Parton shadowing and J/ψ suppression in nuclear collisions at SPS energy regime

Partha Pratim Bhaduri[1], *A. K. Chaudhuri[1],† and *Subhasis Chattopadhyay[1]‡
[1] Variable Energy Cyclotron Centre, 1/AF Bidhan Nagar, Kolkata-700 064, INDIA

Introduction

J/ψ suppression has long been recognized as an important signature for the occurrence of color deconfinement in nuclear collisions [1]. However subsequent experimental investigations have revealed a considerable suppression of the charmonium production already present in proton-nucleus ($p + A$) collisions. In these reactions, the produced $c\bar{c}$ pair may interact with the cold nuclear medium of the target nucleus, hindering the formation of a bound state. To quantify the nuclear effects, data for different target nucleus are conventionally analyzed in the framework of the Glauber model, and the suppression is expressed in terms of an effective "absorption" cross-section $\sigma^{eff}_{\mathrm{J}/\psi}$. With this approach, both NA50 and NA60 collaborations at SPS, observed significant anomalous suppression of J/ψ yield, at 158 A GeV in Pb+Pb [2] and In+In [3] collisions respectively. However in both the measurements, the corresponding value of $\sigma^{eff}_{\mathrm{J}/\psi}$ was extracted from the data collected in $p+A$ collisions at 400 GeV. With the new measurements of charmonium in $p + A$ collisions at 158 GeV [4], where $\sigma^{eff}_{\mathrm{J}/\psi}$ turned out to be almost twice as large as that at 400 GeV, the NA60 experiment reported the relative charmonium yield in In+In collisions to be compatible within errors with absorption in cold nuclear matter; an anomalous suppression of about 25 - 30 % still remains visible in the most central Pb+Pb collisions. In the present article, we plan to analyze the latest SPS data on J/ψ suppression in heavy-ion collisions using phemenologically sucessful QVZ model, which treats the conventional nuclear suppression in an unconventional manner.

Theoretical framework

Details of the QVZ model can be found in [5, 6].In this model, J/ψ production in hadronic collisions, is assumed to be a factorisable two step process: (i) formation of $c\bar{c}$ pair, which is well accounted by perturbative QCD and (ii) formation of J/ψ meson from the $c\bar{c}$ pair, which is non-perturbative in nature, can be conveniently parametrized.Two functional forms namely the Gaussian form ($F^{(\mathrm{G})}(q^2)$) and power law form ($F^{(\mathrm{P})}(q^2)$) respectively bearing the essential features of the Color-Singlet and Color-Octet models have been found to describe the J/ψ production cross section data in $p + A$ collisions reasonably well. Alike $p + A$ collisions, in nuclear collisions also charmonium production gets affected by the prevailing cold nuclear matter. At the initial stage, nuclear modifications of the parton densities inside both the target and projectile nuclei affect the perturbative $c\bar{c}$ pair production cross section. Depending on the collision geometry, either the halo or the core of the nuclei will be mainly involved, and the resulting shadowing effects will be more important in the core than in the periphery. We assume the shadowing to be proportional to local nuclear density [7], approximated by Woods-Saxon (WS) density distribution. Once produced, the nascent $c\bar{c}$ pairs interact with nuclear medium and gain relative square momentum at the rate of ε^2 per unit path length inside the nuclear matter. As a result, some of the $c\bar{c}$ pairs can gain enough momentum to cross the threshold to become open charm mesons, leading to the reduction in J/ψ yield compared to the nucleon-nucleon collisions. For both parameterizations of tran-

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*Electronic address: `partha.bhaduri@vecc.gov.in`
†Electronic address: `akc@vecc.gov.in`
‡Electronic address: `sub@vecc.gov.in`

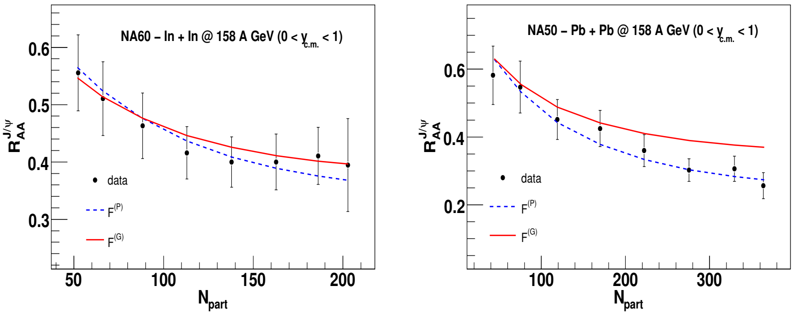

FIG. 1: Centrality dependence of J/ψ production in In+In (top) and Pb+Pb (bottom) collisions measured at same energy (E_b = 158 A GeV) and kinematic domain ($0 < y_{c.m.} < 1$). Data are represented in terms of nuclear modification factor R_{AA} plotted as a function of N_{part} estimating the collision centrality. Error bars include both statistical and systematic uncertainties. Two different parametric forms of the transition function are used for generating the theoretical curves.

sition probability, the corresponding values of ε^2, extracted from the analysis of $p + A$ collision data [6], exhibited non-trivial beam energy dependence. Lower be the beam energy, larger is the value of ε^2. In the present work we have used the previously found ε^2 values.

Analysis of SPS data

Let us now apply the model to analyze heavy-ion data on J/ψ suppression at SPS. Fig.1 shows the variation of $R_{AA}^{J/\psi}$ as a function of N_{part} for In+In and Pb+Pb collisions as calculated from our model in comparison with the available latest data [8]. The In+In data points can be reasonably described within errors by both Gaussian ($F^{(G)}(q^2)$) as well as power law ($F^{(P)}(q^2)$) forms of transition probability. In case of Pb+Pb collisions, $F^{(G)}(q^2)$ gives lower suppression than that observed in data. However $F^{(P)}(q^2)$ can fairly describe the data for all centralities and hence does not provide any additional room for any anomalous suppression mechanism to set in. For $F^{(G)}(q^2)$, the corresponding suppression is equivalent to that obtained in Glauber model with eikonal approximation[6]. The corresponding value of ϵ^2 was obtained by analyzing the recent NA60 data for $p+A$ collisions at 158 A GeV. Thus it can account for the In+In data but fails to generate enough suppression for Pb+Pb case. On the other hand due to threshold effect power law form generates a much stronger suppression for collisions involving heavy nuclei. As all the model parameters are constrained from the $p+p$ and $p+A$ data, in our present calculations, no free parameter is required to be tuned. The observed J/ψ suppression in Pb+Pb collisions can be fully accounted for by the heavy quark rescattering in the cold nuclear medium, without considering further suppression in the hot medium created in the later expansion stages.

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