Karlsruhe Institute of Technology

Investigating the Longitudinal Beam Dynamics of the ANKA Storage Ring using Coherent Synchrotron Radiation

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2nd DITANET Topical Workshop on Longitudinal Beam Profile Measurements

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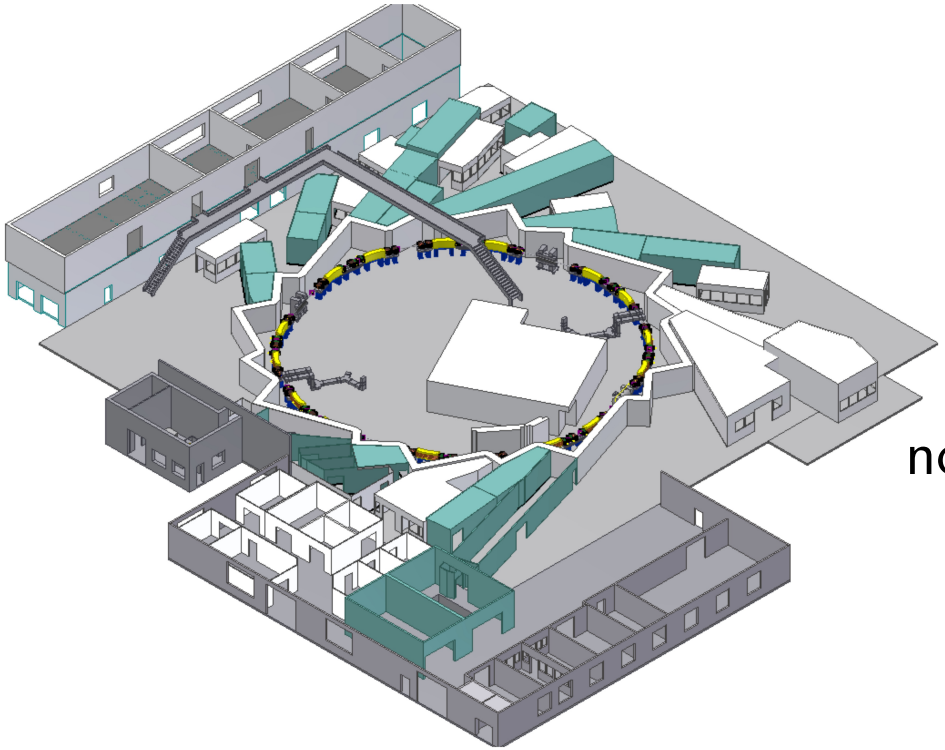
ANKA THZ GROUP

DITANET

Outline

ANKA Storage Ring



(src.: ANKA archive)

Key parameters:

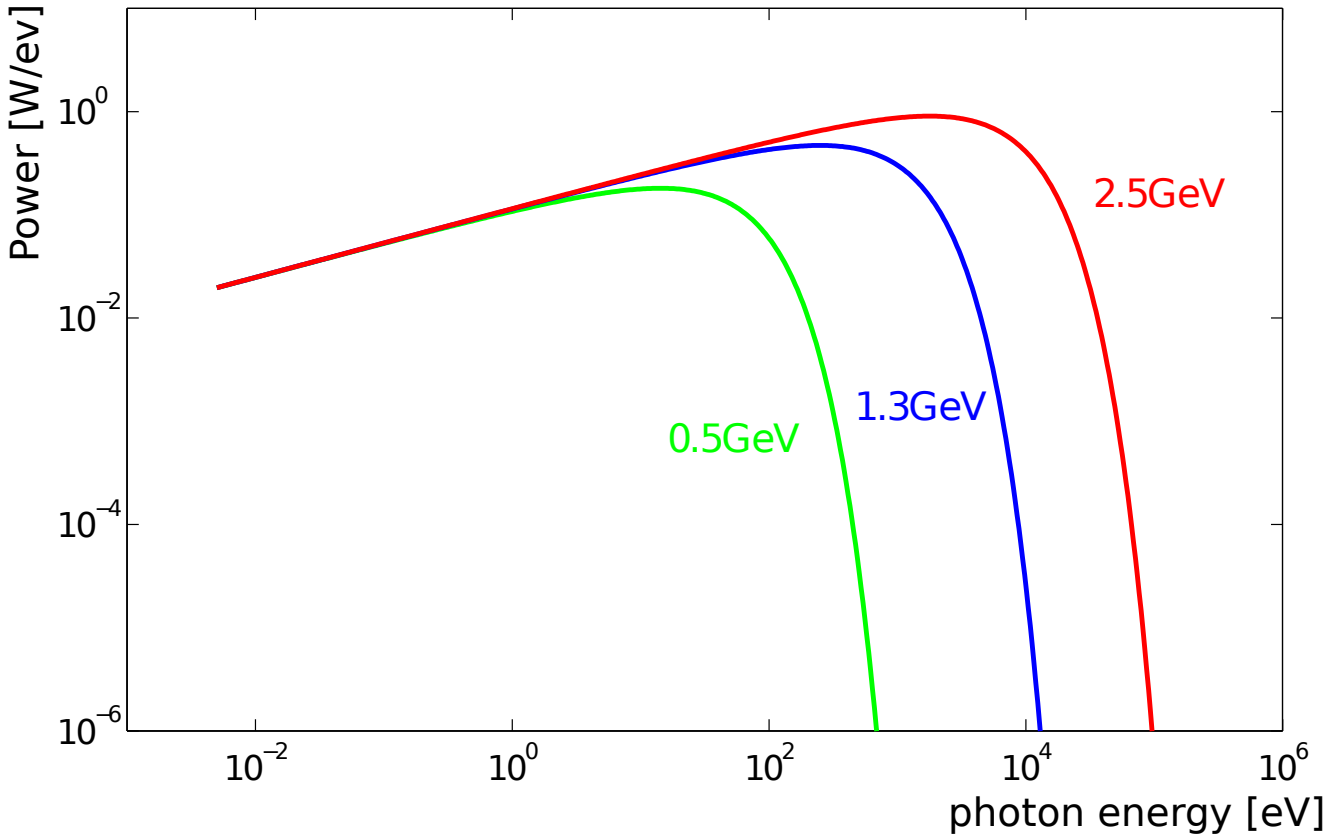
- circumference: 110.4 Meter
- RF-frequency: 500 MHz
- revolution time: $\approx$ 368 ns

normal operation mode:

- beam energy 2.5 GeV
- multibunch mode (up to 150 mA)
- bunch length $>$ 30 ps

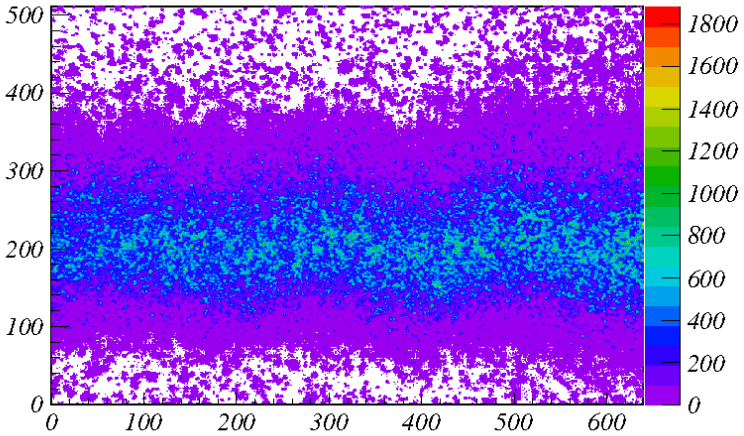
Synchrotron radiation

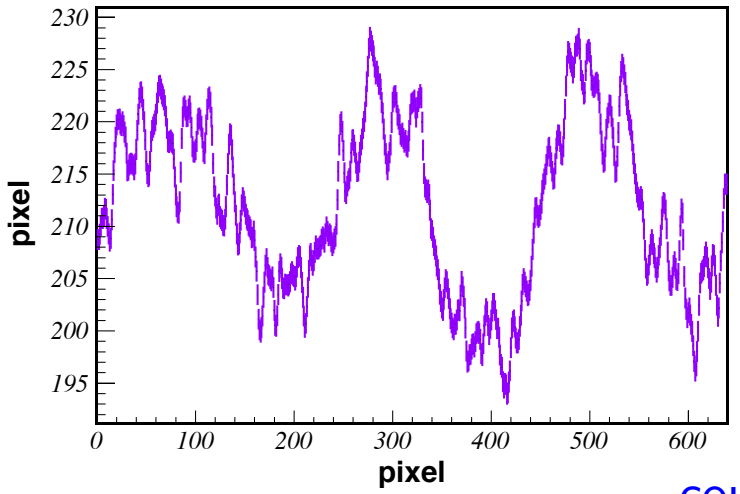
Incoherent spectra for different energies:
(constant current I and radius R)



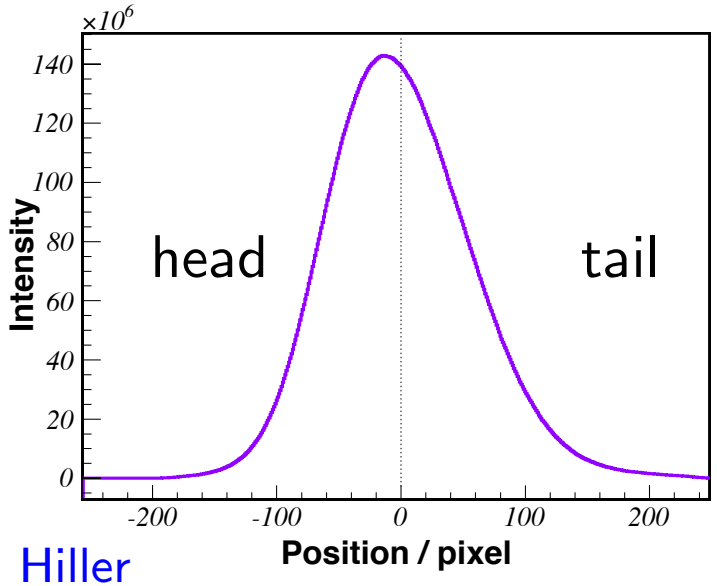
Streak camera measurements

Bunch shape and bunch length determination





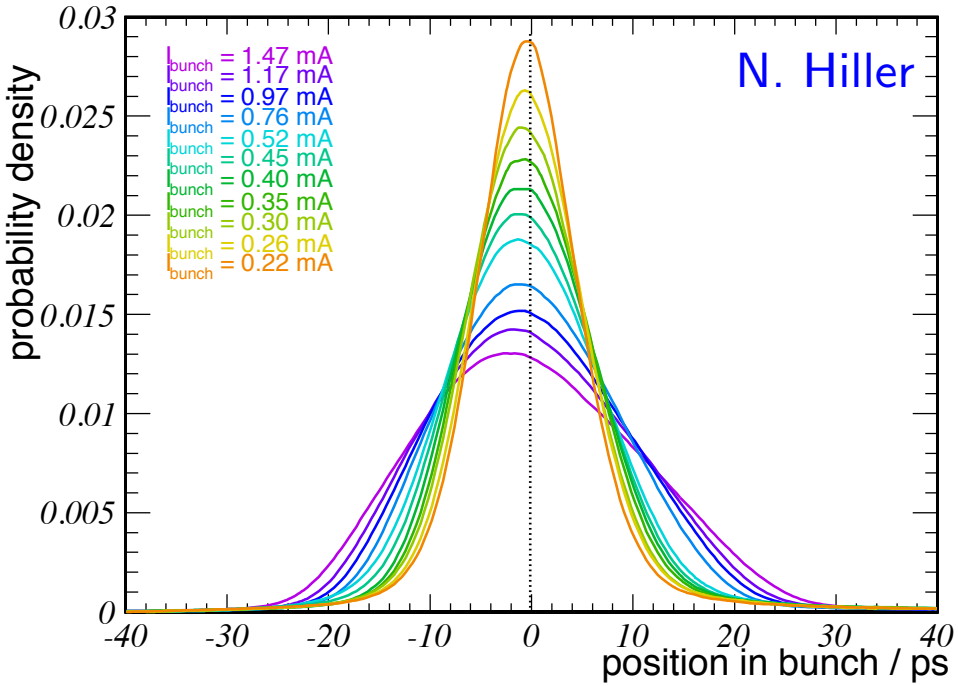
- background substraction is proceed for every image separately
- the image is cut in 1 pixel wide vertical slices
- determination of the centre of mass for each of those slices

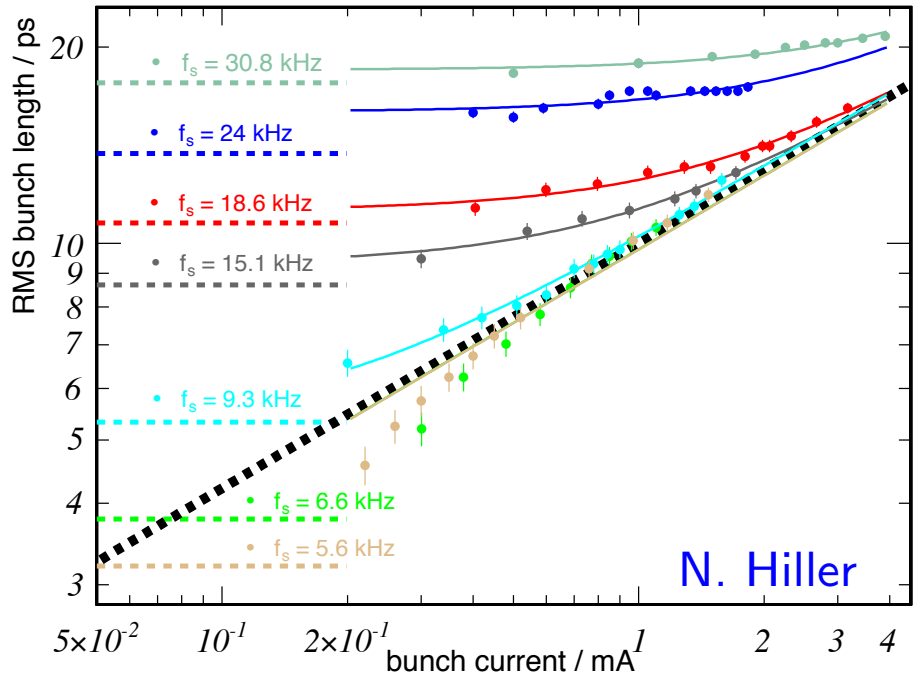


courtesy N. Hiller

Streak camera measurements

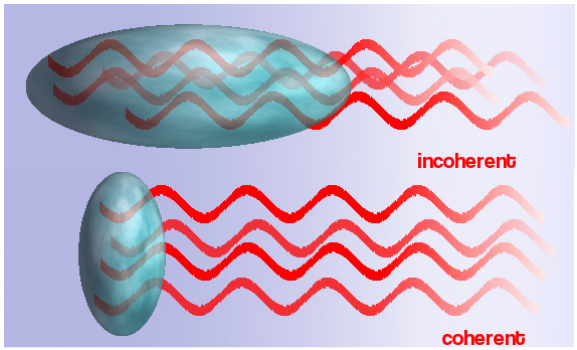
Bunch shape and bunch length determination

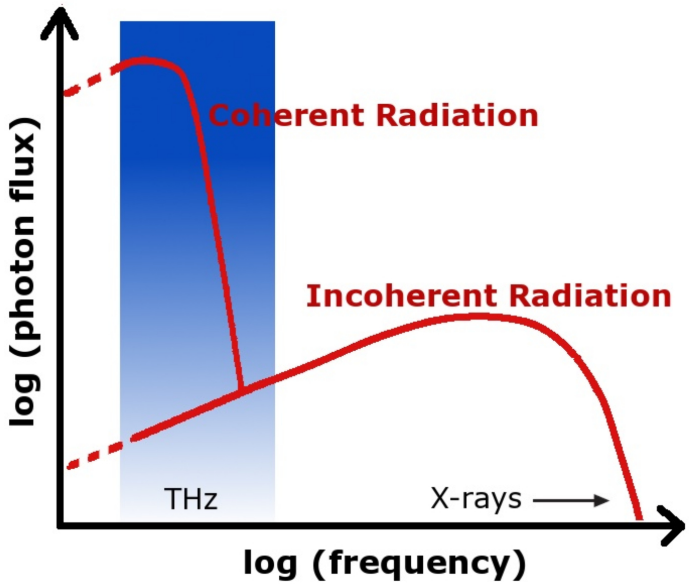




- normalised bunch profiles shows deformation due to bunch current
- the RMS bunch lengths is also variing with current
- mapping of the bunch length at different sqeeze states was performed

Coherent Synchrotron Radiation





(src.: ANKA-archive)

- $P_n = N_e \cdot P_1(1 + N_e g_\lambda)$
- g_λ is a form factor and define a spectral characteristics
- typically $N_e = 10^9$
  Enormous increase in power in comparison to incoherent emission
- Intensity $\propto I^2_{\mathrm{bunch}}$
- very short bunch is needed

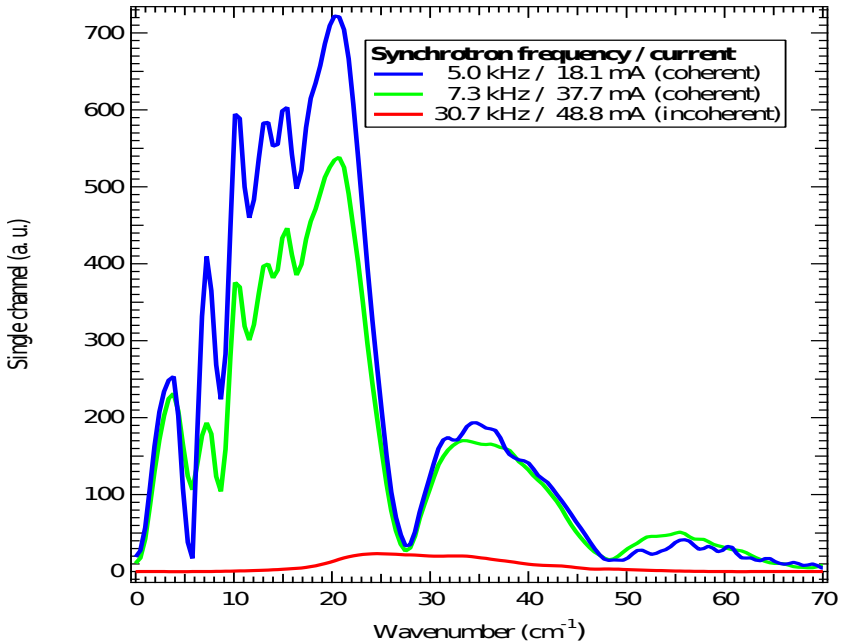
Low-α-mode at ANKA

- CSR condition $\frac{2\pi\sigma_s}{\sqrt{lnN}} < \lambda < 2h\sqrt{\frac{h}{R}}$
- beam energy: 1.3 GeV
- bunch length down to sub-ps

ANKA provides regularly:

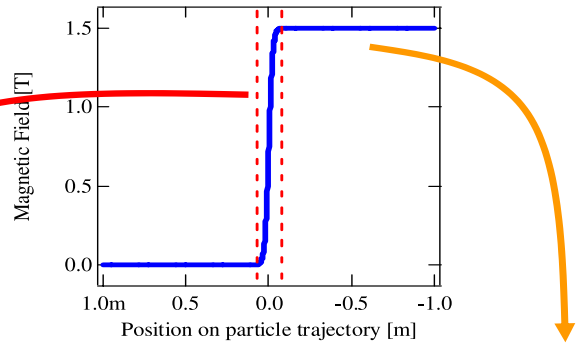
- beam time in low-α-mode
- broadband CSR radiation
- spectral range: up to 1.5 THz
- high brilliance

- Low-α-**squeeze**: change accelerator optics in small steps
- following the pioneering work of e.g. BESSY II

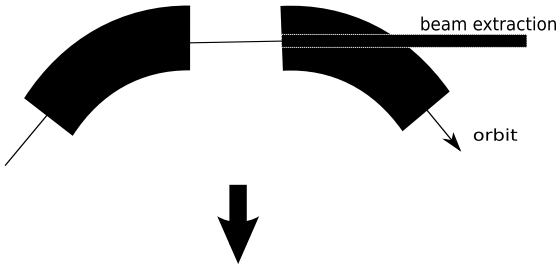


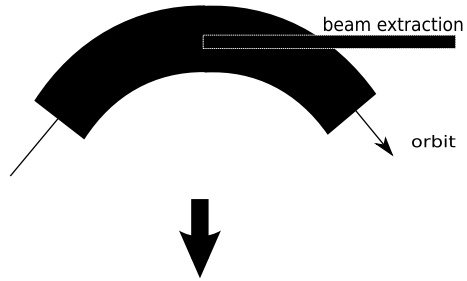
THz source at ANKA

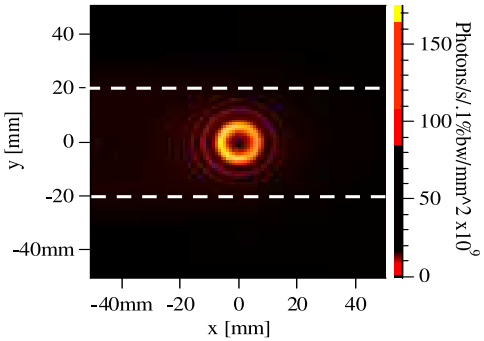
Spatial distribution from the edge at 3m from the source

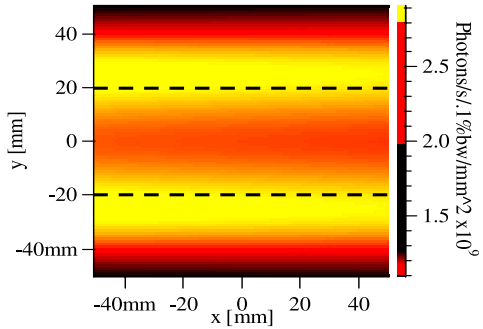


Spatial distribution from the dipole at 3m from the source







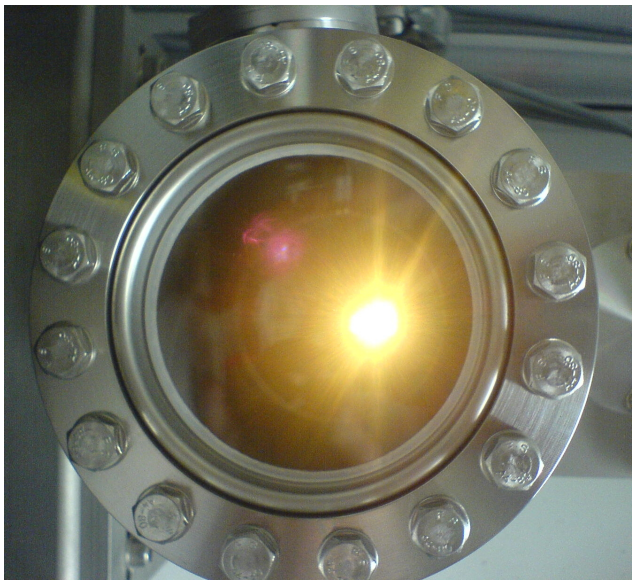


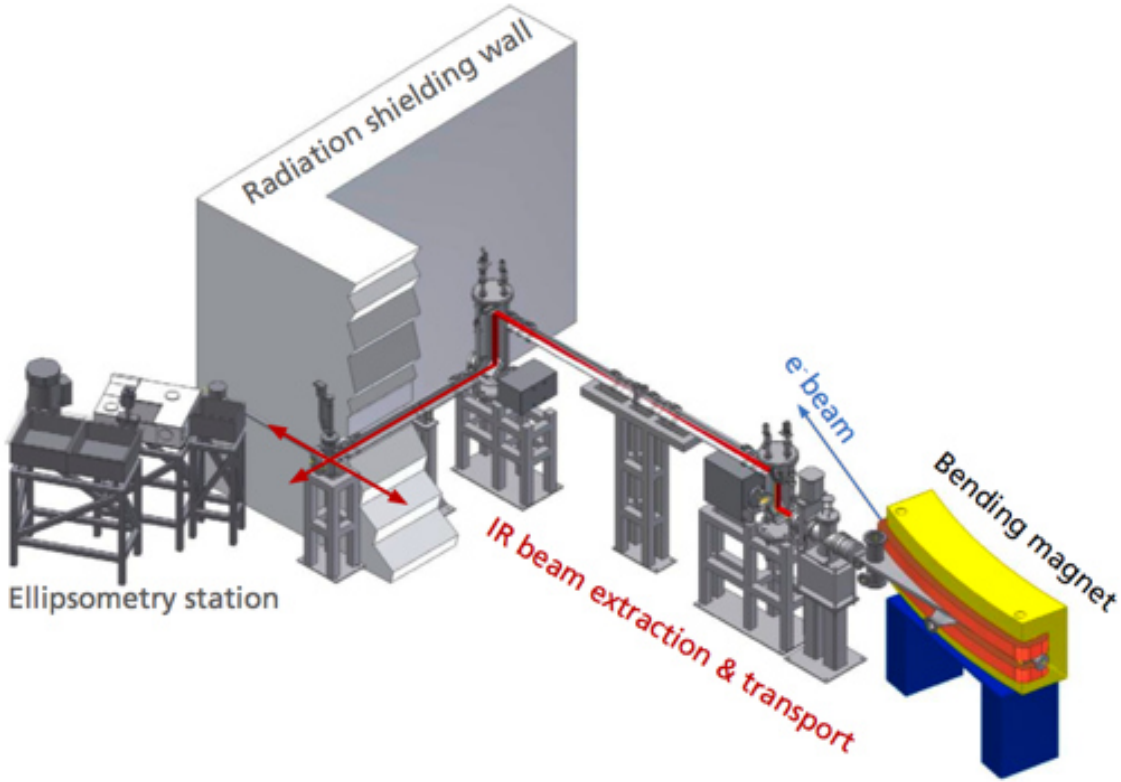
λ = 100 μ m

(src.: WG Y.-L. Mathis)

THz Port at ANKA

IR1 - Diagnostic port





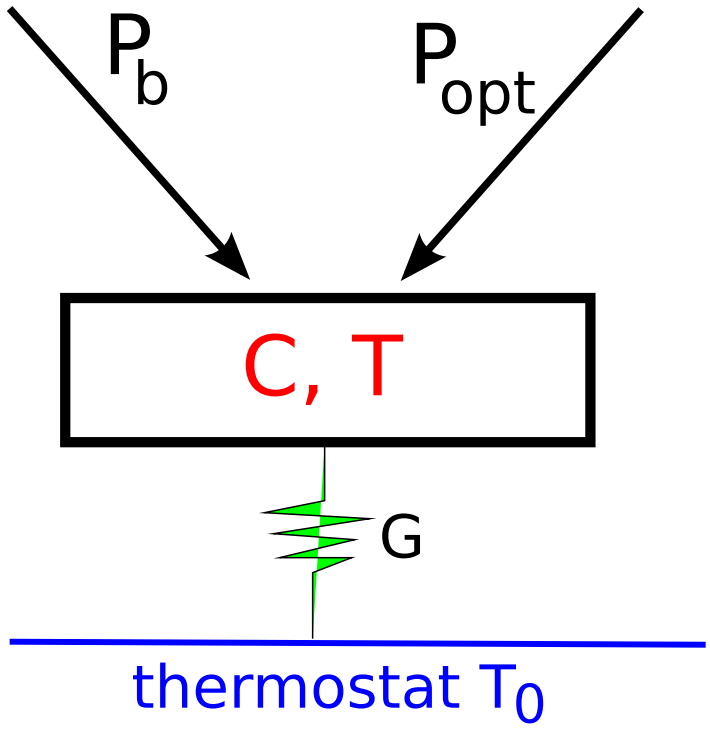
THz detectors

Bolometer general:

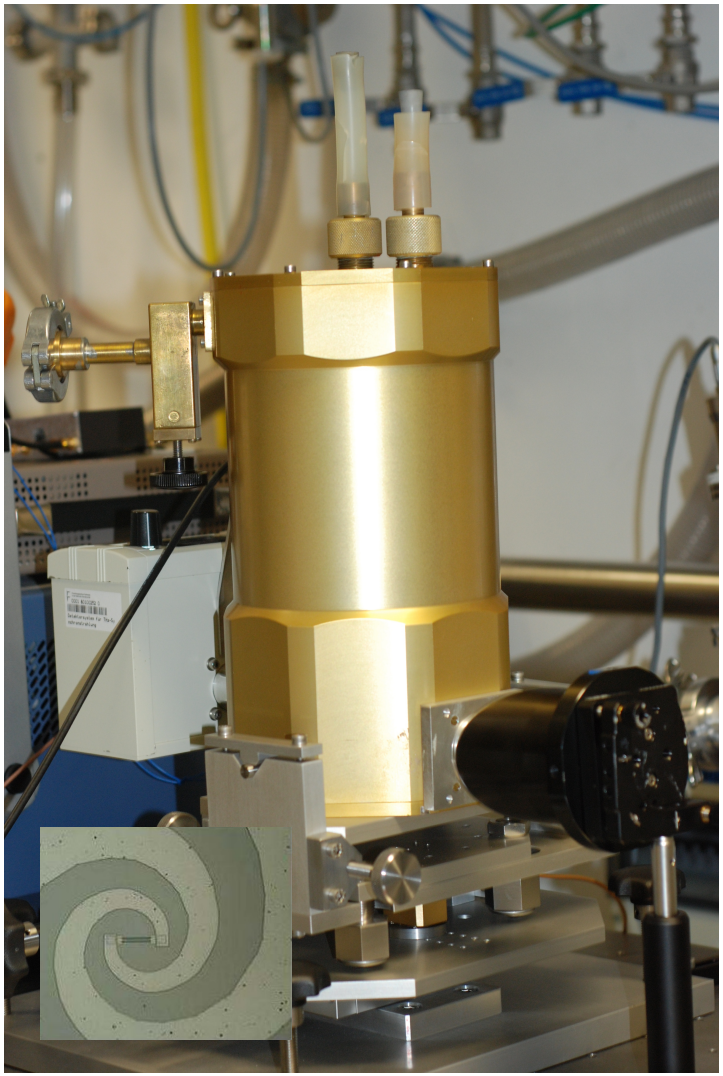
- bolometer is a thermal detector
- $\frac{dR}{dT}$ detection
- fundamental determinants:

  response time $\tau = \frac{C}{G}$

  responsivity $S \propto 1/G$
- detector matter: e.g. superconductor



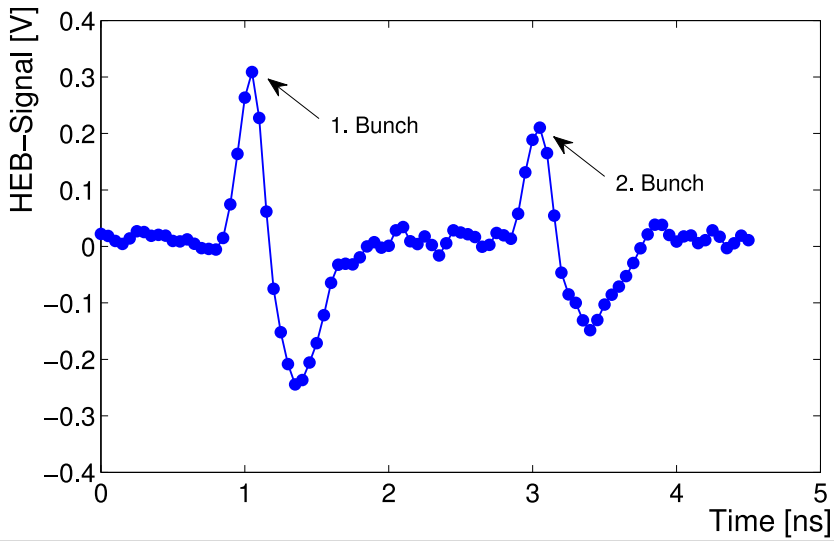
Hot Electron Bolometer (HEB)



(src.: THz-group archive)

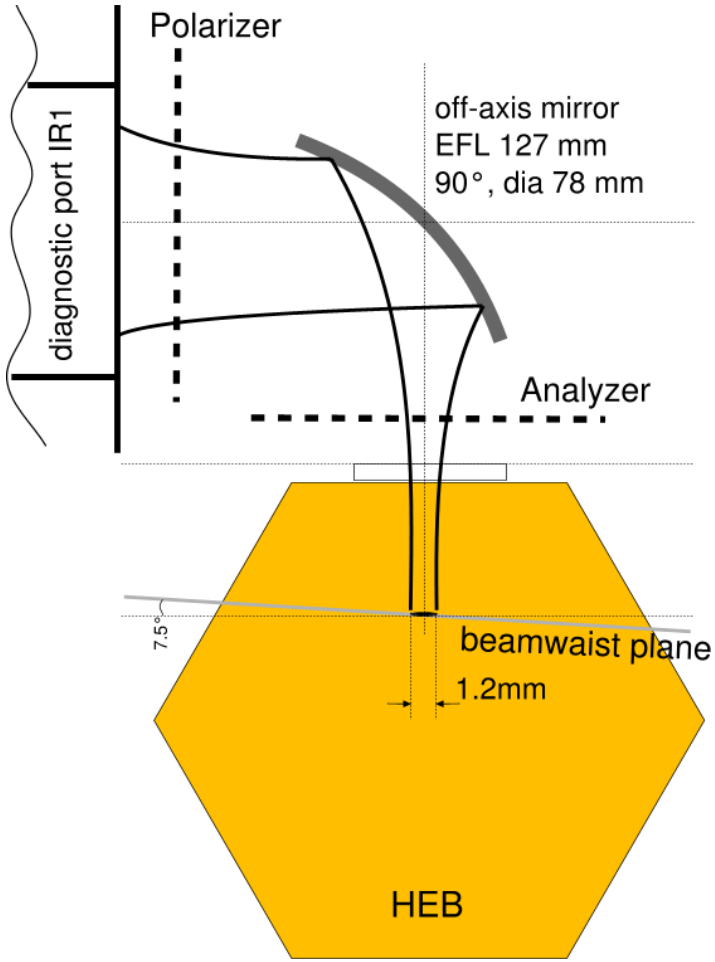
The HEB detector system

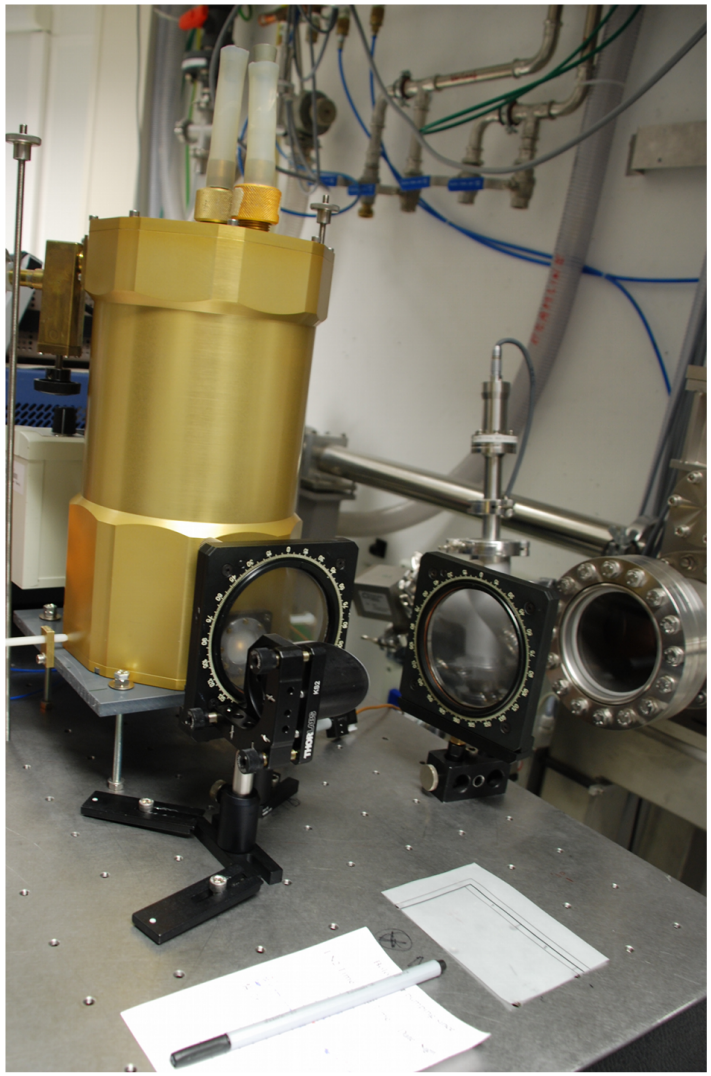
- joint development of IMS (Karlsruhe) & DLR (Berlin)
- SC niobium nitride detector
- spectral range 150 GHz - 3 THz
- response time $< 160\,\mathrm{ps}$



Experimental setup - beam path

Setup with HEB-Bolometer:

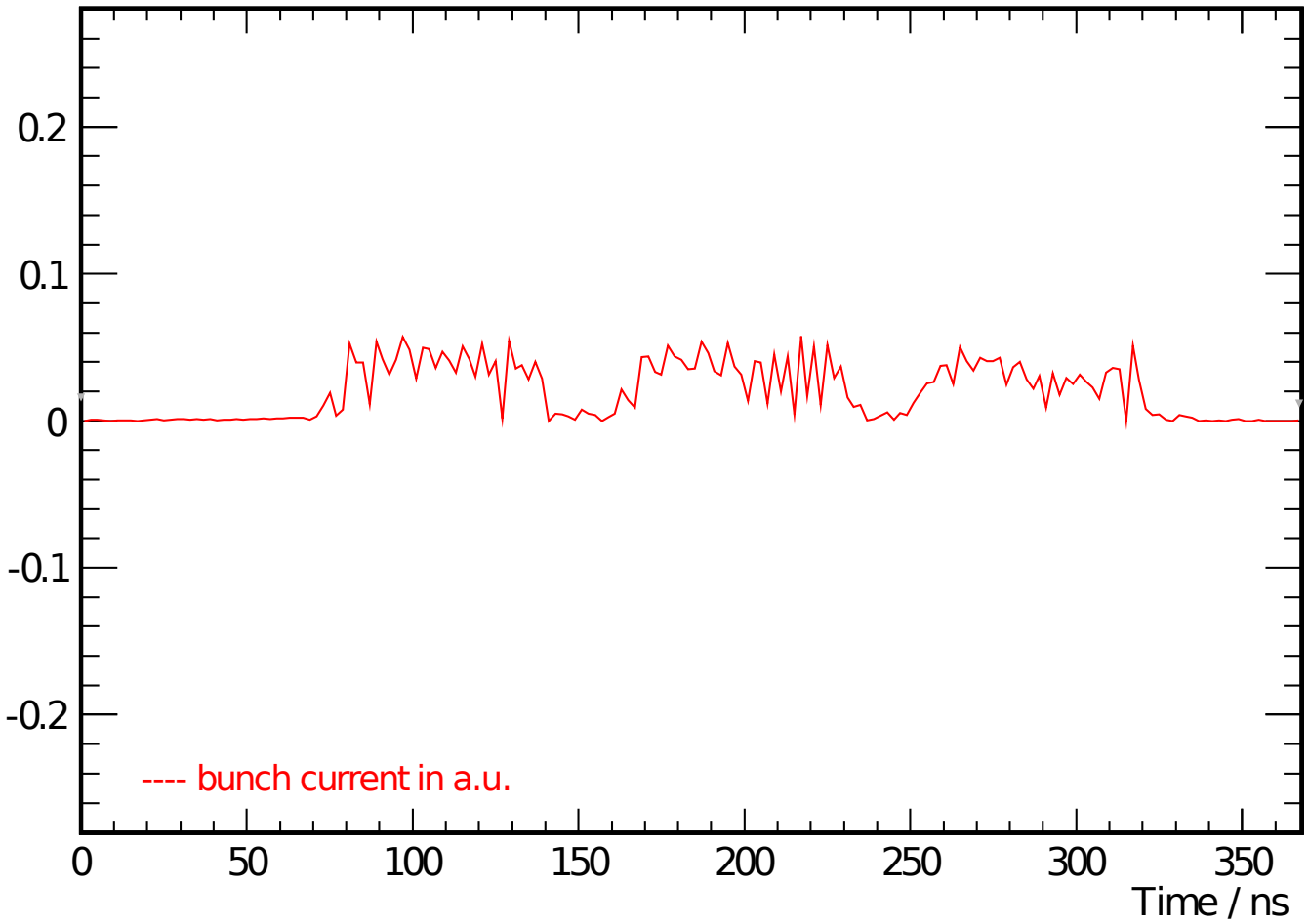




Measurements at ANKA using HEB

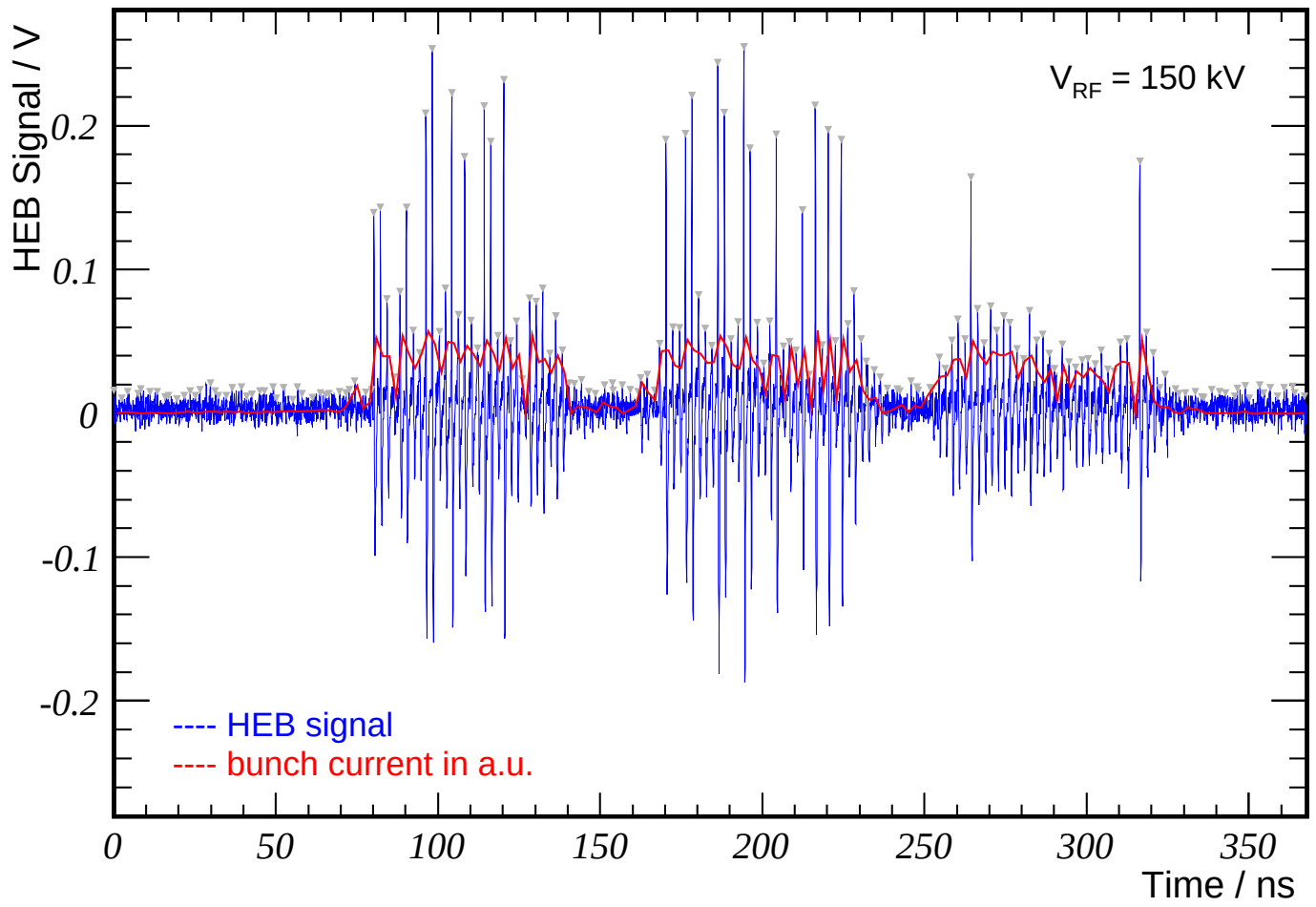
Karlsruhe Institute of Technology

Charge distribution over one revolution:



Measurements at ANKA using HEB

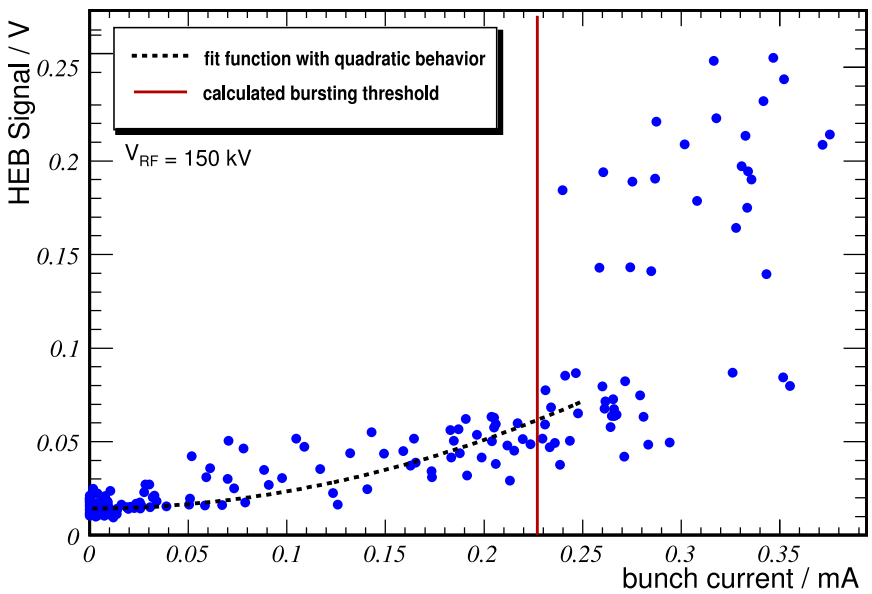
HEB raw data and charge distribution over one revolution:



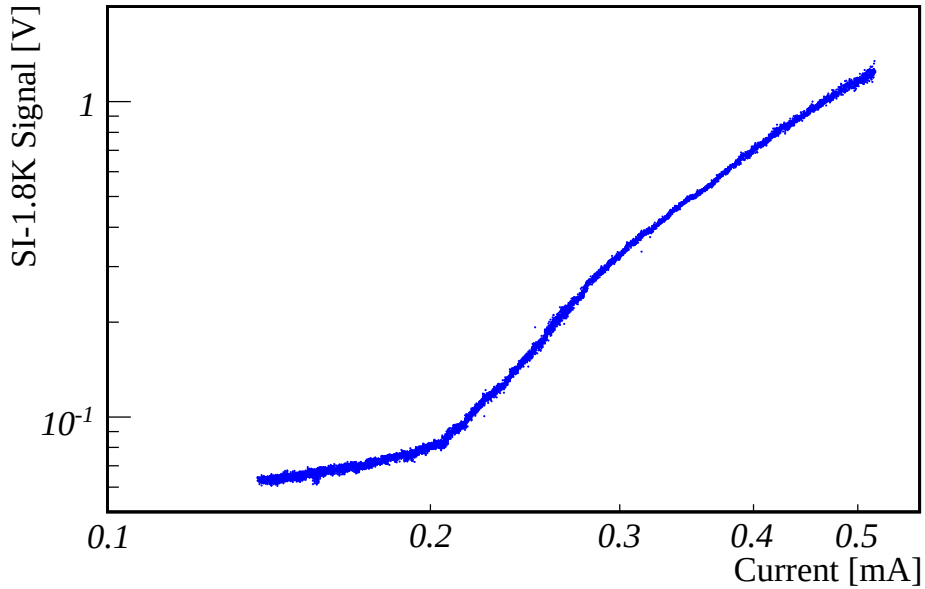
Bursting threshold measurement

One-shot measurement with the HEB

- HEB multibunch measurement
- Si-1.8K-bolometer measurement



duration: **milliseconds**

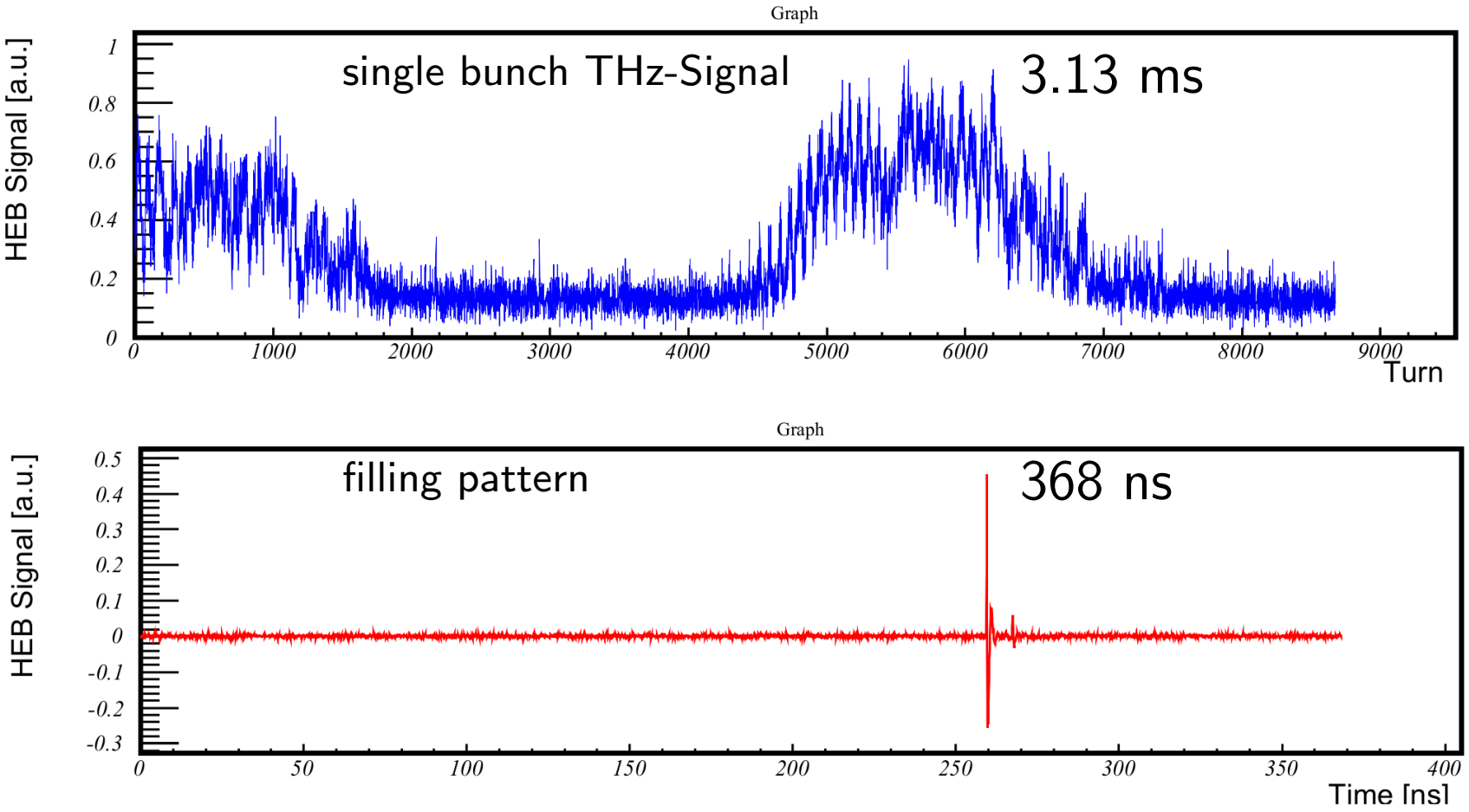


duration: **minutes - hours**

HEB enables high speed detection of bursting threshold

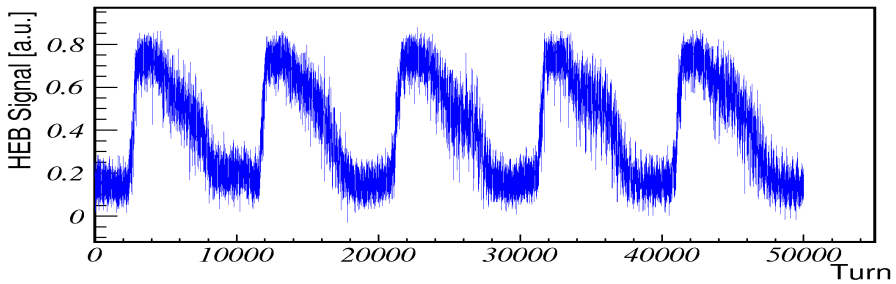
Observation of bursting

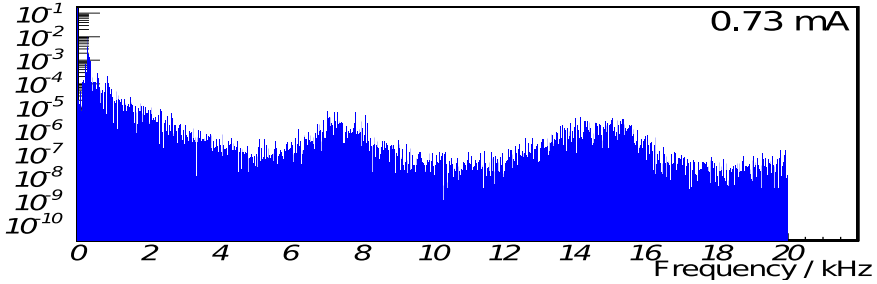
Bursts of radiation in multi turn measurements

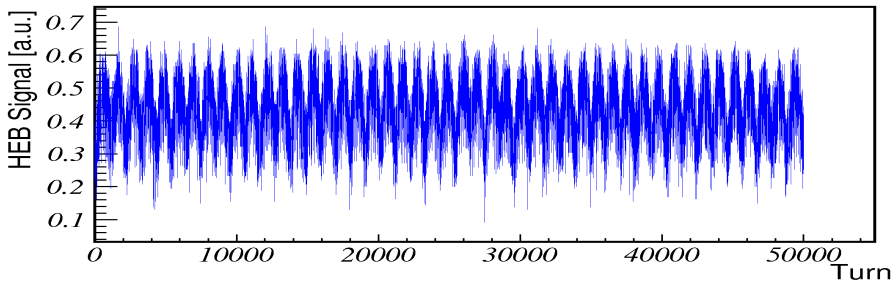


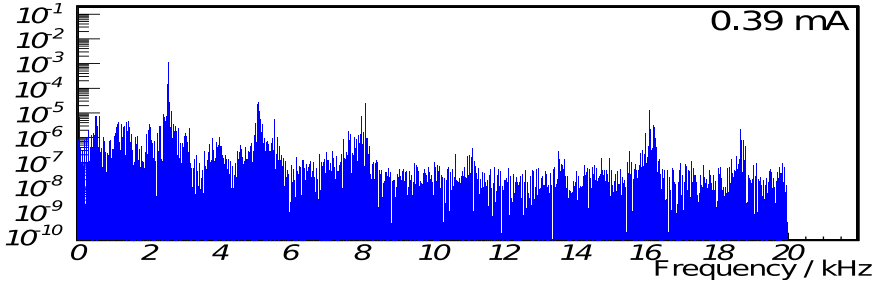
Observation of bursting

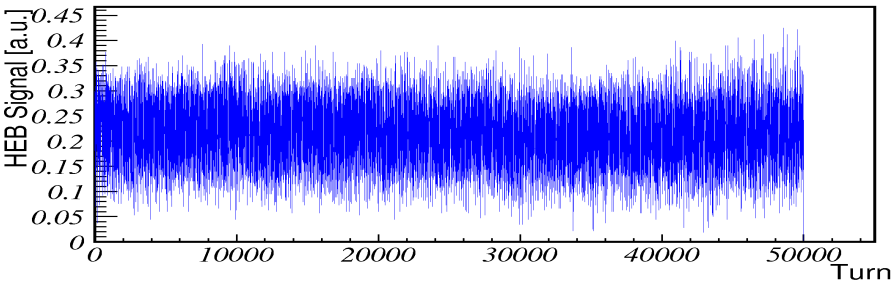
Bursts of radiation in multi turn measurements

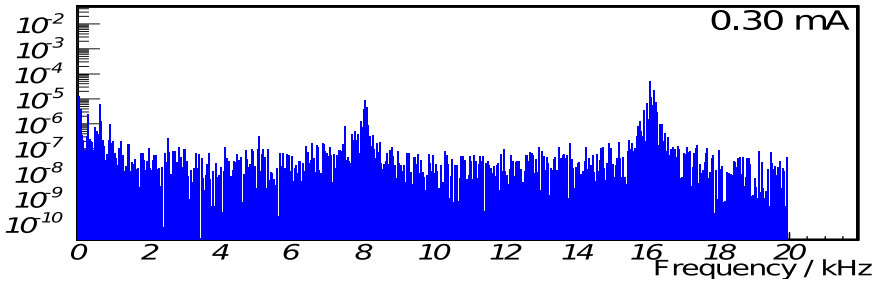






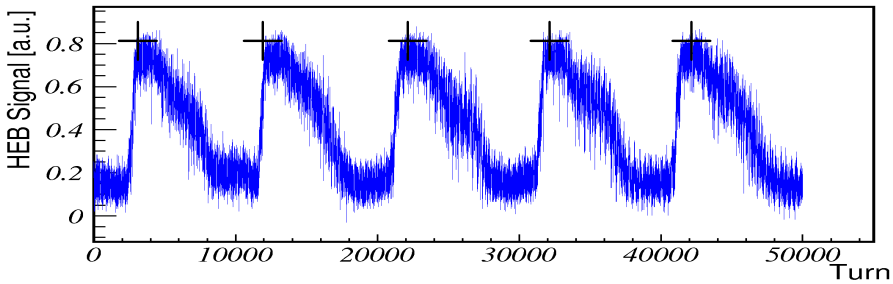


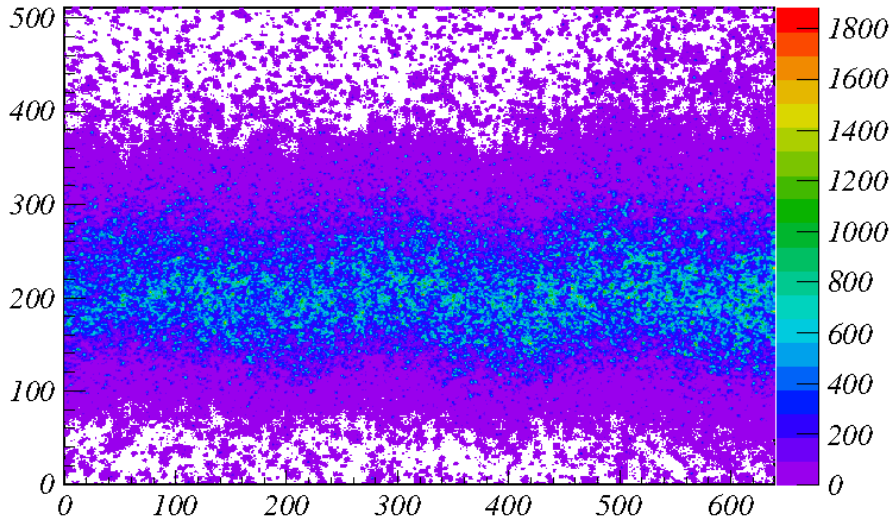




Streak camera measurements

HEB-triggered streak camera data acquisition scheduled

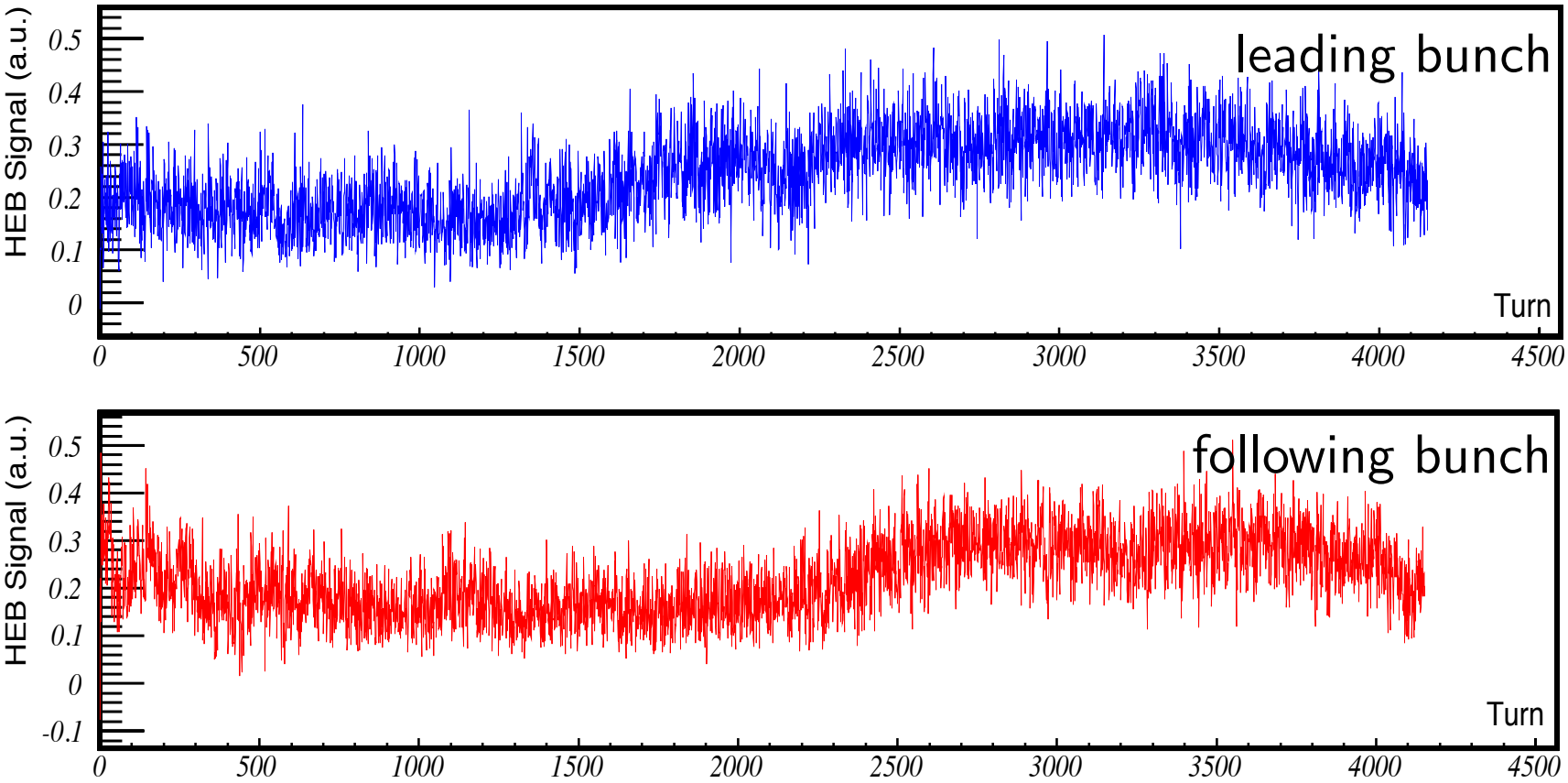




- averaging in bursting mode cause bunch lengthning and substructure blurring
- HEB trigger possibly allows to track only a certain state during bursting
- this could improve slice analysis

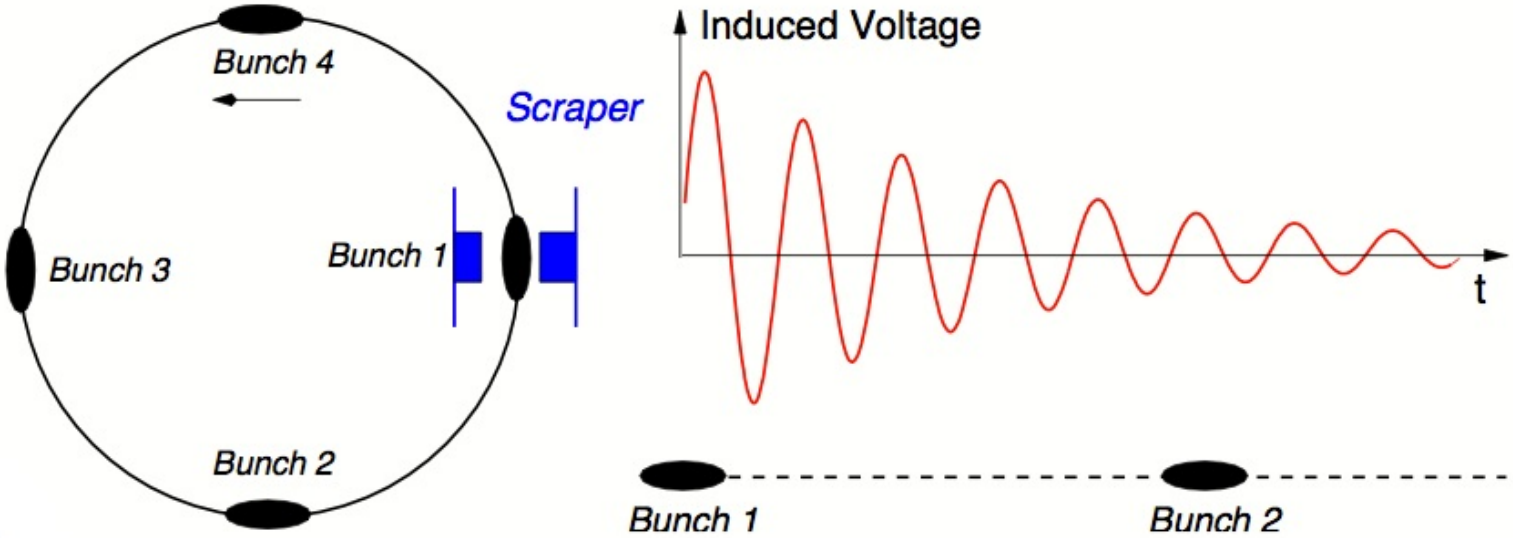
CSR of adjacent bunches

Simultanous increase of the THz-signal intensity

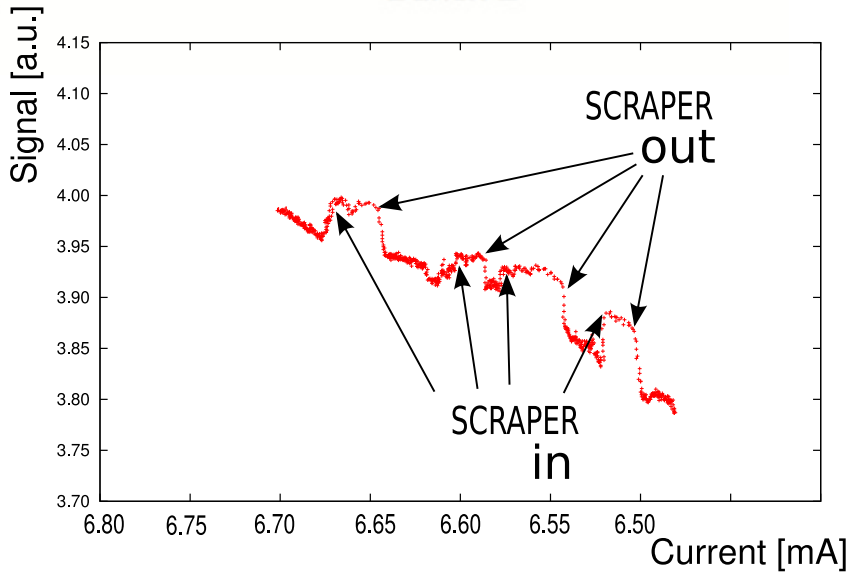


- the signals of the bunches are correlated
- this effect is being investigated

CSR-power and impedance

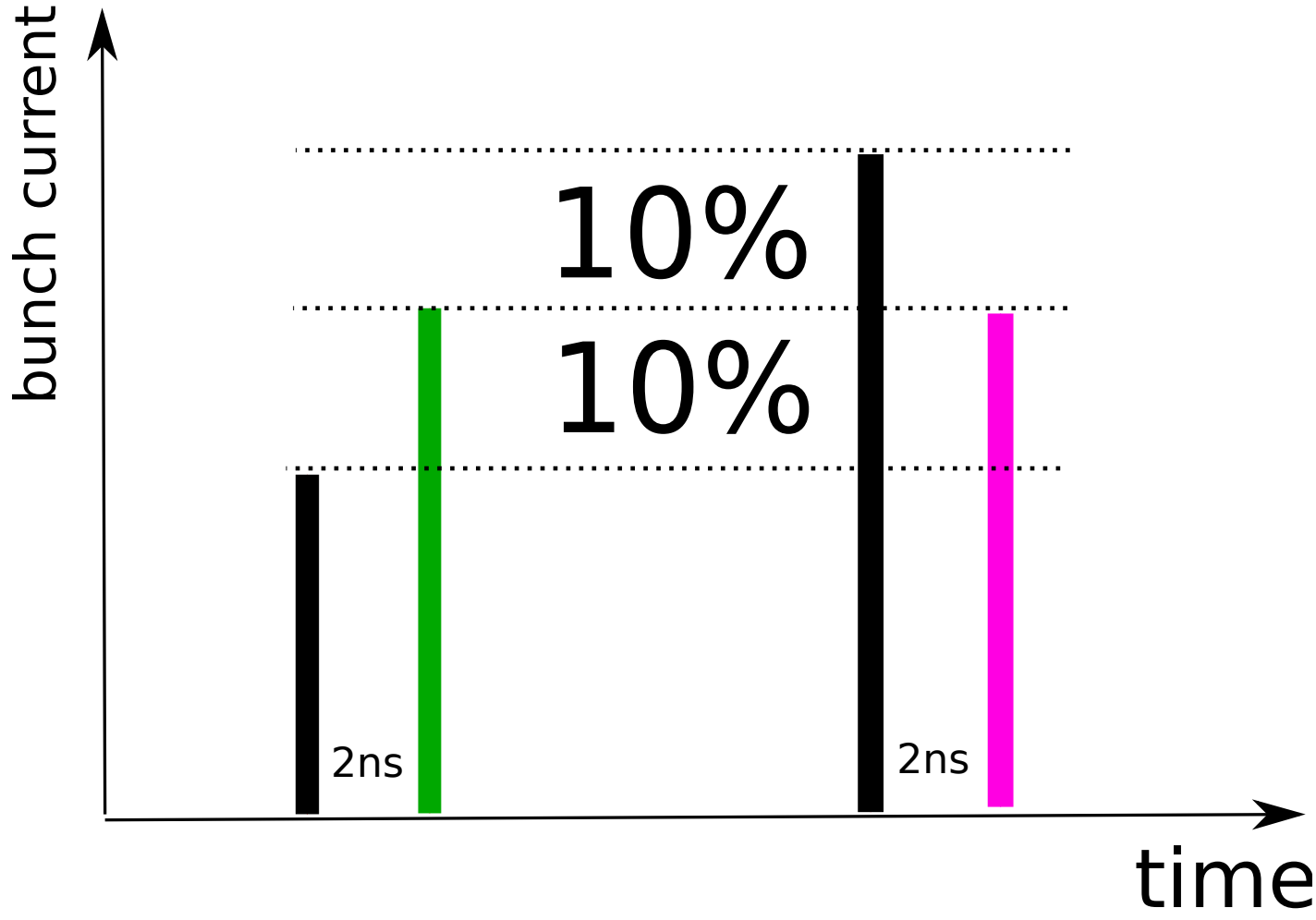


- controlled change of the impedance by an asymmetric vertical scraper
  $\longrightarrow$ **clear effect on CSR-power**
- bunch-bunch influences in multibunch environment



Neighbor interactions

Analysis:



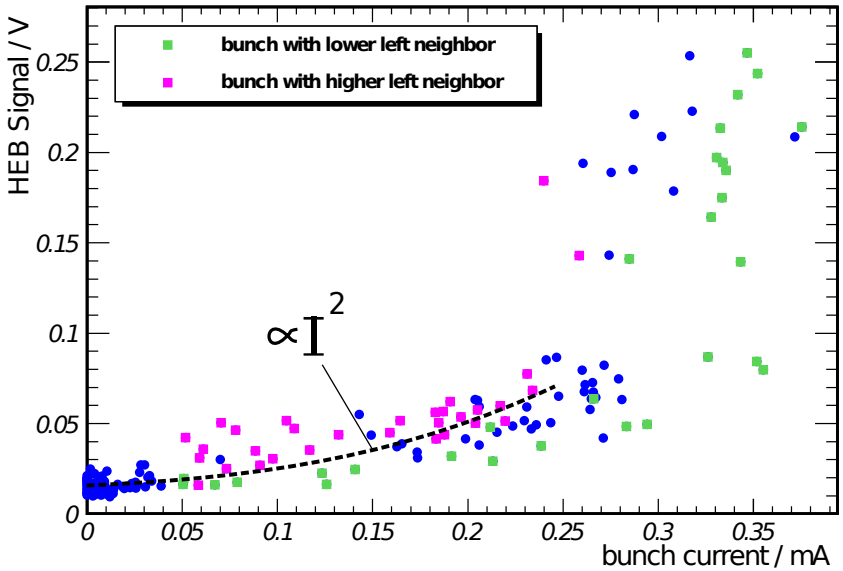
Neighbor interactions

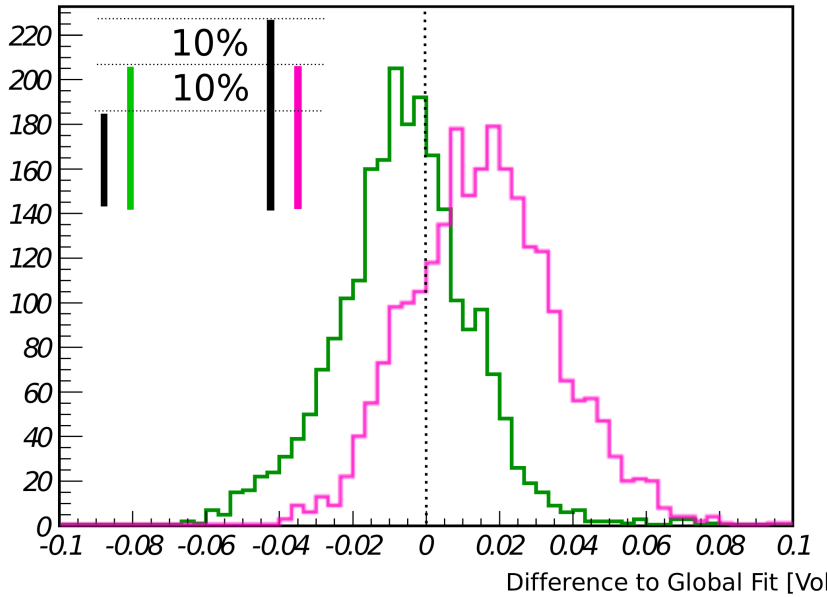
- HEB allows to study CSR signals from individual bunches in multibunch environment
- wakefields caused by leading bunch generate a deformation of the following bunch

$g_\lambda \propto e^{-\left(\frac{2\pi\sigma_s}{\lambda}\right)^2}$ for gaussian

$P_n = N_e \cdot P_1(1 + N_e g_\lambda)$

- **THz emission depends on filling pattern**





Summary and outlook

- the HEB has a high potential as beam diagnostics tool
- combination of HEB with conventional methods like a streak camera or spectrometer opens up new possibilities for longitudinal diagnostics

Next steps:

- understand the physics behind the coupling between adjacent bunches
  $\rightarrow$ more experiments in sb- and mb-mode are scheduled
- we would like to trigger and control bursting radiation

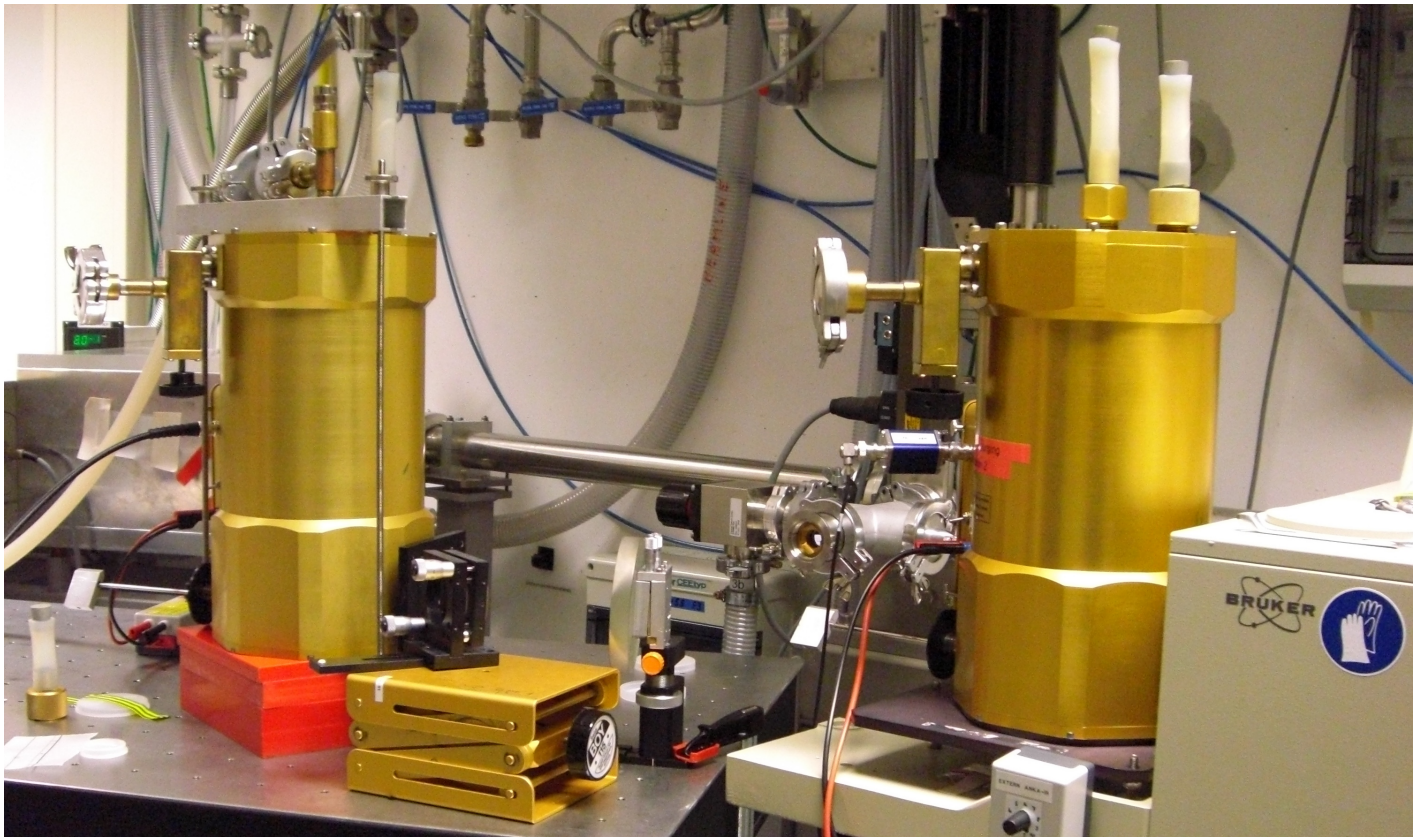
Thank you for your attention!

email: vitali.judin@iss.fzk.de

Experimental setup - reference detectors

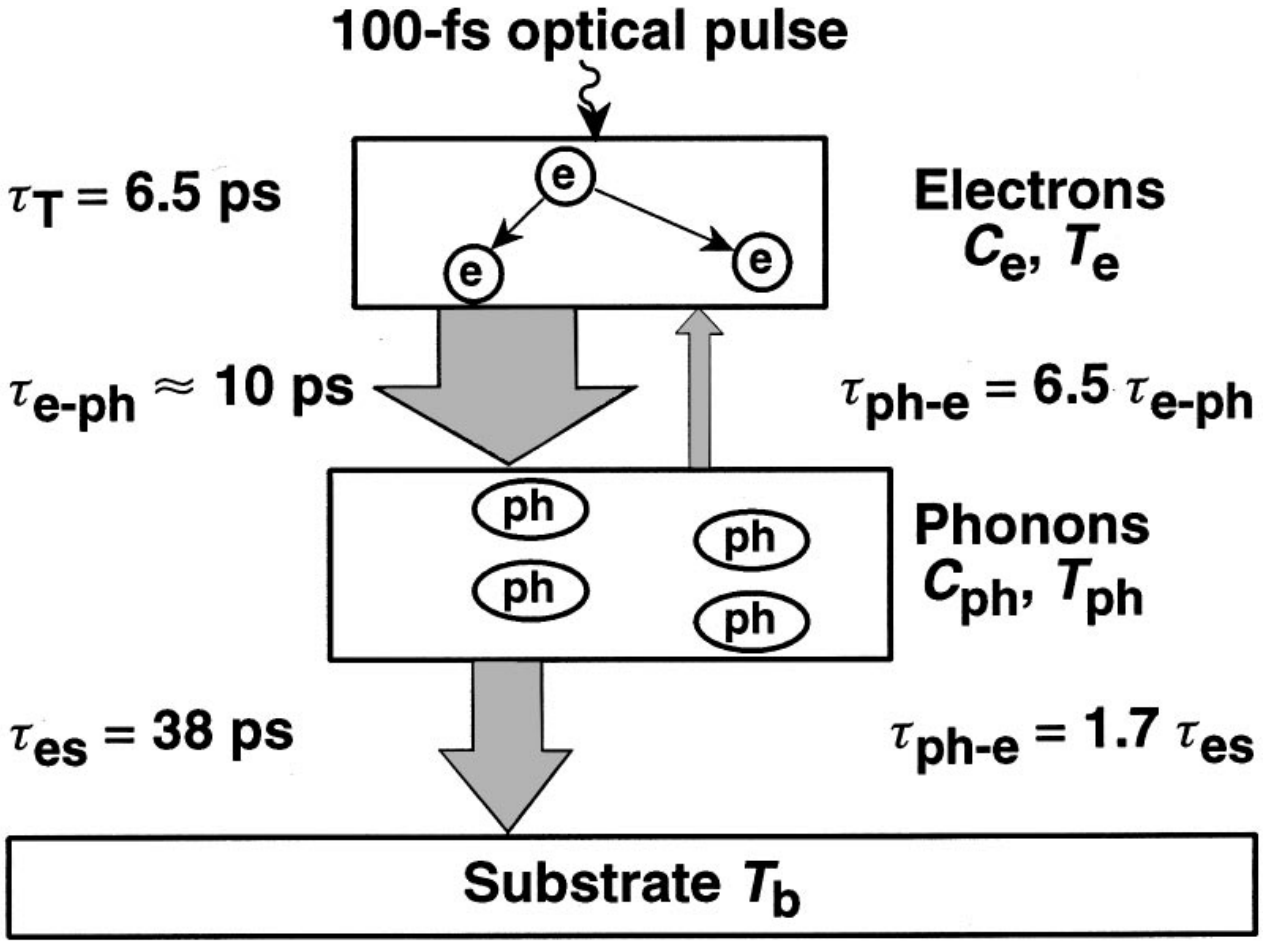
1.8K/4.2K Si Bolometer

- response time $\approx 1\,\mathrm{ms}$
- bandwidth $20 - 4000.0\,\mathrm{cm}^{-1}$



(src: ANKA archive)

Energy relaxation in NbN



(src.: A. Semenov)

Neighbor interactions

Further evidence for coupling between adjacent bunches

- for impedance effect a linear dependence of signal on driver current is expected