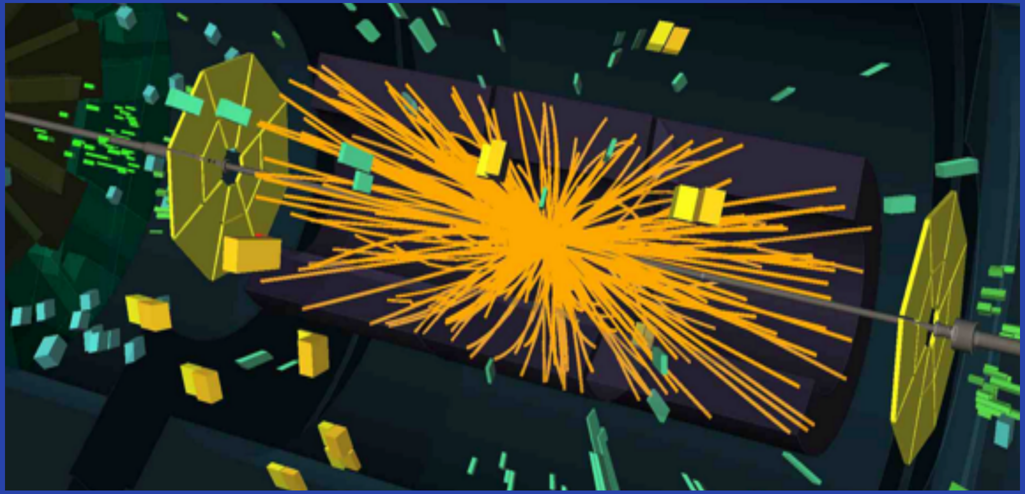
New Results Related to QGP in Small Systems with ATLAS



Adam Trzupek on behalf of the ATLAS experiment
Institute of Nuclear Physics PAS

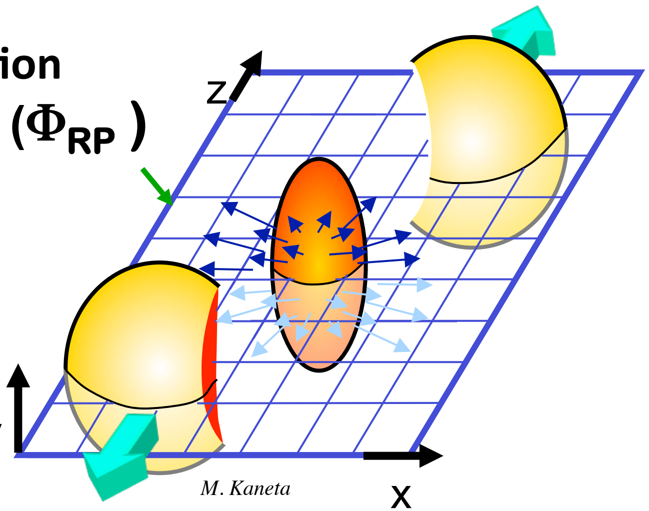
The fourth annual Large Hadron Collider Physics Conference (LHCP2016)

Lund, Sweden, 13th - 18th June 2016

Ridge in Pb+Pb

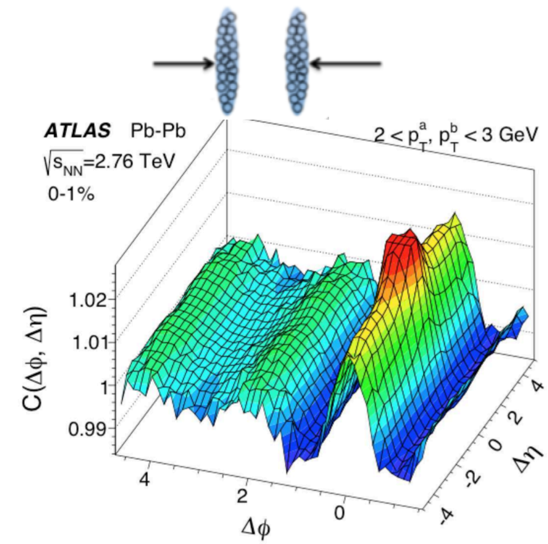
Strongly interacting QGP

Reaction plane (Φ_{RP})



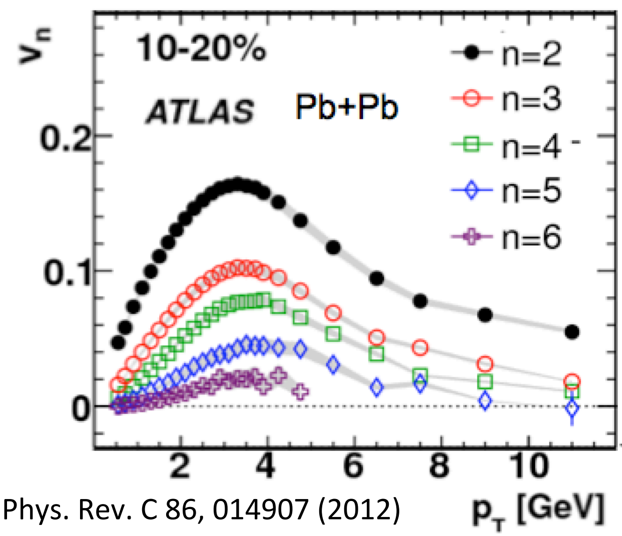
Pressure gradients lead to azimuthal anisotropy

$$v_n = \langle \cos(n(\phi - \Phi_{RP})) \rangle$$



Pb+Pb

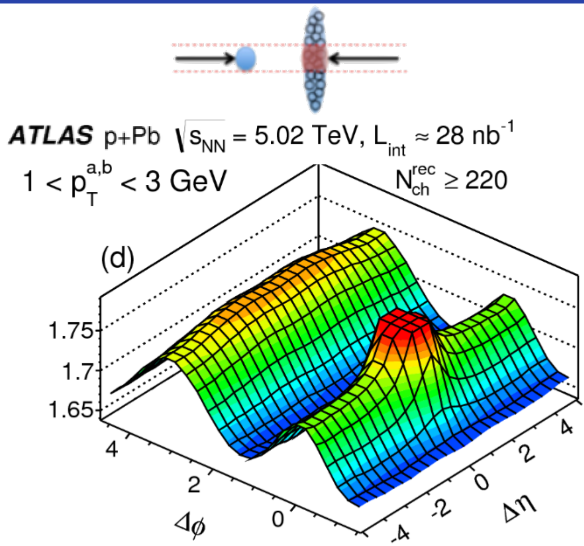
$$C \sim 1 + 2\,\Sigma_n\, v_n^2 \cos n\Delta\phi.$$



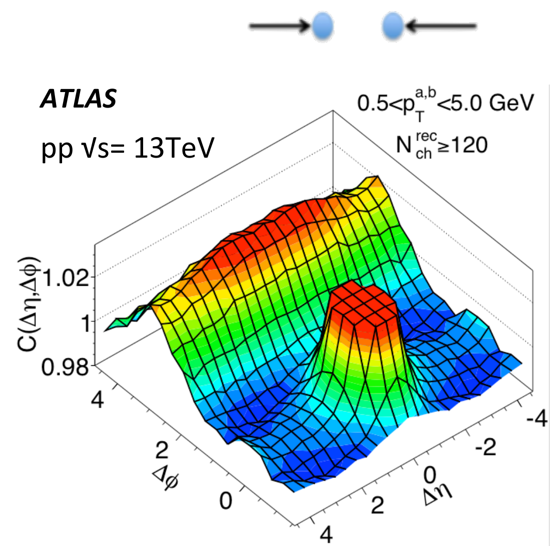
Phys. Rev. C 86, 014907 (2012)

Single-particle v_n was measured

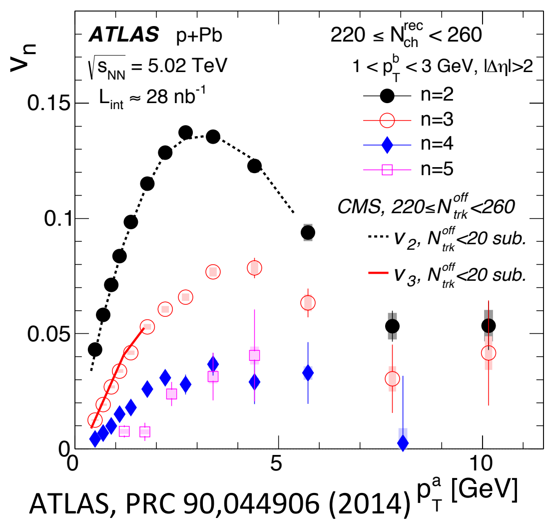
Ridge in p+Pb and pp Collisions



p+Pb ridge



pp ridge

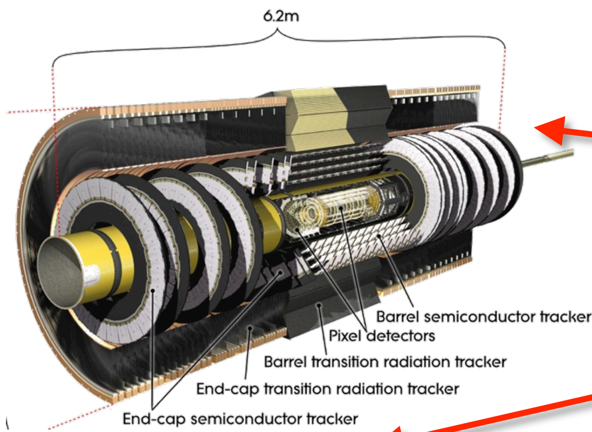


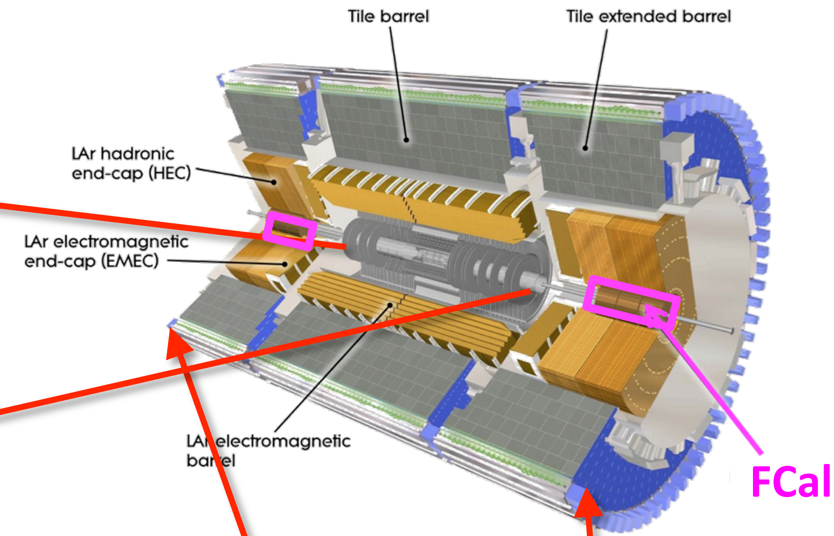
v_n was measured

ATLAS PRL 116, 172301 (2016)
ATLAS-CONF-2016-026 - v_n in 2.76, 5.02 and 13 TeV pp were measured

Strongly interacting QGP in small systems?

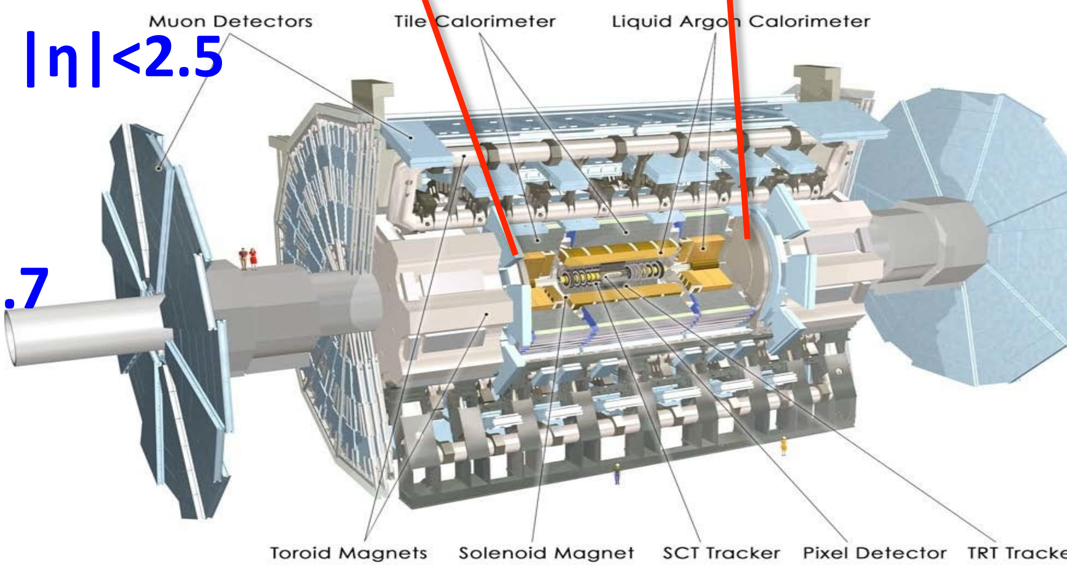
ATLAS Detector





Three main subsystems:

- **Inner Detector (ID)–tracking |η|<2.5**
- **Calorimetry – |η|<4.9**
  - **FCal 3.1<|η|<4.9**
- **Muon Spectrometer - |η|<2.7**



Fast trigger systems:

- **Level 1 (L1)**
- **High Level Trigger (HLT)**

High Multiplicity Triggers in pp and p+Pb Collisions

In addition to minimum bias triggers, High Multiplicity Triggers (HMT) are used

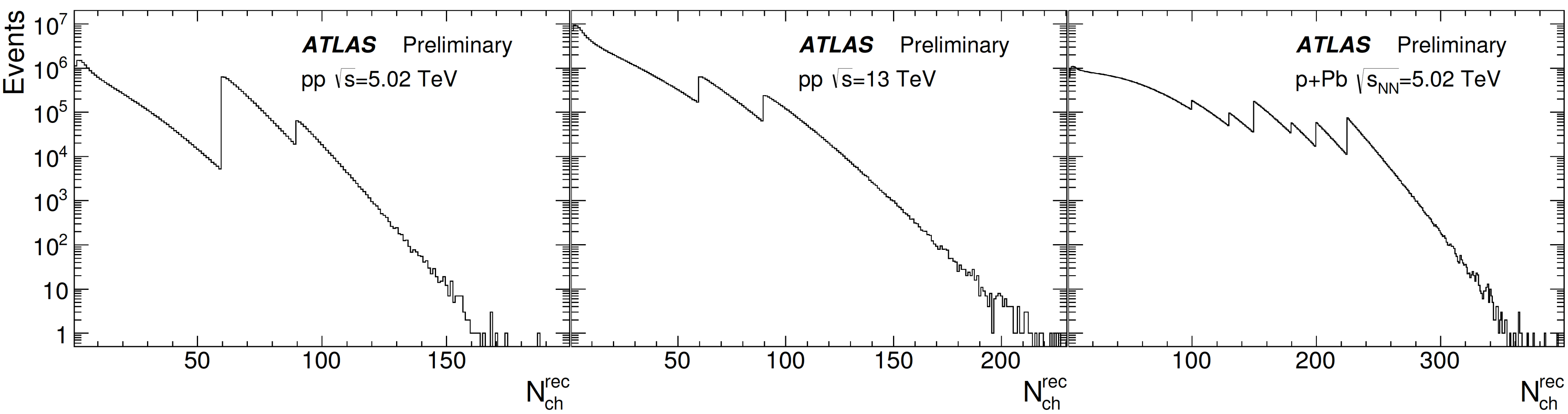
- p+Pb collisions
  - six HMT triggers
- pp collisions
  - N_{ch}^{rec} > 60, > 90

Event activity :

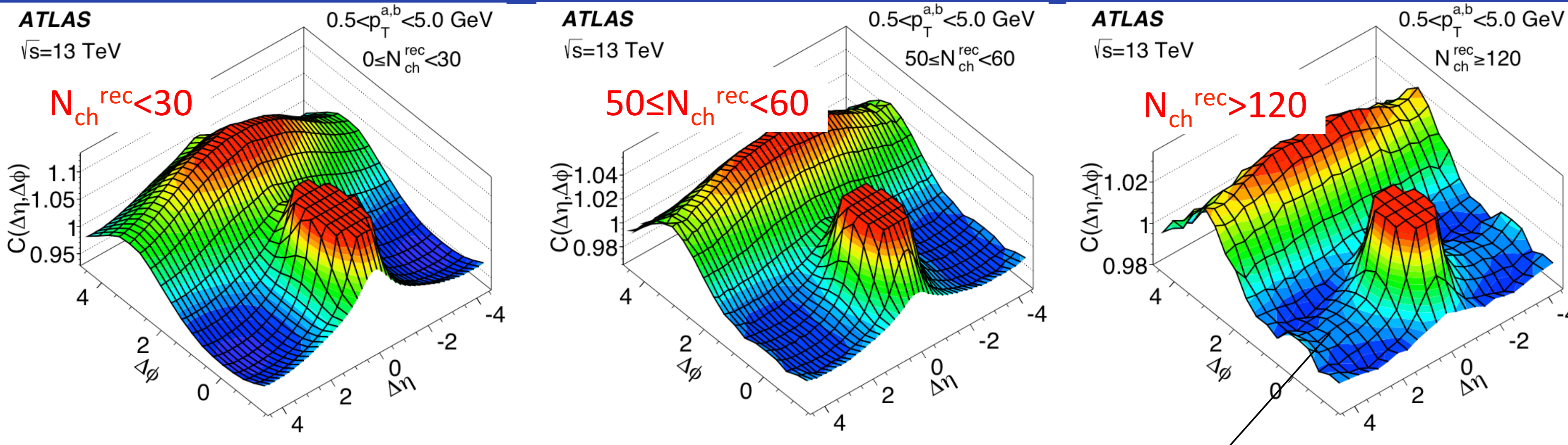
- For p+Pb collisions, both E_T^{Pb} in the FCal on Pb-going side and the number of charged particles with p_T > 0.4 GeV in ID, N_{ch}^{rec} are used
- For pp collisions, only N_{ch}^{rec} is used

ATLAS-CONF-2016-026, ATLAS, PRL 116, 172301 (2016)

N_{ch}^{rec} - number of tracks at primary vertex



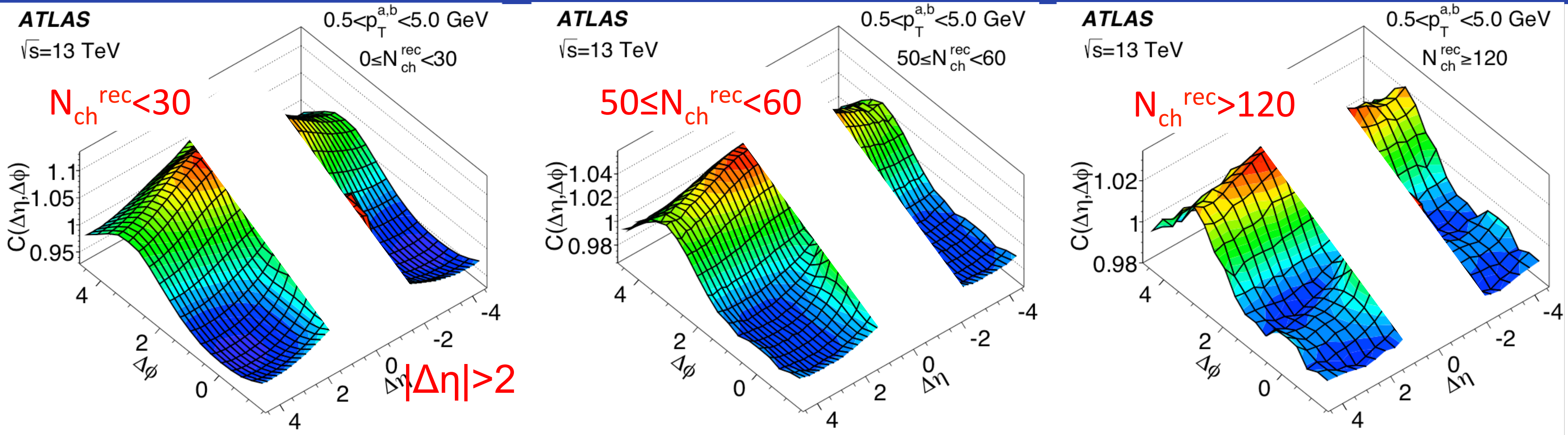
Two-particle Correlations in 13 TeV pp



ATLAS, PRL 116, 172301 (2016)

near-side ridge

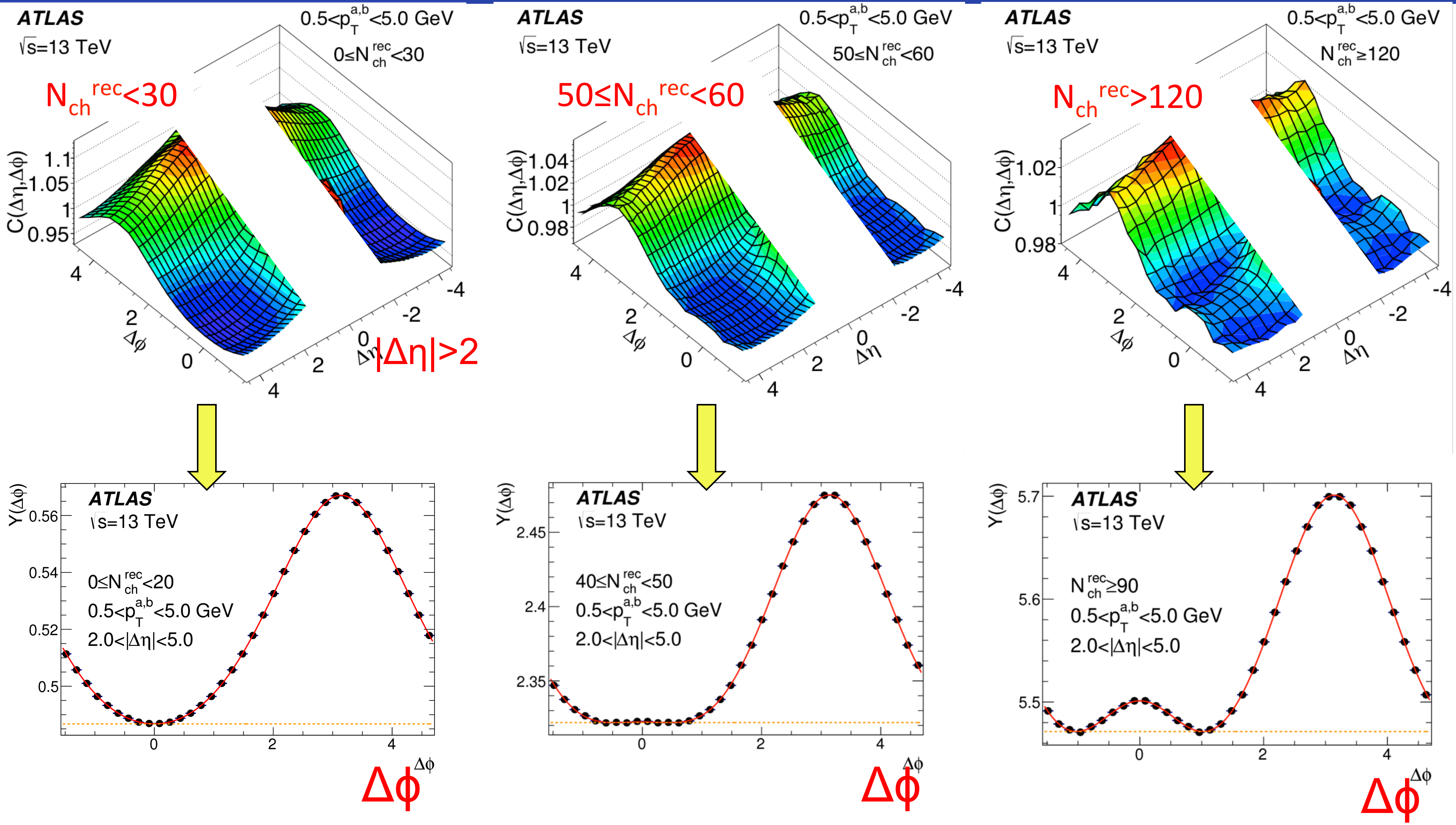
Two-particle Correlations in 13 TeV pp



To quantify the strength of the ridge, the "per-trigger-particle yield" is defined as:

$$Y(\Delta\phi) \equiv C(\Delta\phi) \times \left(\frac{\int B(\Delta\phi) d\Delta\phi}{N^a \int d\Delta\phi} \right)$$

Two-particle Correlations in 13 TeV pp



With increasing N_{ch}^{rec}, the minimum at Δϕ = 0 fills in, and the "ridge " peak appears and increases

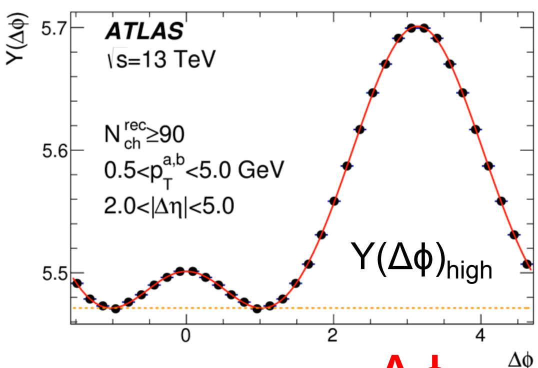
Two-particle Correlations in 13 TeV pp

Template fit function:

$$Y(\Delta\phi)_{\text{high-mult}} \cong F\,Y(\Delta\phi)_{\text{low-mult}} + G\,(1 + 2\Sigma v_{n,n}\cos(n\Delta\phi))$$

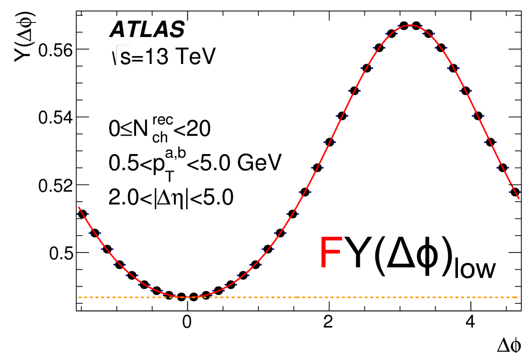
$N_{ch}^{rec}<20$

azimuthal modulation



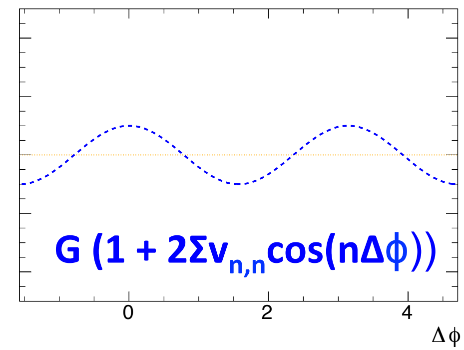
Δφ

=



Δφ

+



Δφ

Template-fitting method

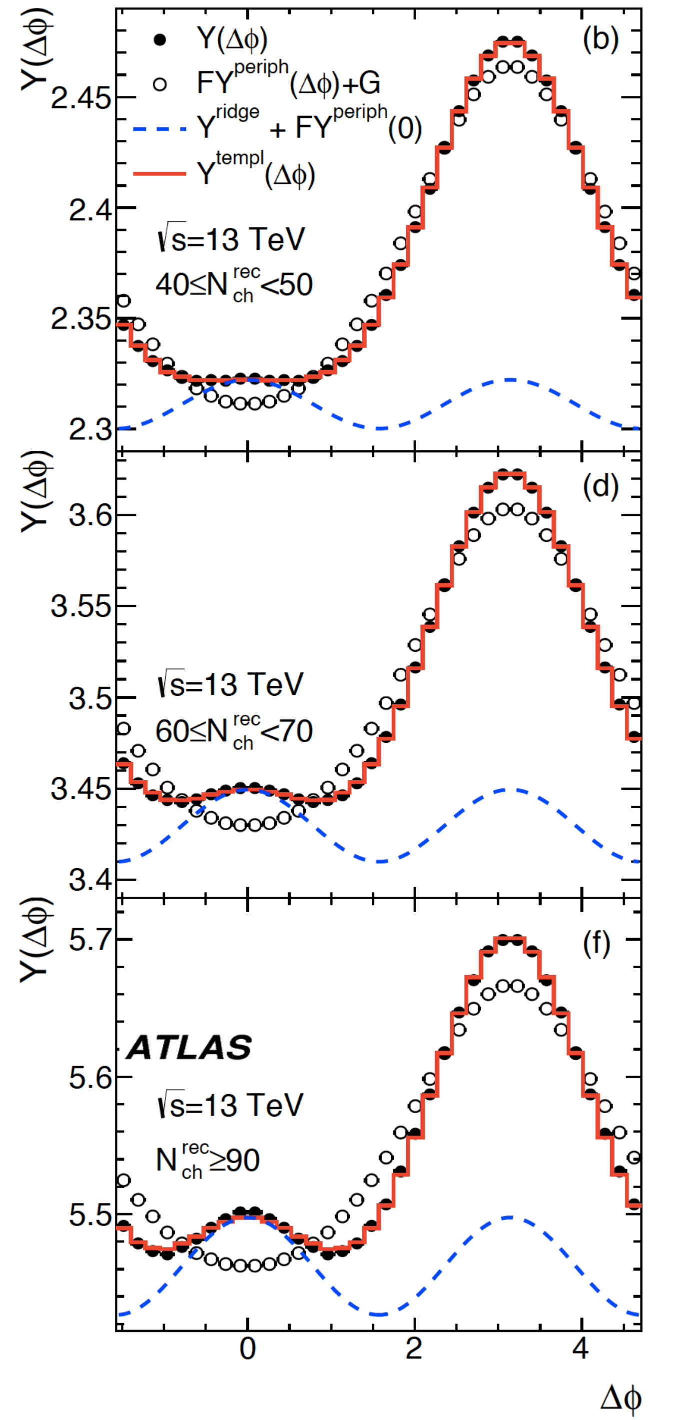
ATLAS, PRL 116, 172301 (2016)

Fit function successfully describes Y distributions in all N_{ch}^{rec} intervals

If $v_{n,n}\cos(n\Delta\phi)$ modulation arises from modulation of the single-particle ϕ distributions, then $v_{n,n}$ should factorize:

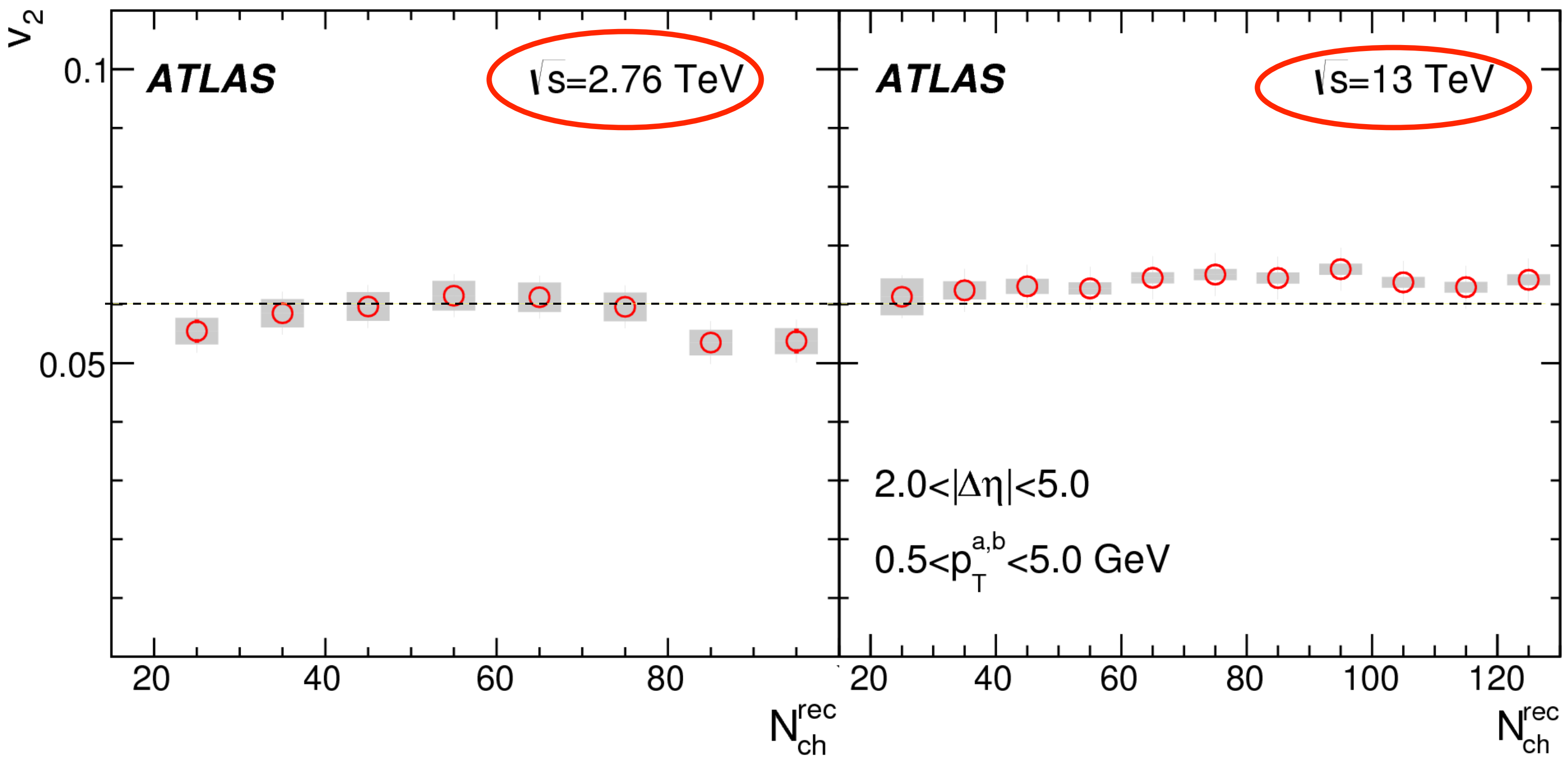
$$v_{n,n} = v_n v_n$$

The factorization was cross-checked in different p_T-ranges



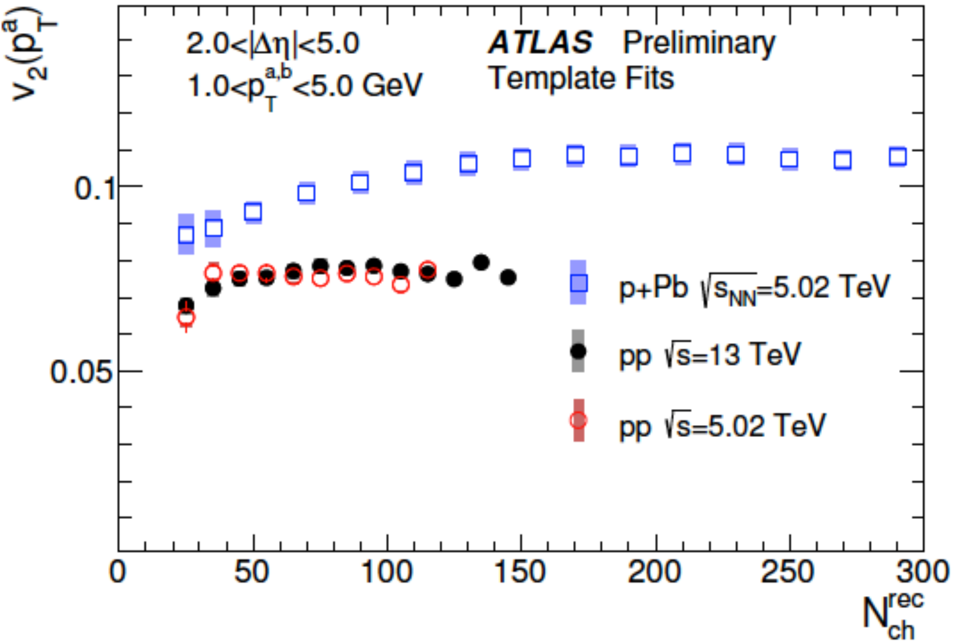
Energy and N_{ch}^{rec} Dependence of v_2

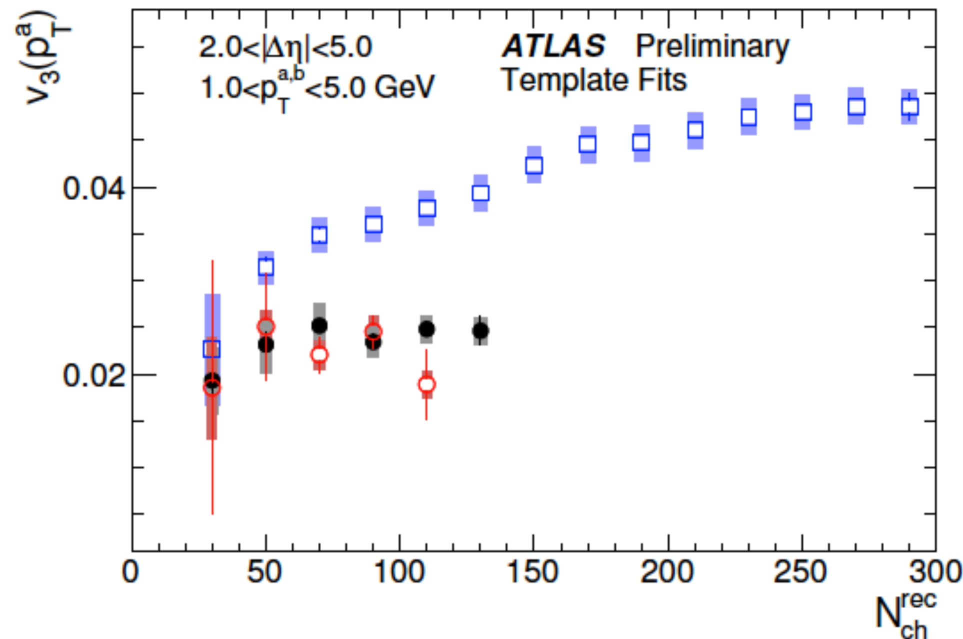
ATLAS, PRL 116, 172301 (2016)



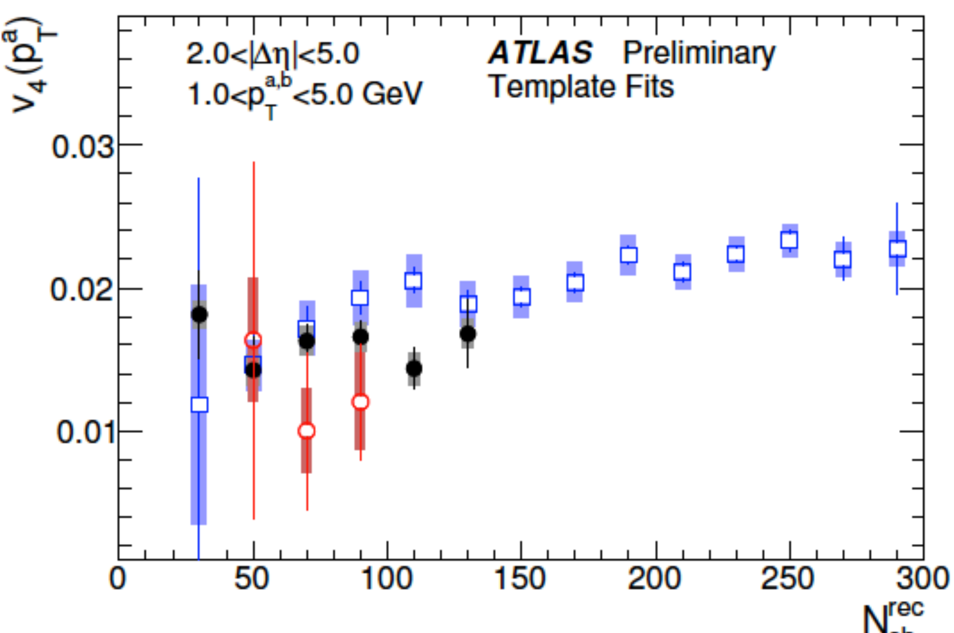
- **First measurements with the new template fitting method showed that v_2 very weakly depends on energy and multiplicity in pp collisions**

System Size, Energy and N_{ch}^{rec} Dependence of v_n





ATLAS-CONF-2016-026

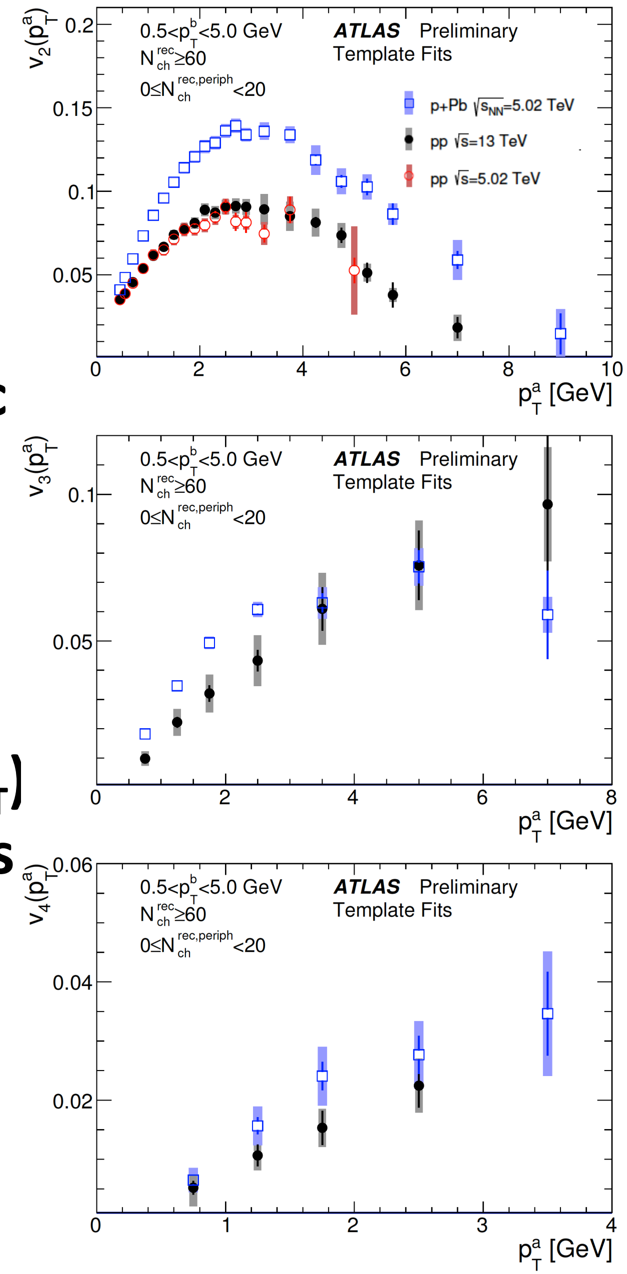


- v_n^{pp} very weakly depends on energy and multiplicity
- v_n^{pp} and v_n^{p+Pb} are similar at low multiplicity, but v_n^{p+Pb} increases with N_{ch}^{rec}
- $v_2 >> v_3 >> v_4$ for all systems

p_T Dependence of v_n

$$v_2(p_T^a) = v_{2,2}(p_T^a, p_T^b) / \sqrt{v_{2,2}(p_T^b, p_T^b)}$$

- $v_2(p_T)$ shows a rise & fall, trend characteristic for collective flow observed in PbPb
- $v_2(p_T)$ in 5.02 and 13 TeV pp collisions agree
- $v_{3,4}(p_T)$ in p+Pb collisions are similar to $v_{3,4}(p_T)$ in 13 TeV pp collisions but a faster increase is observed for p+Pb system



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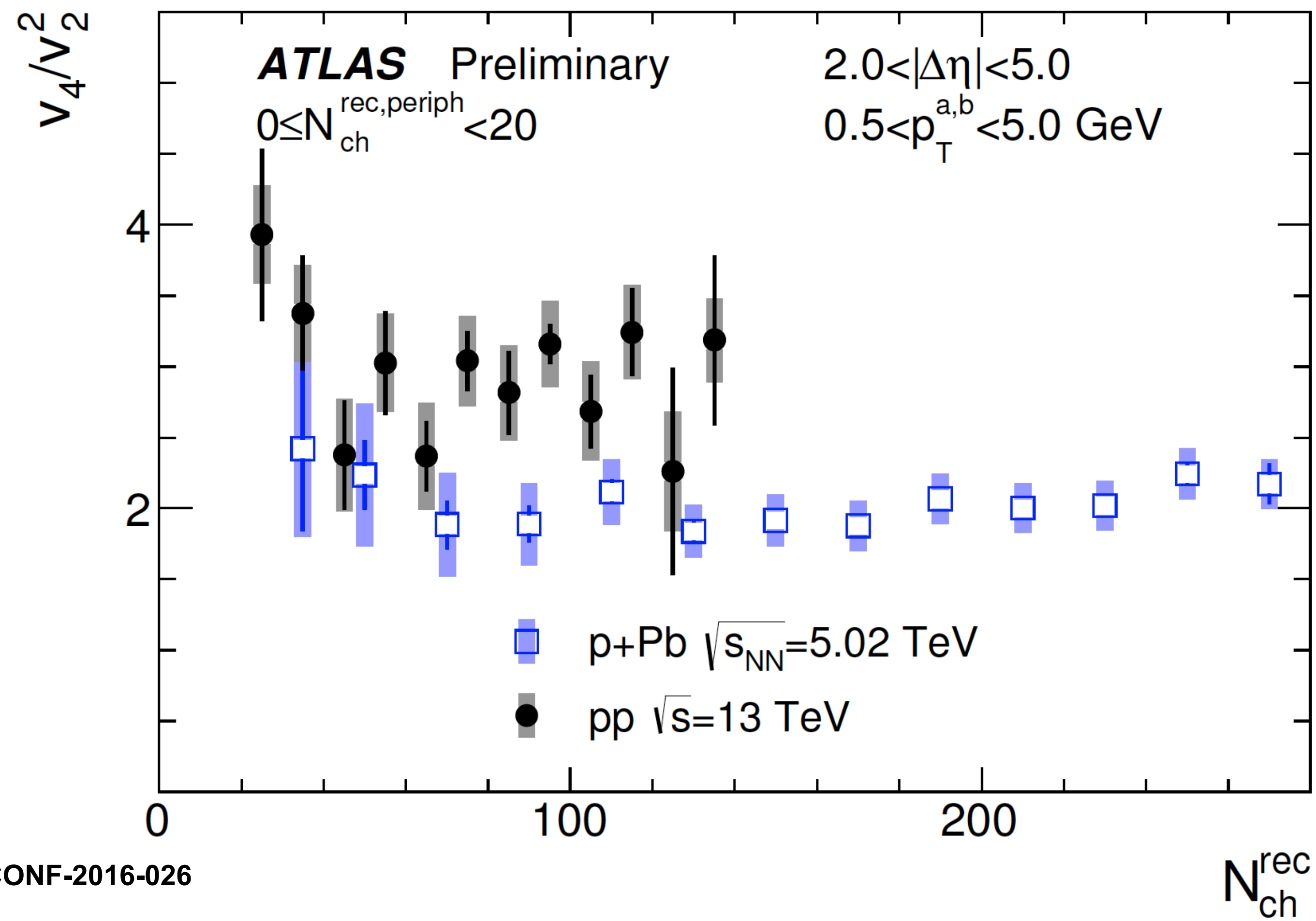
v_4/v_2^2 Ratio in 13 TeV pp and 5.02 TeV p+Pb Collisions



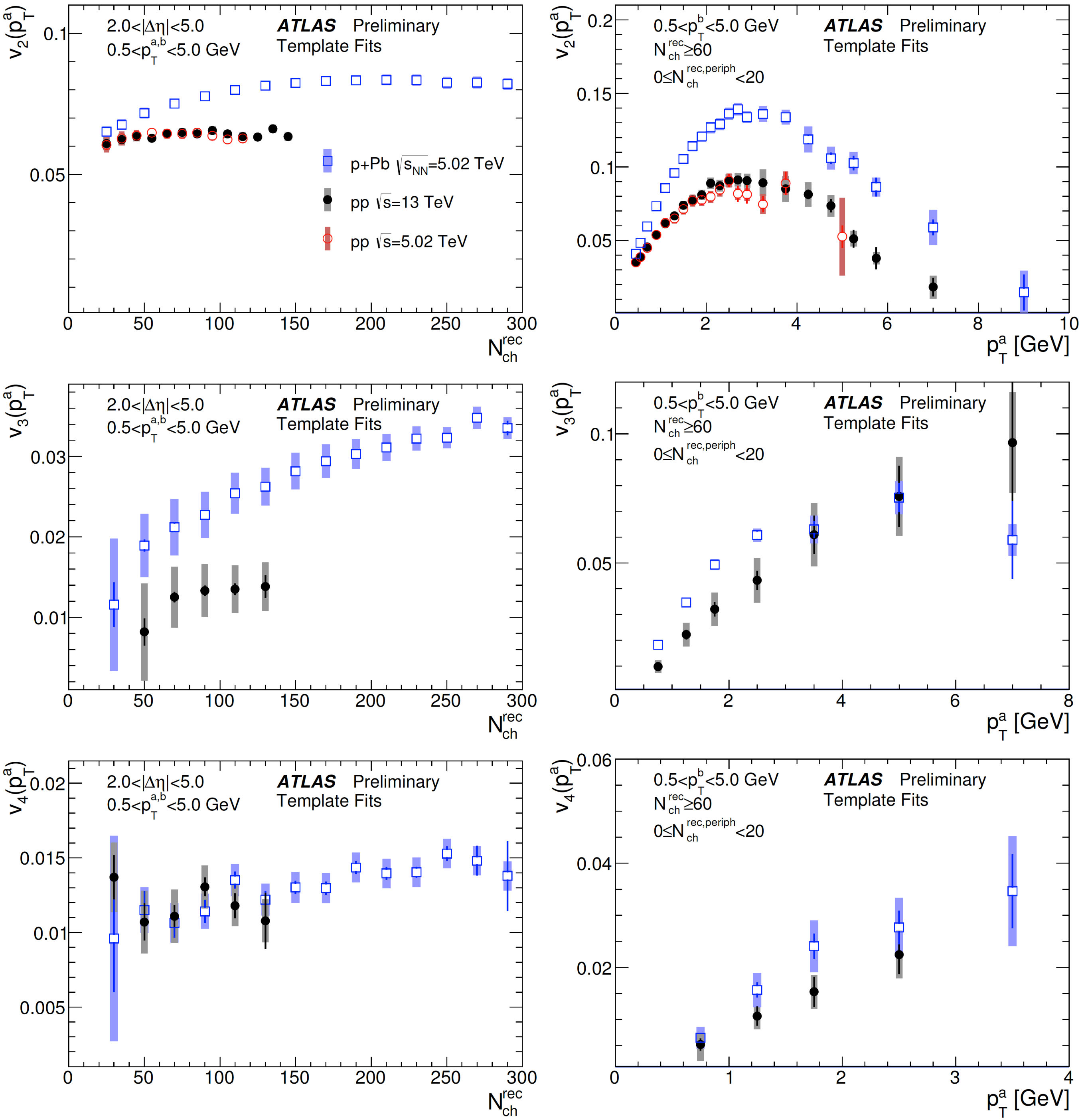
ATLAS-CONF-2016-026

The ratio is constant for both systems but is higher in pp than in p+Pb collisions

- **stronger non-linear coupling in pp**

Summary

- **Using a template fit method ATLAS has observed elliptic, triangular and quadrangular harmonics in 5.02 and 13 TeV pp collisions**
  - v_n^{pp} are almost constant with multiplicity and energy
- **v_n^{pp} and v_n^{p+Pb} are similar at low multiplicity, but v_n^{p+Pb} increase with multiplicity**
  - v_2^{pp} and v_2^{p+Pb} have similar p_T dependence
- **v_4/v_2^2 ratios in pp and pPb collisions are constant with multiplicity**
  - Larger ratio for pp is observed due to larger non-linear contribution to v_4



$v_2(p_T^a)$
2.0<|Δη|<5.0
$0.5<p_T^{a,b}<5.0$ GeV
ATLAS Preliminary
Template Fits
p+Pb $\sqrt{s_{NN}}$=5.02 TeV
pp $\sqrt{s}$=13 TeV
pp $\sqrt{s}$=5.02 TeV
N_{ch}^{rec}
$0.5<p_T^b<5.0$ GeV
$N_{ch}^{rec}\geq60$
$0\leq N_{ch}^{rec,periph}<20$
p_T^a [GeV]
$v_3(p_T^a)$
$v_4(p_T^a)$