ϕ-meson and Λ Global Polarization in Heavy Ion Collisions

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Abstract

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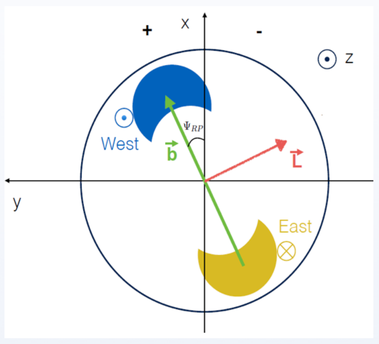
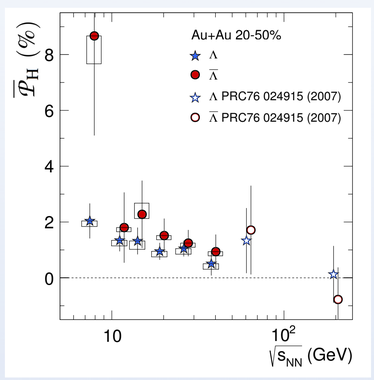
In non-central relativistic heavy ion collisions, the created matter possesses a large initial orbital angular momentum. Particles produced in the collisions could be polarized globally in the direction of the orbital angular momentum due to spin-orbit coupling. Recently, the STAR experiment has presented the polarization signals for Λ hyperons and possible spin alignment for ϕ mesons. These results opened a new direction for better understanding the medium properties in such collisions. Here we present the results of our study on the polarization for both ϕ-mesons and Λ hyperons. A multi-phase transport (AMPT) model is used in our analysis and these results are being compared with published data. We focus on the effects of finite experimental coverage on the global polarizations.

1) Motivation





- Due to spin-orbit coupling, the initial orbital angular momentum may result in a net polarization of produced particles[1] along the direction of the initial angular momentum **(L)**.
- STAR results[5] of **Λ** polarization suggest that the produced fluid in heavy ion collisions is the most vortical system.
- Since the experimental acceptance is limited, we use a modified AMPT[2] model to study the effects of acceptance coverage on global polarization observables.

2) Analysis Method

- ϕ -mesons, which have small hadronic scattering cross sections, are expected to originate predominantly from primordial productions.
- The 00-component of ϕ - meson spin density matrix (ρ_{00})[3] can be measured by the angular distribution of decay daughters of $\phi \rightarrow K^+ + K^-$ using:

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

A deviation of ρ_{00} from 1/3 indicates a spin alignment of ϕ - meson[4].

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

- The global polarization of Λ hyperons can be determined from the angular distribution of Λ decay products relative to the system angular momentum.

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

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

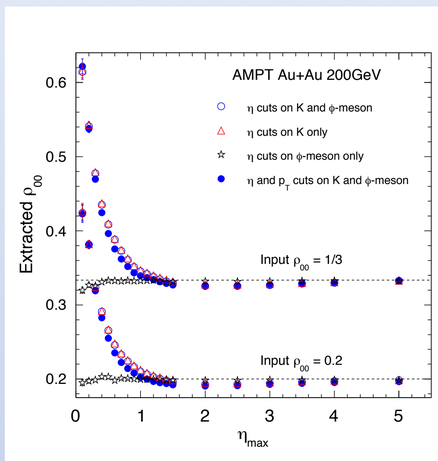
p_H is the Λ polarization parameter.

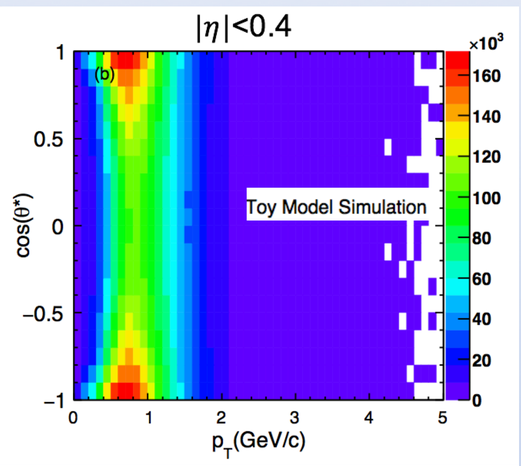
α_H is the decay parameter, where $\alpha_\Lambda = 0.642 \pm 0.013$.

$\phi_p^\star$ is the azimuth of the daughter proton momentum vector in the Λ rest frame.

ϕ_L is the azimuth of the system angular momentum.

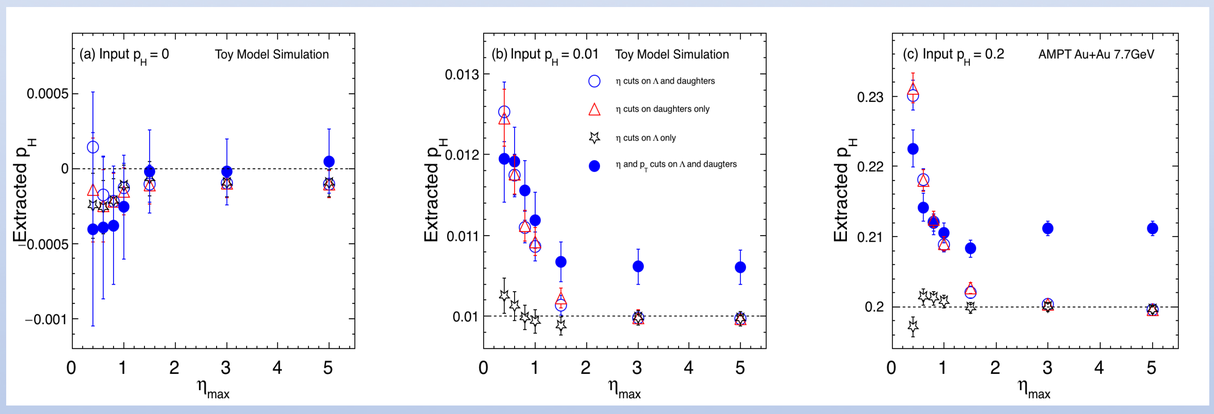
3) Acceptance Effect: ϕ-meson ρ_{00}





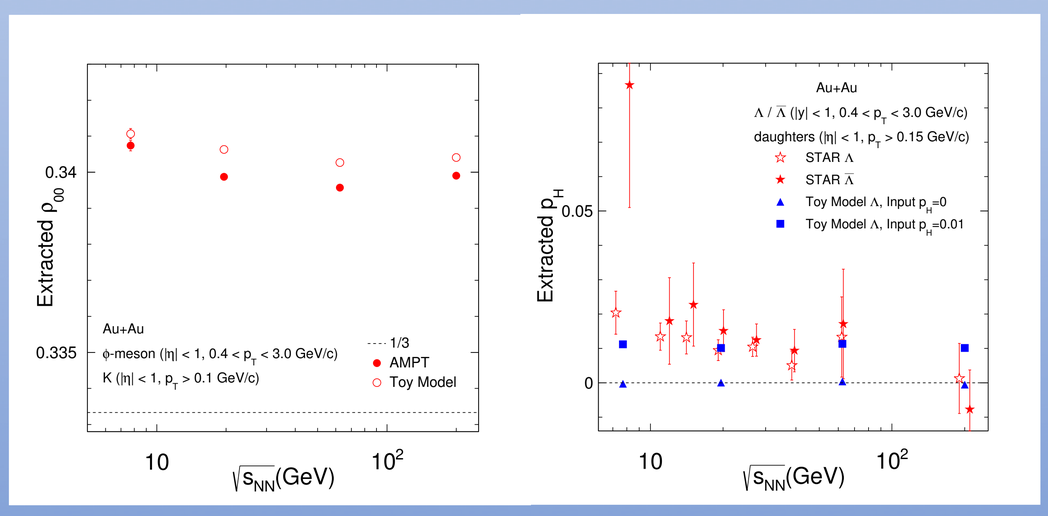
- A narrower η acceptance gives a significantly larger ρ_{00} value than the input ρ_{00} value given to ϕ mesons before their decays in the AMPT model.
- An η cut on kaons tends to exclude kaons along the beam direction, therefore excludes kaons from ϕ decays around θ^* ~ 90 degrees.

4) Acceptance Effect: Λ p_H



- The extracted p_H is consistent with 0 when input $p_H = 0$.
- The extracted p_H is affected by the η cut of decay daughters when input $p_H \neq 0$.
- A narrower η acceptance gives a larger p_H value than the input.

5) A Comparison to STAR data



- With the same phase-space cuts, the extracted ρ_{00} of ϕ-mesons is systematically higher than 1/3. The weak energy dependence is similar as the STAR preliminary measurements.
- With the same phase-space cuts, the extracted p_H of Λ is consistent with 0 when input $p_H = 0$; and it could be slightly higher than the input value (~ 0.3%) when input $p_H = 0.01$.

6) Summary

- η-cuts lead to a larger value than input for ρ_{00} of ϕ-meson and a slightly larger value than input for p_H of the Λ polarization.
- A finite coverage in η and p_T does not lead to a non-zero extracted p_H if there is no polarization.
- Effect of the finite acceptance needs to be considered for polarization observables measured in experiments.

References

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