J/ψ production as a function of charged particle multiplicity in proton + proton collisions at LHC energies

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Introduction

In high energy proton-proton collisions the total event multiplicity can have a substantial contribution from Multi-Parton Interactions (MPI) [1, 2], which is an Underlying Event observable. The sum of all processes that build up the final hadronic state in a collision is referred as the Underlying Event (UE). The Underlying Event includes fragmentation of beam remnant, multi-partonic interactions, and initial and final state radiation (ISR/FSR) associated with each interactions. In MPI, several interactions at the partonic level occurs in a single $p+p$ collision, that leads to a strong dependence of particle production on total event multiplicity. MPI are commonly used to describe the soft underlying events such as the production of light quarks and gluons. But it is observed that it can also contribute on the hard and semi-hard scale such as the production of particles containing heavy quarks like J/ψ, open heavy flavors etc. This contribution become more and more relevant with increasing energy [3].

Recently, ALICE experiment has observed an approximately linear increase of relative J/ψ production yields, $\frac{dN_{J/\psi}/dy}{<N_{J/\psi}/dy>}$ as a function of relative charged particle multiplicity density, $\frac{dN_{ch}/dy}{<dN_{ch}/dy>}$ [4]. The QCD inspired model PYTHIA6 could not describe the results. In the present work, we have studied the effect of MPI with and without Color Reconnection(CR) on J/ψ production as a function of charged particle multiplicity using PYTHIA8 in different center of mass energies. This study will help to provide more insight in to the processes involved in an event in hadronic collisions.

Method

We have generated 100 million events for $p+p$ collisions at $\sqrt{s}$ = 0.9, 2.76, 5.02, 7 and 13 TeV using the option with CR and without CR available in PYTHIA8.2. J/ψ are reconstructed via di-muon channel ($J/\psi \rightarrow \mu^+ + \mu^-$). The relative charged particle multiplicity yield, which is defined as $N_{ch}/ < N_{ch} >$, is measured in mid rapidity ($-1.0 < y < 1.0$), where N_{ch} is the mean of the charged particle multiplicity in a particular bin and $< N_{ch} >$ is the mean of the charged particle multiplicity in minimum bias events. The relative J/ψ yield is measured in forward rapidity ($2.5 < y < 4.0$) using the following relation:

$$\frac{Y_{J/\psi}}{< Y_{J/\psi} >} = \frac{N^i_{J/\psi}}{N^{total}_{J/\psi}} \frac{N_{evt}}{N^i_{evt}}, \qquad (1)$$

where, $N^i_{J/\psi}$ and N^i_{evt} are the number of J/ψ and number of events in i^{th} multiplicity bin respectively, and $N^{total}_{J/\psi}$ and N_{evt} are the total number of J/ψ produced and total number of minimum bias events respectively.

As the frequency of lower multiplicity events is higher, the bin width is taken smaller at lower multiplicities and then subsequently

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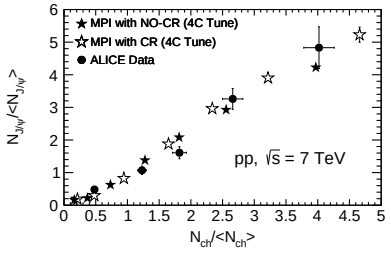

FIG. 1: Comparison of ALICE experiment data [4] and PYTHIA8 results of relative J/ψ yield as a function of the relative charge particle multiplicity densities at forward rapidities ($J/\psi \to \mu^+ + \mu^-$).

higher to maximize the statistics at high multiplicity bin.

Results

Fgure 1 shows the relative J/ψ yield as a function of charged particle multiplicity in $p+p$ collisions at $\sqrt{s} = 7$ TeV for existing ALICE data [4] with our measurements. It is observed that 4C tuned PYTHIA8 with CR and without CR qualitatively reproduce the ALICE data, however quantitatively PYTHIA8 with CR reproducing the result better as compared to PYTHIA8 without CR.

Figure 2 shows the relative J/ψ yield as a function of charged particle multiplicity in $p + p$ collisions at $\sqrt{s}$ = 0.9, 2.76, 5.02, 7 and 13 TeV. Different symbols show the result from MPI with CR and without CR effect. It is observed that for both the cases, relative J/ψ yield increases with increasing multiplicity and CR effect is more prominent at higher center of mass energies, in particular at $\sqrt{s}$ = 7 and 13 TeV. The solid lines and dashed lines show the fitting with percolation inspired function to get the quantitative effect of CR with respect to No-CR effects.

Summary

Relative J/ψ yield has been measured at forward rapidity ($2.5 < y < 4.0$) via di-muon channel using the PYTHIA8 event generator. The results are produced with CR and without CR effect. PYTHIA8 describes the ALICE data at $p+p$ 7 TeV very well. It is found that CR effect dominates at higher center of mass energies as well as at high multiplicity events. We performed a detail quantitative study of CR effects with respect to No-CR, which will be presented.

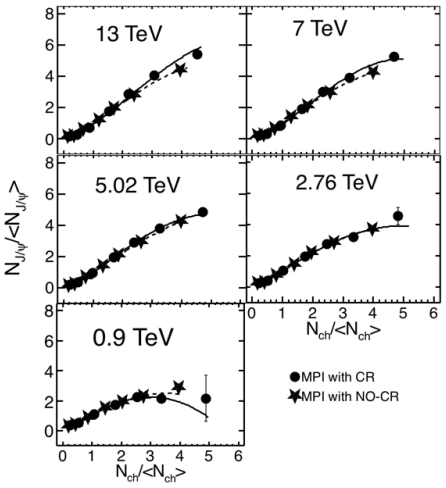

FIG. 2: Relative J/ψ yield as a function of the relative charge particle multiplicity densities at forward rapidities in $p + p$ collisions at $\sqrt{s}$ = 0.9, 2.76, 5.02, 7 and 13 TeV using PYTHIA8 with CR and without CR effects. The solid lines and dashed lines show the fitting with percolation inspired function.

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