Heavy flavour production as a function of multiplicity in small systems with ALICE

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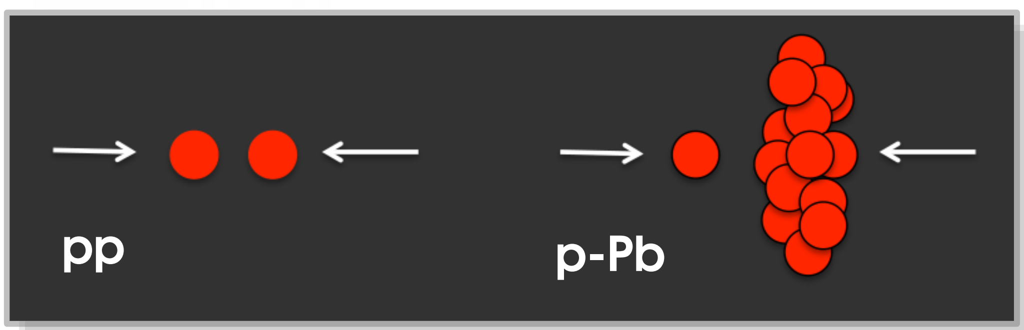

12th Workshop of France China Particle Physics Laboratory

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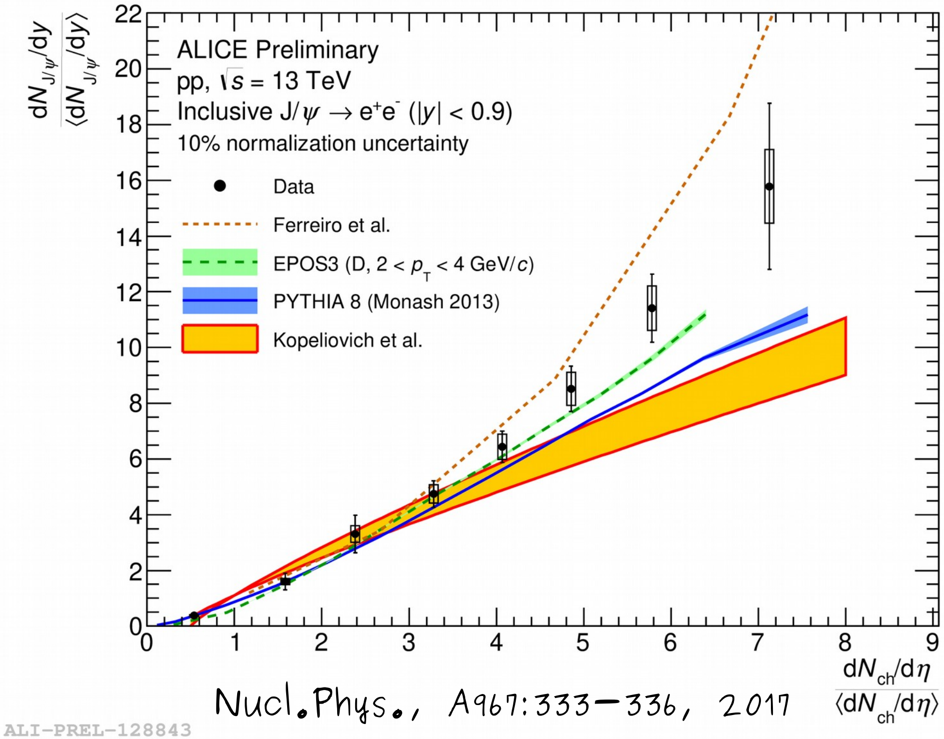
Shanghai Jiao Tong University

Introduction

Charged-particle multiplicity dependence to study:

- Particle production mechanism
- Multiple parton interactions (MPI)
- Interplay between soft and hard processes

J/ψ produciton in pp collisions at $\sqrt{s}$ = 13 TeV



Nucl.Phys., A967:333–336, 2017

-> J/ψ production increases faster than linear with the charged-particle multiplicity

-> This could tie in with hints of a QGP-like behavior at high multiplicity in small systems

-> Models assume J/ψ production in MPI and saturation of soft particle production ("compression of x-axis")

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

Heavy flavours are studied at :

Mid-rapidity: $|y| < 0.5, 0.9$ ...

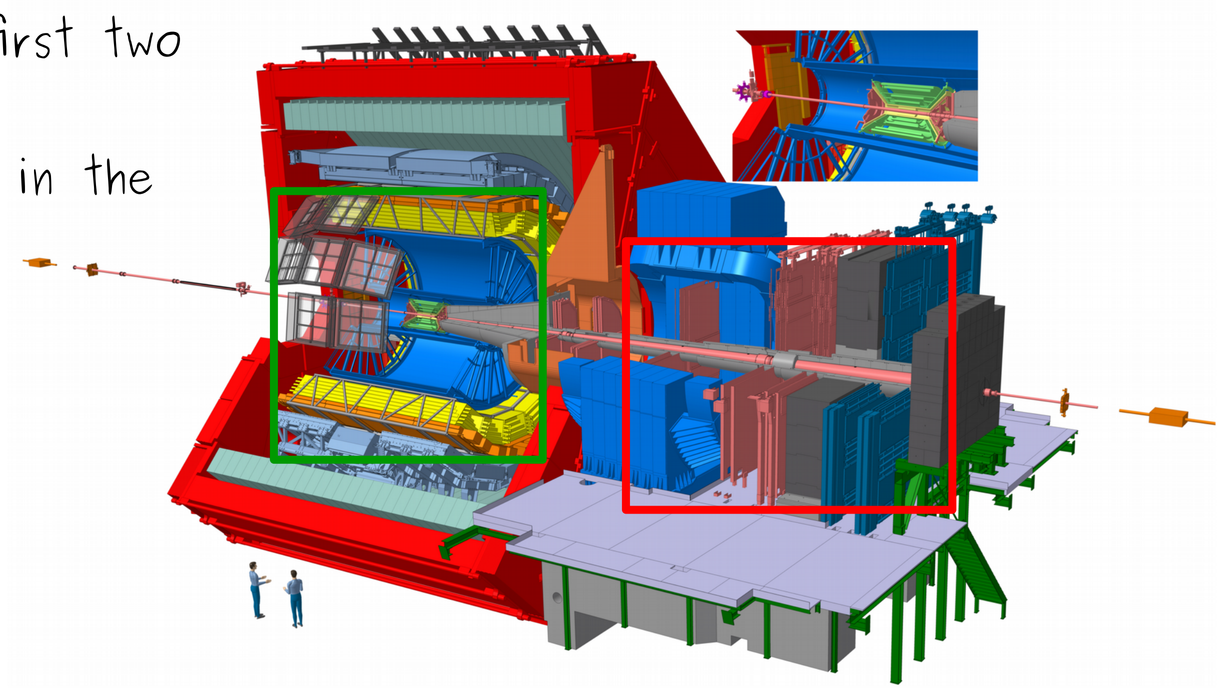
Forward rapidity: $2.5 < y < 4$

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

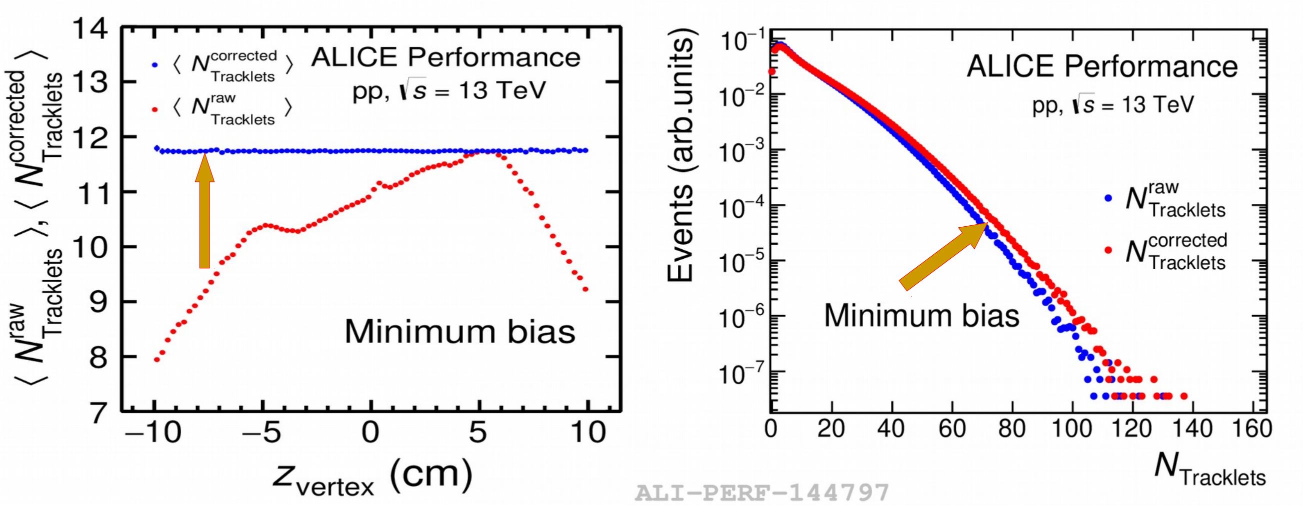


Muon Spectrometer, $-4 < \eta < 2.5$:

- Muon Tracker
- Muon Identifier (triggering)
- Open heavy flavours and quarkonia
- W/Z bosons
- Low mass resonances

Analysis strategy

Multiplicity estimation – SPD tracklets

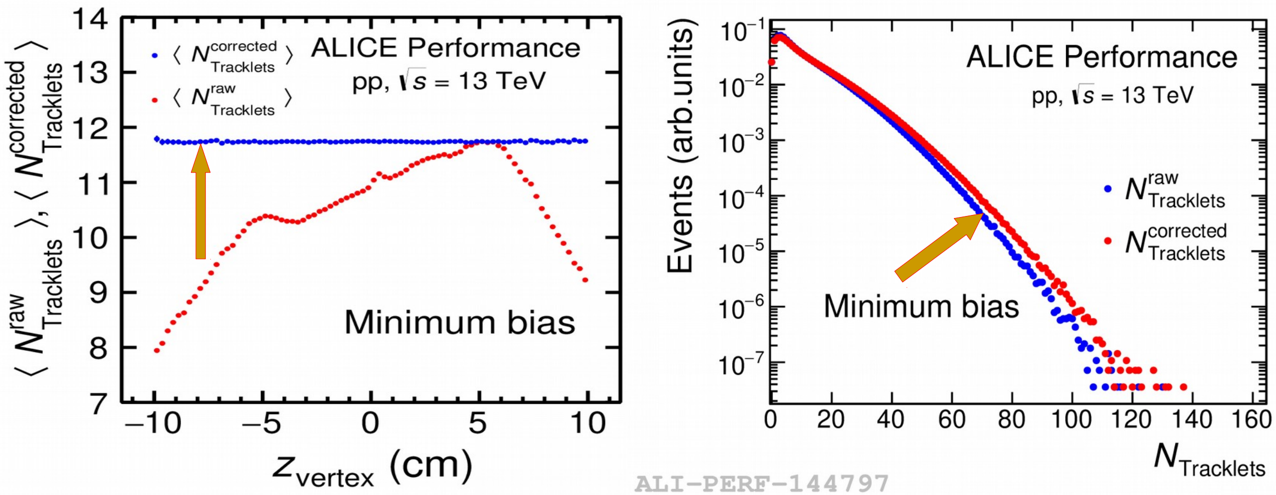


Correction for detector inefficiency

- Equalize acceptance and efficiency along the z−vertex direction

Analysis strategy

Multiplicity estimation – SPD tracklets

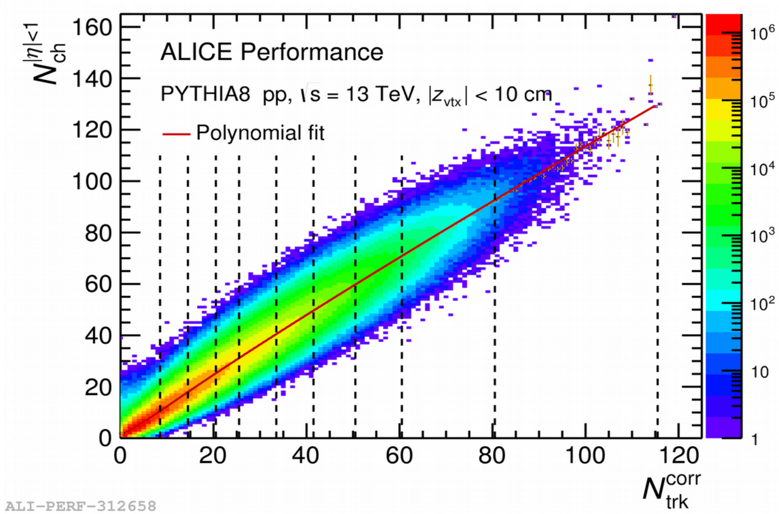


Correction for detector inefficiency

- Equalize acceptance and efficiency along the z-vertex direction

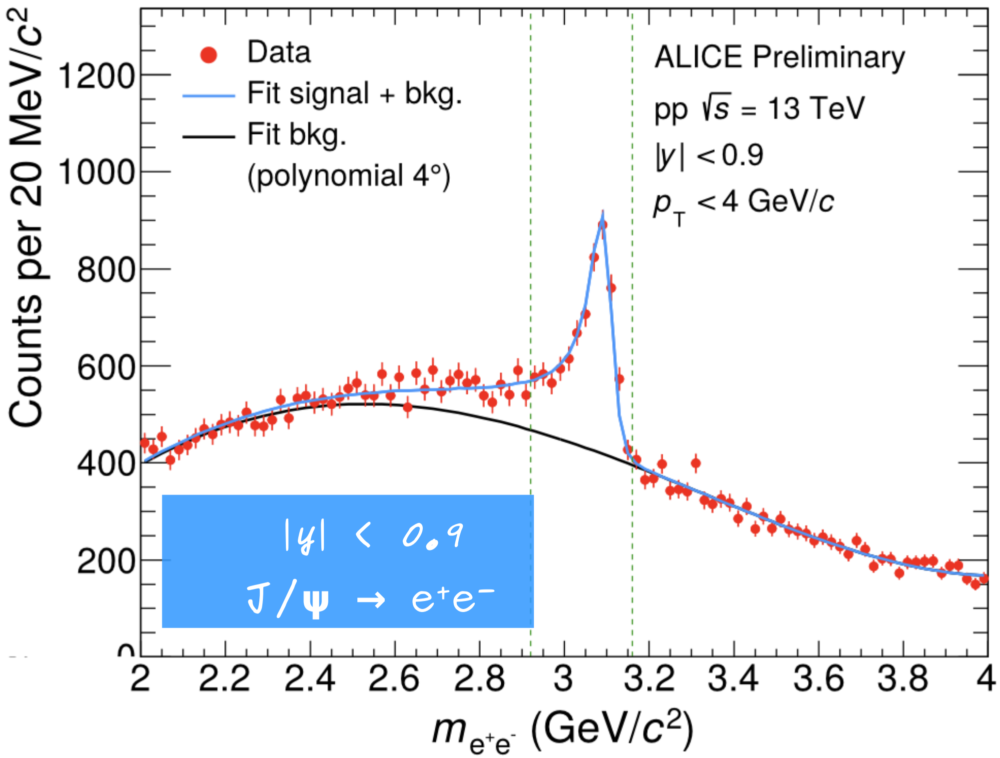
Tracklet-to-charged-particle conversion

- Based on simulations which reproduce the realistic detector transport



Analysis strategy

Signal extraction



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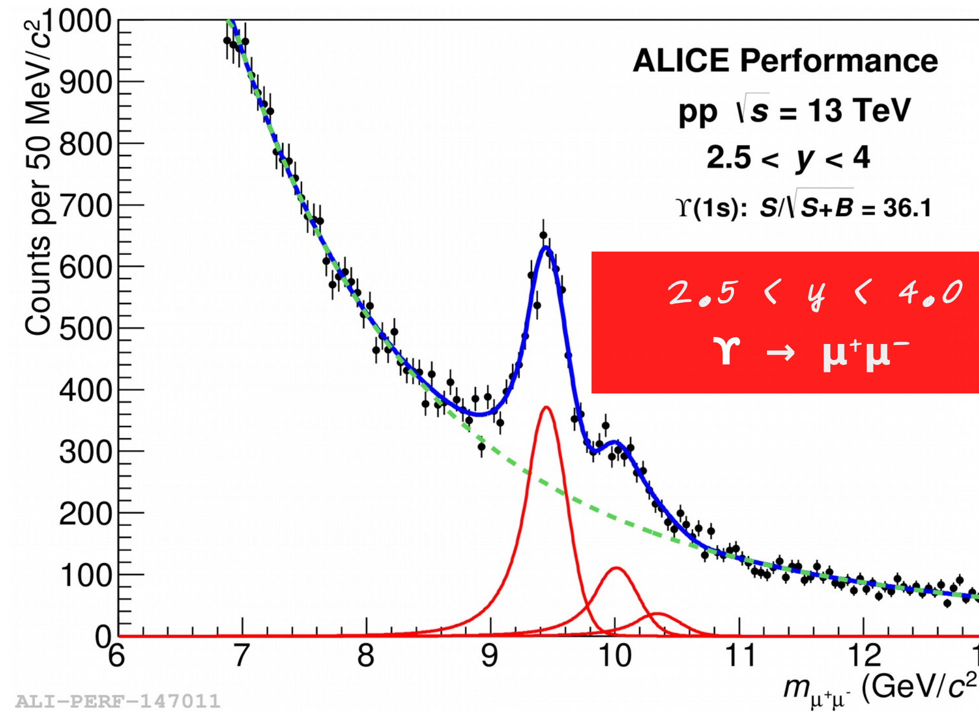
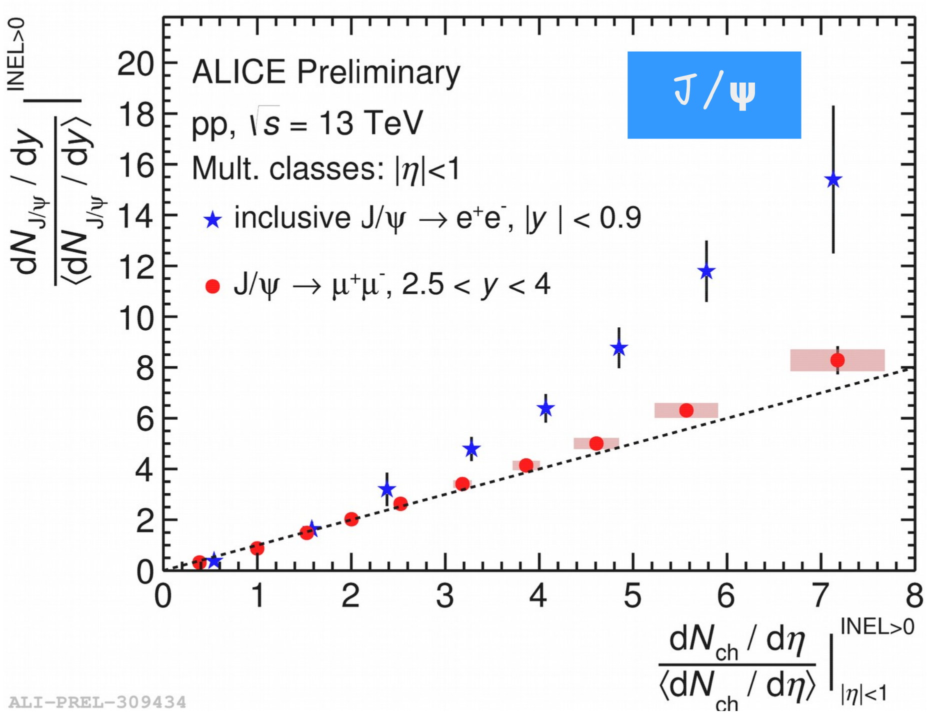


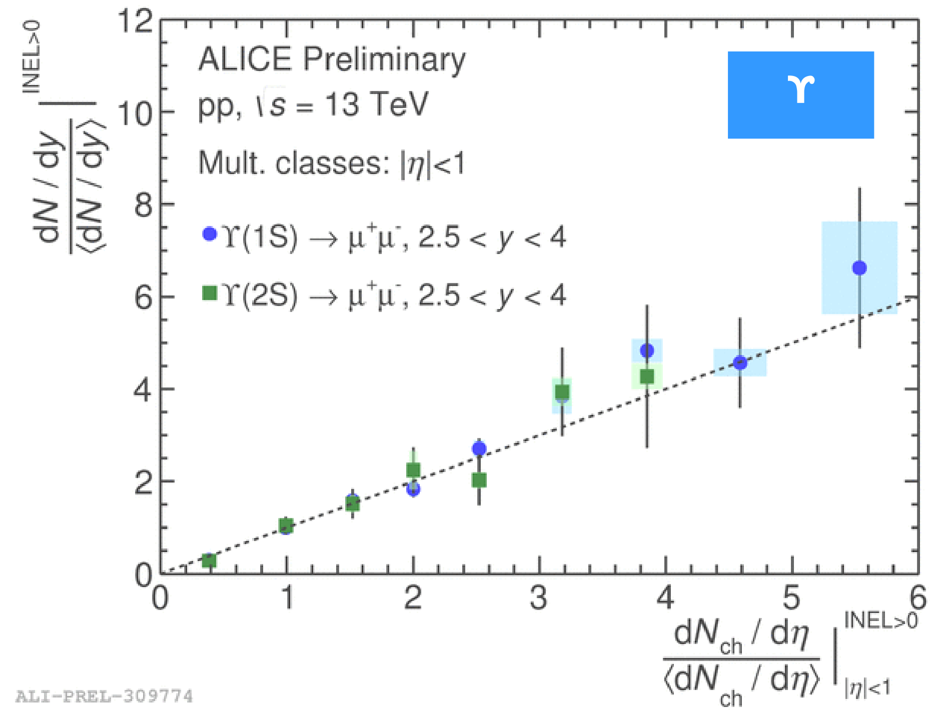
- Clear signal peak at both mid-rapidity and forward rapidity
- A combined fit is applied to disentangle signal and background

Results

pp collisions

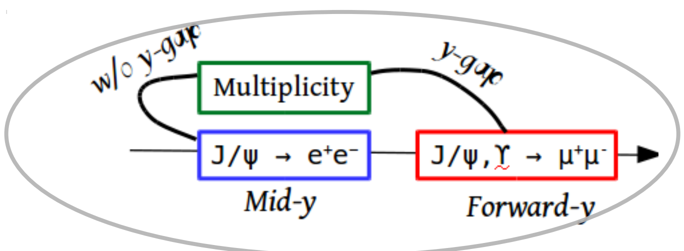
Inclusive J/ψ and ϒ production vs multiplicity





- 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

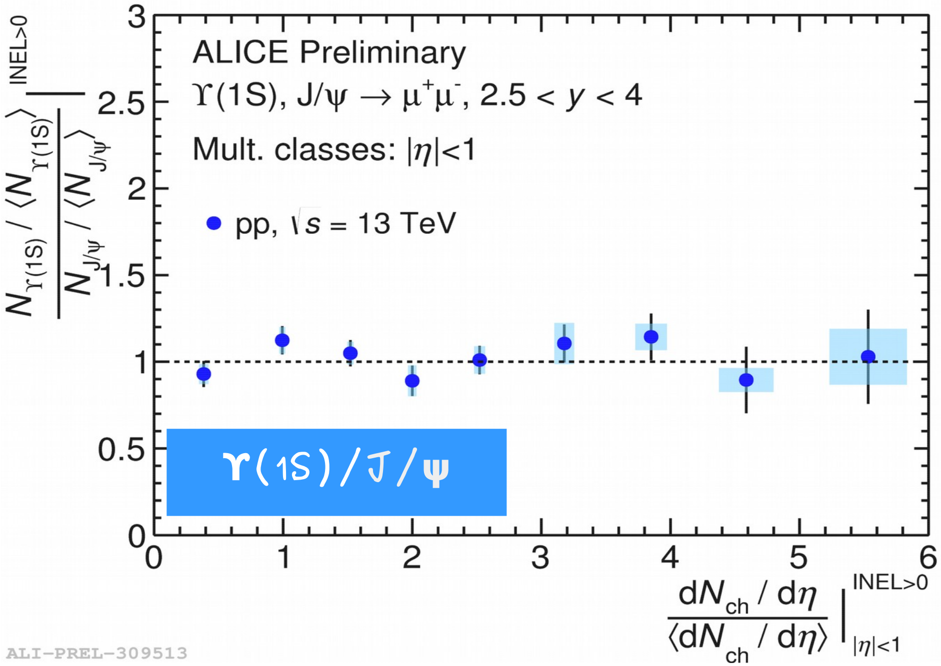
-> Hint of auto-correlation bias

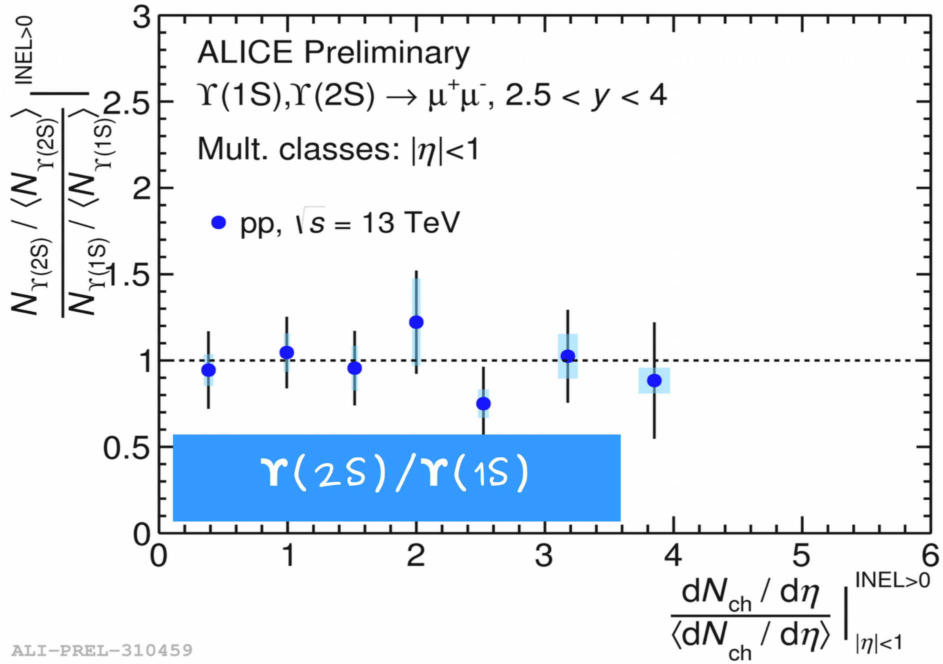


Inclusive J/ψ and ϒ production vs multiplicity

Double ratio of charged-particle multiplicity dependence to study:

- Relative production in terms of mass and flavor content
- Excited to ground state production





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

- Left: No dependence on mass and quark content
- Right: ϒ(2S)/ϒ(1S) ratio is compatible with unity within current uncertainties

D-meson production vs multiplicity

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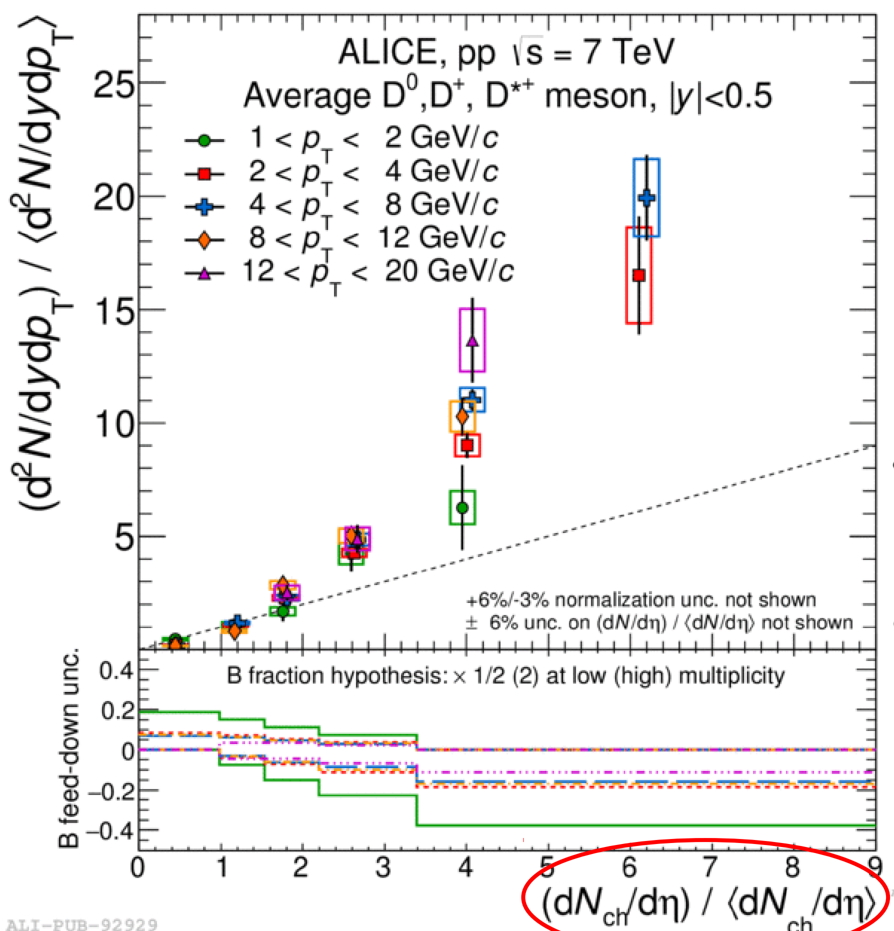
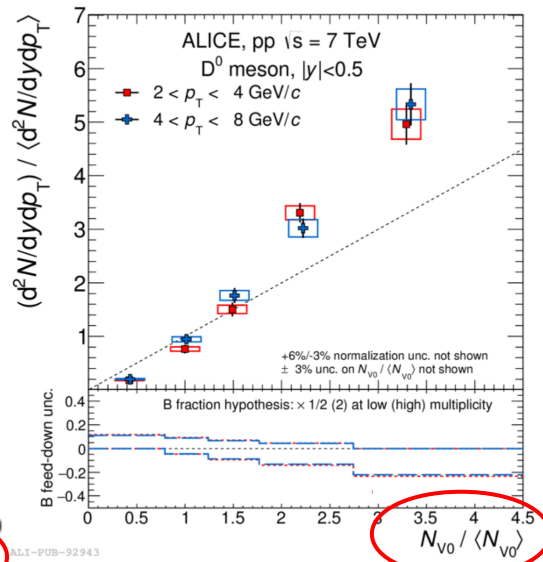


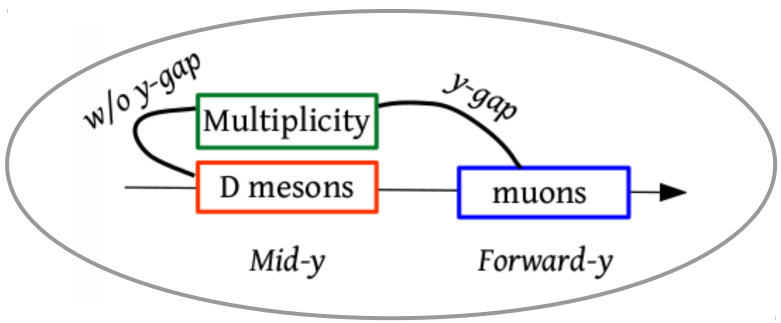
- Approximately linear increase within uncertainties at low multiplicity
- Deviation from linearity in the higher multiplicity bins
- No p_T dependence within uncertainties

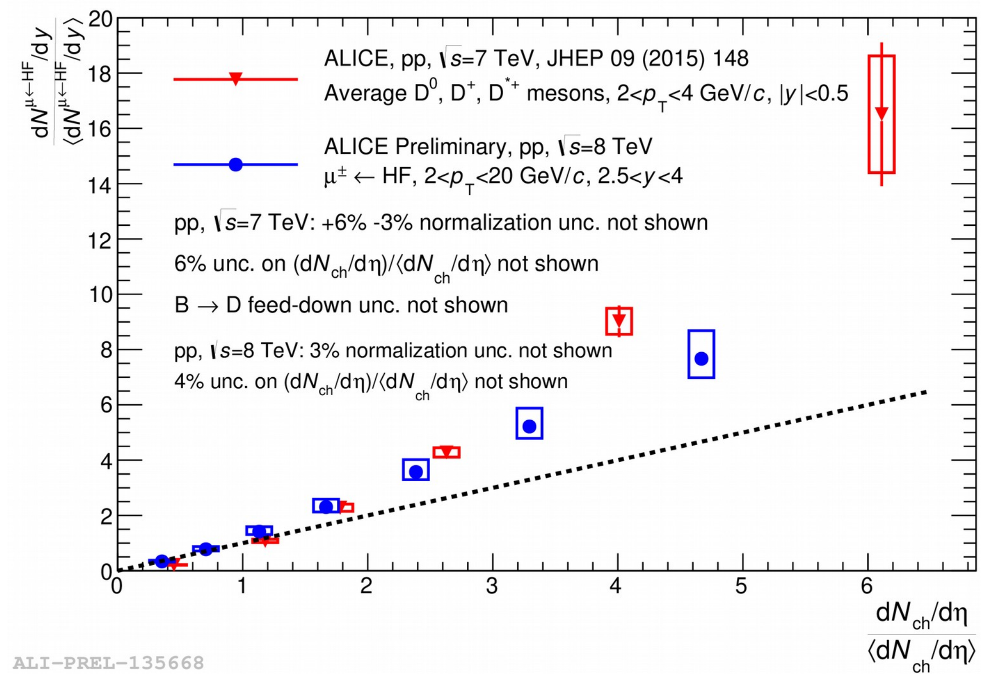


- Test possible auto-correlation: y-gap

-> 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

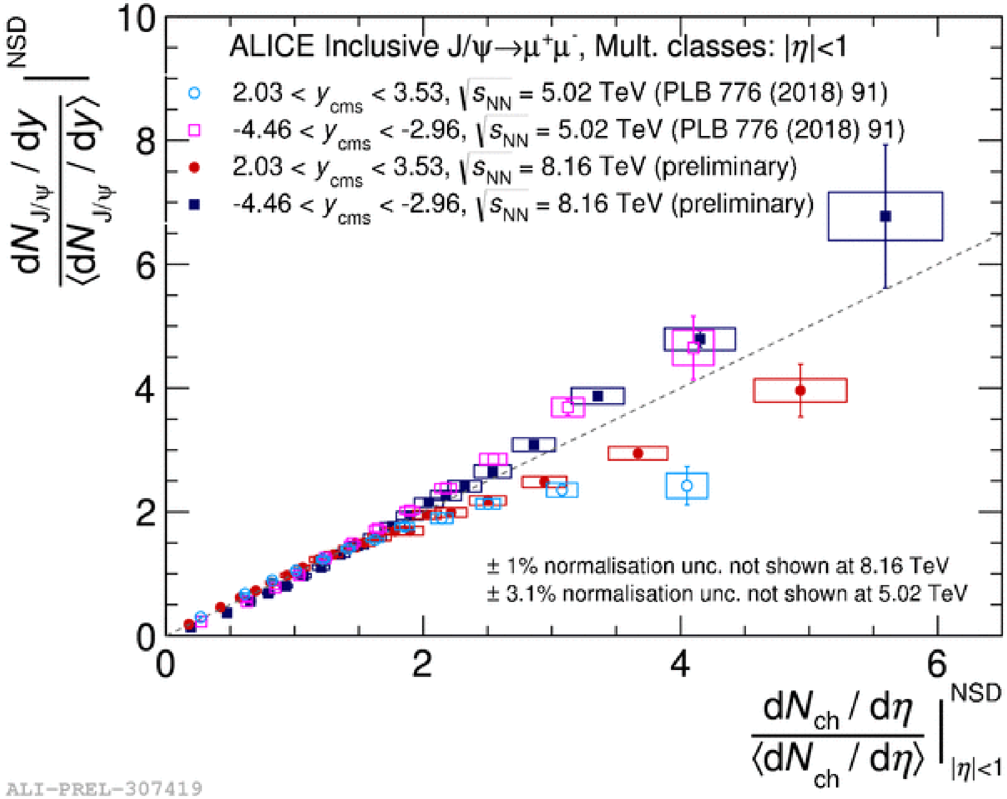
–> The increase appears slightly faster at mid-rapidity than at forward, which is similar to what is observed for J/ψ

–> Need to study the role of jet fragmentation in J/ψ production

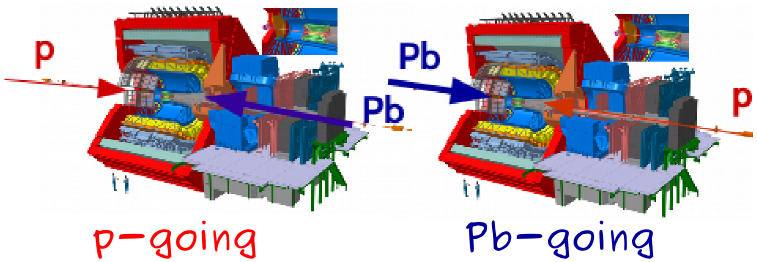
Results

p-Pb collisions

Inclusive J/ψ production vs multiplicity



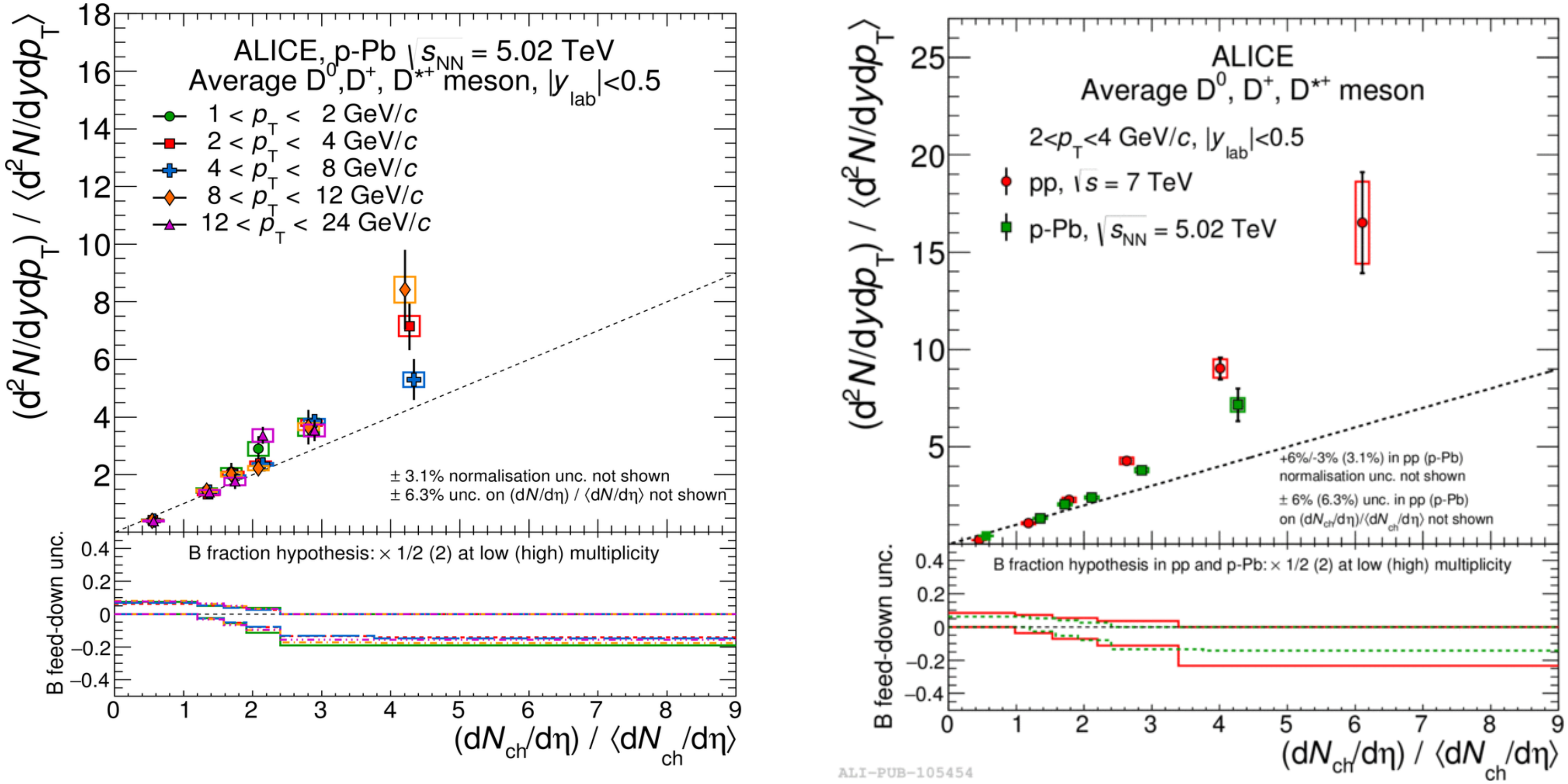
-> J/ψ production vs. multiplicity shows a rapidity dependence while no energy dependence is observed



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

D-meson production vs multiplicity

JHEP 8 (2016) 1–44

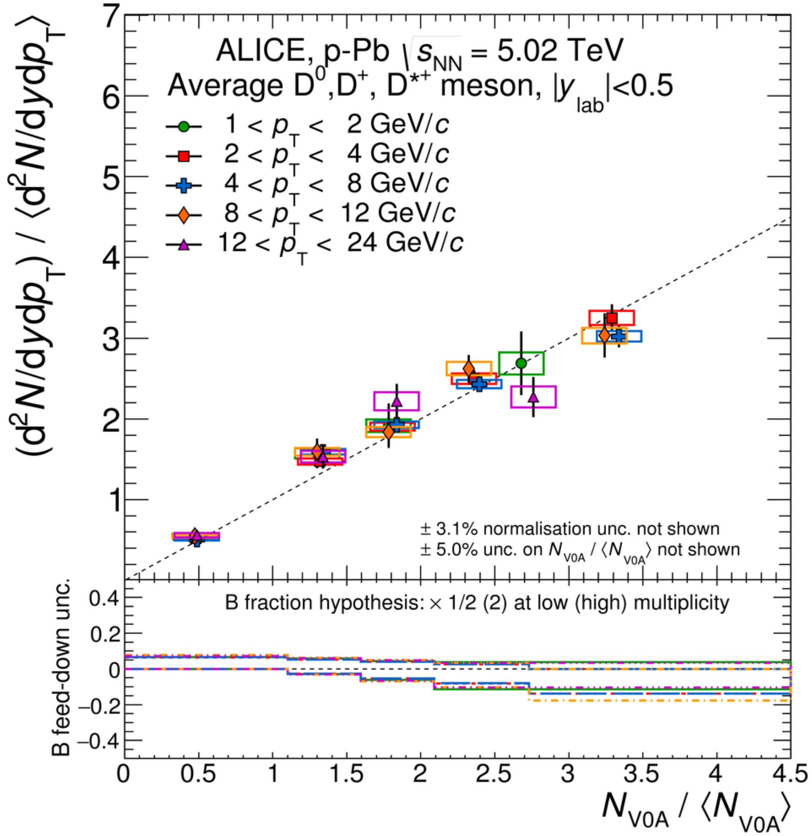


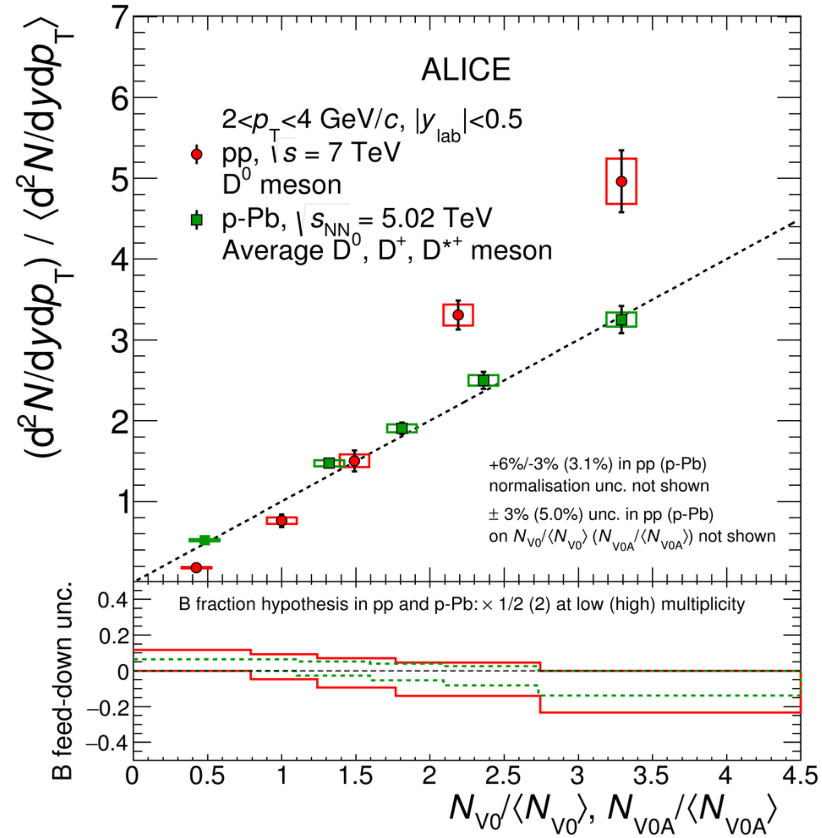
- Independent of transverse momentum within uncertainties
- Faster than linear increase with the charged-particle multiplicity at central rapidity
- Similar trend as pp collisions

D-meson production vs multiplicity

Introduce an η-gap between D-meson and multiplicity

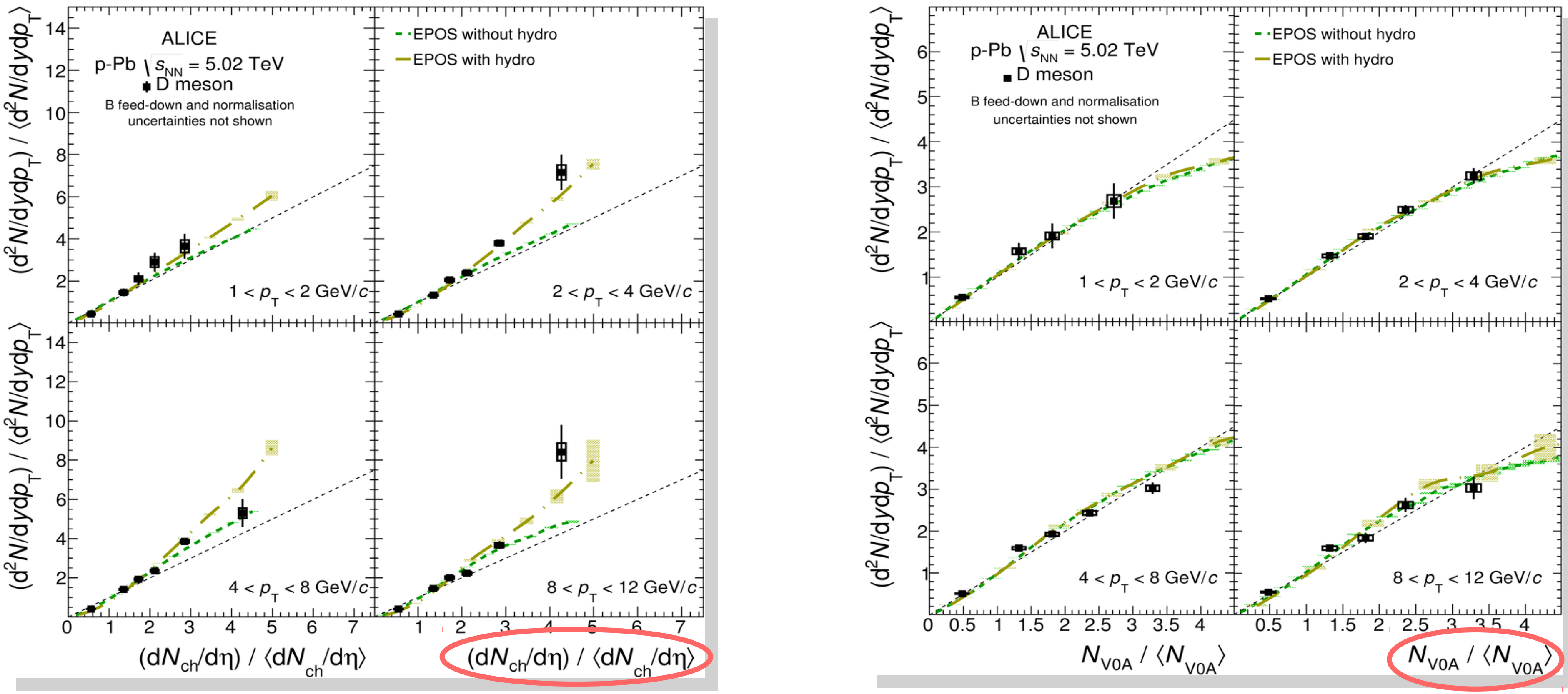
JHEP 8 (2016) 1–44





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

Model predictions for D-meson



- The measurements agree with the EPOS3 model calculations within uncertainties
- At central rapidity, the results at high multiplicity are better reproduced by the calculations including hydrodynamic evolution -> faster than linear increase
- At backward rapidity, the calculations evaluate an approximately linear increase

Summary

- Heavy flavour production as a function of multiplicity is an interesting observable for understanding particle production mechanism, the correlation between soft and hard QCD processes
- ALICE has measured the heavy flavour production at several energies in small systems

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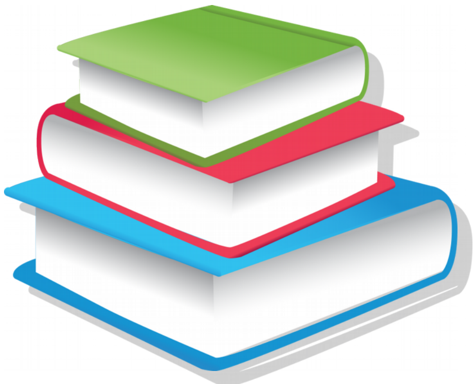
- Linear increase with multiplicity highlights the importance of MPI



Summary

- Heavy flavor production as a function of multiplicity is an interesting observable for understanding particle production mechanism, the correlation between soft and hard QCD processes
- ALICE has measured the 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

  ...

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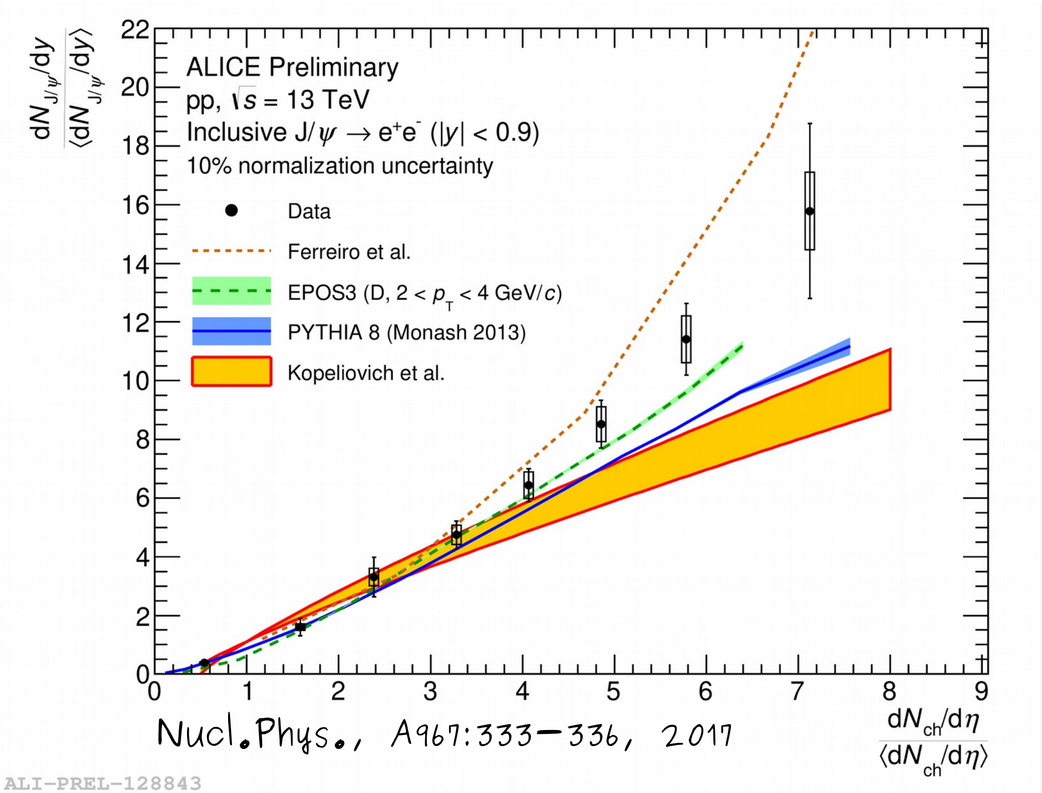
Thank you

Back up



Nucl.Phys., A967:333–336, 2017

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J/ψ in pp collisions at √s = 13 TeV

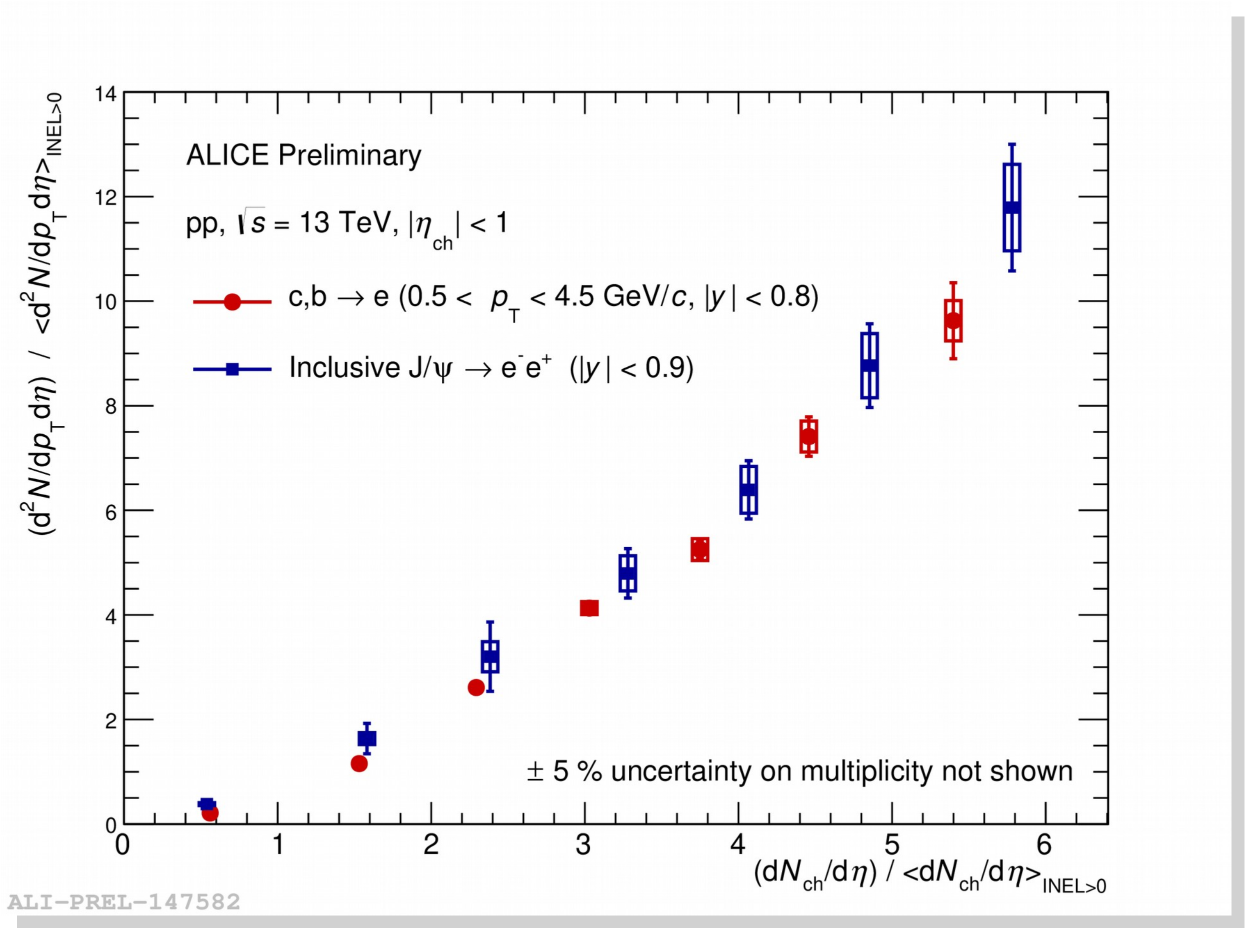
-> Models assume J/ψ production in MPI and saturation of soft particle production ("compression of x-axis")

- Ferreiro: Overlapping strings Phys.Rev . C86 (2012) 034903

- Kopeliovich: Draw analogy between high multiplicity pp an pA collisions Phys. Rev. D 88, 116002 (2013)

- EPOS3: Hydrodynamic expansion reduces particle multiplicity arXiv:1602.03414

Back up


ALICE Preliminary
pp, √s = 13 TeV, |η_ch| < 1
c,b → e (0.5 < p_T < 4.5 GeV/c, |y| < 0.8)
Inclusive J/ψ → e⁻e⁺ (|y| < 0.9)
± 5 % uncertainty on multiplicity not shown
(d²N/dp_T dη) / <d²N/dp_T dη>_INEL>0
(dN_ch/dη) / <dN_ch/dη>_INEL>0
0
1
2
3
4
5
6
0
2
4
6
8
10
12
14
ALI-PREL-147582

Model predictions for D-meson

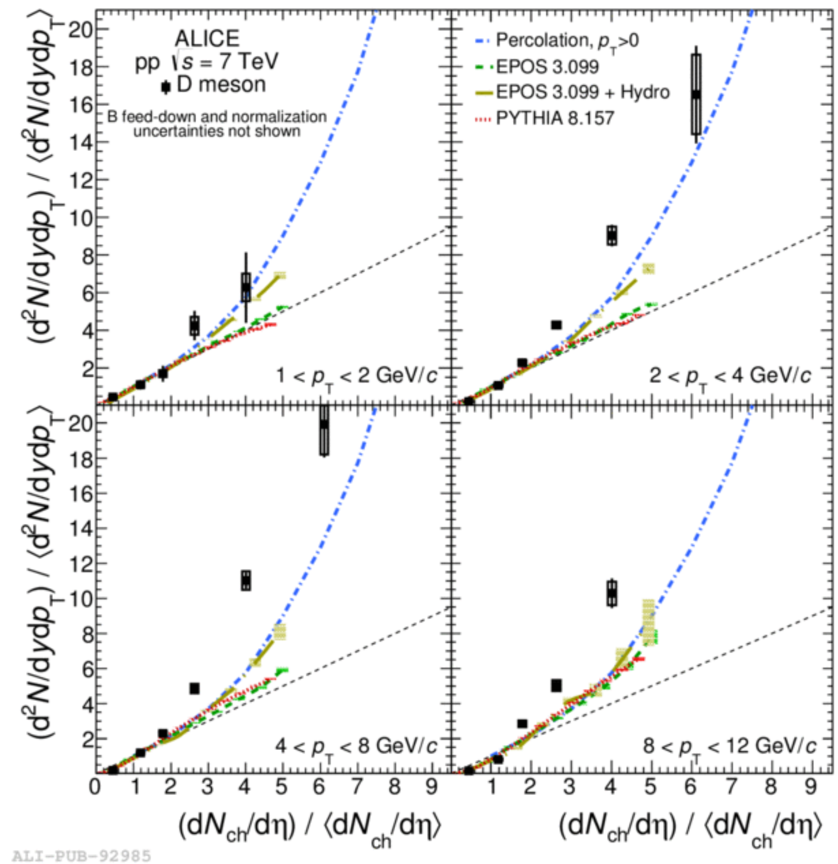
Ferreiro and Pajares, PRC 86 (2012) 034903;
Sjostrand and Mrenna, Comput. Phys. Comm. 178 (2008) 852;
Drescher, Hladik, Ostapchenko, Pierog and Werner, Phys. Rept. 350 (2001) 93

D-meson production in pp collisions at √s = 7 TeV

- PYTHIA 8 and EPOS w/o hydro show linear behavior
- Percolation and EPOS w/ hydro present deviation from linearity at high multiplicity

-> Percolation and EPOS w/ hydro qualitatively supported by data at low p_T

-> General difficulty of the models to reproduce the data especially at high p_T



The ALICE Detector

Charged-particle multiplicity is measured using the number of SPD (the first two layers of the ITS) tracklets in $|\eta| < 1$

Heavy-flavors are studied at :

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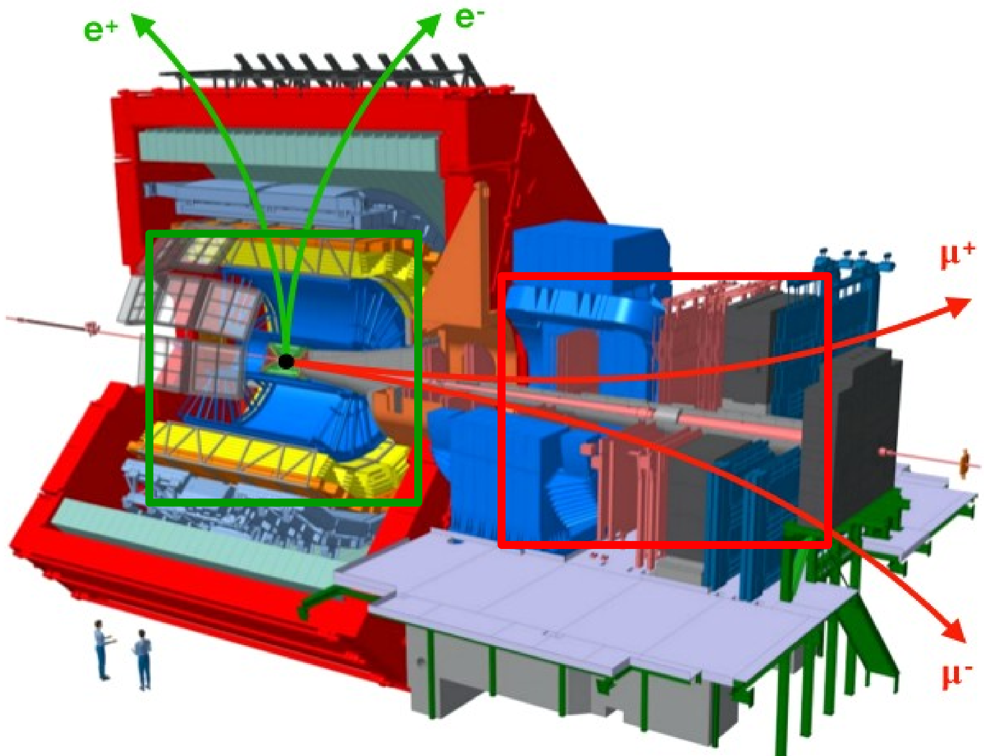
Forward rapidity: $2.5 < y < 4$



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
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D-meson production vs multiplicity

Introduce an η gap between D-meson and multiplicity

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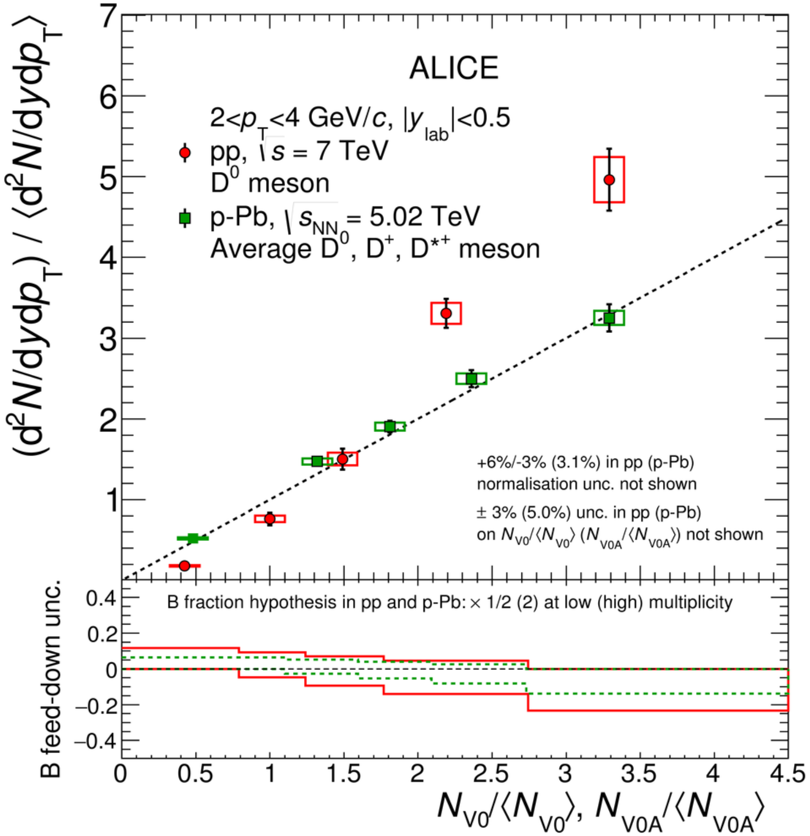

Increase faster in pp than p-Pb collisions at backward rapidity

-> Different pseudorapidity 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

Summary

- ALICE has measured the heavy-flavor production at several energies in small systems
  -> pp collisions: HF measured at central rapidity shows a stronger than linear increase with multiplicity, while at forward rapidity, keeps a linear increase trend, except muon-based analysis
  -> p-Pb collisions:
  Quarkonia measured at forward rapidity, keeps increasing linearly for Pb-going side, but a saturation trend for p-going side;
  Open heavy-flavor production shows dependence of multiplicity estimator: at mid-rapidity → faster than linearly increase; at forward rapidity → linear increase
- It is of interest to investigate more about this details

Thank you