Long-range azimuthal correlations in 2.76 & 13 TeV *pp* with ATLAS

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MPI@LHC 2015,
Trieste, 2015-11-26

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ATLAS EXPERIMENT

Introduction to the ridge

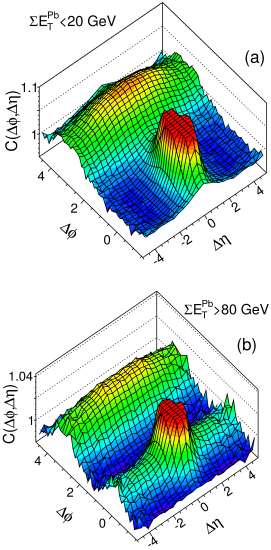
The "near-side ridge" phenomenon has been one of the most prominent and enduring physics puzzles at the LHC.

Expected/hoped-for effect in *pA* and *AA* collisions, from collective flow theory paradigm.

Discovery in high-multiplicity *pp* was a surprise!

Ridge in $p+\mathrm{Pb}$ due to global sinusoidal modulation of particle production… **same in *pp*?**

Today show ATLAS' latest ridge measurements, cf. arXiv:1509.04776



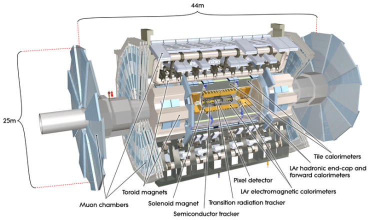
Phys. Rev. Lett. 110, 182302 (2013), arXiv:1212.5198

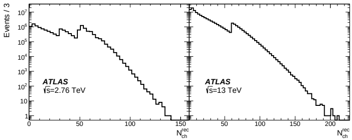
Datasets

***pp* data taken with ATLAS:** $4\,\text{pb}^{-1}$ at 2.76 TeV and $14\,\text{nb}^{-1}$ at 13 TeV.

Pile-up low in both cases: $\langle\mu\rangle \sim 0.5$ at 2.76 TeV and ~ 0.04 at 13 TeV.

Charged tracks with $p_T > 300$ MeV and $|\eta| < 2.5$ used as input to correlation measures. Only tracks with $p_T > 400$ MeV counted in $N_{\text{ch}}^{\text{rec}}$.



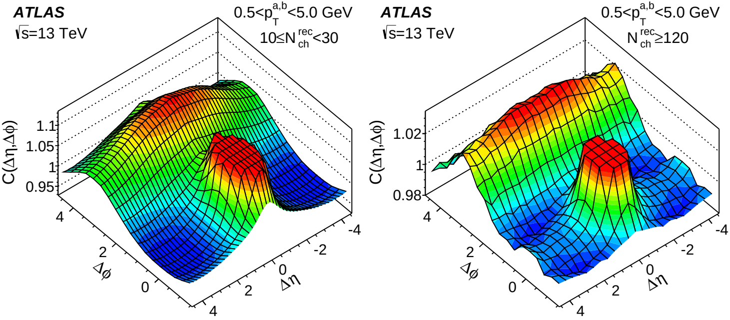


Correlation observables 1: S, B, and C in $\Delta\eta,\Delta\phi$

Raw observable is 2p correlation $C(\Delta\eta, \Delta\phi) = S(\Delta\eta, \Delta\phi)/B(\Delta\eta, \Delta\phi)$.

S and B are distributions of particle a, b separations for a & b in same event and mixed events respectively.

Division cancels acceptance effects and systematics. Not explicitly unfolded, but tracking efficiencies used as weights $1/\epsilon(p_T^a, \eta^a)\,\epsilon(p_T^b, \eta^b)$.



Dominant structure is the dijet system with "this" jet around $(0, 0)$ and the "other" jet's far ridge in $\Delta\eta$ at $\Delta\phi \sim \pi$. Near-side ridge at $\Delta\phi \sim 0$.

Correlation observables 2: per-particle yields

To focus on long-range ridge effects, integrate over large $|\Delta\eta|$ to define S, B, and C functions in $\Delta\phi$ only, e.g.

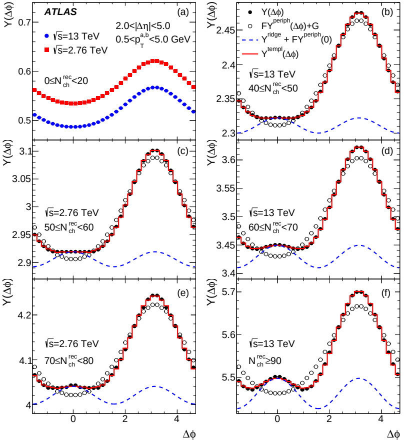
$$S(\Delta\phi) = \int_2^5 \mathrm{d}|\Delta\eta|\, S(\Delta\eta, \Delta\phi)$$

Useful to convert to a per-particle correlation yield:

$$Y(\Delta\phi) = C(\Delta\phi) \cdot \frac{\int B(\Delta\phi)\mathrm{d}\Delta\phi}{\pi N_a} = \frac{S(\Delta\phi)}{\hat{B}(\Delta\phi)} \Big/ \pi N_a$$

Y measures the average number of long-range correlation partners per "trigger" particle a at a given $\Delta\phi$.

Results:



Increasing modulation with N_{ch} fills in the near-side minimum ⇒ produces the ridge, and narrows + heightens the far-side peak.

Interpretation: yield fits

In $p+\mathrm{Pb}$ collisions, the ridge results from sinusoidal global modulation of single-particle azimuthal angle distributions.

This new study uses template fitting of Y to investigate whether the pp ridge has the same origin:

$$Y^{\mathrm{templ}}(\Delta\phi) = FY^{\mathrm{periph}}(\Delta\phi) + Y^{\mathrm{ridge}}(\Delta\phi)$$

where

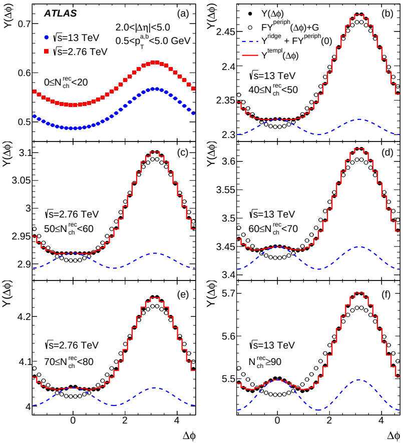
$$Y^{\mathrm{ridge}}(\Delta\phi) = G[1 + 2\,v_{2,2}\cos(2\Delta\phi)].$$

G is fixed by template normalisation = data;

Y^{periph} taken from lowest-multiplicity data bin;

F and $v_{2,2}$ free parameters for χ^2 fit.

Results:



Y^{periph} and Y^{ridge} as open points and blue line respectively; Y^{templ} in red fits several data features with 2 params on one sinusoid.

Interpretation: testing *single* particle modulation

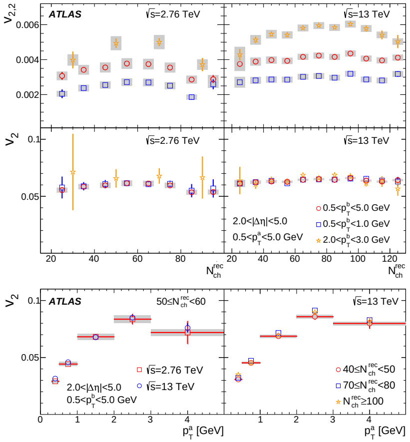
If the ridge is formed by sinusoidal modulation of *individual* particle production, then $v_{2,2}$ should factorise:

$$v_{2,2}(p_T^a, p_T^b) = v_2(p_T^a)v_2(p_T^b).$$

Tested for 3 p_T^b bins vs track multiplicity $N_{\mathrm{ch}}^{\mathrm{rec}}$. Extract v_2 from combinations of $p_T^{a,b}$ bins in $v_{2,2}$:

$$v_2(p_{T1}) = v_{2,2}(p_{T1}, p_{T2})/\sqrt{v_{2,2}(p_{T2}, p_{T2})}.$$

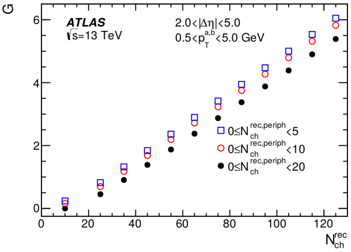
Results: top row shows fitted $v_{2,2}$, middle shows v_2. Latter shows clear agreement between p_T^b and substantial independence of multiplicity at both $\sqrt{s}$. Bottom row shows p_T dependence of v_2.

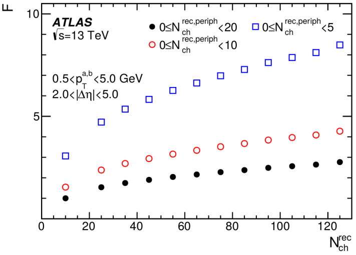


Extraction of $v_2(p_T^a)$ showing stability vs p_T^b bin and $N_{\mathrm{ch}}^{\mathrm{rec}}$.

Interpretation: modulation strength vs. N_{ch}^{rec}

Relative size of ridge modulation $\sim Gv_{2,2}/FY^{periph}(0)$
$\Rightarrow$ study G and F vs N_{ch}^{rec} :





Different datasets study N_{ch}^{rec} dependence of Y^{periph} extraction by subdividing the $N_{ch}^{periph} \in [0, 20]$ range.

$v_{2,2}$ fairly stable with N_{ch}^{rec} + linear growth of G + flattening of F
$\Rightarrow$ increase in ridge visibility with N_{ch}^{rec}

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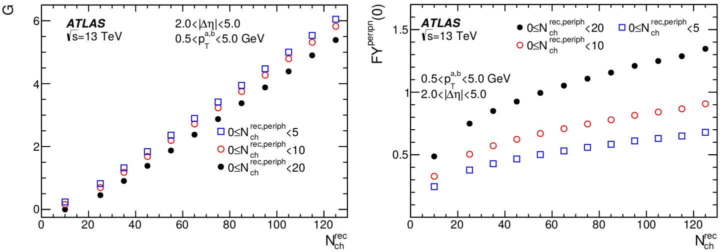

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Summary

- **The near-side ridge is still a major puzzle in LHC physics. Still there in high-multiplicity 13 & 2.76 TeV *pp* events!**
- A new fit of the $\Delta\phi$ modulation in these *pp* events shows excellent consistency with a single $2\Delta\phi$ Fourier mode, which not only produces the near side ridge but also beneficially modifies the away side peak with increasing $N_{\mathrm{ch}}^{\mathrm{rec}}$.
- Comparison of the $v_{2,2}$ Fourier coefficient in $\Delta\phi$ yields between p_T bins of trigger and partner tracks reveals single-particle modulation coefficients, v_2, independent of $N_{\mathrm{ch}}^{\mathrm{rec}}$ and p_T^b: consistent with azimuthal modulation of individual particle production.
- It hence appears that the *pp* and $p + \mathrm{Pb}$ ridge phenomena have the same source…but exactly what that is remains to be seen!