Longitudinal Spin Polarization
in a Thermal Model with Dissipation

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Outline

Barnett Effect

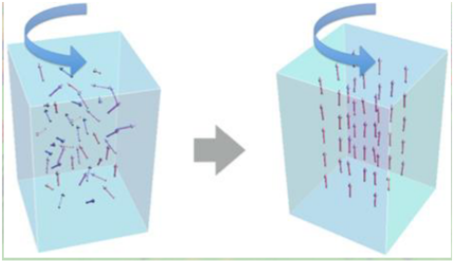


Figure: Mechanical rotation induces spin alignment. (Credit: Mike Lisa, OSU)

Barnett Effect

Mechanical rotation $\longrightarrow$ Spin alignment

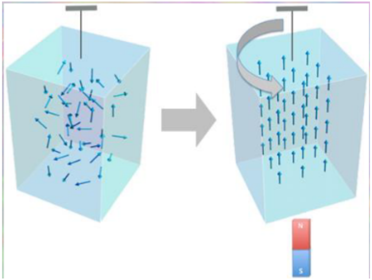


Figure: Magnetic field induces spin alignment. (Credit: Mike Lisa, OSU)

Einstein–de Haas Effect

Magnetic field $\longrightarrow$ Spin alignment

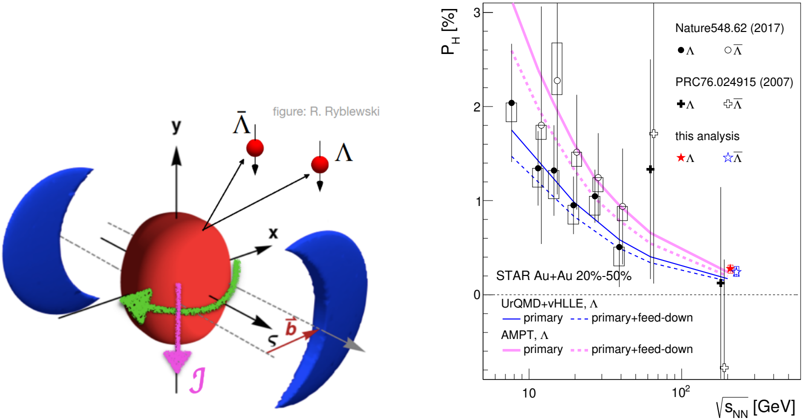
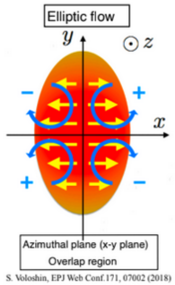
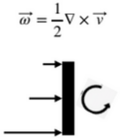
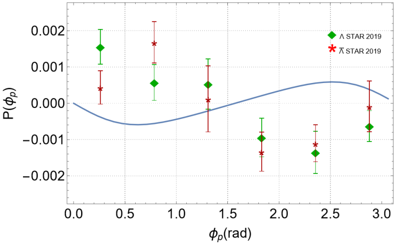


Figure: Global angular momentum. STAR, 2019. Phys. Rev. C 98, 014910

Local Polarization







Thermal Vorticity

$$\varpi_{\mu\nu} = -\frac{1}{2}\left(\partial_\mu \beta_\nu - \partial_\nu \beta_\mu\right)$$

Spin Hydrodynamics

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- $\partial_\mu S^{\mu,\nu\lambda} = 0$ (Spin conservation)

Pauli–Lubanski and the Polarization

- $$E_p \frac{d\Delta\Pi_\tau(x,p)}{d^3p} = -\frac{1}{2}\, \epsilon_{\tau\mu\nu\beta}\, \Delta\Sigma_\lambda\, E_p \frac{dS^{\lambda,\mu\nu}(\omega)}{d^3p}\, \frac{p^\beta}{m}.$$
- $$\langle P(\phi_p)\rangle = \frac{\int p_T\, dp_T\, E_p \frac{d\Pi^z(p)}{d^3p}}{\int d\phi_p\, p_T\, dp_T\, E_p \frac{dN(p)}{d^3p}}.$$
- $$E_p \frac{dN(p)}{d^3p} = \frac{4\cosh\xi}{(2\pi)^3} \int \Delta\Sigma_\lambda\, p^\lambda\, e^{-\beta\cdot p}, \quad \xi = \mu/T,\ \beta^\mu = \frac{u^\mu}{T}.$$
- $\omega \to \varpi$, and $\varpi_{0i} = 0$.
- $$E_p \frac{d\Pi_\tau(p)}{d^3p} = -\frac{1}{2} \frac{1}{(2\pi)^3 m} \int e^{-p\cdot\beta}\, \Delta\Sigma\cdot p\, \epsilon_{\tau\mu\nu\beta}$$
$$\times \left[\left\{ 1 + \frac{\tau_s}{(u\cdot p)}\, p^\rho p^\sigma\, (\xi_{\rho\sigma}) \right\} \omega^{\mu\nu} - \frac{\tau_s}{(u\cdot p)}\, p^\rho\, \partial_\rho\, \omega^{\mu\nu} \right] p^\beta.$$

Thermal Model Setup

- Single freeze-out model.
- $\tau_f^2 = t^2 - x^2 - y^2 - z^2$, with $x^2 + y^2 \leq r_{max}^2$.
- Asymmetric fireball boundary:

$$x = r_{\max}\sqrt{1-\epsilon}\,\cos\phi, \quad y = r_{\max}\sqrt{1+\epsilon}\,\sin\phi.$$

- Asymmetric hydrodynamic flow:

$$u^\mu = \frac{1}{N}\left(t,\ x\sqrt{1+\delta},\ y\sqrt{1-\delta},\ z\right), \quad N = \sqrt{\tau^2 - (x^2 - y^2)\delta}.$$

Ref: W. Broniowski, A. Baran, and W. Florkowski

Spin Polarization Results

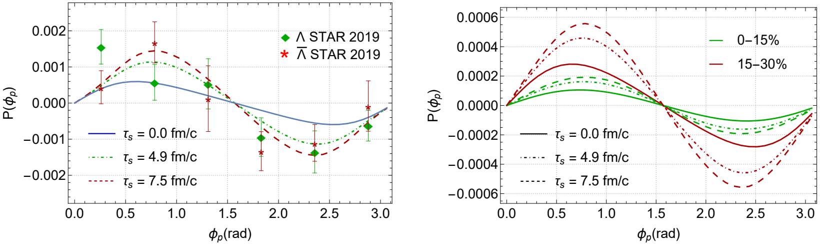

Figure: (Left) Comparison with STAR data for Λ and $\overline{\Lambda}$ hyperons. (Right) Predictions for different centralities.

Summary and Outlook

- Dissipative terms play a significant role in spin polarization.
- We have extracted the spin relaxation time.
- Ongoing work: full $(3+1)$-dimensional hydrodynamic evolution with spin.
- Study of polarization in spin-1 particles.

Thank You