Probing partonic collectivity in pp and p—Pb collisions with ALICE

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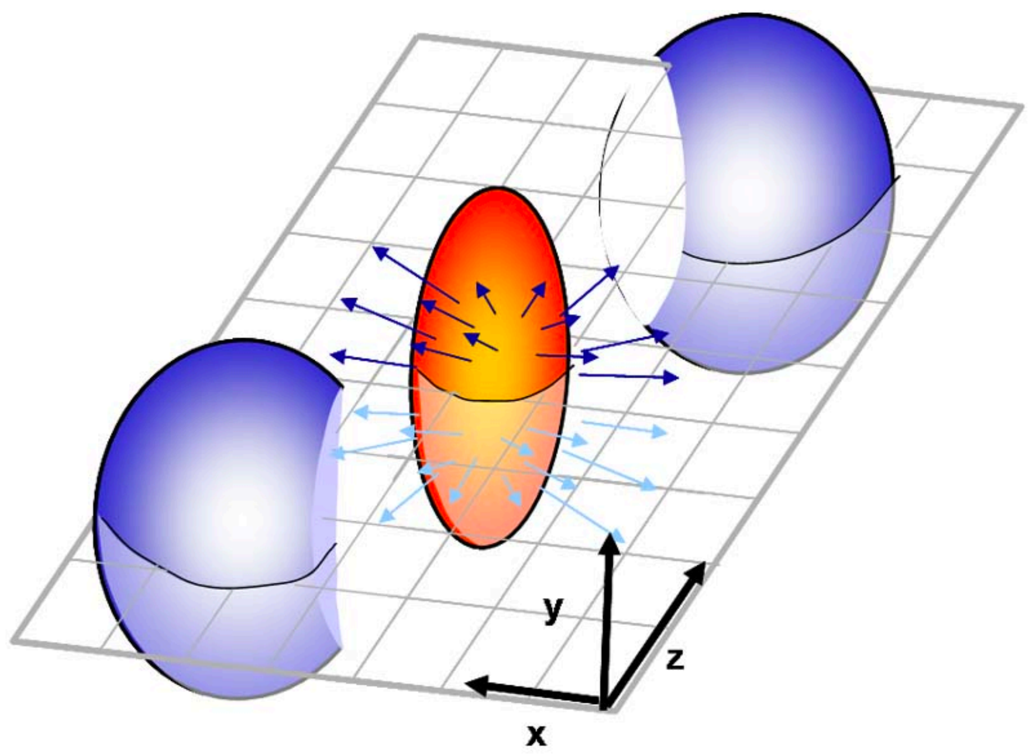
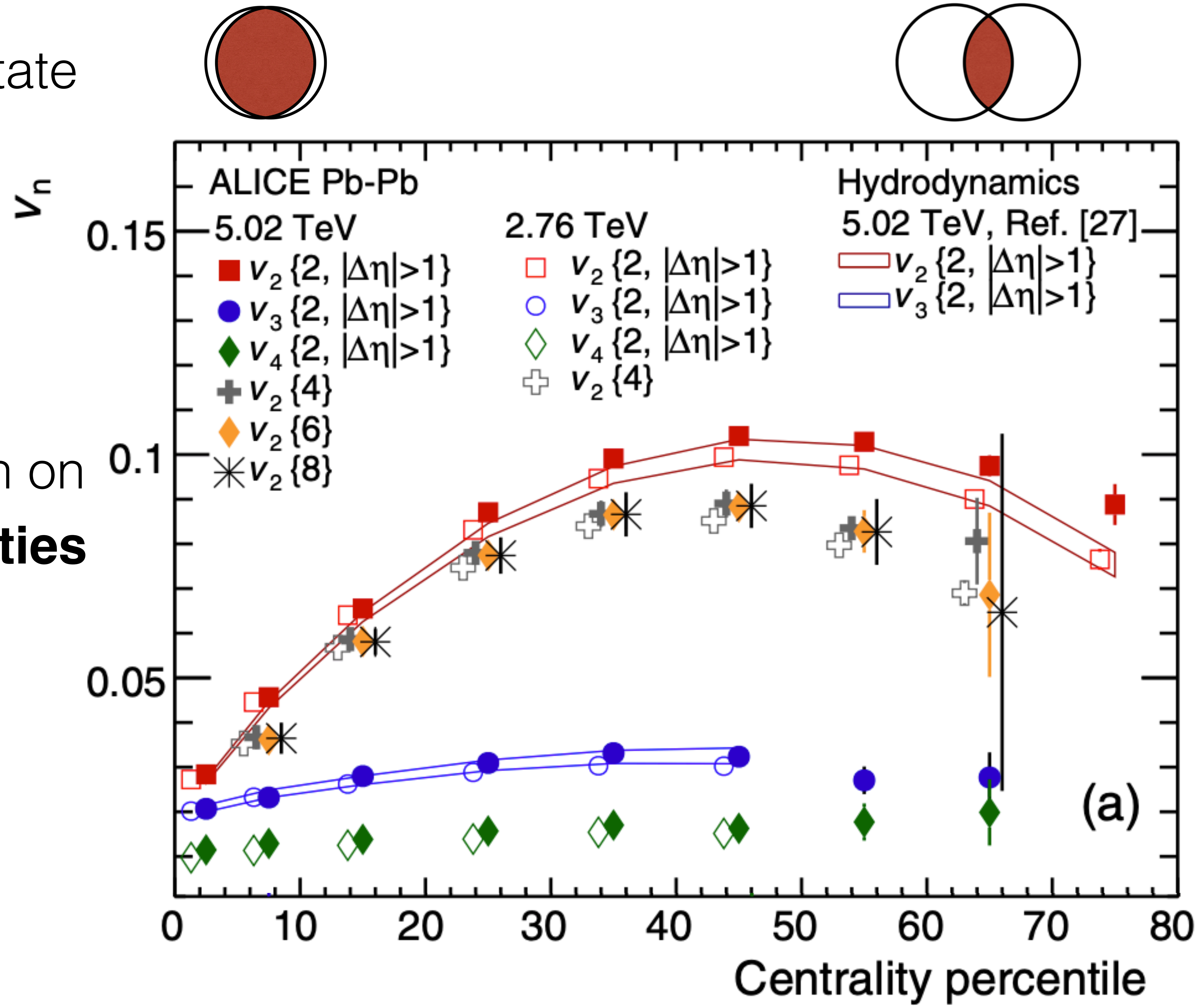
Flow measurements in heavy-ion collisions

- Anisotropy in azimuthal distribution of final-state particles with respect to the reaction plane:

$$\frac{dN}{d\phi} \approx 1 + 2\sum_{n=1}^{\infty} v_n cos(n(\phi - \psi_n))$$

- Flow coefficients $v_n \rightarrow$ their correlation to the initial geometry provides detailed information on the **initial conditions and transport properties of the created medium**
- Well described by hydrodynamic models



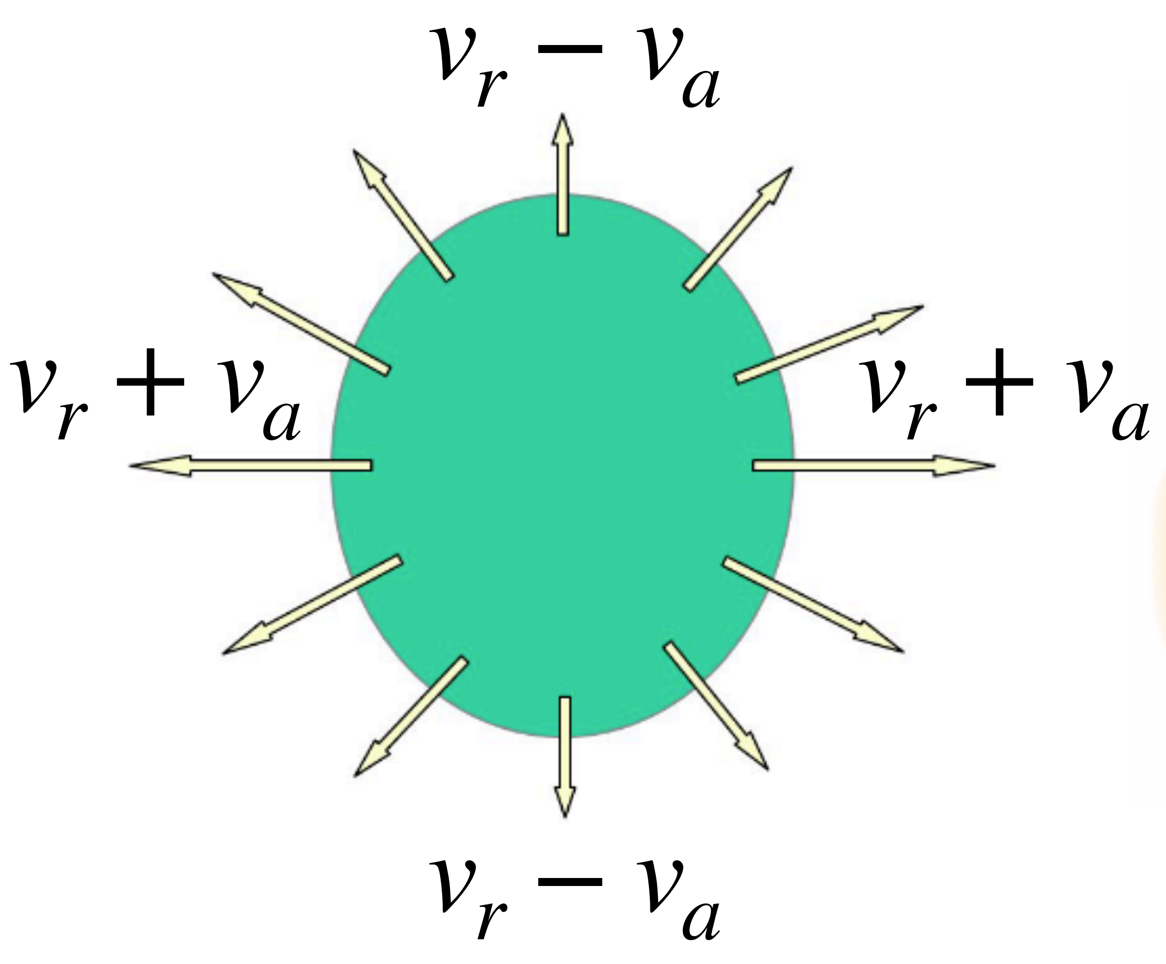


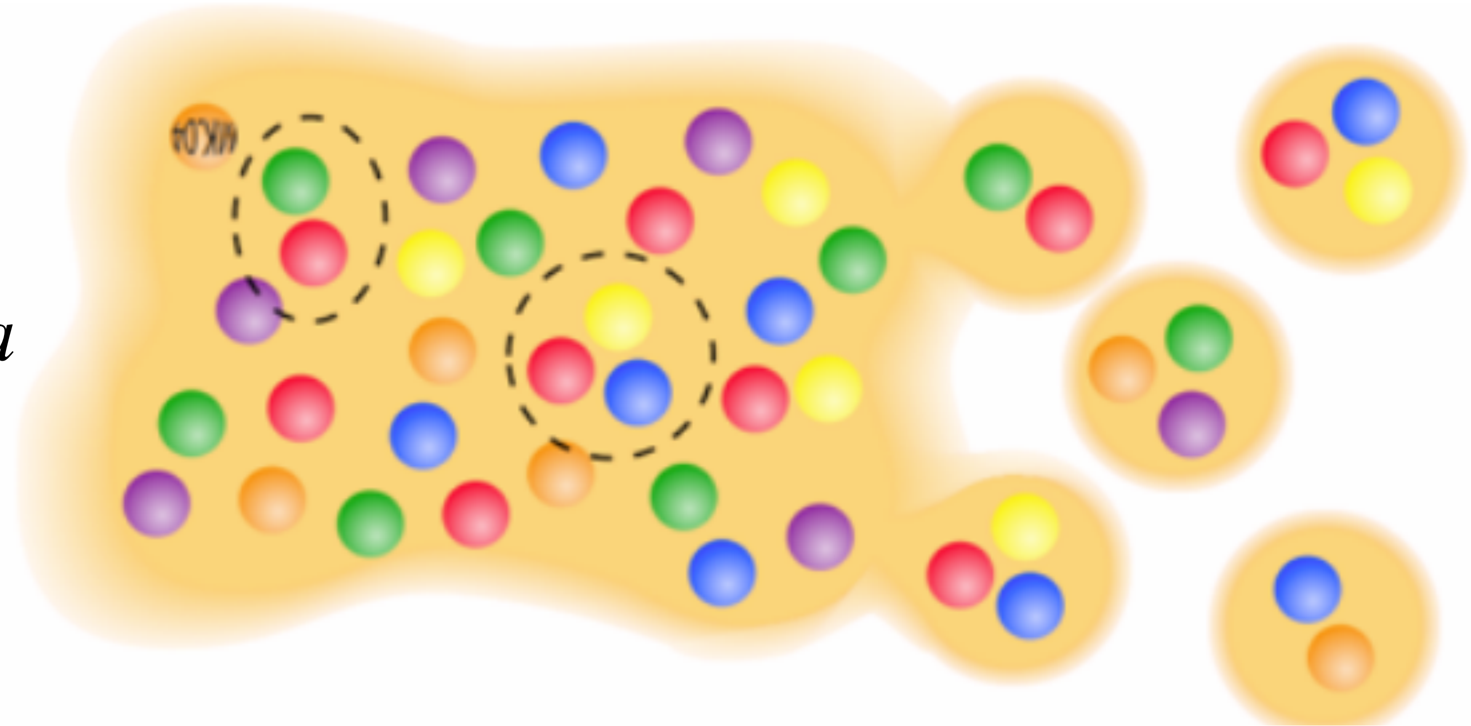
ALICE, PRL 116, 132302 (2016)

Flow of identified particles in Pb—Pb collisions

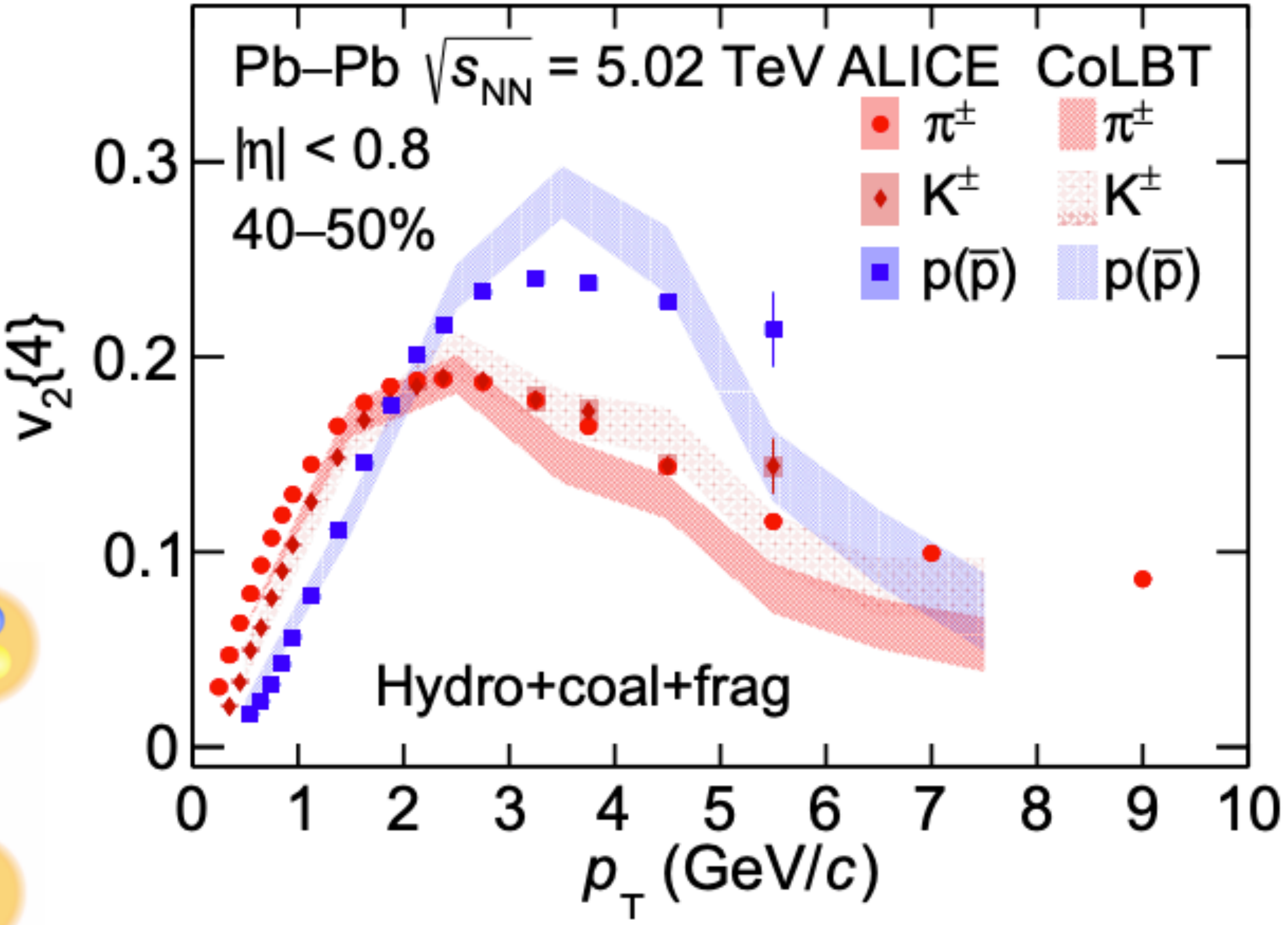
- Low-p_T region: **mass ordering** (anisotropic boost from the medium, described by hydrodynamics)

- Intermediate-p_T region: **baryon-meson grouping** (partonic collectivity, transport effect)



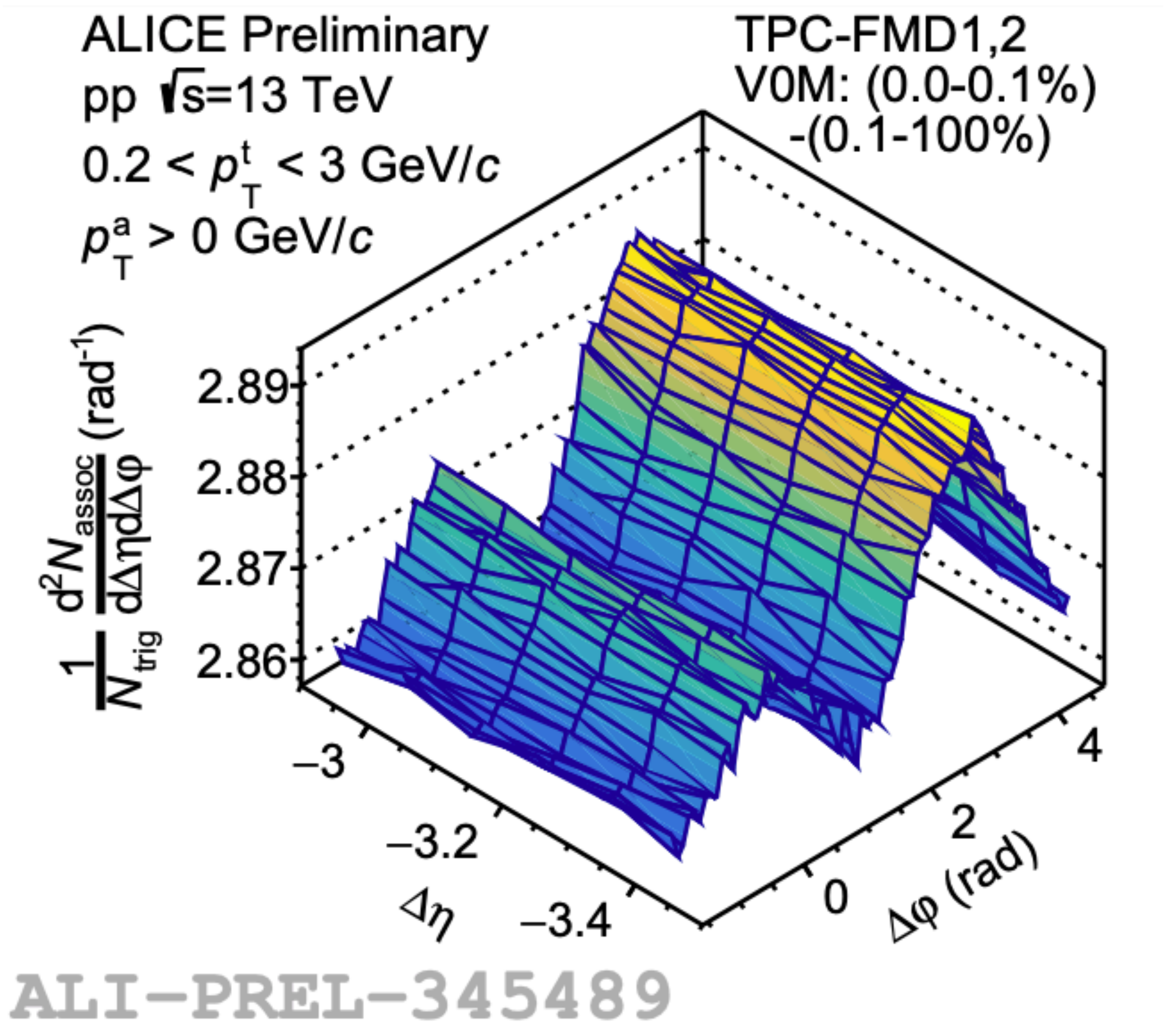


ALICE, JHEP 05 (2023) 243



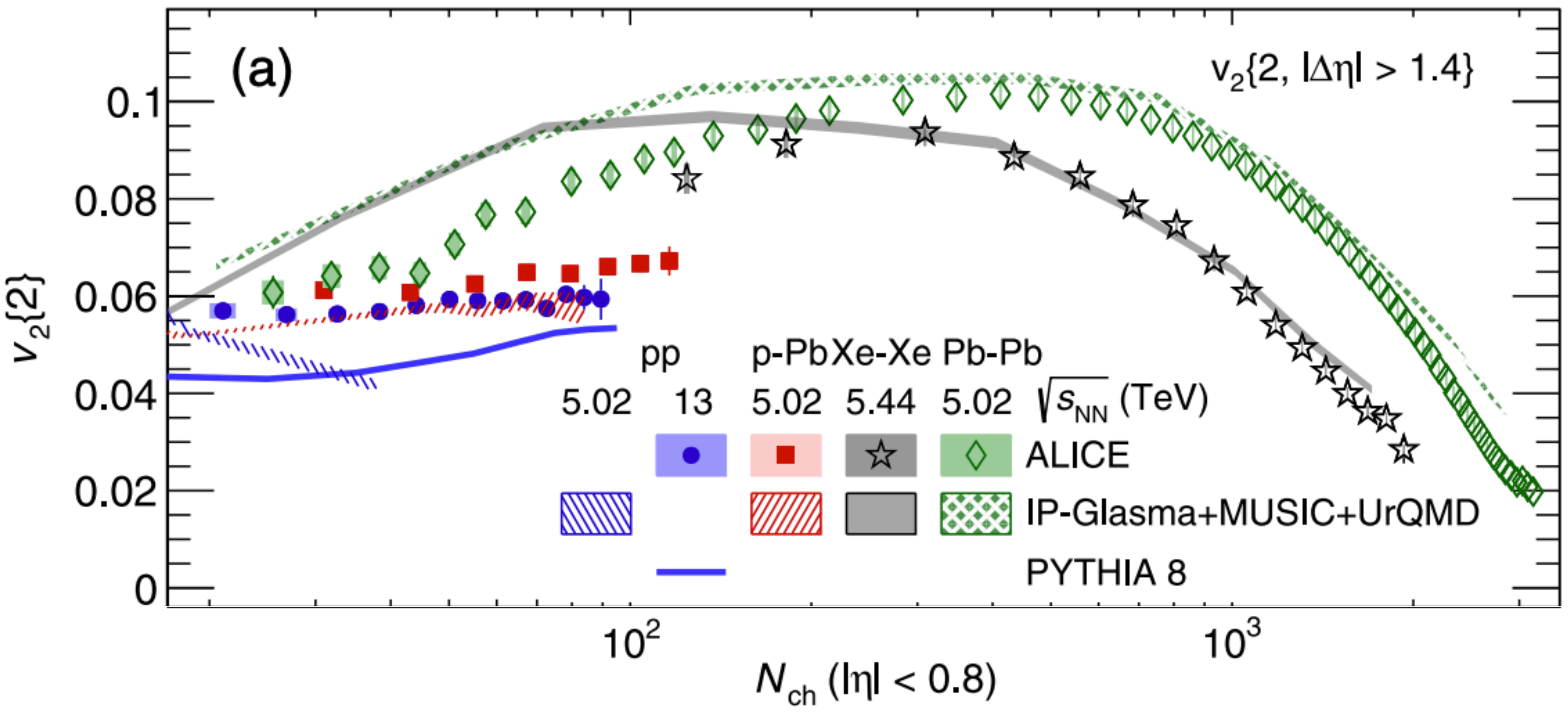
Collectivity in small systems

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



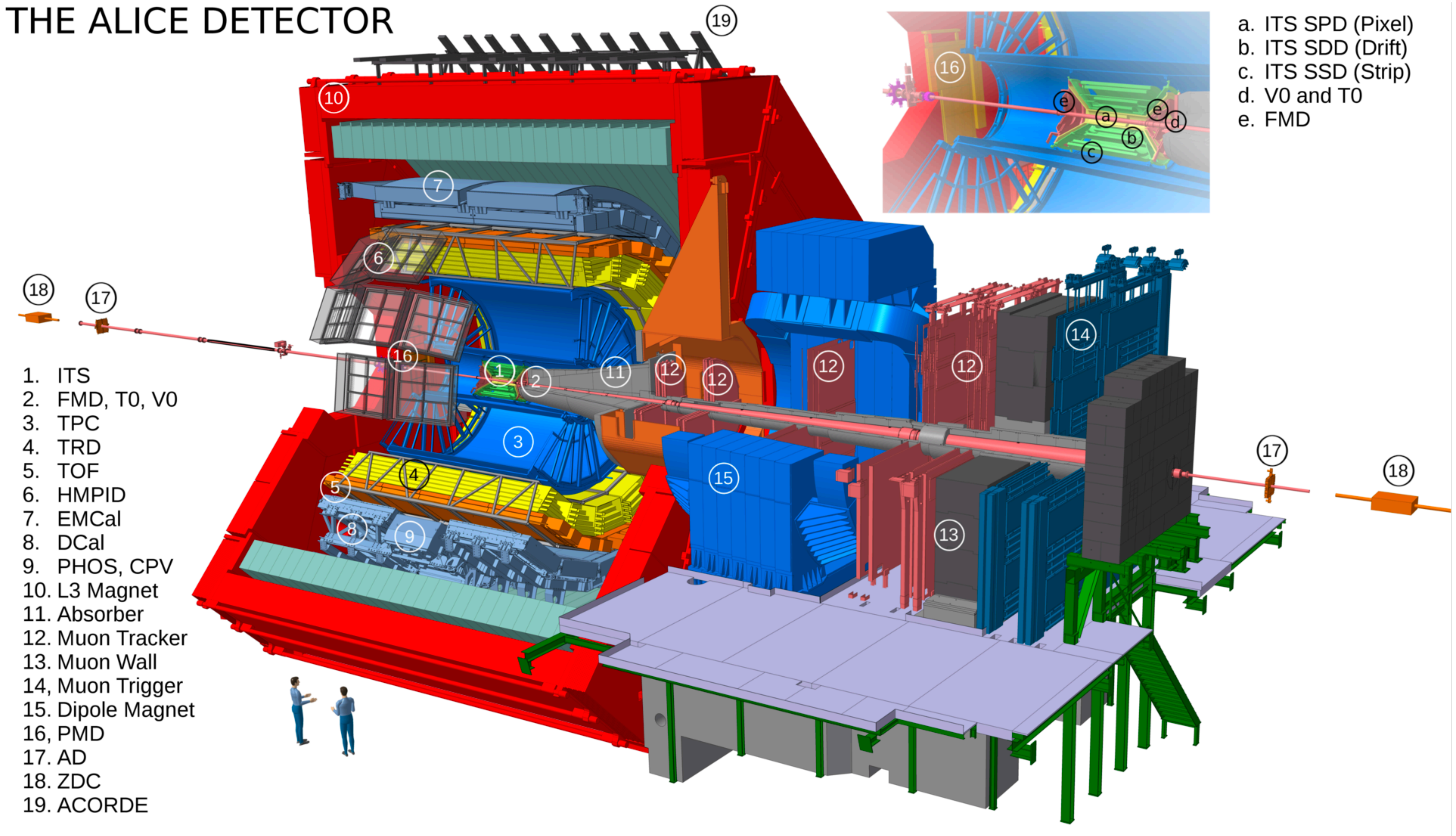
- Sizable flow observed across all collision systems (pp, p—Pb, Xe—Xe, Pb—Pb)
- Multiparticle long-range correlations confirmed **collectivity in small systems**

ALICE, PRL 123, 142301 (2019)



ALICE detector → A Large Ion Collider Experiment

- **Inner Tracking System (ITS)**
  Tracking and triggering
- **V0 Detector**
  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



Non-flow treatment

- Two particle correlation function (same/mixed events)

$$C(\Delta\phi, \Delta\eta) = \frac{1}{N_{trig}} \sum_{Pvz} \frac{SE(\Delta\phi, \Delta\eta)}{\alpha ME(\Delta\phi, \Delta\eta)}$$

- Non-flow suppression (combined):
  - Long-range correlation (large $|\Delta\eta|$ gap between particles)
  - Template fit→ correlation function can be described as **a superposition of non-flow and flow**:

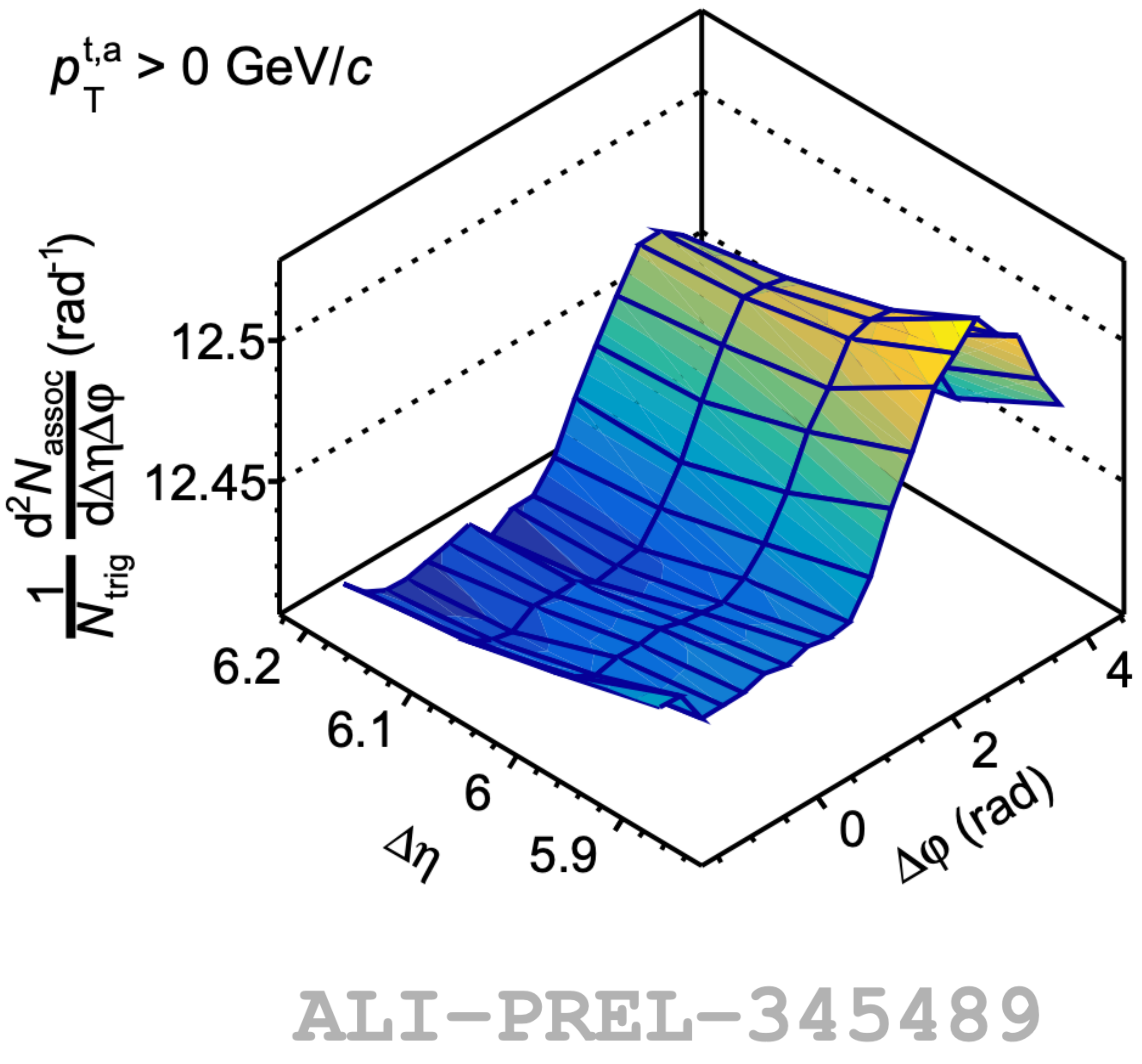
$$Y(\Delta\phi) = FY(\Delta\phi)^{peri} + G[1 + \sum_{n=2}^{\infty} 2V_{n\Delta} cos(n\Delta\phi)]$$

Peripheral events, non-flow dominated

Flow signal

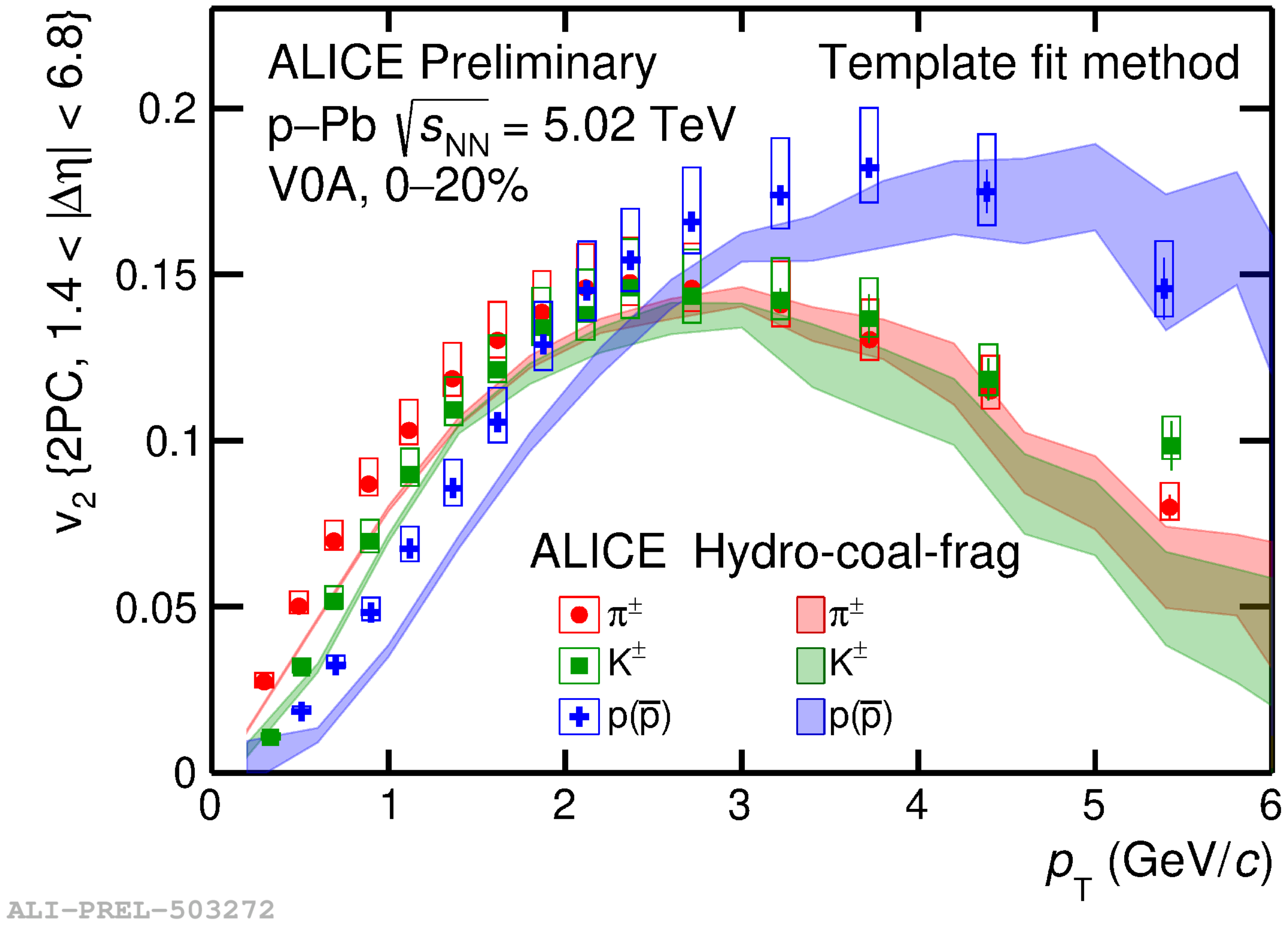
(TF is the best way rather than ITF and subtraction methods)

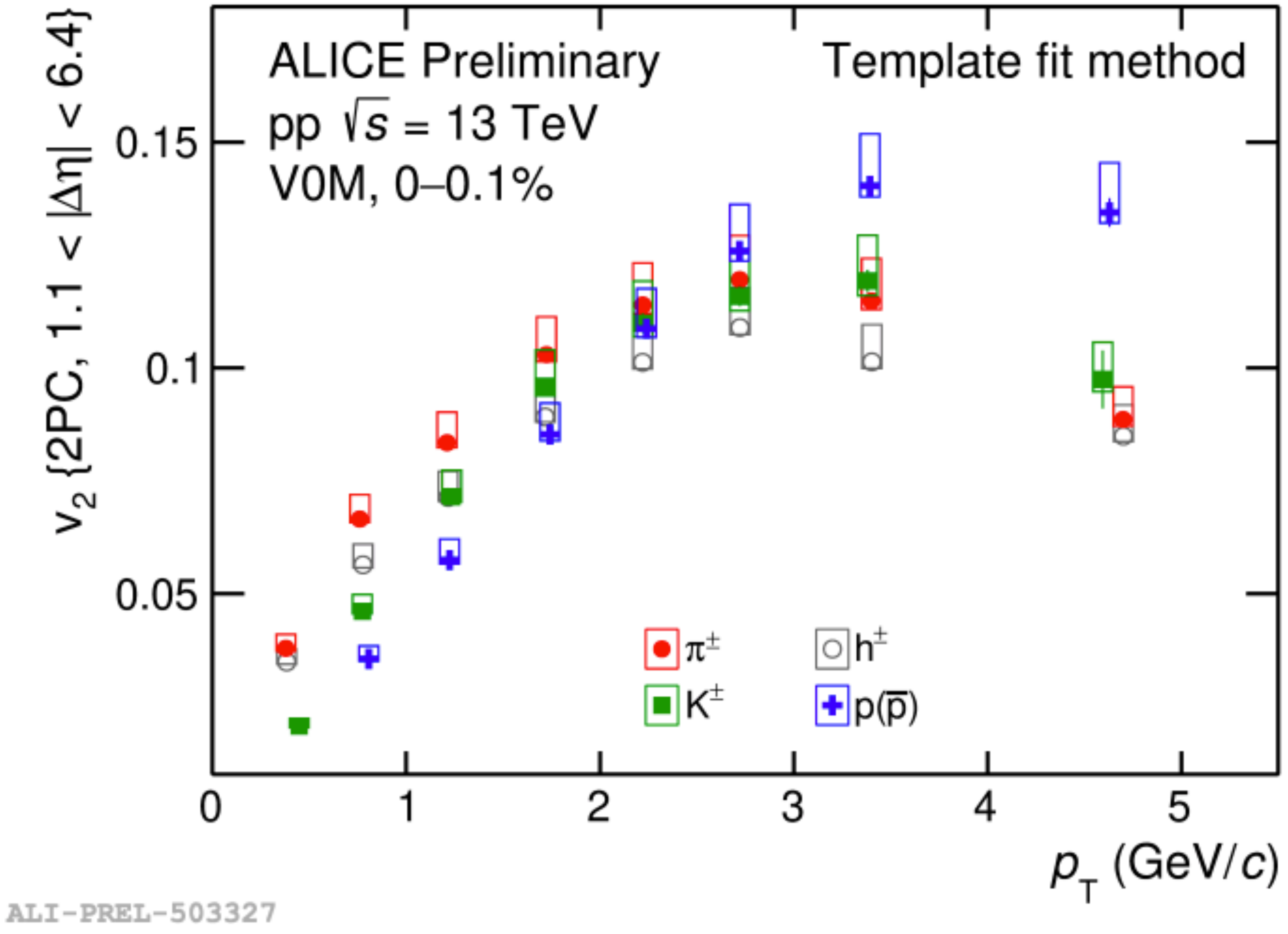
FMDA-FMDC (lonng range) correlation



p_T-differential flow of identified particles in small systems

- **Mass ordering (low-p_T region)** and **baryon-meson grouping (intermediate-p_T region)** are observed **at high multiplicity ranges in p—Pb and pp**
- Probing the **partonic collectivity in small systems**

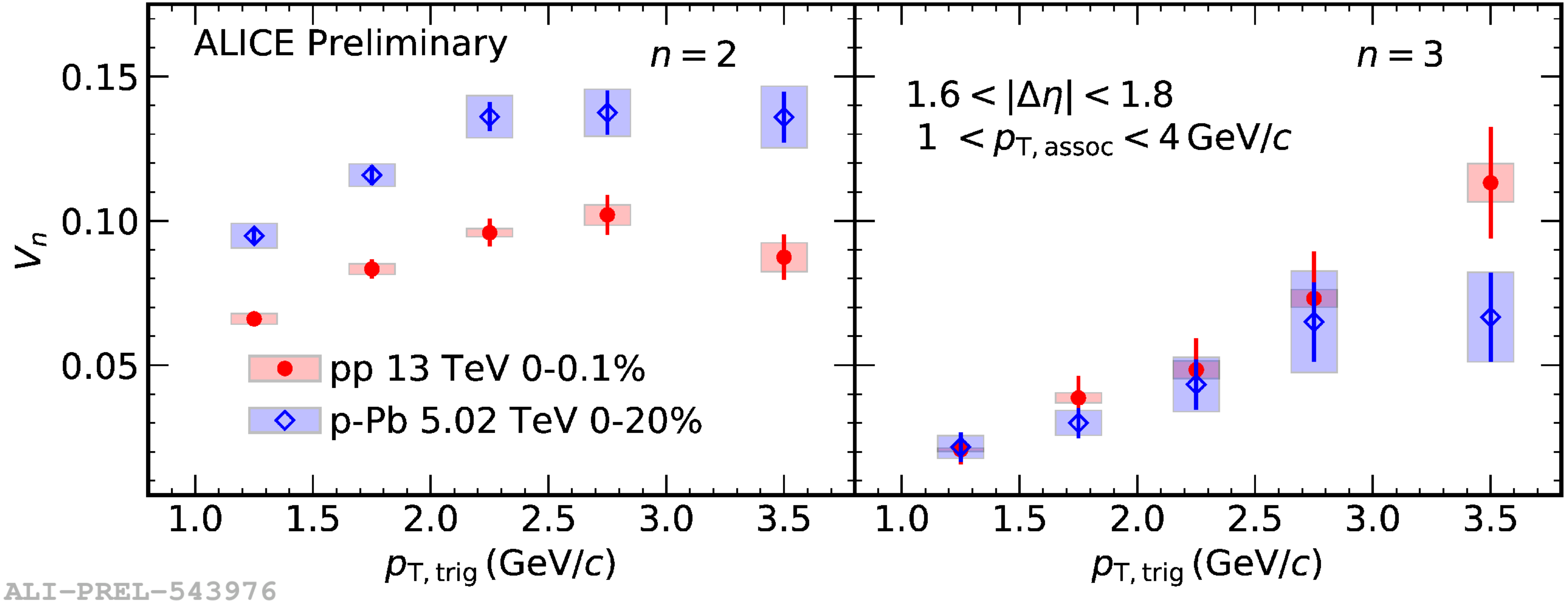




The minimum requirements for observing partonic collectivity in a small system?

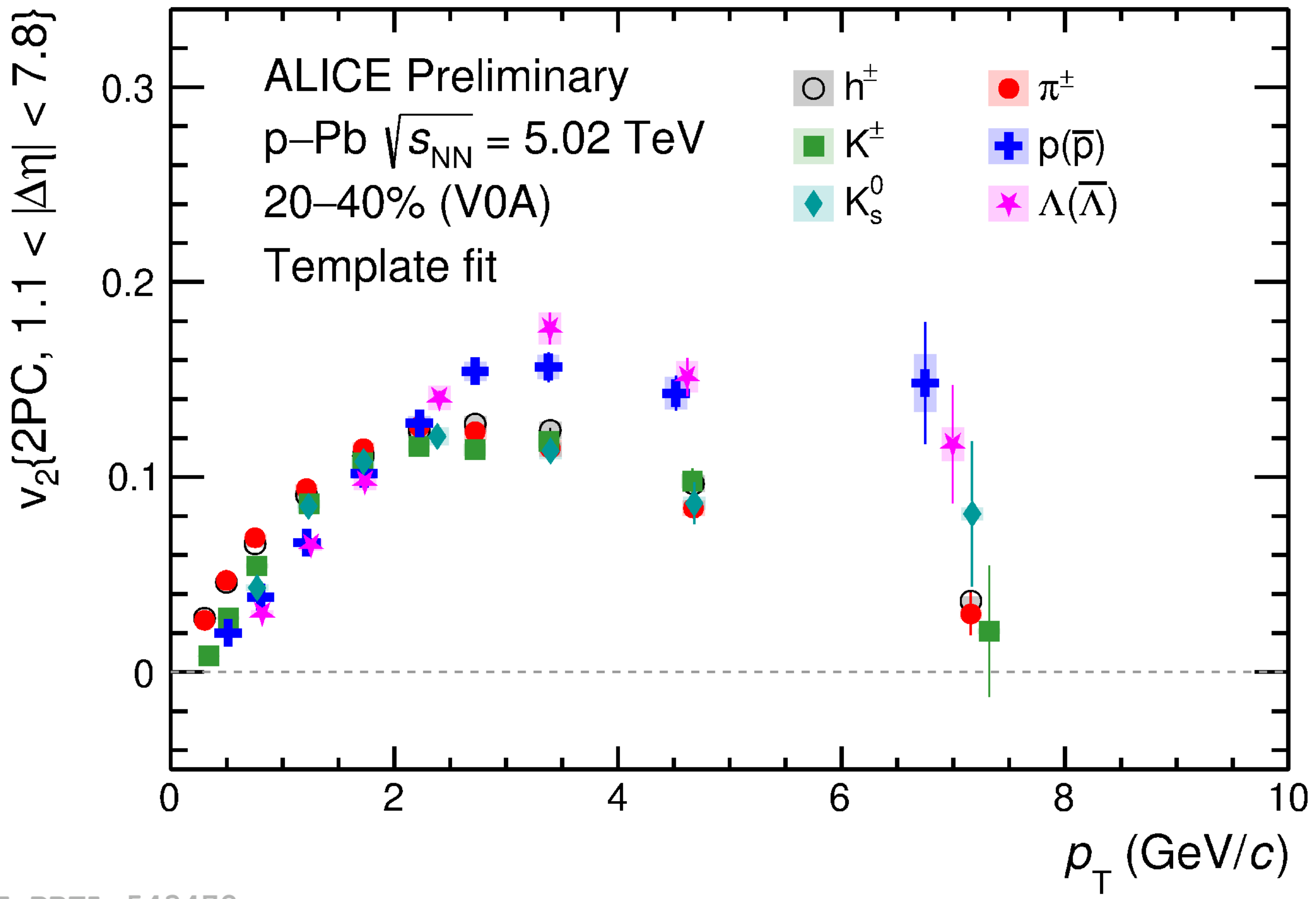
A comprehensive understanding of the centrality/N_{ch} dependence of PID differential-flow

System comparison



- The v_2 magnitude in p—Pb collisions is larger than the one in pp collisions
  - The larger system size and longer-lived medium in p—Pb collisions
- The v_3 magnitudes are similar in both collisions
  - Less sensitive to the collision systems

Centrality dependence of $v_2(p_T)$ with identified particles in p—Pb



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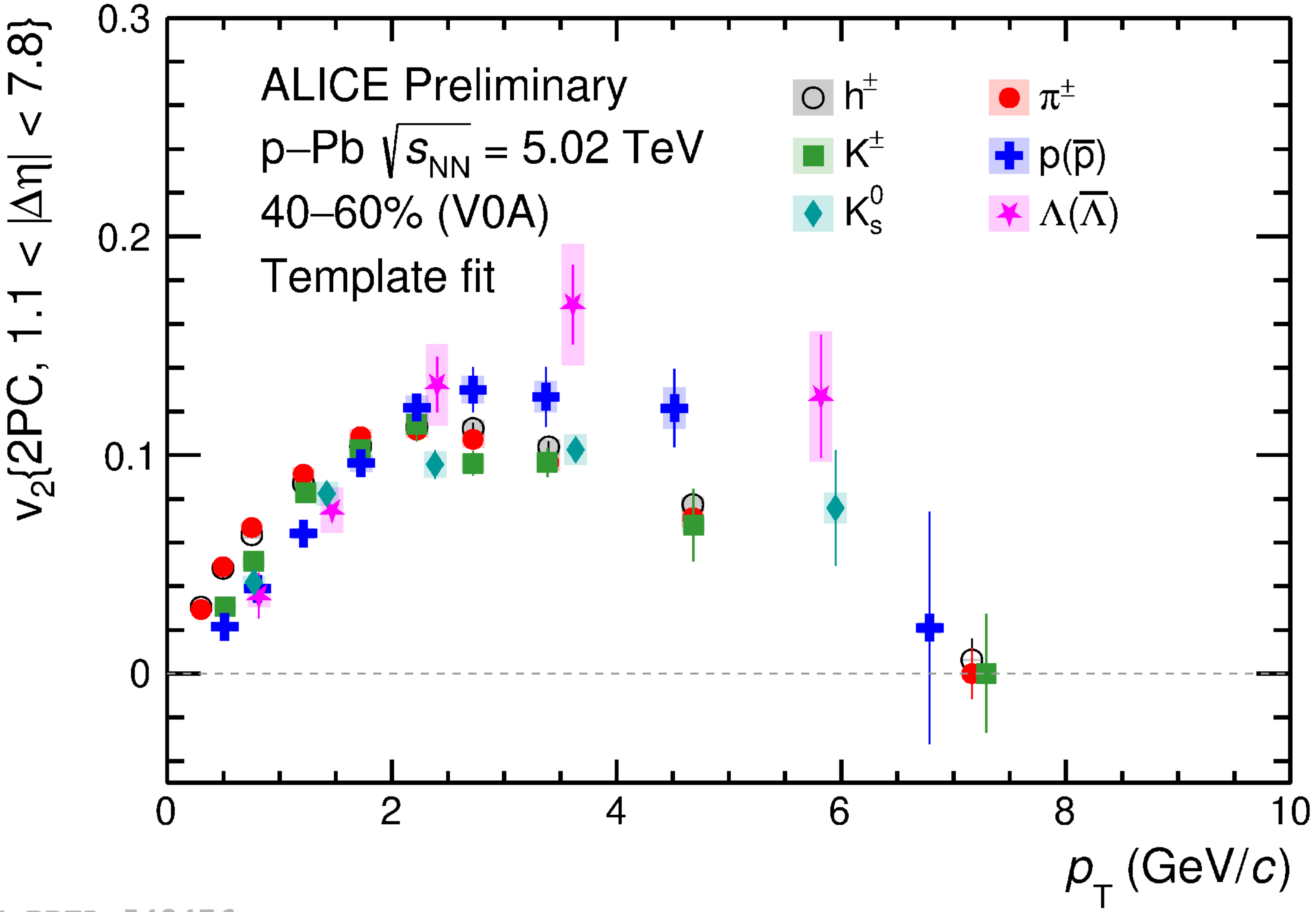

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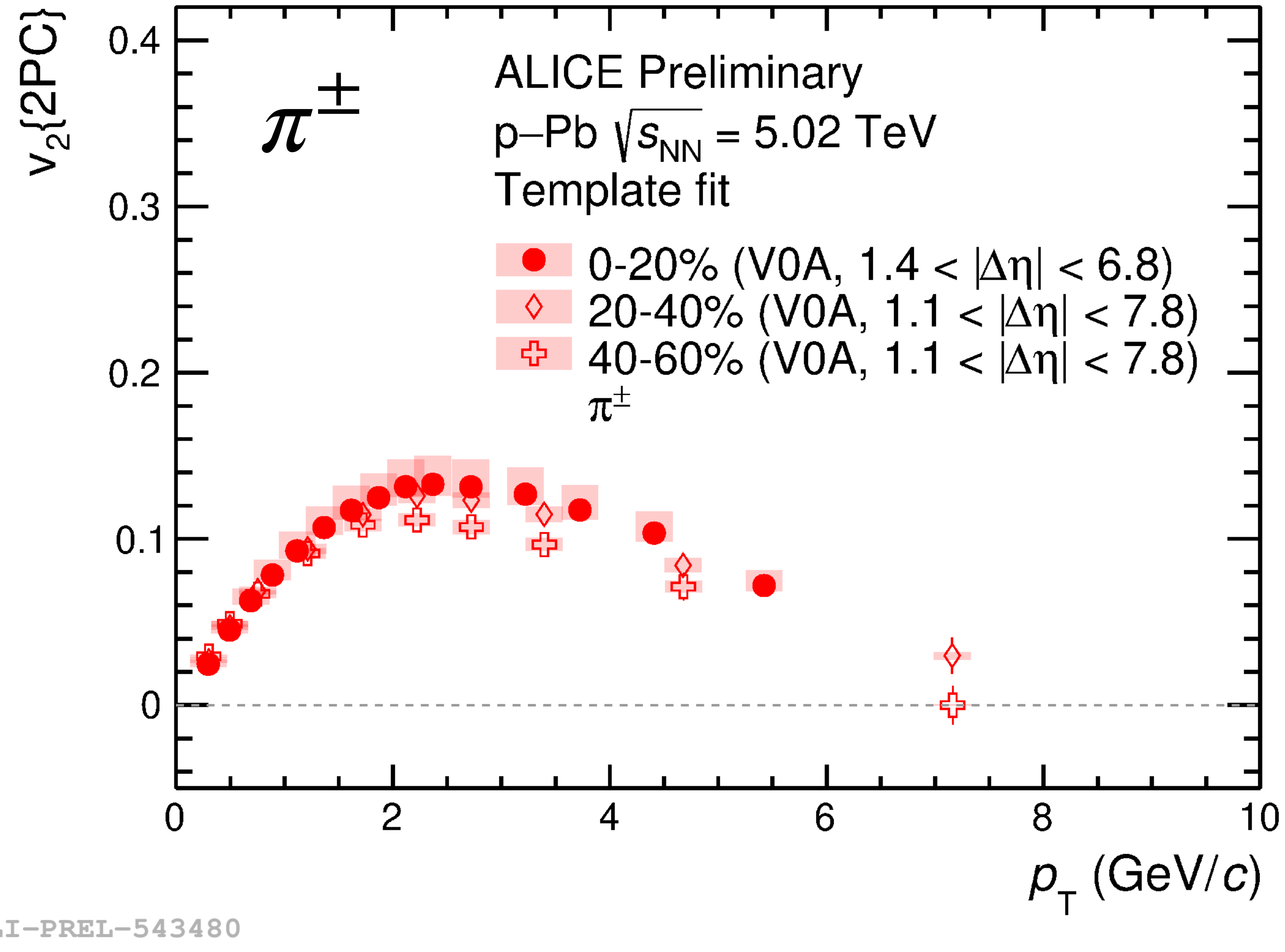
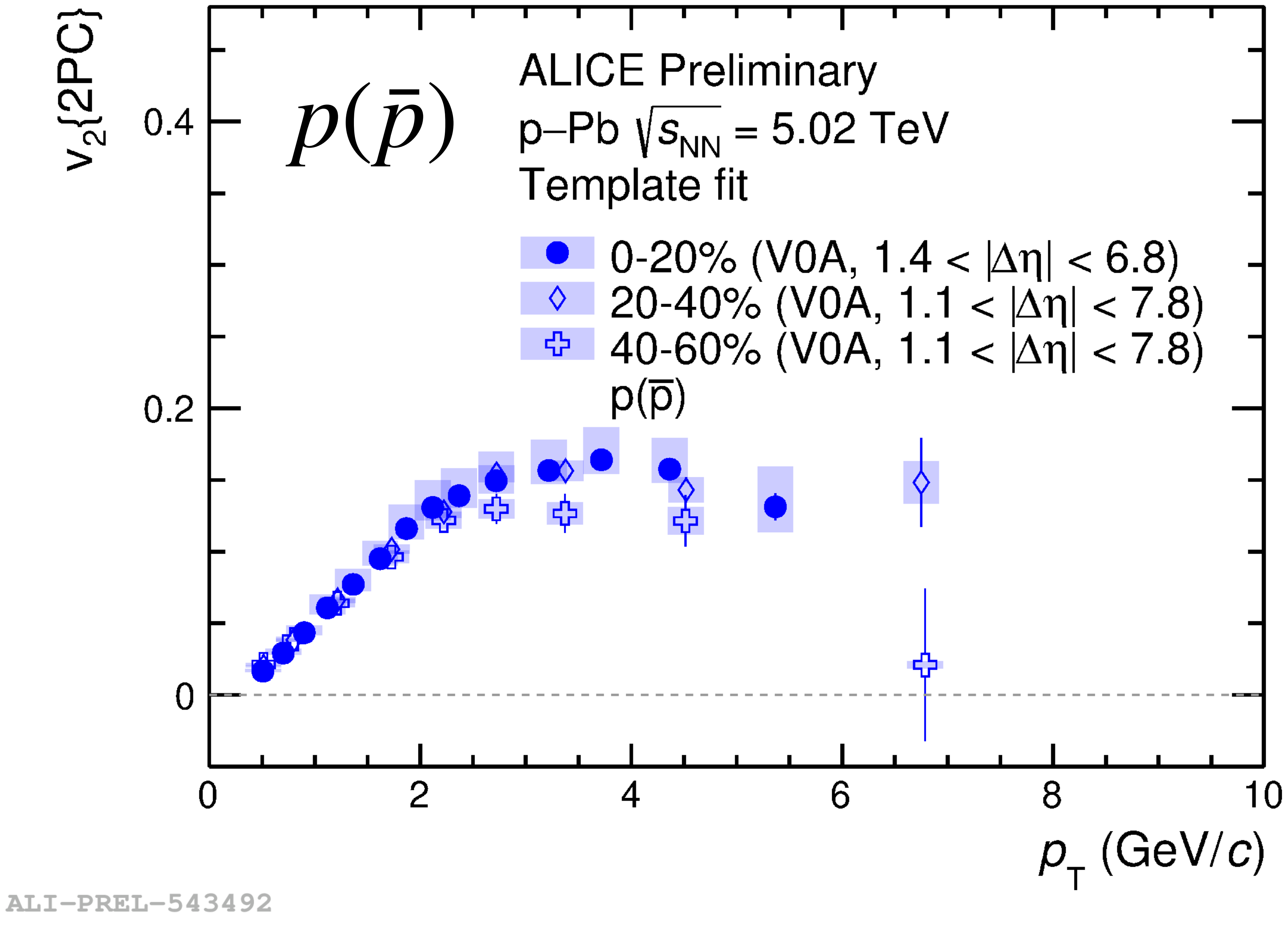
- Hydro-dominated **mass ordering effect** observed in the low p_T region
- **Baryon-meson grouping** at intermediate p_T region presents at all centrality classes
- The "crossing" of baryons and mesons occurs at $p_T \sim 2.5$ GeV/c for both 20-40% and 40-60% (p—Pb), similar to 0-20% (p—Pb), pp and Pb—Pb

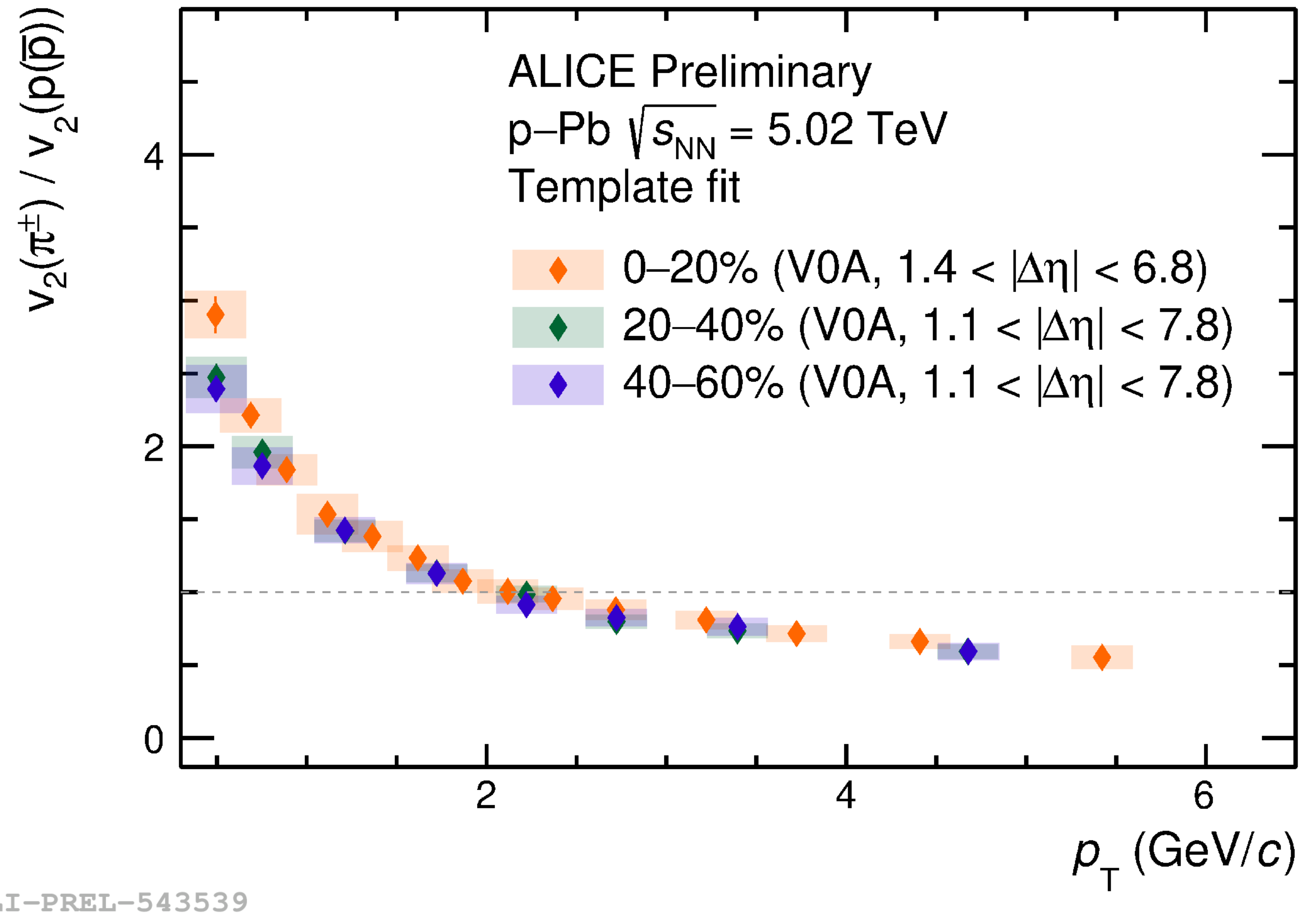
Comparison between centralities in p—Pb

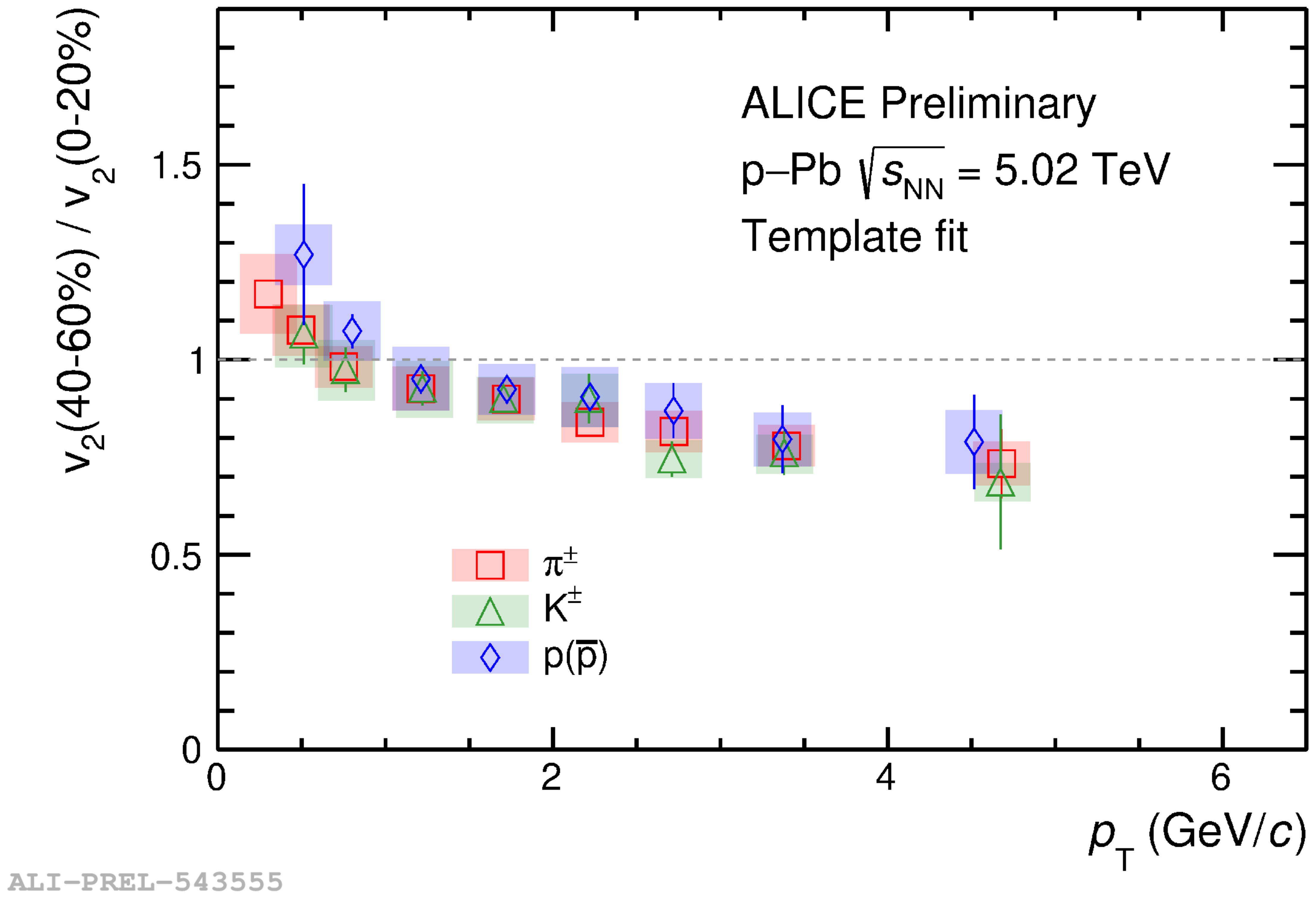




- The absolute value of $v_2(p_T)$ decreases as centrality increases (other species see back up)
- Consistent with the multiplicity-dependent integrated $v_2\{2\}$ results published by ALICE, PRL 123, 142301 (2019) (see slide 4)

Ratio between meson/baryon and centralities in p—Pb

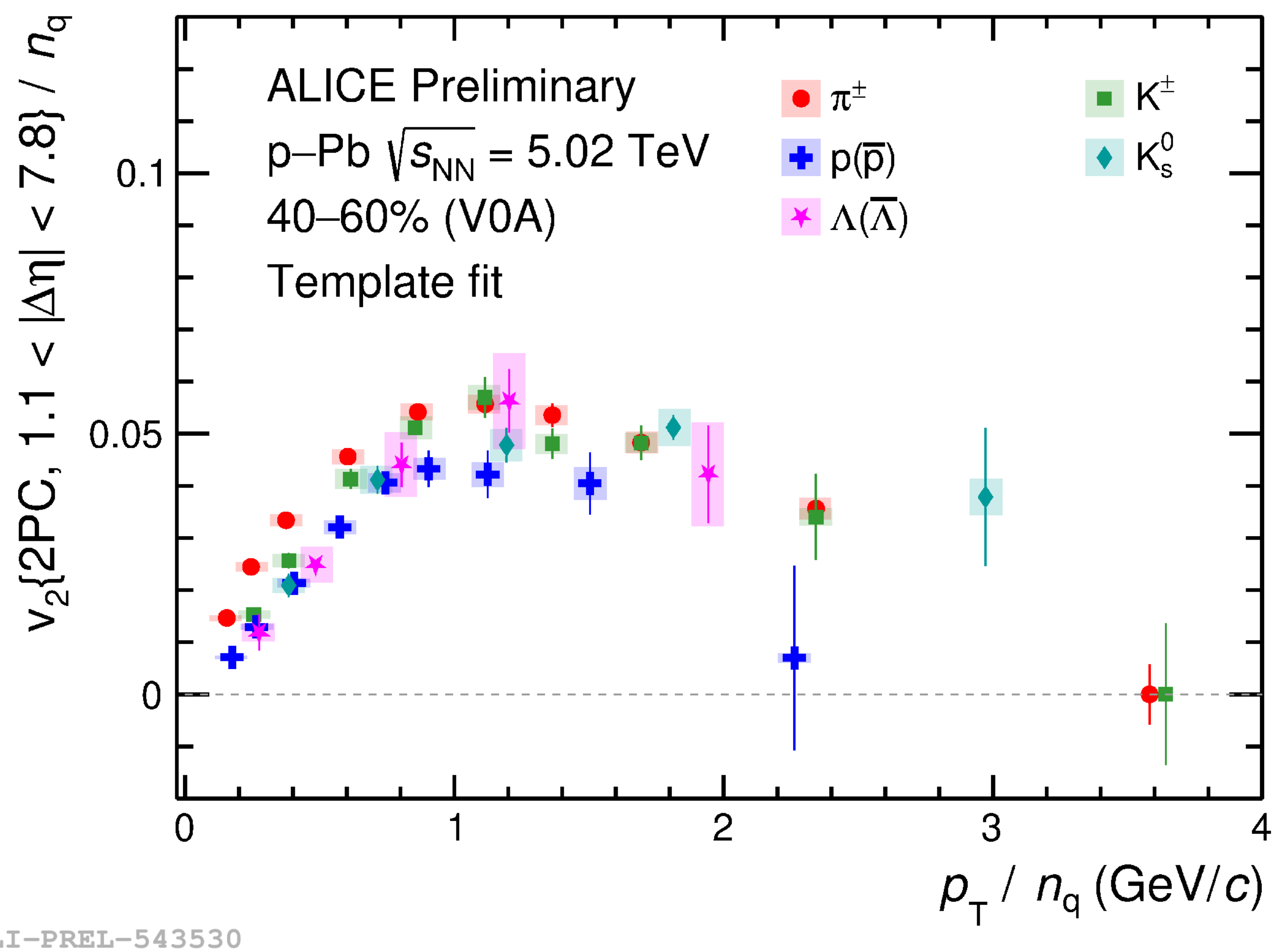




- No centrality dependence was observed for the v_2(meson)/v_2(baryon) ratio (left)
- No significant $v_2(\mathrm{PID})$ dependence observed with variation in centrality/multiplicity (right)

The grouping effect does not show significant changes from 0-20% to 40-60% in p—Pb collisions. (The partonic collectivity does not change a lot to peripheral collisions in p—Pb?)

Number of Constituent Quarks (NCQ) scaling



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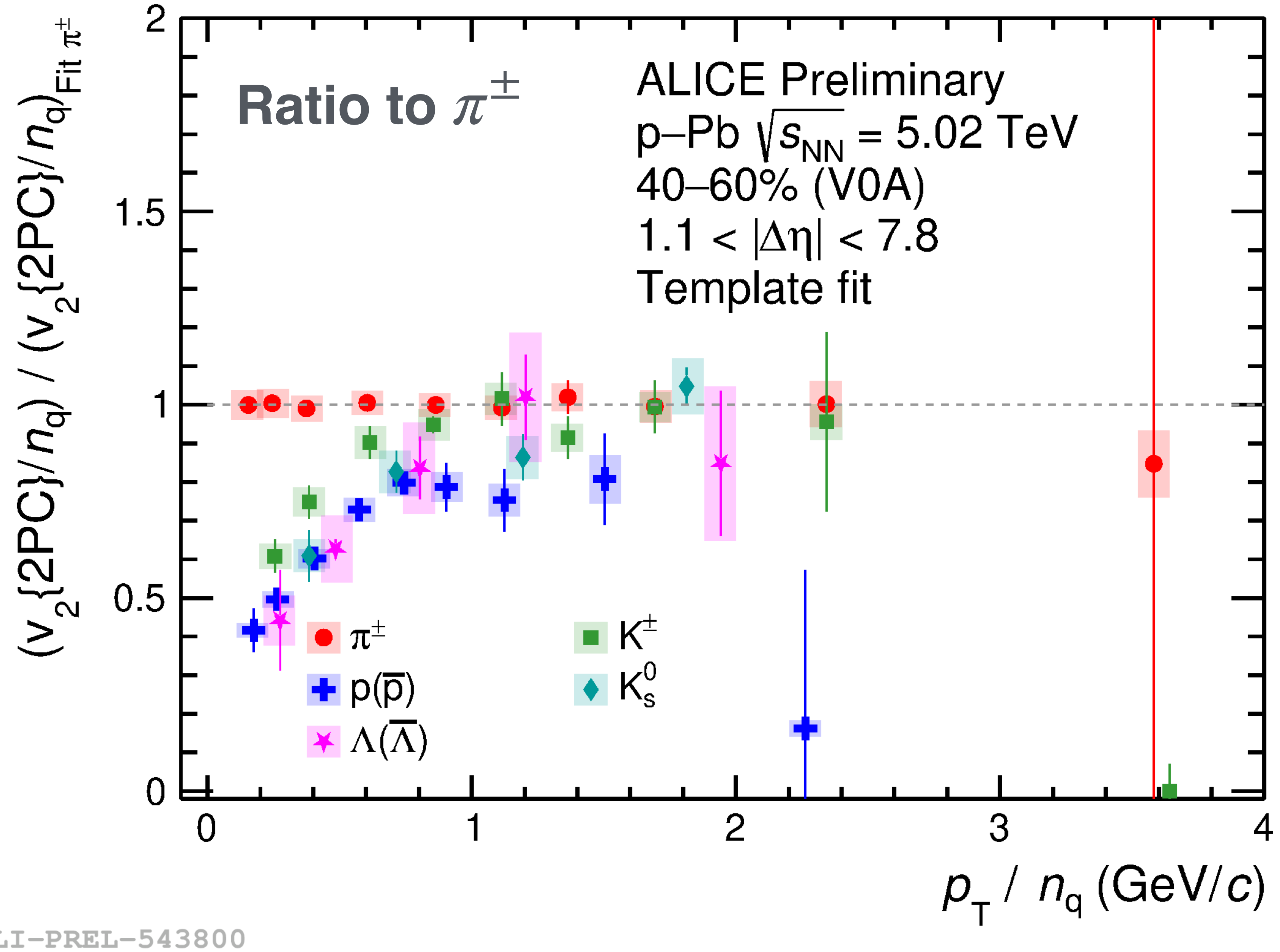

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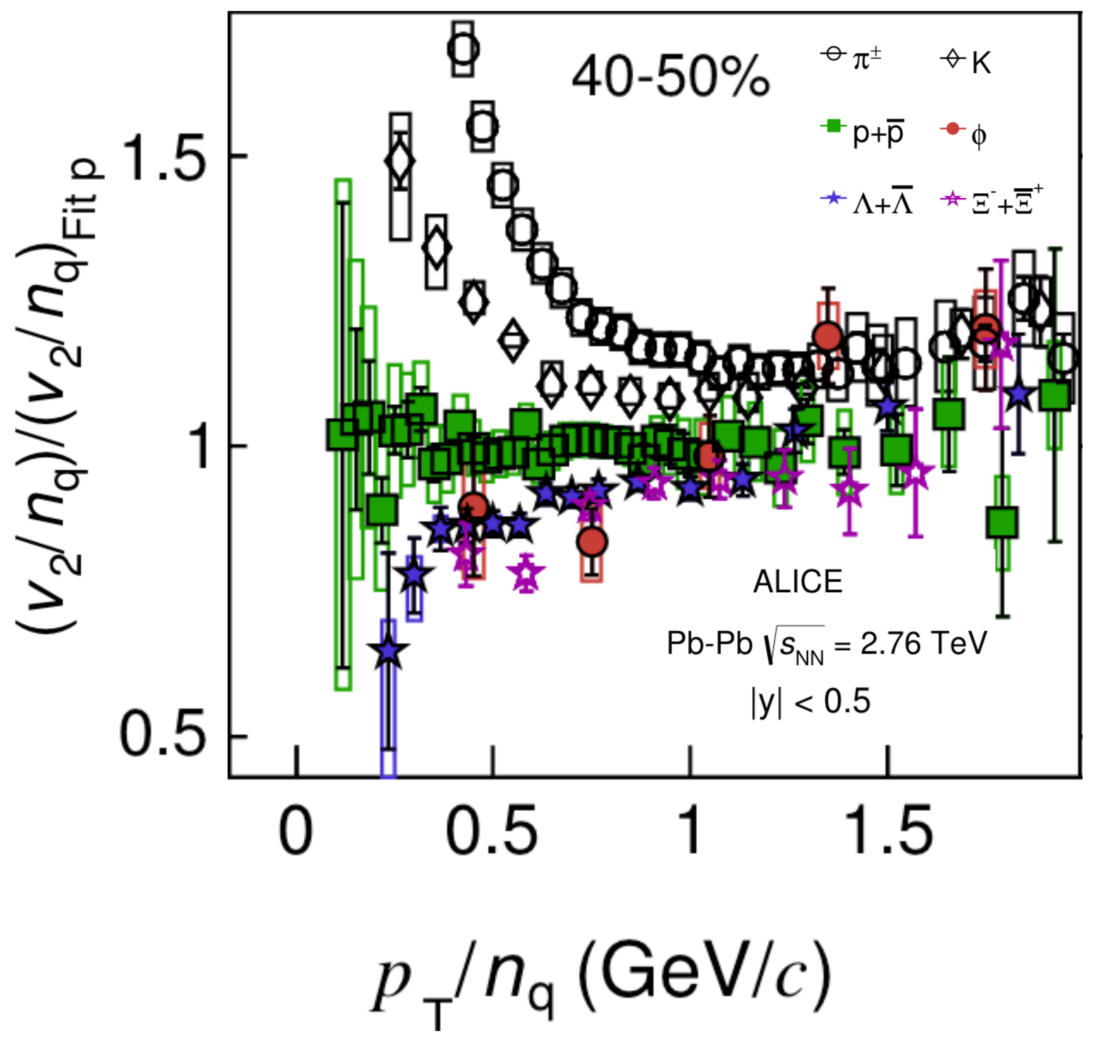
- Baryon-meson grouping doesn't follow perfect NCQ scaling
- Similar pattern observed in Pb—Pb collisions (right bottom)



ALICE, JHEP 06 (2015) 190

Ratio to $p(\bar{p})$

Conclusion

- Many similar observations for small and large systems;
- **Partonic collectivity** is observed in both pp and p—Pb collisions;
- p_{T}-differential flow shows **slight centrality dependence** in p—Pb collisions.
- **Mass ordering** and **baryon-meson grouping effect** observed from the 0-20% to the 40-60% in p—Pb →**The characteristics of behavior for partonic collectivity in p-Pb collisions are similar across different centrality ranges;**

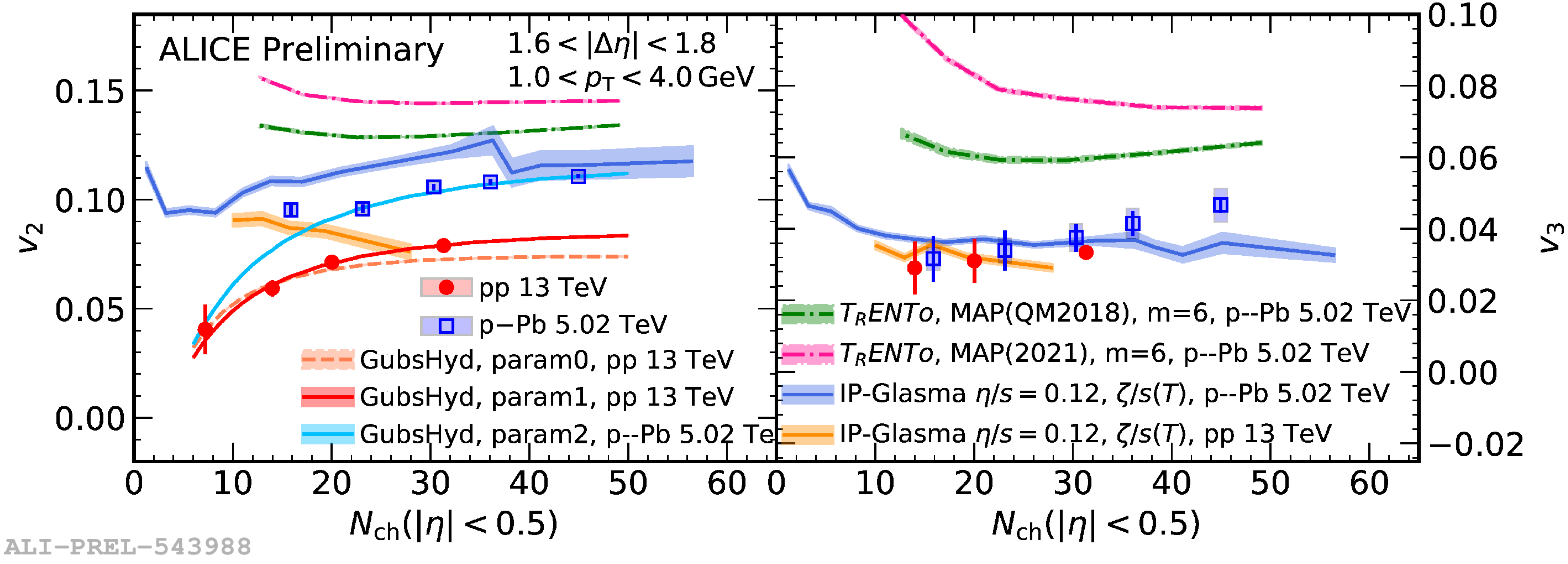
Outlooks:

- N_{ch}/centrality dependence of $v_2(p_{\mathrm{T}})$ in pp collisions;
- System comparisons in same N_{ch} region;

Thanks for your attention!

Backup

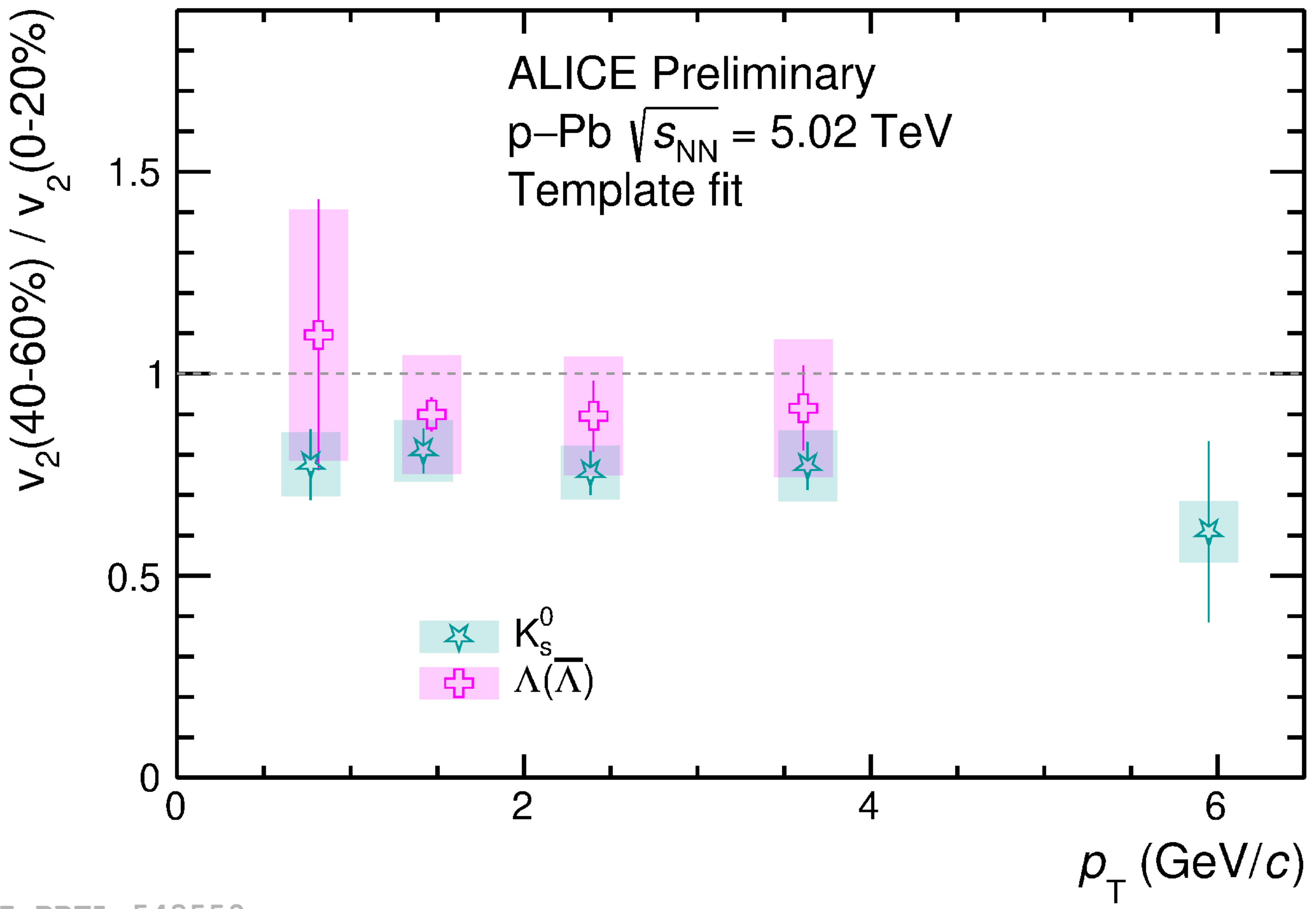
Comparison to models for hadron v_n



- **IP-Glasma** + hydro[1]: captures p—Pb multiplicity dep. but **the opposite trend for pp**
- **TRENTO**+Hydro[2]: **the opposite trend** for both systems and **overestimating**.
- **GubHyd**[3]: capture the multiplicity dep. and magnitudes with tuned model parameters.
- Need more insights from the theories(eg. PRC 106, 054908, necessity of non-equilibrium components?)

[1] B. Shenke et al., PRC 102, 044905 (2020), [2] J.E. Parkkila et al., PLB 835 (2022) 137485, [3] S.F. Taghavi, PShys.Rev.C 104 (2021) 5, 054906

Ratio between meson/baryon and centralities in p-Pb



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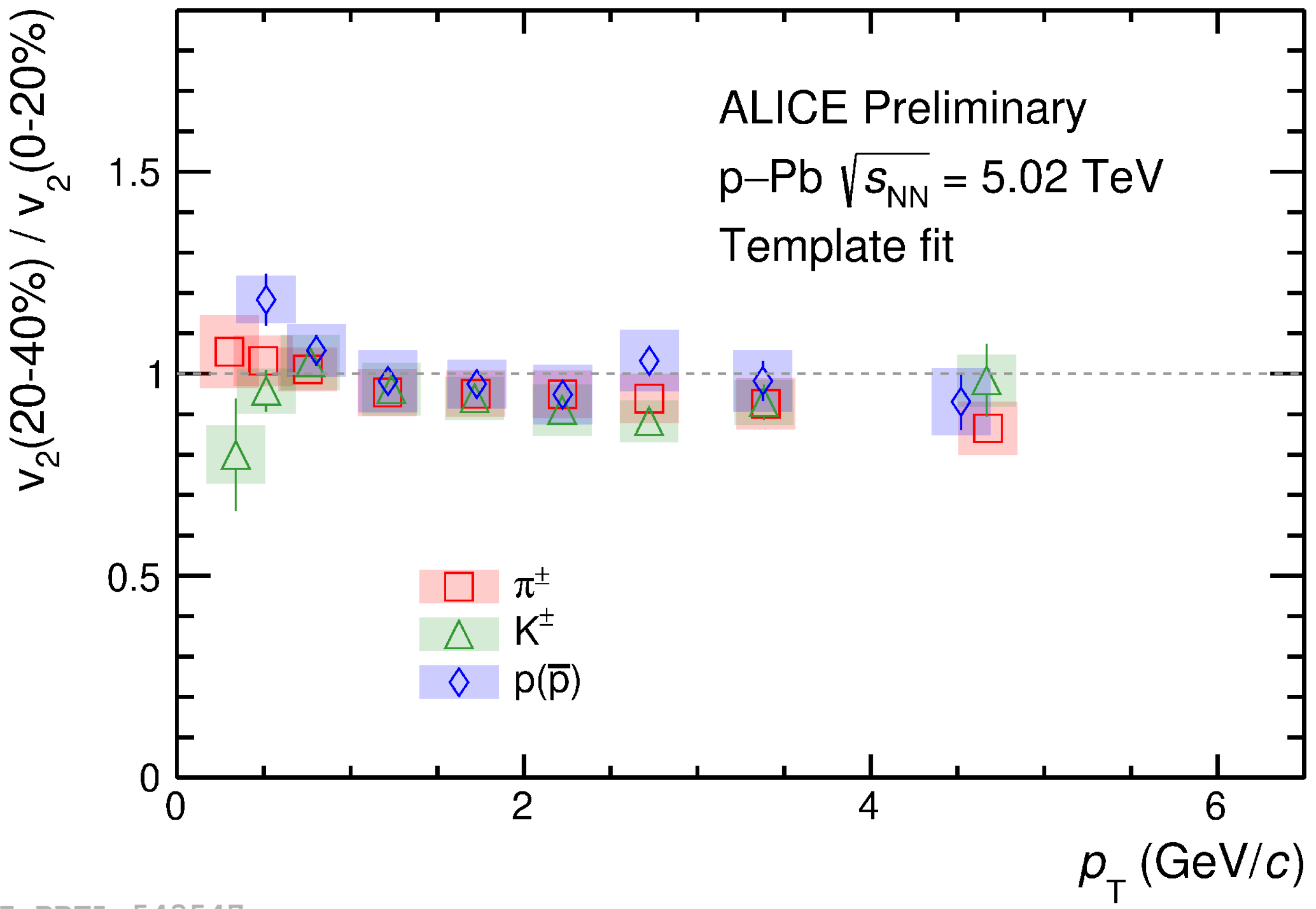

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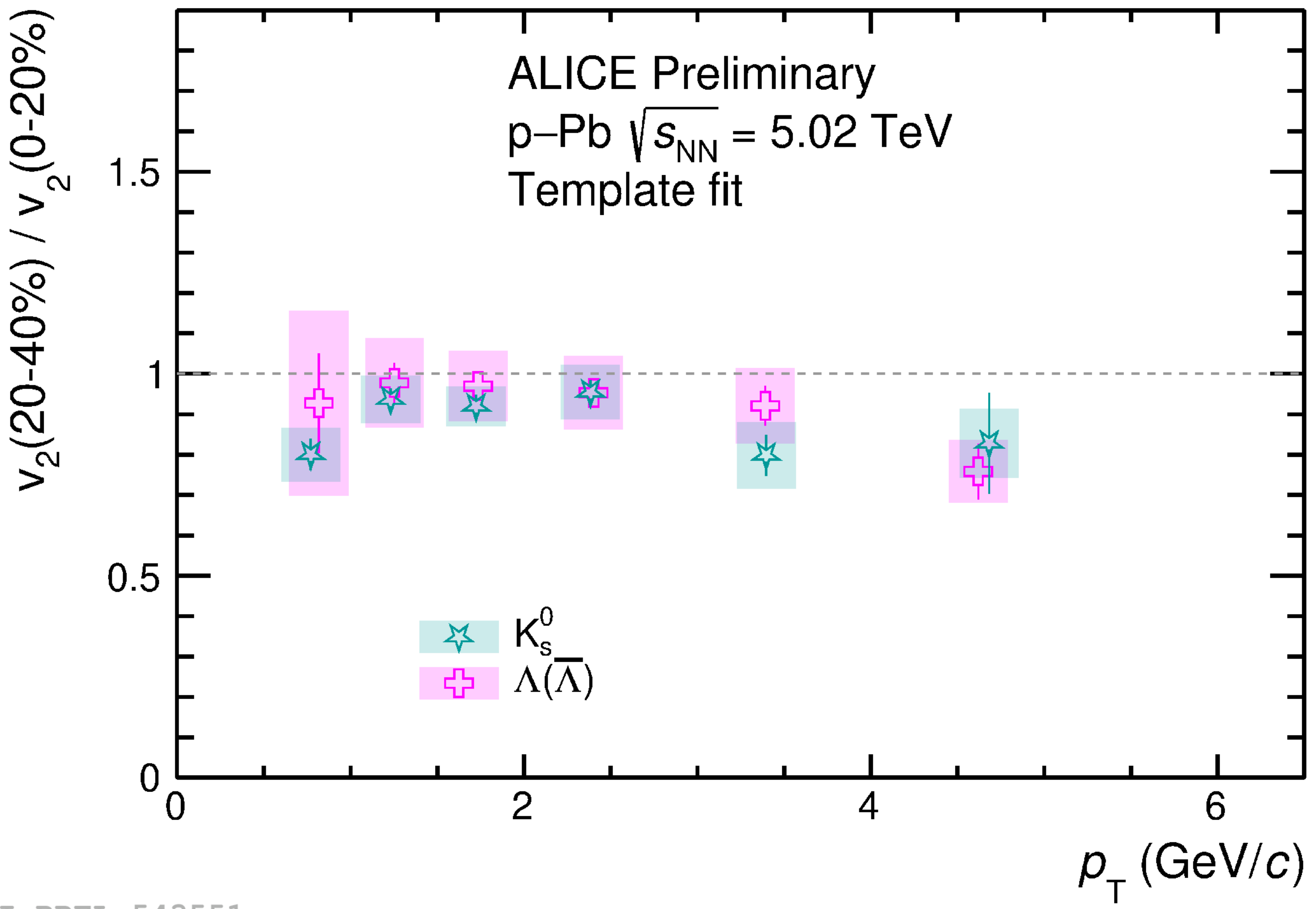

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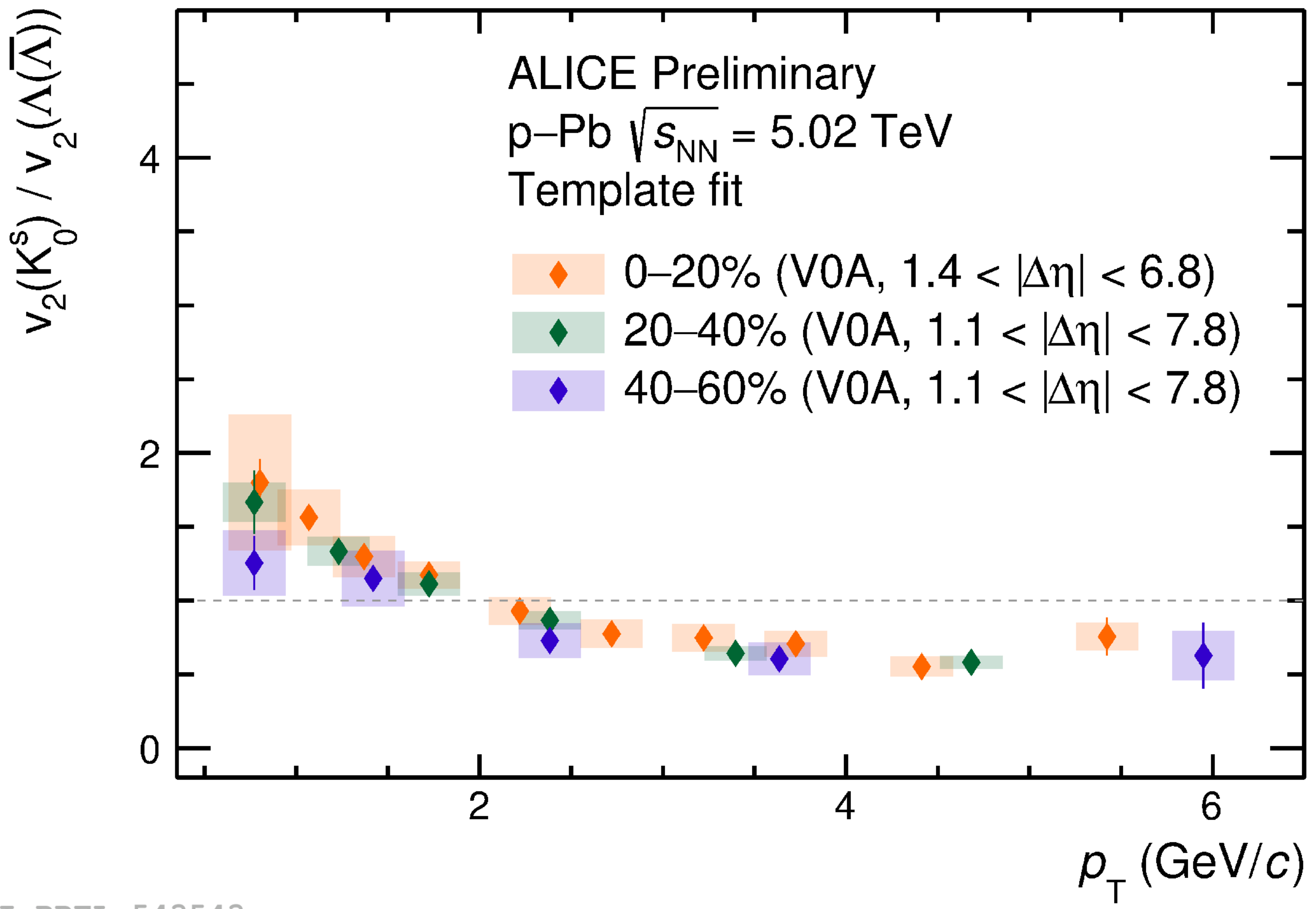

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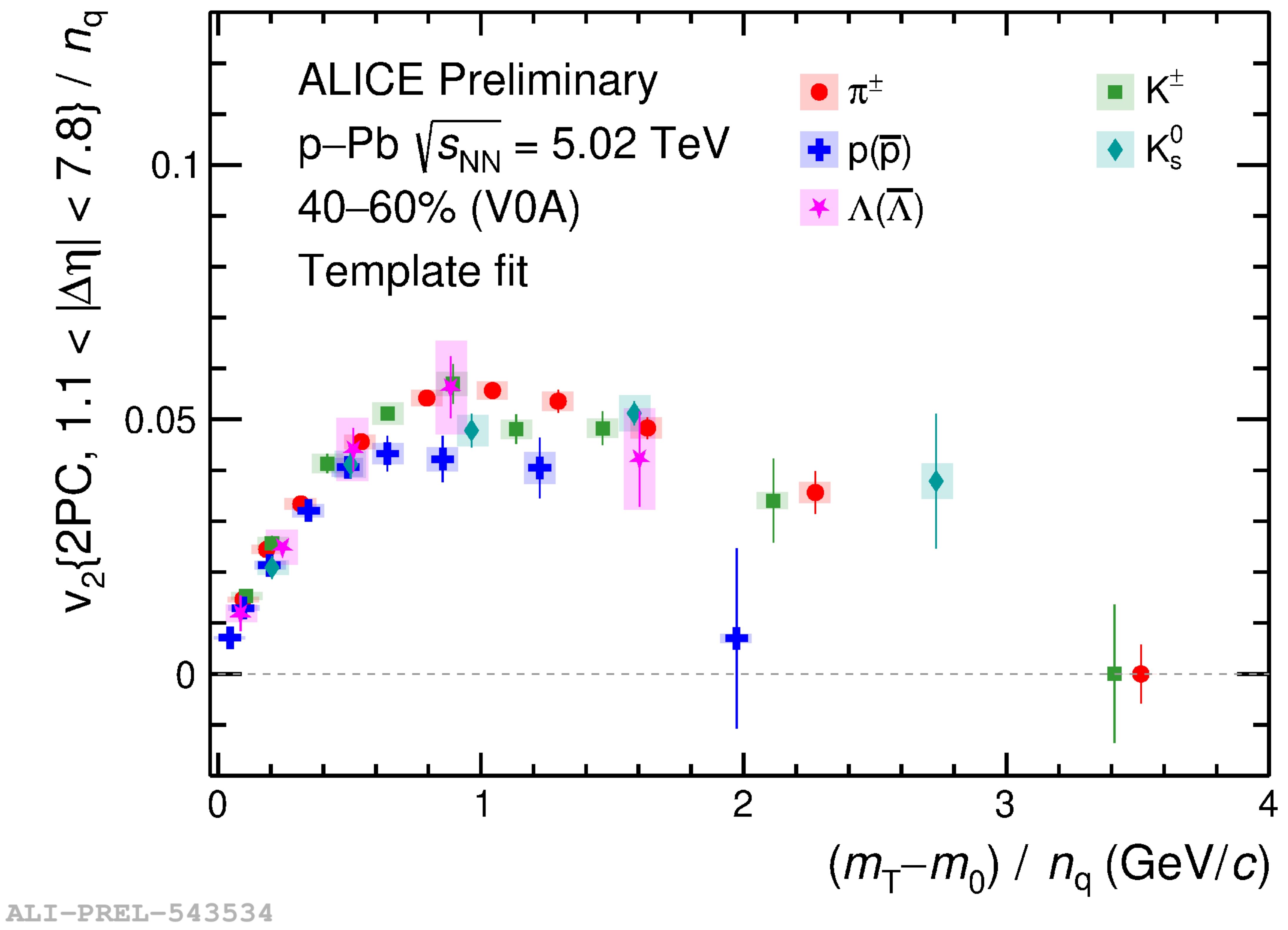
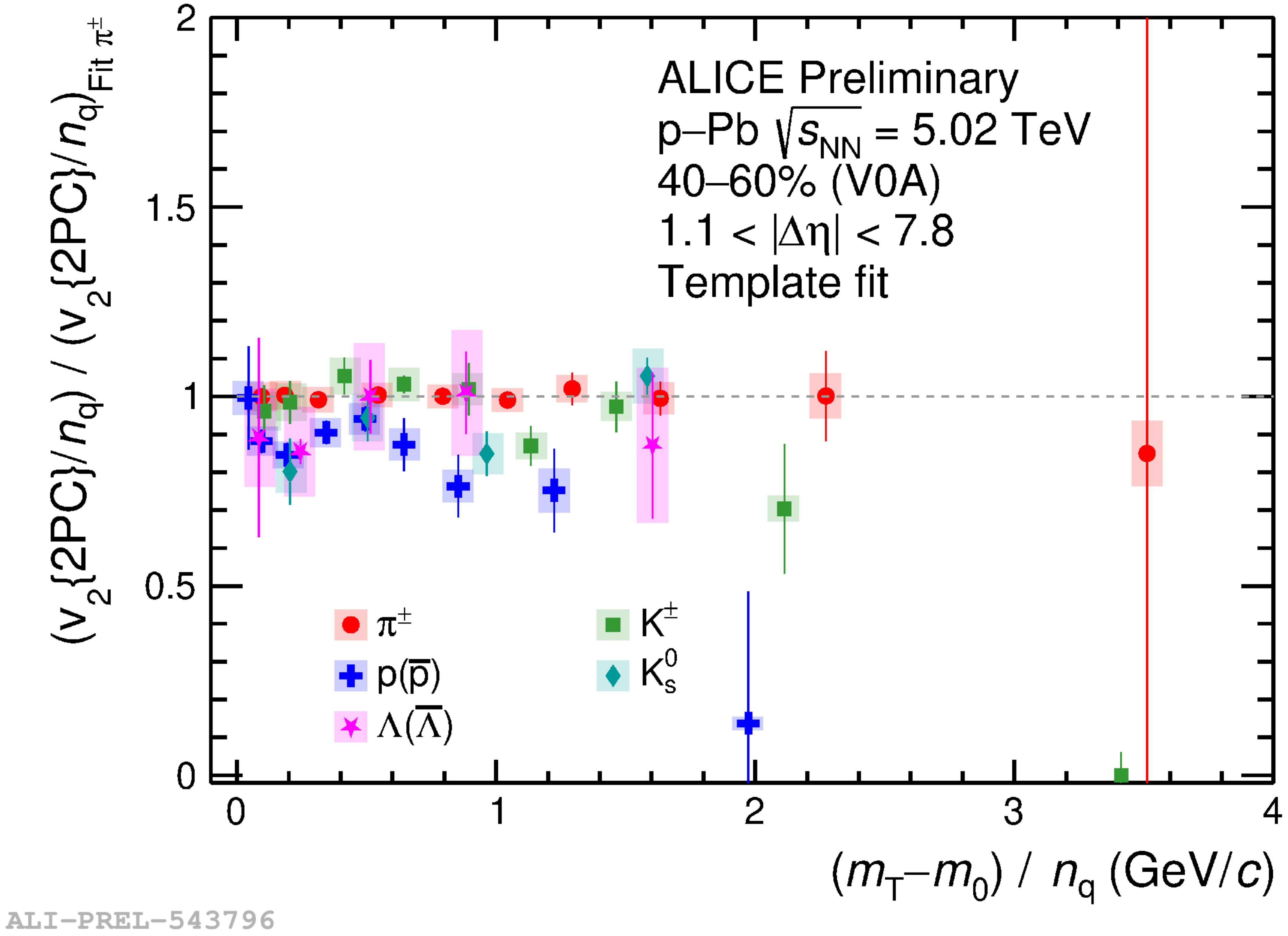
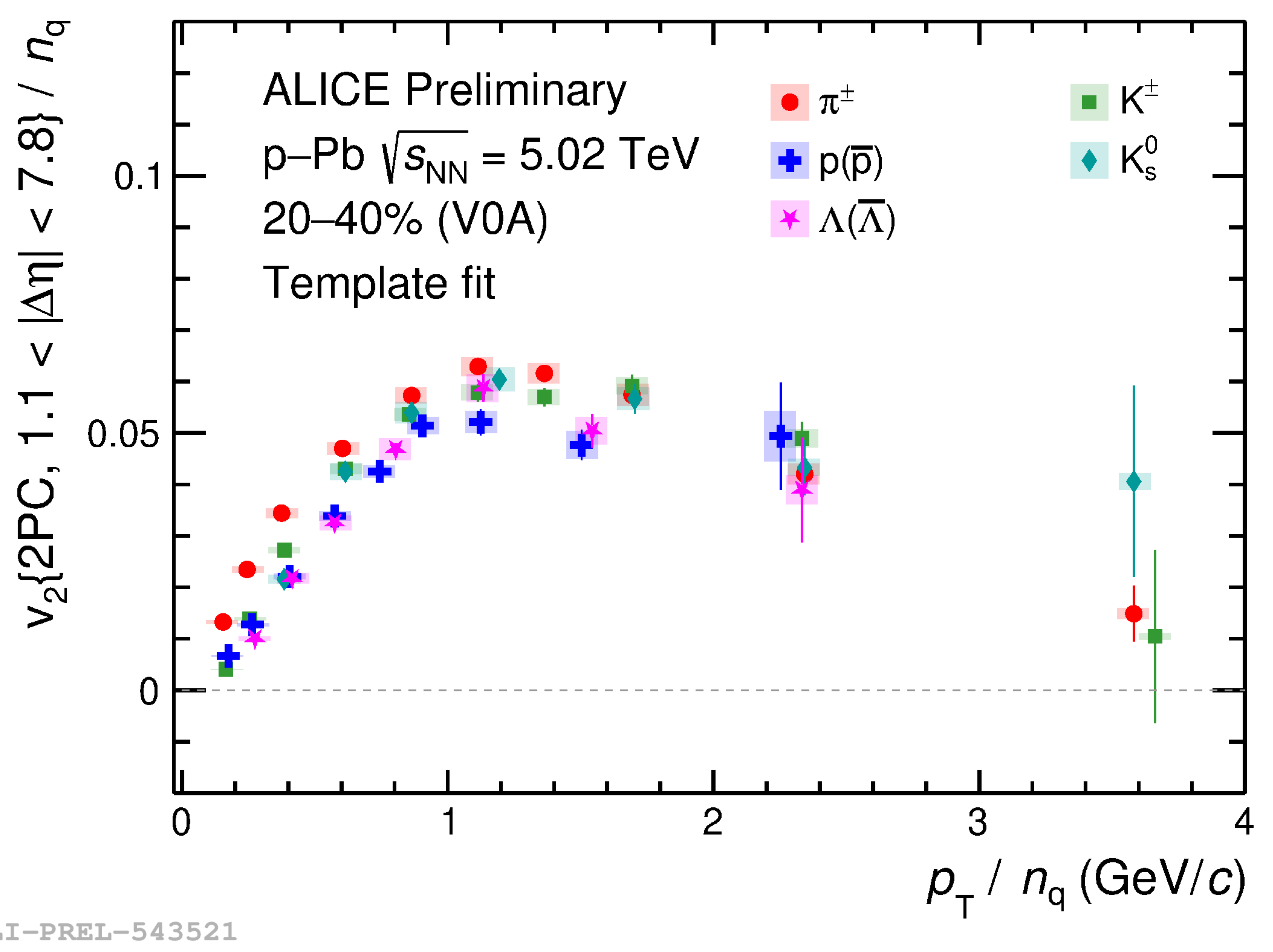
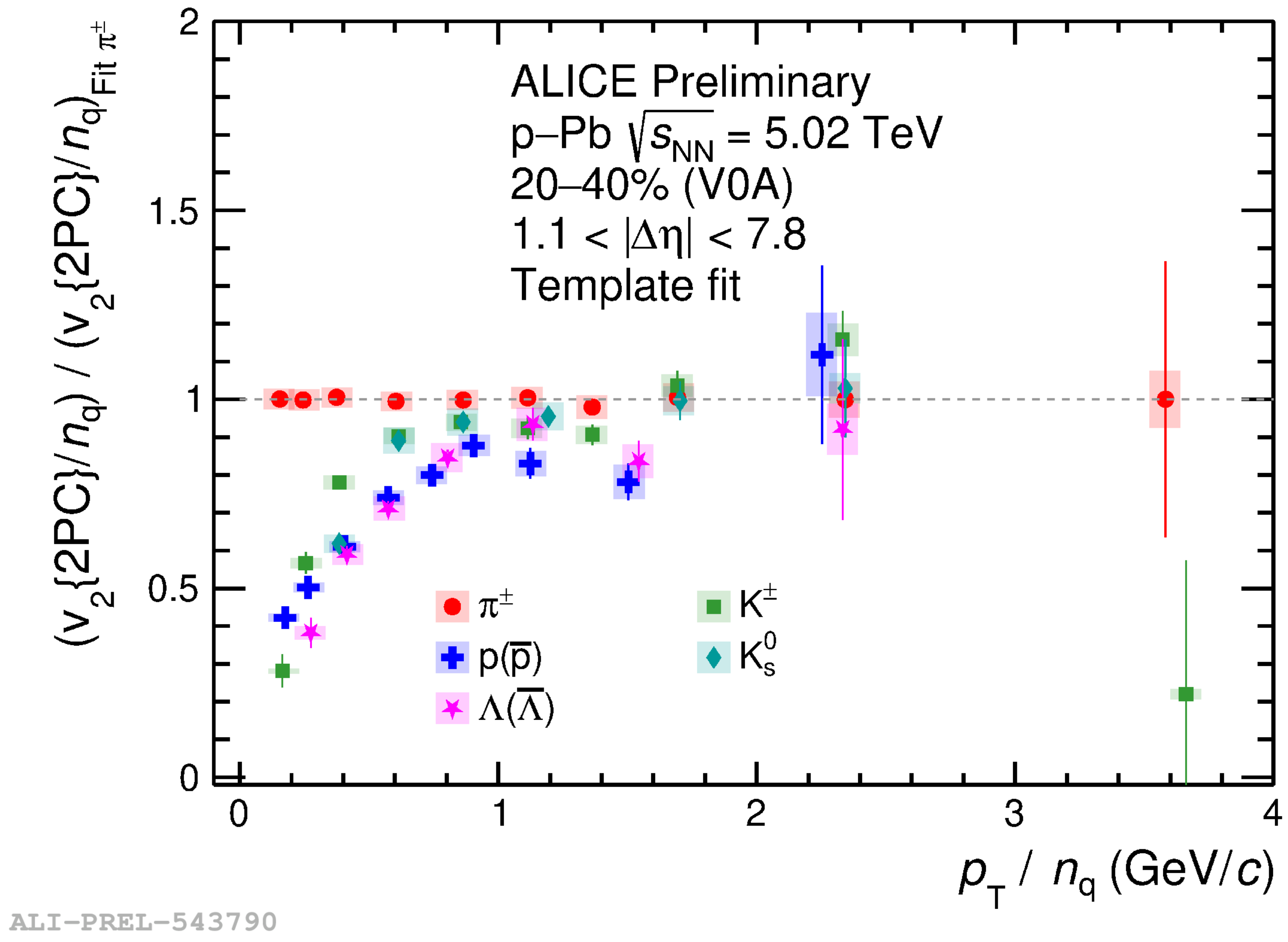
NCQ scaling and broken (40-60% p-Pb as function of KET/n_q)



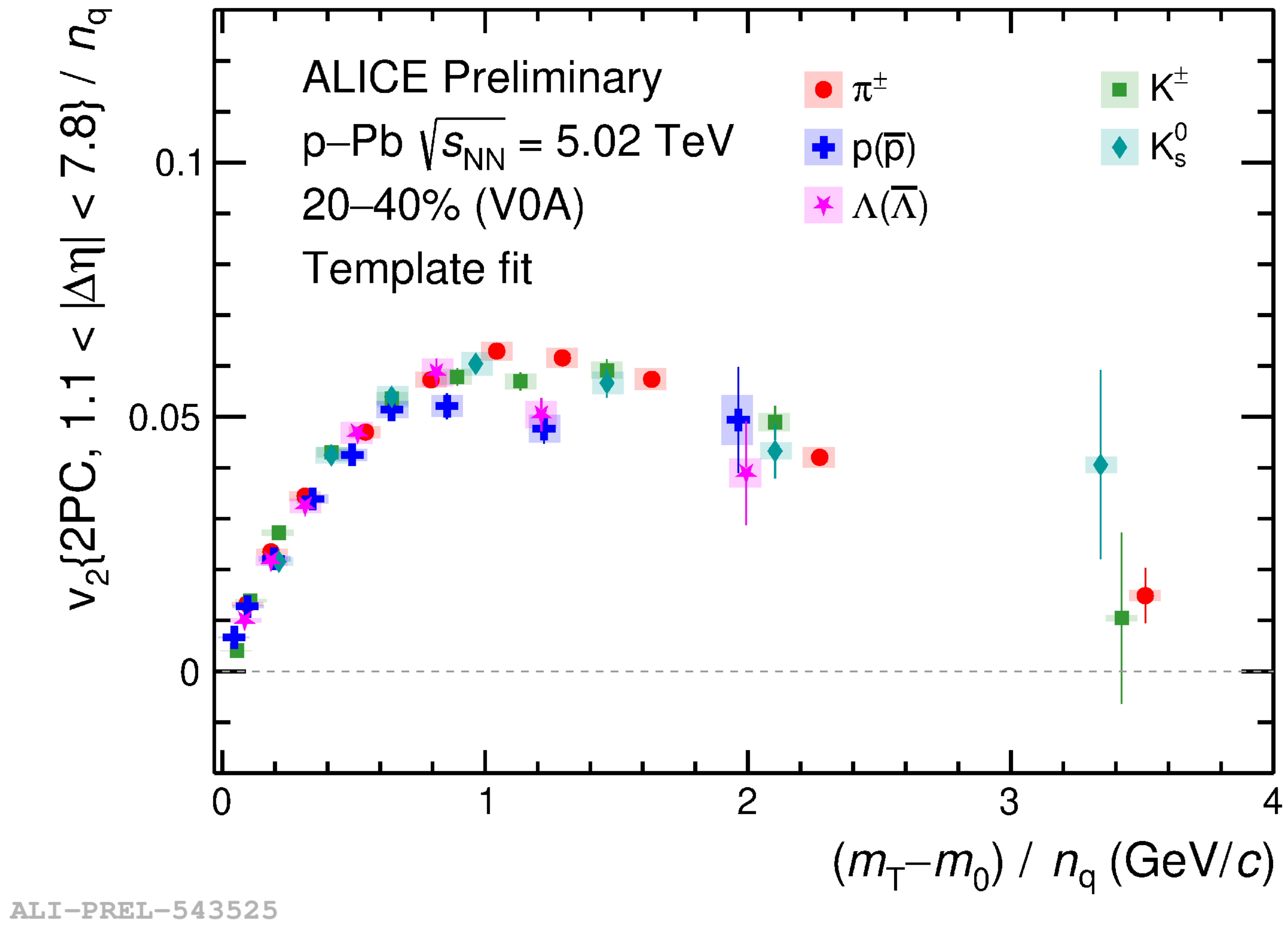


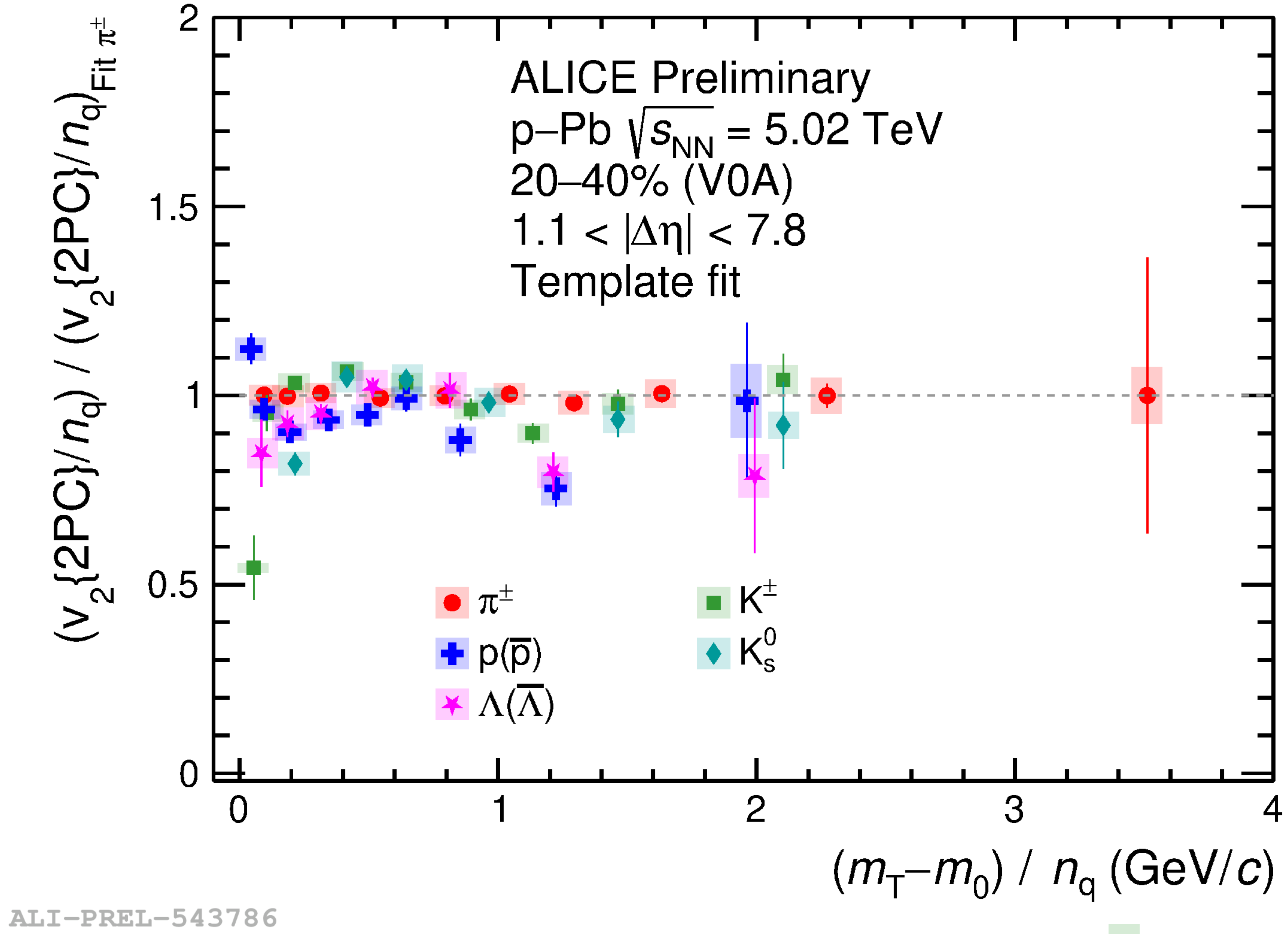
NCQ scaling and broken (20-40% p-Pb as function of p_{T}/n_q)





NCQ scaling and broken (20-40% p-Pb as function of KET/n_q)





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