

Storage Rings for the Search of Charged Particle Electric Dipole Moments

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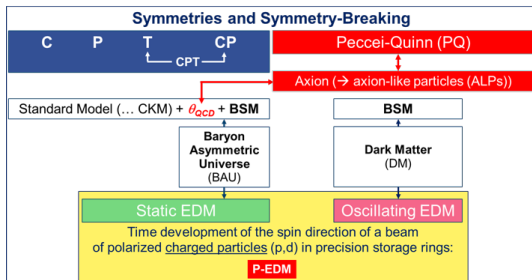
Motivation

Problems

- Preponderance of matter over antimatter
- Nature of Dark Matter (DM)

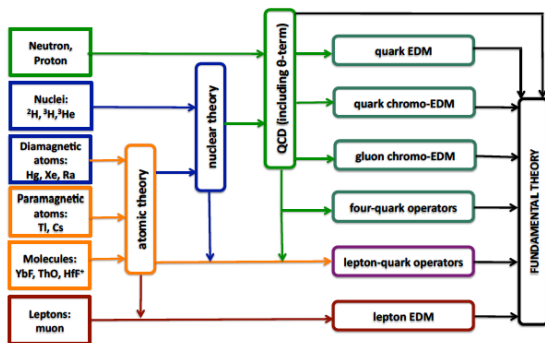
Approach

- Measurements of static Electric Dipole Moments (EDM) of fundamental particles.
- Searches for axion-like particles as DM candidates through oscillating EDM



Why charged particles EDMs?

- **Static EDM:** complementary informations from different systems required
 - ▶ Direct measurement and statistical improvement with respect to neutron



J. de Vries

- **Oscillating EDM:** axion as a solution to the θ_{QCD} problem
 - ▶ Limit on θ_{QCD} comes from n_{EDM}

Strategy: staged approach to a storage ring for precision physics

On the basis of the preparedness of the required technological developments

Stage 1

precursor experiment
at COSY (FZ Jülich)

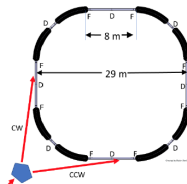


- magnetic storage ring

now

Stage 2

prototype ring

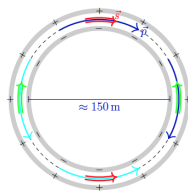


- electrostatic storage ring
- simultaneous \odot and \ominus beams

5 years

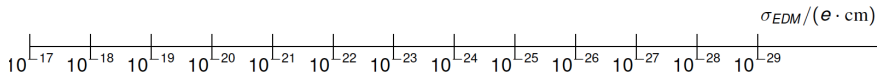
Stage 3

dedicated storage ring



- magic momentum (701 MeV/c)

10 years

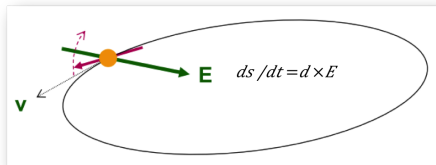
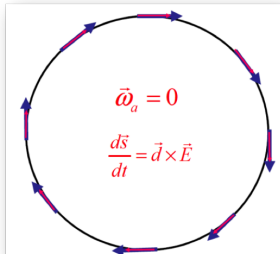


Planned Design Study application: **Prototype ring for charged particle EDM searches**

Search for static EDM in storage rings

Measurement concept

- 1 Inject particles in storage ring
- 2 Align spin along momentum (\rightarrow freeze horiz. spin-precession)
- 3 Search for time development of vertical polarization



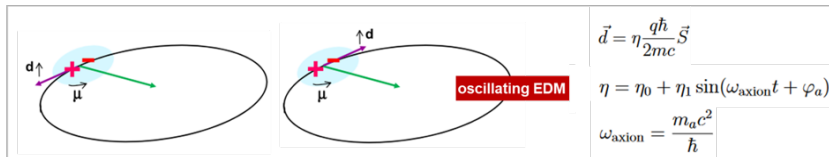
Frozen-spin condition:

- Pure E ring for p
- Combined E/B ring for d and ${}^3\text{He}$

Search for oscillating EDM in storage rings

Axions as light dark matter candidates

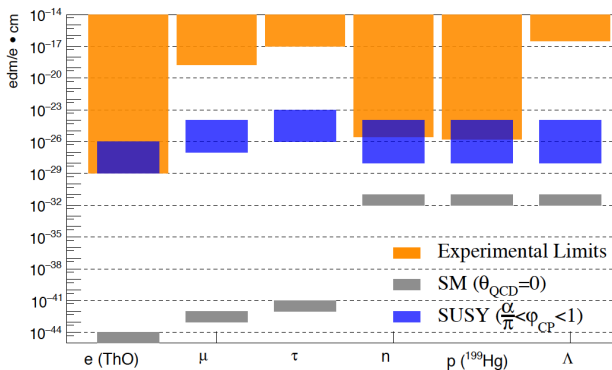
- Axion interaction with ordinary matter: $\frac{a}{f_0} F_{\mu\nu} \tilde{F}_{\mu\nu}$, $\frac{a}{f_0} G_{\mu\nu} \tilde{G}_{\mu\nu}$, $\frac{\partial_\mu a}{f_a} \bar{\Psi} \gamma^\mu \gamma_5 \Psi$
- $\frac{a}{f_0} G_{\mu\nu} \tilde{G}_{\mu\nu} \rightarrow$ coupling to gluons with same structure as QCD- θ term
- Generation of an oscillating EDM



Combined E/B ring

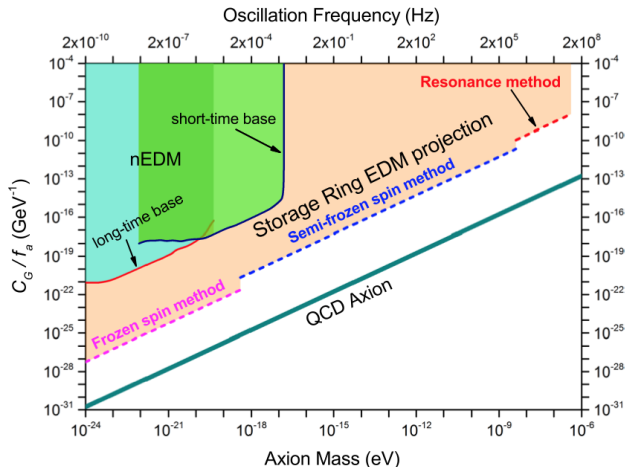
- Mag. dipole moment (MDM) \rightarrow spin prec. in B field \rightarrow nullifies static EDM effect
- Oscillating EDM resonant condition \rightarrow buildup of out-of-plane spin rotation
- Search of resonance (axion/ALP mass) via change of beam momentum

STATIC EDM: current upper limits and perspectives



- **Objective:** EDMs of charged hadrons: p , d , ^3He
 - ▶ Note: current limit on p-EDM: $2.0 \times 10^{-25} e \cdot \text{cm}$ (ind. from $d_p^{199\text{Hg}}$)
- **Final goal:** to bring the limit on p to $10^{-29} e \cdot \text{cm}$

OSCILLATING EDM: axion mass vs gluon coupling



- Experimental limits accessible in one year per single frequency measurement.

Conclusions

New class of precision storage rings

- Static EDM of charged particles
 - ▶ Improvement of the limits on neutron EDM by 2 orders of magnitude
 - ▶ Direct test of BSM theories
 - ▶ Pure experimental effort to contain the systematic error
- Oscillating EDM generated by axion-gluon coupling
 - ▶ Access to axion mass $< 10^{-6}$ eV over 20 orders of magnitude
 - ▶ High sensitivity for dedicated frequency run
 - ▶ Frequency scan to enlarge the experimental range with lower sensitivity
 - ▶ Any mass indication would focus the experimental effort

- Endorsement letter(s) for coming Design Study application highly welcome!

Essential bibliography

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