MPI@LHC 2023

The 14th International Workshop on
Multiple Parton Interactions at the LHC

20-24 Nov 2023, University of Manchester

CENTRAL CHINA NORMAL UNIVERSITY

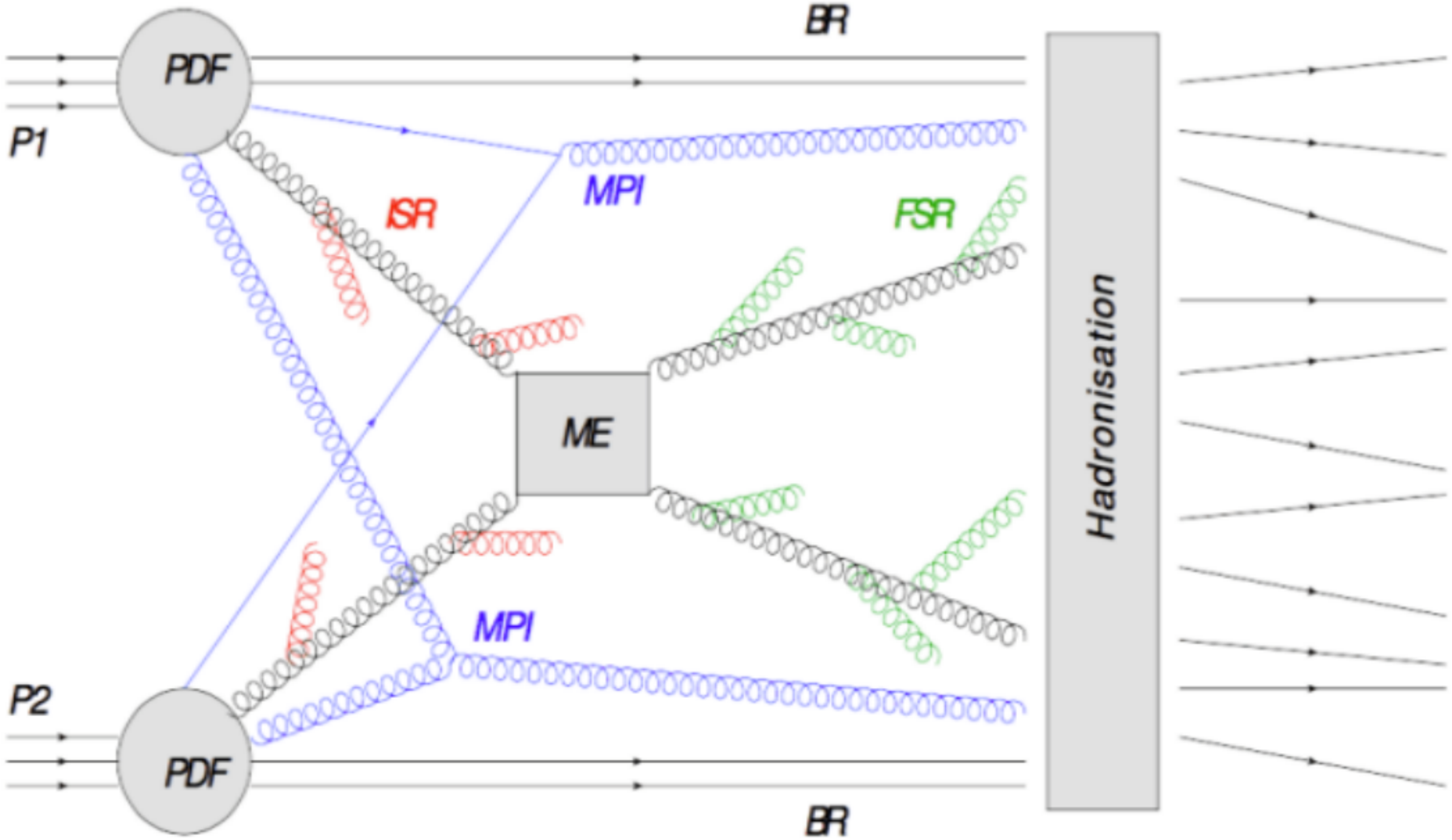
Instituto de Ciencias Nucleares UNAM

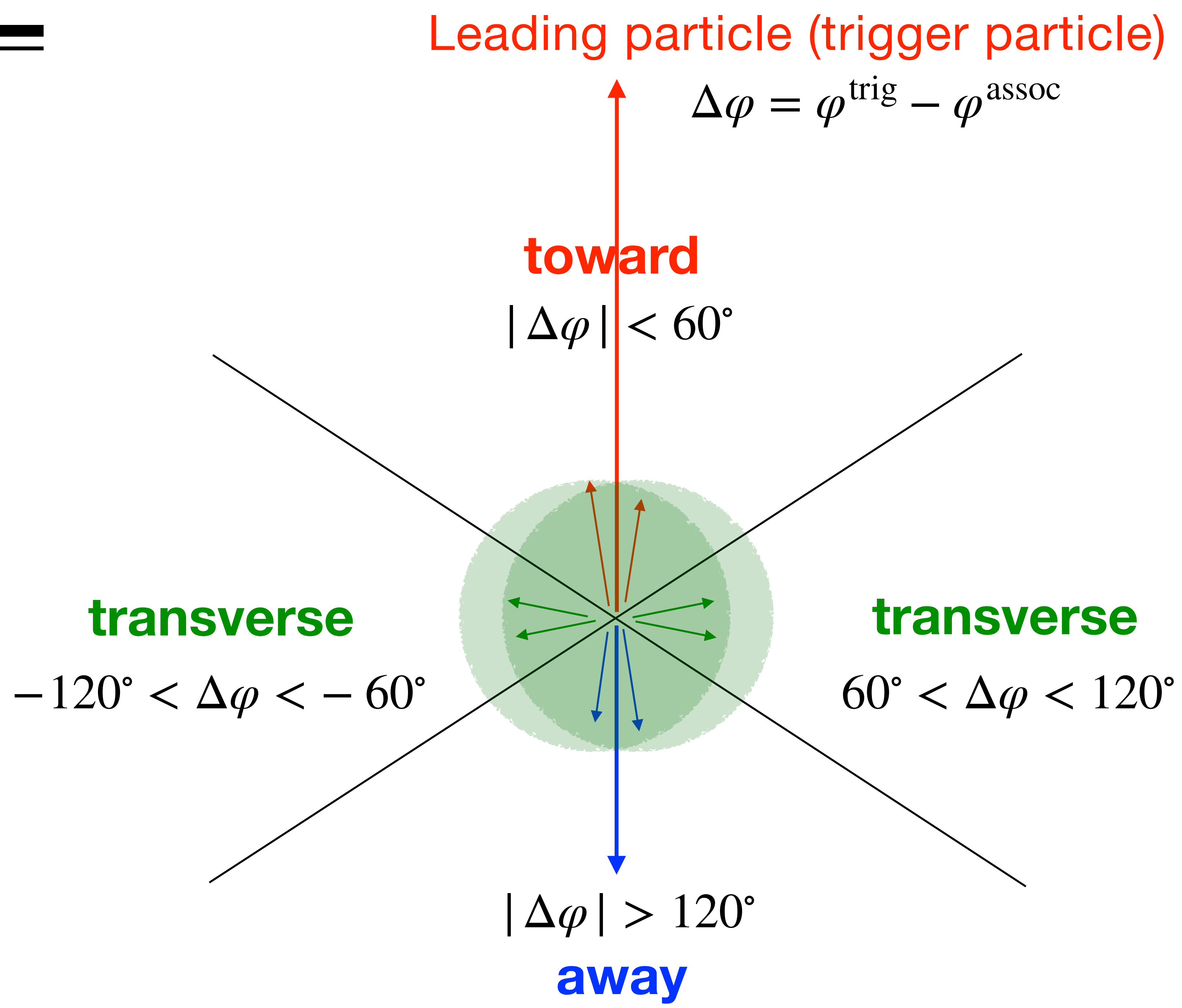
ALICE

Energy dependence of underlying-event observables with ALICE at the LHC

Feng Fan, for the ALICE collaboration

INTRODUCTION & MOTIVATION





PP

main hard partonic scattering

ISR: initial state radiation
FSR: final state radiation

Experimentally, the radiations can not be isolated from UE!

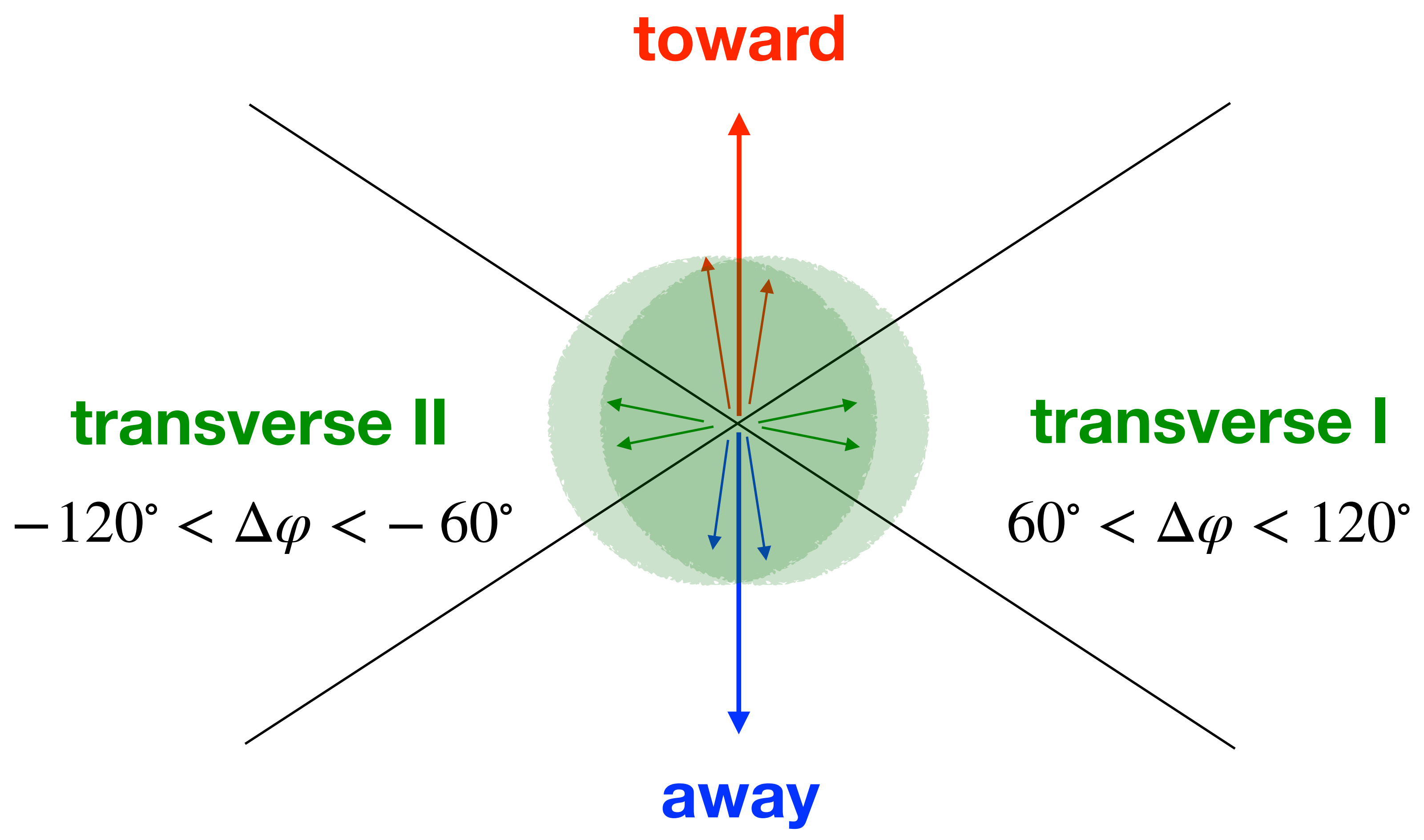
MPI: multiple parton interactions
BR: beam remnants

UE

★ UE is studied using the traditional method from CDF PRD 65 (2002) 092002

★ These three regions have been proposed to investigate the origin of the heavy-ion-like features discovered in small systems
T. Martin et al., EPJC 76 (2016) 5, 299
A. Ortiz et al., PRD 99 (2019) 3, 034027
S. Weber et al., EPJC 79 (2019) 1, 36

INTRODUCTION & MOTIVATION



- ☑ **trans-max:** transverse region with larger multiplicity (more sensitive to ISR-FSR)
- ☑ **trans-min:** transverse region with smaller multiplicity (more sensitive to MPI)

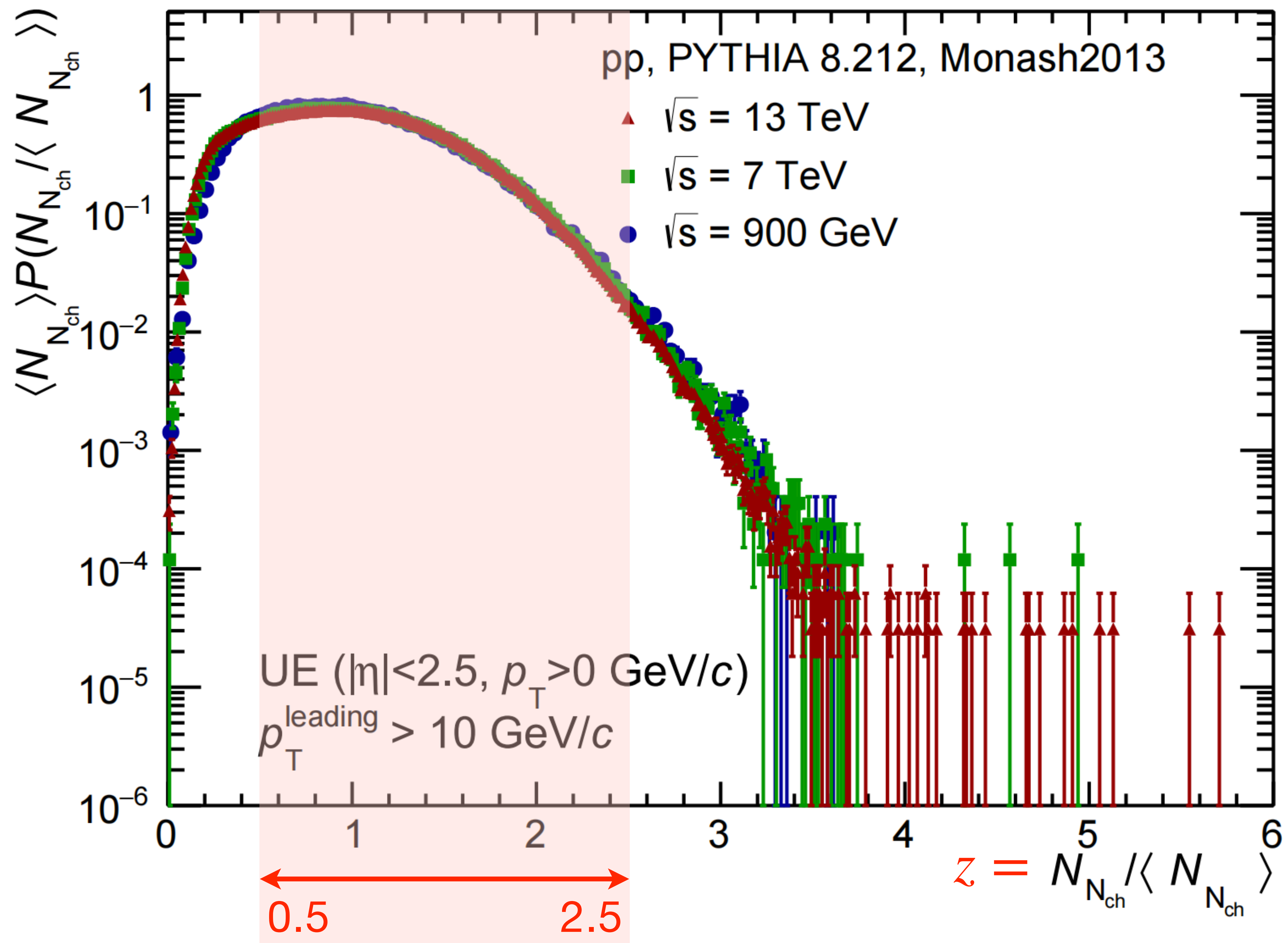
★ Investigate KNO-like scaling properties with ALICE data in pp collisions, improving the sensitivity to MPI

★ Explore the energy $\sqrt{s}$ dependence of $\langle N_{\mathrm{ch}} \rangle$

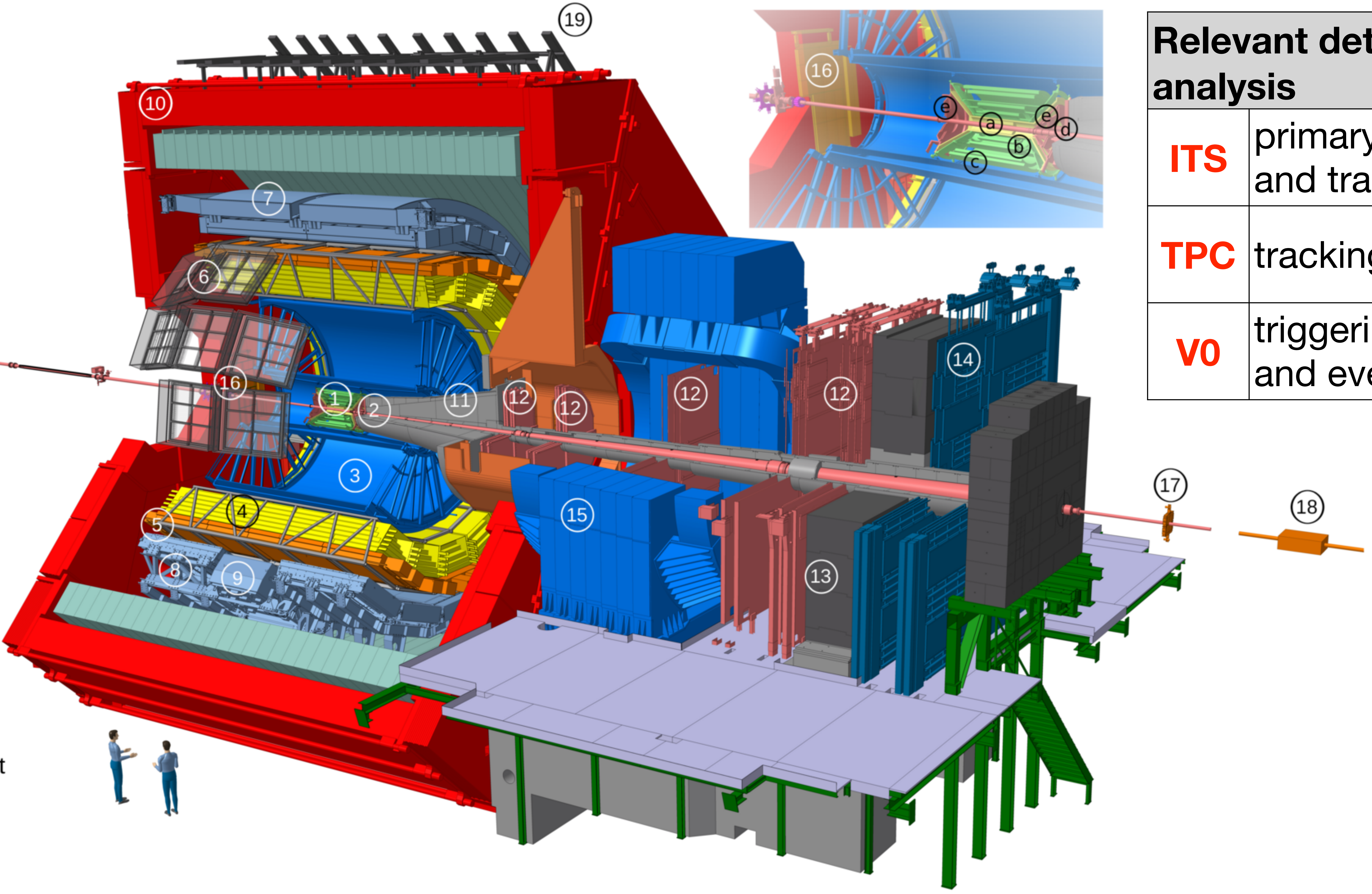
KNO scaling: $\langle N_{\mathrm{ch}} \rangle P(N_{\mathrm{ch}}) = \Psi(N_{\mathrm{ch}}/\langle N_{\mathrm{ch}} \rangle)$ ⟵ Feynman scaling: $\langle N_{\mathrm{ch}} \rangle \propto \ln \sqrt{s}$

ISR-FSR cause the violation of KNO scaling for lower and higher multiplicities?

In a MC study of UE, a KNO scaling is observed for $0.5 < z < 2.5$ A. Ortiz et el., PRD 96 (2017) 11, 114019



THE ALICE DETECTOR IN RUN2



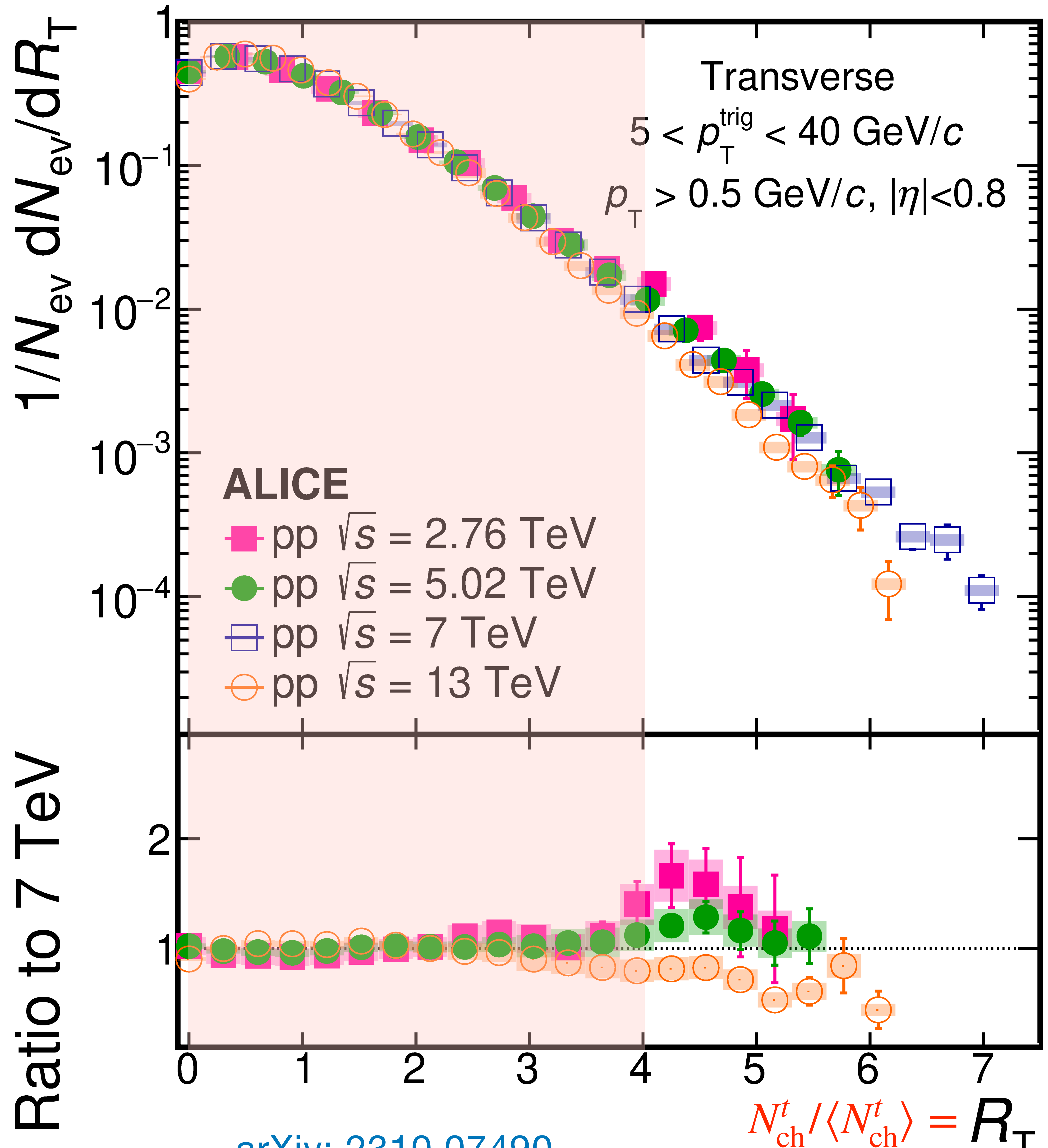
1. ITS
2. FMD, T0, V0
3. TPC
4. TRD
5. TOF
6. HMPID
7. EMCal
8. DCal
9. PHOS, CPV
10. L3 Magnet
11. Absorber
12. Muon Tracker
13. Muon Wall
14, Muon Trigger
15. Dipole Magnet
16, PMD
17. AD
18. ZDC
19. ACORDE

Relevant detectors for the present analysis	
ITS	primary vertex, pile up rejection, and tracking
TPC	tracking
V0	triggering, background rejection, and event classification

MULTIPLICITY DISTRIBUTIONS

- The charged-particle multiplicities are energy dependent in the three topological regions
- Higher multiplicities are reached at higher energies
- Similar behavior is seen in minimum-bias event.

KNO VARIABLES



arXiv: 2310.07490

KNO variables:

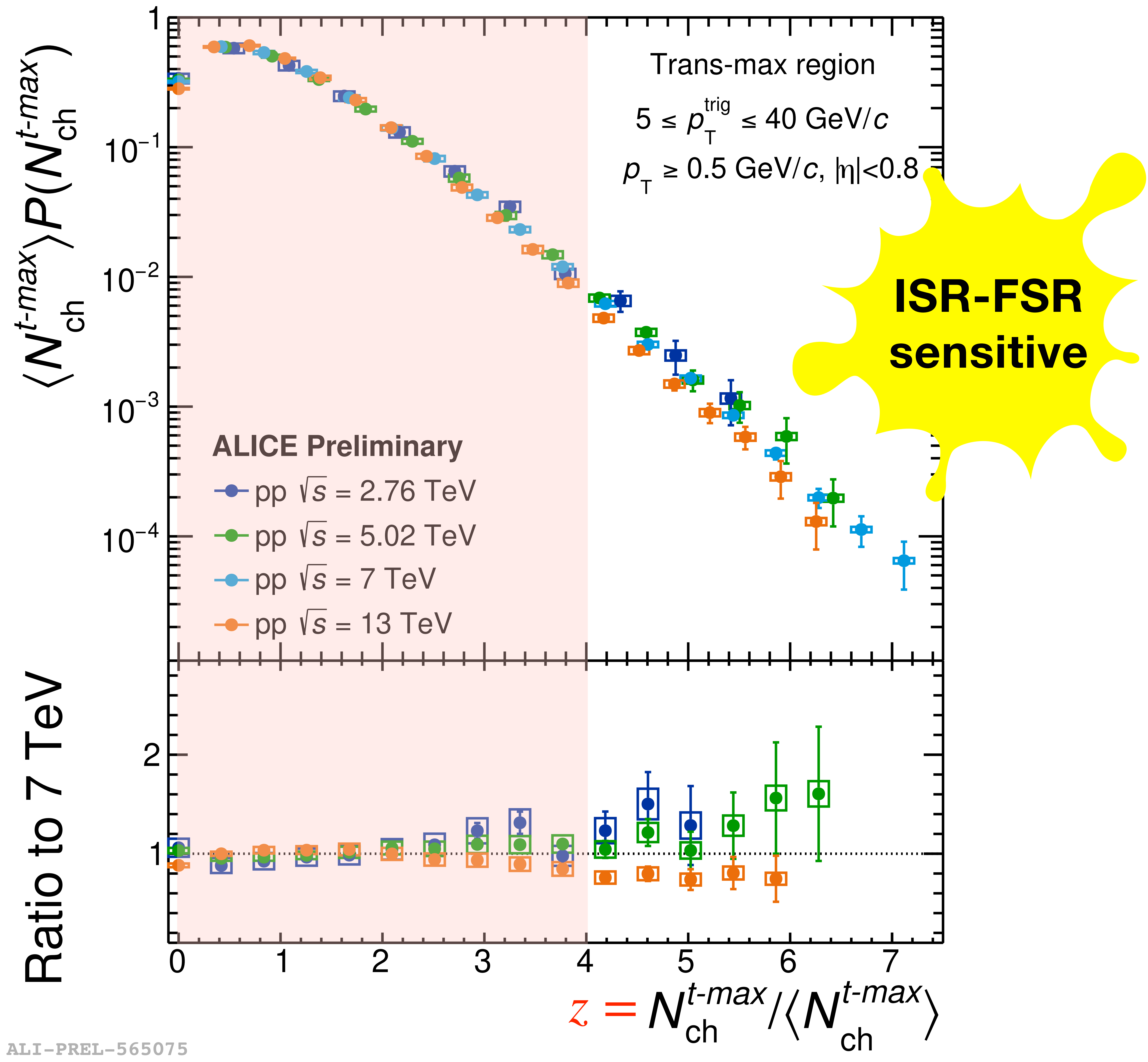
$$z = N_{\rm ch}^{\rm X}/\langle N_{\rm ch}^{\rm X}\rangle$$

where "$\mathrm{X} = t$, *t-min*, & *t-max*" corresponding to the "transverse, trans-max, and trans-min" regions.

Transverse region

- A KNO-like scaling is exhibited for $0 < z < 4$
  - ✴ MPI can explain the scaling PLB 408 (1997) 417-421

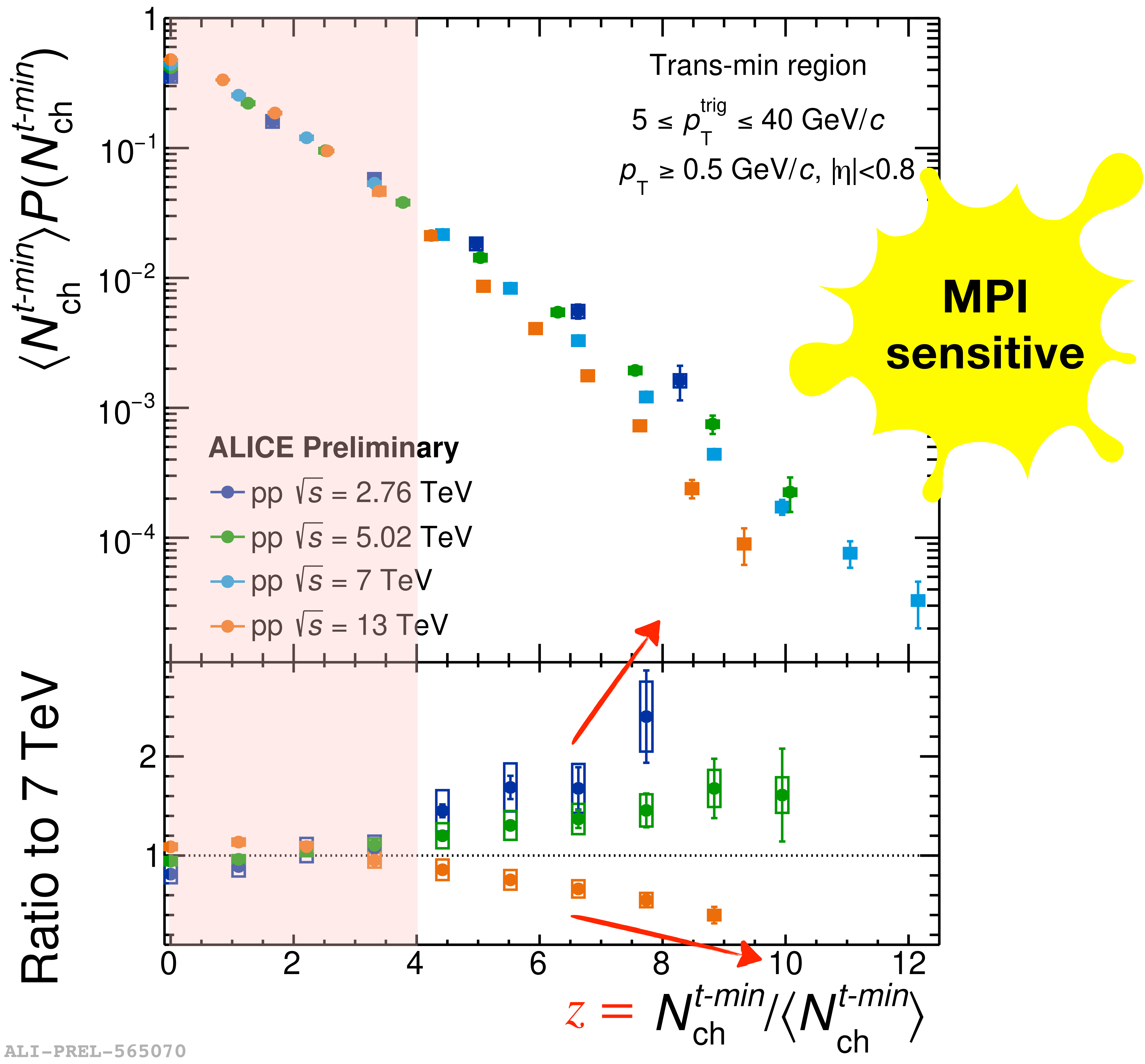
KNO VARIABLES



Trans-max region

- The result is qualitatively similar to the one in the transverse region

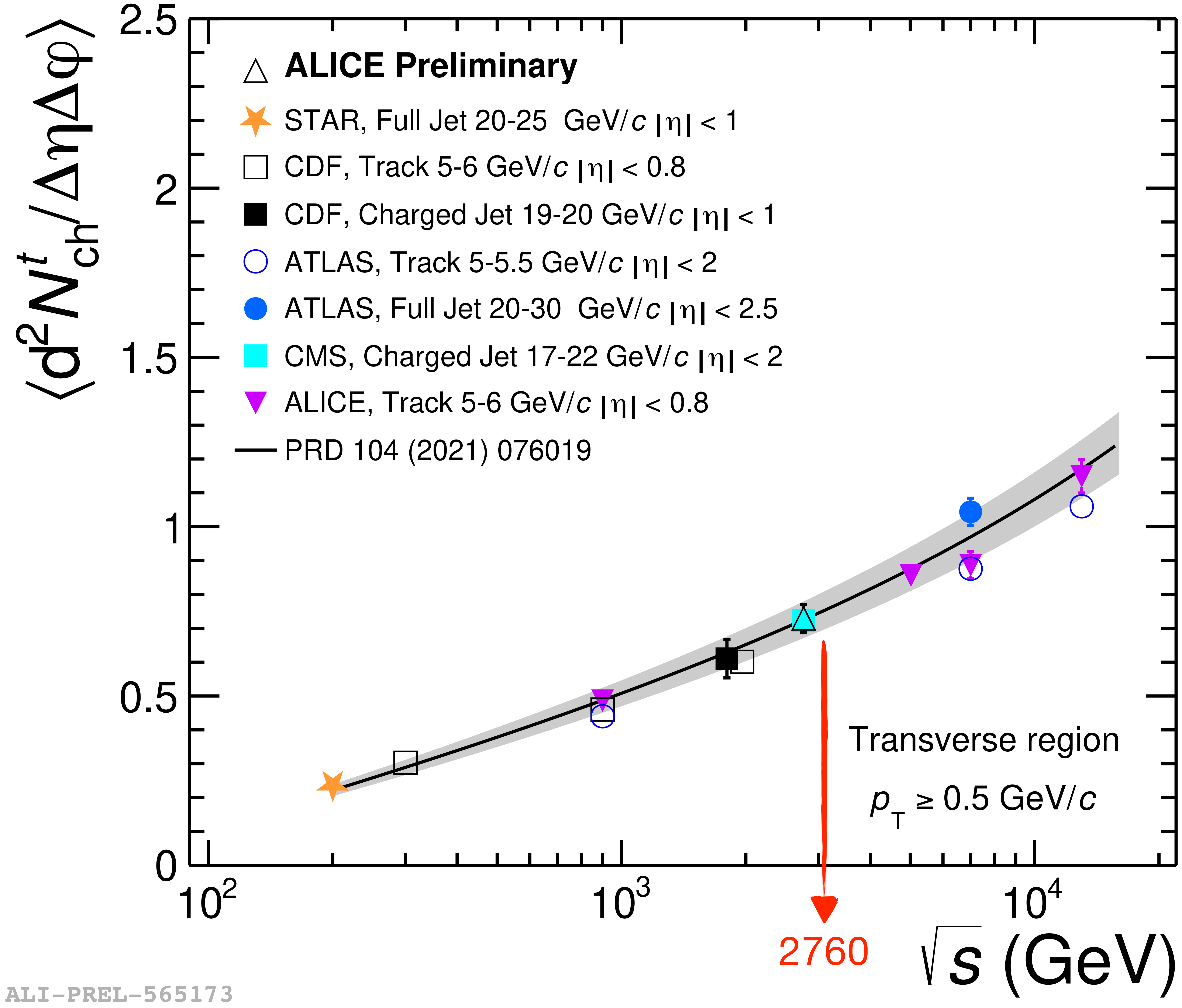
KNO VARIABLES



Trans-min region

- For $0 < z < 4$, a similar KNO-like scaling is also observed with a better agreement
- For $z > 4$, the scaling is broken which might be attributed to high-multiplicity jets
  - ✴ A similar effect is observed for $N_{ch}/\langle N_{ch}\rangle$ > 3~4, the number of MPI as a function of $N_{ch}/\langle N_{ch}\rangle$ deviates from the linear trend suggesting the presence of high-multiplicity jets
    J.Phys.G 48 (2021) 8, 085014 / JHEP 09 (2013) 049
- a higher z reach is achieved, especially for $z > 6$, a larger violation is observed

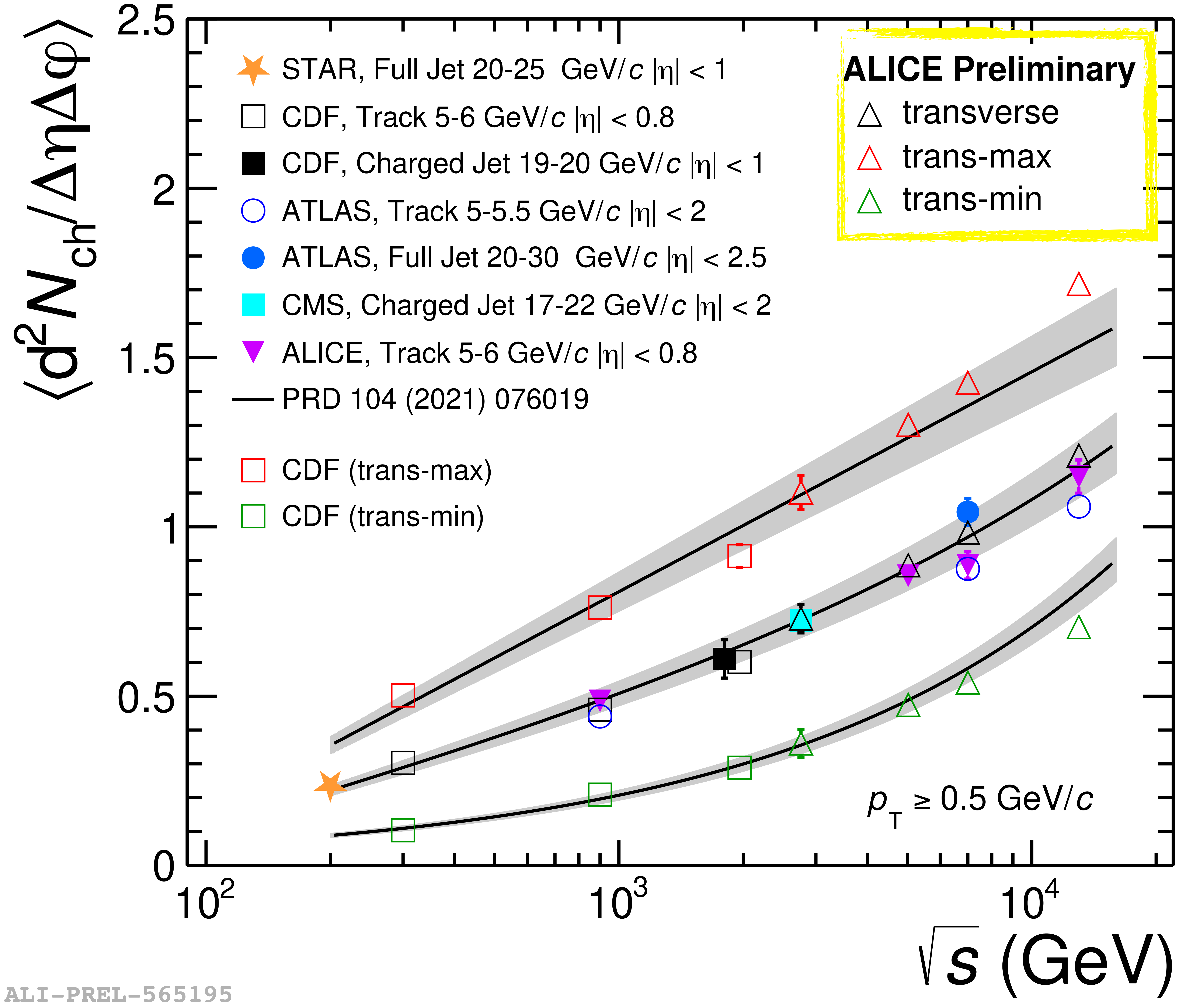
$\sqrt{s}$ vs. MEAN MULTIPLICITY



Transverse region

- Our result, at 2.76 TeV, is consistent with the trend of existing measurements
- Data from different experiments show that the average multiplicity densities do not increase logarithmically with $\sqrt{s}$, namely, the Feynman scaling is broken

$\sqrt{s}$ vs. MEAN MULTIPLICITY



- For the **MPI-sensitive region**, within two sigma systematic uncertainty, the activity inside increases like a power-law with $\sqrt{s}$

- For the **ISR-FSR-sensitive region**, within two sigma systematic uncertainty, the activity inside rises logarithmically with $\sqrt{s}$

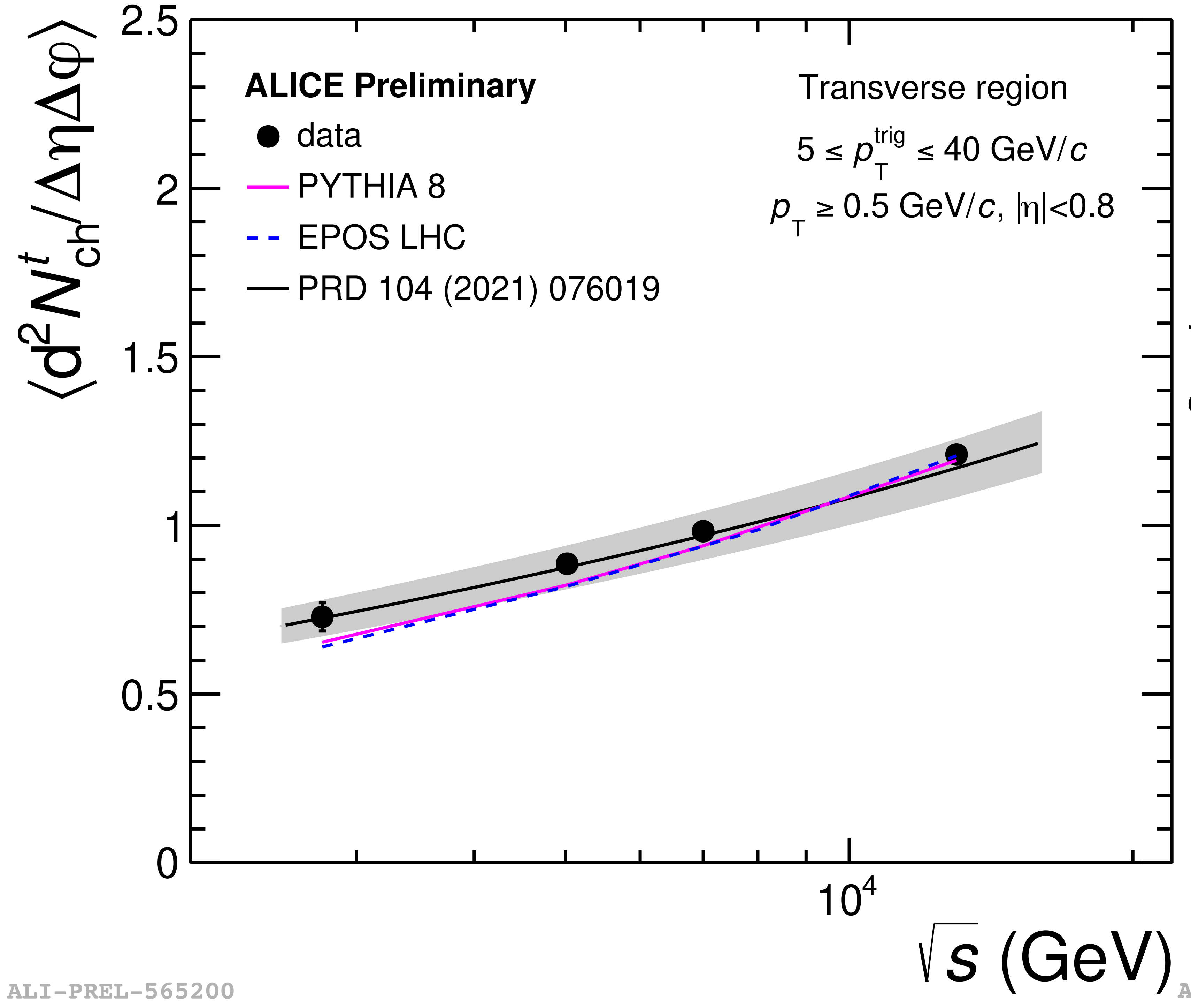
COMPARISON TO MODELS (MULTIPLICITY)

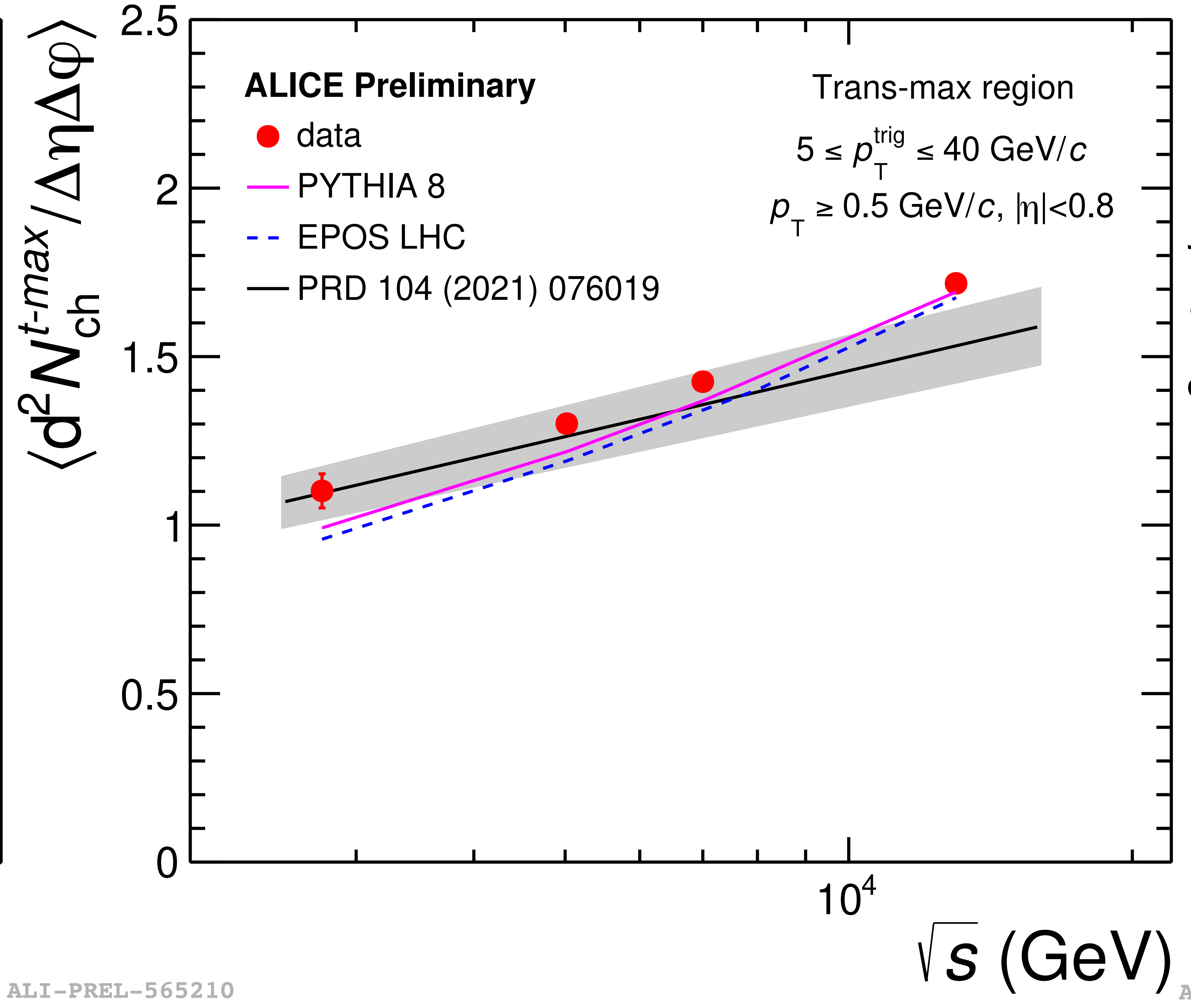
- At low multiplicities, within two standard deviations, both EPOS LHC and PYTHIA 8 are consistent with the data
- At high multiplicities, both models underestimate the data
- A better agreement between data and MC is observed for the trans-min region ($N_{ch}^{t-min} < 6$)

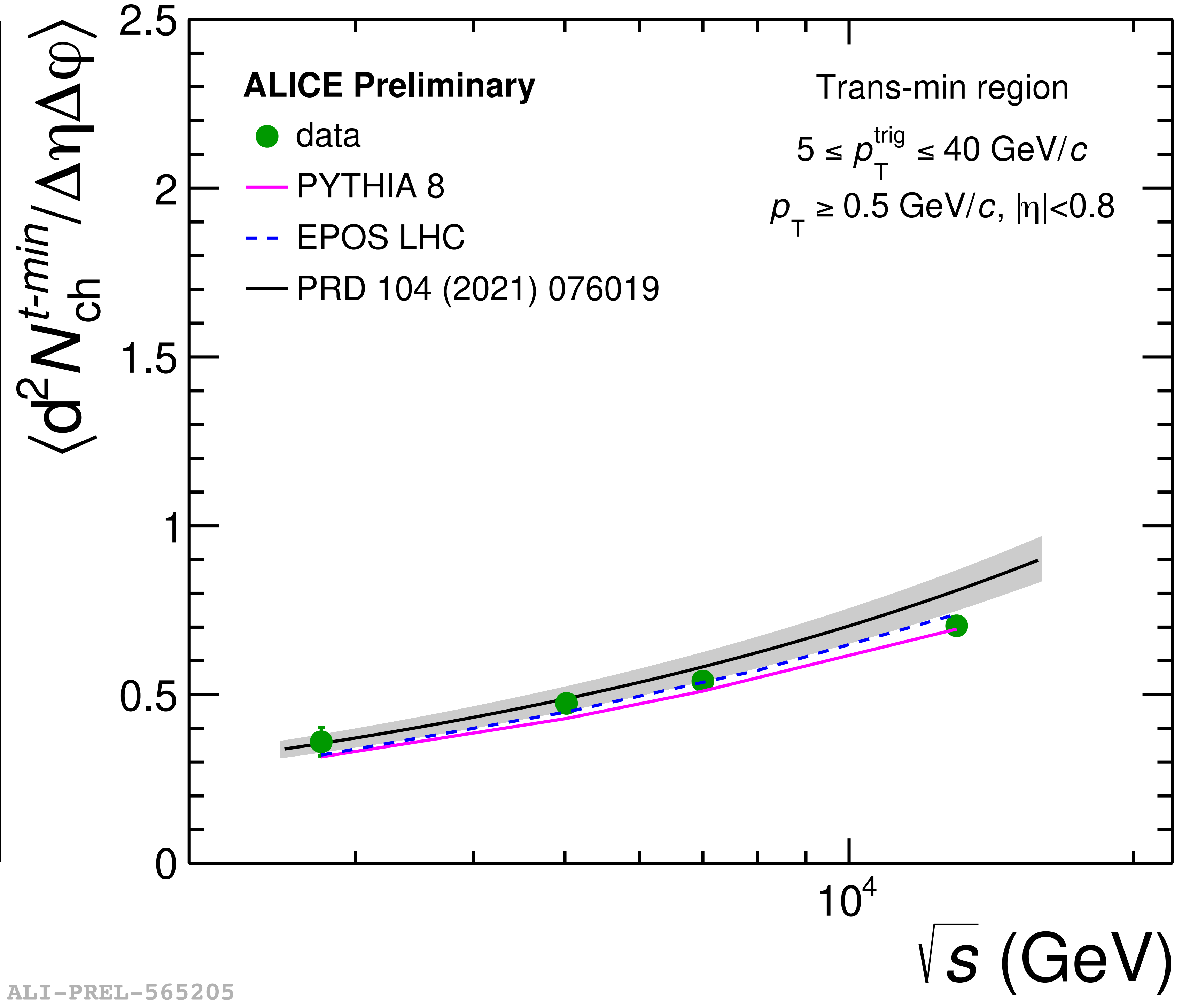
COMPARISON TO MODELS (KNO VARIABLES)

- For low z values, EPOS LHC and PYTHIA 8 are consistent with data within two standard deviations
- At high values of z, both models underestimate data

COMPARISON TO MODELS ($\sqrt{s}$ vs. MEAN MULTIPLICITY)







- Within uncertainties, both EPOS LHC and PYTHIA 8 are consistent with data and a better agreement is reached at higher energies

CONCLUSION

- **The KNO scaling:**
  - ✳ KNO-like scaling holds for $0 < z < 4$ and it is broken above 4. A higher z reach is achieved for the trans-min region, in particular for $z > 6$, a larger violation of the KNO scaling is observed which might be attributed by high-multiplicity jets
  - ✳ EPOS LHC and PYTHIA 8 reproduce the distribution at low z values, and for higher z values they underestimate data

- **Average charged-particle densities as a function of the centre-of-mass energy:**
  - ✳ The results for the transverse region can be described by a function of the form $\propto s^{0.27} + 0.14\log(s)$, where the first (second) term quantifies the MPI- (ISR-FSR-) sensitive topological region of the collision
  - ✳ EPOS LHC and PYTHIA 8, which incorporate MPI, are consistent with data, a better agreement is reached at higher energies