**J/ψ 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/ψ particles are the richest and most interesting probes of QGP [1]. The SPS data show that J/ψ 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/ψ. Here we discuss J/ψ enhancement using both kinetic and statistical models and compare them.

**Kinetic Formation Model**

In this model [5, 6], the total number of J/ψ 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/ψ induced by collision with the gluons of the medium.

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

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

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

**TABLE I: Input parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial time ($\tau_0$)</td>
<td>0.5 fm</td>
</tr>
<tr>
<td>Radius of the nuclei (R)</td>
<td>7.1 fm</td>
</tr>
<tr>
<td>Freeze-out temp ($T_f$)</td>
<td>170 MeV</td>
</tr>
<tr>
<td>Initial number of J/ψ</td>
<td>0.0</td>
</tr>
</tbody>
</table>

The dissociation (formation) rate of J/ψ 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/ψ 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/ψ 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.
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 system can be described as:

$$n_i = \frac{g_i}{2\pi^2} \int_0^\infty \frac{p^2 dp}{e^{E_i(p)/T} + 1} \pm 1$$  \hspace{1cm} (2)

The chemical potential $\mu_i = \mu_B B_i + \mu_S S_i + \mu_I I_3 + \mu_C C_i$. 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 $\gamma_c^2$:

$$N_{J/\psi} = \gamma_c^2 N_{thermal} = 4 \frac{n_{thermal} n_{ch}}{n_{open}^2} \frac{N_{cc}}{N_{ch}}$$  \hspace{1cm} (3)

where, $\gamma_c = \frac{2N_{cc}}{N_{min}}$ 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 $N_{cc}$ with $(N_{cc}(N_{cc}+1))^\pm$ 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 $N_{cc}$ 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