Karlsruhe Institute of Technology

FUTURE CIRCULAR COLLIDER
Innovation Study

KARA
Karlsruhe Research Accelerator

IBPT
Institute for Beam Physics and Technology

Resonant Spin Depolarization at the Karlsruhe Research Accelerator

Edmund Blomley on the behalf of the KIT team

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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
  - Focus on TbT and BbB diagnostics

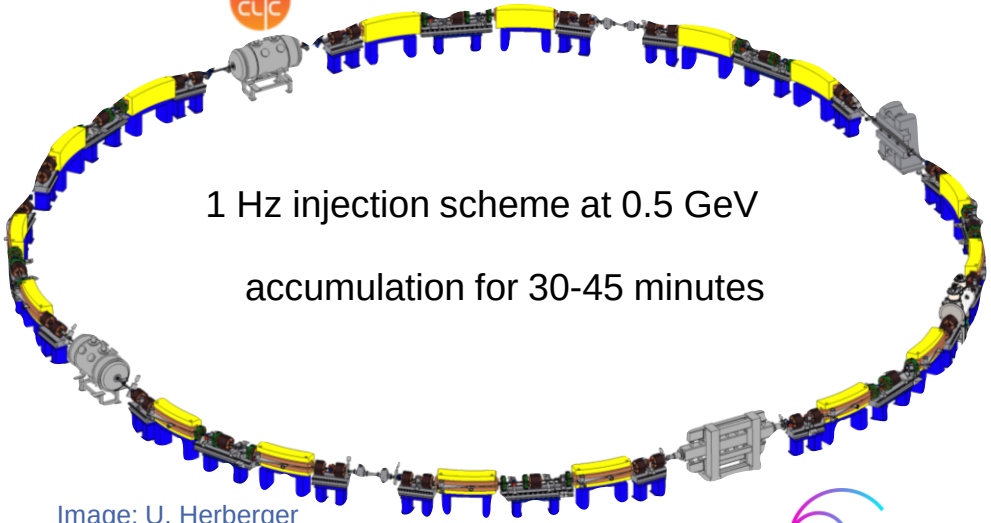

Image: U. Herberger

www.ibpt.kit.edu/kara

Karlsruhe Research Accelerator (KARA)

- Relevance in the context of FCC?

~ 50 days of machine physics per year

- Key parameters
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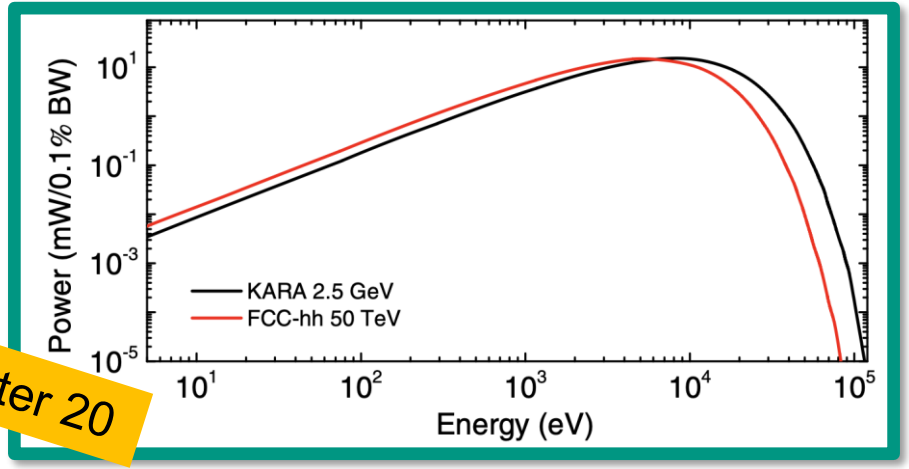
Poster 17

Poster 20

Synchrotron spectrum similar to FCC-hh

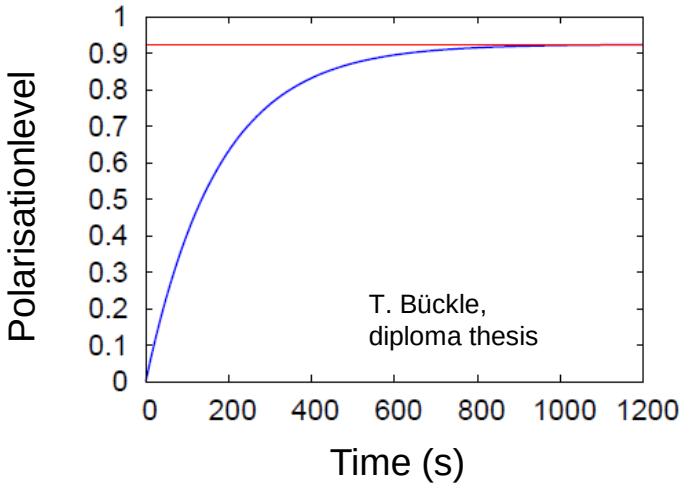


BESTEX, 10.1103/PhysRevAccelBeams.22.083201

Electron Beam Polarization

- Synchrotron radiation leads to beam polarisation over time:

$$\tau_p = (w_{\uparrow\downarrow} + w_{\downarrow\uparrow})^{-1} = \frac{8\sqrt{3}}{15}\frac{m_0^2 c^2}{e^2\hbar}\boxed{\frac{\rho^3}{\gamma^5}} \cdot 4\pi\varepsilon_0$$



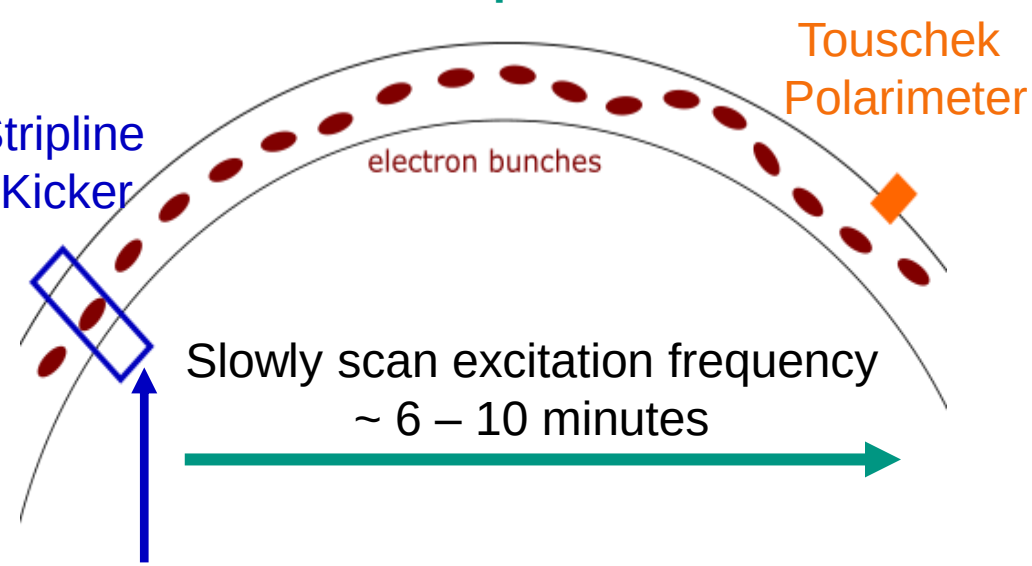
- 2.5 GeV: ~ 9 minutes
- 1.3 GeV: ~ 1.2 hours
- Certain factors can disturbe polarization build up
  - => Resonant Spin Depolarization

Measurement Technique

Polarization

Wait
~10 minutes

Resonant Depolarization



Slowly scan excitation frequency
~ 6 – 10 minutes

Excite beam

Touschek sensitive region

Meausrement Analysis

Change in Touschek lifetime because Møller scattering is dependent on polarization

→ **Change in loss rate visible at depolarization frequency**

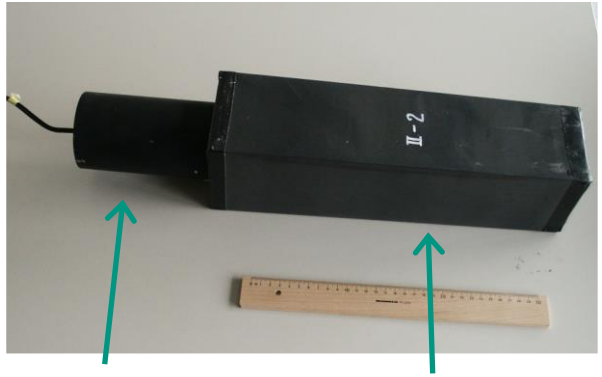
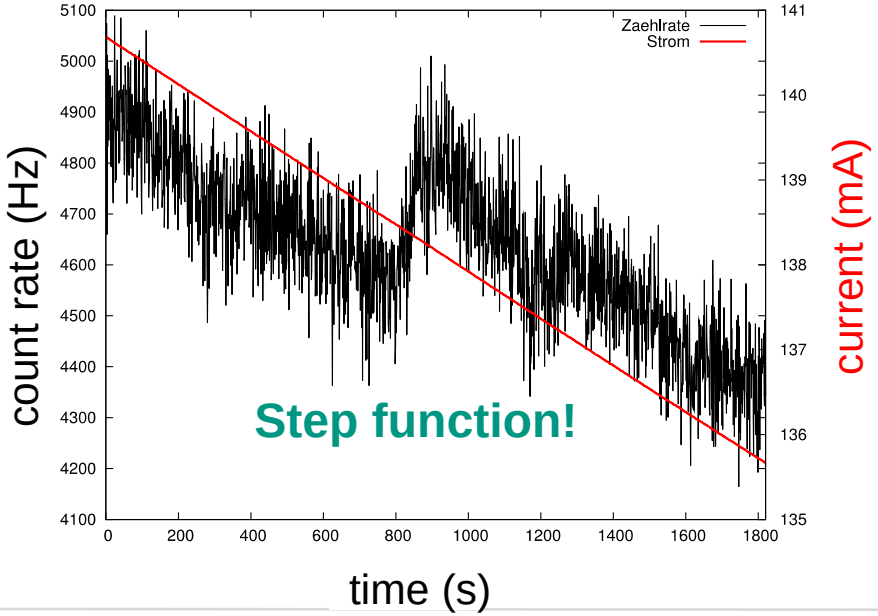


Photo multiplier

Lead-glass block



Measurement History

- **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

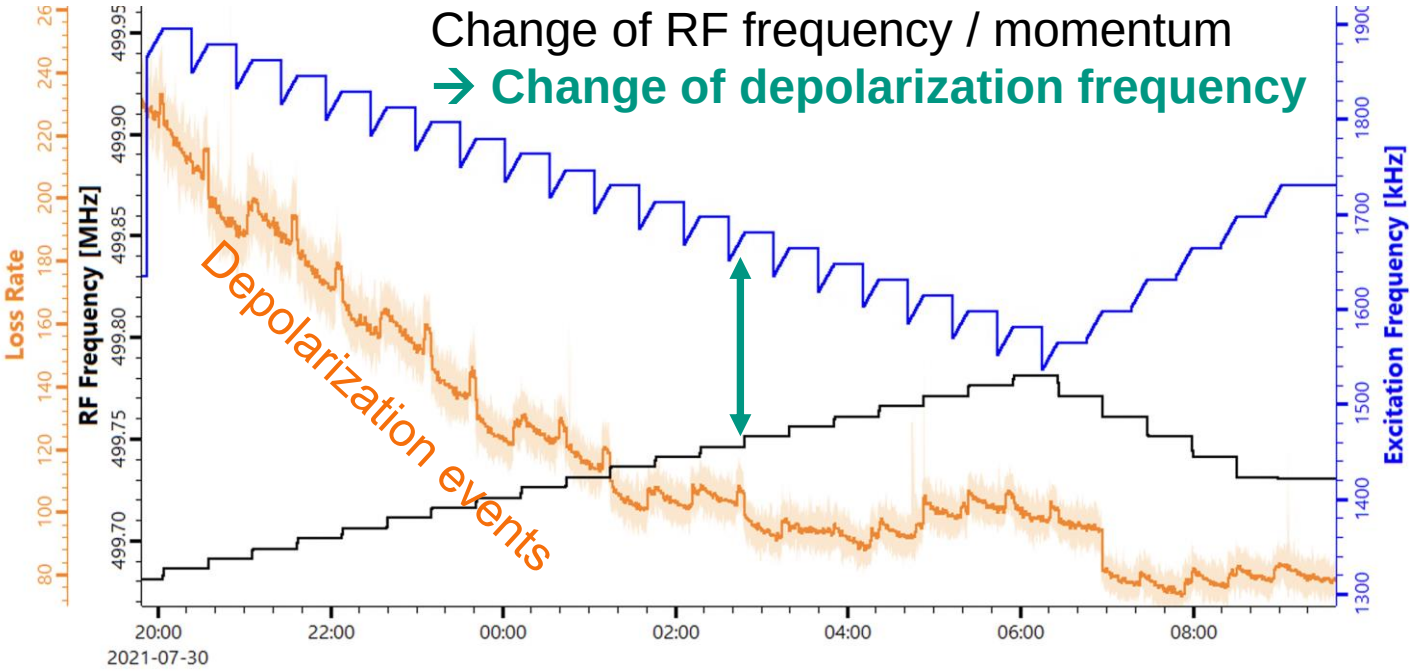
- **2008**: New frequency generator for the stripline kickers
  - T. Bückle, diploma thesis (German)
  - https://publikationen.bibliothek.kit.edu/1000022044

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

- **2014**: Setup updated
  - **Bunch-by-bunch feedback system** to excite beam,
  - new scripts for **fully automated** measurement including analysis

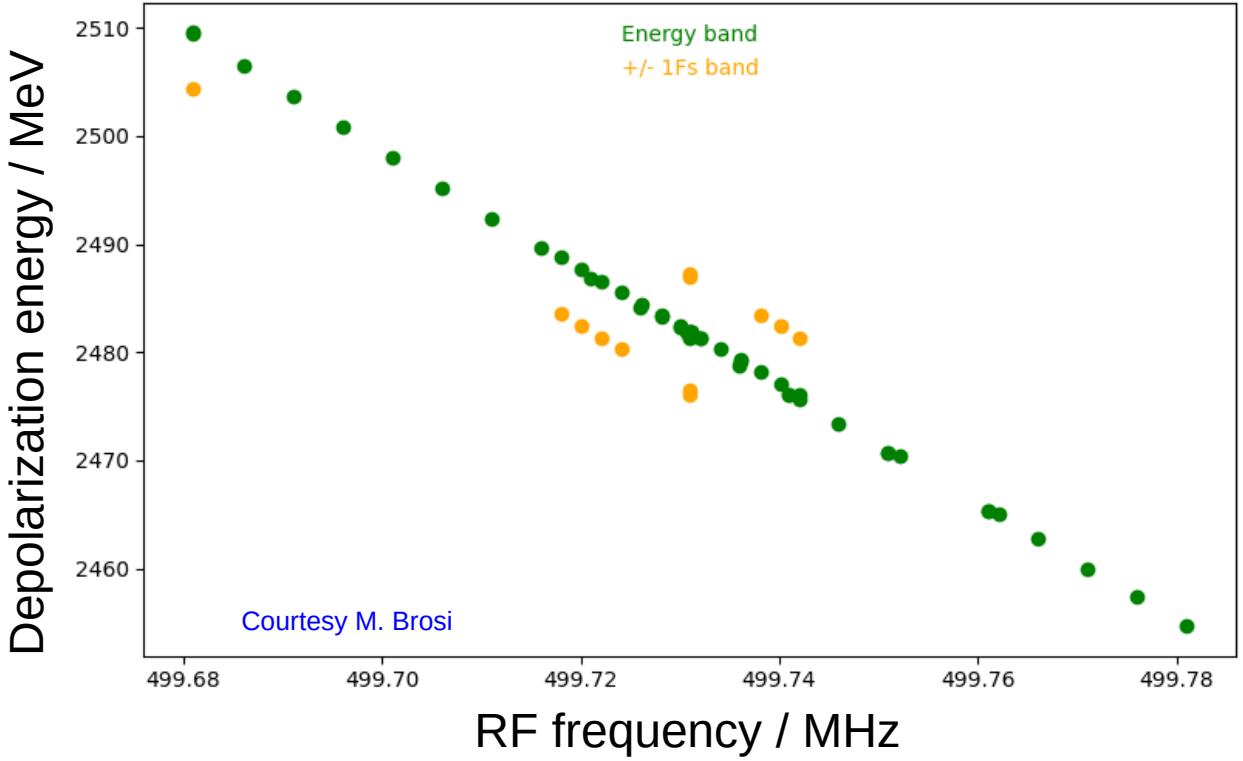
- Setup in operation since then: Measurement campaigns in 2015, 2020, 2021
  - ~ 200 scans since 2015
  - momentum compaction factor and drift of beam energy

Measurement Example – Momentum Scan



Automated overnight meausrement

Measurement Example – Momentum Scan



→ α_c = 0.00909

Resonant spin depolarization at KARA

- A reliable setup for resonant spin depolarization is installed and in operation

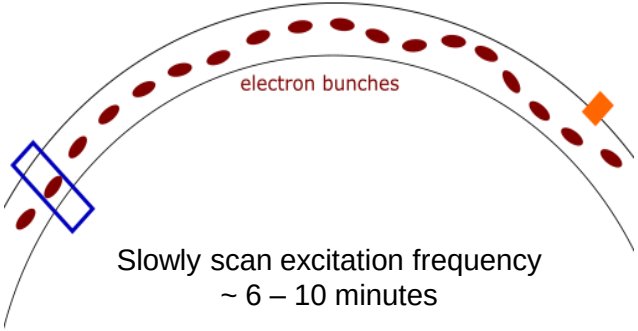
→**Quick measurement** turn-around

→Next measurements planned after this week as we replaced our main dipole power supply after 20 years

→Interest in **systematic** studies? Which “knobs” can we use?

KARA Knobs – Basic Measurement parameters

- Vary **wait time** between sweeps
- Vary **sweep speed** and **frequeny step size**
- Measure on energy **sidebands**

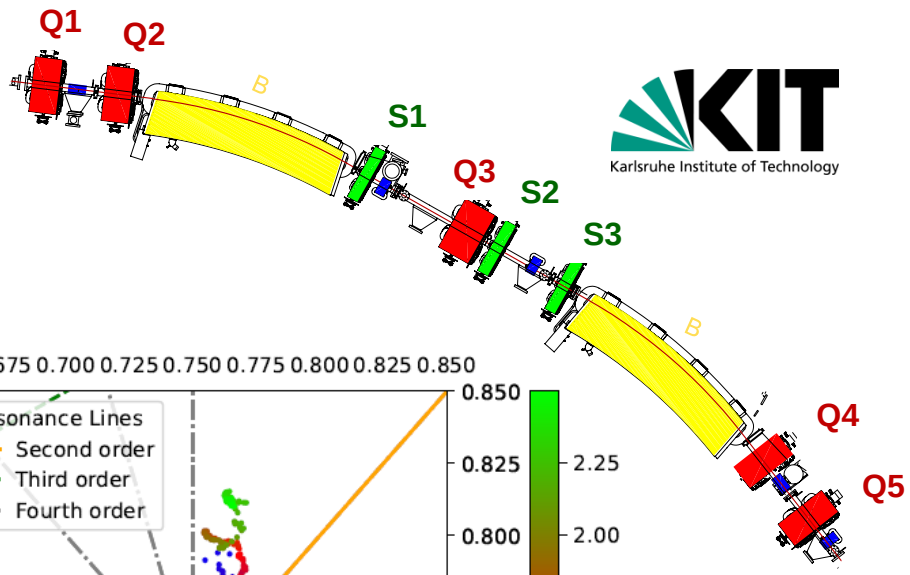


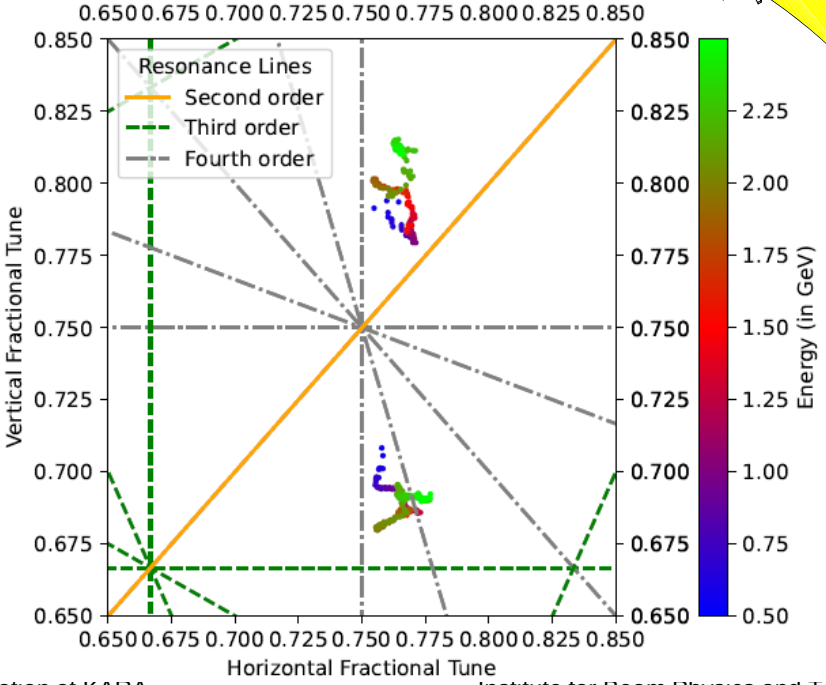
Wait
~10 minutes

Slowly scan excitation frequency
~ 6 – 10 minutes

KARA Knobs – Optics & Orbit

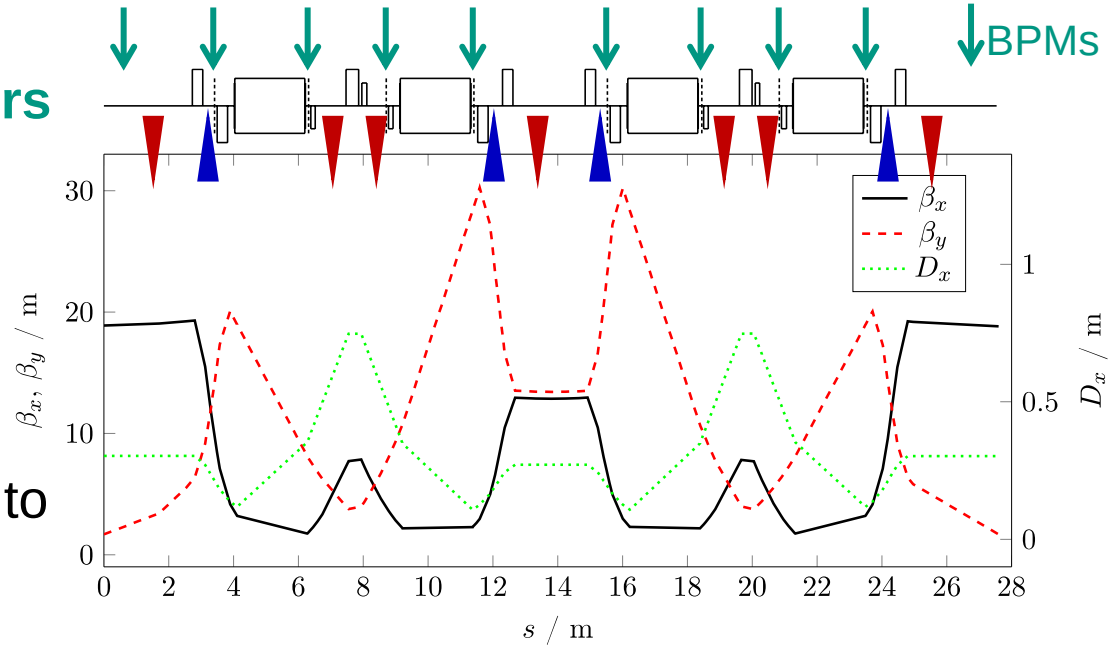
- Doube bend achromat lattice
- Five quadrupole families
- Flexible optics
- Investigate behaviour close to resonances?





KARA Knobs – Optics & Orbit

- **10 Beam position monitors**
- **4 vertical** + **7 horizontal** corrector magnets
- Create closed orbit bumps to pass magnets off-center?



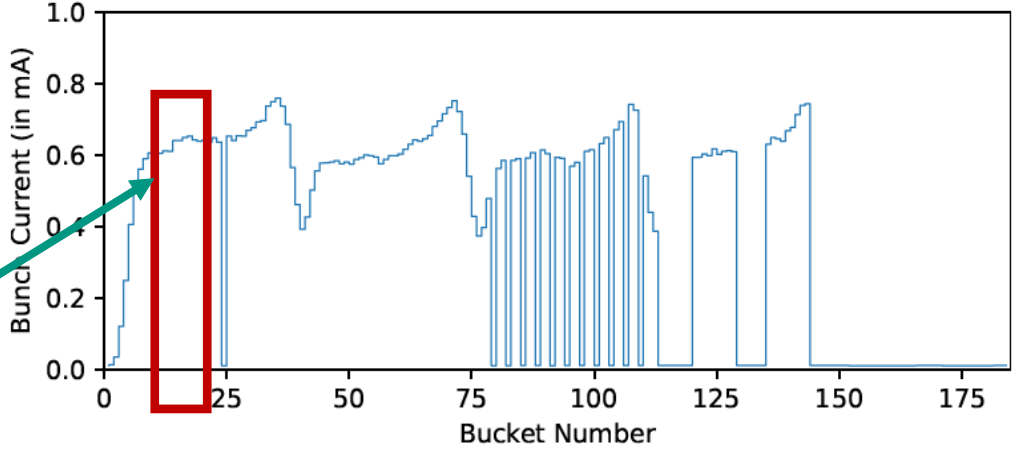
sector 1 (one quarter, 27.6 m)

KARA Knobs – Beam Current & Filling Pattern

- Beam current: 0.1 to 180 mA
- Filling pattern: 1 to 184 bunches in any configuration

- High bunch current → high Touschek losses → improved signal to noise

Depolarize only subset of bunches?

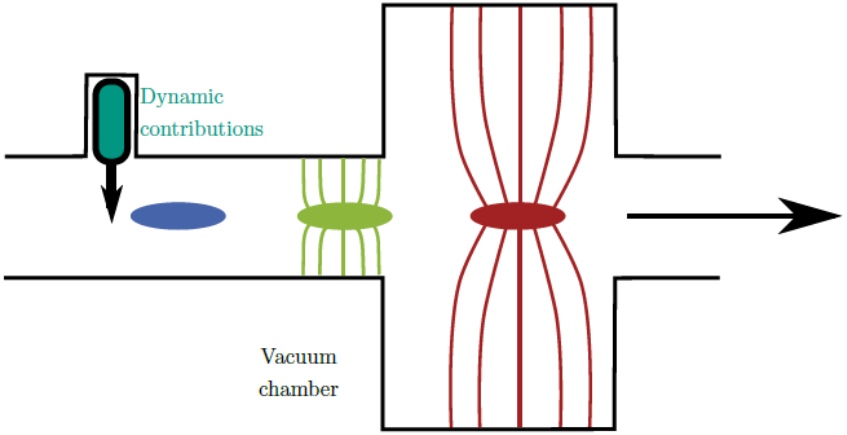


KARA Knobs – Energy, Impedance & SR

- 2.5 GeV: ~ 9 minutes for polarization
  - Measurements at slightly lower **energy**: 2.0 – 2.4 GeV?

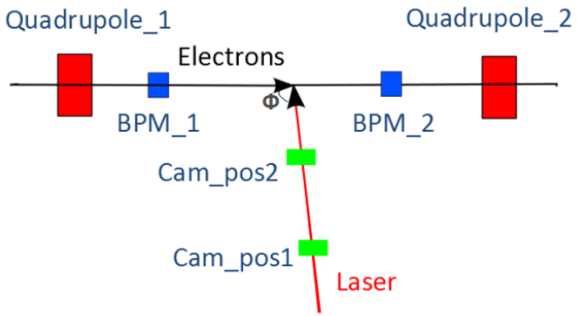
- Increase **synchrotron radiation**
  - Three super-conductive insertion devices: each 2.5 - 2.9 T
  - 2 permant magnet IDs

- Adjust geometric **impedance**
  - In-vaccum movable gaps
  - Vertical and horizontal scraper



Compton Polarimeter?

- Compton back-scattering setup was temporarily available:
  - IPAC'15 contribution C. Chang *et al.*, "First Results of Energy Measurements with a Compact Compton Backscattering Setup at ANKA" (2015)
    - https://accelconf.web.cern.ch/IPAC2015/papers/mopha040.pdf
- 90° setup because of space constraints at that time

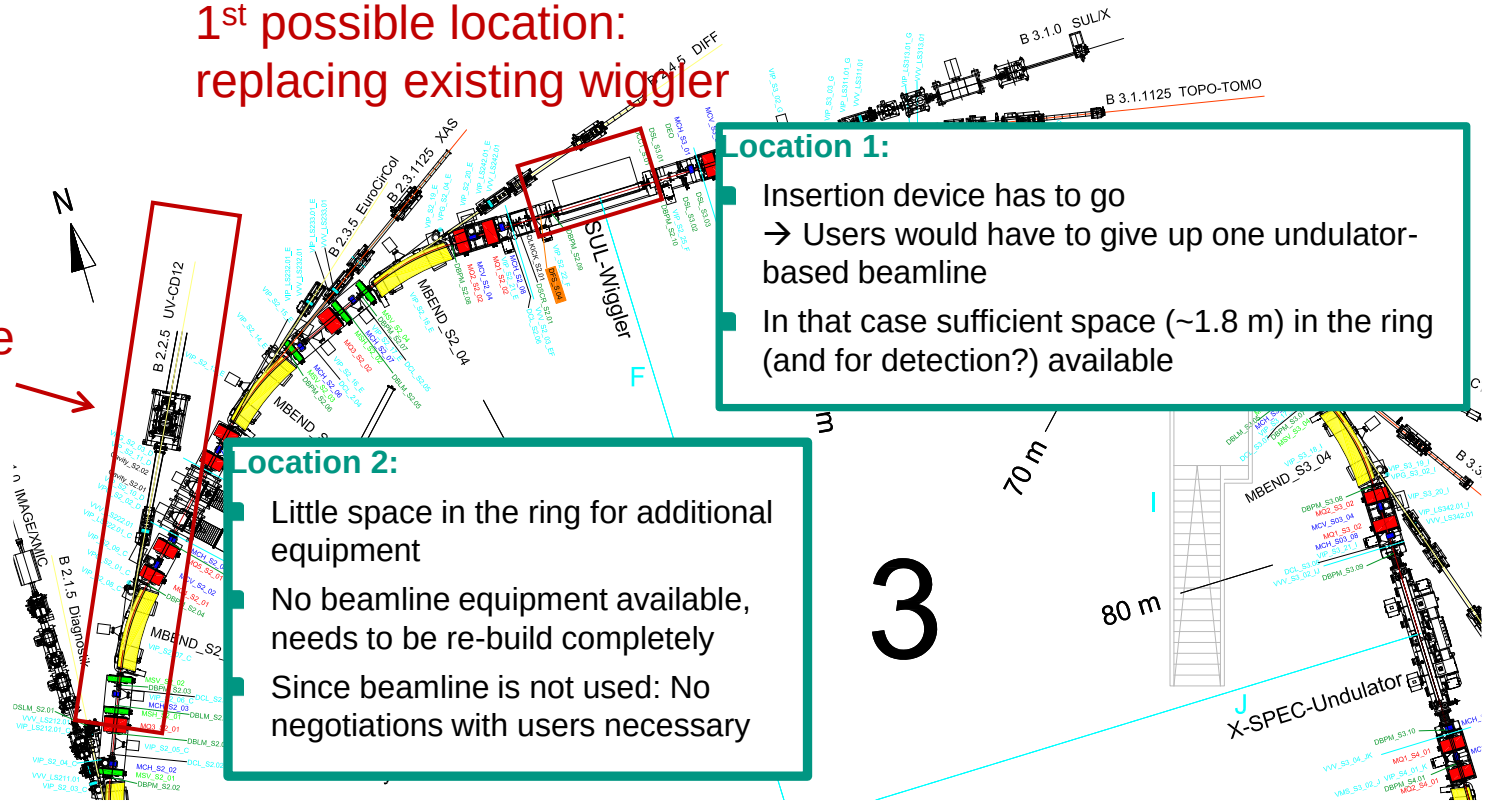


- Setup was decommissioned in 2016 (new undulator has been installed and frontend was no longer available)

Compton polarimeter?

1st possible location:
replacing existing wiggler

2nd possible location:
dismantled beamline



Location 1:

- Insertion device has to go
  → Users would have to give up one undulator-based beamline
- In that case sufficient space (~1.8 m) in the ring (and for detection?) available

Location 2:

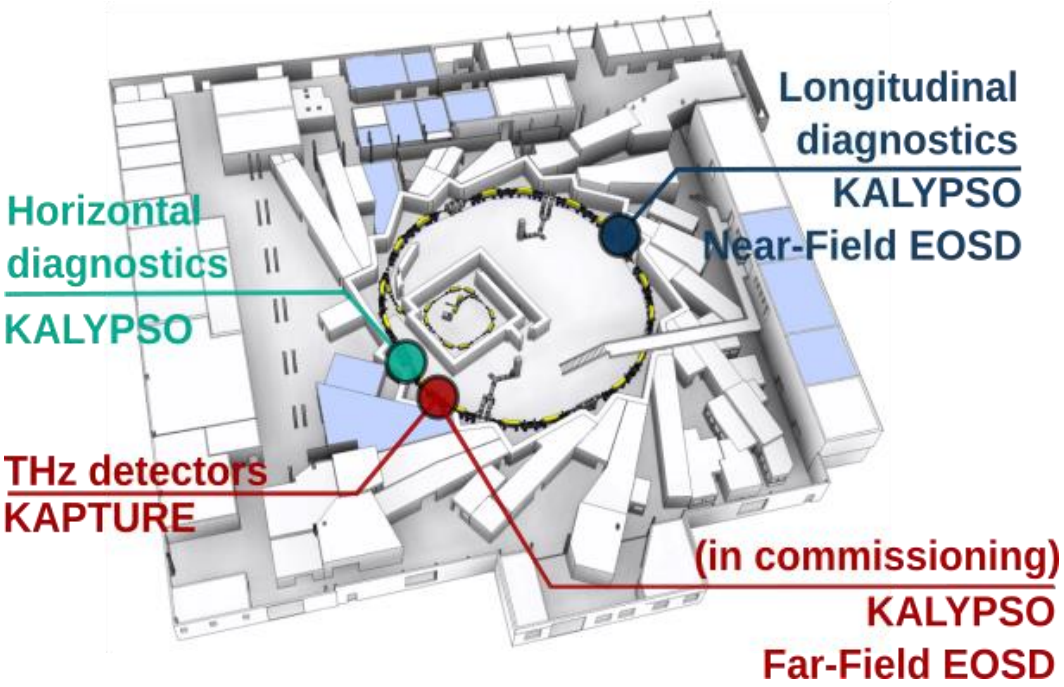
- Little space in the ring for additional equipment
- No beamline equipment available, needs to be re-build completely
- Since beamline is not used: No negotiations with users necessary

Summary

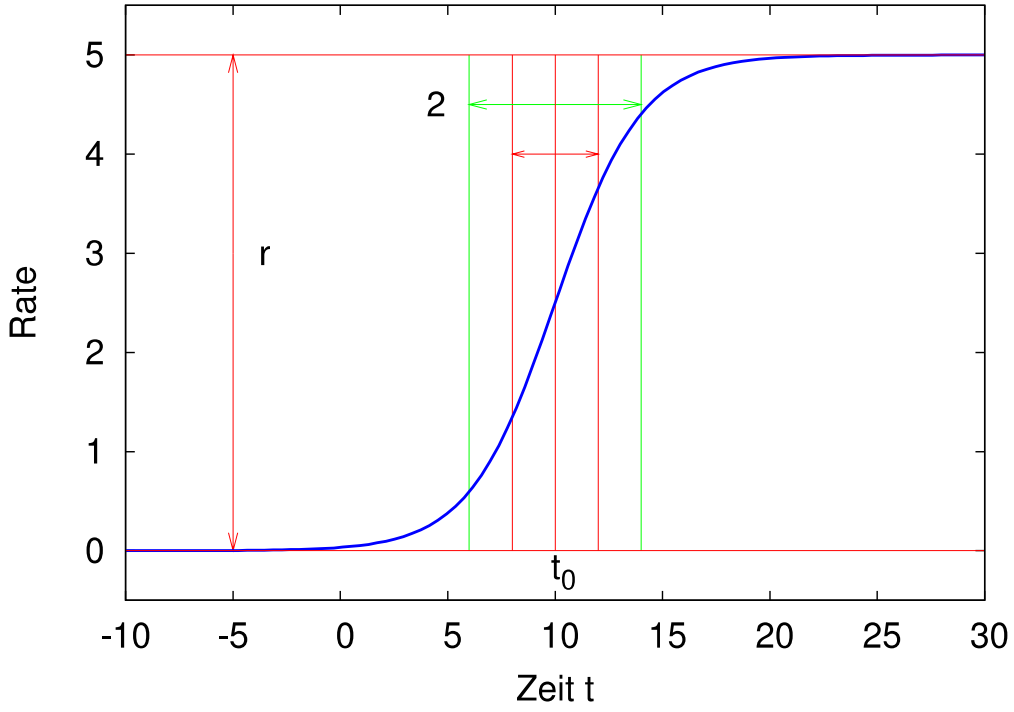
- Resonant spin depolarization is an **established routine measurement** technique at KARA
- Fast polarisation times allow **systematic studies**
- Varity of „**knobs**“ available
- Dedicated beam time is possible (with very **small resource investment**)
- Potential of re-adding compton polarimeter (more **substantial resource investment** necessary)

Back up

More diagnostics…



Step function



$$r(t) = a - b \cdot t + \frac{\Delta r}{1 + \exp\left(-\frac{t - t_\mathrm{d}}{\sigma_\mathrm{d}}\right)}$$

- a, b: linear slope
- Δr: change of count rate
- t_d: time of depolarisation
- σ_d: duration of depolarisation