Insight into J/ψ production with hard-QCD and R_{AA} like factor in high-multiplicity $p+p$ collisions at $\sqrt{s}$ =13 TeV

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Introduction

At very high centre-of-mass energies, the interacting objects in $p+p$ collisions are quarks and gluons (partons). In a single $p+p$ collision, a large number of the interaction of partons occurs in parallel which is called as multiparton interactions (MPIs). In the present day, the multiplicity dependent study in $p+p$ collisions has gathered considerable interest in the scientific community at the LHC. According to several theoretical calculations, high density of gluons created in the the hadronic collisions is the cause for high-multiplicity events. If the interaction involves large p_T transfer, the multiple interactions of partons lead to the production of heavy particles like J/ψ. Recently, in different experimental results, it is observed that the relative J/ψ yield increases nearly linearly with charged particle multiplicity in $p+p$ collisions. In the present work, we have studied the contribution of quarks and gluons to the J/ψ production using pQCD inspired model, PYTHIA8 tune 4C at $\sqrt{s}$ = 13 TeV by measuring relative J/ψ yield as a function of charged particle multiplicity for different hard-QCD processes. For the first time, we also attempt to measure the nuclear modification factor like observables (R_{pp} and R_{cp}) in $p+p$ collisions to understand the possibility of a system formation in high-multiplicity $p+p$ collisions.

In our work, we have simulated inelastic, non-diffractive component of the total cross section for all hard QCD processes (HardQCD:all=on), which includes the production of heavy quarks. Besides these processes, we have also simulated leading order processes for heavy quark production, namely, $gg \to c\bar{c}$, $q\bar{q} \to c\bar{c}$ (HardQCD:gg2ccbar=on and HardQCD:qqbar2ccbar=on), separately. Detailed explanation on the tuning of PYTHIA8 for our study can be found in our recent paper [2]. We have generated 1600 million events for hard QCD processes and 100 million events each for $gg \to c\bar{c}$, $q\bar{q} \to c\bar{c}$ processes for $p+p$ collisions at $\sqrt{s} = 13$ TeV using PYTHIA8.

Results

To check how well PYTHIA8 agrees with the experimental data, we have compared J/ψ production cross-section as a function of transverse momentum and rapidity for minimum-bias events in the same kinematic range as shown in our previous paper [1, 2] and found generated data to explain experimental data very well within uncertainties.

To explore the effect of gluon and quark contributions on quarkonia production in $p+p$ collisions, we have studied different QCD processes of J/ψ production in PYTHIA8 at $\sqrt{s}$ = 13 TeV for different multiplicity classes. It is observed in the left panel of Fig. 1 that all the processes are comparable up to $N_{ch} \sim$ 20-30 and for $N_{ch} \gtrsim 30$ the contributions from $gg \to c\bar{c}$, $q\bar{q} \to c\bar{c}$ become negligible compared to the inclusive hard processes. A similar observation is found in our previous work [1]. One of the main reasons behind this is the dominance of MPI at high multiplicity events. The right panel of Fig. 1 supports this statement, as we can see the relative J/ψ yield increases linearly with the number of MPIs.

To understand the possibility of formation of a system in high-multiplicity $p+p$ collisions at $\sqrt{s} = 13$ TeV, we define two variables [3]:

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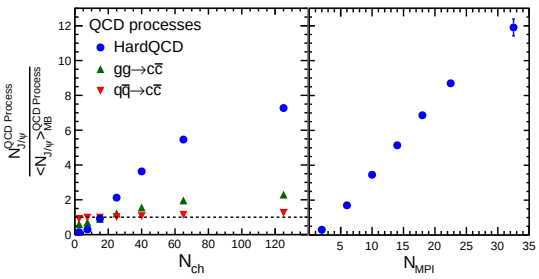

FIG. 1: (Color online) Relative yield of J/ψ as a function of charged particle multiplicity for different hard QCD processes (left) and as a function of number of multi-parton interactions (right), using PYTHA8. The vertical lines in data points are the statistical uncertainties.

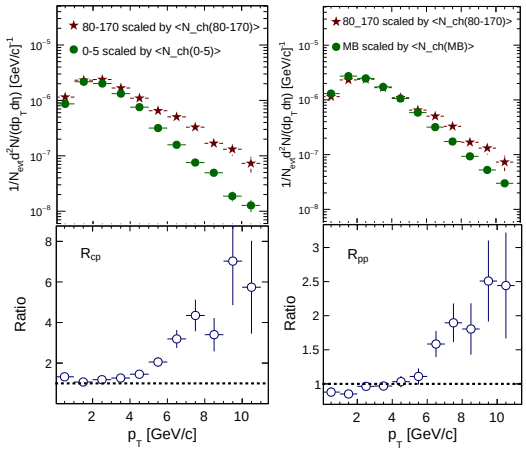

FIG. 2: (Color online) Upper panels shows the invariant yield of J/ψ for different multiplicity classes and are scaled by corresponding $< N_{ch} >$. Lower panel shows R_{cp} (left) and R_{pp} (right) as a function of p_T.

$$R_{pp} = \frac{< N_{ch} >_{MB}}{< N_{ch} >_{80-170}} \frac{(dN/N_{evt}dp_T)_{80-170}}{(dN/N_{evt}dp_T)_{MB}}, \quad (1)$$

$$R_{cp} = \frac{< N_{ch} >_{0-5}}{< N_{ch} >_{80-170}} \frac{(dN/N_{evt}dp_T)_{80-170}}{(dN/N_{evt}dp_T)_{0-5}}, \quad (2)$$

Here, $< N_{ch} >_{80-170}$, $< N_{ch} >_{0-5}$ and $< N_{ch} >_{MB}$ are the average charged particle multiplicity for highest (80-170), lowest (0-5) multiplicity classes and MB events, respectively. Since MPIs are proportional to N_{ch} we take $< N_{ch} >$ as the scaling factor to measure the R_{pp} and R_{cp} for $p+p$ collisions. For R_{pp}, 10% suppression is observed for $p_T < 2$ GeV/c; for mid-p_T region (2-6 GeV/c), its values are unity and for high p_T region ($p_T > 6$ GeV/c), its values increases rapidly. The R_{cp} is consistent with unity up to $p_T < 4$ GeV/c and increases at high-p_T similarly like R_{pp}.

Summary

In summary, following are the important observations in the current study:

- The J/ψ production for inclusive hard-QCD processes is higher compared to $gg \rightarrow c\bar{c}$ and $q\bar{q} \rightarrow c\bar{c}$ processes indicate that MPI plays an important role for events with $N_{ch} \gtrsim 20$.
- R_{pp} shows 10% suppression for $p_T < 2$ GeV/c. However, there is no suppression observed in R_{cp} measurements. This suppression in R_{pp} will be very interesting to measure in experiments as this can reveal whether the suppression is arising due to MPIs or heavy-ion like systems created in $p+p$ collisions.

Acknowledgments

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References

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