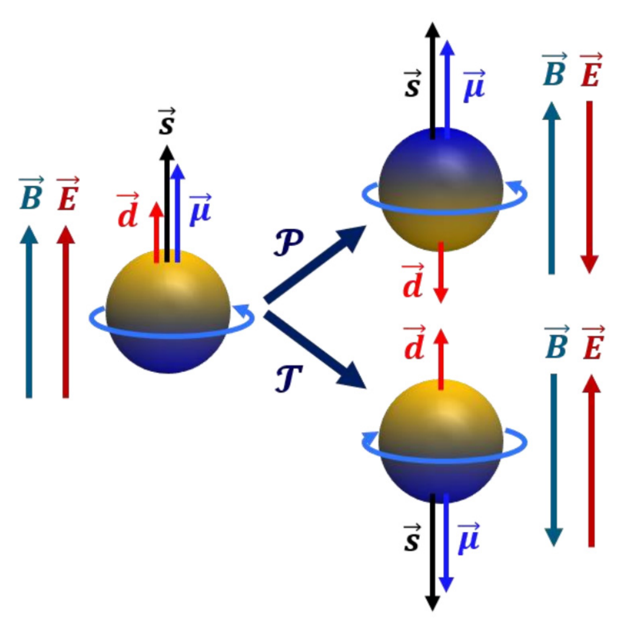
Spin-Tracking Simulations in a Proton Prototype EDM Ring using Bmad

M. Vitz[1], A. Lehrach[1,2], Institut für Kernphysik 4, Forschungszentrum Jülich, 52425 Jülich, Germany,
R. Shankar, Instituto Nazionale di Fiscia Nucleare, sezione di Ferrara, 44122 Ferrara, Italy
[1]also at III. Physikalisches Institut B, RWTH Aachen University [2]and JARA-FAME, 52056 Aachen, Germany
on behalf of the JEDI Collaboration

Physical Motivation

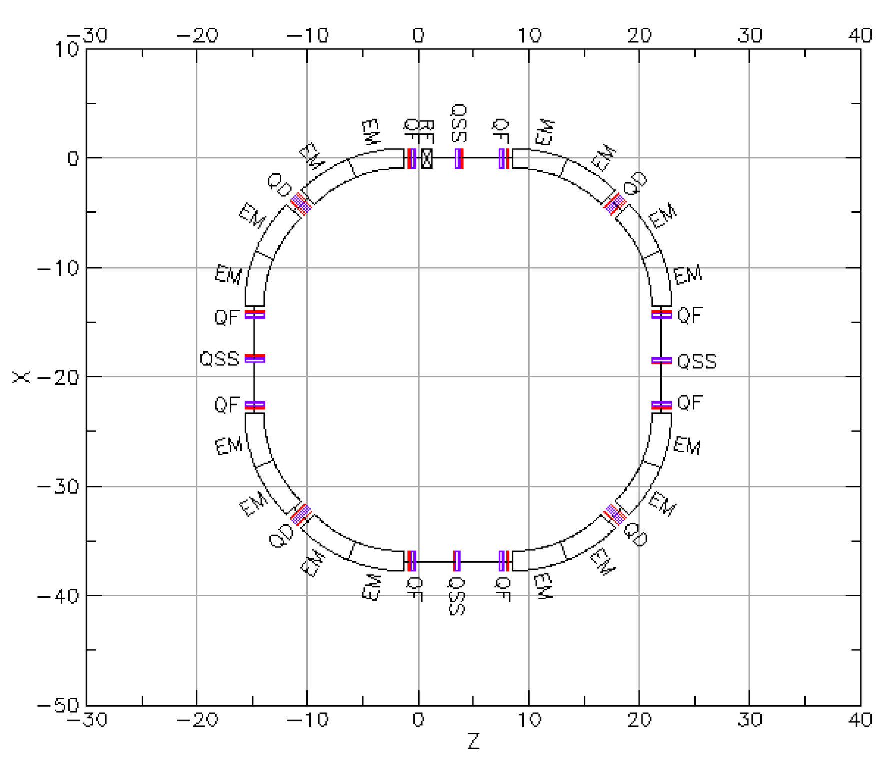
- **Electric Dipole Moment** (EDM) is a fundamental property of a subatomic particle, similar to the Magnetic Dipole Moment (MDM).
- Source of $\mathcal{P}$ and $\mathcal{T}$ violation ($\overset{\mathcal{CPT}}{=}$ $\mathcal{CP}$ violation) and therefore closely connected to **matter antimatter asymmetry**.



- EDM of charged particles can be measured in a storage ring as spin rotation is defined by EDM and MDM contribution [1].
- **Vertical spin build-up** due to EDM needs coherent spin rotation for ∼1000s in the horizontal plan due to MDM.
- Spin tracking simulations with Bmad Software Library [2] to estimate amount of time spins are aligned.
  ⇒ **Spin Coherence Time** (SCT)

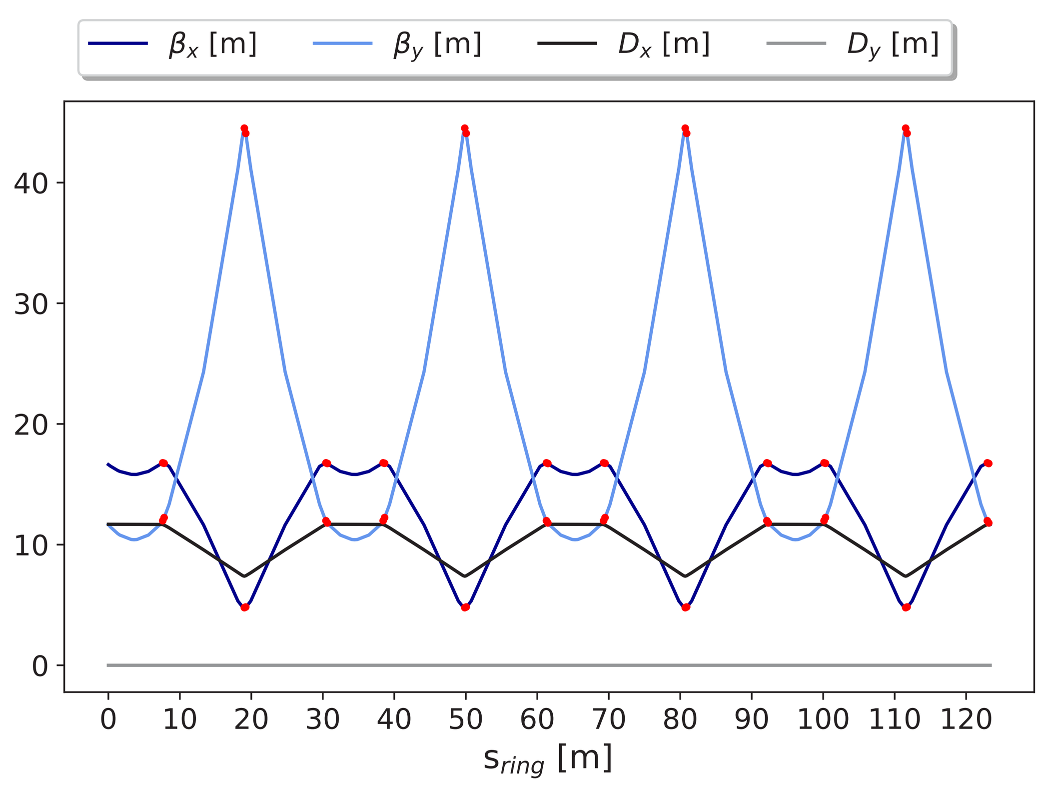
Prototype Design

- The Proton Prototype EDM Ring (PTEDM) **combines E and B** fields so the ref. particle spin is aligned to the momentum [3].



- Particle Species: Proton
- Ref. Momentum: 294 MeV
- Circumference: 123.358 m
- Dipole E-Field: 5.061 MV/m
- Dipole B-Field: 0.023 T

- Design contains two active quadrupole families (QD and QF) with sextupoles (family SXQF and family SXQD) placed on them.

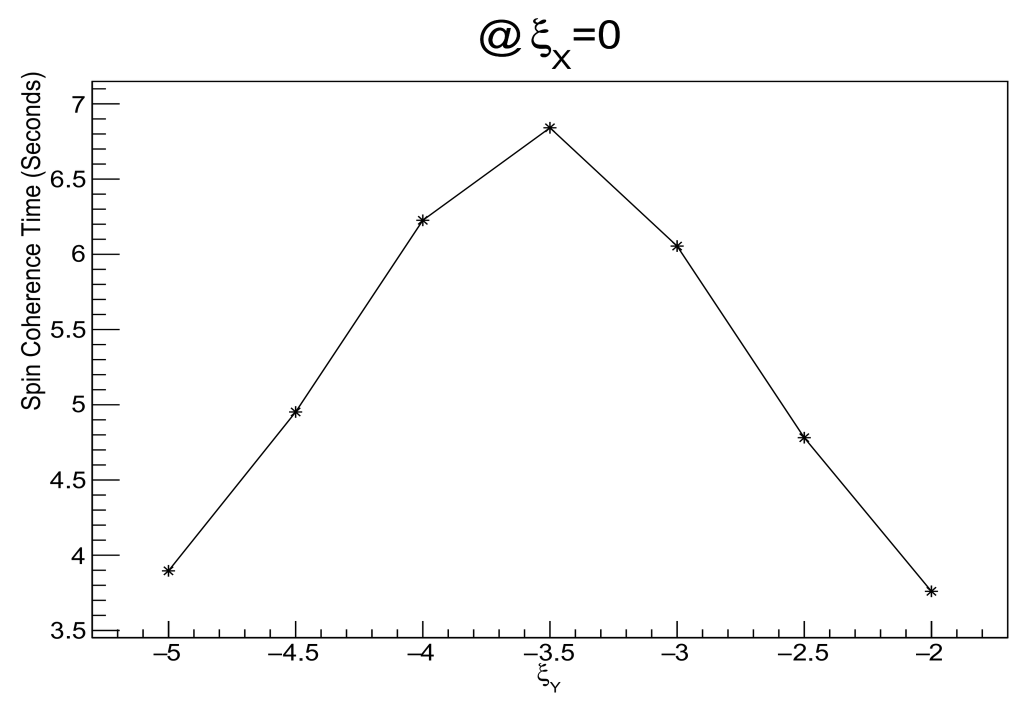


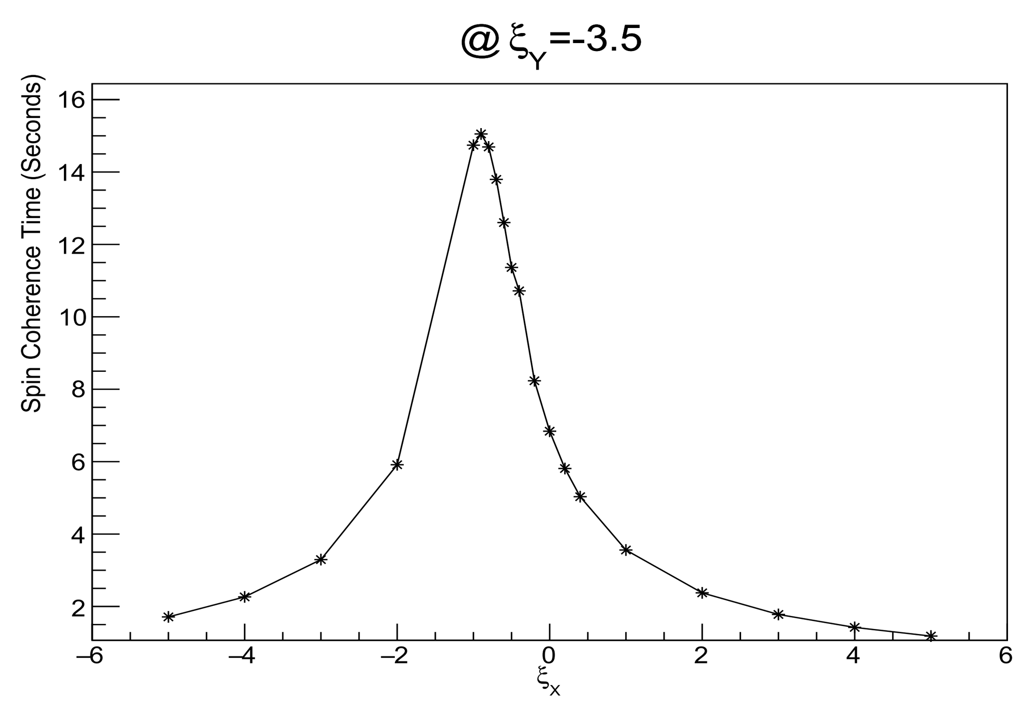
- $Q_x = 1.823$
- $Q_y = 1.123$
- $\xi_x = -0.070$
- $\xi_y = +0.035$

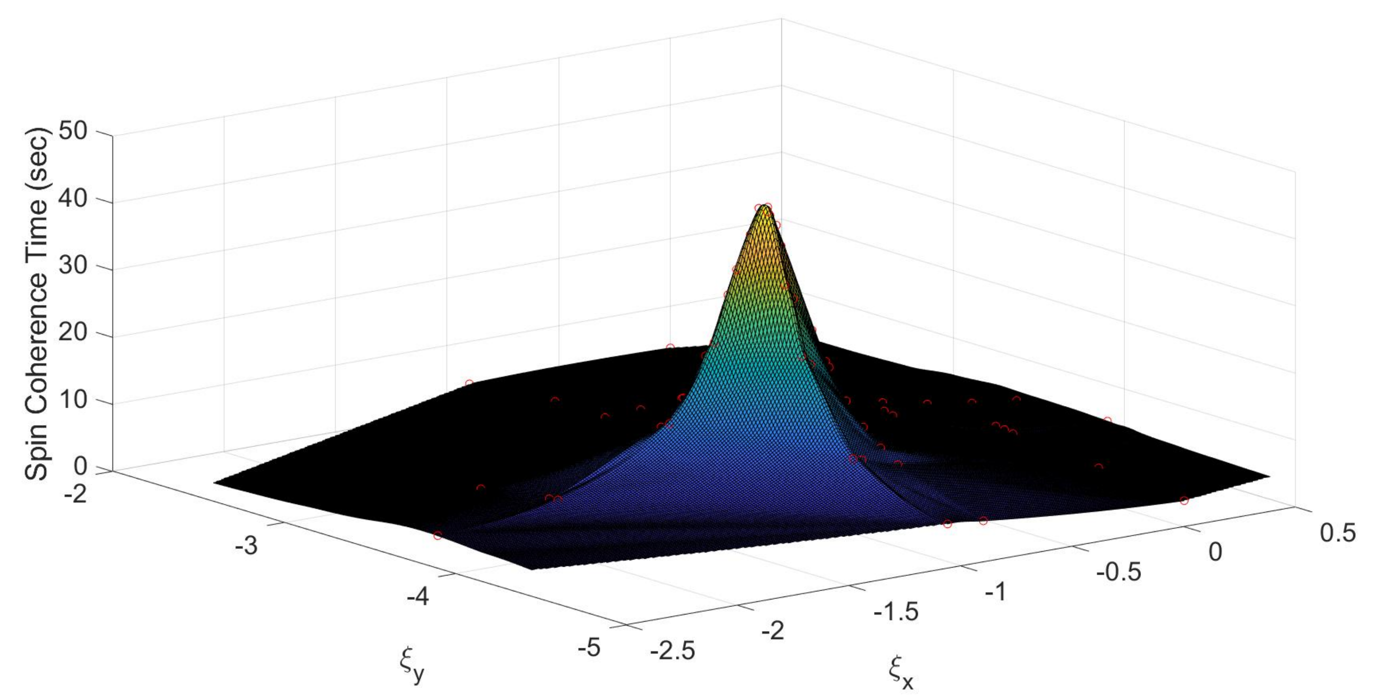
- To estimate SCT a fully longitudinal polarized bunch consisting of 10^3 particles was tracked for 10^6 revolutions (∼1s) in the ring.

Spin Tracking

- Spin depolarization can be optimized by adjusting system parameters like the **chromaticities ξ_x and ξ_y**.
- Chromaticities can be adjusted using the two families of sextupoles which were placed on the quadrupoles.







Summary

- The SCT can be optimized by varying the chromaticity of the ring. One point of **optimal chromaticity** for SCT can be found.
- The reason why the maximal SCT is not at $\xi_x = 0$, $\xi_y = 0$ is only partially understood and related to **intrinsic spin resonances**. Further investigation is needed.

References

[1] 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, 1350147, 2013.

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

[3] A. Lehrach, S. Martin and R. Talman, Design of a Prototype EDM Storage Ring, Proceedings of Science, PoS SPIN2018, 144, 2018.

Contact: Maximilian Vitz - m.vitz@fz-juelich.de