Deciphering hypertriton and antihypertriton spins from their global polarizations in heavy-ion collisions

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We have proposed to decipher the spin structures of hypertriton and antihypertriton by measuring their global polarizations in noncentral heavy-ion collisions [1]. This new approach enables a precise determination of both the total spin and the internal spin structure of hypertriton and antihypertriton. We first demonstrate that hypertriton and antihypertriton can acquire global polarizations through the coalescence of polarized nucleons and Λ hyperons at the kinetic freeze-out of these collisions. We then show that both the magnitude of hypertriton polarization and the angular distribution of the product from its two-body decay ${}^3_\Lambda\mathrm{H} \to \pi^- + {}^3\mathrm{He}$ strongly depend on its total spin and internal spin structure. For ${}^3_\Lambda\mathrm{H}$ with spin-parity $J^\pi = \frac{1}{2}^+$, the angular distribution of ${}^3\mathrm{He}$ from its two-body decay has a $\cos\theta$ dependence, where θ is the azimuthal angle of the ${}^3\mathrm{He}$ momentum with respect to the spin direction of ${}^3_\Lambda\mathrm{H}$. There is, however, a change of sign in the angular distribution for the *np* pair in a spin-triplet state or spin-singlet state. For a ${}^3_\Lambda\mathrm{H}$ with spin-parity $J^\pi = \frac{3}{2}^+$, the angular distribution of ${}^3\mathrm{He}$ from its decay has on the other

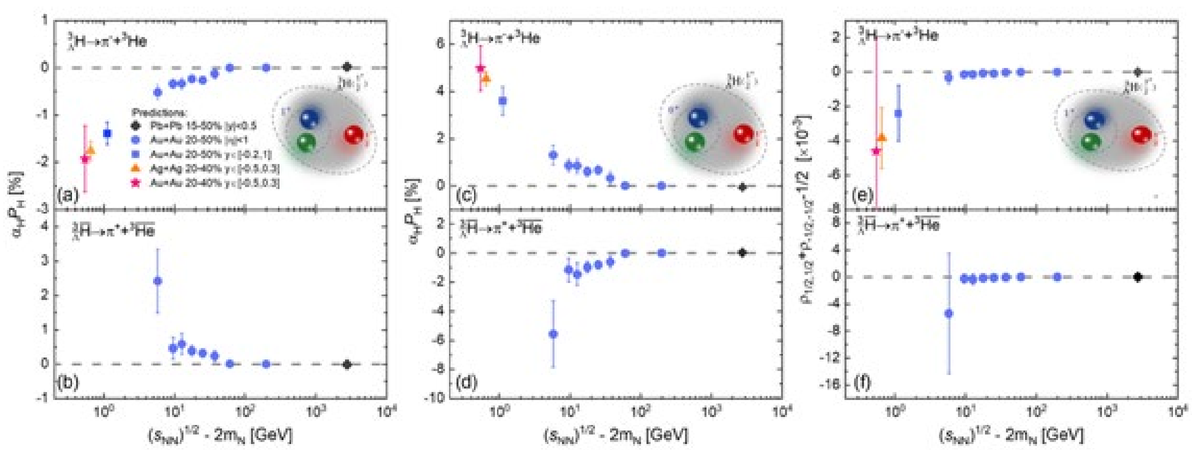

Fig. 1. Collision energy dependence of hypertriton and antihypertriton polarizations predicted from the decay channel ${}^3_\Lambda\mathrm{H} \to \pi^- + {}^3\mathrm{He}$ (upper panels) and ${}^3_\Lambda\overline{\mathrm{H}} \to \pi^+ + {}^3\overline{\mathrm{He}}$ (lower panels) based on the Λ and $\overline{\Lambda}$ polarization data from the STAR [55], ALICE [2], and HADES [3] Collaborations. Panels (a) and (b) depict results of $\alpha_\mathrm{H} P_\mathrm{H}$ for ${}^3_\Lambda\mathrm{H}$ (1/2$^+$) and ${}^3_\Lambda\overline{\mathrm{H}}$ (1/2$^-$), respectively, assuming the two nucleons inside the hypertriton and the two antinucleons inside the antihypertriton are in a spin-triplet state, while results shown in panels (c) and (d) are for the case that the two nucleons and two antinucleons are in a spin-singlet state. Panels (e) and (f) depict results for the combined spin density matrix elements $\hat{\rho}_{\frac{1}{2},\frac{1}{2}} + \hat{\rho}_{-\frac{1}{2},-\frac{1}{2}} - \frac{1}{2}$ for ${}^3_\Lambda\mathrm{H}$ (3/2$^+$) and ${}^3_\Lambda\overline{\mathrm{H}}$ (3/2$^-$), respectively.

hand a $\cos 2\theta$ dependence, and its combined spin density matrix elements $\hat{\rho}_{\frac{1}{2},\frac{1}{2}} + \hat{\rho}_{-\frac{1}{2},-\frac{1}{2}} - \frac{1}{2}$ has a small negative value.

For each hypertriton or antihypertriton spin structure, a distinct beam energy dependence of their polarizations is predicted for heavy-ion collisions from a few GeV to several TeV. These results can be readily confronted with upcoming experimental measurements from HADES, STAR, ALICE, and other collaborations, and the comparisons will allow us to decipher the spin structures of hypertriton and antihypertriton and gain insights to the nature of *Y-N* interactions.

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