

# Preliminary figures request:

Global spin alignment of  $\phi$ -meson in 14.6 and 19.6  
GeV Au+Au collisions in BES-II

Gavin Wilks

University of Illinois at Chicago

08/16/23

# Contact Information

PA name: Gavin Wilks

PA email address: [gwilks3@uic.edu](mailto:gwilks3@uic.edu)

Supervisor email address: [yezhenyu@uic.edu](mailto:yezhenyu@uic.edu)

# Introduction to Spin Alignment

Preferential alignment of a particle's spin with respect to the orbital angular momentum produced in heavy-ion collisions.

$\rho_{00}$ : 00<sup>th</sup> element of the spin density matrix.

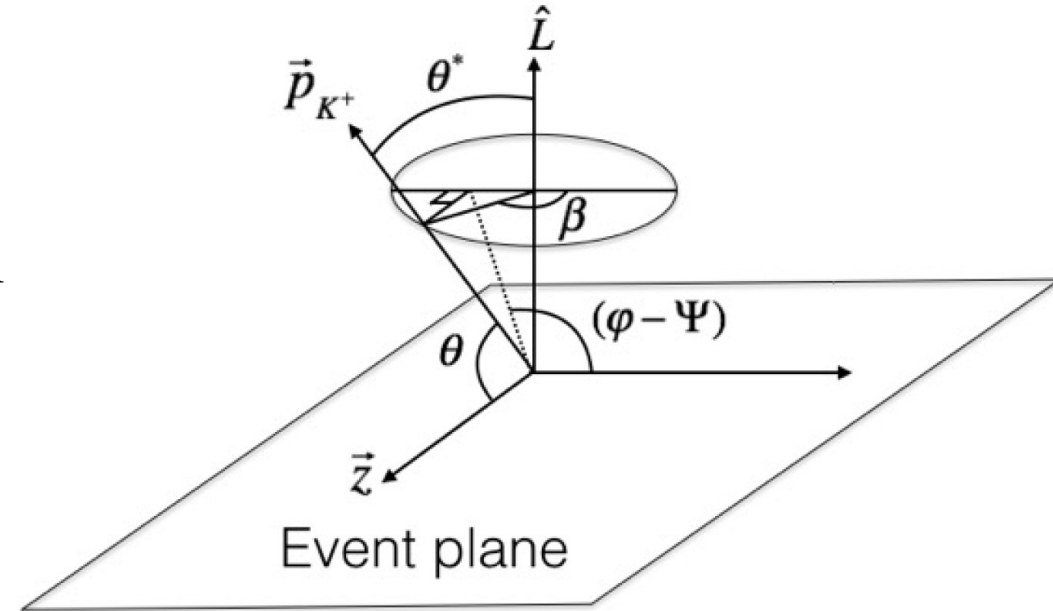
$\theta^*$ : angle between  $K^+$  daughter and polarization axis in parent's rest frame.

$\rho_{00}$  is found by fitting the parent particle's yield ( $N$ ) vs  $\cos(\theta^*)$ .

$$\frac{dN}{d \cos \theta^*} = N_0 \times [(1 - \rho_{00}) + (3\rho_{00} - 1) \cos^2 \theta^*]$$

Nucl. Phys.B18,332(1970)

$\rho_{00} \neq 1/3$  indicates spin alignment.

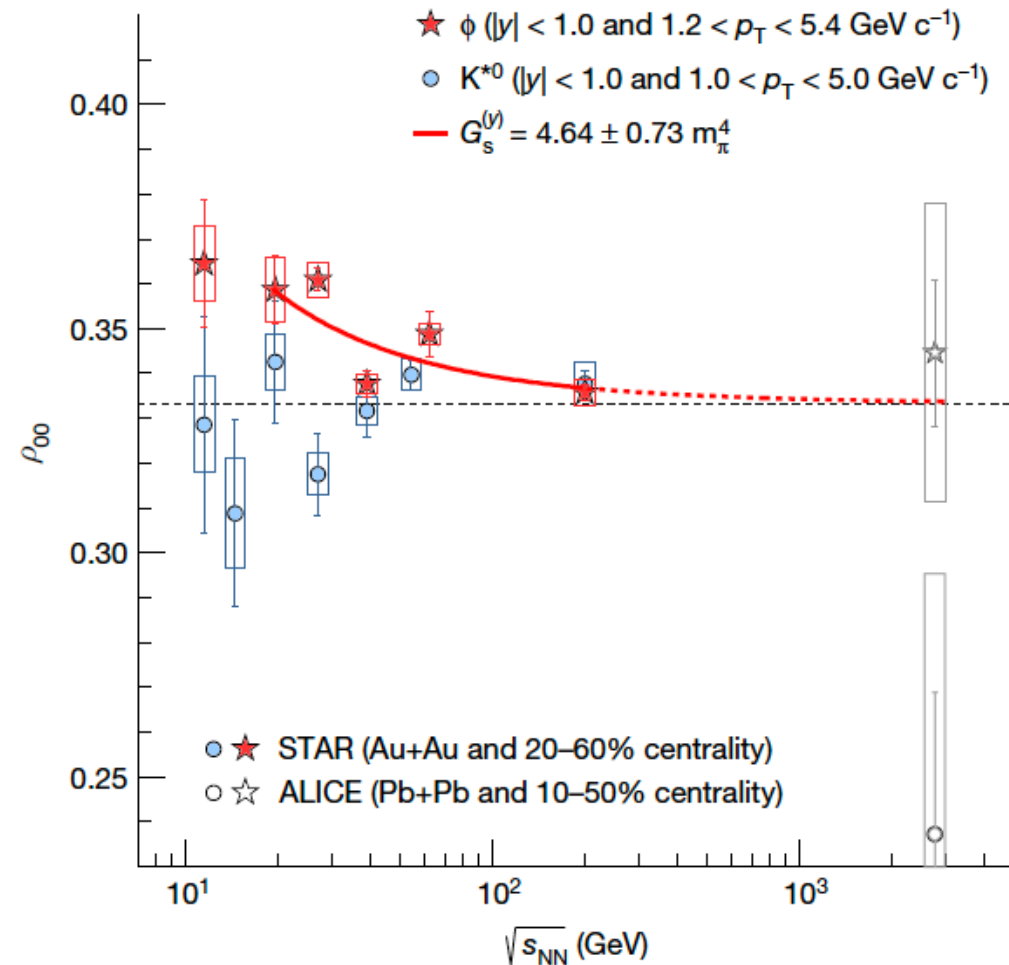


Phys. Rev. C **98**, 044907

# Physics Motivation

STAR Collaboration. *Nature* 614, 244–248 (2023)

- Preliminary studies from BES-I data found a large positive global spin alignment ( $\rho_{00} > 1/3$ ) for  $\phi$  mesons.
- Conventional methods cannot support this value.
- Supported by a theoretical model considering a  $\phi$  meson vector field coupling to  $s$  and  $\bar{s}$  quarks.



*Phys. Rev. D* **101**, 096005 (2020).

# Analysis Motivation

- Preliminary results for BES-I energies show increasing global spin alignment for  $\phi$ -meson at lower Au+Au collision energies ( $\leq 19.6\text{GeV}$ ).
  - Clarify  $\rho_{00}$  behavior in lower energy regime.
- BES-II provides significantly more statistics for lower collision energies.
  - BES-I 19.6 GeV:  $\sim 1.9 \times 10^7$  events after cuts
  - BES-II 19.6 GeV:  $\sim 4.6 \times 10^8$  events after cuts

# Datasets

- Dataset: Au+Au 19.6 GeV BES-II
  - Year: 2019
  - Production tag:  
production\_19GeV\_2019
  - Triggers used: 640001, 640011, 640021,  
640031, 640041, 640051
  - Embedding request id: 20214203,  
20214204
  - Bad run list from StRefMultCorr
- Dataset: Au+Au 14.6 GeV BES-II
  - Year: 2019
  - Production tag:  
production\_14p5GeV\_2019
  - Triggers used: 650000
  - Embedding request id: 20221502,  
20221503
  - Bad run list from StRefMultCorr

# Event level cuts

- $|v_z| < 70$  cm
- $|v_r| < 2$  cm
- $nBToFMatch > 2$
- Pile-up rejection cuts from StRefMultCorr
- Centrality from StRefMultCorr
  
- No. of event before event cuts  $\sim 1.05 \times 10^9$
- No. of event after event cuts  $\sim 4.60 \times 10^8$

# Track level cuts

$$\phi \rightarrow K^+ K^-$$

## TPC Track Cuts for $K^{+/-}$

- $0.1 < p_T < 10 \text{ GeV}/c$
- $|DCA| < 2 \text{ cm}$
- No. TPC hits  $> 15$
- TPC hit ratio  $> 0.52$
- $|\eta| < 1$

## PID Cuts for $K^{+/-}$

- $|n\sigma_K| < 2.5$
- ToF:  $0.16 < M^2 < 0.36$



# TPC 2<sup>nd</sup> Order Event Plane

## TPC Event Plane Cuts

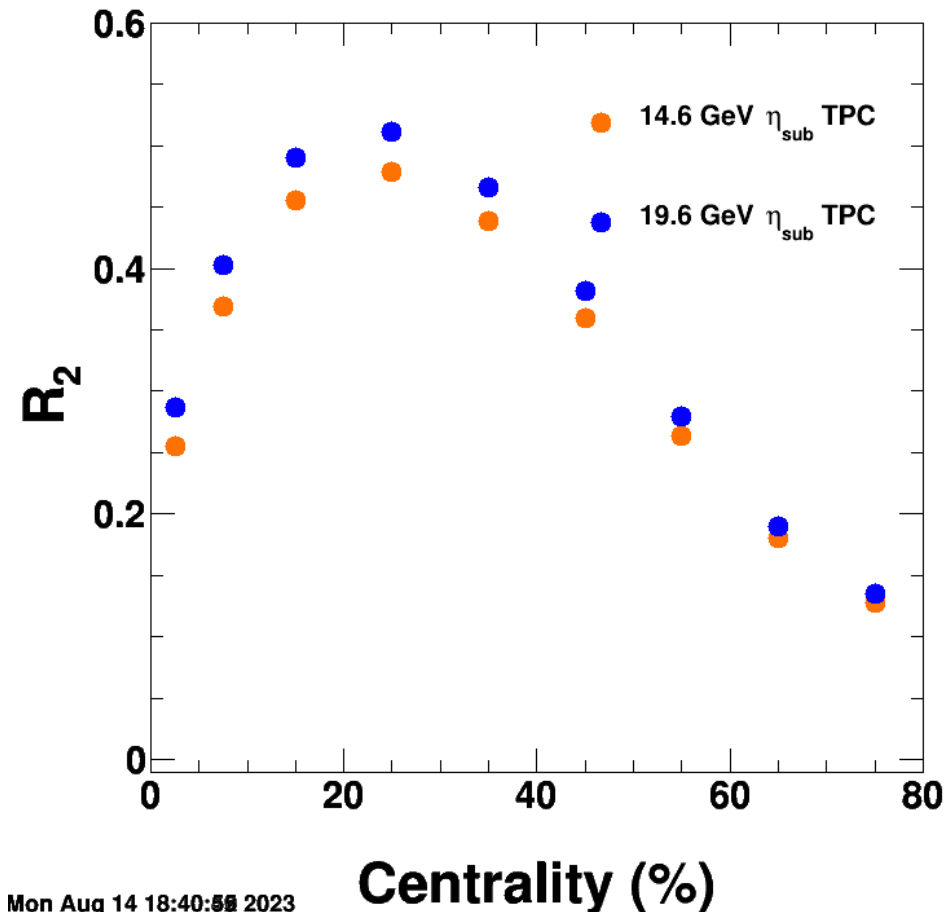
- $0.15 < p_T < 2$  GeV/c
- $|DCA| < 1$  cm
- No. TPC hits  $> 15$
- TPC hit ratio  $> 0.52$
- $|\eta| < 1$

## Sub-event plane method

- $\eta$  gap = 0.1

$$R_2 = \sqrt{\langle \cos 2(\Psi_{2,w} - \Psi_{2,e}) \rangle}$$

Apply run-by-run, centrality and  $v_z$  wise re-centering and shift calibrations



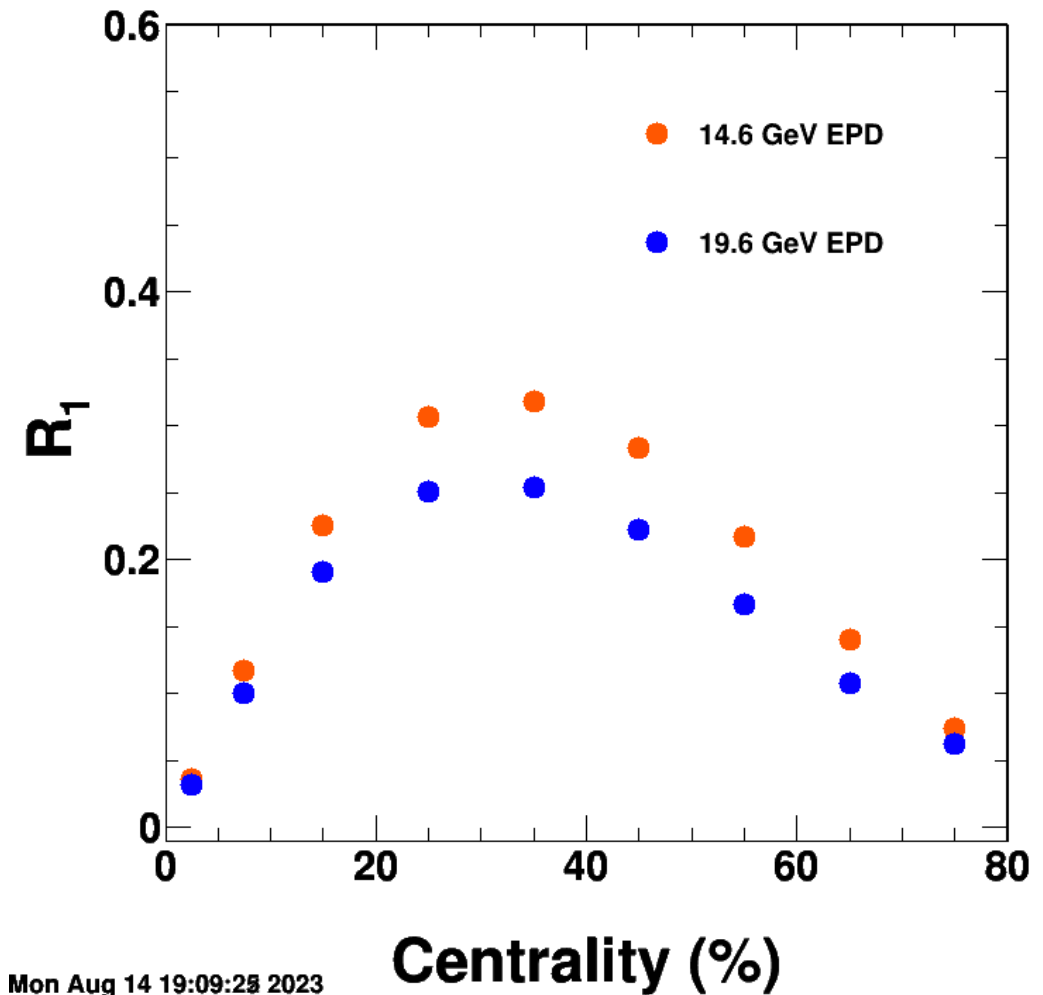
Mon Aug 14 18:40:58 2023

# EPD 1<sup>st</sup> Order Event Plane

- Use StEpdEpFinder
- $v_1$  vs.  $\eta$  weighting as described here:

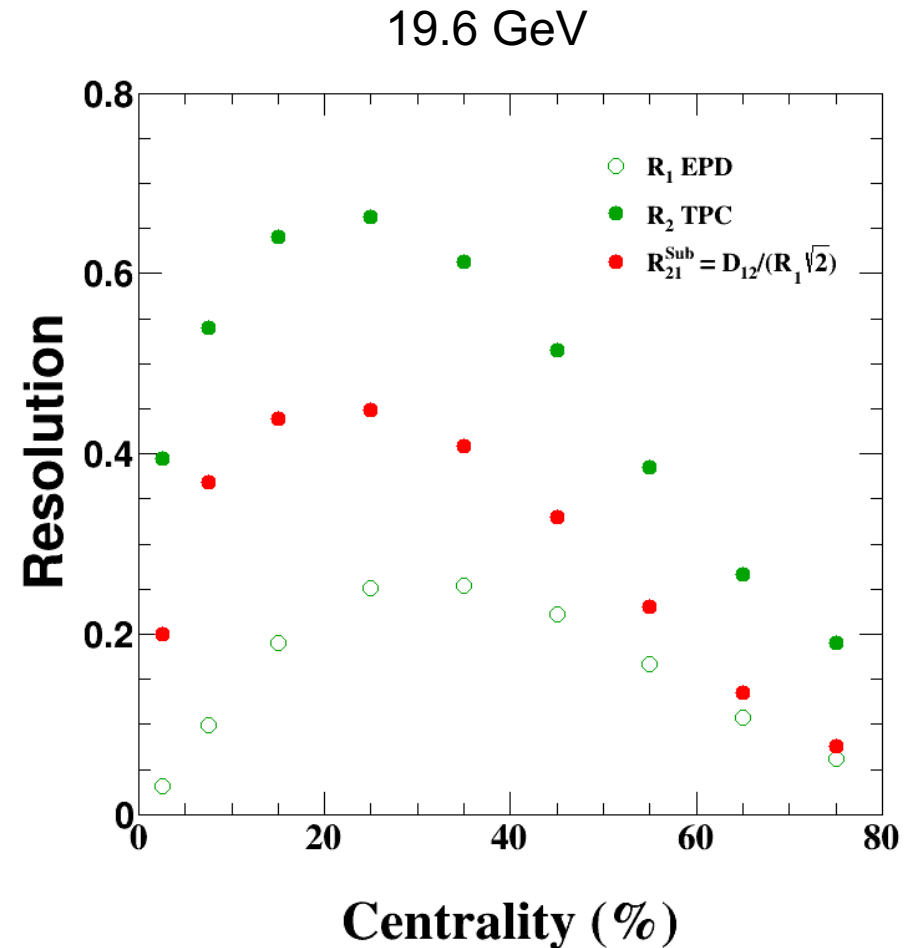
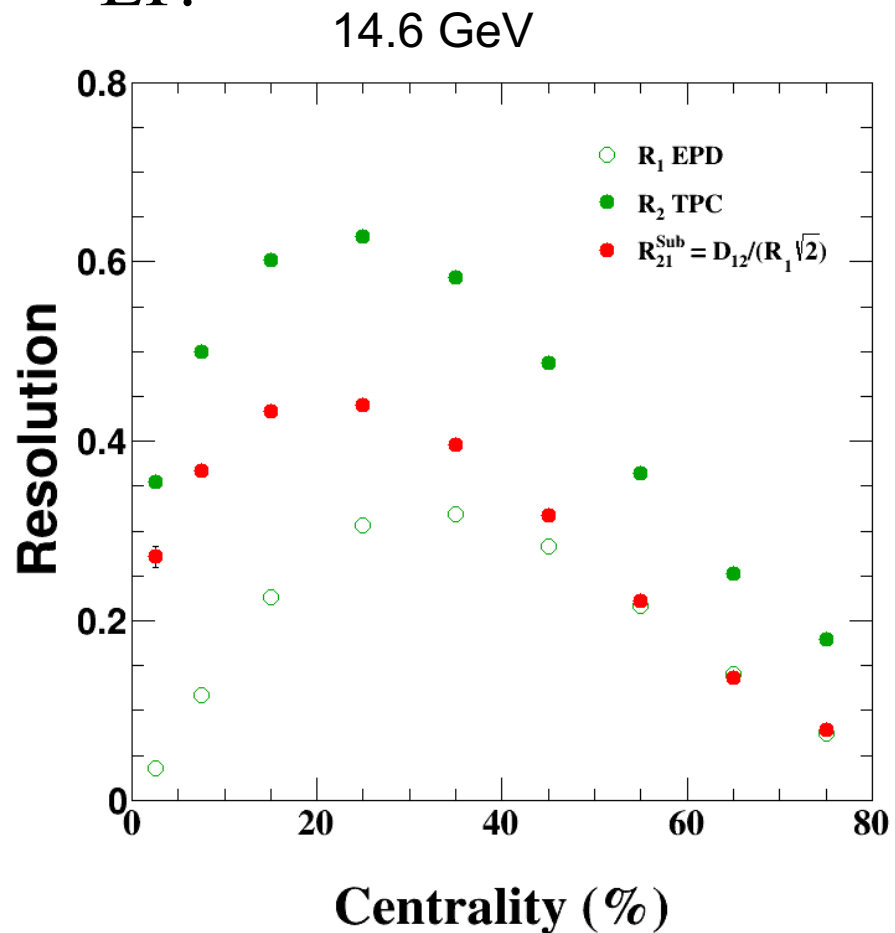
<https://drupal.star.bnl.gov/SSTAR/blog/iupsal/determining-eta-weights-epd-event-plane-analysis>

$$R_1 = \sqrt{\langle \cos 2(\Psi_1 - \Psi_{1,r}) \rangle}$$



# $R_{21}^{\text{Sub}}$

See slide 39 for  $R_{21}^{\text{Sub}}$  calculation. This resolution is used to correct the second order EP results such that they are compatible with first order EP.



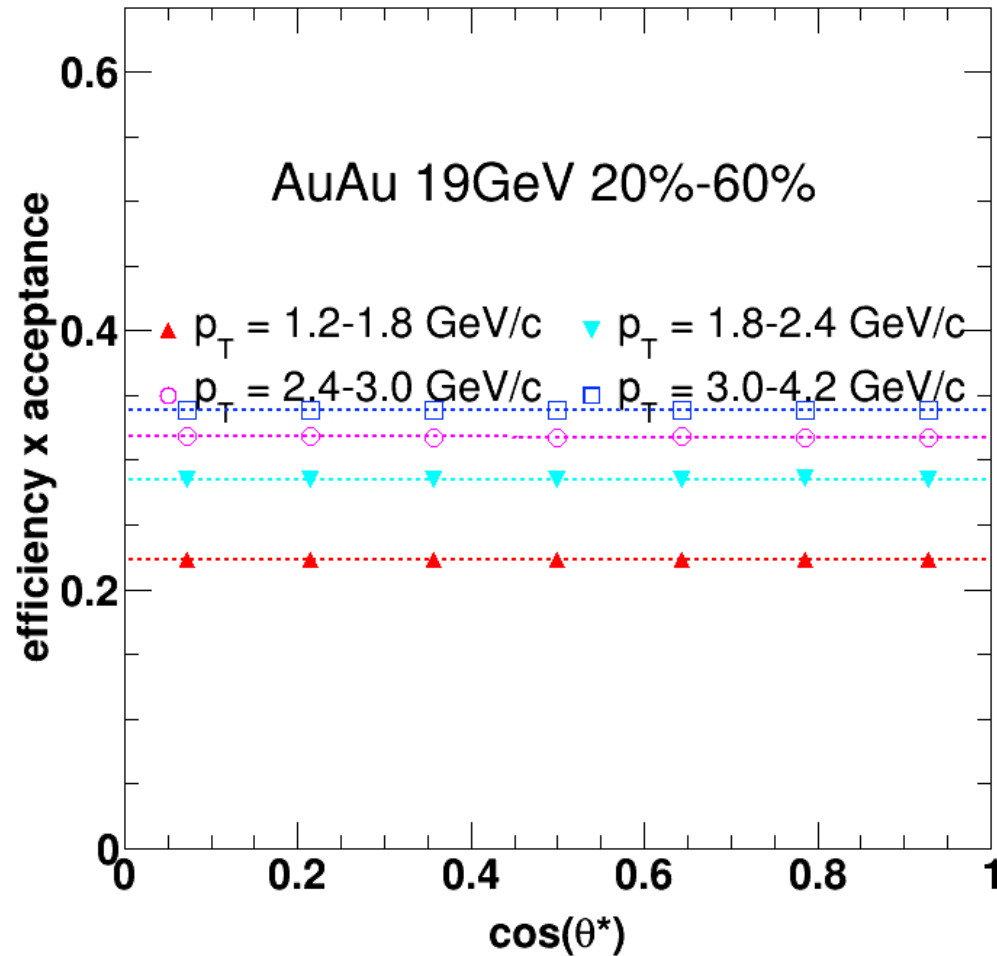
# Analysis Procedure

## Calculating $\rho_{00}$ from angular distribution of decay daughters:

- Total  $\phi$  meson yield calculated for each  $\cos(\theta^*)$  bin.
- Correct yields for TPC tracking x ToF matching efficiency and acceptance.
  - Simulate  $\phi$  decay in Pythia6 and apply efficiency and acceptance cuts to decay daughters to find efficiency vs.  $\cos(\theta^*)$ .
- Event plane resolution ( $R_1$  or  $R_{21}^{\text{sub}}$ ) correction applied with following formula:

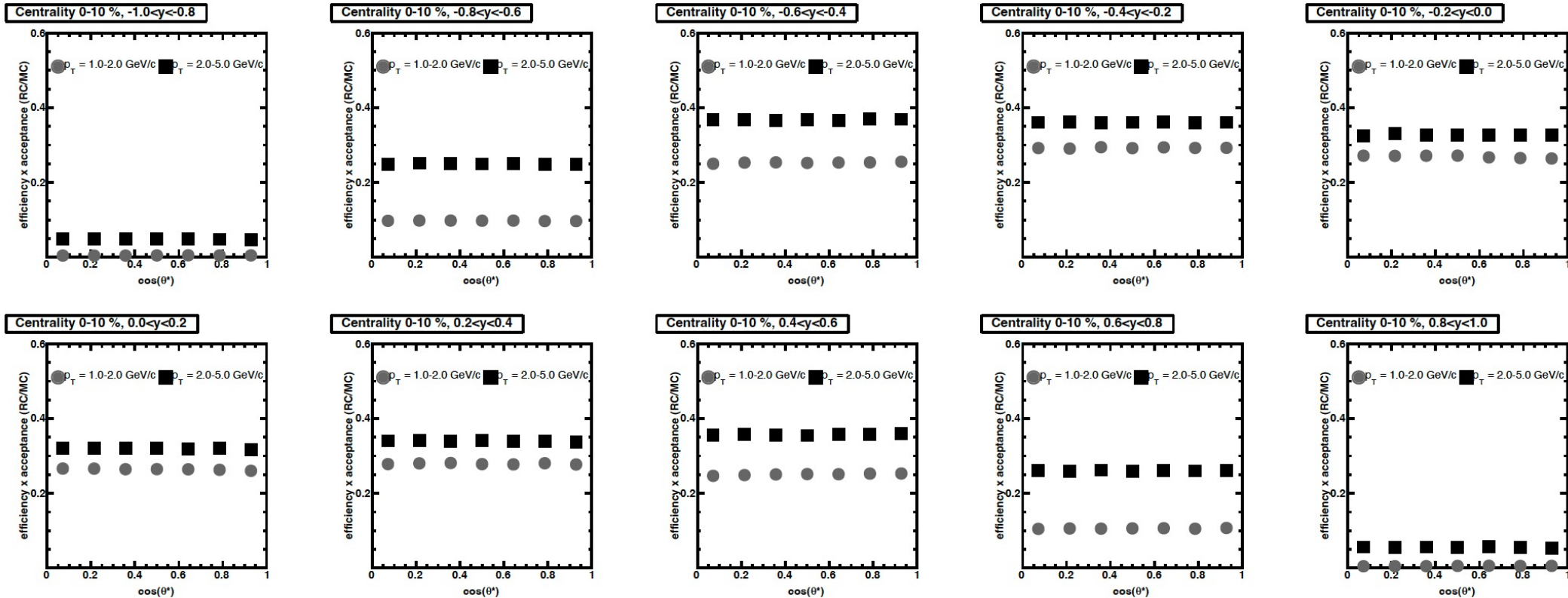
$$\rho_{00} = \frac{1}{3} + \frac{4}{1 + 3R} \left( \rho_{00}^{\text{obs}} - \frac{1}{3} \right)$$

# Efficiency $\times$ Acceptance vs. $\cos(\theta^*)$



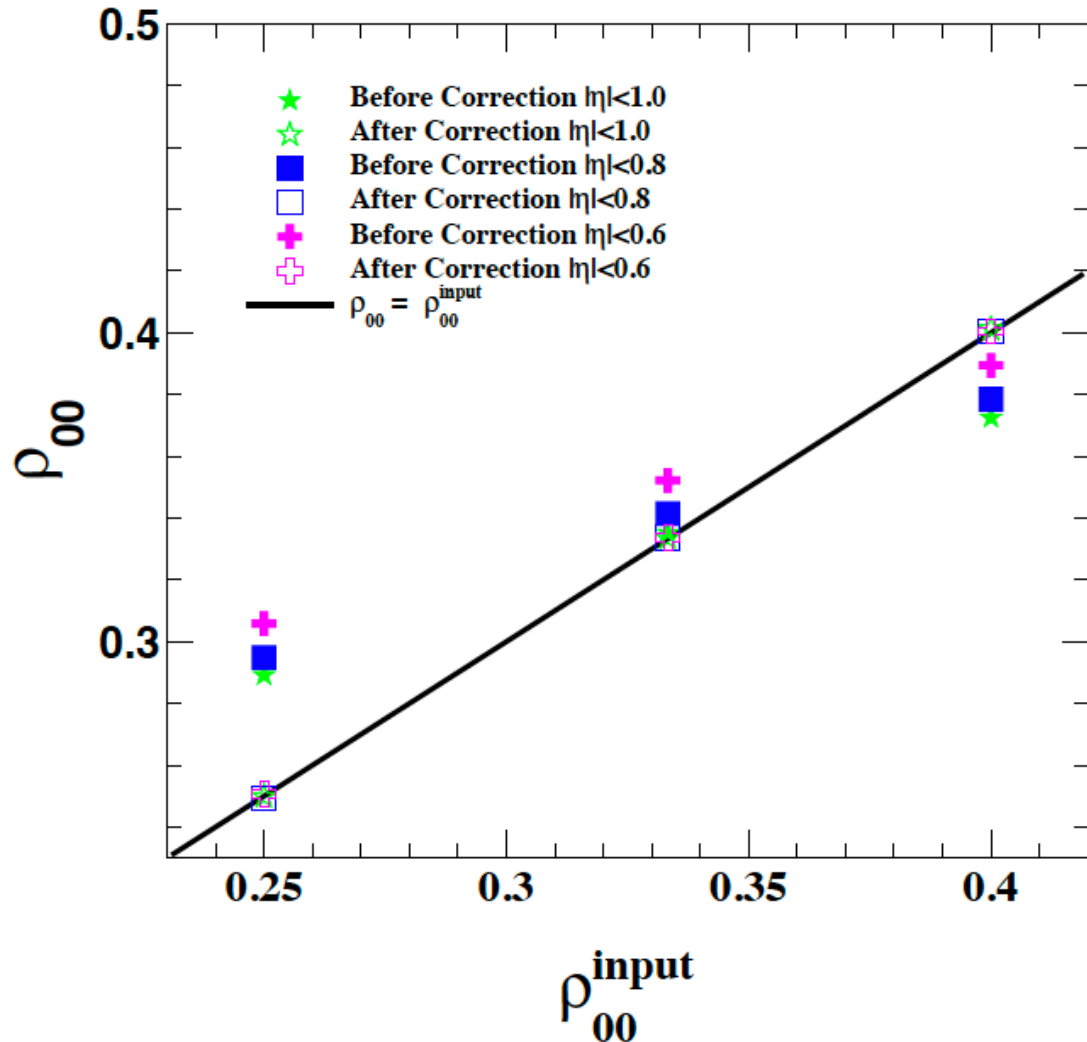
- Use Pythia6 to decay  $\phi \rightarrow K^+ K^-$
- MC  $\phi$  input flat in rapidity
  - $p_T$  from spectra or interpolated
  - $\phi$  from  $v_2$  distribution.
- Drop tracks using TPC tracking and ToF matching efficiency of  $K^+$  and  $K^-$  in each  $\eta$  &  $\phi$  bin.
- If both kaons pass efficiency cuts and  $\eta$  acceptance cut, reconstruct  $\phi$  meson.
- Smear EP according to known EP resolution in each centrality.
- Fill histogram for RC and MC counts in each  $\cos(\theta^*)$  bin.

# Efficiency $\times$ Acceptance vs. $\cos(\theta^*)$ y dependence



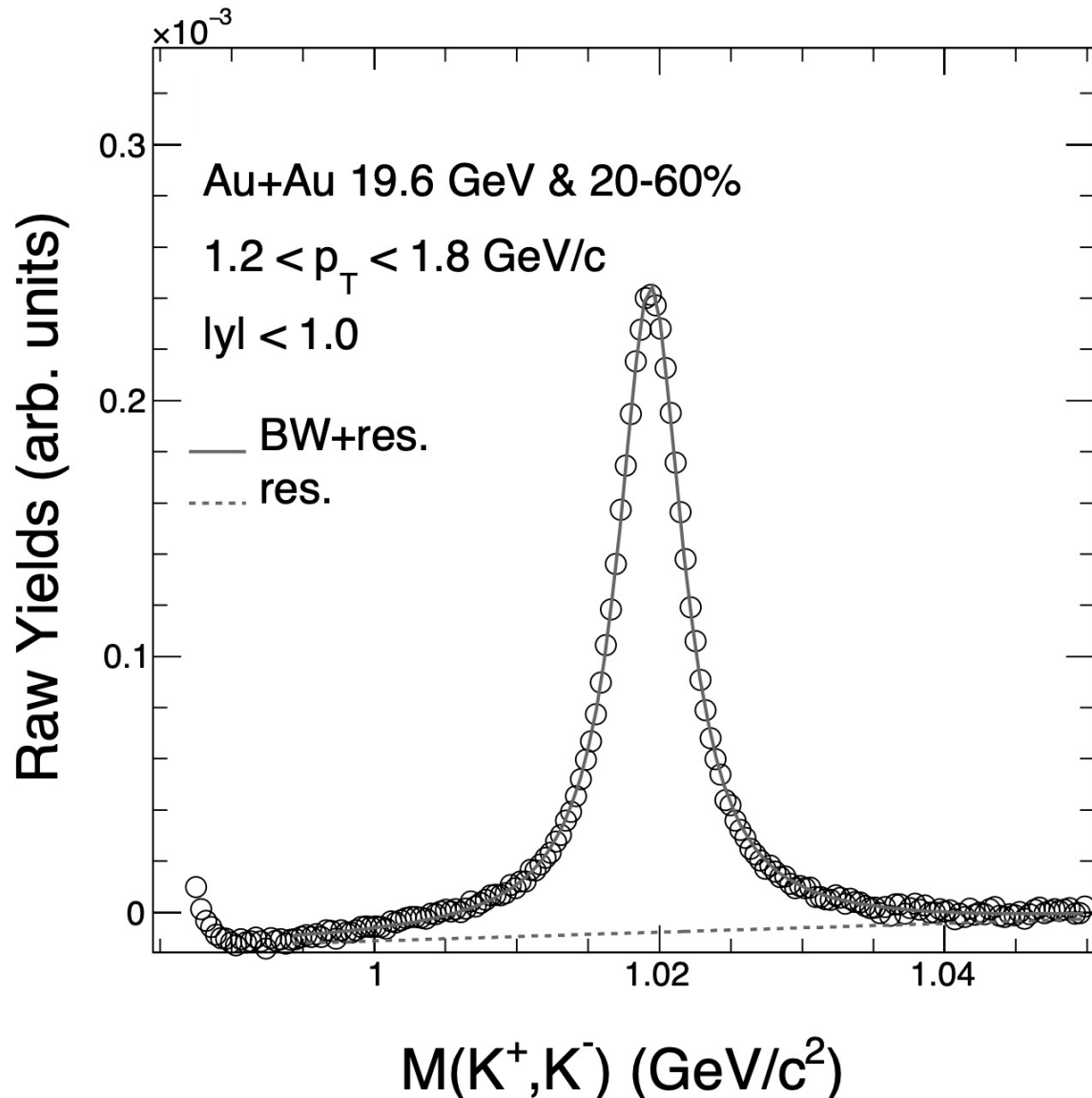
- All cases for our analysis can be found here: <https://drupal.star.bnl.gov/STAR/blog/gwilks3/Preliminary-Request-Details-phi-meson-global-spin-alignment>
- Note that the values for  $p_T = [1.0, 2.0]$  at  $0.8 < |y| < 1.0$  are non-zero and on the order of  $10^{-2}$

# Acceptance and Resolution Correction QA



- We simulated  $\phi$ -mesons with the following inputs:
  - 3 input  $\rho_{00}$  values:  $\{0.25, 0.3333, 0.4\}$
  - $p_T = 1.5 \text{ GeV}/c$
  - $v_2 = 0.075$
  - $y = [-1.0, 1.0]$  flat
- We cut on the daughters with 3 different  $|\eta|$  cuts:  $|\eta| < \{0.6, 0.8, 1.0\}$ .
- What we show is that before corrections the  $\rho_{00}$  we recover is not the same as the input. After we apply the acceptance and resolution corrections, the reconstructed values are equivalent to the input.

# Analysis Method



Event mixing is used to produce  $\phi$ -meson background.

Normalize mixed event background to signal+background and subtract background

Fit signal histogram with Breit Wigner + 3<sup>rd</sup> order polynomial

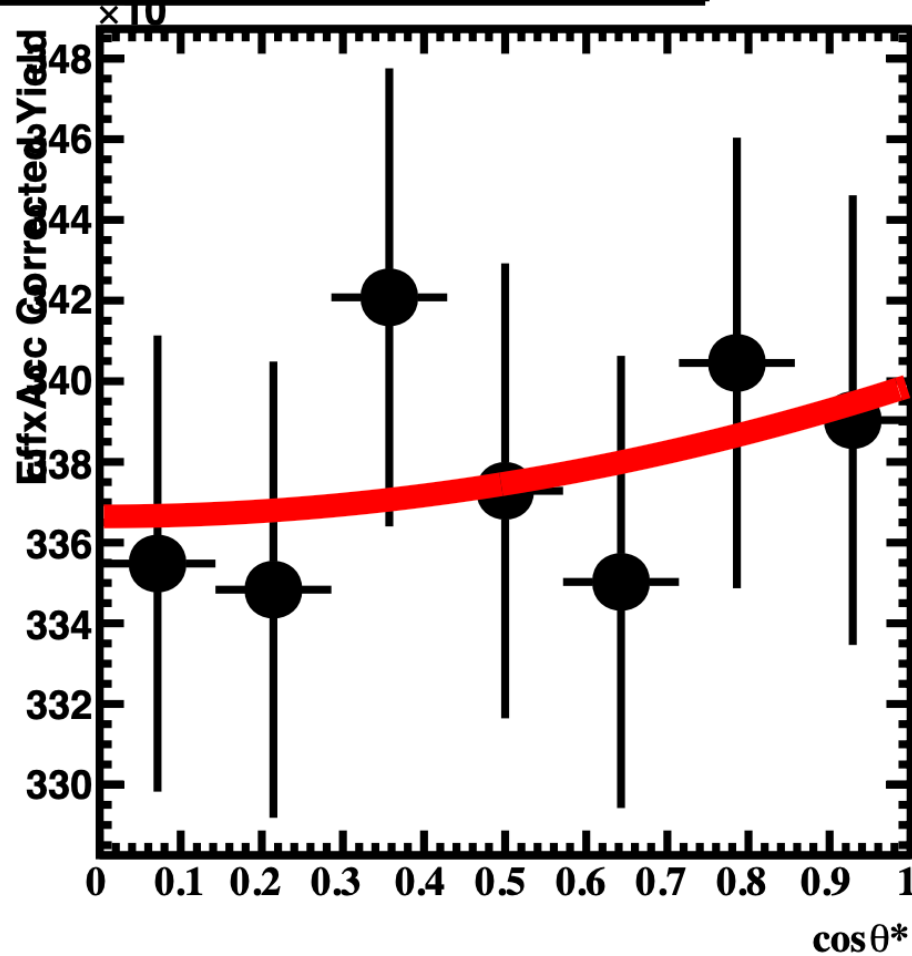
$$\frac{1}{2\pi} \frac{AF}{(m - m_\phi) + (\Gamma/2)^2} + poly3(m)$$

Yields are extracted by histogram integration.



# Signal Reconstruction

0.0 < y < 0.2, 1.0 < p<sub>T</sub> < 2.0 GeV/c, Cent 0-10



Au+Au 19.6 GeV  
20-60% Centrality  
 $\phi \rightarrow K^+ K^-$

$\rho_{00}^{obs}$  is calculated after efficiency and acceptance corrections.

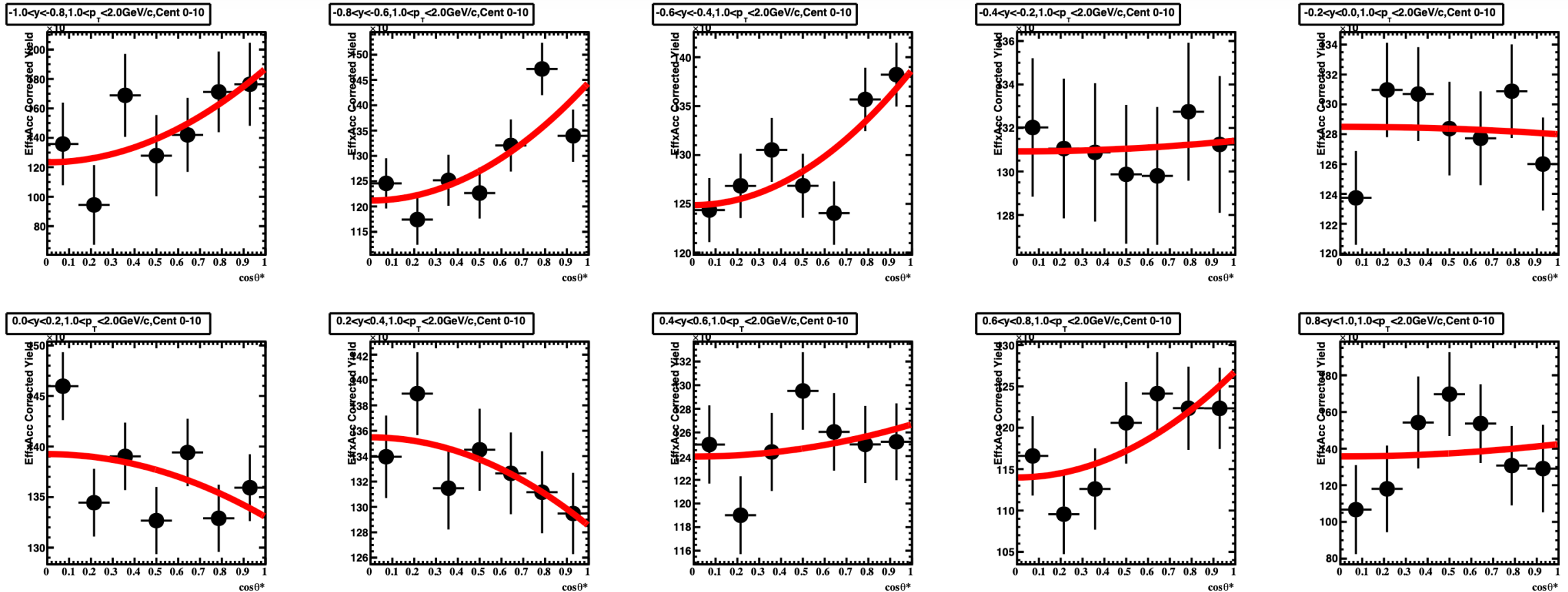
$$\frac{dN}{d \cos \theta^*} = N_0 \times [(1 - \rho_{00}) + (3\rho_{00} - 1) \cos^2 \theta^*]$$

Then calculate  $\rho_{00}$  from  $\rho_{00}^{obs}$  accounting for EP resolution.

$$\rho_{00} = \frac{1}{3} + \frac{4}{1 + 3R} \left( \rho_{00}^{obs} - \frac{1}{3} \right)$$

# Efficiency and Acceptance Corrected Signal Distributions

1st Order 14.6 GeV



- Other distributions can be found here: <https://drupal.star.bnl.gov/STAR/blog/gwilks3/Preliminary-Request-Details-phi-meson-global-spin-alignment>

# Systematics

Systematic Source	Central Value	Variations
dca	< 2.0 cm	< 2.0 cm, < 2.5 cm, < 3.0 cm
$ n\sigma_K $	< 2.5	< 2.0, < 2.5, < 3.0
Background normalization range	[1.04,1.05]	[0.99,1.0], [1.04,1.05], average of both
Yield extraction method	Breit-Wigner integration	Bin counting and Breit-Wigner integration
Yield extraction range	< 2.0 $\sigma$	< 2.0 $\sigma$ , < 2.5 $\sigma$ , < 3.0 $\sigma$

For a given source of systematic uncertainties, we obtained  $\rho_{00}$  with the cut for this sources changed, and other cuts are at the central value. Assuming uniform probability distributions between the maximum and minimum values, the value of the systematic uncertainty for a source is:

$$\Delta\rho_{00,sys}^i = \frac{\rho_{00,max}^i - \rho_{00,min}^i}{\sqrt{12}} \quad (39)$$

and then combine different sources of uncertainties:

$$\Delta\rho_{00,sys} = \sqrt{\sum_i (\Delta\rho_{00,sys}^i)^2} \quad (40)$$

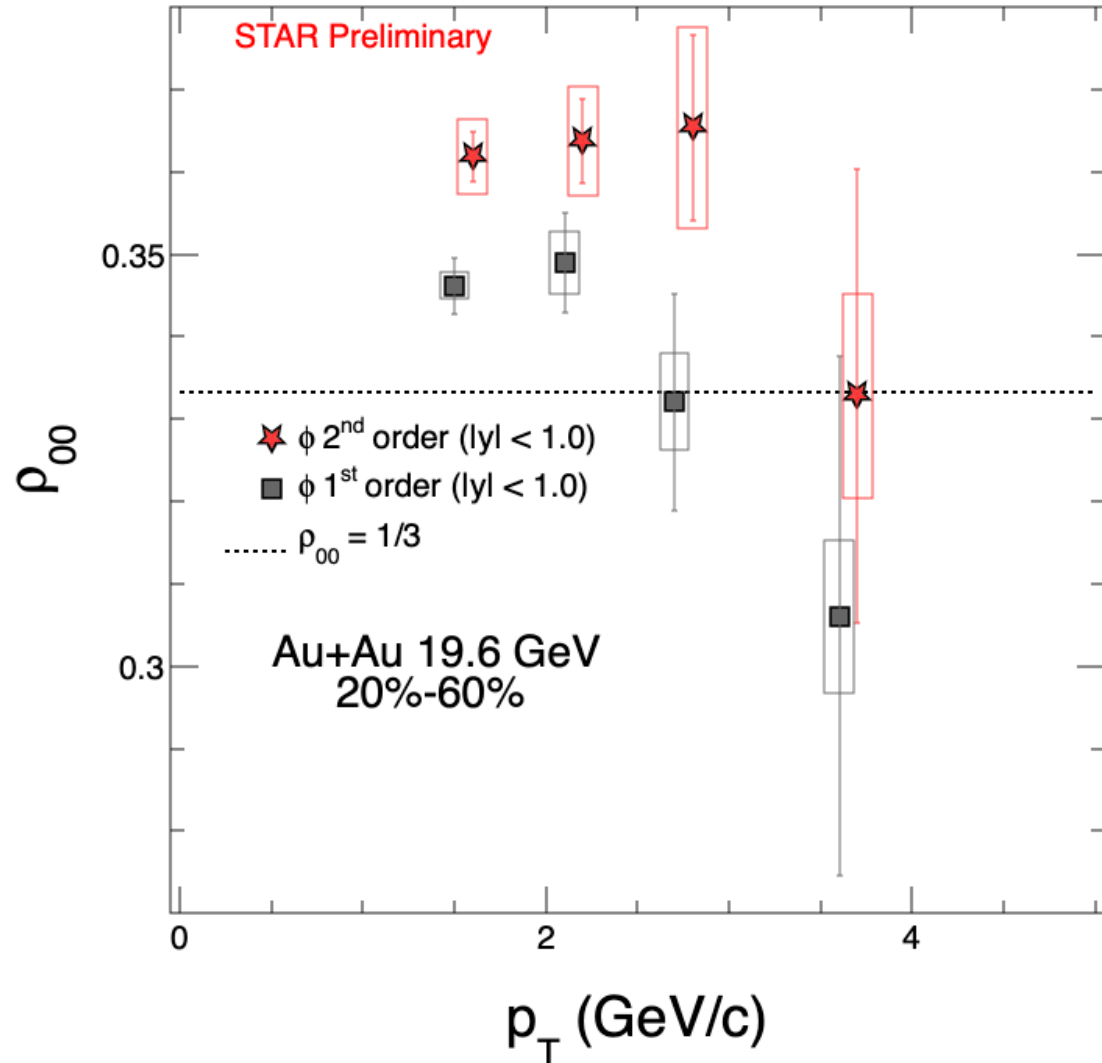
\* For rapidity dependence, we took the statistical weighted average of the symmetric negative and positive bins as the central value. The difference between points was added as a source of systematic error.

# The following slides contain new preliminary requests for data already in preliminary state for STAR

At the SQM 2022 conference, I showed the second order EP results for  $\phi$ -meson  $\rho_{00}$  in Au+Au 19.6 GeV (BES-II). After this point we found that there was an issue with the correction values for acceptance. Namely, they did not include the  $p_T$  spectra or  $v_2$  in the simulation from which they are derived, and this significantly impacts the acceptance parameter values. This was an issue in my analysis and the BES-I analysis and was quickly fixed after the conference. I understand there is a STAR policy that we are not able to override preliminary results, but I thought I would include the new results and the old results just in case.

# SQM2022 RESULTS FOR 19.6 GEV

# $\phi$ meson $\rho_{00}(p_T)$ 19.6 GeV



**Mid-central Au+Au collisions (20-60%)**

**BES-II 1<sup>st</sup> Order** Stat weighted average over  $p_T$ :

$$\rho_{00}^1 = 0.3458 \pm 0.0029 \text{ (stat.)} \pm 0.0015 \text{ (sys.)}$$

$$\rho_{00}^1 > 1/3 \text{ with } 3.8\sigma$$

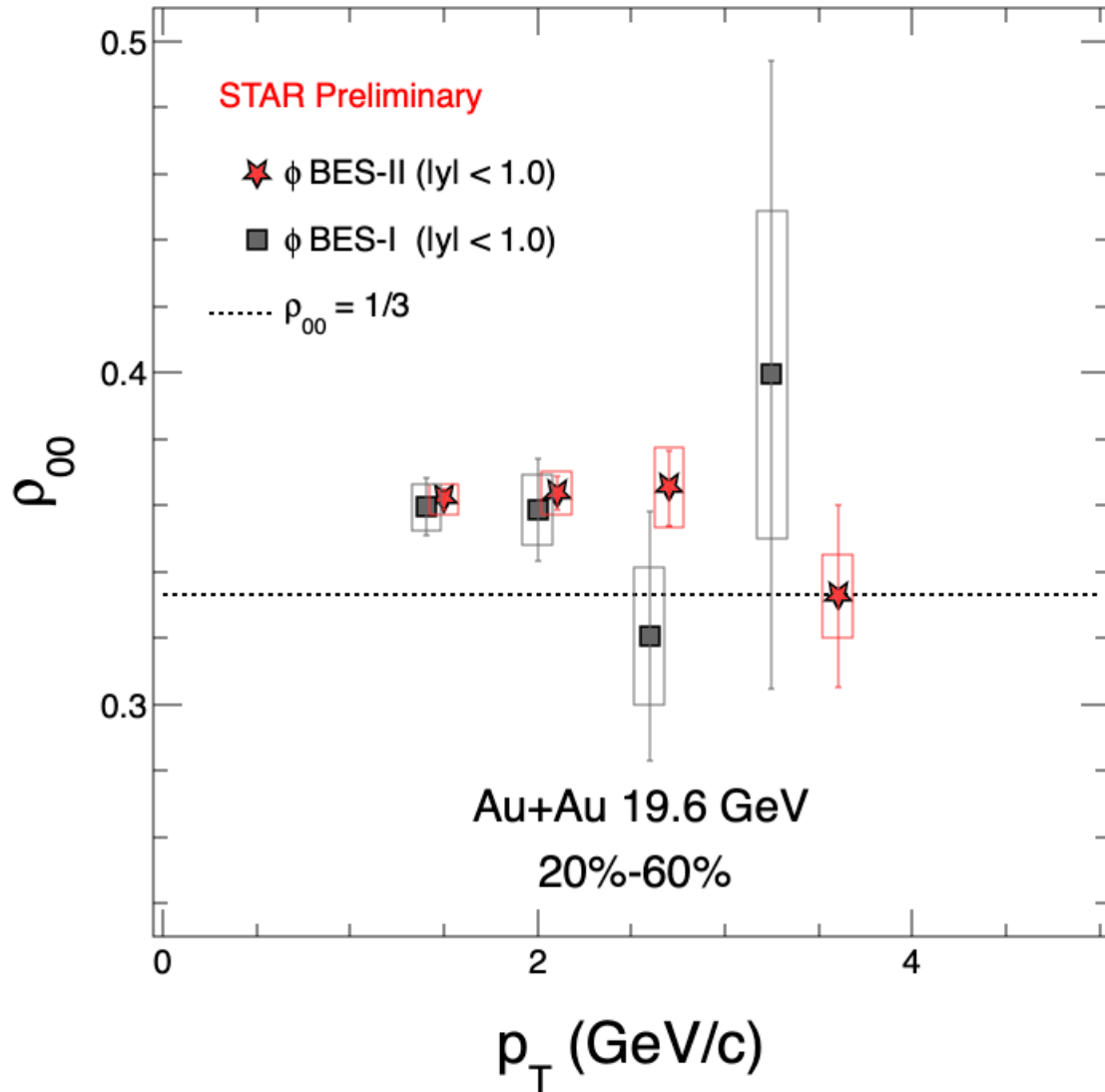
**BES-II 2<sup>nd</sup> Order** Stat weighted average over  $p_T$ :

$$\rho_{00}^2 = 0.3622 \pm 0.0026 \text{ (stat.)} \pm 0.0049 \text{ (sys.)}$$

$$\rho_{00}^2 > 1/3 \text{ with } 5.2\sigma$$

$$\rho_{00}^1 < \rho_{00}^2 \text{ with } 2.5\sigma$$

# $\phi$ meson $\rho_{00}(p_T)$ Second Order EP 19.6 GeV



**Mid-central Au+Au collisions (20-60%)**

**BES-II** Yield weighted average over  $p_T$ :

$$\rho_{00}^{\text{II}} = 0.3622 \pm 0.0026 \text{ (stat.)} \pm 0.0049 \text{ (sys.)}$$

$$\rho_{00}^{\text{II}} > 1/3 \text{ with } 5.2\sigma$$

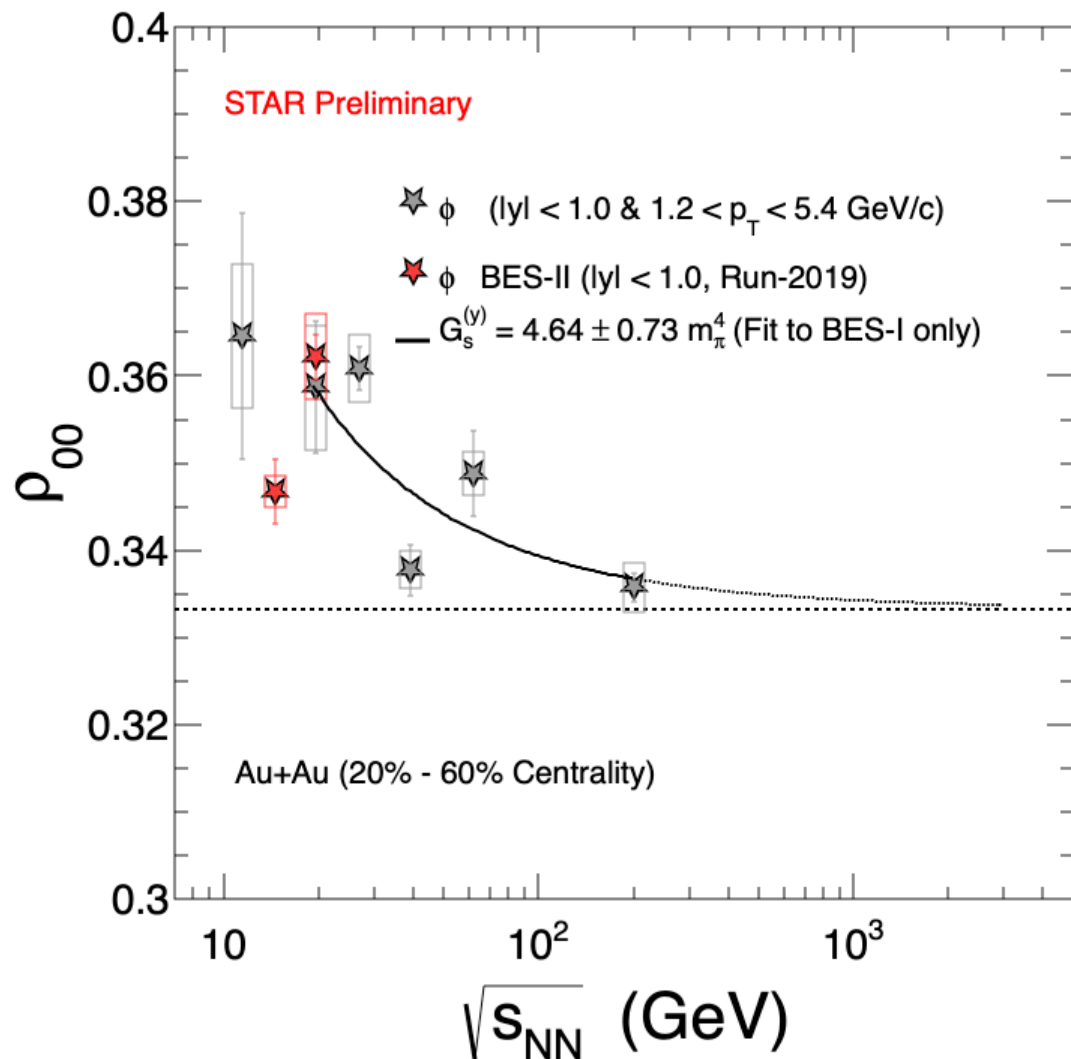
**BES-I** Yield weighted average over  $p_T$ :<sup>1</sup>

$$\rho_{00}^{\text{I}} = 0.3587 \pm 0.0076 \text{ (stat.)} \pm 0.0071 \text{ (sys.)}$$

$$\rho_{00}^{\text{I}} > 1/3 \text{ with } 2.4\sigma$$

$$\rho_{00}^{\text{II}} \sim \rho_{00}^{\text{I}} \text{ with } 0.3\sigma$$

# $\phi$ meson $\rho_{00}(\sqrt{s_{NN}})$ Second Order EP

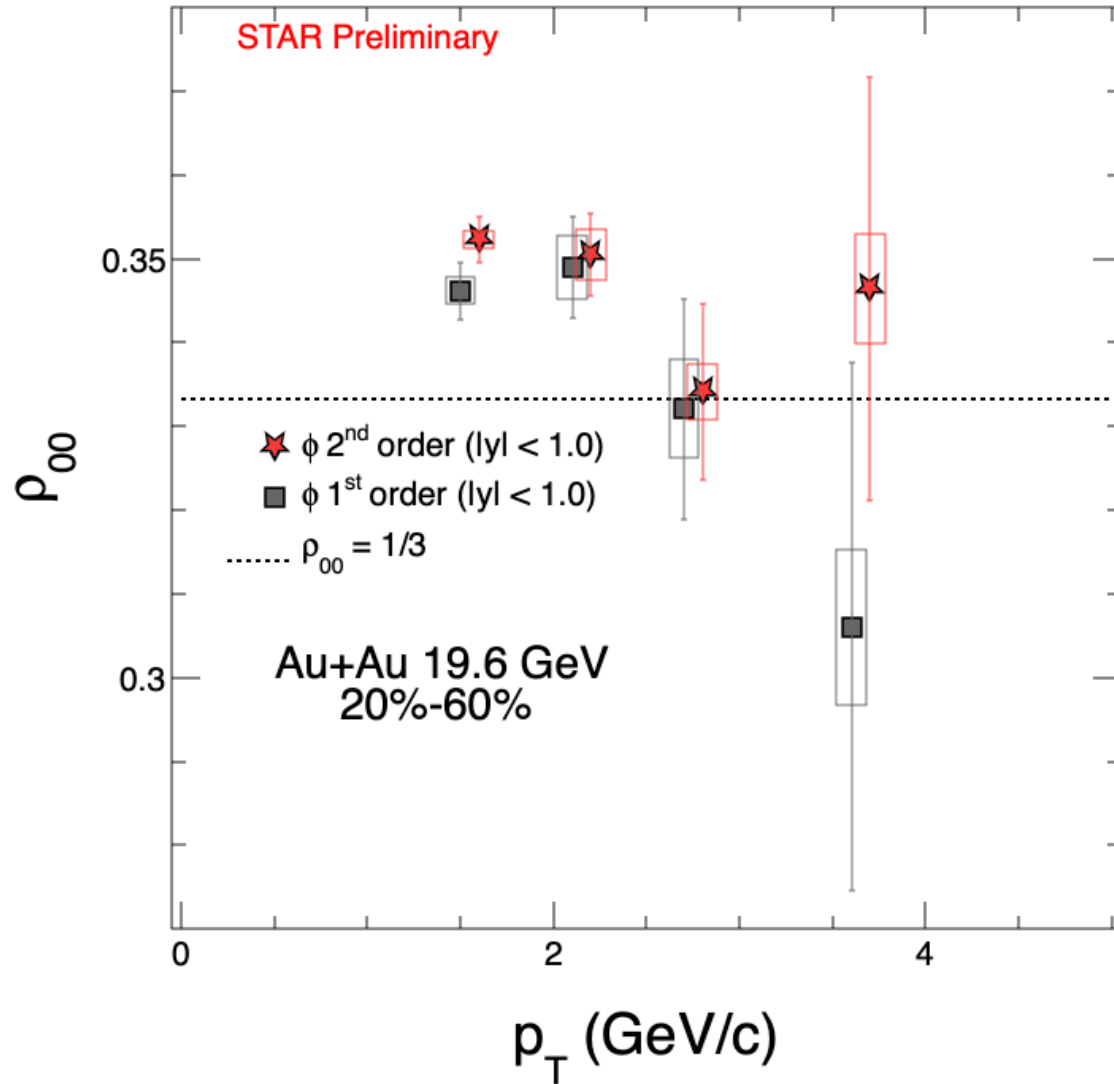


- Second order EP  $\rho_{00}$  collision energy dependence for mid-centrality.
- Solid black line is a fit to the BES-I data.
- Dashed black line is an extrapolation of the fit.



# NEW RESULTS FOR 19.6 GEV

# $\phi$ meson $\rho_{00}(p_T)$ 19.6 GeV



## Mid-central Au+Au collisions (20-60%)

**BES-II 1<sup>st</sup> Order** Stat weighted average over  $p_T$ :

$$\rho_{00}^1 = 0.3458 \pm 0.0029 \text{ (stat.)} \pm 0.0015 \text{ (sys.)}$$

$$\rho_{00}^1 > 1/3 \text{ with } 3.8\sigma$$

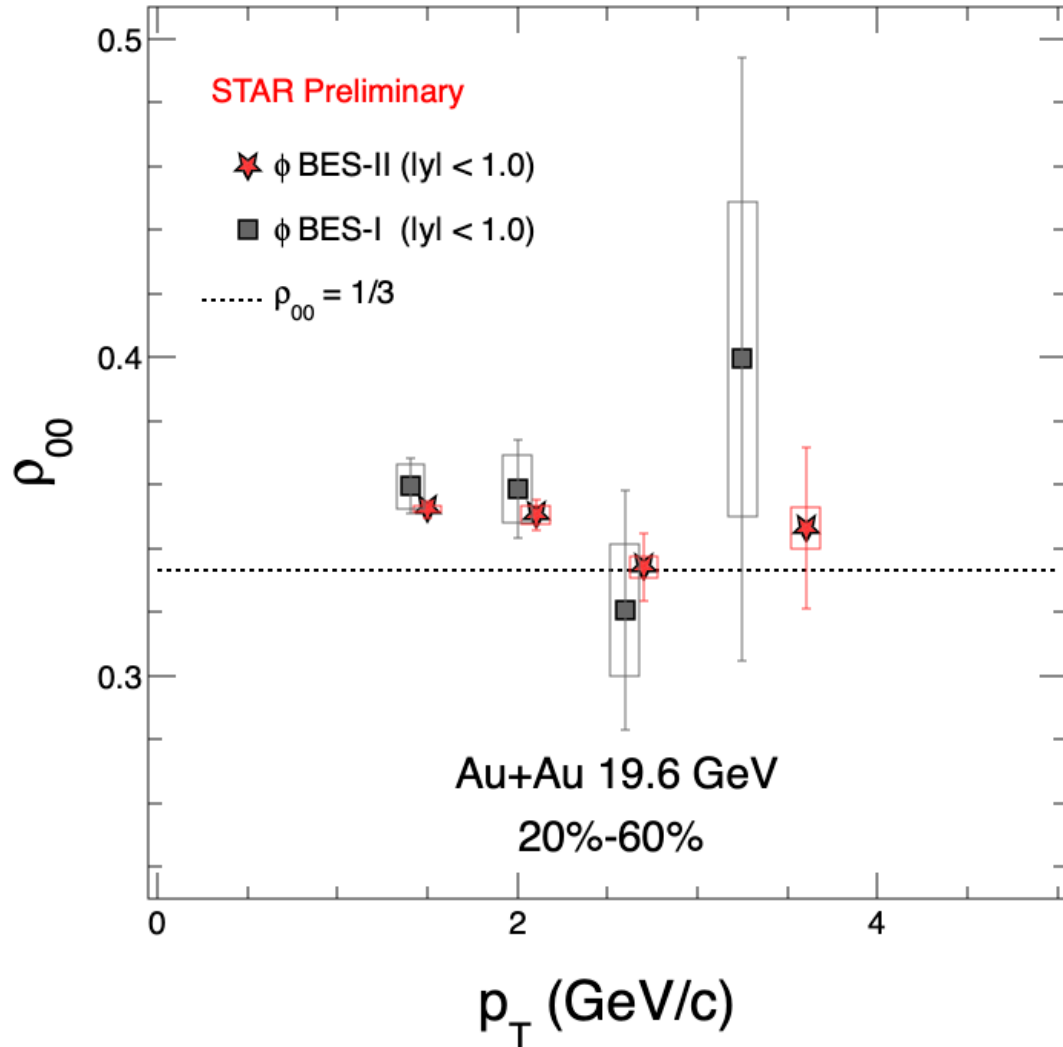
**BES-II 2<sup>nd</sup> Order** Stat weighted average over  $p_T$ :

$$\rho_{00}^2 = 0.3510 \pm 0.0023 \text{ (stat.)} \pm 0.0013 \text{ (sys.)}$$

$$\rho_{00}^2 > 1/3 \text{ with } 6.7\sigma$$

$$\rho_{00}^1 \sim \rho_{00}^2 \text{ with } 1.2\sigma$$

# $\phi$ meson $\rho_{00}(p_T)$ Second Order EP 19.6 GeV



**Mid-central Au+Au collisions (20-60%)**

**BES-II** Yield weighted average over  $p_T$ :

$$\rho_{00}^{\text{II}} = 0.3510 \pm 0.0023 \text{ (stat.)} \pm 0.0013 \text{ (sys.)}$$

$$\rho_{00}^{\text{II}} > 1/3 \text{ with } 6.7\sigma$$

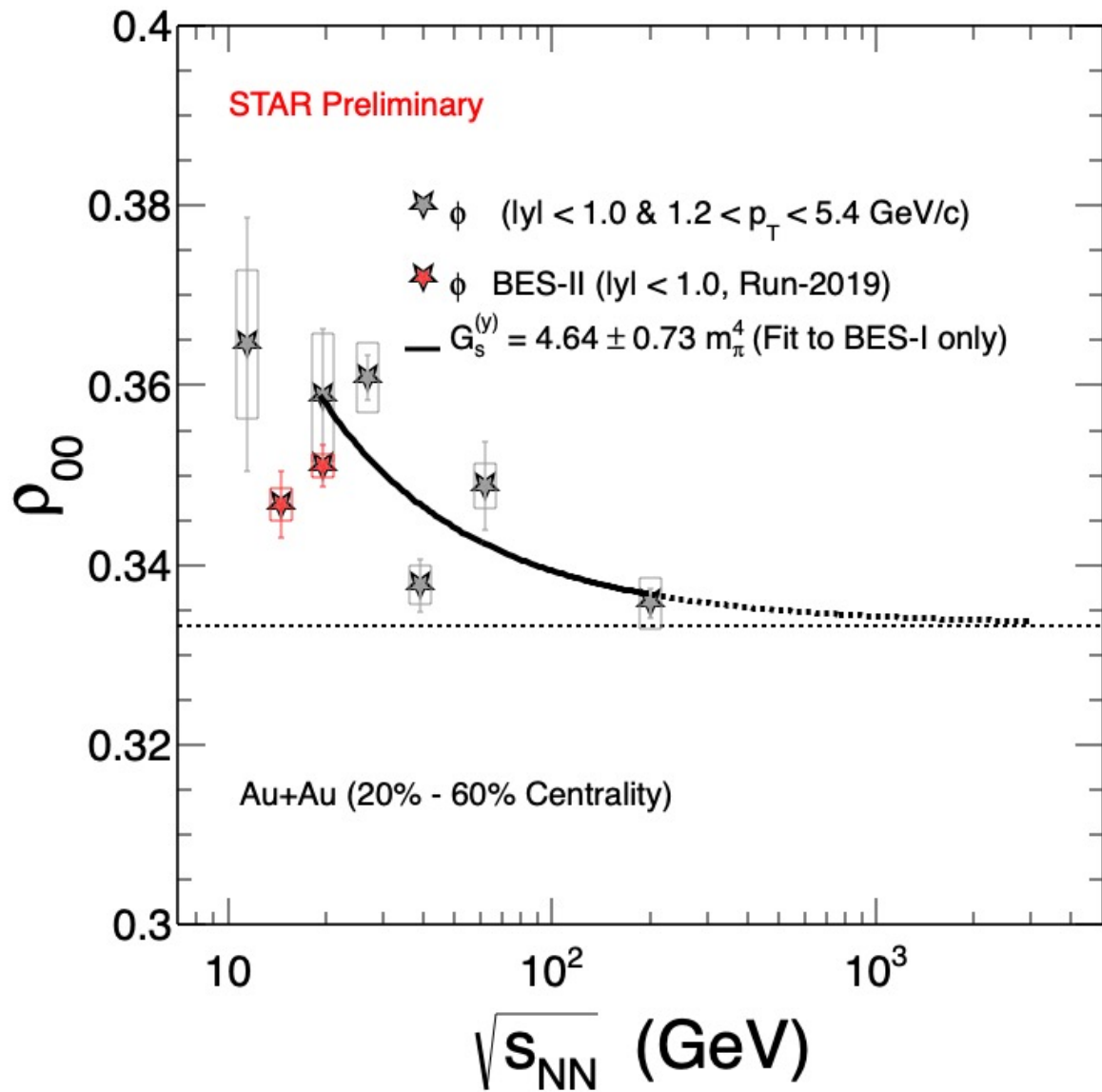
**BES-I** Yield weighted average over  $p_T$ :<sup>1</sup>

$$\rho_{00}^{\text{I}} = 0.3587 \pm 0.0076 \text{ (stat.)} \pm 0.0071 \text{ (sys.)}$$

$$\rho_{00}^{\text{I}} > 1/3 \text{ with } 2.4\sigma$$

$$\rho_{00}^{\text{II}} \sim \rho_{00}^{\text{I}} \text{ with } 0.7\sigma$$

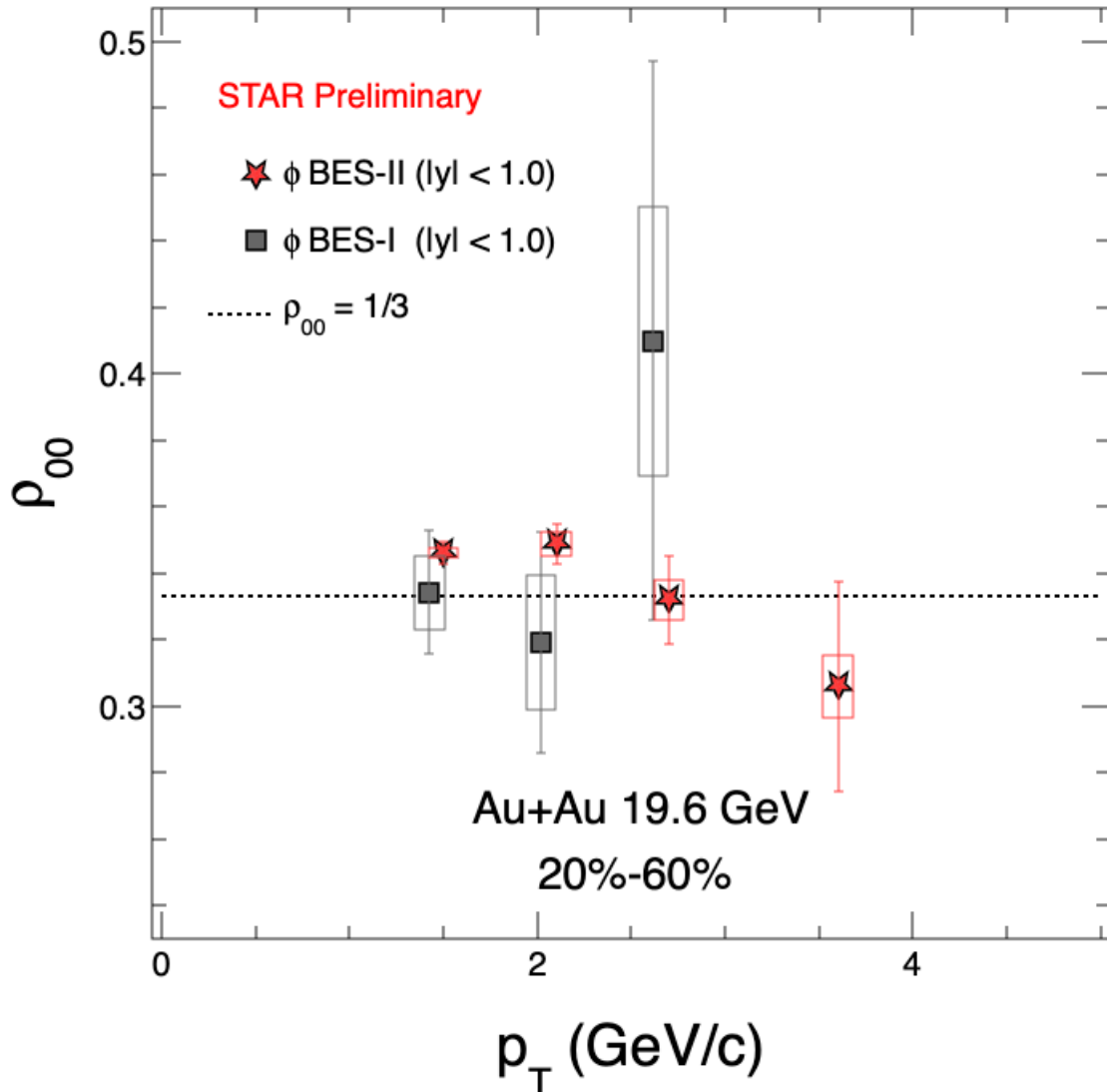
# $\phi$ meson $\rho_{00}(\sqrt{s_{NN}})$ Second Order EP



- Second order EP  $\rho_{00}$  collision energy dependence for mid-centrality.
- Solid black line is a fit to the BES-I data.
- Dashed black line is an extrapolation of the fit.

# THE FOLLOWING RESULTS ARE ALL NEW PRELIMINARY REQUESTS

# $\phi$ meson $\rho_{00}(p_T)$ First Order EP 19.6 GeV



## Mid-central Au+Au collisions (20-60%)

**BES-II** Stat weighted average over  $p_T$ :

$$\rho_{00}^{\text{II}} = 0.3458 \pm 0.0029 \text{ (stat.)} \pm 0.0015 \text{ (sys.)}$$

$$\rho_{00}^{\text{II}} > 1/3 \text{ with } 3.8\sigma$$

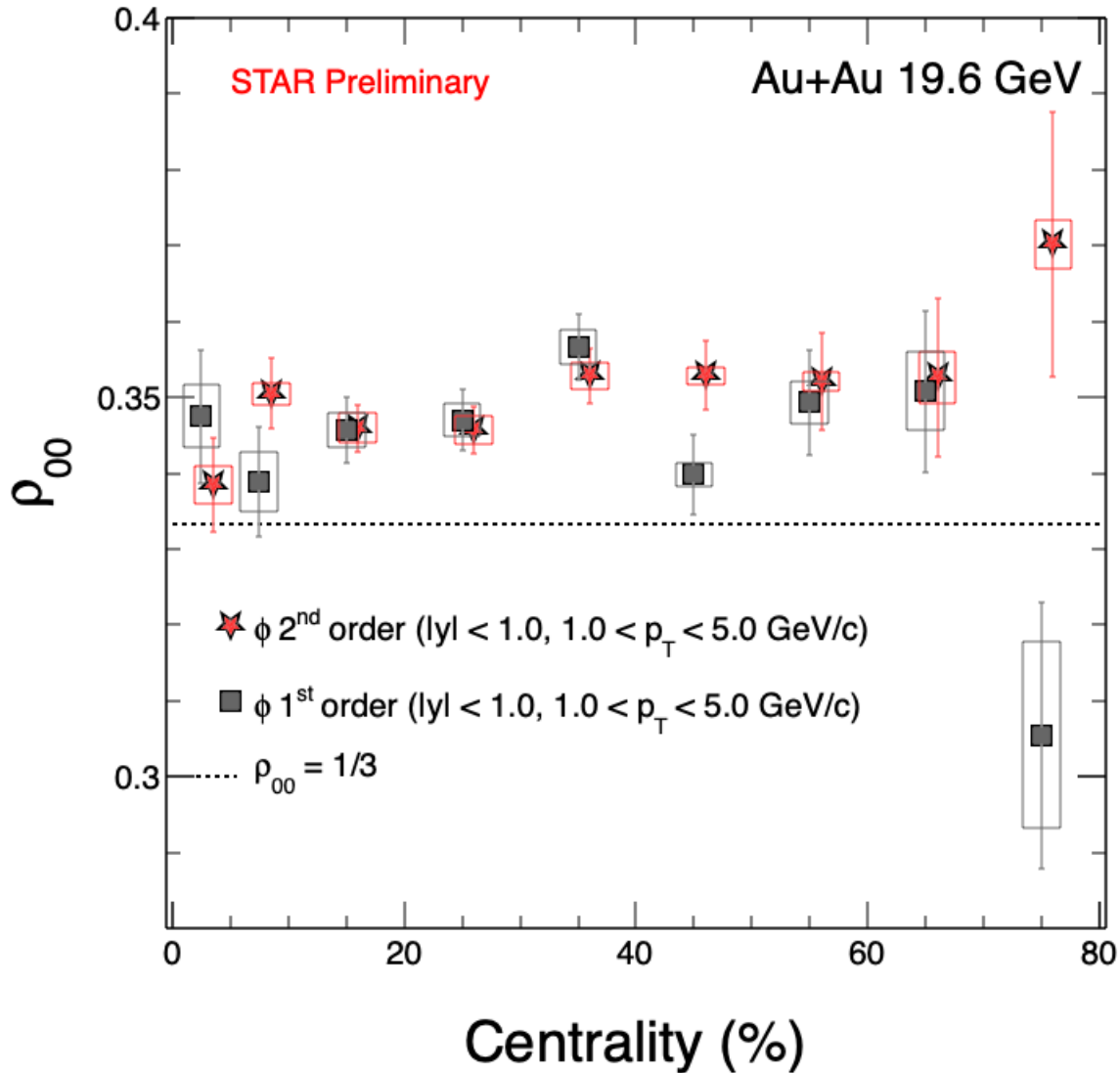
**BES-I** Stat weighted average over  $p_T$ :

$$\rho_{00}^{\text{I}} = 0.3304 \pm 0.0161 \text{ (stat.)} \pm 0.0104 \text{ (sys.)}$$

$$\rho_{00}^{\text{I}} \sim 1/3 \text{ with } 0.2\sigma$$

$$\rho_{00}^{\text{II}} \sim \rho_{00}^{\text{I}} \text{ with } 0.8\sigma$$

# $\phi$ meson $\rho_{00}$ (Centrality) 19.6 GeV



**Au+Au collisions (0-80%)**

**BES-II 1<sup>st</sup> Order** Stat weighted average over Centrality:

$$\rho_{00}^1 = 0.3470 \pm 0.0019 \text{ (stat.)} \pm 0.0016 \text{ (sys.)}$$

$$\rho_{00}^1 > 1/3 \text{ with } 5.5\sigma$$

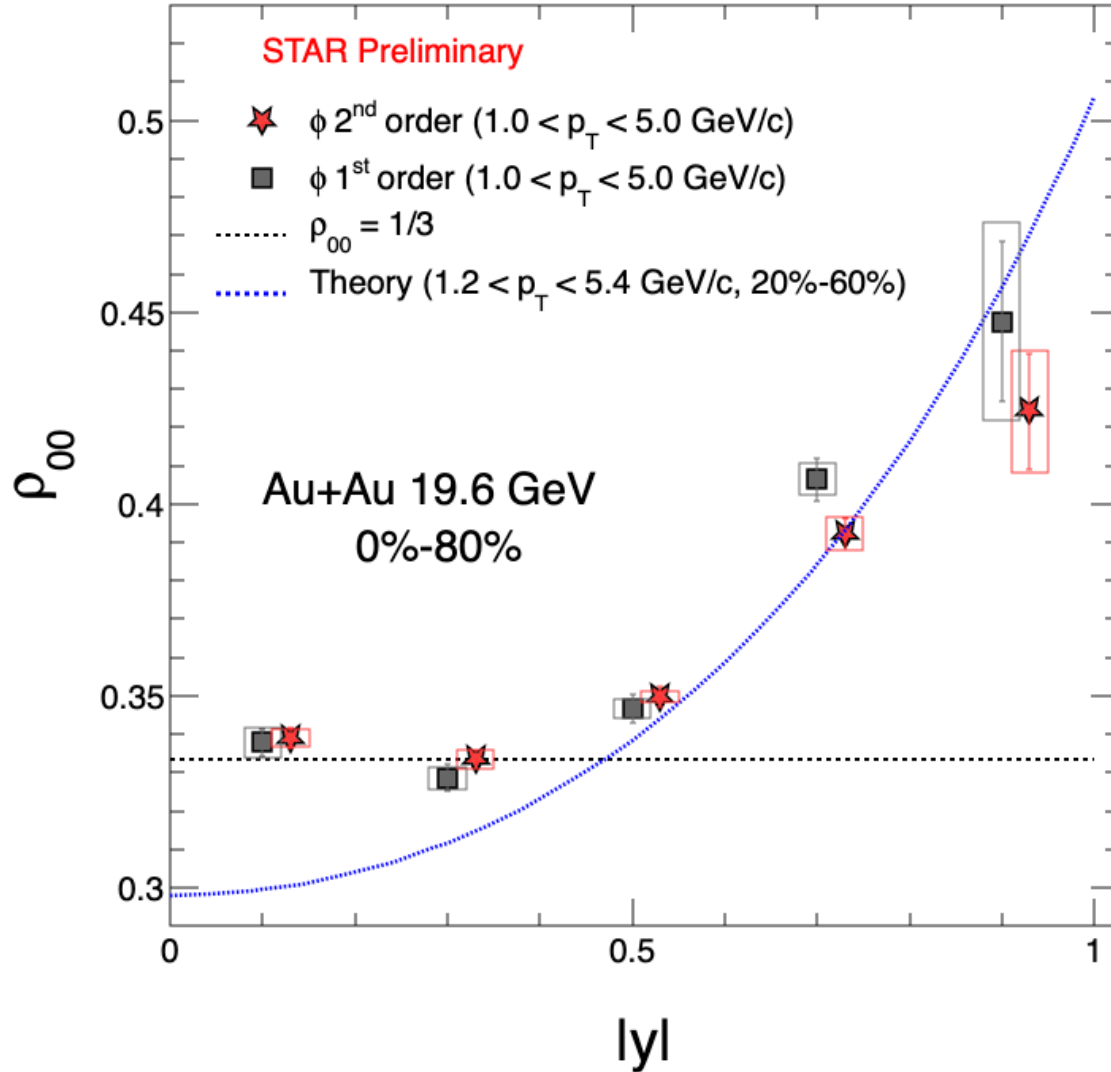
**BES-II 2<sup>nd</sup> Order** Stat weighted average over Centrality:

$$\rho_{00}^2 = 0.3486 \pm 0.0015 \text{ (stat.)} \pm 0.0013 \text{ (sys.)}$$

$$\rho_{00}^2 > 1/3 \text{ with } 7.7\sigma$$

$$\rho_{00}^1 \sim \rho_{00}^2 \text{ with } 0.5\sigma$$

# $\phi$ meson $\rho_{00}$ (rapidity [y]) 19.6 GeV



The blue dashed line is from the  $\phi$ -meson mean field model prediction with BES-I data as input. This prediction is for  $1.2 < p_T < 5.4$  GeV/c and 20-60% Centrality. We include this prediction as it provides some basis for the increase of  $\rho_{00}$  with rapidity. (This theory result is an extension of the paper: arXiv:2205.15689).

Theory result is from private communication with Xin-Li Sheng in August 2023.

## Au+Au collisions (0-80%)

**BES-II 1<sup>st</sup> Order** Stat weighted average over y:

$$\rho_{00}^1 = 0.3467 \pm 0.0019 \text{ (stat.)} \pm 0.0023 \text{ (sys.)}$$

$$\rho_{00}^1 > 1/3 \text{ with } 4.5\sigma$$

**BES-II 2<sup>nd</sup> Order** Stat weighted average over y:

$$\rho_{00}^2 = 0.3474 \pm 0.0014 \text{ (stat.)} \pm 0.0014 \text{ (sys.)}$$

$$\rho_{00}^2 > 1/3 \text{ with } 7.1\sigma$$

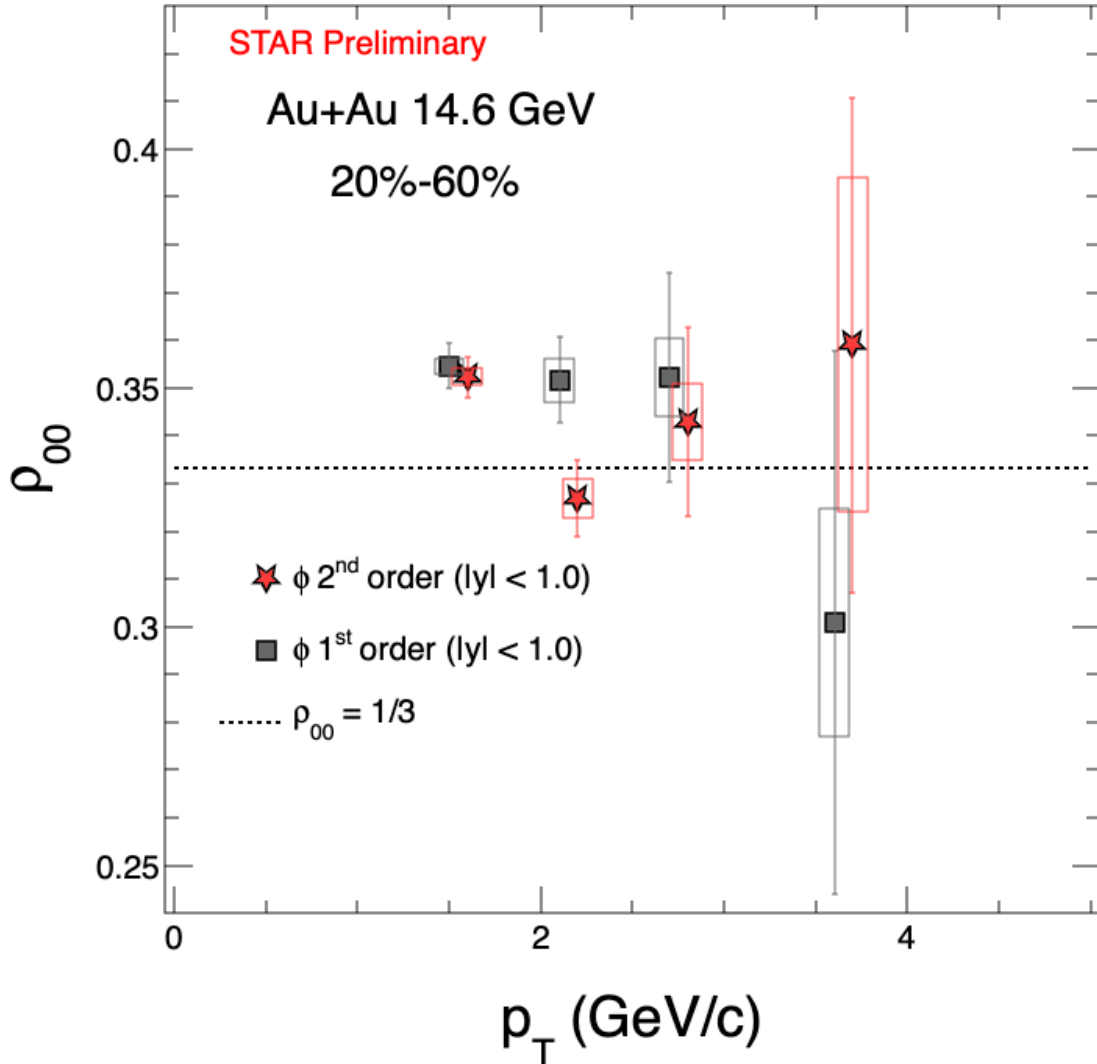
$$\rho_{00}^1 \sim \rho_{00}^2 \text{ with } 0.2\sigma$$



# Current Physical Understanding of Rapidity Dependence in Theory

In the theory of the  $\phi$ -meson strong force field, it is proposed that the spin alignment depends on the anisotropy of field fluctuations in the  $\phi$ -mesons rest frame. Using the input from BES-I data, it was found that there is a break of symmetry from the motion of the  $\phi$ -meson, which causes a small anisotropy. In the observation of the  $\phi$ -meson in the rest frame, the fluctuations in the direction of motion will be smaller than fluctuations in directions perpendicular to the motion. If a meson has  $p_x=p_z=0$  and non-zero  $p_y$ , the fluctuation along the y-direction will be smaller than that of the x and z directions, which would lead to a  $\rho_{00}<1/3$ . On the other hand,  $\phi$ -mesons moving along the x and z directions will have  $\rho_{00}>1/3$ .

# $\phi$ meson $\rho_{00}(p_T)$ 14.6 GeV



## Mid-central Au+Au collisions (20-60%)

**BES-II 1<sup>st</sup> Order** Stat weighted average over  $p_T$ :

$$\rho_{00}^1 = 0.3537 \pm 0.0040 \text{ (stat.)} \pm 0.0016 \text{ (sys.)}$$

$$\rho_{00}^1 > 1/3 \text{ with } 4.7\sigma$$

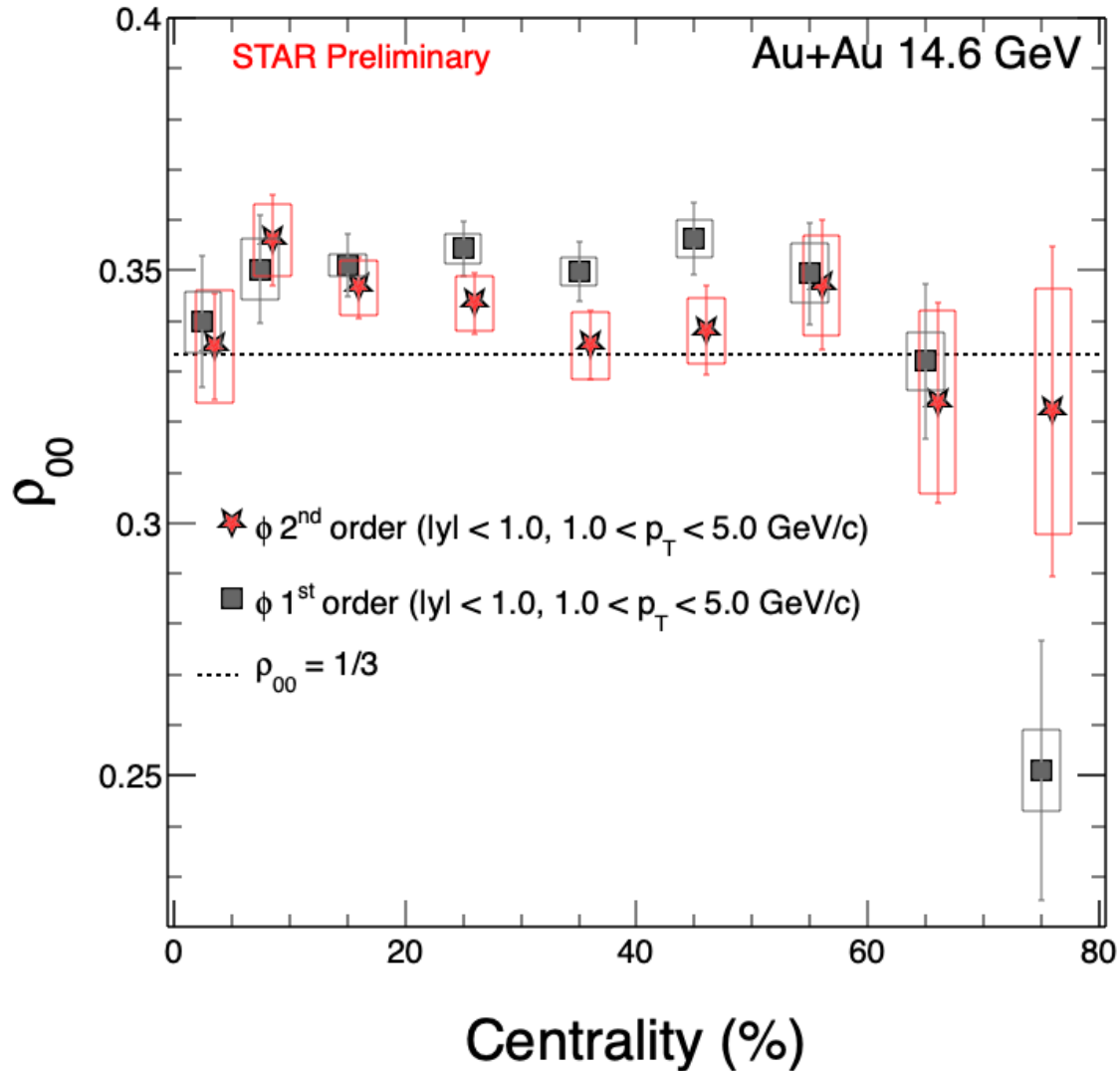
**BES-II 2<sup>nd</sup> Order** Stat weighted average over  $p_T$ :

$$\rho_{00}^2 = 0.3467 \pm 0.0037 \text{ (stat.)} \pm 0.0018 \text{ (sys.)}$$

$$\rho_{00}^2 > 1/3 \text{ with } 3.2\sigma$$

$$\rho_{00}^1 \sim \rho_{00}^2 \text{ with } 1.2\sigma$$

# $\phi$ meson $\rho_{00}$ (Centrality) 14.6 GeV



## Au+Au collisions (0-80%)

**BES-II 1<sup>st</sup> Order** Stat weighted average over Centrality:

$$\rho_{00}^1 = 0.3500 \pm 0.0027 \text{ (stat.)} \pm 0.0013 \text{ (sys.)}$$

$$\rho_{00}^1 > 1/3 \text{ with } 5.6\sigma$$

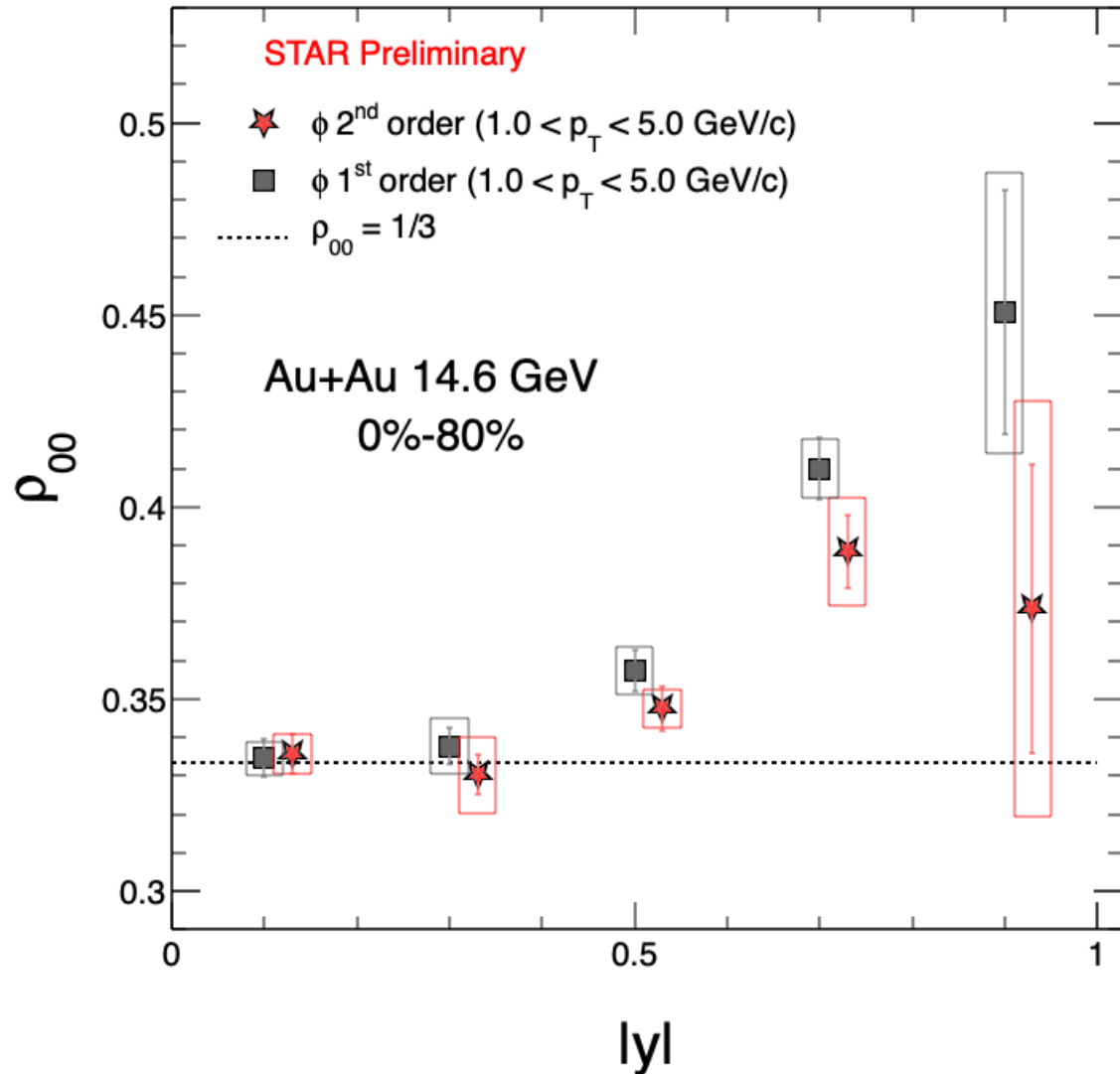
**BES-II 2<sup>nd</sup> Order** Stat weighted average over Centrality:

$$\rho_{00}^2 = 0.3425 \pm 0.0029 \text{ (stat.)} \pm 0.0036 \text{ (sys.)}$$

$$\rho_{00}^2 > 1/3 \text{ with } 2.0\sigma$$

$$\rho_{00}^1 \sim \rho_{00}^2 \text{ with } 1.4\sigma$$

# $\phi$ meson $\rho_{00}$ (rapidity [y]) 14.6 GeV



**Au+Au collisions (0-80%)**

**BES-II 1<sup>st</sup> Order** Stat weighted average over y:

$$\rho_{00}^1 = 0.3512 \pm 0.0027 \text{ (stat.)} \pm 0.0048 \text{ (sys.):}$$

$$\rho_{00}^1 > 1/3 \text{ with } 3.2\sigma$$

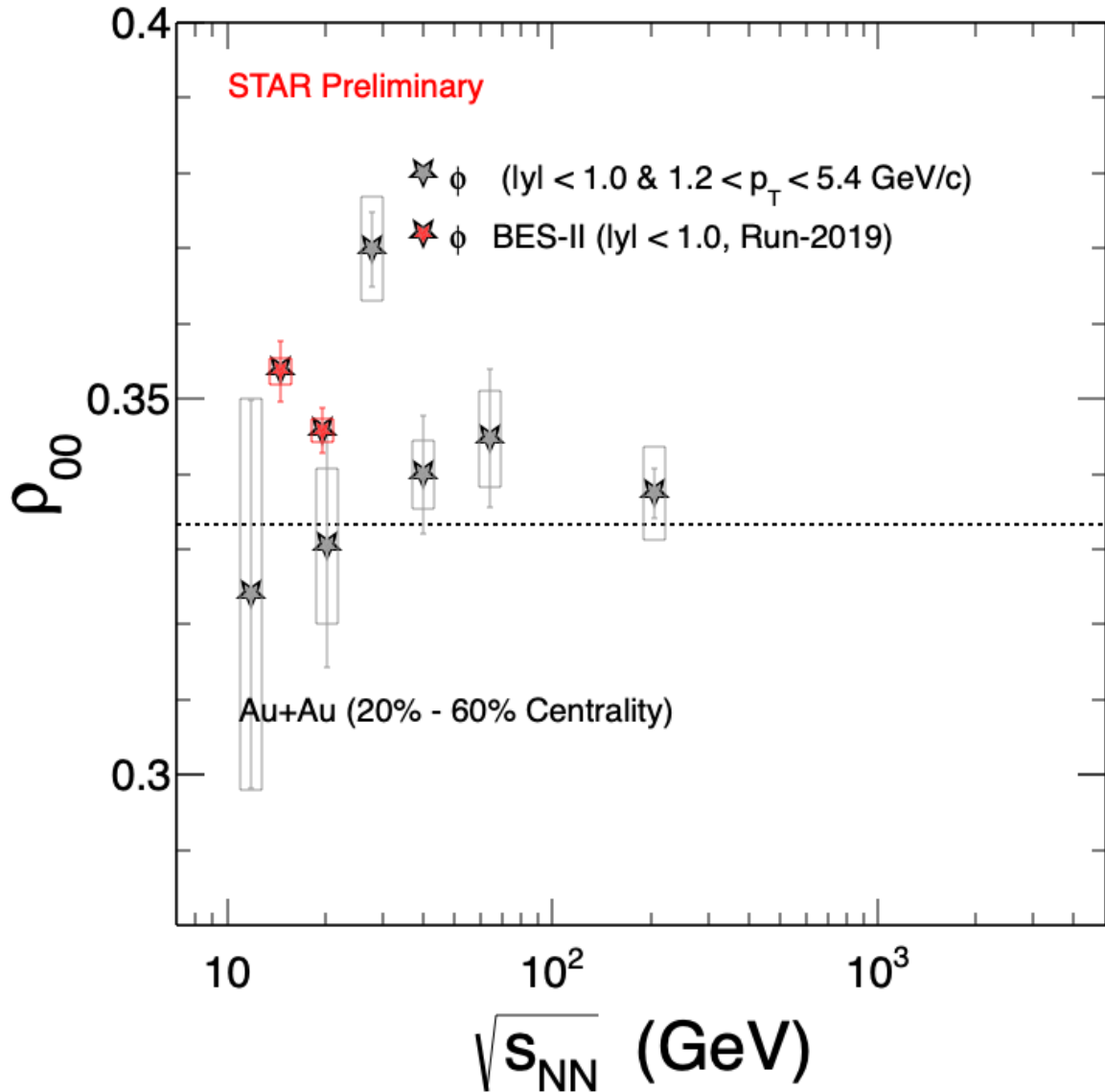
**BES-II 2<sup>nd</sup> Order** Stat weighted average over y:

$$\rho_{00}^2 = 0.3421 \pm 0.0029 \text{ (stat.)} \pm 0.037 \text{ (sys.):}$$

$$\rho_{00}^2 > 1/3 \text{ with } 1.9\sigma$$

$$\rho_{00}^1 \sim \rho_{00}^2 \text{ with } 1.3\sigma$$

# $\phi$ meson $\rho_{00}(\sqrt{s_{NN}})$ First Order EP



- First order EP  $\rho_{00}$  collision energy dependence for mid-centrality.

# BACKUP

# EP Resolution and Acceptance Correction

- To ensure  $\rho_{00}$  with respect to the 2<sup>nd</sup> order EP is consistent with  $\rho_{00}$  with respect to the 1<sup>st</sup> order EP one must use the 2<sup>nd</sup> order EP “resolution” with respect to the reaction plane that the 1<sup>st</sup> order EP is perturbing around.

$$R_{21} = \langle \cos 2(\Psi_2 - \Psi_{r,1}) \rangle$$

- $R_{21}$  can be found by using the following relation.

$$\begin{aligned} D_{12} &\equiv \langle \cos 2(\Psi_1 - \Psi_2) \rangle \\ &= \langle \cos 2(\Psi_1 - \Psi_{r,1} + \Psi_{r,1} - \Psi_2) \rangle \\ &\approx \langle \cos 2(\Psi_1 - \Psi_{r,1}) \rangle \langle \cos 2(\Psi_{r,1} - \Psi_2) \rangle \\ &= R_1 \cdot R_{21}. \end{aligned}$$

- Since we are using the 2<sup>nd</sup> order **sub-event** plane for our  $\rho_{00}$  calculations, we must use  $R_{21}^{Sub}$  instead.

$$R_{21}^{Sub} = R_{21} / \sqrt{2}$$

# $\phi$ -meson $\rho_{00}$ vs $p_T$ : Systematics

1. Choose central values for each source of systematic error.
2. Vary one cut at a time while keeping the others at the default value. Vary yield extraction method for non-default cuts. Calculate  $\rho_{00}$  for each variation and calculate the sources error with:

$$\Delta\rho_{00,sys}^i = \frac{\rho_{00,max}^i - \rho_{00,min}^i}{\sqrt{12}}$$

3. Combine all sources of systematics:

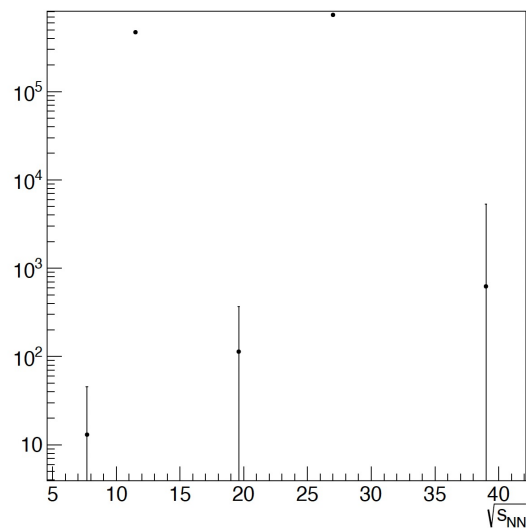
$$\Delta\rho_{00,sys} = \sqrt{\sum_i (\Delta\rho_{00,sys}^i)^2}$$



# Au+Au 14.6 GeV $p_T$ spectra interpolation

$$\frac{1}{2\pi m_T} \frac{d^2N}{dm_T dy} = \frac{dN/dy(n-1)(n-2)}{2\pi n T_{\text{Levy}}(n T_{\text{Levy}} + m_0(n-2))} \times \left(1 + \frac{m_T - m_0}{n T_{\text{Levy}}}\right)^{-n},$$

- Using Lévy function for interpolation is difficult due to parameter  $n$  varying too much energy to energy.
- Function used for sampling  $p_T$  in 19.6 GeV simulations.



$$\frac{1}{2\pi m_T} \frac{d^2N}{dm_T dy} = \frac{dN/dy}{2\pi T_{\text{exp}}(m_0 + T_{\text{exp}})} e^{-(m_T - m_0)/T_{\text{exp}}},$$

- In exponential function we have two well behaved parameters ( $dN/dy$ ) and  $T_{\text{exp}}$
- This will be used for extrapolation.
- Fit the distributions of the two parameters as a function of collision energy.
  - We really only need  $T_{\text{exp}}$  since  $dN/dy$  is just a normalization and we just want the shape.
- Then we can just grab the interpolated parameters for 14.6 GeV and generate the spectra for simulation.

# Au+Au 14.6 GeV $p_T$ spectra interpolation

10-20% centrality

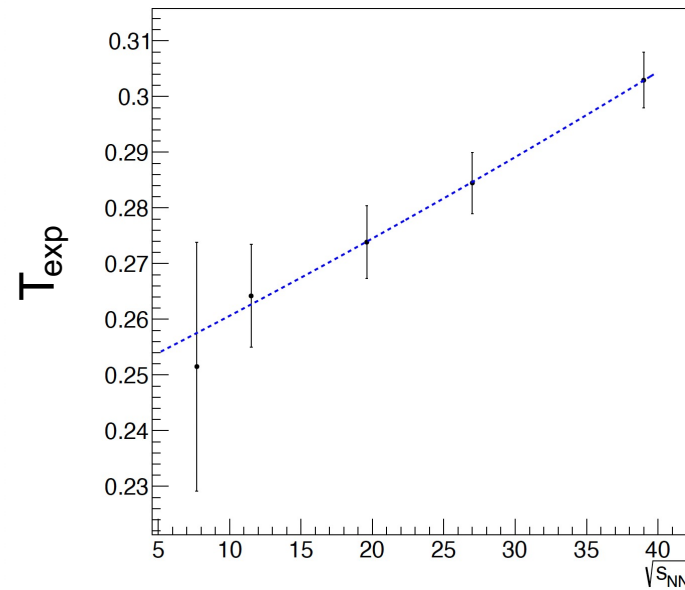
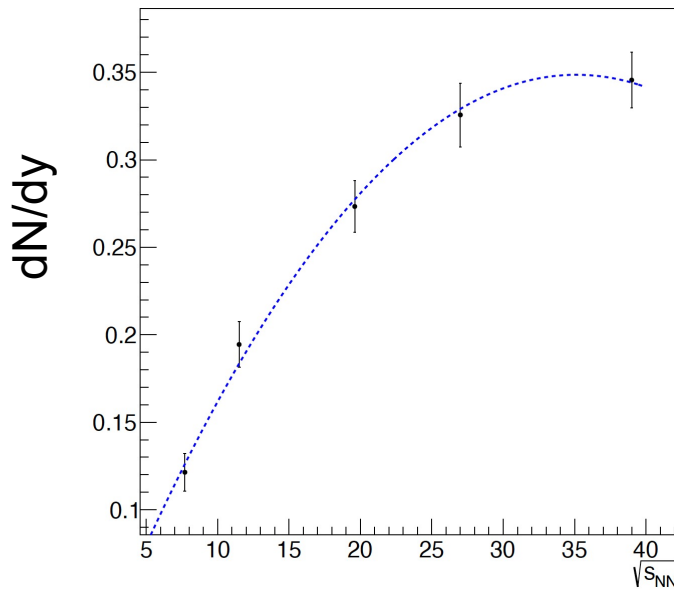
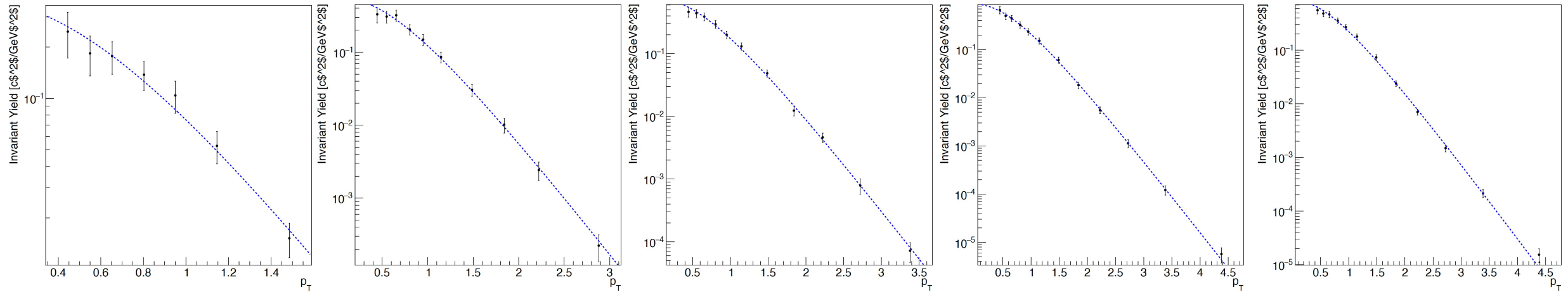
7.7 GeV

11.5 GeV

19.6 GeV

27 GeV

39 GeV



- Use second order polynomial to fit both parameters.
- Fits to parameters are well behaved.
- Performed for each centrality.