Measurements of azimuthal anisotropy of jets in heavy ion collisions

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GSU post-HP Workshop

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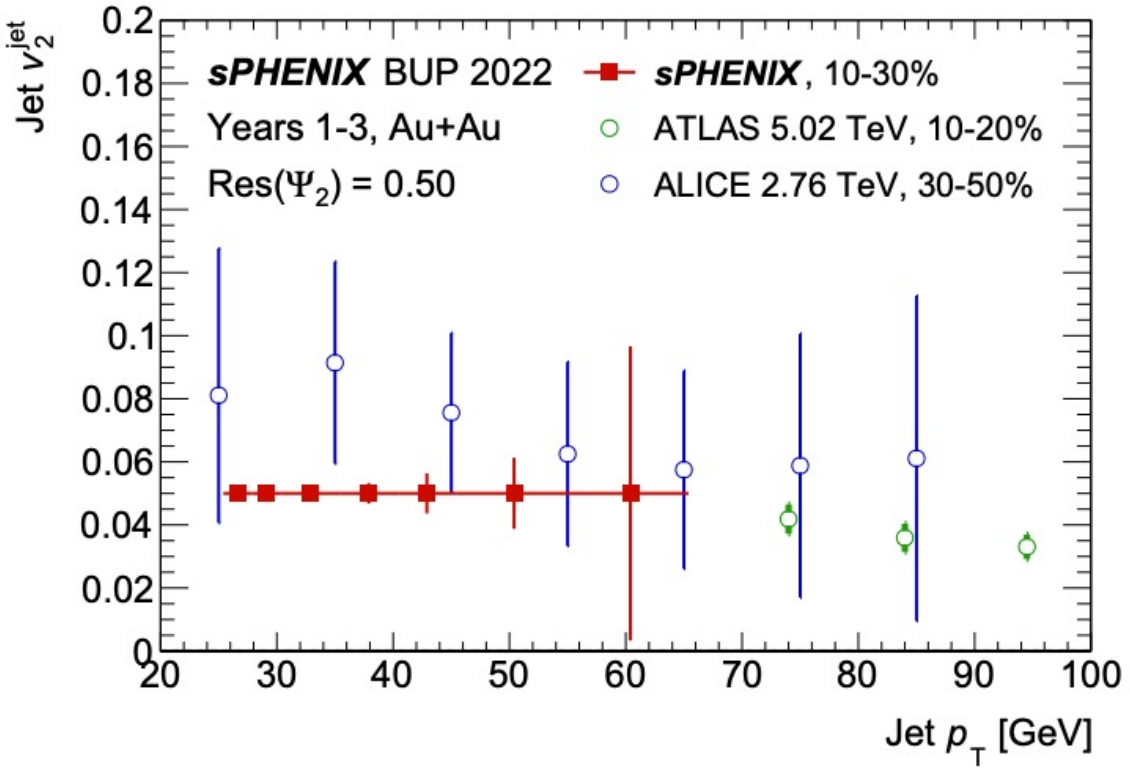
Goals of this presentation

- Introduce jet v_n measurements in heavy ion collisions
- Describe various technical methods used in these analyses
- Describe some experimental challenges in doing such measurements
- Ask questions to our theory friends about what are the most useful measurements for constraining energy loss

Why am I interested?

- We want to measure jet v_n in sPHENIX

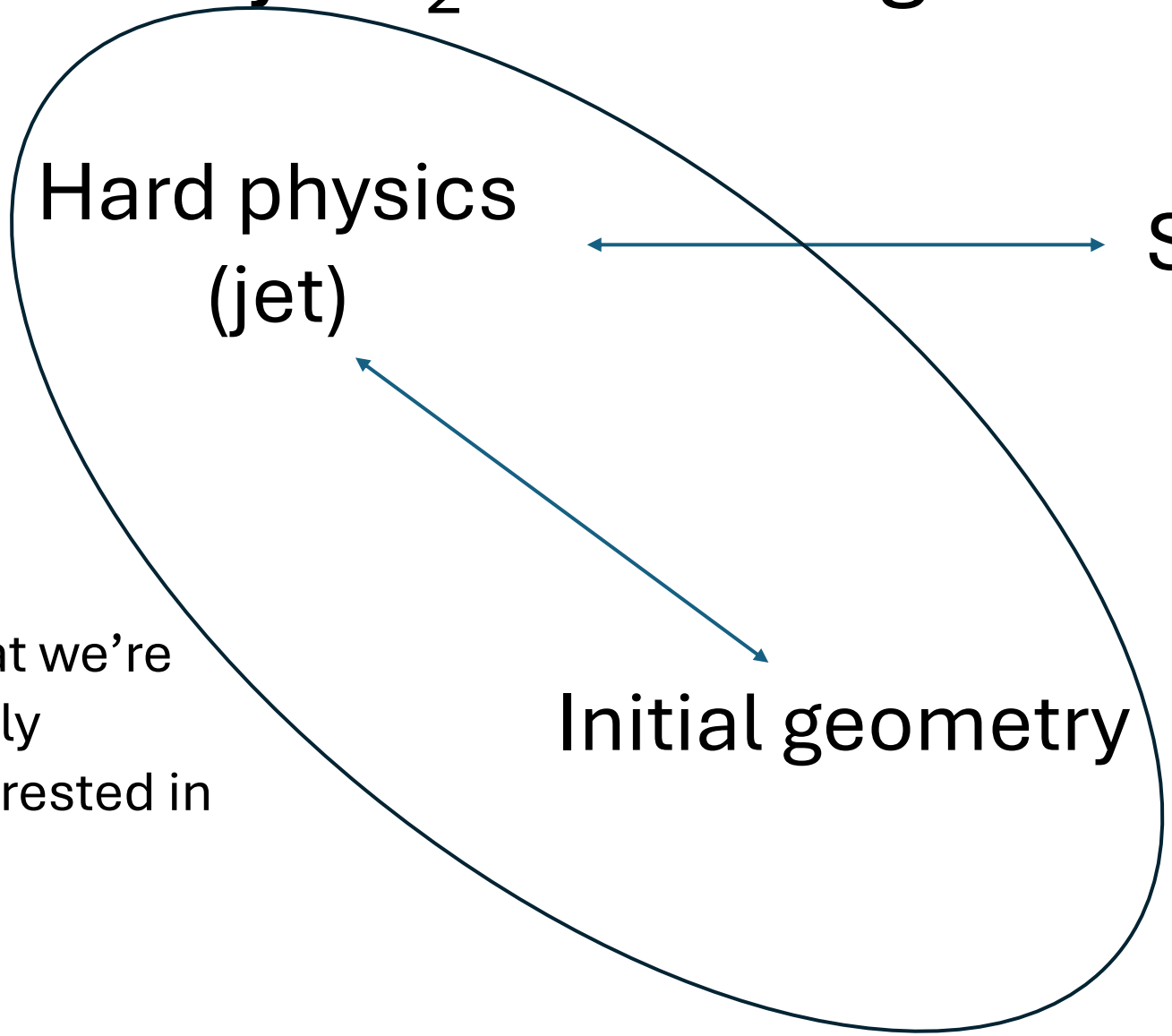
sPHENIX beam use proposal



What is jet v_2 measuring?

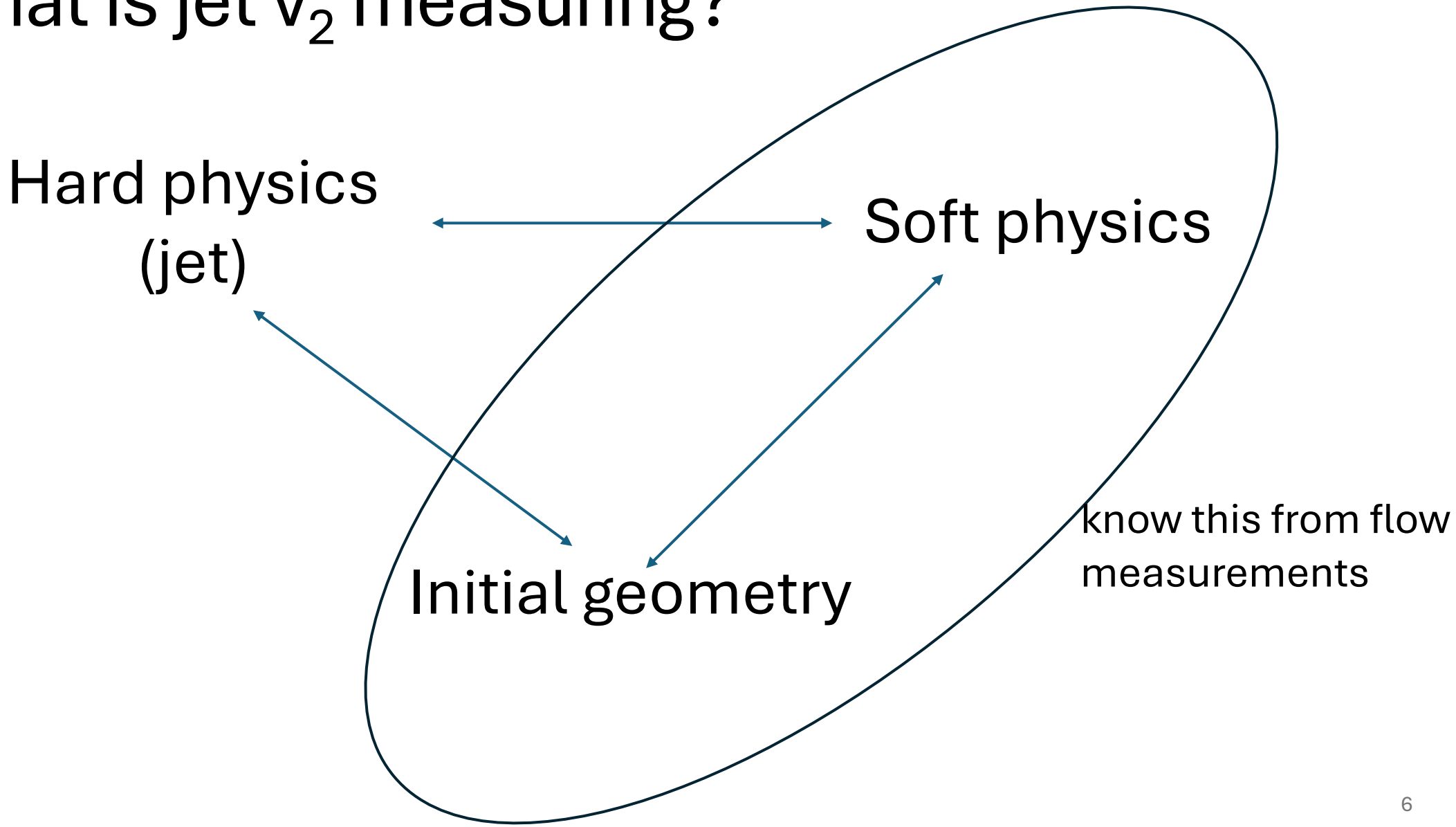
Hard physics (jet)  Soft physics

What is jet v_2 measuring?

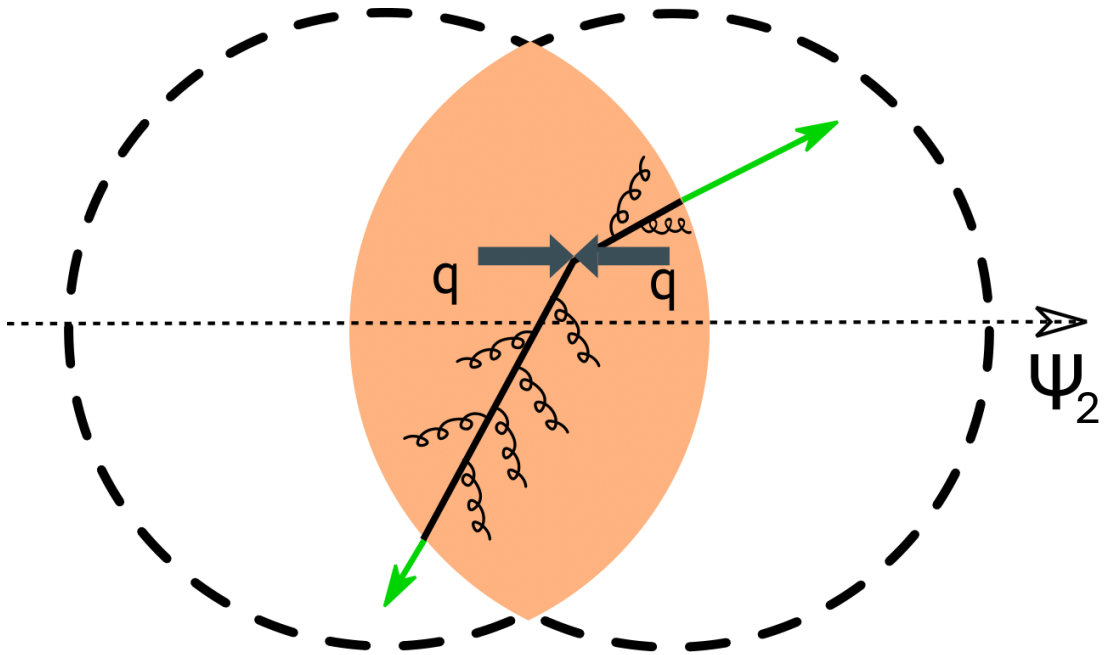


what we're really interested in

What is jet v_2 measuring?

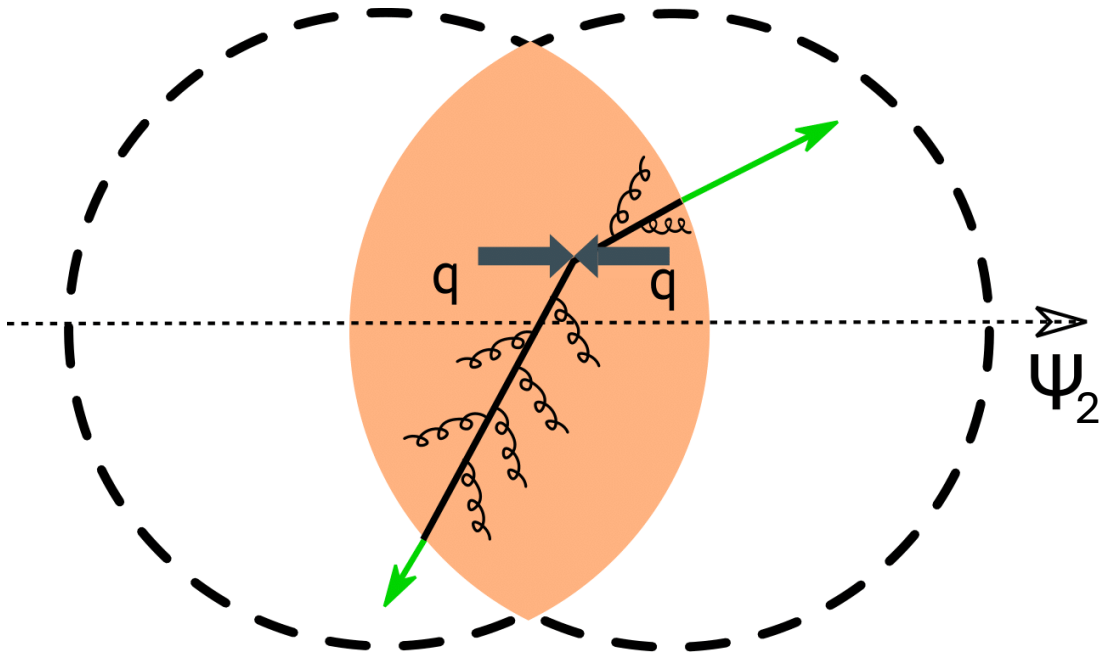


Azimuthal variation of energy loss



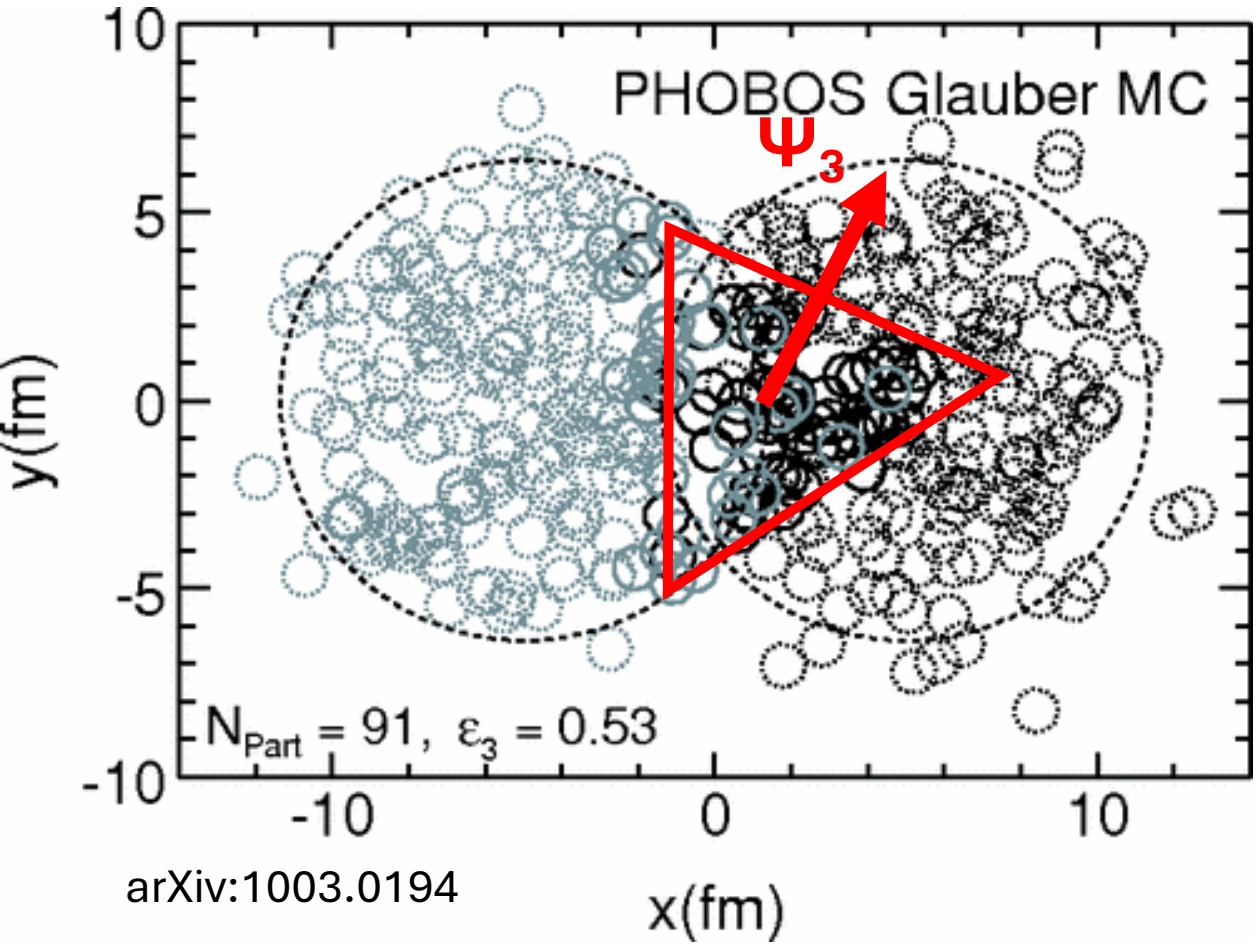
- Partons from hard scatterings lose energy as they traverse the QGP
  - What is the path-length dependence of this energy loss?

Azimuthal variation of energy loss



- Partons from hard scatterings lose energy as they traverse the QGP
  - What is the path-length dependence of this energy loss?
- Geometry of collision produces elliptical QGP → overall circular shape of nuclei
  - Geometry characterized by event plane angles Ψ_n
  - Jets produced in-plane traverse on average less QGP than those produced out-of-plane
  - This leads to an azimuthal modulation of jet yields in Pb+Pb collisions

Azimuthal variation of energy loss

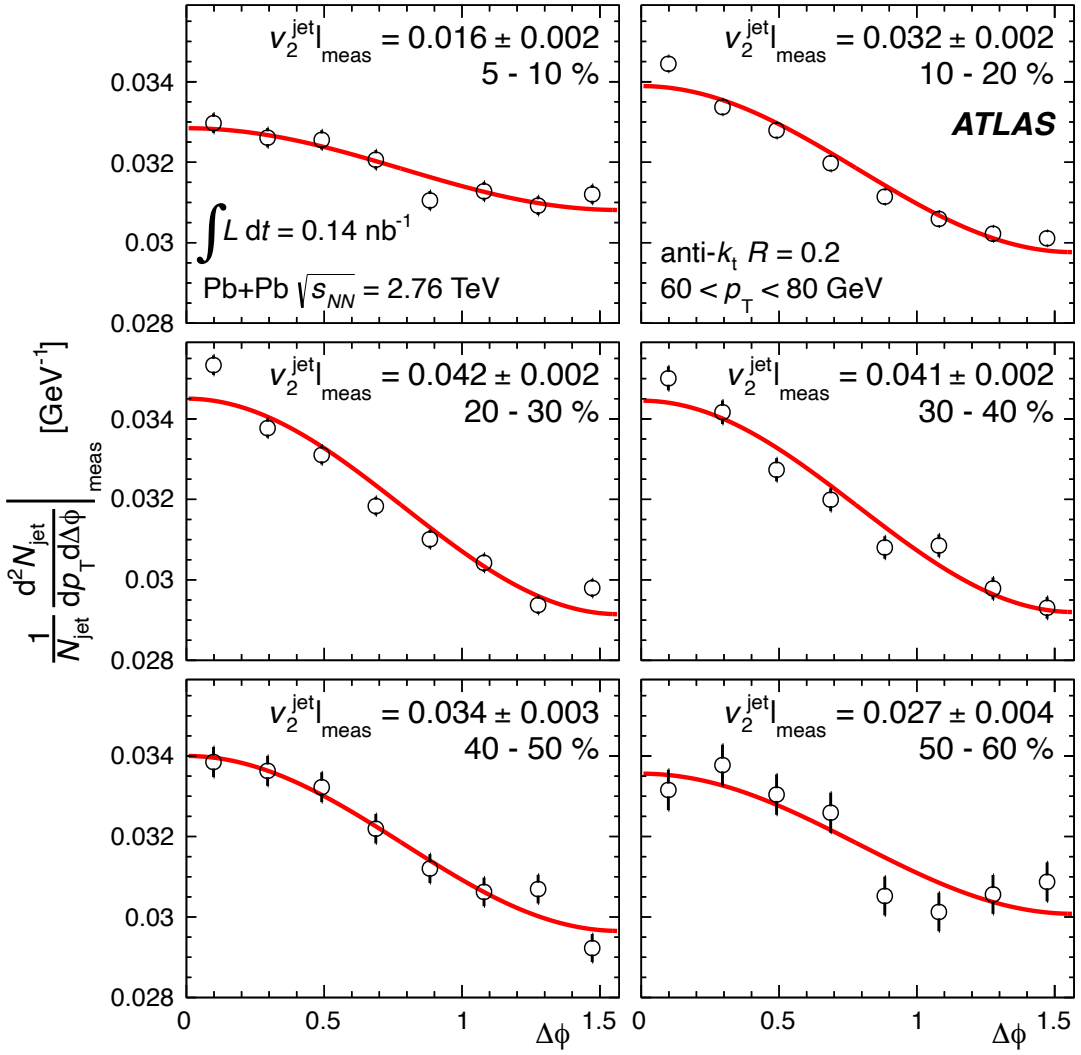


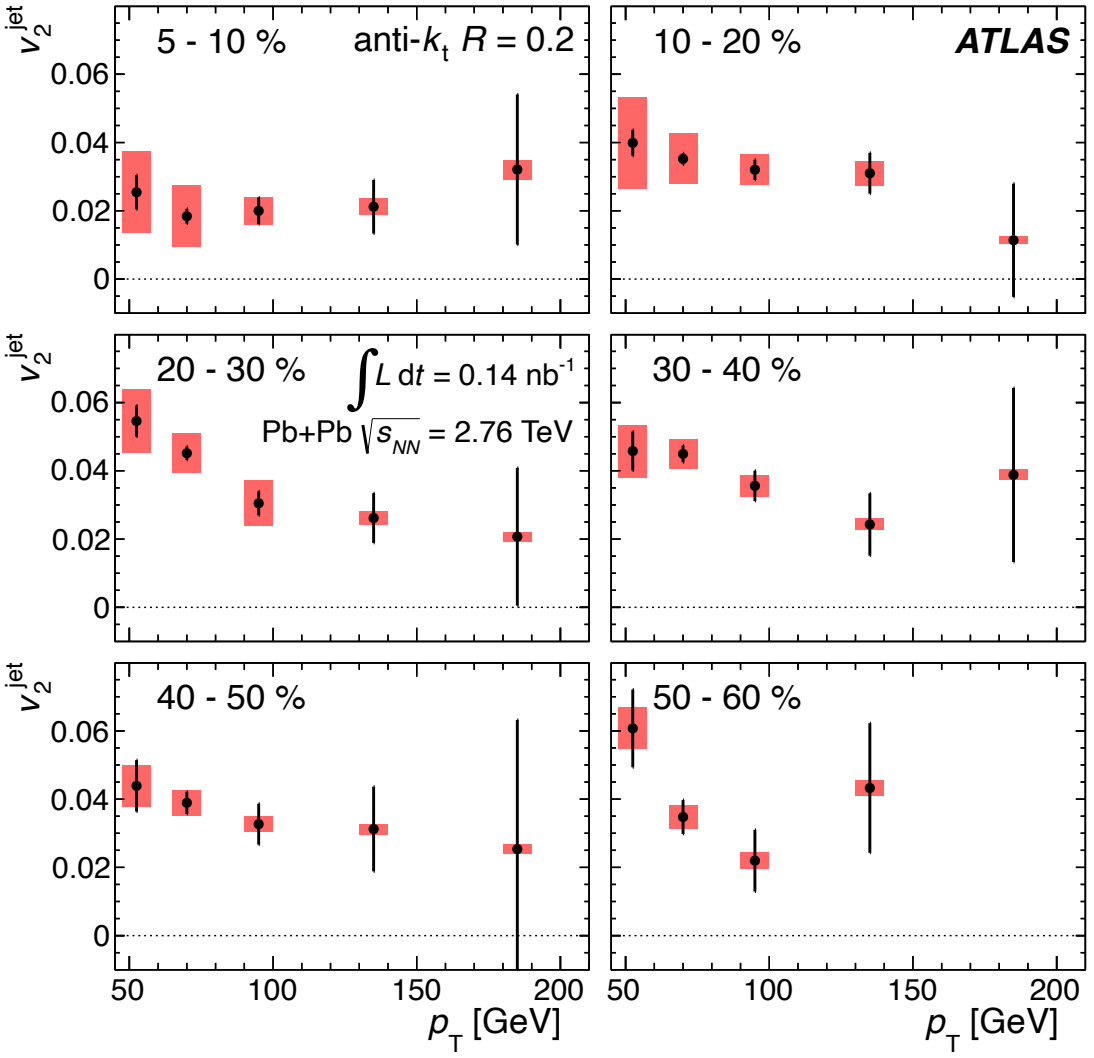
arXiv:1003.0194

- Fluctuations in initial state due to the positions of protons and neutrons in nuclei can potentially produce higher order modulations of the jet yields

Measurements of jet v_n

- ATLAS measurement at 2.76 TeV
- Event plane method – fit $\Delta\phi$
- Calorimeter jets

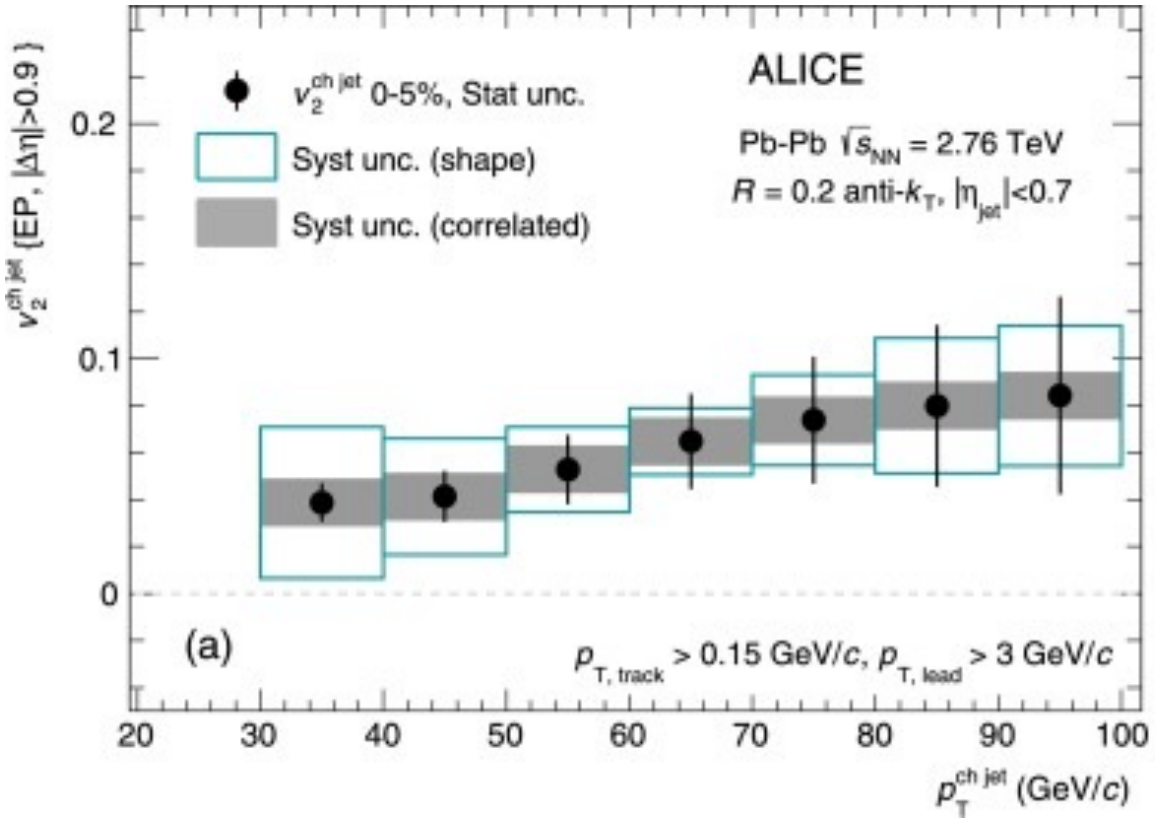


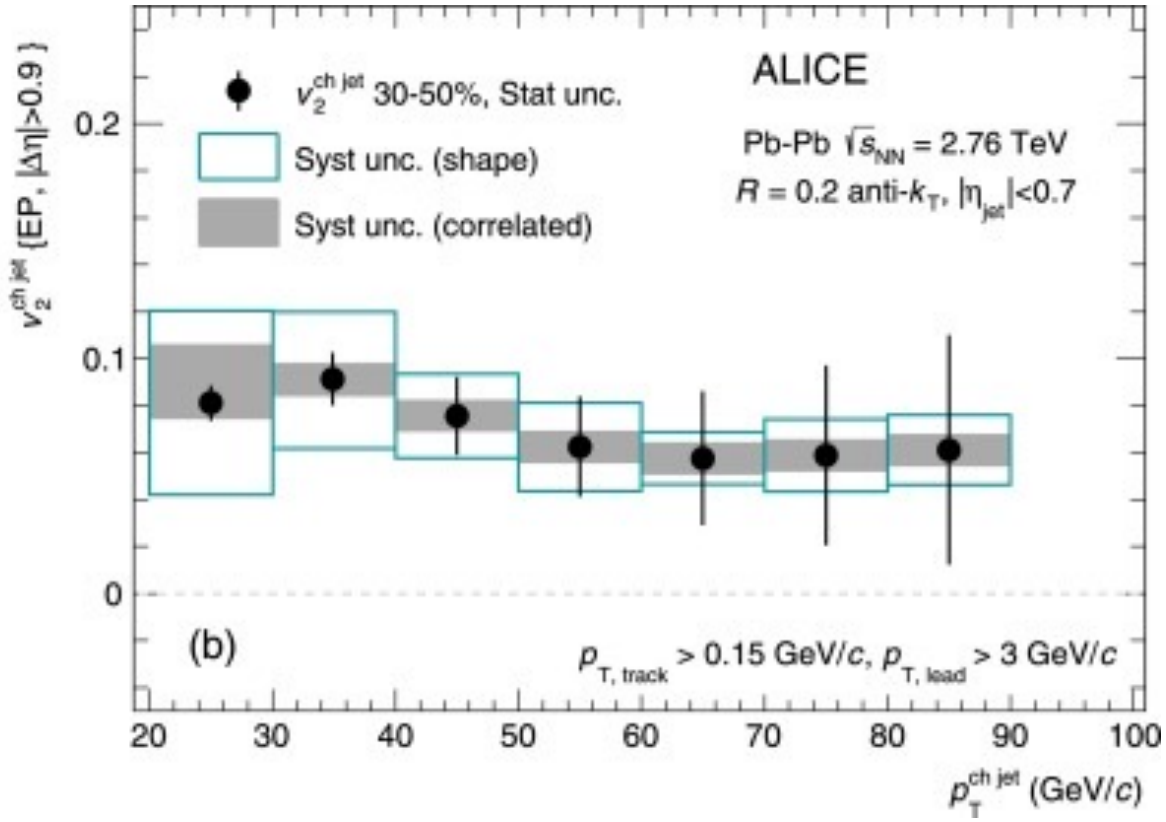


Phys. Rev. Lett. 111 (2013) 152301

Measurements of jet v_n

- ALICE measurement at 2.76 TeV
- In-plane to out-of-plane ratio
- Charged particle jets



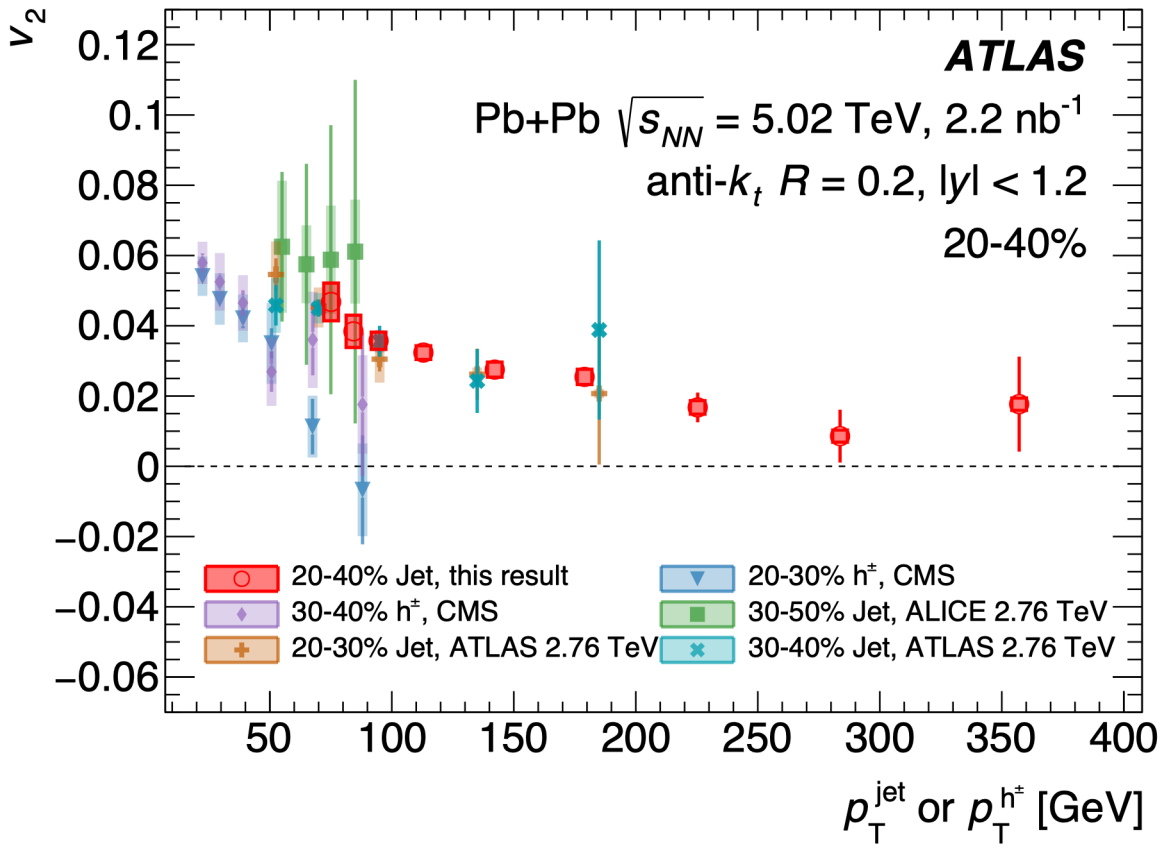


Phys. Lett. B 753, 511 (2016).

Measurements of jet v_n

- ATLAS measurement at 5.02 TeV
- Event plane method – fit $\Delta\phi$
- Calorimeter jets

Phys. Rev. C 105 (2022) 064903



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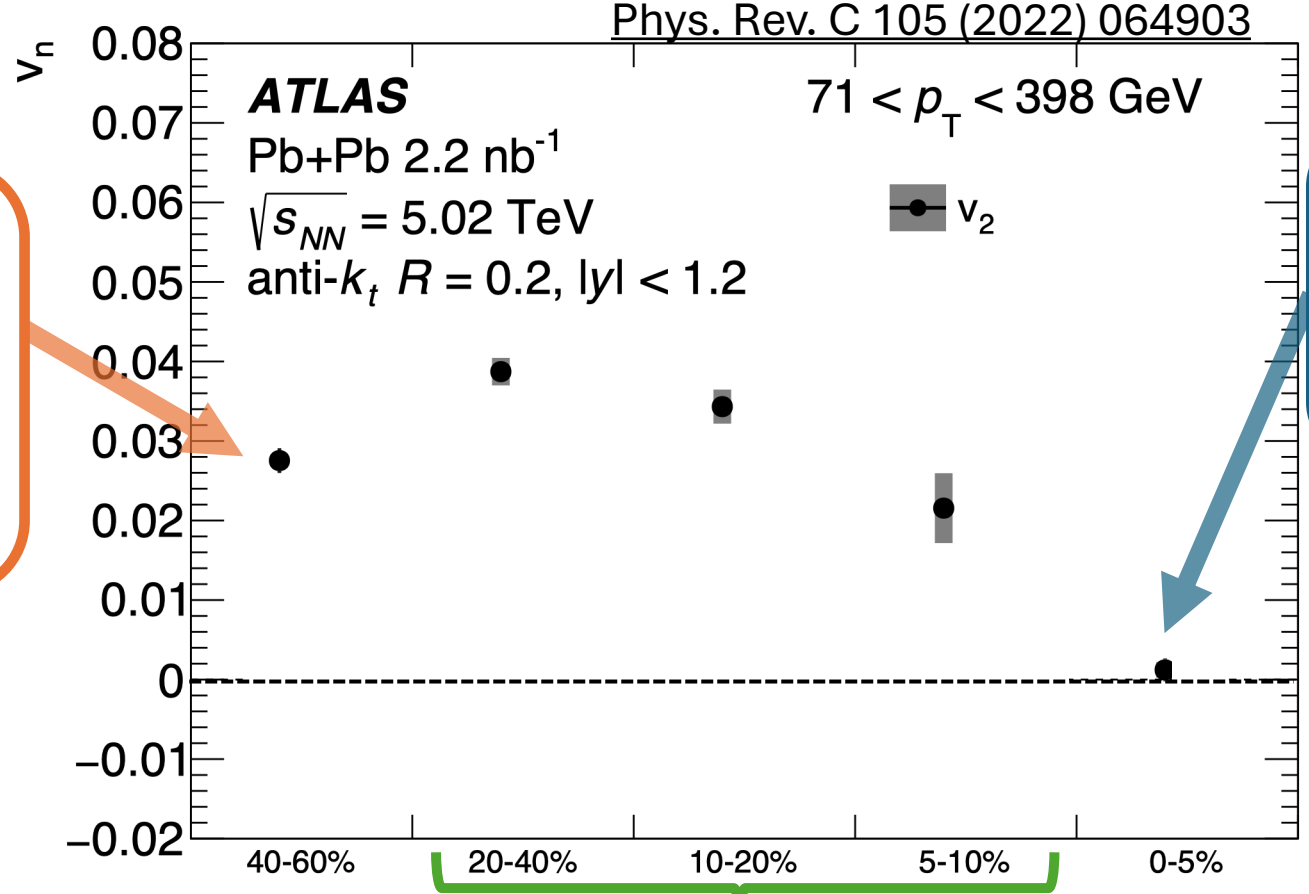
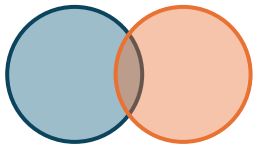
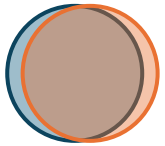


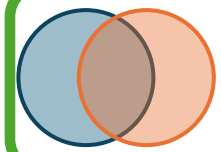
Smaller overlap → less QGP

overall less energy loss



More azimuthally symmetric → less variation in energy loss





Large eccentricity in initial state → large v_2 measured in final state

Measurements of jet v_n

- ATLAS measurement at 5.02 TeV
- Event plane method – fit $\Delta\phi$
- Calorimeter jets

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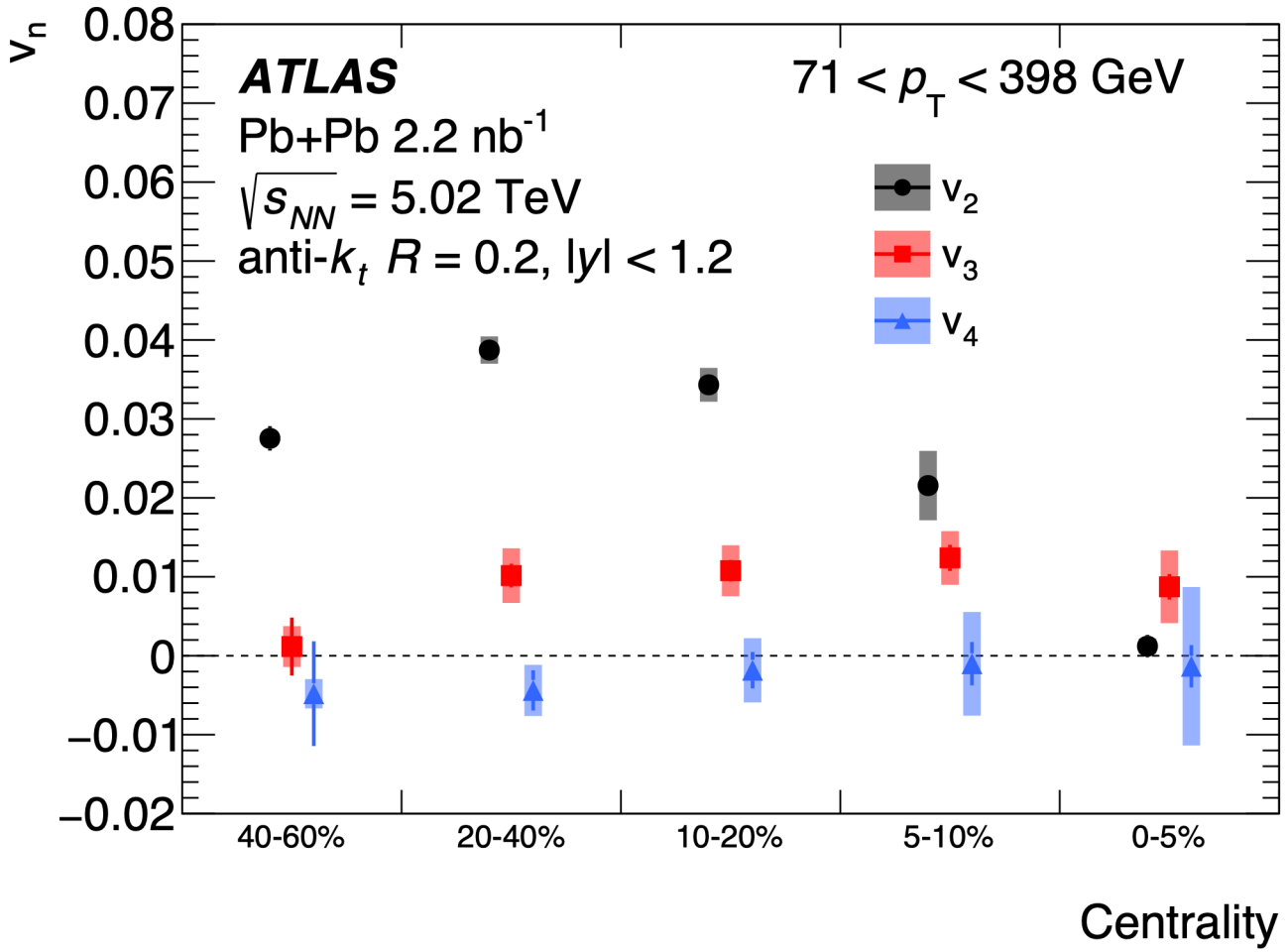
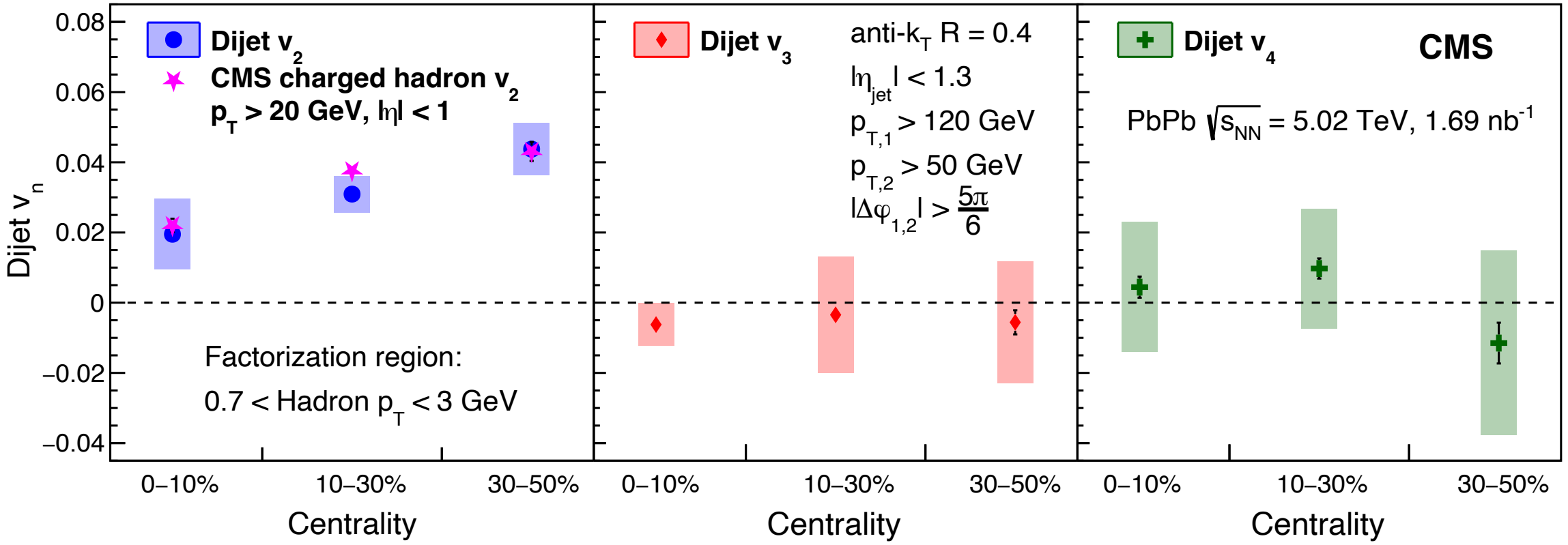


- First measurement of jet $v_{n>2}$
- Jet v_3 shows small non-zero value

Measurements of jet v_n

- CMS measurement at 5.02 TeV
- Jet-hadron correlations
- Calorimeter *dijets*

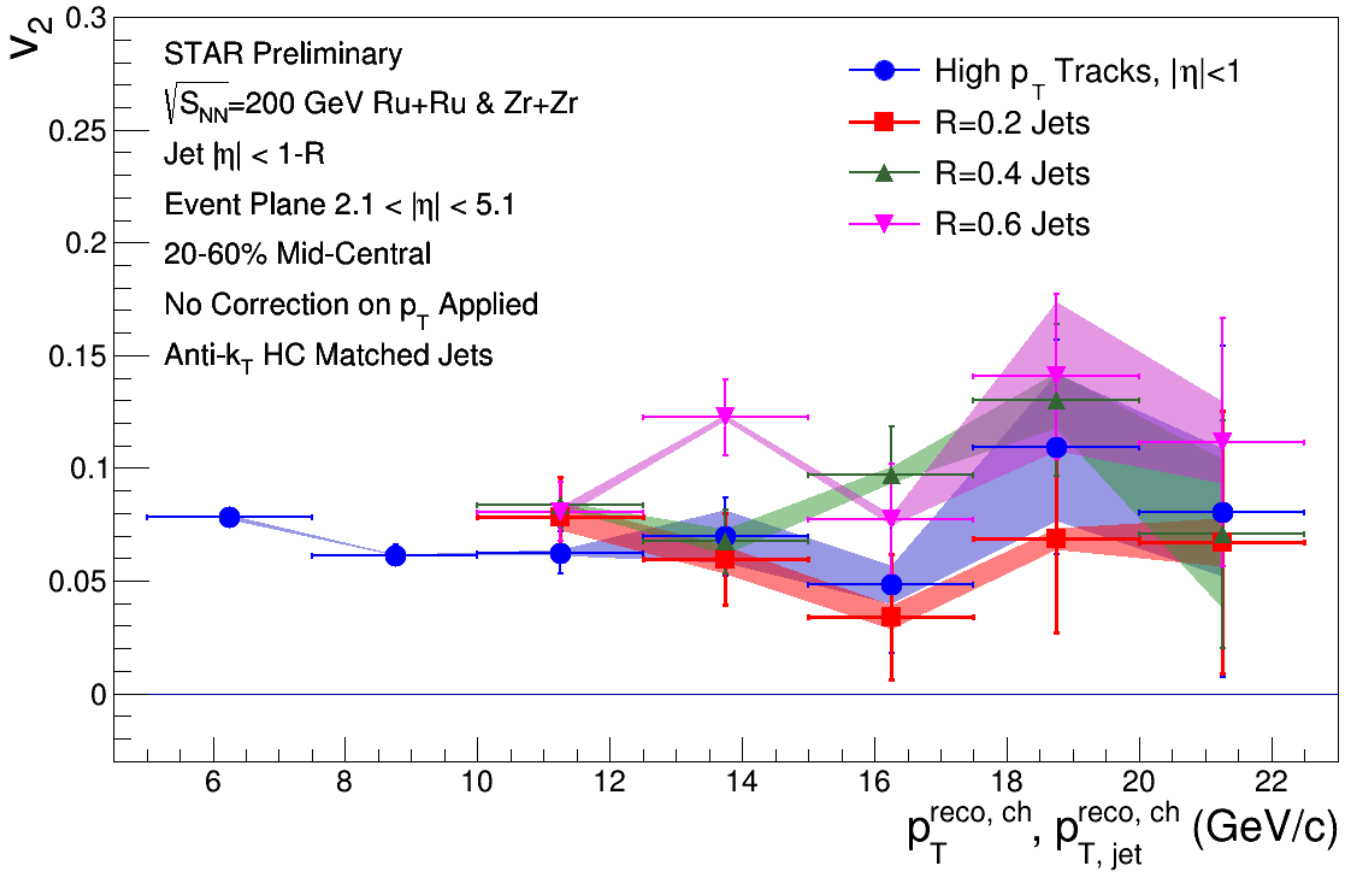


JHEP07(2023)139

Measurements of jet v_n

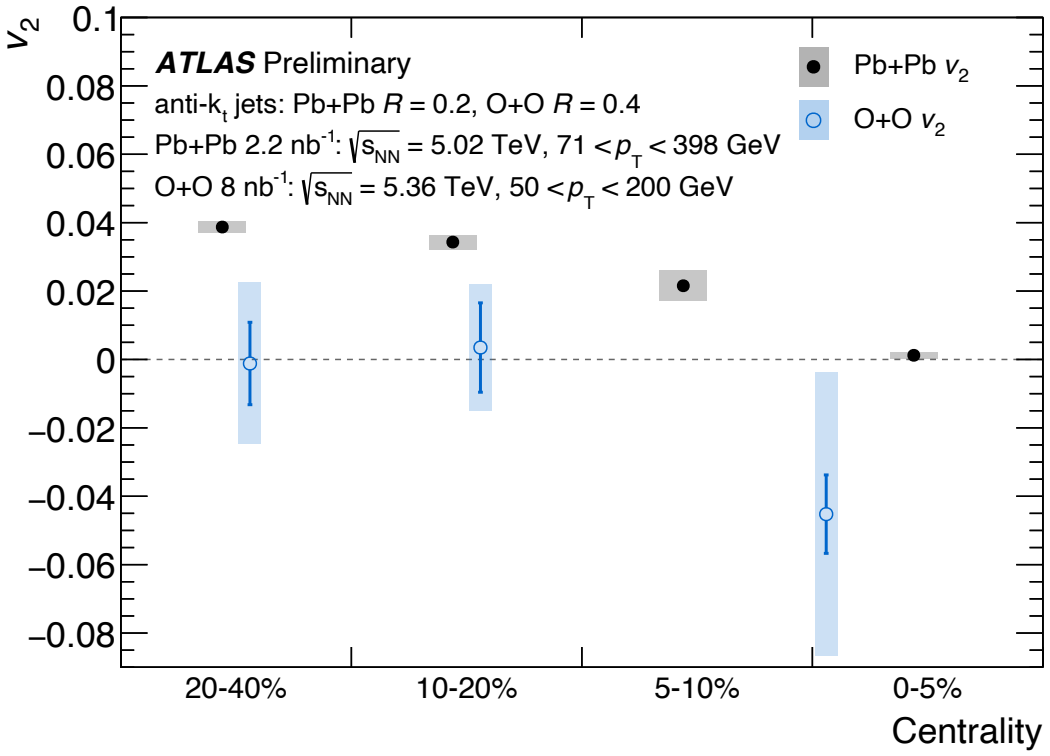
- STAR measurement at 200 GeV isobars
- Event plane method – fit $\Delta\phi$
- Charged particle jets

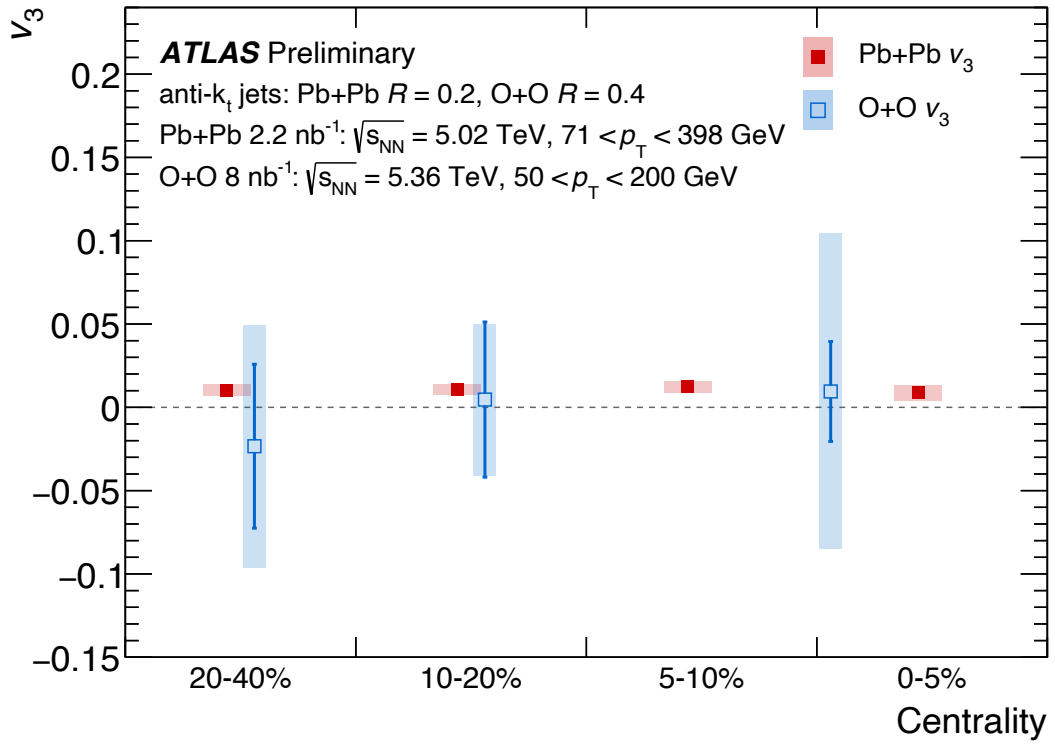
PoS(HardProbes2023)176



Measurements of jet v_n

- ATLAS measurement at 5.36 TeV O+O
- Scalar product method w/ nonflow subtraction
- Calorimeter jets





Experimental challenges- UE

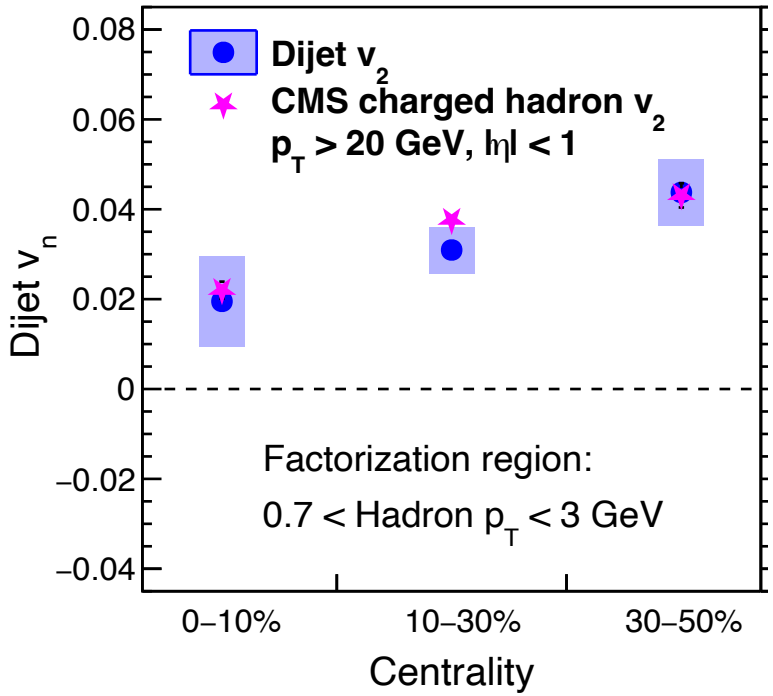
- Large underlying event has same azimuthal anisotropy as signal we are looking for in jets- need to be very careful in subtracting
  - Residual UE can lead to in-plane vs. out-of-plane differences in jet energy scale & resolution, leading to false jet v_n signal
- Large fluctuations in UE can be reconstructed as “fake jets” which again will be preferentially in-plane. Need to either measure at high pt to avoid “fake jet” region or apply some filtering
  - STAR tags with “hard core” cut, but this introduces fragmentation biases

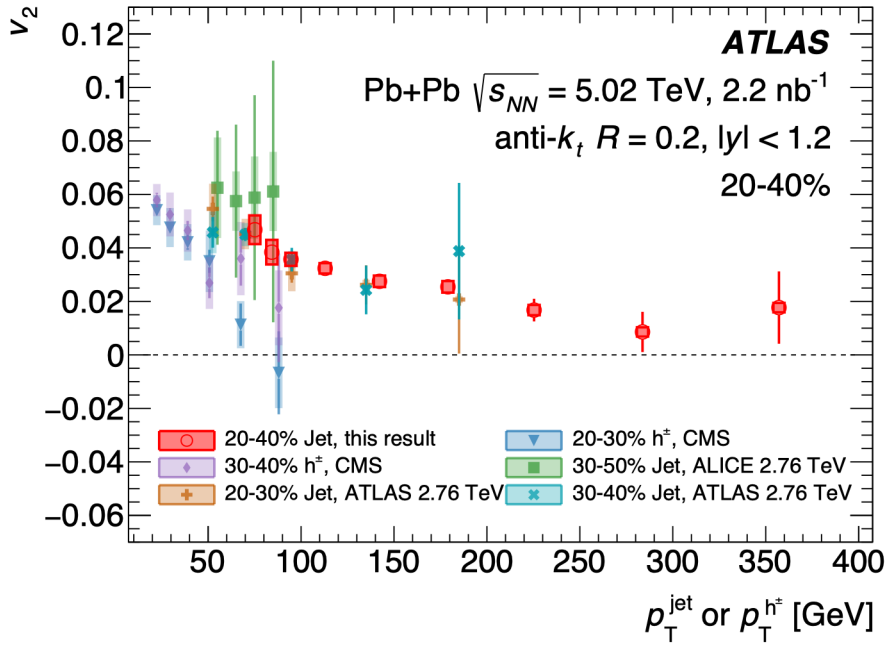
Experimental challenges- non-flow

- Correlations in particles from “non-flow” effects can bias v_n measurements, especially in small systems
- Experimentally need to either 1) reduce this effect or 2) explicitly subtract it

Question- full jet vs high p_T hadron

- What do we gain from measuring a fully reconstructed jet v_n vs. high p_T charged particles + fragmentation functions?





Question- method comparison

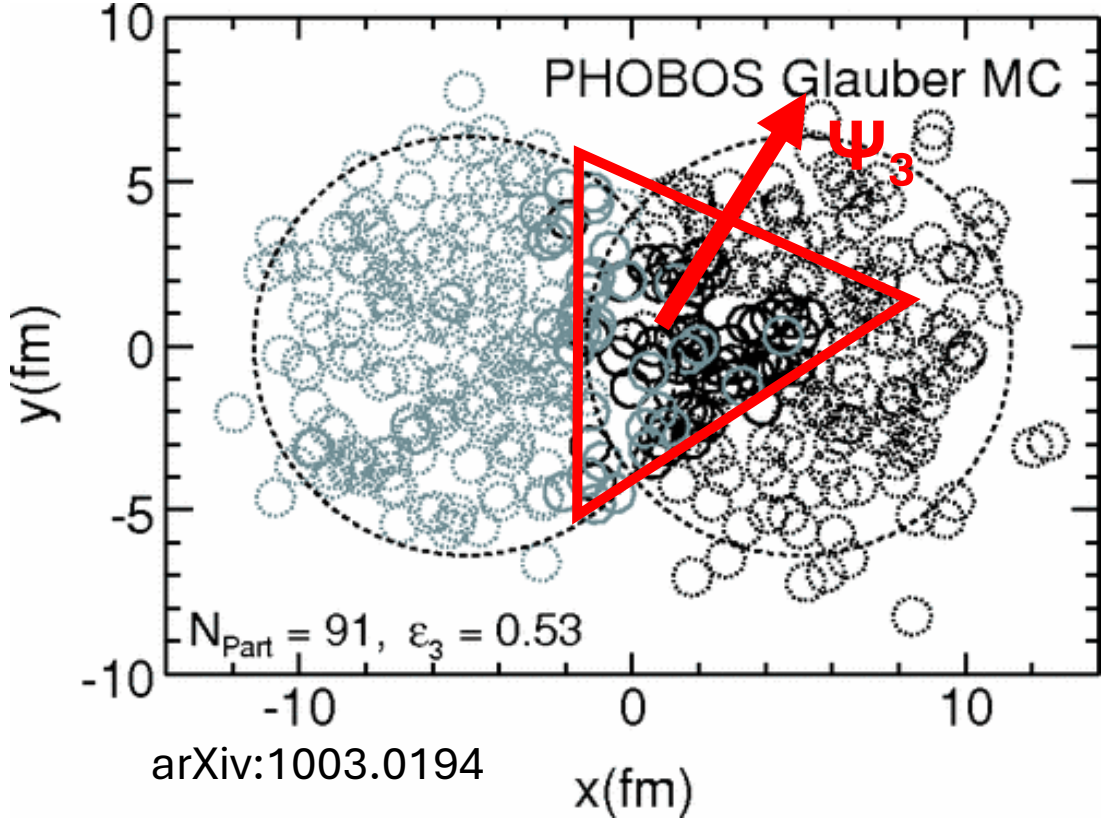
- What are the sensitivities for measuring the jet v_n using different methods (i.e. event plane vs scalar product)? Is one method preferred from the theoretical side?

Question- non-flow subtraction

- How important is the non-flow subtraction in large system measurements?

Question

- Do we gain anything from measuring both jet and dijet systems? Is it possible to measure a dijet v_3?



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