Measurement of J/ψ polarization in Ru+Ru and Zr+Zr collisions at $\sqrt{S_{NN}}$ = 200 GeV at STAR

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Abstract

J/ψ serves as an important probe to study the properties of the quark-gluon plasma (QGP) created in heavy-ion collisions. The polarization is the most fundamental property of particles and is driven by the production mechanism and might be influenced by the QGP. The production mechanism of J/ψ includes direct, feed-down and regeneration. In Ru+Ru and Zr+Zr collisions at $\sqrt{S_{NN}}$ = 200 GeV, it has been observed that the J/ψ yield is strongly suppressed and its elliptic flow (v_2) is consistent with zero, indicating J/ψ's strong coupling with the medium and its potentially small regeneration contribution. Besides those measurements, the J/ψ polarization can shed new light on the QGP properties and the J/ψ production mechanism in heavy-ion collisions. In this poster, we will present the first measurement of J/ψ polarization in heavy-ion collisions at RHIC. The J/ψ polarization in the Helicity frame and Collins-Soper frame, in Ru+Ru and Zr+Zr collisions at $\sqrt{S_{NN}}$ = 200 GeV will be presented.

Motivation and Introduction

➢ Studying the J/ψ polarization in heavy-ion collisions can provide new insight into the interaction between J/ψ and the QGP[1]
  • QGP can potentially alter the J/ψ polarization
  • Modifications to the feed-down structure in the QGP
➢ J/ψ polarization can be extracted via the angular distribution of the decayed positron[2], which can be expressed as:

$$W(\cos\theta, \phi) \propto 1 + \lambda_\theta \cos^2\theta + \lambda_\phi \sin^2\theta\cos2\phi + \lambda_{\theta\phi}\sin2\theta\cos\phi$$
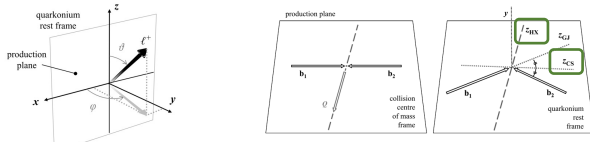
Different definitions of the z-axis
• J/ψ polarization with respect to the production plane

| Frame	Helicity frame (HX)	Collins-Soper frame (CS)
z-axis	direction along the J/ψ momentum in the center-of-mass frame of the colliding beams	bisector of the angle formed by one beam direction and the opposite direction of the other beam in J/ψ rest frame

• **Frame invariant quantity**

$$\lambda_{inv} = \frac{\lambda_\theta + 3\lambda_\phi}{1 - \lambda_\phi}$$

Any arbitrary choice of the experimental observation frame should yield the same value of λ_{inv}
Good cross-check on measurements performed in different frames

STAR Experiment
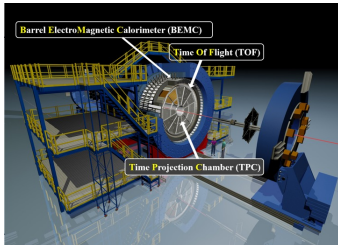
Large acceptance: $|\eta|<1$, $-\pi < \phi < \pi$

• TPC:
    Tracking – momentum, pathlength
    Particle identification – dE/dx
• TOF:
    Particle identification – $1/\beta$
• BEMC:
    Electron identification – E_0/p

References

[1]. B. L. Ioffe and D. E. Kharzeev, *Phys. Rev.* C 68, 061902(R) (2003)
[2]. P. Faccioli et al. *Eur. Phys. J.* C 69, 657 (2010)

Analysis Procedure

➢ **Signal extraction**: extract raw J/ψ yields in different $cos\theta$ and ϕ bins by fitting di-electron invariant mass distribution
➢ **Acceptance × efficiency correction**: calculate $A\times\epsilon$ using detector simulation and apply it to raw yield
    • **Iterative procedure**: tuning of J/ψ polarization in simulation according to data
➢ **Polarization parameters extraction**: simultaneously fit the corrected yield distributions as a function of $cos\theta$ and ϕ to extract λ_θ, λ_ϕ
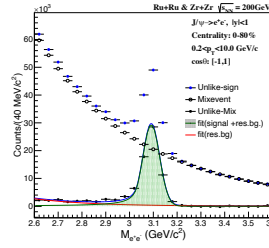
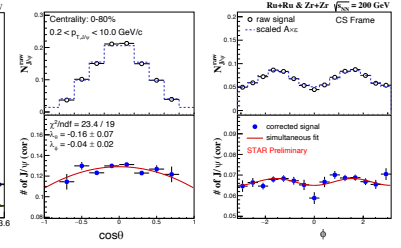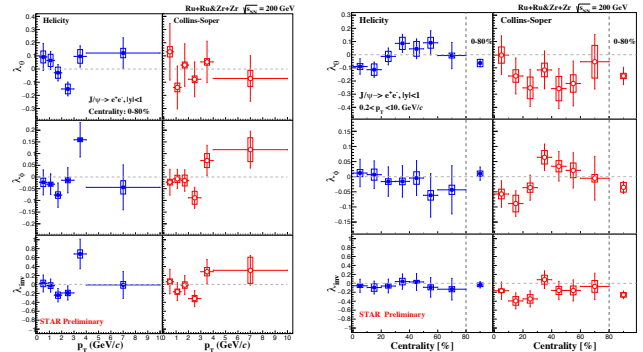Figure 1: Invariant mass distributions of dielectron pairs within $0.2 < p_T < 10.\,GeV/c$

Figure 2: An example of extracting λ_θ and λ_ϕ at the last iteration

Results and Conclusions

➢ First measurement of J/ψ polarization in heavy-ion collisions at RHIC
    • Ru+Ru & Zr+Zr collisions at $\sqrt{S_{NN}}$ = 200 GeV
    • J/ψ: $0.2 < p_T < 10.\,GeV/c$, $|y| < 1$
➢ J/ψ polarization vs p_T:
    • λ_θ, λ_ϕ consistent with zero in HX and CS frames and no obvious p_T dependence
    • Hint of a non-trivial p_T dependence in the HX frame
➢ J/ψ polarization vs centrality:
    • No significant dependence of λ_θ, λ_ϕ on centrality
➢ λ_{inv} as a function of p_T and centrality are consistent between HX and CS frames and their values are zero, within uncertainty.
➢ Outlook: measurement of J/ψ spin alignment with respect to TPC event-plane coming soon

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The STAR Collaboration
https://drupal.star.bnl.gov/STAR/presentations