It is shown that a QCD based nuclear absorption model, with few parameters fixed to reproduce experimental $J/\psi$ yield in 200 GeV pp/pA and 450 GeV pA collisions can explain the preliminary PHENIX data on the centrality dependence of $J/\psi$ suppression in Cu+Cu collisions at RHIC energy, $\sqrt{s_{NN}}=200$ GeV. However, the model does not give satisfactory description to the preliminary PHENIX data on the centrality dependence of $J/\psi$ suppression in Au+Au collisions. The analysis suggest that in Au+Au collisions, $J/\psi$ are suppressed in a medium unlike the medium produced in SPS energy nuclear collisions or in RHIC energy Cu+Cu collisions.

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I. INTRODUCTION

Lattice QCD predicts that under certain conditions (sufficiently high energy density and temperature), ordinary hadronic matter (where quarks and gluons are confined), can undergo a phase transition to a deconfined matter, commonly known as Quark Gluon Plasma (QGP). Nuclear physicists are trying to produce and detect this new phase of matter at RHIC, BNL. $J/\psi$ suppression is recognized as one of the promising signal of the deconfinement phase transition. Due to screening of color force, binding of a $c\bar{c}$ pair into a $J/\psi$ meson will be hindered, leading to the so called $J/\psi$ suppression in heavy ion collisions [1]. However, $J/\psi$'s are absorbed in nuclear collisions also and prior to NA50 158 AGeV Pb+Pb collisions [2], all the experimental data on $J/\psi$ suppression, are explained with nuclear absorption only. NA50 collaboration measured centrality dependence of $J/\psi$ suppression in 158 AGeV Pb+Pb collisions. Data gave the first indication of 'anomalous' mechanism of charmonium suppression which goes beyond the conventional nuclear absorption. The data generated lot of excitement as it was believed to give first indication of QGP formation. Later, the data were explained in a variety of models, with or without the assumption of QGP [3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13]. More recently, NA60 collaboration measured the centrality dependence of charmonium suppression in 158 AGeV In+In collisions [14, 15, 16]. In In+In collisions also, one observes anomalous suppression, which is beyond the conventional nuclear absorption.

In recent Au+Au collisions at RHIC, one observe a dramatic suppression of hadrons with high momentum, transverse to beam direction (high $p_T$ suppression) [17, 18, 19, 20]. This has been interpreted as evidence for the creation of high density, color opaque medium of deconfined quarks and gluons [21]. It is expected that high density, color opaque medium will leave its imprint on $J/\psi$ production. At RHIC energy, it has been argued that rather than suppression, charmoniums will be enhanced [22, 23]. Due to large initial energy, large number of $c\bar{c}$ pairs will be produced in initial hard scatterings. Recombination of $c\bar{c}$ can occur enhancing the charmonium production. PHENIX collaboration have measured the centrality dependence of $J/\psi$ invariant yield in Au+Au collisions at RHIC energy, $\sqrt{s_{NN}}=200$ GeV [24, 25]. More recently, with improved statistics, they have measured $J/\psi$'s in Cu+Cu and in Au+Au collisions. Preliminary results for the centrality dependence of nuclear modification factor ($R_{AA}$) and mean square transverse momentum for $J/\psi$ suppression in Cu+Cu and in Au+Au collisions are available [26, 27]. PHENIX data on $J/\psi$ production in Au+Au/Cu+Cu collisions, are not consistent with models which predict $J/\psi$ enhancement [22, 23]. It was also seen that various models, e.g. co-mover model [3], statistical coalescence model [4] or the kinetic model [5] fail to explain the PHENIX (preliminary) data on the nuclear modification factor for $J/\psi$ in Cu+Cu and in Au+Au collisions. The data are also not explained in normal nuclear absorption model [28].

We have developed a QCD based nuclear absorption model to explain the anomalous $J/\psi$ suppression in 158 AGeV Pb+Pb collisions [3, 13]. Unlike in conventional nuclear absorption model, in the QCD based nuclear absorption model, the $c\bar{c}$ pair interact with the medium and gain relative 4-square momentum. Some of the pairs can gain enough 4-square momentum to cross the threshold for open charm meson, reducing the $J/\psi$ yield. The parameters of the model were fixed to reproduce $J/\psi$ yield in pp and pA collisions. The model give consistent description of the centrality dependence of the $J/\psi$ suppression and $p_T$ broadening in 158 AGeV Pb+Pb collisions and in 200 AGeV S+U collisions [11]. In the present paper we have tested the model against the preliminary PHENIX data on $J/\psi$ suppression in Cu+Cu and Au+Au collisions at RHIC energy, $\sqrt{s_{NN}}=200$ GeV. Centrality dependence of $J/\psi$ suppression, in Cu+Cu collisions, is well explained in the model, but the model fails to explain the suppression in Au+Au collisions. The analysis suggests that in Au+Au collisions at RHIC, $J/\psi$'s are suppressed in a medium unlike the medium

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produced in S+U/Pb+Pb collisions at SPS energy or in Cu+Cu collisions at RHIC energy. We also apply the
model to explain the preliminary PHENIX data on centrality dependence of $p_T$ broadening for $J/\psi$'s. Within
errors, $p_T$ broadening at RHIC seems to be consistent with that at SPS energy.

The paper is organised as follows: in section II, we briefly describe the QCD based nuclear absorption
model. In section III, PHNIX data on the centrality dependence of $J/\psi$ suppression in Cu+Cu and in Au+Au
collisions are analysed. Centrality dependence of $p_T$ broadening of $J/\psi$'s are analysed in section III. Summary
and conclusions are drawn in section IV.

II. QCD BASED NUCLEAR ABSORPTION MODE

In the QCD based nuclear absorption model \cite{9,10,11,12,13}, $J/\psi$ production is assumed to be a two step
process, (a) formation of a $c\bar{c}$ pair, which is accurately calculable in QCD and (b) formation of a $J/\psi$ meson
from the $c\bar{c}$ pair, a non-perturbative process, which is conveniently parameterized. The $J/\psi$ cross section in $p+p$
collisions, at center of mass energy $\sqrt{s}$ is written as,

$$
\sigma_{NN}^{J/\psi}(s) = K \sum_{a,b} \int dq^2 \left( \frac{\hat{\sigma}_{ab\rightarrow c\bar{c}}}{Q^2} \right) \int dx_F \phi_{a/A}(x_a, Q^2) \phi_{b/B}(x_b, Q^2) \frac{x_a x_b}{x_a + x_b} \times F_{c\bar{c} \rightarrow J/\psi}(q^2),
$$

where $\sum_{a,b}$ runs over all parton flavors, and $Q^2 = q^2 + 4m_c^2$. The $K$ factor takes into account the higher order
corrections. We have used the CTEQ5L parton distribution function for $\phi(x, Q^2)$ \cite{29}. The incoming parton mome
momentum fractions are fixed by kinematics and are; $x_a = (\sqrt{x_F^2 + 4Q^2/s} + x_F^2)/2$ and $x_b = (\sqrt{x_F^2 + 4Q^2/s-x_F^2})/2$.
$\sigma_{ab\rightarrow c\bar{c}}$ are the sub process cross sections and are given in \cite{30}. $F_{c\bar{c} \rightarrow J/\psi}(q^2)$ is the transition probability that a
$c\bar{c}$ pair with relative momentum square $q^2$ evolve into a physical $J/\psi$ meson. It is parameterized as,

$$
F_{c\bar{c} \rightarrow J/\psi}(q^2) = N_{J/\psi}(q^2)\theta(4m^2 - 4m_c^2 - q^2) \times (1 - \frac{q^2}{4m^2 - 4m_c^2})
$$

All the energy dependence of $J/\psi$ production is contained in Eq.1. As shown in Fig.1 with $KNJ/\psi$ as a
overall normalisation, over a wide range of energy, including the RHIC energy, the model correctly reproduces
the experimental $J/\psi$ cross sections in $p+p$ collisions.

Our main interest here is to test the model against the preliminary PHENIX data on the centrality dependence
of $J/\psi$ suppression in Cu+Cu and Au+Au collisions at RHIC energy \cite{26,27}. In AA collisions, at impact parameter $b$, number of $J/\psi$ mesons produced is calculated as,

$$
N_{AA}^{J/\psi}(b) = \sigma_{NN}^{J/\psi} \int d^2s T_A(s) T_B(b-s) S(L(b,s)),
$$

where $T_A, T_B$ are the nuclear thickness function,

$$
T_A(b) = \int dz \rho_A(b,z)
$$

For the density we use the Woods-Saxon form,

$$
\rho(r) = \frac{\rho_0}{1 + e^{((r-R)/a)}},
$$

with $R=6.38$ (4.45) fm and $a=0.535(0.54)$ fm for Au(Cu) nucleus \cite{31}.

In Eq.3, $S(L)$ is the suppression factor due to passage of $J/\psi$ through a length $L$ in nuclear environment.
As mentioned earlier, in the QCD based nuclear absorption model, $J/\psi$'s are suppressed due to gain in relative 4-square momentum of a $c\bar{c}$ pair. In a nucleon-nucleus/nucleus-nucleus collision, the produced $c\bar{c}$ pairs interact with the nuclear medium before they exit. Interaction of a $c\bar{c}$ pair with the nuclear environment increases the square of the relative momentum between the pair. As a result, some of the $c\bar{c}$ pairs can gain enough relative square momentum to cross the threshold to become an open charm meson. Consequently, the cross section for $J/\psi$ production is reduced in comparison with nucleon-nucleon cross section. If the $J/\psi$ meson travel a distance $L$, $q^2$ in the transition probability is replaced to,
\[ q^2 \rightarrow q^2 + \varepsilon^2 L, \]  
\( \varepsilon^2 \) being the relative square momentum gain per unit length. The length \( L(b, s) \) that the \( J/\psi \) meson will traverse is obtained as,

\[ L(b, s) = n(b, s)/2 \rho_0 \]  
where \( n(b, s) \) is the transverse density,

\[ n(b, s) = T_A(s)[1 - e^{-\sigma_{NN}\rho(b-s)}] + [A \leftrightarrow B] \]  

\( J/\psi \) suppression in the model is governed by the parameter \( \varepsilon^2 \) and \( L \) (see Eq.6). The length \( L \) is a geometric term. It has weak energy dependence from the energy dependence of \( \sigma_{NN} \), the inelastic NN cross-section. Energy dependence of \( J/\psi \) suppression will reflect, most on the parameter \( \varepsilon^2 \). NA50 data on \( J/\psi \) production in 450 GeV pp/pA collisions and in 200 GeV pA collisions are well fitted with a common square momentum gain factor, \( \varepsilon^2 = 0.187 \, \text{GeV}^2/\text{fm} \) [10]. The model then explains the centrality dependence of S+U and Pb+Pb collisions at SPS energy. As the model parameters are fixed to reproduce \( J/\psi \) production in pA collisions, where deconfined matter formation is unlikely, it was concluded that at SPS energy S+U/Pb+Pb collisions, \( J/\psi \)'s are absorbed in a nuclear medium [9, 10].

If at RHIC energy, \( J/\psi \)'s are suppressed in a medium denser than the medium produced in SPS energy nuclear collisions, \( \varepsilon^2 \) will increase. In a denser medium, the \( c\bar{c} \) pair will interact more with the medium and per unit length will gain more square momentum. Parametric value of \( \varepsilon^2 \) at RHIC energy then can indicate whether or not, a dense medium is produced. We note that due enhanced energy charmonium production increases at RHIC, but as shown in Fig.4 that energy dependence is included in the model.

III. \( J/\psi \) Suppression in Cu+Cu/Au+Au Collisions at RHIC

PHENIX collaboration has measured the centrality dependence of \( J/\psi \) suppression, in Cu+Cu and in Au+Au collisions, in two ranges of rapidity intervals, (i) \(-0.35 \leq y \leq 0.35 \) and (ii) \(1.2 \leq y \leq 2.2 \), [26, 27]. In Fig.2 preliminary PHENIX data on the centrality dependence of nuclear modification factor (\( R_{AA} \)) for \( J/\psi \), in Cu+Cu collisions are shown. Two rapidity ranges of data are not distinguished. We note that the present model is designed for central rapidity only. However, presently we ignore this limitation of the model. As it is evident from Fig.2 rapidity dependence of \( J/\psi \) suppression is not large in Cu+Cu collisions. Using the CERN minimisation programme MINUIT, with \( \varepsilon^2 \) as a parameter of the QCD based absorption model, we fit the data. The best fit is obtained with \( \varepsilon^2 = 0.173 \pm 0.007 \, \text{GeV}^2/\text{fm}. \)

\[ \varepsilon^2 \] is the relative square momentum gain per unit length. The length \( L(b, s) \) that the \( J/\psi \) meson will traverse is obtained as,

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where \( n(b, s) \) is the transverse density,

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\[ \varepsilon^2 \] is the relative square momentum gain per unit length. The length \( L(b, s) \) that the \( J/\psi \) meson will traverse is obtained as,

\[ L(b, s) = n(b, s)/2 \rho_0 \]  
where \( n(b, s) \) is the transverse density,

\[ n(b, s) = T_A(s)[1 - e^{-\sigma_{NN}\rho(b-s)}] + [A \leftrightarrow B] \]  

\( J/\psi \) suppression in the model is governed by the parameter \( \varepsilon^2 \) and \( L \) (see Eq.6). The length \( L \) is a geometric term. It has weak energy dependence from the energy dependence of \( \sigma_{NN} \), the inelastic NN cross-section. Energy dependence of \( J/\psi \) suppression will reflect, most on the parameter \( \varepsilon^2 \). NA50 data on \( J/\psi \) production in 450 GeV pp/pA collisions and in 200 GeV pA collisions are well fitted with a common square momentum gain factor, \( \varepsilon^2 = 0.187 \, \text{GeV}^2/\text{fm} \) [10]. The model then explains the centrality dependence of S+U and Pb+Pb collisions at SPS energy. As the model parameters are fixed to reproduce \( J/\psi \) production in pA collisions, where deconfined matter formation is unlikely, it was concluded that at SPS energy S+U/Pb+Pb collisions, \( J/\psi \)'s are absorbed in a nuclear medium [9, 10].

If at RHIC energy, \( J/\psi \)'s are suppressed in a medium denser than the medium produced in SPS energy nuclear collisions, \( \varepsilon^2 \) will increase. In a denser medium, the \( c\bar{c} \) pair will interact more with the medium and per unit length will gain more square momentum. Parametric value of \( \varepsilon^2 \) at RHIC energy then can indicate whether or not, a dense medium is produced. We note that due enhanced energy charmonium production increases at RHIC, but as shown in Fig.4 that energy dependence is included in the model.

As discussed earlier, if at RHIC energy, \( J/\psi \)'s are suppressed in a medium, denser than the medium created in SPS energy nuclear collisions, \( \varepsilon^2 \) should increase. In Cu+Cu collisions, a contrary result is obtained. Compared to \( \varepsilon^2 \) at SPS energy, at RHIC Cu+Cu collisions, \( \varepsilon^2 \) decreases by a modest 7%. \( J/\psi \)'s are less suppressed.

The result is consistent with the PHENIX measurement of \( J/\psi \) suppression in d+Au collisions at RHIC [32]. At RHIC d+Au collisions, \( J/\psi \)-nucleon absorption cross-section, \( \sigma_{J/\psi N} \approx 1-3 \, \text{mb} \), is less than the \( J/\psi \)-nucleon absorption cross-section at SPS energy, \( \sigma_{J/\psi N} \approx 4-5 \, \text{mb} \) [33]. Good fit to the centrality dependence of \( J/\psi \) suppression in Cu+Cu collisions, data, in the QCD based nuclear absorption model, with \( \varepsilon^2 \) close to the value at SPS energy, indicate that in Cu+Cu collisions, \( J/\psi \)'s are suppressed in a nuclear medium, much like the medium produced in nuclear collisions at SPS energy.

Next we fit the PHENIX data on \( J/\psi \) suppression in Au+Au collisions. Centrality dependence of the nuclear modification factor (\( R_{AA} \)) for \( J/\psi \) in the central rapidity region \(-0.35 < y < 0.35 \), is shown in Fig.5. Data points
are few and error bars are also large. The best fit to the data is obtained with \( \varepsilon^2 = 0.146 \pm 0.014 \) GeV\(^2/\)fm. It is shown as the solid line in Fig. \( \text{3} \). The fit to the data is not satisfactory. In very central collisions, the model over predicts \( R_{AA} \) and in mid central collisions the model under predicts \( R_{AA} \). The best fitted value of \( \varepsilon^2 = 0.146 \pm 0.014 \) GeV\(^2/\)fm is \( \sim 15\% \) lower than the value required to explain the PHENIX data on \( J/\psi \) suppression in Cu+Cu collisions. Apparently, in Au+Au collisions, \( J/\psi \)’s are suppressed in a medium, less dense than that produced in Cu+Cu collisions. This is inconsistent with other results at RHIC Au+Au collisions \( \text{[17, 18, 19, 20]} \). As mentioned earlier, in RHIC Au+Au collisions, deconfined matter can be formed. \( J/\psi \)’s can be suppressed in the deconfined matter. QCD based nuclear absorption model do not account for such a suppression. Unsatisfactory fit to the Au+Au data may be due to neglect of deconfined medium production in Au+Au collisions.

**IV. \( p_T \) BROADENING OF \( J/\psi \) IN CU+CU AND AU+AU COLLISIONS**

It is well known that in pA and AA collisions, the secondary hadrons generally shows a \( p_T \) broadening \( \text{[31, 35]} \). \( p_T \) broadening of \( J/\psi \)’s, in S+U and Pb+Pb collisions are well explained in the QCD based nuclear absorption model. Recently PHENIX collaboration has measured \( p_T \) broadening of \( J/\psi \) in Cu+Cu and Au+Au collisions \( \text{[20, 27]} \). It is interesting to compare the QCD based nuclear absorption model predictions with the PHENIX data.

The natural basis for the \( p_T \) broadening is the initial state parton scatterings. For \( J/\psi \)’s, gluon fusion being the dominant mechanism for \( c\bar{c} \) production, initial state scattering of the projectile/target gluons with the target/projectile nucleons causes the intrinsic momentum broadening of the gluons, which is reflected in the \( p_T \) distribution of the resulting \( J/\psi \)’s. Parameterising the intrinsic transverse momentum of a gluon, inside a nucleon as,

\[
f(q_T) \sim \exp(-q_T^2/\langle q_T^2 \rangle)
\]

m I momentum distribution of the resulting \( J/\psi \) in NN collision is obtained by convoluting two such distributions,

\[
f_{NN}(p_T) \sim \exp(-p_T^2/\langle p_T^2 \rangle) \times \exp(-q_T^2/\langle q_T^2 \rangle)
\]

where \( \langle p_T^2 \rangle \leq \langle q_T^2 \rangle \). In nucleus-nucleus collisions at impact parameter \( b \), if before fusion, a gluon undergo random walk and suffer \( N \) number of subcollisions, its square momentum will increase to \( q_T^2 \rightarrow q_T^2 + N\delta_0 \), \( \delta_0 \) being the average broadening in each subcollisions. Square momentum of \( J/\psi \) then easily obtained as,

\[
< p_T^2 >_AB \ (b) = < p_T^2 >_NN + \delta_0 N_{AB}(b)
\]
where \( N_{AB}(b) \) is the number of subcollisions suffered by the projectile and target gluons with the target and projectile nucleons respectively.

Average number of collisions \( N_{AB}(b) \) can be obtained in a Glauber model \[35\]. At impact parameter \( b \), the positions \((s, z)\) and \((b-s, z')\) specifies the formation point of \( c\bar{c} \) in the two nuclei, with \( s \) in the transverse plane and \( z, z' \) along the beam axis. The number of collisions, prior to \( c\bar{c} \) pair formation, can be written as,

\[
N(b, s, z, z') = \sigma_{gN} \int_{-\infty}^{z} dz_A \rho_A(s, z_A) + \sigma_{gN} \int_{-\infty}^{z'} dz_B \rho_B(b-s, z')
\]

where \( \sigma_{gN} \) is the gluon-nucleon cross-section. Above expression should be averaged over all positions of \( c\bar{c} \) formation with a weight given by the product of nuclear densities and survival probabilities \( S \),

\[
N_{AB}(b) = \int d^2 s \int_{-\infty}^{\infty} dz \rho_A(s, z) \int_{-\infty}^{\infty} dz' \rho_B(b-s, z') \times \]

\[
S(b, s)N(b, s, z, z')/\int d^2 s \int_{-\infty}^{\infty} dz \rho_A(s, z) \times \int_{-\infty}^{\infty} dz' \rho_B(b-s, z') S(b, s, z, z')
\]

(13)

In Fig 4 the centrality dependence of the ratio \( N_{AB}/\sigma_{gN} \) in Au+Au collisions are shown. The solid and dashed lines corresponds to \( \varepsilon^2 =0.14 \text{ GeV/fm} \) and \( 0.18 \text{ GeV/fm} \) respectively. \( N_{AB}/\sigma_{gN} \) do not show large dependence on \( \varepsilon^2 \). Even though \( \varepsilon^2 \) differ by 25%, \( N_{AB} \) differ by less than 3% in central collisions. In less central collisions, the difference is even less. \( p_T \) broadening of \( J/\psi \) will not depend much on the exact value of \( \varepsilon^2 \).

\( p_T \) broadening of \( J/\psi \)'s in AA collisions depends on two parameters, (i) \( <p_T^2>_{NN}^J/\psi \), the mean squared transverse momentum in NN collisions and (ii) the product of the gluon-nucleon cross-section and the average parton momentum broadening per collision, \( \sigma_{gN}\delta_0 \). \( <p_T^2>_{NN}^J/\psi \) is a measured in RHIC energy p+p collisions, \( <p_T^2>_{NN}^J/\psi = 4.2\pm0.7 \text{ GeV}^2 \). The other parameter, \( \sigma_{gN}\delta_0 \) is essentially non-measurable, as gluons are not free. Its value can only be obtained from experimental data on \( p_T \) broadening of \( J/\psi \). At SPS energy S+U/Pb+Pb collisions \( \sigma_{gN}\delta_0 \) is estimated as \( 0.442 \pm 0.056 \text{ GeV}^2 \). PHENIX data on \( J/\psi p_T \) broadening can be used to estimate its value at RHIC energy.

In Fig.5 PHENIX data on the centrality dependence of mean square transverse momentum \( <p_T^2> \), in Cu+Cu and in Au+Au collisions are shown. For comparison purpose, \( <p_T^2> \) in in p+p and in d+Au collisions are also shown. As data points are few, we do not fit the individual Cu+Cu or Au+Au data sets. Rather we fit the combined data sets. We fix \( <p_T^2>_{NN} \) at the measured central value, \( <p_T^2>_{NN} = 4.2 \text{ GeV}^2 \), and vary \( \sigma_{gN}\delta_0 \). Best fit is obtained with \( \sigma_{gN}\delta_0 = 0.03 \pm 0.51 \text{ GeV}^2 \). RHIC data do not show any evidence of \( p_T \) broadening, as indicated by very small value of \( \sigma_{gN}\delta_0 \). In Fig[5] model predictions with the central value, \( \sigma_{gN}\delta_0 =0.03 \text{ GeV}^2 \) are shown. The solid and dashed lines are for Au+Au and Cu+Cu collisions respectively. The predictions for Cu+Cu collisions closely match that for Au+Au collisions and cannot be distinguished.

V. SUMMARY AND CONCLUSIONS

To summarize, we have analysed the (preliminary) PHENIX data \[24, 25\] on the centrality dependence of \( J/\psi \) suppression and \( p_T \) broadening, in Cu+Cu and in Au+Au collisions at RHIC energy, \( \sqrt{s}_{NN}=200 \text{ GeV} \). The data are analysed in the QCD based nuclear absorption model \[9, 10, 11, 12, 13\]. In the model, \( J/\psi \)'s suppression is controlled by a parameter \( \varepsilon^2 \). Larger the \( \varepsilon^2 \), more is the suppression. Centrality dependence of \( J/\psi \) suppression at SPS energy require \( \varepsilon^2_{PS}=0.187 \text{ GeV}^2/fm \). With \( \varepsilon^2 \) as a parameter, we have fitted the PHENIX data on the centrality dependence of \( J/\psi \) suppression in Cu+Cu and in Au+Au collisions. Cu+Cu data are well explained with \( \varepsilon^2 = 0.173 \pm 0.007 \text{ GeV}^2/fm \), close to the SPS energy value. In Cu+Cu collisions, \( J/\psi \)'s are suppressed in a medium much like the medium created in SPS energy collisions. No exotic, high-density matter is created in Cu+Cu collisions.
collisions, is not well explained in the model. Best fitted value, $\varepsilon^2 = 0.146 \pm 0.014 \text{ GeV}^2/fm$, over predict the suppression in mid-central collisions and under predict the suppression in very central collisions. We conclude that in Au+Au collisions, $J/\psi$’s are suppressed in medium unlike the medium created in SPS energy nuclear collisions or in Cu+Cu collisions at RHIC energy. We have also analysed the PHENIX data on $p_T$ broadening of $J/\psi$ in Cu+Cu and Au+Au collisions. RHIC data on $p_T$ broadening do not show any evidence of $p_T$ broadening.

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