

# Measurement of the collective flow in XeXe collisions at 5.44 TeV with the CMS experiment

Quark Matter, Venice, 2018

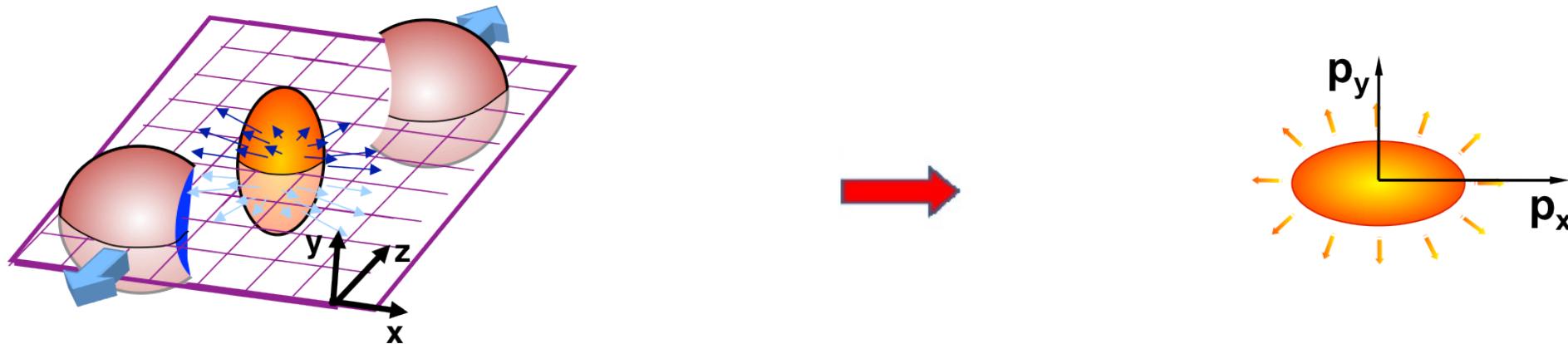


Milan Stojanovic

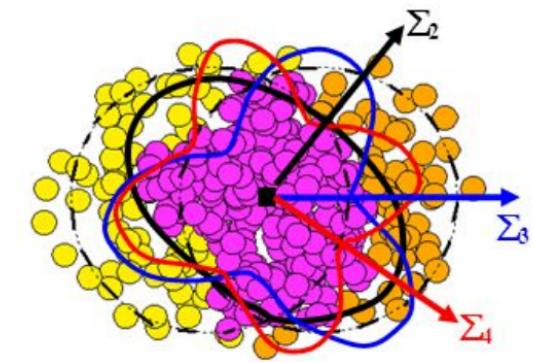
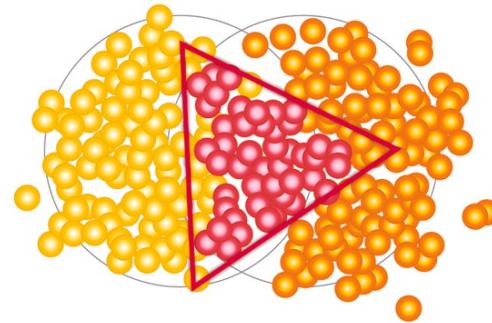
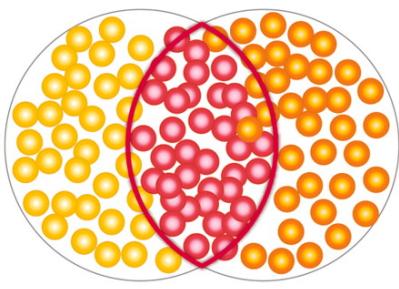
on behalf of the CMS collaboration

VINCA Institute of Nuclear Sciences, University of Belgrade

# Introduction



Lenticular overlapping region → space anisotropy → momentum space anisotropy



System symmetry → elliptic flow,  $v_2$

Fluctuations → triangular flow,  $v_3$

Fluctuations + non-linear part,  $v_4$

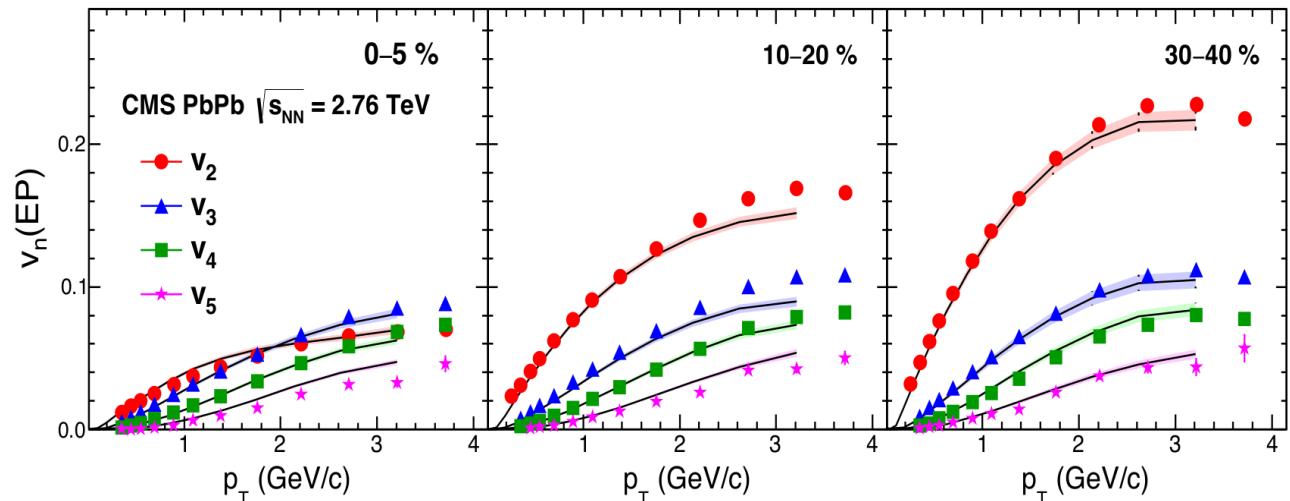
# Introduction



- 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

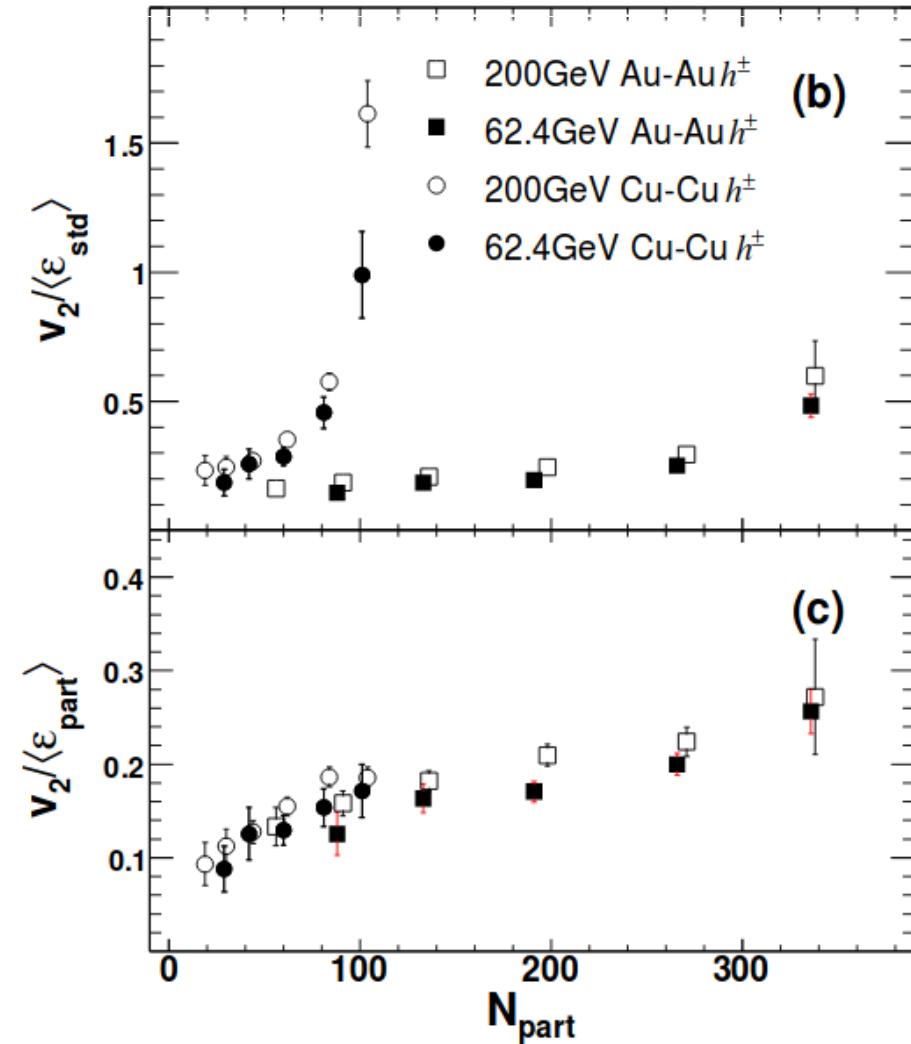
Data points:

Phys.Rev.C89 (2014) 044906

Predictions (IP-Glasma + Music):

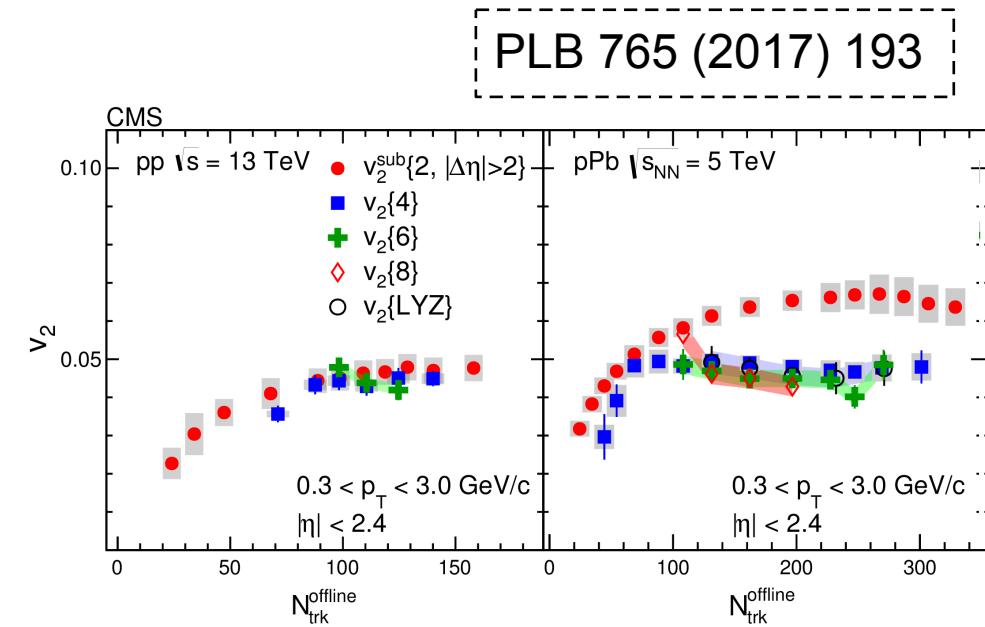
PRL 110 (2013) 012302

# Motivation for studying smaller systems



PRL 98 (2007) 2432302

Participant plane,  
introduced based on  
CuCu results at RHIC!



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?

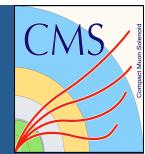
Ideal case – scale invariance, but in reality:

- Initial geometry fluctuations  $\sim 1/R$
- Viscous effects  $\sim 1/R$
- Quadrupole deformation of the Xe shape



This causes system size invariance breaking!

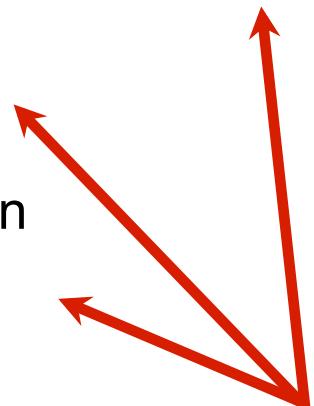
# Motivation for studying smaller systems



What can we expect in XeXe at TeV energies?

Ideal case – scale invariance, but in reality:

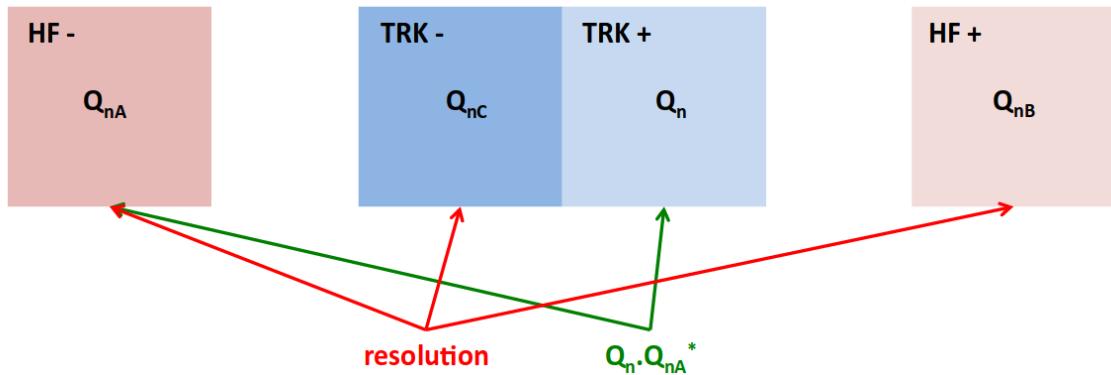
- Initial geometry fluctuations  $\sim 1/R$
- Viscous effects  $\sim 1/R$
- Quadrupole deformation of the Xe shape



- ✓ Simultaneous measurements of  $v_2$ ,  $v_3$  &  $v_4$  provide better understanding of initial states and medium properties
- ✓ Comparison of  $v_n$  measured with different methods is direct probe of flow fluctuations.

This causes system size invariance breaking!

# Methodology

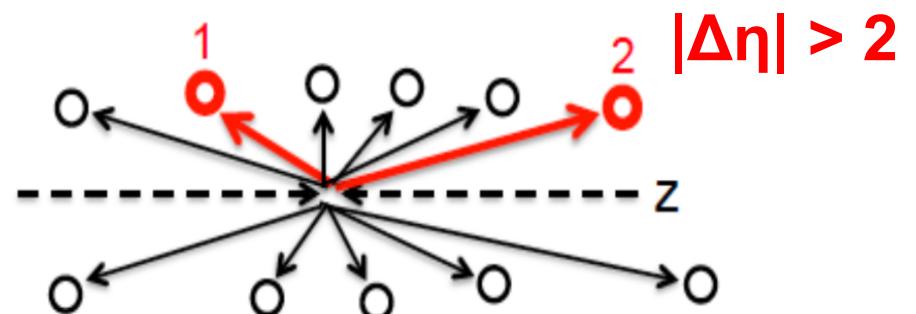


➤ Scalar product:

$$v_n \{ \text{SP} \} \simeq \langle v_n \rangle + \frac{1}{2} \frac{\sigma_{v_n}^2}{\langle v_n \rangle}$$

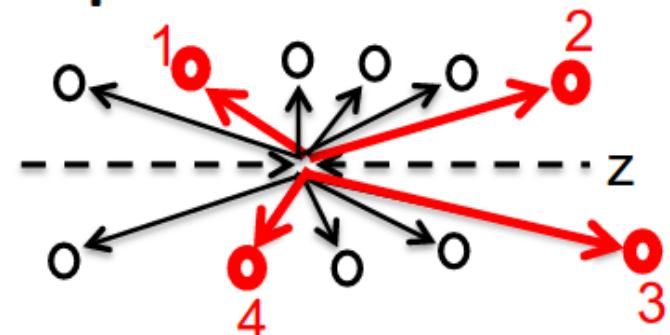
➤ Two-particle correlations

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



➤ Multi-particle cumulants:

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





CMS Experiment at the LHC, CERN

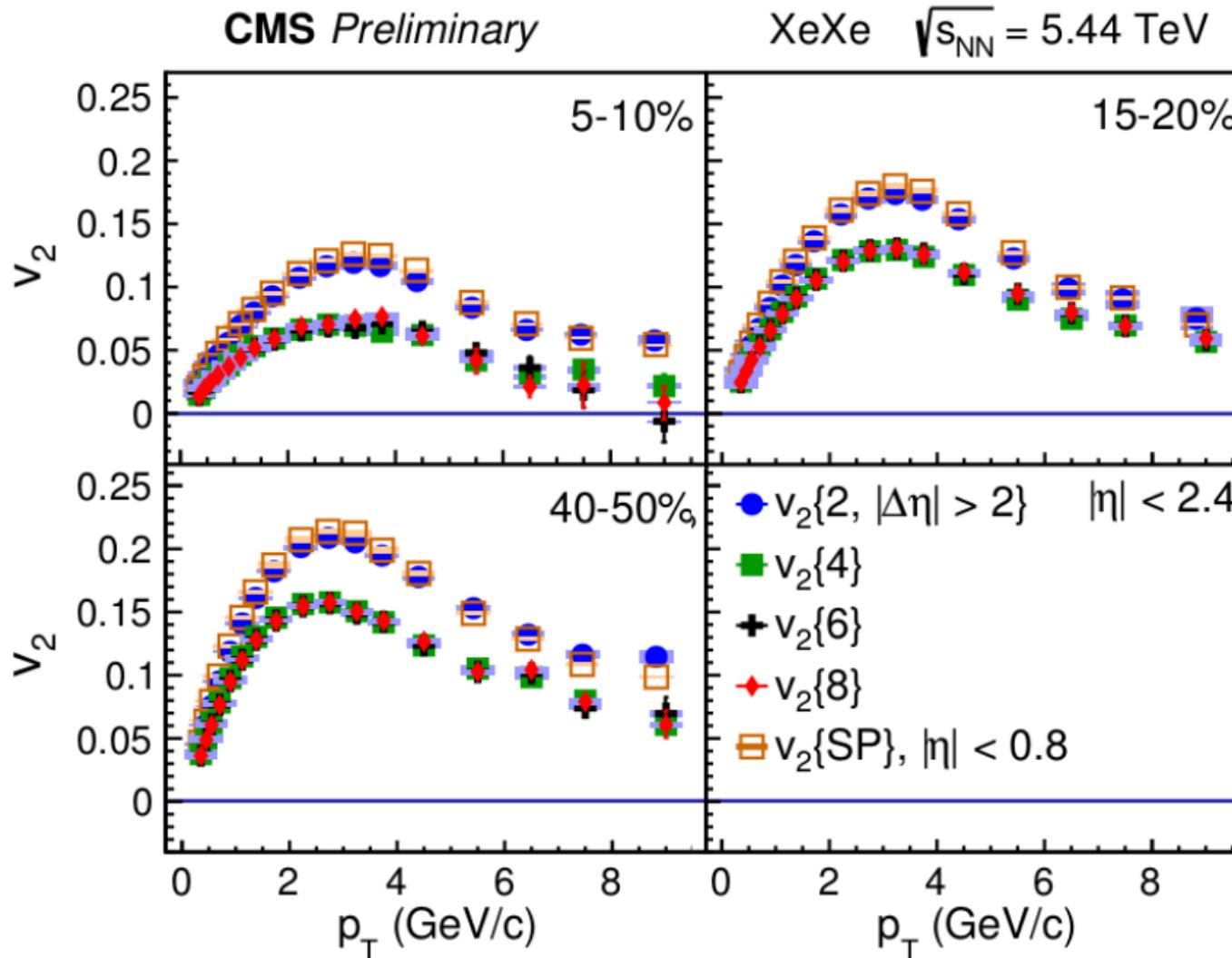
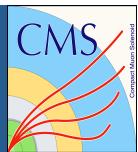
Data recorded: 2017-Oct-12 20:44:56.751360 GMT

Run / Event / LS: 304899 / 8743361 / 90

# What can Xe teach us?



# $v_2$ in XeXe collisions

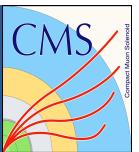


CMS HIN-18-001

- $v_2\{4\} \approx v_2\{6\} \approx v_2\{8\}$ 
  - Collectivity!  
(Still there ☺ )
- $v_2\{2\} > v_2\{4\}$ 
  - E-by-E fluctuations
- Consistent with hydro picture!

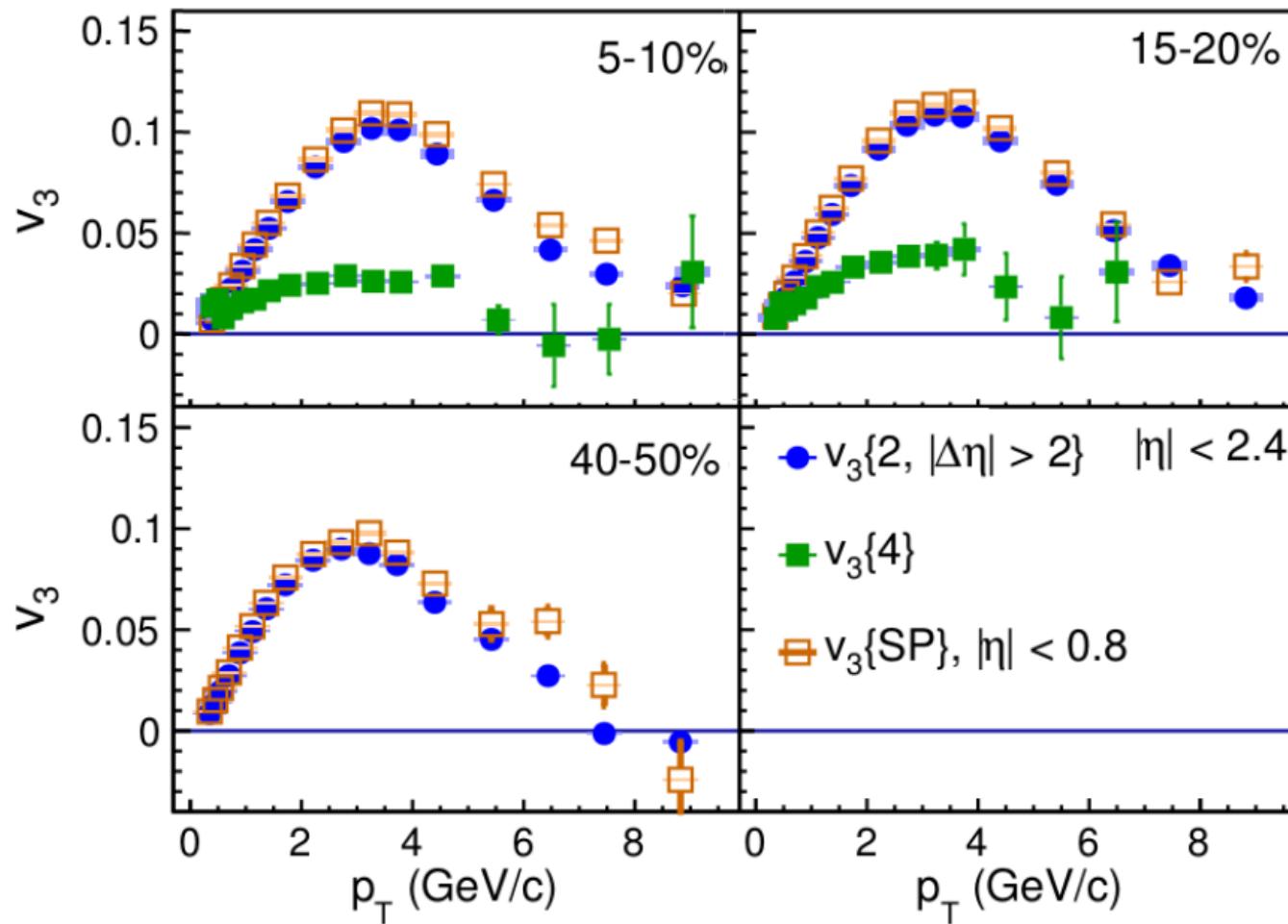


# $v_3$ in XeXe collisions



CMS Preliminary

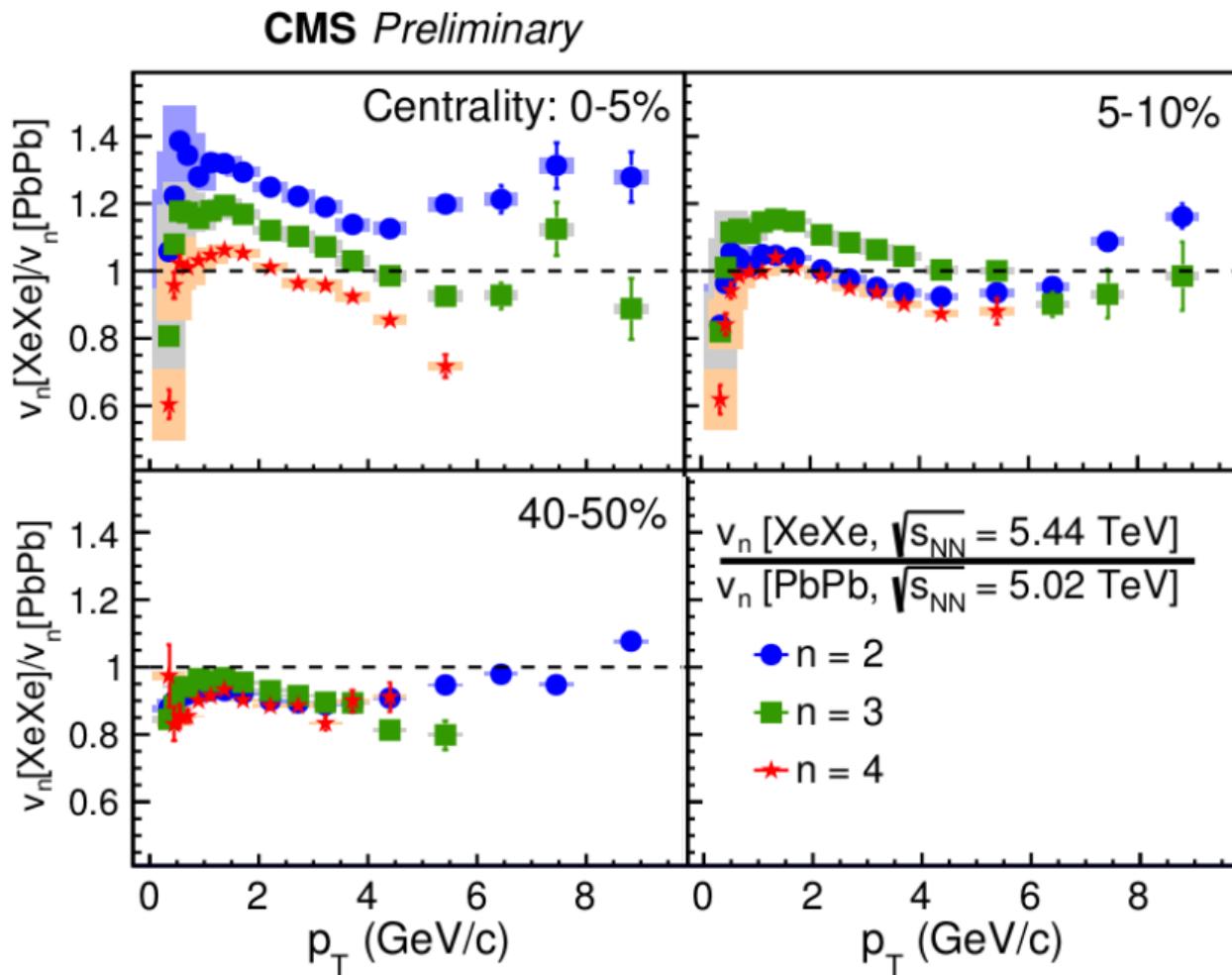
XeXe  $\sqrt{s_{NN}} = 5.44 \text{ TeV}$



CMS HIN-18-001

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

# $v_n[\text{XeXe}]/v_n[\text{PbPb}]$

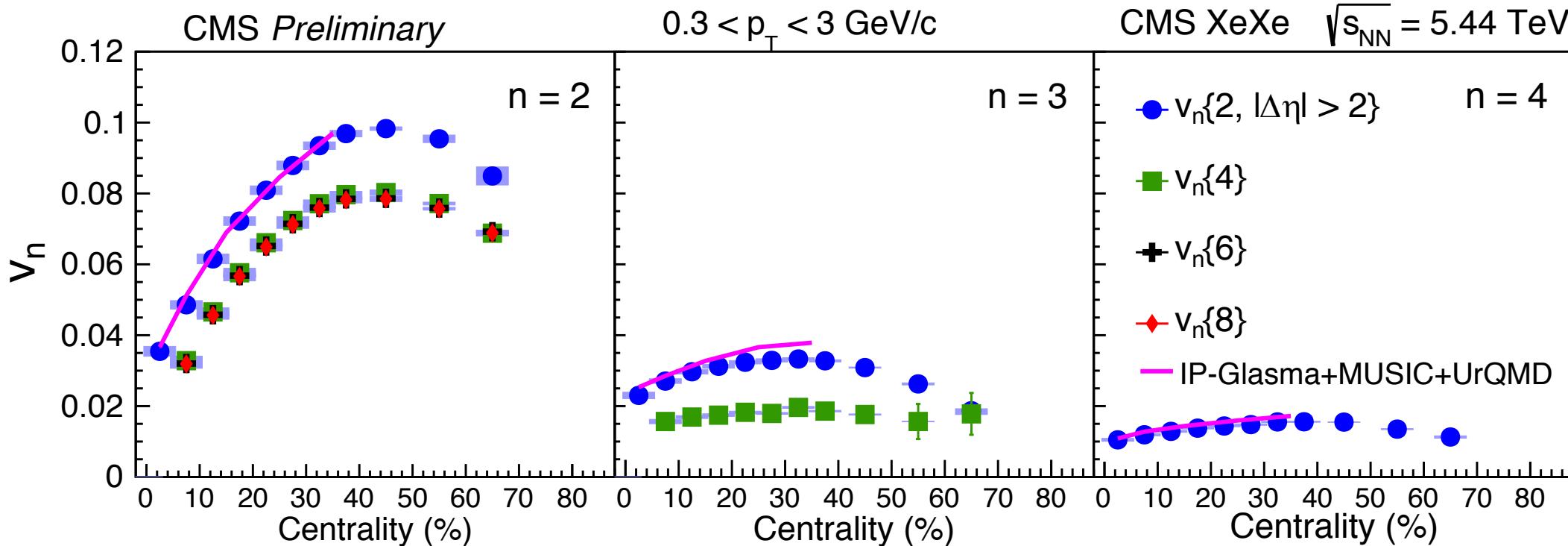
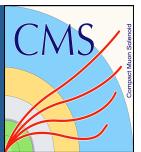


XeXe: CMS HIN-18-001  
 PbPb: CMS HIN-16-018

- Central collisions:  $v_n[\text{XeXe}] > v_n[\text{PbPb}]$ 
  - Main effect: fluctuations
- Peripheral collisions:  $v_n[\text{PbPb}] > v_n[\text{XeXe}]$ 
  - Viscous effects are dominant



# $v_n$ in XeXe vs centrality



Data: CMS HIN-18-001

Model:  $t_0 = 0.4 \text{ fm}$   
 $\eta / s = 0.16$   
 $\zeta / s(T)$  Phys.Rev.Lett 115 (2015) 132301

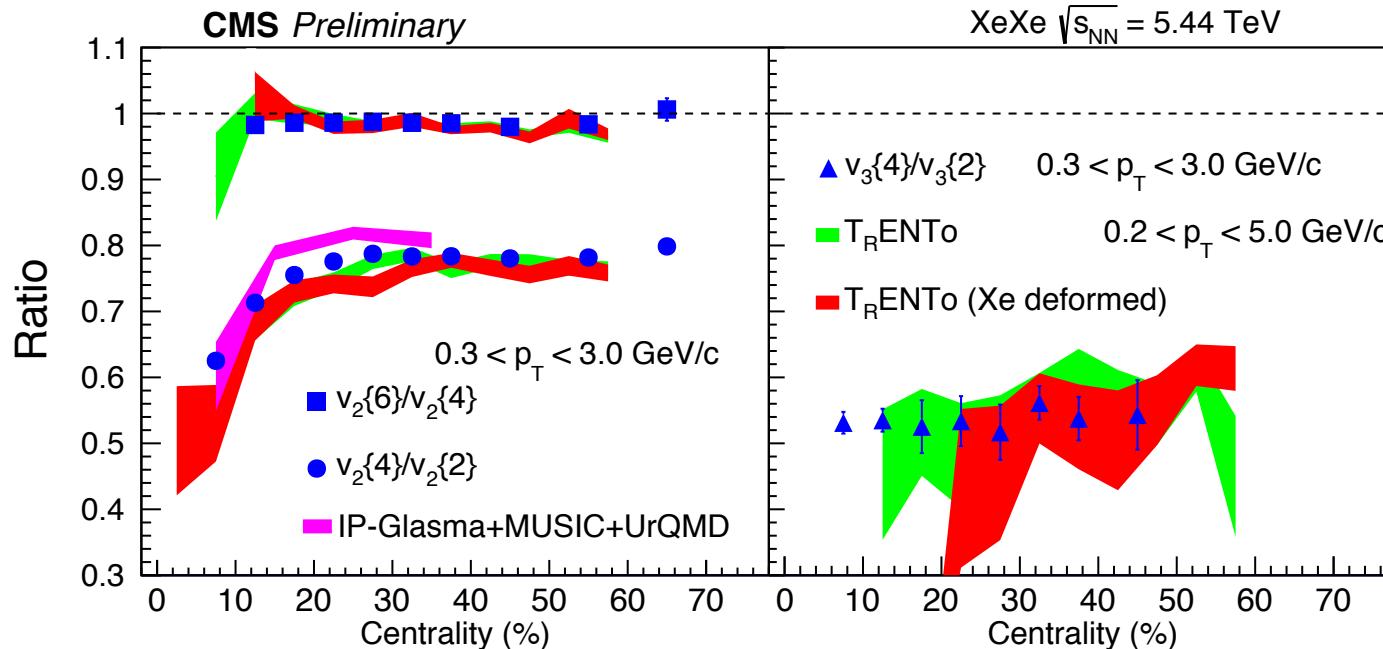
Good agreement! Hydrodynamics works!

# $v_n$ in XeXe vs centrality

Data:

CMS HIN-18-001

➤  $v_2\{4\} > v_2\{6\}$



Non-Gaussian corrections!

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

Good description within  
hydrodynamic picture!

IP-Glasma + MUSIC + UrQMD

$t_0 = 0.4 \text{ fm}$   
 $\eta / s = 0.16$   
 $\zeta / s(T)$

$T_R\text{ENTo} +$

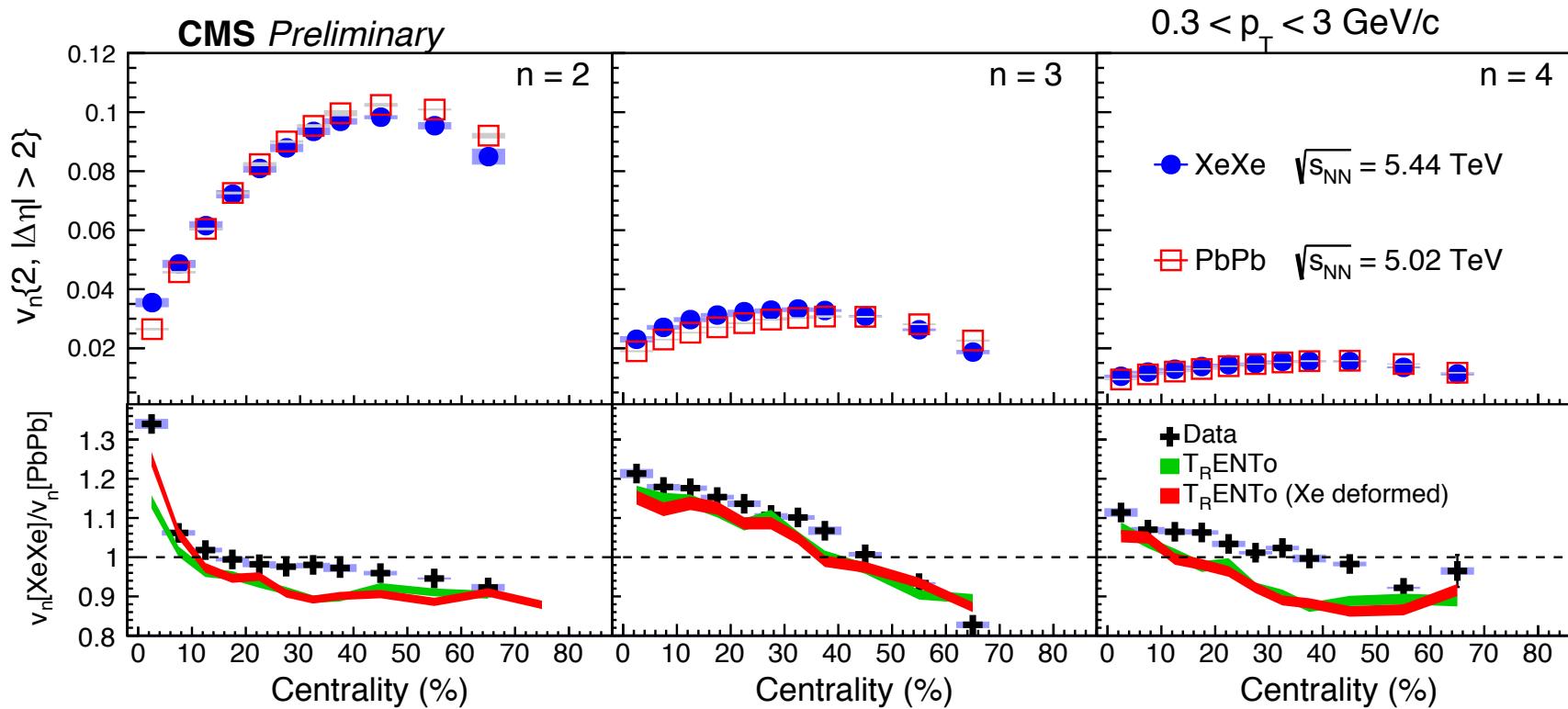
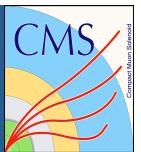
$t_0 = 0.6 \text{ fm}/c$   
 $\eta / s = 0.047$

Phys.Rev.C97 (2018) 034904

➤ Model makes no  
difference for two nuclear  
shapes



# $v_n$ in XeXe & PbPb vs centrality



- Xe deformation increase  $v_2$  in central collisions
- Qualitatively good description with hydrodynamics

XeXe: CMS HIN-18-001

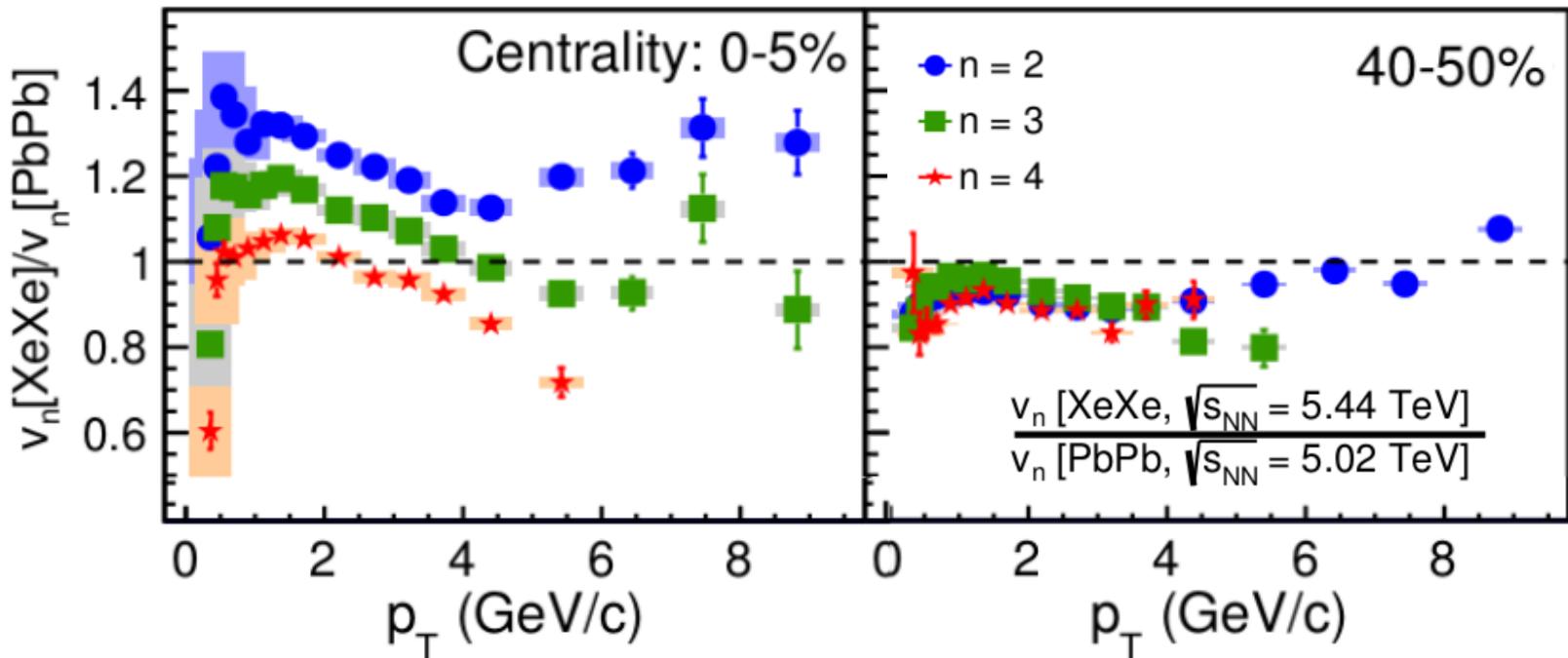
PbPb: CMS HIN-16-081

$T_R$ ENTo +  $t_0 = 0.6 \text{ fm}/c$   
 $\eta/s = 0.047$

Phys.Rev.C97 (2018) 034904

# Summary

CMS Preliminary



- Central collisions:  $v_n[\text{XeXe}] > v_n[\text{PbPb}]$ 
  - fluctuations
- Peripheral collisions:  $v_n[\text{PbPb}] > v_n[\text{XeXe}]$ 
  - viscous effects
- Flow behaves similar as in PbPb
- Hydro still works...
  - ...with additional constraints

# Backup slides

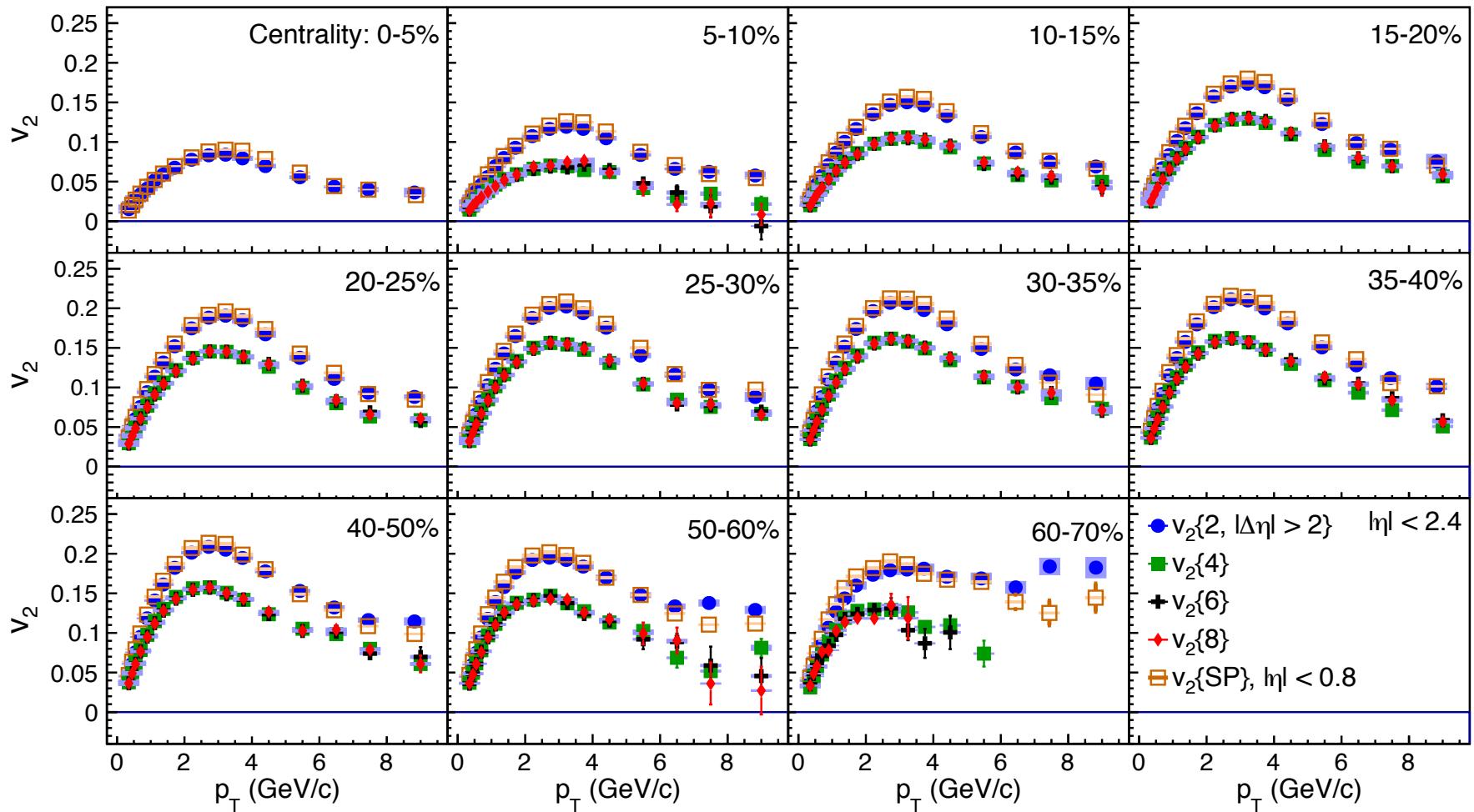


# $v_2$ in XeXe collisions



CMS Preliminary

XeXe  $\sqrt{s_{NN}} = 5.44 \text{ TeV}$



CMS HIN-18-001

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

Collectivity!  
(Still there ☺ )

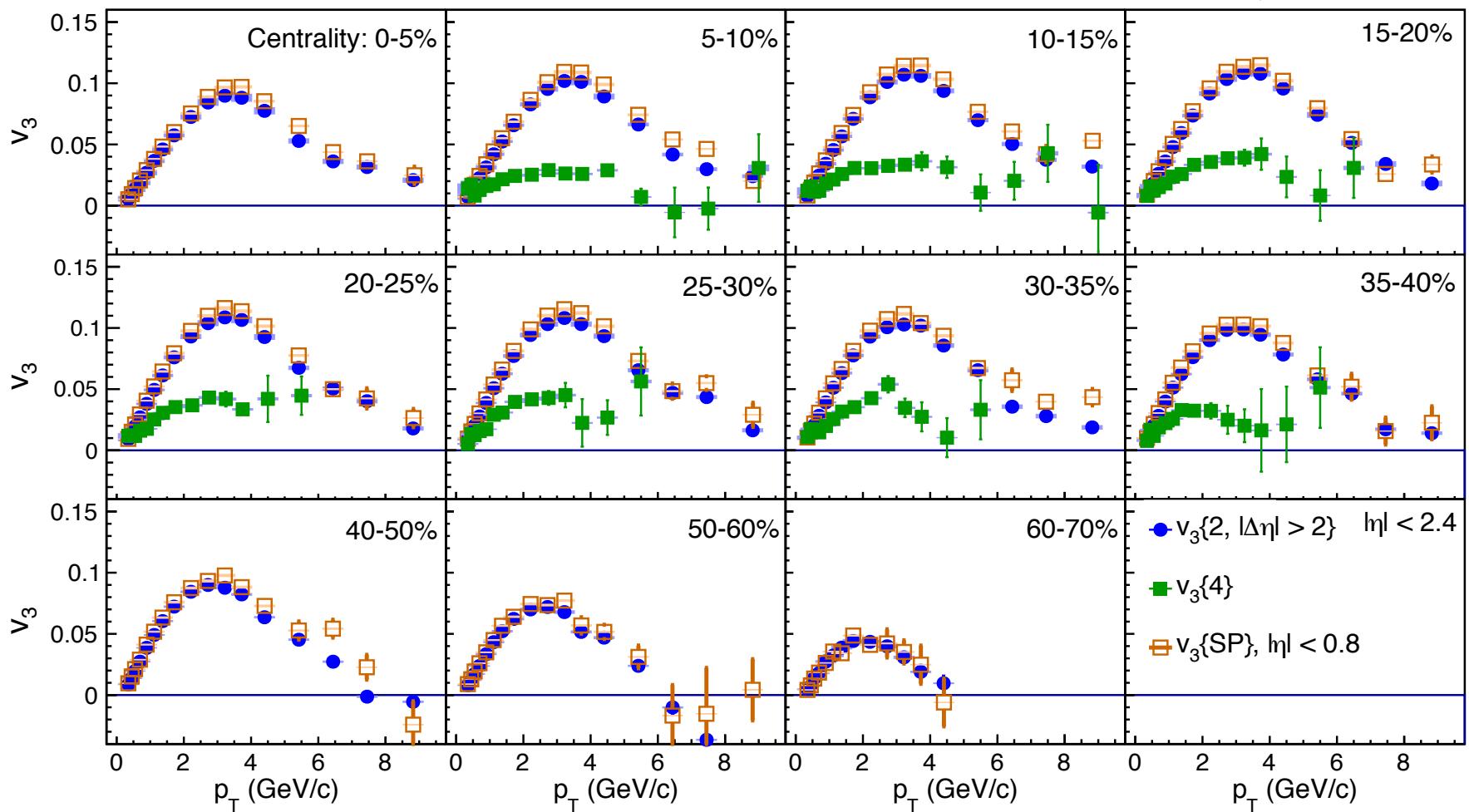


# $v_3$ in XeXe collisions



CMS Preliminary

XeXe  $\sqrt{s_{NN}} = 5.44 \text{ TeV}$



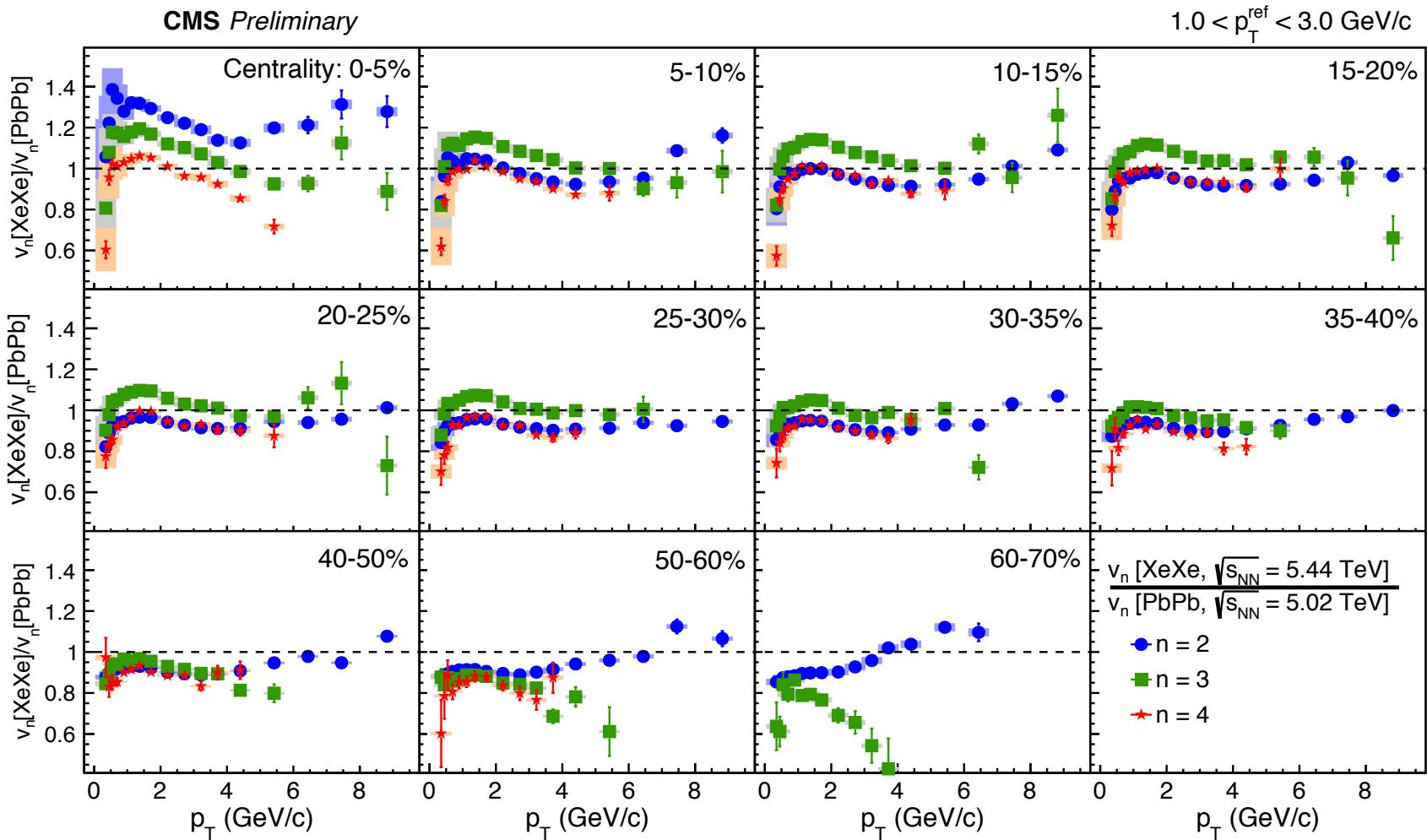
CMS HIN-18-001

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

Collectivity!  
(Still there ☺)



# $v_n[\text{XeXe}]/v_n[\text{PbPb}]$



XeXe:  
CMS HIN-18-001

PbPb:  
CMS HIN-16-018

0-5%  $v_2[\text{XeXe}] > v_2[\text{PbPb}]$

0-30%  $v_3[\text{XeXe}] > v_3[\text{PbPb}]$

5-60%  $v_4[\text{XeXe}] < v_4[\text{PbPb}]$