Excited quarkonia states in pp and p-Pb collisions

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Physics motivation

- Quarkonium production:
  
  **pp collisions:**
  
  - Reference process to understand the pA and A-A collisions
  - Useful to investigate production mechanisms (CEM, NRQCD ...)

  **p-Pb collisions:**
  
  Cold nuclear matter (CNM) effects:
  
  - Initial state effects: Gluon shadowing, gluon saturation
  - Coherent parton energy loss
  - Final state effects: comovers absorption..
Acceptance of J/ψ measurements by the four LHC experiments as a function of $p_T$ and rapidity.

For the mid rapidity detectors (as the ALICE central barrel, ATLAS and CMS) only one half of the acceptance is shown.

For $\Upsilon$ family, all experiments have acceptance down to zero $p_T$. 
$\psi(2S)$ production in pp collisions

- FONLL for $\psi(2S)$ from B decay

- No dependence of $\psi(2S)/J/\psi$ ratio on $\sqrt{s}$
- No change in shape of the $\psi(2S)/J/\psi$ as a function of $p_T$
**Multiplicty dependence of quarkonia in pp collisions**

- **Underlying physics:**
  - Multi-parton interaction (MPI)
  - Interplay between hard and soft QCD process

- **Linear increase of quarkonia yield with multiplicity at ALICE (forward-y)**
- **No strong energy and quarkonia states dependence observed at ALICE**
- **ϒ(2S)/ϒ(1S) has no multiplicity dependence at ALICE (forward-y) while decreasing trend at CMS (mid-y)**
p-Pb

cold nuclear matter effects:
shadowing/CGC, energy loss...
• $\psi(2S)$ suppression is stronger than the $J/\psi$ one, especially at backward rapidity

• No strong $y$ and $p_T$ dependence of $\psi(2S) R_{pPb}$

• Theoretical predictions based on shadowing and energy loss can not describe the stronger $\psi(2S)$ suppression

• Models including final-state effects reproduce $\psi(2S)$ behaviour at both forward and backward rapidity
\( \Upsilon(nS) \mid R_{pPb} \mid \) vs \( y_{\text{cms}} \) at \( \sqrt{s_{NN}} = 8.16 \) TeV

- \( \Upsilon(1S) \) and \( \Upsilon(2S) \mid R_{pPb} \mid \) agree within 0.8\( \sigma \) both at forward and backward rapidity

- The shadowing contribution and most of the theory uncertainties cancel out in the ratio

- The shape of the theoretical calculation is, hence, mainly driven by the interactions with the comoving particles, which affect mostly the \( \Upsilon(2S) \) and \( \Upsilon(3S) \) in the backward rapidity region

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Conclusions

→ CGC + NRQCD describes the low $p_T$ region of charmonium cross section


→ The quarkonium production increases linearly as a function of multiplicity in different rapidity region

→ $\psi(2S)$ shows a stronger suppression than $J/\psi$, final-state effects needed to explain the $\psi(2S)$ behaviour

→ Similar $\Upsilon(1S)$ and $\Upsilon(2S)$ suppression at backward and forward-$y$

→ Model based on shadowing and comover interaction describe the $\Upsilon(2S)$ result
Thank you
$R_i^A(x, Q^2) = \frac{f_i^A(x, Q^2)}{f_i(x, Q^2)}$, 

$R_i^A$
The $\psi(2S)$ suppression is stronger than $J/\psi$ one, especially at backward rapidity.

At forward rapidity the $Q_{pPb}$ of $\psi(2S)$ follows the same trend as $J/\psi$ while at backward rapidity trend is different.

At backward rapidity, final-state effects needed to explain the $\psi(2S)$ behaviour. Some discrepancies between the data and the model in the peripheral region.
Quarkonia in ALICE are measured in two rapidity ranges:

- **Central barrel:**
  \( J/\psi \rightarrow e^+e^- \) \(|y| < 0.9\)
  Electrons tracked using ITS and TPC
  Particle identification: TPC (+TOF)

- **Forward muon arm:**
  \( J/\psi \rightarrow \mu^+\mu^- \) \((2.5 < y < 4)\)
  Muons identified and tracked in the muon spectrometer

Acceptance coverage in both \(y\) regions is down to zero \(p_T\)
$\psi(2S)$ and $\Upsilon(nS)$ in pp collisions at $\sqrt{s} = 13$ TeV