ψ(2S) production as a function of charged-particle multiplicity in pp and p—Pb collisions with ALICE at the LHC

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J/ψ yields, measured at forward rapidity, increase with increasing charged-particle multiplicity, measured at mid rapidity, in pp and p—Pb collisions at the LHC. A weaker than linear increase is observed at forward rapidity in p—Pb.

Possible scenarios

- Multiparton interaction?
  Multiple parton interactions (MPI) affect particle production. (1)

- Initial state effects?
  Initial-state effects, such as the modification of PDFs in nuclei, influence particle production. (2)

- Final state effects?
  For example, in the comovers model, charmonia can be dissociated by interactions with the final state comoving particles. (3)

Self-normalized yields of $\psi(2S)$ and $\psi(2S)$-over-$J/\psi$ vs. multiplicity in pp collisions

- Self-normalized $\psi(2S)$ yields increase with self-normalized charged-particle multiplicity.

- PYTHIA 8\(^{1}\) calculations (including MPI) describe the results. No significant influence of the color-reconnection scenario observed in the simulations.

- At large multiplicity, PYTHIA 8 starts to deviate from linear behaviour vs. multiplicity, which is not seen in data.

- Self-normalized yields of $\psi(2S)$-over-$J/\psi$ : similar behaviour of $J/\psi$ and $\psi(2S)$ self-normalized yields with charged-particle multiplicity.

- Flat ratio described by PYTHIA 8 calculations.

- In the comover model\(^{2}\), charmonia can be dissociated by interacting with the comoving final-state particles. A stronger effect is expected for $\psi(2S)$ due to its lower binding energy. The comover calculation is compatible with data within uncertainties.

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Self-normalized $\psi(2S)$ yields vs multiplicity in $p$–$Pb$ collisions

- Self-normalized $\psi(2S)$ yields increase with self-normalized charged-particle multiplicity in both rapidity ranges for $p$–$Pb$ collisions.

- Percolation$^{(1)}$ + comover$^{(2)}$ + EPS09$^{(3)}$ calculation is compatible with both measurements
  - In the percolation model, the strings, that are formed in each parton interaction, have non-negligible transverse size and can interact.

- EPS09 nPDF uncertainties are large at forward rapidity(low-x).

References:

Self-normalized yields of $\psi(2S)$-over-$J/\psi$ yields vs multiplicity in $p$–$Pb$

- $\psi(2S)$-over-$J/\psi$ self-normalized yields: similar behaviour of $J/\psi$ and $\psi(2S)$ self-normalized yields with charged-particle multiplicity.

- Similar trend of the ratios vs. charged-particle multiplicity at forward and backward rapidity for $p$–$Pb$ collisions.

- Ratios are consistent, within their large experimental uncertainties, with the comover calculation, which takes into account final state effects. A small influence of the rapidity interval is expected in the comover model for the ratio in $p$–$Pb$ collisions.
Normalized $\psi(2S)$ yields increase as a function of charged-particle multiplicity in pp and p–Pb collisions. Similar increasing behaviour with charged-particle multiplicity is found for J/$\psi$.

- PYTHIA 8 simulations, which consider MPIs, describe the pp results.

- Percolation + comover + EPS09 calculation, which considers final-state effects, reproduces $\psi(2S)$ yields in p–Pb collisions in both rapidity regions. However, the theoretical uncertainties at forward rapidity are large.

- Comover model estimates are consistent with the $\psi(2S)$-over-J/$\psi$ ratios in p–Pb collisions within the large experimental uncertainties.

- In pp collisions, the comovers model is compatible with data within theoretical and experimental uncertainties.

- More precise measurements and predictions are needed to disentangle among the different effects at play.

Thank you!
p—Pb at $\sqrt{s_{\text{NN}}} = 8.16$ TeV
(p-going direction)
$2.03 < y_{\text{cms}} < 3.53$
$X_{\text{pb}} \sim 10^{-2}$

p—Pb at $\sqrt{s_{\text{NN}}} = 8.16$ TeV
(Pb-going direction)
$-4.46 < y_{\text{cms}} < -2.96$
$X_{\text{pb}} \sim 10^{-5}$

pp at $\sqrt{s} = 13$ TeV
$2.5 < y_{\text{cms}} < 4.0$