ϕ-meson Local, Global, and Helicity Frame Spin Alignment at STAR

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In non-central heavy-ion collisions, large orbital angular momentum and strong vorticity fields are produced and predicted to polarize quark spins. Unexpectedly large global spin alignment (ρ_{00}) values for $\phi(1020)$ mesons have been reported in the first phase of the RHIC Beam Energy Scan (BES-I) in Au+Au collisions [3]. These values exceed conventional expectations based on global hyperon polarization induced by orbital angular momentum, suggesting the possible presence of a strong force field for ϕ mesons [4].

Previous ρ_{00} measurements use a 1D angular distribution in θ^* (polar angle of a daughter kaon in the ϕ meson's rest frame with respect to the orthogonal of the harmonic event plane). We will use both angular dimensions θ^* and β of a daughter kaon in the ϕ meson's rest frame, where β is the azimuthal angle within the harmonic event plane, measured relative to the positive beam axis. This technique enables off-diagonal element extraction with fewer assumptions regarding the decay daughter distributions. We will present differential measurements of ϕ-meson ρ_{00} and off-diagonal spin density matrix elements, using data from the second phase of the RHIC BES (BES-II) in Au+Au collisions at $\sqrt{s_{NN}} = 7.7 - 19.6$ GeV collected by STAR. Results will be shown as functions of rapidity (y), centrality, and transverse momentum (p_T). Additionally, we will present differential helicity frame spin alignment results to test their predicted relation with global spin alignment [5].

We will also present ρ_{00} results using two alternative extraction methods: (i) $\langle \cos^2 \theta^* \rangle$ and (ii) $\langle \cos 2\phi^* \rangle$ (where ϕ^* is the projection of θ^* onto the transverse plane) as a function of the kaon pair invariant mass. For these approaches, we explore data-driven methods to correct for detector acceptance and efficiency. We further investigate the ϕ meson local spin alignment in Au+Au as well as d+Au collisions at 200 GeV, where the quantization axis lies along the beam axis.

The results presented in this talk can help clarify the possible link of global spin alignment to vector meson fields and their contributions to the evolution of nuclear matter.

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