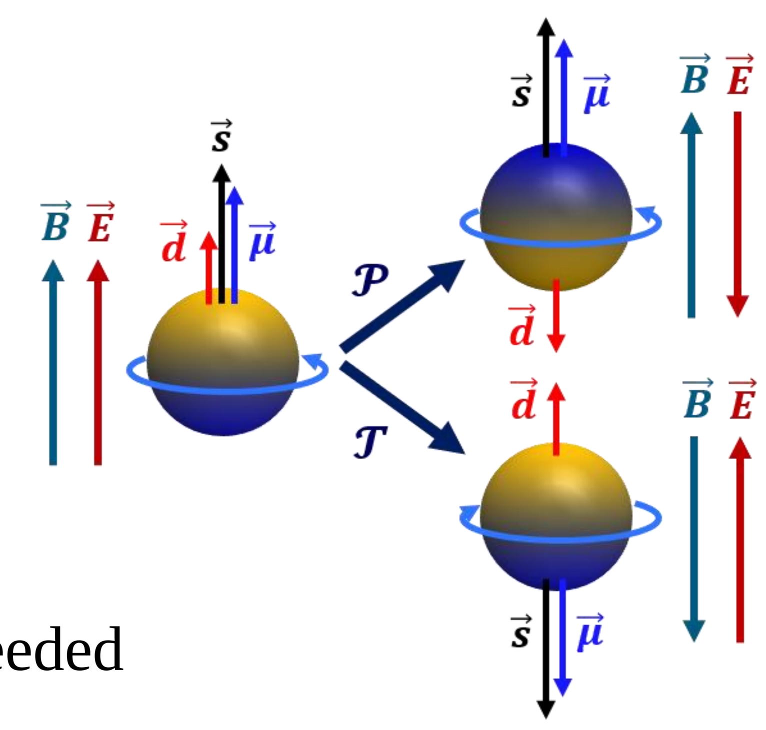
SEARCH FOR ELECTRIC DIPOLE MOMENTS AT COSY IN JÜLICH – SPIN-TRACKING SIMULATIONS USING BMAD

V. Poncza[1], A. Lehrach[1,2], Institut für Kernphysik 4, Forschungszentrum Jülich, 52425 Jülich, Germany,
[1]also at III. Physikalisches Institut B, RWTH Aachen University [2]and JARA-FAME, 52056 Aachen, Germany
on behalf of the JEDI Collaboration

Motivation

- Measure **Electric Dipole Moment** (EDM) of charged hadrons at COSY
- **Vertical spin build-up** as a measure of EDM
- EDM-like signals due to **systematic effects**
- **Spin-tracking** simulations needed to disentangle systematic effects from real EDM signal

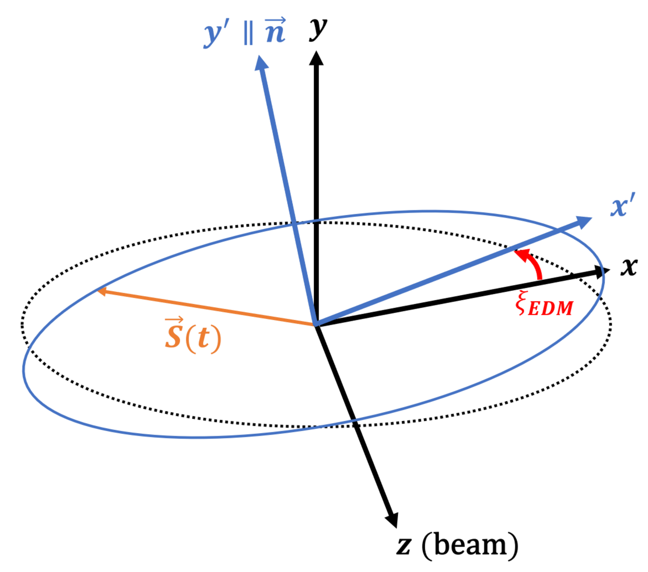


Spin Dynamics

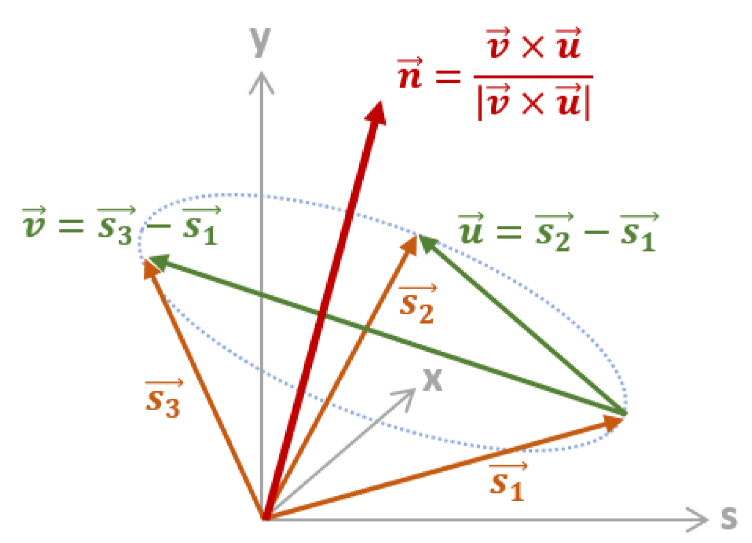
$$\frac{d\vec{S}}{dt} = (\Omega_{MDM} + \Omega_{EDM}) \times \vec{S} = \left(\frac{q}{m} G\vec{B} + \frac{q\eta}{2m}\vec{\beta} \times \vec{B}\right) \times \vec{S}$$

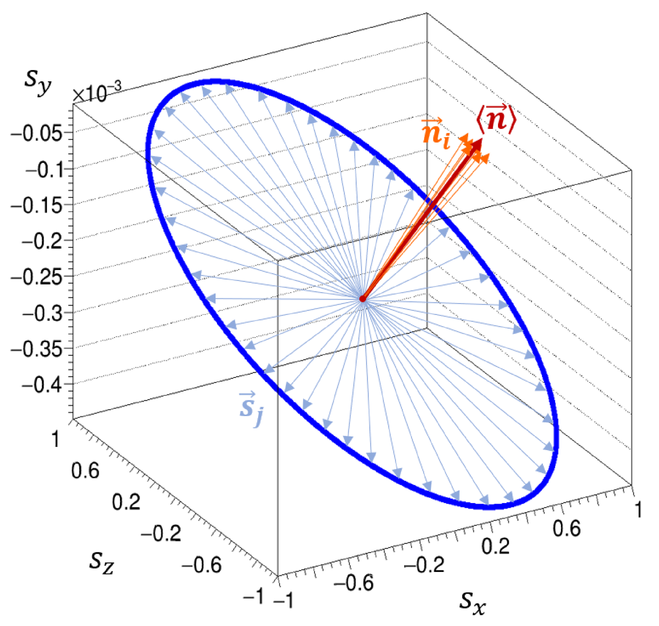
$$\vec{d} = \eta \cdot \frac{q}{2mc}\vec{S} \quad \text{and} \quad \tan(\xi_{EDM}) = \frac{\eta\beta}{2G}$$ [2]

- Spin rotates around **invariant spin axis $\vec{n}$**
- Invariant spin axis is tilted by
  - the **electric dipole moment**
  - **systematic effects** (i.a. misaligned magnets)



Invariant Spin Axis





- Track reference particle for several turns using the Bmad Software Library [1]
- Calculate the normal vector $\vec{n}_i$ for each possible combination of three spin vectors
- The invariant spin axis $\langle\vec{n}\rangle$ is the mean of all normal vectors

benchmarking:

Input: $\eta = 0.0002 \quad \Rightarrow$ theory: $n_x = -0.32127 \cdot 10^{-3}$, $n_z = 0$

Output: $$\langle\vec{n}\rangle = \begin{pmatrix} -0.321269108 \cdot 10^{-3} \pm 7.636 \cdot 10^{-9} \\ 0.999999948393 \pm 2.5 \cdot 10^{-12} \\ 2.568 \cdot 10^{-9} \pm 1.6878 \cdot 10^{-8} \end{pmatrix}$$

Experimental Situation

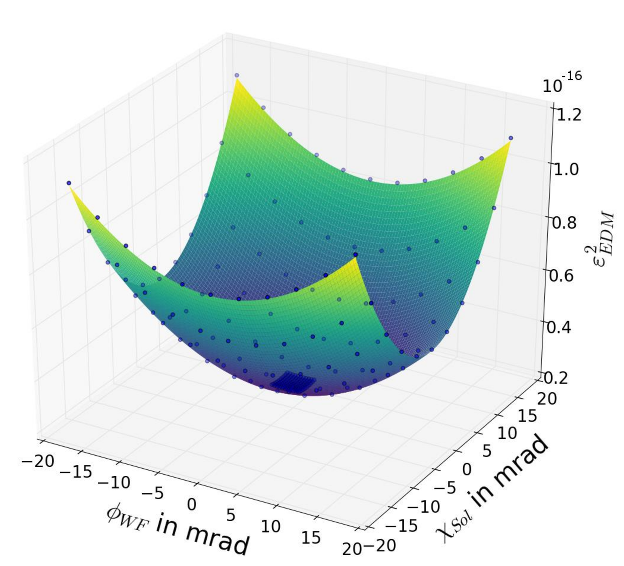
EDM resonance strength: $\varepsilon_{EDM} = \frac{\Omega_{P_y}}{\Omega_{rev}}$

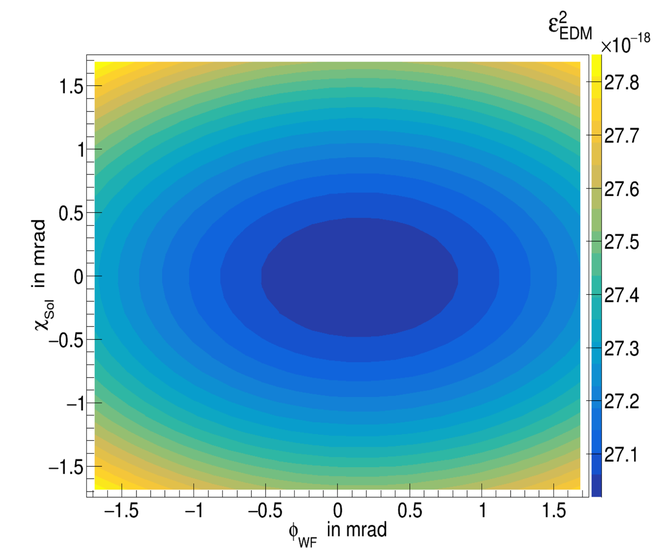
$$\varepsilon^2_{EDM} \propto A \cdot (\phi_{WF} - \phi_0)^2 + B \cdot \left(\frac{\chi_{Sol}}{2\sin(\pi\nu_s)} + \chi_0\right)^2$$ [3]

Basic idea:

- Fit point of minimal resonance strength (ϕ_0, χ_0)
- ϕ_0 is a measure of the EDM + systematic effects

Simulation: $\eta = 0$ + magnet misalignments





Simulation: $\phi_0 = 0.15 \pm 0.02$ mrad, $\chi_0 = 0.01 \pm 0.01$ mrad

Measurement: $\phi_0 = -3.7 \pm 0.04$ mrad, $\chi_0 = -6.96 \pm 0.04$ mrad

$\Rightarrow$ unknown longitudinal field components

Summary & Outlook

- The COSY ring is modeled using Bmad
- The implemented method to determine the invariant spin axis is in agreement with theoretical predictions
- Simulating the experimental situation and comparing the results to the measurement show a lack of knowledge of the net longitudinal field in COSY
- Possible sources of longitudinal fields are fringe fields and the narrow positioning of the COSY magnets which will be added to the model

References

[1] D. Sagan, "Bmad: A relativistic charged particle simulation library", Nuclear Instruments and Methods in Physics Research A, vol. 558, pp. 356-359, 2006.

[2] T. Fukuyama and A. J. Silenko, "Derivation of Generalized Thomas Bargmann-Michel-Telegdi Equation for a Particle with Electric Dipole Moment", Int. J. Mod. Phys. A28, p.1350147, 2013.

[3] A. Saleev, N.N. Nikolaev, and F. Rathmann, "JEDI and RF Wien Filter Driven Spin Dynamics", unpublished.

v.schmidt@fz-juelich.de