Study of Quarkonia Production in proton+proton collisions at the LHC and the Role of Multiple Partonic Interaction

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Introduction and motivation

The event multiplicity yield of J/ψ is of great interest to the scientific community. ALICE has found faster than linear increase of J/ψ w.r.t charged-particle multiplicity [1].

❖ Possible explanations

- Substantial contribution from Multi-Parton Interactions (MPI) on harder scale
- Due to spatial distribution of partons in the transverse plane, there is a possibility of role of collisional geometry
- Contributions from higher folk states
- Final state effects like color reconnection (CR), string percolation e.t.c.

❖ Open questions

- Is the behavior solely due to MPI at the partonic level or has some contribution from CR at the final state ?
- What will be the energy dependent contribution from MPI and CR?
- What will be the behavior for higher states of charmonimum ?

To answer these questions, we have tried to study the multiplicity dependence of charmonia production using PYTHIA8, with MPI and CR effects.

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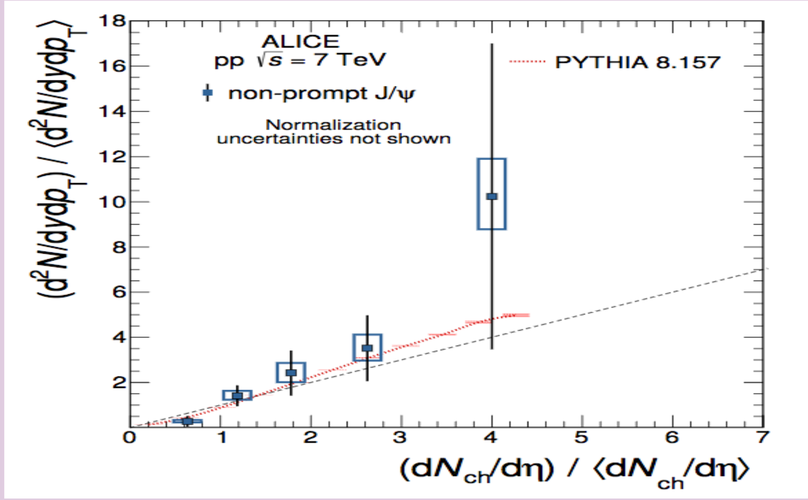

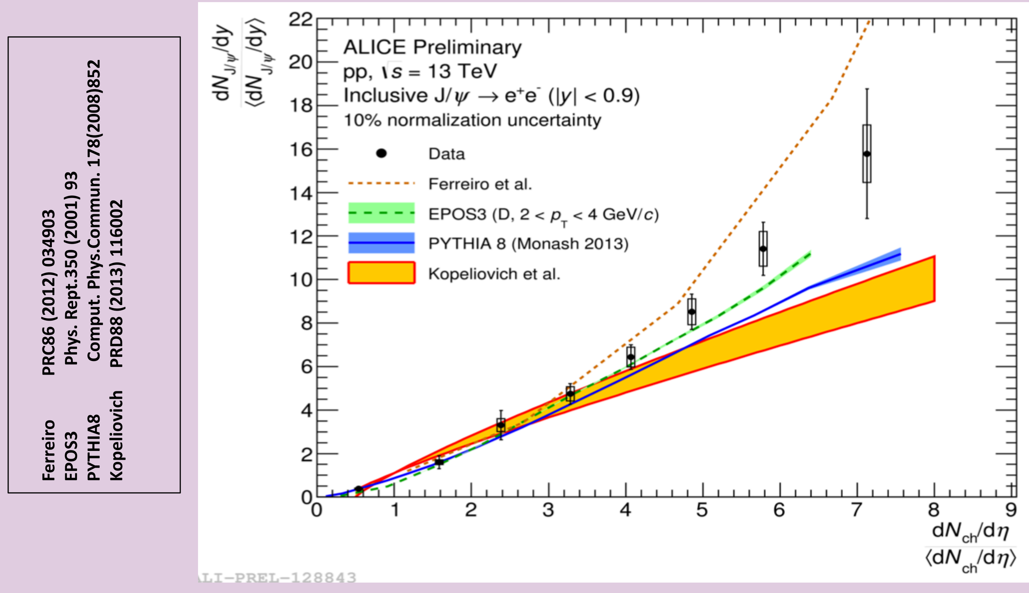

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PYTHIA8 Settings

4C-Tuned PYTHIA8 is used for the analysis, which well explains the charged-particle multiplicity in pp@7 TeV [2].

❖ General settings

- ISR and FSR is ON for the whole analysis
- MPI with CR / MPI with no-CR are used

❖ Specific settings

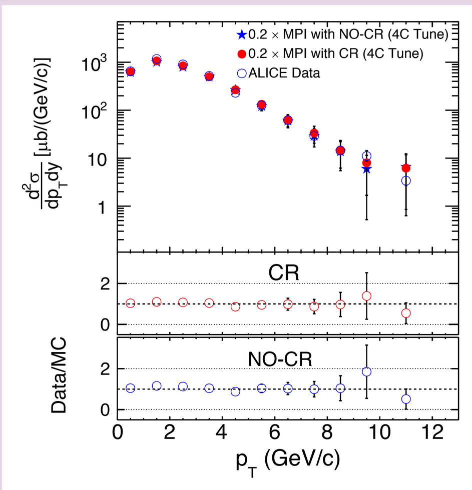
- Multiparton-Interactions:bProfile=3, to allow all incoming partons to undergo hard and semi-hard interactions
- ColourReconnection:mode(0), MPI-based scheme of CR
- HardQCD:all=on, inelastic, non-diffractive component of the total cross section for all hard QCD processes.

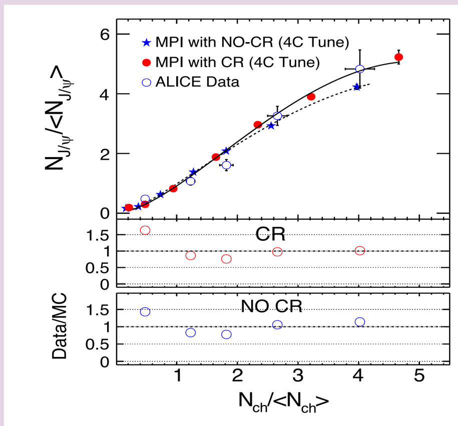
Formula

The relative J/ψ yield is defined as: $\frac{Y_{J/\psi}}{< Y_{J/\psi} >} = \frac{N^i_{J/\psi}}{N^{total}_{J/\psi}} \frac{N_{evt}}{N^i_{evt}}$

Here, i stands for i^{th} multiplicity bin.

- These setting well reproduce the ALICE results
- Keeping the same setting, we have extended the study for all other LHC energies



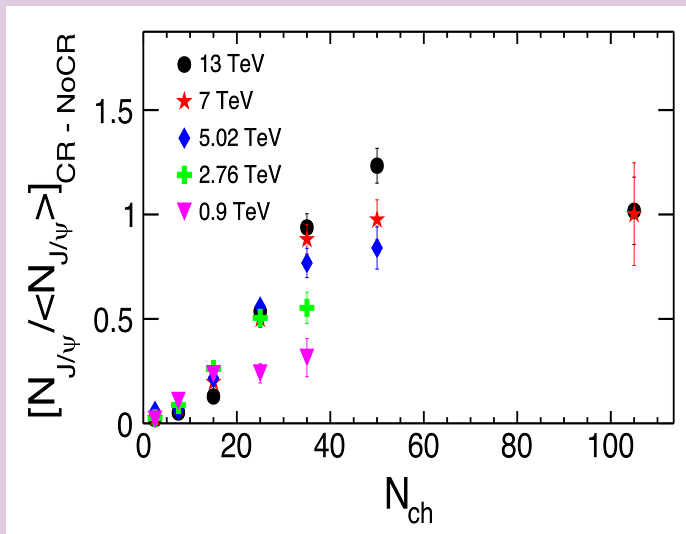


Effect of CR on J/ψ production

CR has more contributions to J/ψ production towards higher multiplicities and higher center of mass energies.

Expected reasons

- ✓ High density of color partons
- ✓ Substantial overlap of color strings in position and momentum space
- ✓ Leads to higher probability of reconnection
- ✓ Partons from two MPIs may connect, hence probability of combination of charm and anti-charm quark increasees

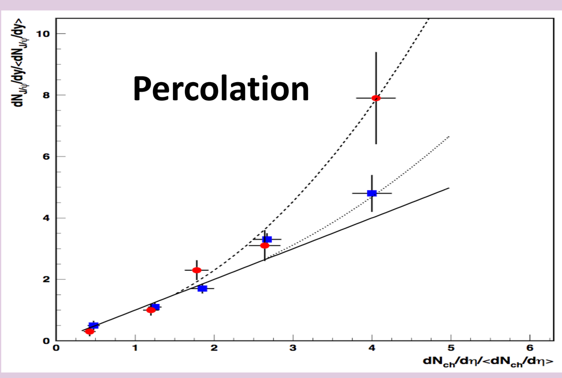


- The difference between CR and no-CR is very less: reveals that final state effects have little contribution to J/ψ production
- J/ψ production has maximum contribution from the partonic level: may be from the hard MPIs

Multiplicity dependence study at LHC energies

- The J/ψ relative yield increases linearly with charged-particle multiplicity
- String percolation theory has been successful in describing the behavior

$$\frac{n_{J/\psi}}{< n_{J/\psi} >} = (1 - < \rho >)\left(\frac{\frac{dN}{d\eta}}{< \frac{dN}{d\eta} >}\right) + < \rho > \left(\frac{\frac{dN}{d\eta}}{< \frac{dN}{d\eta} >}\right)^2$$



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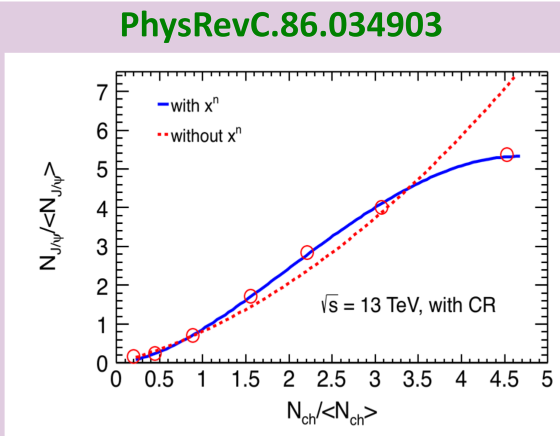
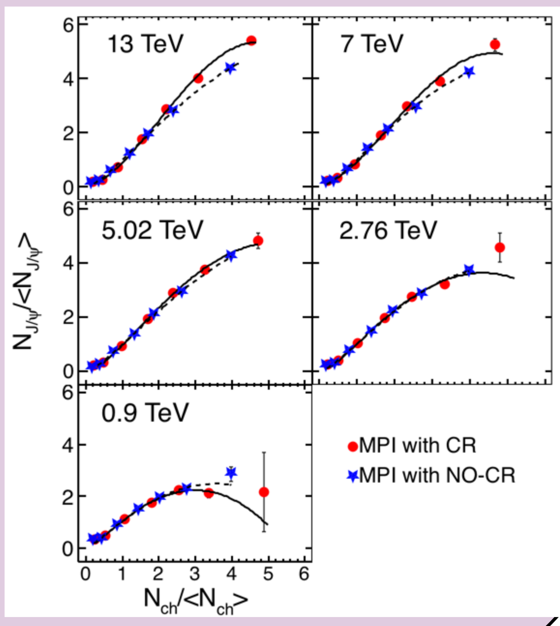
- The saturation effect of J/ψ relative yield towards the higher multiplicities is taken care of by the addition of an extra term:

$$\frac{Y_{J/\psi}}{< Y_{J/\psi} >} = A[Bx + Cx^2 + Dx^n]$$

Here, x = Relative charged-particle multiplicity, $N_{ch}/<N_{ch}>$



- The experimental data of other energies need to be understood for the validity of percolation/tuning PYTHIA8 on describing the J/ψ production
- The CR effect on J/ψ production is more prominent at high multiplicity and high center-of-mass energy
- At the LHC energies due to higher number of colored partons from MPIs, there is a substantial degree of overlap of many colored strings in the position and momentum phase space. Therefore, there is higher probability of color reconnection

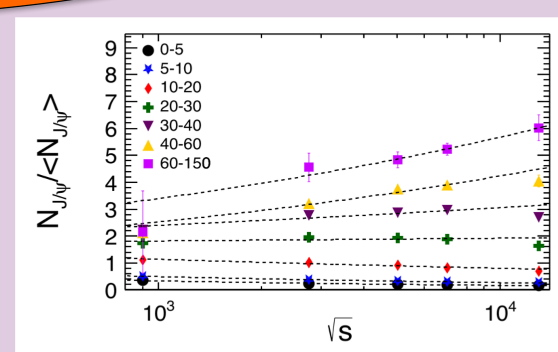


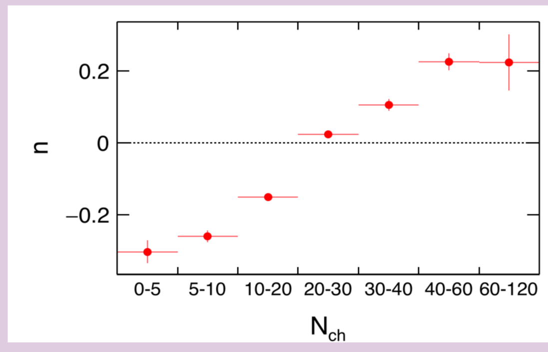
Energy dependence of J/ψ production

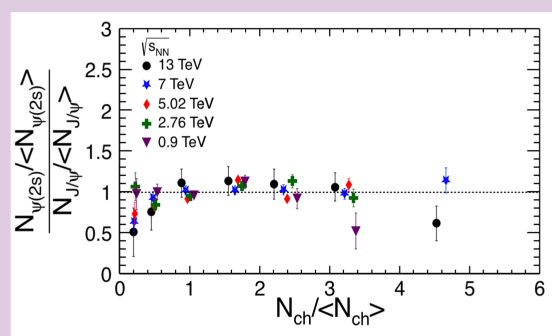
- The hard-MPIs increase with center-of-mass energy and is more significant for higher multiplicities
- To get a qualitative idea, it is fitted with a phenomenological function $f(x) = A\,x^n$. Here "n" indicates the rate of increase of relative J/ψ yield with √s
- ✓ n is negative for $N_{ch} < 20$ and is positive for $N_{ch} > 20$
- $N_{ch} \approx 20$ is the threshold number of charged particle multiplicity in the final state for substantial MPI effects on the charmonium production
- Ψ(2S) as a function multiplicity behaves similarly as J/ψ as does

$$\frac{Y_{\psi(2S)}/ < Y_{\psi(2S)} >}{Y_{J/\psi}/ < Y_{J/\psi} >} = \frac{N^{total}_{\psi}}{N^{total}_{J/\psi}} \frac{N^i_{J/\psi}}{N^i_{\psi}}$$

- The ψ(2S) and J/ψ are produced in equal proportions in each multiplicity bin







Summary

- MPI drives the charmonia production at the initial stages with a little effect of CR in the final stages
- CR has more effect at higher multiplicity classes and higher center-of-mass energies
- $N_{ch} \approx 20$ is the threshold number, for the substantial effect of MPI on charmonium production
- ψ(2S) and J/ψ have similar productions as a function of particle multiplicity

References

[1] J. Adam et al. [ALICE Collaboration], JHEP 1509, 148(2015)
[2] R. Corke and T. Sjostrand, JHEP1103, 032 (2011).

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