Angular Correlations as a function of multiplicity in pp and p-Pb collisions in the ATLAS experiment

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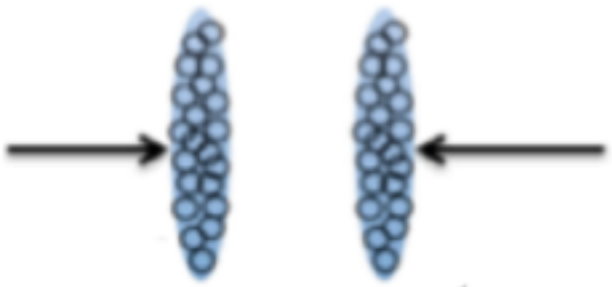
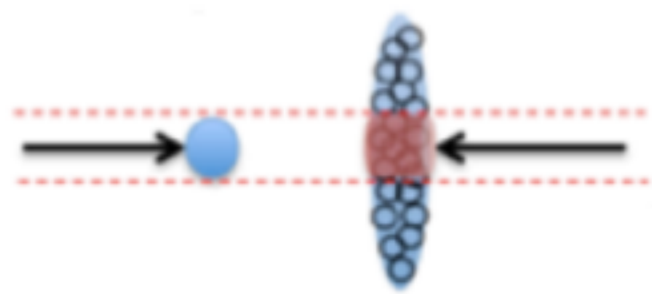
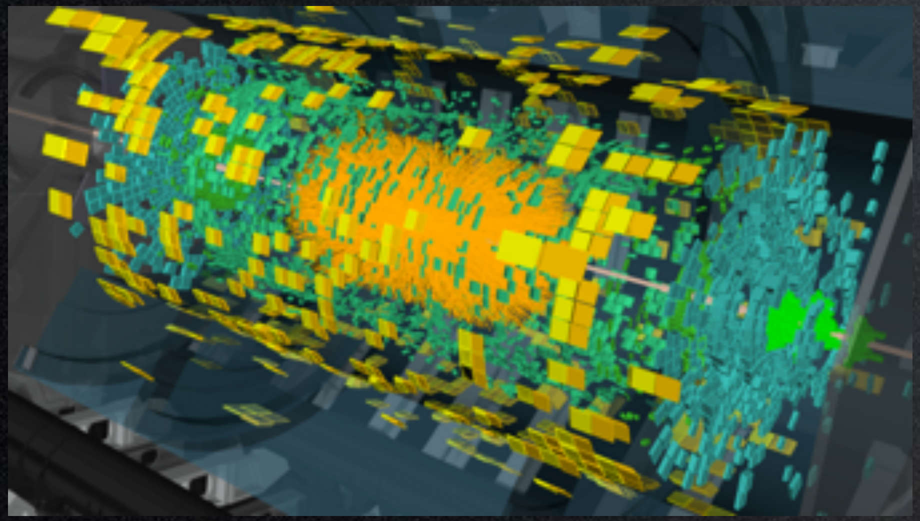
On behalf of ATLAS collaboration

MPI@LHC Workshop,
Chiapas, Mexico, November 2016

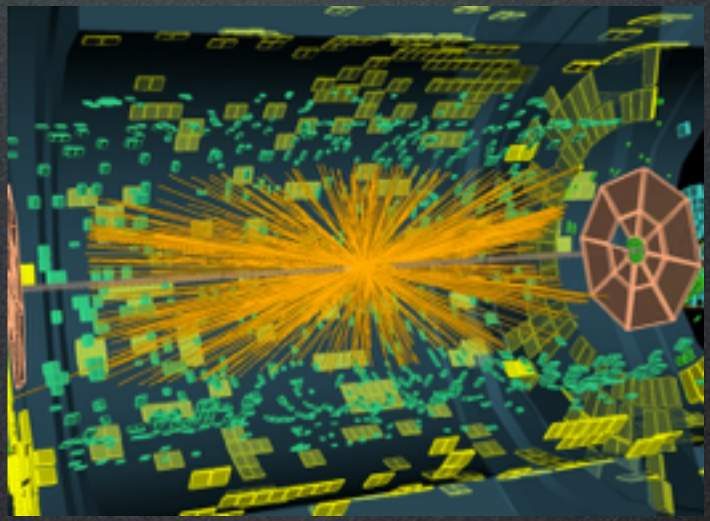
Collective Behaviour in a small system



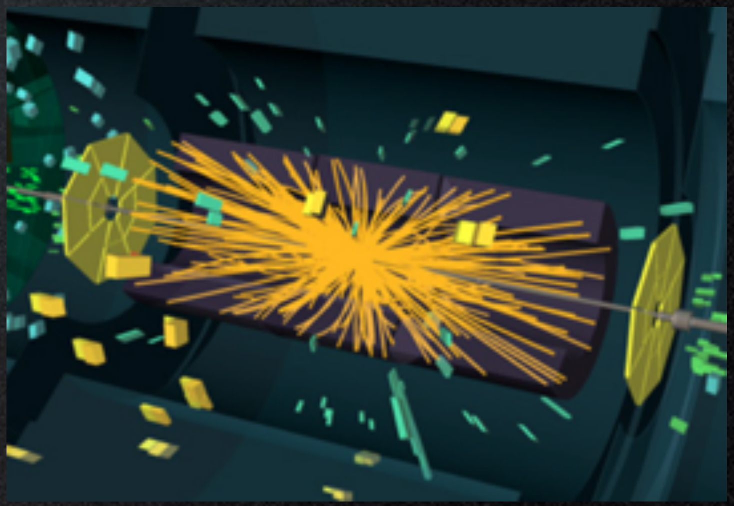




~30000 particles



~1000 particles

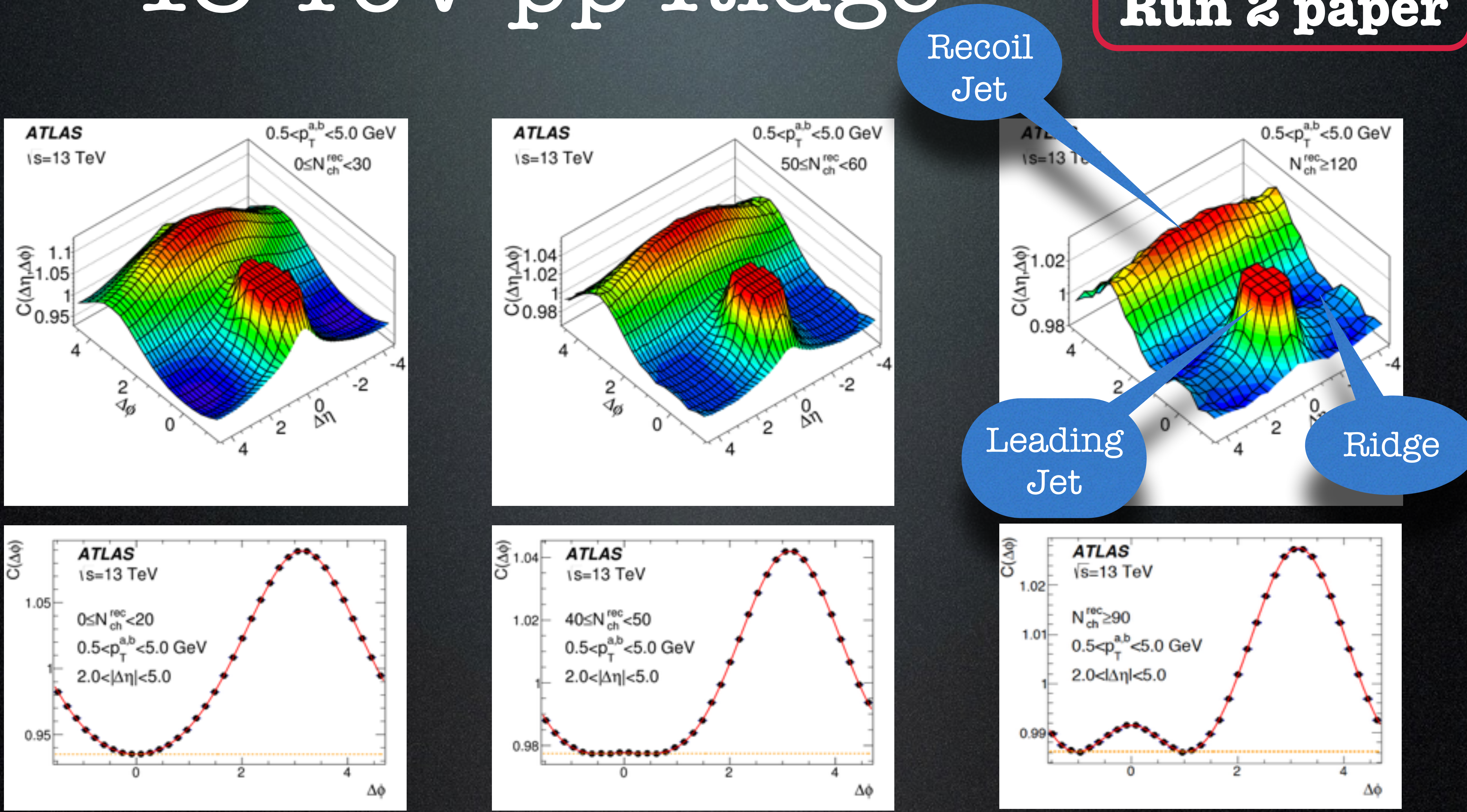


~100 particles

Reveal collective/flow like behaviour via the two particle correlation method

13 TeV pp Ridge

First ATLAS Run 2 paper



In high multiplicity events there is an enhancement in the particle production at $\Delta\varphi \approx 0$ over wide range of $\Delta\eta$

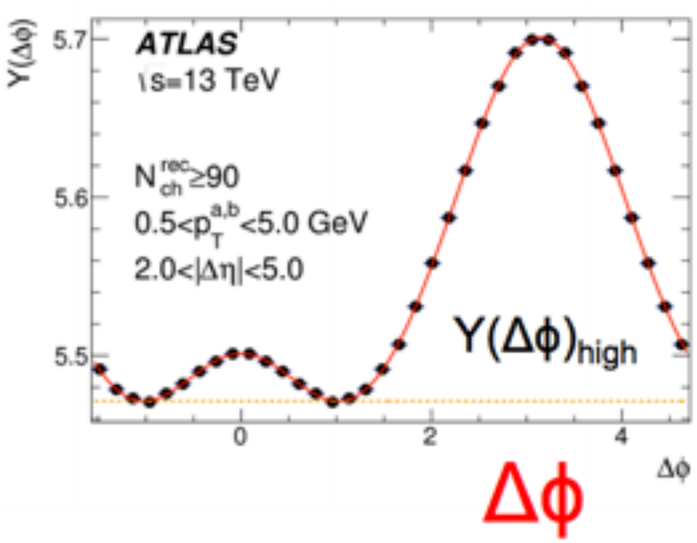
Phys. Rev. Lett. 116, 172301 (2016)

Extracting the Ridge

Observation: $Y(\Delta\phi)_{\text{high-mult}} \cong FY(\Delta\phi)_{\text{low-mult}} + A\cos 2\Delta\phi + C$

Other harmonics much smaller

Suppress dijet system



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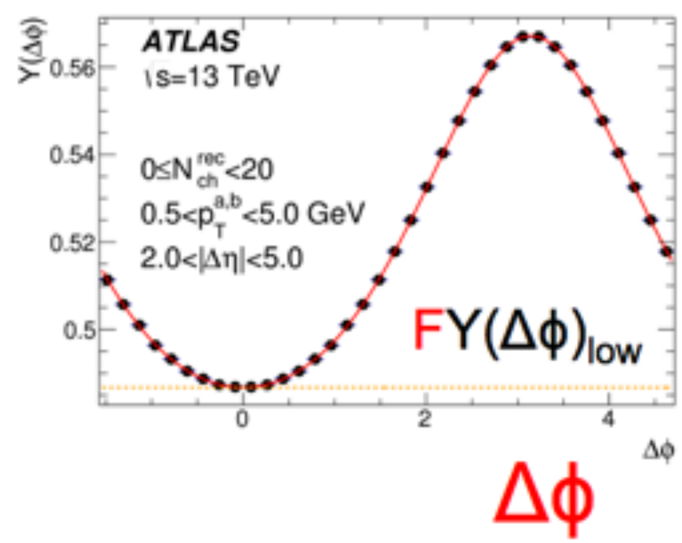

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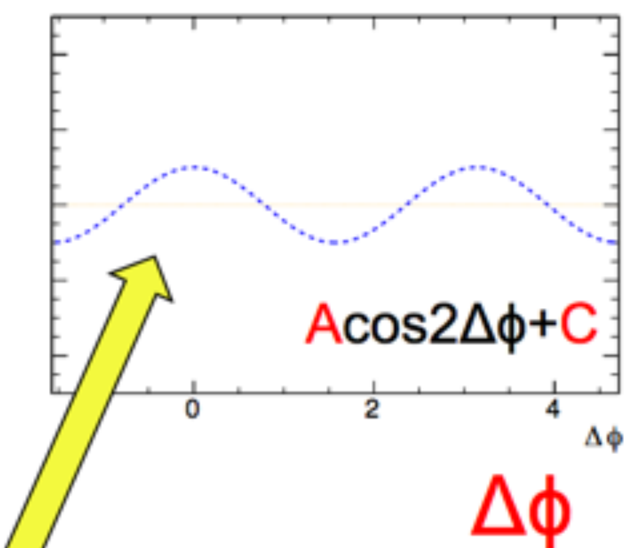
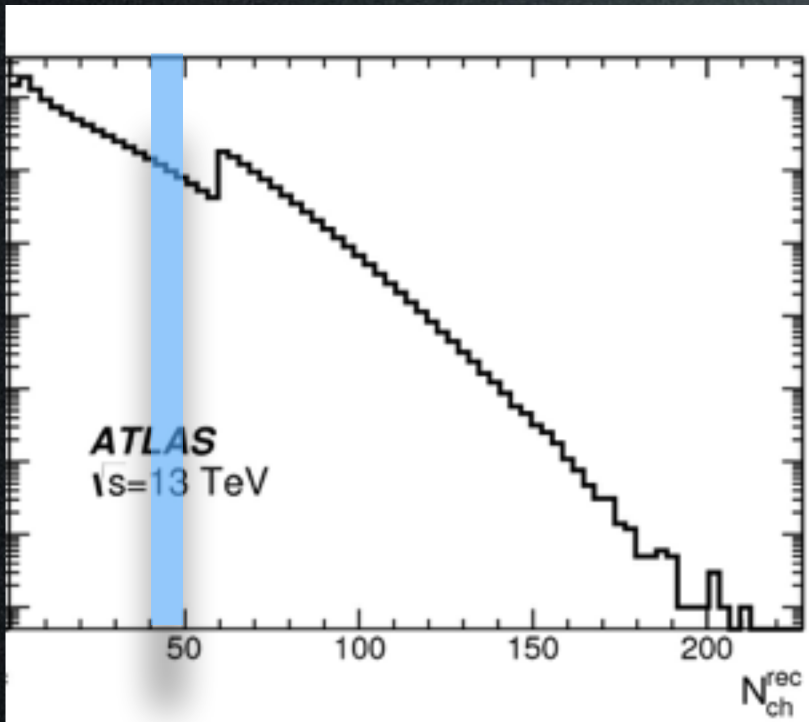


Operational definition of ridge

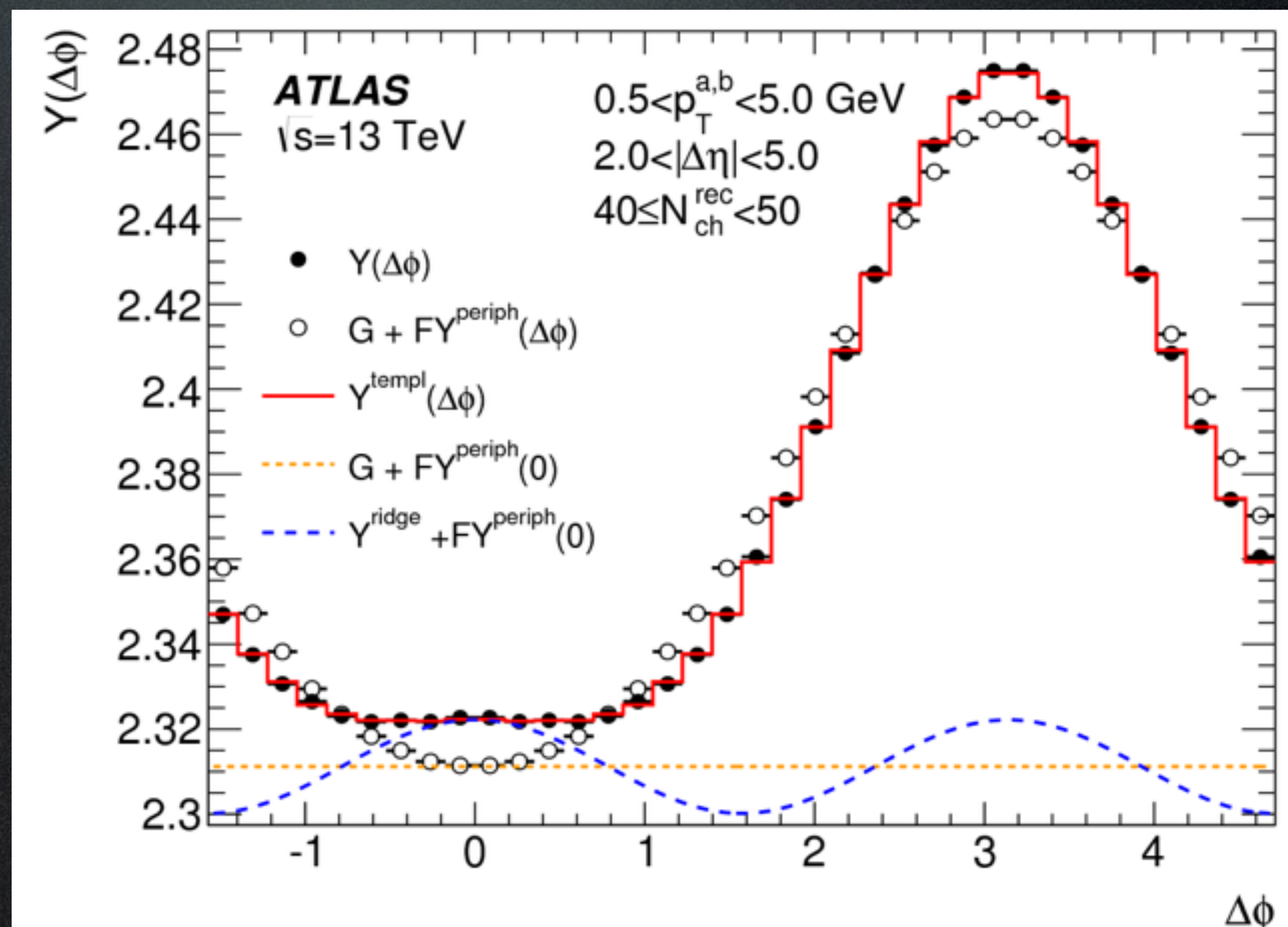
$$A\cos 2\Delta\phi + C = N(1 + 2v_2(p_T^a)v_2(p_T^b)\cos 2\Delta\phi)$$



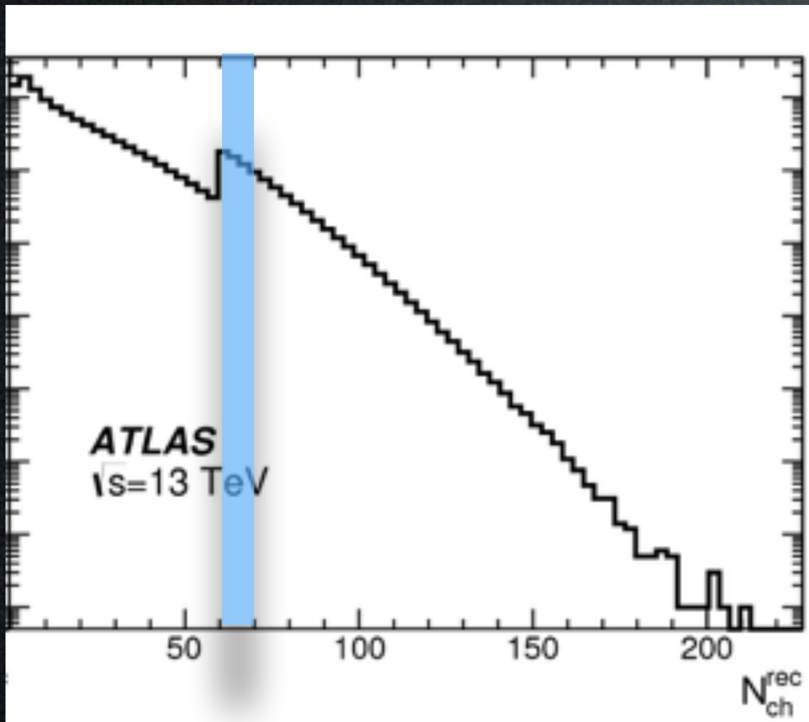
$$\color{red}{Y(\Delta\phi)_{Fit}} \cong FY(\Delta\phi)_{low\text{-}mult} + \color{blue}{A\cos 2\Delta\phi + C}$$

$40 < N_{ch} < 50$

Enhancement of the high N_{ch} region due to a dedicated high-multiplicity track trigger

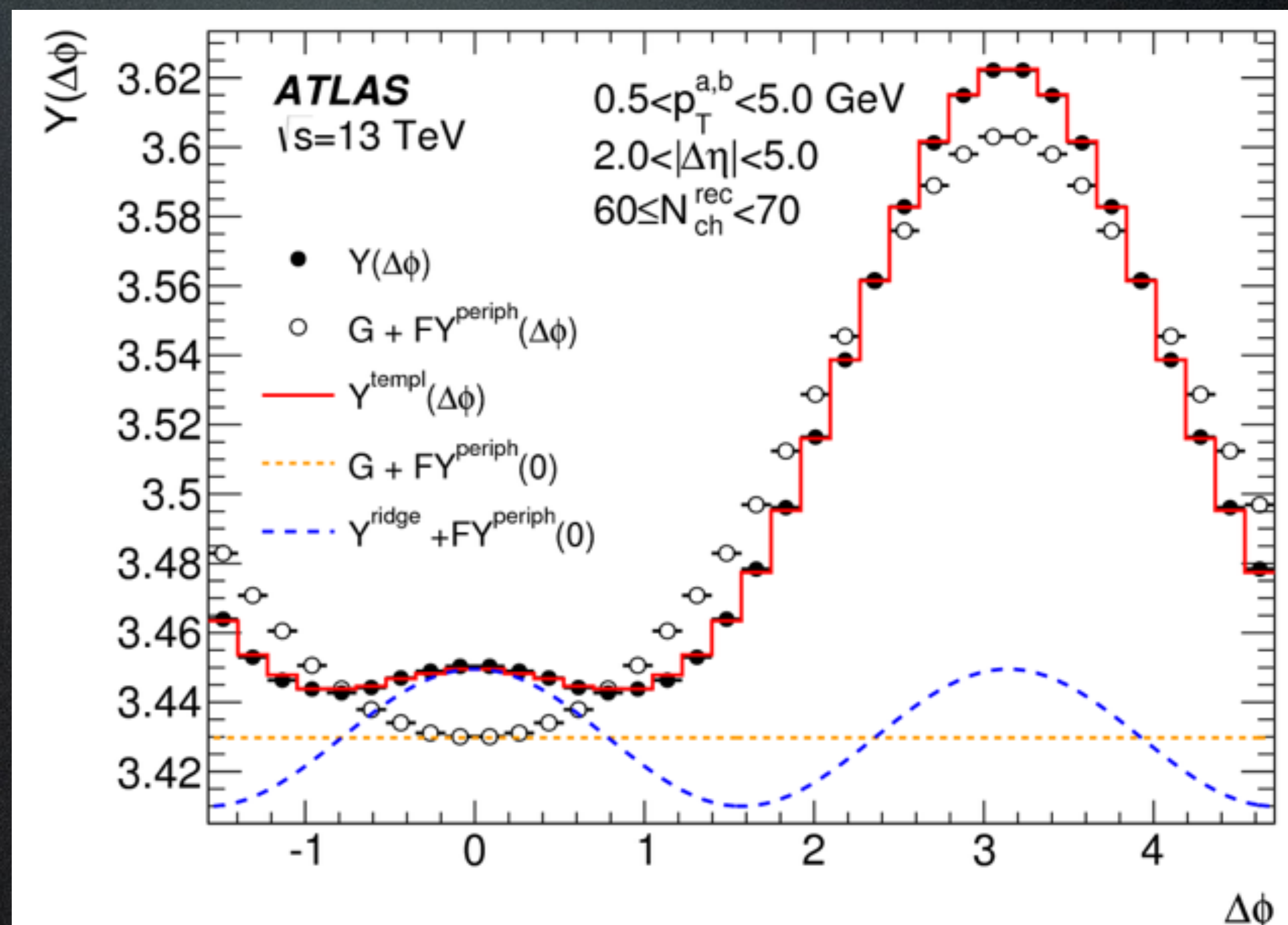


Phys. Rev. Lett. 116, 172301 (2016)



$$Y(\Delta\phi)_{Fit} \cong FY(\Delta\phi)_{low\text{-}mult} + A\cos 2\Delta\phi + C$$

$60 < N_{ch} < 70$



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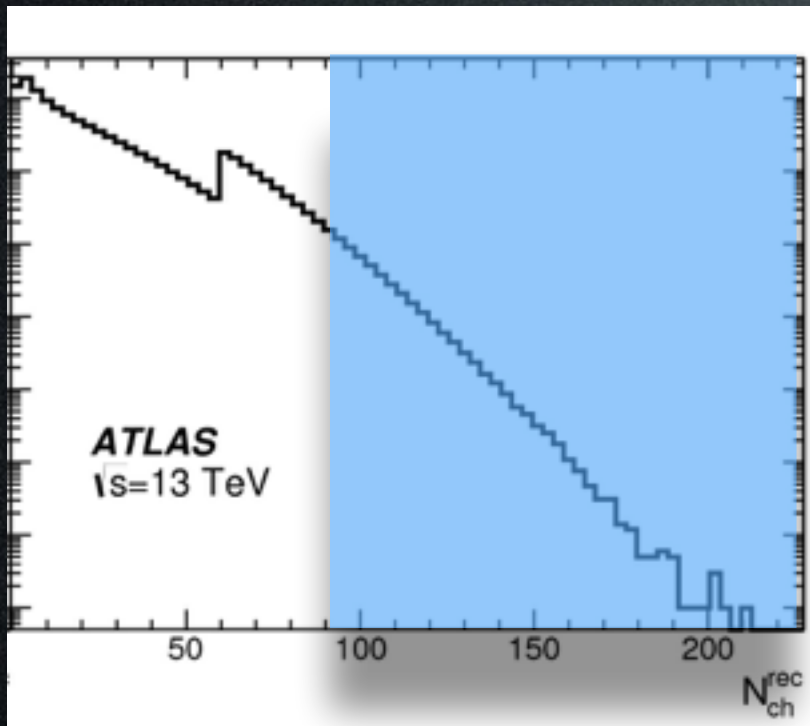
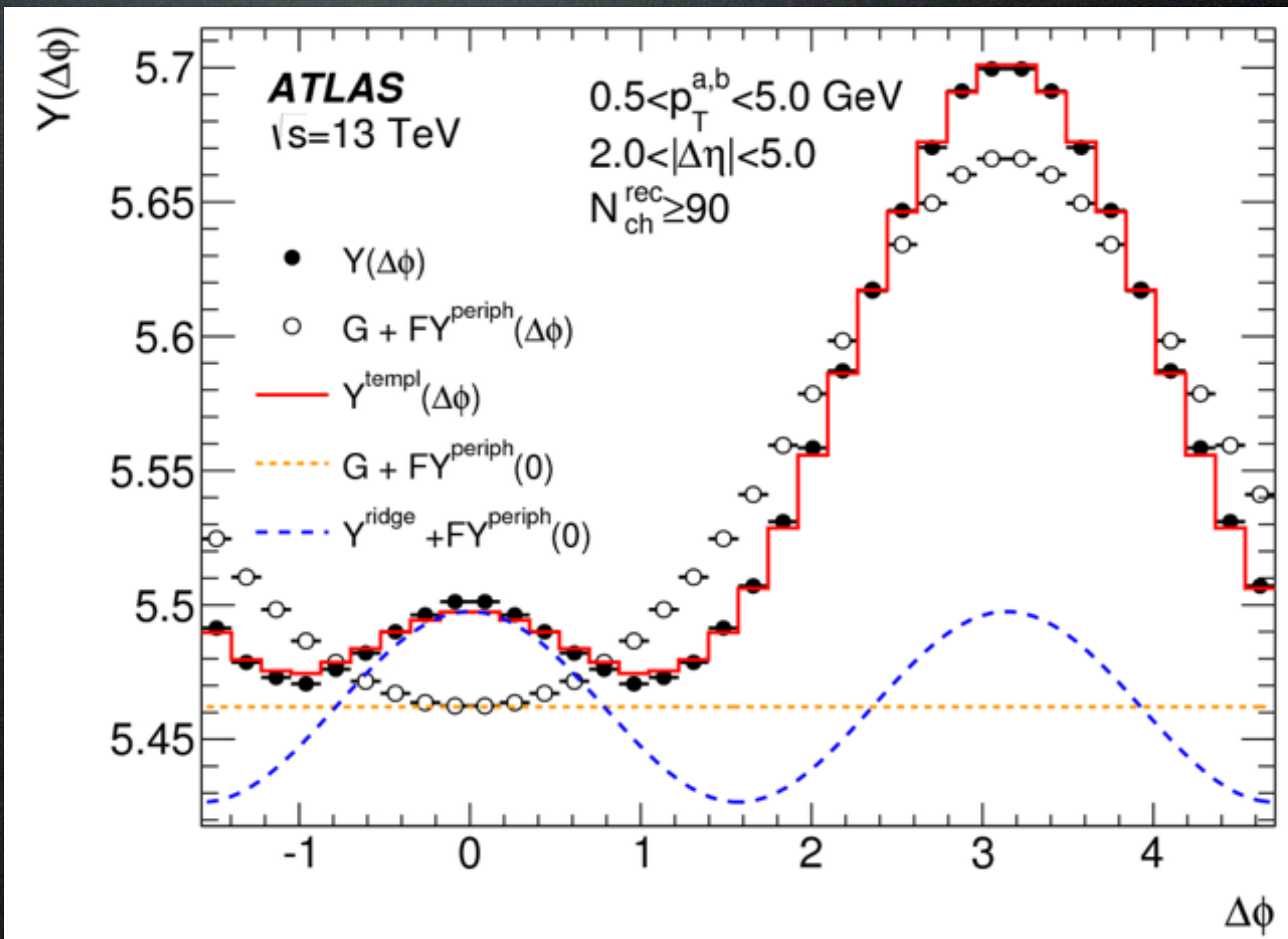


$Y(\Delta\phi)_{Fit} \cong FY(\Delta\phi)_{low\text{-}mult} + A\cos 2\Delta\phi + C$

$N_{ch} > 90$



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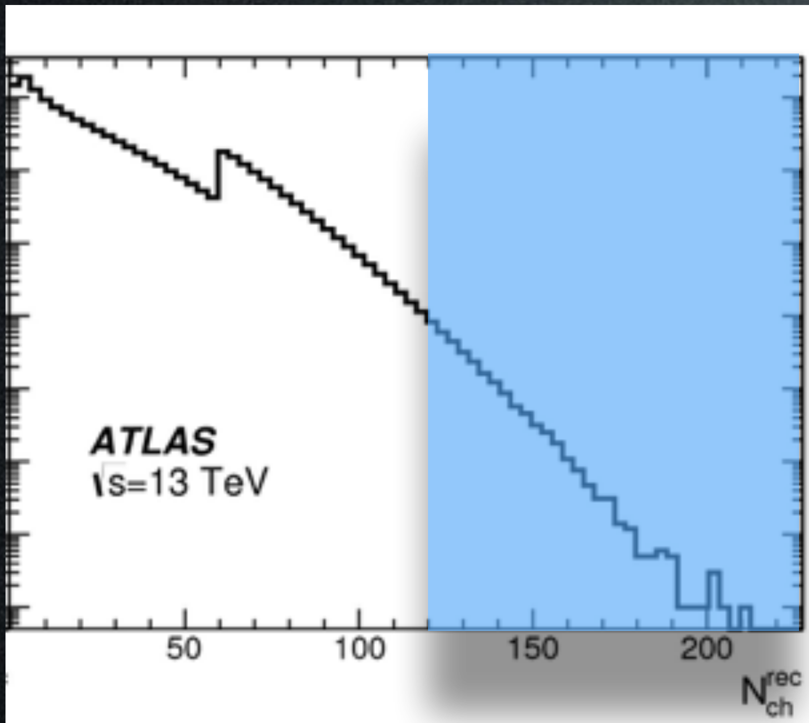
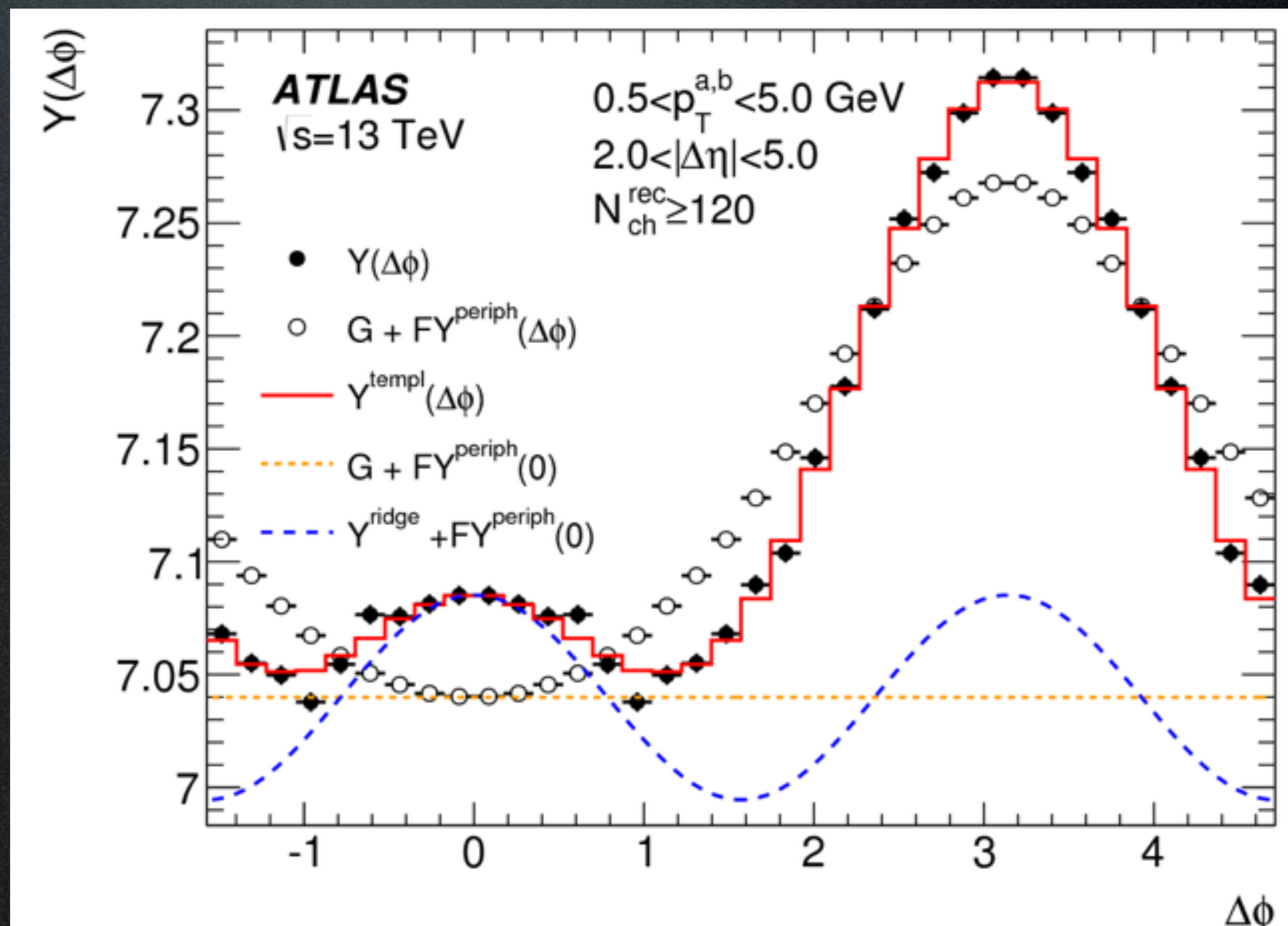
Narrowing of the distribution due to cosine component



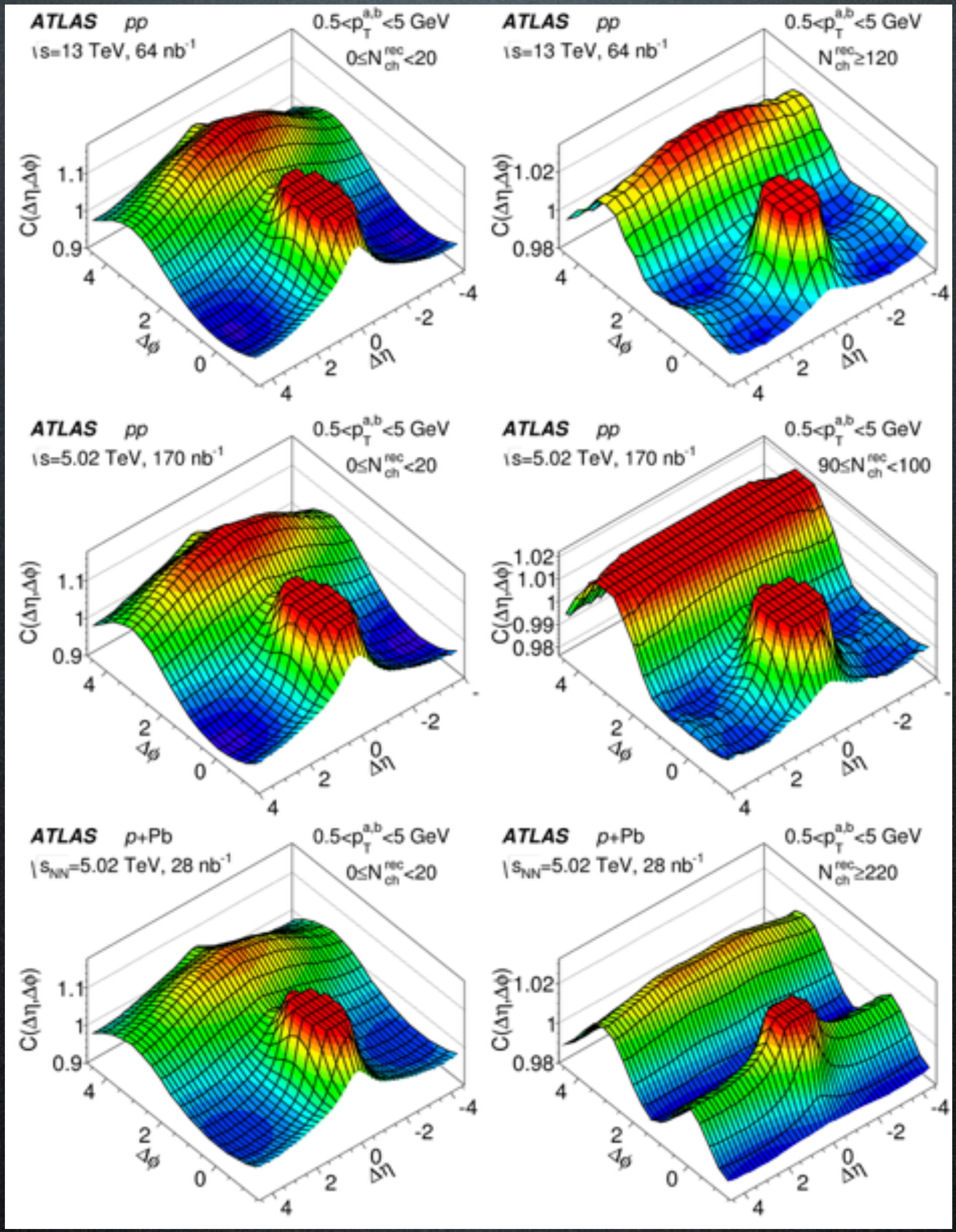
$$Y(\Delta\phi)_{Fit} \cong FY(\Delta\phi)_{low\text{-}mult} + A\cos 2\Delta\phi + C$$

$N_{ch} > 120$



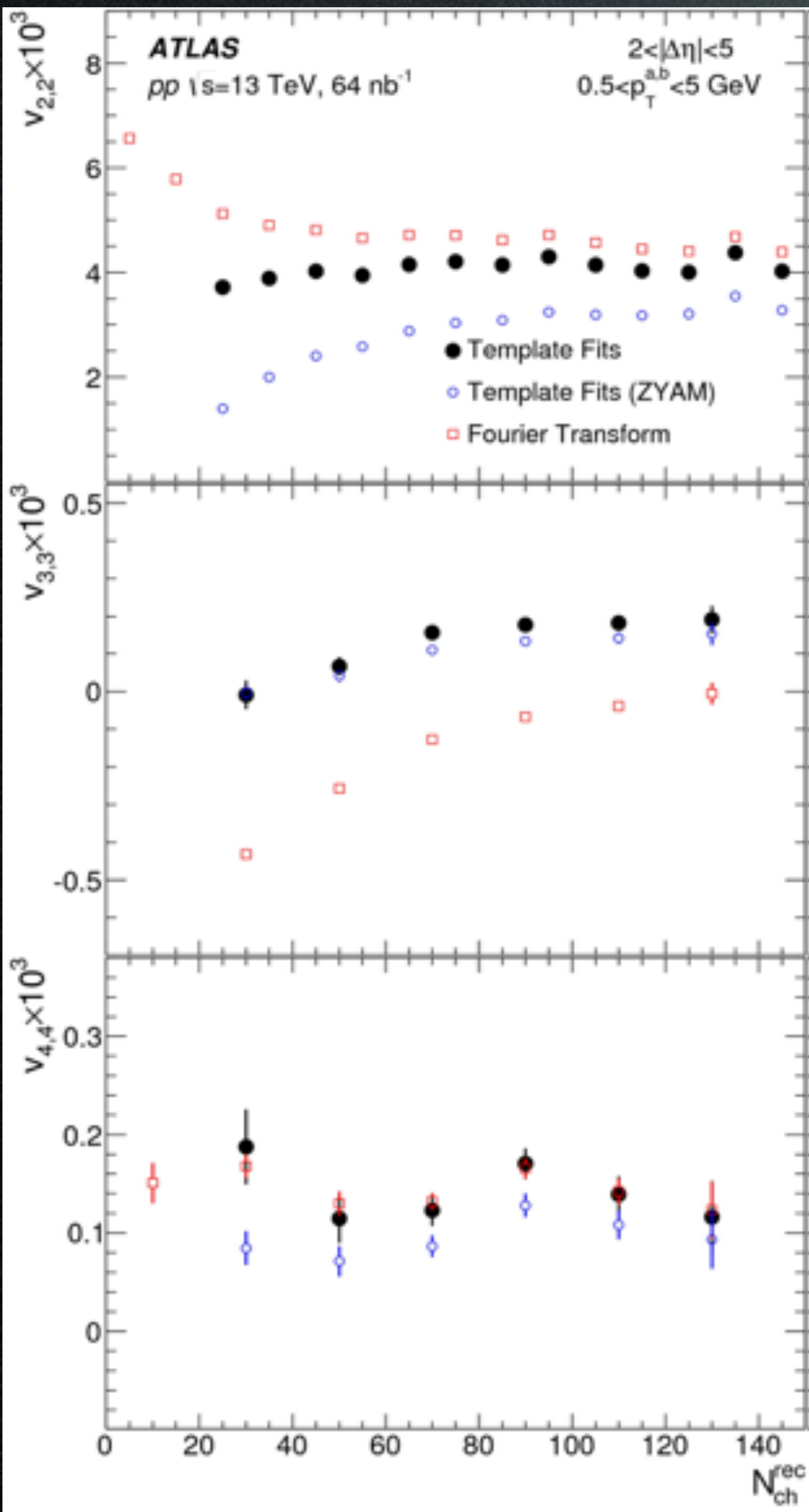
Phys. Rev. Lett. 116, 172301 (2016)

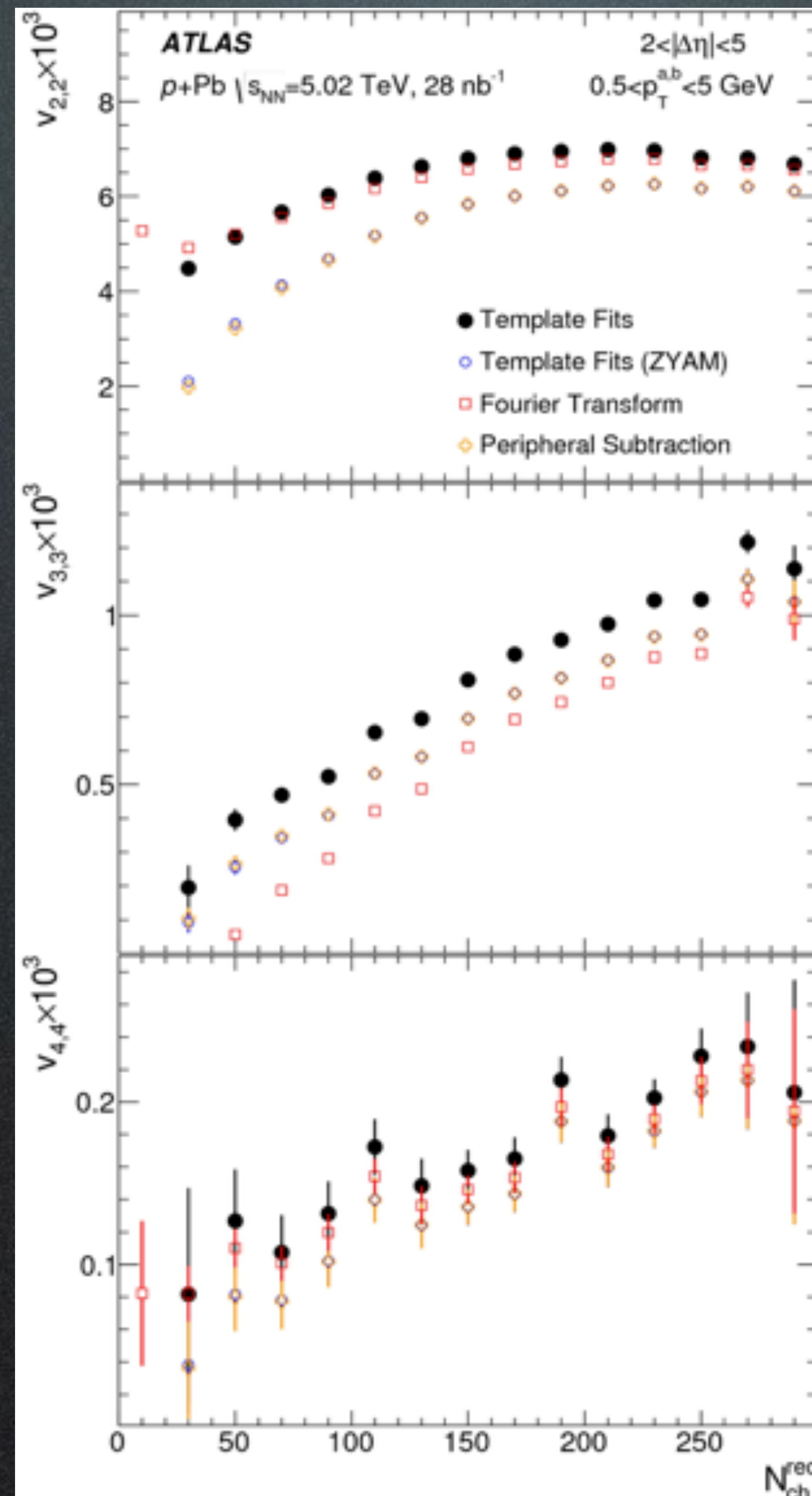
In more Systems



arXiv:1609.06213

Azimuthal Correlations





Characterized by Fourier coefficients to describe relative amplitudes of sinusoidal components

$$\frac{dN}{d\phi} = \left\langle \frac{dN}{d\phi} \right\rangle \left(1 + \sum_n 2v_n \cos\left[n\left(\phi - \Psi_n\right)\right] \right)$$

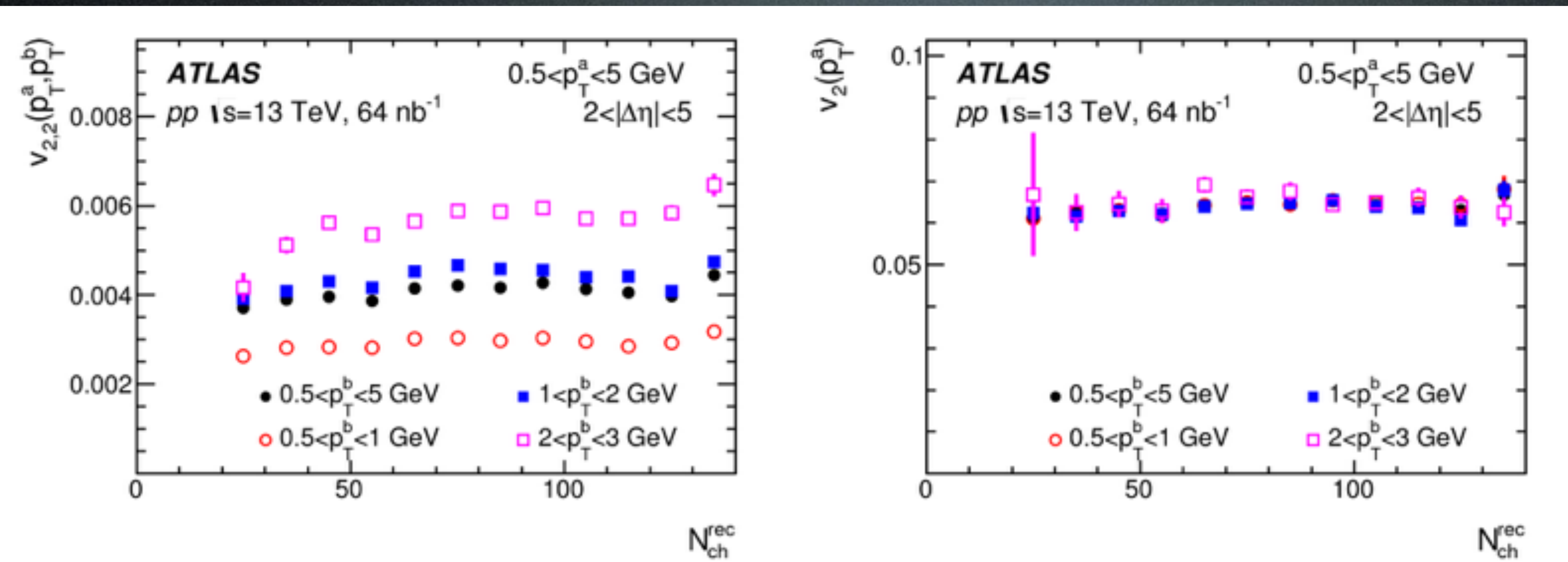
Measured by 2 pc:

$$\frac{dN_{\text{pair}}}{d\Delta\phi} = \left\langle \frac{dN_{\text{pair}}}{d\Delta\phi} \right\rangle \left[1 + \sum_n 2v_{n,n} \cos\left(n\Delta\phi\right) \right]$$

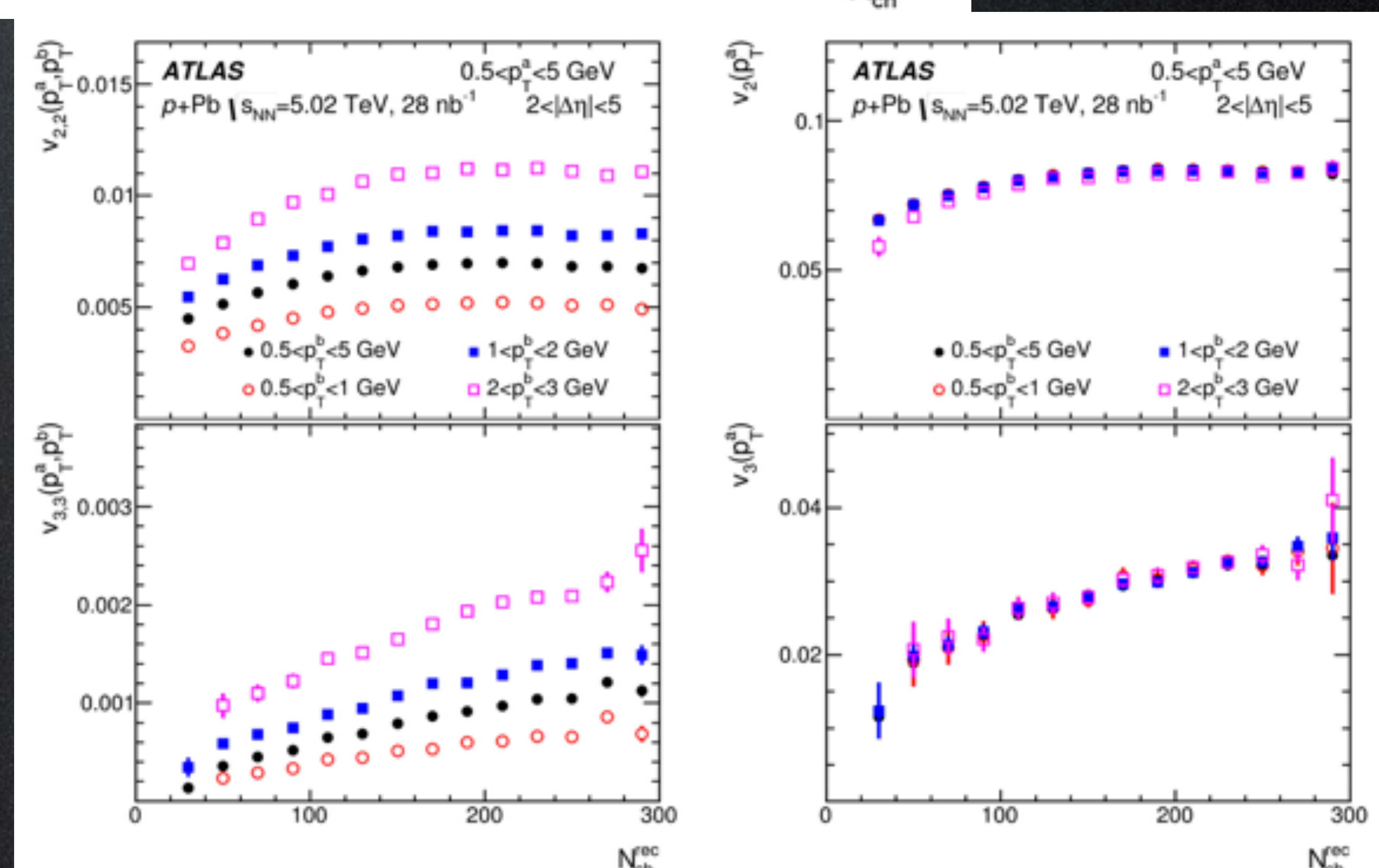
Long range part subtracted by using peripheral events

arXiv:1609.06213

Factorization?



$$v_{n,n}(p_{\mathrm{T}}^{a}, p_{\mathrm{T}}^{b}) = v_{n}(p_{\mathrm{T}}^{a})v_{n}(p_{\mathrm{T}}^{b})$$



While $v_{2,2}$ values vary, v_2 agrees quite well.

Similarly for p-Pb case.

arXiv:1609.06213

Multiparticle Cumulants

Useful tool to study the global nature of correlations

$$\langle\langle corr_2\{2\}\rangle\rangle \equiv \langle\langle e^{i2(\phi_1-\phi_2)}\rangle\rangle$$
$$\langle\langle corr_2\{4\}\rangle\rangle \equiv \langle\langle e^{i2(\phi_1+\phi_2-\phi_3-\phi_4)}\rangle\rangle,$$

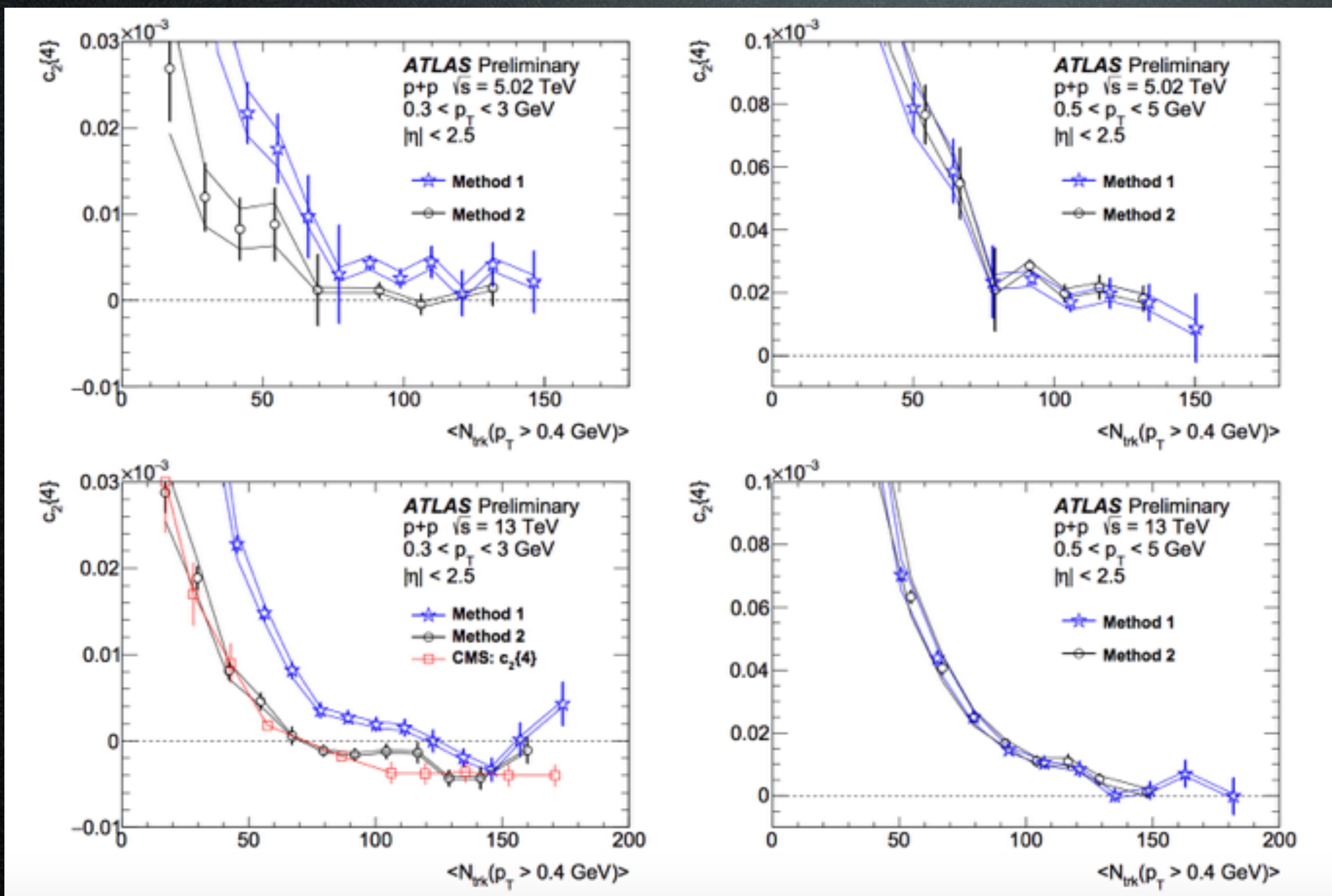
where the brackets "$\langle\langle\rangle\rangle$" denote double averaging, performed first over particles in an event with a given multiplicity and then over all events with this multiplicity. For every event, the average is taken over all combinations of particle multiplets and each combination consists of different sets of $2k$ particles with azimuthal angles $\phi_i (i = 1, \ldots, 4)$.

Cumulants:

$$c_2\{4\} = \langle\langle corr_2\{4\}\rangle\rangle - 2\,\langle\langle corr_2\{2\}\rangle\rangle^2$$

$$v_2\{4\} = \sqrt[4]{-c_2\{4\}}.$$

Results



N^{ref}_{trk}: Ref particles: within a narrow p_T range

Method 1: for a fixed N^{ref}_{trk}

Method 2: fixed multiplicity for fluctuating N^{ref}_{trk}

For lower ref p_T range, method 2 gives smaller values, multiplicity fluctuations lead to negative contributions to cumulants

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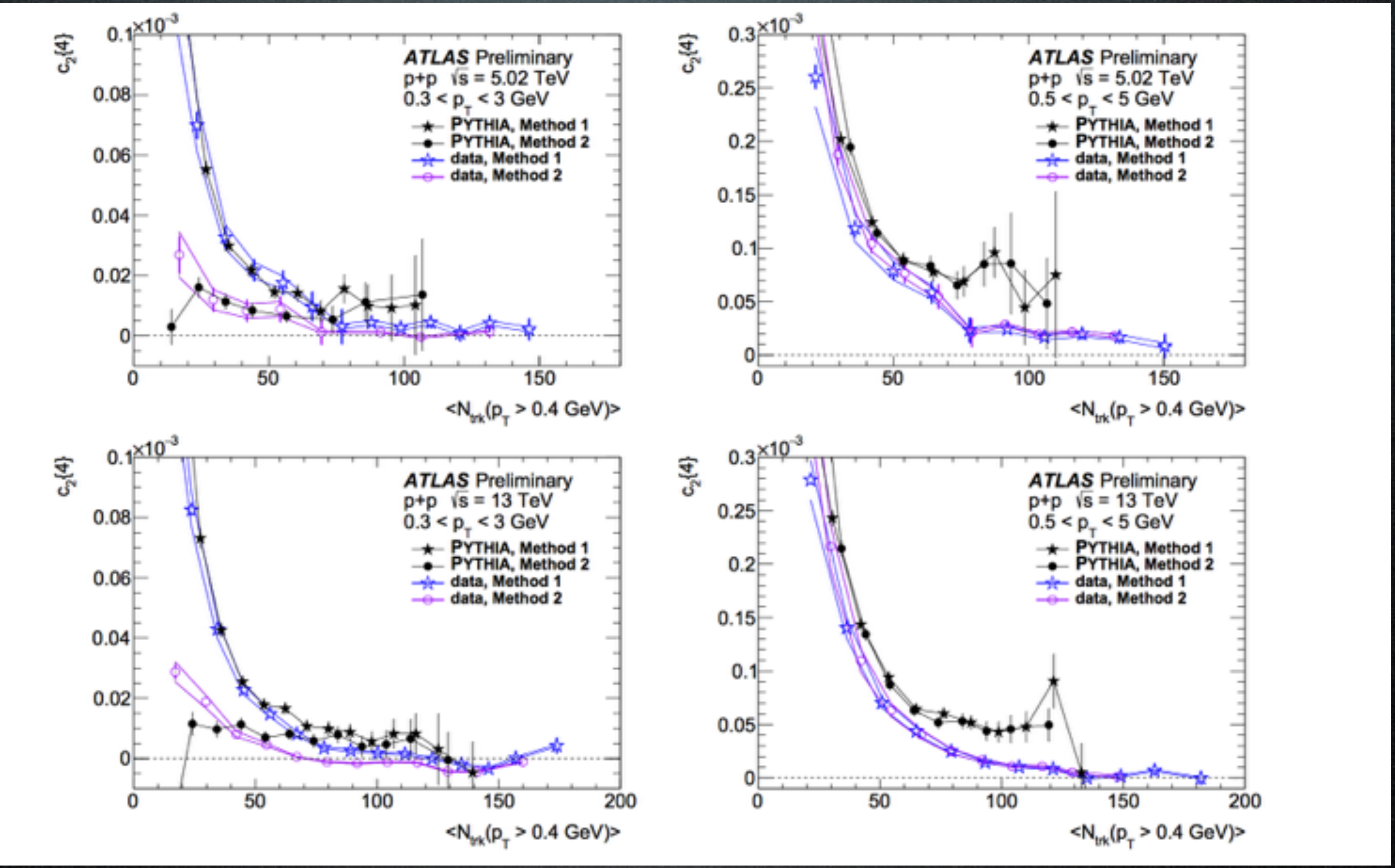
Comparison with MC



As compared to the data, Pythia 8 overestimates the values of cumulants measured for events with high charged particle multiplicities

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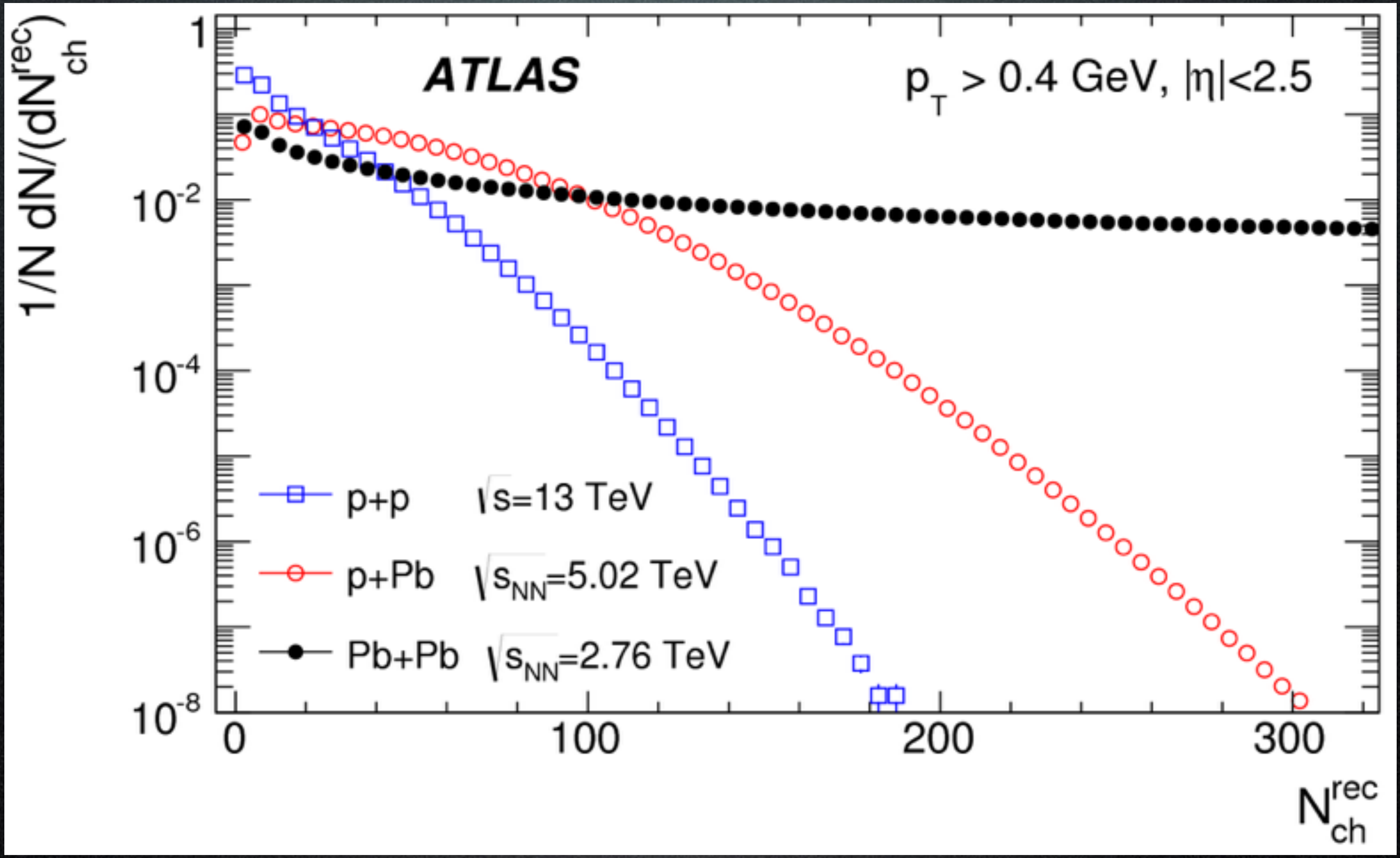
Multiplicity Dependence



arXiv:1606.08170

Observables

2-D pseudorapidity correlation function

$$C = \frac{\langle N(\eta_1) N(\eta_2) \rangle}{\langle N(\eta_1) \rangle \langle N(\eta_2) \rangle} = \langle R_s(\eta_1) R_s(\eta_2) \rangle_{events} \qquad |\eta|<Y=2.4$$

Mixed events

$$R_s(\eta) = \frac{N(\eta)}{\langle N(\eta) \rangle}$$

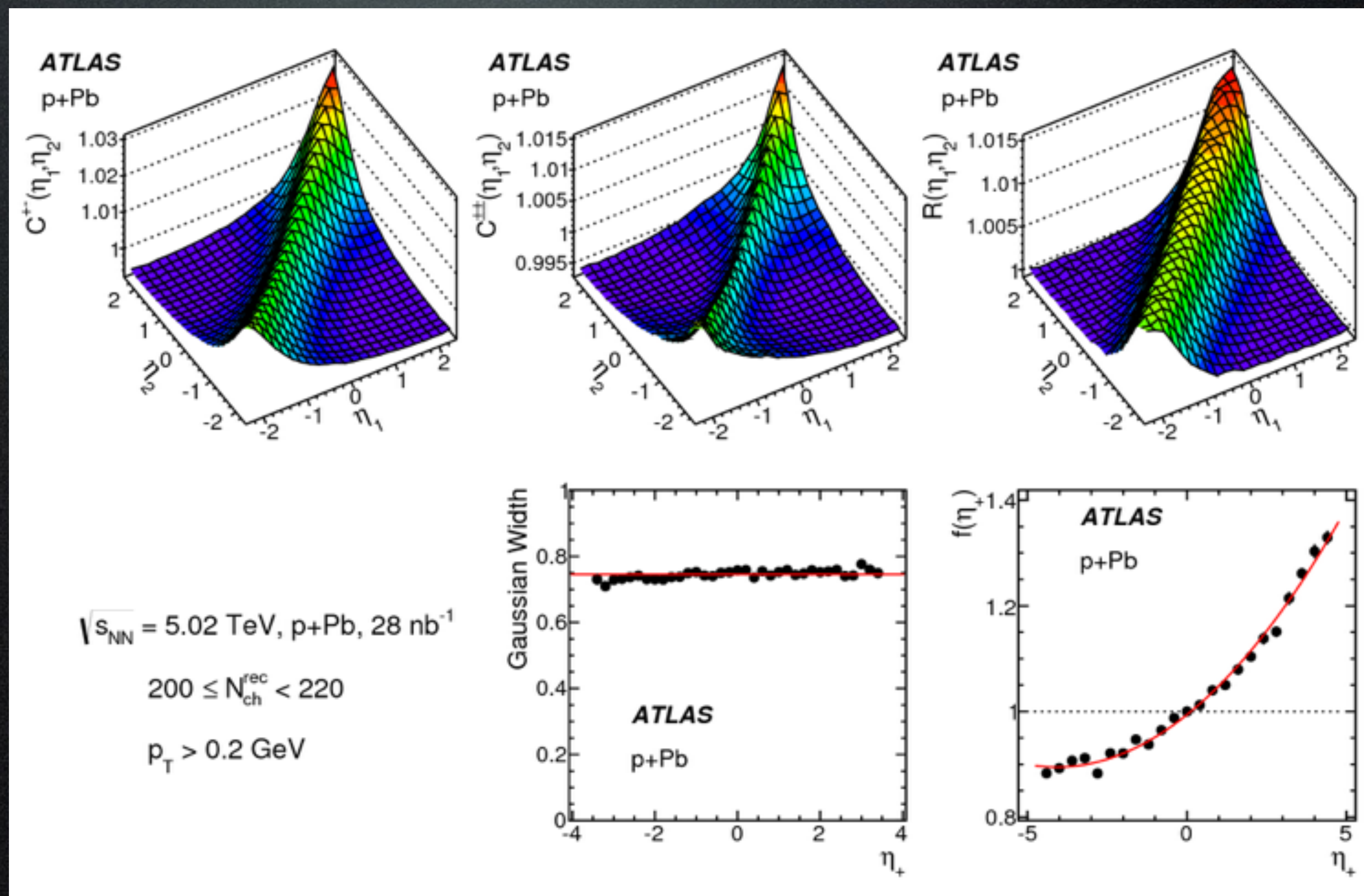
Single particle distribution

oppositely charged pairs

same charged pairs

Ratio

Disentangles statistical and dynamical fluctuations



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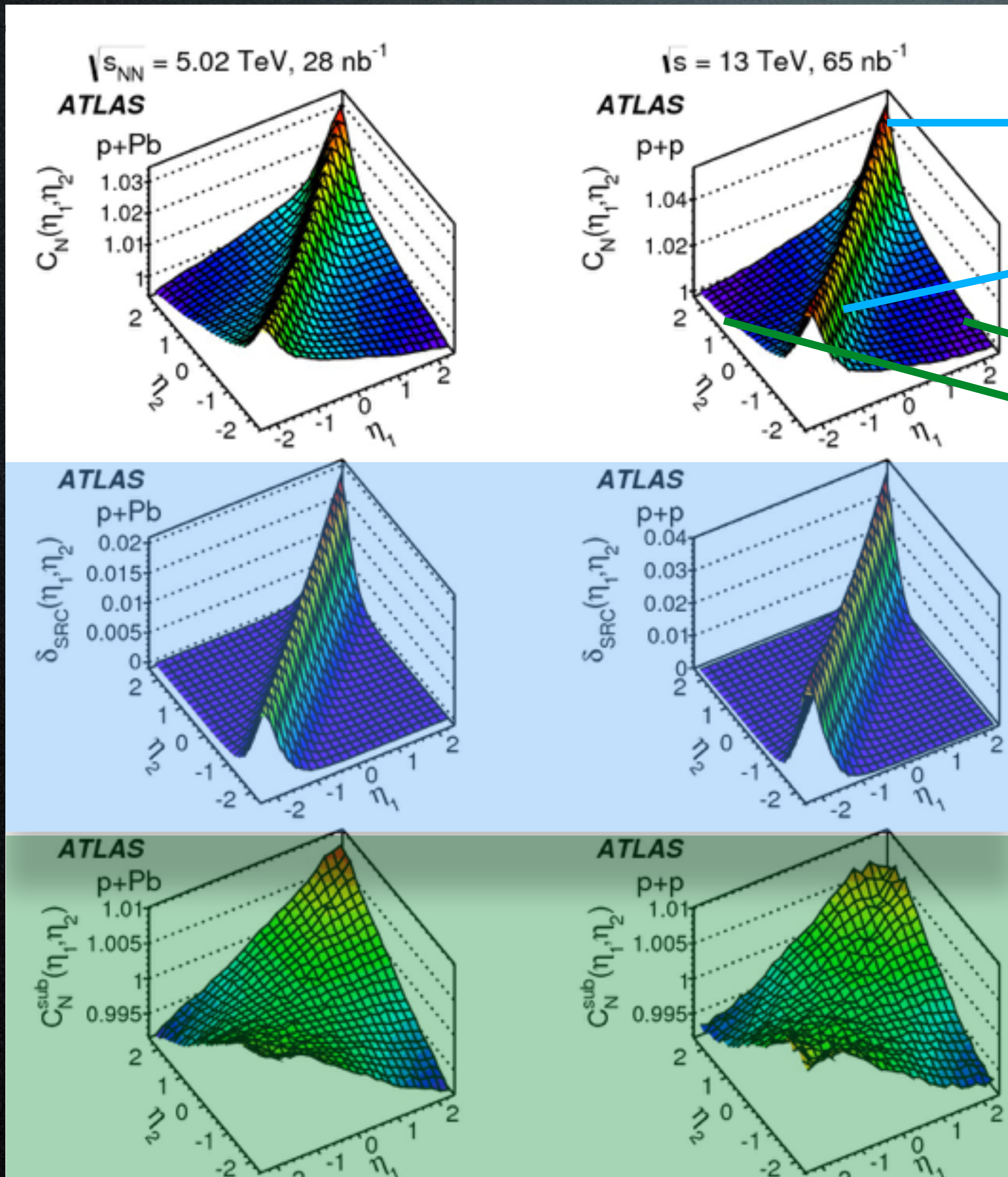


Short
Range Correlations
$\Delta\eta = \eta_1 - \eta_2 \cong 0$
Within same source

Long
Range Correlations
large $|\Delta\eta|$
FB asymmetry of
number of sources

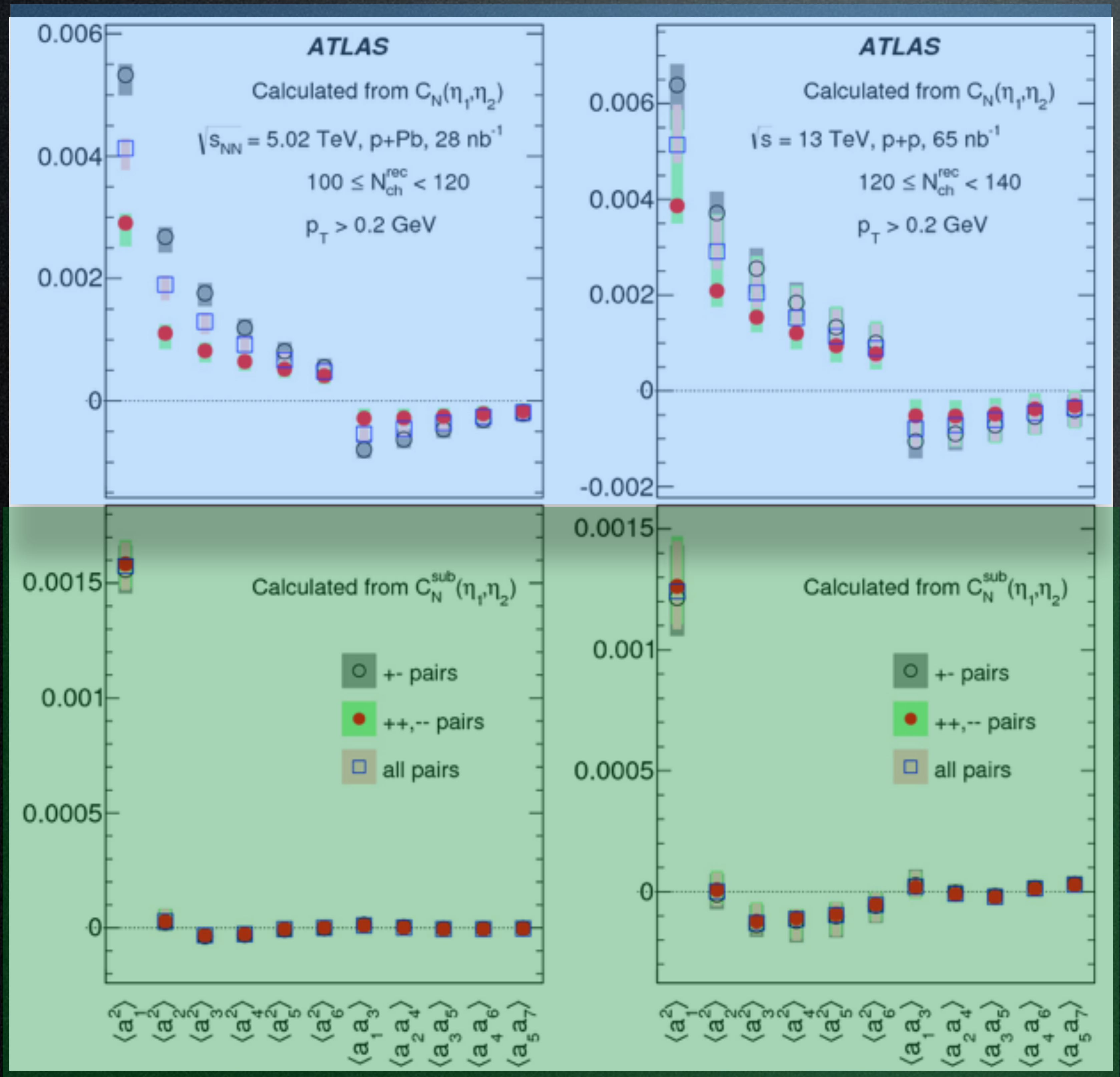
SRC (decays, jet frag, BEC)

LRC

Correlation function decomposed into Legendre Polynomials

Legendre Spectra

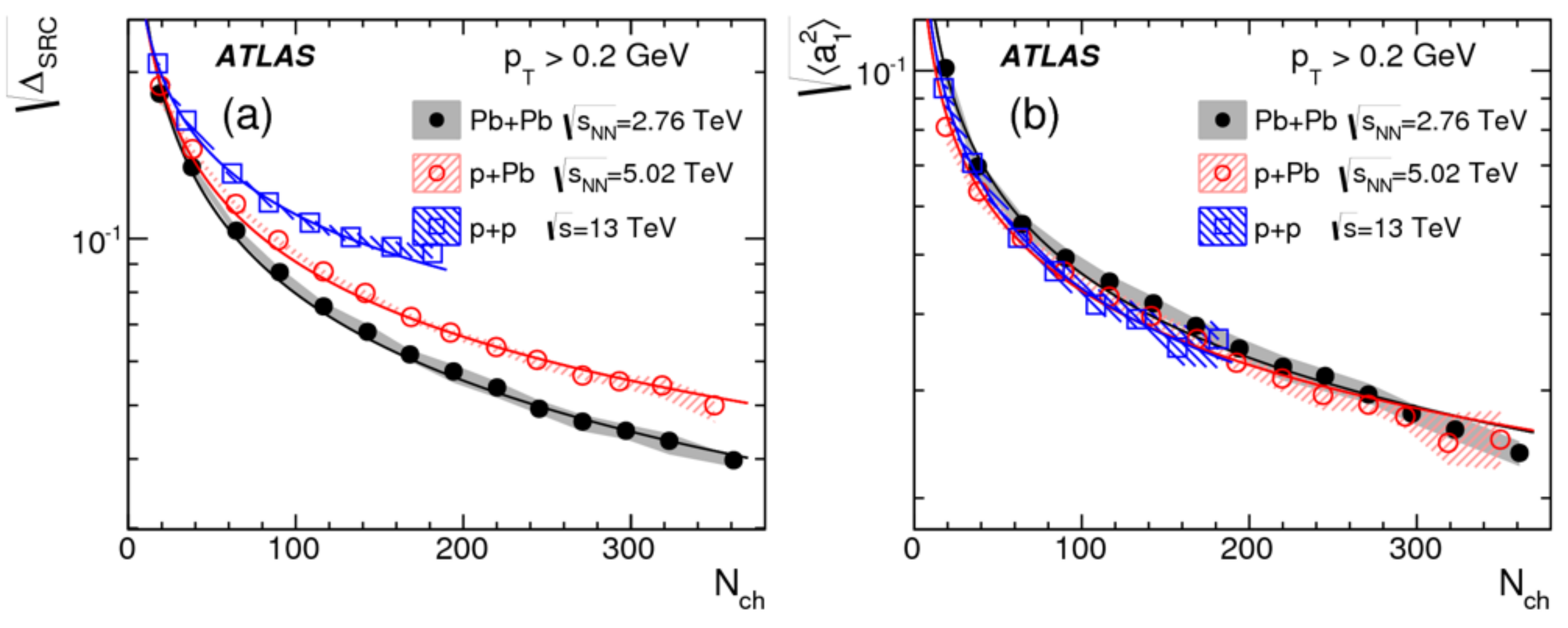
arXiv:1606.08170



More +- pairs than ++— pairs in each source

No charge dependence, reflects global symmetry

Multiplicity vs Shape



Strong system dependance for SRC

Weak or no dependance for LRC

arXiv:1606.08170

Summary

- Strong collectivity observed in high-multiplicity pp collisions, pp ridge described by $\cos 2\Delta\varphi$, has (surprisingly) weak dependence on event activity and $\sqrt{s}$

- LRC controlled by N_{ch}, not by collision systems or charge combination, SRC depends strongly on collision system and charge combination

- N_{ch} dependence of LRC and SRC follows power-law with an index close to 0.5 - information on the number of sources for particle production?

- v_2 from 2PC in pp is independent of $\sqrt{s}$ while v_n are consistent with no N_{ch} dependance in pp, but increase in p+Pb

- Multiplicity fluctuations are important and tend to shift cumulants to more negative values, as such, can mimic the collective-like effects