# $J/\psi$ enhancement in heavy ion collisions: Statistical and Kinetic approach

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## Introduction

At Large Hadron Collider (LHC), collisions of Pb+Pb ions at energy $\sqrt{s_{NN}} = 2.76$ TeV would create strongly interacting matter at very high temperatures, where a phase transition from hadronic phase to quark gluon plasma (QGP) is expected. The J/$\psi$ particles are the richest and most interesting probes of QGP [1]. The SPS data show that J/$\psi$ is suppressed [2, 3], while PHENIX (at RHIC) data are explained by accounting for both partial suppression and enhancement scenarios [4]. At LHC, a large number of initially produced $c\bar{c}$ pairs could lead to an important source of final charmonium, where coalescence mechanism may lead to enhancement instead of suppression of J/$\psi$. Here we discuss $J/\psi$ enhancement using both kinetic and statistical models and compare them.

## Kinetic Formation Model

In this model [5, 6], the total number of $J/\psi$ produced in a deconfined medium are governed by two factors; (i) the formation related to the recombination of $c$ and $\bar{c}$, (ii) the dissociation of $J/\psi$ induced by collision with the gluons of the medium.

In the present study we assume the charm quark pairs and $J/\psi$ in a region of color deconfinement populated by the thermal density of gluons. The time evolution of $J/\psi$ can be written as:

$$\frac{dN_{J/\psi}}{d\tau} = \lambda_F N_c N_{\bar{c}} [V(\tau)]^{-1} - \lambda_D N_{J/\psi} \rho_g \quad (1)$$

The first term of Eq.1, is related to "*formation rate*", where as the second term is related to "*dissociation rate*". In Eq.1, $\tau$ = proper time, $\lambda_F = \langle \sigma_F v_{rel}^{c,\bar{c}} \rangle$ and $\lambda_D = \left\langle \sigma_D v_{rel}^{g,J/\psi} \right\rangle$ are the formation and dissociation rates respectively.

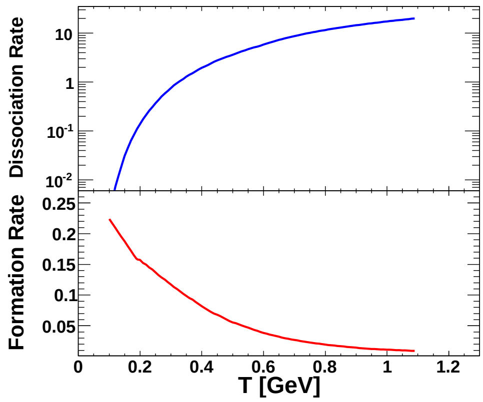


FIG. 1: Dissociation (upper) and formation (lower) rate of $J/\psi$ due to interaction with thermal gluons vs $T$.

TABLE I: Input parameters

| | |
|---|---|
| Initial time ($\tau_0$) | $0.5fm$ |
| Radius of the nuclei ($R$) | $7.1fm$ |
| *Freeze-out* temp ($T_f$) | 170 MeV |
| Initial number of $J/\psi$ | 0.0 |

The dissociation (formation) rate of $J/\psi$ as a function of temperature ($T$) is shown in Fig.1 upper (lower) panel. The upper panel of Fig.2 shows the number of $J/\psi$ expected as a function of initial number of unbound charm quarks $N_{c\bar{c}}$ with different initial temperature (300-700 MeV) using kinetic model, where dissociation and formation rates taken from Fig. 1 using thermal distributions of charms. The lower panel shows the number of $J/\psi$ with fixed formation rate (0.008), where the charm $p_T$ distribution has been taken from perturbative QCD calculation. The parameters which have been used in this calculation are listed in table I.

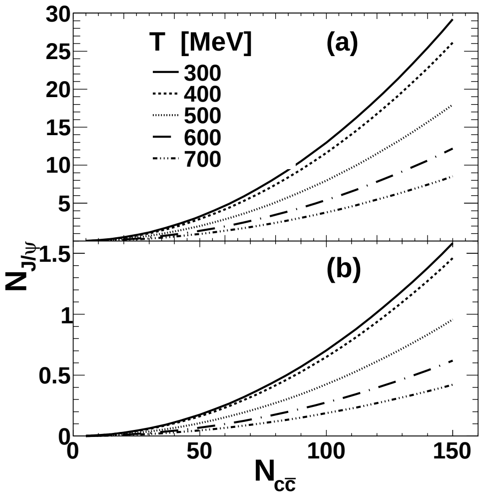


FIG. 2: $N_{c\bar{c}}$ dependence of $N_{J/\psi}$ using Kinetic model.

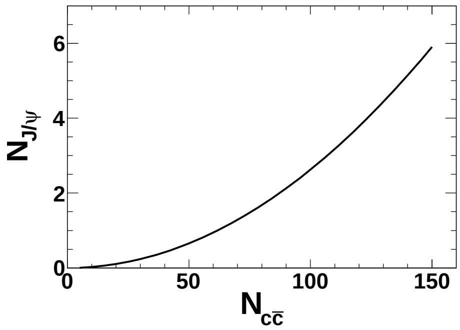


FIG. 3: $N_{c\bar{c}}$ dependence of $N_{J/\psi}$ using Statistical model.

## Statistical Hadronization Model

To study the charm production, we have used the statistical model which has been discussed in [8, 9]. The number density of the particles $i$ in an equilibrated systems can be described as:

$$n_i = \frac{g_i}{2\pi^2}\int_0^\infty \frac{p^2 dp}{e^{(E_i(p)-\mu_i)/T} \pm 1} \quad (2)$$

The chemical potential $\mu_i = \mu_B B_i + \mu_S S_i + \mu_{I_3} I_i^3 + \mu_C C_i$. The values of $\mu$'s are taken from Ref.[9]. The number of $J/\psi$ mesons are then enhanced relative to the thermal model prediction by a factor $\gamma_c^2$:

$$N_{J/\psi} = \gamma_c^2 N_{J/\psi}^{thermal} = 4\frac{n_{J/\psi}^{thermal} n_{ch}}{n_{open}^2}\frac{N_{c\bar{c}}^2}{N_{ch}} \quad (3)$$

where, $\gamma_c = \frac{2N_{c\bar{c}}}{N_{open}}$ is the enhancement factor. The number of $J/\psi$ produced as a function of number of unbound charm quarks using statistical model are shown in Fig.3. The SPS data [10] are well explained using the statistical hadronization model Eq.3. By replacing $N_{c\bar{c}}$ with $(N_{c\bar{c}}(N_{c\bar{c}}+1))^{\frac{1}{2}}$ in $\gamma_c$ allows the grand canonical solutions to incorporate the behaviour of canonical corrections to an impressive degree of accuracy.

## Conclusion

We have studied the $J/\psi$ production using both kinetic and statistical models. The number of $N_{c\bar{c}}$ at $\sqrt{s_{NN}}$ = 2.78 TeV is about 80 for (0-5)% centrality, which corresponds to the number of $J/\psi$ produced are 3 and 0.2 using kinetic model at 600 MeV with thermal and perturbative QCD $p_T$-distribution respectively. Using the statistical model, the number of $J/\psi$ is 1.7.

## References

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