Recent results on collectivity in small systems from ATLAS

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For the ATLAS Collaboration

Wealth of ATLAS results on small systems.*
In these 15 minutes, focus on one recent measurement.

Transverse momentum and process dependent azimuthal anisotropies in $\sqrt{s_{\mathrm{NN}}} = 8.16$ TeV p+Pb collisions with the ATLAS detector

ATLAS collaboration, G. Aad, [...] L. Zwalinski

The European Physical Journal C **80**, Article number: 73 (2020) | Cite this article

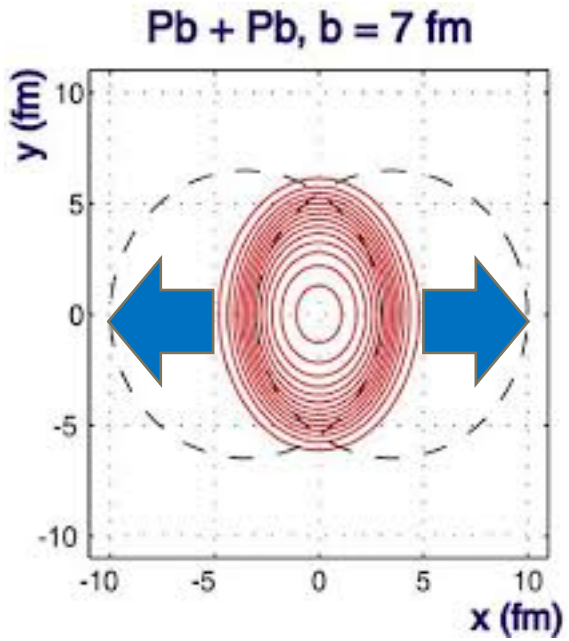
Kurt Hill Ph.D. Thesis: https://arxiv.org/abs/2004.07920

* https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults
HF muon+hadron correlations in 13 TeV pp, Phys.Rev.Lett. 124 (2020) 8, 082301
Z-tagged ridge in pp, Eur. Phys. J. C80 (2020) 1, 64
Photonuclear Ridge, ATLAS-CONF-2019-022
Azimuthal dijets in p+Pb, PRC 100 (2019) 034903
vn-pt correlations in 5.02 TeV Pb+Pb and p+Pb, Eur.Phys.J. C (2019) 12, 985

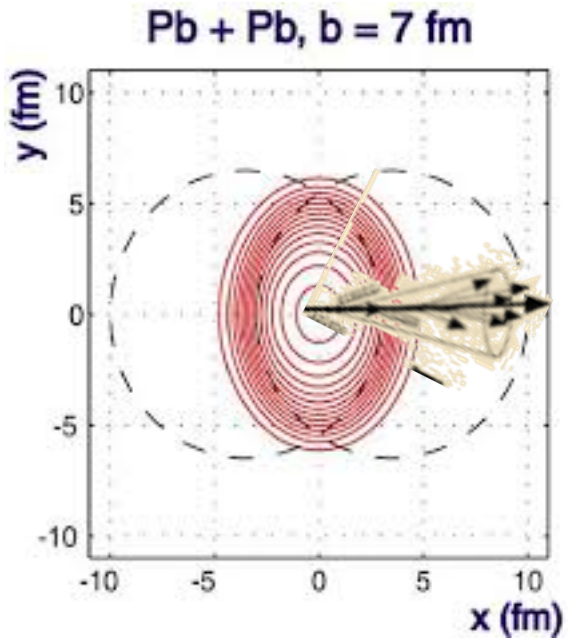
Key features of heavy-ion collisions

Hydrodynamic described "collectivity" of the bulk (p_T < 5-6 GeV)

Jet quenching, suppression of high p_T partons / jets / hadrons (p_T > 10-12 GeV)



steeper density gradients,
more bulk particles along x-axis



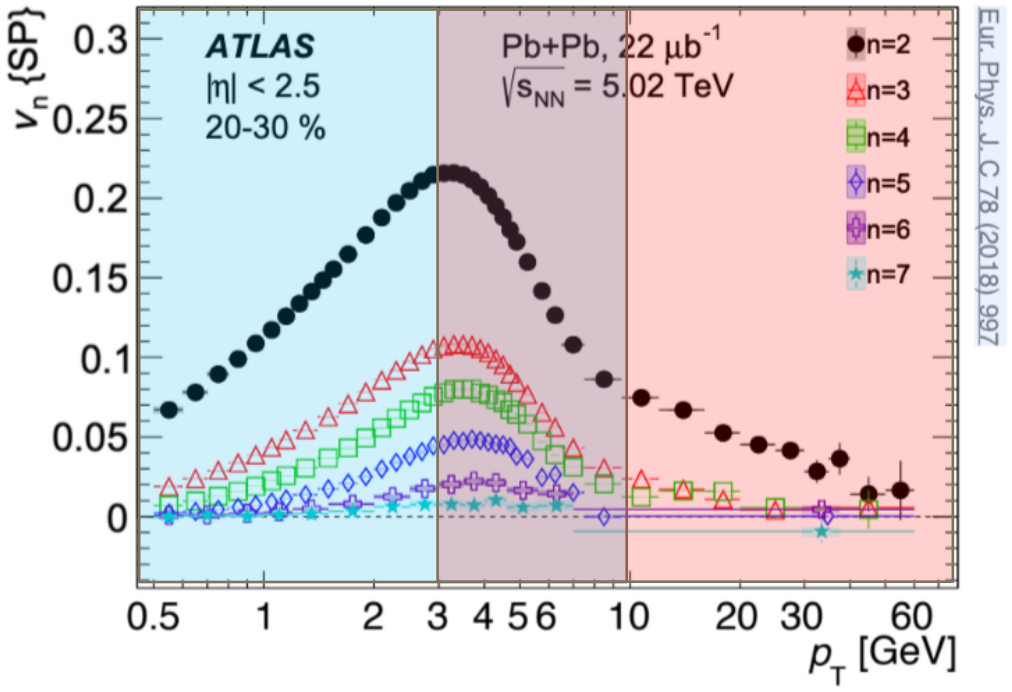
shorter path out of medium,
more jets along x-axis

Low p_T bulk particles are azimuthally correlated with high p_T jet particles

Azimuthal Correlations

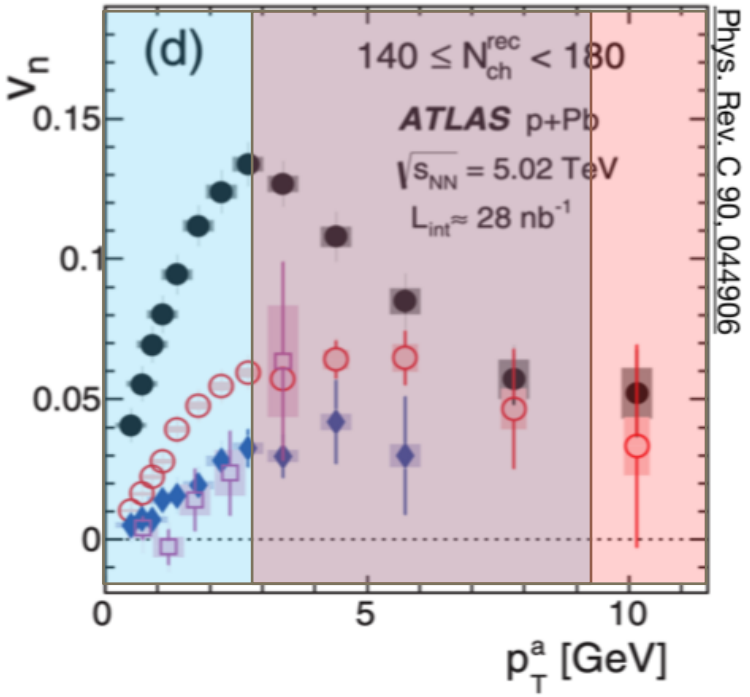
Pb+Pb Collisions

Hydrodynamics Transition Jet Quenching



p+Pb Collisions

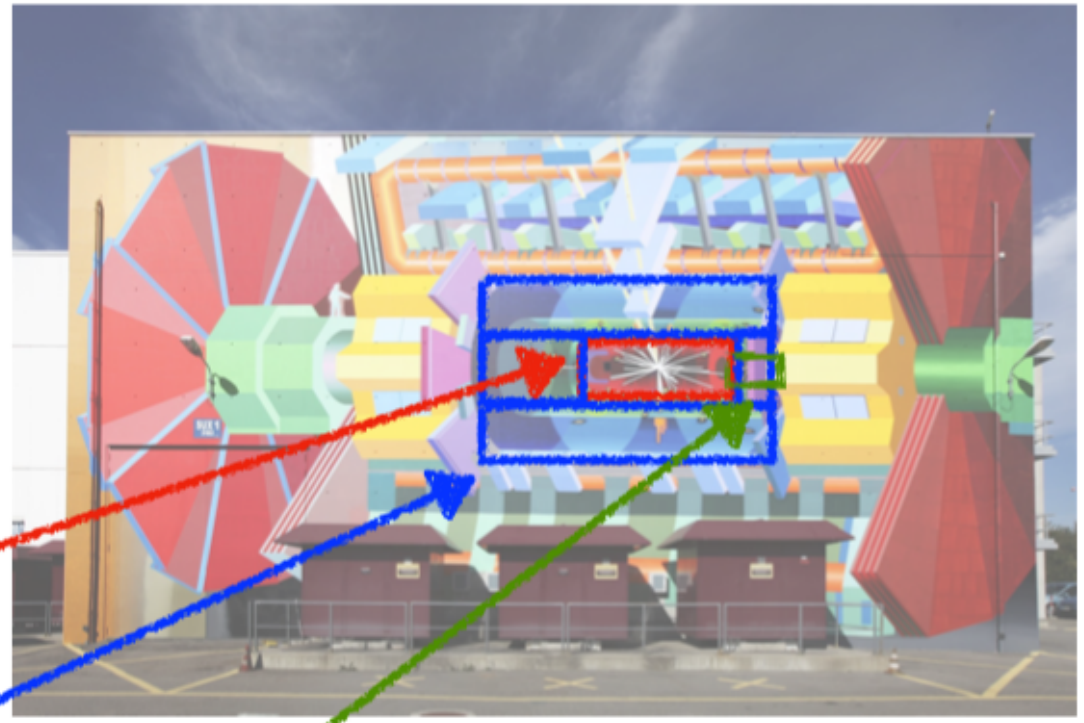
Jet Quenching?



Are low p_T (bulk) and high p_T particles azimuthally correlated in small systems, p+Pb?

ATLAS Analysis

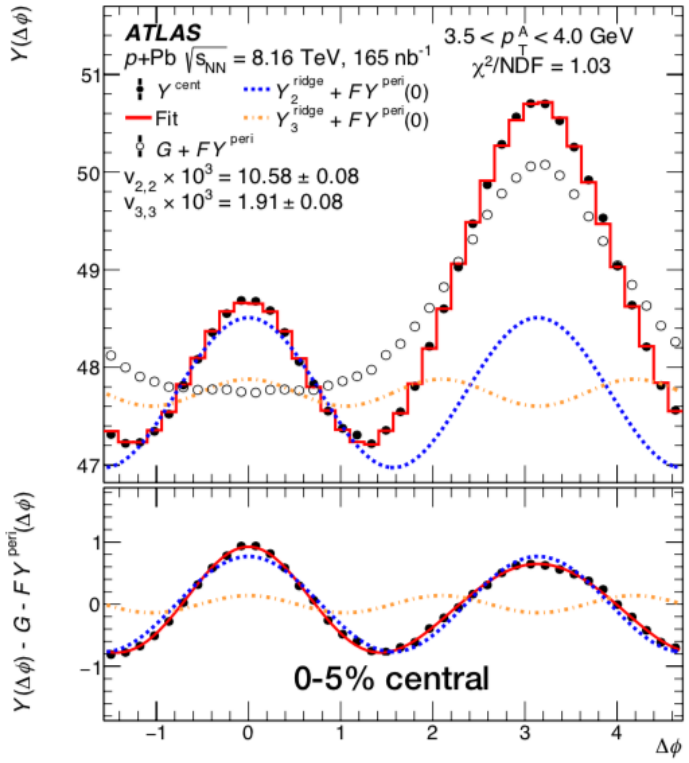
- 165 nb^{-1} of 8.16 TeV p+Pb data taken in 2016
- Select events with three different triggers
  - **Minbias**
  - Jet $p_T > 75$ GeV
  - **Jet $p_T > 100$ GeV**



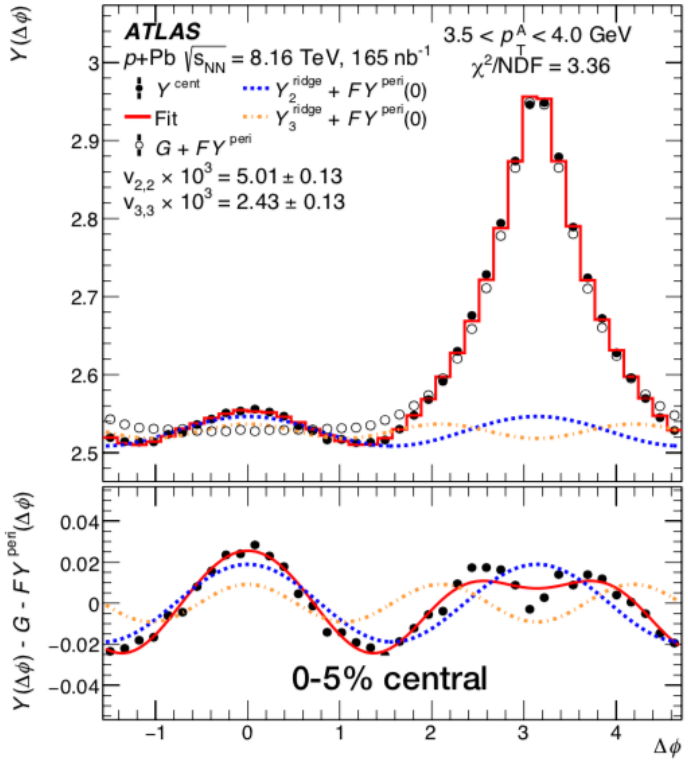
- Charged particles in tracker $|\eta| < 2.5$
- Jets in calorimeter: $|\eta| < 4.9$
- Centrality measured via ΣE_T in Pb-going FCal: $3.1 < \eta < 4.9$

p+Pb Two-Particle Correlations

Minimum Bias Events



Events with Jet > 100 GeV



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Jet events have much larger non-flow background. (small signal/background)

Standard subtraction of non-flow via template method leads to distortions.

SIGNAL "Bulk" particles with "flow" modulation

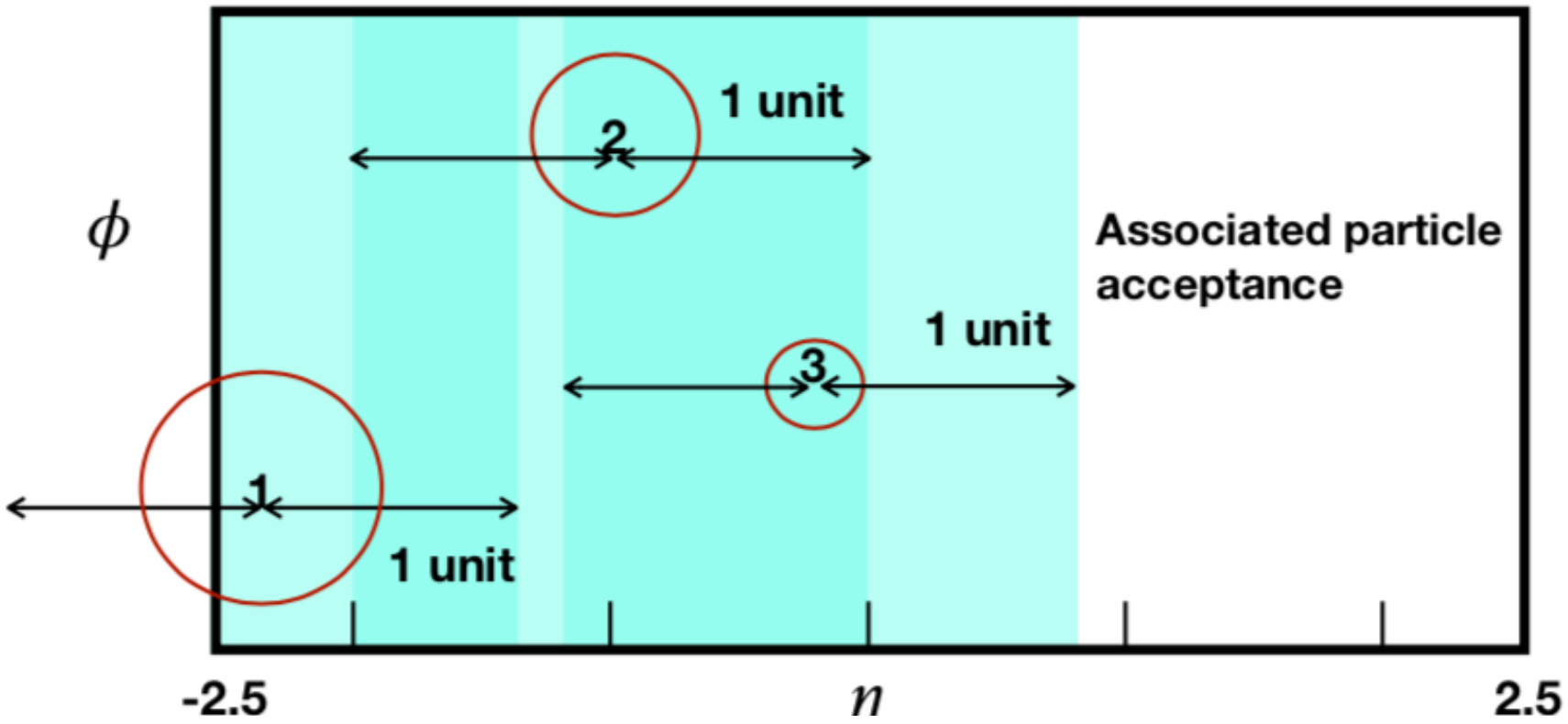
BACKGROUND "Jet" particles with "non-flow" modulation

Need to reduce background

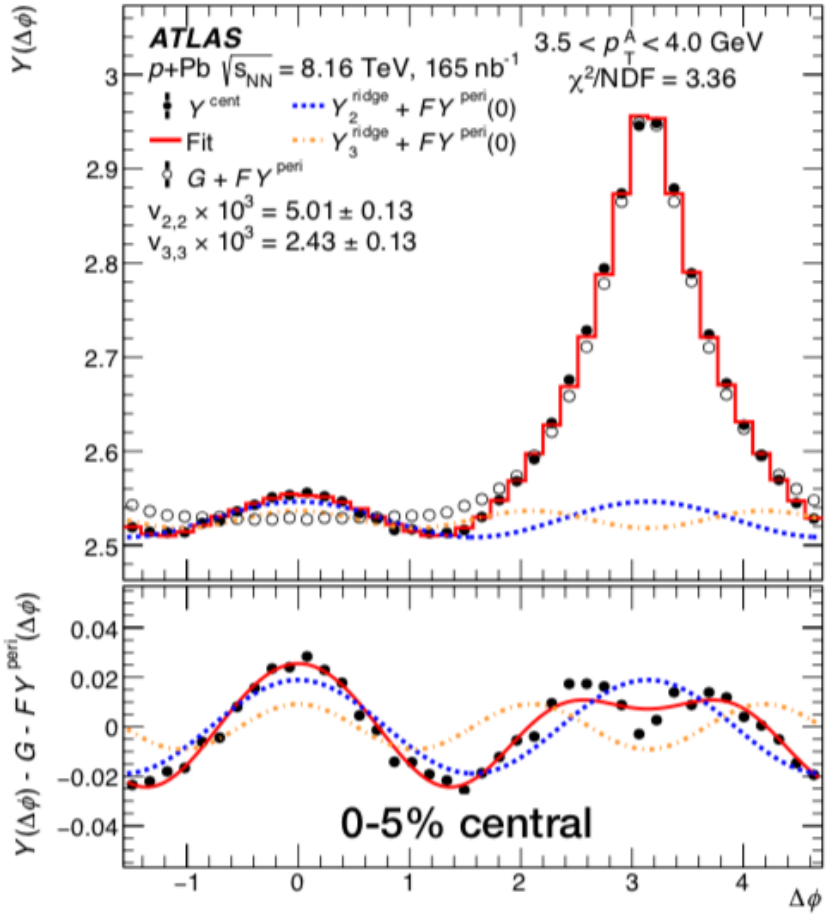
Restricting Associated Particles in Events with 100 GeV Jets

To reduce the non-flow impact of jet correlations:

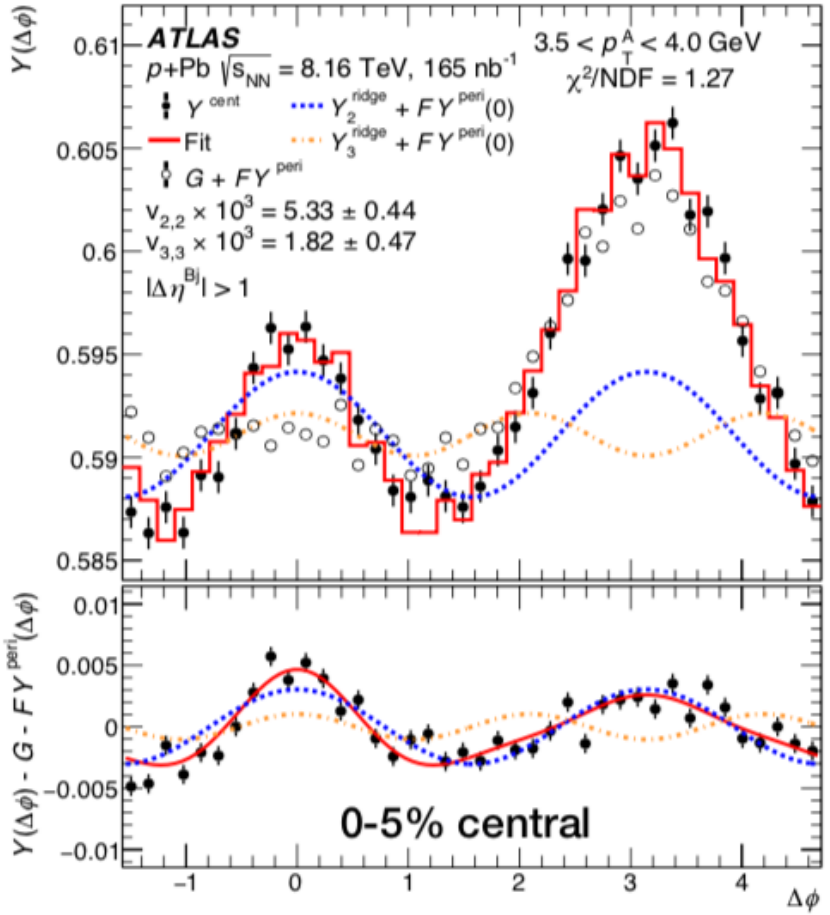
- associated particle must be $|\Delta\eta| > 2$ from the trigger particle
- associated particle must be $|\Delta\eta| > 1$ relative to all jets $p_T > 15$ GeV in the event



Before jet restriction



After jet restriction



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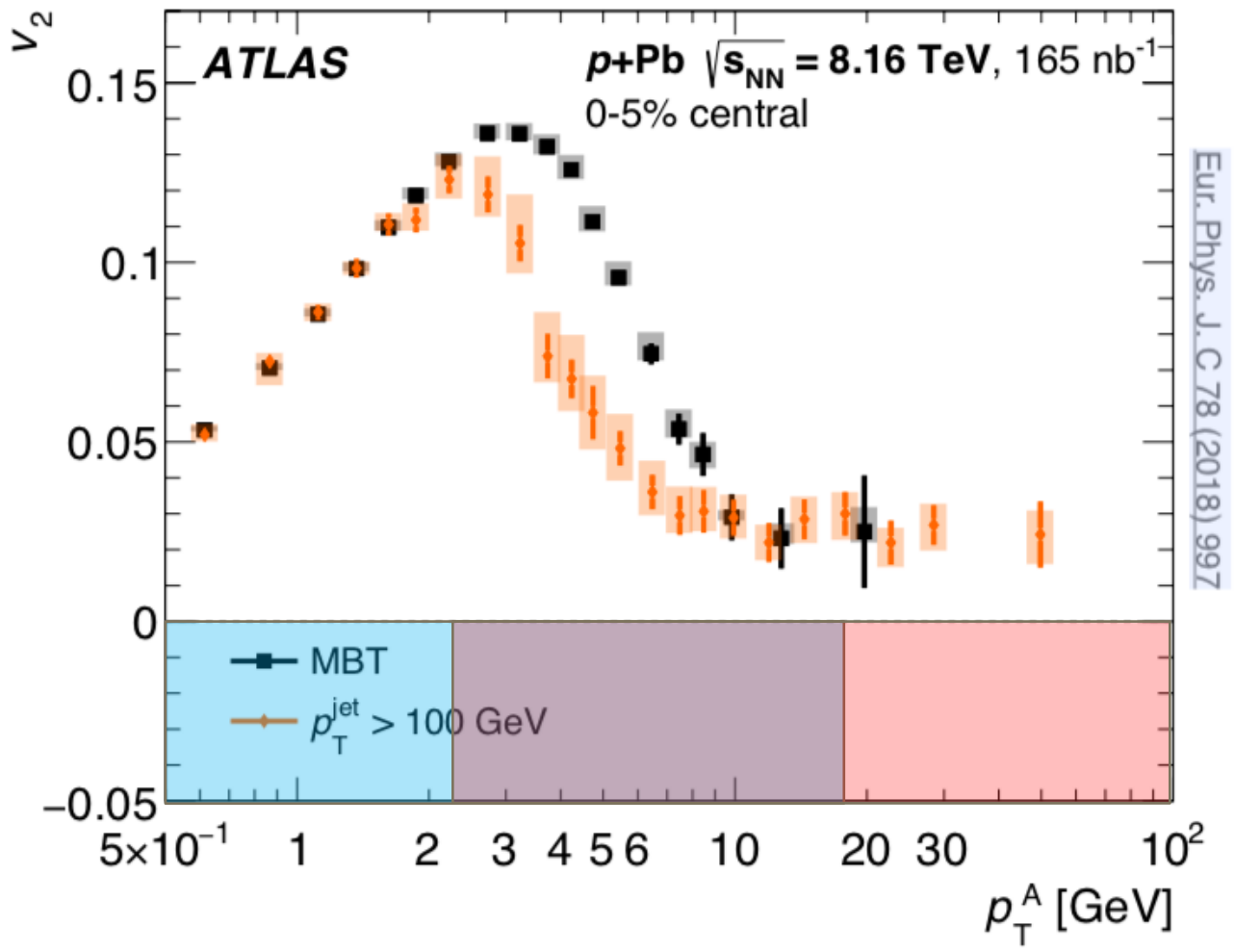
Jet rejection drastically improves 'signal-to-background'
Reduces sensitivity to template method assumptions

Physics Result



Low p_T "bulk" flow

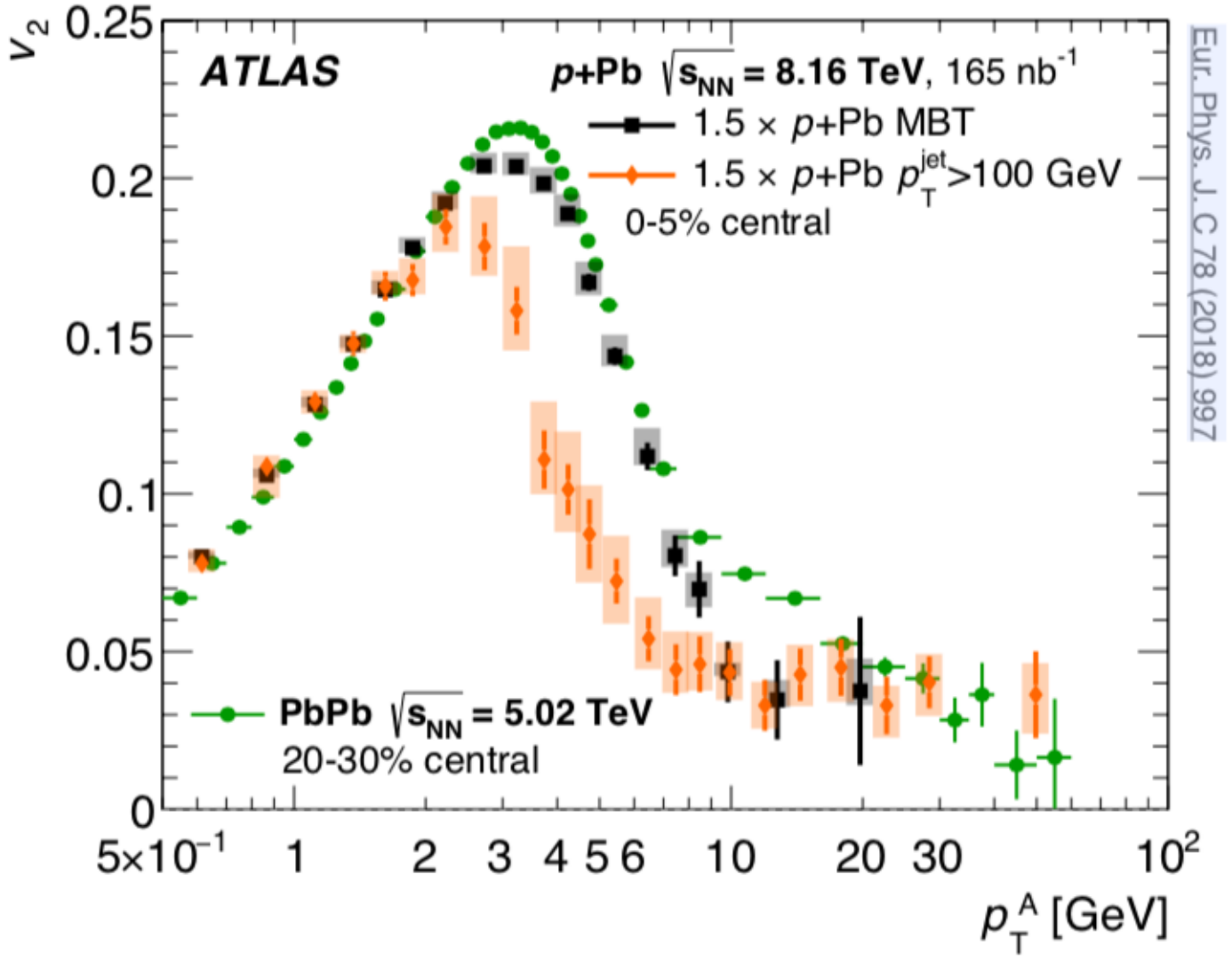
High p_T flow / jet quenching?

What is really measured is azimuthal correlation of low and high p_T particles.

Transition region, with differences in minimum bias and jet samples.

Systematic uncertainties shown as boxes with contributions from multiple sources.

p+Pb and Pb+Pb Comparison



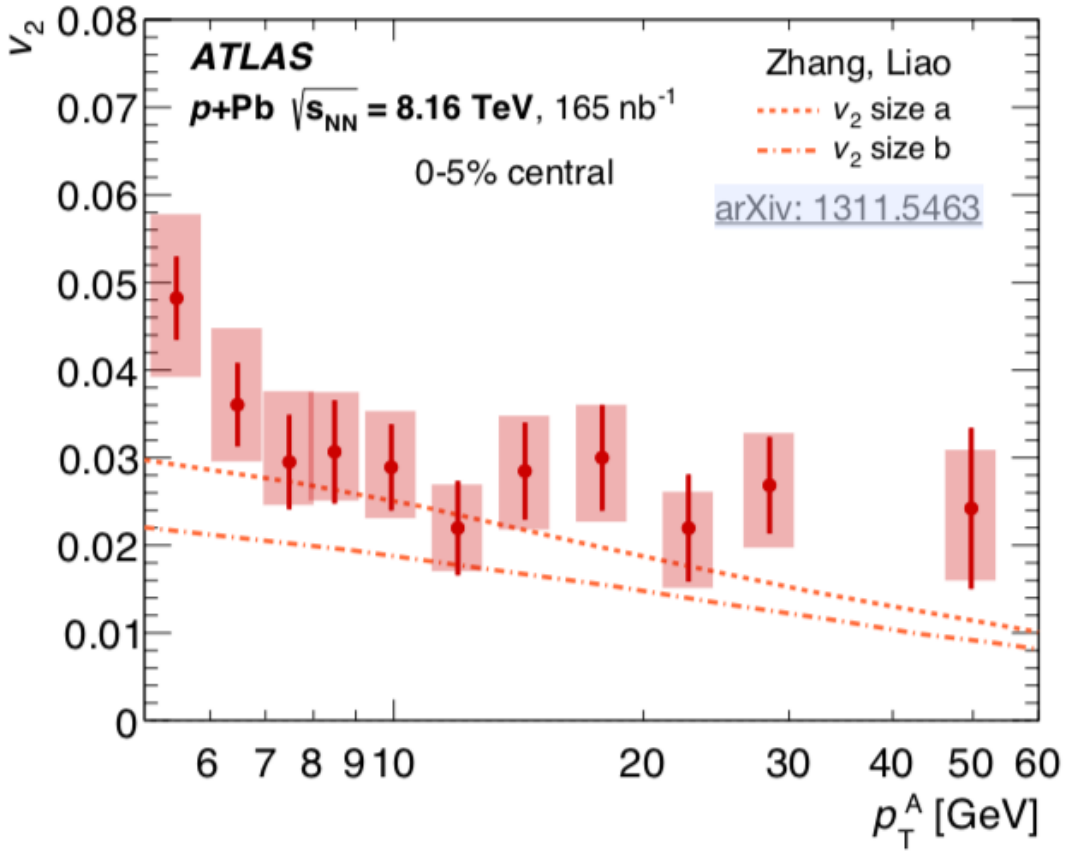
Pb+Pb and
p+Pb (scaled x1.5)
appear very similar

Common hydrodynamic explanation for $p_T < 4$ GeV?

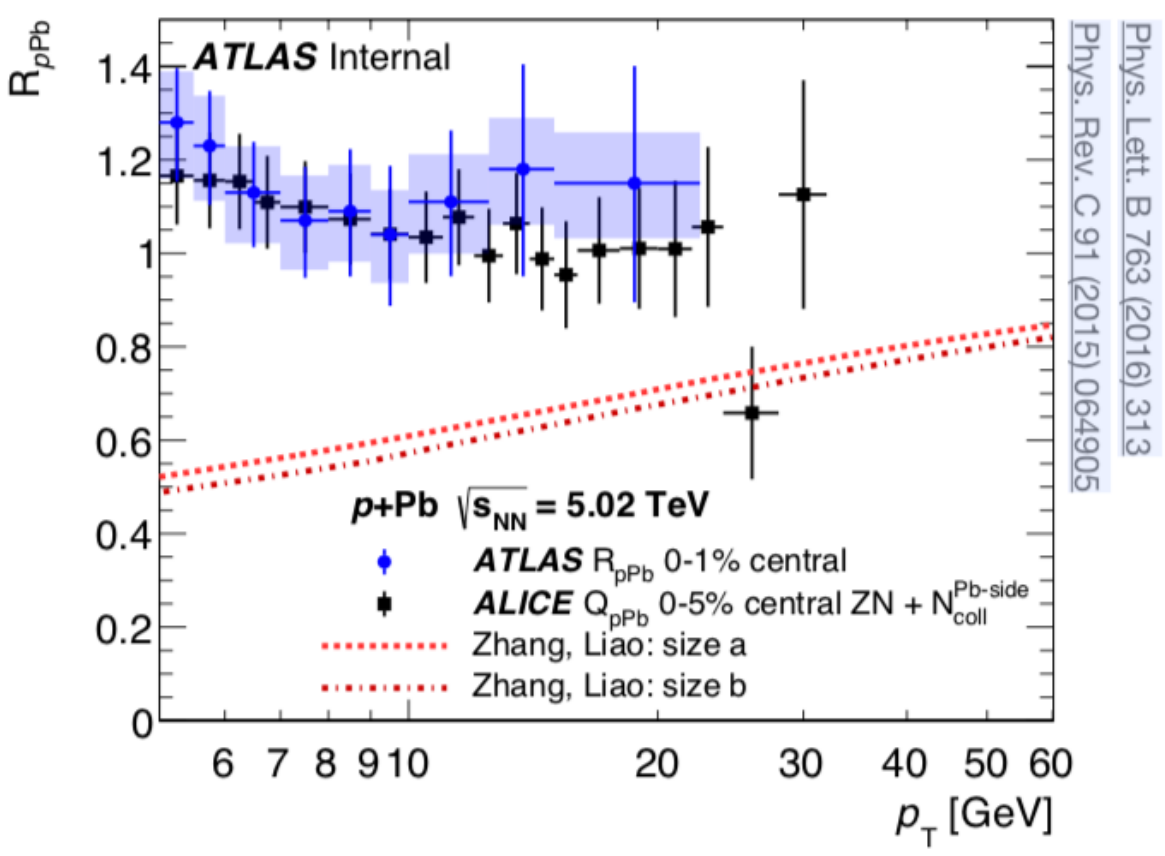
Common explanation for $p_T > 10$ GeV?

Jet Quenching Model for p+Pb

v_2



R_{pPb}

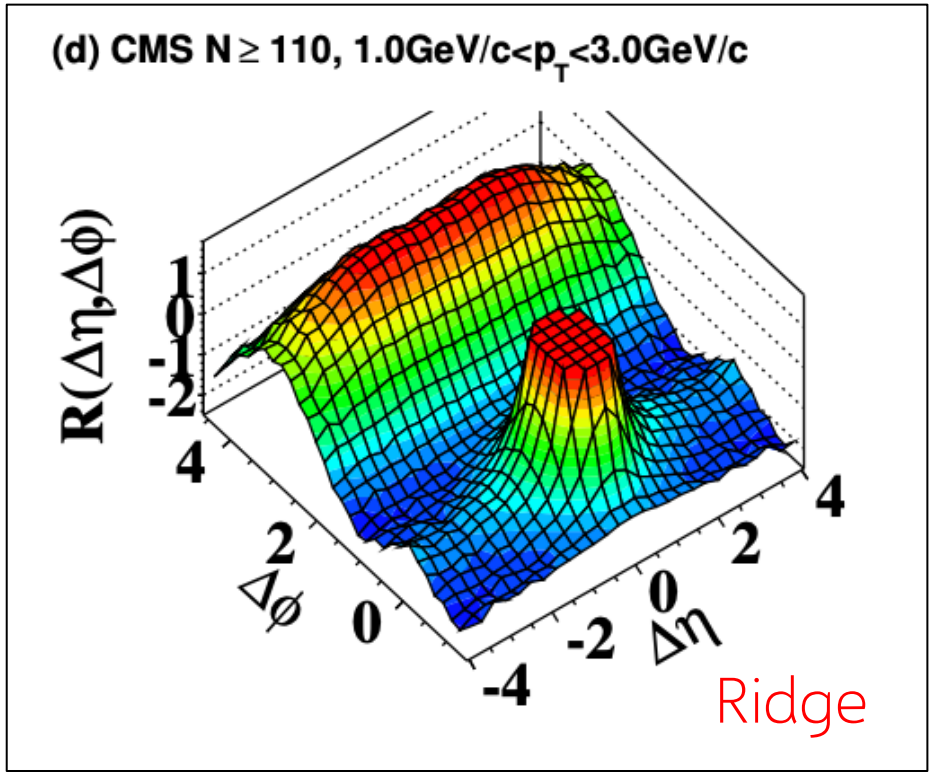


Cannot describe both azimuthal anisotropy and lack of change in p_T spectra

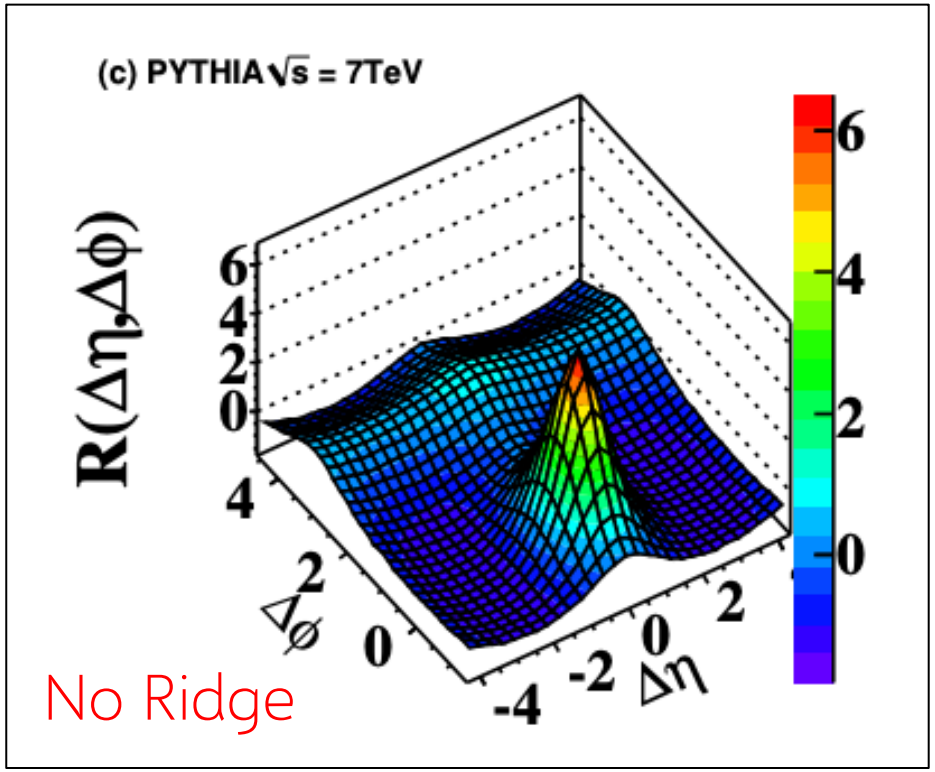
Initial State Effect Model?

A key check for the original pp "ridge" correlation observation by CMS was checking PYTHIA – *CMS Collaboration JHEP 09 (2010) 091*

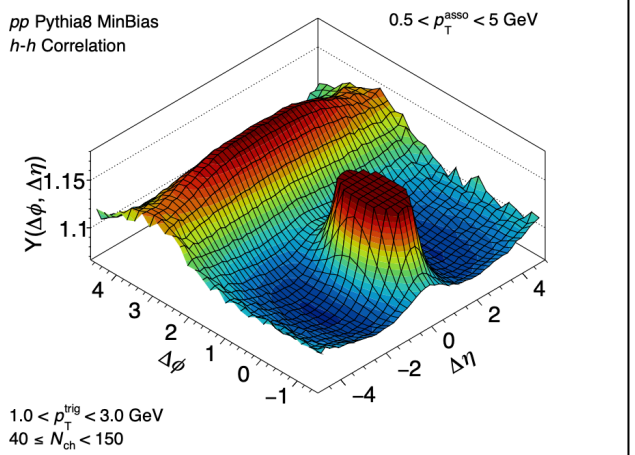
Data



PYTHIA

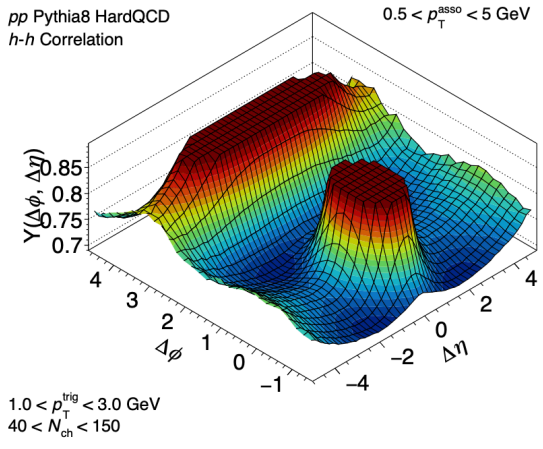


PYTHIA's revenge?



- SoftQCD:nonDiffractive

PYTHIA8 – no long-range ridge



- HardQCD
- pTHatMin = 15 GeV
- AntiKt R = 0.4 truth Jet filter of 60 < p_T < 160 GeV

PYTHIA8 – dijet events

PYTHIA initial-state radiation:

"SpaceShower::phiIntAsym" implementing azimuthal asymmetries in the radiation pattern from colour coherence considerations.

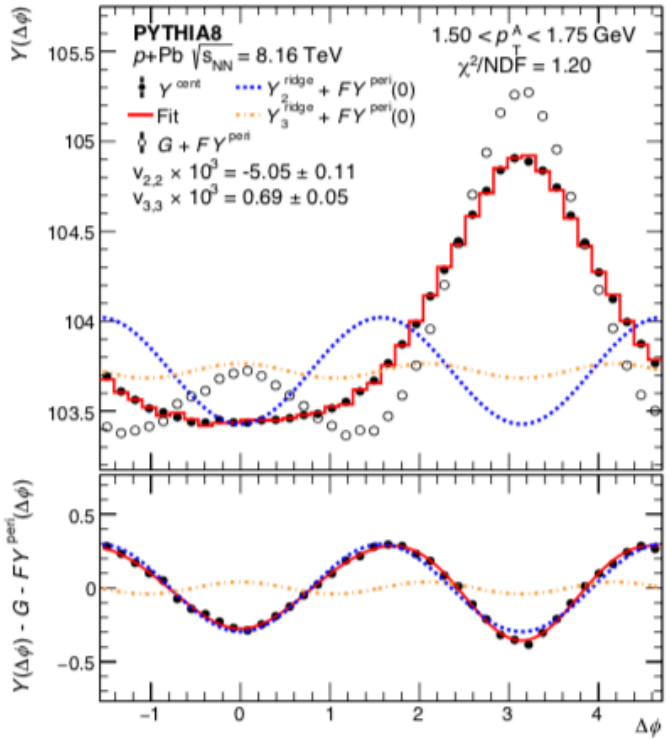
This is without the "string shoving" option!

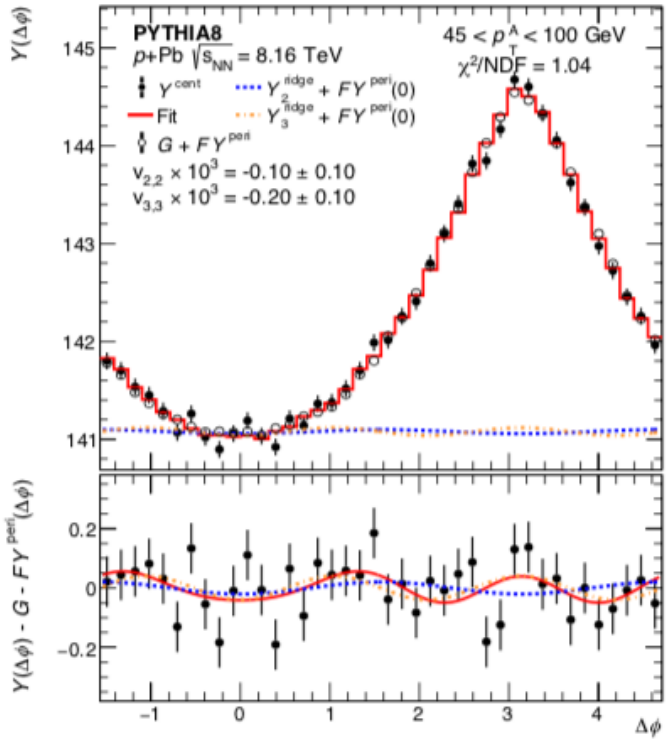
https://doi.org/10.1016/j.physletb.2018.01.069

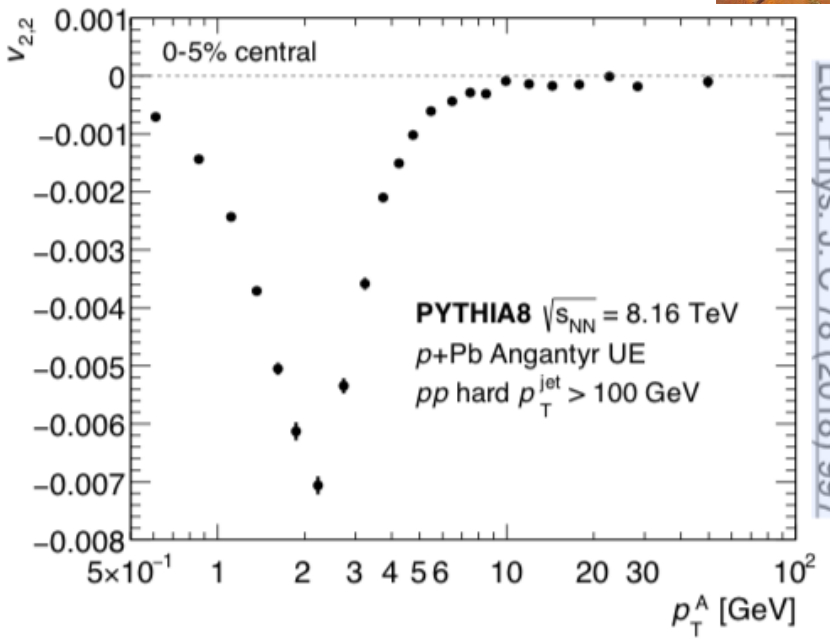
However, effect is biggest in LOW multiplicity events and is watered down in HIGH multiplicity events

Quantitative PYTHIA Angantyr Prediction

How can the Oracle of Delphi be wrong?







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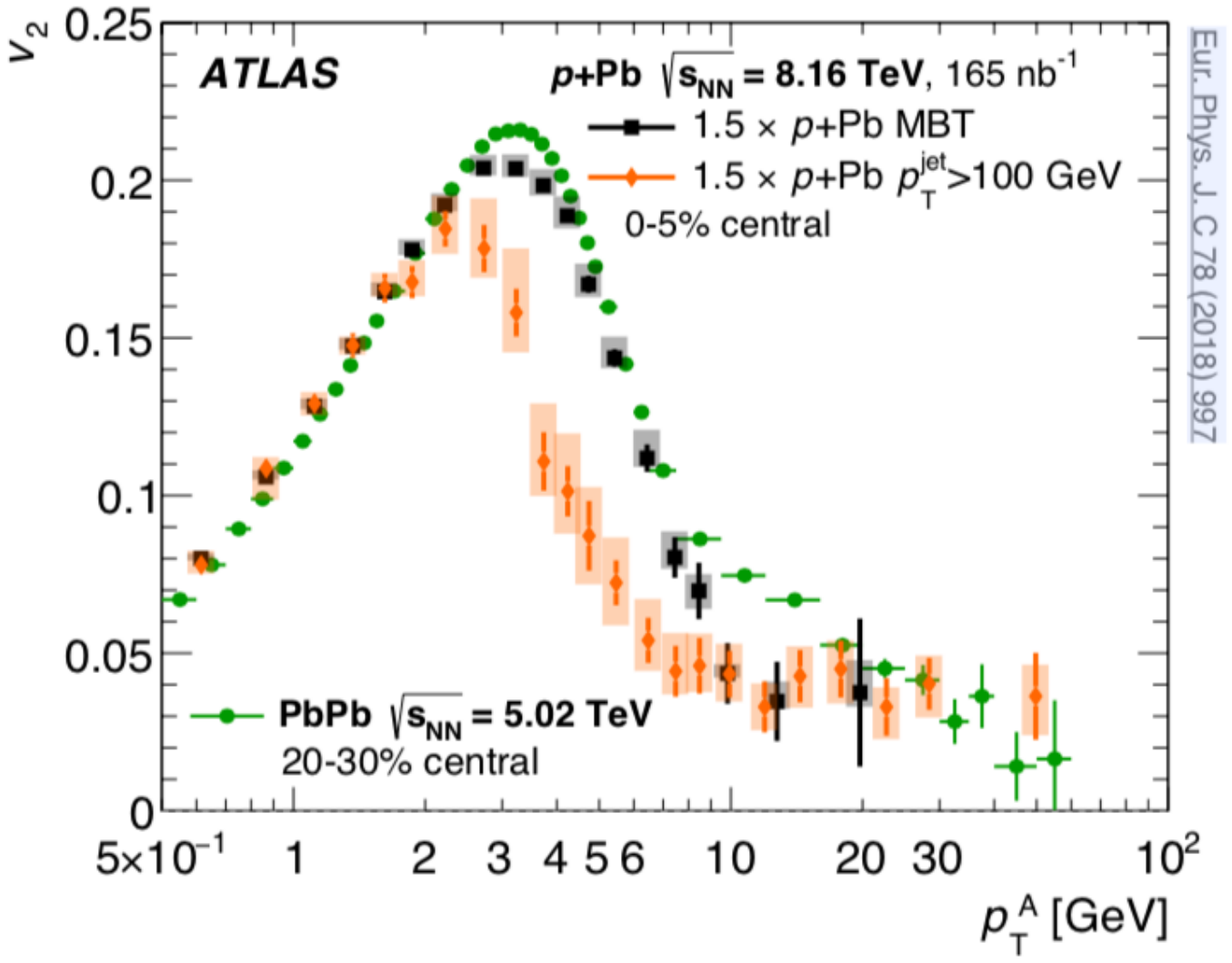
Because correlation is stronger in low-multiplicity, template subtraction yields negative correlation in high-multiplicity events. Opposite sign and trend from experimental data. Problem with any explanation involved n << N_{total} particles.

Summary



New ATLAS result in p+Pb

Definitive correlation of high and low p_T particles, where low p_T particle azimuthal anisotropy explained via hydrodynamics

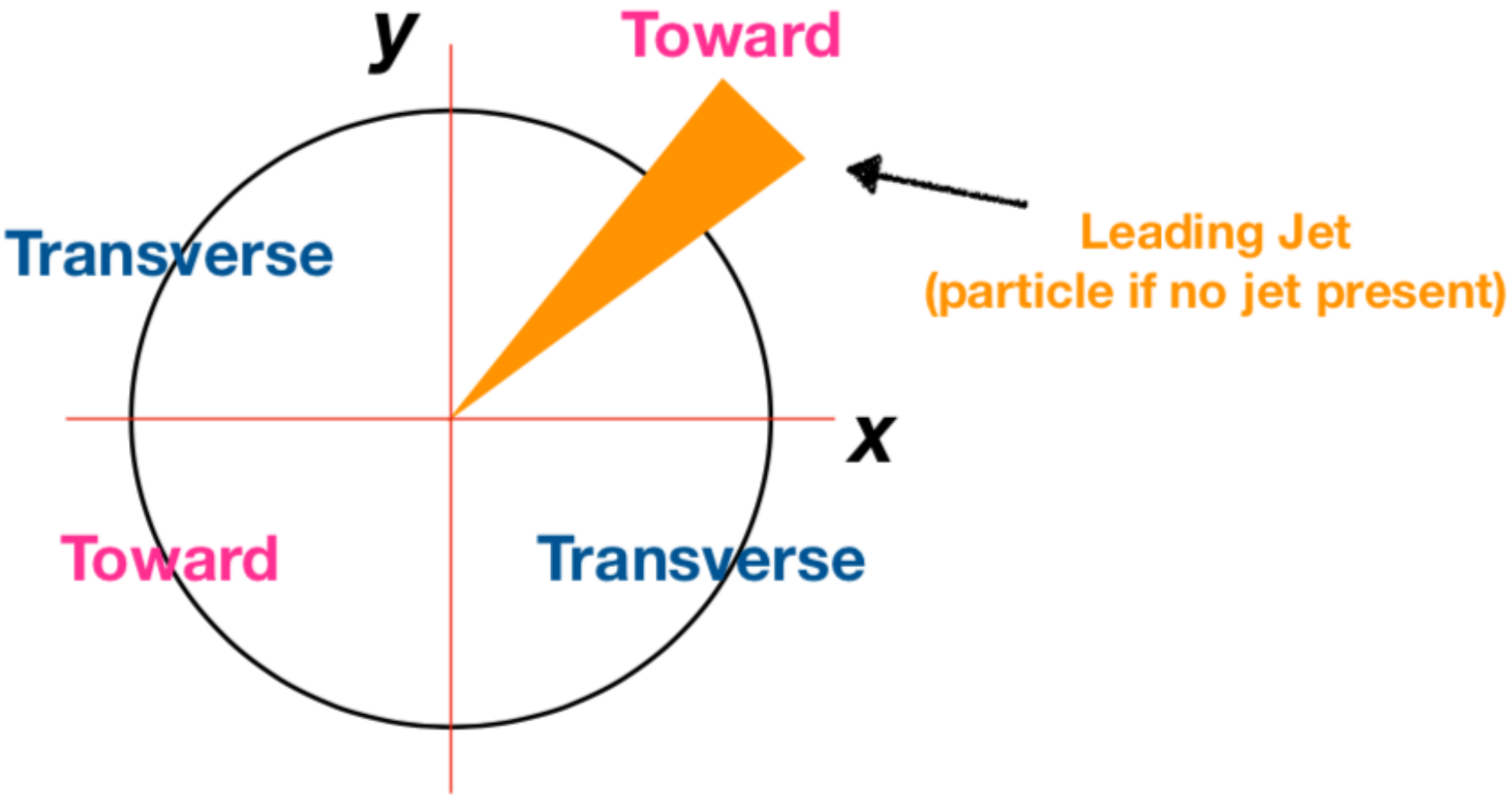
Fundamental conflicts with jet quenching and initial-state explanations.

Good puzzle ready to be solved.

Extra

Talk Logistics:
The talk is 15 + 3
The talk is in a parallel sessions with 4 talks all with the same title for theory, ALICE, CMS, and then ATLAS (this talk).
https://indico.cern.ch/event/856696/sessions/330883/#20200528

Jet and bulk particle yield

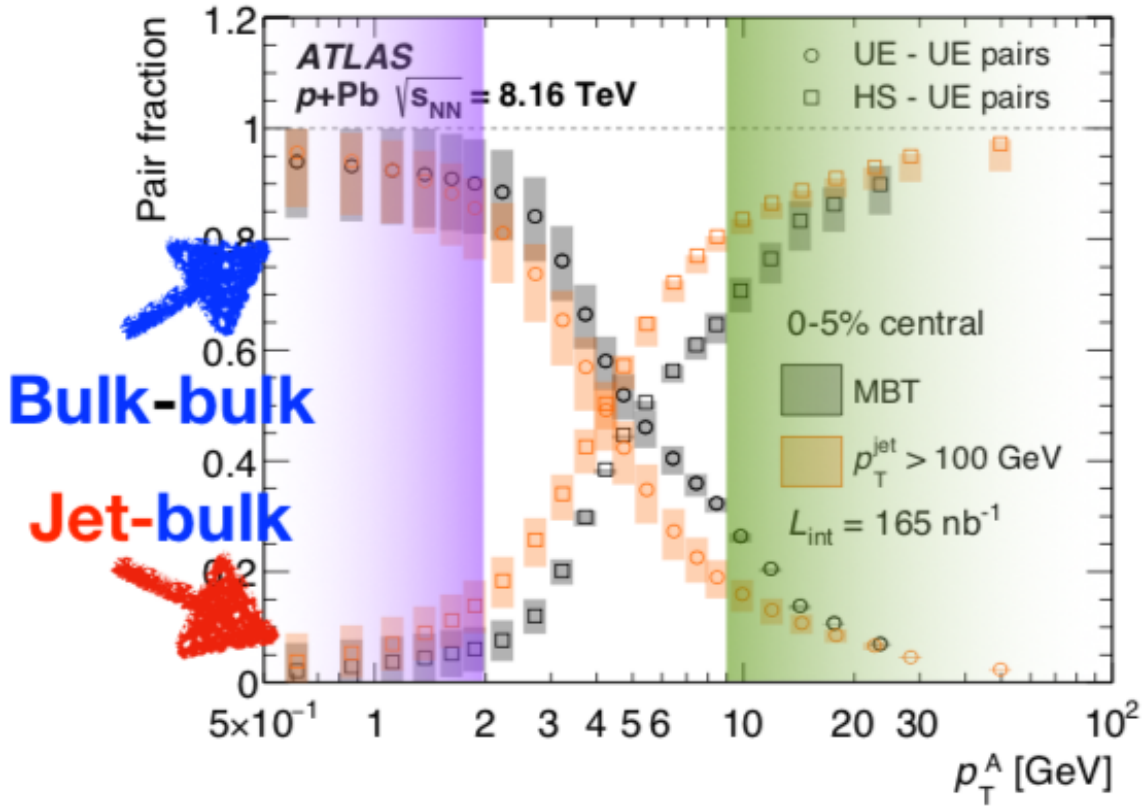


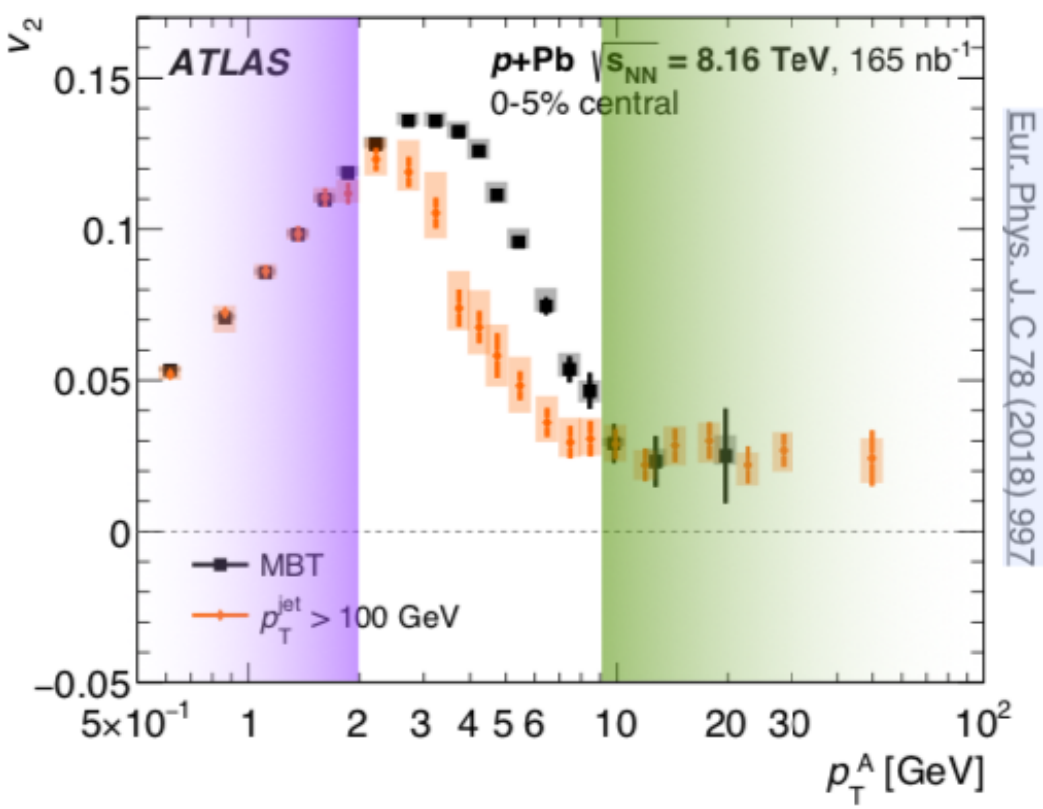
Assume:

1. **Transverse** has only **bulk** particles
2. **Toward** has both **bulk** *and* **jet** particles

→ Solve for yield of **bulk** and **jet**

Particle pair composition





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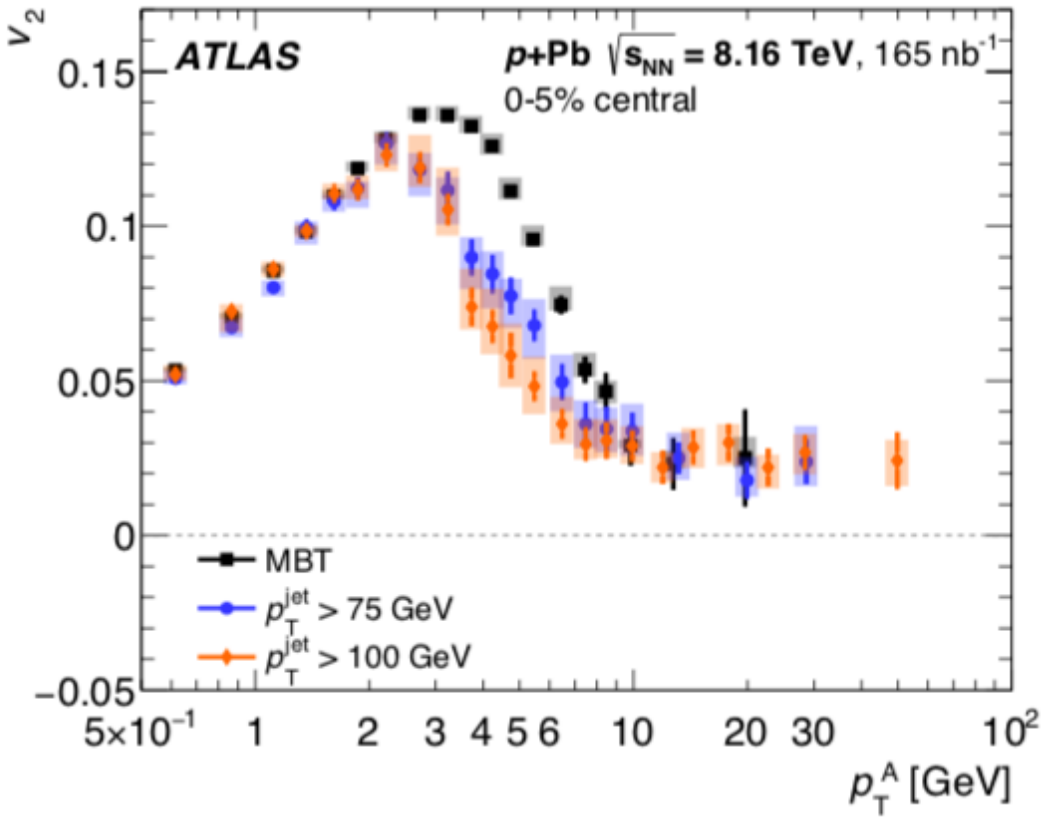
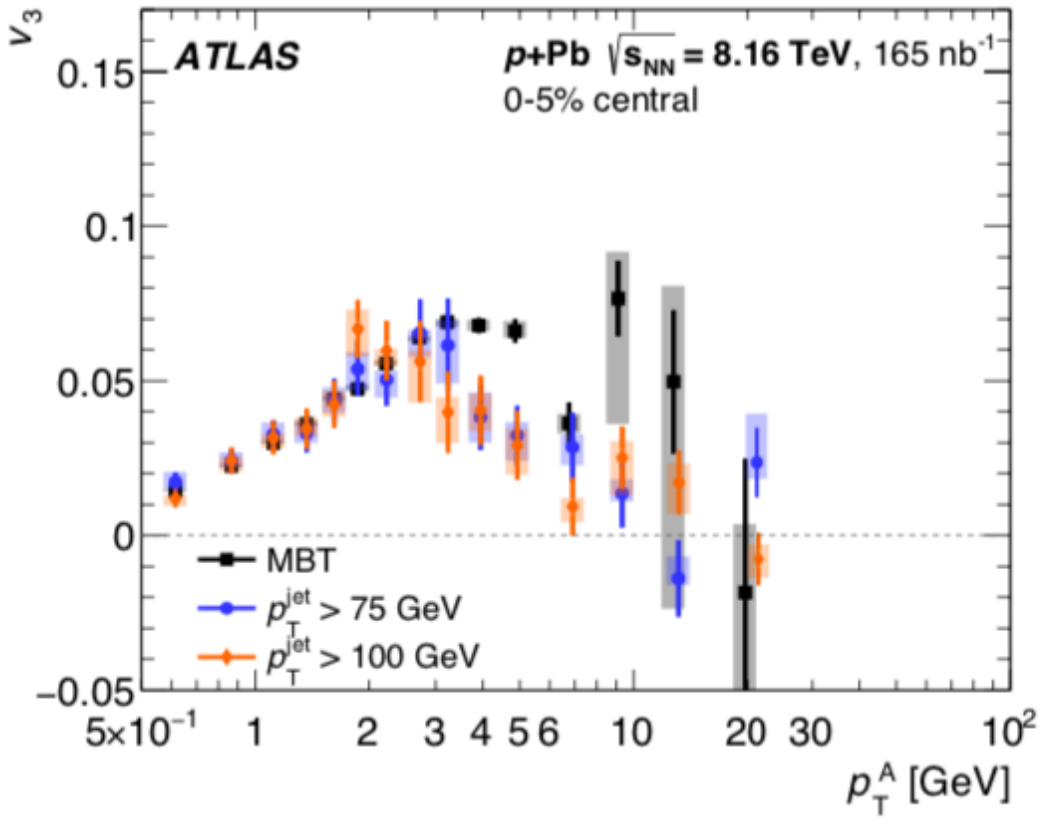
- Associated particles highly likely to be from **bulk**
- *Low* and *high* p_T dominated by **bulk** and **jet** particles respectively

p_T dependent v_n results

v_2



v_3



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- Both v_2 and v_3 show similar behavior between MB and jet events
  - Consistency at *low* and *high* p_T
  - *Transition* to high p_T behavior happens at *lower* p_T for jet events