26th International Symposium on Spin Physics (SPIN2025)

Revealing Proton Spin Polarization via Hypertriton Production in Nuclear Collisions

A Century of Spin

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Qingdao, 23 Sept. 2025

Contents

1. Introduction

- Non-central heavy-ion collisions create fireballs with large global orbital angular momenta

$L_{\text{init}} \sim 10^5\hbar$

Liang, Wang Phys. Rev. Lett. 94, 102301(2005); Phys. Lett. B 629, 20 (2005)
F. Becattini, F. Piccinini, and J. Rizzo, PRC 77, 024906 (2008)

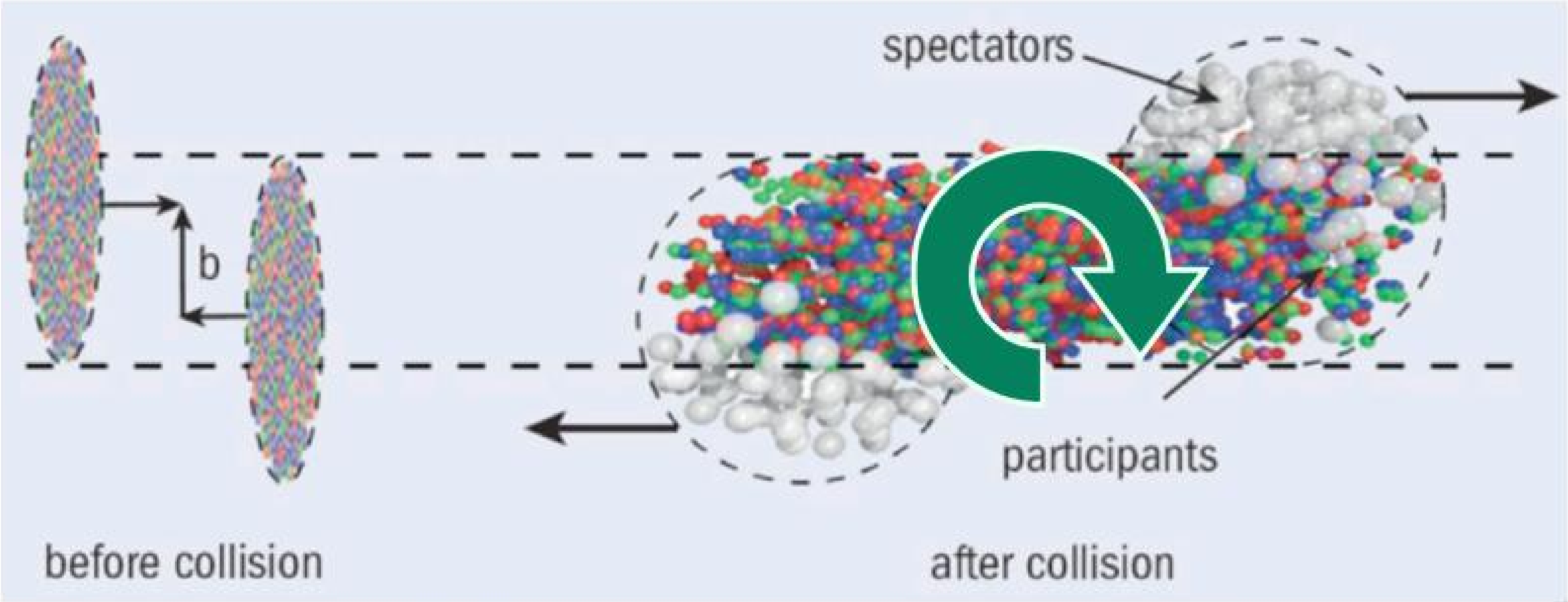
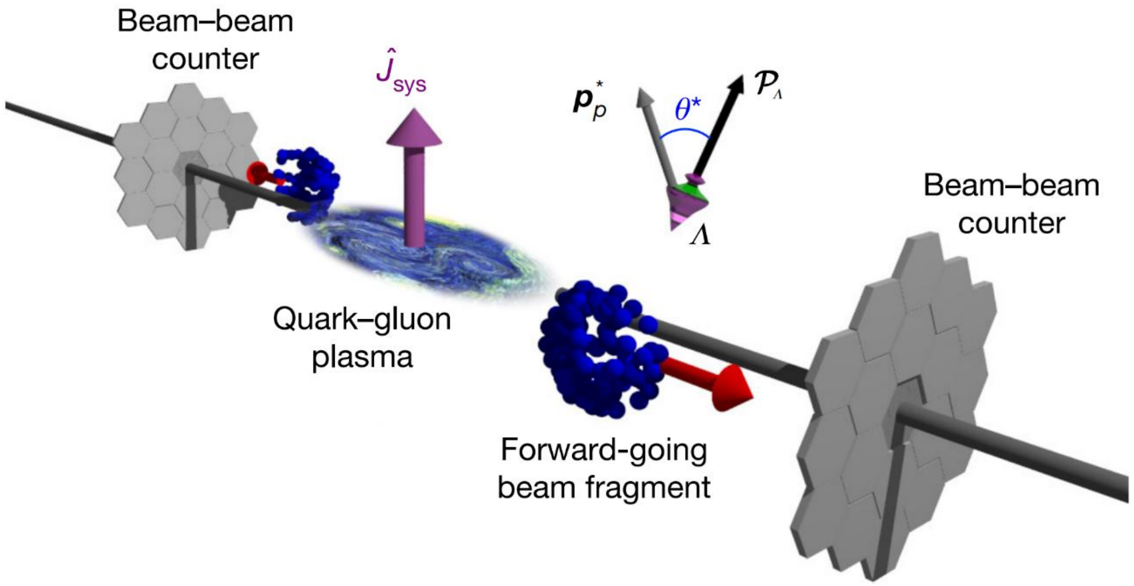


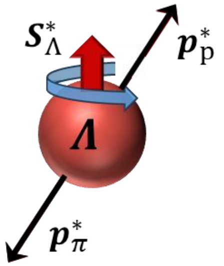
figure: M. Lisa, talk @ "Strangeness in Quark Matter 2016"

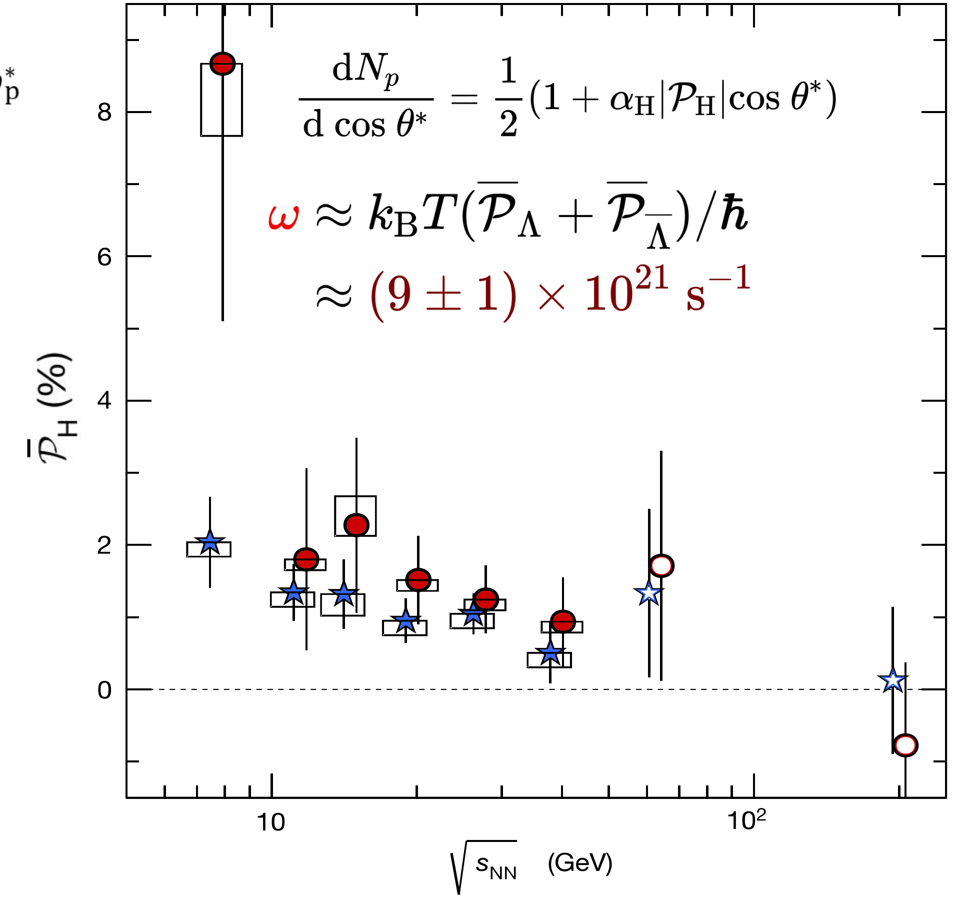
Angular momenta → Rotation (local/global) → Polarization

1. Global polarization in heavy-ion collisions

STAR Col., Nature 548, 62 (2017)



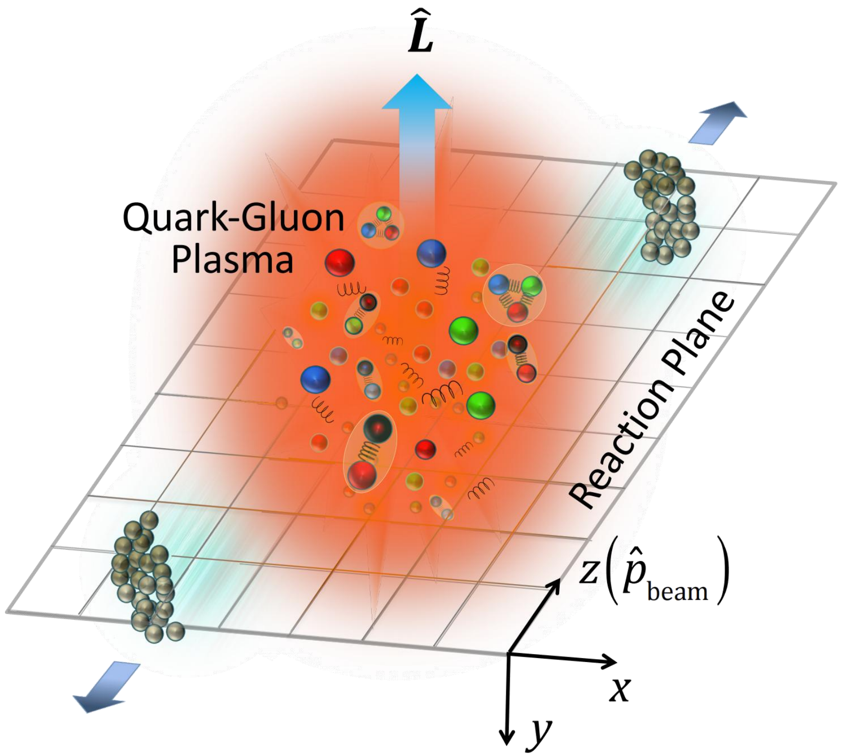


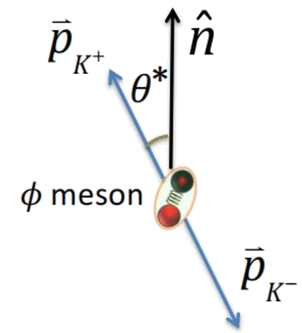


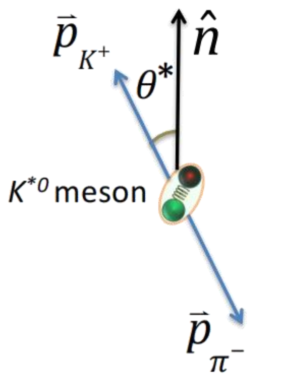
Through spin-orbit interaction, particles tend to align their spins along the direction of the system's orbital angular momentum, resulting in polarization.

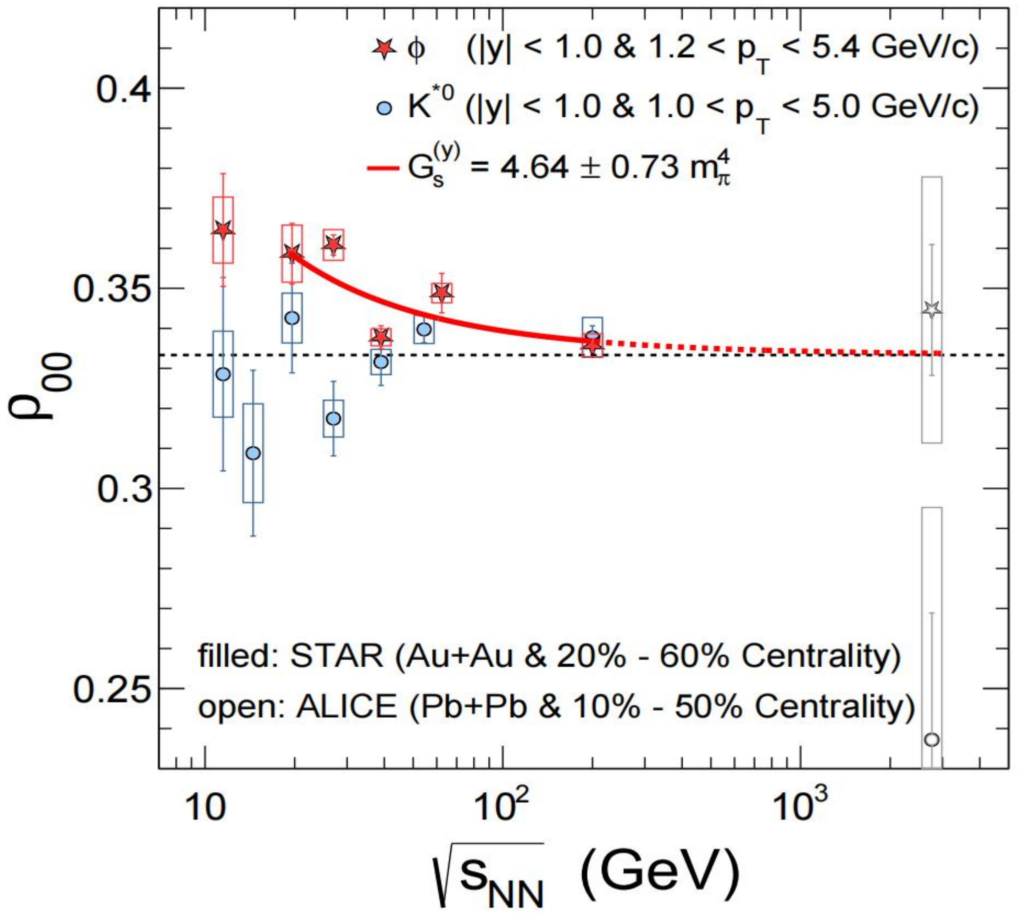
1. Spin alignment in heavy-ion collisions

STAR Col., Nature 614, 244 (2023)









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

Spin alignment of mesons

Fluctuation/correlation of strong force field

X. L. Sheng et al., PRL 131, 042304 (2023)

Quark-antiquark spin correlation

J. P. Lv et al., PRD 109, 114003(2024)

Meson spectral property

F. Li and S. Liu, arXiv:2206.11890

1. Polarization of nucleon?

Unstable hadrons

$\Lambda(uds)$ $\Xi(uss)$ $\Omega(sss)$

$\phi(s\bar{s})$ $K^{*0}(d\bar{s})$ $J/\psi(c\bar{c})$

…

Stable nucleon

$p(uud)$ $n(udd)$

$\bar{p}(\bar{u}\bar{u}\bar{d})$ $\bar{n}(\bar{u}\bar{d}\bar{d})$

$$\mathcal{P}_p = \frac{4\mathcal{P}_u - \mathcal{P}_d}{3}$$ SU(6) quark model

Nucleon is the baisc constituents of visible matter and dominant baryonic dof.

- ➢ Light quark spin polarization
- ➢ Proton spin puzzle
- ➢ Spin Hall effect

Ji, Yuan, Zhao, Nature Rev. Phys. 3, 27–38 (2021)

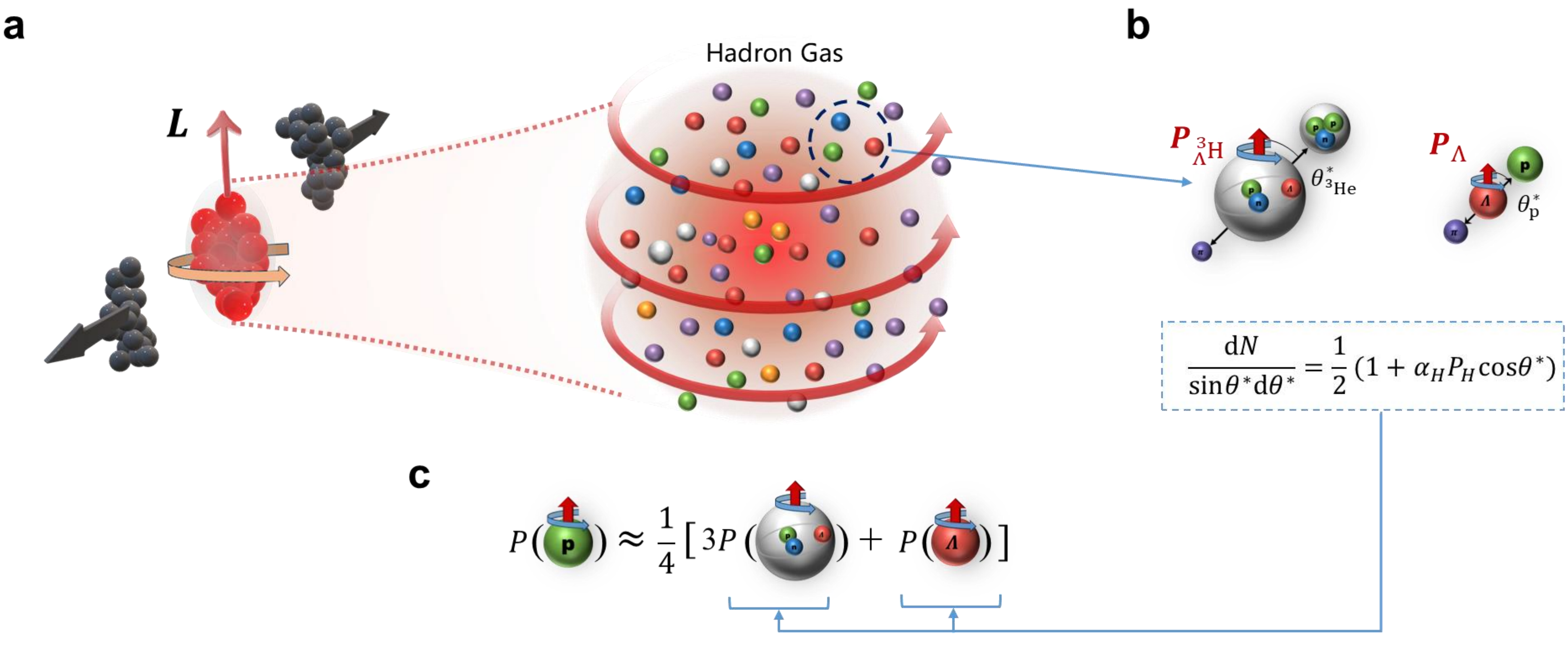
Liu and Yin, Phys. Rev. D 104, 054043 (2021)

From Hyperons to Hypernuclei: A New Route to Unravel Proton Spin Polarization

Dai-Neng Liu, Kai-Jia Sun, Yun-Peng Zheng, Wen-hao Zhou
Jin-Hui Chen, Che Ming Ko, Yu-Gang Ma, Song Zhang

arXiv: 2508.12193

2. Reveal proton spin polarization

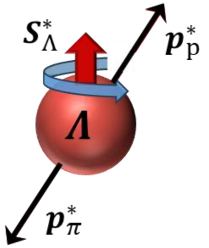


$$\mathcal{P}_p \approx \frac{1}{4}\left(3\mathcal{P}_{{}^{3}_{\Lambda}\mathrm{H}} + \mathcal{P}_{\Lambda}\right)$$

2. Measurements

Weak decay with parity violation

Λ hyperons



$$\frac{dN}{d\cos\theta^*} = \mathrm{Tr}[T^{+}\hat{\rho}T]$$

$$\Lambda \rightarrow p + \pi^-$$

$$\rho_\Lambda = \begin{pmatrix} \frac{1+\mathcal{P}_\Lambda}{2} & \\ & \frac{1-\mathcal{P}_\Lambda}{2} \end{pmatrix}$$

The transition matrix

$$T(\Lambda \rightarrow \pi^- + p) = \frac{1}{\sqrt{4\pi}} \begin{pmatrix} T_s + T_p\cos\theta^*_p & T_p\sin\theta^*_p e^{i\phi^*_p} \\ T_p\sin\theta^*_p e^{-i\phi^*_p} & T_s - T_p\cos\theta^*_p \end{pmatrix}$$

The angular distribution

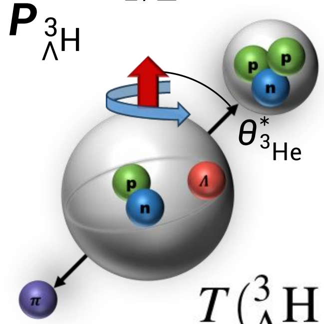
$$\frac{\mathrm{d}N}{\mathrm{d}\cos\theta^*} = \frac{1}{2}(1+\alpha_{\mathrm{H}}|\mathcal{P}_{\mathrm{H}}|\cos\theta^*)$$

$$\alpha_\Lambda = 2\mathrm{Re}(T_s^* T_p) = 0.732 \pm 0.014$$

H denotes Λ and $\bar{\Lambda}$

BESIII, Phys. Rev. Lett. 129, 131801 (2022).

Hypertriton



$$\rho_{^3_\Lambda\mathrm{H}} = \begin{pmatrix} \frac{1+\mathcal{P}_{^3_\Lambda\mathrm{H}}}{2} & \\ & \frac{1-\mathcal{P}_{^3_\Lambda\mathrm{H}}}{2} \end{pmatrix}$$

$$T(^3_\Lambda\mathrm{H} \rightarrow \pi^- + {}^3\mathrm{He}) = \frac{F}{6\sqrt{\pi}} \begin{pmatrix} 3T_s - T_p\cos\theta^* & -T_p\sin\theta^* e^{i\phi^*} \\ -T_p\sin\theta^* e^{-i\phi^*} & 3T_s + T_p\cos\theta^* \end{pmatrix}$$

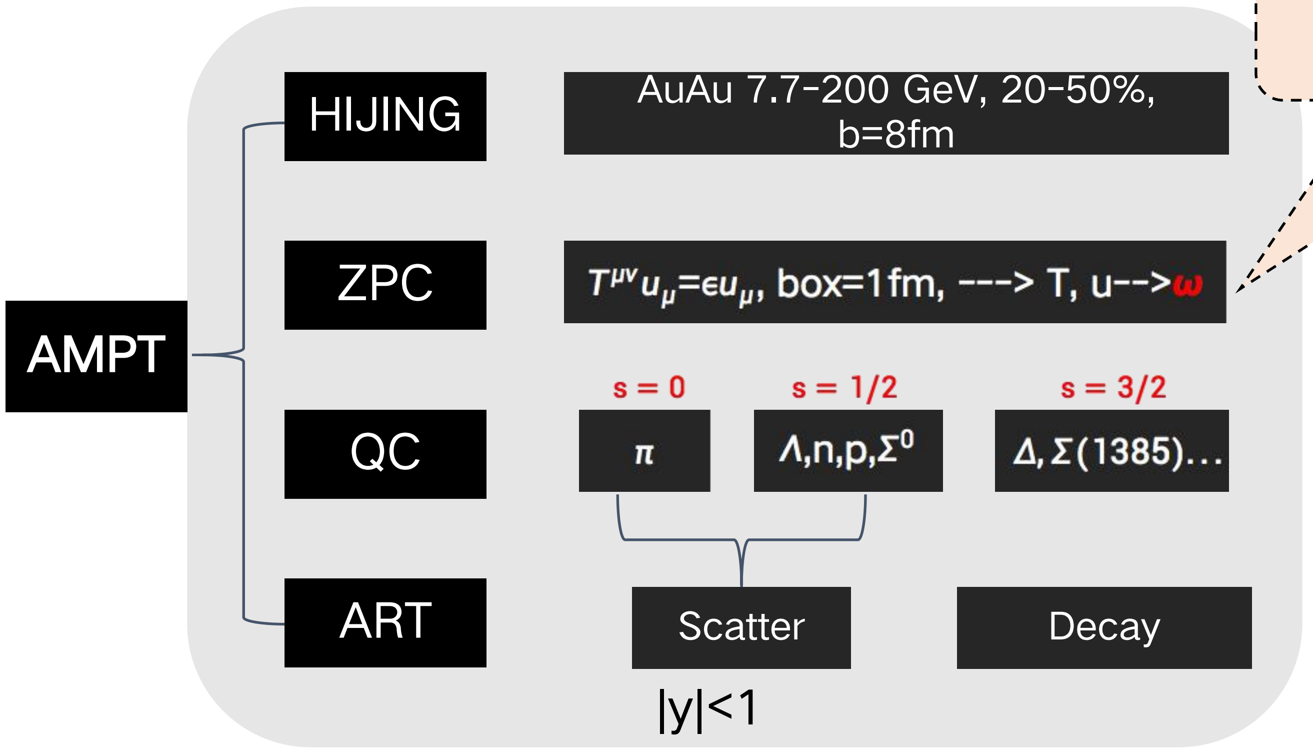
$$\frac{dN}{\mathrm{d}\cos\theta^*} = \frac{1}{2}\left(1+\alpha_{^3_\Lambda\mathrm{H}}\mathcal{P}_{^3_\Lambda\mathrm{H}}\cos\theta^*\right)$$

$$\alpha_{^3_\Lambda\mathrm{H}} \approx -\frac{1}{3T_s^2+\frac{1}{3}T_p^2}\alpha_\Lambda \approx -\frac{1}{2.58}\alpha_\Lambda$$

Sign flip !

Sun, DNL, Zheng, Chen, Ko, Ma, Phys.Rev.Lett. 134, 022301 (2025)

2. Calculation using AMPT



Lin *et.al*, Phys.Rev.C **72,** 064901 (2005)

Hypertriton

Thermal vorticity

$$\varpi_{\mu\nu} = -\frac{1}{2}(\partial_\mu\beta_\nu - \partial_\nu\beta_\mu). \quad \beta^\mu = u^\mu/T$$

Eigen equation

$$T^{\mu\nu}u_\mu = \epsilon u^\mu$$

Fiuld energy-momentum tensor

$$T_{\mu\nu} = \frac{1}{N_e \Delta V}\sum_j^{N_e}\sum_i \frac{P^\mu_{ij}P^\nu_{ij}}{E_{ij}}$$

Velocity field

$$u^\mu u_\mu = 1$$

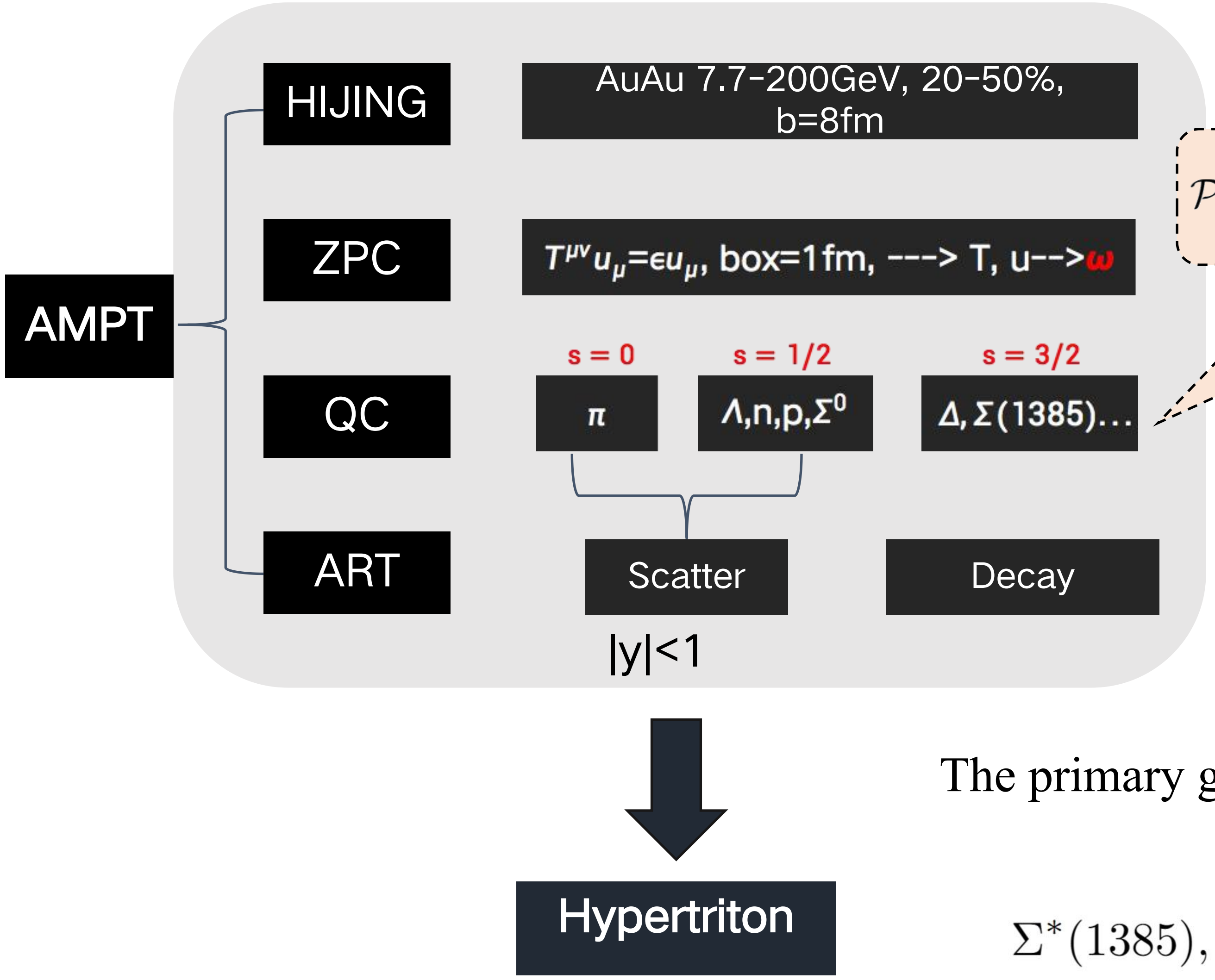
$$g_{\mu\nu} = \mathrm{diag}(1,-1,-1,-1)$$

Temperature

$$T = 0.199\ \mathrm{GeV}\left(\frac{\epsilon/\gamma_q}{1+3N_f/4}\right)^{1/4}$$

$$\gamma_q = \frac{1}{2}\left(\left(\frac{N_+}{N_-}\right)^{N_f/2} + \left(\frac{N_-}{N_+}\right)^{N_f/2}\right)$$

2. Hadron polarization from vorticity



Spin polarization vector of single pariticle

$$\mathcal{P}^\mu(x,p) = -\frac{s+1}{6m}(1-n_F)\epsilon^{\mu\nu\rho\sigma}p_\nu\varpi_{\rho\sigma}(x),$$

in the c.m. frame by a Lorentz boost

$$\boldsymbol{\mathcal{P}}^* = \boldsymbol{\mathcal{P}} - \frac{\boldsymbol{p}\cdot\boldsymbol{\mathcal{P}}}{E(m+E)}\boldsymbol{p},$$

$$\mathcal{P} \propto s+1$$

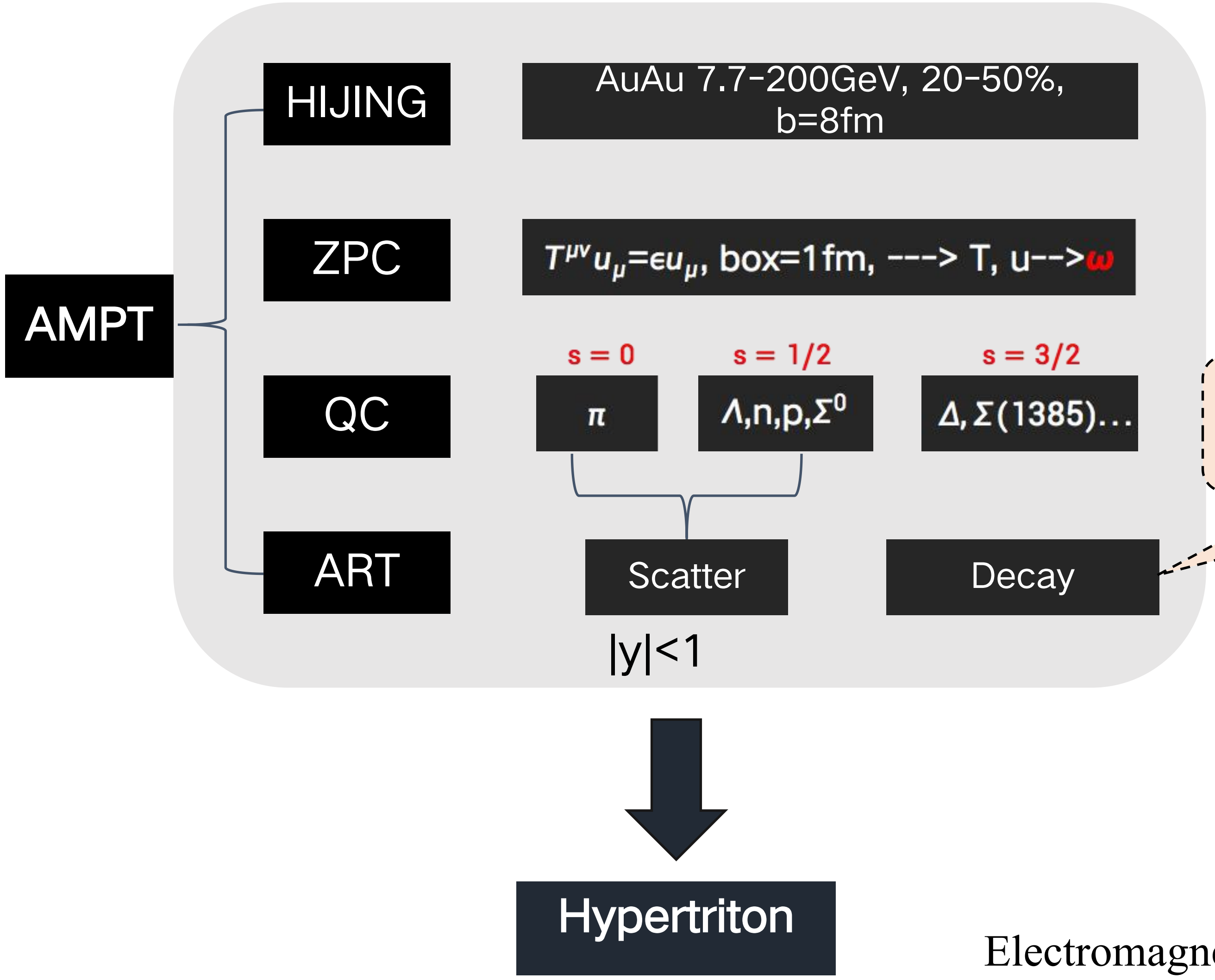
The primary global polarization at hadronization stage

$$\Sigma^*(1385), \Delta(1232) \;\; J^\pi = \frac{3}{2}^+$$

$$\mathcal{P}_\Delta = \frac{5}{3}\mathcal{P}_N$$

$$\mathcal{P}_{\Sigma^*} = \frac{5}{3}\mathcal{P}_\Lambda$$

2. Hadronic decay



Xia, Li, Huang, Huang, Phys.Rev.C **100**, 014913 (2019)

	Spin and parity	$\mathcal{C}$
Strong decay	$1/2^+ \to 1/2^+0^-$	-1/3
	$1/2^- \to 1/2^+0^-$	1
	$3/2^+ \to 1/2^+0^-$	1
	$3/2^- \to 1/2^+0^-$	-3/5
Weak decay	$1/2 \to 1/2\ 0$	$(2\gamma+1)/3$
	$3/2 \to 1/2\ 0$	$(4\gamma+1)/5$
EM decay	$1/2^+ \to 1/2^+1^-$	-1/3

Decay from mother particles

$$\mathcal{P}_D = \mathcal{C}_{M\to D}\mathcal{P}_M$$

Single particle feed-down

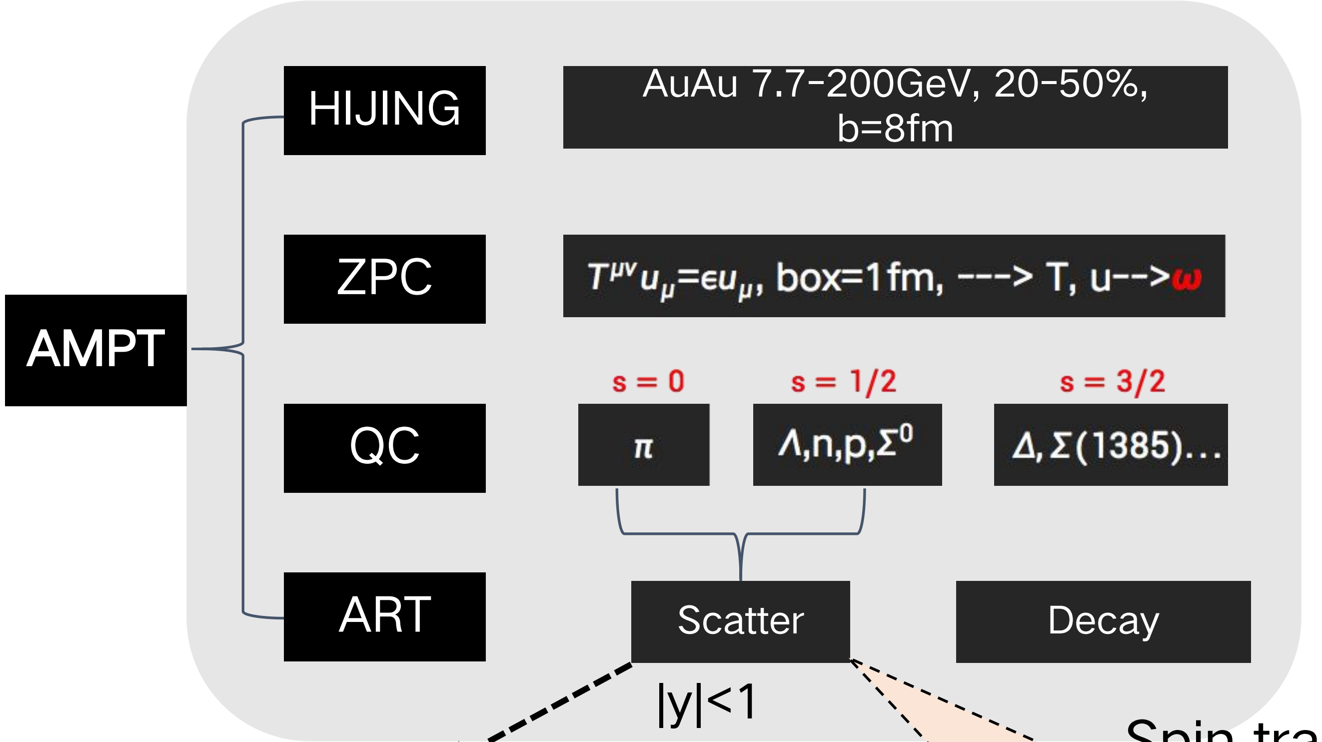
$$\mathcal{P}_N^{\mathrm{fd}} = \mathcal{P}_\Delta$$

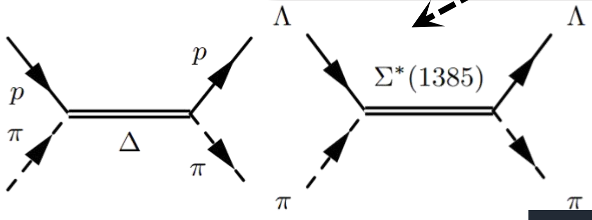
$$\mathcal{P}_\Lambda^{\mathrm{fd}} = \mathcal{P}_{\Sigma^*(1385)}$$

Electromagnetic decay

$$\mathcal{P}_\Lambda^{\mathrm{fd}} = -\frac{1}{3}\mathcal{P}_{\Sigma^0}$$

2. Hadronic scatterings





Hypertriton

$N\pi \leftrightarrow \Delta(1232) \leftrightarrow N\pi$

$\Lambda(\Sigma^0)\pi \leftrightarrow \Sigma^*(1385) \leftrightarrow \Lambda(\Sigma^0)\pi$

Cross section $\Lambda(\Sigma^0)\pi \leftrightarrow \Sigma^*(1385)$

$$\sigma_{ab\to R}(s) = \frac{8\pi}{k^2}\frac{s\Gamma_{ab\to R}(s)\Gamma_{tot}(s)}{(s-s_0)^2+s\Gamma^2_{tot}(s)}$$

$$\Gamma_{ab\to R} = \Gamma_{R\to ab} = 36\ \text{MeV}$$

$$\Gamma_{\Sigma^*(1385)\to\Lambda\pi} : \Gamma\sigma_{\Sigma^*(1385)\to\Sigma\pi} = 87\% : 11.7\%$$

$$k = \sqrt{\frac{[s-(m_H+m_\pi)^2][s-(m_H-m_\pi)^2]}{4s}}$$

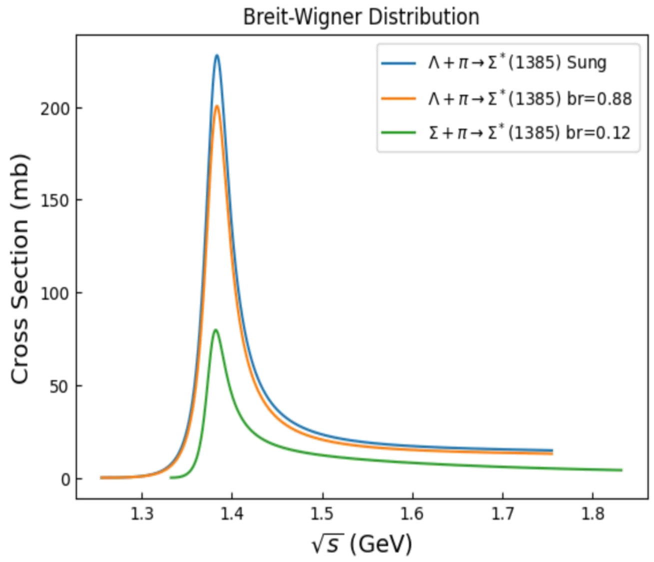
$$m_{\Sigma^0} = 1192\ \text{MeV} \quad m_\Lambda = 1116\ \text{MeV}$$

Sung, Ko, and Lee, Phys.Lett.B 858, 139004 (2024)
SMASH, Phys.Rev.C 94, 054905 (2016)

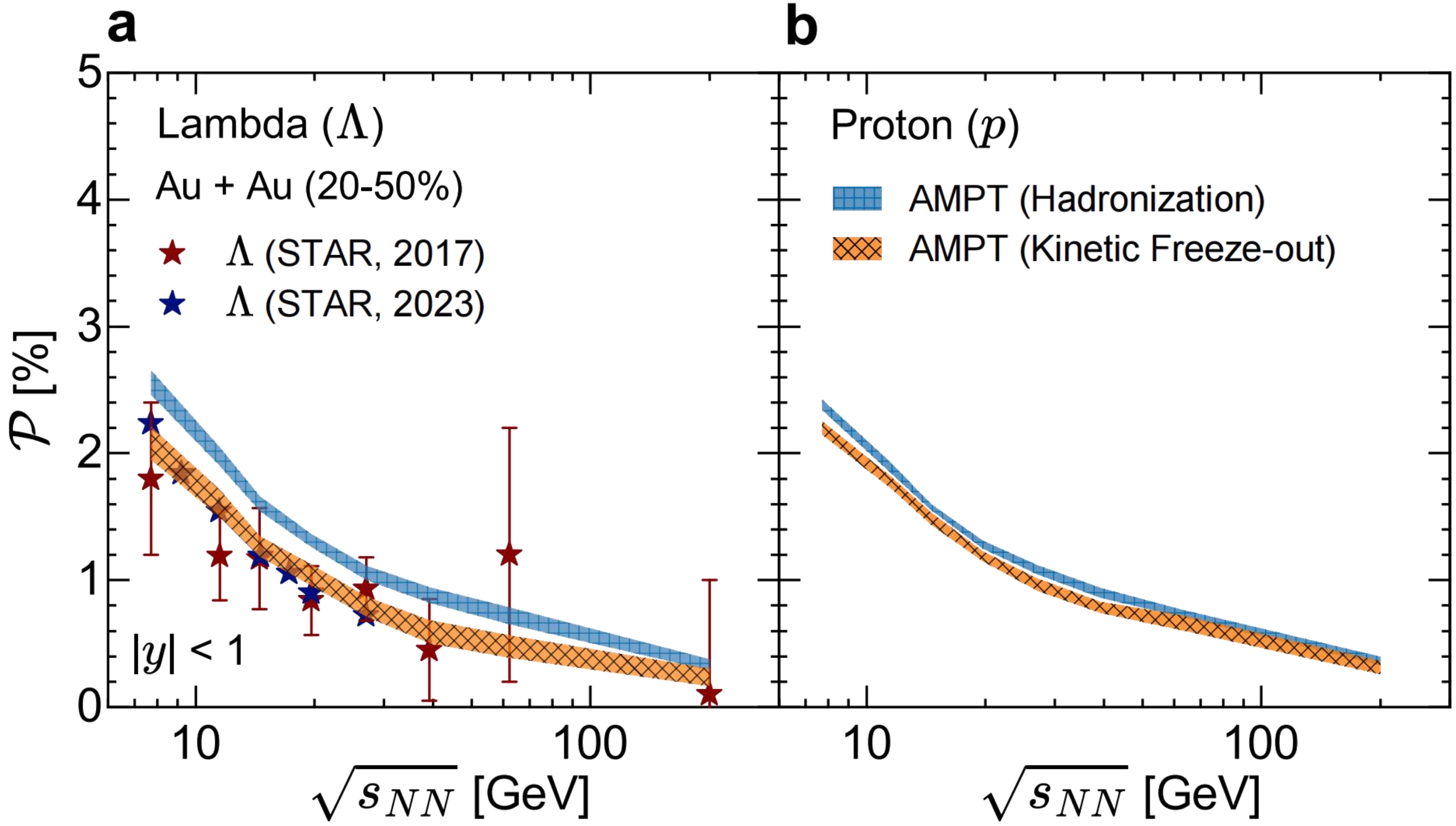
Spin transfer coefficient

$$\mathcal{P}_R = \mathcal{C}_{D\to R}\mathcal{P}_D, \quad \mathcal{C}_{D\to R} = 5/9$$

$\sigma_{+-}/\sigma_{++} = 2/7$



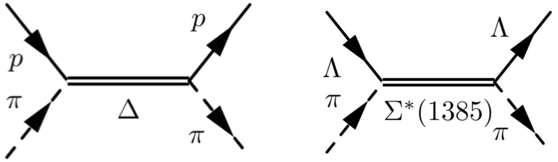
2. Results---global Λ and proton polarization



Feed-down effect on global polarization

$$\mathcal{P}_D = \frac{N_D^* + \sum_i \frac{s_{M_i}+1}{s_D+1} \mathcal{C}_{M_i \to D} \mathcal{B}_{M_i \to D} N_{M_i}}{N_D^* + \sum_i b_{M_i \to D} N_{M_i}} \mathcal{P}_D^* \quad \mathcal{P}_\Lambda^{\mathrm{fd}} = -\frac{1}{3}\mathcal{P}_{\Sigma^0}$$

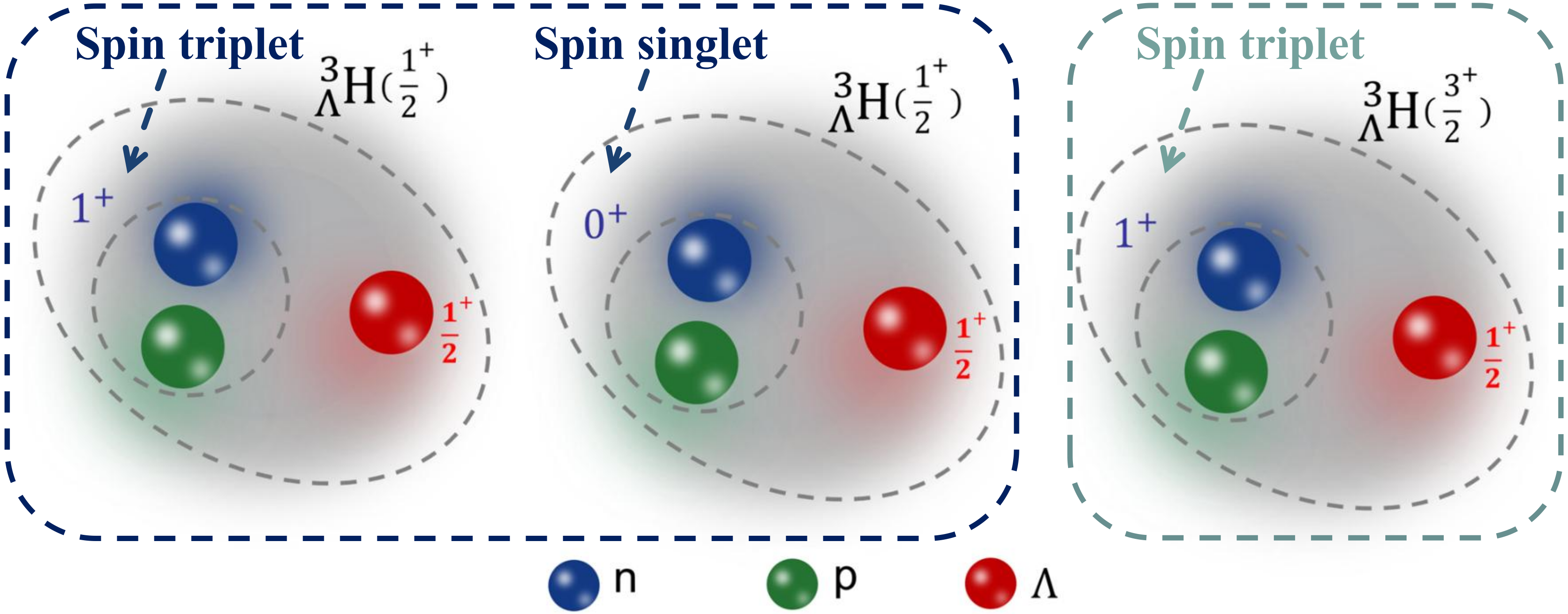
Scattering effect on the polarization



$$\mathcal{C}_{D \to R} = \frac{5}{9}$$

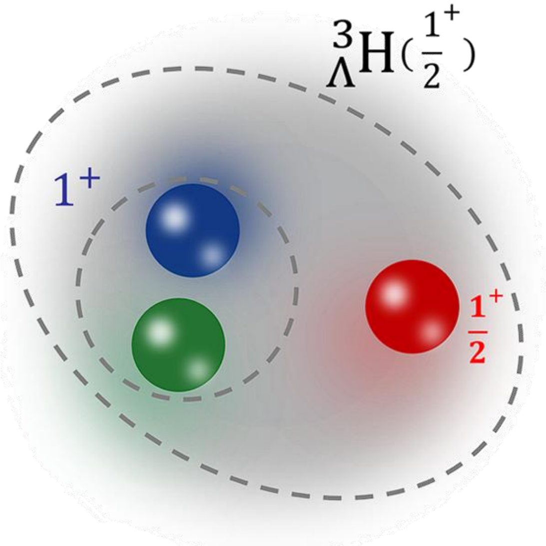
3. Three kinds of spin structure of (anti)hypertriton

Possible spin configurations



Sun, DNL, Zheng, Chen, Ko, Ma, Phys.Rev.Lett. 134, 022301 (2025)

3. (Anti)hypertriton polarization with spin-1/2



➢ Spin wavefunction

$$|\frac{1}{2},\uparrow\rangle_{^3_\Lambda\mathrm{H}} = \frac{\sqrt{6}}{3}|\frac{1}{2},\frac{1}{2}\rangle_n|\frac{1}{2},\frac{1}{2}\rangle_p|\frac{1}{2},-\frac{1}{2}\rangle_\Lambda - \frac{\sqrt{6}}{6}(|\frac{1}{2},\frac{1}{2}\rangle_n|\frac{1}{2},-\frac{1}{2}\rangle_p|\frac{1}{2},\frac{1}{2}\rangle_\Lambda + |\frac{1}{2},-\frac{1}{2}\rangle_n|\frac{1}{2},\frac{1}{2}\rangle_p|\frac{1}{2},\frac{1}{2}\rangle_\Lambda),$$

$$|\frac{1}{2},\downarrow\rangle_{^3_\Lambda\mathrm{H}} = -\frac{\sqrt{6}}{3}|\frac{1}{2},-\frac{1}{2}\rangle_n|\frac{1}{2},-\frac{1}{2}\rangle_p|\frac{1}{2},\frac{1}{2}\rangle_\Lambda + \frac{\sqrt{6}}{6}(|\frac{1}{2},\frac{1}{2}\rangle_n|\frac{1}{2},-\frac{1}{2}\rangle_p|\frac{1}{2},-\frac{1}{2}\rangle_\Lambda + |\frac{1}{2},-\frac{1}{2}\rangle_n|\frac{1}{2},\frac{1}{2}\rangle_p|\frac{1}{2},-\frac{1}{2}\rangle_\Lambda).$$

➢ Coalescence model for hypertriton production (without baryon spin correlation)

$$\hat{\rho}_{np\Lambda} = \hat{\rho}_n \otimes \hat{\rho}_p \otimes \hat{\rho}_\Lambda$$

$$E\frac{d^3N_{^3_\Lambda\mathrm{H},\pm\frac{1}{2}}}{d\mathbf{P}^3} = E\int \prod_{i=n,p,\Lambda} p_i^\mu d^3\sigma_\mu \frac{d^3p_i}{E_i}\bar{f}_i(\mathbf{x}_i,\mathbf{p}_i) \times \left(\frac{2}{3}w_{n,\pm\frac{1}{2}}w_{p,\pm\frac{1}{2}}w_{\Lambda,\mp\frac{1}{2}} + \frac{1}{6}w_{n,\pm\frac{1}{2}}w_{p,\mp\frac{1}{2}}w_{\Lambda,\pm\frac{1}{2}} + \frac{1}{6}w_{n,\mp\frac{1}{2}}w_{p,\pm\frac{1}{2}}w_{\Lambda,\pm\frac{1}{2}}\right) \times W_{^3_\Lambda\mathrm{H}}(\mathbf{x}_n,\mathbf{x}_p,\mathbf{x}_\Lambda;\mathbf{p}_n,\mathbf{p}_p,\mathbf{p}_\Lambda)\delta(\mathbf{P}-\sum_i\mathbf{p}_i)$$

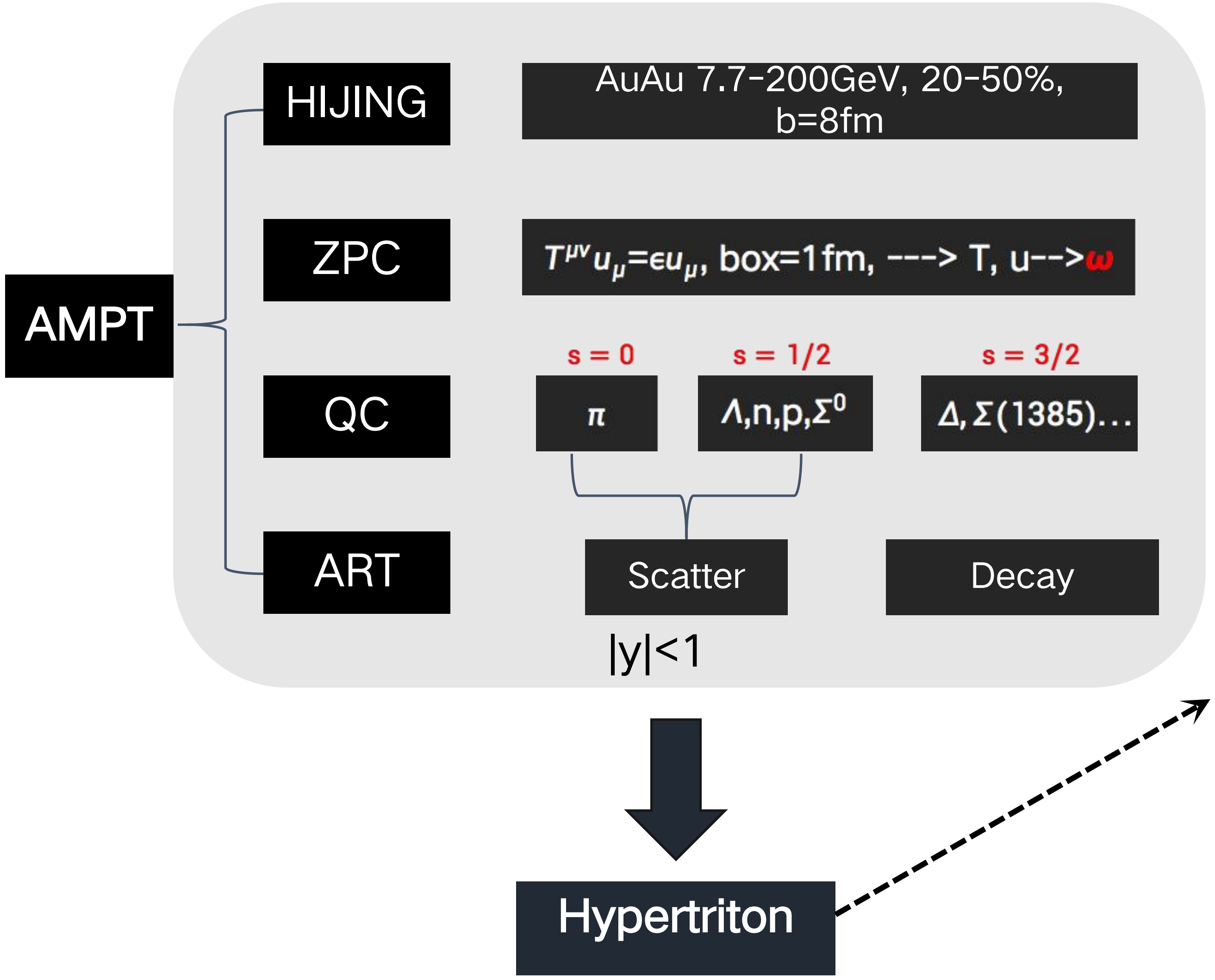
$$\mathcal{P}_{^3_\Lambda\mathrm{H}} \approx \frac{\frac{2}{3}\mathcal{P}_n + \frac{2}{3}\mathcal{P}_p - \frac{1}{3}\mathcal{P}_\Lambda - \mathcal{P}_n\mathcal{P}_p\mathcal{P}_\Lambda}{1-\frac{2}{3}(\mathcal{P}_n+\mathcal{P}_p)\mathcal{P}_\Lambda + \frac{1}{3}\mathcal{P}_n\mathcal{P}_p} \approx \frac{2}{3}\mathcal{P}_n + \frac{2}{3}\mathcal{P}_p - \frac{1}{3}\mathcal{P}_\Lambda \approx \mathcal{P}_\Lambda$$

$\mathcal{P}_p \approx \mathcal{P}_n \approx \mathcal{P}_\Lambda$

Spin polarizations and correlations are small

Sun, DNL, Zheng, Chen, Ko, Ma, Phys.Rev.Lett. 134, 022301 (2025)

3. Coalescence model for hypertriton production



Coalescence with spin degree of freedom

Spin-dependent Coalescence model

Production

$$N_{{}^3_\Lambda\mathrm{H},\pm\frac{1}{2}} = \sum_{np\Lambda} g_{{}^3_\Lambda\mathrm{H},\pm\frac{1}{2}} W_{{}^3_\Lambda\mathrm{H}}(\mathbf{x}_n,\mathbf{x}_p,\mathbf{x}_\Lambda;\mathbf{p}_n,\mathbf{p}_p,\mathbf{p}_\Lambda),$$

$$W_3(\rho,\lambda,p_\rho,p_\lambda) = 8^2\exp\left[-\frac{\rho^2}{\sigma_\rho^2}-\frac{\lambda^2}{\sigma_\lambda^2}-p_\rho^2\sigma_\rho^2-p_\lambda^2\sigma_\lambda^2\right]$$

$$\sigma_\rho = 2.26\ \mathrm{fm}$$
$$\sigma_\lambda = 6.52\ \mathrm{fm}$$
$$B_\Lambda = 0.164\ \mathrm{MeV}$$

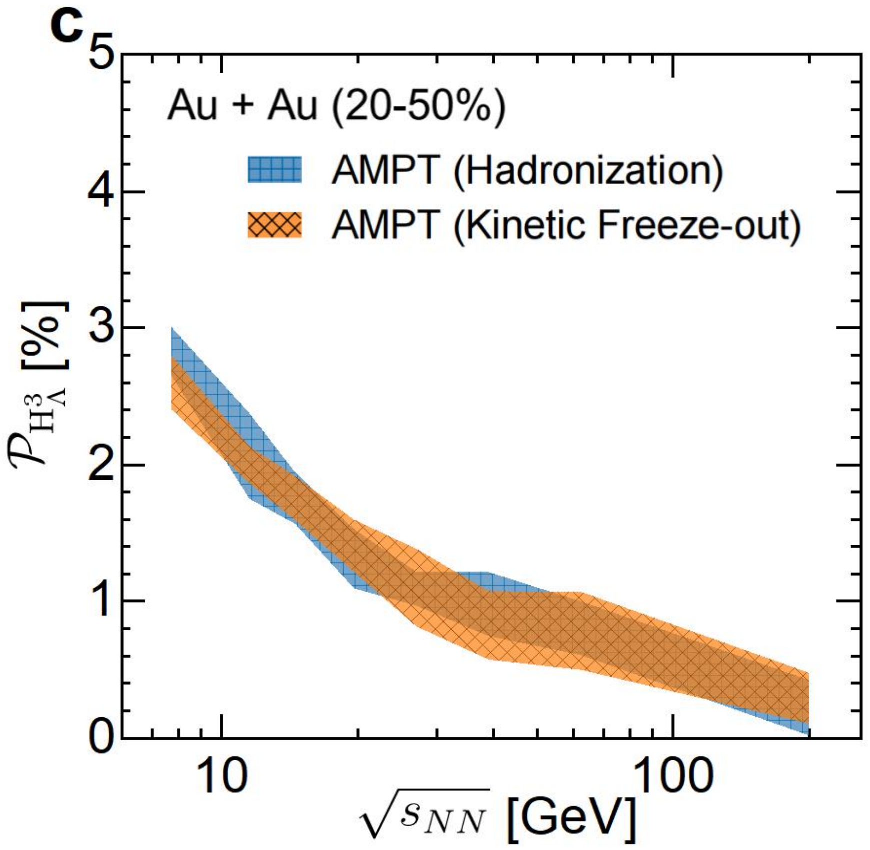
$$\rho=\frac{1}{\sqrt{2}}(x_1'-x_2'),\quad p_\rho=\frac{\sqrt{2}(m_2p_1'-m_1p_2')}{m_1+m_2},$$
$$\lambda=\sqrt{\frac{2}{3}}\left(\frac{m_1x_1'+m_2x_2'-x_3'}{m_1+m_2}\right),$$
$$p_\lambda=\sqrt{\frac{3}{2}}\frac{m_3(p_1'+p_2')-(m_1+m_2)p_3'}{m_1+m_2+m_3}.$$

Spin statistical factor

$$g_{{}^3_\Lambda\mathrm{H},\pm\frac{1}{2}} = \frac{2}{3}w_{n,\pm\frac{1}{2}}w_{p,\pm\frac{1}{2}}w_{\Lambda\mp\frac{1}{2}} + \frac{1}{6}w_{n,\mp\frac{1}{2}}w_{p,\pm\frac{1}{2}}w_{\Lambda\pm\frac{1}{2}} + \frac{1}{6}w_{n,\pm\frac{1}{2}}w_{p,\mp\frac{1}{2}}w_{\Lambda\pm\frac{1}{2}},$$

$$w_{i,\pm\frac{1}{2}} = \frac{1}{2}(1\pm\mathcal{P}_i)$$

3. Global hypertriton polarization

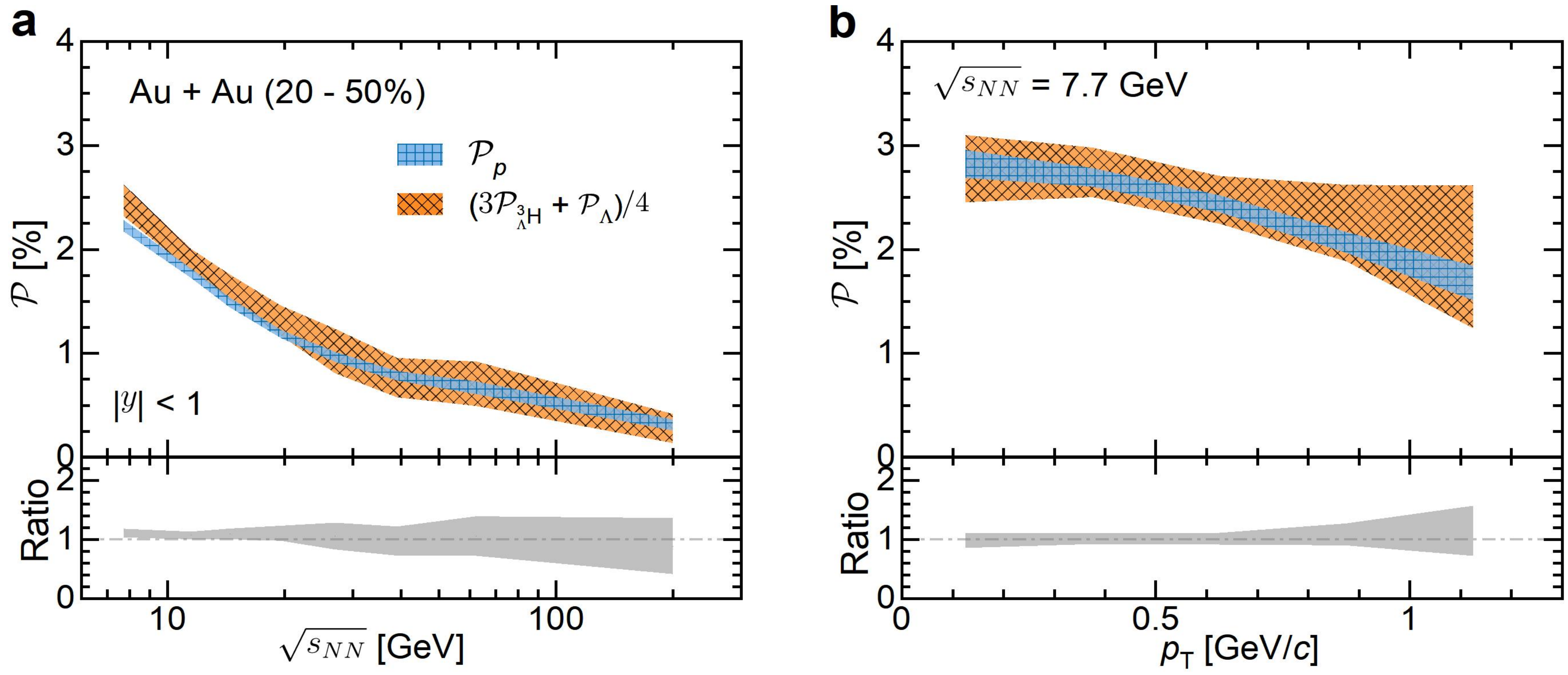


Polarization

$$\mathcal{P}_{^3_\Lambda\mathrm{H}} = \frac{N_{^3_\Lambda\mathrm{H},+\frac{1}{2}} - N_{^3_\Lambda\mathrm{H},-\frac{1}{2}}}{N_{^3_\Lambda\mathrm{H},+\frac{1}{2}} + N_{^3_\Lambda\mathrm{H},-\frac{1}{2}}}$$

$$\mathcal{P}_{^3_\Lambda\mathrm{H}} \approx \frac{2}{3}\mathcal{P}_n + \frac{2}{3}\mathcal{P}_p - \frac{1}{3}\mathcal{P}_\Lambda \approx \frac{1}{3}\left(4\mathcal{P}_p - \mathcal{P}_\Lambda\right),$$

4. Global proton polarization via hypertriton and hyperon



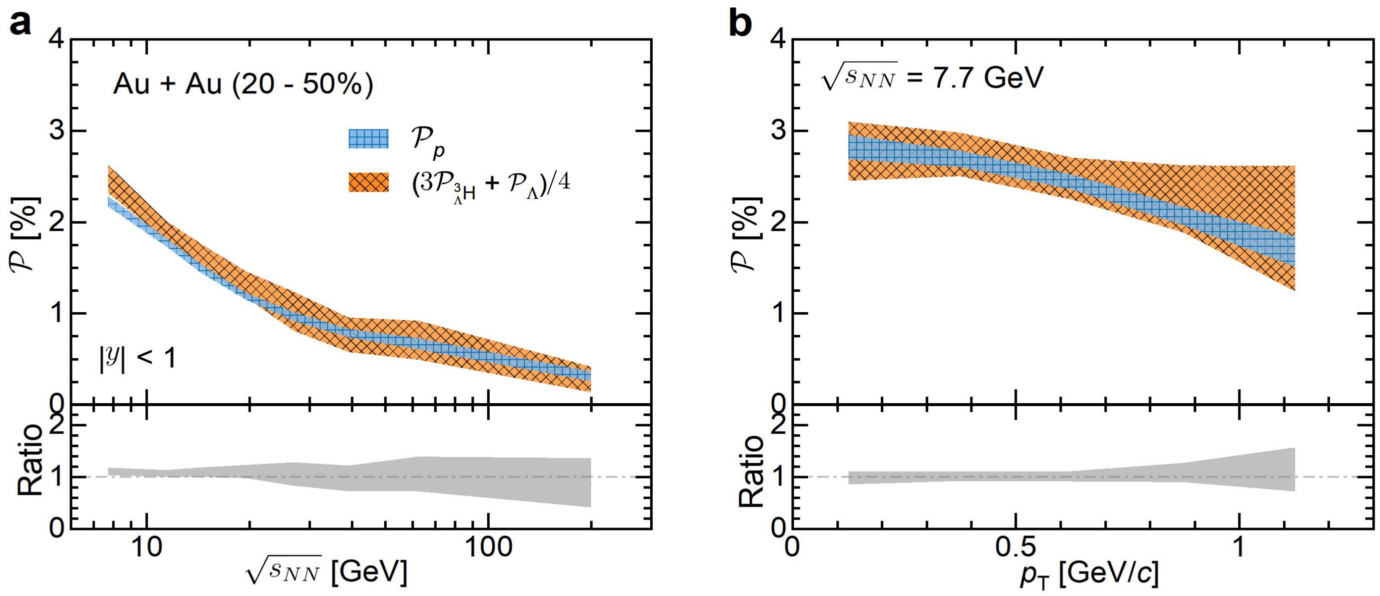
$$\mathcal{P}_{^3_\Lambda\mathrm{H}} \approx \frac{2}{3}\mathcal{P}_n + \frac{2}{3}\mathcal{P}_p - \frac{1}{3}\mathcal{P}_\Lambda \approx \frac{1}{3}\left(4\mathcal{P}_p - \mathcal{P}_\Lambda\right)$$

➢ Linear relationship $\mathcal{P}_p \approx \frac{1}{4}\left(3\mathcal{P}_{^3_\Lambda\mathrm{H}} + \mathcal{P}_\Lambda\right)$

5. Summary

- **Calculating global Lambda, nculeon, hyprtriton polarization** from spin-dependent coalescence approach with rescattering effect at hadronic phase
- **Revealing proton polarization via hypertriton** with a linear relationship

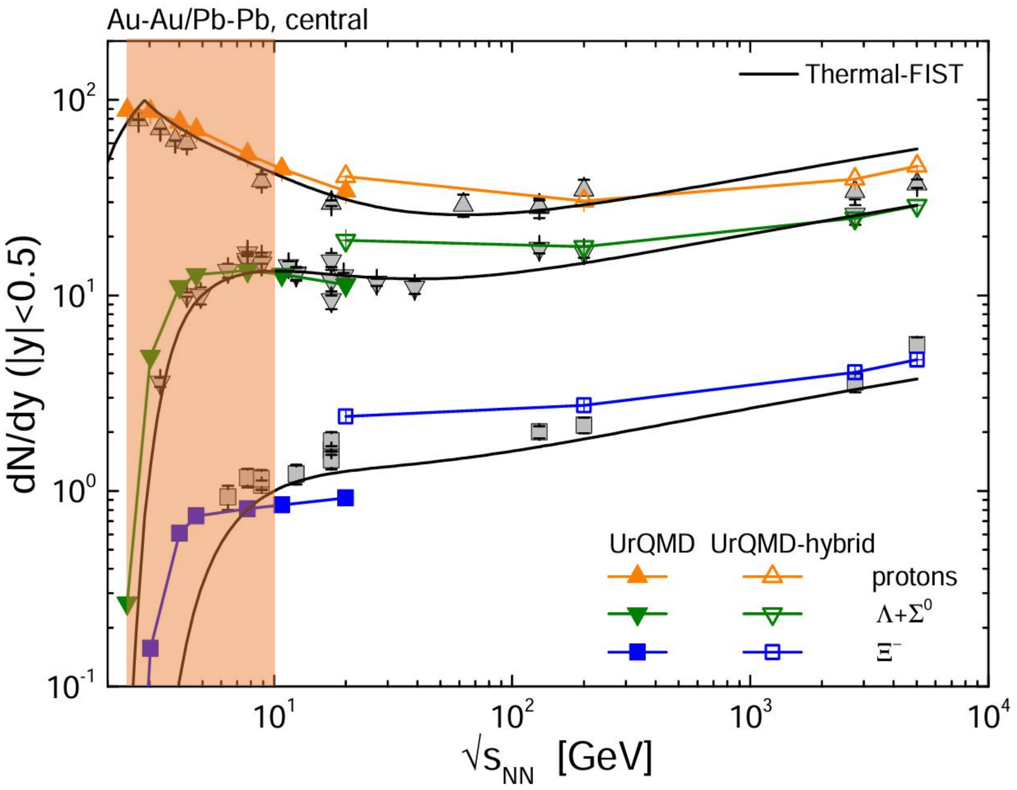
$$\mathcal{P}_p \approx \frac{1}{4}\left(3\mathcal{P}_{^3_\Lambda\mathrm{H}} + \mathcal{P}_\Lambda\right)$$



5. Outlook

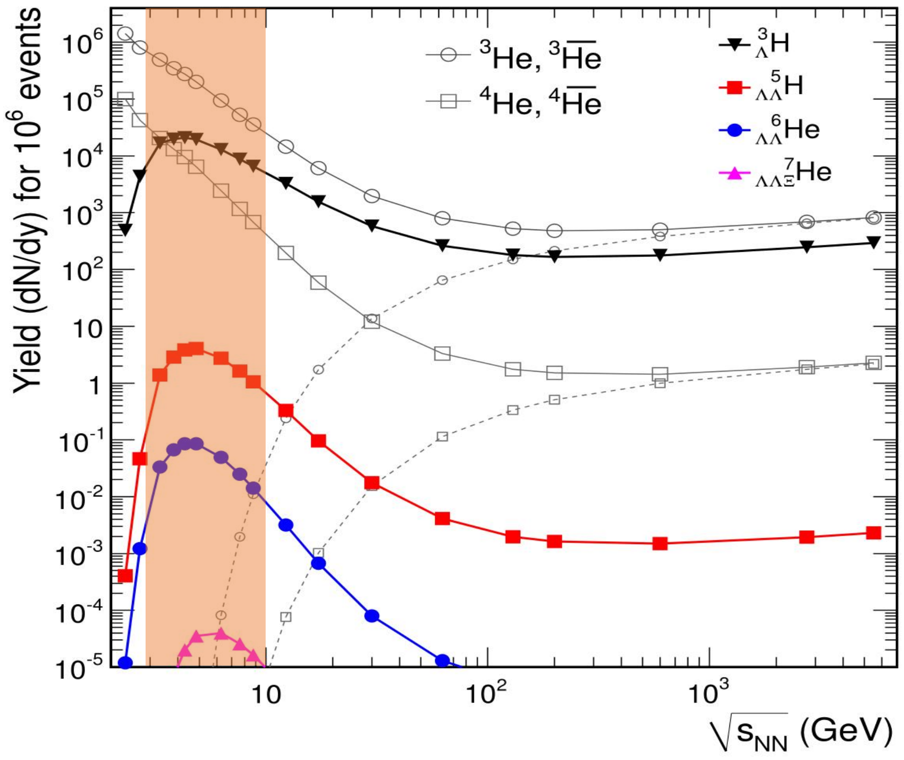
A pronounced maximum production.

Hyperon production



Tom Reichert et al., Phys.Rev.C 107 (2023), 014912

Hyper-nuclei production



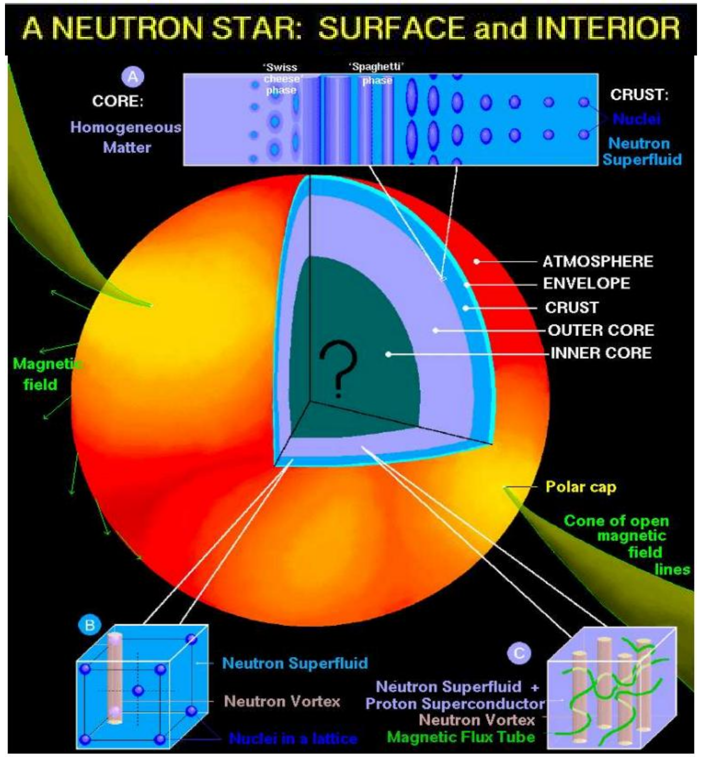
A. Andronic et al., PLB 697, 203(2011)

- **FAIR/CBM (2.4-4.9 GeV)**
- **HIAF/CEE (2.1-4.5 GeV)**
- **NICA/MPD (4-11 GeV)**

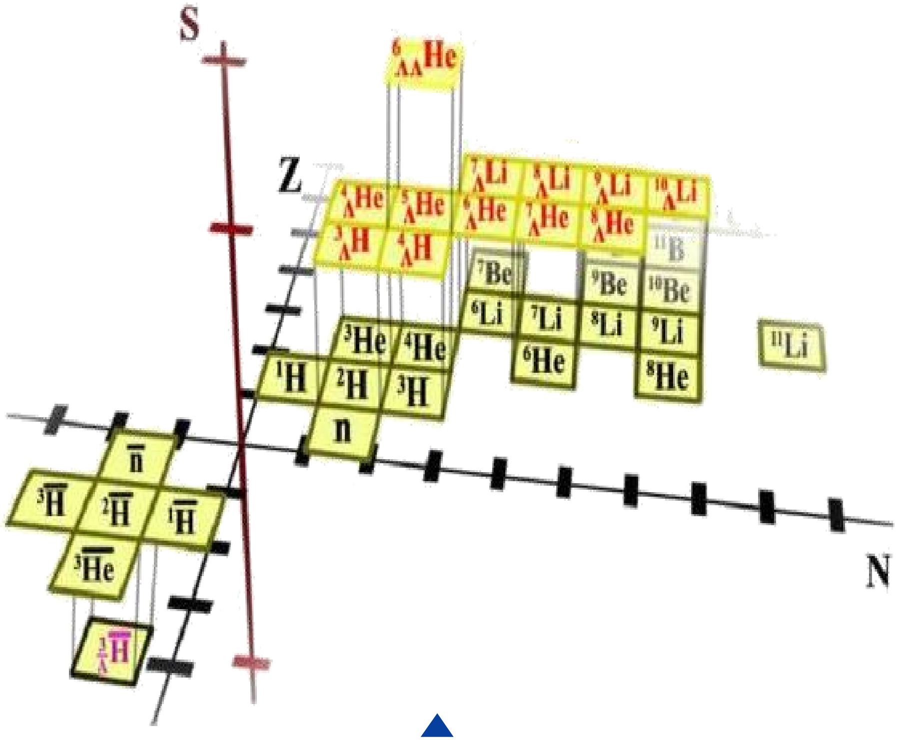
Thank you!

Appidx 1

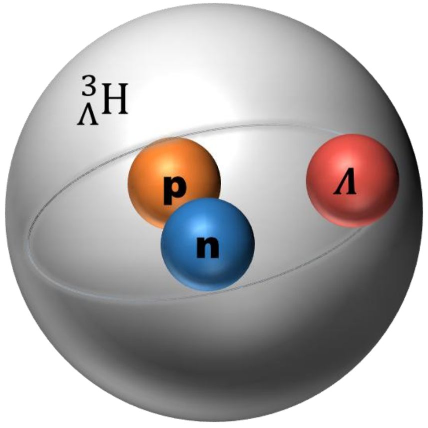
- Hypernucleus, bound system with at least one hyperon
- Hyperon–nucleon (Y-N) interactions



J. M. Lattimer and M. Prakash, Science 304, 536 (2004)



Three-dimensional nuclear chart

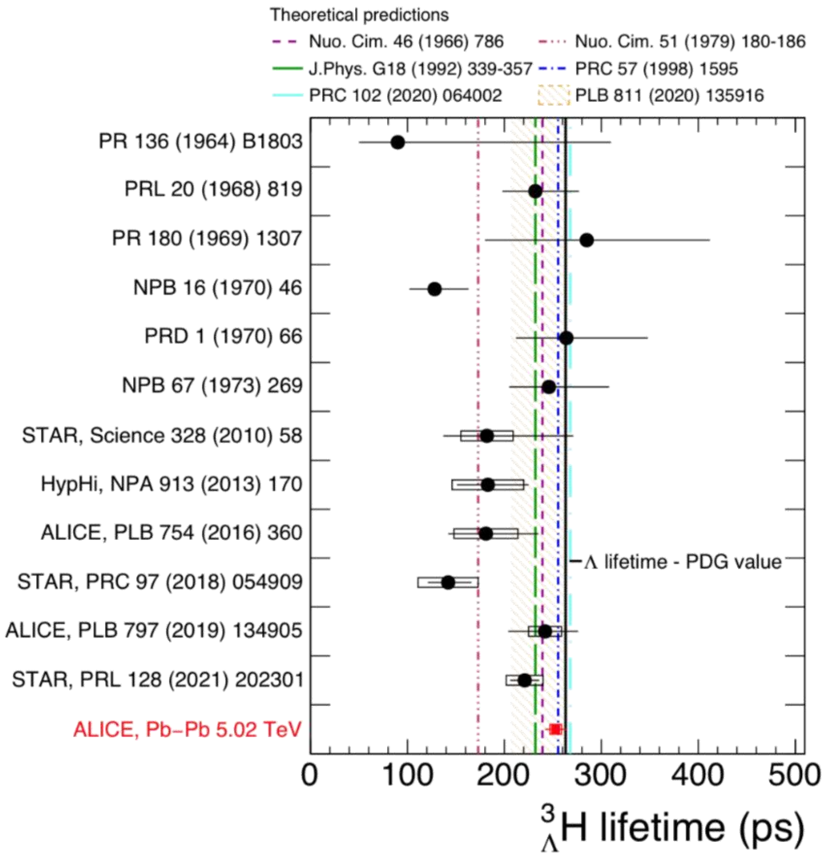


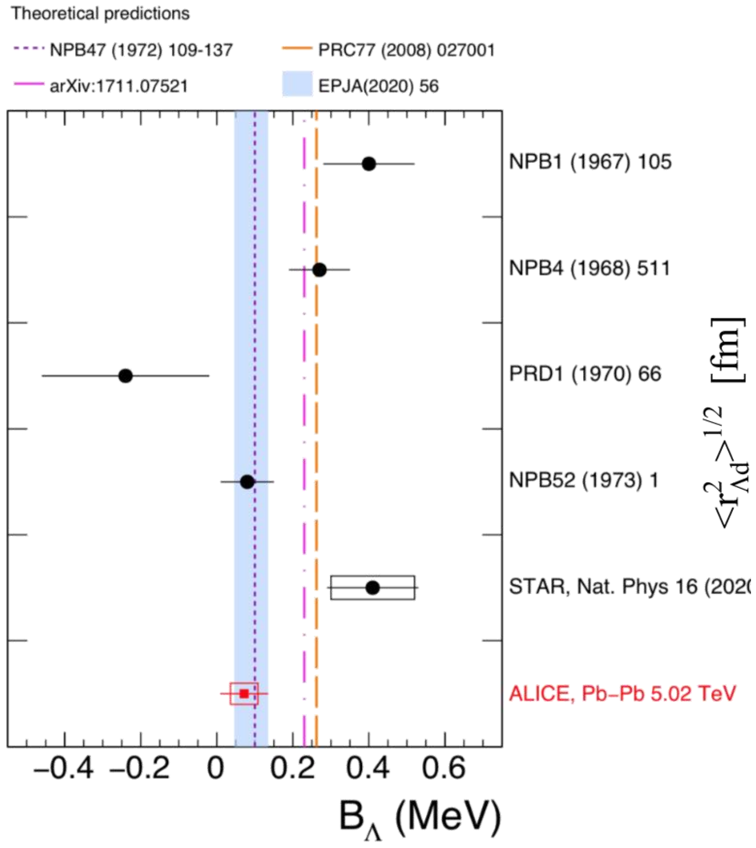
$^{3}_{\Lambda}H$ $r_{d-\Lambda} \approx 10fm$
(distance)

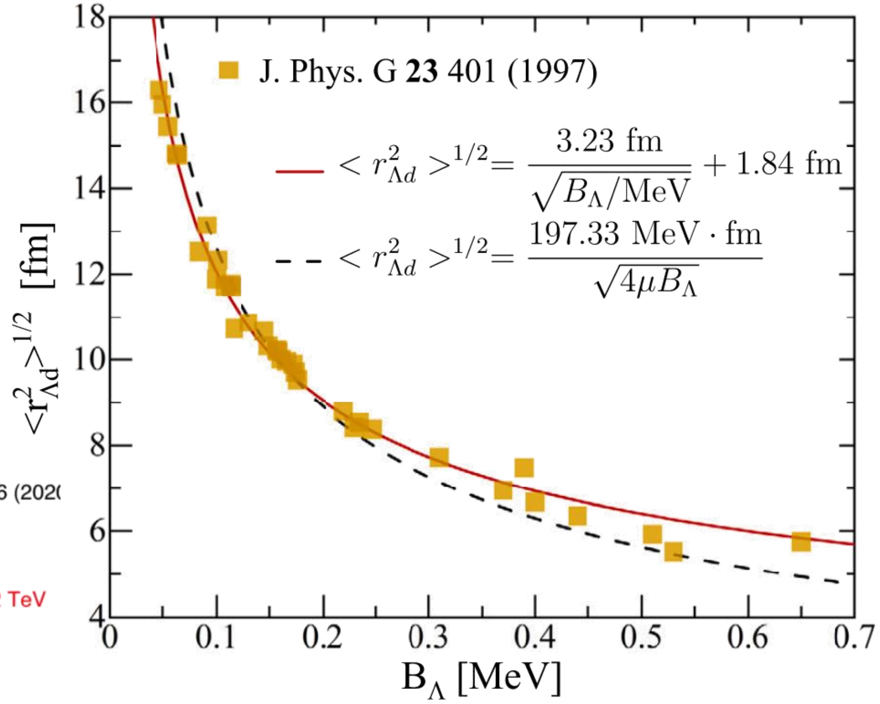
Appidx 2 Structure of (Anti-)Hypertriton

ALICE, Phys.Rev.Lett. 131, 102302 (2023)

Y. G. Ma, Nucl. Sci. Tech. 3497 (2023)
J. Chen *et al.*, Sci. Bull. 68, 3252 (2023)







A. Cobis *et al.*, J. Phys. G 23 401 (1997)

Lifetime ≈ free Λ lifetime τ_Λ

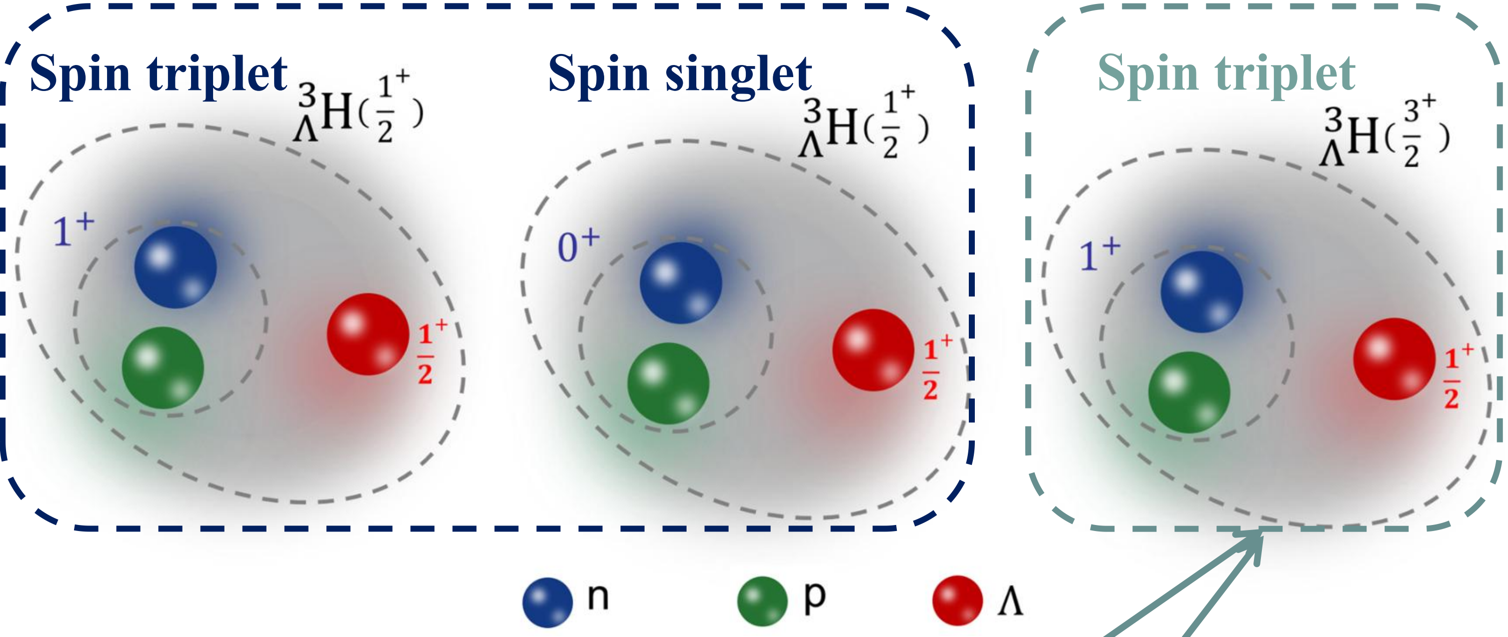
$$B_\Lambda \equiv M_d + M_\Lambda - M_{^3_\Lambda \text{H}}$$

1. $B_{\Lambda d} \approx 0.41 \pm 0.12 \pm 0.11$ MeV STAR(Nat. Phys. 16 409(2020))
2. $B_{\Lambda d} \approx 0.102 \pm 0.063 \pm 0.067$ MeV ALICE (Phys.Rev.Lett. 131,102302 (2023))
3. $B_{\Lambda d} \approx 0.164 \pm 0.043$ MeV Include heavy ion collision and emulsion

Separation energy and root-mean-square radius

Appidx 3 Spin Structures of (Anti-)Hypertriton

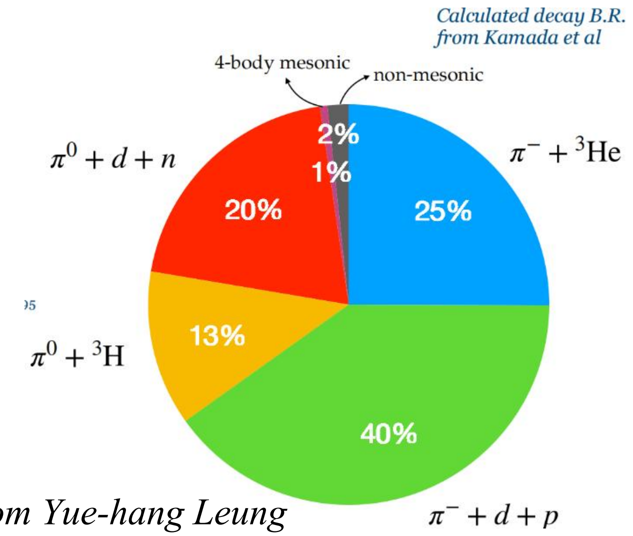
Possible spin configurations



Favors spin 1/2

$$^3_\Lambda\mathrm{H} \mapsto \pi^- + {}^3\mathrm{He}, \qquad {}^3_\Lambda\mathrm{H} \mapsto \pi^0 + {}^3\mathrm{H},$$
$$^3_\Lambda\mathrm{H} \mapsto \pi^- + d + p, \qquad {}^3_\Lambda\mathrm{H} \mapsto \pi^0 + d + n,$$
$$^3_\Lambda\mathrm{H} \mapsto \pi^- + p + n + p, \qquad {}^3_\Lambda\mathrm{H} \mapsto \pi^0 + p + n + n.$$

Kamada *et al.*, Phys. Rev. C 57, 1595(1998)



From Yue-hang Leung

Favors spin 3/2

PHYSICAL REVIEW D **87,** 034506 (2013)

Light nuclei and hypernuclei from quantum chromodynamics in the limit of SU(3) flavor symmetry

S. R. Beane,[1] E. Chang,[2] S. D. Cohen,[3] W. Detmold,[4,5] H. W. Lin,[3] T. C. Luu,[6] K. Orginos,[4,5] A. Parreño,[2] M. J. Savage,[3] and A. Walker-Loud[7,8]

Appidx Polarization of hypertriton

PHYSICAL REVIEW LETTERS **134,** 022301 (2025)

Deciphering Hypertriton and Antihypertriton Spins from Their Global Polarizations in Heavy-Ion Collisions

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Appidx Polarization from hadrons to light (anti-)(hyper-)nuclei

Polarization of light (anti-)(hyper-)nuclei?

Unstable hadrons

$\Lambda(uds)$ $\Xi(uss)$ $\Omega(sss)$

$\phi(s\bar{s})$ $K^{*0}(d\bar{s})$ $\rho^{+}(u\bar{d})$

$J/\psi(c\bar{c})$ $\cdots$

Decay approach

Stable (anti-)(hyper-)nuclei

$d(np)$ $^{3}\mathrm{He}(npp)$

$\bar{d}(\bar{n}\bar{p})$ $^{3}\overline{\mathrm{He}}(\bar{n}\bar{p}\bar{p})$

$\cdots$

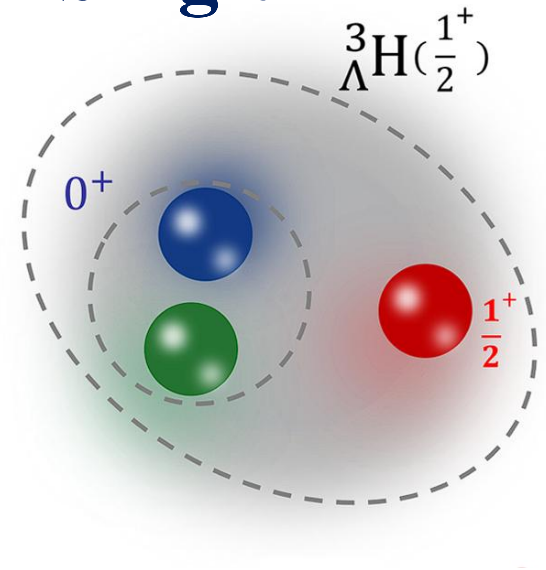
Unstable (anti-)(hyper-)nuclei

$^{3}_{\Lambda}\mathrm{H}(np\Lambda)$ $^{4}\mathrm{Li}(\mathrm{nppp})$

$^{3}_{\Lambda}\overline{\mathrm{H}}(\bar{n}\bar{p}\bar{\Lambda})$ $^{4}\overline{\mathrm{Li}}(\bar{n}\bar{p}\bar{p}\bar{p})$

$\cdots$

Appidx (Anti-)Hypertriton Polarization with Spin-1/2 Singlet

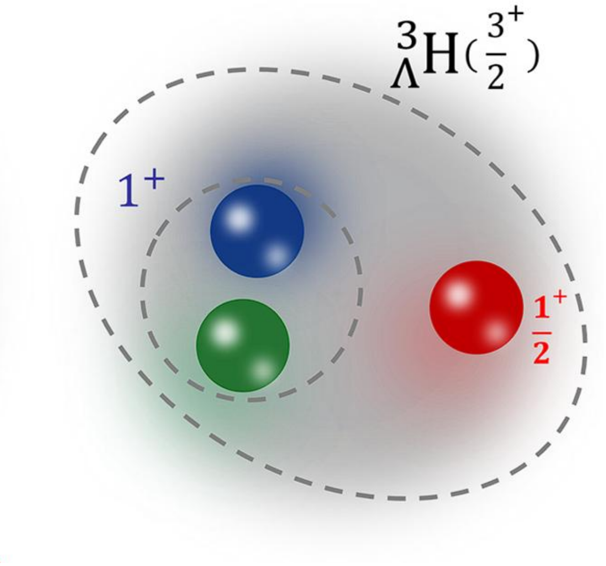


The polarization of hypertriton is solely determined by that of the Λ hyperon

$$\mathcal{P}_{^3_\Lambda\mathrm{H}} \approx \mathcal{P}_\Lambda$$

$$\alpha_{^3_\Lambda\mathrm{H}} \approx \alpha_\Lambda$$

Appidx (Anti-)Hypertriton Polarization with Spin-3/2



- **Density matrix**

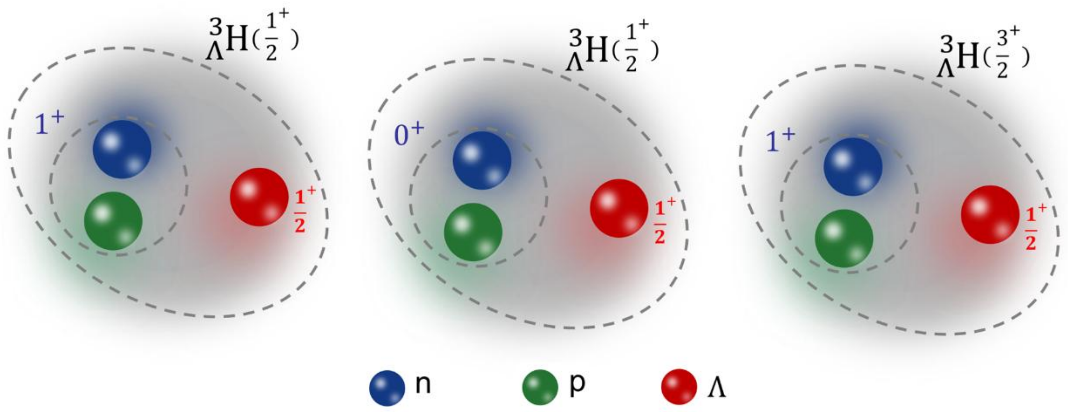
$$\hat{\rho}_{^3_\Lambda H} \approx \mathrm{diag}\left[\frac{(1+\mathcal{P}_\Lambda)^3}{4(1+\mathcal{P}_\Lambda^2)}, \frac{(1-\mathcal{P}_\Lambda)(1+\mathcal{P}_\Lambda)^2}{4(1+\mathcal{P}_\Lambda^2)}, \frac{(1-\mathcal{P}_\Lambda)^2(1+\mathcal{P}_\Lambda)}{4(1+\mathcal{P}_\Lambda^2)}, \frac{(1-\mathcal{P}_\Lambda)^3}{4(1+\mathcal{P}_\Lambda^2)}\right]$$

$$T(^3_\Lambda H \to \pi^- + ^3He) = \frac{FT_p}{\sqrt{6\pi}}\begin{pmatrix} e^{i\phi^*}\sin\theta^* & 0 \\ -\frac{2}{\sqrt{3}}\cos\theta^* & \frac{e^{i\phi^*}\sin\theta^*}{\sqrt{3}} \\ -\frac{e^{-i\phi^*}\sin\theta^*}{\sqrt{3}} & -\frac{2}{\sqrt{3}}\cos\theta^* \\ 0 & -e^{-i\phi^*}\sin\theta^* \end{pmatrix}$$

$$\hat{\rho}_{\frac{1}{2},\frac{1}{2}} + \hat{\rho}_{-\frac{1}{2},-\frac{1}{2}} - \frac{1}{2} \approx -\frac{\mathcal{P}_\Lambda^2}{1+\mathcal{P}_\Lambda^2} \approx -\mathcal{P}_\Lambda^2.$$

$$\frac{dN}{d\cos\theta^*} = \frac{1}{2}\left[1 + \left(\hat{\rho}_{\frac{1}{2},\frac{1}{2}} + \hat{\rho}_{-\frac{1}{2},-\frac{1}{2}} - \frac{1}{2}\right)(3\cos^2\theta^* - 1)\right]$$

Appidx (Anti-)Hypertriton Polarization with Spin Structure



J^P	structure	decay mode	$\frac{dN}{d\cos\theta^*}$
$\frac{1}{2}^+$	$\Lambda(\frac{1}{2}^+) - np(1^+)$	$^3_\Lambda H \to \pi^- + ^3He$	$\frac{1}{2}(1 - \frac{1}{2.58}\alpha_\Lambda \mathcal{P}_\Lambda \cos\theta^*)$
$\frac{1}{2}^+$	$\Lambda(\frac{1}{2}^+) - np(0^+)$	$^3_\Lambda H \to \pi^- + ^3He$	$\frac{1}{2}(1 + \alpha_\Lambda \mathcal{P}_\Lambda \cos\theta^*)$
$\frac{3}{2}^+$	$\Lambda(\frac{1}{2}^+) - np(1^+)$	$^3_\Lambda H \to \pi^- + ^3He$	$\frac{1}{2}(1 - \mathcal{P}_\Lambda^2(3\cos^2\theta^* - 1))$
$\frac{1}{2}^-$	$\bar{\Lambda}(\frac{1}{2}^-) - \overline{np}(1^-)$	$^3_{\bar{\Lambda}}\overline{H} \to \pi^+ + ^3\overline{He}$	$\frac{1}{2}(1 - \frac{1}{2.58}\alpha_{\bar{\Lambda}} \mathcal{P}_{\bar{\Lambda}} \cos\theta^*)$
$\frac{1}{2}^-$	$\bar{\Lambda}(\frac{1}{2}^-) - \overline{np}(0^-)$	$^3_{\bar{\Lambda}}\overline{H} \to \pi^+ + ^3\overline{He}$	$\frac{1}{2}(1 + \alpha_{\bar{\Lambda}} \mathcal{P}_{\bar{\Lambda}} \cos\theta^*)$
$\frac{3}{2}^-$	$\bar{\Lambda}(\frac{1}{2}^-) - \overline{np}(1^-)$	$^3_{\bar{\Lambda}}\overline{H} \to \pi^+ + ^3\overline{He}$	$\frac{1}{2}(1 - \mathcal{P}_{\bar{\Lambda}}^2(3\cos^2\theta^* - 1))$

(Anti-)Hypertriton Polarization with Spin Structure

The measurement of hypertriton polarization provides a novel method to uniquely determine its internal spin structure

$\alpha_{^3_\Lambda H} \approx -\frac{1}{2.58}\alpha_\Lambda$ $\alpha_{^3_\Lambda H} \approx \alpha_\Lambda$