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J/ψ production in U+U collisions at $\sqrt{s_{NN}} = 193$ GeV in the STAR experiment

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Extensive studies of quark-gluon plasma (QGP), the novel state of strongly interacting matter governed by partonic degrees of freedom, have been conducted at RHIC for over a decade. Suppression of quarkonia production in high energy nuclear collisions relative to proton-proton collisions, due to Debye screening of the quark-antiquark potential, has been predicted to be a sensitive indicator of the temperature of the created QGP. However, cold nuclear matter effects, production via recombination of quark-antiquark pairs in the QGP and dissociation in hadronic phase could also alter the observed quarkonia yields. Indeed, recent measurements in Au+Au and d+Au collisions at RHIC show that these effects play a non-negligible role. Hence systematic measurements of the quarkonia production for different colliding systems are crucial for understanding the quarkonium interactions with the partonic medium, and then the QGP properties. To further study the pattern of quarkonia suppression we can utilize the collisions of non-spherical nuclei such as uranium. In this paper, we will present the analysis status on J/ψ production, measured at midrapidity via di-electron decay channel, in U+U collisions at $\sqrt{s_{NN}} = 193$ GeV in the STAR experiment.

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1. Motivation

Measurements of J/ψ in-medium dissociation in heavy ion collisions are expected to provide an estimate of the initial temperature of the system [1]. To understand medium induced modification it is beneficial to study J/ψ in various colliding systems. In STAR, J/ψ has been measured in p+p, d+Au, Au+Au and Cu+Cu collisions at $\sqrt{s_{NN}} = 200$ GeV [2][3] and Au+Au collisions at $\sqrt{s_{NN}} = 39$ GeV and 62 GeV [4]. U+U collisions are of interest since uranium nucleus is non-spherical, which leads to higher initial energy density compared to Au+Au not only in tip-to-tip collision, but even when averaged over all possible orientations of colliding nuclei [5].

2. Data Analysis

STAR is a multi-purpose detector excelling at tracking and identification of charged particles at mid-rapidity in the high multiplicity environment of heavy ion collisions. The main subsystems used for electron selection in this analysis are:

– Time Projection Chamber (TPC): momentum reconstruction together with particle identification via specific ionization energy loss dE/dx.
– Time of Flight (TOF): particle identification by measuring velocity β.
– Barrel Electromagnetic Calorimeter (BEMC): electron-hadron separation via momentum/energy ratio.

These results are based on analysis of 377 millions of minimum bias uranium collisions at $\sqrt{s_{NN}} = 193$ GeV taken in 2012 by the STAR experiment at RHIC. Sample of 0-80 % most central events with vertex z position within 30 cm of the center of the detector are used. Electrons were selected from good quality tracks by requiring $-1.5 < n\sigma_{\mathrm{electron}} < 2$ and $|n\sigma_{\mathrm{pion}}| > 2.5$ where $n\sigma$ is a distance from the expected mean value of the energy loss expressed as a number of standard deviations. The value of $1/\beta$ was required to be between 0.97 and 1.03. This cut has to be fulfilled for all particles with momentum lower then 1.4 GeV/c, for particles with p > 1.4 GeV/c the cut is applied only if they have a valid TOF signal. For particles with p > 1.4 GeV/c information from BEMC is also used for electron-hadron separation requiring the ratio 0.3 < p/E < 1.5, where E is an energy deposited by particle in a single BEMC tower. This takes advantage of the fact that electrons, unlike hadrons, deposit most of their energy in the calorimeter. Fig. 1 shows $n\sigma_{\mathrm{electron}}$ and $1/\beta$ distributions and applied cuts.

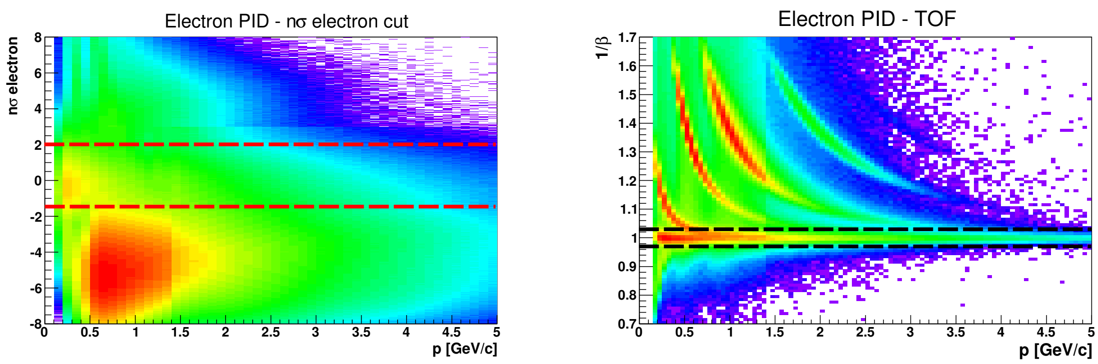

Figure 1: Left: TPC $n\sigma_{\mathrm{electron}}$ for particles which have already fulfiled TOF and BEMC cuts. Right: TOF $1/\beta$ vs. momentum for particles which have already passed TPC and BEMC cuts. Dashed lines show the selected region.

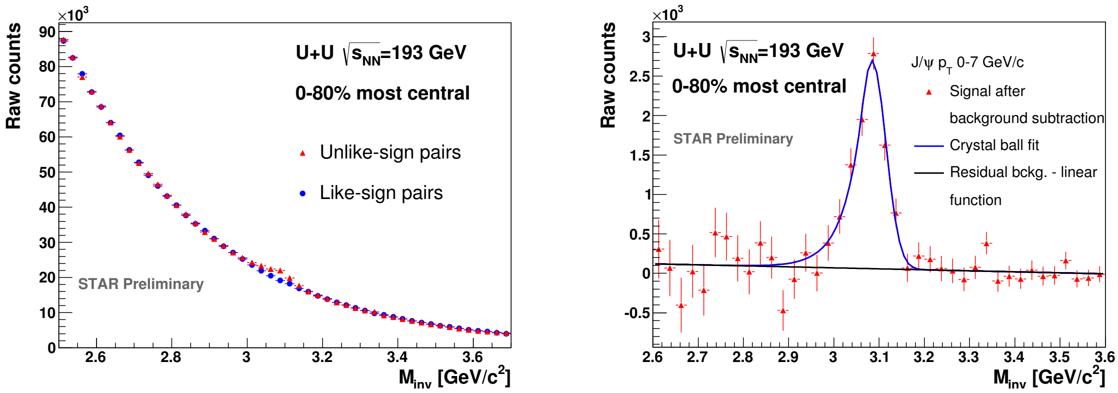

Figure 2: Left: Invariant mass of unlike-sign and like-sign electron (positron) pairs in 0-80 % most central U+U collisisons at $\sqrt{s_{NN}} = 193$ GeV. Right: Signal after background subtraction fitted with crystal ball function superimposed on a linear residual background.

3. Results and Summary

J/ψ is reconstructed via di-electron decay channel with branching ratio of 5.9 %. Combinatorial background is reconstructed using invariant mass of like-sign pairs. Signal after background subtraction is than fitted with crystal ball function[6] to describe the signal and linear function to account for residual background. Signal before and after combinatorial background subtraction is shown on Fig. 2. Signal in mass region $(2.9-3.2)$ GeV/c^2 is 9440 ± 640 with significance of 12.9σ. This will make possible to divide the signal into several p_T bins going up to 7 GeV/c.

To conclude, in this work we have presented the current status of J/ψ analysis in U+U collisions at $\sqrt{s_{NN}} = 193$ GeV collected by the STAR experiment. Strong J/ψ signal has been observed in 0-80 % most central miminum bias collisions. This available statistics will allow us to extract nuclear modification factor R_{AA} as a function of p_T and centrality, therefore shedding more light on the effects associated with in-medium dissociation of heavy quarkonia.

Acknowledgments

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