Karlsruhe Institute of Technology

ANKA THZ GROUP

Analysis of CSR - multibunch studies

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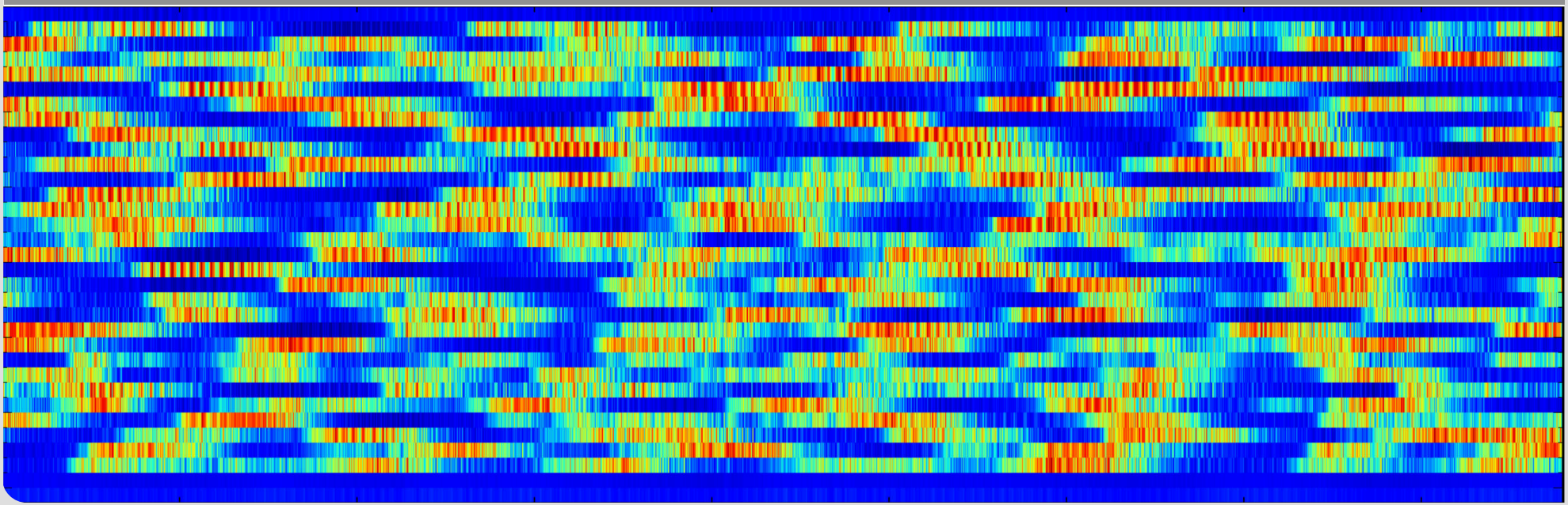
N. Smale, J. Steinmann | February 27th, 2014

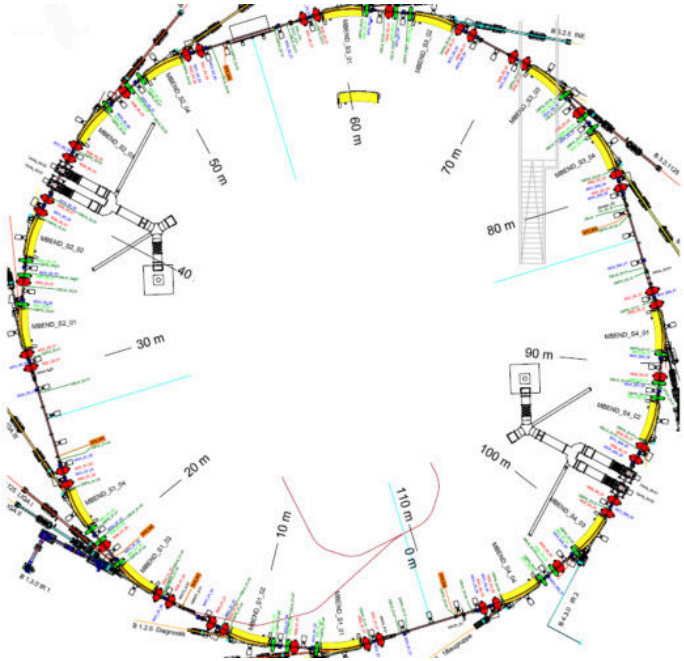
LABORATORY FOR APPLICATIONS OF SYNCHROTRON RADIATION (LAS)



ANKA

Parameter:

- Circumference: 110.4 m
- Revolution time: 368 ns
- RF-frequency: 500 MHz
- 2 ns bunch spacing
- Harmonic number: 184



Normal operation mode:

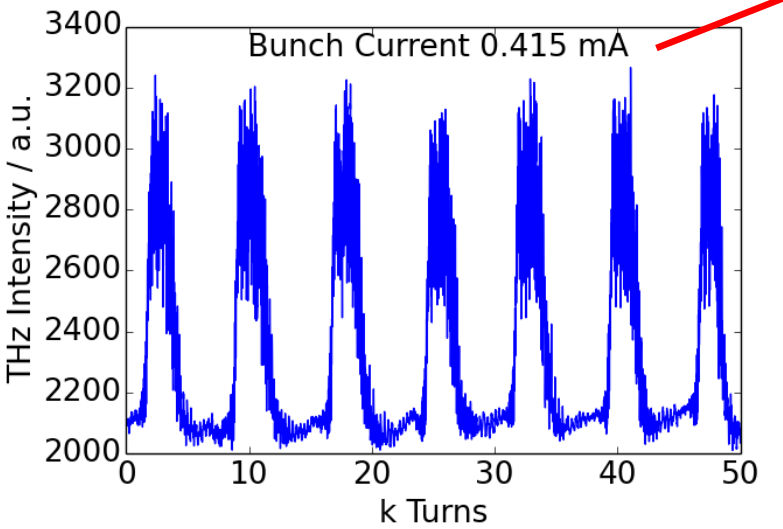
- 2.5 GeV beam energy
- 200 mA beam current
- 45 ps RMS bunch length

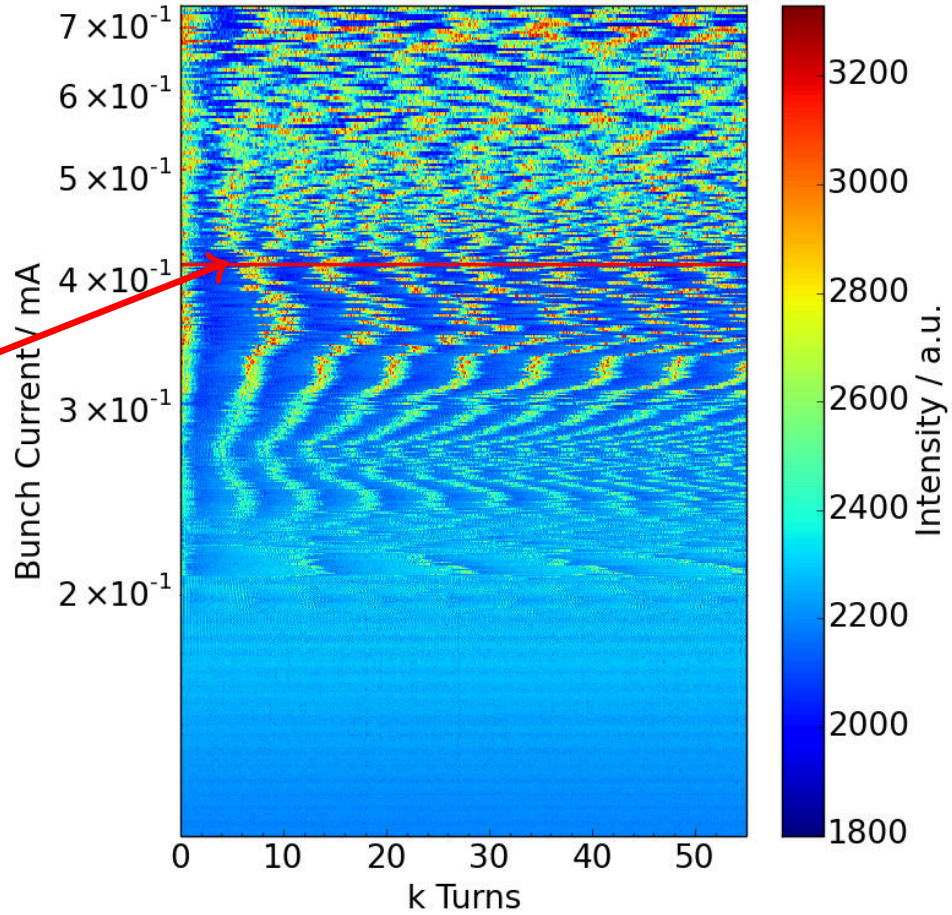
Low alpha mode:

- 1.3 GeV beam energy
- Single or multibunch operation
- $<$6 ps RMS bunch length

Motivation

- Low-alpha operation mode
- RMS bunch length of few ps
- CSR up to a few THz
- Fluctuating radiation (“bursts”)

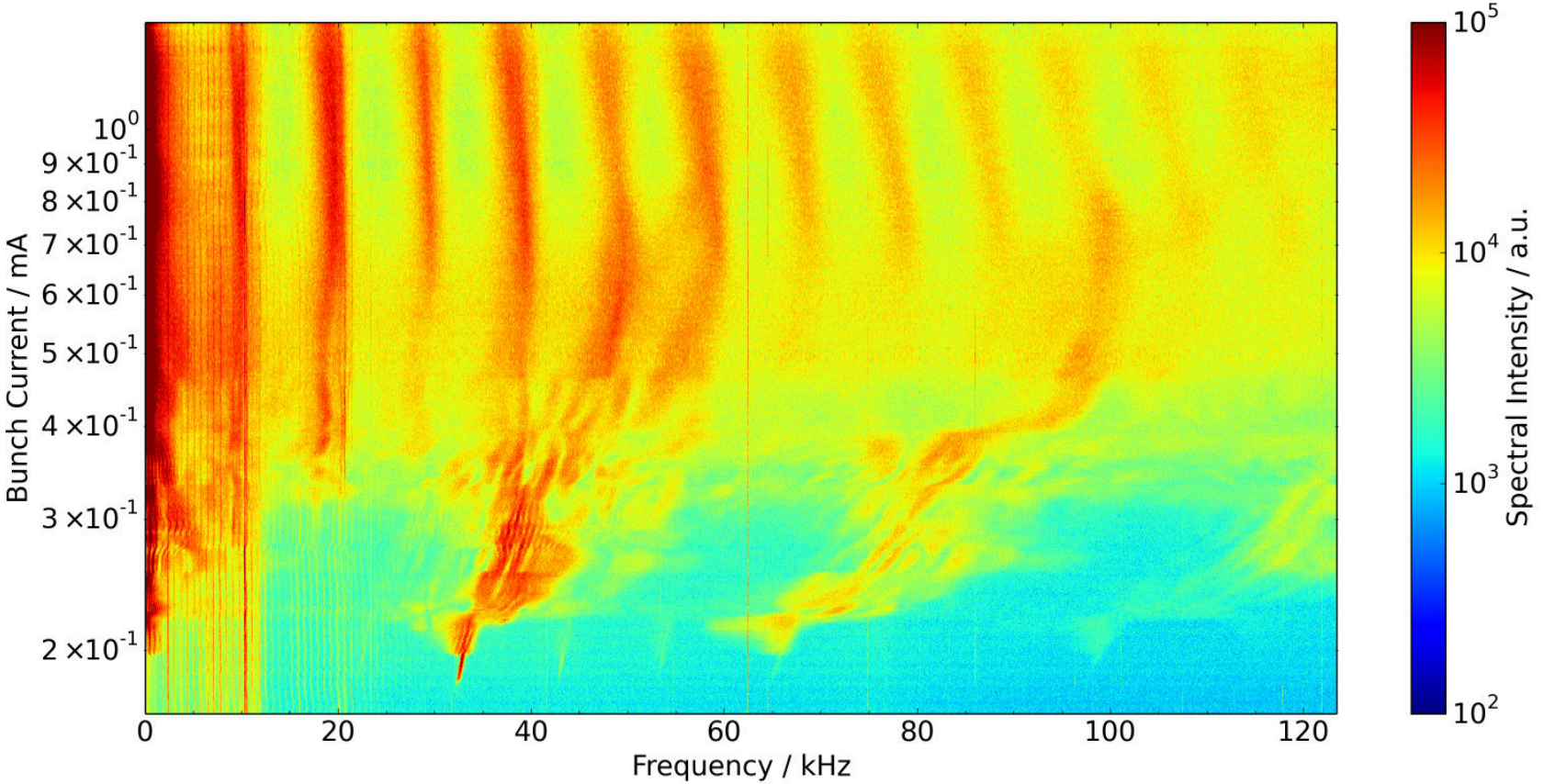




50k Turns = 18.4 ms

Spectrogram

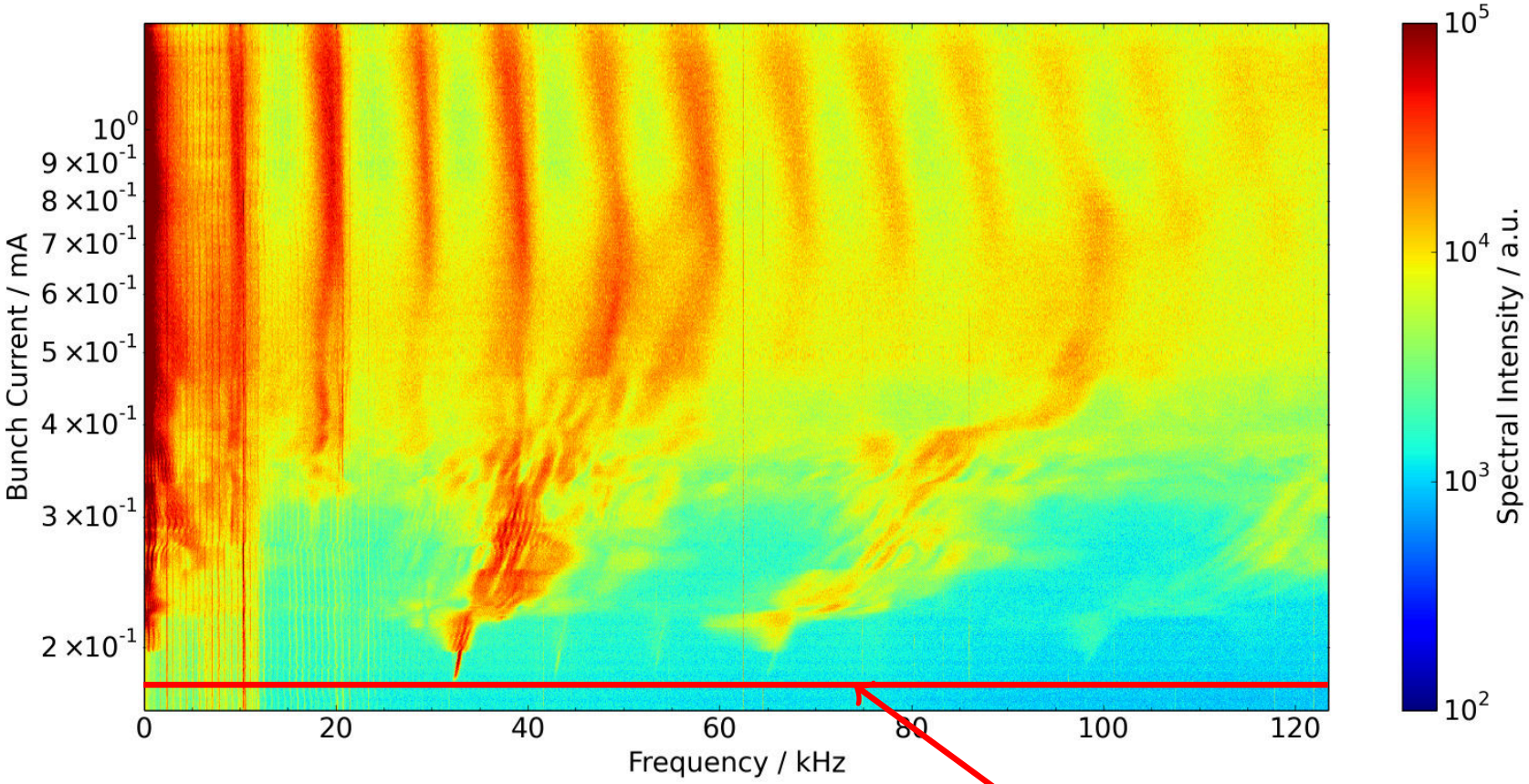
Fill 4935 Synchrotron frequency 10.3 kHz - σ_0 3.3 ps



- Reproducible
- Depending on machine parameters
  (beam optics, RF-potential, geo. impedance)

Spectrogram

Fill 4935 Synchrotron frequency 10.3 kHz - σ_0 3.3 ps

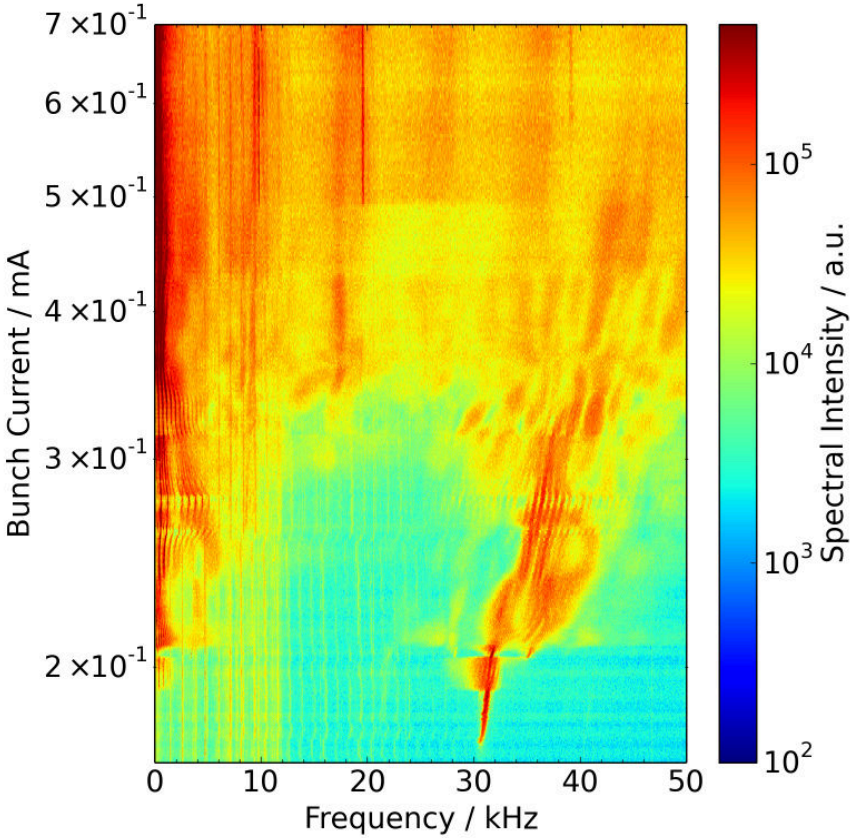


- Reproducible
- Depending on machine parameters
  (beam optics, RF-potential, geo. impedance)

Spectrogram

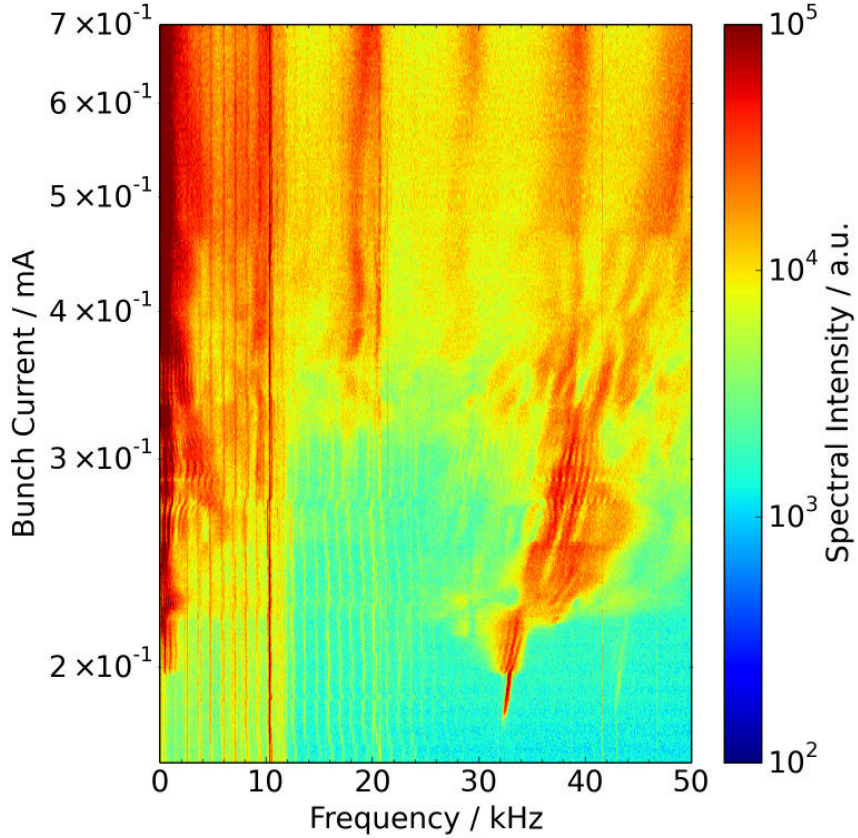
Fill 4922

Synchrotron frequency 9.8 kHz - σ_0 3.4 ps



Fill 4935

Synchrotron frequency 10.3 kHz - σ_0 3.3 ps



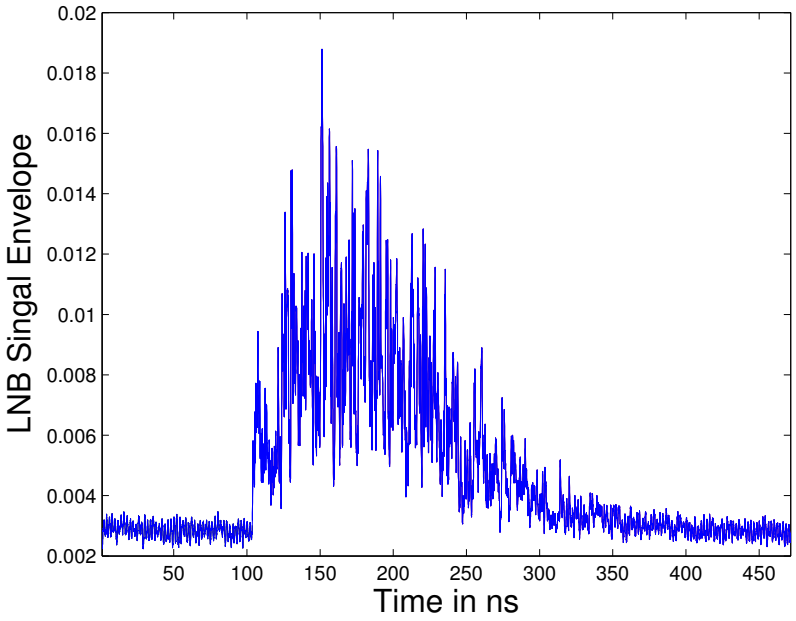
- Similar patterns, but subtitle changes due to small differences in machine settings

Long-Range Wake-Fields

Low Noise Block (LNB)

(10.7 - 12.75 GHz)

$\rightarrow$ response to single bunch much longer than 2 ns

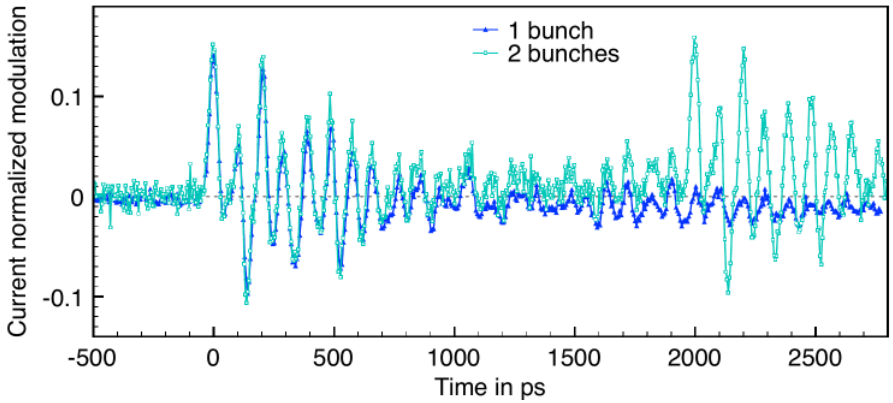


(J. Schwarzkopf)

Electro-Optical Setup (EO)

$\rightarrow$ sees electromagnetic fields

$<$2ns

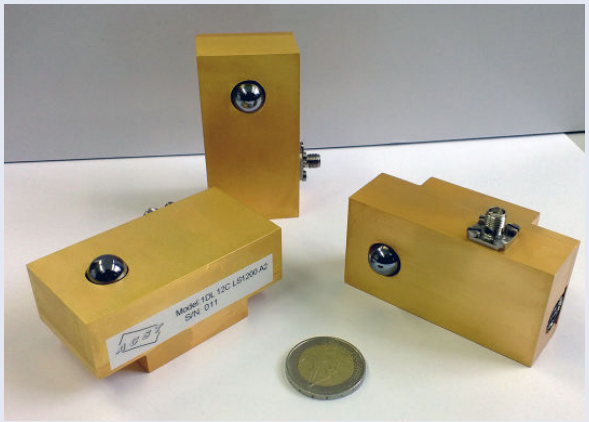


(N. Hiller, see talk “Electro-optic sampling for electron bunch diagnostic @ ANKA and FLUTE”(ID 26))

long-range wake-fields in beam pipe $\rightarrow$**Inter-bunch effects possible!**

Fast THz Detectors

Quasi-optical broadband detector



room temperature

response time $<$200ps

50 GHz up to 1 THz

based on schottky diode

ACST (acst.de)

Hot Electron Bolometer (NbN)

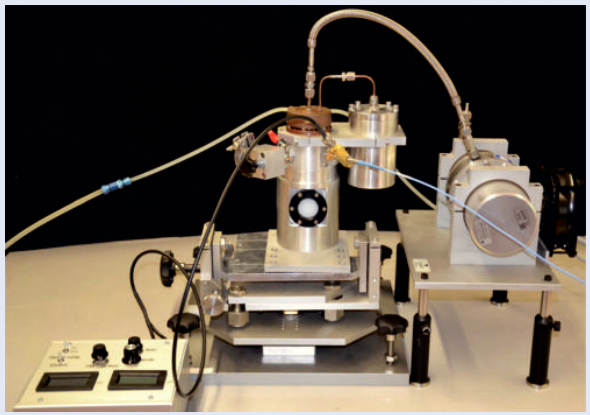
cryogenic (LHe)

response time $<$165ps

200 GHz up to 4 THz

high sensitivity

YBCO detector



cryogenic (LN2)

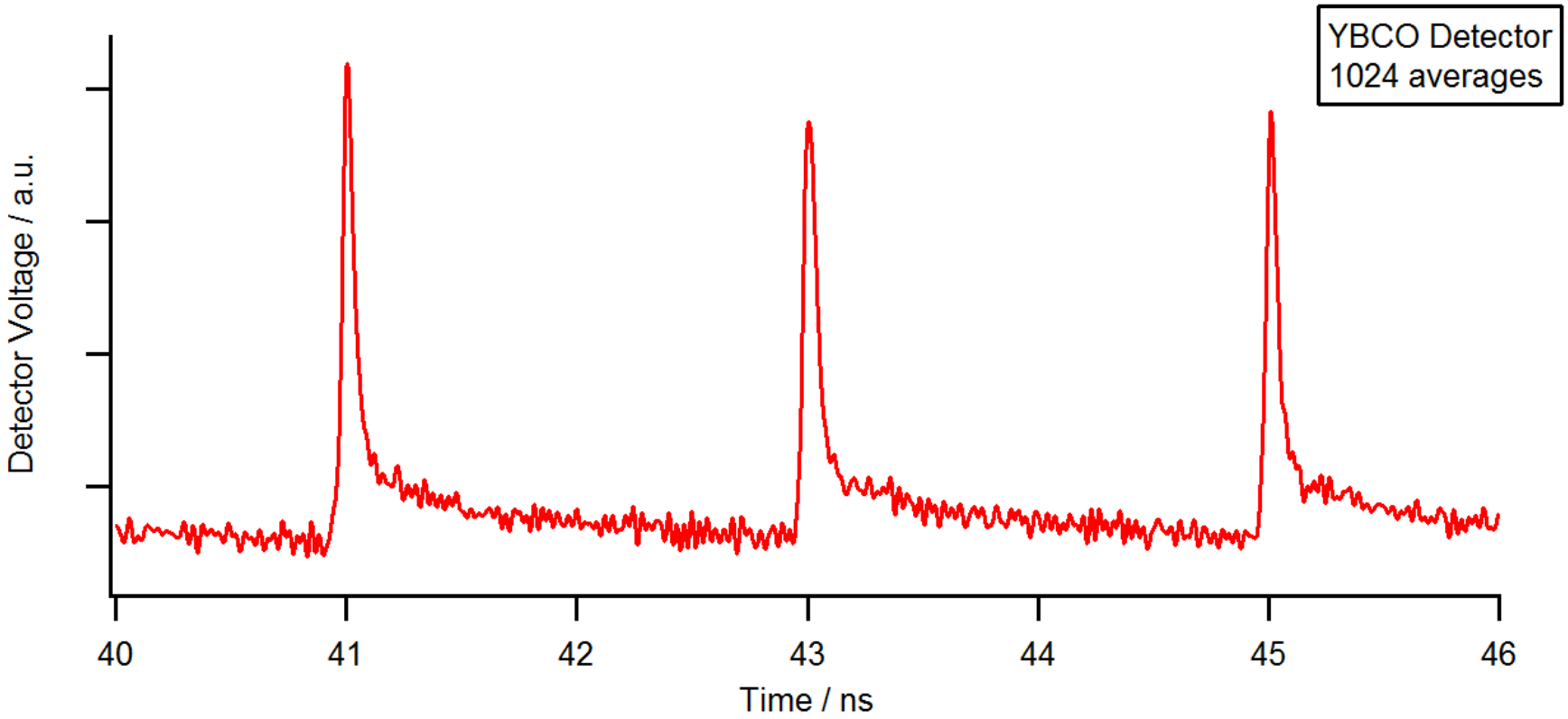
response time $<$15ps

30 GHz up to 2.5 THz

(J. Raasch, see talk “Fast THz detectors”(ID 20))

- Resolve intensity of each bunch (minimal bunch spacing 2 ns)

Fast THz Detectors

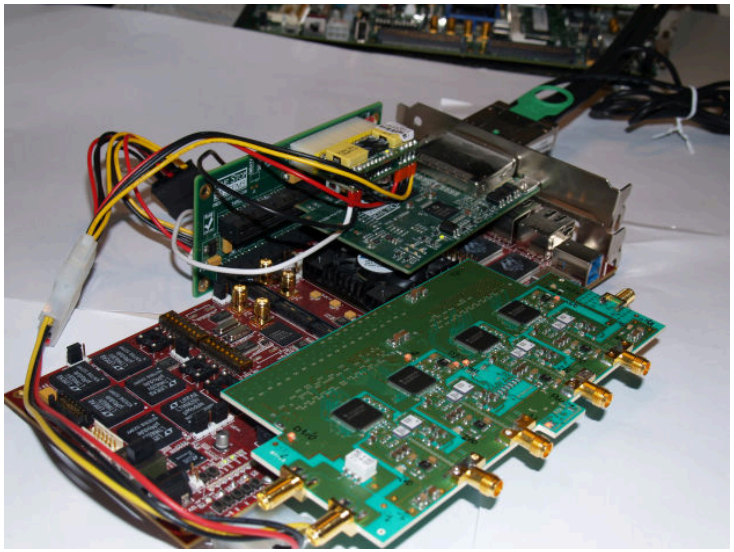


THz-Signal of three consecutive bunches with 2 ns distance

$\Rightarrow$Clear isolated pulses

(J. Steinmann, J. Raasch)

Ultra Fast DAQ Board



FPGA - four ADC board (M. Caselle, see talk “Fast board electronics”(ID 28))

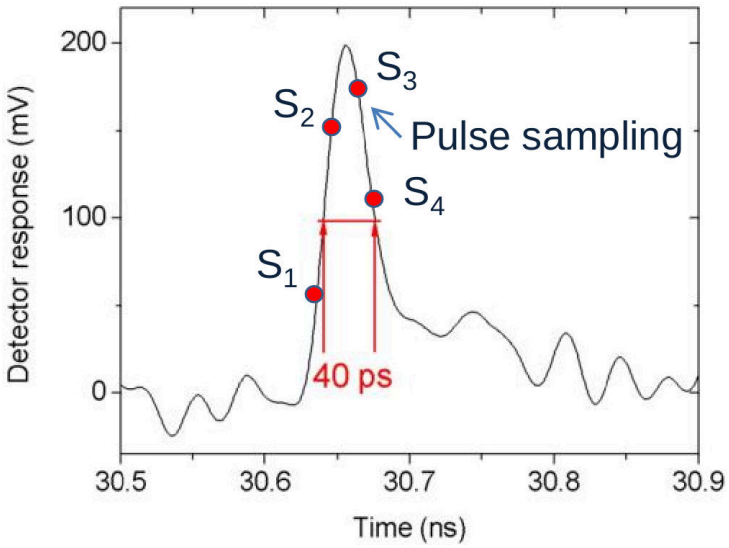
Four ADC channels:

- Reconstruction of the detector signal
- Adjustable delay for each sampling stage in 3ps steps
- Optional: read out multiple detectors simultaneously

Online monitoring of each bucket at every turn (500MHz) $\rightarrow$ 4 GB/s
Continuous data capturing only limited by storage performance.

$\Rightarrow$Possibility for live analysis

Ultra Fast DAQ Board



Peak reconstruction (M. Caselle, see talk “Fast board electronics”(ID 28))

Four ADC channels:

- Reconstruction of the detector signal
- Adjustable delay for each sampling stage in 3ps steps
- Optional: read out multiple detectors simultaneously

Online monitoring of each bucket at every turn (500MHz) $\rightarrow$ 4 GB/s
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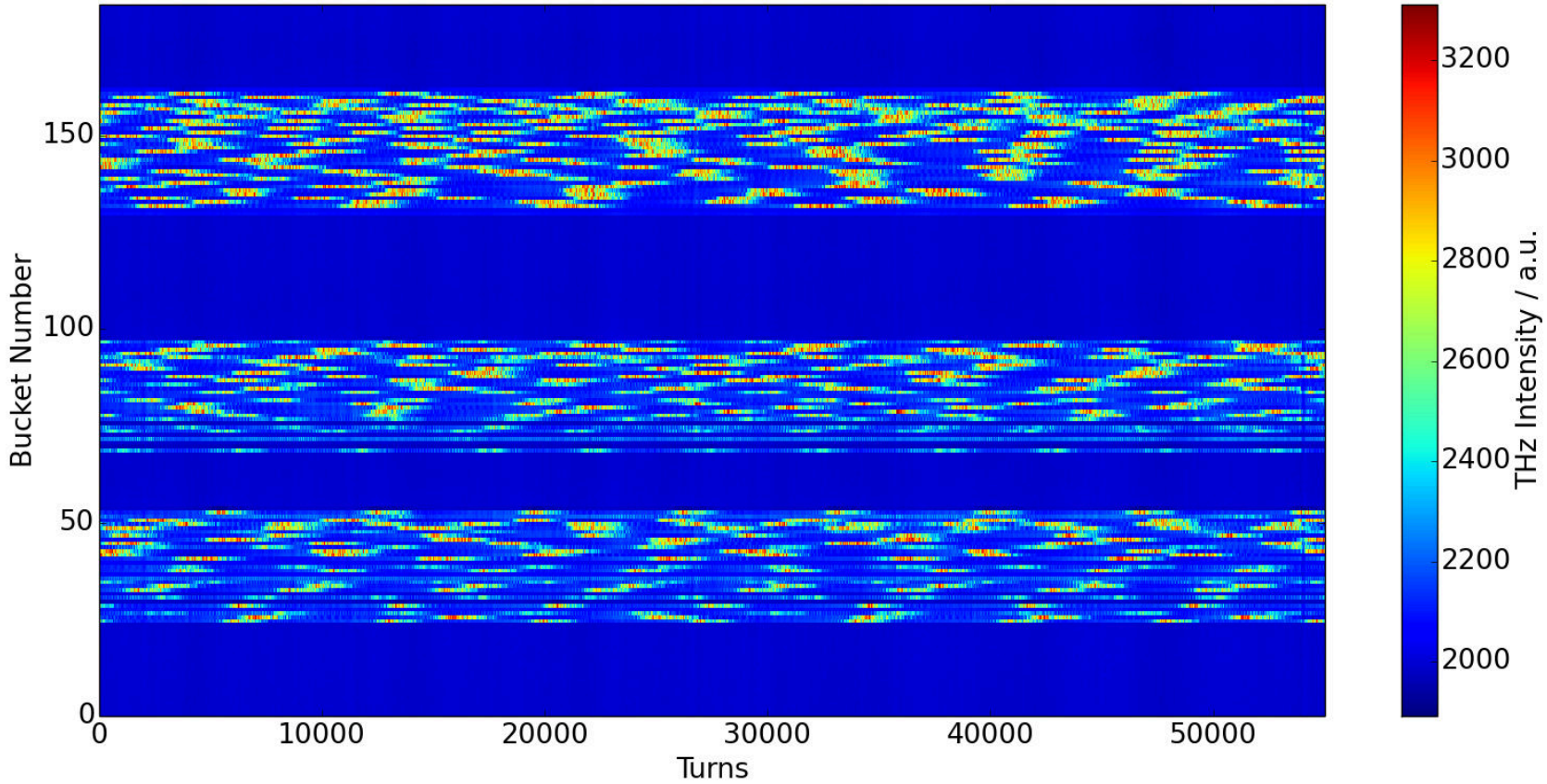
$\Rightarrow$Possibility for live analysis

Intensity of all Buckets

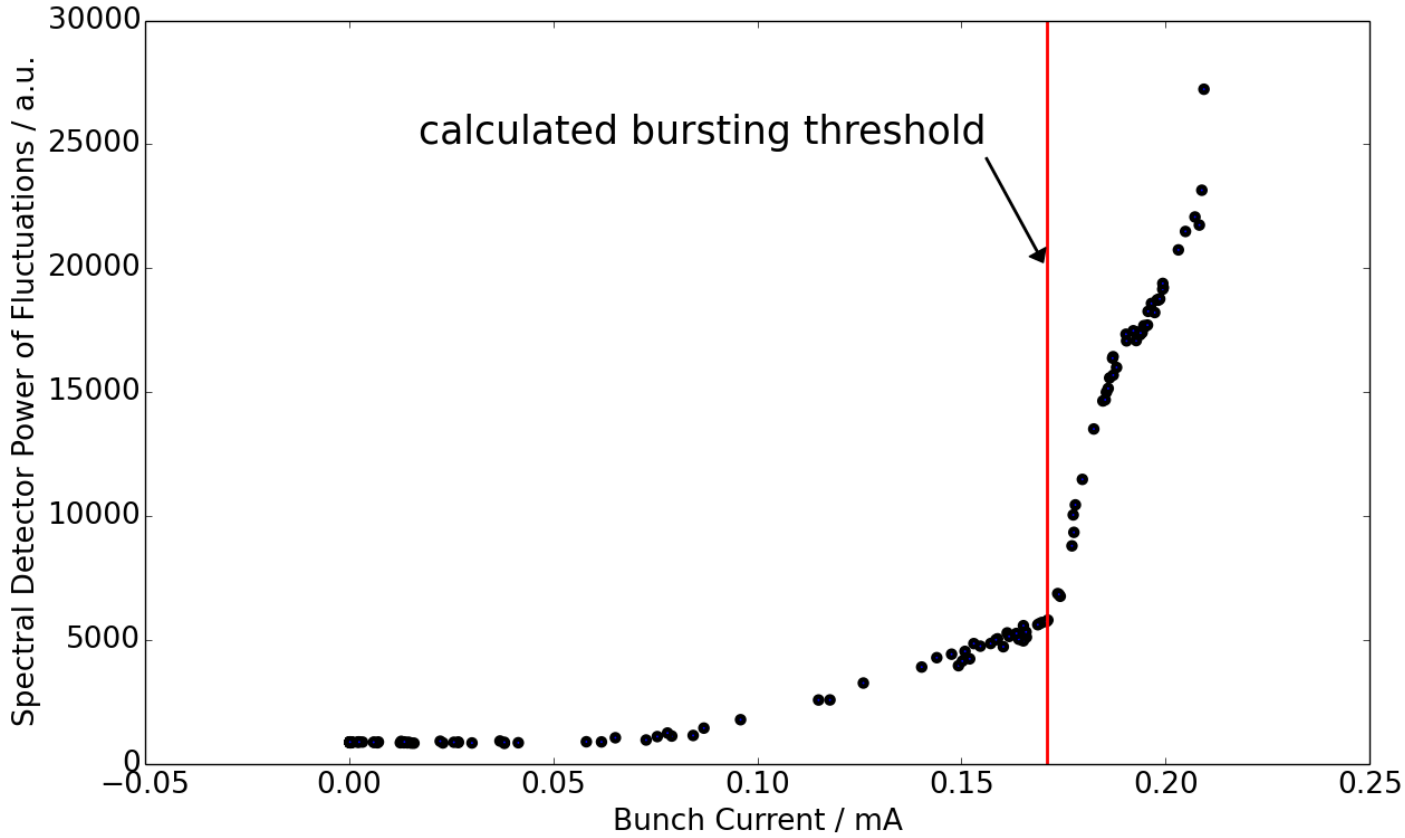
Simultaneous monitored intensity of all buckets over turns detected with Schottky diode and DAQ board.



- Filling pattern of 3 trains visible

Bursting Threshold

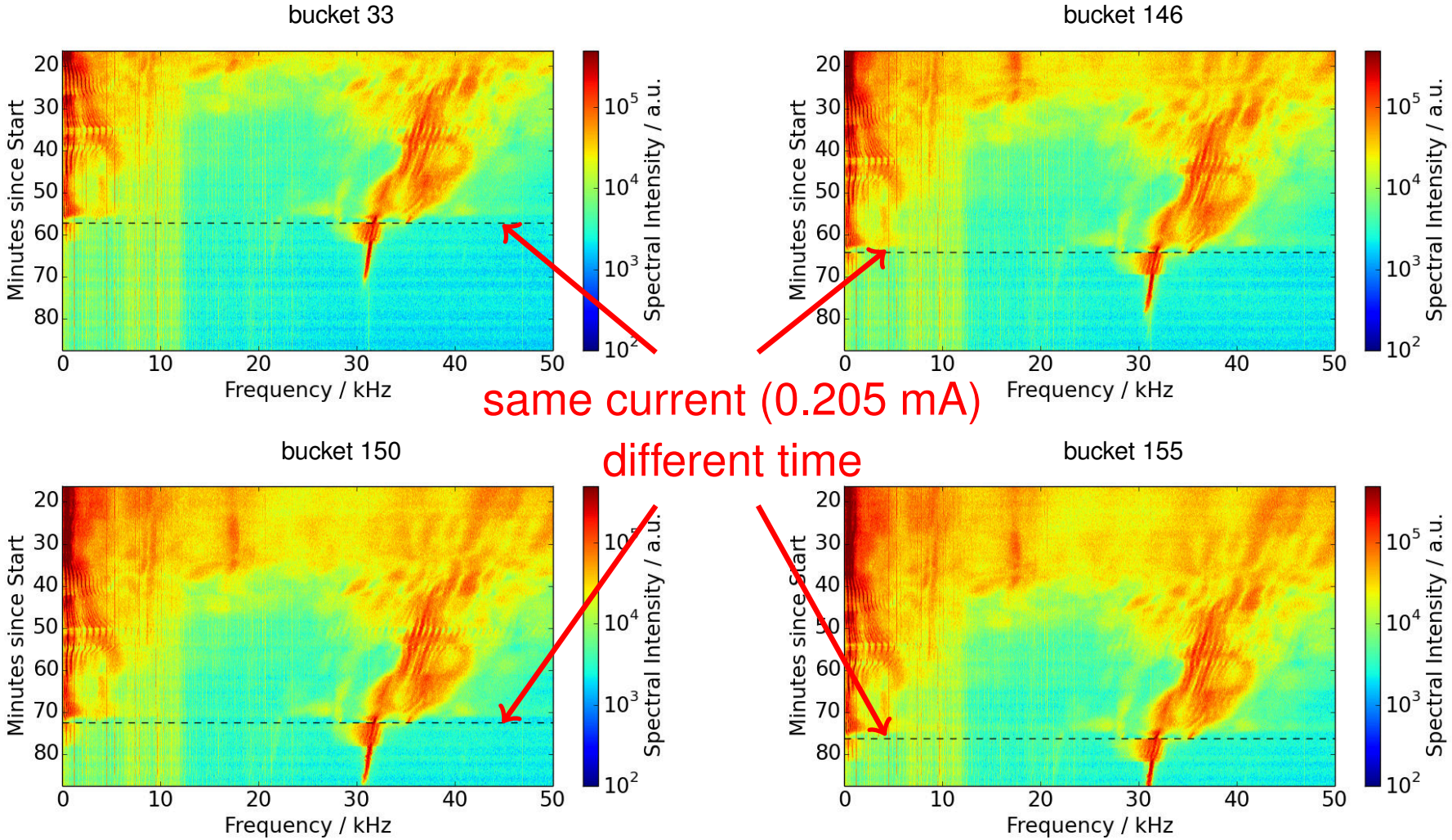
Determination of the bursting threshold from a single shot.
(here overall beam current was 15 mA)



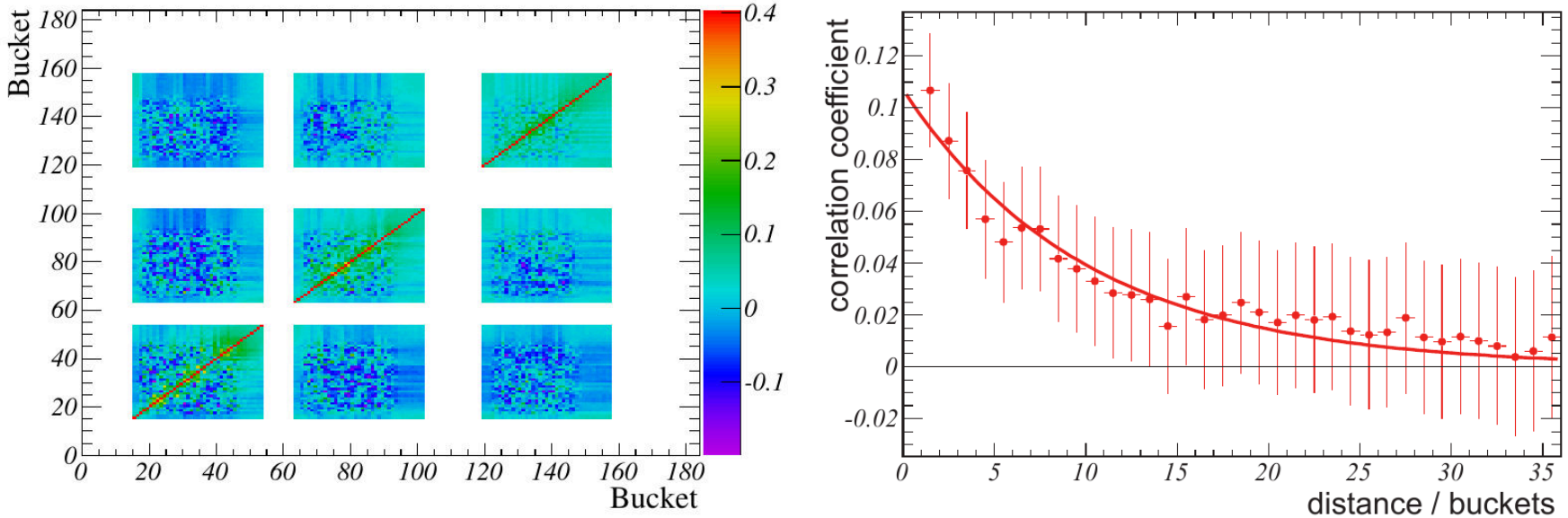
AC-coupled spectral detector power over bunch current

Comparison of Spectrograms

All bunches show a similar behavior for same bunch currents.



Correlation between Bunches in Multibunch Operation



Correlation matrix (left) and calculated correlation length (right) for intensity data measured with YBCO and DAQ board (V.Judin)

[1] A.-S. Müller, IPAC2013 Shanghai, MOPEA019

Conclusion & Outlook

- Online monitoring of each bunch in multibunch operation possible
- Single-shot bursting threshold determination
- Indication for bunch-bunch interactions
- DAQ board usable for balanced detections and detector studies
- Possible usage of GPU calculations for live analysis

Thank you for your attention!

Questions?

Thanks to:
E. Hertle, N. Hiller, V. Judin, A.-S. Müller, M. Schuh, J.Schwarzkopf, N. Smale, J. Steinmann, M. Caselle, J. Raasch, Y.-L. Mathis & the whole THz-Group & technical staff at ANKA