New method to search for axion-like particles with a polarized beam at the COSY storage ring

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Axion – axion-like particle (ALPs)

• Proposed to explain the lack of CP violation in the strong interaction.
• Candidates for dark-matter in the universe.
• Axion/ALPs – gluon coupling induces an oscillating Electric Dipole Moment (EDM).

\[ d = d_{\text{static}} + d_{\text{osc}} \cos(\omega t + \phi) \]

Oscillation frequency connected to axion mass \( \omega = \frac{m_a c^2}{\hbar} \)
Phase of the oscillating EDM is unknown.

See: P. W. Graham et al., PRD 84, 055013 (2011)
Cooler Synchrotron (COSY)

- A proof-of-principle experiment to search for ALPs
- Polarized deuterons
- WASA detector as the polarimeter
How to search for ALPs in a storage ring?

- Horizontally polarized beam
- \( \text{Spintune}(\nu_S) = \frac{\text{#spin rotation}}{\text{#particle revolution}} \)
  \[ \nu_S = G\gamma \]
  
  \( G \): anomalous magnetic moment
  
  \( \gamma \): Lorentz factor
How to search ALPs in a storage ring?

Static EDM

Oscillating EDM

Axion oscillation frequency \( = \) Spin tune frequency \( \Rightarrow \) Accumulation of vertical polarization
Model calculations

- Ramp frequency in search of resonance
- Describe the polarization jump at resonance crossing.
- Phase plays an important role in determining the jump.

Unknowns of the experiment: frequency and phase

\[
\text{Phase} = \frac{\pi}{2} \text{ rad}
\]

\[
\text{Phase} = 0 \text{ rad}
\]
Phase problem and 4 bunches

• Simultaneous searches with perpendicular beam polarization using 4 bunches.

• RF solenoid run at $f_{\text{rev}}(1 + G\gamma)$
Measurement procedure

- Vary the spintune frequency (ramp rate ≈ 0.1Hz/s) in search of resonance.
- Measure polarization.
- About 100 scans
  - Frequency Range
    119997 Hz – 121457 Hz
  - Total width ≈ 1500 Hz
  - ALP mass range
    \(4.96 \times 10^{-9}\text{eV} – 5.02 \times 10^{-9}\text{eV}\)
RF Wien filter scan and analysis of data

- A test of methodology.
- A check for the calibration used to calculate the $d_{osc}$ from data.
Axion scan

- Analysis is ongoing.
- No signal seen.
Summary

• ALP induces an oscillating EDM ($d_{osc}$), allows searching for ALPs in a storage ring.

• Polarized deuteron beam to search for resonance between the oscillating EDM frequency and the spintune frequency.
  o Frequency Range 119997 Hz – 121457 Hz. Total width $\approx$ 1500 Hz.
  o ALP mass range $4.96 \times 10^{-9}$eV – $5.02 \times 10^{-9}$eV.

• RF Wien filter used as a test to observe a signal at resonance crossing.

• No signal was found.
Thank You