Studying the p+Pb ridges using two-particle correlations and cumulants with the ATLAS detector

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Outline

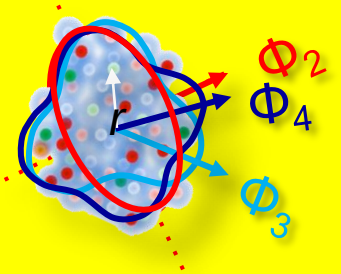
- Introduction
- Event and track selection
- p+Pb ridge
- two particle correlations in p+Pb collisions
- p+Pb: v_2 from cumulants
- Summary

Introduction

- collective flow of particles produced in nuclear collisions ⇒ significant anisotropy in the plane perpendicular to the beam direction ⇒ extensively studied in heavy-ion experiments.

- In p+Pb collisions the small size of the produced system compared to the mean free path of the interacting constituents might have been expected to generate weaker collective flow, if any, compared to heavy ion collisions.

- Geometry of initial state produces a pressure gradient, driving the expansion of the hadronic system and overlapping with non-flow dynamics (resonance decay, Bose-Einstein correlations, jets…)

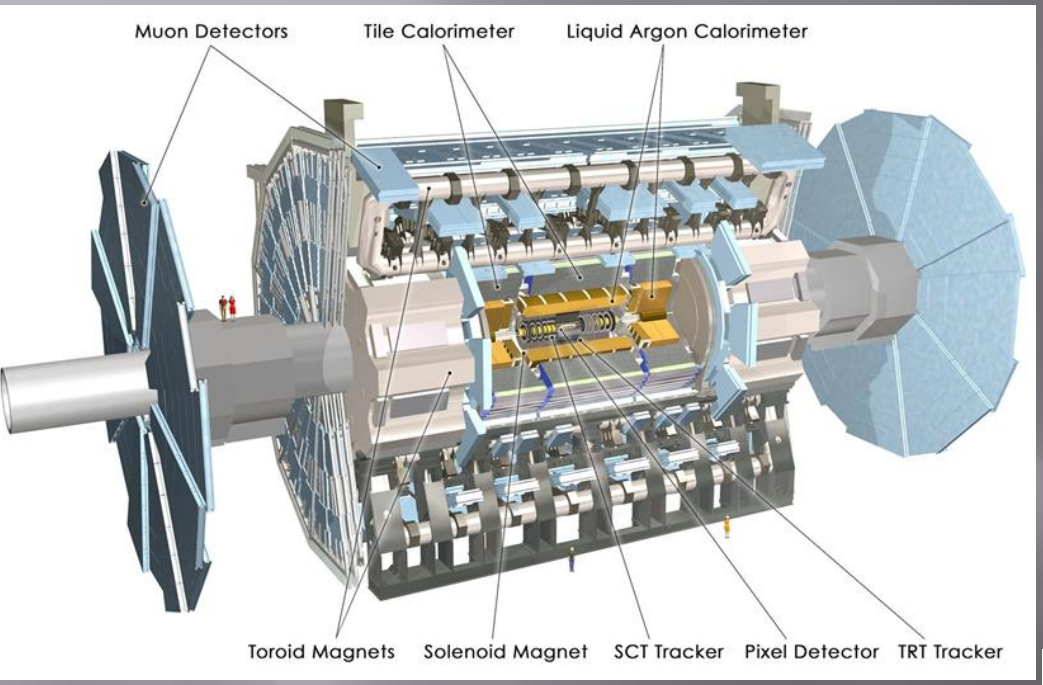


- Observables:
  - Particle azimuthal distribution ⇒ using v_n Fourier coefficients
  - Two-particle / multi-particle correlations
    (N. Borghini, P. M. Dinh, J. -Y. Ollitrault, Phys. Rev. C63 (2001) 054906, Phys. Rev. C64 (2001) 054901)

- Previous measurements:
  - v_n measured up to v_6 ⇒ special emphasis on elliptic flow v_2 (p_T, centrality, η dependencies)
- Discussed today:
  - New analysis using cumulant-based v_2 determination applied to p+Pb collisions
    - reduce non-flow contribution by computing multi-particle correlations

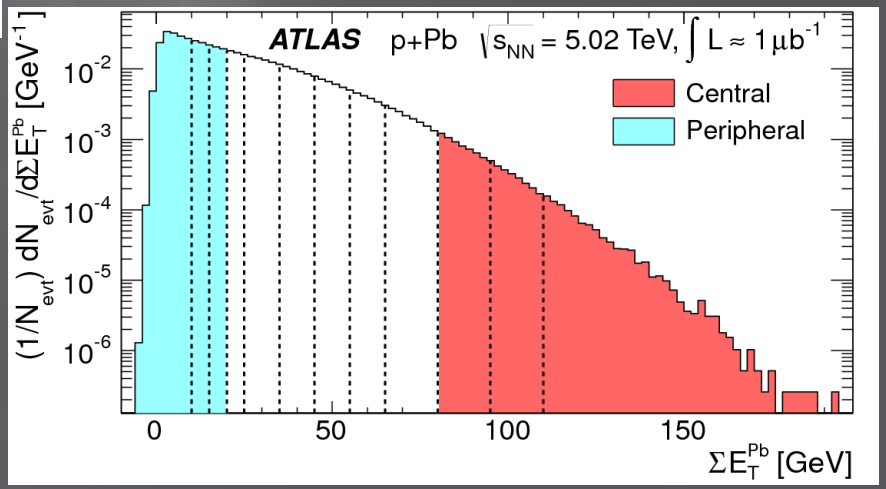
Event and track selection

- **Data sample: 1 μb^{-1}** p-Pb at $\sqrt{s_{NN}}$=5.02 TeV (2012)



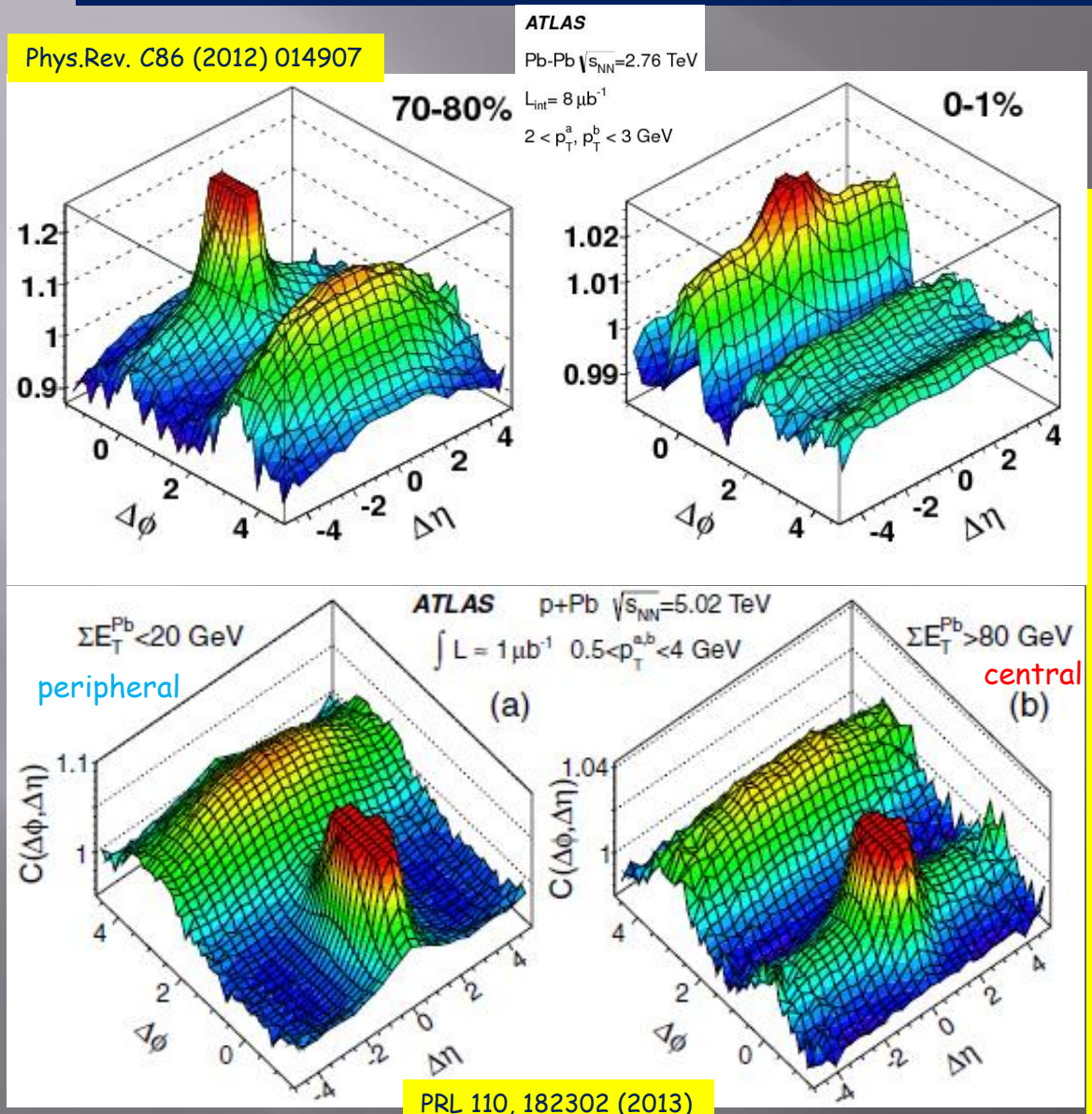
Particle distribution from tracks in the **Inner Detector** $-2.5 < \eta < 2.5$

Centrality defined from $\sum E_T^{Pb}$ (total **FCal** E_T on Pb side) -- $3.1 < \eta < 4.9$



The p+Pb ridge

Phys.Rev. C86 (2012) 014907



PRL 110, 182302 (2013)

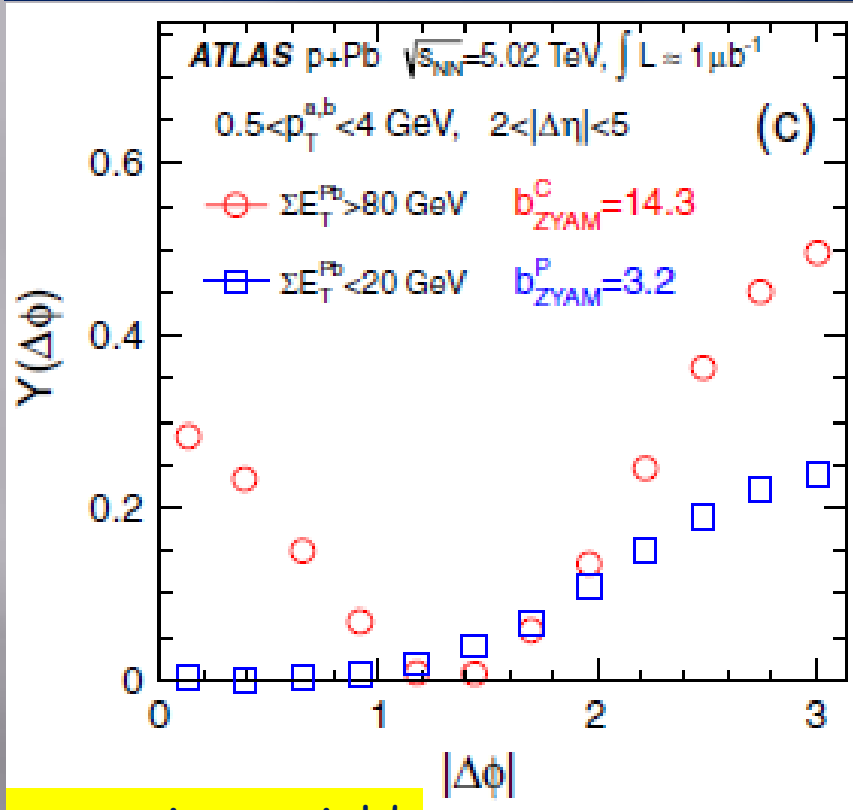
The correlation functions is given by:

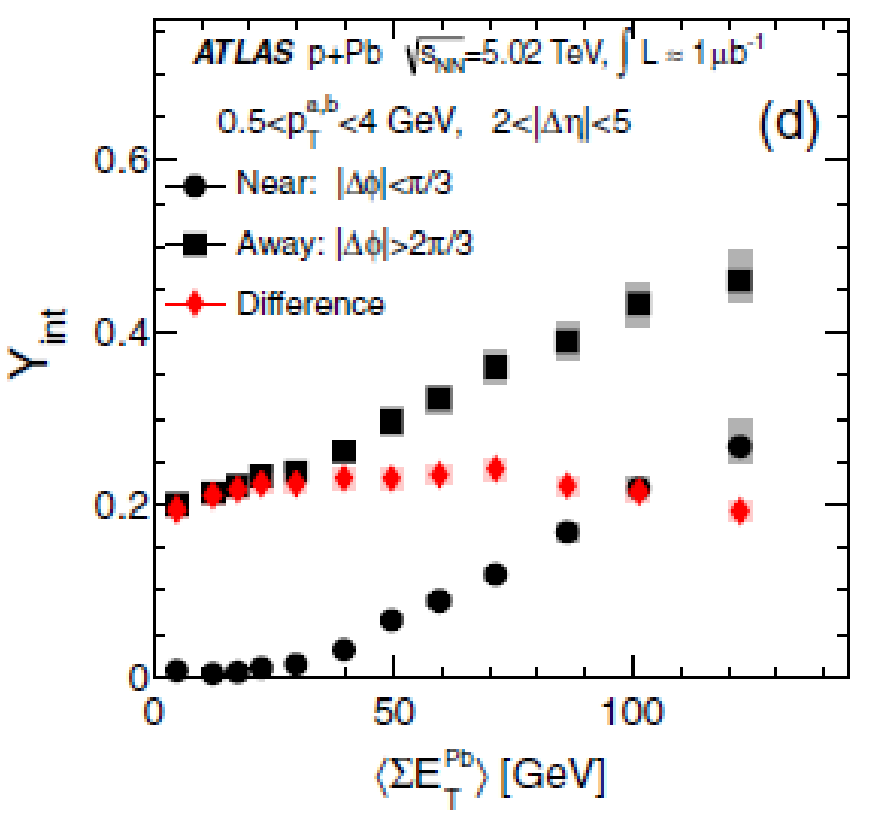
$$C(\Delta\phi, \Delta\eta) = \frac{S(\Delta\phi, \Delta\eta)}{B(\Delta\phi, \Delta\eta)}$$

- $\Delta\varphi = \varphi_a - \varphi_b$
- $\Delta\eta = \eta_a - \eta_b$
- S and B represent pair distributions constructed from the same event and from "mixed events," respectively.
- a and b denote the two particles in the pair ("trigger" and "associated")

- two-particle correlation studies performed recently on data from p+Pb collisions revealed the presence of a "ridge", a structure extended in the relative pseudorapidity, η, while narrow in the relative azimuthal angle, Δφ, on both the near-side (Δφ ~ 0) and away-side (Δφ ~ π)
- the "ridge" ⇒ combination of all v_n
- complicated correlations interpreted as flow
- also resembling the flow modulation of the Δφ distributions in Pb+Pb collisions

Two particle correlations in p+Pb collisions





per-trigger yield

$$Y(\Delta\phi) = \left(\frac{\int B(\Delta\phi)d\Delta\phi}{\pi N_a}\right) C(\Delta\phi) - b_{ZYAM}$$

N_a – total number of trigger particles
b_{ZYAM} – determinated by zero-yield-at-minimum method

$$Y_{\text{int}} = \int Y(\Delta\phi)d(\Delta\phi)$$

- Y_{int} increase in similar way with centrality.
- Difference is approximately constant.

PRL 110, 182302 (2013)

Two particle correlations in p+Pb collisions

Per-trigger yield in several p_T ranges.
The difference between yields for central and peripheral events is consistent with modulation:

$$a_0 + 2a_2 \cos 2\Delta\phi$$

where:

$$a_0 = < \Delta Y(\Delta\phi) >$$
$$a_2 = < \Delta Y(\Delta\phi) cos\, 2\Delta\phi >$$

The same type of modulation in all p_T intervals.

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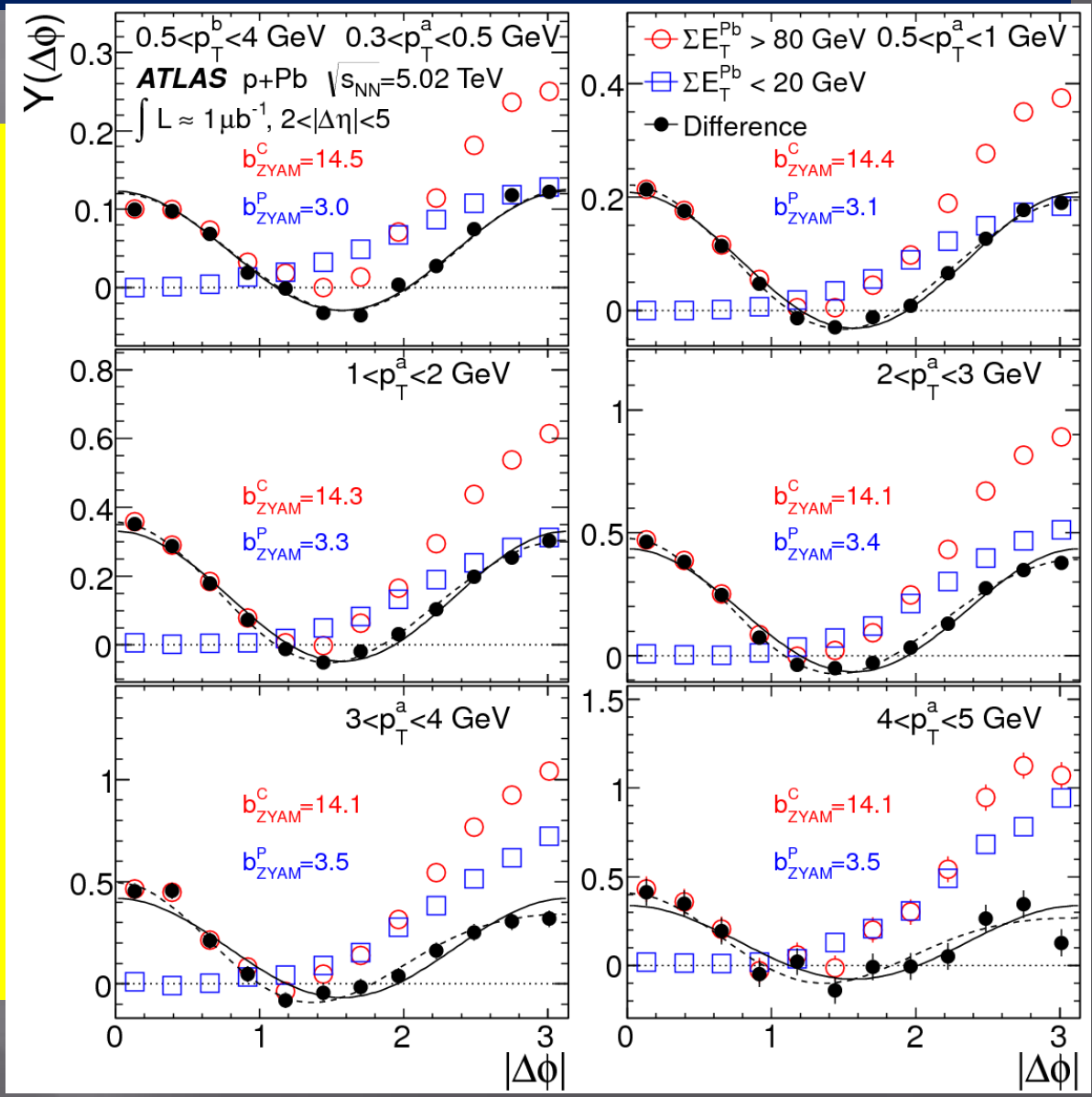
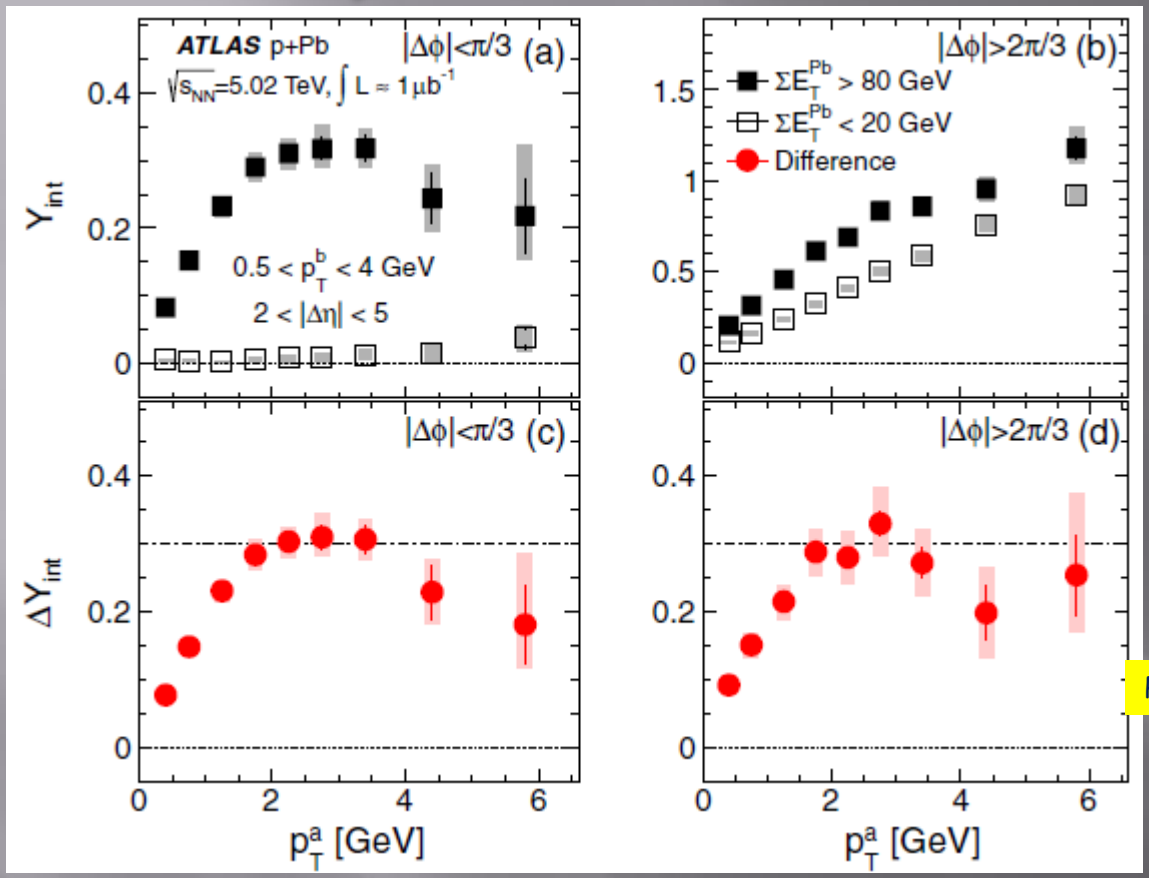


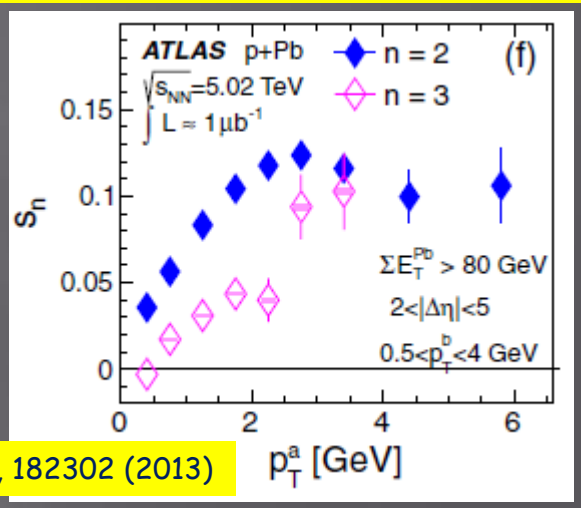
Two particle correlations in p+Pb collisions



Differences between yields for central and peripheral events in near side and away side are very similar.

Ridge v_2-*like* extraction

Can be translated into v_n-equivalent variables.



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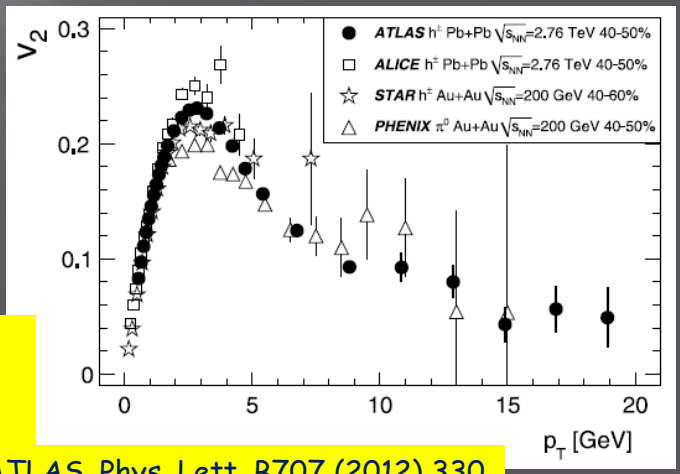
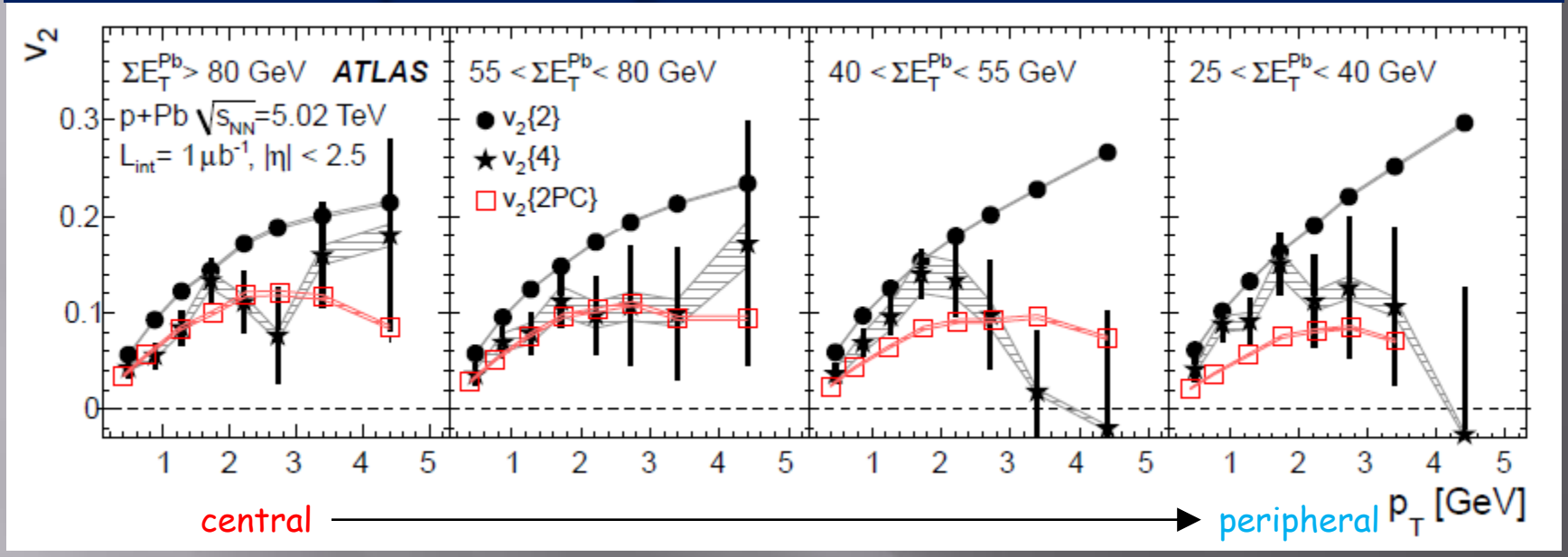
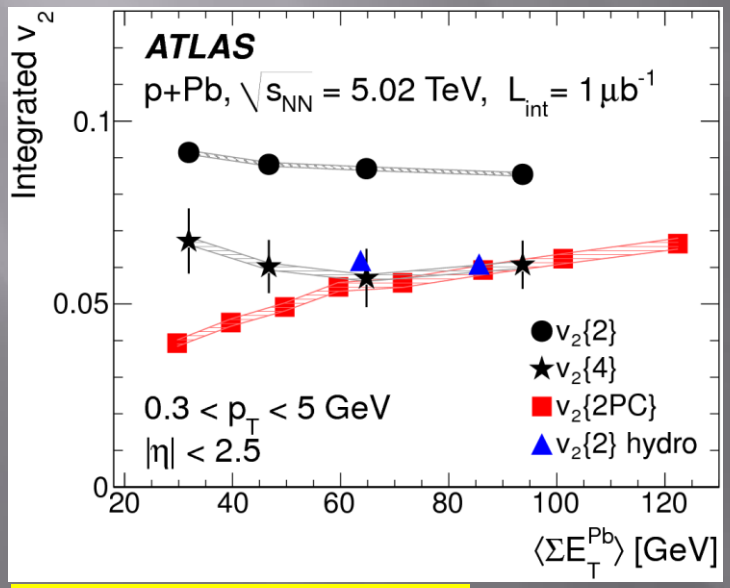


ATLAS, Phys. Lett. B707 (2012) 330

The s_2 modulation parameter has similar p_T dependence as elliptic flow in Pb+Pb collisions

p+Pb: v_2 from cumulants





arXiv:1303.2084v1 [hep-ex]

- large magnitude of $v_2\{2\}$ compared to $v_2\{4\}$ suggests a substantial contamination from non-flow correlations.
- Results consistent with two-particles correlation measurement
- different suppression of non-flow correlation (visible in peripheral events)
- the hydrodynamic predictions agree with our measurements over the centrality range where the model predictions are available (P. Bożek and W. Broniowski, Phys. Lett. B 718 (2013) 1557).

Summary

- ATLAS has measured the second harmonic coefficient in p+Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV using two- and four-particle cumulants.
- A significant magnitude of v_2 is observed using both two- and four-particle cumulants, although $v_2\{2\}$ is consistently larger than $v_2\{4\}$, indicating a sizeable contribution of non-flow correlations to $v_2\{2\}$.
- Transverse momentum dependence of $v_2\{4\}$ shows a behavior similar to that measured in Pb+Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV.
- Good agreement is also found with the predictions of a hydrodynamic calculation for p+Pb collisions.
- The multi-particle cumulant results presented here provide additional evidence for the importance of final-state effects in the highest multiplicity p+Pb reactions which may lead to collective flow similar to that observed in the hot, dense system created in high-energy heavy-ion collisions.