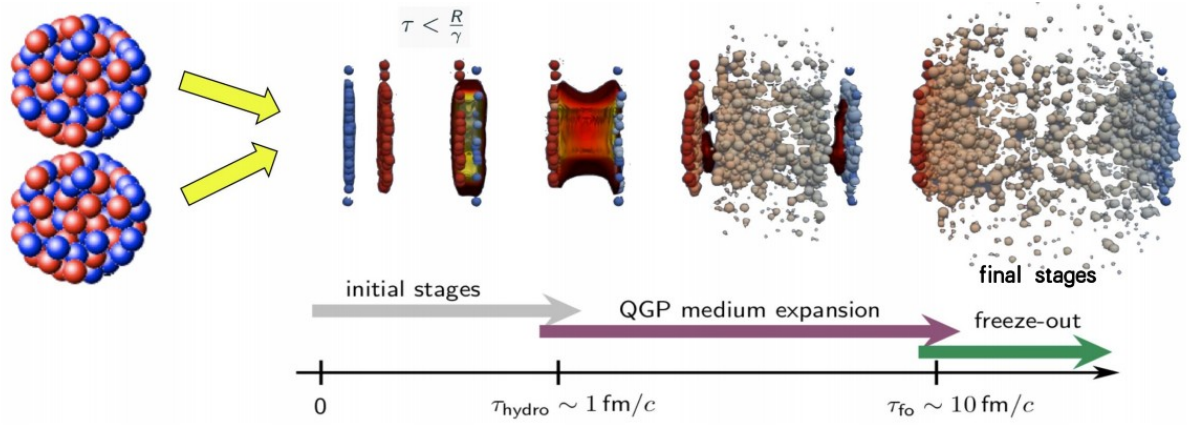
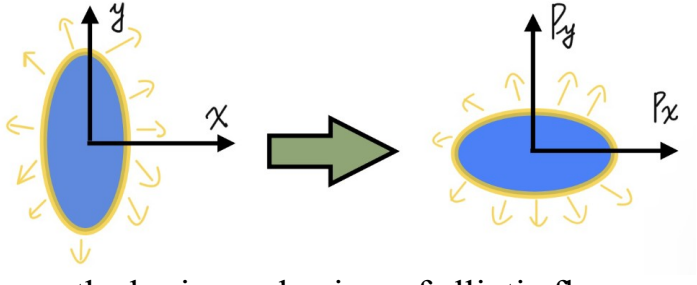
# Collective flow measurements in OO and NeNe collisions with CMS

Jiateng Peng (彭佳腾), Fudan University
For the CMS collaboration
the 16th Workshop on QCD Phase Transition and Relativistic Heavy-Ion Physics, Guilin

# 1 Flow in heavy ion collisions




typical evolution of HIC




the basic mechanism of elliptic flow

The azimuthal ($\phi$) distributions of particles:

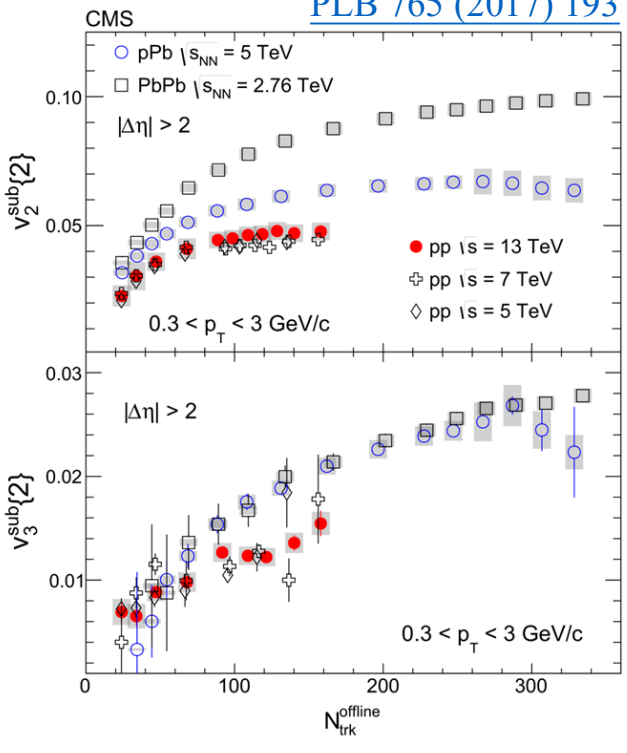
$$\frac{2\pi}{N}\frac{\mathrm{d}N}{\mathrm{d}\phi} = 1 + 2\sum_{n=1}^{\infty} v_n \cos(n(\phi - \Psi_n))$$

Flow coefficient: $v_n = \langle \cos[n(\phi_i - \Psi_n)] \rangle$

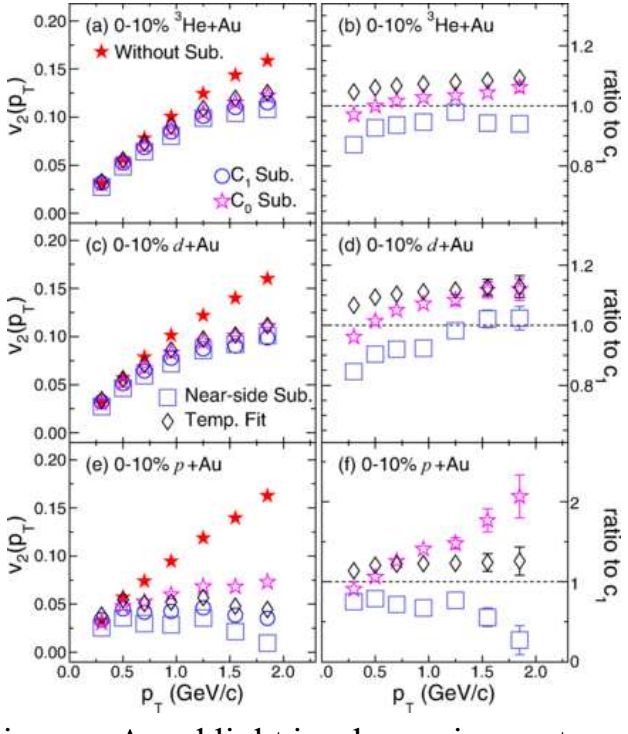
$v_2$: elliptic flow $v_3$: triangular flow

# 1 QGP in small systems

PLB 765 (2017) 193




STAR PRC 110 (2024) 064902

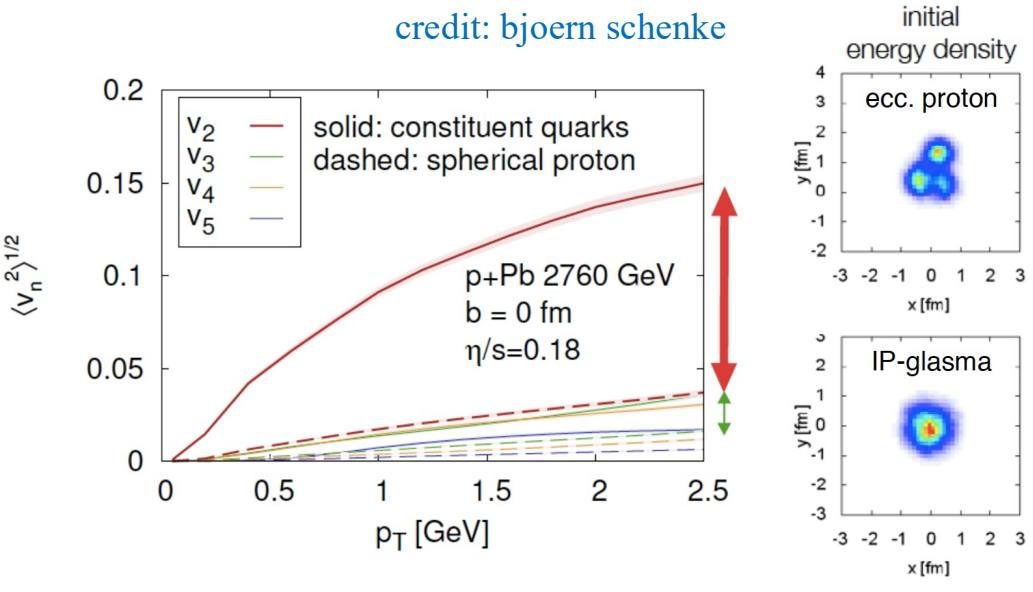



Flow-like signals have been observed in pp, pA and light ion-heavy ion systems.

**Is QGP produced in small systems?**

# 1 QGP in small systems

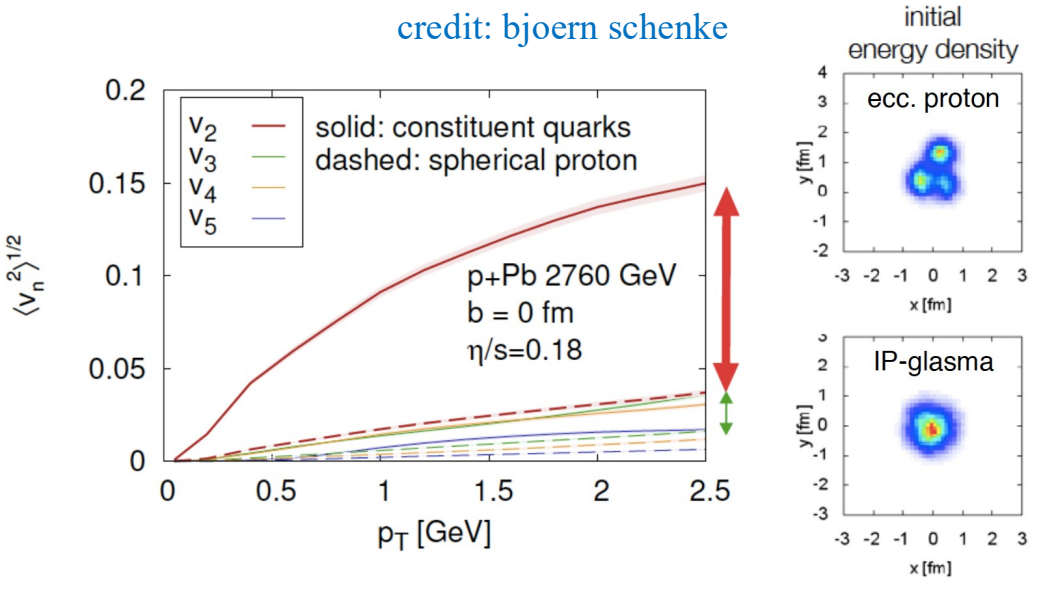
credit: bjoern schenke




Challenge from the proton structure

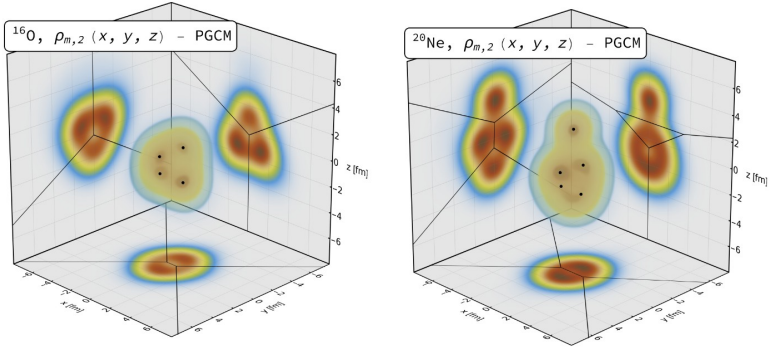
# 1 QGP in small systems

credit: bjoern schenke




Challenge from the proton structure

PRL 135 (2025) 012302




*ab initio* models of $^{16}O$ and $^{20}Ne$

Advantages:

a. The nucleon-level geometry dominates over the subnucleon structure

b. The comparable size leads to similar hydrodynamic evolution

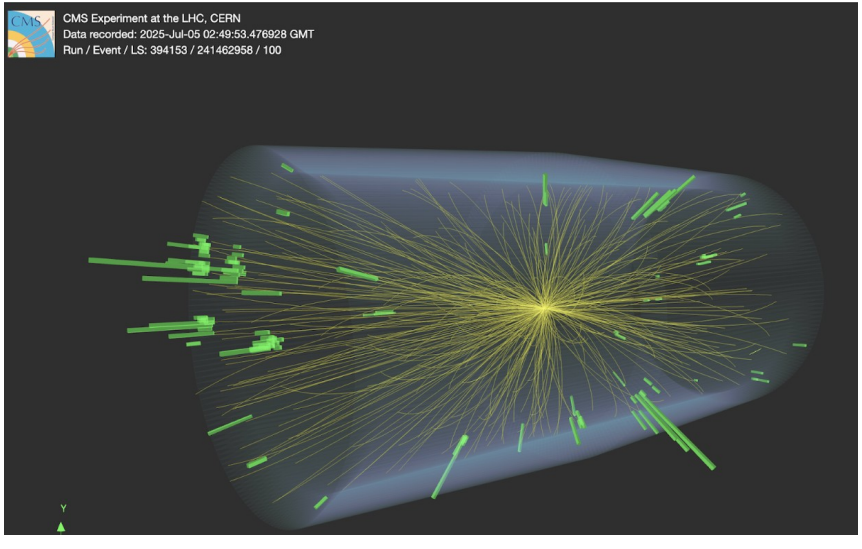
# 2 Dataset

public article: arXiv:2510.02580

Collision systems:
$^{16}$O-$^{16}$O (7nb$^{-1}$) & $^{20}$Ne-$^{20}$Ne (0.8nb$^{-1}$)

Collected in July 2025 at CMS, $\sqrt{s_{NN}} = 5.36$TeV

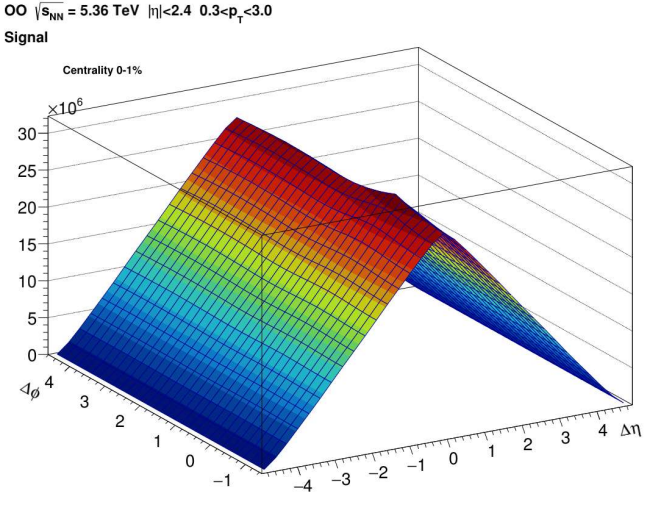
Standard CMS HIN event and track selection
- Minimum bias events, only one reconstructed vertex
- $0.3 < p_T < 3.0$ GeV/c, $|\eta| < 2.4$



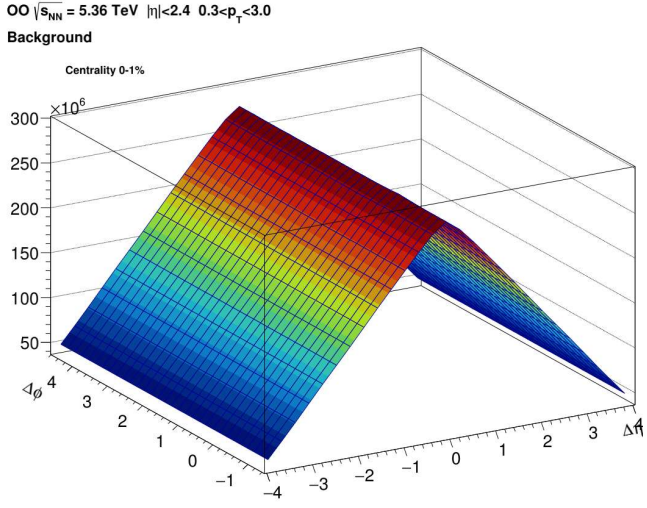

event display of OO collisions

# 2 Flow measurement method

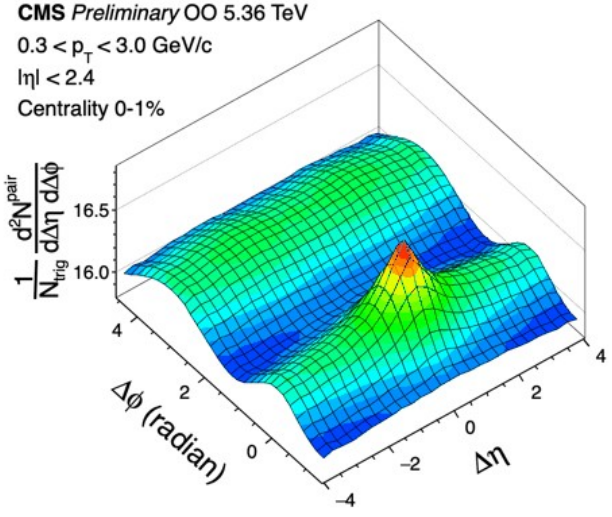
- Two-particle correlation： $$\frac{1}{N_{trig}}\frac{\mathrm{d}^2N^{pair}}{\mathrm{d}\Delta\eta d\Delta\phi} = B(0,0)\times\frac{S(\Delta\eta,\Delta\phi)}{B(\Delta\eta,\Delta\phi)}$$




Signal



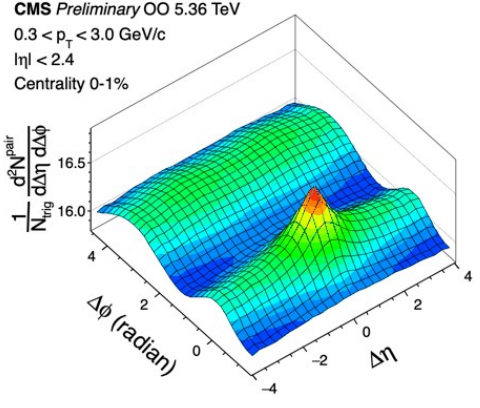

Background



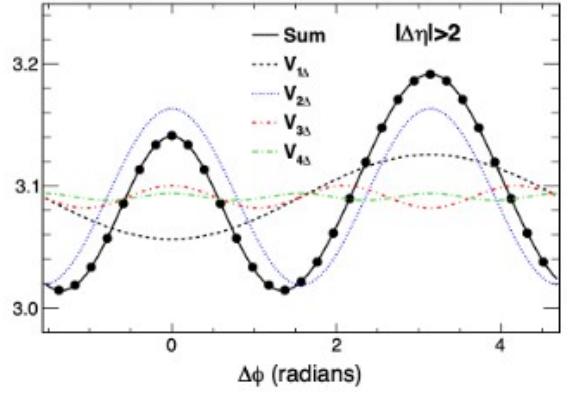

2D function: S/B

# 2 Flow measurement method

- 1D projection: $\frac{1}{N_{trig}}\frac{\mathrm{d}N^{pair}}{\mathrm{d}\Delta\phi} = \frac{N_{assoc}}{2\pi}\left[1 + \sum_n 2V_{n\Delta}\cos(n\Delta\phi)\right]$




$|\Delta\eta| > 2$




$v_n\{2\} = \sqrt{V_{n\Delta}}$

- In line with previous CMS analyses, the peripheral subtraction method is employed to suppress non-flow

$$V_{n\Delta}^{sub} = V_{n\Delta} - V_{n\Delta}(\text{peripheral}) \times \frac{N_{assoc}(\text{peripheral})}{N_{assoc}} \times \frac{Y_{jet}}{Y_{jet}(\text{peripheral})}$$

In this analysis, events from 70-80% centrality are selected as peripheral events

# 2 Flow measurement method

- Four-particle correlation (Q-cumulant)： PRC.96.034906

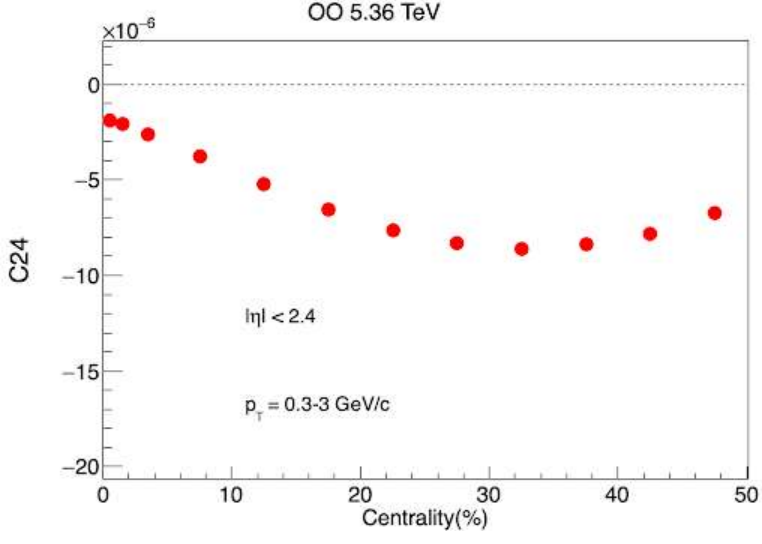
$$\vec{Q}_n \equiv \sum_i e^{in\vec{\phi}_i} = |Q_n| e^{in\vec{\Psi}_n}$$

$$\langle 2 \rangle = \frac{\vec{Q}_n^2 - \mathrm{M}}{M(M-1)},$$

$$\langle 4 \rangle = \frac{\vec{Q}_n^4 - 2\mathrm{Re}[\vec{Q}_{2n}\vec{Q}_n^{*2}] - 4(\mathrm{M}-2)\vec{Q}_n^2 + 2M(M-3) + \vec{Q}_{2n}^2}{M(M-1)(M-2)(M-3)}$$

$$c_n\{4\} = \langle\langle 4 \rangle\rangle - 2\langle\langle 2 \rangle\rangle^2$$

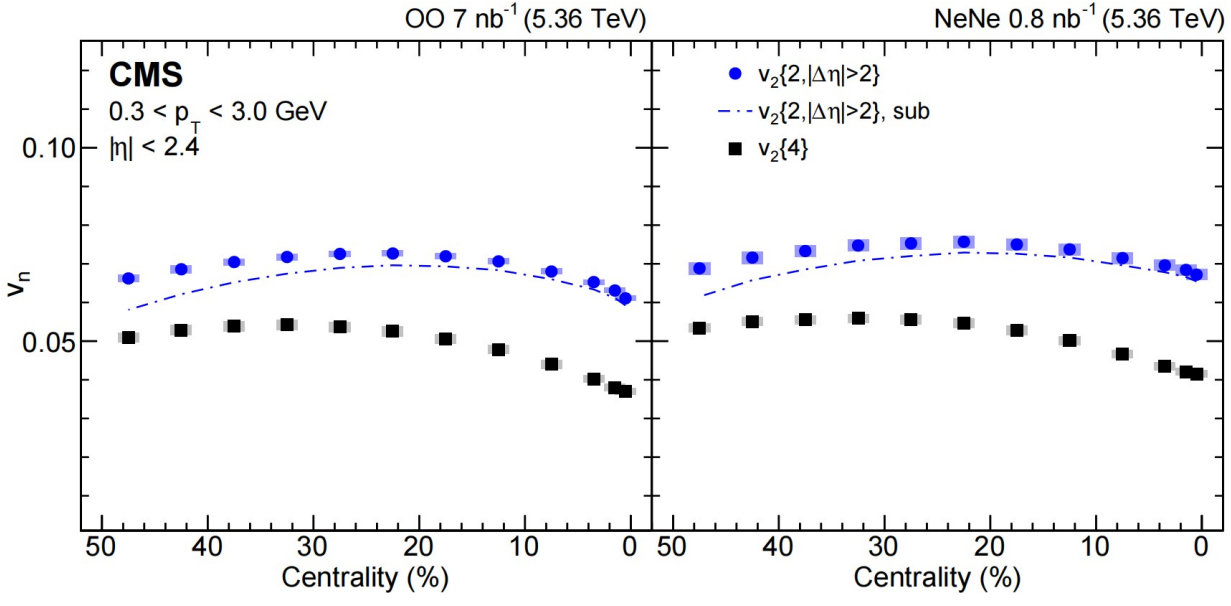
$$v_n\{4\} = \sqrt[4]{-c_n\{4\}}$$




$c_2\{4\}$ vs centrality in OO collisions

# 3 Results: $v_n$ values

public article: arXiv:2510.02580




- Significant flow is observed
- $v_2$ increase and then decrease, from peripheral to central events -- the same as PbPb
- Non-flow contribution is small -- 4 to 15%
- $v_2\{4\} < v_2\{2\}$ -- impact of event-by-event fluctuations

# 3 Results: $v_n$ values

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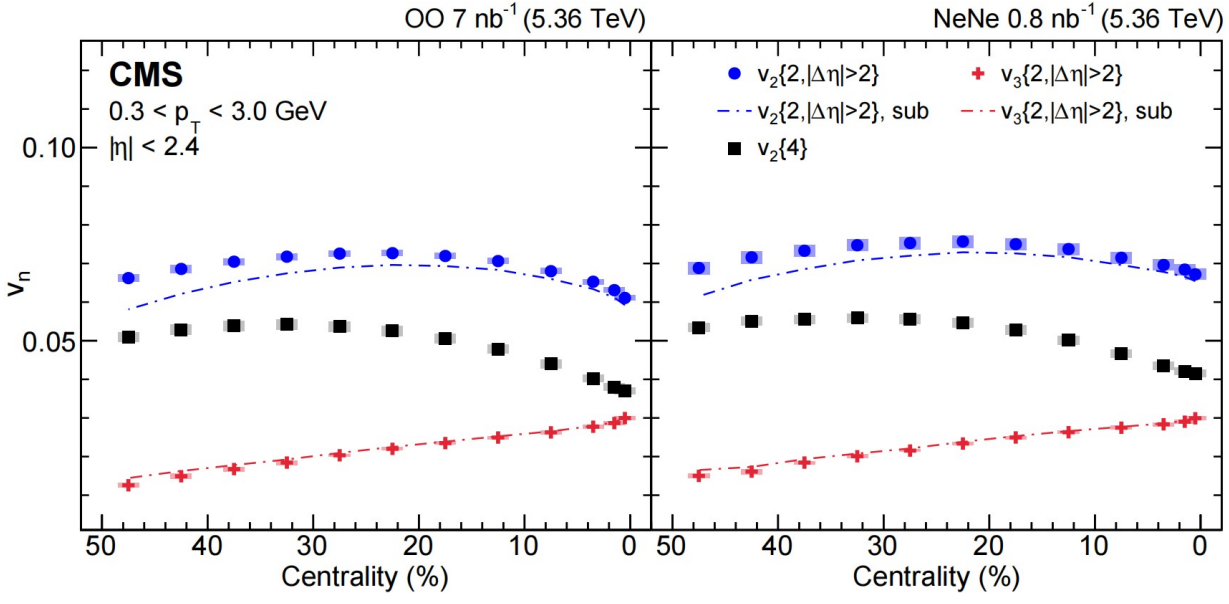


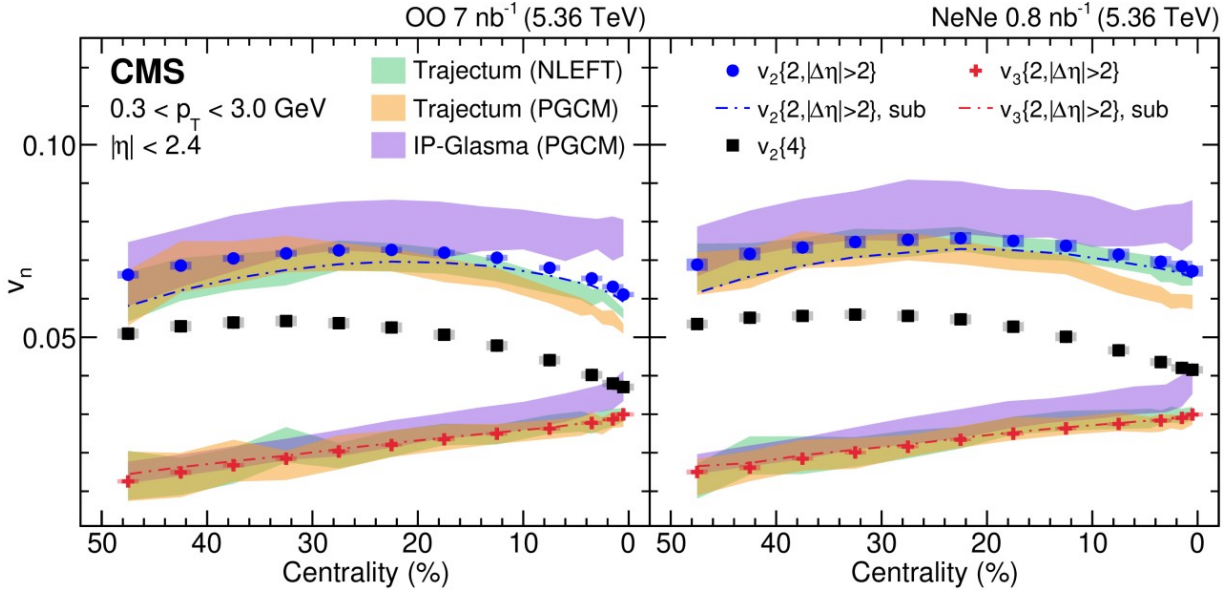

- $v_3$ increase from peripheral to central events

-- different from Pb-Pb, but the same as where mutiplicities are comparable in PbPb collisions

- Non-flow contribution is small

# 3 Results: $v_n$ values

public article: arXiv:2510.02580
Trajectum from PRL 135 (2025) 012302
IP-Glasma from PRL 135 (2025) 022302



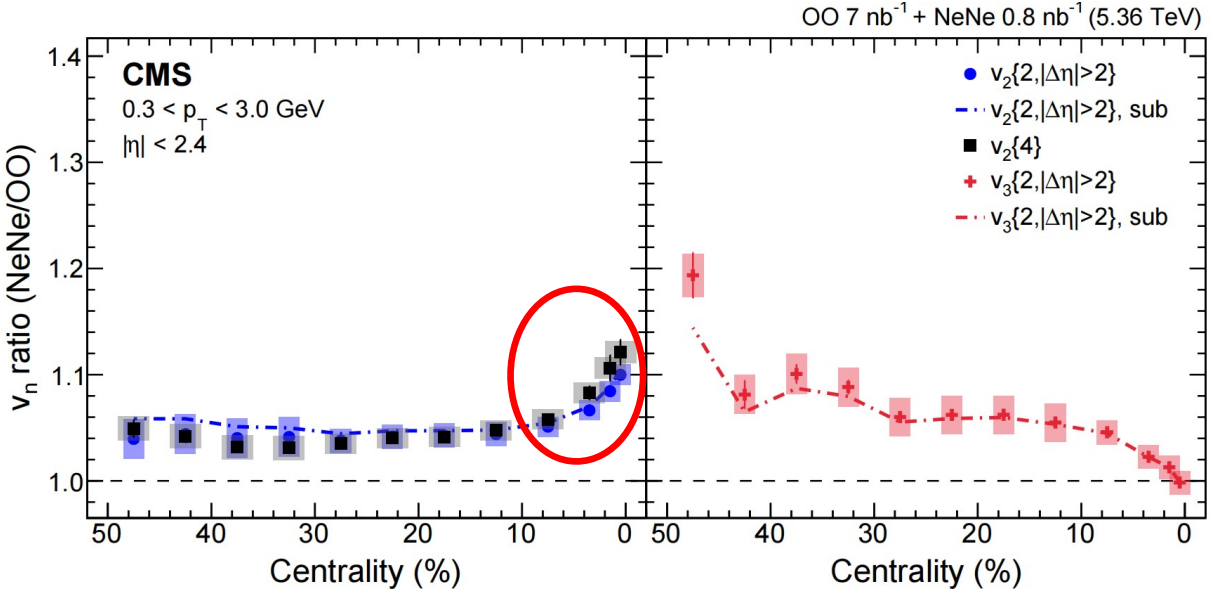

NLEFT:
nuclear lattice effective field theory
PGCM:
projected generator coordinate method

For $v_2$ values:
- All three models agree with the trend
- Trajectum with NLEFT is the best in central collisions

For $v_3$ values:
- All three models agree well with trend
- IP-Glasma overestimates in central collisions

# 3 Results: Ne/O ratios of $v_n$

public article: arXiv:2510.02580




- $v_2$ ratio significantly increase in the most central collisions
- non-flow is negligible
- $v_2\{4\}$ and $v_2\{2\}$ ratio are consistent
  In central collisions, it seems that $v_2\{4\}$ ratio are larger than $v_2\{2\}$ ratio

# 3 Results: Ne/O ratios of $v_n$

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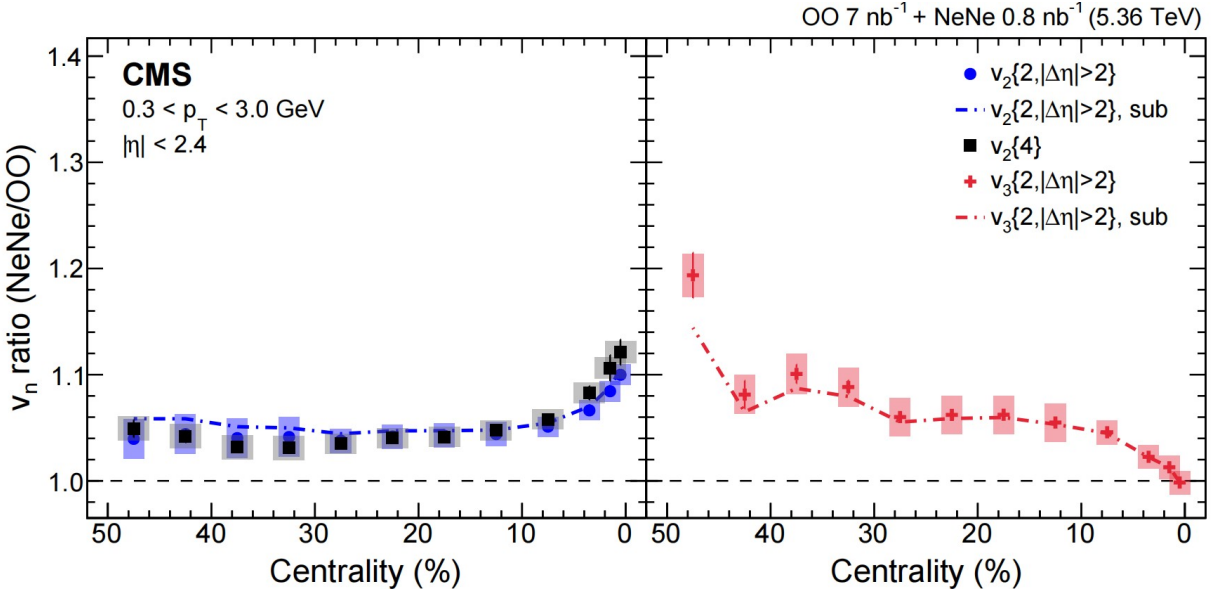


- $v_3$ ratios exhabit a decreasing trend from peripheral to central collisions
- non-flow is negligible

# 3 Results: Ne/O ratios of $v_n$

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Trajectum from PRL 135 (2025) 012302
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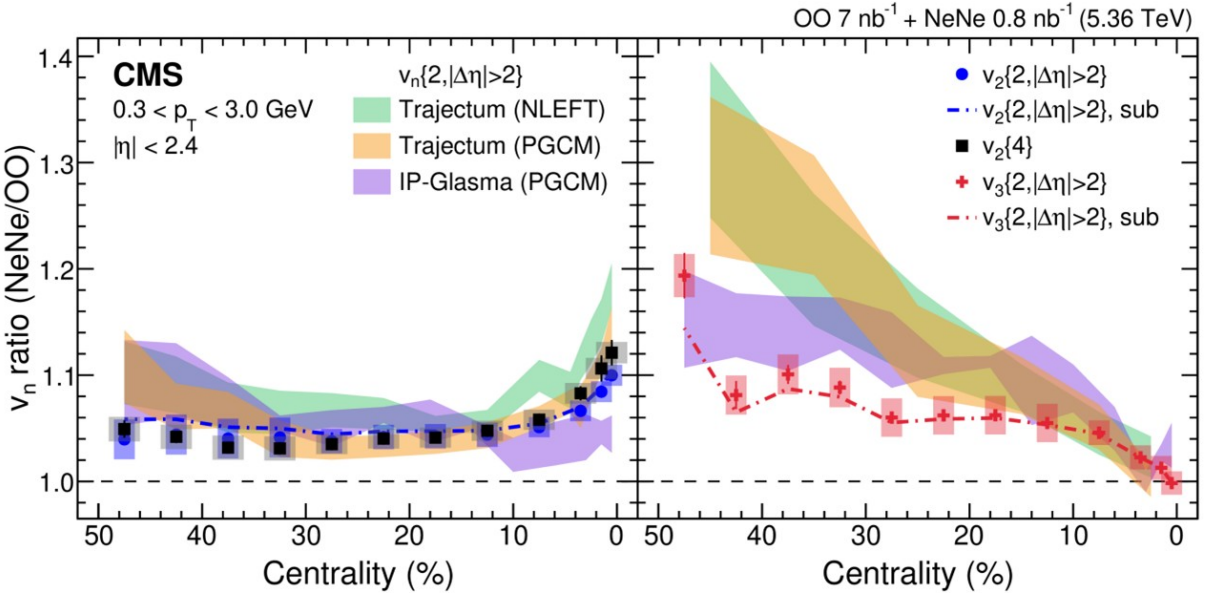
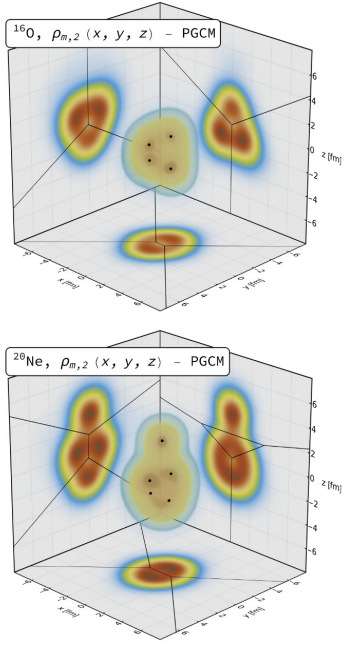



For $v_2$ ratios:

- Trajectum PGCM agrees with data, Trajectum NLEFT overestimates
- IP-Glasma predicts no rising trend towards central collisions

For $v_3$ ratios:

- All three model predict the decreasing trend
- None of the three models agrees with data quantitatively




*ab initio* models of $^{16}$O and $^{20}$Ne

# 4 Summary

public article: arXiv:2510.02580

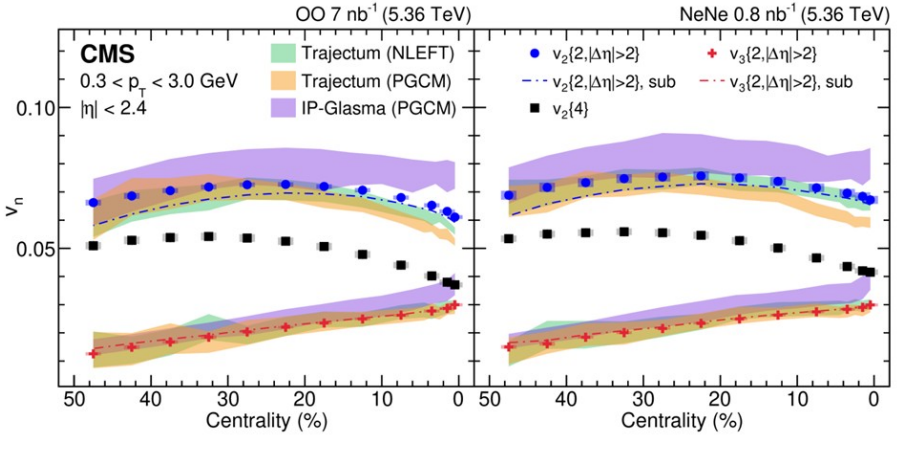
- New measurement of $v_2\{2\}$, $v_2\{4\}$ and $v_3\{2\}$ in OO and NeNe collisions at 5.36TeV

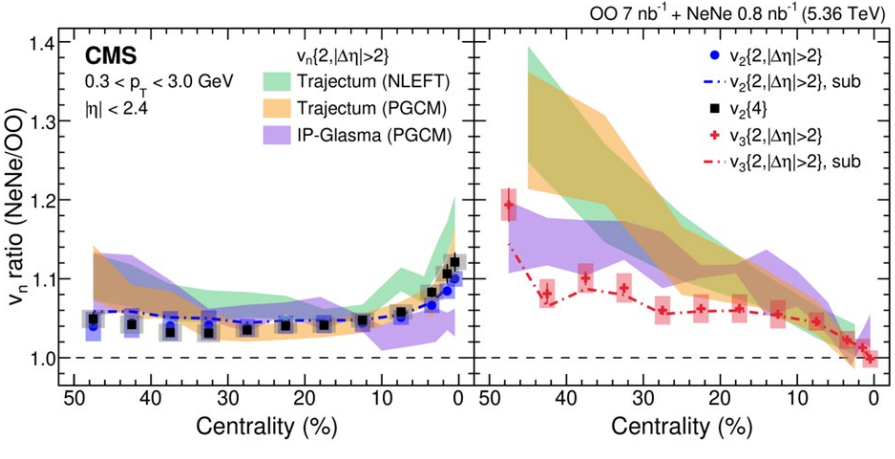
Significant flow is observed

- Measurement of the ratios of NeNe to OO $v_n$ values

Significant rising trend towards central collisions in $v_2$ ratio

ALICE and ATLAS have similar measurements



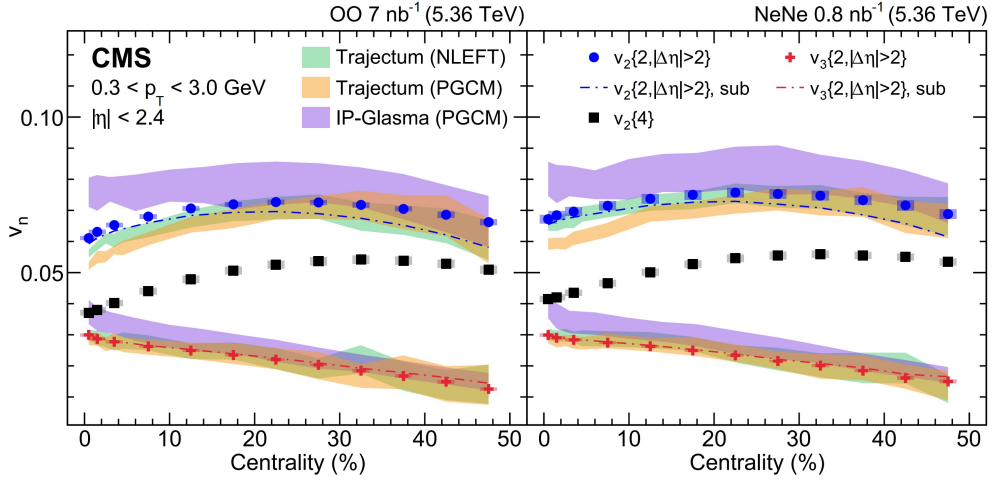



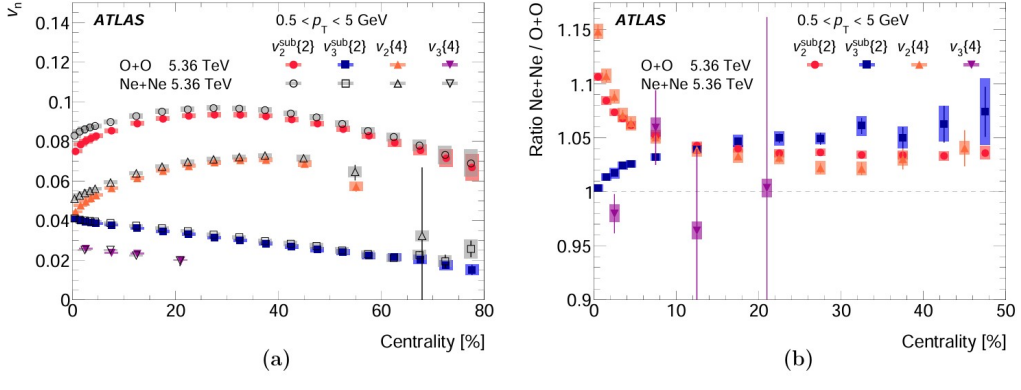
# Thanks for your attention !

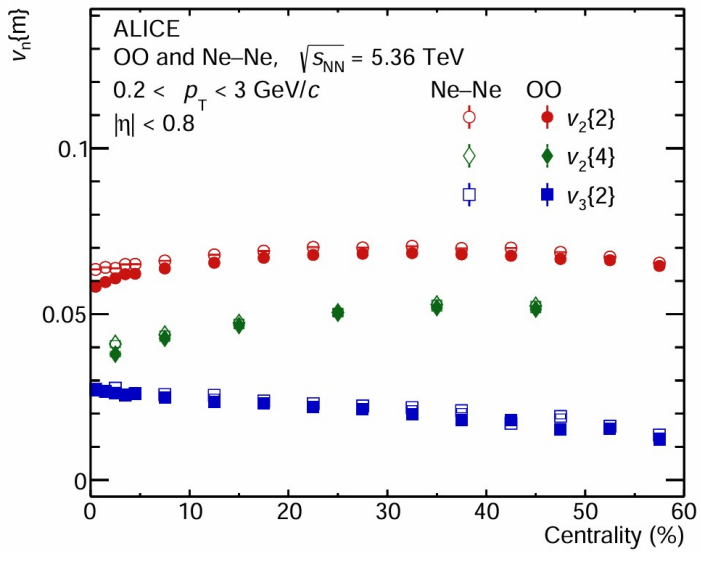
Jiateng Peng, FDU
For the CMS collaboration

# Backup: results from ALICE and ATLAS

CMS: arXiv:2510.02580
ALICE: arXiv:2509.06428
ATLAS: arXiv:2509.05171



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