CLHCP 2019

Quarkonium production as a function of multiplicity in small systems with ALICE

Yanchun Ding (for the ALICE collaboration)

23^{th}, Oct – 27^{th}, Oct

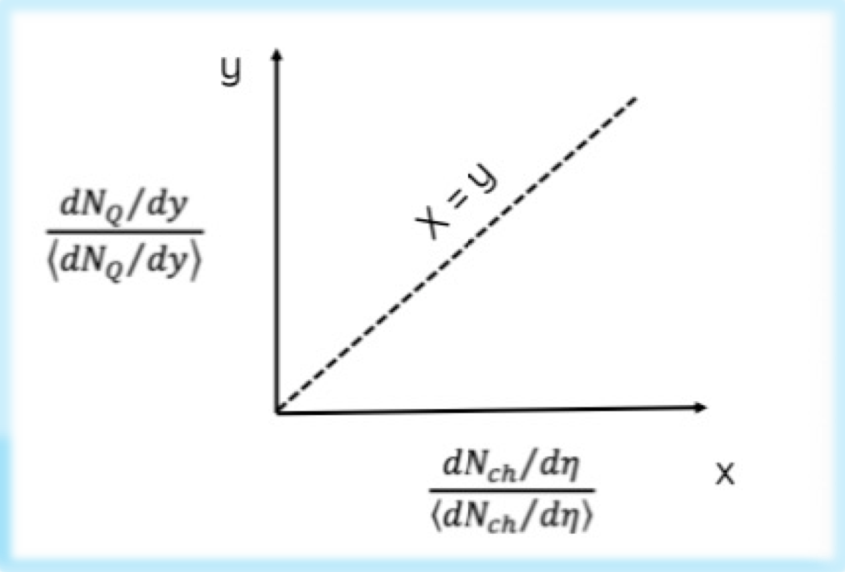
Introduction

Quarkonium: bound state of $c\bar{c}$ pair [J/ ψ, ψ(2S)] or $b\bar{b}$ pair [Υ(1S), Υ(2S) and Υ(3S)]

Charged-particle multiplicity: the number of primary charged particles produced in the collision

Charged-particle multiplicity dependence to study:

- Particle production mechanism
- Multiple Parton Interactions (MPI)
- Interplay between soft and hard processes



Observables:

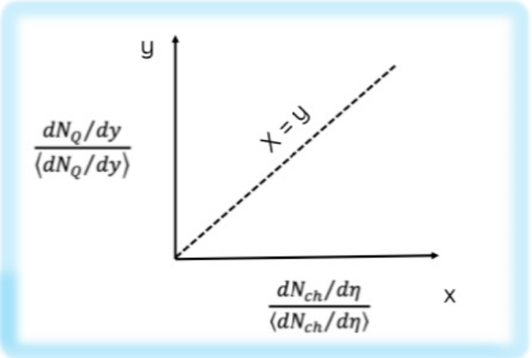
- x-axis: relative charged-particle pseudo rapidity density
- y-axis: relative quarkonium yield

* Self-normalized quantities : Some uncertainties cancel out; possibility to compare different experiments, colliding systems, energies ...

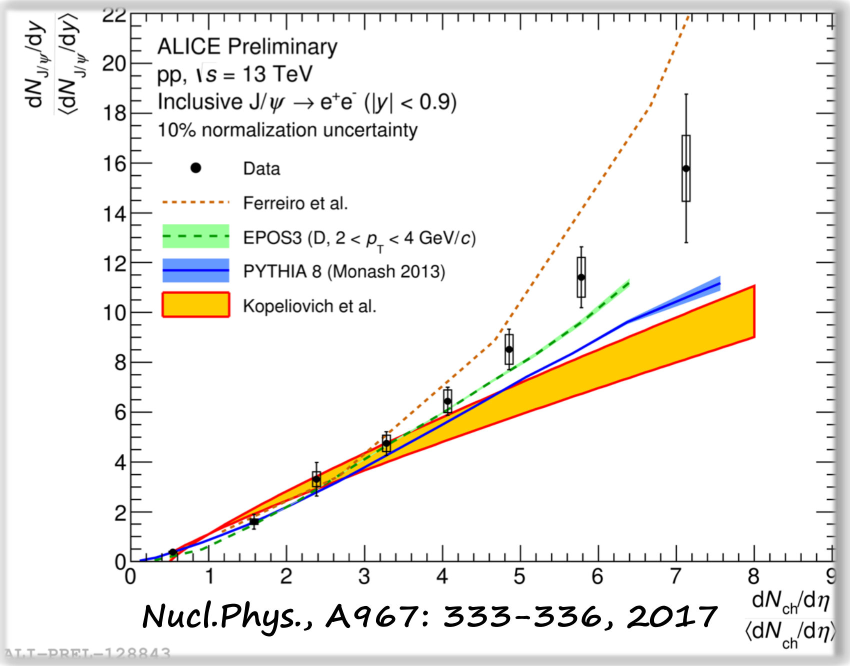
Introduction

Charged-particle multiplicity dependence to study:

- Particle production mechanism
- Multiple Parton Interactions (MPI)
- Interplay between soft and hard processes



J/ψ in pp collisions at √s = 13 TeV



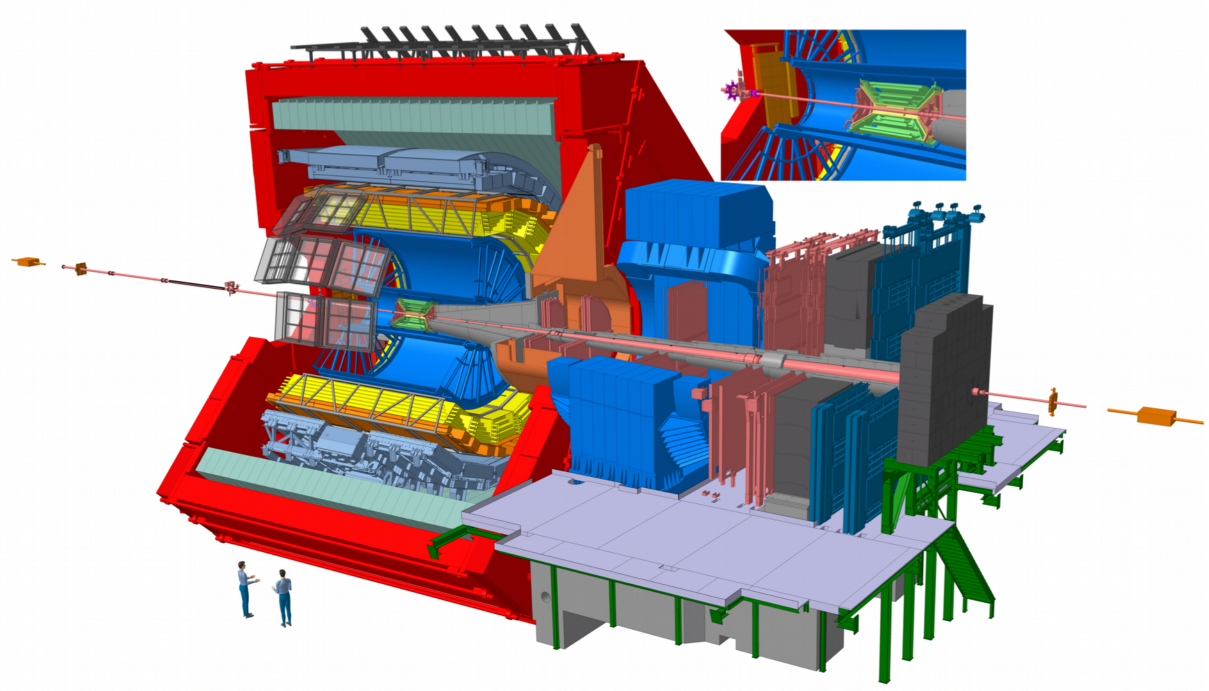
Nucl.Phys., A967: 333-336, 2017

- J/ψ production increases faster than linear with the charged-particle multiplicity
- Models assume J/ψ production in MPI and saturation of soft particle production (“compression of x-axis”)

Hint of a QGP-like behavior in high-multiplicity in small systems?

The ALICE Detector

- **Charged-particle multiplicity** is measured:
  - Mid-rapidity: number of SPD (the first two layers of the ITS) tracklets
  - Forward rapidity: sum of amplitudes in the V0 scintillator arrays



- Quarkonia are studied at :
  - Mid-rapidity: $|y| < 0.9$
  - Forward rapidity: $2.5 < y < 4$

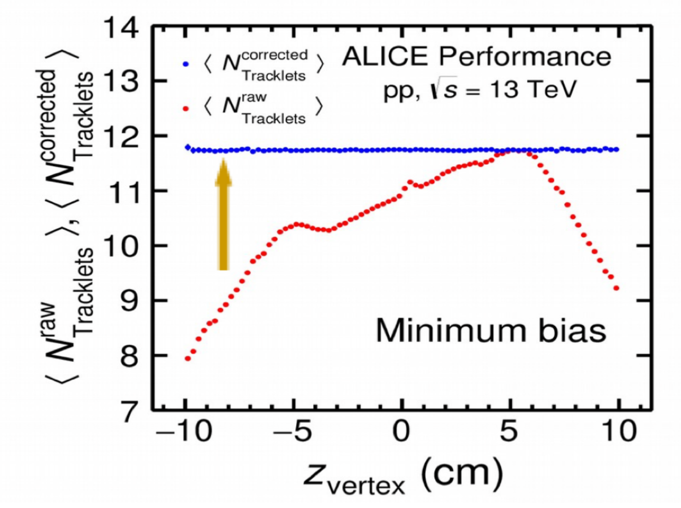
- Central barrel, $|\eta| < 0.9$:
  - ITS: Tracking, vertexing, multiplicity
  - TPC: Tracking, PID
  - EMCal: High-p_T electrons, triggering, PID

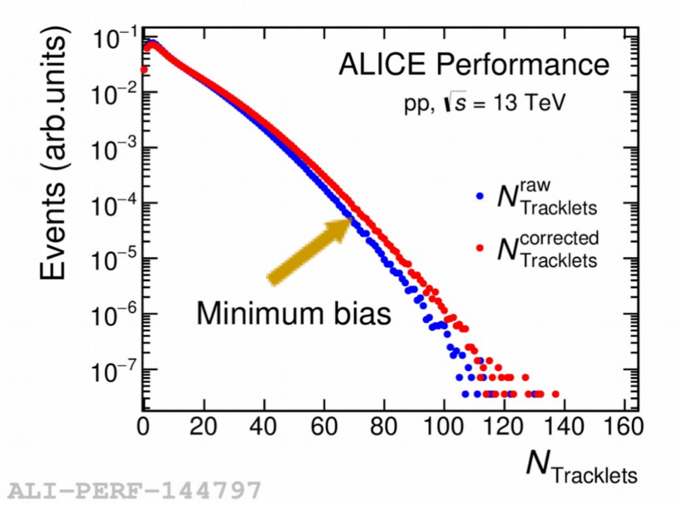
- Smaller detectors :
  - V0, T0, ZDC
  - Event activity characterization

- Muon Spectrometer, $-4 < \eta < 2.5$:
  - Muon Tracker
  - Muon Identifier (triggering)
  - Open heavy flavours and quarkonia
  - W/Z bosons
  - Low mass resonances

Analysis strategy

Multiplicity estimation – SPD tracklets



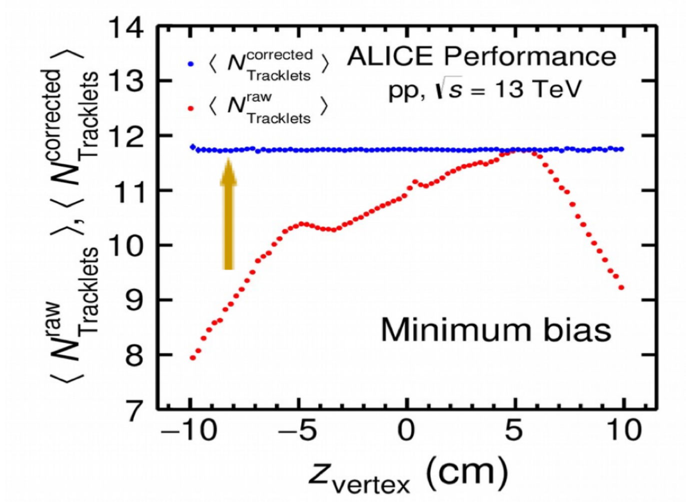


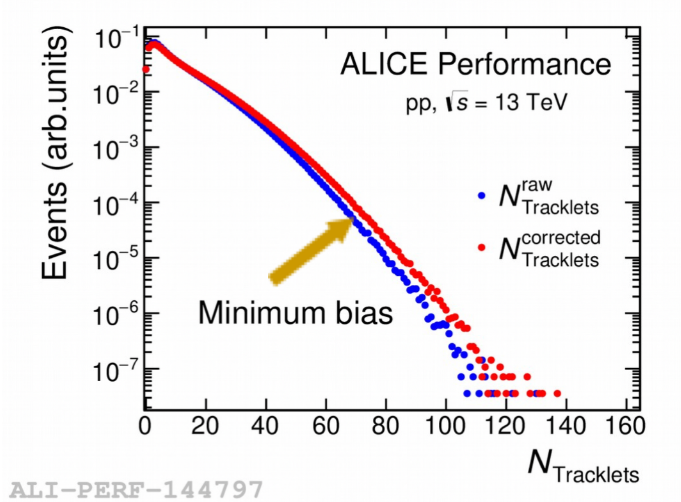
Correction for detector inefficiency

- Equalize the acceptance and the efficiency along z direction

Analysis strategy

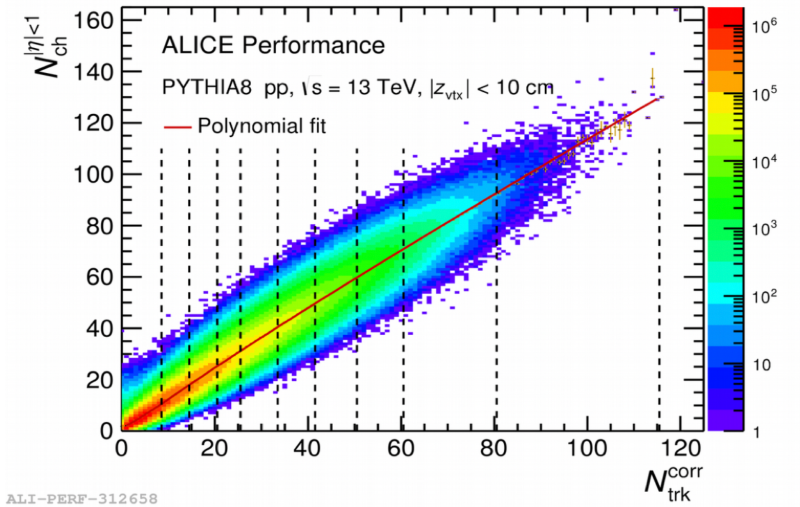
Multiplicity estimation – SPD tracklets





Correction for detector inefficiency

- Equalize the acceptance and the efficiency along z direction

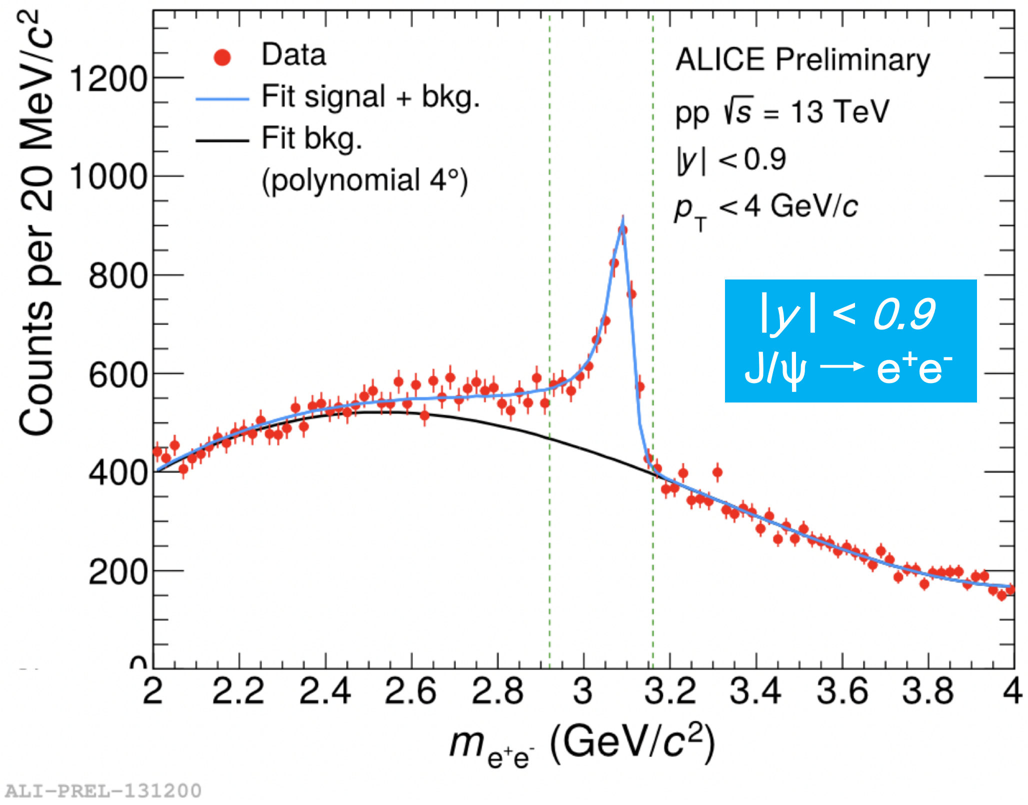


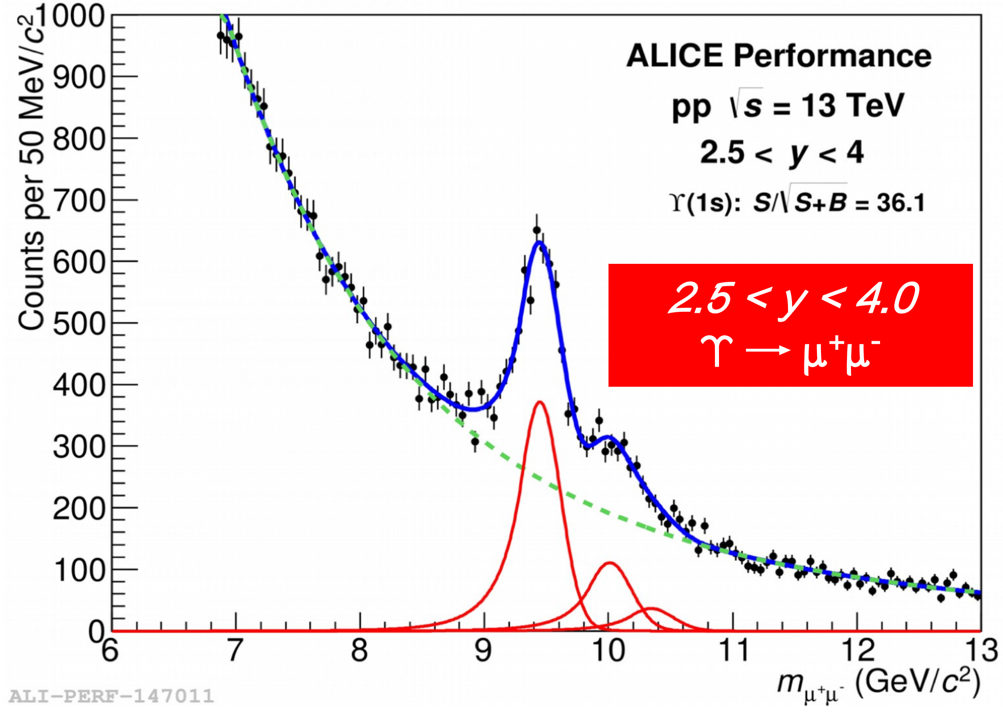
Tracklet-to-charged-particle conversion

- Based on simulations which reproduce the realistic detector transport

Analysis strategy

Signal extraction



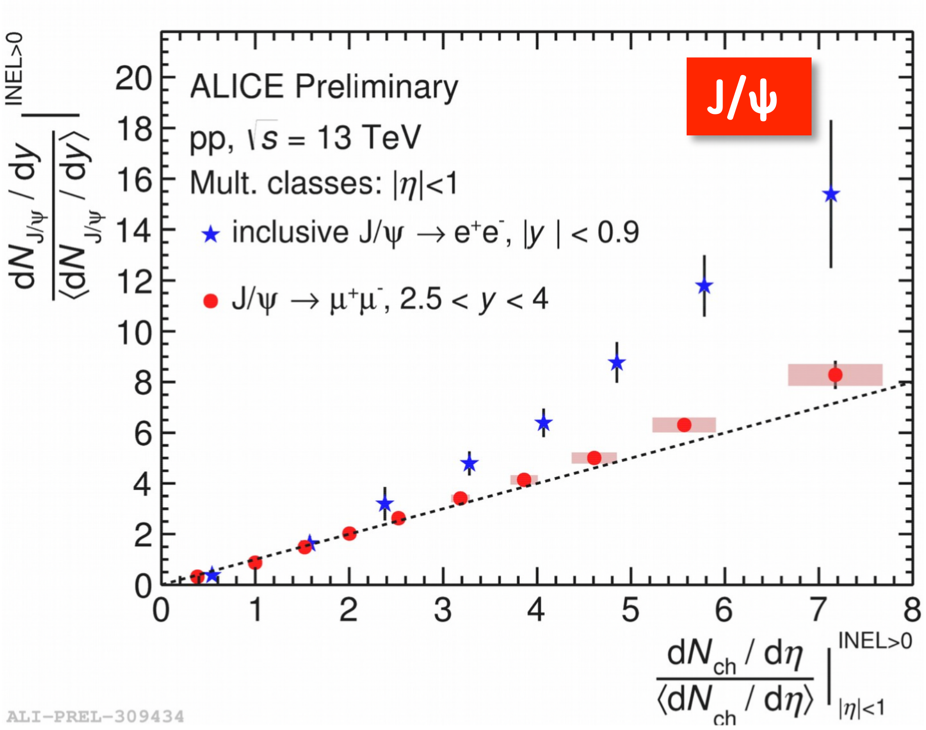


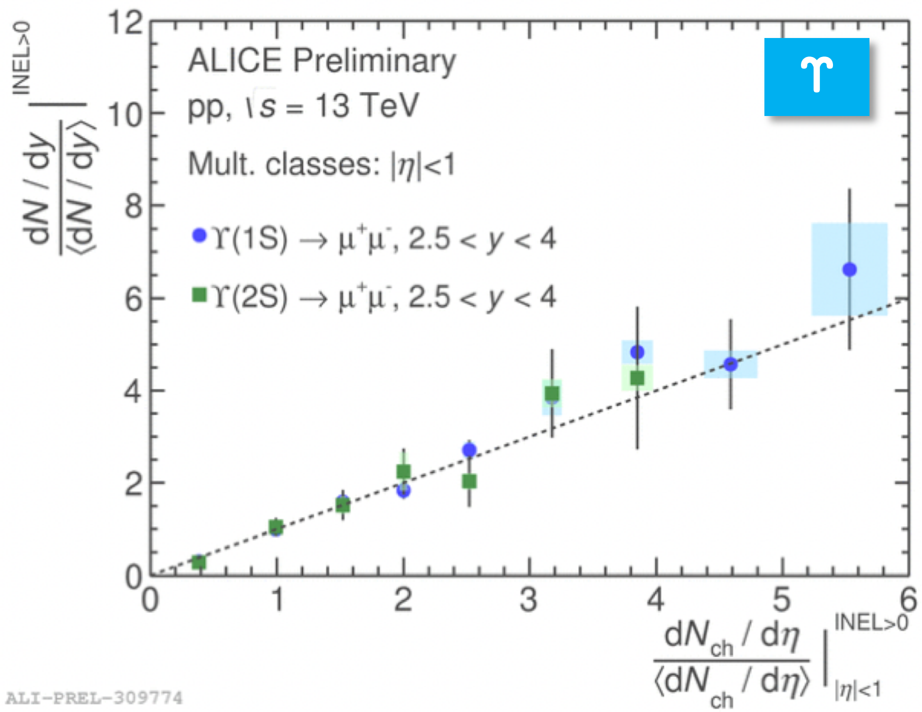
- Clear signal peak at both mid-rapidity and forward rapidity
- A combined fit is applied to disentangle signal and background

Results

pp collisions

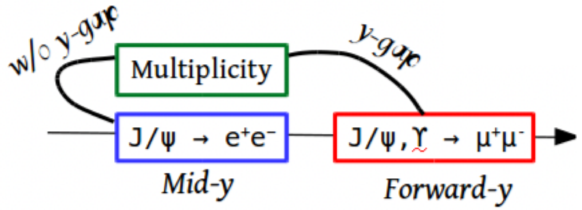
Inclusive J/ψ and ϒ production vs. multiplicity



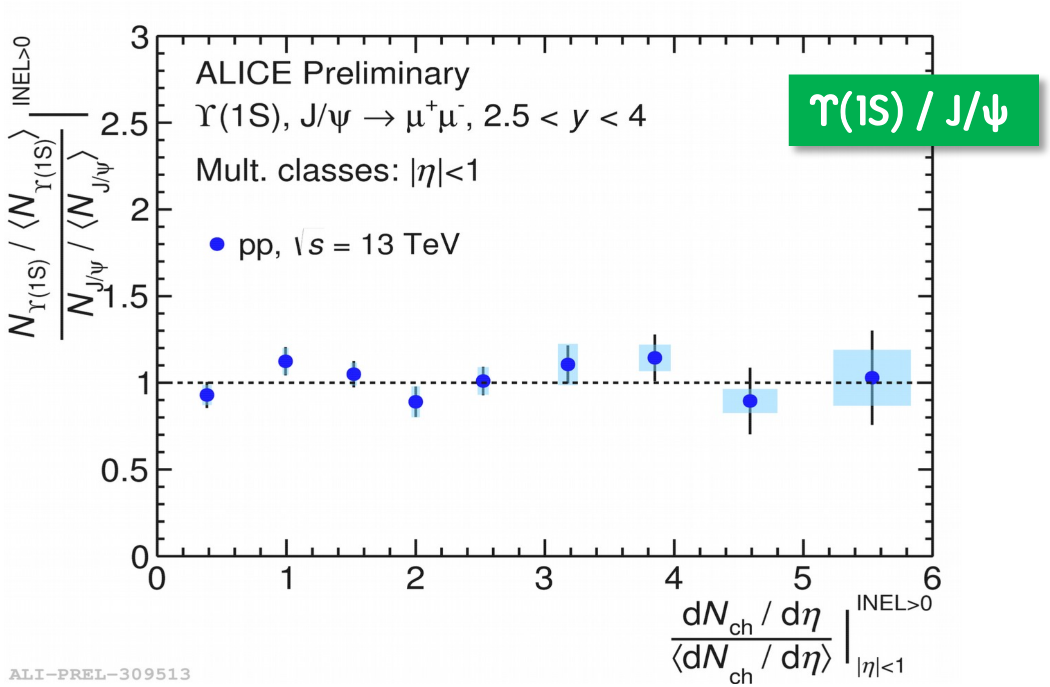


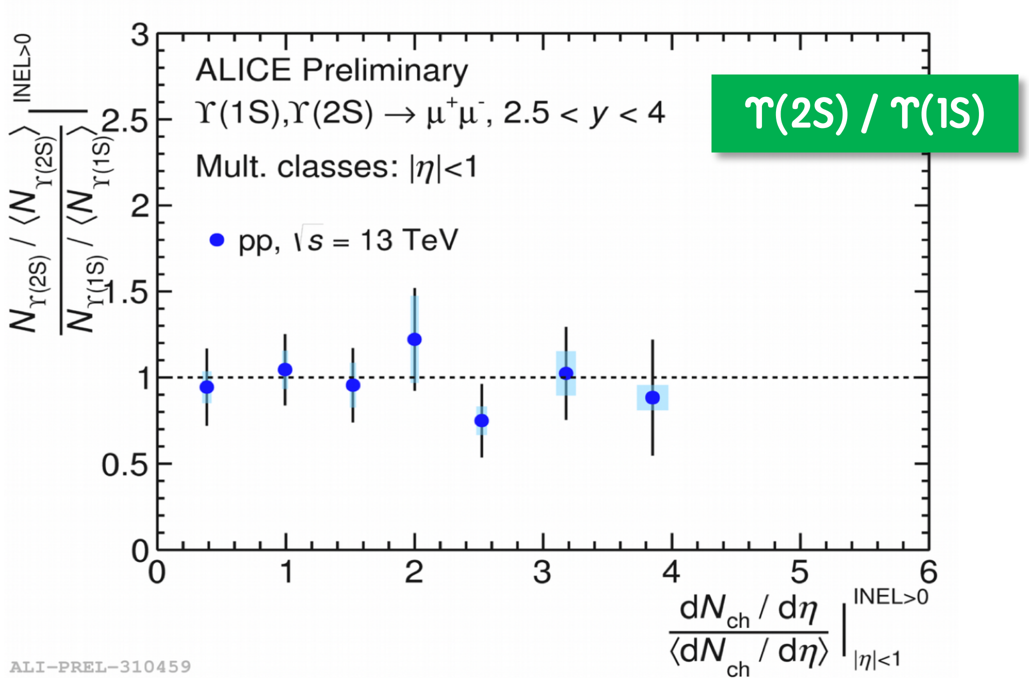
- Forward rapidity (with y-gap): Linear increase for J/ψ, ϒ(1S) and ϒ(2S)
- Mid-rapidity (without y-gap): Stronger than linear increase for J/ψ

Hint of auto-correlation bias



Double yield ratios of Υ (1S) / J/ψ and Υ(2S) / Υ(1S) vs. multiplicity

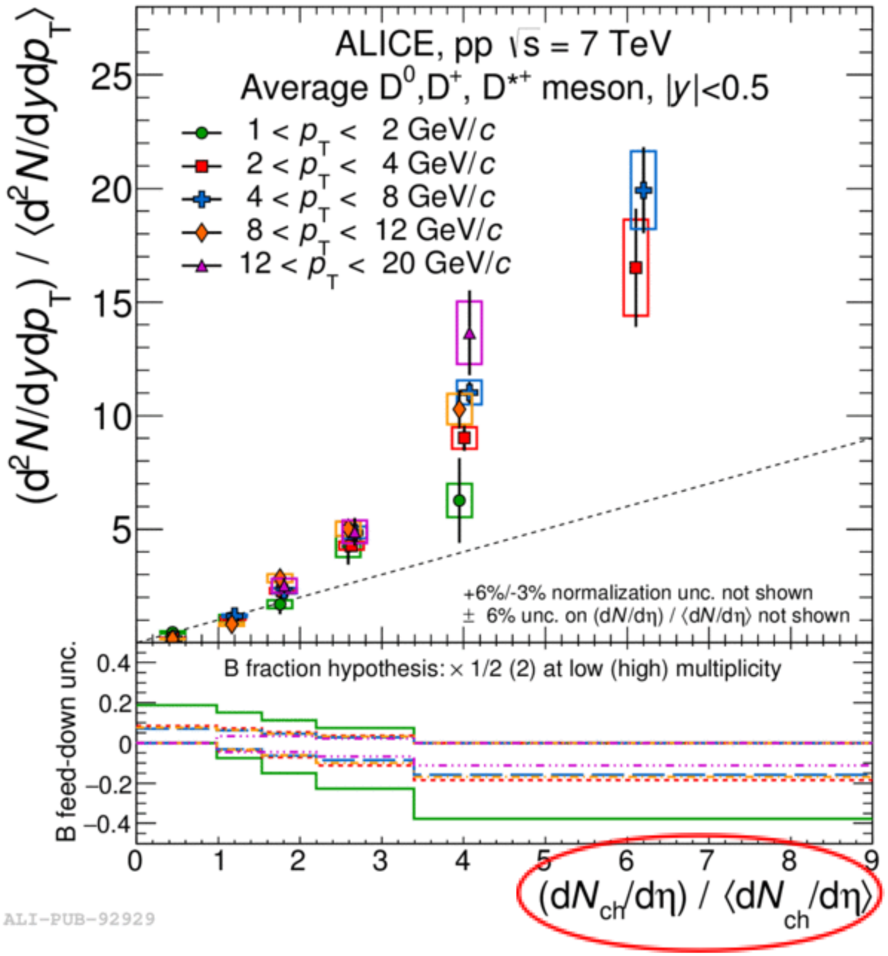




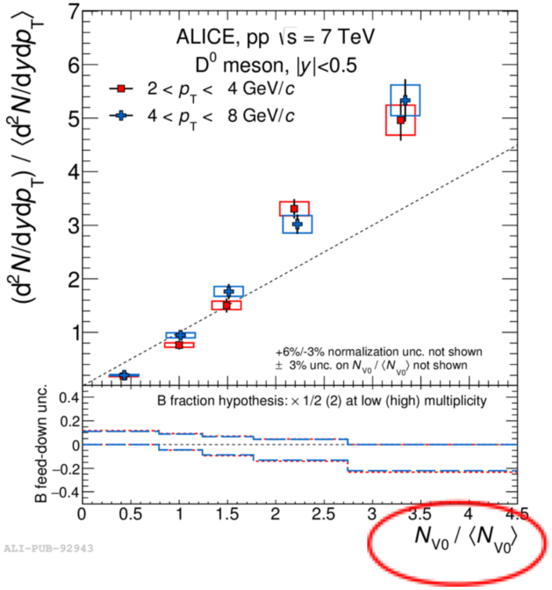
Measurements performed at forward rapidity, i.e. with *y* gap:

- The self-normalized yield ratios of Υ(1S)/ J/ψ and Υ(2S) / Υ(1S) are independent on multiplicity within uncertainties
  - No effect is seen w.r.t quark component and resonance mass

D-meson production vs. multiplicity



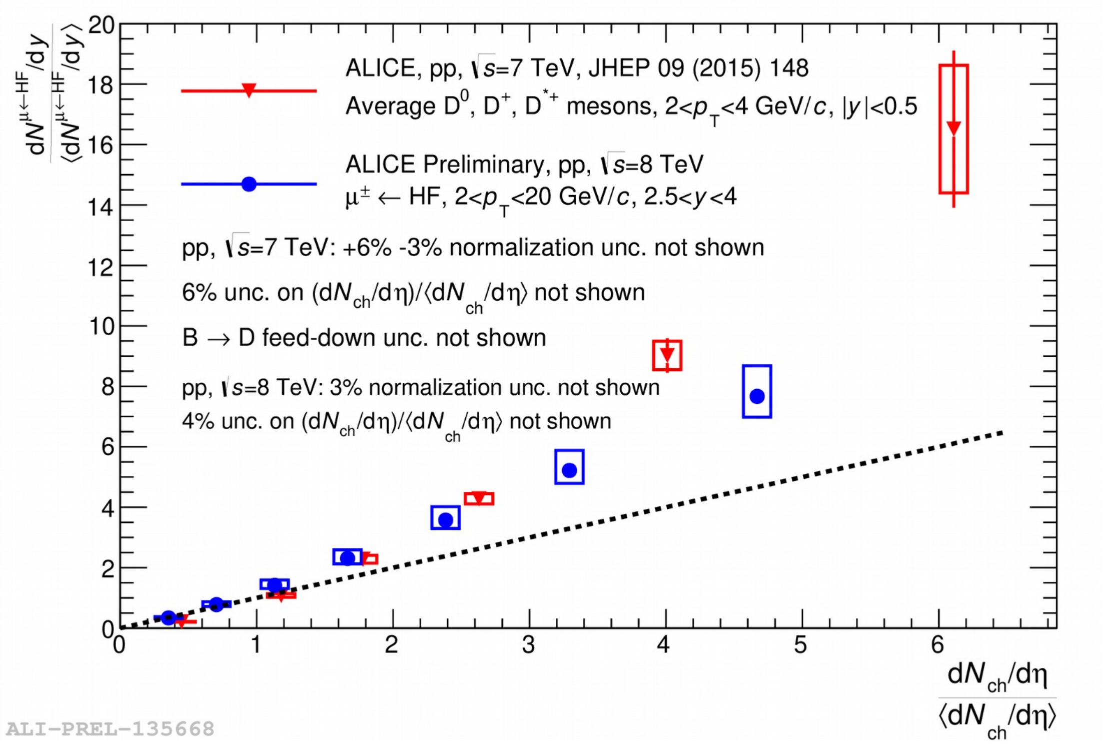
- Approximately linear increase with charged- particle multiplicity within uncertainties
- Deviation from linearity in the highest multiplicity bins
- No p_T dependence within uncertainties



Test possible auto-correlation: rapidity gap

- Qualitatively similar increasing trend

Semi-leptonic decay: μ ← HF vs. multiplicity



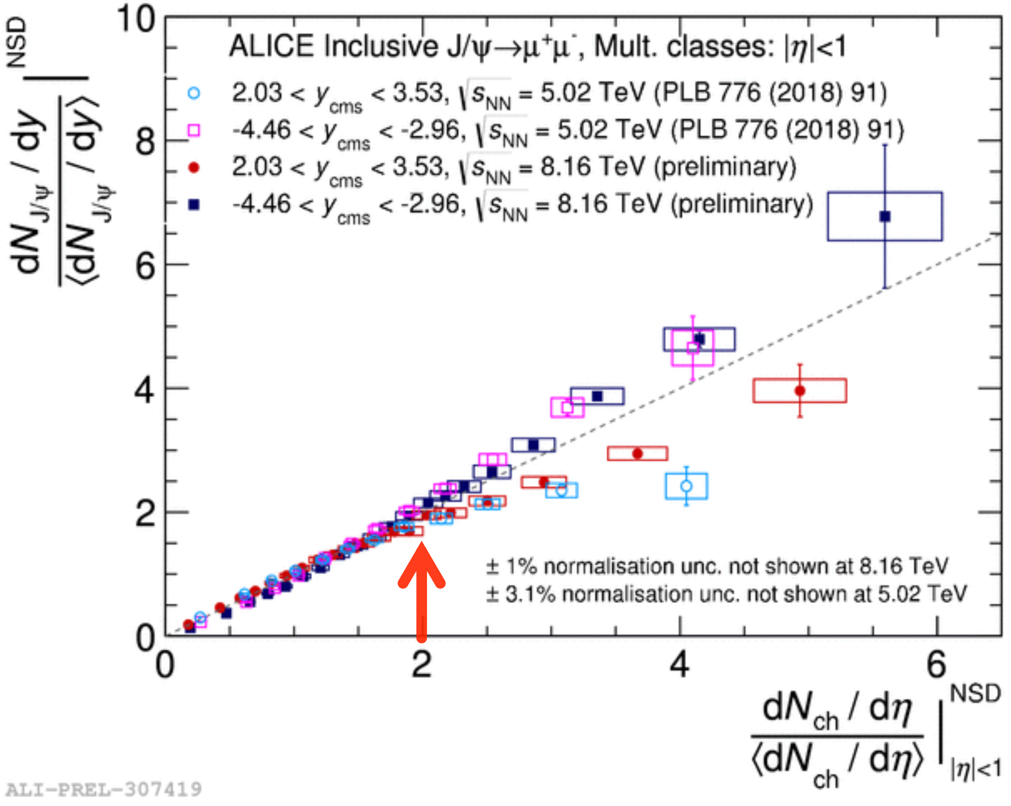
- Low multiplicity : Similar multiplicity dependence as J/ψ and ϒ
- High multiplicity : Stronger than linear increase
- The increase appears slightly faster at mid-rapidity than at forward, which is similar to what is observed for J/ψ

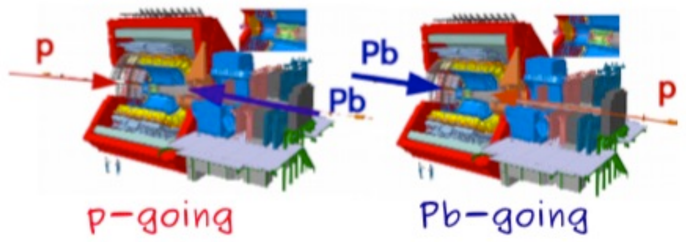
Need to study the role of jet fragmentation for J/ψ production

Results

p-*P*b collisions

Inclusive J/ψ production vs. multiplicity

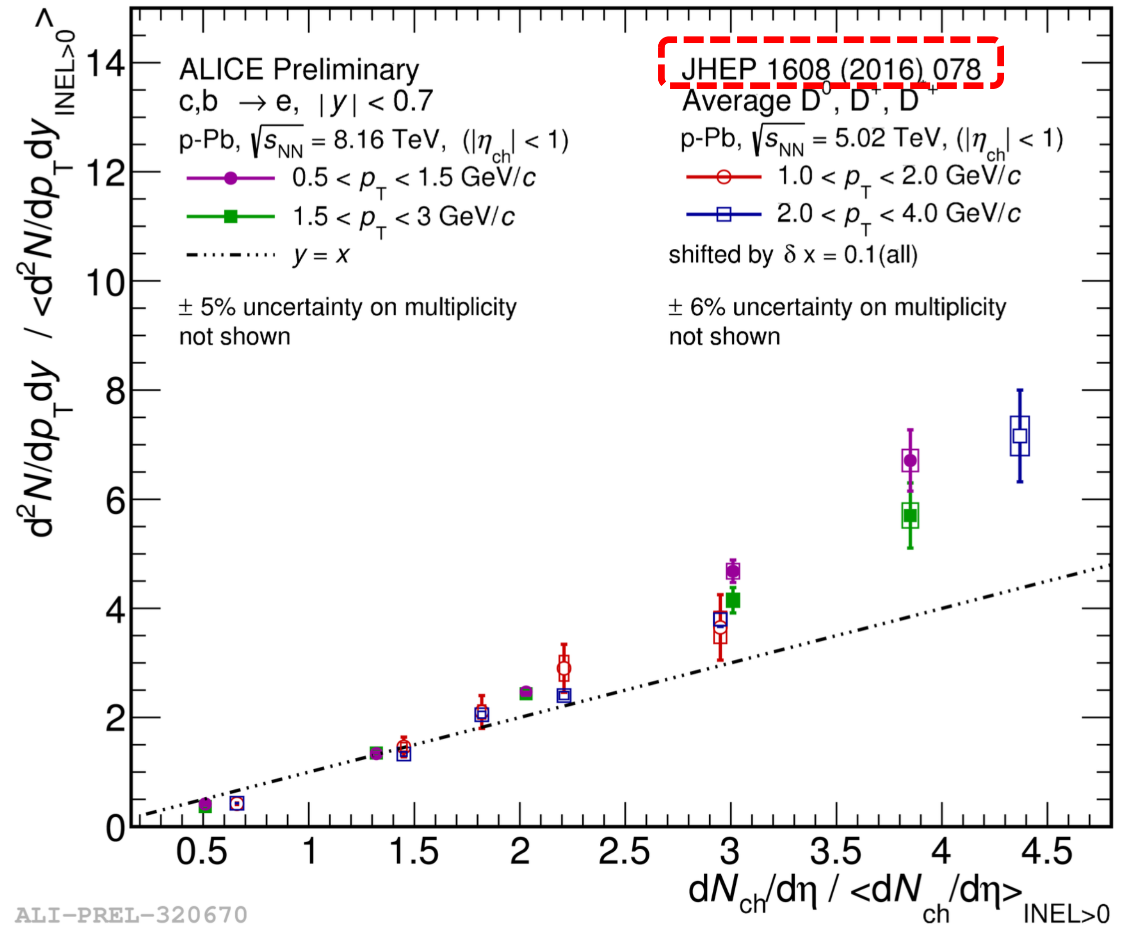




- Low multiplicity: both backward and forward results show a linear increase with multiplicity
- High multiplicity, i.e.: $dN_{ch}/d\eta$ /<$dN_{ch}/d\eta$> > 2:
  - Forward (p-going side): shows slower than linear increase (saturation?)
  - Backward (Pb-going side): keeps increasing linearly within uncertainties

J/ψ production vs. multiplicity shows a rapidity dependence while no energy dependence is observed

D-meson production and e ← HF vs. multiplicity

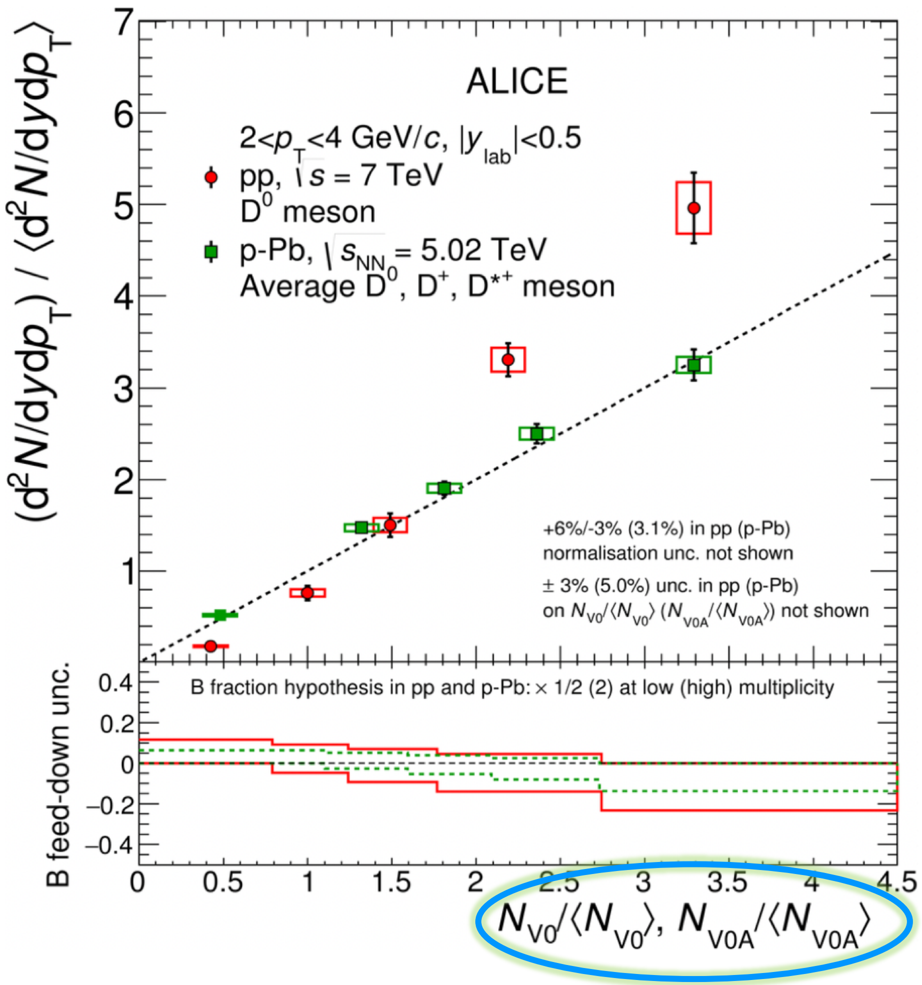


Both D-meson and e ← HF:

- Independent of transverse momentum within uncertainties
- Faster-than-linear increase with the charged-particle multiplicity at central rapidity

D-meson production vs. multiplicity

JHEP 8 (2016) 1-44



Introduce a rapidity gap between D-meson and multiplicity

- Consistent with a linear growth as a function of multiplicity
- Increase faster in pp than p–Pb collisions at backward rapidity

Summary

ALICE has measured the quarkonium and open heavy-flavour production at several energies in small systems

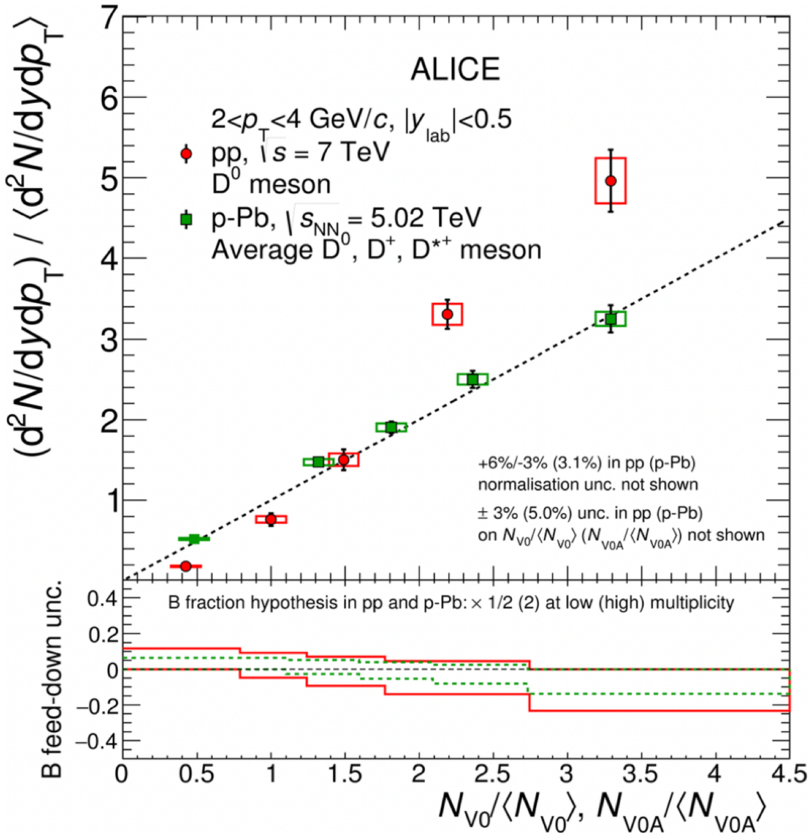
- ☐ Linear increase with multiplicity highlights the importance of MPI
- ☐ Stronger than linear increase could be explained by:
  - Auto-correlation with associated multiplicity production
  - Soft particle saturation
  - Bias from jet fragmentation/decay daughters

  ...
- ☐ Finalize the upsilon analysis by analyzing the full statistics in view of publication

Thanks for your attention !

BACK UP

Introduce an η gap between D-meson and multiplicity



Increase faster in pp than p–Pb collisions at backward rapidity

- Different pseudo-rapidity intervals of the multiplicity measurement
- The initial conditions of the collision are affected by the presence of the Pb nucleus
- Multiple binary nucleon–nucleon interactions per p–Pb collision