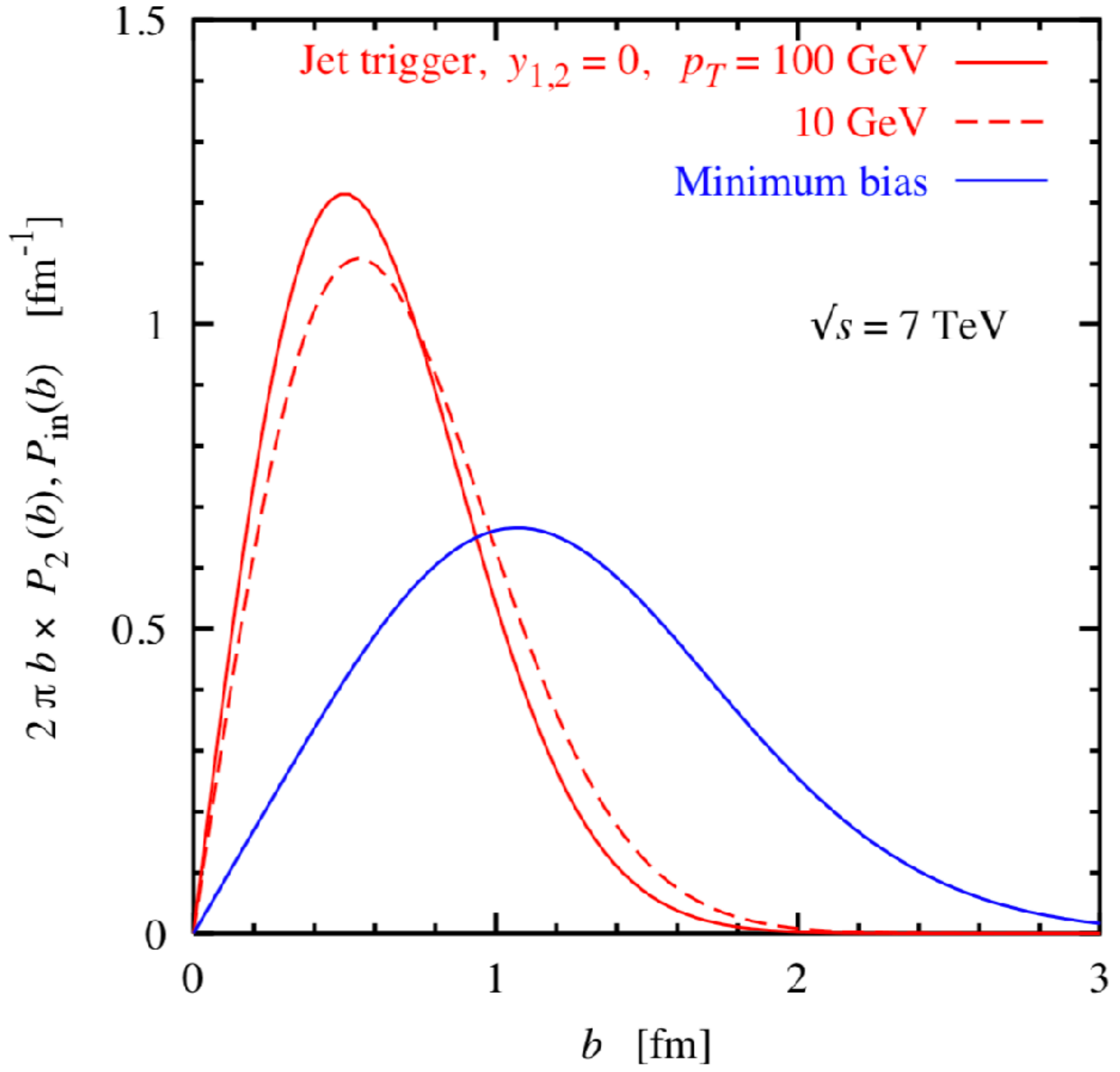
Particle production at midrapidity in correlation with the very forward energy in pp collisions with ALICE ZDC

C. Oppedisano
for the ALICE Collaboration

pp collisions

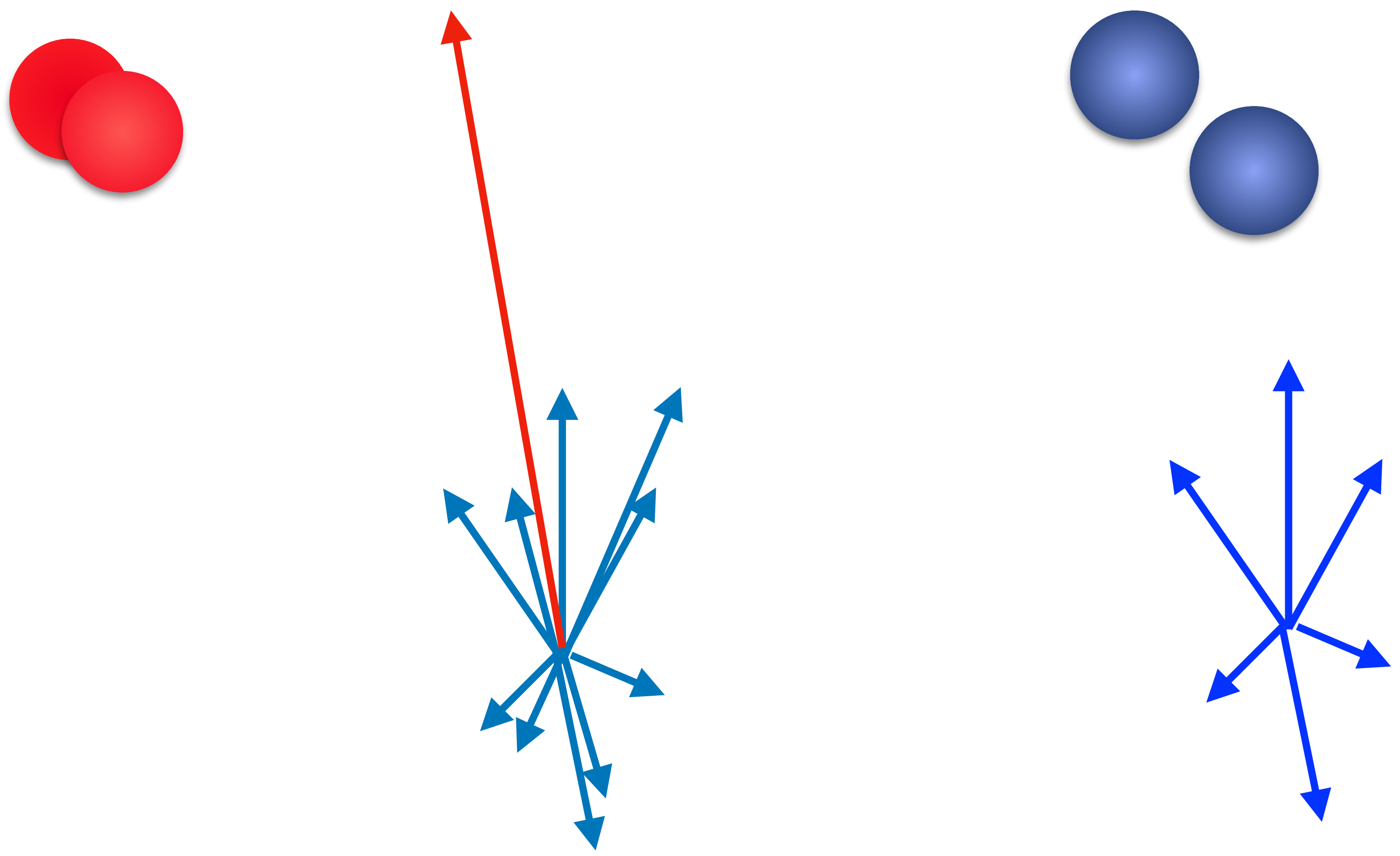
Particle production at **midrapidity**

➧ selecting events with higher than average multiplicity or with a high p_T particle corresponds to selecting smaller than average impact parameters, and a larger than average number of Multi Parton Interactions (MPI).



M. Strikman et al., PRD 83 054012 (2011)

impact parameter distributions of inelastic pp collisions at $\sqrt{s}$ = 7 TeV



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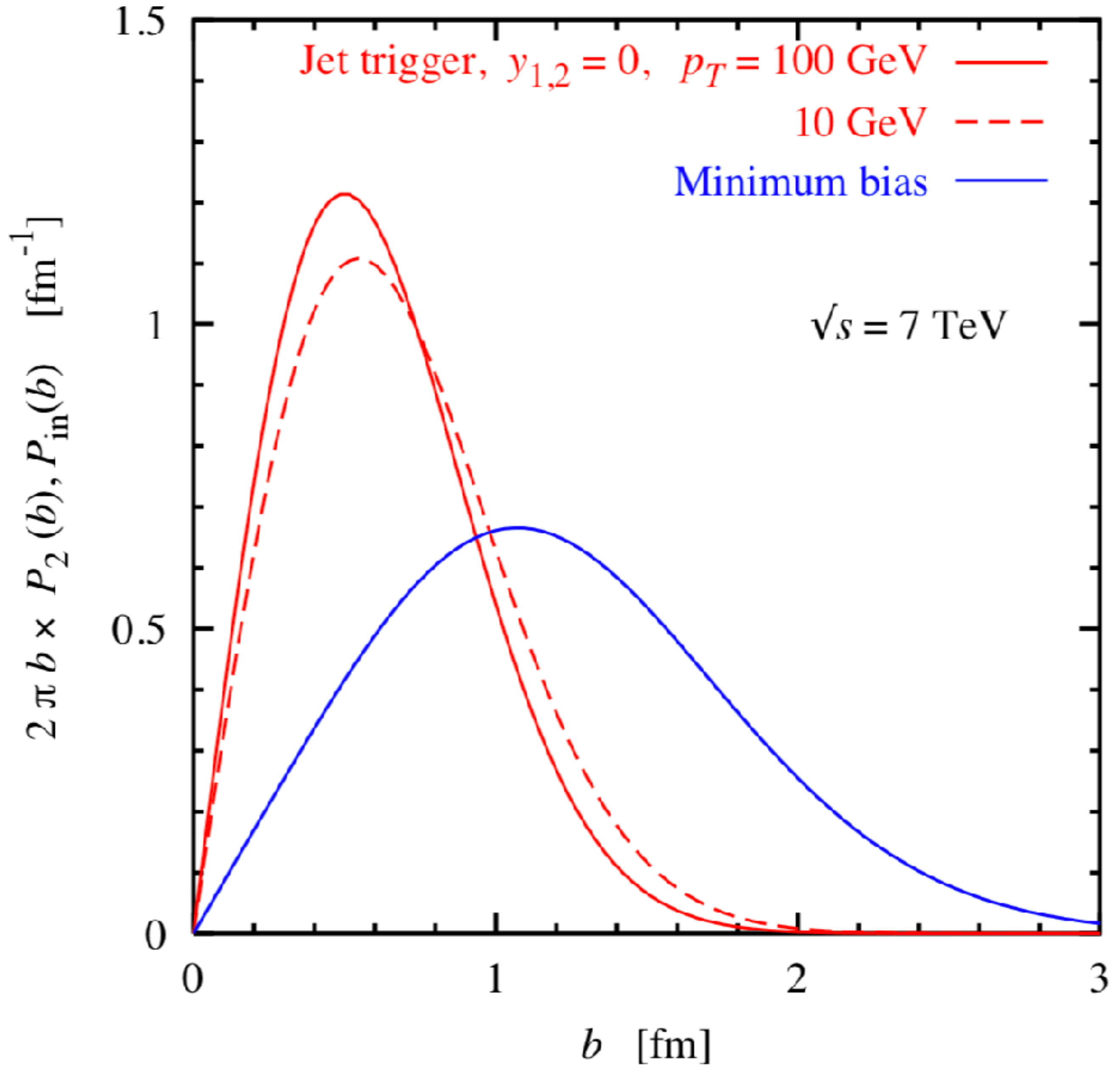

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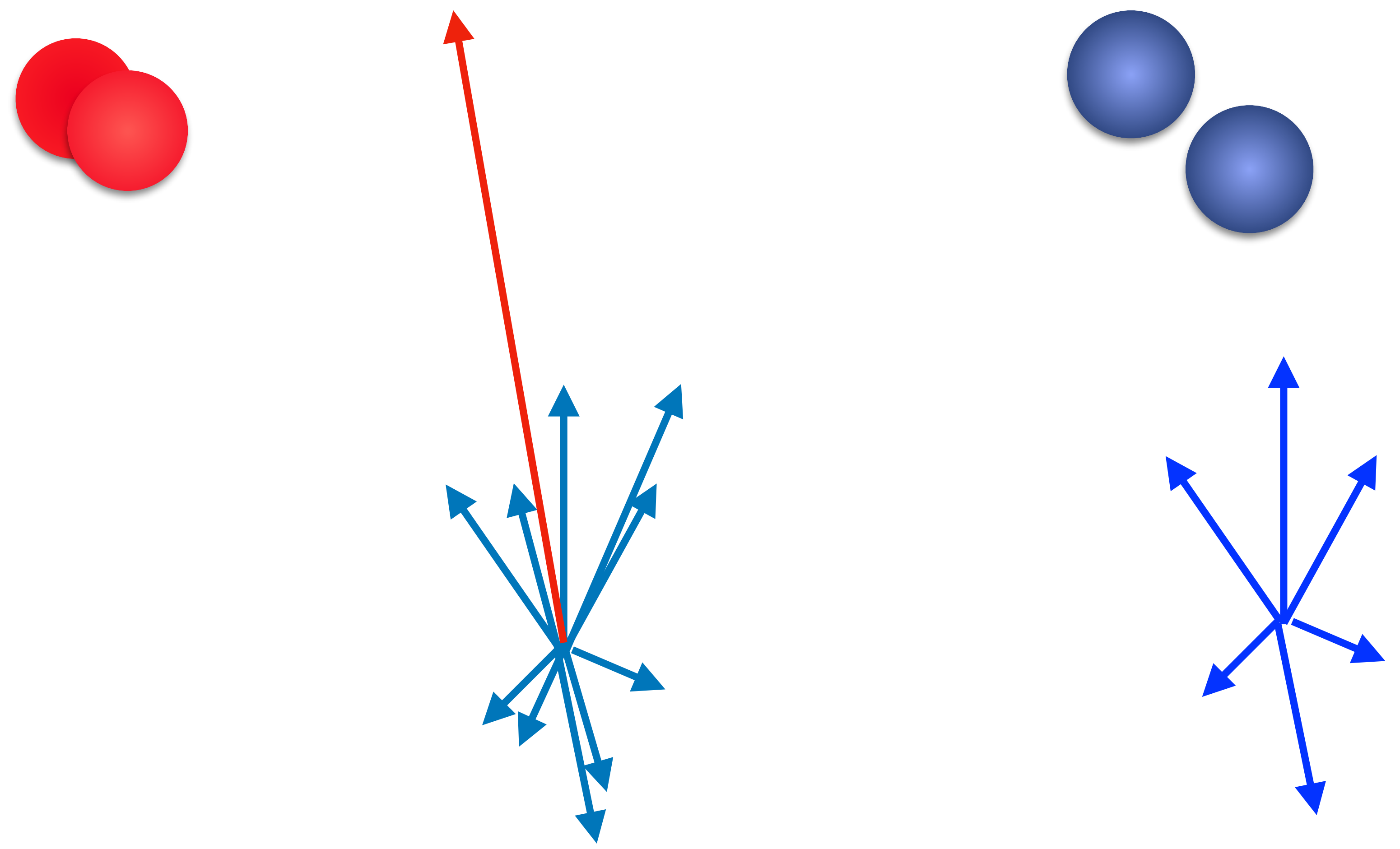

Energy at **very forward rapidities**

- a powerful tool for characterising the proton fragmentation in pp and p-Pb collisions

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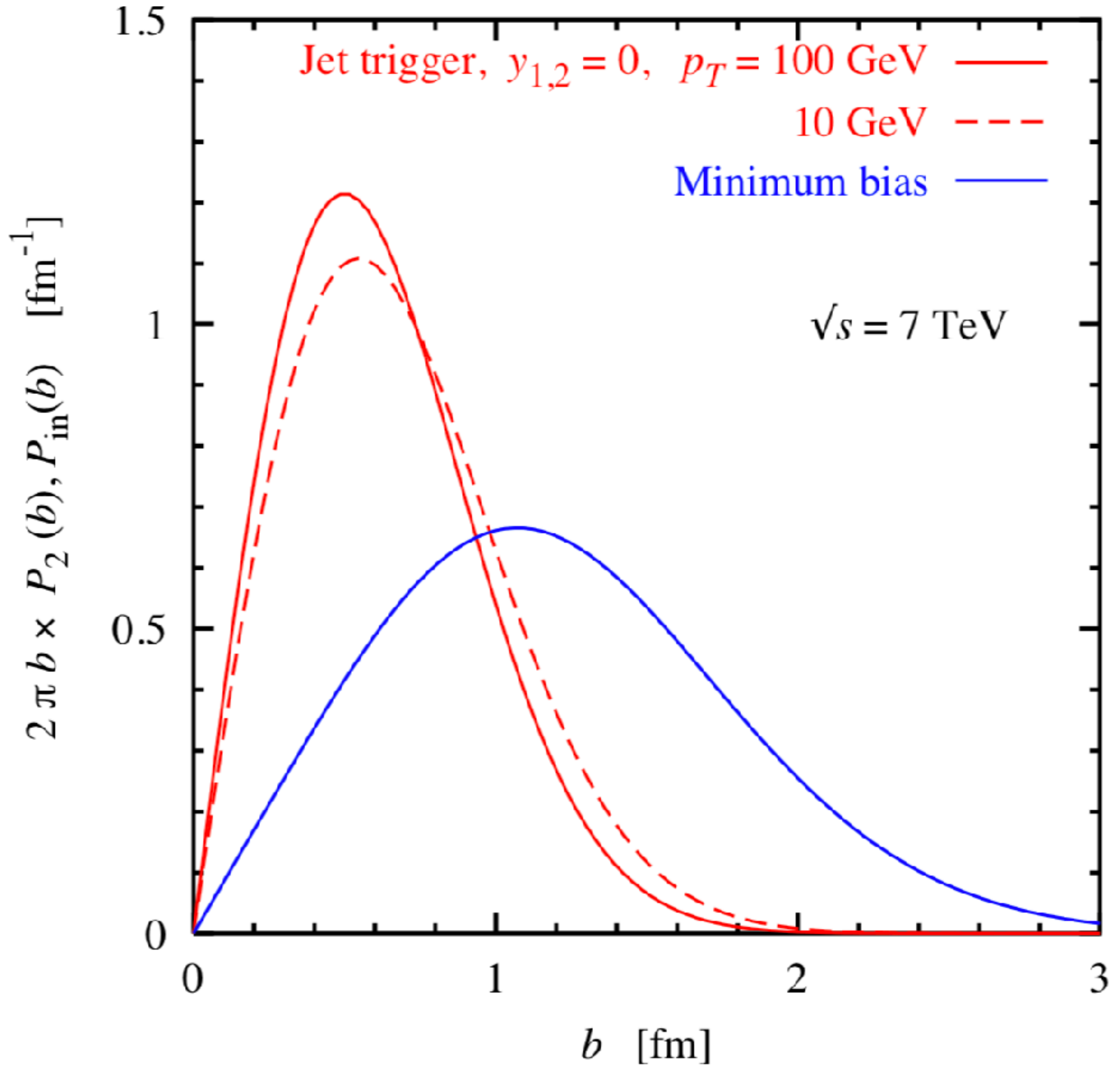

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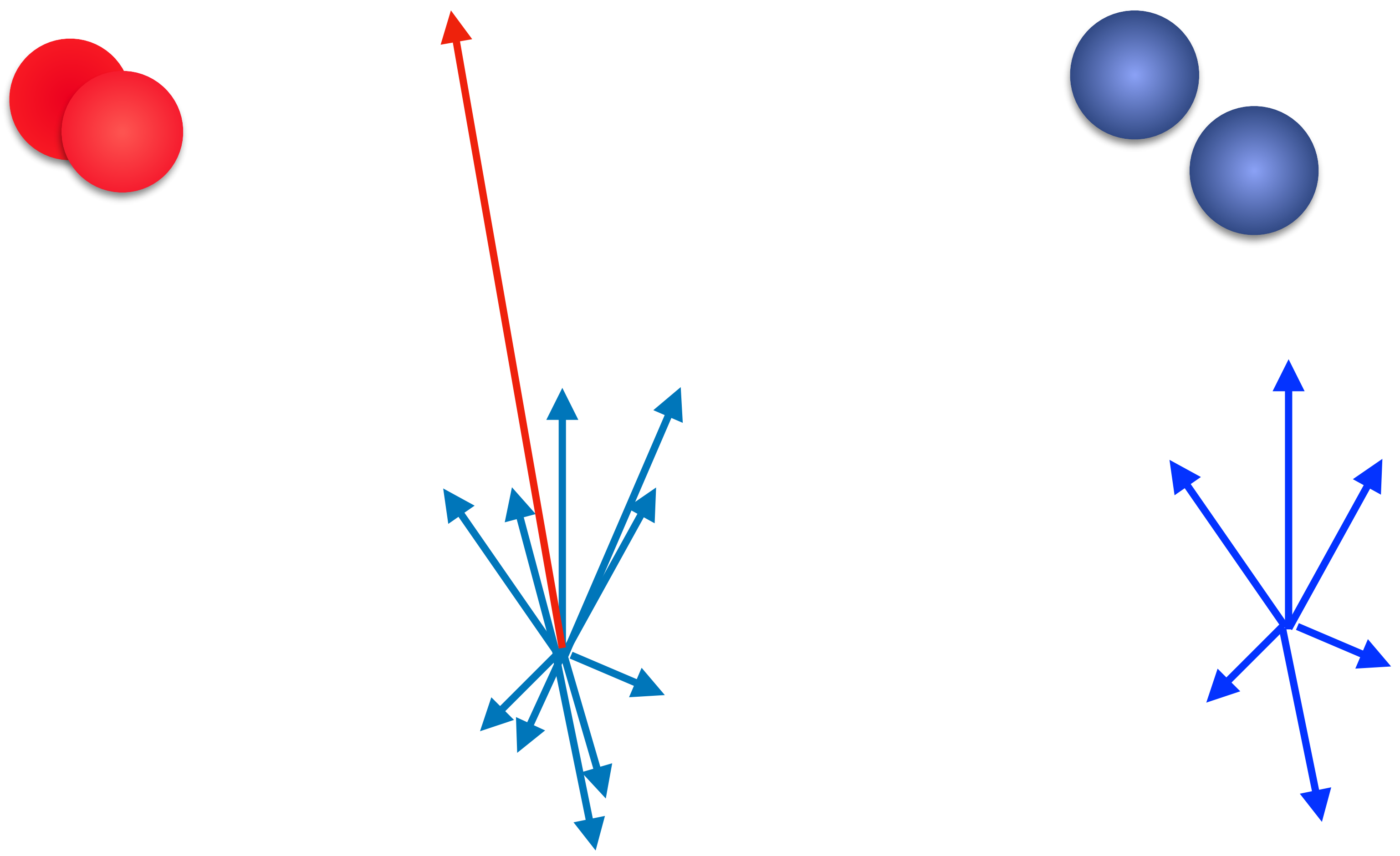
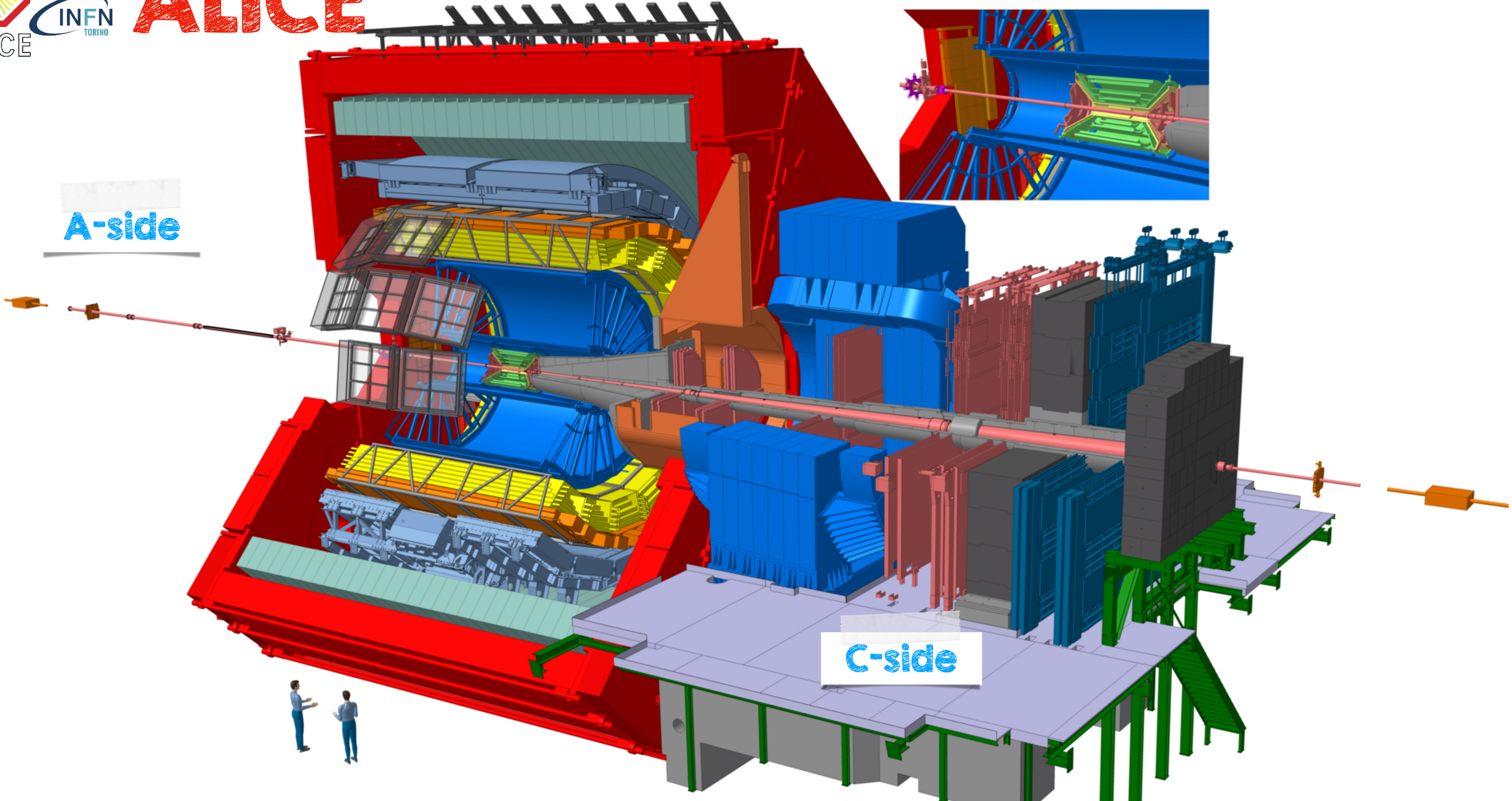


Energy at **very forward rapidities**

- a powerful tool for characterising the proton fragmentation in pp and p-Pb collisions

The correlation between **very forward** energy and particle production at **midrapidity** provides direct insights into initial stages and evolution of the collision

ALICE



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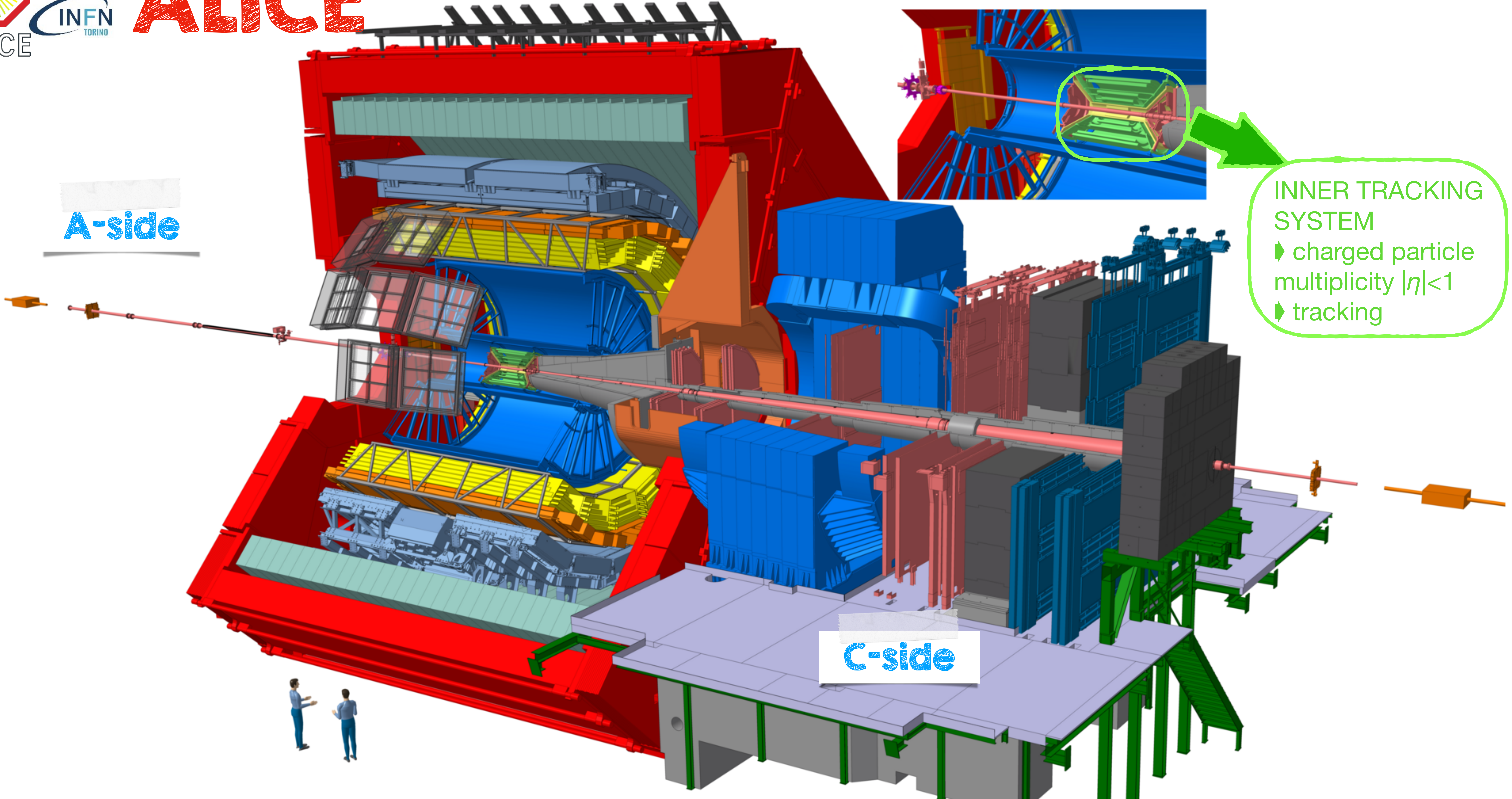
A-side
C-side
INNER TRACKING SYSTEM
➧ charged particle multiplicity |η|<1
➧ tracking

ALICE

A-side
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TIME PROJECTION CHAMBER
tracking and p_T measurement in $|\eta|<0.8$
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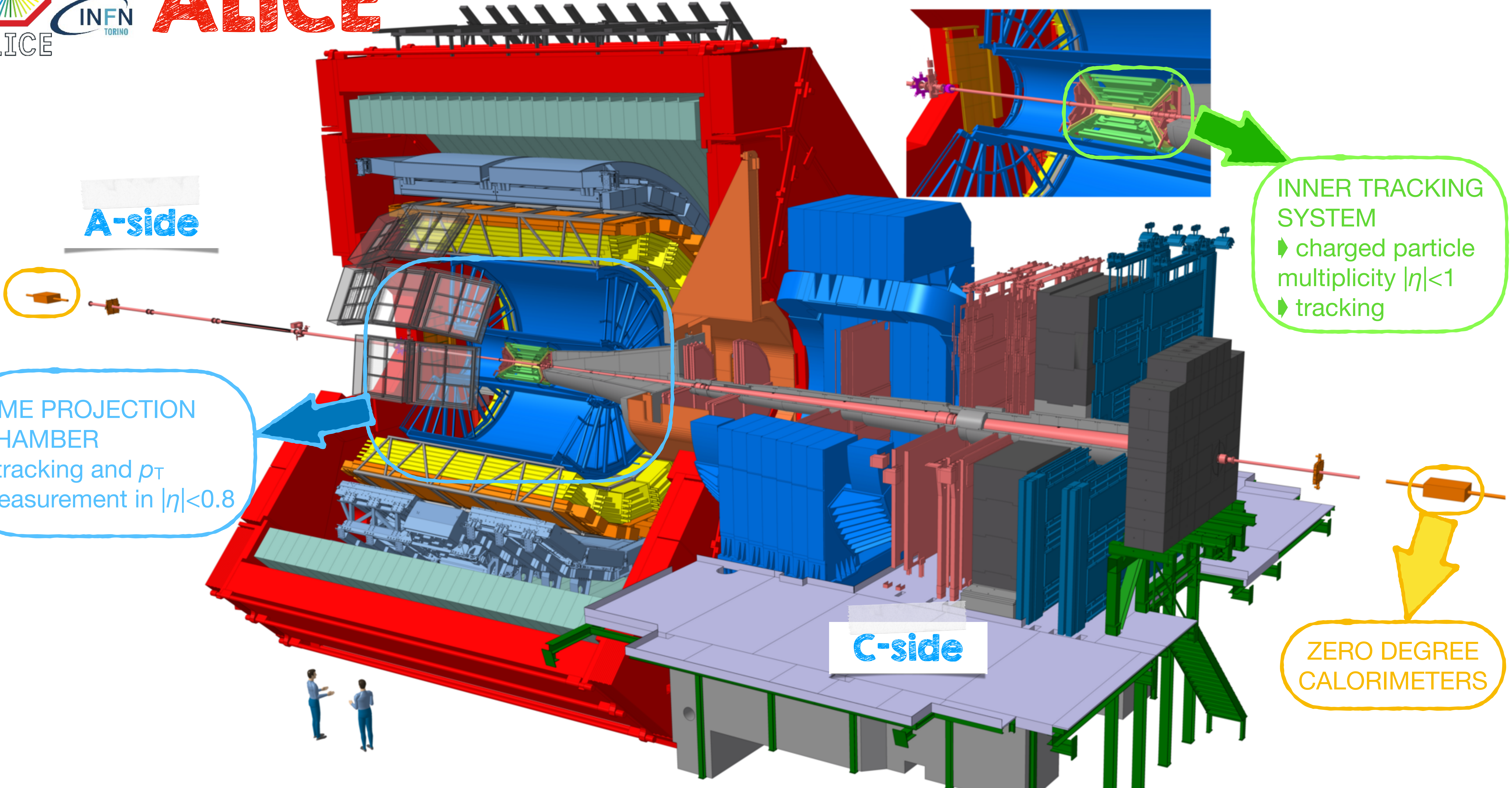

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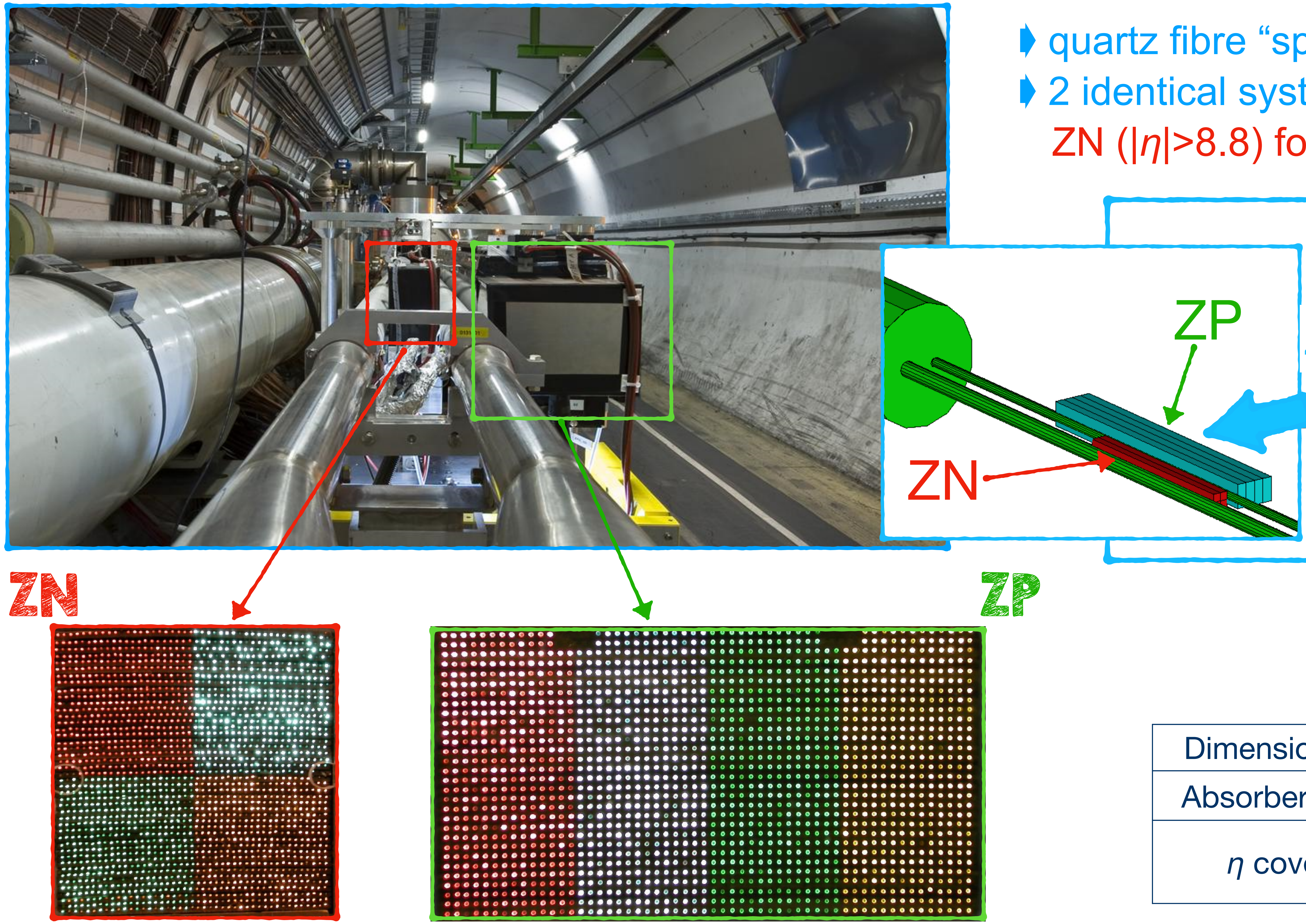
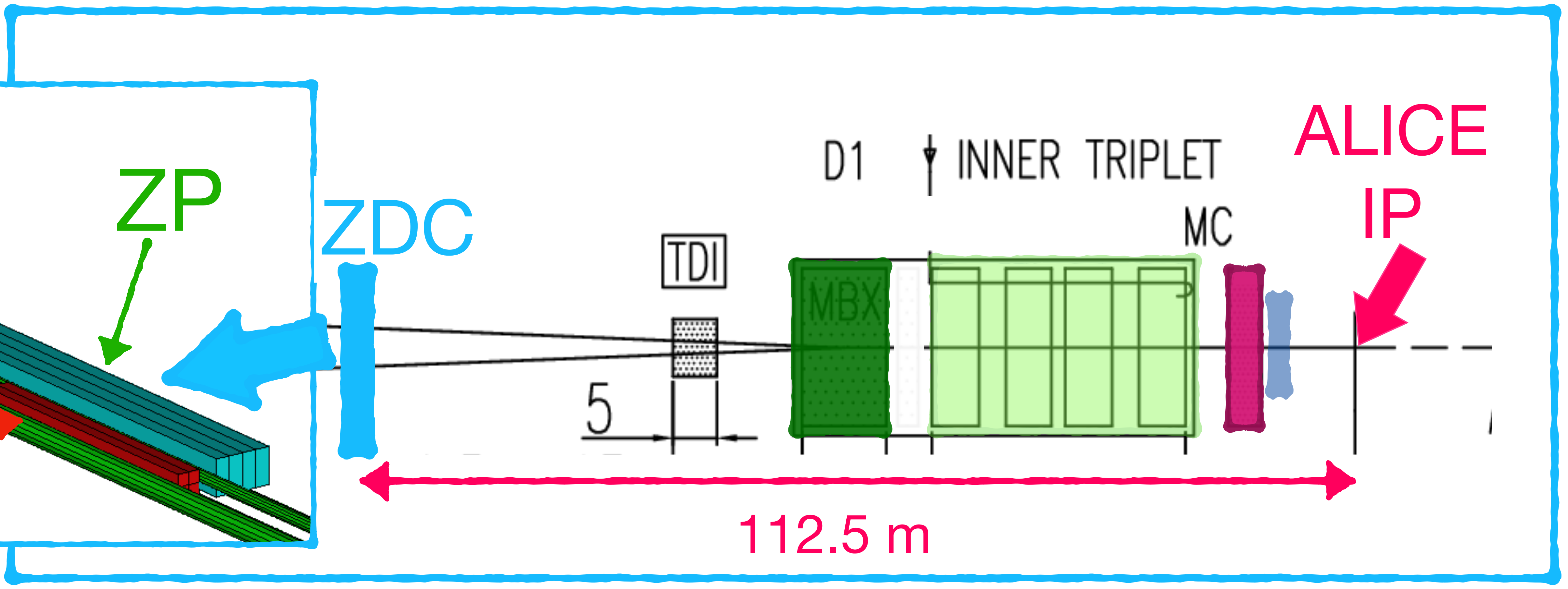
C-side
ZERO DEGREE CALORIMETERS

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



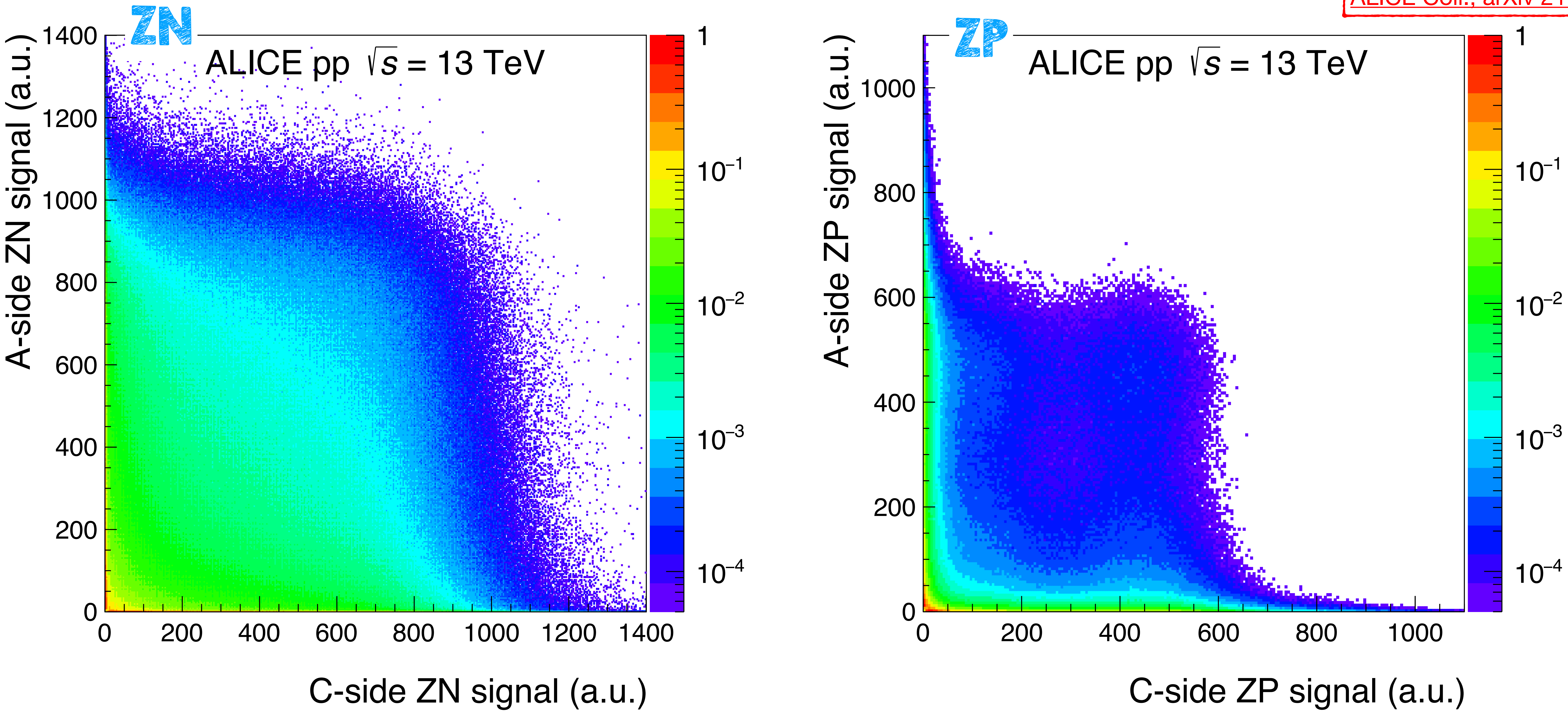


	ZN	ZP
Dimensions (cm^3)	7.04 x 7.04 x 100	12 x 22.4 x 150
Absorber material	W alloy	brass
η coverage	|η|>8.8	depends on LHC optics

Forward-backward energy in pp

The emission of very forward energy can be investigated over a η gap of more than 18 units

ALICE Coll., arXiv 2107.10757



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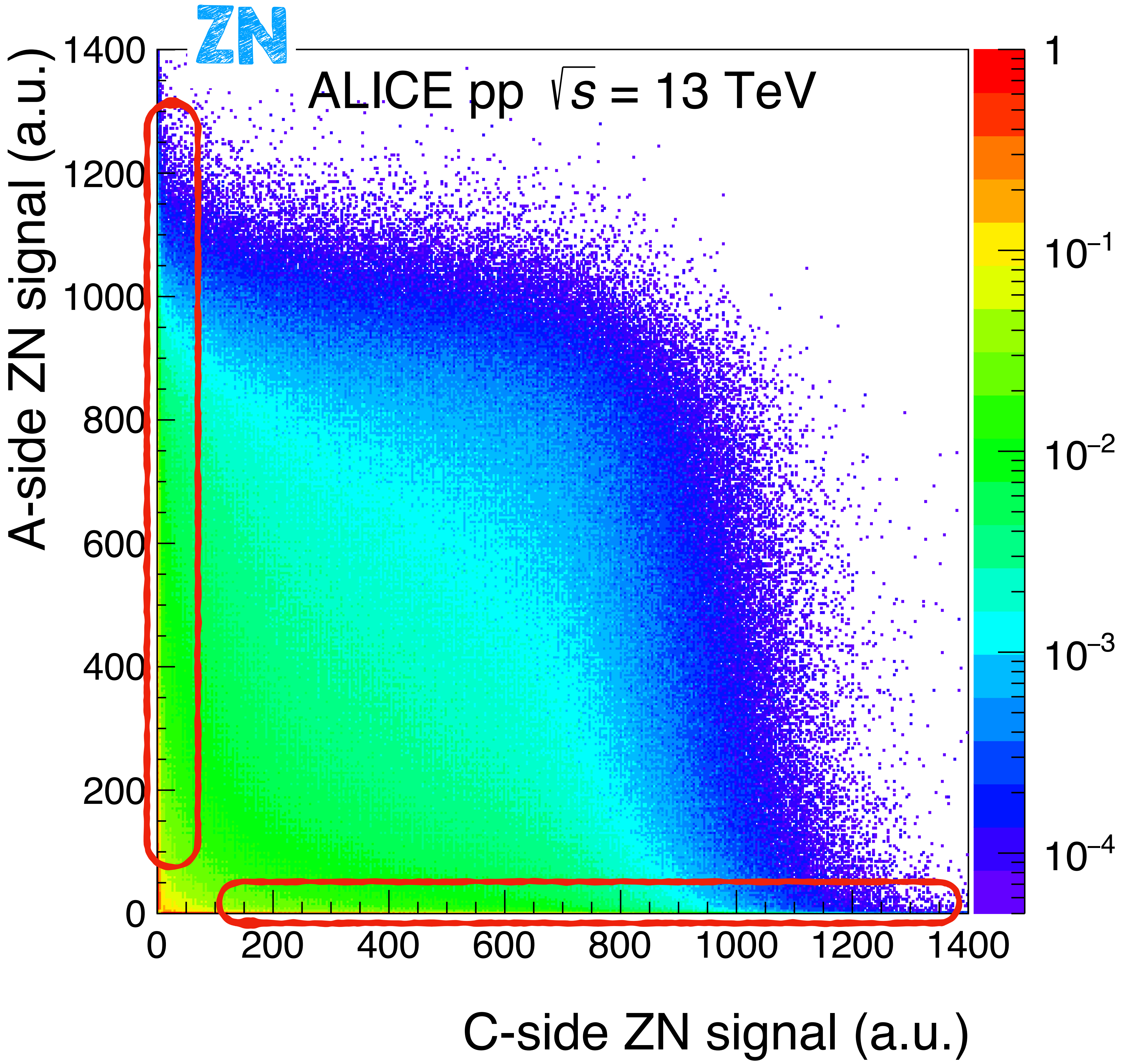

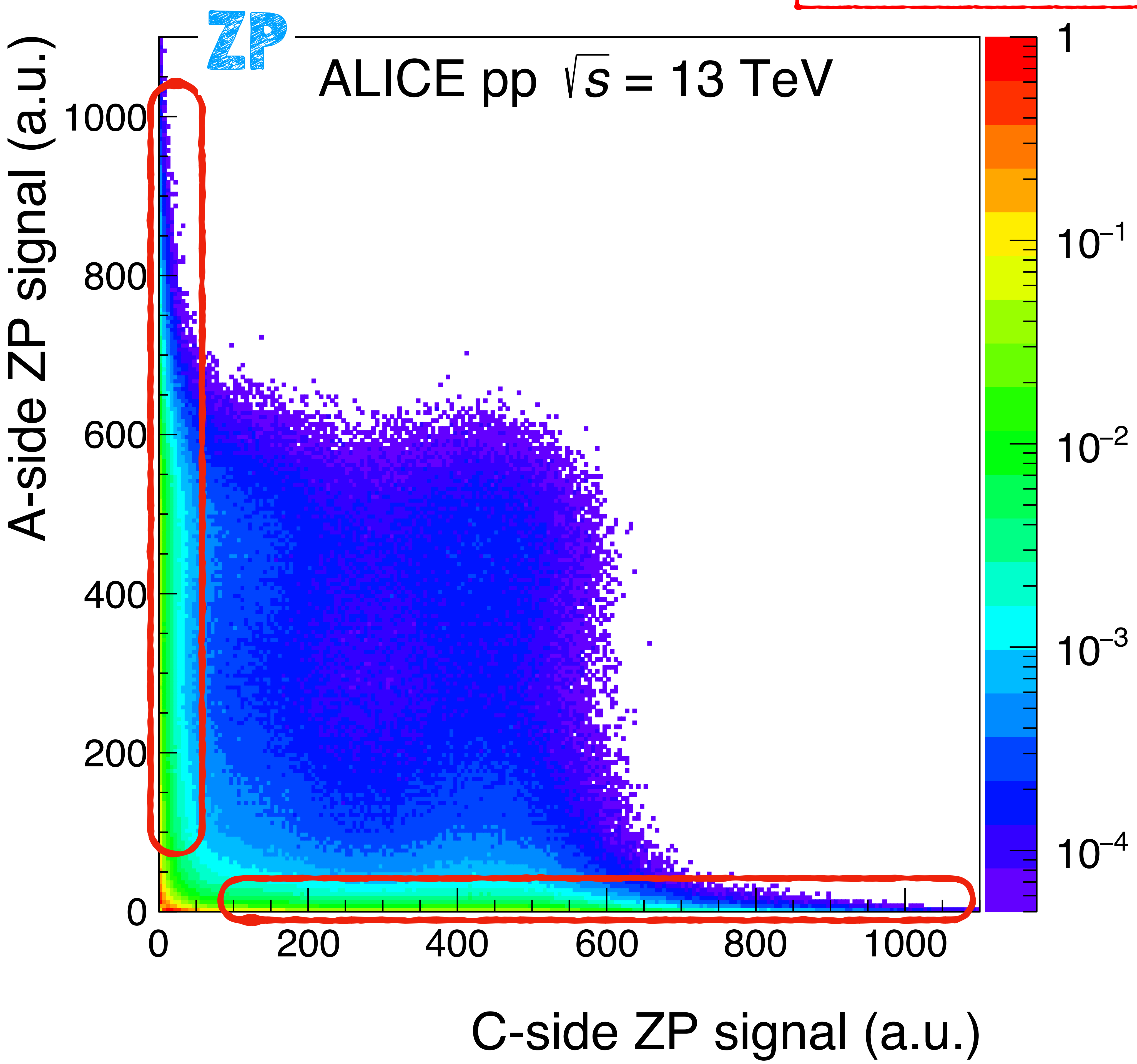

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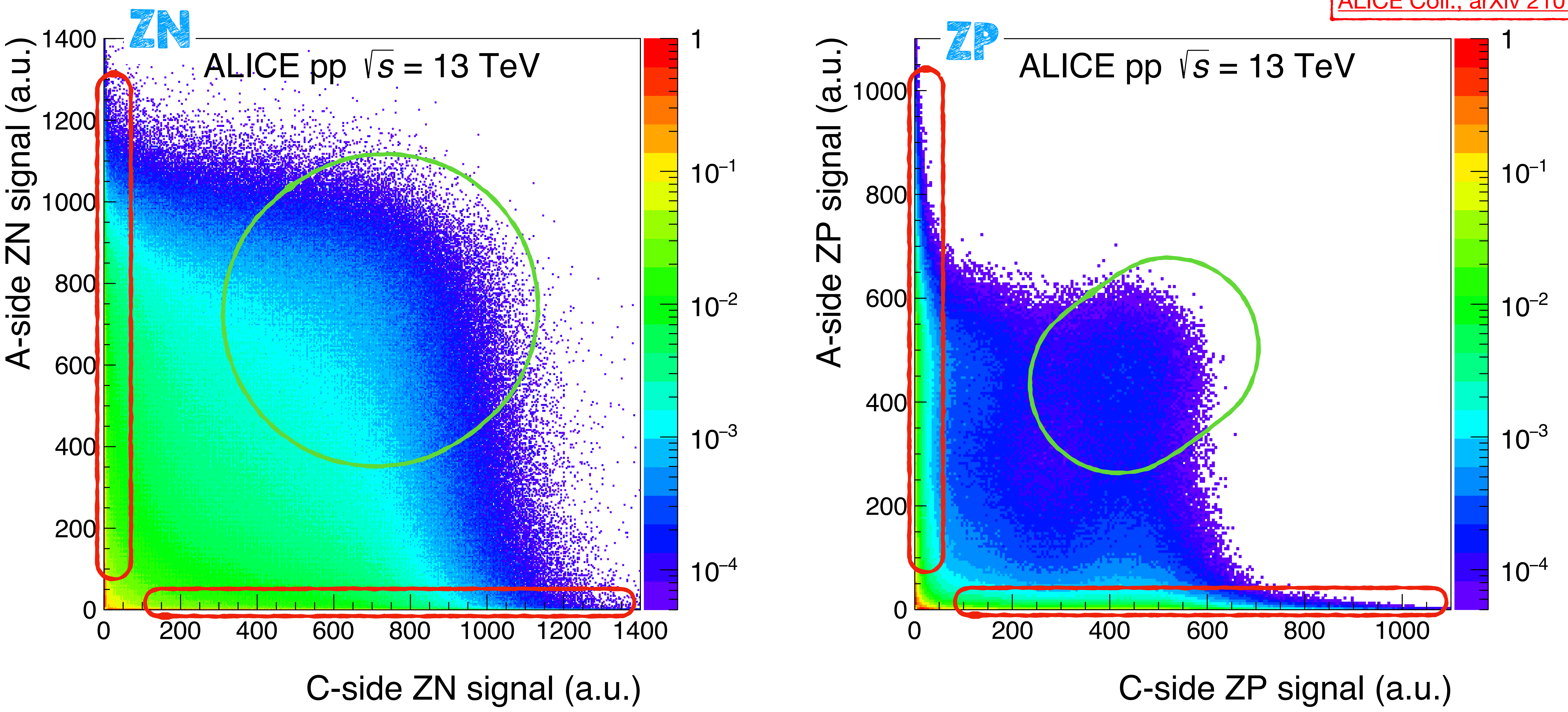


Forward-backward correlations are characterised by:

- a large fraction of events with high energy emission only on one side
- a smaller fraction of correlated events

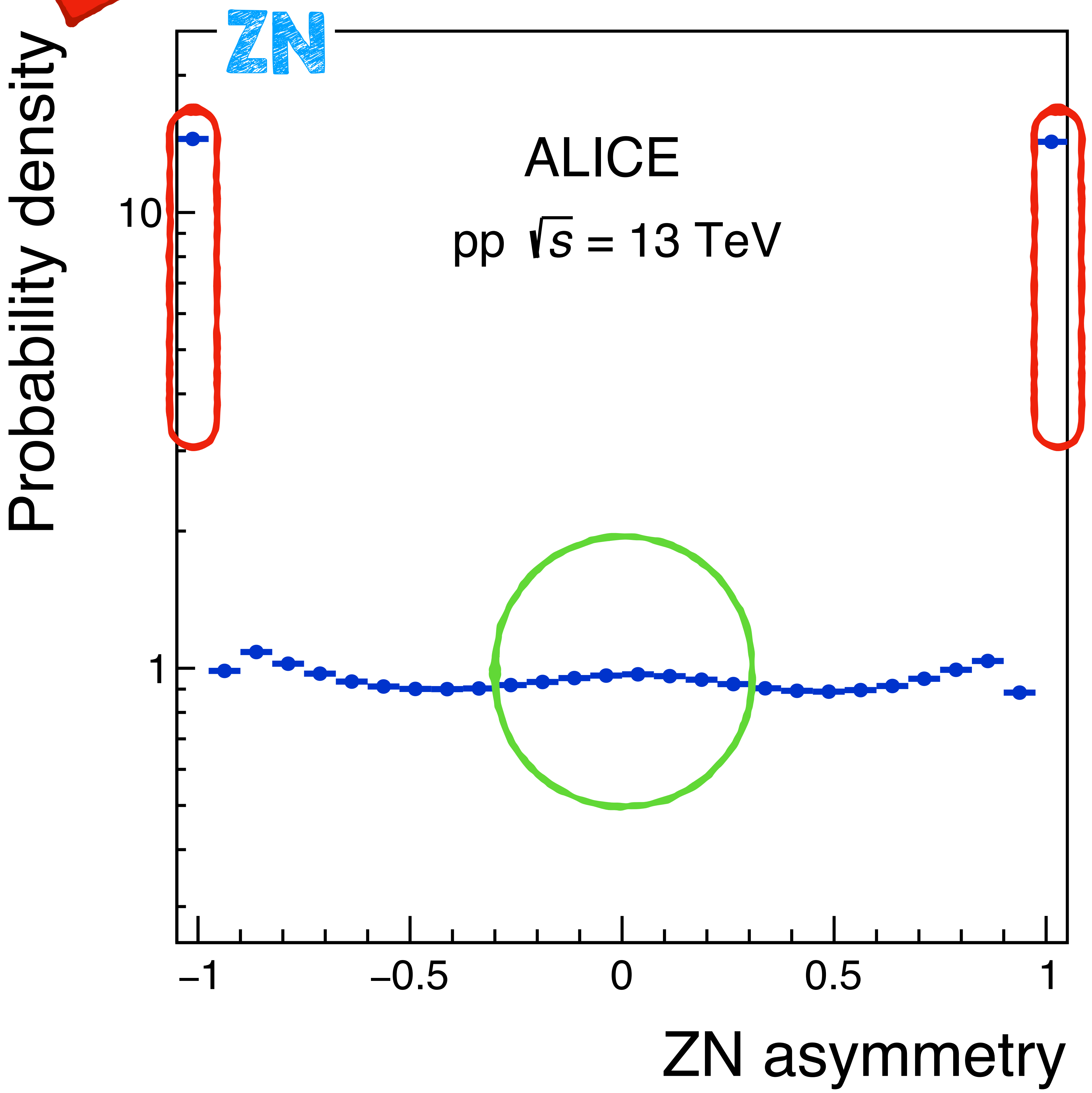
Asymmetry

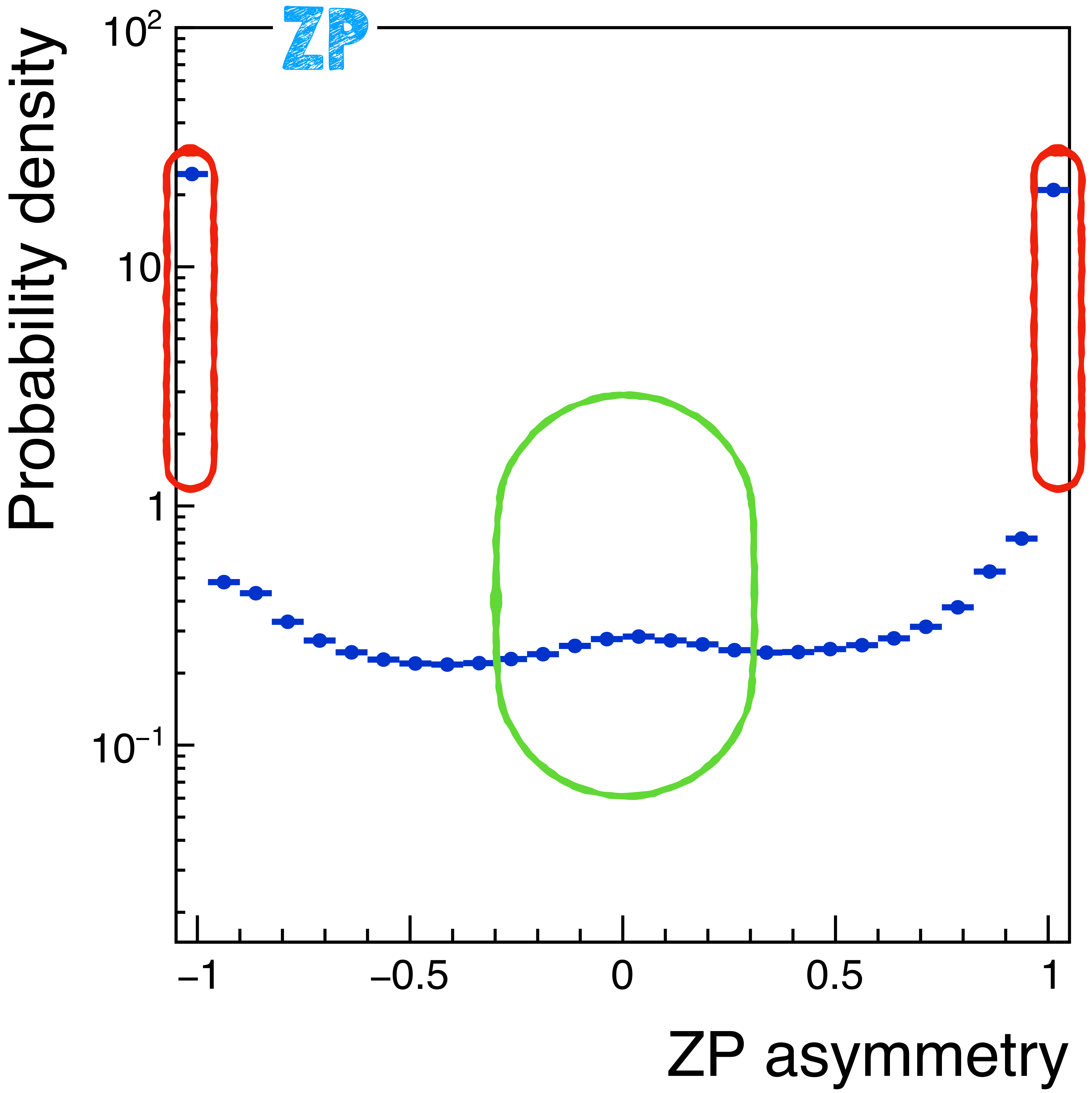
ALICE Coll., arXiv 2107.10757

NEW

$$\text{ZN asymmetry} = \frac{ZNA - ZNC}{ZNA + ZNC}$$

$$\text{ZP asymmetry} = \frac{ZPA - ZPC}{ZPA + ZPC}$$





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- smaller fraction of correlated events: asymmetry ~ 0

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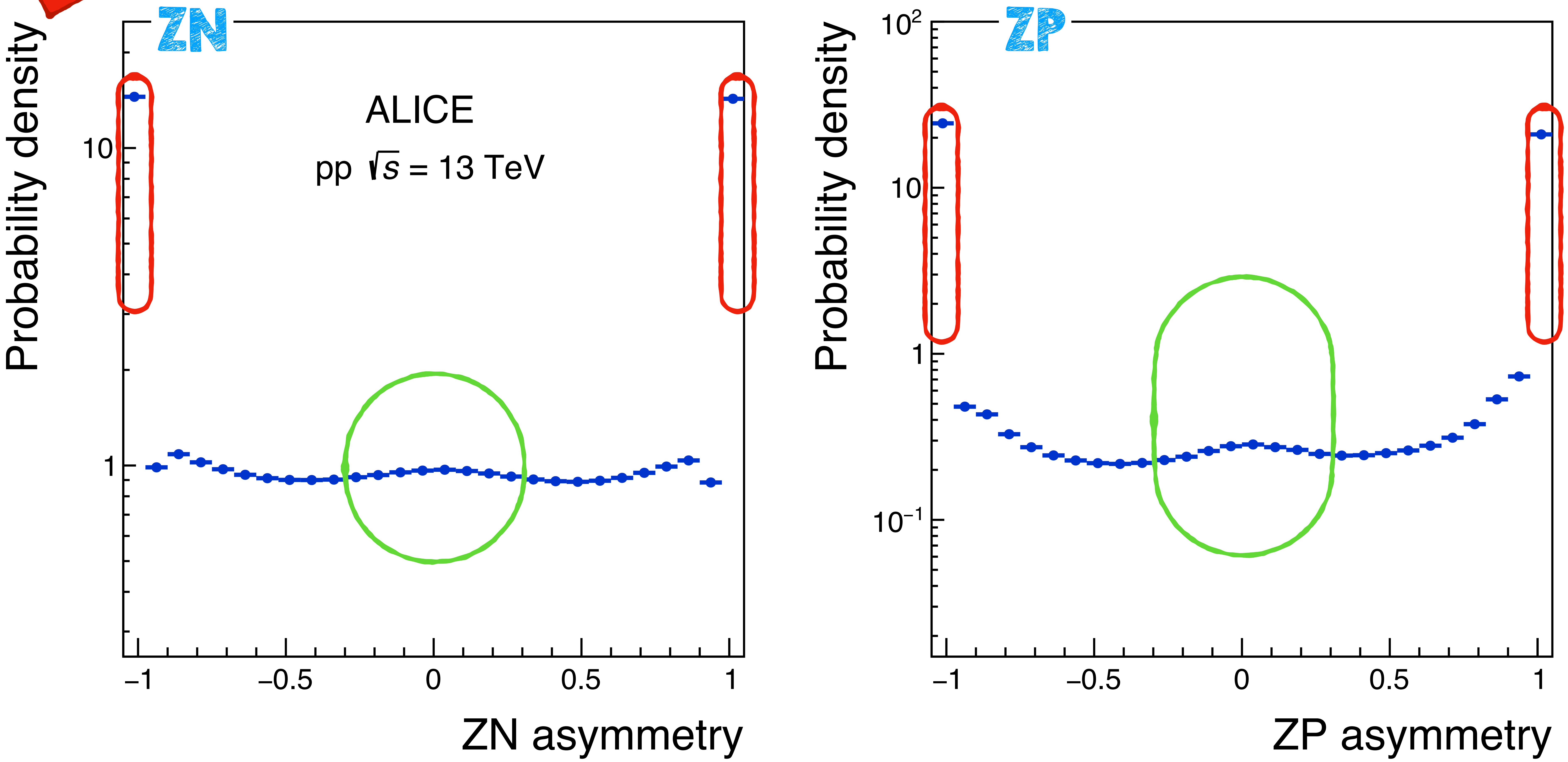

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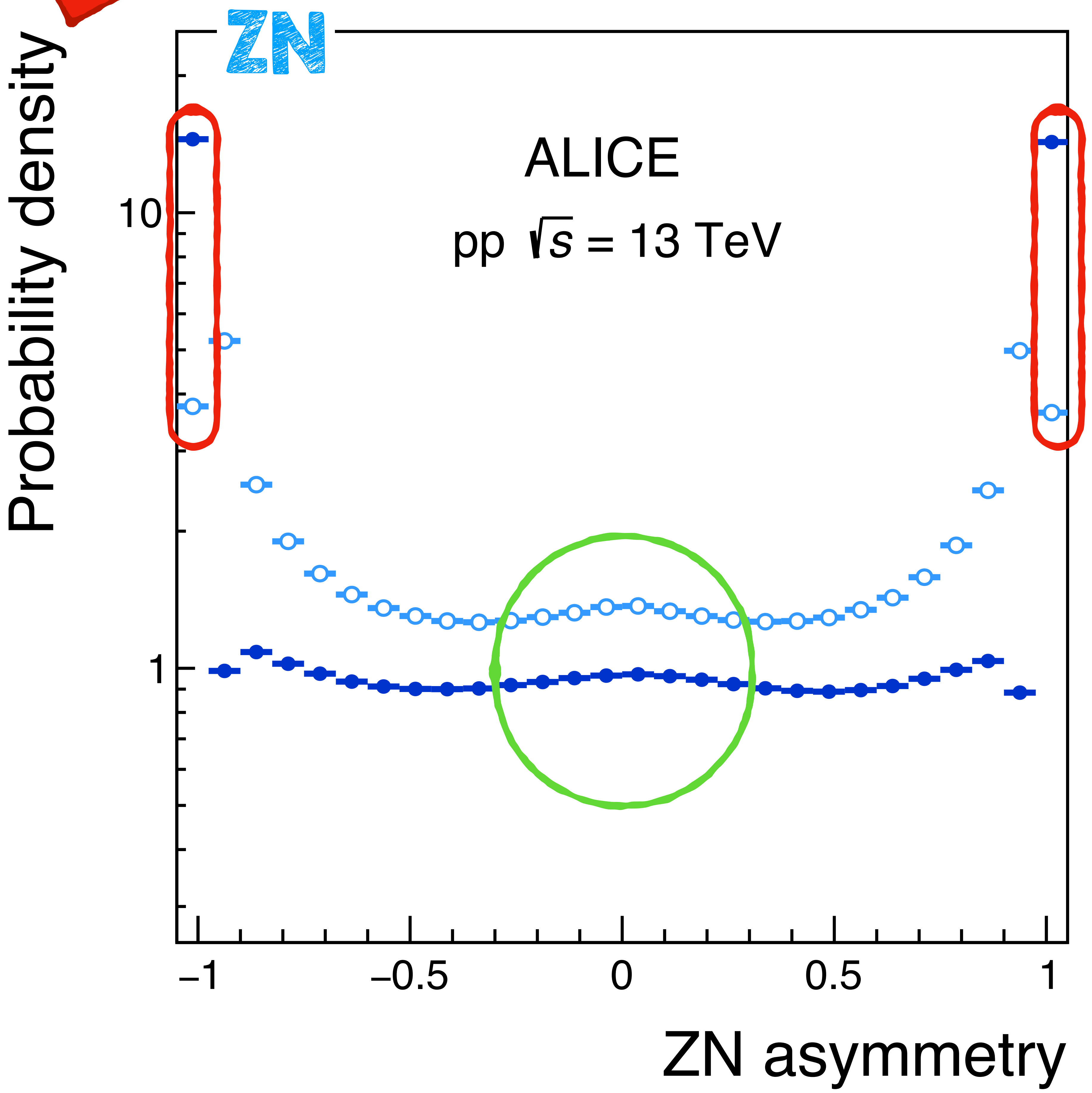

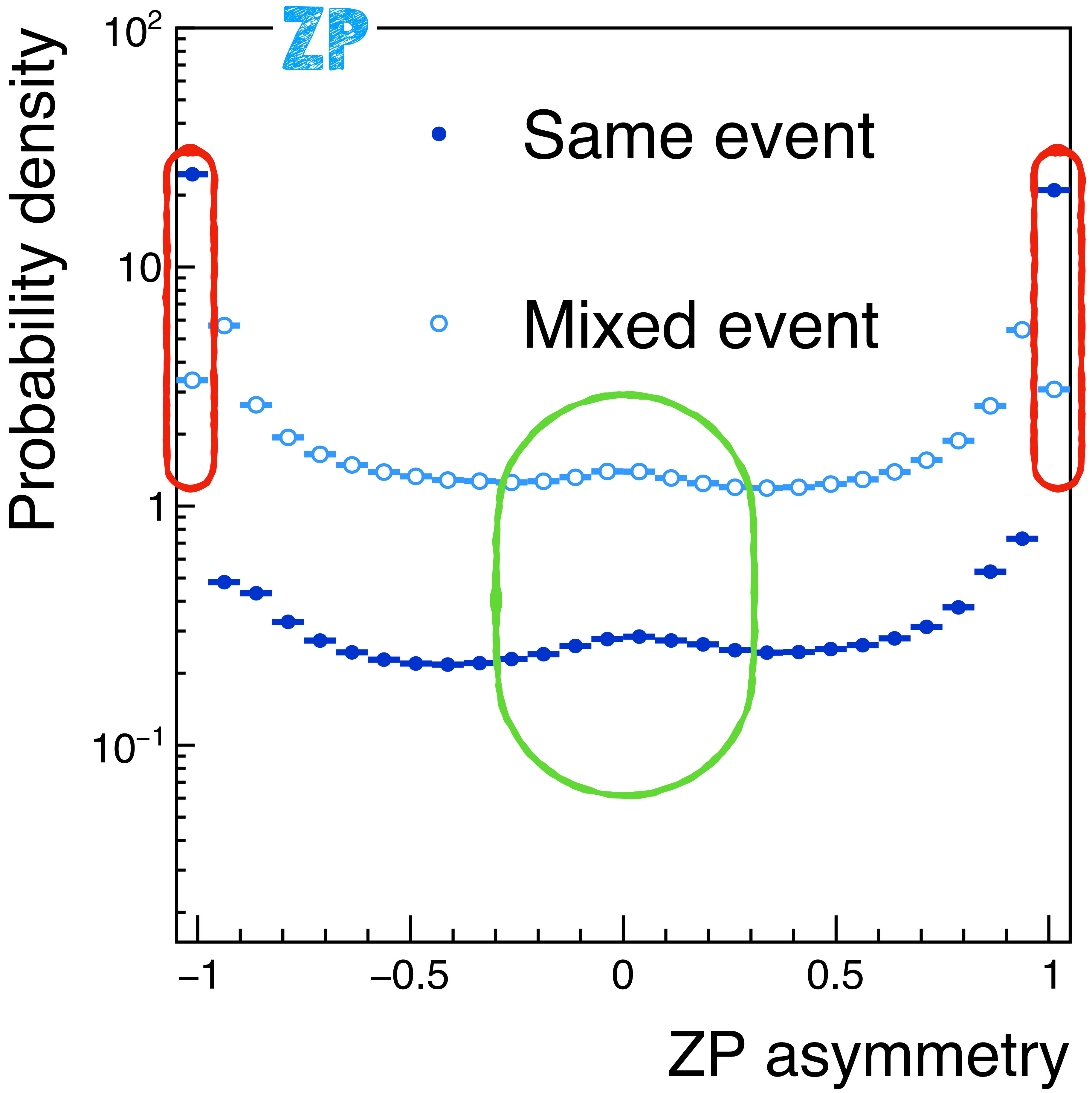

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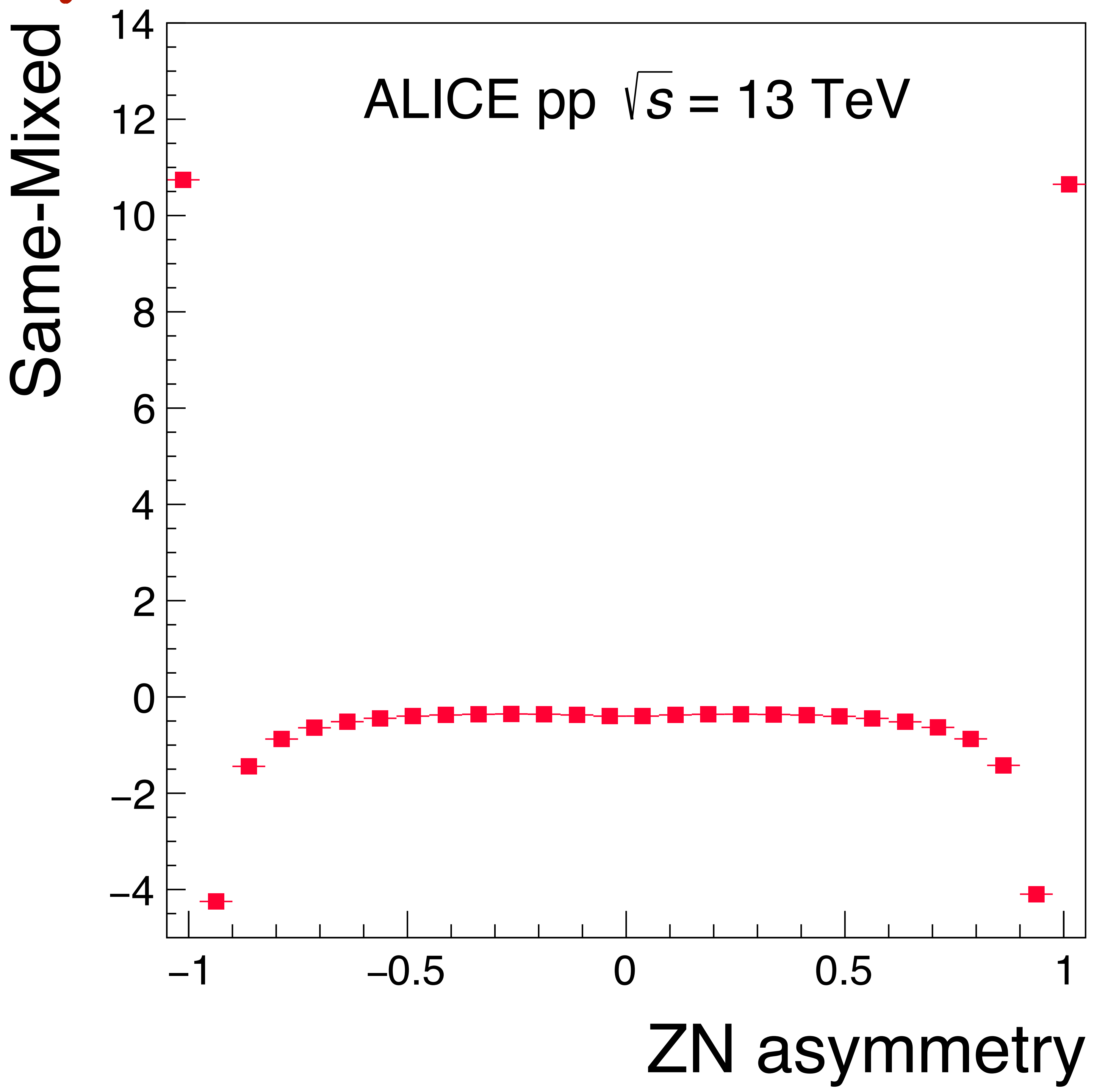

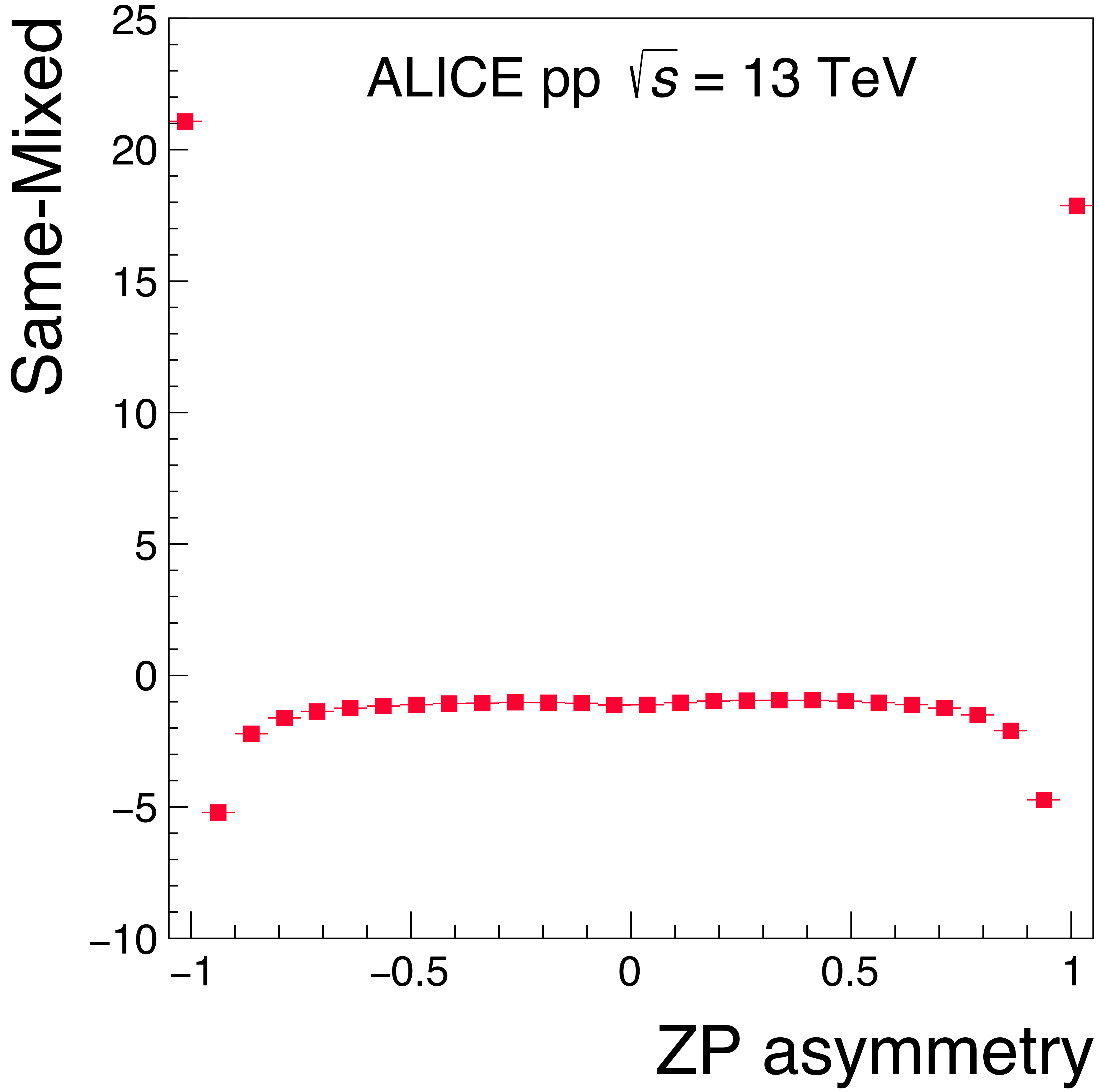

Mixed - same distributions ➧ the prevailing feature remains the presence of asymmetric events, while the peak around null asymmetry is washed out both in data and in simulated events

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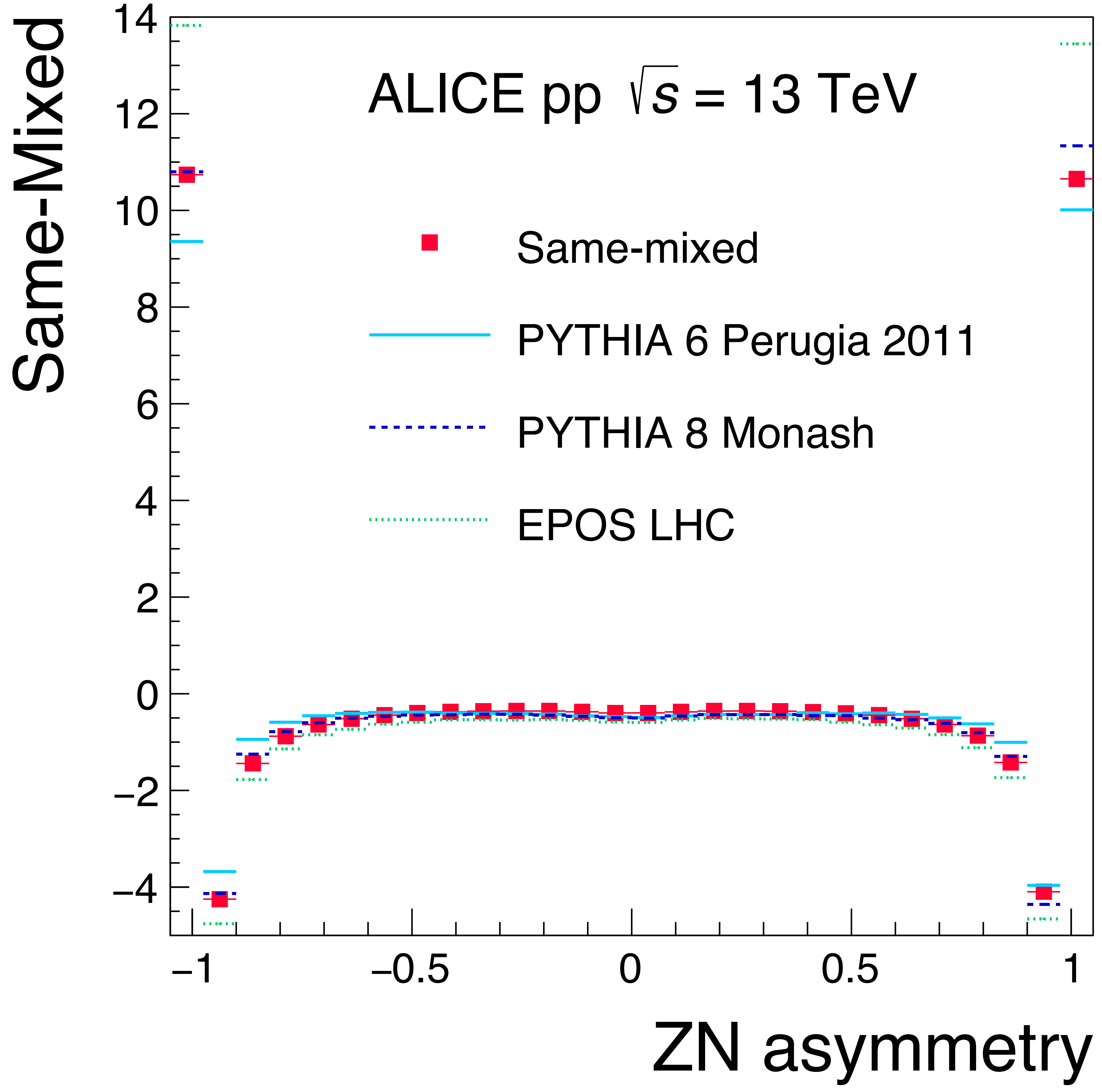

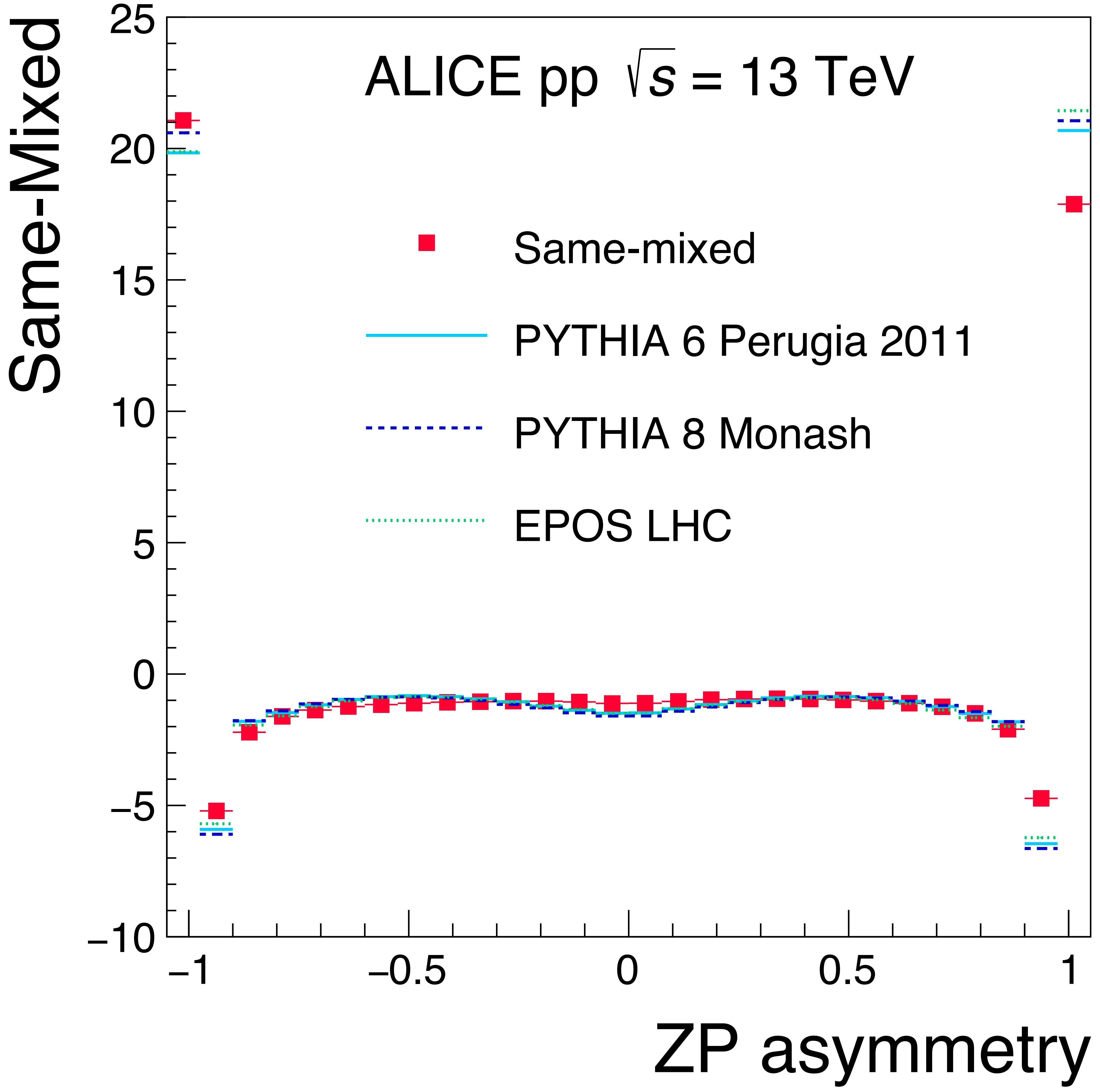

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Forward-backward correlation

Average signal on one side as a function of the signal on the other side

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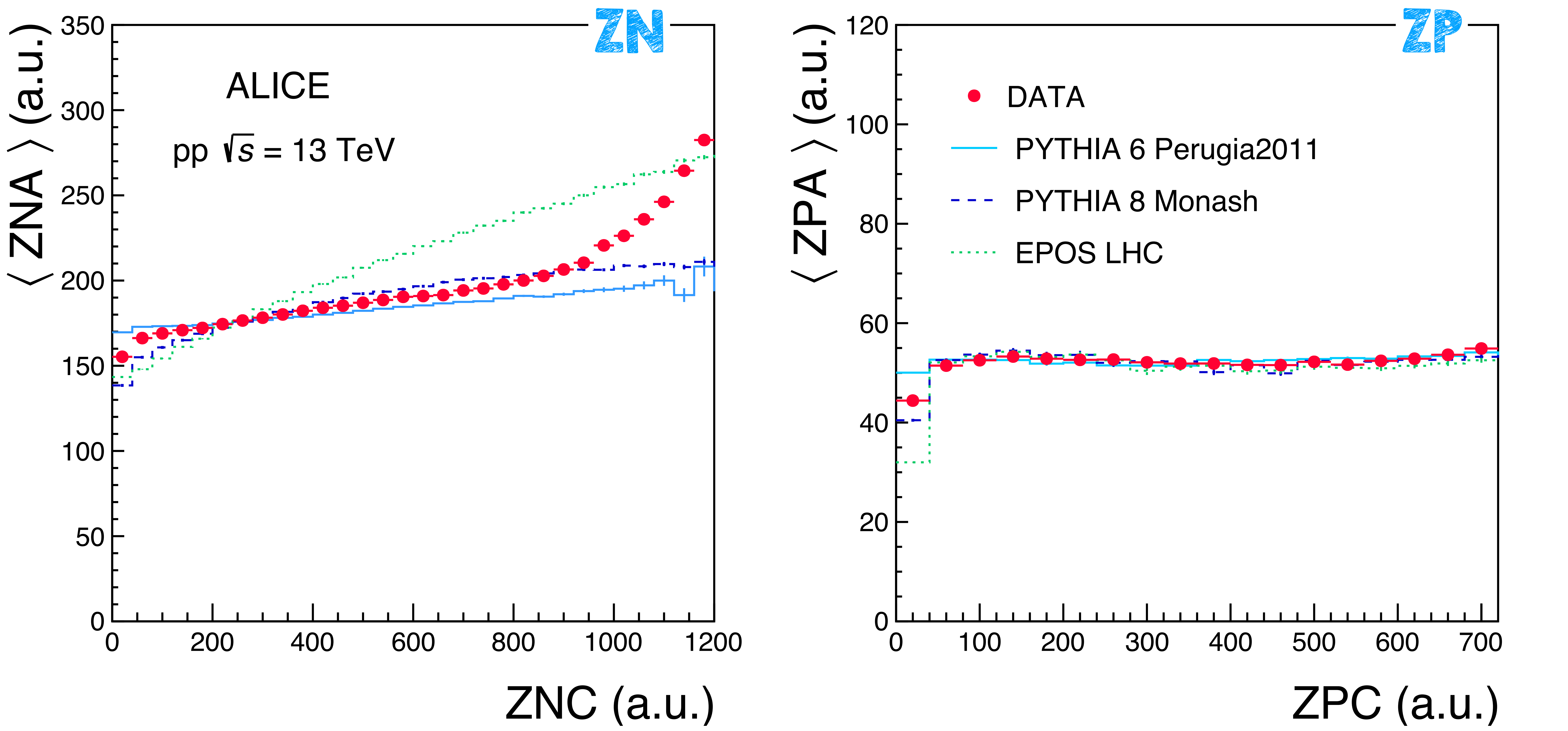

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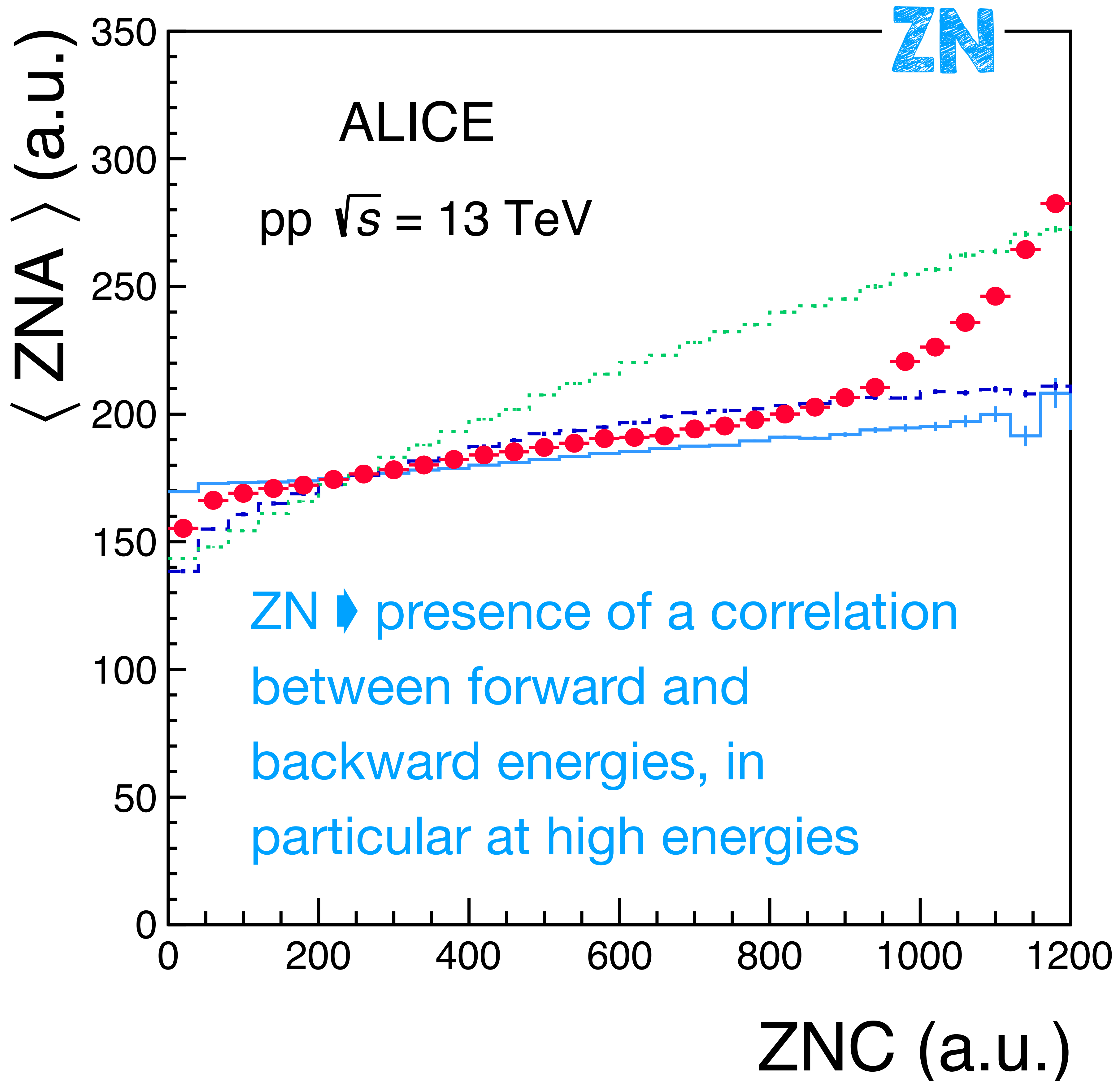
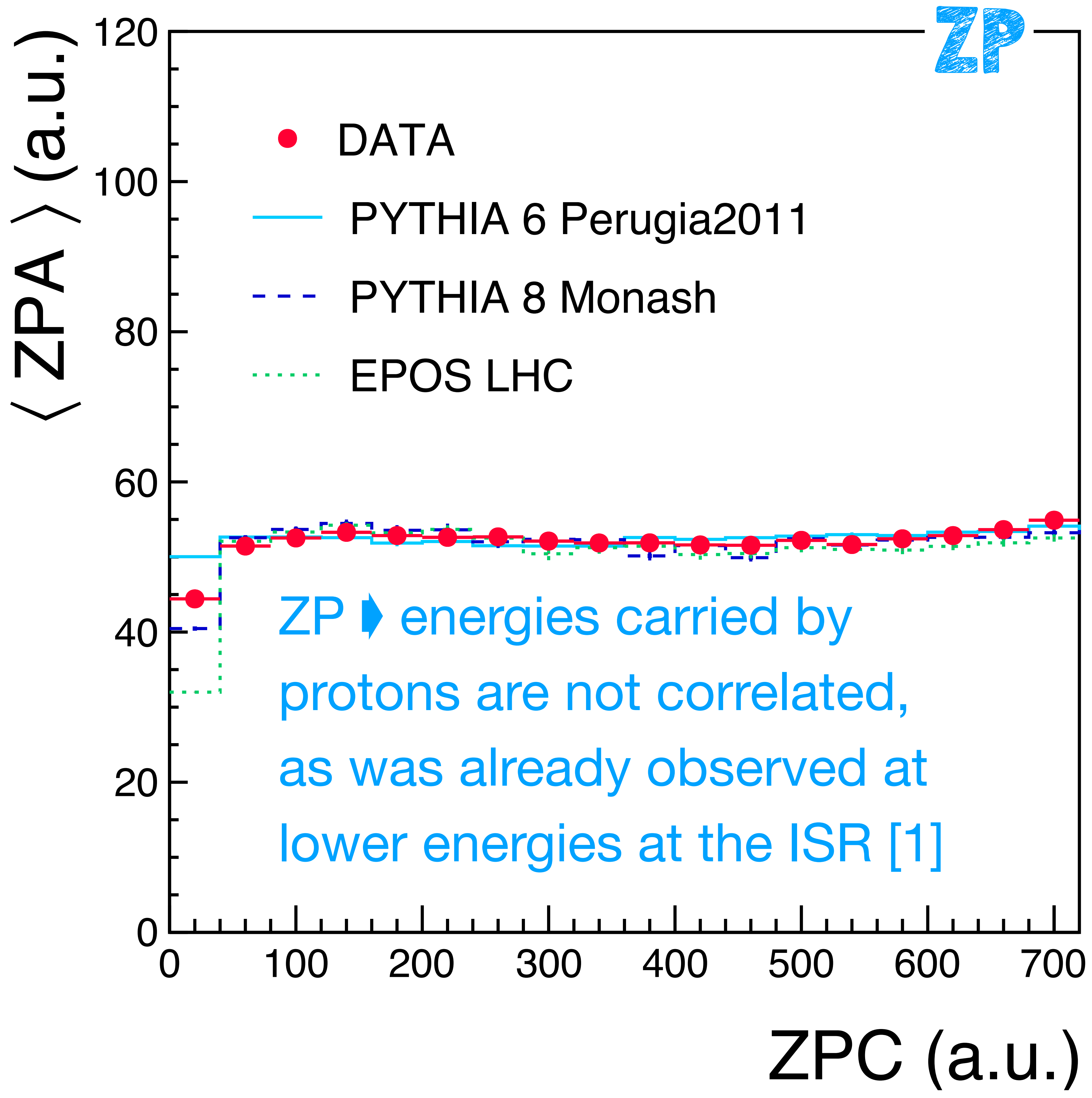


ZN ➧ presence of a correlation between forward and backward energies, in particular at high energies



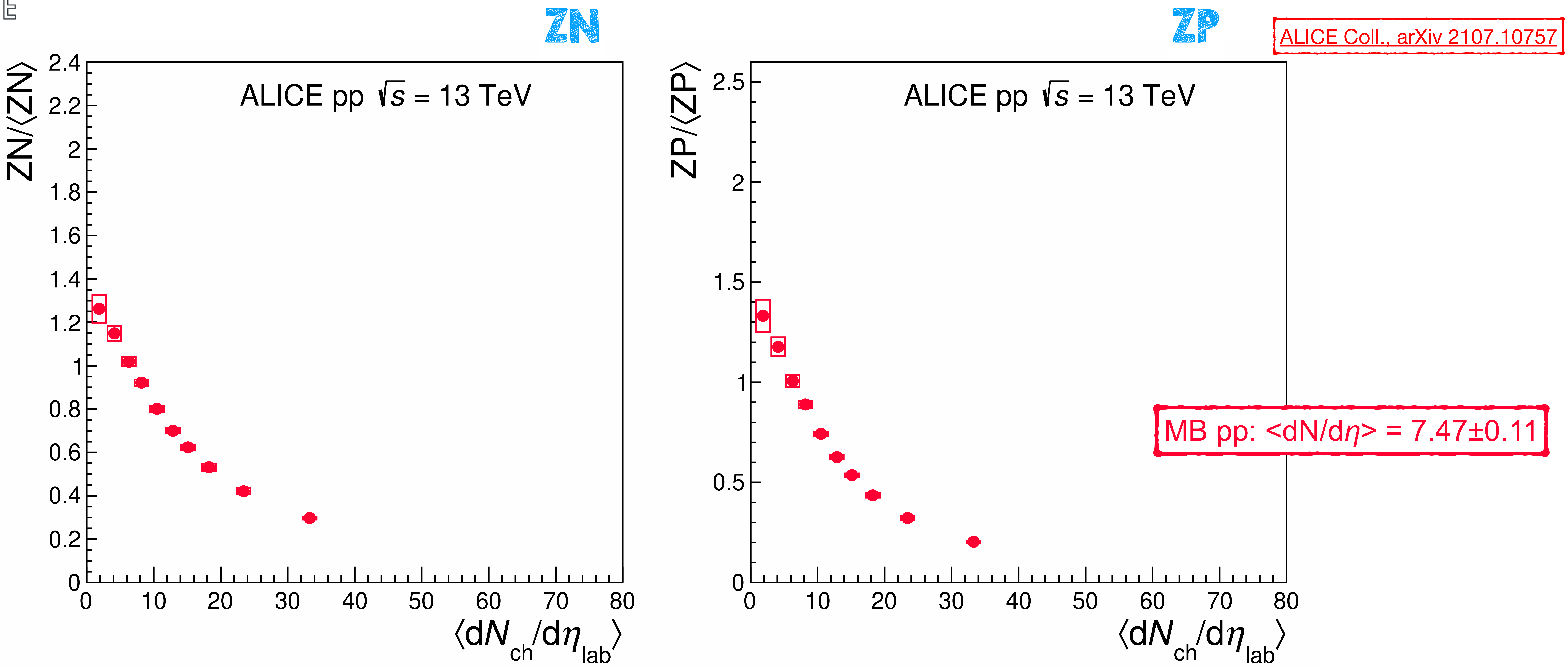
ZP ➧ energies carried by protons are not correlated, as was already observed at lower energies at the ISR [1]

Models predict a flat behaviour for ZP in agreement with data, but are not able to reproduce quantitatively the measured ZN dependence over the whole range

[1] M. Basile et al., Nuovo Cim. 353 A 73 (1983) 329

Forward energy vs. mid rapidity multiplicity

ALICE Coll., arXiv 2107.10757



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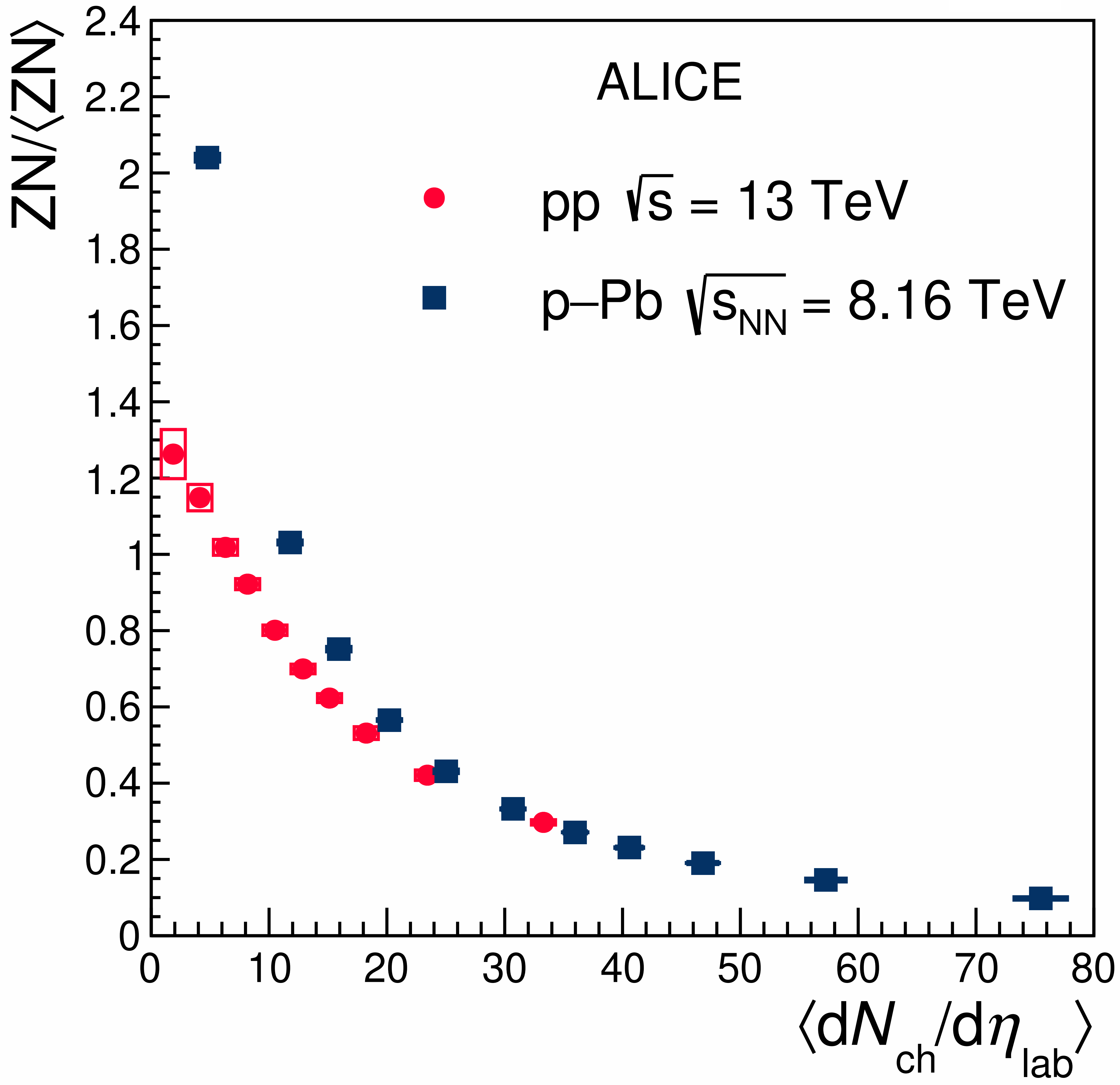
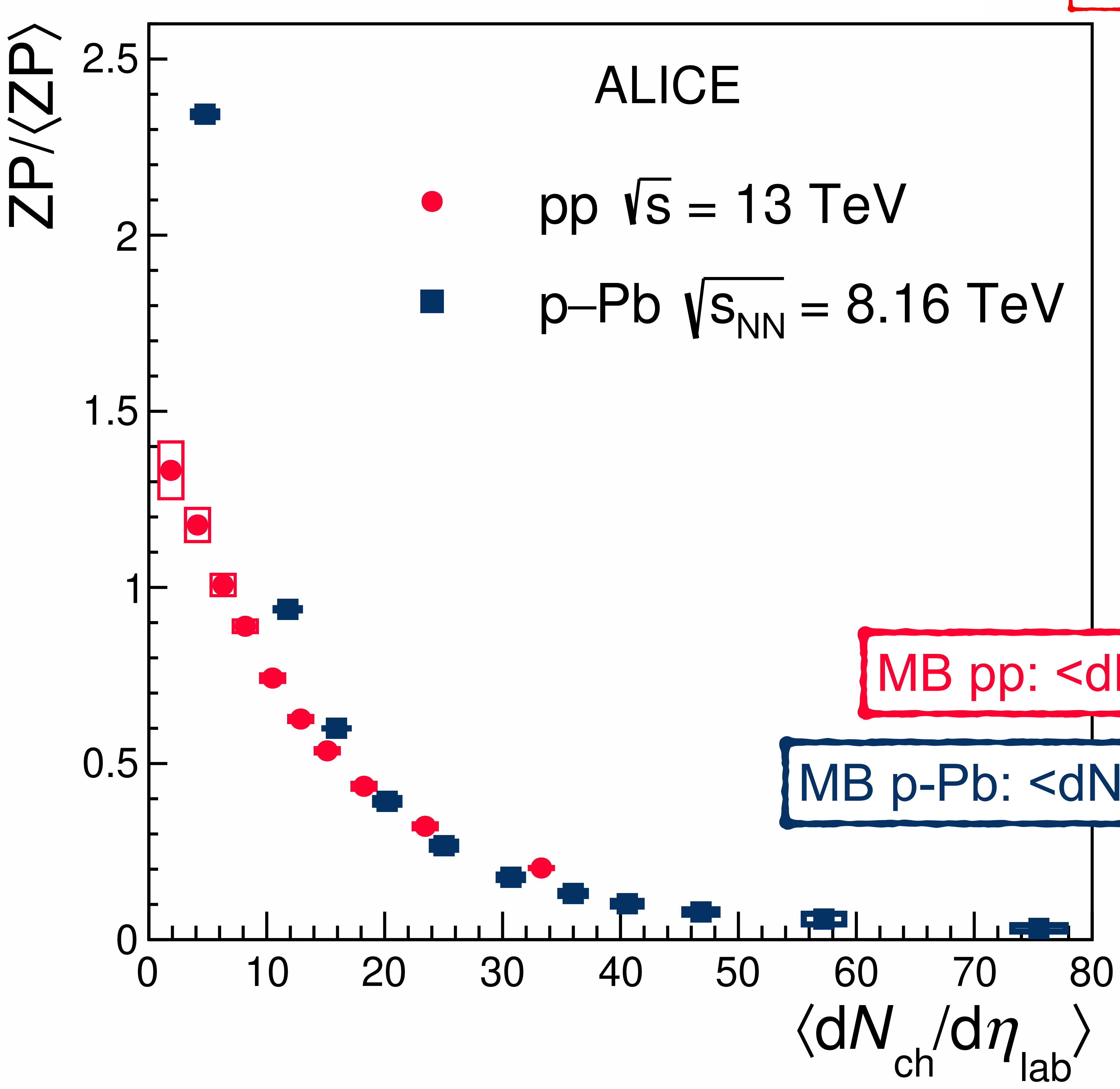
ZN



ZP



MB pp: <dN/dη> = 7.47±0.11

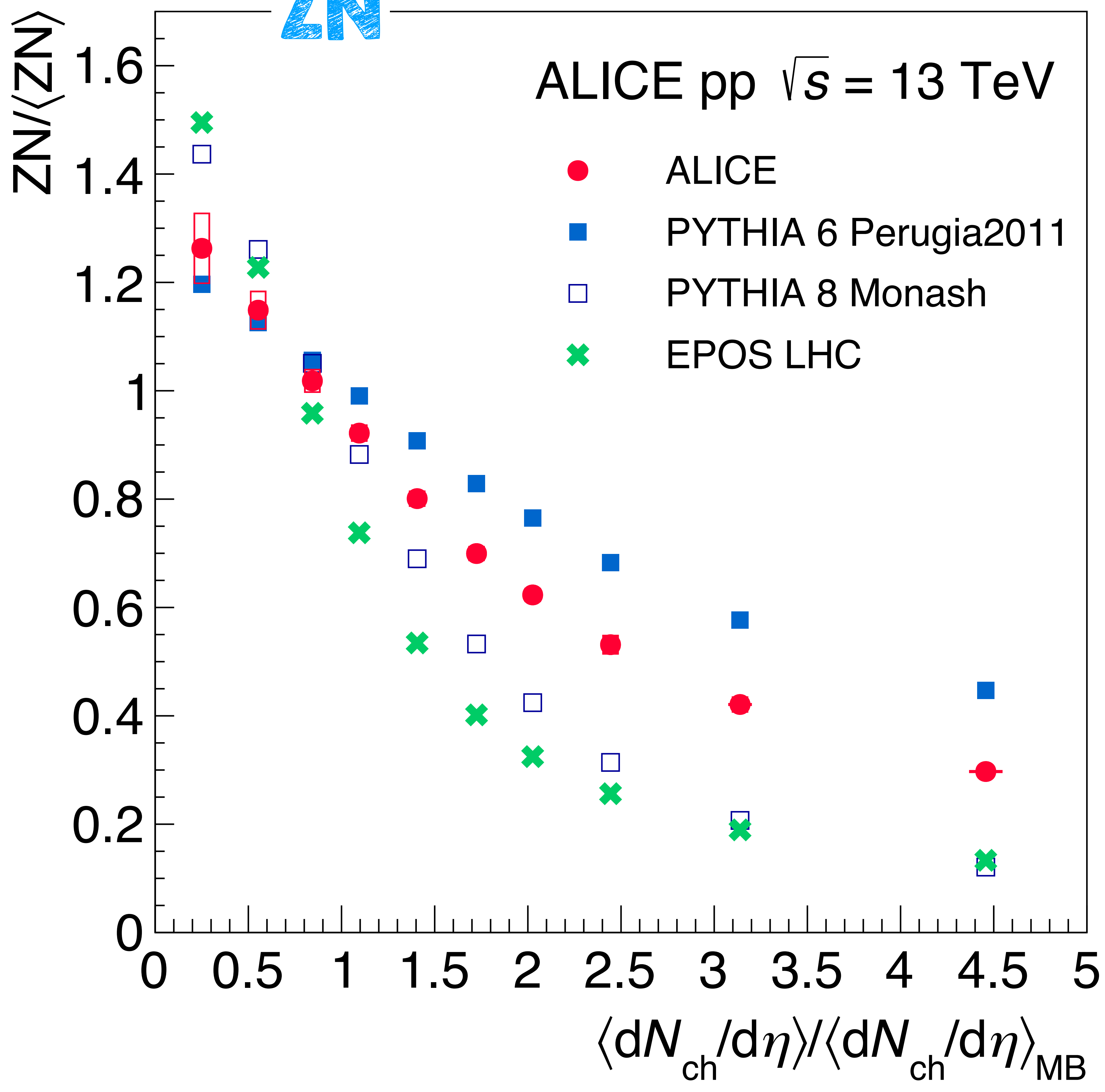
MB p-Pb: <dN/dη> = 20.61±0.62

Similar features in pp and in the p-fragmentation region in p-Pb collisions for self-normalized values: the higher the activity measured at midrapidity, the smaller the forward energy.

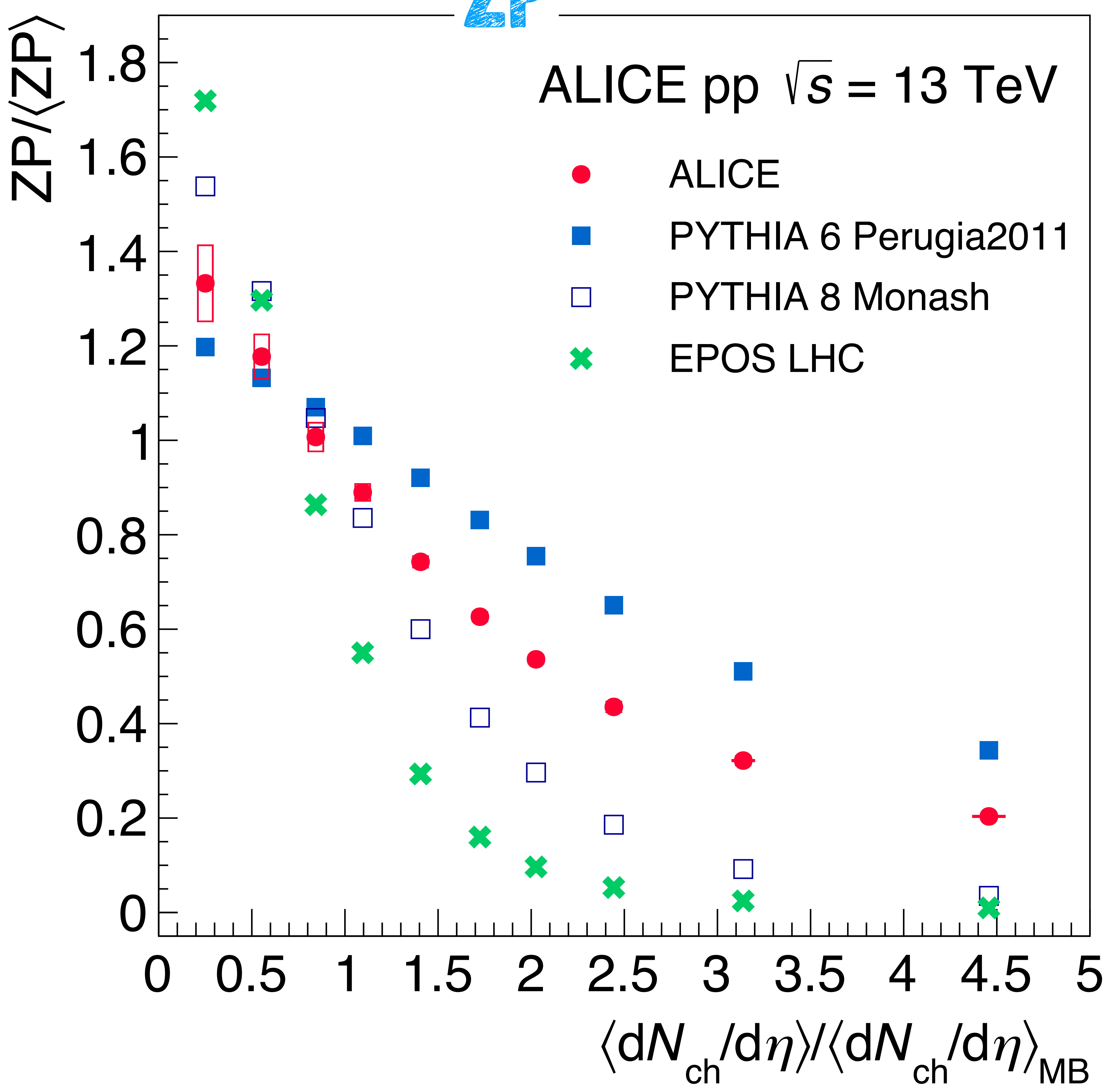
Comparison with models in pp

ALICE Coll., arXiv 2107.10757

ZN



ZP

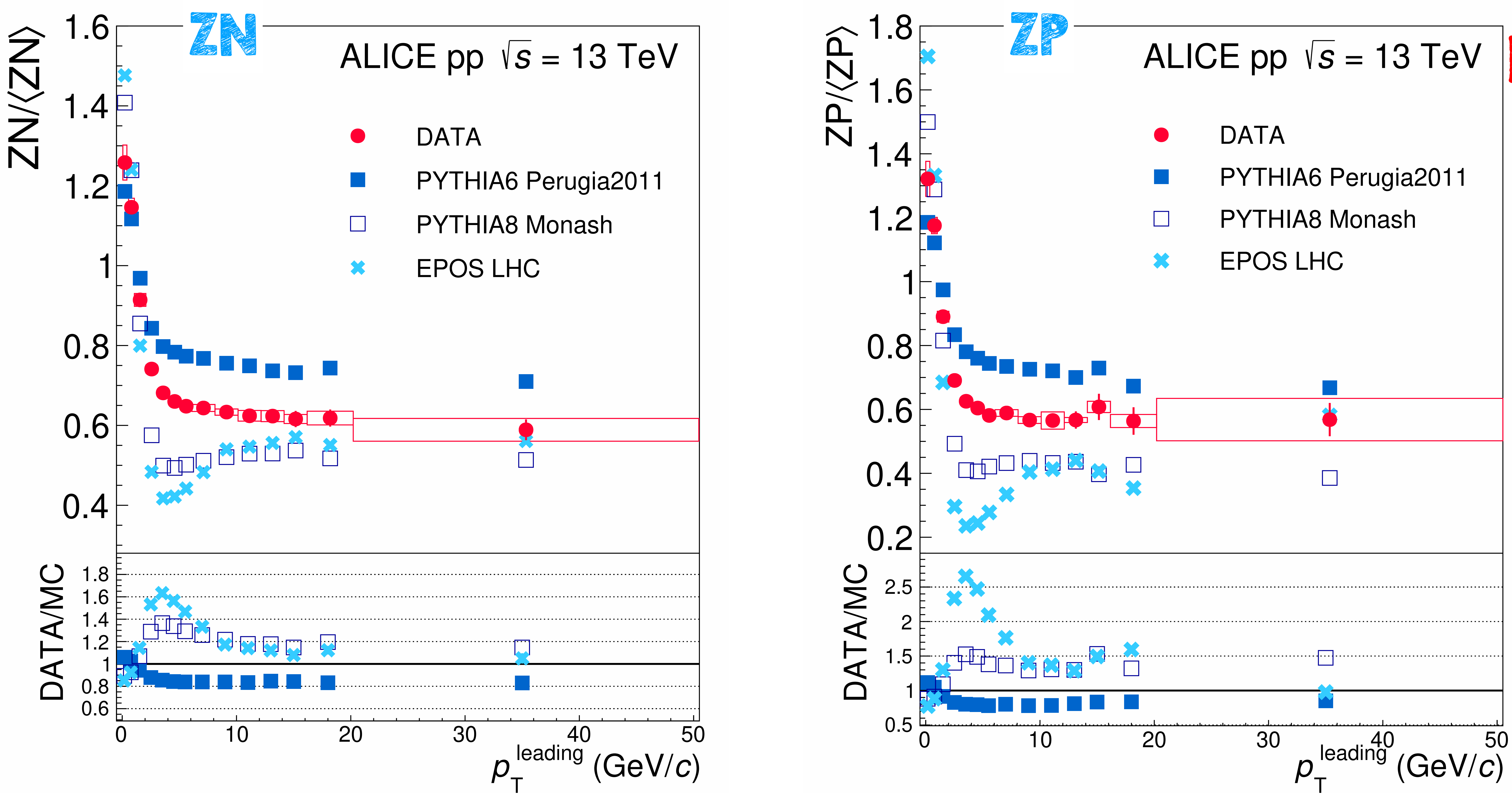


All models are able to describe the overall trend, PYTHIA 6 Perugia 2011 is the one showing a better agreement

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

Forward energy vs. $p_T^{leading}$

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

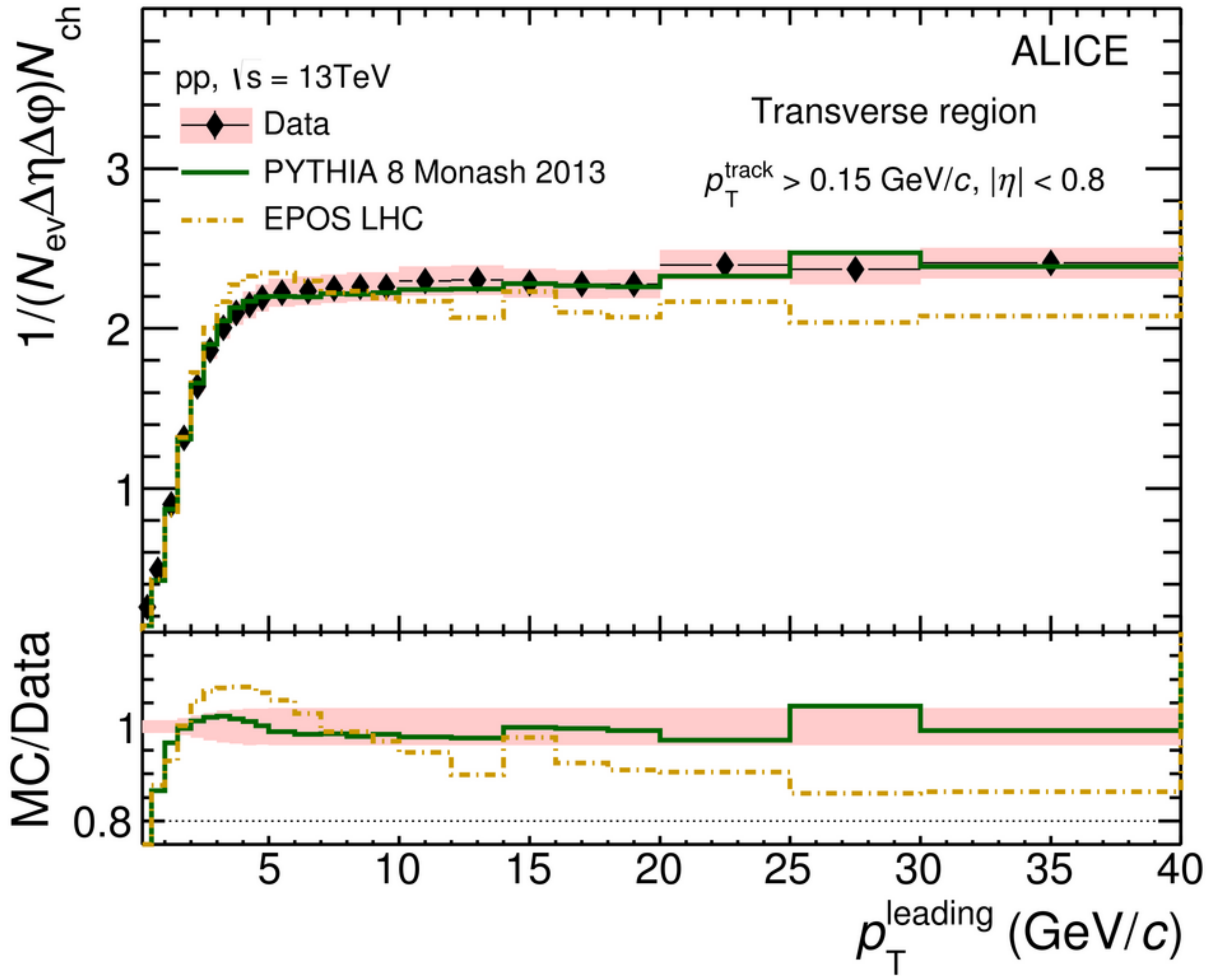


ALICE Coll., arXiv 2107.10757

For $p_T^{leading} > 5$ GeV/c ➧ ZN and ZP normalised signals do not decrease anymore

Forward energy and UE

UE measurements ➧ the transverse multiplicity (separation in azimuthal angle) efficiently trigger on central pp collisions selecting events with a large number of MPIs [2]



ALICE Coll., JHEP 04 (2020) 192

[2] Martin, Skands, Farrington, Eur.Phys.J. C76 (2016) 299

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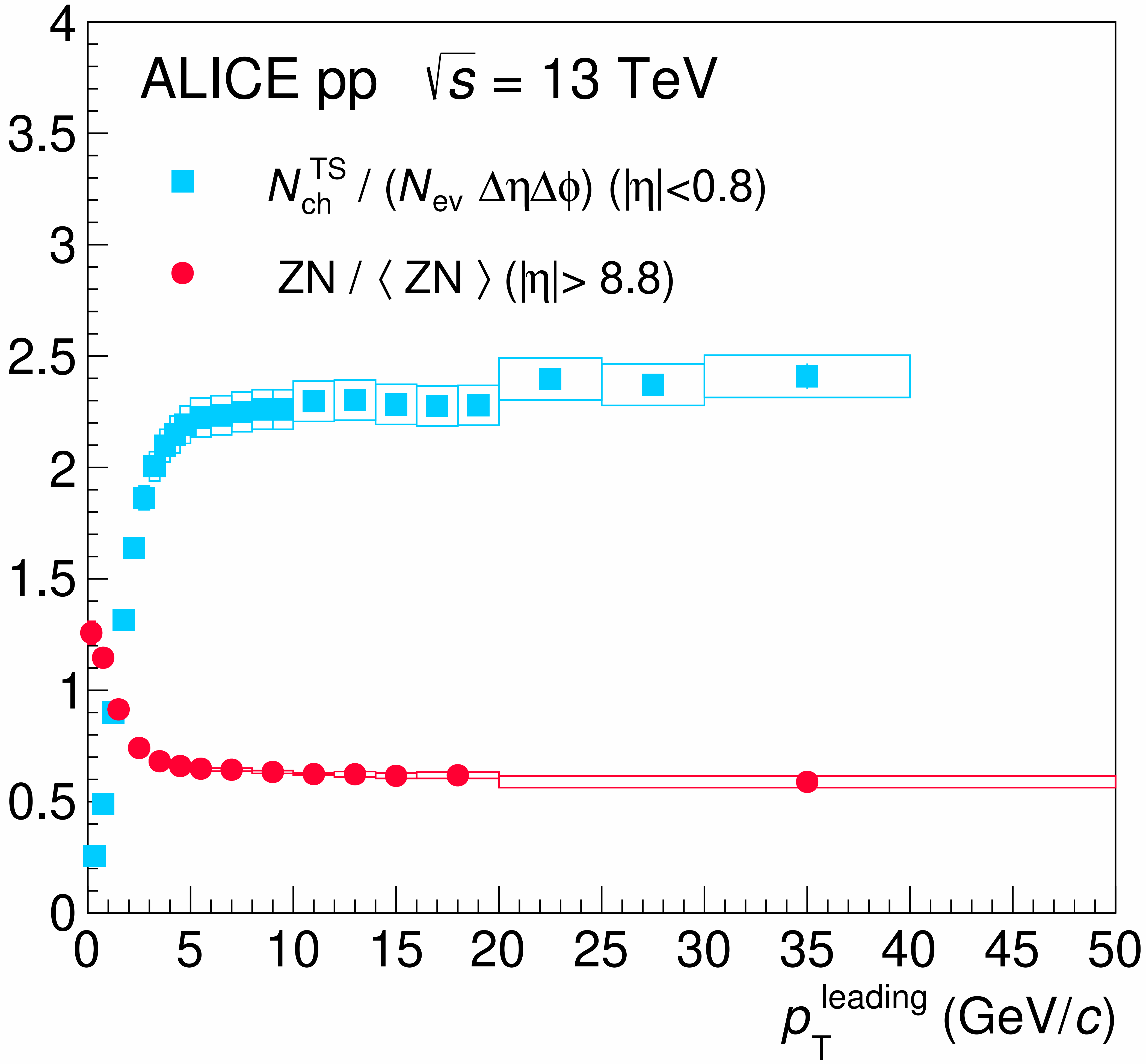
The forward energy (separation in rapidity) shows a complementary behaviour to that observed for transverse charged particle multiplicity

➧ 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



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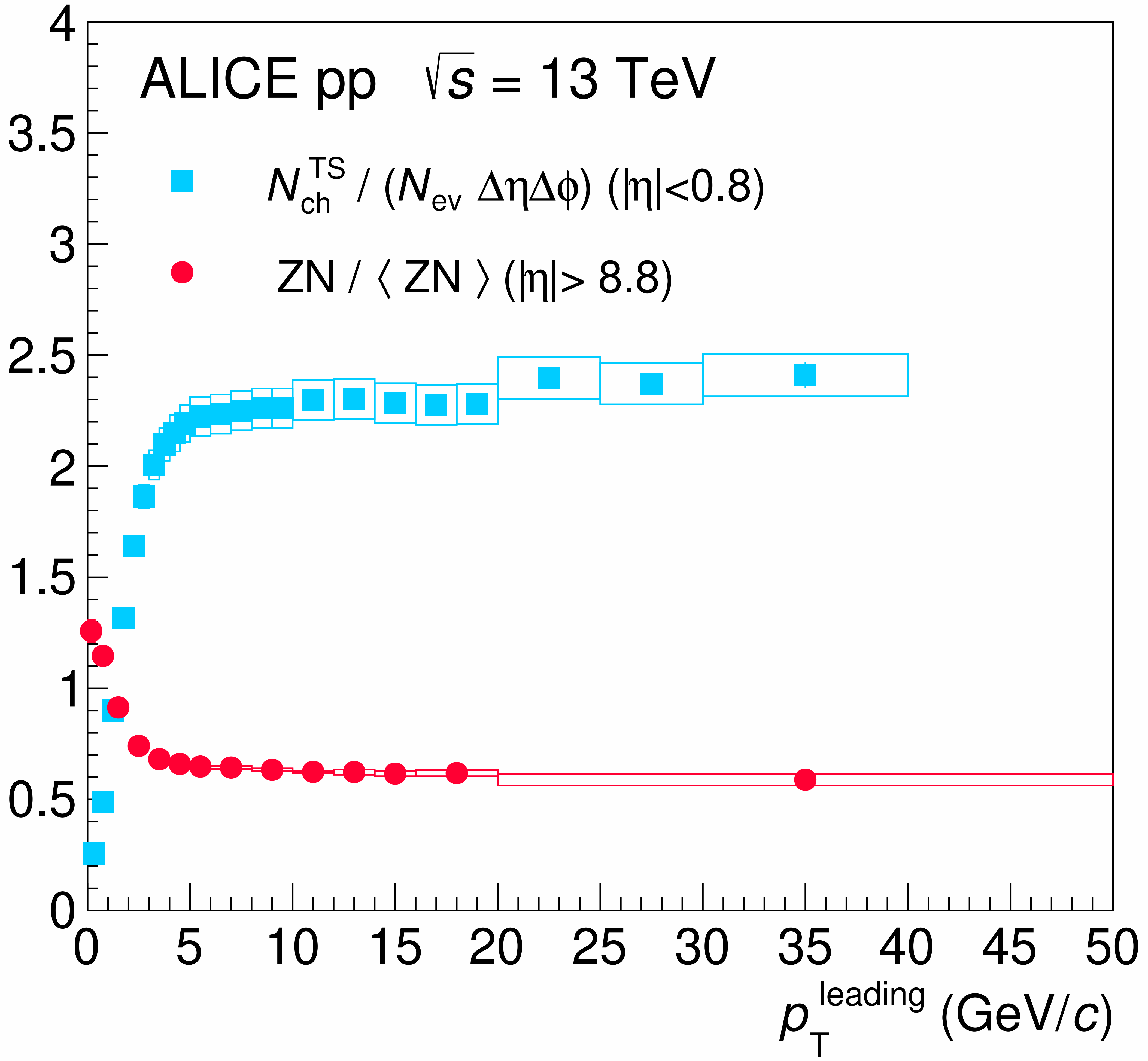
Small energy at very forward rapidities selects:
- ➧ larger than average N_{MPI}
- ➧ higher than average multiplicity
- ➧ high-p_T particle at midrapidity



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Very forward energy and central collisions

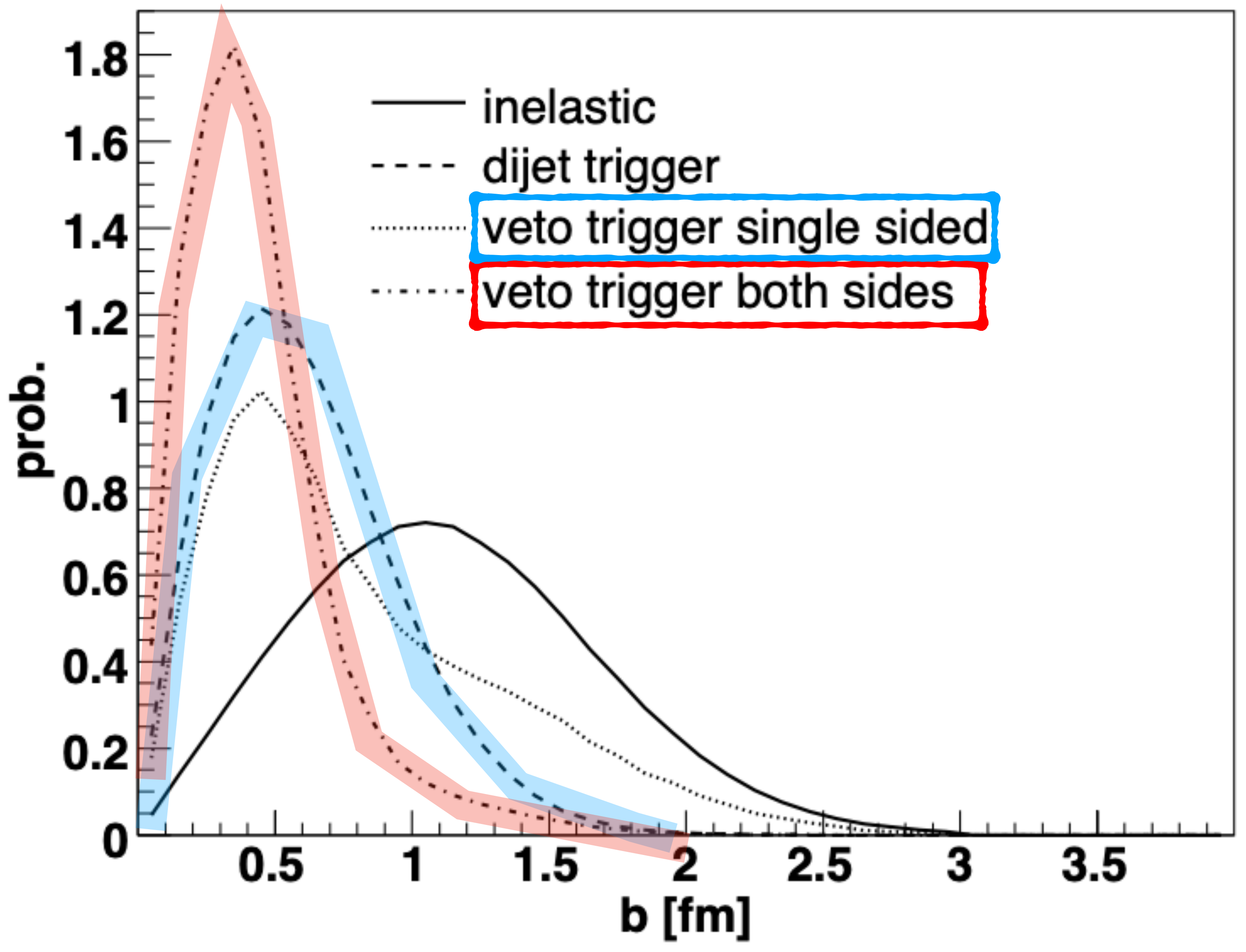

FIG. 5: Impact parameter distributions for inelastic events, the dijet trigger and single and double sided veto-trigger (no baryon in the region $x_F > 0.1$).

H. J. Drescher, M. Strikman, Phys. Rev. Lett. 100 (2008) 152002

- a central collision results in additional energy flow at midrapidity and in suppression of leading baryon production

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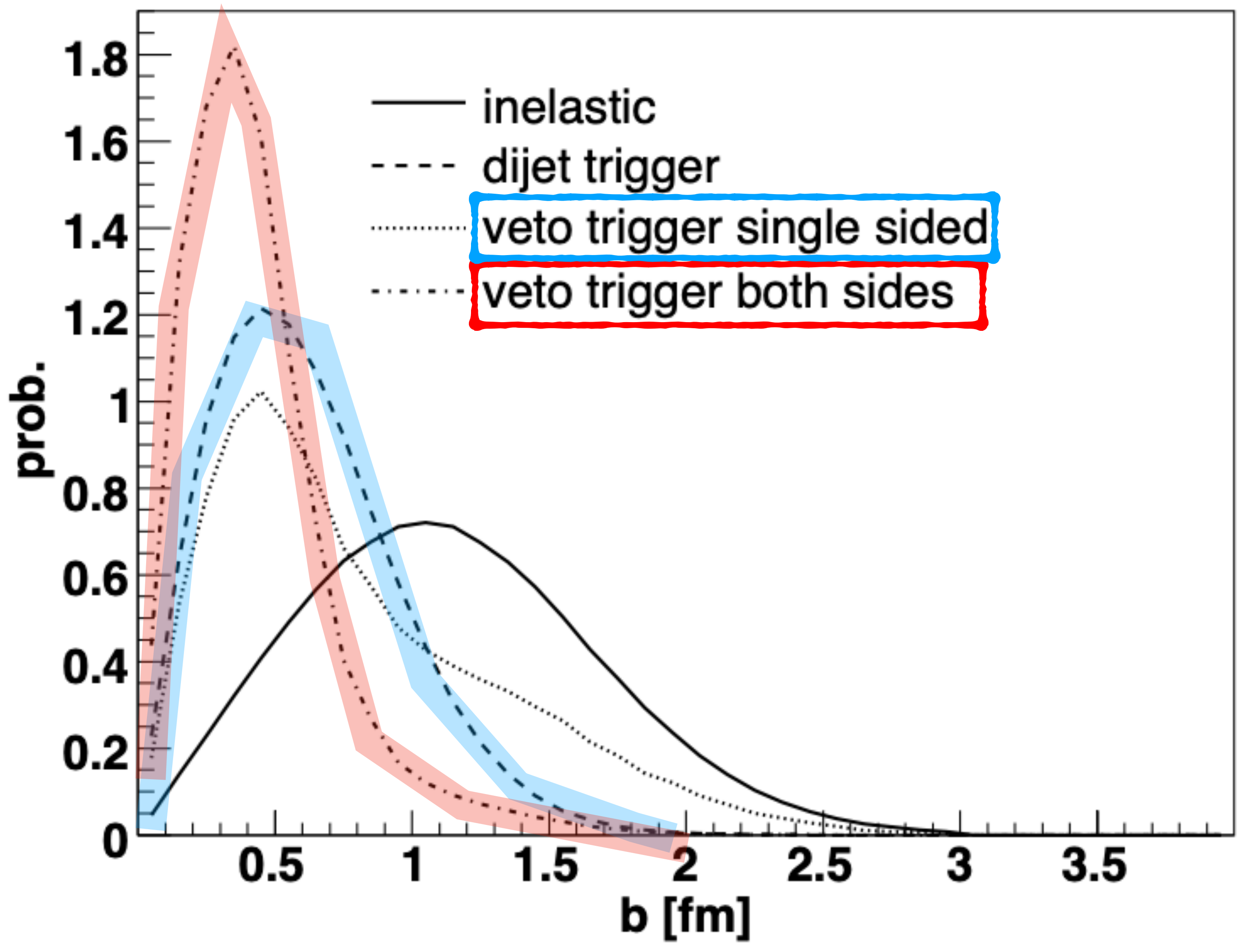

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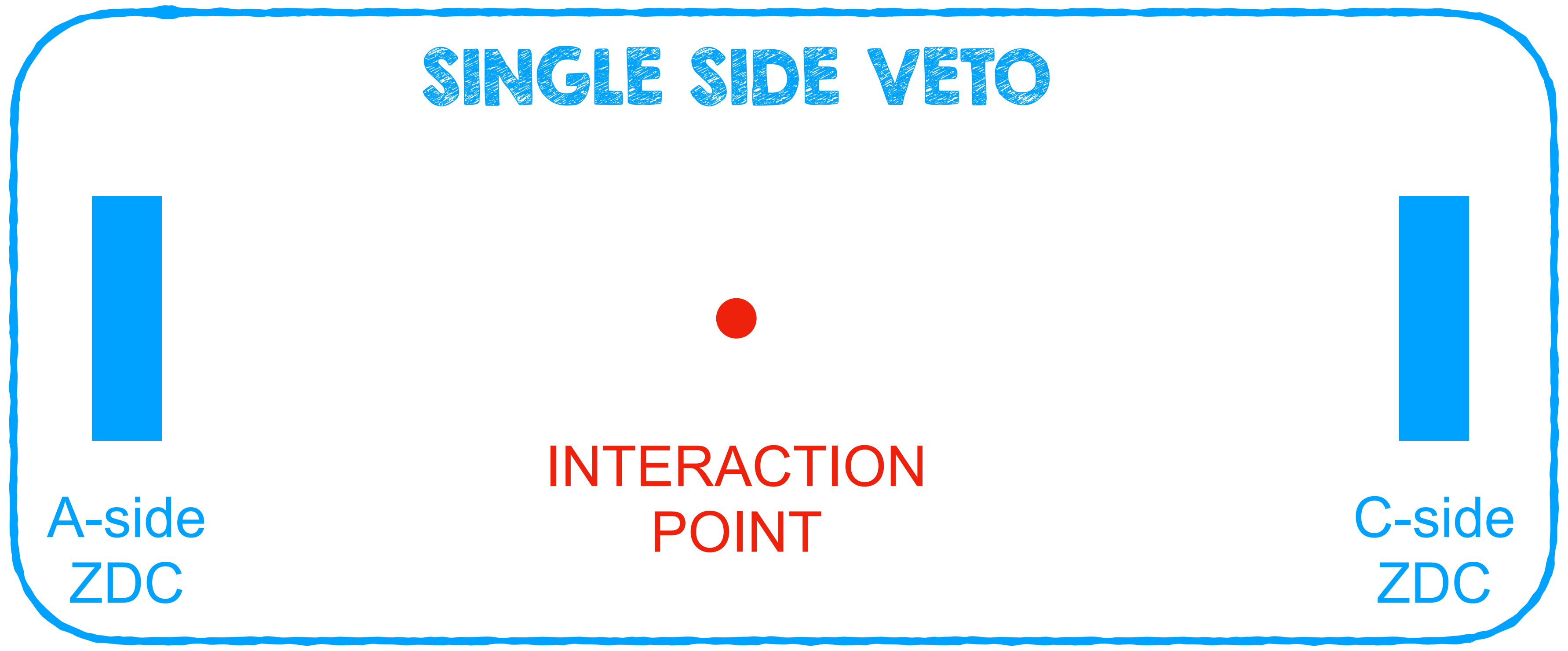

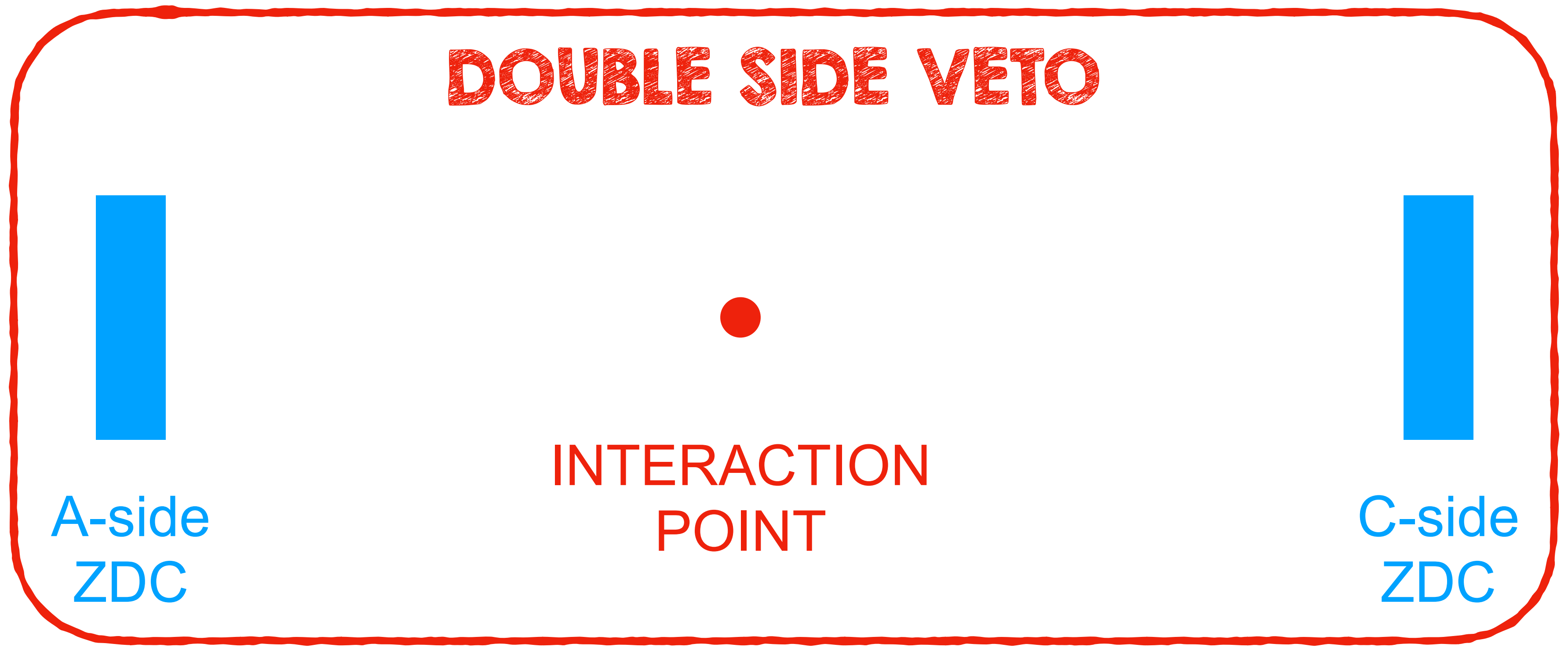

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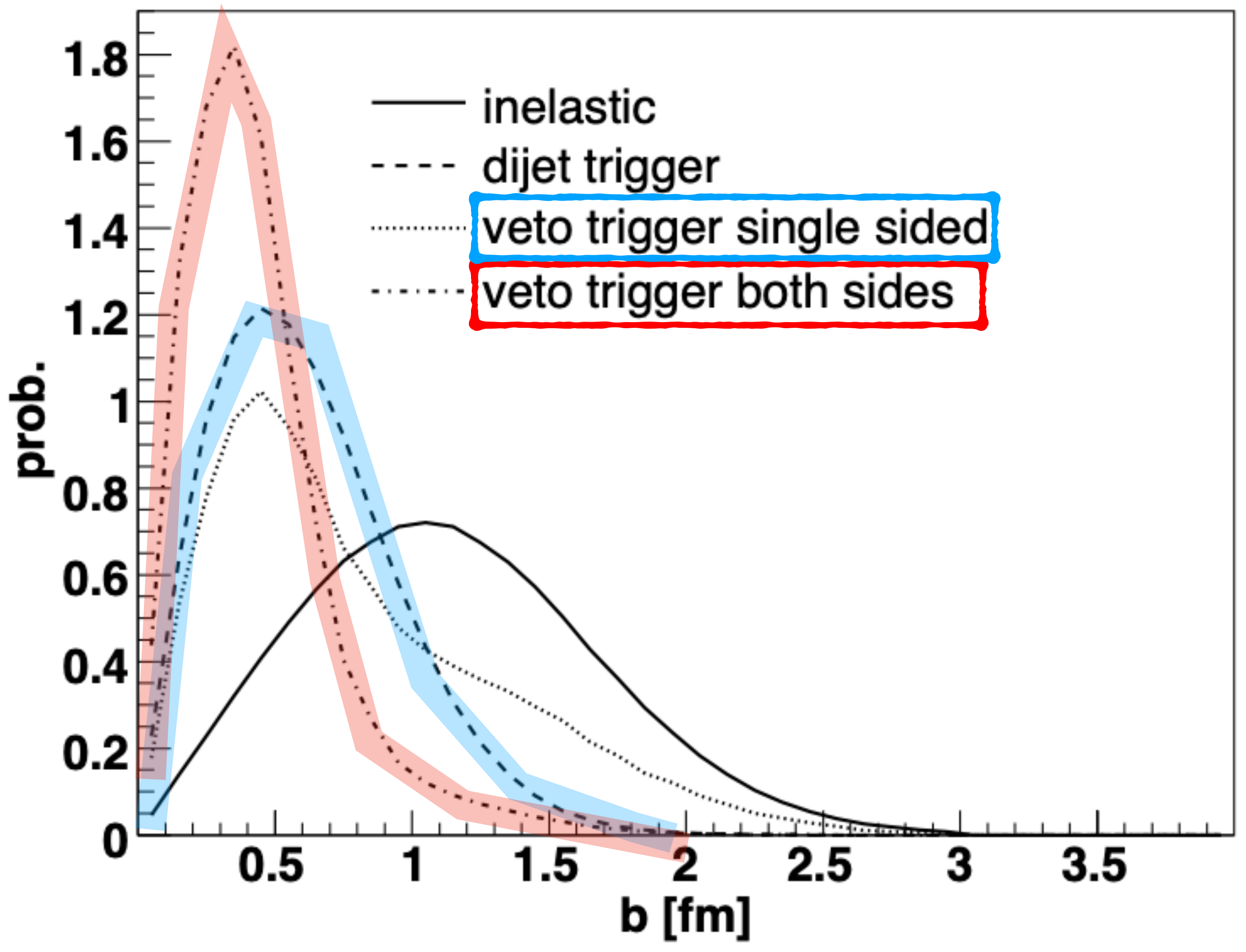

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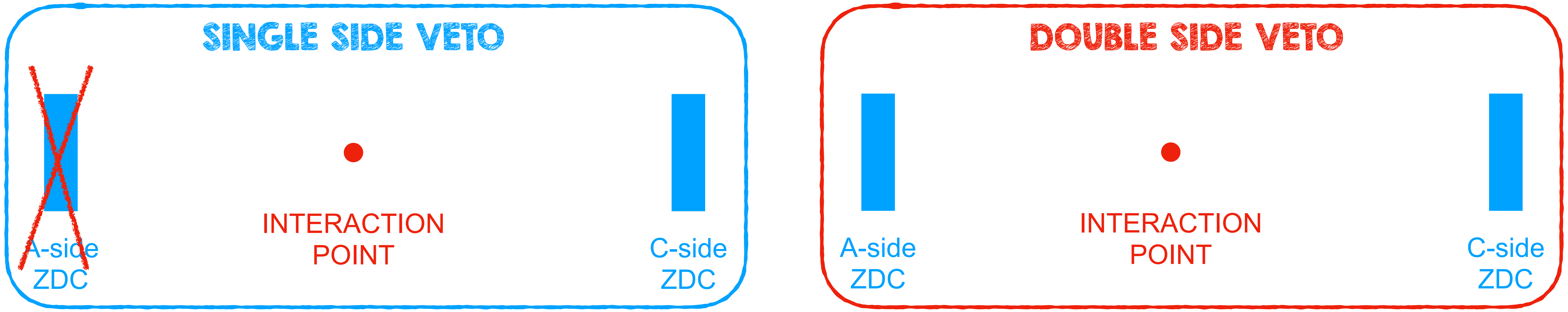

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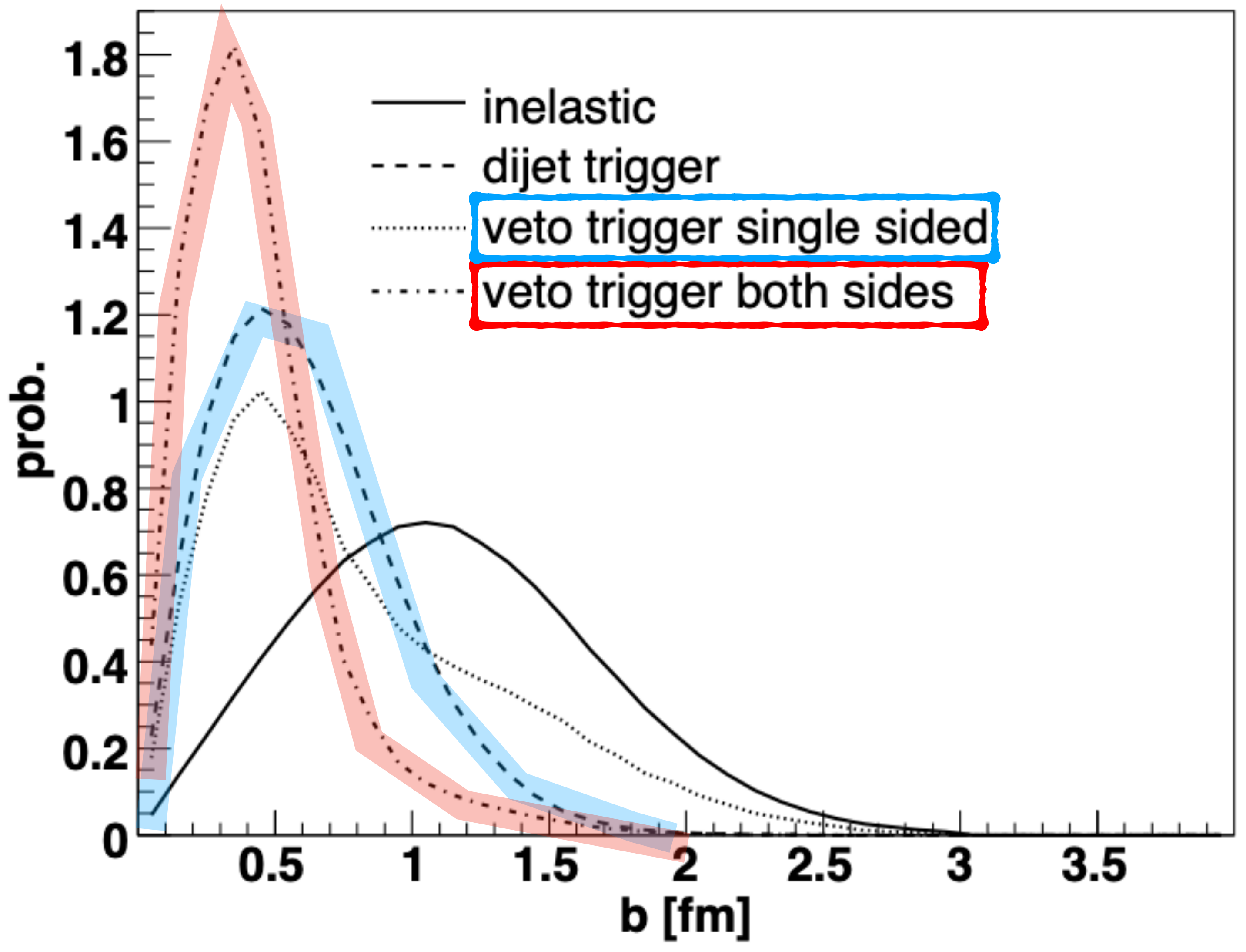

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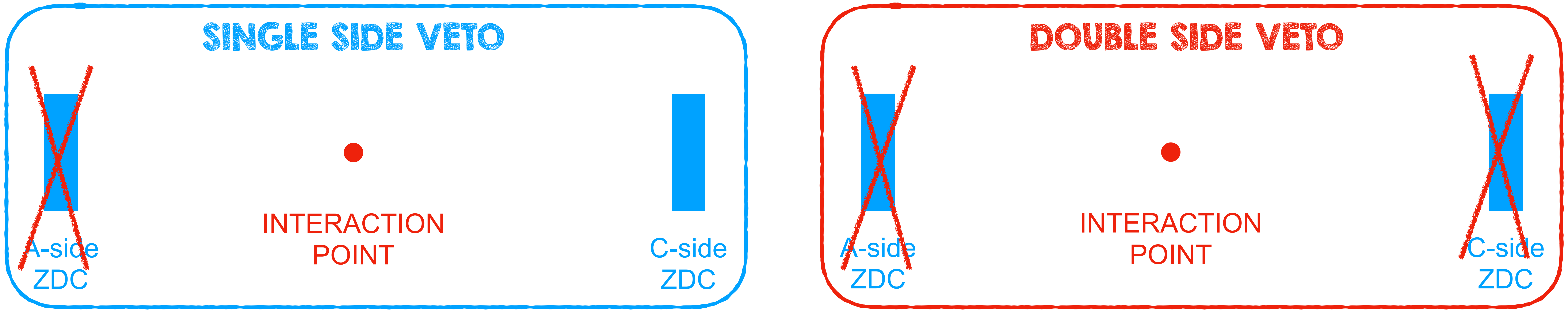
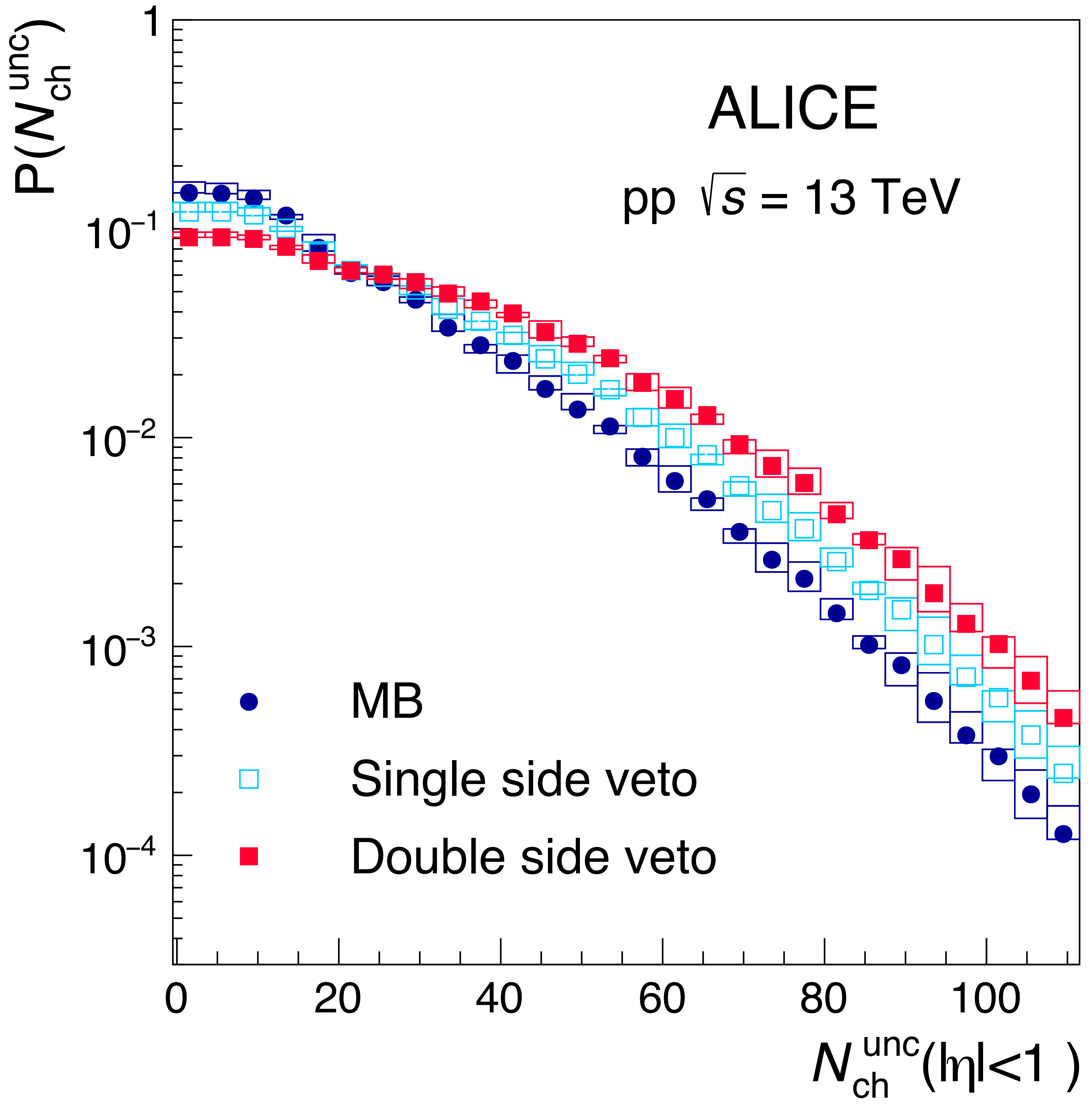
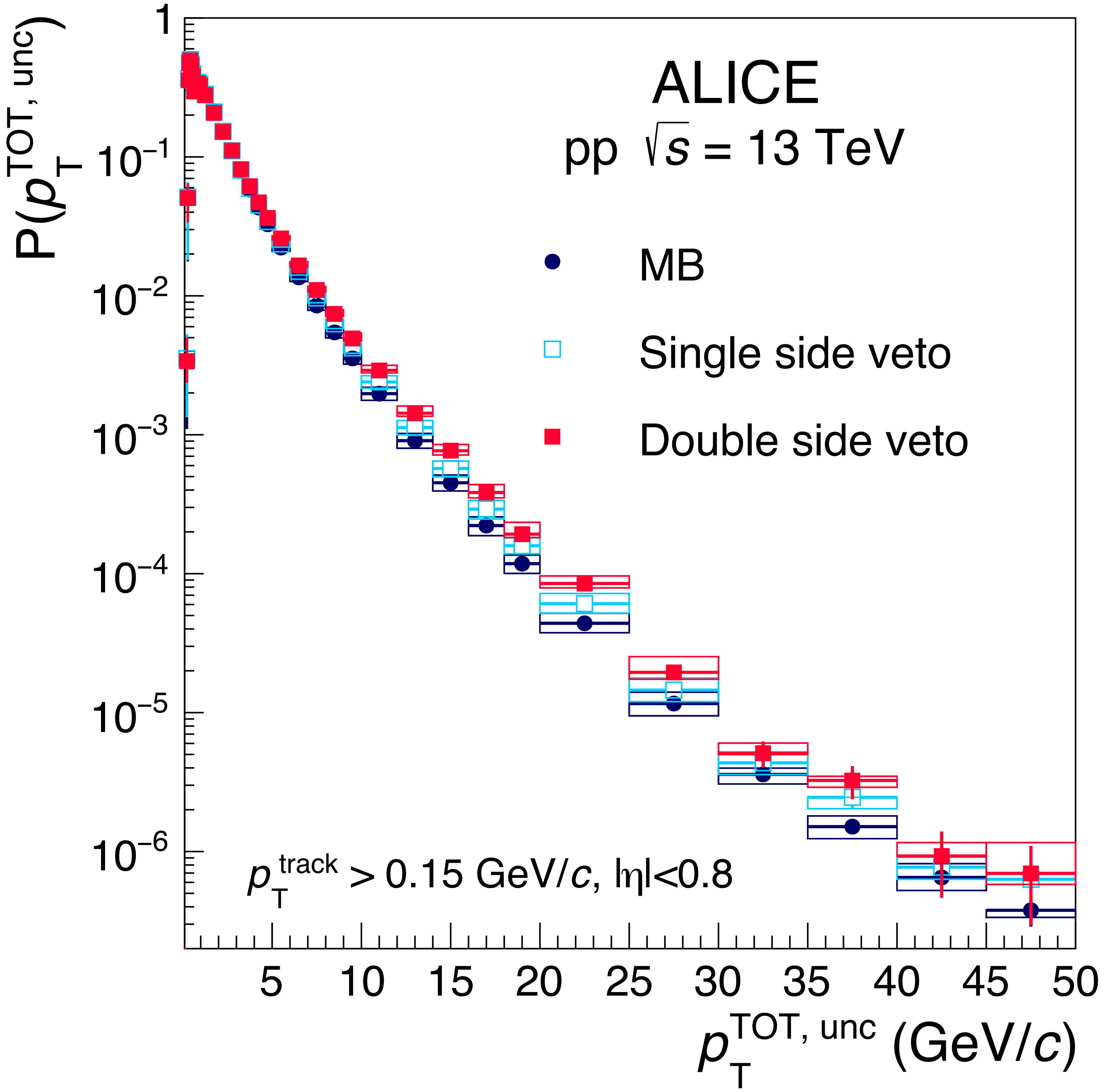


Very forward energy and central collisions

ALICE Coll., arXiv 2107.10757

- What happens putting a single side or double side veto on ZN and ZP signals?





- N_{ch} in $|\eta|<1$ is on average a factor (1.2) and (1.5) higher than in the MB sample for the (single) double veto selection.
- MC simulations provide similar increases for the average values of N_{ch} and total transverse momentum.

SUMMARY

First results about very forward energy in correlation with event activity at midrapidity at LHC energies covering more than 18 units in pseudorapidity provide insights on initial stages of pp collisions

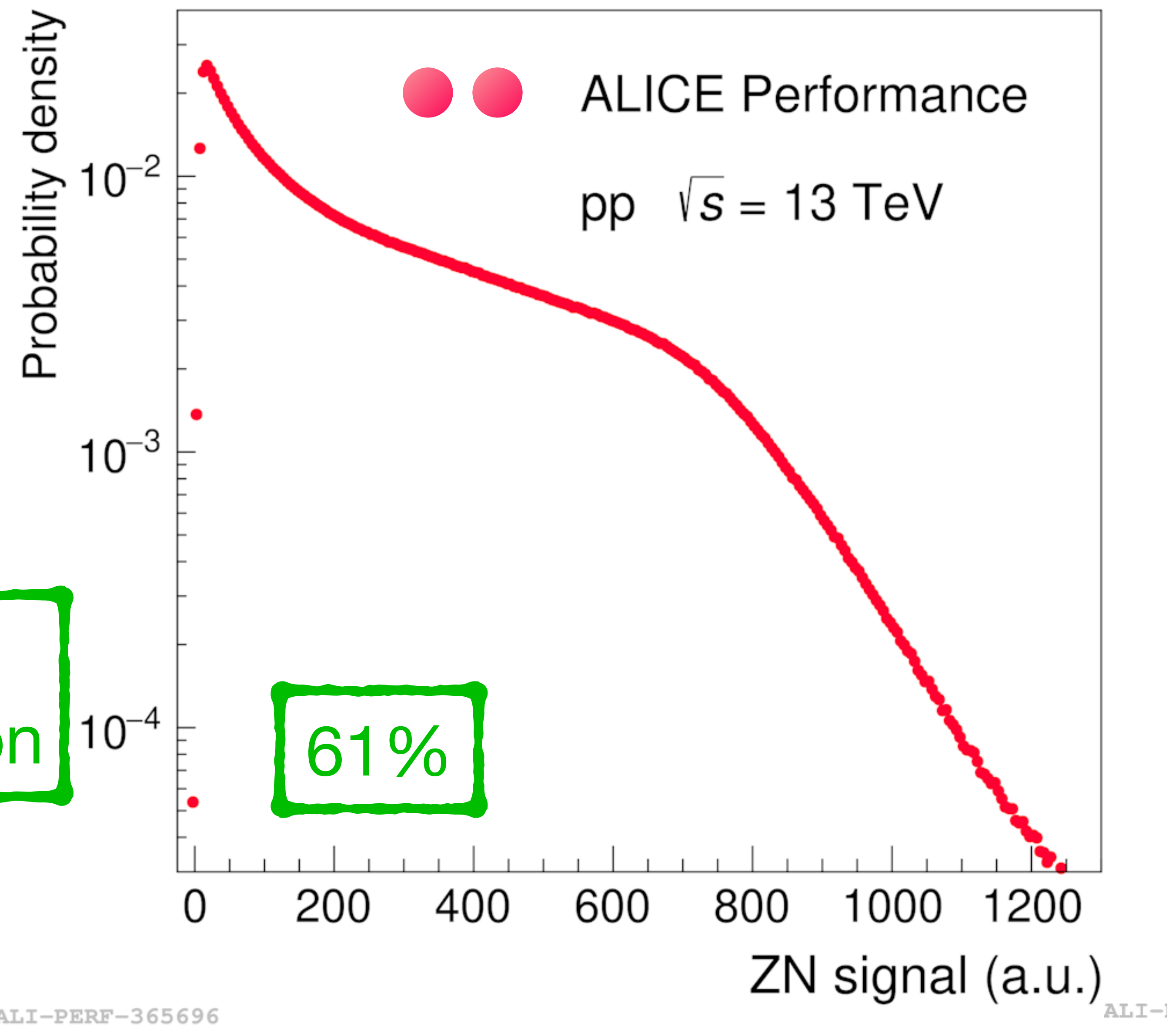
- forward-backward energy is largely asymmetric
- very forward energy decreases with increasing midrapidity activity and is anti—correlated with the number of MPI
- models (PYTHIA 6 Perugia 2011, PYTHIA 8 Monash and EPOS LHC) do not reproduce the measurements: challenge remains to reproduce beam remnants 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
- a veto on ZDC energy selects higher than average multiplicity at midrapidity and harder than average collisions

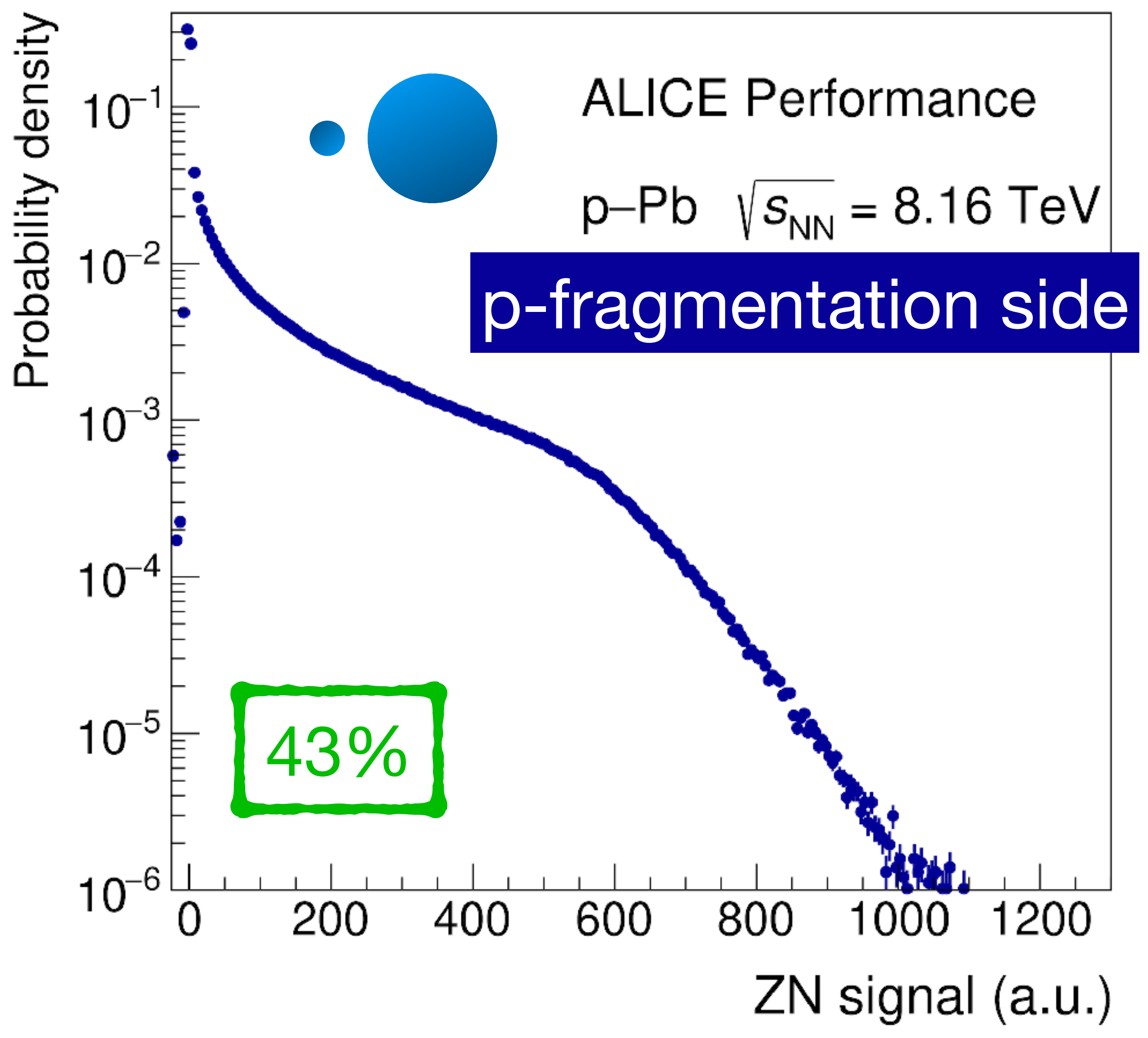
Additional material…

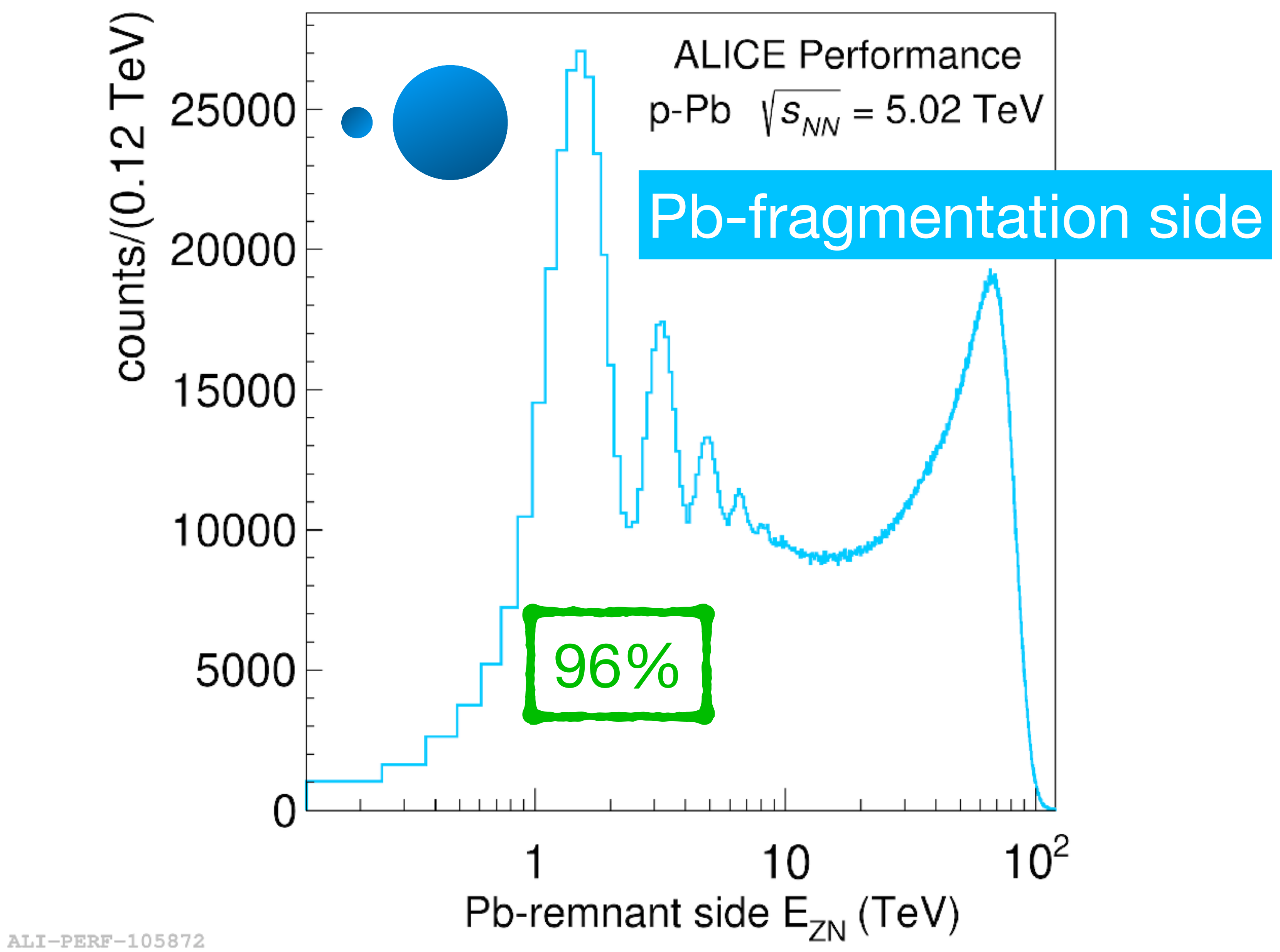
ZDC spectra in pp and p-Pb collisions

ZN

Event selection fraction

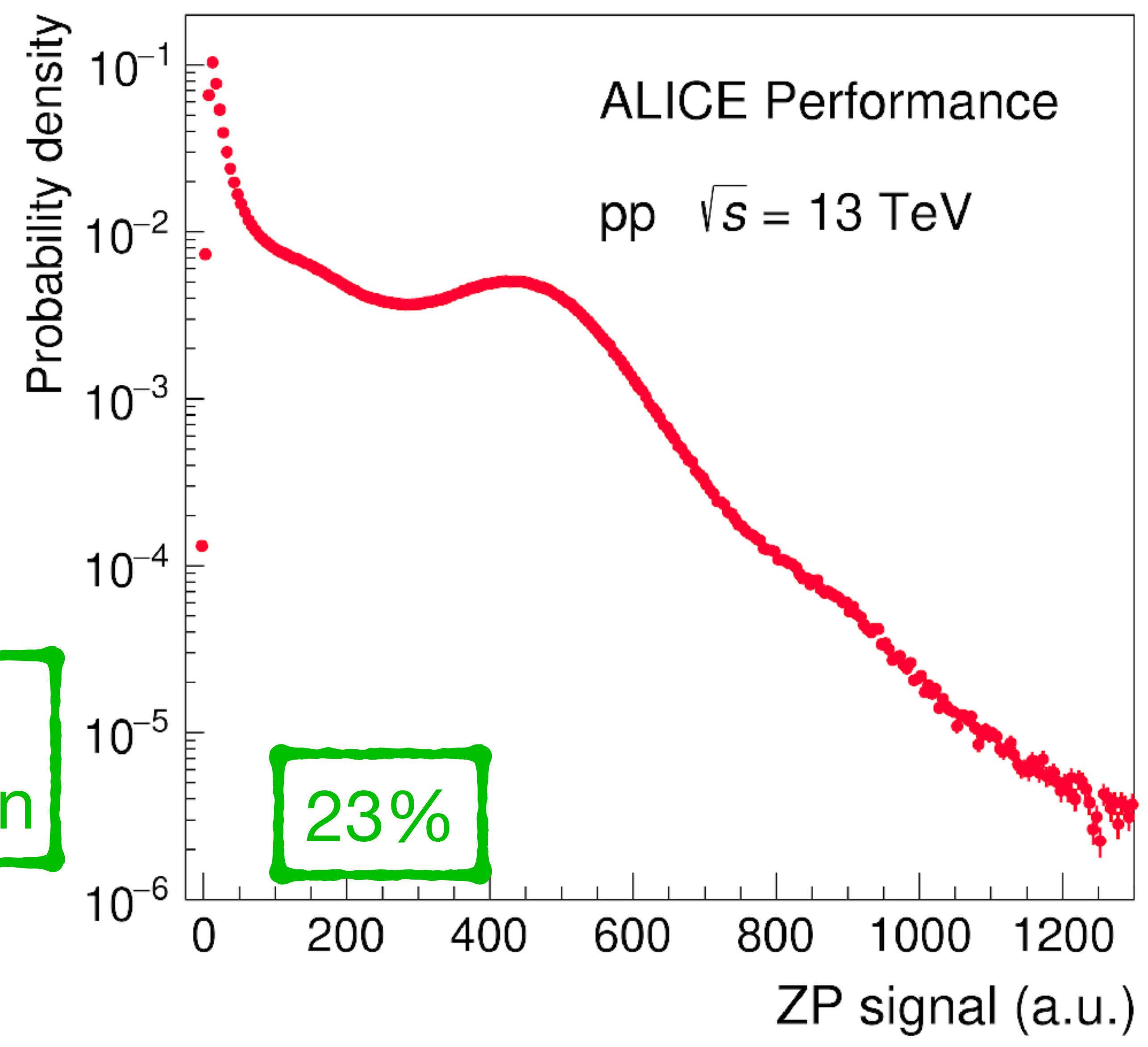


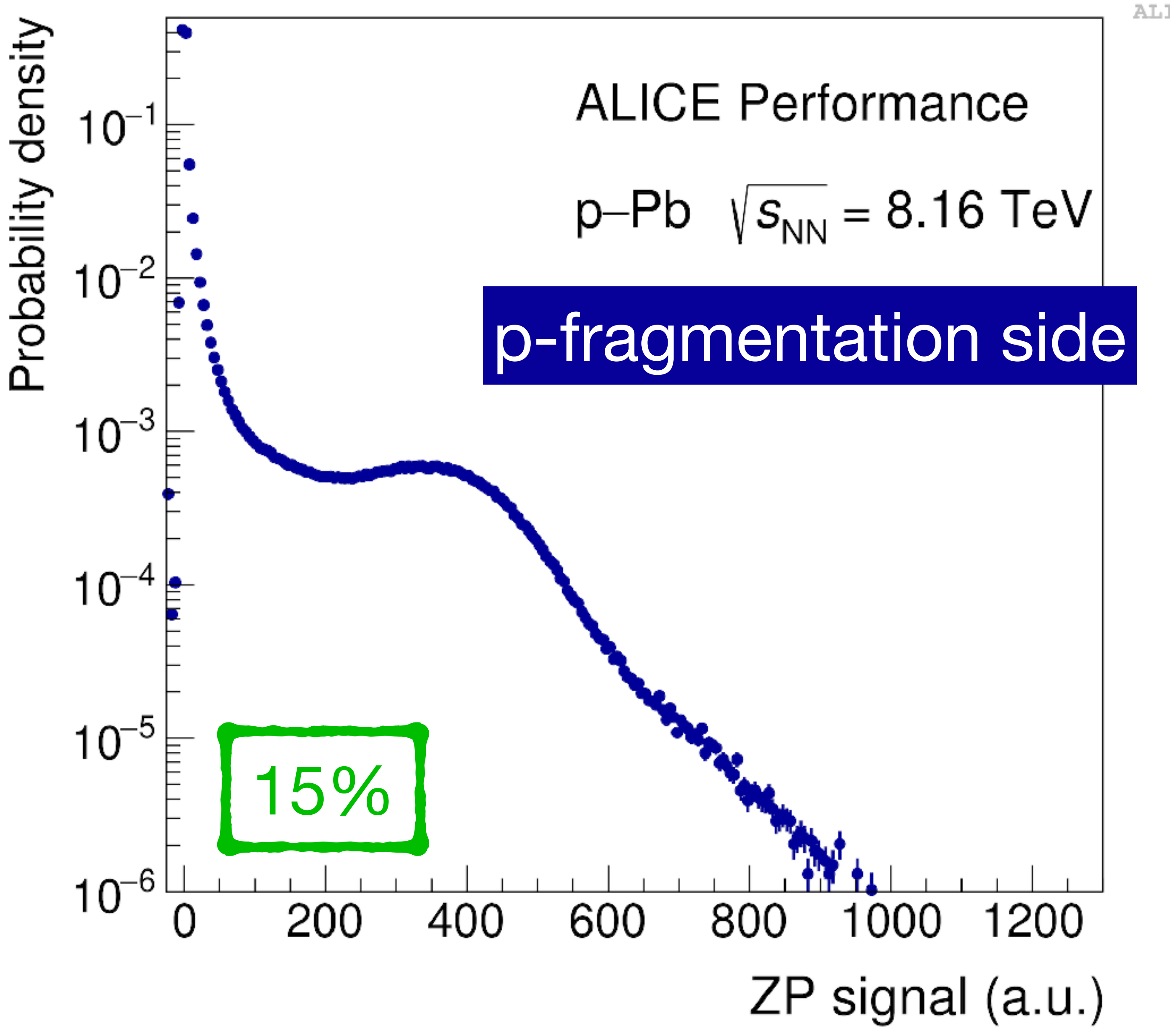


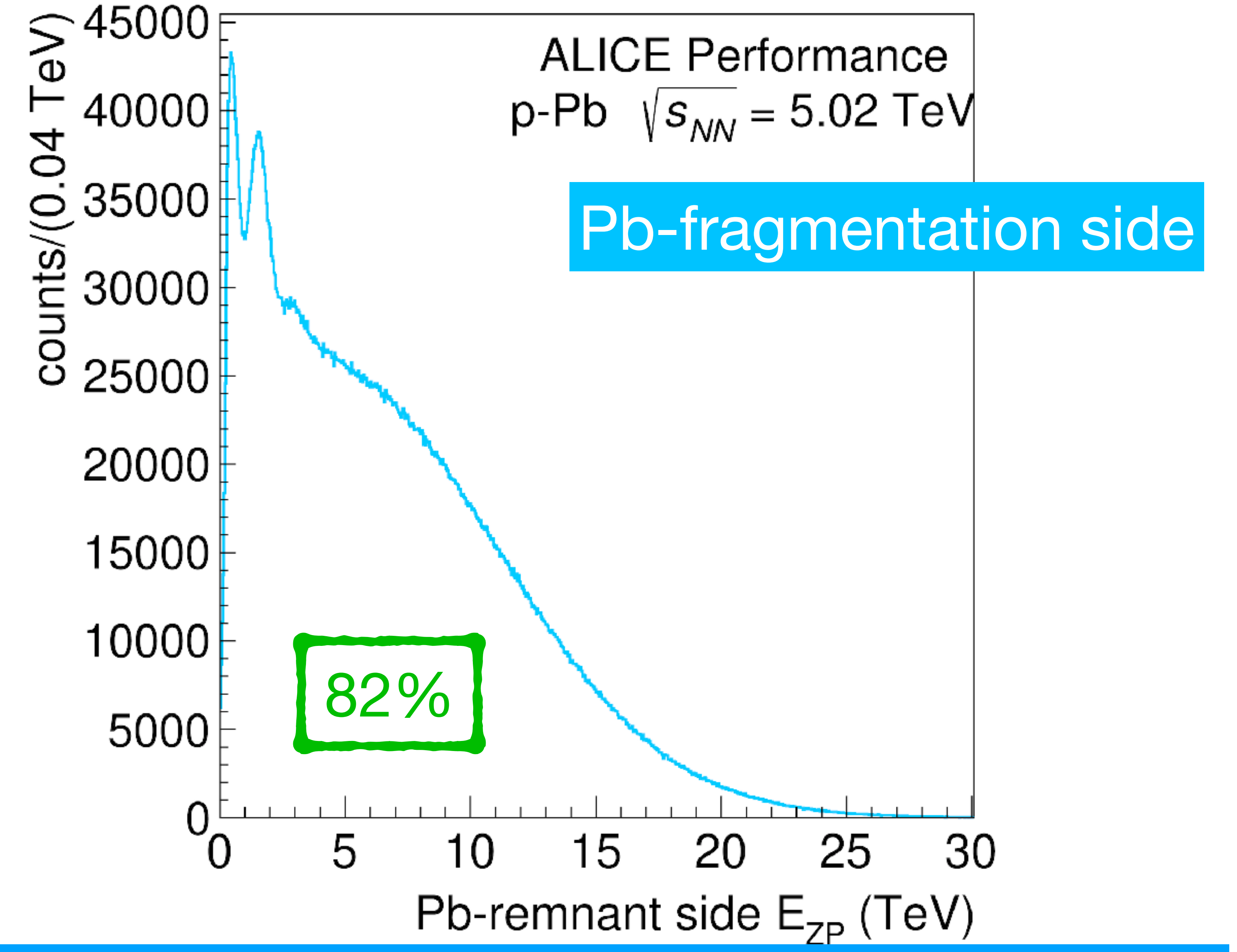


ZP

Event selection fraction



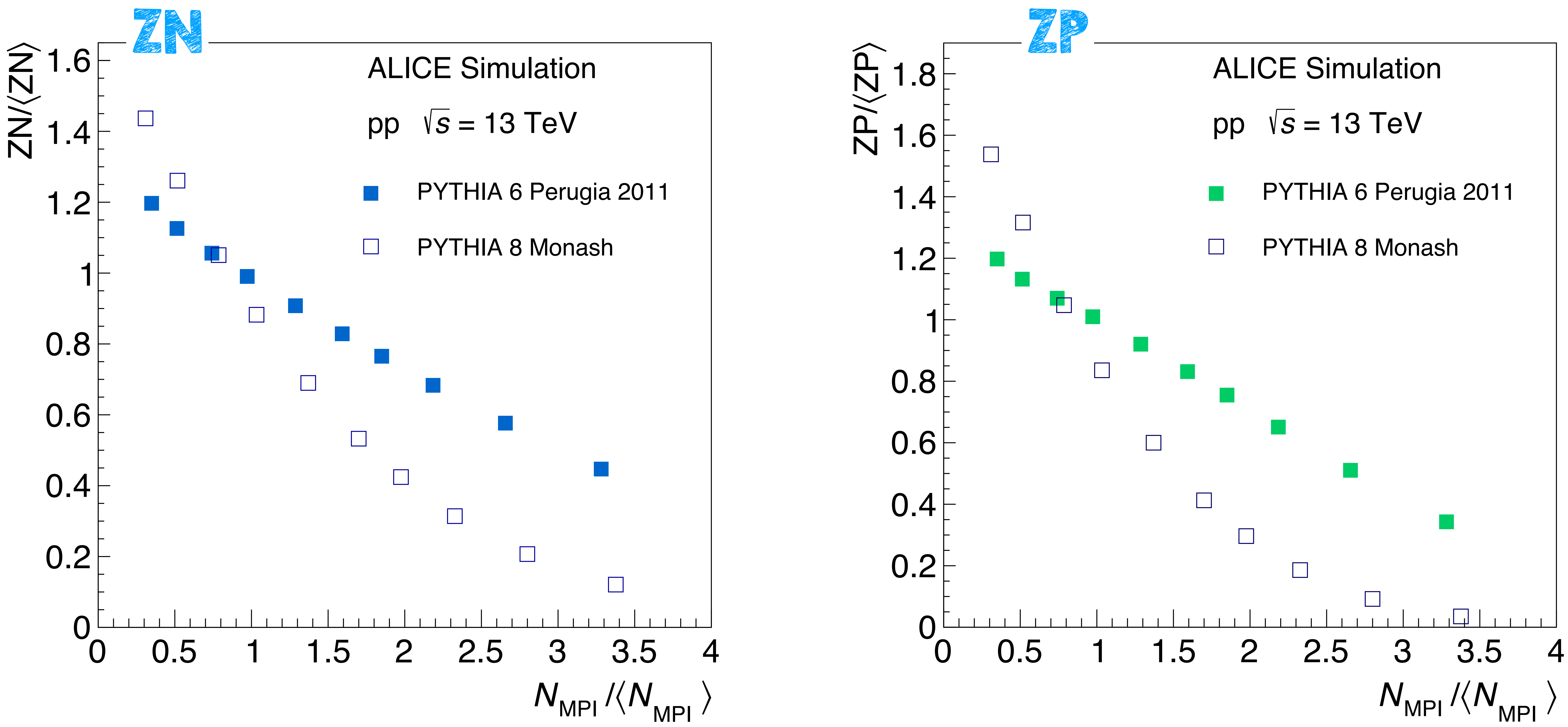




Very forward energy and MPI

Self-normalized ZN and ZP simulated signals vs. number of MPIs

ALICE Coll., arXiv 2107.10757



- PYTHIA 6 and PYTHIA 8 predict a decrease in the average very forward energy for an increasing number of MPIs
- the pattern resembles the observed dependence on charged-particle multiplicity, as expected in an impact-parameter dependent MPI picture