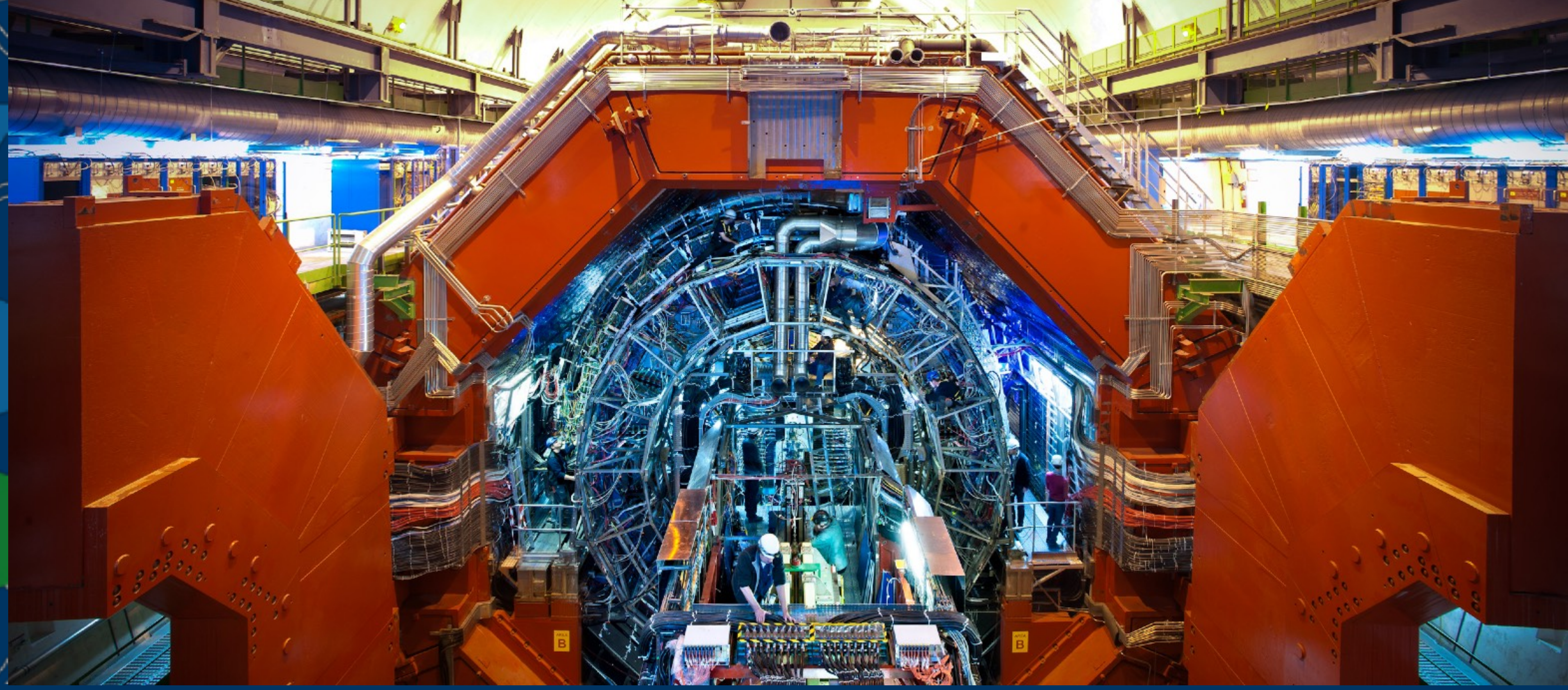
12th MPI at LHC



Minimum Bias and Underlying Event studies at ALICE

C. Oppedisano
for the ALICE Collaboration


INNER TRACKING SYSTEM (ITS)
➧ charged particle multiplicity $|\eta|<1$
➧ tracking
TIME PROJECTION CHAMBER (TPC)
➧ tracking and p_T measurement in $|\eta|<0.8$
ZERO DEGREE CALORIMETERS (ZDC)
➧ 1 neutron (ZN) and 1 proton (ZP) calorimeters
➧ $|\eta|>8.8$

UE event
in different
colliding systems

Underlying event

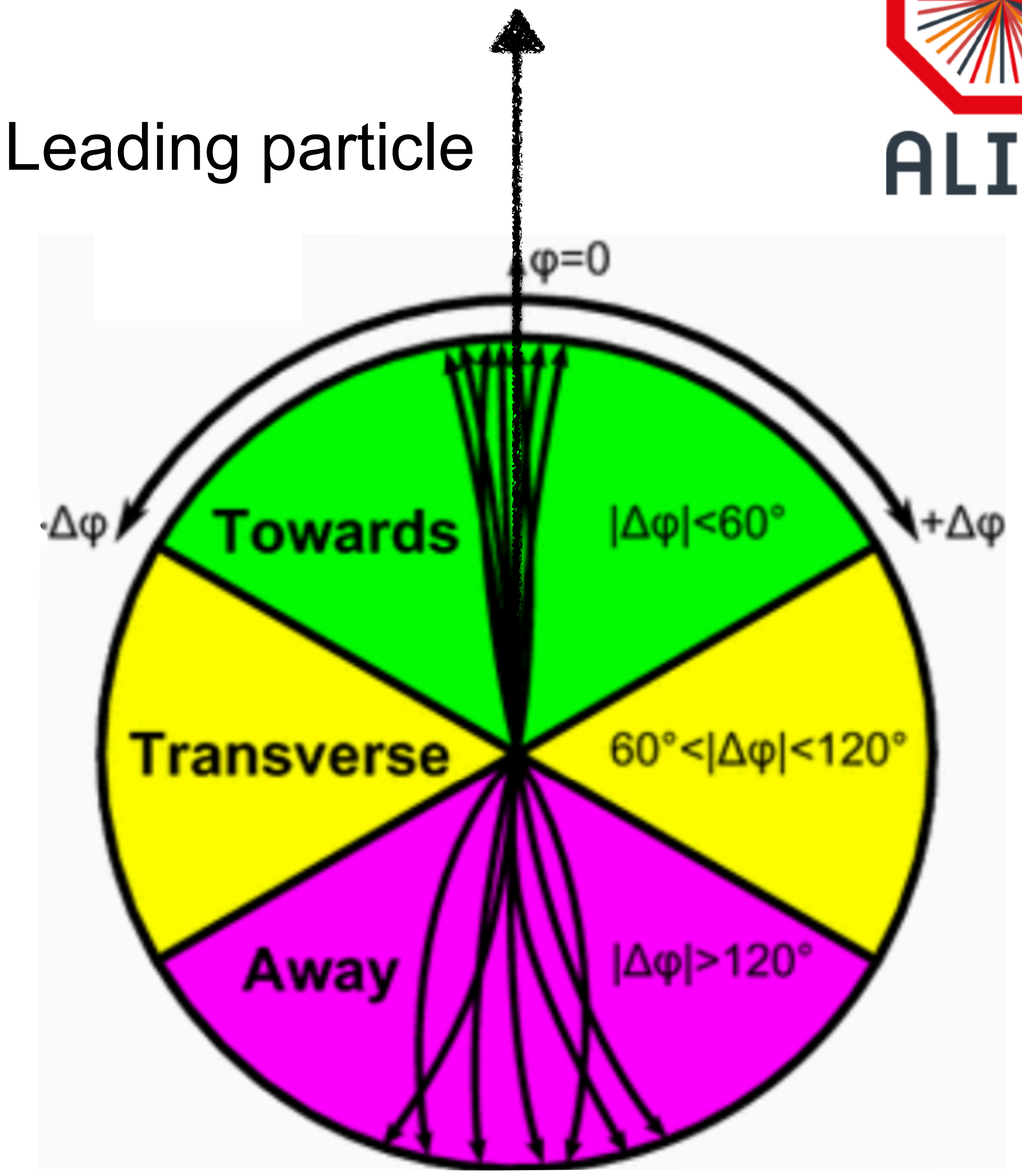
Analysis of particle multiplicity and momentum density in the presence of a leading particle (hard scattering) in 3 different regions:

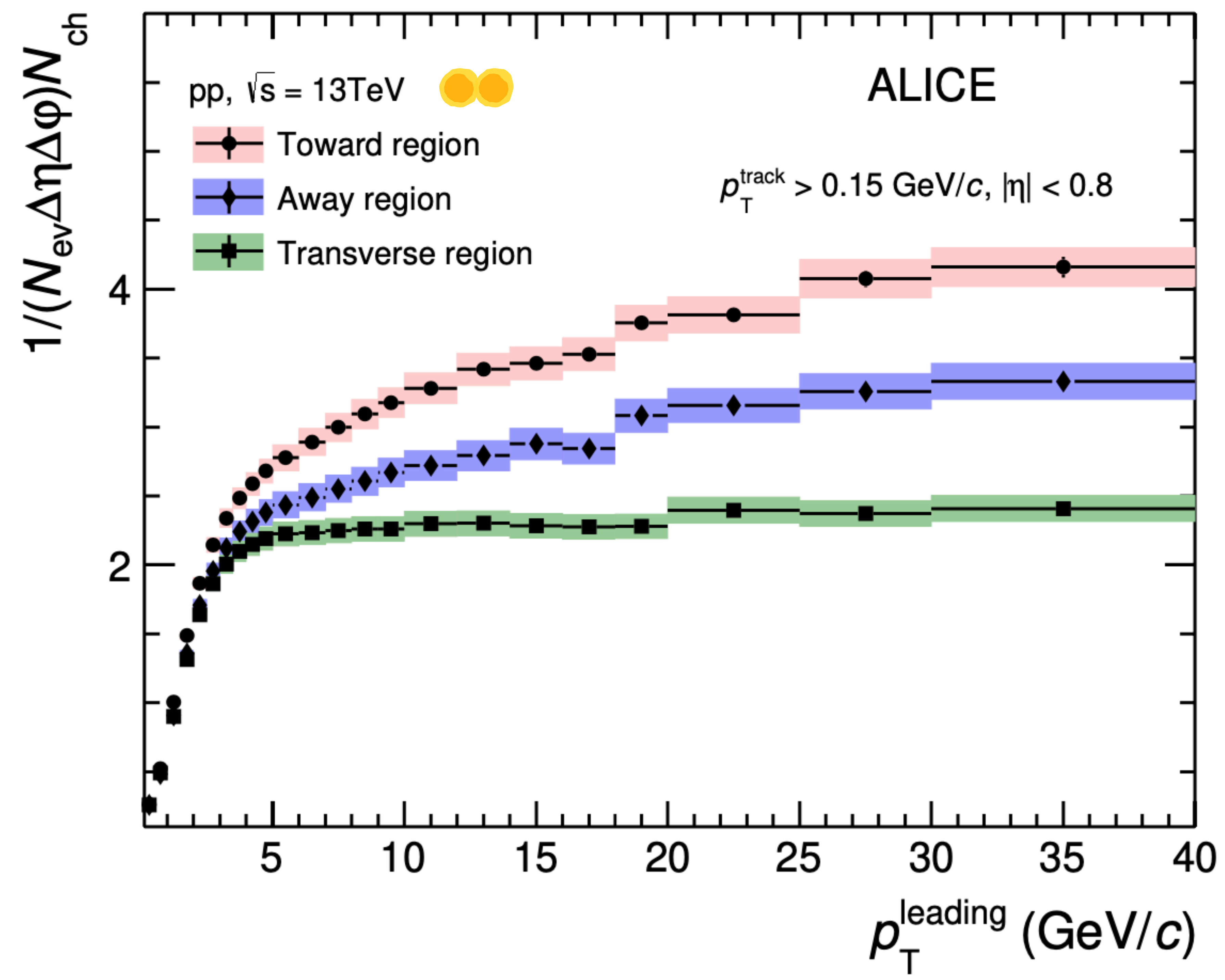
- TOWARDS ($|\Delta\varphi|<60°$)
- AWAY ($|\Delta\varphi|>120°$)

→ Fragmentation products from hard scatterings

- TRANSVERSE ($60°<|\Delta\varphi|<120°$)

→ Underlying Event (UE), MultiParton Interactions (MPI), ISR/FSR, beam remnants





TRANSVERSE REGION:

- MultiParton Interactions (MPI) with impact-parameter dependence: small impact parameter ➧ larger matter overlap ➧ larger N_{MPI} ➧ higher probability of a hard interaction
- for $p_T^{leading}$ >5 GeV/c: saturation (pedestal effect, UE) ➧ particle density insensitive to the hard component ➧ dominated by MPI

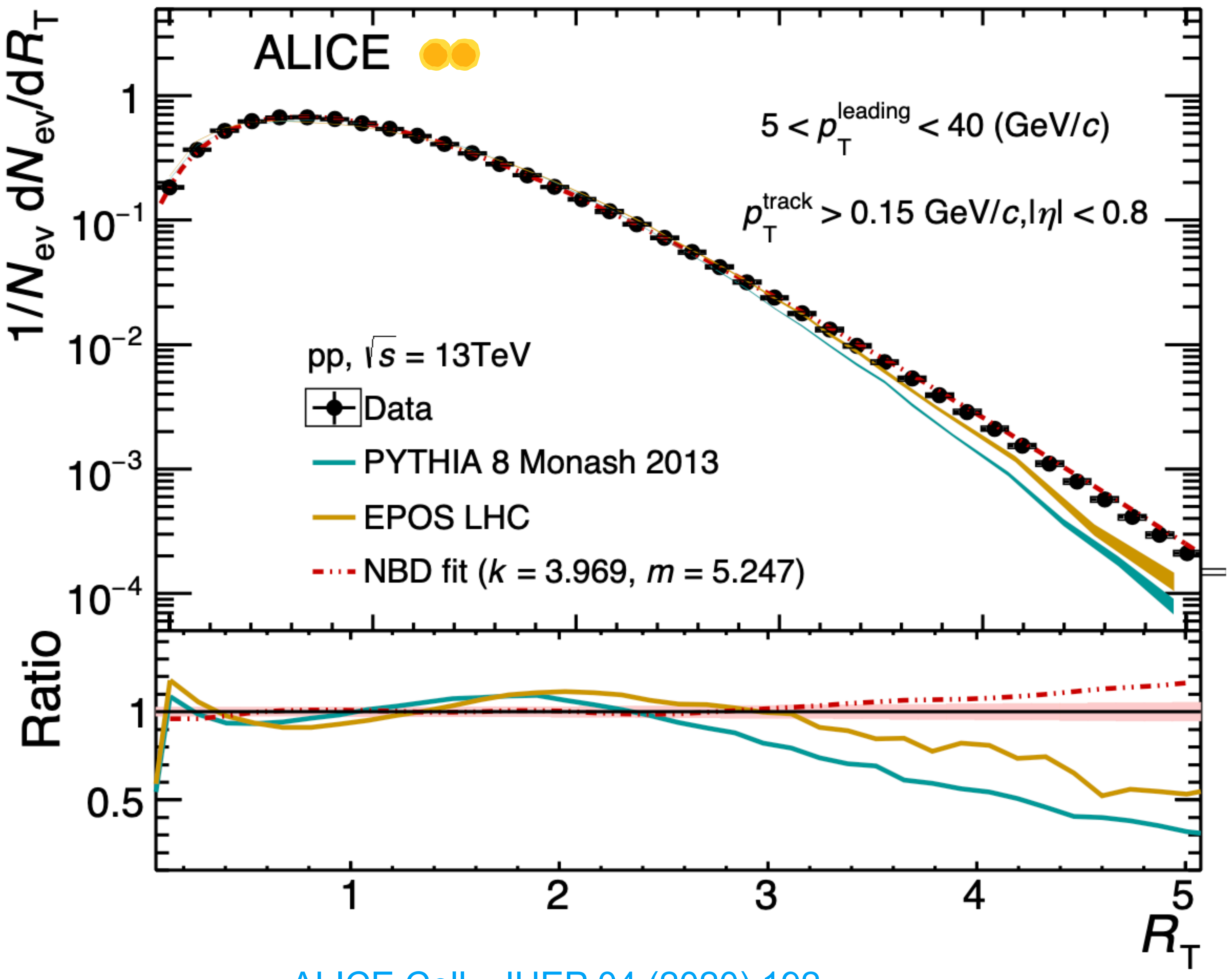
ALICE Coll., JHEP 04 (2020) 192

R_T estimator

$$R_T = \frac{N^{TR}}{\langle N^{TR} \rangle}$$

Relative Transverse activity classifier R_T: multiplicity in the TRANSVERSE REGION (p_T>5 GeV/c) normalised to MB

- study particle production as a function of UE activity



ALICE Coll., JHEP 04 (2020) 192

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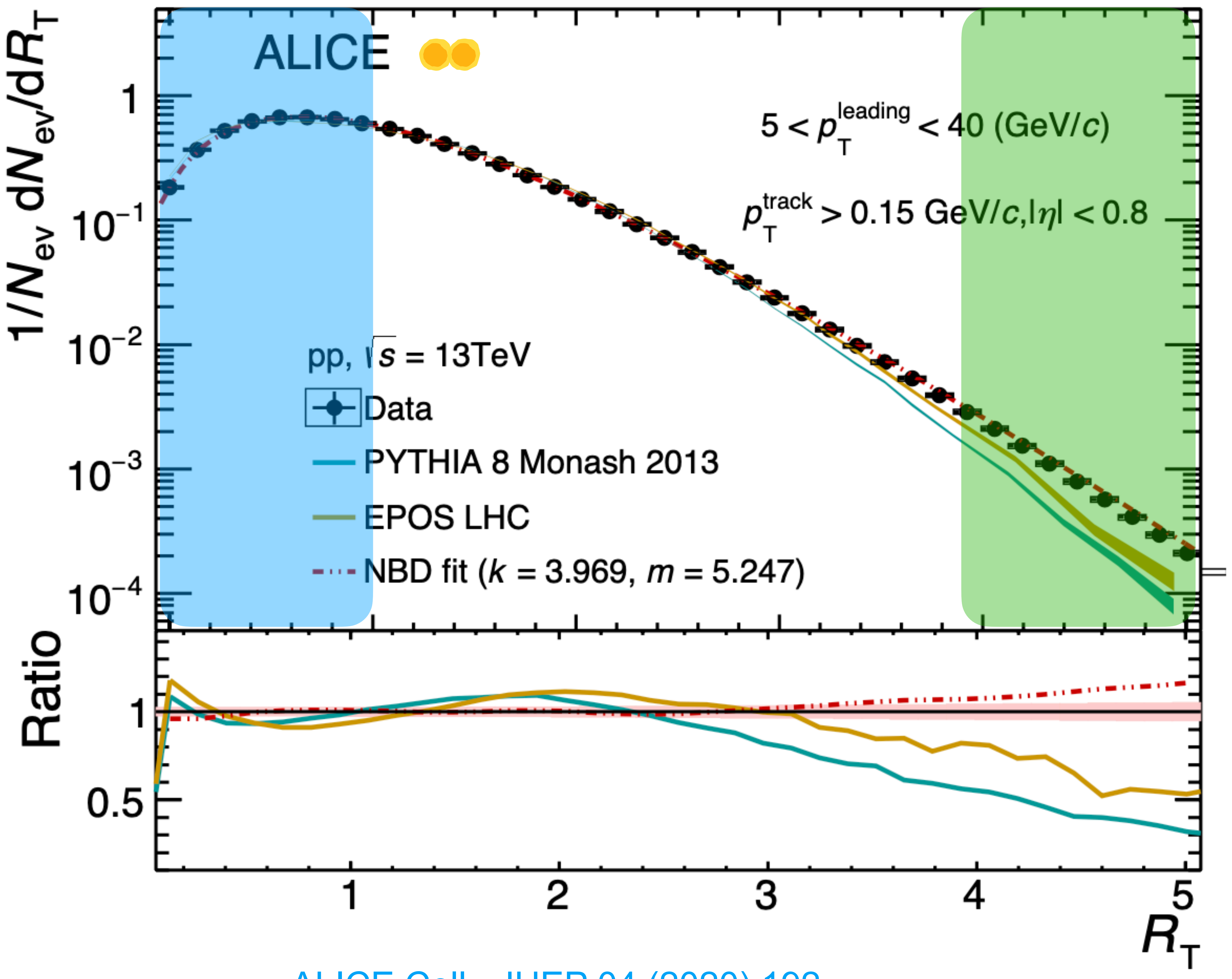
ALICE

Relative Transverse activity classifier R_T: multiplicity in the TRANSVERSE REGION (p_T>5 GeV/c) normalised to MB

➧ study particle production as a function of UE activity

low-UE (R_T~0) ➧ low N_{MPI}, jet-dominated

high-UE (high R_T) ➧ high N_{MPI}



ALICE Coll., JHEP 04 (2020) 192

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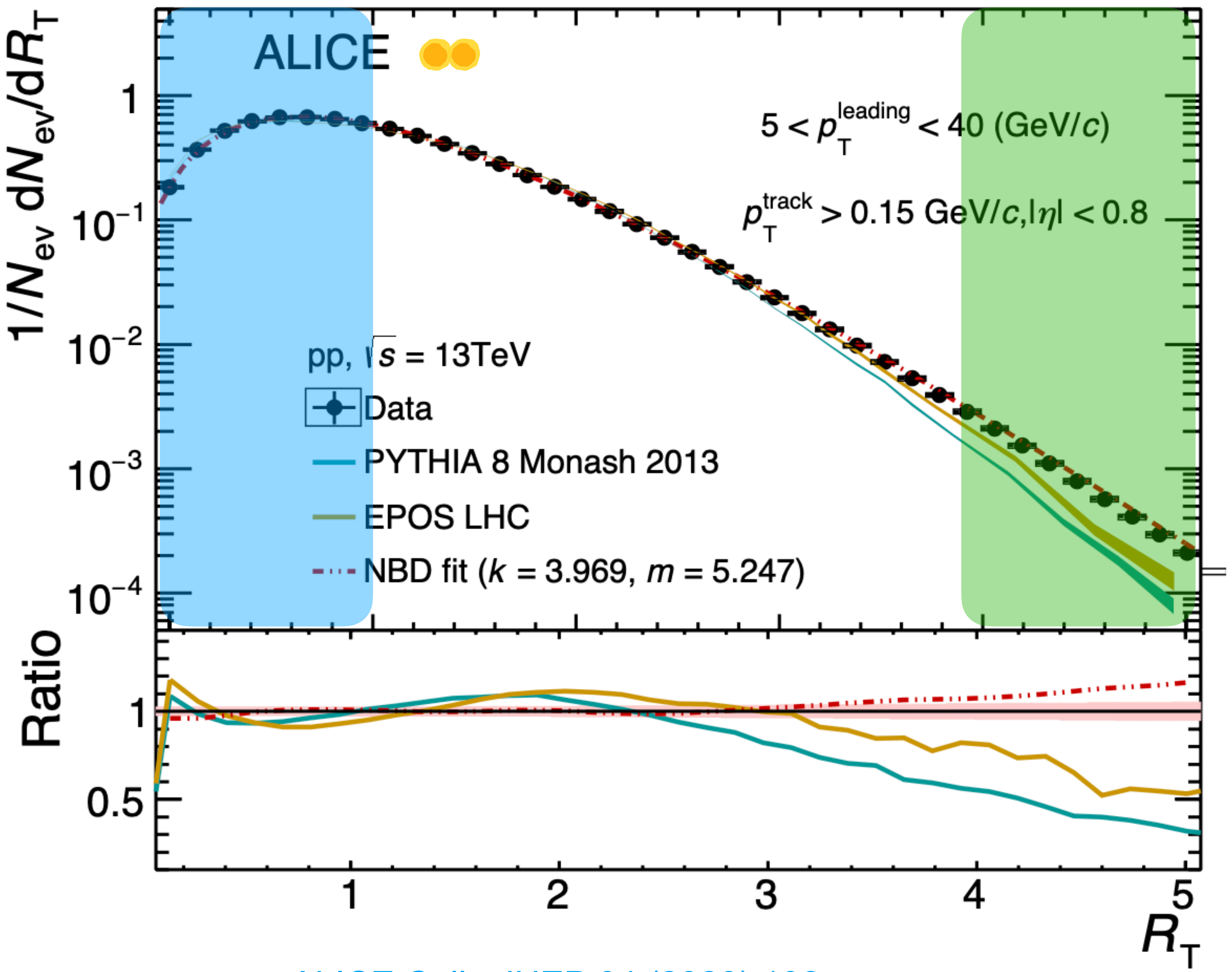
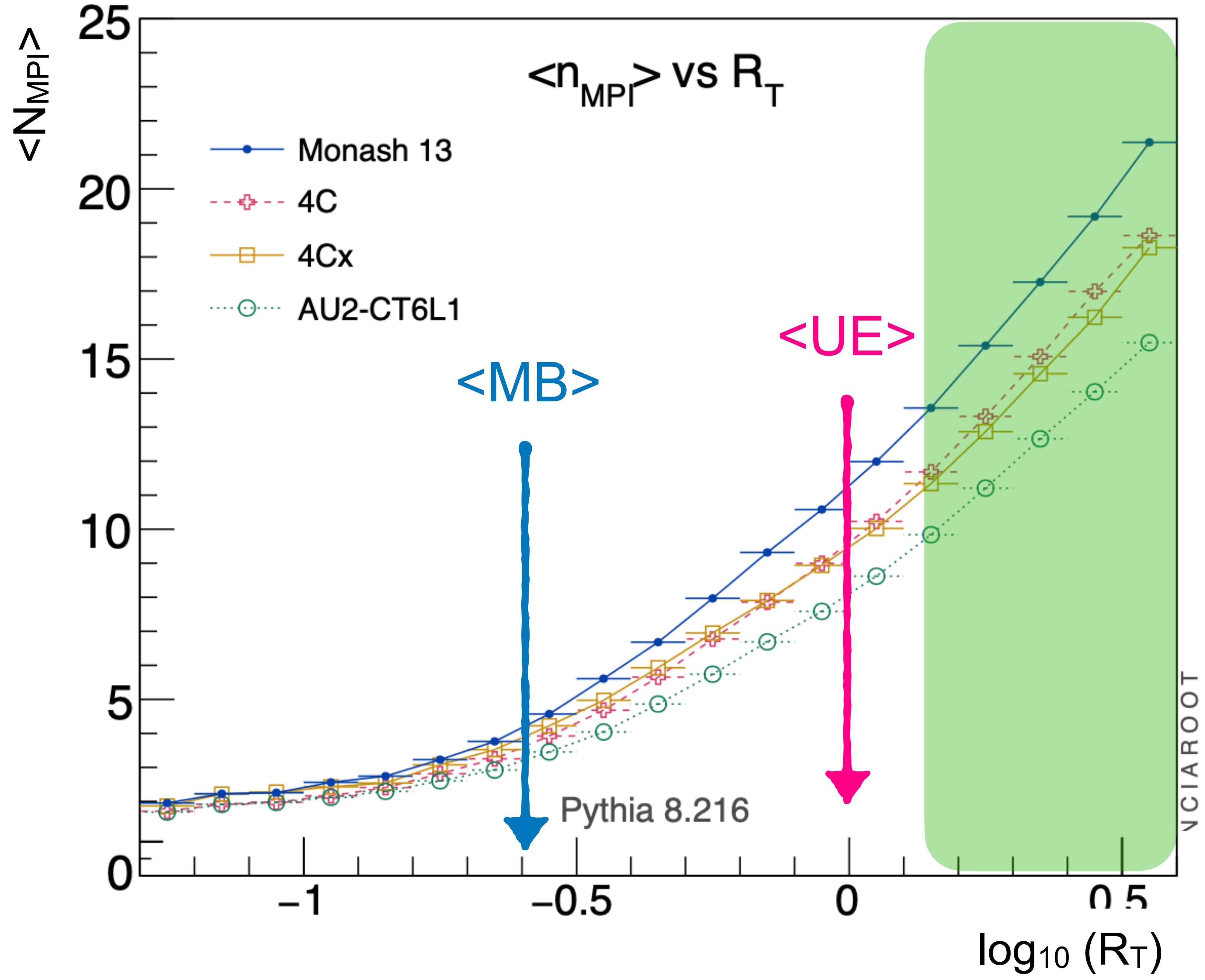
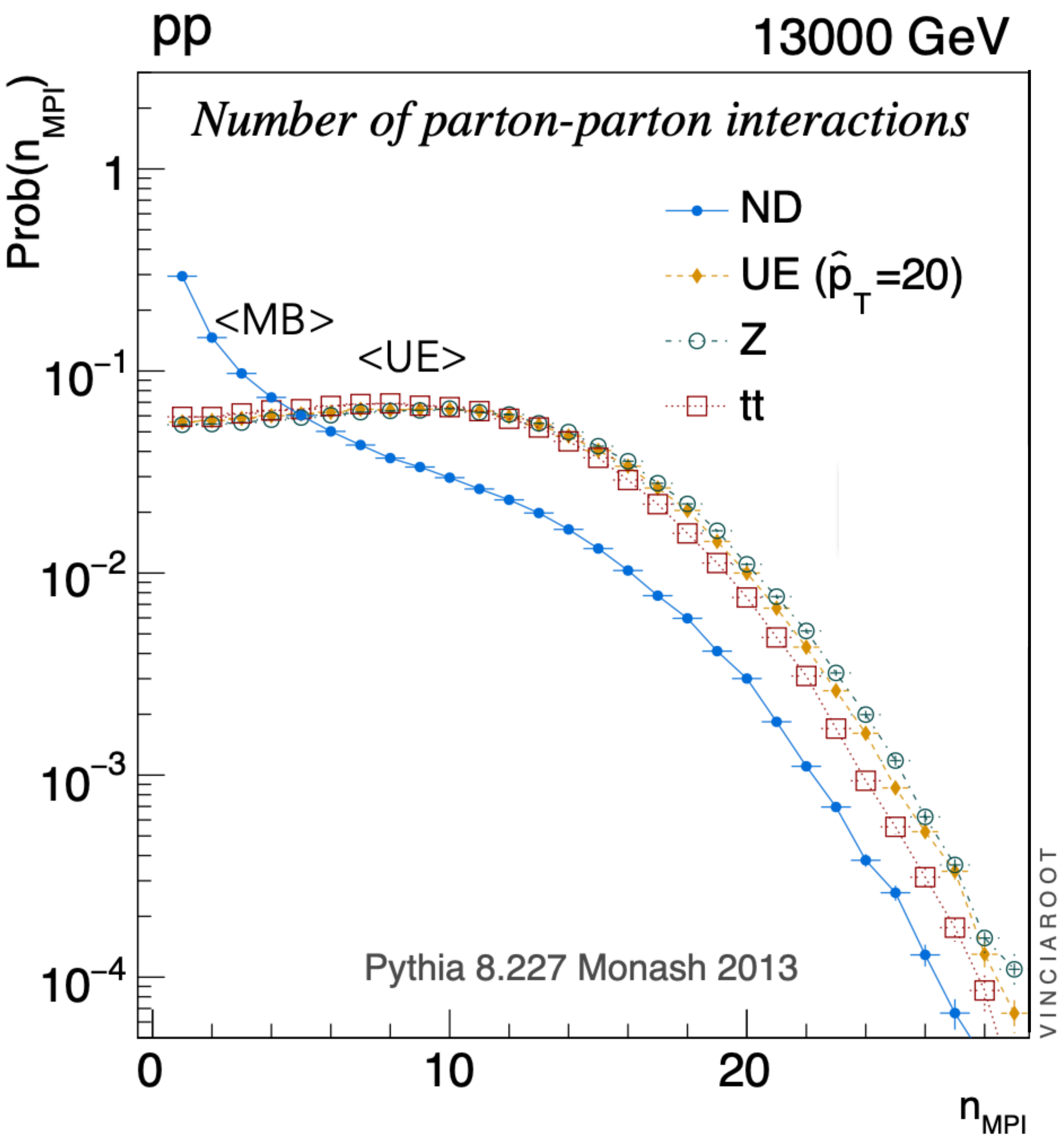


ALICE Coll., JHEP 04 (2020) 192



T. Martin et al., Eur. Phys. J. C76 5, (2016) 299

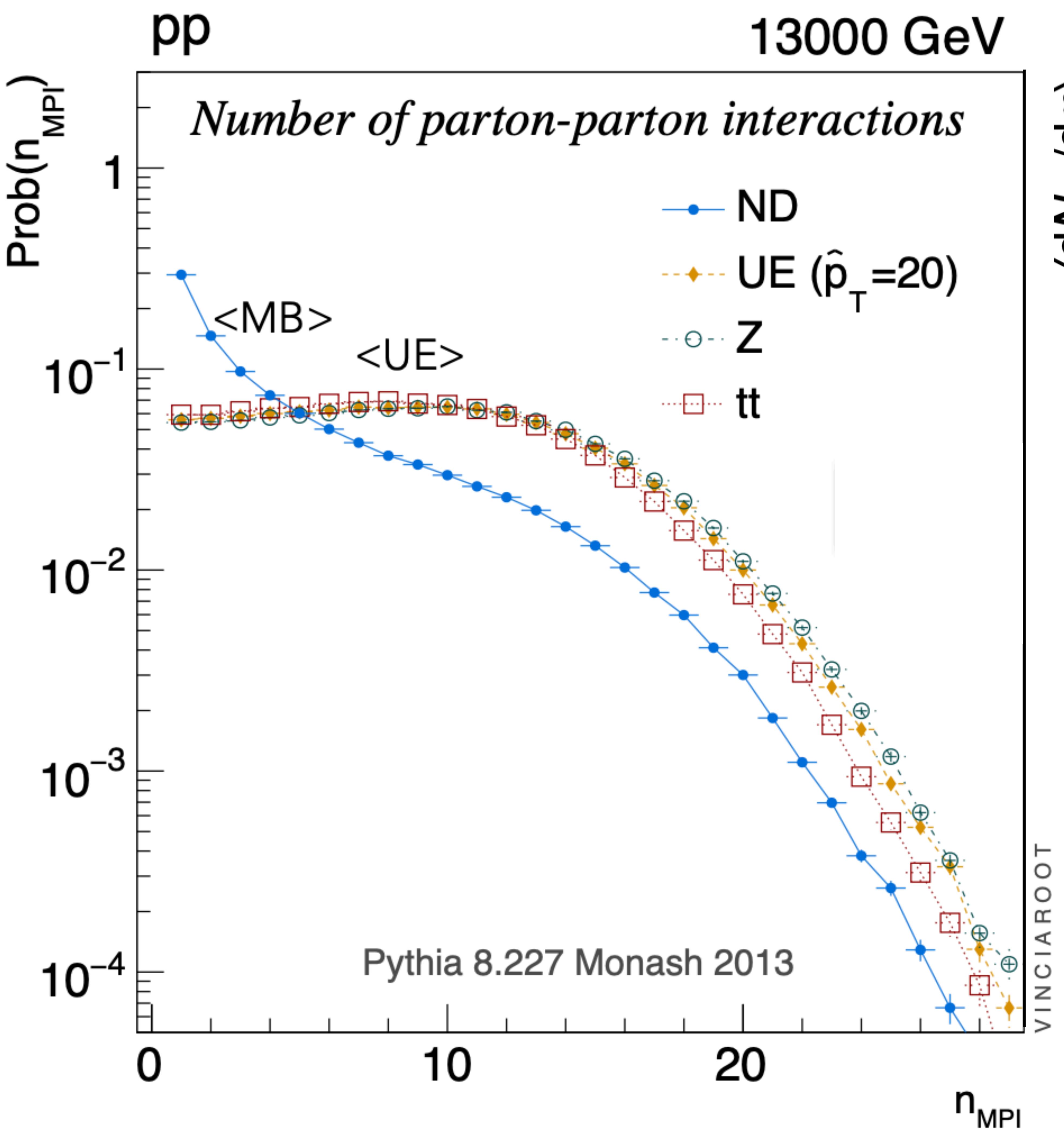
MPI & multiplicity in MB and in UE

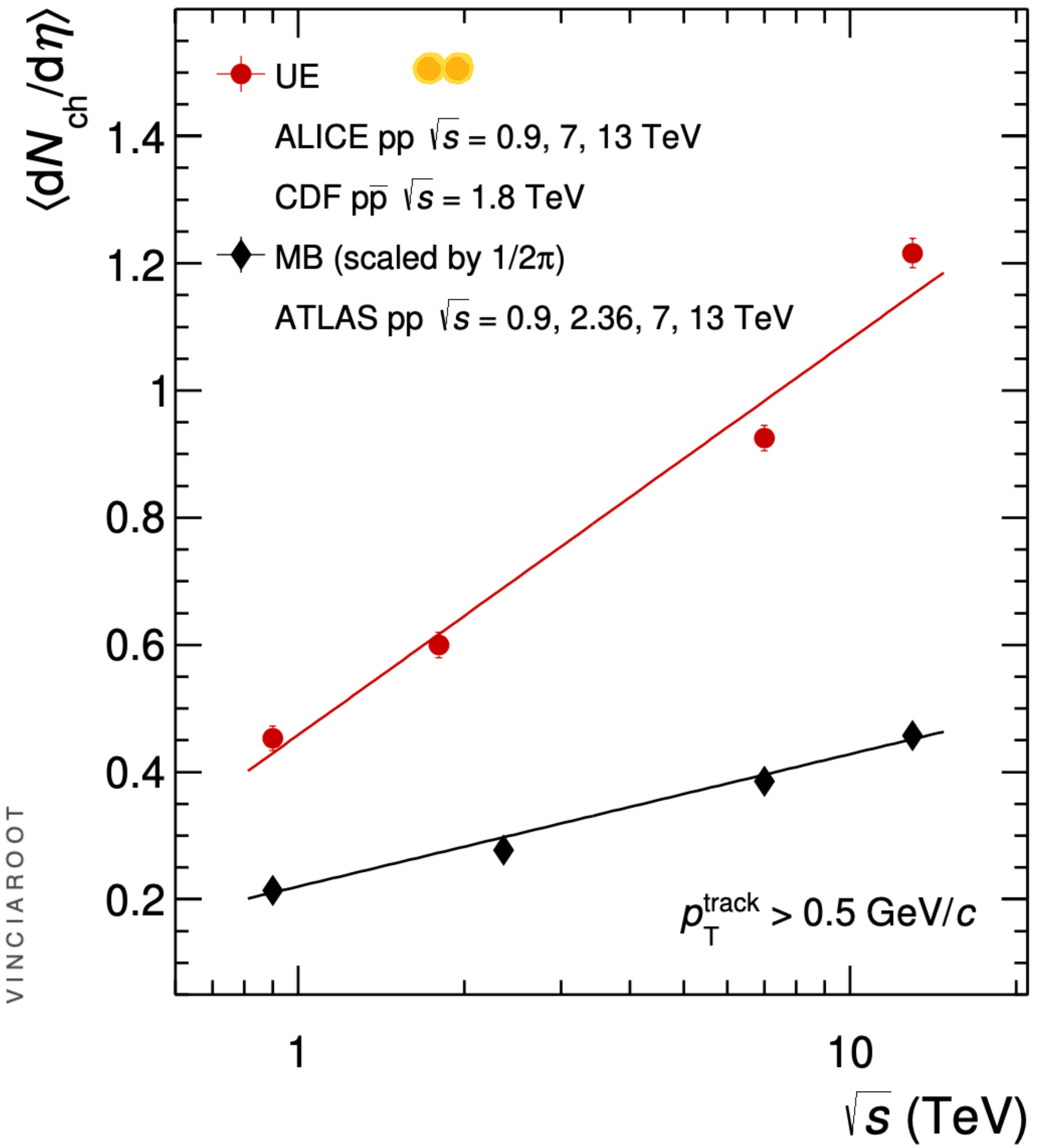


T. Martin et al., Eur. Phys. J. C76 5, (2016) 299

- UE has larger than average N_{MPI} than MB event

MPI & multiplicity in MB and in UE



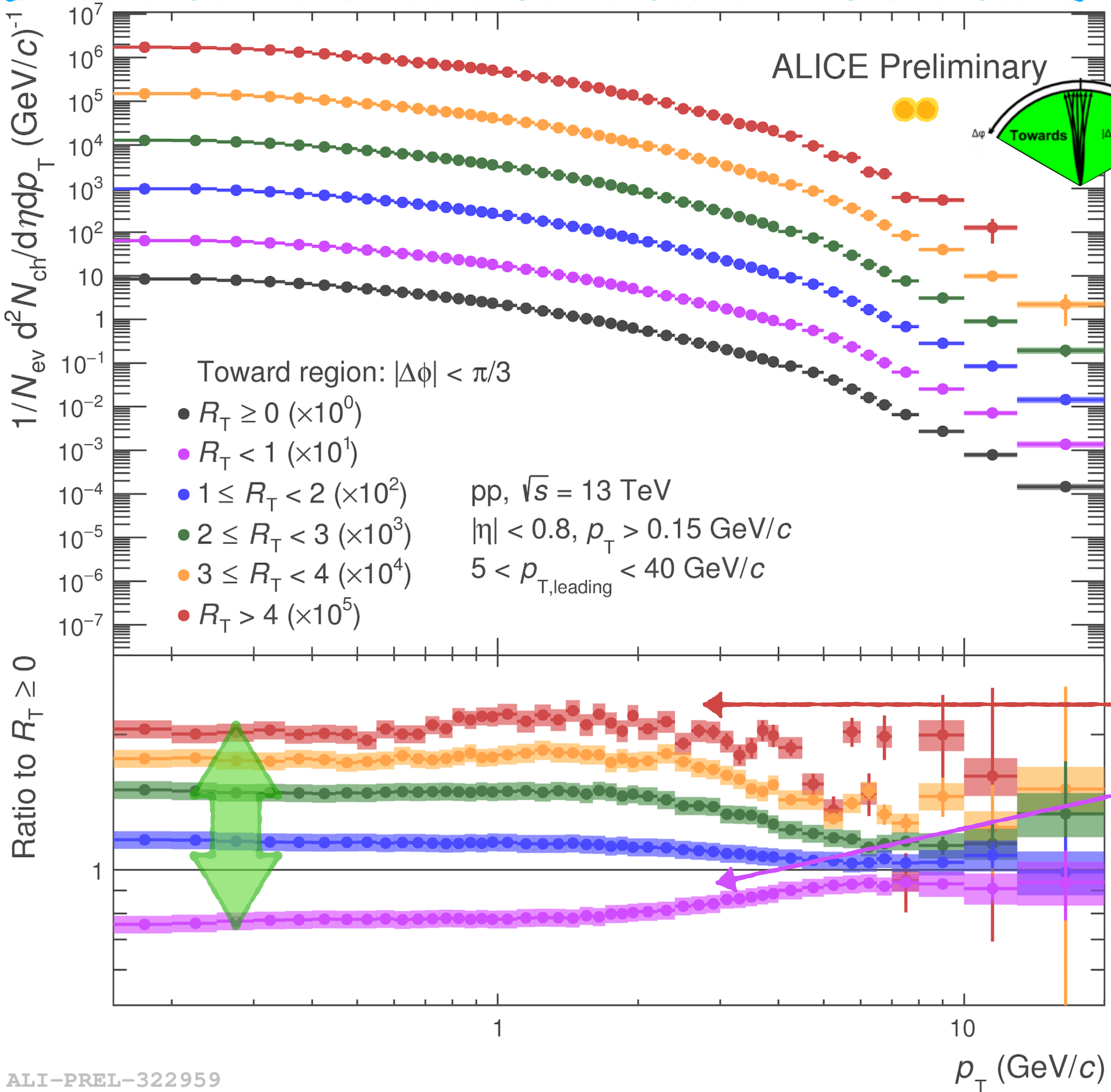


- UE has larger than average N_{MPI} than MB event
- UE multiplicity increases faster than MB multiplicity

T. Martin et al., Eur. Phys. J. C76 5, (2016) 299

ALICE Coll., JHEP 04 (2020) 192

Spectra vs. R_T in pp collisions



TOWARD SIDE

- jet fragmentation region
- soft "jet pedestal" from UE whose relevance varies with R_T
- UE has no influence on the hard part of the jet

Spectra in R_T intervals:

high UE ➧ "background" from UE to jet

low UE ➧ jet almost free from background

Spectra vs. R_T in pp collisions

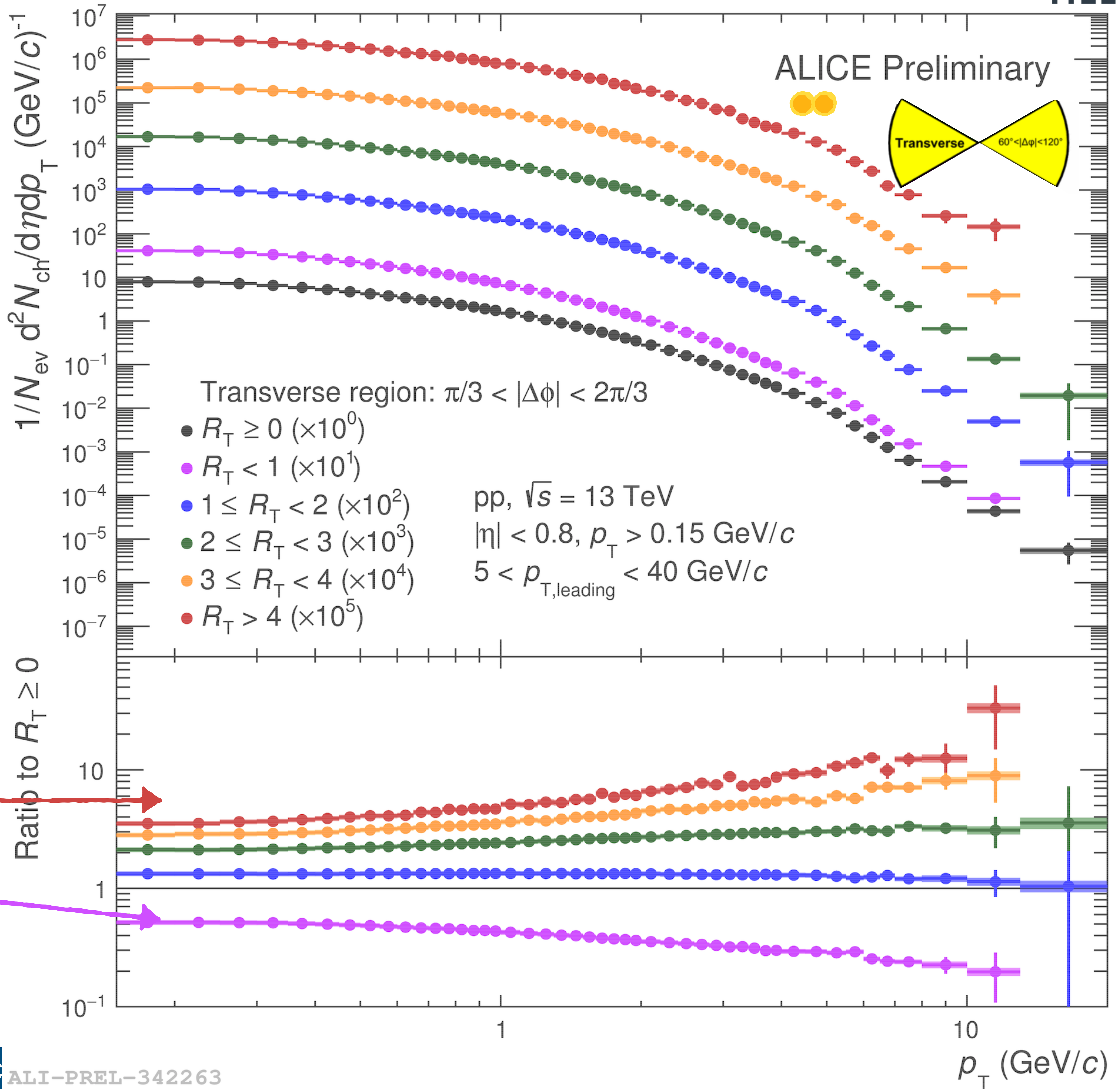
TRANSVERSE SIDE

- UE region
- $\langle p_T \rangle$ increases with UE (and with MB)

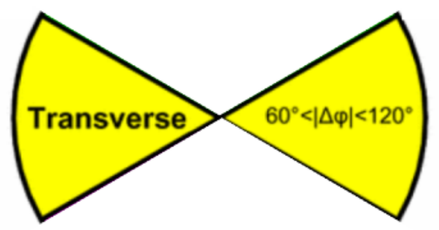
Spectra in R_T intervals:

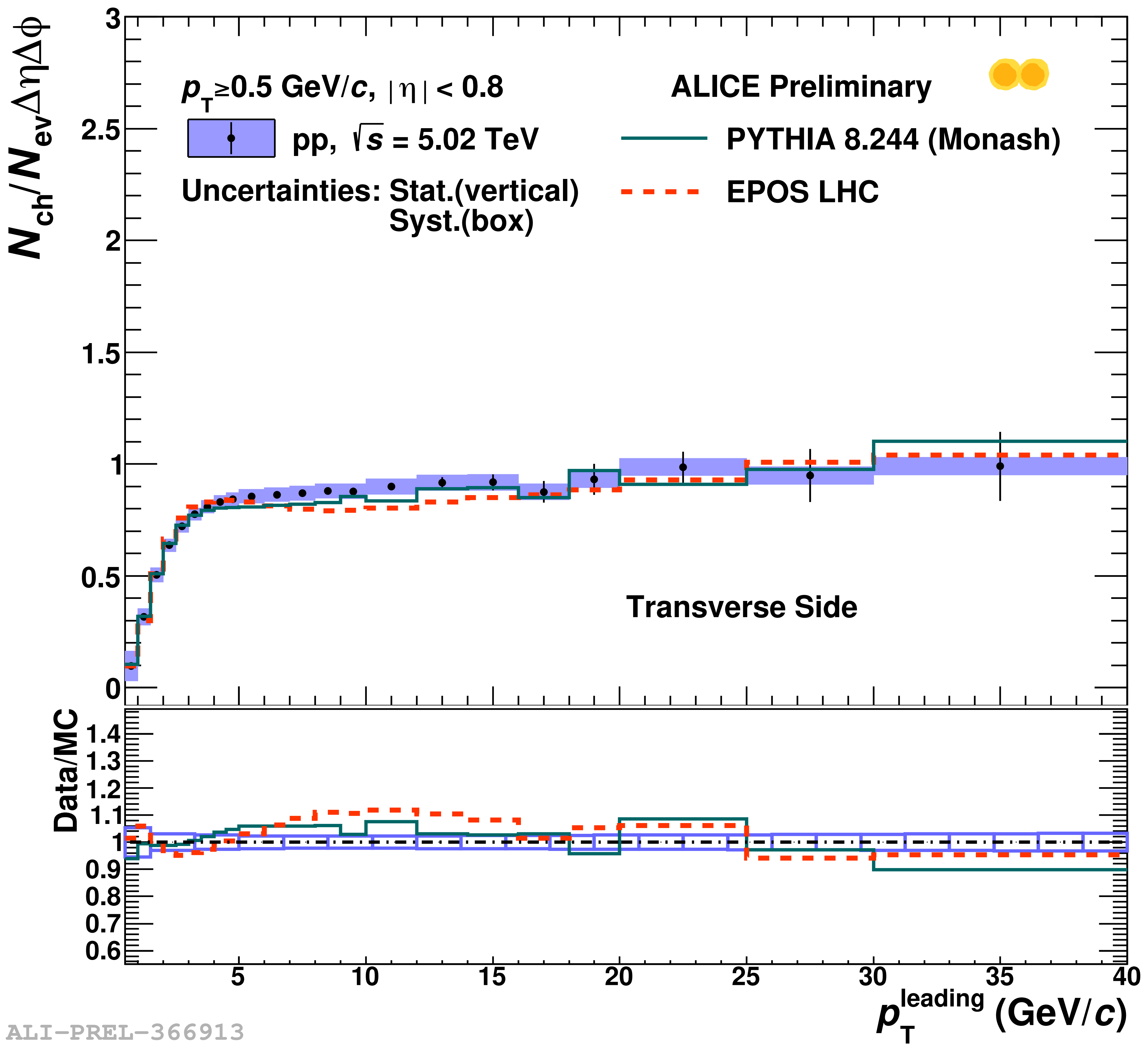
high UE ➧ harder spectra

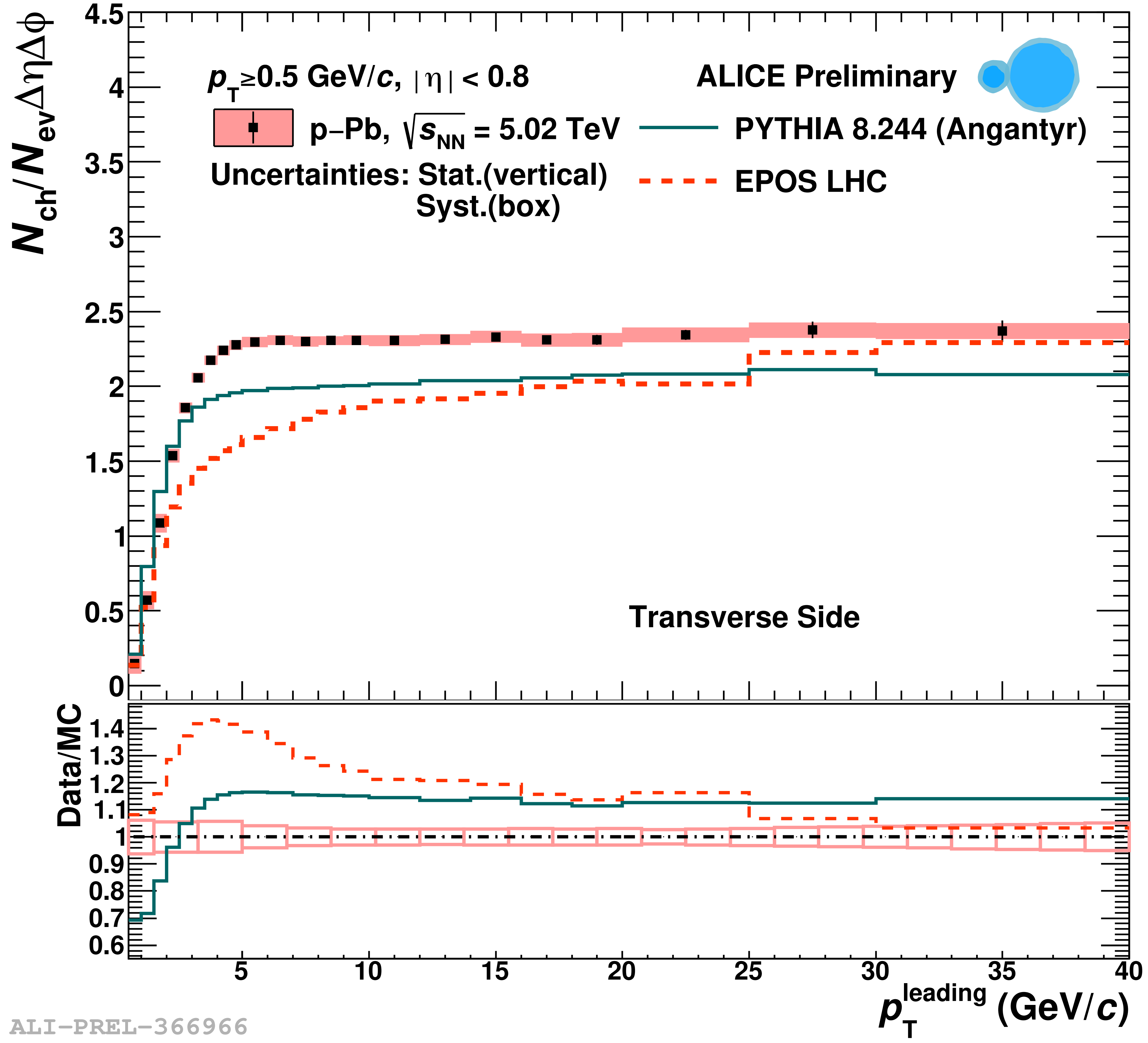
low UE ➧ softer spectra



UE in larger colliding system

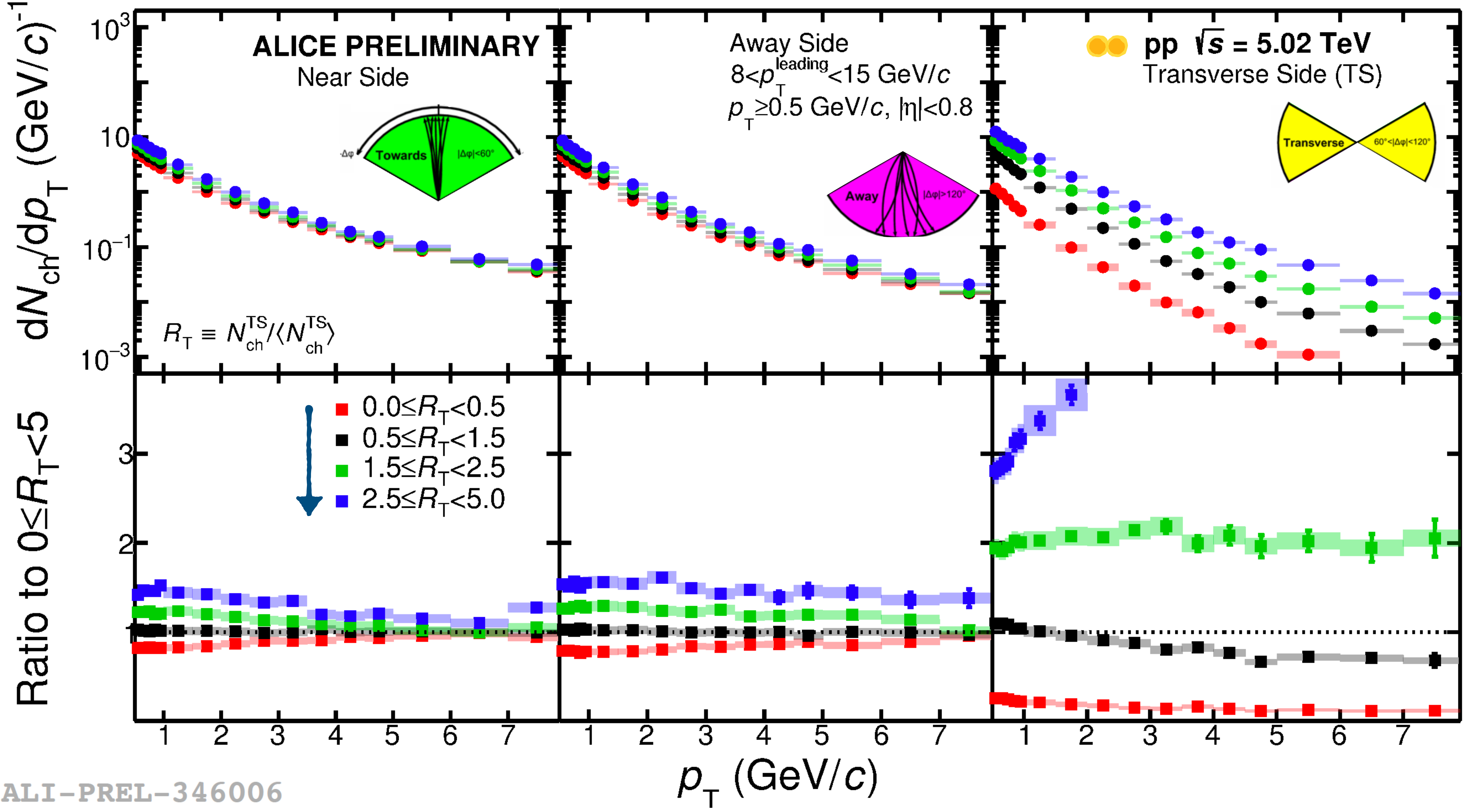






- UE plateau observed also in p-Pb collisions
- larger UE magnitude in p-Pb collisions
- models able to describe the UE in pp collisions are not reproducing p-Pb results

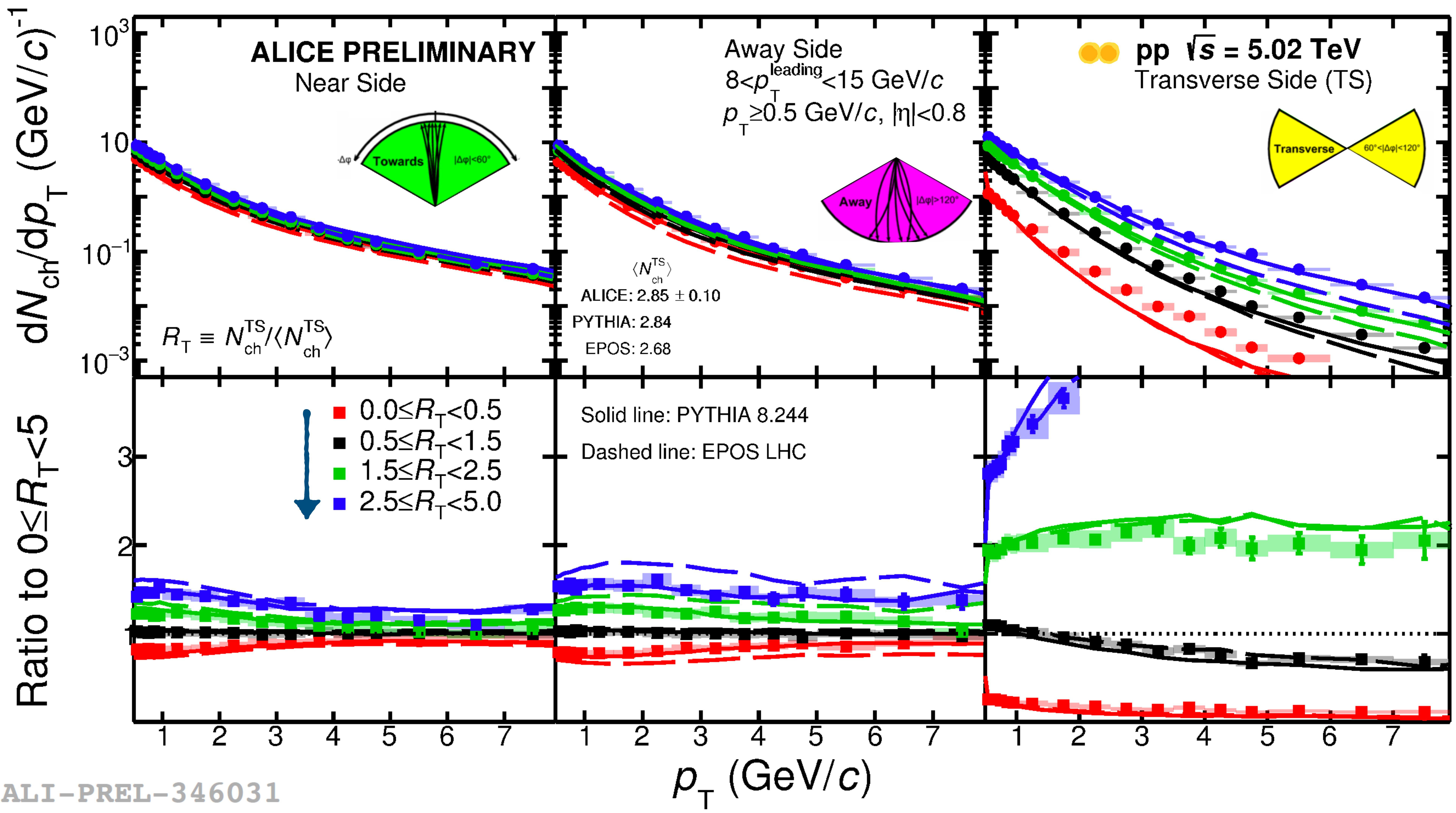
Spectra vs. R_T in pp collisions



TRANSVERSE REGION

➧ hardening of p_T spectra with increasing R_T

Spectra vs. R_T in pp collisions



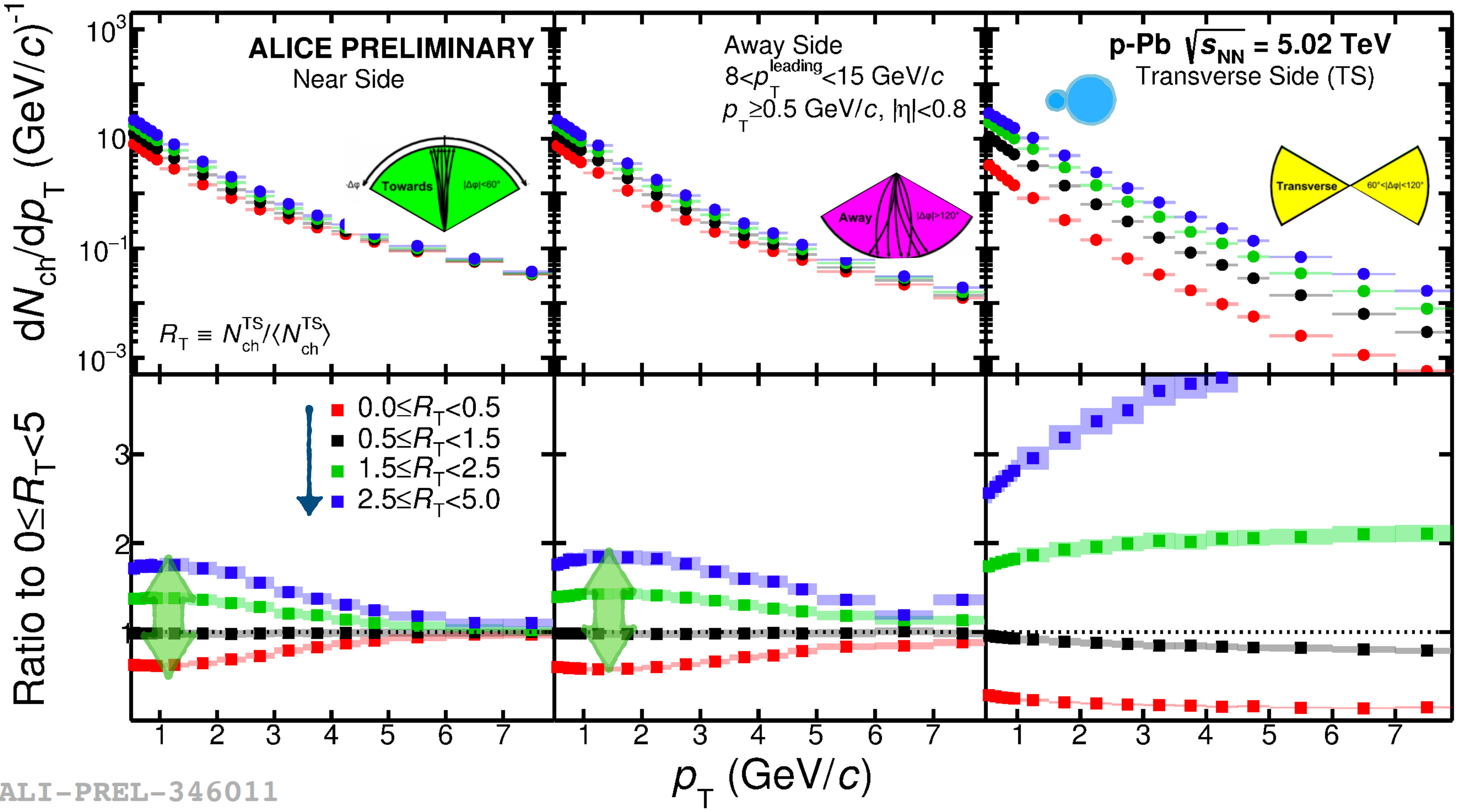
TRANSVERSE REGION

➧ hardening of p_T spectra with increasing R_T

high-UE ➧ PYTHIA gives reasonable description of data (MPI and CR modelling)

low-UE ➧ activity PYTHIA and EPOS predictions are softer than data

Spectra vs. R_T in p-Pb collisions



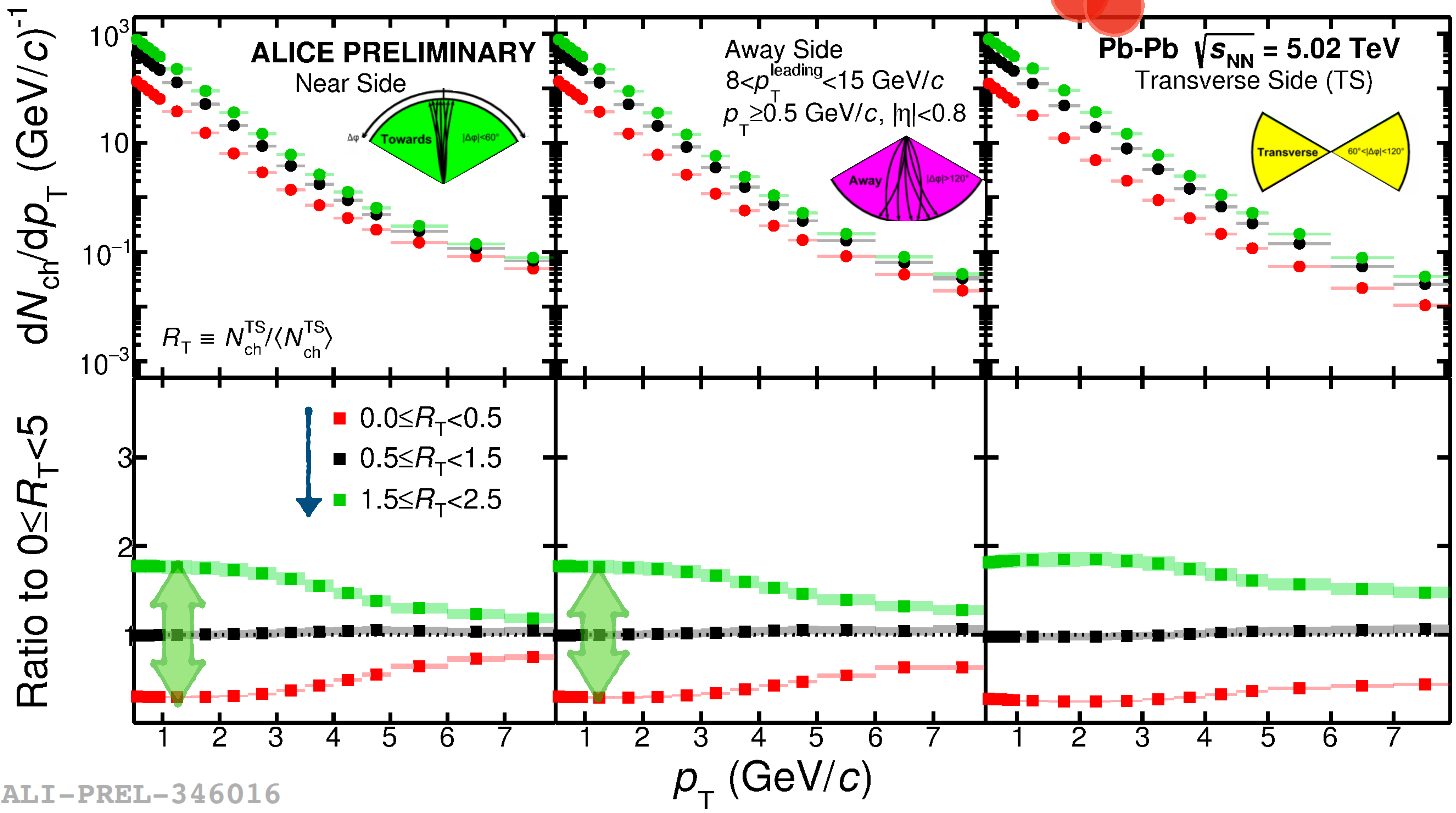
TRANSVERSE REGION

- hardening of p_T spectra with increasing R_T
- softer rise relative to pp

TOWARD AWAY SIDES

- UE contribution more important than in pp collisions

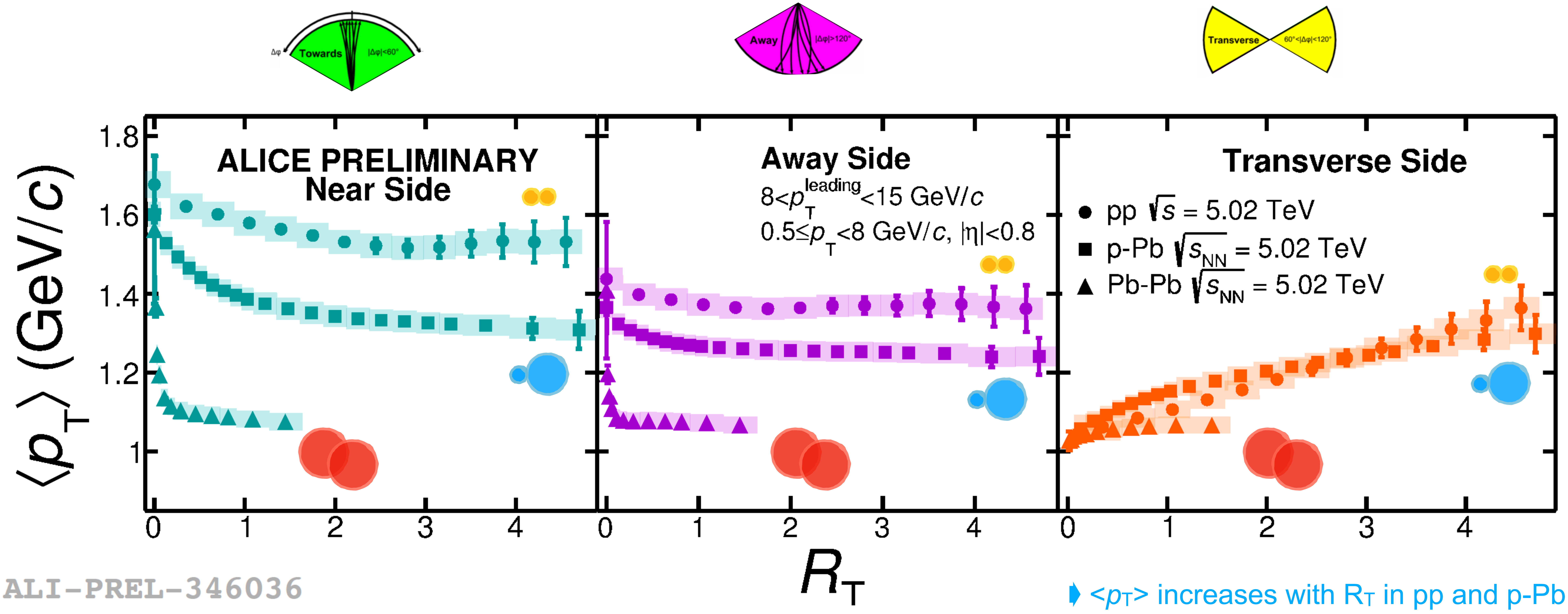
Spectra vs. R_T in Pb-Pb collisions



TRANSVERSE REGION

- similar behaviours in the 3 regions
- R_T is dominated by soft production

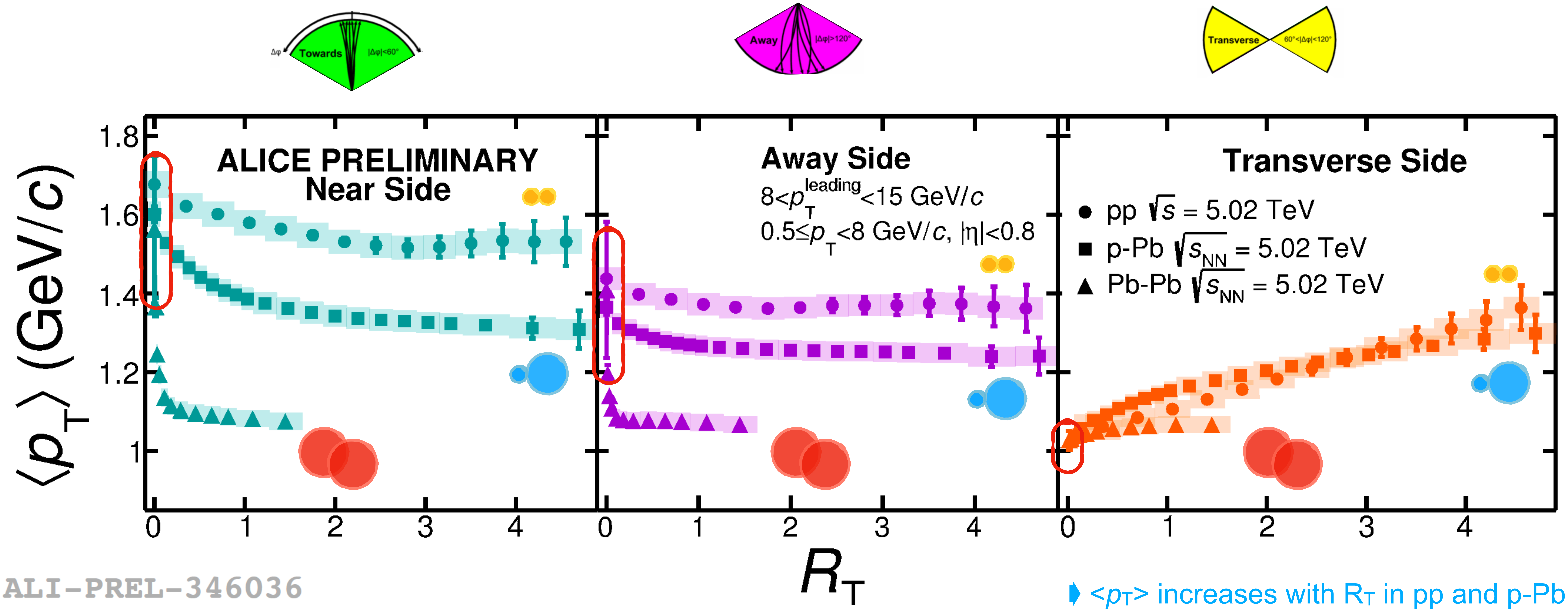
<p_T> vs. R_T



ALI-PREL-346036

<p_T> increases with R_T in pp and p-Pb, it is ~ constant in Pb-Pb collisions

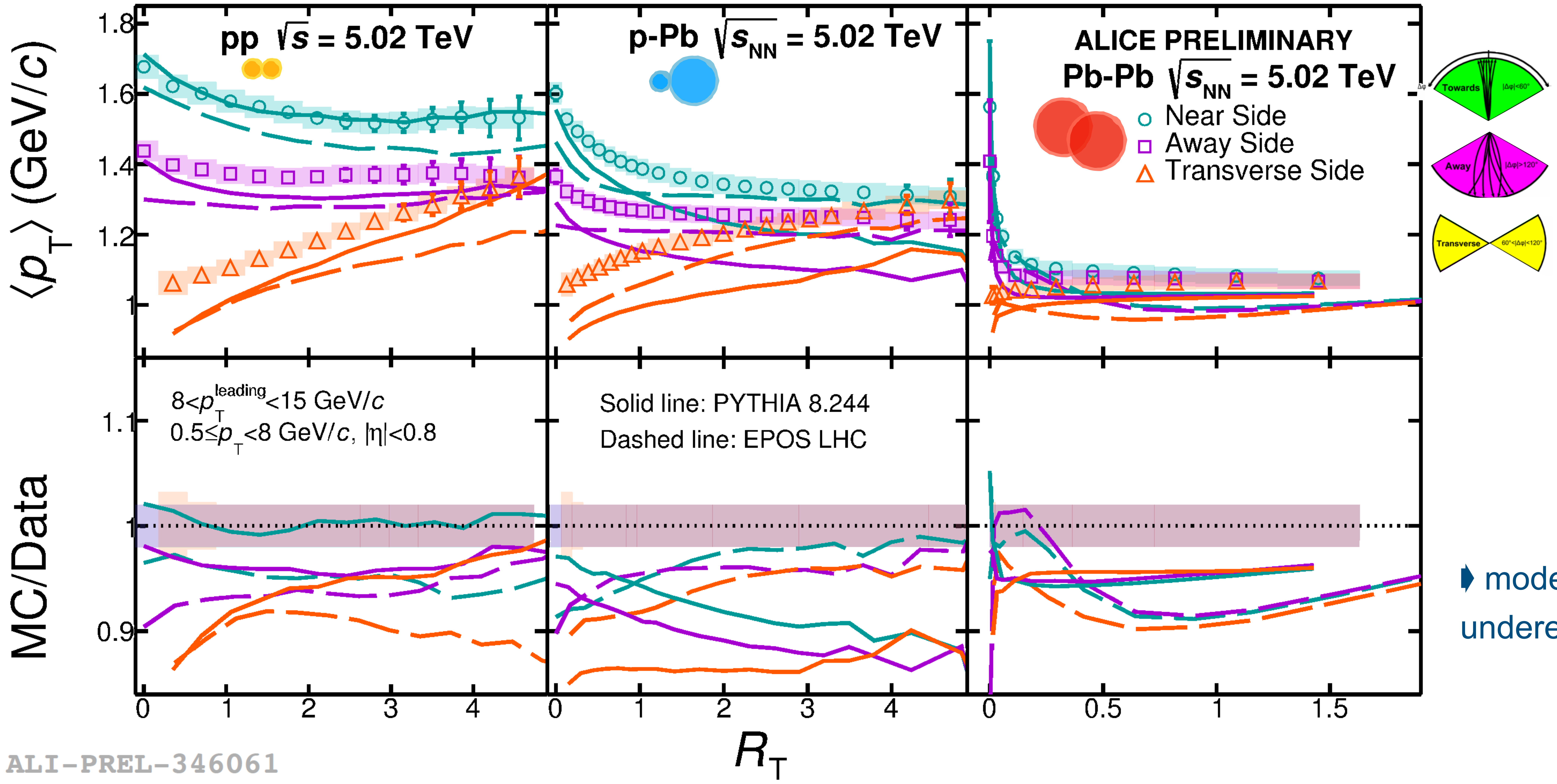
$\langle p_T \rangle$ vs. R_T



➧ $\langle p_T \rangle$ increases with R_T in pp and p-Pb, it is ~ constant in Pb-Pb collisions

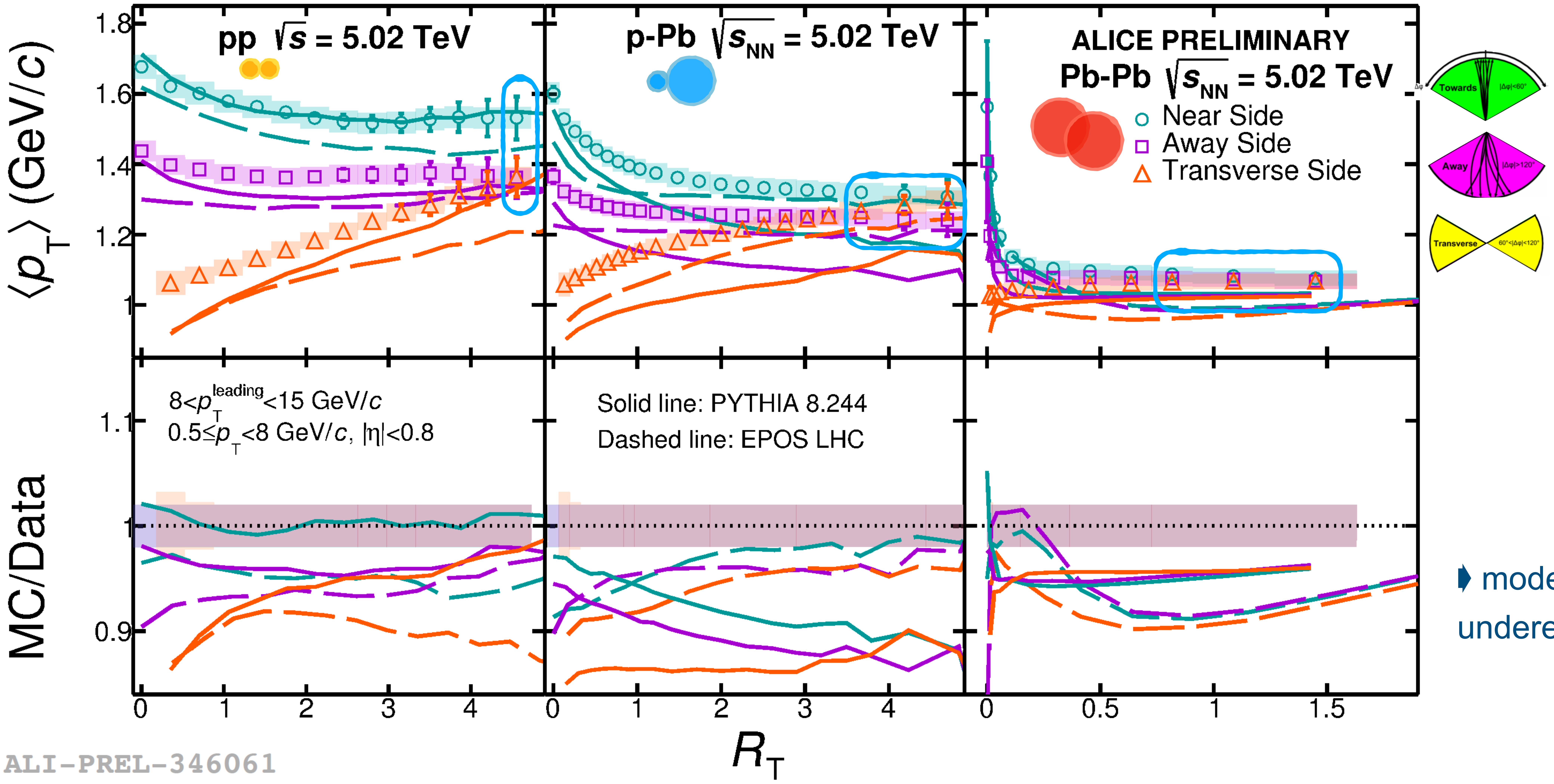
$R_T \rightarrow 0$ ➧ jet contribution dominates ➧ similar $\langle p_T \rangle$ values across different colliding systems

<p_T> vs. R_T



- models tend to underestimate <p_T>

<p_T> vs. R_T



➧ models tend to underestimate <p_T>

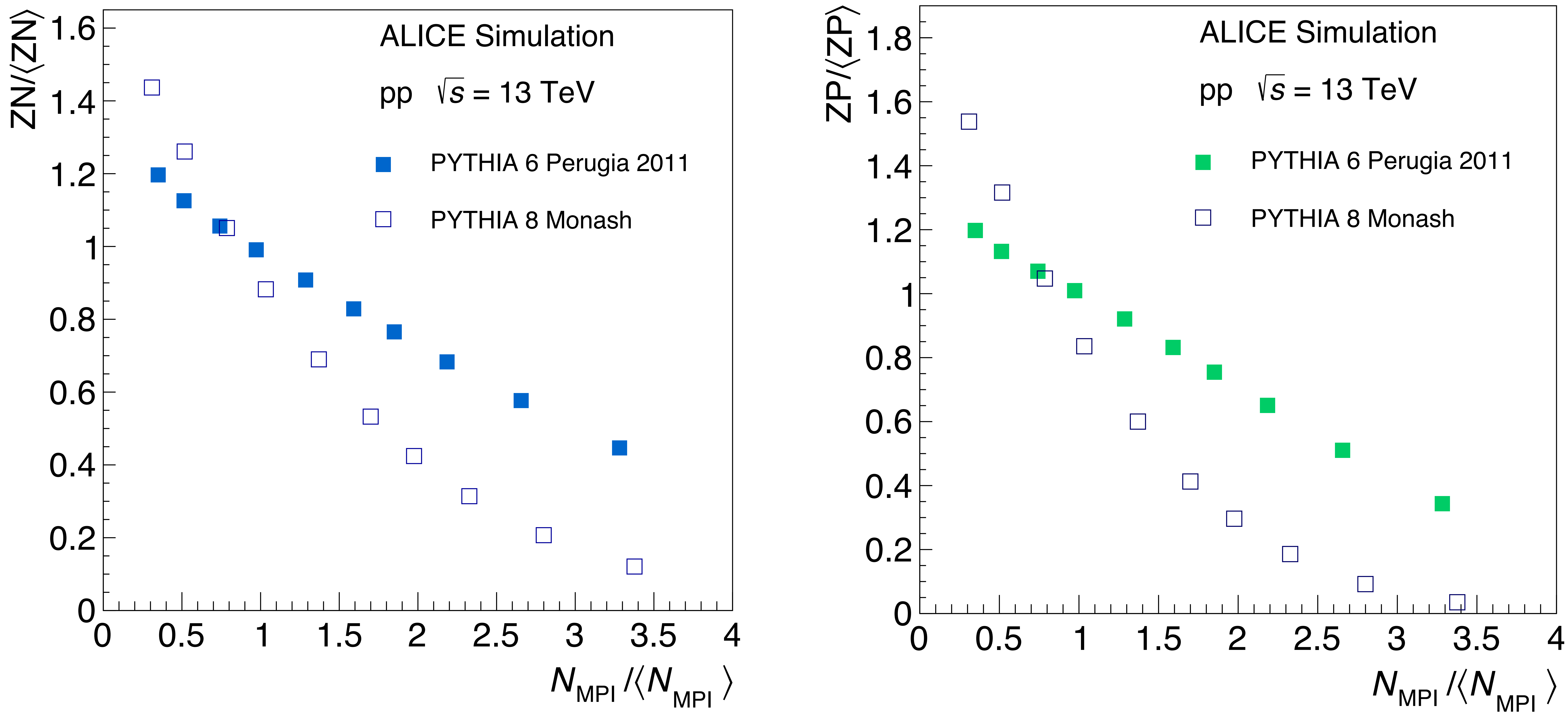
high R_T ➧ UE dominates ➧ similar <p_T> values in the 3 topological regions for each colliding system

Very forward energy vs. mid rapidity activity

ZDC energy vs. MPI in pp collisions

ALICE Coll., arXiv 2107.10757

A zero-degree calorimeter for neutrons (ZN) and one for protons (ZP) ➧ beam remnants

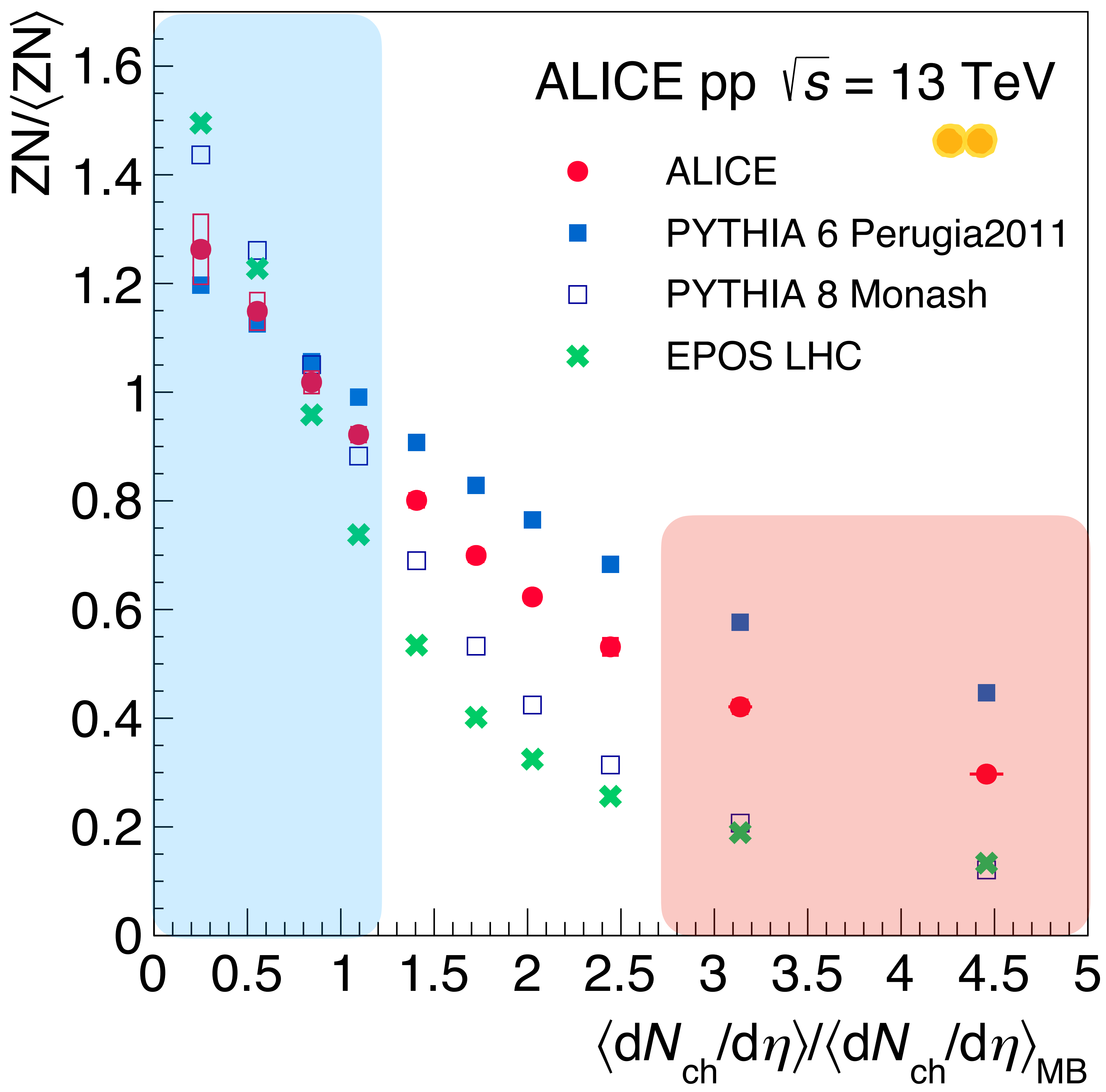


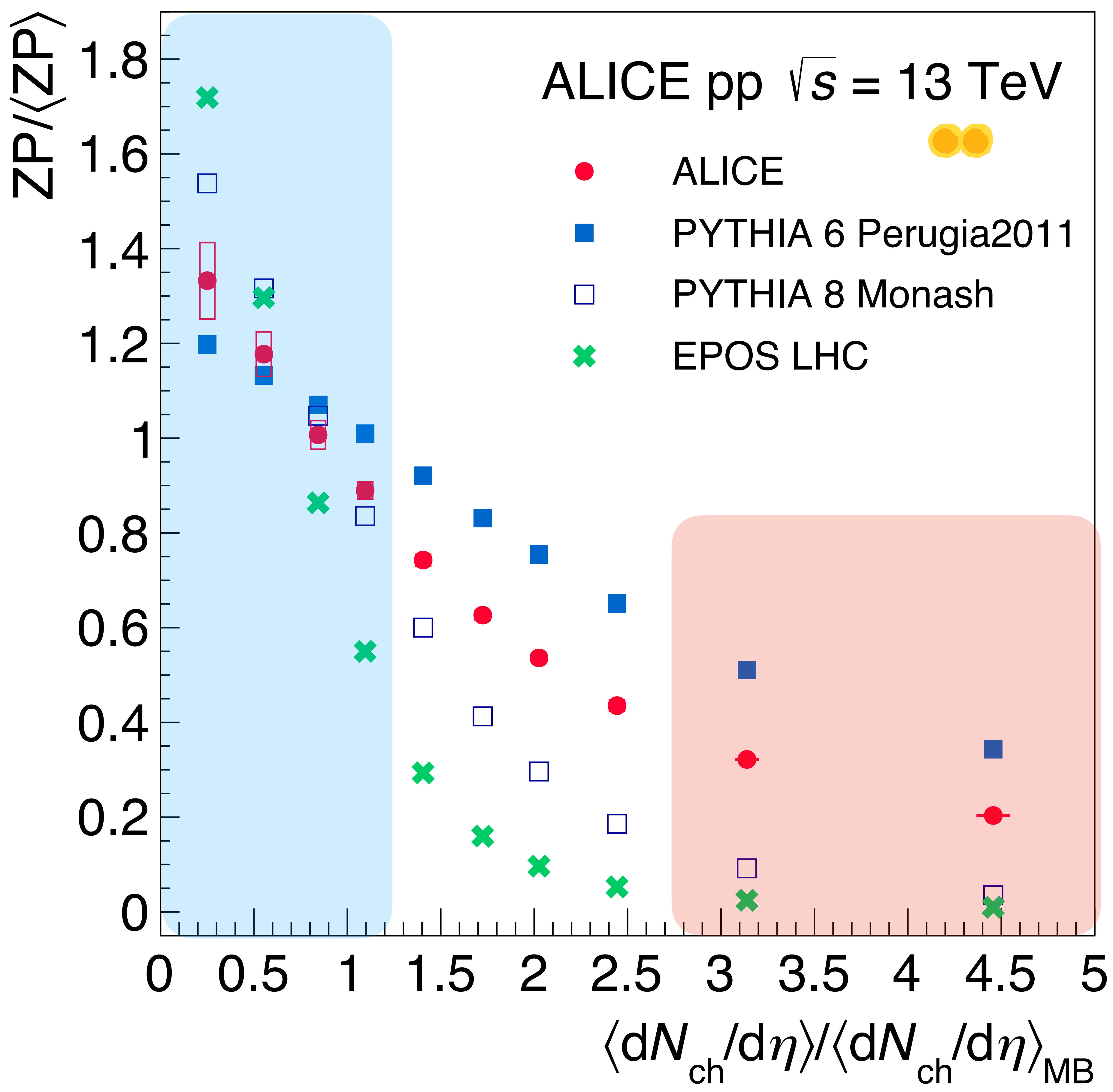
➧ PYTHIA models predict inverse dependence of very forward energy as a function of the number of N_{MPI}

ZDC energy vs. midrapidity multiplicity

ALICE Coll., arXiv 2107.10757

- characterise midrapidity particle production vs. ZDC energy





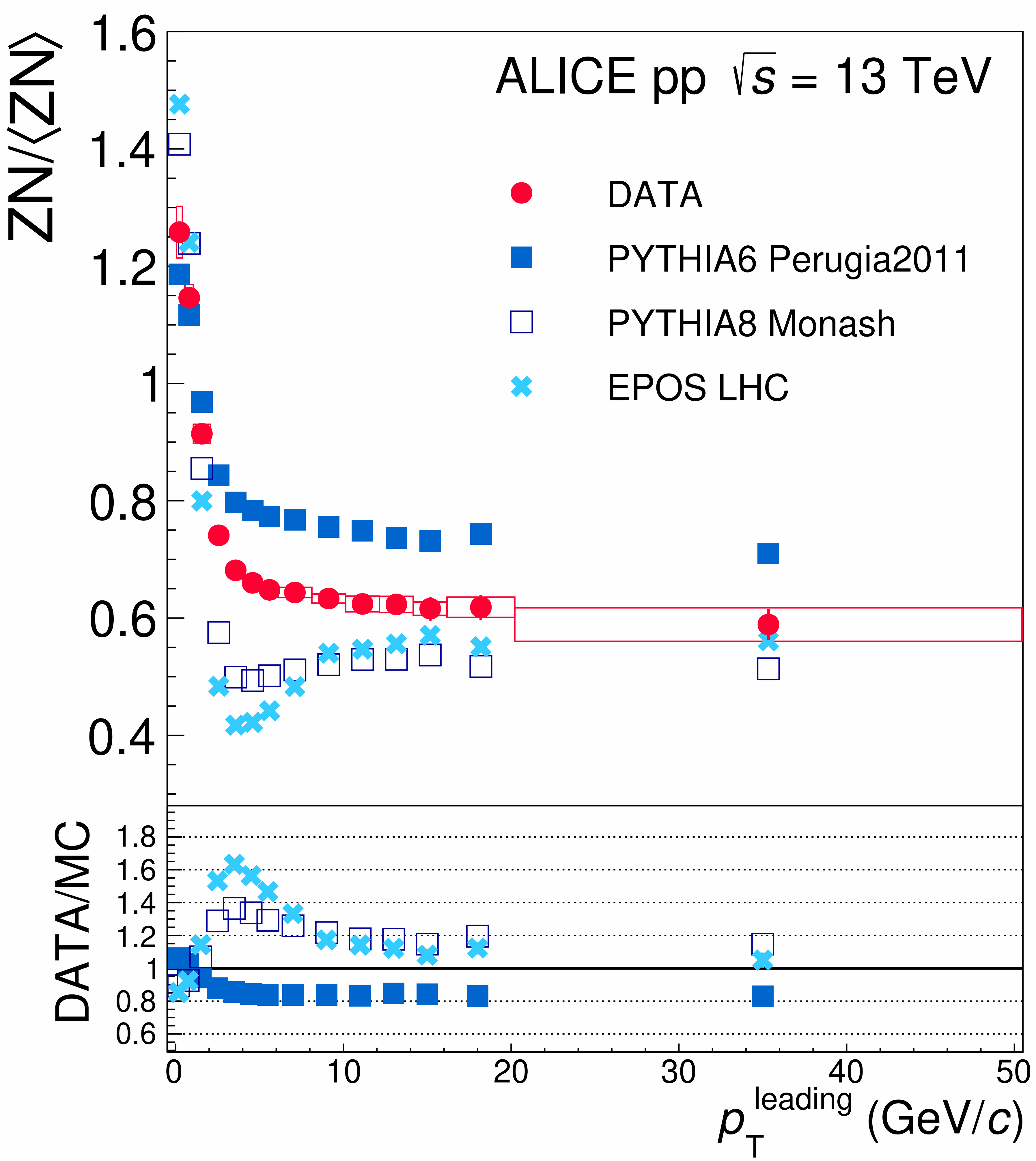
- lower N_{MPI}
- higher N_{MPI}

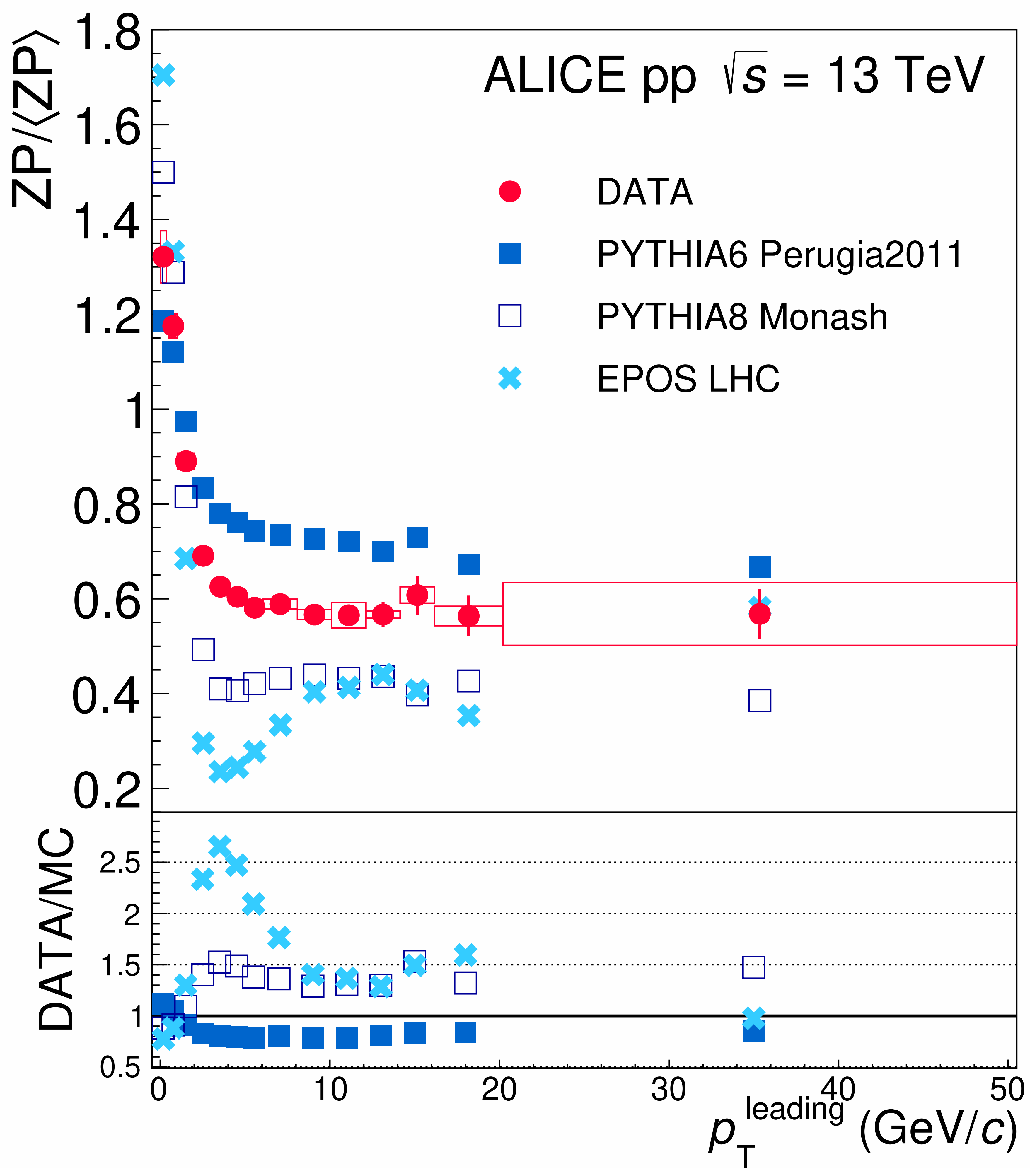
Models are able to describe the overall trend, PYTHIA 6 Perugia 2011 is the one showing a better agreement

However, models reproduce the trend for average values but do not describe ZN and ZP spectra in multiplicity bins

ZDC energy vs. midrapidity leading p_T

ZDC energy as a function of $p_T^{leading}$ (track with largest transverse momentum) in $|\eta| < 0.8$





For leading $p_T > 5$ GeV/c very forward neutron and proton energies, normalised to MB value, do not decrease anymore (saturation)

ZDC energy and UE

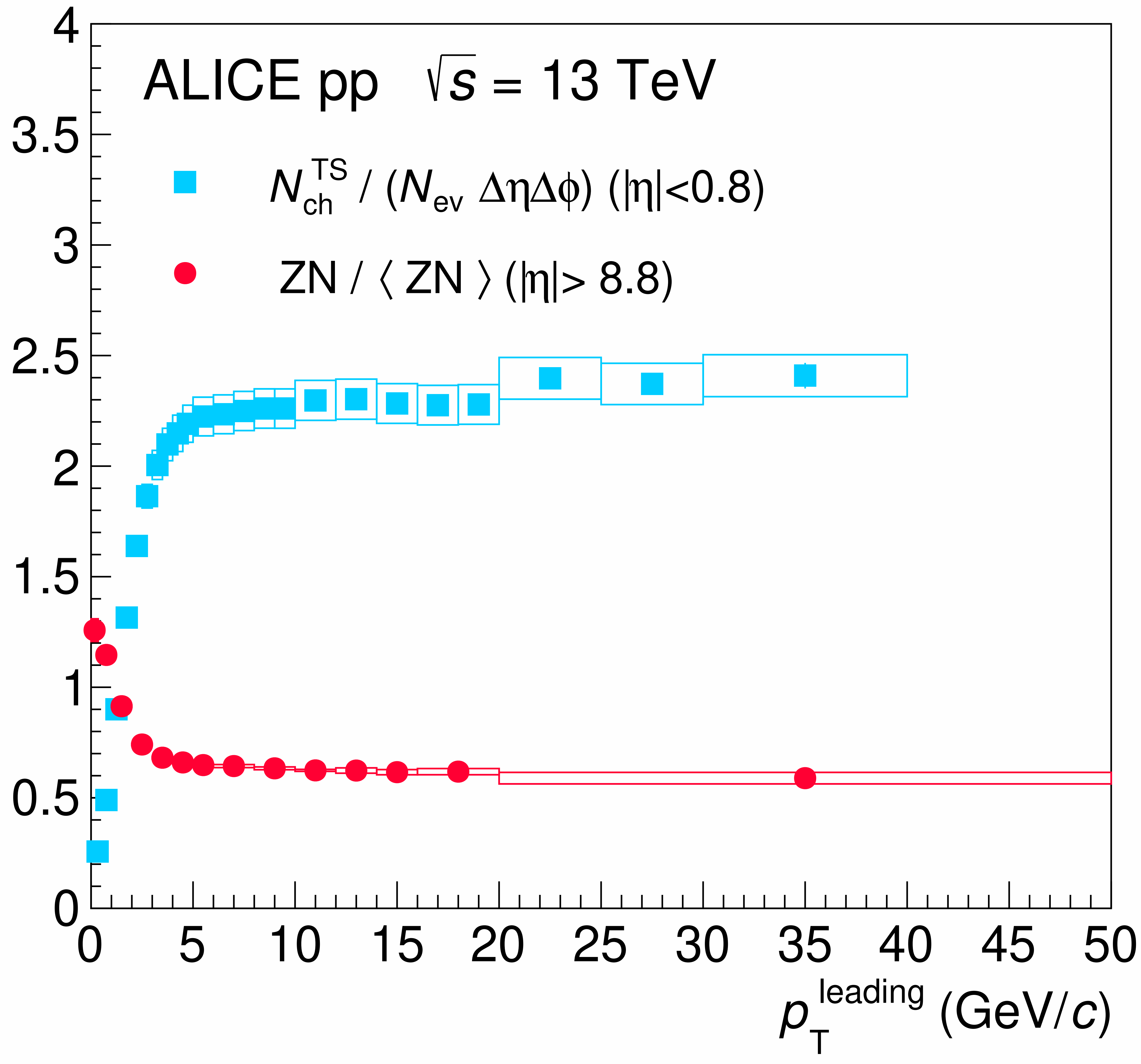
ALICE Coll., arXiv 2107.10757

UE measurements ➧ the transverse multiplicity (separation in azimuthal angle) efficiently trigger on central pp collisions selecting events with a large number of MPIs

ZDC energy (separation in rapidity) shows a complementary behaviour to that observed for transverse charged particle multiplicity

➧ both observables saturate for leading p_T > 5 GeV/c

➧ saturation in transverse region at midrapidity and in very forward energy is built in the initial stages of the collision



Small energy at very forward rapidities and large UE activity select:

- ➧ larger than average N_{MPI}
- ➧ higher than average multiplicity
- ➧ high-p_T particle at midrapidity

Outlook & perspectives

Many observables and different approaches to access MPI in ALICE in the different colliding systems

➧ constraints for models

Several ongoing analyses studying the UE (R_T) dependence:

π, K, p production, strange particle and anti-deuteron production ➧ many results in a very near future!

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ALICE is ready for Run 3, with new and upgraded detectors:

- ITS: monolithic active silicon pixel sensors ➧ smaller material budget, closer to IP, improved resolution
- TPC based on GEM technology ➧ continuous readout at 50 kHz

50x faster readout rate, access to rarer probes, improved tracking resolution down to very low p_T

➧ more results and more differential studies available soon

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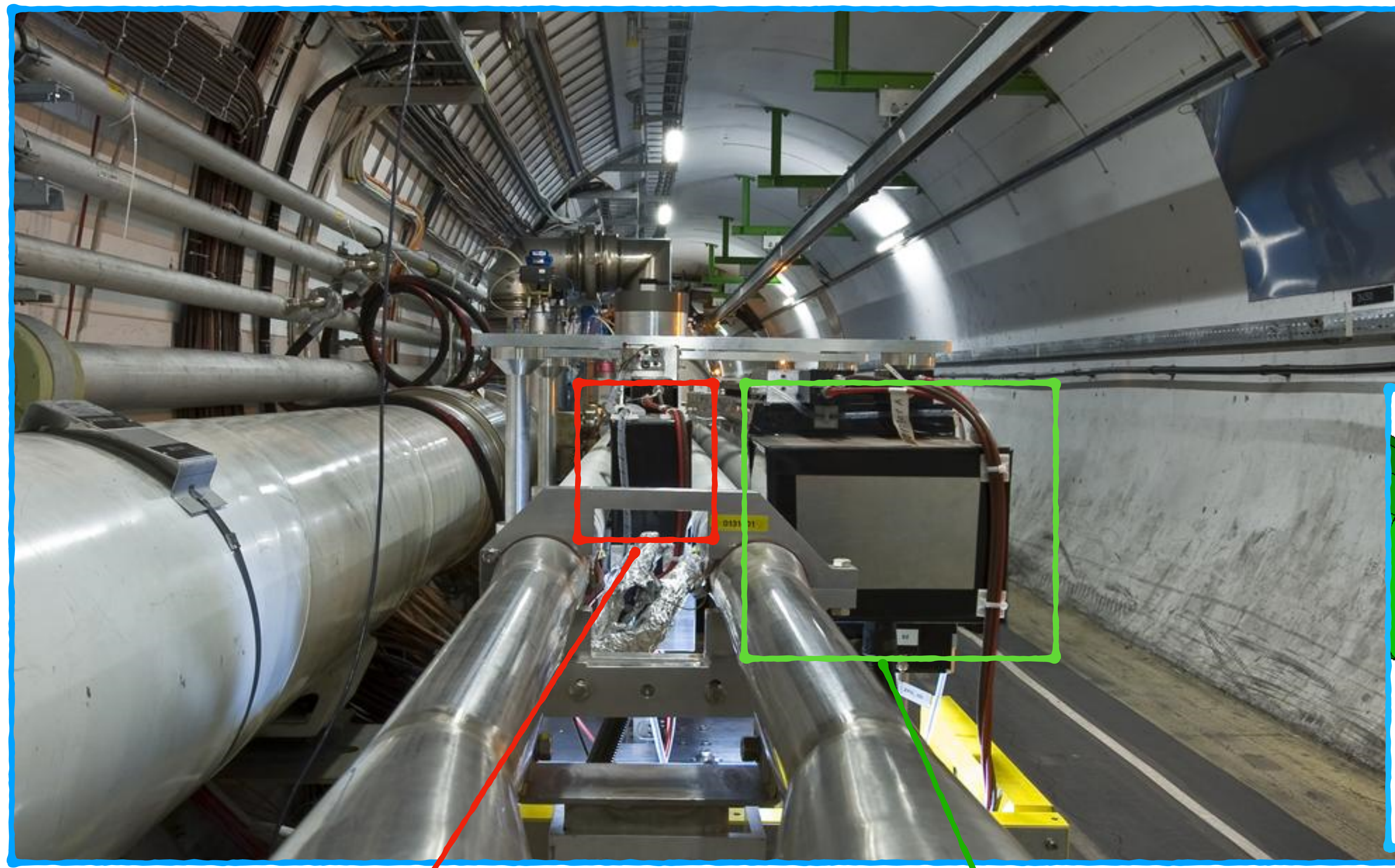
A new detector proposal (ALICE3) for LHC Run 5 is under preparation

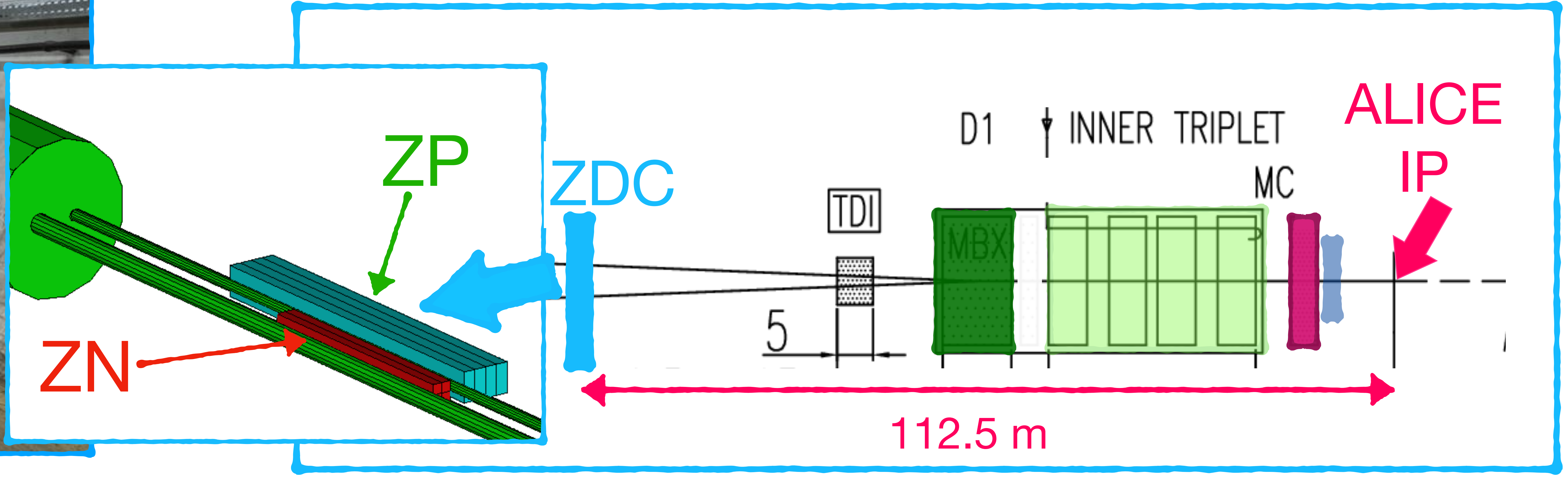
compact Si tracker with unprecendented tracking and vertexing capabilities at high rates

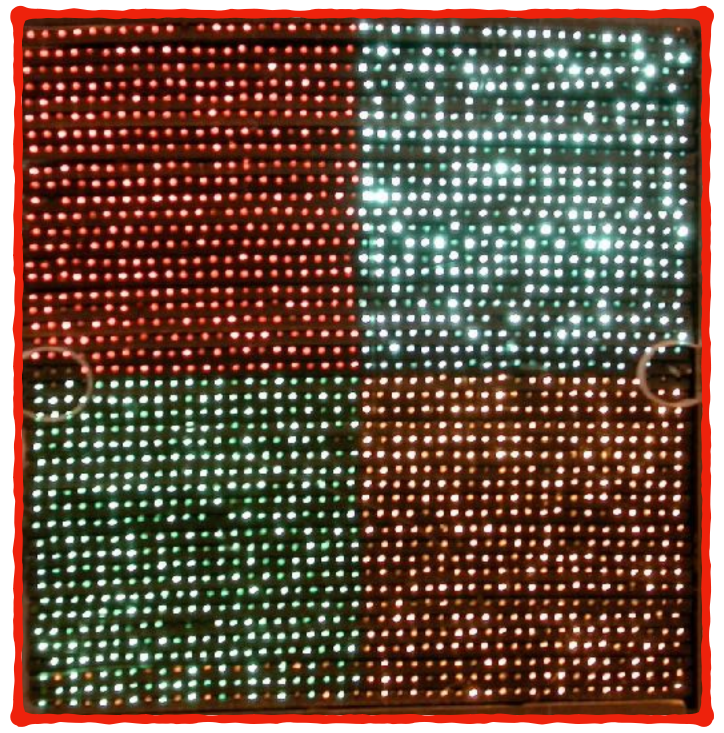
BACKUP SLIDES

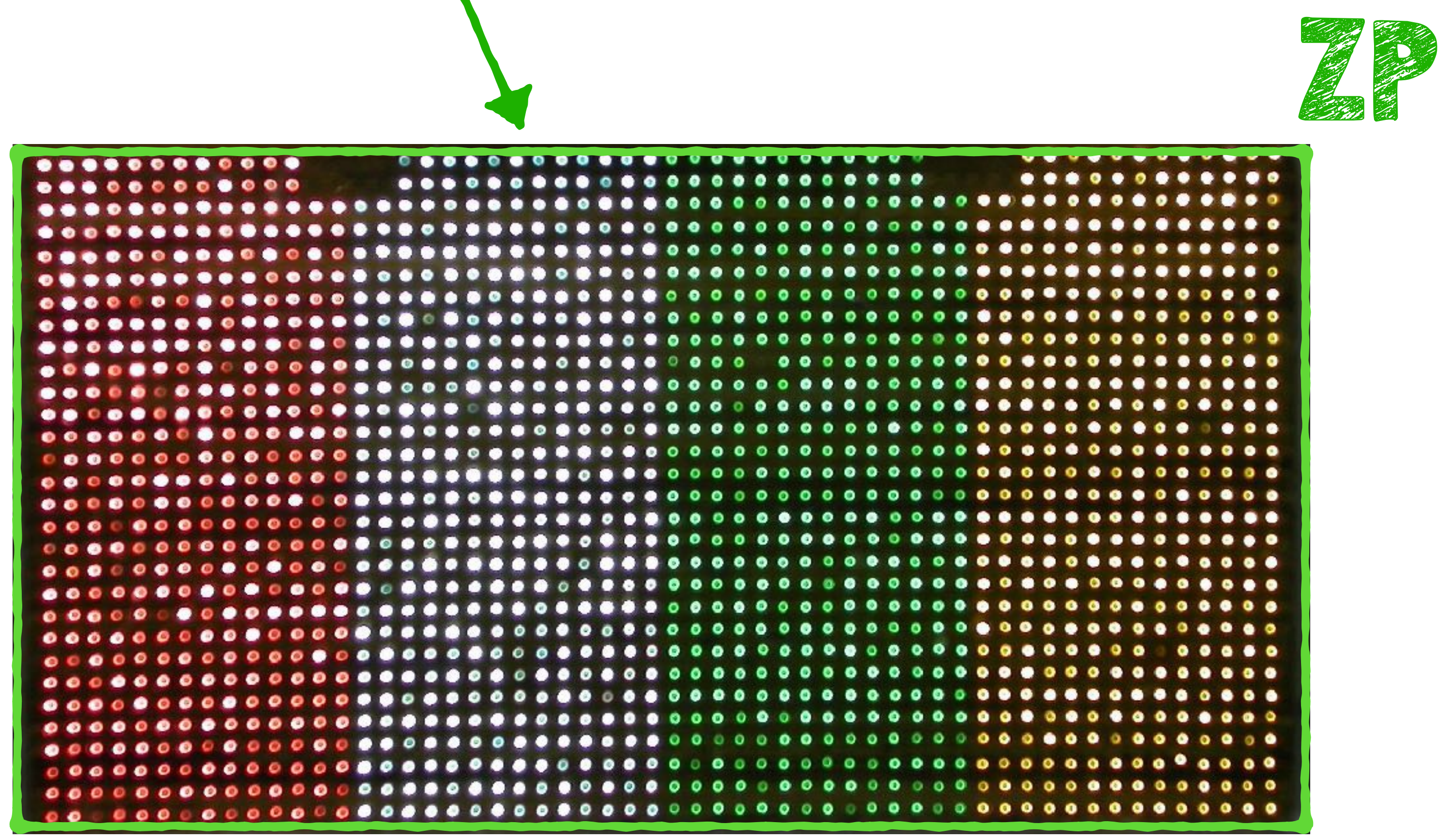
Zero Degree calorimeters



- quartz fibre “spaghetti” calorimeters
- 2 identical systems, placed at 112.5 m from IP
  ZN (|η|>8.8) for neutrons ZP (6.5<η<7.4) for protons







	ZN	ZP
Dimensions (cm^3)	7.04 x 7.04 x 100	12 x 22.4 x 150
Absorber material	W alloy	brass
η coverage	|η|>8.8	depends on LHC optics