



Probing the initial geometry and the onset of collectivity with anisotropic flow in light-ion collisions at LHC-ALICE

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EMMI Workshop: Light-ion collisions 2026 – 23rd of September

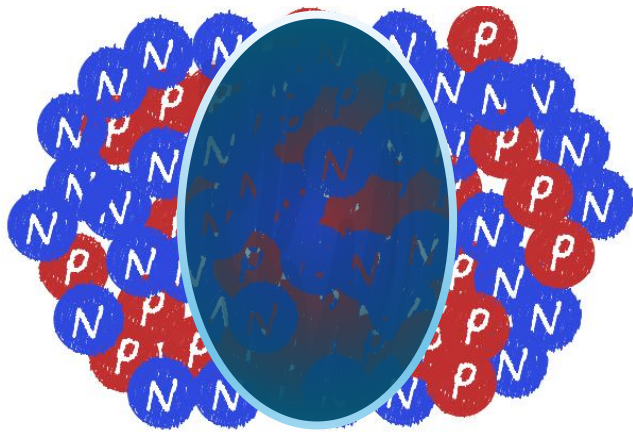


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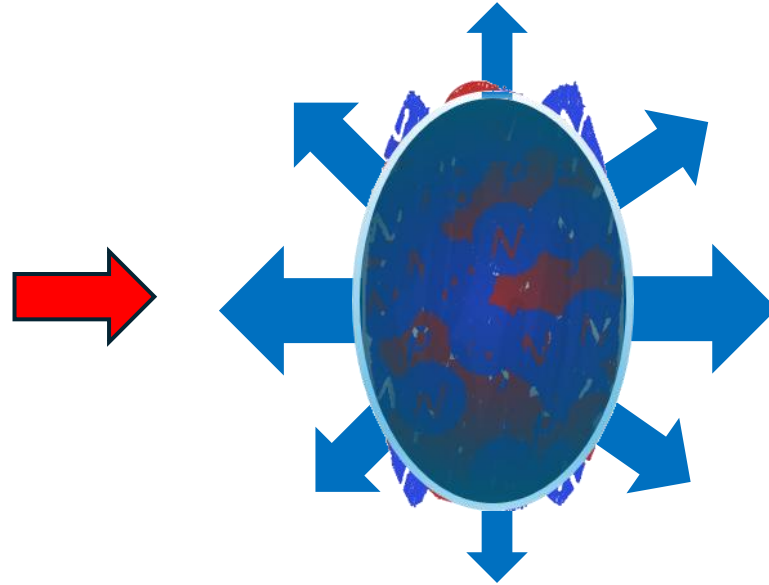
Why anisotropic flow?

Initial spatial anisotropy



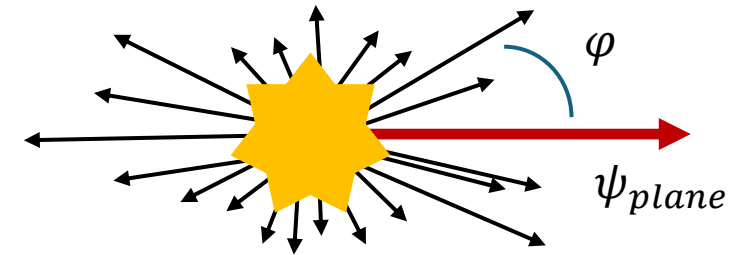
Eccentricity ε_n
“how the initial state is distributed”

Expansion due to pressure gradients within the medium



QGP-like phase

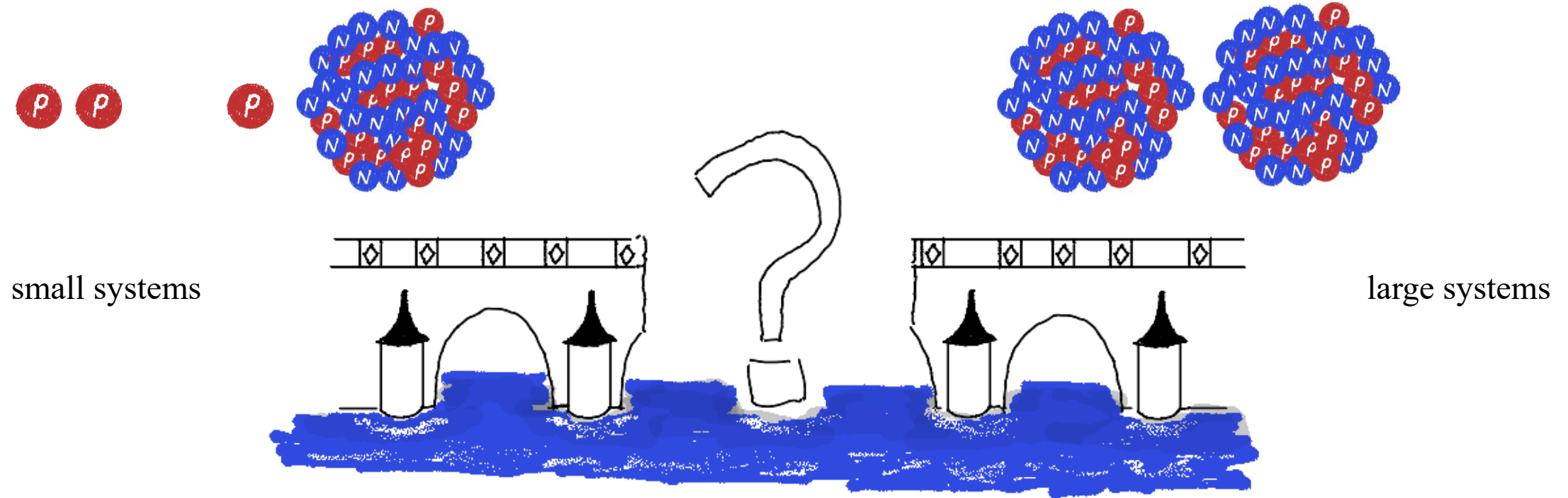
Anisotropic distribution of final-state particles



$$\frac{dN}{d\varphi} \propto 1 + 2 \sum_{n=1}^{\infty} \mathbf{v}_n \cos[n(\varphi - \psi_n)]$$

“how strongly correlated is the particle with the reaction plane ψ_n ”

Why are light ions so interesting?



Dominated by QCD effects
Signs of collective behavior

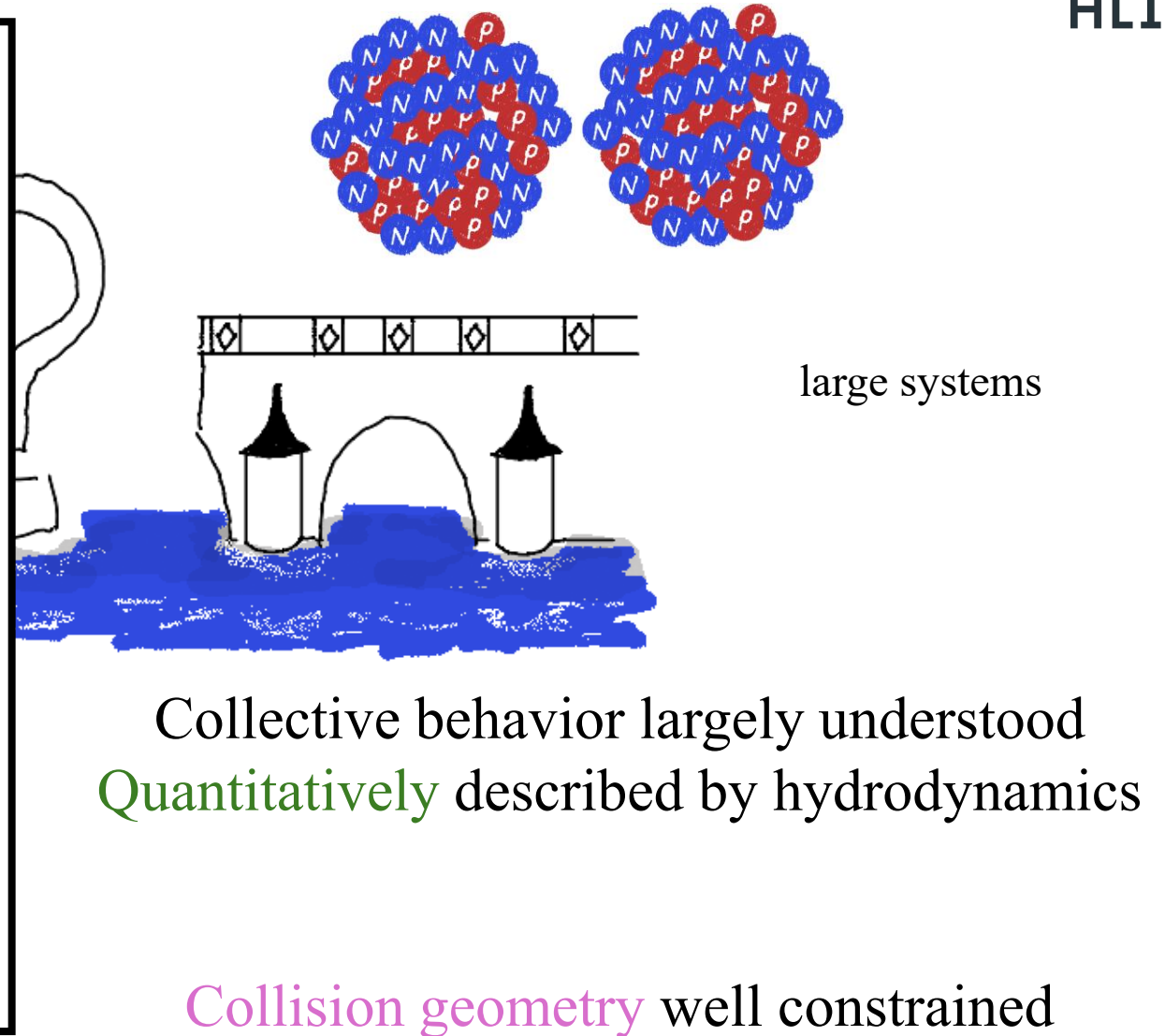
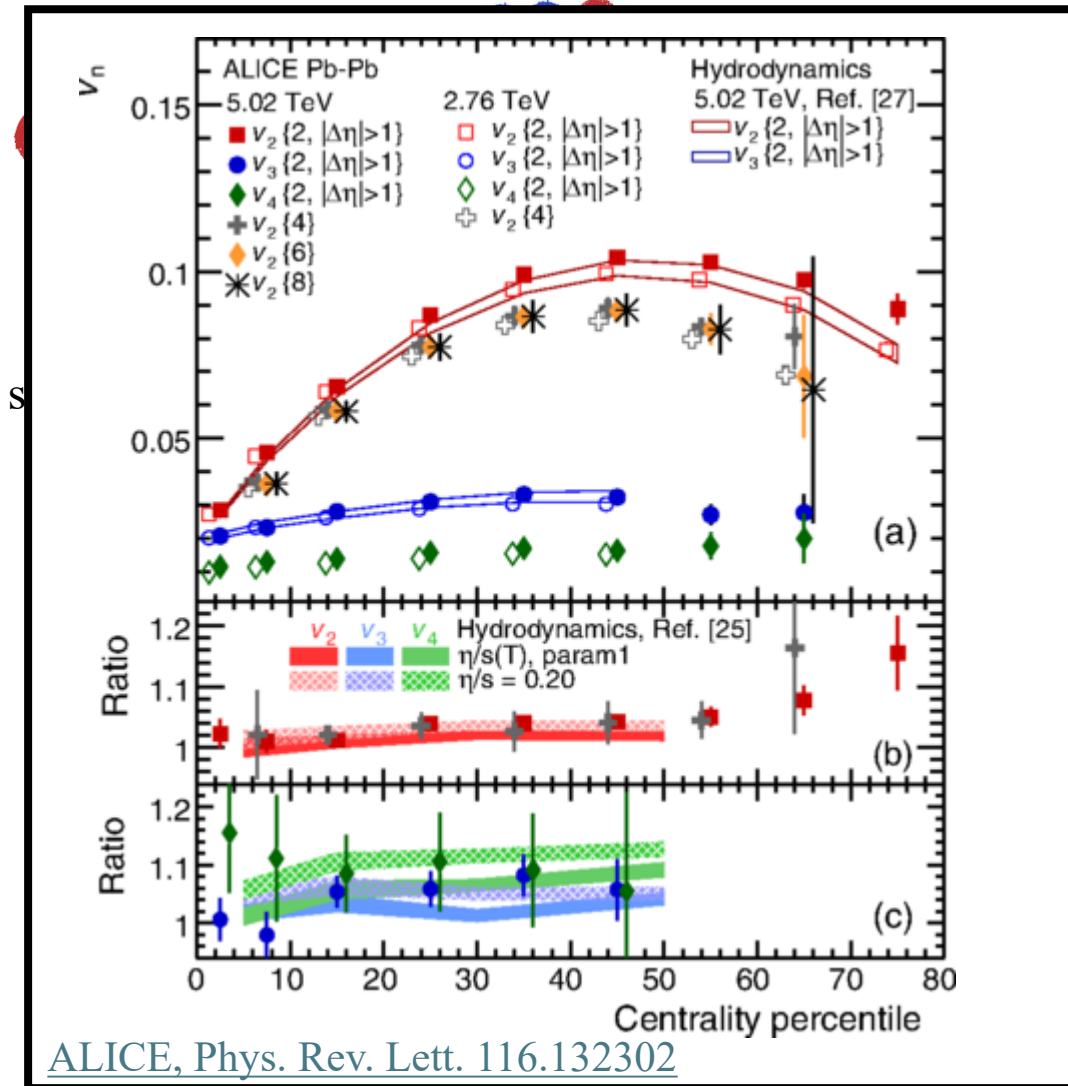
Qualitatively described by hydrodynamics

Collective behavior largely understood
Quantitatively described by hydrodynamics

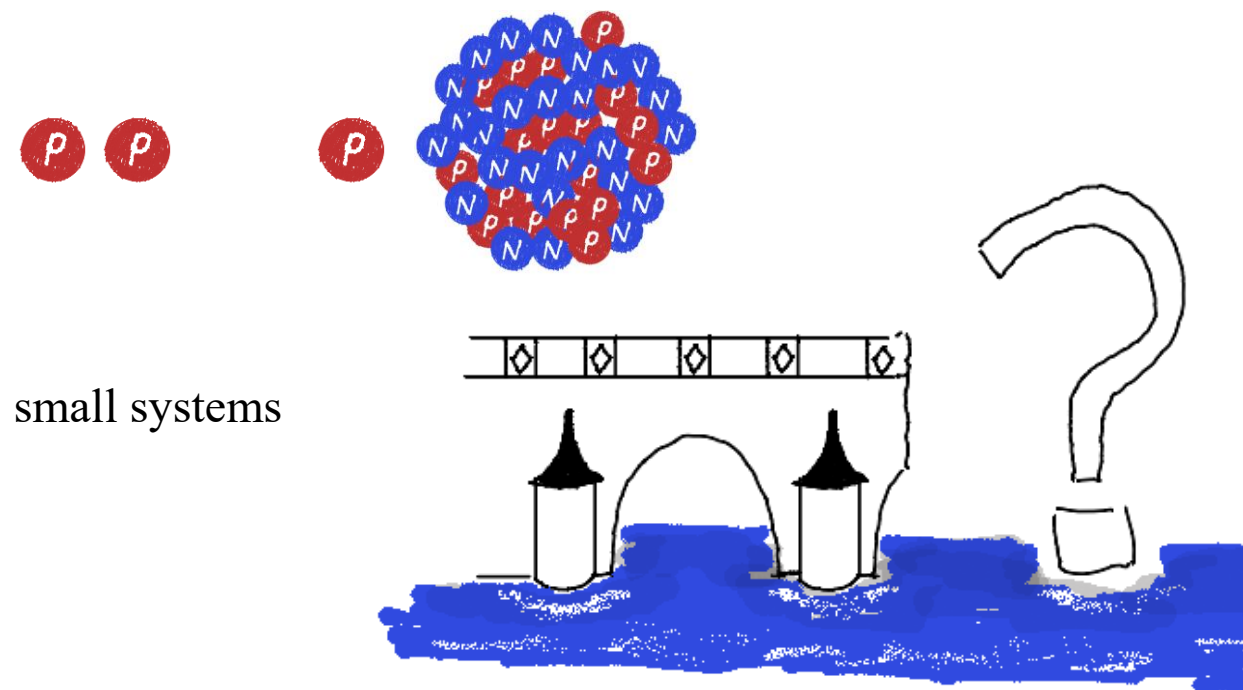
Collision geometry poorly constrained

Collision geometry well constrained

Why are light ions so interesting?



Why are light ions so interesting?



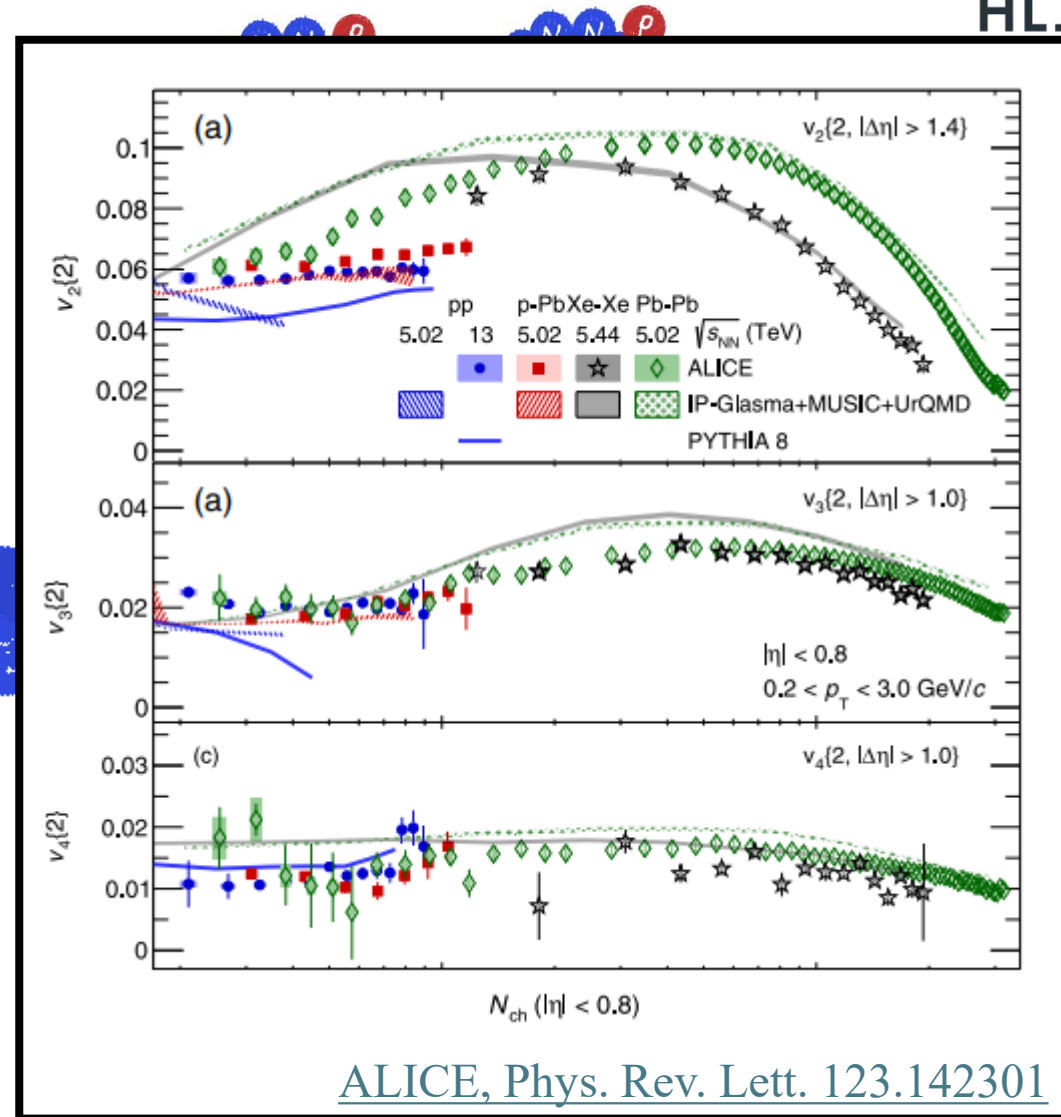
small systems

Dominated by QCD effects

Signs of collective behavior

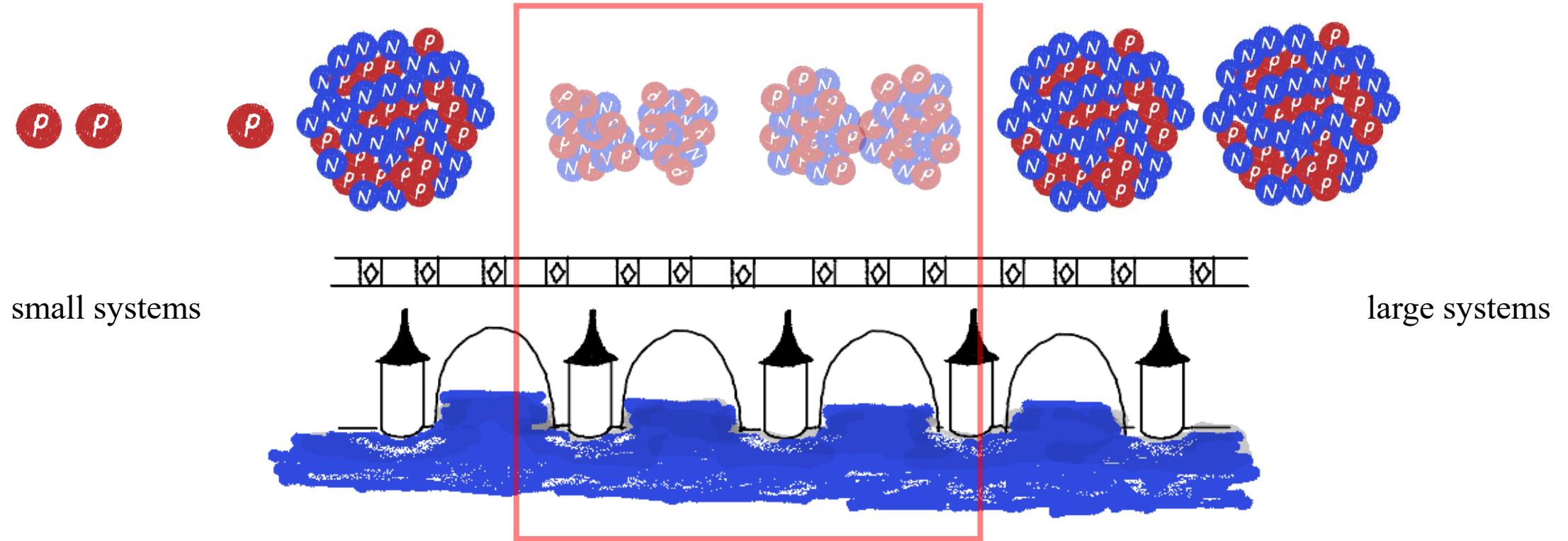
Qualitatively described by hydrodynamics

Collision geometry poorly constrained



ALICE, Phys. Rev. Lett. 123.142301

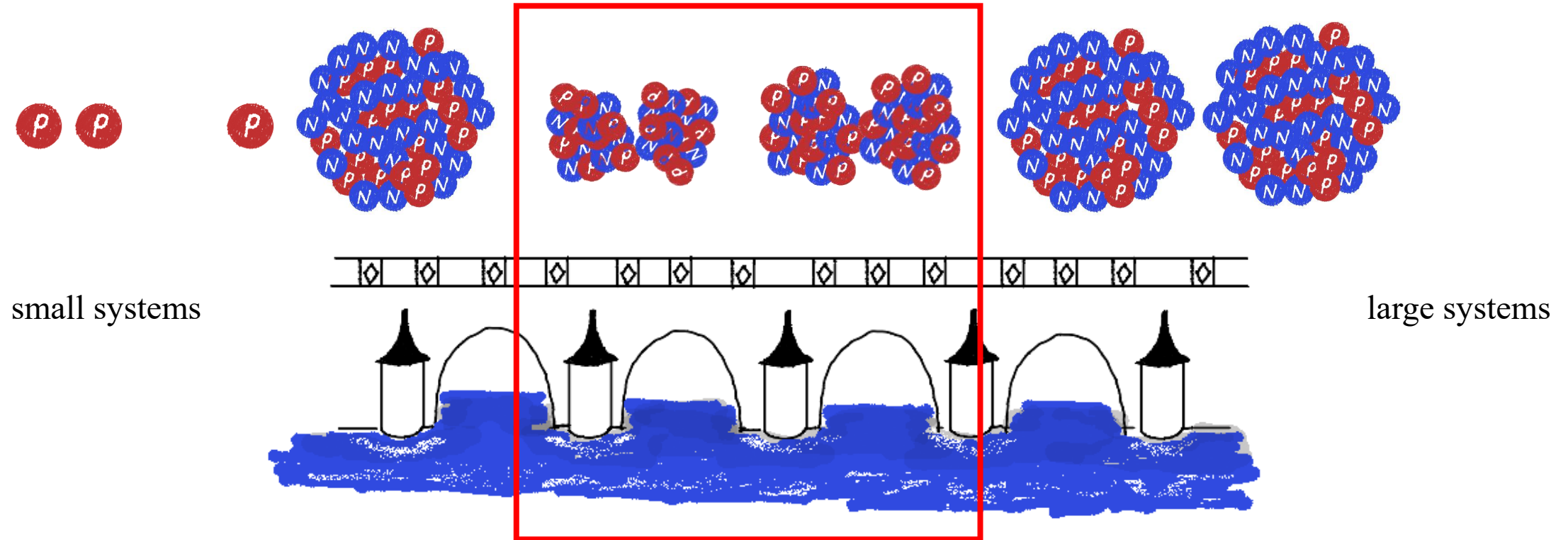
Why are light ions so interesting?



Newcomers at the LHC: ^{16}O and ^{20}Ne !

The **initial state** is better constrained than in pp by theoretical models!
Overlapping multiplicity with smaller systems with constrained **collision geometry**

Why are light ions so interesting?



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The ALICE setup in Run 3



(GEM)-Time Projection Chamber

main tracking device
particle identification

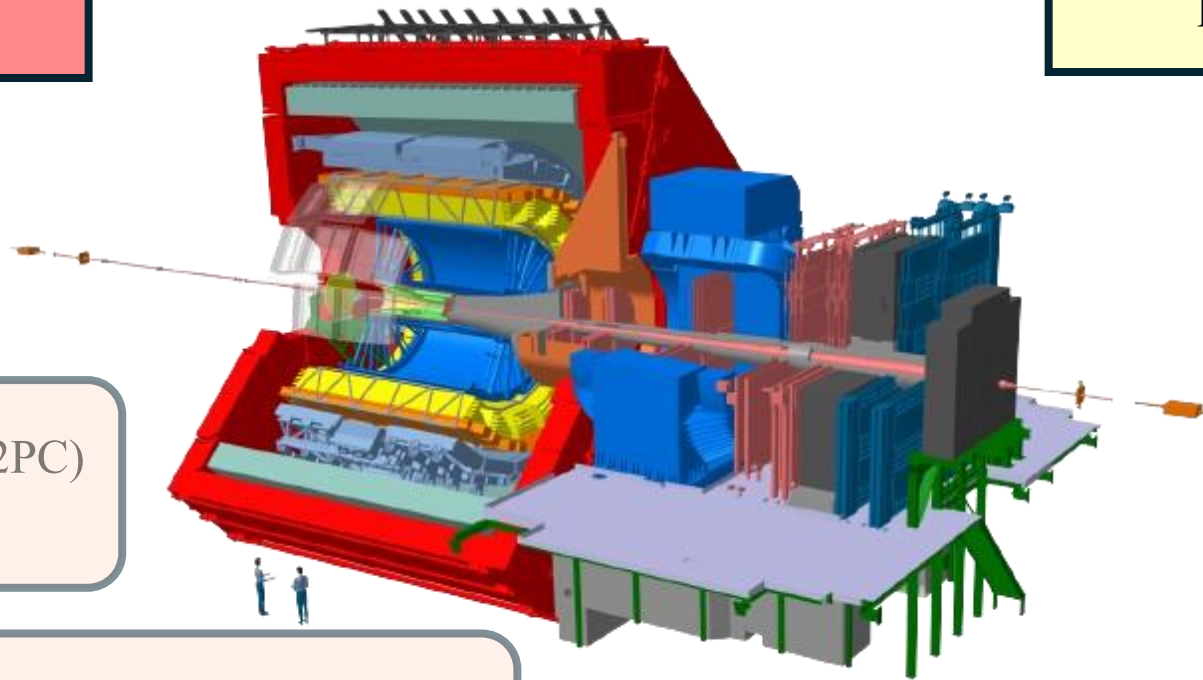
Inner Tracking System 2
tracking and vertex determination

Time Of Flight
particle identification

Cumulants
TPC + ITS

Two-particle correlations (2PC)
TPC + ITS

Three times two-particle correlations (3x2PC)
FT0C + TPC + ITS + FT0A



Fast Interaction Trigger
(A & C)
centrality/multiplicity
determination
forward particle detection
(C: $-3.3 < \eta < -2.1$)
(A: $3.5 < \eta < 4.9$)

The ALICE setup in Run 3



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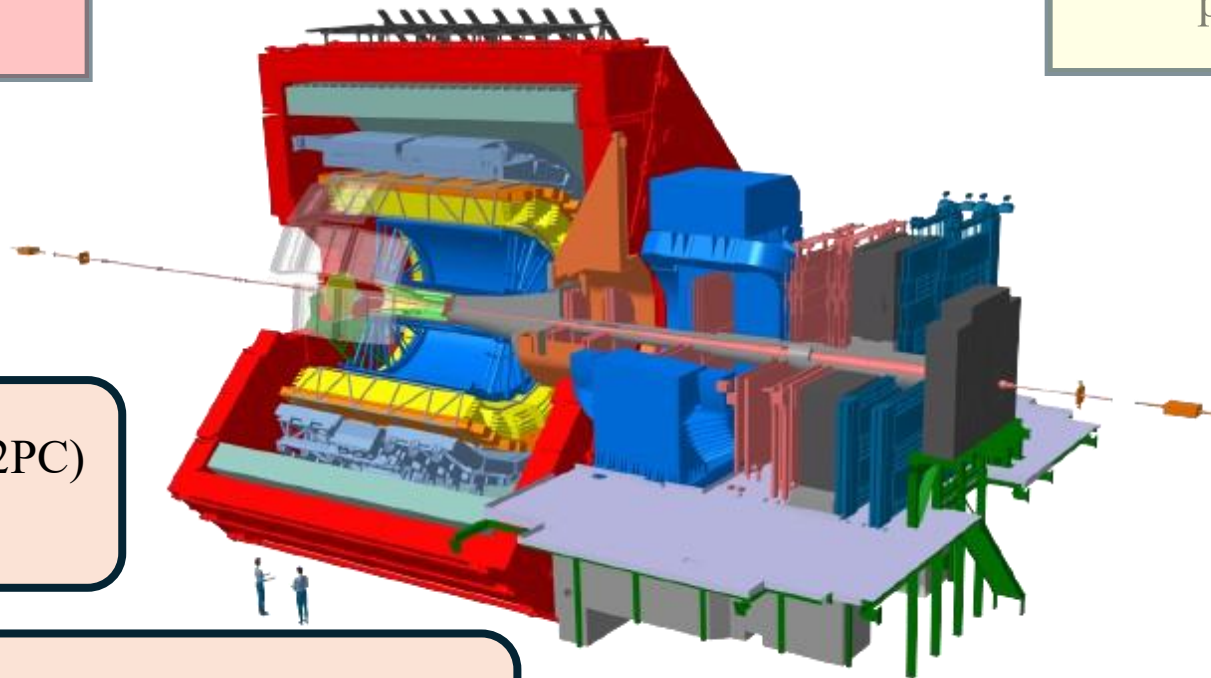
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FT0C + TPC + ITS + FT0A



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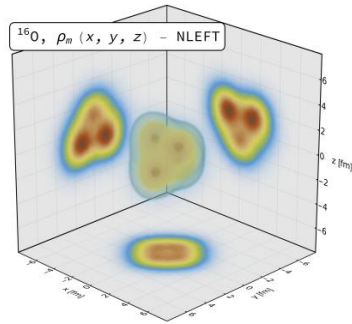
Probing the initial geometry

multi-particle cumulants



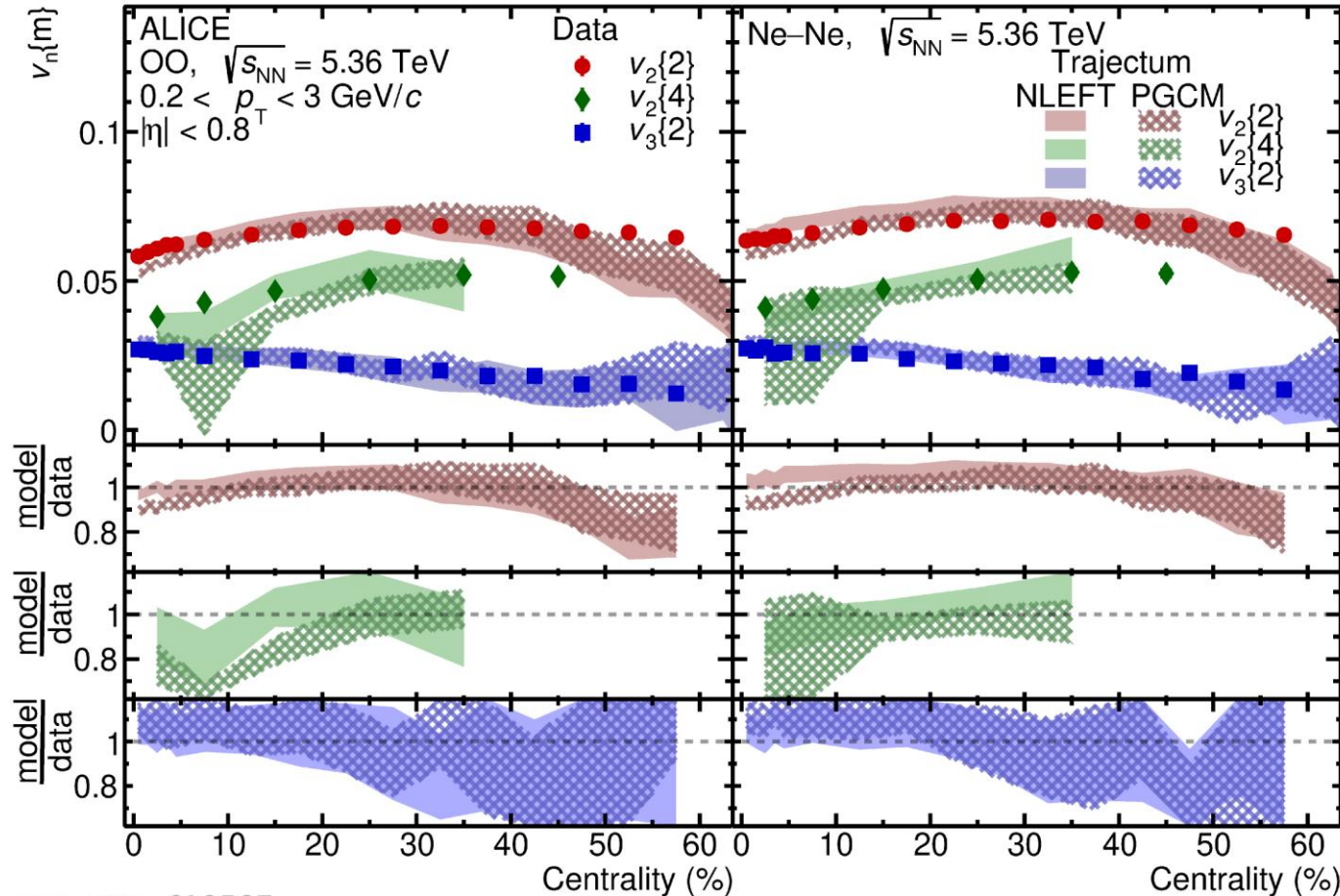
Cross collaboration observation: [ATLAS](#), [CMS](#)

Nuclear Lattice
Effective Field Theory

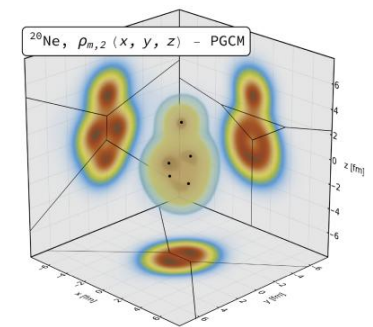


as input...

Hydrodynamics
(Trajectum)



Projected Generator
Coordinate Method



as input...

Hydrodynamics
(Trajectum)

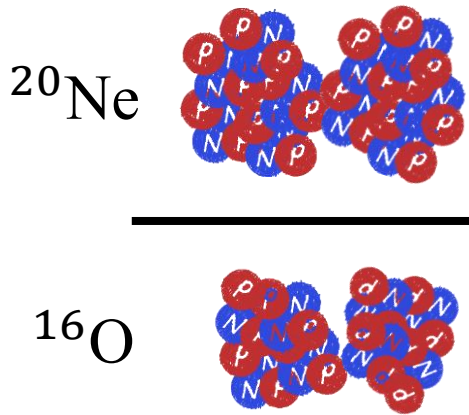
[ALICE, Phys. Rev. Lett. 137, 082301 \(2026\)](#)

Probing the initial geometry

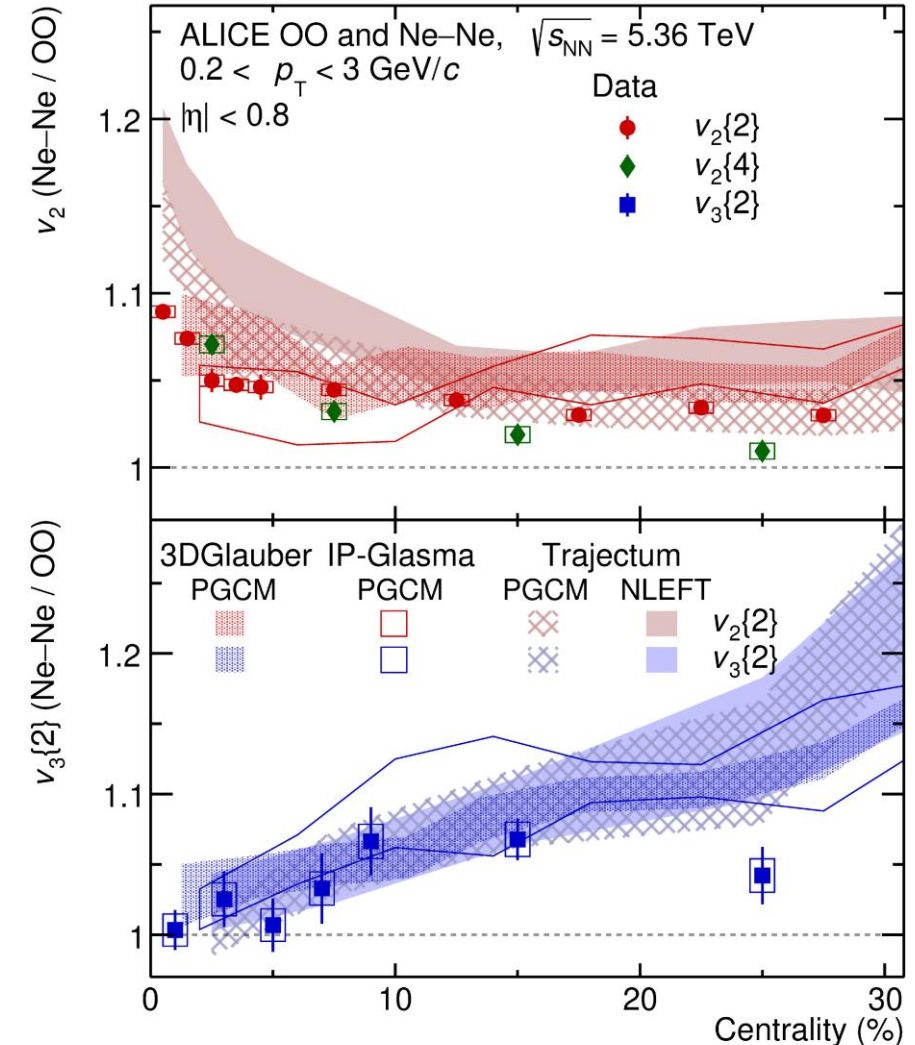
multi-particle cumulants



ALICE, Phys. Rev. Lett. 137, 082301 (2026)



- Mostly cancels out final-state effects (similar size of the systems)
 - reduce uncertainties for both measurement and models
- = Cleaner probe into the **initial state**!



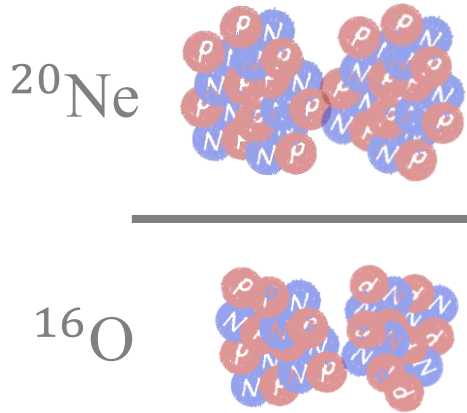
ALI-PUB-610602

Probing the initial geometry

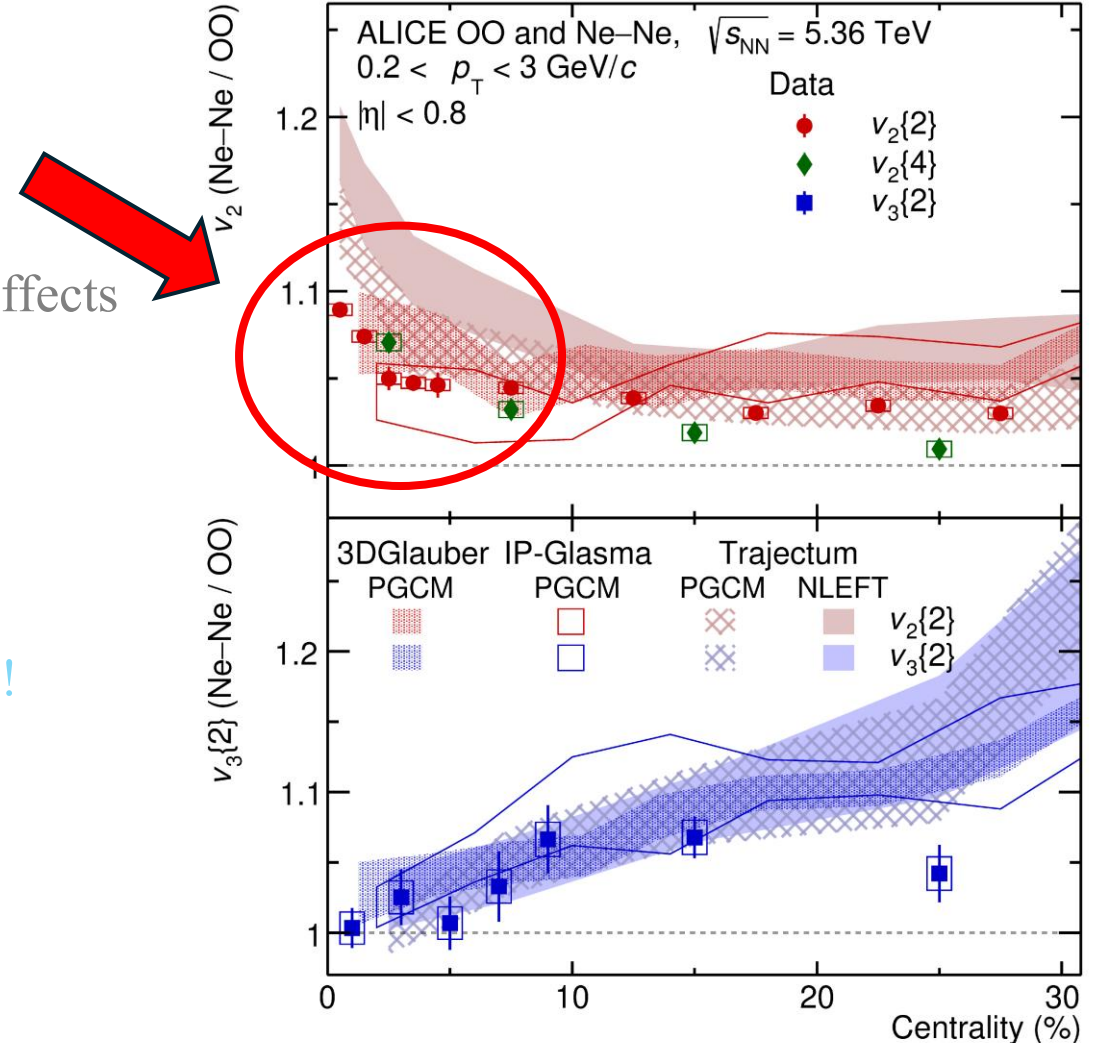
multi-particle cumulants



Stronger quadrupole deformation of ^{20}Ne ?



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ALICE, Phys. Rev. Lett. 137, 082301 (2026)

ALI-PUB-610602

Probing the initial geometry

multi-particle cumulants



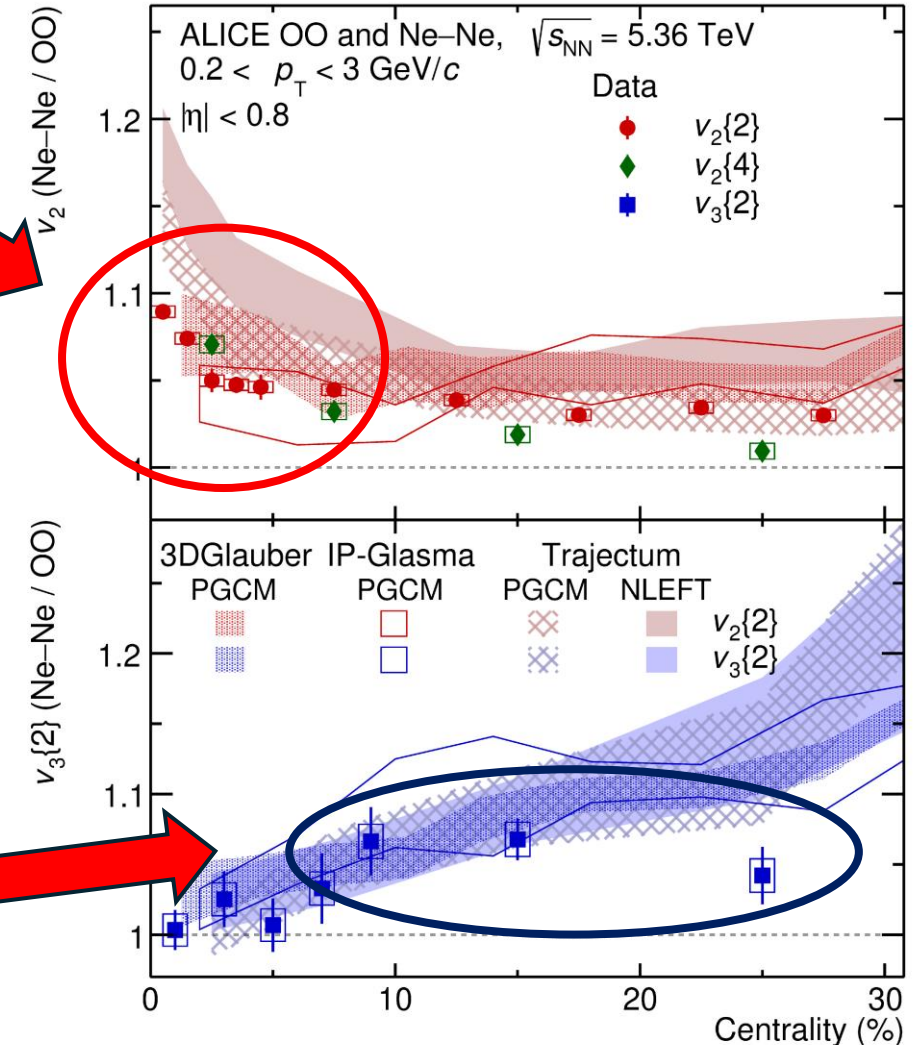
ALICE

Stronger quadrupole deformation of ^{20}Ne ?

- Mostly cancels out final-state effects (similar size of the systems)
- reduce uncertainties for both measurement and models

= Clean probe into the **initial state!**

Stronger octupole deformation of ^{16}O ?
Larger $\varepsilon_3 \rightarrow$ smaller $v_3\{2\}(\text{Ne-Ne}/\text{OO})$

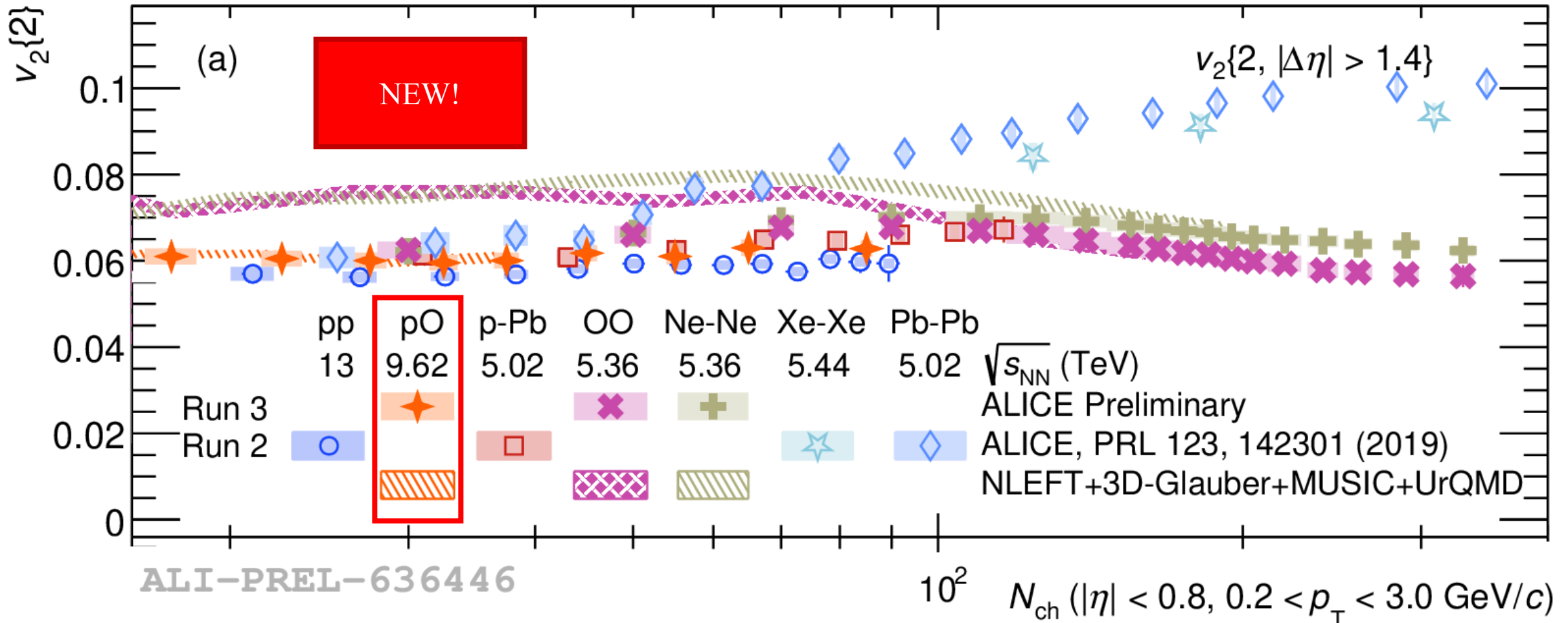


ALICE, Phys. Rev. Lett. 137, 082301 (2026)

ALI-PUB-610602

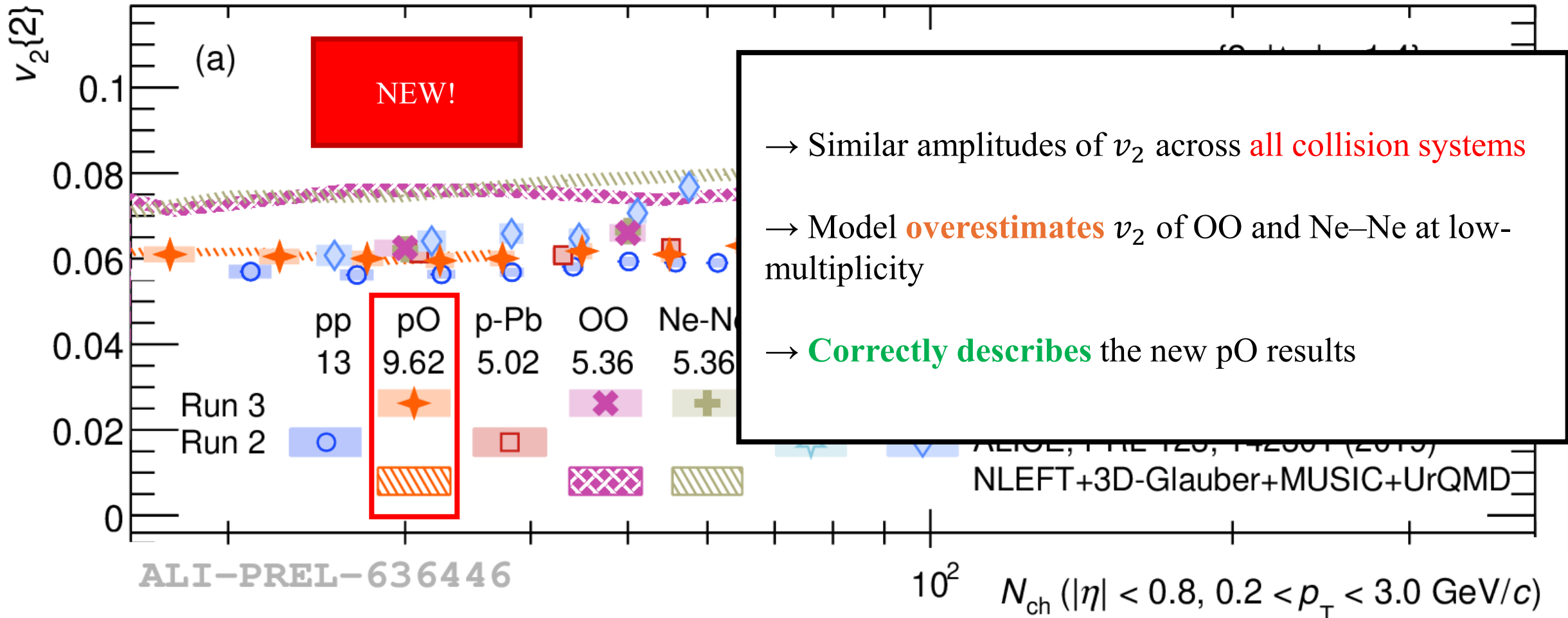
Geometry scan of flow at the LHC

two-particle cumulants



Geometry scan of flow at the LHC

two-particle cumulants

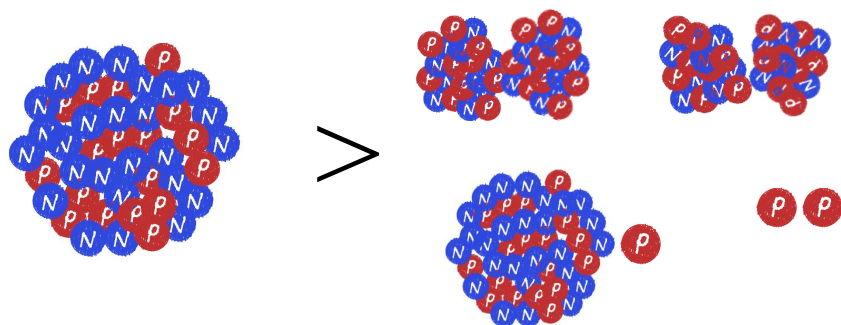


Geometry scan of flow at the LHC

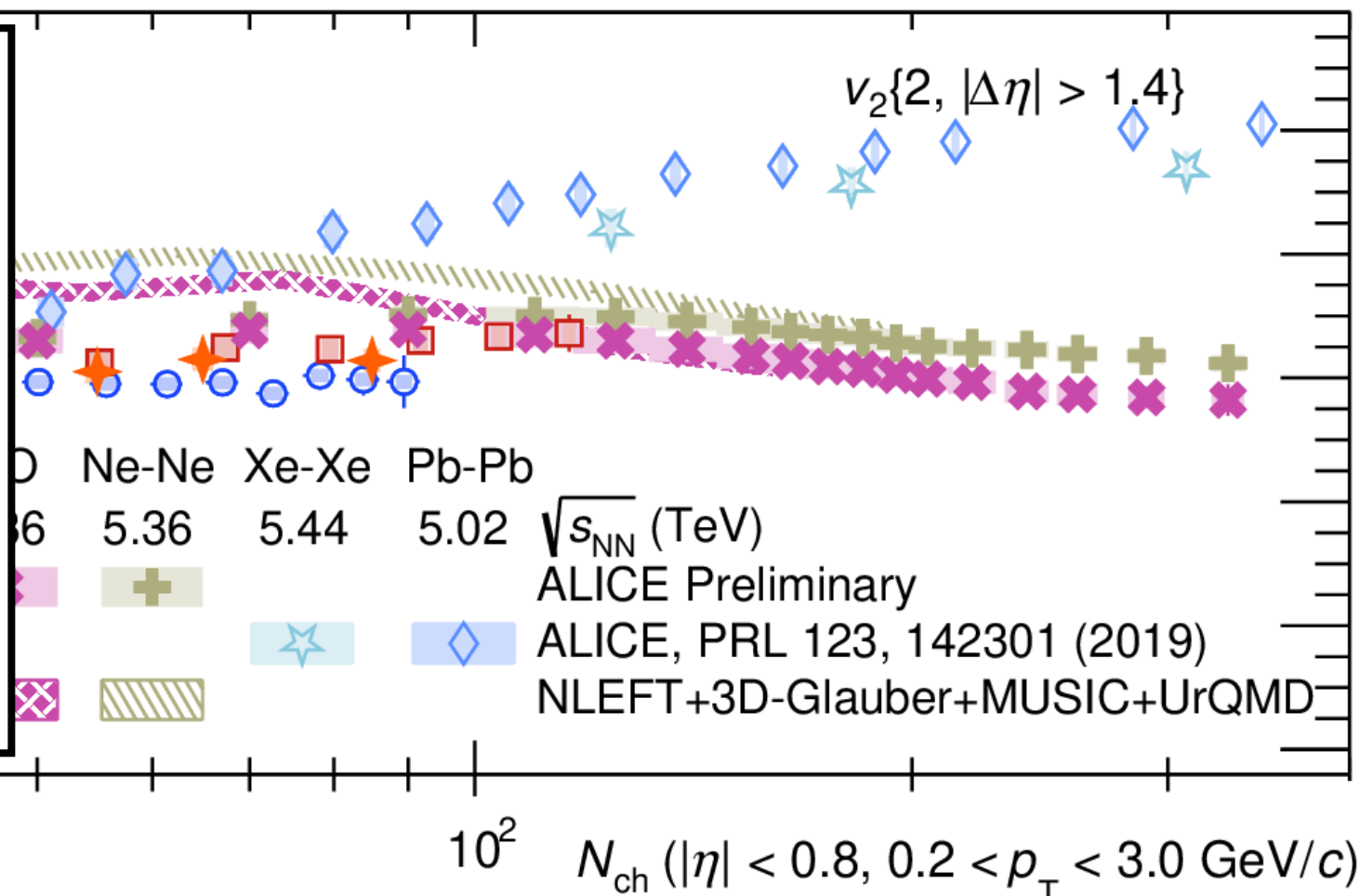
two-particle cumulants



→ Hierarchy between **heavy-ions** collisions and **smaller systems**



→ Model **correctly** describes high-multiplicity Ne–Ne and OO collisions



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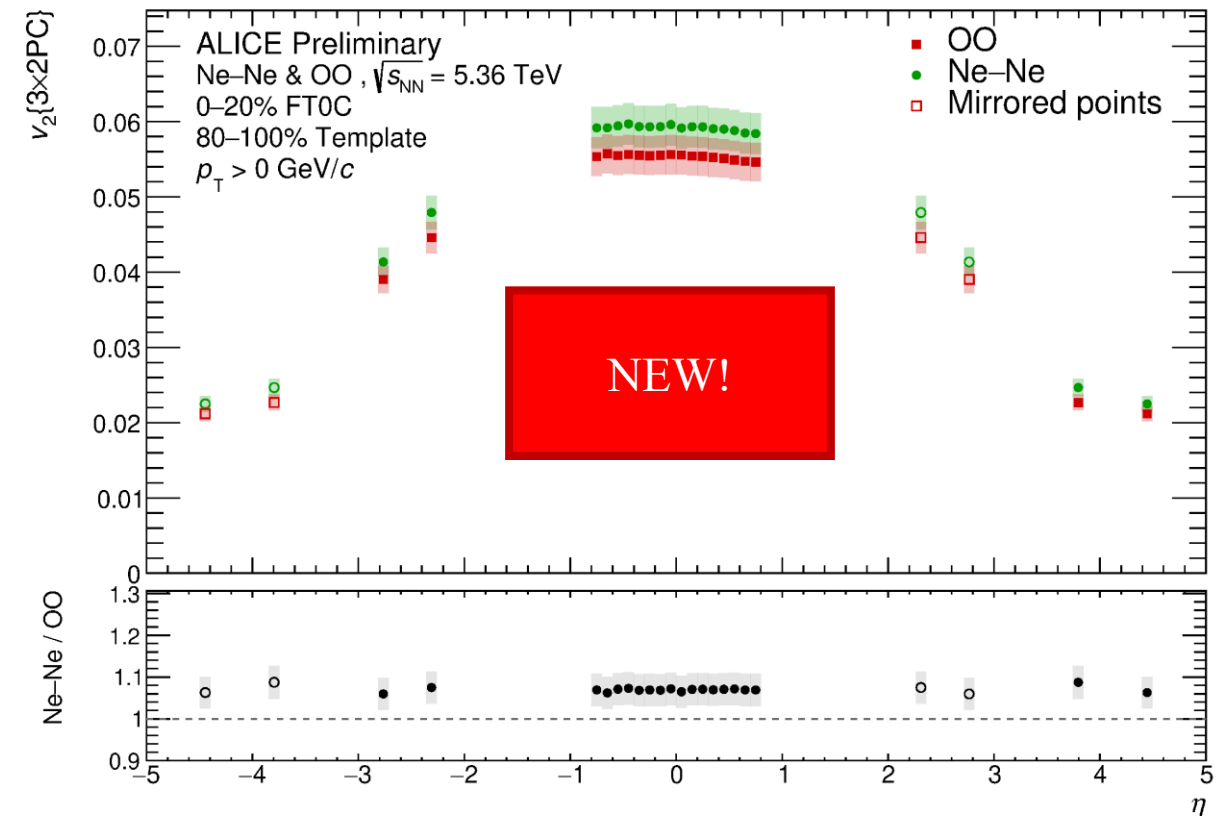
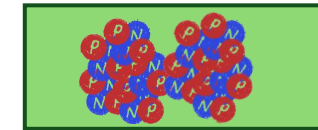
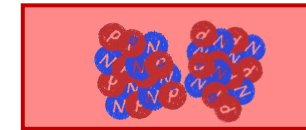
Constraining models even more



Three times two-particle correlations (+ template fit)

$$v_2(\eta_a) = \sqrt{\frac{v_{2\Delta}(\eta_a, \eta_b) \times v_{2\Delta}(\eta_a, \eta_c)}{v_{2\Delta}(\eta_b, \eta_c)}}$$

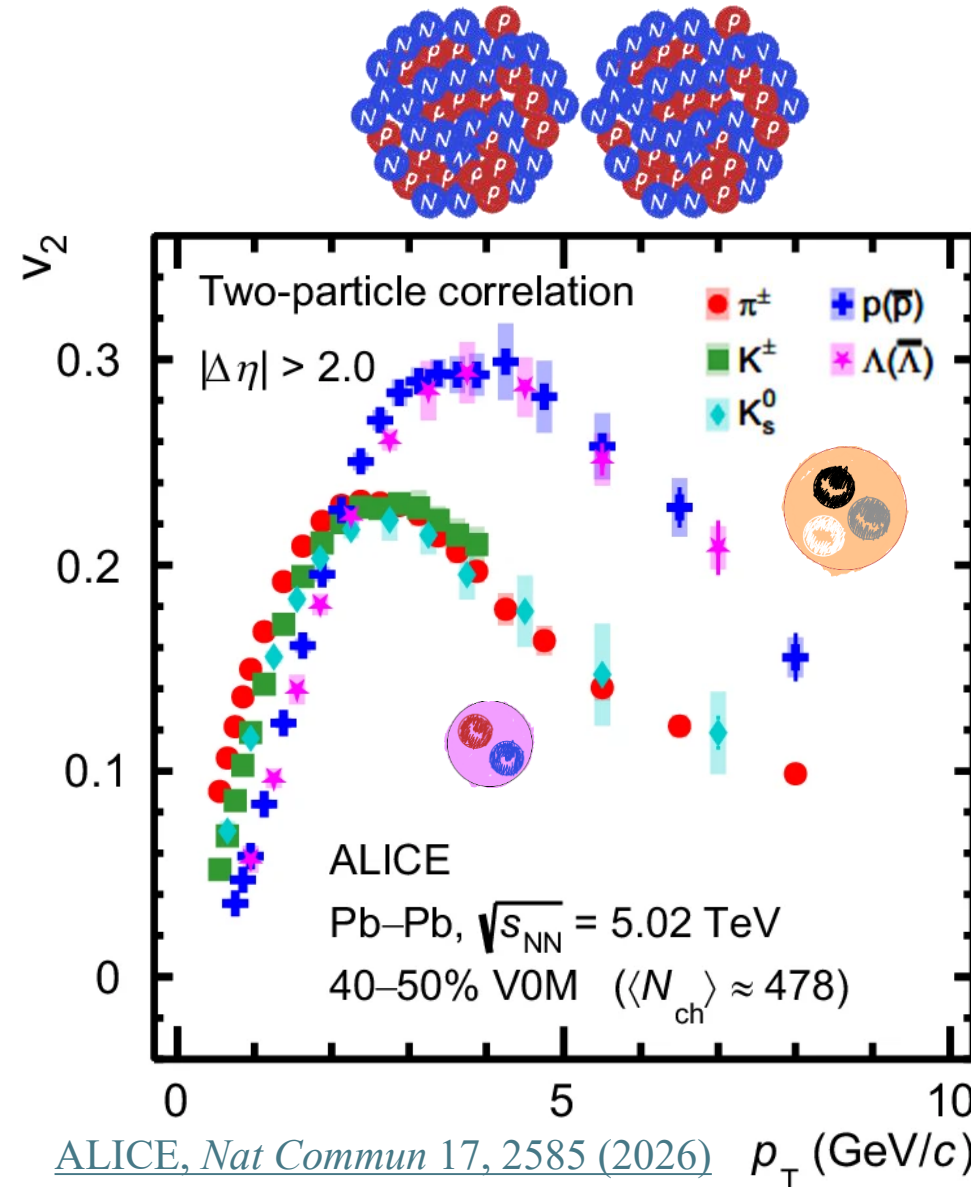
- Flow signal over a large pseudorapidity range
- Valuable constraint on the longitudinal structure of the **initial state** and the evolution of the system



ALI-PREL-639376

Towards the onset of collectivity

Two-particle correlations
(+ template fit)



[ALICE, Nat Commun 17, 2585 \(2026\)](#)

p_T (GeV/c)

Towards the onset of collectivity

Two-particle correlations
(+ template fit)

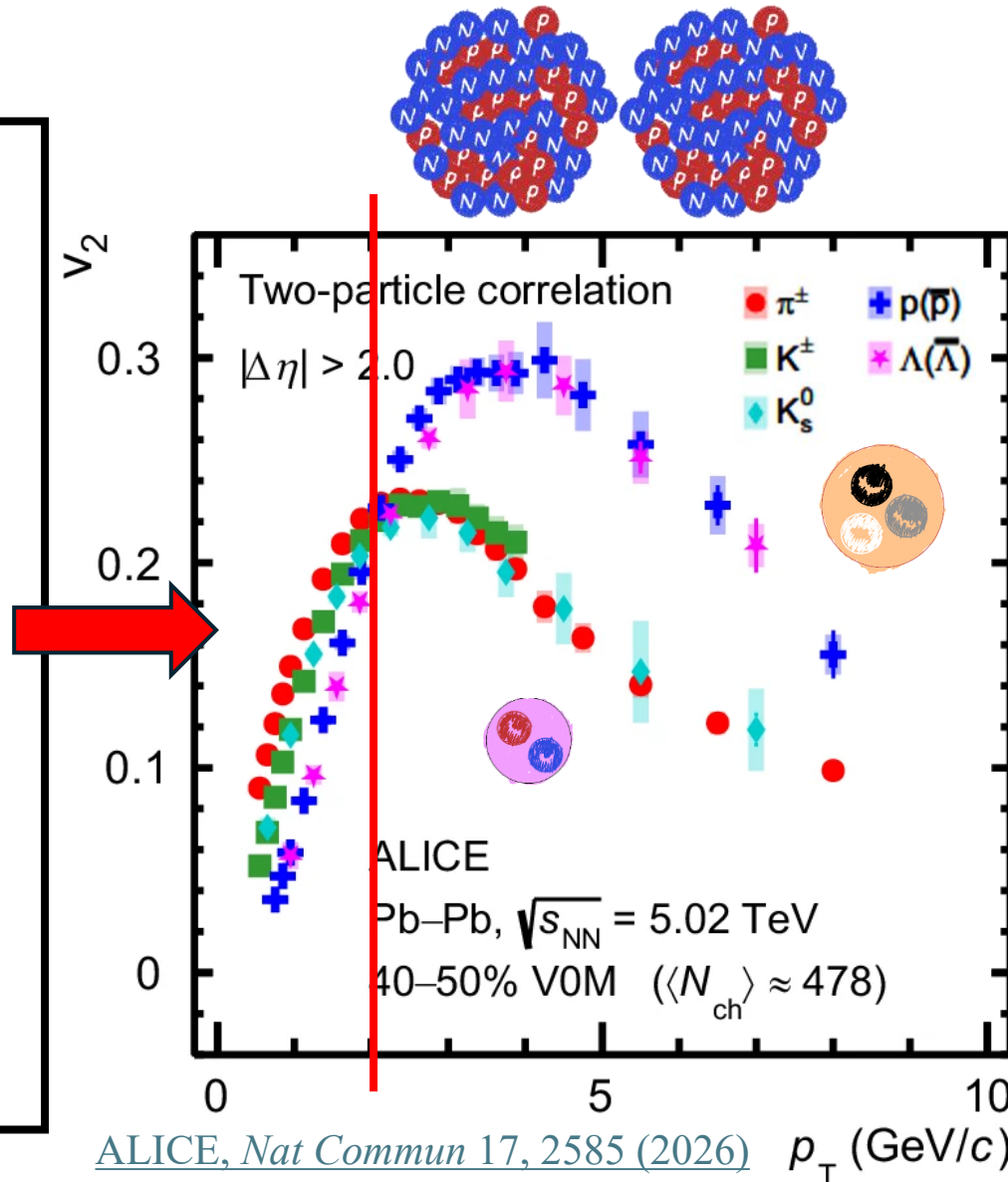


Low p_T region

$p_T < 2 \text{ GeV}/c$

→ Mass ordering

heavier particles are
pushed to higher p_T by
hydrodynamics



ALICE, *Nat Commun* 17, 2585 (2026)

Towards the onset of collectivity

Two-particle correlations
(+ template fit)

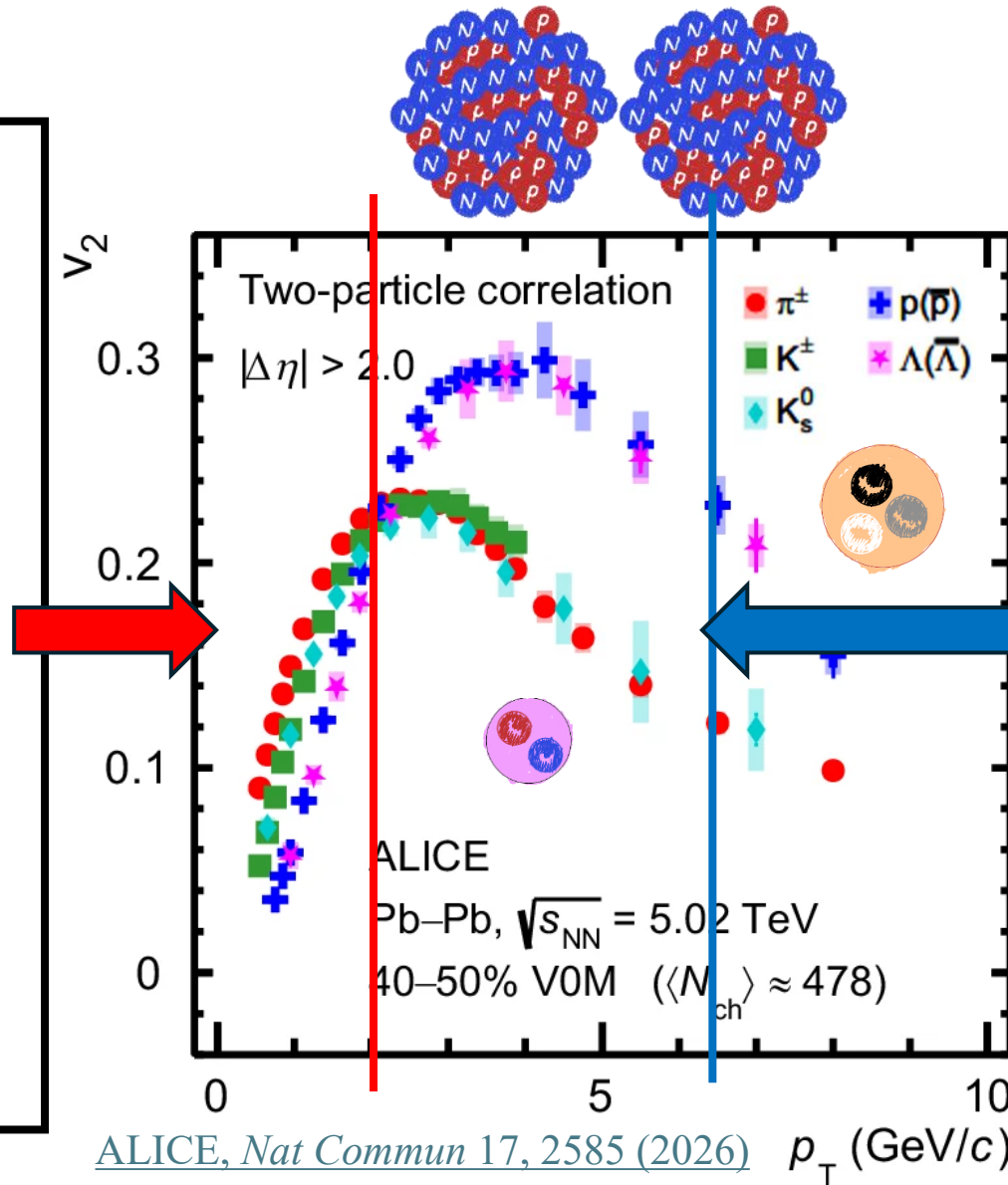


Low p_T region

$p_T < 2 \text{ GeV}/c$

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hydrodynamics



Intermediate p_T region

$p_T > 2.5 \text{ GeV}/c$

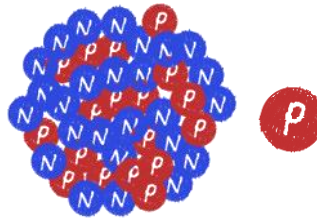
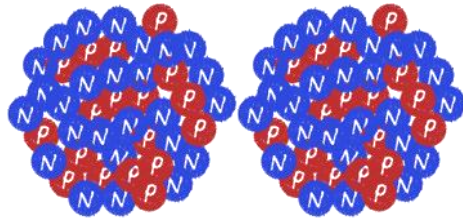
→ Baryon-meson grouping
and splitting

→ Sign of quark coalescence
the medium flows at the
partonic level

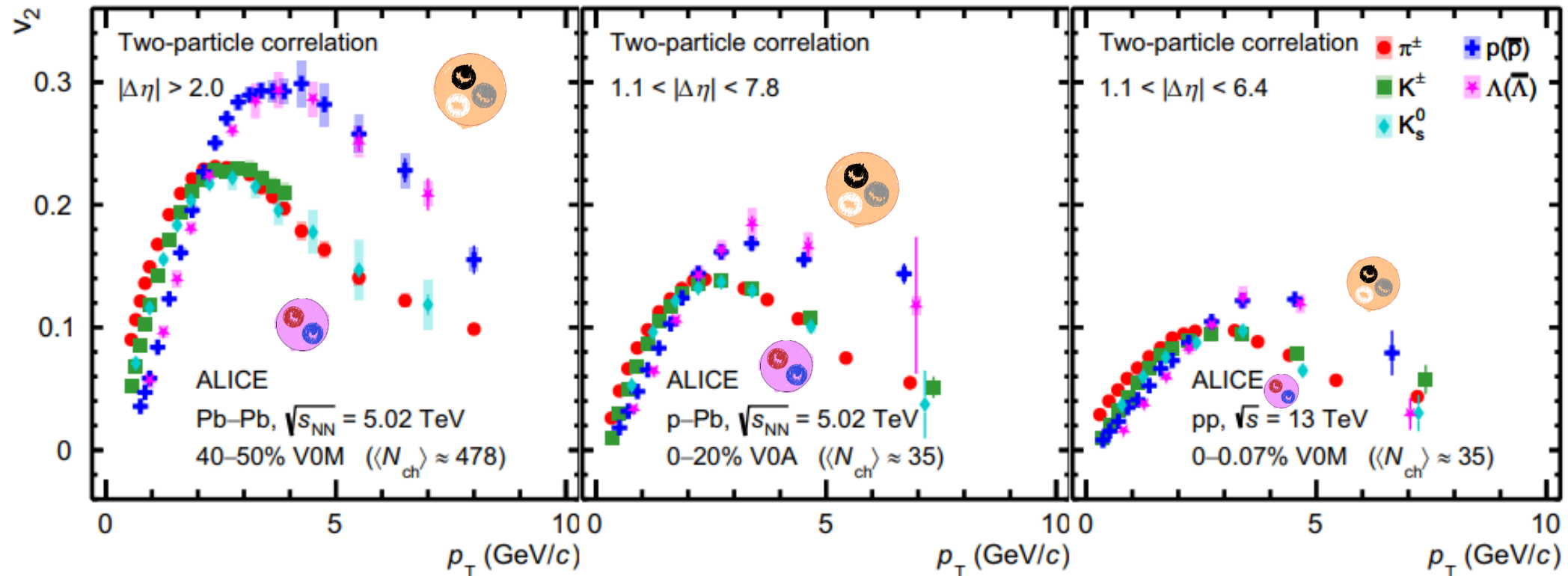
ALICE, *Nat Commun* 17, 2585 (2026) $p_T \text{ (GeV}/c\text{)}$

Towards the onset of collectivity

2PC + 3x2PC
(+ template fit)



The three systems feature **qualitatively** the same behavior!



ALICE, Nat Commun 17, 2585 (2026)

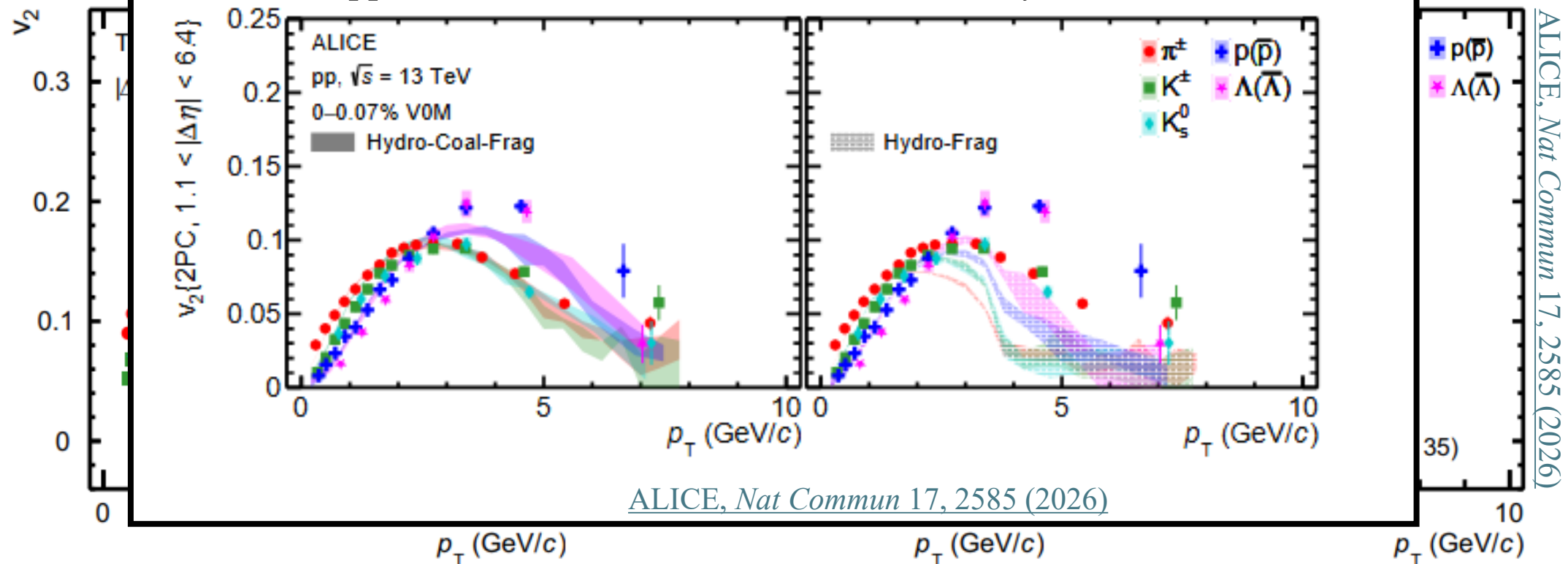
Towards the onset of collectivity

2PC + 3x2PC
(+ template fit)



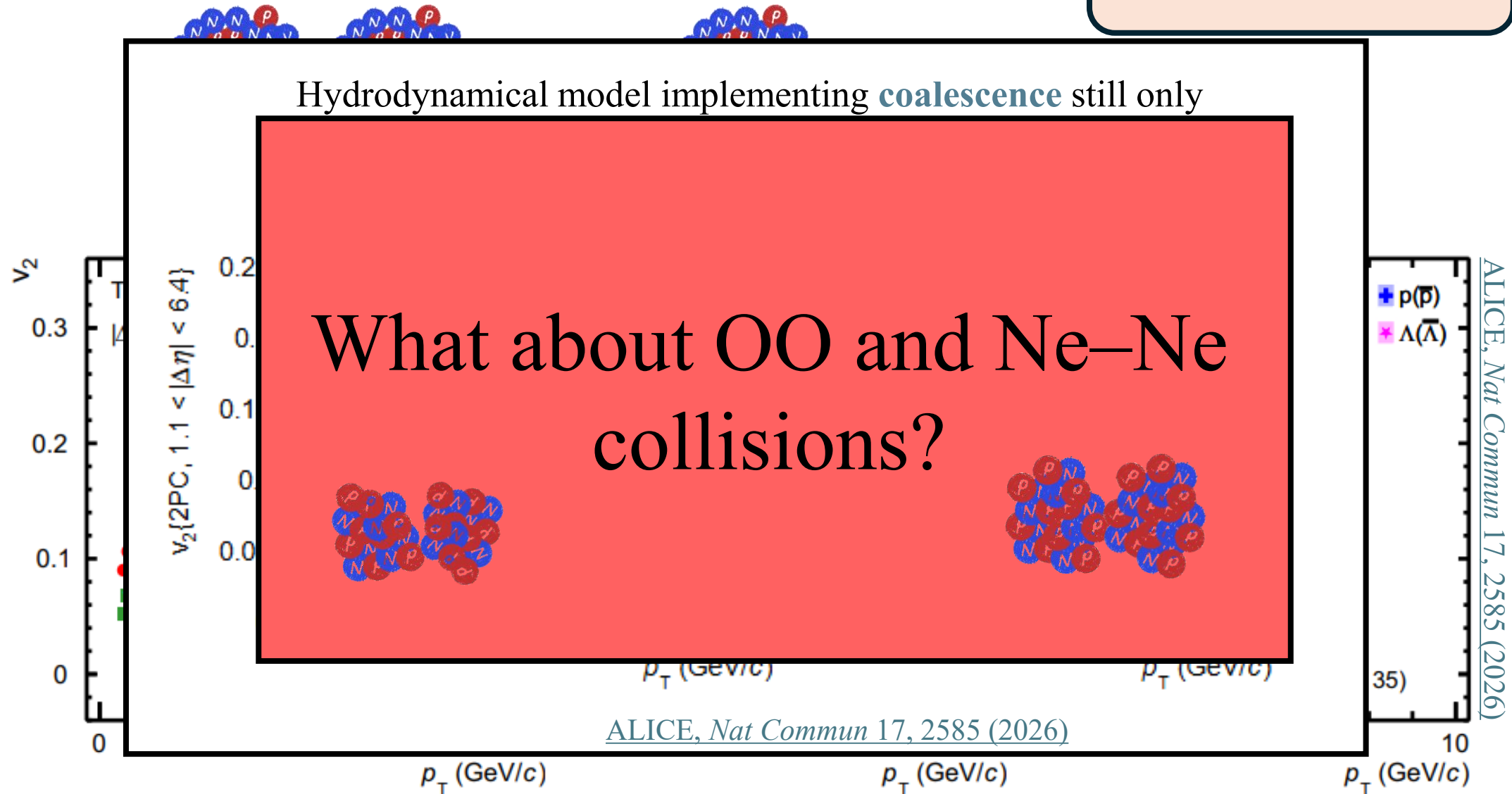
Hydrodynamical model implementing **coalescence** still only **qualitatively** describes particle correlations in pp collisions...

In pp collisions, the **initial state** is still not fully understood



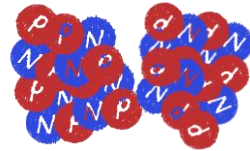
Towards the onset of collectivity

2PC + 3x2PC
(+ template fit)

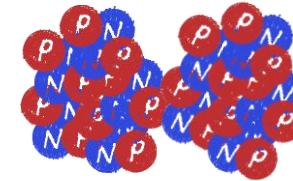


Towards the onset of collectivity

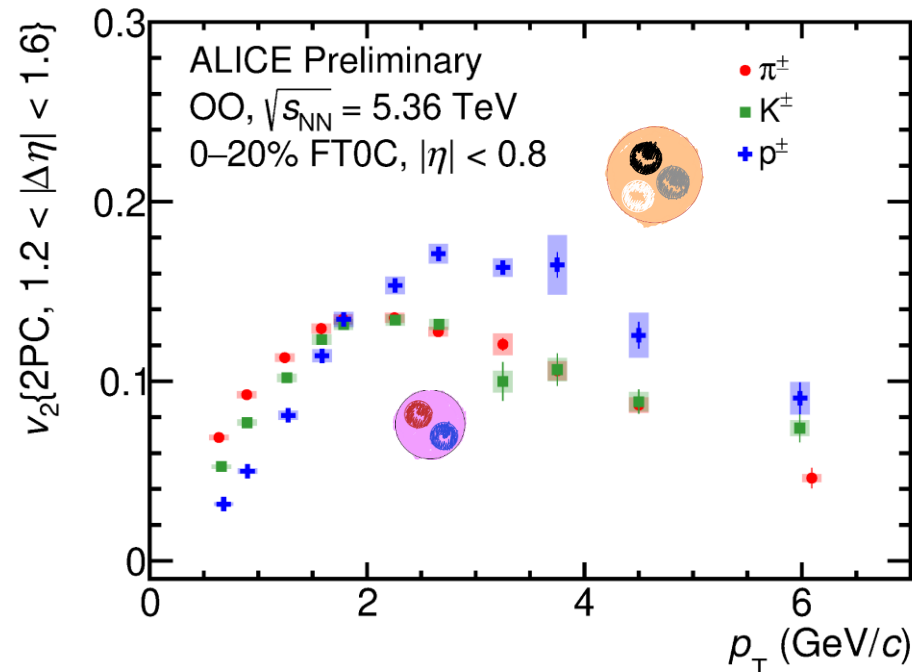
Two-particle correlations
(+ template fit)



NEW!



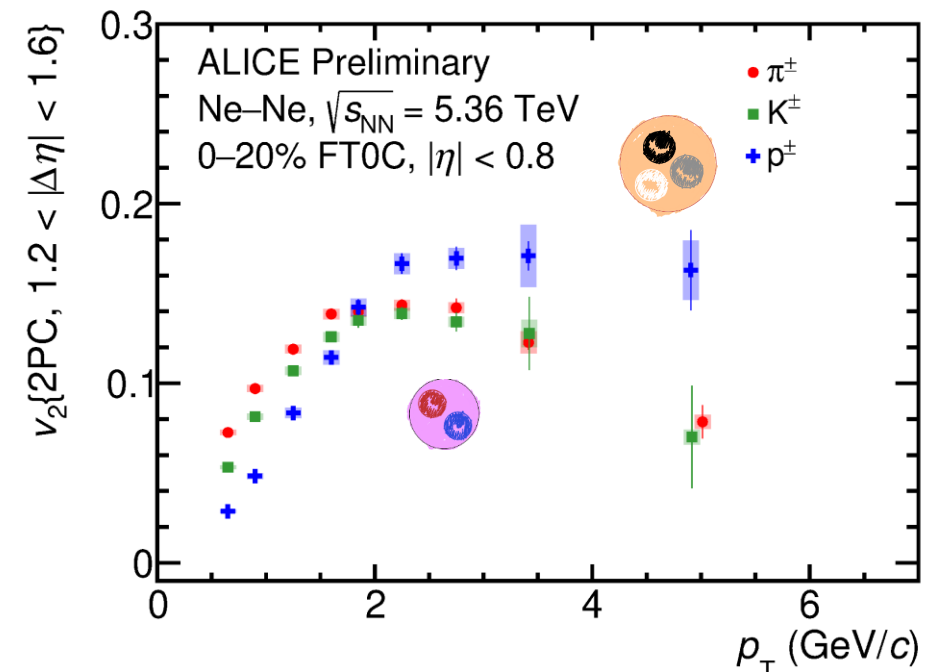
Low p_T **mass ordering** and intermediate p_T **baryon-meson** grouping and splitting are present in both systems!



ALI-PREL-635190

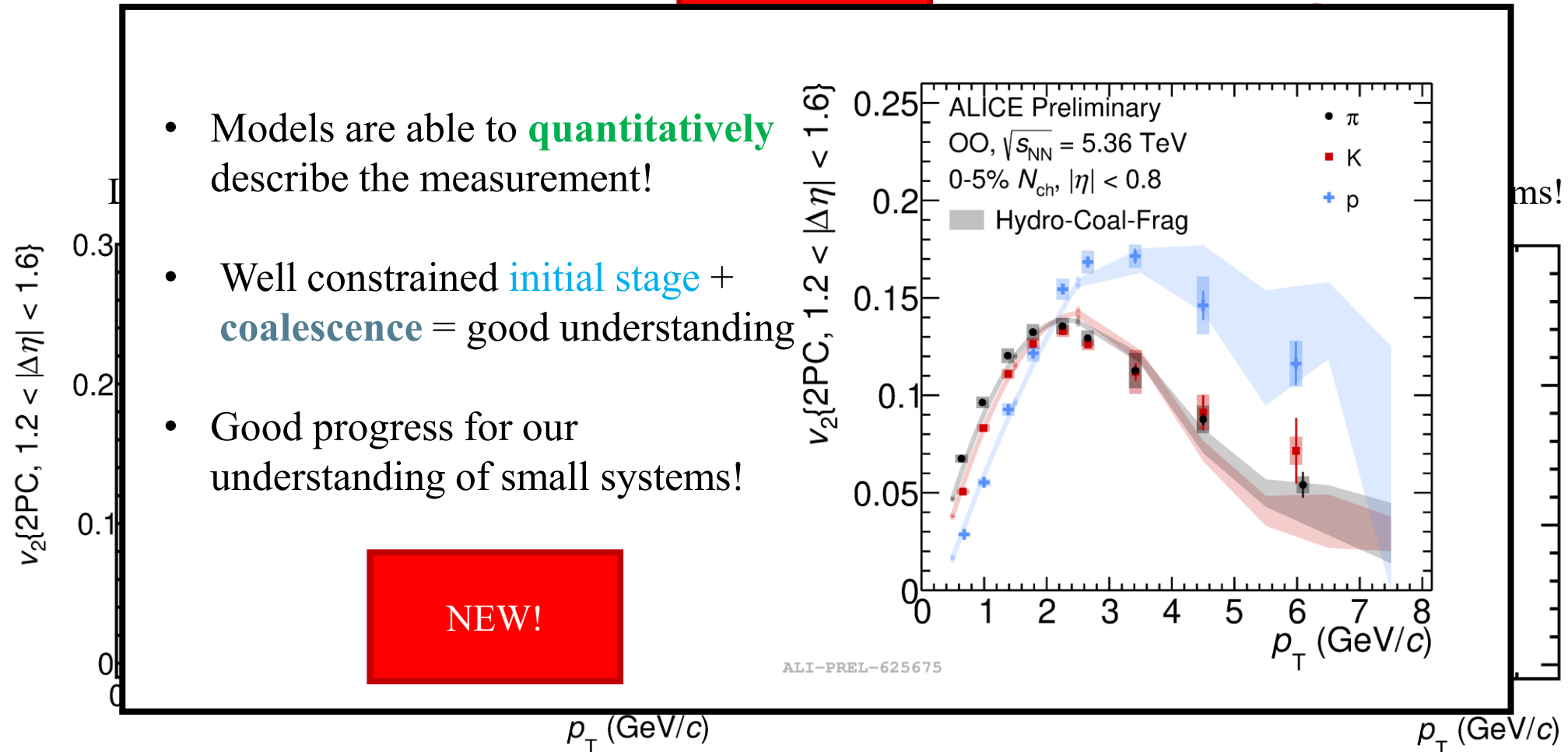
Elliptic flow of strange hadrons in OO in backup!

ALI-PREL-635195



Towards the onset of collectivity

Two-particle correlations
(+ template fit)



ALI-PREL-635190

Elliptic flow of strange hadrons in OO in backup!

ALI-PREL-635195

Summary & take-home messages

Initial geometry

Light-ions have a well-constrained initial state and collision geometry

Bridge the gap in system size and help us understand the onset of collective phenomena

Anisotropic flow

Describes the interplay between initial-state and final-state interactions
→ ideal observable!

Well described when the initial state and collision geometry are well constrained

Understanding the initial state is crucial for describing collectivity in smaller systems

Onset of collectivity

Light ions display signs of collectivity



Thank you very much!



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BACK UP

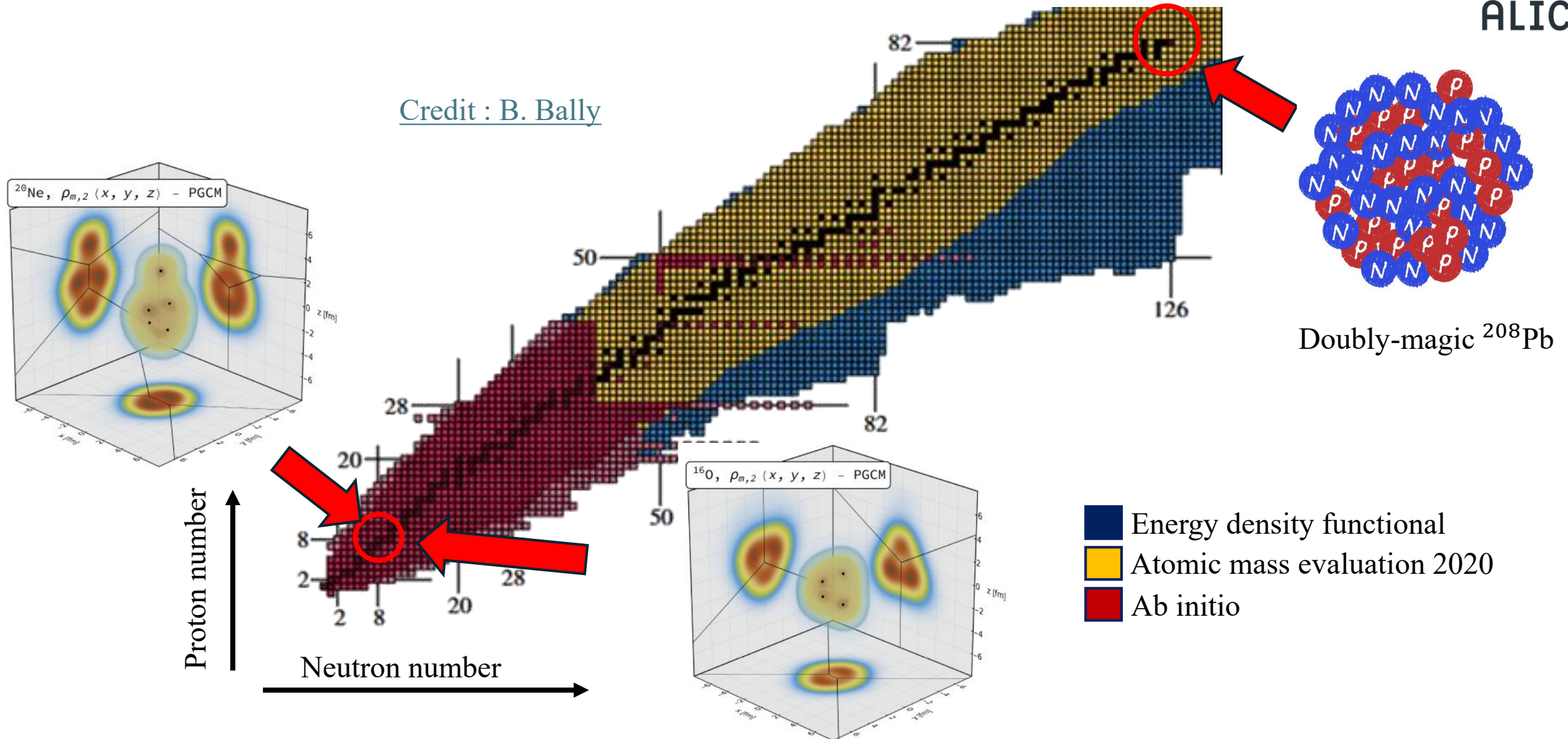


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Why specifically ^{16}O and ^{20}Ne ?

Credit : B. Bally



Template fit

$$\gamma^{template}(\Delta\varphi) = F \cdot \gamma^{peripheral}(\Delta\varphi) + \gamma^{ridge}(\Delta\varphi)$$

Our measurement at given multiplicity → Contains **non-flow** & **collective effects**

Non-flow component
→ Assumption: **low-multiplicity** sample contains only **non-flow**

Collective flow component
→ Fourier expansion

Fit inputs:

- measurement at high multiplicity
- measurement at low multiplicity

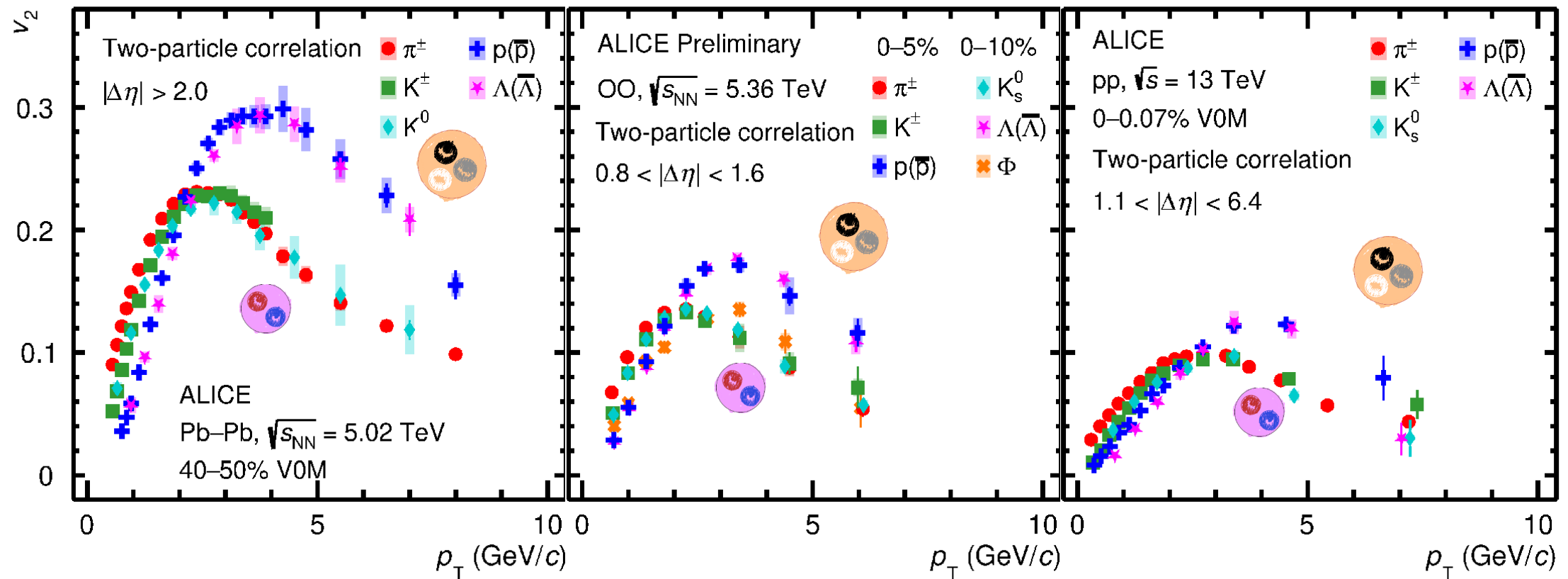
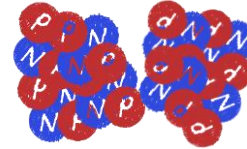
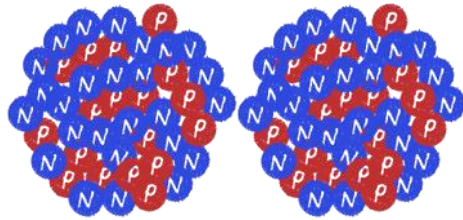
$$\gamma^{ridge}(\Delta\varphi) = G \left[1 + 2 \sum_{n=2}^3 V_{n\Delta} \cdot \cos(n\Delta\varphi) \right]$$

Fit outputs:

- F, G, **$V_{n\Delta}$**

Identified particle elliptic flow

2PC + 3x2PC
(+ template fit)



ALI-PREL-637688

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