Towards axion searches with polarized hadron beams at GSI/FAIR

Daoning Gu, Andreas Lehrach, Jörg Pretz on behalf of the JEDI Collaboration

1. GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany, 2. Forschungszentrum Jülich, Jülich, Germany, 3. RWTH Aachen University, Aachen, Germany.

Introduction

❖ Spin motion in storage rings:

$$\frac{d\vec{s}}{dt} = \left(\vec{\Omega}_{MDM} + \vec{\Omega}_{EDM} + \vec{\Omega}_{wind}\right) \times \vec{s}$$

$$\vec{\Omega}_{MDM} = -\frac{q}{m} G\vec{B}, \qquad \vec{\Omega}_{EDM} = -\frac{1}{S\hbar} dc\vec{\beta} \times \vec{B}.$$

$$d = d_{DC} + d_{AC}\cos(\omega_a t + \varphi_o)$$

oEDM induced by axion field

Spin Coherence Time (SCT)

❖ Spin tune: $\nu_s = G\gamma$.

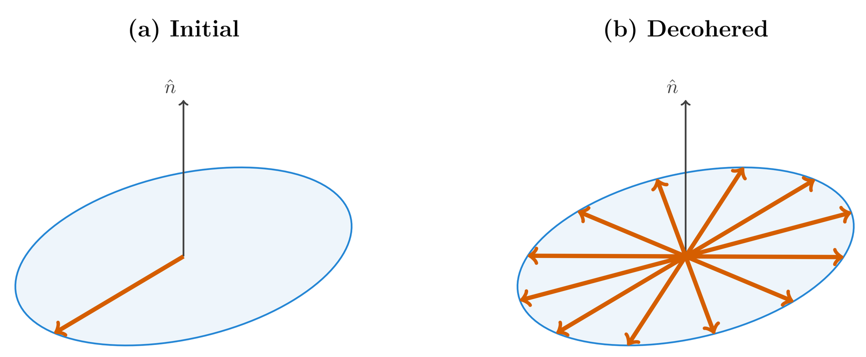
❖ SCT: time after total polarization drops to 1/e.

❖ Optimization:

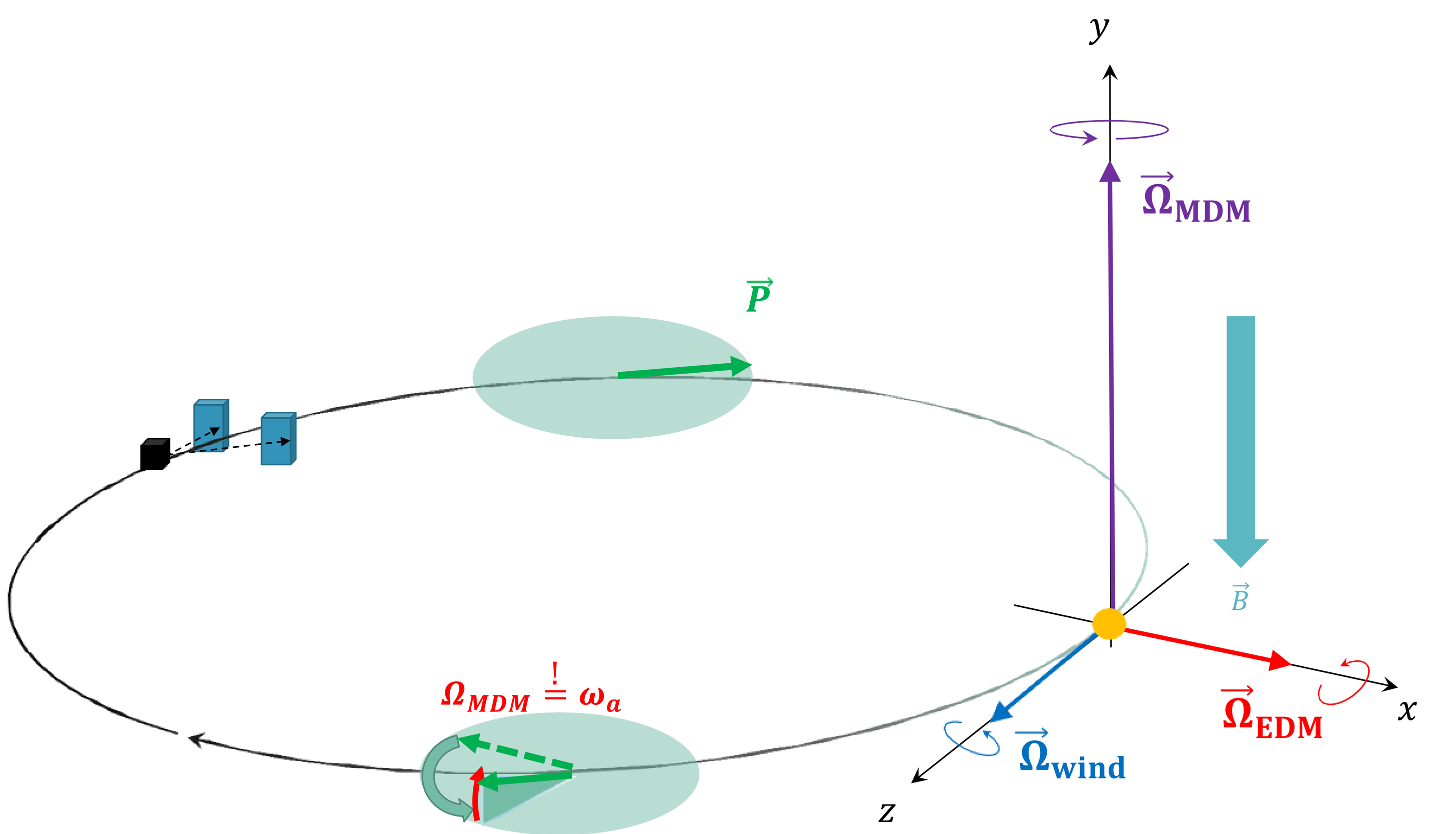
① Electron cooling.

② Beam bunching.

③ Sextupole correction.



Experimental Method

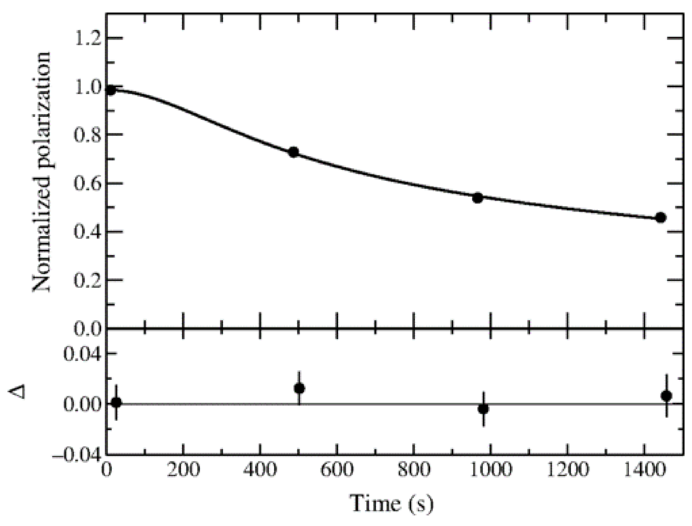


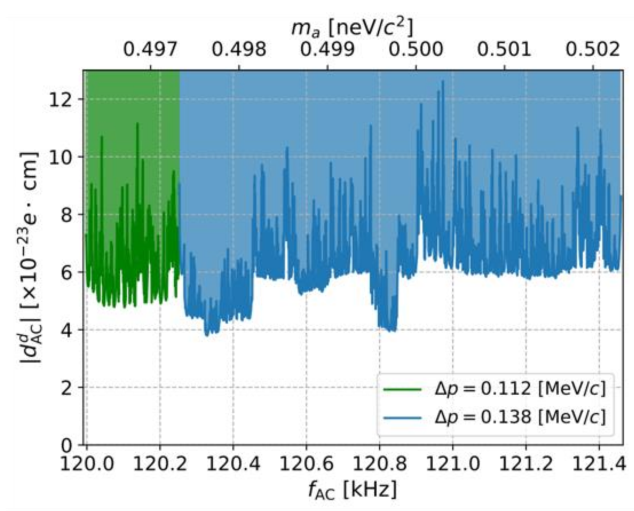
❖ Store polarized hadrons.

❖ If $m_a c^2 \equiv \hbar\omega_a = \Omega_{MDM}\hbar$, the spin tilts out of the horizontal plane into an experimentally observable vertical polarization.

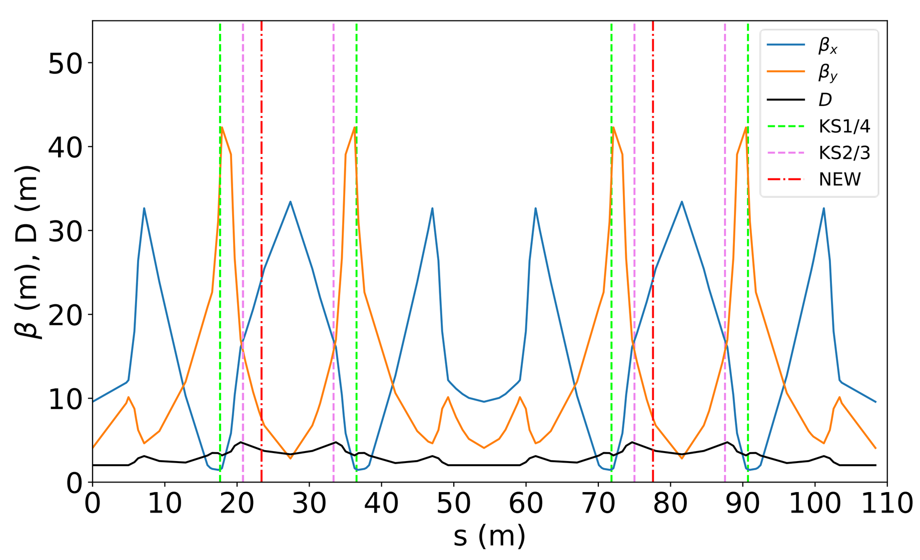
❖ Long spin coherence time is required to preserve polarization.

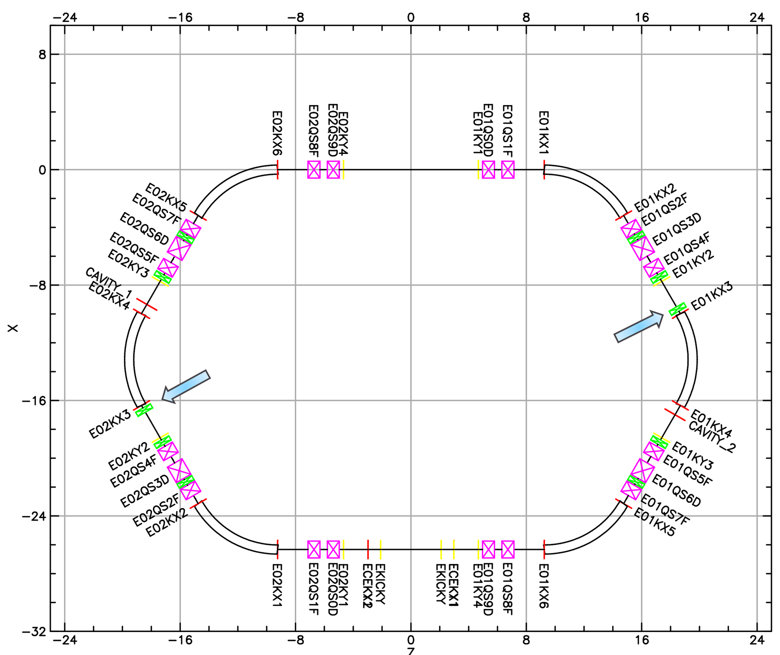
❖ First proof-of-principle experiment was performed with a polarized deuteron beam at COSY, Forschungszentrum Jülich.





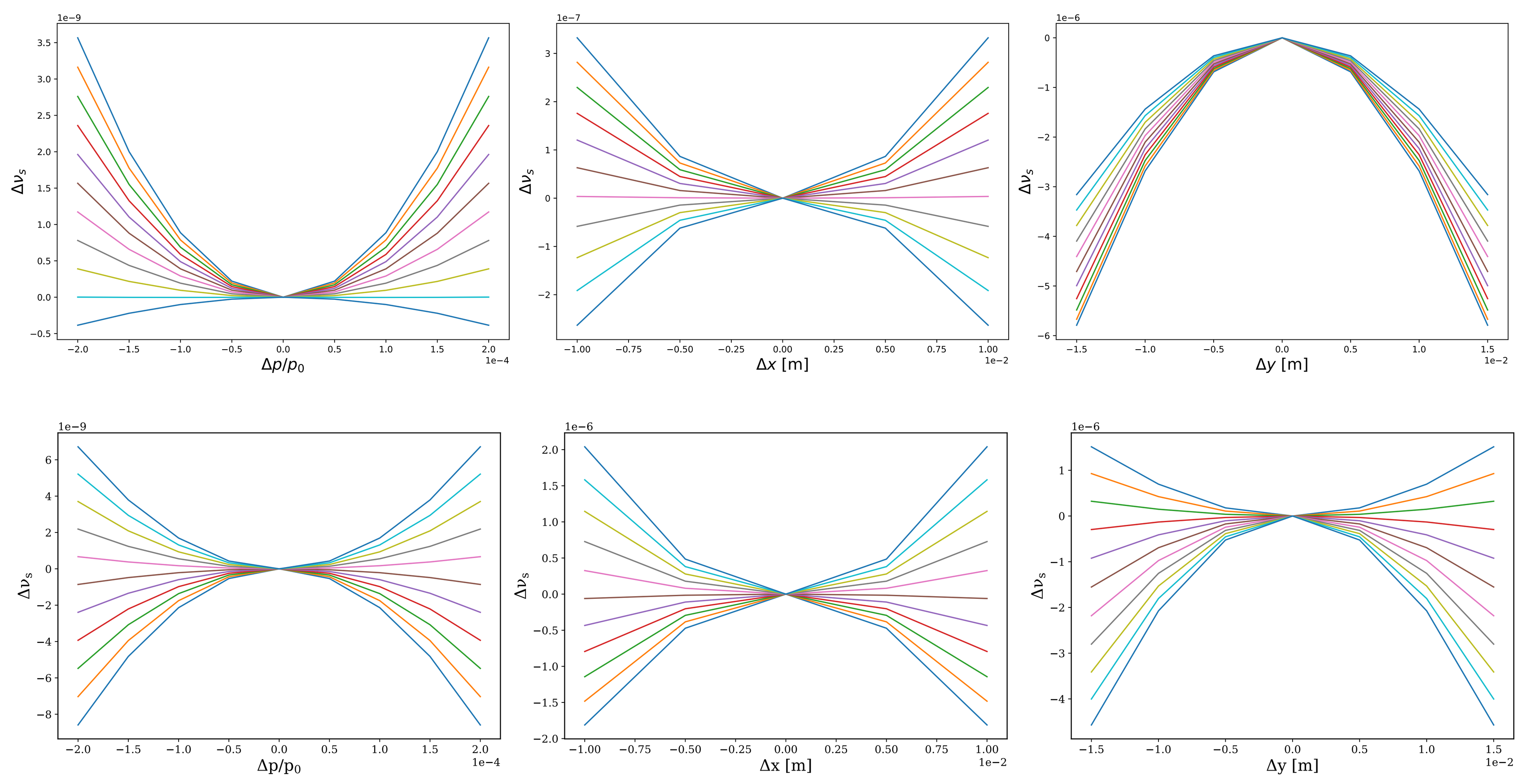
ESR at GSI





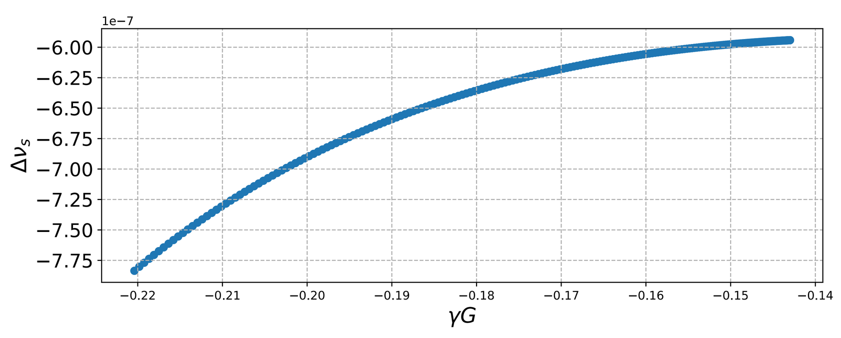
❖ Path lengthening correction requires at least 3 sextupole families at large β_x, β_y and dispersion D.

▼ Two-family vs. three-family configurations.



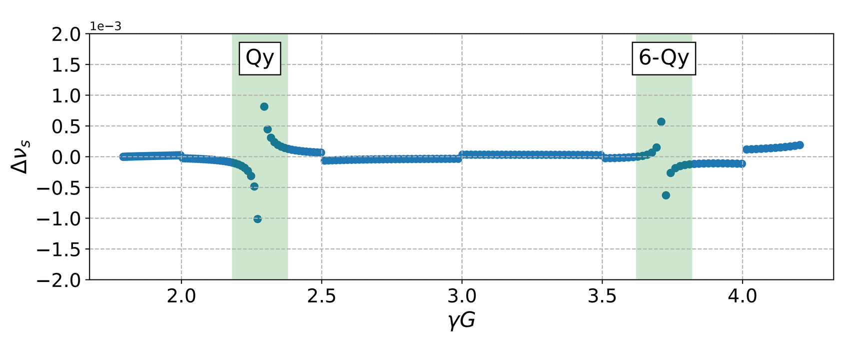
Simulation Results

❖ Intrinsic resonance : $\gamma G = nP \pm Q_y$



▲ Deuteron: far from resonance

▼ Proton: multiple resonances

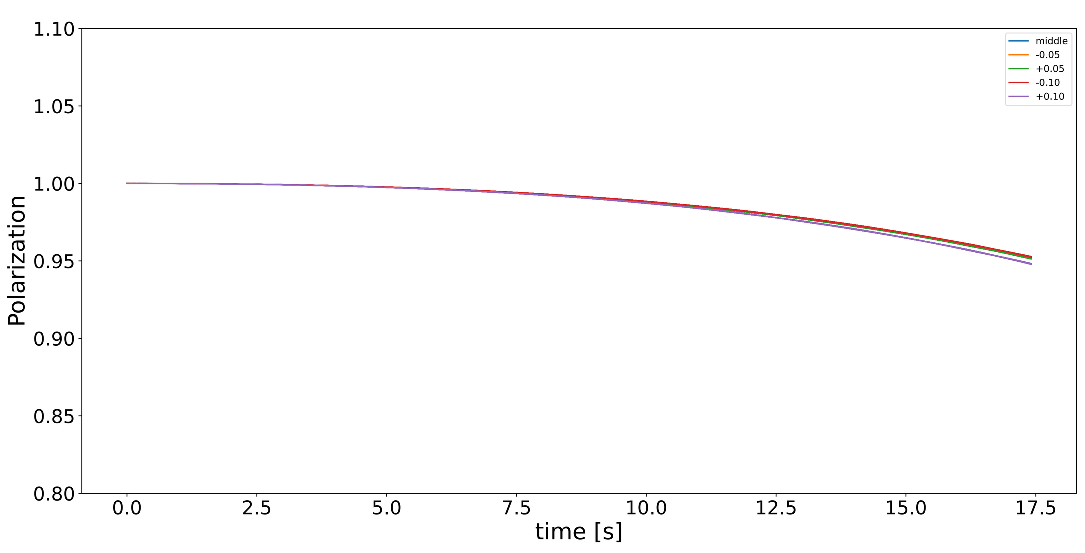


❖ Positional dependence of SCT on newly added sextupoles

Deuteron: Position-insensitive

❖ Low sext. strength

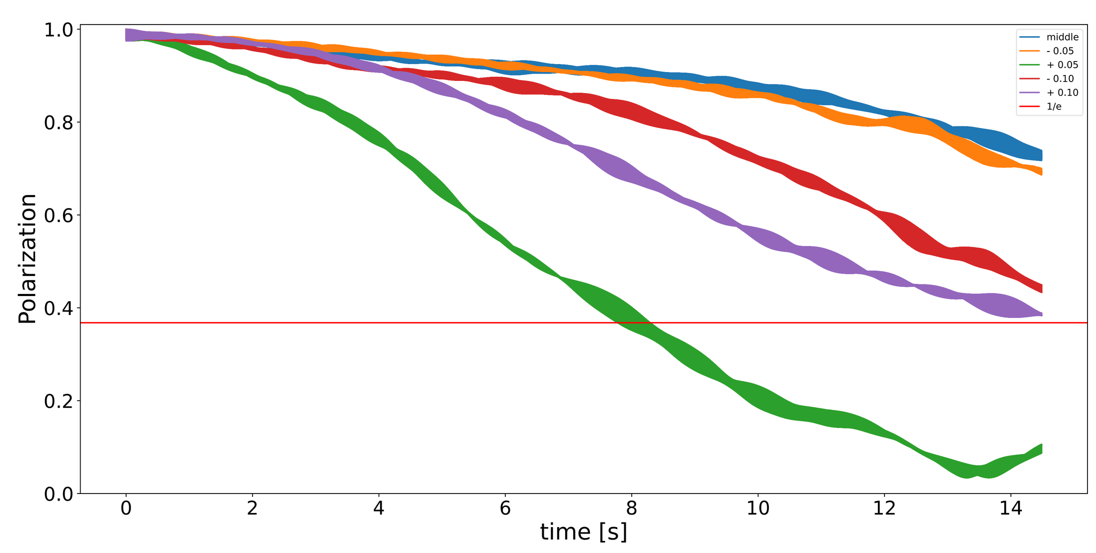
❖ Key params: ξ_x, ξ_y, α_1



Proton: Position-sensitive

❖ Sext. strength ≥ 10× deuteron

❖ Long-term tracking required



References

1. Stoehlker, T., et al. "Towards experiments with polarized beams and targets at the GSI/FAIR storage rings." 19th Workshop on Polarized Sources, Targets and Polarimetry (PSTP2022).
2. Guidoboni, G., et al. "How to Reach a Thousand-Second in-Plane Polarization Lifetime with 0.97-GeV/c Deuterons in a Storage Ring." Phys. Rev. Lett. 117 (2016): 054801.
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daoning.gu@rwth-aachen.de