Karlsruhe Institute of Technology

FUTURE CIRCULAR COLLIDER
Innovation Study

KARA
Karlsruhe Research Accelerator

IBPT
Institute for Beam Physics and Technology

Polarisation studies at KARA

Bastian Haerer on the 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
  - Focus on TbT and BbB diagnostics

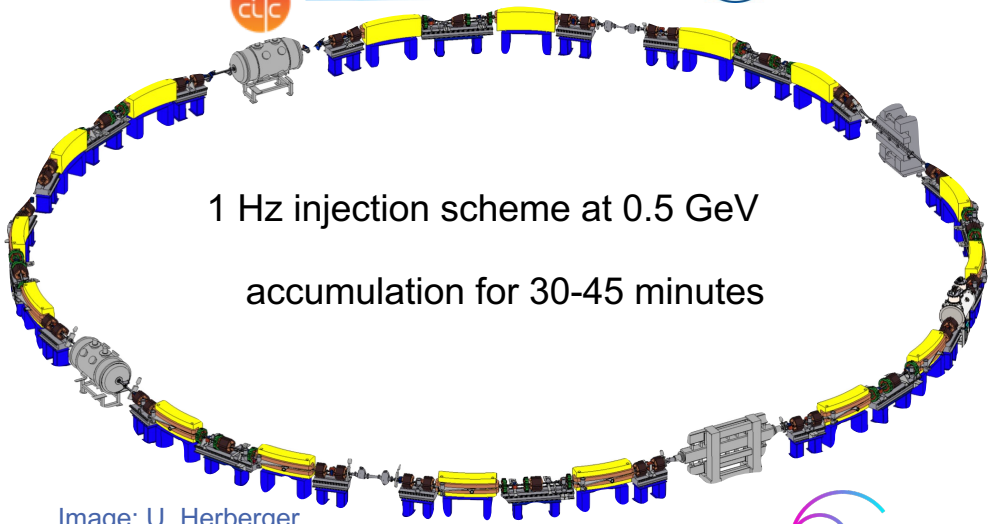


Image: U. Herberger

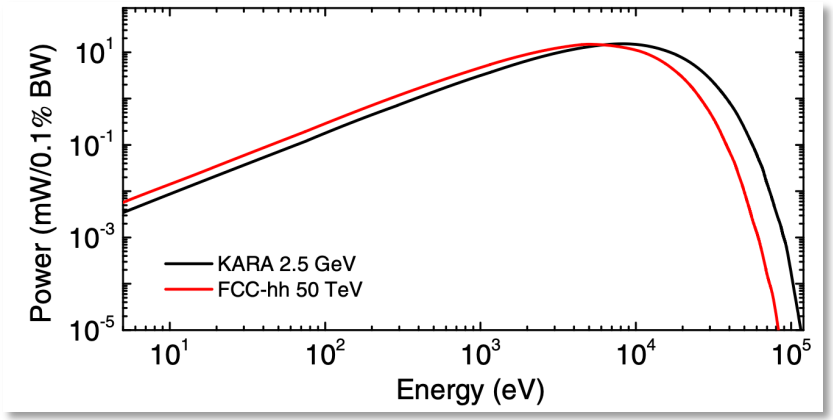
www.ibpt.kit.edu/kara

KARA – relevance in the context of FCC

~ 50 days of machine physics per year

FCCIS

Synchrotron radiation spectrum similar to FCC-hh



BESTEX, 10.1103/PhysRevAccelBeams.22.083201

Task 2.5: Polarisation and energy calibration

- Energy measurements with highest possible precision required for FCC-ee

  → Resonant Spin Depolarisation
- Setup available at KARA

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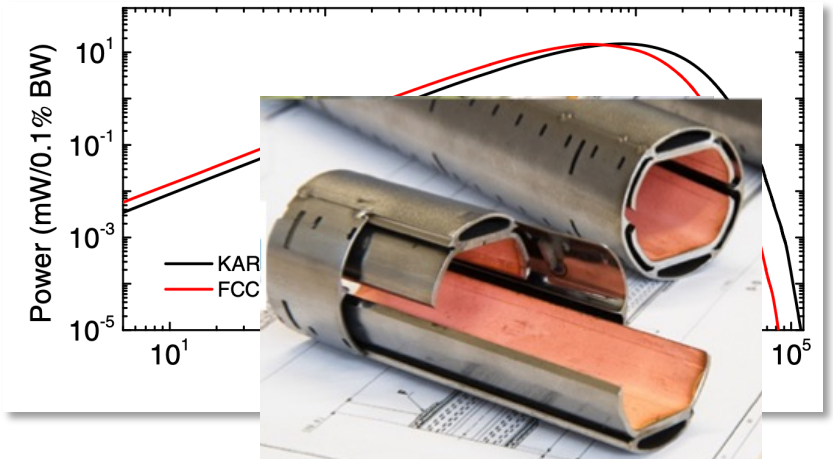

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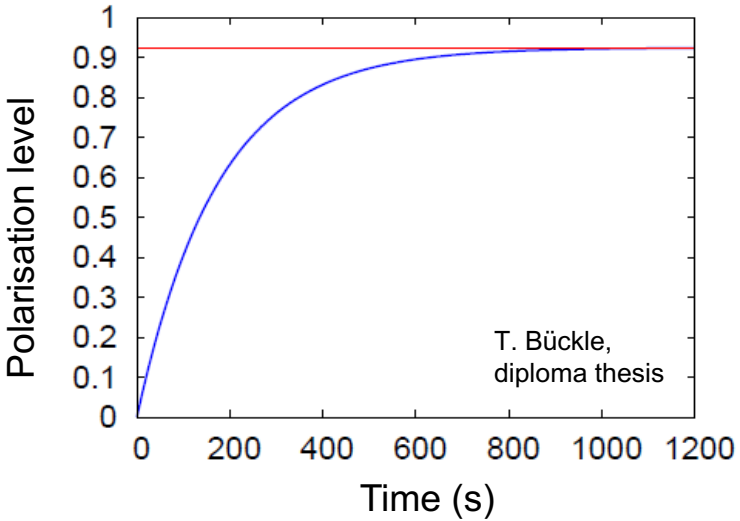
Electron beam polarisation

- Asymmetry in the spin-flip probability due to emission of synchrotron radiation leads to spin polarisation over time:

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

- KARA, 2.5 GeV: ~ 9 minutes
- Spin vector precedes in presence of electric and magnetic fields

$$\nu = a\gamma$$



$$a = (g_e - 2)/2 = 0.001159652193$$
$$\gamma = E_{\mathrm{beam}}/m_0 c^2$$

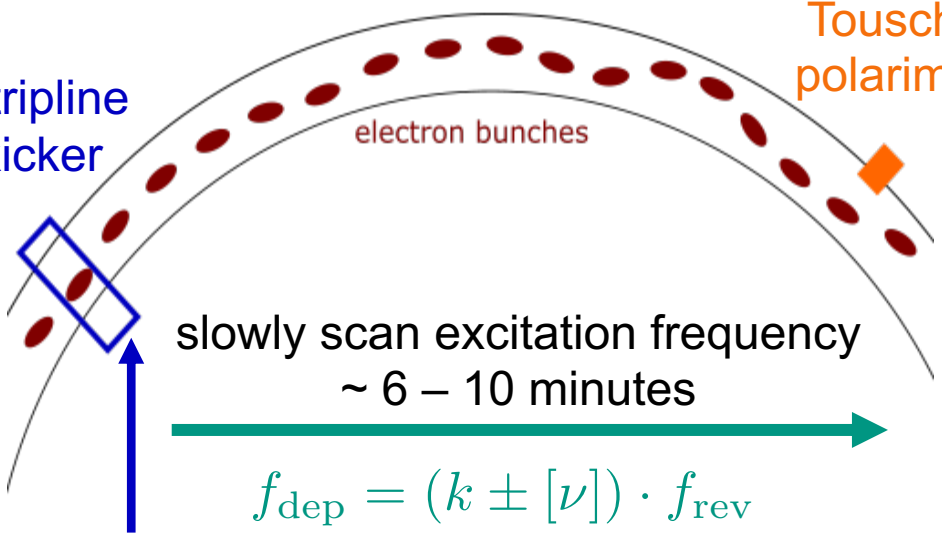
- If a horizontal excitation with spin-tune resonance is applied, the polarization is resonantly destroyed. → Resonant spin depolarisation

RSD measurement technique

polarisation

wait
~10 minutes

resonant depolarisation



Touschek sensitive region

Measurement analysis

Change in Touschek lifetime because Møller scattering is dependent on polarization

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

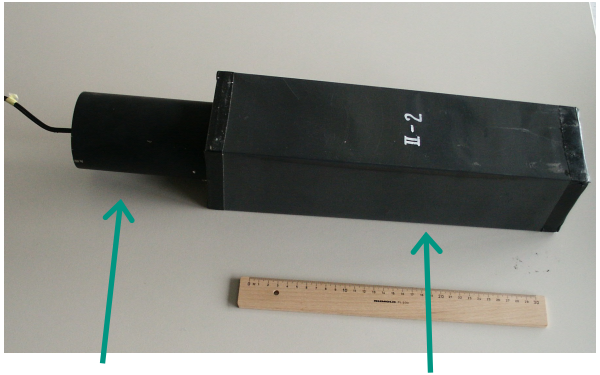
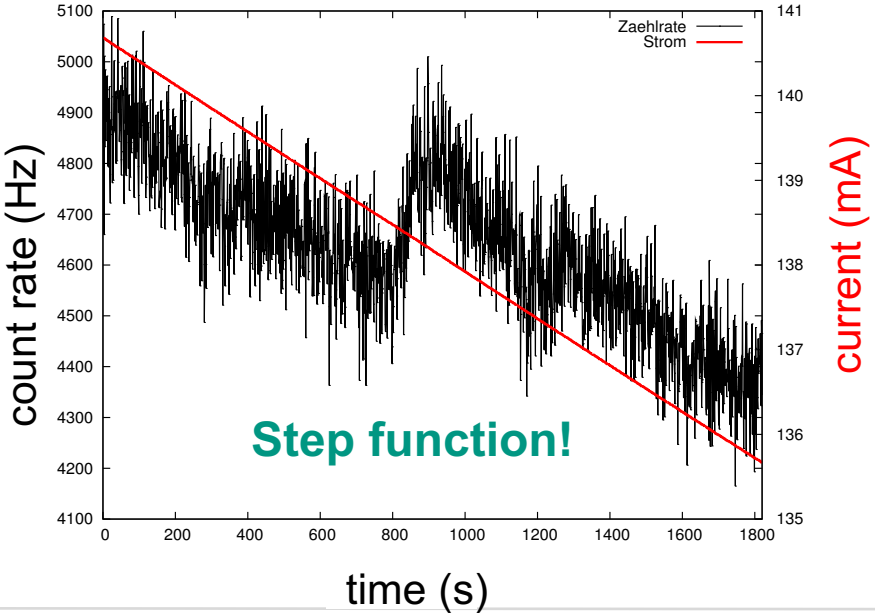


photo multiplier

lead-glass block



First beam time at KARA: 30/10 & 31/10/2023

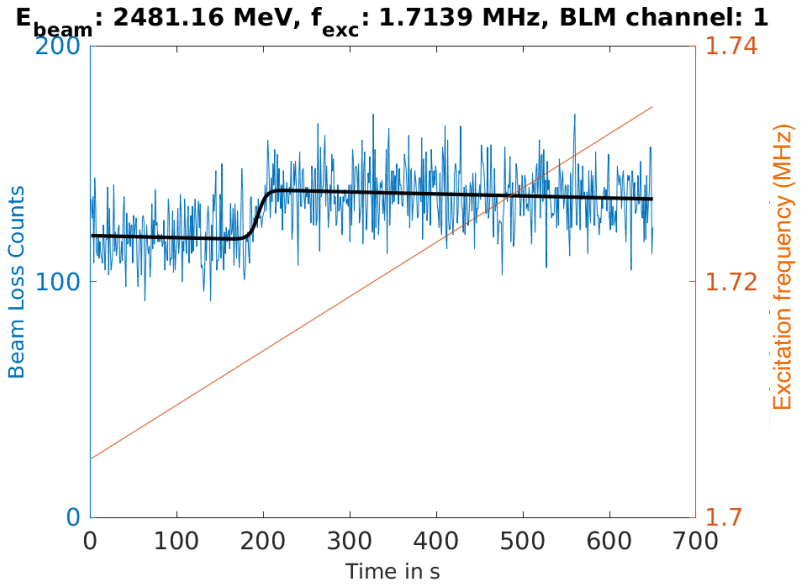
Jacqueline and Frank visited for

- Detailed optics measurements as input for simulations
  - Transverse kicks, tbt data → Jacqueline
  - (K modullation → in preparation)

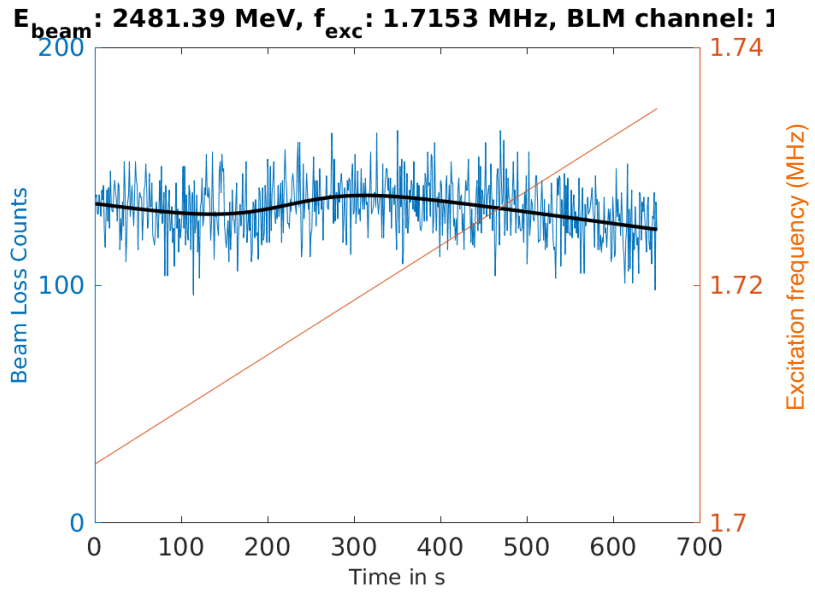
- Resonant spin depolarisation
  - 34 successful scans
  - Scan direction: up/down
  - Scanning time: 100 s – 600 s

Evaluation ongoing

First scans – determination of waiting time



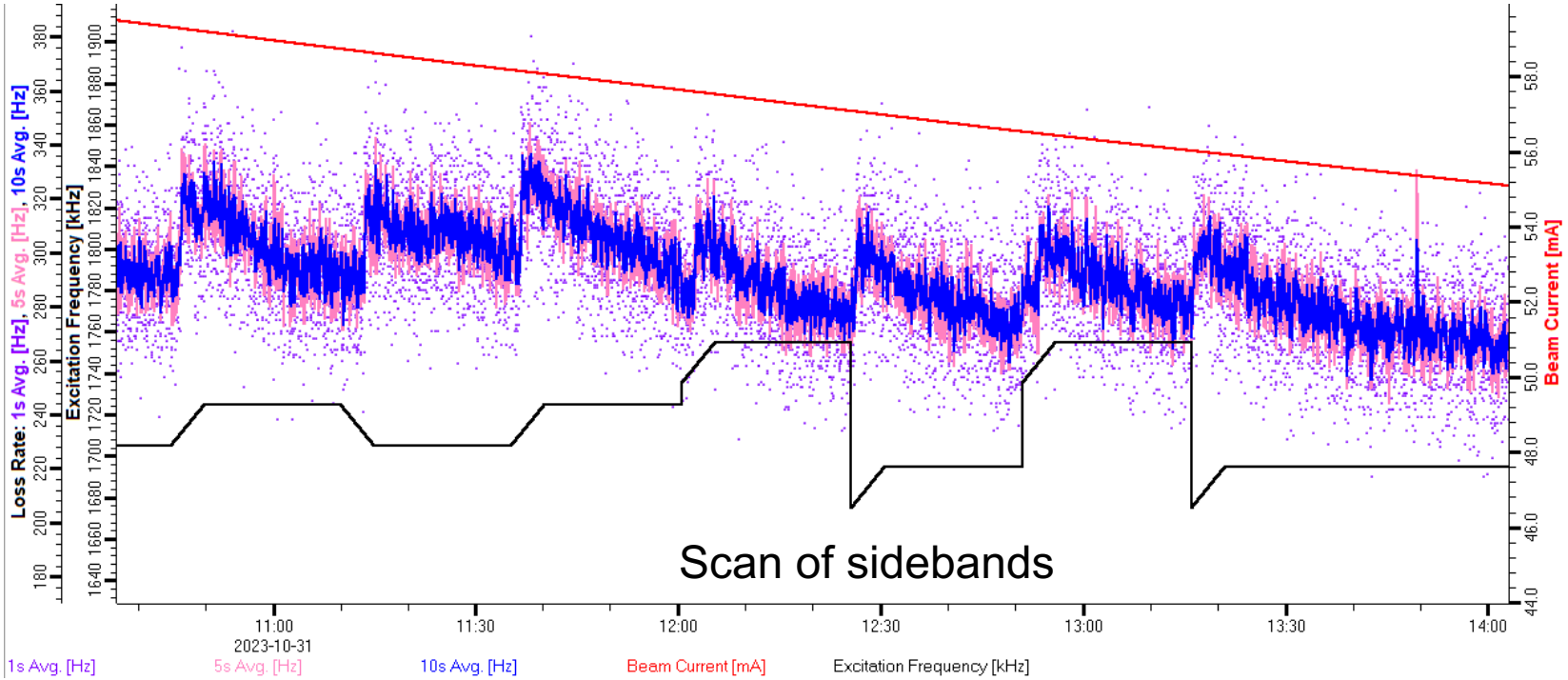
first scan



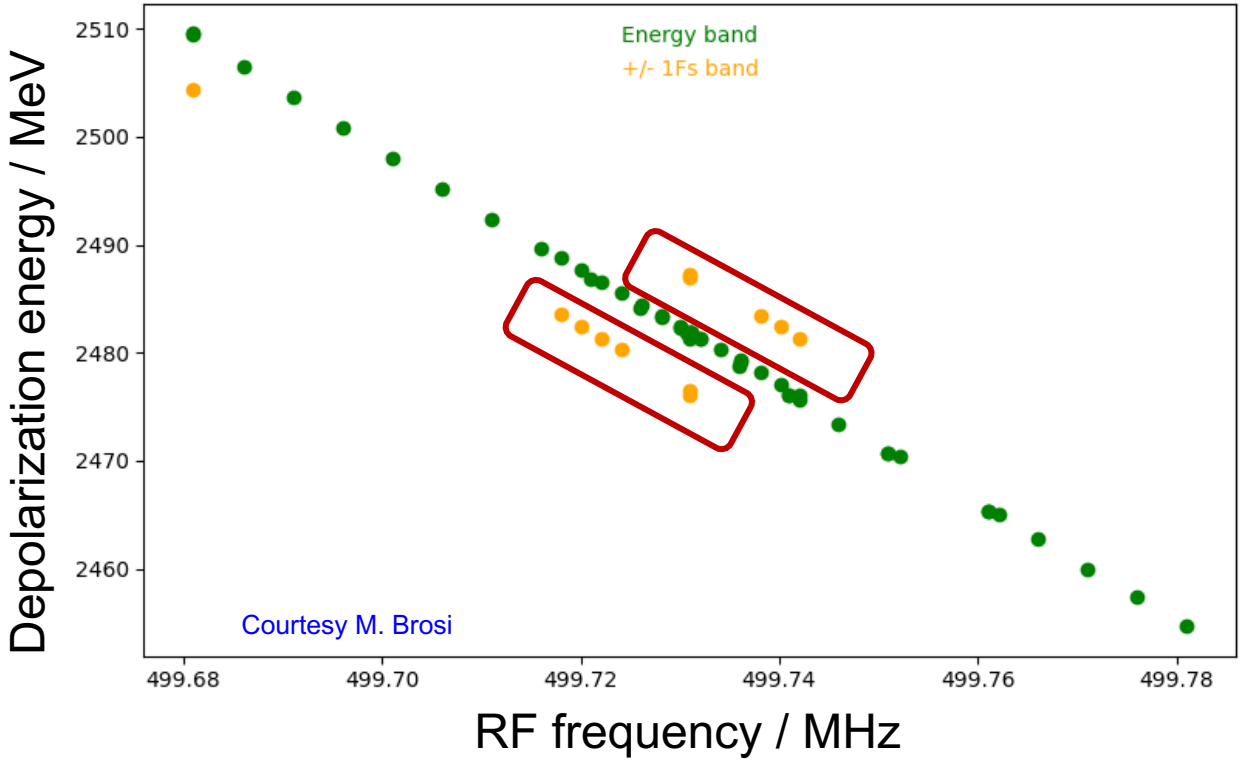
10 minutes later

→ wait 20 minutes to get higher polarization level

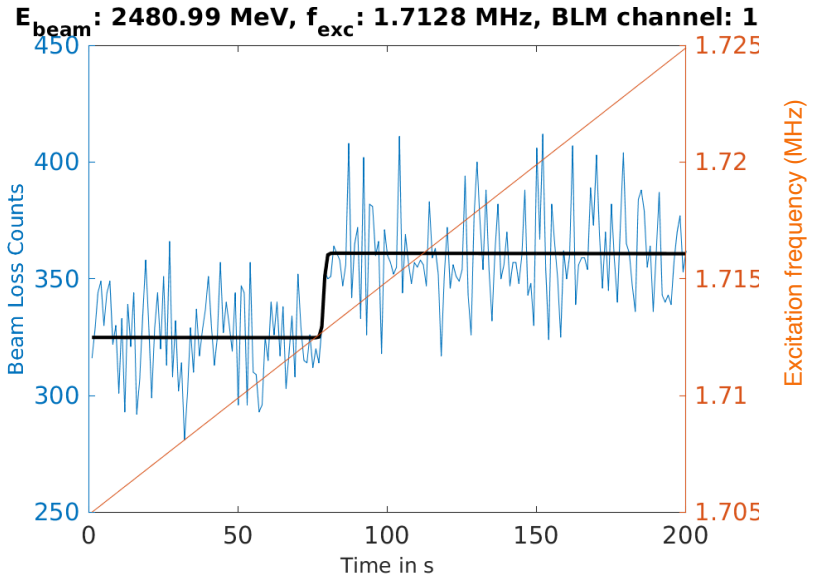
Automated scans

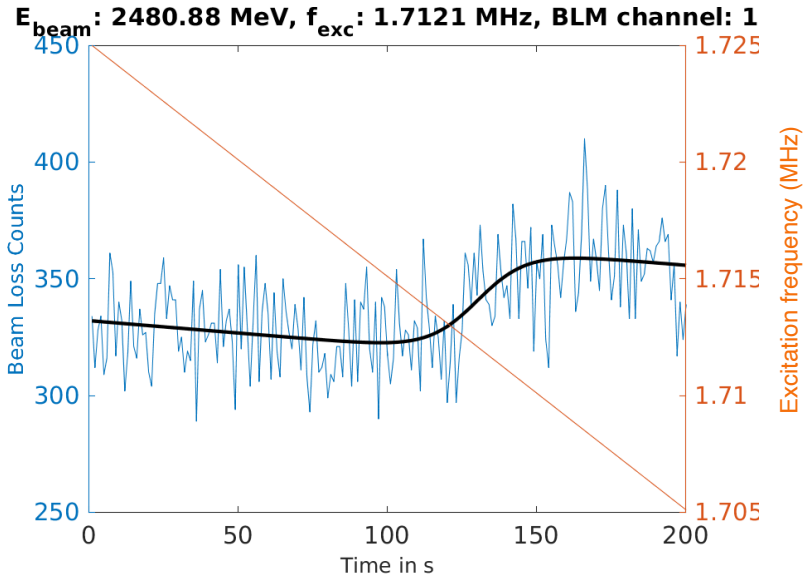


Sidebands: old measurement for illustration



Frequency scan direction





Effect due to scan direction → detailed analysis pending

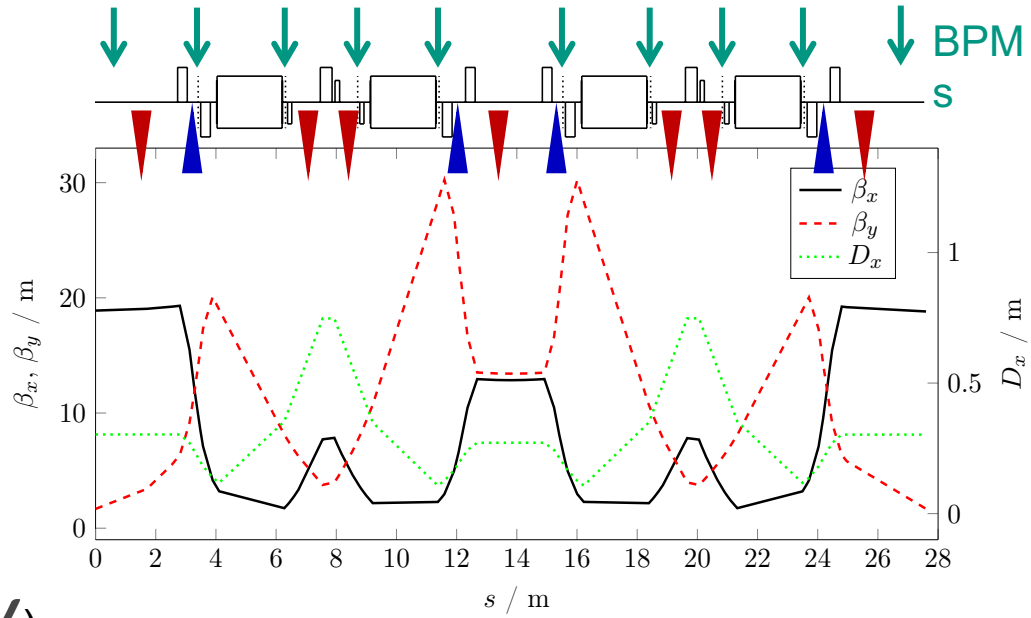
Measurements at lower energies

- Encounterd difficulties at 2.3 GeV
- Could be critical since non-integer part .220 is close to our betatron non-integer tunes.
- At 2.5 GeV: low emittance optics (dispersion leak in all sections)
  Lower energies: achromatic optics (higher emittance and less Touschek)
- To be continued …

Energy (GeV)	Spin tune	Pol. time (s)	(min)	Depol. freq. (MHz)
2.5	5.673	567	9.4	1.74
2.4	5.446	675	11.2	1.21
2.3	5.220	835	13.9	3.31
2.2	4.993	1042	17.4	2.70
2.1	4.766	1316	21.9	2.08
2.0	4.539	1679	28.0	1.46
1.9	4.312	2170	36.2	3.56
1.8	4.085	2843	47.4	2.95
1.7	3.858	3784	63.1	3.56
1.6	3.631	5124	85.4	1.71
1.5	3.404	7075	117.9	1.10

Outlook 1: Spin matching with vertical orbit bumps

- **10 beam position monitors**
- **4 vertical** + **7 horizontal** corrector magnets
- Allows to investigate the effect of vertical orbit bumps to mitigate spin diffusion due to misalignments.
- Simulation requirements
  → Detailed optics measurements (✓)
  → Misalignments measured ✓



sector 1 (one quarter, 27.6 m)

Outlook 2: polarisation measurements?

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Continuous energy measurement of the electron beam in the storage ring of Diamond Light Source with resonant spin depolarization

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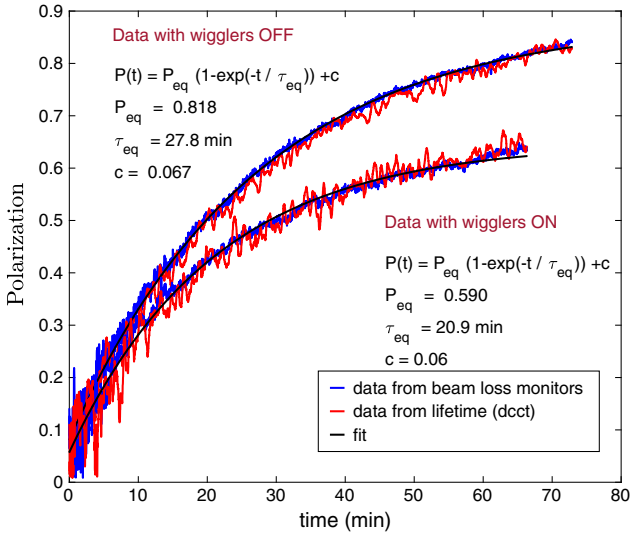

$$P(t) = P_{\mathrm{ST}} \frac{\tau_d}{\tau_d + \tau_{\mathrm{ST}}} \left[1 - \exp\left(-\frac{t}{\tau_{\mathrm{ST}}} \left(\frac{\tau_d + \tau_{\mathrm{ST}}}{\tau_d} \right) \right) \right]$$

- Paper presents polarisation measurement based on Touschek lifetime

(D. P. Barber et al., Nucl. Instrum. Methods Phys. Res., Sect. A 338, 166 (1994).)

Summary & Outlook

- First measurements in context of FCCIS performed at KARA
  - Optics measurements using turn-by-turn data after transverse kicks
  - RSD scans focusing on scanning direction and scanning speed

- Measurements at lower energies need more attention
- New BLMs as counters for scattered electrons in commissioning

- Spin matching with vertical orbit bumps
  - Simulations are in preparation
  - Corresponding measurements would be conducted next year
- Measurement of polarisation via Touschek lifetime under investigation

Thank you for listening!

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E. Blomley, J. Gethmann, E. Huttel, J.L. Steinmann
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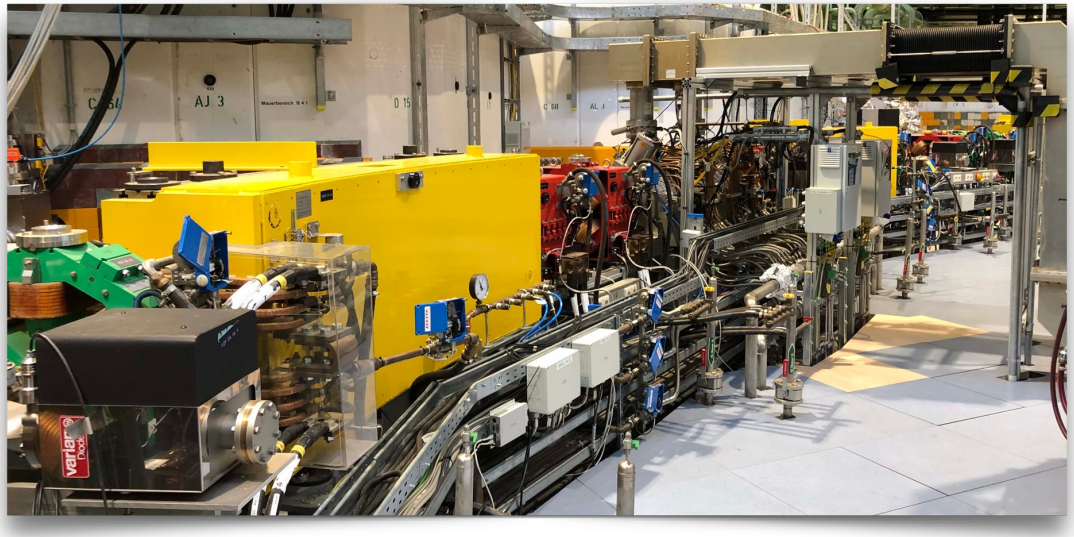

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