Effects of finite coverage on global polarization observables in heavy ion collisions

Phys. Lett. B 780,319-324(2018)

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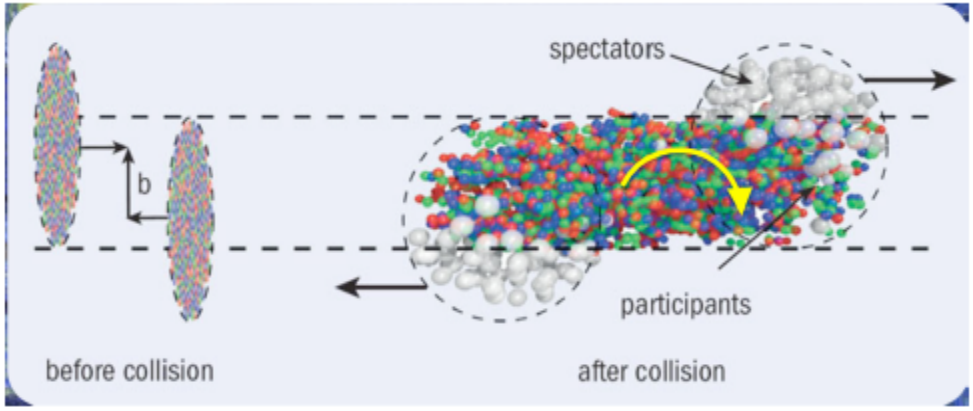
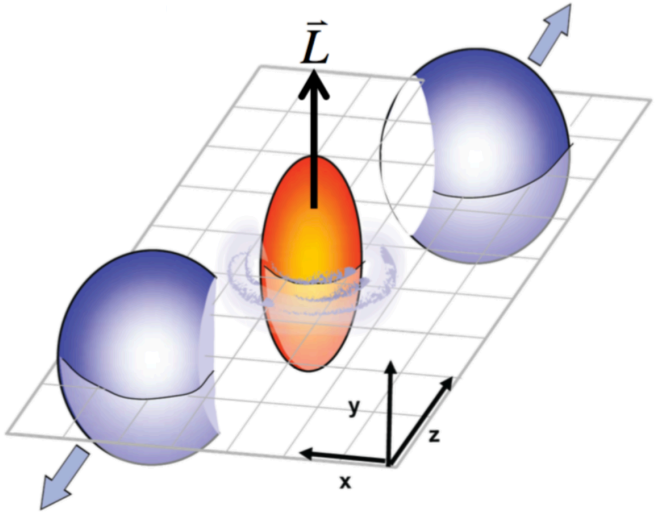
Outline

- **Introduction & Motivation**
- **Modified AMPT model**
- **Analysis method and results**
- **Summary**

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.

Λ polarization

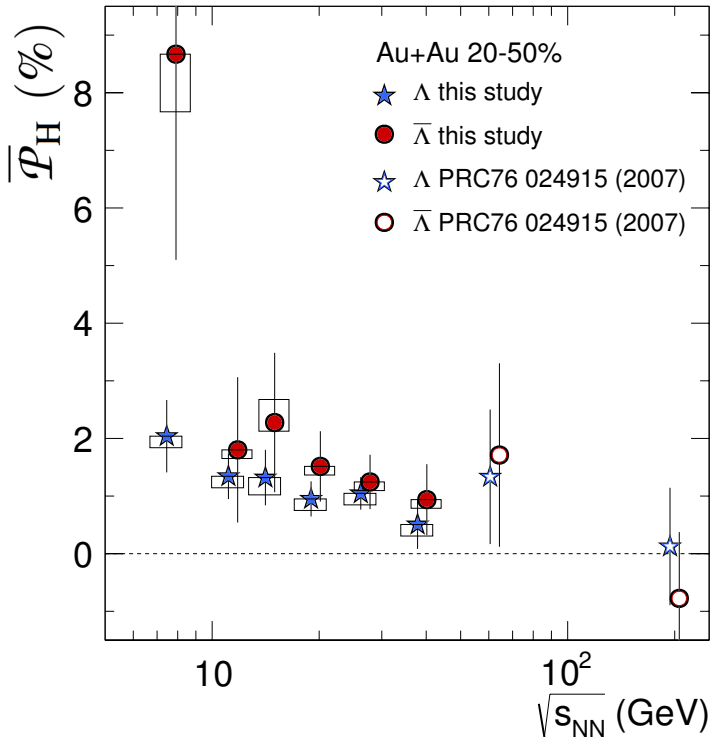
- The global polarization of Λ hyperons can be determined from the angular distribution of Λ decay products relative to the system angular momentum $\vec{L}$.

$$\frac{dN}{dcos\theta^{\star}} \propto 1 + \alpha_H p_H cos\theta^{\star} \quad (1)$$

At all azimuthal space:

$$p_H = \frac{3}{\alpha_H}\langle cos\theta^{\star}\rangle = \frac{8}{\pi\alpha_H}\langle cos(\phi_p^{\star} - \phi_L)\rangle \quad (2)$$

- $\theta^{\star}$ is the angle between $\vec{L}$ and the momentum of daughter proton in the rest frame of parent Λ hyperon.
- α_H is the decay parameter, $\alpha_\Lambda = 0.642$.
- $\phi_p^{\star}$ is the azimuth of the daughter proton momentum vector in the Λ rest frame.
- ϕ_L is the azimuth of the system angular momentum.



(STAR), Nature 548, 62 (2017)

ϕ-meson spin alignment

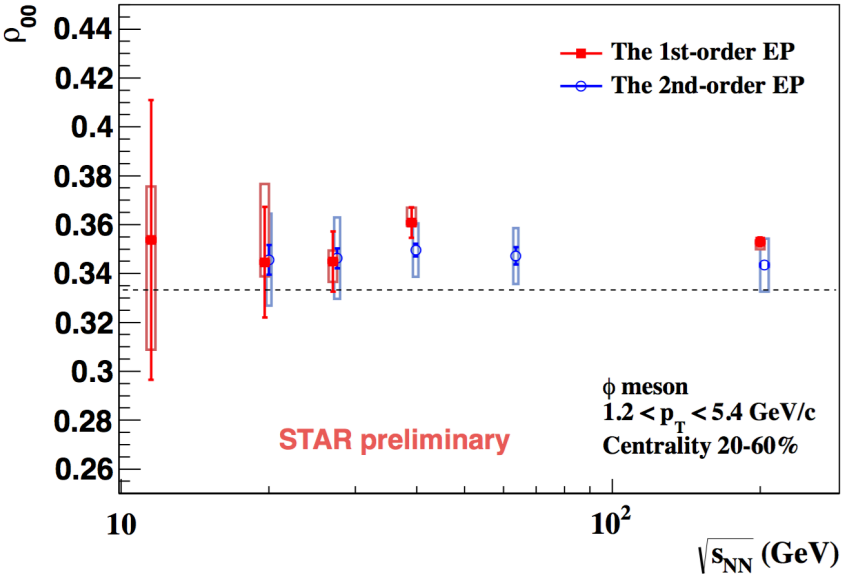
Z. Liang and X. Wang, Phys. Lett. B 629,20-26(2005)

STAR: QM2017 Xu Sun
STAR: QM2018 Chengsheng Chou

- The 00-component of ϕ-meson spin density matrix (ρ_{00}) can be measured by angular distribution of decay daughter using:

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

- θ* is the angle between $\vec{L}$ and the momentum of daughter K^+ in the rest frame of parent ϕ-meson.



- **ρ_{00} ≠1/3 indicates ϕ-meson spin alignment.**

- Systematically larger than 1/3.

A Multi-Phase Transport Model

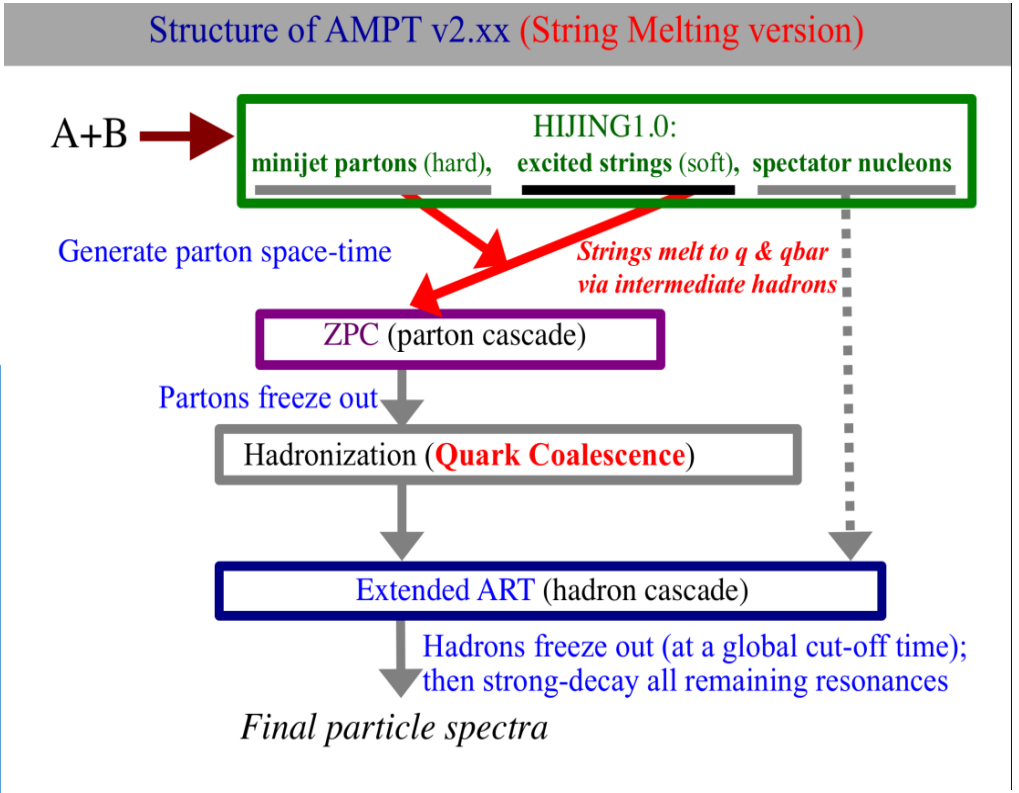
Zi-Wei Lin, Ko, Li, Zhang and Pal, Phys. Rev. C 72, 064901 (2005)

Four Main Parts:

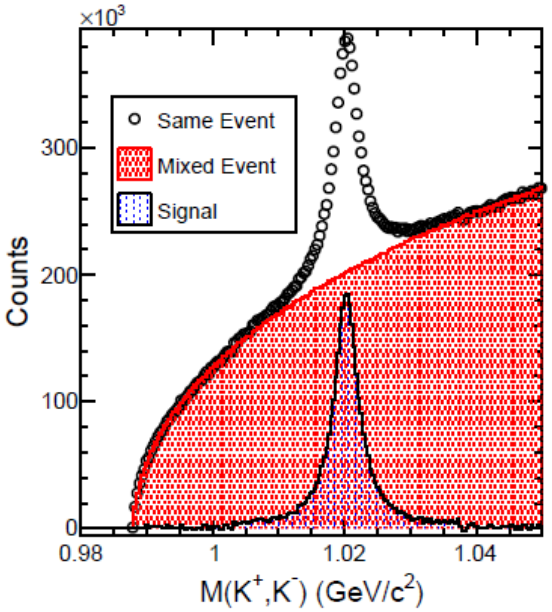
- The initial condition.
- Partonic scattering.
- Hadronization.
- Hadronic scattering.

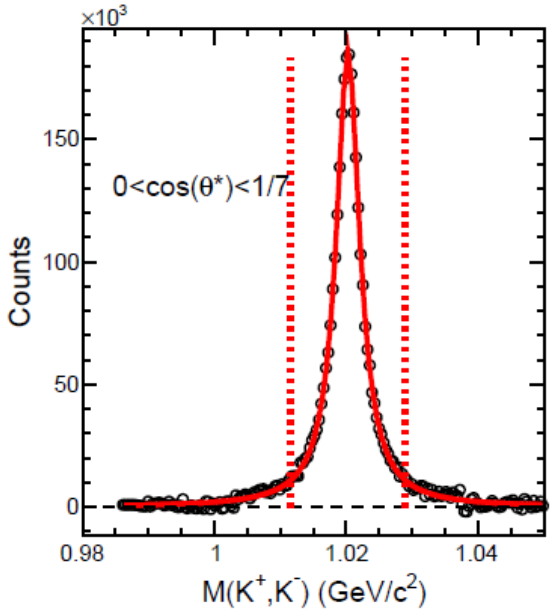
Modified part :

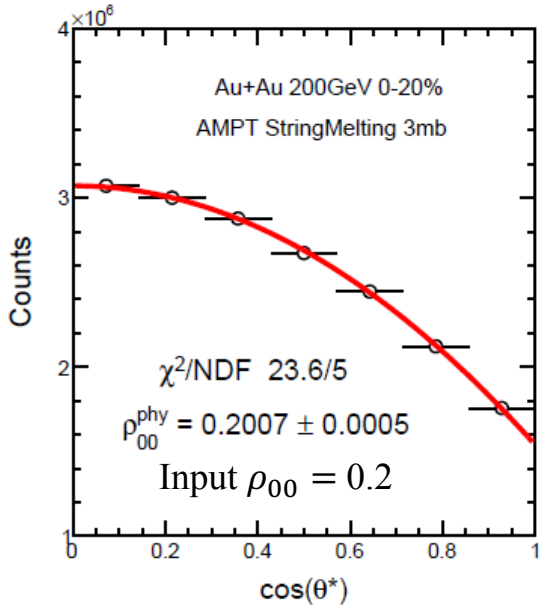
- Added input ρ_{00} and p_H parameter to specify the degree of spin alignment of ϕ-meson and Λ polarization at decay.
- System angular momentum direction is calculated event-by-event.



ρ_{00} extraction





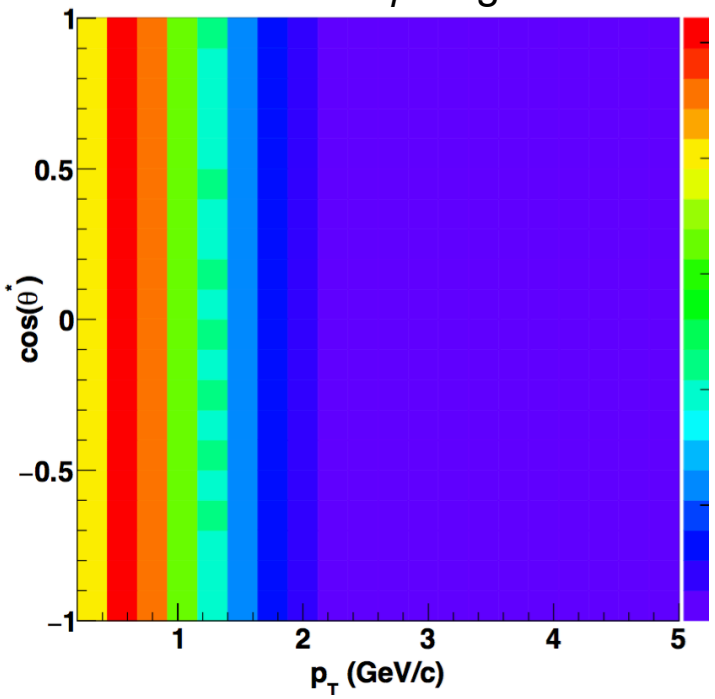


- Background : Event Mixing technique.
- Invariant mass distributions for 7 different $cos\theta^*$ bins.
- Fit $cos\theta^*$ distribution with: $\frac{dN}{dcos\theta^*} = N_0 * [(1-\rho_{00}) + (3\rho_{00} - 1) * cos^2\theta^*]$

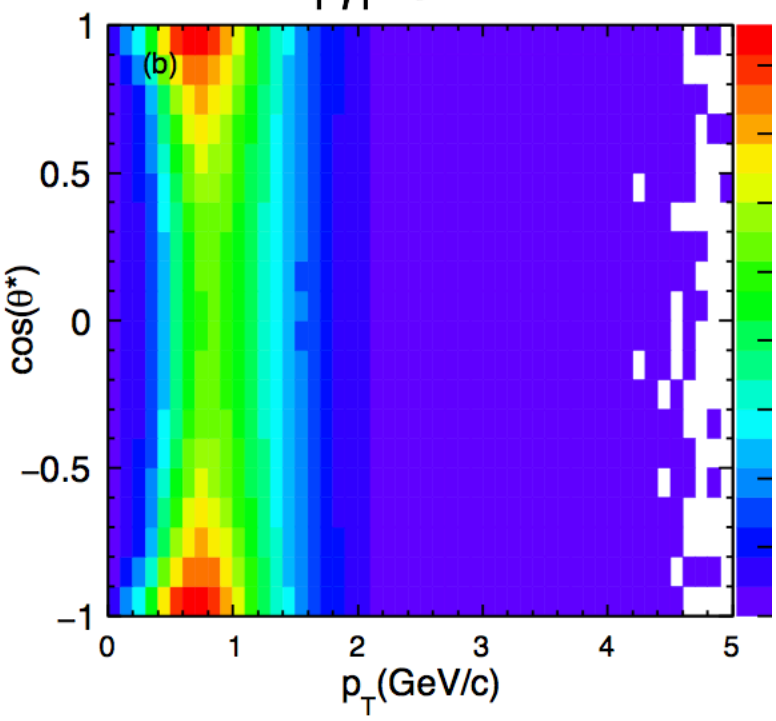
- **Fitted results well reproduce the input value with no phase space cut.**

η-cut effect on ρ_{00}

Full η range



$|\eta|$<0.4



➢ η-cut excludes more kaons around $\cos\theta^{\star} \sim 0$.

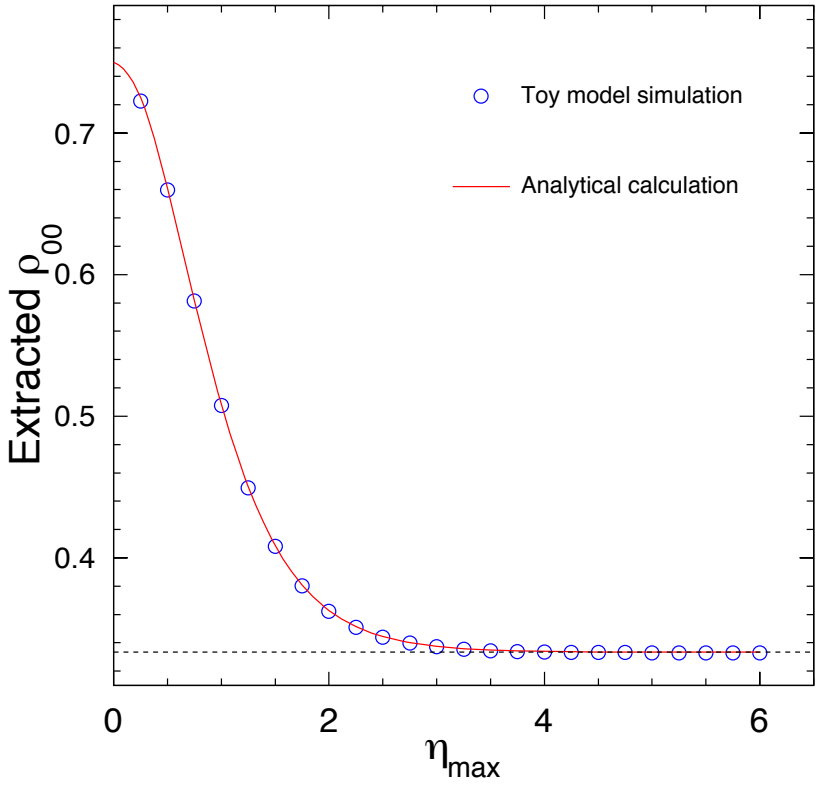
η-cut effect on ρ_{00} (ϕ at rest)

When decay daughter particle can only be measured within a finite η range $|\eta|<\eta_{max}$, the range of θ_K is given by :$\theta_K^\star \in [\epsilon, \pi-\epsilon]$, where $\epsilon = 2\mathrm{atan}(e^{-\eta_{max}})$

Then we have :

$$\rho_{00}^{extracted} = \frac{1}{3} + \frac{5sin^2\epsilon}{12}$$

- Toy model simulation well agree with analytical calculation.



η-cut effect on p_H (Λ at rest)

When decay daughter particle can only be measured within a finite η range $|\eta|<\eta_{max}$, the range of θ_p is given by :$\theta_p^\star \in [\epsilon, \pi-\epsilon]$, where $\epsilon = 2\text{atan}(e^{-\eta_{max}})$

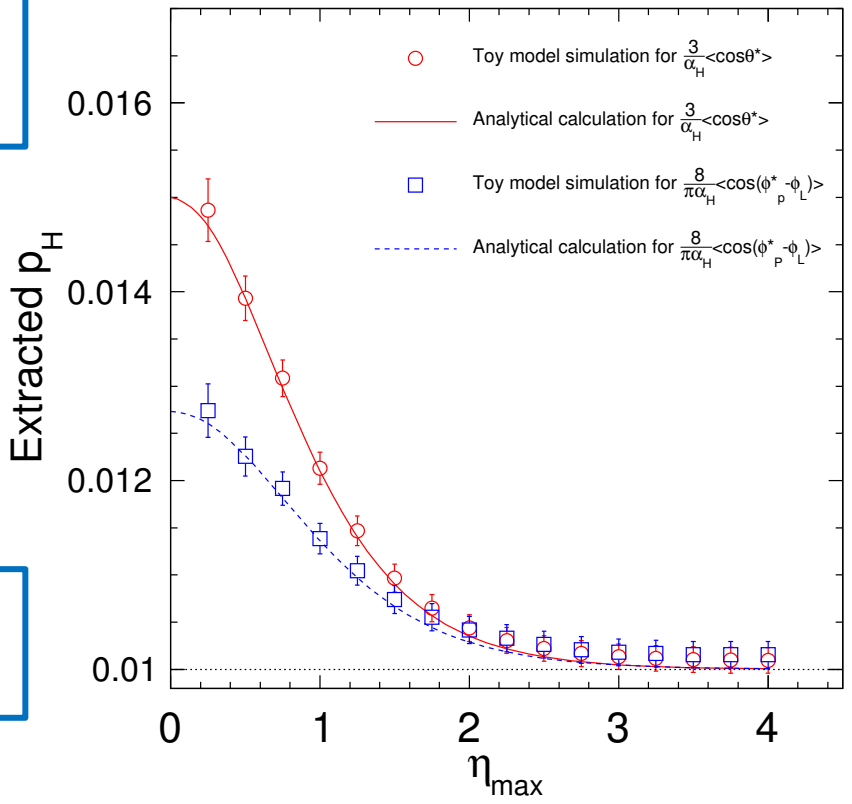
Then we have :

$$p_H^{extracted} = p_H[5-cos(2\epsilon)]/4$$

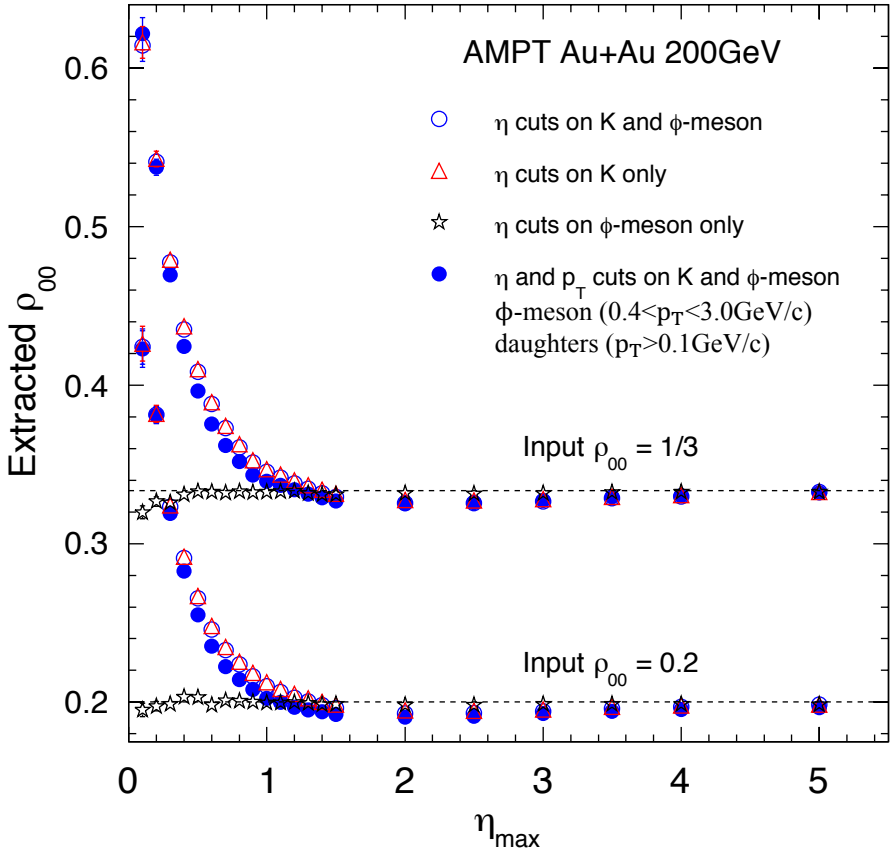
and:

$$p_H^{extracted} = p_H[1+\frac{sin(2\epsilon)-2\epsilon}{\pi}]/cos\epsilon$$

- Toy model simulation well agree with analytical calculation.

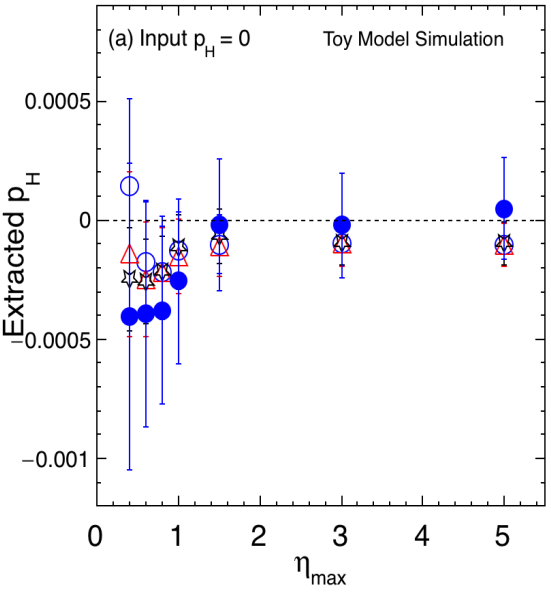


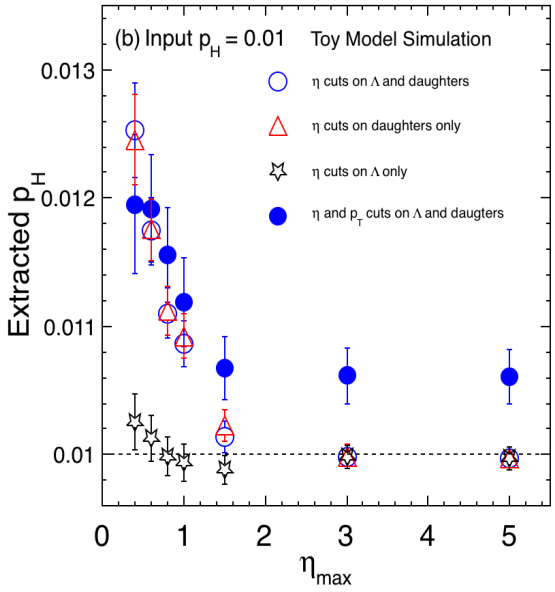
η-cut effect on ρ_{00}

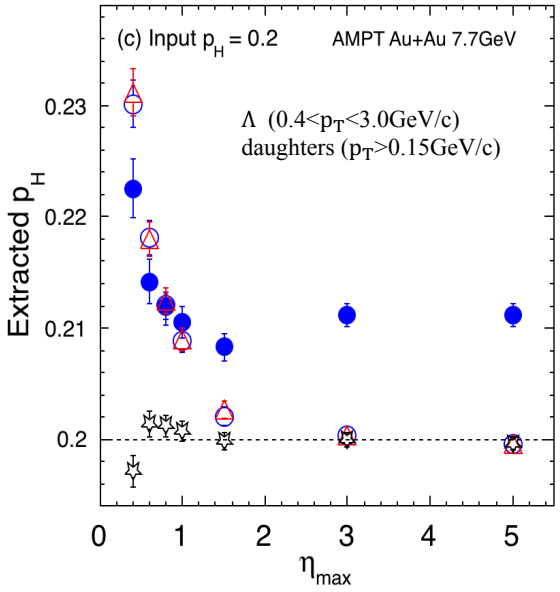


- Apply $|\eta|<\eta_{max}$ for kaons, when the cut is below $|\eta|<1.3$, a narrower η acceptance gives a significantly larger ρ_{00} value than the input value.
- p_T cuts lead to small reduction of ρ_{00}.

η-cut effect on p_H

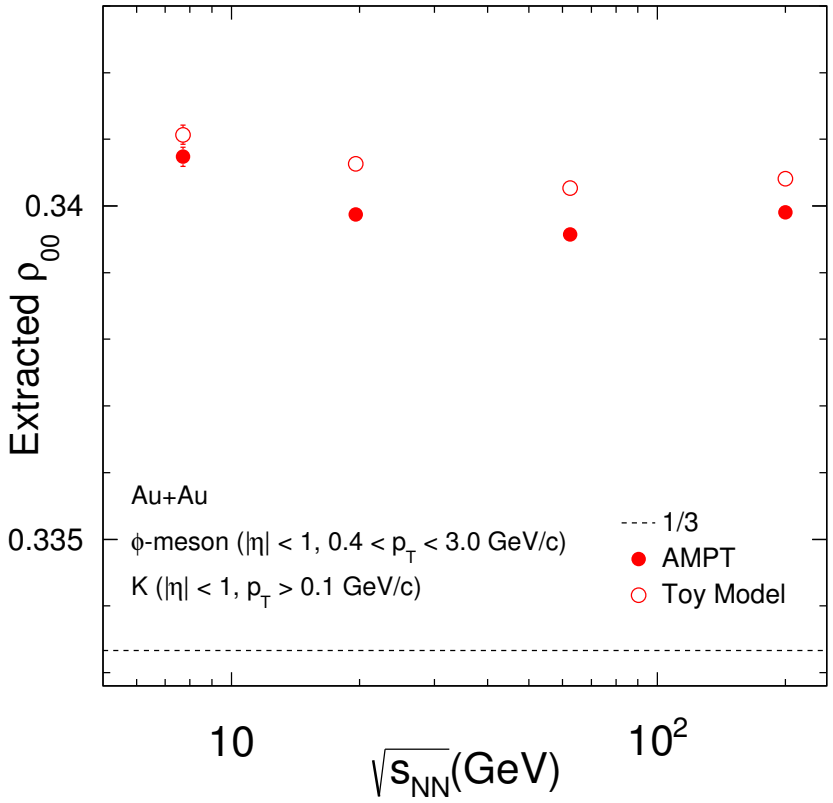






- Extracted p_H is always consistent with 0 when input $p_H = 0$.
- The effects of η-cut on p_H are similar as those on ρ_{00} of ϕ-mesons.
- p_T cut can lead to deviation of the extracted p_H from the input value.

Energy dependence on ρ_{00}

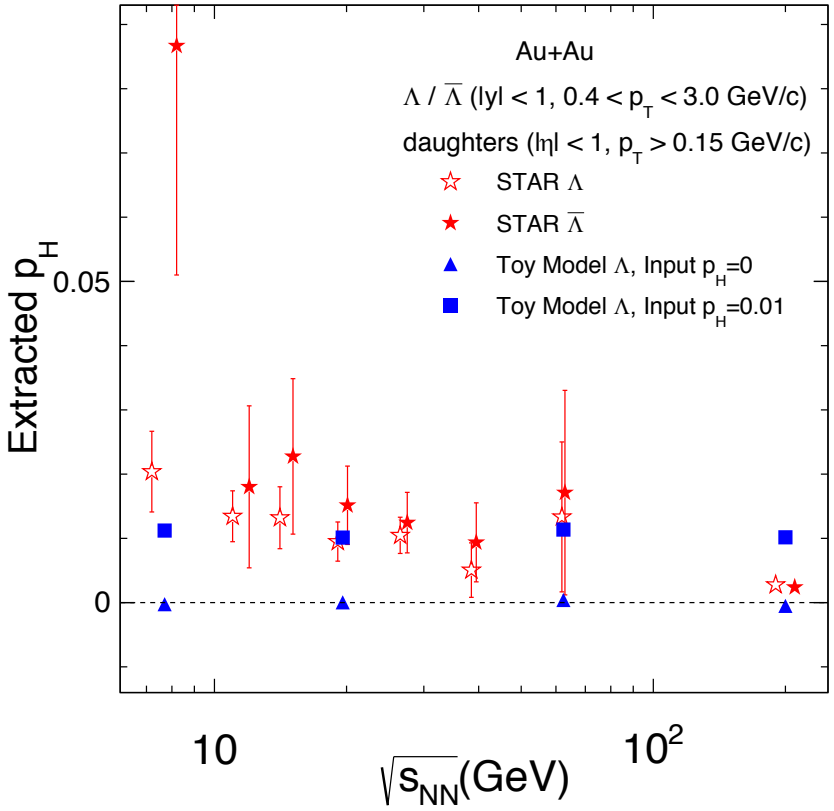


- Systematically higher than 1/3.
- Similar weak energy dependence to the STAR preliminary measurement.
- May be a dominant contribution to the deviation of the current experiment data of ρ_{00} from 1/3.

Energy dependence on p_H

(STAR), Nature 548, 62 (2017)

arXiv:1805.04400



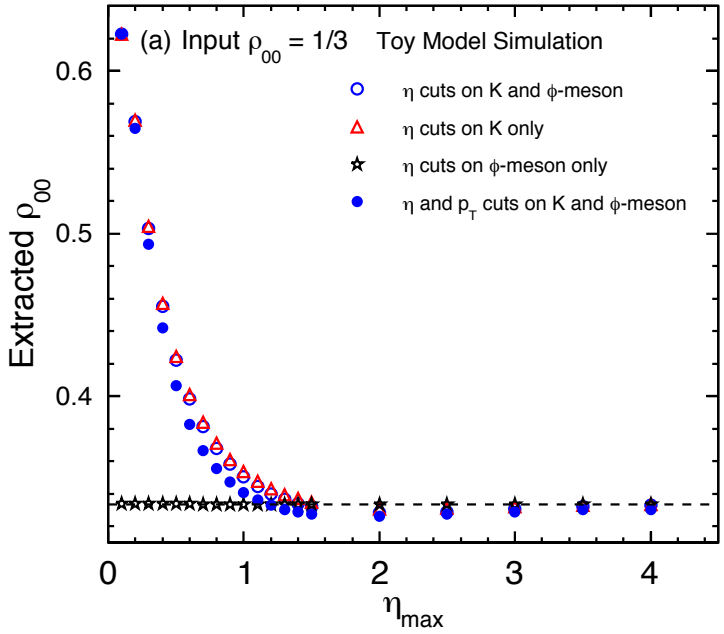
- Consistent with zero when input polarization signal is null.
- Rather close to the input value (within ~ 0.3%) when input p_H = 0.01.
- The phase-space cuts do not introduce an energy dependence for the extracted p_H value.

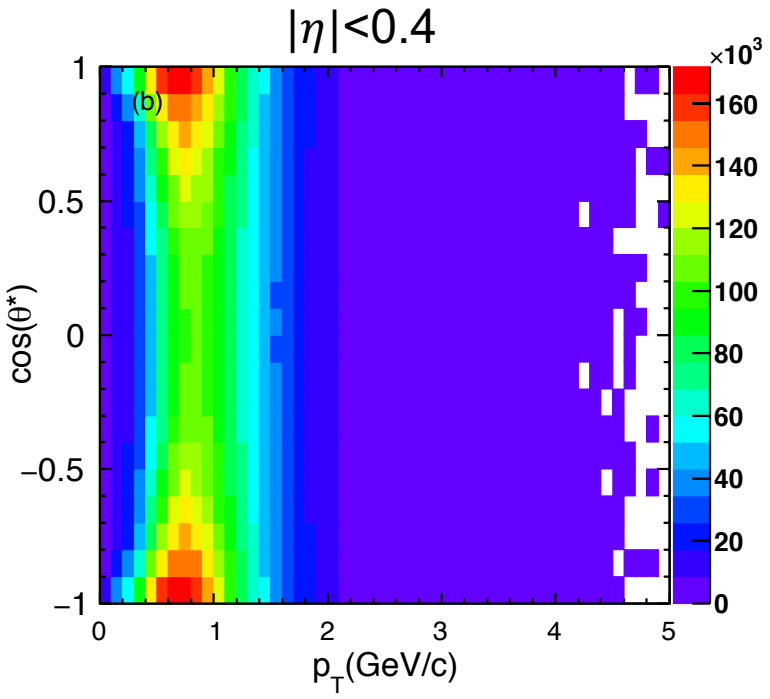
Summary

- We present finite acceptance(η and p_T) effect on global polarization observables (ρ_{00} and p_H).
- η-cuts lead significantly larger value than input for ϕ-meson spin alignment and slightly larger value than input for global Λ polarization in AMPT model.
- A finite coverage in η and p_T has no effect on the extracted p_H when assuming no polarization.
- We suggest measured polarization observables need to be corrected for a finite acceptance.

Thank you.

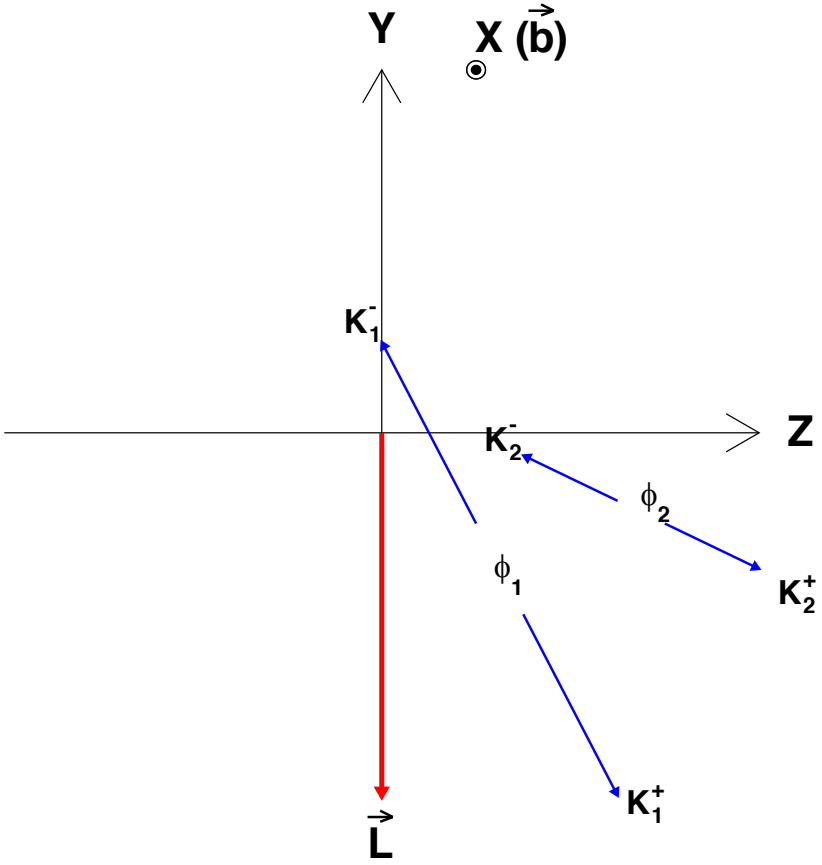
η-cut effect on ρ_{00}



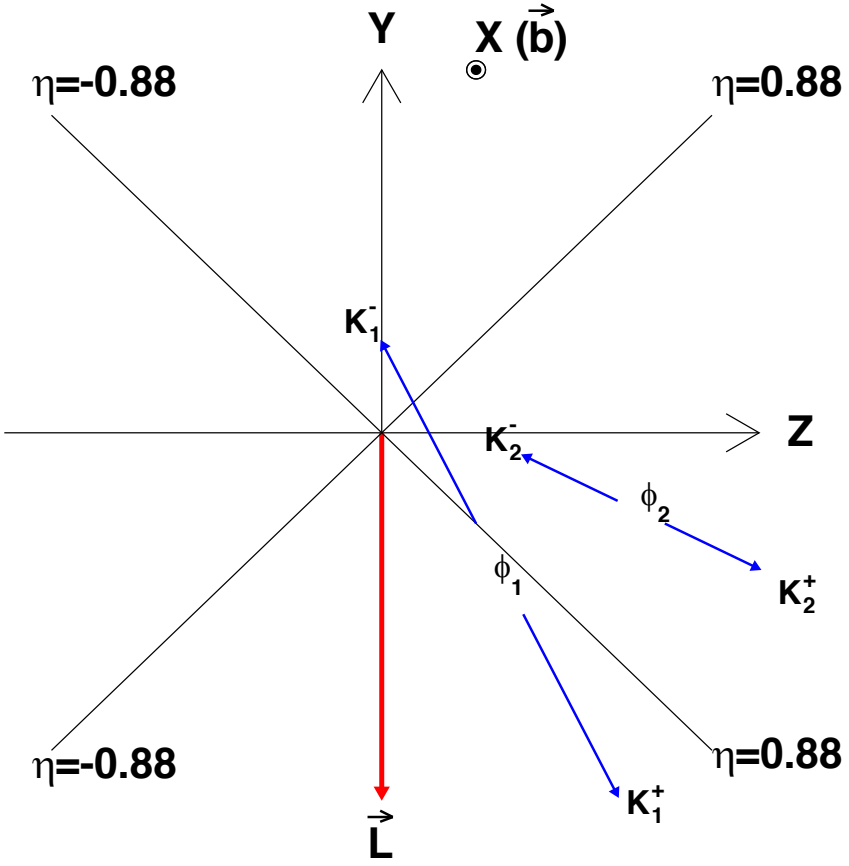


- η-cut excludes more kaons around $\cos\theta^{\star} \sim 0$.
- η-cut mostly affects low p_T region.

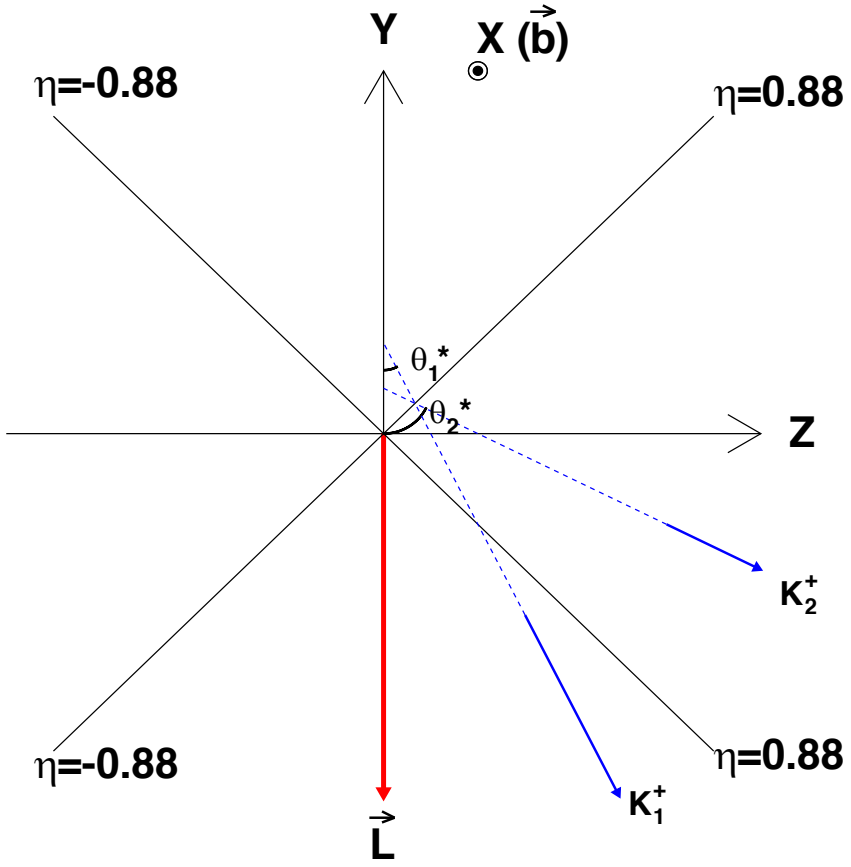
η cut effect on ϕ



η cut effect on ϕ



η cut effect on ϕ



- A narrow η cut on kaons tends to exclude kaons along beam directions, therefore exclude kaons from ϕ decays around $\theta^* \sim 90$ degrees.