Quarkonia suppression in PbPb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV

Vineet Kumar,* Abdulla Abdulsalam, and P. Shukla
Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai

Introduction

Heavy ion collisions at relativistic energies are performed to create and characterize Quark Gluon plasma (QGP), a phase of strongly interacting matter at high energy density where quarks and gluons are no longer bound within hadrons. Quarkonia state (J/ψ and Υ) have been one of the most popular tools since their suppression was proposed as a signal of QGP [1]. In this paper, we calculate the quarkonia production and suppression in a kinetic model which includes dissociation due to thermal gluons, modification of yield due to change in parton distribution functions inside nucleus and due to collisions with comover hadrons. Regeneration by thermal heavy quark pairs is also taken into account. Our goal is to obtain the nuclear modification factor of quarkonia as a function of transverse momentum and centrality of collision to be compared with experimental data from LHC.

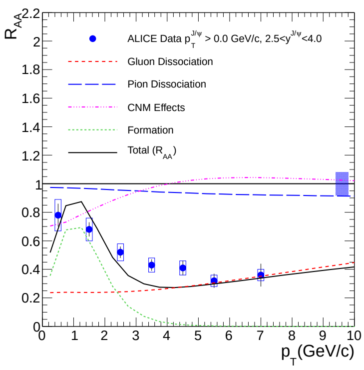

FIG. 1: Calculated nuclear modification factor (R_{AA}) as a function of J/ψ transverse momentum compared with ALICE measurements.

Modification of Quarkonia in presence of QGP

In the kinetic approach [2], the proper time (τ) evolution of the quarkonia population N_{QO} is given by the rate equation

$$\frac{dN_{QO}}{d\tau} = -\lambda_D \rho_g N_{QO} + \lambda_F \frac{N^2_{Q\bar{Q}}}{V(\tau)} \qquad (1)$$

where $V(\tau)$ is the volume of the deconfined spatial region and $N_{Q\bar{Q}}$ is the number of initial heavy quark pairs produced per event depending on the centrality ($N_{\rm part}$). The λ_D is the dissociation rate obtained by the dissociation cross-section averaged over the momentum distribution of gluons and λ_F is the formation rate obtained by the formation cross-section averaged over the momentum distributions of Q and $\bar{Q}$. ρ_g is the density of thermal gluons. The number of quarkonia at freeze-out time τ_f is given by solution of Eq. (1) as

$$N_{QO}(p_T) = S(p_T)\, N^{\rm PbPb}_{QO}(p_T) + N^F_{QO}(p_T)$$

Here $N^0_{QO}(p_T)$ is the number of initially produced quarkonia (including shadowing) as a function of p_T and $S(p_T)$ is their survival probability from gluon collisions at freeze-out time τ_f and is written as

$$S(p_T) = \exp\left(-\int_{\tau_0}^{\tau_f} f(\tau)\lambda_{\rm D}(T,p_T)\,\rho_g(T)\,d\tau\right)$$

The temperature $T(\tau)$ and the QGP fraction $f(\tau)$ evolve from initial time τ_0 to freeze-out time τ_f due to expansion of QGP. The initial

*Electronic address: Vineet.Kumar@cern.ch

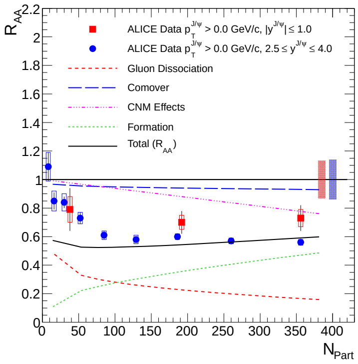

FIG. 2: Calculated nuclear modification factor (R_{AA}) as a function of $N_{\rm Part}$ compared with ALICE measurements at LHC.

temperatures and thus the evolution is dependent on $N_{\rm part}$. $N^F_{QO}(p_T)$ is the number of regenerated quarkonia per event and is given by

$$N^F_{QO}(p_T) = S(p_T) N^2_{Q\bar{Q}} \int_{\tau_0}^{\tau_f} \frac{\lambda_{\rm F}(T, p_T)}{V(\tau)\, S(\tau, p_T)} d\tau$$

The nuclear modification factor (R_{AA}) can be written as

$$R_{AA}(p_T) = S(p_T)\, R(p_T) + \frac{N^F_{QO}(p_T)}{N^{pp}_{QO}(p_T)} \quad (2)$$

Here $R(p_T)$ is the shadowing factor. R_{AA} as a function of collision centrality is calculated by integrating over p_T coverage of different experiments [3, 4].

The suppression of quarkonia by comoving pions is calculated by folding the quarkonium-pion dissociation cross section ($\sigma_{\rm I}$) over thermal pion distributions. Effect of hadronic comovers is obtained by assuming same interaction cross-section for both J/ψ and Υ.

Results and discussion

Figure 1 show different contributions in nuclear modification factor (R_{AA}) of J/ψ as a function of transverse momentum compared with ALICE measurements [3]. At low p_T, regeneration of J/ψ is the dominant process and this seems to be the process for the enhancement of J/ψ in the ALICE low p_T data. The gluon suppression is also more at low p_T and it reduces as we move to high p_T. We have also calculated R_{AA} as a function of system size. Figure 2 shows different contributions of J/ψ nuclear modification factor as a function of system size along with the measurements by ALICE [3]. It indicates that J/ψ's are increasingly suppressed when system size grows. Since the number of regenerated J/ψ's also grow the nuclear modification factor remains flat for most of the centrality regions.

Summary

We estimate the modification of quarkonia yields due to different processes in the medium produced in PbPb collisions at LHC energy. A kinetic model is employed which incorporates quarkonia suppression inside expanding QGP, suppression due to hadronic comovers and regeneration from charm pairs. The manifestations of these effects in different kinematic regions in the nuclear modification factors for both J/ψ and Υ has been compared with measurements [3, 4].

References

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