# $J/\psi$ suppression in an anisotropic Quark-Gluon-Plasma

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We calculate the gluon dissociation cross-section in an anisotropic medium. Such an anisotropy can result from the initial rapid longitudinal expansion of the matter created in relativistic heavy-ion collisions. We show that the thermally weighted cross-section of gluon dissociation undergoes modification in anisotropic plasma leading to a decreased probability of $J/\psi$ suppression both for RHIC and LHC energies. The survival probability of $J/\psi$ is also sensitive to the initial condition.

## 1. Introduction

Heavy quarkonium states are the sensitive probes of the strongly-interacting deconfined medium expected to be formed in the early stages of relativistic heavy-ion collision[1]. The production of heavy quark resonances ($J/\psi$) will be suppressed as a result of colour Debye screening in a hot and dense system of quarks, anti-quarks and gluons.

In equilibrating plasma, the gluons have much harder momentum sufficient to dissociate the charmonium[2]. Such study has been performed from the very beginning, that the plasma is isotropic which may not necessarily be true. The measurement of elliptic flow parameter and its theoretical explanation suggest that the matter quickly comes into thermal equilibrium [3]. But one of the major difficulty is to measure the thermalization($\tau_{therm}$) and isotropization ($\tau_{iso}$) time of the QGP. Perturbative estimation suggests relatively slower thermalization of QGP [4]. However, recent hydrodynamical studies [5] have shown that due to the poor knowledge of the initial conditions there is a sizable amount of uncertainty in the estimate of thermalization or isotropization time. It is suggested that (momentum) anisotropy driven plasma instabilities may speed up the process of isotropization. The rapid expansion of the matter along the beam direction causes faster cooling in the longitudinal direction than in the transverse direction [4]. As a result, the system becomes anisotropic with $\langle {p_L}^2 \rangle << \langle {p_T}^2 \rangle$ in the local rest frame. The effects of pre-equilibrium momentum anisotropy on various observables have been studied quite extensively over the past few years. Heavy quark energy loss and momentum broadening in anisotropic QGP have been studied in Refs. [6] and [7]. It is to be noted that the calculations of $J/\psi$ dissociation cross-section in Ref. [2] have been performed in an equilibrating plasma and it is found that the survival probability increases in such system. In the present work, we shall extend the above work assuming initial state momentum space anisotropy.

## 2. Formalism

The gluon-$J/\psi$ dissociation cross section can be calculated using perturbative QCD and is given by[8]

$$\sigma(q^0) = \frac{2\pi}{3}\left(\frac{32}{3}\right)^2\left(\frac{16\pi}{3g_s^2}\right)\frac{1}{m_Q^2} \times \frac{(q^0/\epsilon_0 - 1)^{3/2}}{(q^0/\epsilon_0)^5}\,, \quad (1)$$

The J/$\psi$ will move with four-momentum

$$P = (M_T \cosh y, 0, p_T, M_T \sinh y) \quad (2)$$

A gluon with a four-momentum $K = (k^0, \mathbf{k})$ in the rest frame of the parton gas has energy $q^0 = K.u$ in the rest frame of the $J/\psi$. Now to calculate the velocity averaged cross section in anisotropic media we note that the anisotropicity enters through the distribution function [9, 10],

$$f(k^0, \xi, p_{\rm hard}) = \frac{1}{e^{k^0/p_{\rm hard}\sqrt{1+\xi(\hat{k}.\hat{n})^2}} - 1} \quad (3)$$

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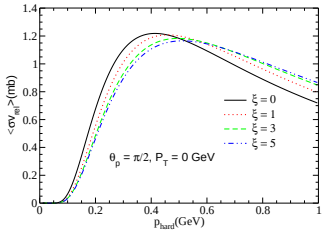


FIG. 1: The thermal-averaged gluon-$J/\psi$ dissociation cross section as function of the hard momentum scale at central rapidity ($\theta_p = \pi/2$) for $\xi = \{0, 1, 3, 5\}$.

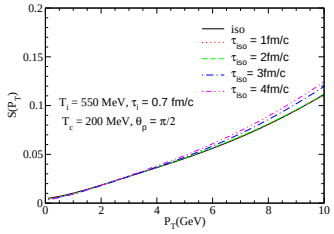


FIG. 2: The survival probability of $J/\psi$ in an anisotropic plasma at RHIC energies

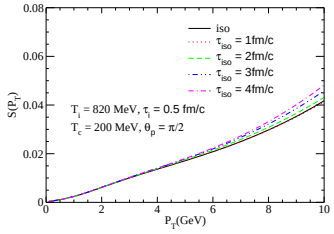


FIG. 3: The survival probability of $J/\psi$ in an anisotropic plasma at LHC energies

where $p_{\rm hard}$ is the hard momentum scale, $\hat{n}$ is the direction of anisotropy which is along the beam axis and $\xi$ is the anisotropy parameter($-1 < \xi < \infty$). $p_{\rm hard}$ is related to the average momentum in the partonic distribution function. The gluon-$J/\psi$ dissociation cross section[2] becomes in the rest frame of $J/\psi$ [11],

$$\langle\sigma(K.u)v_{\rm rel}\rangle_k = \int d^3q \frac{M_{J/\psi}}{E}\sigma(q^0)f(k^0,\xi,p_{hard}) \times \frac{1}{\sqrt{1+\xi}}8\pi\zeta(3)p_{\rm hard}^3 \quad (4)$$

The maximum value of the gluon $J/\psi$ dissociation cross section [8] is about 3 $mb$ in the range $0.7 \geq q^0 \leq 1.7$ GeV. We calculated the survival probability of $J/\psi$, with the velocity averaged dissociation cross sections in an anisotropic media.

## 3. Results

Fig.(1) shows the cross-section for $P_T = 0$ GeV for a set of values of the anisotropy parameter. It is seen that the cross section decreases with $\xi$ for $p_{\rm hard}$ up to $\sim 500$ MeV and then increases as compared to the isotropic case ($\xi = 0$). In Fig.(2) and Fig.(3) show the survival probability and it is observed that it remains same as the isotropic case upto $p_T \sim 4$ GeV in the central region. Beyond that marginal increase is observed. It is also found that the results are not much sensitive to the direction of propagation of the $J/\psi$ with respect to the anisotropy axis. It is to be noted that the results are extremely sensi- tive to the initial conditions, in particular, to the choice of the initial time.

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