III. Physikalisches Institut B

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Recent Progress of the JEDI Collaboration

Martin Gaißer on behalf of the

JEDI

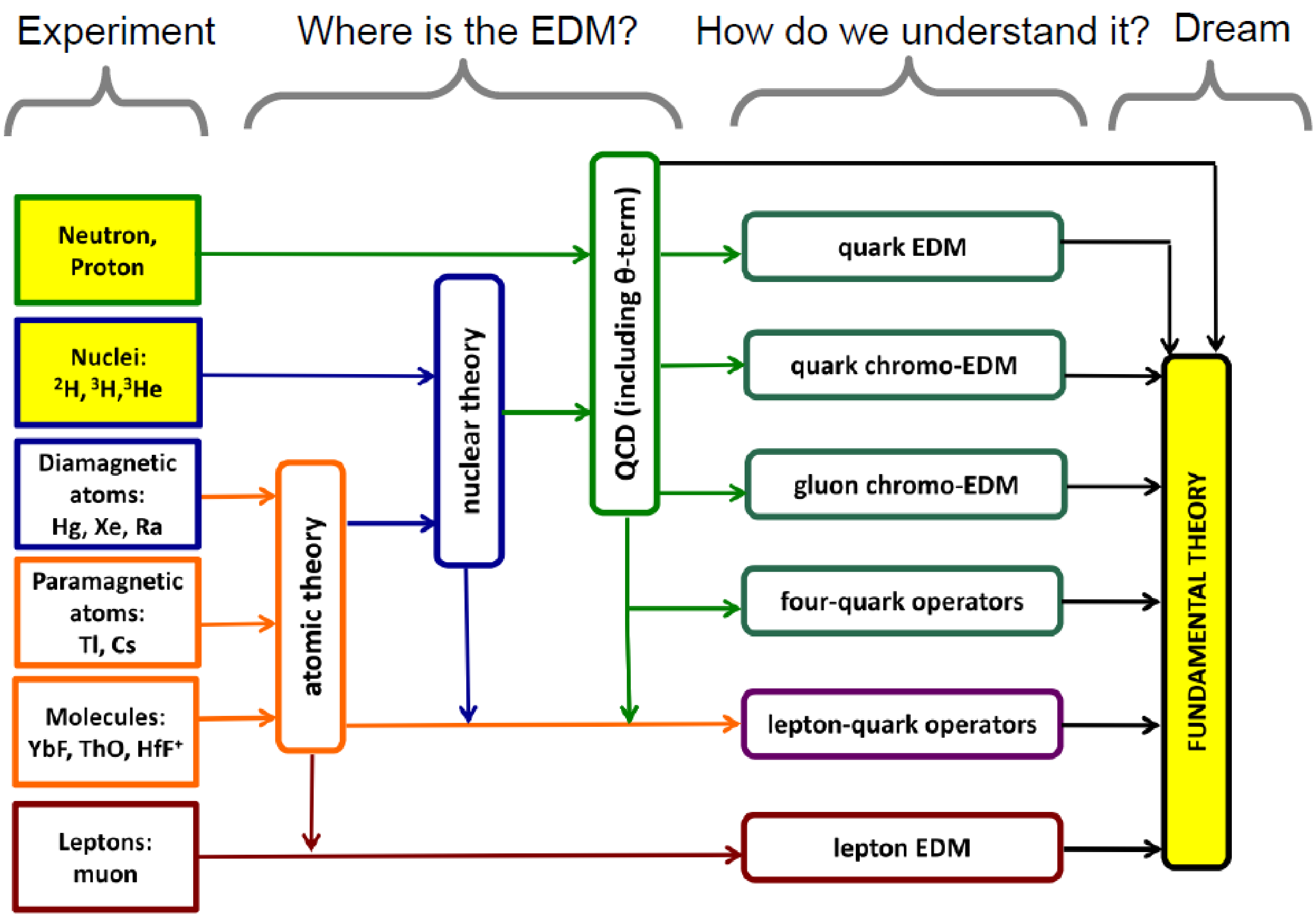
collaboration

erc

European Research Council

Established by the European Commission

Electric Dipole Moments of Charged Particles



Spin in Electromagnetic Field

In rest frame: $\frac{d\vec{S}}{d\tau} = \vec{\mu} \times \vec{B}^* + \vec{d} \times \vec{E}^*$

Transform fields into rest frame, use equation of motion
→ get T-BMT Equation, $G = \frac{g-2}{2}, \; \eta \approx 10^{-15} \text{ for } |\vec{d}| = 10^{-29}\, e \cdot \text{cm}$

$$\frac{d\vec{S}}{dt} = \vec{S} \times (\vec{\Omega}_{MDM} + \vec{\Omega}_{EDM})$$

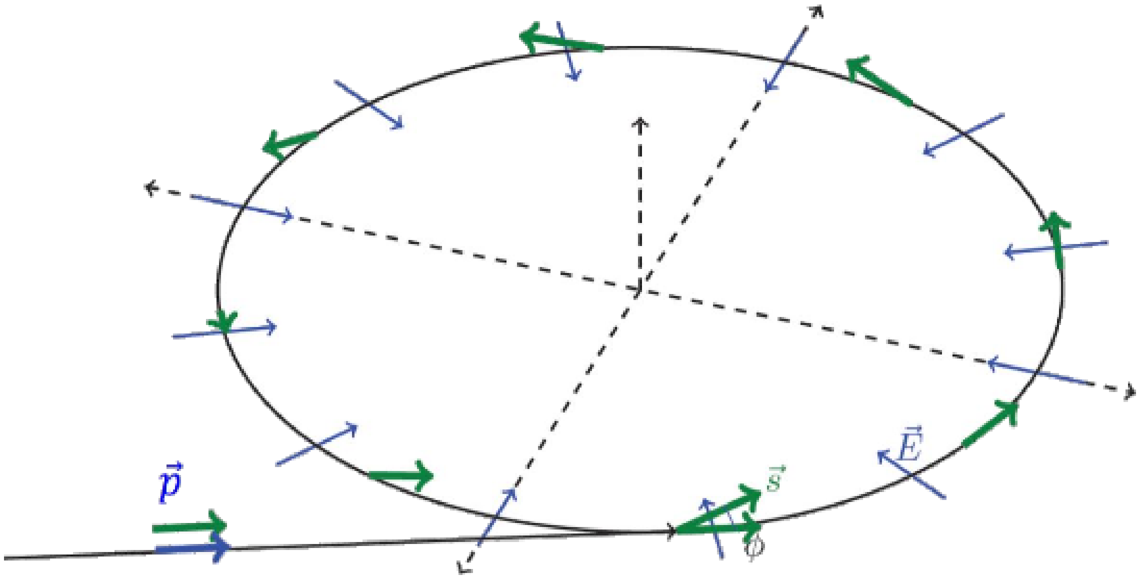
$$\vec{\Omega}_{MDM} = \frac{q}{m}\left(G\vec{B} - \frac{\gamma G}{\gamma+1}\vec{\beta}(\vec{\beta}\cdot\vec{B}) - \left(G - \frac{1}{\gamma^2-1}\right)\frac{\vec{\beta}\times\vec{E}}{c}\right)$$

$$\vec{\Omega}_{EDM} = \frac{\eta q}{2mc}\left(\vec{E} - \frac{\gamma}{\gamma+1}\vec{\beta}(\vec{\beta}\cdot\vec{E}) + c\vec{\beta}\times\vec{B}\right)$$

$|\Omega_{EDM}| \ll |\Omega_{MDM}| \Rightarrow \text{ want } \Omega_{MDM} = 0$

- Possible for $\vec{B} = 0, \; p = \frac{mc}{\sqrt{G}} \approx 0.7\,\text{GeV/c}$ (for protons)
- Have $\Omega_{EDM} \propto E$ → **want strong electric field!**

Measurement Principle (Frozen Spin)



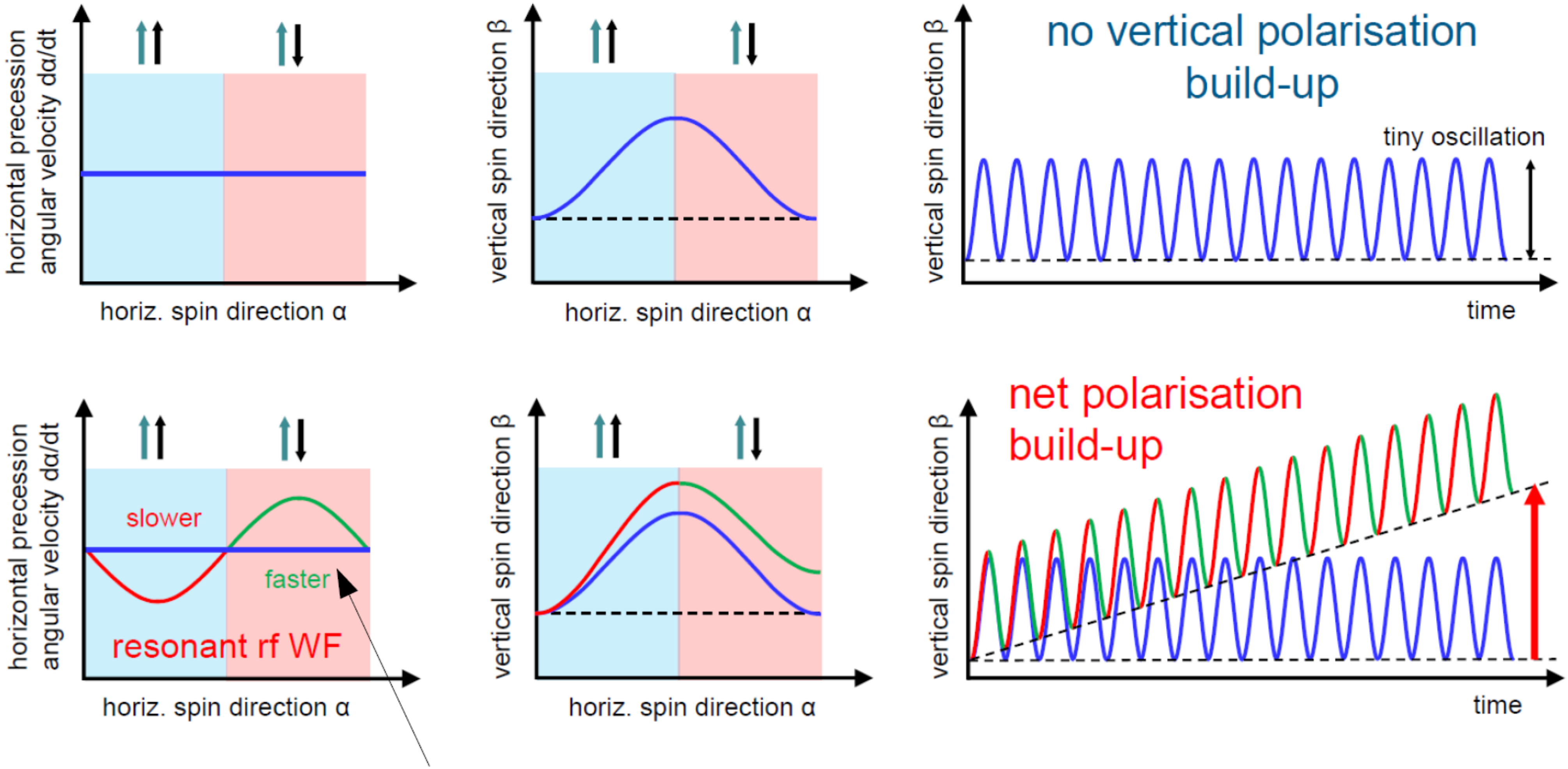
- Inject longitudinal polarized beam
- Run in frozen spin mode
- Observe build-up of vertical polarization

$$(|\vec{E}| = 10\,\mathrm{MV/m},\ \eta = 10^{-15})$$

Expected build-up rate for protons (all electric ring):
$|\vec{\Omega}_{EDM}| \approx 1.6 \cdot 10^{-9}\,\mathrm{rad/s}$
→ **requires long (polarization) lifetime, at least 1000s**
Bending radius (beam): $R \approx 42\,\mathrm{m}$

RF Wien Filter Method

Spin behavior in purely magnetic ring:



Wien Filter has to be always **in phase** with the horizontal spin precession!

RF Wien Filter

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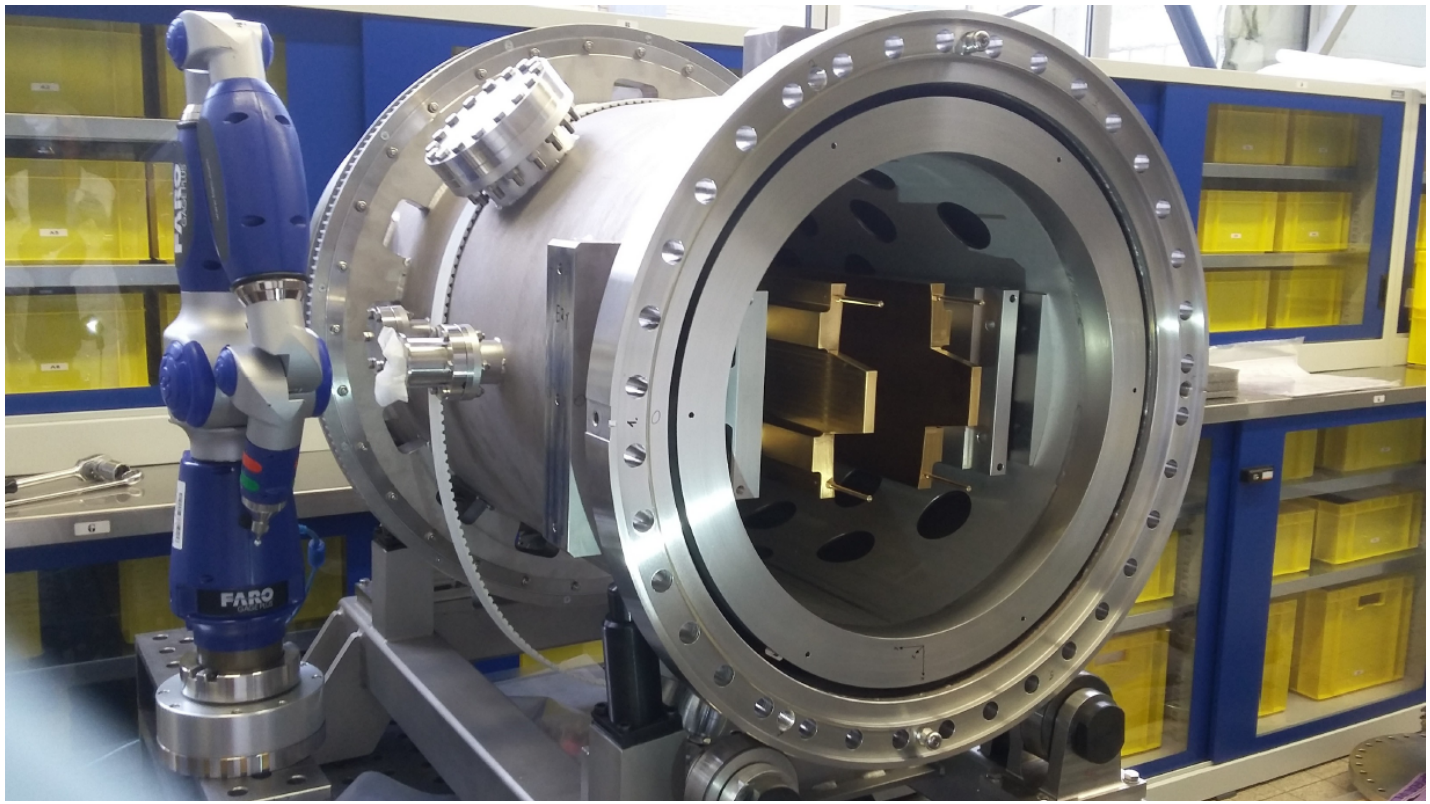
At present: Only magnetic rings → no frozen spin method possible



Already had successful commissioning run

→ **Need feedback system**

For Wien filter method: To keep Wien filter in phase with spin precession

For frozen spin method: To keep spin in forward direction

→ **Requires several steps to get there!**

Spin Coherence Time (SCT)

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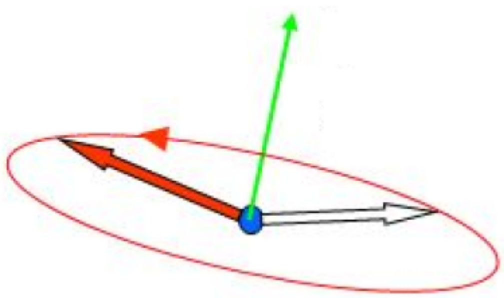
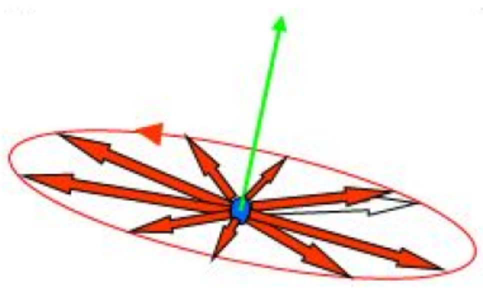


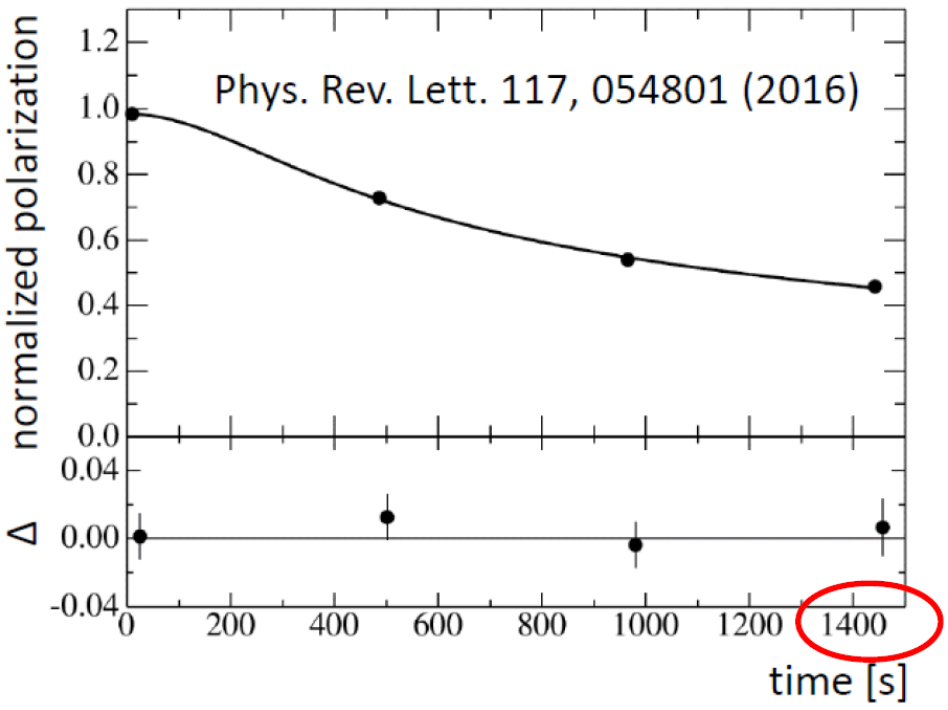
At the beginning all spin vectors aligned



After some time spin vectors all out of phase

- Use bunched beam
- Use small beam (electron-cooling)
- Use special sextupole settings (zero chromaticity)

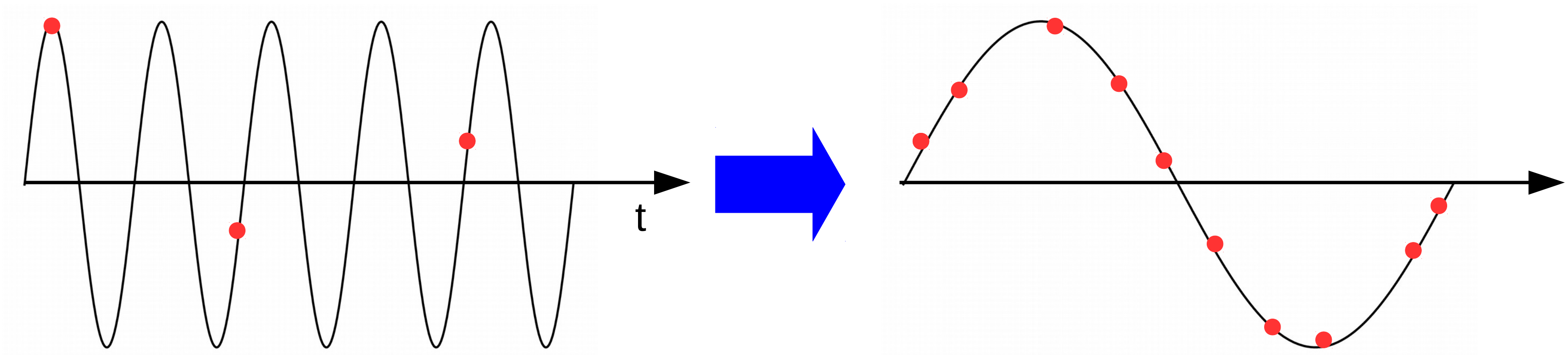
→ similar for all EDM measurement methods



Measure In-plane Polarization

$$\nu_s = \frac{\text{spin revolutions}}{\text{turn}} \approx G\gamma \approx -0.16$$

→ (Deuteron) Spin precesses at ca. 120 kHz!

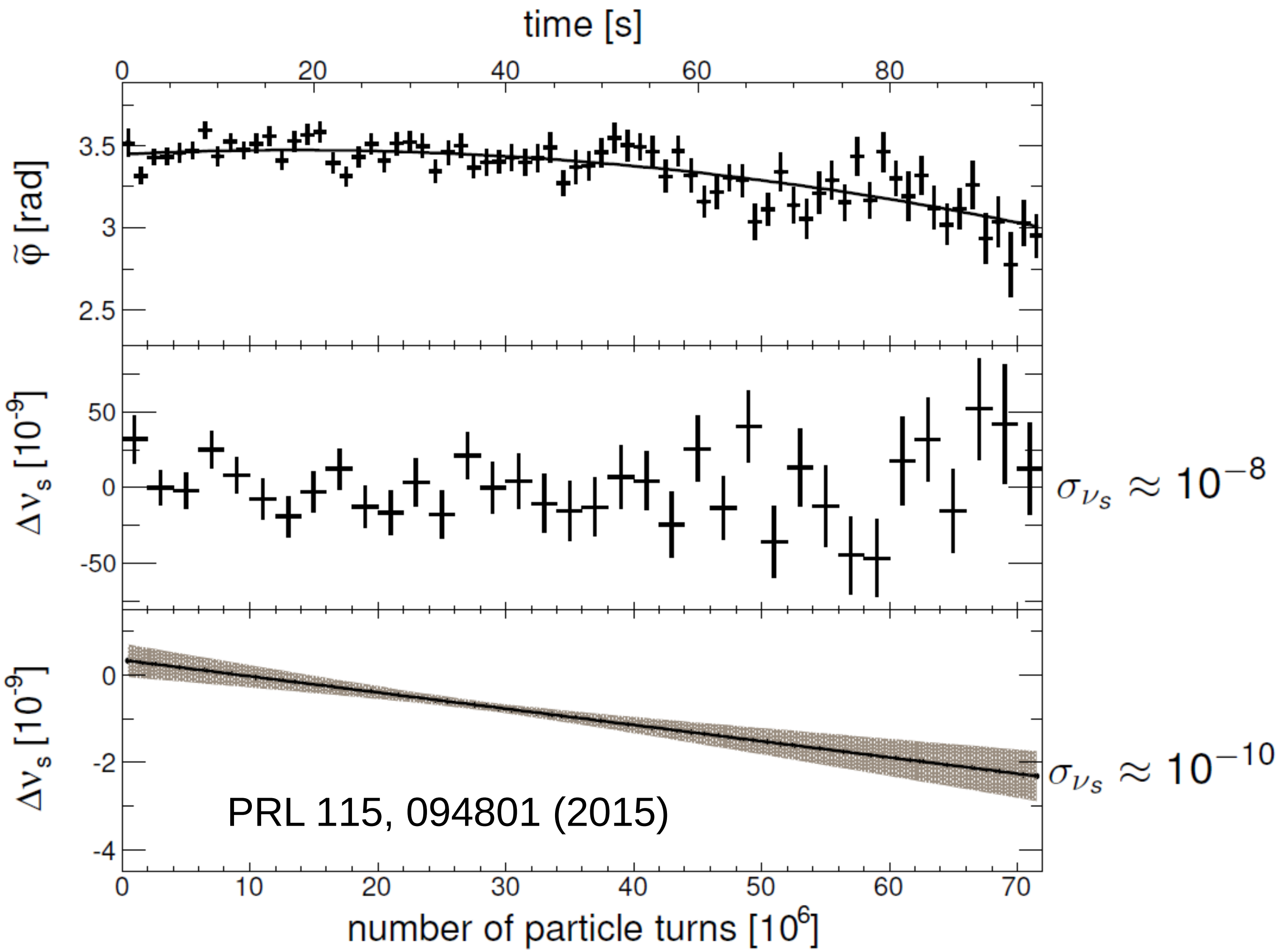


Too few polarimeter events to resolve oscillation directly!

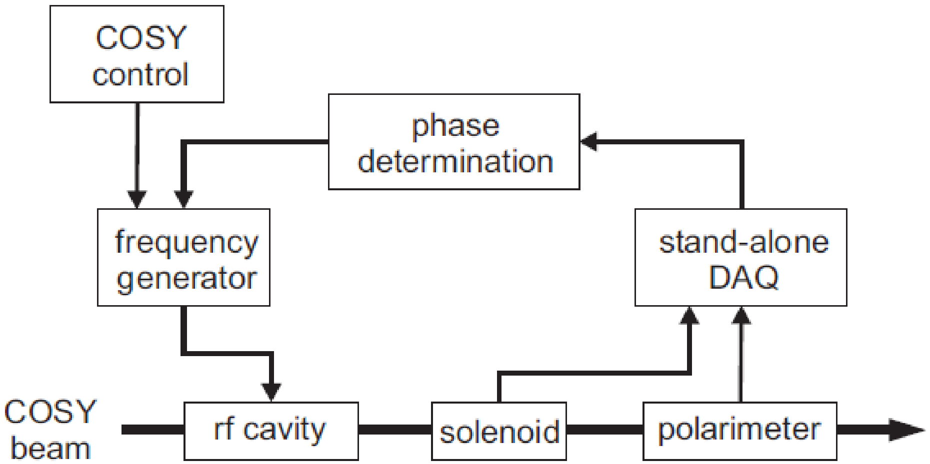
Map many events to one cycle

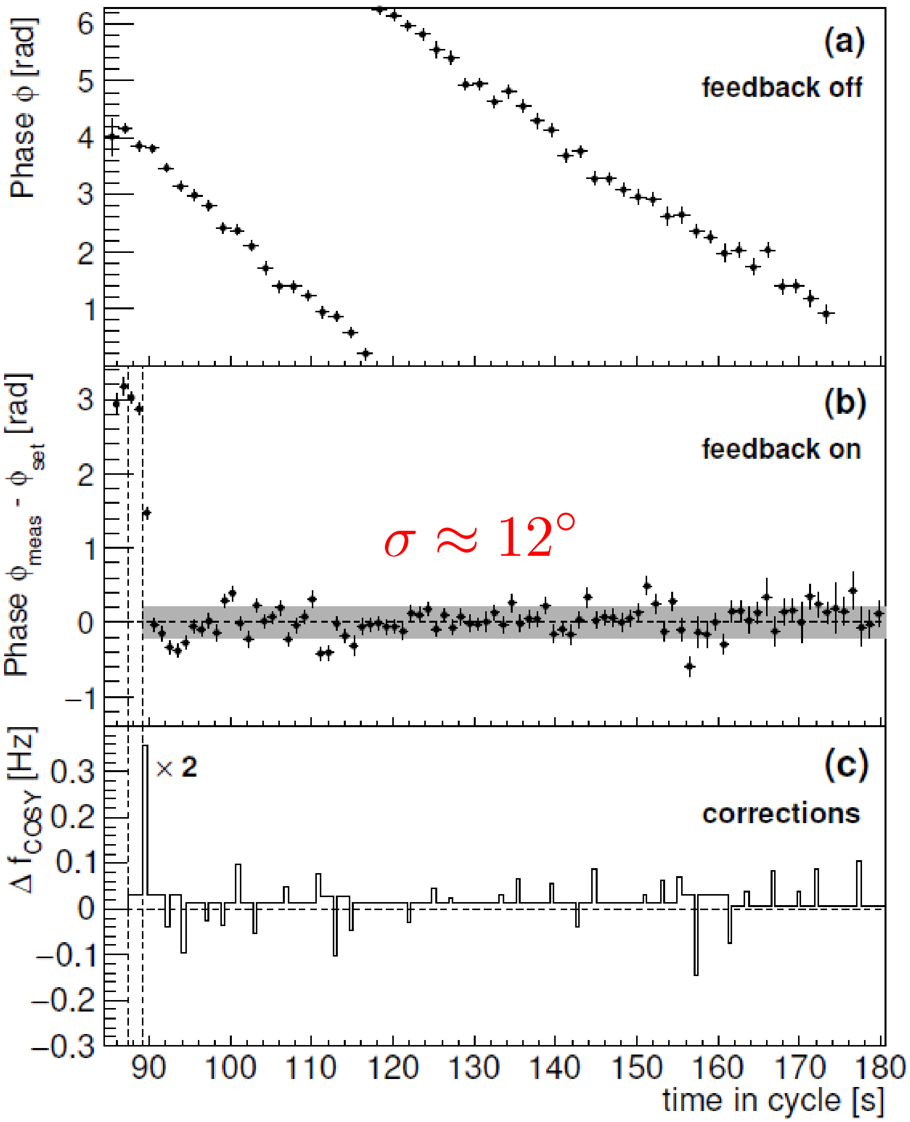
Phys. Rev. ST Accel. Beams 17, 052803 (2014)

Spin Tune Measurement



Feedback System





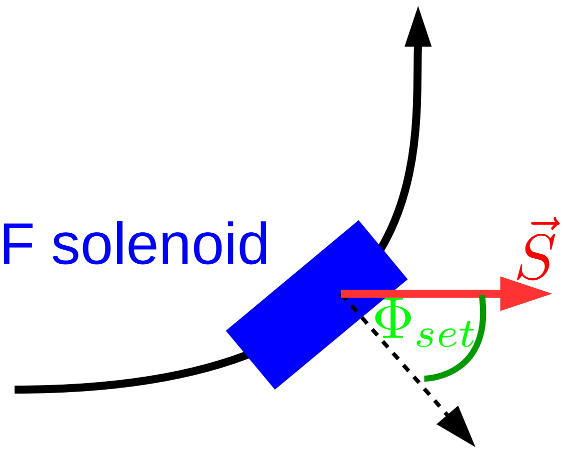
Use RF cavity to change spin tune via $\nu_s = G\gamma$

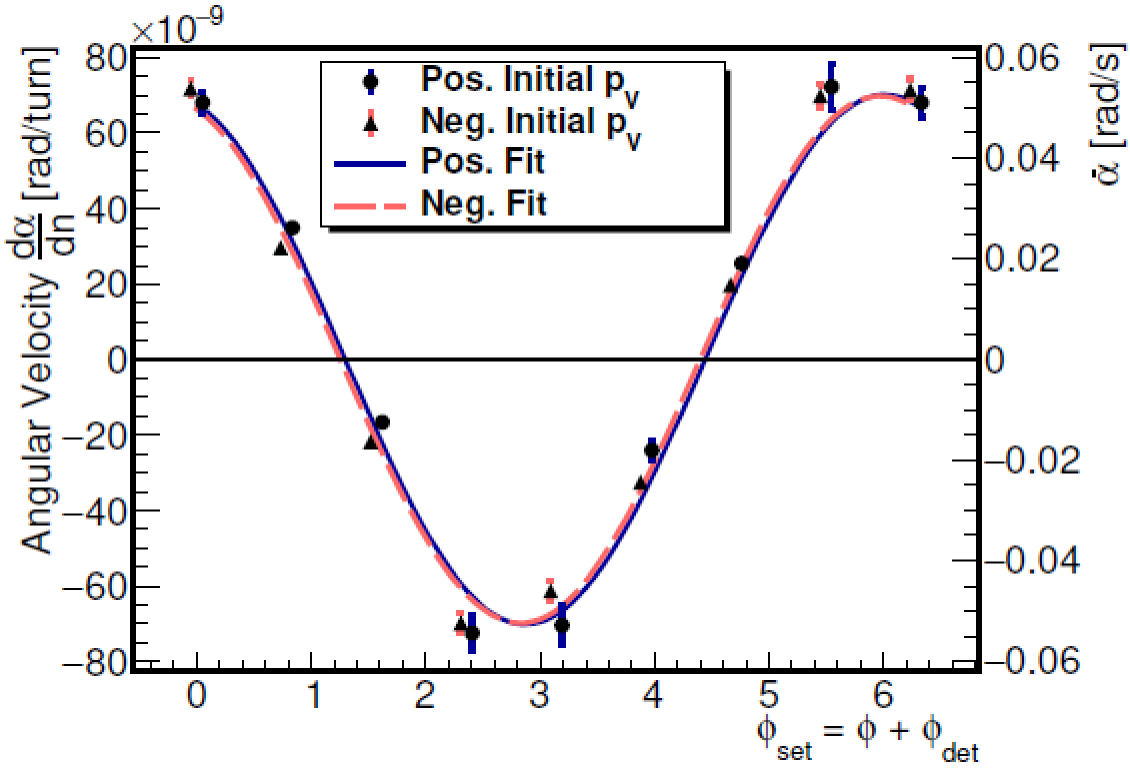
Now: change Wien filter frequency!

PRL, 119, 014801 (2017)

Test of Feedback System

Feedback system allows to set arbitrary phase relations between spin and RF elements
→ Rotate spin back into vertical direction using rf solenoid, rate depends on phase between spin and solenoid





Outlook

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1st deuteron EDM measurement at COSY

Planned for 2019, expected sensitivity: $\approx 10^{-19} \mathrm{e} \cdot \mathrm{cm}$

Prototype ring

- Proof of principle
- Test deflectors/instrumentation
- Check lifetime
- Test CW/CCW operation
- Test frozen spin (needs additional B-Field at low energy)

Dedicated ring

Highly sensitive EDM measurement

Summary

- Achieved long spin coherence time + rapid & precise spin tune measurement
- Can use this as input for feedback system
- Can use spin tune as diagnostic tool, e.g. determining stable spin axis
- Other activities: Build dedicated polarimeter, develop electrostatic deflectors, work on beam position monitors, beam based alignment, etc.
- All techniques relevant to future EDM ring **and** current ring with RF Wien filter

→ JEDI is on track to directly measure the deuteron EDM for the first time