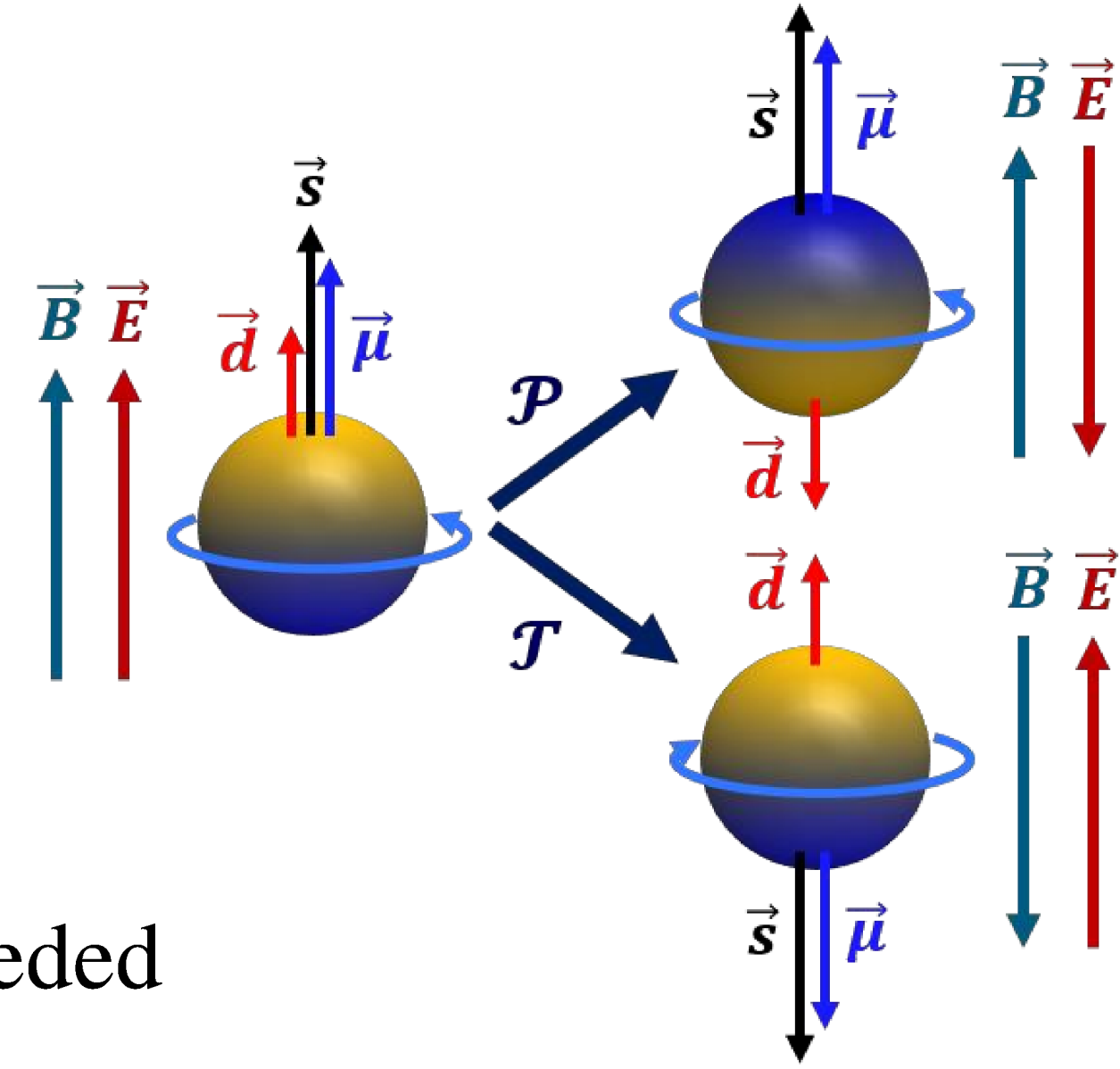


# SEARCH FOR ELECTRIC DIPOLE MOMENTS AT COSY IN JÜLICH – SPIN-TRACKING SIMULATIONS USING BMAD

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## 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

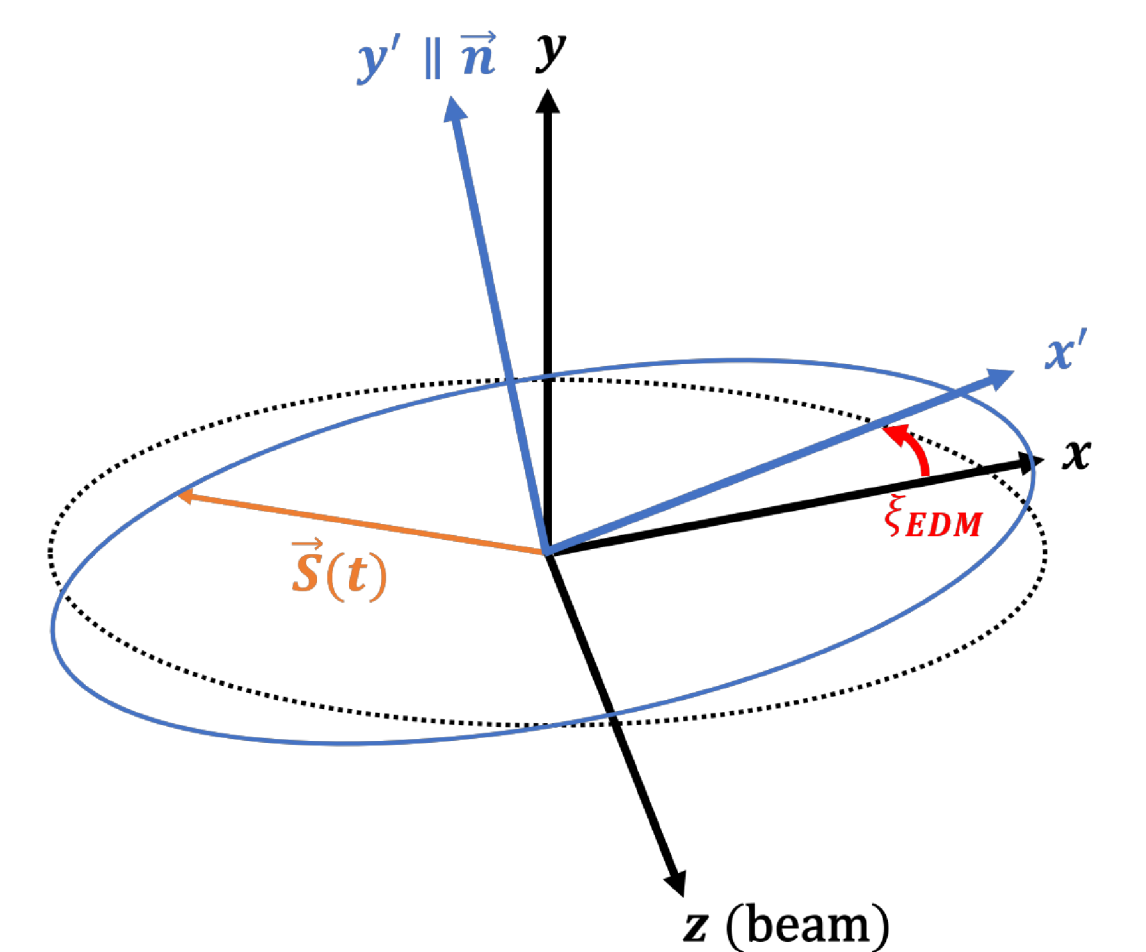


## Spin Dynamics

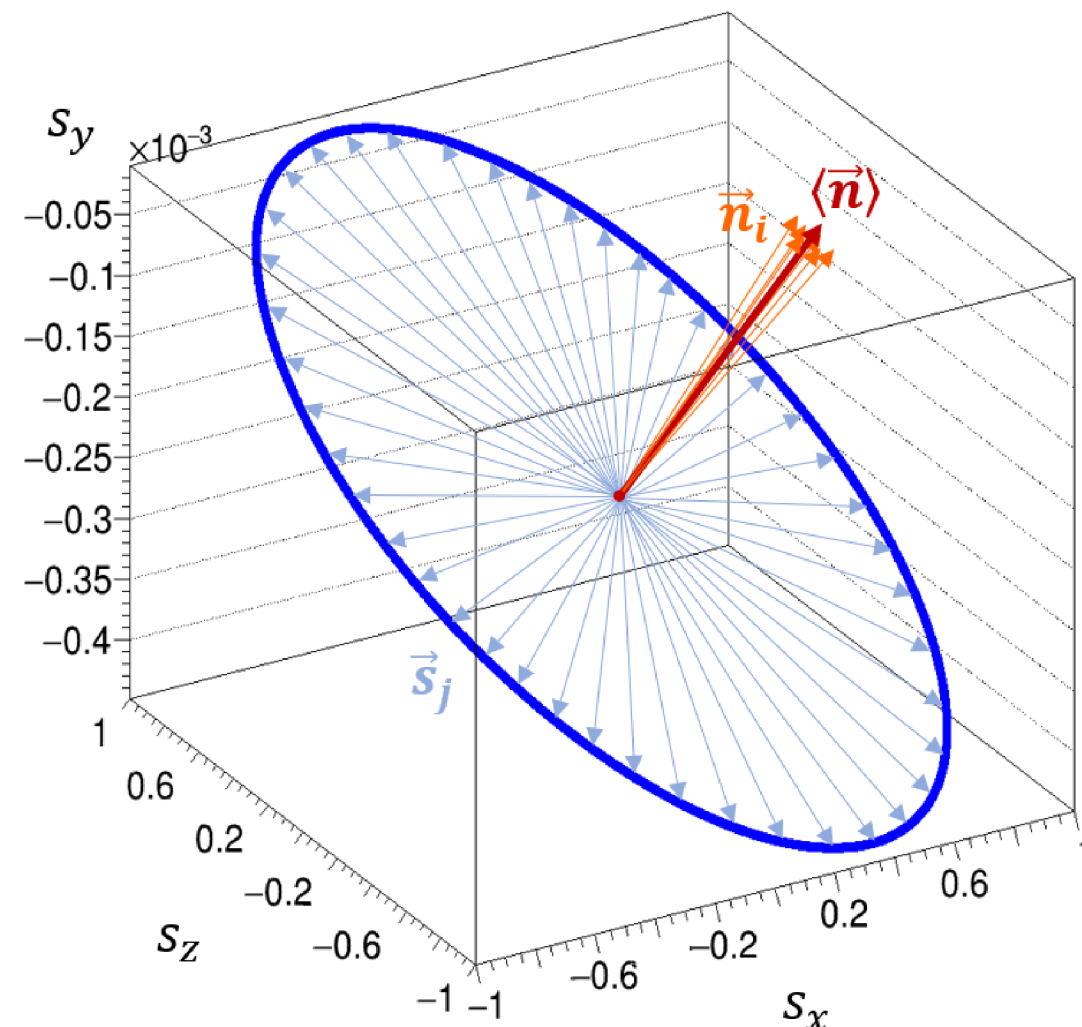
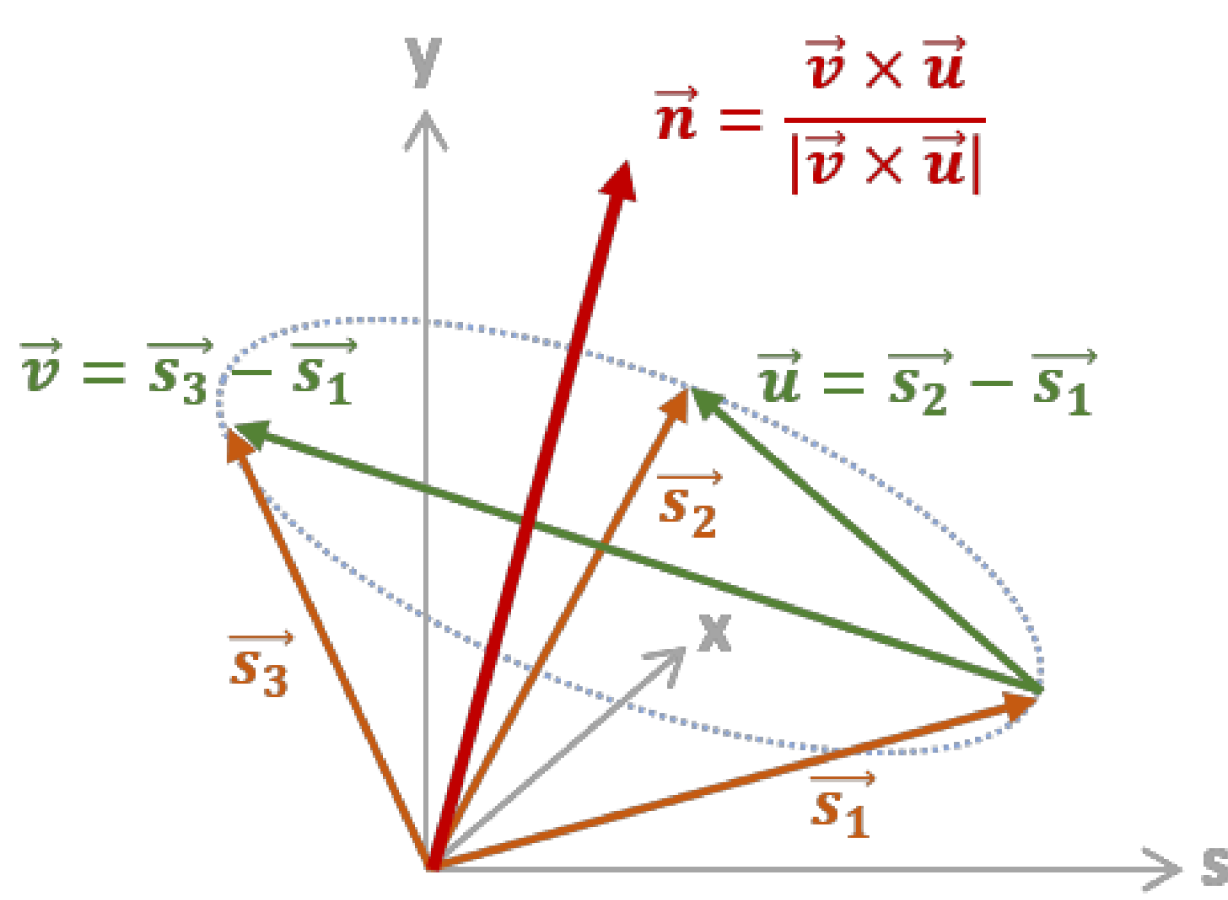
$$\frac{d\vec{S}}{dt} = (\Omega_{MDM} + \Omega_{EDM}) \times \vec{S} = \left( \frac{q}{m} G \vec{B} + \frac{q\eta}{2m} \vec{\beta} \times \vec{B} \right) \times \vec{S}$$

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

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

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

## Experimental Situation

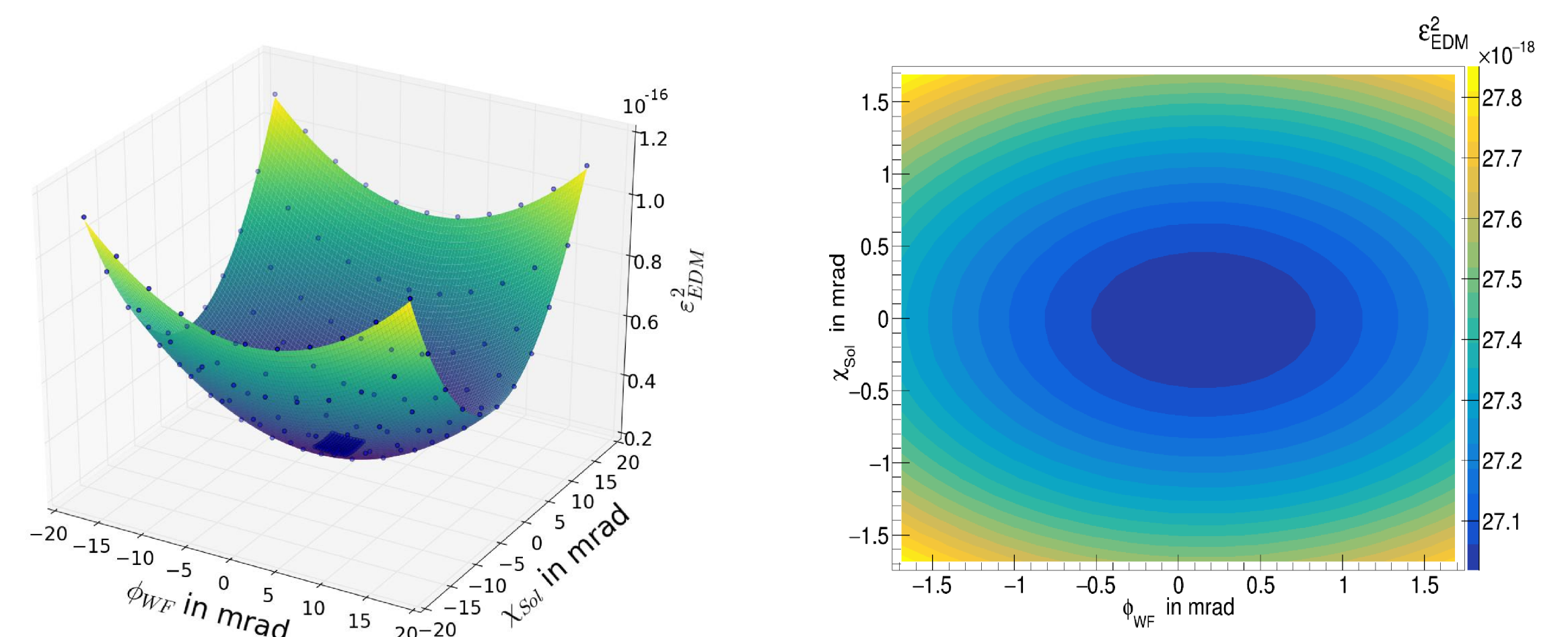
$$\text{EDM resonance strength: } \varepsilon_{EDM} = \frac{\Omega_{py}}{\Omega_{rev}}$$

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

### Basic idea:

- Fit point of minimal resonance strength  $(\phi_0, \chi_0)$
- $\phi_0$  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.