Karlsruhe Institute of Technology

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ANKA THZ GROUP

Single-Shot EOSD Measurements at ANKA

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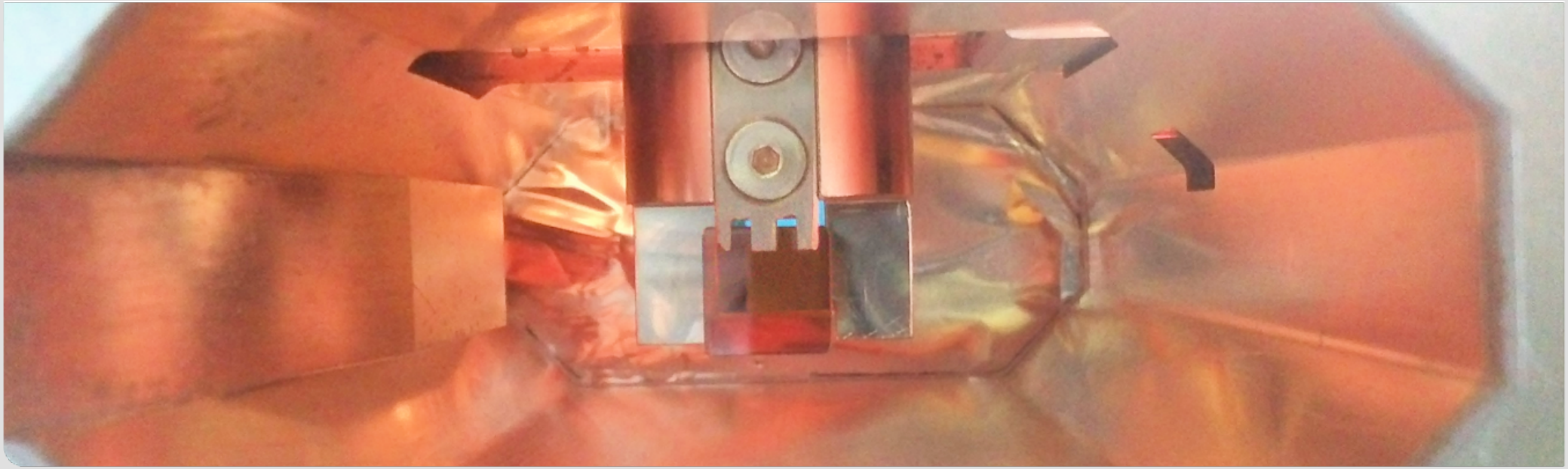
Institute for Photon Science and Synchrotron Radiation (IPS) / Laboratory for the Applications of Synchrotron Radiation (LAS)

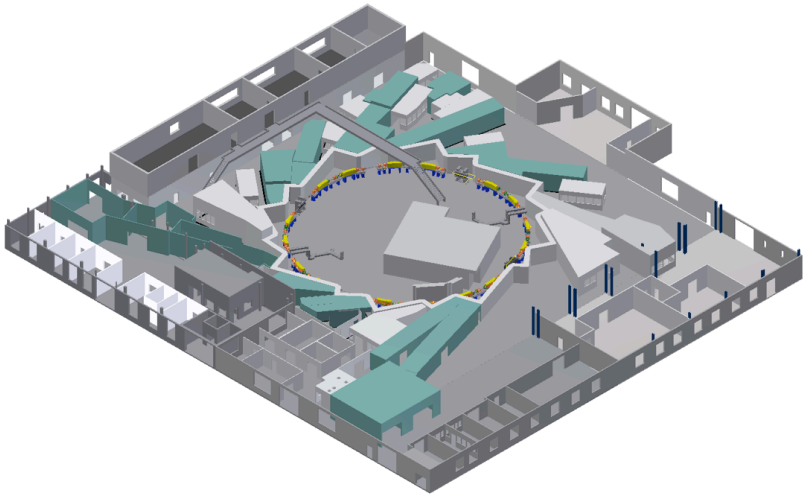


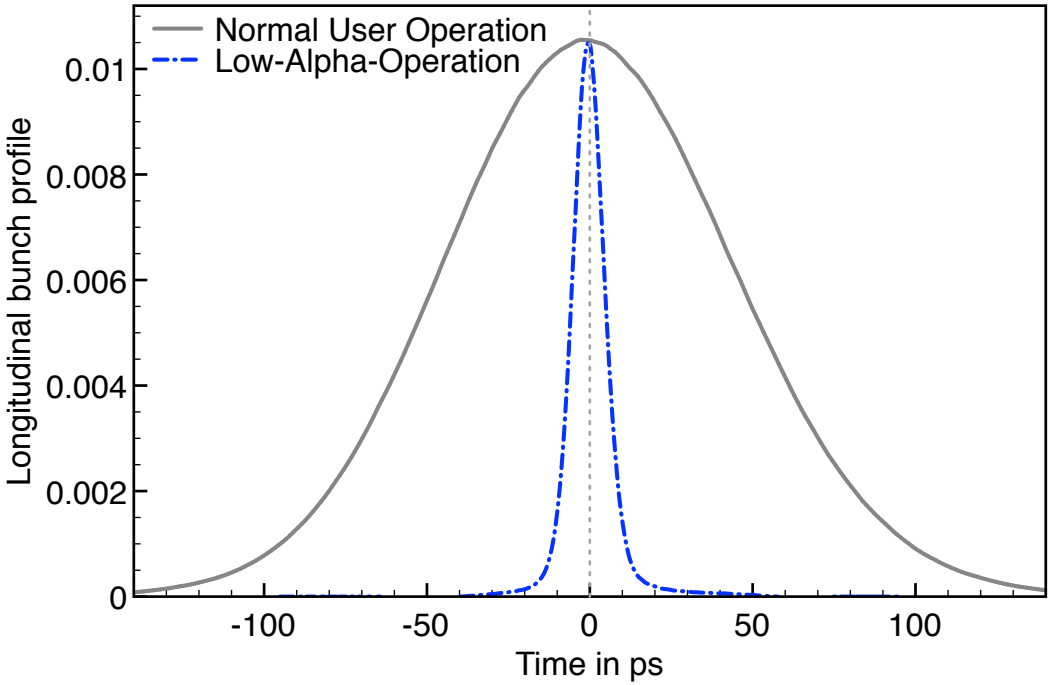
Outline

- Introduction
- Electro-Optical Sampling (EOS)
  - Long-Range Wake-Field Studies
- Electro-Optical Spectral Decoding (EOSD)
  - Single-Shot Bunch Profiles
- Summary & Next Steps

Introduction: Low-α_c-Operation at ANKA

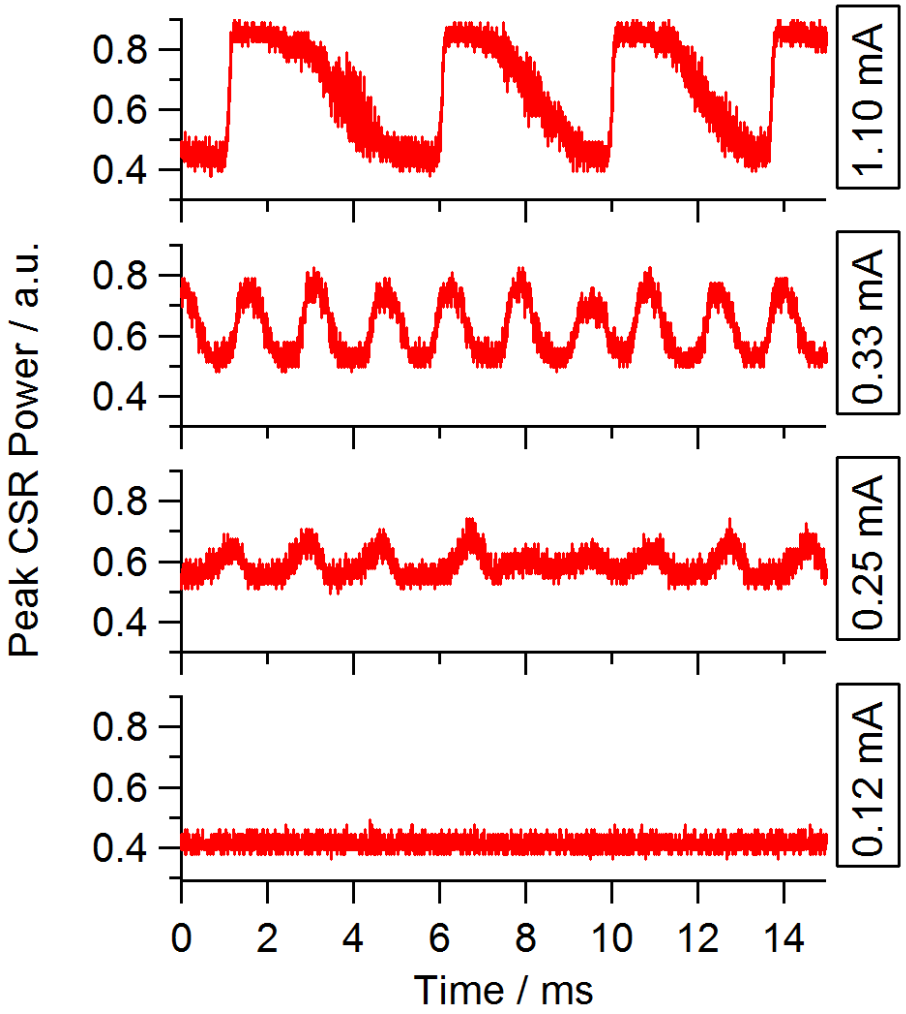
- **Generation of coherent synchrotron radiation (CSR)**
- Circumference: 110.4 m
- Revolution frequency: 2.715 MHz
- Energy: 0.5 - 2.5 GeV (0.8 - 1.6 GeV during low-α_c-mode)
- RMS bunch length:
  45 ps (for 2.5 GeV),
  10 ps down to 1-2 ps (for 1.3 GeV)
- Filling pattern:
  single- or multi-bunch
  (min. bunch spacing 2 ns)



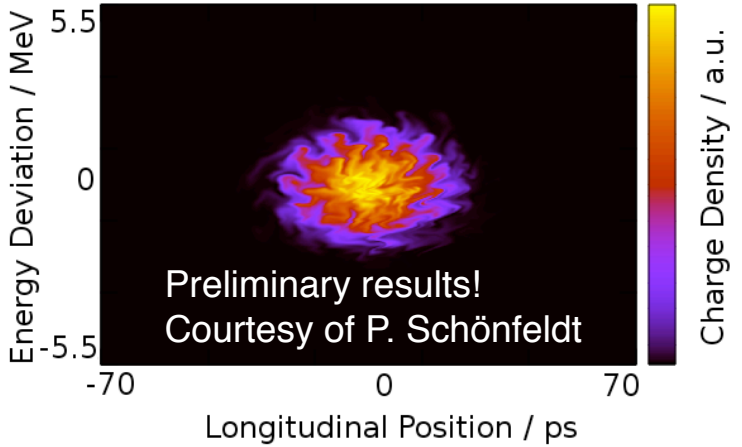


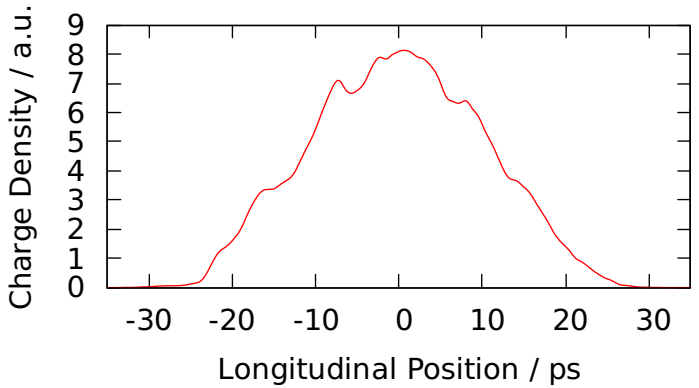
Motivation

Bursting behavior of CSR ↔ microbunching



Courtesy of J. Steinmann





- **What we want to measure:**
  - **Ideally:** Long. phase space for every bunch and every revolution
  - **Realistically:** THz-signal (bunch by bunch) & longitudinal bunch profile (turn by turn)

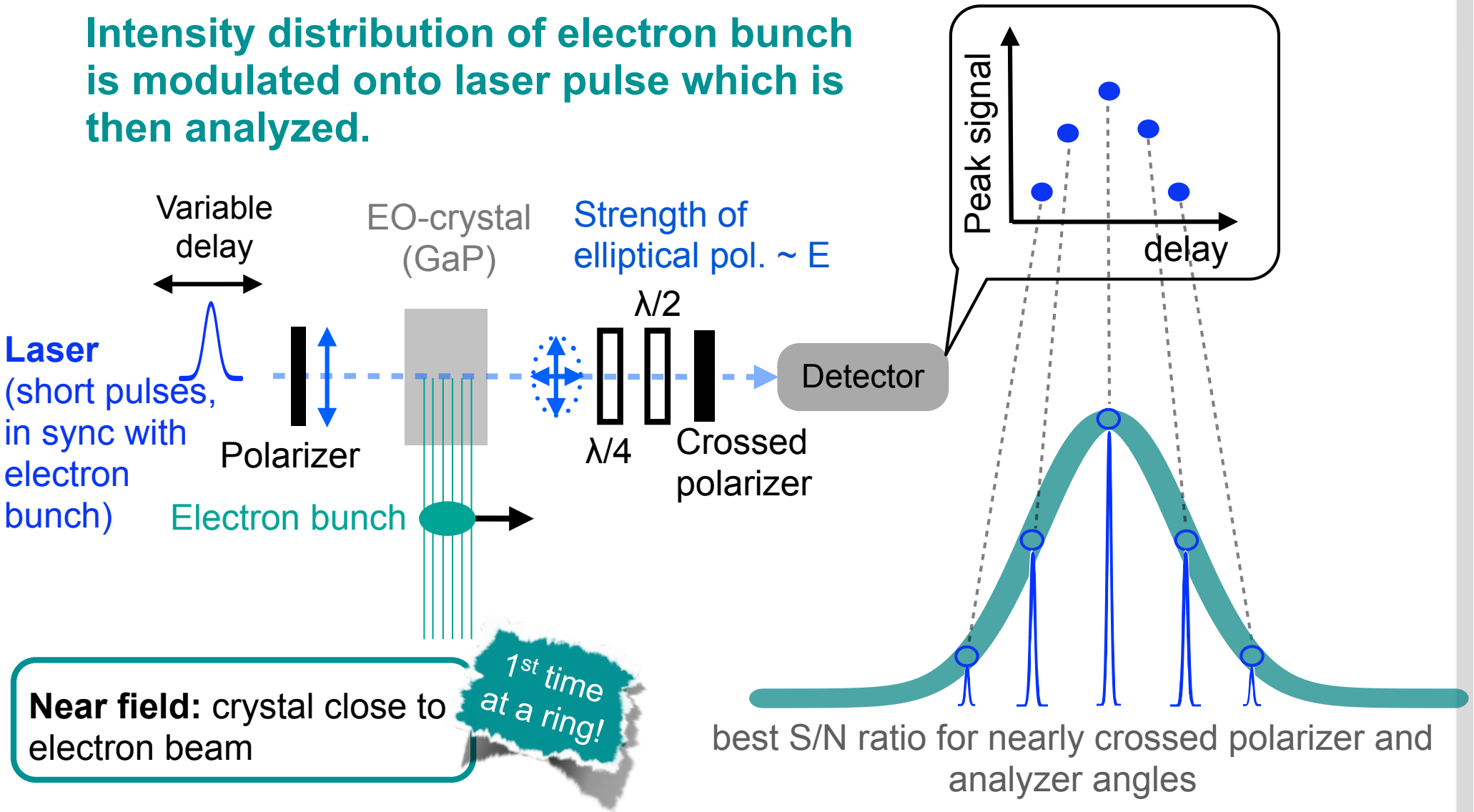
Longitudinal Diagnostics at ANKA

- **Time domain:**
  - Time-correlated single photon counting ➜ filling pattern
  - Fast-THz-detectors + KAPTURE-system ➜ THz-intensity of every bunch for every revolution
    J. Raasch et al.: **THPME125**
    M. Caselle et al.: **THPME113**
    V. Judin et al.: **MOPRO063**
  - Low-Noise Block (LNB) microwave detector
    J. Schwarzkopf et al.: **MOPRO062**
  - Streak camera ➜ averaged bunch profiles, evolution over consecutive revolutions
    P. Schönfeldt et al.: **MOPRO068**
  - Electro-Optical methods (EOS, EOSD) ➜ long-ranged wake-fields, single-shot bunch profiles
    A. Borysenko et al.: **THPME123**
- **Frequency domain:**
  - Martin-Puplett interferometer
  - FTIR Michelson interferometer

  ➜ Spectrum of CSR
  J. Steinmann et al.: **THPME124**

Electro-Optical Sampling (EOS)

Intensity distribution of electron bunch is modulated onto laser pulse which is then analyzed.

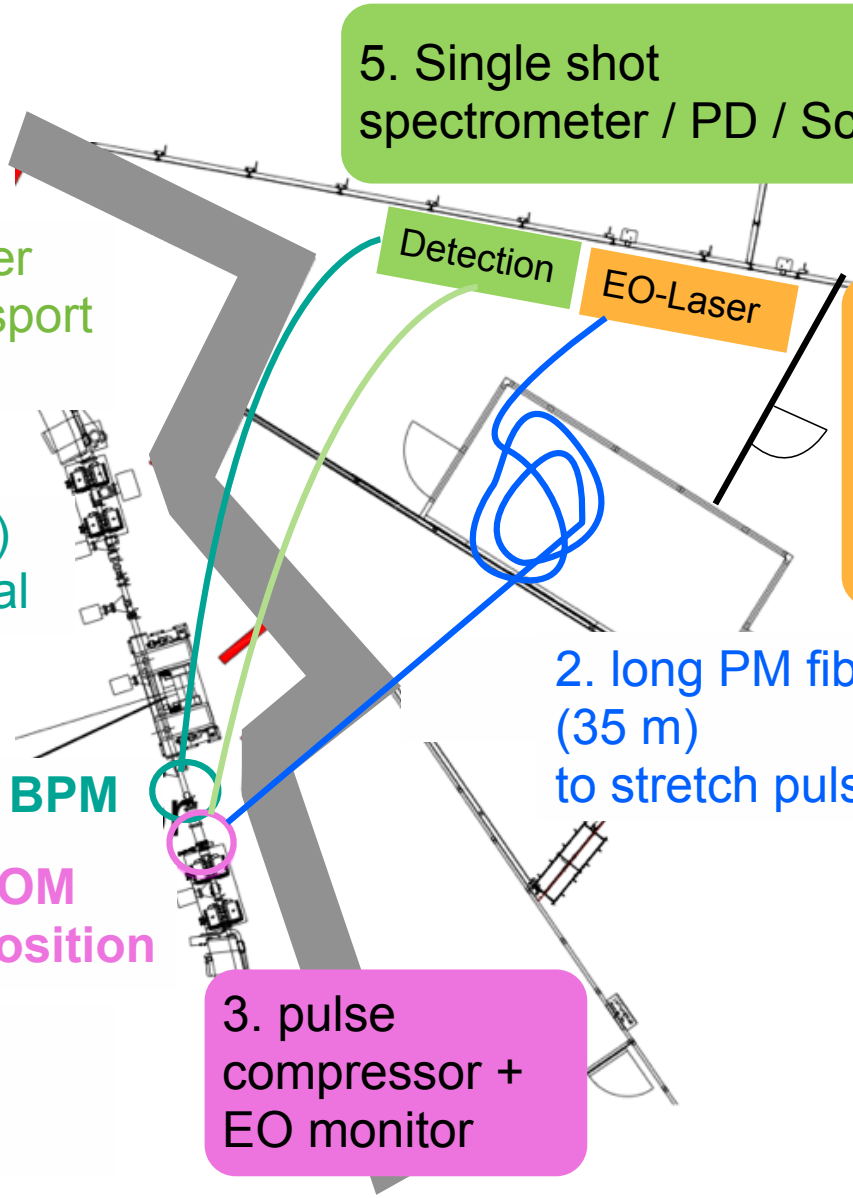


Near field: crystal close to electron beam

Far field: CSR at beam line

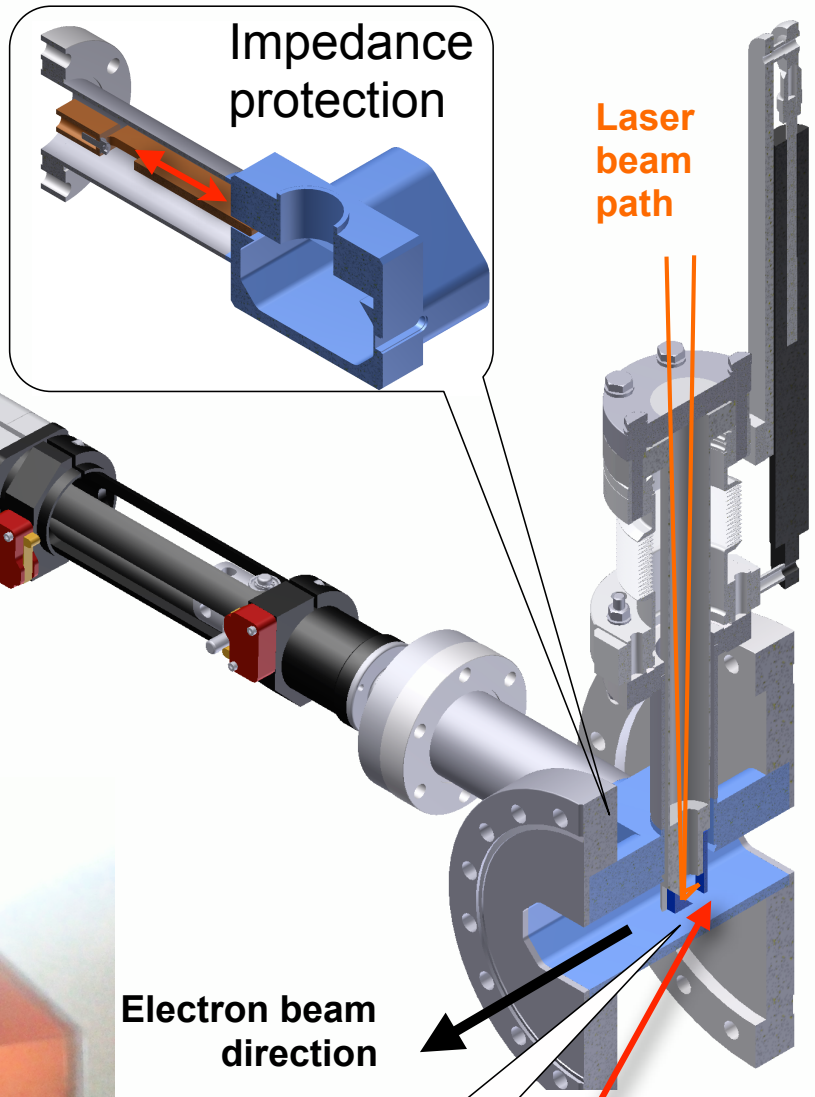
At ANKA: A. Plech et al. (PAC'09): **TU5RFP026**

Near-field EO setup at ANKA

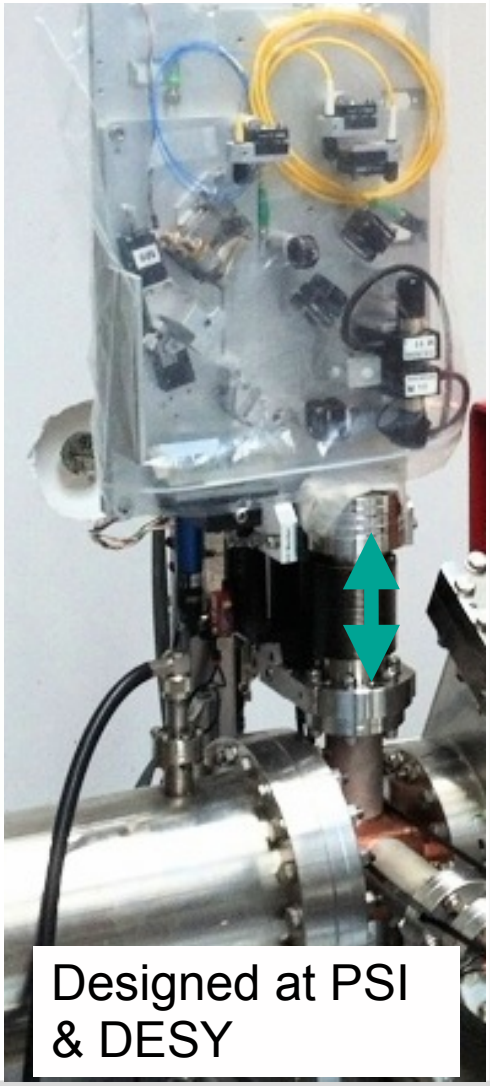


Yb-doped fiber laser system (1030 nm) developed at PSI (PhD thesis F. Müller)

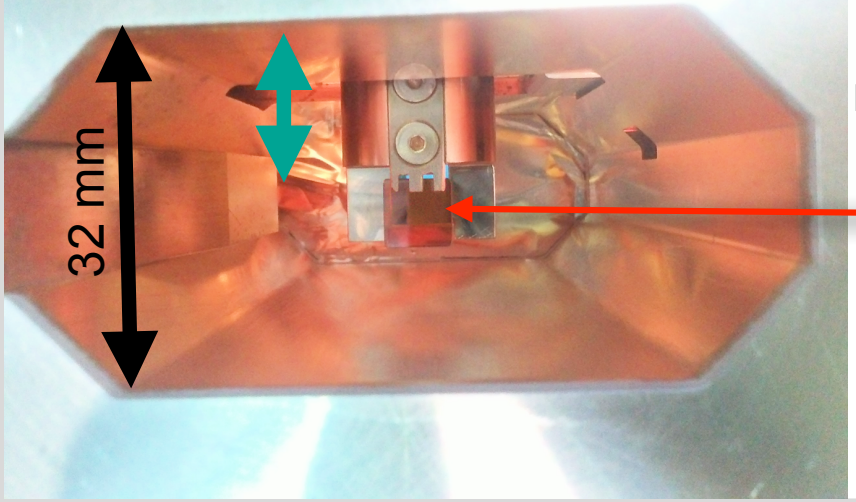
Near-Field setup at ANKA: EO-Monitor



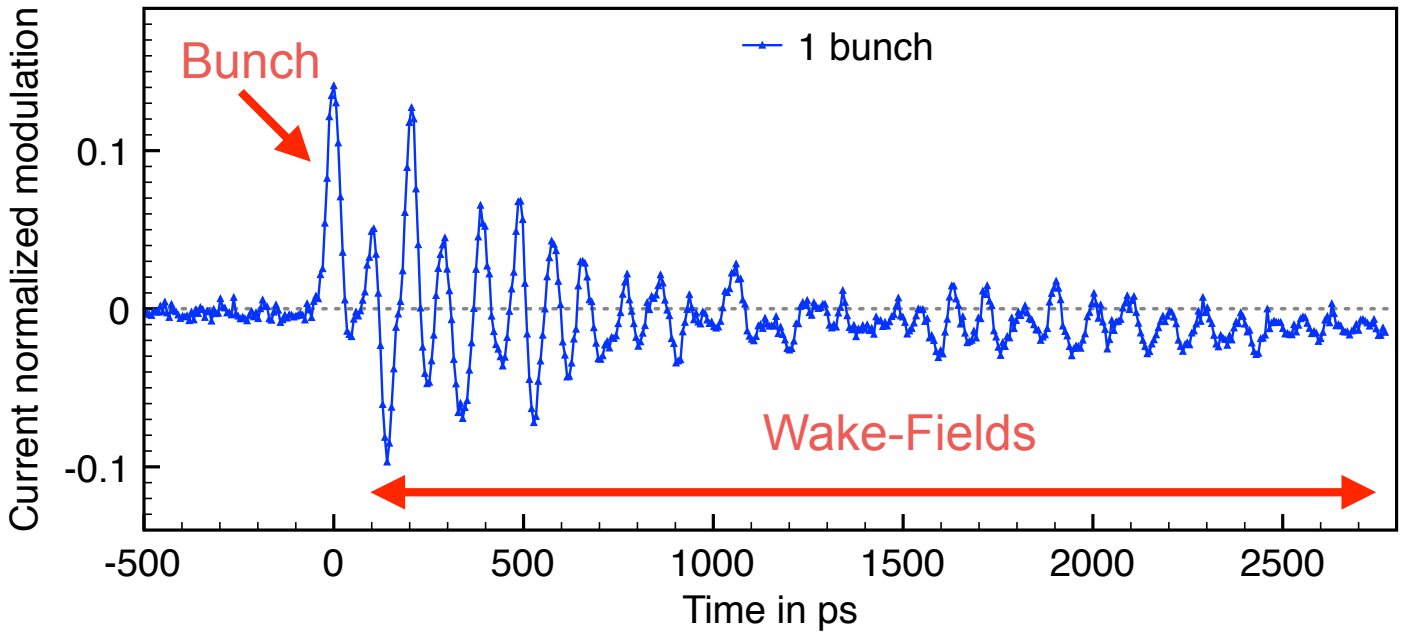
EO monitor with grating compressor and wave plates

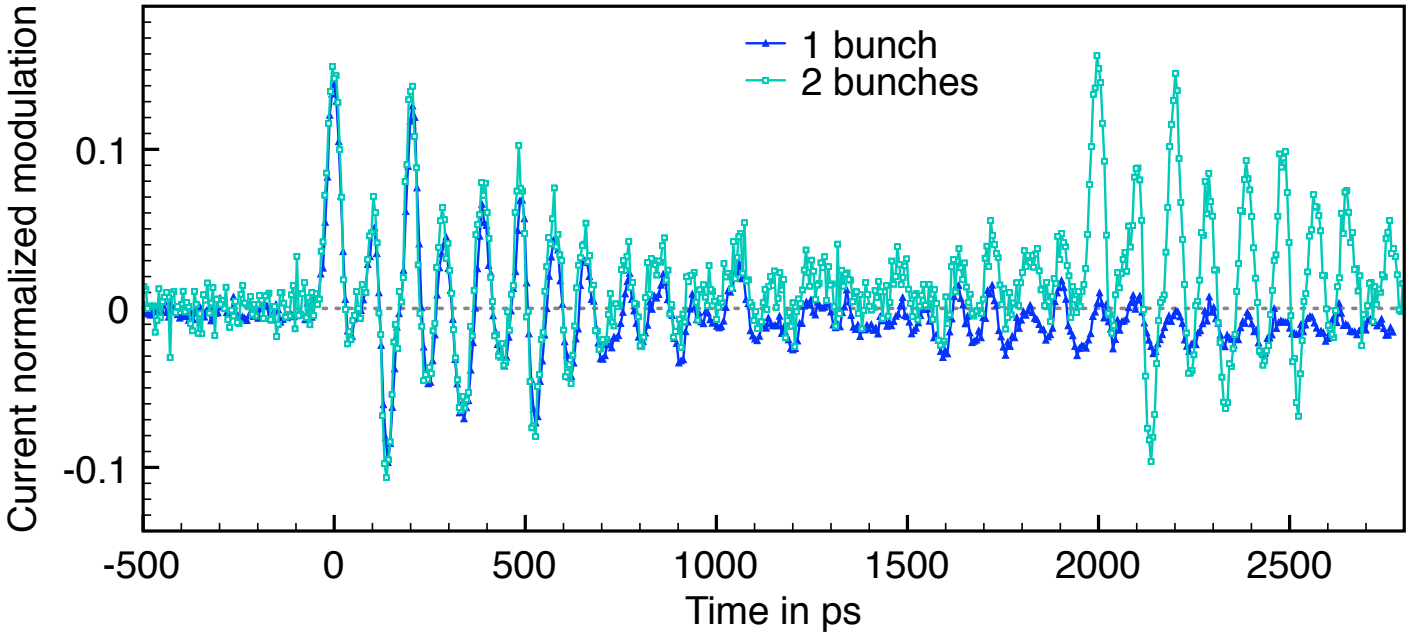


Electrons flying into plane of view



EOS: Long-Range Wake-Fields





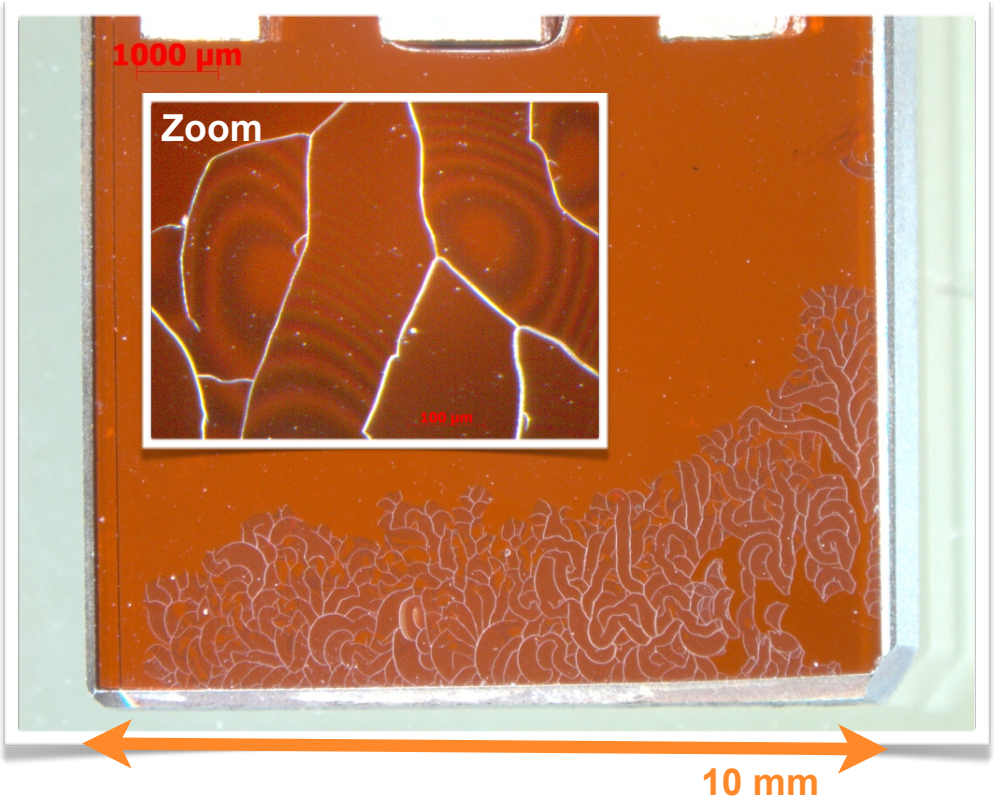
Bunch spacing 2 ns

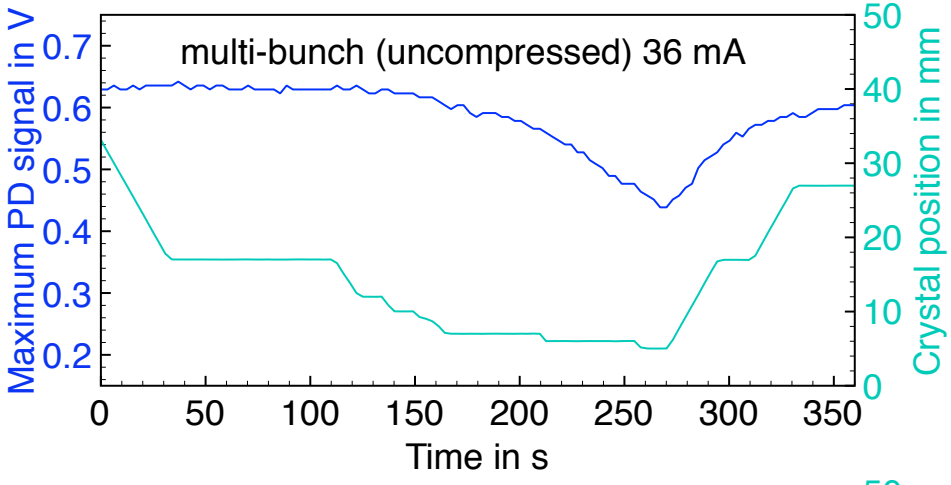
Wake-fields reach long enough to influence following bunch!

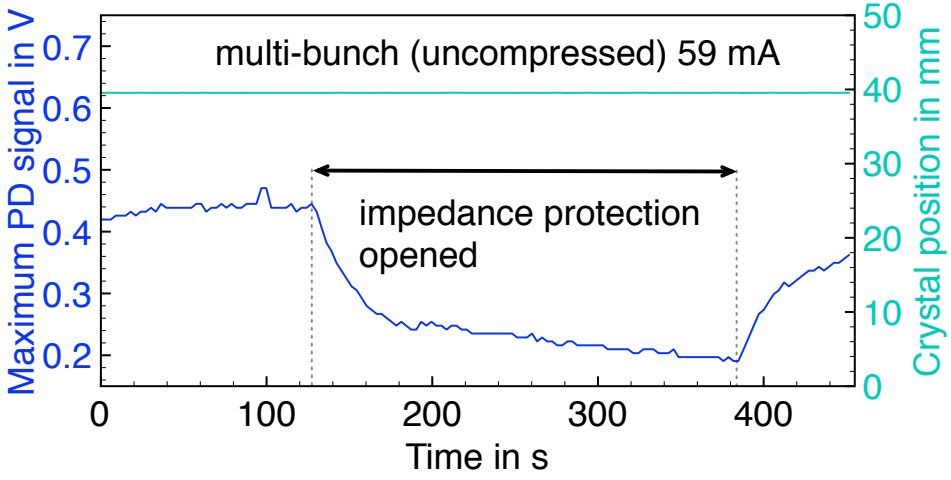
Heat load on crystal

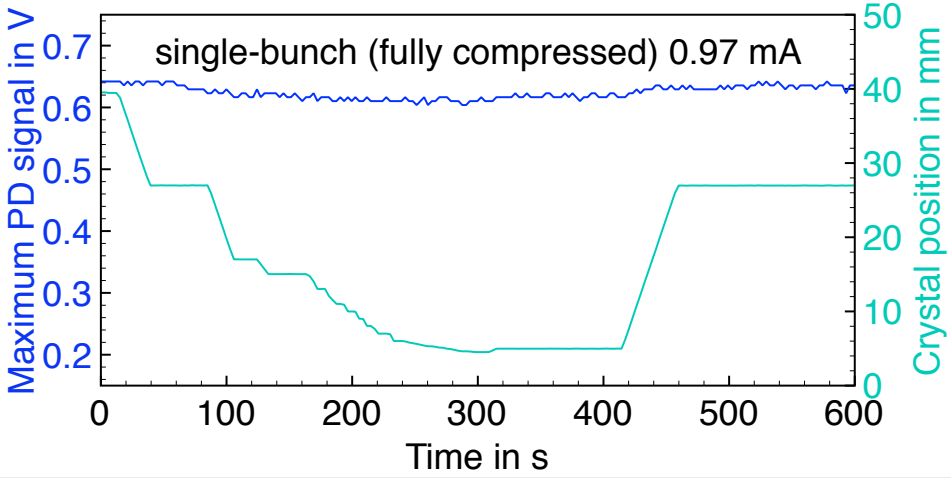
- Heat load on crystal due to wake-fields
- Estimated heat power 10 W for 31 mA multi-bunch current (CST)

In the ring from Oct 2012 - Jan 2013



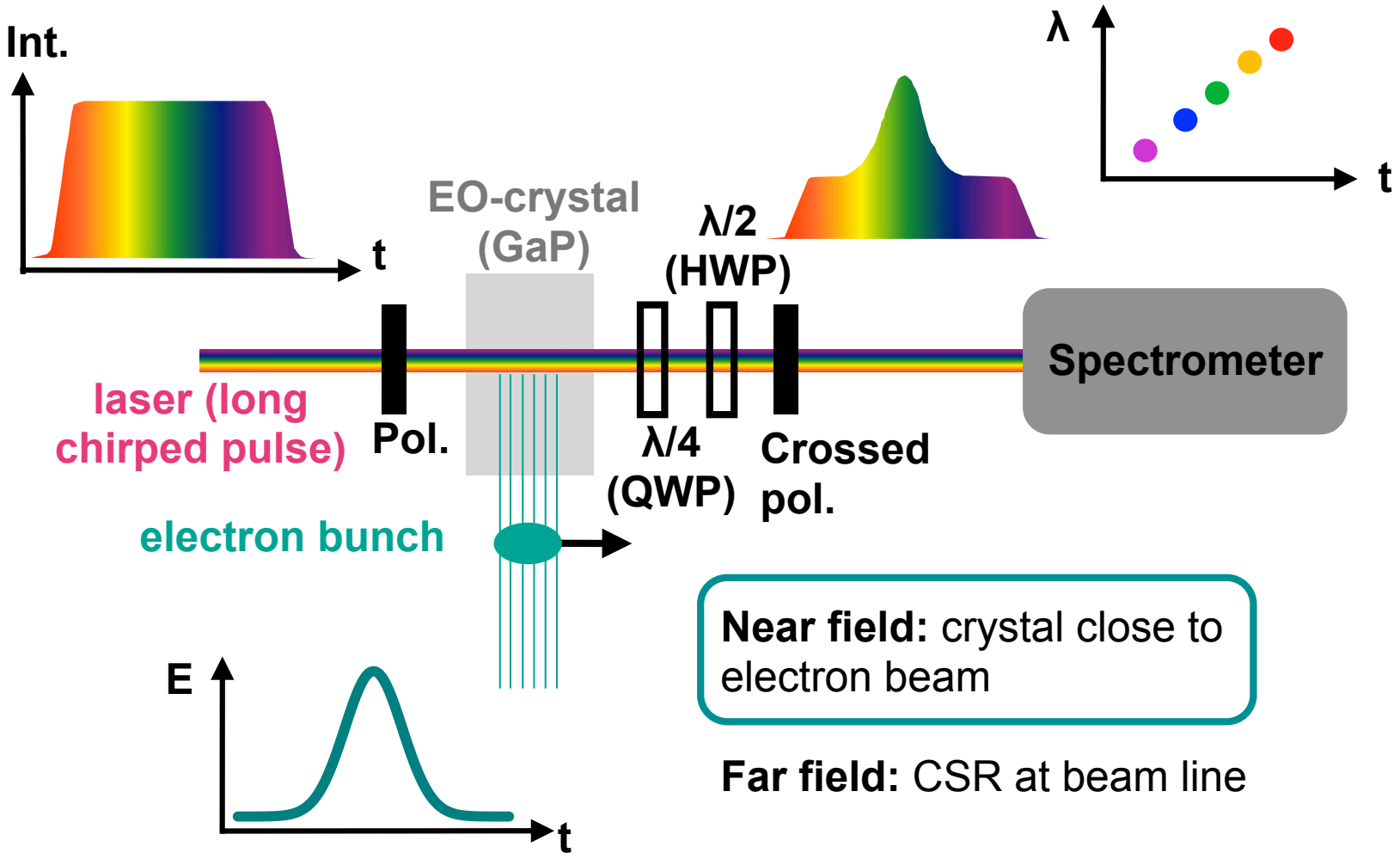






B.Kehrer et al., IPAC2013, MOPME015

Spectral Decoding (single shot) - EOSD



Near field: crystal close to electron beam

Far field: CSR at beam line

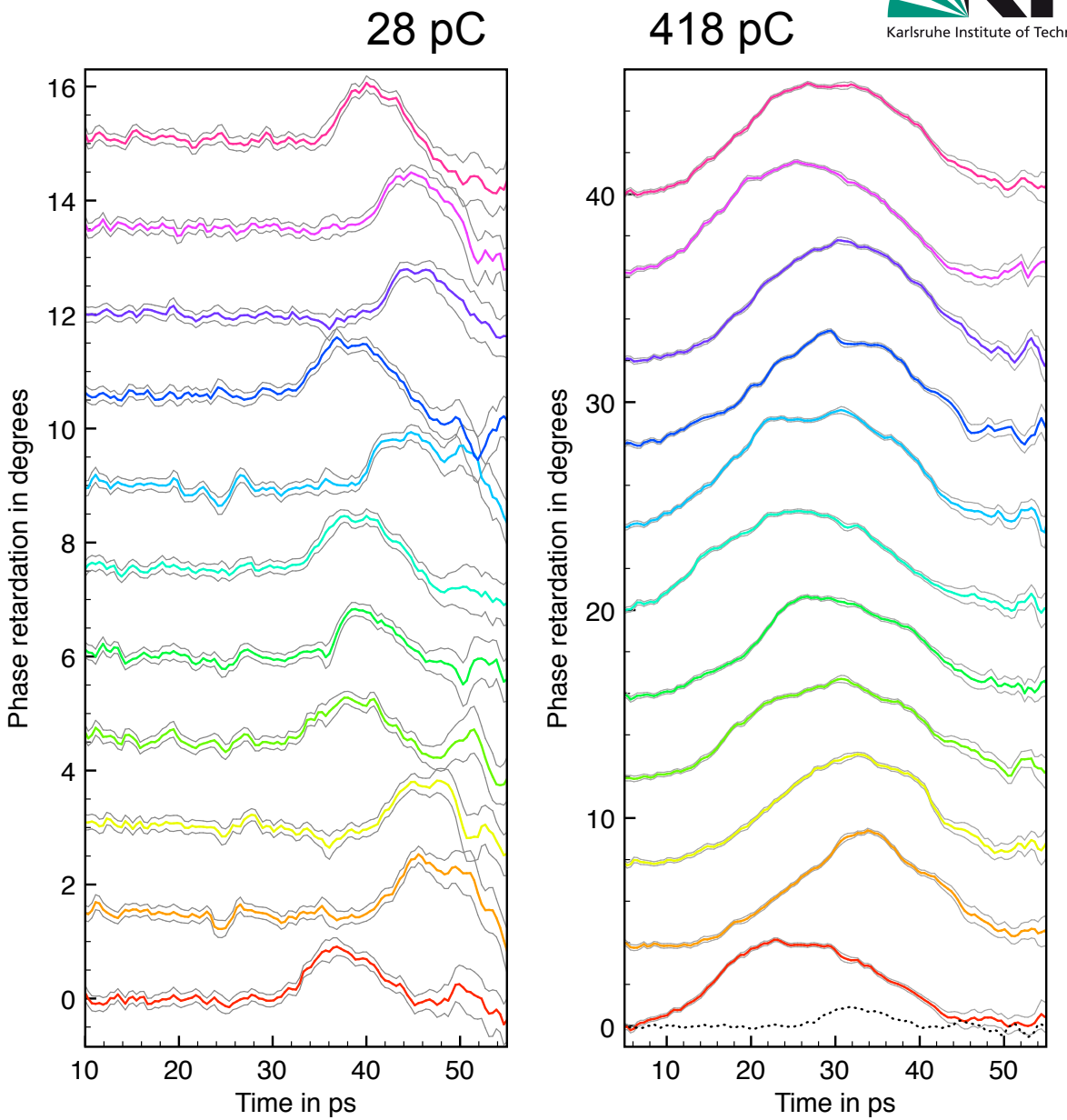
λ/4: compensate intrinsic birefringence of crystal
λ/2: control transmission through crossed polarizer

EOSD: Results

± 1σ error bands from background fluctuation measurements

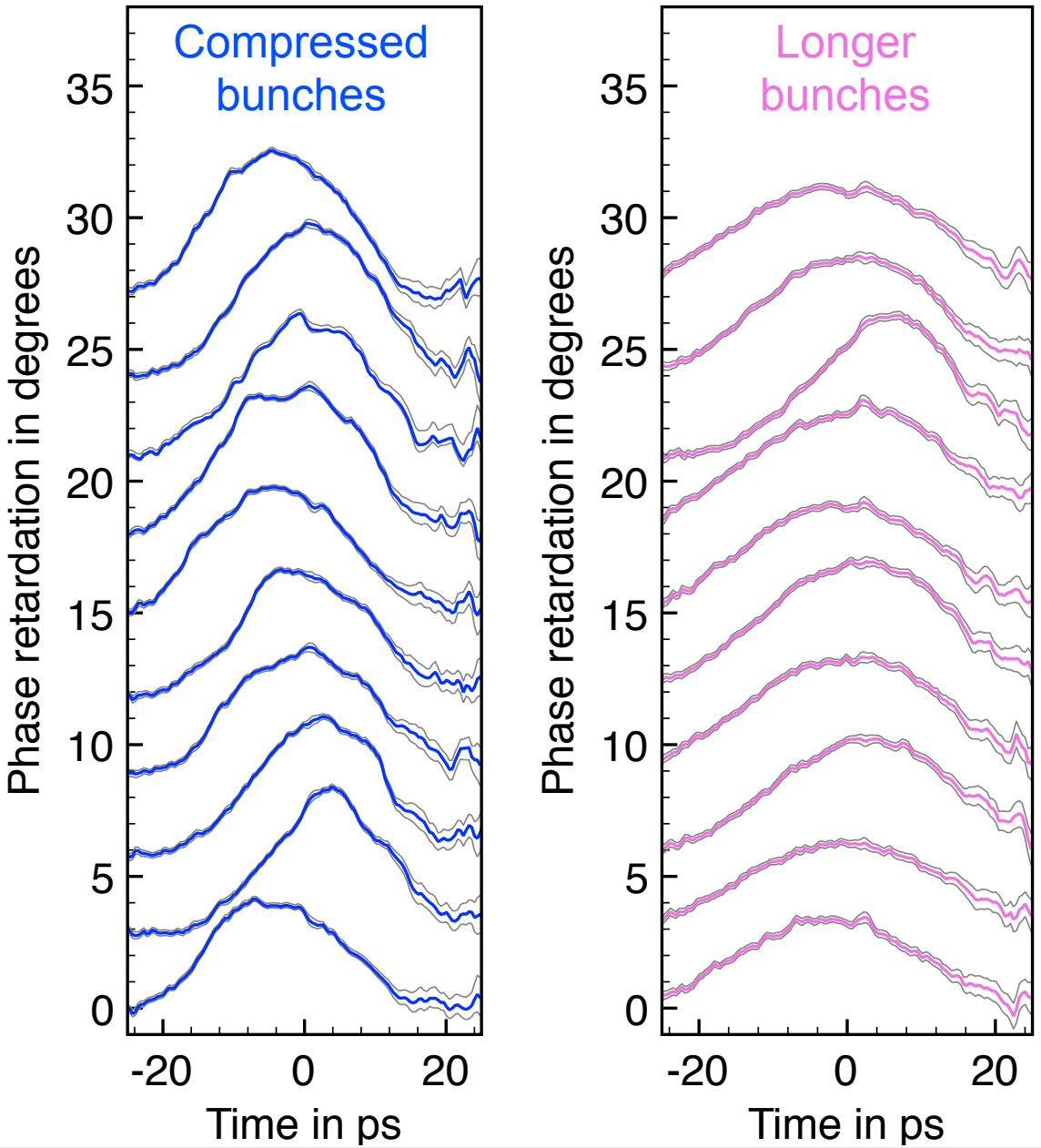
We see highly significant substructures for high bunch charges!

Resolution:
0.33 ps (granularity)
1.5 ps (point spread function)



Delay within acquisition window not ideal.

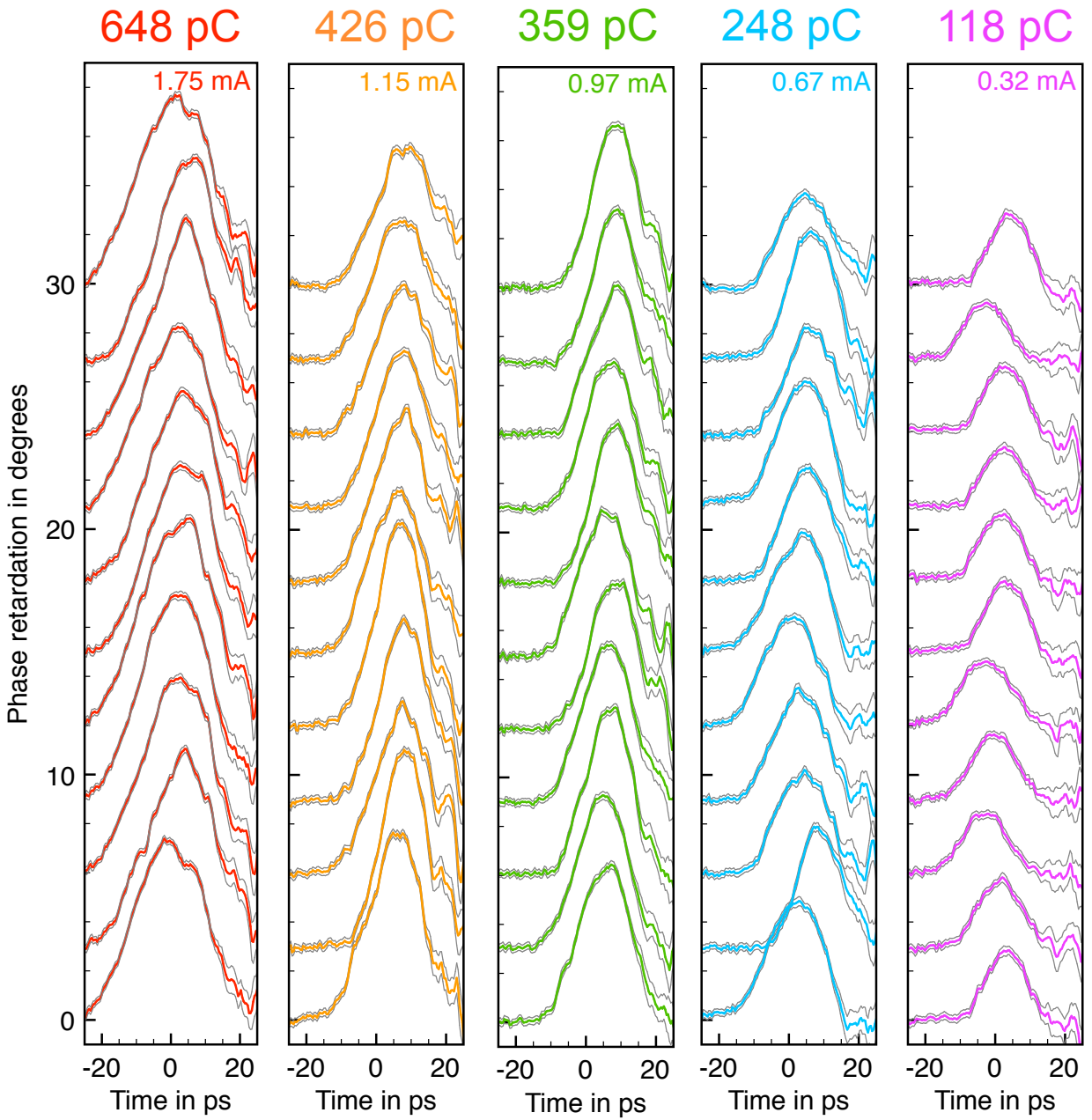
EOSD: Single-Shot Bunch Profiles for Different Electron Beam Parameters



418 pC
8.79 ± 0.63 ps

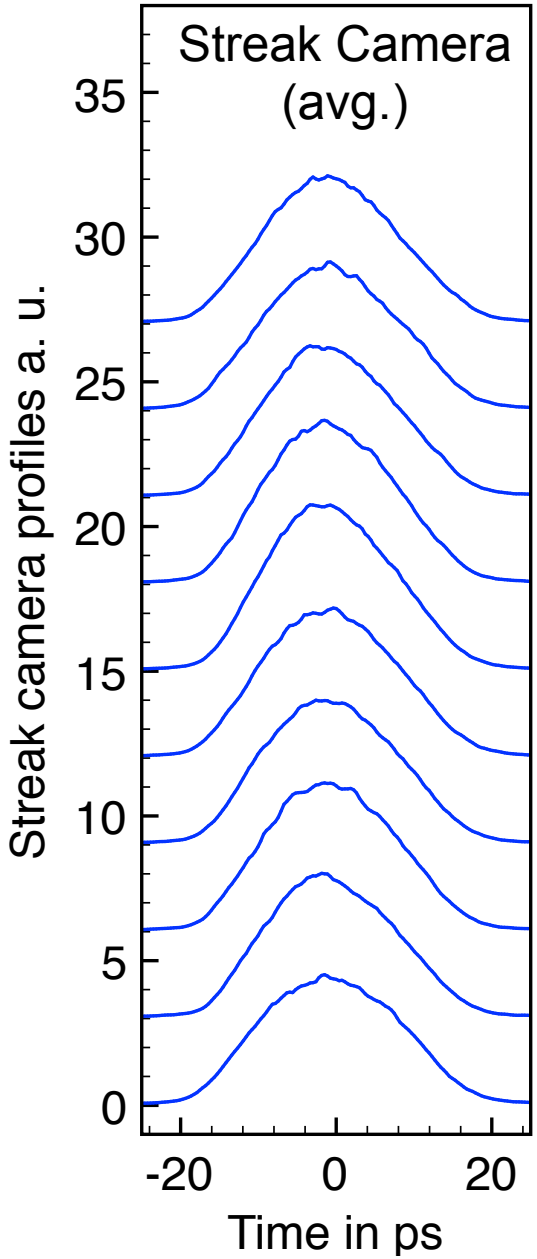
422 pC
13.56 ± 1.26 ps

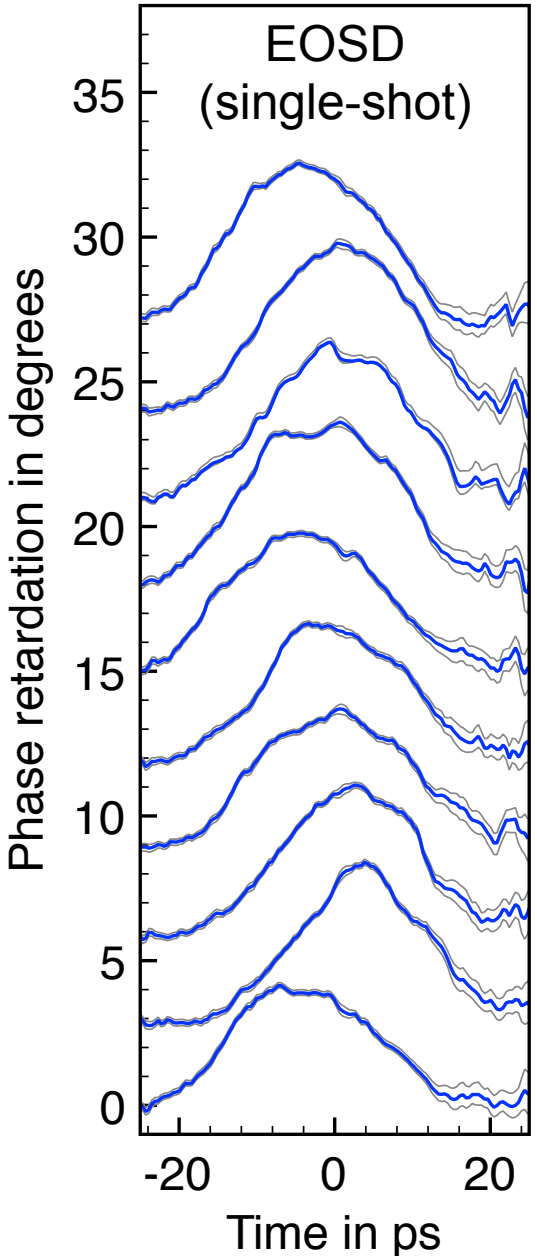
EOSD for Different Beam Currents



1 mA ≙ 370 pC
@ ANKA

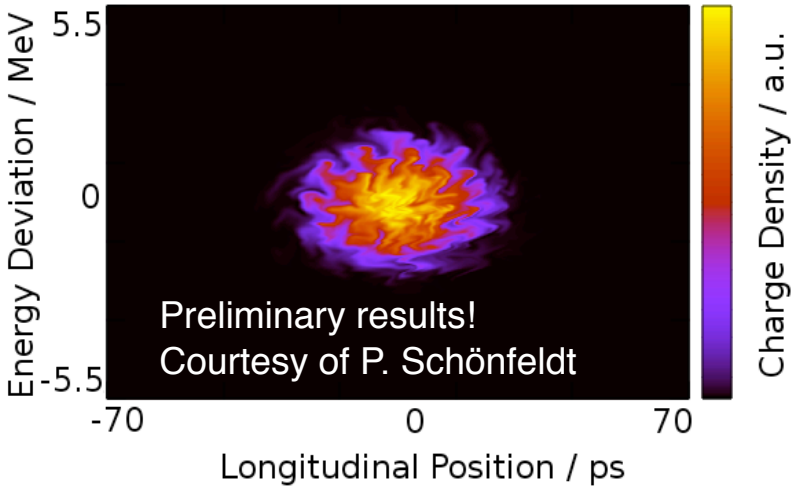
EOSD - Streak Camera - Comparison

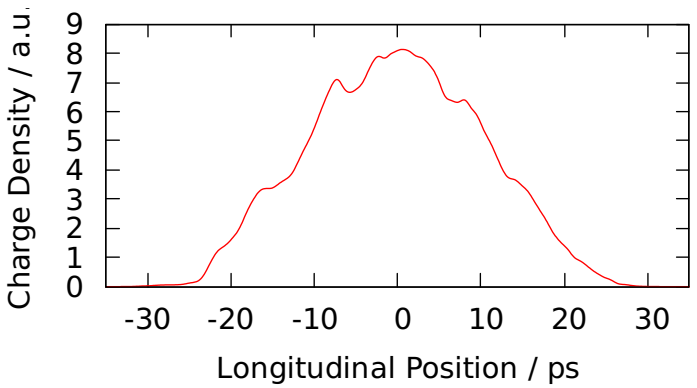




418 pC
(both recorded
at same time)

EOSD can
resolve
substructures!





Summary

- EO setup at ANKA installed & commissioned
  - ➜ Highly sensitive and reliable diagnostics tool
  - ➜ Now a standard measurement tool during low-α_c-operation
- EOS (averaged) ➜ observe long-range wake-fields spanning the distance between bunches
- EOSD (single-shot) ➜ detect bunch-substructures

Next Steps

- **Direct correlation of THz signal and bunch profiles on a turn-by-turn basis**
- **EO-Methods**
  - Fast-Readout of Spectrometer (spectra with up to 2.7 MHz rep. rate with GOTTHARD chip)
  - Optimize geometry to minimize wake-fields and allow measurements in multi-bunch operation
  - Increase of the resolution

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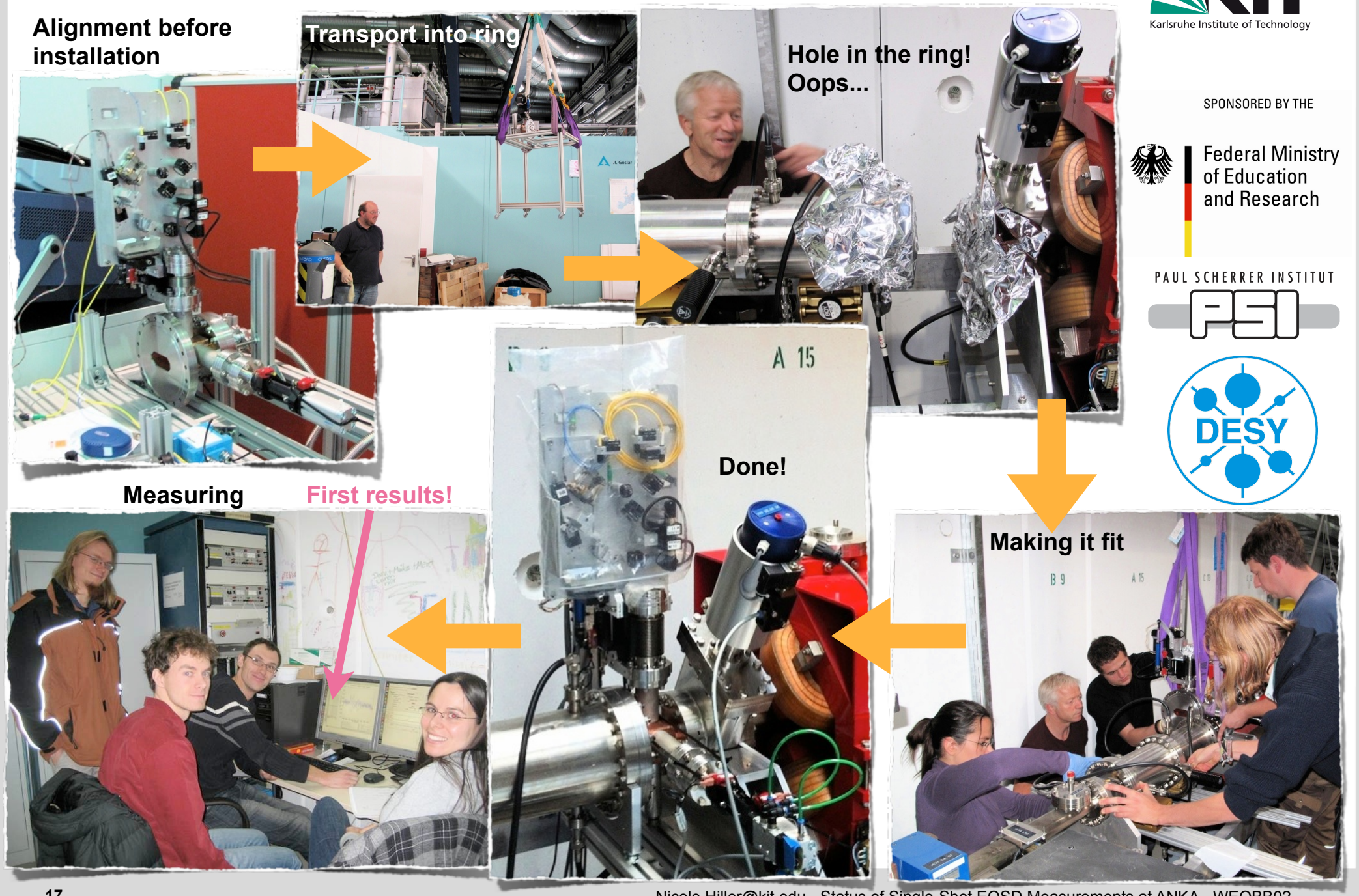
Thank you for your attention/support!



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