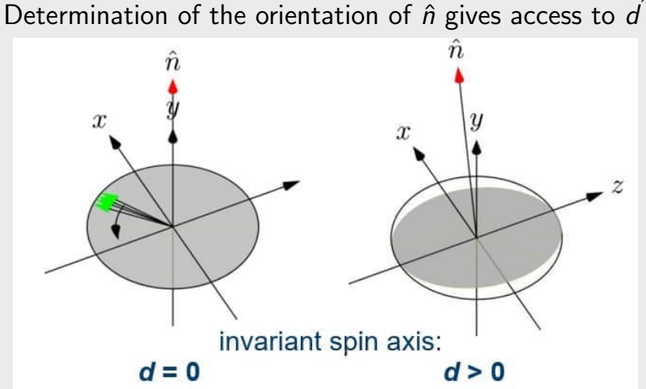
The Search for Electric Dipole Moments of Charged Particles in Storage Rings

Achim Andres for the JEDI Collaboration - RWTH Aachen University & Forschungszentrum Jülich

Physics Motivation

Electric Dipole Moments (EDMs)

- Fundamental (vector) property of a particle aligned with the particles spin axis
- Requires $\mathcal{P}$ and $\mathcal{T} \overset{\mathcal{CPT}}{=} \mathcal{CP}$ violation
- **Basic Idea:** Measure influence of EDM on beam polarization
- COSY: Magnetic ring $\rightarrow$ Horizontal polarization precesses (f_s) around **invariant spin axis** $\hat{n}$
- Non-zero EDM tilts $\hat{n}$ in radial (x) direction
- Determination of the orientation of $\hat{n}$ gives access to $\vec{d}$



- However, ring imperfections (magnet misalignments,..) also lead to rotations of $\hat{n}$ in radial and longitudinal direction
- **Siberian Snake** adds polarization rotation (ξ^{Sol}) in **longitudinal direction** and is therefore used to measure longitudinal (z) component of $\hat{n}$
- **RF Wien Filter** operating on the spin precession frequency (f_s) leading to a rotation of the polarization in **radial direction** (x) by a rotation of the device around the beam pipe (ϕ^{WF})

Technique

- Fix Wien Filter ϕ^{WF} and Siberian Snake ξ^{Sol} rotation angle
- Measurement repeated for 31 different settings of Wien Filter and Siberian Snake
- Determine the initial slope of vertical polarization after switching on the RF Wien Filter and the Siberian Snake at 155 s in the Cycle
- Beam polarization is determined by scattering the particle beam onto a accelerator internal polarimeter (**JePo** - Jedi Polarimeter)

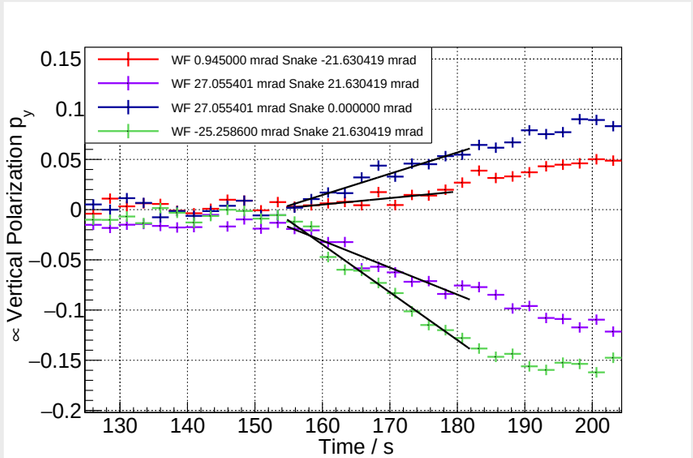
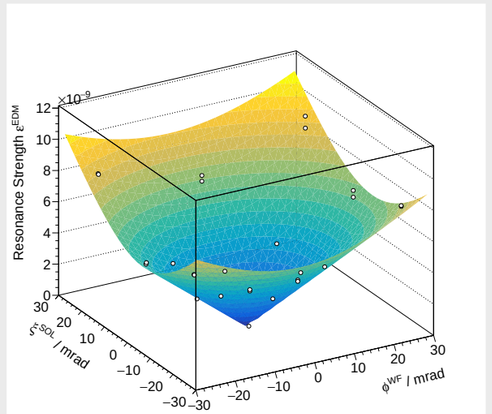


Figure: Build-up of the vertical polarization for different settings of the RF Wien Filter and the Siberian Snake

EDM resonance strength ϵ^{EDM} is given by the slope of the increasing vertical polarization

$$\epsilon^{\mathrm{EDM}}(\phi^{\mathrm{WF}}, \xi^{\mathrm{Sol}}) \sim \dot{p_y}$$

Preliminary Results - Precursor I



$$\epsilon^{\mathrm{EDM}}(\phi^{\mathrm{WF}}, \xi^{\mathrm{Sol}}) = \left[A_{\mathrm{WF}}^2 \left(\phi^{\mathrm{WF}} - \phi_0^{\mathrm{WF}}\right)^2 + A_{\mathrm{Sol}}^2 \left(\frac{\xi_0^{\mathrm{Sol}} - \xi^{\mathrm{Sol}}}{2 \sin\left(\pi f_s / f_{\mathrm{Rev.}}\right)} \right)^2 \right]^{\frac{1}{2}}$$

Orientation of invariant spin axis $\hat{n}$ including ring imperfections is experimentally given by the minimum of the paraboloid [1]

$$\phi_0^{\mathrm{WF}} = -2.91(8)\,\mathrm{mrad}$$
$$\xi_0^{\mathrm{SOL}} = -5.22(7)\,\mathrm{mrad}$$

1. Minimum represents spin rotation axis **including** EDM
2. Simulated spin tracking shall determine orientation of stable spin axis **without** an EDM
3. EDM limit is determined from the difference of 1. and 2.

References

[1] F. Rathmann, N. Nikolaev, and J. Slim, *Spin dynamics investigations for the electric dipole moment experiment*, Physical Review Accelerators and Beams, 23 (2020).

Contact: Achim Andres - a.andres@fz-juelich.de