Very forward energy emission as a function of particle production at midrapidity in pp and p-Pb collisions with ALICE ZDC

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for the ALICE Collaboration

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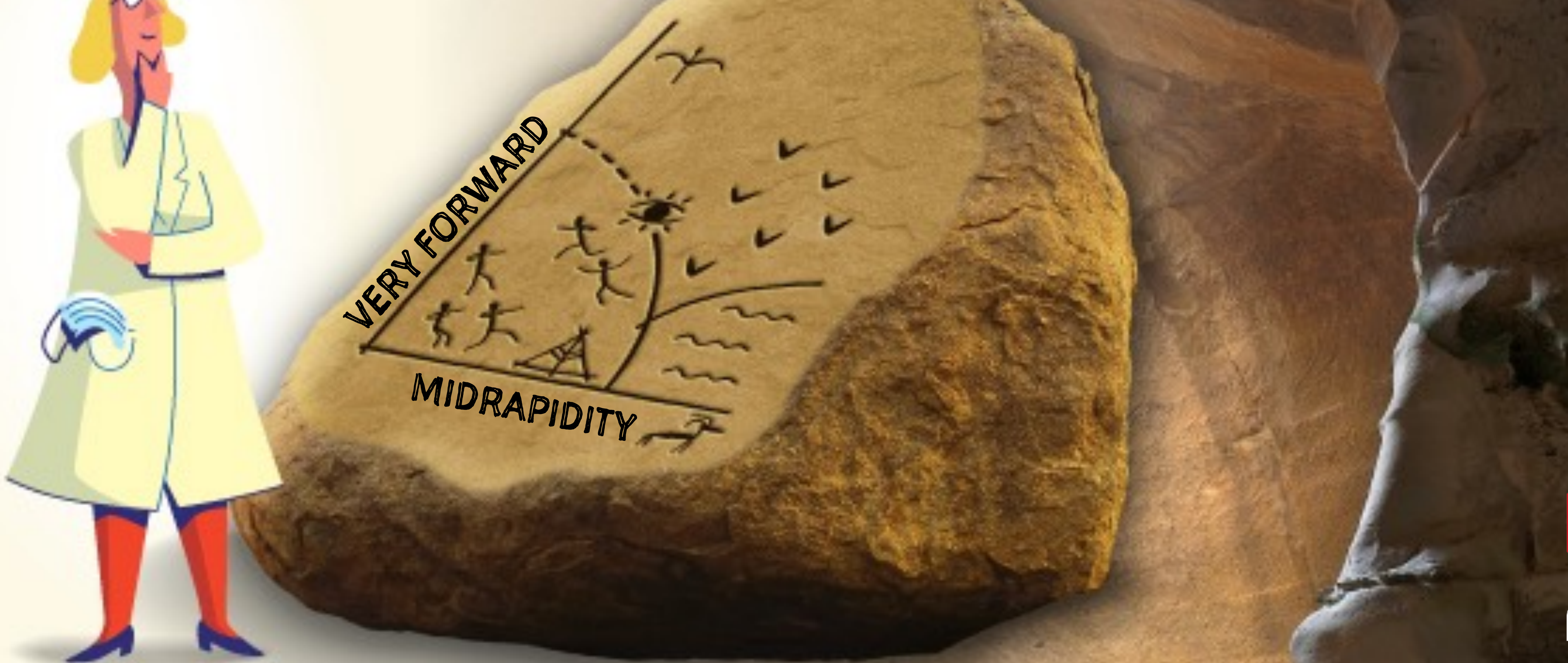
The VI[th] International Conference on the
INITIAL STAGES
OF HIGH-ENERGY NUCLEAR
COLLISIONS



ALICE

pp and p-A collisions

Collective fluid-like behaviour observed in high-multiplicity pp and p-A collisions

- MB observables studied as a function of final state multiplicity at midrapidity

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At midrapidity:

- high multiplicity events are generated in collisions with smaller than average impact parameter
- requesting a high p_T particle at midrapidity, events with larger than average multiplicity (~ factor 2) in the Underlying Event (UE)

Small b collisions ➧ larger matter overlap ➧ enhanced probability for partonic scattering with large momentum transfer, larger N_{MPI}

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- ❑ complementary information to UE measurements
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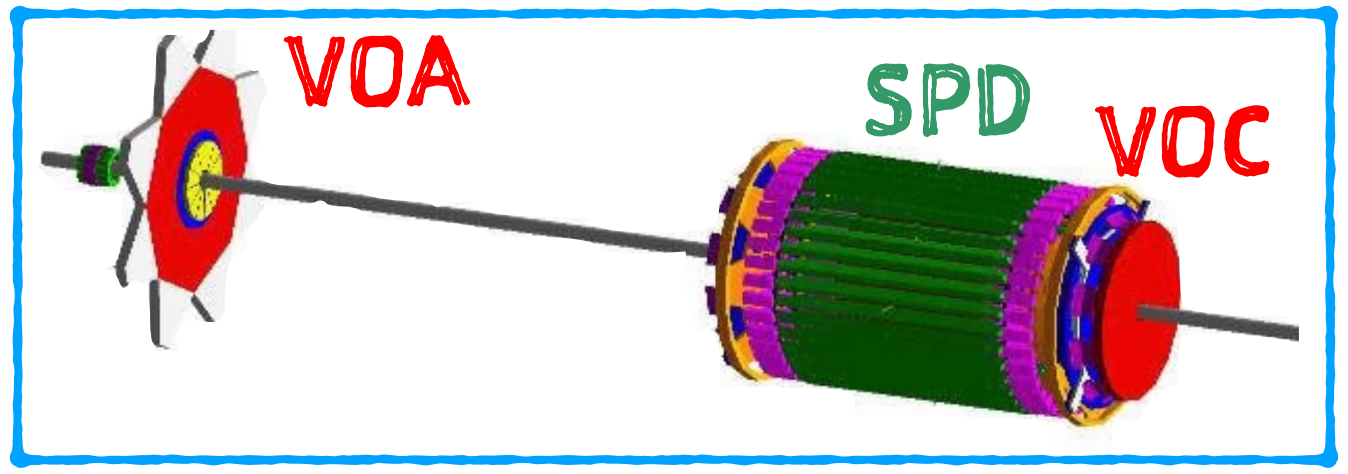
Very forward energy detected by ALICE ZDC vs. midrapidity activity
➧ study the proton breakup in pp collisions at 13 TeV and in p-Pb collisions at 8.16 TeV
➧ signals separated by large rapidity gap can be only correlated via the initial stages of the collision

ALICE detectors



SPD ➧ 2 innermost layers of the ITS |η|<1.4 and |η|<2, used to measure charged-particle multiplicity

VZERO ➧ scintillator hodoscopes used for triggering, covering 2.8<η<5.1 (V0-A) -3.7<η<-1.7 (V0-C)

TPC ➧ main tracking detector, covering |η|<0.9

Charged particle tracks formed combining ITS hits and TPC reconstructed clusters

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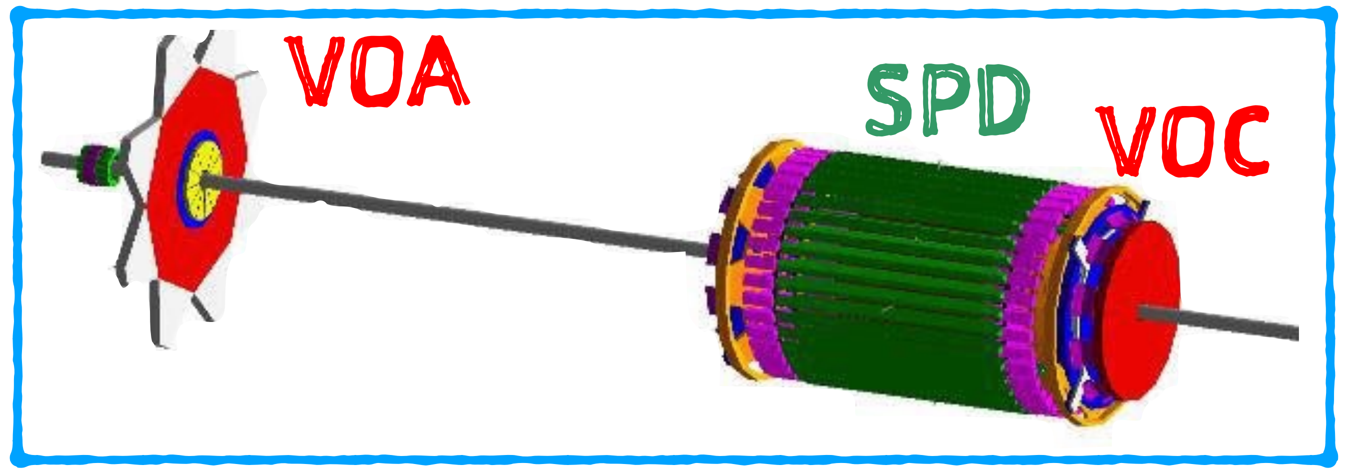

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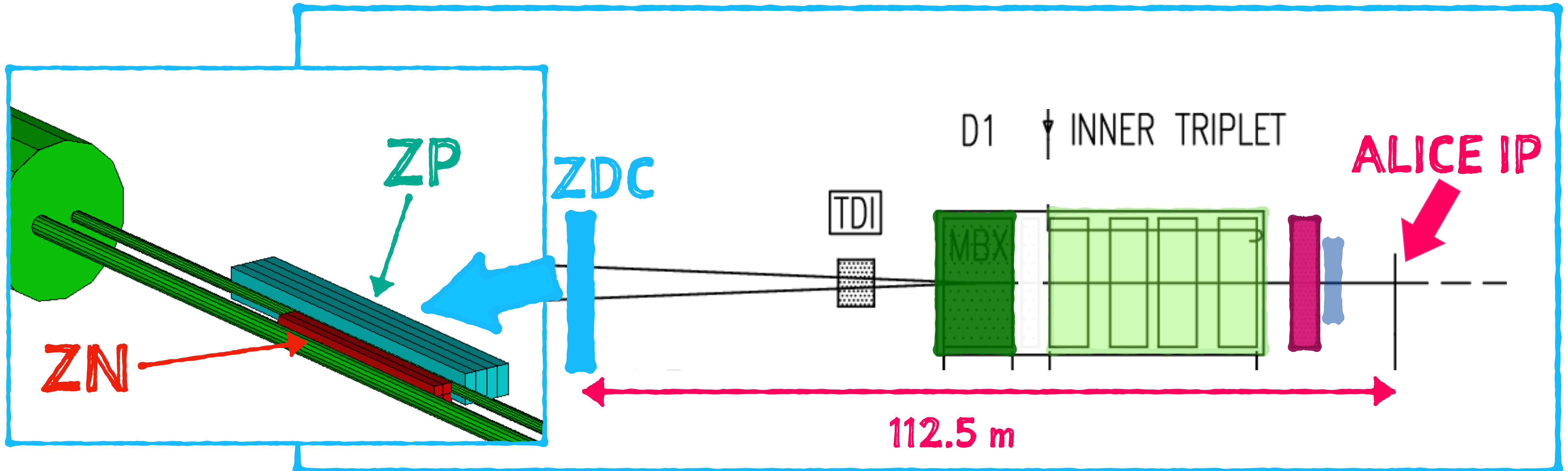
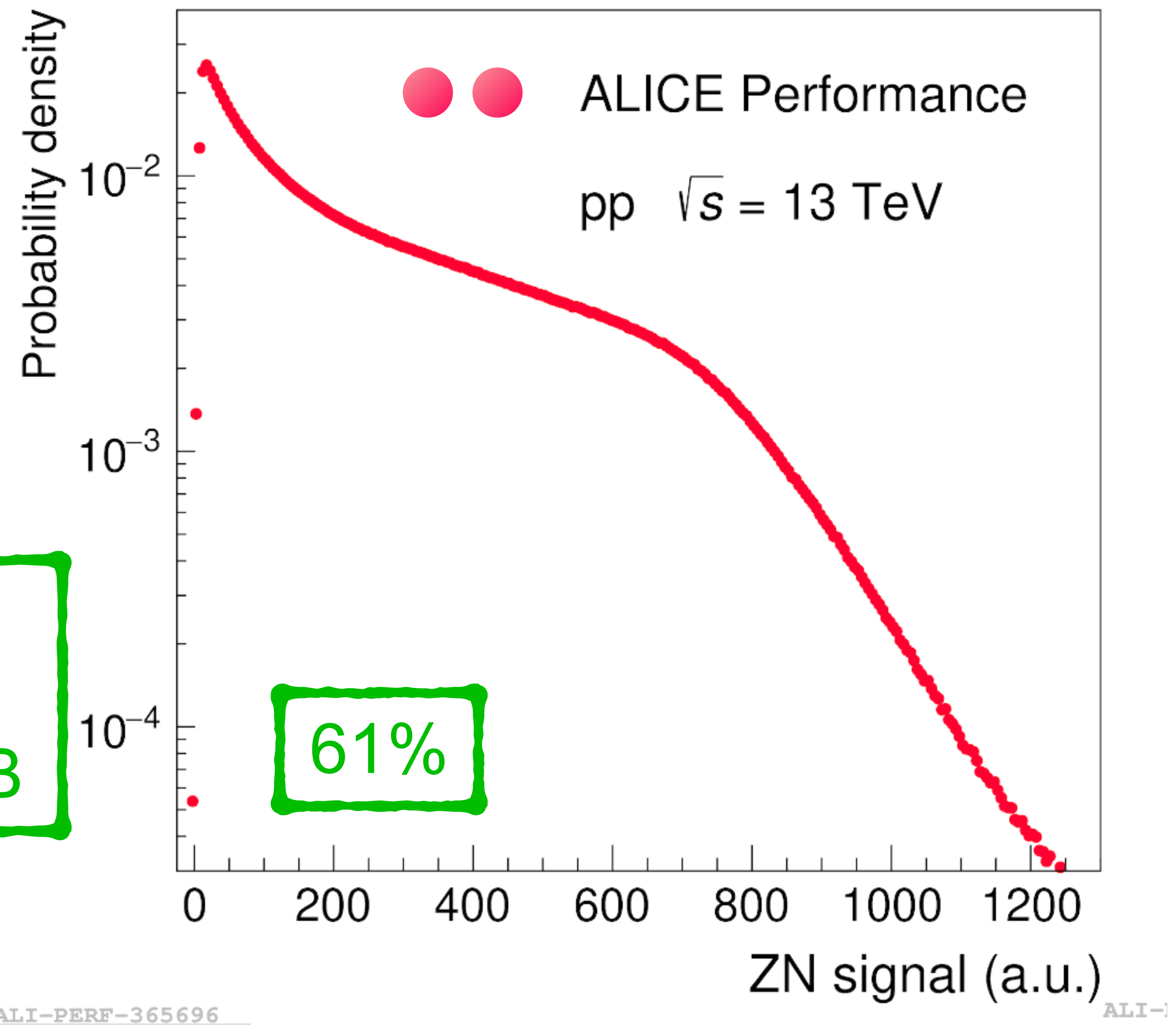
ZDC ➧ quartz fibre “spaghetti” calorimeters, 2 identical systems, 112.5 m from IP
ZN ($|\eta|>8.8$) for neutrons ZP ($6.5<\eta<7.4$) for protons

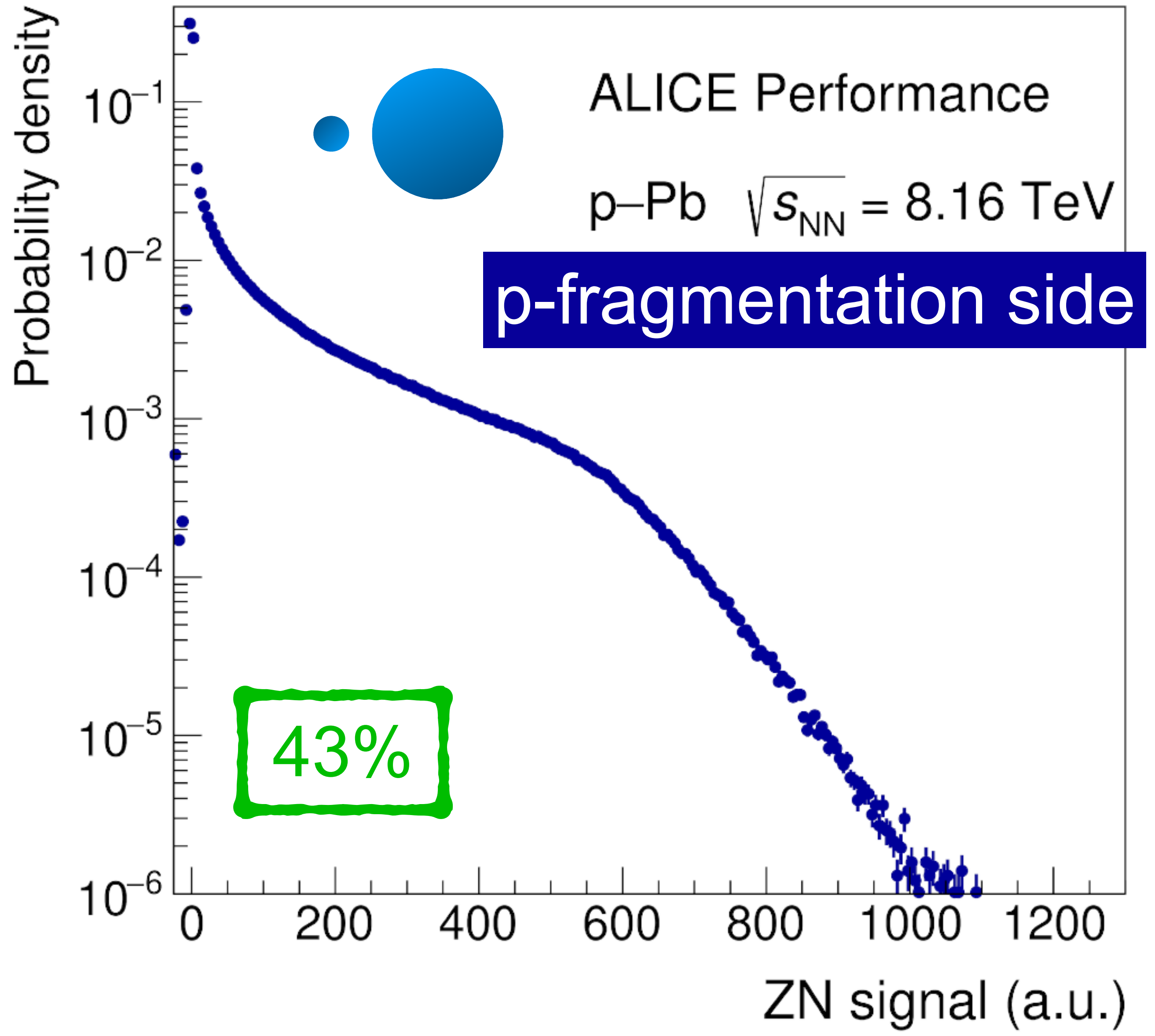


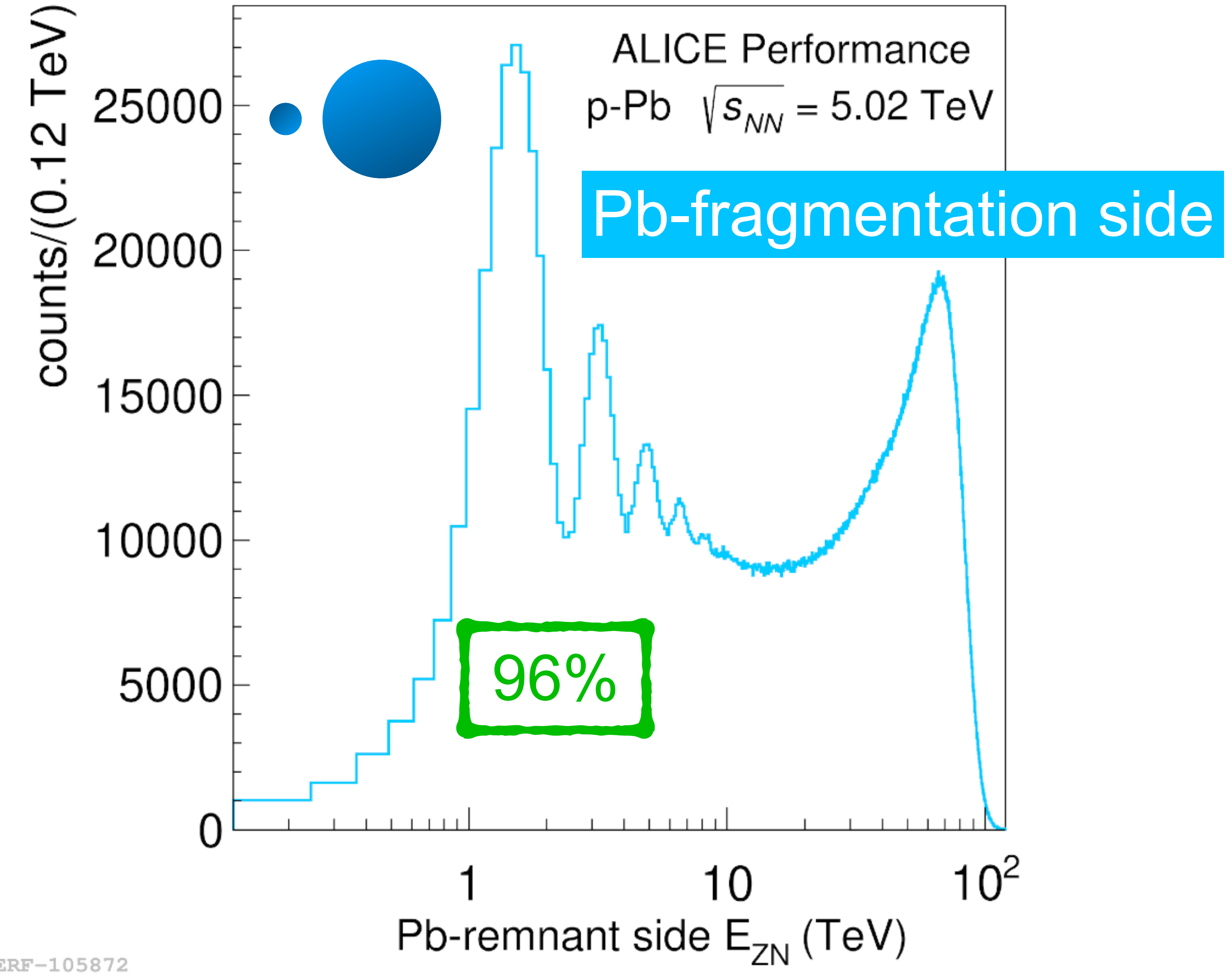
ZDC spectra in pp and p-Pb collisions

ZN

Fraction of events with ZN signal/MB







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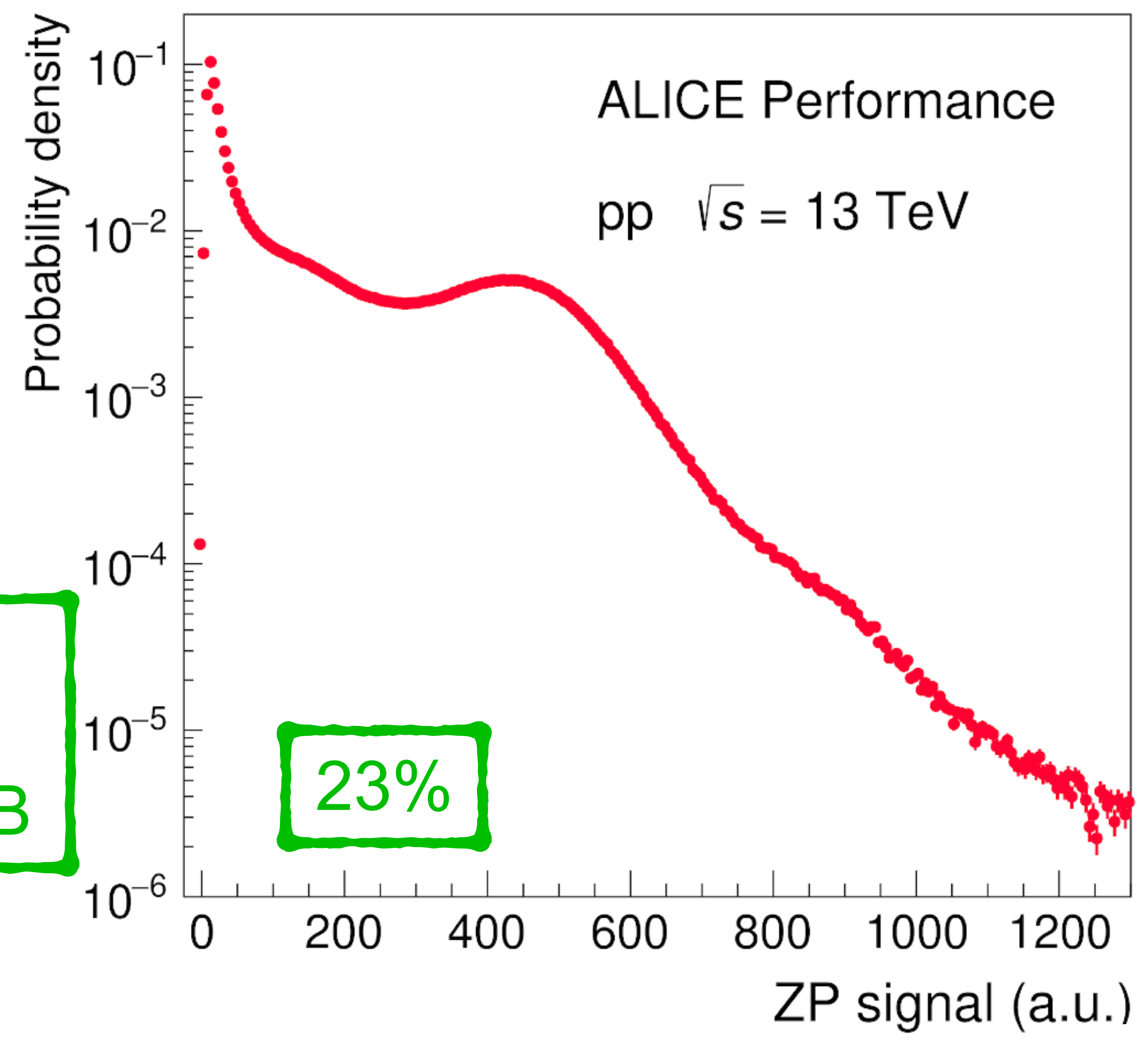
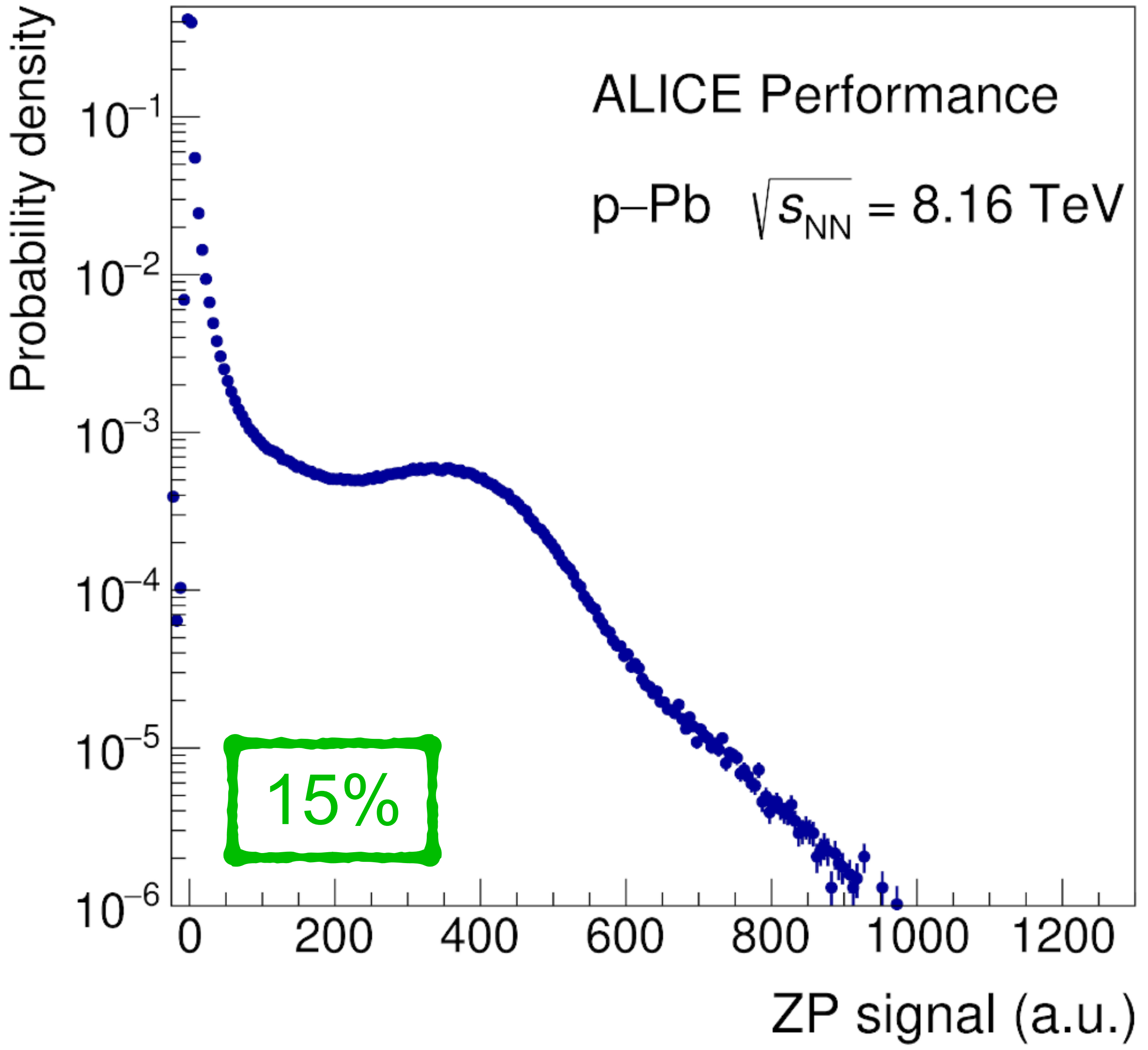
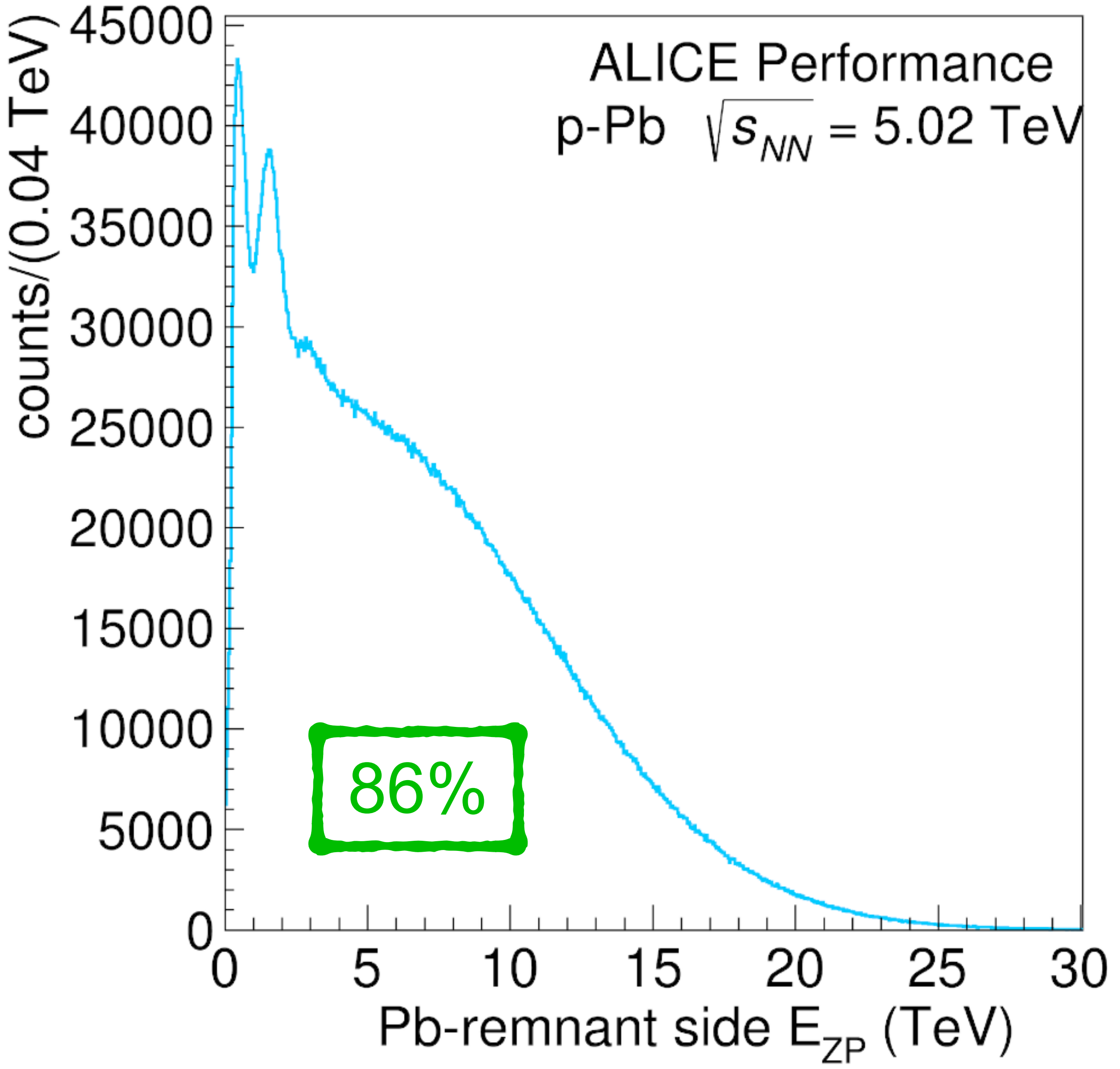


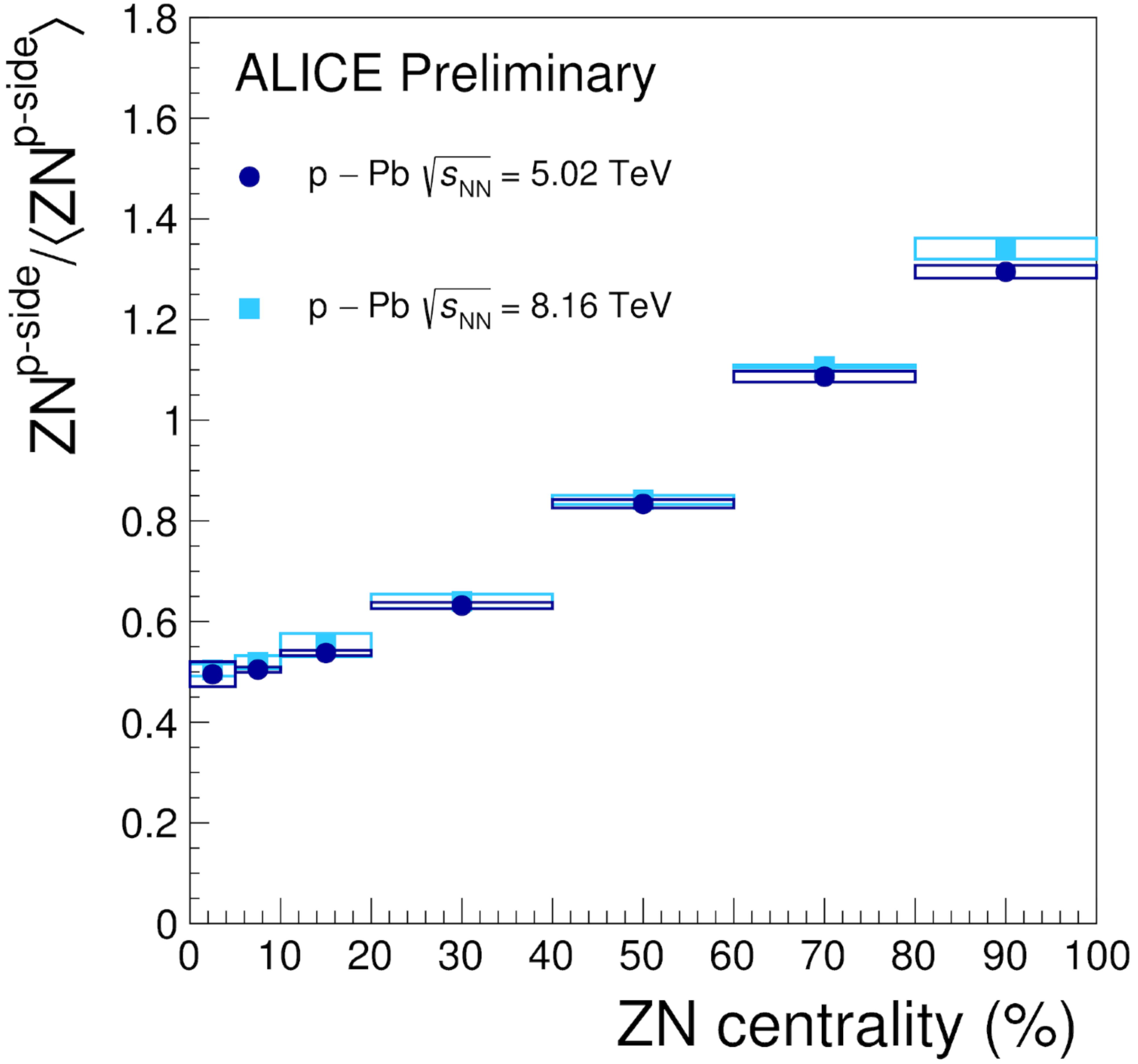




p-fragmentation region in p-Pb collisions

In p-Pb collision, the very forward neutron energy detected in the p-fragmentation region is inversely proportional to collision centrality [1] estimated through the ZN energy at 5.02 TeV and at 8.16 TeV

➧ energy vs. centrality does not depend on $\sqrt{s_{NN}}$



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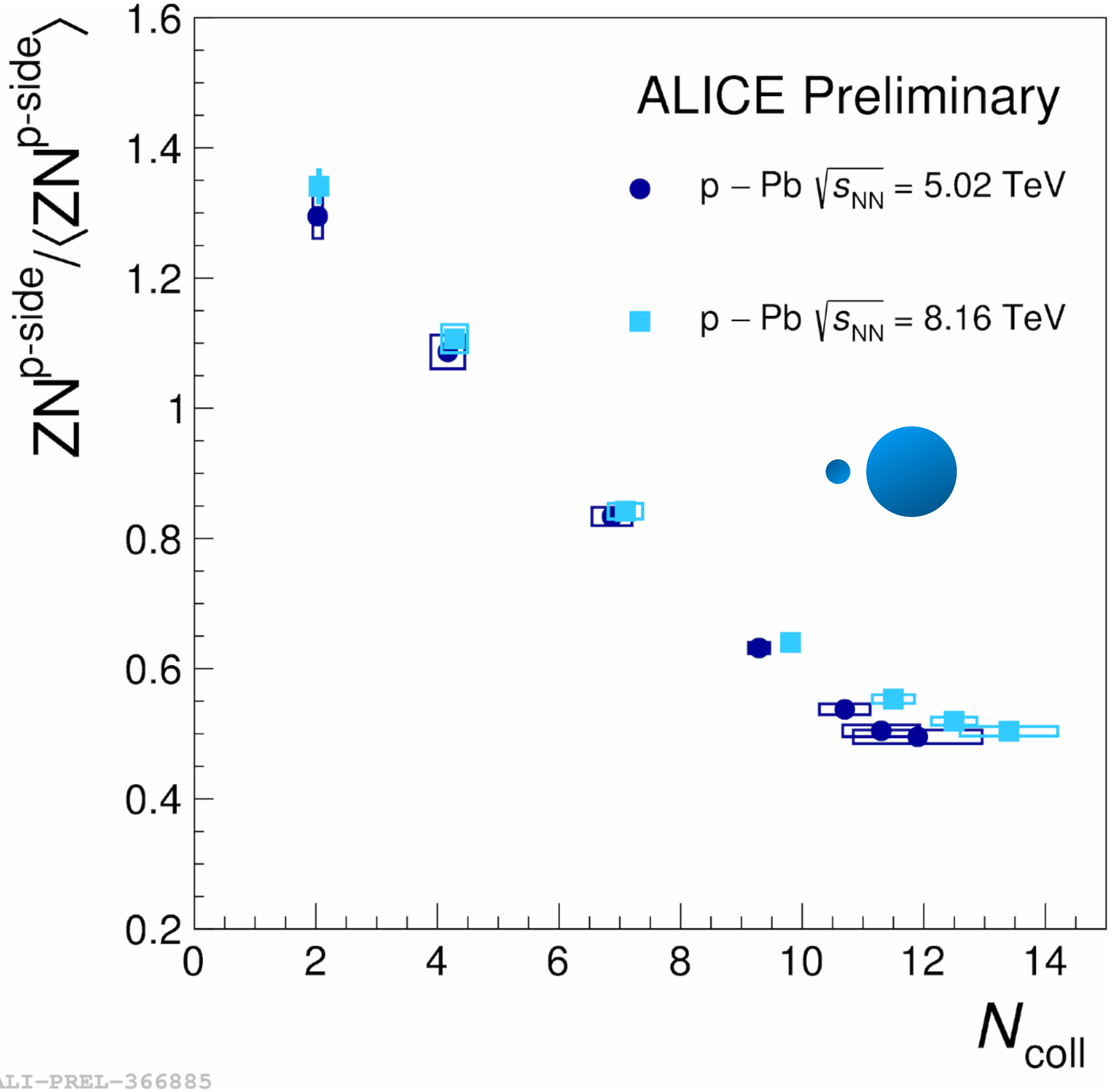

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[1] ALICE Collaboration, Phys. Rev. C 91, 064905

Forward-backward emission in pp

Correlation between forward and backward energy emission in pp

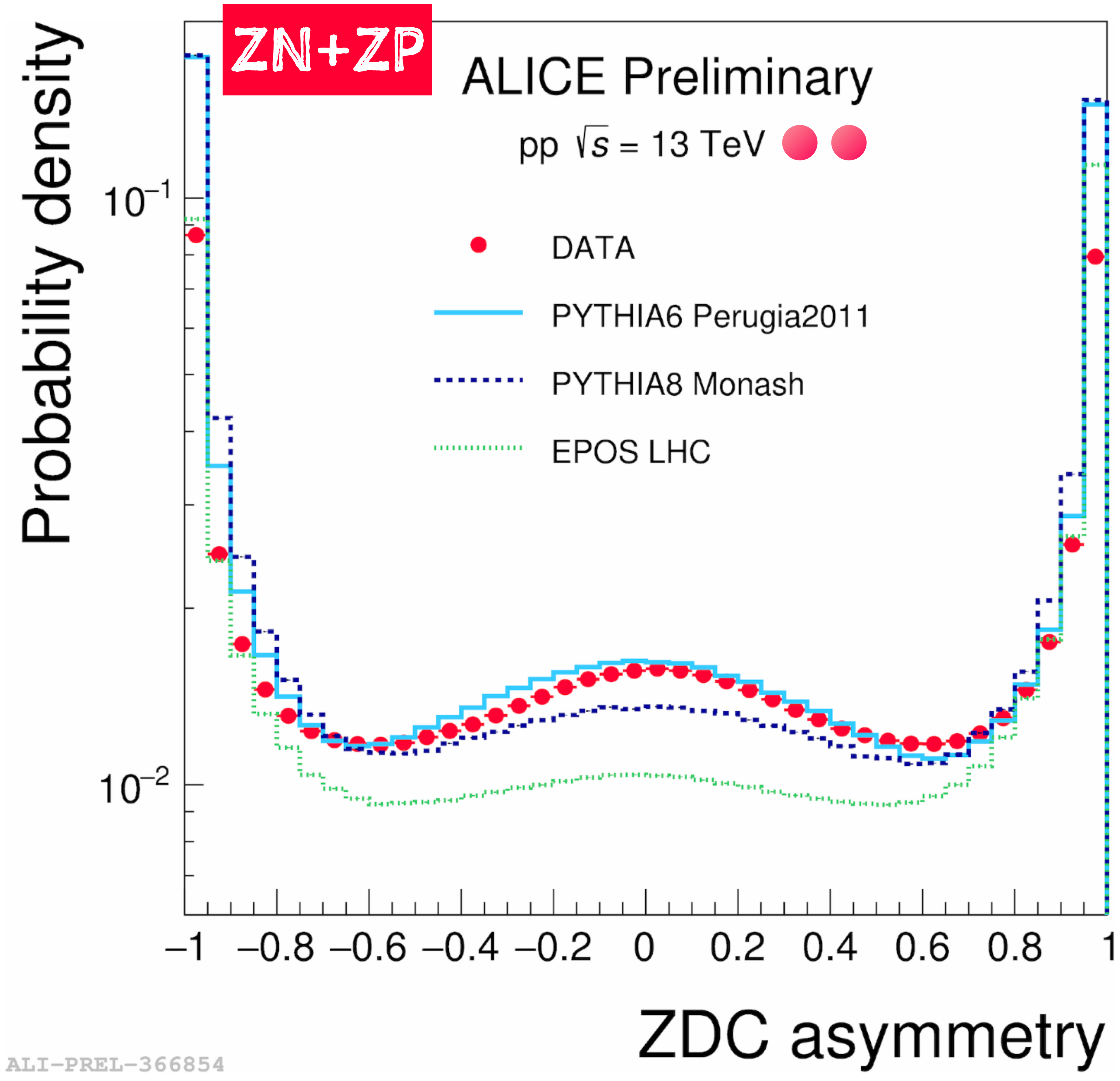
- to a large energy deposit on one side corresponds a very low energy deposit on the opposite side
- some events show a mild correlation, in particular for ZN, as predicted in [2]

[2] Drescher and Strikman, PRL 100 (2008) 152002

ZDC asymmetry in pp collisions

ZDC asymmetry defined for events where a signal is present either in forward or backward side
(ZNA OR ZNC)/MB~85% (ZPA OR ZPC)/MB~42%

$$\text{ZDC asymmetry} = \frac{ZDCA - ZDCC}{ZDCA + ZDCC}$$



Reasonable agreement with PYTHIA6

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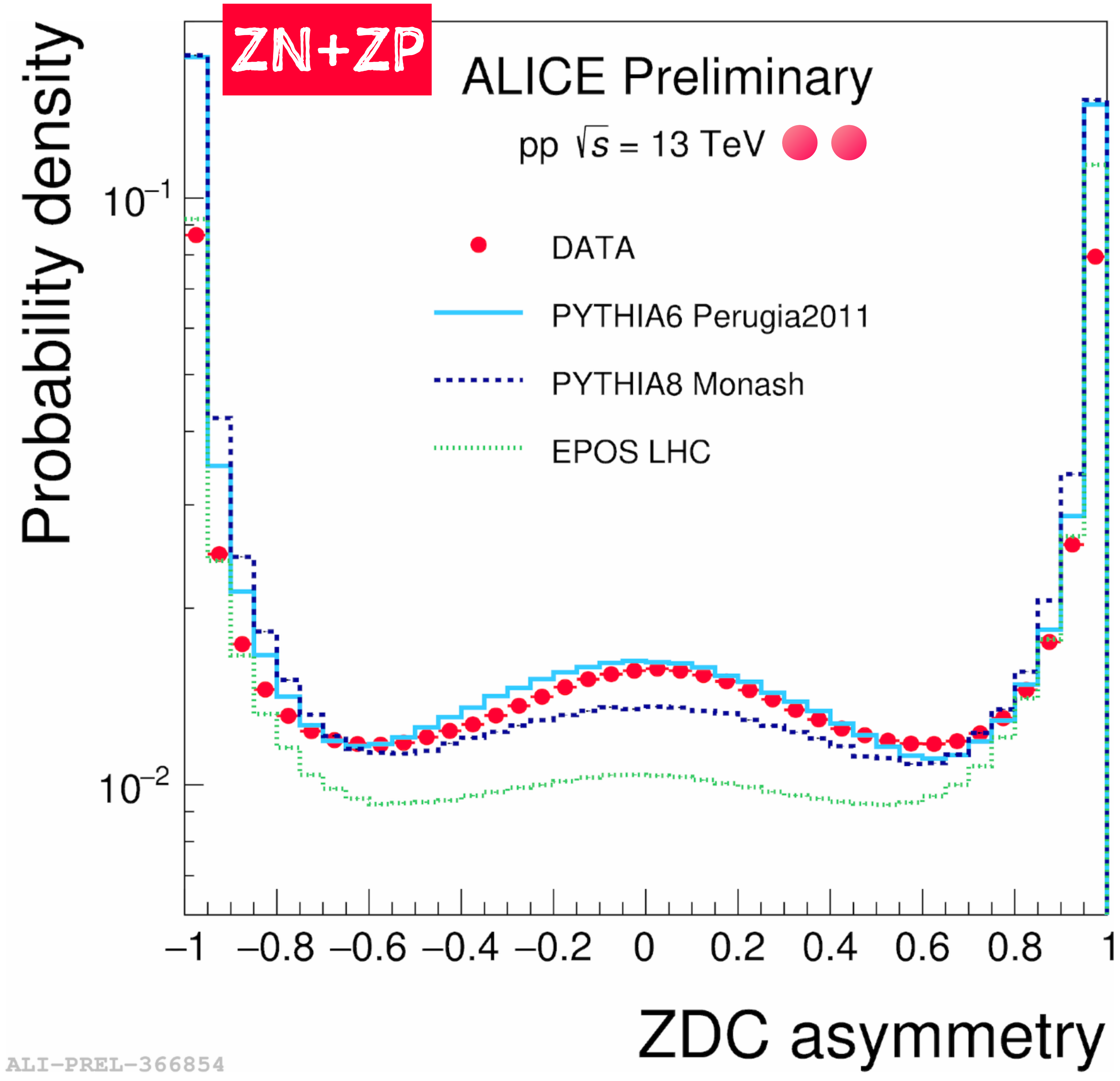
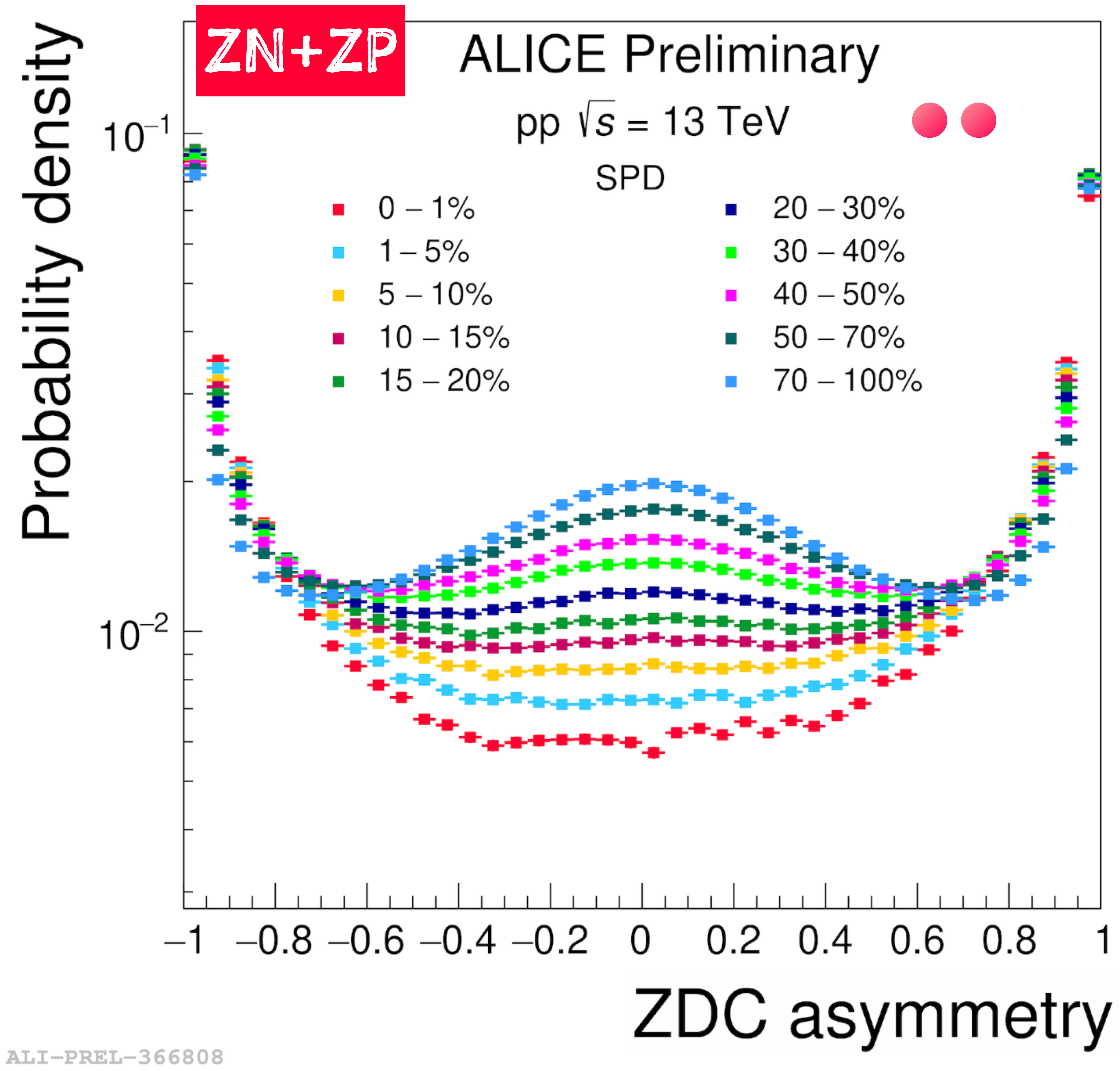


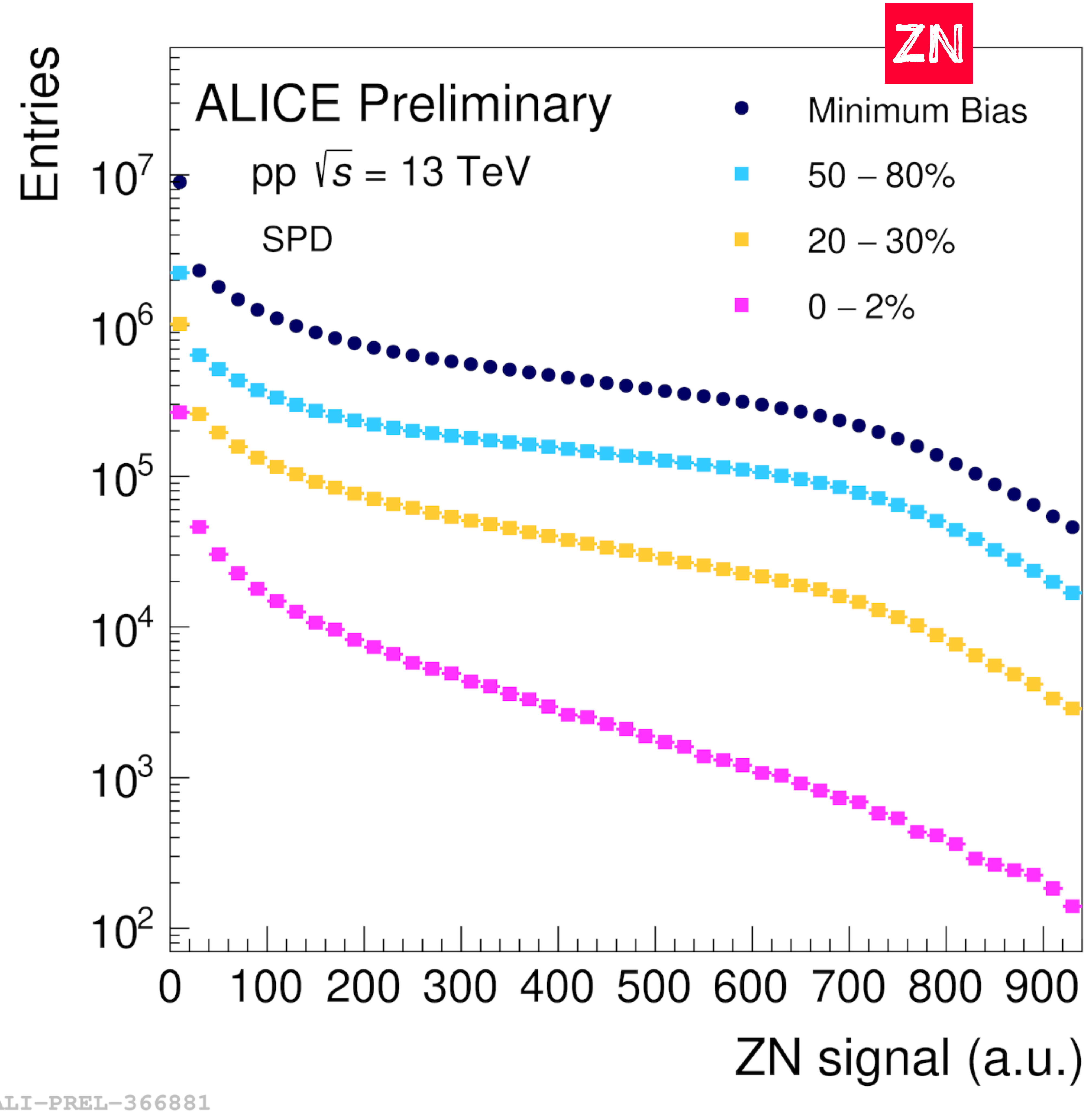


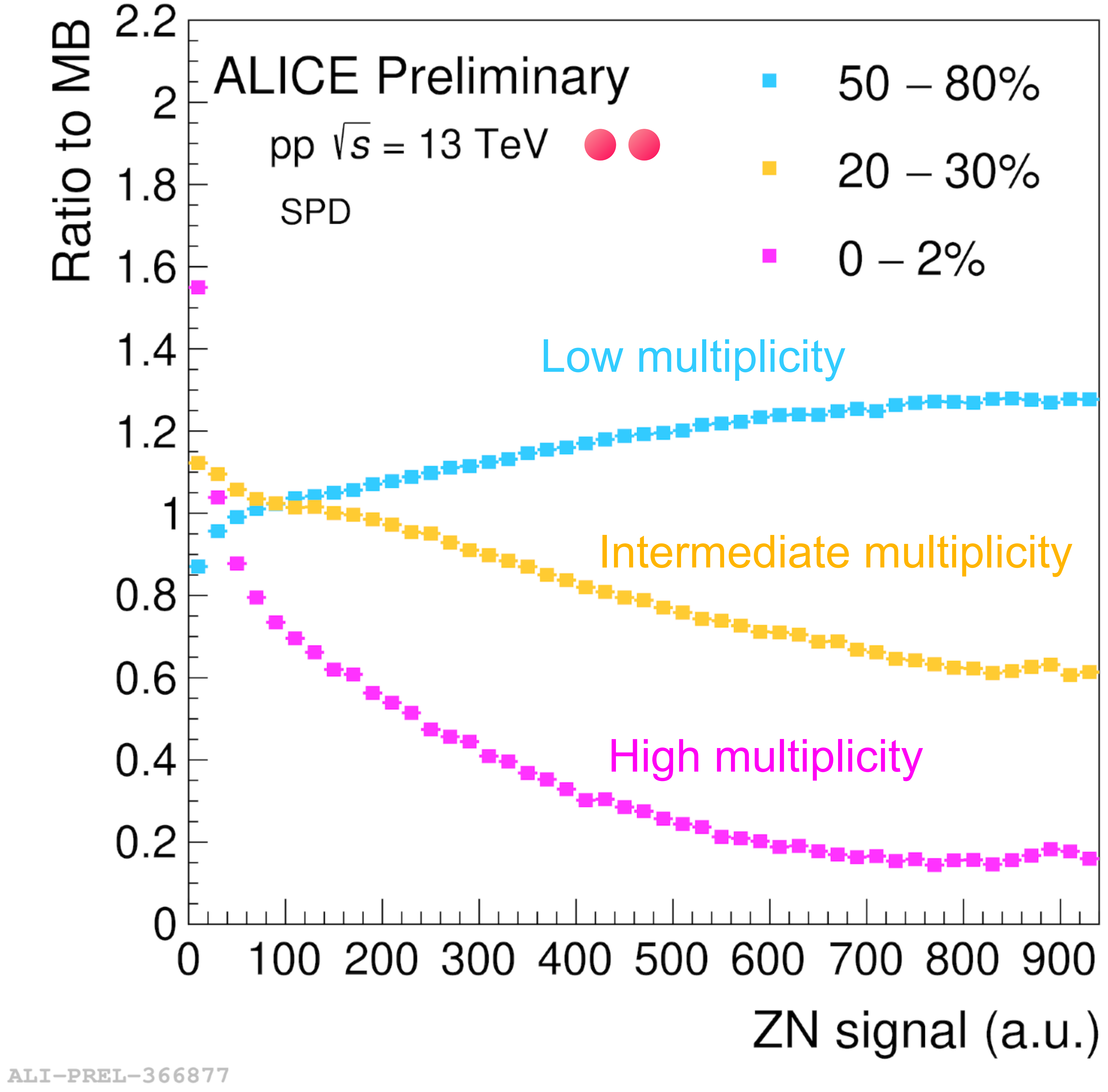
Clear dependence on particle multiplicity at midrapidity
➧ events with smaller multiplicity are more symmetric

Reasonable agreement with PYTHIA6

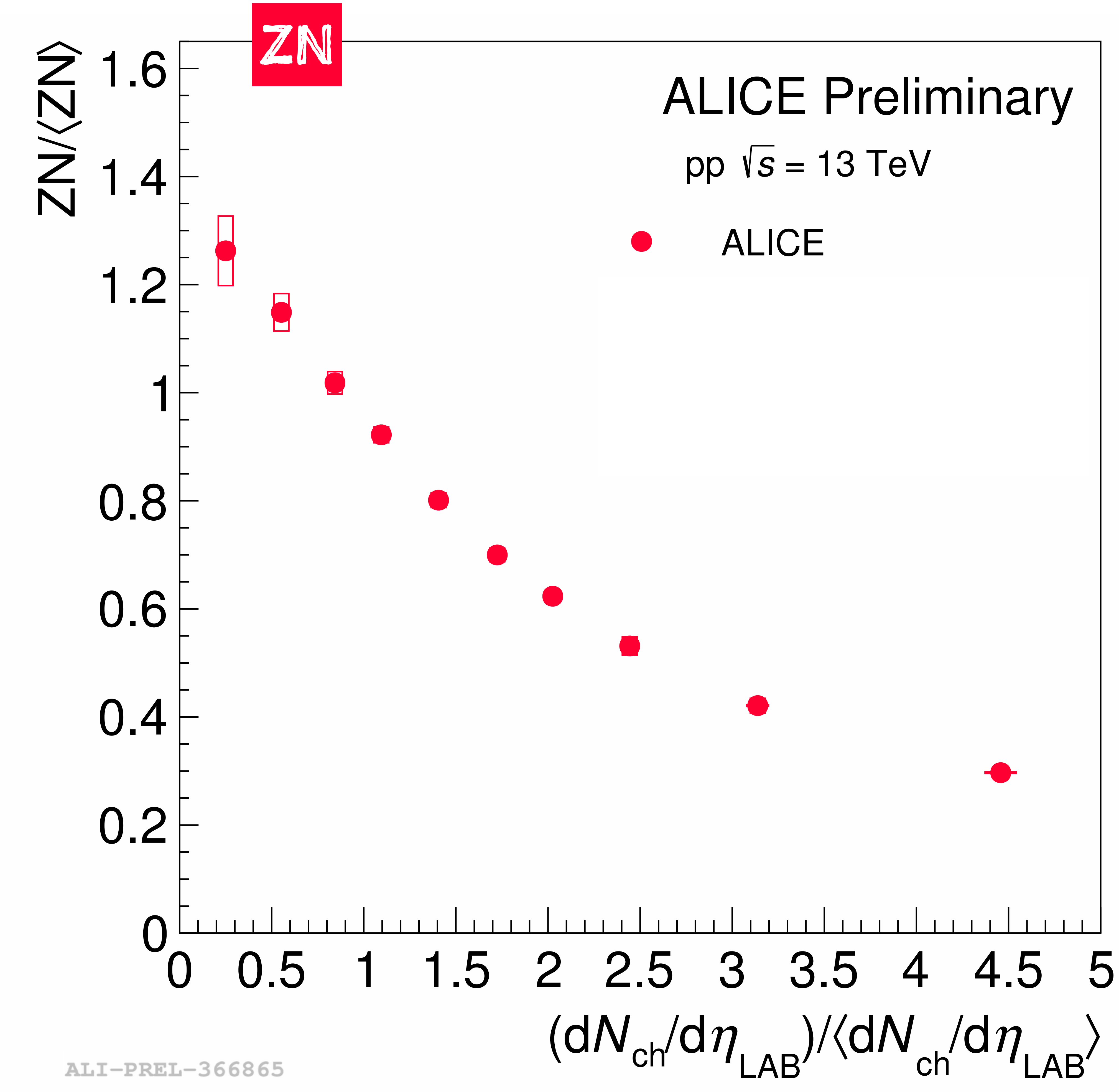
ZN spectrum vs. multiplicity in pp

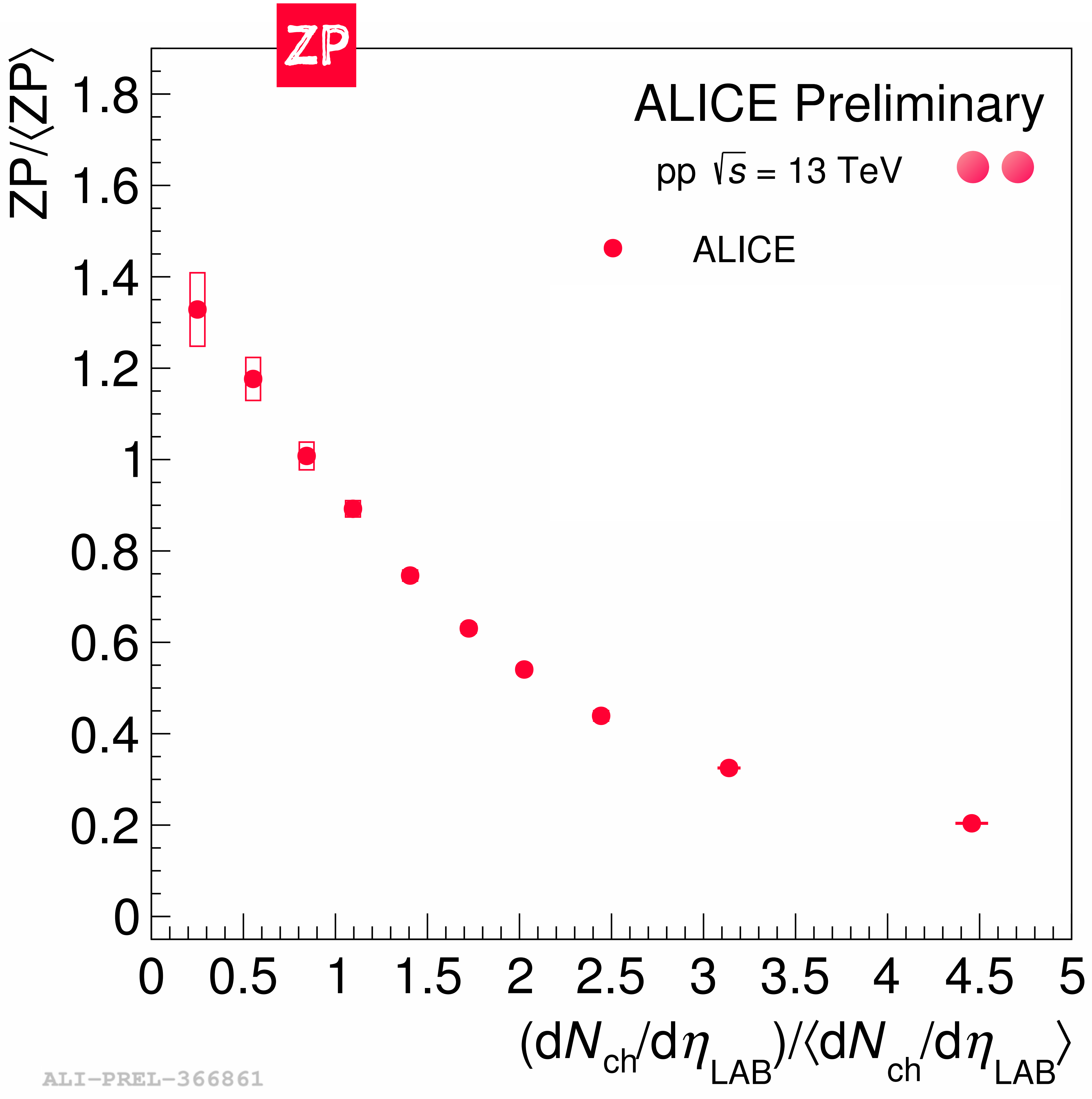
ZN spectrum shape in pp collisions changes relative to MB spectrum in different multiplicity bins





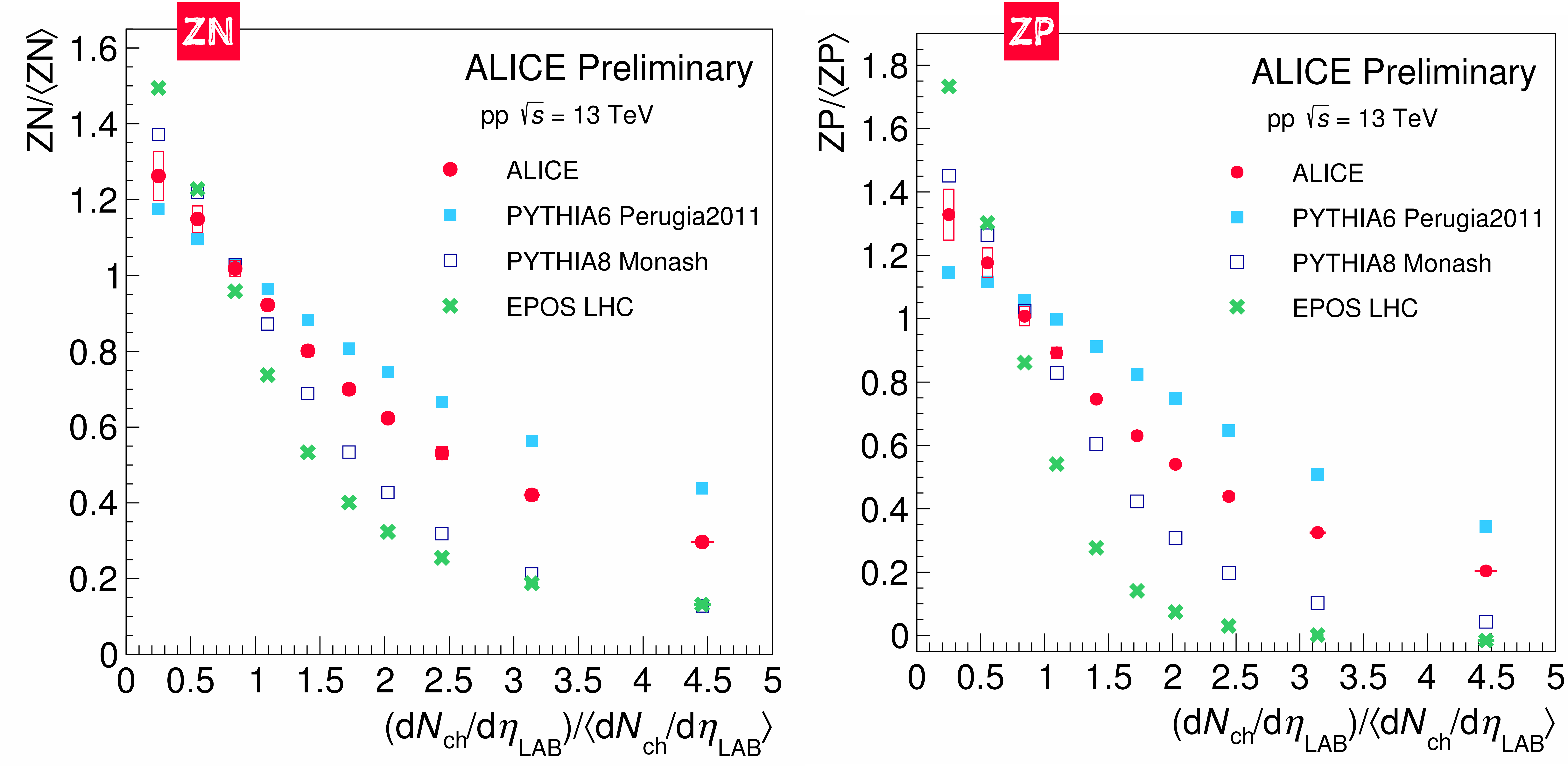
Forward energy vs. multiplicity in pp





Forward energy decreases with increasing particle multiplicity at midrapidity

Forward energy vs. multiplicity in pp

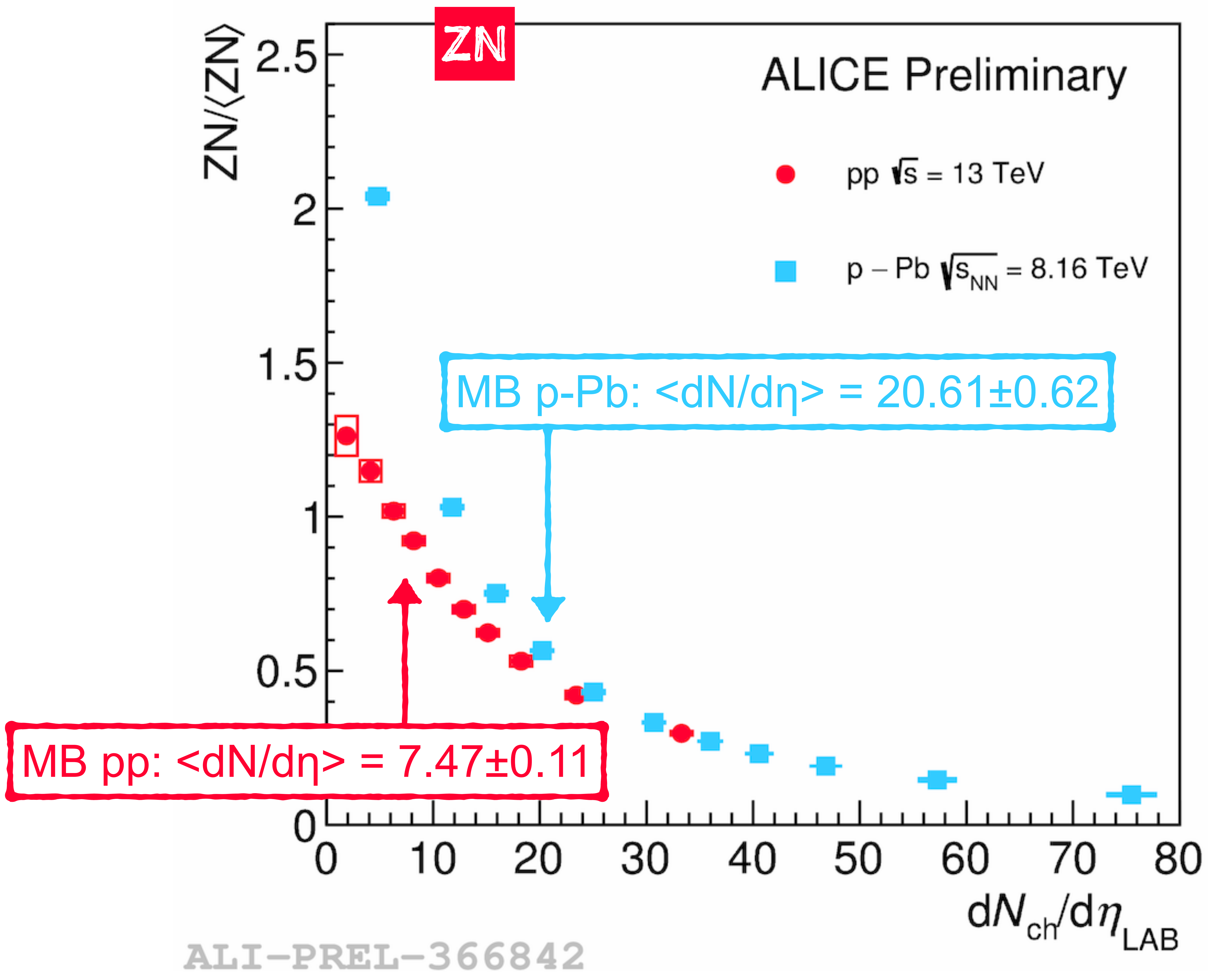


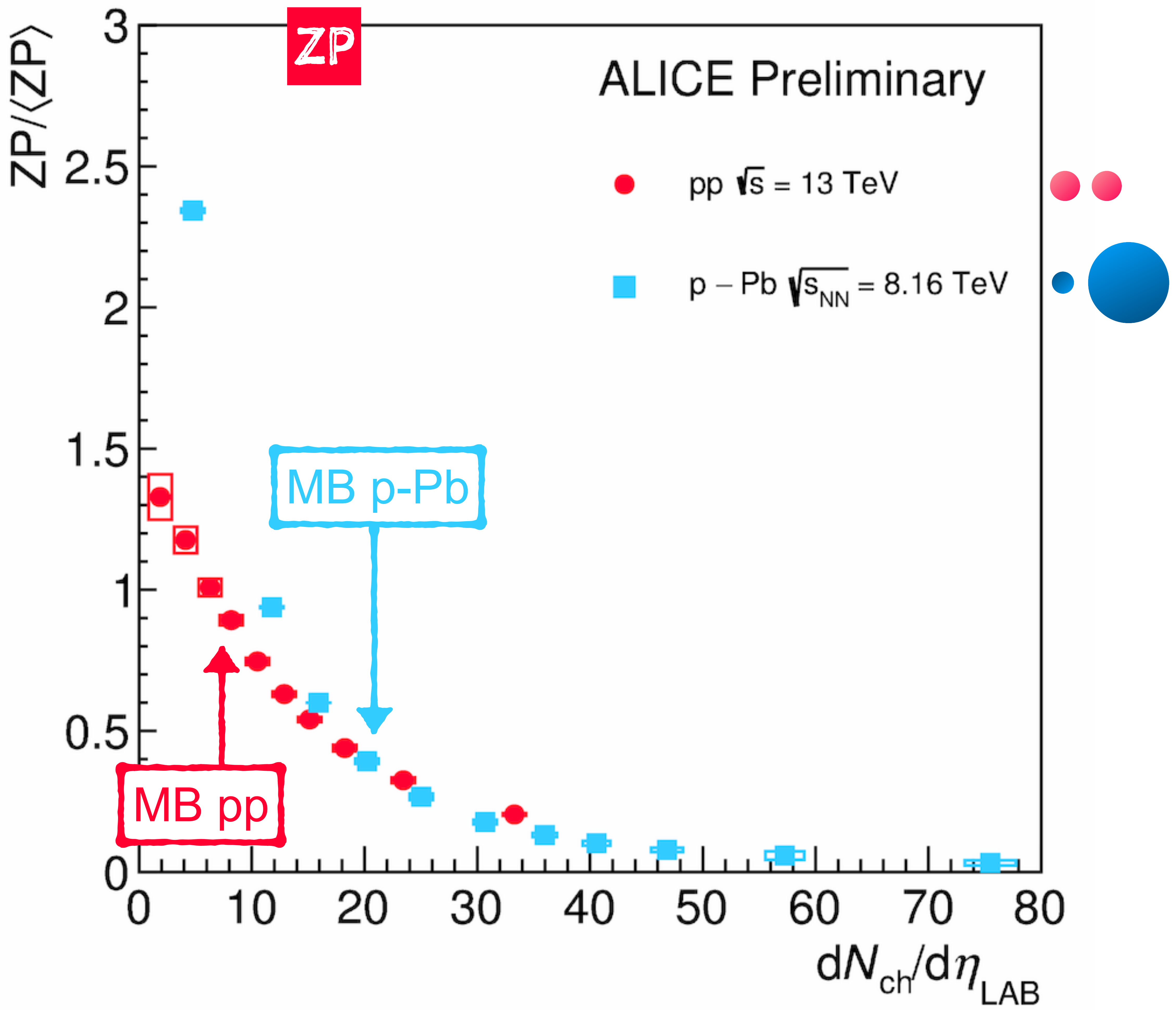
Forward energy decreases with increasing particle multiplicity at midrapidity

PYTHIA6 Perugia2011, PYTHIA8 Monash and EPOS-LHC predictions describe the overall pattern, but are not able to quantitatively reproduce experimental results in multiplicity bins.

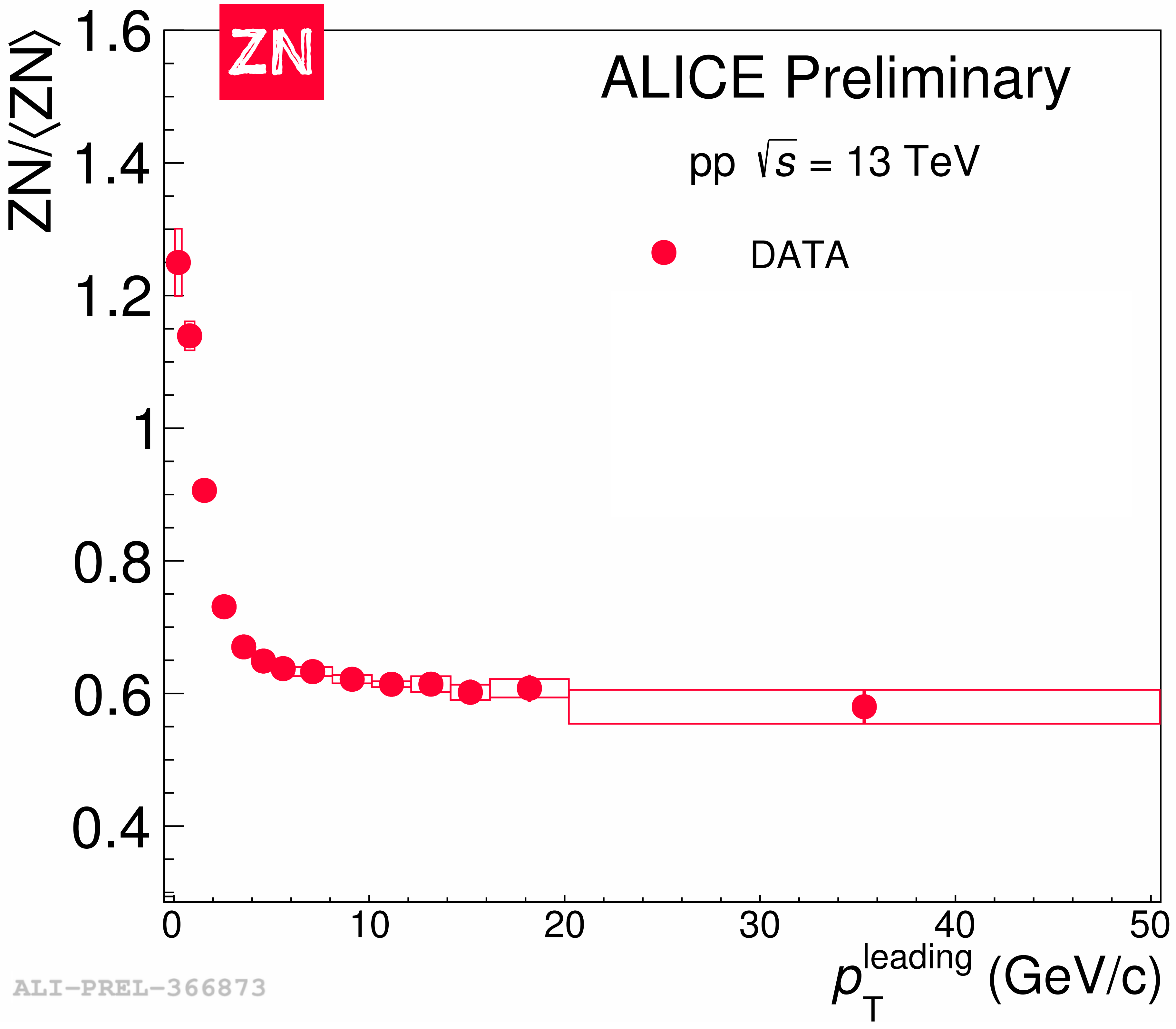
Forward energy vs. multiplicity

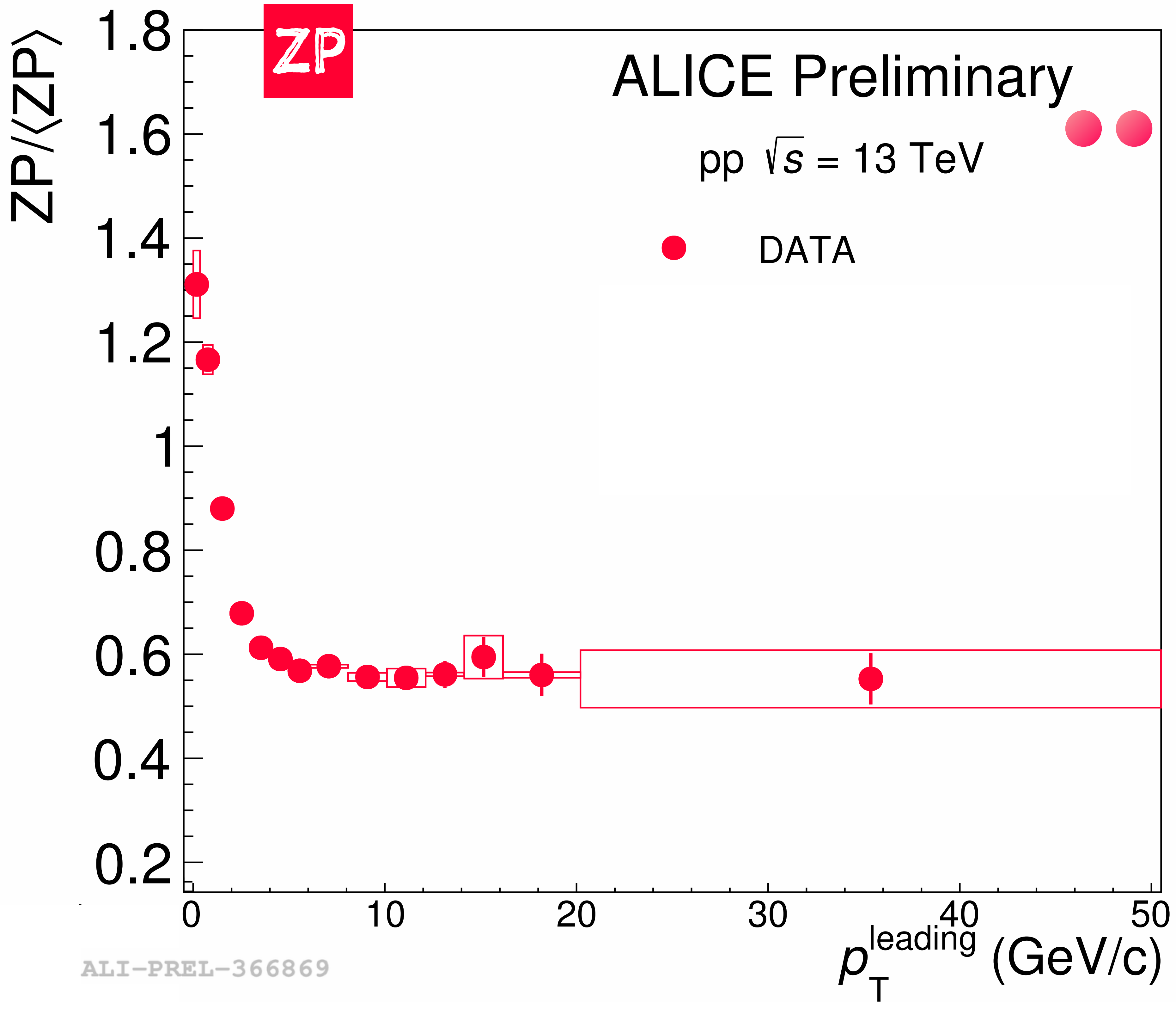
ZN, ZP energies normalized to MB values decreases rapidly with increasing multiplicity at midrapidity, both in pp and in in p-Pb interactions in the p-fragmentation region (same p beam energy)





ZDC energy vs. leading p_T in pp





The forward energy decreases rapidly and then saturates vs. leading particle p_T measured in $|\eta|<0.8$

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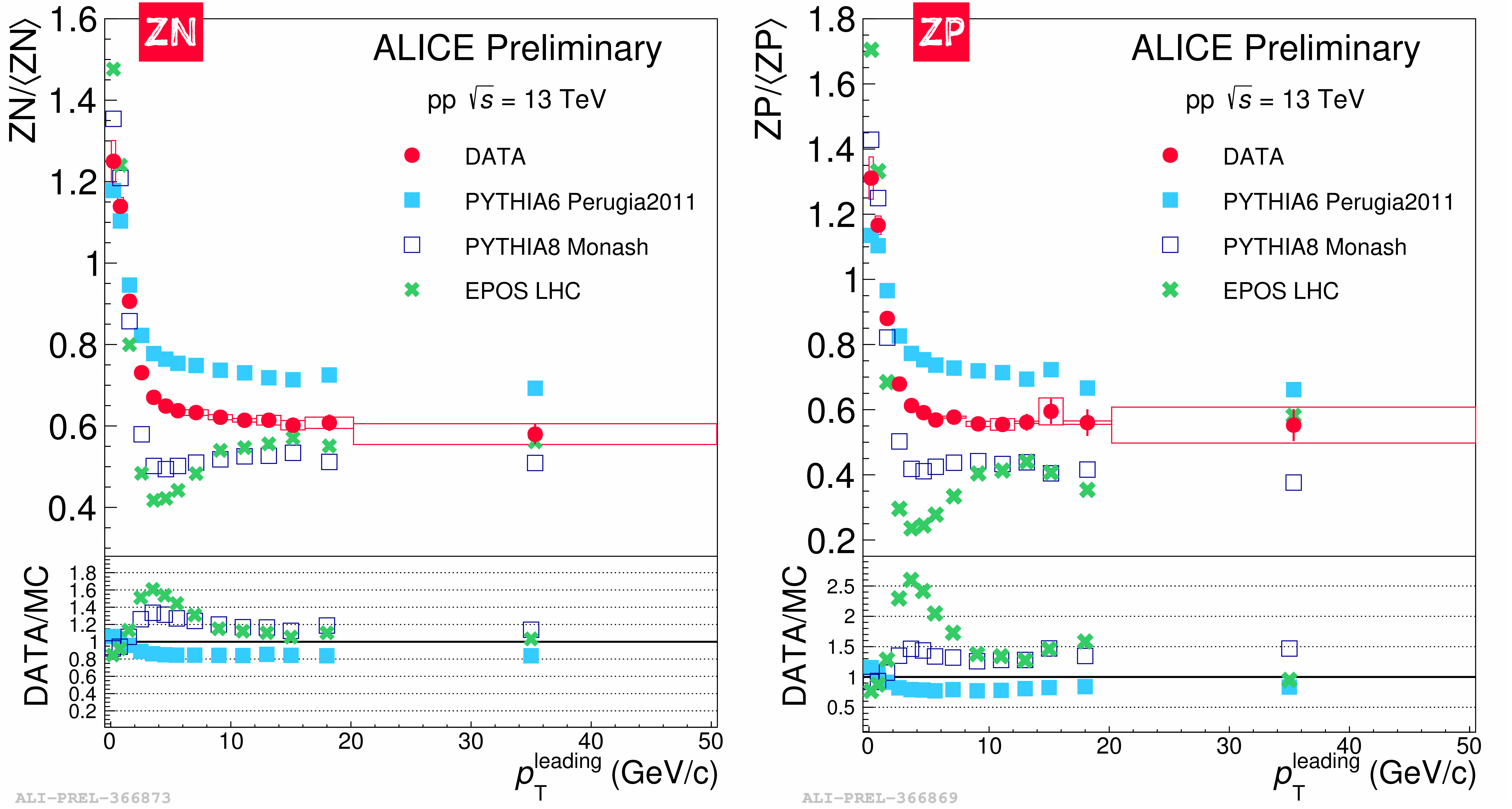

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➧ the models do not reproduce quantitatively ALICE data, PYTHIA6 has a similar shape vs. p_T

Very forward energy and MPI in pp

- forward energy decreases with increasing charged particle multiplicity at midrapidity
- forward energy decreases rapidly as a function of leading particle p_T measured in $|\eta|<0.8$, and saturates as a function of particle leading p_T

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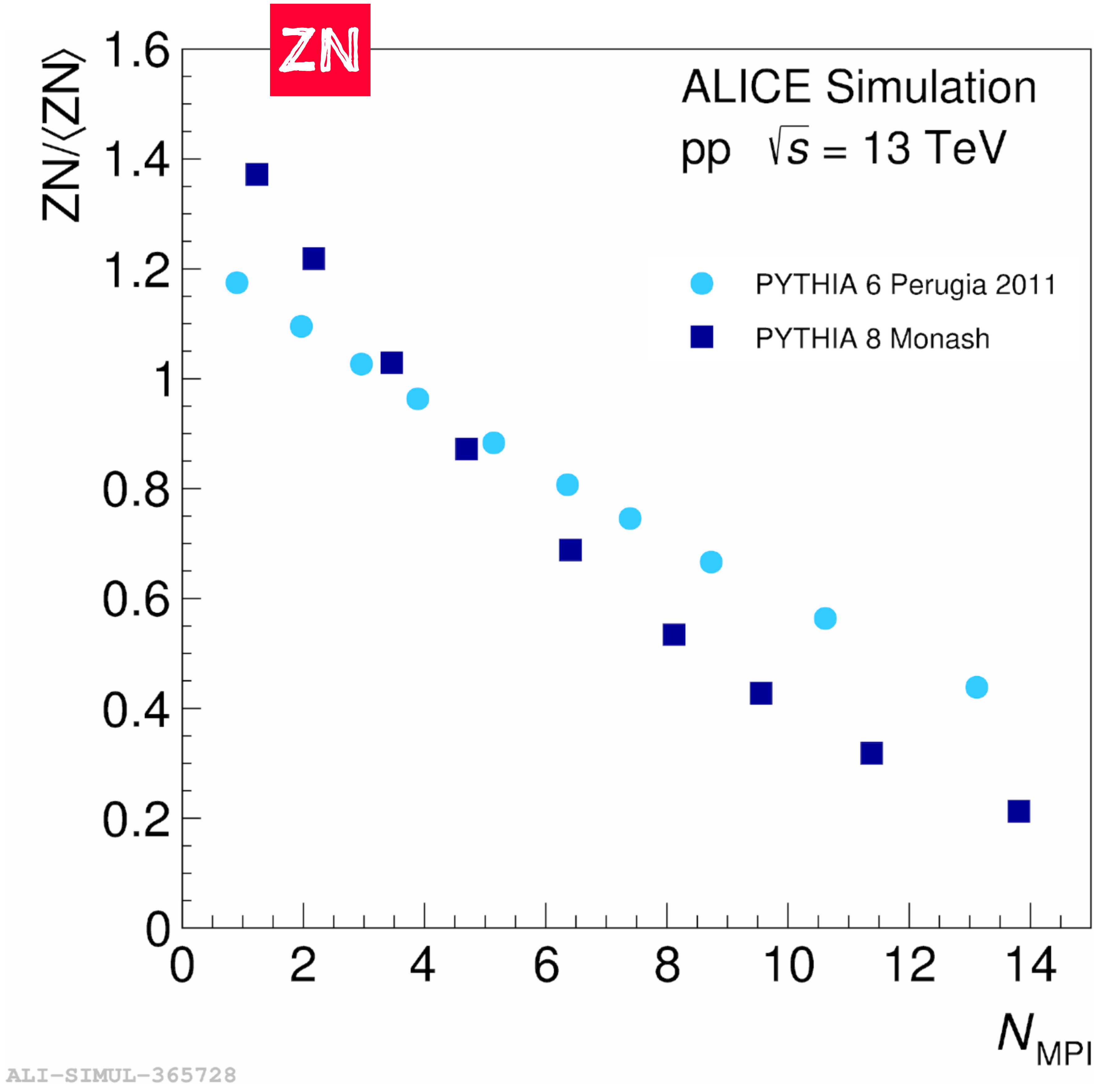
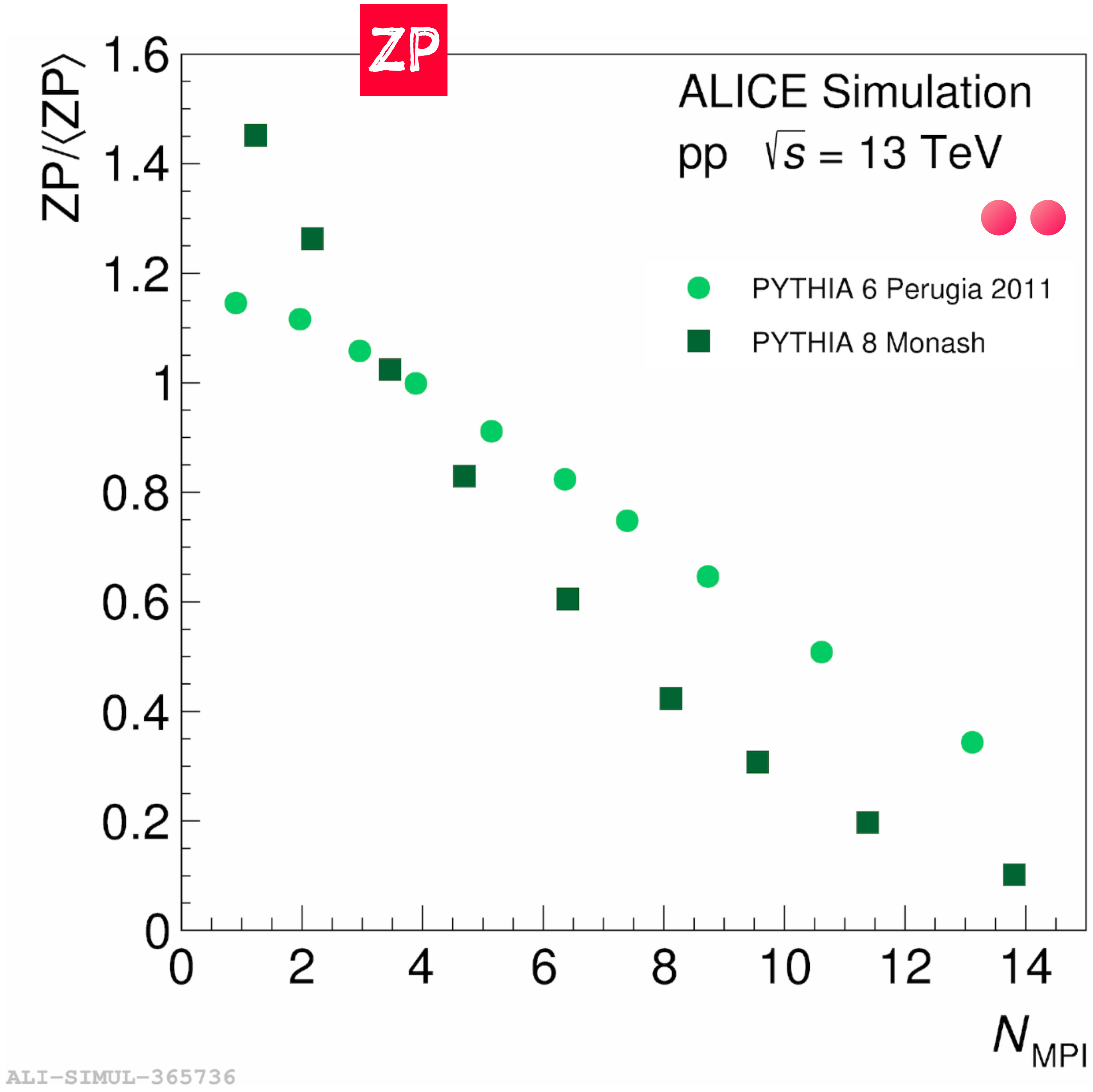
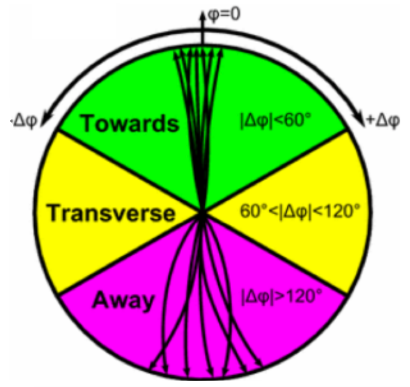


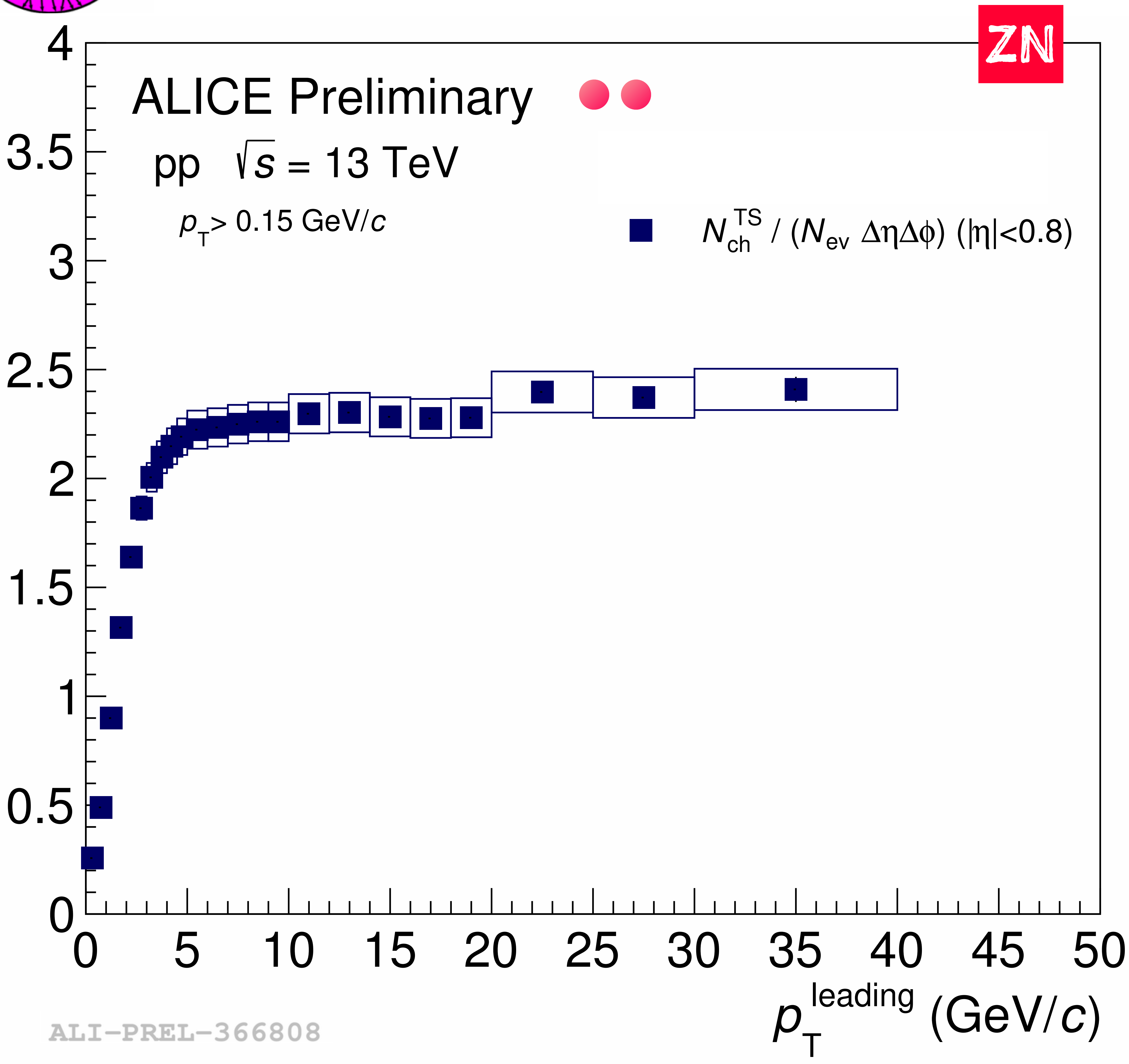


➧ inverse dependence of very forward energy as a function of the number of MPIs in PYTHIA models

Very forward and UE in pp

In the framework of the UE, the transverse multiplicity (separation in azimuthal angle) efficiently trigger on central pp collisions selecting events with a large number of MPIs [3]





[3] Martin, Skands, Farrington, Eur.Phys.J, C**76** (2016) 299

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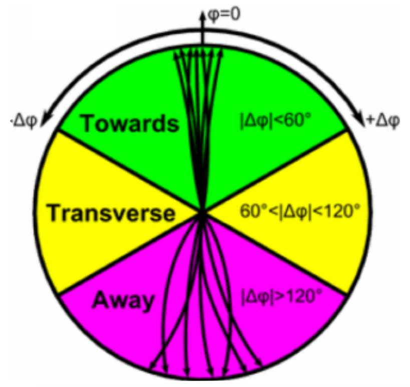
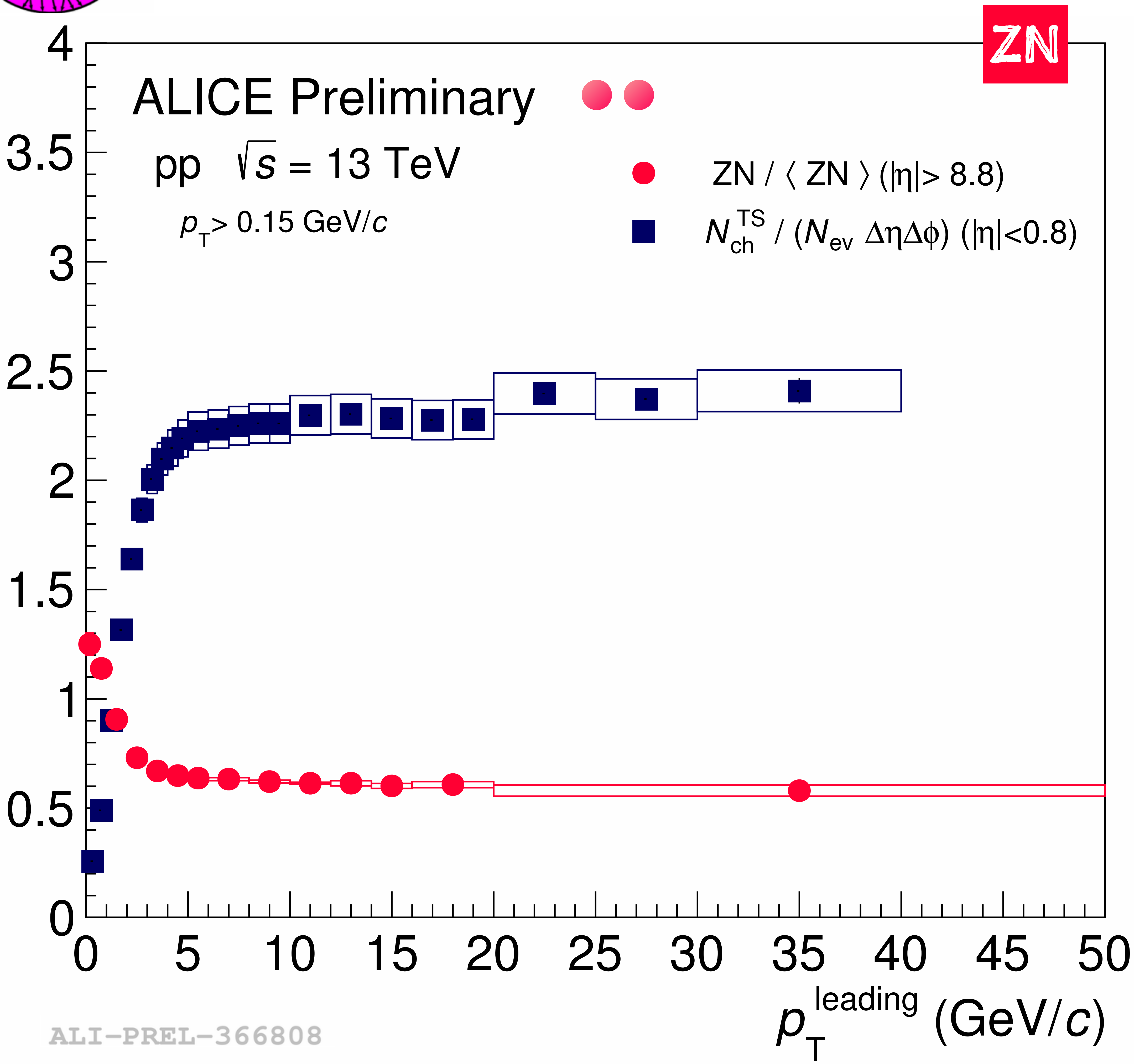


The forward energy (separation in rapidity) shows a complementary behaviour to that observed for transverse charged particle multiplicity



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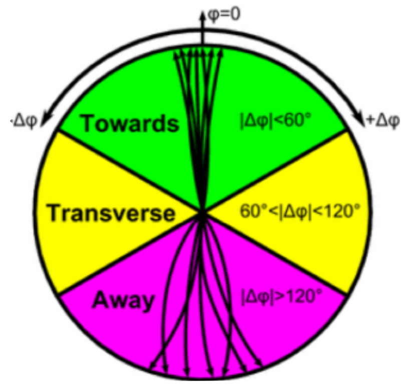

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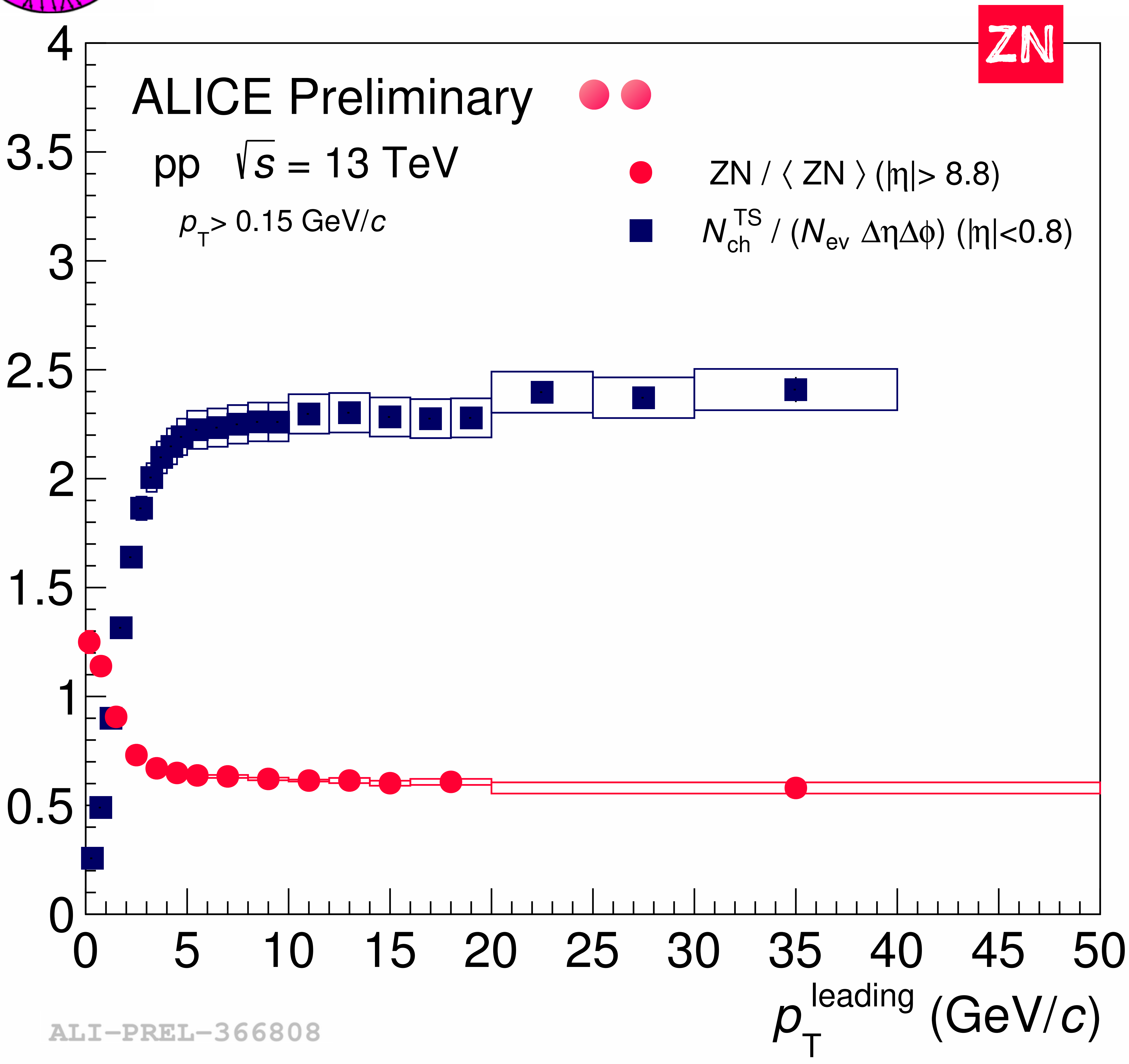
- both observables saturate for leading p_T ~ 5 GeV/c
- saturation in transverse region at midrapidity and in very forward energy is built in the initial stages of the collision



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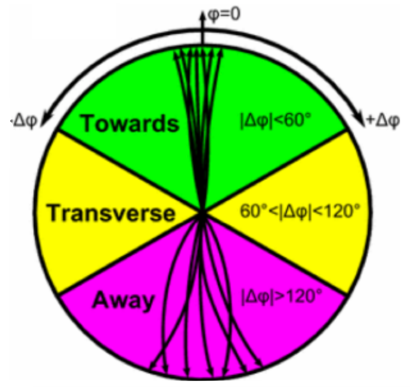

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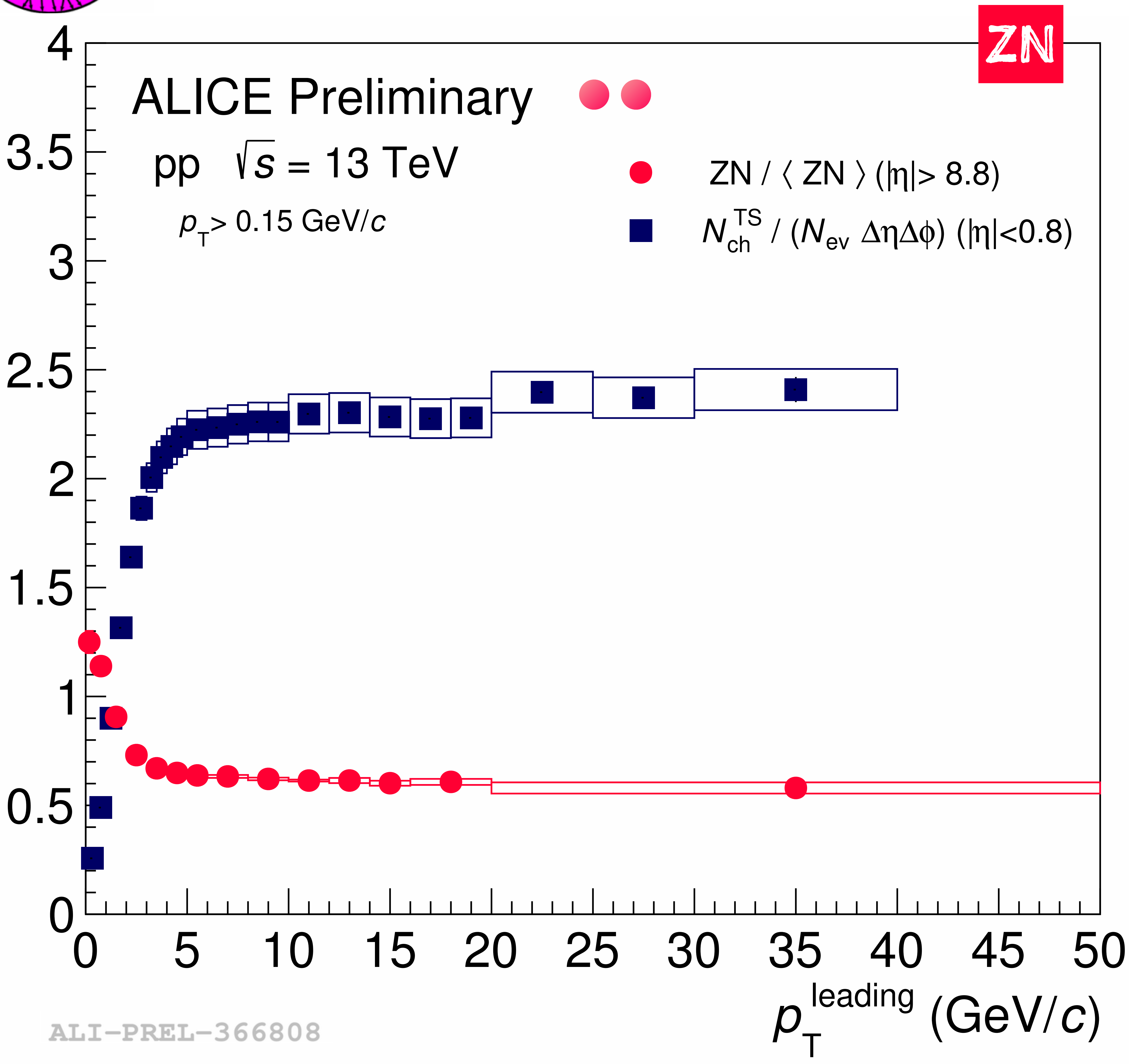

- both observables saturate for leading p_T ~ 5 GeV/c
- saturation in transverse region at midrapidity and in very forward energy is built in the initial stages of the collision

Small forward energy detected selects:
- high multiplicity and high-p_T trigger particle at midrapidity
- larger than average N_{MPI}

[3] Martin, Skands, Farrington, Eur.Phys.J, C**76** (2016) 299

Summary

First results about very forward energy production in correlation with the event activity at midrapidity in pp and in p-Pb collisions (p-fragmentation region) at LHC energies covering more than 18 units in pseudorapidity provide insights on initial stages of pp and p-Pb collisions

- forward-backward energy symmetry is related to charged particle multiplicity at midrapidity in pp
- very forward energy is anticorrelated to midrapidity activity, and to number of MPIs (PYTHIA) in pp and p-Pb collisions
- tested models do not reproduce the results: challenge remains to reproduce beam remnants and very forward energy emission
- UE and forward energy studies show largely suppressed contribution from final state correlations: the observed saturation is built in the initial stages of the collision