First Measurements of Hyper-Nucleus ${}^{3}_{\Lambda}\mathrm{H}$ Global Polarization in Au+Au Collisions at STAR

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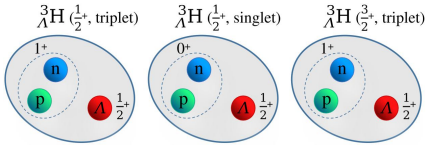
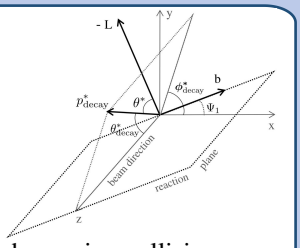
Abstract

The large angular momentum generated in non-central heavy-ion collisions contributes to the formation of vorticity within the medium, which subsequently induces polarization of particles with non-zero spin. In regions of high baryon density, the enhanced production of hyper-nucleus ${}^{3}_{\Lambda}\mathrm{H}$ makes their polarization measurement feasible, shedding light on its spin structure and production mechanism [1]. About 2 billion events collected during 2021 by STAR FXT offer a unique opportunity to investigate this using 3 GeV Au+Au collisions. In this poster, we will present the feasibility of measuring the global polarization of ${}^{3}_{\Lambda}\mathrm{H}$ via its two-body and three-body decays at 3 GeV in Au+Au collisions using data from the STAR experiment.

Motivation

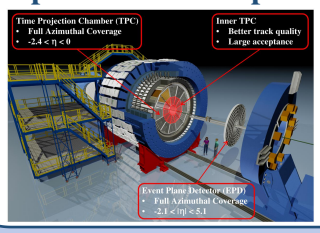
- Spin structure of hypernuclei [1];





- Production mechanism of hypernuclei in heavy-ion collisions;
  - Role of nucleon-nucleon (N-N) and hyperon-nucleon (Y-N) interactions in nuclei formation;

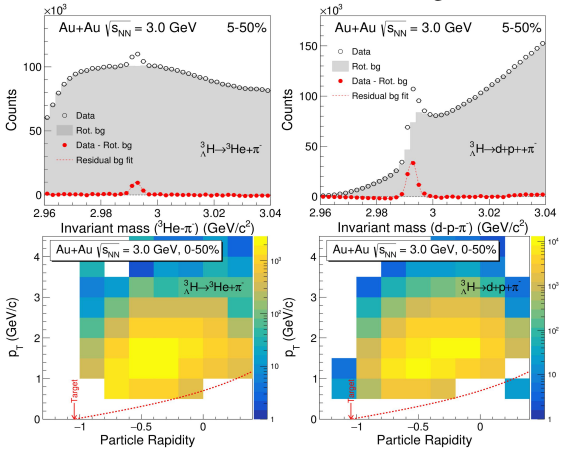
Experimental Setup



- The STAR detector upgrade
  - Inner TPC
    - Better track quality
    - Large acceptance
  - EPD ($2.1 < |\eta| < 5.1$)

Particle Reconstruction

- ${}^{3}_{\Lambda}\mathrm{H}$ are reconstructed by 2-body (${}^{3}_{\Lambda}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + \pi^{-}$) and 3-body (${}^{3}_{\Lambda}\mathrm{H} \rightarrow \mathrm{d} + \mathrm{p} + \pi^{-}$) decay channels using KFParticle package;
- Rotation method is used to estimate the background;



Invariant mass distribution (upper panel) and acceptance (lower panel) of ${}^{3}_{\Lambda}\mathrm{H}$ 2-body decay (left panel) and 3-body decay (right panel)

Analysis Method

Global polarization: measured from the azimuthal distribution of daughters in the ${}^{3}_{\Lambda}\mathrm{H}$ rest frame relative to the reaction plane:

$$P_H = \frac{8}{\pi \alpha_H} \frac{1}{A_0} \frac{< \sin(\Psi_1 - \phi^{*}_{\mathrm{decay}}) >}{Res(\Psi_1)}$$

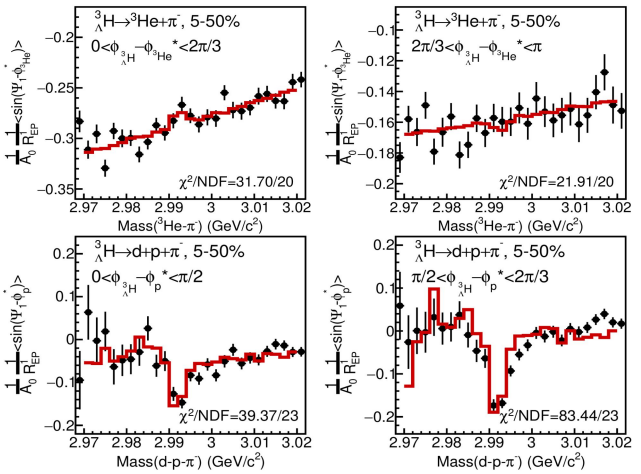
here, α_{H} is the ${}^{3}_{\Lambda}\mathrm{H}$ decay constant [1], $\phi^{*}_{\mathrm{decay}}$ is the azimuthal distribution of daughters in the ${}^{3}_{\Lambda}\mathrm{H}$ rest frame, for 2-body decay, using ^{3}He, for 3-body decay, using proton, A_0 is a detector acceptance correction factor, $A_0 = <\sin\theta^{*}_{\mathrm{decay}}>$ [2].

- Event plane resolution: measured by 3-sub events (using EPD and TPC);
- Invariant mass method: extract the polarization signal (for ${}^{3}_{\Lambda}\mathrm{H}$ 3-body decay, include correction for correlated background (d+Λ) contribution);

$$P_H(M_{inv}) = \frac{S}{S+B} P_H^{Sig} + \frac{B}{S+B} P_H^{Bkg}$$

- Flow-driven contributions subtracted in $\mathrm{P_H}$ extraction [3], here the coefficient c depends on $\mathrm{v_1}$;

$$\frac{8}{\pi \alpha_H R_{EP}} < \sin(\Psi_1 - \phi^{*}_{\mathrm{decay}}) >_{\mathrm{observe}} = \mathrm{P_H^{real}} + \mathrm{c} \cdot \sin(\phi_{{}^{3}_{\Lambda}\mathrm{H}} - \phi^{*}_{\mathrm{decay}})$$



Raw distributions of ${}^{3}_{\Lambda}\mathrm{H}$ 2-body decay (upper panel) and 3-body decay (lower panel) as a function of invariant mass in different bins of emission angle ($\phi_{{}^{3}_{\Lambda}\mathrm{H}} - \phi^{*}_{\mathrm{decay}}$)

Summary

- Good signal of ${}^{3}_{\Lambda}\mathrm{H}$ in mid-central (5-50%) Au+Au collisions;
- Methodology is being refined, correction of polarization (acceptance and purity) and estimation of systematic uncertainty are ongoing;

References

[1] Kai-Jia Sun et al., Phys.Rev.Lett. 134 (2025) 2, 022301
[2] STAR Collaboration, Phys.Rev.C 76 (2007) 024915
[3] STAR Collaboration, Phys.Rev.C 104 (2021) 6, L061901

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