J/ψ production in Au+Au collisions at $\sqrt{s_{\rm NN}}$ = 200 GeV

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In high-energy nuclear collisions at RHIC, charm quarks are mostly produced by hard scatterings in the initial stages. Since their masses are much larger than the expected thermalization temperature, they are one of the most powerful probes for studying the matter at the early hot and dense stage. Charmonium yields are interesting as they are sensitive to the gluon structure function [1], the effect of the color screening [2], and the possible statistical coalescence of quarks near hadronization [3]. The whole evolution history of the partonic matter in such collisions can be embedded in the charmonium distributions. Here, we will report the STAR preliminary results on the centrality dependence of the J/ψ production in $Au + Au$ collisions at $\sqrt{s_{\rm NN}} = 200$ GeV.

J/ψ were reconstructed via the leptonic decay $J/\psi \rightarrow e^- + e^+$. The electron and positron pairs were measured using the STAR Time Projection Chamber (TPC). After imposing a vertex cut of 30cm along the beam axis, a sample of 12.2 million minimum biased events were extracted from the total event pool of 20 million events.

Assuming the overall efficiency for reconstructing the J/ψ is the same for peripheral $Au + Au$ collisions as in $p + p$ collisions, and that the efficiency does not change drastically from peripheral to central collisions, the integrated yields in $Au + Au$ collisions were extracted using the following formula for the effective total reconstruction efficiency:

$$\epsilon' = dN^{NN}_{J/\psi}/dy * \frac{\langle N_{bin} \rangle}{dN/dy}|^{40-80\%}_{Au+Au}, \qquad (1)$$

where $dN^{NN}_{J/\psi}/dy$ is the yield per unit rapidity in $p + p$ collisions, dN/dy is the yield per unit rapidity in peripheral $Au + Au$ collisions, and $\langle N_{bin} \rangle$ is the corresponding average number of binary collisions. Due to the fact that the prefactor $dN^{NN}_{J/\psi}/dy$ is affected by the uncertainty in the total cross section of charm hadrons, we used two cases in determining the yields. The first one is based on the STAR measurements [4] and the second one is from PHENIX [5], both of which are shown in Figure 1 as circles and squares, respectively. The systematic errors are dominated by the total charm-hadron cross section uncertainty in $p + p$ collisions and is estimated to be of the order of 35%.

As one can see in the figure, the normalized yields are decreasing as with increasing collision centrality. These results clearly demonstrate a trend that is in contrast to some statistical coalescence predictions, shown as curves in the figure. The possible explanations behind the observations are: (i) There is no enhancemed J/ψ yield due to statistical coalescence at the kinetic equilibrium stage as predicted by theoretical models. The initial J/ψ production from gluon-gluon fusion dominates and the total yield, in central collisions, is suppressed by color screening; and/or (ii) the nuclear shadowing effect [1] is so strong that it affects the final yields of both open-charm and J/ψ . The effect depends on the nuclear atomic number.

Future measurement of the transverse momentum distribution for J/ψ will shed light on the J/ψ production mechanism.

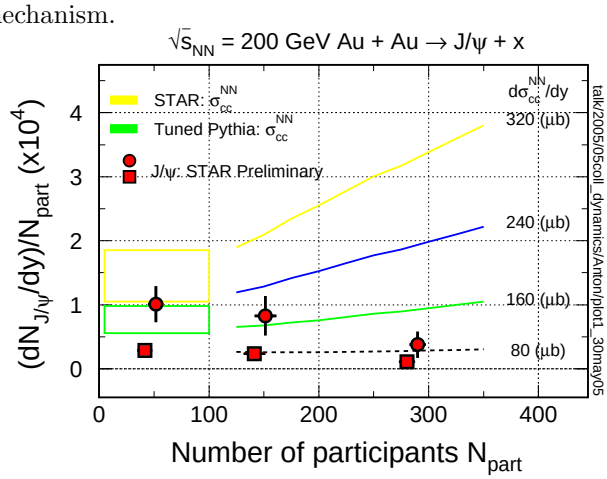

FIG. 1: The STAR preliminary results of the mid-rapidity J/ψ yields as a function of collision centrality. Circles and squares represent two different scaling factors; one for $\sigma^{NN}_{c\bar{c}} = 1400$ (μb) [4] and the other for $\sigma^{NN}_{c\bar{c}} = 350$ (μb) [5], respectively. The raw yields were extracted by assuming a peak width of 26 MeV/c^2 for all centralities, which was fixed by the peak observed in minimum biased events. All errors are statistical and the estimated systematical errors are of the order of 35%, which are dominated by the uncertainty in the total charm-hadron cross section in $p + p$ collisions. In both cases the N_{part} normalized yields are decreasing with increasing collision centrality. The model predictions are from [6].

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