Vector Meson Global Spin Alignment Measurements in Heavy Ion Collisions from STAR

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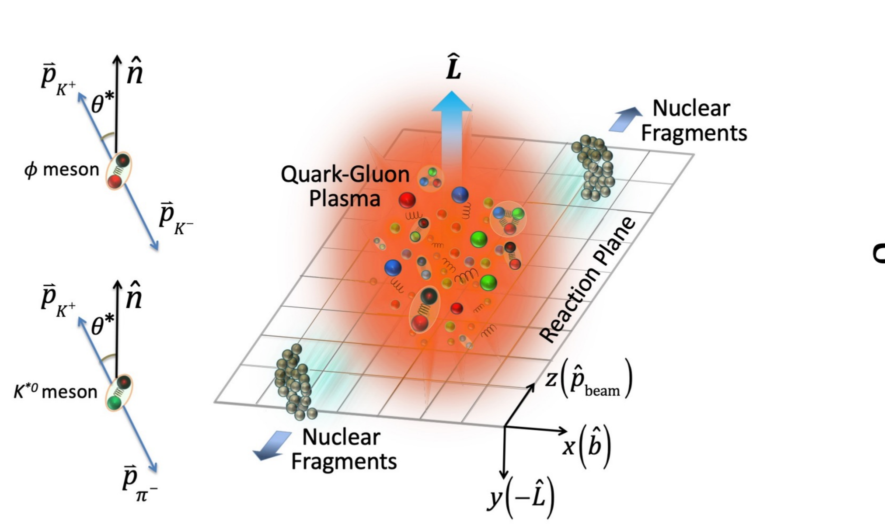
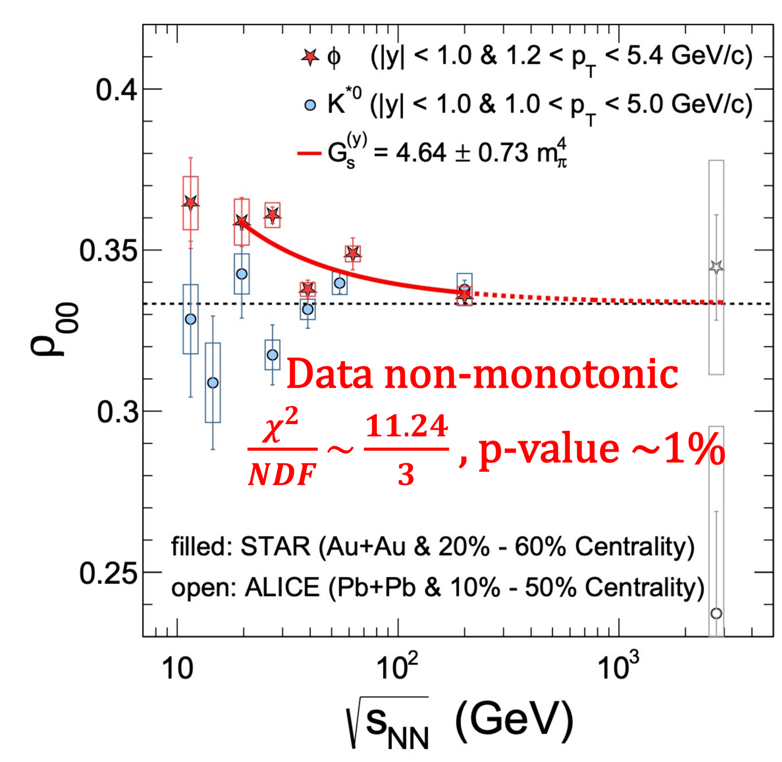
Abstract: In non-central heavy ion collisions, a large Orbital Angular Momentum (OAM) is produced. A part of the OAM can polarize the quarks and anti-quarks, hence the vector mesons, inside the medium. Recently, STAR measured the global spin alignment of the φ(1020) meson in collisions from the first phase of the RHIC Beam Energy Scan I (BES I) Au+Au collisions [1]. The global spin alignment, quantified by the 00^{th} coefficient of the spin density matrix, ρ_{00}, is measured by a fit to the acceptance and efficiency corrected φ meson yield versus polar angle (θ^*) between the daughter kaon in the parent's rest frame and the OAM direction. In this poster, we present an alternative approach to extract ρ_{00} by utilizing the $\langle \cos^2\theta^* \rangle$ as a function of pair-invariant mass instead of analyzing the φ meson yields in $\cos\theta^*$ bins. The acceptance and efficiency effects are taken into account by using the combinatorial background. This method only uses the signal to background ratio and is robust to few percent variations in the yield vs. θ^*.

[1] M. Abdallah et al. (STAR Collaboration), Nature 614, 244–248 (2022).

Motivation

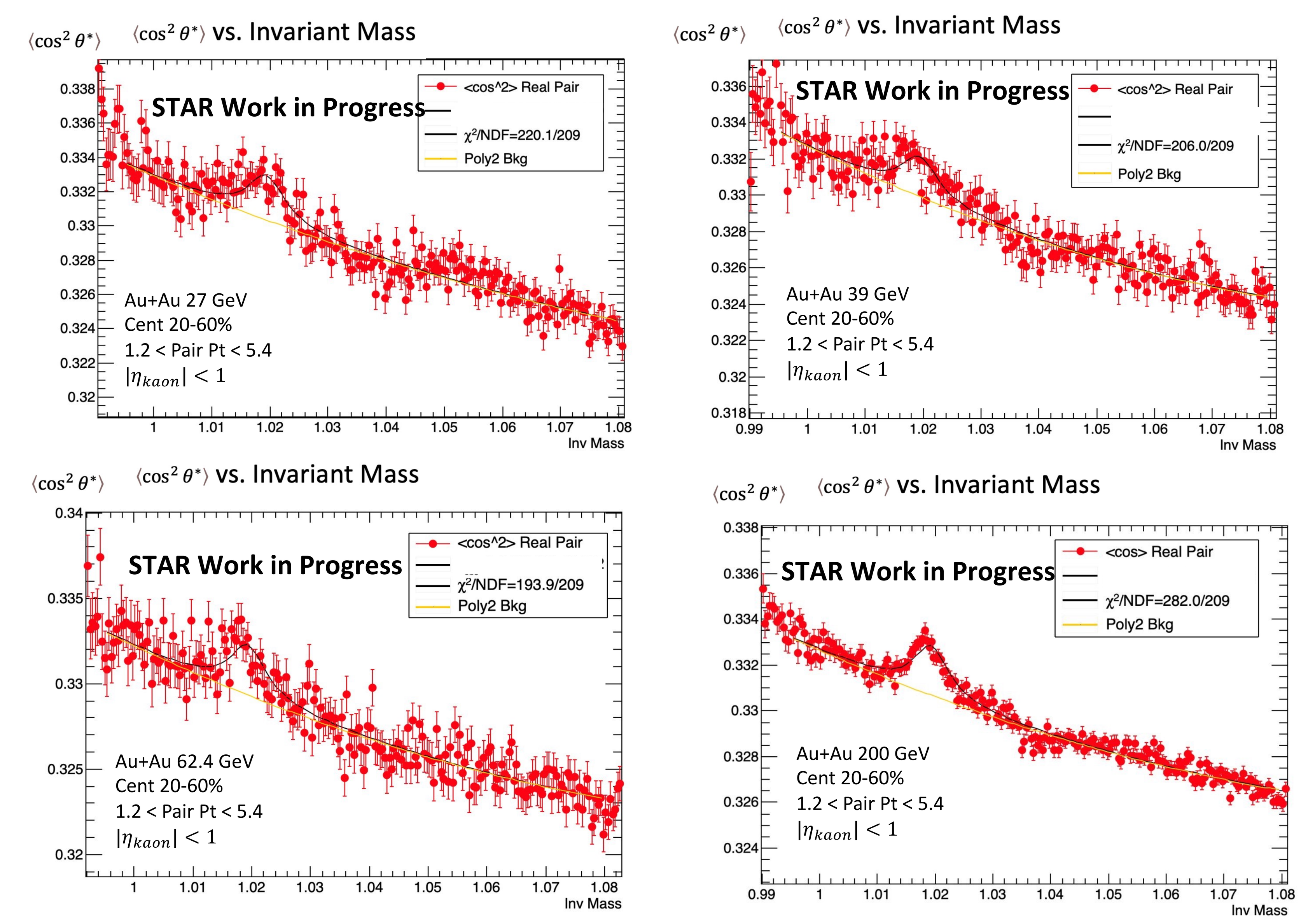


θ^*: polar angle between decay daughter in parent rest frame and total Orbital Angular Momentum

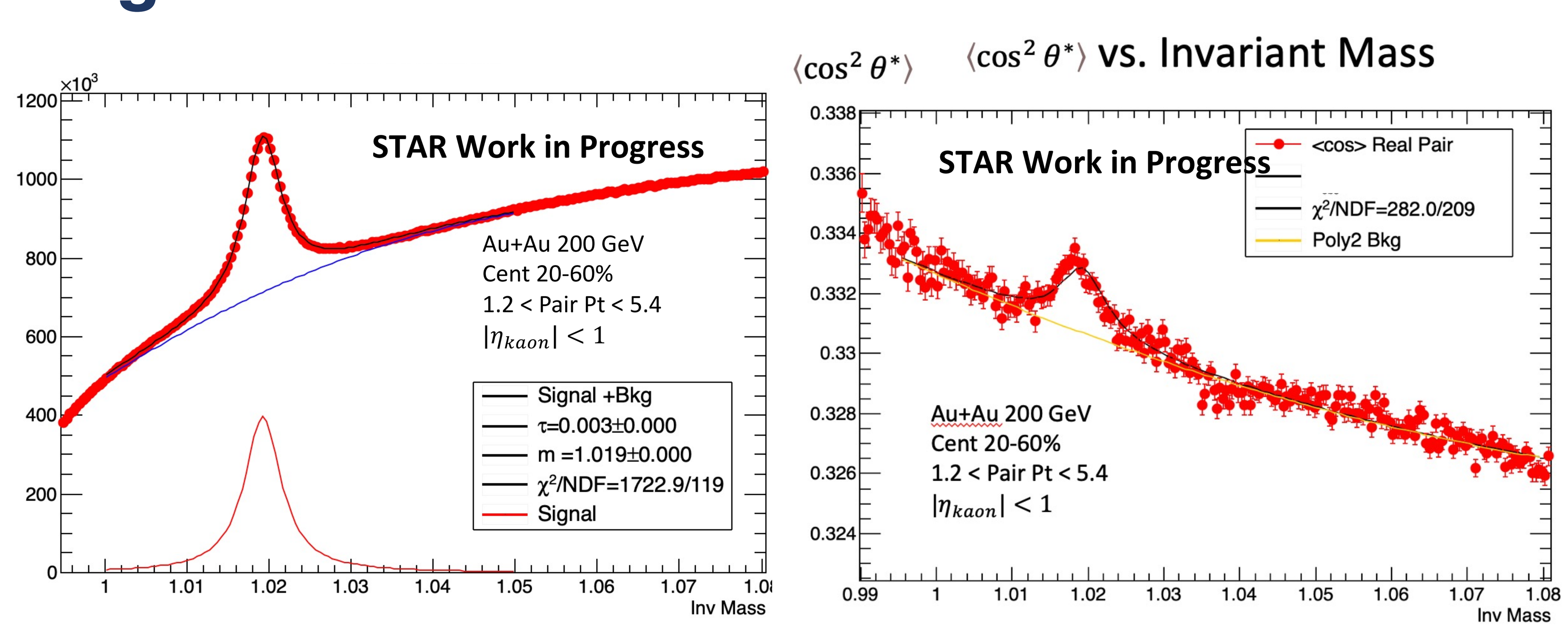


- Spin alignment of vector mesons characterized by spin density matrix element ρ_{00}
- Measure ρ_{00} via yield vs. $\cos\theta^*$: $\frac{dN}{d\cos\theta^*} \propto (1-\rho_{00}) + (3\rho_{00}-1)\cos^2\theta^*$
- Variation in yield across $\cos\theta^*$ is only a few percent; requires corrections for detector acceptance and efficiency as function of θ^*
- Spin alignment ρ_{00}, θ^* dependent efficiency, and elliptic flow v_2 likely entangled
- We present another method to measure ρ_{00}, by using the signal/noise ratio from invariant mass distribution in a fit to the $\langle \cos^2\theta^* \rangle$ vs. mass.

Raw Data Distributions



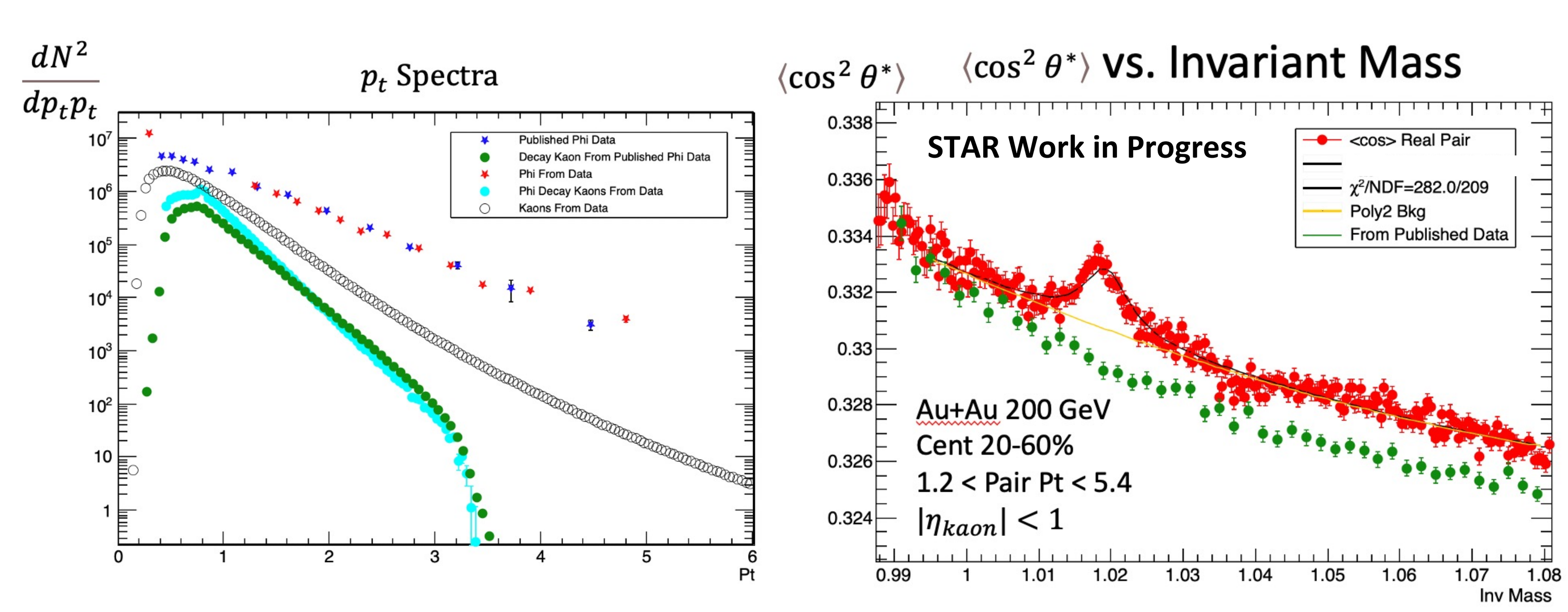
Signal Extraction



- Invariant mass distribution of kaon pairs (left) and $\langle \cos^2\theta^* \rangle$ vs. mass (right)
- Use the signal/noise ratio from left plot to fit the $\langle \cos^2\theta^* \rangle$ vs. mass for ρ_{obs}
- Correct for Event Plane Resolution R: $\rho_{00} = \frac{4}{(1+3R)}\left(\rho_{obs} - \frac{1}{3}\right) + \frac{1}{3}$

  EP resolution at 200 GeV ~.69, at 62.4 GeV ~ .57, at 39 GeV ~ .55, and at 27 GeV ~ .51

Future Work: Corrections



Data-driven correction procedure for detector effects:

- Use published φ meson p_t spectrum (left panel blue points) and $v_2(p_t)$ to estimate the "true" $\langle \cos^2\theta^* \rangle$ for combinatorial background of decay kaons (right panel green points)
- Get decay kaon spectrum in data via peak – sideband; scale measured kaons to that spectrum in (p_t, $\phi - \psi$); get $\langle \cos^2\theta^* \rangle$ of those scaled kaons in data. This is the background $\langle \cos^2\theta^* \rangle$ affected by detector effects.
- The ratio of two is the correction factor, to be applied to φ meson ρ_{00}

Systematic Uncertainty

- Signal is only a few percent and greatly depends on the background modeling
- Will assess systematic uncertainties from varying background functions in fits to $\langle \cos^2\theta^* \rangle$ vs. invariant mass and other sources

Summary

- Use signal/noise ratio to Fit $\langle \cos^2\theta^* \rangle$ vs. invariant mass to get φ meson raw ρ_{00}
- φ meson raw ρ_{00} results will be obtained at various beam energies
- Future work to correct for detector effects

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