Scaling properties of the underlying event in high-energy *pp* collisions

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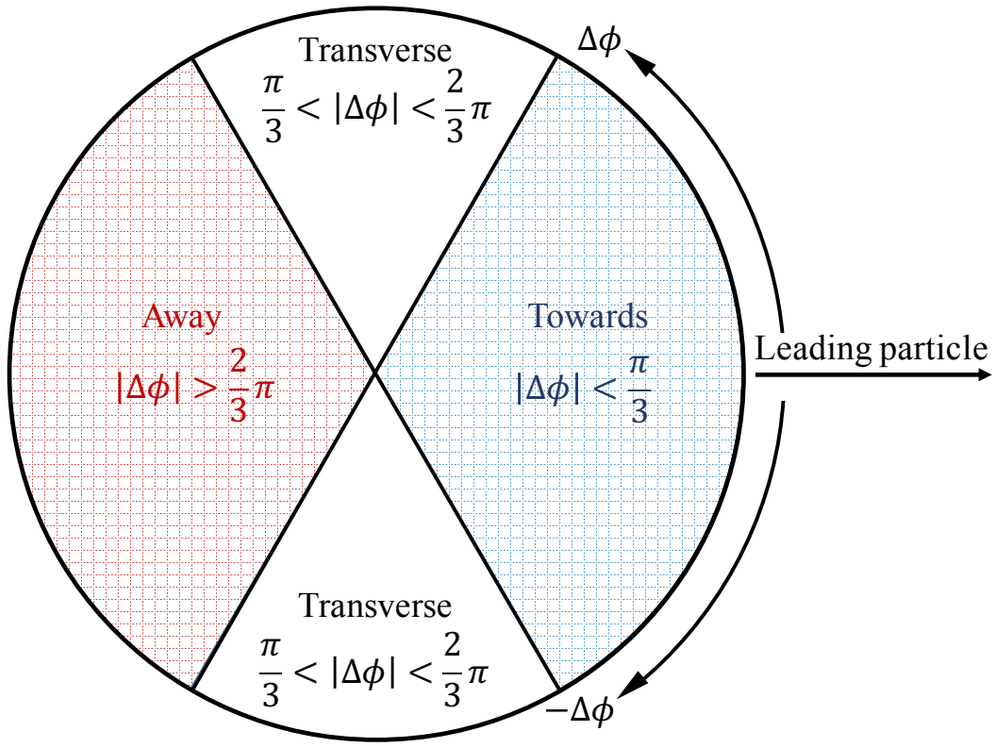
arXiv:1710.04741

Underlying Event (UE)

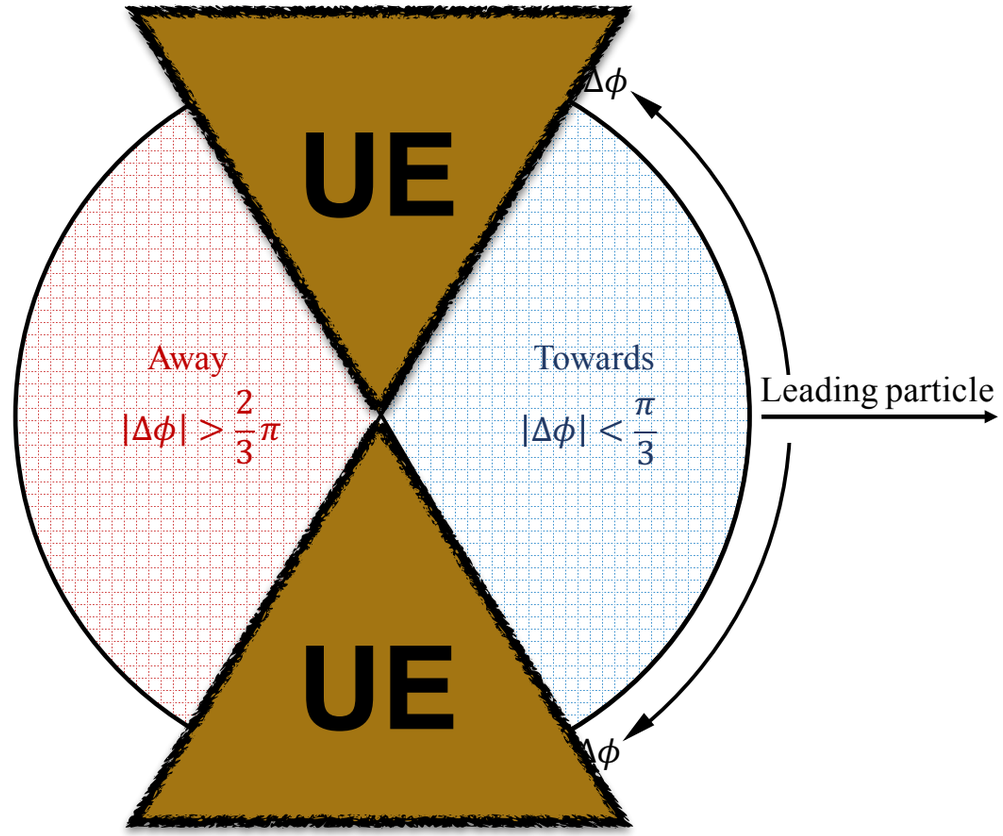
- In the context of event simulation the Underlying Event refers to everything that does not originate from the main hard scattering



Underlying Event (UE)

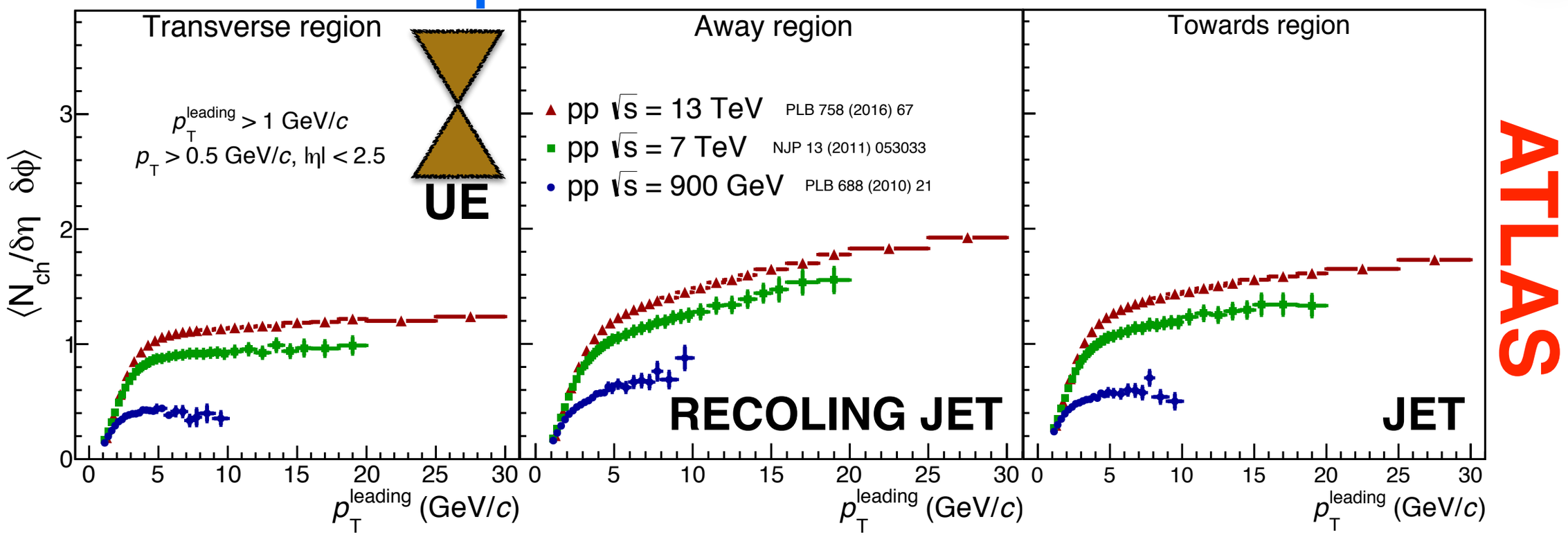
- In the context of event simulation the Underlying Event refers to everything that does not originate from the main hard scattering

- Experimentally we measure quantities which are sensitive to UE: particle production within a region which is perpendicular to the direction of the main scattering



Initial observations, ATLAS results

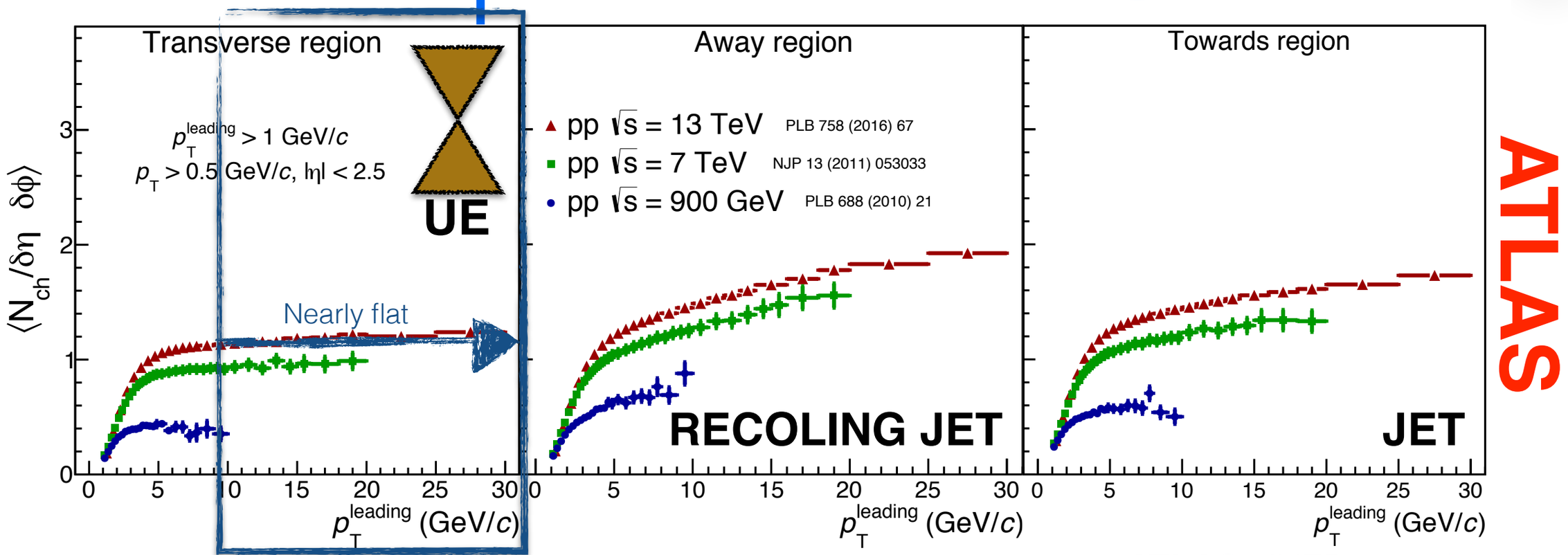
Properties of UE



ATLAS, JHEP 1703 (2017) 157

Multiplicity density of primary charged-particles (number density) as a function of the largest transverse momentum (leading charged particle) of the event

Properties of UE

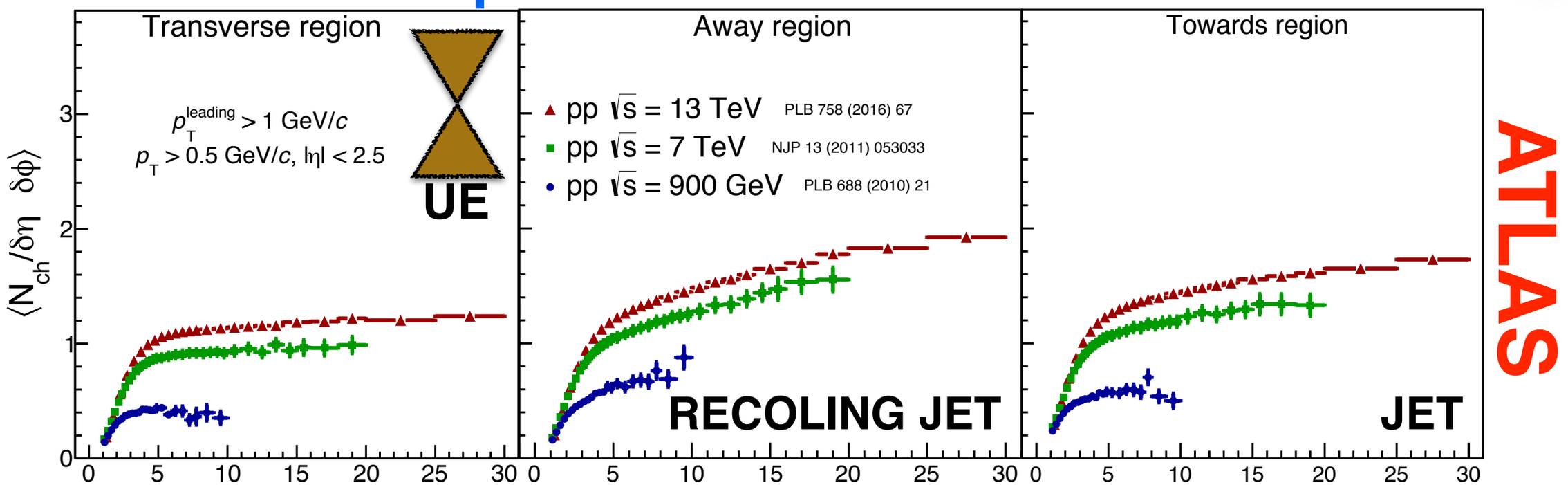


ATLAS, JHEP 1703 (2017) 157

Evidence of the impact parameter dependence in the hadronic collisions: the harder the p_T scale is, the more central the collision

GOAL: Understand the energy dependence of the quantities sensitive to the underlying event

Properties of UE



ATLAS, JHEP 1703 (2017) 157

$\sqrt{s}$ (TeV)

0.9 → 7 → 13

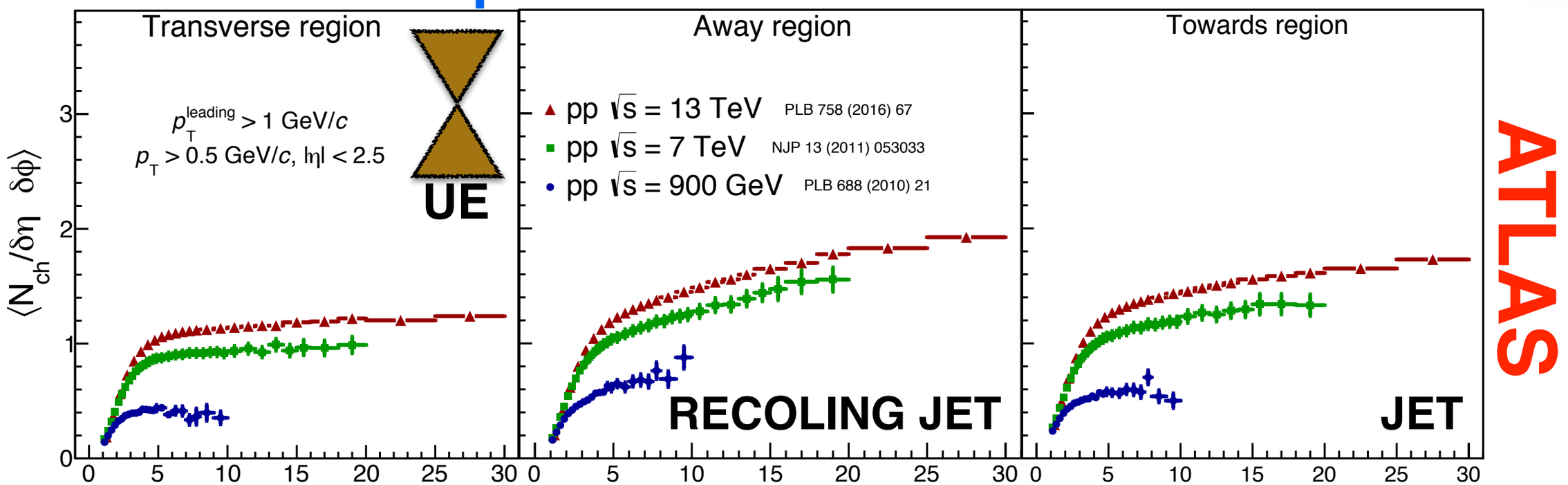
$\langle dN_{ch}/d\eta \rangle$ 1.306 2.405 2.862

$p_T > 0.5$ GeV/c

$|\eta| < 2.5$

$N_{ch} > 1$

Properties of UE



ATLAS, JHEP 1703 (2017) 157

$\sqrt{s}$ (TeV)

0.9 → 7 → 13

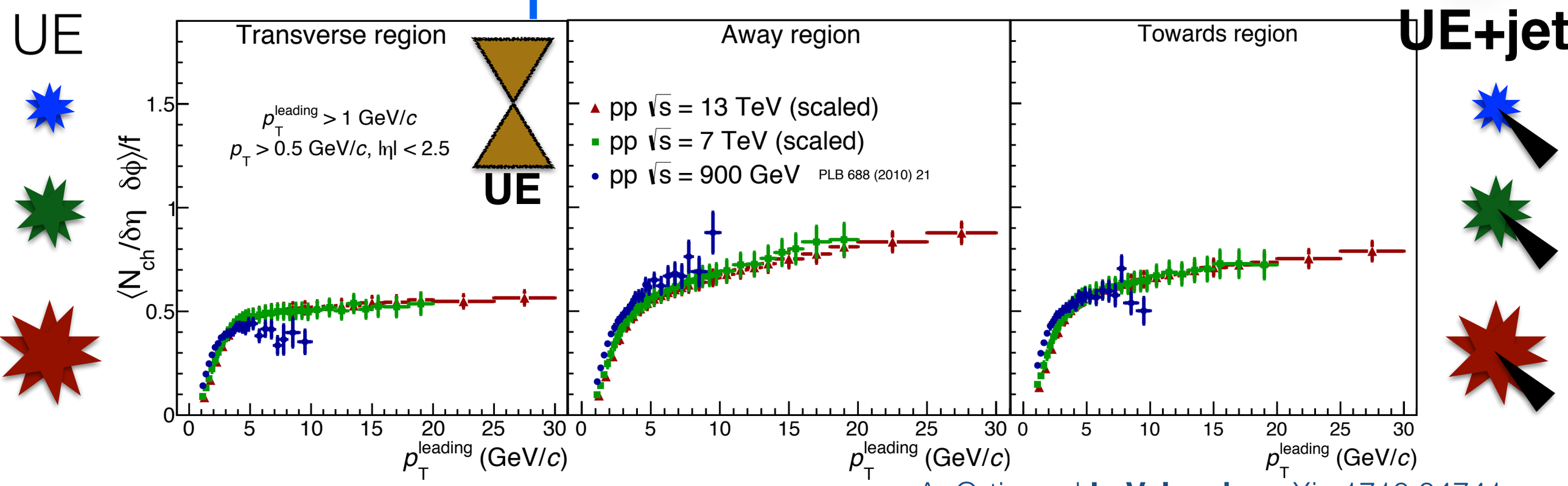
$\langle dN_{ch}/d\eta\rangle$ 1.306 2.405 2.862

$p_T > 0.5$ GeV/c
$|\eta|<2.5$
$N_{ch}>1$

We quantify the multiplicity increase with f defined as:

$$f = \frac{\langle dN_{ch}/d\eta\rangle^{pp\ \sqrt{s}=X\ TeV}}{\langle dN_{ch}/d\eta\rangle^{pp\ \sqrt{s}=0.9\ TeV}}$$

Properties of UE



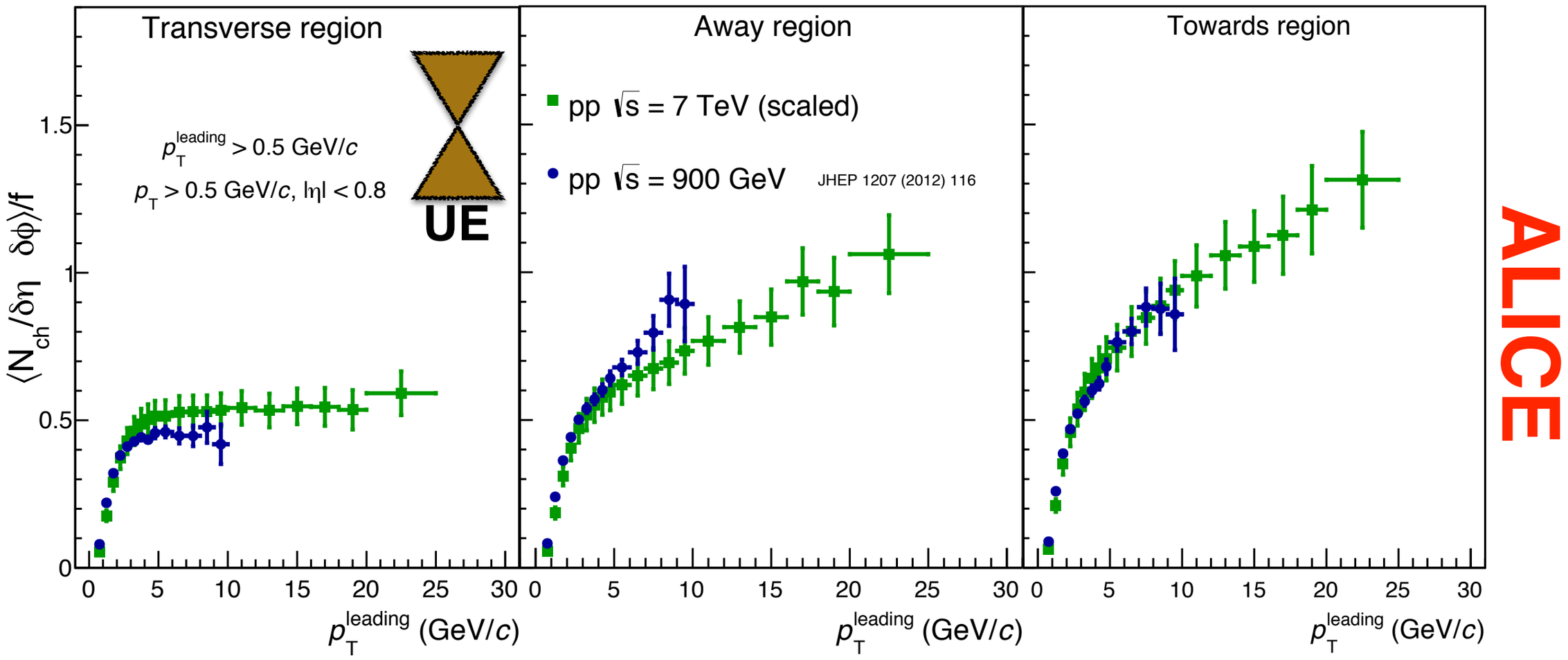
A. Ortiz and **L. Valencia**, arXiv:1710.04741

- Interesting scaling of the number density as a function of the leading p_T. The effect is unveiled once the number density is scaled according with the change of the average multiplicity wrt pp at $\sqrt{s}$ = 0.9 TeV
- Same factor for regions sensitive to different physics

Properties of UE

- Same effect seen in ALICE data (*f* is that from ATLAS data)

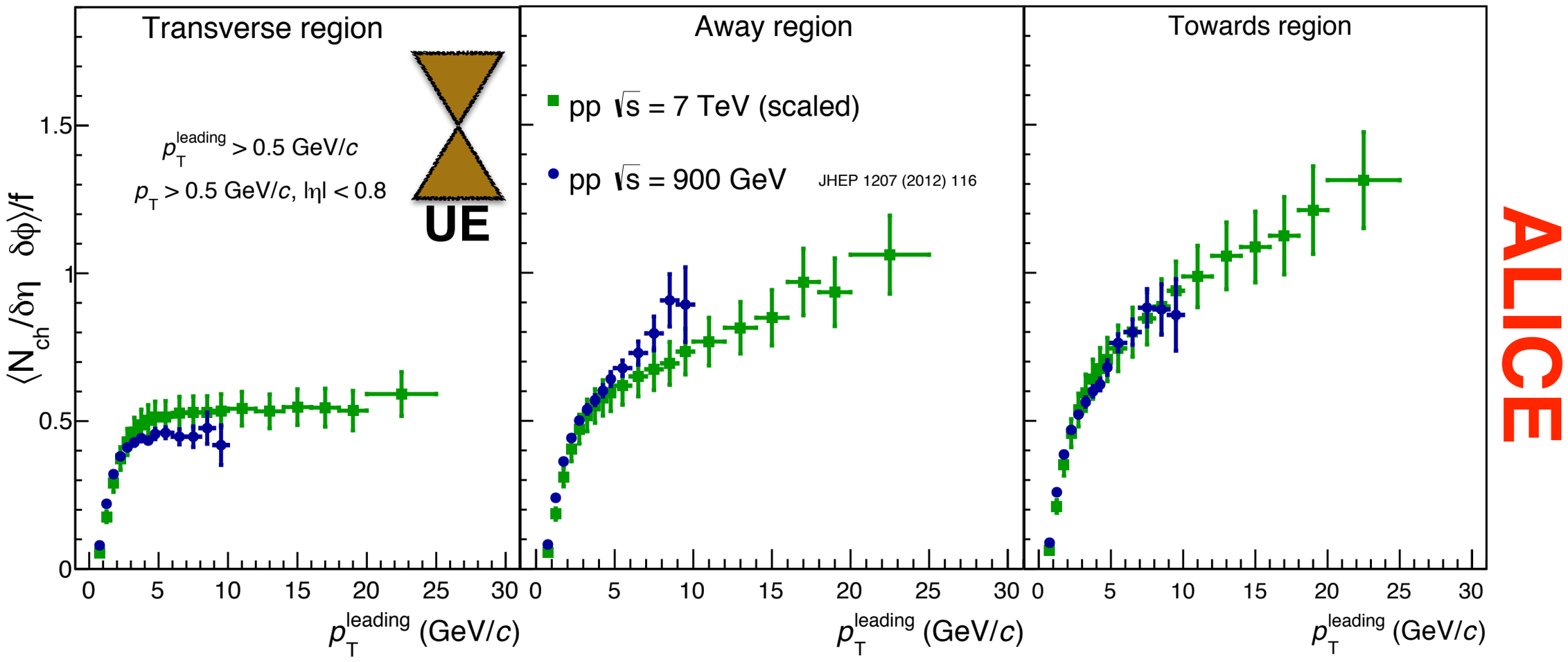
ALICE, JHEP 07 (2012) 116



Properties of UE

- The scaling also holds for the summed transverse momentum
- PYTHIA 8.212 reproduces the scaling properties

ALICE, JHEP 07 (2012) 116



$\sqrt{s}$ dependence of UE vs MB

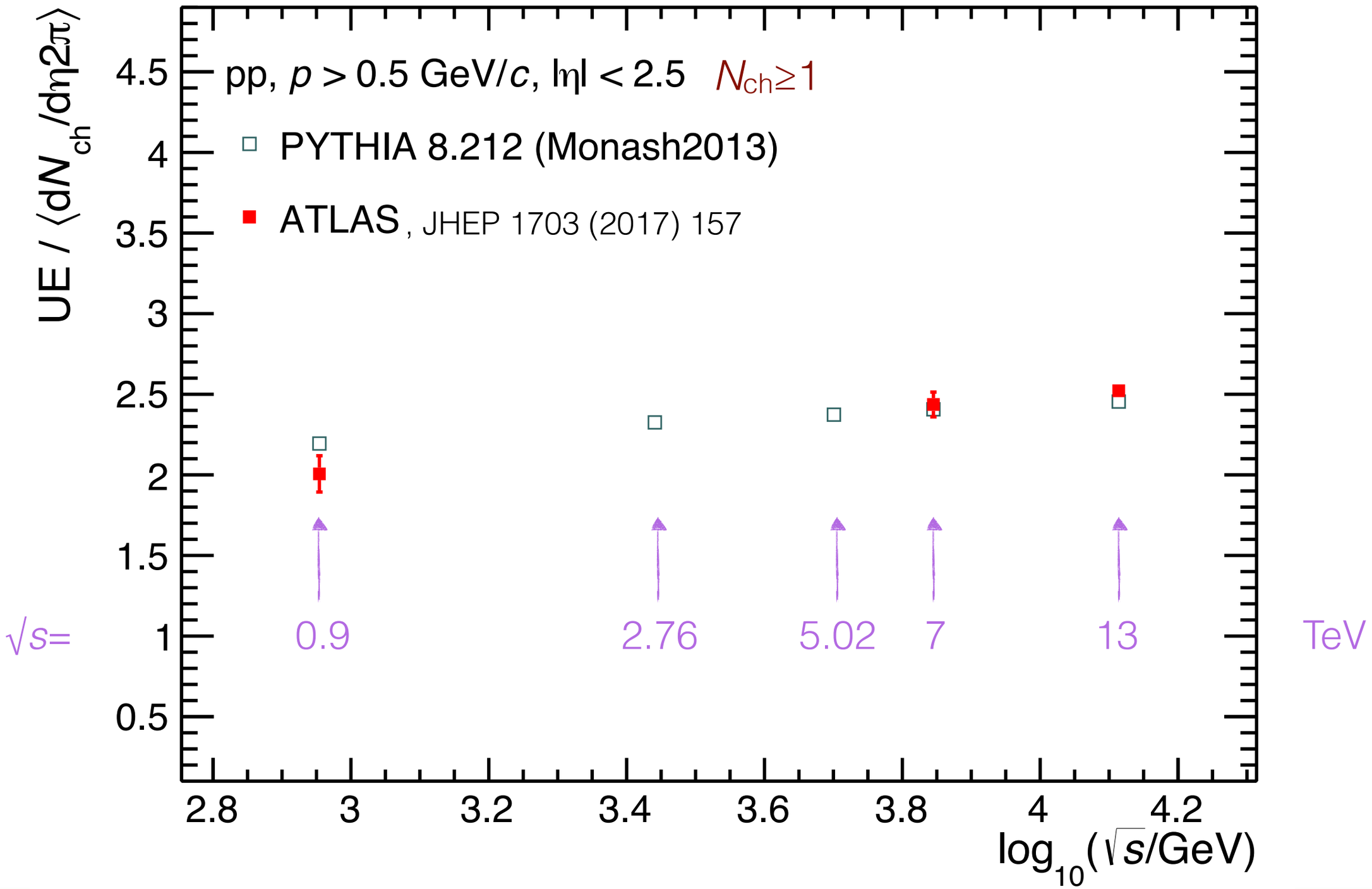
Within uncertainties, we obtain the following approximate relations:

$$\mathrm{UE}^{13\,\mathrm{TeV}}\,\frac{\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle^{0.9\,\mathrm{TeV}}}{\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle^{13\,\mathrm{TeV}}} \approx \mathrm{UE}^{0.9\,\mathrm{TeV}} \approx \mathrm{UE}^{7\,\mathrm{TeV}}\,\frac{\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle^{0.9\,\mathrm{TeV}}}{\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle^{7\,\mathrm{TeV}}}$$

UE: mean multiplicity in the transverse region ($p_{\mathrm{T}}^{\mathrm{leading}}$>7 GeV/$c$)
$\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle$: inclusive average multiplicity for the specific event class, e.g. events with at least one charged particle within $|\eta|$ <2.5 and p_{T}>0.5 GeV/c

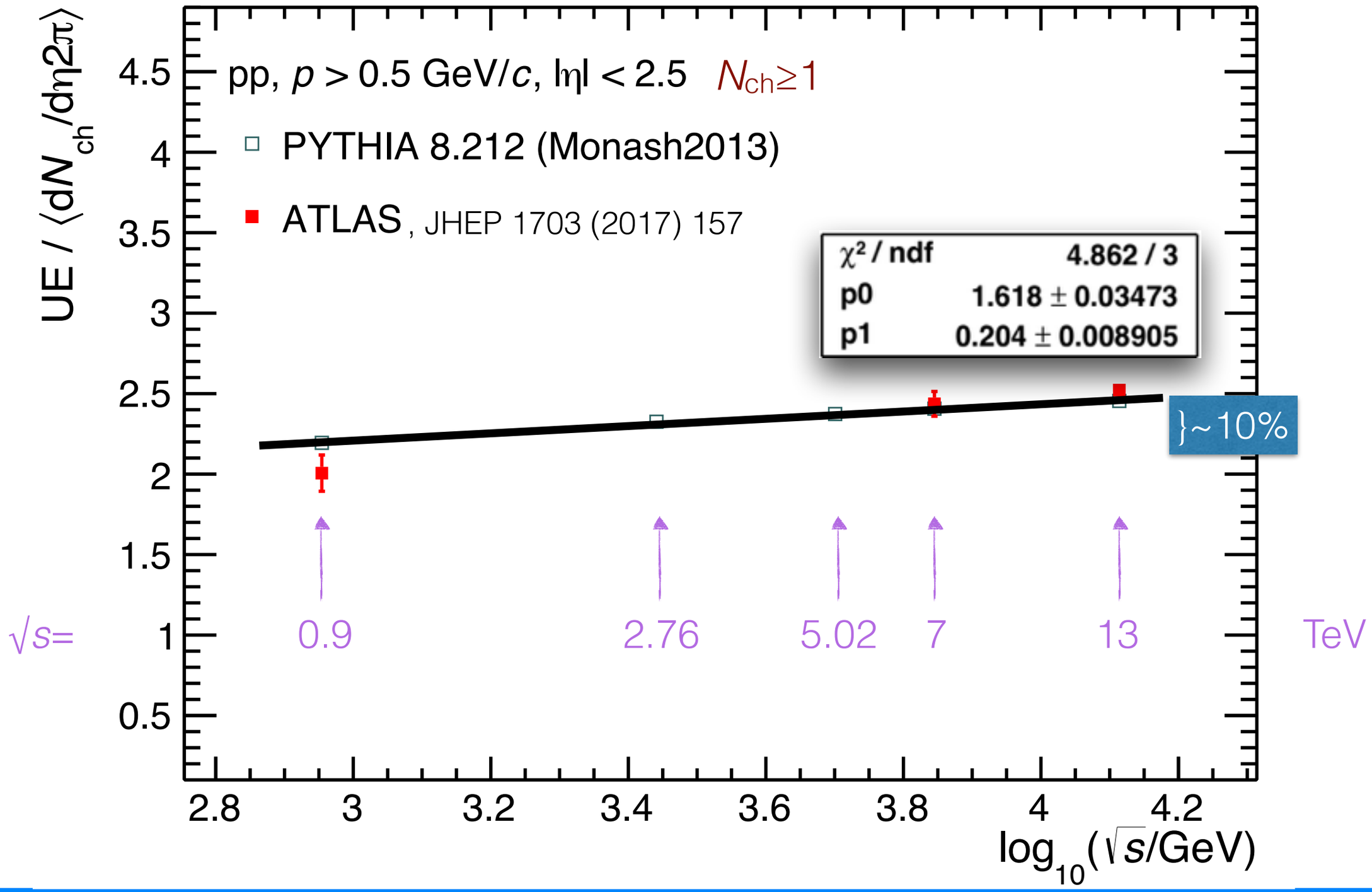
Therefore, $\dfrac{\mathrm{UE}}{\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle}$ would be little dependent on $\sqrt{s}$

PYTHIA vs data



UE was extracted for $p_{T\text{leading}} > 7$ GeV/c

PYTHIA vs data



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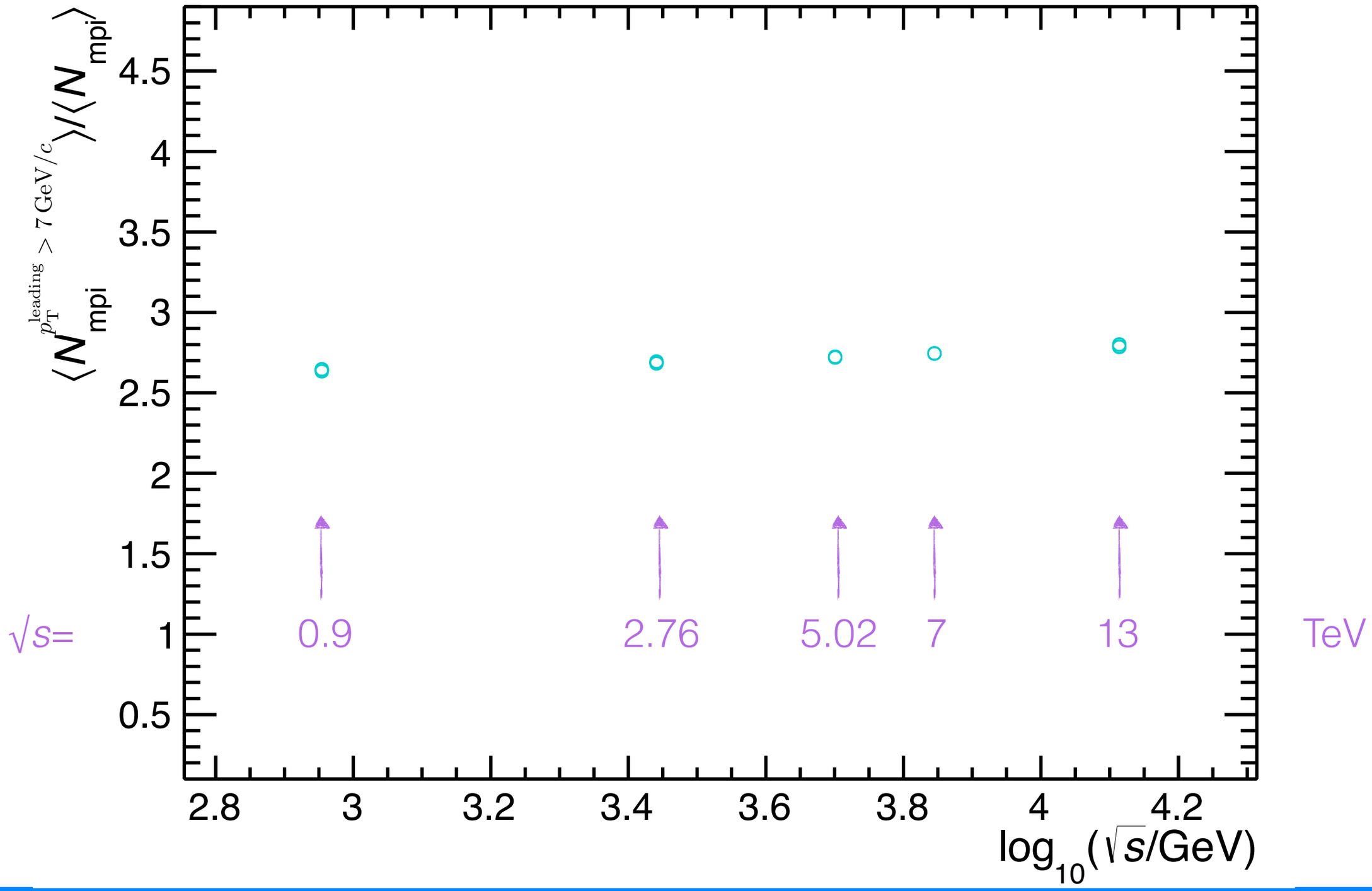
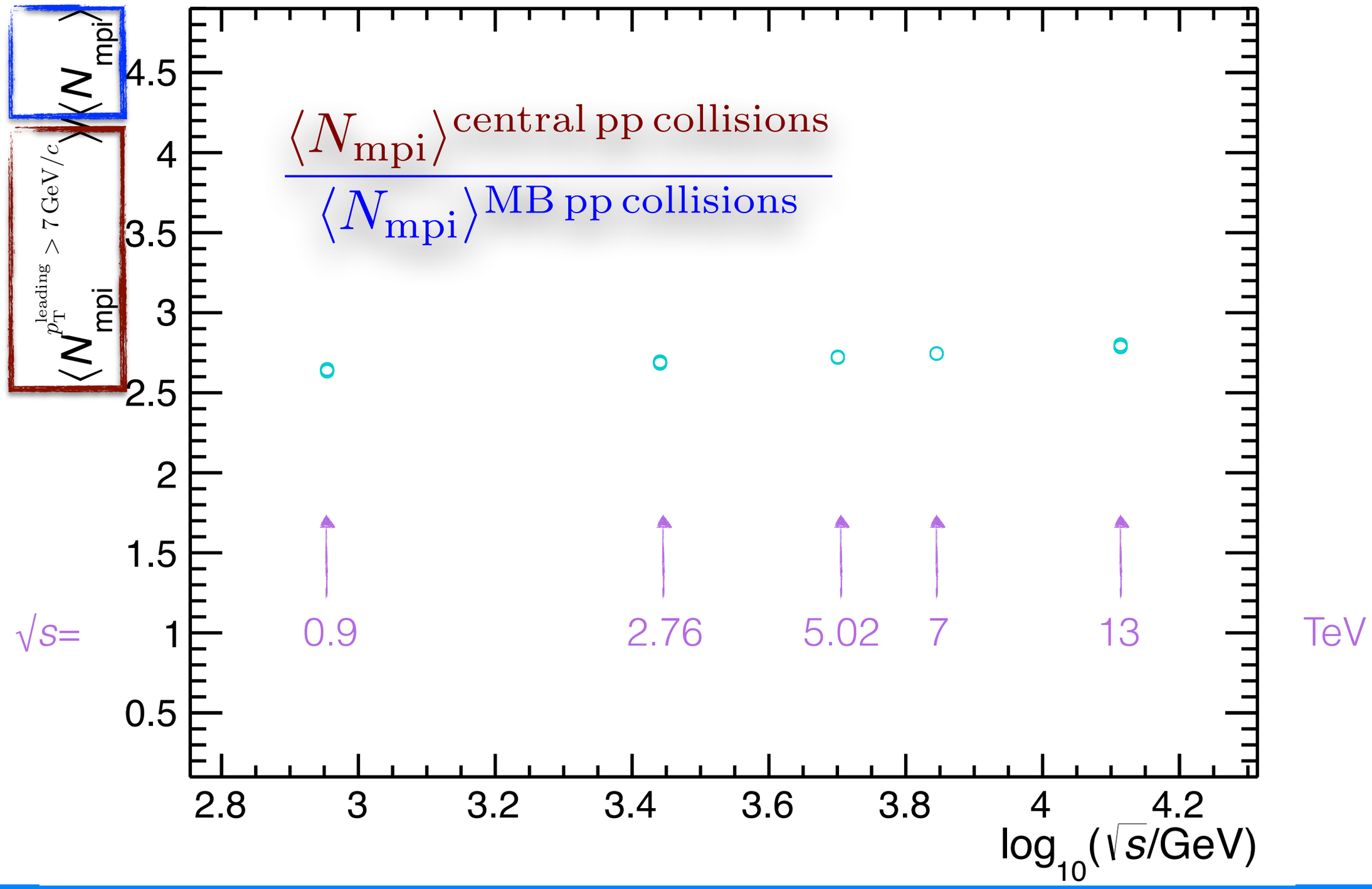
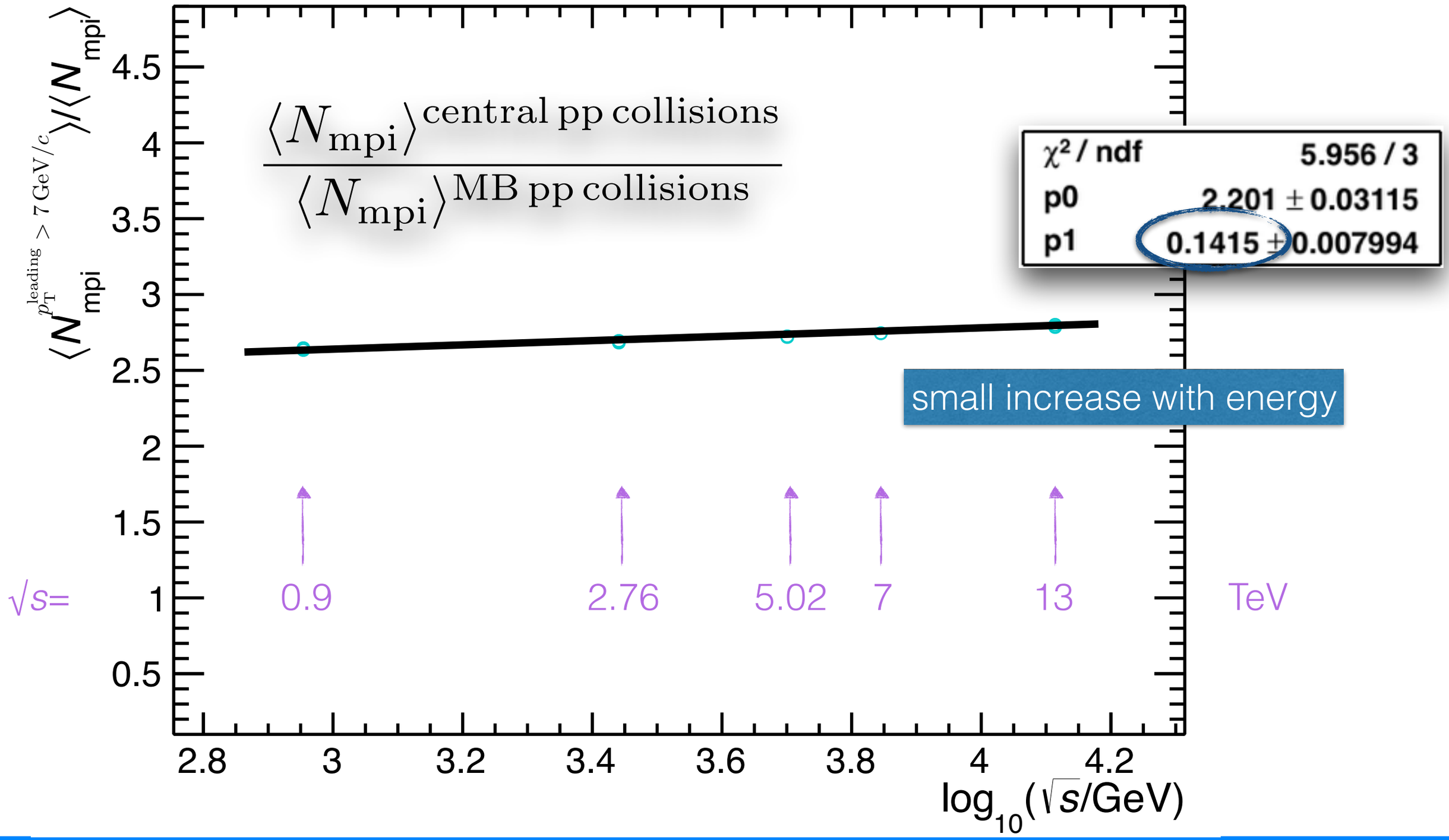
Similar effects in MPI



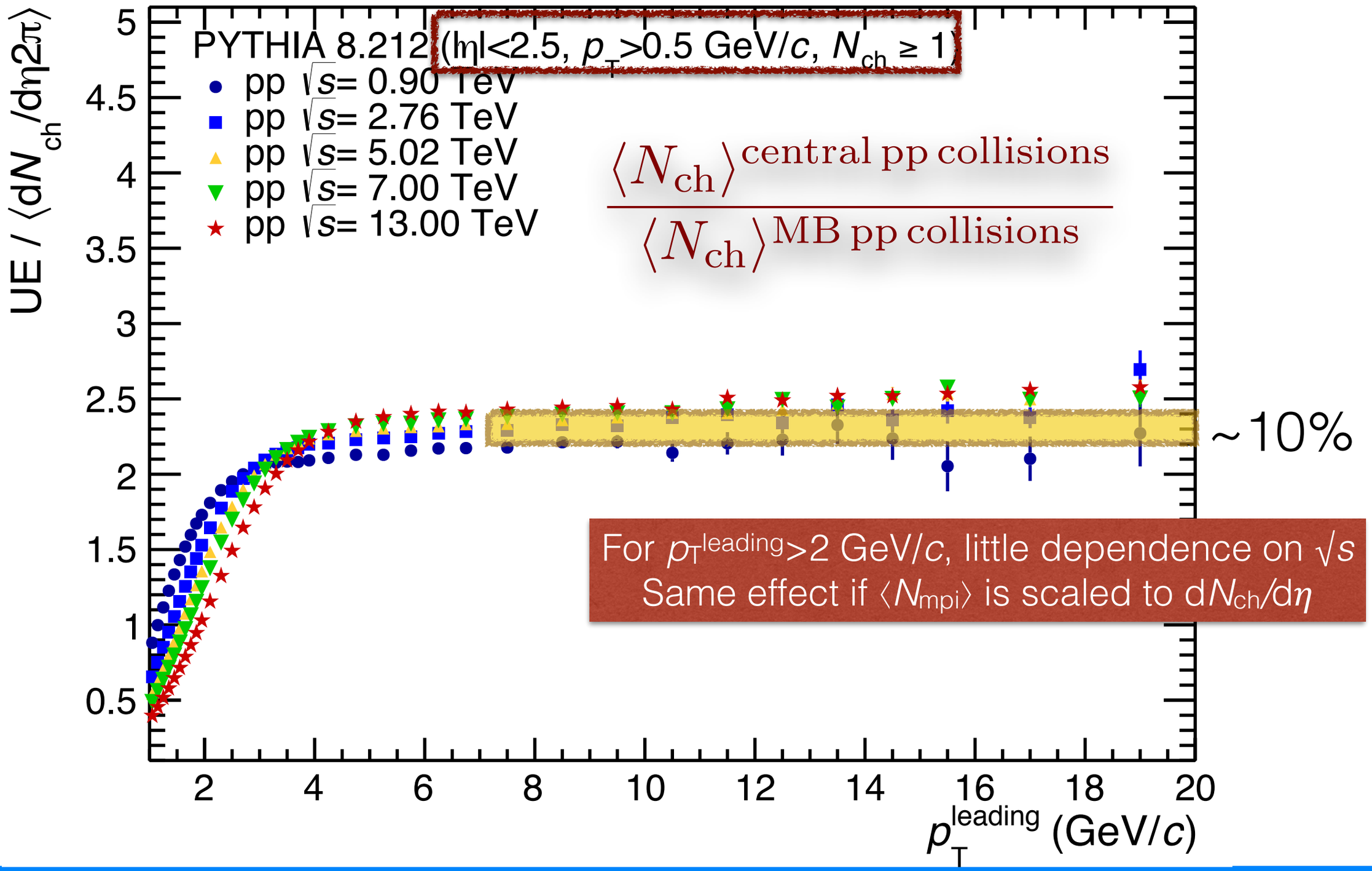
Similar effects in MPI



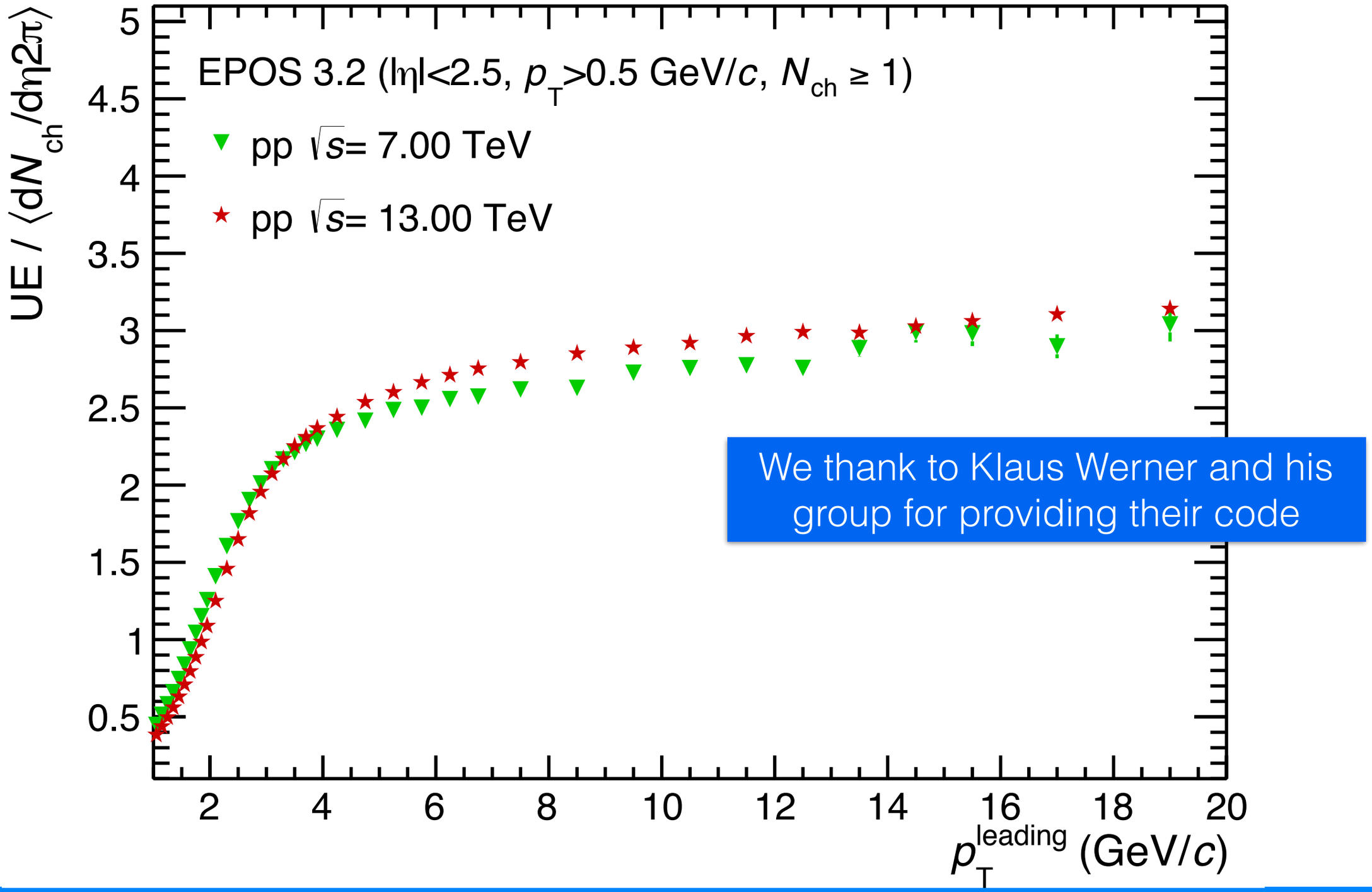
Similar effects in MPI



p_T-differential UE

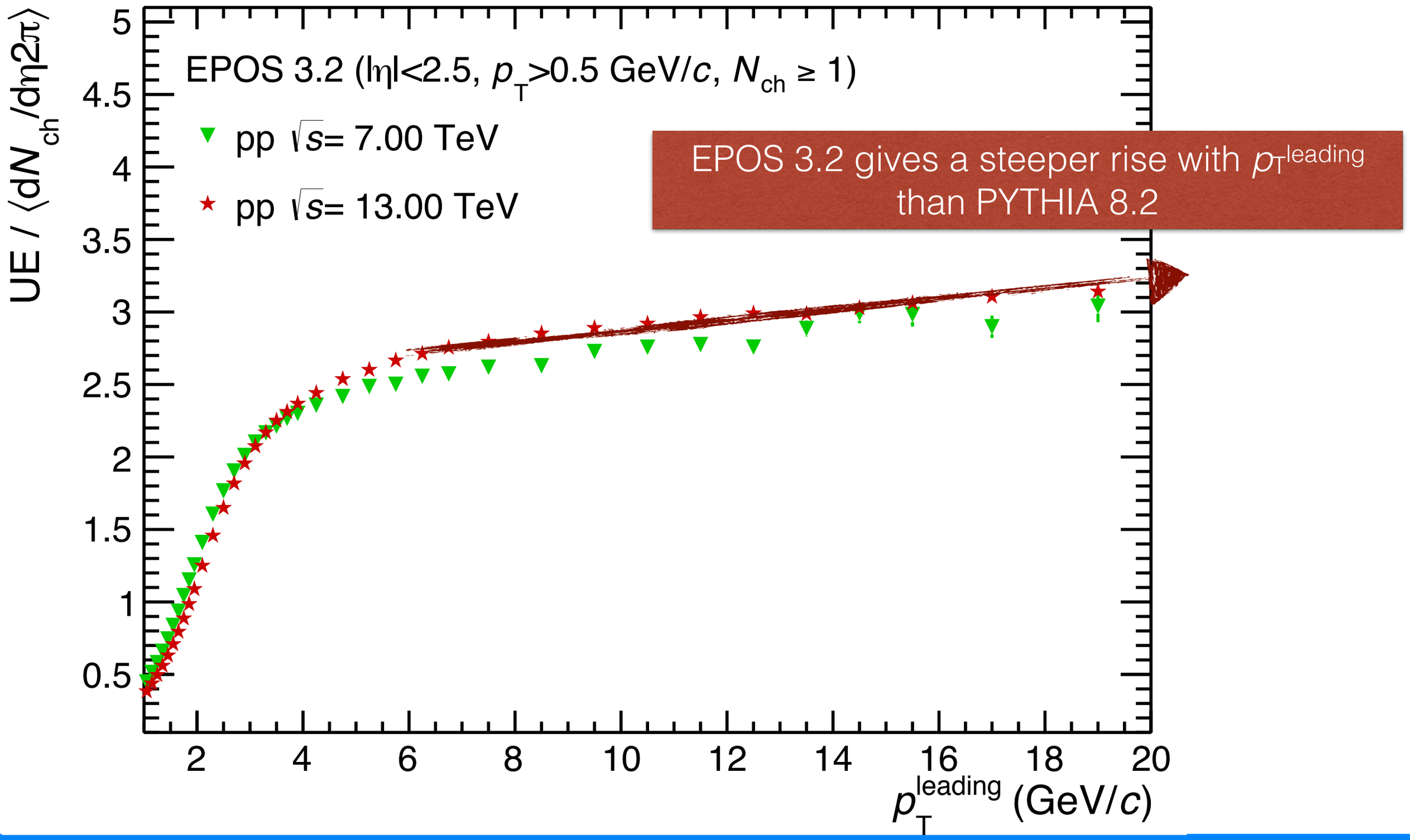


EPOS 3.2 predictions

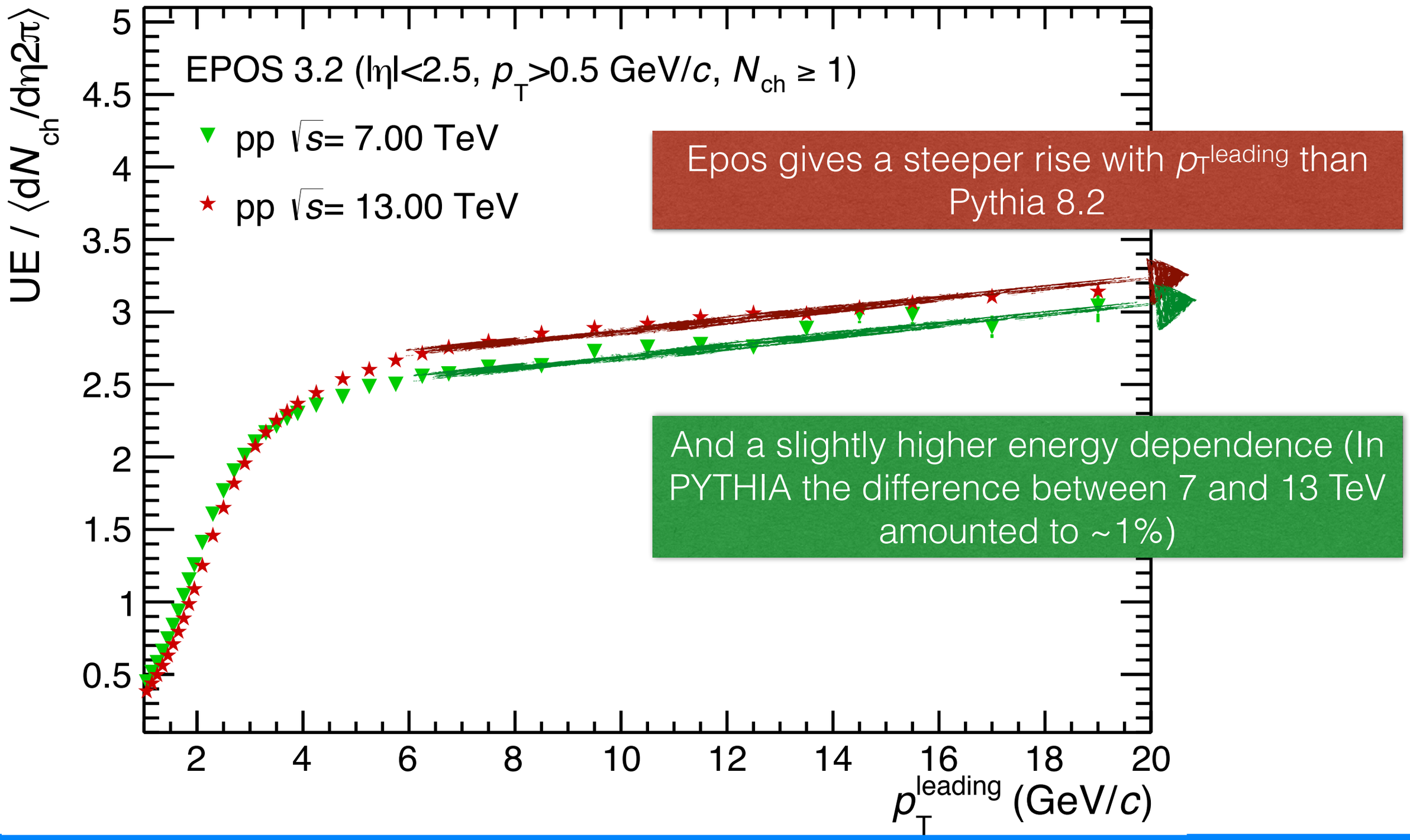


We thank to Klaus Werner and his group for providing their code

EPOS 3.2 predictions

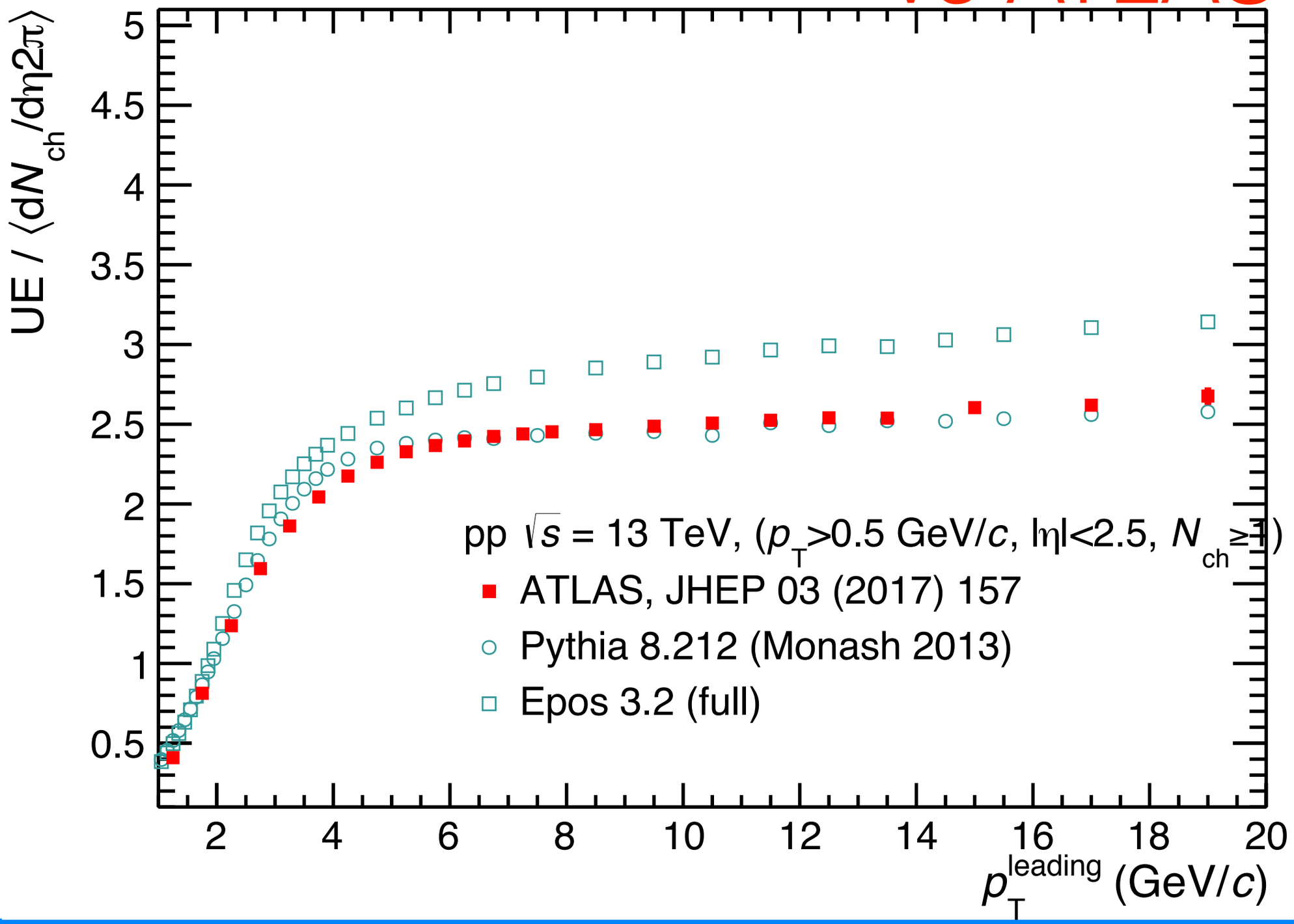


EPOS 3.2 predictions



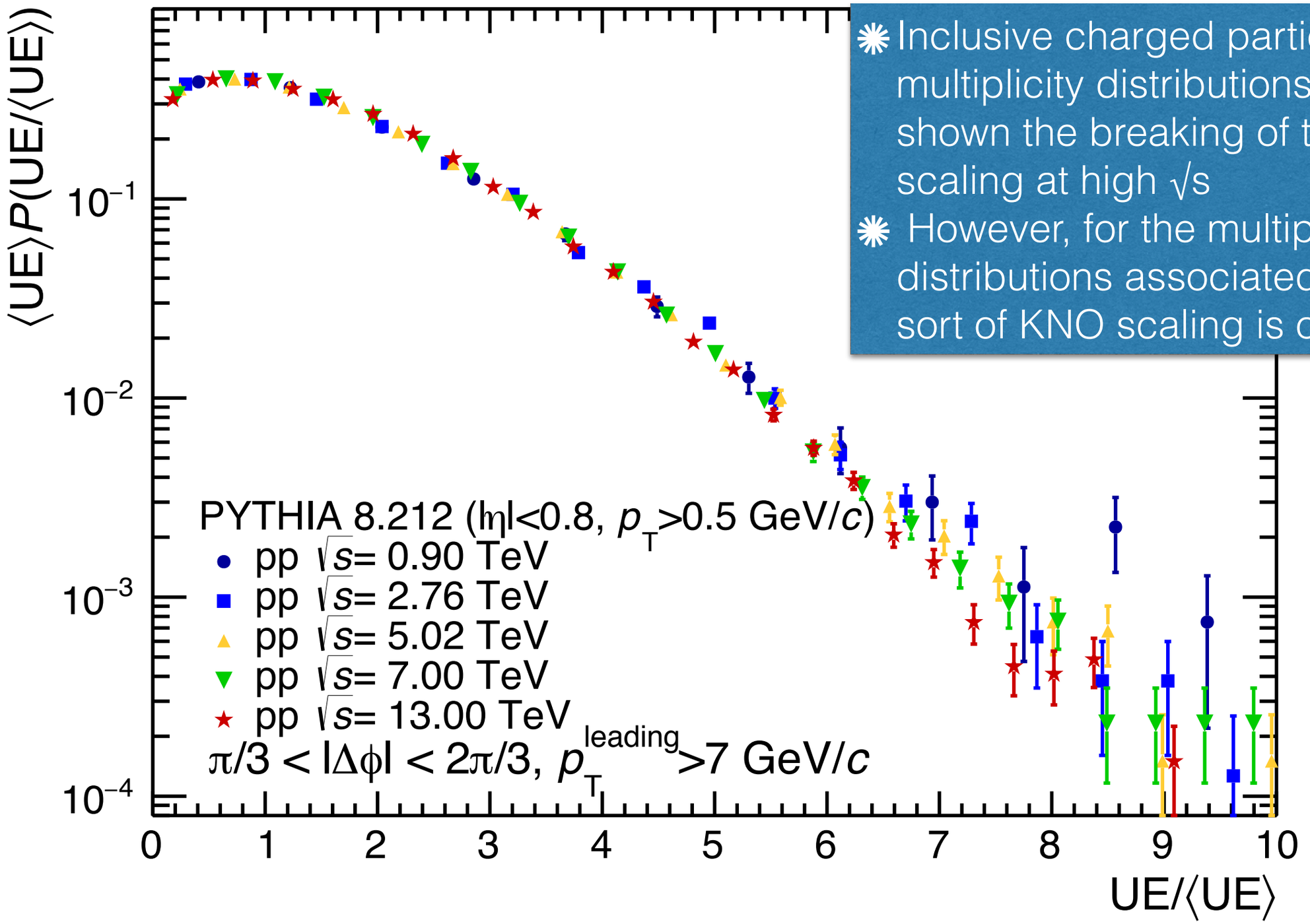
EPOS 3.2 - PYTHIA 8.2

vs ATLAS data



Multiplicity distributions associated to UE

N_{ch} distributions of UE



- Inclusive charged particles multiplicity distributions have shown the breaking of the KNO scaling at high √s
- However, for the multiplicity distributions associated to UE a sort of KNO scaling is observed

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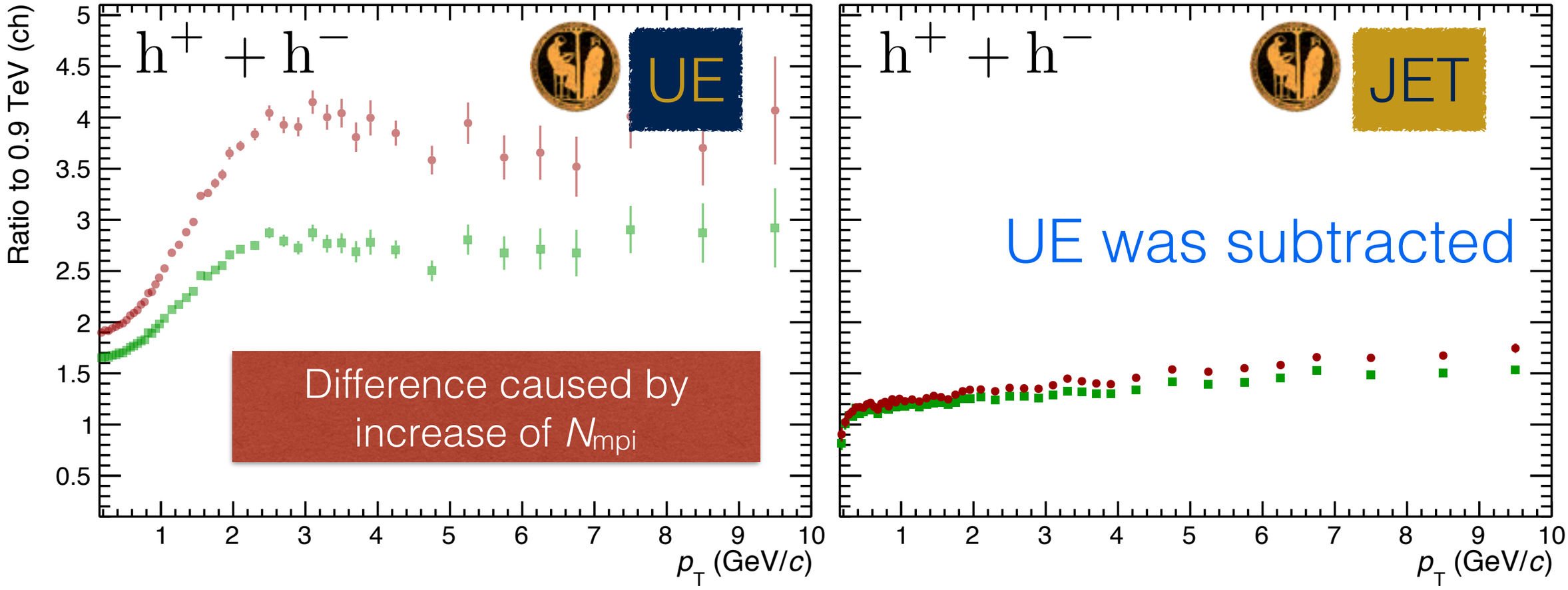
π/K/p p_T distributions associated to UE

- $p_T^{leading}$ >10 GeV/c charged particles within $|\eta|$<2.5

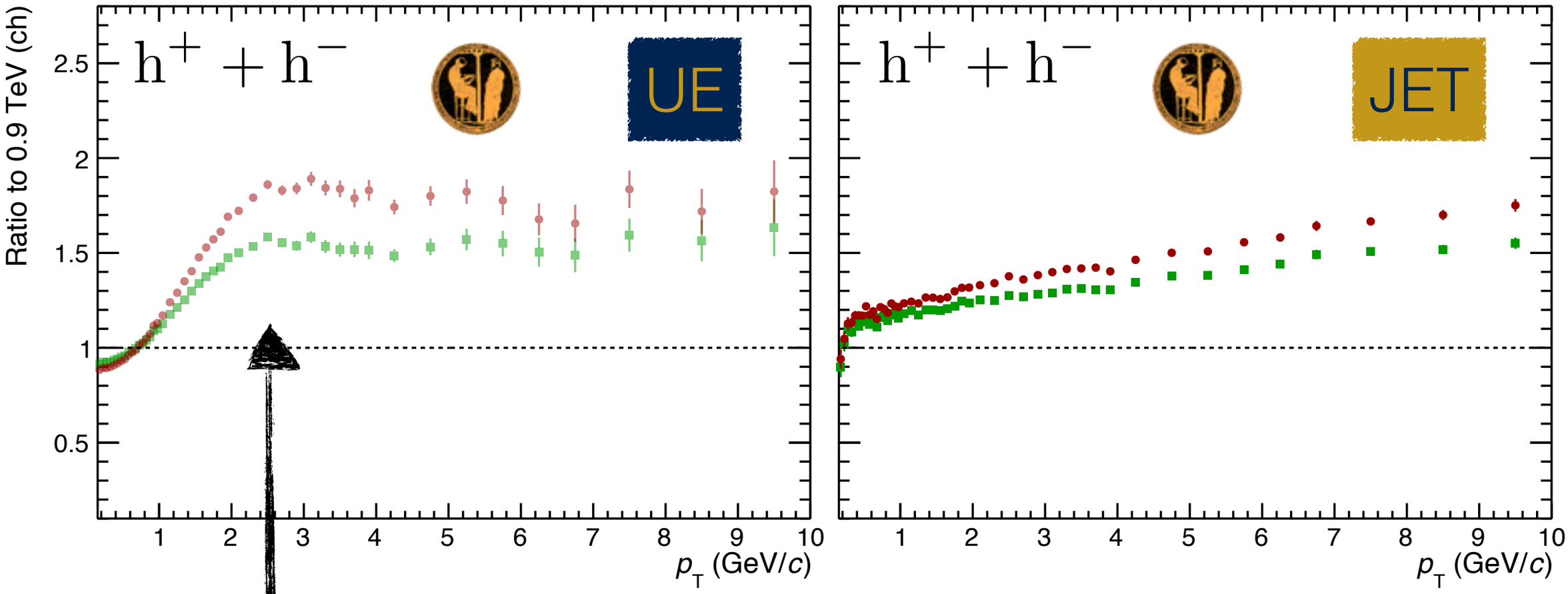
Inclusive charged particles



$$\frac{\text{Yield}^{\text{pp}\ \sqrt{s}=13\ \text{TeV}}}{\text{Yield}^{\text{pp}\ \sqrt{s}=0.9\ \text{TeV}}}\ \text{vs}\ p_{\text{T}}$$

$$\frac{\text{Yield}^{\text{pp}\ \sqrt{s}=7\ \text{TeV}}}{\text{Yield}^{\text{pp}\ \sqrt{s}=0.9\ \text{TeV}}}\ \text{vs}\ p_{\text{T}}$$

Inclusive charged particles

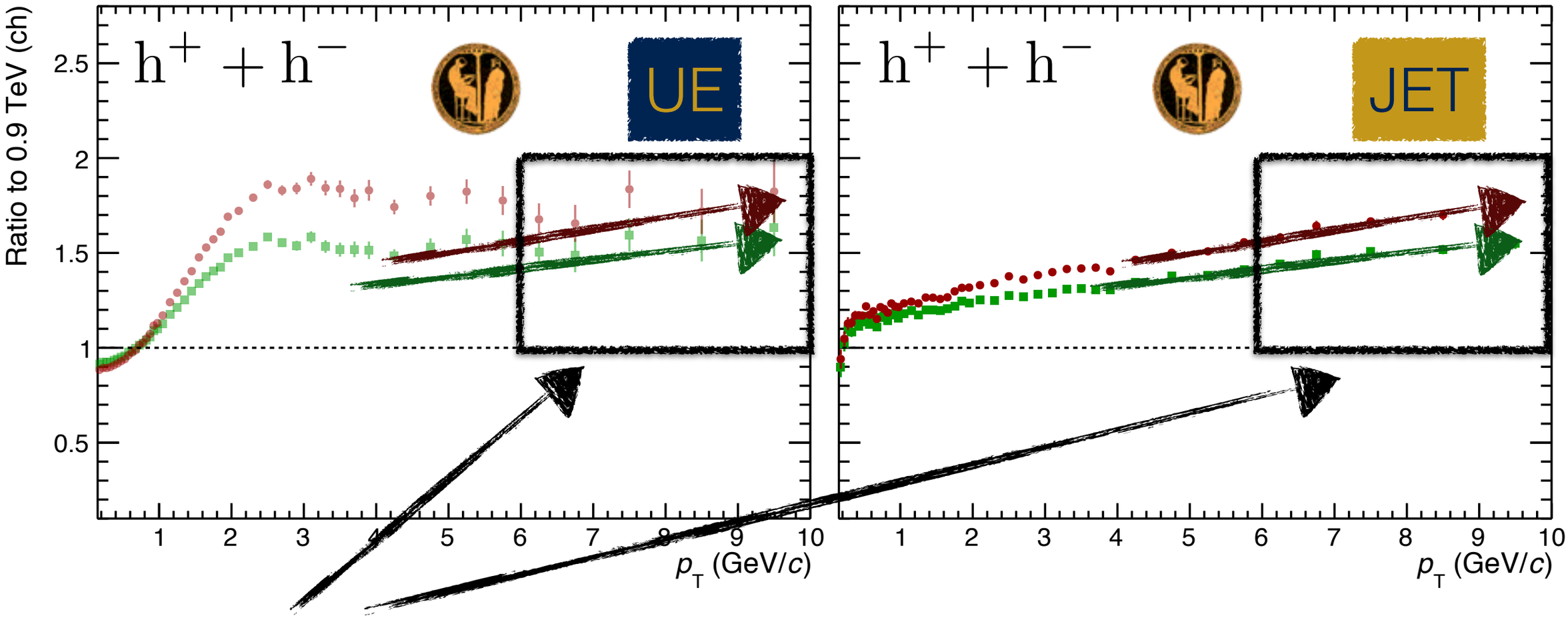


$$\left\{ \frac{\text{Yield}^{\text{pp}\ \sqrt{s}=13\ \text{TeV}}/\langle N_{\text{ch}}\rangle}{\text{Yield}^{\text{pp}\ \sqrt{s}=0.9\ \text{TeV}}/\langle N_{\text{ch}}\rangle} \right.$$

$$\left. \frac{\text{Yield}^{\text{pp}\ \sqrt{s}=7\ \text{TeV}}/\langle N_{\text{ch}}\rangle}{\text{Yield}^{\text{pp}\ \sqrt{s}=0.9\ \text{TeV}}/\langle N_{\text{ch}}\rangle} \right\}$$

Only UE was scaled by the corresponding dN/dη (KNO scaling)

Inclusive charged particles

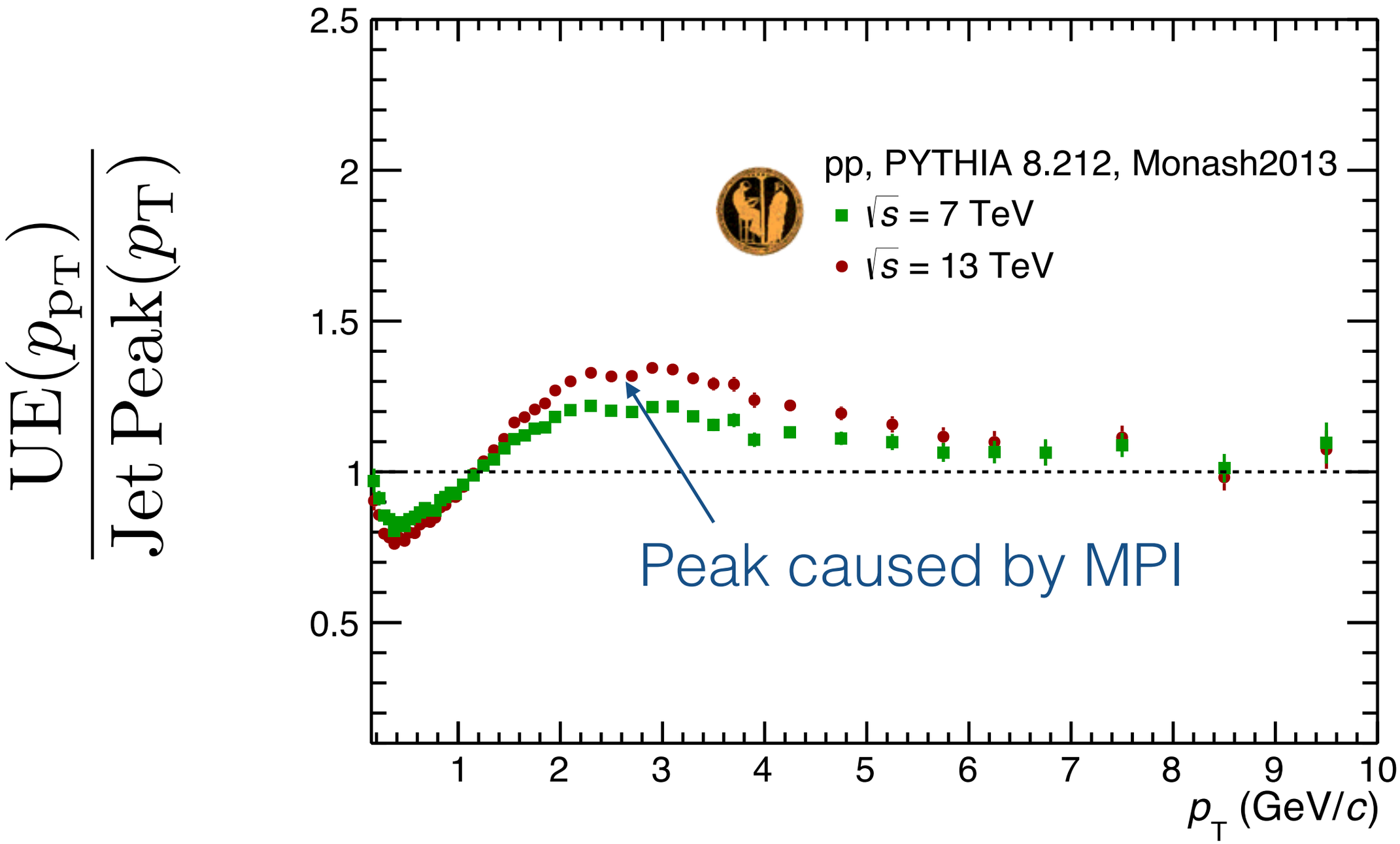


~Same slope (same origin)

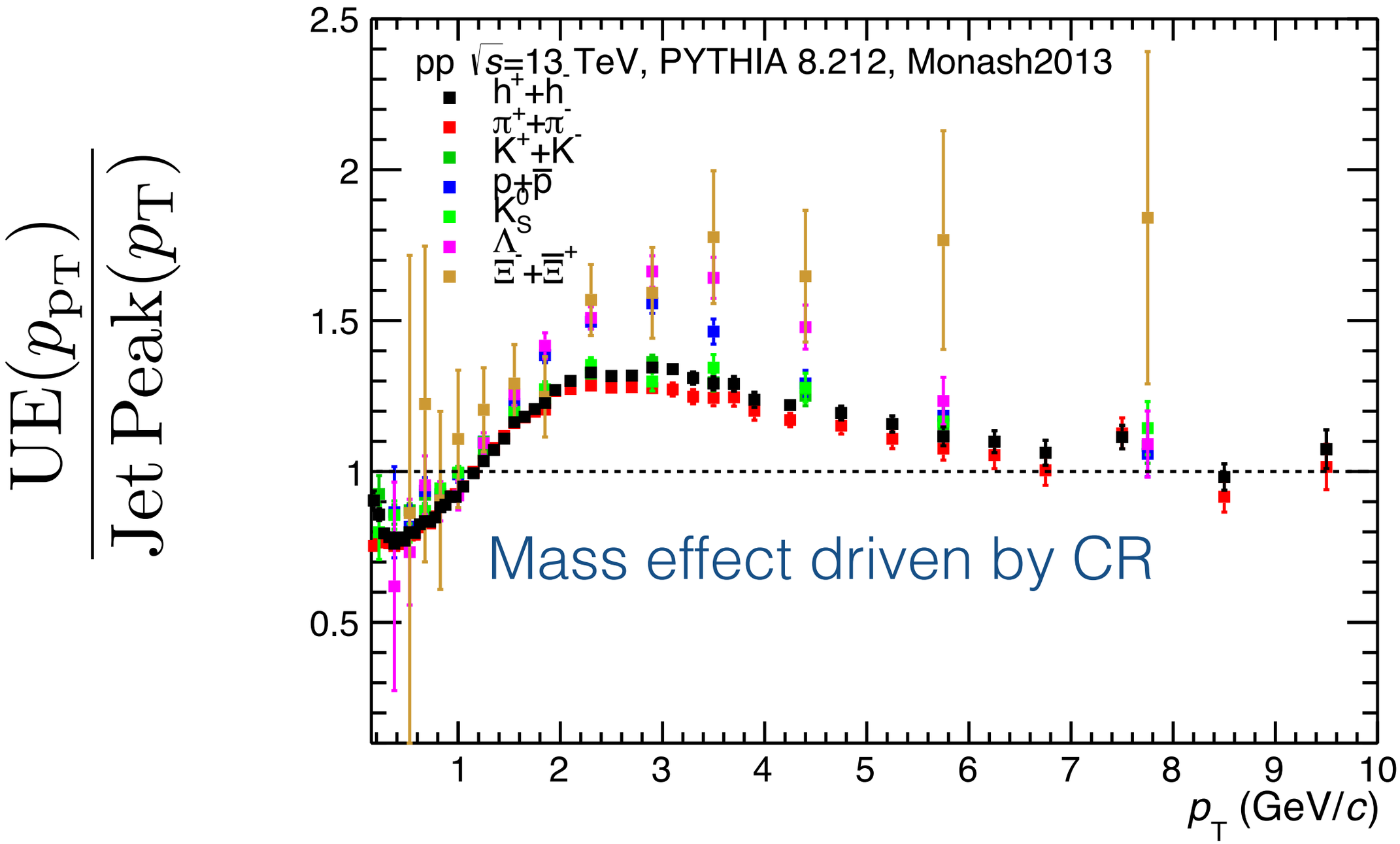
- Remaining hard component
- To remove the remaining jet contamination (from UE) we can compute the ratio:

$$\frac{\mathrm{UE}(p_{\mathrm{pT}})}{\mathrm{Jet\ Peak}(p_{\mathrm{T}})}$$

UE/Jet ratio



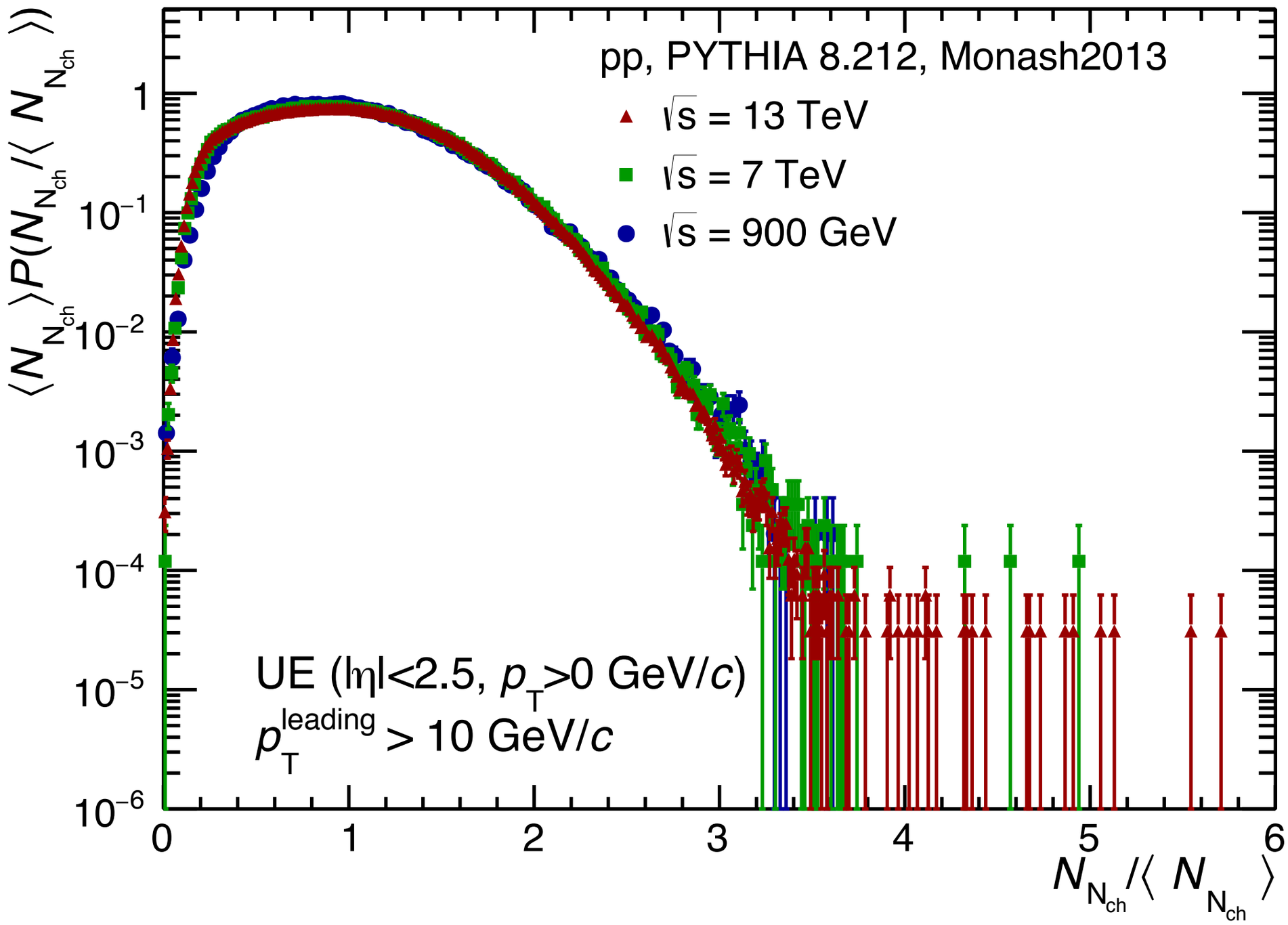
Identified particles



Summary

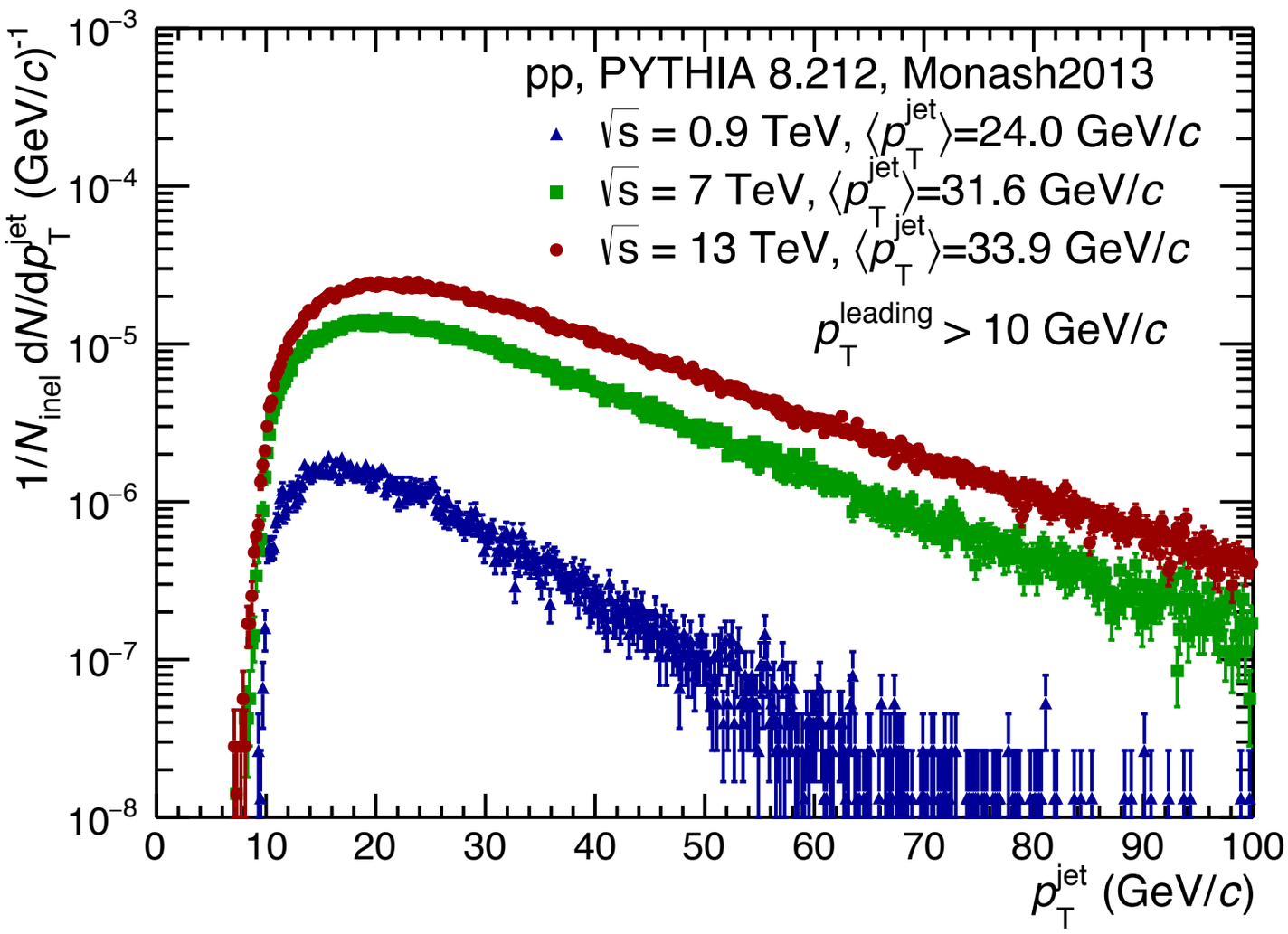
- The impact parameter dependence of the underlying event (≈activity in the transverse region vs $p_T^{leading}$) was studied as a function of $\sqrt{s}$
- The UE activity in central pp collisions (high $p_T^{leading}$ values), scaled to the "MB" inclusive average multiplicity, exhibits a little increase with $\sqrt{s}$ (≈10% from 0.9 to 13 TeV). Therefore, the ratio UE/$\langle$ dN/dη $\rangle$ is sensitive to the collision centrality
- PYTHIA 8.212 (tune Monash 2013) reproduces the behaviour of data. The scaling properties observed at measurable particle level are also observed at partonic level
- The multiplicity distributions associated to the underlying event obey a KNO scaling

BACKUP

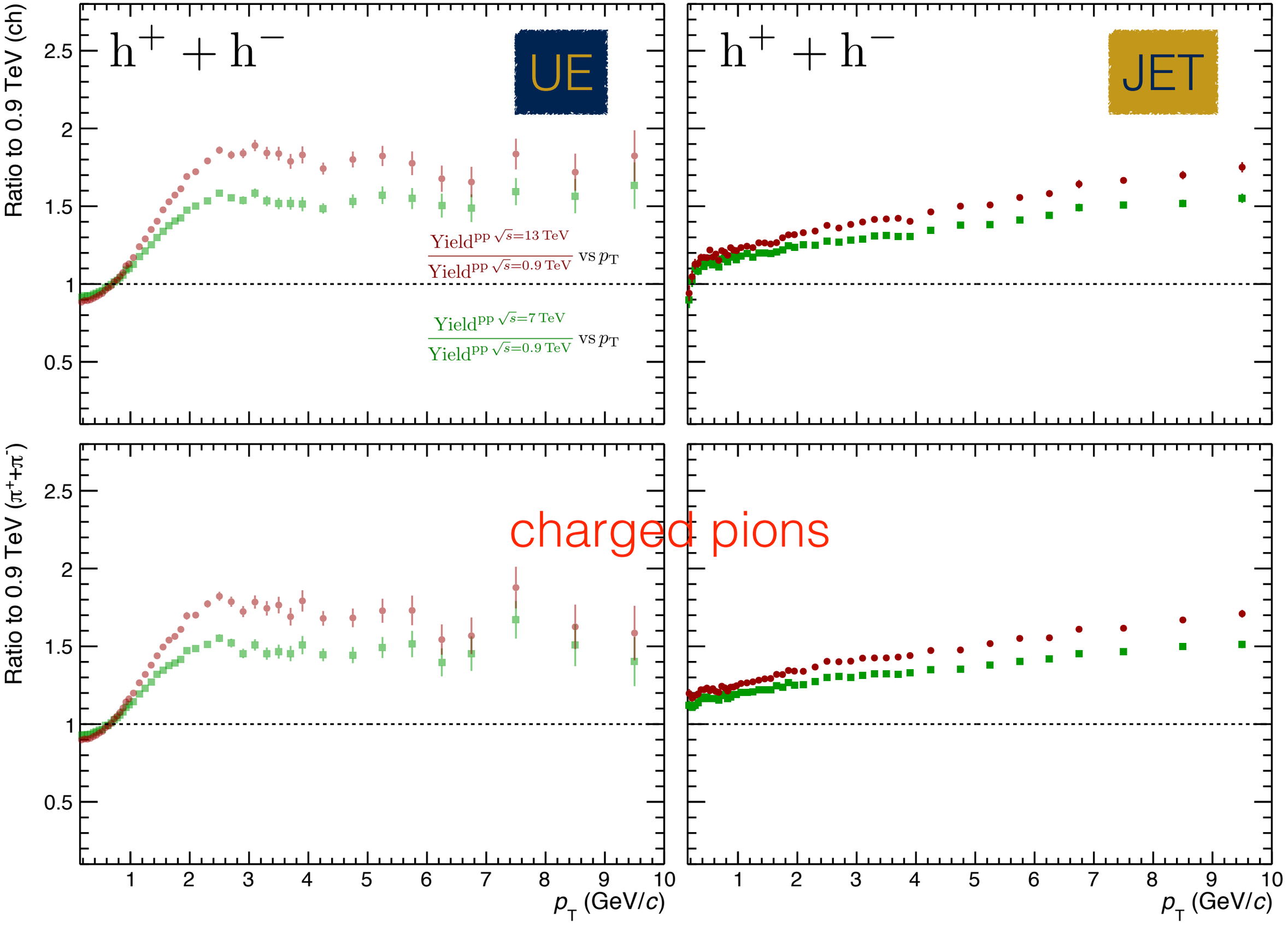


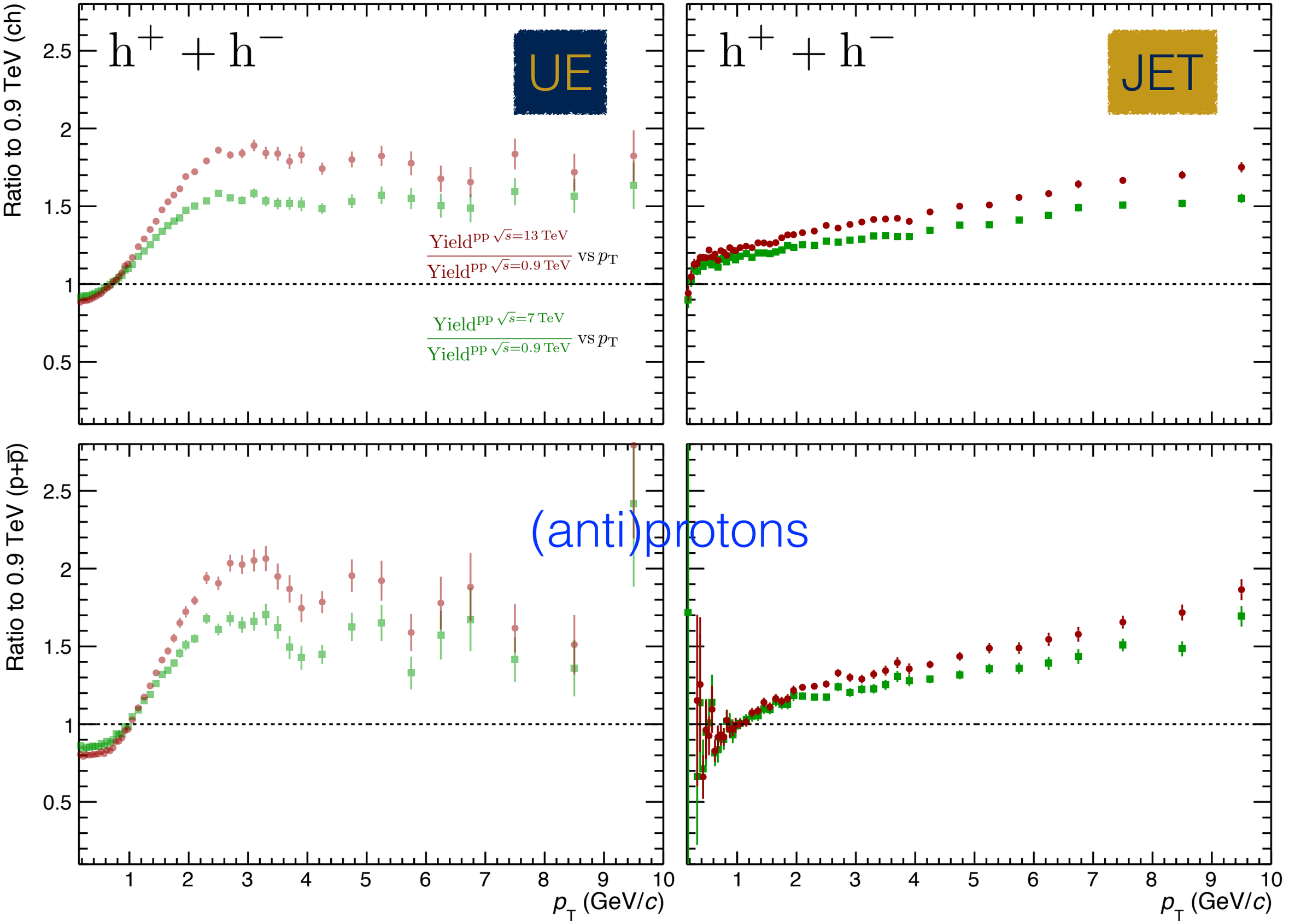
KNO scaling of UE?

- Check with PYTHIA 8.212 + FastJet 3.1
- Events with $p_T^{leading} > 10$ GeV/c within $|\eta|<2.5$

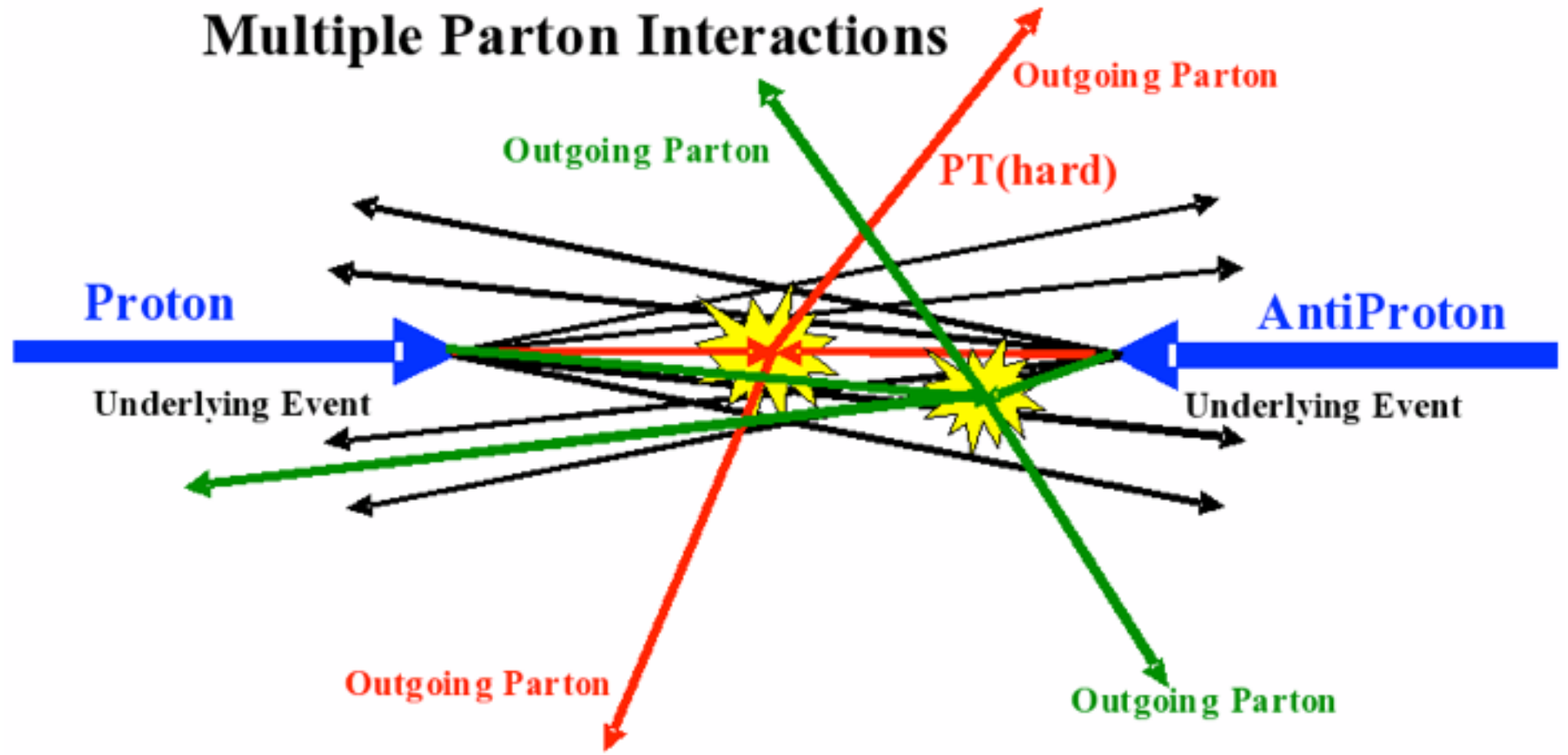


In this study I considered visible particles





UE studies



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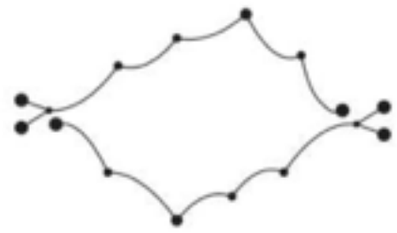
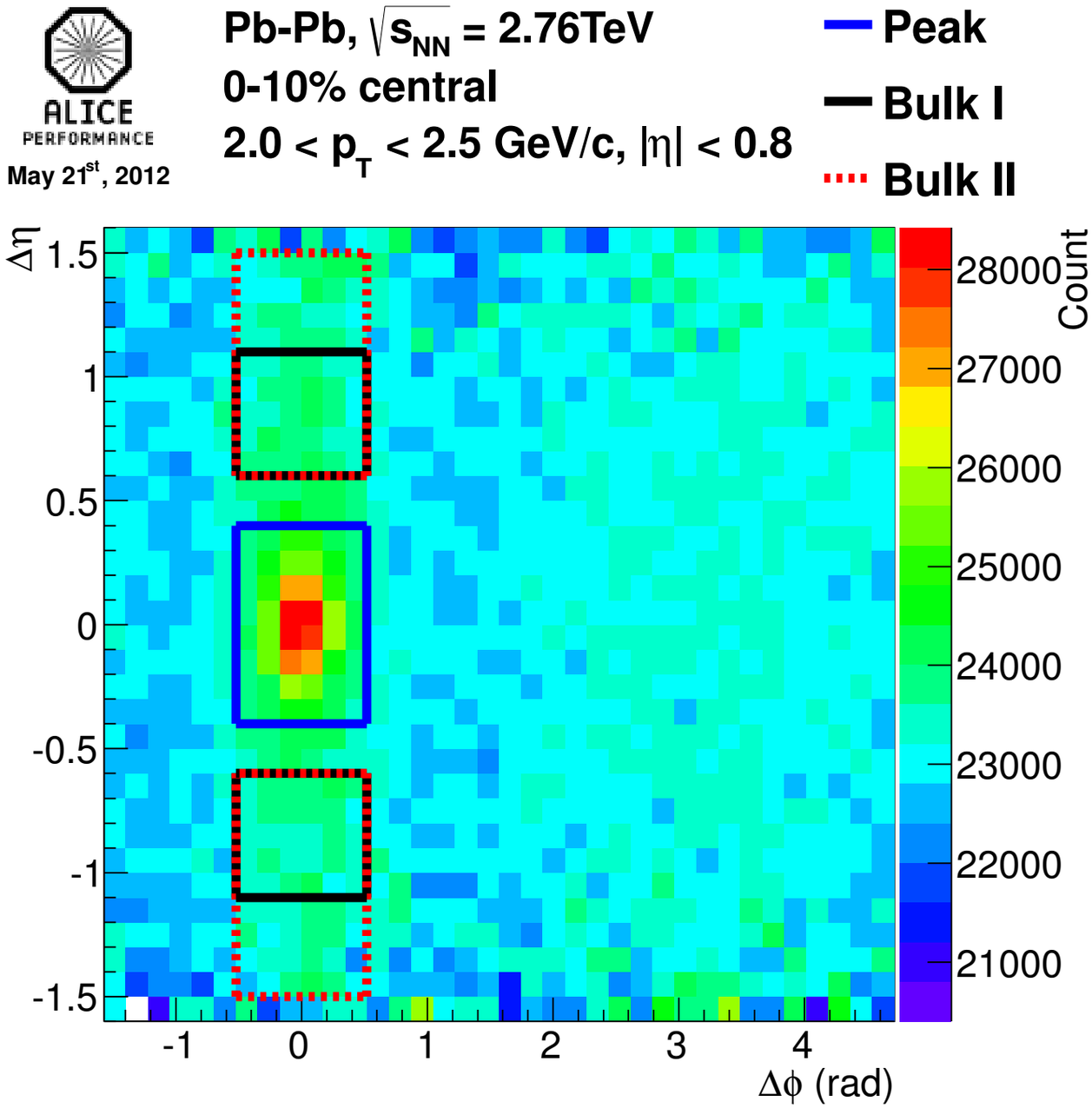
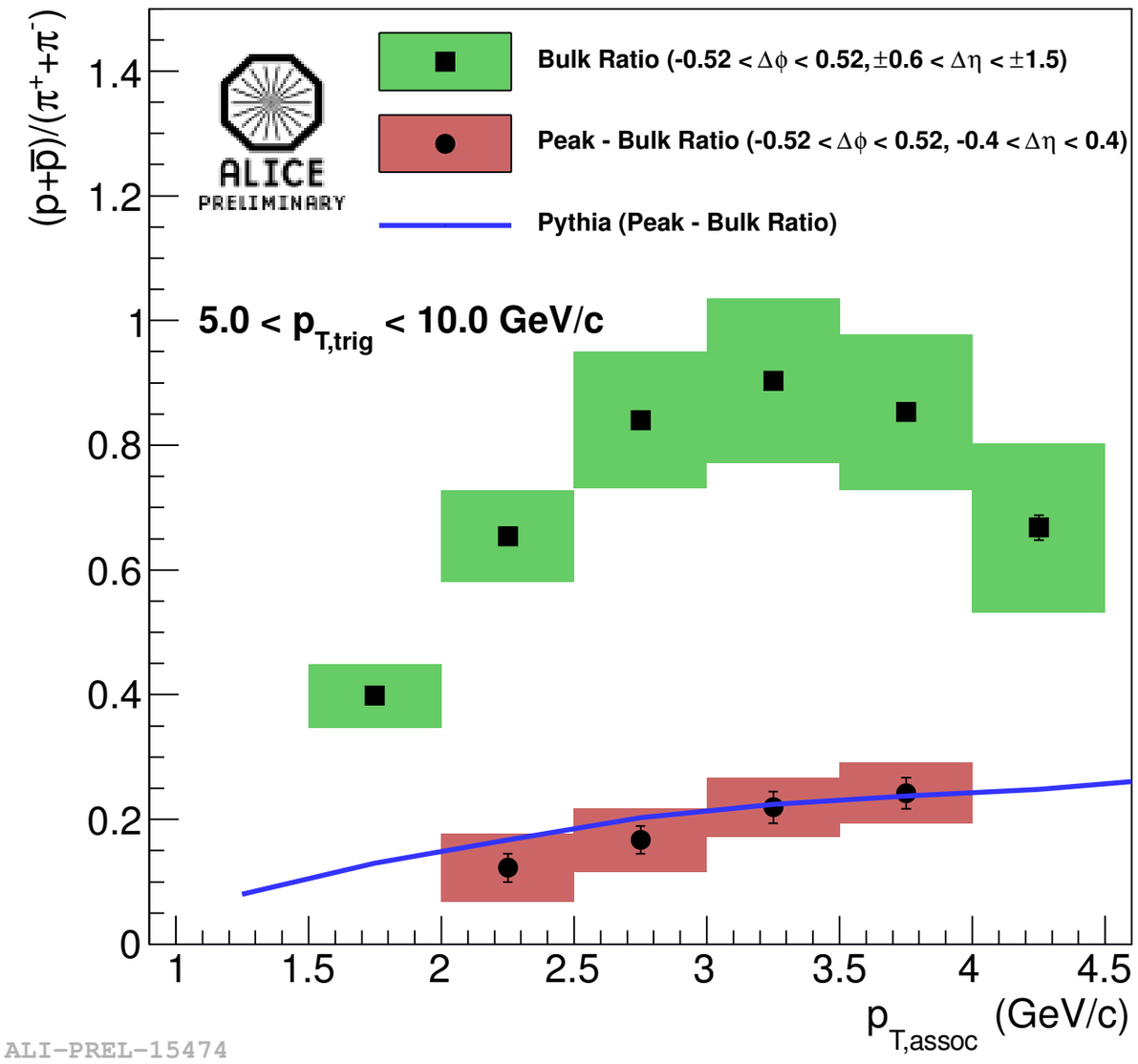
Color reconnection: Interaction among final partons just before the hadronization



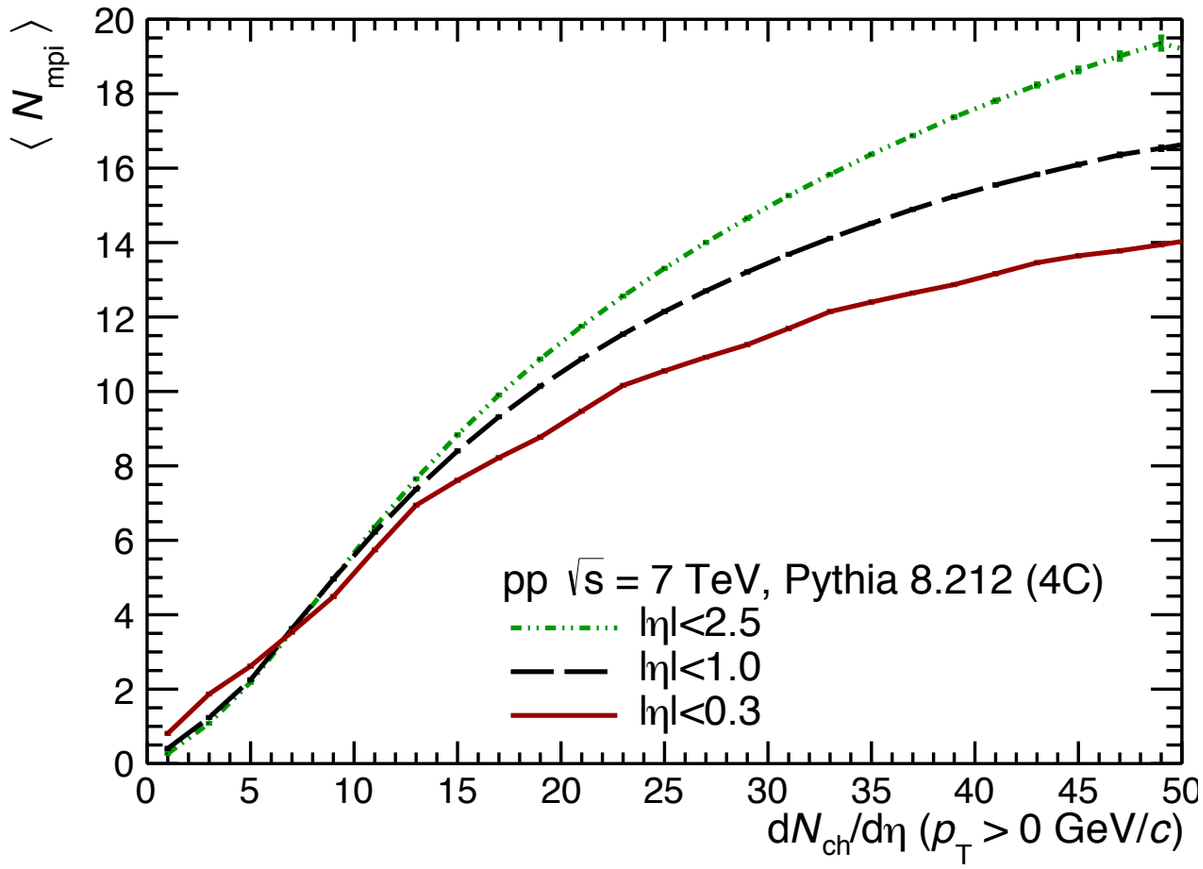
How to study the new phenomena in pp?

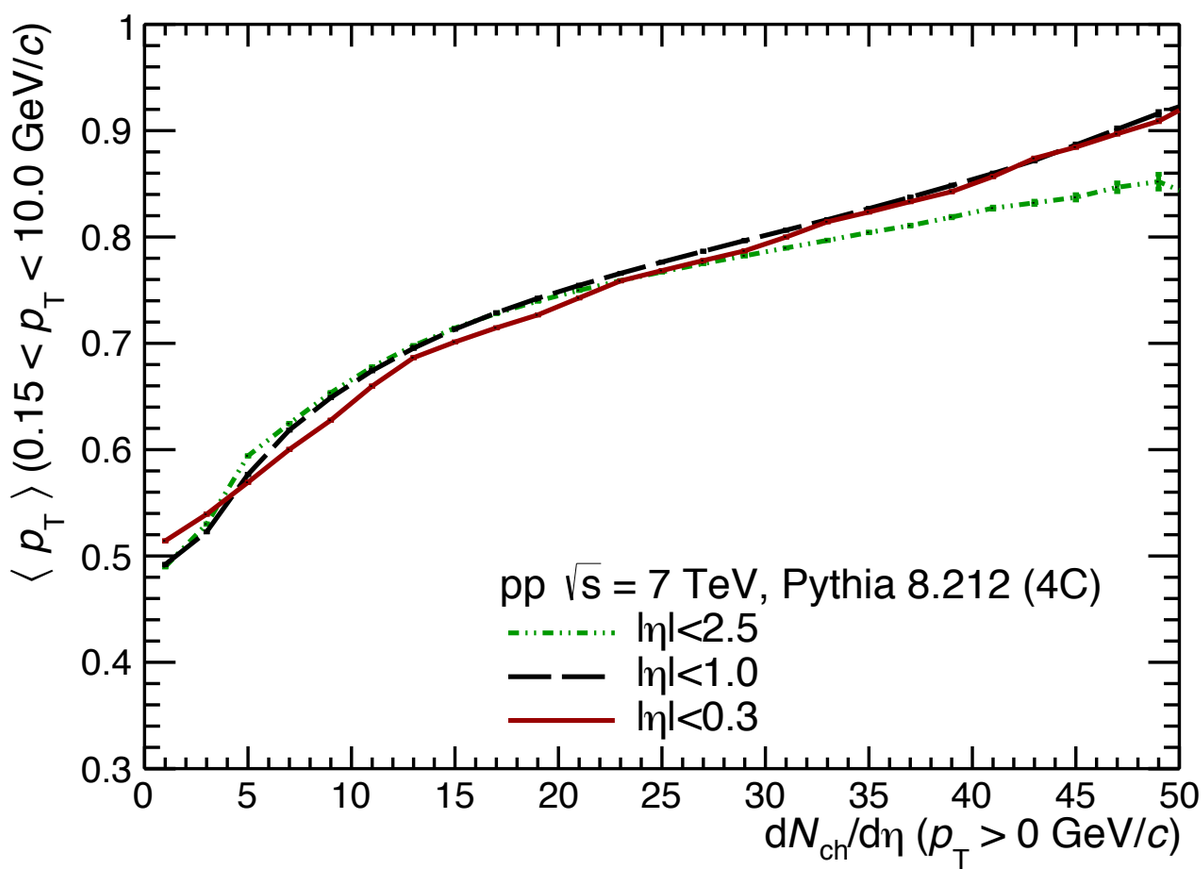




Figures taken from: M. Veldhoen (ALICE), NPA 910-911 (2013) 306-309

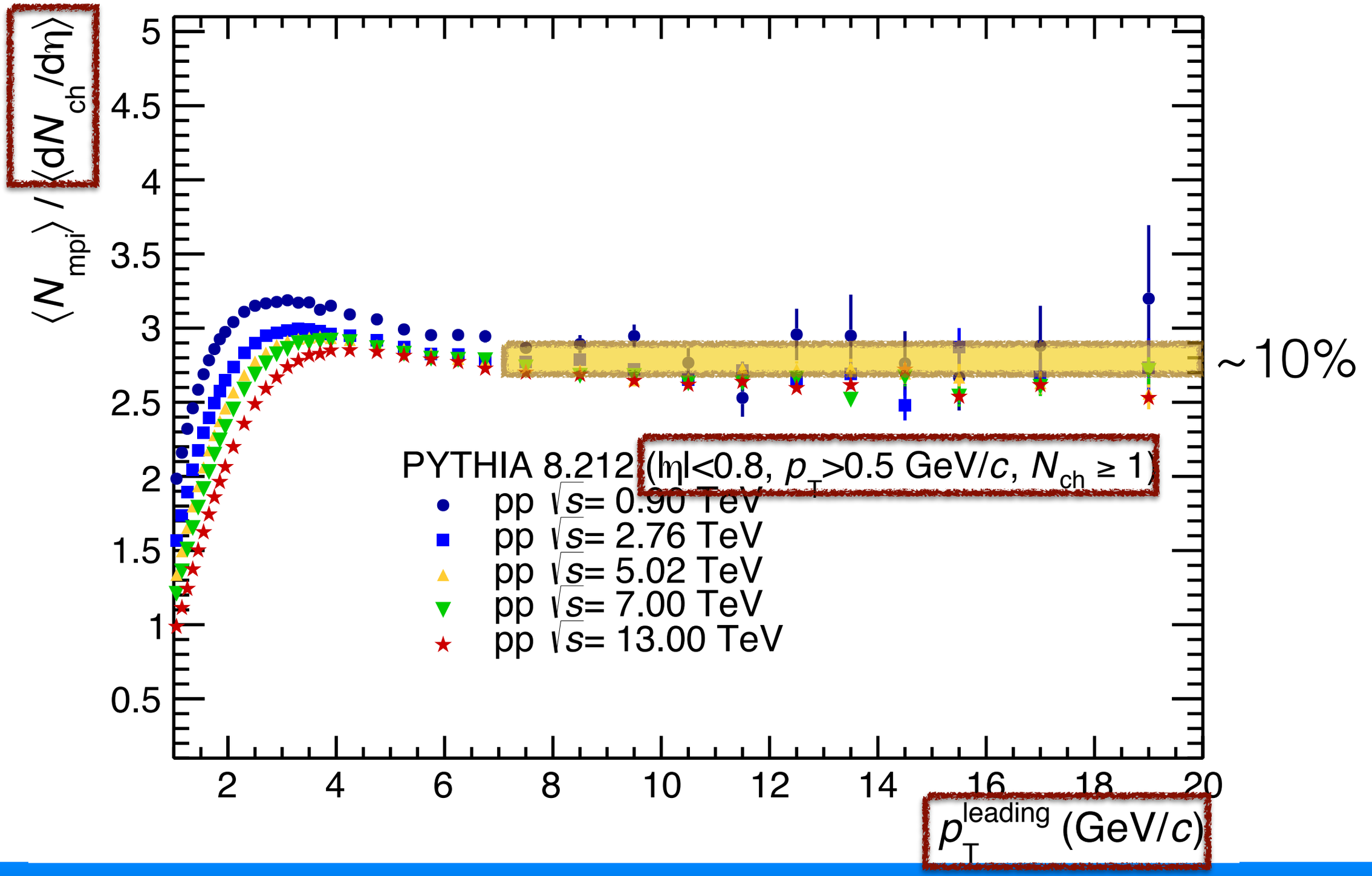
From MC we know that different sensitivities can be achieved depending on the pseudorapidity region





Nucl. Phys. A956 (2016) 749-752

Same effect in MPI



EPOS 3.2 vs PYTHIA 8.2