# Search for axion-like particles at the FINESSE beamline

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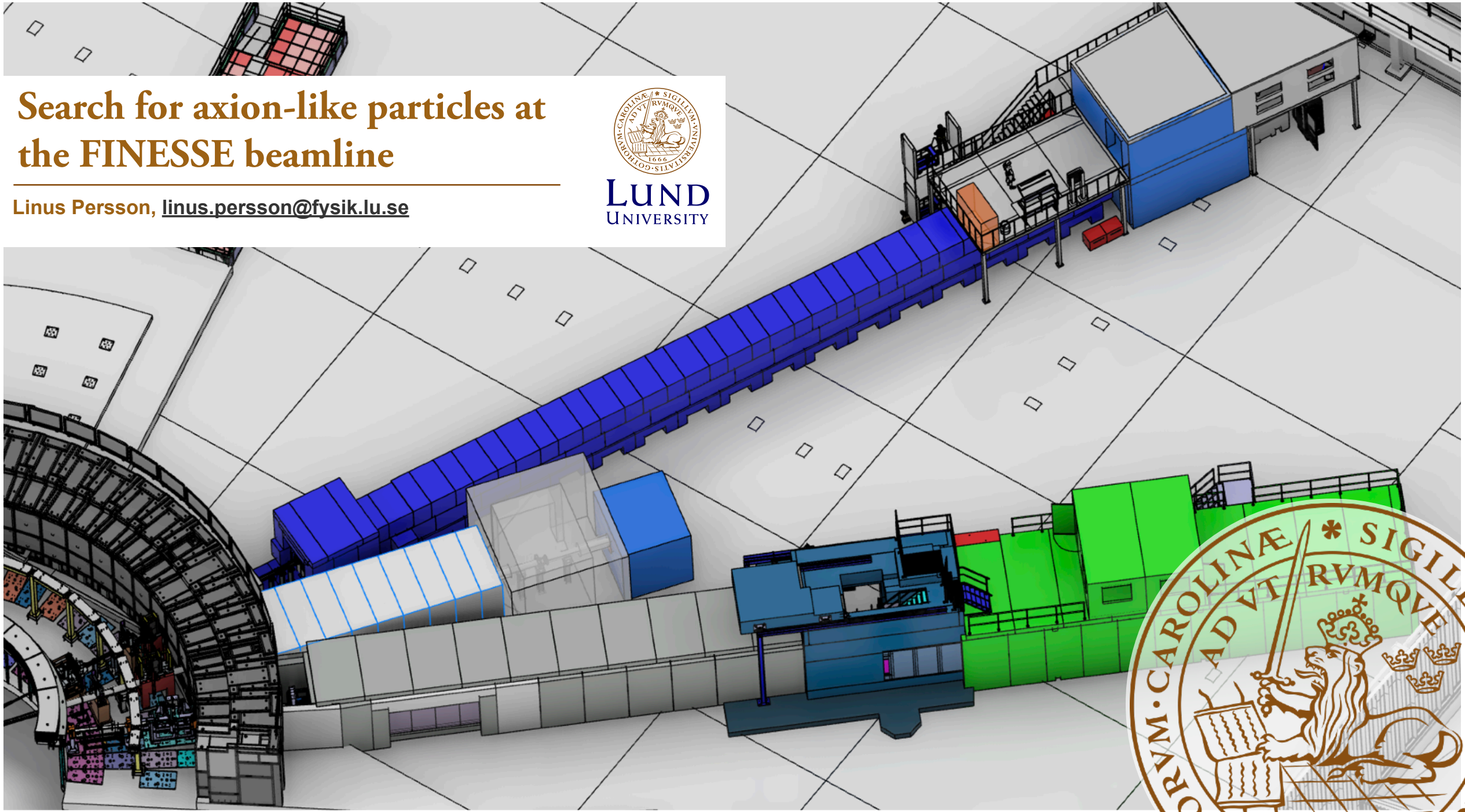
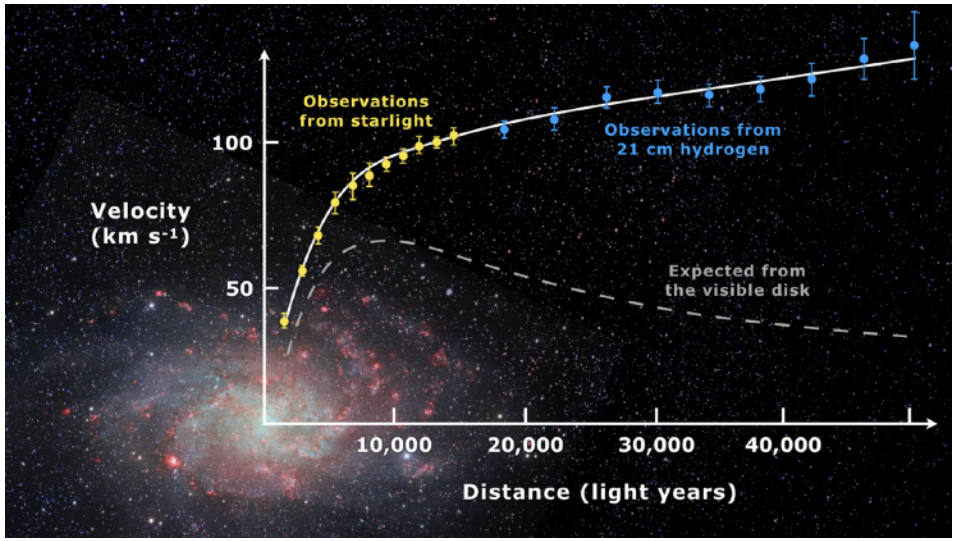


# Dark matter and the axion

- Based on galactic rotation curves, gravitational lensing and large-scale cosmological structure, dark matter is known to constitute ~25% of the Universe's energy density.
- Ultralight axion-like particles (≪eV mass) act as coherent fields. Can detect their wavelike properties using interferometry.
- A suitable day-1 experiment for the FINESSE beamline at ESS.

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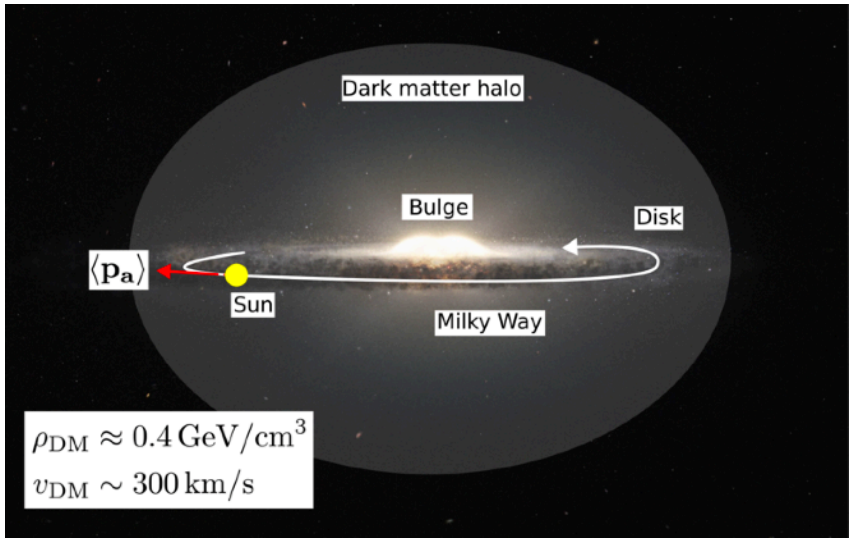


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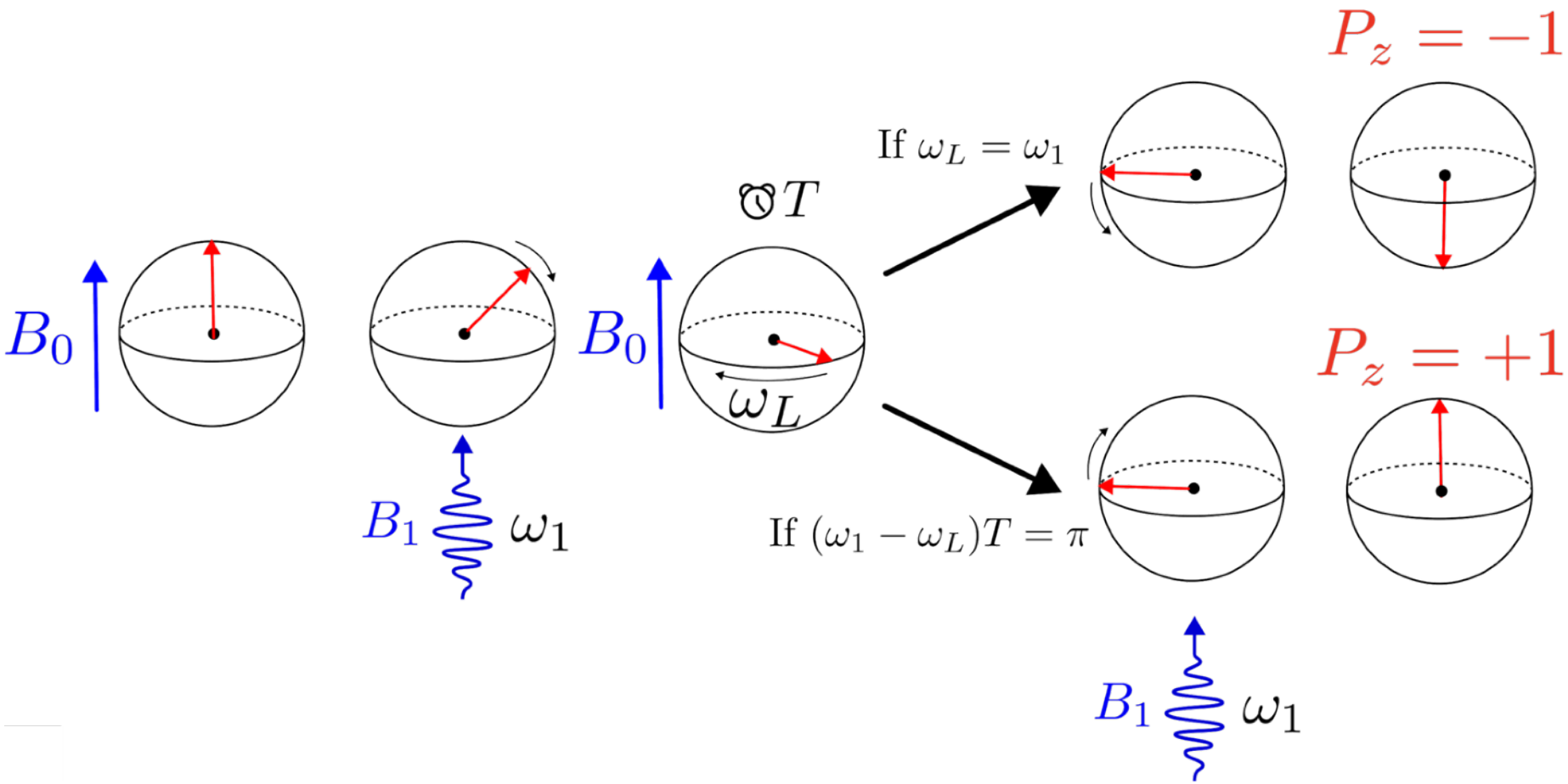
# Ramsey interferometry




Further reading: N. F. Ramsey. *Phys. Rev.* **78**, 695 (1950).

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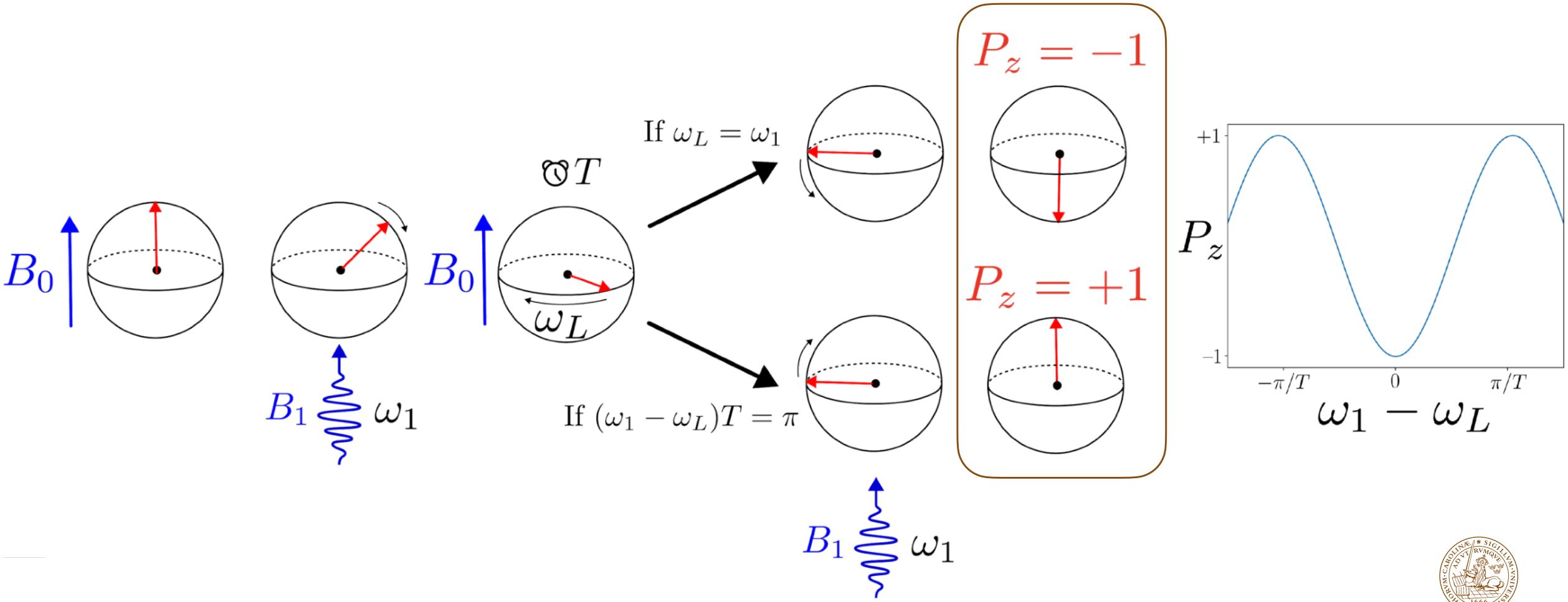
# Ramsey interferometry

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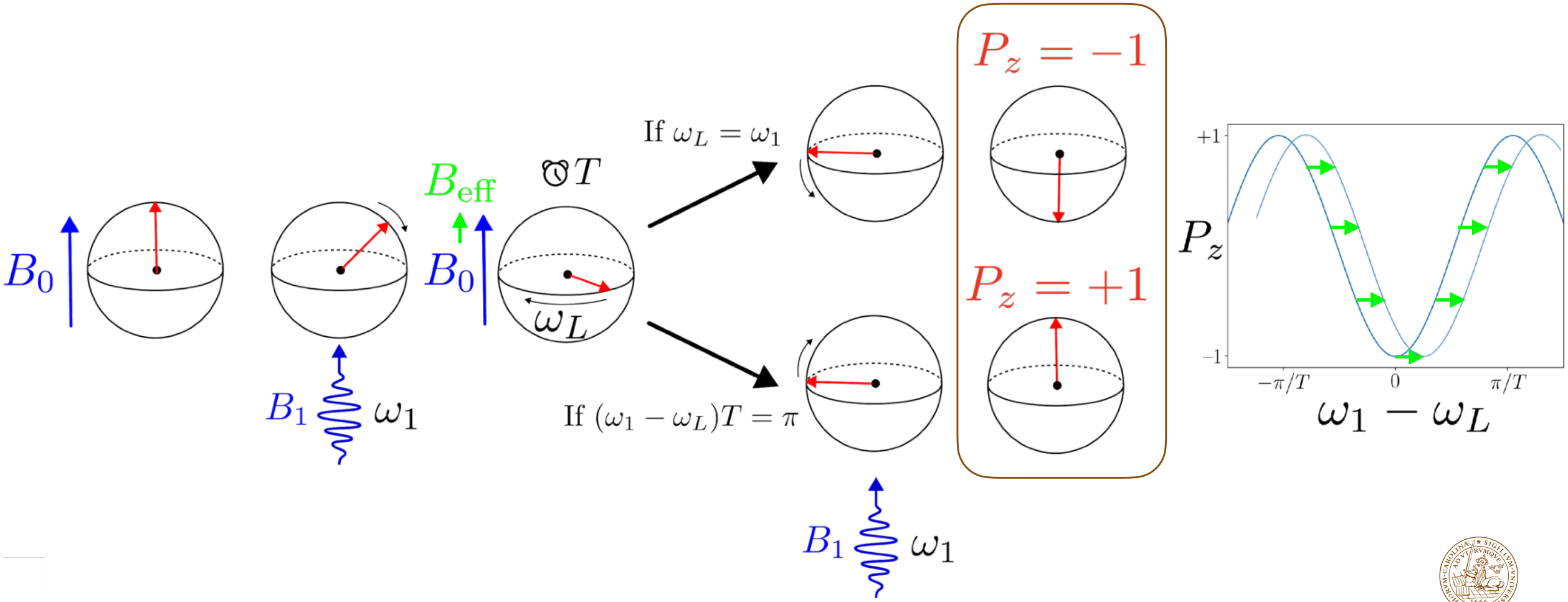
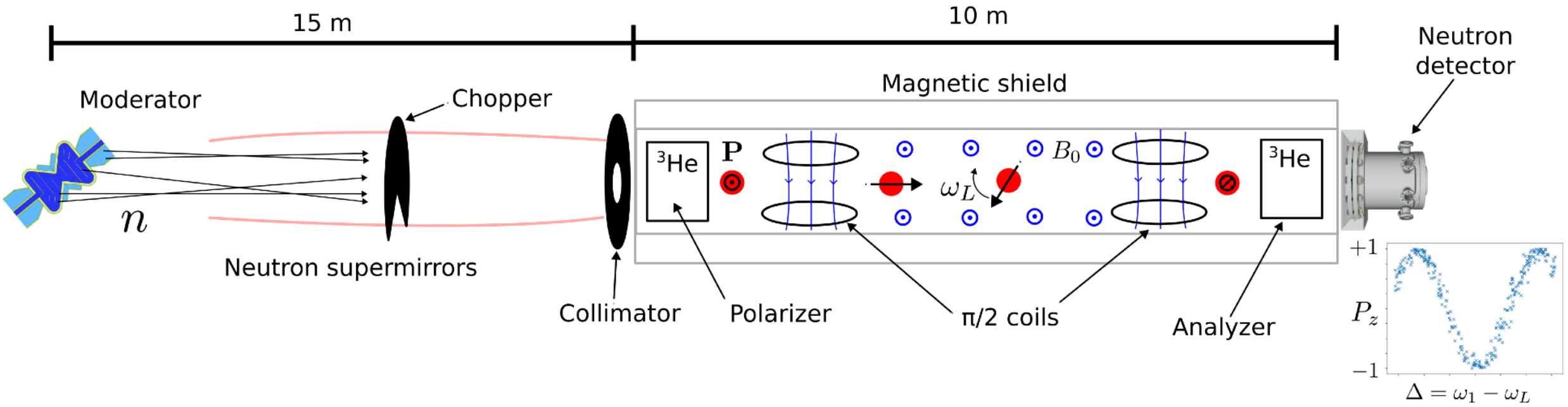
# Ramsey interferometry



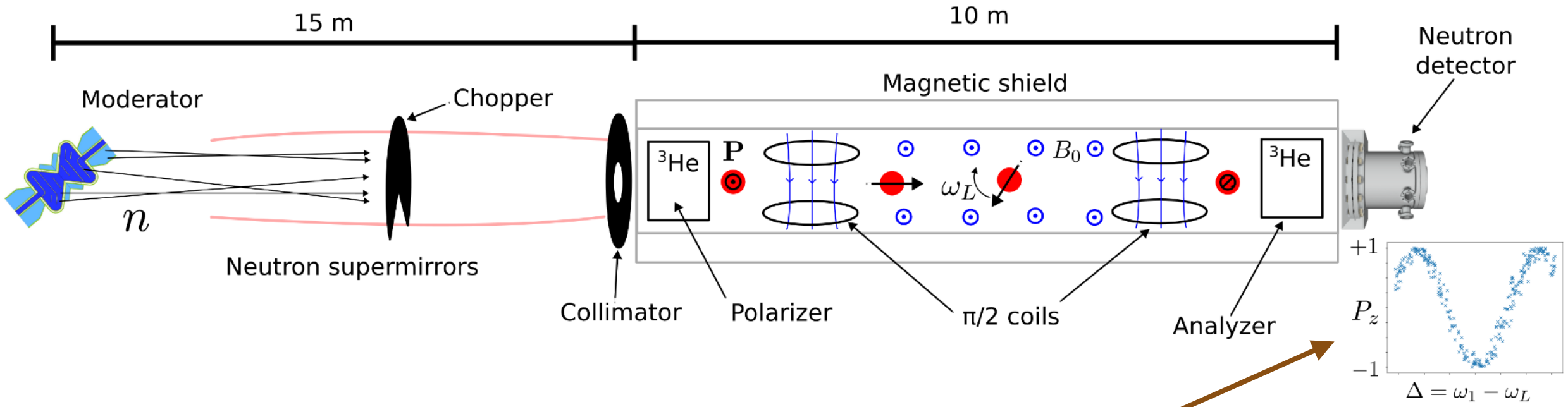

Further reading: N. F. Ramsey. *Phys. Rev.* **78**, 695 (1950).

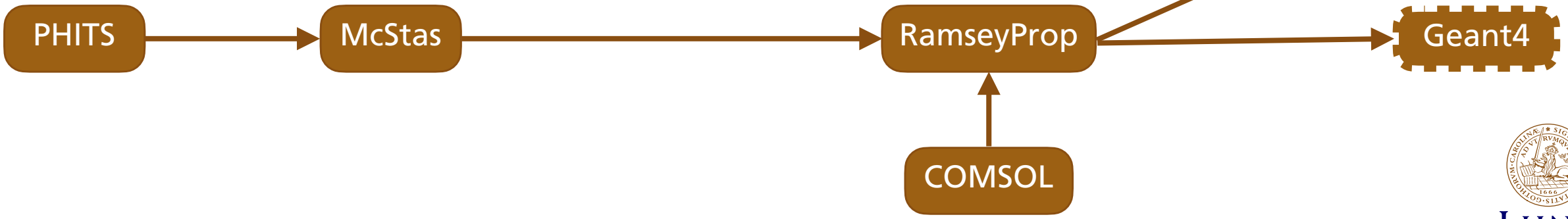
# A neutron beamline for Ramsey interferometry




Further reading: P. Fierlinger *et al*. *Phys. Rev. Lett.* **133**, 181001 (2024).

# A neutron beamline for Ramsey interferometry

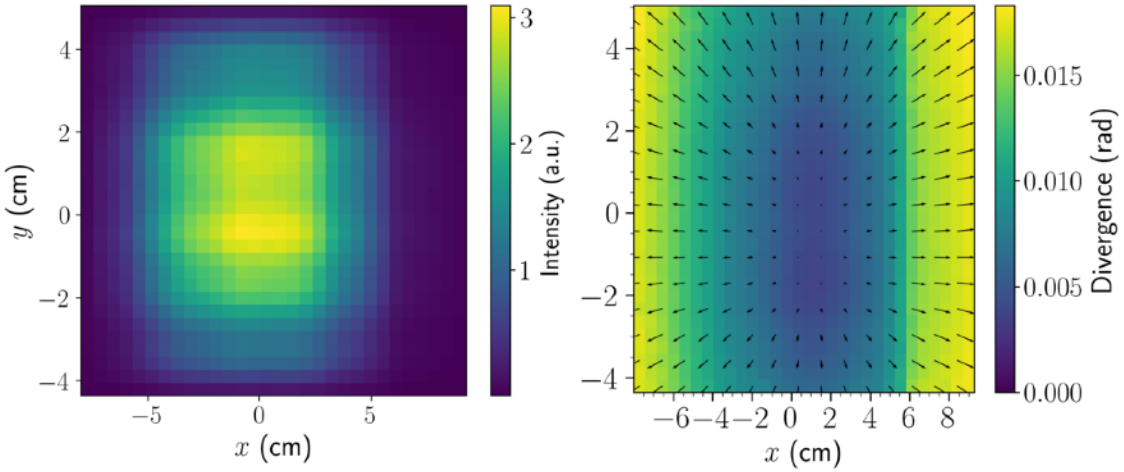


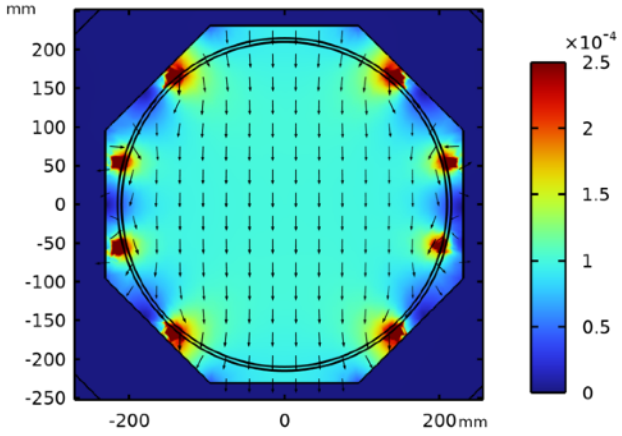

Further reading: P. Fierlinger *et al*. *Phys. Rev. Lett.* **133**, 181001 (2024).

# Magnetics and spin dynamics simulations

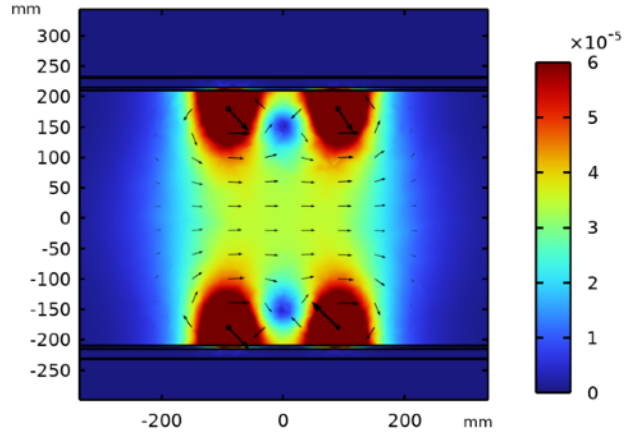
Neutron trajectories



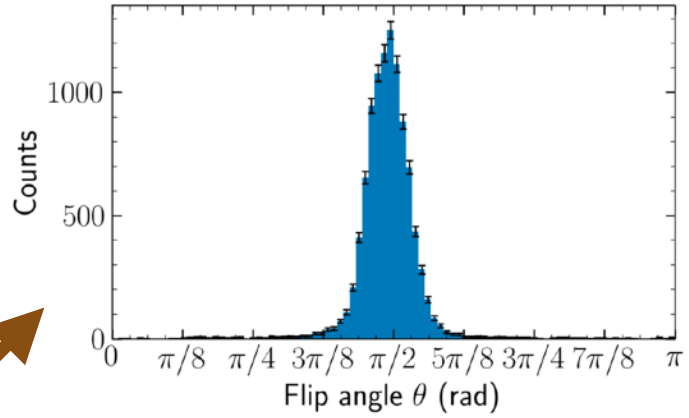

DC $B_0$-fields



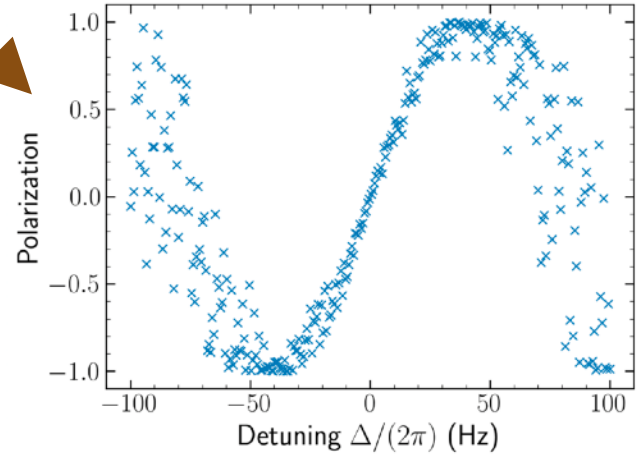

AC $B_1$-fields




RamseyProp




Spin-flip distributions

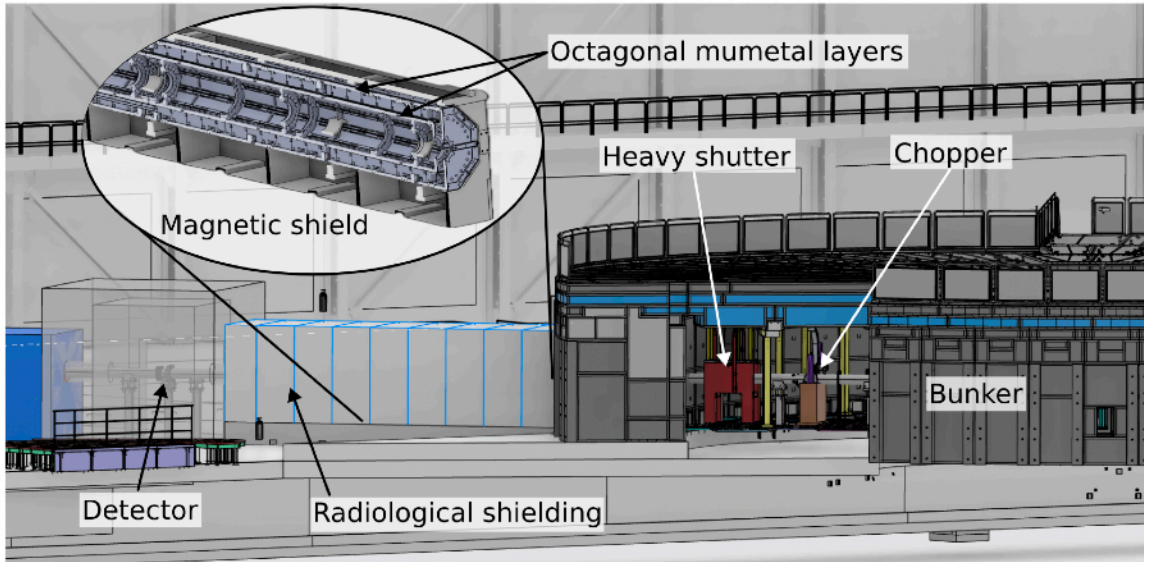


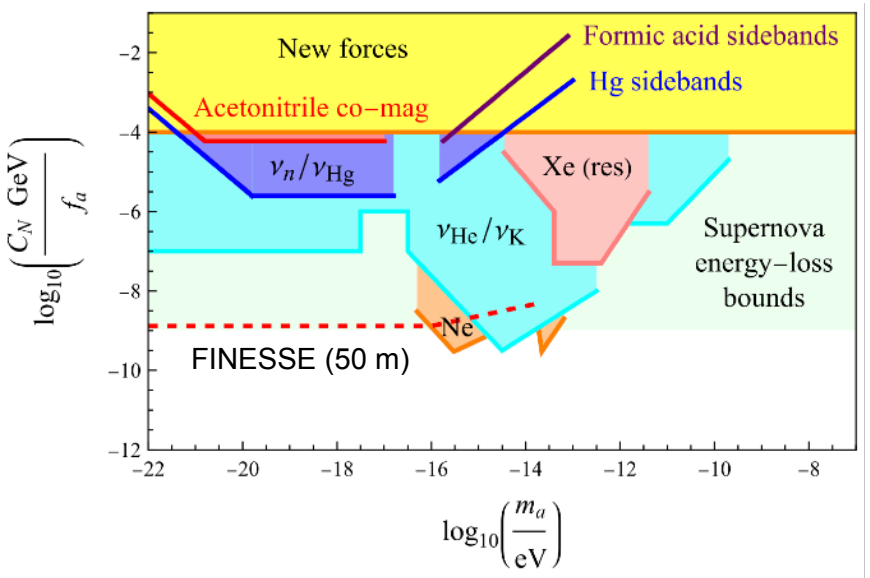

Ramsey fringes

Further reading: L.B. Persson, P. Fierlinger, M. Holl & V. Santoro (2026). arXiv: 2603.24049

# Conclusion and outlook

- Ultralight ALPs have wave-like signatures detectable by Ramsey interferometry.
- Already mostly funded by the Swedish Foundation for Strategic Research (15 MSEK) and Swedish Research Council (4.7 MSEK), intended for the FINESSE beamline.
- Ongoing work on neutronics, neutron optics, neutron detectors, polarization, magnetics and spin dynamics.
- A 10-meter magnetic shield prototype soon to be procured.

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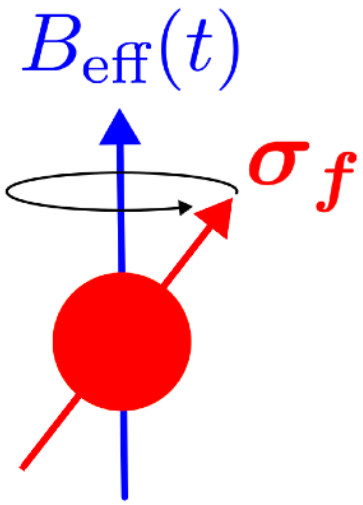
# Backup: Axion interaction with neutrons

$$\mathcal{L}_f = -\frac{C_f}{2f_a}\partial_i \left[a_0 \cos(m_a t - \boldsymbol{p_a}\cdot\boldsymbol{x})\right] \bar{f}\gamma^i\gamma^5 f$$

$$\Longrightarrow \quad H_{\text{eff}}(t) \propto \boldsymbol{\sigma_f}\cdot\boldsymbol{p_a}\sin(m_a t) \propto \boldsymbol{\sigma_f}\cdot\boldsymbol{B}_{\text{eff}}(t)$$

Axion interaction leads to spin precession!




Further reading: Y. V. Stadnik & V. V. Flumbaum. *Phys. Rev. D.* **89**, 043522 (2014).

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