J/Ψ-hadron correlation at LHC energy to study the production mechanism of J/Ψ

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Introduction

In high-energy collisions, production of heavy qaurkonium is an important tool to study the interplay between perturbative and non-perturbative QCD dynamics. In nucleus-nucleus collisions , production of heavy quarks from the hard scattering processes follow the perturbative QCD and the subsequent formation of bound states follows the non-perturbative process. Production cross section can therefore be factorized into two factors. The first factor is the production of heavy quark c and an antiquark $\bar{c}$ from hard collisions of incident particles. In the hard scattering process, participants can be gluon from one nucleon interacting with the gluon from another nucleon or a quark from one nucleon interacting an antiquark from other nucleon via the formation of an intermediate virtual gluon. Contribution of gluon fusion is believed to be higher compared to the quark-antiquark annihilation process. Production of unbound $c\bar{c}$ pair from the hard scattering process is concerned with the short distance part of the production process in perturbative QCD. The second part is the fromation of bound state of $c\bar{c}$ pair which can be specified by phenomenological model of J/Ψ formation[1]. Heavy quarkonia are considered to be suitable probe to study the medium formed in heavy ion collisions, because of their early creation at the time of collision [2]. Suppression of J/Ψ has been predicted to be the signature of of the formation of teh deconfined state of quarks and gluons commonly known as Quark Gluon Plasma (QGP) in high energy heavy ion collisions[5]. It is therefore important to understand the formation mechanism of J/Ψ at an elementary level. Two models are commonly used describe the J/Ψ production data i.e., Color-Singlet model (CSM) and Color-octet model (COM). Analysis of direct J/Ψ and Ψ(2s) has been done for the first time by the CDF collaboration at $\sqrt{s}$= 1.8 TeV. Production cross sections of J/Ψ at $\sqrt{s}$=1.8 is higher than those predicted by the Color-singlet model and p_T spectrum also could not be explained by the CSM. To solve this puzzle , another model, i.e. Color-Octet model has been proposed. This model is quite successful in describing the quarkonium transverse momentum spectra. Motivation of the present work is to study the sensitivity of the J/Ψ-hadron correlation to distinguish between the two production mechanisims.

J/Ψ Event Generation

J/Ψ are produced using PYTHIA-8.201 event generator in pp collisions at 8 TeV CM energy. J/Ψ are produced using Color-singlet and Color-Octet mechanisims separately. We use Onia processes in PYTHIA-8.201. We have switched on different flags for producing J/Ψs in singlet or in octet state. "Charmonium: gg2ccbar(3S1)[3S1(1)]g = on,on" –The flag to produce J/Ψ in color-singlet state. "Charmonium: gg2ccbar(3S1)[3S1(8)]g = on,on" – The flag to produce J/Ψ in color-octet state.

Results and Discussion

In this work, we have studied the azimuthal correlations between J/Ψ used as trigger particle and charged hadrons as associated particles. Fig.1 shows the ΔΦ correlation at different Pt bins of the trigger (J/Ψ) as produced

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using the CSM, COM and both models taken together. Form this figure , It is seen that the near side correlation is clearly visible if the trigger and the associate particles are in same the pseudorapidity range. The near side correlation peak is seen to disappear if the trigger and the associated particles are in different pseudorapidity regions as is seen in Fig.2.

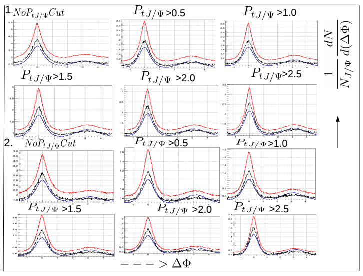

FIG. 1: $\Delta\phi$ correlations functions for (1) both the J/Ψ and the associated charged hadrons are at midrapidity (2) Both the J/Ψ and the charged hadrons are at forward rapidity. (*Red line for Color-octet, Blue line for color-singlet and Black line for all (both CSM and COM) processes for charmonium production*)

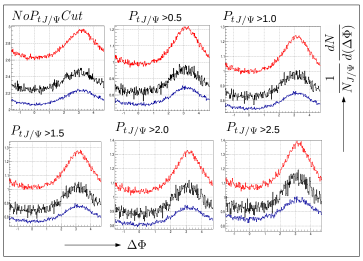

FIG. 2: ΔΦ correlation with J/Ψ at forward rapidity and Charged hadrons are midrapidity

We have fitted the correlation functions whenever possible with double gaussian functions and the yields of the near side peaks are studied with respect to p_T of the trigger particle as shown in Fig.3. We observe an enhancement of the near-side yield of the J/Ψ hadron azimuthal correlation for color-octet model as compared to the yields from the color-singlet model.

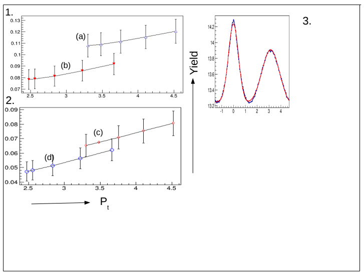

FIG. 3: Fitting of the correlation function (marked as 3) and the variation of the near side yield vs p_T of J/Ψ for two cases. (1) Both J/Ψ and Charged hadrons at midrapidity and (2) both J/Ψ and Charged hadrons are also forward rapidity.

This can be explained by the fact that in case of color-octet states, the gluon radiation may evolve into a shower and give extra hadronic activity around the direction of J/Ψ. But ifthe J/Ψ is produced in the color-singlet state then the produced $c\bar{c}$ pair does not radiate gluons. This difference in near side yields of CSM and COM can be utilised to distinguish between two production mechanisms from data. The procedure can however be applied only for the cases when both the trigger and the associated particles are at similar rapidity regions. For the case of trigger at forward rapidity and the associated particles at midrapidity , the near side peak almost vanishes , thereby making it difficult to apply the method for J/Ψ (Muon detector used fo J/ψ is at forward rapidity) and charged hadrons (TPC at midrapidity) in ALICE.

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