Measurement of *J/ψ* Azimuthal Anisotropy in U+U Collisions at $\sqrt{s_{\mathrm{NN}}}$ = 193 GeV by the STAR Experiment

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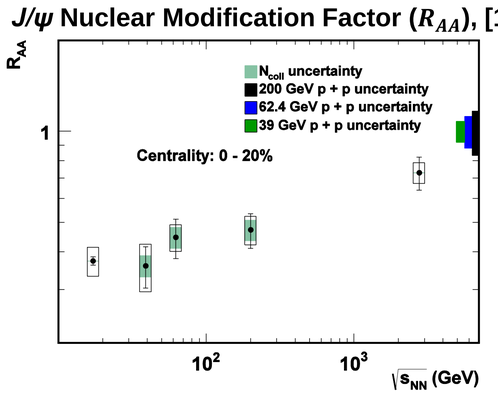
Abstract

The existence of the Quark-Gluon Plasma (QGP) is predicted by lattice QCD at high temperatures or large nuclear densities. Various probes were proposed to study this phase of matter, among which *J/ψ* suppression due to color screening of the quark potential in the QGP is of special interest since this mechanism implies the formation of the deconfined matter. However, contribution from the recombination of charm and anti-charm quarks in the medium complicates the interpretation of the observed modification to the *J/ψ* production in heavy-ion collisions. Measurement of the second-order harmonic coefficient (v_2) of *J/ψ* azimuthal anisotropy can help disentangle different contributions. For primordial *J/ψ* produced in hard scatterings at the beginning of the collisions, v_2 is expected to be close to zero, whereas regenerated *J/ψ* should inherit the anisotropy of the constituent charm quarks. U+U collisions provide a unique opportunity to test the current understanding of *J/ψ* production mechanisms due to their higher energy density in comparison to Au+Au collisions. In this poster, we present the first measurement of *J/ψ* v_2 in U+U collisions at $\sqrt{s_{\mathrm{NN}}}$ = 193 GeV, which is found to be consistent with zero for *J/ψ* with $p_T > 2$ GeV/*c*.

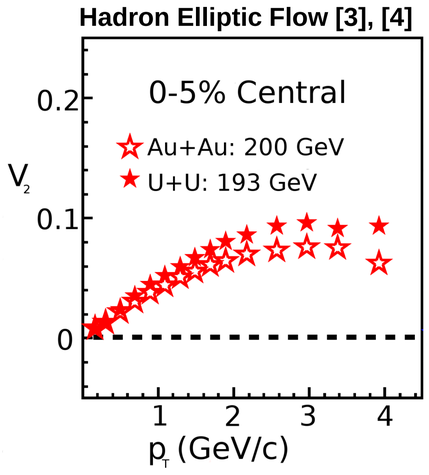
Motivation

- The potential between bound $c\bar{c}$ pairs is color-screened in the Quark-Gluon Plasma (QGP) → *J/ψ* yield is suppressed in the QGP. However, the interpretation of the observed modification to the *J/ψ* production in heavy-ion collisions is complicated by several competing processes, e.g. recombination and cold-nuclear matter effects [1].
- Primordial *J/ψ* are colorless, thus should not interact strongly with the medium→ zero elliptic flow. *J/ψ* created via recombination should inherit the flow of charm quarks → non-zero elliptic flow.
- Measurement of *J/ψ* v_2 can help disentangle the contributions from the recombination and primordial production.

J/ψ Nuclear Modification Factor (R_{AA}), [1]



Hadron Elliptic Flow [3], [4]

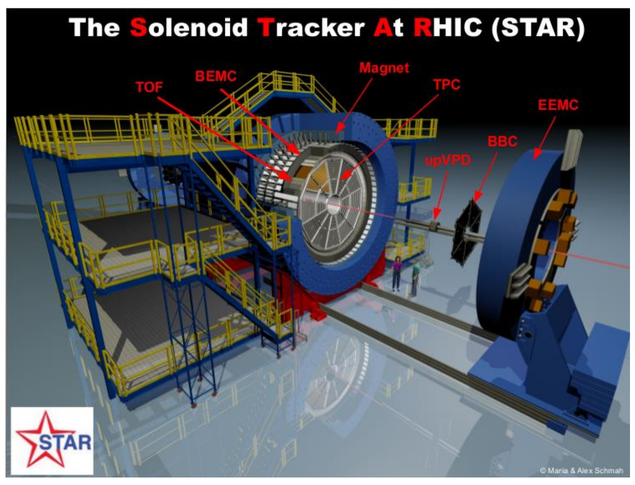


U+U Collisions

- 20% higher energy densities than those in Au+Au collisions with the same center-of-mass energy [2].
- Larger hadron v_2 observed in central U+U collisions than that in central Au+Au collisions [3, 4].

J/ψ Reconstruction by the STAR Experiment

- STAR: multi-purpose detector built for examining strongly interacting matter
- Reconstructing *J/ψ* signal via the *J/ψ*→ e^+e^- decay channel (Br. = 5.9%)



Time Projection Chamber (TPC)

- Tracking of charged particles
- Reconstruction of particle momentum
- Particle identification via energy loss define $n\sigma_e$

Time of Flight (TOF) detector

- Timing resolution <100 ps
- Particle identification via $1/\beta$
- TPC and TOF together provide good electron-hadron separation for p < 1.5 GeV/*c*

Barrel Electromagnetic Calorimeter (BEMC)

- Measuring energy of electrons and photons
- Particle identification via $\frac{pc}{E}$
- Triggering on high-p_T electrons

Electron Identification

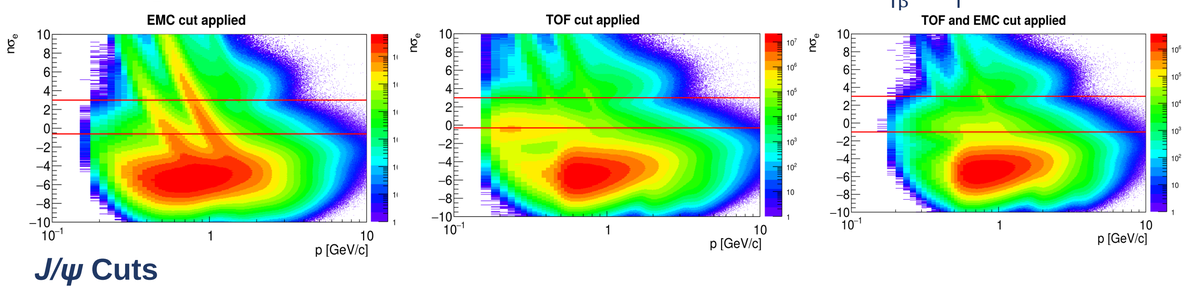
- $-0.6 < n\sigma_e < 3$
- $p > 1.5$ GeV/*c*
- $0.3 < \frac{pc}{E} < 1.5$

or

- $-0.3 < n\sigma_e < 3$
- $\left|\frac{1}{\beta} - 1\right| < 0.03$

or

- $-1 < n\sigma_e < 3$
- $0.3 < \frac{pc}{E} < 1.5$
- $\left|\frac{1}{\beta} - 1\right| < 0.03$



J/ψ Cuts

- Daughter momentum: $p_1 > 1.4$ GeV/*c*, $p_2 > 1.2$ GeV/*c*
- *J/ψ* rapidity cut: $|y| < 1.2$

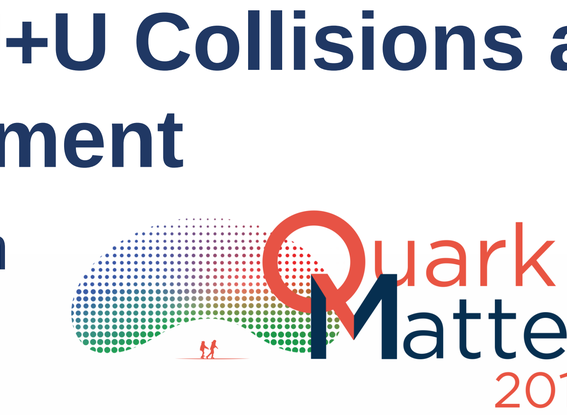
Elliptic Flow Measurement

- U+U events at $\sqrt{s_{\mathrm{NN}}}$ = 193 GeV
  - i. Both minimum-bias and BEMC-triggered data are used
  - ii. Recorded in year 2012

Elliptic Flow Extraction

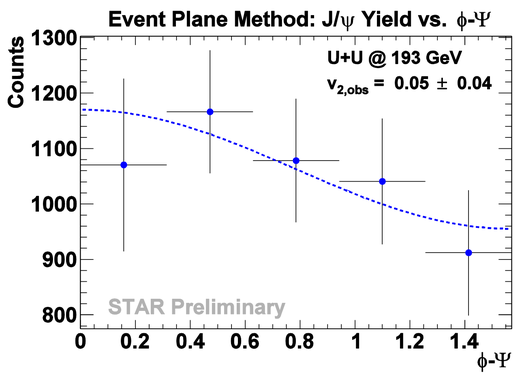
- v_2 obtained using two methods:
  - i. Invariant mass method: fit v_2 vs. m by the function $\frac{v_2^{J/\Psi} \cdot Sig(m) + (a_0 + a_1 \cdot m) \cdot Bg(m)}{(Bg(m) + Sig(m))}$,

    where $Sig(m)$ ($Bg(m)$) is the unlike-sign (like-sign) yield

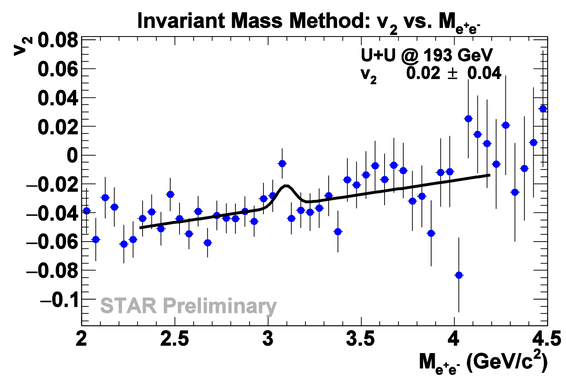


  - ii. Event plane method: fit *J/ψ* yield as the function of the relative angle between *J/ψ* (φ) and the event plane (Ψ) by the function $N \cdot (1 + 2 \cdot v_{2,obs} \cdot \cos(2 \cdot (\varphi - \Psi)))$

Event Plane Method: J/ψ Yield vs. ϕ-Ψ



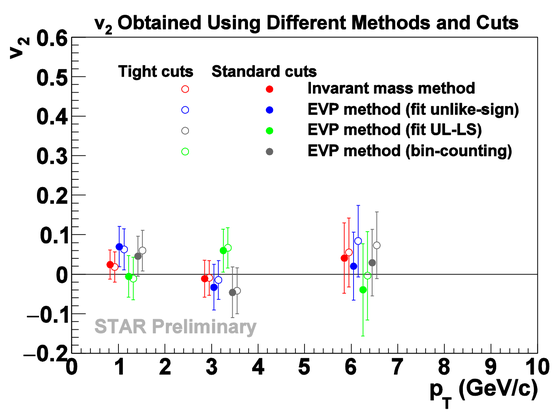
Invariant Mass Method: v_2 vs. $M_{e^+e^-}$

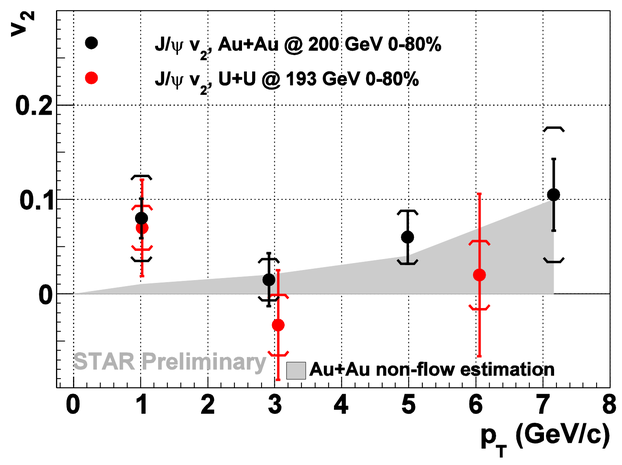


J/ψ v_2 in U+U Collisions

- The result from the event plane method with *J/ψ* yields extracted by fitting the unlike-sign invariant mass distribution is taken as the central value
- Systematic uncertainties are evaluated by comparing v_2 estimated using different methods and cuts

v_2 Obtained Using Different Methods and Cuts





J/ψ v_2 in U+U collisions (red cyrcles) compared to that in Au+Au (black cyrcles), and they are seen to be consistent within uncertainities. The non-flow contributions estimated for Au+Au collisions are shown as gray band. The *J/ψ* v_2 in U+U collisions is consistent with zero above 2 GeV/c, which suggests that $c\bar{c}$ recombination is unlikely to be the dominant contribution to the *J/ψ* production in this kinematic region.

Conclusion

- First measurement *J/ψ* v_2 in U+U collisions at $\sqrt{s_{\mathrm{NN}}}$ = 193 GeV
- Measured *J/ψ* v_2 is consistent with zero above 2 GeV/c suggesting non-significant contribution of $c\bar{c}$ recombination to *J/ψ* production in this kinematic region

References

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