Global Spin Alignment of $^{4}\mathrm{Li}$ in Heavy-Ion Collisions

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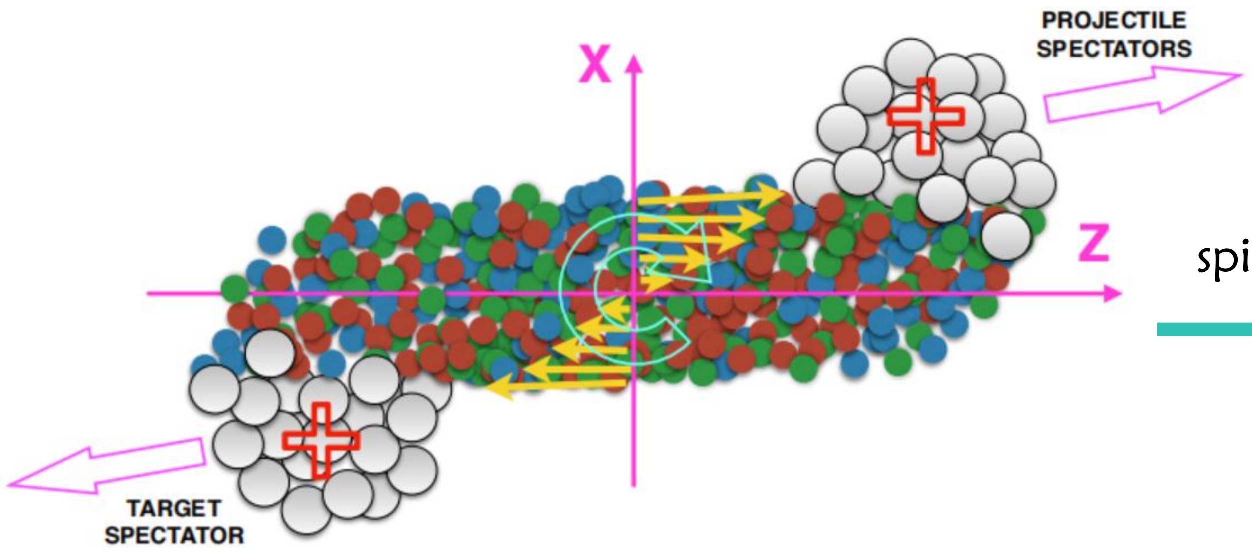
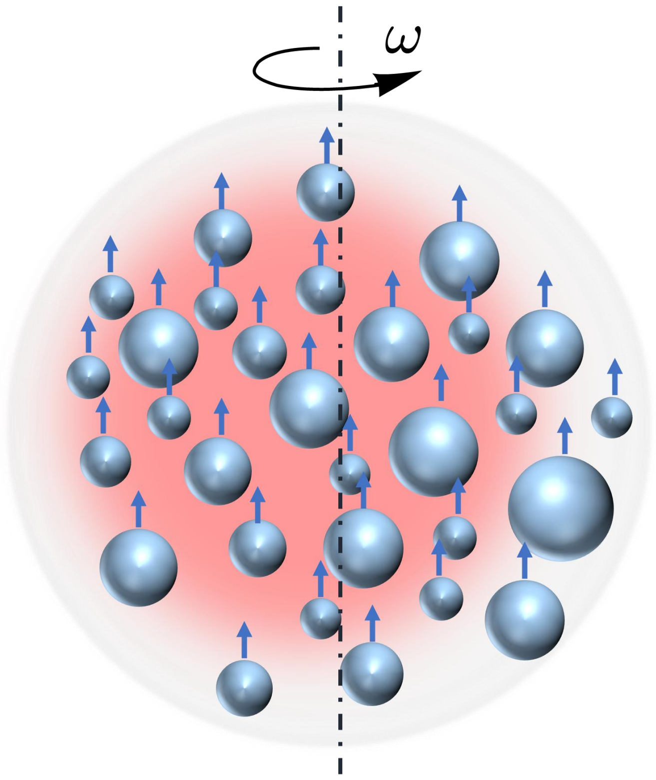
In Collaborated with Dai-Neng Liu, Lie-Wen Chen, Jin-Hui Chen, Che Ming Ko, Yu-Gang Ma, Kai-Jia Sun, Jun Xu and Bo Zhou

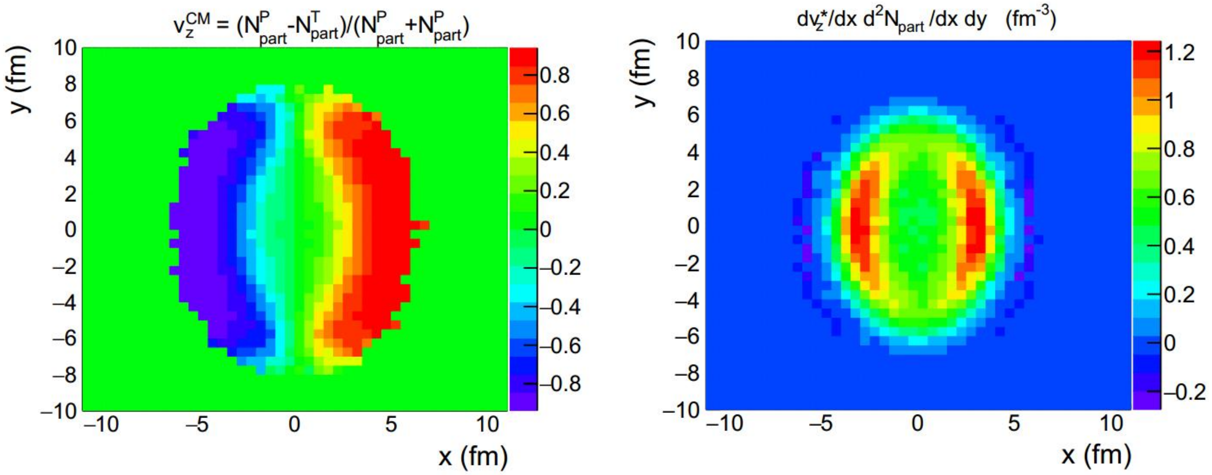
Qingdao, September. 24, 2025

Globally polarized QGP in Heavy-ion Collisions



spin-orbital coupling

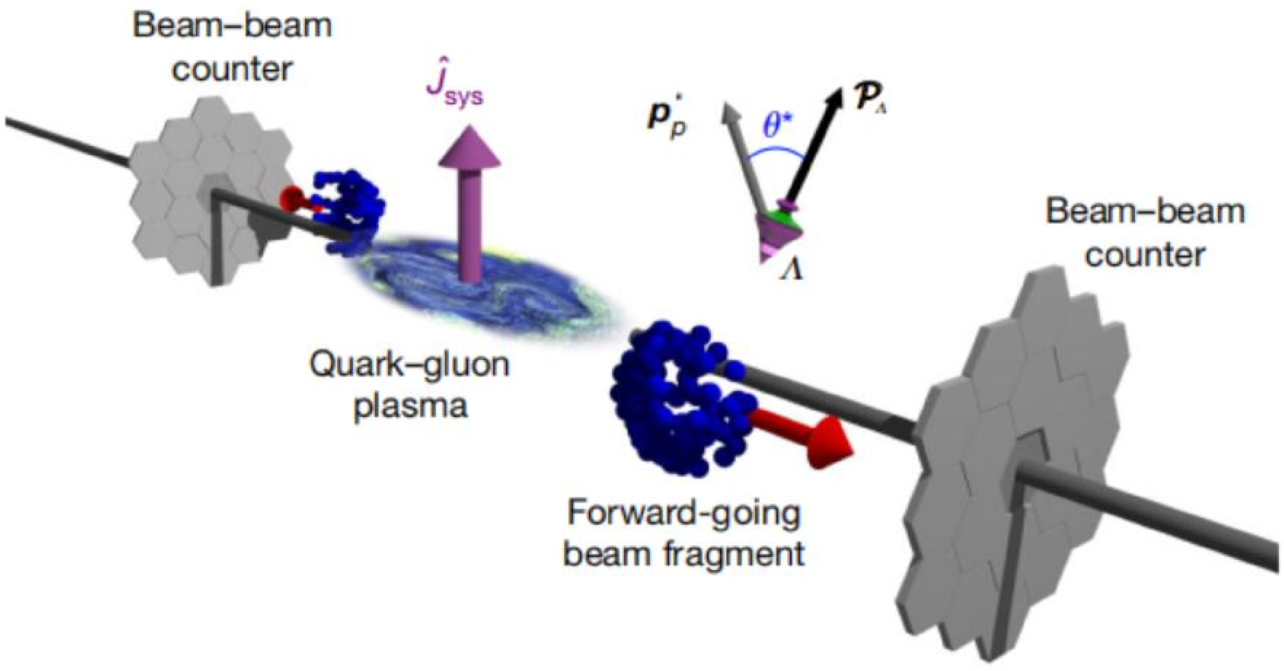


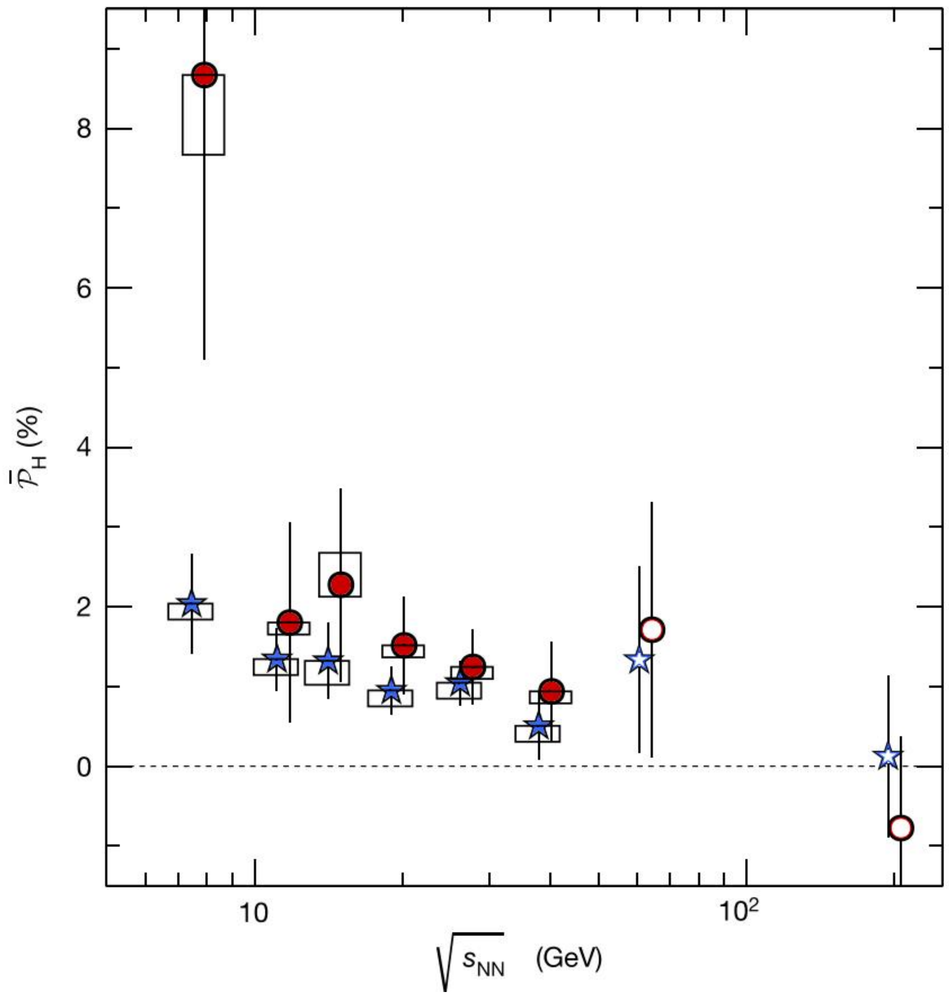


Z.-T. Liang and X.-N. Wang, Phys. Rev. Lett. 94, 102301 (2005)
Z.-T. Liang and X.-N. Wang, Phys. Lett. B 629, 20 (2005)

Niida and S. A. Voloshin, Int. J. Mod. Phys. E 33, 2430010(2024)

Global Λ hyperon polarization



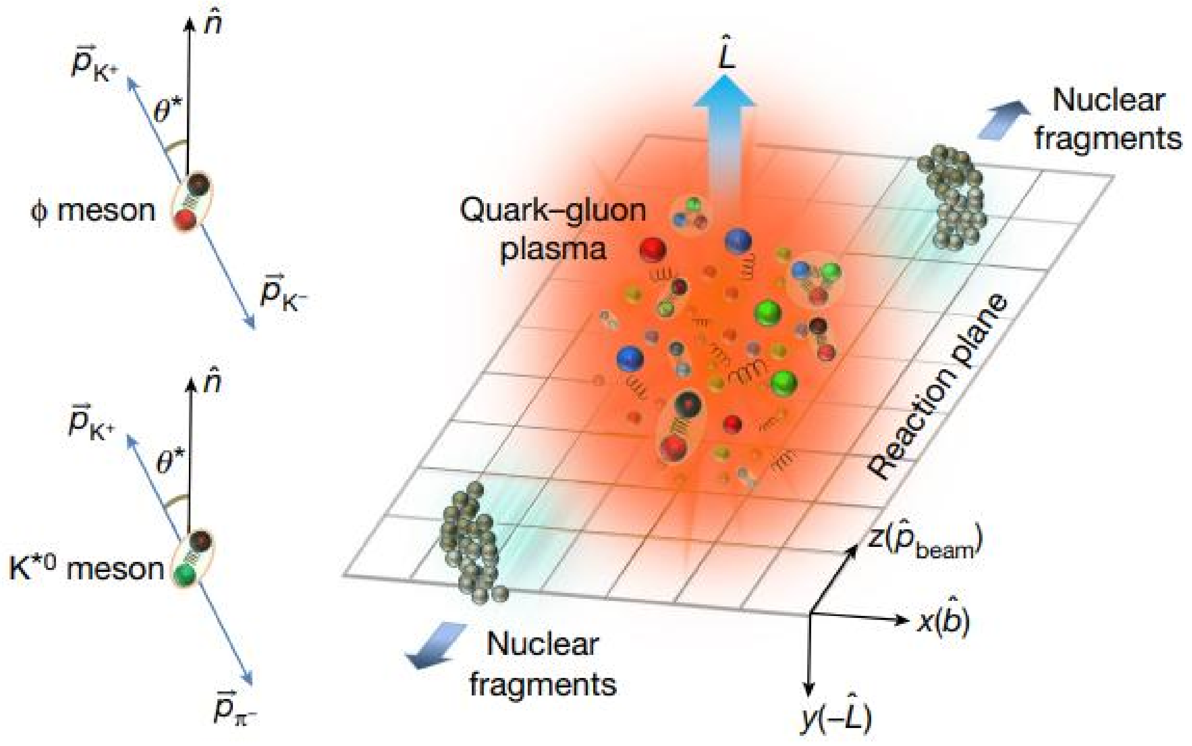


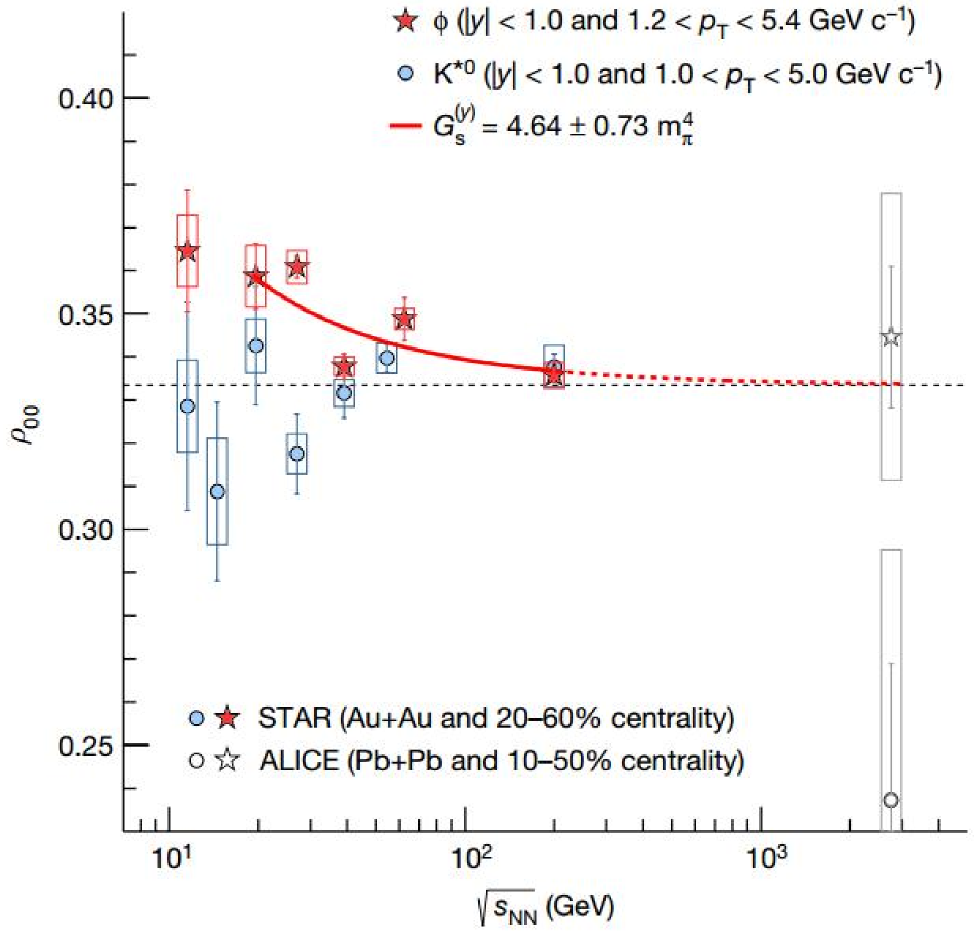
$$\Lambda \to p + \pi^-$$

$$\frac{dN}{d\Omega} = \frac{1}{4\pi}(1 + \alpha_\Lambda |P_\Lambda| \cos\theta^*)$$

L. Adamczyk et al. (STAR), Nature 548, 62 (2017)

Spin alignment of vector meson

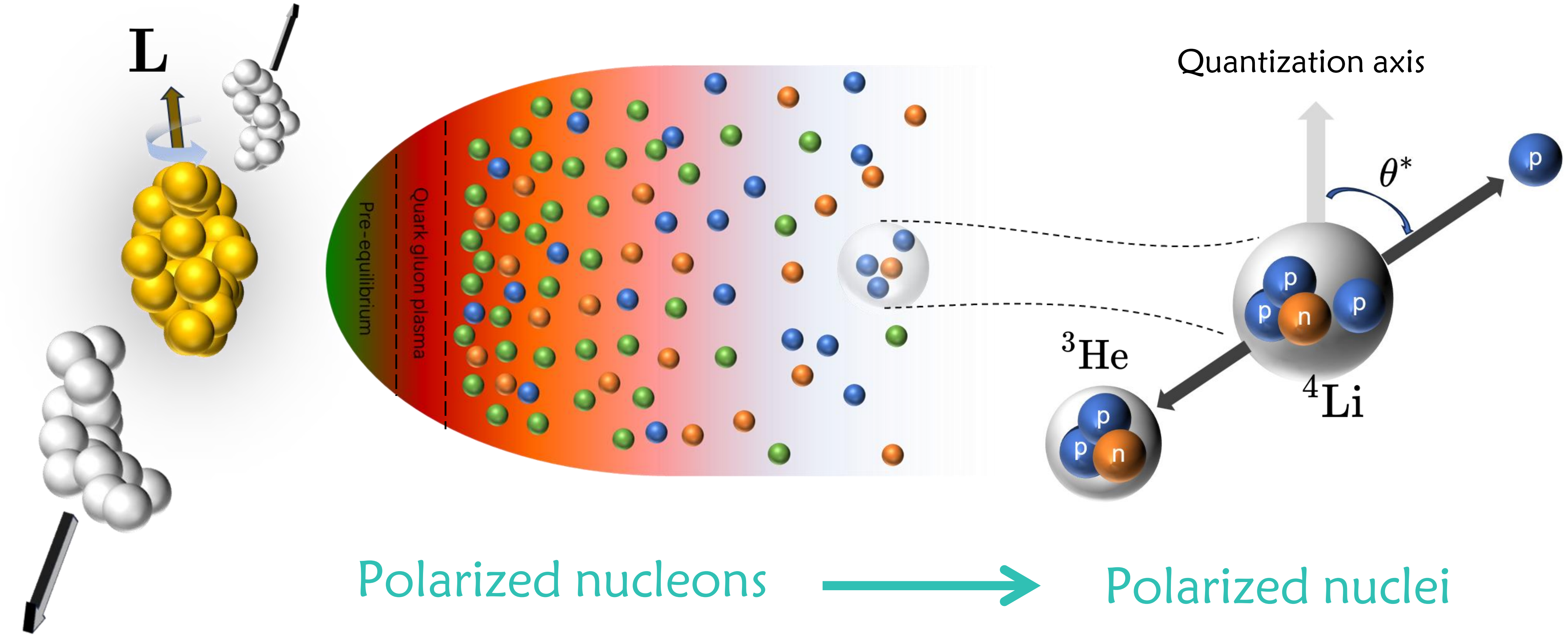




$$\frac{dN}{d(\cos\theta^*)} \propto (1-\rho_{00}) + (3\rho_{00}-1)\cos^2\theta^*$$

STAR Collaboration, M. S. Abdallah et al., Nature 614, 244 (2023)

Polarized nuclei



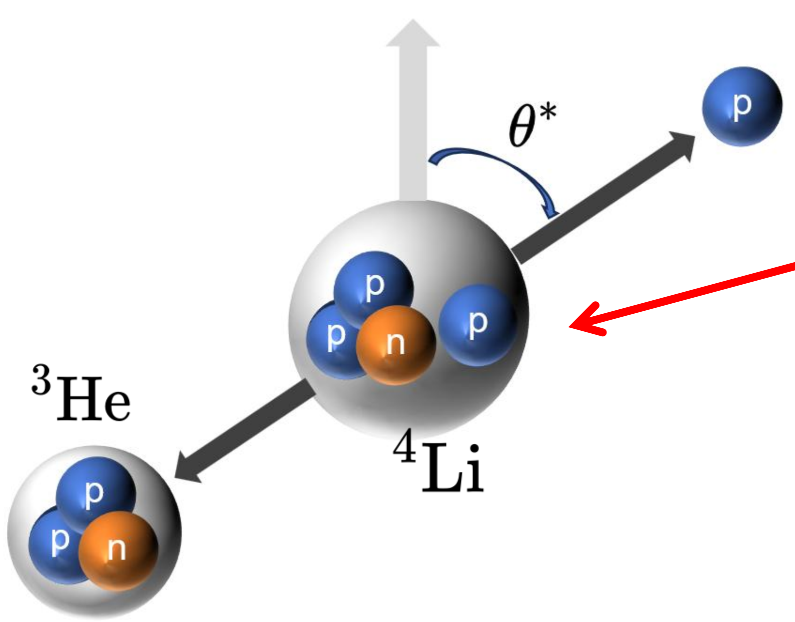
Polarized nucleons → Polarized nuclei

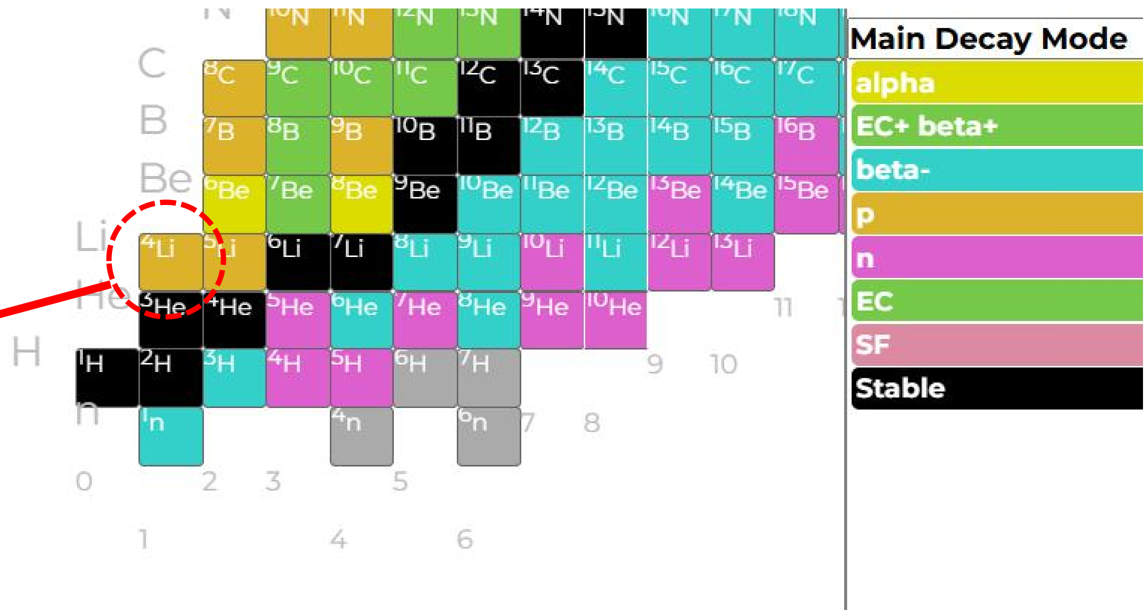
R.-J. Liu and J. Xu, Phys. Rev. C 109, 014615 (2024)

Kai-Jia Sun et al., Phys. Rev. Lett. 134, 022301 (2025)

Yun-Peng Zheng et al., arXiv:2509. 15286 (2025)

Unstable nucleus ^{4}Li





$A=4$	E_x(MeV)	J^π	Decay channels
^{4}Li	g.s.	2^-	p(100%)
	0.32	1^-	p(100%)
	2.08	0^-	p(100%)
	2.85	1^-	p(100%)

Decay angular distribution :

$$\frac{dN}{d\Omega^*} = \frac{\mathrm{Tr}[\hat{T}^\dagger \hat{\rho} \hat{T}]}{\int d\Omega^* \ \mathrm{Tr}[\hat{T}^\dagger \hat{\rho} \hat{T}]} \longleftrightarrow \frac{dN}{\sin\theta^* d\theta^*} = 2\pi \frac{\mathrm{Tr}[\hat{T}^\dagger \hat{\rho} \hat{T}]}{\int d\Omega^* \ \mathrm{Tr}[\hat{T}^\dagger \hat{\rho} \hat{T}]}$$

T_{ij} : initial spin state i $\longrightarrow$ final spin state j

V. Vovchenko, B. D¨onigus, B. Kardan, M. Lorenz, and H. Stoecker, Phys. Lett. B, 135746 (2020)

^{4}Li production within coalescence model in a vortical fluid

Productions of the ground states with defferent J_z

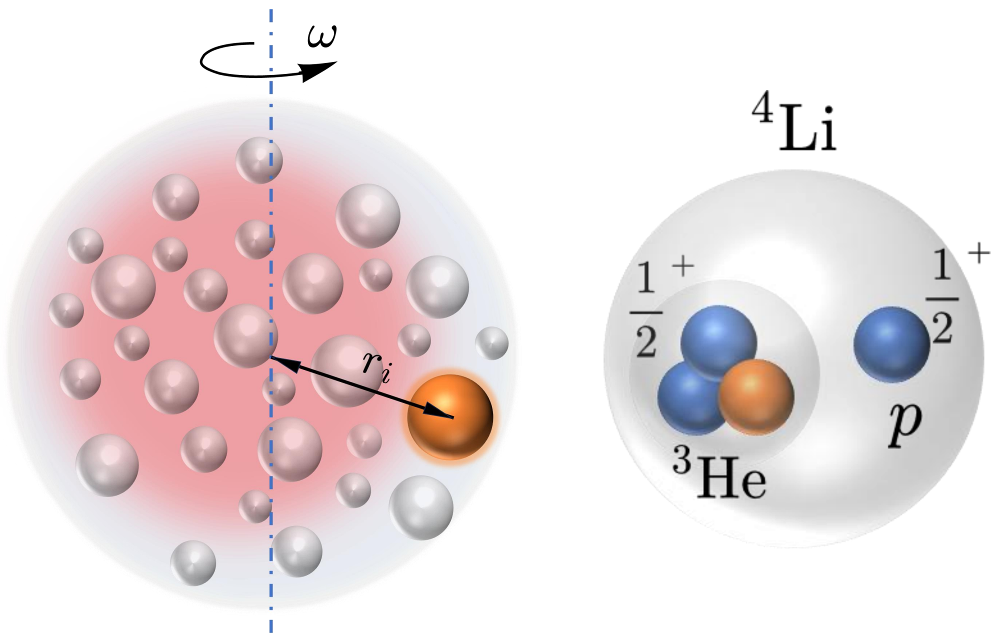
$$E\frac{\mathrm{d}^3N_{^4\mathrm{Li},J_z=m}}{\mathrm{d}\mathbf{K}^3} = E\int\left[\prod_{i=1,2,3,4} k_i^\mu \mathrm{d}^3\sigma_\mu \frac{\mathrm{d}^3k_i}{E_i}\bar{f}_i(\mathbf{x}_i,\mathbf{k}_i)\right] \times \mathrm{Tr}_s[\hat{W}(\mathbf{r}_1',\mathbf{k}_1',\mathbf{r}_2',\mathbf{k}_2',\mathbf{r}_3',\mathbf{k}_3';J_z=m) \times \hat{\sigma}_{p_1p_2p_3n}] \times \delta(\mathbf{K}-\sum_i \mathbf{k}_i).$$

$$W^{m_1m_2m_3m_4}_{\tilde{m}_1\tilde{m}_2\tilde{m}_3\tilde{m}_4} = \int d\eta_1' d\eta_2' d\eta_3' e^{-i(\eta_1'\mathbf{k}_1'+\eta_2'\mathbf{k}_2'+\eta_3'\mathbf{k}_3')} \times \left\langle \mathbf{r}_1'+\frac{\eta_1'}{2},\mathbf{r}_2'+\frac{\eta_2'}{2},\mathbf{r}_3'+\frac{\eta_3'}{2};\tilde{m}_1\ldots\tilde{m}_4|2,m\right\rangle_{\mathrm{rel}} \times \left\langle 2,m|\ \mathbf{r}_1'-\frac{\eta_1'}{2},\mathbf{r}_2'-\frac{\eta_2'}{2},\mathbf{r}_3'-\frac{\eta_3'}{2};m_1\ldots m_4\right\rangle_{\mathrm{rel}}.$$

（without hadron spin correlation）

$$\hat{\sigma}_{p_1p_2p_3n} = \hat{\sigma}_{p_1}\otimes\hat{\sigma}_{p_2}\otimes\hat{\sigma}_{p_3}\otimes\hat{\sigma}_n$$

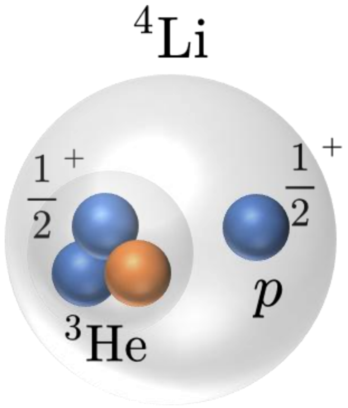
$$\hat{\sigma}_j = \mathrm{diag}[\frac{1+\mathcal{P}_j}{2},\frac{1-\mathcal{P}_j}{2}]$$



Single particle distribution in a vortical fluid

$$f(\mathbf{r}_i,\mathbf{k}_i) = \frac{2\xi_i}{(2\pi)^3}e^{-\frac{(\mathbf{k}_i-m\omega\times\mathbf{r}_i)^2}{2mT}}$$

Wavefunctions of ^{4}Li ground state in shell model



$$V = \frac{1}{2}m_1\omega^2 r_1^2 + \frac{1}{2}m_2\omega^2 r_2^2 + \frac{1}{2}m_3\omega^2 r_3^2 + \frac{1}{2}m_4\omega^2 r_4^2$$
$$= \frac{1}{2}M\omega^2 R^2 + \frac{1}{2}\mu_1\omega^2 {r'_1}^2 + \frac{1}{2}\mu_2\omega^2 {r'_2}^2 + \frac{1}{2}\mu_3\omega^2 {r'_3}^2$$

$$\langle \mathbf{r_1},\ldots,\mathbf{r_4}|2,2\rangle = \sqrt{\frac{1}{3!}}\begin{bmatrix} \phi^{L=1}_{M=1}(\mathbf{r_1})\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_1} & \phi^{L=1}_{M=1}(\mathbf{r_2})\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_2} & \phi^{L=1}_{M=1}(\mathbf{r_3})\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_3} \\ \phi^{L=0}_{M=0}(\mathbf{r_1})\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_1} & \phi^{L=0}_{M=0}(\mathbf{r_2})\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_2} & \phi^{L=0}_{M=0}(\mathbf{r_3})\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_3} \\ \phi^{L=0}_{M=0}(\mathbf{r_1})\left|\frac{1}{2},-\frac{1}{2}\right\rangle_{p_1} & \phi^{L=0}_{M=0}(\mathbf{r_2})\left|\frac{1}{2},-\frac{1}{2}\right\rangle_{p_2} & \phi^{L=0}_{M=0}(\mathbf{r_3})\left|\frac{1}{2},-\frac{1}{2}\right\rangle_{p_3} \end{bmatrix}\phi^{L=0}_{M=0}(\mathbf{r_4})\left|\frac{1}{2},\frac{1}{2}\right\rangle_n$$

$$= \sqrt{\frac{1}{6}}(\phi^{L=1}_{M=1}(\mathbf{r_1})\phi^{L=0}_{M=0}(\mathbf{r_2})\phi^{L=0}_{M=0}(\mathbf{r_3})\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_1}\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_2}\left|\frac{1}{2},-\frac{1}{2}\right\rangle_{p_3}$$
$$-\phi^{L=1}_{M=1}(\mathbf{r_1})\phi^{L=0}_{M=0}(\mathbf{r_2})\phi^{L=0}_{M=0}(\mathbf{r_3})\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_1}\left|\frac{1}{2},-\frac{1}{2}\right\rangle_{p_2}\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_3}$$
$$+\phi^{L=1}_{M=1}(\mathbf{r_3})\phi^{L=0}_{M=0}(\mathbf{r_1})\phi^{L=0}_{M=0}(\mathbf{r_2})\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_3}\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_1}\left|\frac{1}{2},-\frac{1}{2}\right\rangle_{p_2}$$
$$-\phi^{L=1}_{M=1}(\mathbf{r_2})\phi^{L=0}_{M=0}(\mathbf{r_1})\phi^{L=0}_{M=0}(\mathbf{r_3})\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_2}\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_1}\left|\frac{1}{2},-\frac{1}{2}\right\rangle_{p_3}$$
$$-\phi^{L=1}_{M=1}(\mathbf{r_3})\phi^{L=0}_{M=0}(\mathbf{r_2})\phi^{L=0}_{M=0}(\mathbf{r_1})\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_3}\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_2}\left|\frac{1}{2},-\frac{1}{2}\right\rangle_{p_1}$$
$$+\phi^{L=1}_{M=1}(\mathbf{r_2})\phi^{L=0}_{M=0}(\mathbf{r_3})\phi^{L=0}_{M=0}(\mathbf{r_1})\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_2}\left|\frac{1}{2},\frac{1}{2}\right\rangle_{p_3}\left|\frac{1}{2},-\frac{1}{2}\right\rangle_{p_1})\phi^{L=0}_{M=0}(\mathbf{r_n})\left|\frac{1}{2},\frac{1}{2}\right\rangle_n$$

One dimension harmonic oscillator wavefunction

$$\phi_0 = \frac{1}{\sqrt{b\sqrt{\pi}}}\exp\left[-\frac{x^2}{2b^2}\right]$$

$$\phi_1 = \sqrt{\frac{2}{b\sqrt{\pi}}}\frac{x}{b}\exp\left[-\frac{x^2}{2b^2}\right]$$

Construct three dimension harmonic oscillator wavefunction

$$\phi^{L=1}_{M=1}(\mathbf{r}) = \frac{1}{\sqrt{2}}[\phi_1(x)\phi_0(y) + i\phi_0(x)\phi_1(y)]\phi_0(z)$$

$$\phi^{L=1}_{M=-1}(\mathbf{r}) = \phi^{L=1}_{M=1}(\mathbf{r})^*$$

$$\phi^{L=1}_{M=0}(\mathbf{r}) = \phi_0(x)\phi_0(y)\phi_1(z)$$

A. J. Baltz and C. Dover, Phys. Rev. C 53, 362 (1996)

Decay angular distribution for $^4\mathrm{Li}(2^-)$ state

Productions of the ground states with defferent J_z

$$N_{^4Li,J_z=2} \approx 8\frac{N_p^3 N_n}{V^3}\left(\frac{2\pi}{mT}\right)^{\frac{9}{2}}\frac{(1+\mathcal{P}_N)^3(1-\mathcal{P}_N)}{16}\left(1+2\mathcal{P}_L+2\mathcal{P}_L^2\right).$$

$$N_{^4Li,J_z=1} \approx 8\frac{N_p^3 N_n}{V^3}\left(\frac{2\pi}{mT}\right)^{\frac{9}{2}}\left(\frac{1}{2}\frac{(1+\mathcal{P}_N)^2(1-\mathcal{P}_N)^2}{16}\left(1+2\mathcal{P}_L+2\mathcal{P}_L^2\right) + \frac{1}{2}\frac{(1+\mathcal{P}_N)^3(1-\mathcal{P}_N)}{16}\right),$$

$$N_{^4Li,J_z=0} \approx 8\frac{N_p^3 N_n}{V^3}\left(\frac{2\pi}{mT}\right)^{\frac{9}{2}}\left(\frac{1}{6}\frac{(1+\mathcal{P}_N)^3(1-\mathcal{P}_N)}{16}\left(1-2\mathcal{P}_L+2\mathcal{P}_L^2\right) + \frac{2}{3}\frac{(1+\mathcal{P}_N)^2(1-\mathcal{P}_N)^2}{16} + \frac{1}{6}\frac{(1+\mathcal{P}_N)(1-\mathcal{P}_N)^3}{16}\left(1+2\mathcal{P}_L+2\mathcal{P}_L^2\right)\right),$$

$$N_{^4Li,J_z=-1} \approx 8\frac{N_p^3 N_n}{V^3}\left(\frac{2\pi}{mT}\right)^{\frac{9}{2}}\left(\frac{1}{2}\frac{(1+\mathcal{P}_N)^2(1-\mathcal{P}_N)^2}{16}\left(1-2\mathcal{P}_L+2\mathcal{P}_L^2\right) + \frac{1}{2}\frac{(1+\mathcal{P}_N)(1-\mathcal{P}_N)^3}{16}\right),$$

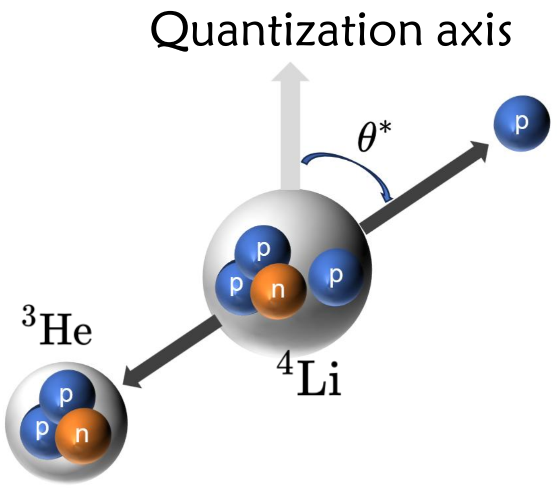
$$N_{^4Li,J_z=-2} \approx 8\frac{N_p^3 N_n}{V^3}\left(\frac{2\pi}{mT}\right)^{\frac{9}{2}}\frac{(1+\mathcal{P}_N)(1-\mathcal{P}_N)^3}{16}\left(1-2\mathcal{P}_L+2\mathcal{P}_L^2\right).$$

polarization of orbital motion $\mathcal{P}_L \approx \dfrac{\omega}{2T}$

$$\hat{\rho}\left(^4\mathrm{Li}(2^-)\right) = \mathrm{diag}\left[\frac{3(\mathcal{P}_N+1)^2(2\mathcal{P}_L(\mathcal{P}_L+1)+1)}{4\left(2\mathcal{P}_N^2+5\right)\mathcal{P}_L^2+20\mathcal{P}_N\mathcal{P}_L+5\left(\mathcal{P}_N^2+3\right)}, \frac{3\left(-\mathcal{P}_L(\mathcal{P}_L+1)\mathcal{P}_N^2+\mathcal{P}_N+\mathcal{P}_L^2+\mathcal{P}_L+1\right)}{4\left(2\mathcal{P}_N^2+5\right)\mathcal{P}_L^2+20\mathcal{P}_N\mathcal{P}_L+5\left(\mathcal{P}_N^2+3\right)}, \frac{-\mathcal{P}_N^2-4\mathcal{P}_L\mathcal{P}_N+2\left(\mathcal{P}_N^2+1\right)\mathcal{P}_L^2+3}{4\left(2\mathcal{P}_N^2+5\right)\mathcal{P}_L^2+20\mathcal{P}_N\mathcal{P}_L+5\left(\mathcal{P}_N^2+3\right)}, -\frac{3(\mathcal{P}_N-1)((\mathcal{P}_N+1)(\mathcal{P}_L-1)\mathcal{P}_L+1)}{4\left(2\mathcal{P}_N^2+5\right)\mathcal{P}_L^2+20\mathcal{P}_N\mathcal{P}_L+5\left(\mathcal{P}_N^2+3\right)}, \frac{3(\mathcal{P}_N-1)^2(2(\mathcal{P}_L-1)\mathcal{P}_L+1)}{4\left(2\mathcal{P}_N^2+5\right)\mathcal{P}_L^2+20\mathcal{P}_N\mathcal{P}_L+5\left(\mathcal{P}_N^2+3\right)}\right],$$

$$T = \sqrt{\frac{3}{8\pi}}\begin{bmatrix} -\sin\theta^* e^{i\phi^*} & 0 & 0 & 0 \\ \cos\theta^* & -\frac{1}{2}\sin\theta^* e^{i\phi^*} & -\frac{1}{2}\sin\theta^* e^{i\phi^*} & 0 \\ \sqrt{\frac{1}{6}}\sin\theta^* e^{-i\phi^*} & \sqrt{\frac{2}{3}}\cos\theta^* & \sqrt{\frac{2}{3}}\cos\theta^* & -\sqrt{\frac{1}{6}}\sin\theta^* e^{i\phi^*} \\ 0 & \frac{1}{2}\sin\theta^* e^{-i\phi^*} & \frac{1}{2}\sin\theta^* e^{-i\phi^*} & \cos\theta^* \\ 0 & 0 & 0 & \sin\theta^* e^{-i\phi^*} \end{bmatrix},$$

$$\frac{dN}{\sin\theta^* d\theta^*} = \frac{1}{2} + \left(\frac{3}{8}\hat{\rho}_{1,1} + \frac{3}{8}\hat{\rho}_{-1,-1} + \frac{1}{2}\hat{\rho}_{0,0} - \frac{1}{4}\right)\left(3\cos^2\theta^* - 1\right)$$
$$\approx \frac{1}{2}\left[1 - \frac{7}{30}\left(\mathcal{P}_N^2 + 4\mathcal{P}_N\mathcal{P}_L + \mathcal{P}_L^2\right)\left(3\cos^2\theta^* - 1\right)\right].$$



Decay angular distribution for ^{4}Li excited states

Decay angular distribution for $^4\mathrm{Li}(^3P_1)$ state

$$\hat{\rho}(^4\mathrm{Li}(^3P_1)) = [\frac{-\mathcal{P}_L(\mathcal{P}_L+1)\mathcal{P}_N^2+\mathcal{P}_N+\mathcal{P}_L^2+\mathcal{P}_L+1}{(\mathcal{P}_N-2\mathcal{P}_L)^2+3}, \frac{\mathcal{P}_N^2-4\mathcal{P}_L\mathcal{P}_N+2\left(\mathcal{P}_N^2+1\right)\mathcal{P}_L^2+1}{(\mathcal{P}_N-2\mathcal{P}_L)^2+3}, -\frac{(\mathcal{P}_N-1)((\mathcal{P}_N+1)(\mathcal{P}_L-1)\mathcal{P}_L+1)}{(\mathcal{P}_N-2\mathcal{P}_L)^2+3}].$$

$$\hat{T}(^4\mathrm{Li}(^3P_1) \to ^3\mathrm{He}+p) = \sqrt{\frac{3}{8\pi}}\begin{bmatrix} -\cos\theta^* & -\frac{1}{2}\sin\theta^* e^{i\phi^*} & -\frac{1}{2}\sin\theta^* e^{i\phi^*} & 0 \\ -\sqrt{\frac{1}{2}}\sin\theta^* e^{-i\phi^*} & 0 & 0 & -\sqrt{\frac{1}{2}}\sin\theta^* e^{i\phi^*} \\ 0 & -\frac{1}{2}\sin\theta^* e^{-i\phi^*} & -\frac{1}{2}\sin\theta^* e^{-i\phi^*} & \cos\theta^* \end{bmatrix}$$

$$\frac{dN}{\sin\theta^* d\theta^*} = \frac{1}{2} - \frac{3}{8}(\hat{\rho}_{0,0} - \frac{1}{3})(3\cos^2\theta^* - 1)$$

$$\approx \frac{1}{2}\left(1 - \frac{1}{6}(\mathcal{P}_N^2 - 4\mathcal{P}_N\mathcal{P}_L + \mathcal{P}_L^2)(3\cos^2\theta^* - 1)\right),$$

Decay angular distribution for $^4\mathrm{Li}(^1P_1)$ state

$$\hat{\rho}(^4\mathrm{Li}(^1P_1)) = \begin{bmatrix} \frac{2\mathcal{P}_L(\mathcal{P}_L+1)+1}{4\mathcal{P}_L^2+3} & 0 & 0 \\ 0 & \frac{1}{4\mathcal{P}_L^2+3} & 0 \\ 0 & 0 & \frac{2(\mathcal{P}_L-1)\mathcal{P}_L+1}{4\mathcal{P}_L^2+3} \end{bmatrix}$$

$$\hat{T}(^4\mathrm{Li}(^1P_1) \to ^3\mathrm{He}+p) = \sqrt{\frac{3}{8\pi}}\begin{bmatrix} 0 & -\sqrt{\frac{1}{2}}\sin\theta^* e^{i\phi^*} & \sqrt{\frac{1}{2}}\sin\theta^* e^{i\phi^*} & 0 \\ 0 & \cos\theta^* & -\cos\theta^* & 0 \\ 0 & \sqrt{\frac{1}{2}}\sin\theta^* e^{-i\phi^*} & -\sqrt{\frac{1}{2}}\sin\theta^* e^{-i\phi^*} & 0 \end{bmatrix}$$

$$\frac{dN}{\sin\theta^* d\theta^*} = \frac{1}{2} + \frac{3}{4}(\hat{\rho}_{0,0} - \frac{1}{3})(3\cos^2\theta^* - 1)$$

$$\approx \frac{1}{2}\left(1 - \frac{2}{3}\mathcal{P}_L^2(3\cos^2\theta^* - 1)\right)$$

State	E (MeV)	Structure	L	Decay mode	Γ(MeV)	$\frac{dN}{\sin\theta^* d\theta^*}$
$^4\mathrm{Li}(^3P_2)$	g.s.	$^3\mathrm{He}(\frac{1}{2}^+) - p(\frac{1}{2}^+)$	1	$^4\mathrm{Li} \to {}^3\mathrm{He} + p$	6.03	$\frac{1}{2}\left(1 - \frac{7}{30}\left(\mathcal{P}_N^2 + 4\mathcal{P}_N\mathcal{P}_L + \mathcal{P}_L^2\right)(3\cos^2\theta^* - 1)\right)$
$^4\mathrm{Li}(^3P_1)$	0.32	$^3\mathrm{He}(\frac{1}{2}^+) - p(\frac{1}{2}^+)$	1	$^4\mathrm{Li} \to {}^3\mathrm{He} + p$	7.35	$\frac{1}{2}\left(1 - \frac{1}{6}\left(\mathcal{P}_N^2 - 4\mathcal{P}_N\mathcal{P}_L + \mathcal{P}_L^2\right)(3\cos^2\theta^* - 1)\right)$
$^4\mathrm{Li}(^1P_0)$	2.08	$^3\mathrm{He}(\frac{1}{2}^+) - p(\frac{1}{2}^+)$	1	$^4\mathrm{Li} \to {}^3\mathrm{He} + p$	9.35	$\frac{1}{2}$
$^4\mathrm{Li}(^1P_1)$	2.85	$^3\mathrm{He}(\frac{1}{2}^+) - p(\frac{1}{2}^+)$	1	$^4\mathrm{Li} \to {}^3\mathrm{He} + p$	13.51	$\frac{1}{2}\left(1 - \frac{2}{3}\mathcal{P}_L^2(3\cos^2\theta^* - 1)\right)$

Averaged decay angular distribution : $\frac{dN}{\sin\theta d\theta} = \frac{1}{2}\left(1 - \frac{1}{36}\left(5\mathcal{P}_N^2 + 8\mathcal{P}_N\mathcal{P}_L + 11\mathcal{P}_L^2\right)(3\cos^2\theta - 1)\right)$

^{4}Li decay angular distribution within thermal model

$$\hat{\rho}(^4\mathrm{Li}(2^-)) = \frac{1}{1 + 2\cosh(\frac{\omega}{T}) + 2\cosh(\frac{2\omega}{T})}\begin{bmatrix} e^{\frac{2\omega}{T}} & 0 & 0 & 0 & 0 \\ 0 & e^{\frac{\omega}{T}} & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & e^{-\frac{\omega}{T}} & 0 \\ 0 & 0 & 0 & 0 & e^{-\frac{2\omega}{T}} \end{bmatrix}, \hat{\rho}(^4\mathrm{Li}(1^-)) = \frac{1}{1 + 2\cosh(\frac{\omega}{T})}\begin{bmatrix} e^{\frac{\omega}{T}} & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & e^{-\frac{\omega}{T}} \end{bmatrix}, \hat{\rho}(^4\mathrm{Li}(0^-)) = 1.$$

Let $\mathcal{P} = \frac{\omega}{2T}$,

Averaged decay angular distribution from thermal model

$\mathcal{P}_L = \mathcal{P}_N = \mathcal{P}$

$$\frac{dN}{\sin\theta d\theta} = \frac{1}{2}\left(1 - \frac{2}{3}\mathcal{P}^2(3\cos^2\theta - 1)\right)$$

Summary and outlook

1. The coalescence of polarized nucleons results in polarized light nuclei, the polarization of unstable nuclei can be measured.
2. We calculate the decay angular distribution of $^4\mathrm{Li}$ which can be measured experimentally.
3. These results provide a viable probe to study nucleon polarization and the vortical structure of nuclear matter.

State	E (MeV)	Structure	L	Decay mode	Γ(MeV)	$\frac{dN}{\sin\theta^* d\theta^*}$
$^4\mathrm{Li}(^3P_2)$	g.s.	$^3\mathrm{He}(\frac{1}{2}^+) - p(\frac{1}{2}^+)$	1	$^4\mathrm{Li} \to {}^3\mathrm{He} + p$	6.03	$\frac{1}{2}\left(1 - \frac{7}{30}\left(\mathcal{P}_N^2 + 4\mathcal{P}_N\mathcal{P}_L + \mathcal{P}_L^2\right)(3\cos^2\theta^* - 1)\right)$
$^4\mathrm{Li}(^3P_1)$	0.32	$^3\mathrm{He}(\frac{1}{2}^+) - p(\frac{1}{2}^+)$	1	$^4\mathrm{Li} \to {}^3\mathrm{He} + p$	7.35	$\frac{1}{2}\left(1 - \frac{1}{6}\left(\mathcal{P}_N^2 - 4\mathcal{P}_N\mathcal{P}_L + \mathcal{P}_L^2\right)(3\cos^2\theta^* - 1)\right)$
$^4\mathrm{Li}(^1P_0)$	2.08	$^3\mathrm{He}(\frac{1}{2}^+) - p(\frac{1}{2}^+)$	1	$^4\mathrm{Li} \to {}^3\mathrm{He} + p$	9.35	$\frac{1}{2}$
$^4\mathrm{Li}(^1P_1)$	2.85	$^3\mathrm{He}(\frac{1}{2}^+) - p(\frac{1}{2}^+)$	1	$^4\mathrm{Li} \to {}^3\mathrm{He} + p$	13.51	$\frac{1}{2}\left(1 - \frac{2}{3}\mathcal{P}_L^2(3\cos^2\theta^* - 1)\right)$

Averaged decay angular distribution : $\frac{dN}{\sin\theta d\theta} = \frac{1}{2}\left(1 - \frac{1}{36}\left(5\mathcal{P}_N^2 + 8\mathcal{P}_N\mathcal{P}_L + 11\mathcal{P}_L^2\right)(3\cos^2\theta - 1)\right)$

Thanks for your attention !

$\mathcal{P}_N$: nucleon polarization

$\mathcal{P}_L = \frac{\omega}{2T}$: orbital motion polarization