Measurements of J/Ψ polarization in p+p,p+Au and Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV by the STAR experiment

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Abstract

Quarkonium production mechanisms in hadron collisions are not fully understood. Different models on quarkonium production can describe the measured production cross-sections in p+p collisions but have significantly different predictions on quarkonium polarization. Measurements of *J/Ψ* polarization in p+p collisions can distinguish these models to test the fundamental theory on quarkonium production. Measurements of *J/Ψ* polarization in p+Au and Au+Au collisions may provide insights into cold and hot nuclear matter effects on quarkonium production, which has been used extensively to study the properties of Quark-Gluon Plasma. In this poster, we present the measurements of *J/Ψ* polarization in p+p collisions at √s = 200 GeV using data taken in 2012 by the STAR experiment. We also present the progress on *J/Ψ* polarization measurements in p+Au and Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV using the data taken in 2011 and 2015.

Introduction

The angular distribution of the leptons from *J/Ψ* decay in the *J/Ψ* rest frame reflects *J/Ψ* polarization. It can be written as 2D Fourier expansion, whose leading-order term coefficients are directly related to the direction and magnitude of the *J/Ψ* polarization.

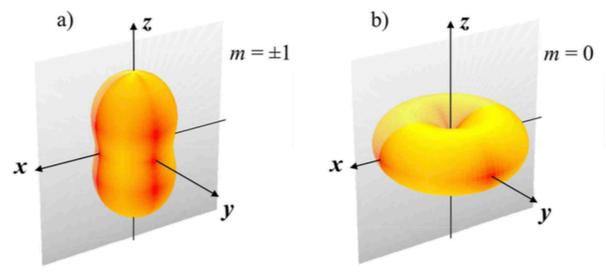


Fig.1 Angular distribution of decayed leptons from transversely (a) and longitudinally (b) polarized *J/Ψ* in the *J/Ψ* rest frame.[1]

The angular distribution of the decayed leptons can be written as the following:

$$\frac{d^2\sigma}{d(\cos\theta)d\phi} = 1 + \lambda_\theta \cos^2\theta + \lambda_\phi \sin^2\theta\cos(2\phi) + \lambda_{\theta\phi}\sin(2\theta)\cos\phi$$

The goal of our study is to extract parameters, λ_θ and λ_ϕ, using the data taken by the STAR experiment.

Method

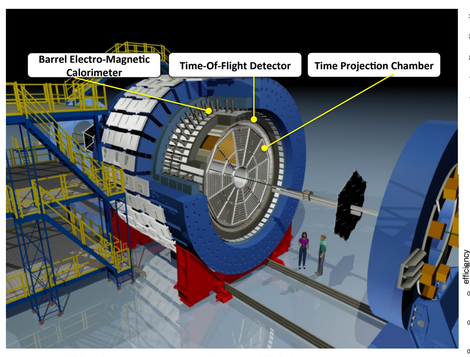


Fig.2 Complex of the STAR detector

Time Projection Chamber (0<ϕ<2π,|η|<1)
- Tracking - momentum
- Particle identification - dE/dx

Time Of Flight
- Particle identification - 1/β

Barrel Electro-Magnetic Calorimeter
- Particle identification - p/E
- Trigger on high p_T electrons

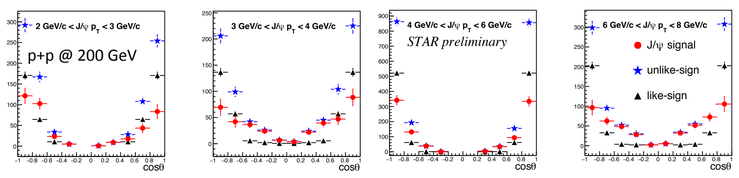


Fig.3 Distribution of unlike-sign, like-sign dielectron pairs as well as *J/Ψ* candidates as a function of cosθ in p+p collisions using data taken in 2012.

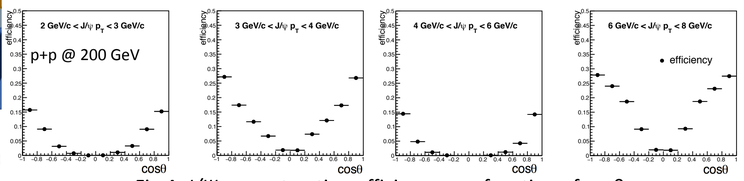


Fig.4 *J/Ψ* reconstruction efficiency as a function of cosθ . Efficiency is extracted from Geant detector simulation.

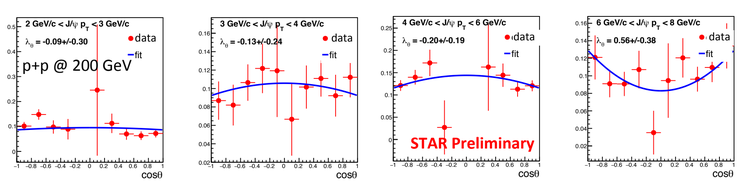


Fig.5 Corrected *J/Ψ* yield as a function of cosθ.

The corrected *J/Ψ* yield as a function of cosθ is obtained by dividing raw *J/Ψ* yield by the reconstruction efficiency and then fitted with function $W(\cos\theta) = norm(1 + \lambda_\theta \cos^2\theta)$.

The same approach can be applied to the corrected *J/Ψ* yield as a function of ϕ, which is fitted with the function $W(\phi) = norm(1 + \frac{2\lambda_\phi}{3+\lambda_\theta}\cos(2\phi))$.

Results

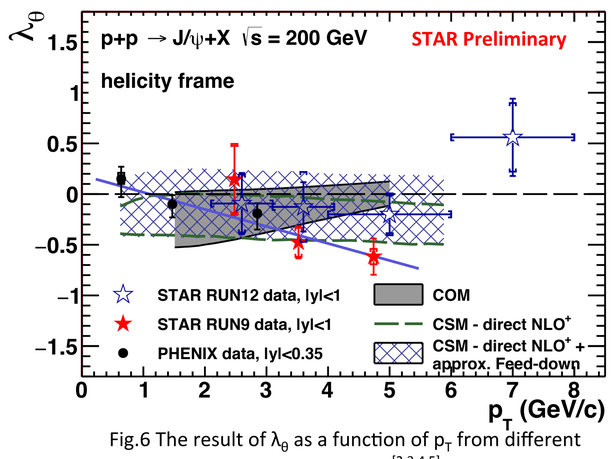


Fig.6 The result of λ_θ as a function of p_T from different measurements. [2,3,4,5]

1. The measurement is extended up to 8 GeV/c with Run12 data.

2. The previous measurement indicates a declining trend of λ_θ towards high p_T, but the result using Run12 data does not seem to follow this trend.

Improved method

Density function $f_{(\lambda_\theta,\lambda_\phi)}(\cos\theta,\phi)$

$$f_{(\lambda_\theta,\lambda_\phi)}(\cos\theta,\phi) = (\frac{\partial^2\sigma}{\partial\cos\theta\partial\phi} * eff)^{N_{J/psi}}$$

Negative logarithmic likelihood function $-\ln(L(\lambda_\theta,\lambda_\phi))$

$$-\ln(L(\lambda_\theta,\lambda_\phi)) = -ln(\prod_k f_{(\lambda_\theta,\lambda_\phi)}(\cos\theta,\phi)) = -\sum_k \ln f(\cos\theta,\phi) = -\sum_k N_{J/psi} * \ln(\frac{\partial^2\sigma}{\partial\cos\theta\partial\phi} * eff)$$

where, *k* is *J/Ψ* candidate index for each cosθ and ϕ bin.

The true decayed-lepton angular distribution function minimizes the negative logarithmic likelihood function among all possible angular distributions.

A toy Monte Carlo study is preformed with input polarization parameters equal to zero. The calculated negative logarithmic likelihood function from one pseudo-experiment is shown in Fig.7. The contour of minimum negative logarithmic likelihood value plus 1/2 is used to estimate the uncertainty of parameters and these results from ~250 pseudo-experiments are shown in Fig.8. The extracted polarization parameters are consistent with the input values, and the uncertainties associated with the parameters are also estimated.

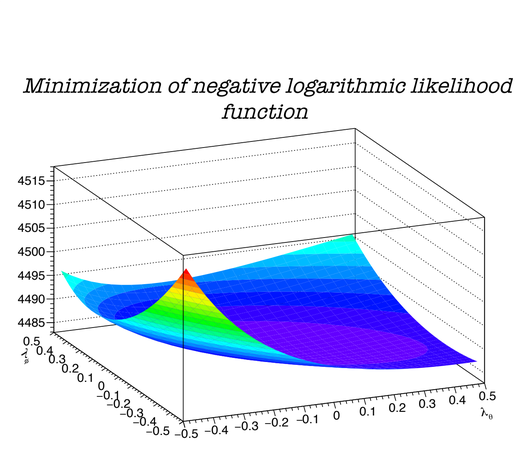


Fig.7 The process of extracting polarization parameters

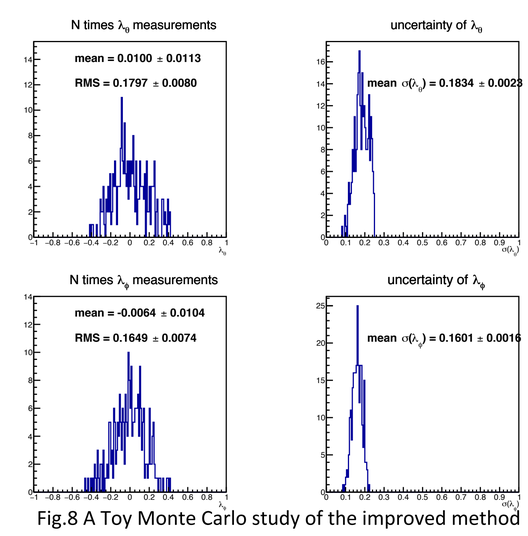
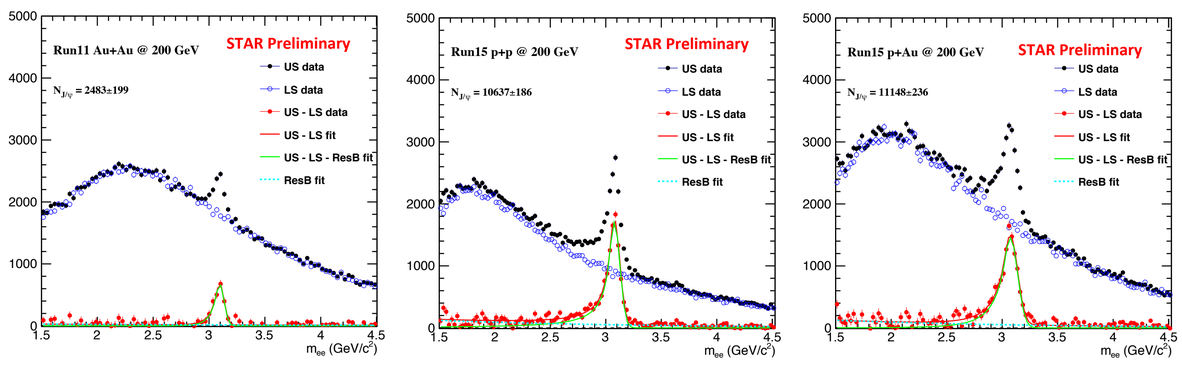


Fig.8 A Toy Monte Carlo study of the improved method

New datasets



Conclusion and Outlook

1. λ_θ is extracted up to 8 GeV/c using the STAR Run12 data. Results don't seem to indicate the negative trend at high p_T seen in previous measurements.
2. Extraction of λ_ϕ and λ_{inv} in both helicity and Collins-Soper frames using Run12 data is underway.
3. The 200 GeV p+p and p+Au data taken in 2015 have significantly more statistics to improve the measurement and possibly distinguish different models.
4. *J/Ψ* polarization measurement in Au+Au collisions using 2011data may help to understand the formation of the Quark-Gluon Plasma phase at temperatures where the $c\bar{c}$ bound state dissociates due to the screening of the color potential by surrounding quarks and gluons.

References

[1] P. Faccioli, C. Laorenco, J. Seixas, H.K. Wohri, Eur. Phys. J. C 69, 657 (2010)
[2] STAR Collaboration. "*J/ψ* polarization in p+ p collisions at in STAR." Physics Letters B 739 (2014): 180-188.
[3] Adare, A., et al. "Transverse momentum dependence of *J/ψ* polarization at midrapidity in p+ p collisions at √s = 200 GeV." Physical Review D 82.1 (2010): 012001.
[4] Chung, Hee Sok, et al. "Polarization of prompt *J/ψ* in proton-proton collisions at RHIC." Physical Review D 81.1 (2010): 014020.
[5] Lansberg, J. P. "QCD corrections to *J/ψ* polarisation in pp collisions at RHIC." Physics Letters B 695.1 (2011): 149-156.

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