Study of K* spin alignment with the toy model

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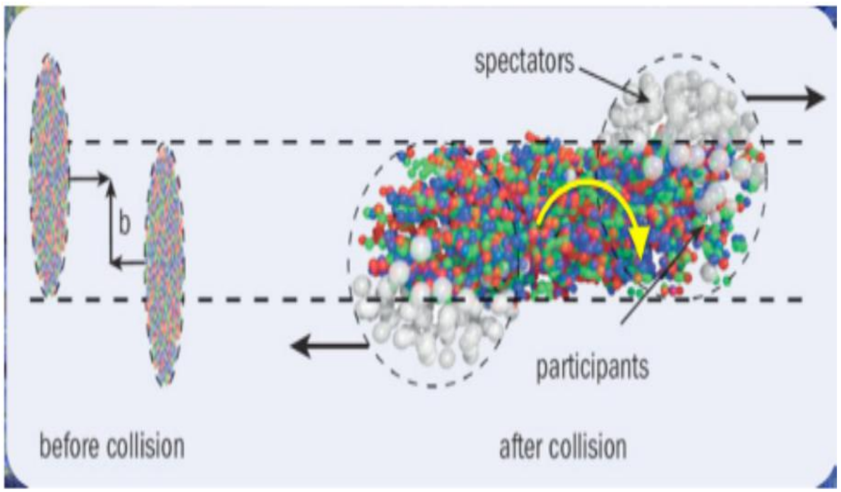
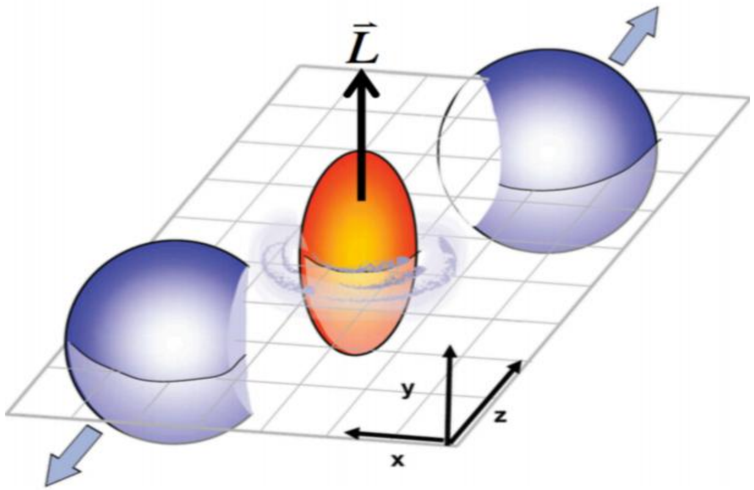
Introduction





Large initial angular momentum in non-central heavy ion collisions.

Due to spin-orbit coupling, it may result in net polarization of produced particles along the direction of initial angular momentum.

The information of $K^*(892)^0$

$$K^{*0} \longrightarrow K^+ + \pi^-$$

$$\overline{K^{*0}} \longrightarrow K^- + \pi^+$$

K^{*0} (The spin 1 vector meson)	
Mass	895.9 MeV
Quark Content	$\bar{s}$, d
Width	47.4 MeV
Lifetime	4.16 fm/c
Decay Chanel	K^+ π^-

The description of spin alignment

For spin-1 vector mesons, like the ϕ meson and K* meson, their spin alignment can be described by a spin density matrix ρ. The ρ_{00} can be measured by angular distribution of decay daughter using:

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

θ* is the angle between the polarization direction and the momentum direction of decay daughters in the rest frame of K* meson.

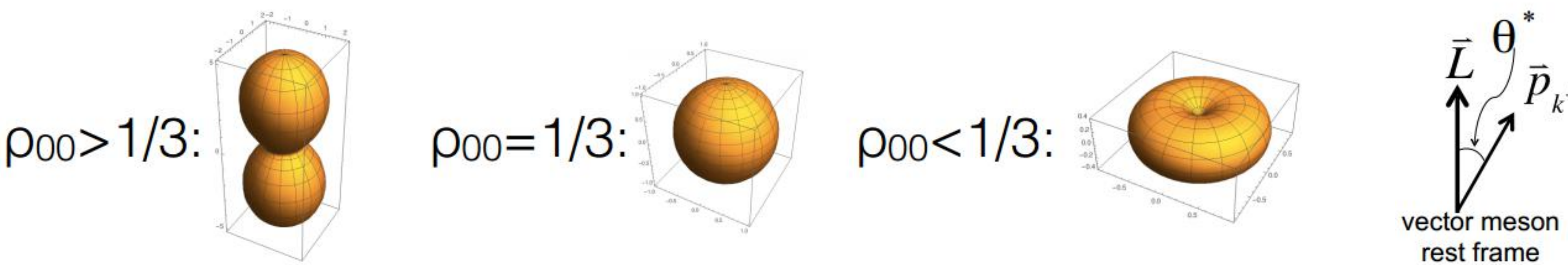
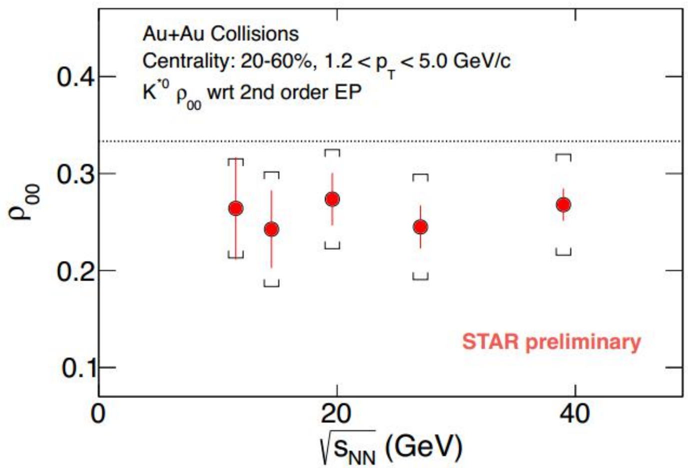


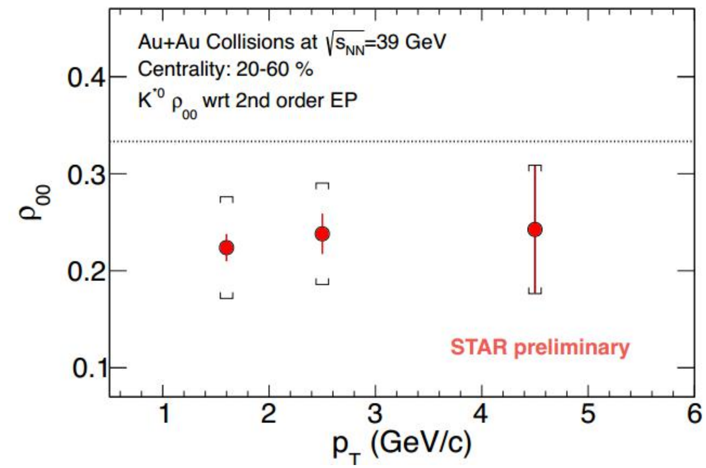
Figure: C.S. Zhou, Quark Matter 2018

Results of K^{*0} spin alignment from STAR

Energy Dependence of K^{*0} ρ_{00}



p_T Dependence of K^{*0} ρ_{00}



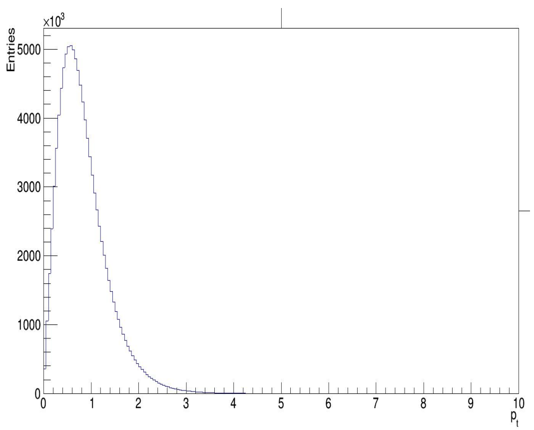
C.S. Zhou, Quark Matter 2018

Non-1/3 ρ_{00} is observed.

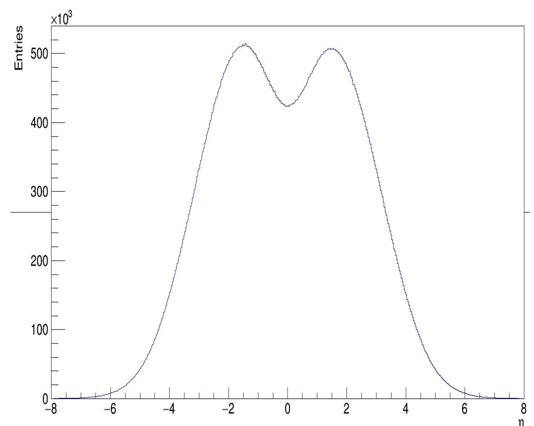
Analysis method

In the toy model, we input the p_T, η and ϕ information of K^* from AMPT （200GeV, String Melting). Phythia is used for the decay kinematics

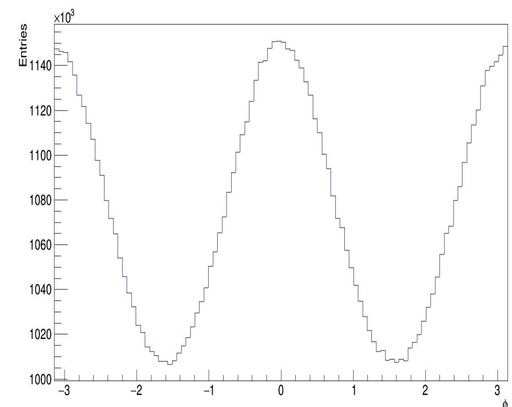
$K^* \rightarrow K^+ + \pi^-$.



p_t

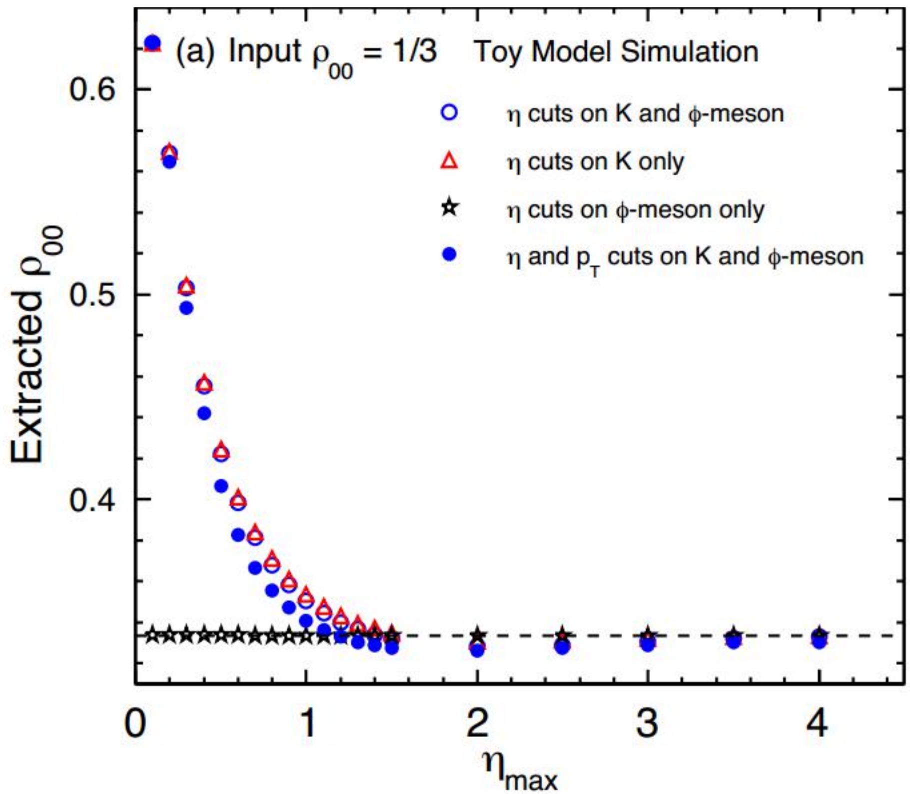


η



φ

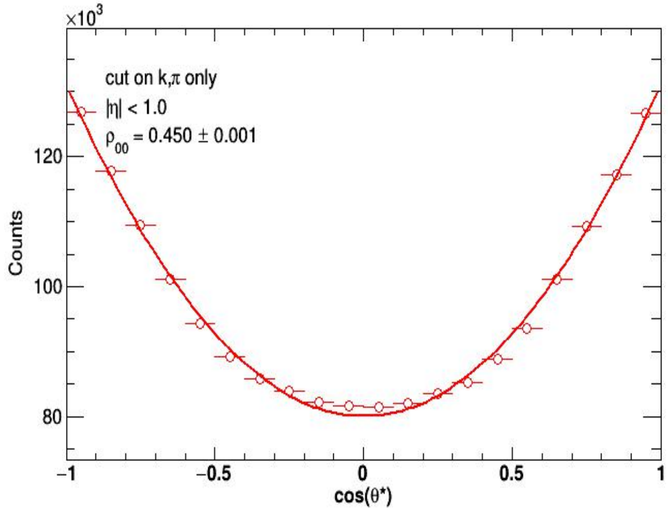
The finite accpeptance effect on ρ_{00} for ϕ meson



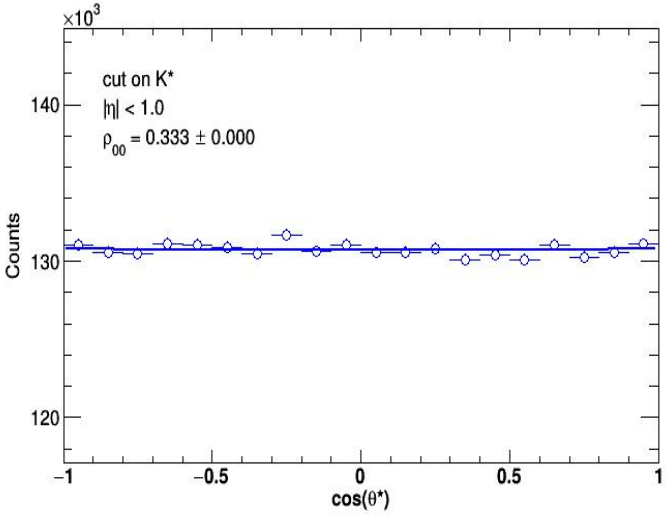
Shaowei Lan, Zi-Wei Lin Shusu Shi, Xu Sun,Phys. Lett. B 780,319-324(2018)

When the cut is below |η| <1, a narrower η acceptance gives a significantly larger ρ_{00} value than the input.

Results of K* spin alignment with toy model



a



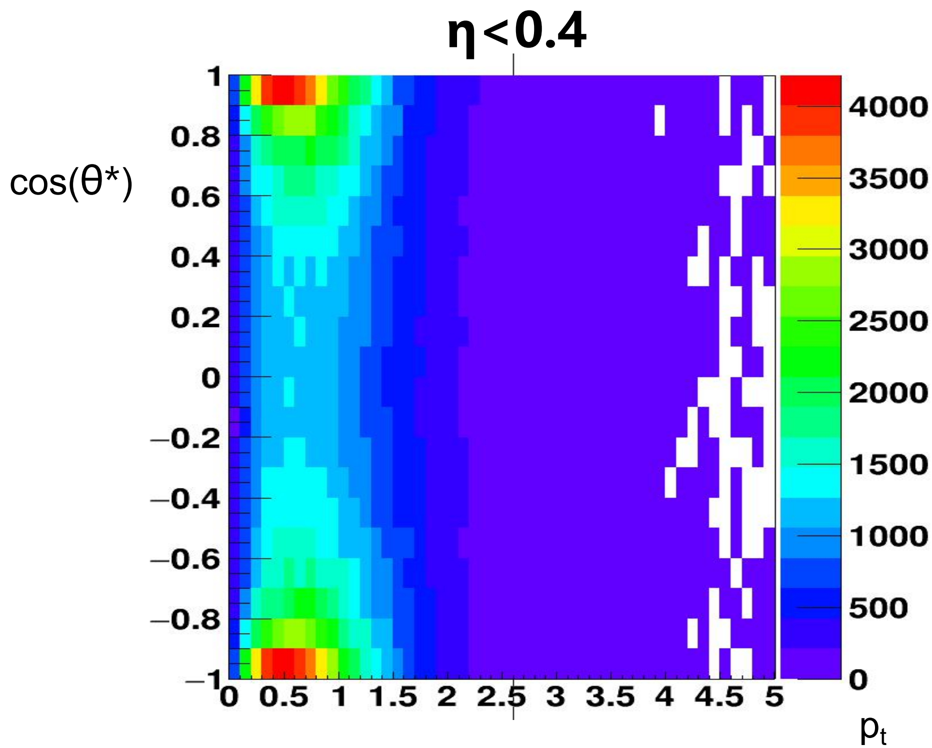
b

The curves represent fits based on Eq:

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

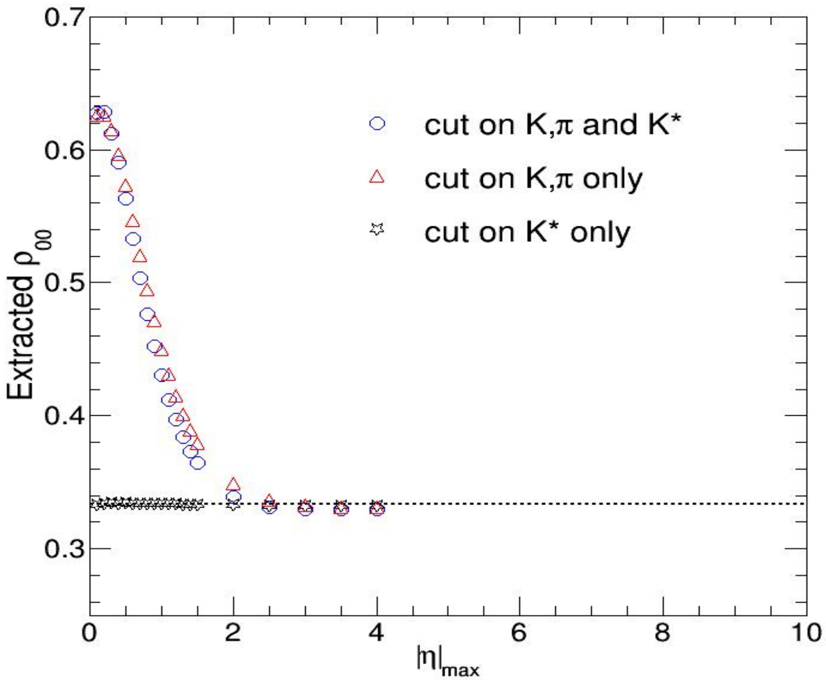
It shows that the extracted ρ_{00} is larger than the input value 1/3 (a) when cut on daughters.

p_T versus $\cos(\theta^*)$



We can clearly observe that the η cut excludes more kaons from K* decays around around cos θ*~0.

η cut effect on ρ_{00}



It shows the extracted ρ_{00} of K* mesons as a function of η acceptance with toy model.

The extracted ρ_{00} deviates from the input value significantly when we cut on daughter particles in a narrow η acceptance.

With in STAR η acceptance $|\eta| < 1$, the extracted ρ_{00} = 0.425 is larger than 1/3.

Summary

- We used the toy model to study the effects of η cuts on the extracted polarization parameters ρ_{00}.

- We found η-cuts on daugters can lead larger value than input by using toy model.

Thank you!

Backups

The angular distribution W(θ,φ) ≡ dN/dΩ of the decay products is given by[1]:

$$
\begin{aligned}
W(\theta,\phi) \\
&= \frac{3}{4\pi}\{\cos^2\theta\rho_{00} + \sin^2\theta(\rho_{11}+\rho_{-1-1})/2 \\
&\quad - \sin 2\theta(\cos\phi \operatorname{Re}\rho_{10} - \sin\phi \operatorname{Im}\rho_{10})/\sqrt{2} \\
&\quad + \sin 2\theta(\cos\phi \operatorname{Re}\rho_{-10} + \sin\phi \operatorname{Im}\rho_{-10})/\sqrt{2} \\
&\quad - \sin^2\theta[\cos(2\phi)\operatorname{Re}\rho_{1-1} - \sin(2\phi)\operatorname{Im}\rho_{1-1}]\}
\end{aligned}
$$

Here θ is the polar angle between the direction of motion of h and the quantization axis, φ is the azimuthal angle. By integrating over φ, we obtain

$$W(\theta) = \frac{3}{4}[(1-\rho_{00}) + (3\rho_{00}-1)\cos^2\theta].$$

[1]: Physics Letters B 629 (2005) 20–26 , Zuo-Tang Liang a, Xin-Nian Wang

For hadronization scenario of constituent quark recombination in which both quarks and anti-quarks are polarized.

$$\rho_{00}^{K^*(\mathrm{rec})} = \frac{1 - P_q P_s}{3 + P_q P_s}.$$

For Fragmentation of polarized quarks

$$\rho_{00}^{K^{*0}(frag)} = \frac{f_s}{n_s + f_s}\frac{1+\beta P_q^2}{3-\beta P_q^2} + \frac{n_s}{n_s + f_s}\frac{1+\beta P_s^2}{3-\beta P_s^2}$$

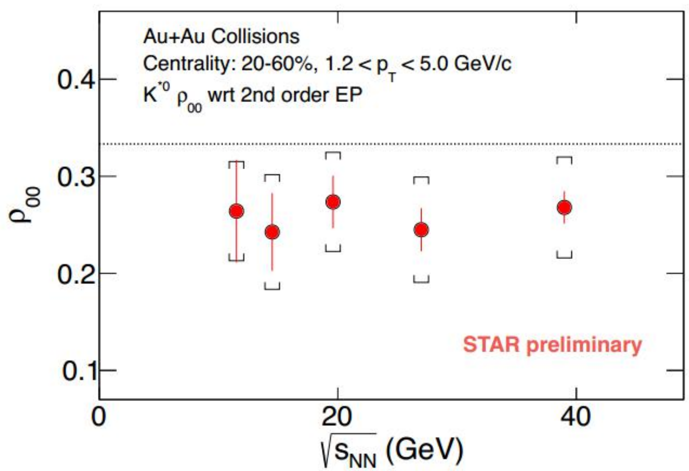
$P_q = -\frac{\pi}{4}\frac{\mu p}{E(E+m_q)}$ is the global quark polarization

$P_{\bar{q}}^{frag} = -\beta P_q$ is the polarization of the (anti-)quark created in the fragmentation process

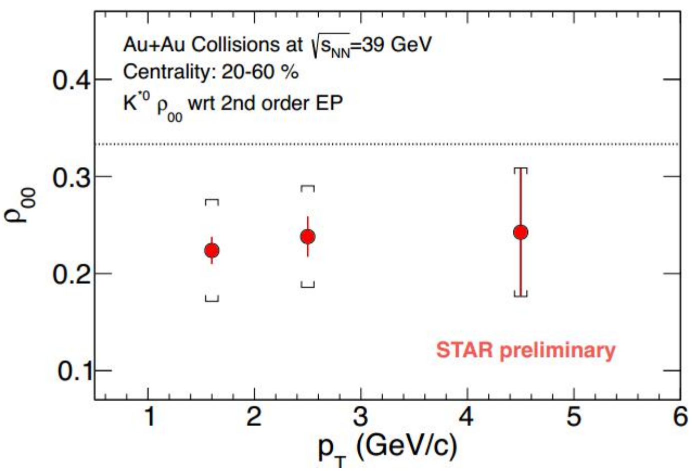
n_s and f_s are the strange quark abundances relative to up or down quarks in QGP and quark fragmentation, respectively.

Results of K* spin alignment from STAR

Energy Dependence of K^{*0} ρ_{00}



p_T Dependence of K^{*0} ρ_{00}



Chensheng Zhou.Quark matter.2018

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