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VIRTUAL EDITION

Measurement of the jet-particle v_2 in p–Pb and Pb–Pb collisions at 5.02 TeV with ALICE at the LHC

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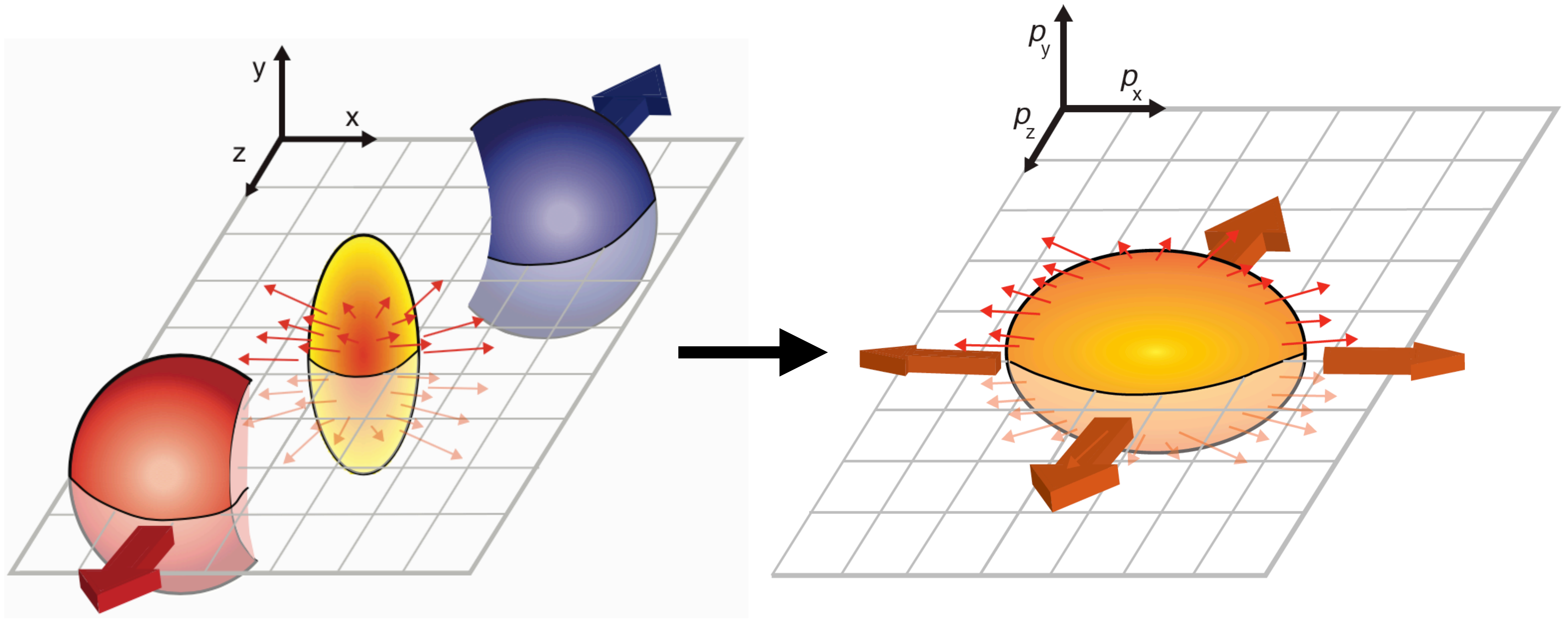
ALICE

CENTRAL CHINA NORMAL UNIVERSITY

LPC Particules pLasmas Univers applicationS
Laboratoire de Physique de Clermont

Anisotropic flow in heavy-ion collisions

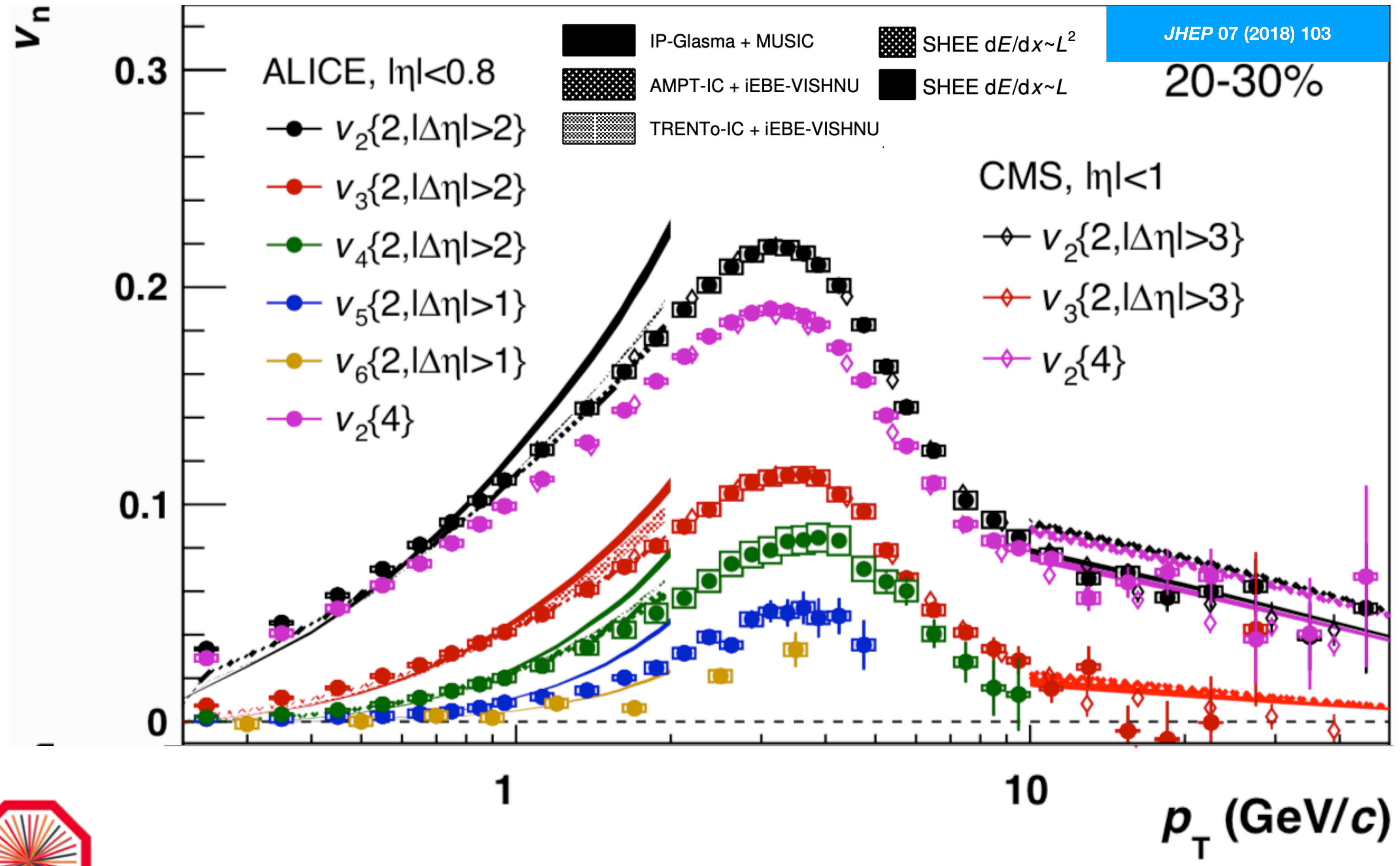


➡The **azimuthal anisotropy** is studied by a Fourier expansion of azimuthal distribution of final-state particles:

$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T\,dp_T\,dy}\left(1+\sum_{n=1}^{\infty}2v_n\cos(n(\varphi-\Psi_n))\right)$$

Flow coefficients $v_n = \langle\cos(n(\varphi-\Psi_n))\rangle$

n=2, elliptic flow



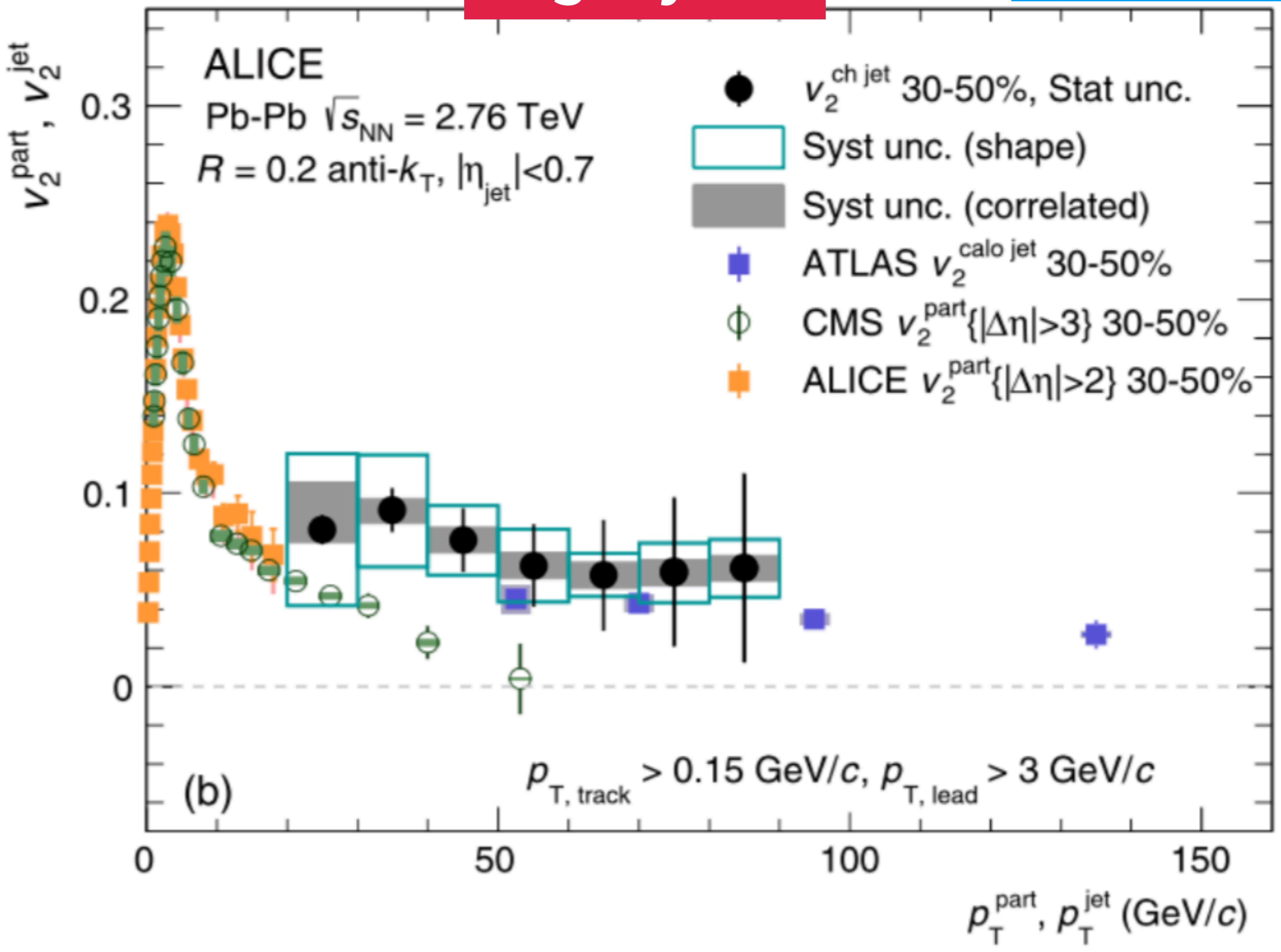
Elliptic flow in heavy-ion collisions:

- **Low and intermediate p_T:** collective hydrodynamic evolution
- **High p_T:** path-length dependent parton energy loss in the QGP medium

High-p_T v_2 from large to small collision systems

Large system

Phys.Lett. B 753 (2016) 511-525



- Consistent jet v_2 and high-p_T charged-particle v_2 in Pb–Pb collisions interpreted by jet-quenching effect
  - High-p_T charged particles originate dominantly from jet fragmentation

High-p_T v_2 from large to small collision systems

Large system

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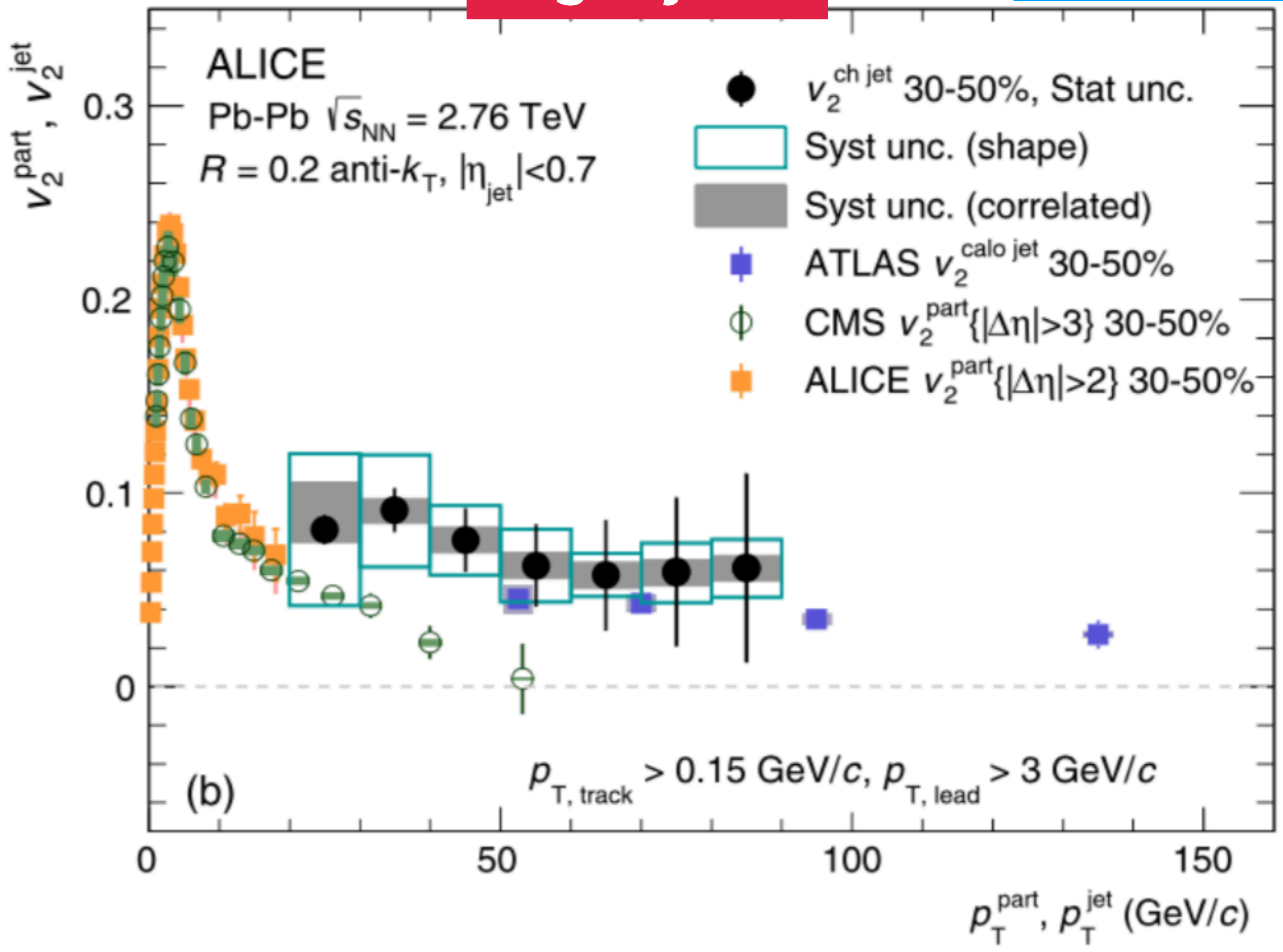
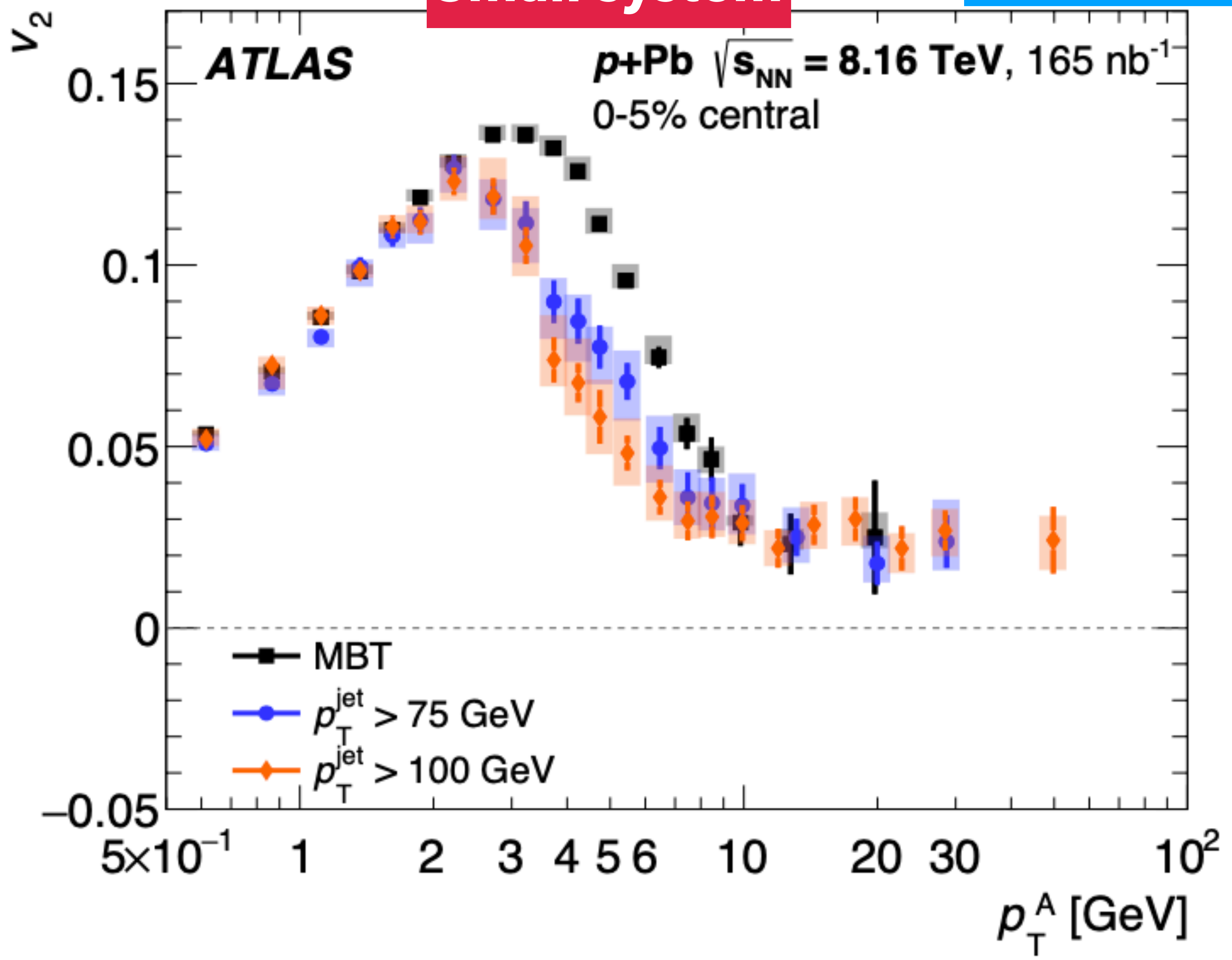


Small system

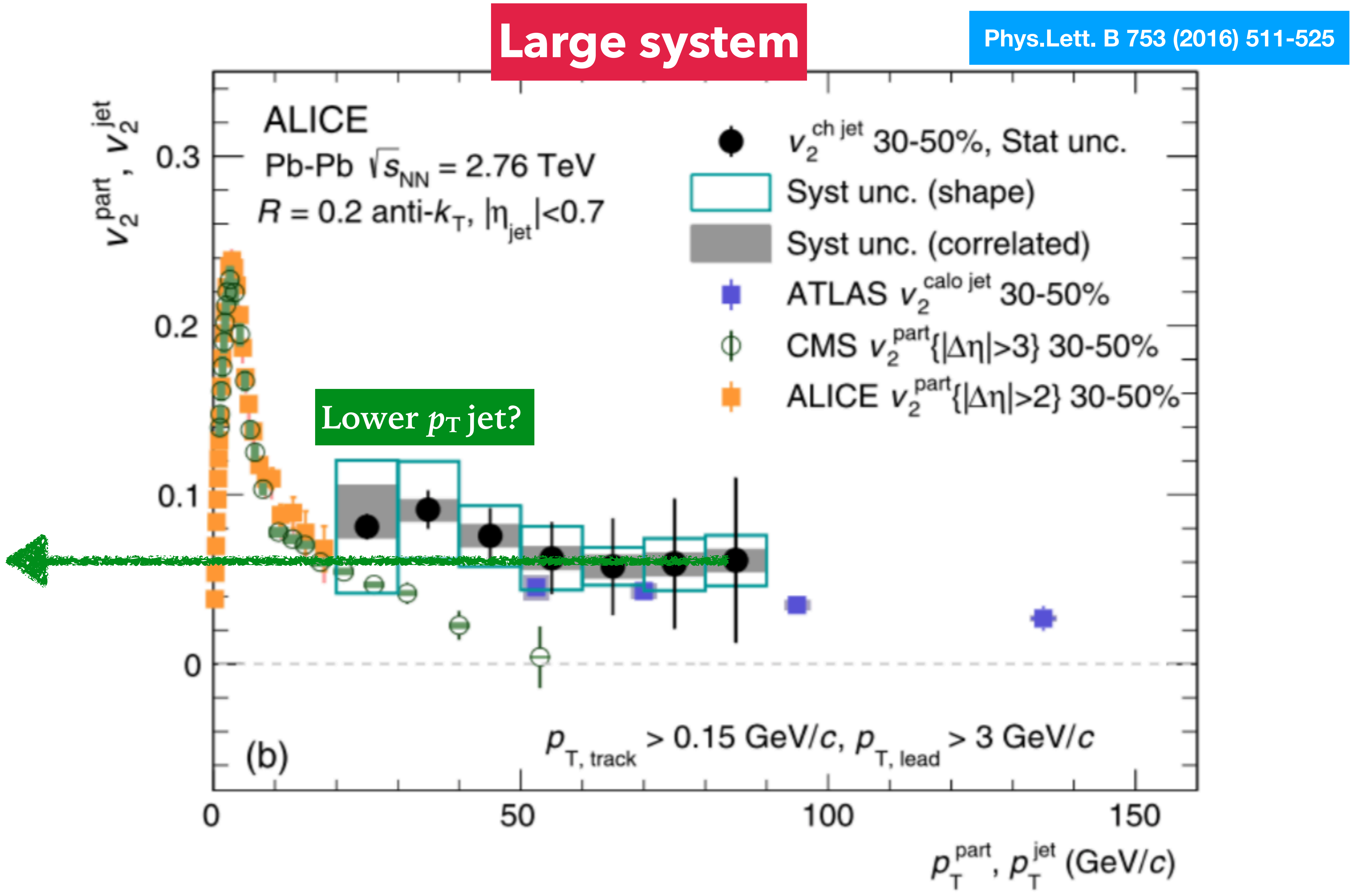
Phys. J. C 80 (2020) 73

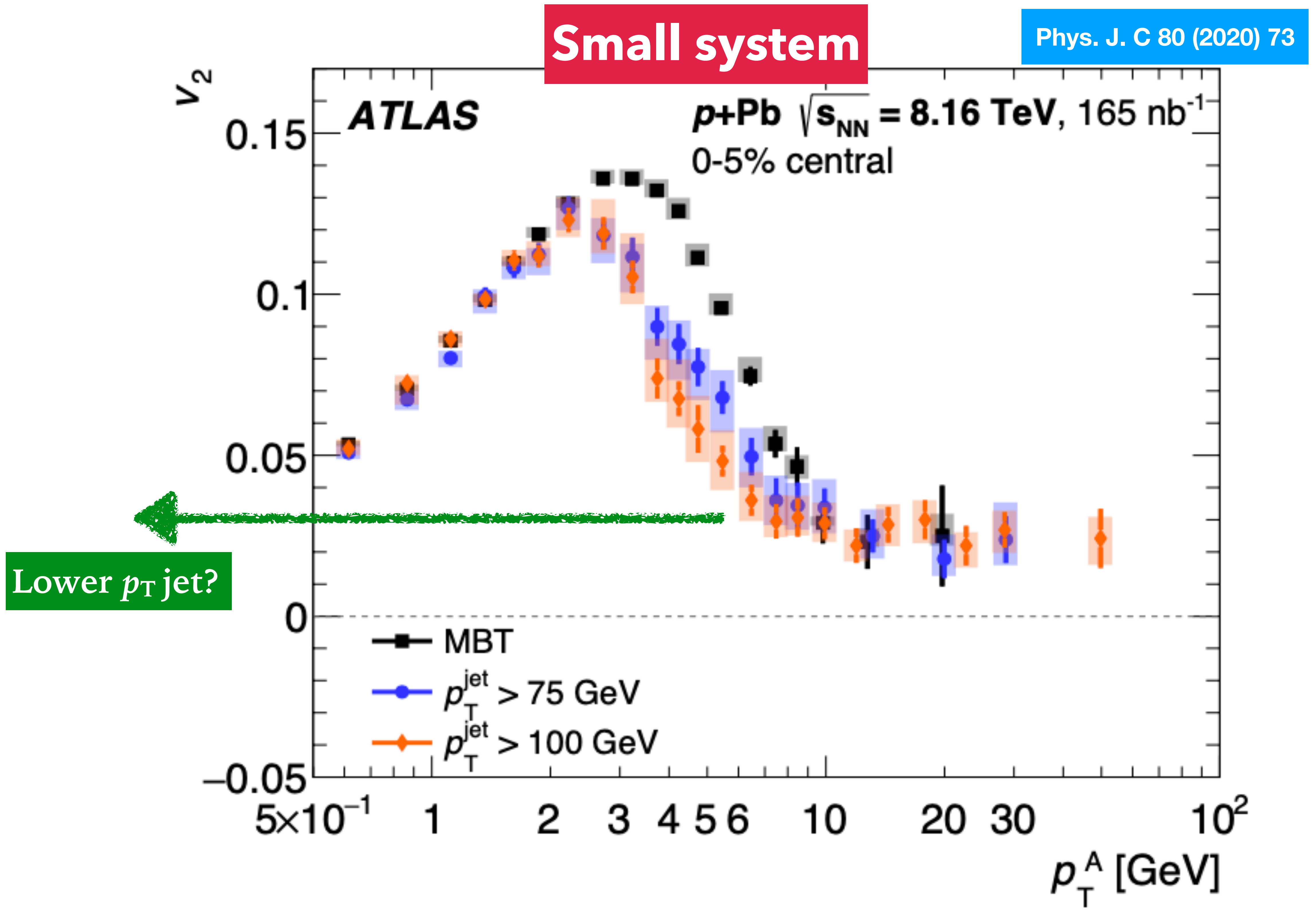


- Consistent jet v_2 and high-p_T charged-particle v_2 in Pb–Pb collisions interpreted by jet-quenching effect
  - High-p_T charged particles originate dominantly from jet fragmentation
- However, in small systems, a non-zero v_2 is observed at high p_T, for both minimum bias and jet-triggered events
  - — no jet-quenching effect is observed from the measurement of R_{pPb} [1] and hadron-jet correlations [2] in small systems

[1] JHEP 1811 (2018) 013
[2] Phys. Lett. B 783 (2018) 95

High-p_T v_2 from large to small collision systems





In this presentation, the v_2 of particles produced in jets is measured:

- lower p_T can be accessed
- further separation of hard and soft components in collectivity in small system

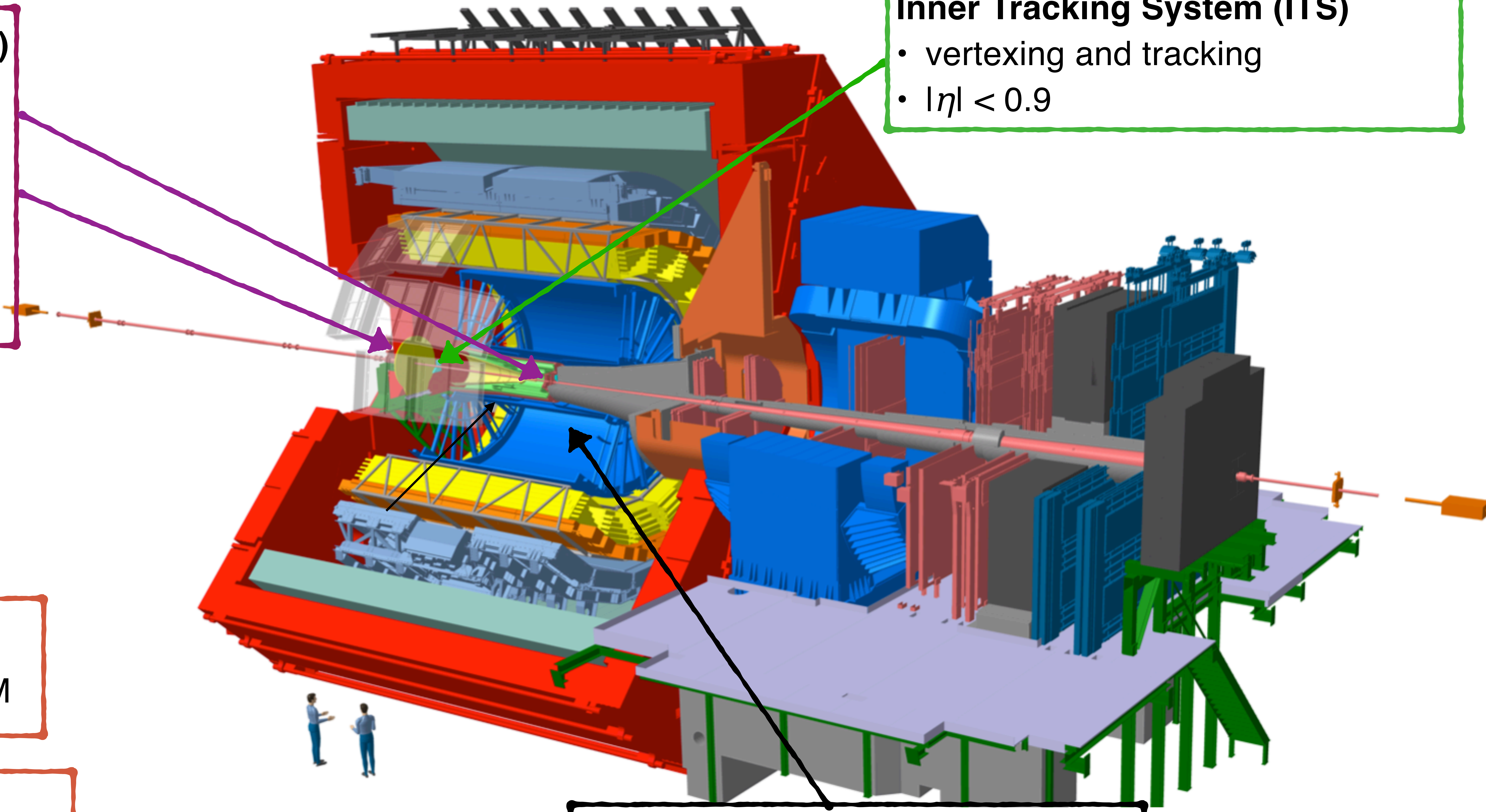
[1] JHEP 1811 (2018) 013
[2] Phys. Lett. B 783 (2018) 95

ALICE Detector

- **Forward Multiplicity Detector (FMD)**
  - FMD3: $-3.4<\eta<-1.7$
  - FMD1&2: $1.7<\eta<5.1$
- **V0**
  - Trigger and centrality
  - V0C: $-3.7<\eta<-1.7$, V0A: $2.8<\eta<5.1$

Inner Tracking System (ITS)

- vertexing and tracking
- $|\eta| < 0.9$



Pb–Pb 5.02 TeV (2015)
Minimum bias triggered events ≈ 60M

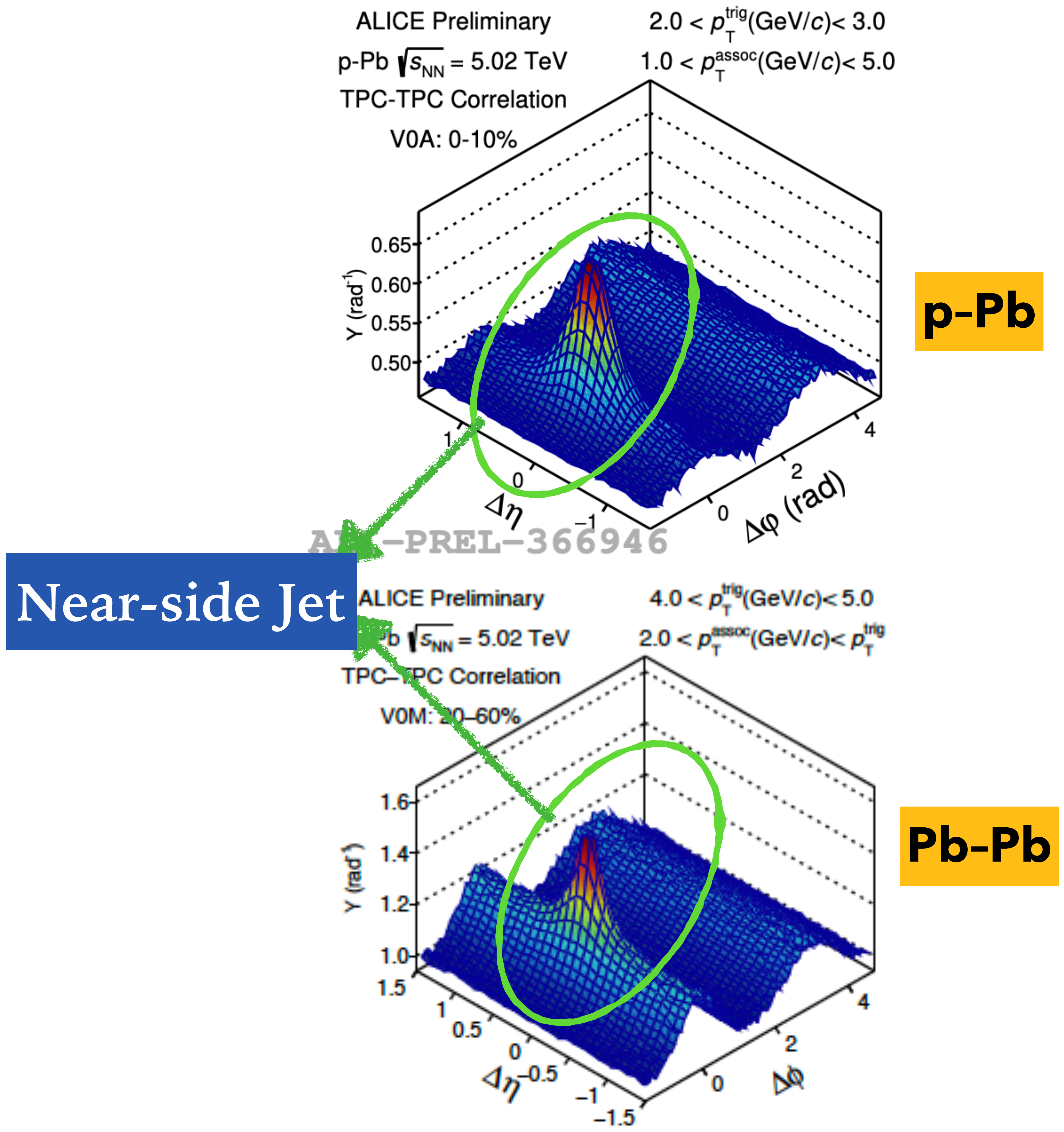
p–Pb 5.02 TeV (2016)
Minimum bias triggered events ≈ 520M

Time Projection Chamber (TPC)

- Tracking of charged particles
- $|\eta| < 0.9$

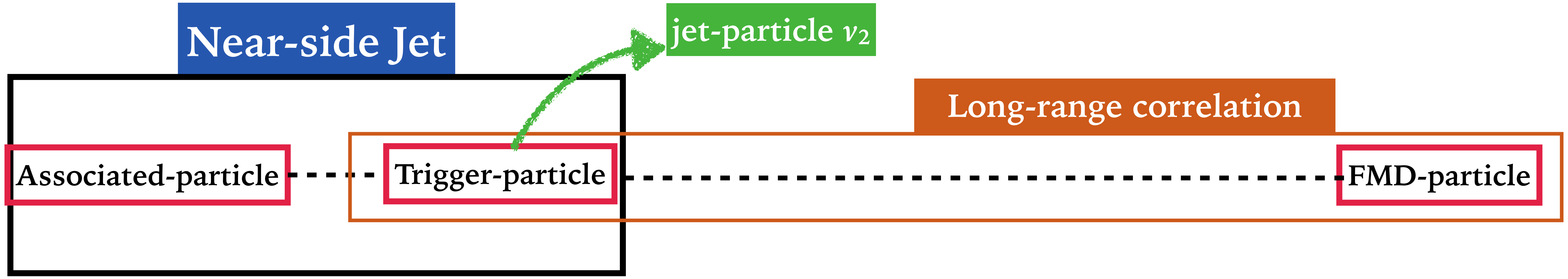
Analysis Strategy

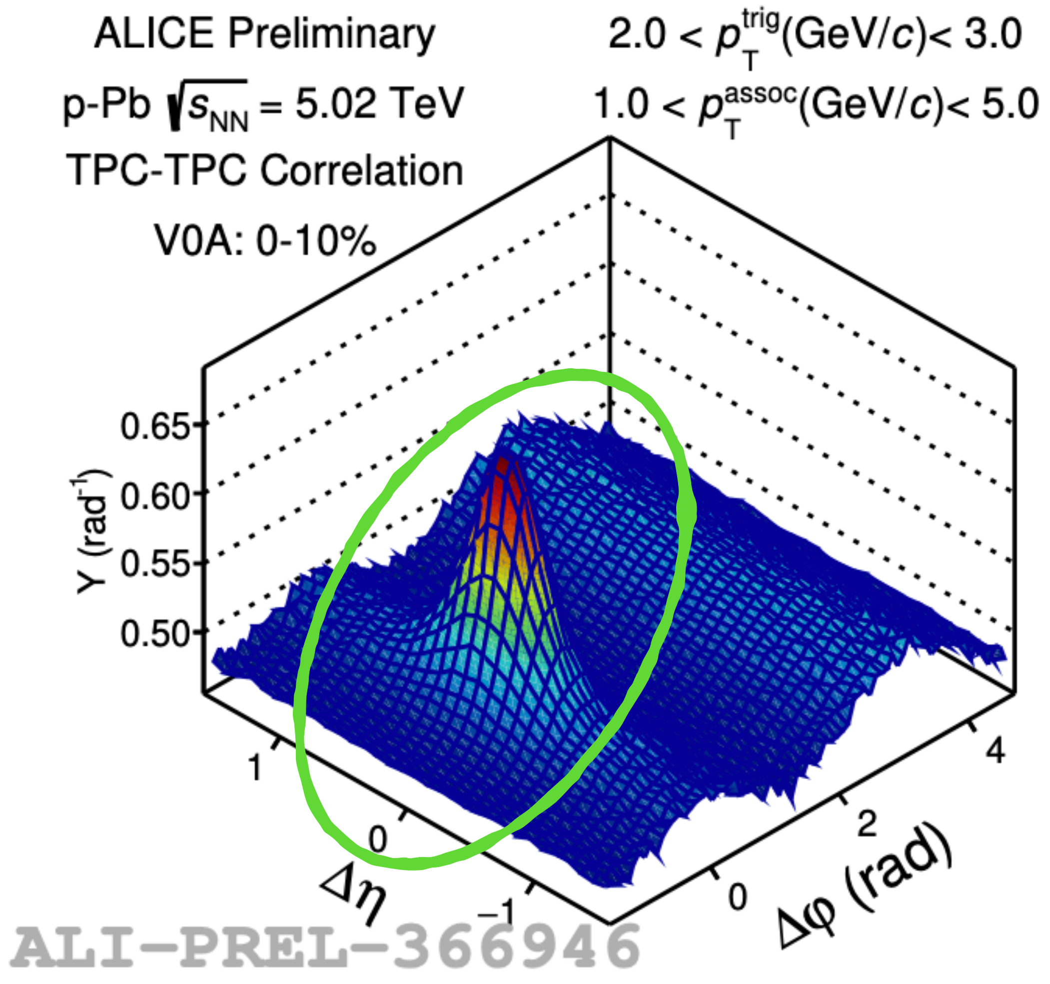
- Two-particle correlations to isolate the particles from near-side jet peak
  - Selection of same-sign charged particles at midrapidity ($|\eta|<0.8$) as trigger and associated particles



Analysis Strategy

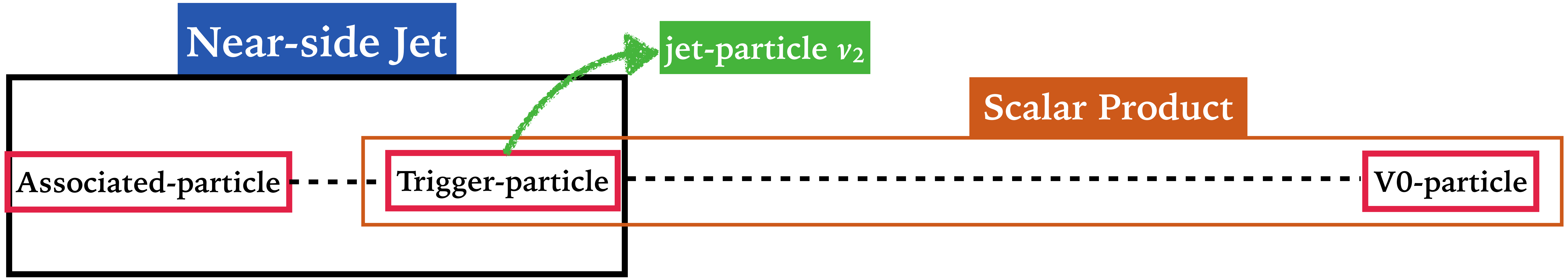
- Two-particle correlations to isolate the particles from near-side jet peak
  - Selection of same-sign charged particles at midrapidity ($|\eta|<0.8$) as trigger and associated particles
- Calculation of jet-particle v_2
  - p–Pb: three-particle correlations

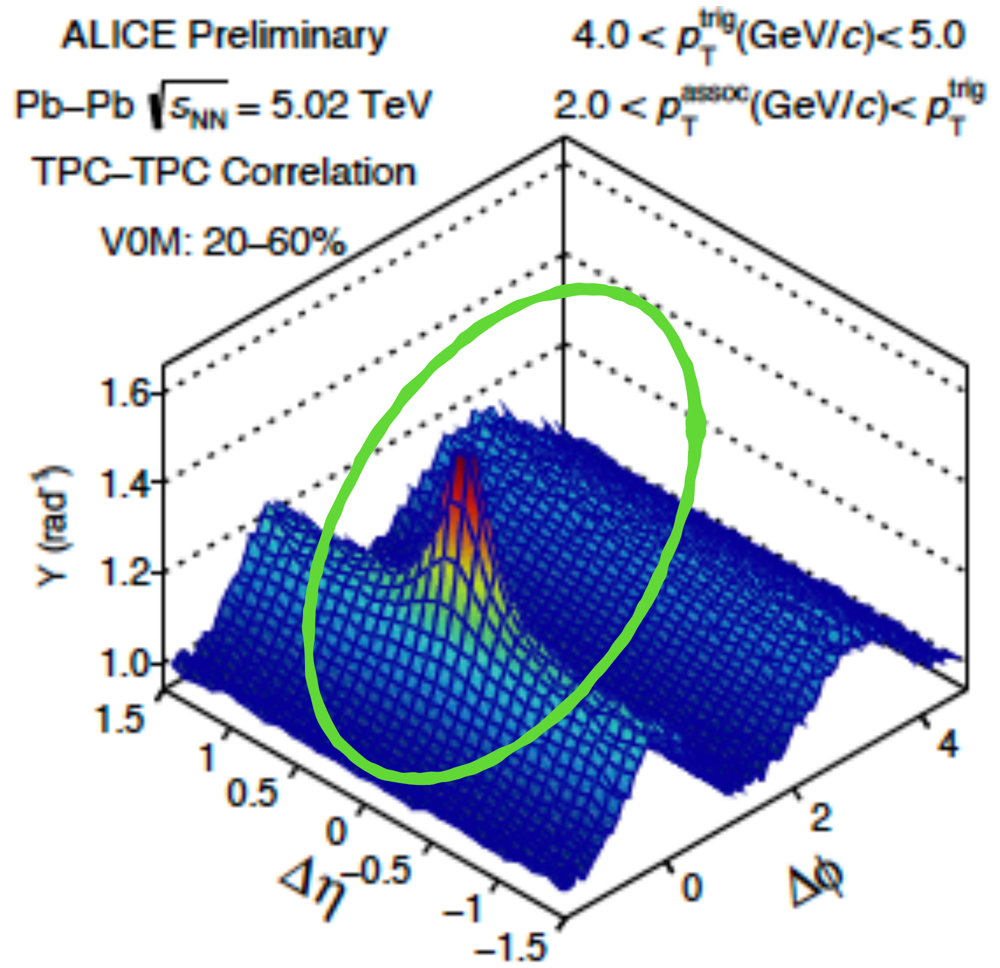




p-Pb

  - Pb–Pb: two-particle correlations + Scalar product method

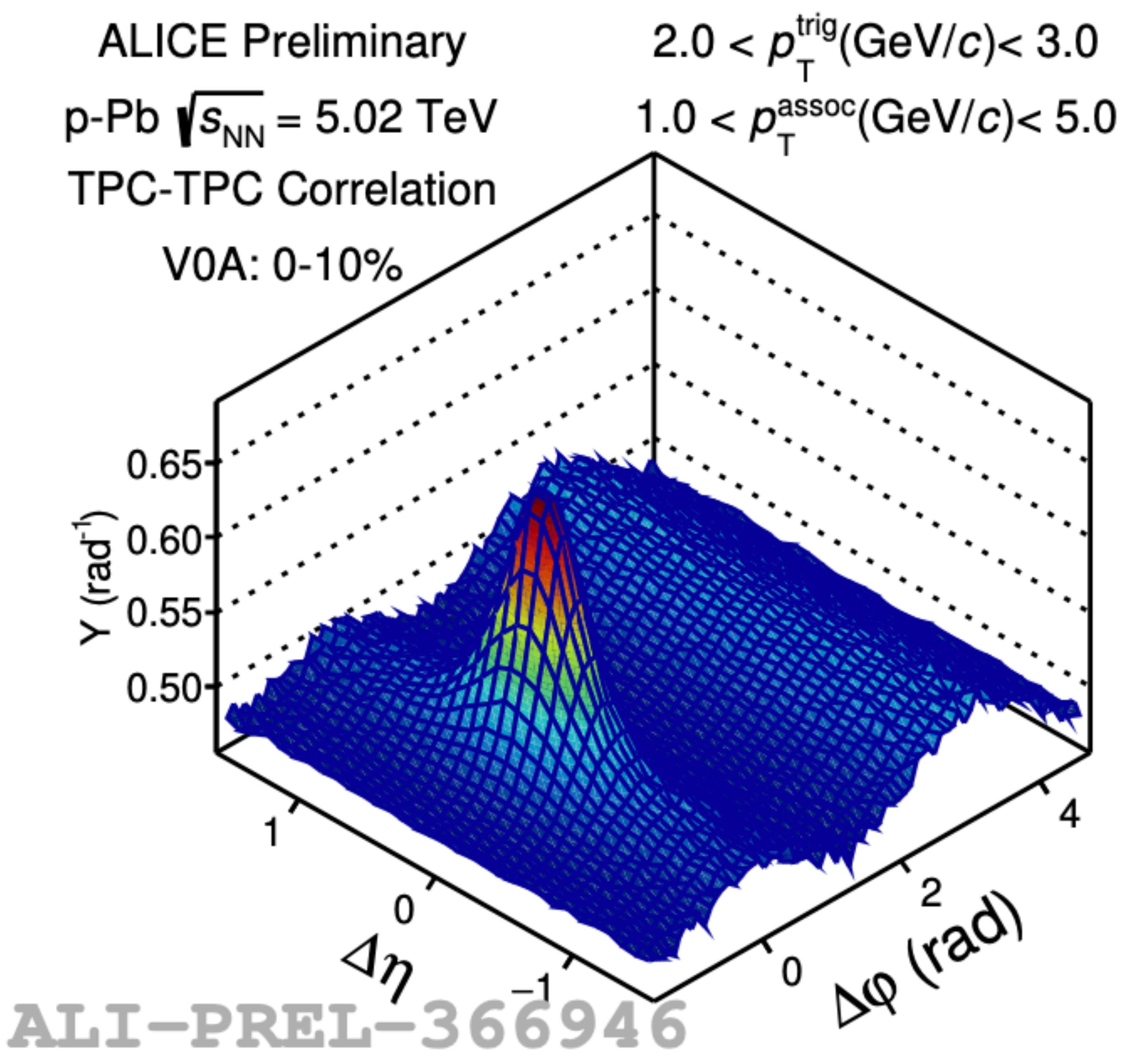




Pb-Pb

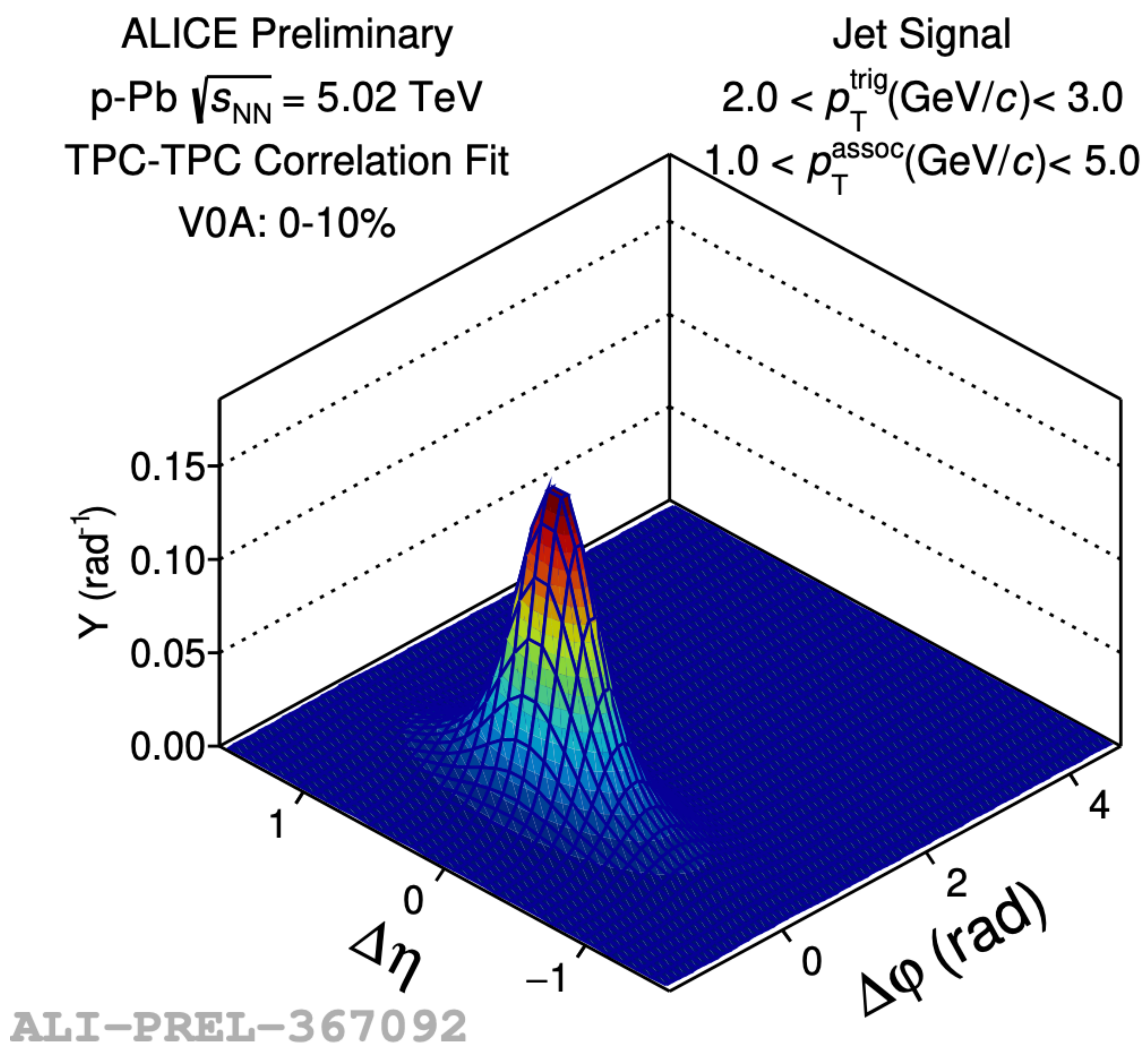
Extraction of jet signal

Data

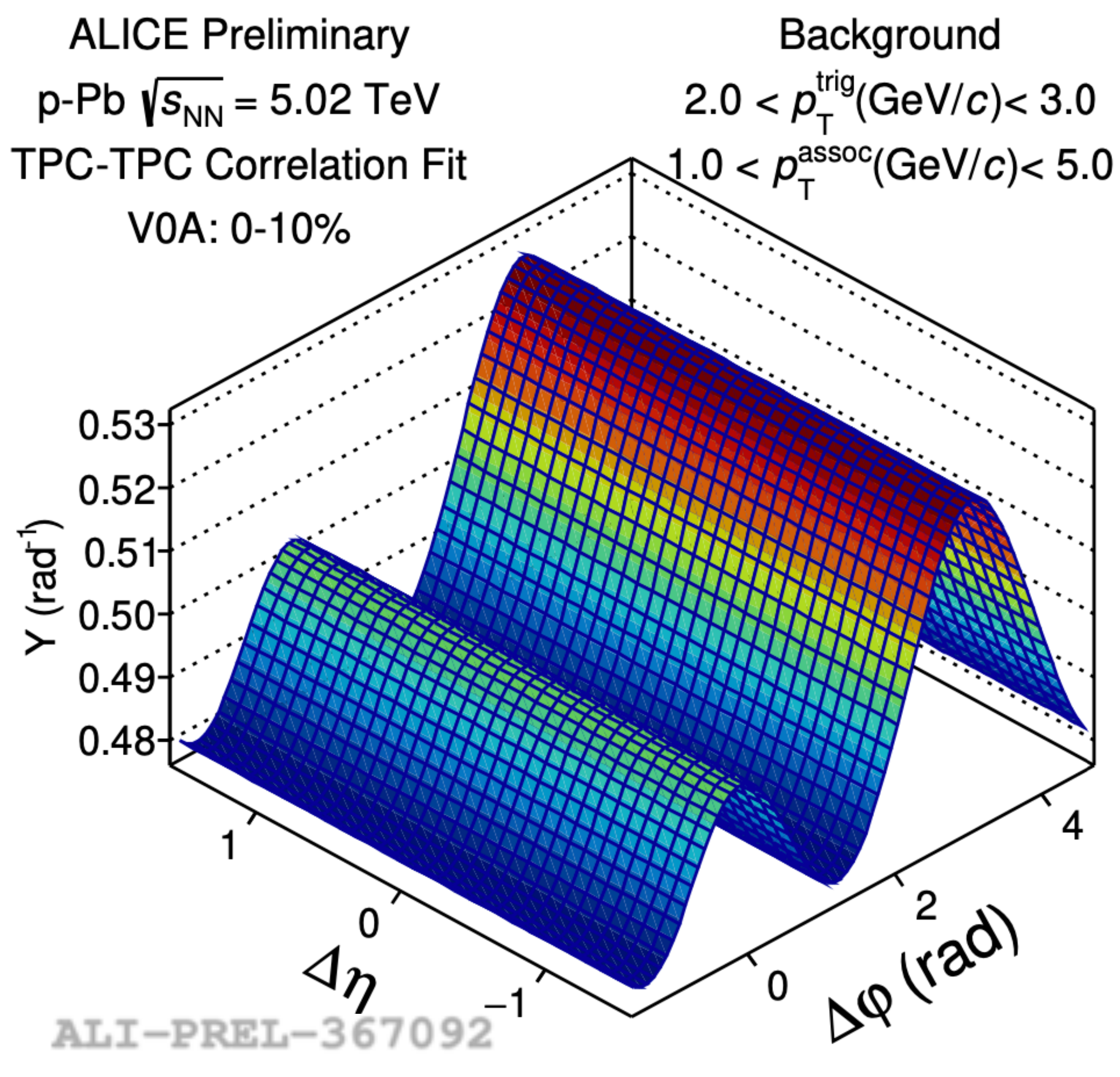


Fit →

Fit jet signal (S)

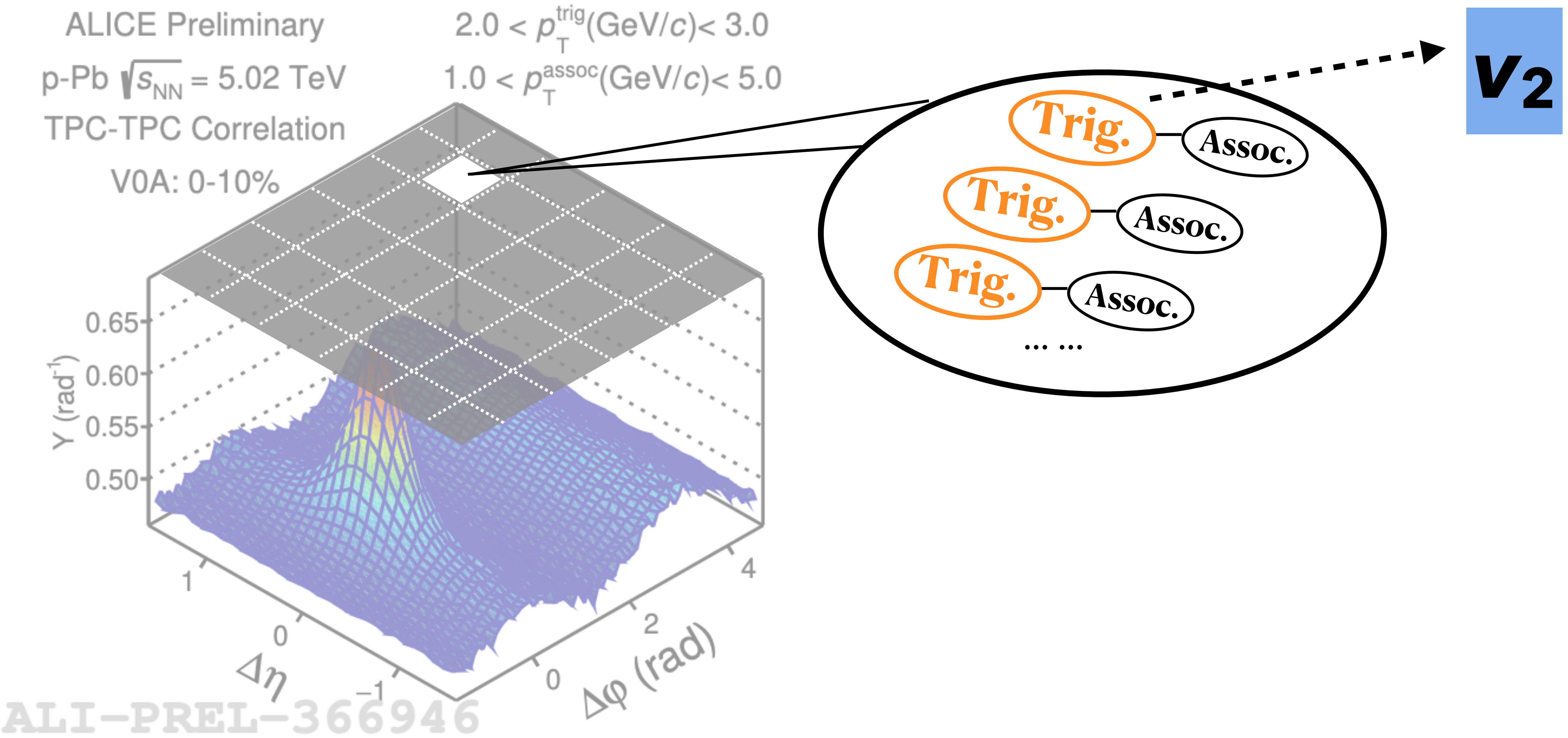


Fit background (B)



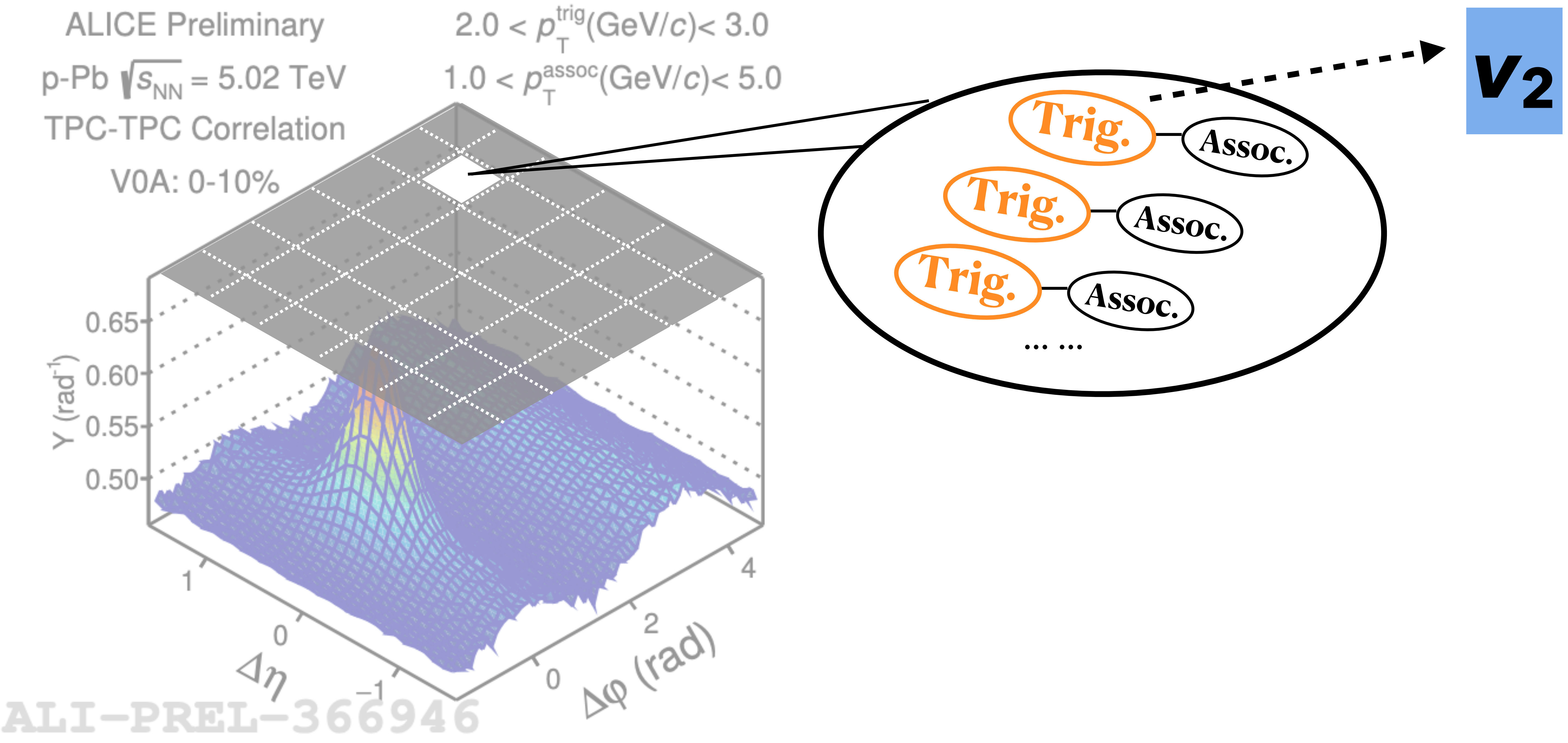
- Double Gaussian function is introduced to fit the jet signal, the sum of flow harmonics is used to fit the background
- Jet signal and background are extracted separately to calculate S/B $(\Delta\varphi, \Delta\eta)$

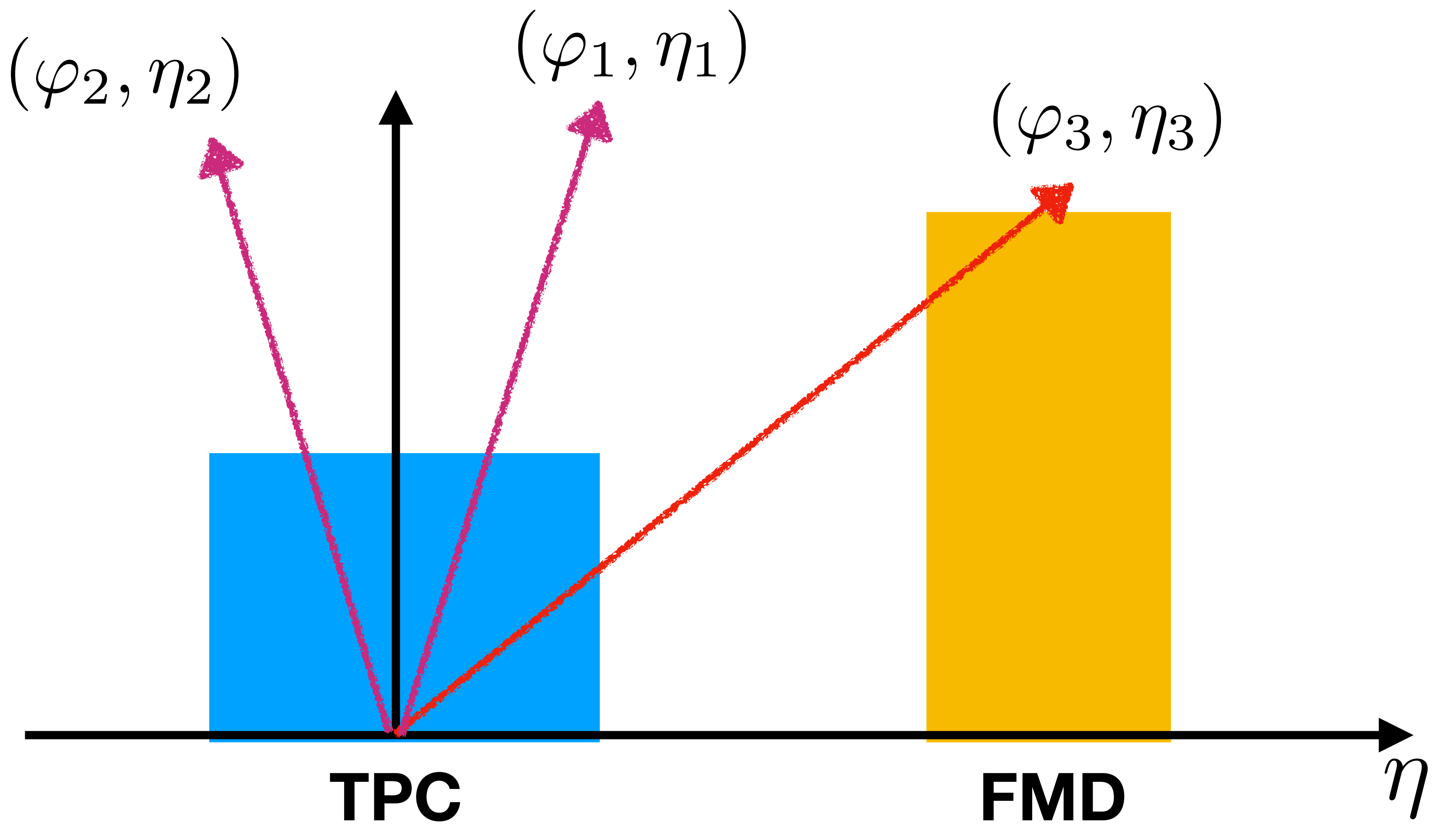
Calculation of trigger-particle v_2



- For each $(\Delta\varphi, \Delta\eta)$ region, the v_2 of **trigger particle** in particle pairs can be calculated

Calculation of trigger-particle v_2 in p–Pb collisions





p–Pb: three-particle correlation

- Construct long-range correlation with forward rapidity particles detected in the FMD

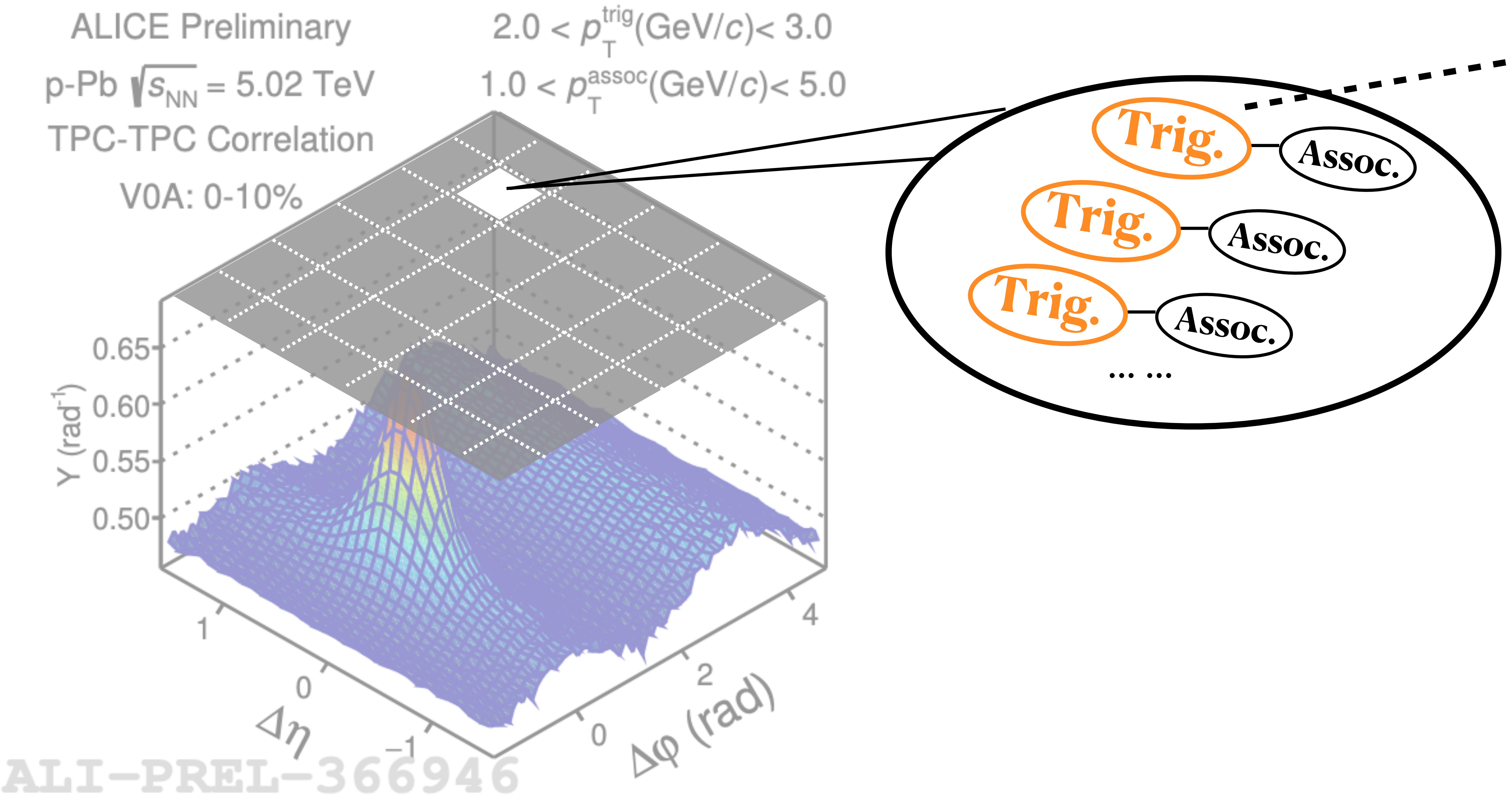
$$\frac{dN}{d\Delta\varphi'} \propto 1 + 2\sum_{n=1}^{3} \Delta V_n(\Delta\varphi, \Delta\eta)\cos(n\Delta\varphi'), |\Delta\eta| > 1$$

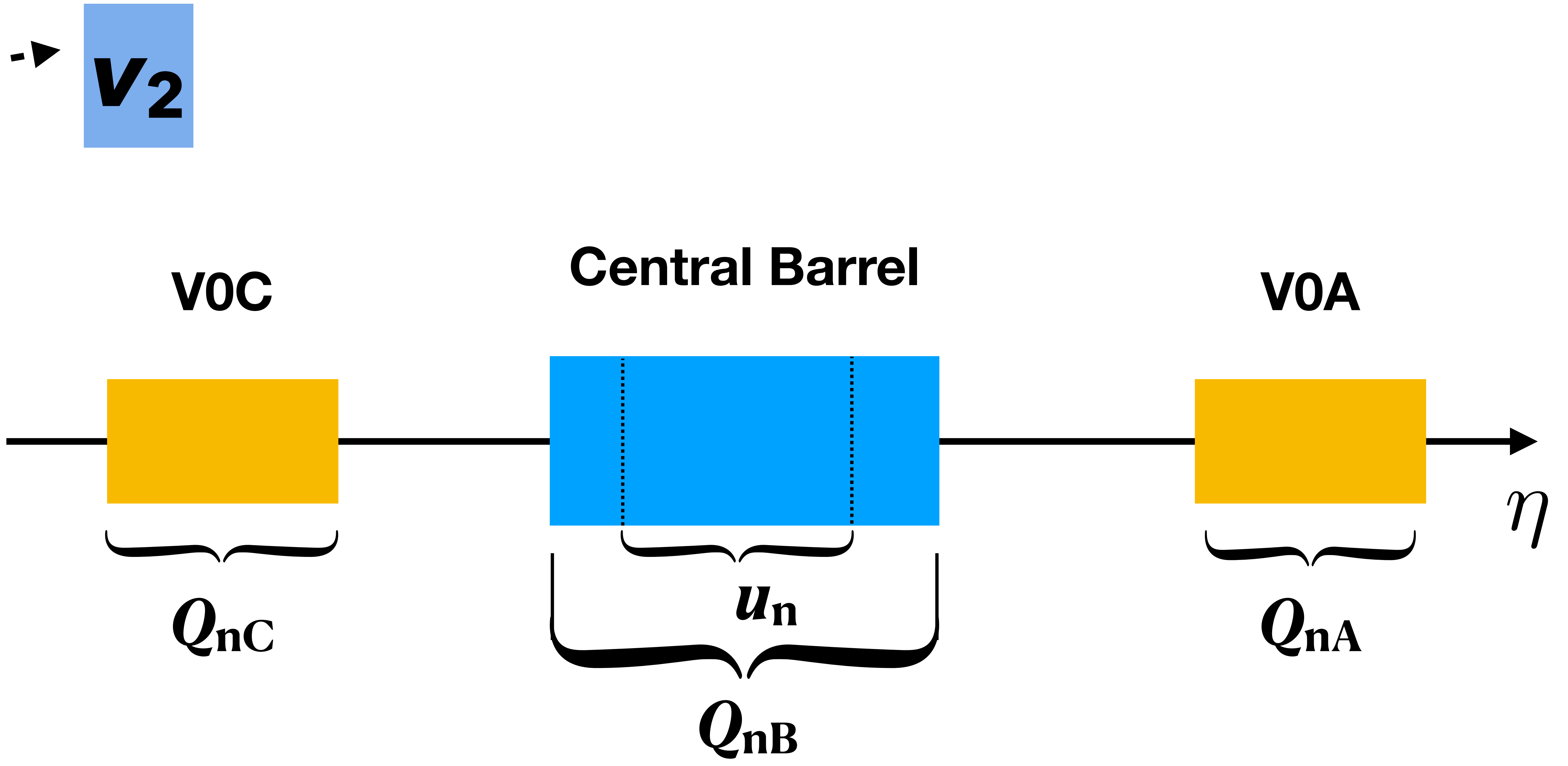
$$\Delta\varphi = \varphi_1 - \varphi_2 \quad \Delta\eta = \eta_1 - \eta_2$$
$$\Delta\varphi' = \varphi_1 - \varphi_3 \quad \Delta\eta' = \eta_1 - \eta_3$$

  - Non-flow contribution is suppressed by subtraction of scaled low-multiplicity events

  - Factorization: $\Delta V_2(\Delta\varphi, \Delta\eta) = v_2(\Delta\varphi, \Delta\eta) v_2^{\mathrm{FMD}}$

Calculation of trigger-particle v_2 in Pb–Pb collisions



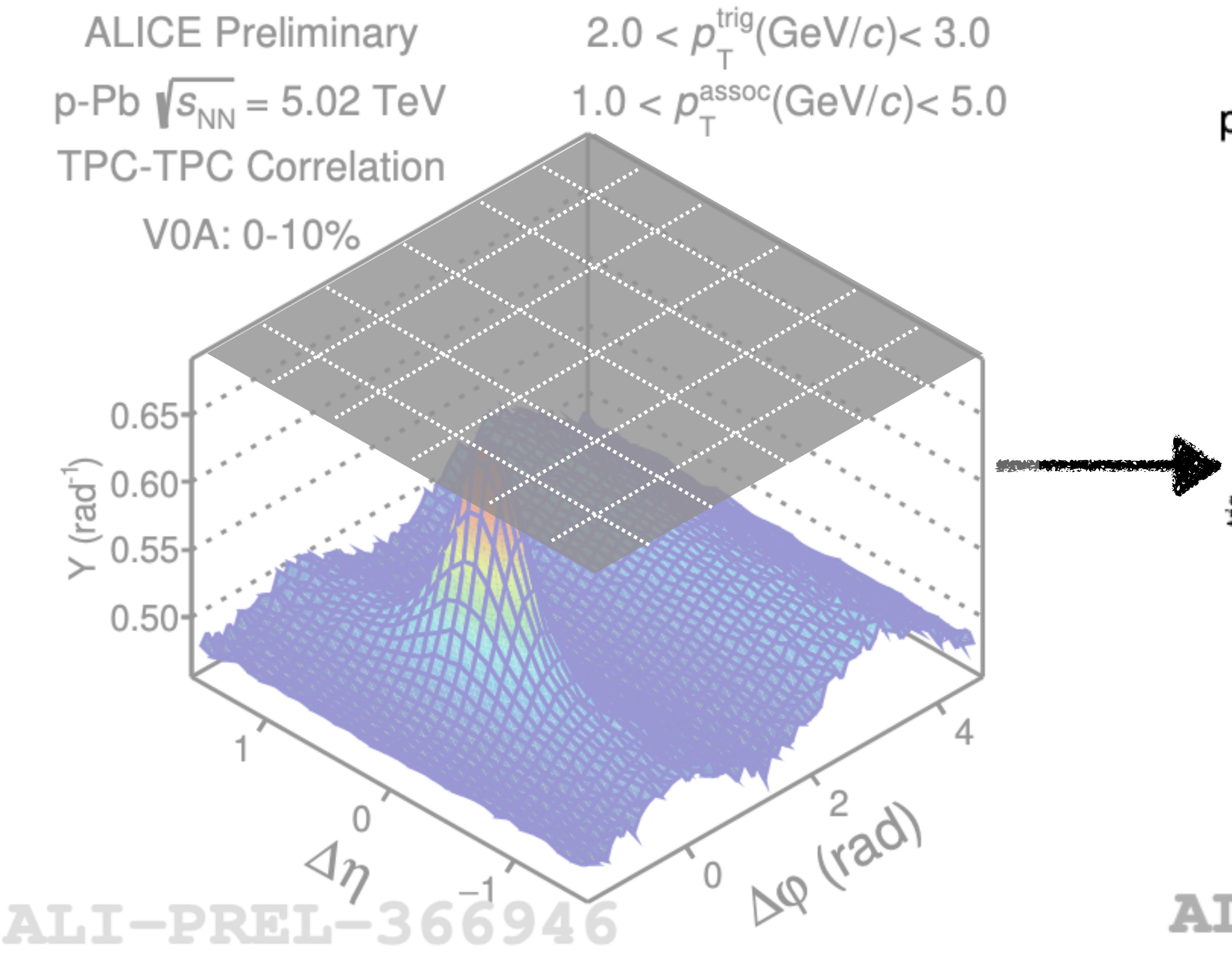


Pb–Pb: Scalar product method

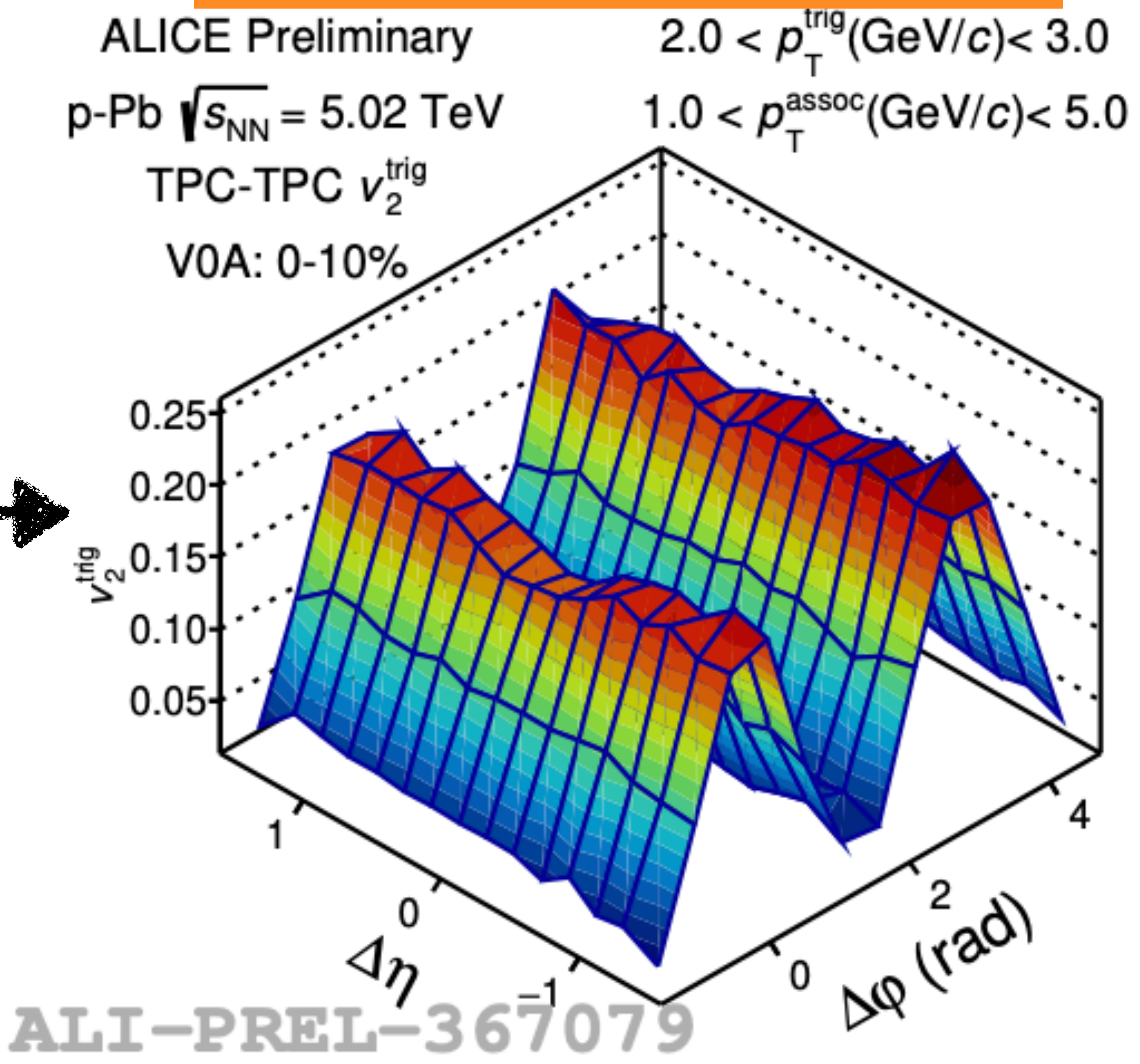
- Based on the measurement of *Q*-vector at forward and midrapidity
- Non-flow contribution is suppressed by applying $|\Delta\eta| > 2$

$$v_n(\Delta\varphi, \Delta\eta) = \langle \frac{\vec{u}_n(\Delta\varphi, \Delta\eta)\vec{Q}^*_{nA}}{R_n} \rangle \qquad R_n = \sqrt{\frac{\langle \vec{Q}_{nA}\vec{Q}^*_{nB}\rangle \langle \vec{Q}_{nA}\vec{Q}^*_{nC}\rangle}{\langle \vec{Q}_{nB}\vec{Q}^*_{nC}\rangle}}$$

Extraction of jet-particle v_2



Trigger particle v_2 distribution



- For each $(\Delta\varphi, \Delta\eta)$ region, the v_2 of **trigger particle** in particle pairs can be calculated

Extraction of jet-particle v_2

Trigger particle v_2 distribution

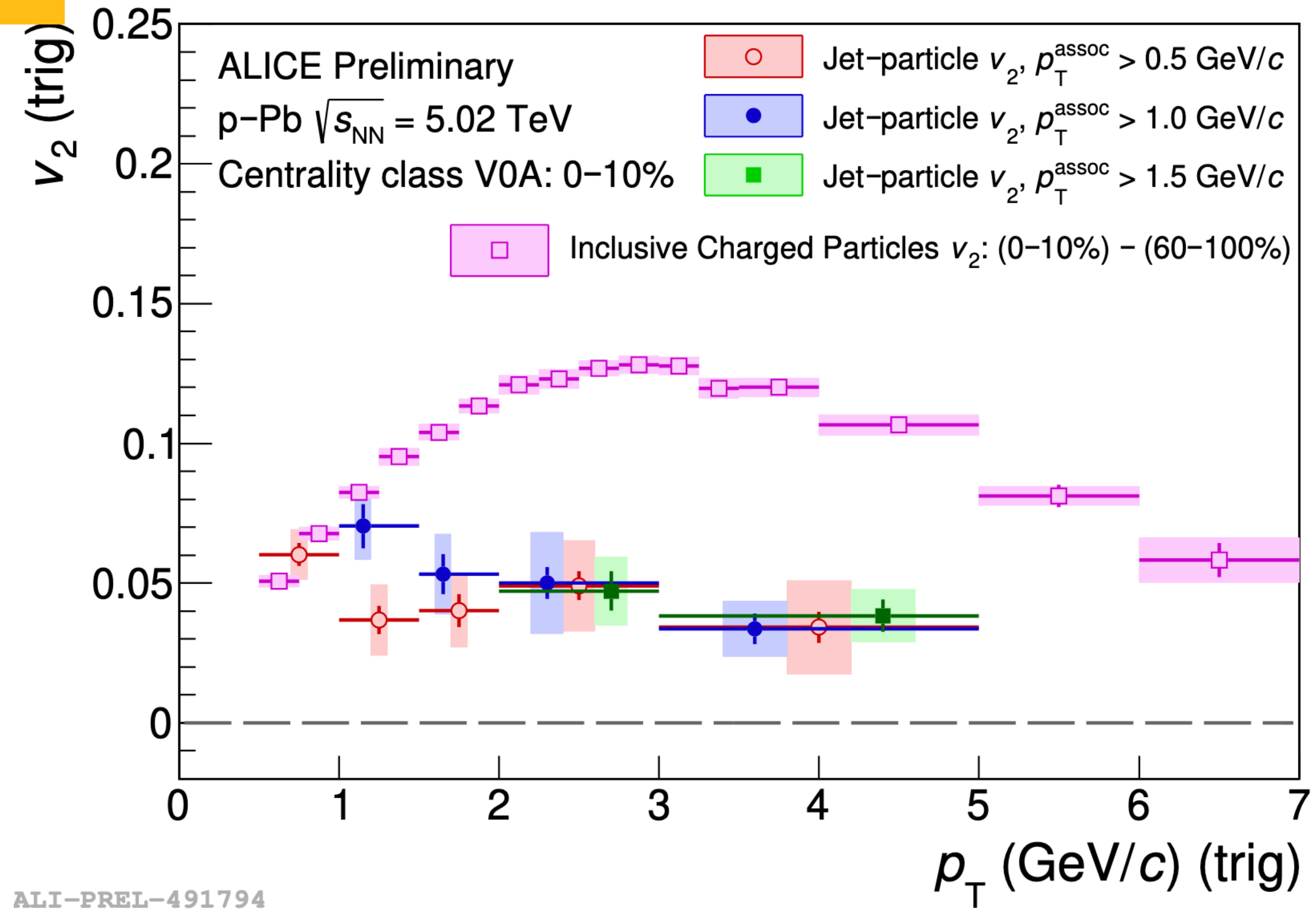
- For each $(\Delta\varphi, \Delta\eta)$ region, the v_2 of **trigger particle** in particle pairs can be calculated
- The **S/B** (jet/background) is used for the fit of $v_2(\Delta\varphi,\Delta\eta)$ in each p_T interval :
  - $v_2(\Delta\varphi,\Delta\eta) = S/(S+B) \times$ **v_2(Jet)** $+ B/(S+B) \times v_2$(Background)

What we study

Sum of 1st->5th harmonics

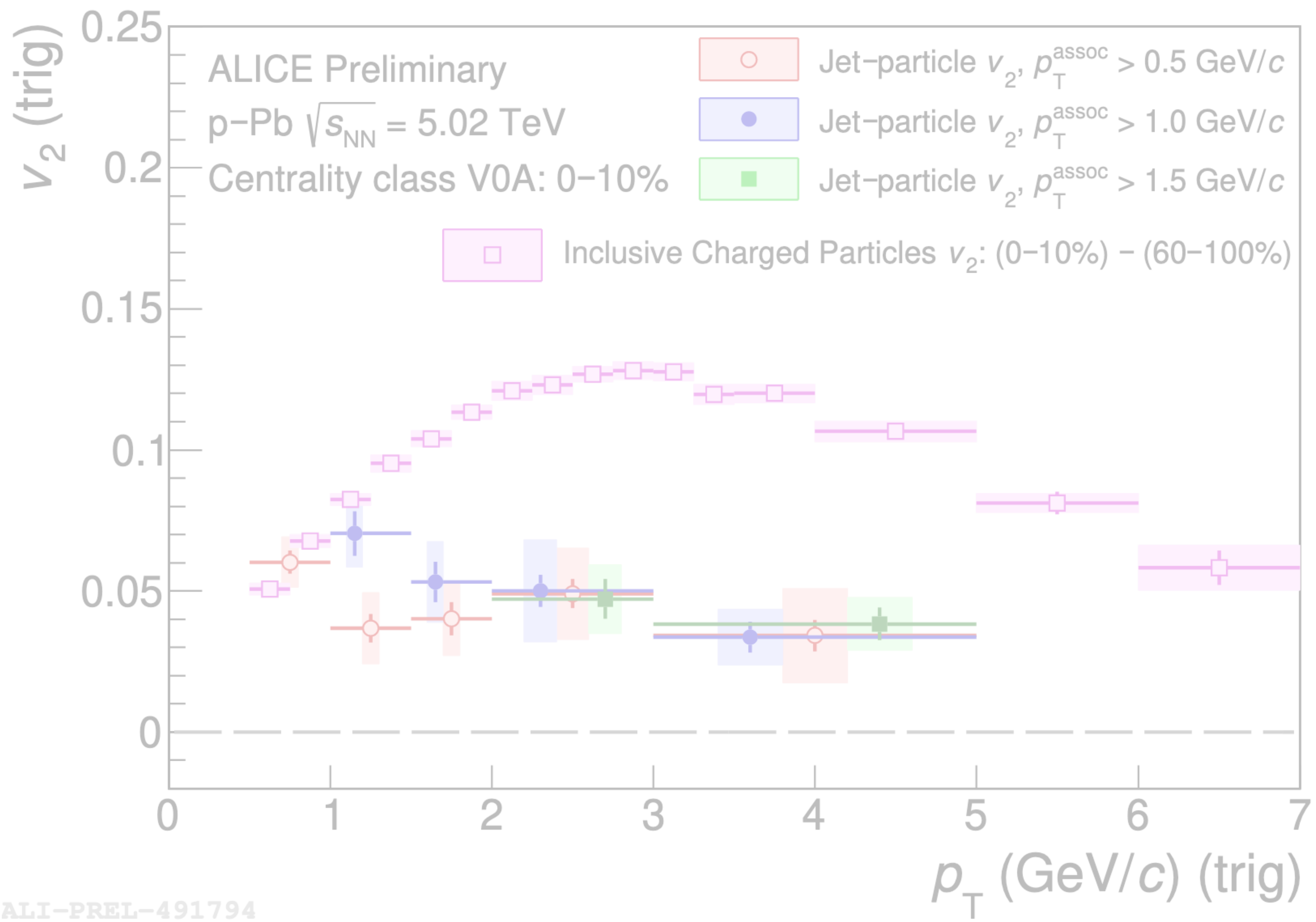
Jet-particle v_2 in p–Pb collisions

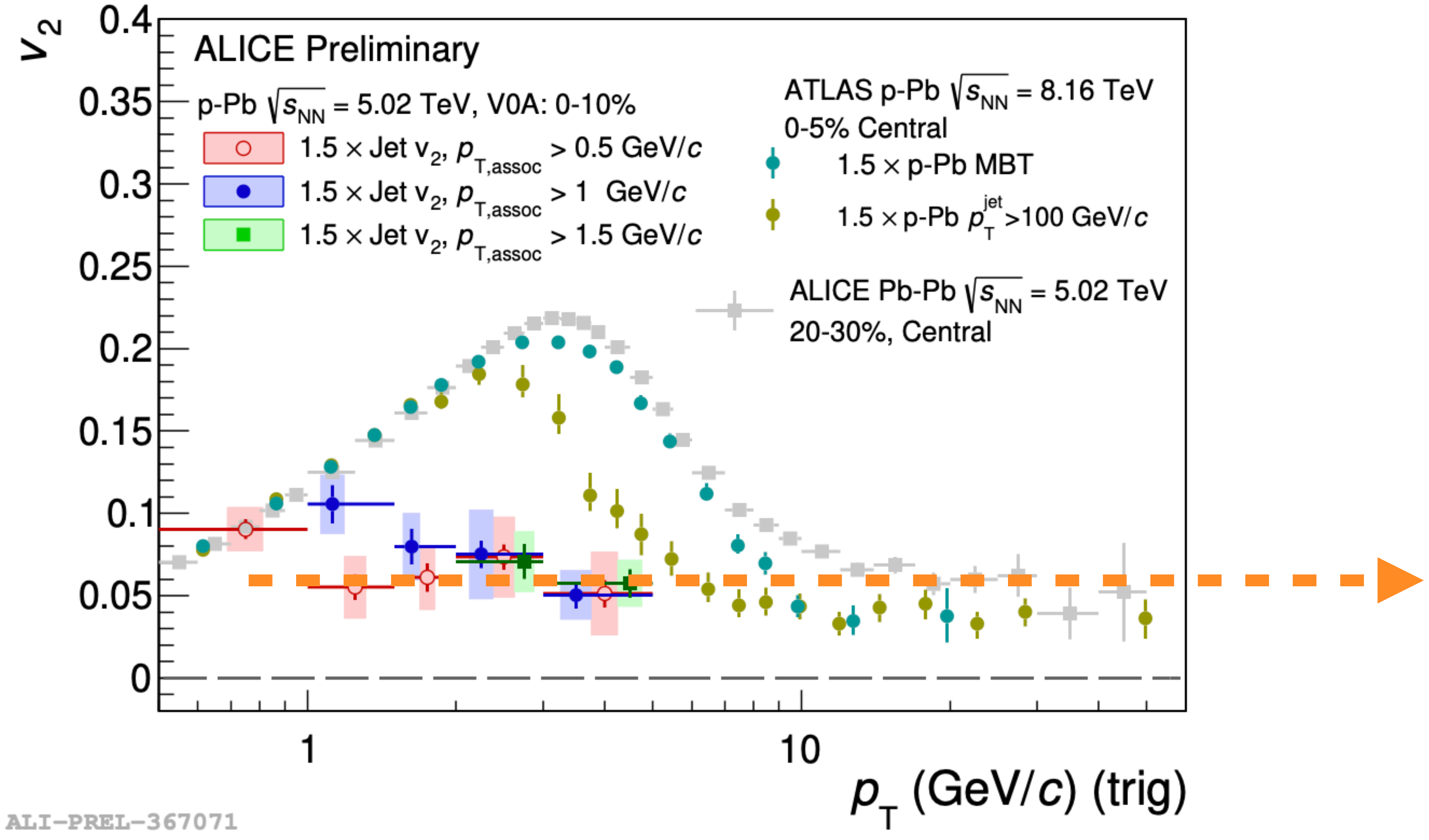
NEW



- The **first measurement** of jet-particle v_2 in p–Pb collisions at the LHC
- Positive v_2 of particles in jets significantly lower than the inclusive v_2 of charged particles
- Consistent v_2 is observed with different associated-particle p_T selection

Comparison to ATLAS results





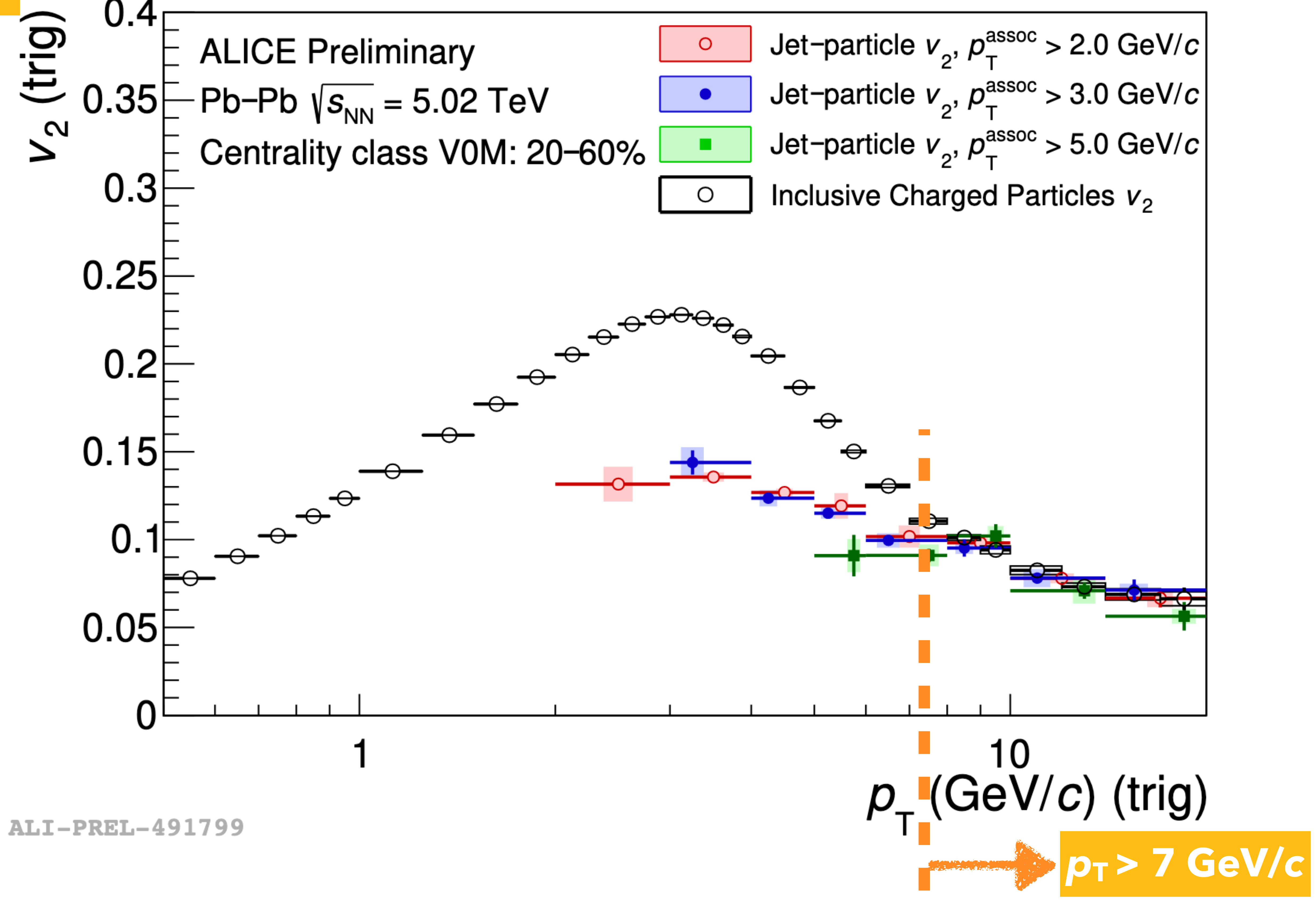
- The v_2 of particles in the jet:
  - fully separated from soft components compared to the charged-particle v_2 in jet-triggered events from ATLAS
  - comparable to high-p_T v_2 in p–Pb and Pb–Pb collisions

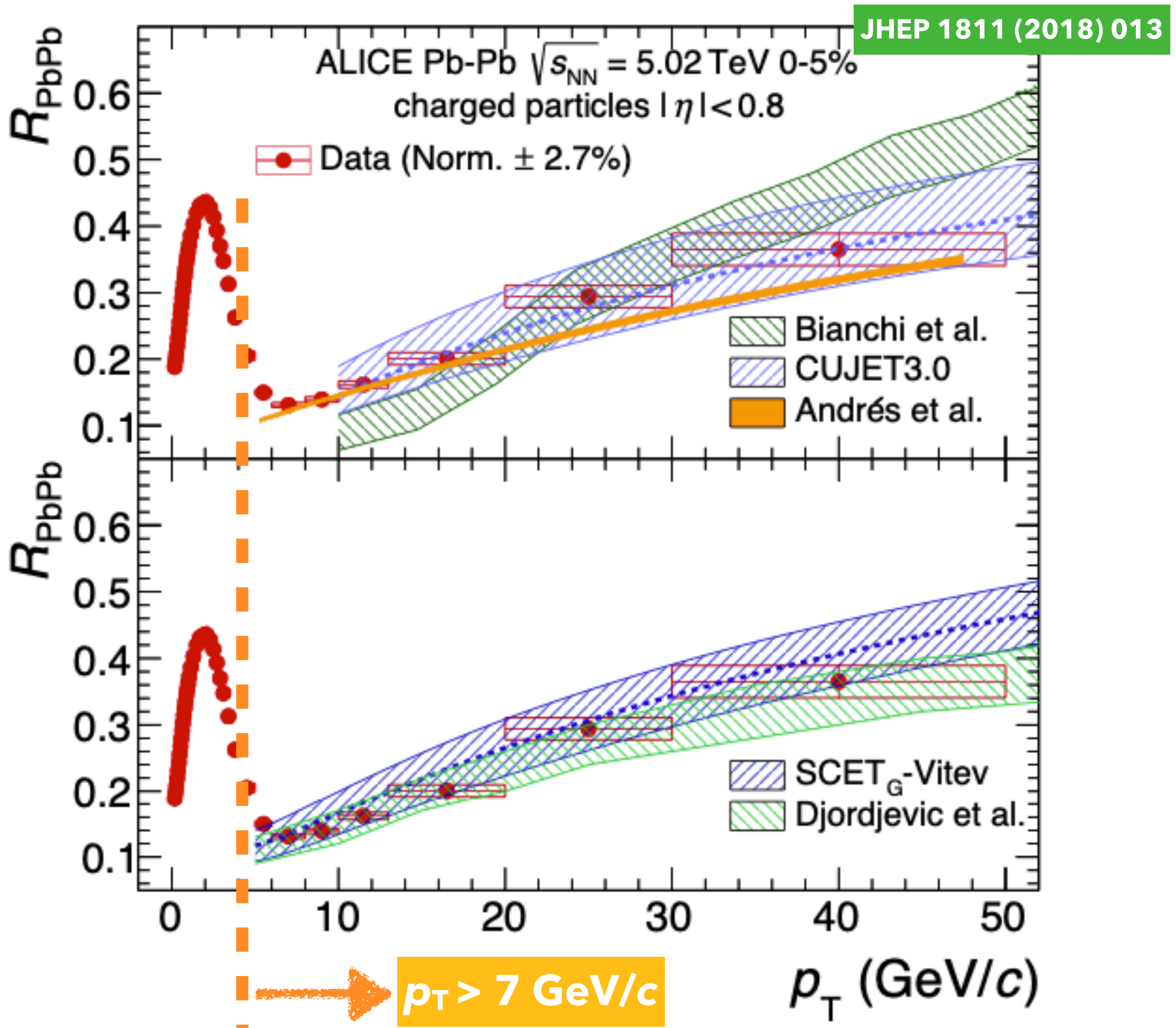
Factor 1.5[1] is applied in p–Pb v_2 to compare with Pb–Pb results

[1] An empirically determined factor from ATLAS paper: Eur. Phys. J. C 80 (2020) 73

Jet-particle v_2 in Pb–Pb collisions

NEW

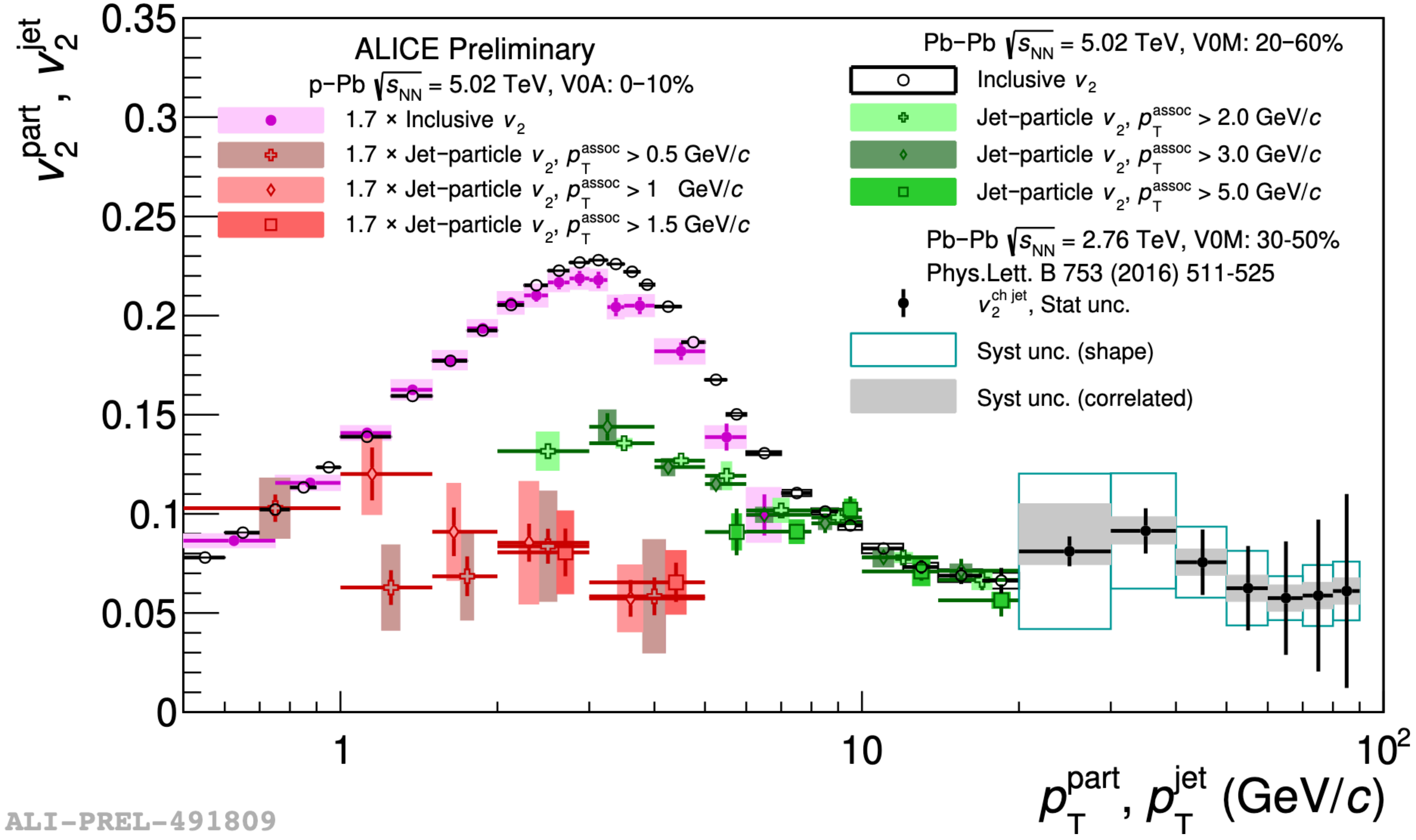




- Positive jet-particle v_2 is obtained in 20–60% Pb–Pb collisions, and no dependence on associated p_T selection is observed
- The jet-particle v_2 is consistent with inclusive v_2 at $p_T > 7$ GeV/c, where parton energy loss is dominant (also seen in R_{PbPb})

Final comparison

NEW



ALI-PREL-491809

Final comparison

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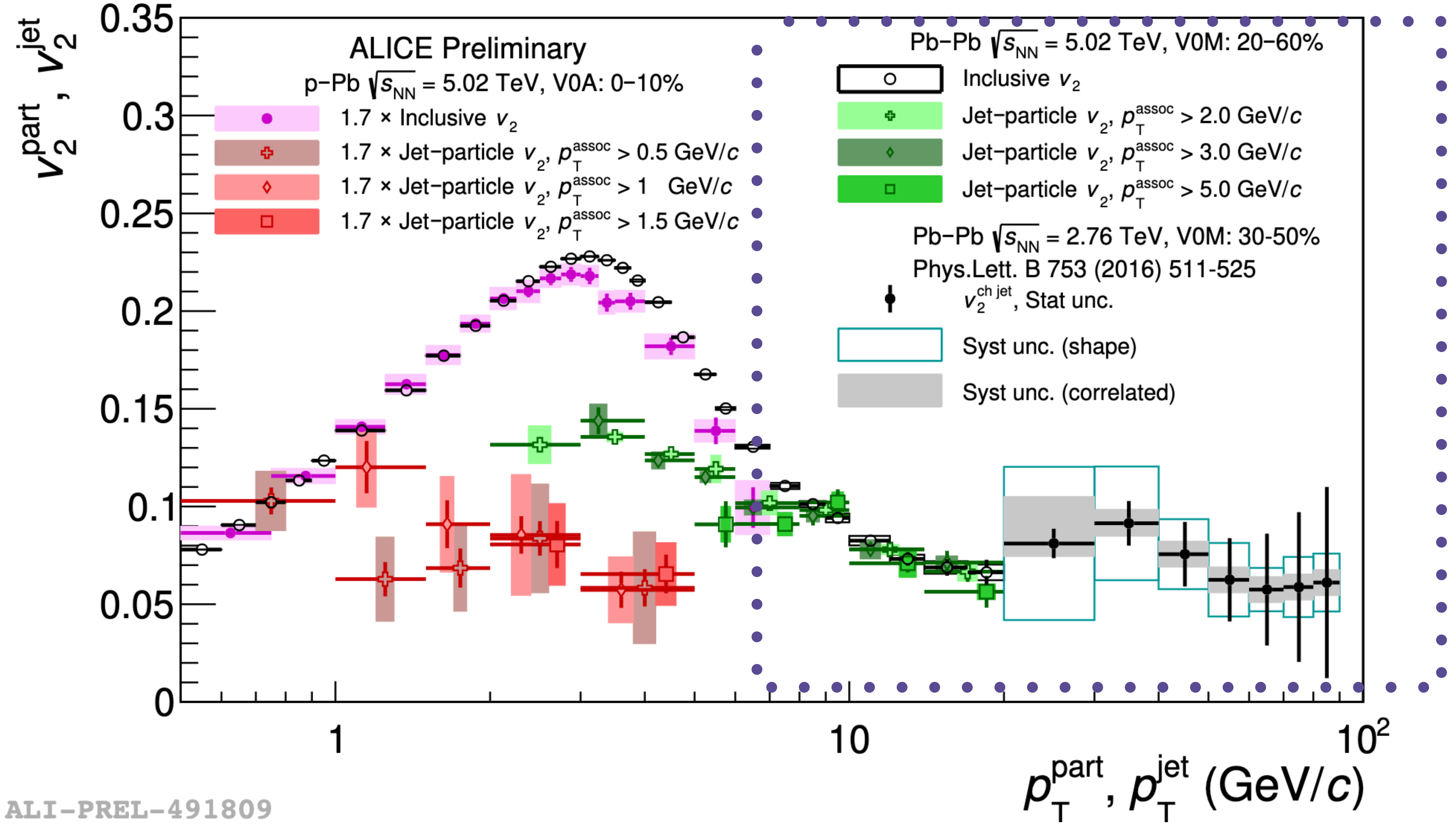
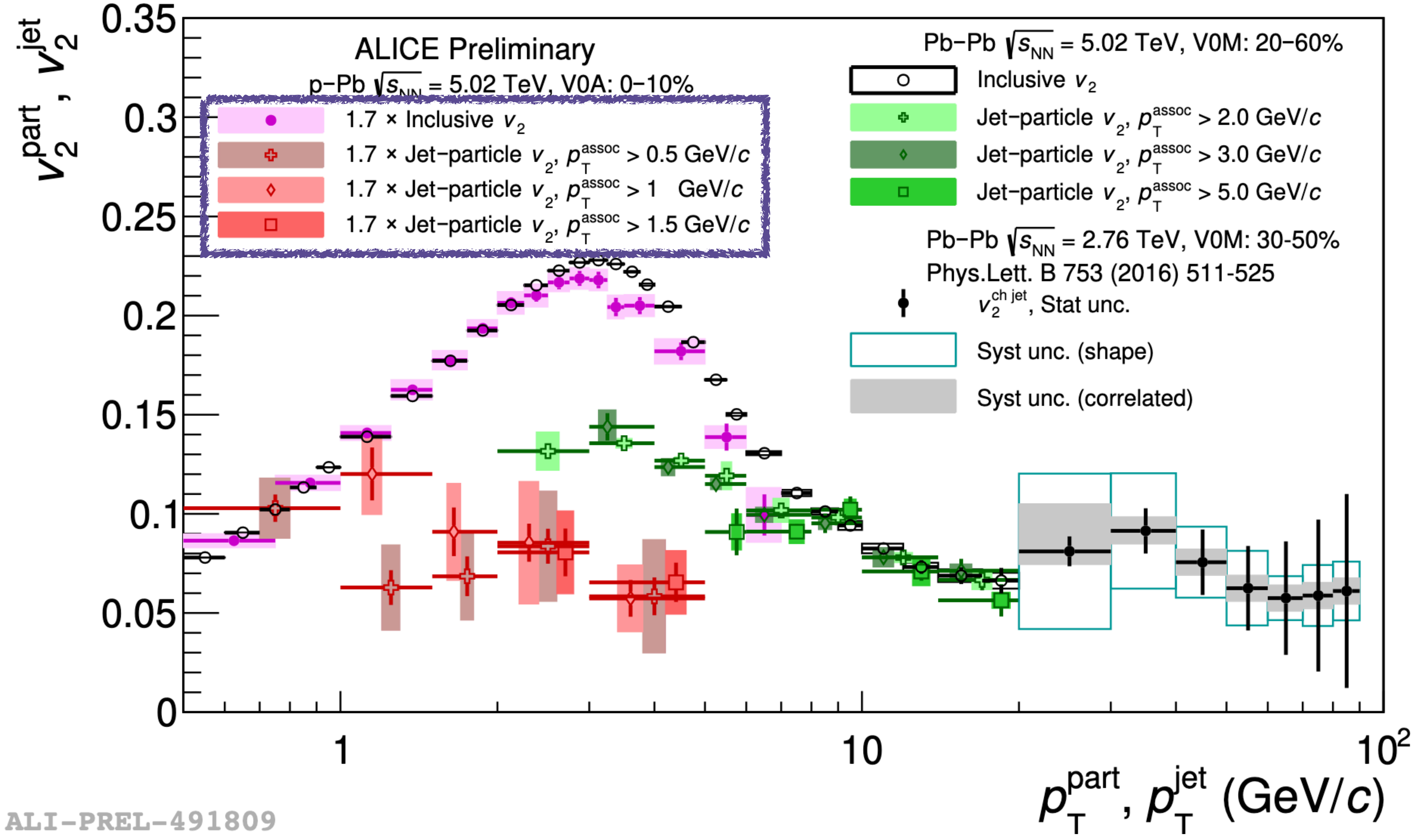


- In Pb–Pb collisions, jet-particle v_2 at high p_T is consistent with the reconstructed-jet v_2

— both interpreted by path-length dependent jet-quenching effect

Final comparison

NEW



- Factor 1.7 is applied in p–Pb v_2 to compare with Pb–Pb results

- In Pb–Pb collisions, jet-particle v_2 at high p_T is consistent with the reconstructed-jet v_2

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Final comparison

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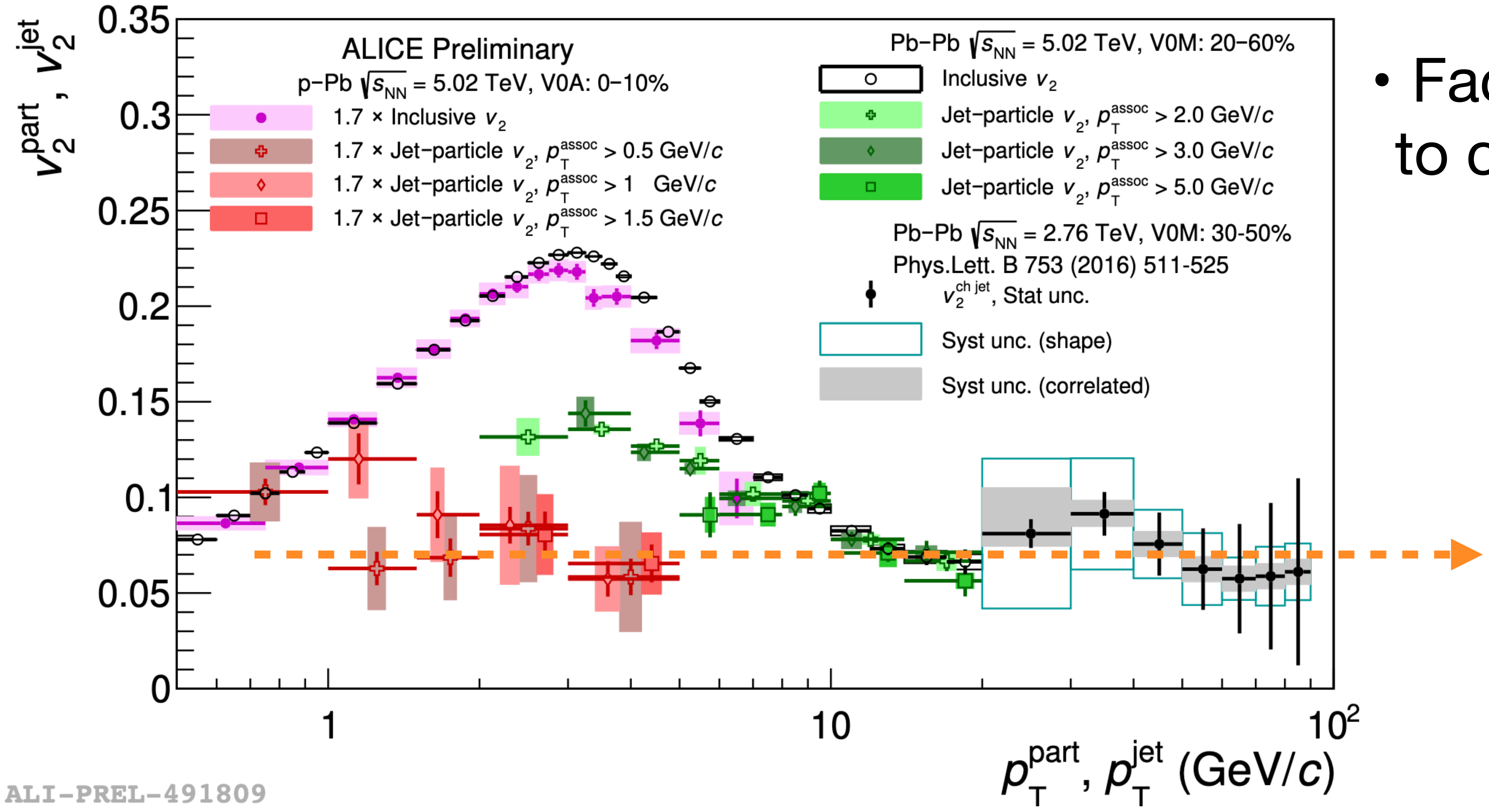


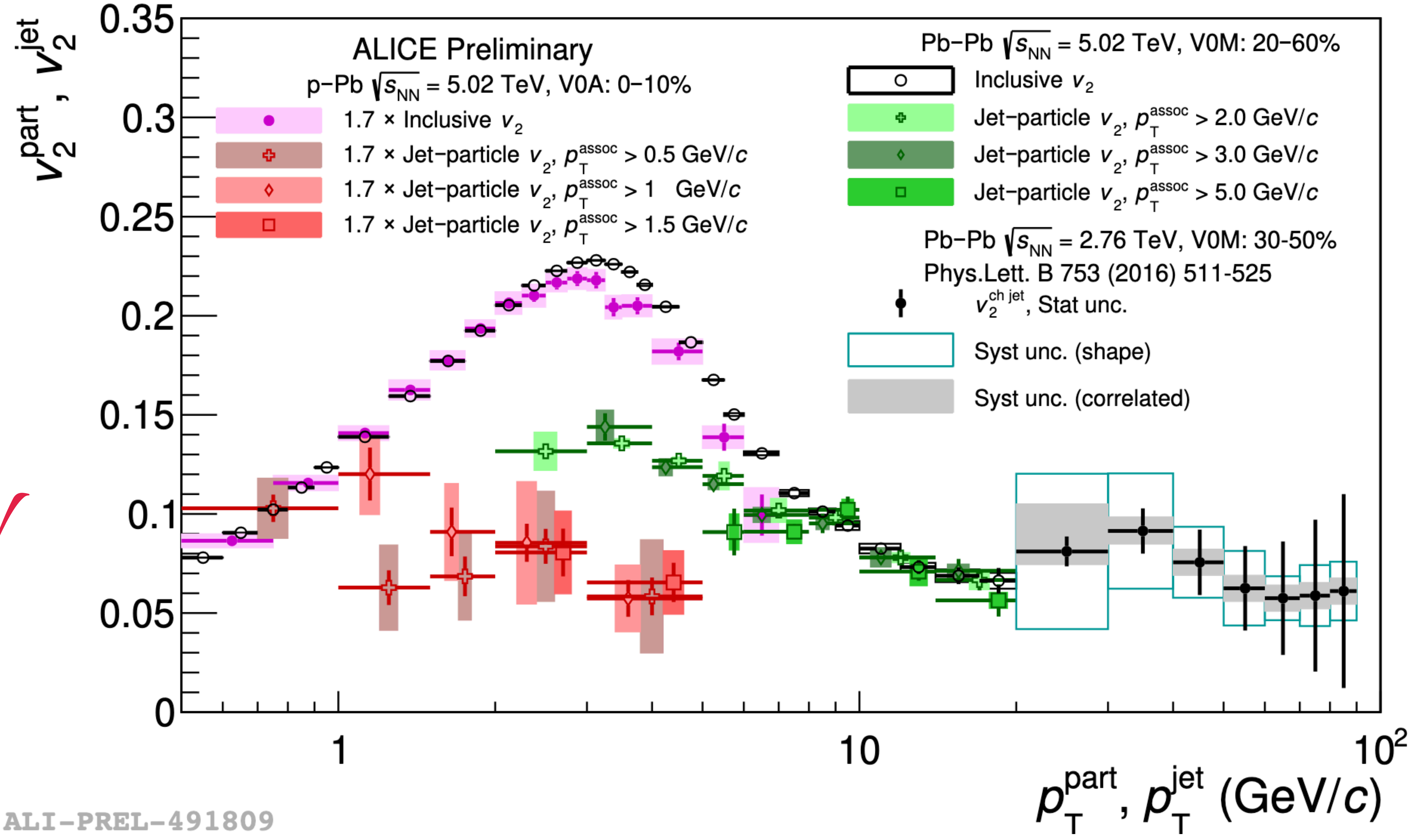
- Factor 1.7 is applied in p–Pb v_2 to compare with Pb–Pb results

- In Pb–Pb collisions, jet-particle v_2 at high p_T is consistent with the reconstructed-jet v_2
  — both interpreted by path-length dependent jet-quenching effect
- v_2 of jet particles in p–Pb is consistent with jet-particle v_2 and inclusive v_2 in Pb–Pb at high p_T
  — "Jet-quenching like effects"? Initial-state effects (CGC)? or final-state scatterings (AMPT)?

Summary

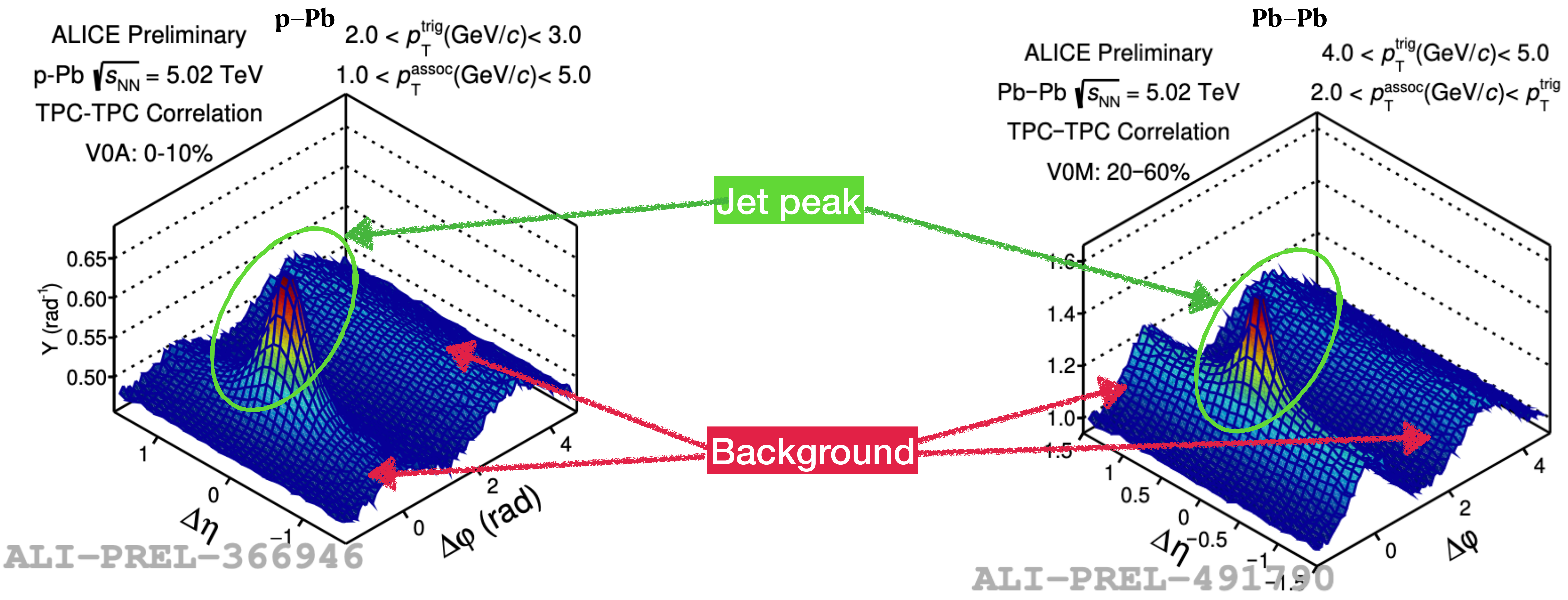
- First measurement of v_2 of jet particles in p–Pb and Pb–Pb collisions
- Positive jet-particle v_2 in p–Pb collisions is observed, comparable with the high-p_T inclusive and jet-particle v_2 in Pb–Pb collisions
  - No dependence on associated-track p_T within uncertainties

Thank you for your attention!



Back up

Two-particle correlation in p–Pb and Pb–Pb collisions



- Selection of same sign charged particles in TPC acceptance as trigger and associated particles
  - Transverse momentum ordering: $p_T^{\text{trig}} > p_T^{\text{assoc}}$
- Finite-acceptance effects are corrected by standard mixed-event technique: $Y(\Delta\eta,\Delta\varphi) = \frac{1}{N_{\rm trig}}\frac{d^2N_{\rm assoc}}{d\Delta\eta d\Delta\varphi} = \frac{S(\Delta\eta,\Delta\varphi)}{B(\Delta\eta,\Delta\varphi)}$

Near-side jet peak is observed at $(\Delta\eta \sim 0, \Delta\varphi \sim 0)$

Extraction of jet correlation yield

- Double gaussian function is introduced to fit the jet signal, the sum of harmonics is used to fit the background