Spin Manipulation at COSY

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(on behalf of the JEDI Collaboration)
WE-Heraeus-Seminar

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- Milestones achieved at COSY
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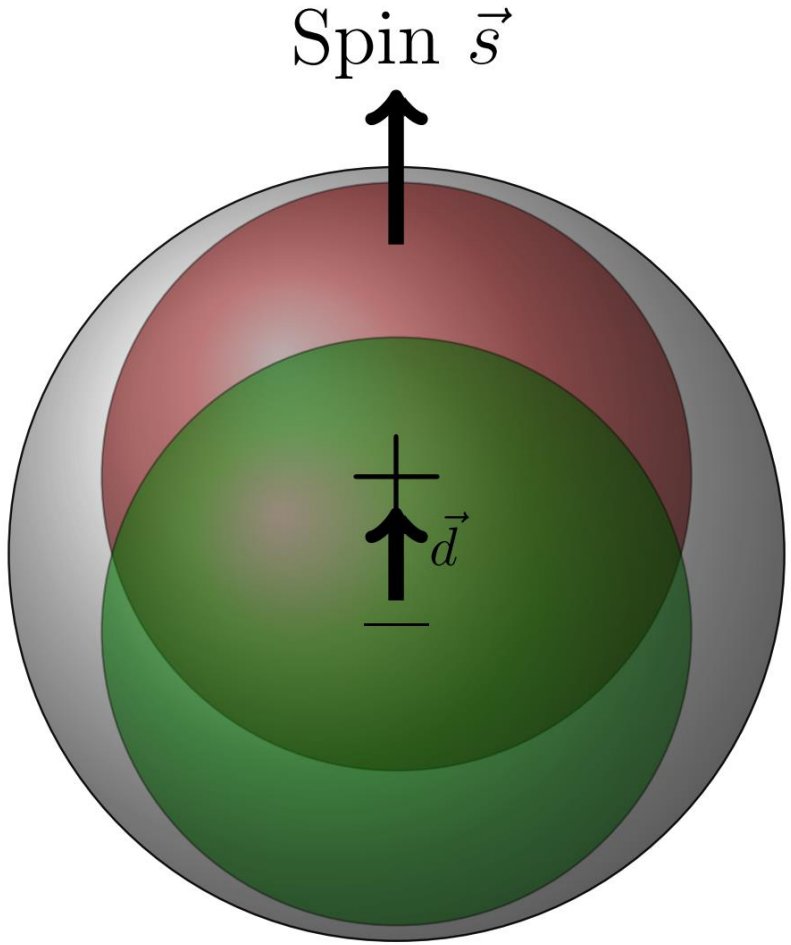
- Preliminary results (1 day old)
- Summary

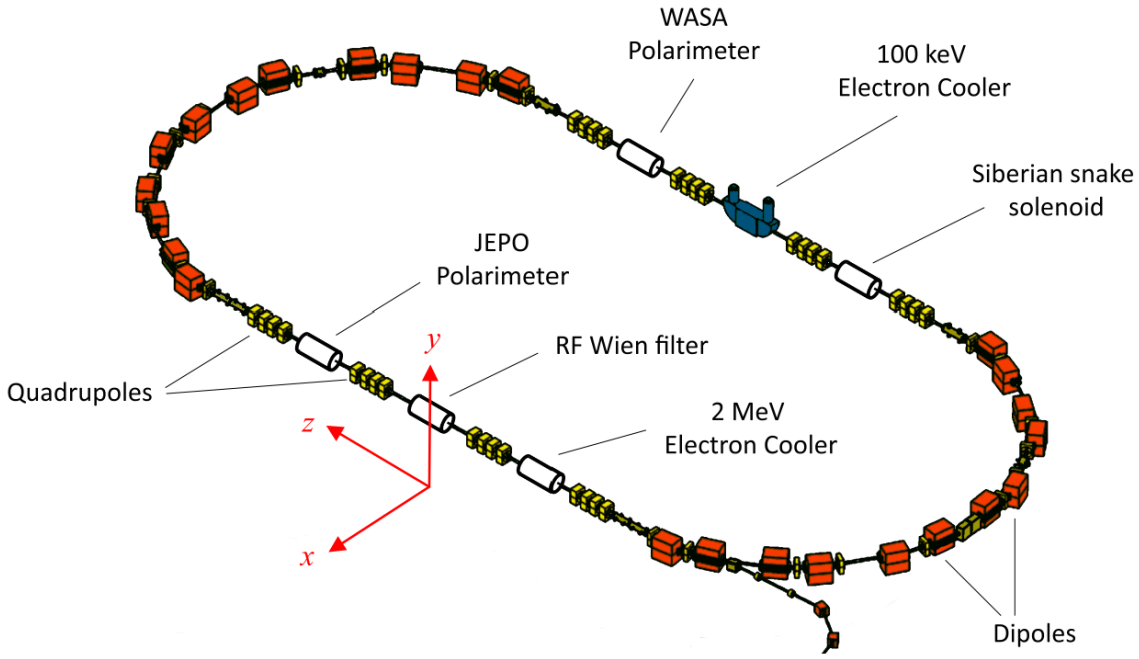
Electric Dipole Moment (EDM)

- Permanent separation of positive and negative charge
- Fundamental property of particles
  - magnetic moment, mass and charge.
- Existence of EDM is only possible via violation of time reversal T and parity P symmetry
- Predominance of matter over antimatter in the Universe

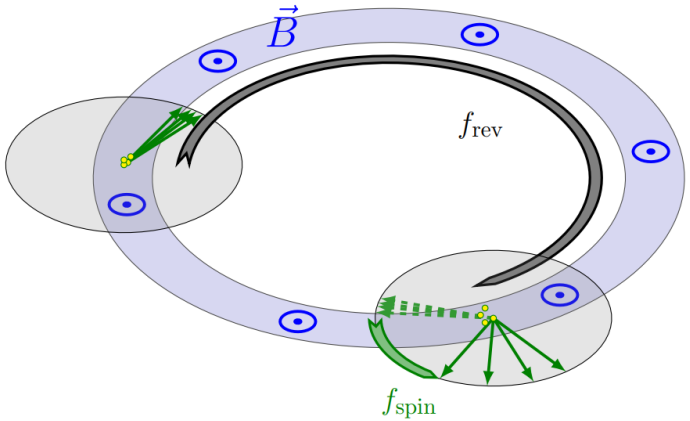


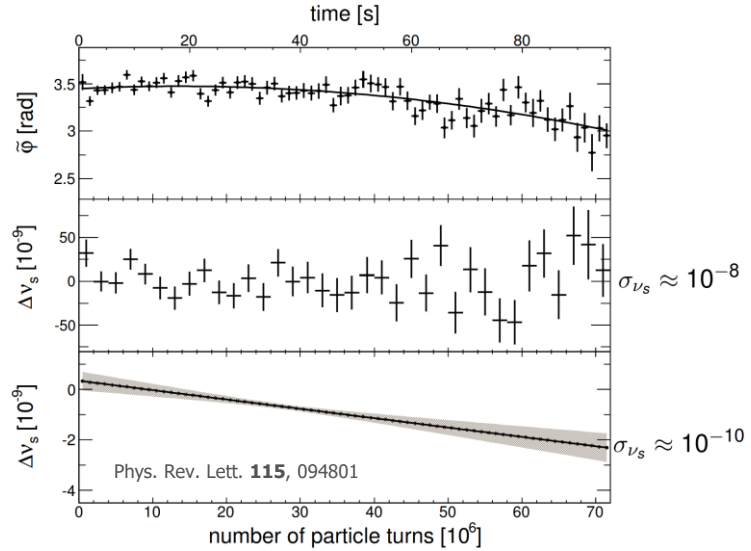
Cooler Synchrotron as a test bench for EDM

- Circumference $\approx$ 184 m
- Momentum: 970 MeV/c
  - $\beta \approx 0.459.$
  - $f_{\mathrm{rev}} \approx 750\ \mathrm{kHz}.$
  - $f_{\mathrm{spin}} \approx 120\ \mathrm{kHz}.$
- First magnetic storage ring used to measured the EDM of deuterons
  - Equipped with an RF Wien Filter

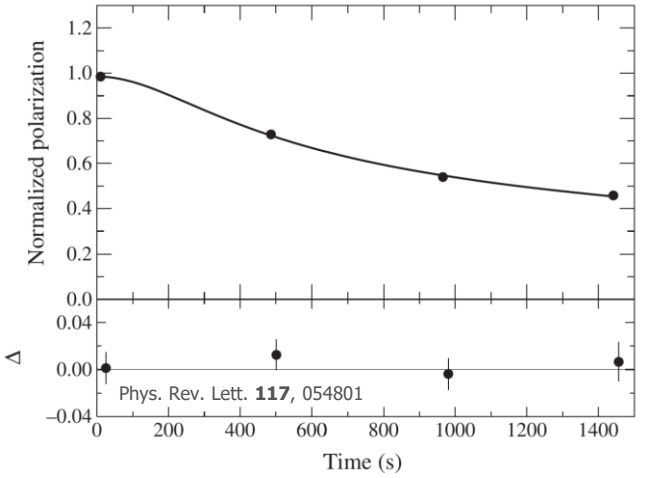


Milestones towards deuterons EDM at COSY



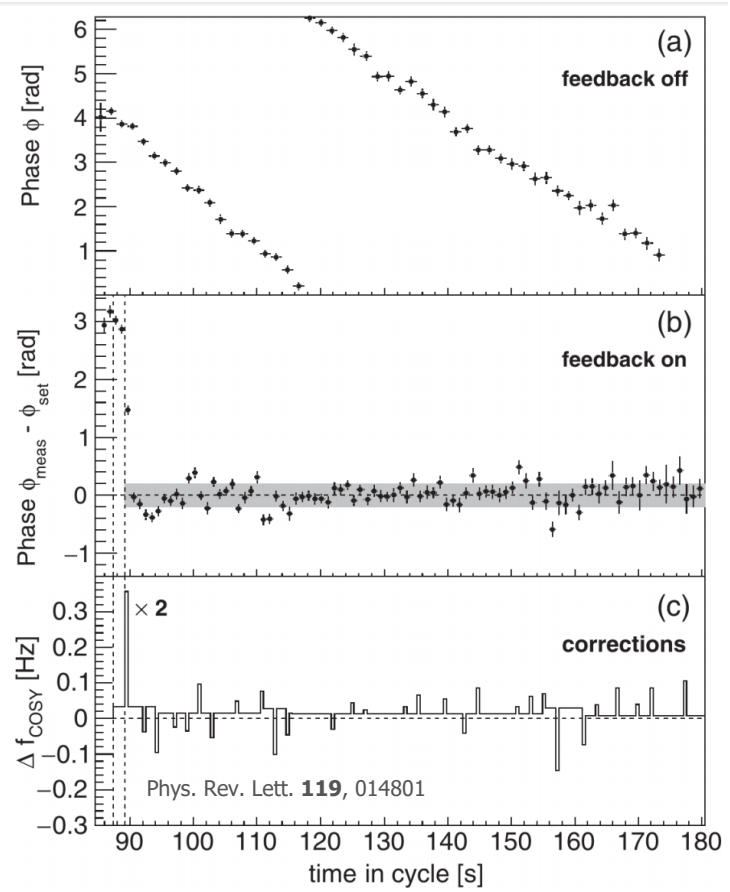


- Spin tune ν_s:
  - Spin revolution per turn
- Precision determination of spin tune
  - $\Delta\nu_s / \nu_s \approx 10^{-10}$
- Spin coherence time ≈ 1000 s



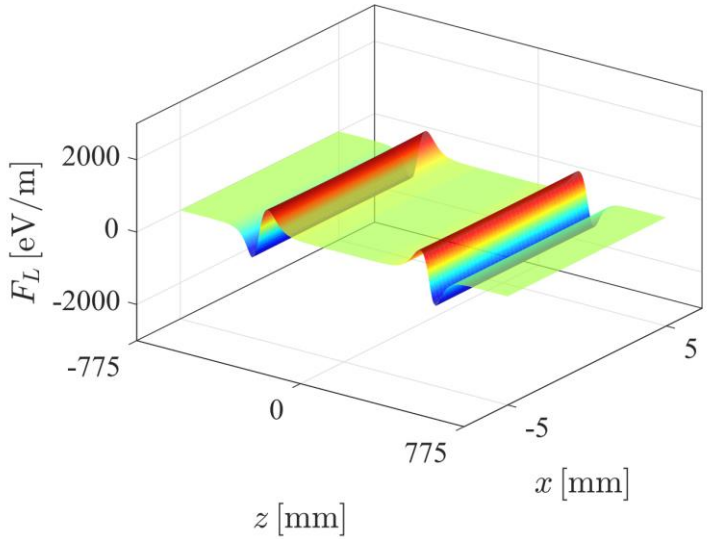
Phase-locking system I

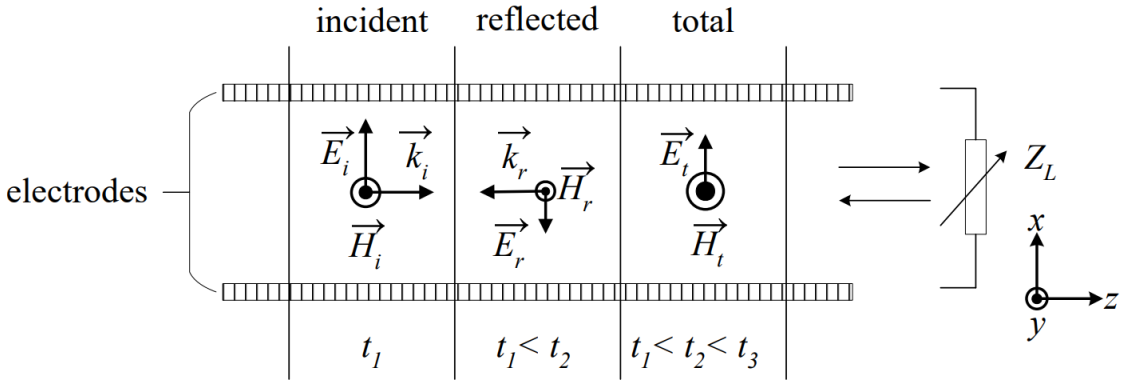
- Phase locking spin precession in machine to device RF required to maintain:
  - Resonance frequency
  - Phase between spin precession and the RF Wien filter (phase locking)

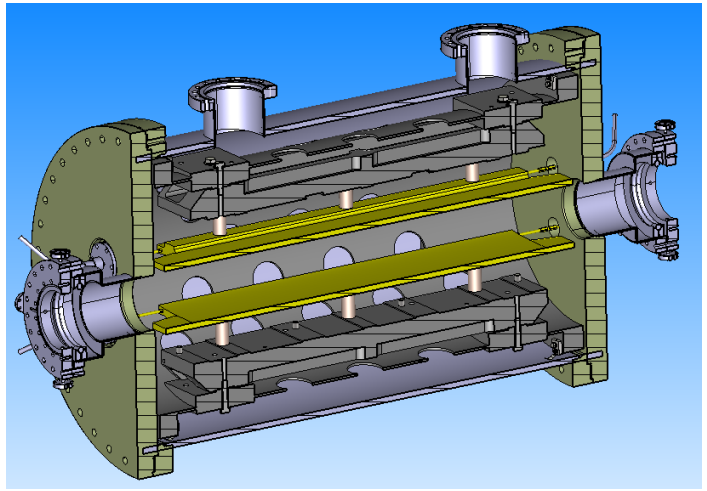


RF Wien Filter

- Waveguide-based, provides
  - $\vec{E} \times \vec{B}$ by design
  - Minimal Lorentz force – variable field quotient
- Transverse spin manipulator



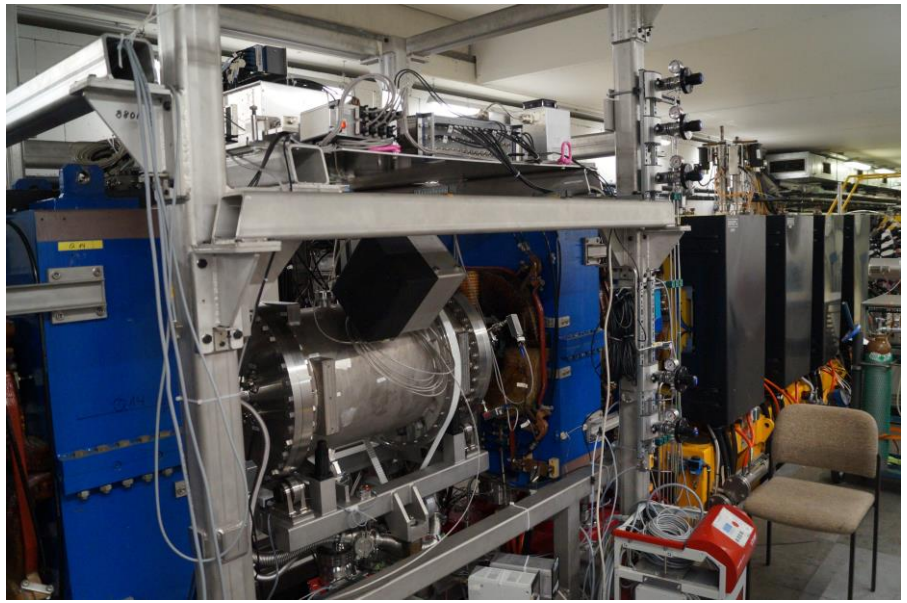


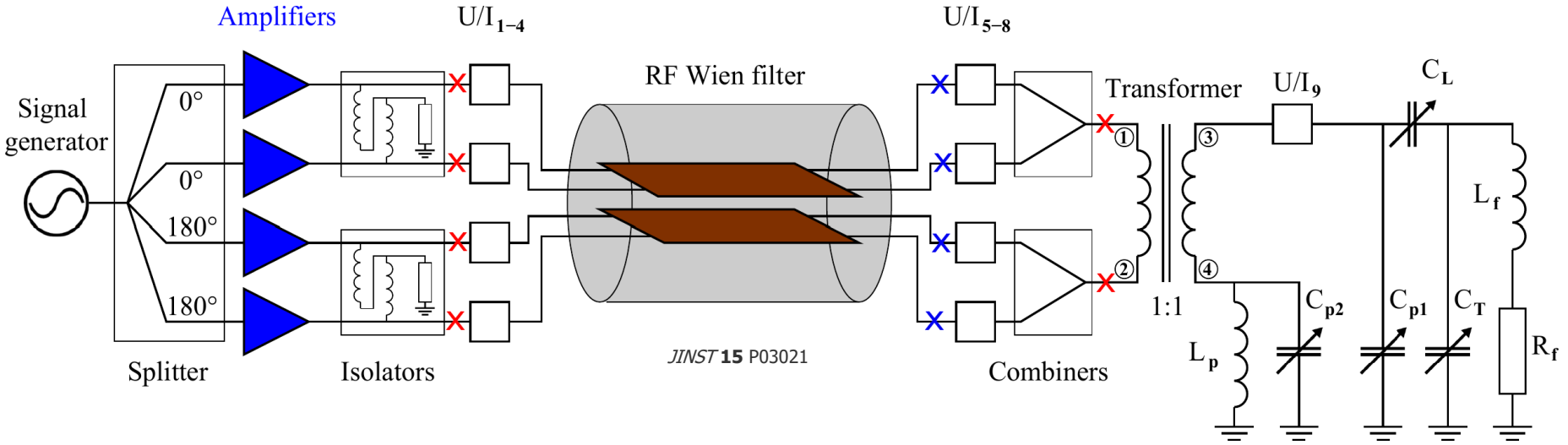


$$Z_q = \frac{E^{\text{total}}}{H^{\text{total}}} = \frac{E^+ + E^-}{H^+ - H^-} = \frac{E^+ + \Gamma \cdot E^+}{H^+ - \Gamma \cdot H^+} = Z_{\text{w}} \frac{1+\Gamma}{1-\Gamma} = Z_0 \frac{d}{W} \frac{1+\Gamma}{1-\Gamma}$$

RF Wien Filter

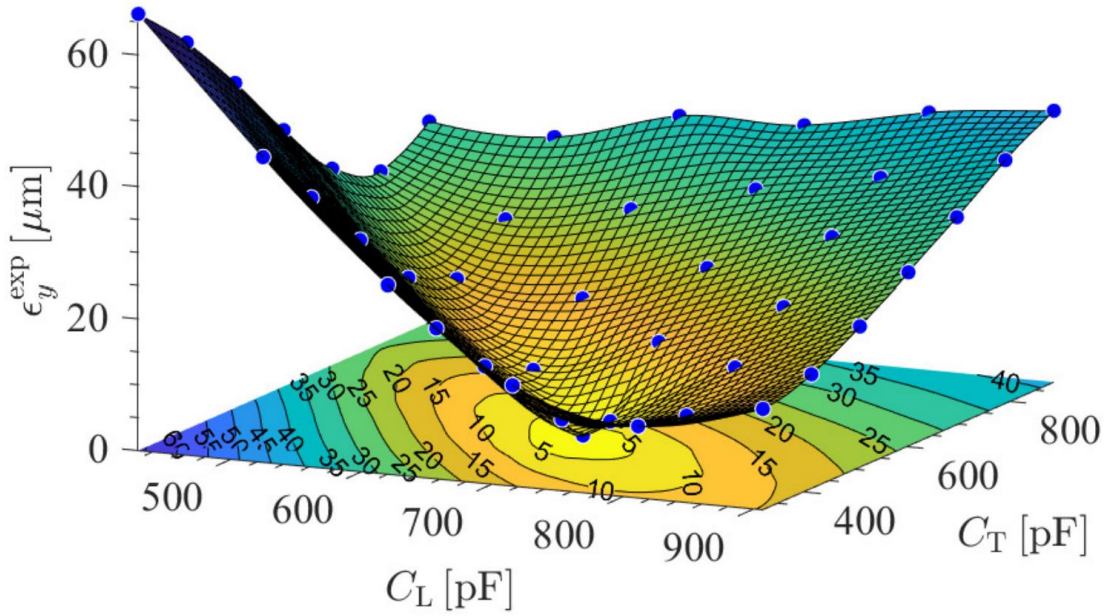
- Circuit realization

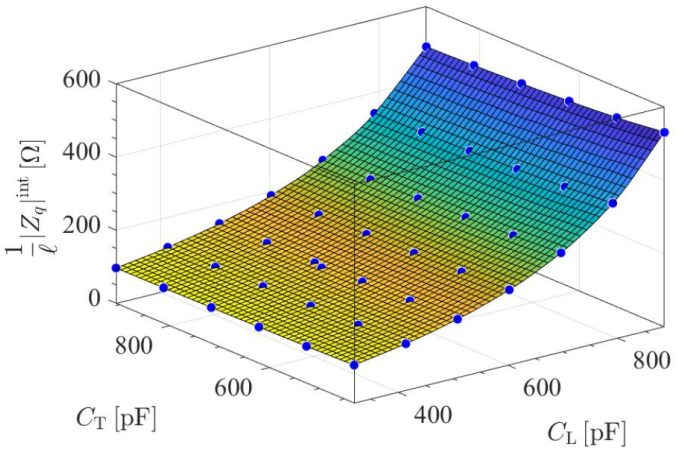


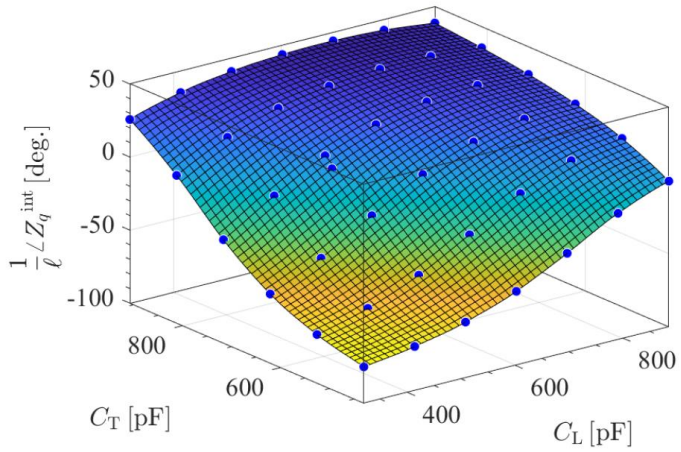


Beam Oscillations

- Scanning the capacitors 2D grid
  - Complex variation of the load impedance
  - Span a large set of the field-quotient
  - Minimum $1\ \mu\mathrm{m}$







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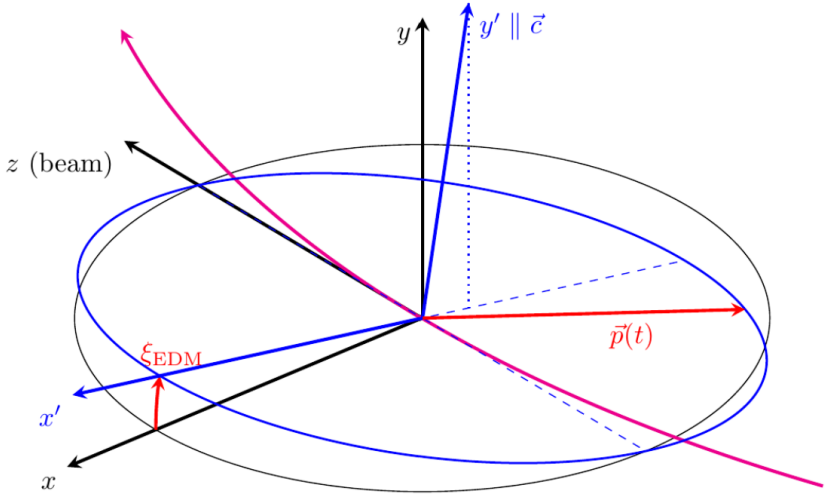
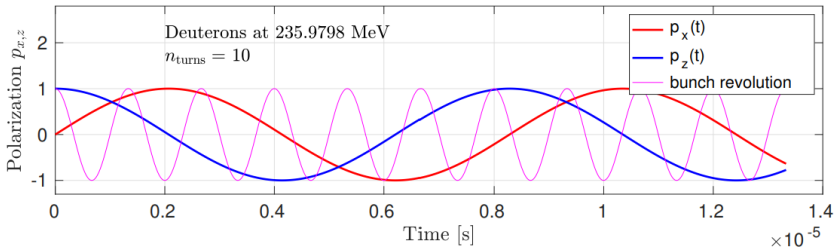
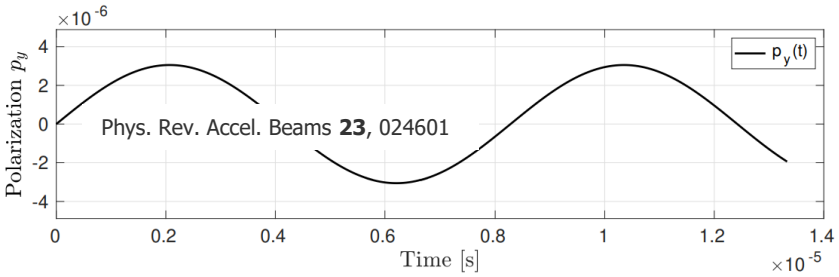
RF Wien Filter

- RF Wien filter method
- Beam particles move along the z direction
  - Spins precess around the c-axis
  - Oscillating vertical polarization component $p_y(t)$ is generated.
  - **Oscillation amplitude corresponds to tilt angle ξ_{EDM}.**
- Problem:
  - With RF fields, spin tune is not well-defined
  - Operating RF WF modifies $\nu_s \Rightarrow$ unavoidable
  - New phase-lock system is required

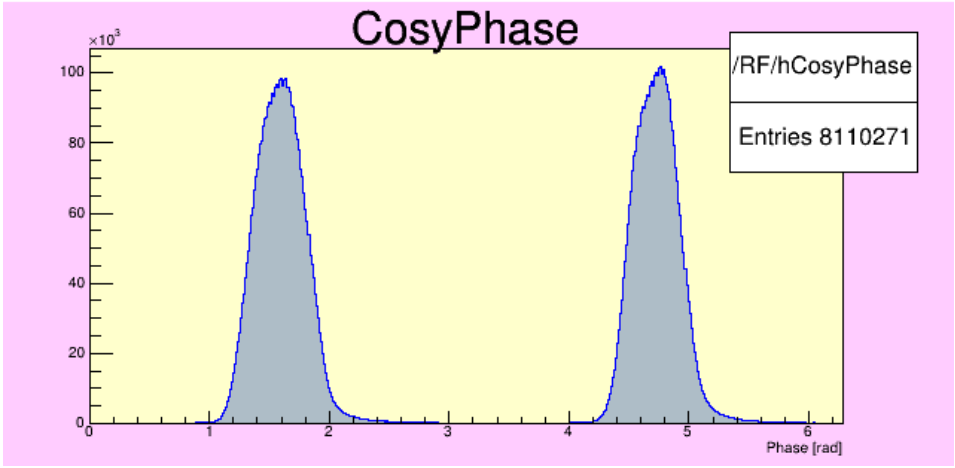


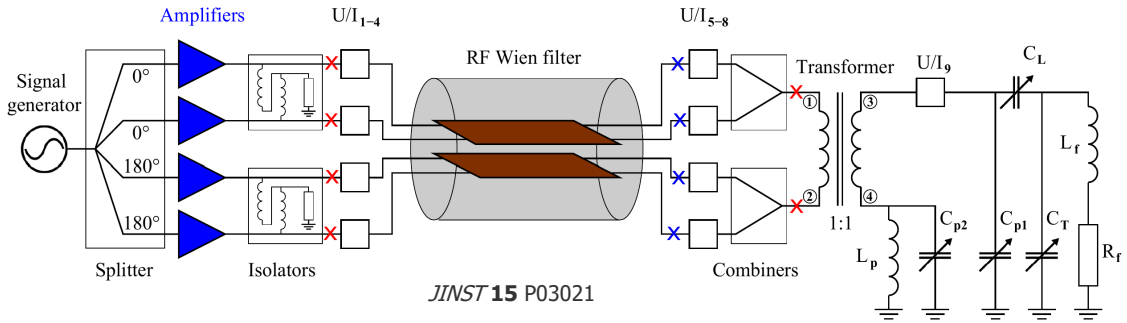


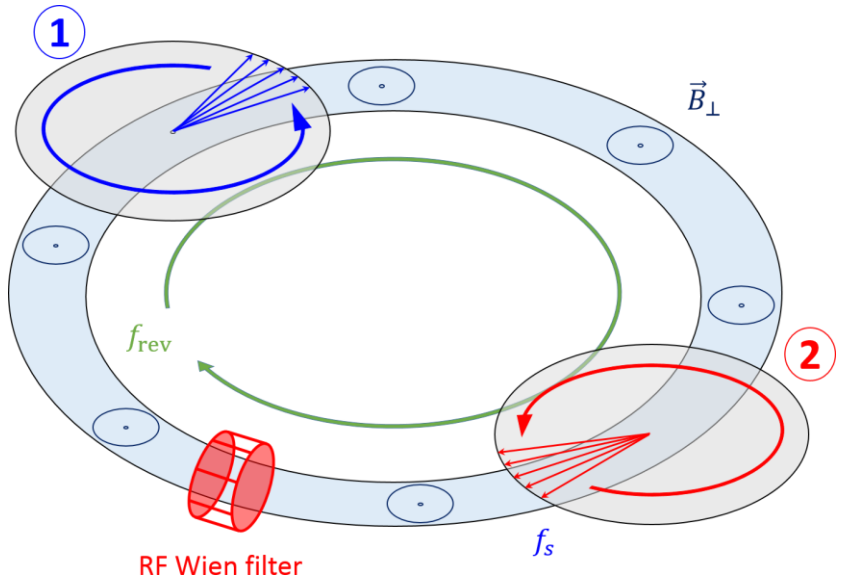


Phase locking spin precession in machine to device RF

- New scheme with multiple bunches:
  - 1 of 2 bunches is used to measure the EDM
  - The other bunch is not exposed to the RF fields of the Wien filter
  - Pilot-bunch technique provides a co-magnetometer

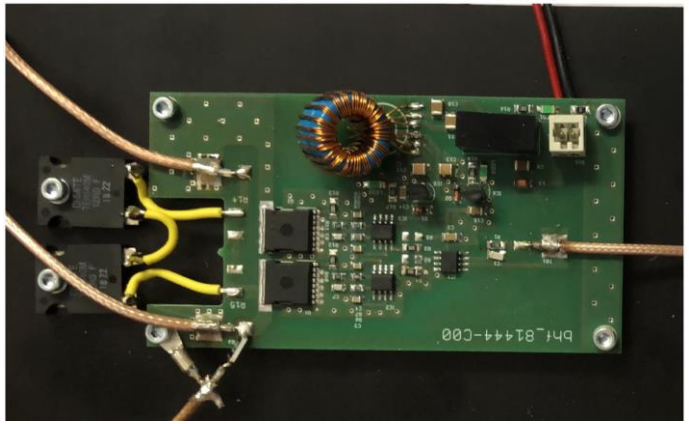


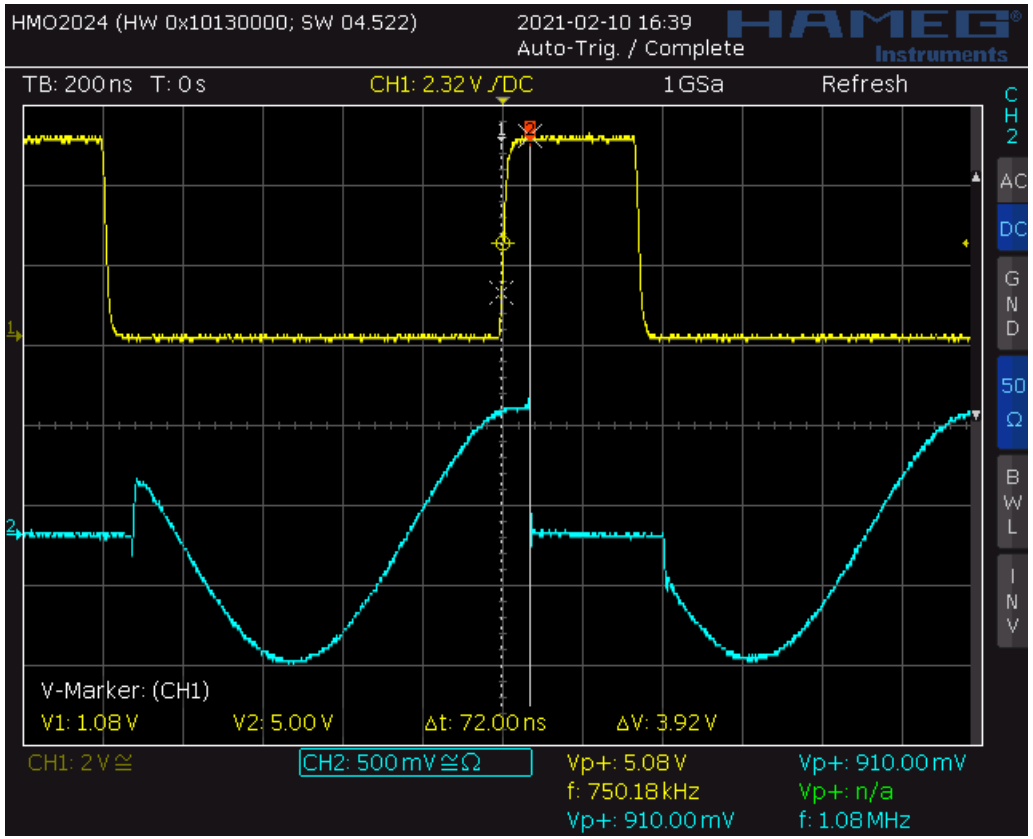




Phase locking spin precession in machine to device RF

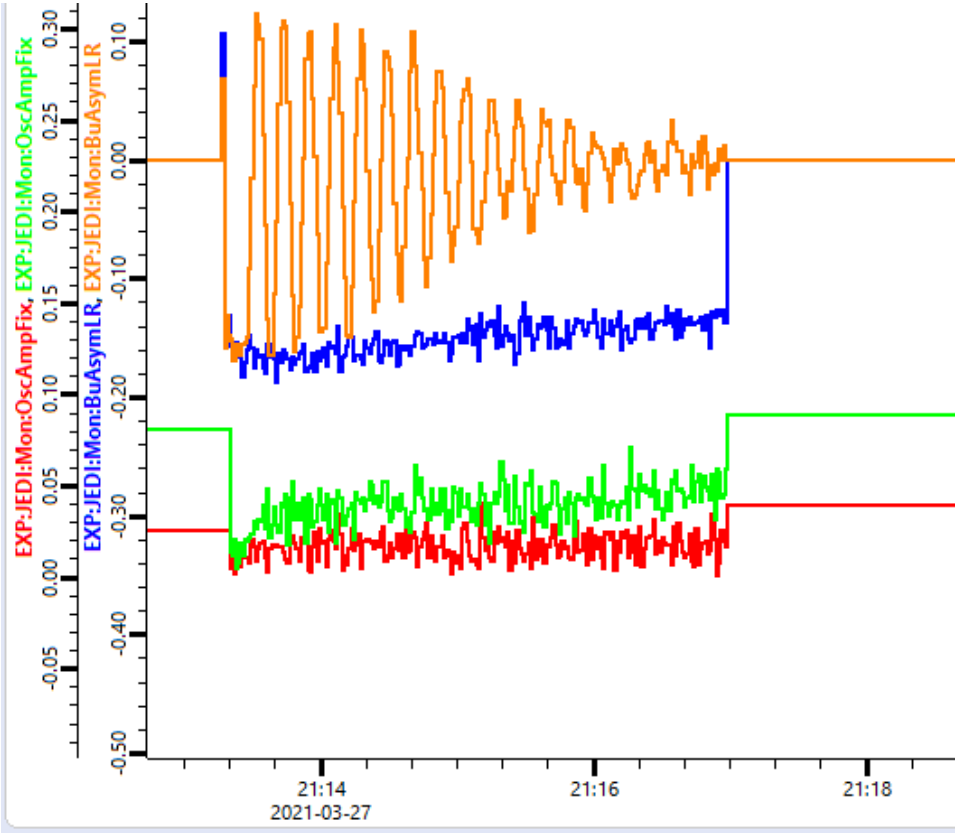
- Requires High-power, high-speed RF switches
- Tested element and system wise
- Switching speed; 5-25 ns





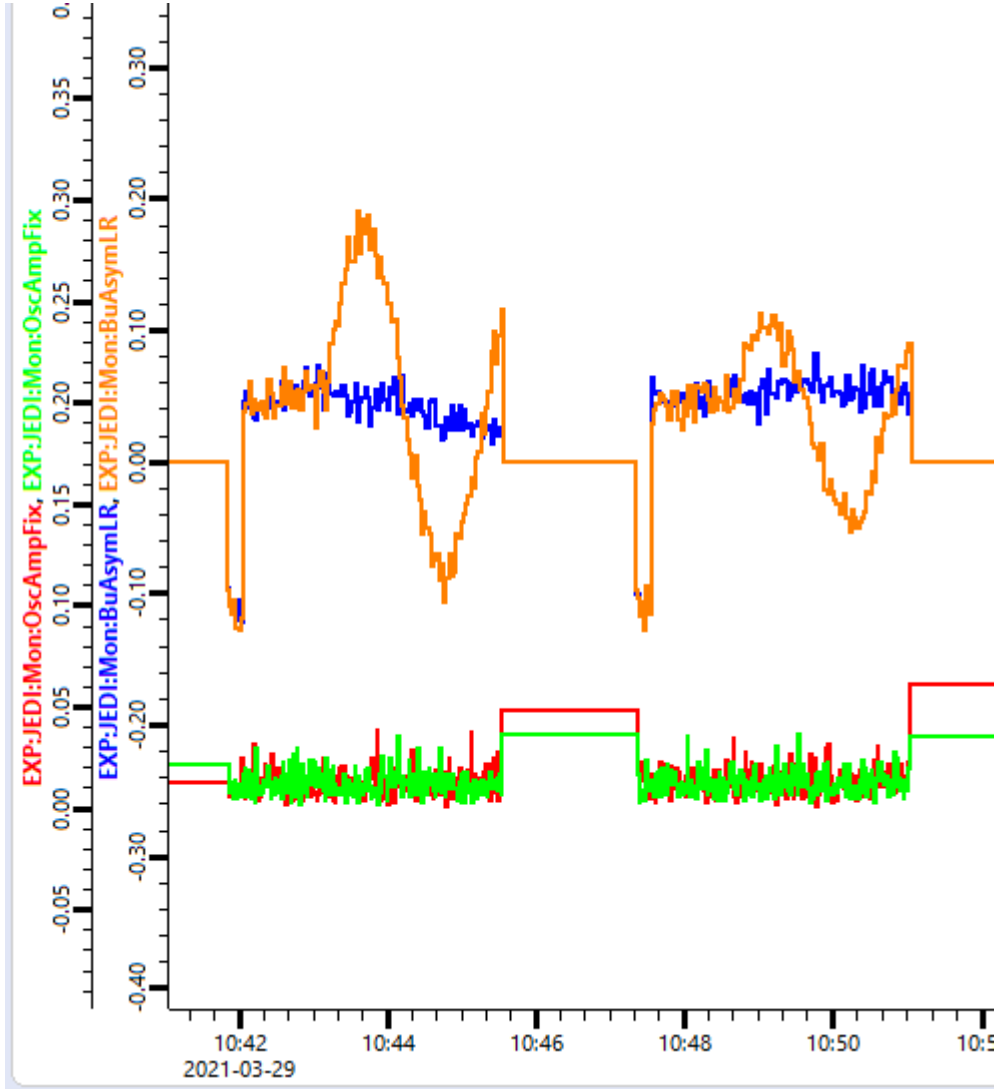
Test in MDM Mode

- RF Wien filter
  - Vertical E-field
  - Horizontal B-field
- Spin
  - Vertical polarized
- Observables
  - Only the polarization of one bunch rotates
  - The other stay on the zero-level
    - Ideally it should not have a slope



Test in EDM Mode

- RF Wien filter
  - Vertical B-field (aligned with the B_{ring})
  - Horizontal B-field
- Spin
  - horizontal polarized
- Observables
  - Polarization build up for only one bunch
  - full-oscillation for the first time



Summary

- Many milestones have been achieved in COSY towards the deuteron EDM experiment
- An RF Wien filter, as a transverse spin manipulator, has been developed and commissioned at COSY for EDM measurements
- A new system for an improved spin phase lock system
  - Based on the pilot bunch principle
  - Has successfully commissioned
  - World-first bunch selective spin manipulation
  - Still under experimental improvements

Question

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