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

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DPG SPRING CONFERENCE

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).

$$d = d_{static} + \mathbf{d}_{osc} \cos(\omega t + \phi)$$

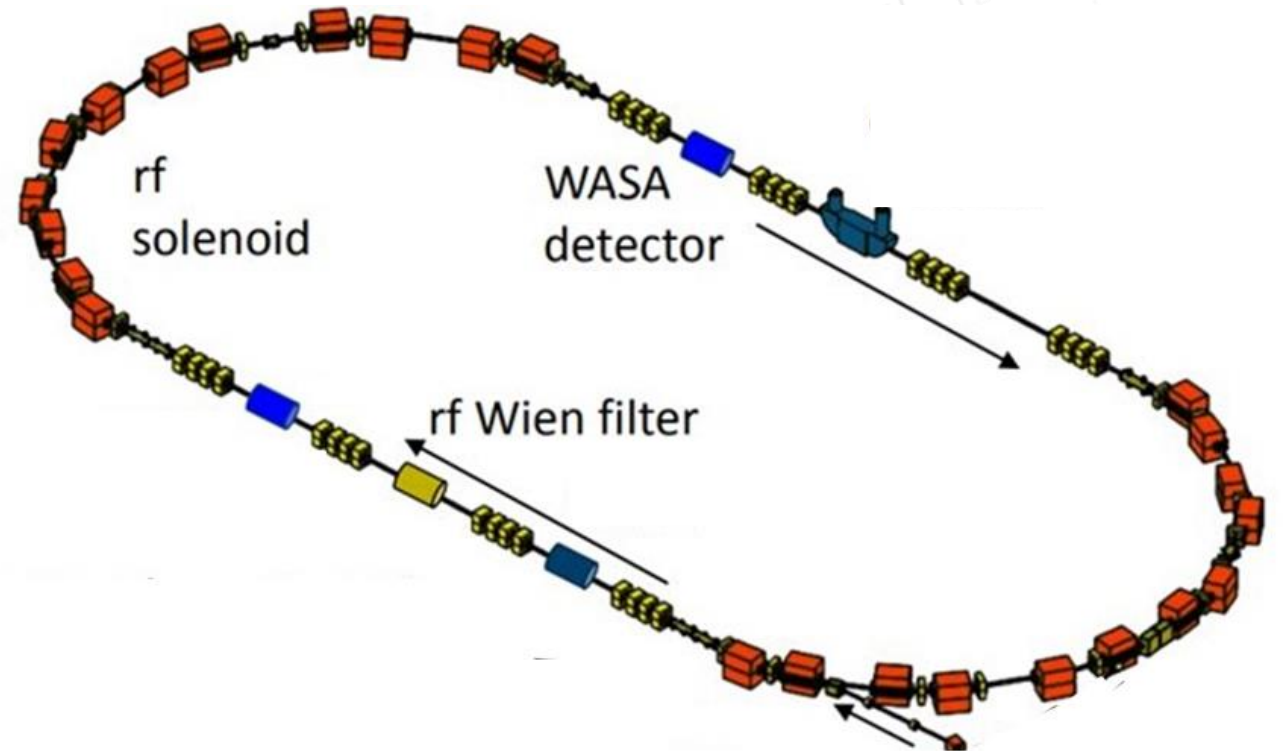
Oscillation frequency connected to axion mass $\omega = \frac{m_a c^2}{\hbar}$

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 and cooled deuterons
- WASA detector as the polarimeter



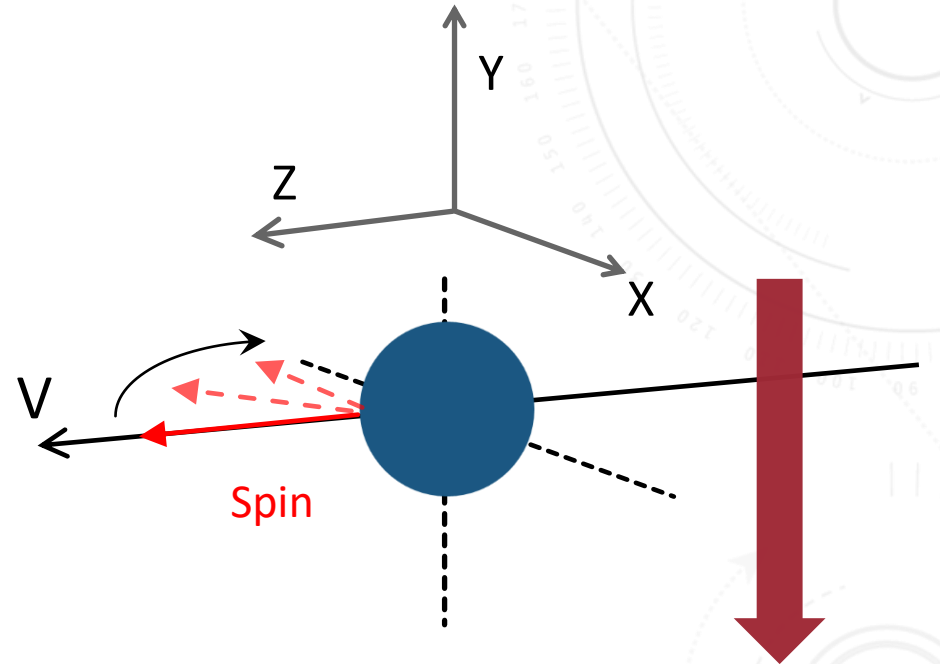
How to search for ALPs in a storage ring?

- Horizontally polarized beam
- Spintune(ν_s) = $\frac{\text{\#spin rotation}}{\text{\#particle revolution}}$

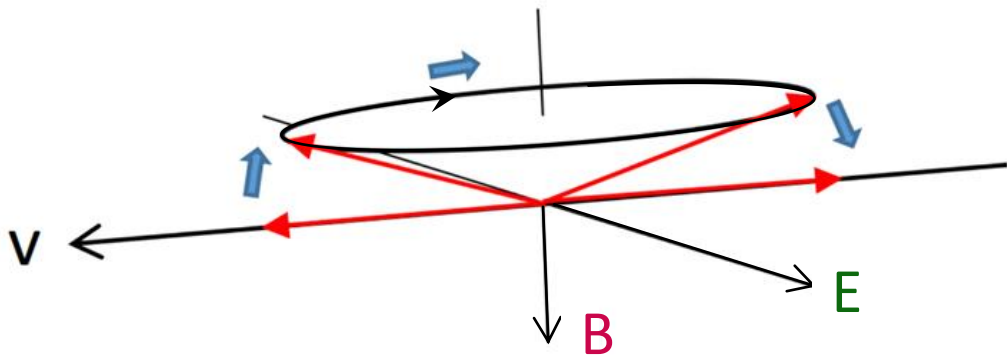
$$\nu_s = G\gamma$$

G : anomalous magnetic moment

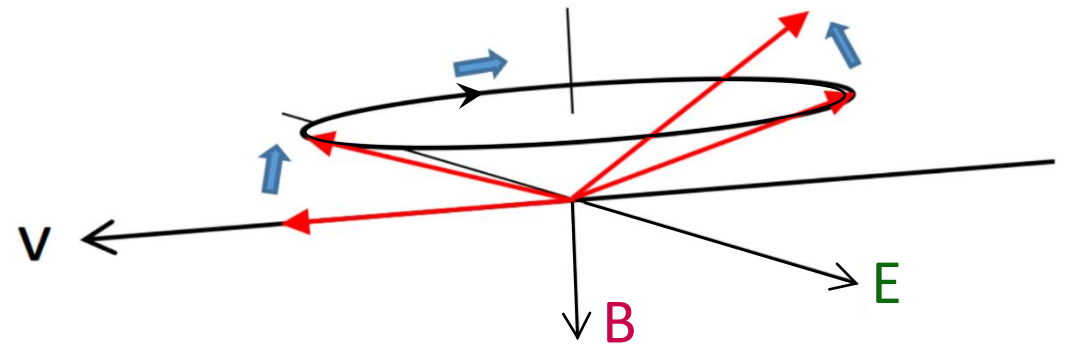
γ : Lorentz factor



How to search ALPs in a storage ring?



Static EDM



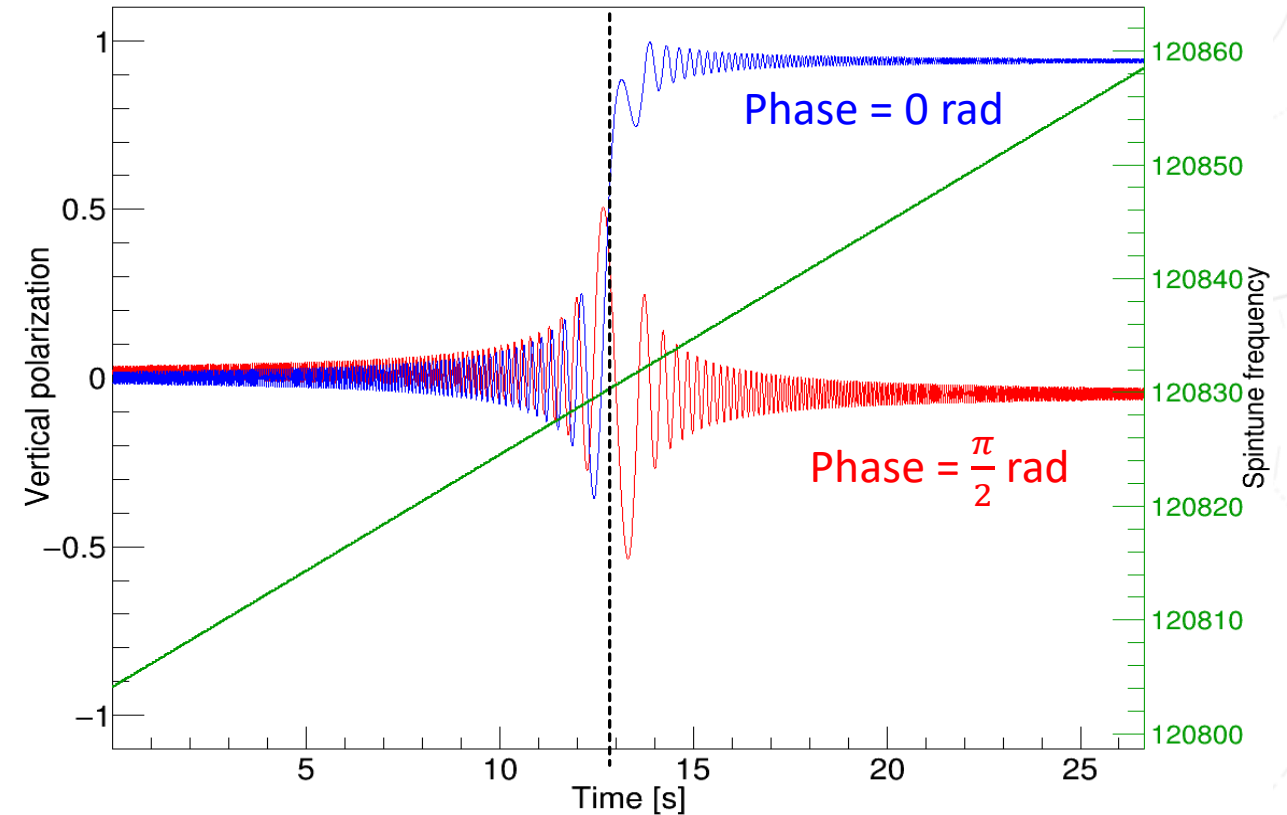
Oscillating EDM

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.

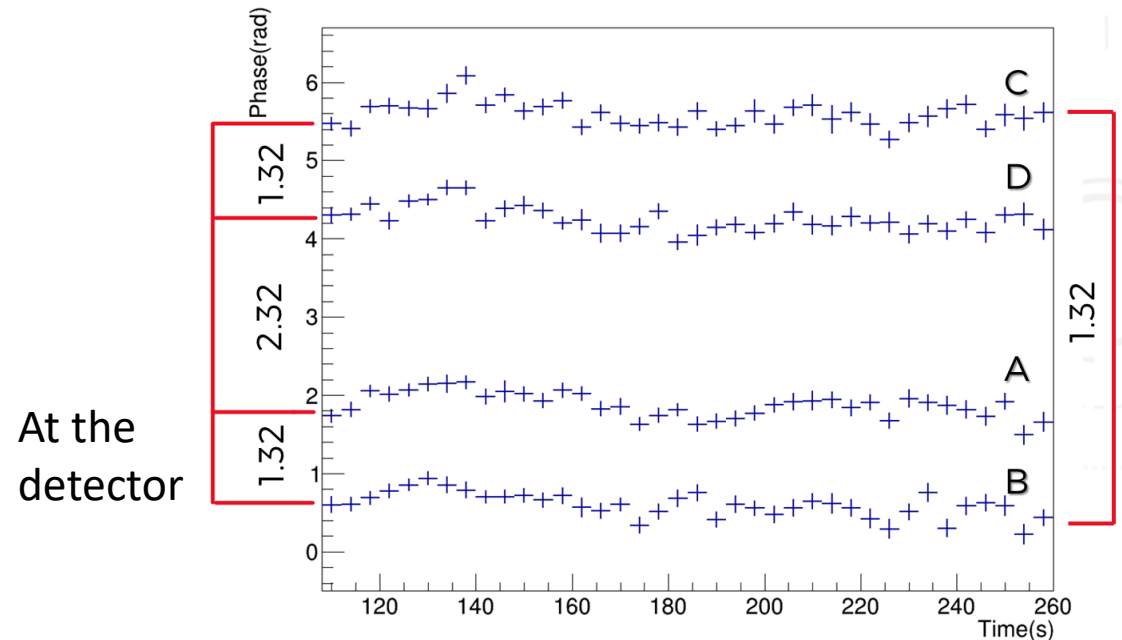
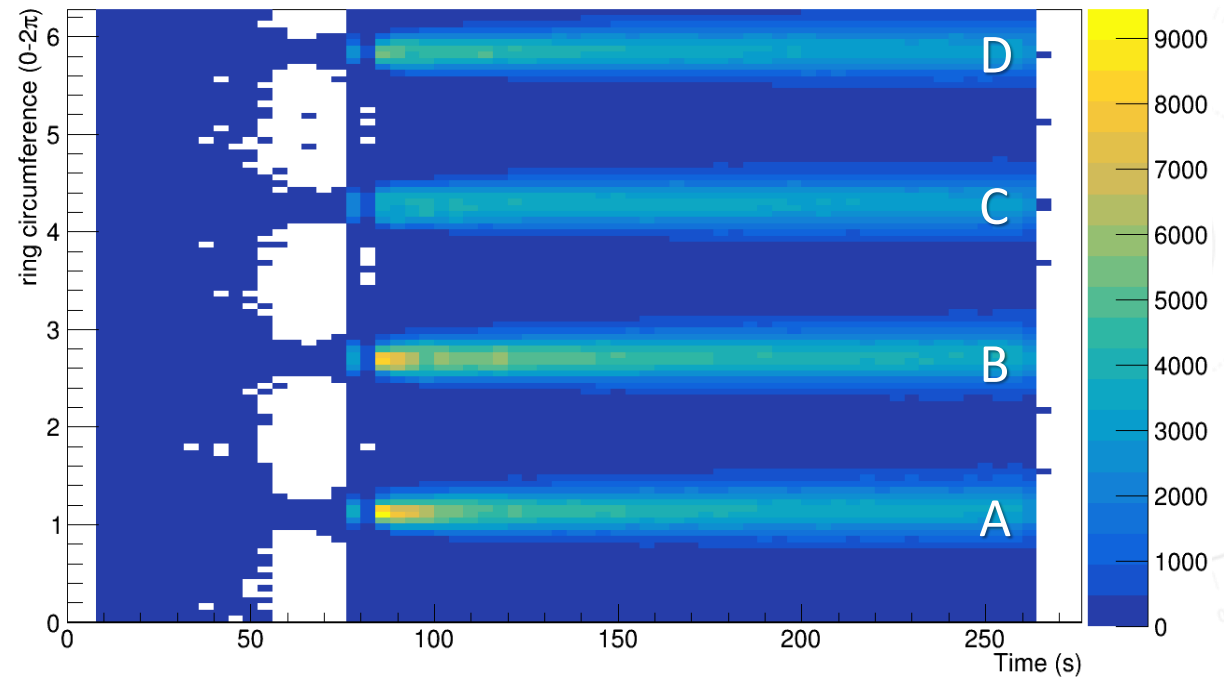
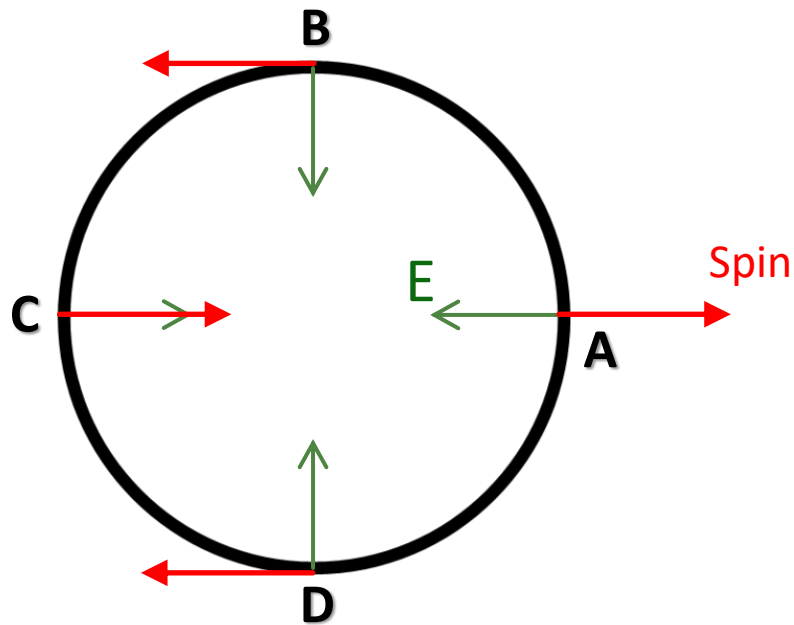
← Unknowns of the experiment:
frequency and phase



Phase problem and 4 bunches

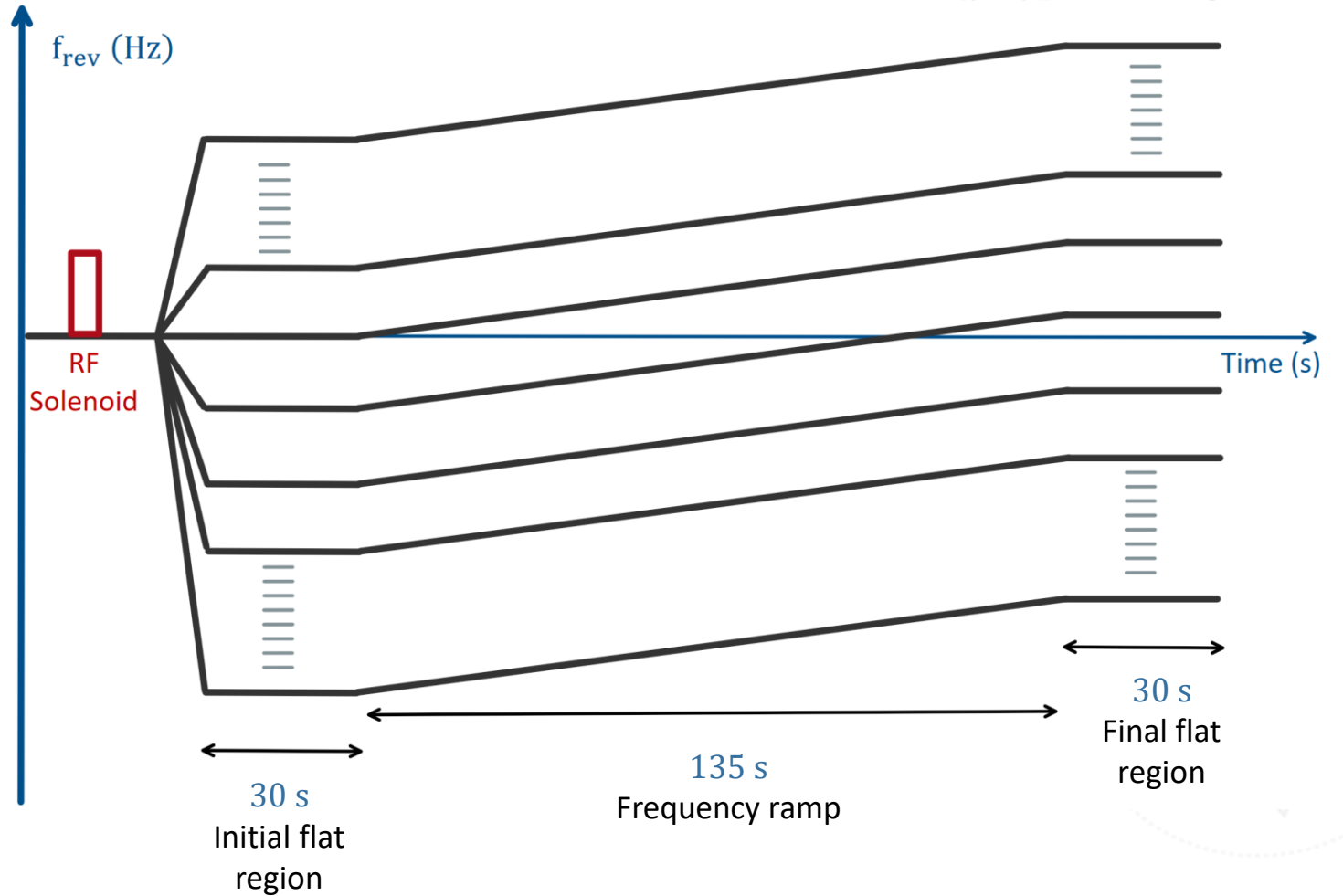
- Simultaneous searches with perpendicular beam polarization using 4 bunches.
- RF solenoid run at $f_{\text{rev}}(1 + G\gamma)$

A top down view of the ring.



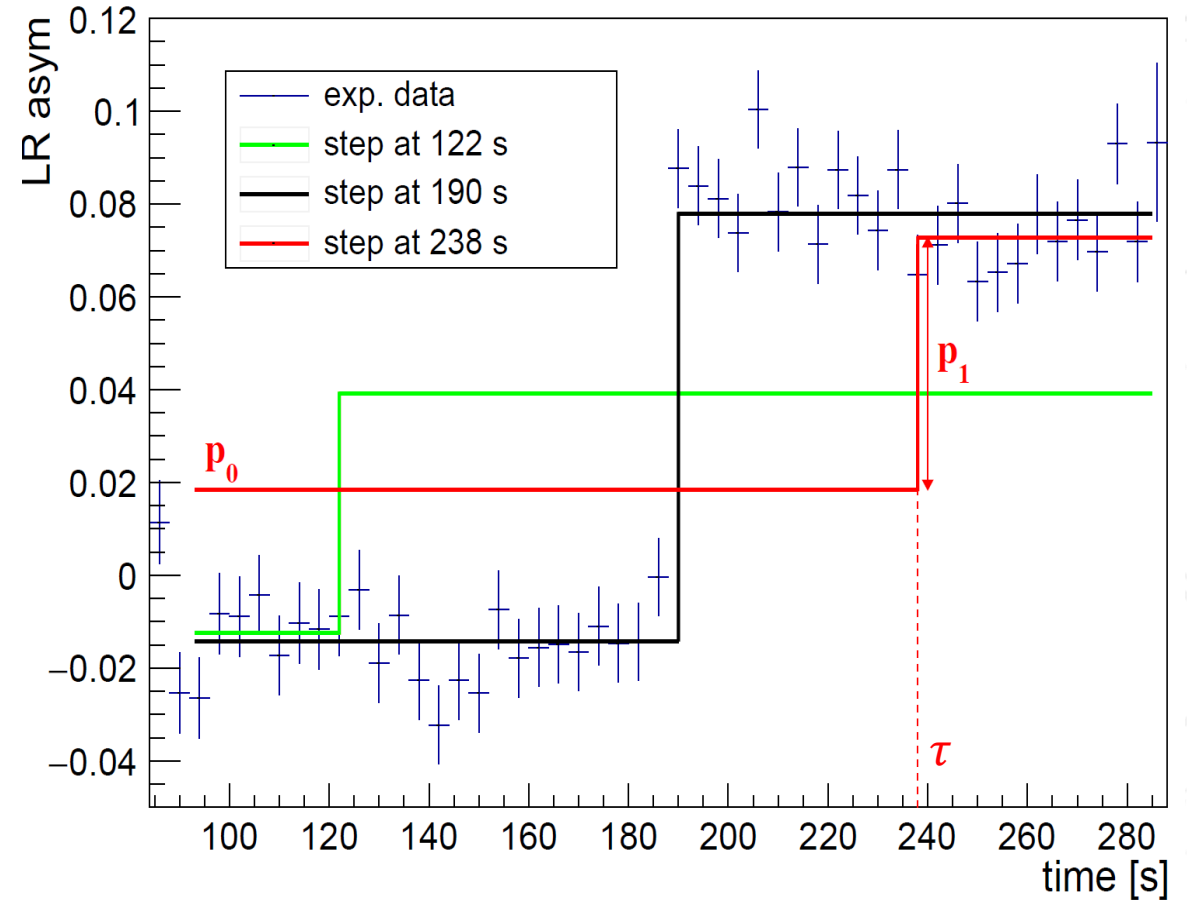
Measurement procedure

- Vary the spintune frequency (ramp rate $\approx 0.1\text{Hz/s}$) in search of resonance.
- Measure polarization.
- About 100 scans
 - Frequency Range
119997 Hz – 121457 Hz
 - Total width $\approx 1.5\text{ kHz}$
 - ALP mass range
 $4.96 \times 10^{-9}\text{eV} - 5.02 \times 10^{-9}\text{eV}$



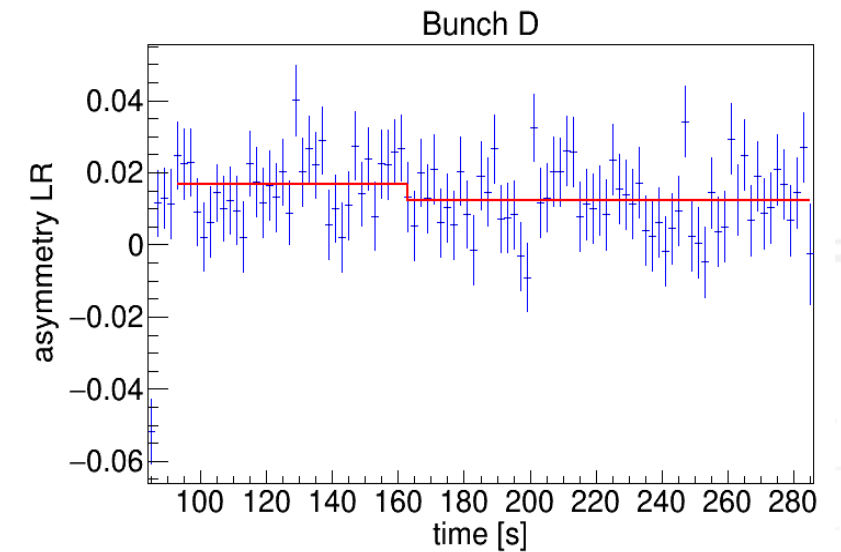
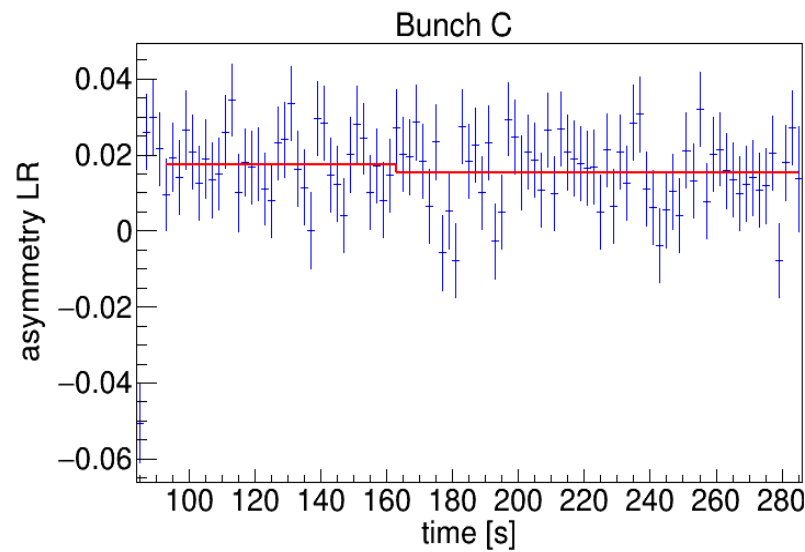
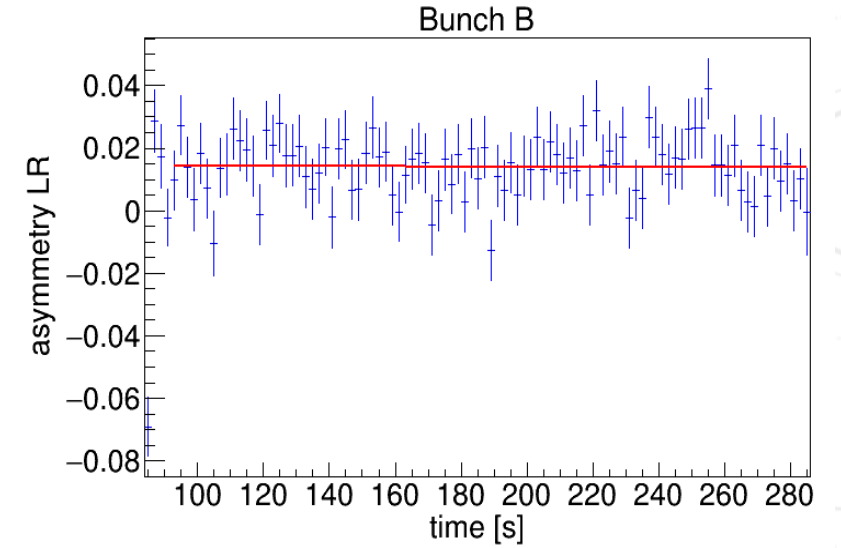
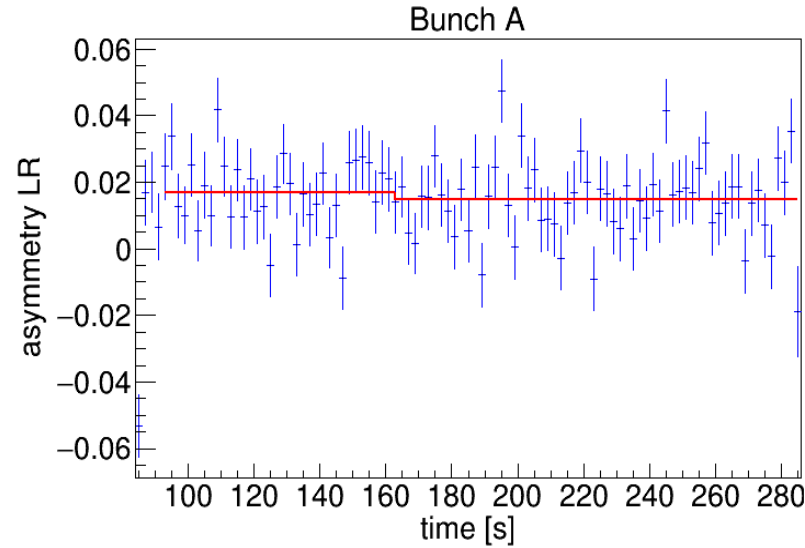
Wien filter scan and analysis of data

- 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.
 - Frequency Range 119997 Hz – 121457 Hz. Total width \approx 1.5 kHz.
 - ALP mass range 4.96×10^{-9} eV – 5.02×10^{-9} eV.
- Wien filter used as a test to observe a signal at resonance crossing.
- No signal was found.



Thank You