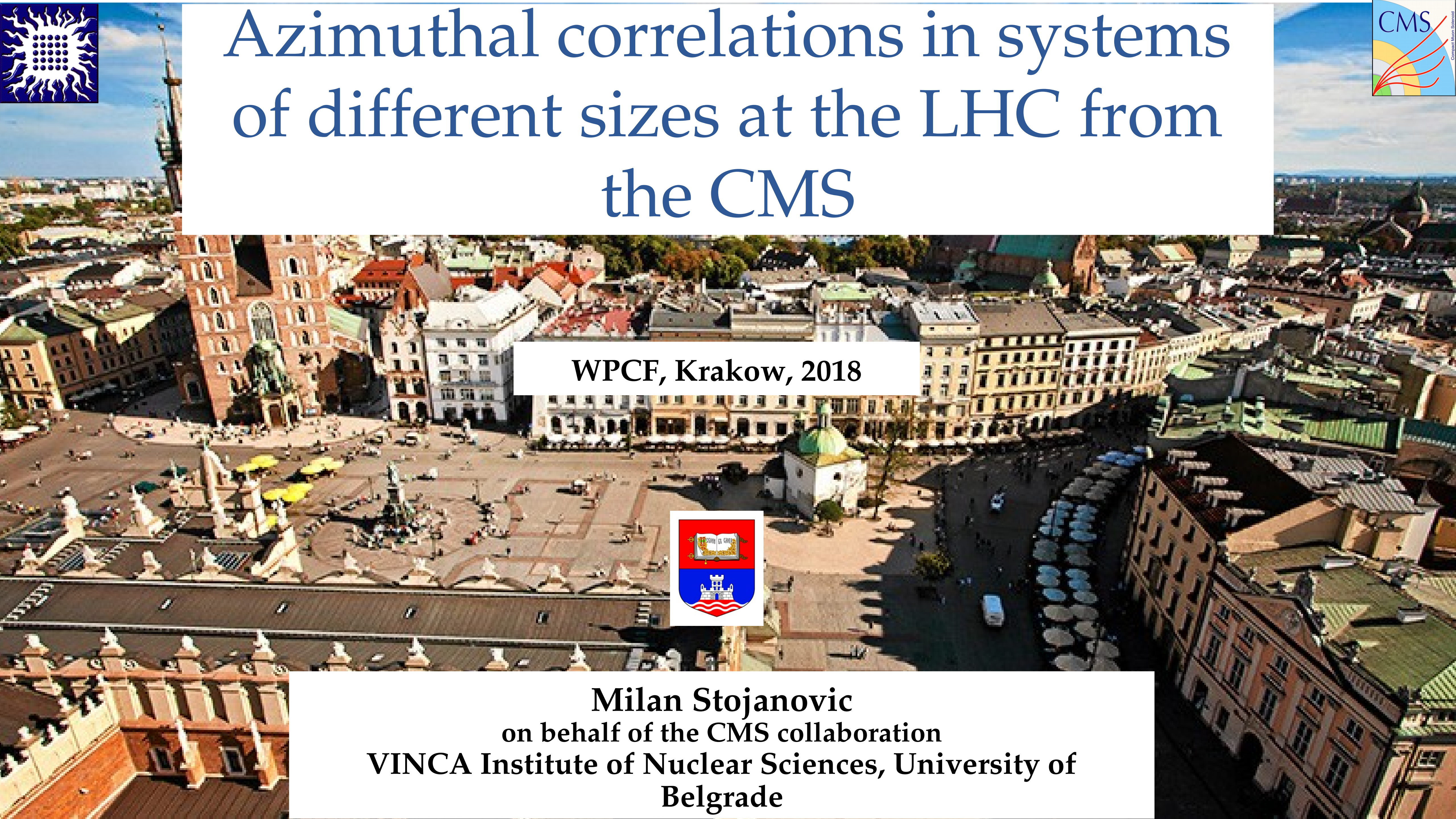


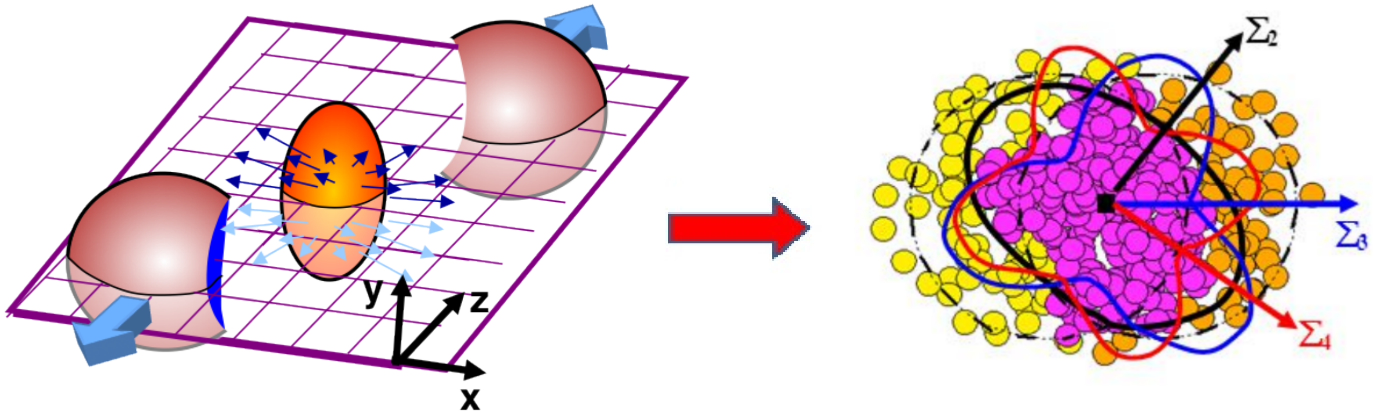
Azimuthal correlations in systems of different sizes at the LHC from the CMS

WPCF, Krakow, 2018

Milan Stojanovic
on behalf of the CMS collaboration
VINCA Institute of Nuclear Sciences, University of Belgrade

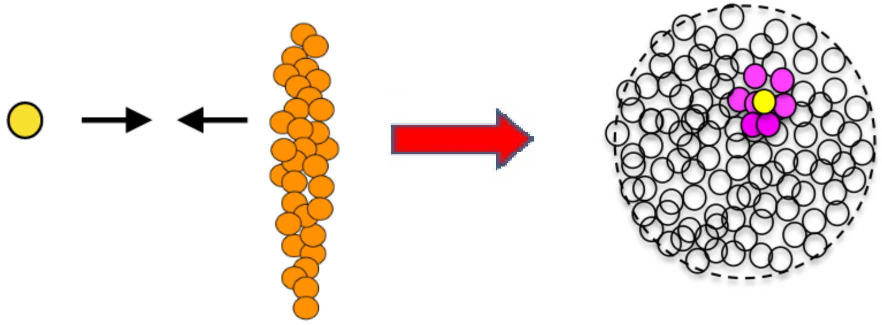
Introduction

A + A collisions



- $v_2 \rightarrow$ system geometry
- $v_3 \rightarrow$ initial fluctuations
- $v_4 \rightarrow$ fluctuations + non-linear part

p + A collisions



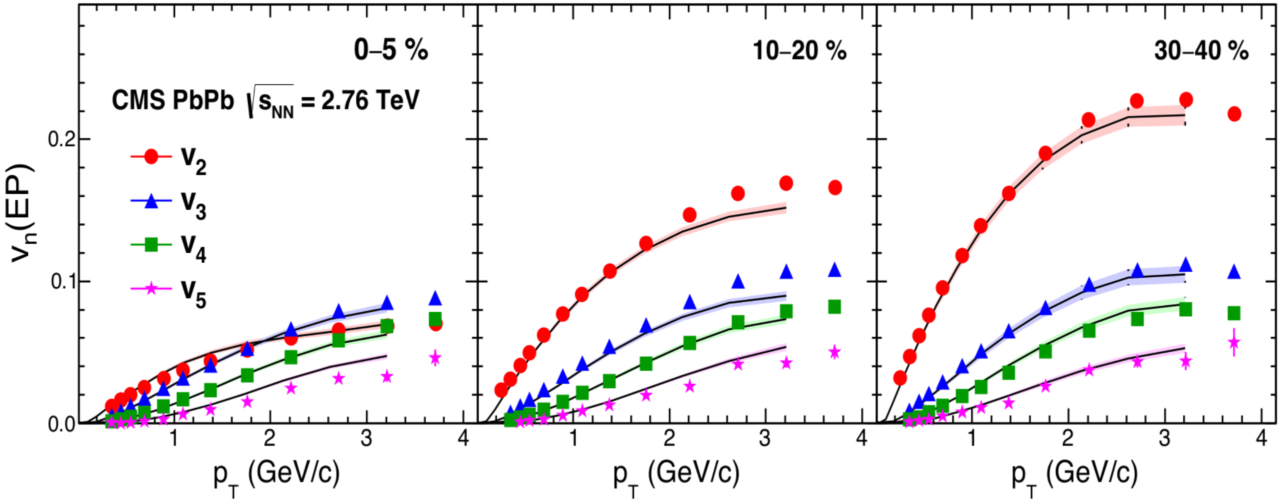
- $v_{2,}\, v_3 \rightarrow$ initial fluctuations!

Introduction

- Particle distribution over azimuthal angle:

$$\frac{dN}{d\phi} \propto 1 + \sum_n 2v_n \cos[n(\phi - \Psi_n)]$$

- V_n coefficients driven by:
  - Initial geometry;
  - Medium properties.

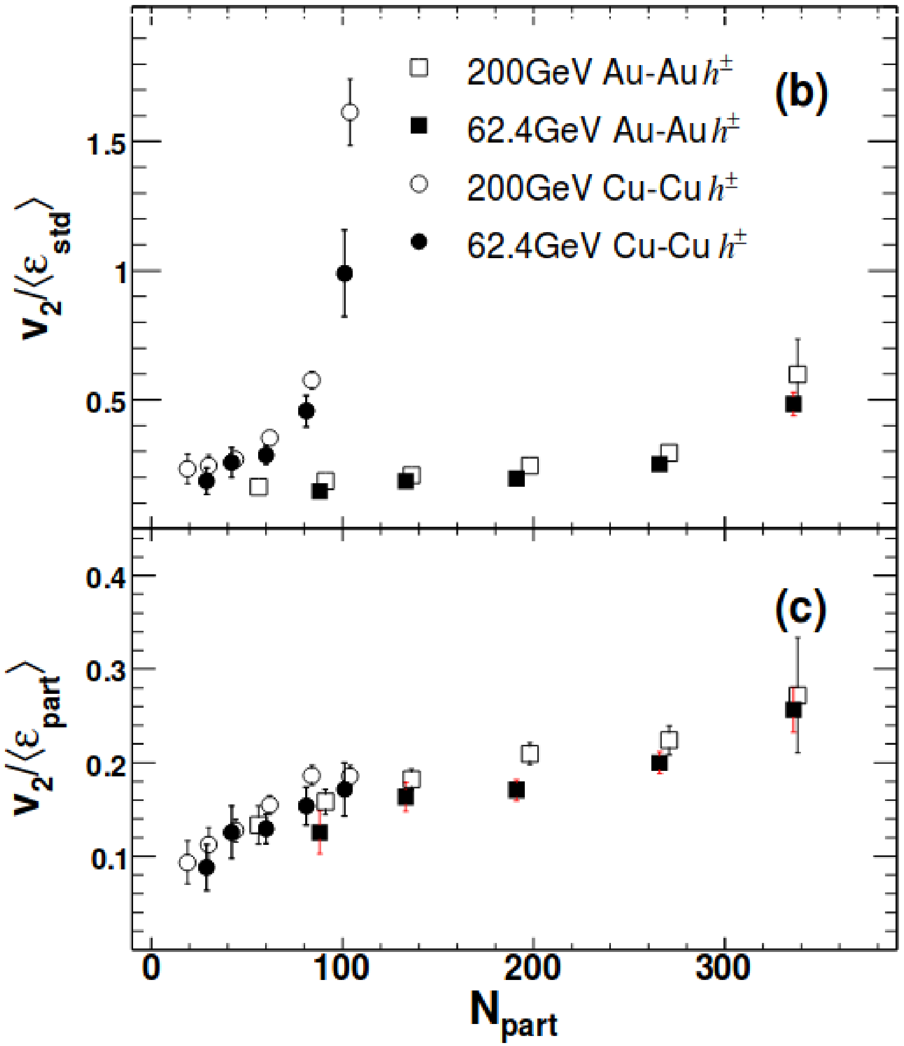


- Well understood in large systems with hydrodynamics

Data points: Phys.Rev.C89 (2014) 044906

Predictions (IP-Glasma + Music): PRL 110 (2013) 012302

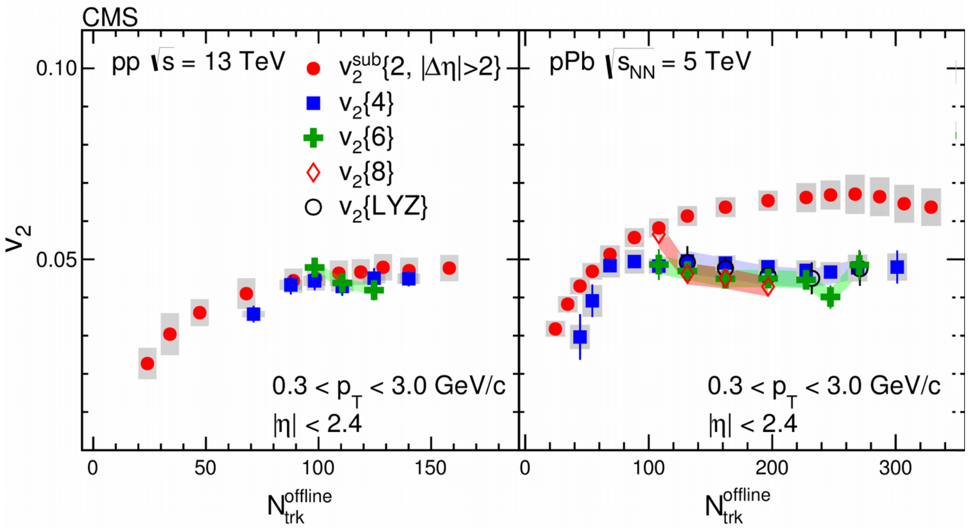
Motivation for studying smaller systems



PRL 98 (2007) 2432302

Participant plane, introduced based on CuCu results at RHIC!

PLB 765 (2017) 193



Collectivity observed in small systems!

XeXe – chance to bridge the gap between large and small systems

Motivation for studying smaller systems

What can we expect in XeXe at TeV energies?

Ideal case – scale invariance, but in reality:

- Initial geometry fluctuations ~ 1/R
- Viscous effects ~1/R
- Quadrupole deformation of the Xe shape

This causes system size invariance breaking!

Motivation for studying smaller systems

XeXe case:

Ideal case – scale invariance, but in reality:

- ➢ Initial geometry fluctuations ~ 1/R
- ➢ Viscous effects ~1/R
- ➢ Quadrupole deformation of the Xe shape

This causes system size invariance breaking!

pPb case:

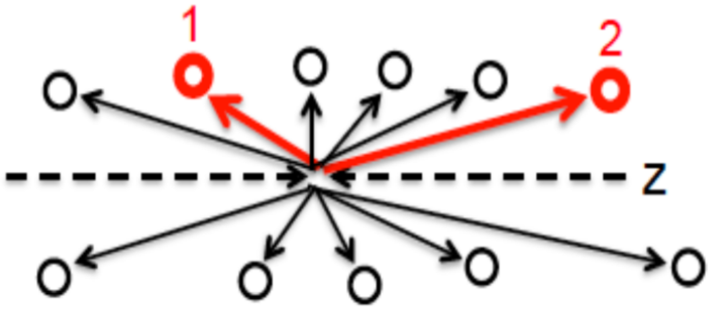
- ➢ Does collectivity shows up with higher harmonics?
- ➢ What is the origin of this collectivity?

Methodology

- Two-particle correlations

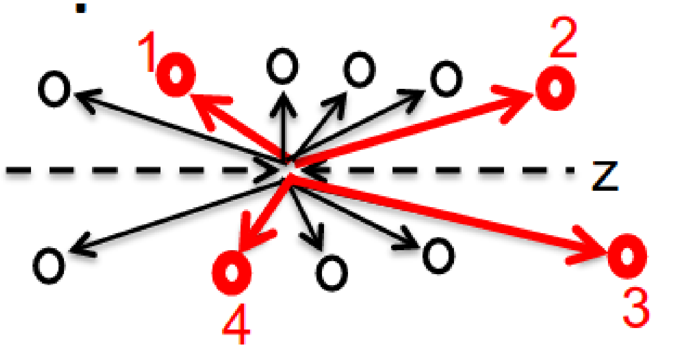
$|\Delta\eta| > 2$

$$v_n\{2, |\Delta\eta| > 2\} \quad \simeq \quad \langle v_n \rangle + \frac{1}{2}\frac{\sigma_{v_n}^2}{\langle v_n \rangle}$$



- Multi-particle cumulants:

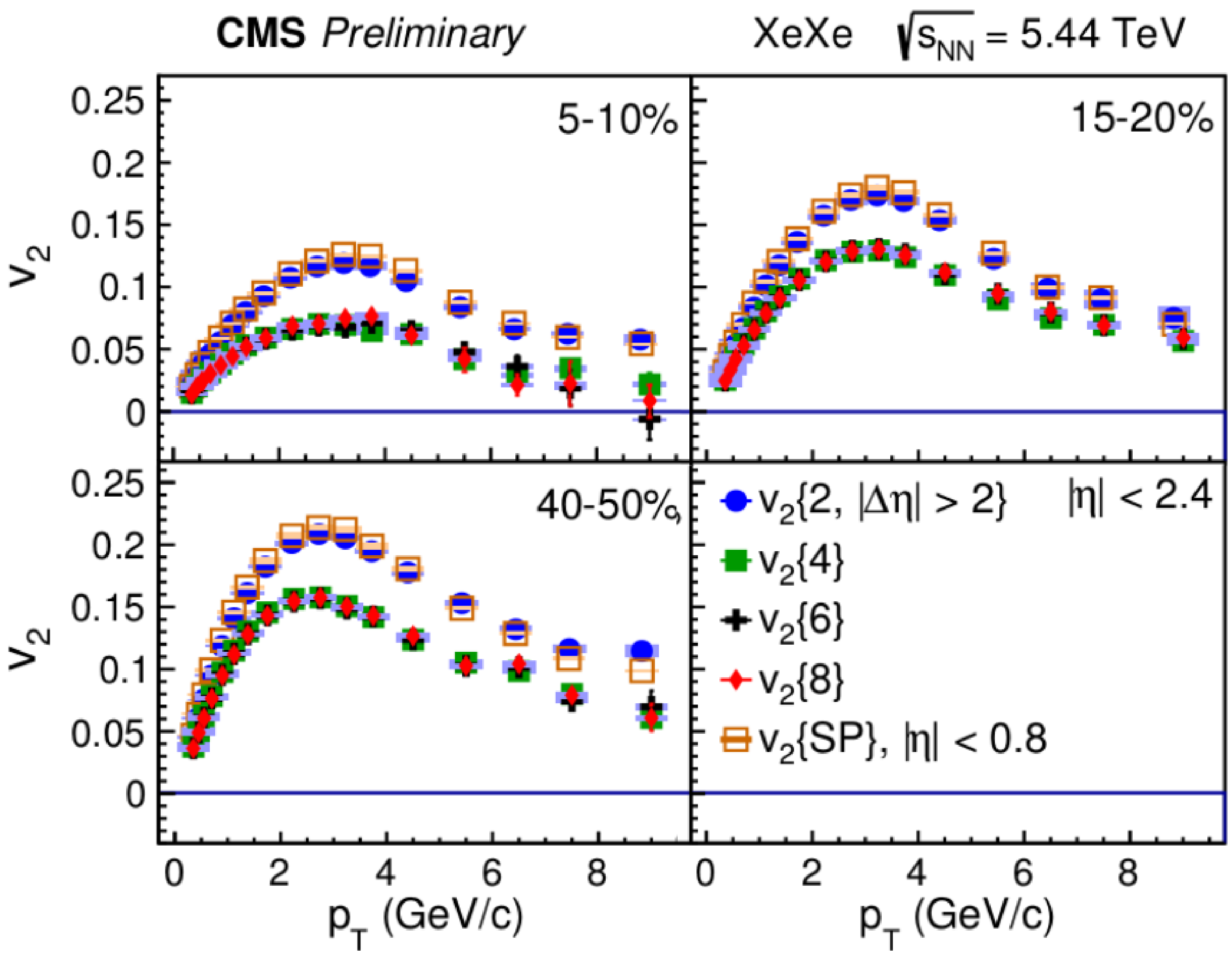
$$v_n\{4\} \quad \simeq \quad \langle v_n \rangle - \frac{1}{2}\frac{\sigma_{v_n}^2}{\langle v_n \rangle}$$



Gaussian E-by-E fluctuations: $v_n\{4\} = v_n\{6\} = v_n\{8\}$

v_2 in XeXe collisions

CMS HIN-18-001



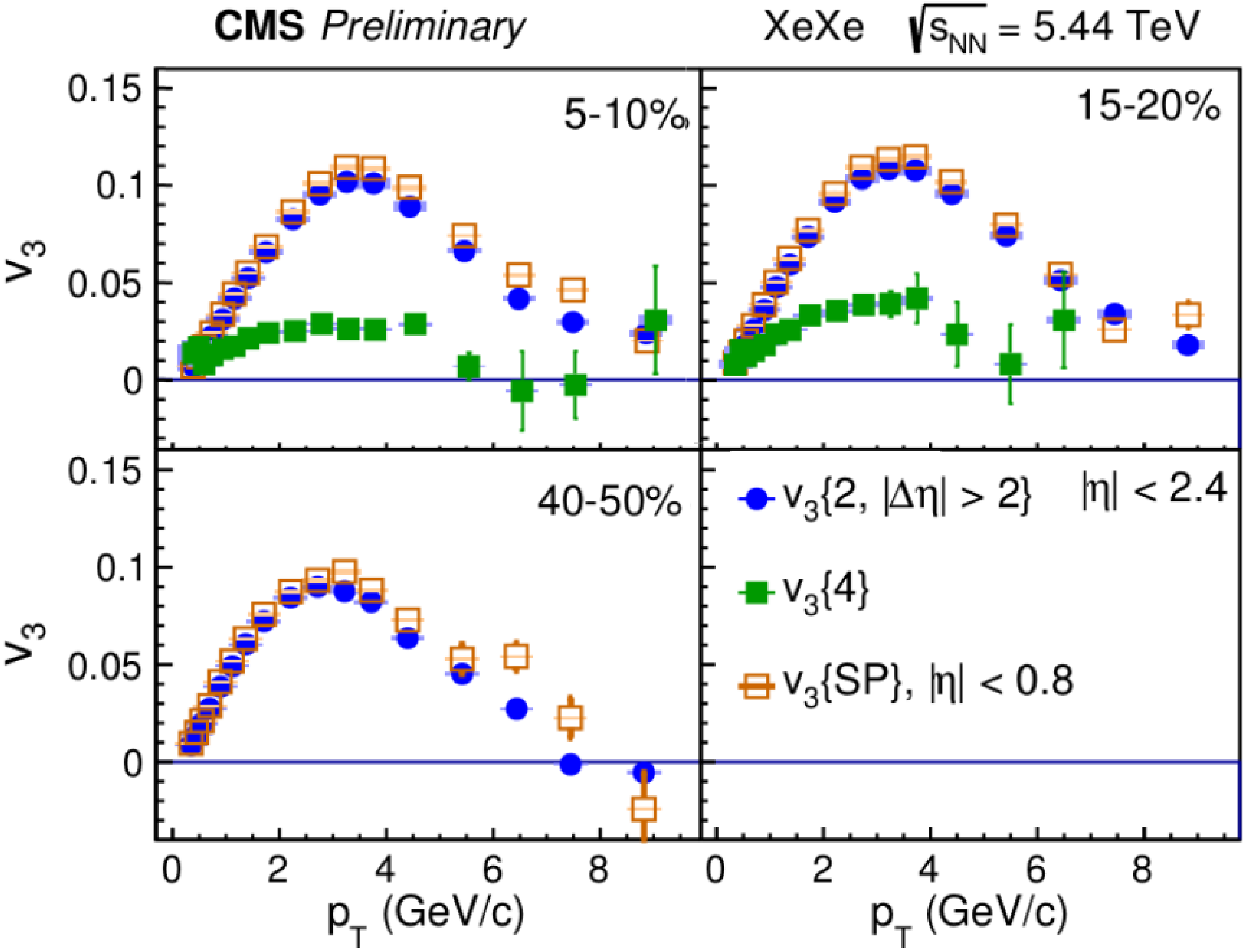
- $v_2\{4\} \approx v_2\{6\} \approx v_2\{8\}$
  - Collectivity!
    (Still there!)

- $v_2\{2\} > v_2\{4\}$
  - E-by-E fluctuations

- Consistent with hydro picture!

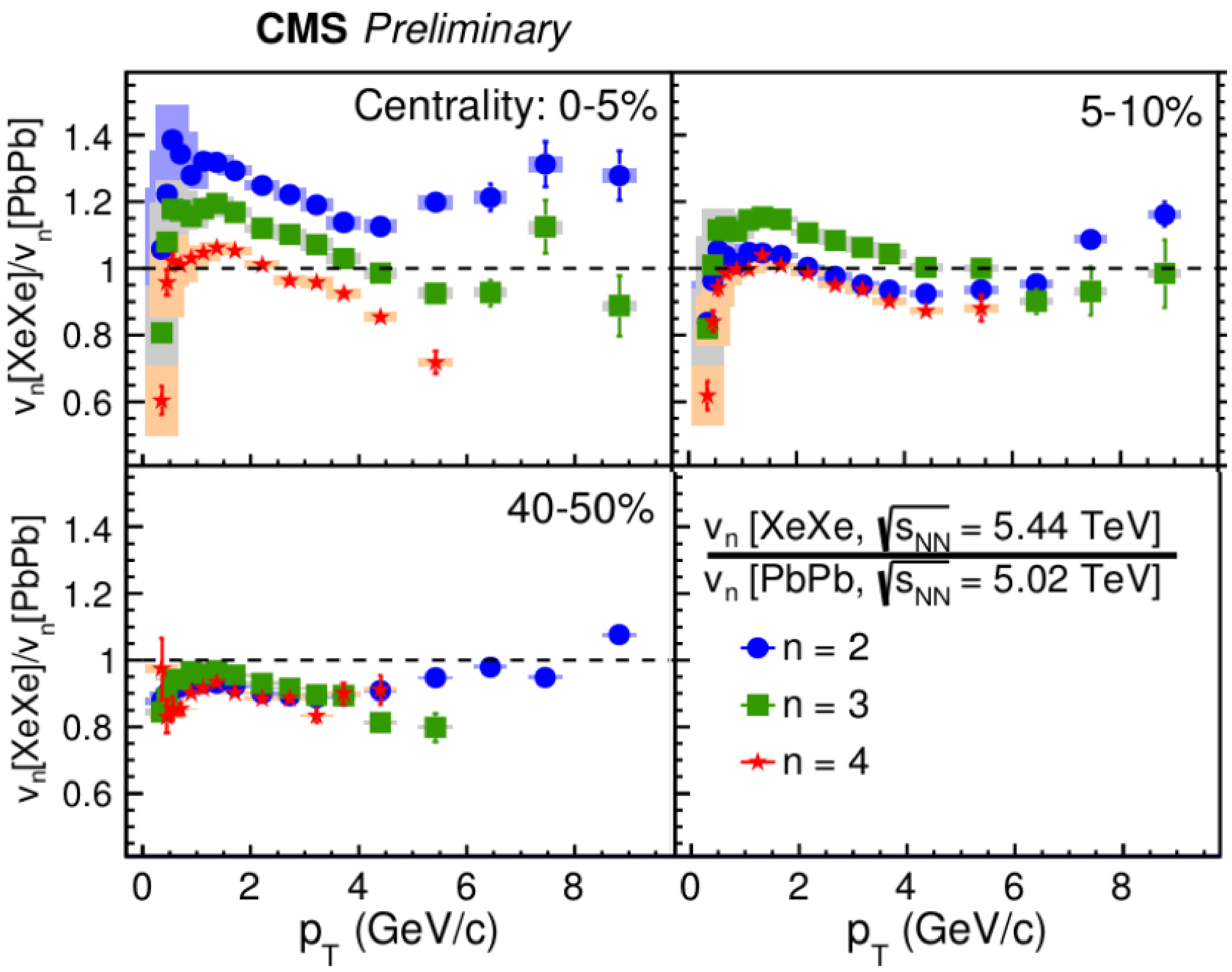
v_3 in XeXe collisions

CMS HIN-18-001



- ➢ $v_3\{2\} > v_3\{4\}$
  - E-by-E fluctuation
  - Larger than for v_2
- ➢ Consistent with hydro picture!

v_n[XeXe]/v_n[PbPb]

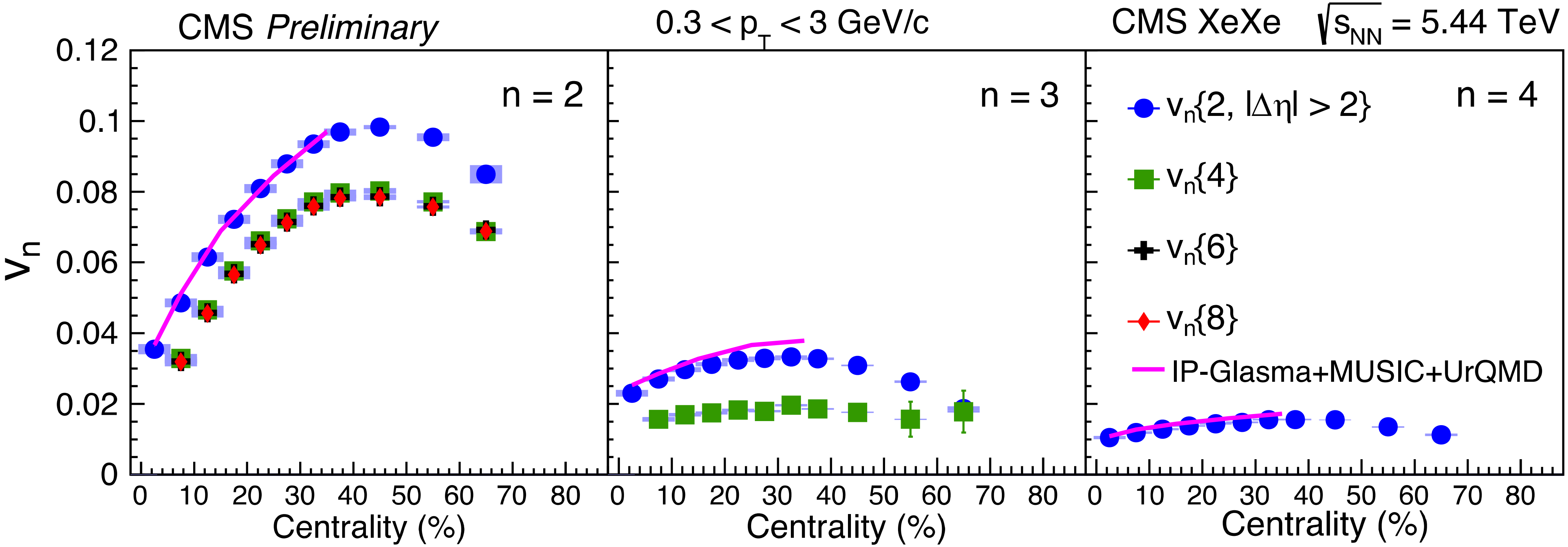


XeXe: CMS HIN-18-001

PbPb: CMS HIN-16-018

- Central collisions: v_n[XeXe] > v_n[PbPb]
  - Main effect: fluctuations
- Peripheral collisions: v_n[PbPb] > v_n[XeXe]
  - Viscous effects are dominant

v_n in XeXe vs centrality

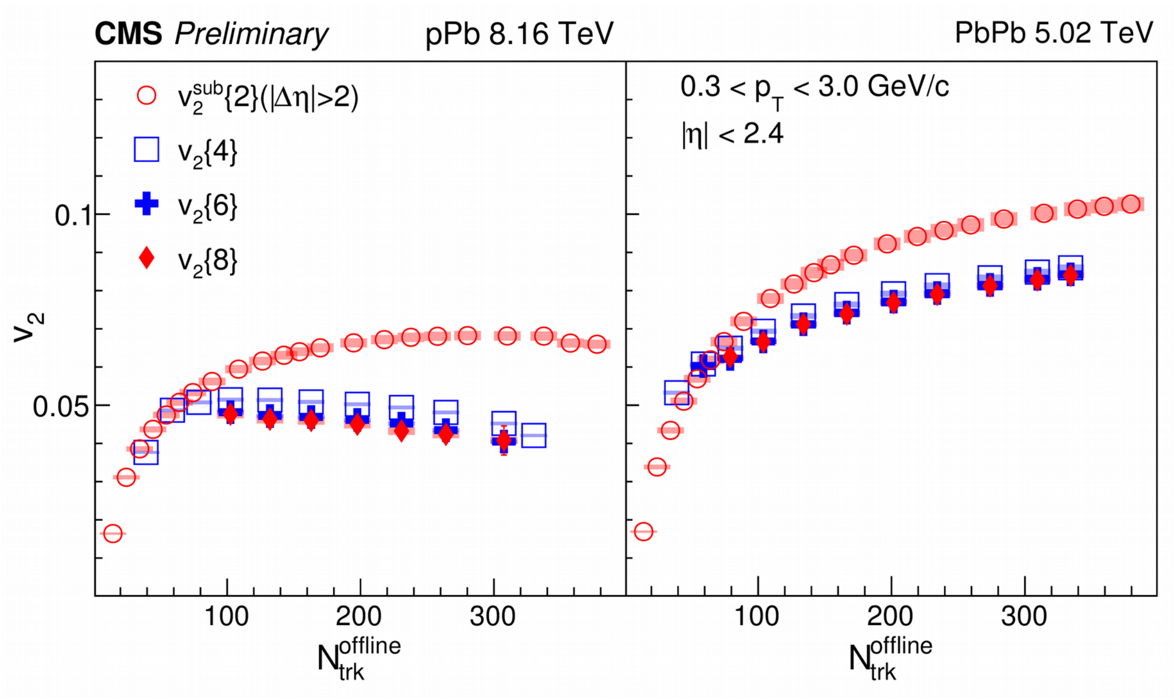


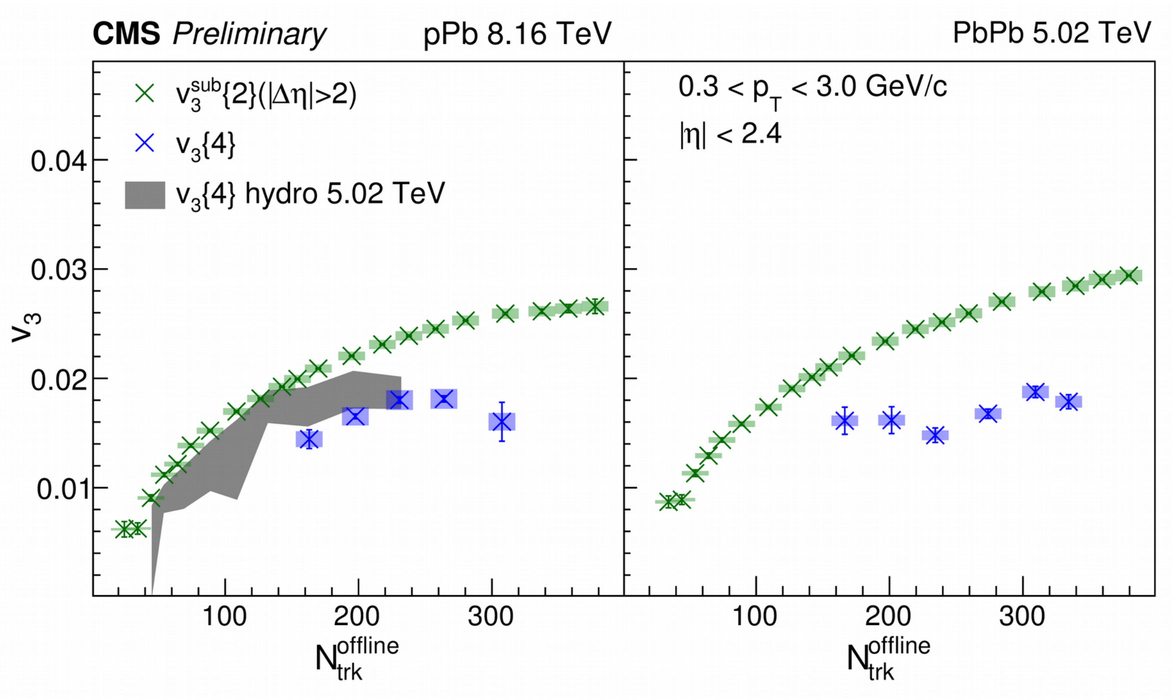
Data: CMS HIN-18-001

Model: t_0 = 0.4 fm/c
η /s = 0.16
ς/s(T) Phys.Rev.Lett 115 (2015) 132301

Good agreement! Hydrodynamics works!

v_n in pPb vs multiplicity





- $v_2\{2\} > v_2\{4\} \approx v_2\{6\} \approx v_2\{8\}$
- $v_2[PbPb] > v_2[pPb]$

- $v_3\{2\} > v_3\{4\}$
- $v_3[PbPb] \approx v_3[pPb]$

Data: CMS HIN-17-004

Hydro model: $\sigma = 0.4$ fm

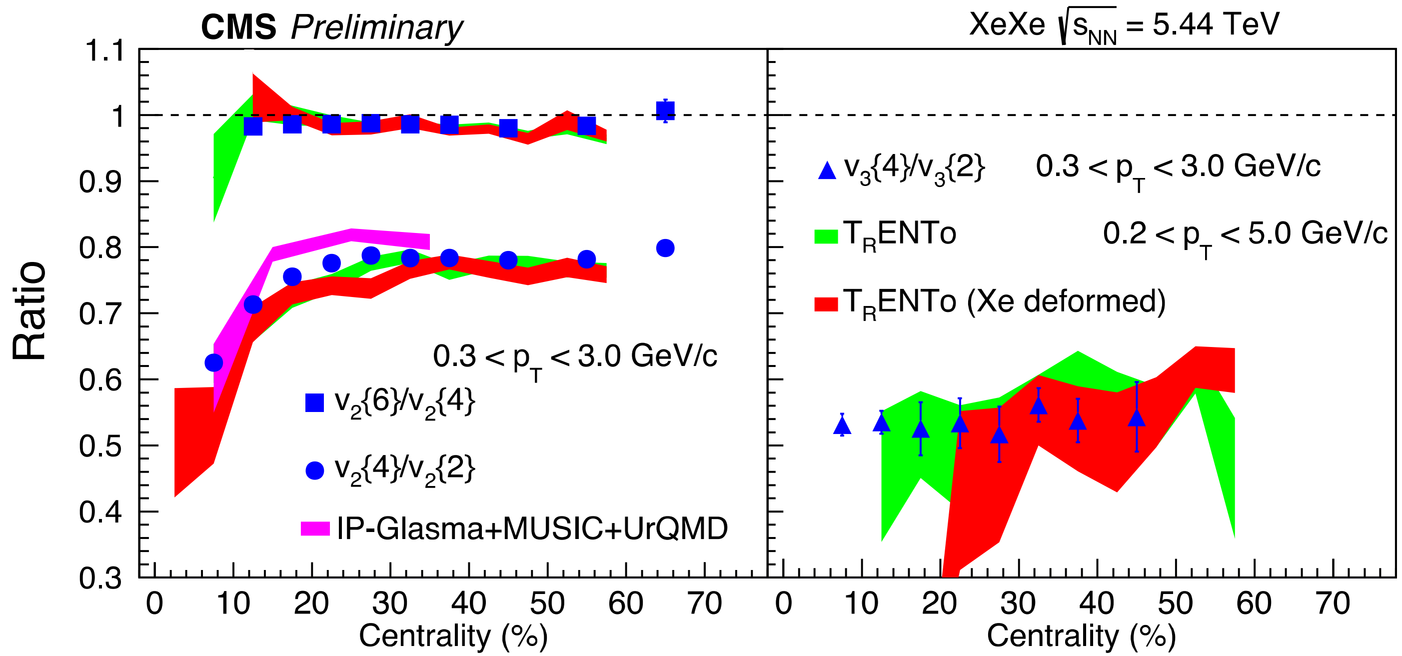
$\eta/s = 0.8$

arXiv:1405.3976

Consistent with data!

v_n in XeXe vs centrality

Data: CMS HIN-18-001



- $v_2\{4\} > v_2\{6\}$

Non-Gaussian corrections!

- $v_3\{4\}/v_3\{2\}$ & $v_2\{4\}/v_2\{4\}$

Good description within hydrodynamic picture!

IP-Glasma + MUSIC + UrQMD

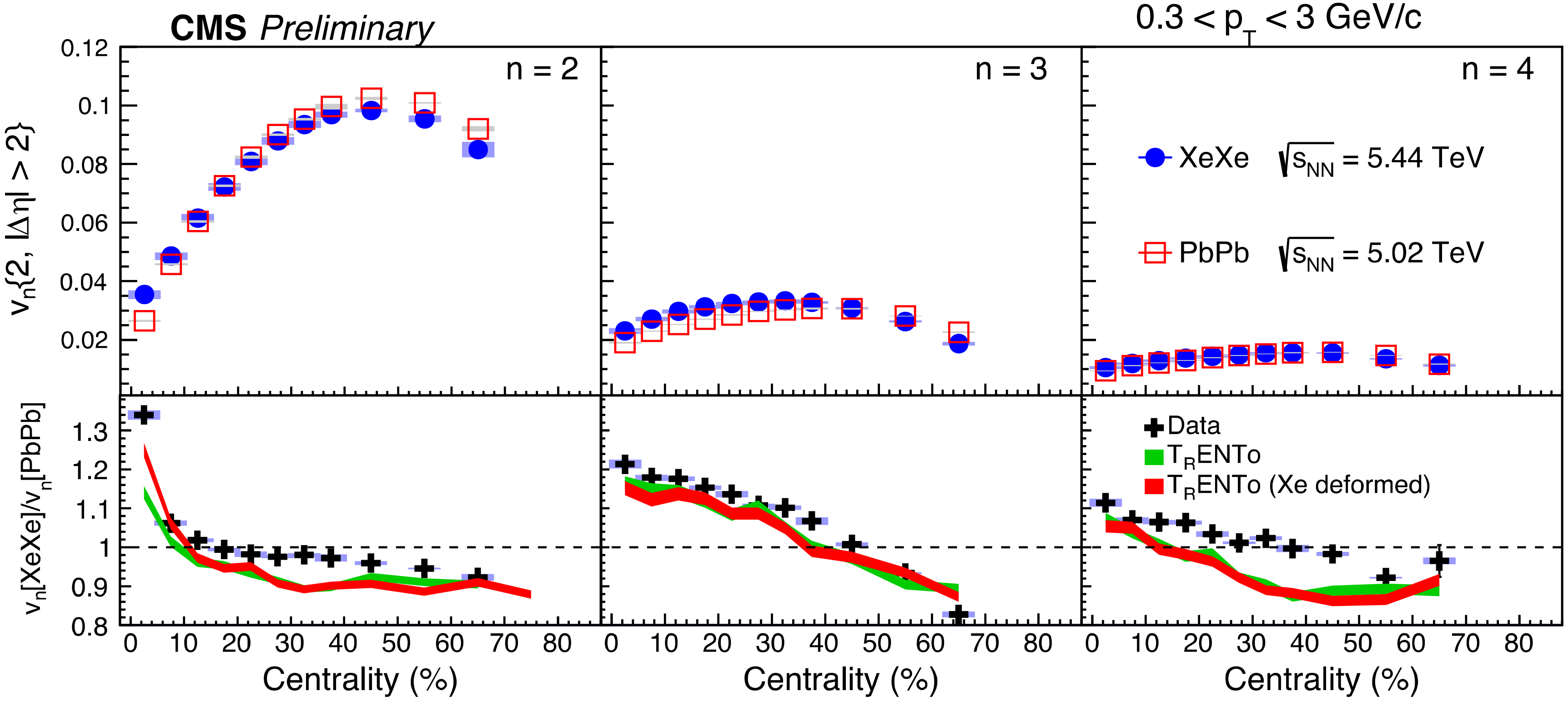
$t_0 = 0.4$ fm/c
$\eta/s = 0.16$
$\varsigma/s(T)$

T_RENTo + $t_0 = 0.6$ fm/c
$\eta/s = 0.047$

Phys.Rev.C**97** (2018) 034904

- Model makes no difference for two nuclear shapes

v_n in XeXe & PbPb vs centrality



- ➢ Xe deformation increase v2 in central collisions
- ➢ Qualitatively good description with hydrodynamics

XeXe: CMS HIN-18-001

PbPb: CMS HIN-16-081

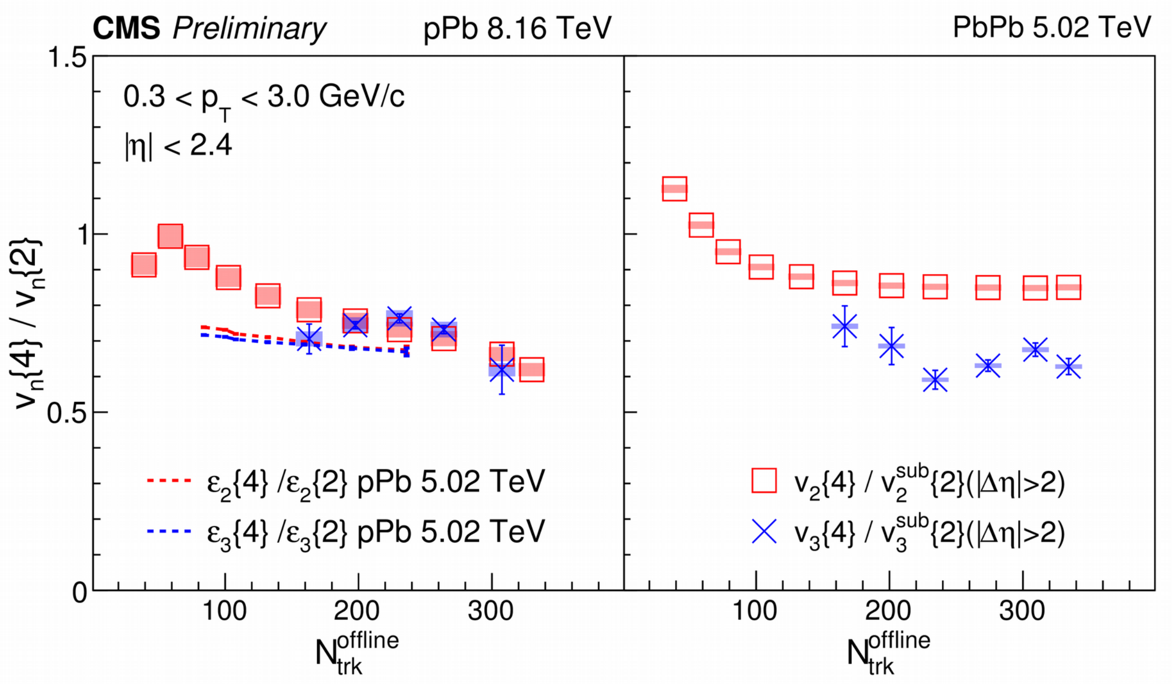
T_RENTo + t_0 = 0.6 fm/c
η/s = 0.047

Phys.Rev.C**97** (2018) 034904

v_n in pPb vs multiplicity

pPb 8.16 TeV: CMS HIN-17-004

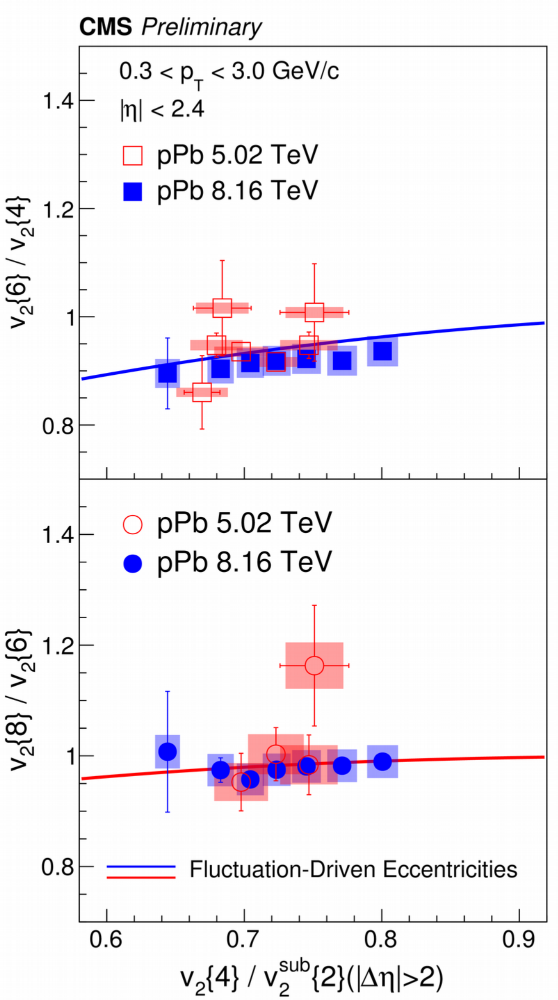
pPb 5.02 TeV: Phys.Rev.Lett**115** (2015) 012301



- PbPb: larger fluctuations for v_2
- pPb: Similar fluctuations for v_3
- Consistent with predictions:

- Non-Gaussian fluctuations
- Power law distribution for ε_2
- Universal curves

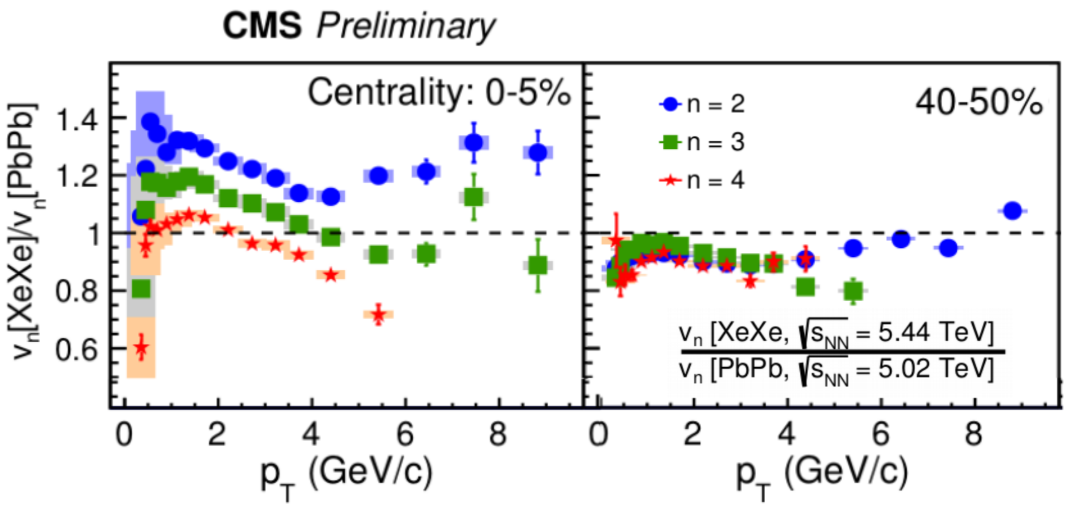
Phys.Rev.Lett**112** (2014) 082301



T_RENTo, $\sigma = 0.3$ fm, insensitive to other parameters

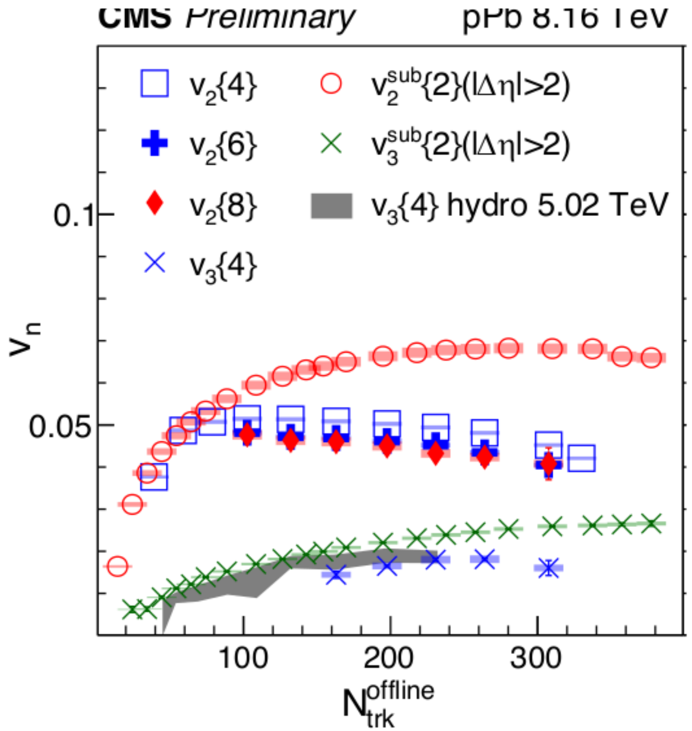
Phys.Rev.C**92** (2017) 034911

Summary



XeXe:

- Consistent with PbPb
- Central collisions: v_n[XeXe] > v_n[PbPb]
  - fluctuations
- Peripheral collisions: v_n[PbPb] > v_n[XeXe]
  - viscous effects

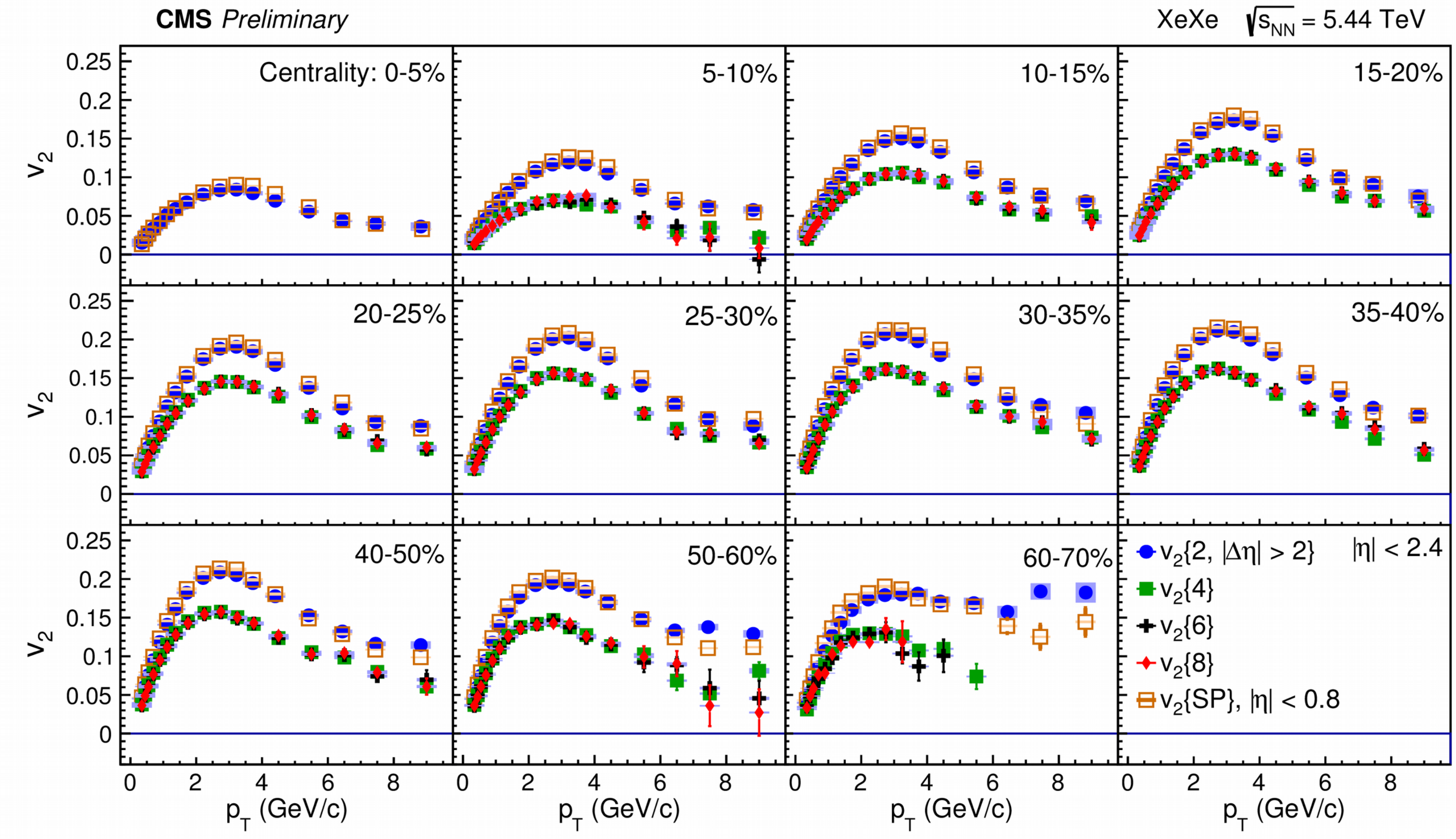


pPb:

- In pPb V2, v3 completely dominated by fluctuations
- Non-Gaussian fluctuations in good agreement with hydro, TRENTo, power distribution

Backup slides

v_2 in XeXe collisions

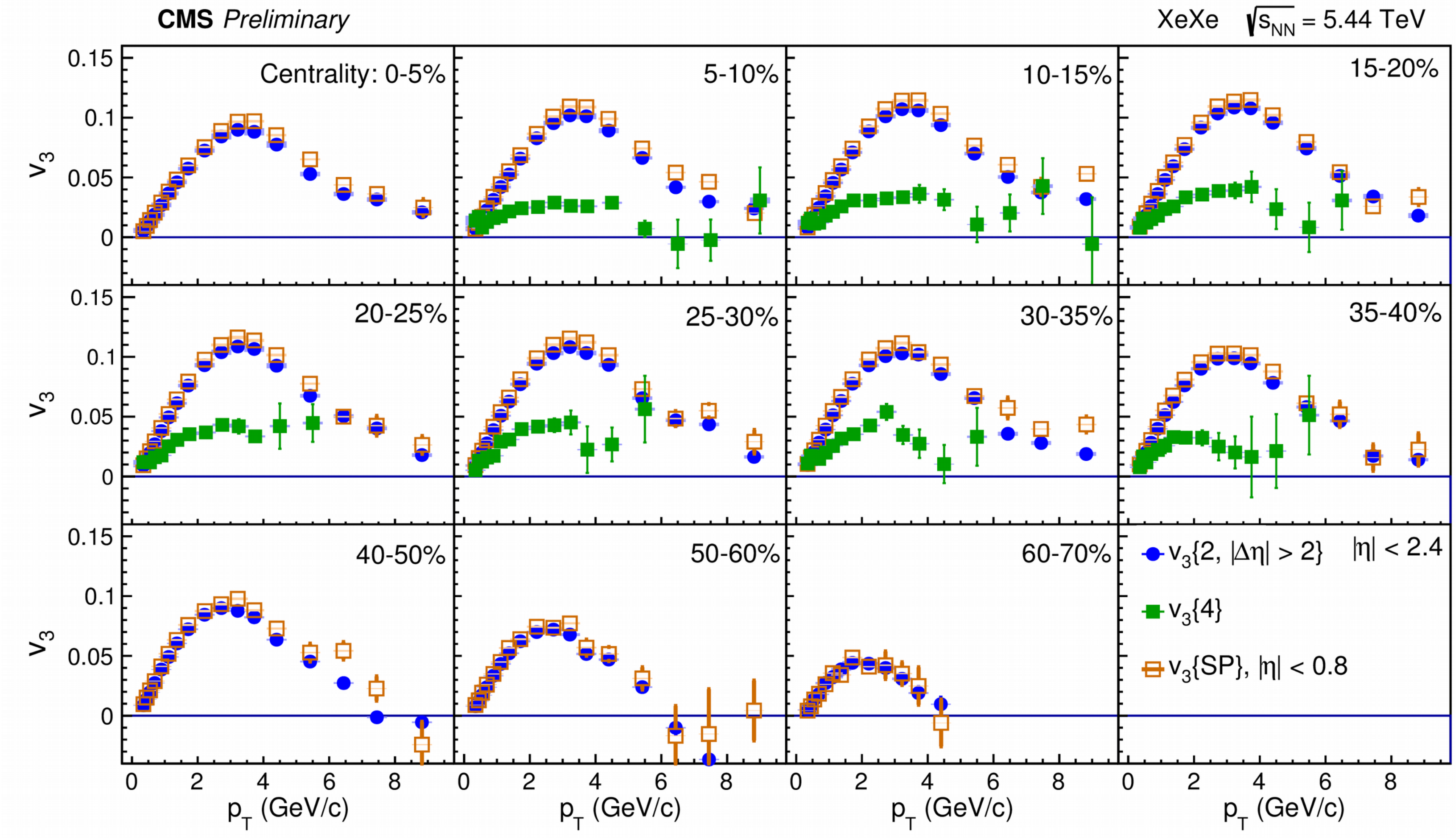


CMS HIN-18-001

$v_2\{2\} > v_2\{4\} \approx v_2\{6\} \approx v_2\{8\}$

Collectivity!
(Still there!)

v_3 in XeXe collisions



CMS HIN-18-001

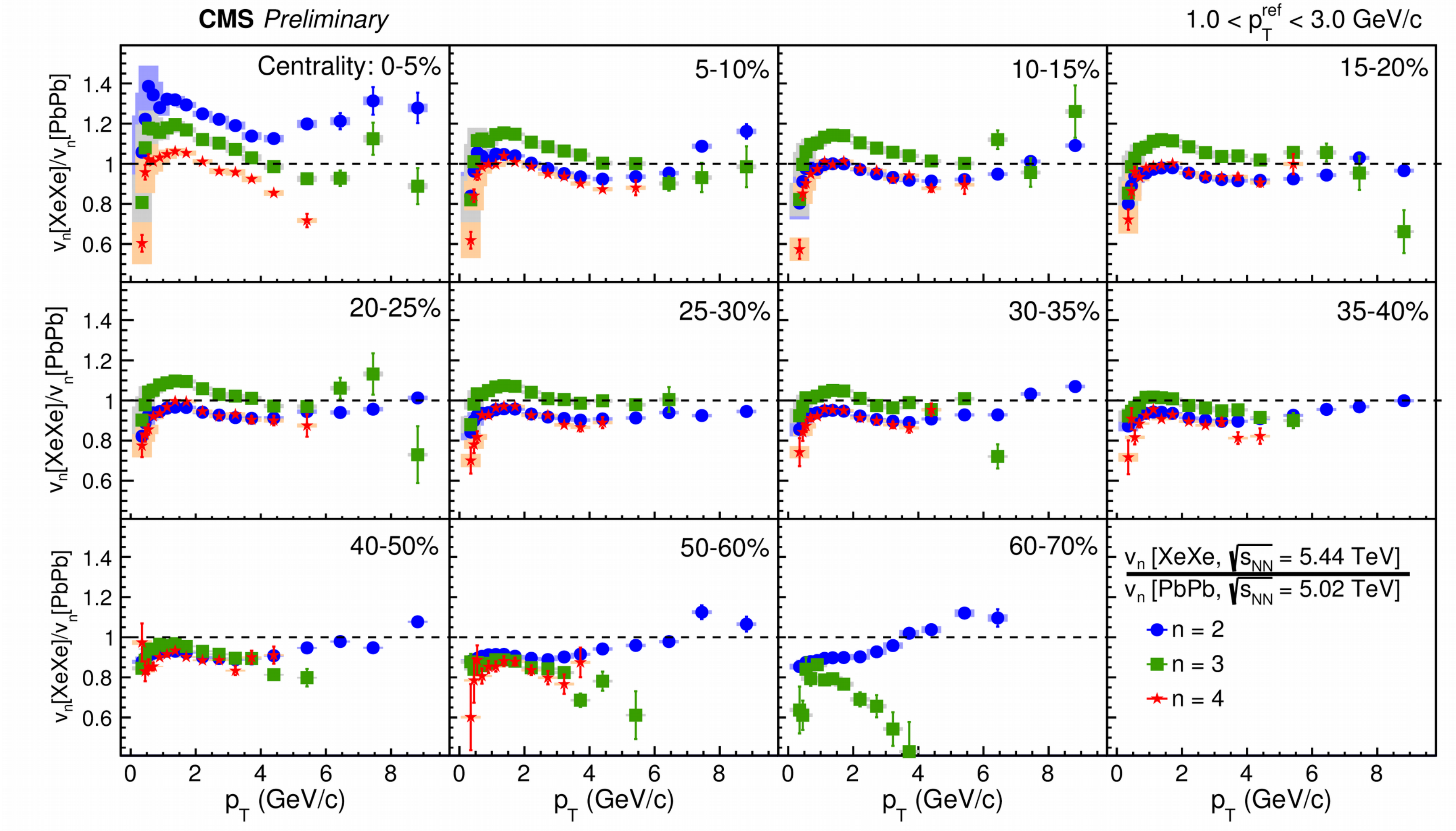
$v_3\{2\} > v_3\{4\}$

Collectivity!
(Still there!)

v_n[XeXe]/v_n[PbPb]

XeXe: CMS HIN-18-001

PbPb: CMS HIN-16-018



0-5% v_2[XeXe] > v_2[PbPb]

0-30% v_3[XeXe] > v_3[PbPb]

5-60% v_4[XeXe] < v_4[PbPb]