Study of multiplicity dependence of quarkonium production in pp collisions

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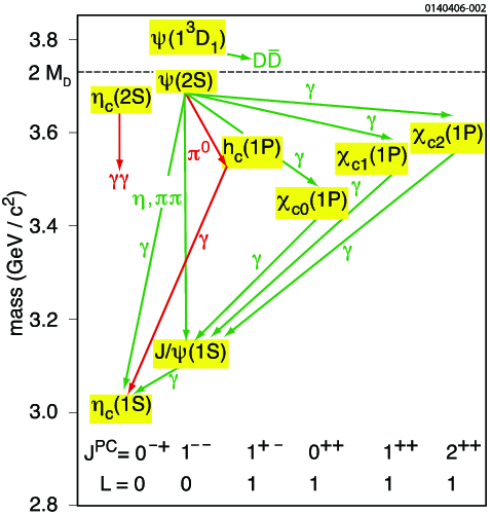
Outline

Quarkonia production

- Charmonia are bond states of charm quark and antiquark.
- Bottomonia are bond states of bottom quark and antiquark.
- Quarkonia are produced primarily in early phase of collision via the hard scattering of two partons.
- Studies of quarkonium production allow to test QCD by comparing it with production models.
- Quarkonium can be used to study QGP.
- QGP can be created in heavy-ion collisions.



[Metreveli, Z. eConf C070805 (2007) 16]

Quarkonium in QGP

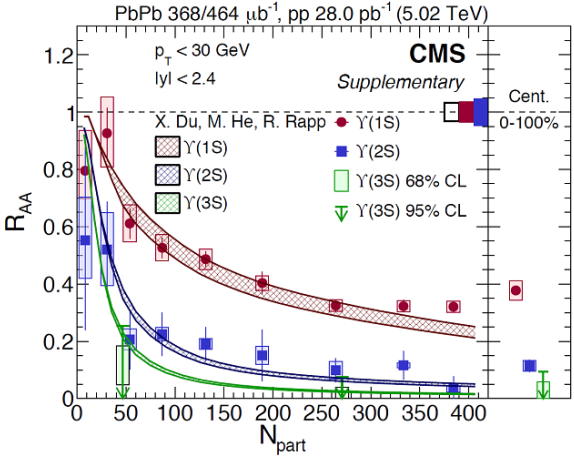
Suppression

- Nuclear modification factor
$$R_{AA}(p_T) = \frac{dN_{AA}/dp_T}{\langle T_{AA} \rangle d\sigma_{pp}/dp_T}$$
- It is caused by Debye-like color screening mechanism.

[Phys.Lett.B 178(4),416-422(1986)]

- The suppression depends on the **temperature of the plasma** and the **binding energy of the quarkonium**. That causes a sequential suppression.

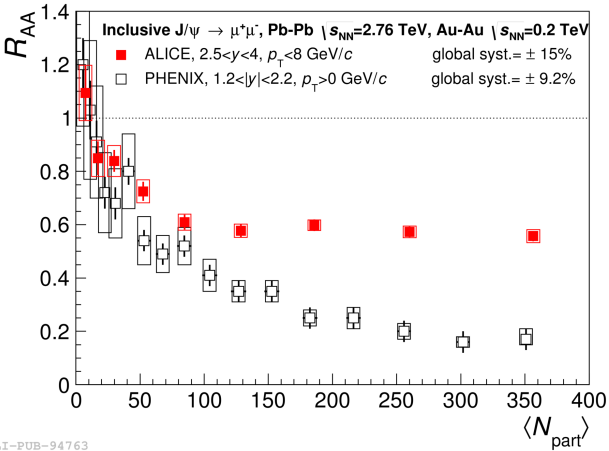
[Phys. Rev. Lett. 109 (2012) 222301]



[Pereira Da Costa, H.D.A. PoS(HardProbes2018)016]

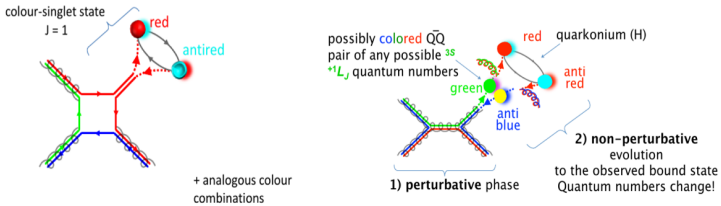
Enhancement [Phys.Rev.C63:054905,2001]

- It is caused by recombination of uncorrelated heavy quark pairs from the hot medium.
- The enhancement happens because there is an **abundance of the heavy quarks**.
- It depends on the **collision energy** and **heavy quark mass**.
- Recombination effect play smaller role for bottomonium than for charmonium.



[Arnaldi, Roberta Nucl.Phys. A956 (2016) 128-135]

Quarkonium production models

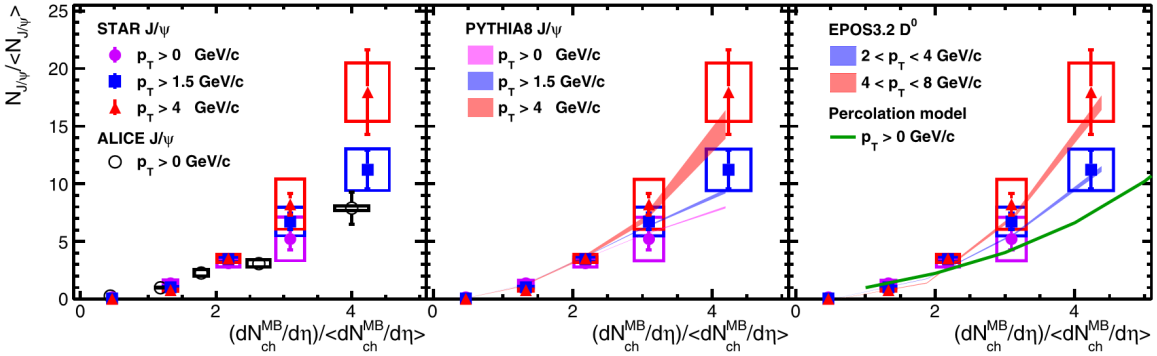


[B. Trzeciak, HQPC 2015]

Models [Phys.Rev. D72 (2005) 014004]

- Color Singlet Model - $Q\bar{Q}$ pair is produced directly in a colorless state.
- Color Octet Model - takes into account all possible $Q\bar{Q}$ pair. It is implemented in NRQCD framework.
- Color Evaporation Model - the $Q\bar{Q}$ pair neutralizes its color by interaction with the collision-induced color field. Gluons are emitted from the initial- and final-state partons.

J/ψ production vs. event activity



[Phys.Lett.B 786,87-93(2018)]

- A strong increase in J/ψ relative yields with N_{ch} is observed.
- A weak dependence on $\sqrt{s}$ of the underlying mechanism is suggested.

Quarkonium production vs. charge particle multiplicity

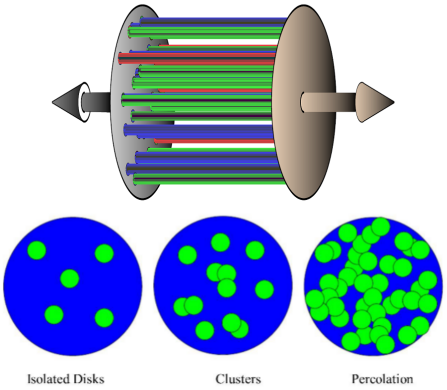
String Precolation Model

- It describes the interaction between strings or color field and its effects on particle production.
- Relation between hard and soft particle production.

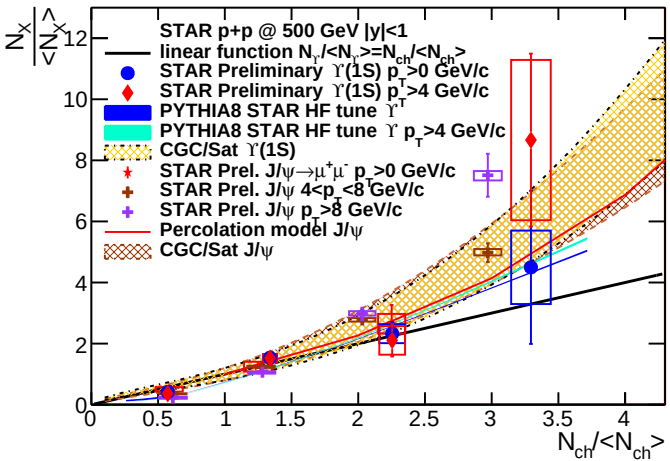
$$\frac{N_{hard}}{\langle N_{hard}\rangle} = \langle\rho\rangle \left(\frac{\frac{dN_{ch}}{d\eta}}{\langle \frac{dN_{ch}}{d\eta} \rangle} \right)^2$$

PYTHIA

- A leading order pQCD-based event generator.



Υ production vs. event activity



- Similar trend can be seen for Υ production as for J/ψ production.
- PYTHIA describes the data well, which suggests that Upsilons are produced in MPI.

Bottomonium Υ

- The current results of the Υ production are mostly obtained on LHC energies.
  [JHEP 04 (2014) 103]
- It has to be expanded to RHIC energies in order to investigate the collision energy dependence for Upsilons.
- Mesaurement of the Υ production for high p_T at RHIC energies is needed to more precisely constrain the models.
- Today STAR has collected $10\times$ more data at high N_{ch} and high p_T using high energy treshold trigger. Such trigger should select Upsilon events.
- Results of this study may provide much better precision: $10\times$ more data $\Rightarrow \sim 1/\sqrt{10}$ $\sim 1/3.16$ statistical uncertainity.

Summary

- A brief overview of physics of charmonium and bottomonium was presented.
  - sequential suppression observed for bottomonium states
  - charmonium enhancement at LHC is possibly due to regeneration
- Quarkonium production models described:
  - Color Singlet model
  - Color Octet model
  - Color Evaporation model
- The predictions of the models were compared in the J/ψ production.
- The J/ψ results were compared with Υ production results from different experiments.
- The STAR has collected more data then previous studies that are waiting to be analyzed and the results will be compared with the J/ψ results and models.

Thank you for your attention!

Backup

BACKUP

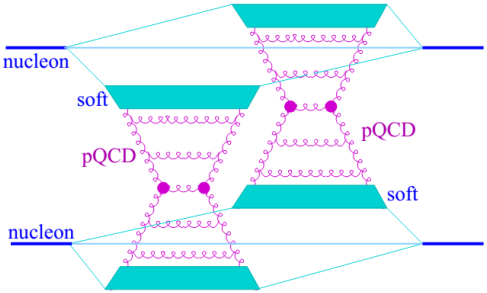
Nucelar modification factor

$$R_{AA}(p_T) = \frac{dN_{AA}/dp_T}{\langle T_{AA} \rangle d\sigma_{pp}/dp_T} \tag{1}$$

- dN_{AA}/dp_T - differential yield in nucleus-nucleus collisions
- $d\sigma_{pp}/dp_T$ - differential cross section in p-p collisions
- nuclear overlap function $\langle T_{AA} \rangle = \langle N_{coll} \rangle / \sigma^{NN}$ - from Glauber model and proportional to the average number of binary nucleon-nucleon collisions $\langle N_{coll} \rangle$
- $R_{AA} = 1$ in absence of initial and final state effects in nuclear collisions

[J. Phys.: Conf. Ser. 458 012013]

EPOS



[https://ejc2018.sciencesconf.org/data/pages/joliot.20.pdf]

- Individual scatterings are referred to as Pomerons, and are identified with parton ladders.
- It assumes initial conditions followed by a hydrodynamical evolution.
- Each parton ladder is composed of a pQCD hard process with initial and final state radiation.
- Non-linear effects are considered by means of a saturation scale.
- The hadronisation is performed with a string fragmentation procedure.

[JHEP 09 (2015) 148]