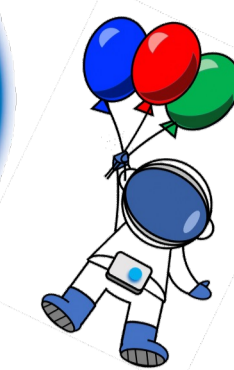# Measurements of long-range two-particle correlation over a wide pseudorapidity range in p–Pb collisions at 5.02 TeV

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Introduction

- A near-side "ridge" was observed in heavy-ion collisions and later found in pp and p–Pb collisions.
- The elliptic flow (v_2) of the identified particles shows clear mass ordering in small systems. (ALICE, PLB. 726 (2013) 164-177)

→Extending these measurements over a wider range in pseudorapidity and multiplicity dependence is important to understand the underlying dynamics and emergence of collectivity in small systems.
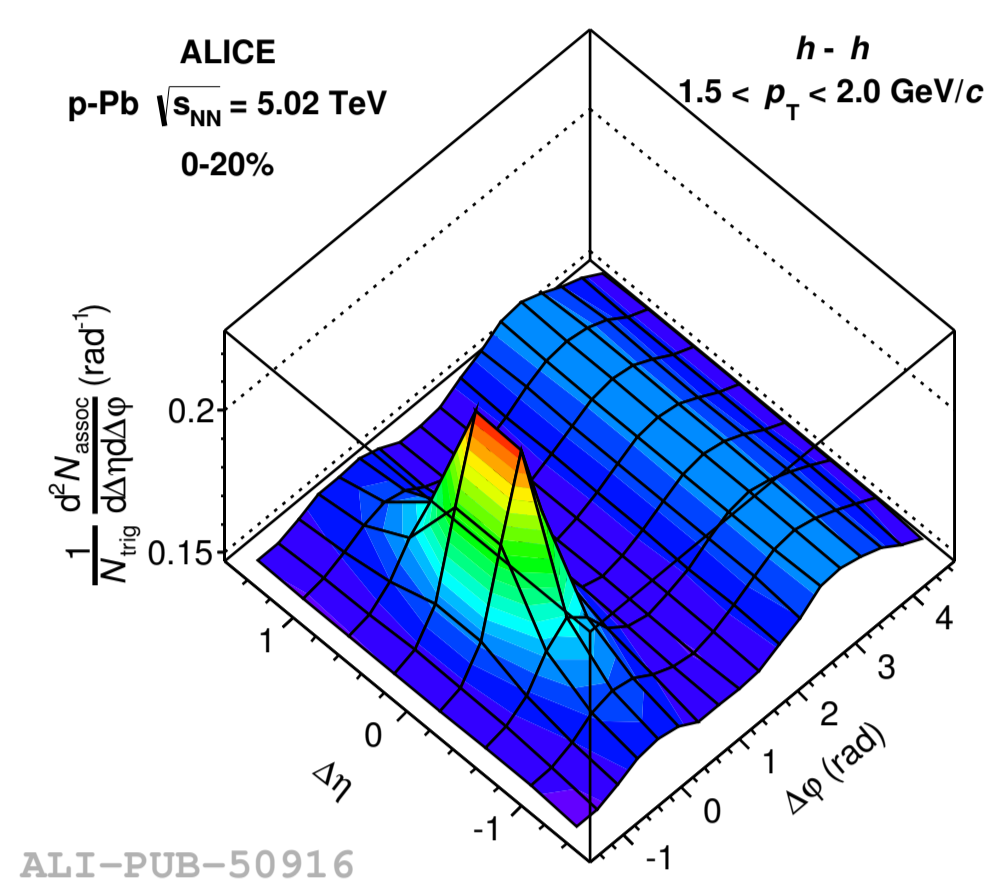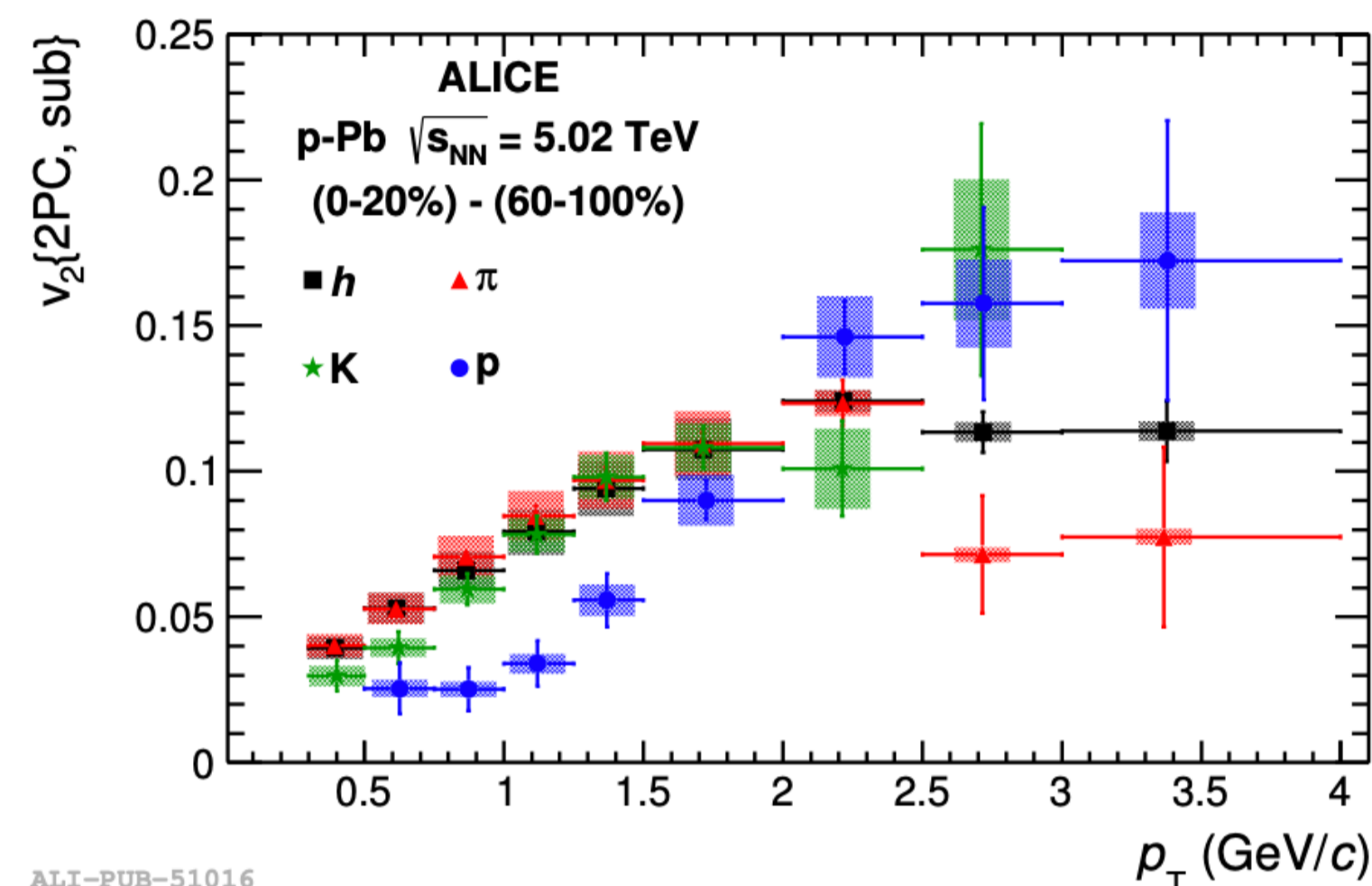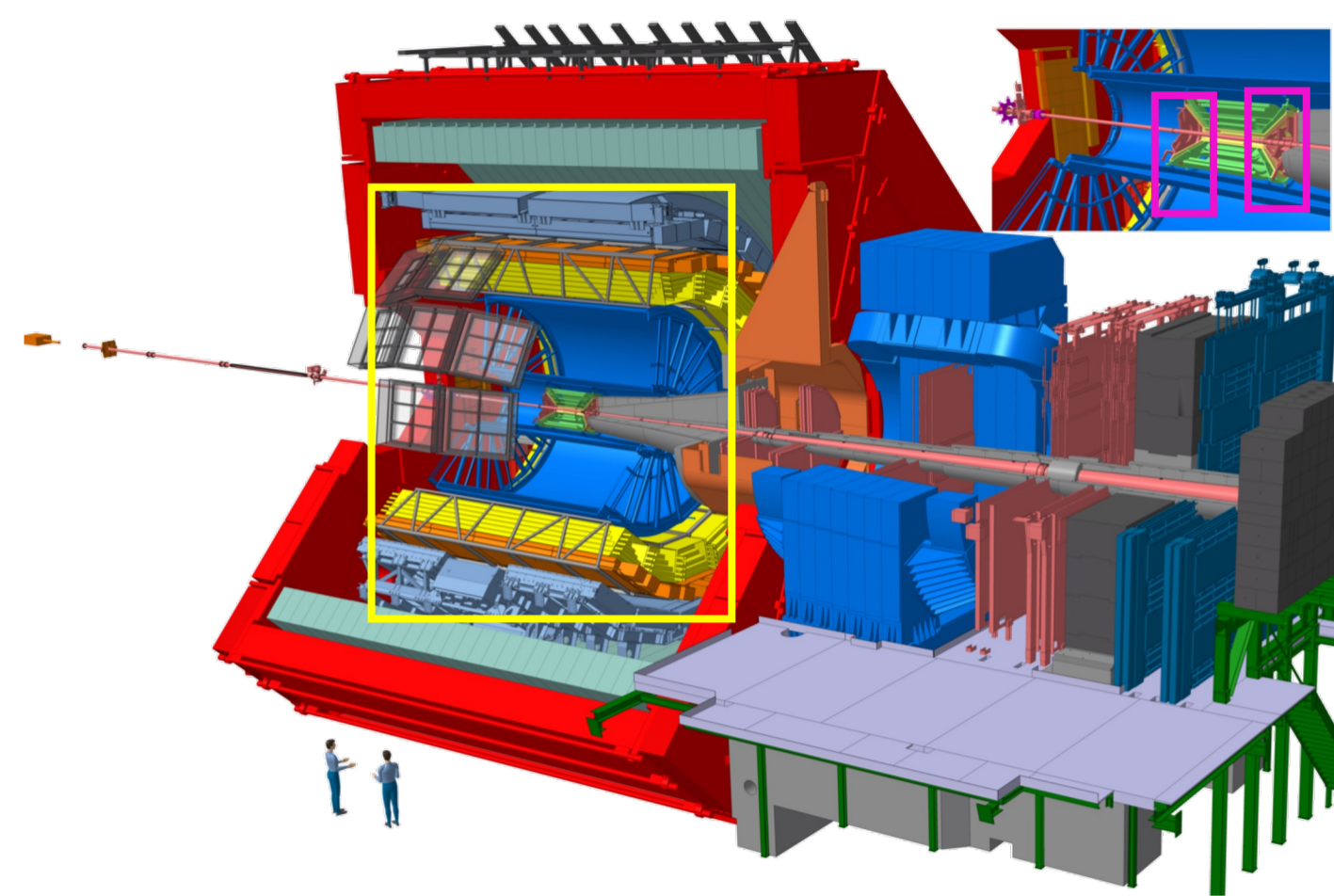

ALICE

~500 M events with MB trigger in p–Pb at 5.02 TeV

- **Inner Tracking System (ITS) and Time Projection Chamber (TPC)**
  - Charged-particle tracking
  - $|\eta|<0.8$
- **Forward Multiplicity Detector(FMD)**
  - FMD3: $-3.4<\eta<-1.7$
  - FMD1,2: $1.7<\eta<5.1$
  - Segmentation in $(\Delta\eta,\Delta\varphi)=(0.05,\pi/20)$
  - Charged-particle counter
- **V0 Detector**
  - Trigger and centrality determination
  - V0C: $-3.7<\eta<-1.7$, V0A: $2.8<\eta<5.1$

Long-range correlations up to $\Delta\eta\sim8$ and $v_2(\eta)$ at $-3.4<\eta<5.1$ by using FMD in p–Pb collisions.

FMD3 -3.4 -1.7 TPC -0.8 0.8 FMD1,2 1.7 5.1
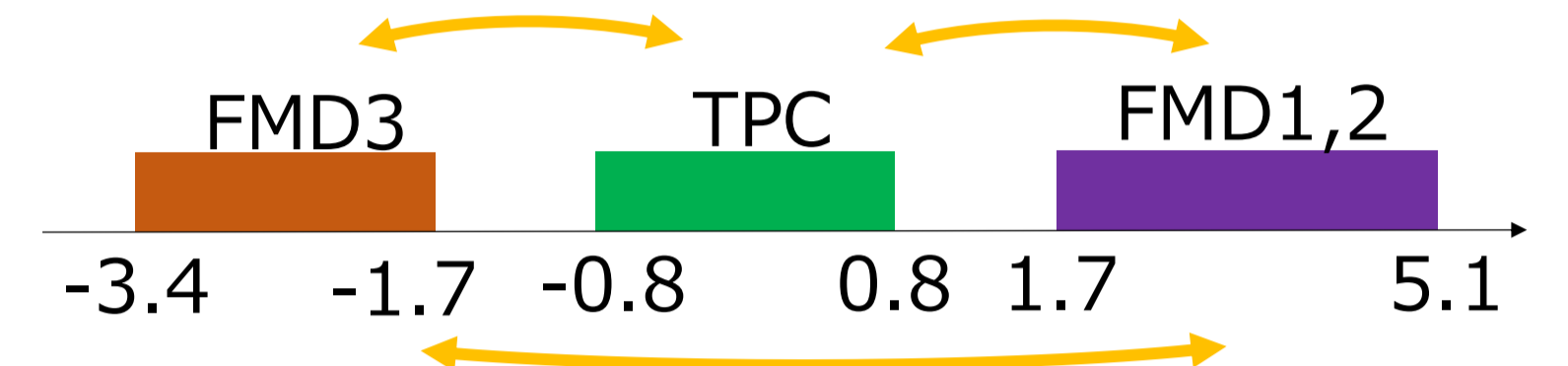
Two-particle correlations and extraction of $v_2(\eta)$

- The associated yield to a trigger particle as a function of $\Delta\eta$ and $\Delta\varphi$ is defined as

$$\frac{1}{N_{\mathrm{trig}}}\frac{d^2 N_{assoc}}{d\Delta\eta d\Delta\varphi}=\frac{S(\Delta\eta,\Delta\varphi)}{B(\Delta\eta,\Delta\varphi)}, \quad S(\Delta\eta,\Delta\varphi)=\frac{1}{N_{\mathrm{trig}}}\frac{d^2 N_{\mathrm{same}}}{d\Delta\eta d\Delta\varphi}, \quad B(\Delta\eta,\Delta\varphi)=\alpha\frac{d^2 N_{\mathrm{mixed}}}{d\Delta\eta d\Delta\varphi}.$$

The near-side ridge structure is observed in the central 0–5% (right figure) and other centralities up to 40%, while no significant "ridge" is observed in the 60–100% event class.

- To estimate and subtract the non-flow effects due to recoil jets and resonance decays, the template fit procedure developed by the ATLAS Collaboration is employed. (ATLAS, PRL 116 (2016) 172301)

$$Y^{\mathrm{temp}}(\Delta\varphi)=FY^{\mathrm{peri}}(\Delta\varphi)+G\left\{1+2\sum_{n=2}^{3}V_{n,n}\cos(n\Delta\varphi)\right\}$$

- v_2 at a certain η is extracted by assuming factorization, $V_{2,2}(\eta_a,\eta_b)=v_2(\eta_a)v_2(\eta_b)$, using TPC–FMD1,2, TPC–FMD3, and FMD1,2–FMD3 as

$$v_2(\eta_a)=\sqrt{\frac{V_{2,2}(\eta_a,\eta_b)V_{2,2}(\eta_a,\eta_c)}{V_{2,2}(\eta_b,\eta_c)}}.$$

0-5%

60-100%

Results and discussion

- A non-zero v_2 is observed over a wide pseudorapidity range for the first time in p–Pb collisions.
  - Significant pseudorapidity dependence for all four centrality classes.
  - v_2 in the Pb-going direction (positive η) is larger than in the p-going direction (negative η).
- In a fixed range of pseudorapidity, v_2 depends on the local multiplicity, but at fixed local multiplicity, it depends on the pseudorapidity.
- The v_2 in p–Pb collisions is comparable with the v_2 in peripheral Pb–Pb collisions (ALICE, PLB 762 (2016) 376–388), where their multiplicities at forward pseudorapidity are comparable.
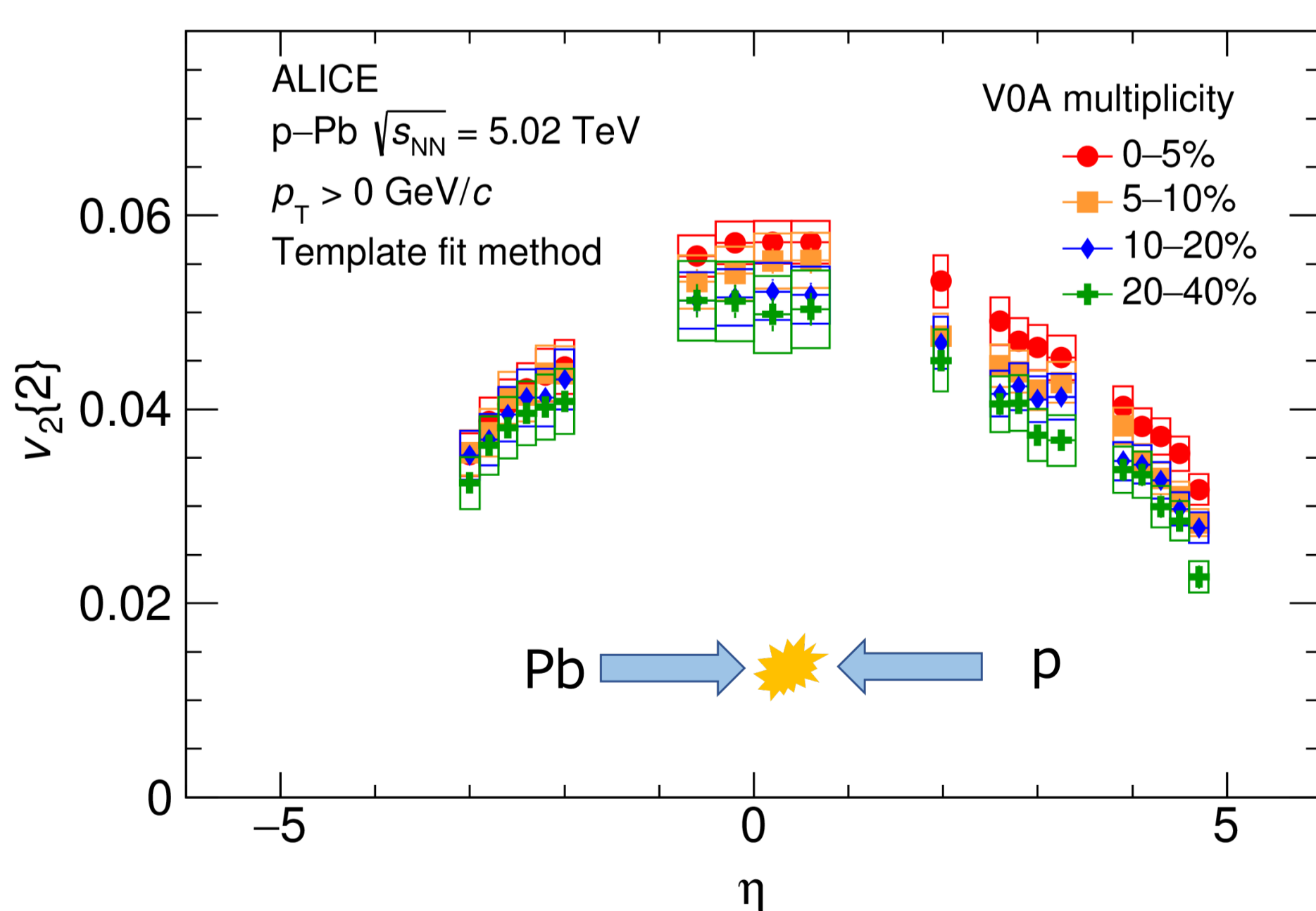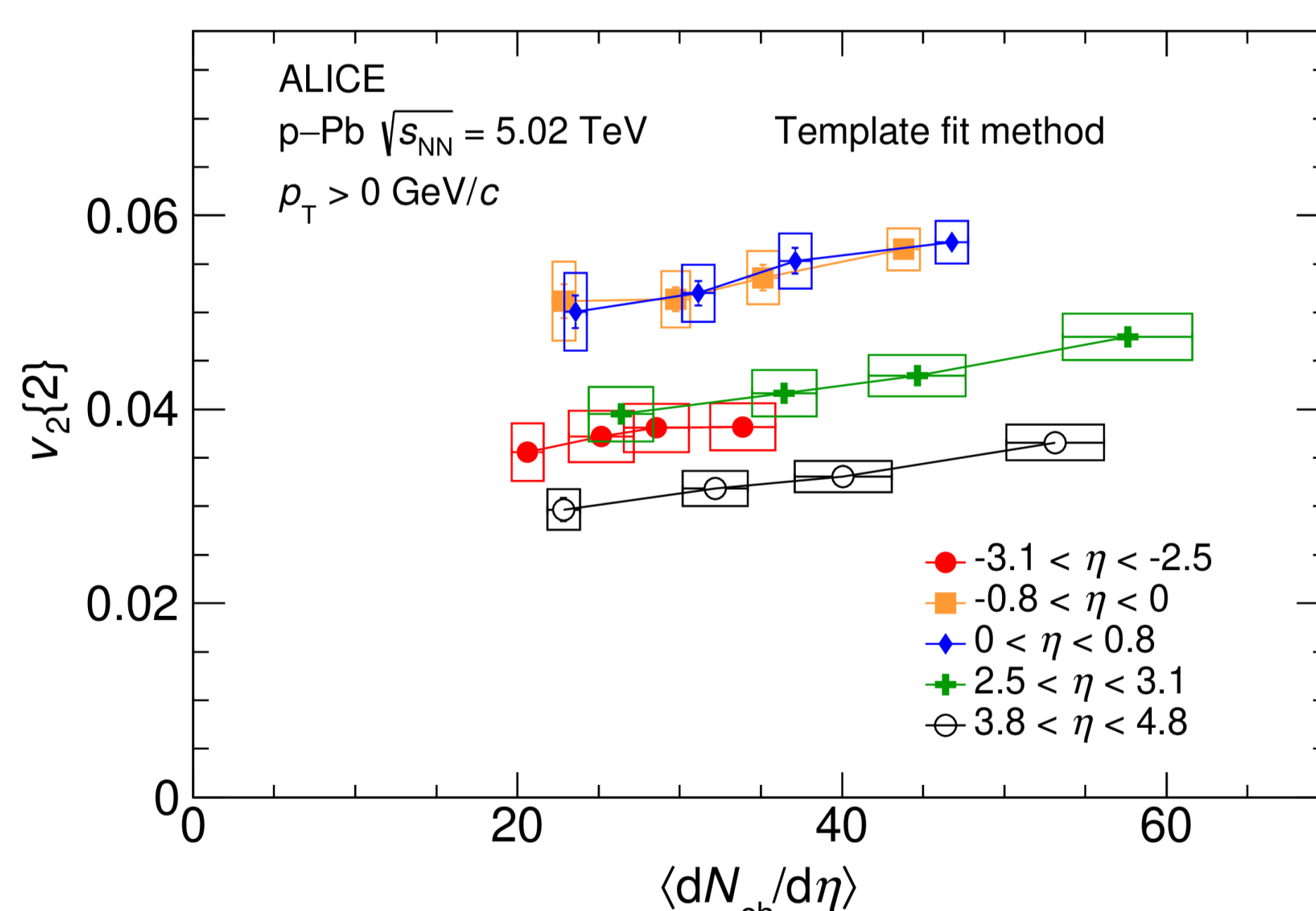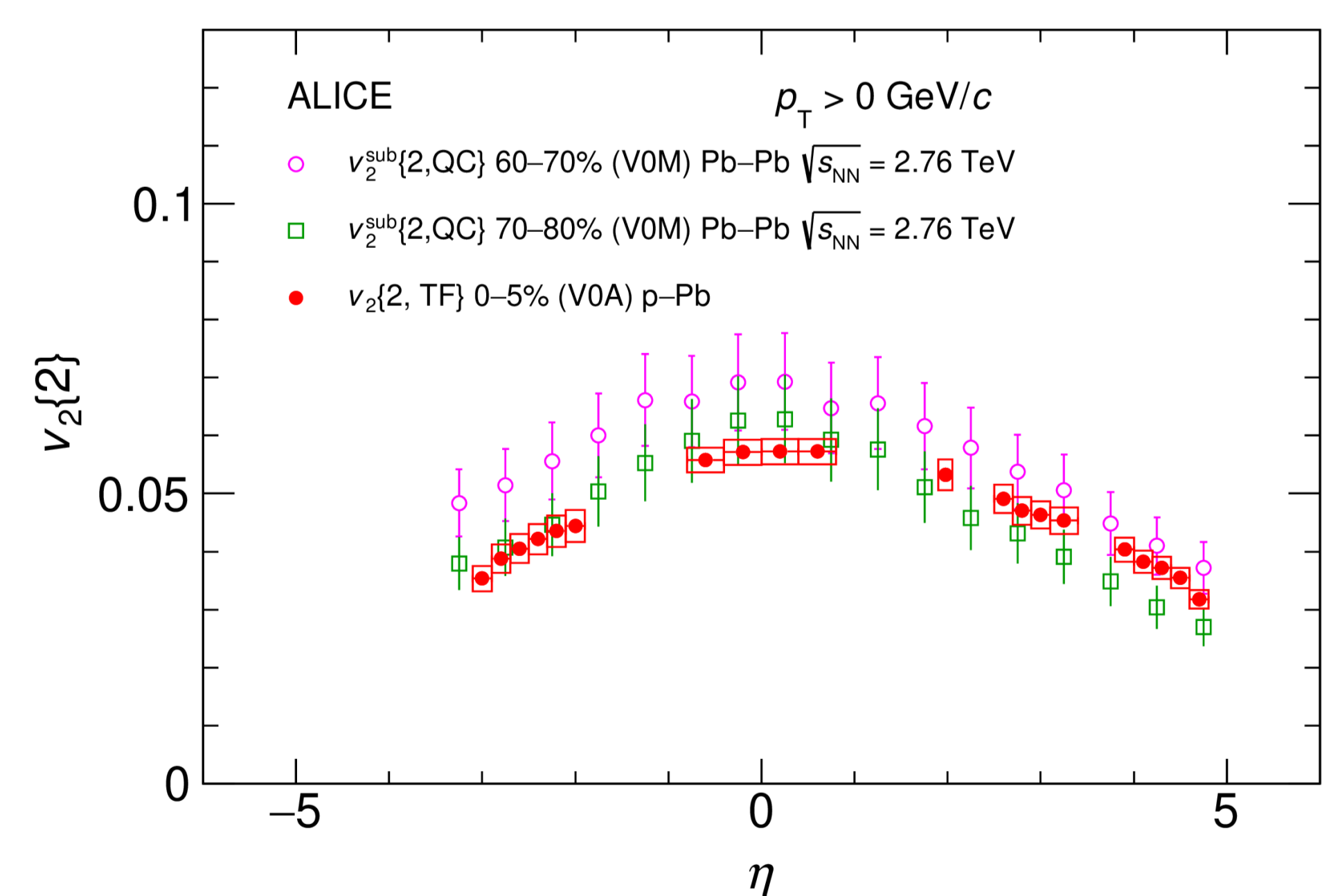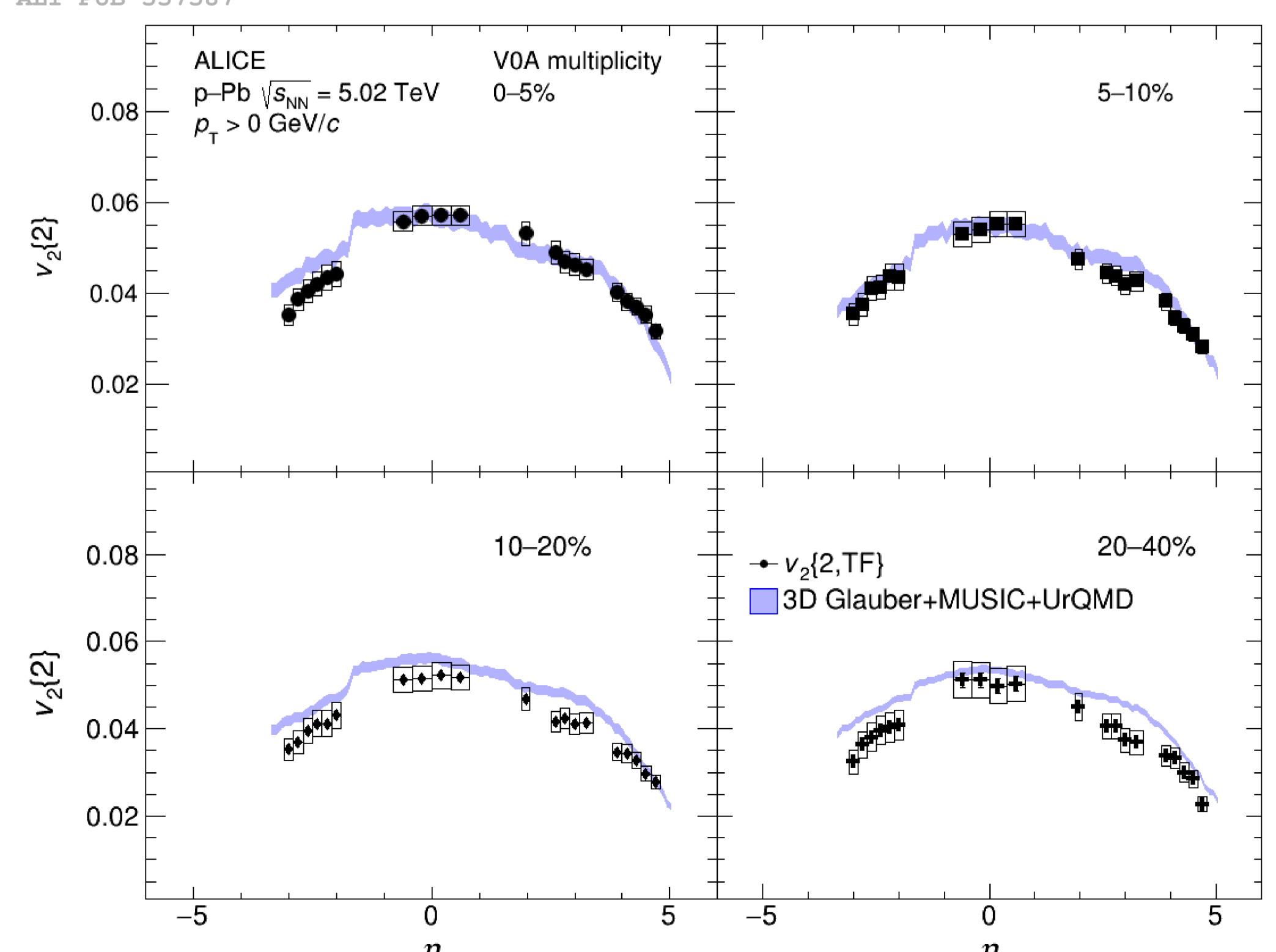

- v_2 results are compared to the hydrodynamical calculations. (W. Zhao et al., PRL 129 (2022) 252302)
  - 3D Glauber as initial condition + viscous hydrodynamics based on MUSIC + UrQMD
- The hydrodynamical model describes $v_2(\eta)$ in 0–5% and 5–10%, while it somewhat overestimates it in 10–20% and 20–40% at both forward and backward rapidity.

Summary

- The significant ridge structure is observed up to $\Delta\eta\sim8$ in 0–5% p–Pb collisions at 5.02 TeV.
- Non-zero v_2 is observed over a wide pseudorapidity range after the non-flow subtraction with the template fit approach, and v_2 depends on charged-particle pseudorapidity density.
- The v_2 measurements of central p–Pb and peripheral Pb–Pb collisions are comparable at similar multiplicity.
- The hydrodynamical model reproduces $v_2(\eta)$ well in up to 0–10%, which suggests the emergence of collective flow even at forward and backward rapidity in p–Pb collisions.