J/ψ production in U+U collisions at the STAR experiment

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Introduction

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 the production of heavy quarkonia (e.g. J/ψ, Υ) is expected to be supressed. However, there are also other effects that may influence the suppression pattern of heavy quarkonia (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 reconstructed at midrapidity via di-electron decay channel in minimum-bias U+U collisions at $\sqrt{s_{NN}} = 193$ GeV at the STAR experiment and current status of analysis of J/ψ production in central U+U collisions.

Motivation

- In the most central U+U collisions the energy density of the created medium is expected to be higher than in Au+Au collisions [1].

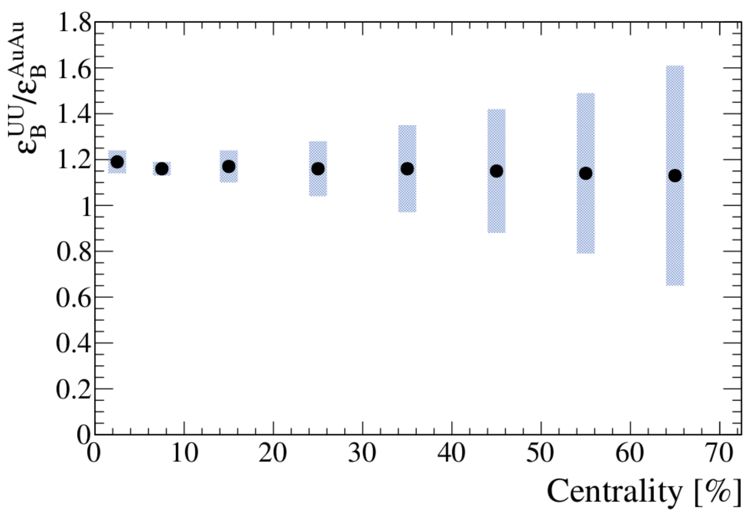

Fig. 1: Estimate of the ratio of energy density in U+U and Au+Au collisions as a function of centrality [1].

- 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 and in U+U collisions at $\sqrt{s_{NN}} = 193$ GeV.

- In minimum-bias U+U collisions the nuclear modification factor R_{AA} as a function of p_T is similar to that observed in Au+Au at $\sqrt{s_{NN}} = 200$ GeV.

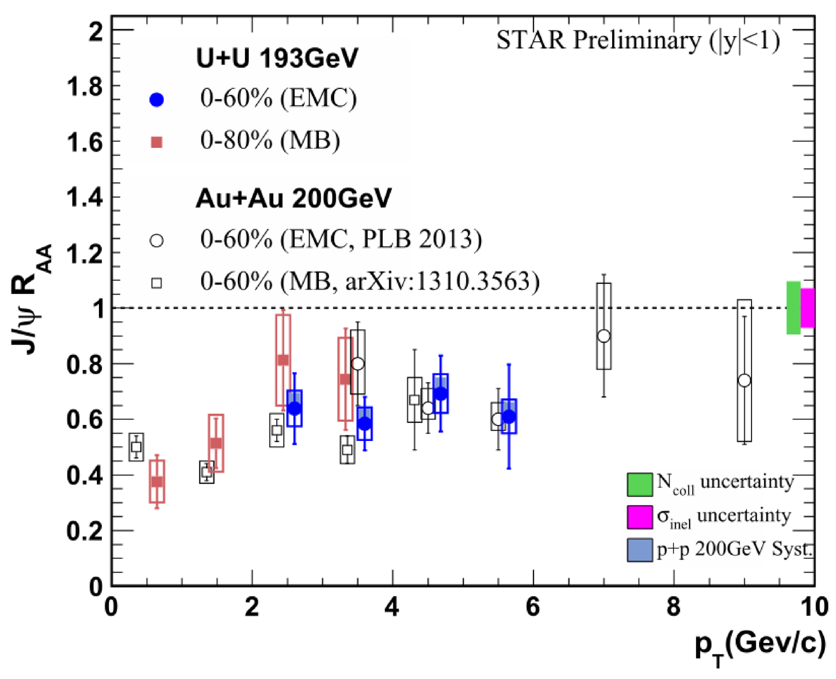

Fig. 2: R_{AA} p_T dependence of J/ψ in minimum bias and high tower triggered Au+Au and U+U collisions [2].

- 0-5 % most central U+U collisions enable to study the centrality dependence of J/ψ R_{AA}.

STAR Detector

- The Solenoidal Tracker at RHIC (STAR) was designed to investigate the strongly interacting matter by detecting charged particles emerging from collisions.

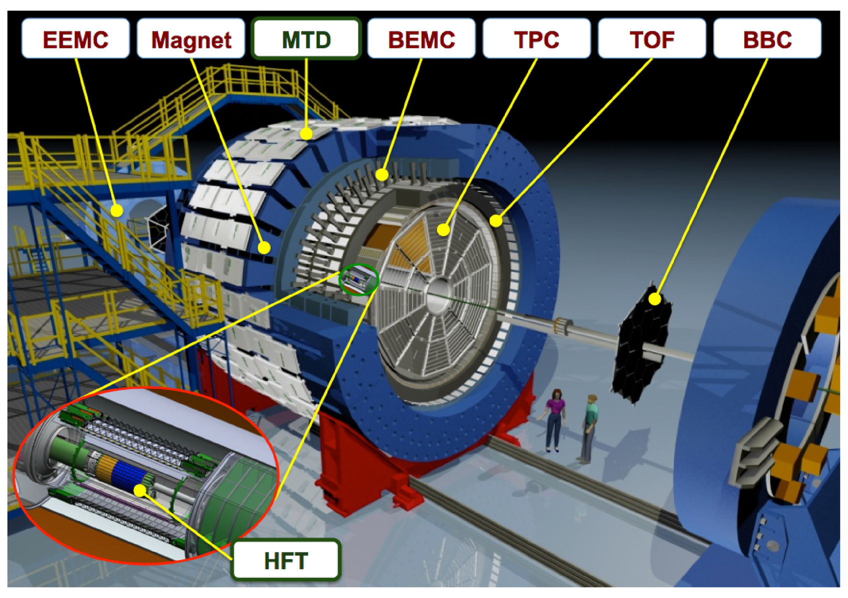

Fig. 3: Layout of the STAR detector.

- STAR excels in tracking and identification of charged particles in midrapidity and 2π in azimuth.
- Most of the subsystems of the experiment are located in 0.5 T of solenoidal magnetic field.
- **Trigger detectors** decide which collisions are suitable for detection and recording.
  - → Centrality triggers: centrality is determined by **Zero Degree Calorimeters** based on measured energy of spectator neutrons combined with multiplicity information from TOF.

- Main subdetectors used for this analysis are:
  - → **Time Projection Chamber** (TPC): main tracking device of STAR, particle identification via their specific energy loss dE/dx.

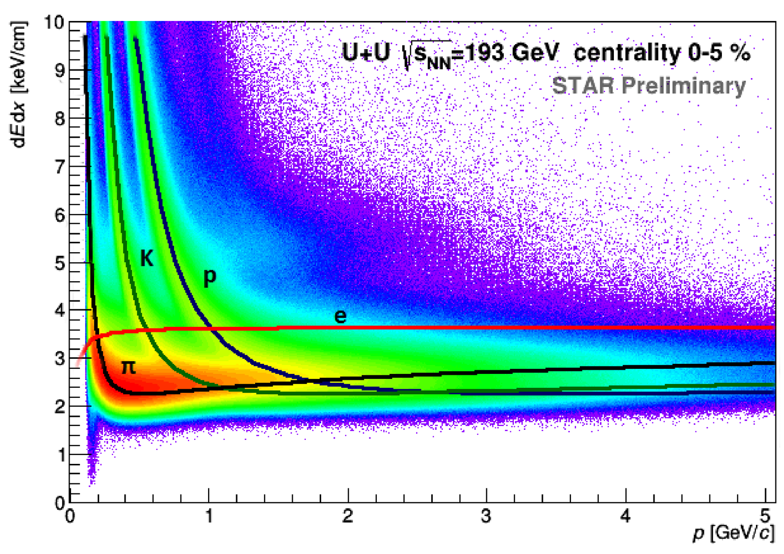

Fig. 4: dE/dx of charged particles.

  - → **Time of Flight** (TOF) detector: $1/\beta$ of the particles, together with TPC: separation of electrons from hadrons up to 1.4 GeV/c.
  - → **Barrel Electromagnetic Calorimeter** (BEMC): electron-hadron separation via p/E at high momentum.

Data analysis in 0-5 % most central U+U collisions

- Data used for this analysis are 115 M of 0-5 % most central U+U collisions at $\sqrt{s_{NN}} = 193$ GeV taken in 2012.
- J/ψ decay electron candidates are selected from good quality tracks satisfying the following criteria:

→ TPC:
- $p_T > 1.0$ GeV/c
- $-1.5 < n\sigma_e < 2.0$
  $n\sigma_e$ is the distance from the expected dE/dx for electrons expressed in terms of standard deviation units
- required for all particles

→ TOF:
- $0.97 < 1/\beta < 1.025$
- required for $p < 1.4$ GeV/c
- for $p > 1.4$ GeV/c required only if particle has signal in TOF

→ BEMC:
- $E > 0.15$ GeV
  E is energy deposited in the BEMC tower
- $0.7 < pc/E < 2.0$
- required for $p > 1.4$ GeV/c

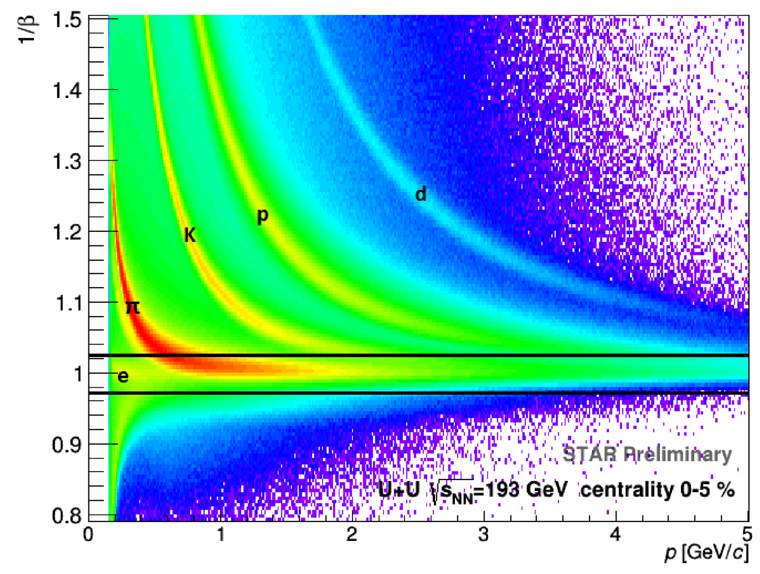

Fig. 5: $1/\beta$ of particles with cut applied on electron candidates (black lines).

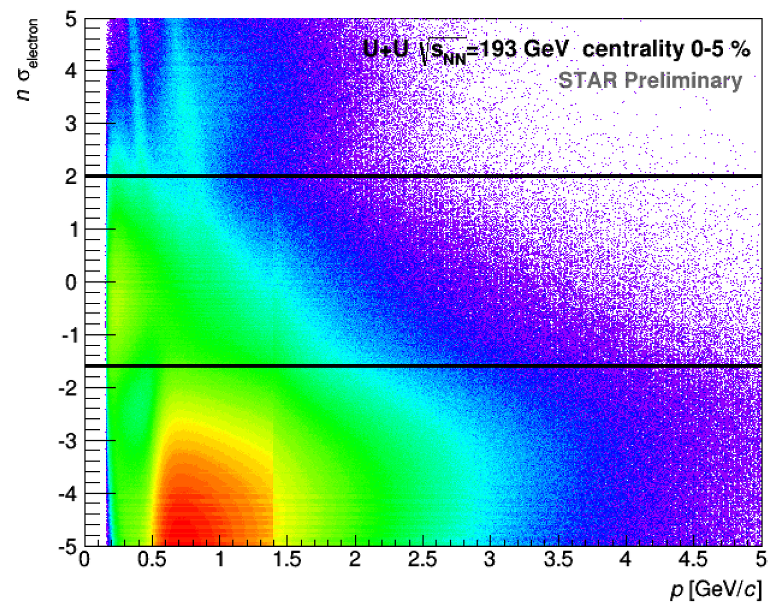

Fig. 6: $n\sigma_e$ of particles satisfying TOF and BEMC cuts, black lines denote $n\sigma_e$ cut.

Results

- J/ψ reconstructed at midrapidity via di-electron decay channel: $J/\psi \to e^+e^-$ (B.R. 5.9%)
- Combinatorial background reconstructed via the mixed-event background method
- J/ψ yields calculated by the bin counting method in the invariant mass region 2.9-3.2 GeV/c^2
  - → $S = 4960 \pm 580$
  - → significance 8.6 σ
  - → divided into 3 p_T bins

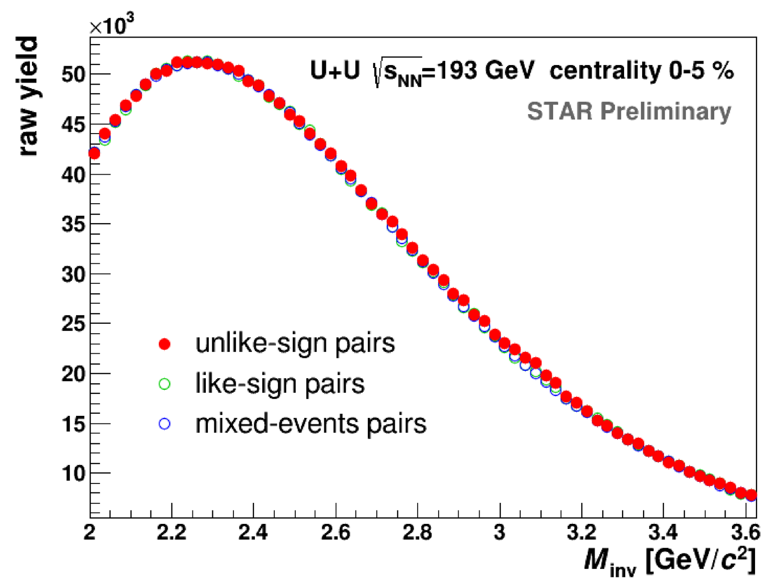

Fig. 7: Invariant mass spectra of unlike-sign, like-sign and mixed-event electron pairs.

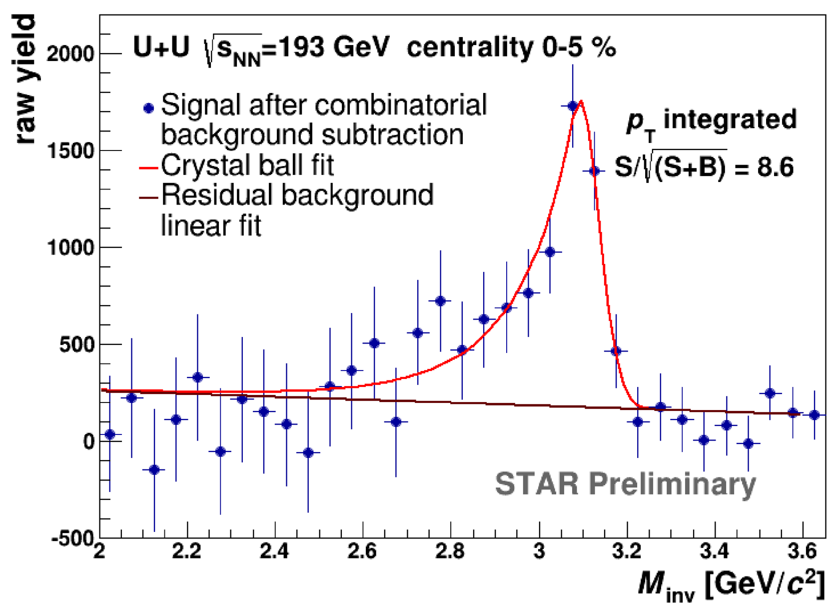

Fig. 8: J/ψ signal for p_T integrated.

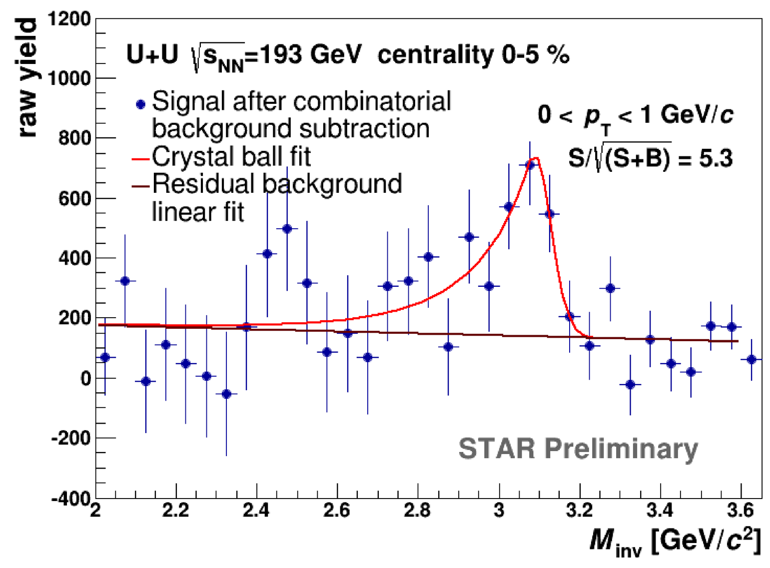

Fig. 9: J/ψ signal with p_T 0-1 GeV/c.

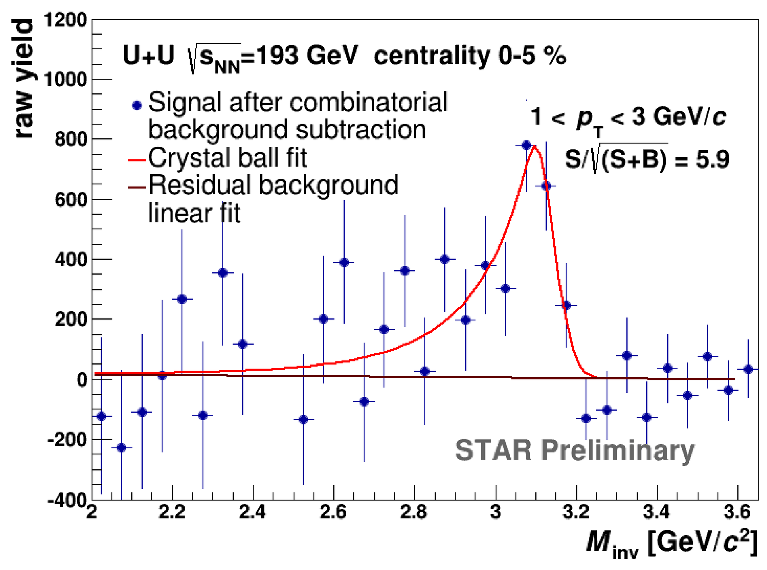

Fig. 10: J/ψ signal with p_T 1-3 GeV/c.

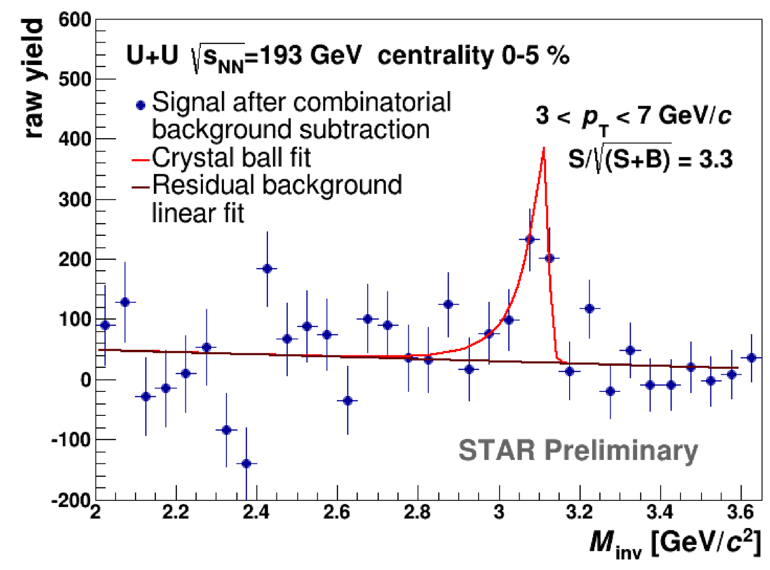

Fig. 11: J/ψ signal with p_T 3-7 GeV/c.

References

[1] D. Kikola et al., Phys.Rev. C84, 054907 (2011).

[2] W. Zha (STAR Collaboration), Nuclear Physics A931, 596-600 (2014).

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Conclusions

- Suppression of J/ψ production in minimum-bias U+U collisions at $\sqrt{s_{NN}} = 193$ GeV is similar to that observed in $\sqrt{s_{NN}} = 200$ GeV Au+Au collisions.
- Significant signal of J/ψ observed in 0-5 % most central U+U collisions. Data analysis to extract R_{AA} is underway.