

# Measuring the Global Spin Alignment of Vector Mesons in Heavy Ion Collisions by STAR

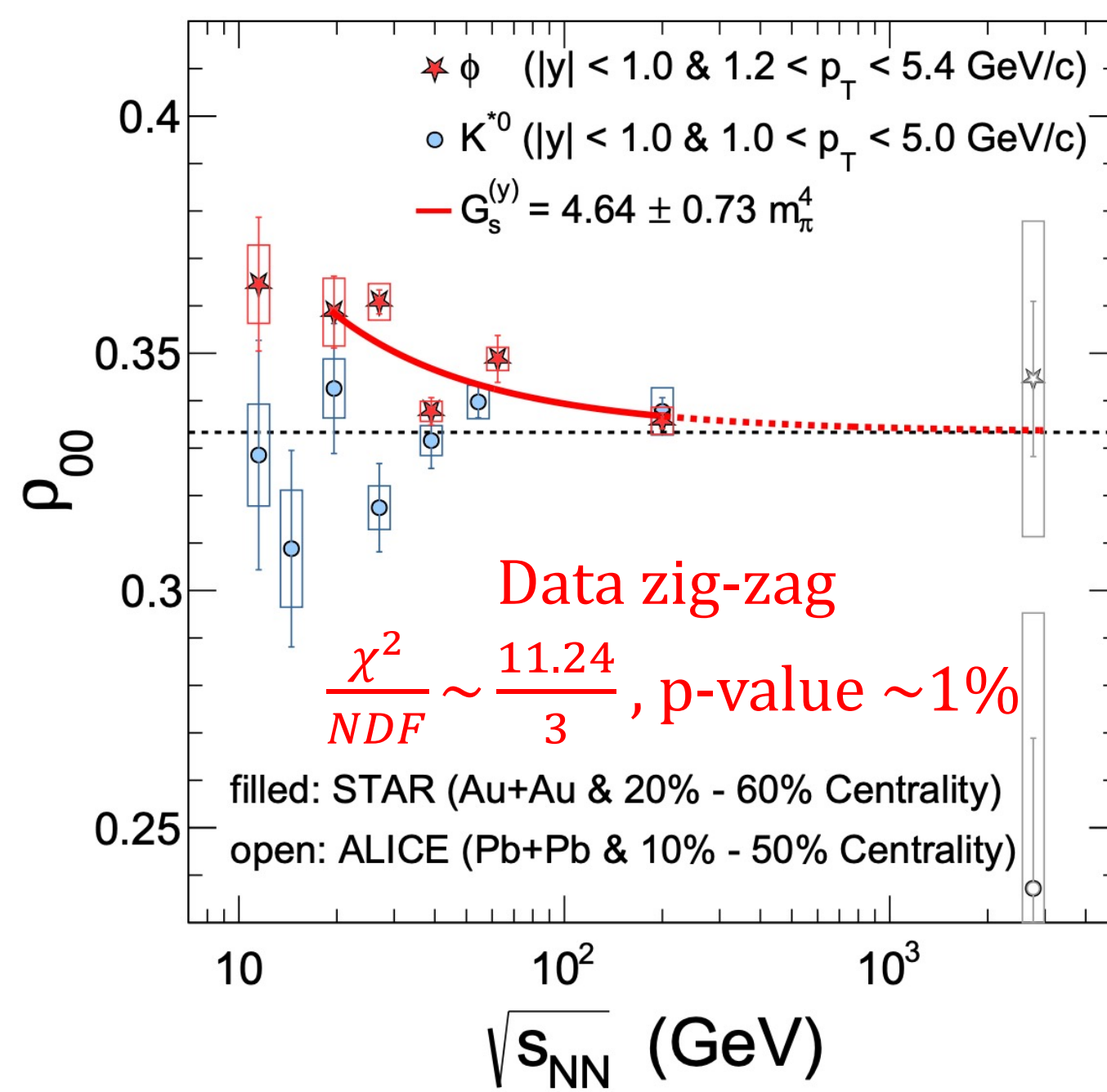
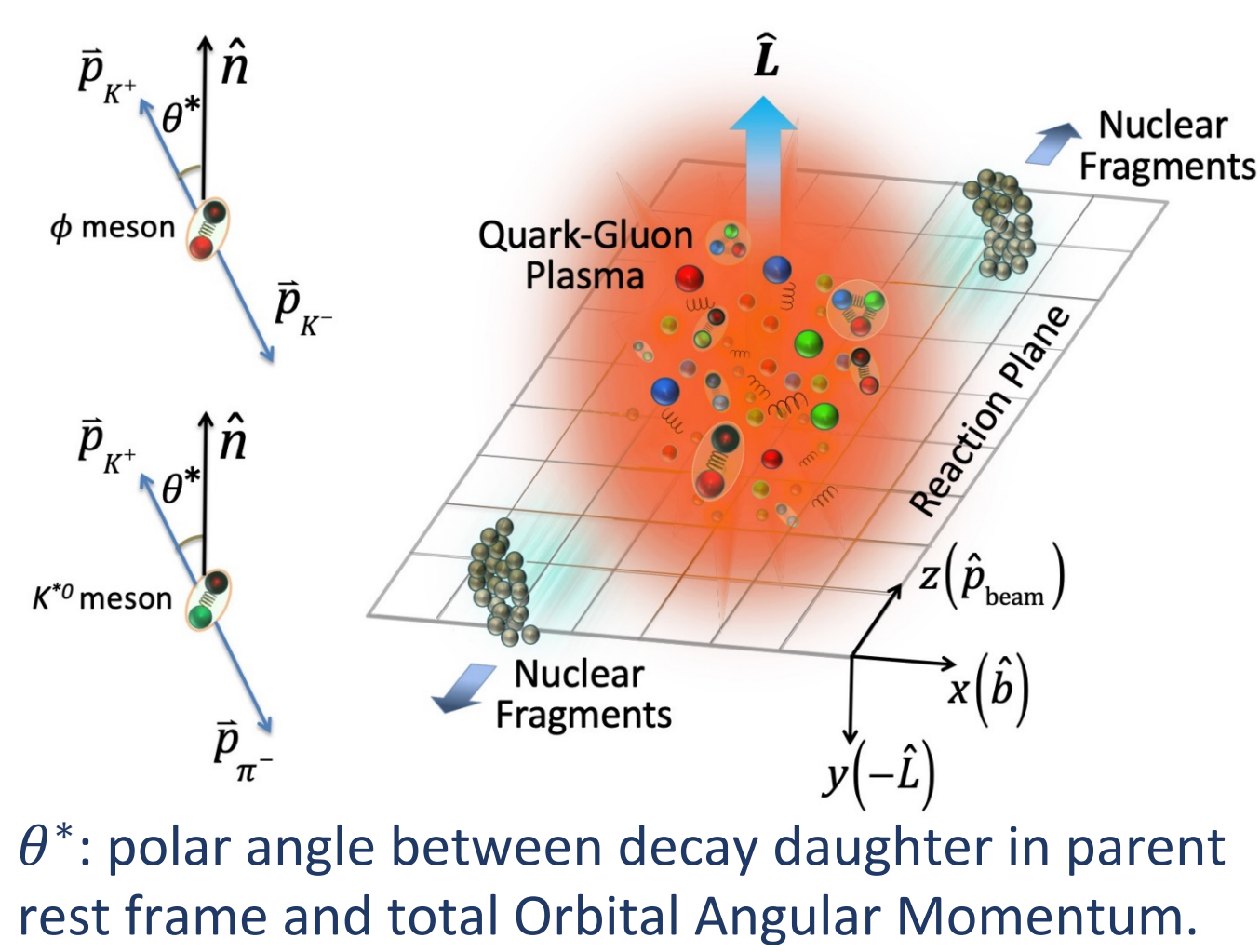
C.W. Robertson (rober558@purdue.edu), Purdue University  
for the STAR Collaboration



**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  $\phi(1020)$  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,  $\rho_{00}$ , is measured by a fit to the acceptance and efficiency corrected  $\phi$  meson yield versus polar angle ( $\theta^*$ ) between the daughter kaon in the parent's rest frame and the OAM direction. In this poster, we present an alternative approach to extract  $\rho_{00}$  by utilizing the  $\langle \cos^2 \theta^* \rangle$  as a function of pair-invariant mass instead of analyzing the  $\phi$  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.  $\theta^*$ .

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

## Motivation

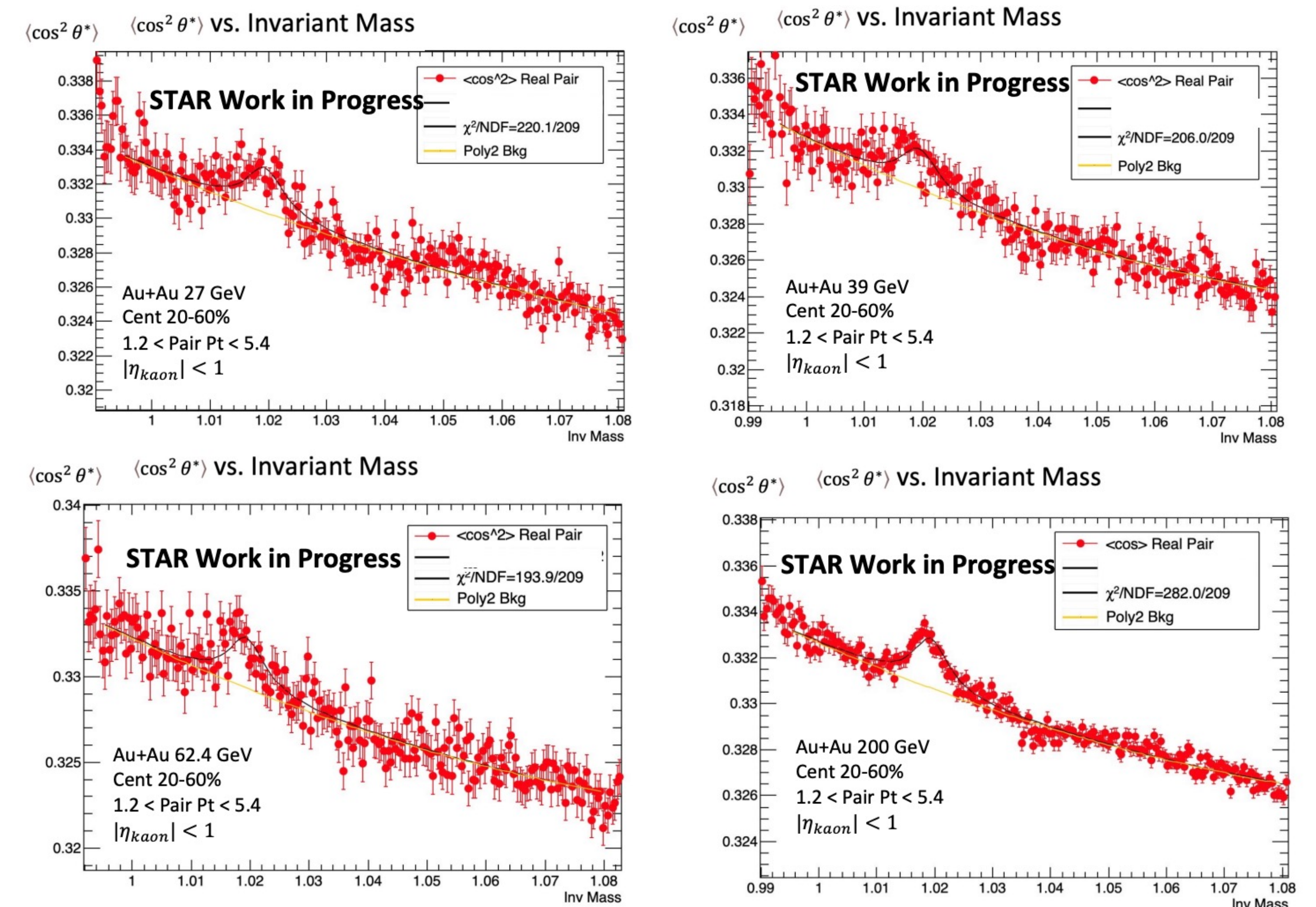


**NEW SINCE QM 23:**

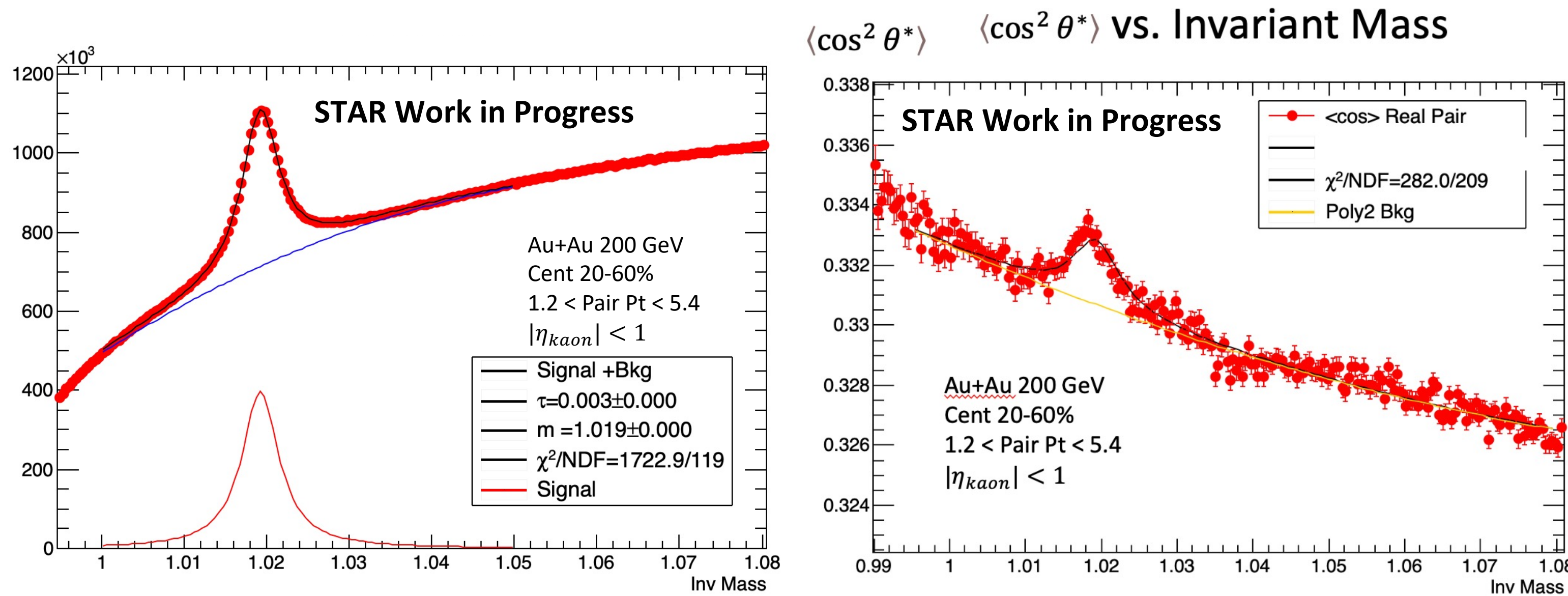
- Error Identified in Nature Publication
- ERRATUM in Preparation

- Spin alignment of vector mesons is characterized the spin density matrix element  $\rho_{00}$
- Measure  $\rho_{00}$  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  $\theta^*$
- Spin alignment  $\rho_{00}$ ,  $\theta^*$  dependent efficiency, and elliptic flow  $v_2$  are likely entangled
- We present another method to measure  $\rho_{00}$ , 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

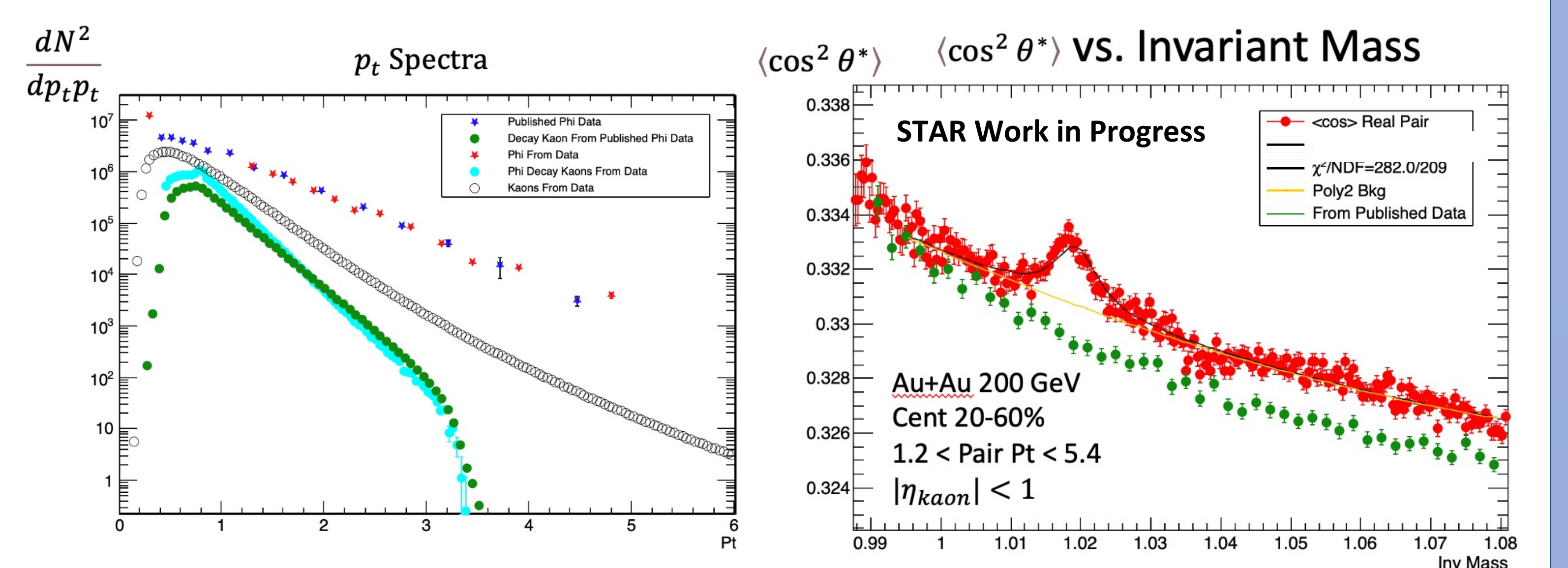


- Invariant mass distribution of kaon pairs (left) and  $\langle \cos^2 \theta^* \rangle$  vs. mass (right)
- We use the signal/noise ratio from left plot to fit the  $\langle \cos^2 \theta^* \rangle$  vs. mass for  $\rho_{obs}$
- Correct for Event Plane Resolution:  $\rho_{00} = \frac{4}{(1+3R)} \left( \rho_{obs} - \frac{1}{3} \right) + \frac{1}{3}$   
EP resolution at 200 GeV  $\sim 0.69$ , 62.4 GeV  $\sim .57$ , at 39 GeV  $\sim .55$ , and at 27 GeV  $\sim .51$

## 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. mass and other sources

## Future Work: Corrections



**Data-driven correction procedure for detector effects:**

- Use published  $\phi$  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  $\phi$  meson  $\rho_{00}$

## Summary

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

Supported in part by the



The STAR Collaboration

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