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FORSCHUNGSZENTRUM

An Active Spin Tune Feedback System for the Cooler Synchrotron (COSY)

23.3.2017 | Nils Hempelmann for the JEDI collaboration |

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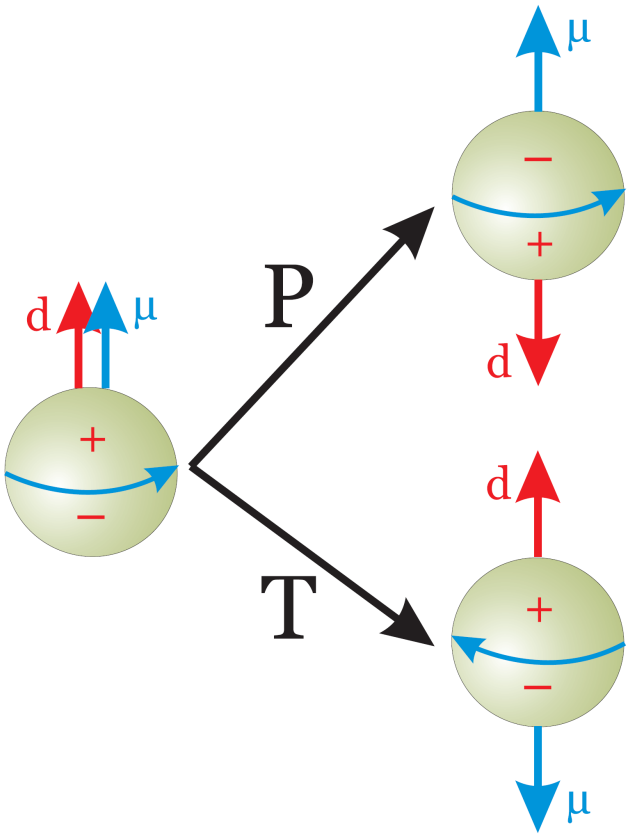
Electric Dipoles and Fundamental Symmetries



- Nonzero electric dipole moment (EDM) of elementary particles violates CP-Symmetry

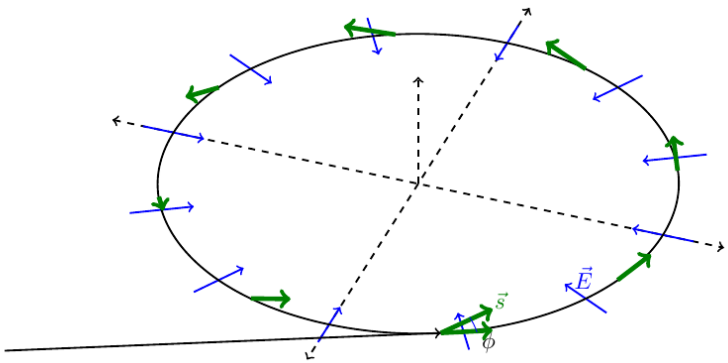
$$H = -\mu\boldsymbol{\sigma}\cdot\boldsymbol{B} - d\boldsymbol{\sigma}\cdot\boldsymbol{E}$$

$$\mathcal{T}: H = -\mu\boldsymbol{\sigma}\cdot\boldsymbol{B} + d\boldsymbol{\sigma}\cdot\boldsymbol{E}$$

$$\mathcal{P}: H = -\mu\boldsymbol{\sigma}\cdot\boldsymbol{B} + d\boldsymbol{\sigma}\cdot\boldsymbol{E}$$

- Standard Model prediction: 10^{-32} to $10^{-31}\,\mathrm{e\,cm}$
- New physics?

EDM Measurements in Storage Rings



- $\frac{d\mathbf{S}}{dt} = \mathbf{d} \times \mathbf{E}^* + \mu \times \mathbf{B}^*$
- Different methods proposed, E-field, B-field, combined
- Signal is build-up of vertical polarization
- COSY is a magnetic storage ring

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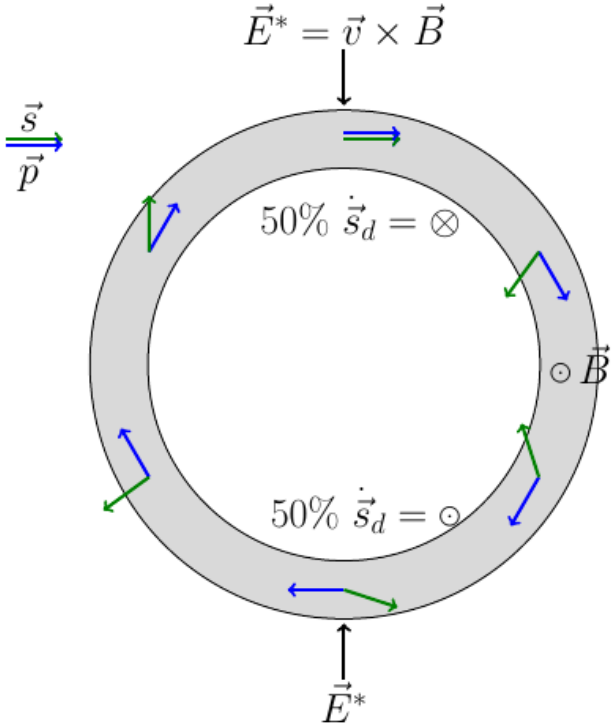
Spin in Magnetic Storage Rings



- Spin rotates rapidly (120 kHz) around vertical axis
- Define spin tune $\nu_s \approx \gamma G$: spin rotations per turn
- EDM causes small up-down-oscillation of spin, no useful signal
- Need Wien filter in phase with spin over 1000 s, $\Delta f/f < 10^{-10}$

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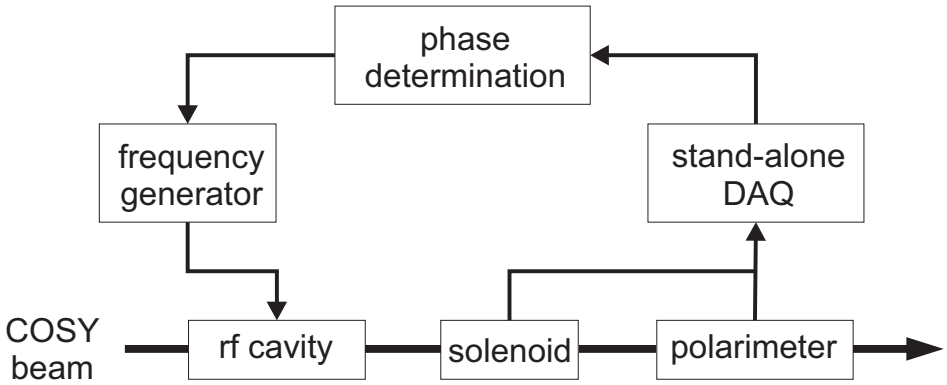
Feedback System - I



- Spin tune can be measured to a precision of $\mathcal{O}(10^{-8})$ in 2 s (PRL 115, 094801 (2015))
- Wien filter not available, use solenoid
- COSY accelerator frequency is adjusted
- This changes the spin tune and the time at which the beam arrives at the detector

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Feedback System - II

- $f_{\mathrm{COSY}} \approx 750\,\mathrm{kHz}$, $f_{\mathrm{spin}} \approx 120\,\mathrm{kHz}$ and $f_{\mathrm{sol}} \approx 871\,\mathrm{kHz}$:
- $\frac{|\Delta\phi|}{\Delta T} = 7.7\,\frac{\mathrm{rad}}{\mathrm{Hz\,s}}\,\Delta f_{\mathrm{COSY}}$
- Frequency can be adjusted in steps of 3.7 mHz corresponding to $\Delta\phi/\Delta T \approx \pm 30\,\mathrm{mrad/s}$

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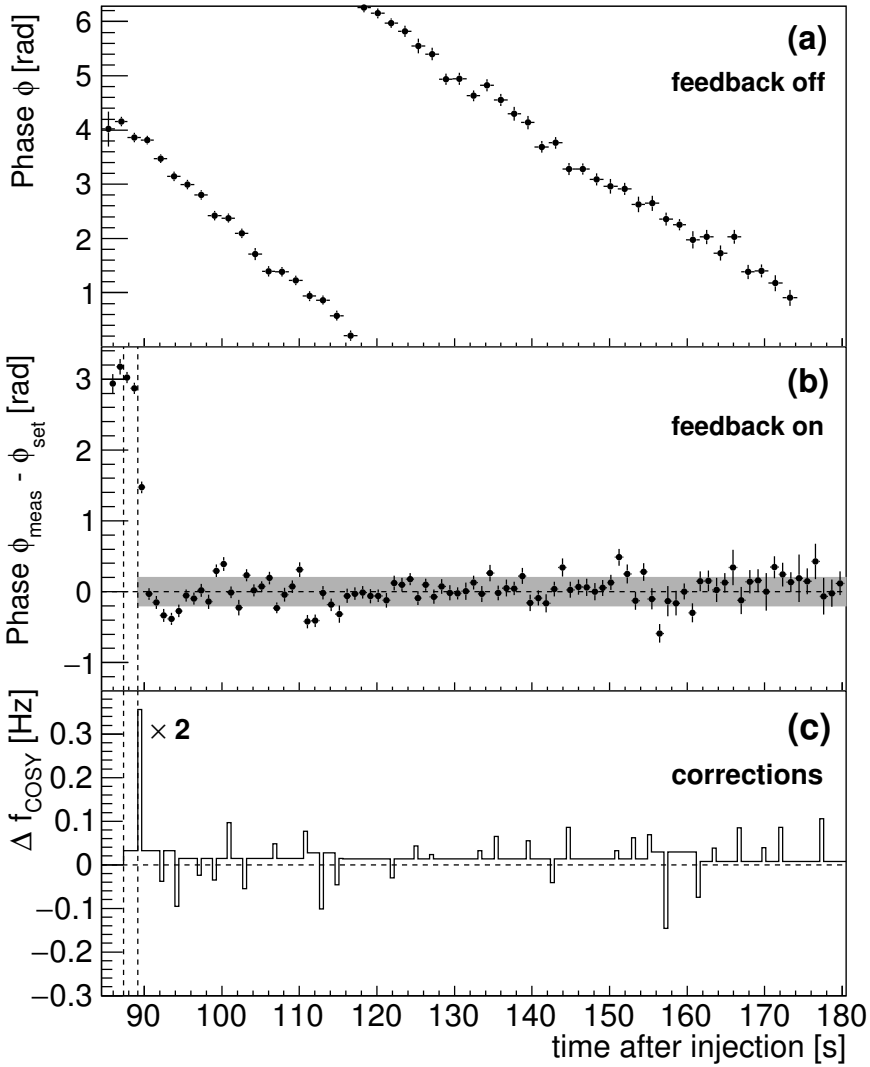
Phase Over One Cycle



- Without feedback: relative phase drifts
- With feedback: relative phase fixed over cycle
- Stable within $\sigma = 12°$

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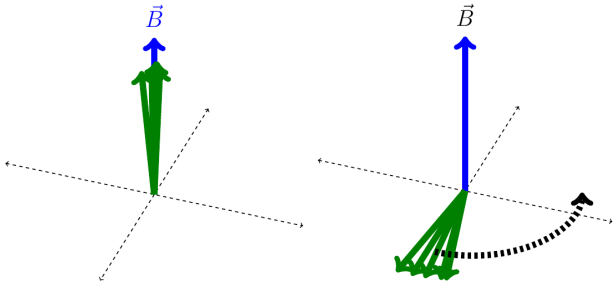
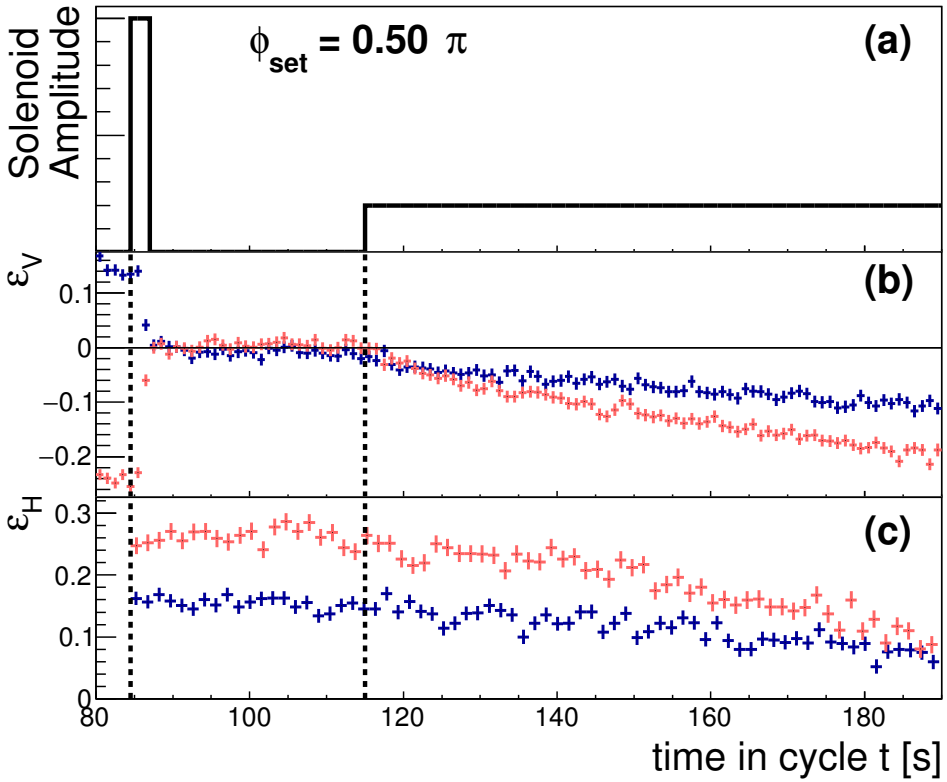
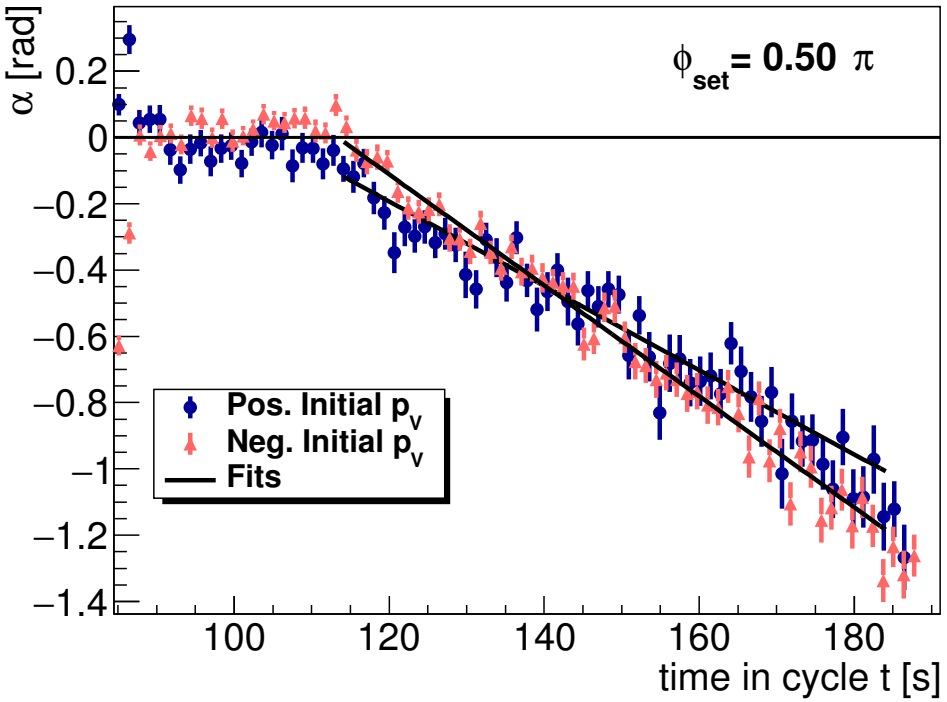
Vertical Spin Build-Up - I





- Confirm that phase is fixed
- Solenoid is switched back on with active feedback system
- Polarization tilted into vertical direction at a speed proportional to sin ϕ

Vertical Spin Build-Up - II



- Examine angle $\alpha = \arctan\left(\frac{p_V}{p_H}\right)$
- Blue: positive initial polarization, Red: negative
- Increases at roughly constant rate
- Feedback stops when spin is vertical

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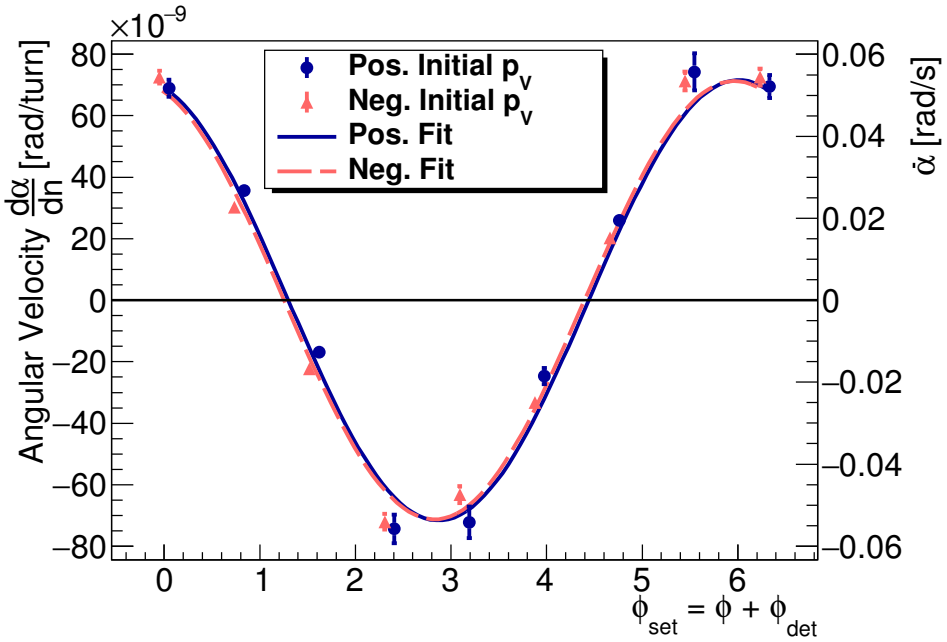
Vertical Spin Build-Up - III



- Slope of build-up has expected sinusoidal shape
- Independent from initial polarization
- Confirms that the feedback system works

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Conclusion

- Successfully tested spin feedback system
- Confirmed by direct measurement of relative phase and vertical build-up experiments
- Phase stable within $\sigma = 12°$
- Will be used with RF Wien Filter in precursor experiments

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