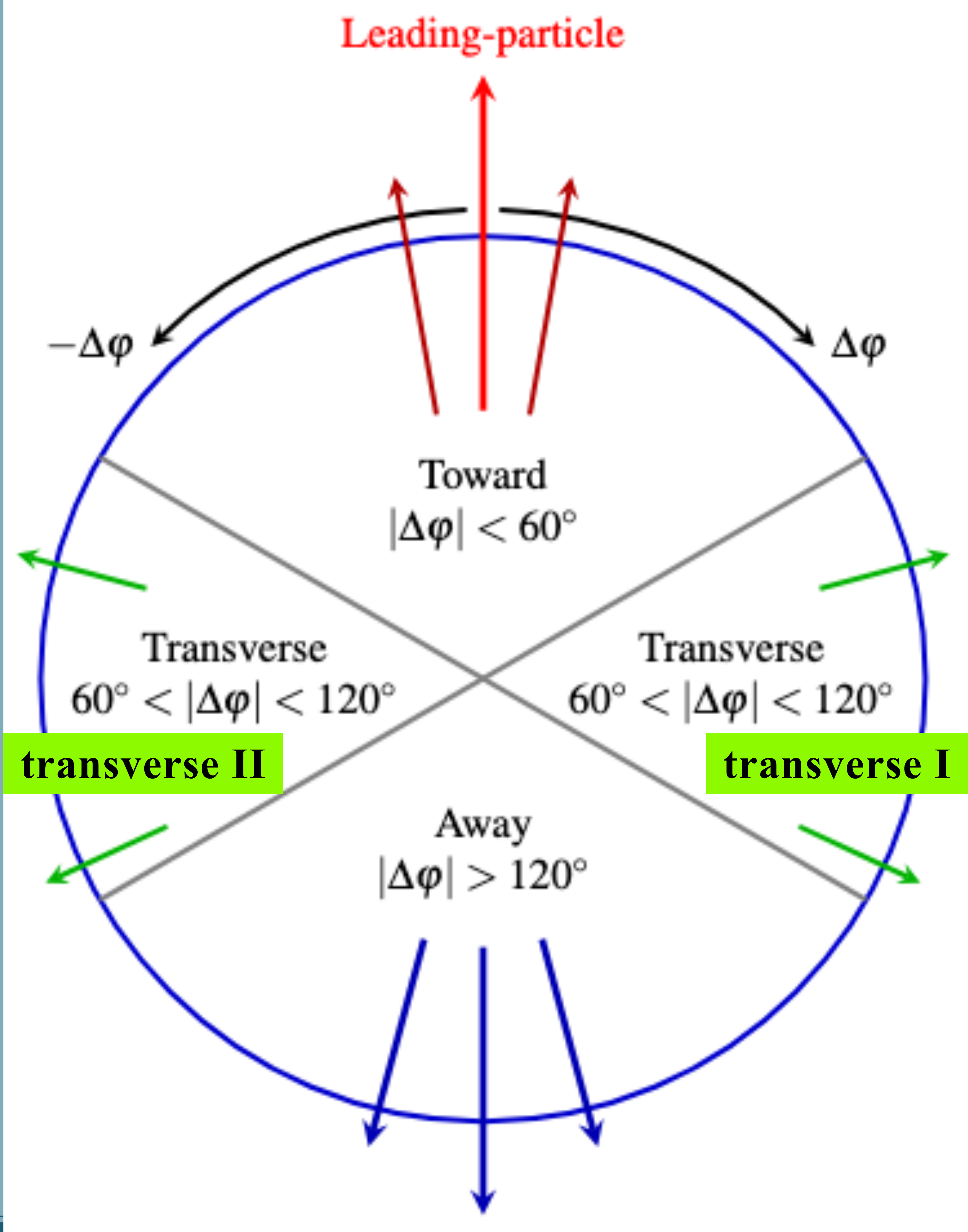
Energy dependence of underlying-event observables measured with ALICE at the LHC

Feng Fan, for the ALICE collaboration

1. Introduction

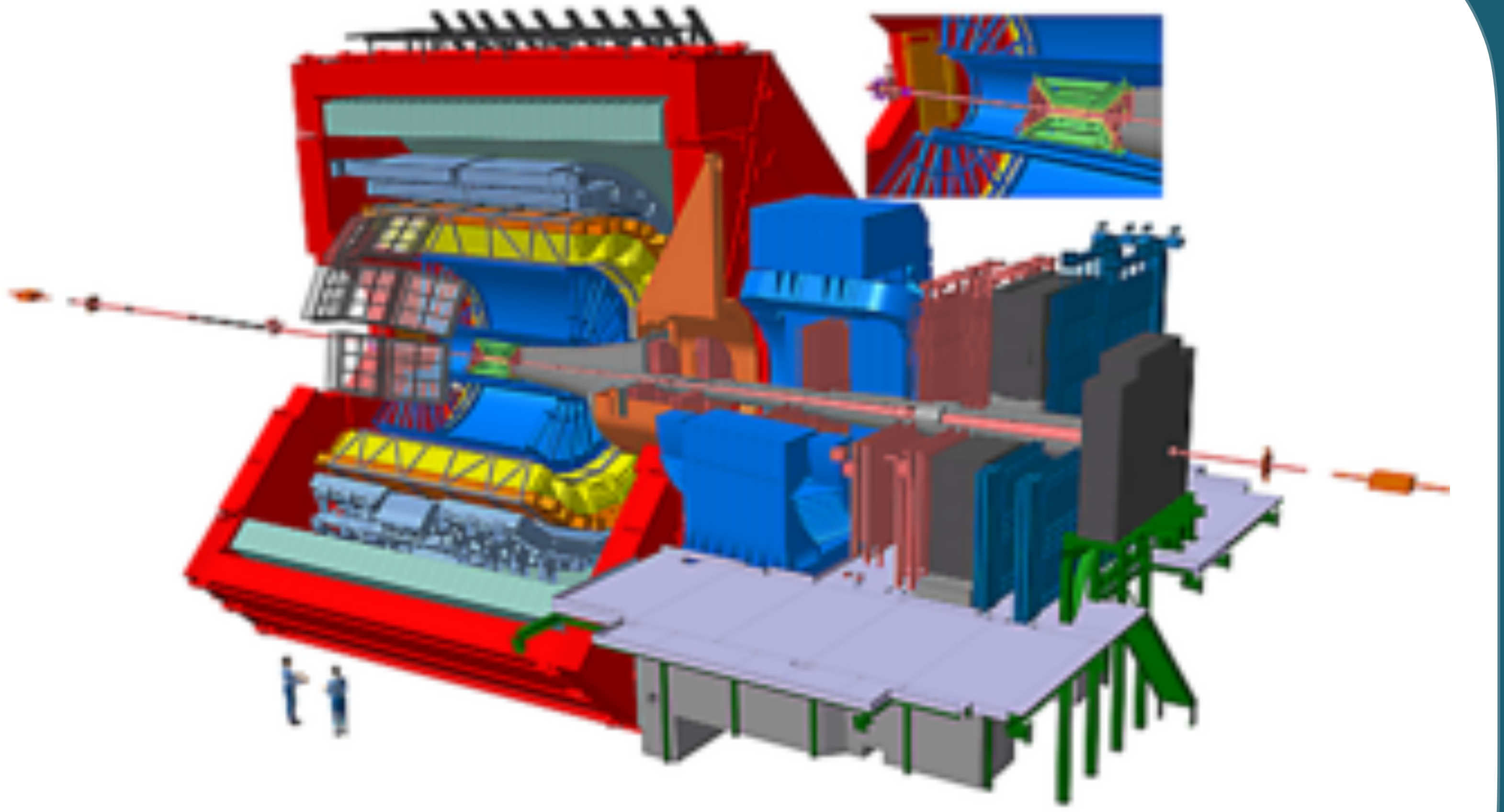
- High-multiplicity pp collisions unveiled heavy-ion-like effects such as collectivity and strangeness enhancement. In PYTHIA 8, multiparton interactions (MPI) and color reconnection (CR) produce collective-like effects, therefore, it is pertinent to measure quantities sensitive to MPI
- The underlying event (UE) [1] consists of particles from beam-beam remnants and MPI
- The transverse region, relative to the track with the highest transverse momentum of the event (p_T^{trig}), is the most sensitive to UE [2], but it has contributions from initial- and final-state radiation (ISR and FSR)
- In this work, the multiplicity distributions in the transverse region measured in pp collisions at $\sqrt{s}$ = 2.76, 5.02, 7 and 13 TeV are reported. The transverse region is further subdivided into trans-max and trans-min regions corresponding to the sub-transverse region (I or II) with the largest and smallest charged-particle multiplicity which have an enhanced sensitivity to ISR-FSR and UE, respectively. Scaling properties are explored [3]



2. Analysis details

✤ **Relevant detectors**:

- ✳ ITS: primary vertex reconstruction, pile up rejection, tracking
- ✳ TPC: tracking
- ✳ V0: triggering and beam background rejection



✤ **Datasets**

Energy	Year	Statistics
2.76 TeV	2011	22M
5.02 TeV	2015	176M
7 TeV	2010	171M
13 TeV	2016	199M

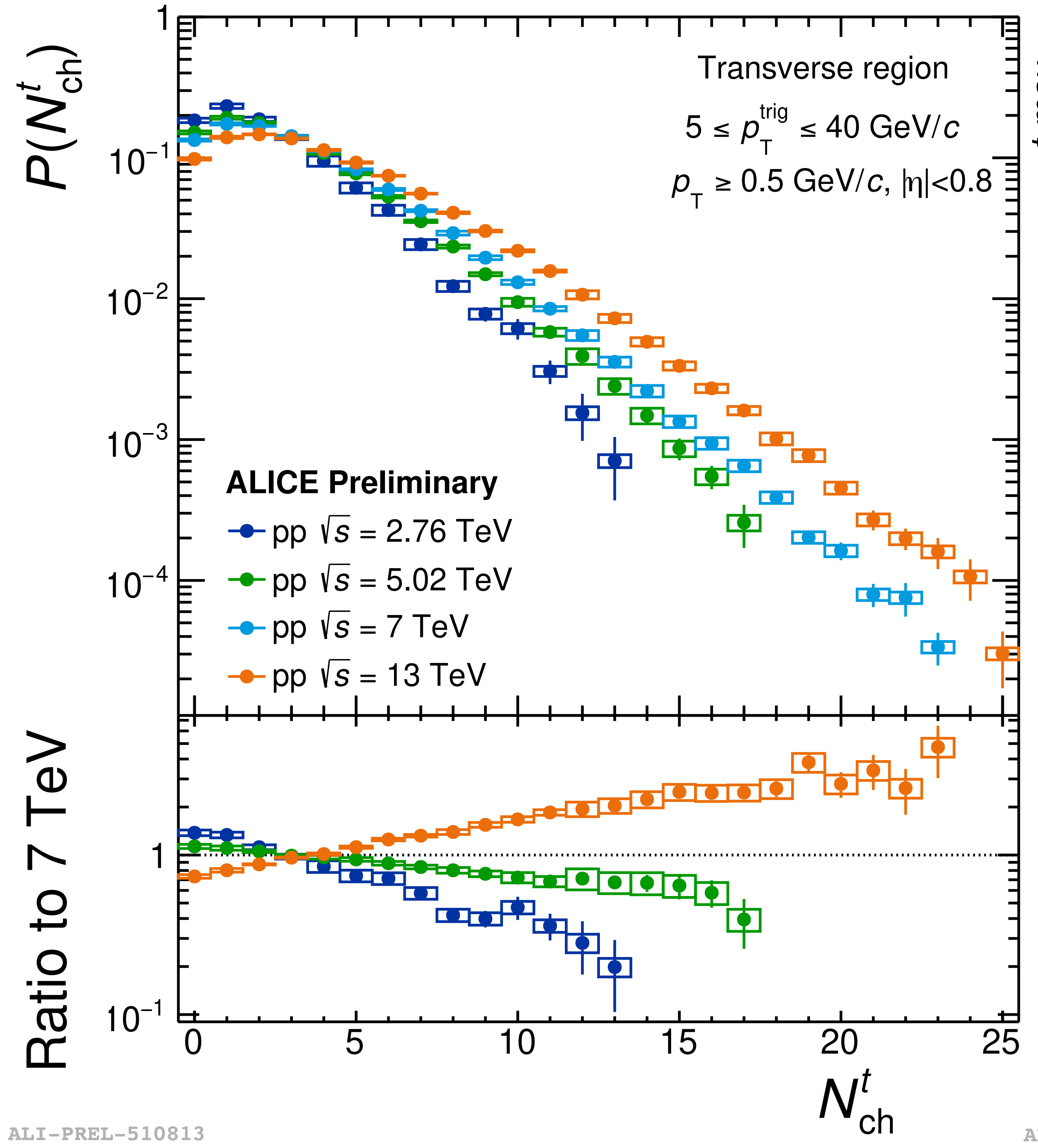
✤ **Event selection:** $5 \leq p_{\mathrm{T}}^{\mathrm{trig}} \leq 40\,\mathrm{GeV}/c$ in $|\eta| < 0.8$

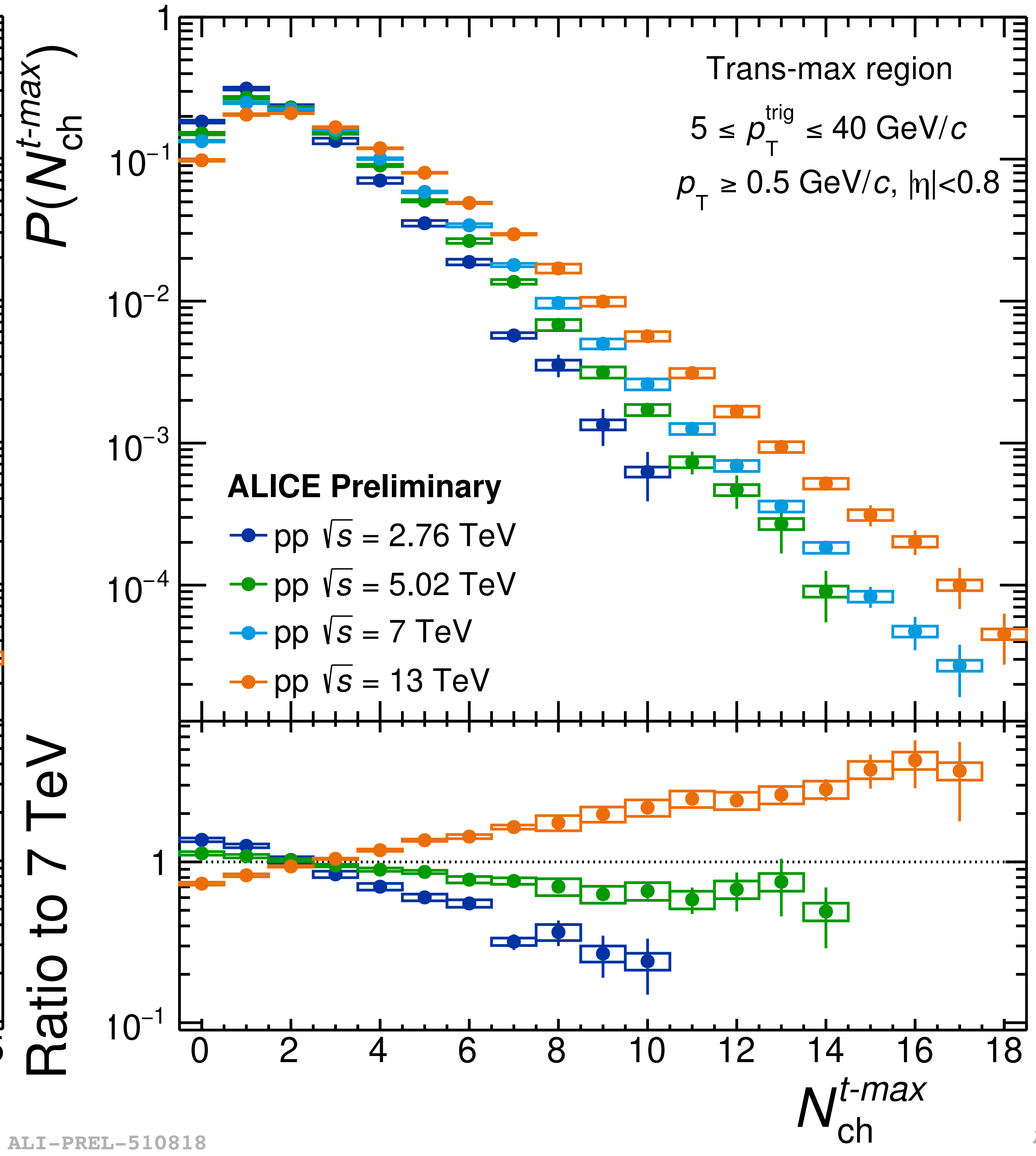
✤ **Leading particle:** standard track cuts optimized for high p_{T} [4]

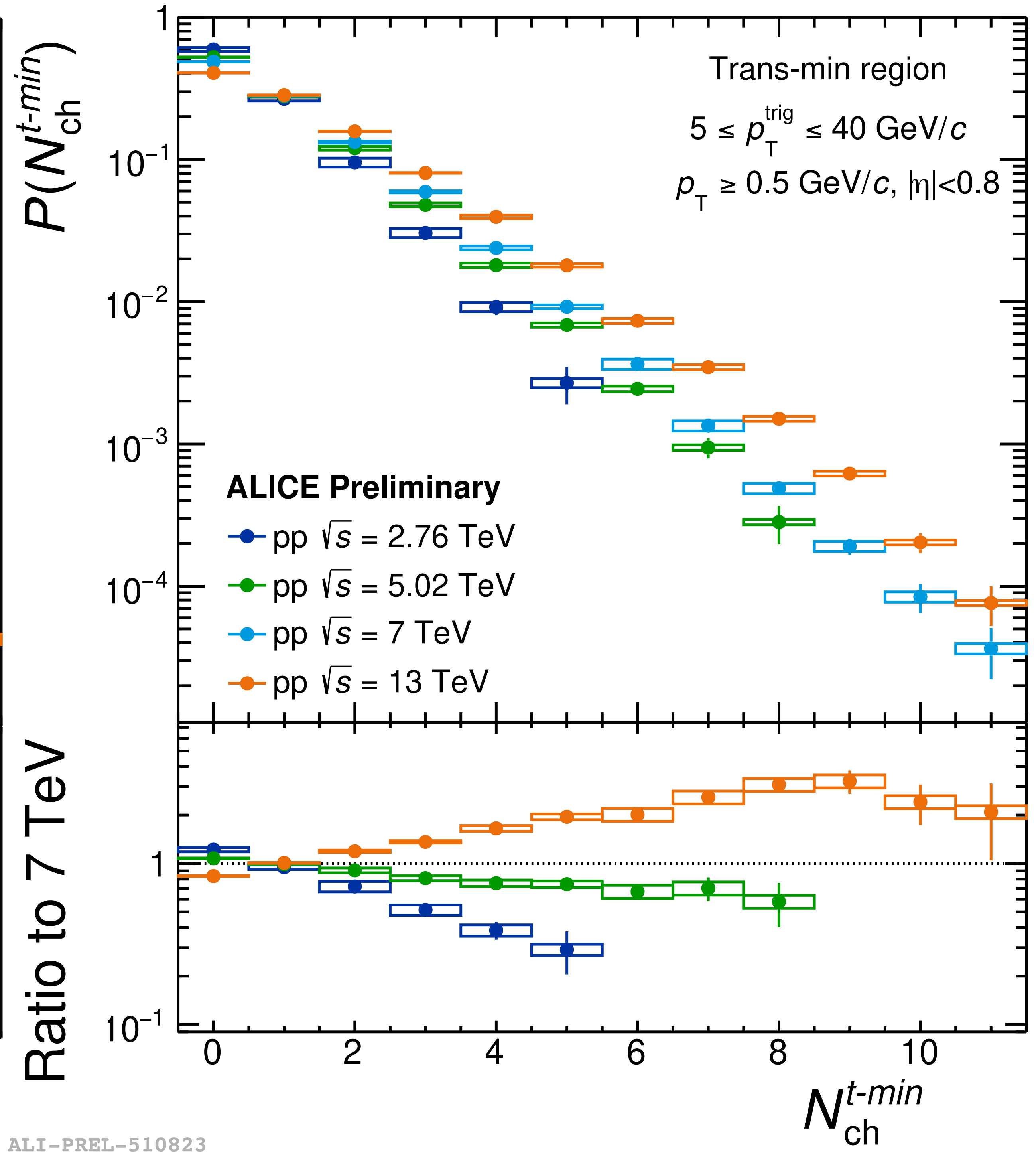
✤ **Track selection for multiplicity:** uniform distributions in azimuth

✤ **Correction method:** bayesian unfolding

✤ **Systematic uncertainties:** track selection, event selection, MC closure test, and model dependence







3. Results

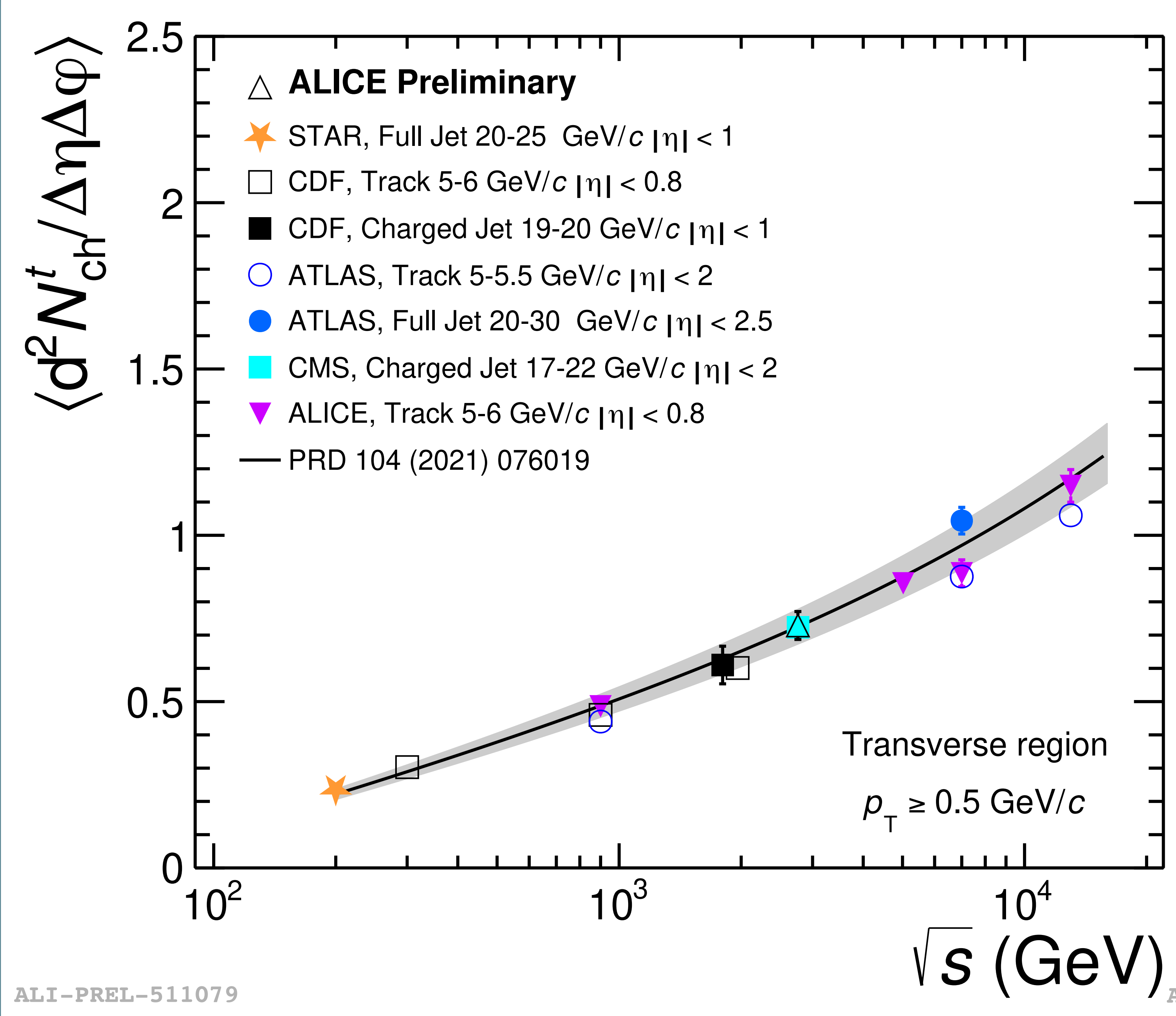
✤ The charged-particle multiplicity distributions are energy dependent in the three topological regions

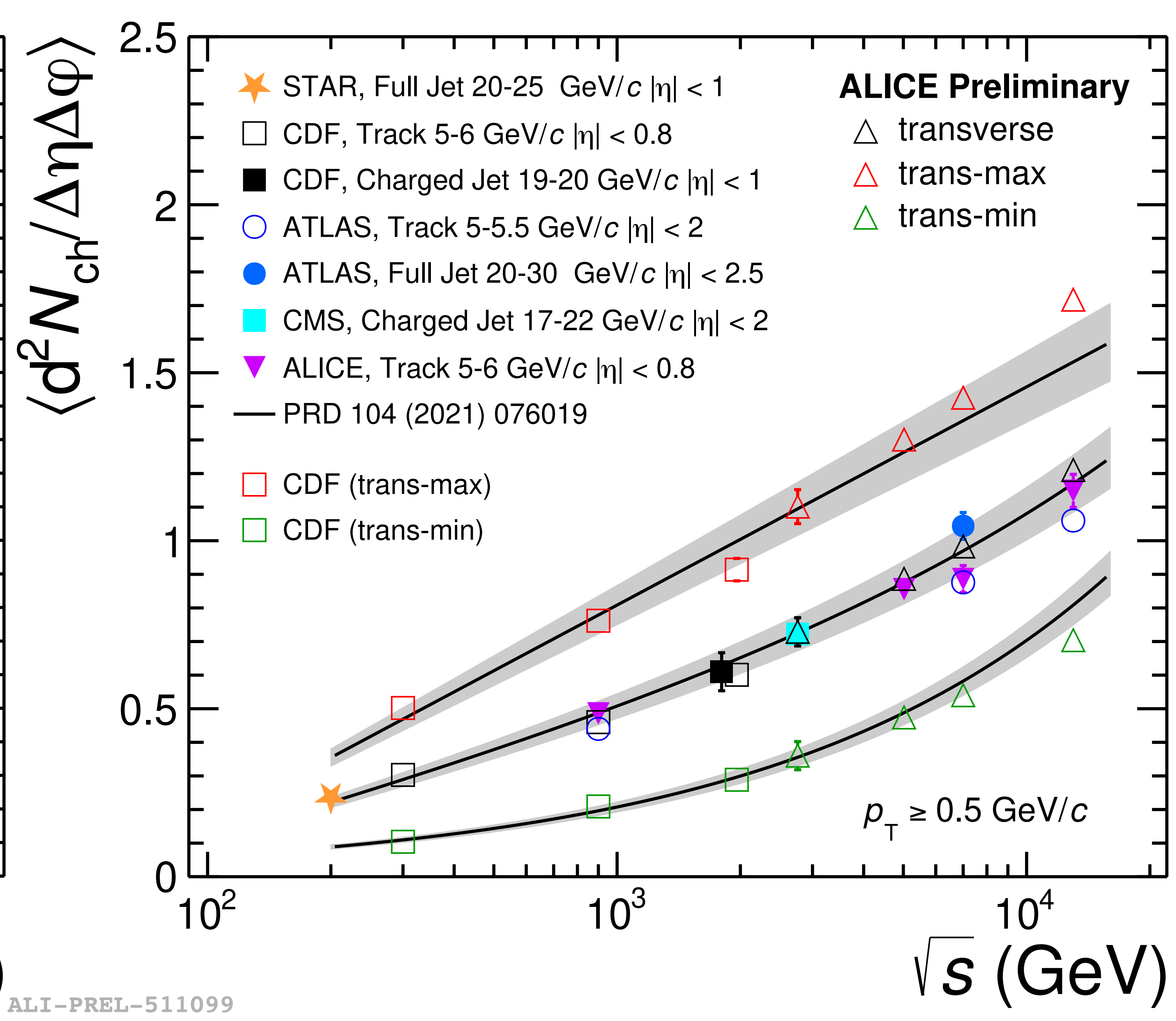
✤ Higher multiplicities are reached at higher energies.

Central China Normal University & Nuclear Sciences Institute, National Autonomous University of Mexico

- In the three topological regions the KNO-like scaling holds for $0 < z(= N_{ch}/\langle N_{ch} \rangle) < 3.5$
  - MPI can explain the effect [5]
- In the trans-min region, a higher z reach is achieved, in particular for $z > 6$, a lager deviation is seen

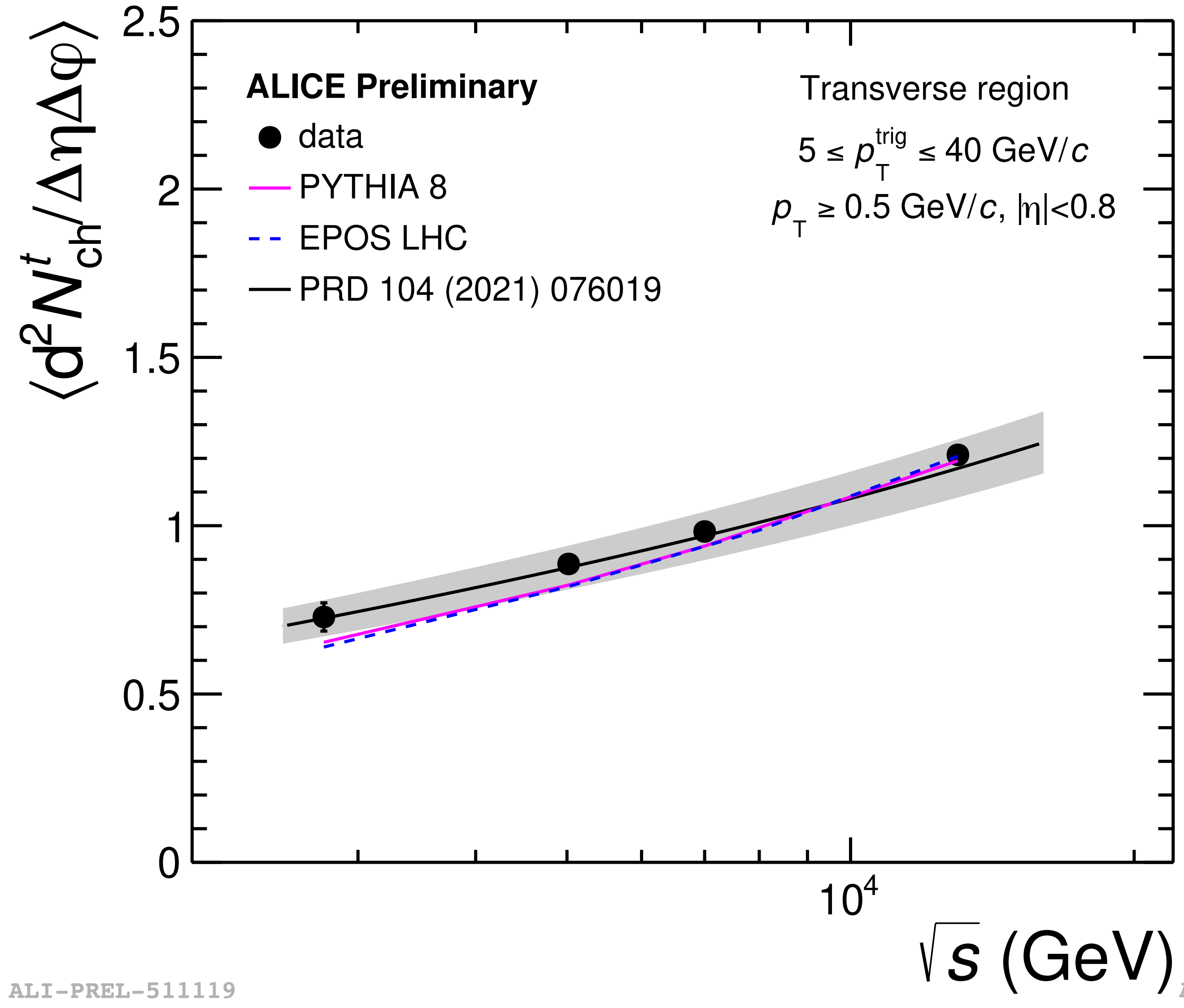
- For low z values, EPOS LHC and PYTHIA 8 are consistent with data within two standard deviations
- At high values of z, both models underestimate data
- In the transverse region, a similar behavior was reported in Ref. [2]

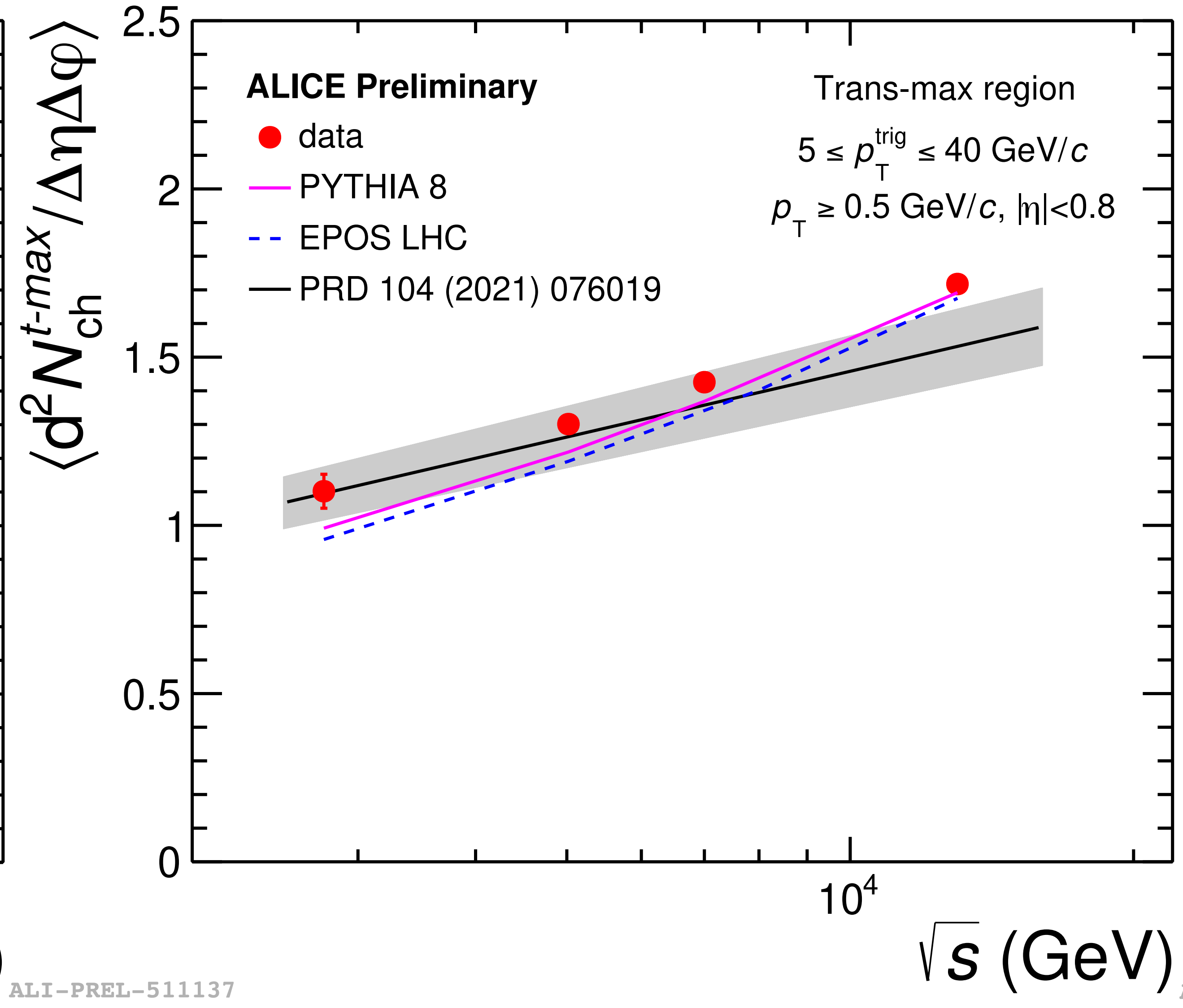


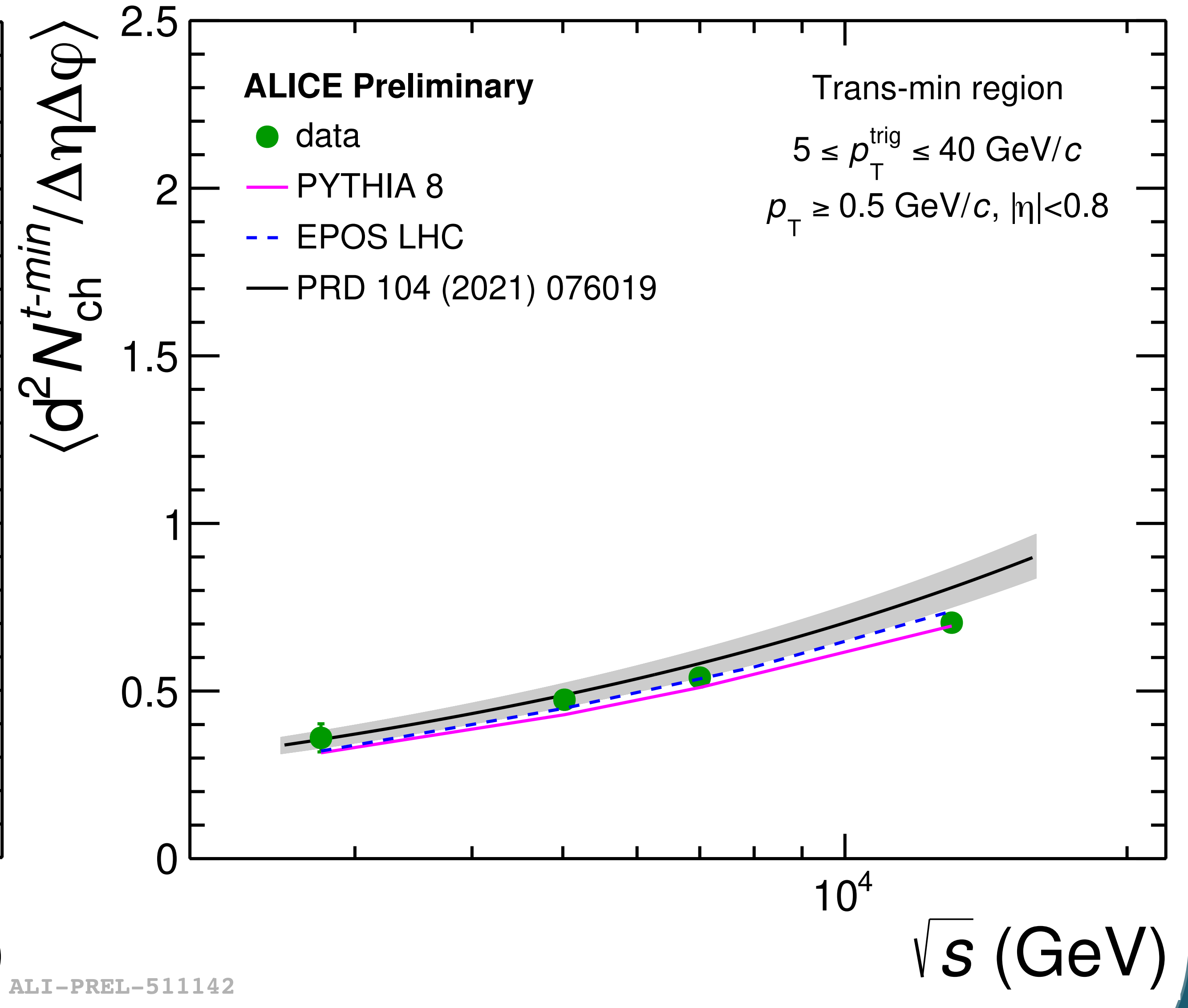


- ✤ In the transverse region, our results are consistent with the trend of existing measurements
- ✤ Data are consistent with an extrapolation of the CDF results to LHC energies, where the ISR-FSR component increases logarithmically, while the UE component increases like a power of the centre-of-mass energy

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







4. Summary

- Average charged-particle densities as a function of the centre-of-mass energy:
  - The results for the transverse side 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.
  - PYTHIA 8 and EPOS LHC, which incorporate MPI, are consistent with data, a better agreement is reached at higher energies.

- The KNO scaling:
  - KNO-like scaling holds for $0 < z < 3.5$ and it is broken above 3.5. 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.
  - PYTHIA 8 and EPOS LHC reproduce the distribution at low values of z, and for higher z values they underestimate data.

5. Acknowledgement

Support for this work has been received from CONACyT under the Grant No. A1-S-22917 and CF No. 2042. It is also supported by the the NSFC Key Grant 12061141008 and the National key research and development program of China under the Grant 2018YFE0104700 and 2018YFE0104800.

6. References

[1] CDF Collaboration, T. Affolder *et al.*, “Charged jet evolution and the underlying event in $p\bar{p}$ collisions at 1.8 TeV”, *Phys. Rev. D* **65** no. 092002, (2002) .

[2] ALICE Collaboration, S. Acharya *et al.*, “Underlying event properties in pp collisions at $\sqrt{s}$ = 13TeV, *JHEP* 04 (2020) 192.

[3] A. Ortiz and L. Valencia Palomo, “Universality of the underlying event in pp collisions”, *Phys. Rev. D* 96 no. 11, (2017) 114019.

[4] ALICE Collaboration, S. Acharya *et al.*, “Transverse momentum spectra and nuclear modification factors of charged particles in pp, p-Pb and Pb-Pb collisions at the LHC”, *JHEP* 11 (2018) 013.

[5] J. Dias de Deus, C. Pajares, C.A. Salgado, “Production associated to rare events in high energy hadron-hadron collisions”, *Phys. Lett. B* 408 (1997) 417-421.