J/ψ PRODUCTION IN U+U COLLISIONS AT THE STAR EXPERIMENT*

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Quark–gluon plasma (QGP), a novel state of deconfined nuclear matter, has been studied in high-energy heavy-ion collisions at the Relativistic Heavy Ion Collider (RHIC). Due to the color screening of the quark–antiquark potential in the QGP, production of heavy quarkonia (*e.g.* J/ψ, Υ) is expected to be suppressed. However, there are also other effects that may influence the observed quarkonium yields (*e.g.* secondary production in the QGP, cold-nuclear-matter effects). To understand those effects, we need to study production of heavy quarkonia in various colliding systems. We present preliminary results on nuclear modification factor of J/ψ production at mid-rapidity via the di-electron decay channel in minimum bias U+U collisions at $\sqrt{s_{NN}} = 193$ GeV at the STAR experiment and the current status of analysis of J/ψ production in central U+U collisions.

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1. Introduction

Measurements of heavy quarkonium production in heavy-ion collisions are used to study properties of the QGP. Heavy quarkonium production is expected to be suppressed in the presence of the QGP compared to production in $p + p$ collisions due to the color screening of the quark–antiquark potential in the deconfined medium. This phenomenon has long been considered as one of the most prominent signatures of the QGP [1].

However, there are other effects that may modify the observed suppression such as cold-nuclear-matter effects, feed down effects, secondary production via coalescence of charm quarks. To understand these different

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mechanisms it is important to study the heavy quarkonium production in different collision systems and at different collision energies and centralities.

Modification of heavy quarkonium production in nucleus+nucleus collisions ($A+A$) compared with $p+p$ collisions is usually quantified by the so-called nuclear modification factor R_{AA}. It is defined as the ratio of the number of particles produced in $A+A$ collisions to the number of particles produced in $p+p$ collisions scaled by the average number of binary nucleon–nucleon collisions $\langle N_{\rm bin}\rangle$. With no medium effect, the yield of heavy quarkonia in heavy-ion collisions should scale with the number of elementary binary collisions and the resulting R_{AA} should be equal to unity. As it turns out, the medium produced in heavy-ion collisions can modify this scaling resulting in the effect of suppression $R_{AA} < 1$ or enhancement $R_{AA} > 1$.

At the STAR experiment, effects of the hot medium on J/ψ production have been studied in Au+Au collisions at $\sqrt{s_{NN}} = 39$, 62.4, 200 GeV [2–4]. STAR has also collected data on U+U collisions at $\sqrt{s_{NN}} = 193$ GeV. Since U nuclei are larger than Au nuclei, it is expected that in the U+U collisions, the energy density of the created medium is higher than in Au+Au collisions [5]. This applies particularly for the most central U+U collisions in which the achievable energy density is expected to be up to $\sim 20\%$ larger relative to Au+Au collisions. Thus, they allow for further testing of the color screening hypothesis [5].

2. Data analysis

The Solenoidal Tracker at RHIC (STAR) [6] is a multi-purpose detector composed of various subsystems. It excels in tracking and identification of charged particles at mid-rapidity and with full coverage in azimuth.

In the analyses presented here, J/ψ was studied in 377 M of minimum bias and 115 M of 0–5% most central U+U collisions collected in 2012 at $\sqrt{s_{NN}} = 193$ GeV at STAR. J/ψ signal was reconstructed via the di-electron decay channel ($J/\psi \rightarrow e^+e^-$) with a branching ratio $B_{ee} = 5.9\%$. Electron candidates were selected from tracks which satisfied selection criteria on signals in the STAR Time Projection Chamber (TPC) [7], Time-of-Flight (TOF) [8] detector and Barrel Electromagnetic Calorimeter (BEMC) [9]. The TPC provides particle tracking and identification via their specific energy loss dE/dx. $n\sigma_e^{\rm TPC}$, the difference from the expected $\ln(dE/dx)$ for electrons expressed in terms of standard deviation units, was required to be in the range of $(-1.5, 2.0)$ for all electron candidates. The TOF detector measures velocity $\beta^{\rm TOF}$ of the particles and together with TPC enables separation of electrons from hadrons up to 1.4 GeV/c. For particles with momenta lower than stated, we required $0.970 < 1/\beta^{\rm TOF} < 1.025$. The cut on $1/\beta^{\rm TOF}$ for $p > 1.4$ GeV/c was used if particles had a signal in TOF.

The BEMC measures energies of high-p_{T} particles. Its fast response allows to trigger on high-p_{T} electrons. This is called the High Tower (HT) trigger. Since electrons are expected to deposit all of their energy in the detector while hadrons not, the BEMC is used for electron–hadron separation by pc/E^{BEMC} cut, where E^{BEMC} is the energy deposited in the BEMC and p is the momentum of the track. For particles with $p > 1.4$ GeV/c, we required $E^{\mathrm{BEMC}} > 0.15$ GeV and $0.5 < pc/E^{\mathrm{BEMC}} < 2.0$ in minimum bias and $0.7 < pc/E^{\mathrm{BEMC}} < 2.0$ in 0–5% most central collisions. Figure 1 shows $1/\beta^{\mathrm{TOF}}$ and $n\sigma_e^{\mathrm{TPC}}$ distributions and application of corresponding cuts in 0–5% most central collisions.

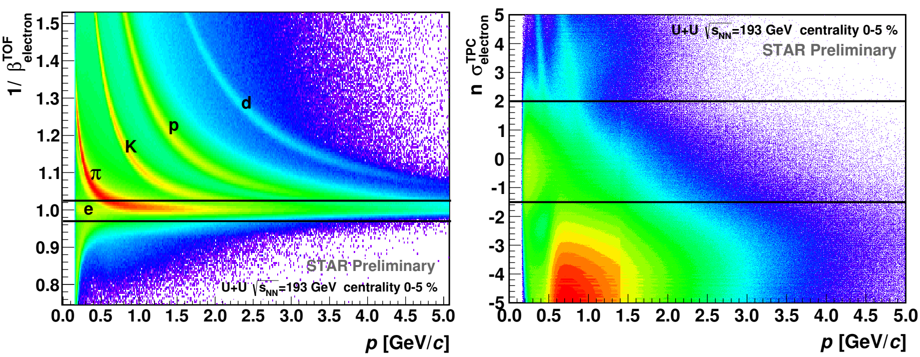

Fig. 1. Left: $1/\beta^{\mathrm{TOF}}$ of particles with depicted cut for electron candidates (black lines). Right: $n\sigma_e^{\mathrm{TPC}}$ of particles satisfying TOF and BEMC cuts, black lines denote the $n\sigma_e^{\mathrm{TPC}}$ cut.

3. Results

J/ψ signal was reconstructed from the invariant mass distributions of the e^+e^- pairs. Combinatorial background of the J/ψ signal was estimated by the like-sign in minimum bias and mixed-event background method in 0–5% central data. After the combinatorial background subtraction, the invariant mass distribution of di-electron pairs was fitted with a crystal ball function to describe the signal, while the residual background was fitted with a linear function. Figure 2 shows J/ψ signal after combinatorial background subtraction and fits for the signal and the background in minimum bias (left panel) and 0–5% central (right panel) U+U collisions. The J/ψ yield calculated by the bin counting method in the invariant mass region (2.9, 3.2) GeV/c^2 was 9440 ± 640 with a significance of 12.9σ in minimum bias and 4960 ± 580 with a significance of 8.6σ in 0–5% central U+U data.

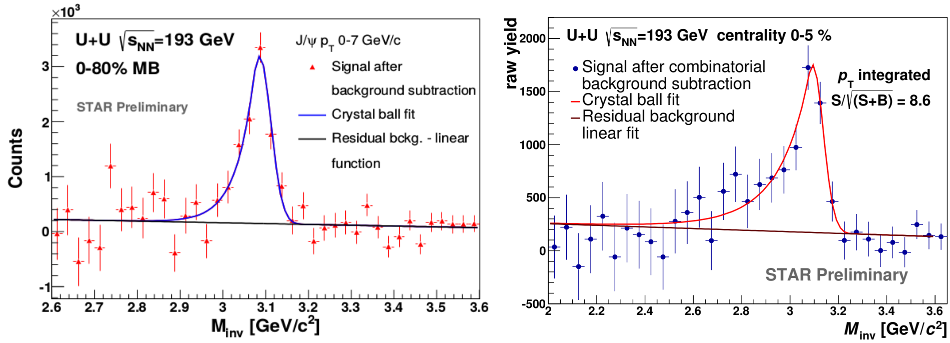

Fig. 2. J/ψ signal after combinatorial background subtraction fitted with a crystal ball function together with a linear function used to describe the residual background in minimum bias (left) and 0–5% central (right) U+U collisions.

Figure 3 (left panel) shows STAR preliminary results on J/ψ invariant yield in minimum bias and HT triggered U+U collisions. To quantify the hot medium effects on J/ψ production, nuclear modification factor in minimum bias Au+Au and U+U collisions has been measured [2–4]. The right panel of figure 3 shows the nuclear modification factor in minimum bias and HT triggered U+U collisions [2]. R_{AA} as a function of $p_{\rm T}$ is similar to that observed in Au+Au at $\sqrt{s_{NN}} = 200$ GeV [2].

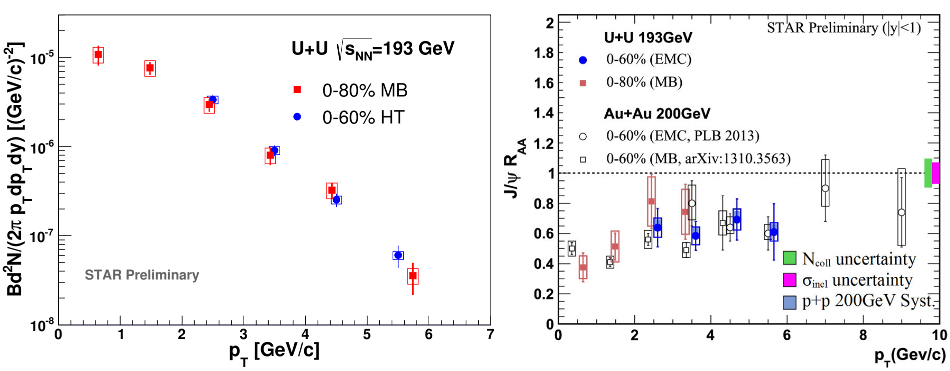

Fig. 3. Left: J/ψ invariant yield *versus* transverse momentum in minimum bias and HT triggered U+U collisions. Right: J/ψ R_{AA} as a function of $p_{\rm T}$ in minimum bias and HT triggered Au+Au and U+U collisions [2].

4. Summary

In this work, we have presented preliminary results on nuclear modification factor for J/ψ production in minimum bias U+U collisions at $\sqrt{s_{NN}} = 193$ GeV at the STAR experiment and the current status of J/ψ production analysis in 0–5% most central U+U collisions. Suppression of J/ψ production in minimum bias U+U collisions is similar to that observed in $\sqrt{s_{NN}} = 200$ GeV Au+Au collisions. In 0–5% most central U+U collisions, a strong signal of J/ψ of significance 8.6σ has been observed.

Data analysis leading to the extraction of J/ψ nuclear modification factor in 0–5% most central U+U collisions is underway. Results of this analysis will extend our knowledge of J/ψ production modification in U+U collisions at the highest achievable energy density at RHIC.

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