

# $J/\psi$ as a function of charged-particle multiplicity in pp collisions with ALICE at the LHC

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# **1. Physics Motivation**

### Heavy-flavor vs. multiplicity

Observable related to the underlying event accompanying heavy-flavour (HF) production in pp collisions, helps in understanding the interplay between the soft and hard processes

Connection to Multiple Partonic Interactions (MPIs)

Connection to final-state effects (color reconnection etc.)

 $J/\psi \langle p_T \rangle$  vs. multiplicity

 $\langle p_T \rangle$  of charged particles as a function of multiplicity has been measured

- > An increasing trend for pp collisions
- Saturation towards higher multiplicity
- for p–Pb and Pb–Pb collisions (role of collectivity?)



 $\langle p_T \rangle$  of J/ $\psi$  vs. multiplicity in pp collisions could help us to understand mechanisms like MPI, color-correlations, collectivity etc. for heavy flavors

#### ALI-PUB-92964

#### ALI-DER-55987

#### J. Adam et al. [ALICE Collaboration], JHEP1509, 148 (2015)

#### B. Abelev et al. [ALICE Collaboration], Phys. Lett. B 727 (2013) 371-380

## **2.** A Large Ion Collider Experiment (ALICE)

- \* The Inner Tracking System (ITS) is used for the measurement of charged particles using the number of SPD tracklets in  $|\eta| < 1$
- Forward muon spectrometer is used to study quarkonium decaying to a muon pair in 2.5 < y < 4

ITS



#### Inner Tracking System

□ 6 layers (2 drifts, 2 strips, 2 pixels) **U** Vertex measurement The 2 innermost ITS layers called Silicon Pixel Detector (SPD) are used for multiplicity measurement

#### **Muon Spectrometer**

- **Consists of absorbers, dipole magnet,** tracking system and trigger system. Tracking system used to reconstruct muon tracks, consists of 5 stations of
- cathode pad chambers.
- □ Trigger system consists of two stations of RPC planes, used to trigger single muons and dimuons

### 5. J/ $\psi$ yield as a function of charged-particle multiplicity

- Faster than linear increase with multiplicity for  $J/\psi$ measured at mid-rapidity in pp at  $\sqrt{s} = 13$  TeV
  - (i.e. w/o rapidity gap between signal and multiplicity estimator)
- Introducing a rapidity gap: significantly reduces deviation from linear multiplicity scaling (almost linear increase) Multiplicity

$$-\frac{J/\psi \rightarrow e^+e^-}{-1 \quad 0 \quad 1 \quad 2.5 \quad 4}$$

- Physics scenario: such as saturation would influence differently HF production at mid or forward rapidity (Y. Q. Ma et al., Phys.Rev. D98, 074025(2018))
- A linear increase of relative Y(1S) and Y(2S) yield as a function of relative charged-particle multiplicity is observed



### 6. J/ $\psi$ ( $p_{T}$ ) as a function of charged-particle multiplicity

### **3. Multiplicity determination**

The charged-particle measurement is based on a SPD tracklets analysis ( $|\eta| < 1$ ). The variation of the SPD efficiency with the z position of the primary vertex ( $z_{vertex}$ ) is corrected using a data-driven method.

$$\Delta N = \frac{\langle N_{\text{trk}} \rangle (z_{\text{v}}^0) - \langle N_{\text{trk}} \rangle (z_{\text{v}})}{\langle N_{\text{trk}} \rangle (z_{\text{v}})} \qquad N_{trk}^{corr}(z) = N_{tr}(z) + \Delta N_{rand}$$

- Here,  $\Delta N_{rand}$  follows a Poissonian distribution centered around  $\Delta N$
- $\succ$   $Z_v^0$  corresponds to  $z_{vertex}$  position at which  $\langle N_{trk} \rangle$  is maximum



- $\succ$  The correction equalizes the number of tracklets as a function of  $z_{vertex}$  to the value obtained at chosen reference  $z_0$ .
- > The charged-particle density in the *i*<sup>th</sup> multiplicity interval is calculated as:



- > The measurement is performed for inelastic pp collisions with at least one charged particle in  $|\eta| < 1$  (INEL >0)

\* The extraction of the average transverse momentum of  $J/\psi$  mesons is done via a fit to the dimuon mean transverse momentum as a function of the invariant mass,  $\langle p_{T}^{\mu+\mu-} \rangle$ (m<sub>μ+μ</sub>\_).

### $\langle p_T \rangle$ of J/ $\psi$ is increasing with multiplicity and saturates towards higher multiplicity : Presence of collectivity?

(B. Abelev et al. [ALICE Collaboration], Phys. Lett. B 727 (2013) 371-380)

- \* Possible explanation in the context of MPI: the high multiplicity events are produced by MPIs and incoherent superposition of such interactions would lead to constant  $\langle p_T \rangle$  at high multiplicity (B. Abelev et al. [ALICE Collaboration], Phys. Lett. B 727 (2013) 371-380)
- $\langle p_T \rangle$  of J/ $\psi$  vs. multiplicity trend is independent of Vs
- Comparison of pp with p–Pb collisions:
  - $\succ$  For p–Pb: becomes flat beyond relative  $N_{ch} \sim 1.0 \rightarrow$  Cold Nuclear Matter effect, collectivity?
  - For pp: The trend is similar to p–Pb up to  $N_{ch} \sim 1.0$  and beyond, p–Pb saturates faster than pp
  - > A similar behavior is also observed for light charged particles



 $\succ$  Here, The correlation function f is calculated using MC simulations

### 4. Signal extraction versus multiplicity for $J/\psi \rightarrow \mu^+ + \mu^-$

The J/ $\psi$  are extracted by fitting the opposite sign dimuon invariant mass spectra in different multiplicity intervals.



**Sources of systematic uncertainty** 

- Choice of different signal/background
  - shapes
- Fit ranges
- Different sets of tail parameters

Example of  $J/\psi$  signal extraction in low and high multiplicity intervals.

(B. Abelev et al. [ALICE Collaboration], Phys. Lett. B 727 (2013) 371-380)

### 7. Summary

- Forward rapidity quarkonium yields vs. mid rapidity charged-particle multiplicity are showing almost a linear increase, irrespective of collision energy
- 4 J/ $\psi$  production at forward rapidity is approximately linear as a function of mid-rapidity multiplicity, while a faster than linear increase is observed for  $J/\psi$  measured at midrapidity
- Multiplicity dependent quarkonia production is independent of quark content i.e same for  $J/\psi$  and Y
- $\Rightarrow$  The J/ $\psi$  ( $p_T$ ) vs. multiplicity shows a saturation for increasing multiplicities which may be a sign for phenomena like MPI, color reconnection, collectivity