

Multibunch spin manipulation for the deuteron EDM measurement in storage rings

Jamal Slim

III. Physikalisches Institut B, RWTH Aachen University
(on behalf if the JEDI Collaboration)
DPG Spring Meeting – Dortmund 2021



slim@physik.rwth-aachen.de



Contents

- Symmetries
- EDM
- Milestones achieved at COSY
- Phase-locking system I
- RF Wien filter
- Phase-locking system II



slim@physik.rwth-aachen.de



Discrete Symmetries

- Discrete symmetries
 - The Parity: inversion of the spatial coordinates
 - Invert polar vectors.
 - Conserves axial vectors.
 - Charge Conjugation: particle \leftrightarrow antiparticle
 - Inverts charge, baryon and lepton number.
 - Conserves spin, momentum, mass.
 - Time reversal: $t \rightarrow -t$



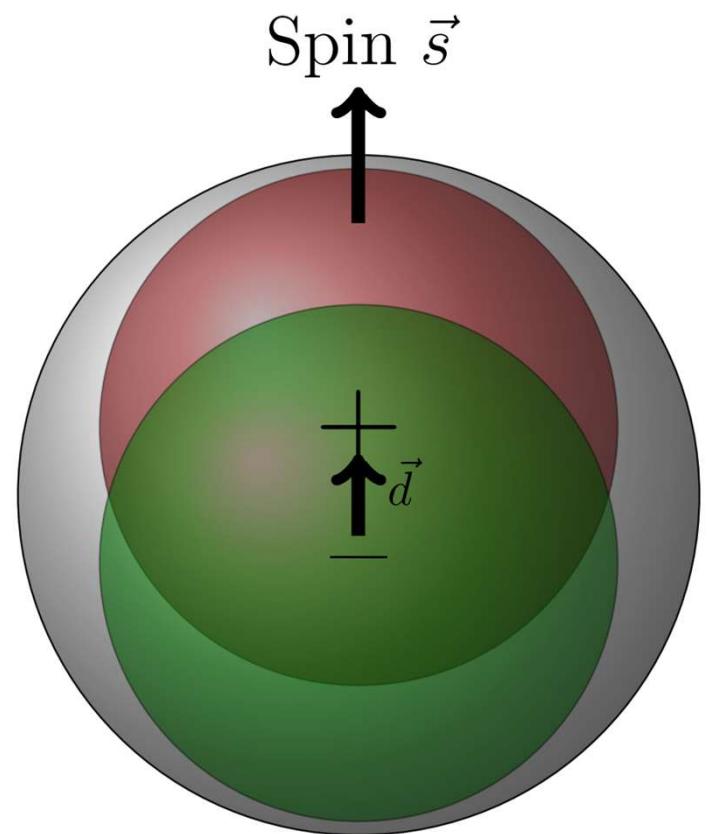
slim@physik.rwth-aachen.de



RWTHAACHEN
UNIVERSITY

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



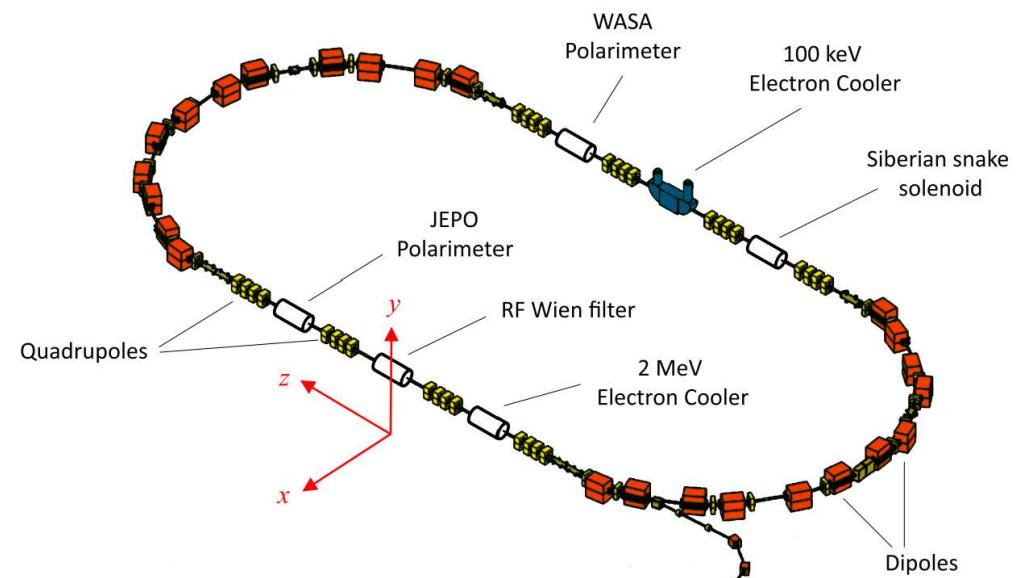
slim@physik.rwth-aachen.de



RWTHAACHEN
UNIVERSITY

Cooler Synchrotron as a test bench for EDM

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

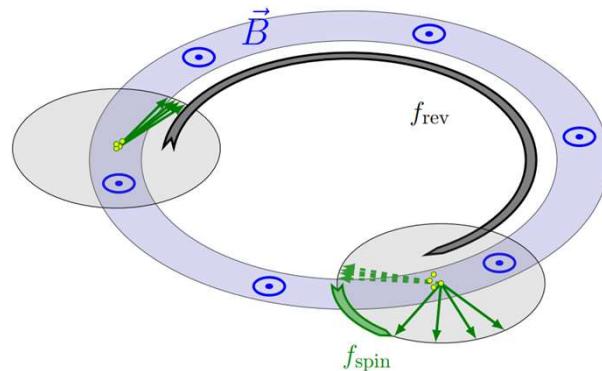


slim@physik.rwth-aachen.de

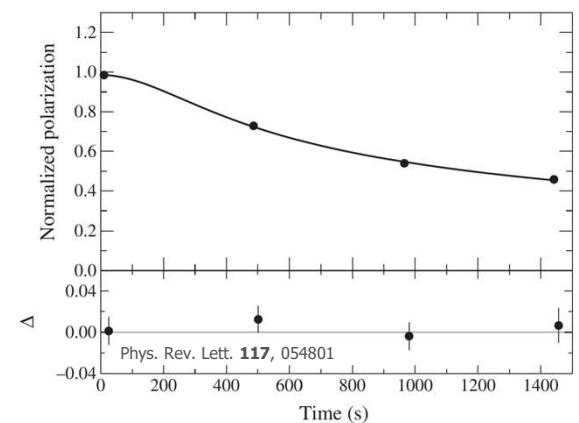
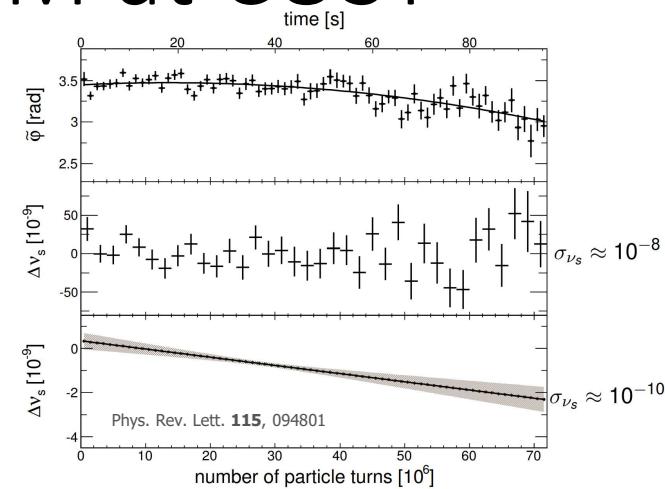


RWTH AACHEN
UNIVERSITY

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

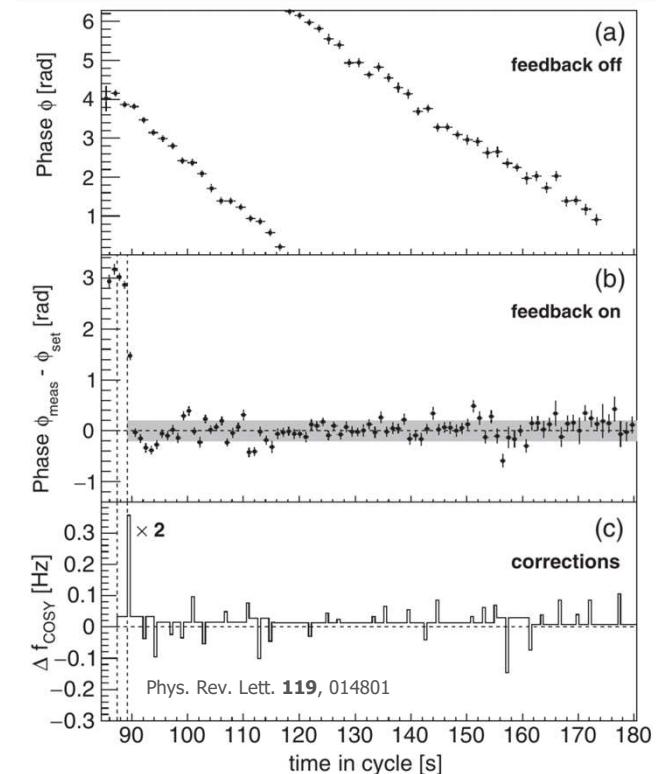


slim@physik.rwth-aachen.de



Phase-locking system I

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



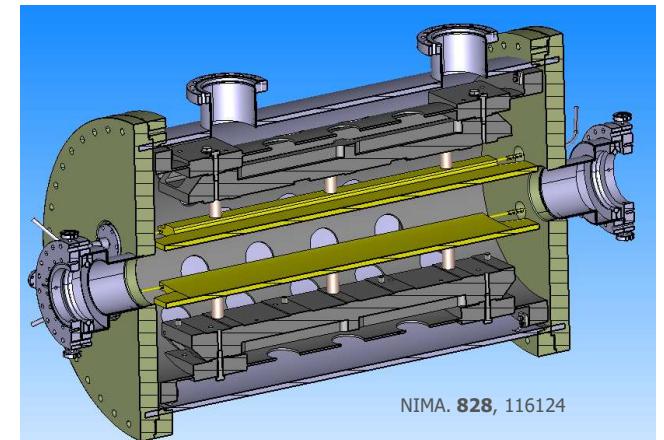
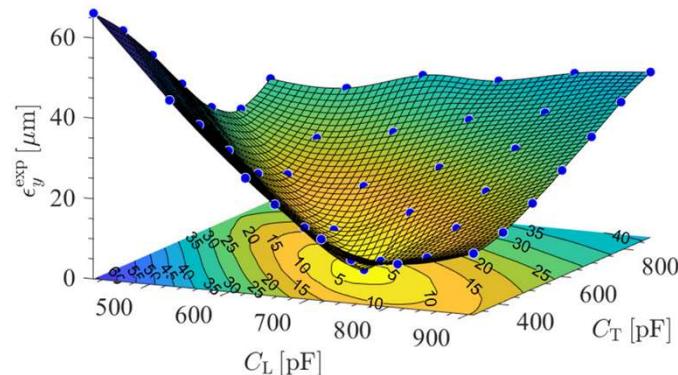
slim@physik.rwth-aachen.de



RWTH AACHEN
UNIVERSITY

RF Wien Filter

- Waveguide-based, provides $\vec{E} \times \vec{B}$ by design
- Minimal Lorentz force
 - Measured beam oscillations
 - Minimum 1 μm
 - One order of magnitude away from the quantum-limit
- Transverse spin manipulator

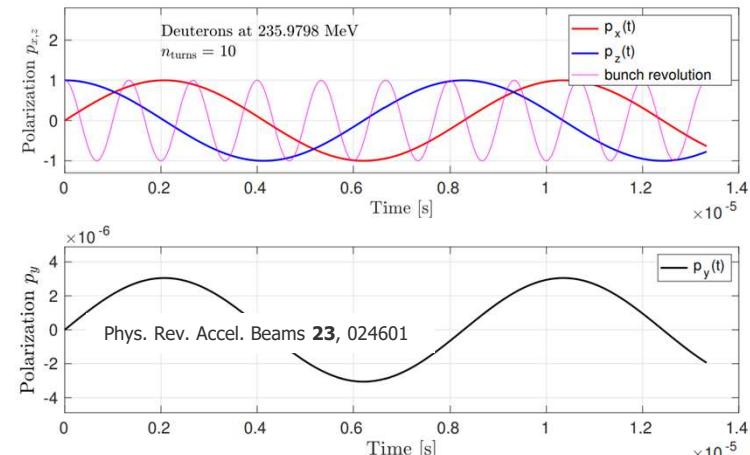
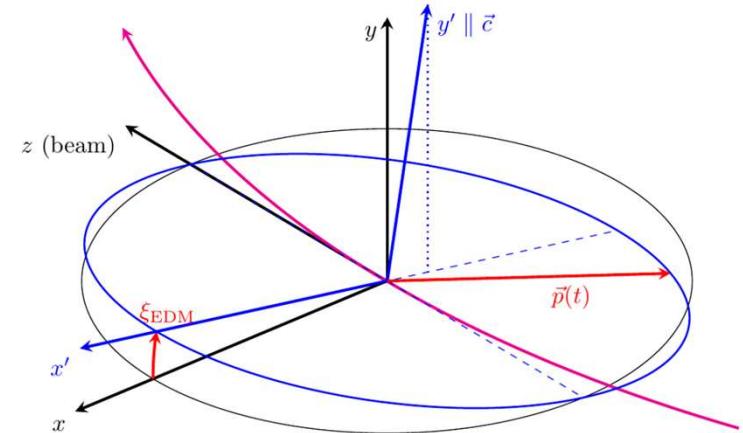


slim@physik.rwth-aachen.de



RF Wien Filter

- RF Wien filter method
 - Transversal spin rotator
- Beam particles move along z direction
 - Spins precess around the 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



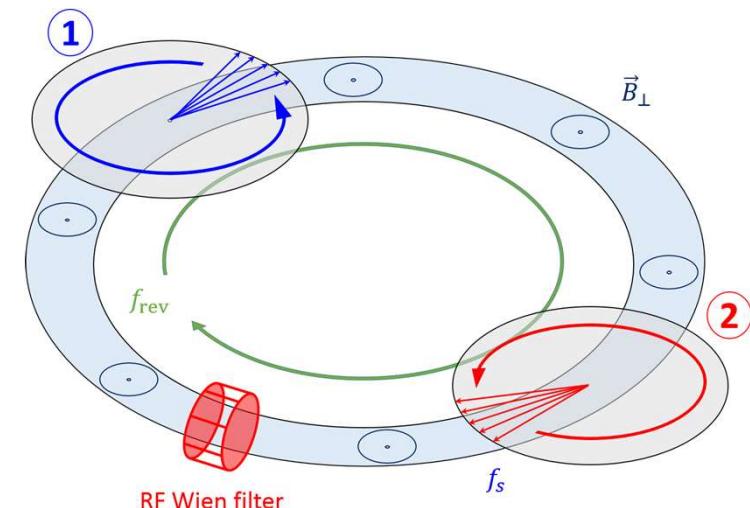
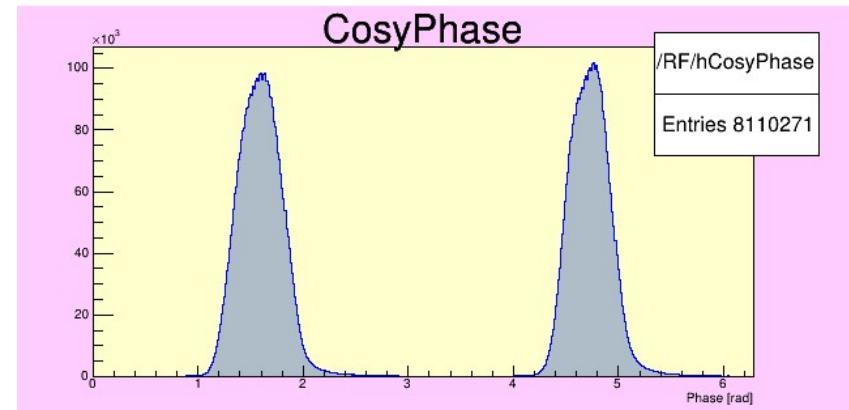
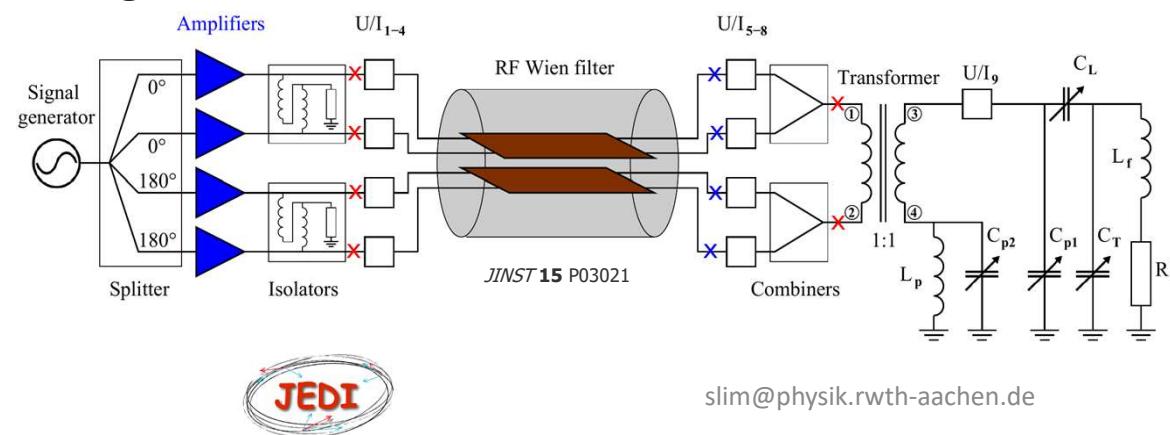
slim@physik.rwth-aachen.de



RWTH AACHEN
UNIVERSITY

Phase locking spin precession in machine to device RF

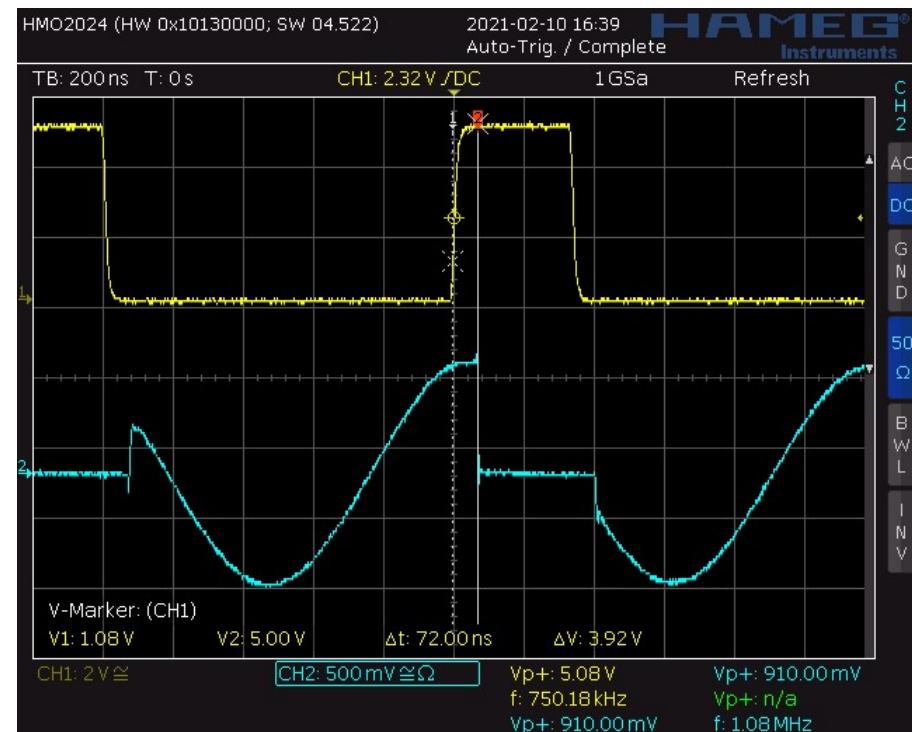
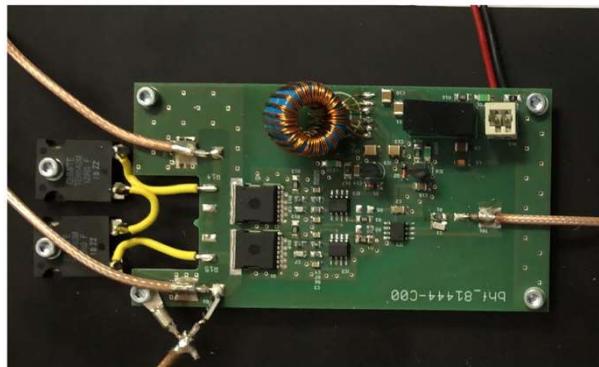
- New scheme with multiple bunches:
 - 1 of 2 bunches is used to measure the EDM
 - The other bunch is not exposed to the RF fields of the Wien filter
 - Pilot-bunch technique provides a co-magnetometer



slim@physik.rwth-aachen.de

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



slim@physik.rwth-aachen.de

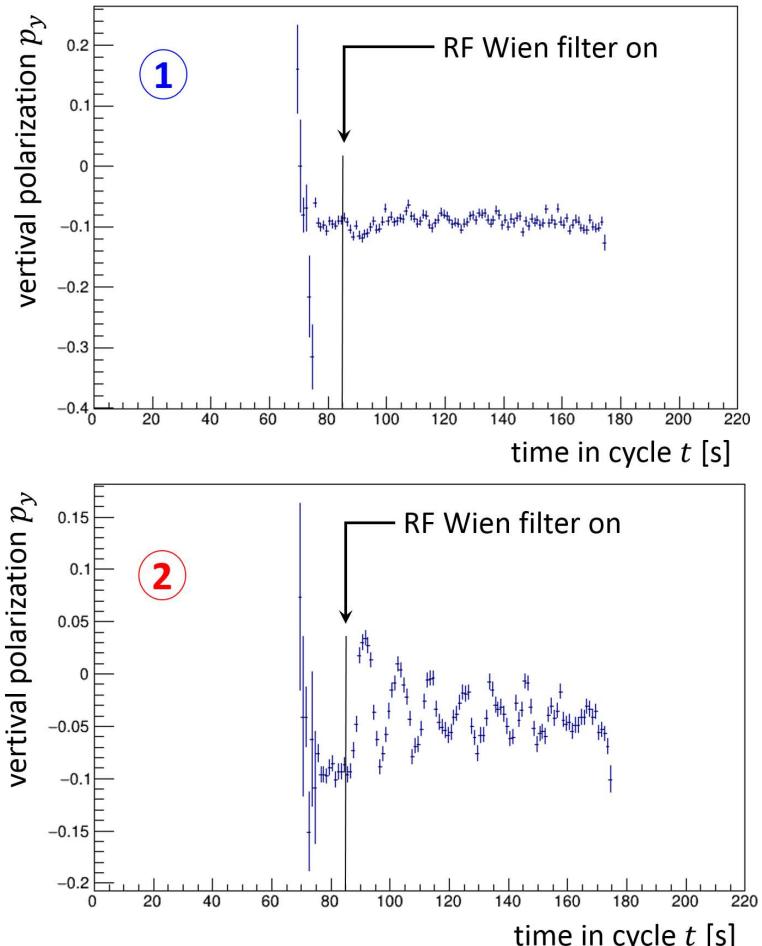


RWTHAACHEN
UNIVERSITY

11

Phase-locking system II

- Commissioned successfully in Sep. 2020
- World-first bunch selective spin manipulation
- Oscillation of vertical polarization is observed only for bunch 2
- The pilot bunch can be in real-time selected (bunch 1 or 4)
- The system was tested as with 4 bunches



slim@physik.rwth-aachen.de



RWTHAACHEN
UNIVERSITY

Summary

- Many milestones have been achieved in COSY towards the deuteron EDM experiment
- 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



slim@physik.rwth-aachen.de



Physics
Institute III B

RWTHAACHEN
UNIVERSITY

Question

slim@physik.rwth-Aachen.de



slim@physik.rwth-aachen.de



Physics
Institute III B

RWTHAACHEN
UNIVERSITY