



Multiplicity dependence of γ production at forward rapidity in pp collisions at $\sqrt{s} = 13$ TeV with ALICE

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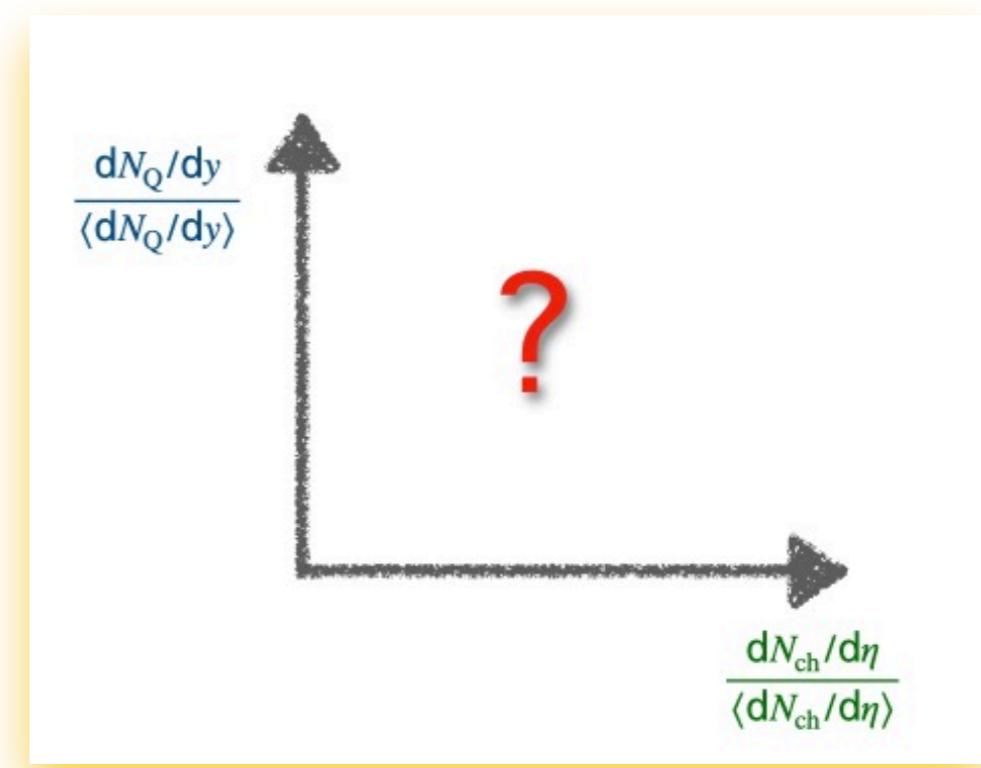
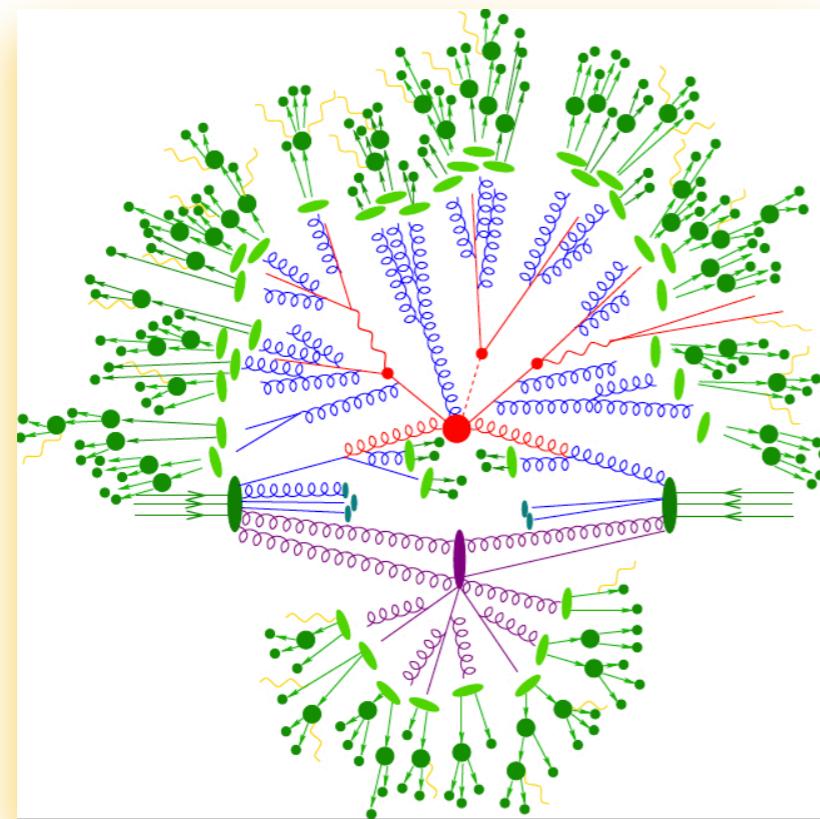


Introduction

Quarkonium: a distinguished tool to study the strongly-interacting medium formed in ultra-relativistic heavy-ion collisions

Charged-particle multiplicity dependence on quarkonium production in pp collisions:

- Understand particle production mechanisms (such as **Multiple Parton Interactions (MPI)**)
- Provide insight into the interplay between soft and hard processes



The ALICE detector



$J/\Psi \rightarrow e^+e^-$, HF $\rightarrow e$ ($|y| < 0.9$)

$J/\Psi, \Psi(2S), \Upsilon(nS) \rightarrow \mu^+\mu^-$, HF $\rightarrow \mu$ ($2.5 < y < 4$)

Inner Tracking System

- Tracking, vertexing and multiplicity estimation

Time Projection Chamber

- Tracking and PID

Time-of-Flight detector

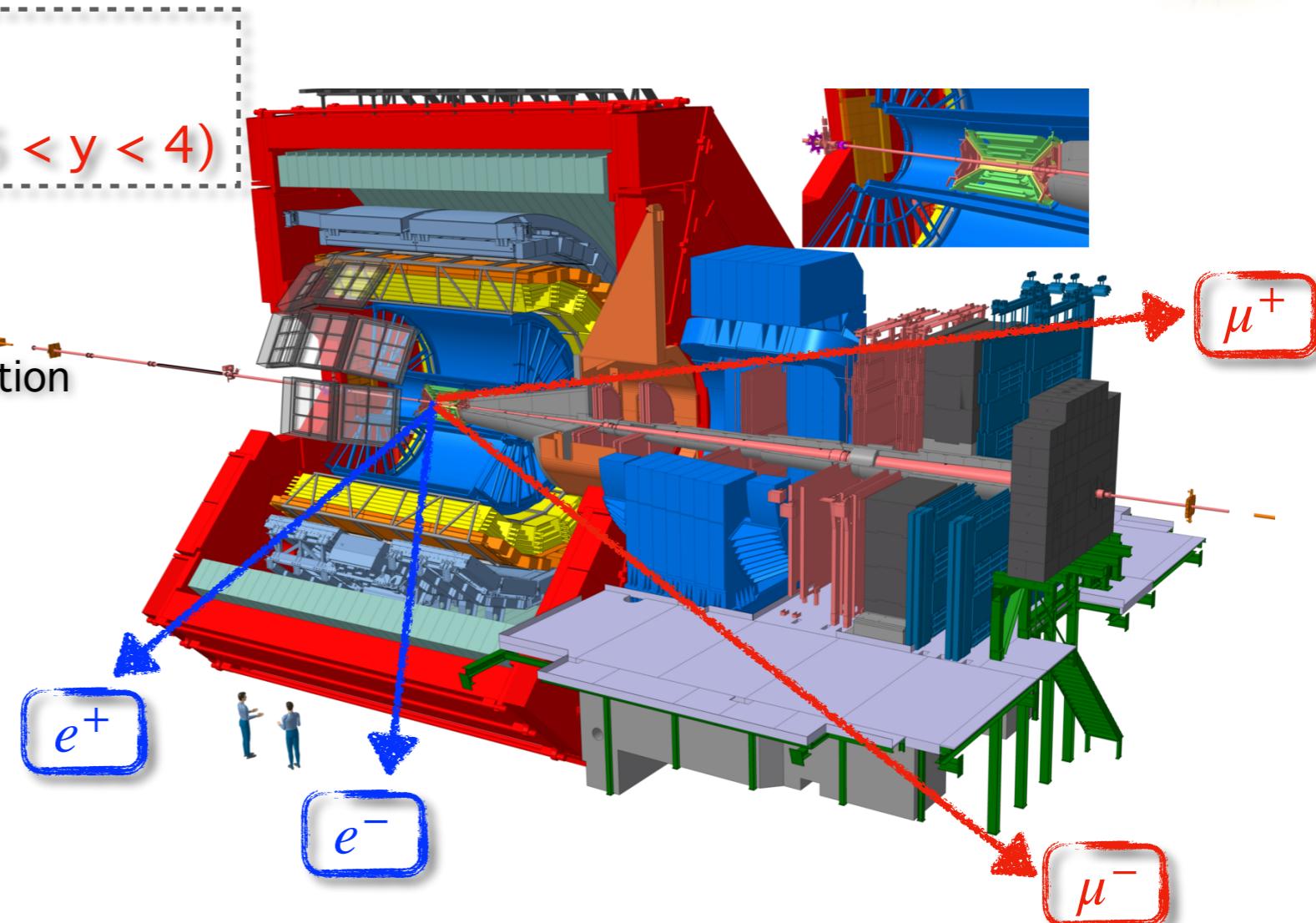
- PID

Electromagnetic Calorimeter

- Trigger and PID

V0 detectors

- Trigger and event characterisation



Muon spectrometer

- Muon tracking and muon triggering
- Heavy flavours, W/Z bosons and low mass resonance measurement



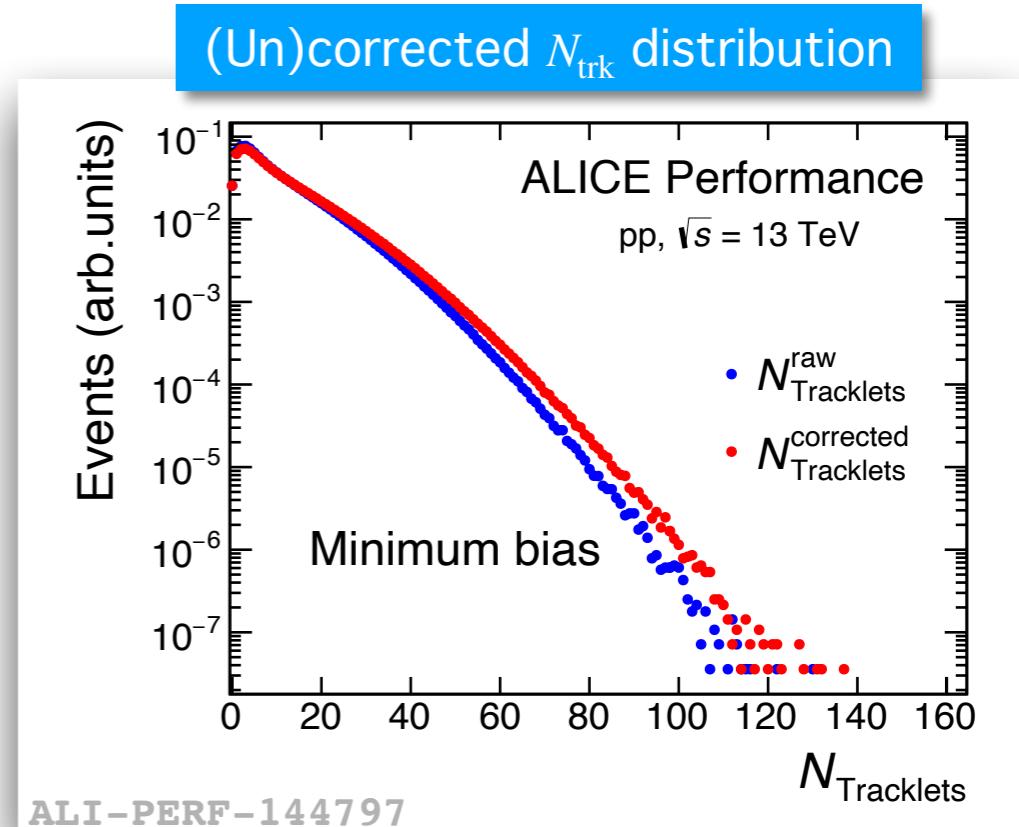
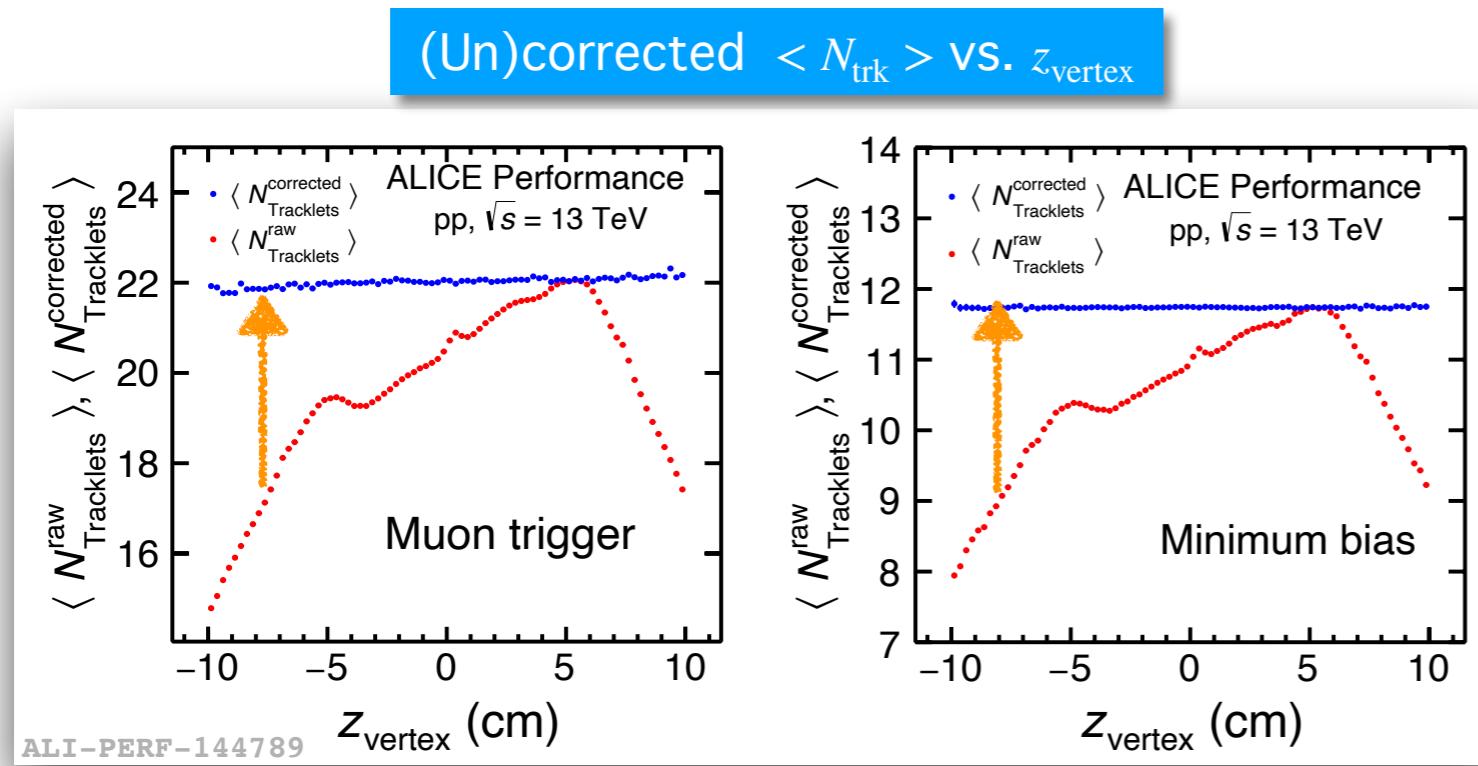
Analysis strategy

Multiplicity estimation — SPD tracklets (the two innermost ITS layers)

1) $N_{\text{trk}} \rightarrow N_{\text{trk}}^{\text{corr}}$

- The multiplicity estimation is affected by the detector inefficiency: strong effect as a function of primary vertex z position
- Data-driven method: correct for the detector inefficiency

$$N_{\text{trk}}^{\text{corr}}(z_{\text{vertex}}) = N_{\text{trk}}(z_{\text{vertex}}) + \Delta N, \quad \Delta N = N_{\text{trk}}(z_{\text{vertex}}) \times \frac{\langle N_{\text{trk}} \rangle(z_{\text{vertex}}^{\text{ref}}) - \langle N_{\text{trk}} \rangle(z_{\text{vertex}})}{\langle N_{\text{trk}} \rangle(z_{\text{vertex}})}$$



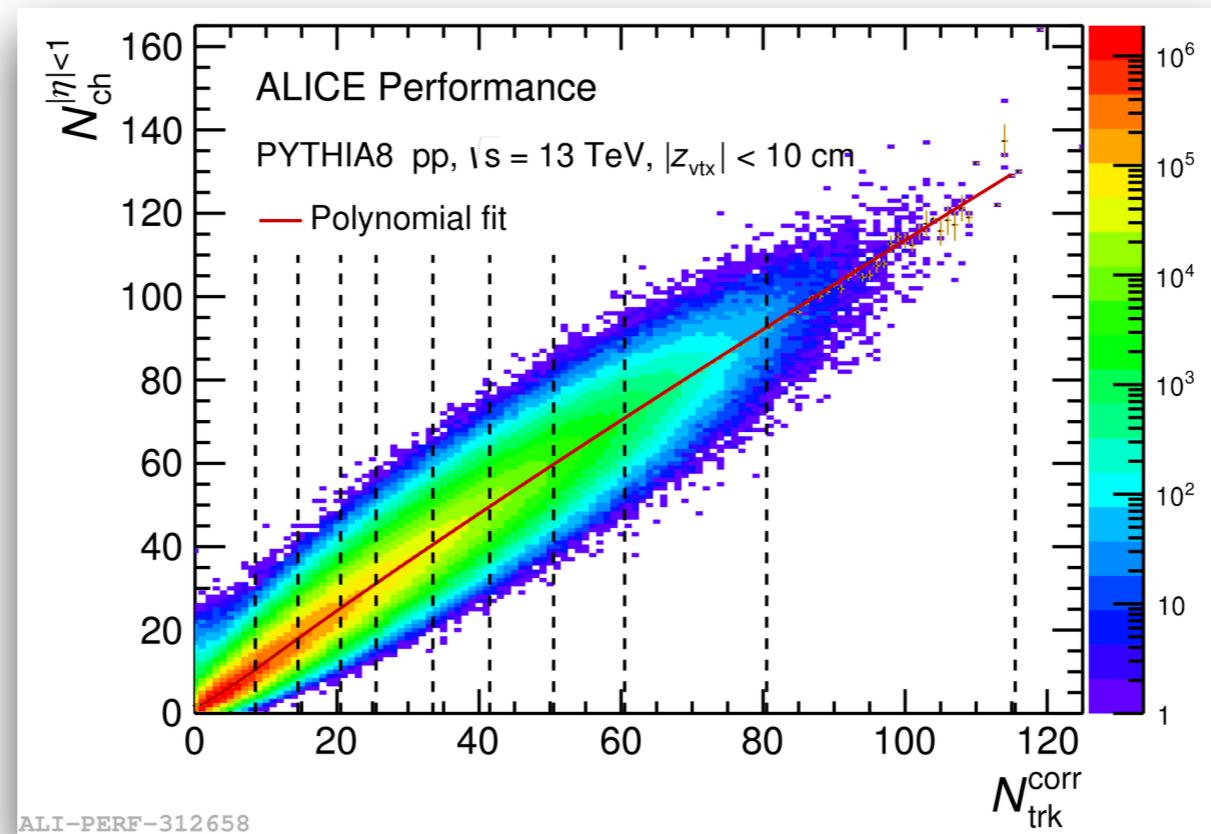


Analysis strategy

Multiplicity estimation — SPD tracklets (the two innermost ITS layers)

2) $N_{\text{trk}}^{\text{corr}} \rightarrow N_{\text{ch}}$

- Tracklet-to-charged particle conversion: $\langle N_{\text{ch}} \rangle = f(\langle N_{\text{trk}}^{\text{corr}} \rangle)$

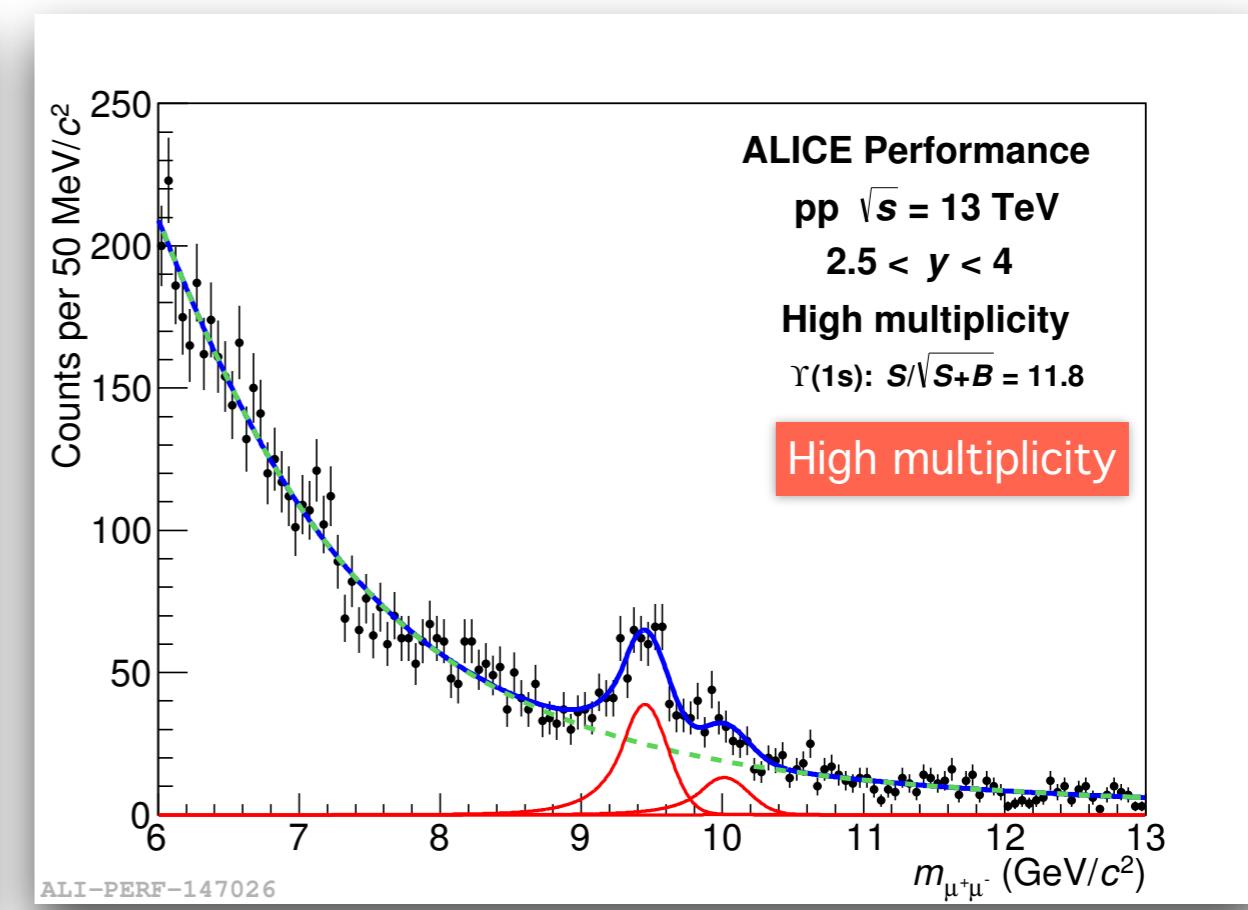
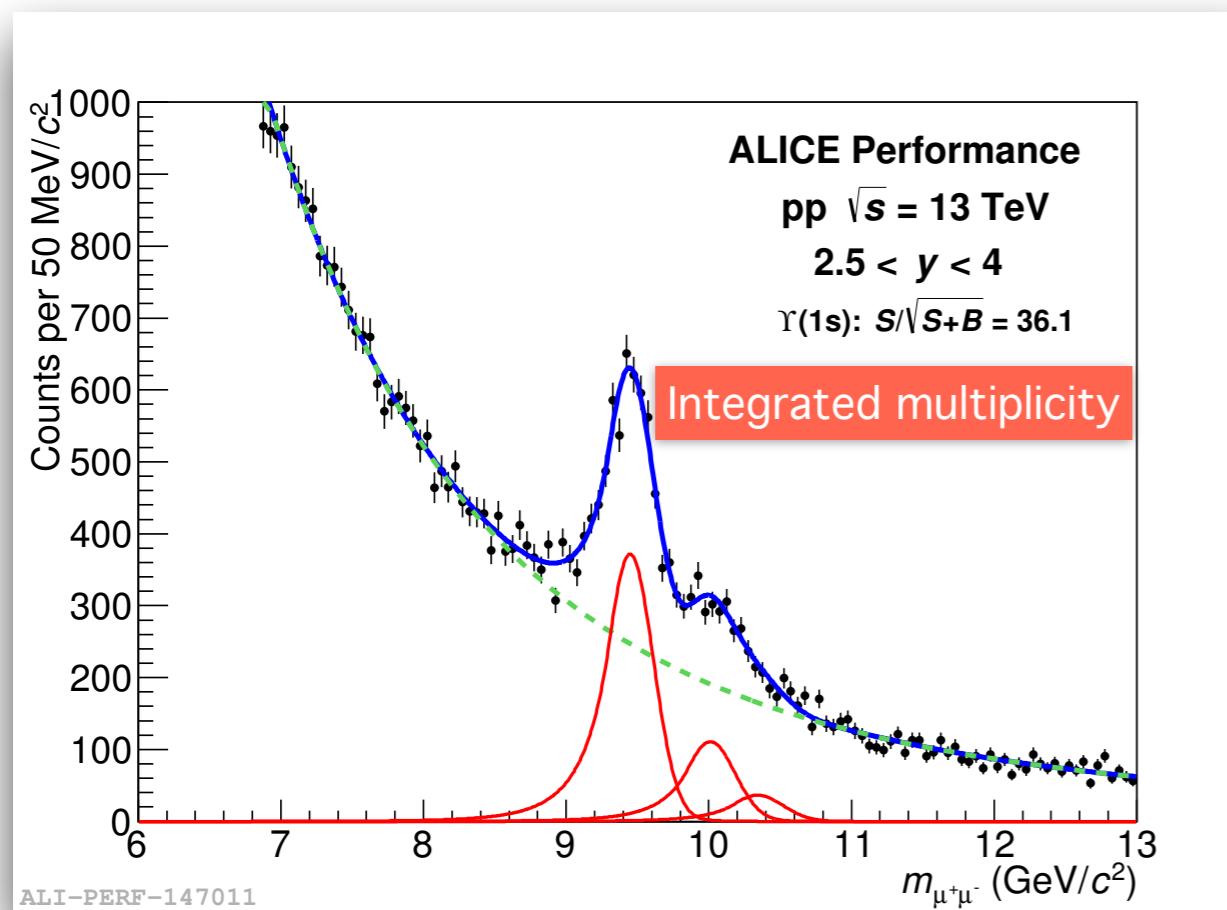


- The correlation between the corrected tracklet multiplicity $N_{\text{trk}}^{\text{corr}}$, and the number of primary charged particles N_{ch} is determined via a Monte Carlo simulation based on the PYTHIA8 generator

Analysis strategy



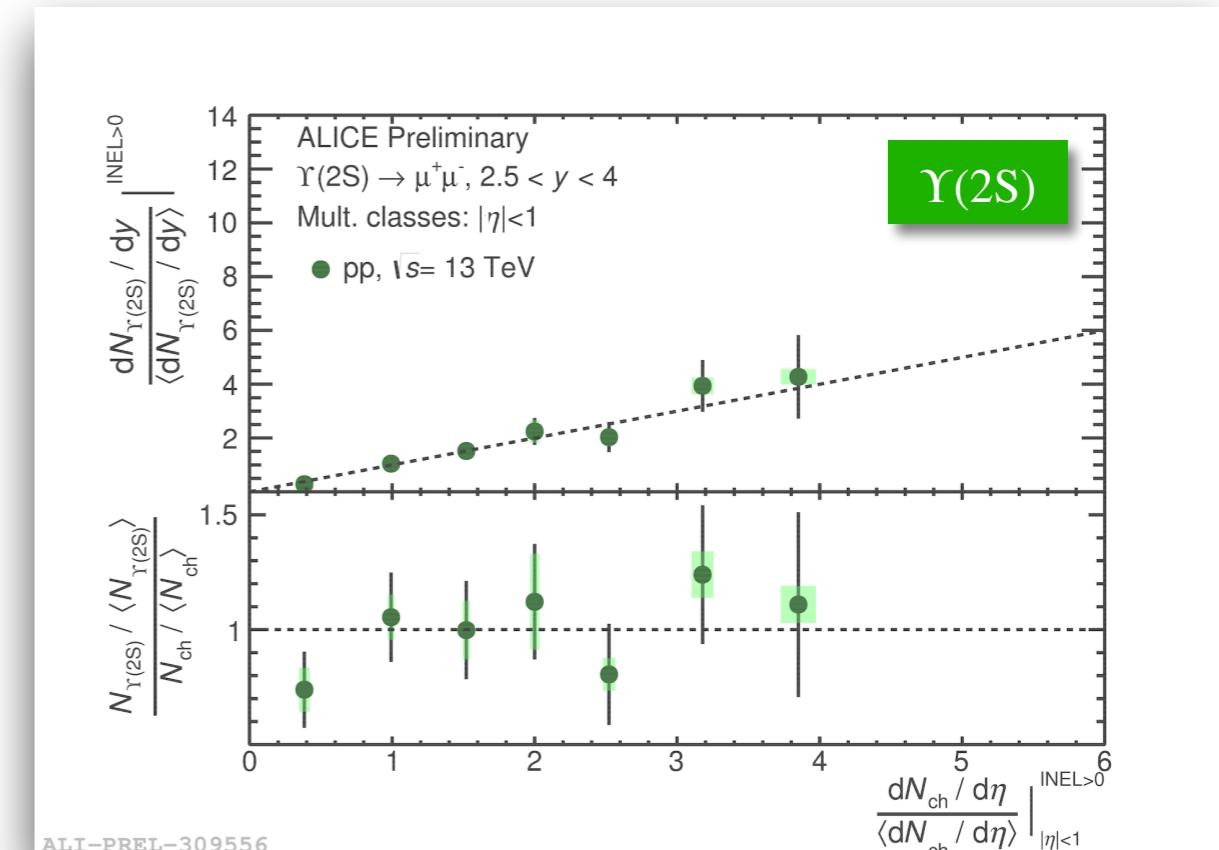
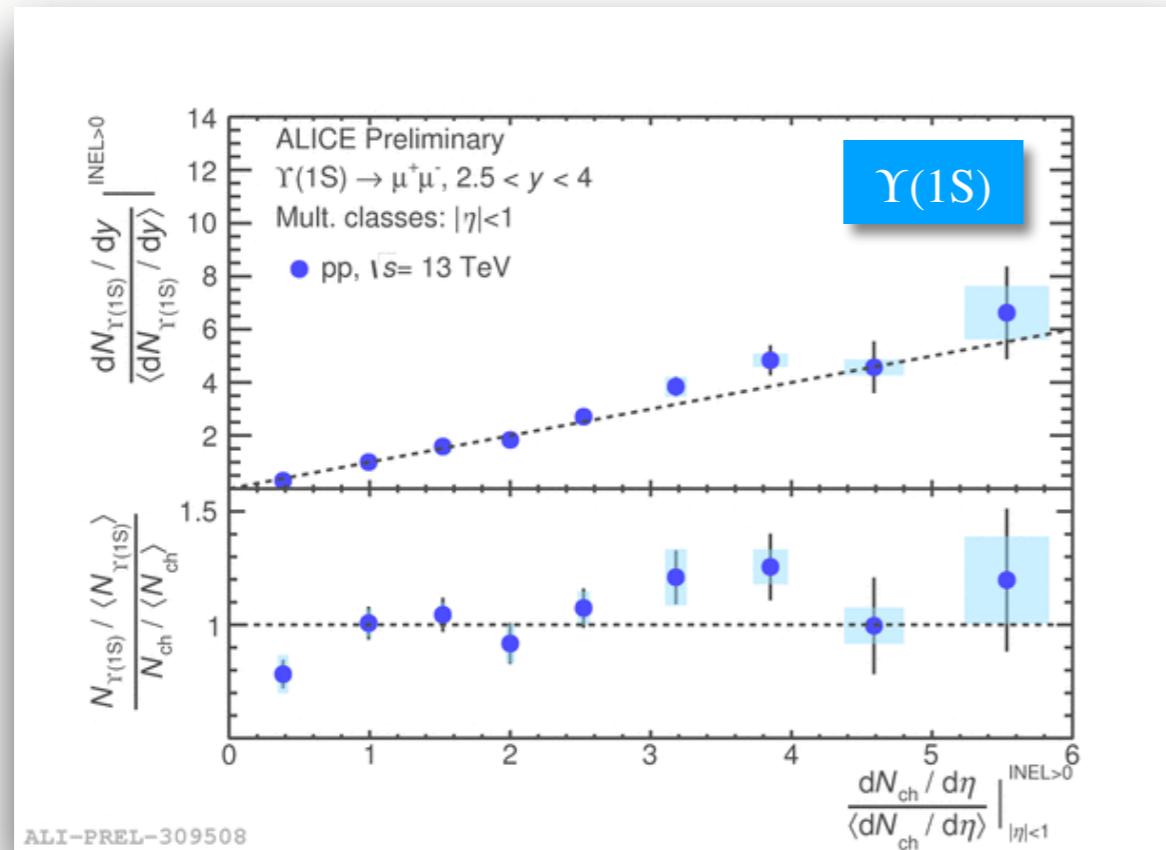
Signal extraction



- Clear $\Upsilon(nS)$ signal peaks are observed at forward rapidity in the dimuon invariant mass distribution
- A combined fit is applied to disentangle signals and background



$\Upsilon(1S)$ and $\Upsilon(2S)$ production vs. multiplicity

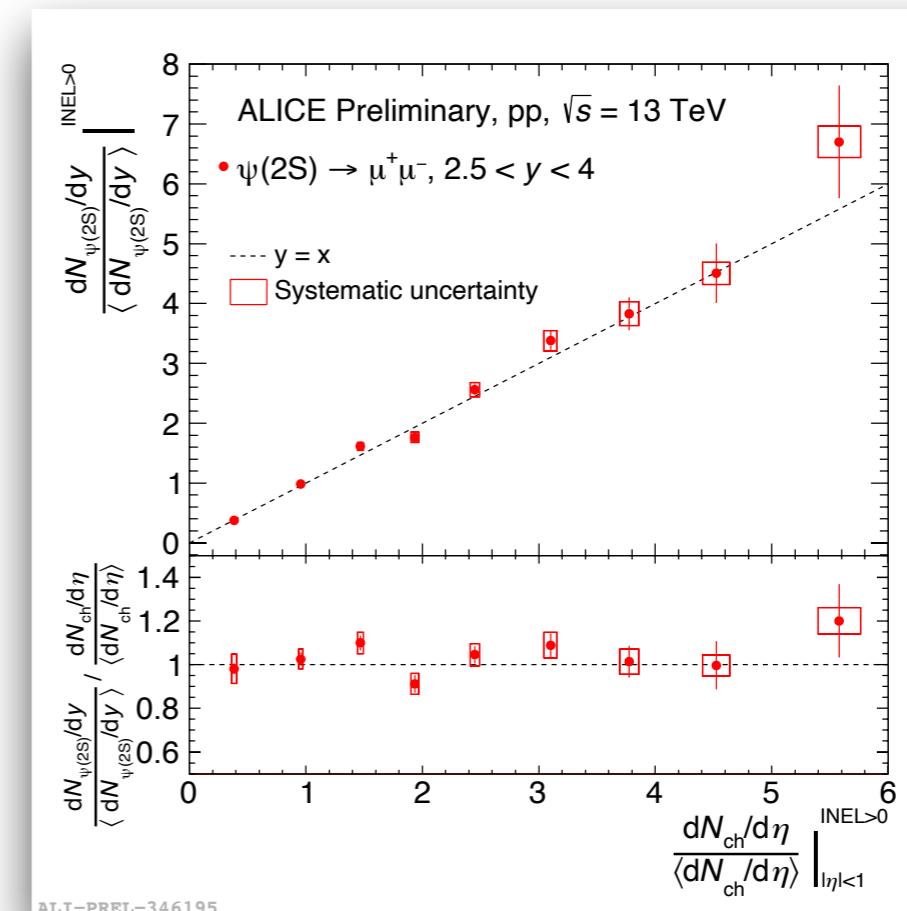
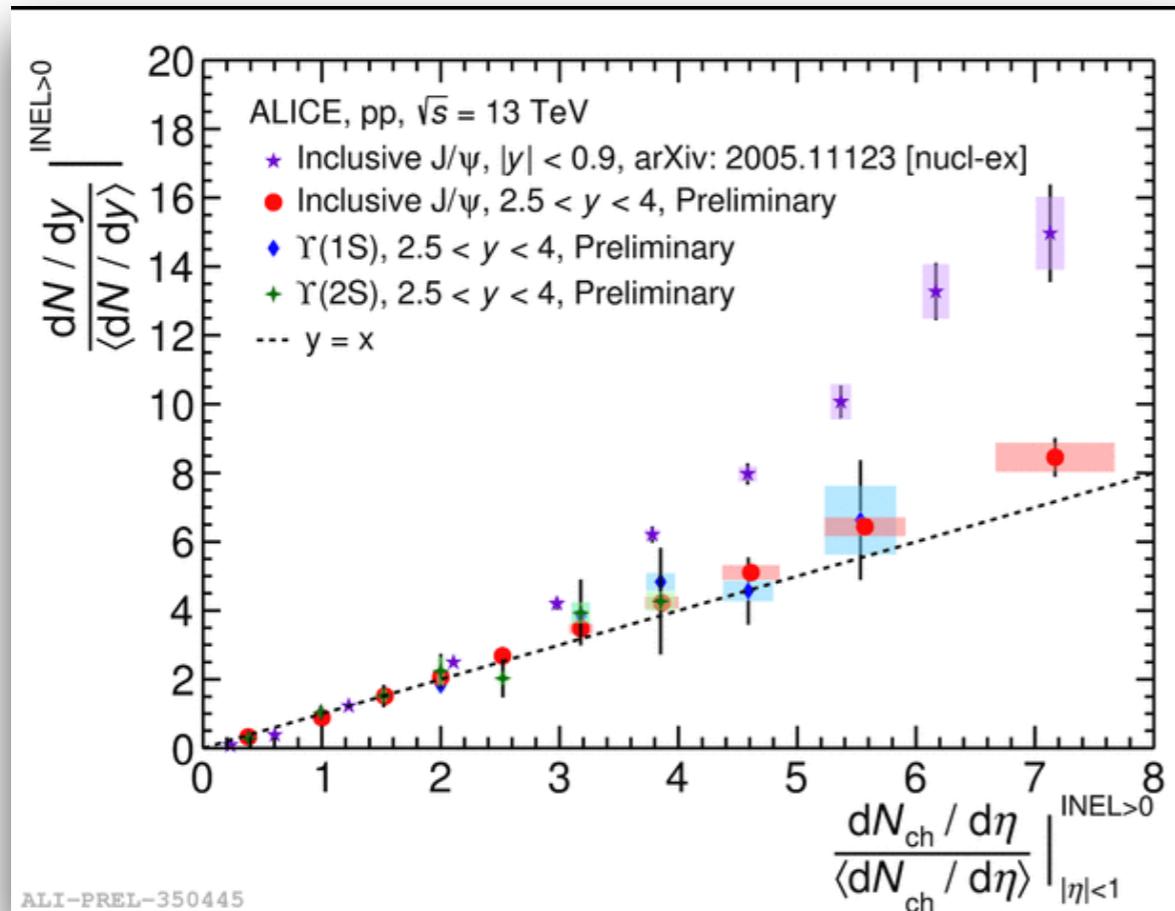


- Self-normalised yield of $\Upsilon(1S)$ and $\Upsilon(2S)$ at forward rapidity (only 2016 data sample): compatible with linear dependence on multiplicity with uncertainties
- The linear trend results in a flat trend of the double ratio of the self-normalised $\Upsilon(nS)$ yield to the self-normalised multiplicity
- Full LHC RUN2 $\Upsilon(nS)$ (including 3S state) results coming soon

Multiplicity dependent quarkonium measurement



Charmonium: measured at forward rapidity; multiplicity: measured at midrapidity

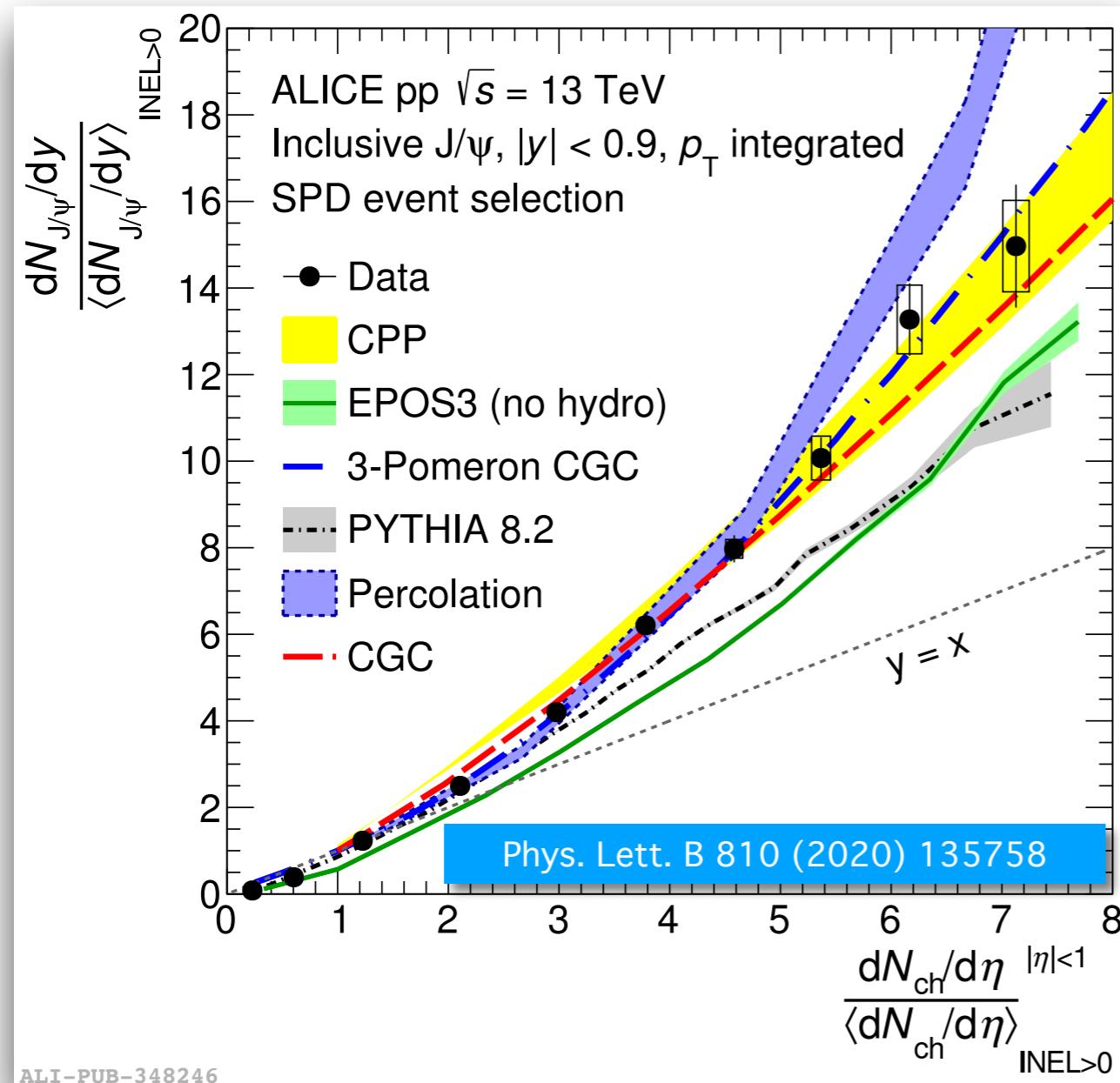


- J/Ψ and $\Psi(2S)$ self-normalised yield **at forward rapidity**: compatible with linear dependence on multiplicity within uncertainties (consistent with bottomonium)

Multiplicity dependent J/ Ψ measurement



J/ Ψ : measured at midrapidity; multiplicity: measured at midrapidity



J/ Ψ self-normalised yield:

- Stronger than linear increase with multiplicity
- Quantitatively described by Coherent Particle Production (CPP), Color Glass Condensate (CGC) and 3-Pomeron CGC model predictions
- Stronger than linear increase of J/ Ψ yields in models arises from a reduction of the charged-particle multiplicity

CPP: Phys. Rev. D88 (2013) 116002

EPOS3: Phys. Rev. C89 (2014) 064903

3-Pomeron CGC: Eur. Phys. J. C 80 (2020) 560

PYTHIA 8.2: Comput. Phys. Commun. 191 (2015) 159-177
Eur. Phys. J. C79 (2019) 36

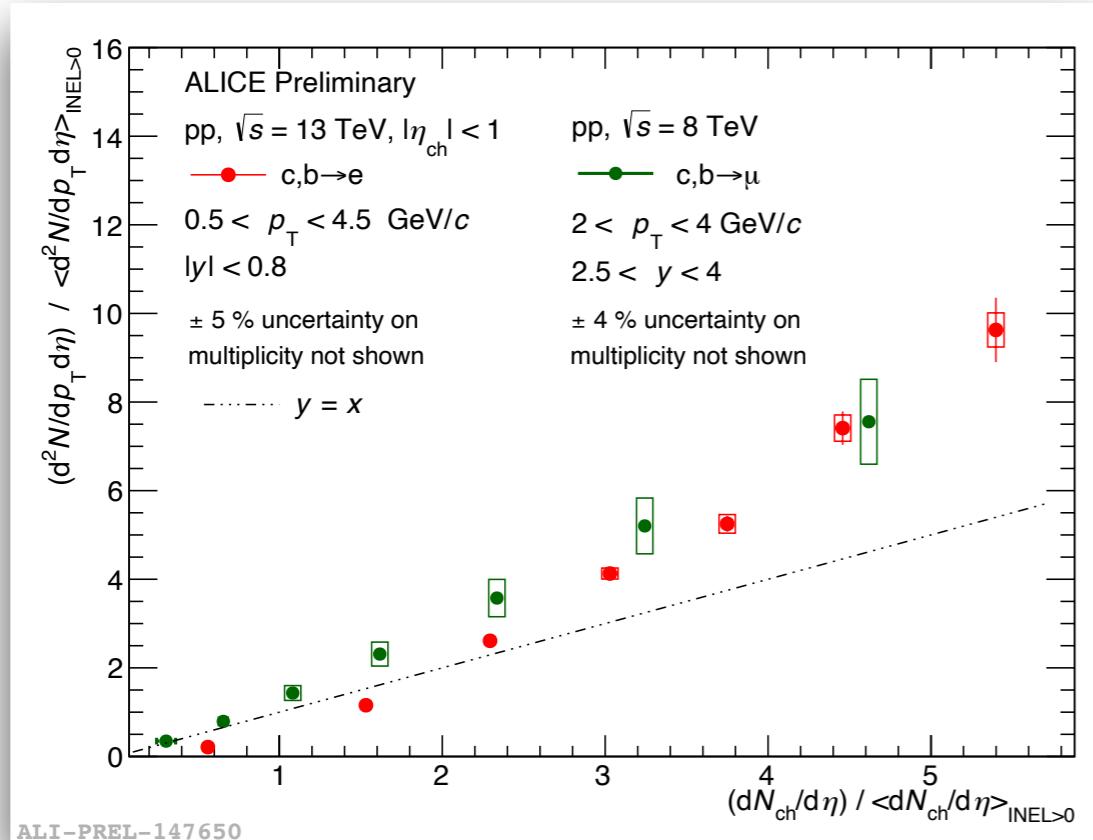
Percolation: Phys. Rev. C86 (2012) 034903

CGC: Phys. Rev. D98 (2018) 074025

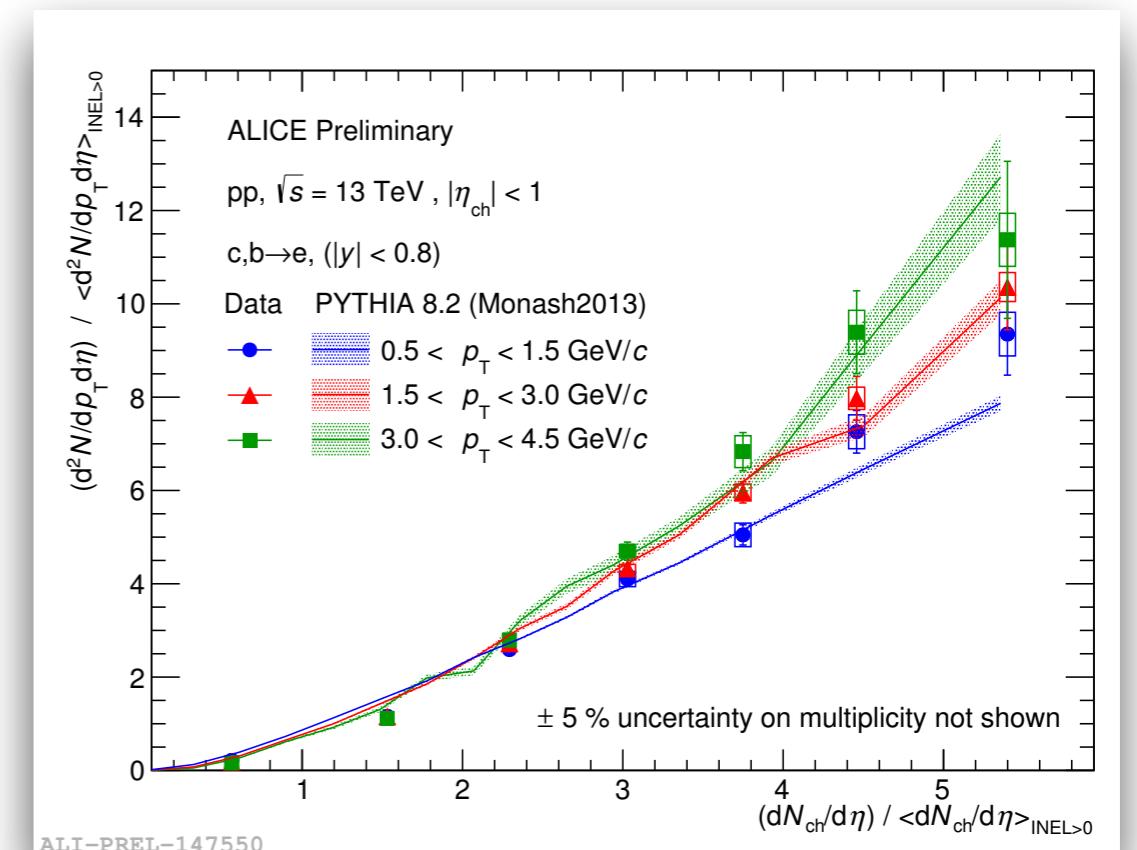
HFe and HF μ production vs. multiplicity



Multiplicity: measured at **midrapidity** ($|\eta| < 1$)



→ Stronger than linear increase of open heavy-flavour hadrons decay leptons [$\text{HF} \rightarrow e$ (midrapidity), $\text{HF} \rightarrow \mu$ (forward rapidity)]



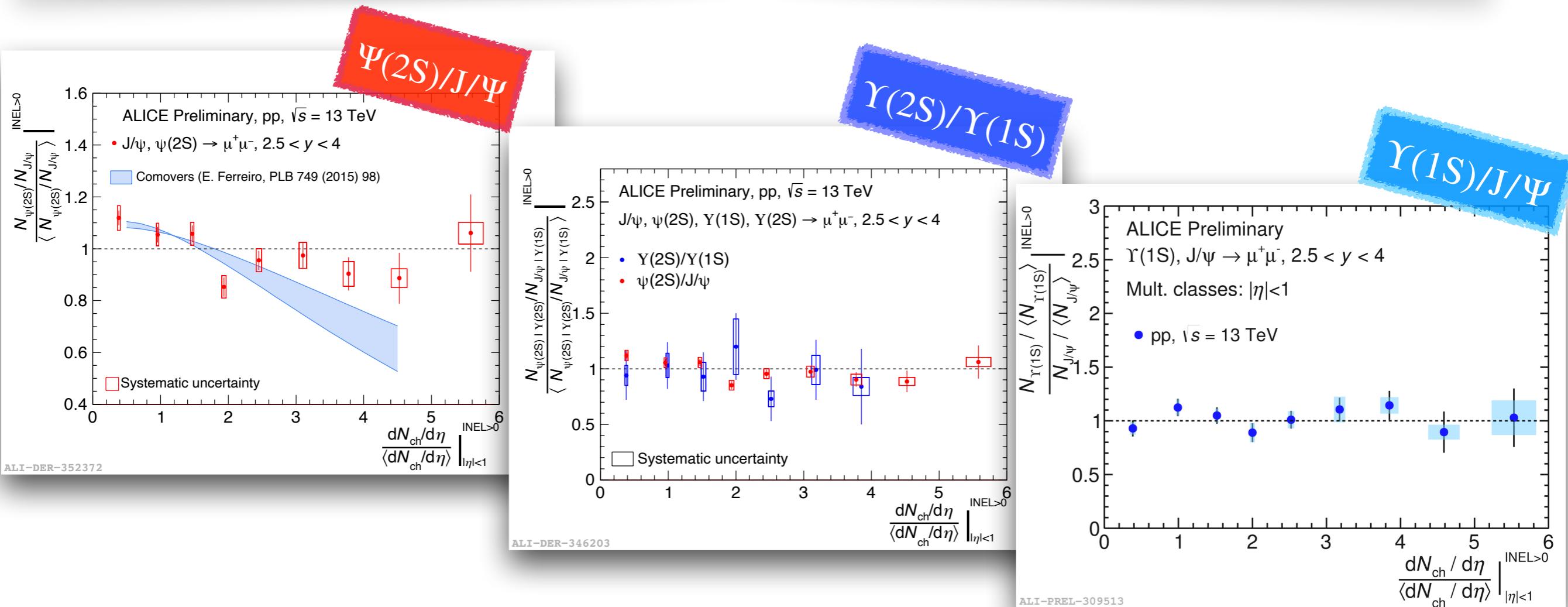
$\text{HF} \rightarrow e$

- A steeper increase at high p_T
- PYTHIA 8.2 including **MPI effects** well reproduces ALICE data in all p_T intervals



Multiplicity dependence of quarkonium excited state

Quarkonium: measured at forward rapidity; multiplicity: measured at midrapidity



- $\Psi(2S)/J/\Psi$: maximum deviation from unity is around 2.2σ related to the **first multiplicity bin**
- The suppression is **stronger in comover approach** than in data at high multiplicity
- $\Upsilon(2S)/\Upsilon(1S)$ and $\Upsilon(1S)/J/\Psi$: compatible with unity within uncertainties (**indicating no dependence on resonance mass and quark component**)

Summary and outlook

Multiplicity dependence of quarkonia production:

- **Rapidity dependence** for J/ Ψ production
- Compatible behaviour between charmonium and bottomonium at forward rapidity

Multiplicity dependence of excited state suppression:

- Predictions based on comovers approach tend to overestimate the $\Psi(2S)$ at high multiplicity
- Incoming more significant $\Upsilon(nS)$ results will improve the charmonium/bottomonium comparison

Multiplicity dependence of open heavy flavours production:

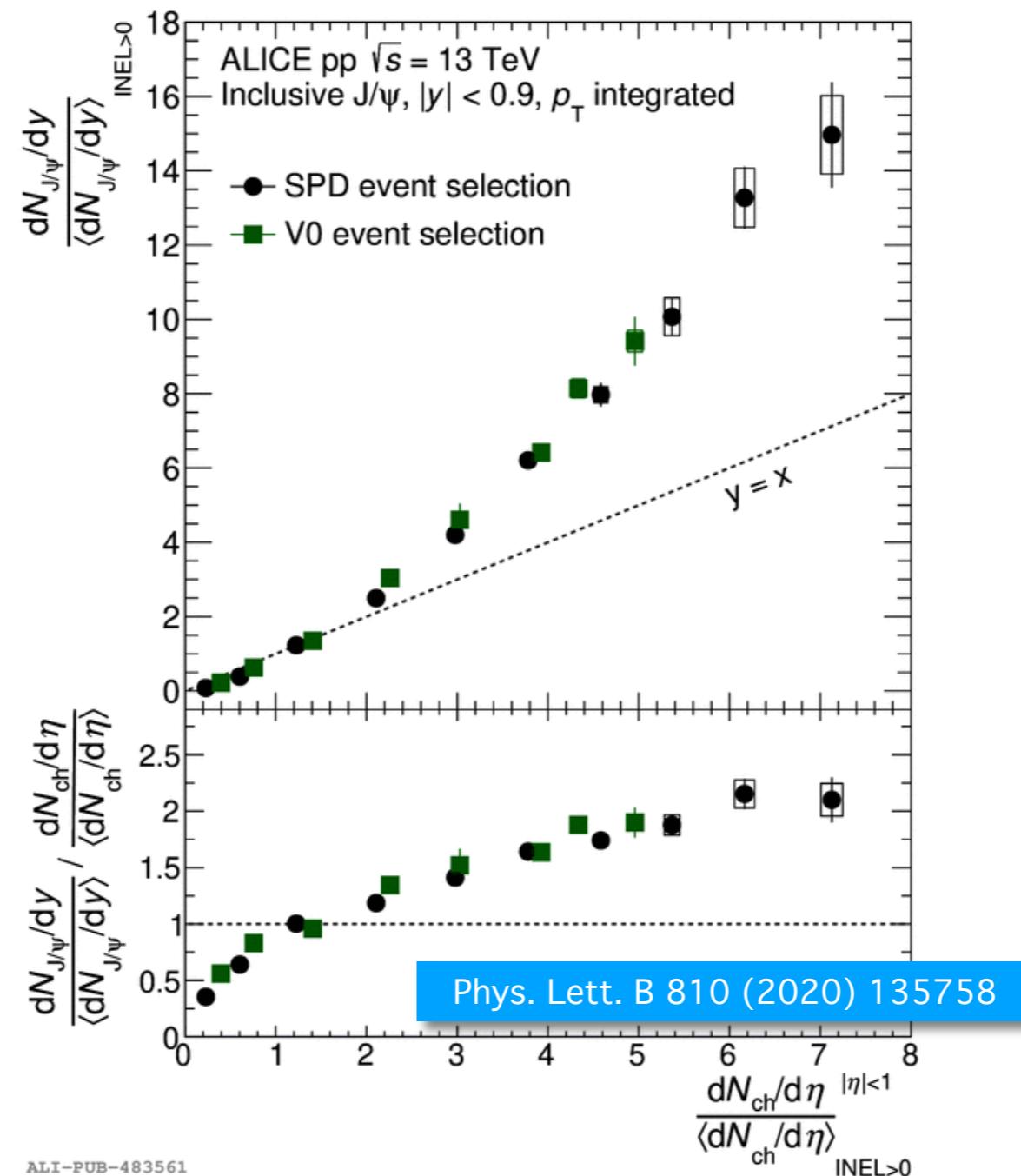
- Stronger than linear enhancement with charged-particle multiplicity

THANK
You!



Back up

Multiplicity dependent J/ ψ production at midrapidity



Back up

Event-activity dependence of $\Upsilon(nS)$ relative production

