Azimuthal anisotropy of charged particles with transverse momentum up to 200 GeV in Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$ GeV

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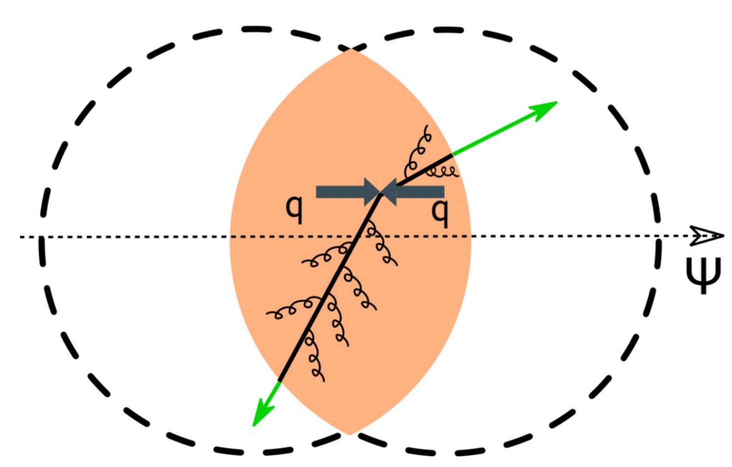
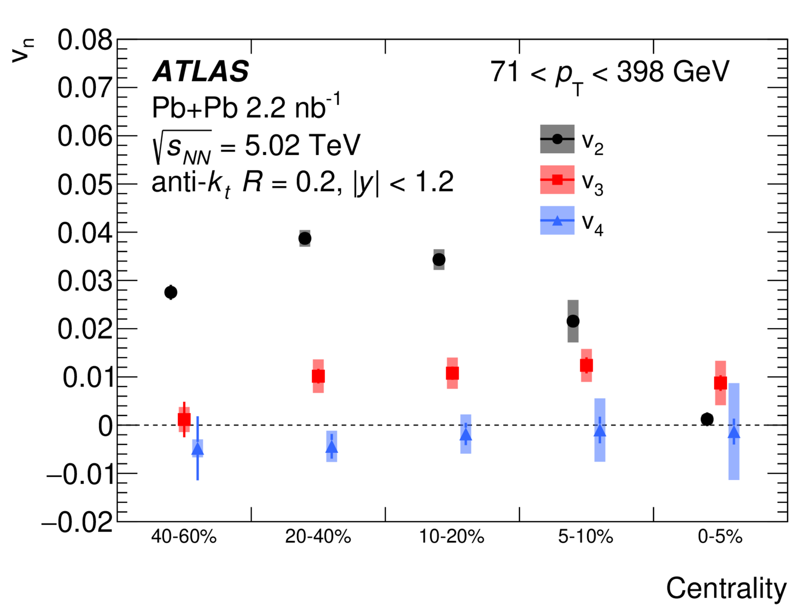
Motivation: Energy Loss Anisotropy in QGP

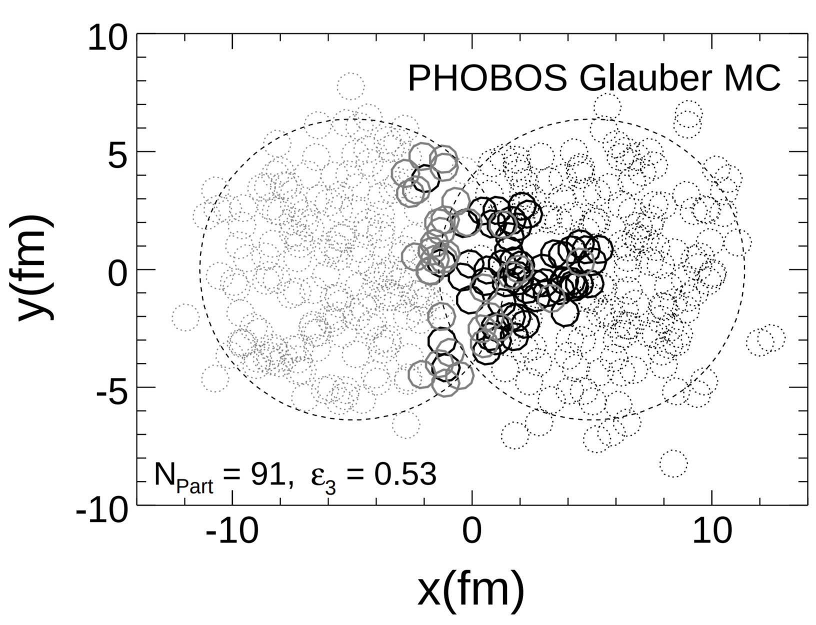
The **azimuthal anisotropy** v_n of high-p_T particles is sensitive to both the geometry of the Quark Gluon Plasma (QGP) and the energy loss mechanisms of jets.

$$\frac{dN}{d\phi} \propto 1 + 2\sum_{n=1}^{\infty} \cos(n(\phi - \Psi_n))$$



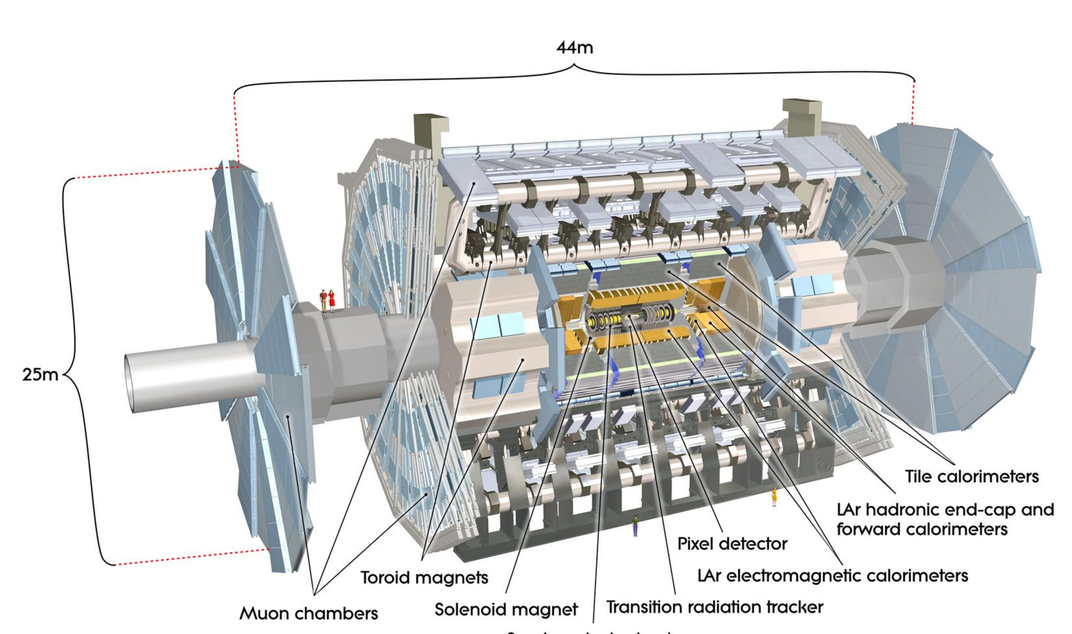
- Reveal the **short-distance interactions**.
- $v_{n>2}$ probes event-by-event **fluctuation**.
- **Follow up to the successful ATLAS jet v_n measurement[1] and extend the charged particle v_n to 200 GeV!**





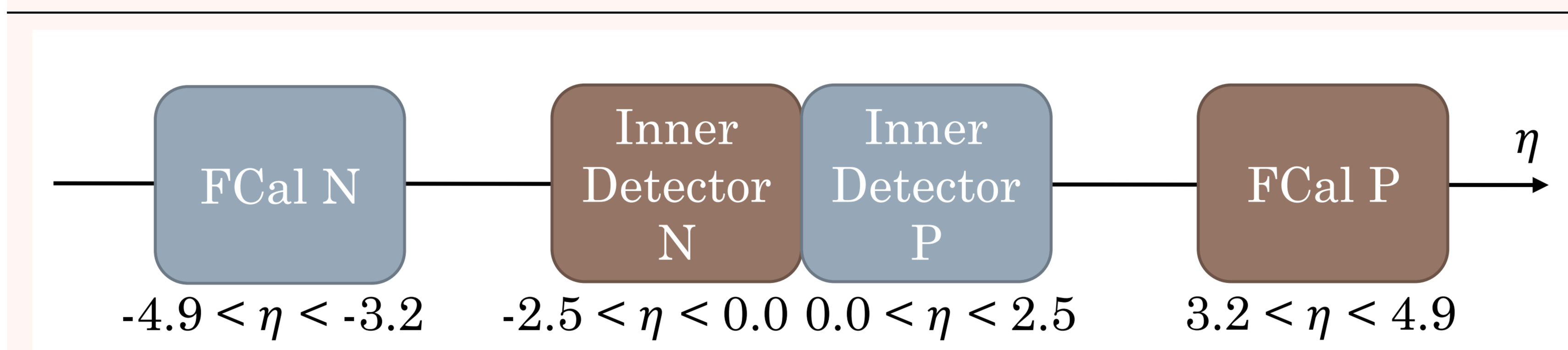
The ATLAS Detector

ATLAS is a general purpose detector at the LHC with 2π azimuthal coverage. The inner-detector system (ID) provides high-resolution charged-particle tracking in the pseudorapidity range $|\eta| < 2.5$. The calorimeter system covers a wide pseudorapidity range of $|\eta| < 4.9$.



The Pb+Pb dataset used in this analysis corresponds to an integrated luminosity of 1.72 nb^{-1} taken in 2018 Run II.

The Scalar-Product Method



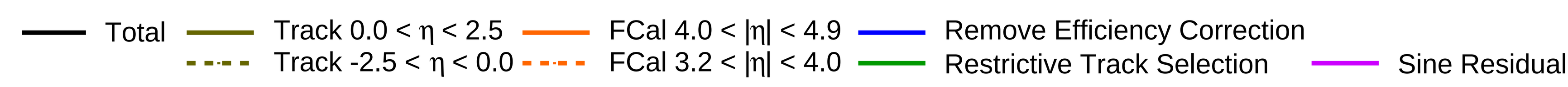
The scalar product method correlates the flow vectors of two subevents. In this analysis, we correlated,

- $q_{n,j}$, the flow vector of charged particles (Inner Detector)
- Q_n, the flow vector of the Forward calorimeter (FCal)

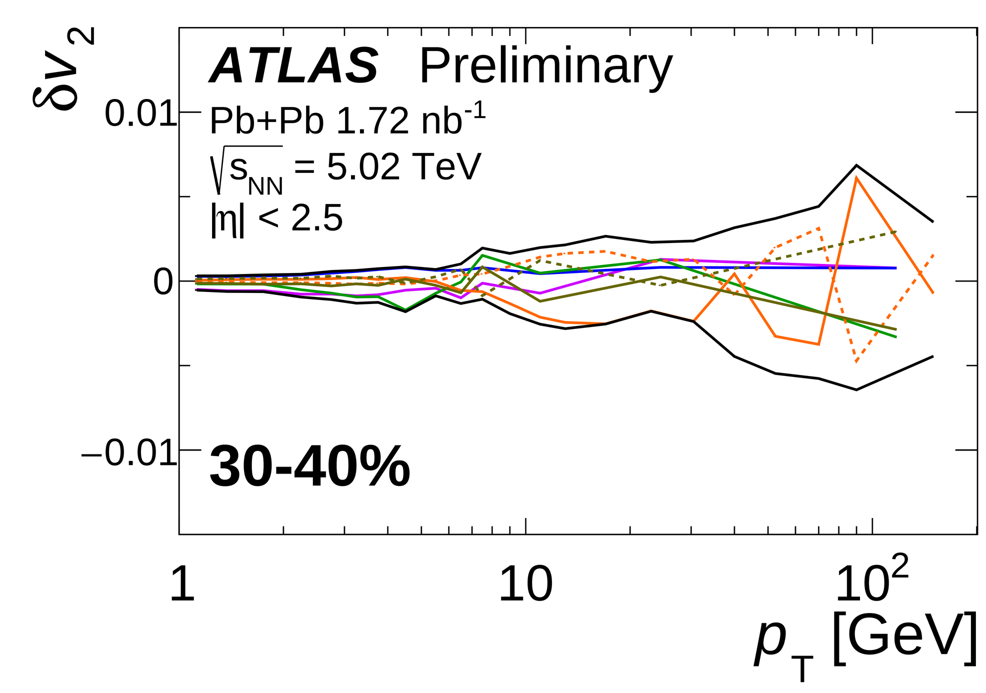
Positive half of inner detector is correlated with only negative half of the FCal and vice versa, thus imposing a minumum **pseudorapidity gap of 3.2** to **suppress non-flow signals** including resonance decay and di-jet.

$$v_n\{SP\} \equiv Re\frac{\left\langle q_{n,j} Q_n^{N|P*} \right\rangle}{\sqrt{\langle Q_n^P Q_n^{N*} \rangle}} = \sqrt{\langle v_n^2 \rangle}$$

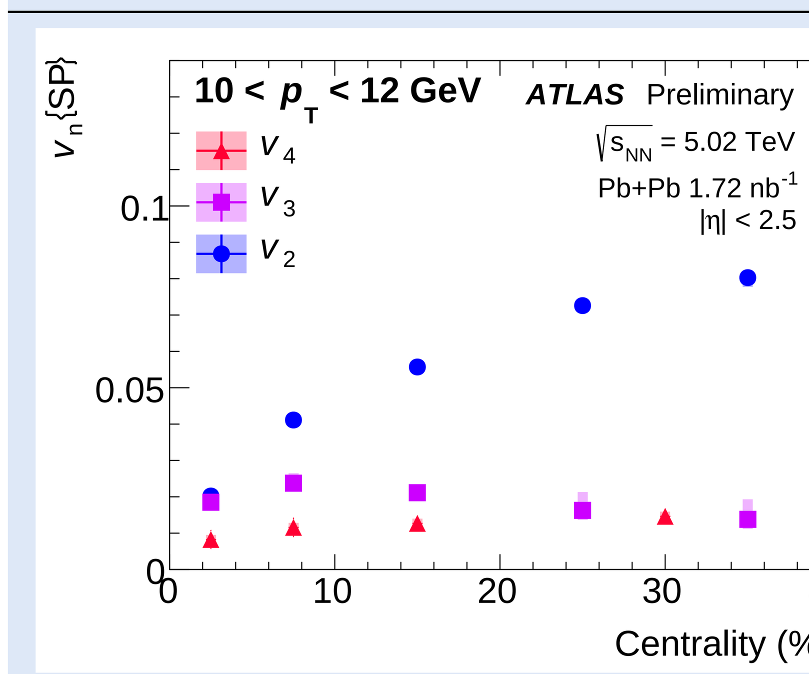
Uncertainties

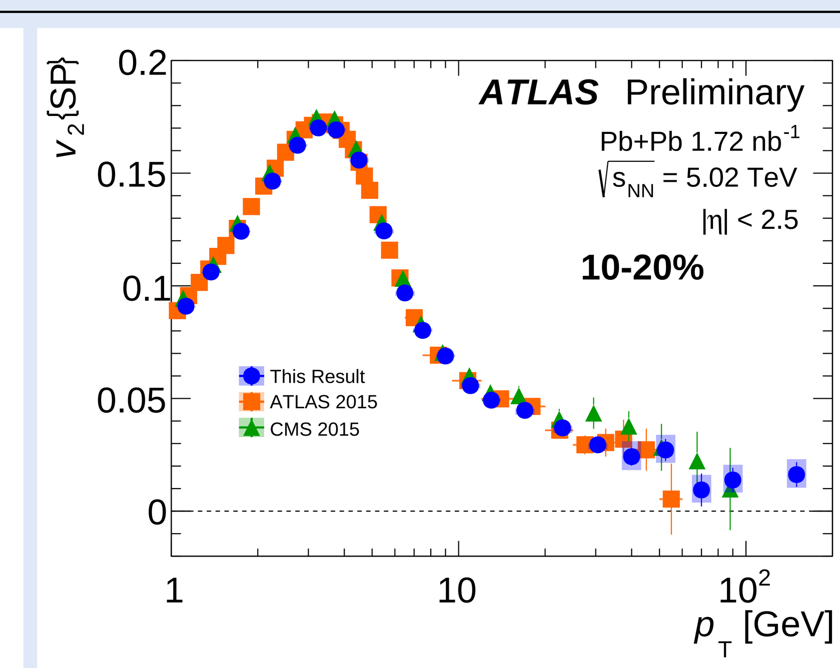


The measured v_n are subject to systematic uncertainties (box) associated with flow vector measurements, tracking selection and reconstruction efficiency. At high-p_T, statistical uncertainties (bar) dominate the uncertainty.

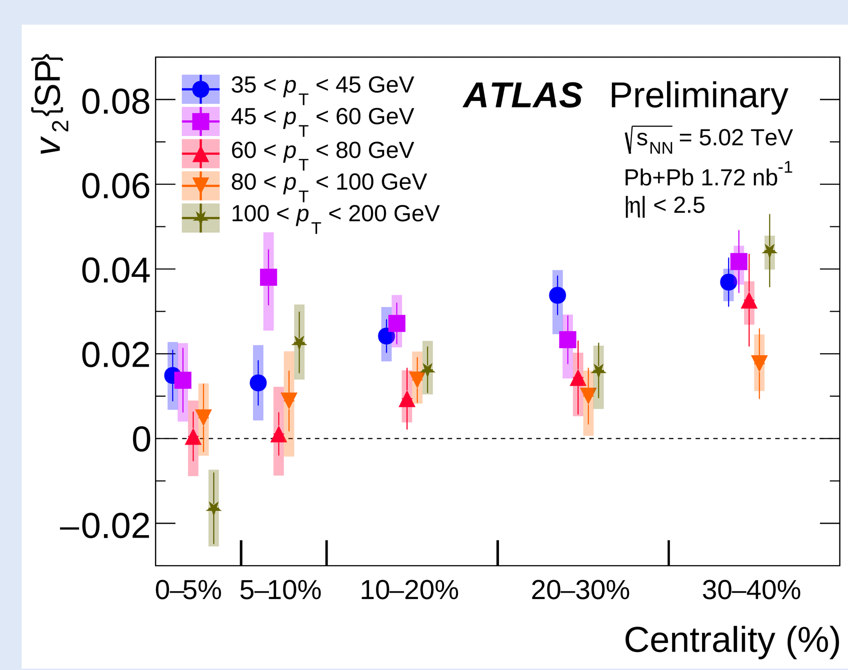


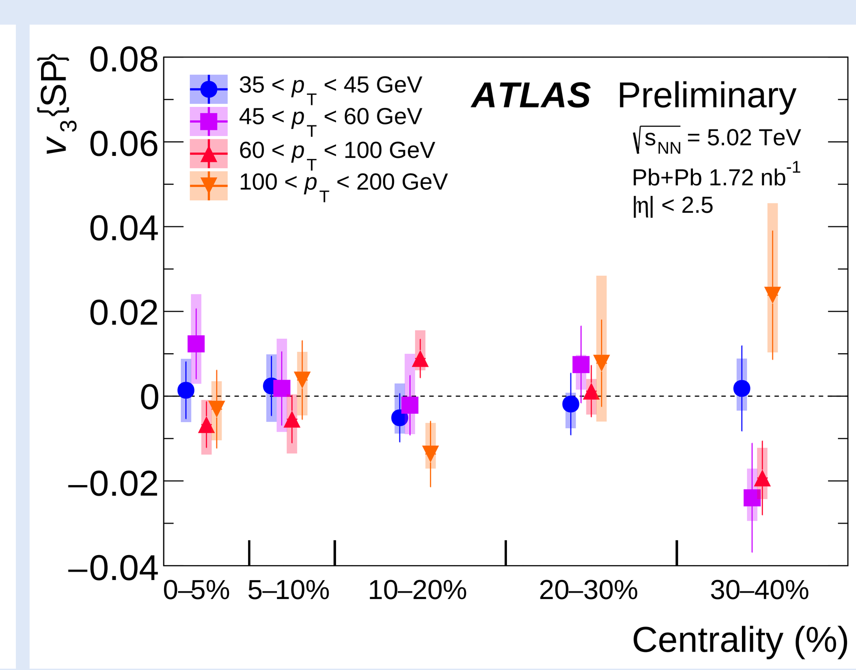
Result: High-p_T v_2, v_3 and v_4





Left plot shows v_2, v_3 and v_4 as a function of centrality. The centrality dependence is qualitatively consistent with the jet measurements. The geometry resultant v_2 increases up to mid-centrality as expected, while the fluctuation generated v_3 and v_4 show weaker centrality dependence. The right plot shows the comparison of v_2 versus p_T up to 200 GeV, which greatly expands from previous measurements[2,3].





In the high-p_T region, p_T-dependence of v_2 and v_3 are shown. v_2 is non-zero and decreases with p_T while v_3 is consistent with zero.

Conclusion, Take-away and Outlook

The azimuthal anisotropies v_2, v_3 and v_4 of charged particles were measured using the scalar product method in Pb+Pb collisions at 5.02 TeV with 1.72 nb[1] of data collected with the ATLAS detector.

- The increased luminosity has enabled **additional precision** for charged particle v_n measurements, and expand the transverse momentum up to 200 GeV for v_2 and v_3.
- v_2 is **positive** with a value of 1–2% at high-p_T for all except for most central events.
- v_3 and v_4 are **consistent with zero** at high-p_T for all centralities.

More measurements feasible with the good statistics of the ATLAS Run II data!

[1] ATLAS Collaboration. *Eur. Phys. J. C*, 78(2):142, 2018.
[2] ATLAS Collaboration. *Phys. Rev. C*, 105(6):064903, 2022.
[3] CMS Collaboration. *Phys. Lett. B*, 776:195–216, 2018.

This work is supported by the US National Science Foundation Award Number 2111046.