Unraveling the origin of collectivity in high and low multiplicity pp and p–Pb collisions in ALICE at the LHC

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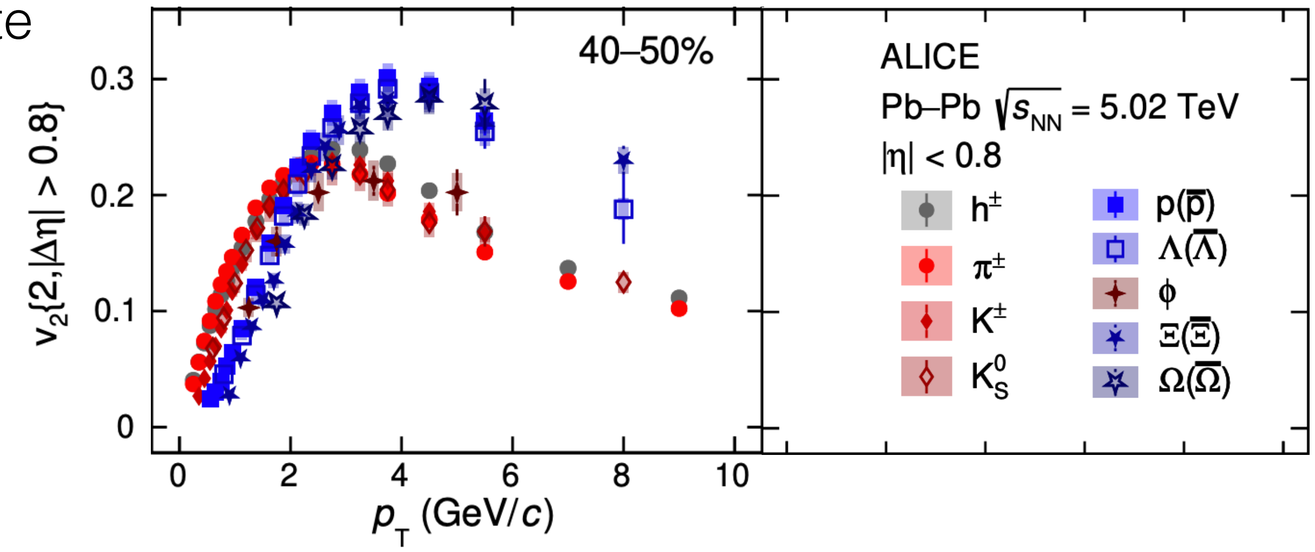
Flow of identified particles in Pb–Pb collisions

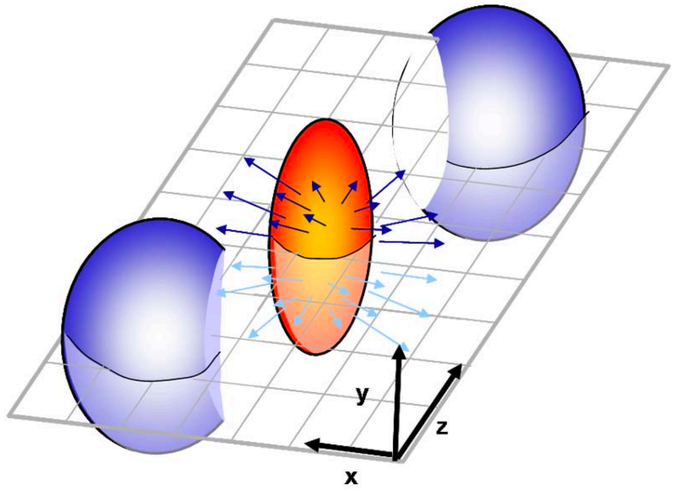
- Anisotropy in azimuthal distribution of final-state particles with respect to the reaction plane:

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

- Initial conditions + collective expansion of the medium → flow coefficients v_n

ALICE, JHEP 05 (2023) 243





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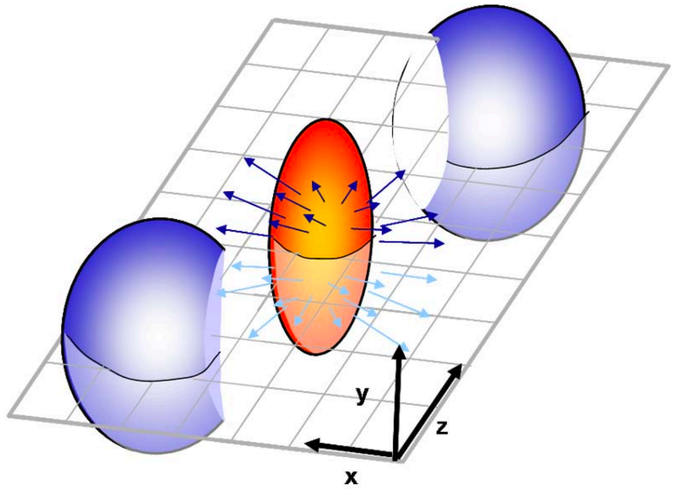

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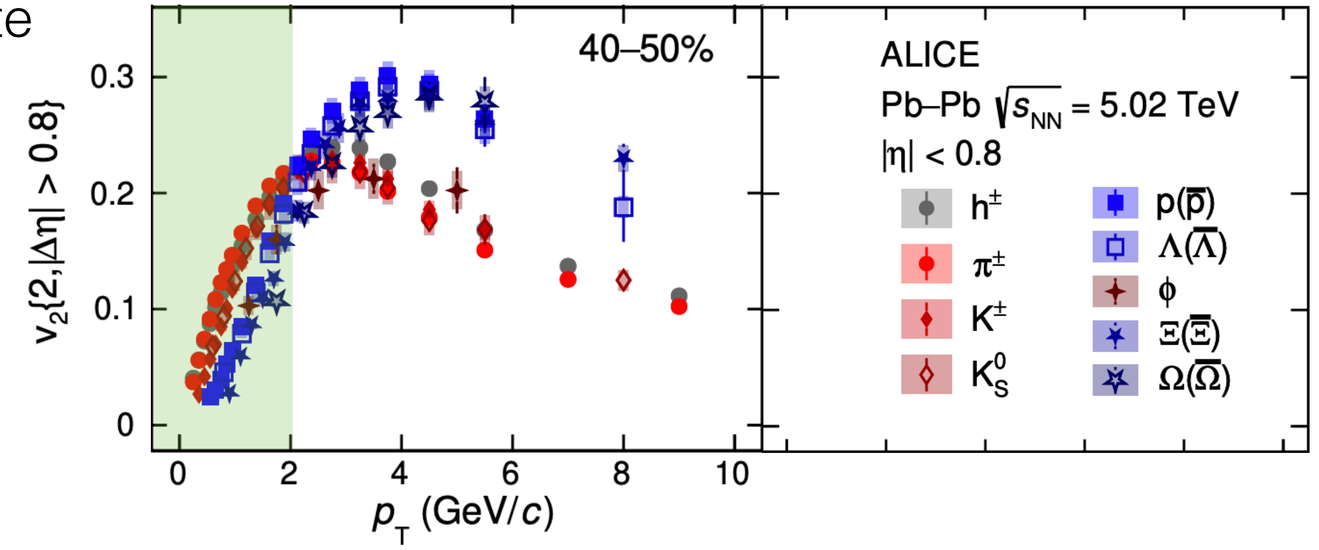

- Low-p_{T} region: **mass ordering** (hydrodynamics)

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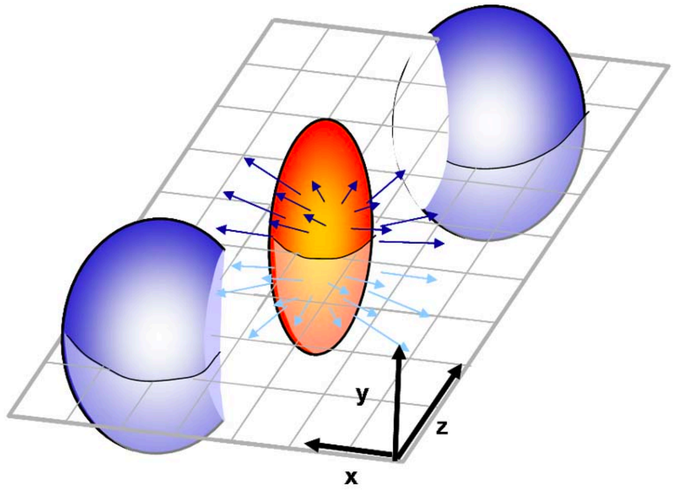

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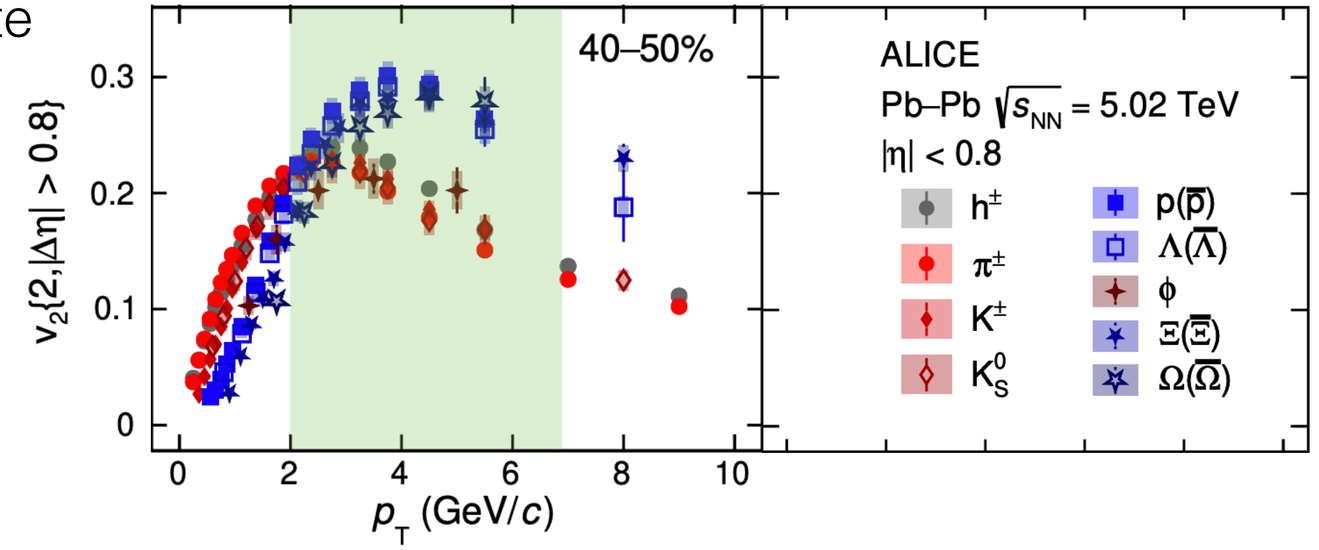

- Low-p_T region: **mass ordering** (hydrodynamics)
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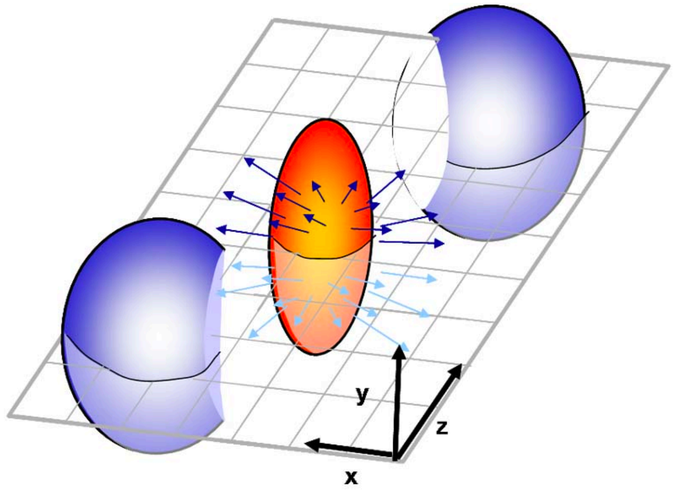
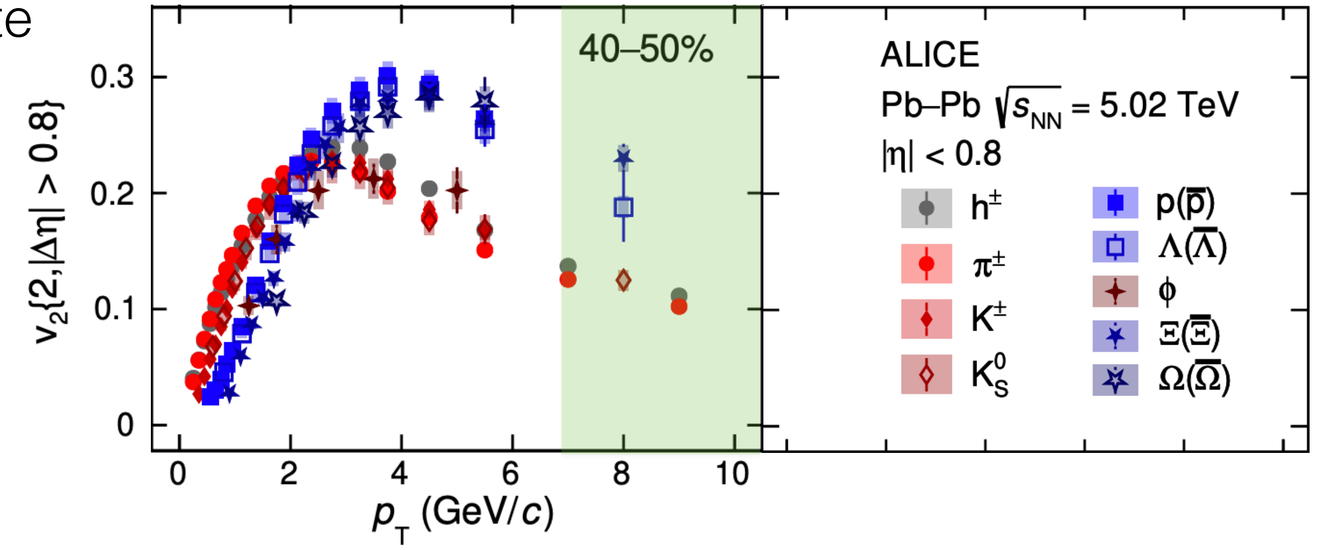


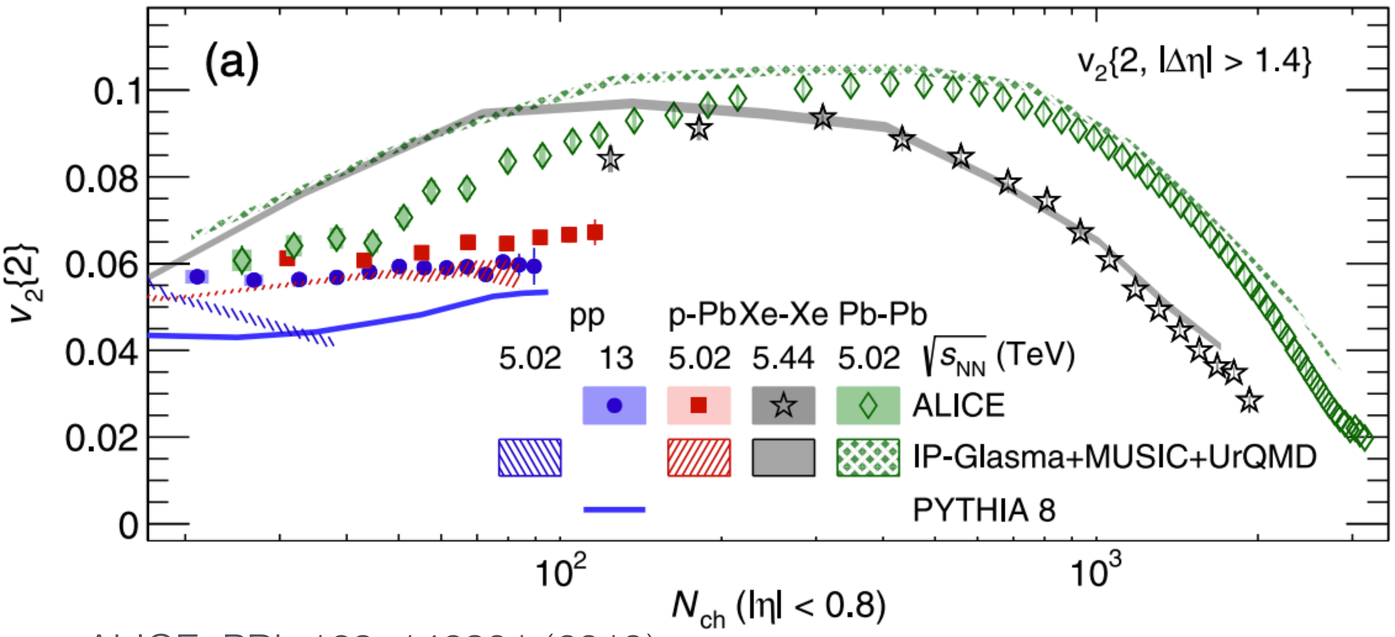
ALICE, JHEP 05 (2023) 243



- ☑ Low-p_{T} region: **mass ordering** (hydrodynamics)
- ☑ Intermediate-p_{T} region: **baryon-meson grouping/ splitting** (partonic collectivity, quark coalescence)
- ☑ High-p_{T} region: jet-fragmentation

Collective flow in small systems

- Sizable flow observed across all collision systems
- Long-range correlations confirmed **collectivity in small systems**



ALICE, PRL 123, 142301 (2019)

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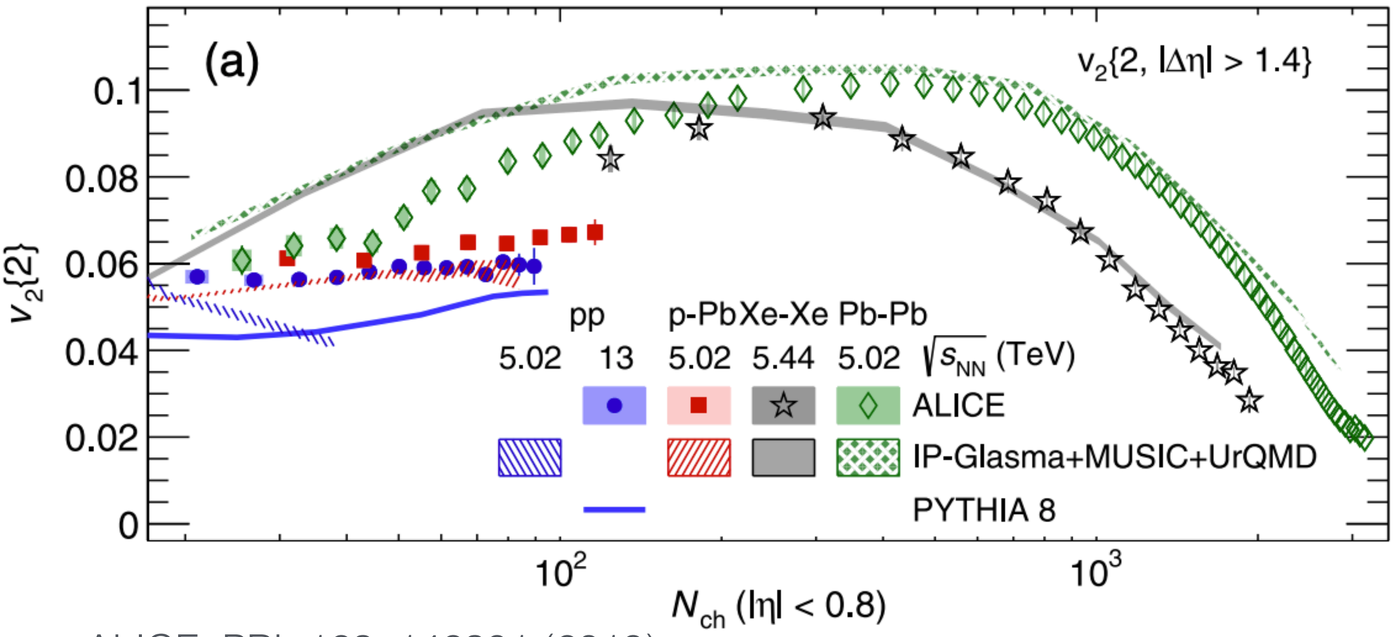
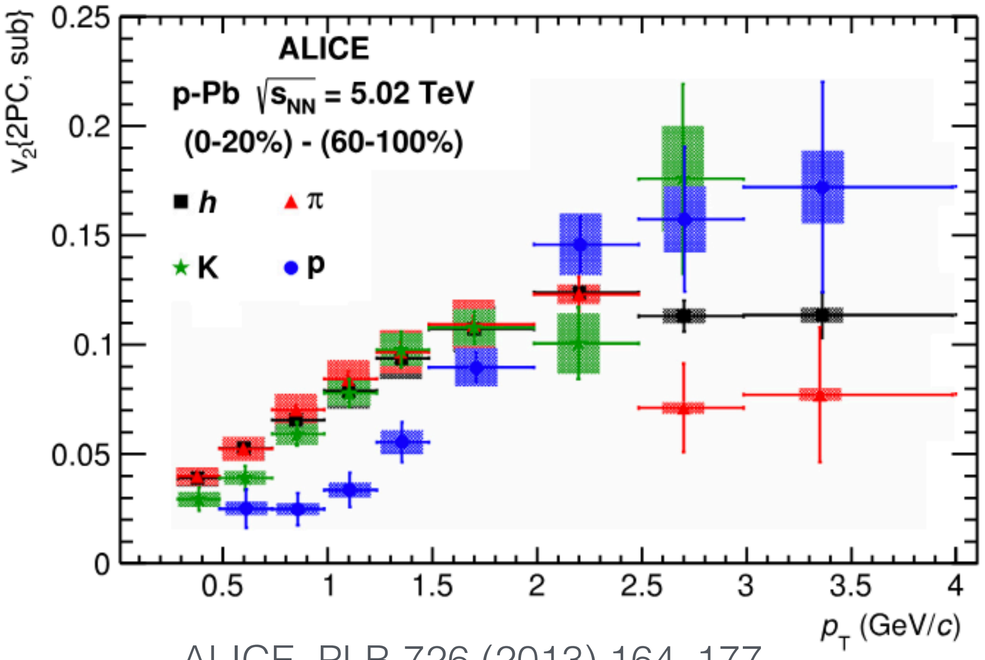


ALICE, PRL 123, 142301 (2019)

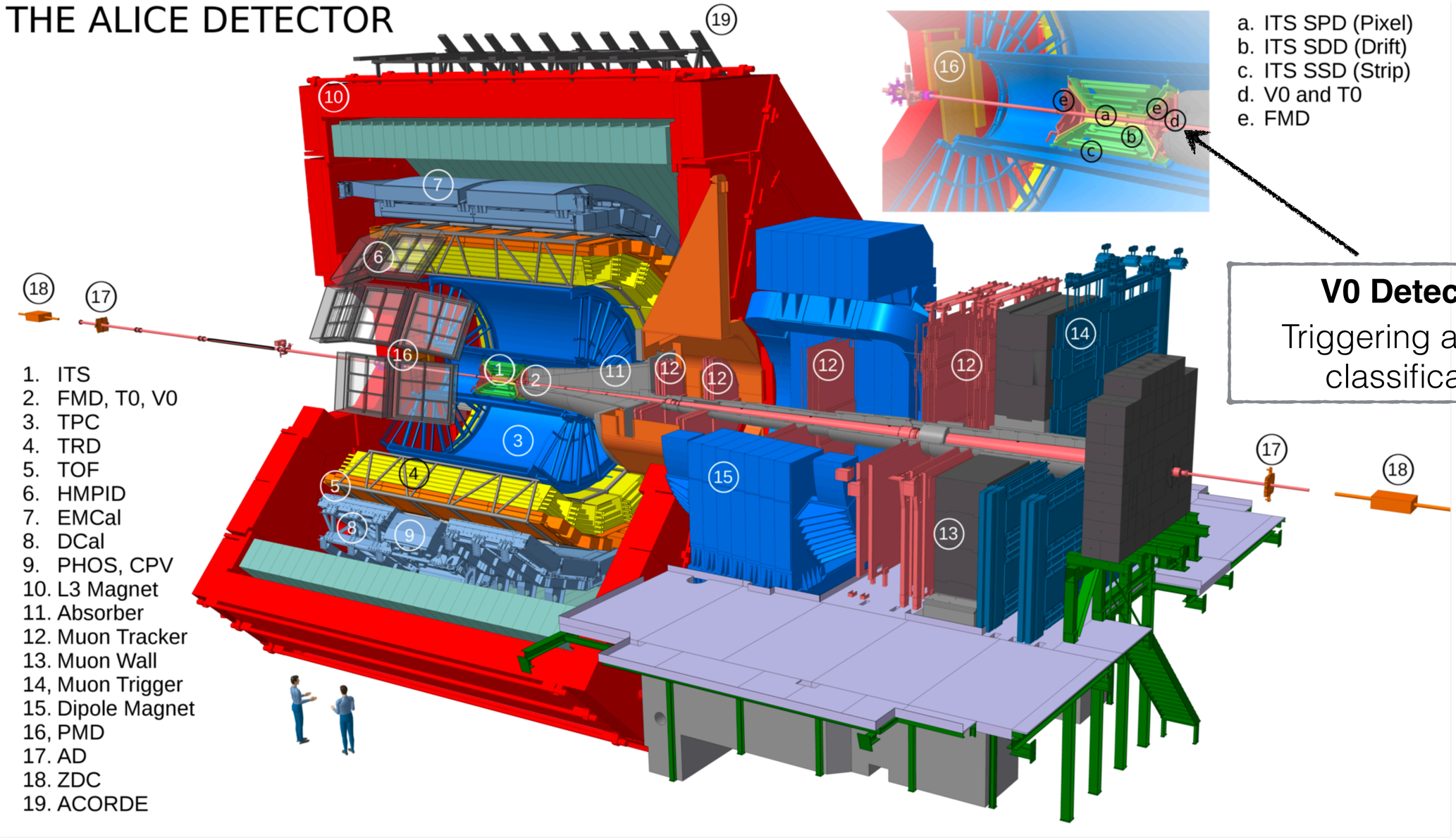
- **Mass ordering** is observed but not significant
- No concrete evidence of **baryon-meson grouping/splitting**



ALICE, PLB 726 (2013) 164–177

The methodology is peripheral subtraction → contribution of non-flow?

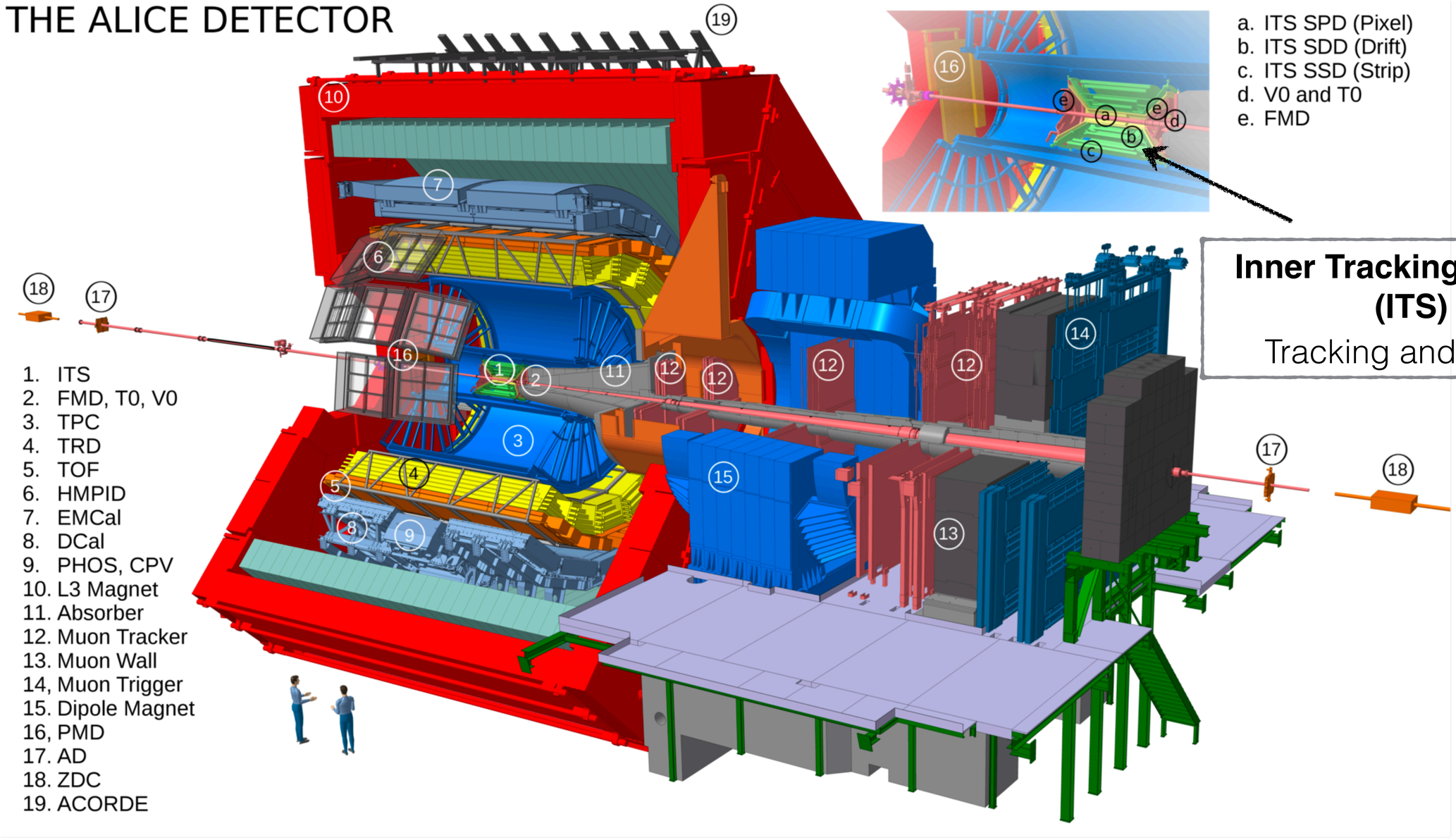
ALICE detector in Run 2



V0 Detector

Triggering and event classification

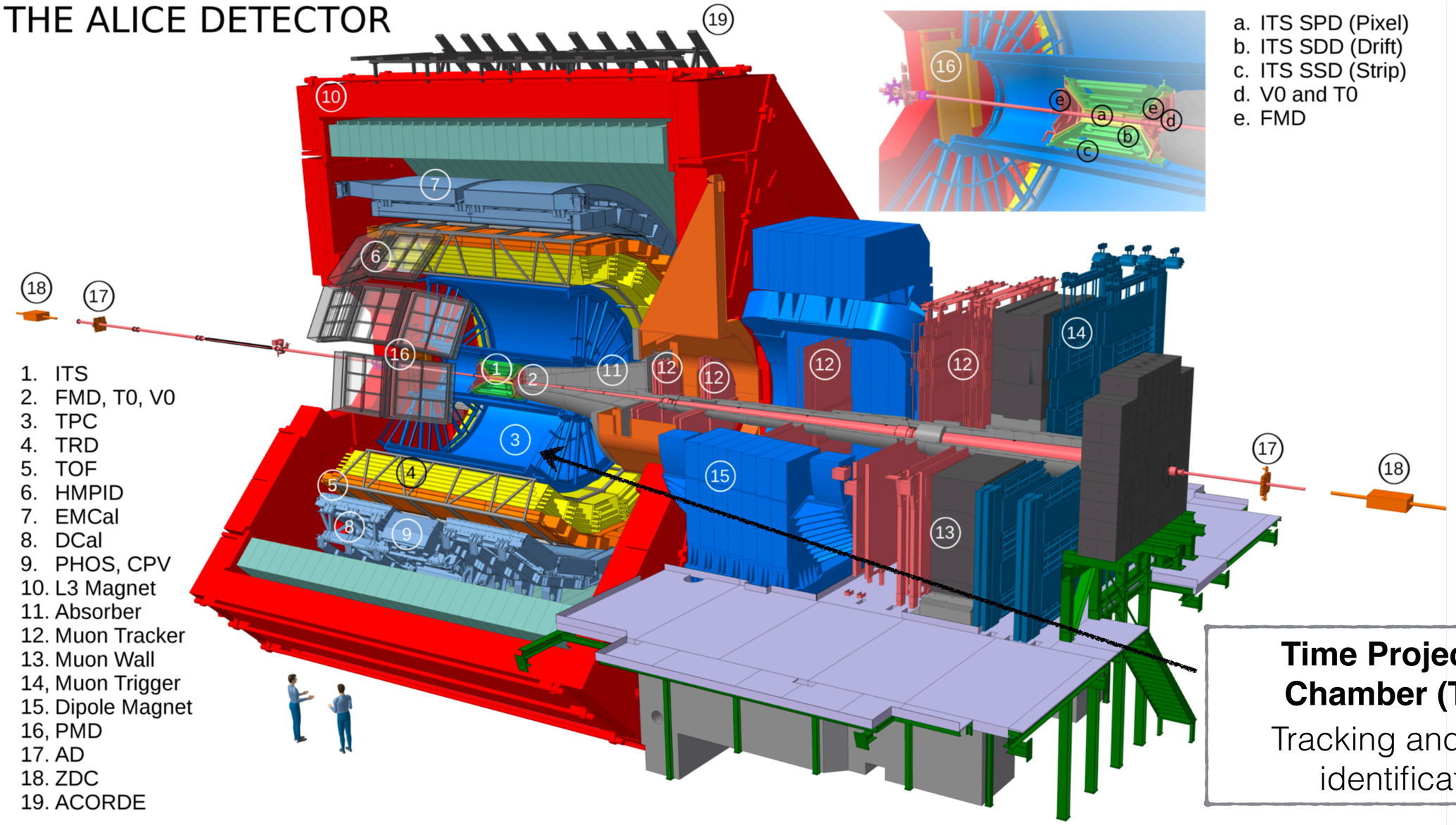
ALICE detector in Run 2



Inner Tracking System (ITS)

Tracking and triggering

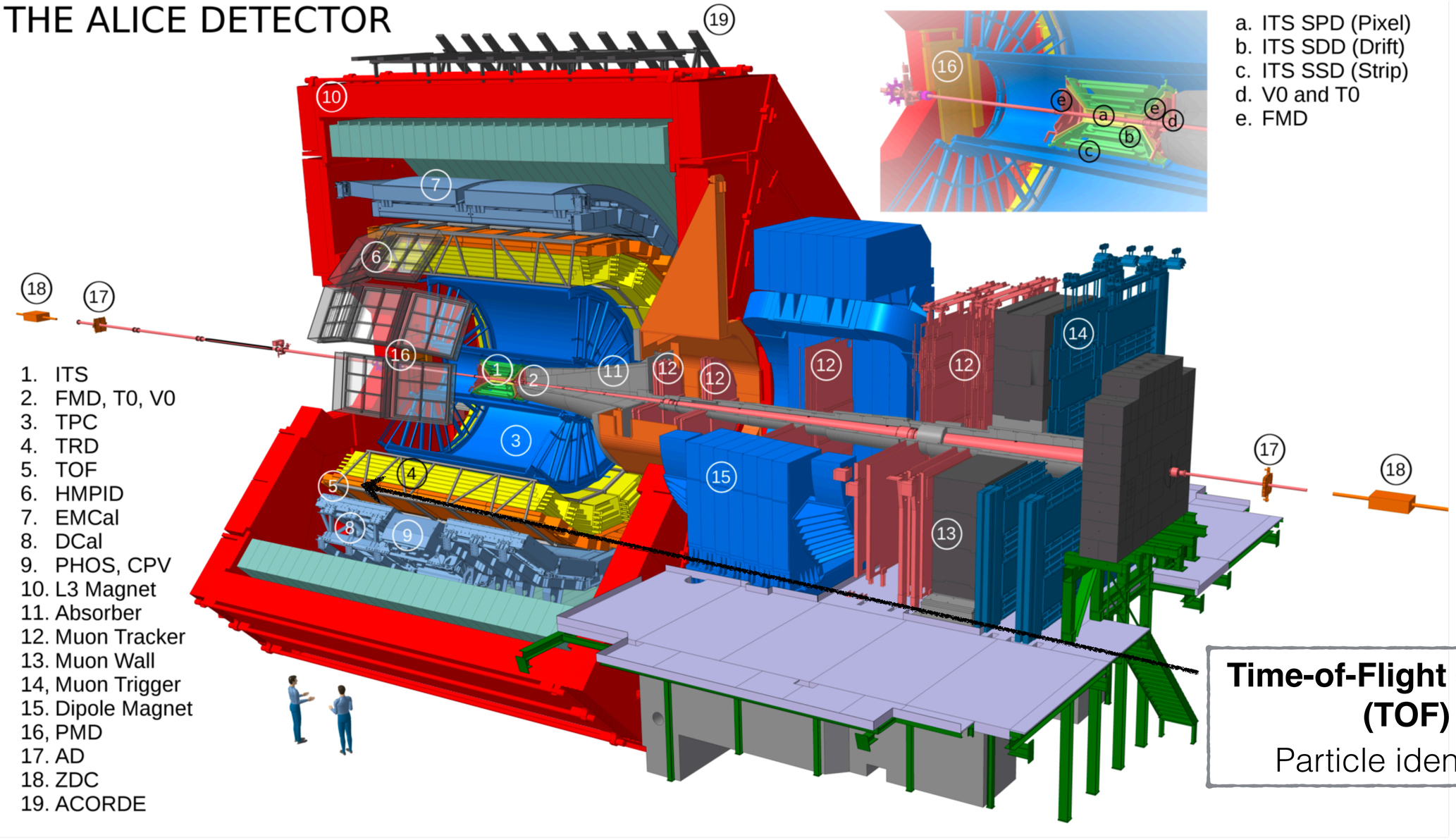
ALICE detector in Run 2



Time Projection Chamber (TPC)

Tracking and particle identification

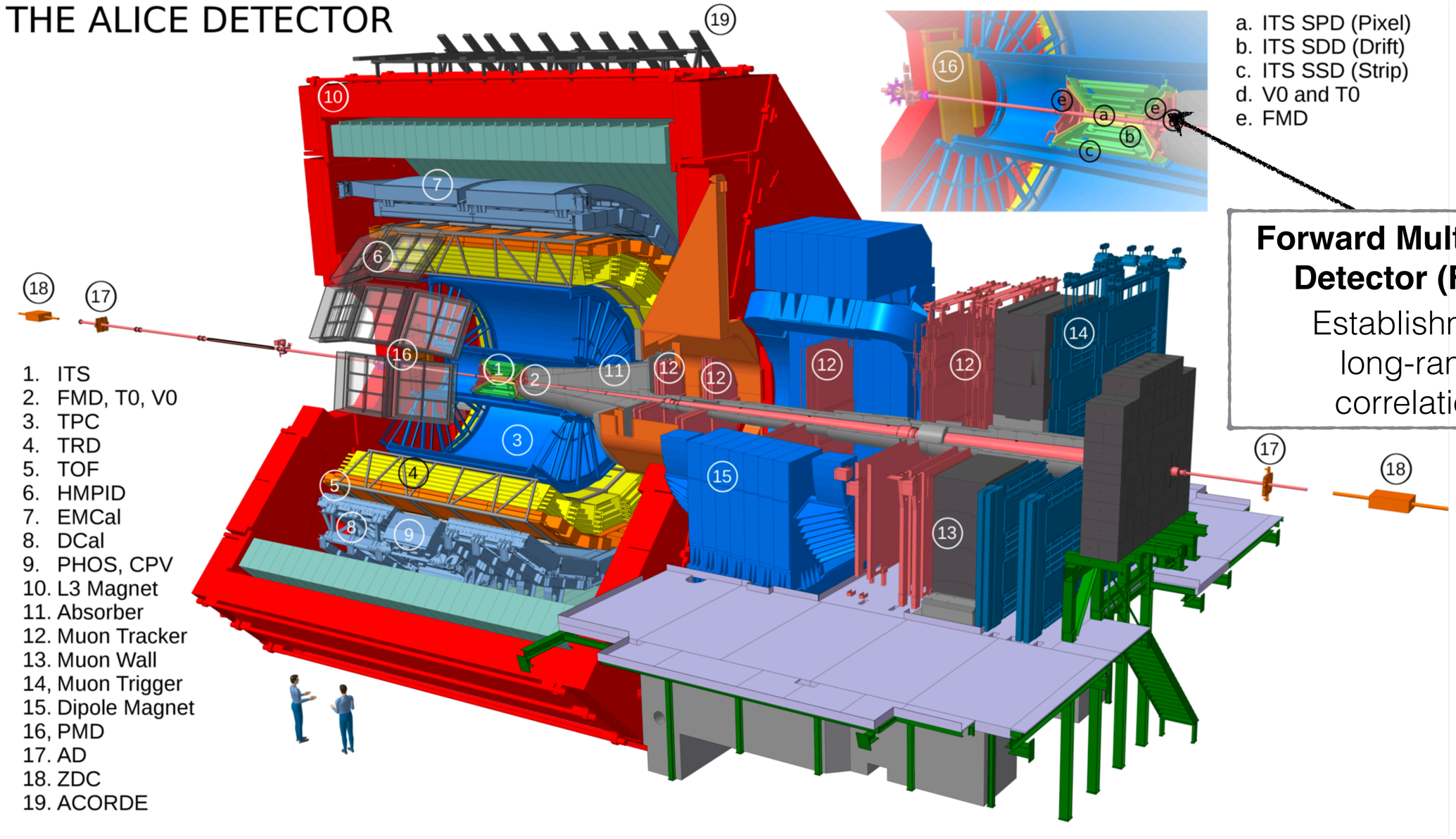
ALICE detector in Run 2



Time-of-Flight detector (TOF)

Particle identification

ALICE detector in Run 2



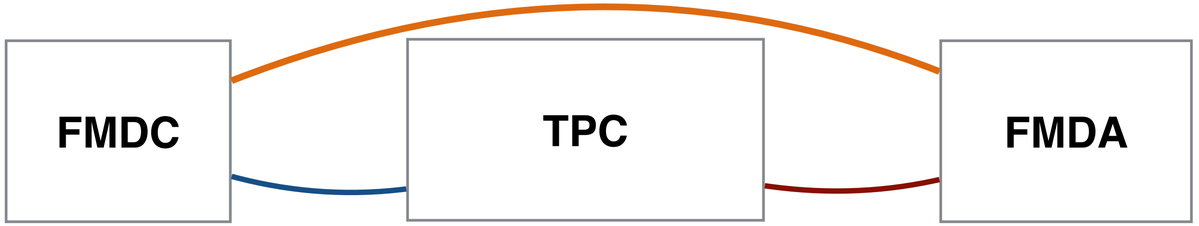
Forward Multiplicity Detector (FMD)

Establishment of long-range correlations

Long-range correlation

Non-flow suppression:

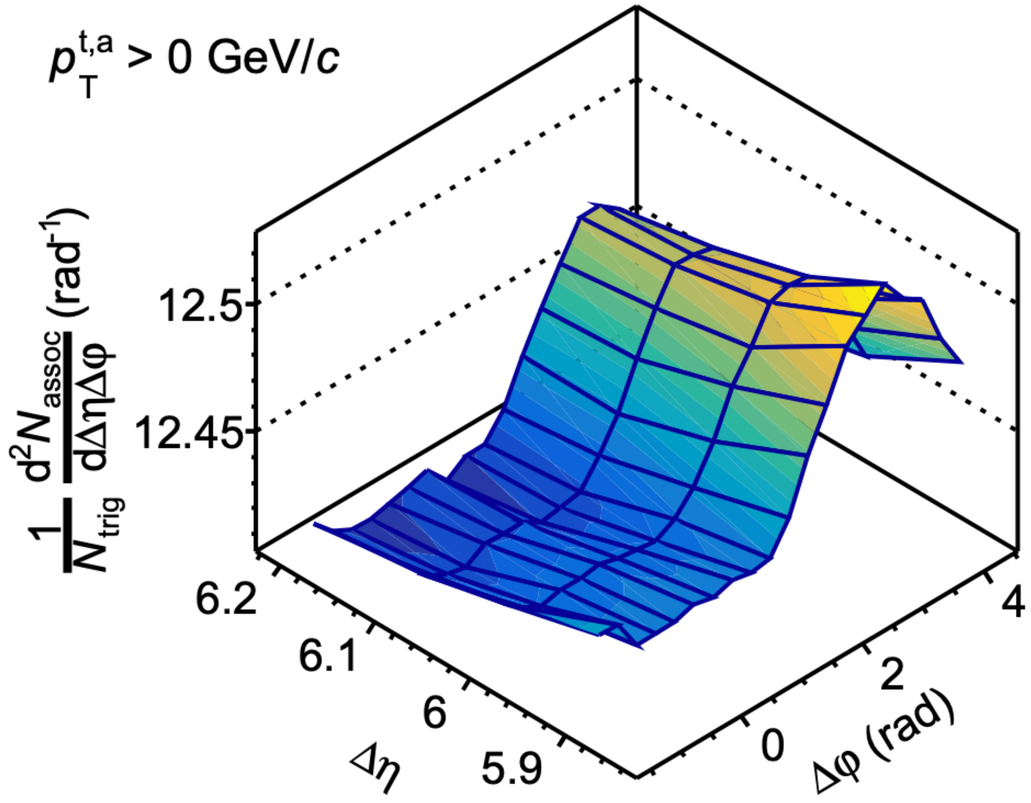
- Long-range correlation



-3.4<η<-1.7 -0.8<η<0.8 1.7<η<5.1

$$v_n\{2\} = \sqrt{\frac{V_{n\Delta}^{\mathrm{TPC-FMDA}} V_{n\Delta}^{\mathrm{TPC-FMDC}}}{V_{n\Delta}^{\mathrm{FMDA-FMDC}}}}$$

FMDA-FMDC (long-range) correlation



ALI-PREL-345489

Template fit

Non-flow suppression:

- Template fit→ correlation function can be described as **a superposition of non-flow and flow**:

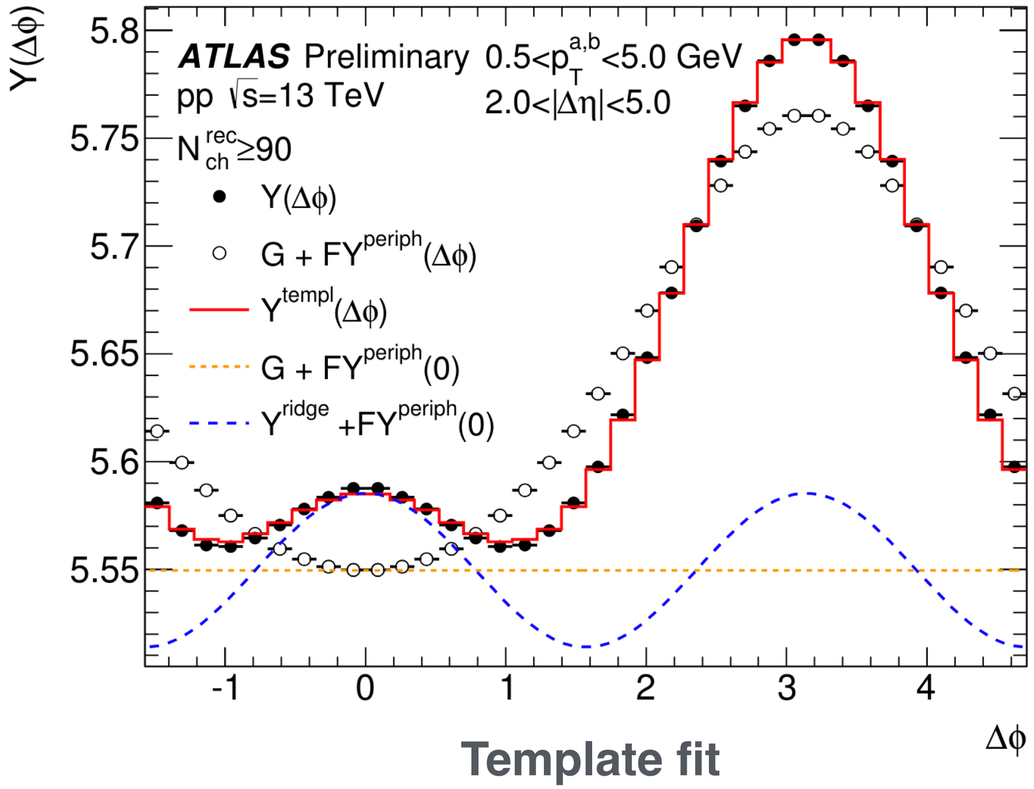
$$Y(\Delta\phi) = FY(\Delta\phi)^{peri} + G[1 + \sum_{n=2}^{\infty} 2V_{n\Delta} cos(n\Delta\phi)]$$

Peripheral events, non-flow dominated

Flow signal

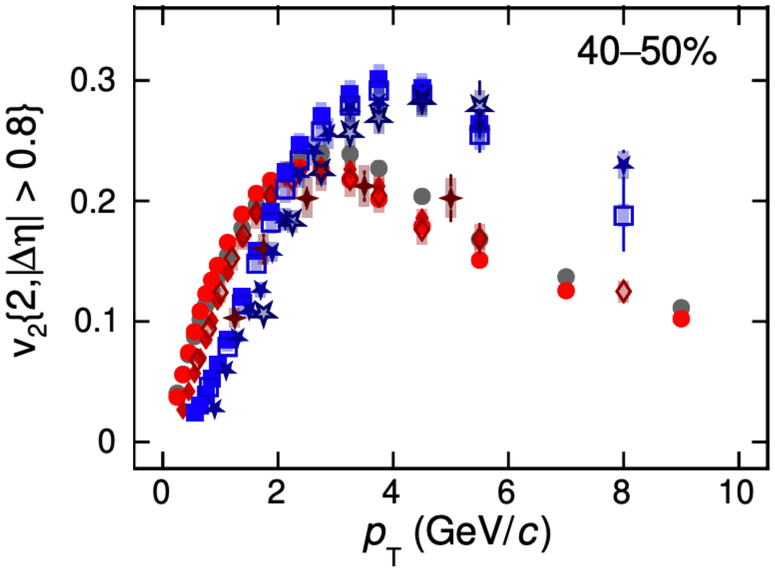
TF is the state of the art approach to extract the v_2 coefficient in analysis of small collision systems

ATLAS PRC 101, 024906 (2020)



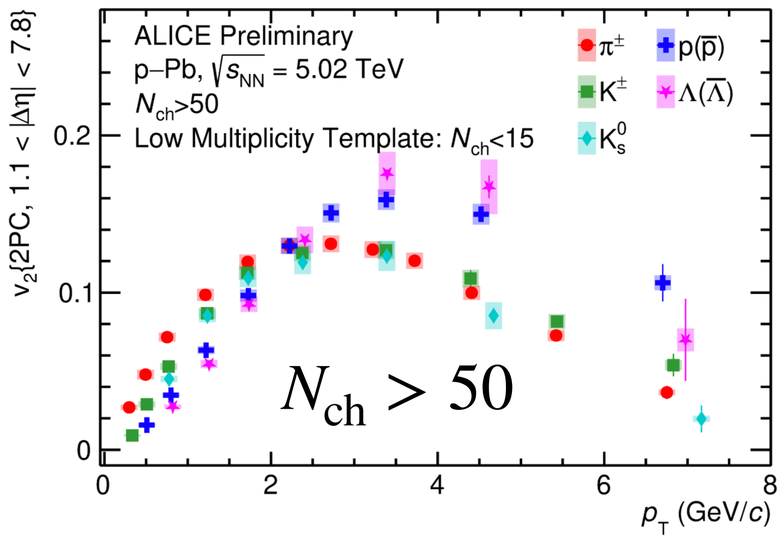
Flow of identified particles Pb–Pb, p–Pb, and pp

Semi-central Pb–Pb



ALICE, JHEP 05 (2023) 243

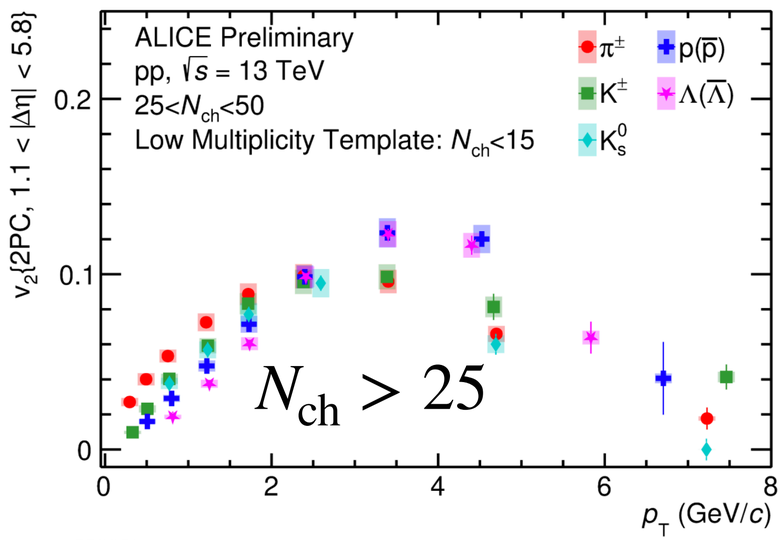
High multiplicity p–Pb



ALI-PREL-573065

ALICE NEW

High multiplicity pp



ALI-PREL-573050

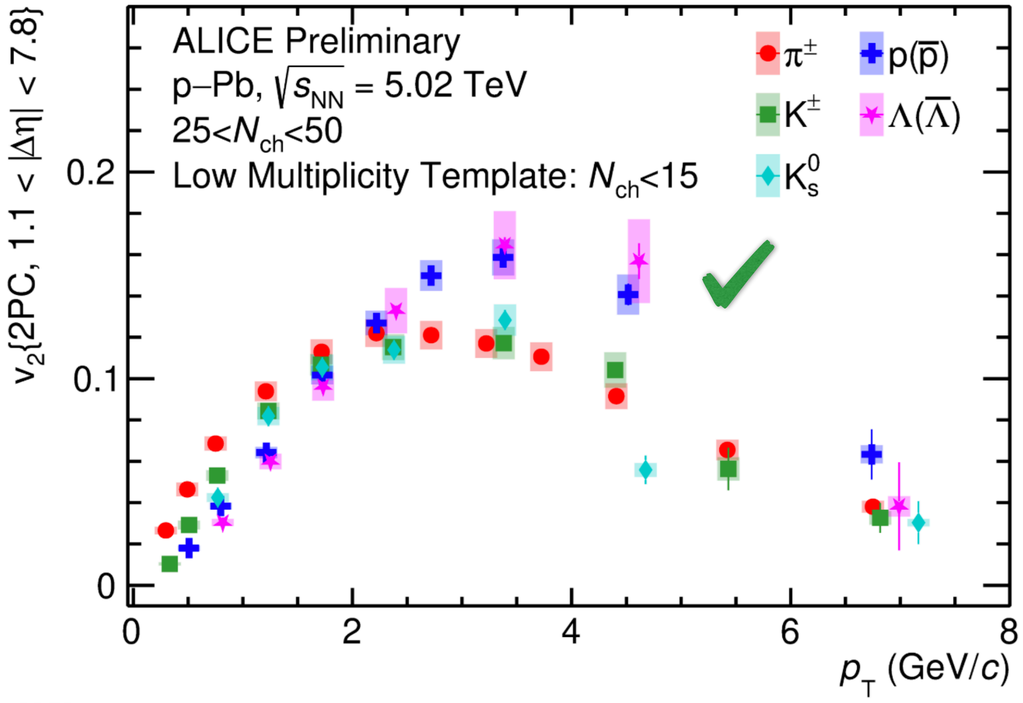
ALICE NEW

- Hydro-dominated **mass ordering** at low p_T ($p_T < 3$GeV/c) in all systems
- **Baryon-meson grouping ($\sim 1\sigma$ confidence) /splitting ($> 5\sigma$ confidence)** at intermediate p_T ($3 < p_T < 5$GeV/c) in all collision systems → **partonic collectivity** in small collision systems

N_{ch} dependence of identified-particle v_2 in p–Pb collisions

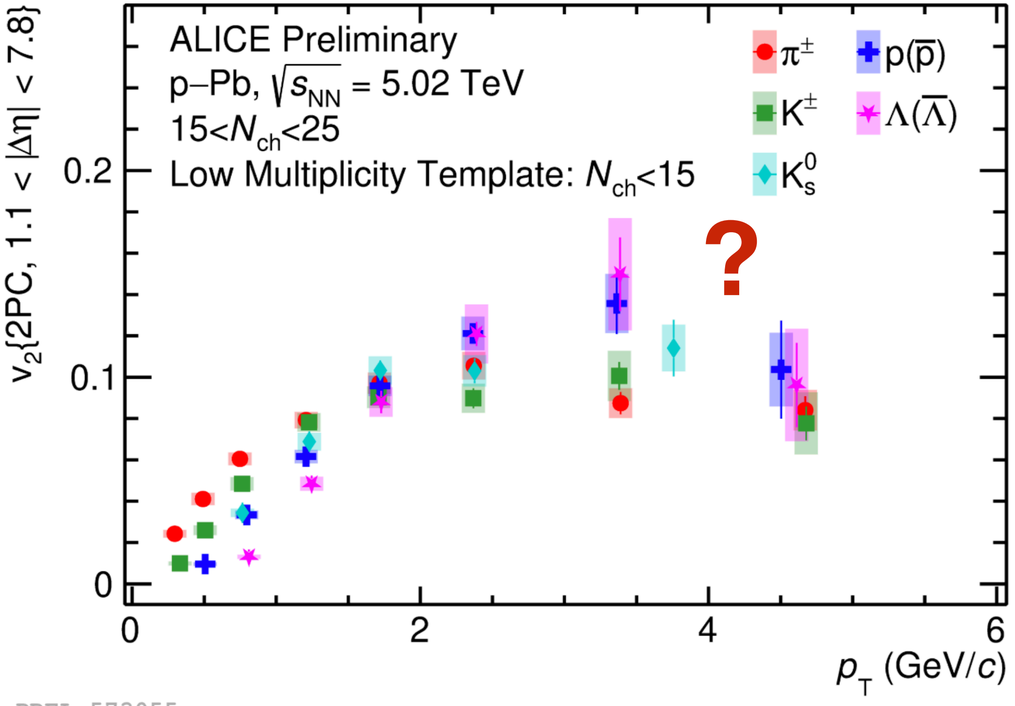
ALICE

ALICE NEW $25 < N_{\mathrm{ch}} < 50$



ALI-PREL-573060

ALICE NEW $15 < N_{\mathrm{ch}} < 25$

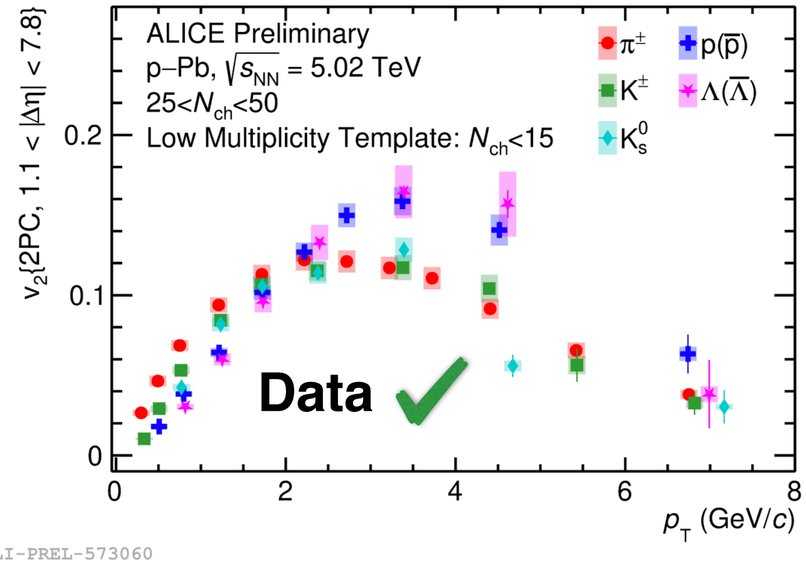


ALI-PREL-573055

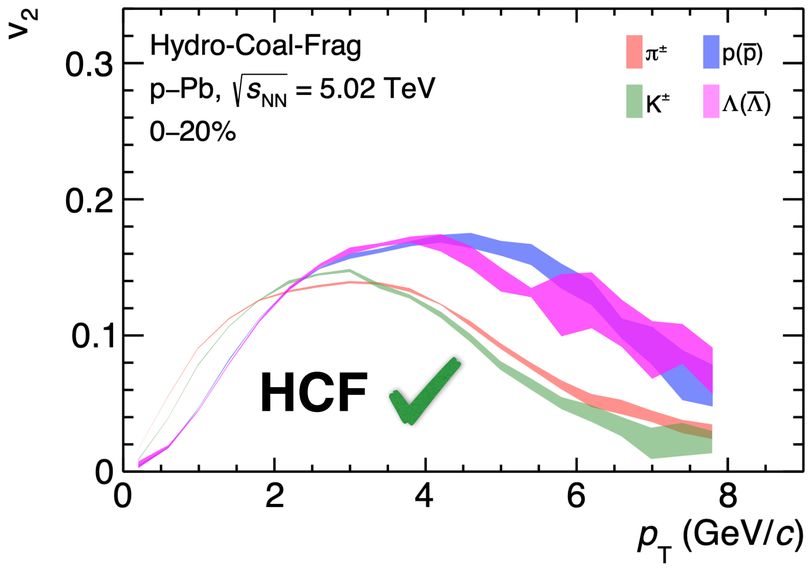
- **Mass ordering** observed in all multiplicity intervals in p–Pb
- **Baryon-meson grouping ($\sim 1\sigma$) and splitting ($> 5\sigma$)** are observed in N_{ch}>25
- In N_{ch}<25, **grouping and splitting ($\sim 2\sigma$)** is diluted

Model comparison in high-multiplicity p–Pb collisions

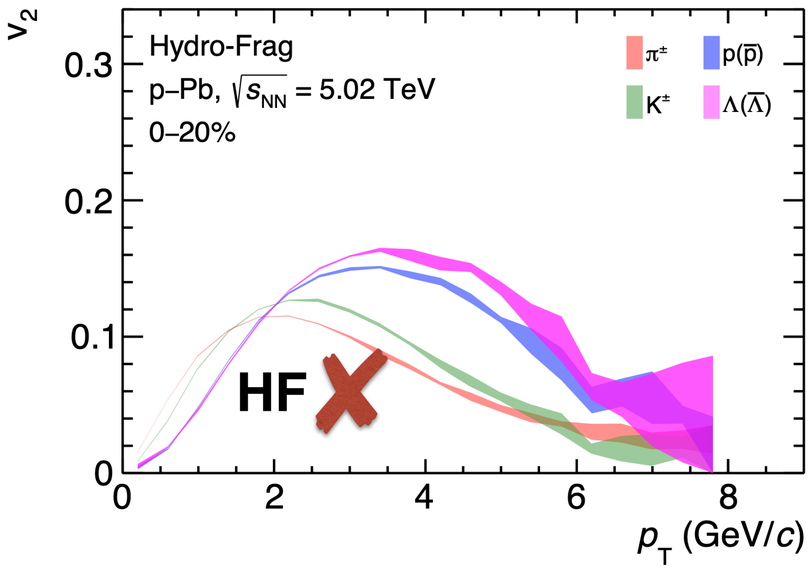
Data and model have different N_{ch}/centrality cuts



ALI-PREL-573060



Y. Wang, arXiv:2401.00913



Y. Wang, arXiv:2401.00913

- Baryon-meson grouping/splitting reproduced by **Hydrodynamic+Coalescence +Fragmentation (HCF)** model
- **Hydrodynamic+Fragmentation (HF)** model underestimates the v_2, fails to explain the grouping/splitting

Model comparison in high-multiplicity p–Pb collisions

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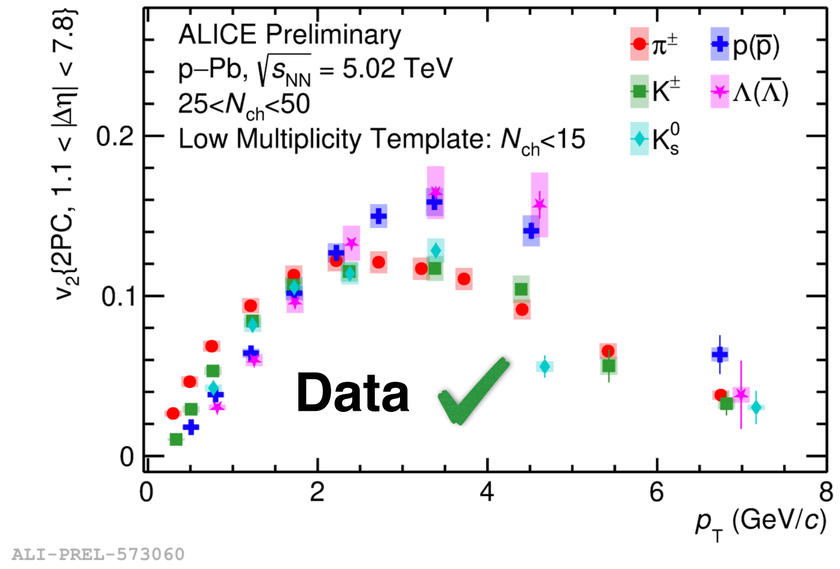

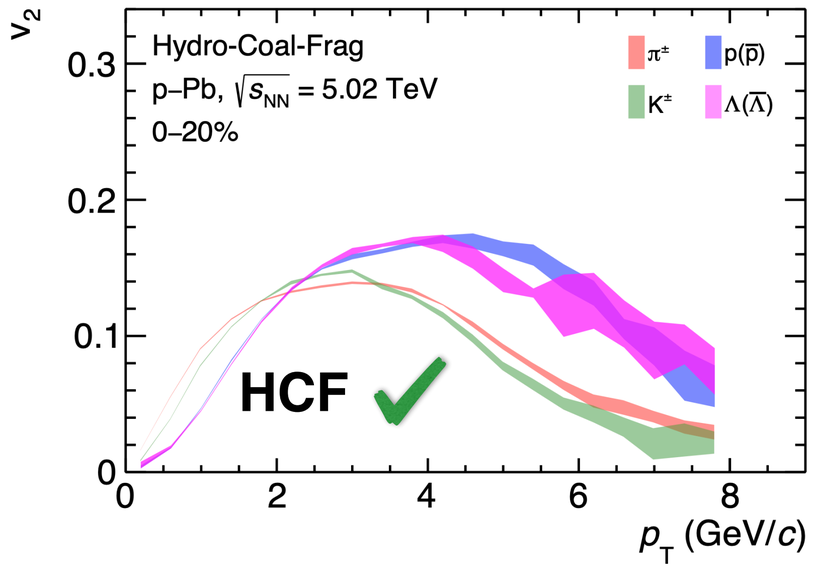

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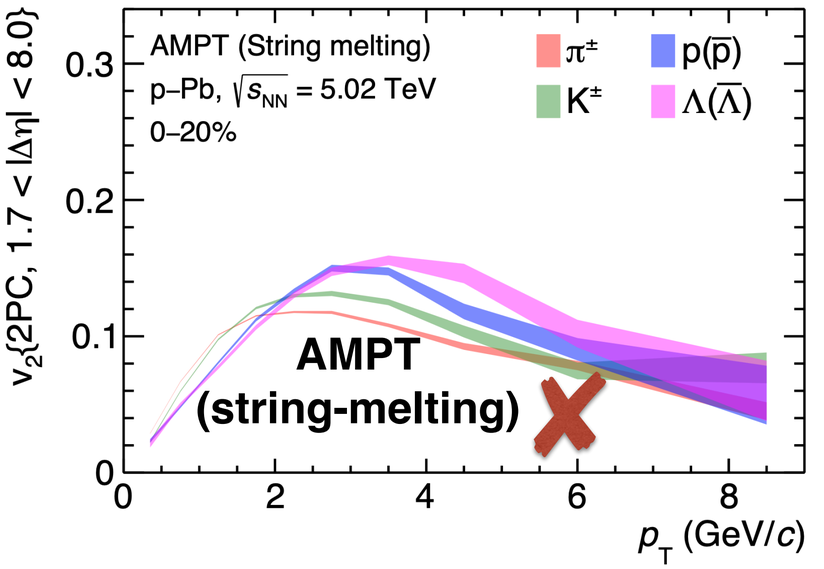
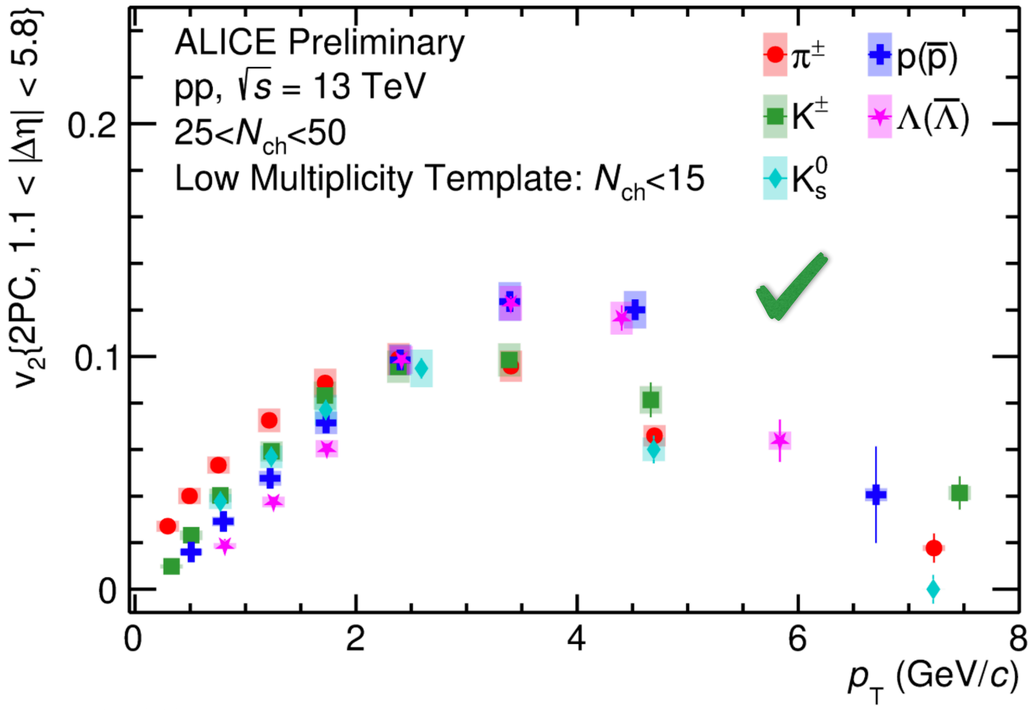


S. Tang NUCL SCI TECH 35, 32 (2024)

- Baryon-meson grouping/splitting is reproduced by **Hydrodynamic+Coalescence +Fragmentation (HCF) model**
- **AMPT** with string-melting configuration fails to explain the grouping/splitting

N_{ch} dependence of identified-particle v_2 in pp collisions

ALICE NEW $25 < N_{\mathrm{ch}} < 50$



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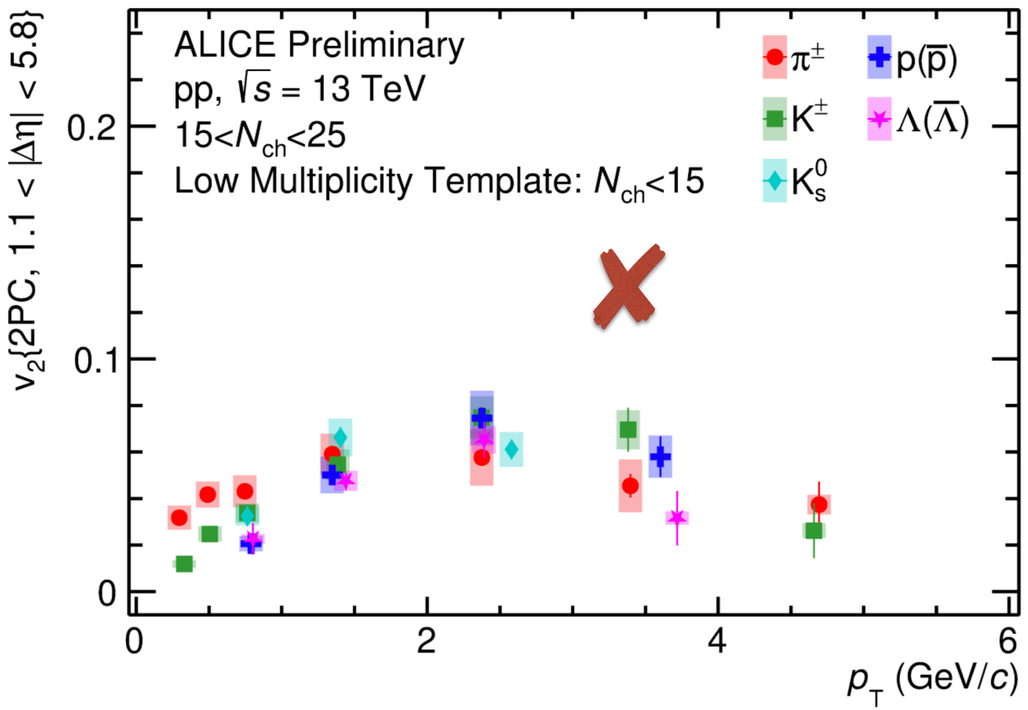


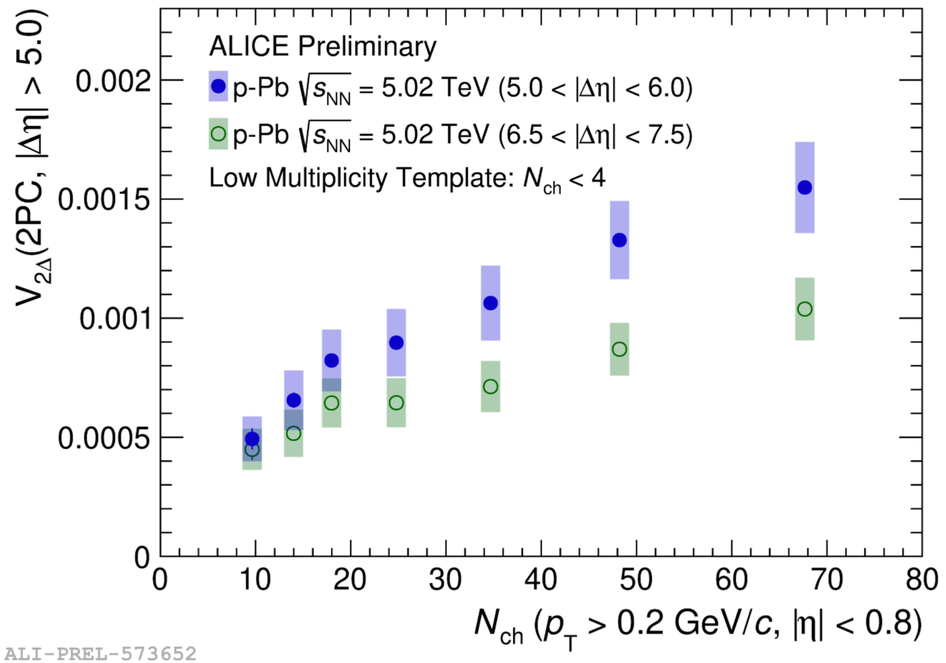
ALI-PREL-573045

- **Mass ordering** only observed in N_{ch}>25 in pp
- **Baryon-meson grouping ($\sim 1\sigma$) and splitting ($> 5\sigma$)** are observed in N_{ch}>25
- In N_{ch}<25, **grouping and splitting ($< 1\sigma$) disappears**

Ultra long-range correlation in ALICE

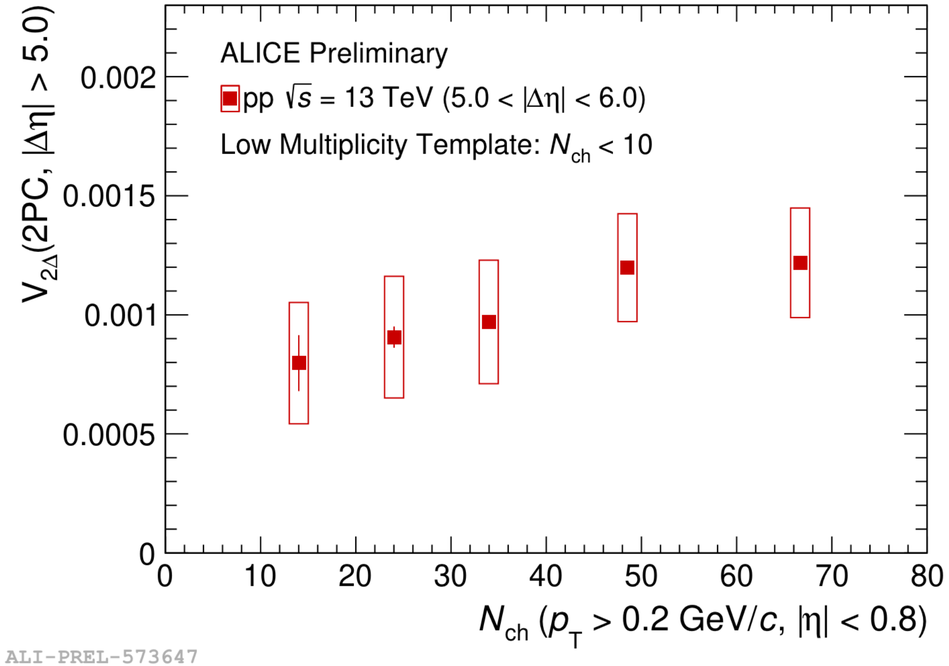
Non-flow removal by the template fit

ALICE NEW



ALI-PREL-573652

ALICE NEW



ALI-PREL-573647

- **Longest-range correlation** of charged hadrons in low multiplicity in pp and p–Pb
- Source of long-range correlation at low multiplicity pp and p–Pb?

Conclusion

- **Partonic collectivity** observed in small collision systems;
- In low multiplicity ($N_{\mathrm{ch}} < 25$) : Baryon-meson grouping/splitting **is diluted in p–Pb, disappears in pp**
- The **HCF** model reproduces the grouping/splitting of v_2;
- **Ultra long-range correlation** found in low multiplicity in small collisions;
- Search for partonic collectivity and long-range correlation in **lower** N_{ch} events in small collisions with **ALICE Run 3 data**.

Talks/posters about ALICE Run 3 and flow at ALICE:

- The silicon tracking system of the future ALICE 3 experiment at the LHC (Terrace 2B, 18/7, 15:39)
- The ALICE 3 particle identification systems (Terrace 2B, 18/7, 17:36)
- Innovative silicon timing sensors for the future ALICE 3 experiment (Foyer Floor 2, 19/7, 19:00)
- Polarization and flow of multi-strange hadrons with ALICE (Club B, 18/7, 15:04)
- Light-flavour particle production as a function of transverse spherocity with ALICE (Club B, 19/7, 08:47)
- Study of collective phenomena via the production of heavy quarks and quarkonia in hadronic collisions with ALICE (Club B, 19/7, 17:53)

Thanks for your attention!

Back up

Validation of template–fit by PYTHIA