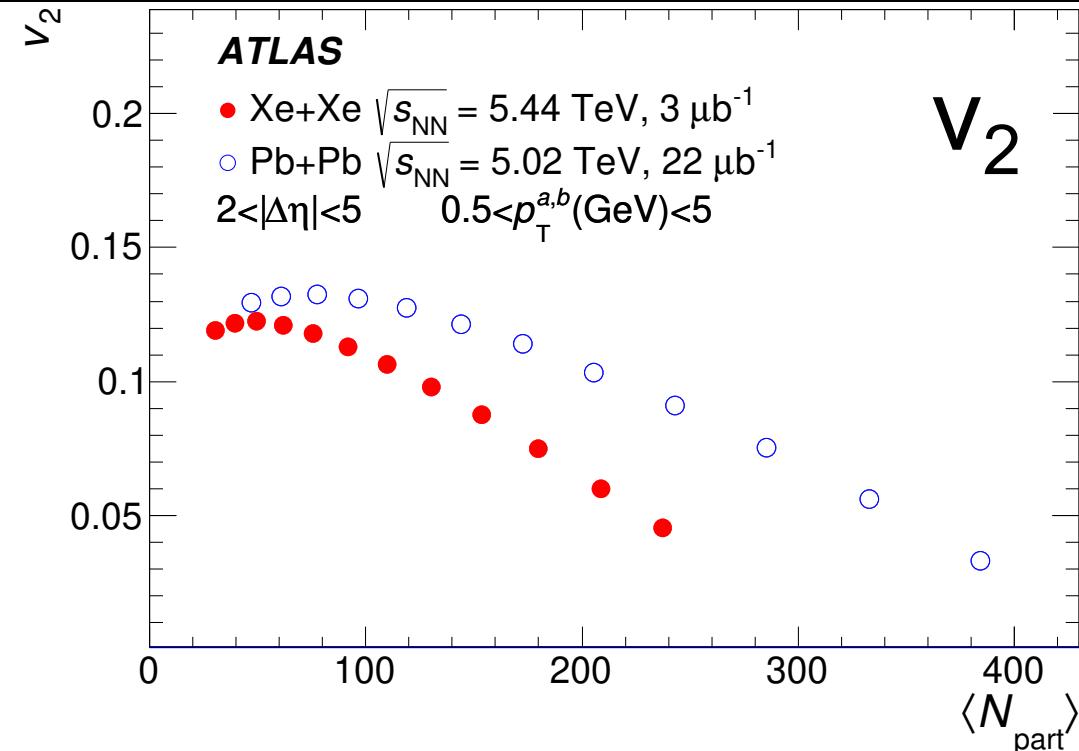
Comparison of Xe+Xe and Pb+Pb v_n : $\langle N_{\text{part}} \rangle^{15}$

At same N_{part} v_2 , smaller in XeXe compared to PbPb.

XeXe geometry is less elliptic than Pb+Pb at the same N_{part} . Thus this difference.

However v_3 values similar except in most central events.

v_3 is largely driven by fluctuations, thus similar at same N_{part} .



Comparison of Xe+Xe and Pb+Pb v_n : $\langle N_{\text{part}} \rangle^{16}$

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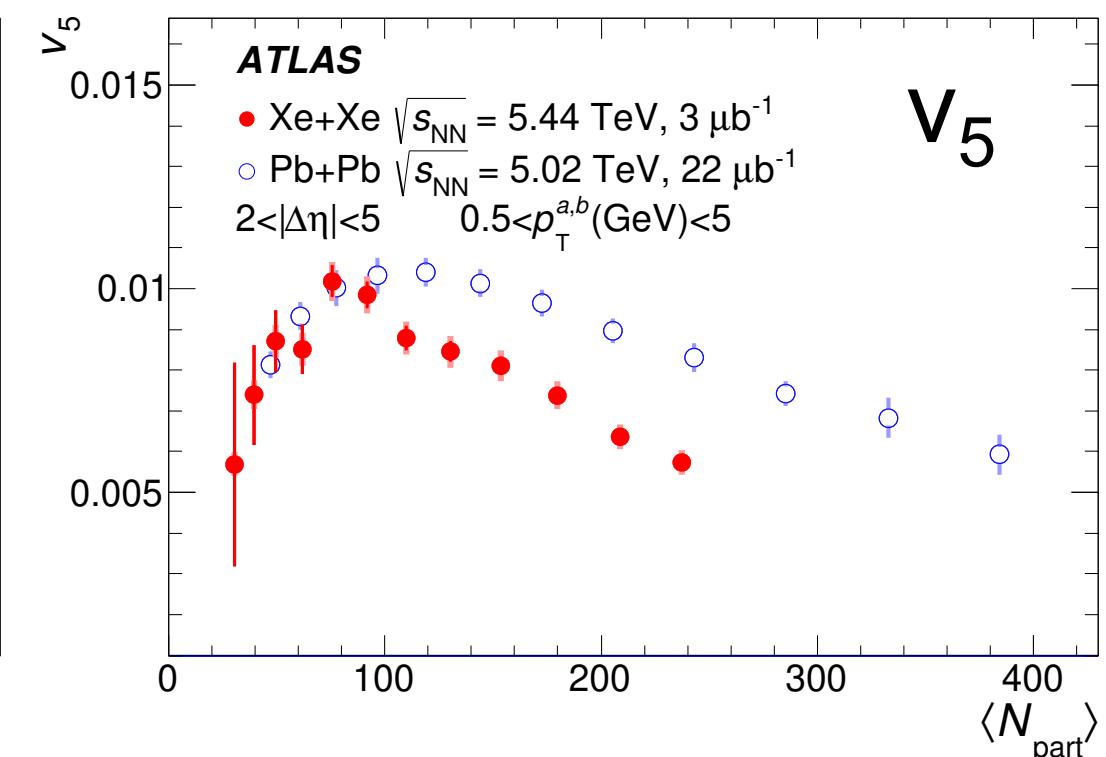
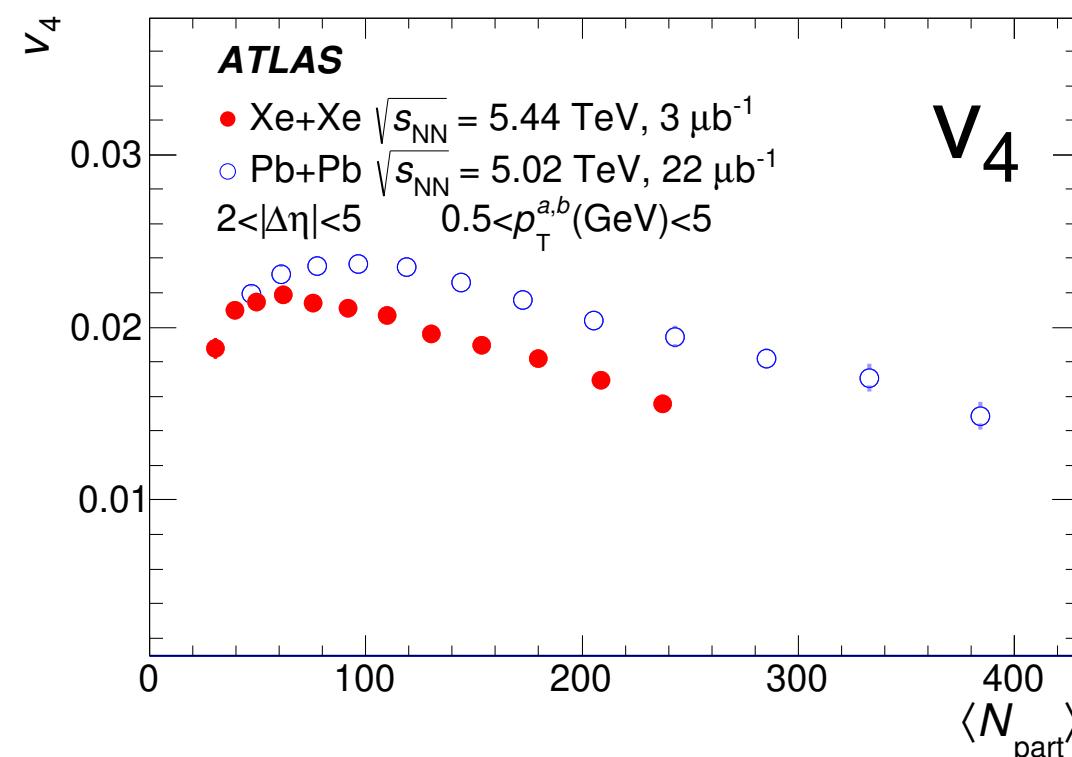
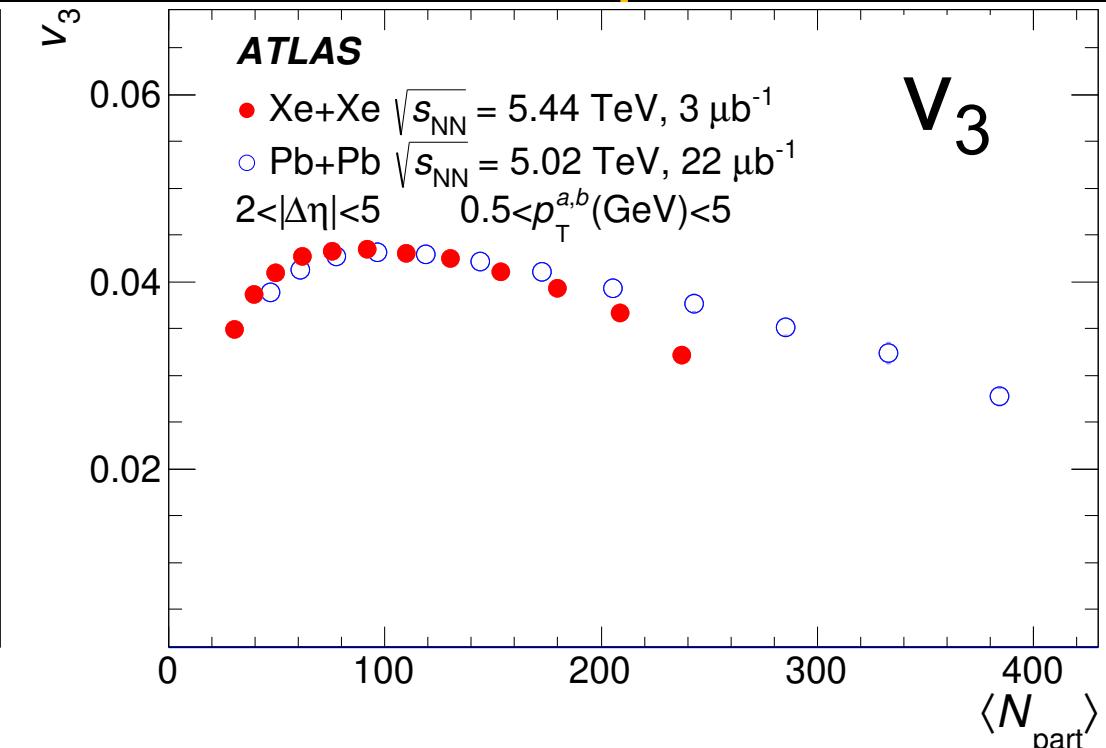
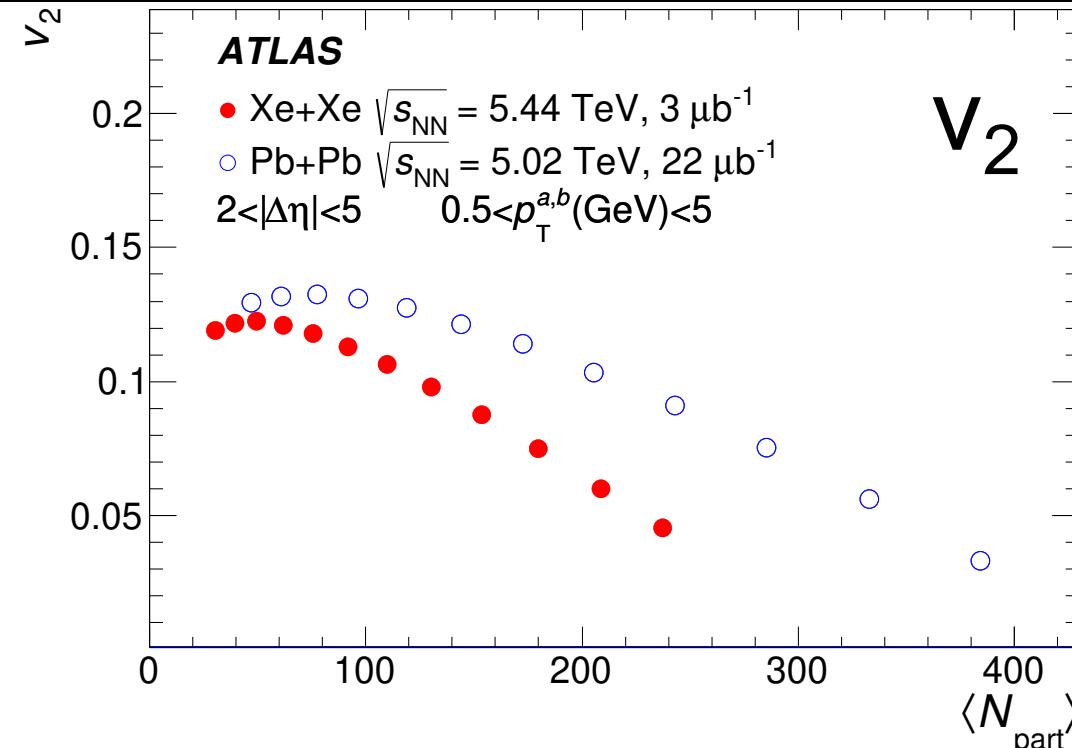
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Trends for v_4 and v_5 more similar to v_2 than to v_3 .

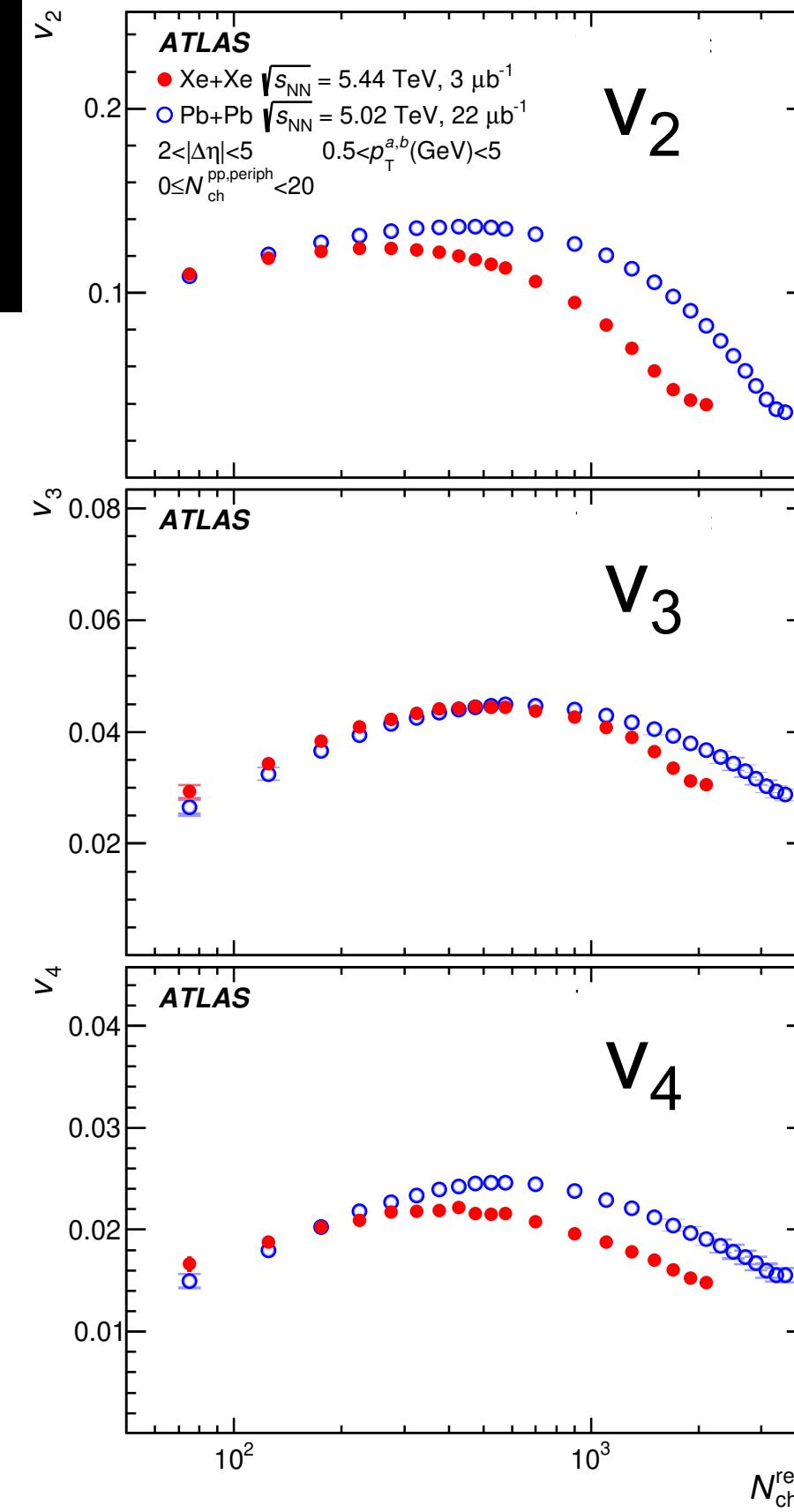
Perhaps because of non-linear response effects.

For peripheral collisions, all harmonics are similar between the two systems!



Xe+Xe vs Pb+Pb vs p +Pb

Multiplicity dependence trends for Xe+Xe vs Pb+Pb largely follow the N_{part} dependence trends.



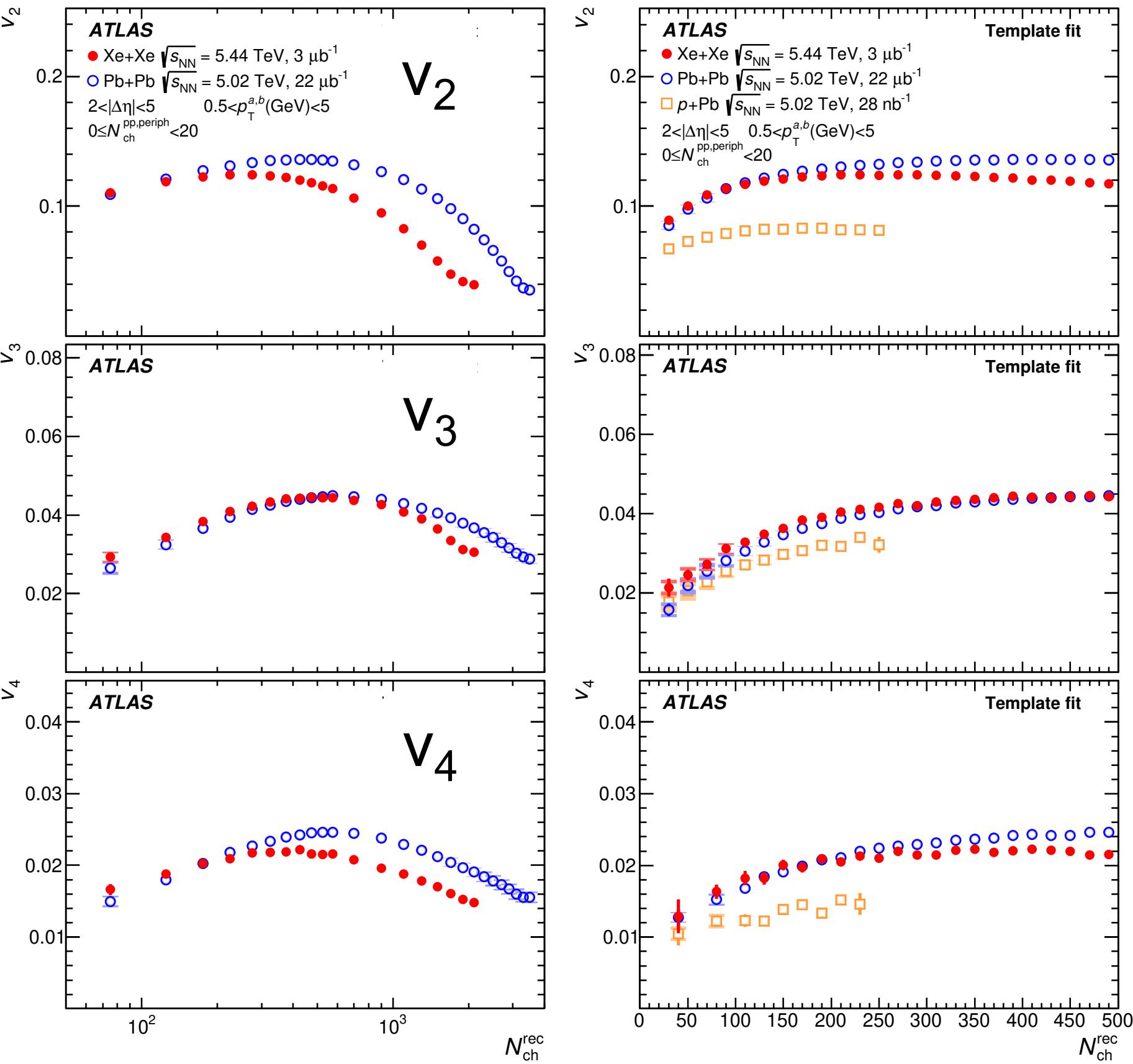
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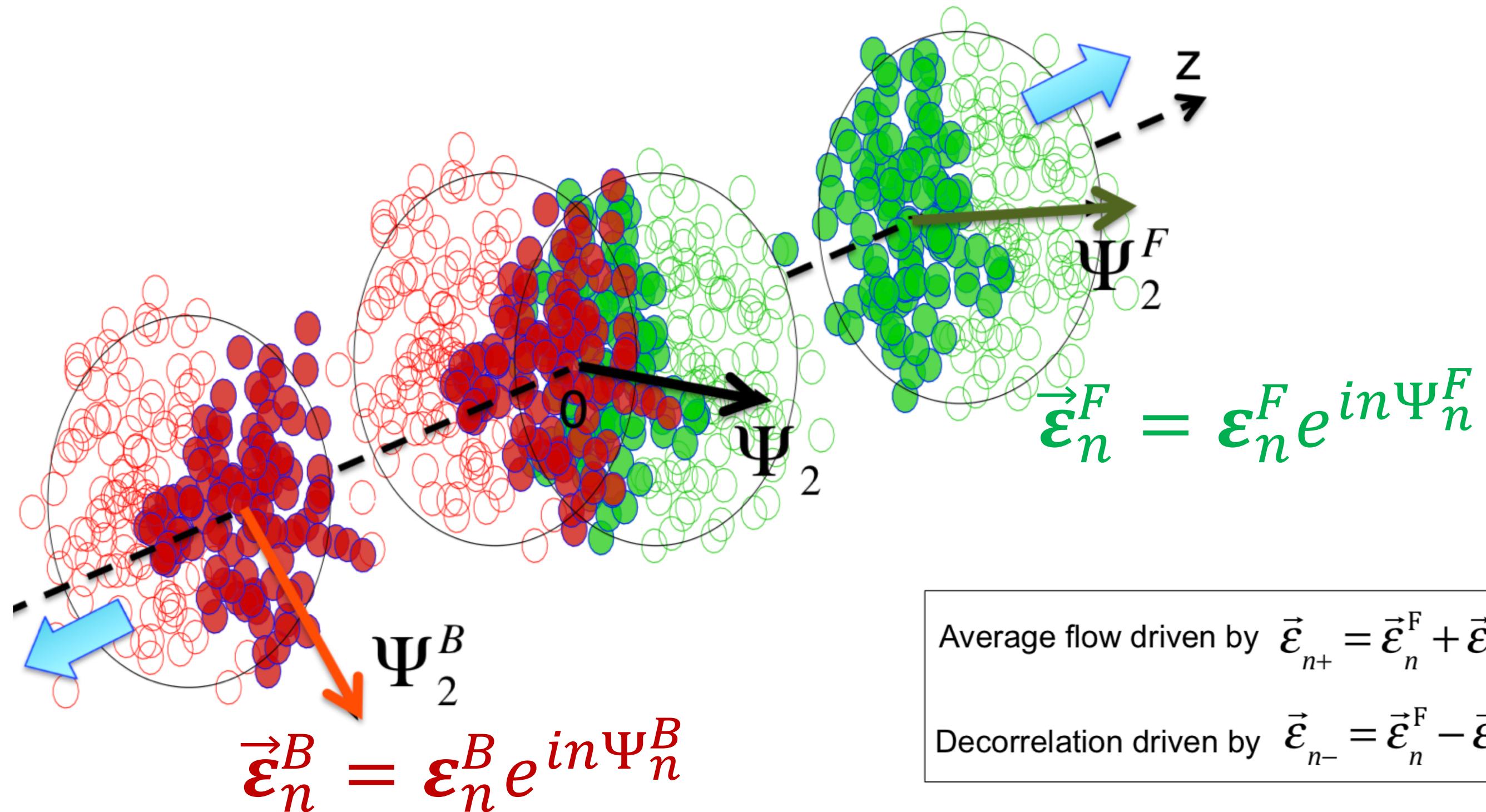
Also compare to p +Pb for multiplicity < 300

Larger difference seen for v_2 and v_4 compared to v_3 !

Similar nature of geometry fluctuations?



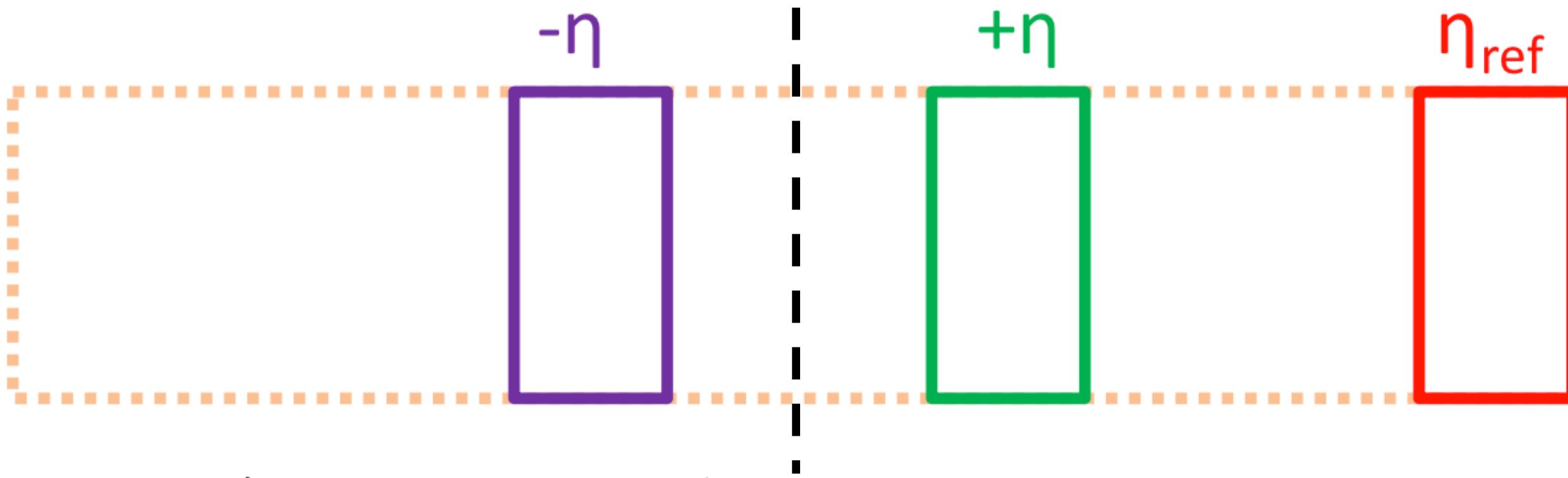
Longitudinal flow fluctuations



Longitudinal flow fluctuations

Flow Vector $\mathbf{q}_n \equiv \frac{\sum_i w_i e^{in\phi_i}}{\sum_i w_i} \equiv q_n e^{in\Psi_n}$

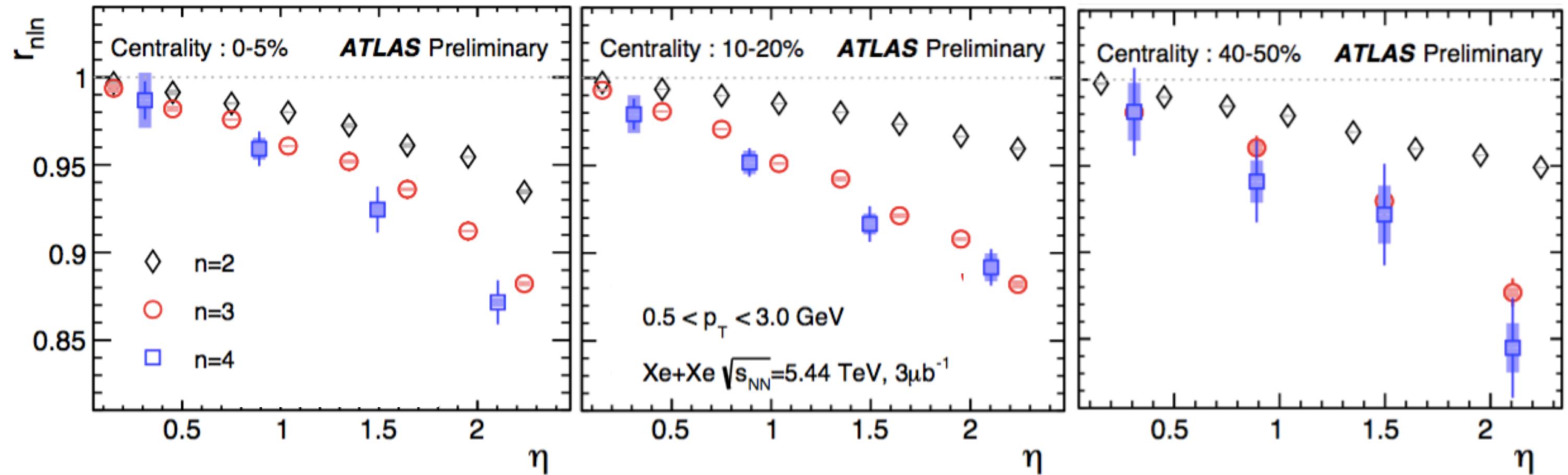
Correlate flow-vectors at $-\eta$ and $+\eta$ with flow-vector at forward-rapidity η_{ref}



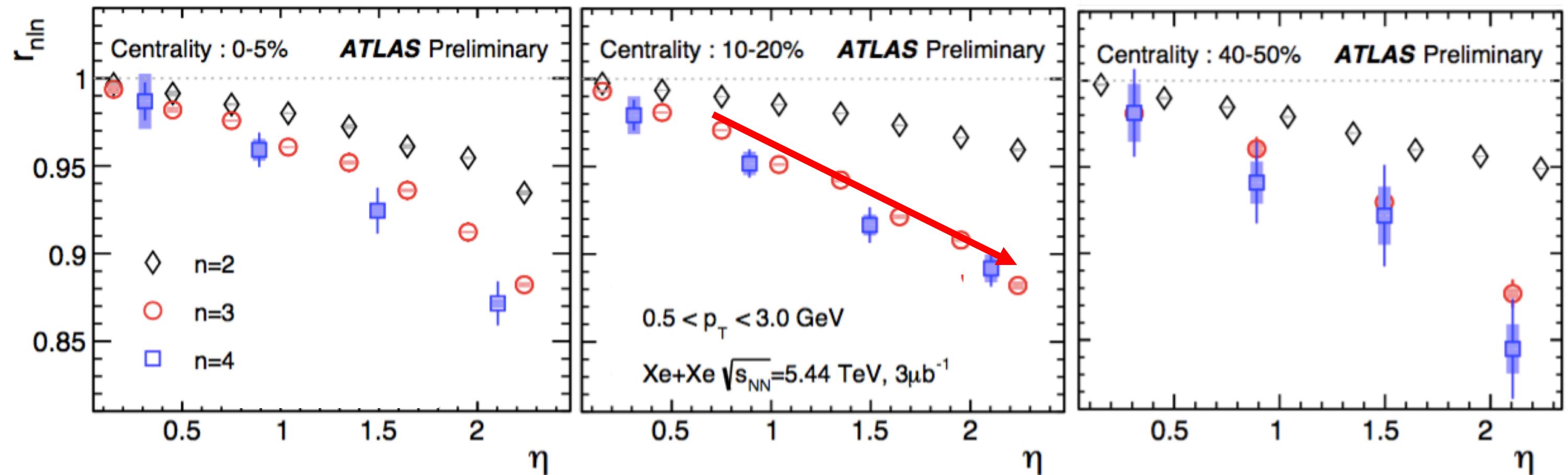
$$r_{n|n} = \frac{\langle q_n(-\eta) q_n^*(\eta_{ref}) \rangle}{\langle q_n(+\eta) q_n^*(\eta_{ref}) \rangle}$$

In this ratio, dependence on η_{ref} drops out, and it gives the v_n decorrelation between $-\eta$ and $+\eta$

Longitudinal flow fluctuations

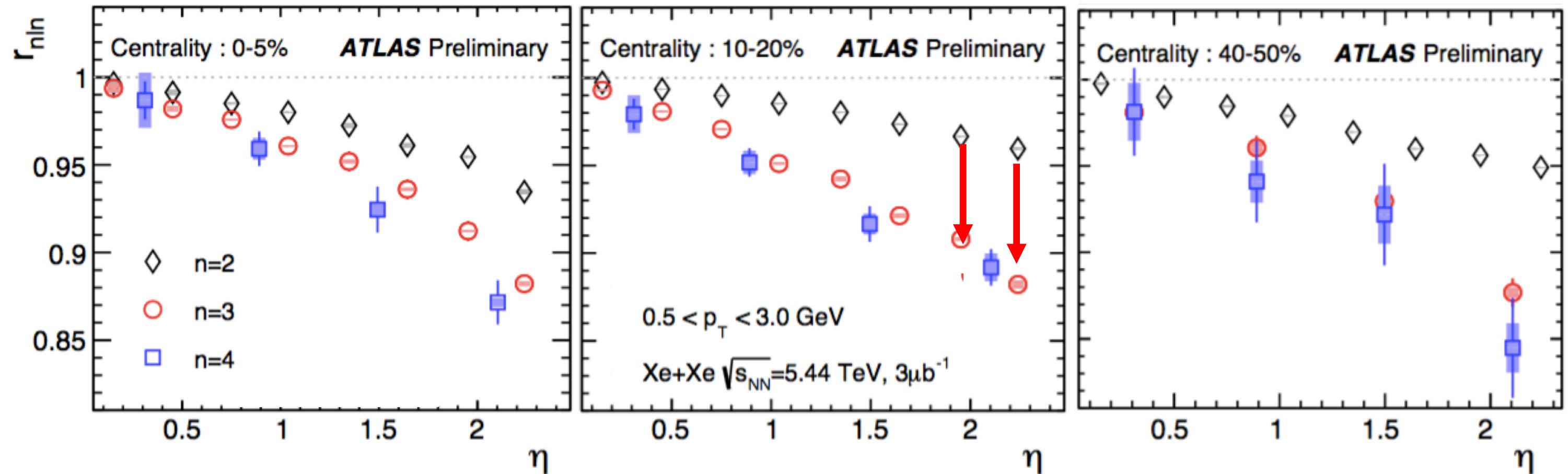


Longitudinal flow fluctuations



De-correlations increase with increasing n

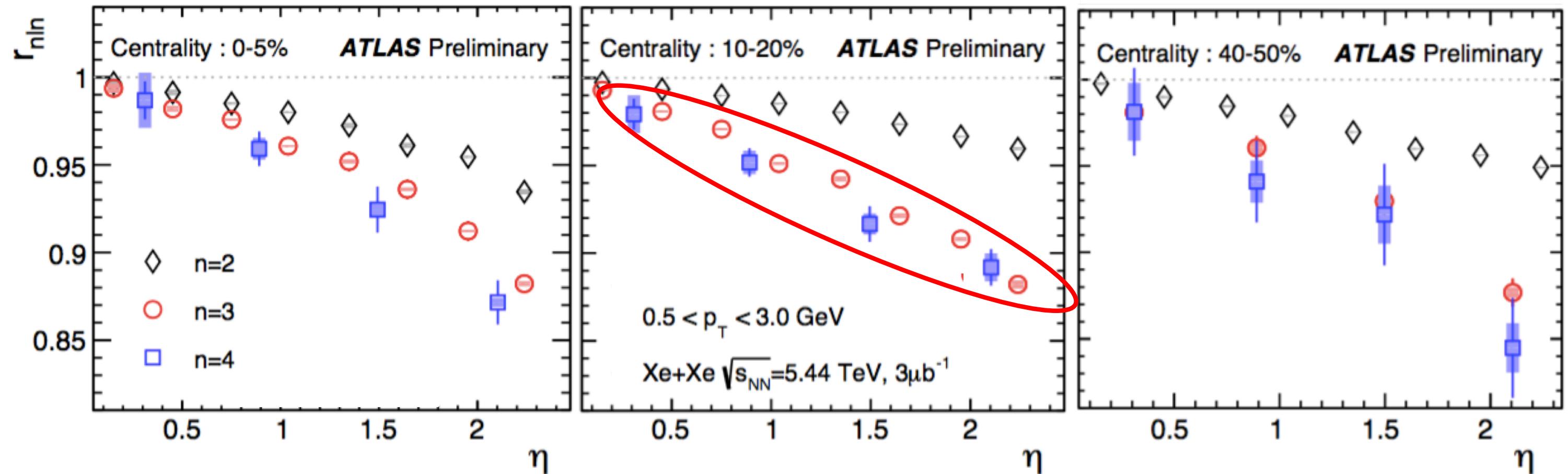
Longitudinal flow fluctuations



De-correlations increase with increasing n

De-correlations increase significantly from $n=2$ to $n=3$.

Longitudinal flow fluctuations

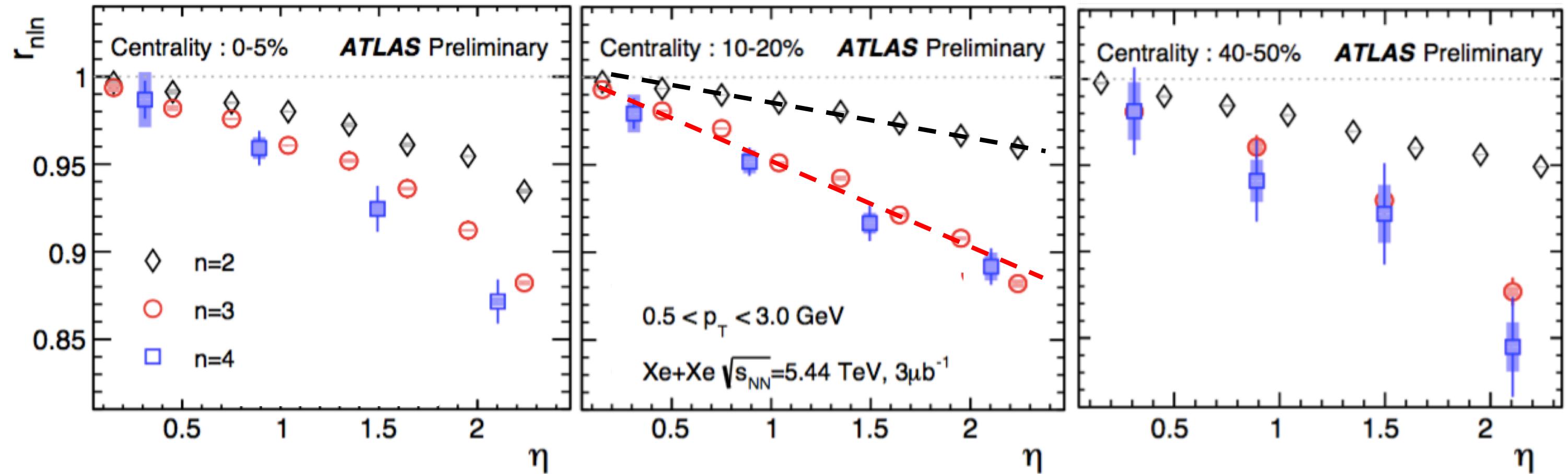


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Relatively smaller change from $n=3$ to $n=4$

Longitudinal flow fluctuations



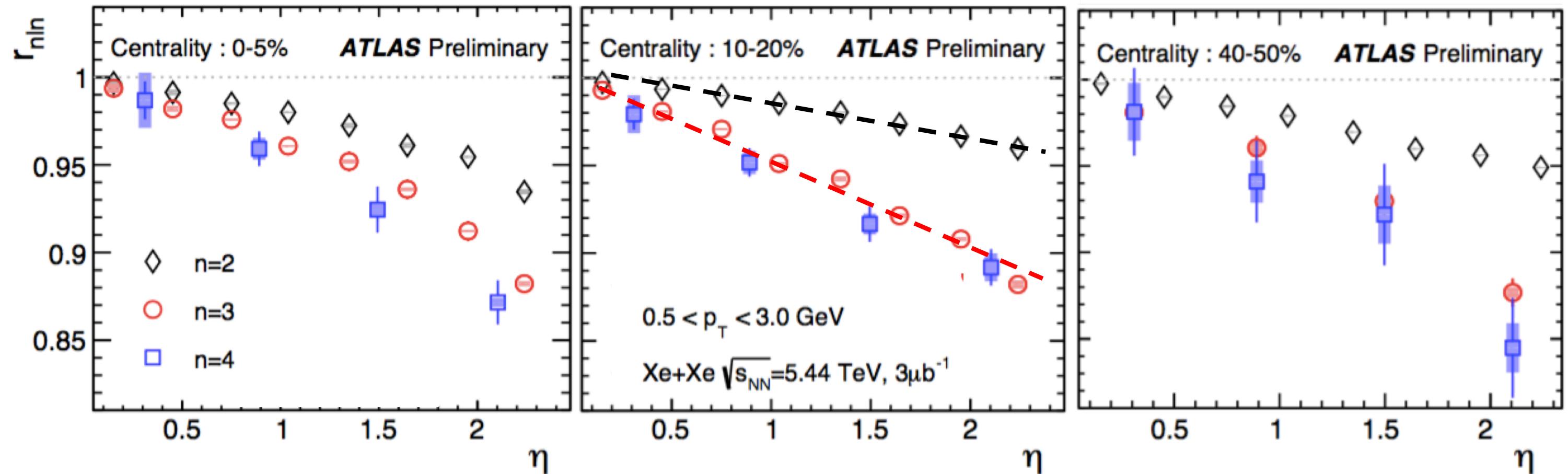
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De-correlations increase linearly with increasing η gap.
Some hints on non-linearity in 0-5% central collisions

Longitudinal flow fluctuations



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Relatively smaller change from $n=3$ to $n=4$

Quantify decorrelation by slope: $r_{n|n}(\eta) = 1 - 2F_n\eta$

De-correlations increase linearly with increasing η gap.
Some hints on non-linearity in 0-5% central collisions

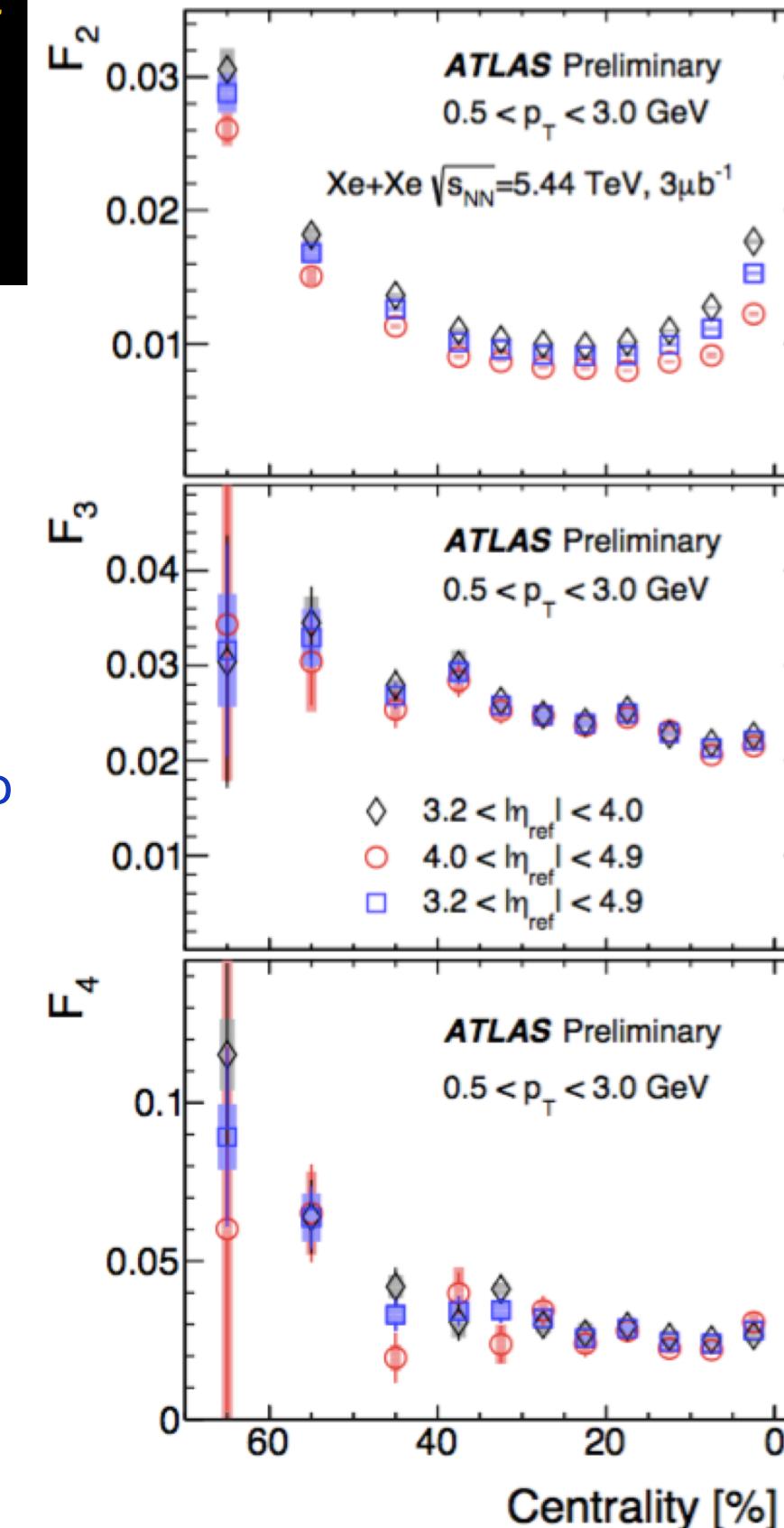
Longitudinal flow fluctuations

27

η_{ref} dependence:

- For $n=2$ decorrelations vary with choice of reference η region.
- For $n=3$ there is no such variation.
- Indicates that non-flow contributes slightly to the $n=2$ decorrelation.

$$r_{n|n} = \frac{\langle q_n(-\eta) q_n^*(\eta_{\text{ref}}) \rangle}{\langle q_n(+\eta) q_n^*(\eta_{\text{ref}}) \rangle}$$



Longitudinal flow fluctuations

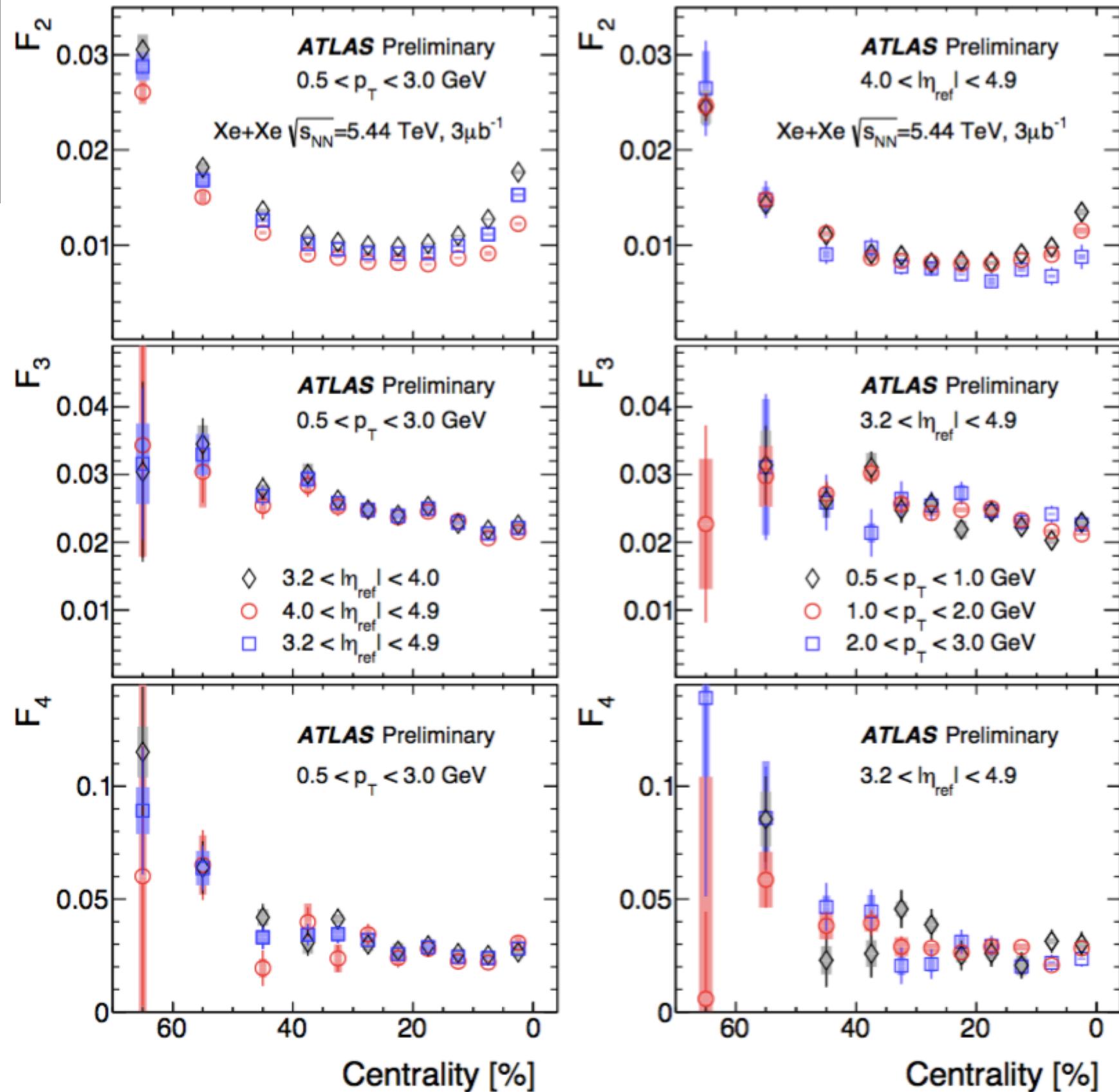
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η_{ref} dependence:

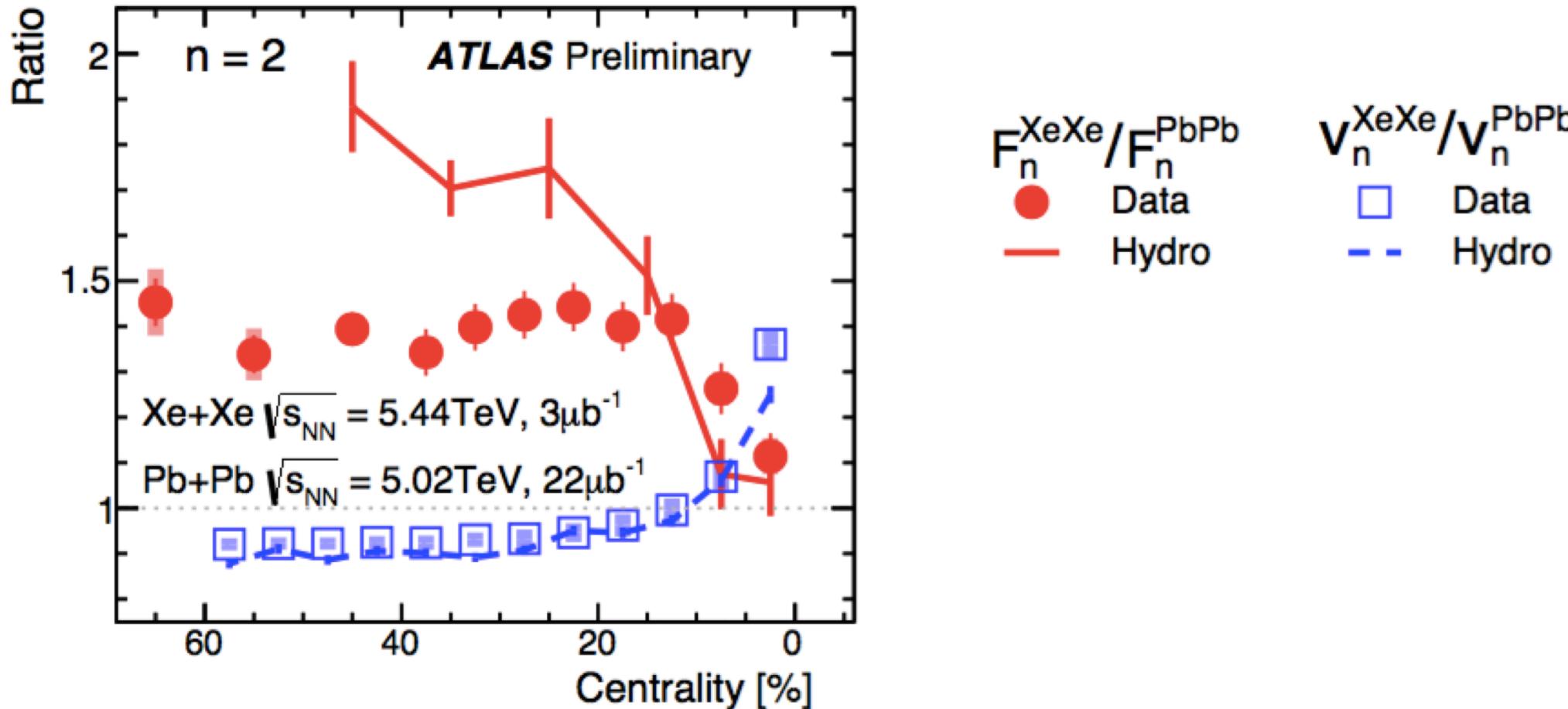
- For $n=2$ decorrelations vary weakly with choice of reference η region.
- For $n=3$ there is no such variation.
- Indicates that non-flow contributed slightly to the $n=2$ decorrelation.

p_{T} dependence:

- Decorrelation is slightly smaller at higher p_{T} for $n=2$
- Larger flow \rightarrow smaller decorrelation.
- Difficult to observe for $n=3,4$ given the uncertainties



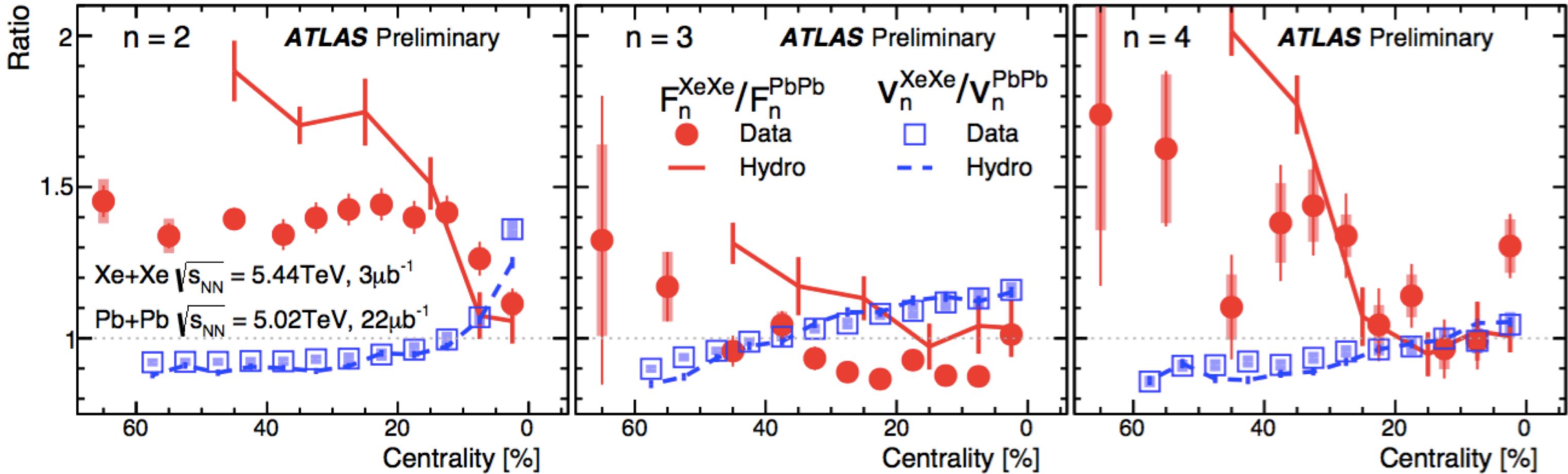
Average flow vs longitudinal flow-fluctuation



- Comparison of v_n ratio and F_n ratio (Xe-Xe/Pb-Pb)
 - Observe opposite trend for $n=2$
 - Larger flow \rightarrow smaller longitudinal flow fluctuation

Hydro calculations:
arXiv: 1711.08499,
arXiv: 1805.03762

Average flow vs flow-fluctuation



- Comparison of v_n -ratio and F_n -ratio (Xe-Xe/Pb-Pb)
 - Observe opposite trend for $n=2$
 - Larger flow → smaller longitudinal flow fluctuation
- Trend also observed for $n=3$ and $n=4$
 - But some difference in detailed features
 - Hydro predictions do not describe fluctuation data as well as v_n -data

Hydro calculations:
arXiv: 1711.08499,
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Summary

- ATLAS has performed detailed measurement of flow and longitudinal flow-correlations in Xe+Xe collisions
- Comparison to Pb+Pb measurements shows interesting interplay of
 - fluctuations in geometry: increase Xe+Xe v_n , dominant in central collisions
 - viscous corrections: decrease Xe+Xe v_n , dominant in mid-central, peripheral collisions
- As function on N_{part} /multiplicity, v_3 values are similar, but v_2, v_4 and v_5 are different
- Longitudinal fluctuations also studied
 - XeXe and Pb+Pb : mean v_n and longitudinal- v_n fluctuations follow opposite trends
- Dual sensitivity to initial geometry and viscous corrections:
 - Measurements can further constrain models.

Posters:

Pengqi Yin (Flow in Xe+Xe)

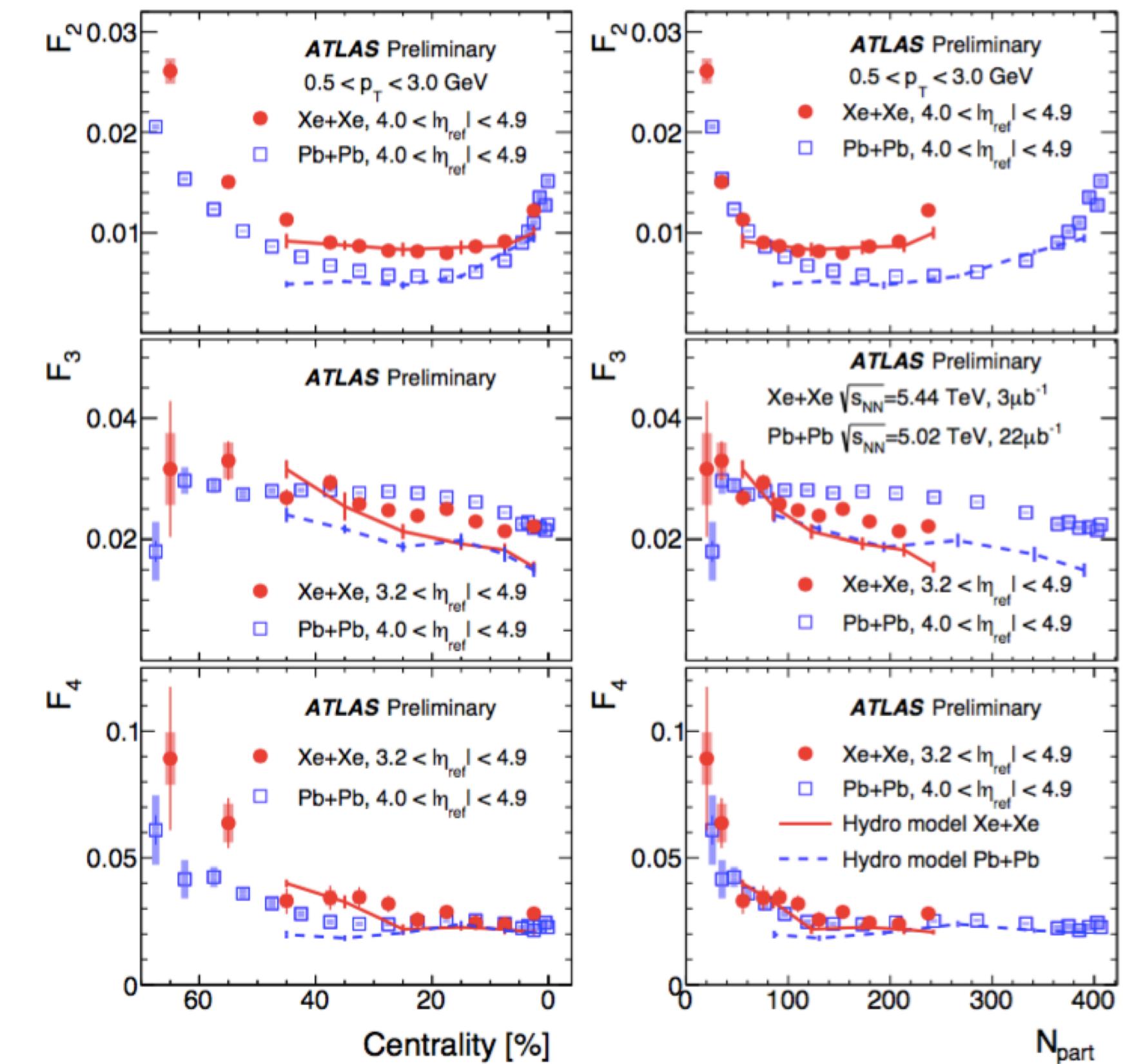
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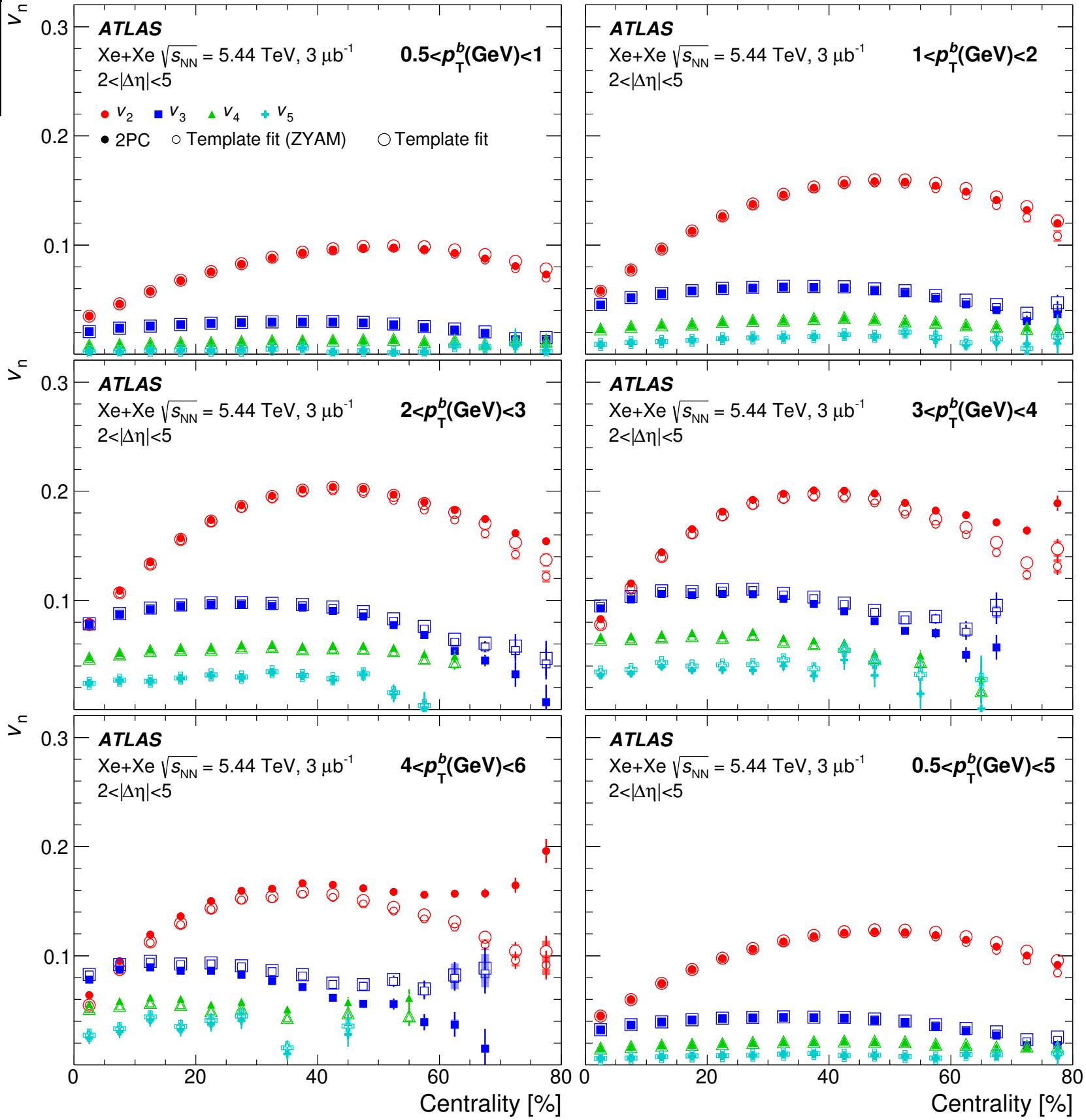
Xe+Xe vs Pb+Pb F_n

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Xe+Xe v_n vs centrality

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Xe+Xe v_n 2PC vs SP

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