Transport model studies of polarization

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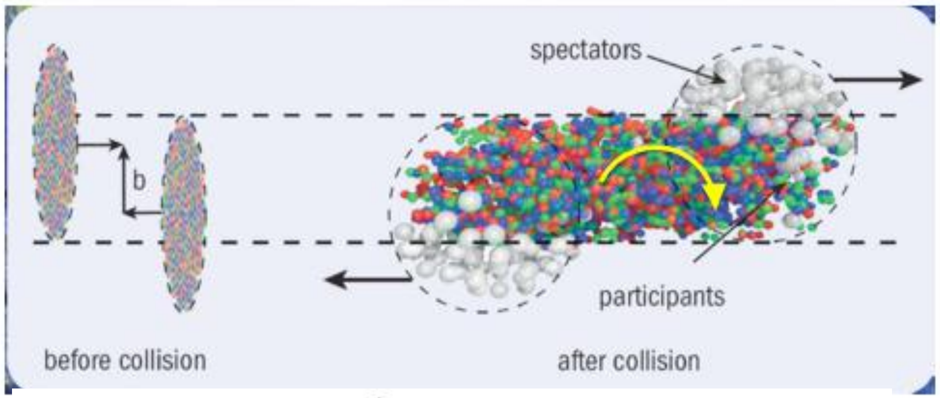
Outline

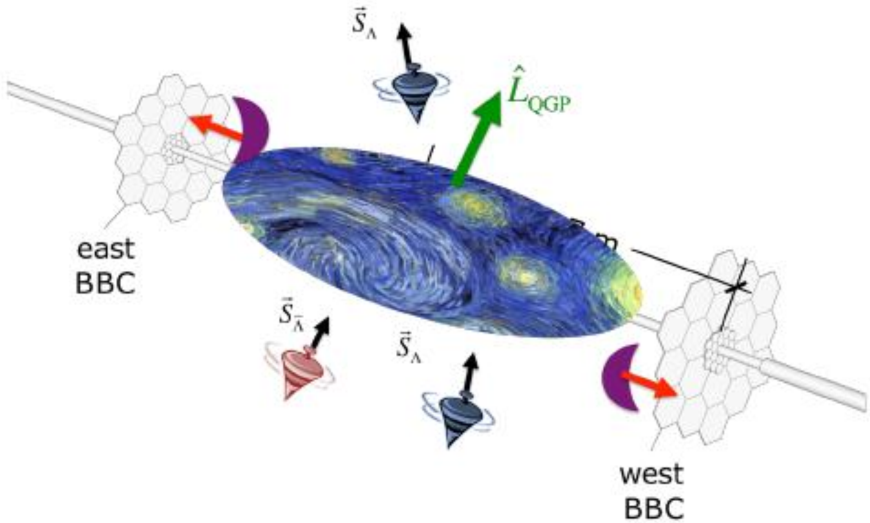
- **Introduction**
- **Modified AMPT model**
- **Analysis method and results**
  - **Extraction of ϕ-meson spin alignment parameter ρ_{00}**
  - **Hadronic scattering effect**
  - **Acceptance effect: pseudorapidity coverage effect**
    transverse momentum dependence
- **Summary**

Introduction

STAR Phys. Rev. C 77, 061902(R)(2008)

Mike Lisa. https://drupal.star.bnl.gov/STAR/system/files/UCLAvorticityWorkshopFeb2016v3.pdf





- Non-central heavy ion collisions have large initial angular momentum.
- Due to spin-orbit coupling, this orbital angular momentum may result in net polarization of produced particles along the direction of the initial angular momentum (L) perpendicular to the reaction plane.

ϕ-meson spin alignment

Why ϕ meson spin alignment

- ϕ-mesons, which have small hadronic scattering cross sections, are expected to originate predominantly from primordial production.

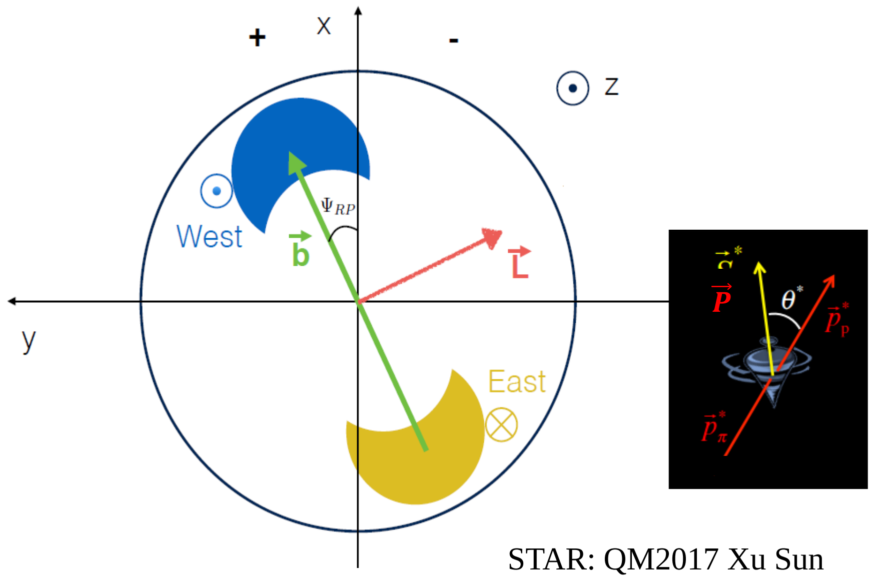
Z. Liang and X. Wang, Phys. Lett. B 629,20-26(2005)

- The 00-component of ϕ-meson spin density matrix (ρ_{00}) can be measured by angular distribution of decay daughter $\phi \rightarrow K^{+}+K^{-}$ using:

$$\frac{dN}{d\cos\theta^*} \sim (1-\rho_{00}) + (3\rho_{00} - 1) * \cos^2\theta^*$$

- A deviation of ρ_{00} from 1/3 indicates a spin alignment of ϕ-meson.

Coordinate System



STAR: QM2017 Xu Sun

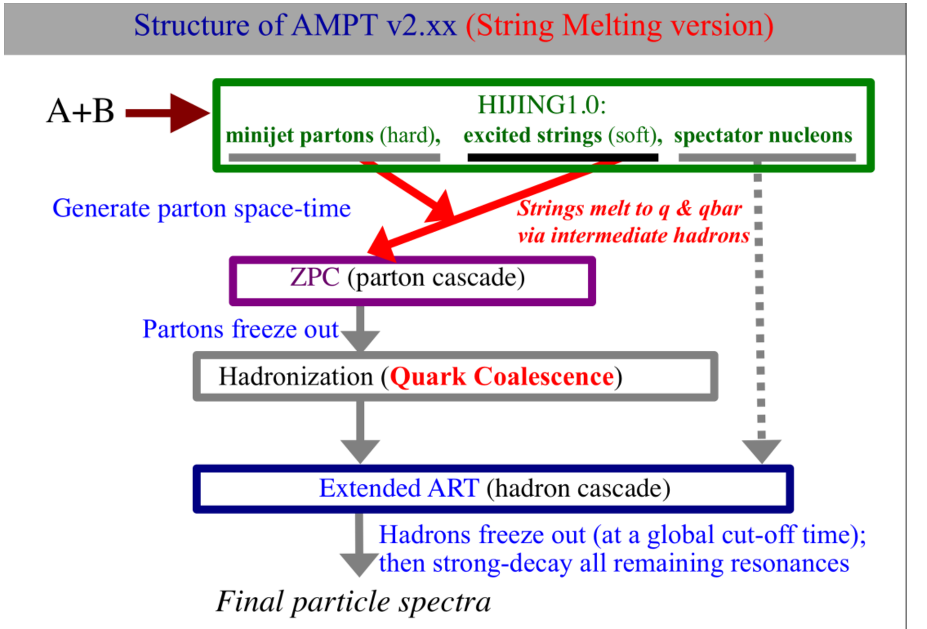
- θ* is the angle between the **polarization direction** and the **momentum direction of K^{-}** in the rest frame of ϕ-meson.

A Multi-Phase Transport Model

Zi-Wei Lin, Ko, Li, Zhang and Pal, Phys. Rev. C 72, 064901 (2005)

Four Main Parts:

- The initial condition.
- Partonic interaction.
- Hadronization.
- Hadronic interaction.

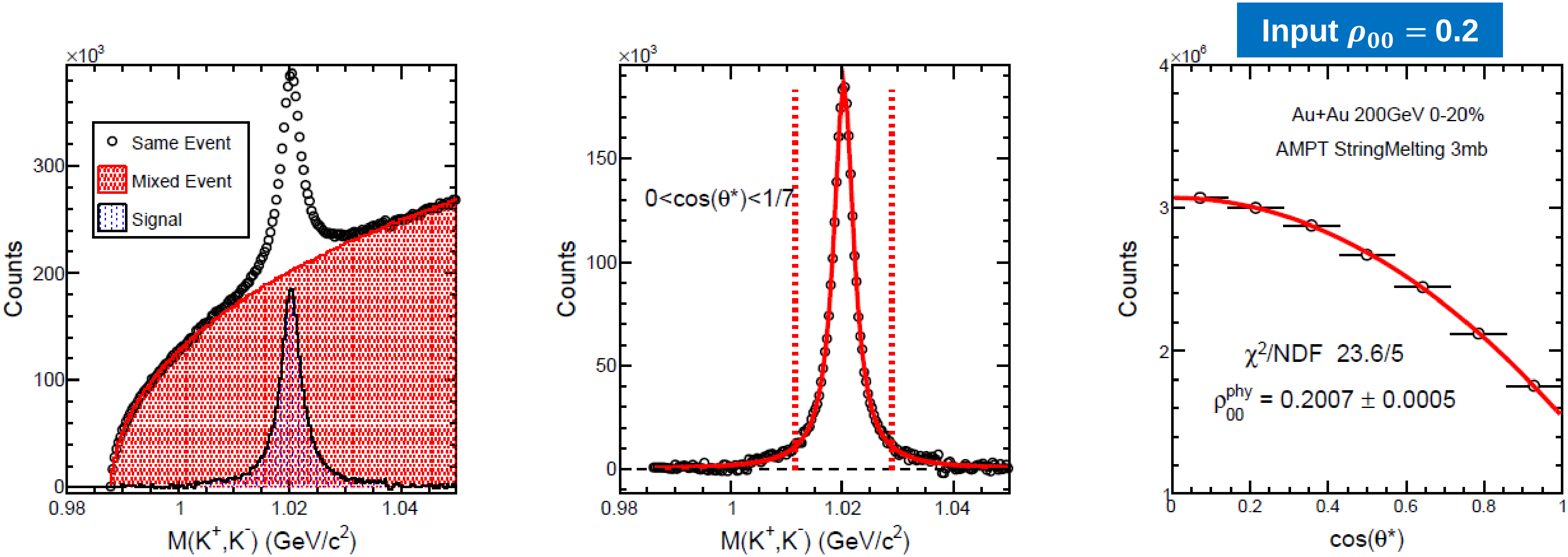


Modified part :

- Added input ρ_{00} and P_H parameters to specify the degree of spin alignment of ϕ (K^*) mesons and Λ hyperons at decay.
- Angular momentum direction is calculated event-by-event.

- Au+Au at $\sqrt{s_{NN}}$ = 200GeV with String Melting, partonic scattering cross section = 3 mb.

ρ_{00} extraction

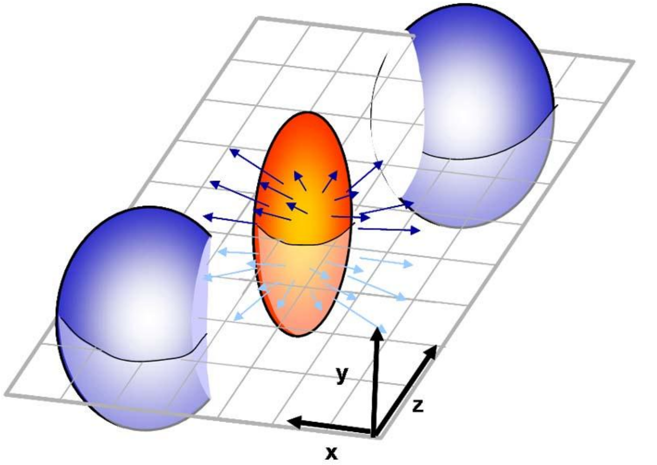


- Background : Event Mixing technique.
- Invariant mass distributions for 7 different $cos\theta^*$ bins.
- Fit $cos\theta^*$ distribution with:

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

Direction of angular momentum

Physical: the initial angular momentum of the overlap volume can be directly calculated in AMPT model.



Observed: experimentally the direction of angular momentum can be estimated by the normal of the reconstructed event plane.

Event plane method:

$$Q_{n,x} = \sum w_i \cos(n\phi_i)$$

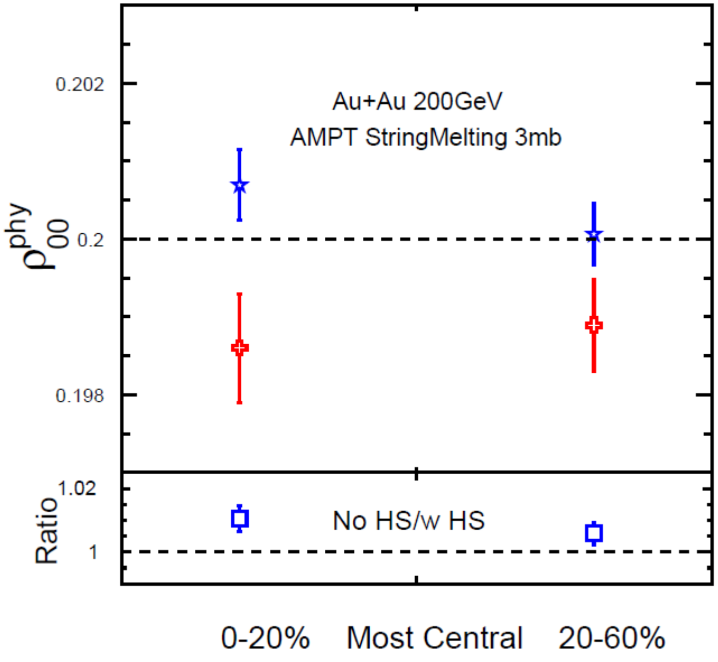
$$Q_{n,y} = \sum w_i \sin(n\phi_i)$$

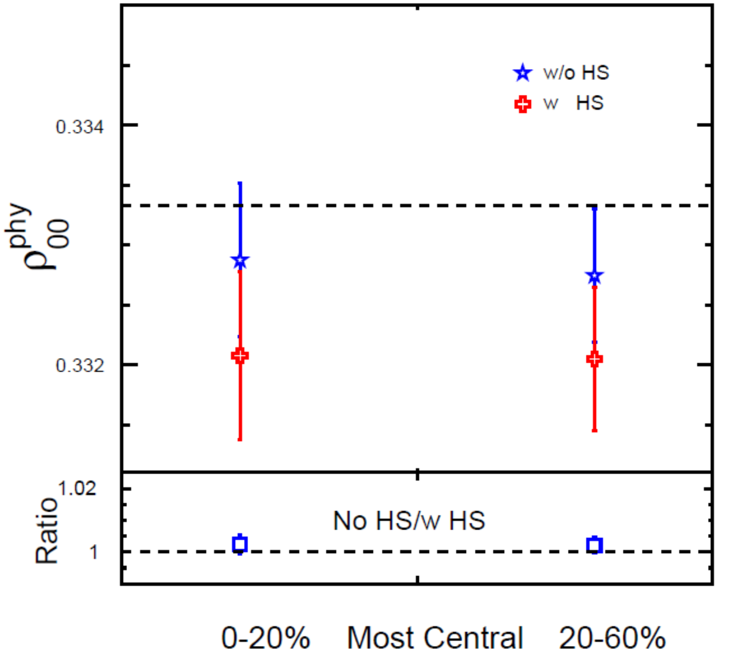
$$\psi_n = \frac{1}{n} \tan^{-1} \frac{Q_{n,y}}{Q_{n,x}}$$

Poskanzer and Voloshin Phys. Rev. C 58.1671(1998)

Hadronic scattering effect

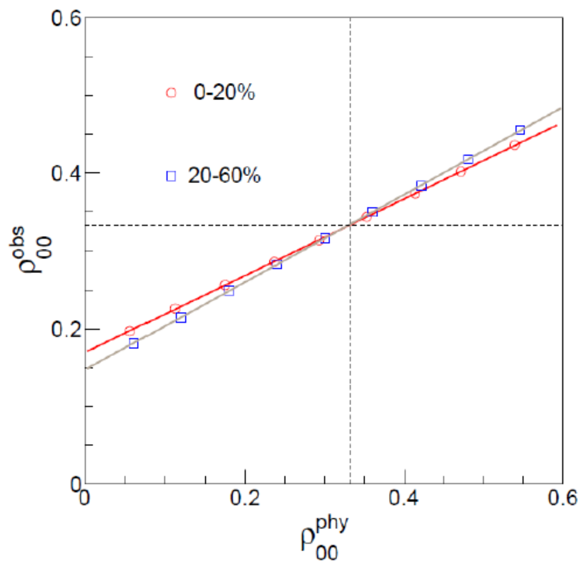
Input $\rho_{00} = 0.2$	Input $\rho_{00} = 1/3$

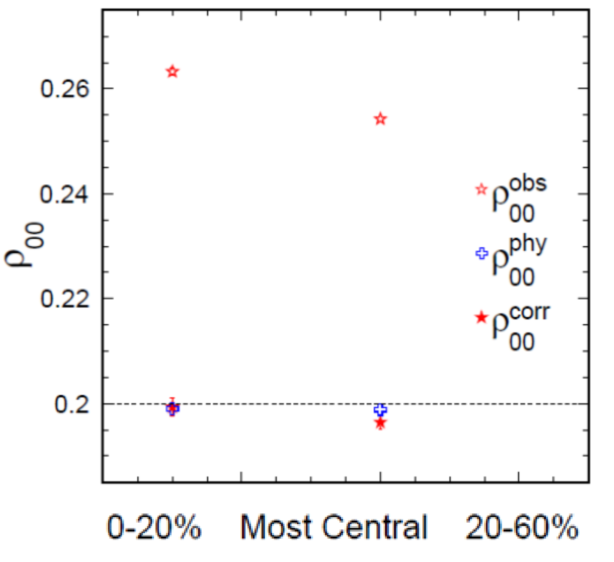




- ρ_{00}^{phy}: calculated with direction of angular momentum.
- Hadronic scatterings (HS) after ϕ-meson decays are irrelevant for ϕ-meson ρ_{00}^{phy}.

Use ρ_{00}^{obs} to extract ρ_{00}^{phy}



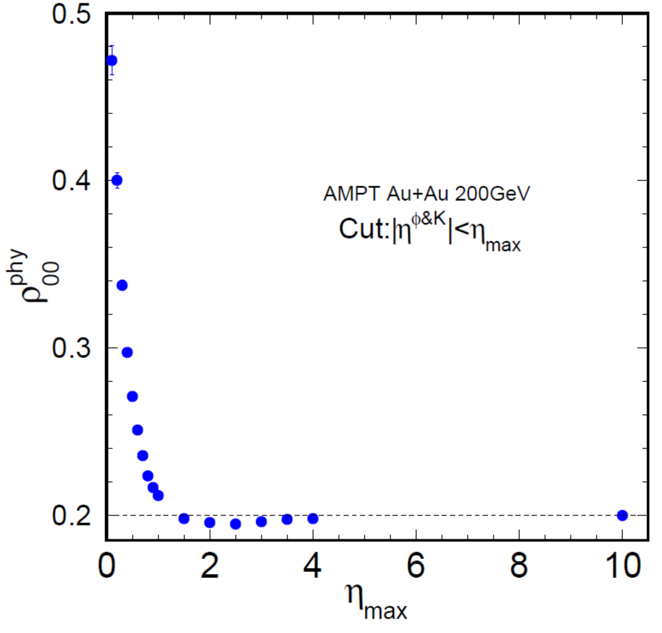


- ρ_{00}^{obs} : calculated with reconstructed event plane.
- ρ_{00}^{phy}: calculated with direction of angular momentum.
- ρ_{00}^{obs} and ρ_{00}^{phy} are found to be linearly correlated.
- In experiment only ρ_{00}^{obs} can be measured.

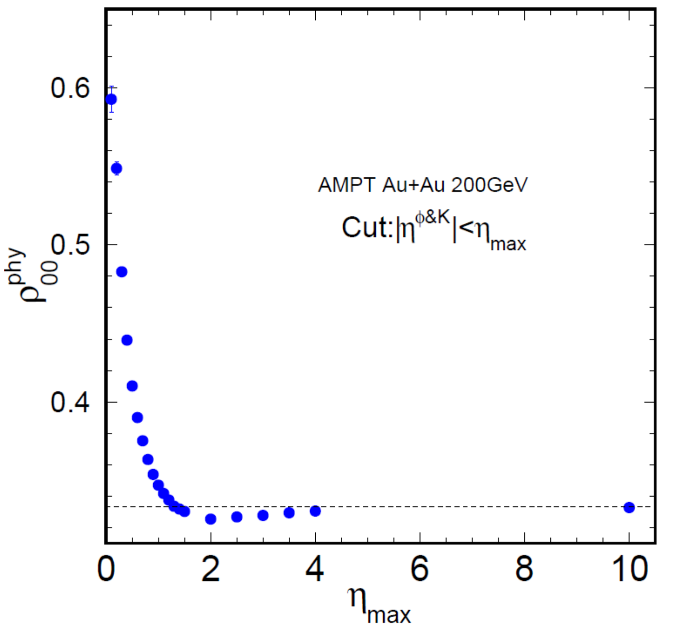
  However, ρ_{00}^{obs} needs to be corrected to extract ρ_{00}^{phy}.

Effect of finite η coverage

Input $\rho_{00} = 0.2$

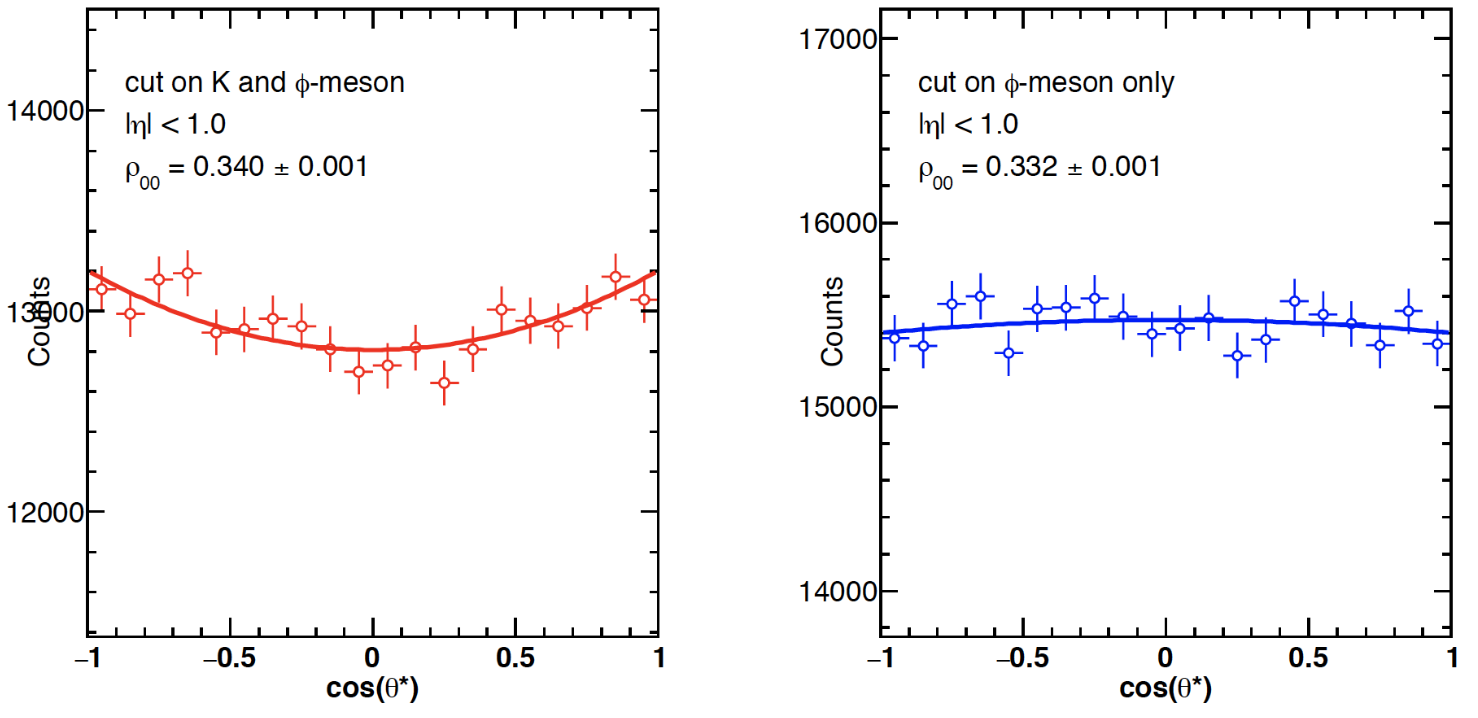


Input $\rho_{00} = 1/3$



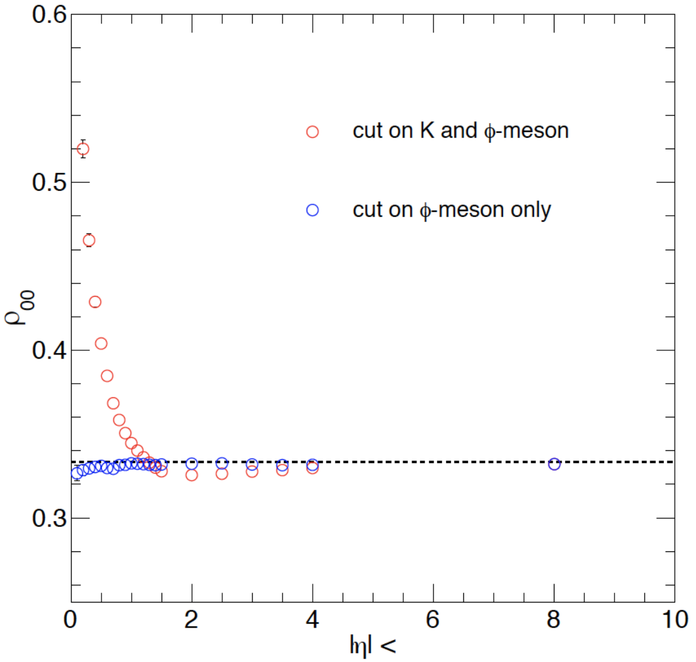
- The extracted ρ_{00} depends on the η cut of kaons.
- When the cut is below $|\eta|$<1, a narrower η acceptance gives a significantly larger ρ_{00}^{phy} value than the input ρ_{00}.
- A narrow η cut on kaons tends to exclude kaons along beam directions, therefore exclude kaons from ϕ decays around $\theta^* \sim 90$ degrees.

Toy model simulation

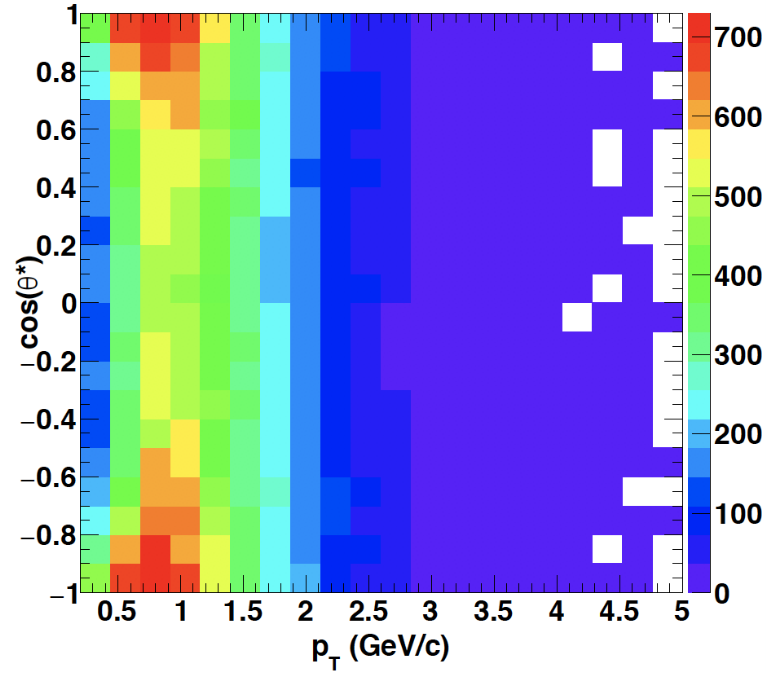


- Sample p_T distribution with published ϕ-meson spectra
- Sample azimuth distribution with published v_2 results
- Sample rapidity distribution with AMPT result
- η cut on daughter particle creates a non-1/3 ρ_{00} value

Toy model simulation



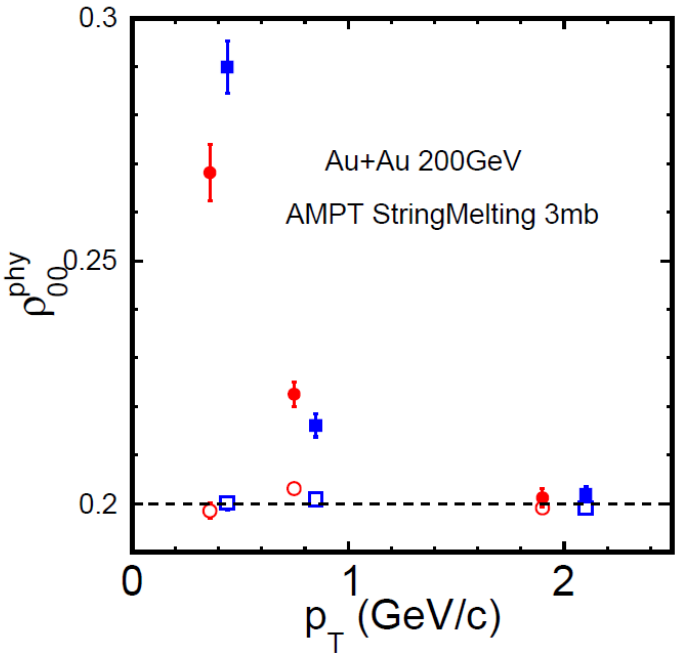
|η^K| < 0.3



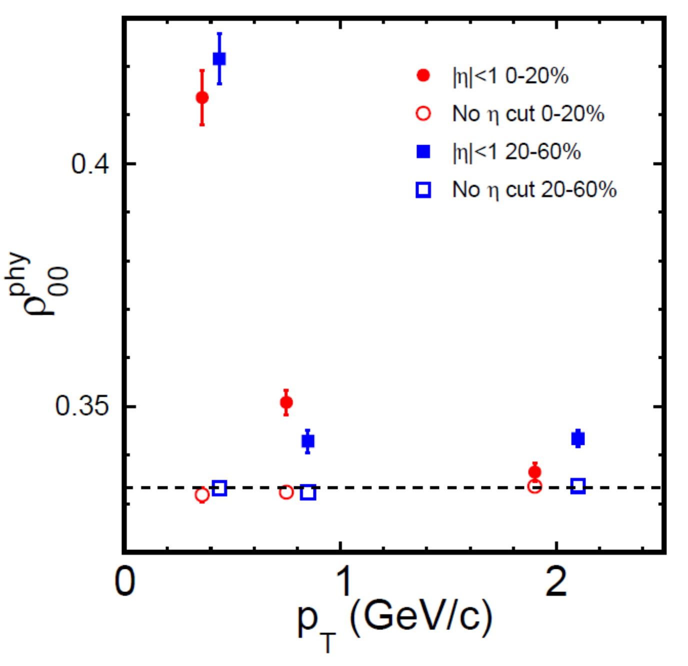
- ➢ Similar as AMPT results (model independent)
- ➢ η cut mostly affects the low p_T region

Effect of finite p_T^{ϕ} coverage

Input $\rho_{00} = 0.2$



Input $\rho_{00} = 1/3$



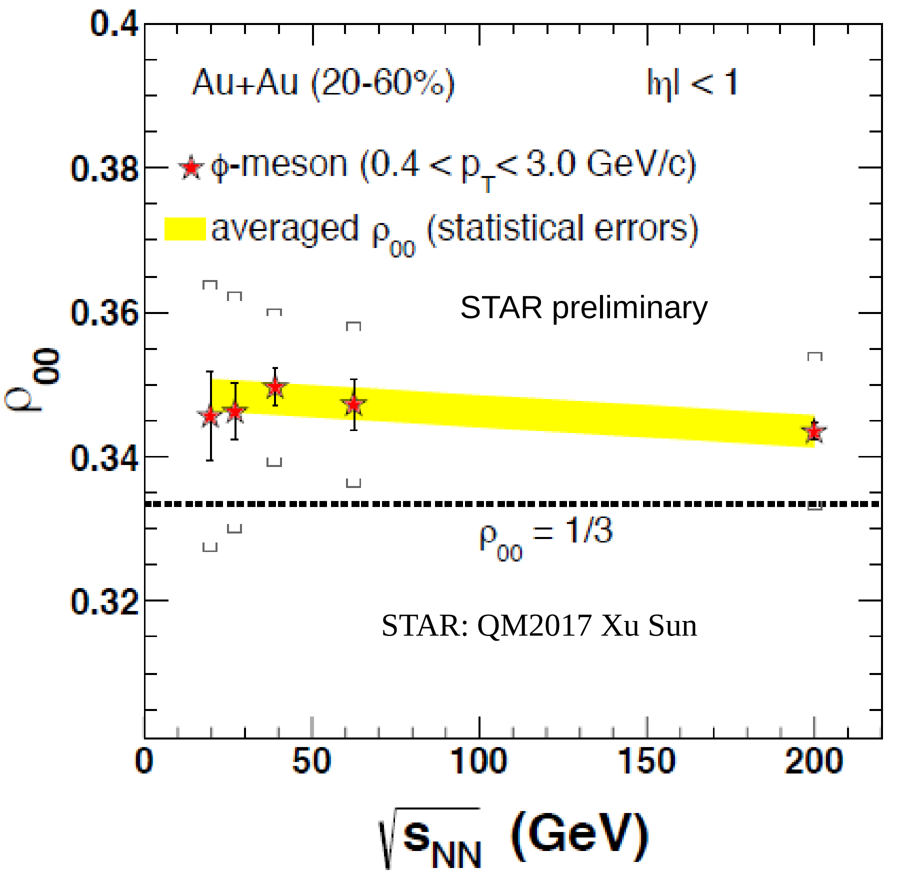
- With the η coverage of $|\eta|<1$, the extracted ρ_{00}^{phy} depends on transverse momentum.
- Larger deviation from the input ρ_{00} value is observed in low p_T range.
- Without η cut, p_T cut does not affect the extracted ρ_{00}^{phy} value (same as input ρ_{00}).

Summary

- AMPT extended with an input ρ_{00} parameter specifies the degree of ϕ-meson spin alignment versus the direction of angular momentum when ϕ mesons decay.
- Hadron scatterings after ϕ-meson decays are found to have no effect on the extraction of the ϕ-meson ρ_{00} parameter.
- A narrow η coverage strongly affects the extracted ϕ-meson ρ_{00} value.
- This η-cut effect mainly comes from low-p_T ϕ mesons.

Backup

Experimental data



Effect of finite η coverage