Spin Alignment of Vector Mesons $K^{*0}(892)$ and $\phi(1020)$ in Au+Au and p+p Collsions at $\sqrt{s_{NN}} = 200GeV$ *

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Abstract We present the preliminary results on the spin alignment matrix element ρ_{00} for vector mesons $K^{*0}(892)$ and $\phi(1020)$ in mid-central (20%—60%) Au+Au and p+p collisions at $\sqrt{s_{NN}} = 200GeV$. The values of ρ_{00} with respect to reaction plane in Au+Au collisions are $0.36 \pm 0.02(stat) \pm 0.13(sys)$ for $K^{*0}(892)$ and $0.38 \pm 0.01(stat) \pm 0.04(sys)$ for $\phi(1020)$. No evident global spin alignment with respect to reaction plane is observed in the measured p_T region up to $5GeV/c$ with current sensitivity. ρ_{00} with respect to the production plane of the vector meson is also measured for $K^{*0}(892)$ and $\phi(1020)$ in Au+Au collisions, and for $\phi(1020)$ in p+p collisions. No significant difference for the ρ_{00} between Au+Au and p+p collisions is observed with our data sample.

Key words spin alignment, global polarization, vector meson

1 Introduction

The system created in non-central relativistic nucleus-nucleus collisions carries large angular orbital momentum. Due to the spin-orbital coupling, quarks and anti-quarks produced in such a system could become globally polarized along the direction of the initial system angular momentum[1]. The degree of the polarization of the final hadrons is argued to be sensitive to the hadronization mechanism[2]. Since the direction of the initial system angular momentum is perpendicular to the impact parameter vector, one can measure such global quark polarization via global spin alignment of vector meson with respect to reaction plane. It has also been pointed out that this global polarization is correlated with transverse polarization measured with respect to the particle's production plane[3].

To measure the hyperon polarization, one needs to know not only the orientation but also the sign (or direction) of the reaction plane which can only be determined by the directed flow in each event class. We measure the global spin alignment of vector meson rather than the global polarization of hyperon.

The angular distribution of its decay products is analyzed to measure the spin alignment of a vector meson. However, the angular distribution of the $\lambda = 1$ and $\lambda = -1$ stats are degenerate thus the value of the ρ_{11} and ρ_{-1-1} elements in the spin alignment matrix can not be distinguish and only one variable, e.g. $\rho_{00} = 1 - \rho_{11} - \rho_{-1-1}$, is accessible. ρ_{11}, ρ_{00} and ρ_{-1-1} should be equal to 1/3 in the unpolarized case and a deviation of ρ_{00} from 1/3 manifests the spin alignment of vector meson. For the case of a vector meson

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decaying to two pseudoscalar mesons, the angular distribution can be written[4]

$$W(\cos\theta^*) = \frac{3}{4}\left[(1-\rho_{00}) + (3\rho_{00}-1)\cos^2\theta^*\right], \quad (1)$$

where θ^* is the angle between the polarization direction and a daughter particle momentum direction in the rest frame of the parent vector meson. Since the angular distribution is only depend on $\cos^2\theta^*$, we don't need to know the sign of the reaction plane.

2 Data analysis and results

The detector used for these studies is the Solenoidal Tracker at RHIC (STAR) which has full azimuthal and over 3 units pseudorapidity coverage. The data set used in this analysis are from the run-4 (2004) Au+Au collisions and the run-2(2001/2002) p+p collisions at $\sqrt{s_{NN}} = 200$GeV. About 12M mid-central (20%—60%) Au+Au events and 4M p+p events are analyzed.

$K^{*0}(892)$ and $\phi(1020)$ are reconstructed through their hadronic decay channels: $K^{*0} \to K^+\pi^-$, $\overline{K^{*0}} \to K^+\pi^-$[5] and $\phi \to K^+K^-$[6]. For larger statistic, $K^{*0}(892)$ and $\overline{K^{*0}(892)}$ were added together and the term $K^{*0}(892)$ in this analysis refers to the average of $K^{*0}(892)$ and $\overline{K^{*0}(892)}$ unless specified. Mixed-event technique[7, 8] is used to describe the combinatorial background in the $K\pi$ or KK invariant mass spectrum. The upper panels of Fig. 1 show the invariant mass distribution after combinatorial background subtraction for $\phi(1020)$ and $K^{*0}(892)$ from mid-central Au+Au collisions at $\sqrt{s_{NN}}$ = 200GeV. Raw $\phi(1020)$ and $K^{*0}(892)$ yields are extracted from fitting to the combinatorial background subtracted invariant mass distribution with a Breit-Wigner function and a residual background polynomial curve. The raw yields are then corrected for detection acceptance and efficiency. The correction factors are determined by embedding simulated tracks into real events at the raw data level, reconstructing the full events and comparing the simulated input to the reconstructed output. The lower panels in Figure 1 show the corrected $\cos(\theta^*)$ distribution for $\phi(1020)$ and $K^{*0}(892)$. The ρ_{00} are extracted via fitting with Eq. (1). The polarization direction is taken as the normal of reaction plane to determine the parameter θ^*. The reaction plane is estimated with the second order event plane reconstructed using the charged primary tracks from STAR TPC[9, 10]. Finally, the ρ_{00} is corrected by finite reaction plane resolution. The systematic errors include contributions from different methods of yield extraction, variations of the charged particles selection cuts and from uncertainty in detector acceptance analysis.

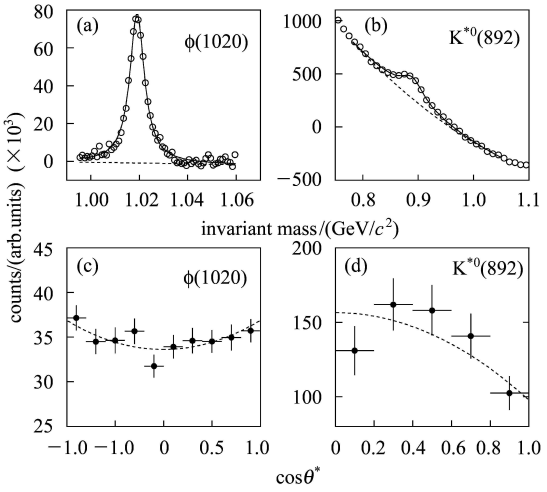

Fig. 1. (a) $\phi(1020)$ and (b) $K^{*0}(892)$ invariant mass distribution after combinatorial background subtraction in mid-central (20%—60%) Au+Au collisions. Dashed lines represent the residual background. (c) $\phi(1020)$ and (d) $K^{*0}(892)$ are the $\cos(\theta^*)$ distribution with respect to reaction plane fitted with Eq. (1).

2.1 Spin alignment with respect to reaction plane

Figure 2 shows the preliminary STAR measurements of global spin alignment from mid-central Au+Au collisions at $\sqrt{s_{NN}}$ = 200GeV for vector mesons ($K^{*0}(892)$, $\phi(1020)$) as a function of transverse momentum(p_T). The ρ_{00} are around 1/3 in the measured p_T region ($0.8 < p_T < 5.0$GeV/c for $K^{*0}(892)$, $0.4 < p_T < 5.0$GeV/c for $\phi(1020)$) indicating no significant global spin alignment of vector mesons $K^{*0}(892)$ and $\phi(1020)$ produced in the colliding system with current statistic. Integrated over the measured p_T region, we have $\rho_{00} = 0.36 \pm 0.02(\text{stat}) \pm 0.13(\text{sys})$ for $K^{*0}(892)$ and $\rho_{00} = 0.38 \pm 0.01(\text{stat}) \pm 0.04(\text{sys})$ for $\phi(1020)$.

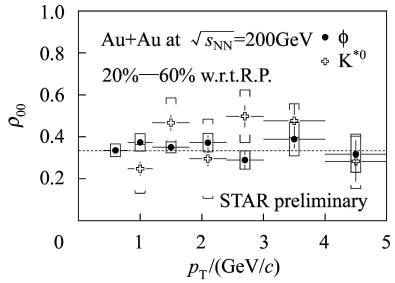

Fig. 2. $K^{*0}(892)$ (open cross) and $\phi(1020)$ (filled circle) ρ_{00} as a function of p_T in mid-central Au+Au collisions at $\sqrt{s_{NN}} = 200$GeV with respect to reaction plane. Caps and boxes show the systematic errors while bars are the statistical errors.

Figure 3 shows the preliminary STAR results on collision centrality dependence of ρ_{00} with respect to reaction plane from Au+Au collisions at $\sqrt{s_{NN}} =$ 200GeV. Within statistical and systematic uncertainties, no evidence of global spin alignment has been observed from the current data sample.

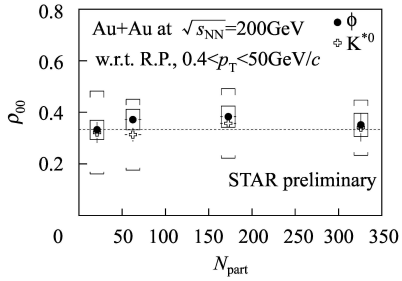

Fig. 3. $K^{*0}(892)$ (open cross) and $\phi(1020)$ (filled circle) ρ_{00} as function of centralities (0—10%, 10%—40%, 40%—60%, 60%—80%) in Au+Au collisions at $\sqrt{s_{NN}} = 200$GeV with respect to reaction plane. Caps and boxes show the systematic errors while bars are the statistical errors.

2.2 Spin alignment with respect to production plane

Usually, hyperon polarization and vector meson spin alignment are measured with respect to the production plane. Hyperon produced in high energy unpolarized hadron-hadron collisions have been found to be transversely polarized with respect to the production plane[11, 12]. Leading vector meson $K^{*+}(892)$ from neutron-carbon interactions has also been observed to be significantly aligned in its transverse frame[13]. Thus, it's of great interest to measure the vector meson spin alignment in the transverse frame at RHIC. Possible correlations in vector meson spin alignment between reaction plane and production plane can be explored to study particle production and spin dynamics.

Figure 4 shows the results of ρ_{00} with respect to the production plane as a function of p_T in mid-central Au+Au collisions at $\sqrt{s_{NN}}$=200GeV. The production plane is define as the plane on which momentum vectors of the projectile and produced vector mesons ($K^{*0}(892)$, $\phi(1020)$) lie. Over the measured p_T range, ρ_{00} is consistently larger than 1/3. Following the suggestion of observing global spin alignment in the lower p_T region[2], we have measured the ρ_{00} in p_T <1.2GeV/c range. The values of ρ_{00} with respect to production plane in this p_T range is $0.44 \pm 0.04(\text{stat}) \pm 0.08(\text{sys})$ for $K^{*0}(892)$ and $0.43 \pm 0.01(\text{stat}) \pm 0.08(\text{sys})$ for $\phi(1020)$. Here, the systematic errors are dominated by the detector acceptance uncertainties which are estimated via differences between correction factors calculated from GEANT simulations and from real data background analysis. For $1.2 < p_T < 3.0$GeV/c, ρ_{00} approaches 1/3 within errors. For $p_T > 3.0$GeV/c, the indication of an increase in ρ_{00} values with increasing p_T needs to be carefully studied, as for such p_T region the current statistics are limited.

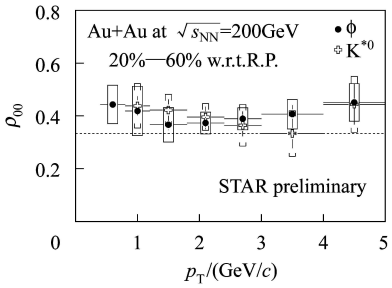

Fig. 4. $K^{*0}(892)$ (open cross) and $\phi(1020)$ (filled circle) ρ_{00} as a function of p_T in mid-central Au+Au collisions at $\sqrt{s_{NN}} = 200$GeV with respect to the vector mesons' productions plane. Caps and boxes show the systematic errors while bars are the statistical errors.

The spin alignment of $\phi(1020)$ with respect to production plane is also measured in p+p collisions at $\sqrt{s_{NN}} = 200$GeV and compared to the results measured in mid-central Au+Au collisions at the same beam energy in Fig. 5 to learn the possible different dynamics between the two system. No significant

difference is observed with current statistics. Further exploration (higher statistics in p+p collisions) is warranted.

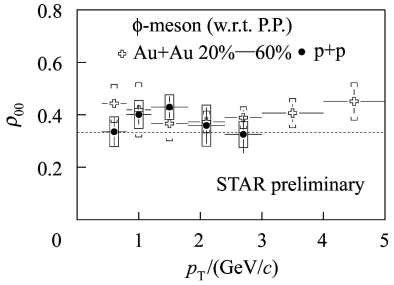

Fig. 5. $\phi(1020)$ ρ_{00} as a function of p_T compared between mid-central Au+Au (open cross) and p+p (filled circle) collisions at $\sqrt{s_{NN}}$ = 200GeV with respect to production plane. Caps and boxes show the systematic errors while bars are the statistical errors.

3 Summary

Preliminary results on the spin alinement element ρ_{00} for vector mesons $K^{*0}(892)$ and $\phi(1020)$ with respect to reaction plane and production plane at mid-rapidity measured by the STAR detector in $\sqrt{s_{NN}}$ = 200 mid-central (20%—60%) Au+Au and p+p collisions GeV at RHIC were presented. The values of ρ_{00} with respect to reaction plane in mid-central Au+Au collisions are $0.36 \pm 0.02(\text{stat}) \pm 0.13(\text{sys})$ for $K^{*0}(892)$ and $0.38 \pm 0.01(\text{stat}) \pm 0.04(\text{sys})$ for $\phi(1020)$. No evident global spin alignment for $K^{*0}(892)$ and $\phi(1020)$ was observed in the measured p_T region up to 5GeV/c with current sensitivity. The spin alignment measurements with respect to the vector mesons' production plane for $K^{*0}(892)$ and $\phi(1020)$ in Au+Au collisions and for $\phi(1020)$ in p+p collisions were also discussed. No significant difference in $\phi(1020)$ spin alignment between Au+Au and p+p collisions has been observed.

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