Karlsruhe Institute of Technology

ANKA THZ GROUP

HELMHOLTZ ASSOCIATION

Coherent Synchrotron Radiation in the ANKA Storage Ring

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On behalf of the ANKA THz-Group

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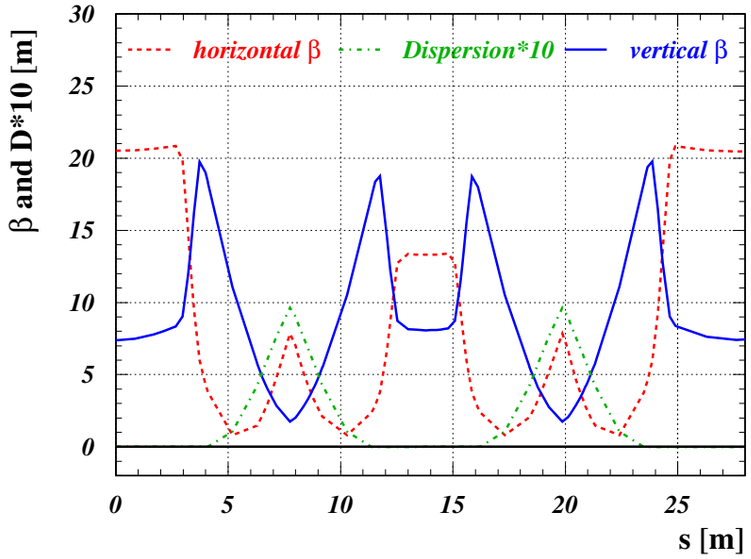
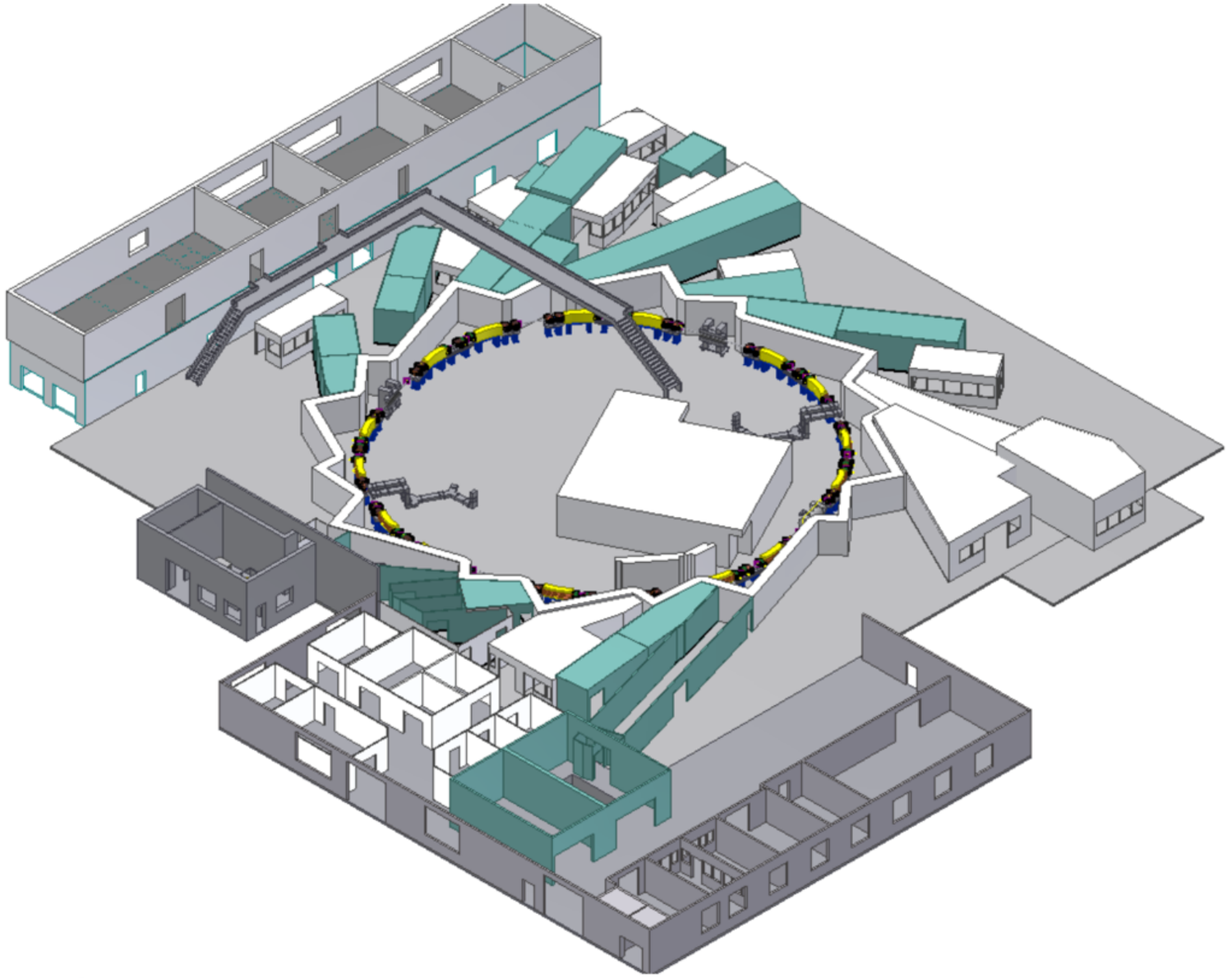
Outline

- ANKA storage ring
  - ➜ Operating with a low-alpha optics
- Studies of / with CSR
  - ➜ Bursting patterns & micro bunching instability
  - ➜ Influence of geometric impedance
  - ➜ Influence of long range wake fields
- Next steps
- Summary

ANKA Storage Ring

- Key parameters:
  - ➜ Circumference: 110.4 Meter
  - ➜ RF-frequency: 500 MHz
  - ➜ Revolution time: ≈ 368 ns
  - ➜ Harmonic number: 184
  - ➜ Lattice: double DBA





- Normal operation mode:
  - ➜ Beam energy: 2.5 GeV
  - ➜ Multi bunch mode: up to 200 mA
  - ➜ Bunch length: > 30 ps

Ports Used for Accelerator Studies

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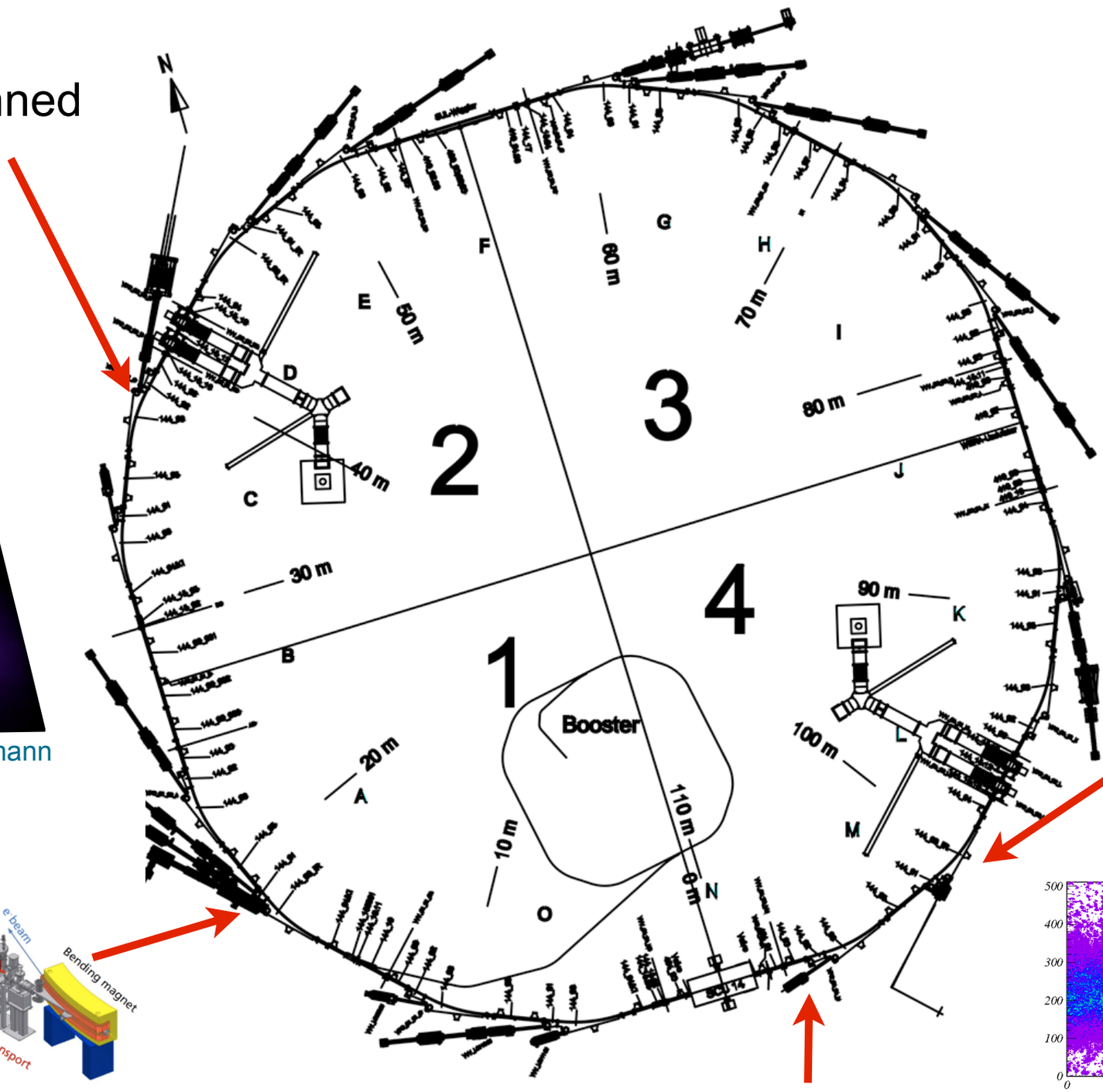
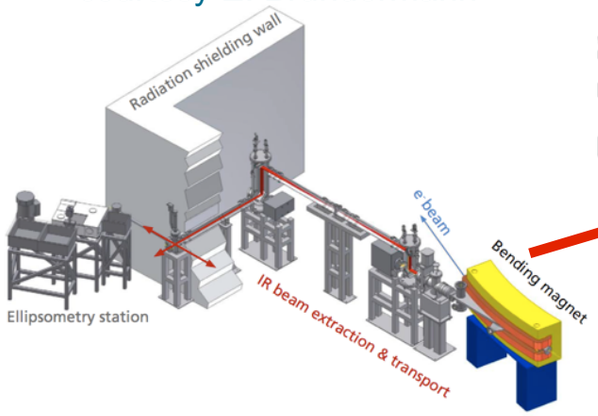
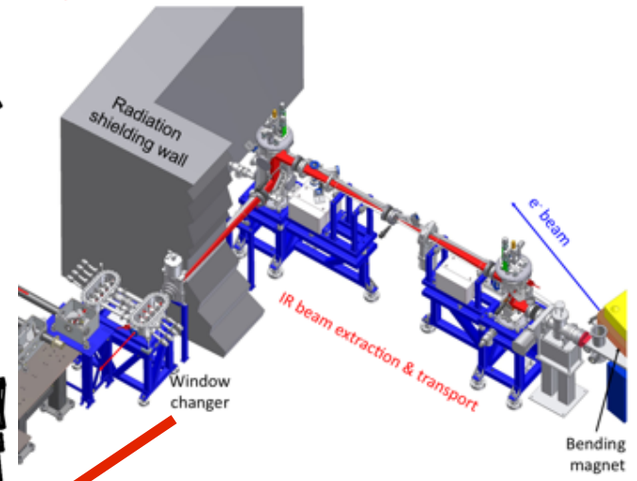
THz port planned



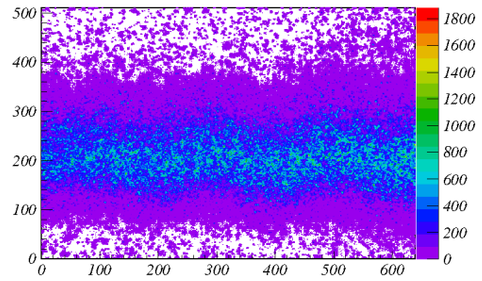
courtesy E. Bründermann



IR1 beamline



IR2 beamline
in commissioning



Optical light diagnostics port

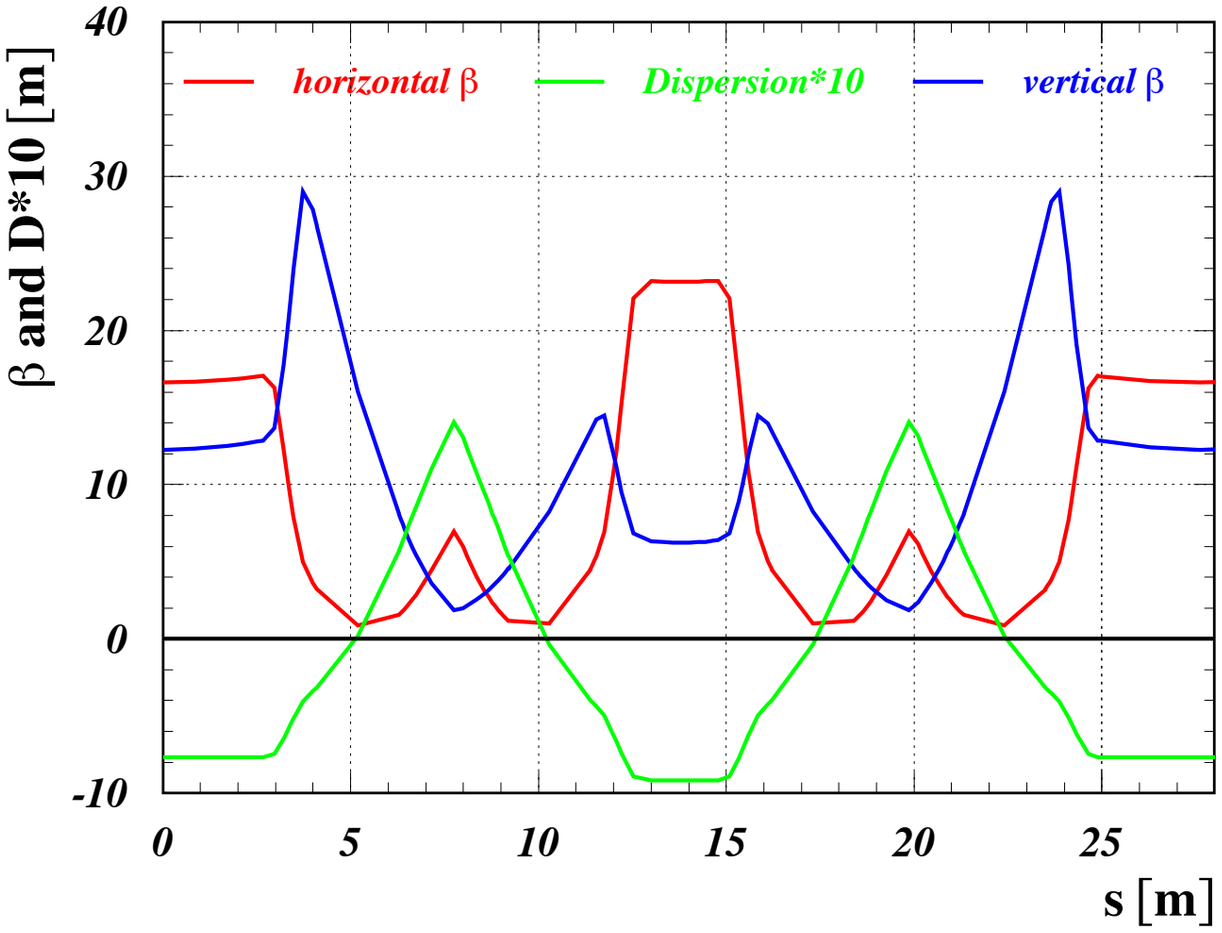
Low-α_c Optics at ANKA

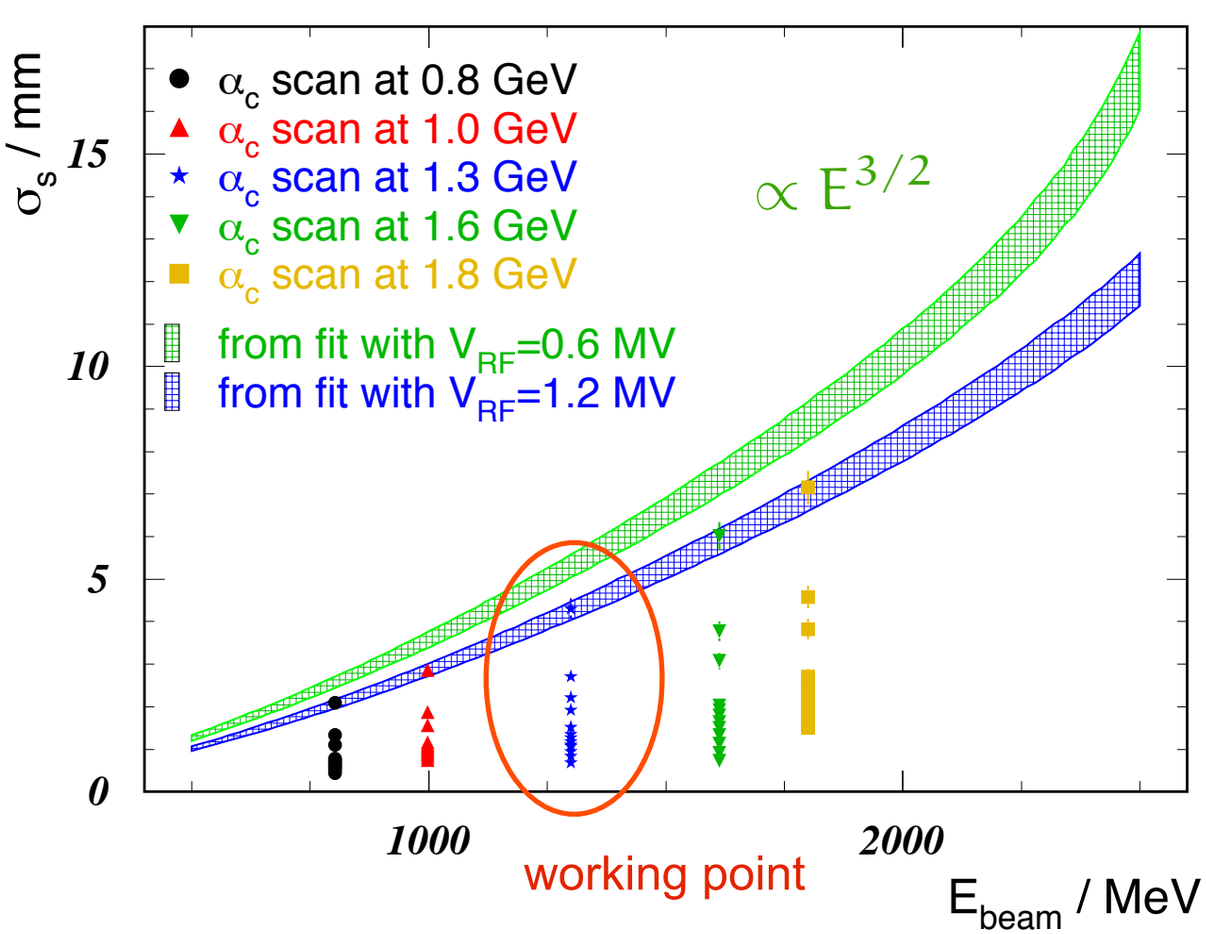
- Dedicated low-α_c optics with negative dispersion in the long and short straight sections for flexible bunch length tuning following the pioneering work of e.g. BESSY II

$$\alpha_c = \frac{1}{L}\oint ds \frac{D(s)}{\rho(s)}$$

- At ANKA: Observed momentum compaction factor range as extrapolated from Q_s measurements:

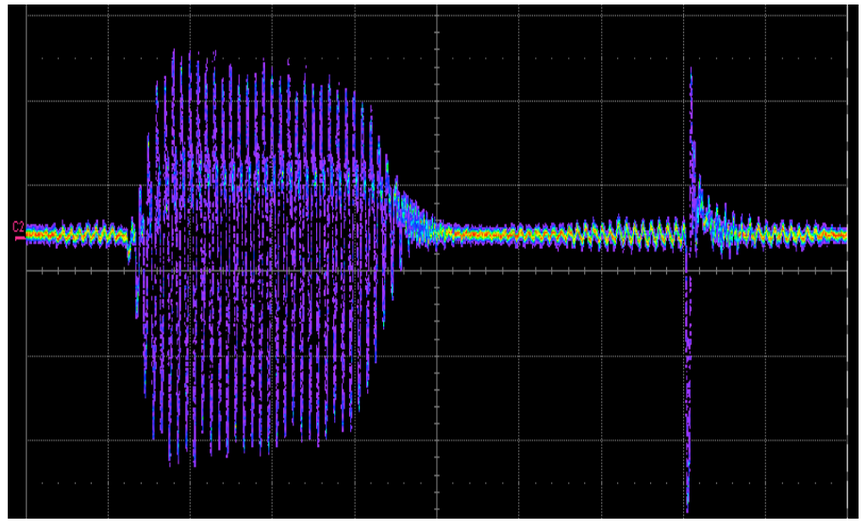
  ➜ from 7.2 10^{-3} to 1.4 10^{-4}

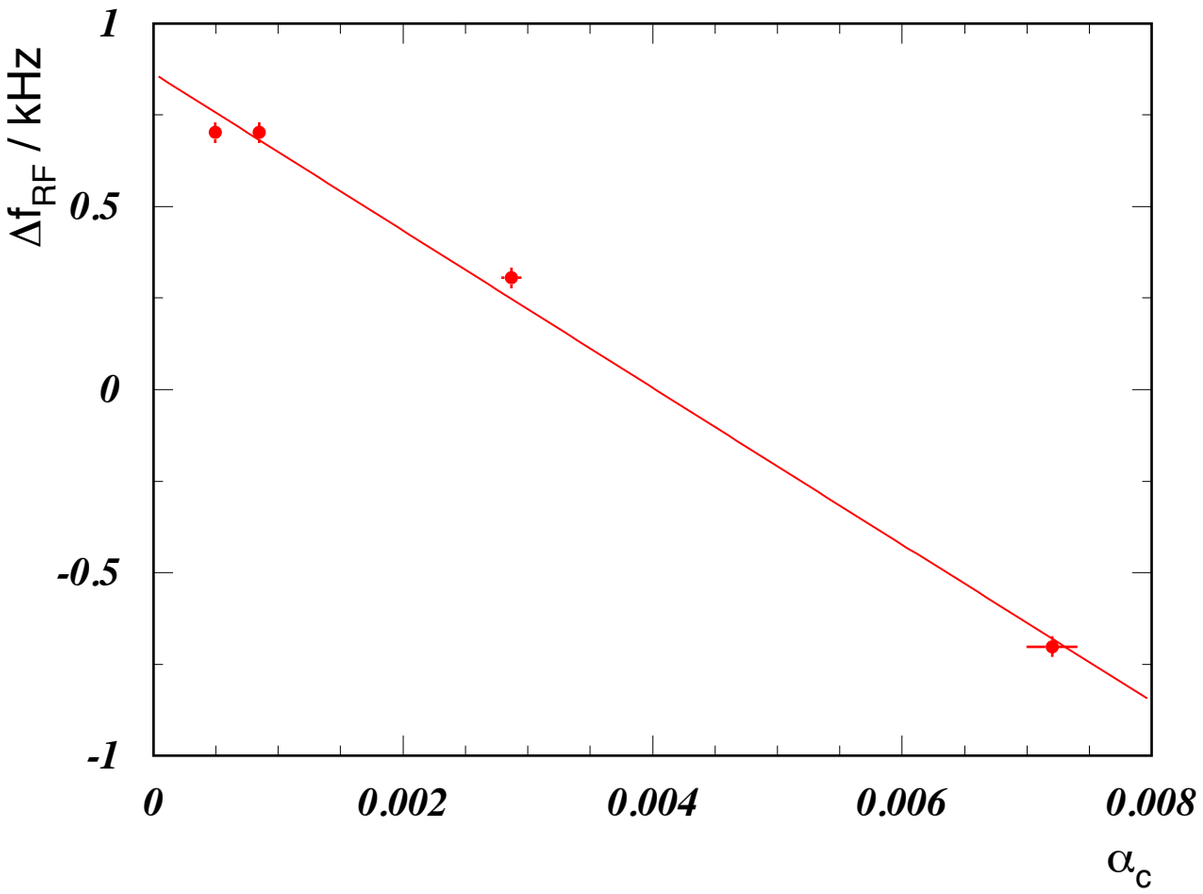




Operation in the Low-α_c Mode

- Energy ramp (reguar optics)
  - ➜ fill various pattern at 0.5 GeV
- Low-α_c “squeeze”
  - ➜ change quadrupoles & sextupoles
  - ➜ orbit correction between steps





- RF frequency adjustment
  - ➜ Beam energy: $E \propto \oint B\,dL$
  - ➜ contribution from correctors
  - ➜ depends on α_c
  - ➜ solution: correct simultaneously orbit and f_{RF}

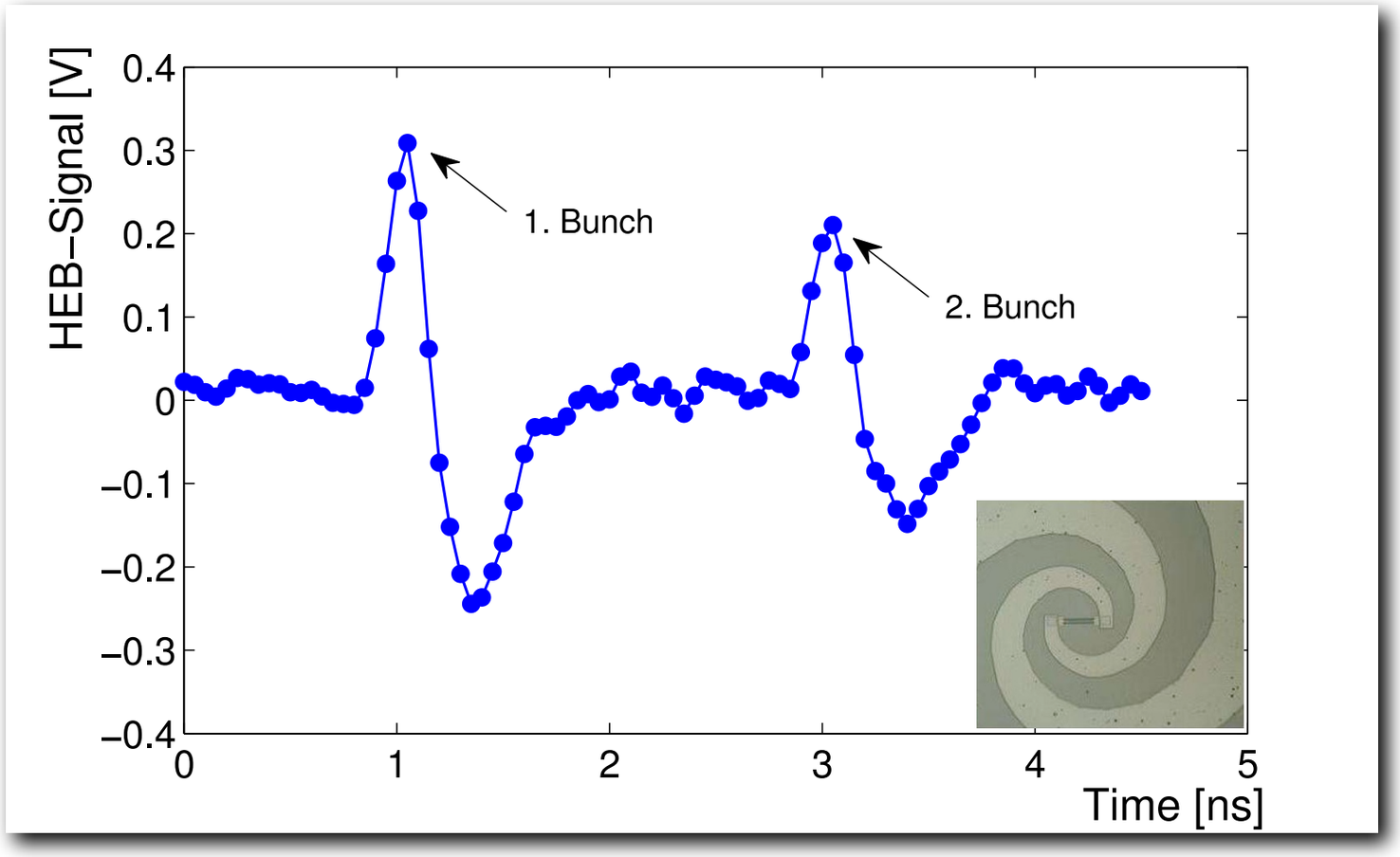
$$\frac{\Delta p}{p} = -\frac{1}{\alpha_c}\,\frac{(f_{RF}-f_{RF}^{c})}{f_{RF}}$$

THz Detector System

- Hot Electron Bolometer (HEB) detector
- Based on: SC niobium nitride
- Response time < 160 ps
- Spectral range 150 GHz - 3 THz

High temporal resolution of HEB allows to study signals from individual bunches in multi- and single bunch environment.

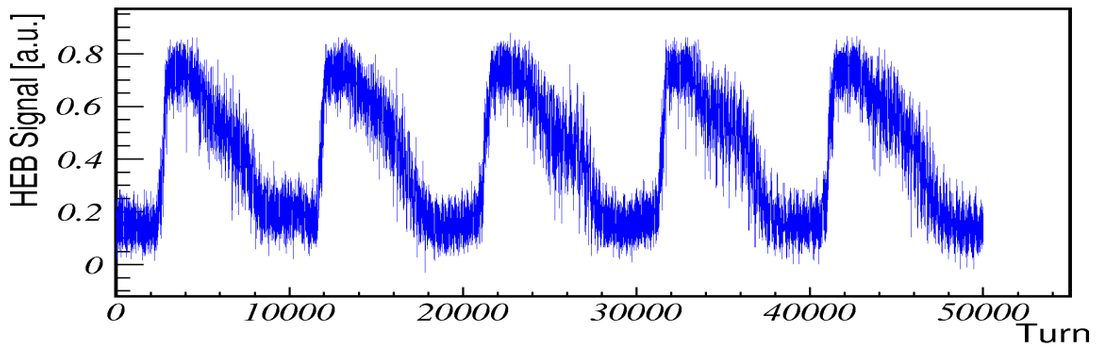
Joint development of IMS (KIT) & DLR (Berlin)

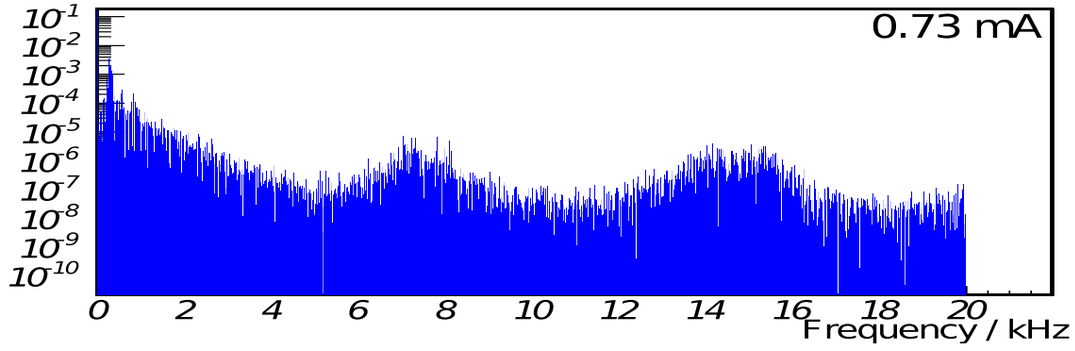


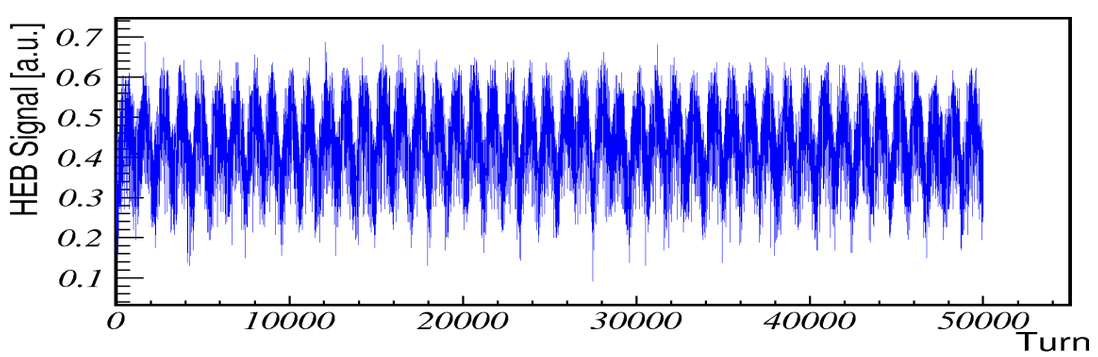
courtesy V. Judin

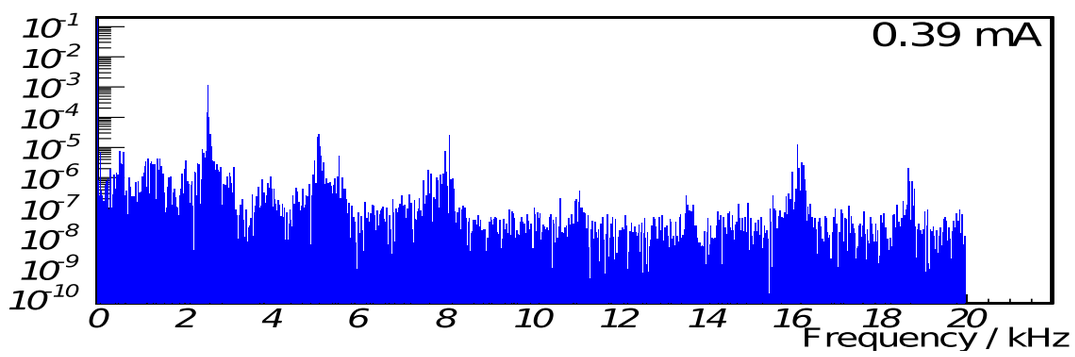
THz Bunch Signals in Time Domain

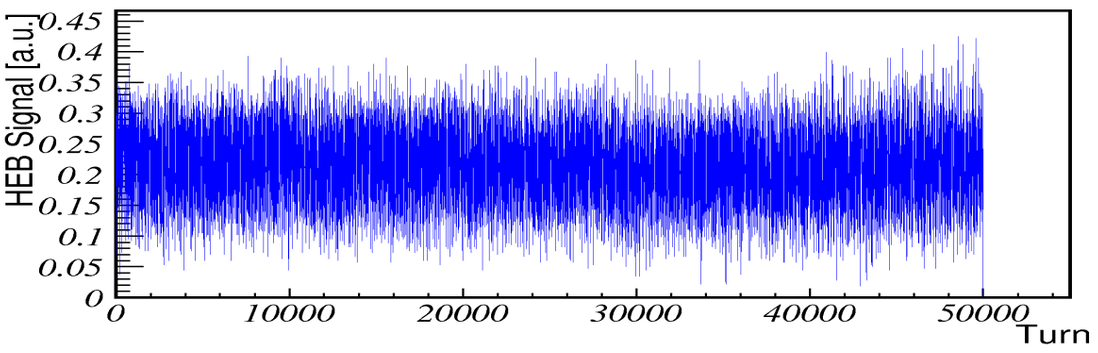
- Observe one bunch in its natural environment over many turns
- Saturation of the generating instability and subsequent radiation damping leads to a sawtooth-like pattern as a function of time

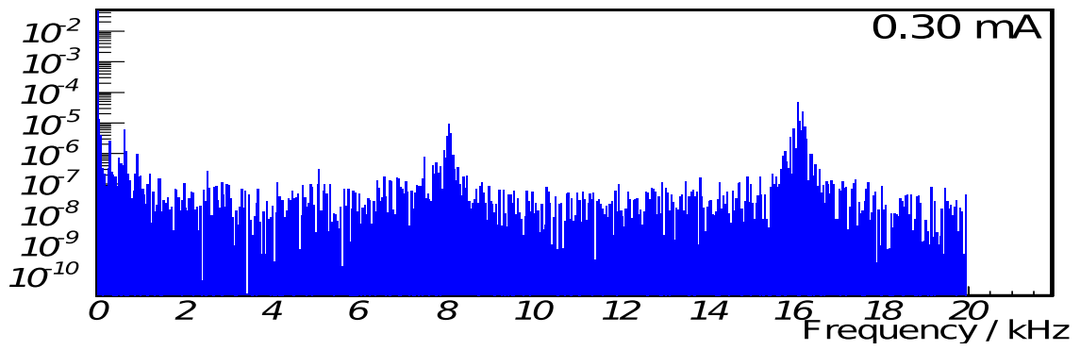










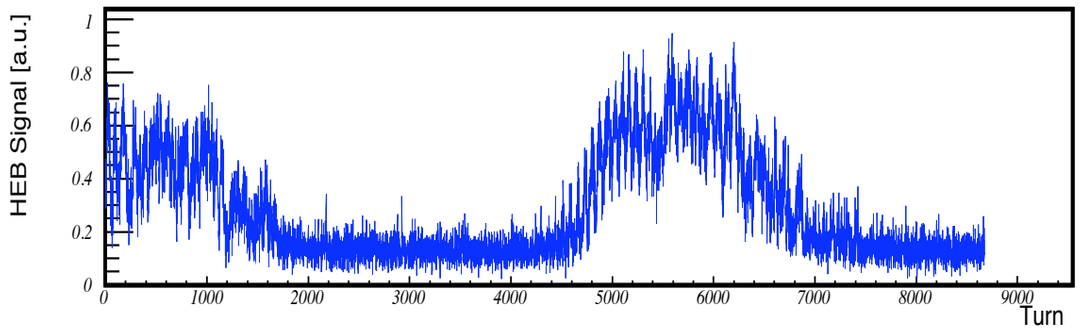


V. Judin

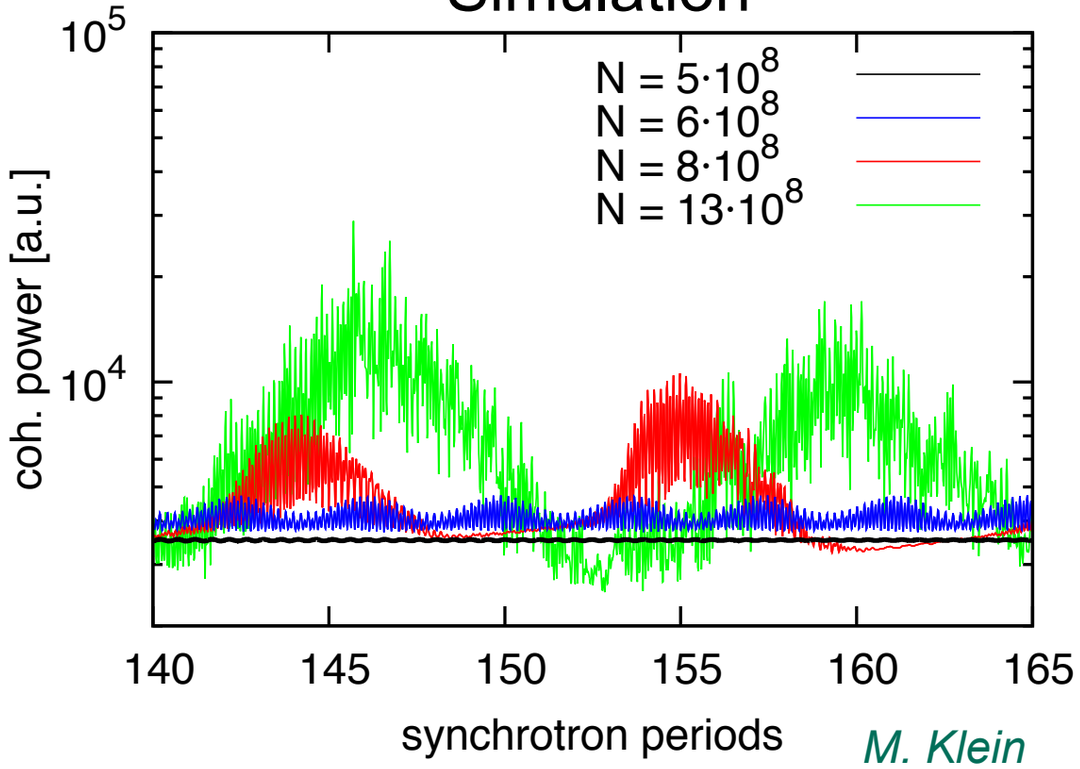
Current and Bursting Spectrum

Spectrogram for a decaying current (fs = 9 kHz)

Measurement

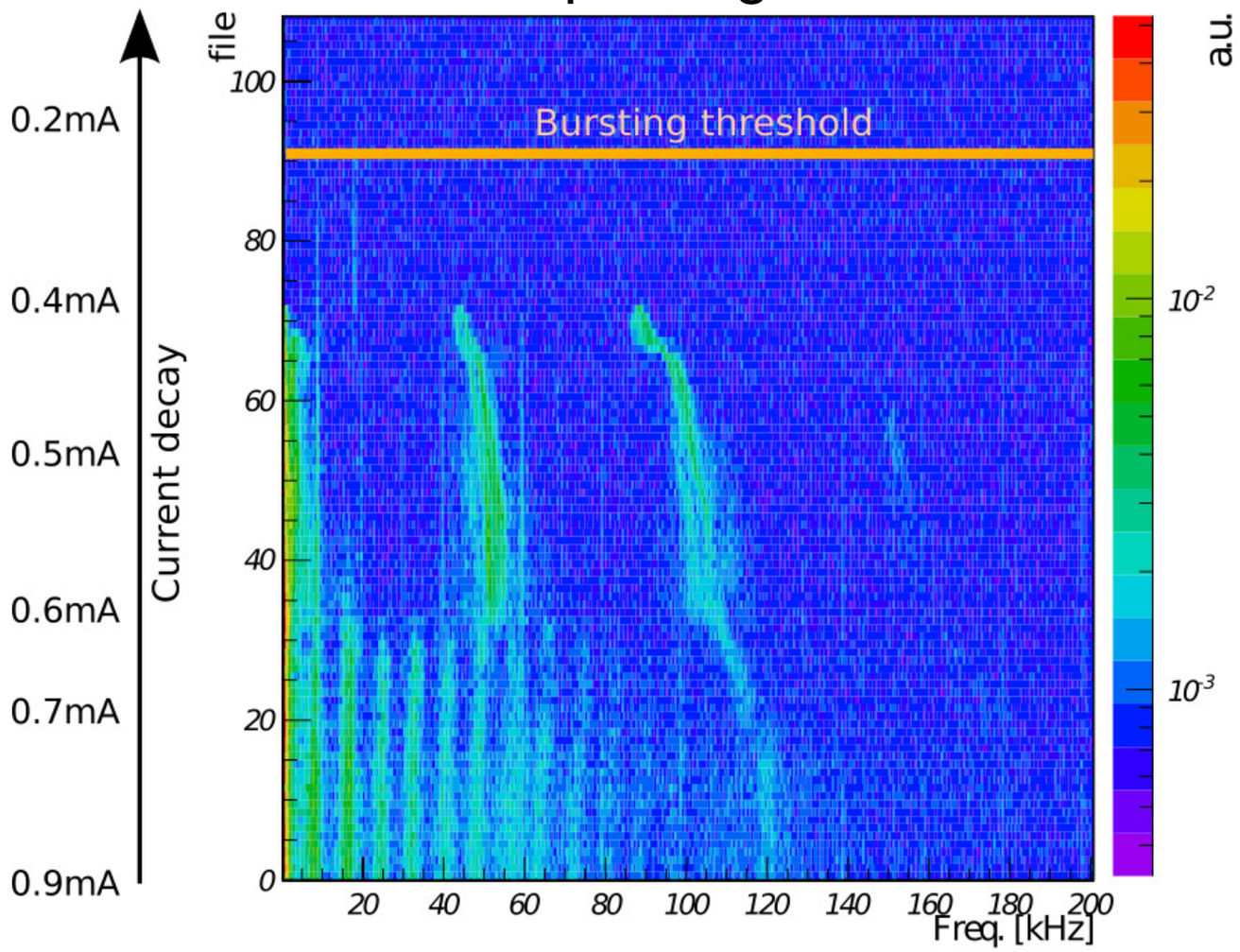


Simulation



M. Klein

Spectrogram



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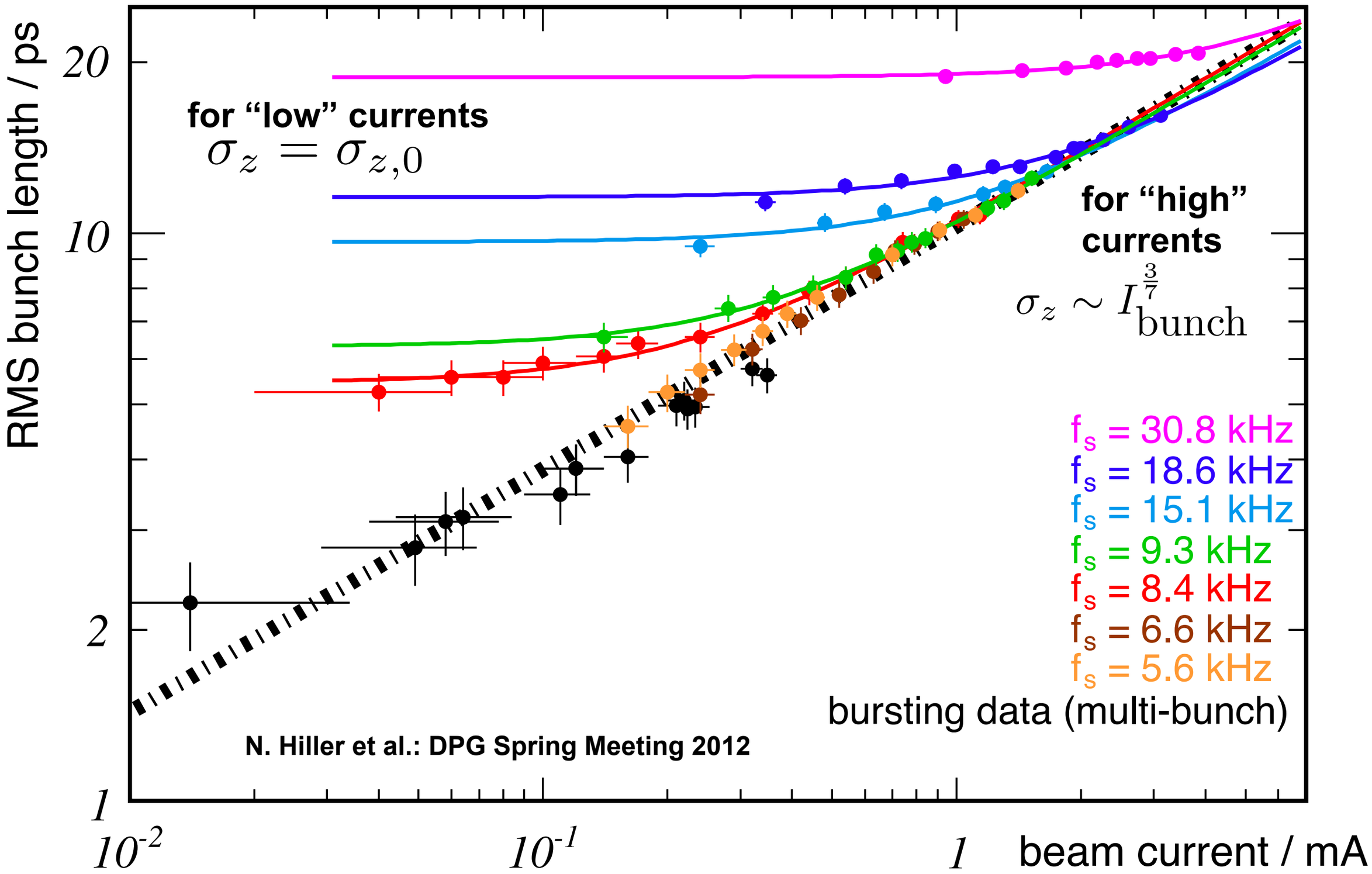
Bunch Lengthening for Different α_c-Settings



Electro Optical Bunch Length Measurement

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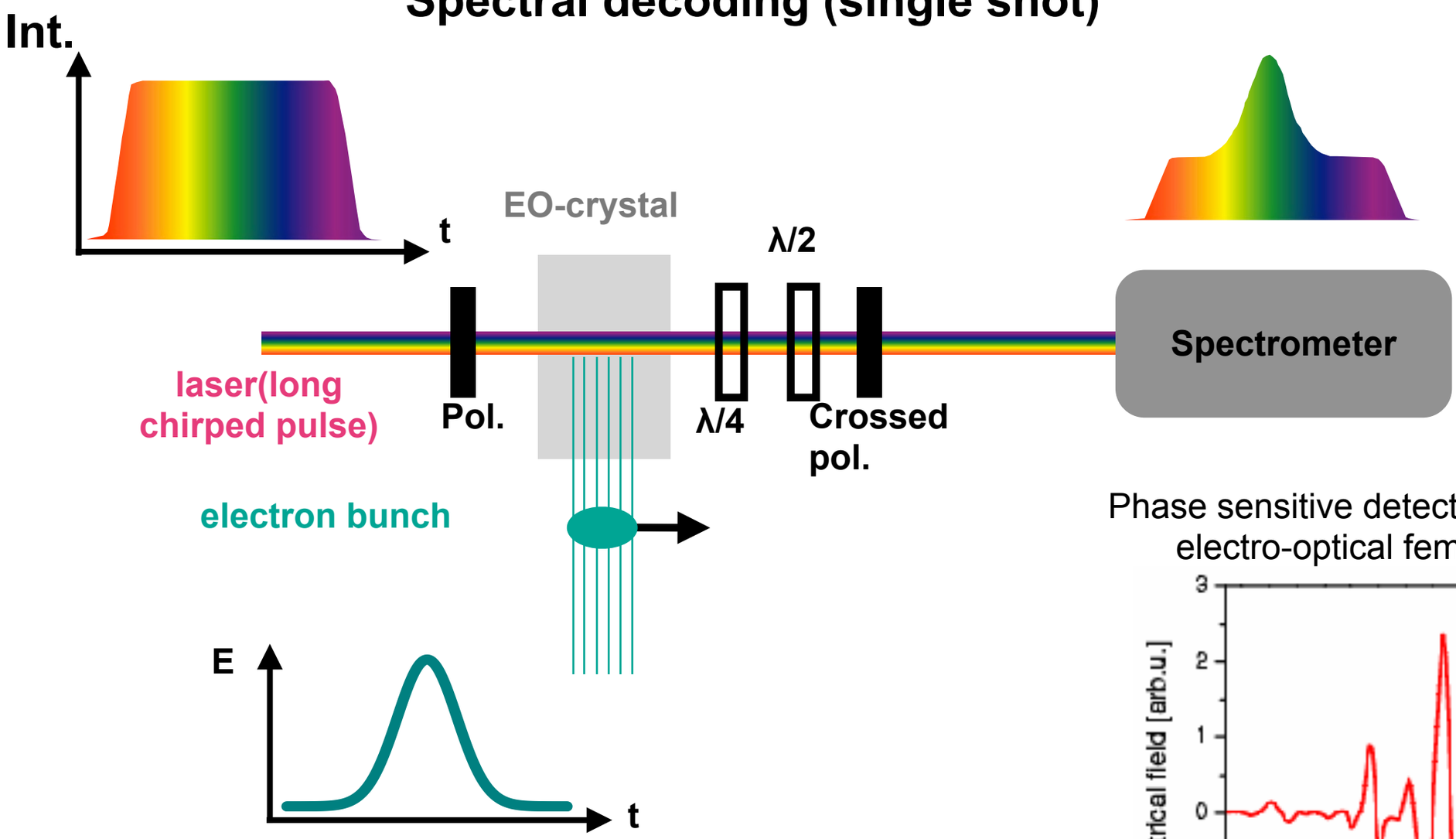
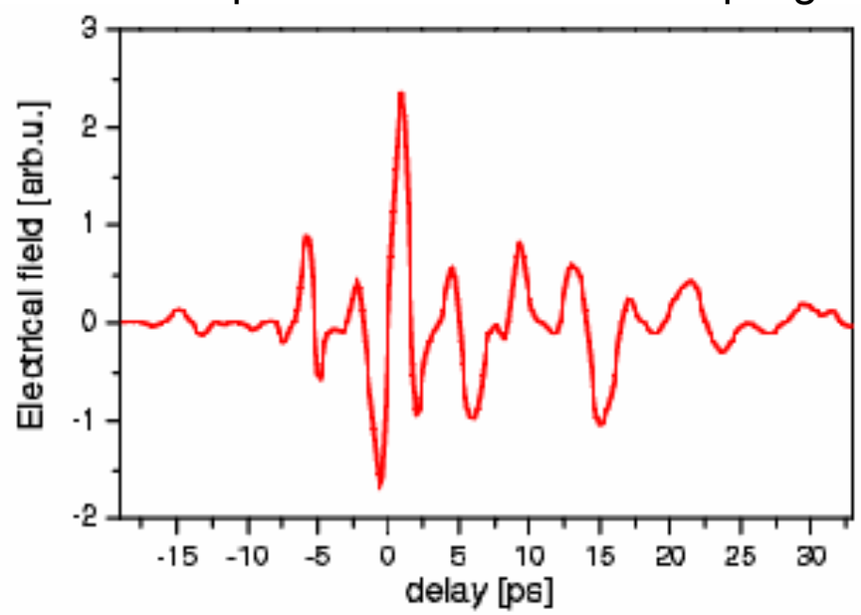
Spectral decoding (single shot)



Installation at ANKA ➡ Spring 2012

N. Hiller et al.: IPAC11, TUPC086

Phase sensitive detection of THz radiation with electro-optical femto-second sampling



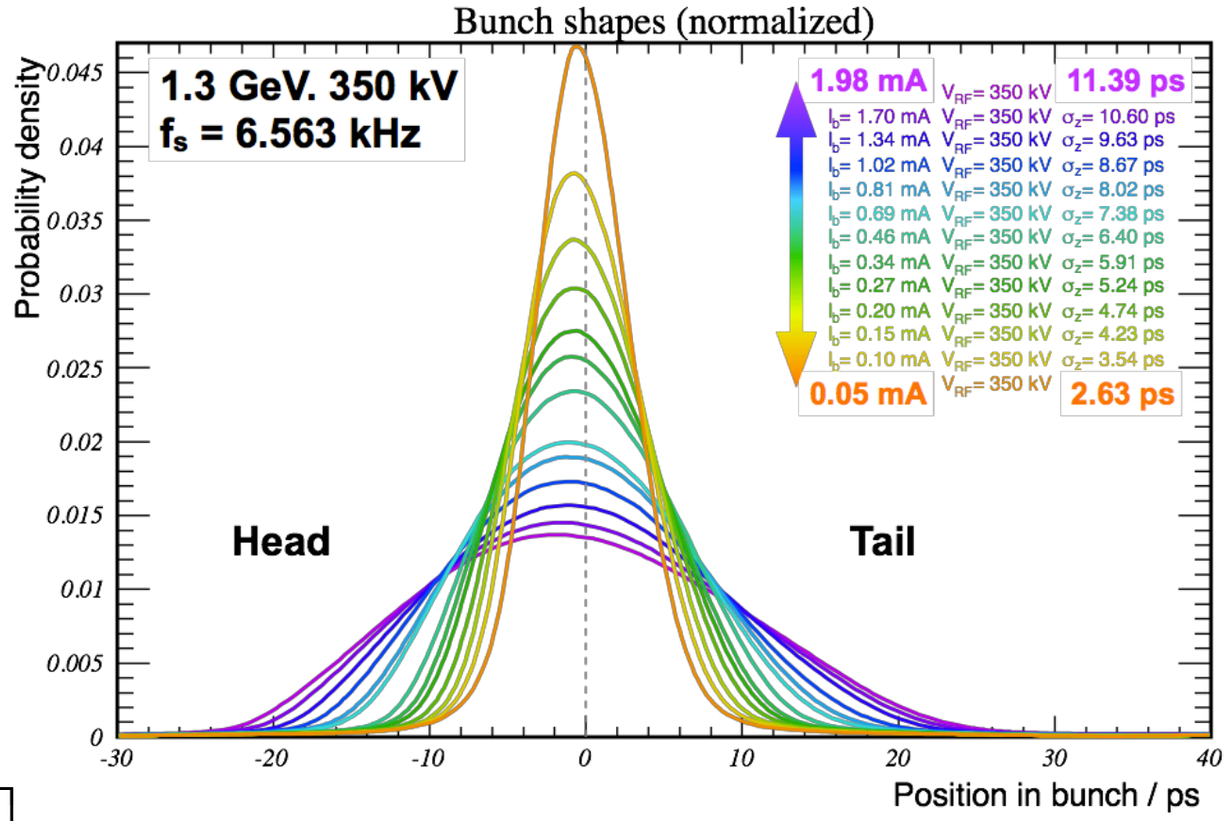
A. Plech et al.: PAC 2009, TU5RFP026

Impedance & CSR Power

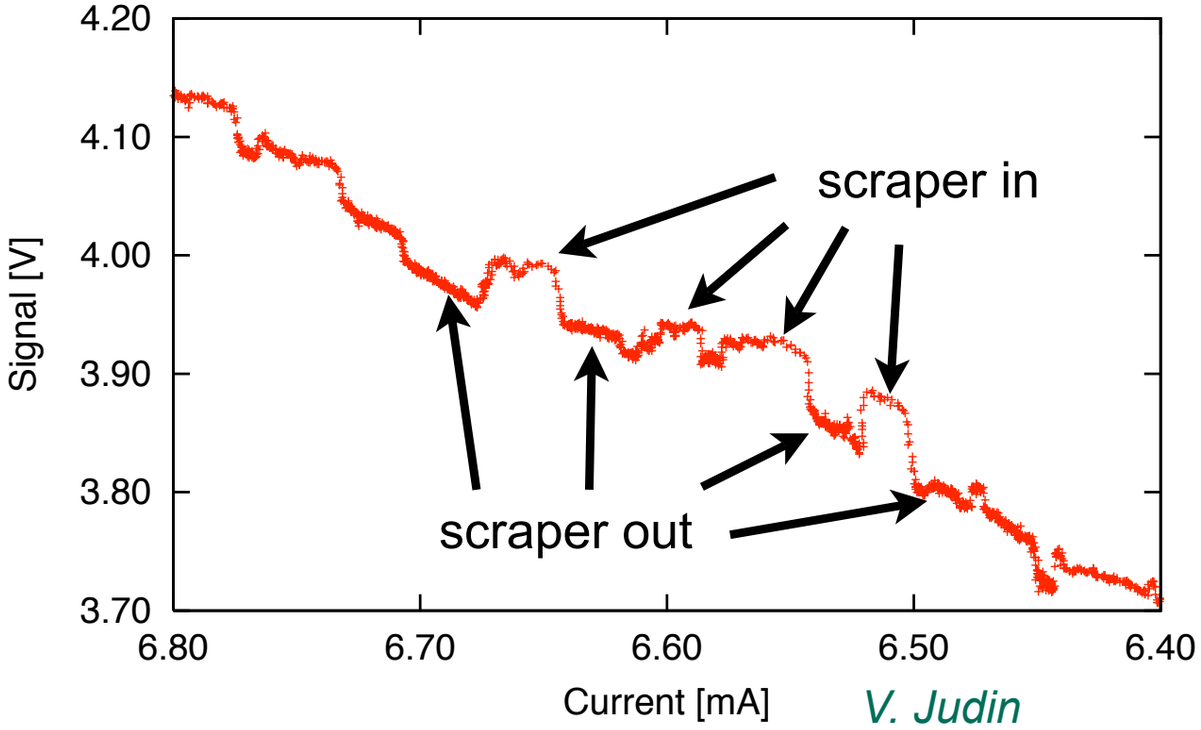
- The total power radiated by a bunch of N particles is described by

$$P_{total} = N\, P_{incoh}(1 + N\, f_\lambda)$$

  - ➜ change in form factor f_λ is seen on the emitted THz power



N. Hiller

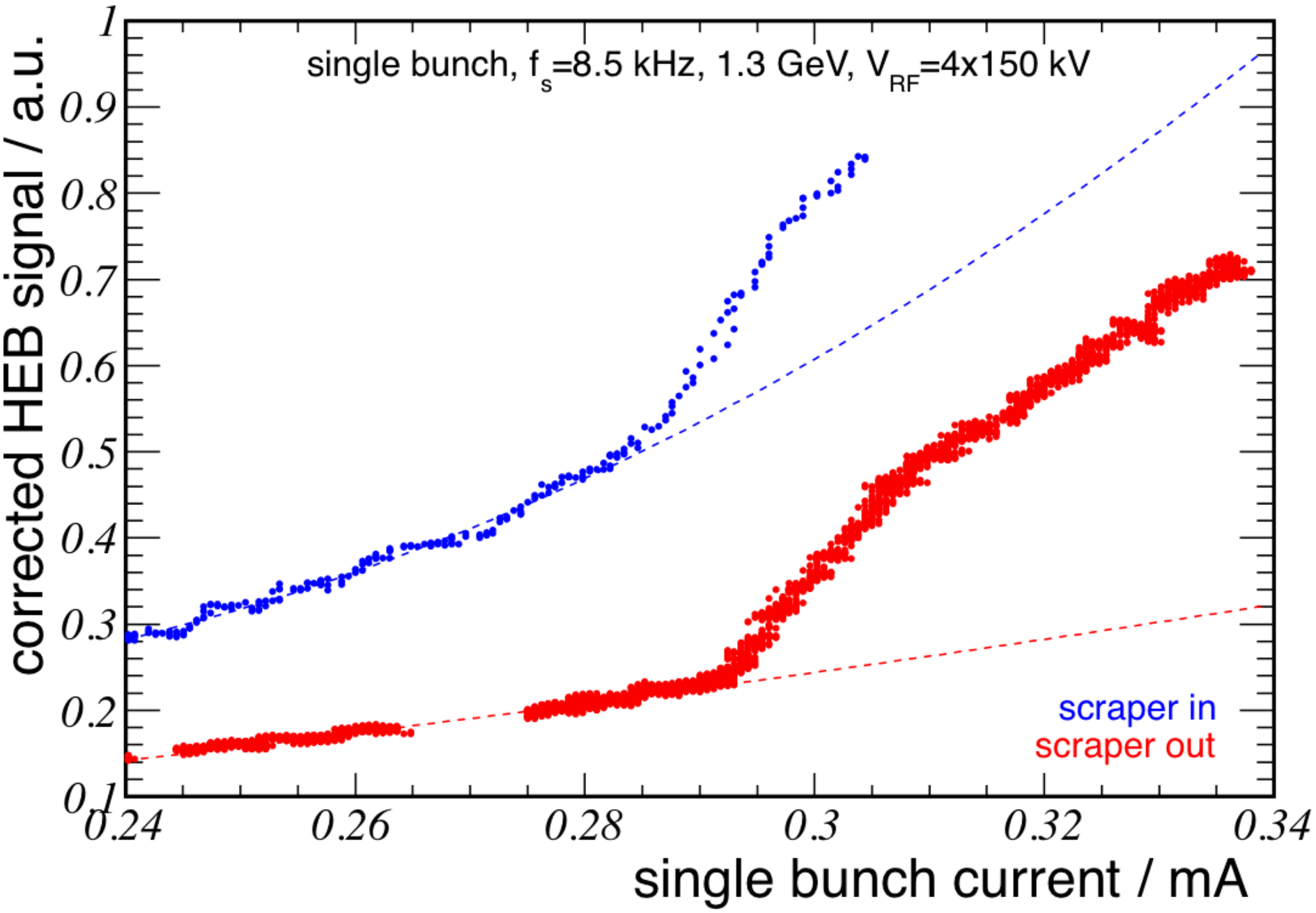


V. Judin

- Controlled change of the impendance by an asymmetric vertical scraper

  - ➜ clear influence on emitted CSR

Scraper Effects

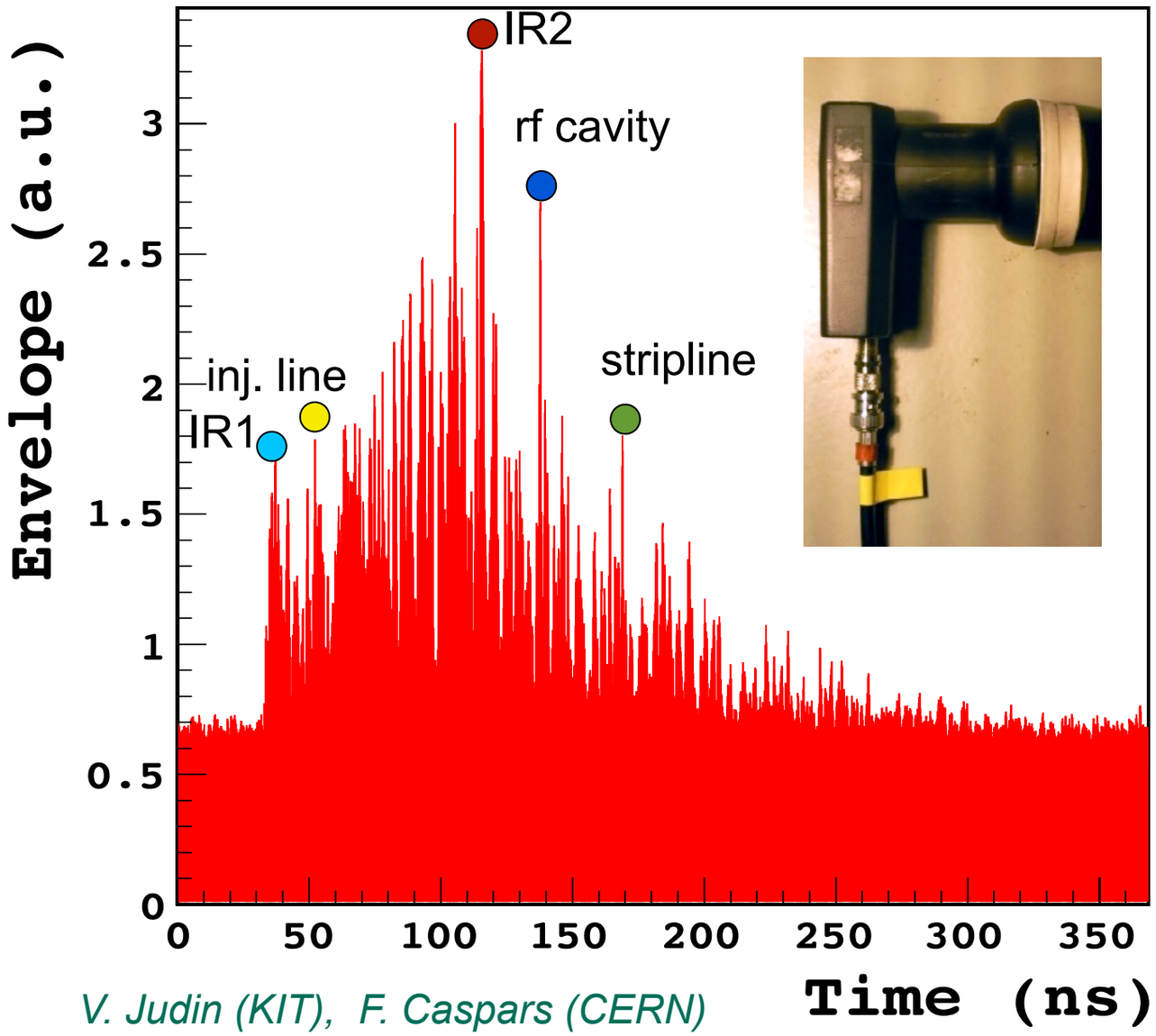


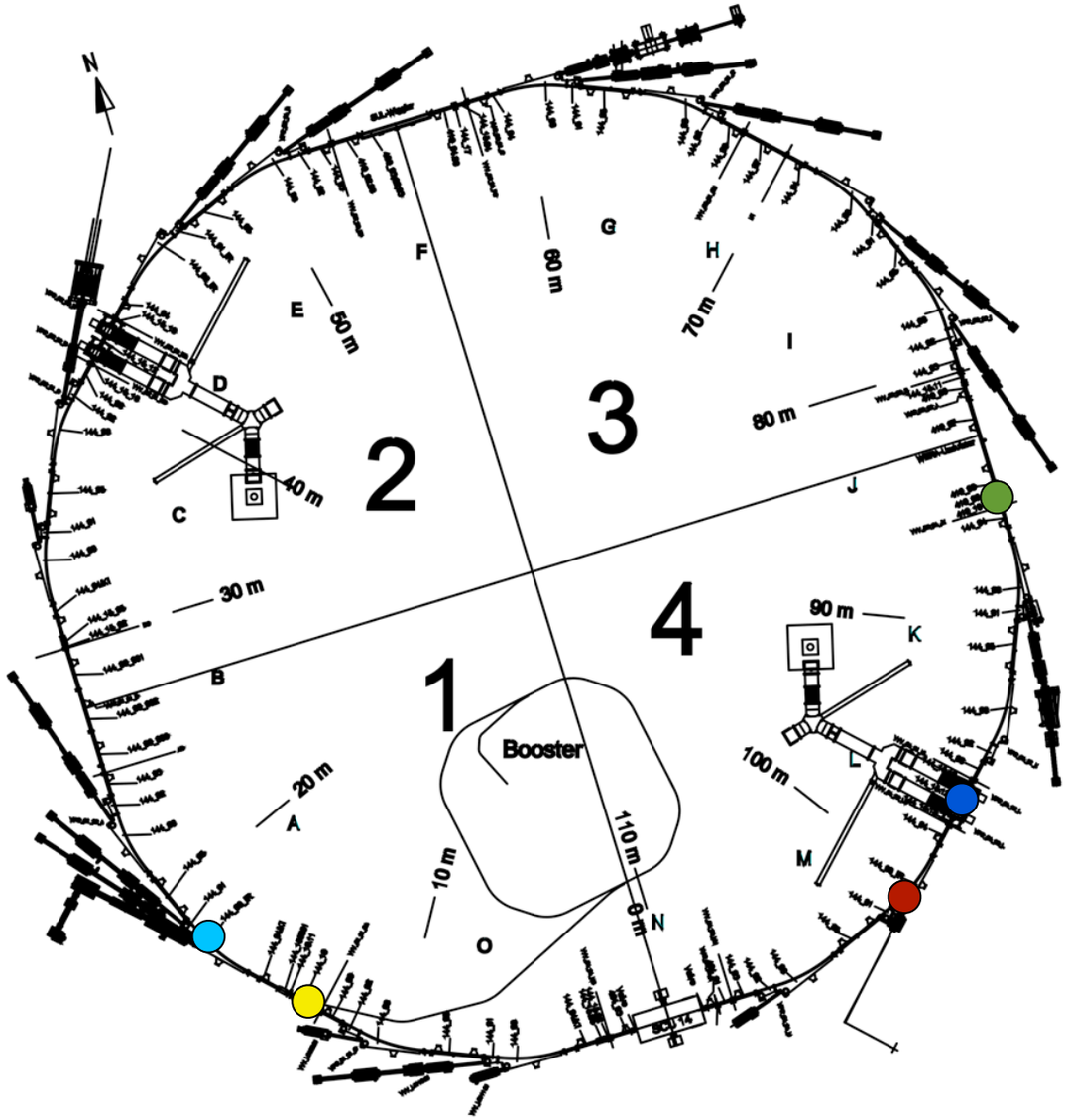
courtesy
A.-S. Mueller

➡ Geometrical impedance plays an important role for CSR!

Microwave Wake at ANKA

- Low cost Low Noise Block (LNB) device used as detector (~11 GHz)
- Signal shows spikes corresponding to ring structure

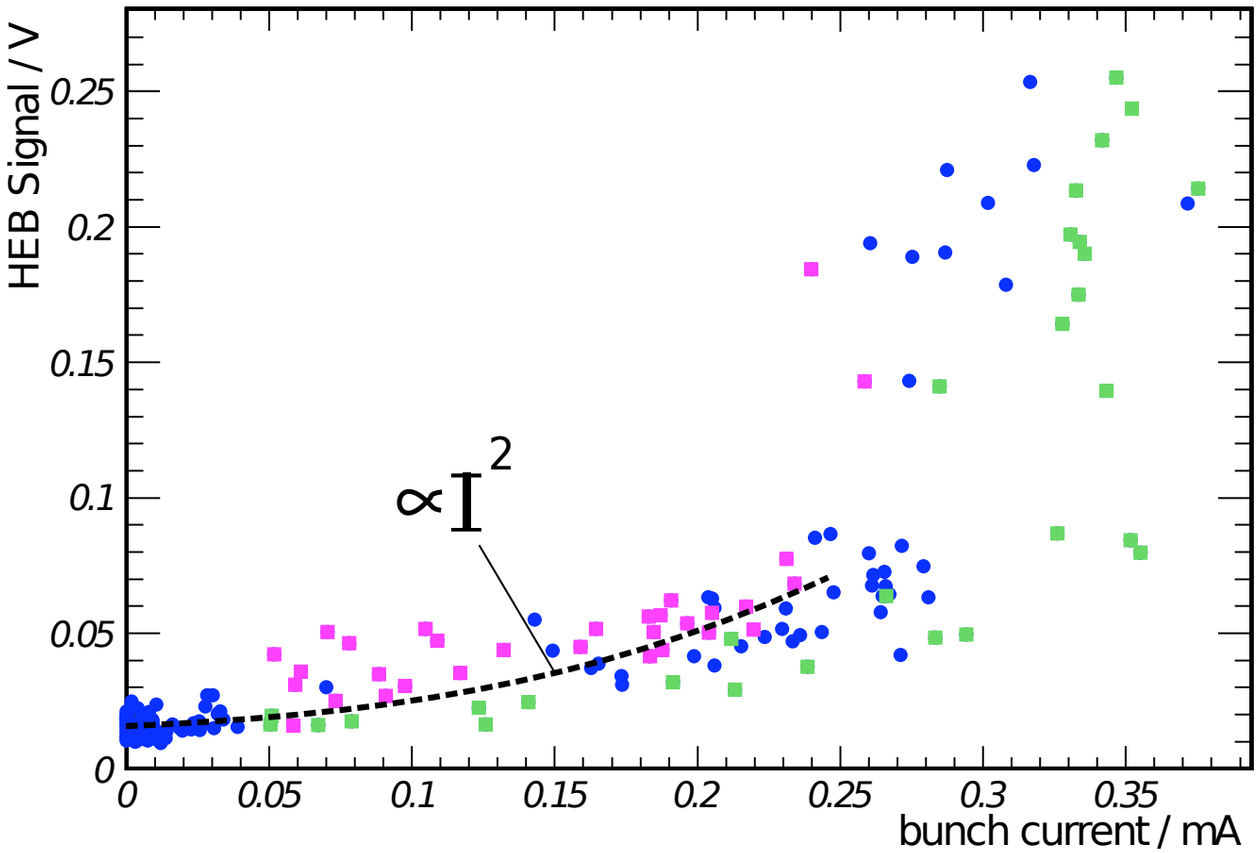


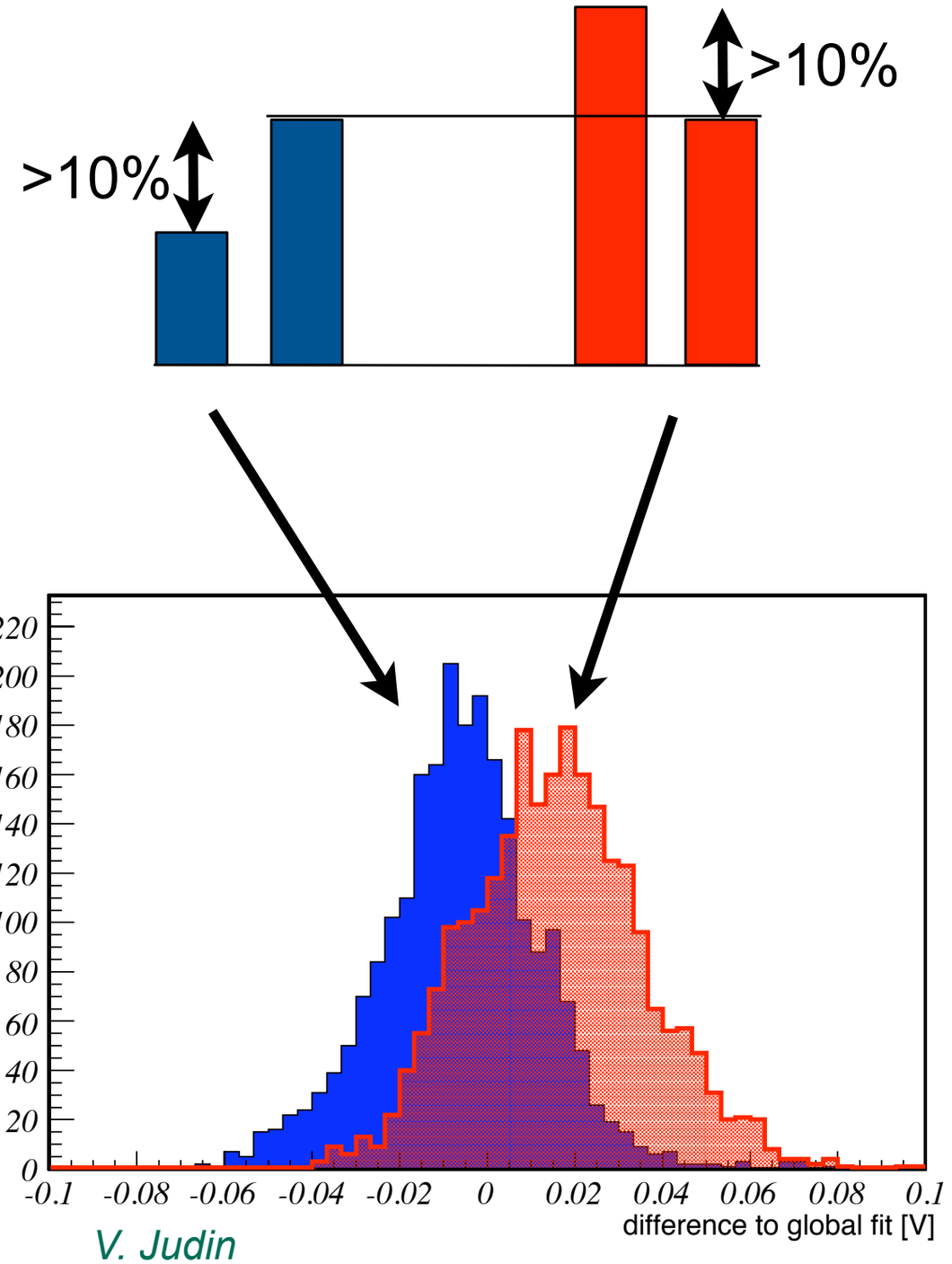


V. Judin (KIT), F. Caspars (CERN)

Single & Multi-Bunch Effects

- Fast THz detector (HEB) allows to study signals from individual bunches in a multi-bunch environment





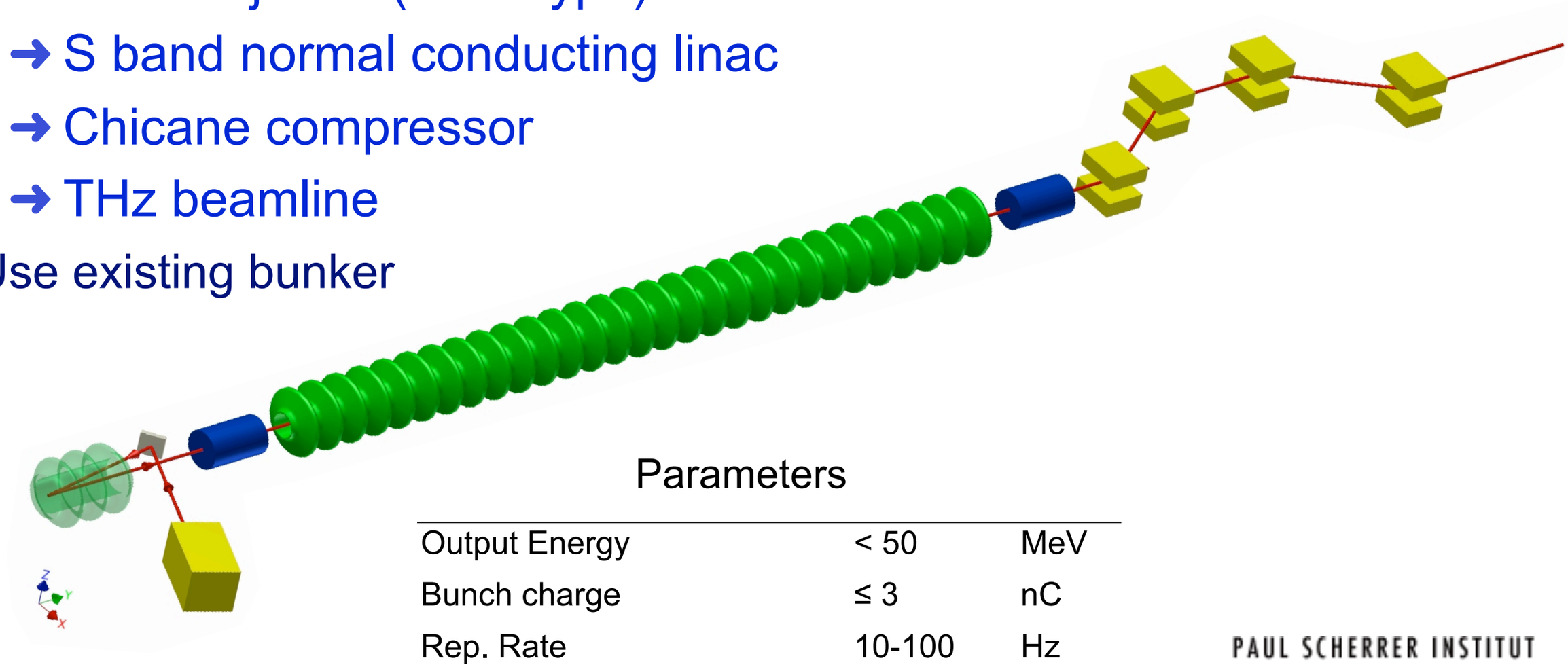
➜ THz emission depends on filling pattern

Next steps

- New HEB + fast readout electronics, developed by KIT, allows continuous bunch by bunch and turn by turn measurements in order to study bursting dynamics.

FLUTE: A Test Experiment

- Allow small scale tests of THz generation, compression, radiation transport and instrumentation, ...
- Outline:
  - ➜ Photo injector (CTF Type)
  - ➜ S band normal conducting linac
  - ➜ Chicane compressor
  - ➜ THz beamline
- Use existing bunker



Parameters

Output Energy	< 50	MeV
Bunch charge	≤ 3	nC
Rep. Rate	10-100	Hz
Used bandwith	0.05 - 5	THz

Summary

- Low Alpha operation for different energies and machine settings (fill pattern, RF) on a regular basis
- CSR emission is influenced by the beam current, fill pattern and geometrical impedance
- Ongoing projects to study bursting dynamics, bunch deformations, and micro bunching with novel high resolution detector systems

Thank you for your attention!

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P. Peier, V. Schlott

CERN, Geneva, Switzerland:
F. Caspers