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Quarkonia in d + Au and vector mesons in the forward rapidity at Phenix detector

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Quarkonia measurements in deuteron+gold(d + Au) collisions are important for understanding production mechanisms and cold nuclear effects like shadowing, nuclear absorption, or initial state energy loss of gluon. These cold nuclear effects serve as a baseline for detecting additional effects from a Quark-Gluon Plasma(QGP) created in Au+Au collisions. Different quarkonia have different Debye screening lengths in the QGP depending on their radii. By measuring the relative yields of different quarkonia, one can quantitatively compare the experimental results to the theoretical predictions from finite temperature lattice QCD and possibly deduce the initial temperature of the QGP created. The PHENIX muon arms can measure quarkonia production in the deuteron-going ($1.2 < \eta < 2.2$) and the gold-going($-2.2 < \eta < -1.2$) directions. Nuclear modification factors and cross sections of and $\Upsilon_{1S+2S+3S}$ from d + Au and $p+p$ collisions at $\sqrt{s_{NN}} = 200$ GeV are shown. In addition, nuclear modification factors of J/ψ and light vector mesons are shown from d + Au collision.

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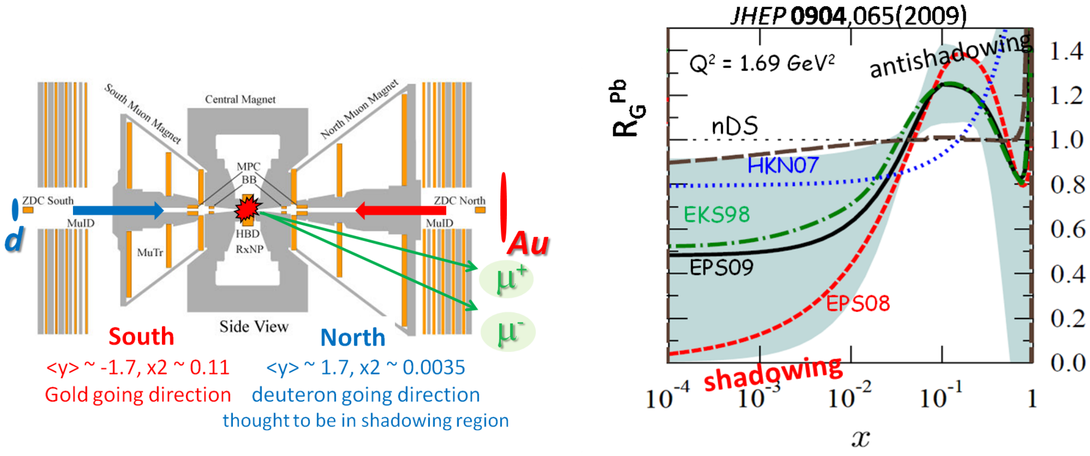

Figure 1: (Color online) PHENIX muon arms. Deuteron goes from south to north and gold goes from north to south(left). Gluon modification for Pb nucleus from EKS98, EKPS, nDS, HKN07, and EPS09LO(right)[1].

1. Introduction

Given that quarkonia have different binding radii, they should melt at different temperatures due to color screening in the QGP. [2]. The observation of quarkonia suppression in $A+A$ collisions can be used to estimate the temperature of the medium, or test models, like regeneration. Quarkonia suppression can also be produced by cold nuclear matter effects. Quarkonia measurements in d + Au collisions allows one to parametrize cold nuclear matter effects and can give insight into production mechanisms. In positive rapidity(deuteron-going direction), gluons, which are the dominant source of quarkonia production, are estimated to be in the shadowing region with momentum fractions in Au, $x_2 \sim 3\times10^{-3}$ for PHENIX muon arm in d + Au collision(Figure 1)[3]. This measurement will also be the baseline to understand the hot dense matter of Au + Au collision. To measure the nuclear effect, nuclear modification factors are calculated using R_{dAu} or R_{cp}.

$$R_{dAu} = \frac{(\frac{dN_{d+Au}}{dy} / < N_{coll} >)}{(\frac{dN_{p+p}}{dy})} \tag{1.1}$$

$$R_{cp} = \frac{(\frac{dN_{d+Au}}{dy} / < N_{coll} >)}{(\frac{dN^{60-88\%}_{d+Au}}{dy} / < N^{60-88\%}_{coll} >)} \tag{1.2}$$

For R_{dAu}, N_{coll} is the number of binary collisions and dN/dy is the invariant yield of each rapidity region. For R_{cp}, peripheral collisions are used as a reference rather than $p+p$ collisions. So $N^{60-88\%}_{coll}$ is the number of binary collisions in peripheral collision of 60-88% centrality. If there is no nuclear matter modification, these nuclear modification factors become one[4].

2. J/ψ measurement

In 2008, the integrated luminosity accumulated in d + Au collisions was about 40 nb^{-1}, which

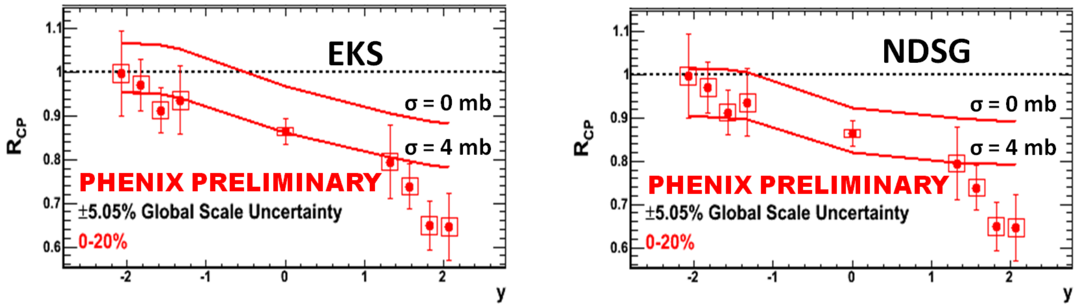

Figure 2: (Color online) J/ψ nuclear modification R_{cp} versus rapidity compared to shadowing models of EKS [5] and NDSG [6] nuclear parton distribution modification fuctions(nPDFs). Each shadowing model has uniform breakup cross sections of 0 mb and 4mb.

is about thirty times larger than 2003 Run which was from 1.4 to 1.7 nb^{-1}[4]. Figure 2 shows the preliminary result of J/ψ nuclear modification factor R_{cp} vs. rapidity of 0-20% central region from 2008 data. They show suppression at small x region, but when we compare the data with shadowing models of EKS[5] and NDSG[6] nuclear parton distribution modification functions(nPDFs) which is using Color Evaporation Model(CEM)[7], data doesn't match with the models with fixed breakup cross sections. They show steeper suppression than fixed breakup cross sections. We need to understand the suppression of shadowing region. Upcoming R_{dAu} result of J/ψ will extend this study.

3. $\Upsilon_{1S+2S+3S}$ measurement

A minimum-bias trigger that required hits in each of the two beam-beam counters (BBCs) located at positive and negative rapidity ($3 < |\eta| < 3.9$) was used to record the data for Υ analysis. Pythia event generator and GEANT simulation package was used to estimate the physical backgroud of the Drell-Yan, the correlated open bottom and correlated open charm around $\Upsilon_{1S+2S+3S}$ mass region (Figure 3). When we see the rapidity dependence of $\Upsilon_{1S+2S+3S}$ cross section in $p+p$ collisions, the points, together with the mid-rapidity point[9], follow the shape of Color Evaporation Model with CTEQ6M PDF[8](Figure 4). And for the R_{dAu} of $\Upsilon_{1S+2S+3S}$, one can note a trend for a stronger suppression at the forward rapidity as we see for J/ψ(Figure 4).

4. Light vector meson measurement

Figure 5 shows first nuclear modification factor measurement for low mass vector mesons in forward rapidity, which is from 2008 d + Au data. Signal was extracted after subtracting the background using vertex χ^2. There is significant suppression at deuteron going direction where ρ/ω are suppressed more strongly than ϕ and J/ψ. That might be due to lighter quark content, and/or different production mechanisms.

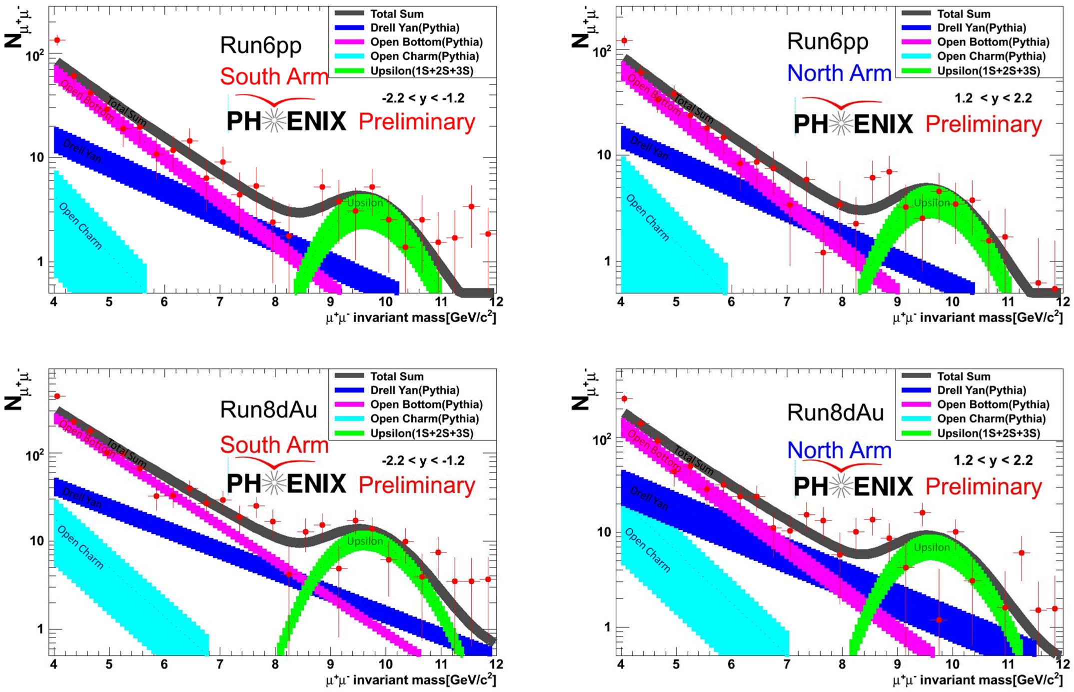

Figure 3: (Color online) Invariant mass distiributions of dimuons in the mass region of $\Upsilon_{1S+2S+3S}$ got from 2006 $p+p$ collisions (top) and 2008 d + Au collision(bottom). After combinatorial background subtraction, data points are drawn together with expected contributions for spectrum.

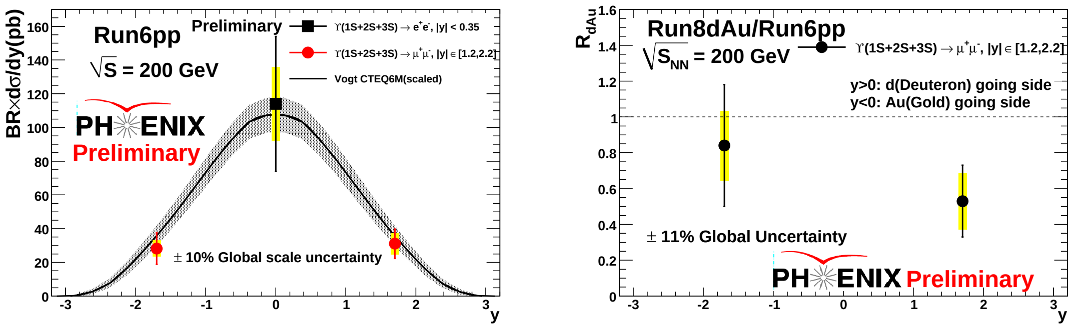

Figure 4: (Color online) $\Upsilon_{1S+2S+3S}$ cross section versus rapidity. Fit by Color Evaporation Model(CEM)-CTEQ6M(PDF) after arbitrary normalization(left)[8]. R_{dAu} of $\Upsilon_{1S+2S+3S}$ versus rapidity. Positive rapidity is deuteron-going direction, i.e. small x region(right).

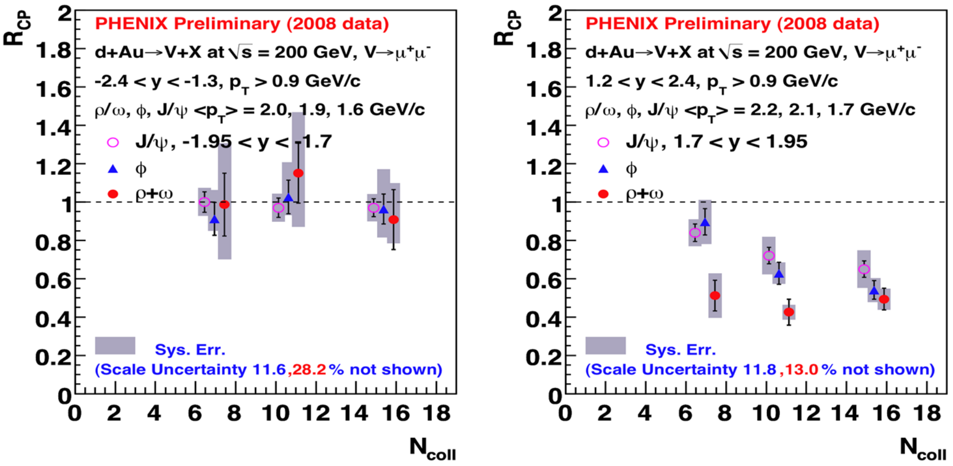

Figure 5: (Color online) R_{cp} vs N_{coll} of ϕ, $\rho+\omega$ and J/ψ in the backward region (left) and forward region (right).

5. Summary and future

Nuclear modification factors of $\Upsilon_{1S+2S+3S}$, J/ψ and light vector mesons are shown. They show suppression at low x region, but not clearly understood yet. Recent R_{cp} of J/ψ is not explained well with shadowing model and fixed breakup cross sections. New R_{dAu} of $\Upsilon_{1S+2S+3S}$ shows suppression in low x region and is waiting for having theoretical comparision for better understanding. Low mass vector mesons suppression requires the understanding of their production mechanisms. In future, PHENIX FVTX/VTX upgrade can help to reduce the background and improve the mass resolution of dimuon, turning possible the discrmination of ψ' mesons.

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