

Resonant spin depolarization – Beam test at KIT/KARA

Bastian Härer on behalf of the KIT team



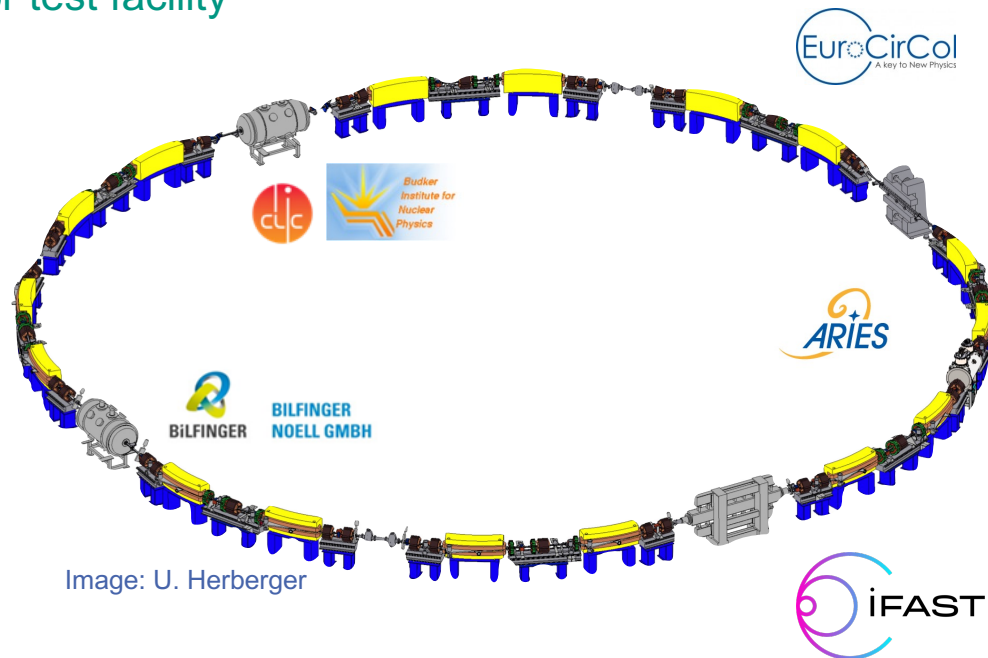
Karlsruhe Research Accelerator (KARA)

■ KIT synchrotron lightsource & accelerator test facility

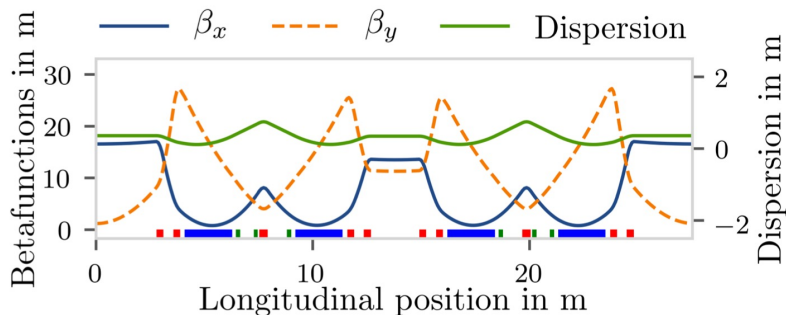
- until 2015 known as „ANKA“

■ Key parameters

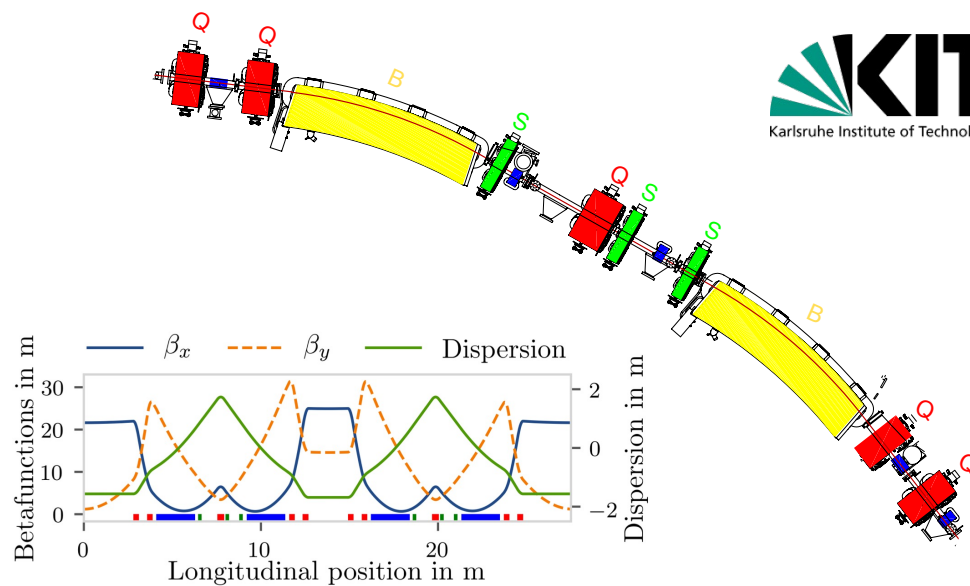
- Circumference: 110.4 m
- Energy range: 0.5 - 2.5 GeV
- RF frequency: 500 MHz
- Revolution frequency: 2.715 MHz
- Beam current up to 200 mA
- RMS bunch length:
 - 45 ps (for 2.5 GeV)
 - down to a few ps (for 1.3 GeV)
- Single or multi-bunch operation



KARA operation modes



User optics: $\alpha_c = 9 \times 10^{-3}$



Negative alpha optics: $\alpha_c = -8 \times 10^{-3}$

■ Operation modes in 2022:

0.5/2.3/2.5 GeV user optics, 0.5/1.3 GeV low-alpha, 0.5/1.3 GeV negative alpha

Resonant spin depolarization – reminder

- Asymmetry in the spin-flip probability due to emission of synchrotron radiation
→ build-up of transverse polarization
- Spin vector precesses in presence of electric and magnetic fields

$$\nu = a\gamma \quad a = (g_e - 2)/2 = 0.001159652193$$

$$\gamma = E_{\text{beam}}/m_0c^2$$

- If a horizontal excitation with spin-tune resonance is applied, the polarization is resonantly destroyed.
- The resonance is very narrow, so if the frequency of the depolarizer field is swept slowly, the resolution is very good.

$$f_{\text{dep}} = (k \pm [\nu]) \cdot f_{\text{rev}}$$

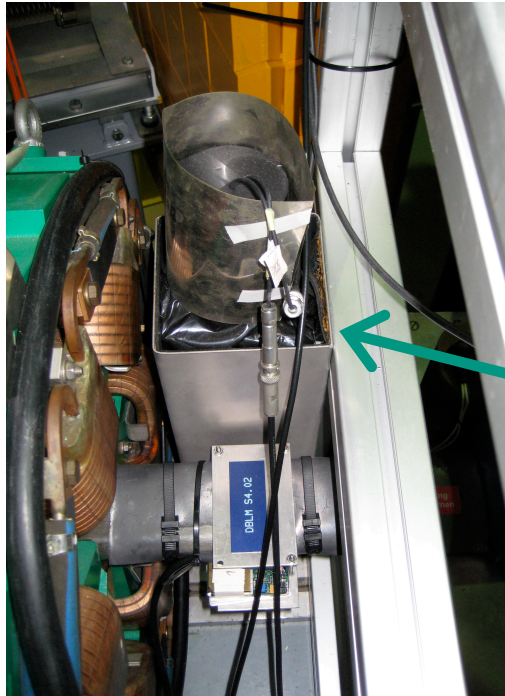
- If depolarization occurs, spin tune and beam energy can be determined.

Resonant spin depolarization – KIT history

- Since 2004: Setup to measure beam energy at ANKA/KARA with resonant spin depolarization
 - A.-S. Mülller *et al.*, “Energy calibration of the ANKA storage ring”,
<https://accelconf.web.cern.ch/e04/PAPERS/THPKF022.PDF>
- 2008: New frequency generator for the stripline kickers
 - T. Bückle, diploma thesis (German)
<https://publikationen.bibliothek.kit.edu/1000022044>
- 2014: Setup updated: frequency generator replaced by bunch-by-bunch feedback system, new Matlab scripts for automated procedure including analysis
- Setup in operation since then: Measurement campaigns in 2015, 2020, 2021
 - momentum compaction factor and drift of beam energy

$$\Rightarrow \frac{\Delta E}{E} = 2.88 \times 10^{-5}$$

Resonant spin depolarization – setup



Touschek sensitive region

- Change in Touschek lifetime because Møller scattering is dependent on polarization
→ Change in loss rate visible at depolarization

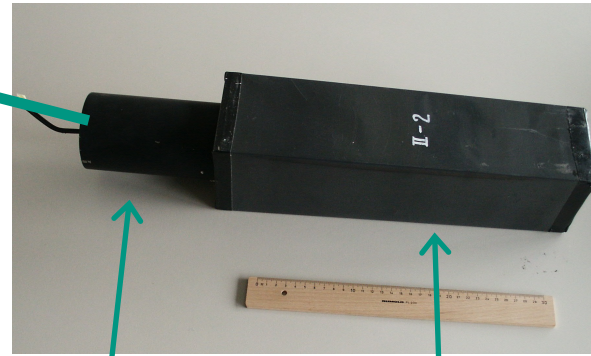


Photo multiplier

Lead-glass block

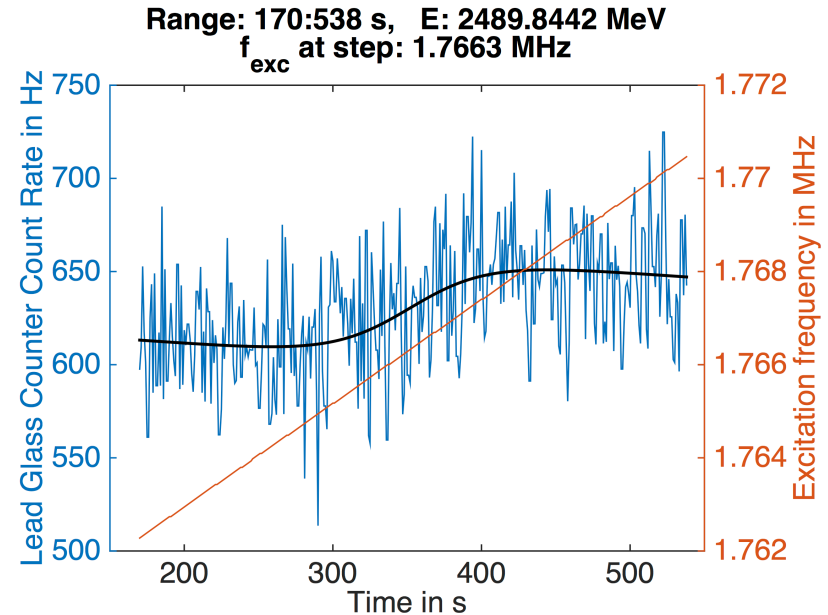
- Logging lossrate and excitation frequency
- Monitoring the vertical beam size to ensure that there is no betatron resonance

Resonant spin depolarization – analysis

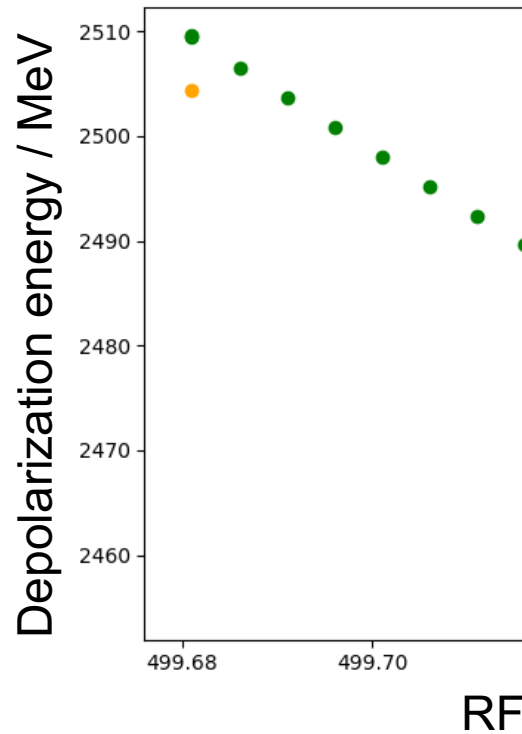
- Step function fit to determine frequency at which depolarization occurs

$$r(t) = a - b \cdot t + \frac{\Delta r}{1 + \exp\left(-\frac{t-t_d}{\sigma_d}\right)}$$

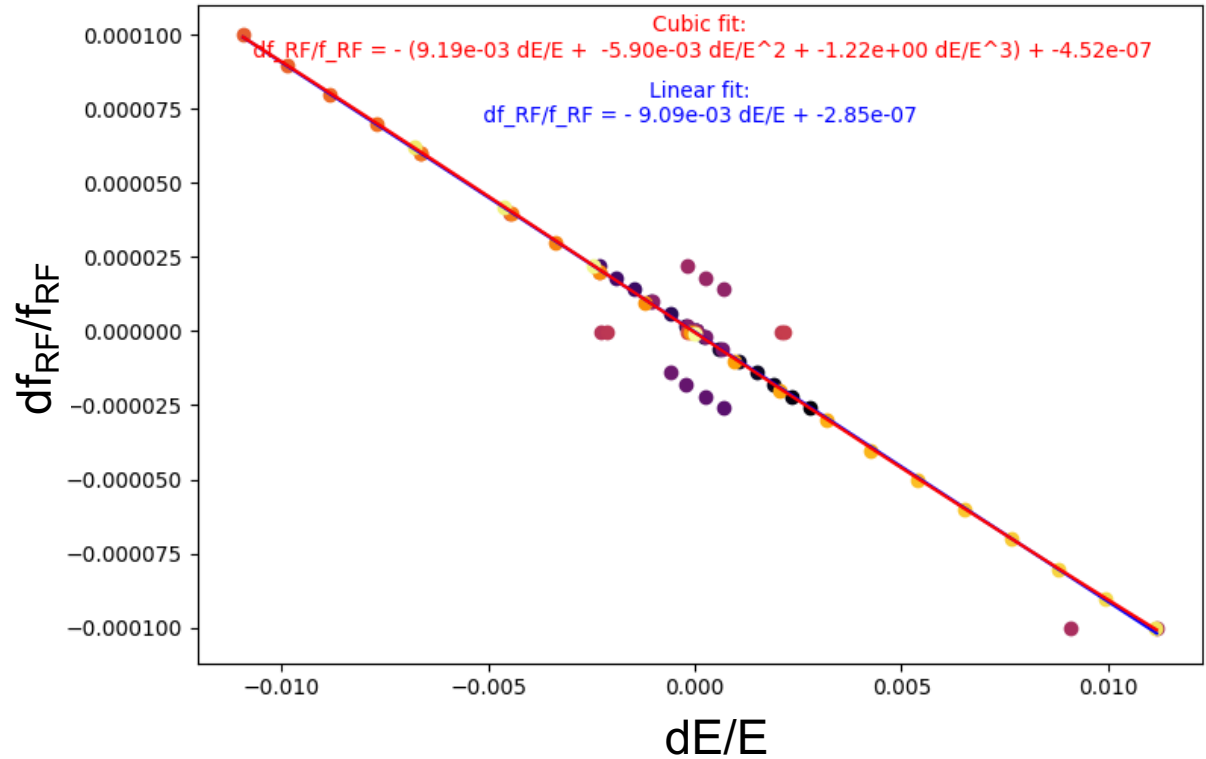
- Matlab script automatically
 - scans excitation frequency,
 - creates Elog entry, saves data
 - fits step function and creates plot.
- Typical **relative energy uncertainties** determined from the width σ_d are of the order of 2×10^{-5} .



Results from 2021



Courtesy M. Brosi



Resonant spin depolarization at KARA

- A reliable setup for resonant spin depolarization is installed and in operation
 - Typical time for polarization build-up at 2.5 GeV: 10 min
 - Matlab scripts are available that allow fully automated measurements
 - Change of beam energy via frequency modifications
 - Change of RF voltage
 - Scans of side bands
 - Read-out, analysis, visualization, and documentation
- Measurements can be performed overnight
- No idle time during polarization build-up

Outlook

- Scripts are currently written in Matlab but will be migrated to Python before the next measurement run
- A new BLM system is currently being installed, evaluations are going on, if it can be used for resonant spin depolarization
- Resonant spin depolarization at 2.3 GeV

Potential beam tests at KARA

- Polarization time: 10 min (“unlimited potential for measurements”)

Questions discussed at the FCC Epol workshop:

- Feasibility of second spin flip
- Does the scanning direction of the depolarizer frequency have an influence on the result?
- Does the scanning speed affect the measurement results?
- Does the measurement work reliably in vicinity of tune resonances?
- Can single bunches be polarized?

- Measurement environment to validate simulations
 - We can provide optics files (MAD-X, elegant, ocelot) and machine parameters during measurements.

Measurements in 2023

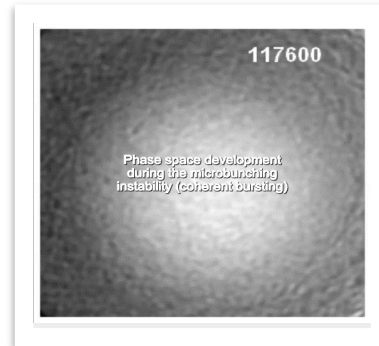
- Start-up will be in March
- Main operation energy will be 2.3 GeV, but for RSD we would temporarily increase to 2.5 GeV
- We will install new power supplies for the dipole magnets
 - In production, will be shipped soon
- Before and after installation we will have energy measurement runs
 - First week of april 3-7 April (before)
 - Somewhen in summer (after)

Special diagnostics at KARA

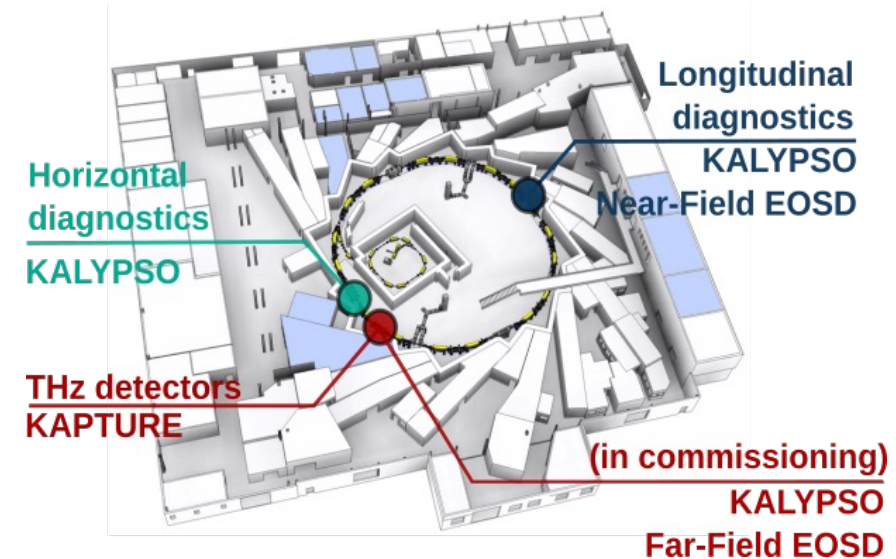
- Measurements of resonant spin depolarization
- Turn-by-turn and bunch-by-bunch diagnostics @KARA

phase space tomography

- Complete phase space image reconstructed from time interval of 61 μ s
- “Randon morphing“ between independent measurement



S. Funkner et al. arXiv preprint, arXiv:1912.01323



Get in touch with us! 😊

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Thank you for your attention!

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