Karlsruhe Institute of Technology

KARA
Karlsruhe Research Accelerator

IBPT
Institute for Beam Physics and Technology

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

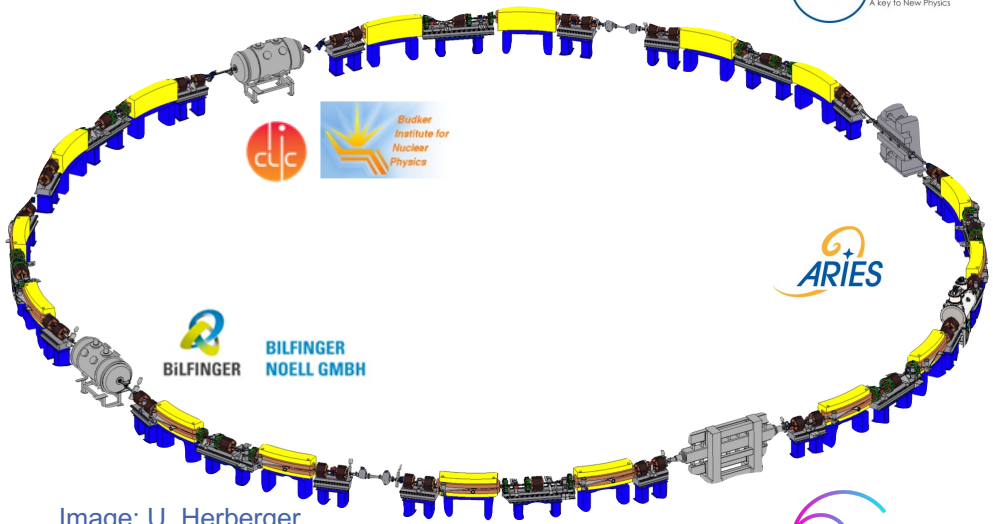
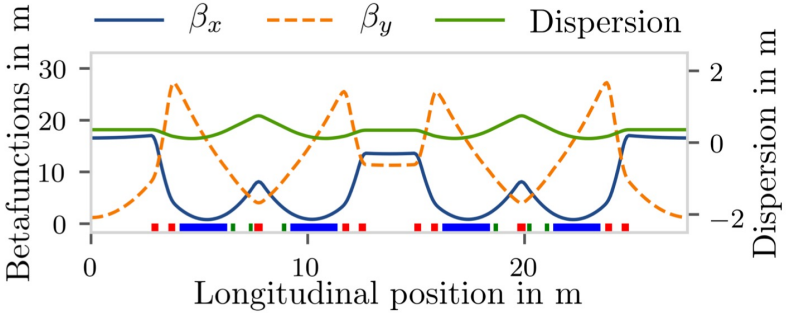
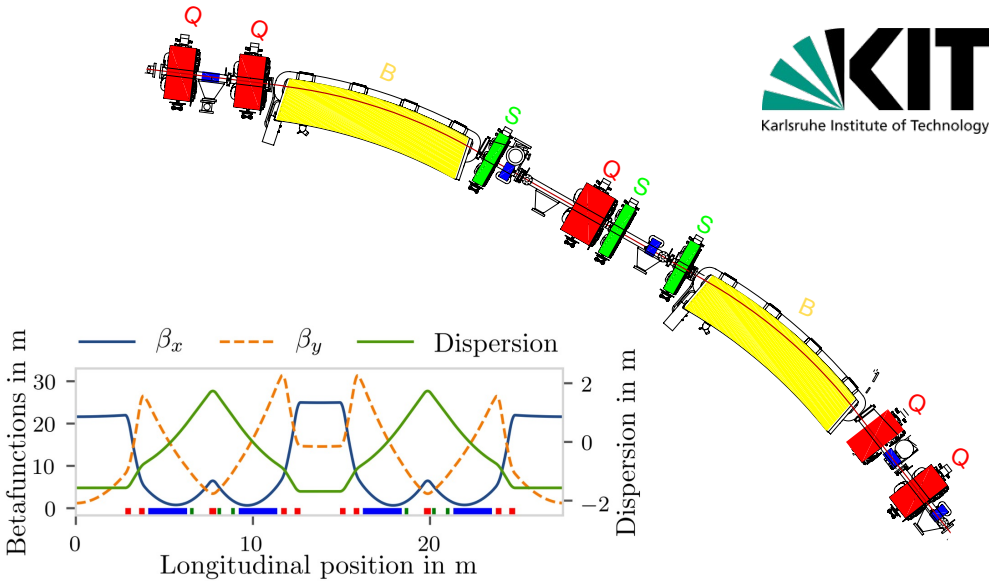


Image: U. Herberger

www.ibpt.kit.edu/kara

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 precedes in presence of electric and magnetic fields

$$\nu = a\gamma \qquad a = (g_\mathrm{e} - 2)/2 = 0.001159652193$$
$$\gamma = E_\mathrm{beam}/m_0c^2$$

- 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.

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

- 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. Müller *et al.*, "Energy calibration of the ANKA storage ring", https://accelconf.web.cern.ch/e04/PAPERS/THPKF022.PDF

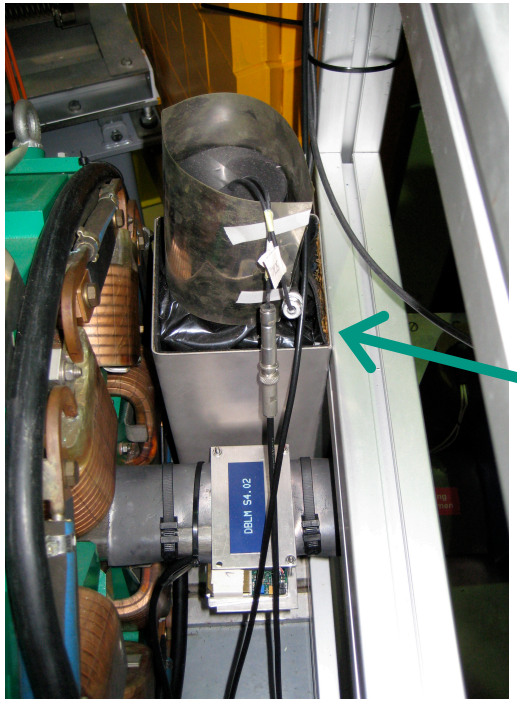
- 2008: New frequency generator for the stripline kickers
  - T. Bückle, diploma thesis (German) https://publikationen.bibliothek.kit.edu/1000022044

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

- 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

Resonant spin depolarization – setup



Toushek sensitive region

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

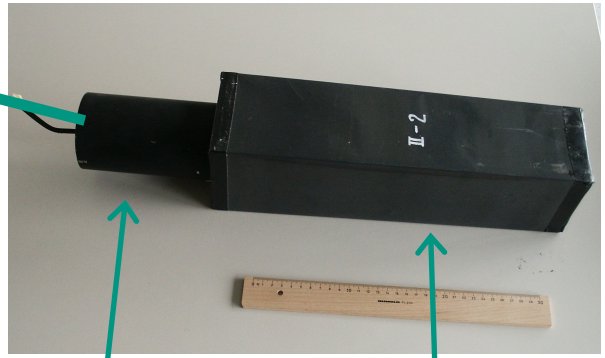


Photo multiplier

Lead-glass block

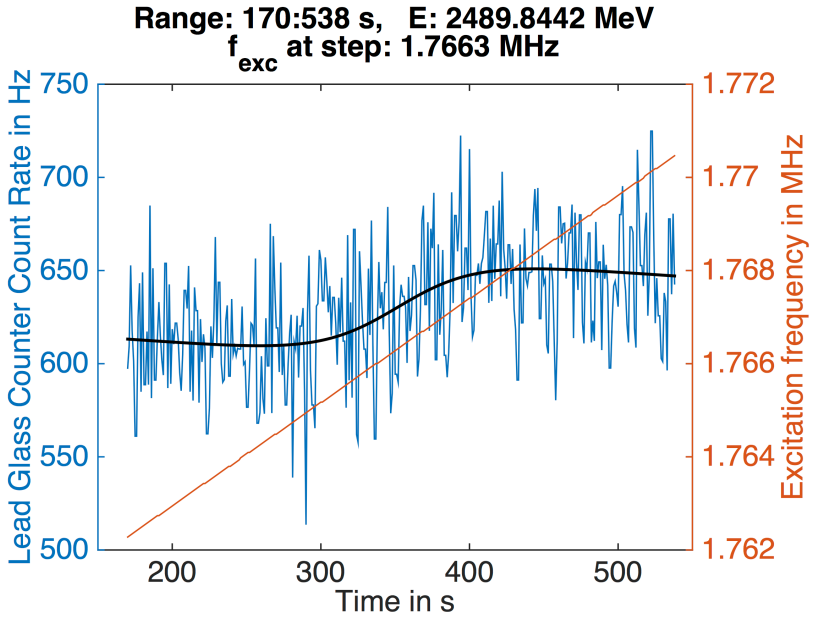
- Logging lossrate and excitation frequency
- Monitoring the vertical beam size to ensure that there is no betatron resonance

Resonant spin depolarization – analysis

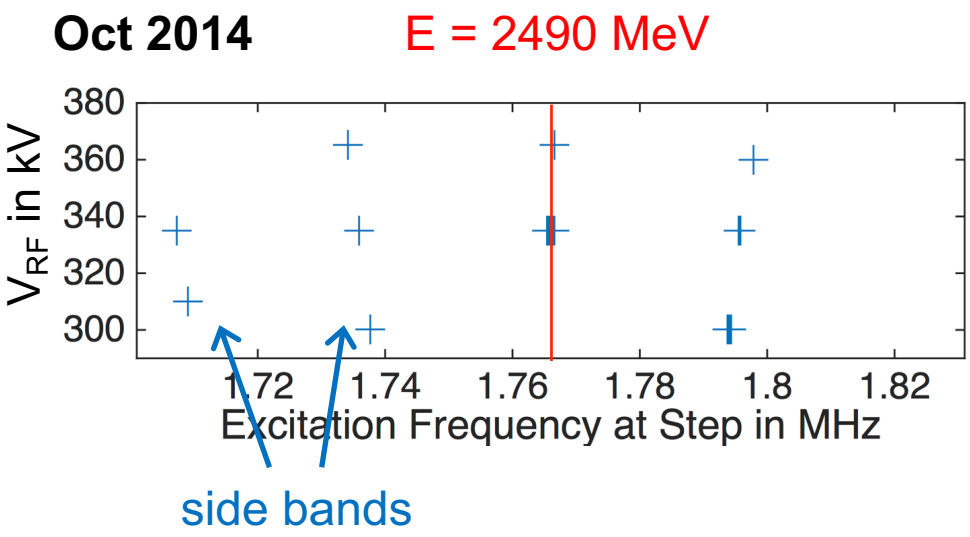
- Step function fit to determine frequency at which depolarization occurs

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

- 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}.

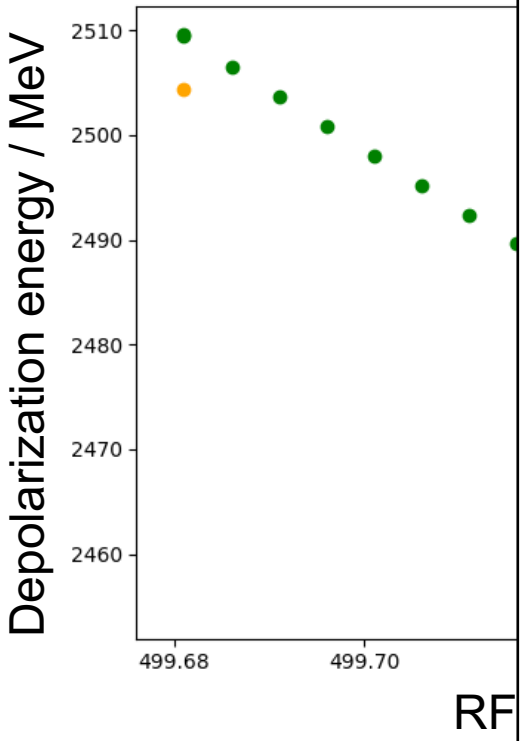


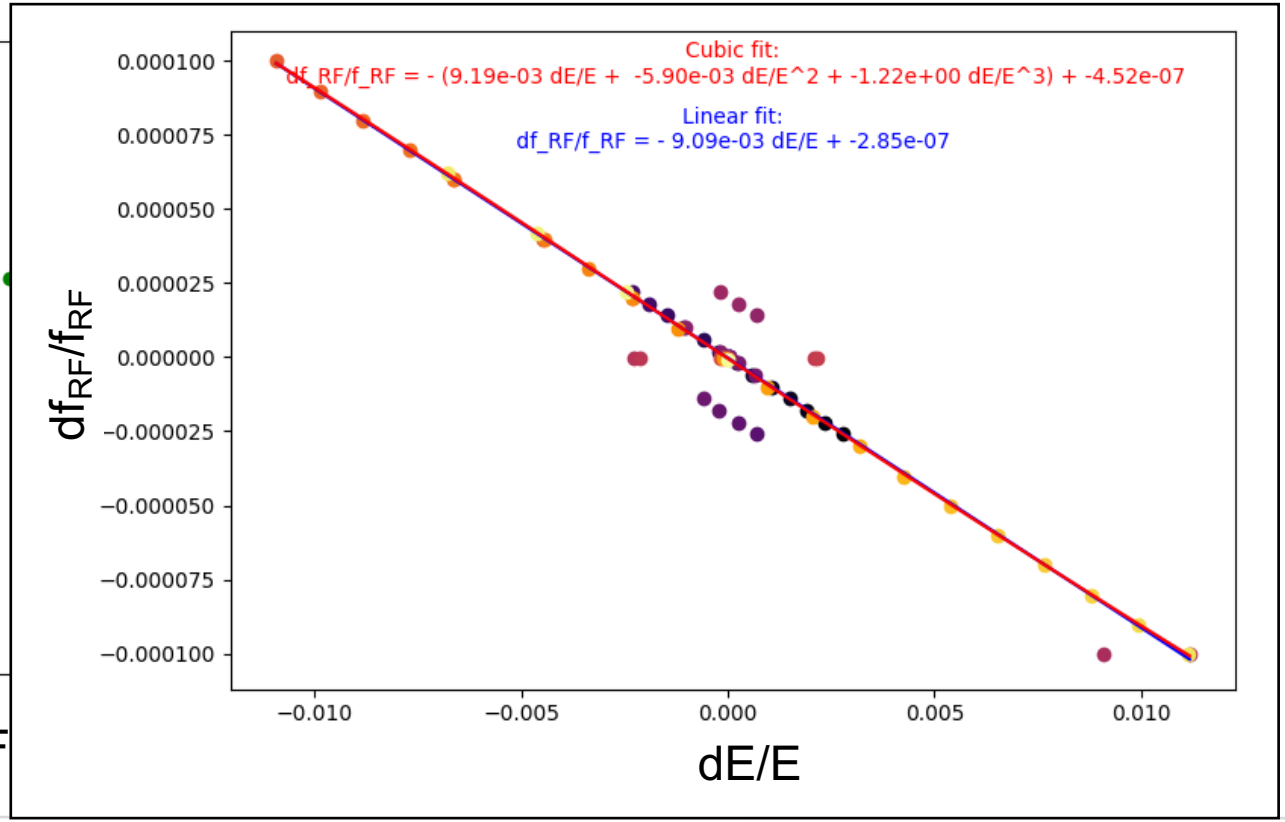
Resonant spin depolarization – results



- **Important:** Resonant depolarization also occurs on side bands!
- Variation of RF voltage changes synchrotron tune, but not beam energy
- Side band: excitation frequency shifts
- Energy band: excitation frequency stays the same

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

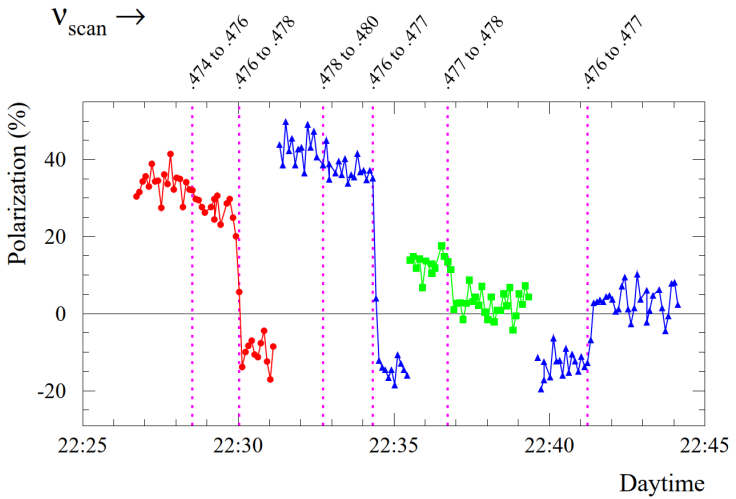
Outlook

- Scripts are currently written in Matlab but will be migrated to Python
- 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

Discussion at the FCC-ee Polarization Workshop

- **LEP:** Energy calibration at the end of fills with non-colliding beams
- **FCC-ee:** Continuous energy measurements using non-colliding pilot bunches
  → But: Polarization time of 240 h

- Measurements at LEP indicated polarization flip instead of depolarization
  → **Can the polarization be flipped back?**



*The colors refers to different bunches, in one case (**blue**) the polarization is flipped, and flipped polarization is used to re-depolarize a second time .*

1 point every ~ 8 seconds.

J. Wenninger: FCC EPOL Workshop

Potential beam tests at KARA

- Polarization time: 10 min (“unlimited potential for measurements”)
- Investigate the feasibility of second spin flip

Additional questions discussed at the FCC Epol workshop:

- 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

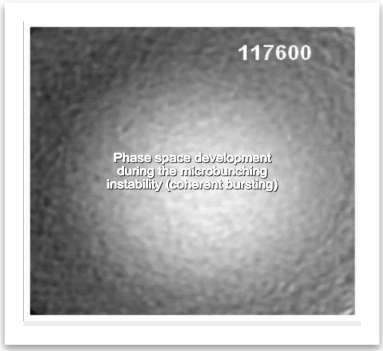
Special diagnostics at KARA

- Measurements of resonant spin depolarization

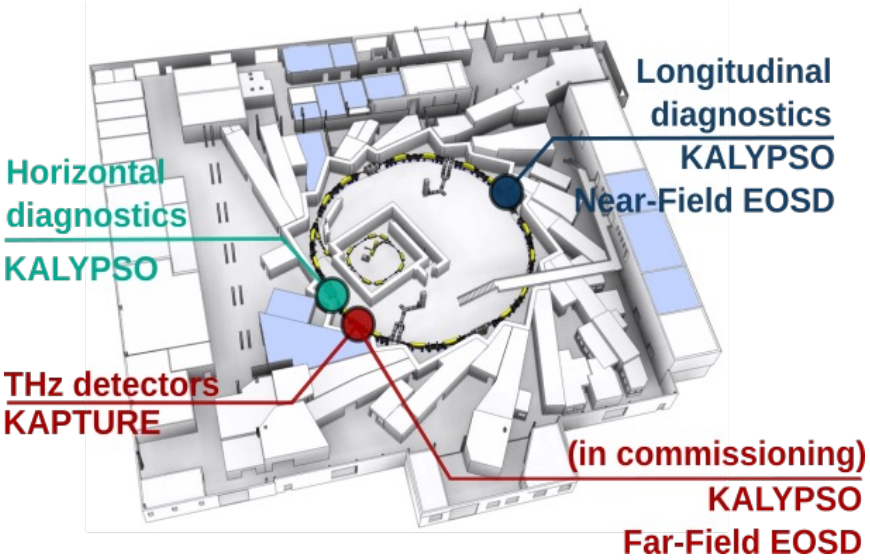
- Turn-by-turn and bunch-by-bunch diagnostics @KARA

phase space tomography

- Complete phase space image reconstructed from time interval of 61 µs
- “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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