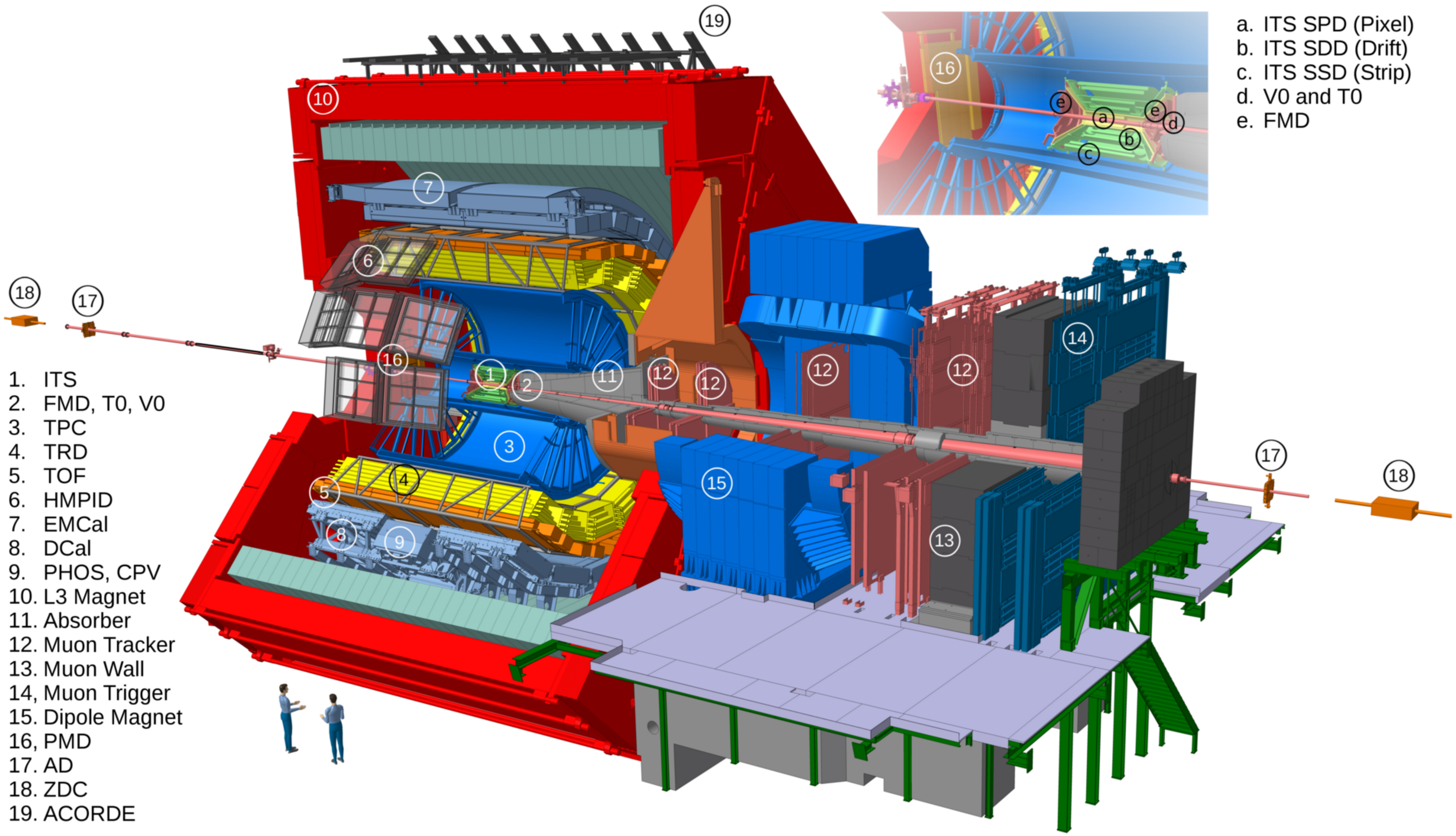
Particle production as a function of charged-particle flattenicity in small collision systems with ALICE

Antonio Ortiz, for the ALICE Collaboration
Instituto de Ciencias Nucleares, UNAM

SQM Strasbourg 2024
Strangeness in Quark Matter

ALICE in Run 2

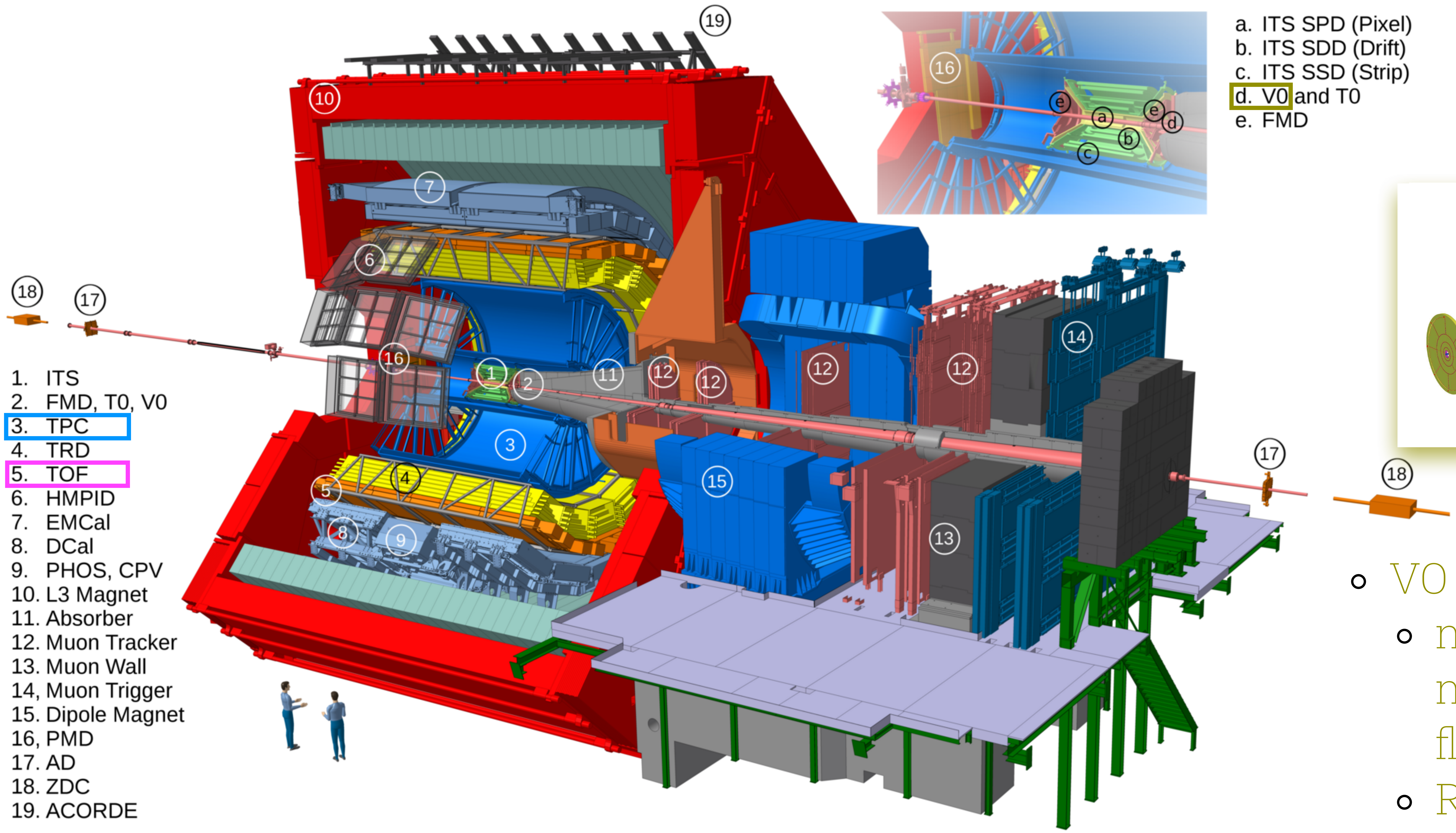


a. ITS SPD (Pixel)
b. ITS SDD (Drift)
c. ITS SSD (Strip)
d. V0 and T0
e. FMD

1. ITS
2. FMD, T0, V0
3. TPC
4. TRD
5. TOF
6. HMPID
7. EMCal
8. DCal
9. PHOS, CPV
10. L3 Magnet
11. Absorber
12. Muon Tracker
13. Muon Wall
14, Muon Trigger
15. Dipole Magnet
16, PMD
17. AD
18. ZDC
19. ACORDE

ALICE in Run 2

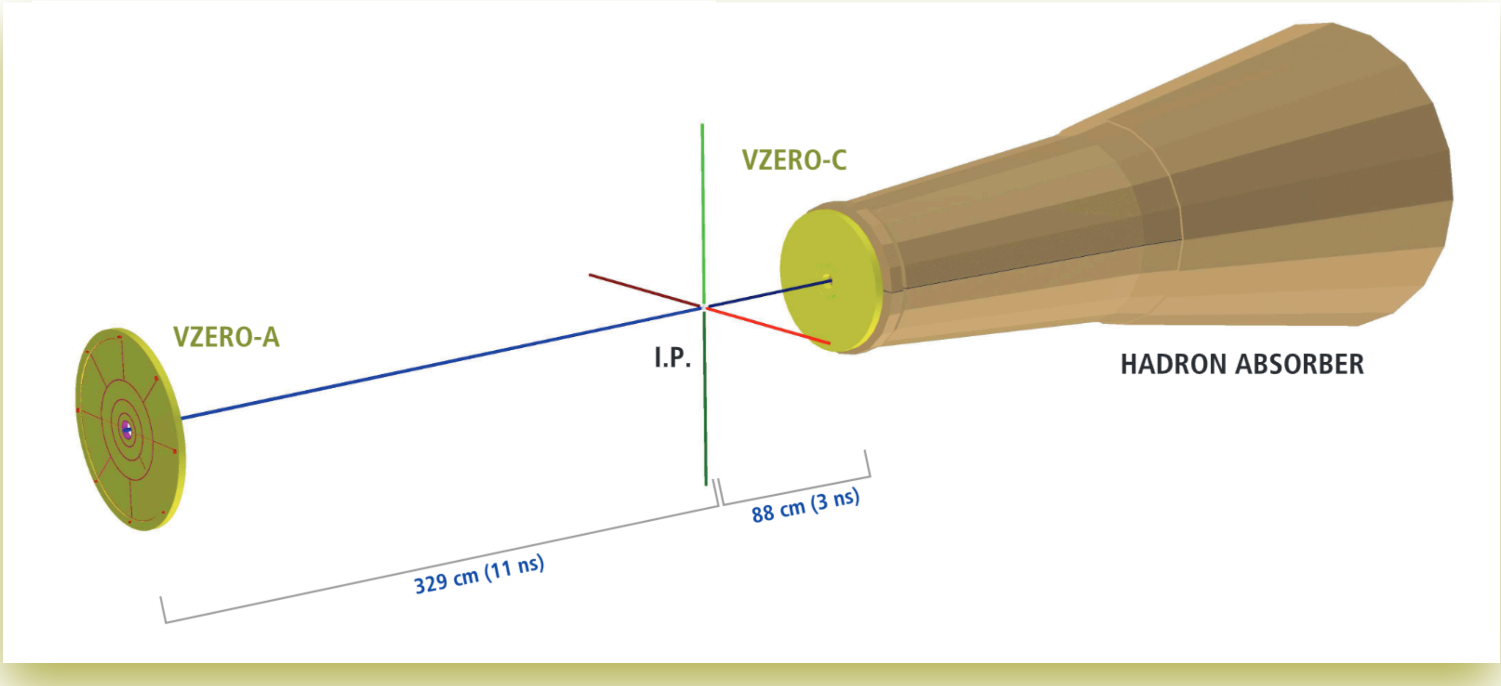
Instituto de Ciencias Nucleares UNAM



a. ITS SPD (Pixel)
b. ITS SDD (Drift)
c. ITS SSD (Strip)
d. V0 and T0
e. FMD

V0A: $2.8 < \eta < 5.1$

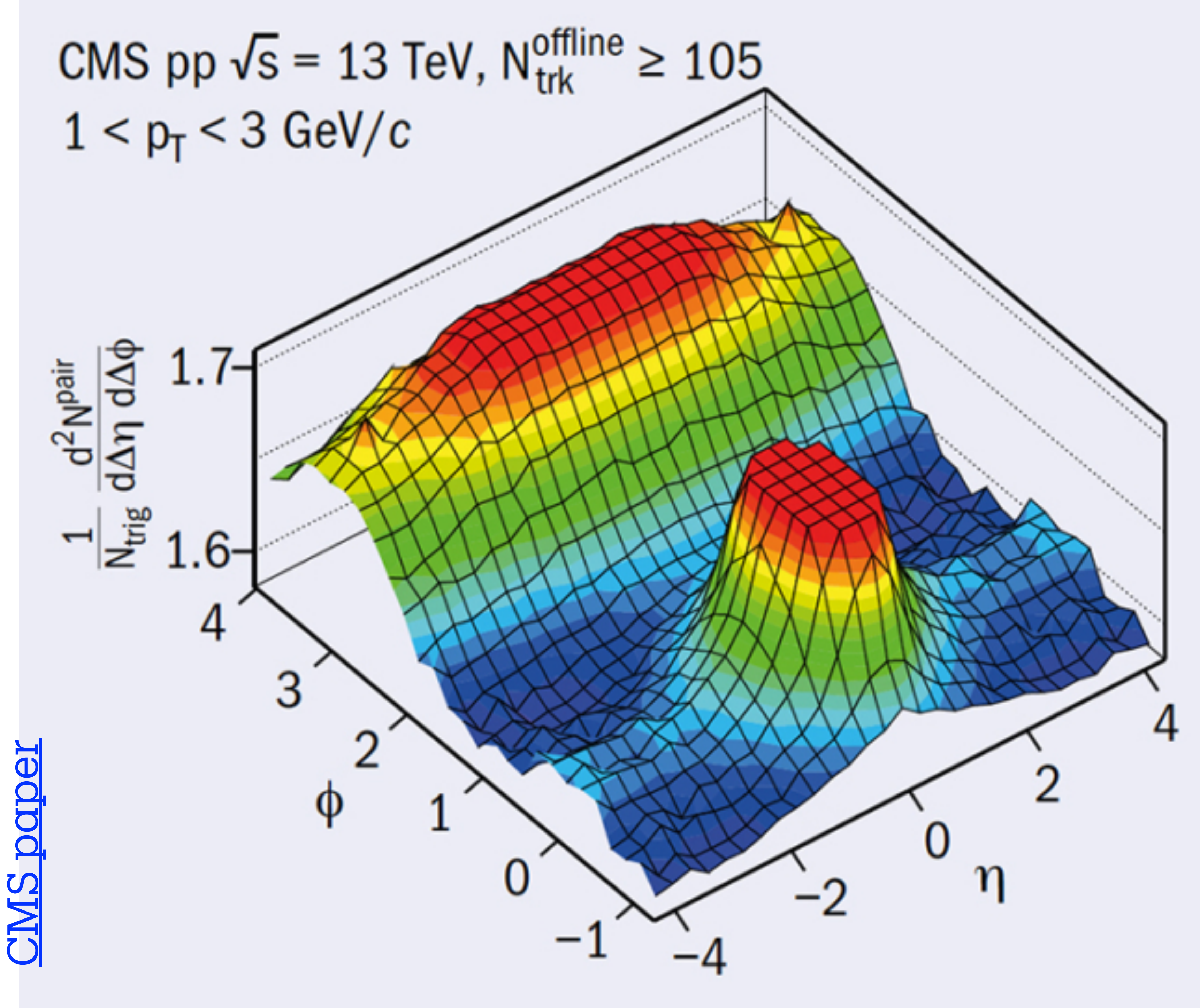
V0C: $-3.6 < \eta < -1.7$



- V0 detector:
  - minimum-bias (MB) trigger, multiplicity (V0M), and flattenicity
  - Rejection of beam induced background

- TPC: tracking and particle identification (PID) using dE/dx in gas
- TOF: Particle velocity (PID)

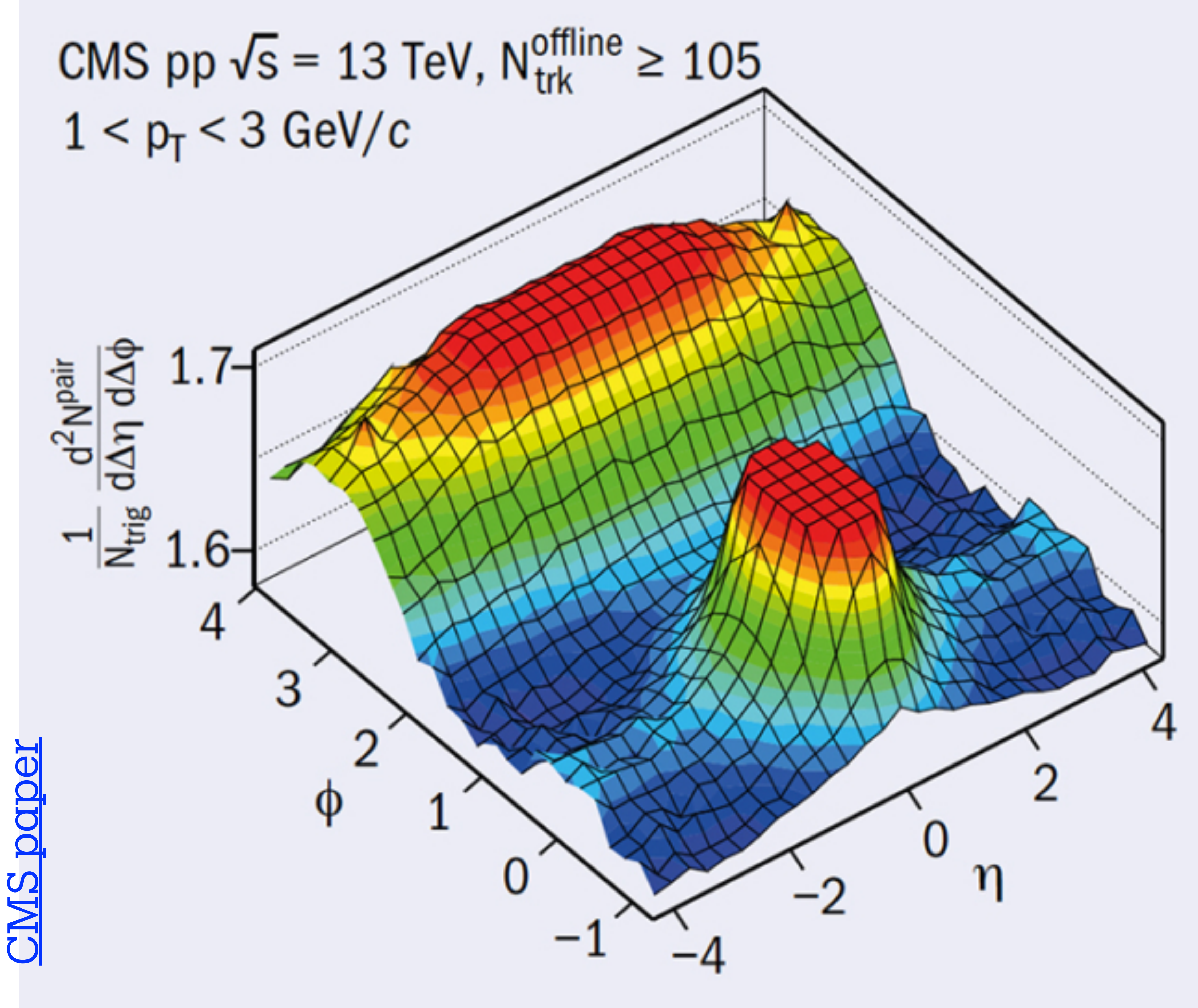
sQGP in pp collisions?



CMS paper

Long range angular correlations in low- and high-multiplicity (HM) pp collisions ALICE. Phys. Rev. Lett. 132 (2024) 17, 172302

sQGP in pp collisions?



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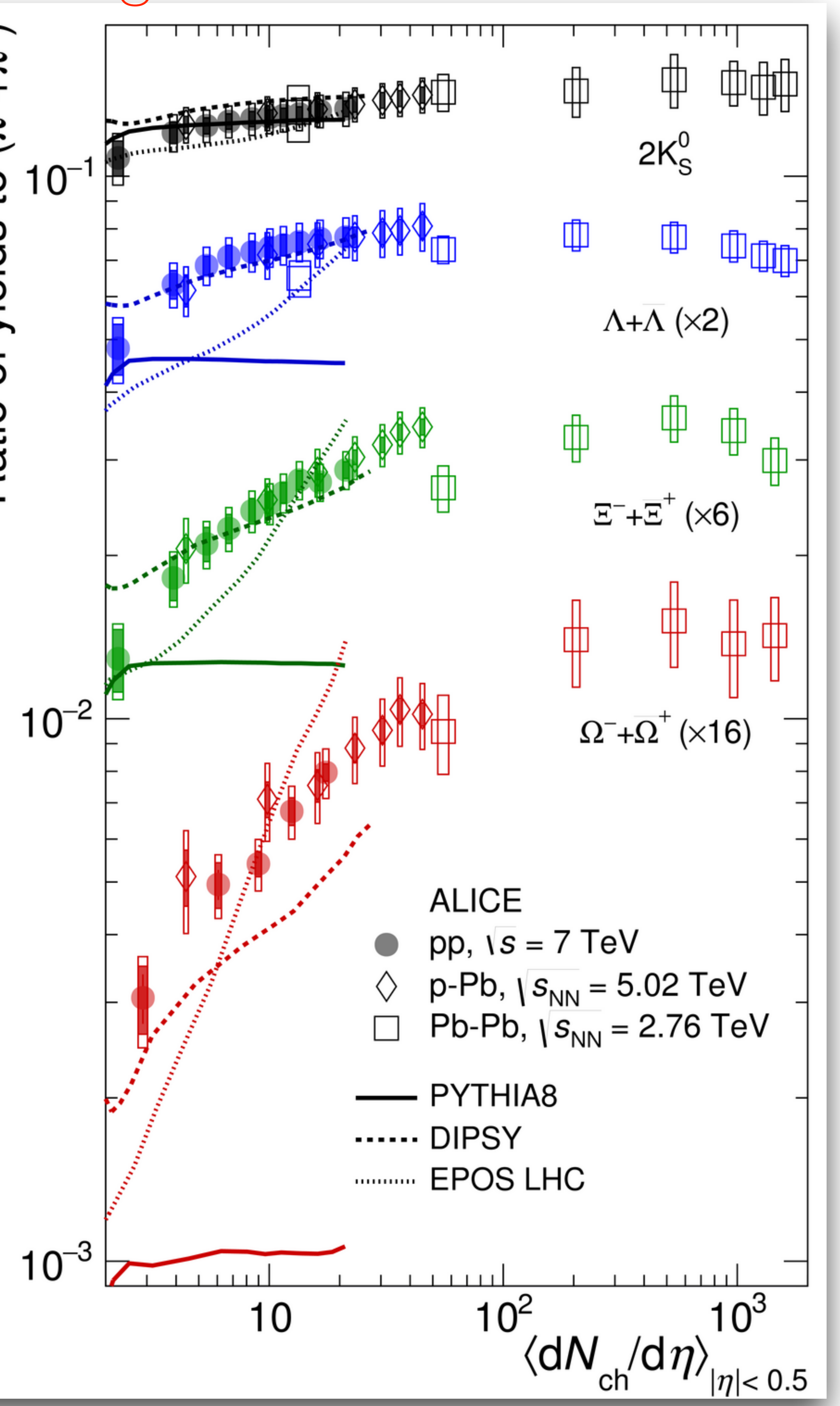
Strangeness enhancement



ALICE, Nat. Phys. volume 13, 535-539 (2017)

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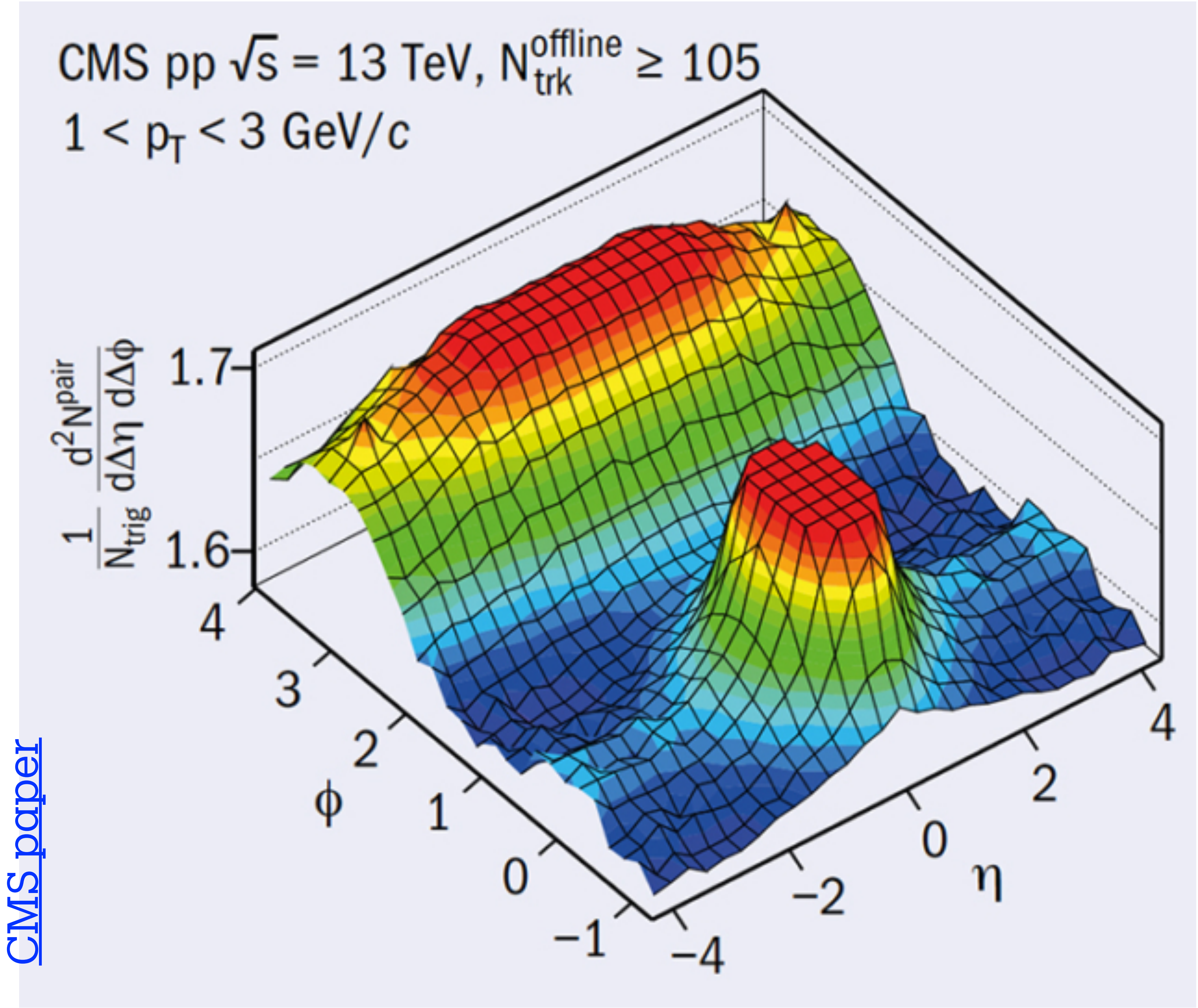
CMS paper



Long range angular correlations in low- and high-multiplicity (HM) pp collisions ALICE. Phys. Rev. Lett. 132 (2024) 17, 172302

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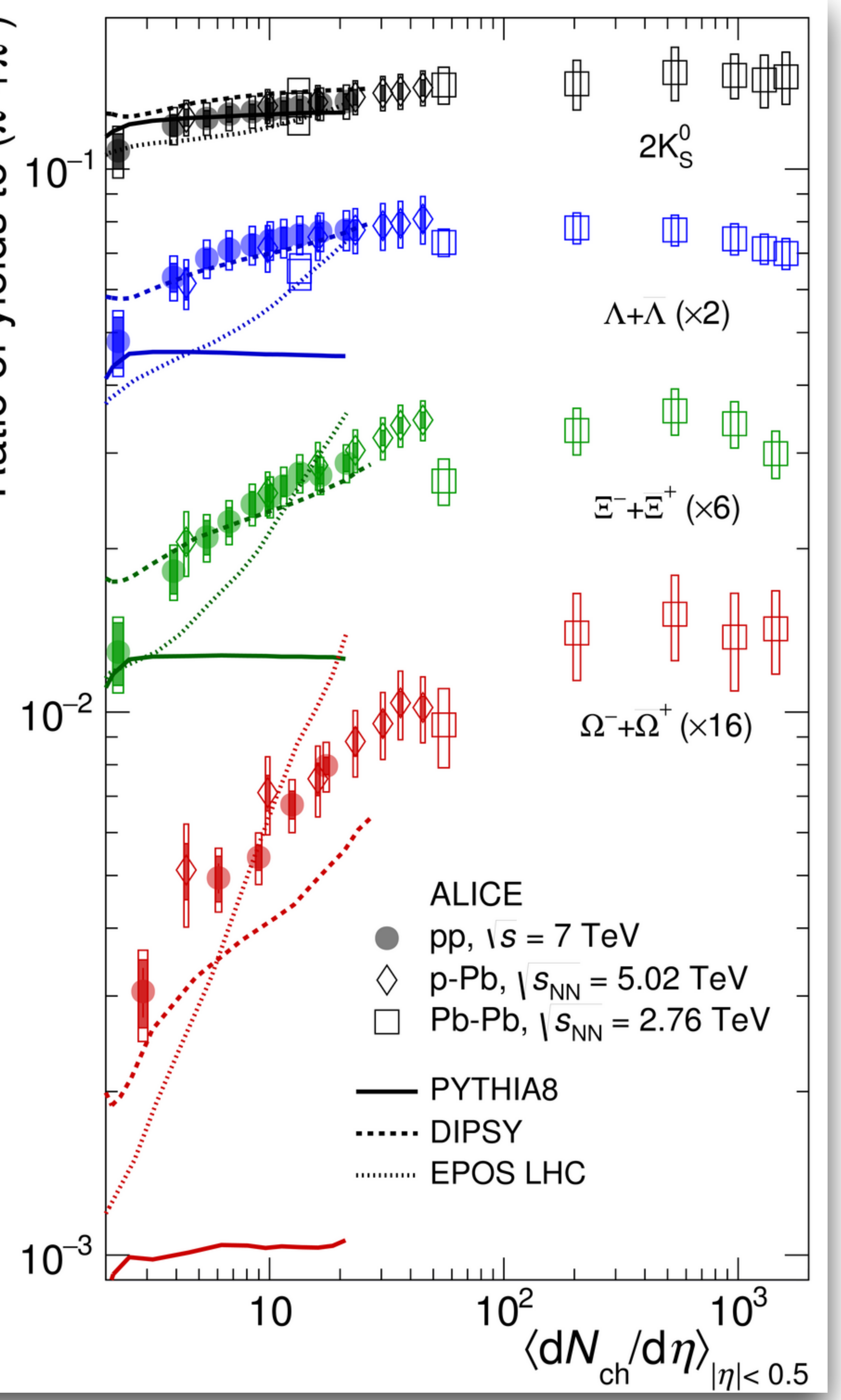
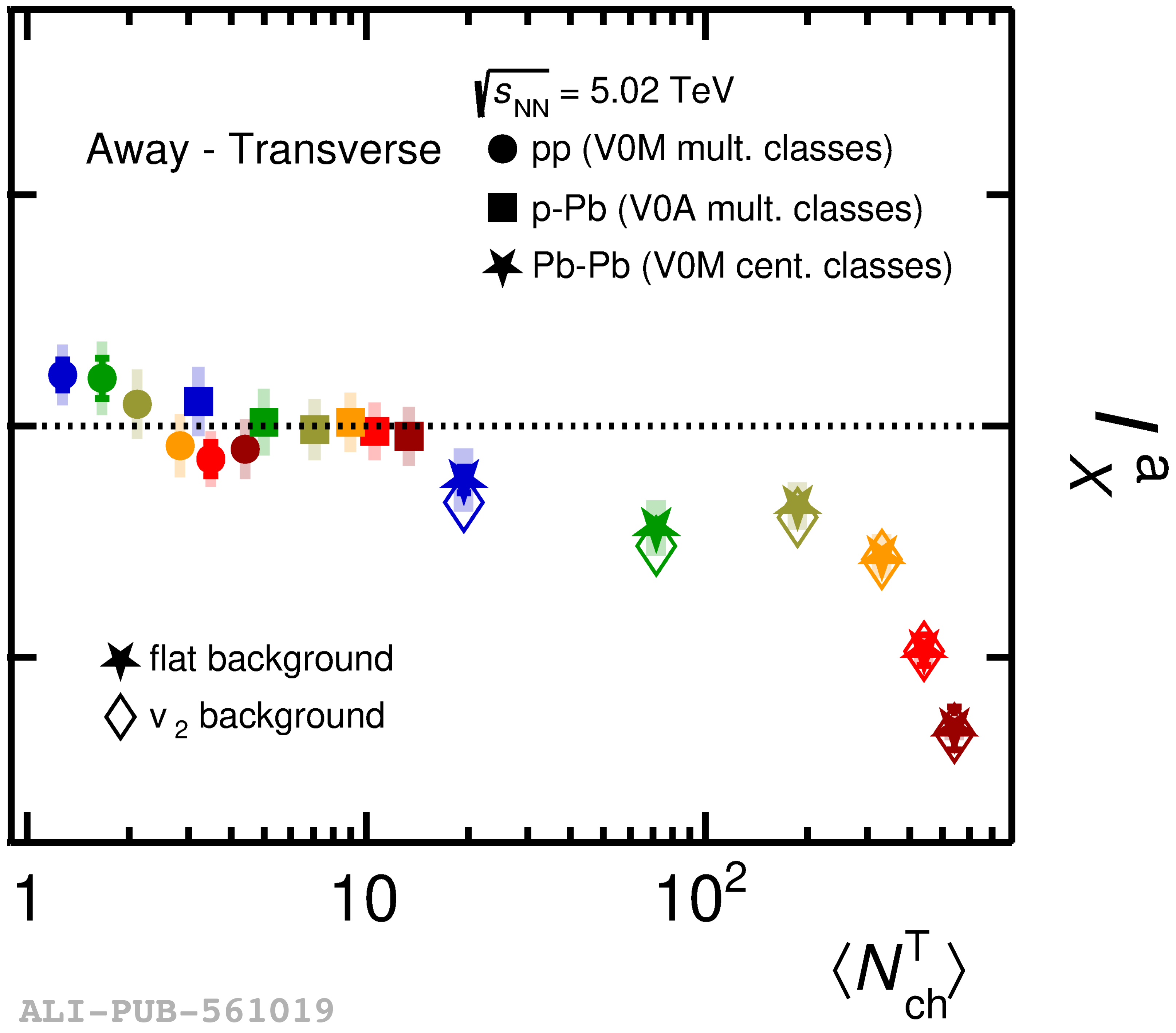


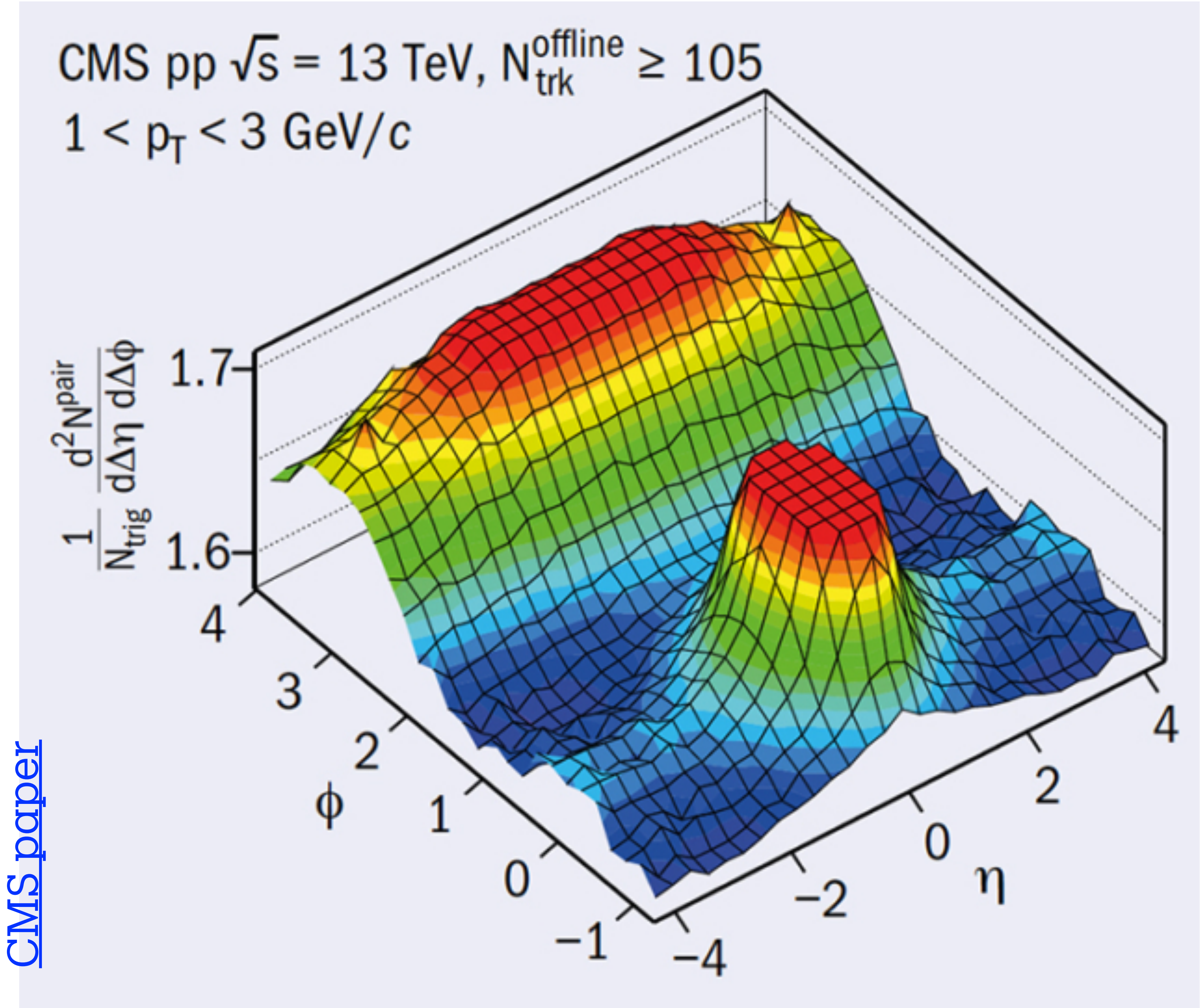
Jet quenching?

ALICE, Phys. Lett. B 843 (2022) 137649



pp and p-Pb collisions: no hint of jet quenching

sQGP in pp collisions?



CMS paper

Long range angular correlations in low- and high-multiplicity (HM) pp collisions ALICE, Phys. Rev. Lett. 132 (2024) 17, 172302

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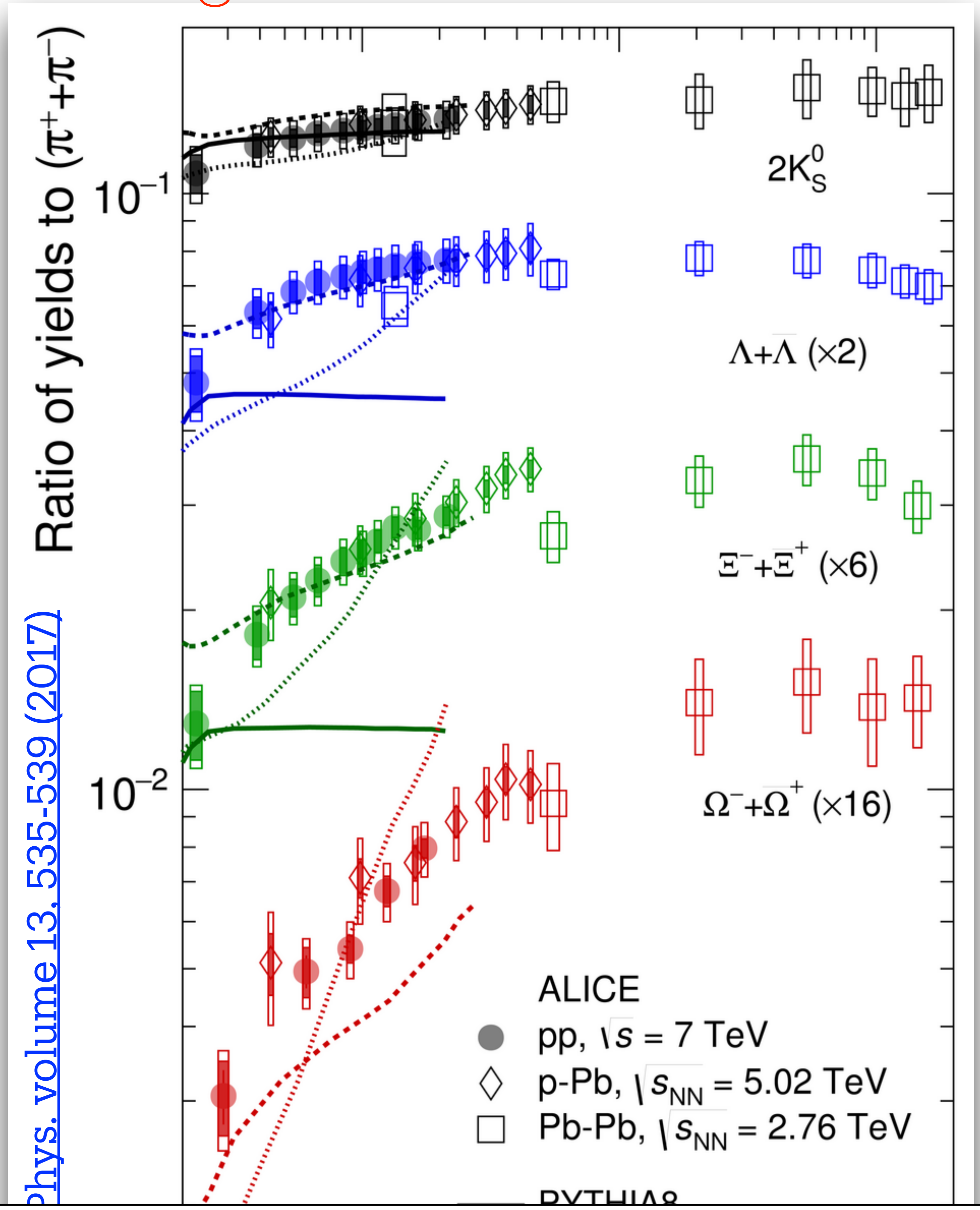

Nature Phys. volume 13, 535-539 (2017)

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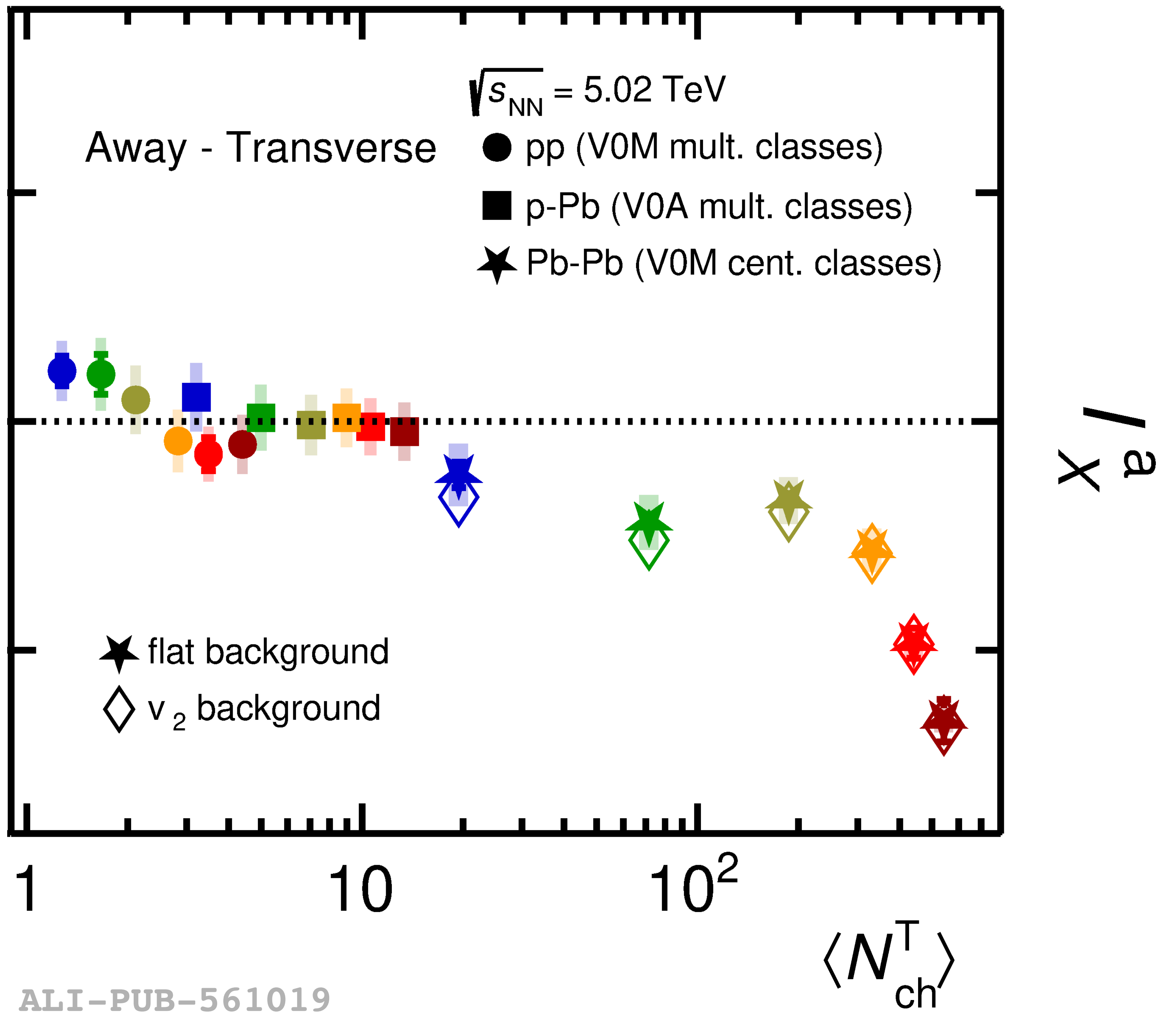
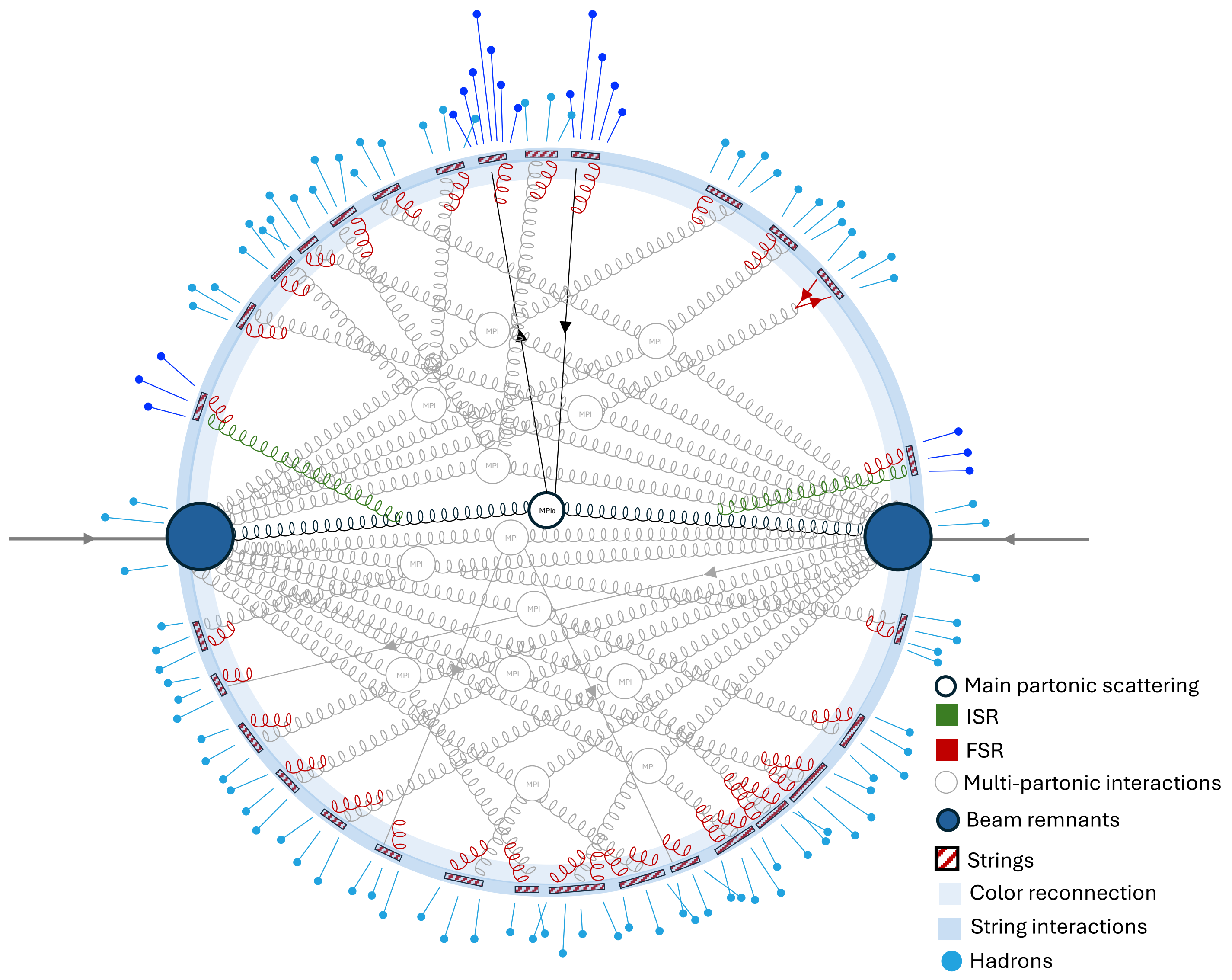


ALICE, Phys. Lett. B 843 (2022) 137649

pp and p-Pb collisions: no hint of jet quenching

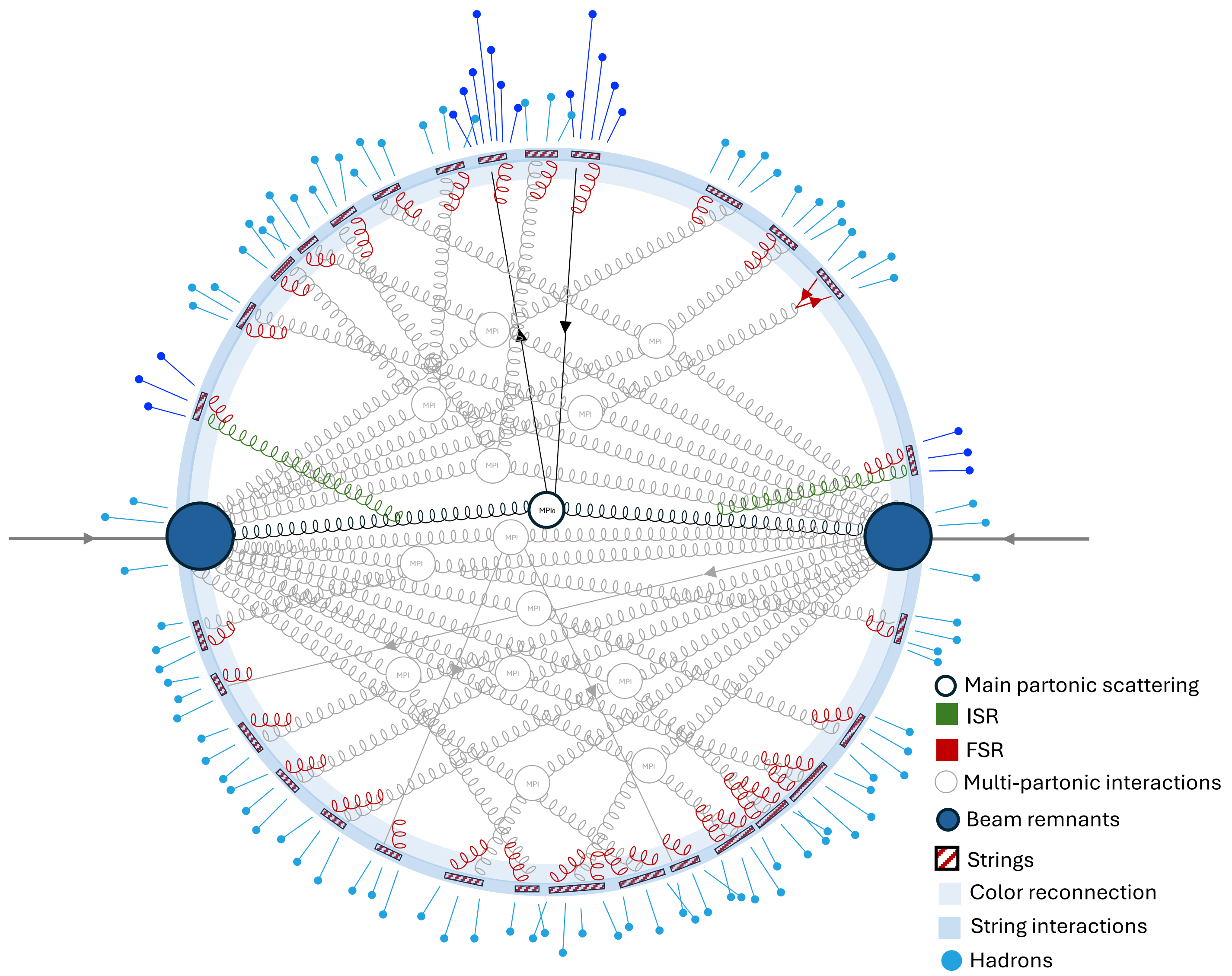
Collectivity in small systems [Track 6]	Strangeness in small systems [Track 1]			
Debojit Sarkar 4/06/24, 8:30 h	Roman Nepeivoda 4/06/24, 11:20 h	Chiara De Martin 4/06/24, 12:00 h	Oliver Matonoha 4/06/24, 17:30 h	Gijs van Weelden 5/06/24, 9:50 h

Bias due to local mult. fluctuations



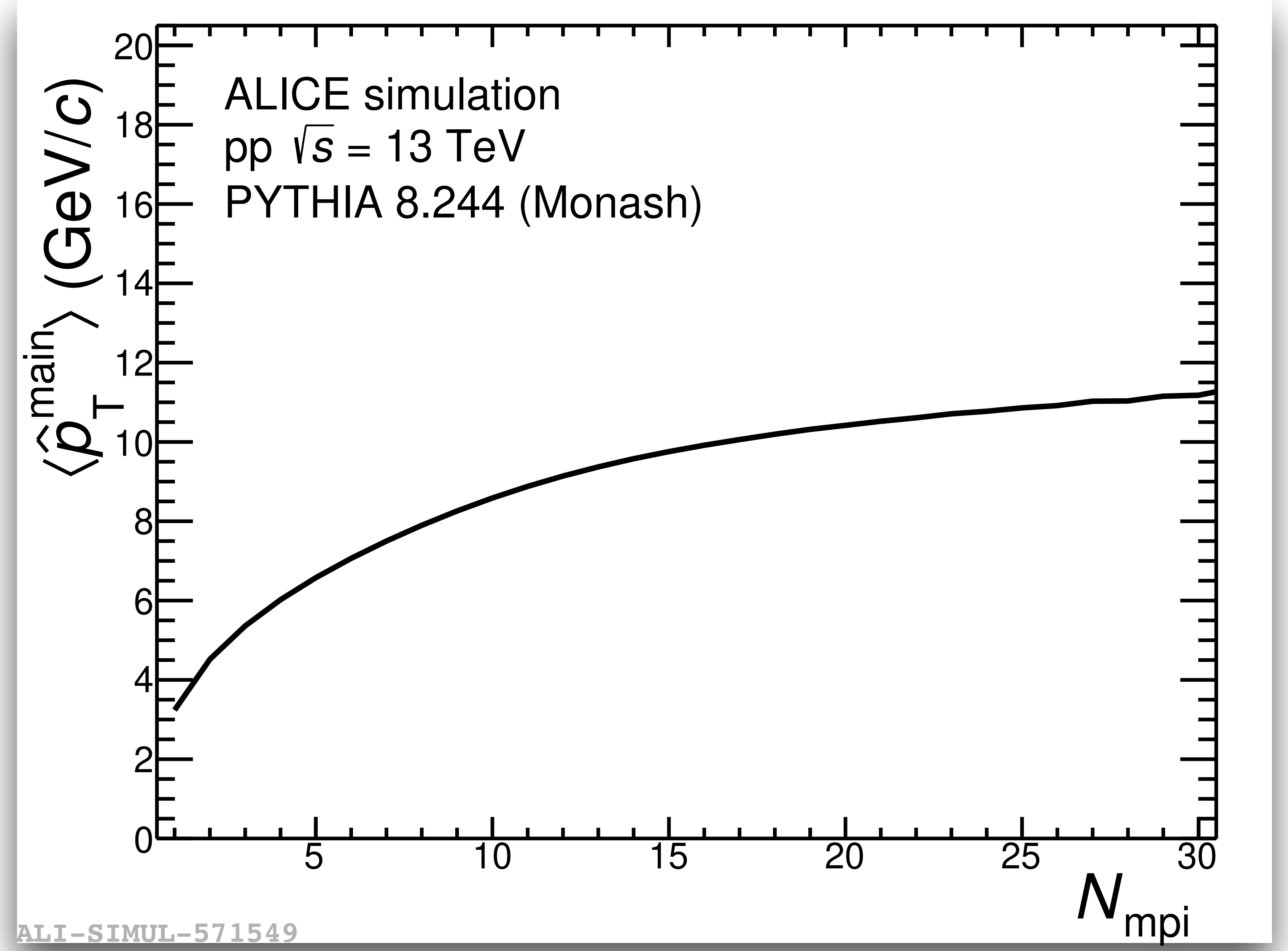
Multiparton interactions (MPI): more than one parton-parton scattering occurring in the same pp collision. Color reconnection (CR) produce collective-like effects

Bias due to local mult. fluctuations



Multiparton interactions (MPI): more than one parton-parton scattering occurring in the same pp collision. Color reconnection (CR) produce collective-like effects

The more central the pp collision, the higher the probability to find a high-p_{T} parton ($\hat{p}_{\mathrm{T}}^{\mathrm{main}}$)



Bias due to local mult. fluctuations

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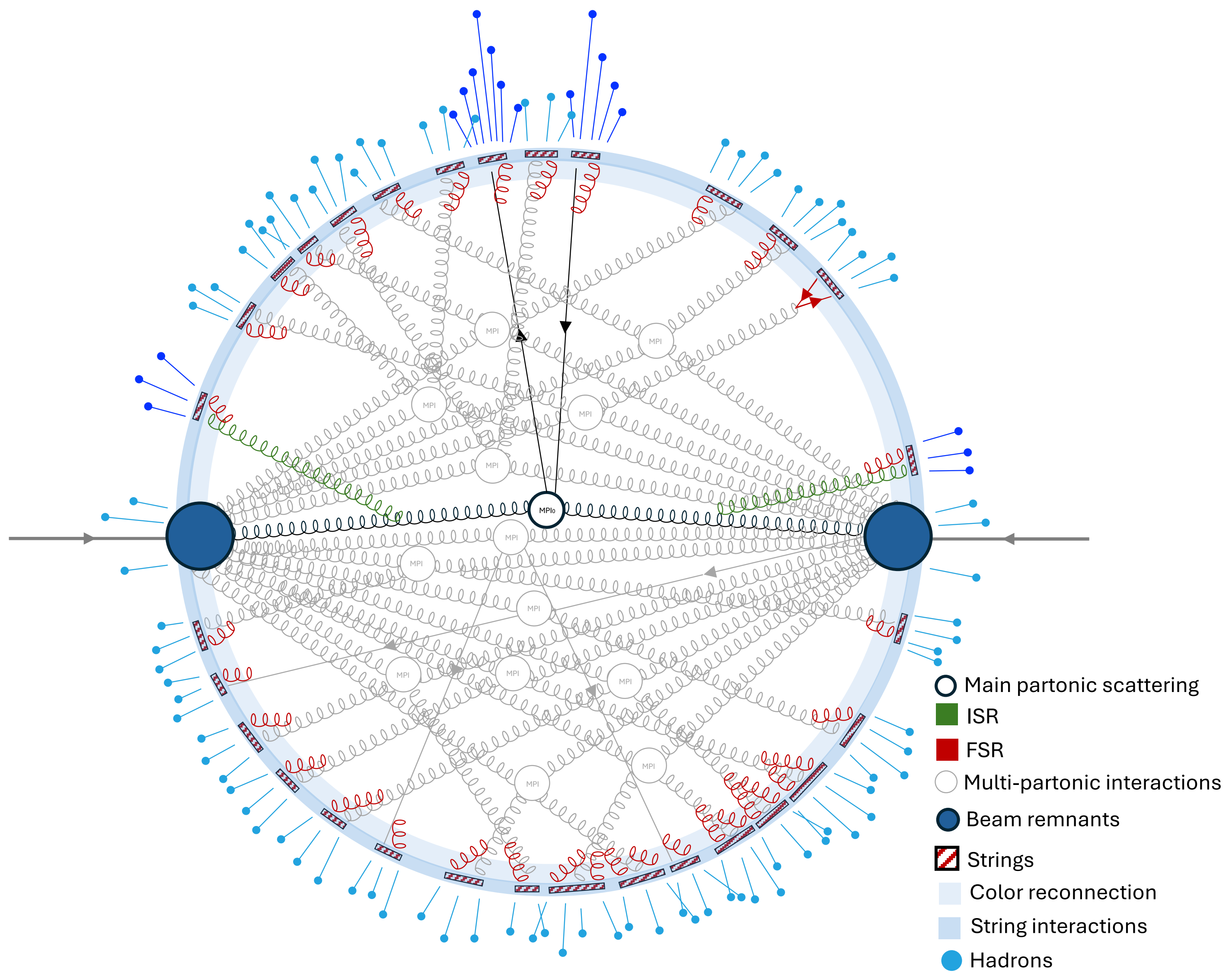

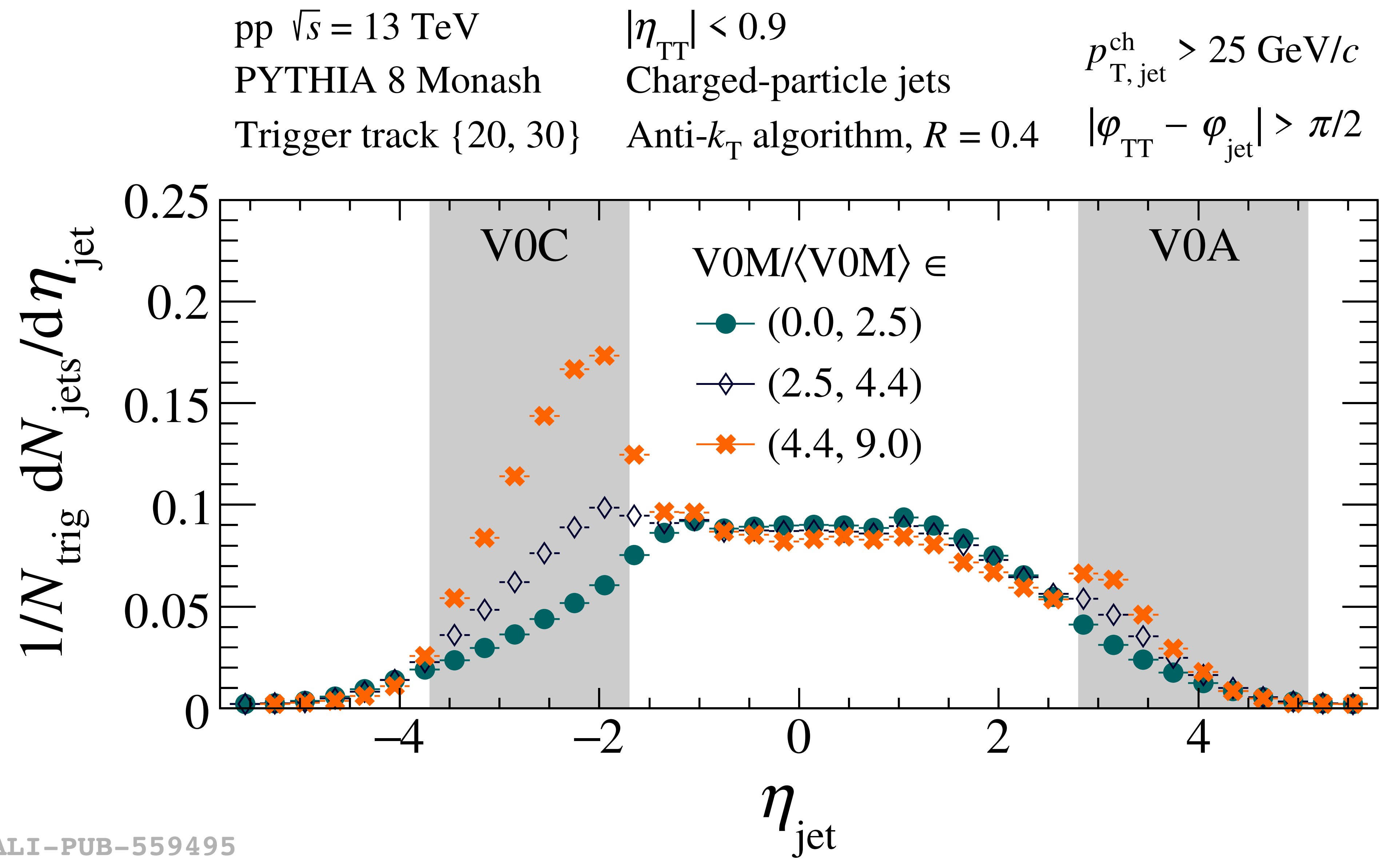

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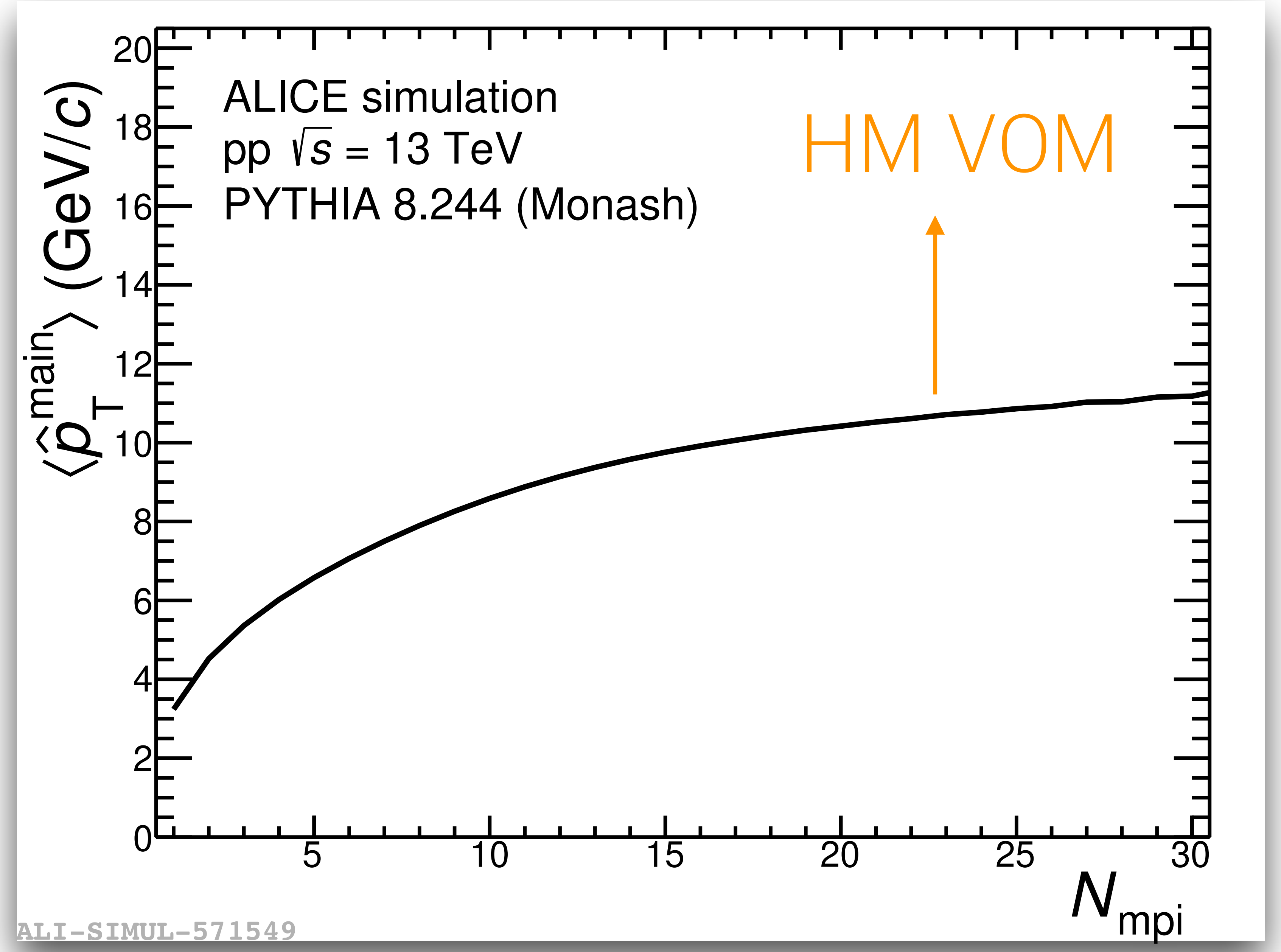

The high-V0M multiplicity class selects pp collisions with jets in the forward detector

ALICE, arXiv:2309.03788 ALICE, Phys. Lett. B 843 (2022) 137649

Flattenicity

Event-by-event selection based on the relative standard deviation of the multiplicity measured in the 64 V0 channels, $N^{(\mathrm{ch.}\,i)}$

Phys. Rev. D107 (2023) 7, 076012

$$\rho = \sqrt{\sum_{i}^{64}\left(N^{(\mathrm{ch}.i)} - \langle N^{(\mathrm{ch})}\rangle\right)^2/64^2} \Big/ \langle N^{(\mathrm{ch})}\rangle$$

Flattenicity

Event-by-event selection based on the relative standard deviation of the multiplicity measured in the 64 V0 channels, $N^{(\mathrm{ch.}\,i)}$

[Phys. Rev. D107 (2023) 7, 076012](https://doi.org/10.1103/PhysRevD.107.076012)

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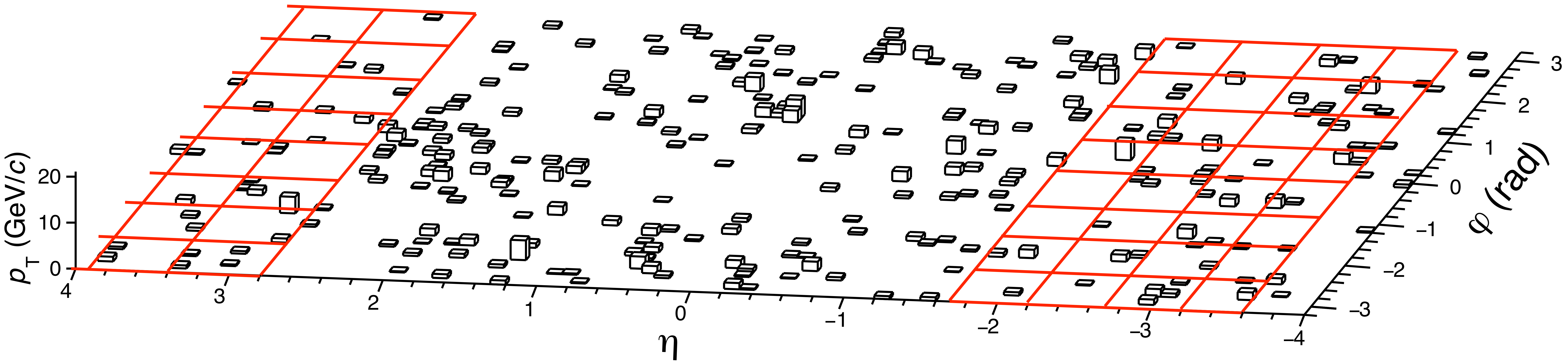
PYTHIA 8.303 (Monash 2013), pp $\sqrt{s}$ = 13 TeV, N_{mpi}=24



Small local $N^{(\mathrm{ch.}\,i)}$ fluctuations in the V0 acceptance: small flattenicity values

- "isotropic" distribution of particles in the V0 acceptance (large multiplicities)

Flattenicity

Event-by-event selection based on the relative standard deviation of the multiplicity measured in the 64 V0 channels, $N^{(\mathrm{ch.}\, i)}$

Phys. Rev. D107 (2023) 7, 076012

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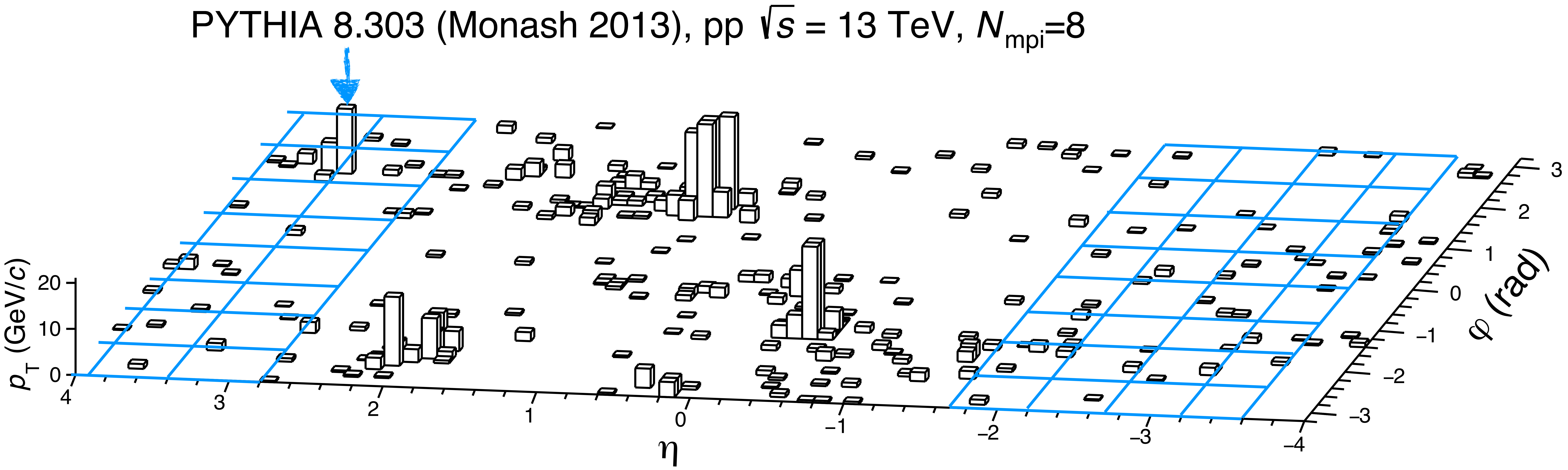
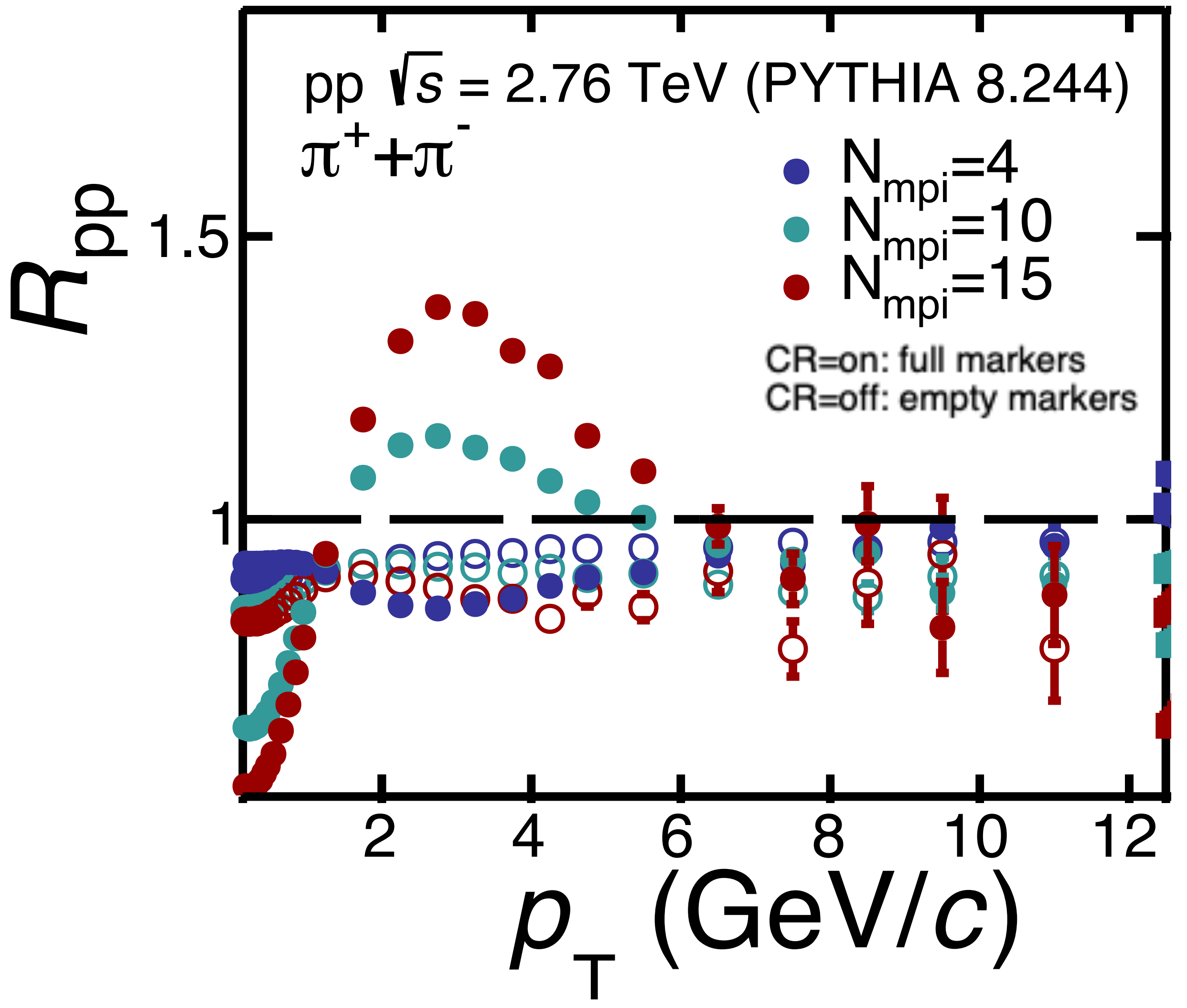


Large local $N^{(\mathrm{ch.}\, i)}$ fluctuations in the V0 acceptance: large flattenicity values

- jet structures, small multiplicity

High-p_T physics: V0M vs flattenicity

Phys. Rev. D102 (2020) 7, 076014

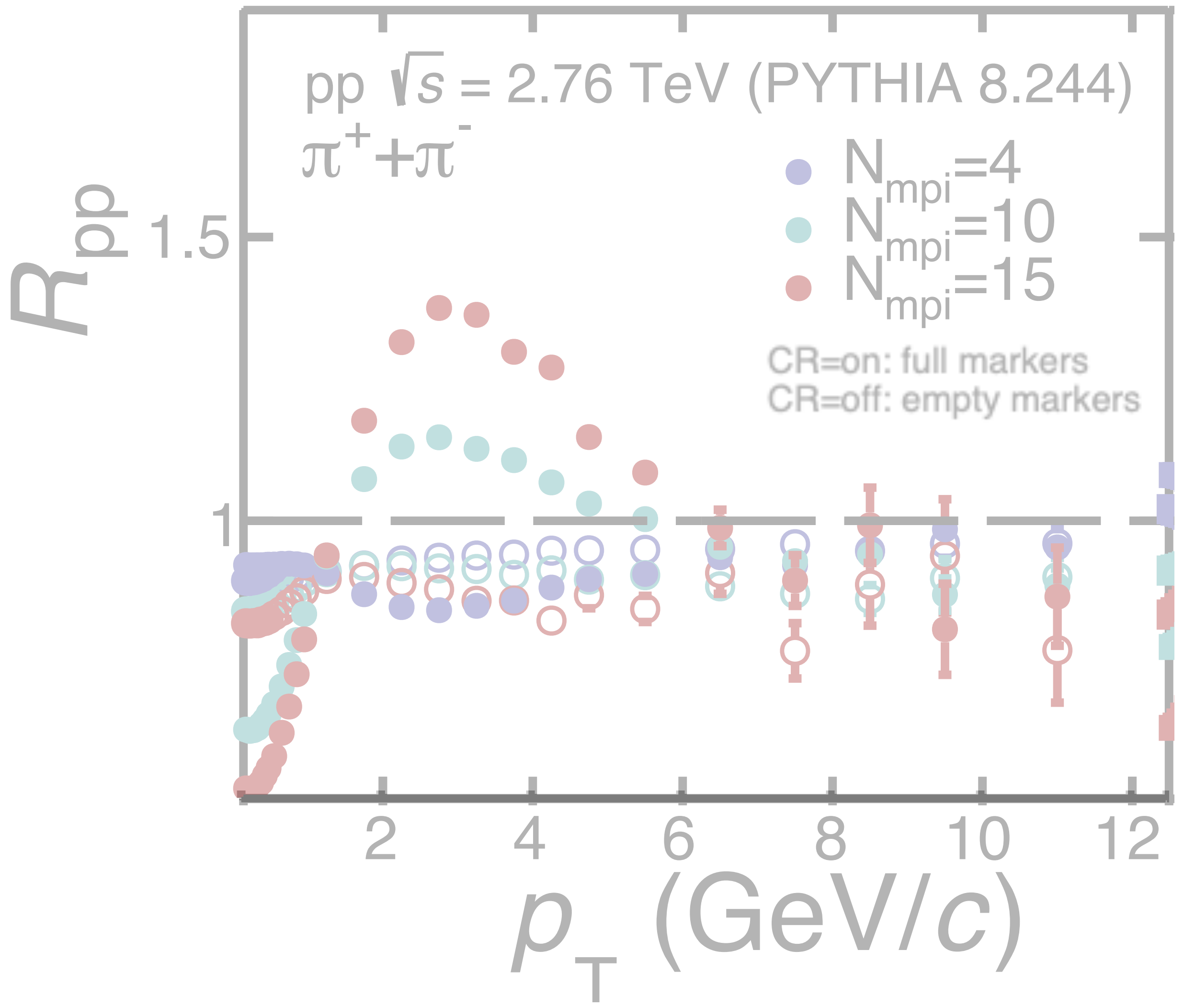


$$R_{pp}(p_T) = \frac{\left. \frac{1}{N_{ev}} \frac{dN_{ch}}{dp_T} \frac{1}{\langle N_{mpi} \rangle} \right|_{\text{high MPI}}}{\left. \frac{1}{N_{ev}} \frac{dN_{ch}}{dp_T} \frac{1}{\langle N_{mpi} \rangle} \right|_{\text{MB}}}$$

- Intermediate p_T: CR peak
- High p_T: the ratio is flat and in the vicinity of unity

High-p_T physics: V0M vs flattenicity

Phys. Rev. D102 (2020) 7, 076014



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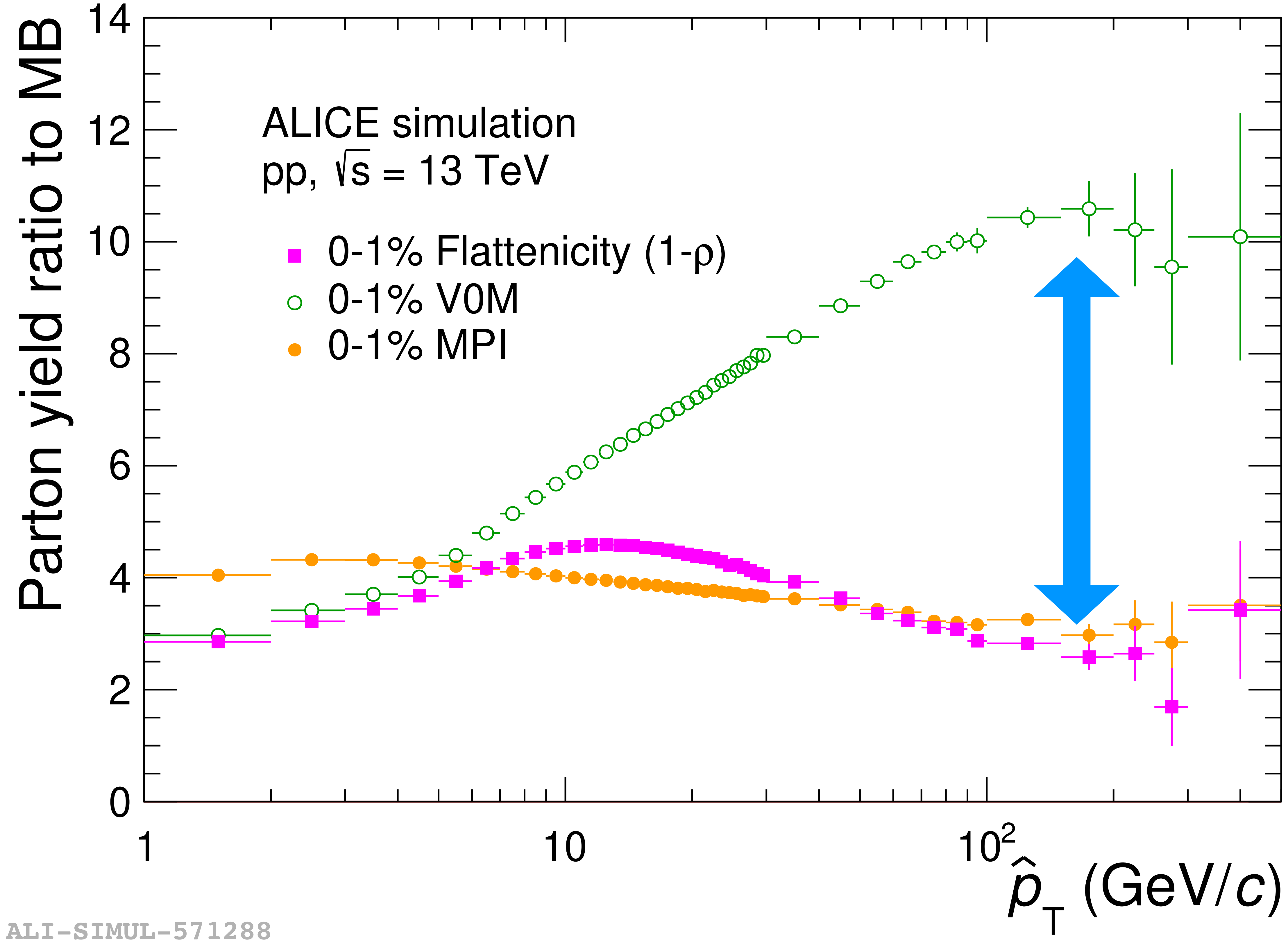
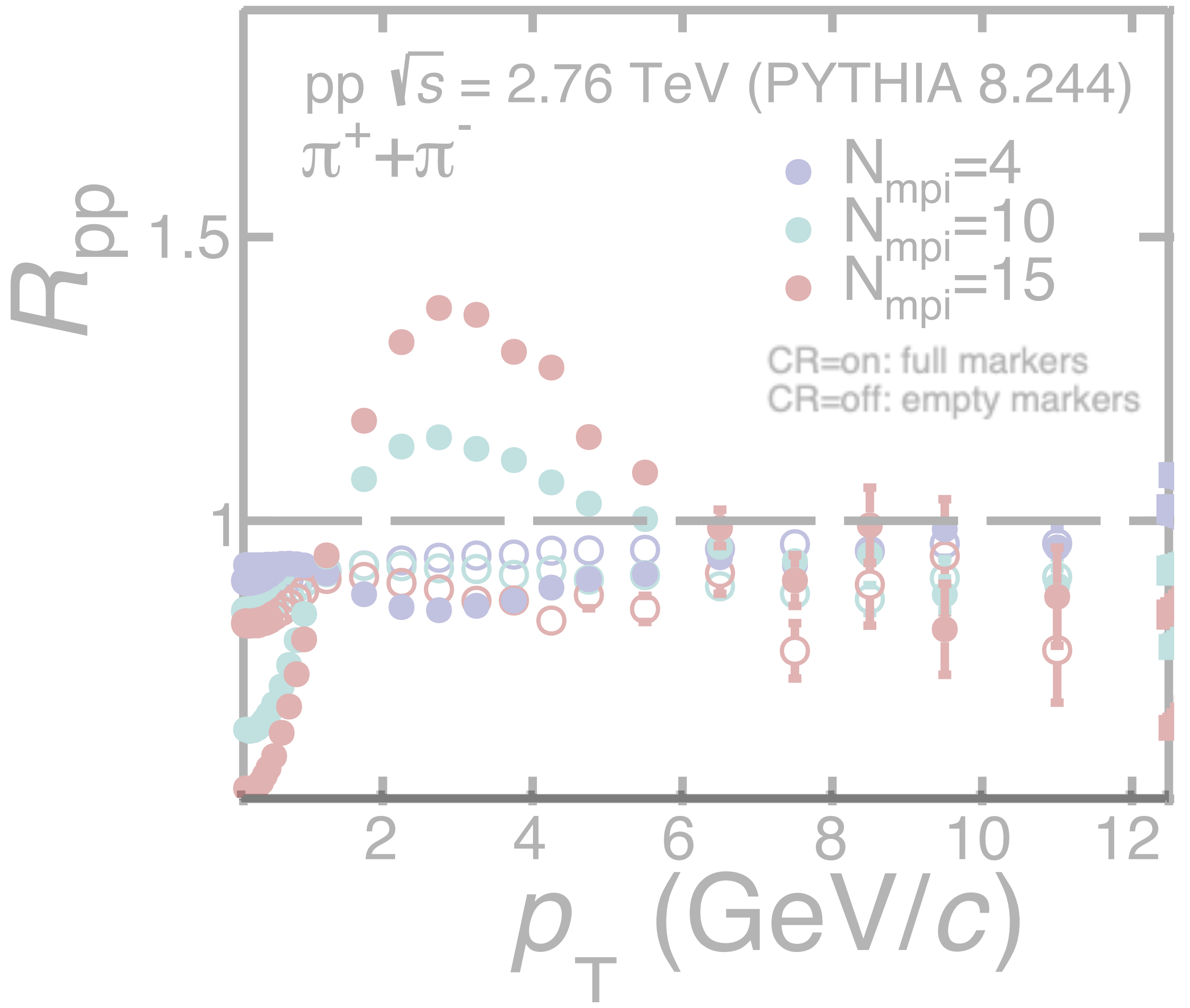
$$\text{ratio}(\hat{p}_T) = \frac{\frac{1}{N_{ev}}\frac{dN_{parton}}{d\hat{p}_T}\Big|_{1\%\ \text{xsec}}}{\frac{1}{N_{ev}}\frac{dN_{parton}}{d\hat{p}_T}\Big|_{\text{MB}}}$$



High-p_T physics: V0M vs flattenicity

Phys. Rev. D102 (2020) 7, 076014



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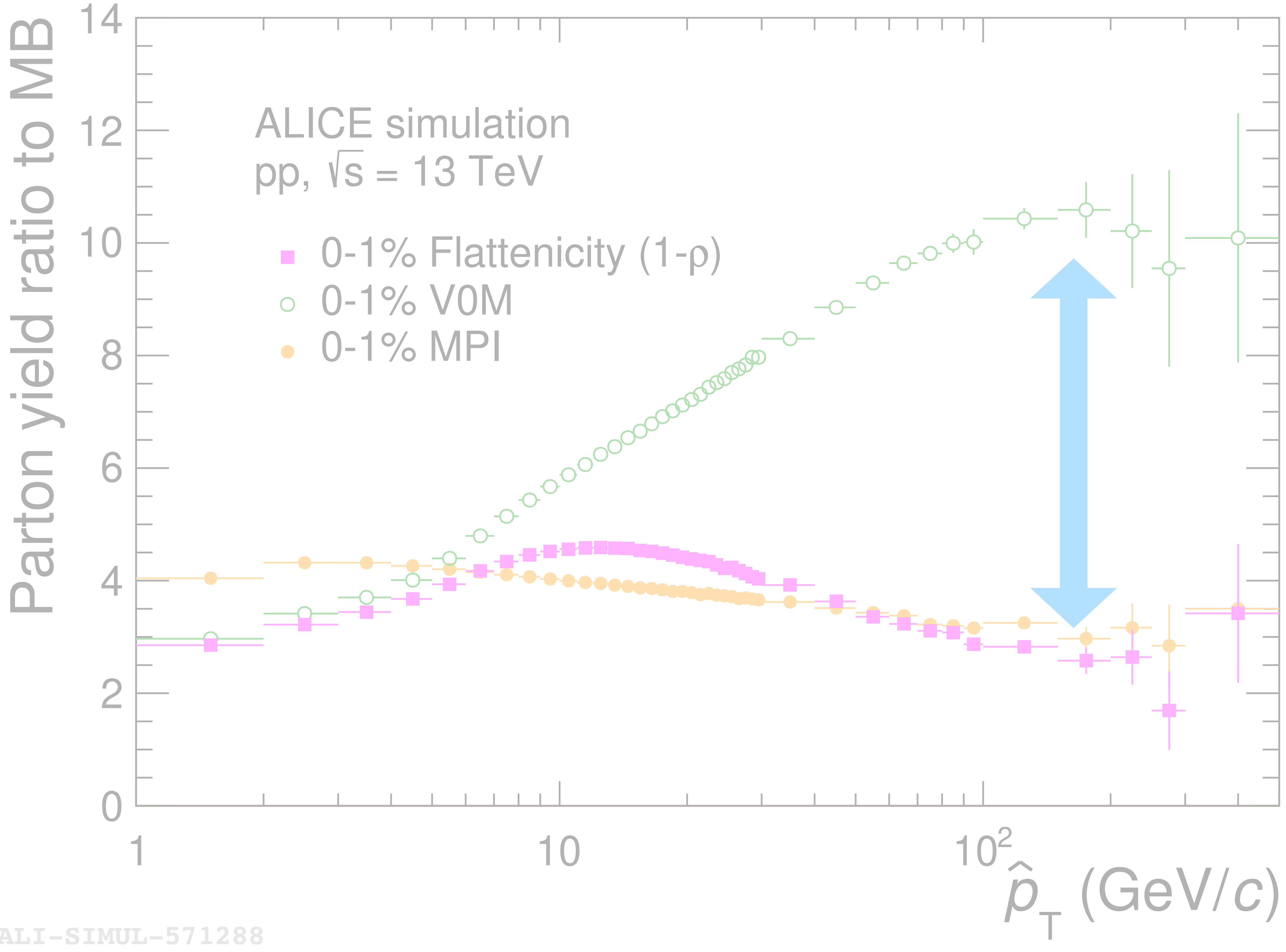
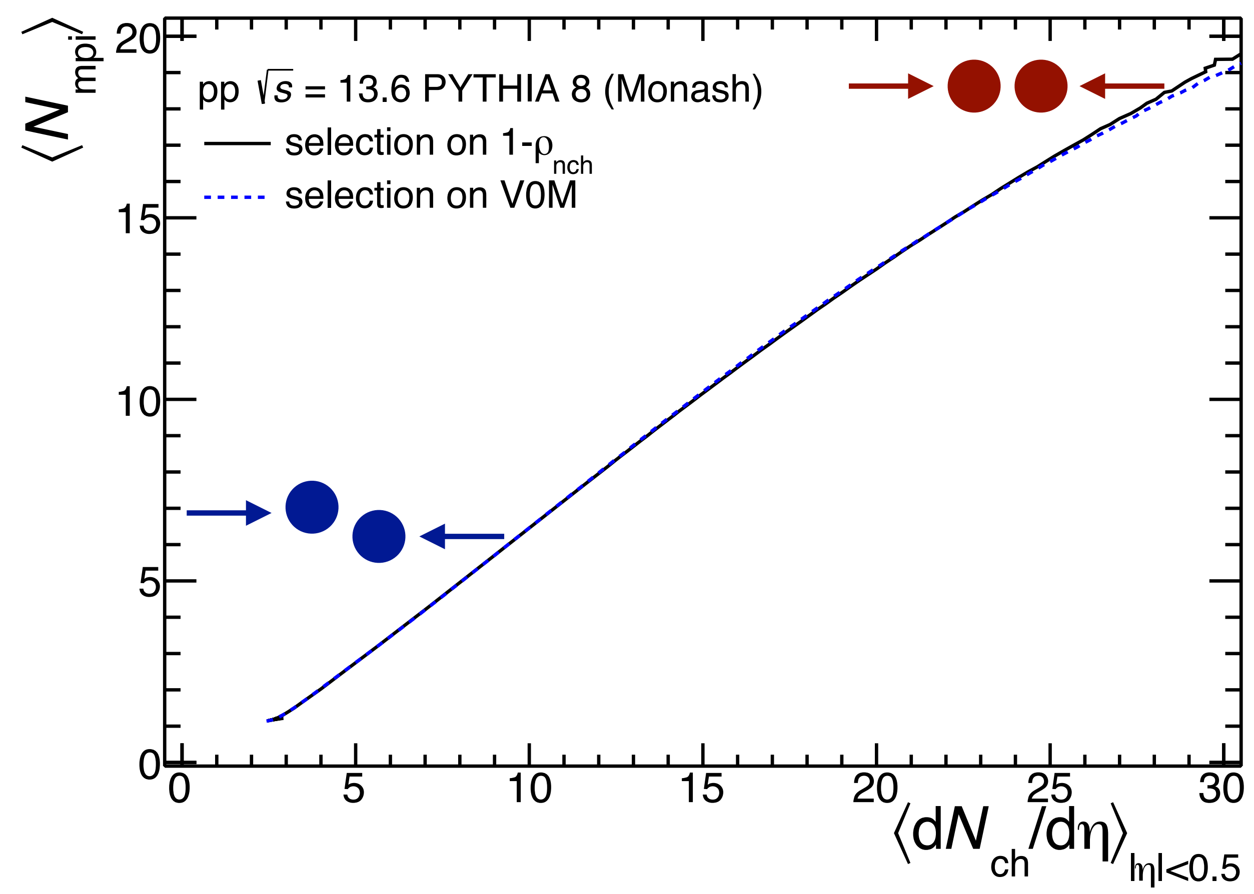


Phys. Rev. D107 (2023) 7, 076012



$$\left\langle \frac{dN_{ch}}{d\eta} \right\rangle \propto \langle N_{mpi} \rangle$$

Experimentally:

$$Q_{pp}(p_T) = \frac{\frac{1}{N_{ev}}\frac{dN_{ch}}{dp_T}\frac{1}{\langle N_{ch}\rangle}\Big|_{\text{HM}}}{\frac{1}{N_{ev}}\frac{dN_{ch}}{dp_T}\frac{1}{\langle N_{ch}\rangle}\Big|_{\text{MB}}}$$

Data analysis

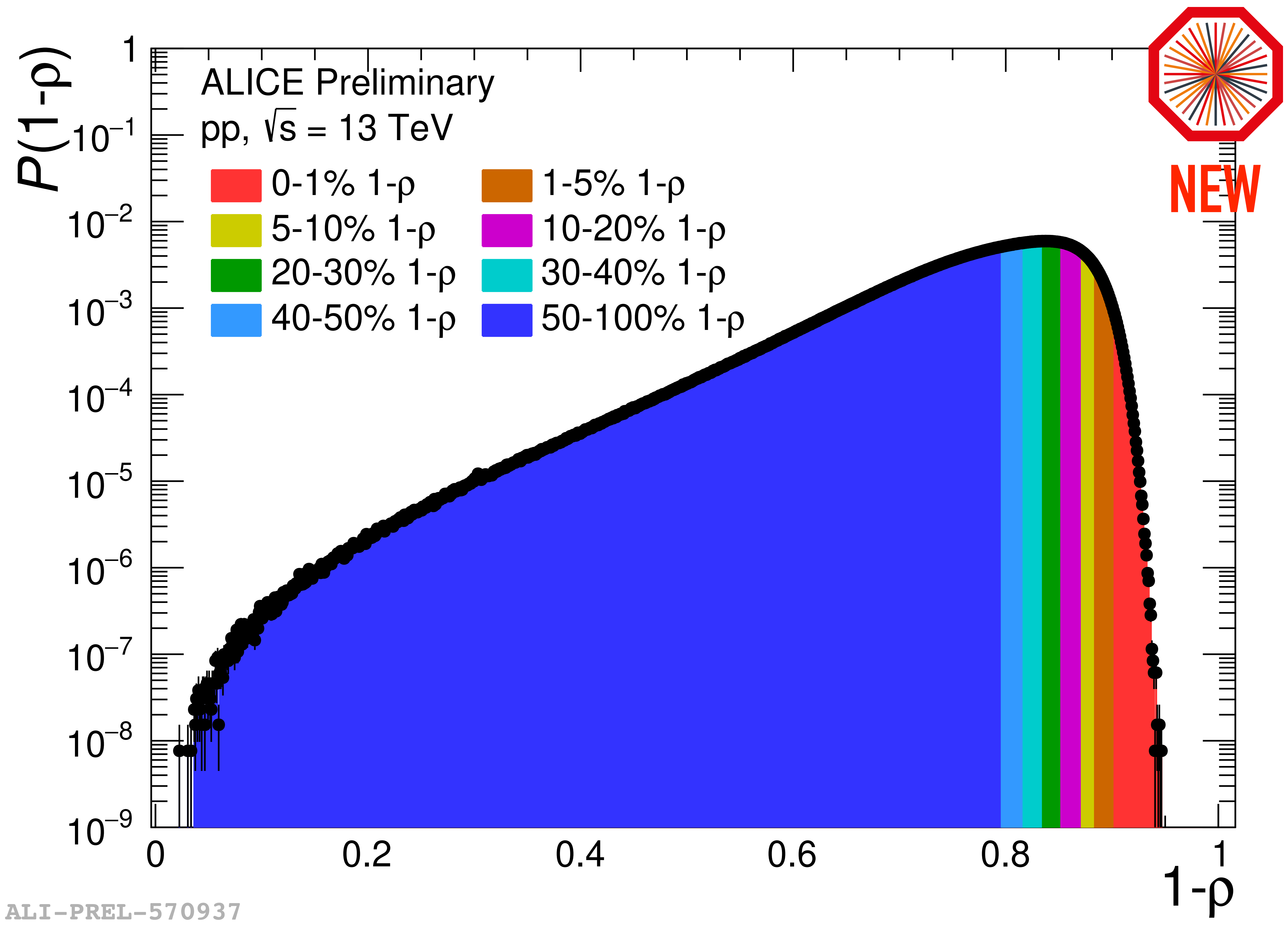
Integrated luminosity ~21 nb^{-1}

MB trigger: signals in both V0 detectors
Vertex position within $|v_z|$<10 cm (SPD)
Events with multiple primary vertexes are rejected

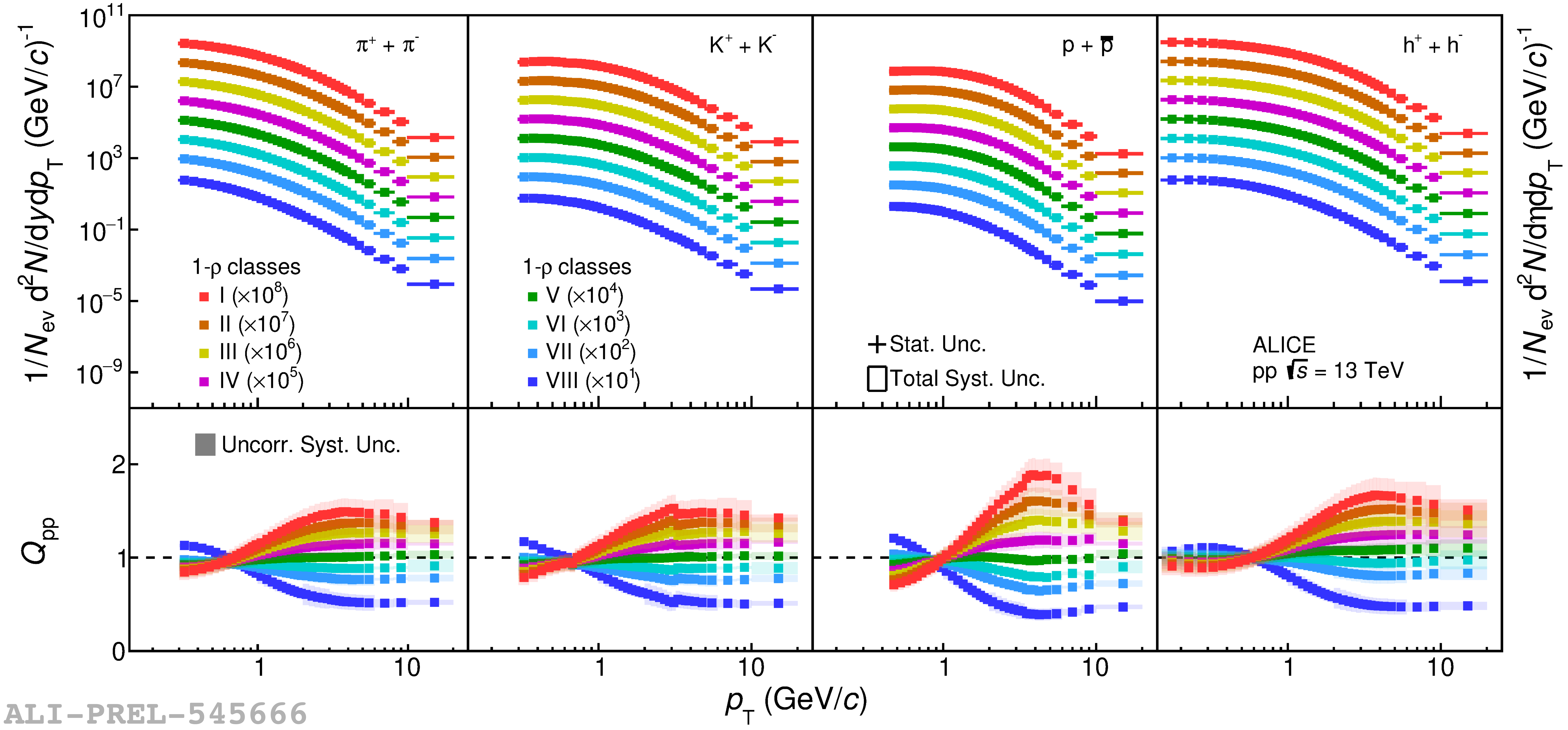
Particle identification with TPC and TOF detectors
Flattenicity is measured with the V0 detector

Systematic uncertainties: vertex, track selection, MC non-closure, signal extraction (PID): up to 10%

Low N_{mpi} High N_{mpi}

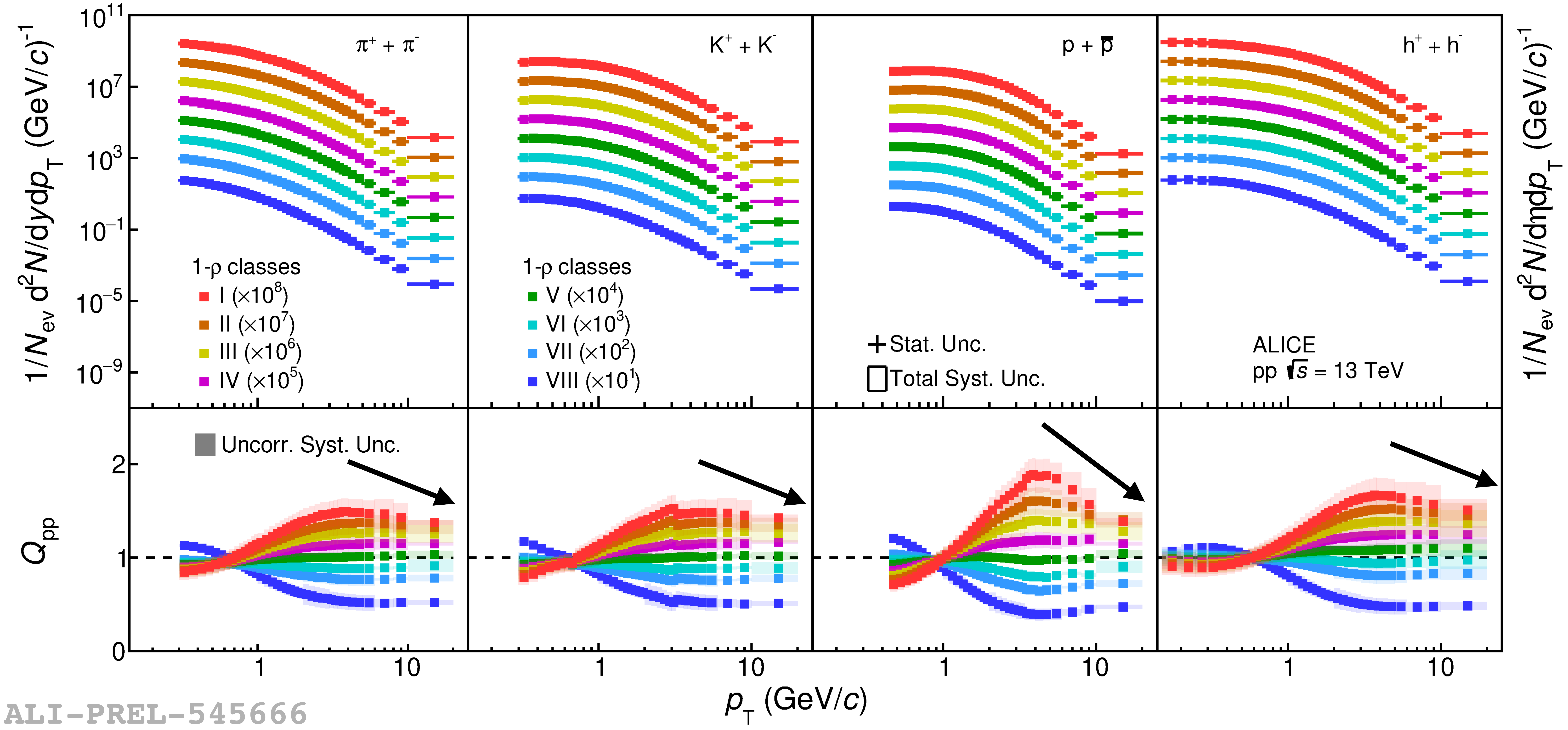


Q_{pp} as a function of p_T



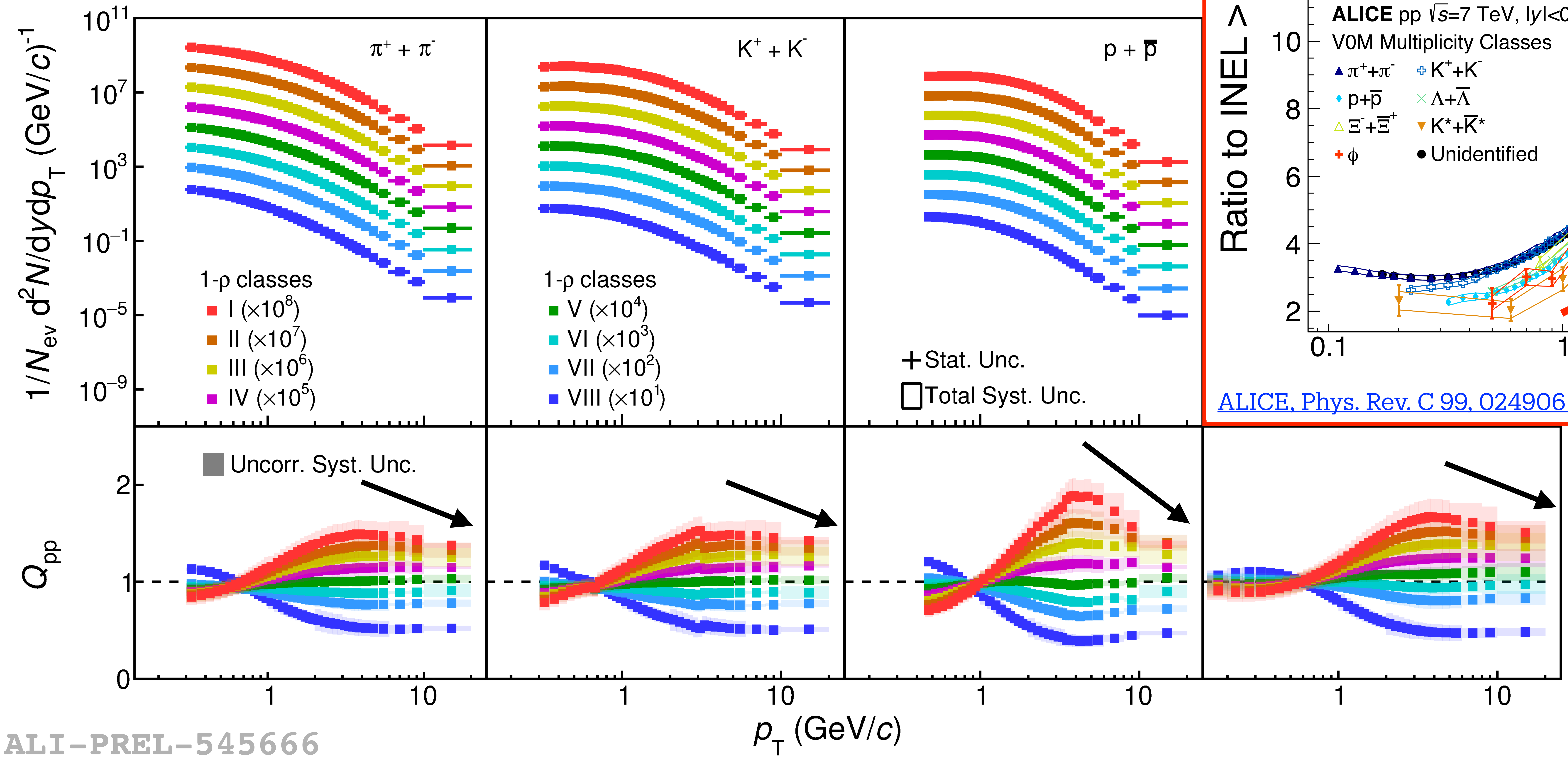
- Intermediate p_T: a bump structure is developed with increasing multiplicity

Q_{pp} as a function of p_T



- Intermediate p_T: a bump structure is developed with increasing multiplicity
- High p_T: Q_{pp} seems to approach to the vicinity of one

Q_{pp} as a function of p_T



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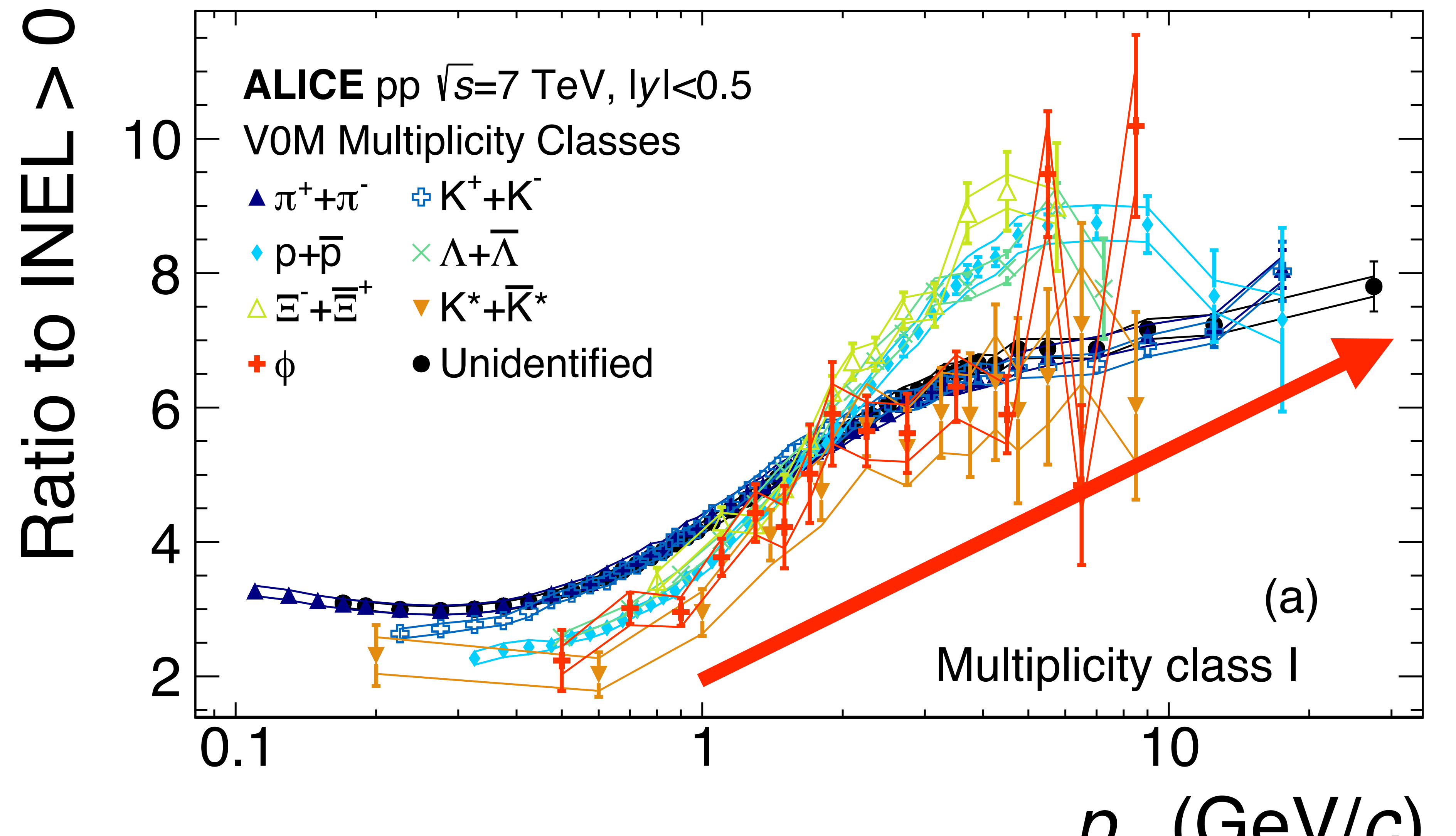

ALICE, Phys. Rev. C 99, 024906 (2019)

The effect is not seen in the V0M analysis!

- Intermediate p_T: a bump structure is developed with increasing multiplicity
- High p_T: Q_{pp} seems to approach to the vicinity of one

Q_{pp}: data vs MC models

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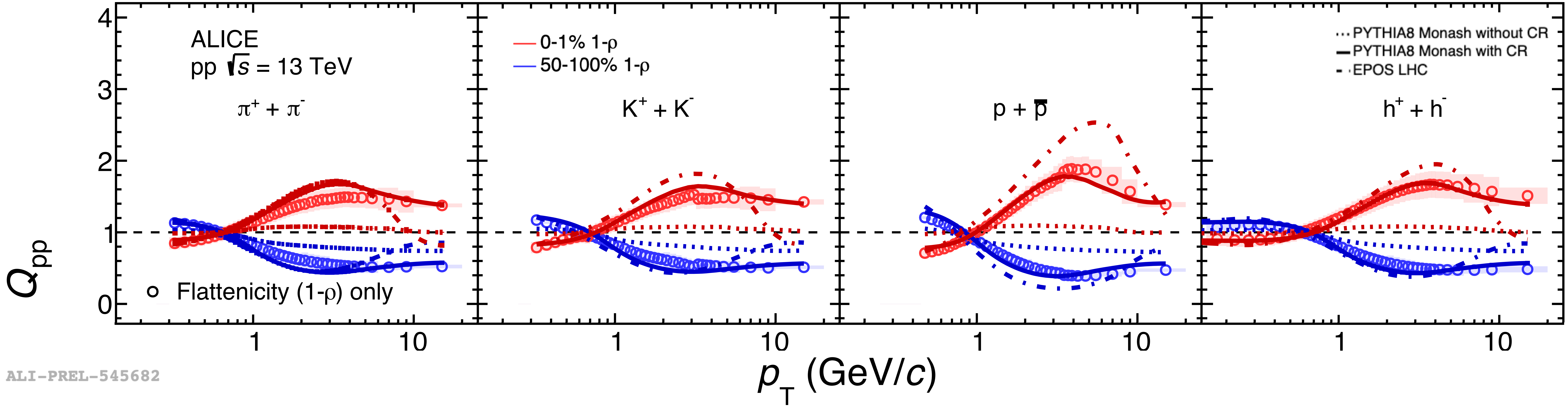
ALICE

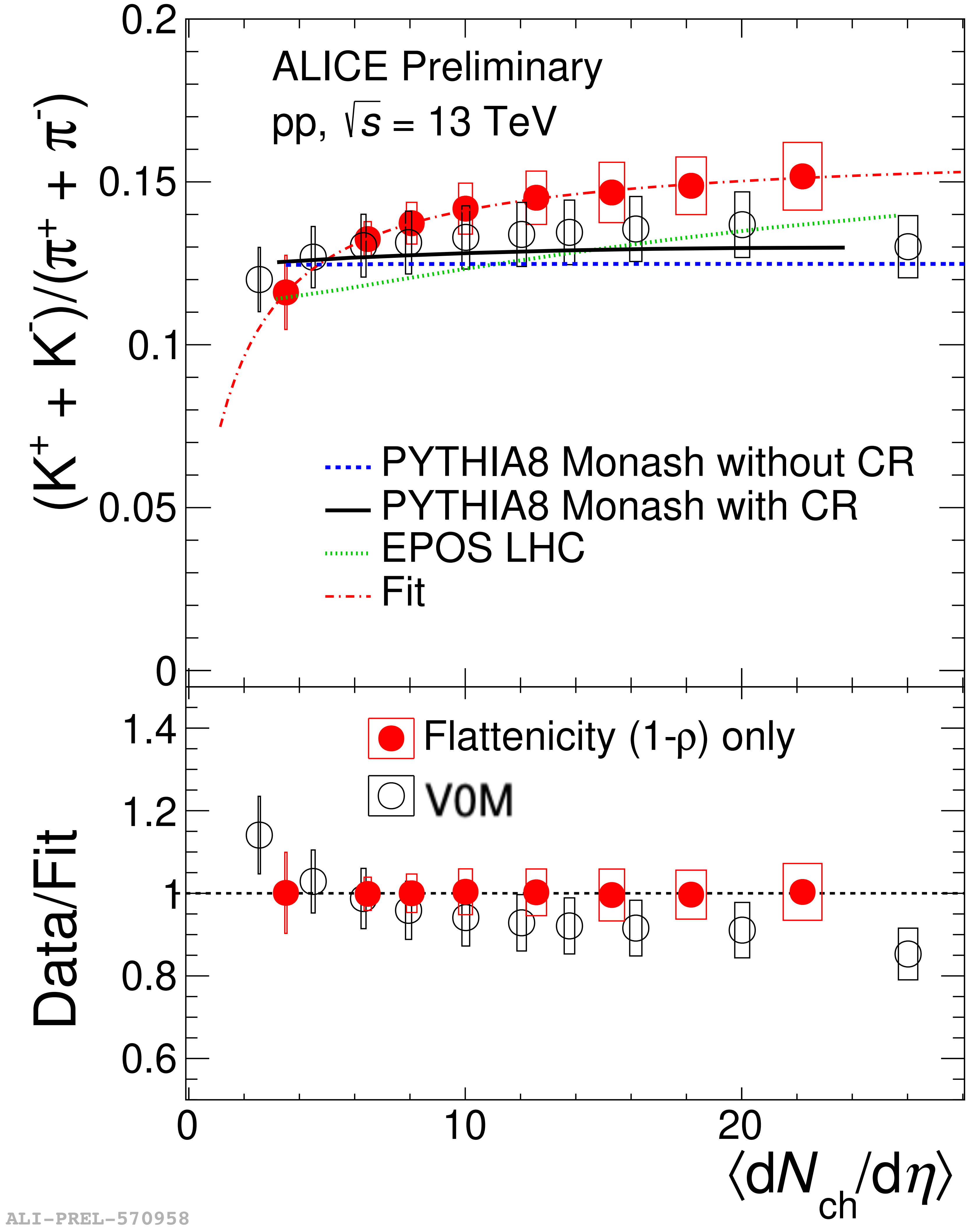


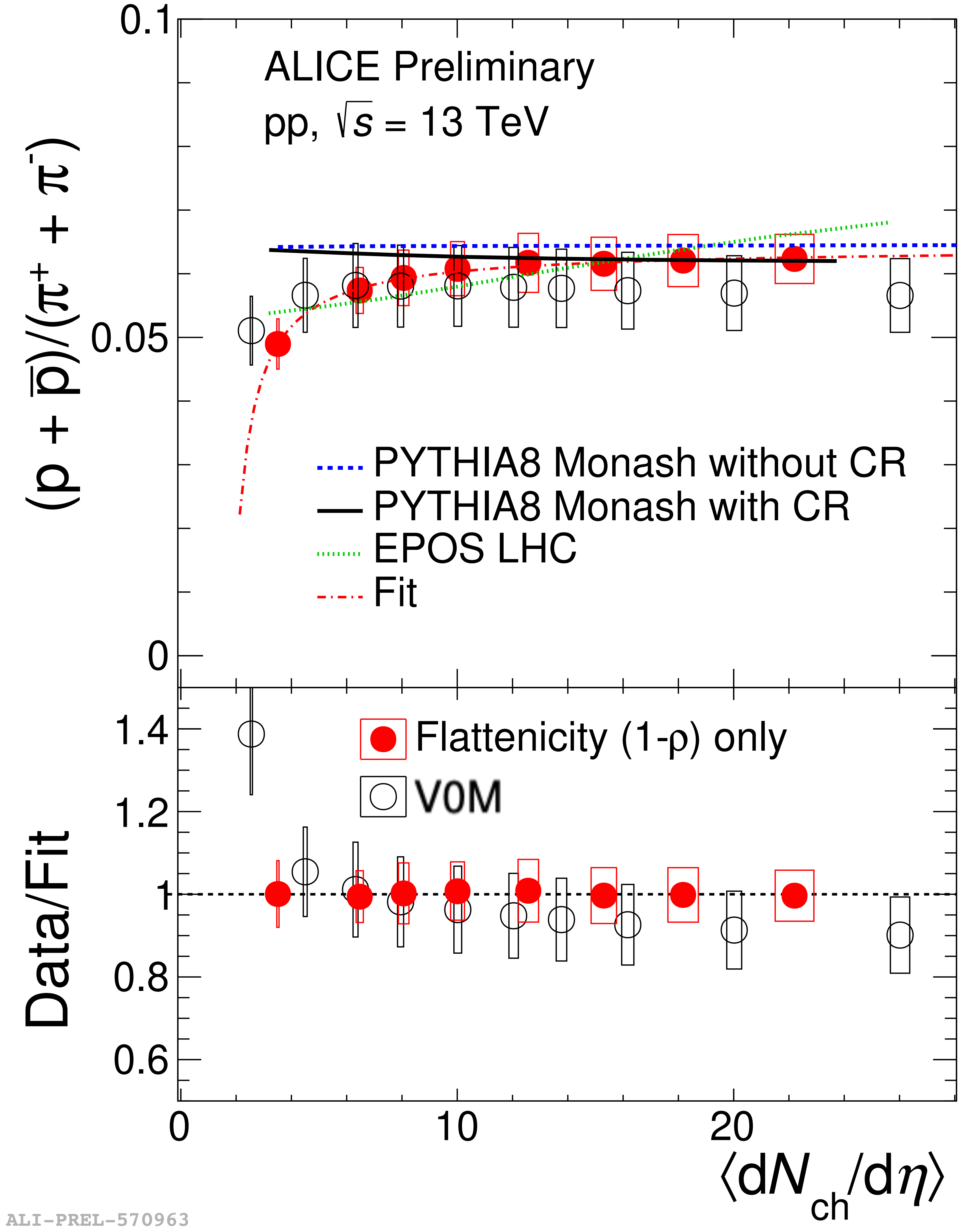
PYTHIA 8 without CR: a nearly flat Q_{pp} as a function of p_T

Pythia Monash (with CR): overall the best description of data

EPOS LHC overestimates and underestimates Q_{pp} at intermediate and high p_T values, respectively

Particle ratios: flattenicity vs V0M

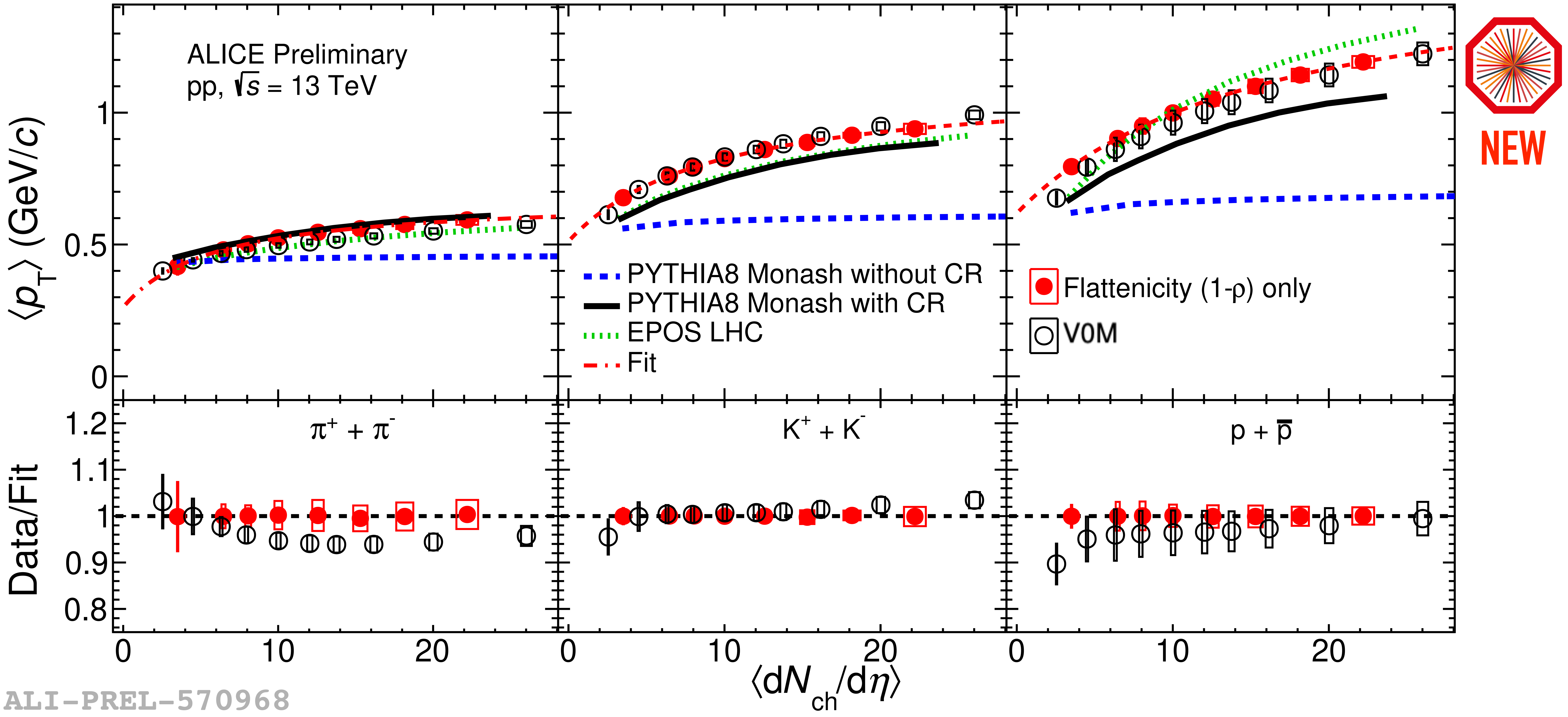




NEW

The particle ratios as a function of flattenicity exhibit a steeper increase with multiplicity than those as a function of V0M

Average p_T



Little or no difference is observed between flattenicity and V0M selections for kaons and protons

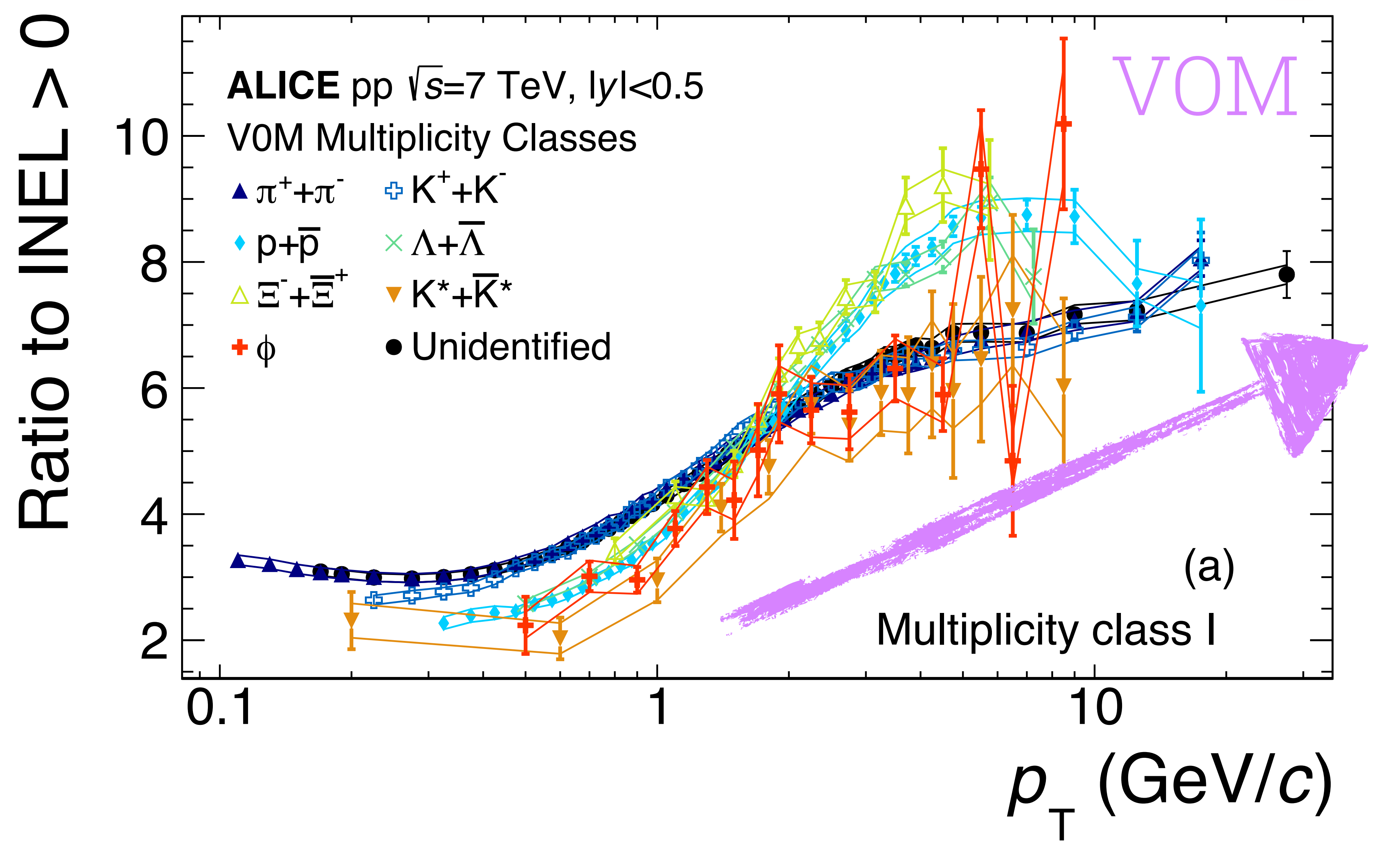
A slightly larger mean p_T as a function of multiplicity for flattenicity selection

Summary

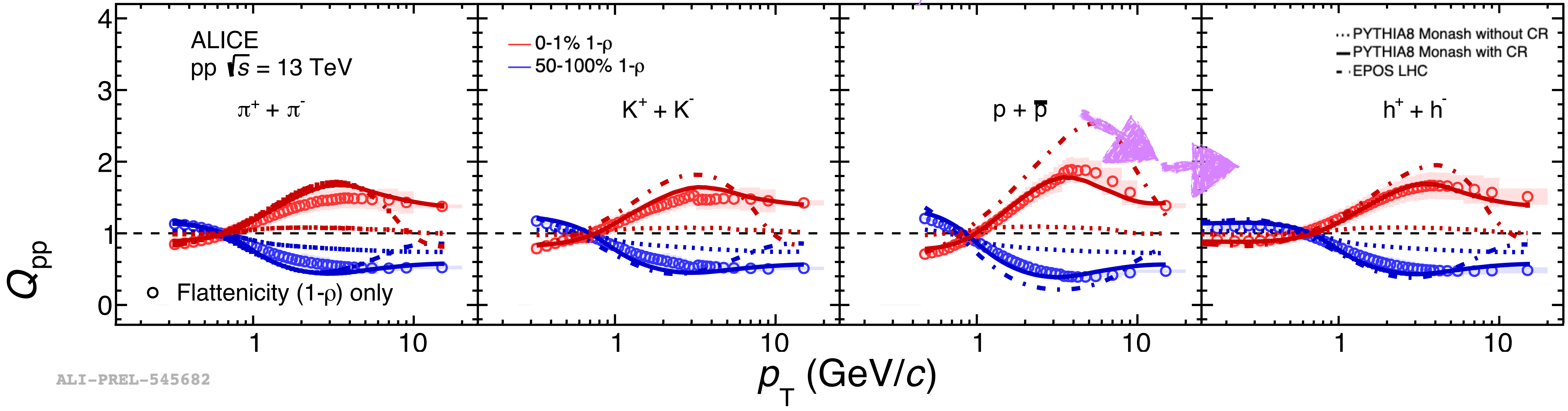
Flattenicity is more sensitive to MPI (and therefore to the impact parameter of the collision) than the V0M multiplicity estimator

An approximately scaling with MPI is seen at large p_T

Promising tool to study QGP observables at both low and high p_T



Flattenicity



Thank you!

backup

Particle ratios: flattenicity vs V0M

ALICE

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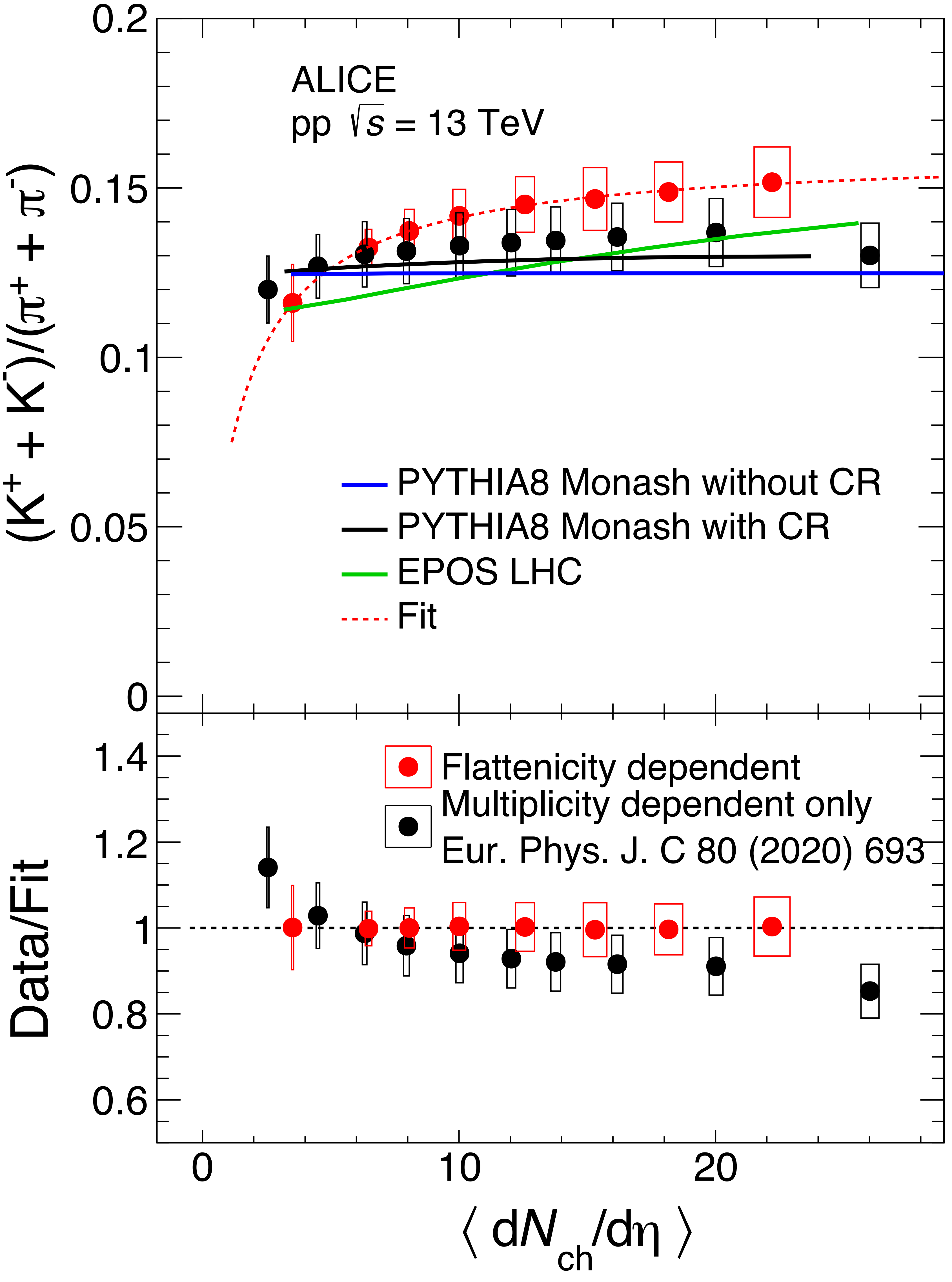
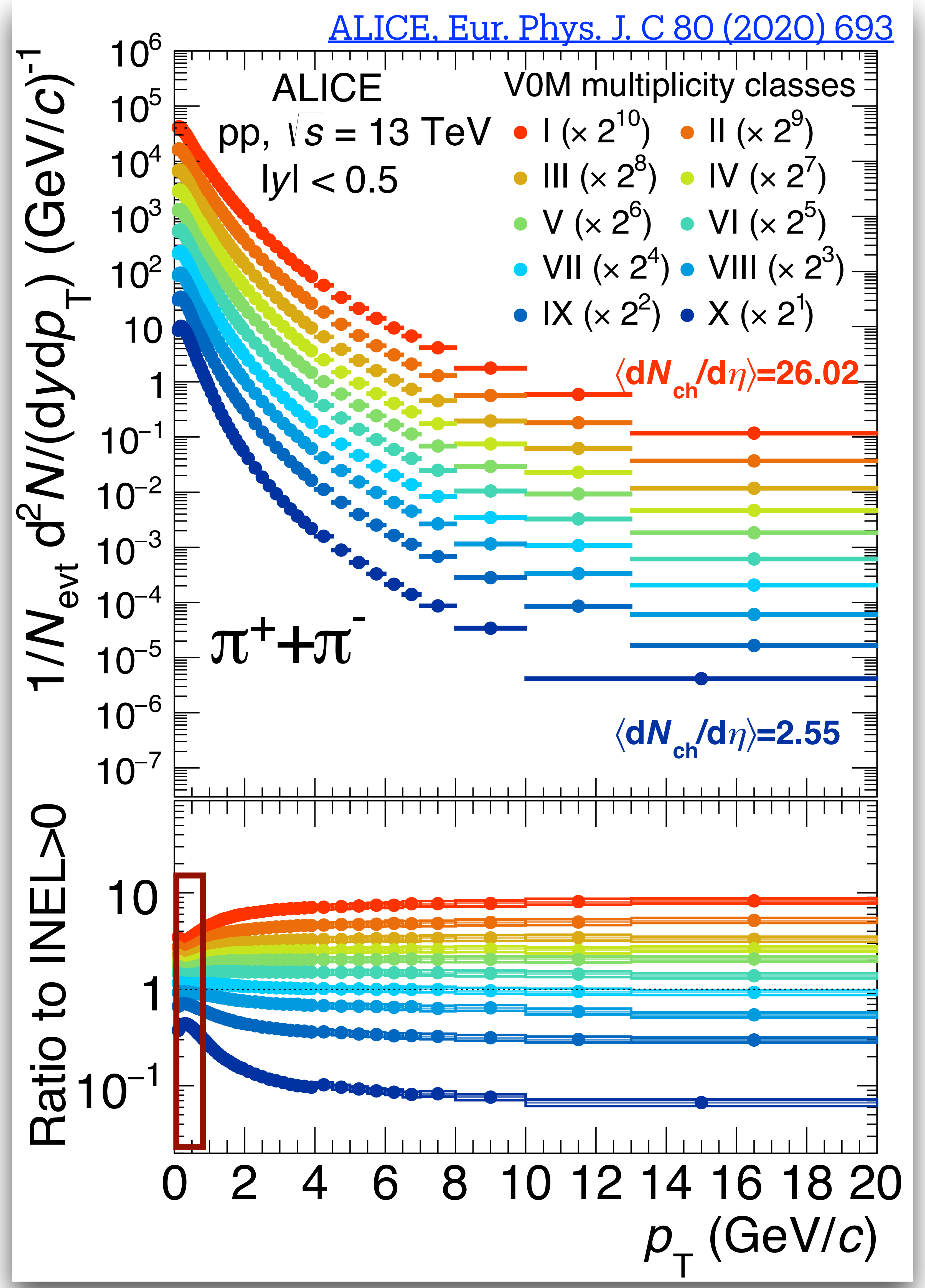
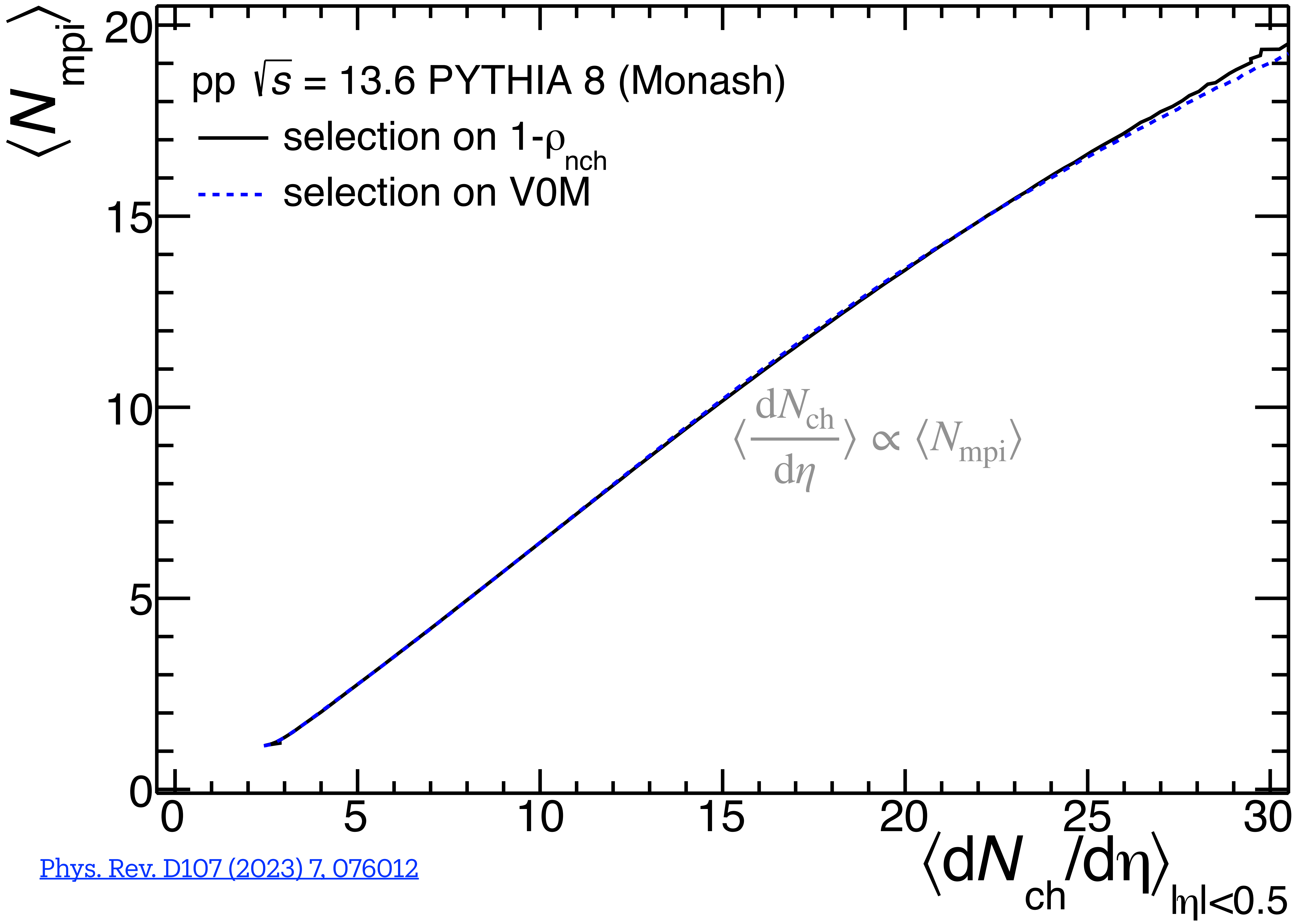




The particle ratios as a function of flattenicity (red) exhibit a steeper increase with multiplicity than those as a function of V0M (black)

The reason is that V0M multiplicity biases the low p_T pion yield

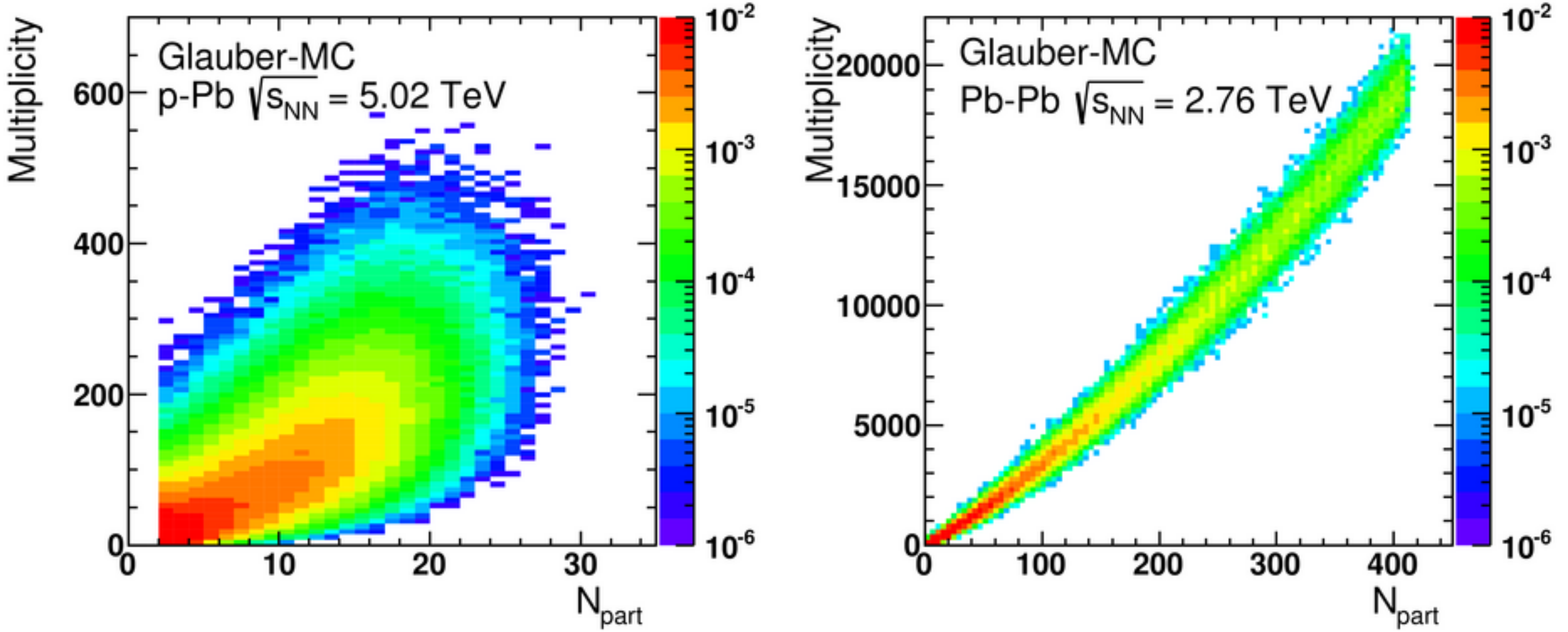
High-p_T physics: V0M vs flattenicity



Phys. Rev. D107 (2023) 7, 076012

Centrality in small systems (p-Pb)

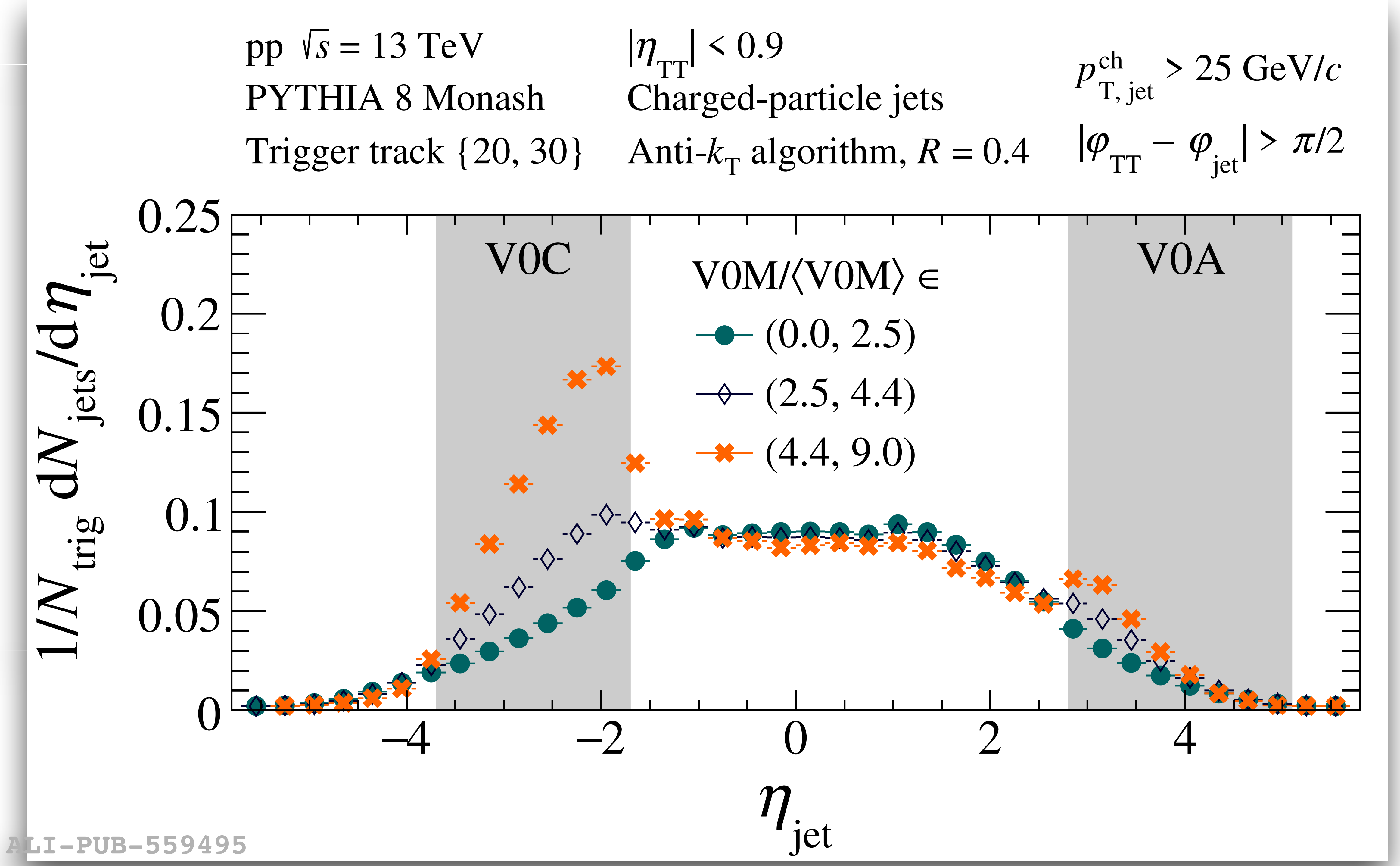
In contrast to Pb–Pb collisions, for p–Pb collisions the multiplicity (V0A) fluctuations are sizeable compared to the width of the N_{part} distribution

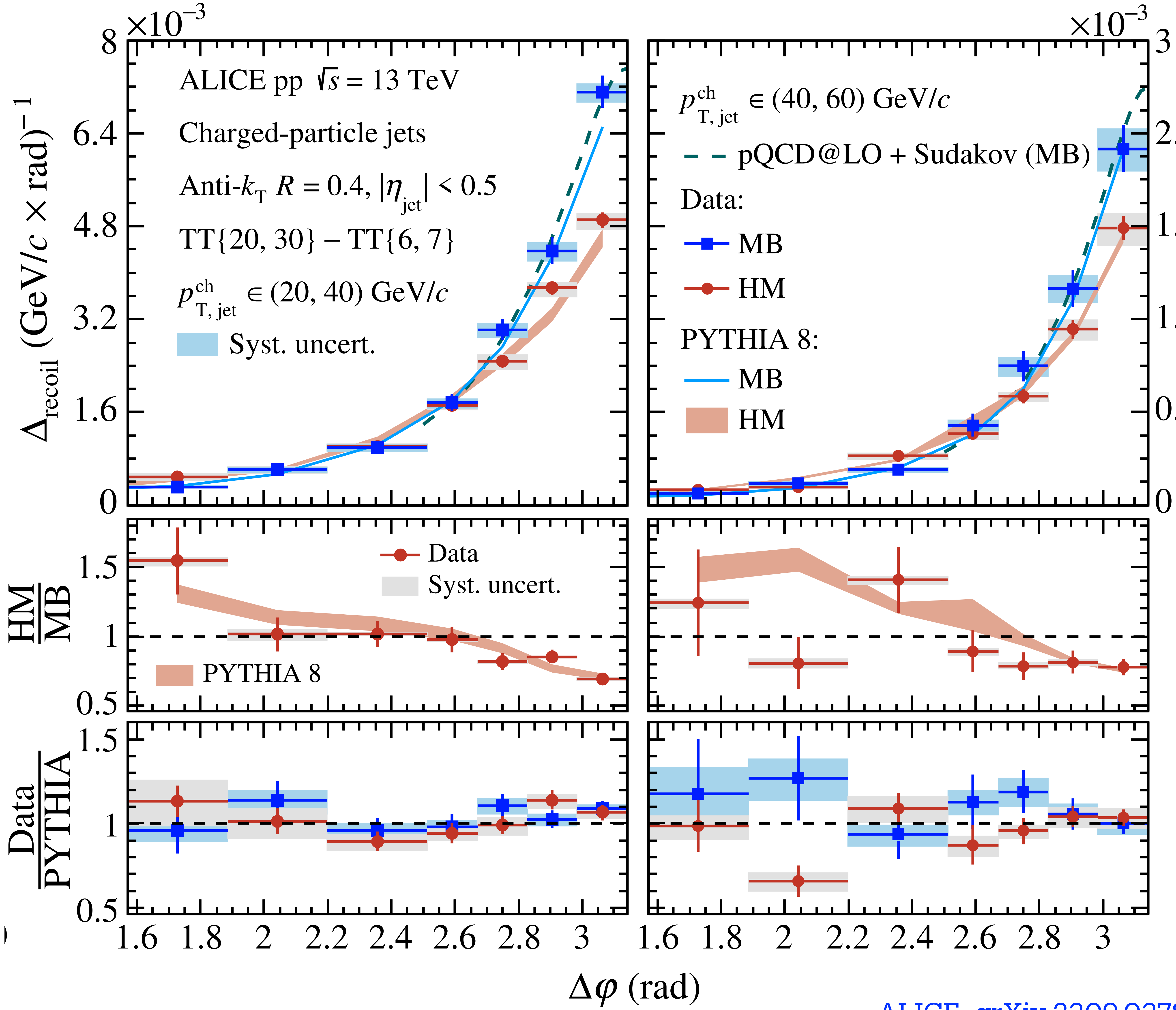


Phys. Rev. C 91 (2015) 064905

Weak correlation between geometry and event activity

Issues to search for jet quenching





The HM V0M multiplicity class selects pp collisions with jets in the forward detector, consequently biasing the acoplanarity distribution measured in the central region

ALICE, arXiv:2309.03788