Method to search for axion-like particles at storage rings, demonstrated at COSY

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Axions or Axion-Like Particles (ALPs)

- Proposed to explain the lack of CP violation in the strong interaction
- Candidate for dark matter in the universe
- Axion–gluon coupling introduces an oscillating Electric Dipole Moment (EDM)
- Light mass and weakly coupled to nucleons

Oscillating EDM allows us to search for ALPs in a storage ring.

Search using in-plane polarized deuterium beam at COSY

- Axion oscillation frequency $g = 2$ spin precession frequency
- Accumulation of vertical polarization $P_z$

Assumptions:
- Axion field has large spatial and time coherence.
- Axions are dense and extend beyond the ring.
- EDMs oscillate coherently. Phase is unknown.

Plan for frequency scanning

- Vary the spin precession frequency $f_{g-2}$ in search of resonance.
- Ramp speed $\approx 0.1$ Hz/s
- Compare initial and final polarization measurements.

Expected results

- Simulations with a single bunch for 4 different phases $90^\circ$ apart
- Resonance crossing speed $0.5$ Hz/s
- Strength of oscillating EDM $1.6 \times 10^{-21} e \cdot cm$
- Tests with RF Wien filter:
  - Generate signal similar to axion.
  - Calibrate polarization jumps.

Experimental setup

- Unknown phase problem:
  - right frequency + right phase $\Rightarrow P_z$ accumulation
  - right frequency + wrong phase $\Rightarrow P_z$ accumulation

Solution

Simultaneous searches with beams having perpendicular polarization.

Results of the first COSY experiment

- Preliminary analysis: Sensitivity for oscillating EDM, from the scans of 1kHz range, quoted at a 3σ limit

See S.-P. Chang et al., PRD 90, 033002 (2014)