Quarkonia as tools,Aussois 2020

A density operator model for Quarkonia production in PbPb collision

Denys Yen Arrebato Villar
in collaboration with
Pol Bernard Gossiaux and Joerg Aichelin

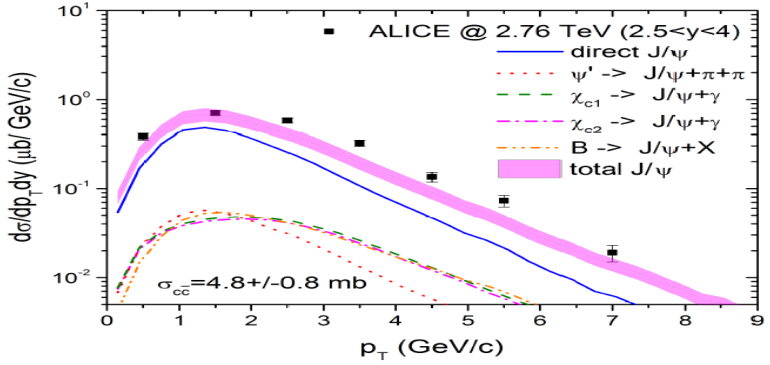
Background

The idea of the formalism goes back to Remler's work in which a general formula connecting composite particle cross section with time-dependent density operators was presented. The formalism is able to deal with many particles (nucleons ⟶ deuterium)

E.A. Remler, ANNALS OF PHYSICS 136, 293-316 (1981)

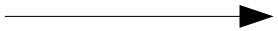
Taesoo .S, J.Aichelin and E.Bratkovskaya , Physical Review C 96. 014907 (2017)

The model was also applied to Quarkonia production in pp and heavy ion collision. And for the case of pp collision the model was able to reproduce the experimental data.



Motivation

However in the same contribution was pointed out that for heavy ion collision a considerable enhancement of primordial (in the initial state) J/Psi was found when QGP effects are ignored.

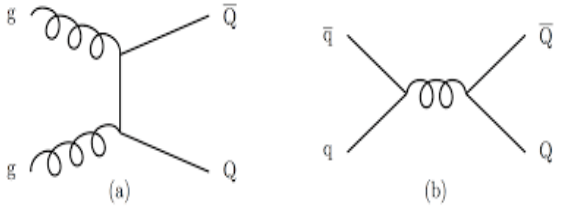


Apply the formalism to quarkonia production in heavy ion collisions

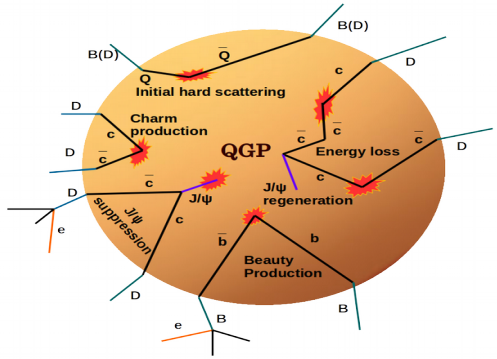
- Interaction of heavy quarks with the bulk particles
- Expansion of the medium
- Off-diagonal contributions

How does it work

HQ production



Quarkonia interaction with QGP



The probability of a quarkonia state formation in the medium is given by

$$P^{\Psi}(t) = Tr[\rho^{\Psi}_{QQ}\rho_N(t)]$$

$$\rho^{\Psi}_{Q\bar{Q}} = \sum_i |\Psi^i_{Q\bar{Q}}\rangle\langle\Psi^i_{Q\bar{Q}}|$$

Two-body density matrix

$$\frac{\partial \rho_N(t)}{\partial t} = -i[H_N, \rho_N(t)]$$

N-body system density matrix

How does it work

The effective rate for quarkonia state creation(dissociation) in the medium will be

$$\Gamma^{\Psi}(t)=\frac{\partial P^{\Psi}(t)}{\partial t}=Tr[\rho^{\Psi}_{Q\bar{Q}}\frac{\partial \rho_N(t)}{\partial t}]$$

Working in the phase space through Wigner function

$$W^{\Psi^i}=\int d^3y\, e^{ipy}\left\langle r-\frac{y}{2}\middle|\Psi^i\right\rangle\left\langle\Psi^i\middle|r+\frac{y}{2}\right\rangle$$

Semi-classical approach

$$W_N=\prod_i \hbar^3\delta(x_i-x_{i0}(t))\delta(p_i-p_{i0}(t))$$

Double Gaussian approximation

$$W^{\Psi}_{QQ}(r_{rel},p_{rel})=C\,e^{r^2_{rel}\sigma^2}e^{\frac{p^2_{rel}}{\sigma^2}}$$

The Gaussian width σ

$$[\frac{\hbar^2}{2\mu}\nabla^2+V(r)]\Psi_{Q\bar{Q}}(r)=E_{Q\bar{Q}}\Psi_{Q\bar{Q}}$$

$\Leftarrow \langle r^2\rangle \Leftarrow$

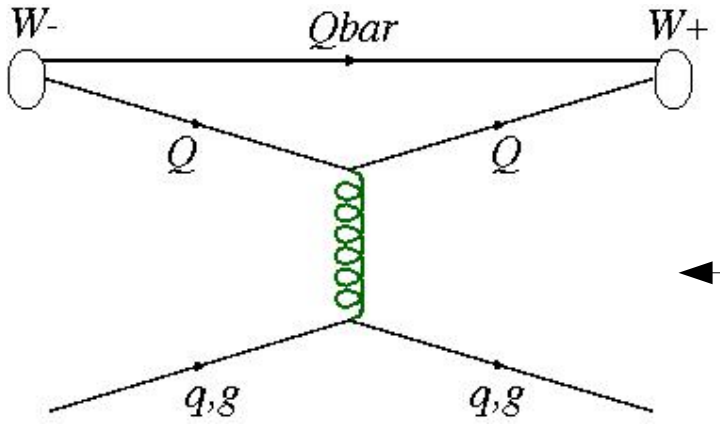
$$\frac{\int e^{-\frac{r^2}{\sigma^2}}r^2d^3r}{\int e^{-\frac{r^2}{\sigma^2}}d^3r}$$

How does it work

Combining the expression of the Wigner's functions and substituting in the effective rate equation

$$\Gamma(t)=\sum_{i=1,2}\sum_{j\geq 3}\delta(t-t_{ij}(\nu))\int\frac{d^3p_i d^3x_i}{h^3}W^{\Psi}_{Q\bar{Q}}(p_1,x_1;p_2,x_2)[W_N(t+\epsilon)-W_N(t-\epsilon)]$$

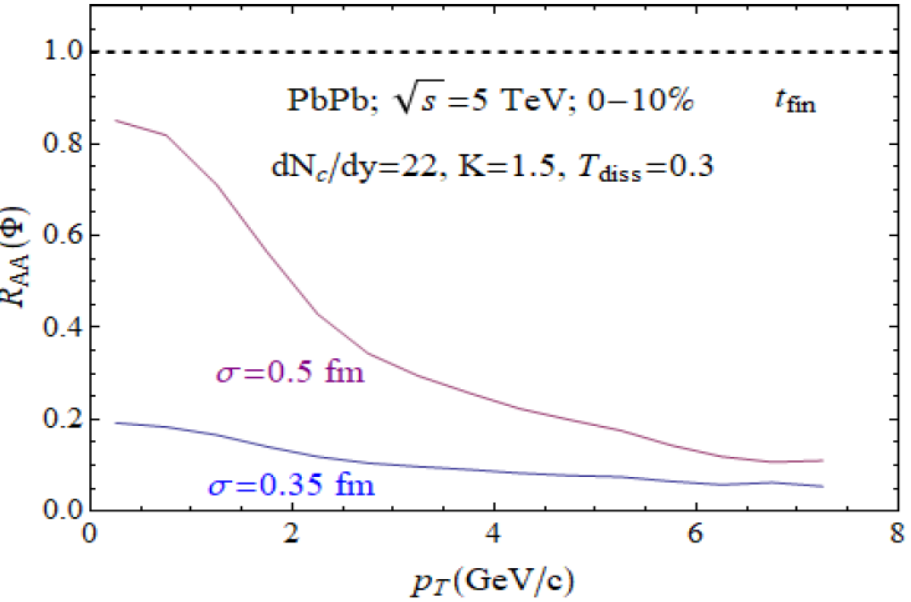
- The quarkonia production in our model is a three body process, the HQ(anti-quark) interact only by collision !!
- Very good results for D and B mesons production



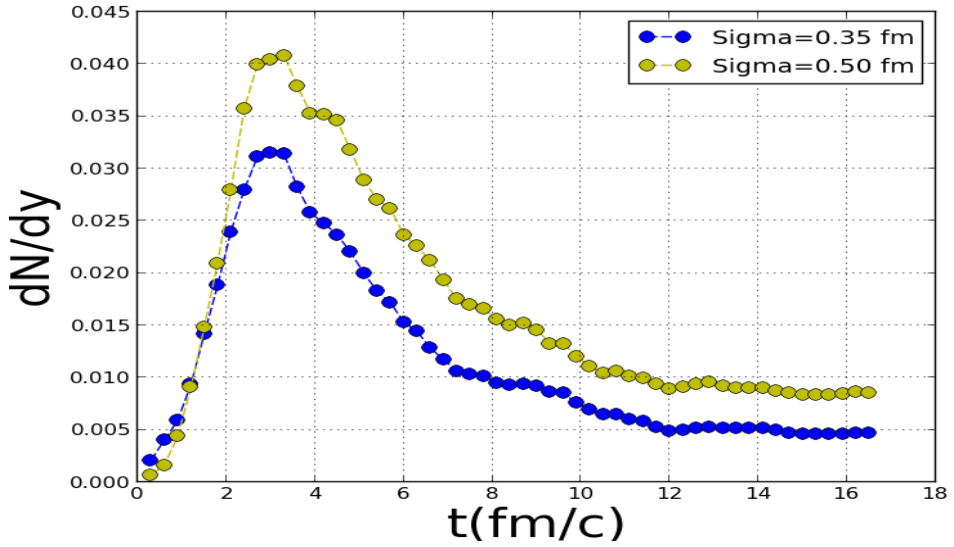
Interaction of HQ with the QGP were carried out by EPOSHQ

$$P^{\Psi}(t)=P^{\Psi}(t^{\Psi}_{init})+\int_{t^{\Psi}_{init}}^{t}\Gamma(t)\,dt$$

Preliminary Results J/Psi

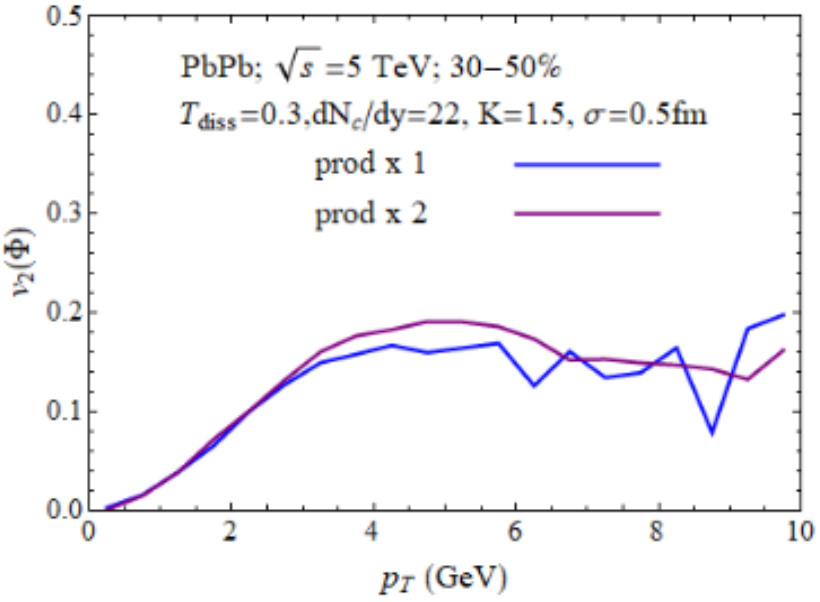


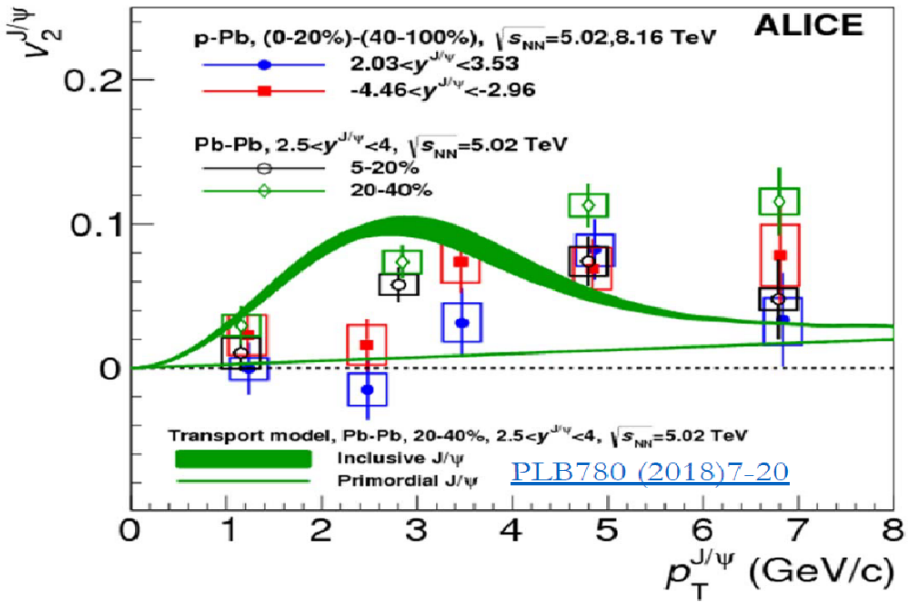
Mid-rapidity and $\sqrt{s}=2.76\,TeV$



Need for temperature dependent Wigner function

Preliminary Results J/Psi





v_2 that extend at rather large p_T

Conclusions

We have presented a model based on the probability density operator that allows us to obtain the evolution of the effective rate of Quarkonia production in QGP.

According with the results, the temperature dependence of the Quarkonia radius needs to be taken into account via optical potential with a temperature dependence (currently on going)

Thanks!!!

Back up

The detail balance law

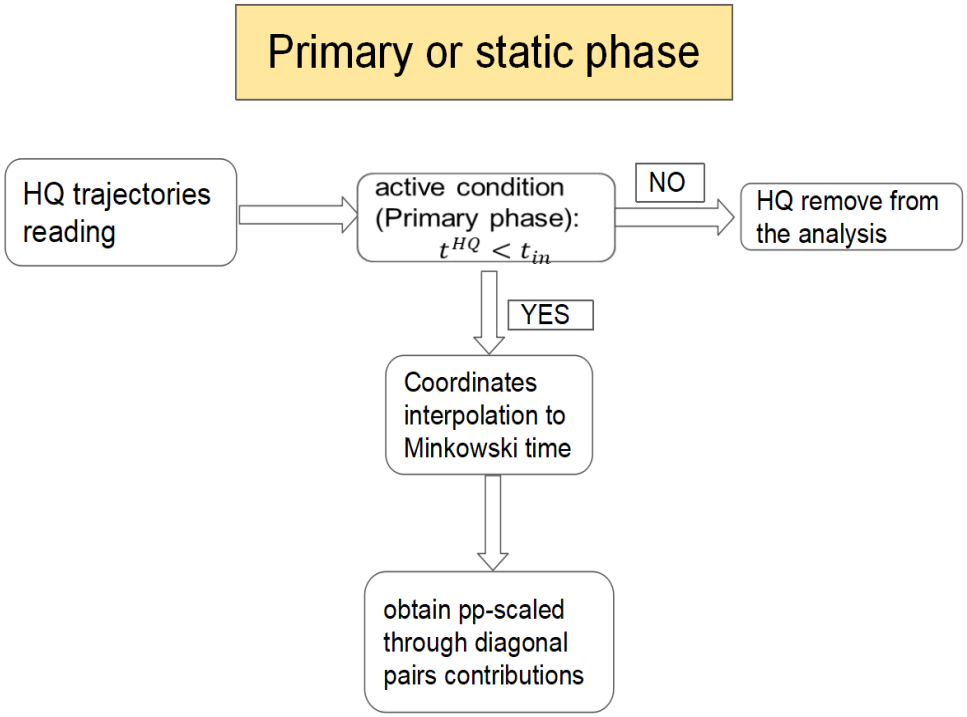
$$J/\Psi + g \Leftrightarrow c + \bar{c} + X$$

Rates Equation

$$\frac{dN_{\Psi}}{d\tau} = \Gamma_{recomb} N_c N_{\bar{c}} [V_{FB}(\tau)]^{-1} - \Gamma_{diss} N_{\Psi}$$

$$\frac{dN_{\Psi}}{d\tau} = -N_{\Psi} L\tau + G(\Psi) = \frac{-1}{\tau_{\Psi}} [N_{\Psi}(\tau) - N_{\Psi}^{eq}(\tau)]$$

Analysis implementation



Analysis implementation