FLOW AND TRANSVERSE MOMENTUM CORRELATIONS AT ALICE

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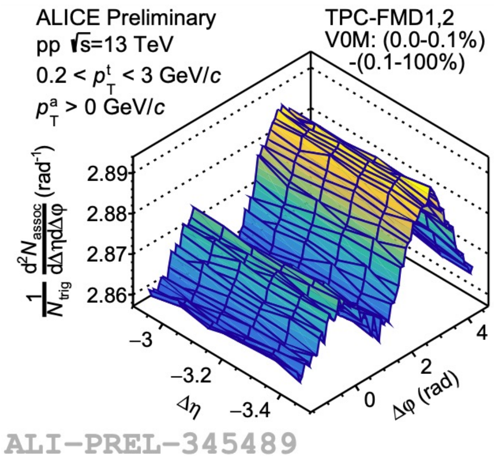
COLLECTIVITY IN SMALL SYSTEMS

- Double ridge structure, a **sign of collectivity** in heavy-ion collisions, also observed in **pp and p–Pb collisions**

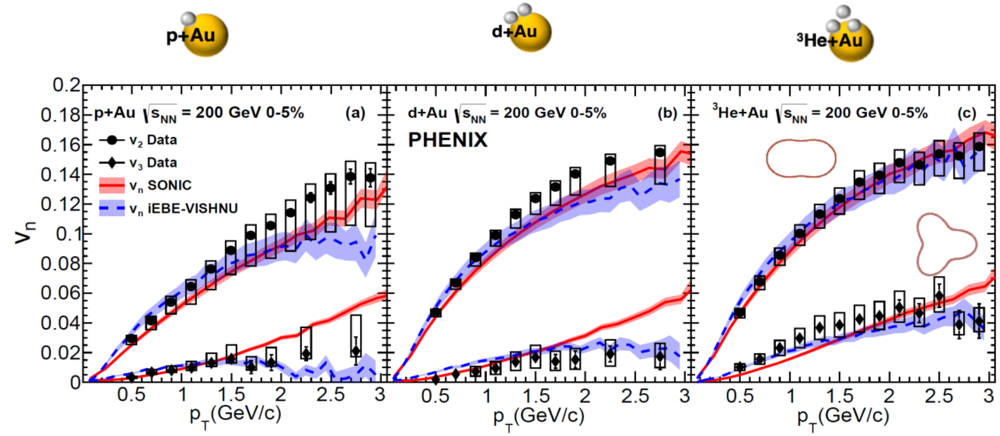


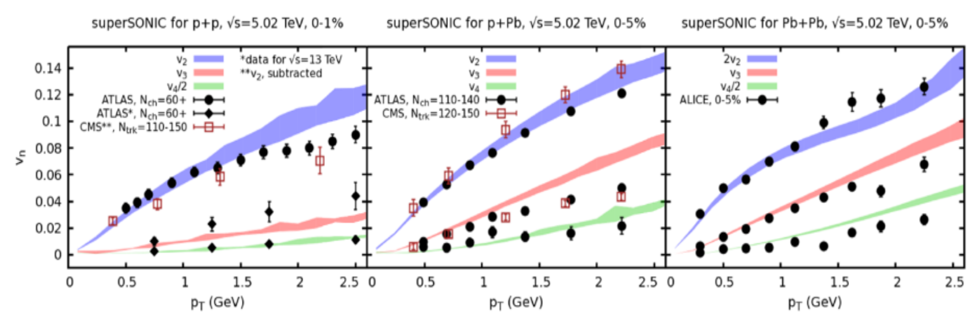
- **The puzzle:**
  - Is there any fundamental difference between the flow-like signals in large and small systems
  - To answer the question, one need to know:
    - The role of initial stages (**initial geometry** and initial coupling)
    - The role of final stage effects
- **The known thing:**
  - **Geometry** and **fluctuations** are important in small collision systems
  - Hydrodynamic works well on many of the signatures

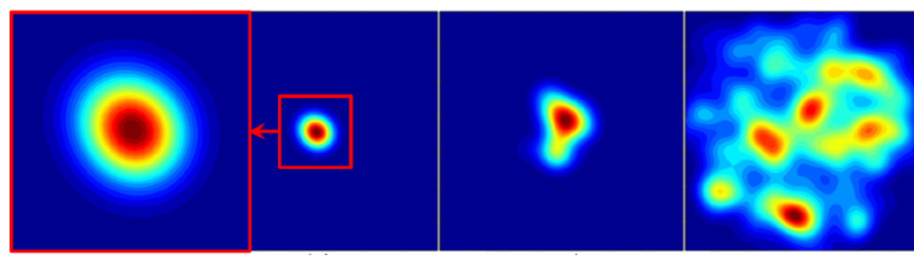
GEOMETRY AND FLUCTUATION

- **Geometry** plays an important role in small system.
- **Geometry + hydrodynamic** provides reasonable description of p_T-differntial flow in small systems geometry scan.
- Can they go further to describe the **event-by-event fluctuations** of the system?

PHENIX, Nature Phys. 15 (2019) no.3





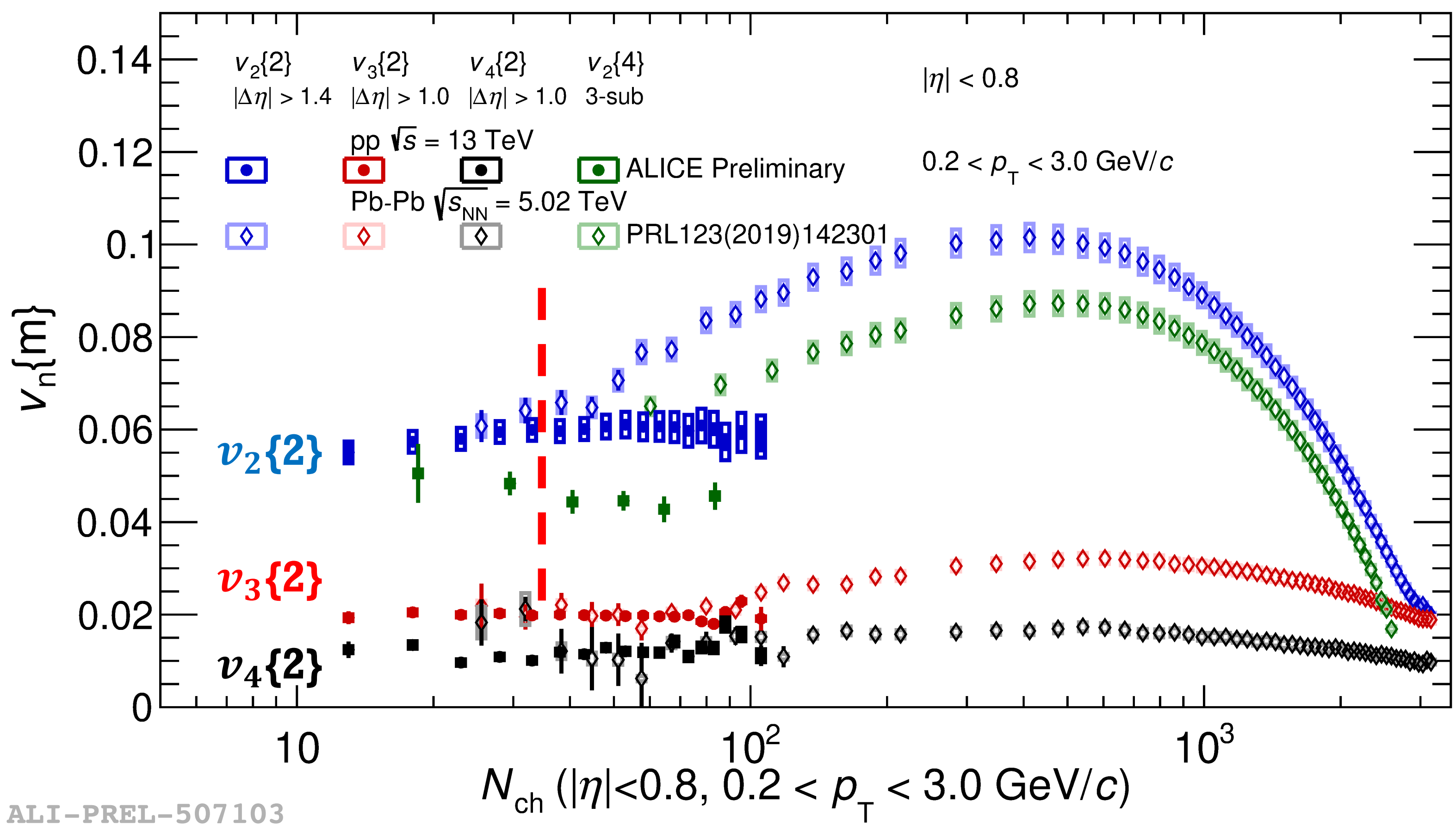


R. D. Weller, P. Romatschke Phys.Lett.B 774 (2017) 351-356

GEOMETRY AND FLUCTUATION

ALICE

Solid: pp **Open: Pb–Pb**

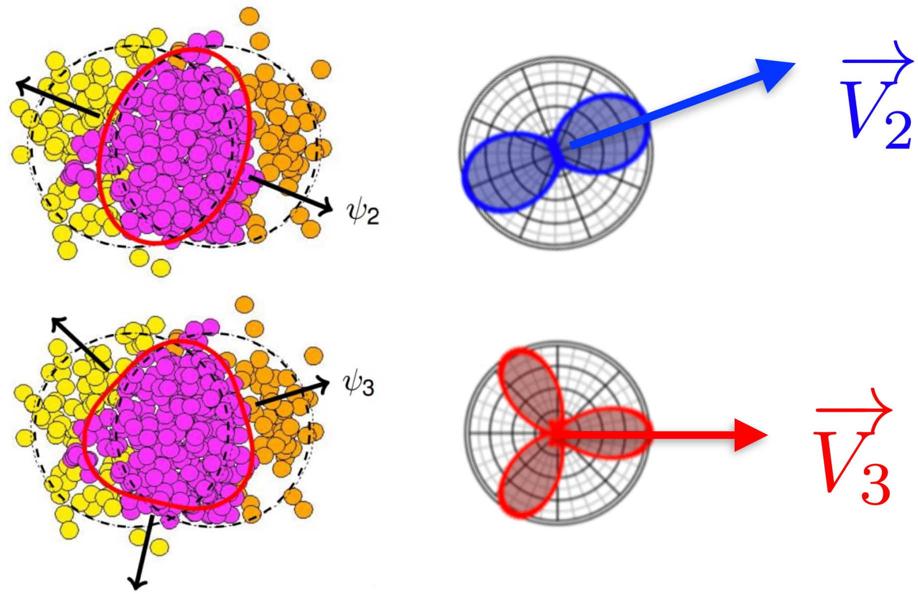


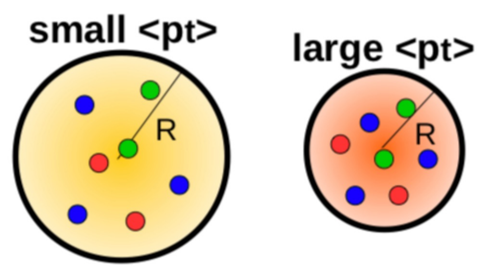
- The magnitudes of v_n in pp are similar as in Pb–Pb at low multiplicities (**flow fluctuation dominates region**)
- Flow harmonics provide constraints for modeling of the **initial geometry and its fluctuations**, as well as **the transport parameters**

GEOMETRY AND FLUCTUATION

In heavy-ion collisions:

- **Shape** of the fireball:
  - $\varepsilon_2 \rightarrow v_2$
  - $\varepsilon_3 \rightarrow v_3$
  - $\varepsilon_4, \varepsilon_2 \rightarrow v_4$
- **Size** of the fireball:
  - radial flow, $1/R \rightarrow [p_T]$
- Measurements of the fluctuations and the correlation between the flow and transverse momentum helps to understand the **event-by-event initial geometry** of the matter





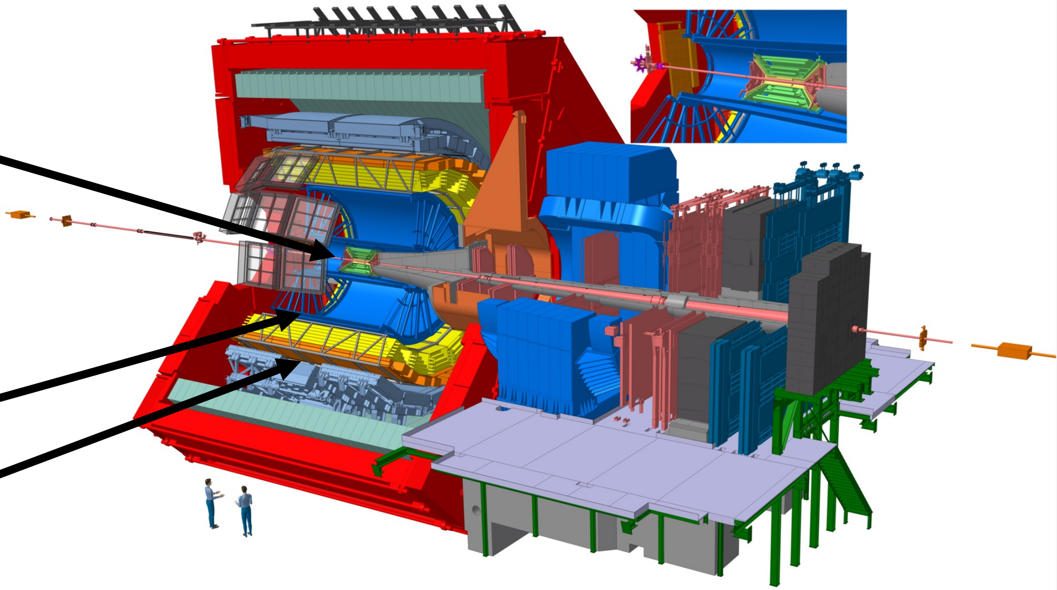
Methodology:

Measure the **same** observables in **large and small systems** and compare them to see see if they can be explained in a **coherent way**

ALICE EXPERIMENT

ALICE

- **Inner Tracking System (ITS)**
  - Tracking, triggering and vertexing
- **V0 Detector (V0A/V0C)**
  - Triggering and event classification
- **Forward Multiplicity Detector (FMD)**
  - Unique pseudorapidity coverage
  - $-3.4 < \eta < -1.7$
  - $1.7 < \eta < 5.0$
- **Time Projection Chamber (TPC)**
  - Tracking and particle identification
- **Time-of-Flight detector (TOF)**
  - Particle identification

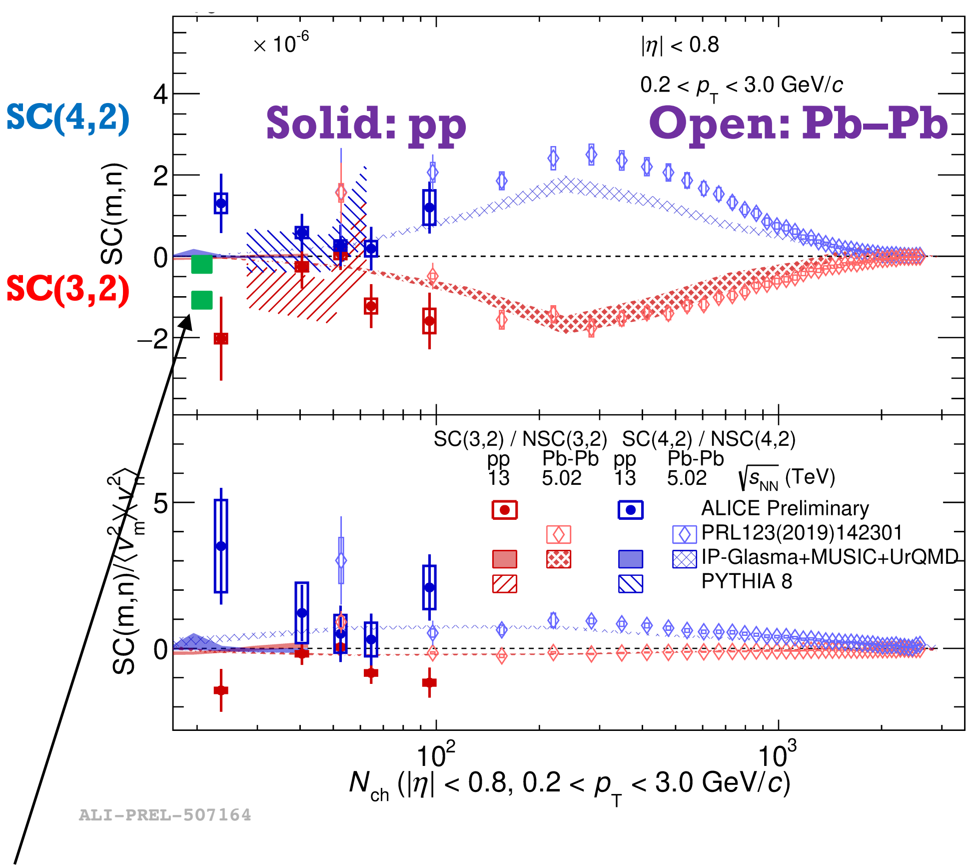


Data sample: LHC Run2 sample

Collision system	Energy
pp	13 TeV
p–Pb	5.02 TeV
Pb–Pb	5.02 TeV

FLOW CORRELATIONS IN SMALL SYSTEMS

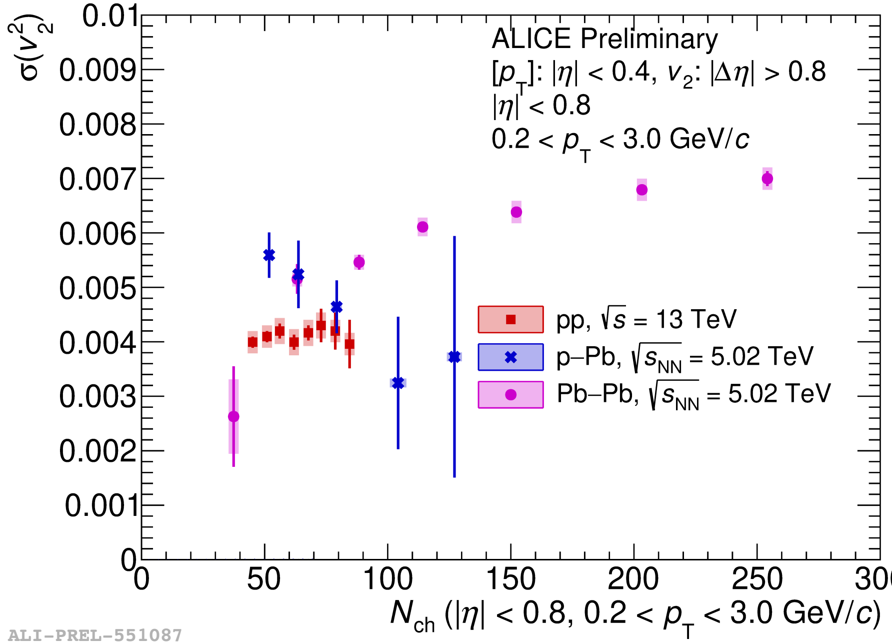
- $\mathrm{SC}(m,n) = \mathrm{cov}(v_m^2, v_n^2)$: correlation of **event-by-event** v_n

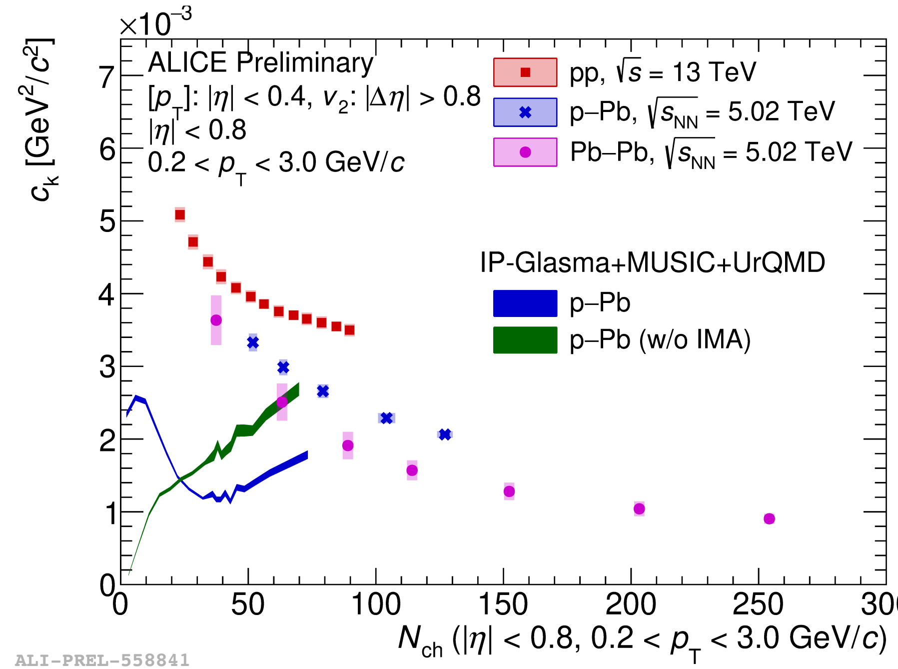


- Hint of **negative SC(3,2)** (2.1σ significance) and **positive SC(4,2)** (1.9σ significance) in pp collisions, having the **same sign** as Pb–Pb collisions
- Constraints on **initial geometry fluctuations**
- Best non-flow control technique utilized, but still not non-flow free

Precision needed to prove or disprove the geometry correlation

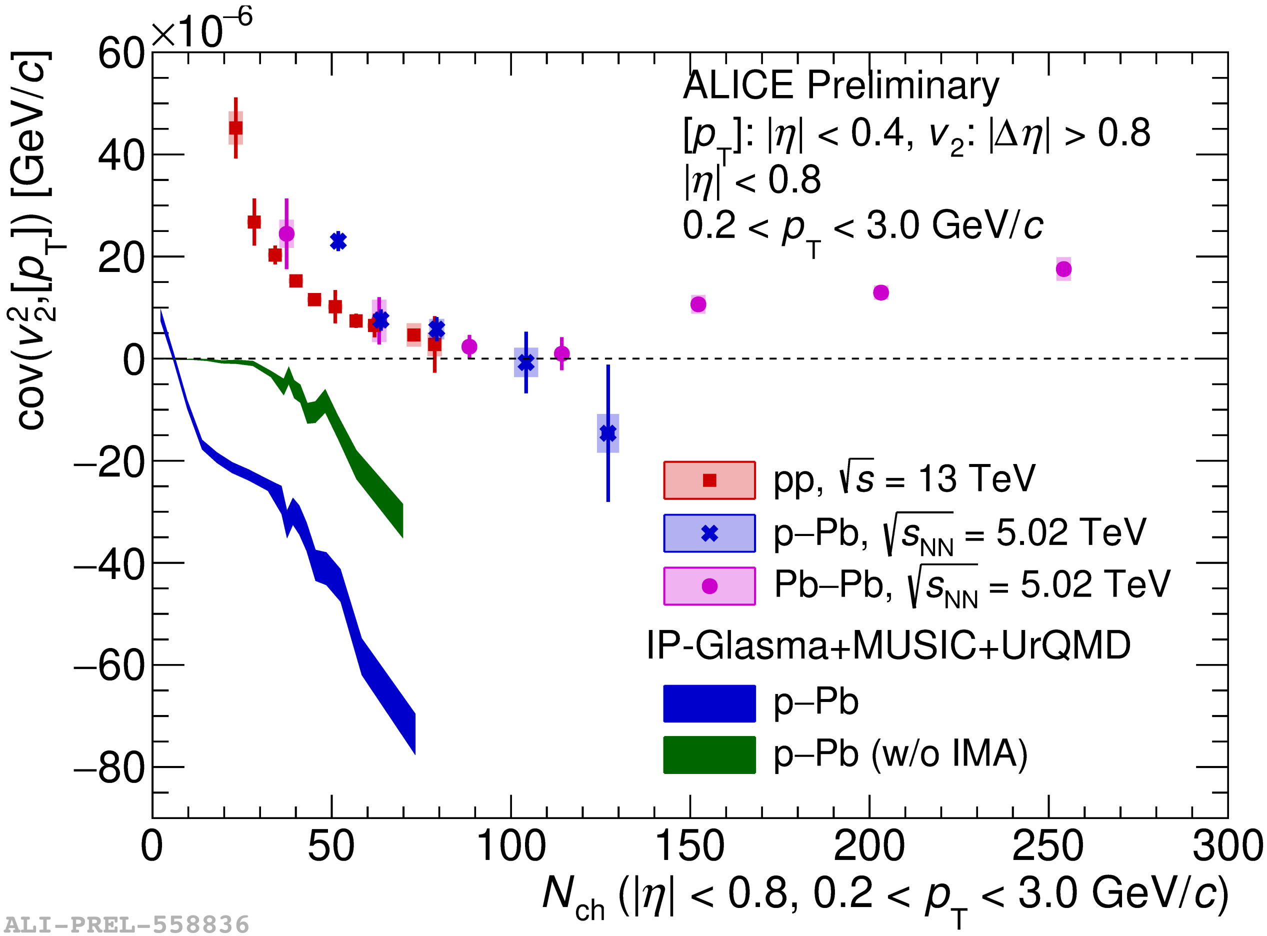
FLOW AND $[p_T]$ FLUCTUATIONS





- A decreasing trend observed for c_k, inconsistent with the hydrodynamics predictions
- Constraints on **initial shape fluctuations** and **initial size fluctuations**

$v_2^2 - [p_\mathrm{T}]$ COVARIANCE IN SMALL SYSTEMS

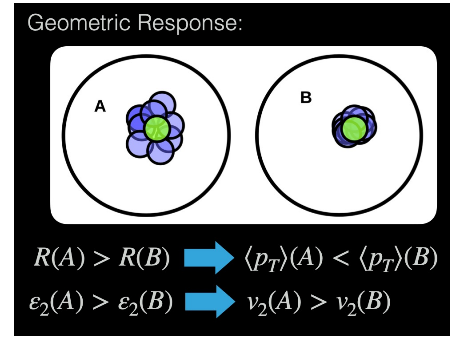


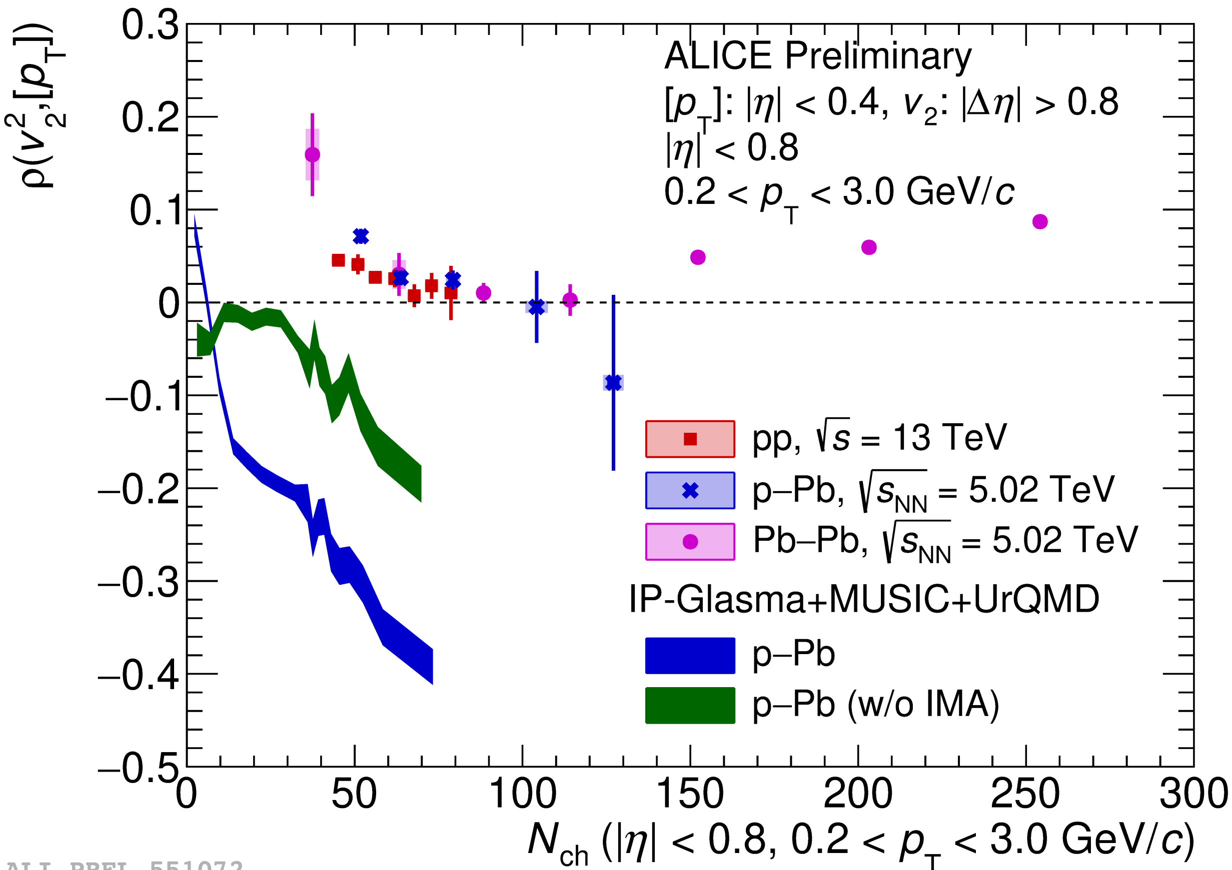
- A **decreasing trend** is observed in pp and p–Pb collisions
- IP-Glasma + MUSIC + UrQMD fails to describe the data (with and without initial momentum anisotropy (IMA))

$v_2^2 - [p_T]$ CORRELATION IN SMALL SYSTEMS

$$\rho_n\left(v_n^2, [p_T]\right) = \frac{\mathrm{cov}\left(v_n^2, [p_T]\right)}{\sqrt{\mathrm{var}\left(v_n^2\right)}\sqrt{\mathrm{var}\left([p_T]\right)}}$$

$\rho < 0$





- A **decreasing trend** is observed in pp and p–Pb collisions
- Cannot be explained by simple geometry picture
- IP-Glasma + MUSIC + UrQMD fails to describe the data (with and without initial momentum anisotropy (IMA))

SUMMARY

Observables	Physics messages
Symmetric cumulants SC(3,2)	Correlation between ε_2 and ε_3
Symmetric cumulants SC(4,2)	Correlation of ε_2 and ε_4 Nonlinear contribution of v_4 from ε_2
$\sigma(v_2^2)$	Fluctuation of ε_2
c_k	Fluctuation of size of the matter
$\mathrm{cov}(v_2^2, [p_\mathrm{T}])$	Correlation between shape and size of the matter
$\rho(v_2^2, [p_\mathrm{T}])$	Correlation between shape and size of the matter

- Constraining the geometry and geometry fluctuation of the initial stage.

Thank you for your attention