Rescattering effect on the measurement of K* spin alignment in heavy-ion collisions with UrQMD

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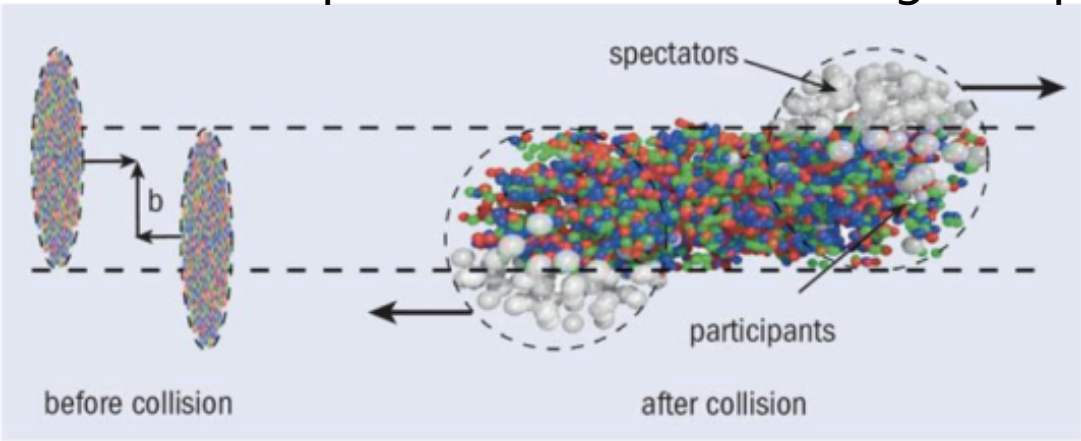
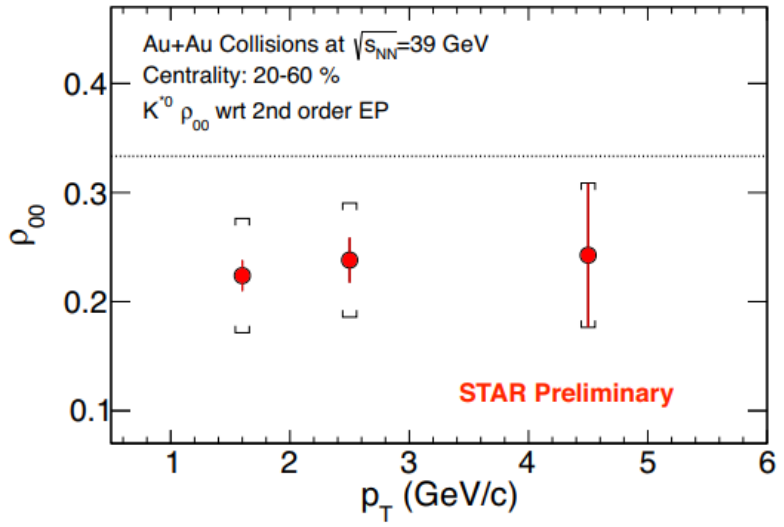
Motivation

- Large initial orbital angular momentum **L** in non-central relativistic heavy ion collisions.
- Due to spin-orbit coupling, Particles could be polarized globally in the direction of **L**.
- The spin alignment of vector mesotns K^* and φ can provide information of the large vorticity of the hot, dense medium created in non-central heavy-ion collisions.
- STAR have presented results on the global polarization.



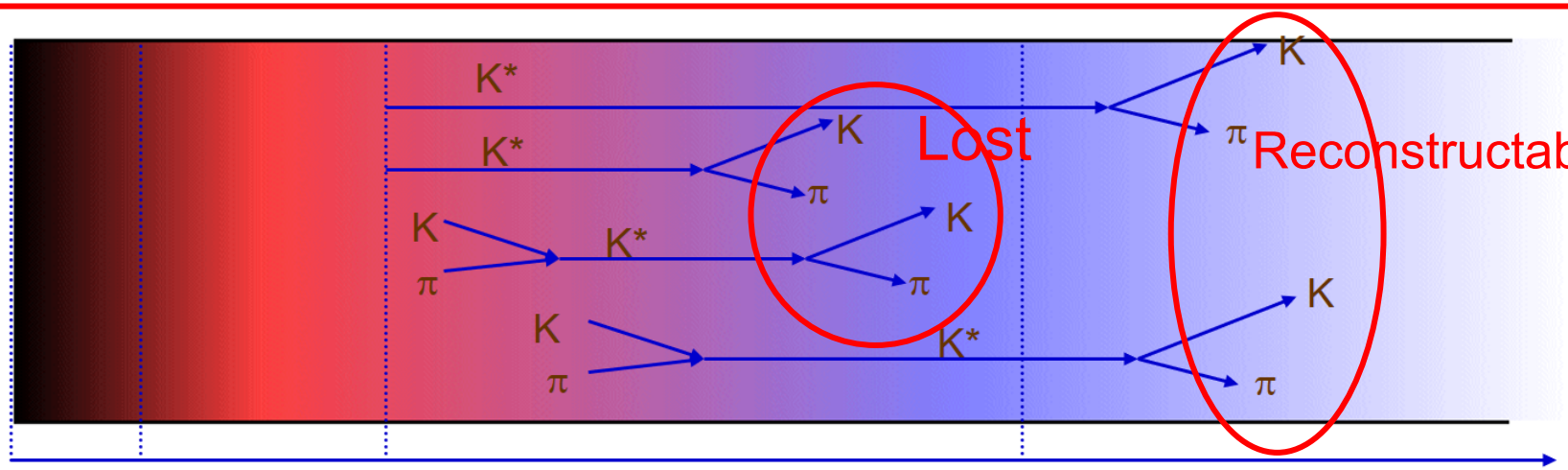
*Zuo-Tang Liang and Xin-Nian Wang, **PRL 94** 102301(2005)
Sergei A. Voloshin, nucl-th/0410089, and many others



Global Λ hyperon polarization in nuclear collisions-STAR Collaboration
Nature 548,62-65(2017)

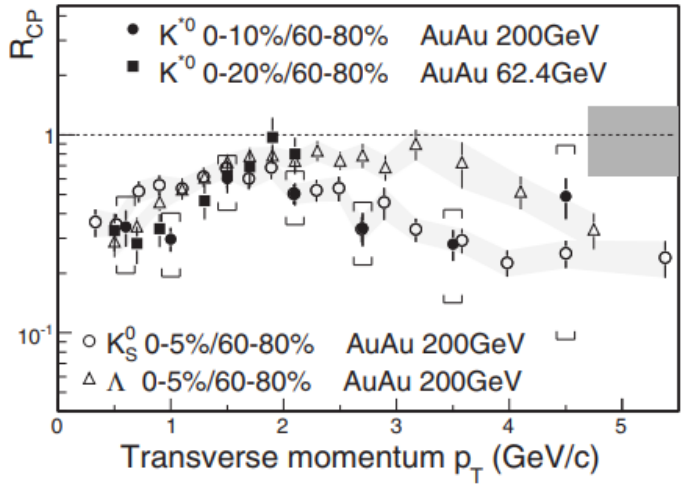
Chensheng Zhou
Nuclear Physics A 982 (2019) 559–562

K* Rescattering

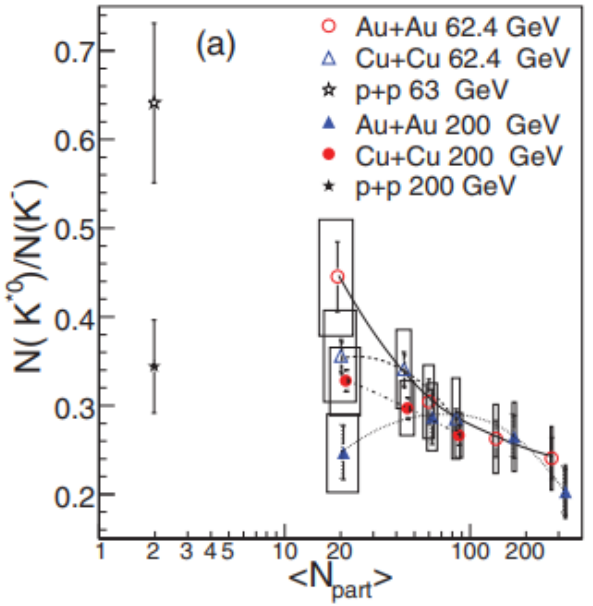


hadronization begins → Chemical freeze-out ~10fm/c Thermal freeze-out

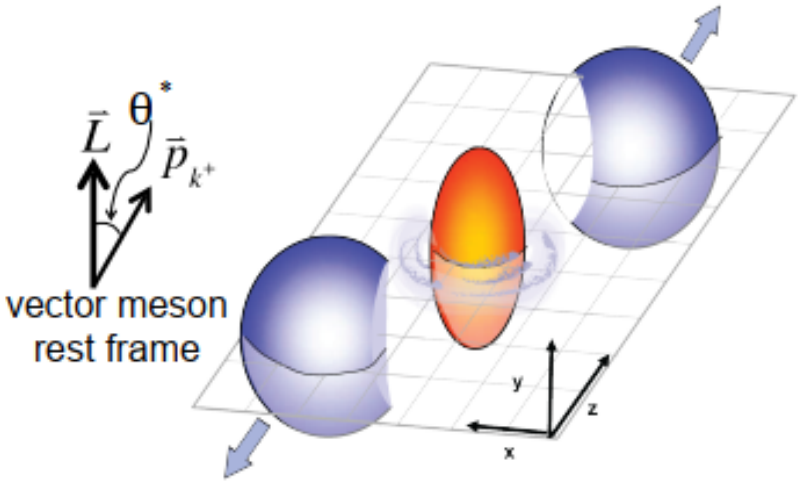
K*(892)
life time： 4 fm/c

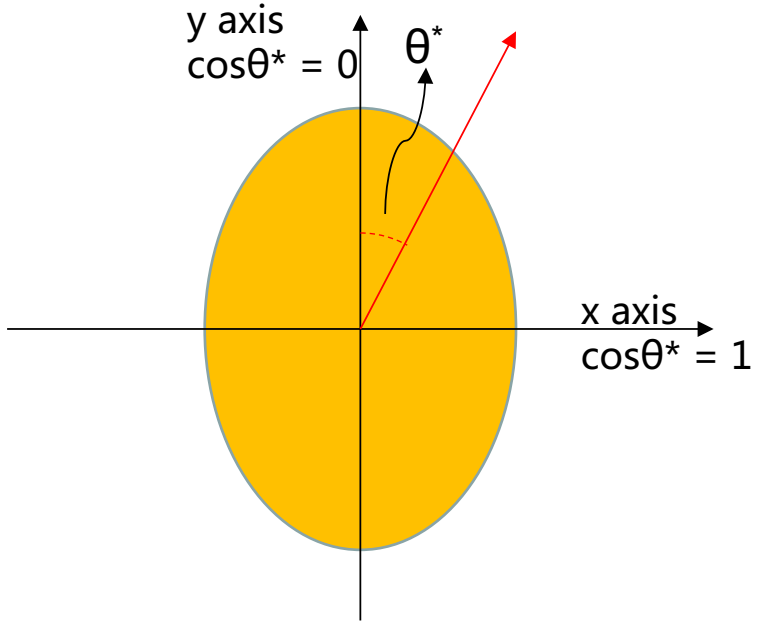


(STAR Collaboration)
PHYSICAL REVIEW C 84, 034909 (2011)



Rescattering effect on spin alignment





- Anisotropy of the medium in coordination space.
- Non-uniform cosθ* distribution for reconstructable K*.
- Important background for the study of global polarization.

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

K. Schilling el al., Nucl. Phys. B 15, 397 (1970)

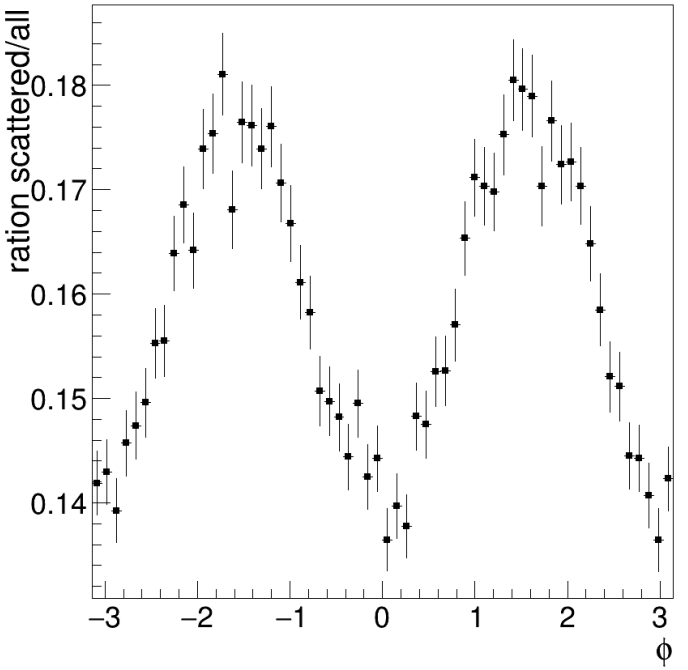
UrQMD model

- Choose UrQMD model to test
- History file can trace K* decays and select the reconstructable K*

- Select all decay K*
- Get daughter index
- Identify the scattered daughter
- Distinguish reconstructable and lost K*

Collision system and energy : Au-Au 200GeV
output time: 100fm/c

Collision Centrality	No. of events
0-20%	0.1M
20-60%	1M
60-80%	1M
80-100%	1M



Scattered/all π from K* decay as function of φ

Global Spin Alignment

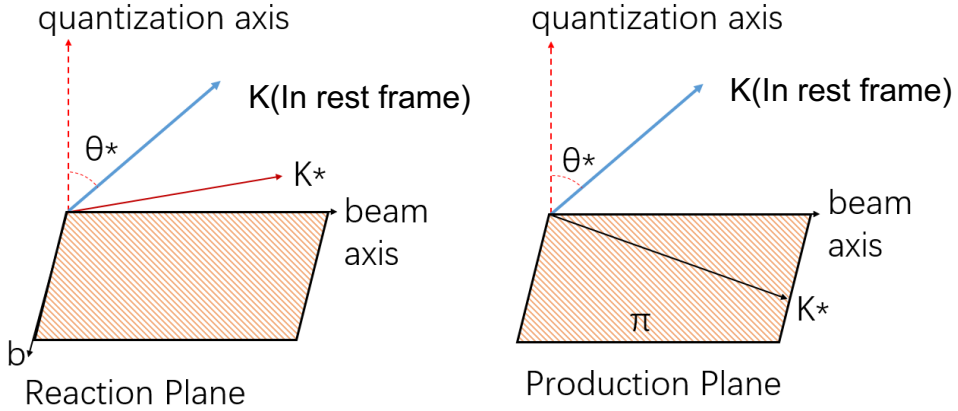
- For vector meson, spin alignment can be described by ρ_{00}.
- ρ_{00} can be determined from the angular distribution of the decay products:

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

K. Schilling el al., Nucl. Phys. B 15, 397 (1970)

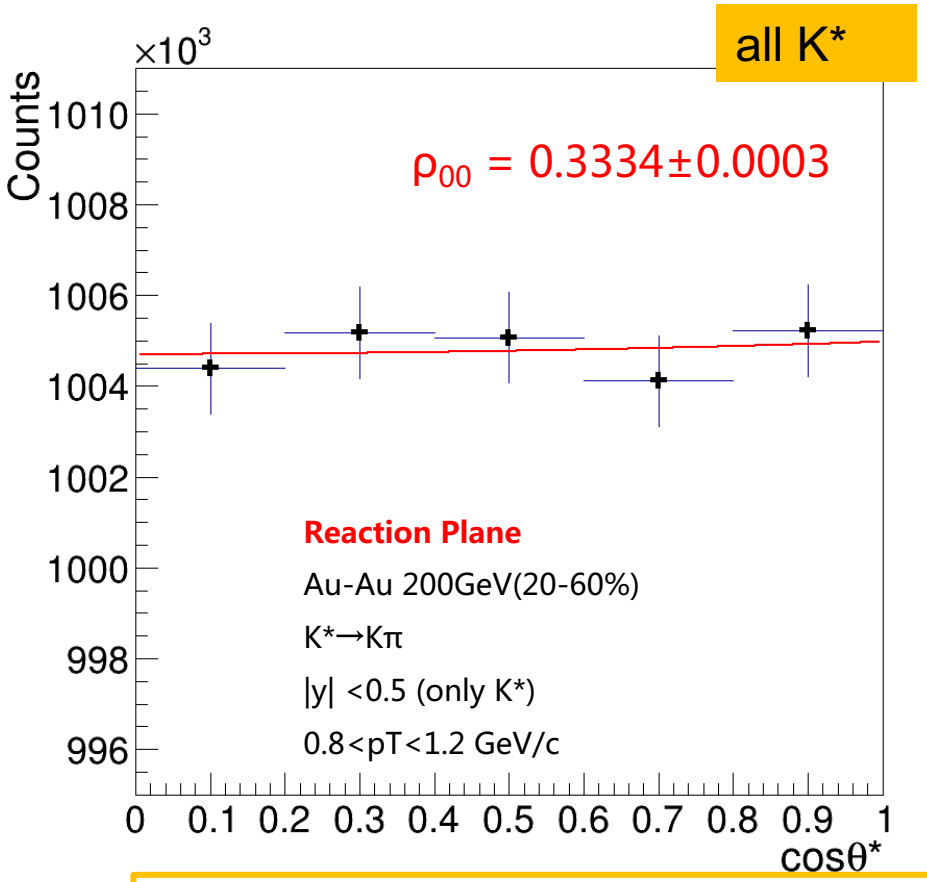
A deviation of ρ_{00} from 1/3 signals the net spin alignment

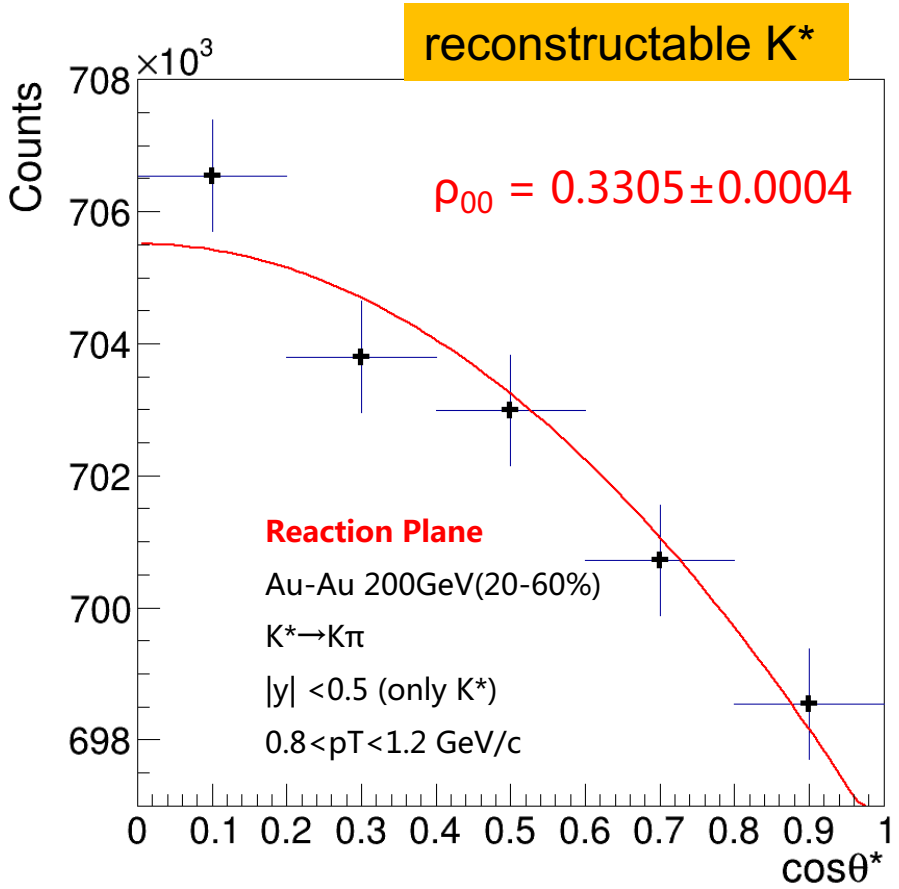
θ^*: the angle between the quantization direction and the momentum direction of a daughter particle in the rest frame of the parent vector meson



quantization direction
Normal to Production plane
Normal to Reaction plane

Angular distribution w.r.t. Reaction plane





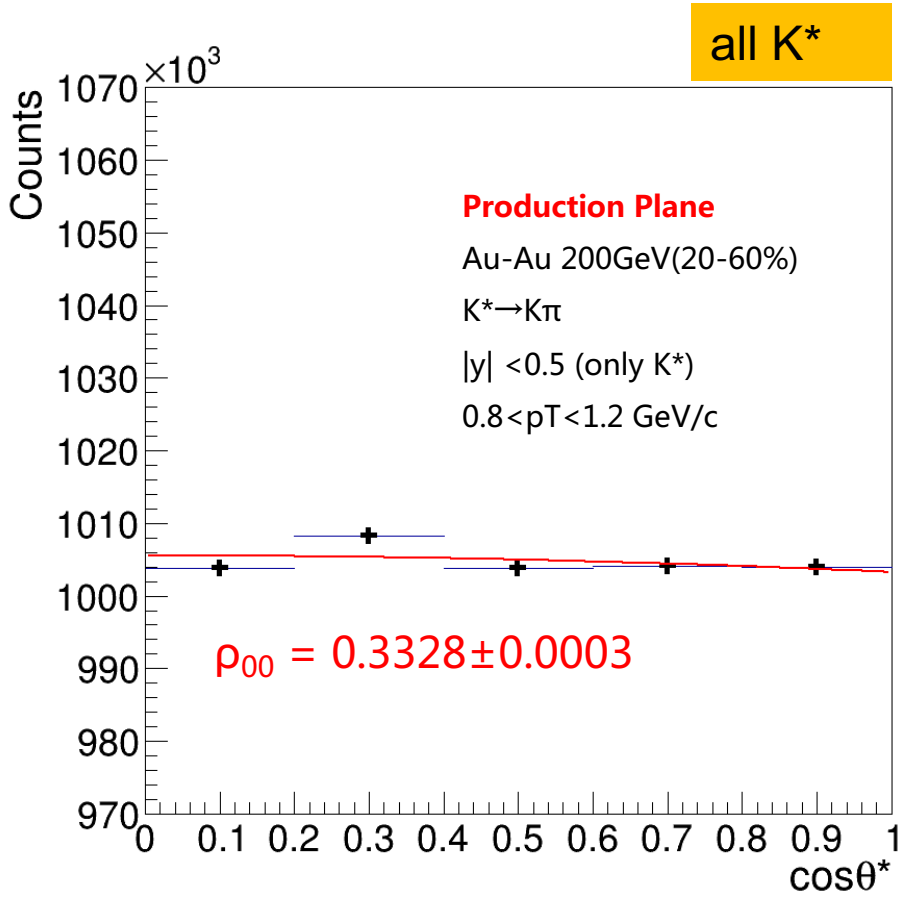
Consider all decays K*, ρ_{00} ~ 1/3

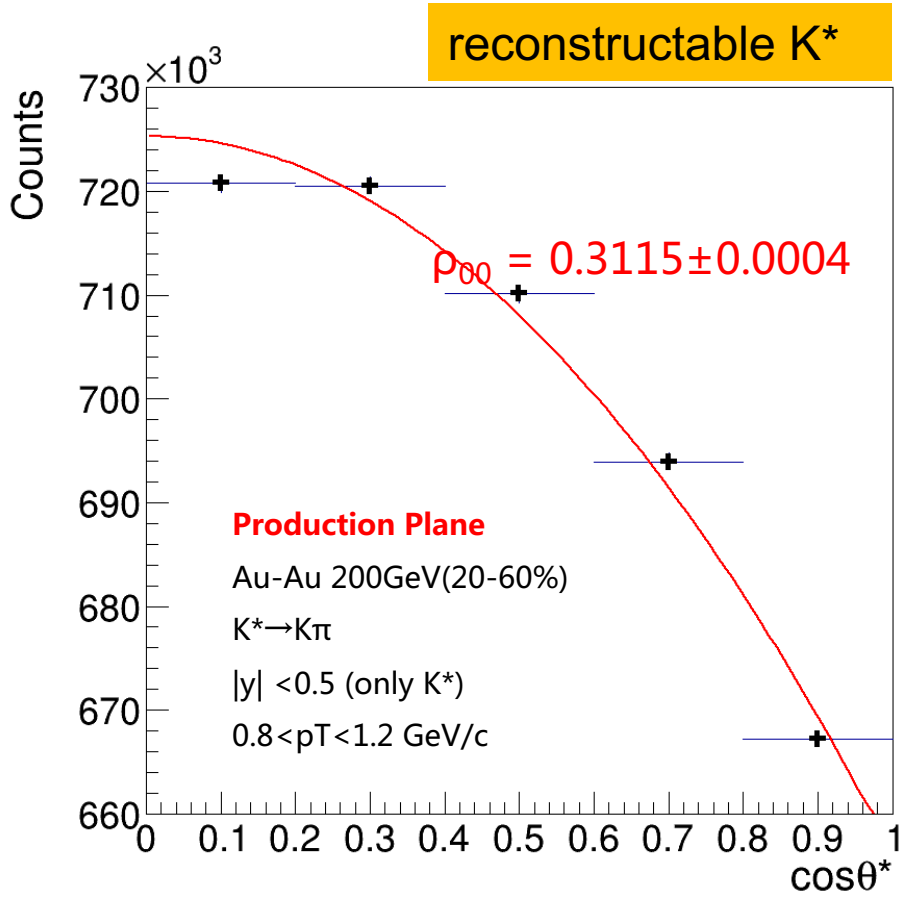
Reconstructable ρ_{00} values below 1/3

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

K. Schilling el al., Nucl. Phys. B 15, 397 (1970)

Angular distribution w.r.t. Production plane





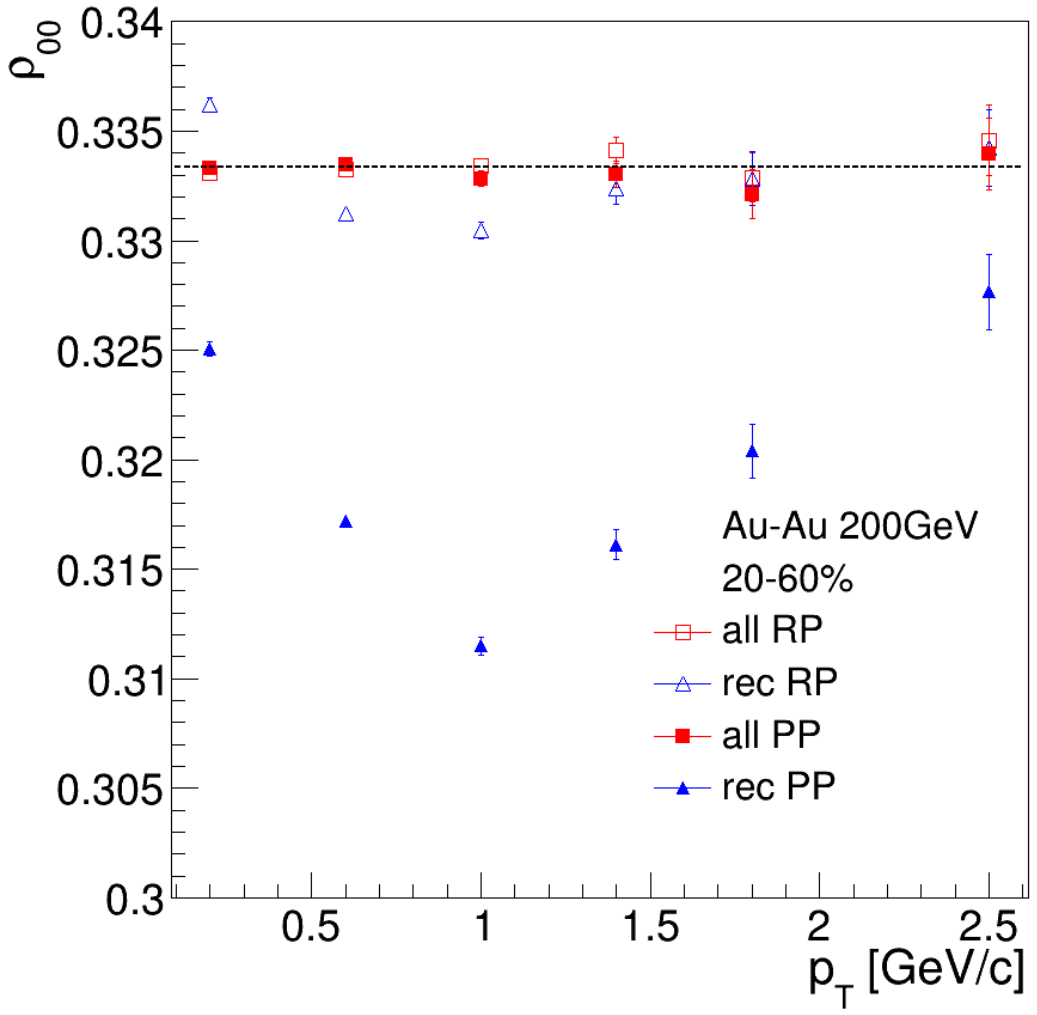
Consider all decays K*, ρ_{00} ~ 1/3

Reconstructable ρ_{00} values below 1/3

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

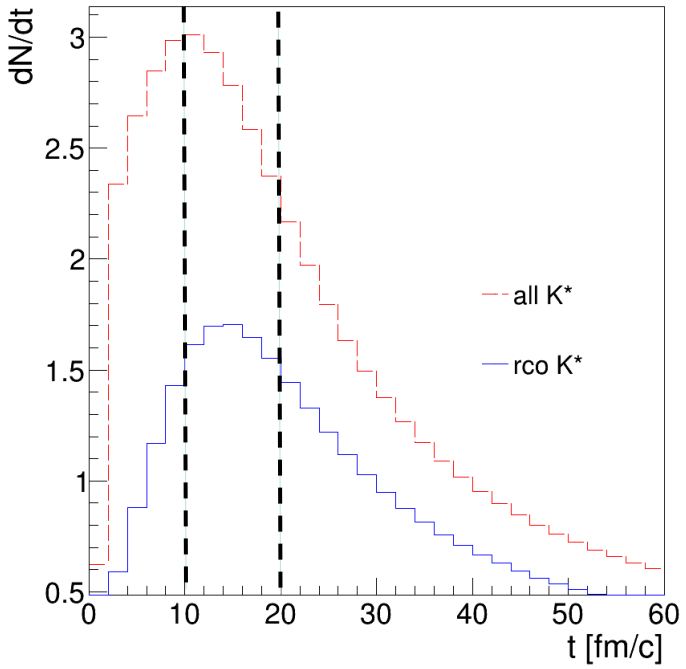
K. Schilling el al., Nucl. Phys. B 15, 397 (1970)

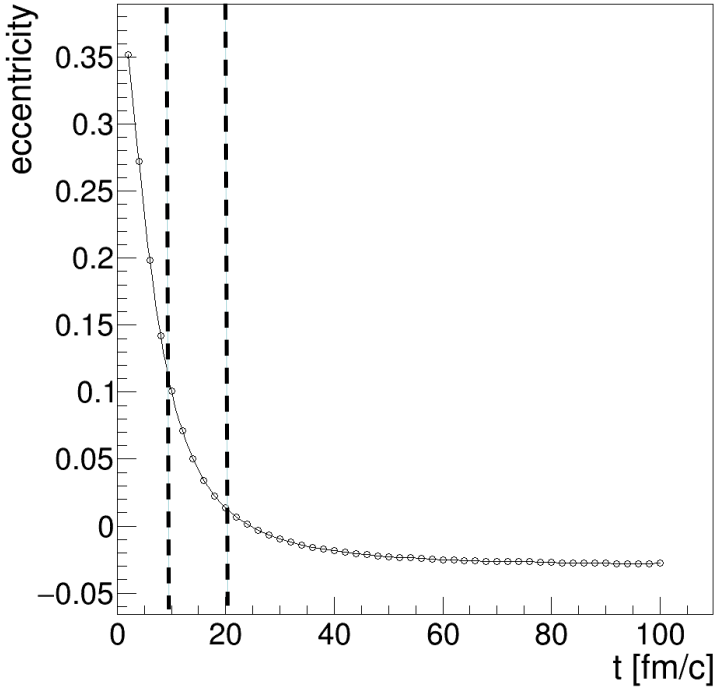
ρ_{00} as function of p_T

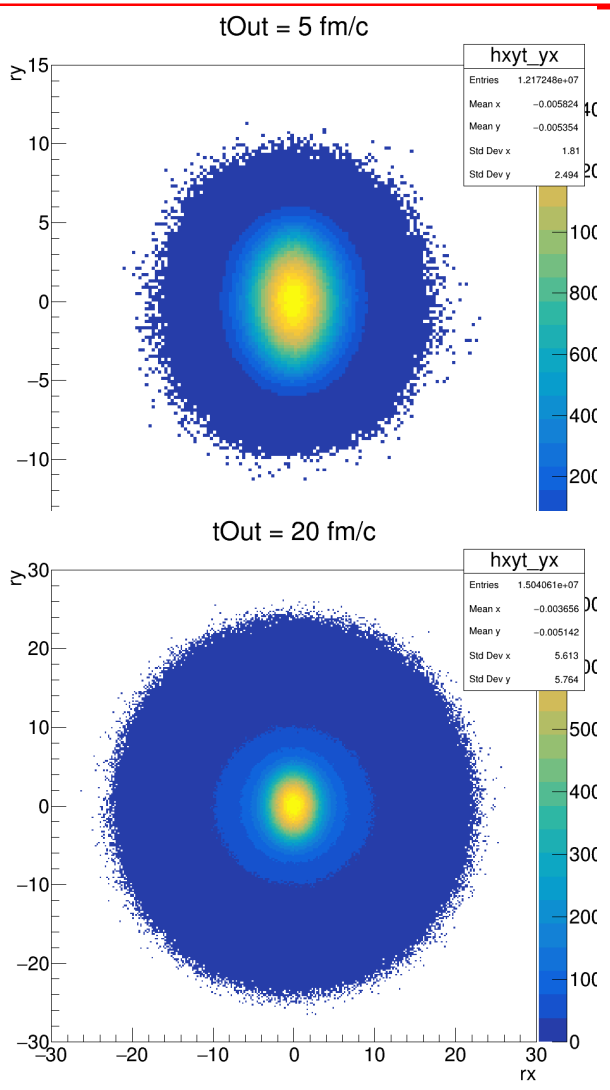


- Consider all decay K*, ρ_{00} ~ 1/3 : no spin alignment
- Reconstructable ρ_{00} values below 1/3 both Reaction and Production plane
- ρ_{00} deviate larger in Production plane
- ρ_{00} shows p_T dependence and maximum deviation from 1/3 for p_T class 0.8-1.2 GeV/c

Eccentricity of particles

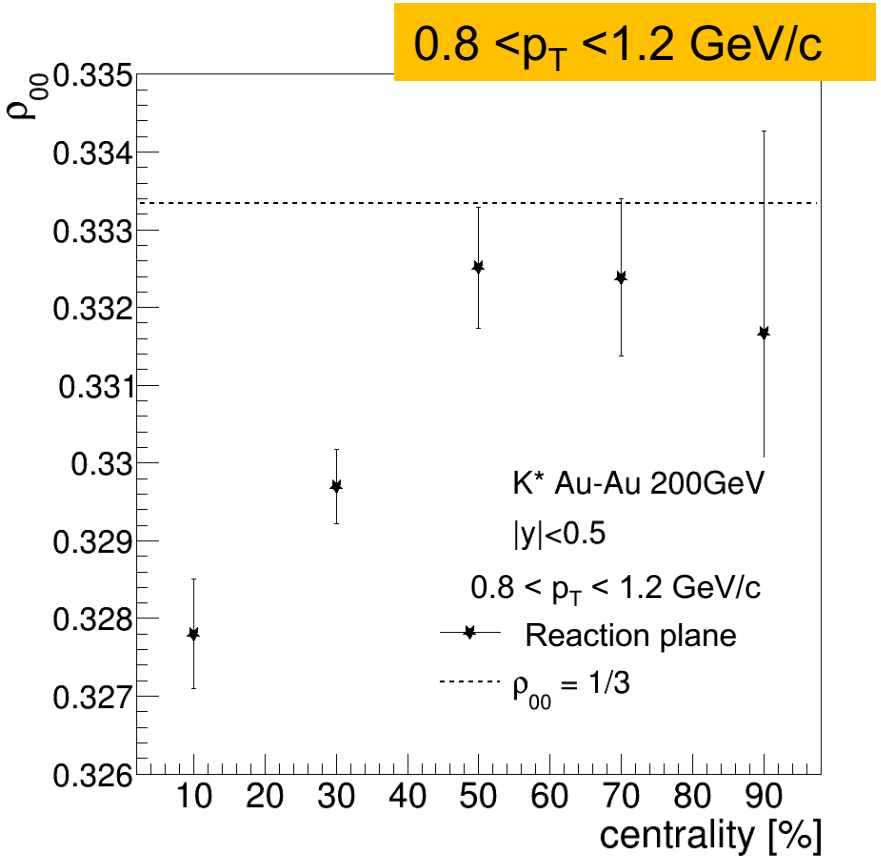


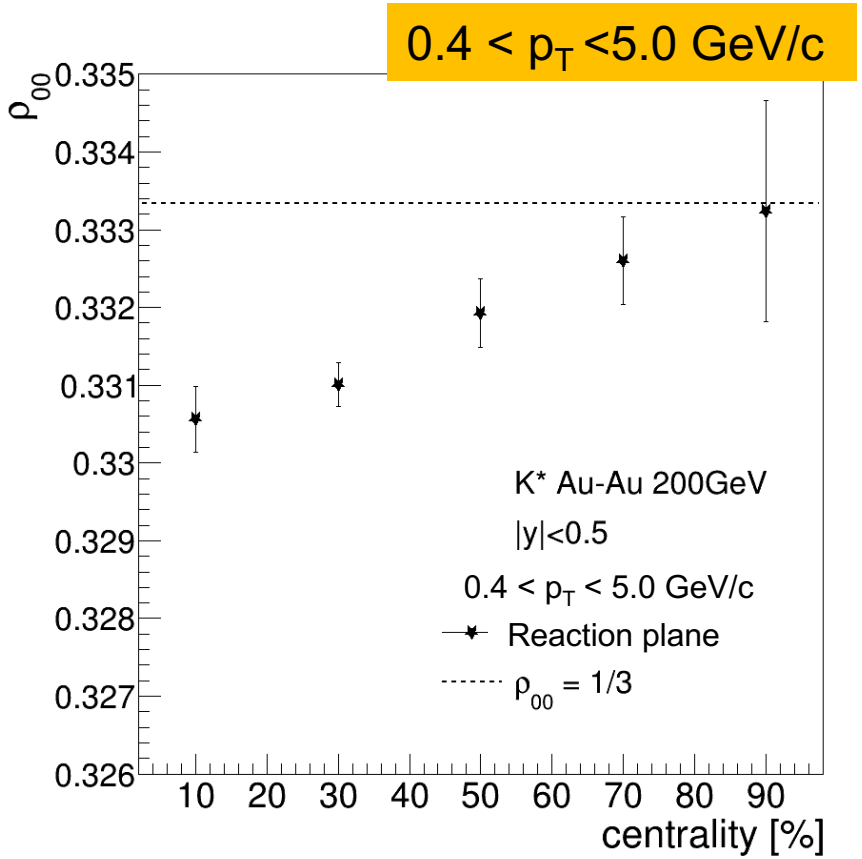




- Most K* decay ~ (10 – 20) fm/c
- The eccentricity decreases with time.

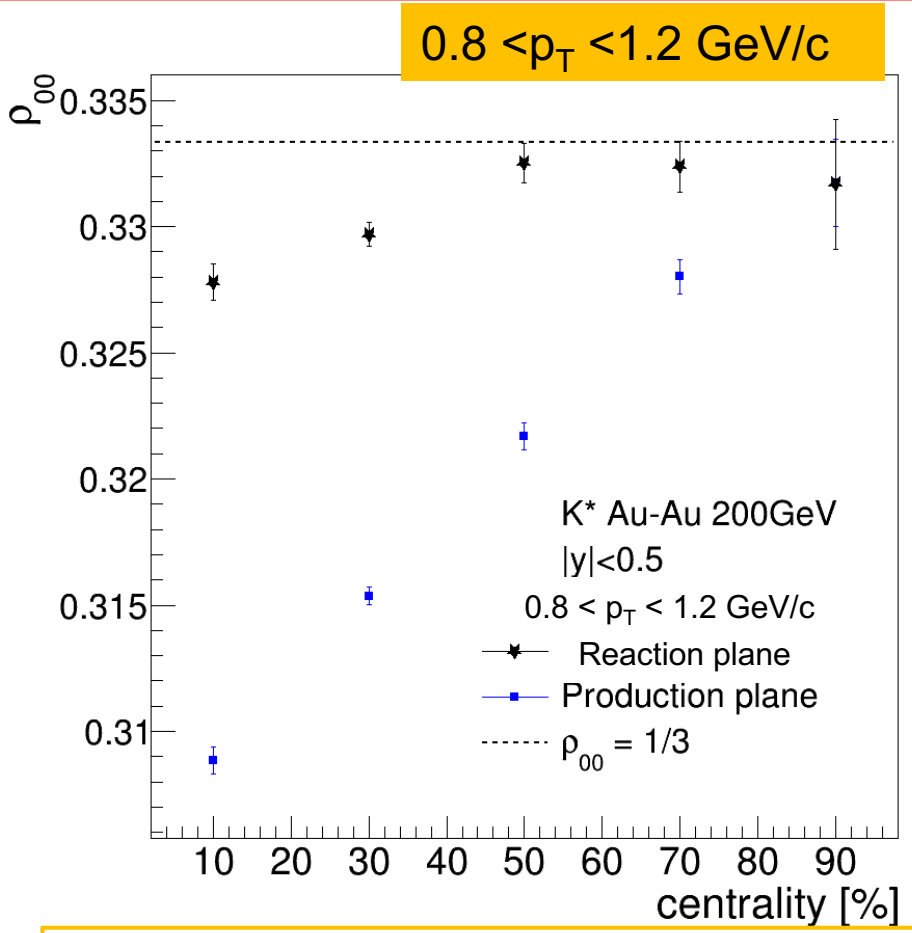
Centrality dependence of ρ00 w.r.t. Reaction plane

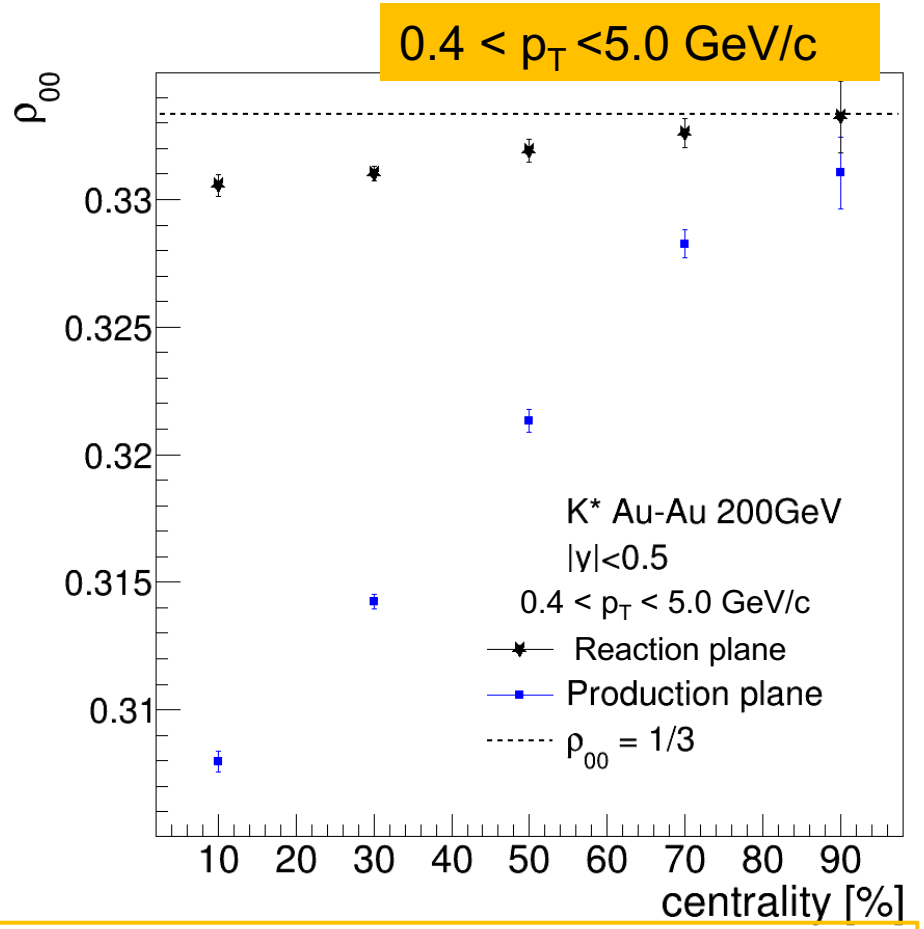




- ρ_{00} shows centrality dependence and maximum deviation from 1/3 for centrality class 0-20%
- Consistent with the STAR result about K* rescattering centrality dependence

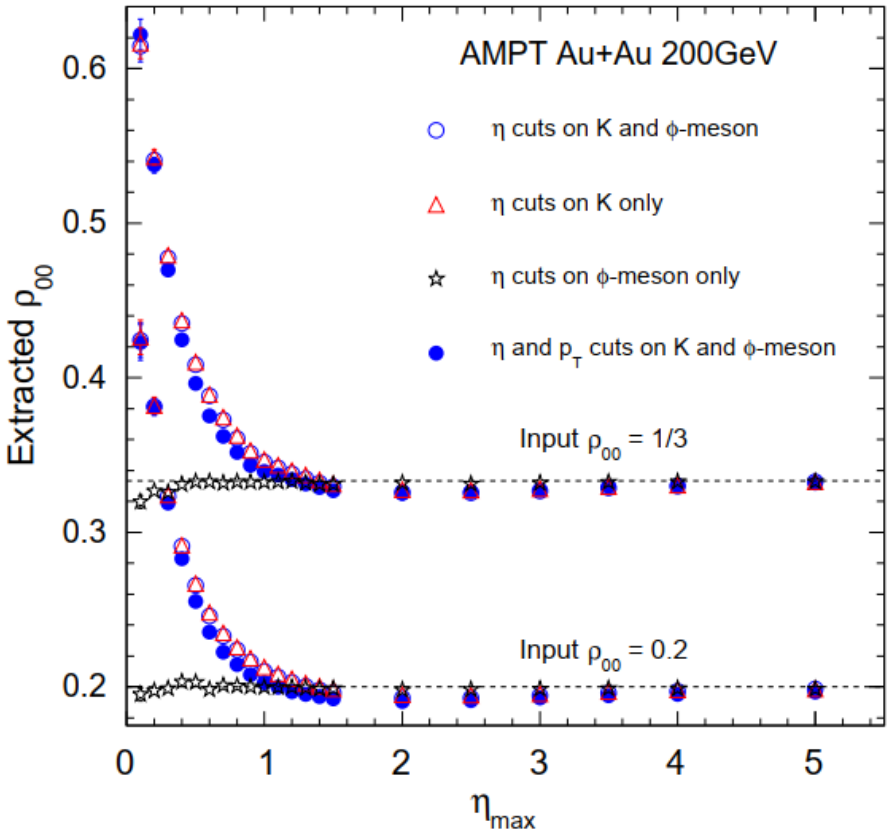
Centrality dependence of ρ_{00} :Reaction plane vs. Production plane



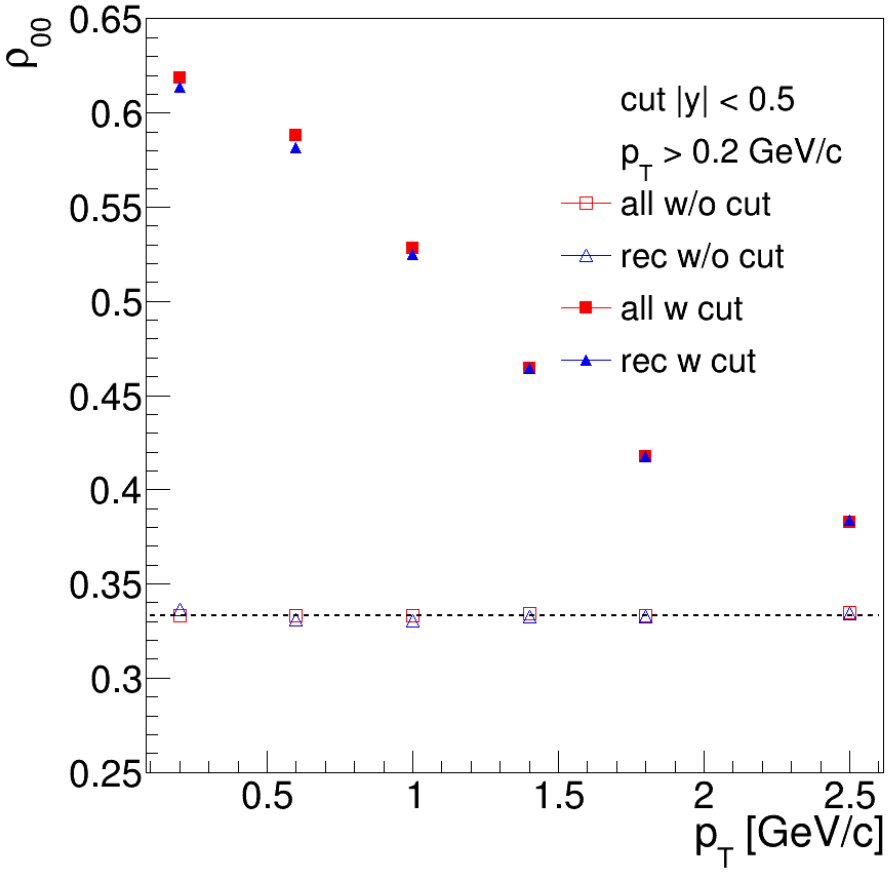


- ρ_{00} shows centrality dependence in both Production and Reaction plane and maximum deviation from 1/3 for centrality class 0-20%
- ρ_{00} deviation from 1/3 is larger in Production plane than in Reaction plane

Effects of finite coverage w.r.t. Reaction plane

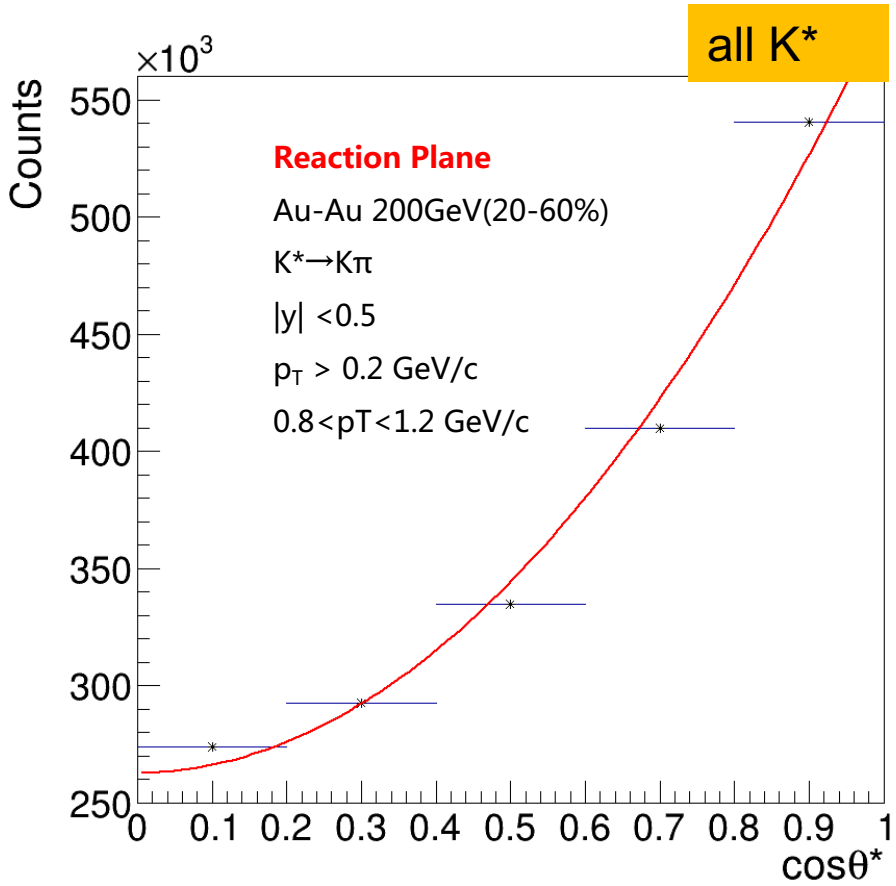


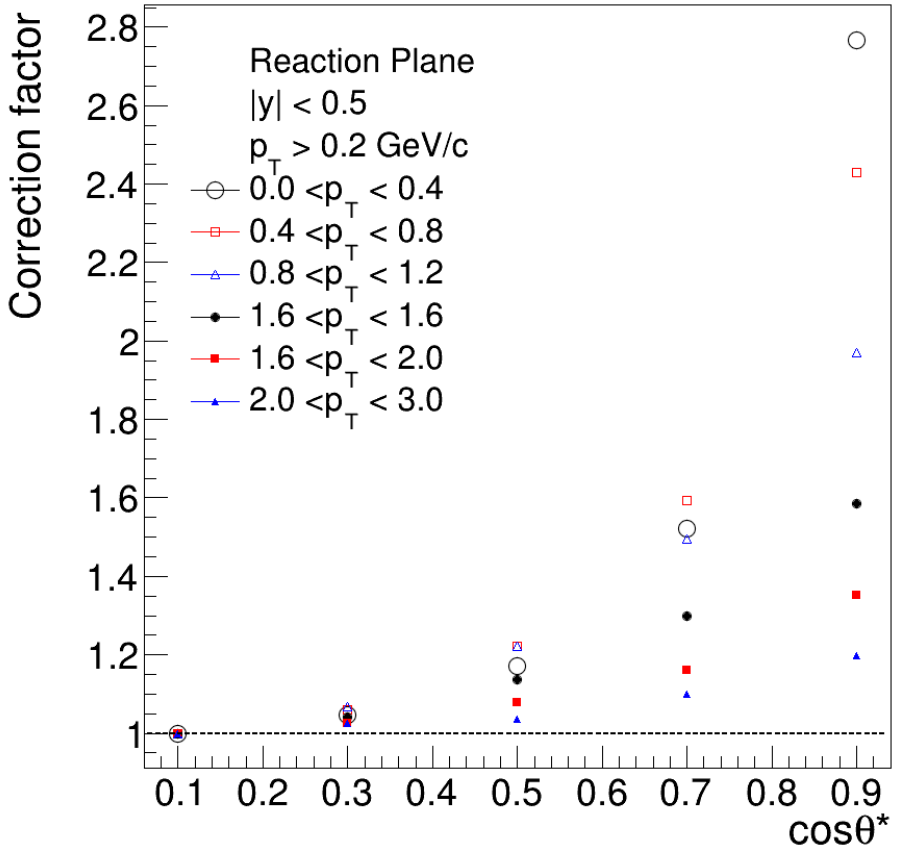
Shaowei Lan, Zi-Wei Lin, Shusu Shi, Xu Sun
Phys. Lett. B 780 (2018) 319



Acceptance also effect ρ_{00} value, so correction is needed.

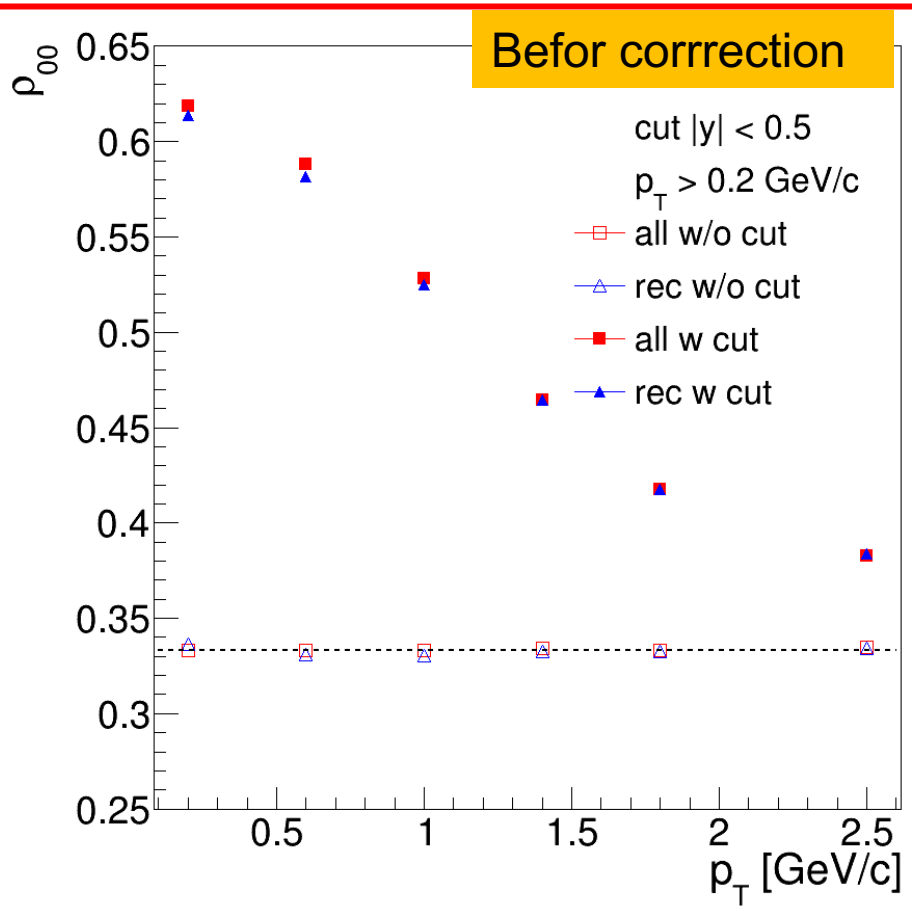
Correction factor w.r.t. Reaction plane

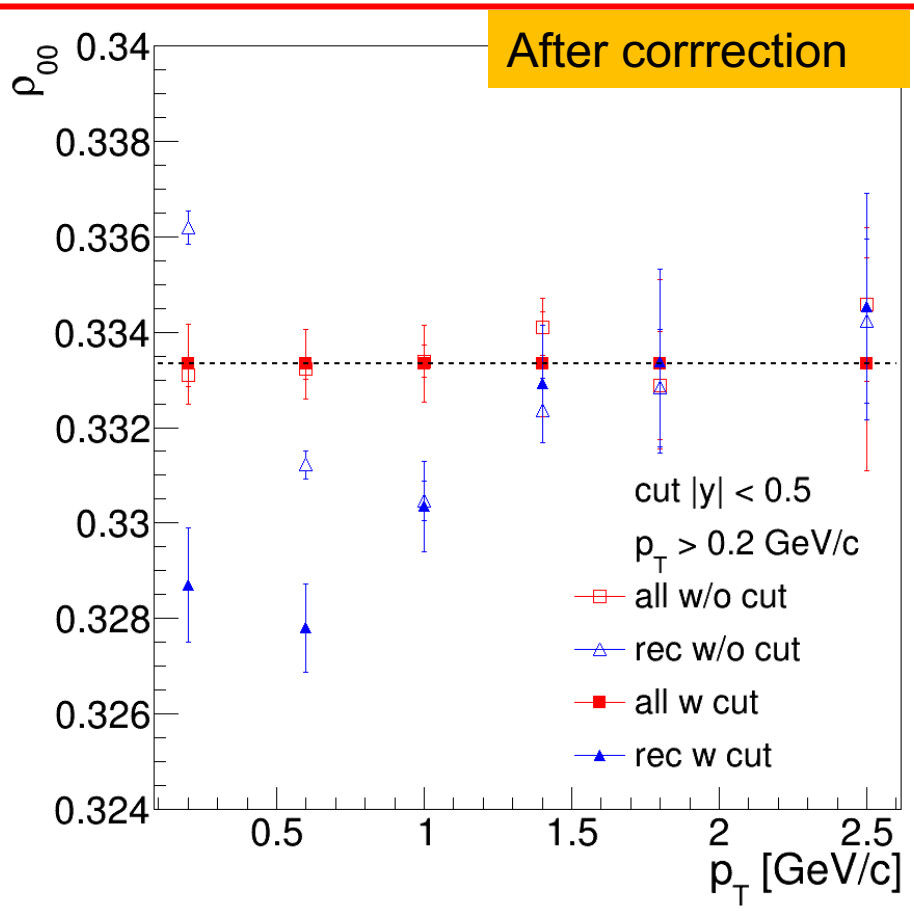




Assume the number of all decay K* in different cosθ* bins equal to each other, and get the correction factors in different p_T bins.

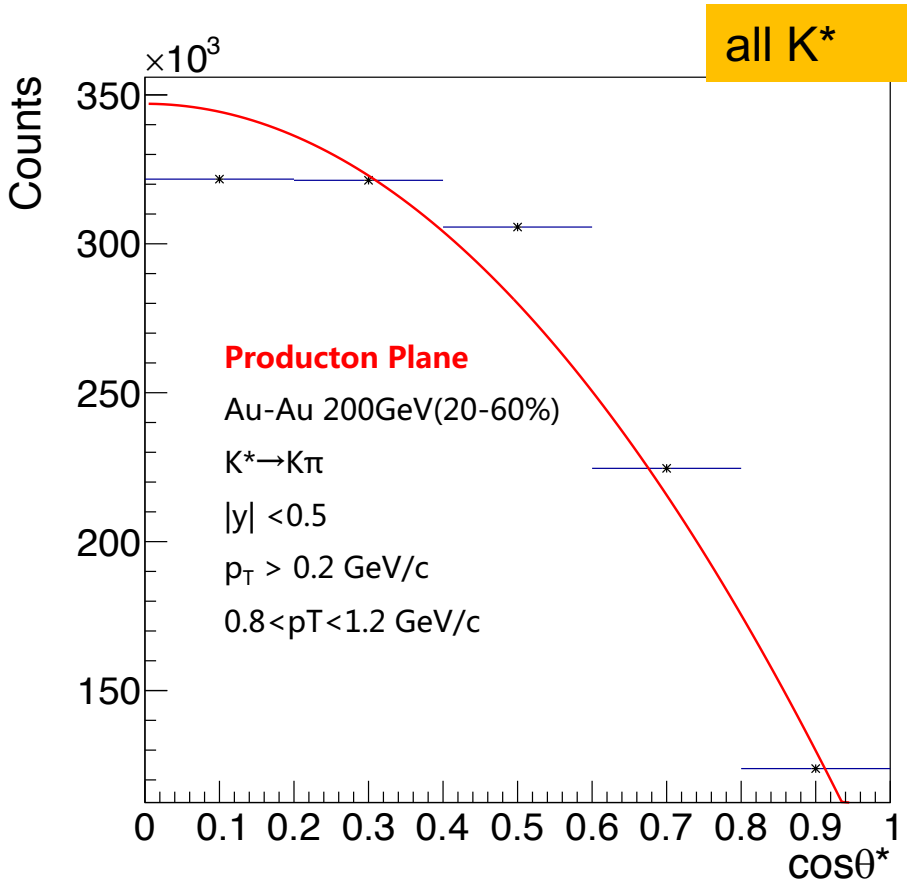
Correction result w.r.t. Reaction plane

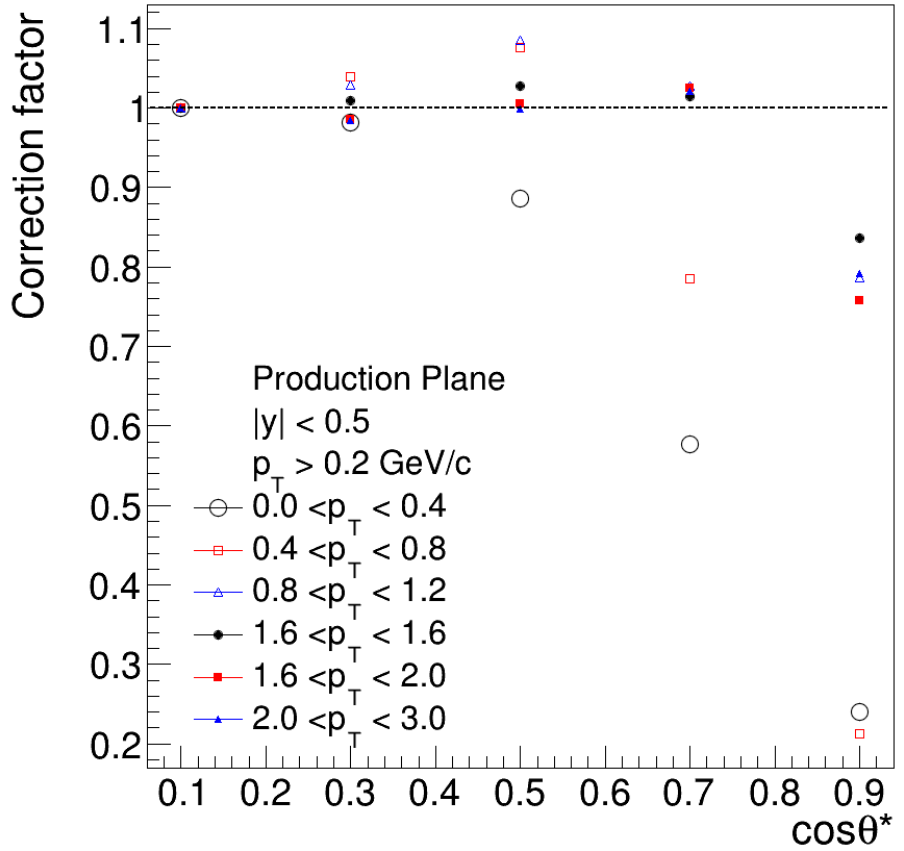




Finite coverage has obvious effect on the ρ_{00} value, but can be corrected in part.

Correction factor w.r.t. Production plane

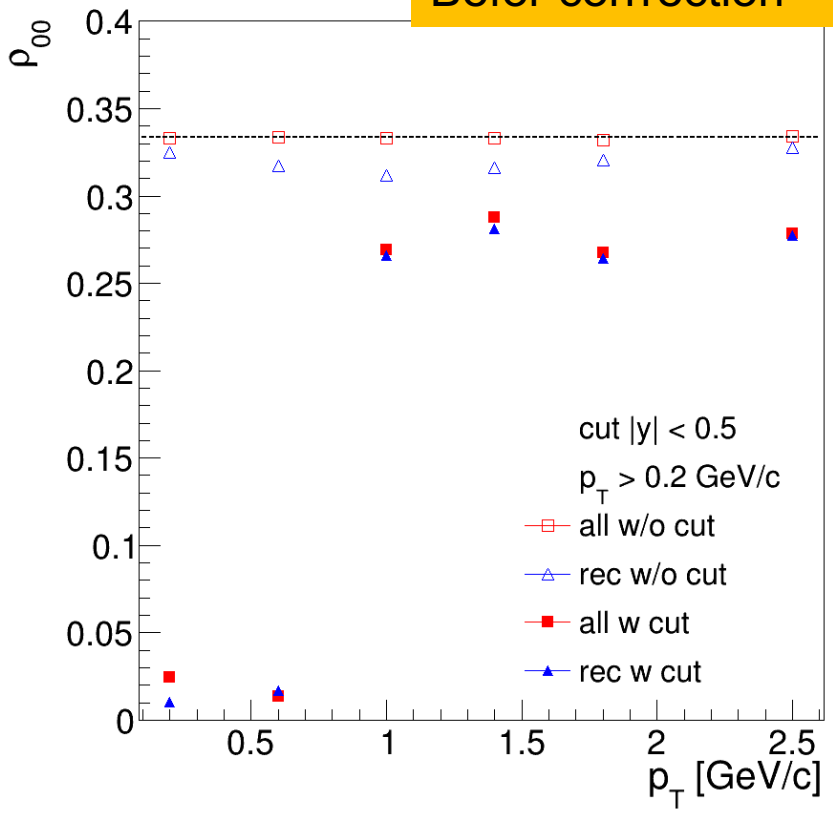




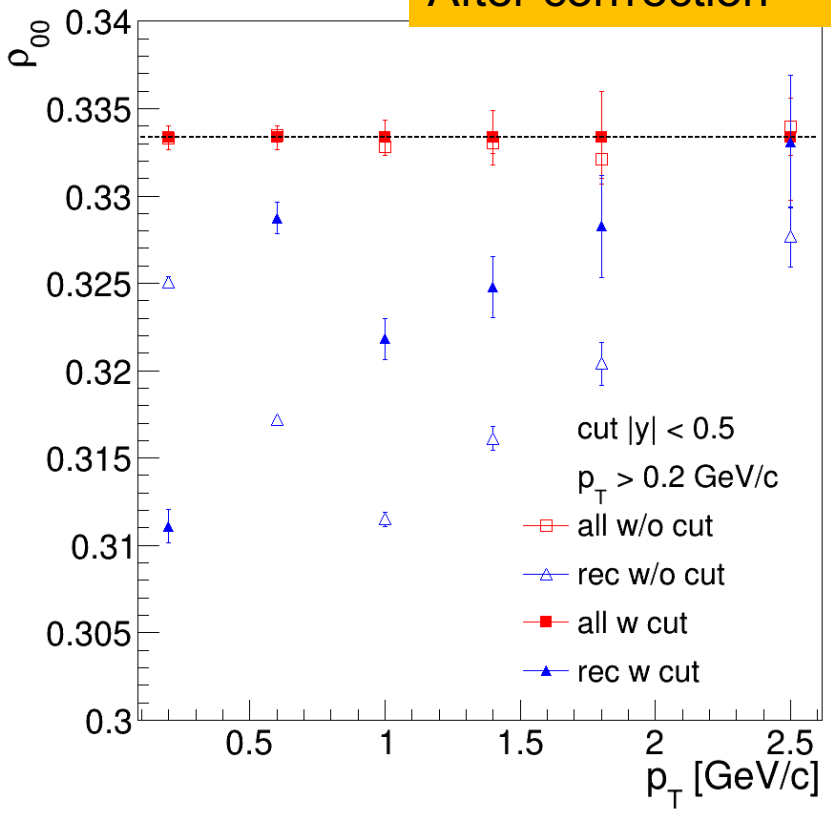
The effect on the production plane is different with the reaction plane.

Correction result w.r.t. Production plane

Befor corrrection



After corrrection



Finite coverage has obvious effect on the result, but can be corrected in part.

Summary

- ✓ Use UrQMD history file to distinguish all and reconstructable K*.
- ✓ ρ_{00} consistent with 1/3 for all K* and below 1/3 for reconstructable K* both in Reaction plane and Production plane.
- ✓ ρ_{00} deviation is larger in Production plane.
- ✓ Eccentricity decreases with time, so the rescattering effect is small.
- ✓ ρ_{00} shows centrality dependence in both Reaction and Production plane.
- ✓ Finite coverage has obvious effect on the result, but can be corrected.

Thanks