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ANKA THZ GROUP

Single-Shot EOSD Measurements at ANKA

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for the KIT-THz-Team

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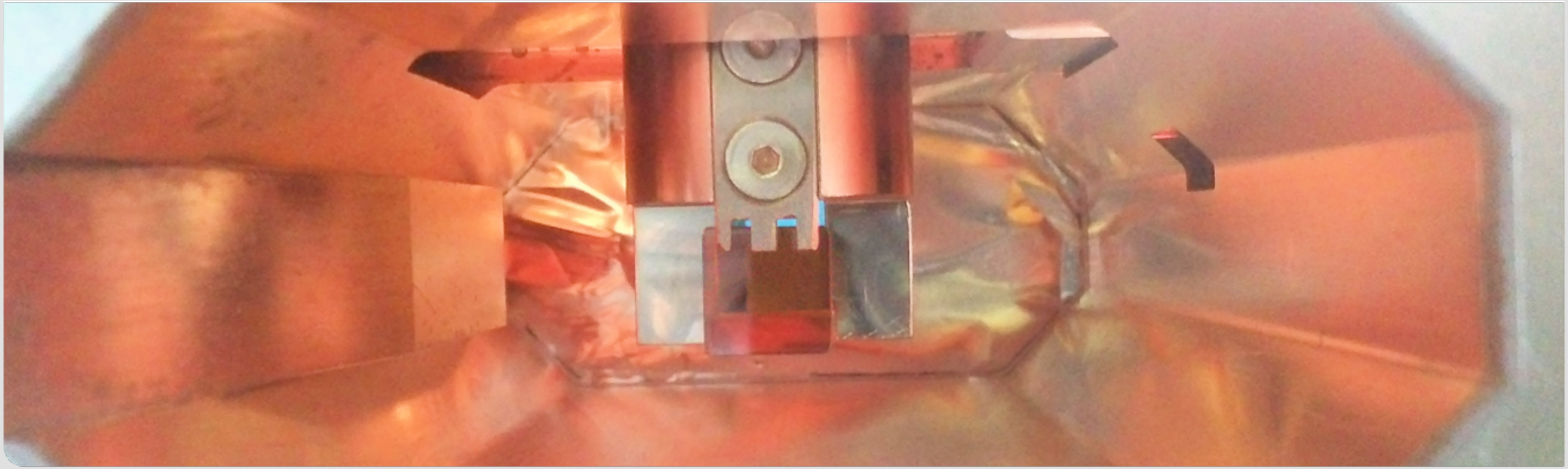
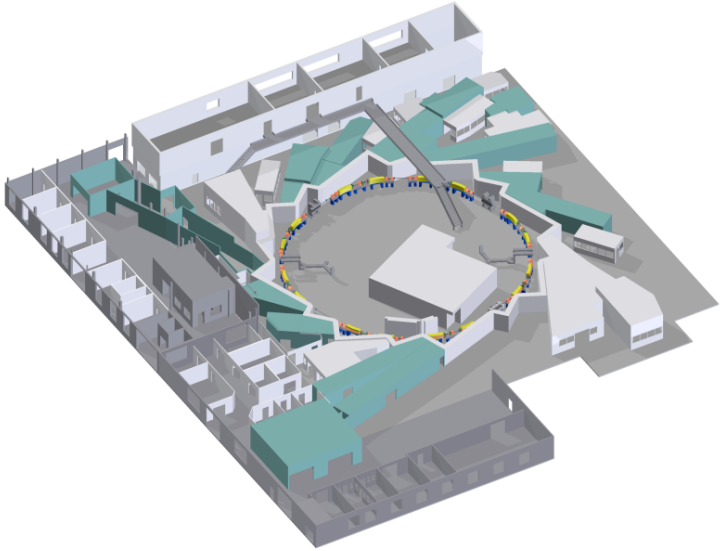


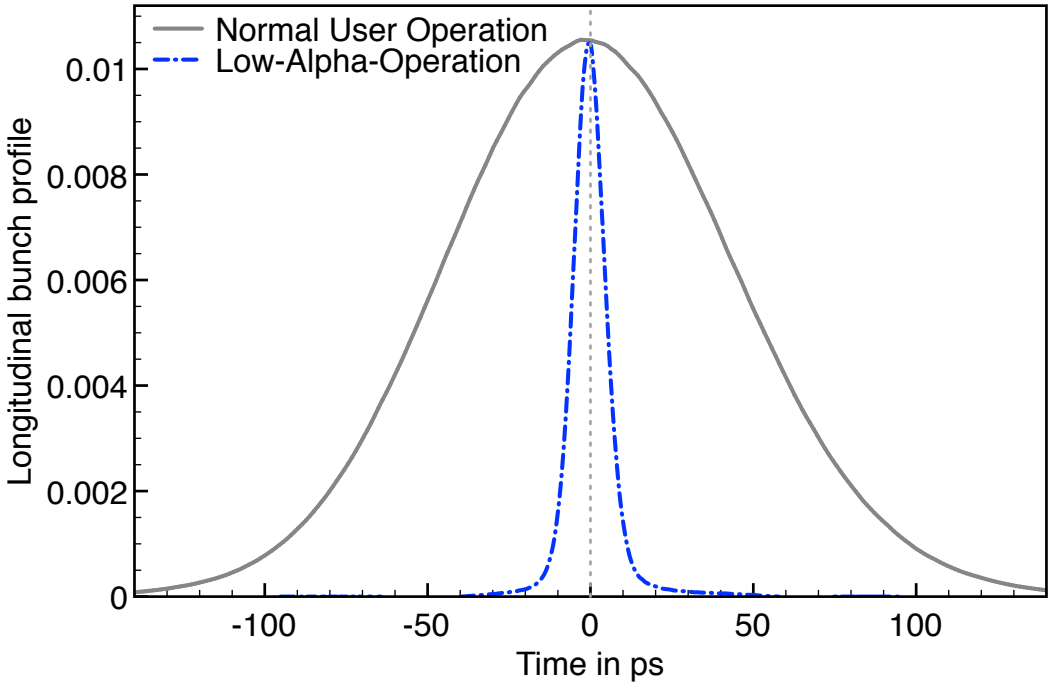
Outline

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

Introduction: Low-α_c-Operation at ANKA

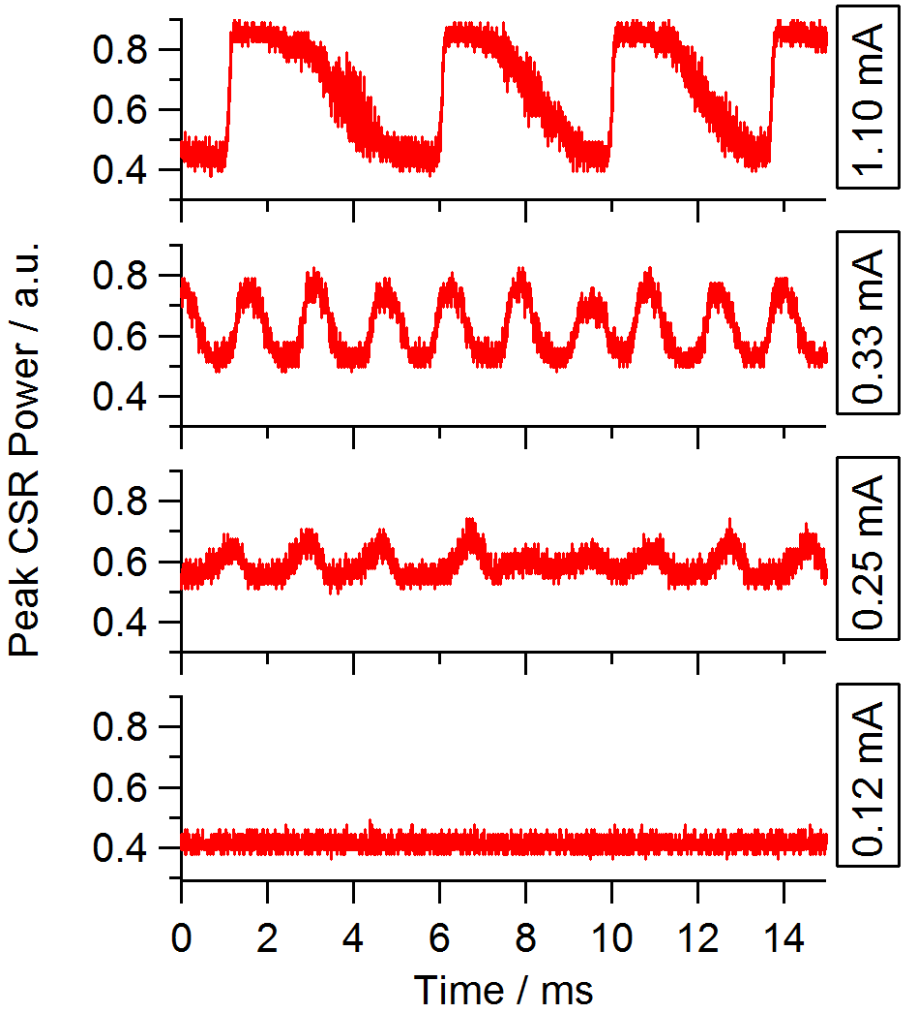
- **Generation of coherent synchrotron radiation (CSR)**
- Circumference: 110.4 m
- Revolution frequency: 2.715 MHz
- Energy: 0.5 - 2.5 GeV (0.8 - 1.6 GeV during low-α_c-mode)
- RMS bunch length: 45 ps (for 2.5 GeV), **10 ps down to 1-2 ps (for 1.3 GeV)**
- Filling pattern: **single- or multi-bunch (min.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



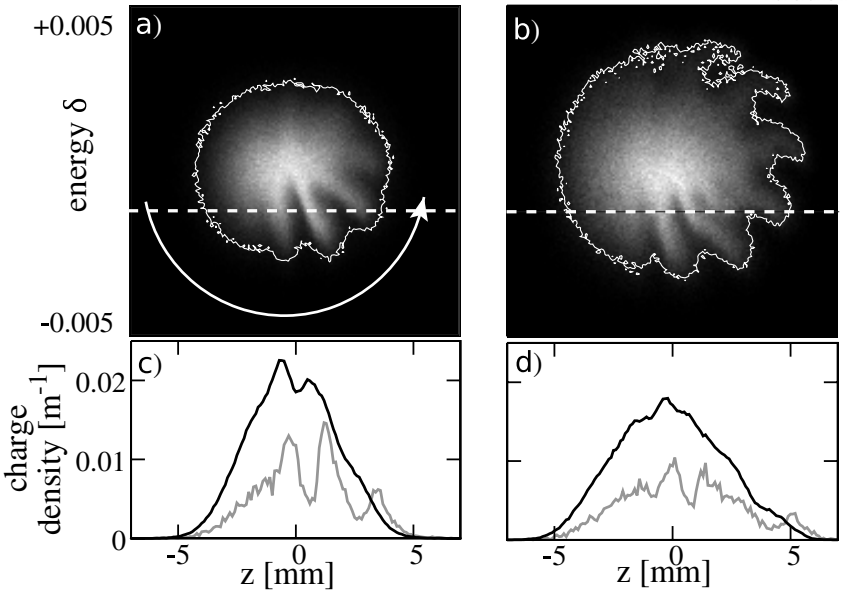


Motivation

Bursting behavior of CSR → microbunching



Courtesy of J. Steinmann



C. Evain, et al., "Spatio-temporal dynamics of relativistic electron bunches during the micro-bunching instability in storage rings," EPL (Europhysics Letters), vol. 98, no. 4, p. 40006, May 2012.

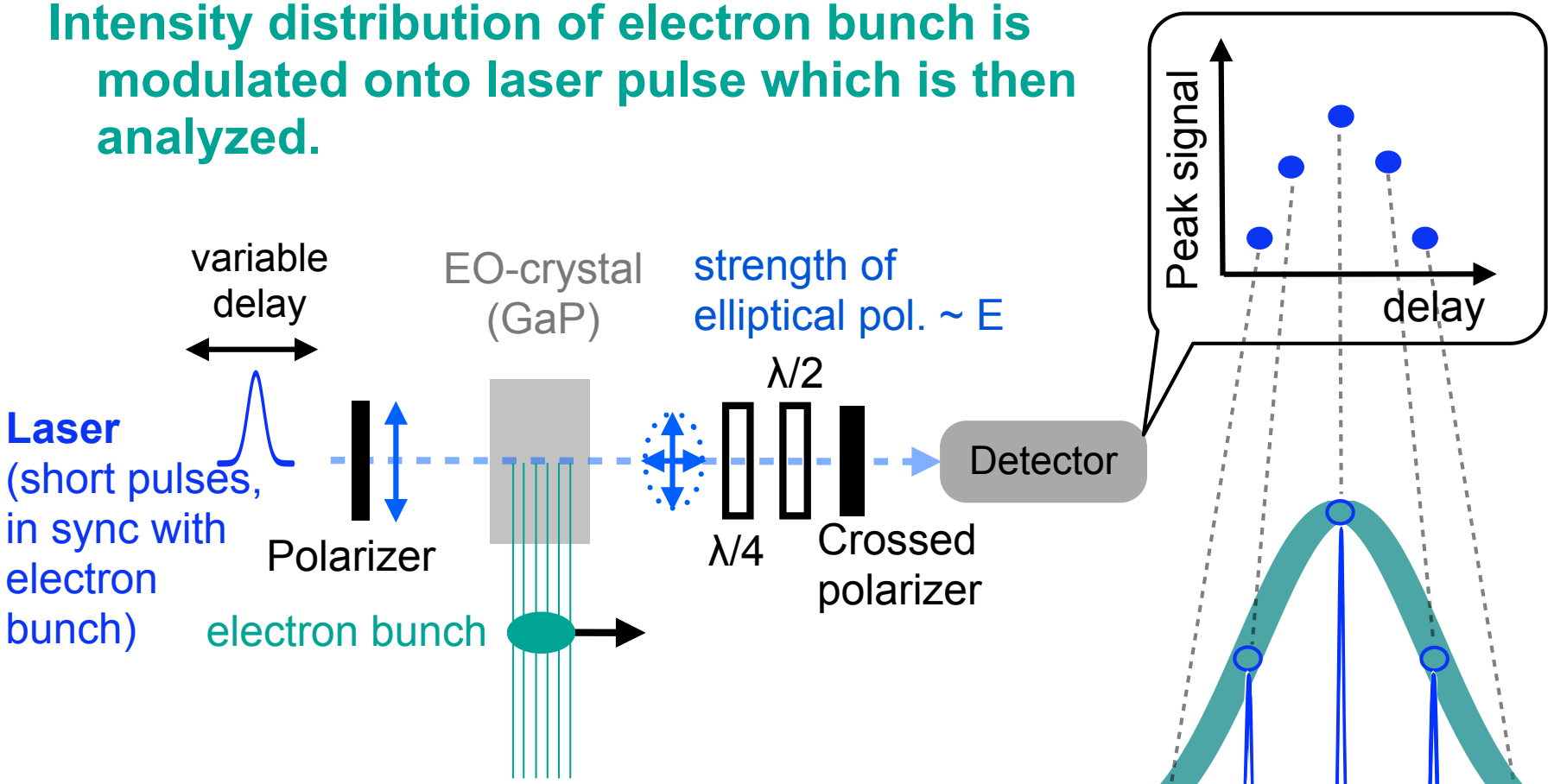
- **What we want to measure:**
  - **Ideally:** Long. phase space for every bunch and every revolution
  - **Realistically:** THz-signal & longitudinal bunch profile on a bunch-by-bunch & turn-by-turn basis

Longitudinal Diagnostics at ANKA

- **Time domain:**
  - Time-correlated single photon counting ➜ filling pattern
  - Fast-THz-detectors + DAQ-board ➜ THz-intensity of every bunch for every revolution
  - Low-Noise Block (LNB) microwave detector
  - Streak camera ➜ averaged bunch profiles, evolution over consecutive revolutions
  - Electro-Optical methods (EOS, EOSD) ➜ long-ranged wake-fields, single-shot bunch profiles
- **Frequency domain:**
  - Martin-Puplett interferometer ➜ Spectrum of CSR
  - FTIR Michelson interferometer

Electro-Optical Sampling (EOS)

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



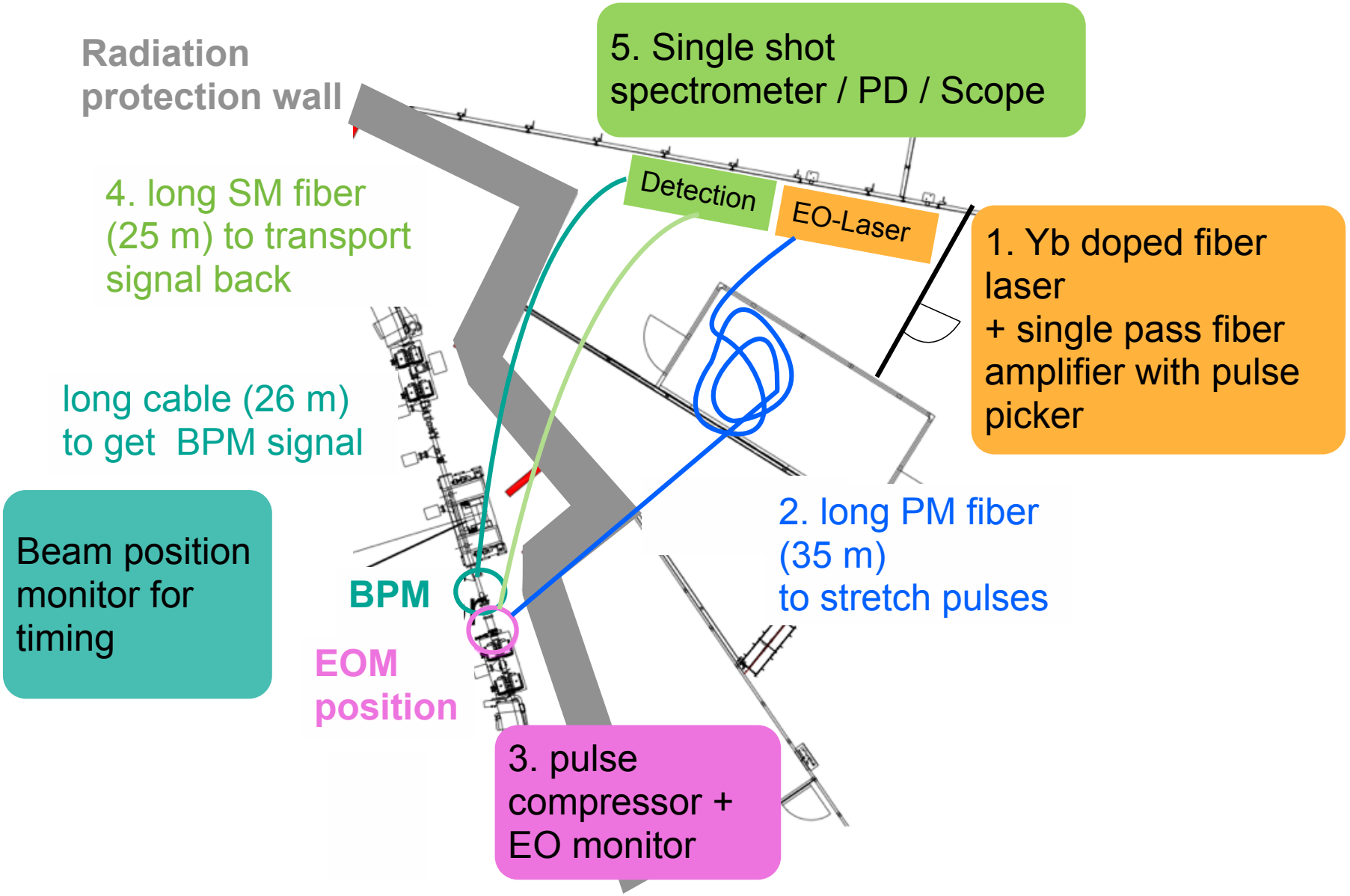
Near field: crystal close to electron beam

1st time at a ring!

Far field: CSR at beam line

best S/N ratio for nearly crossed polarizer and analyzer angles

Near-field EO set up at ANKA



Near-Field setup at ANKA: EO-Monitor

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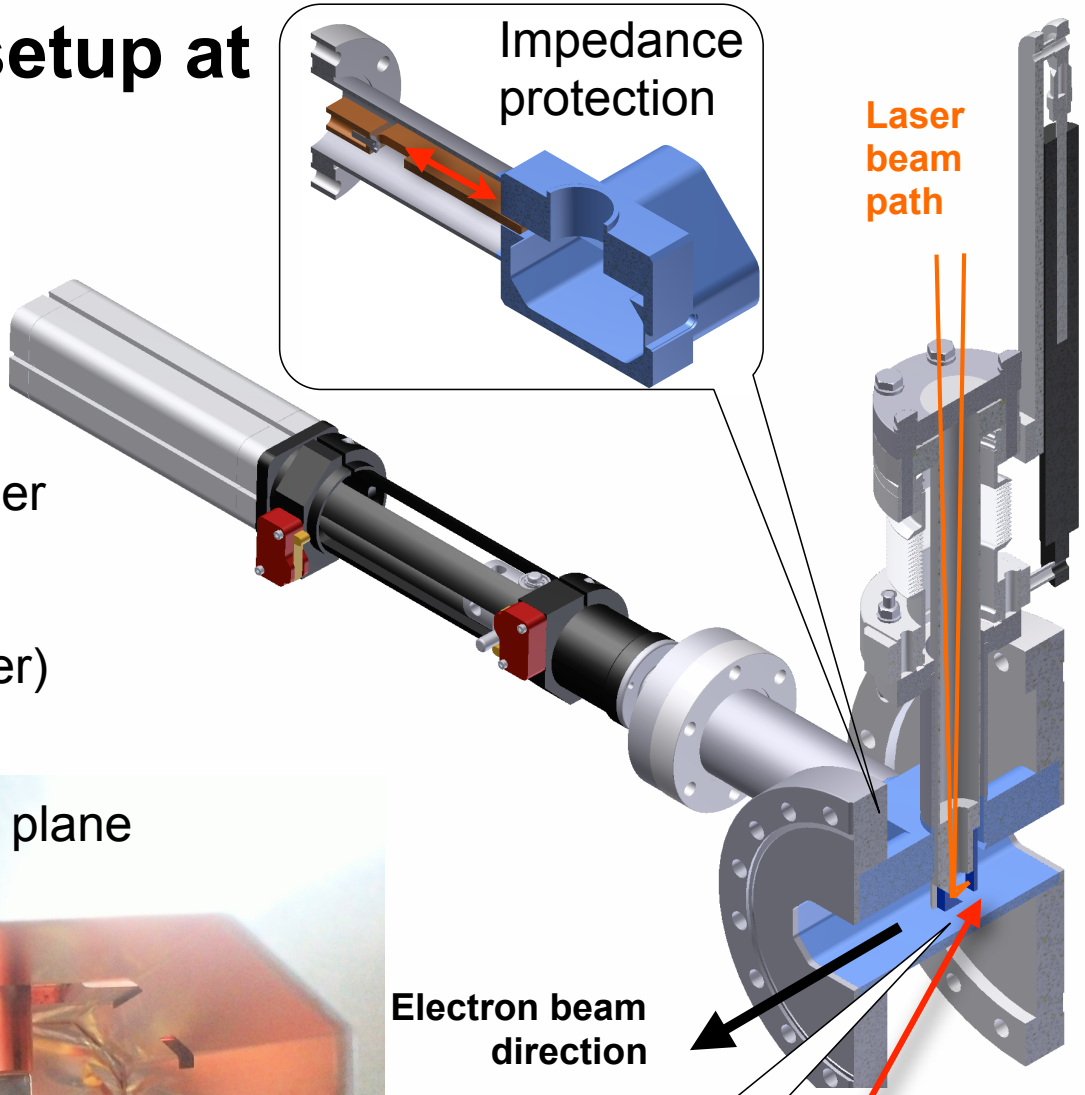
Impedance protection

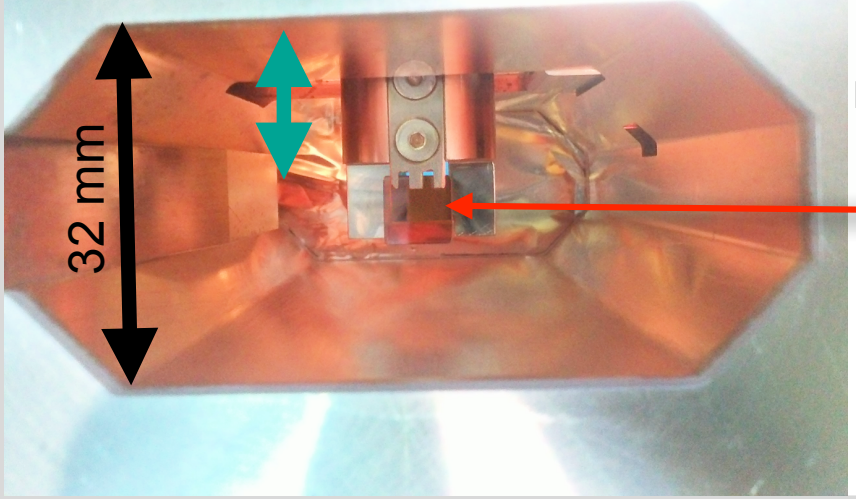
Laser beam path

EO monitor with grating compressor and wave plates

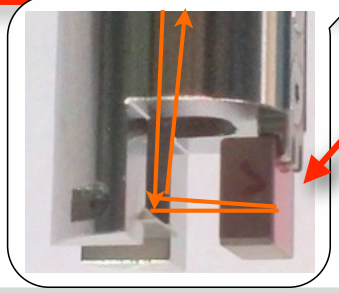
Yb-doped fiber laser system (1030 nm) developed at PSI (PhD topic F. Müller)



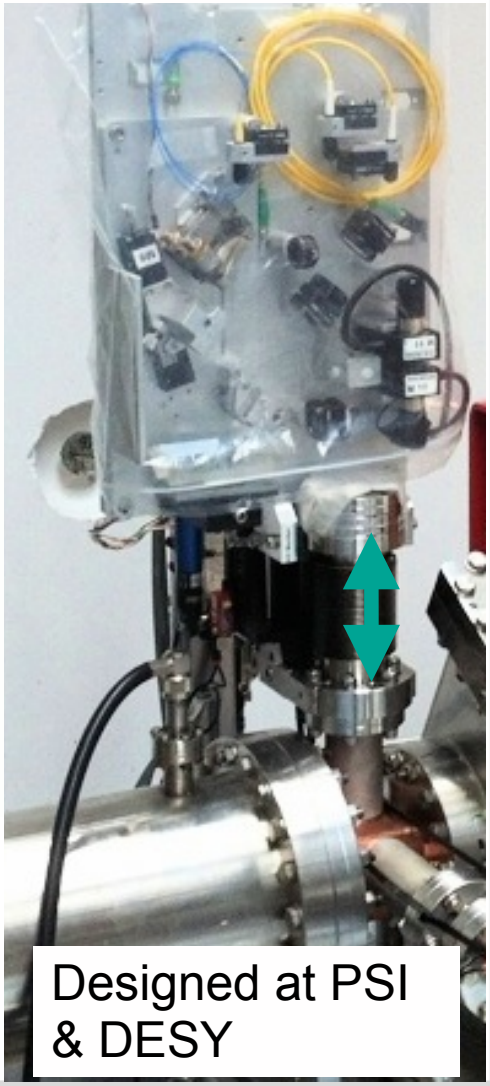
Electrons flying into plane of view



Electron beam direction

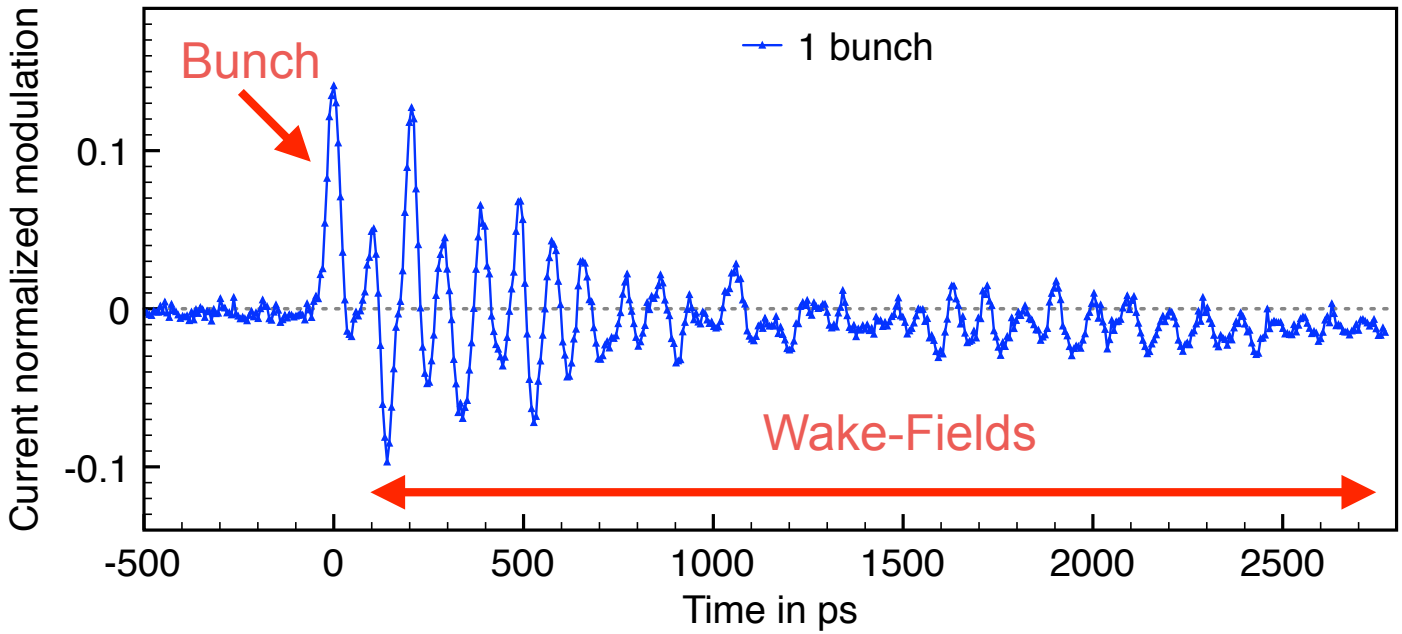


crystal (laser is reflected at HR coated back surface)



Designed at PSI & DESY

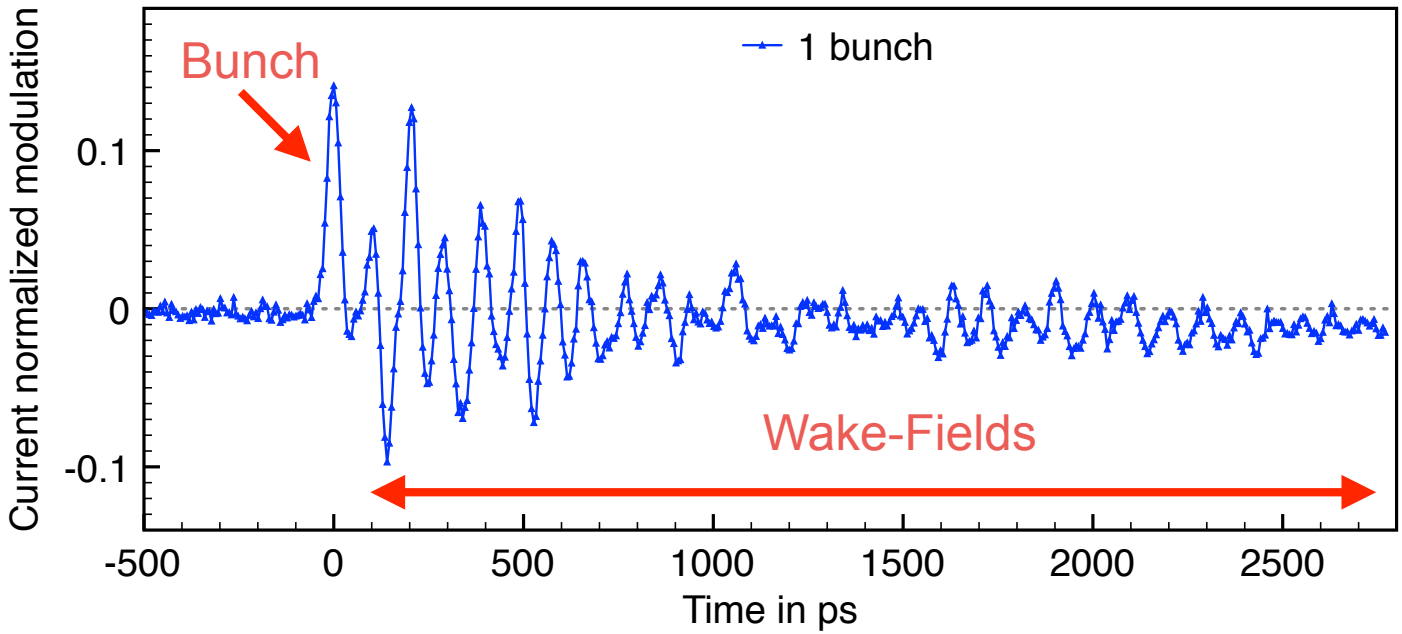
EOS: Long-Range Wake-Fields

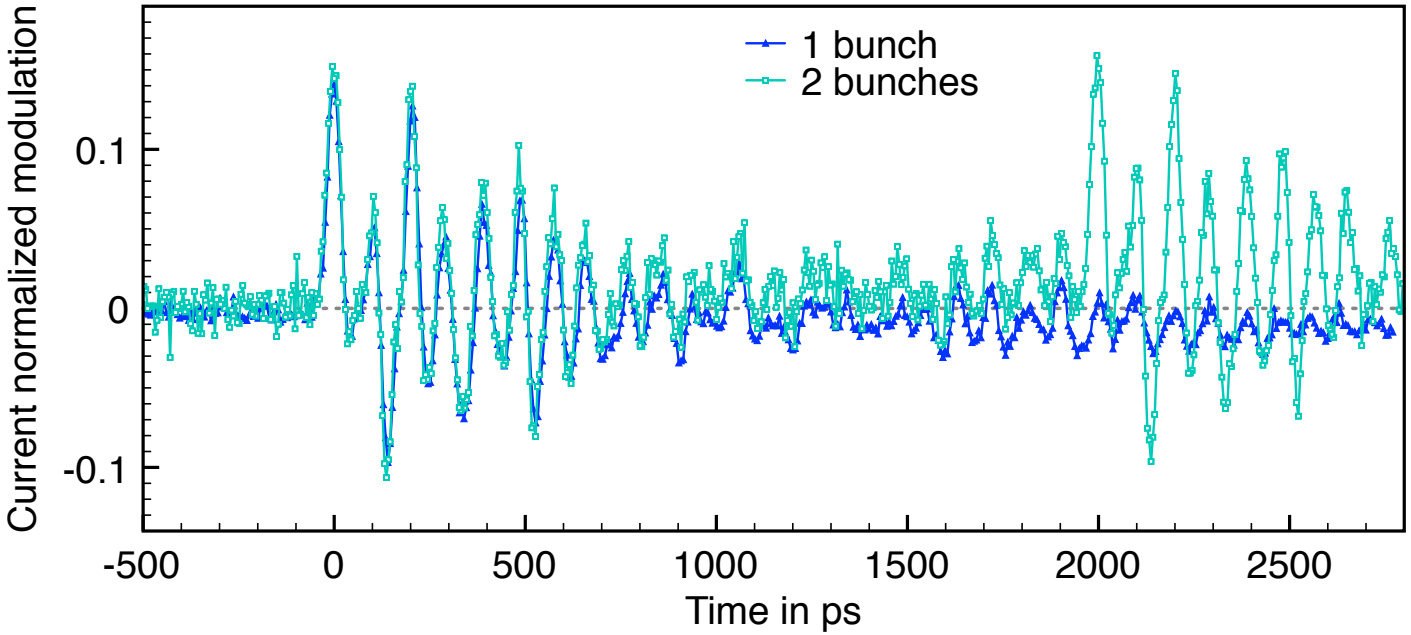


Bunch spacing 2 ns

Wake-fields reach long enough to influence following bunch!

EOS: Long-Range Wake-Fields

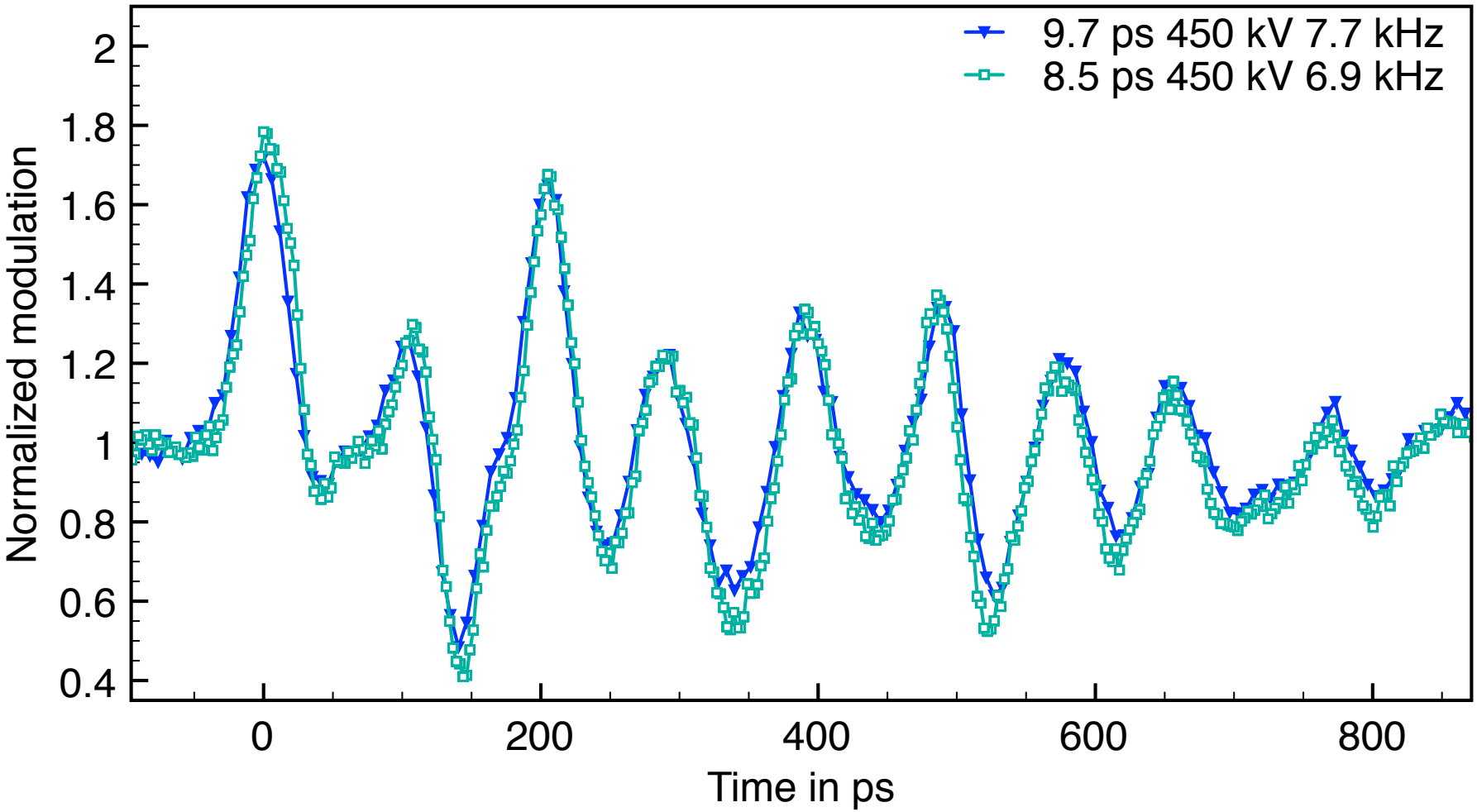




Bunch spacing 2 ns

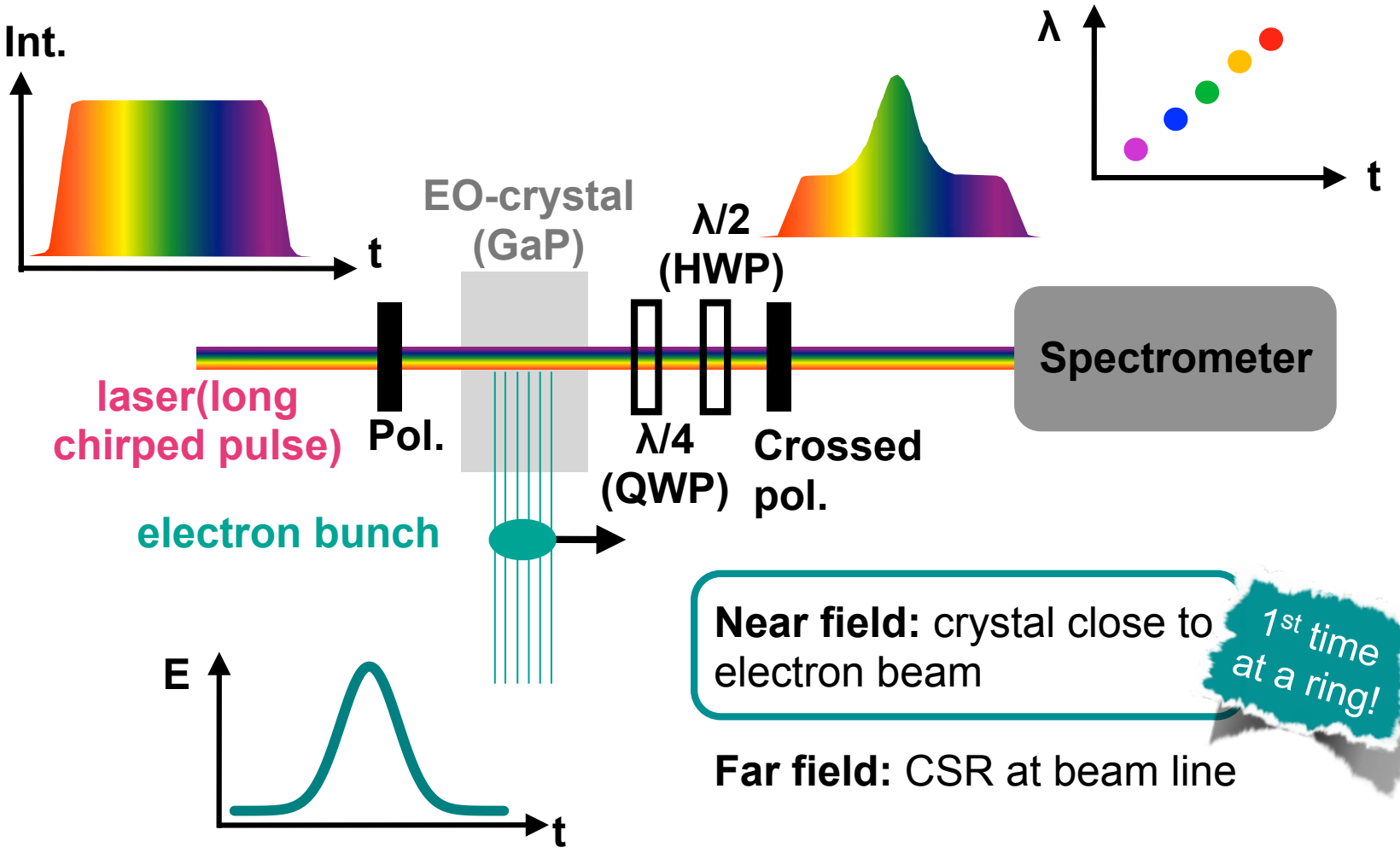
Wake-fields reach long enough to influence following bunch!

EOS: Signal Reproducibility



Signal normalized to beam current.

Spectral Decoding (single shot) - EOSD



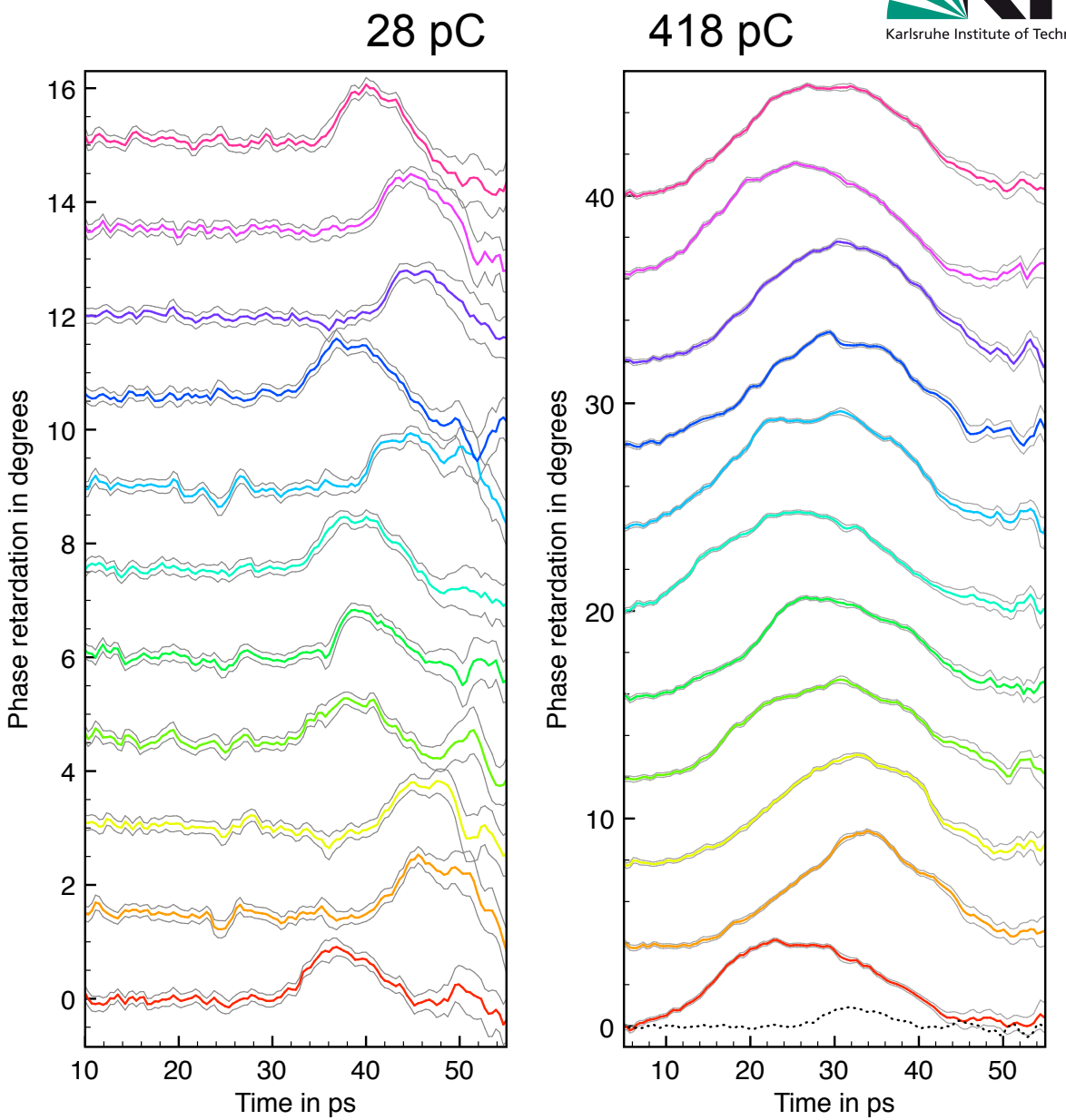
λ/4: compensate intrinsic birefringence of crystal
λ/2: control transmission through crossed polarizer

EOSD: Results

± 1σ error bands from background fluctuation measurements

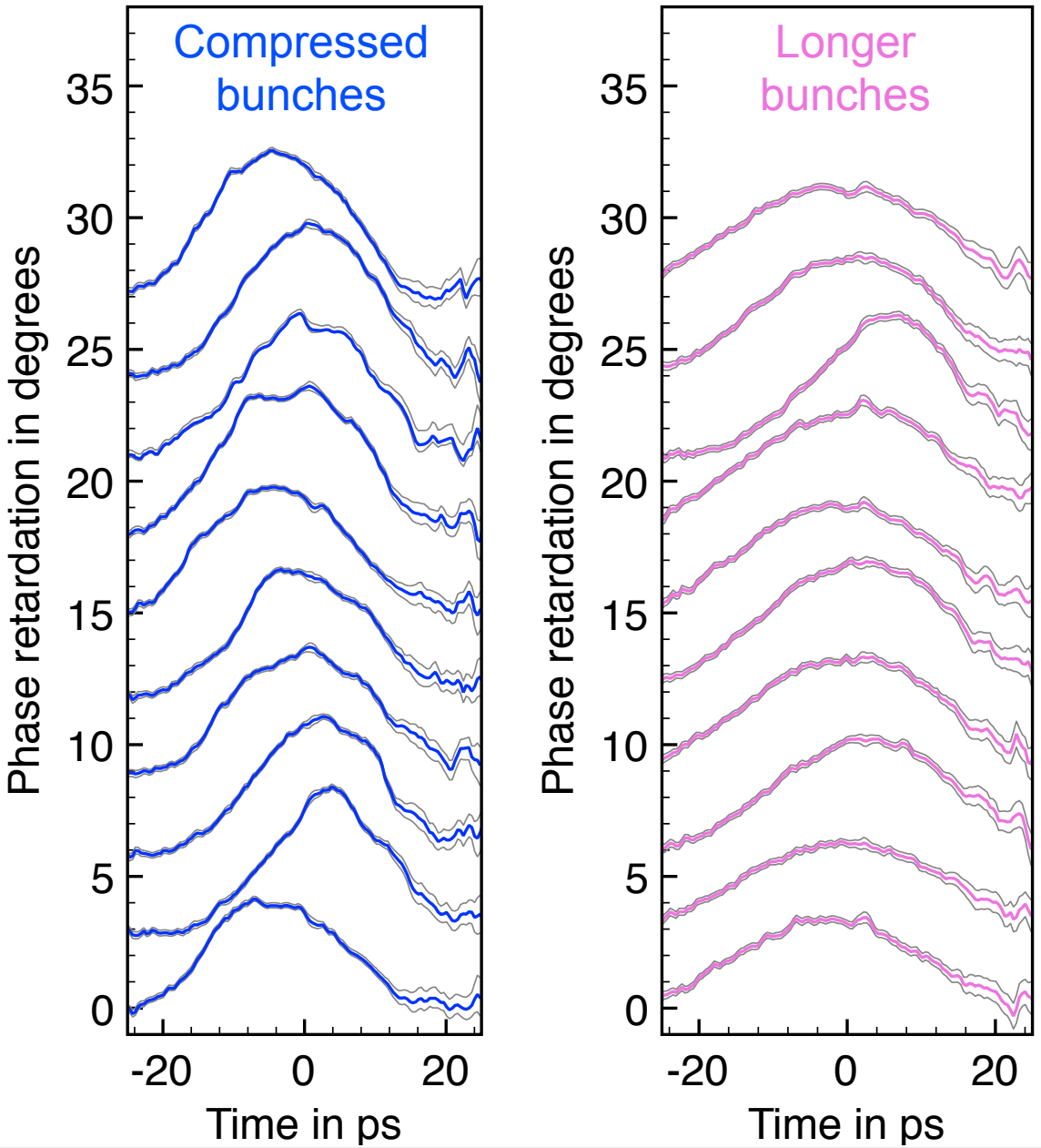
We see highly significant substructures for high bunch charges!

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



Delay within acquisition window not ideal.

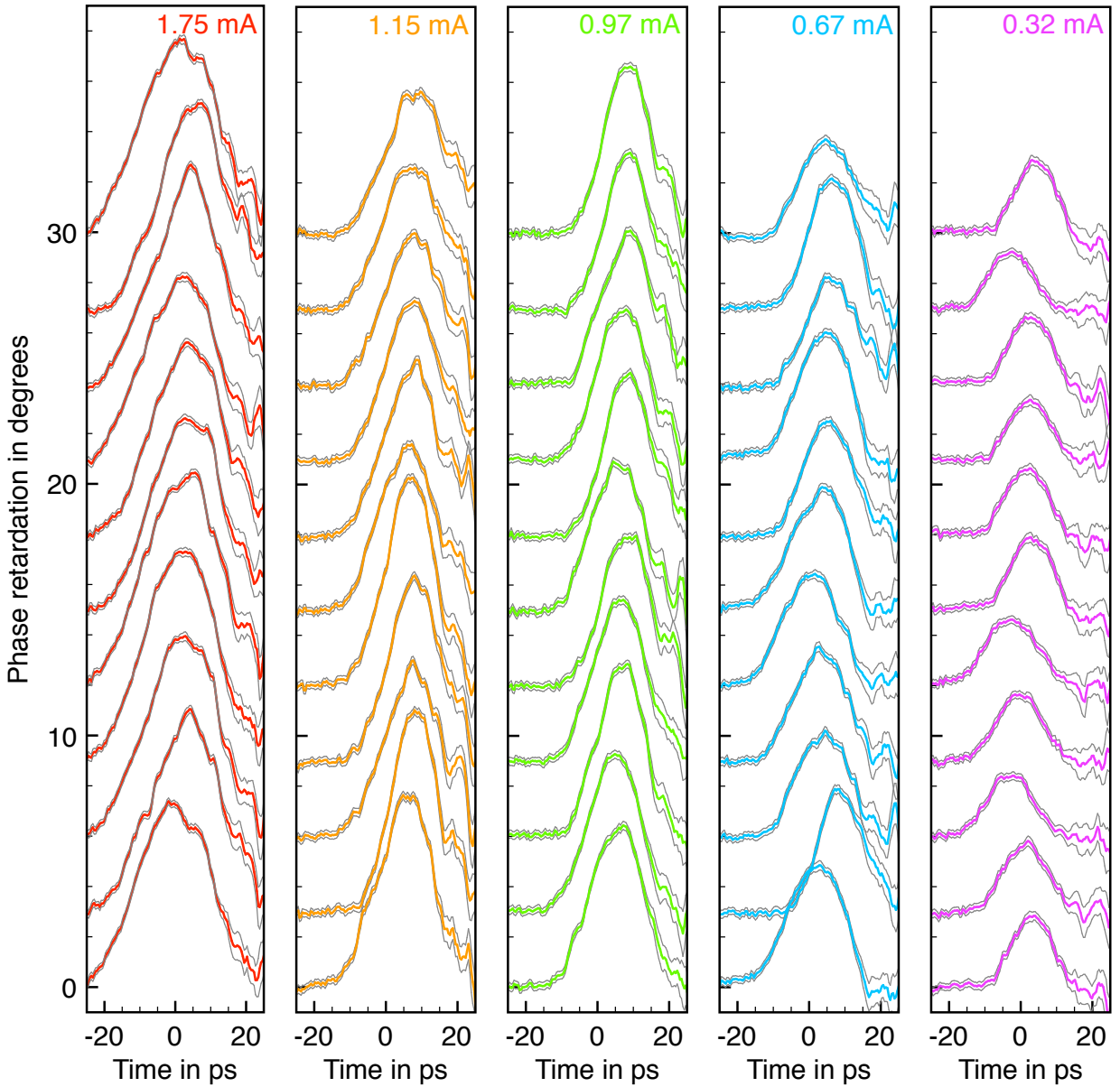
EOSD: Single-Shot Bunch Profiles for Different Electron Beam Parameters



418 pC
8.79 ± 0.63 ps

422 pC
13.56 ± 1.26 ps

EOSD for Different Beam Currents



648 pC

426 pC

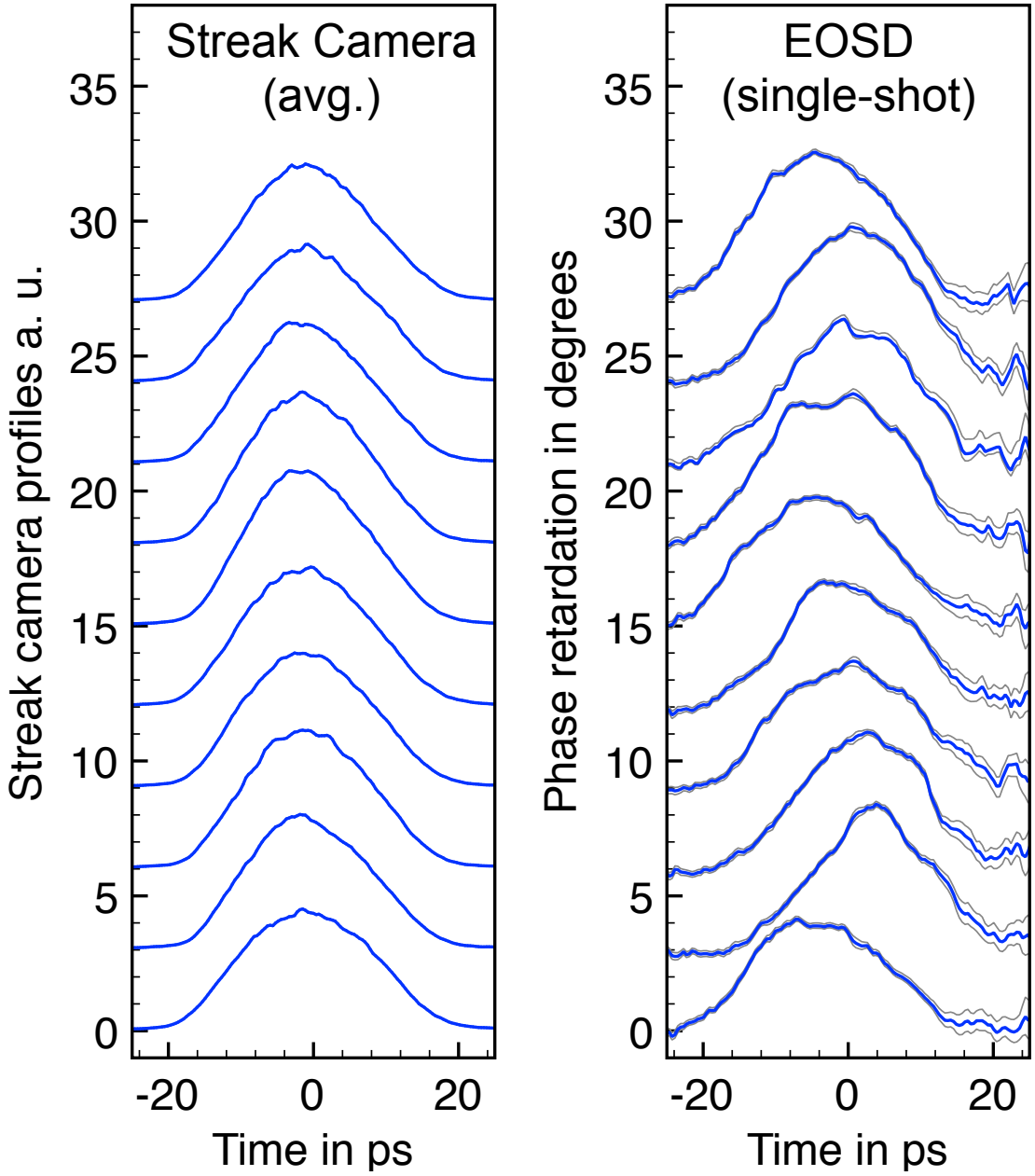
359 pC

248 pC

118 pC

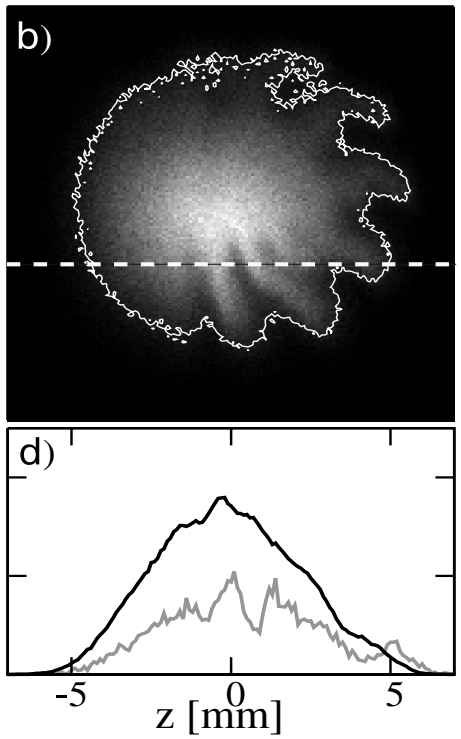
1 mA ≙ 370 pC
@ ANKA

EOSD - Streak Camera - Comparison



418 pC
(both recorded
at same time)

EOSD can
resolve
substructures!



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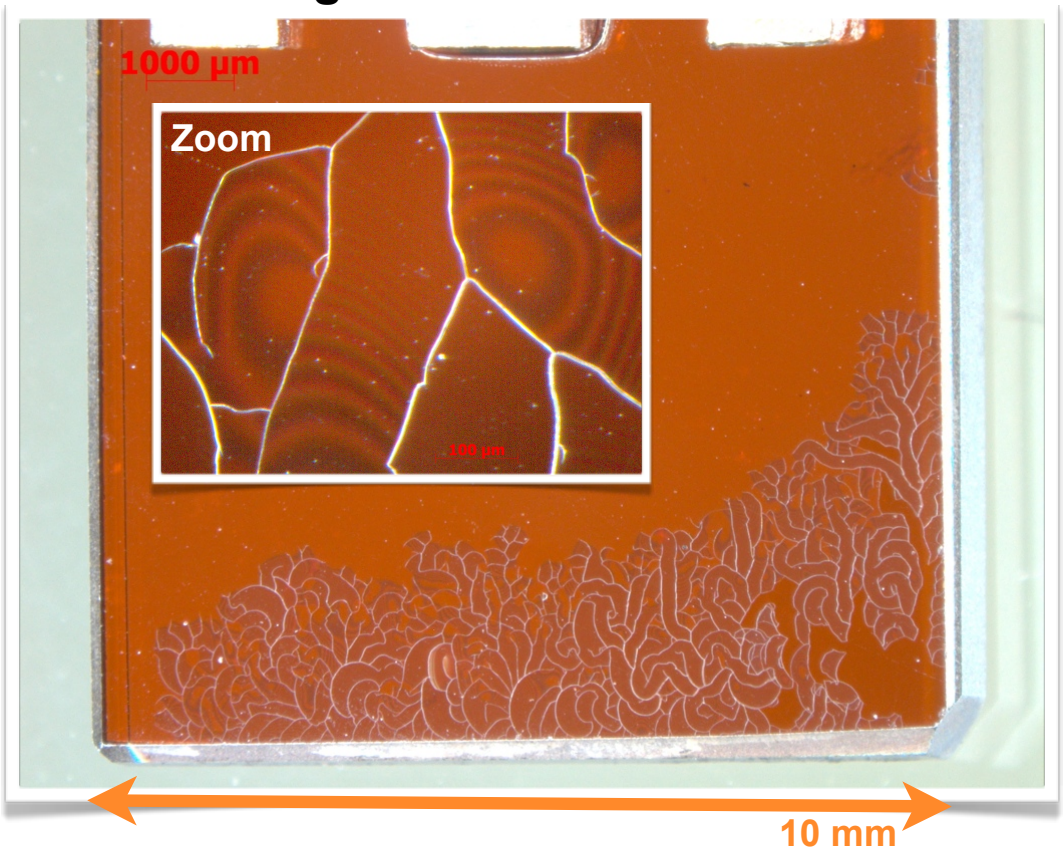
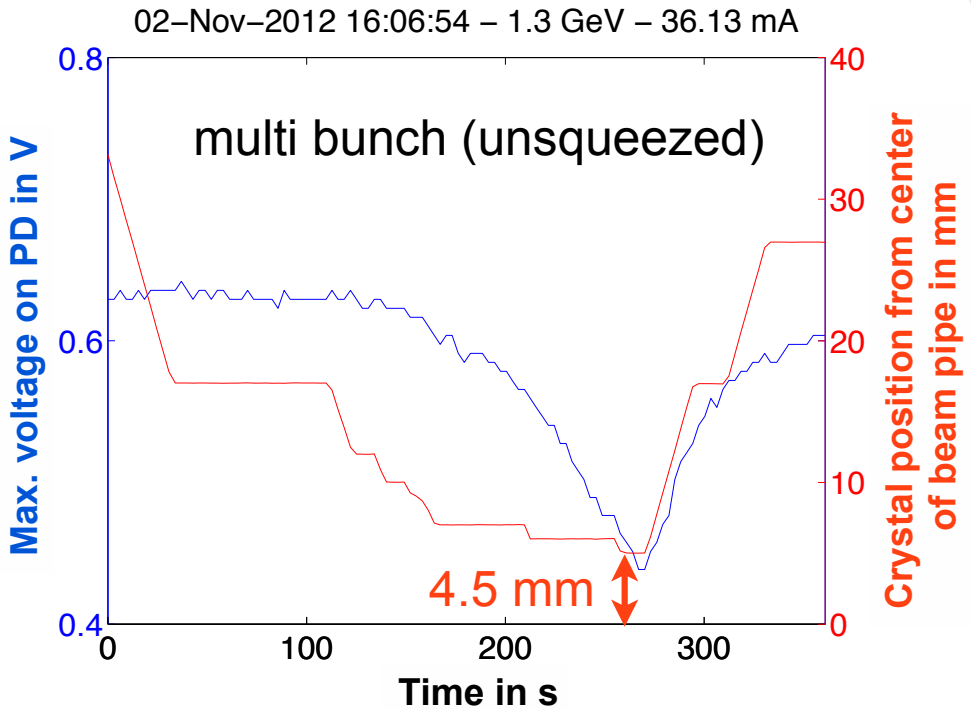
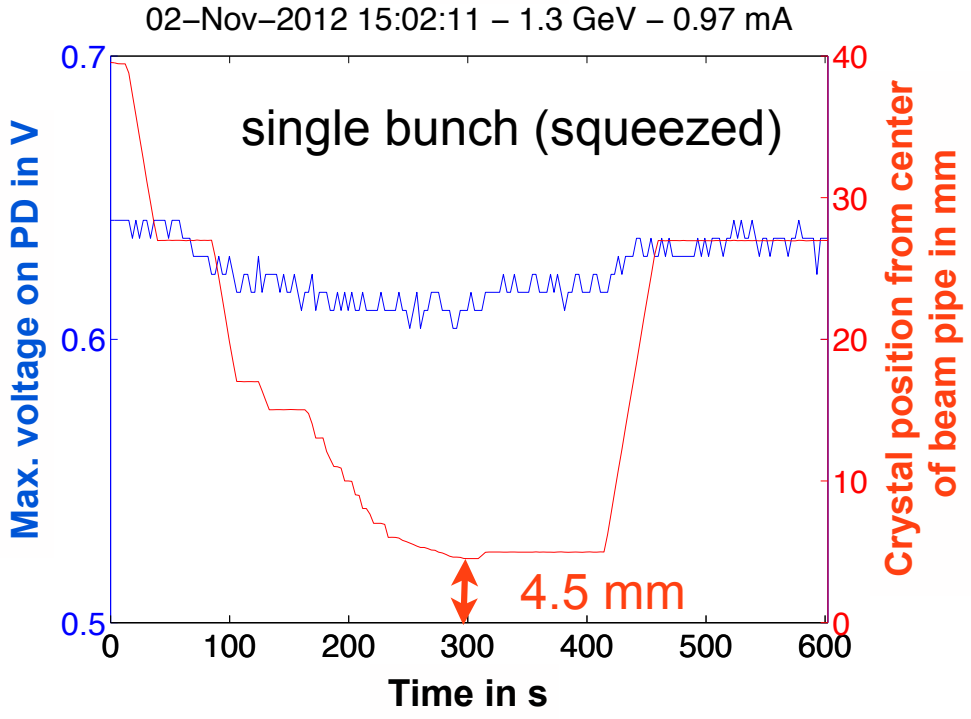
Heat load on crystal

- 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







Summary

- EOS ➜ observe long-range wake-fields spanning the distance between bunches
- EOSD ➜ detect bunch-substructures

Next Steps

- **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
- **Direct correlation of THz signal and bunch profiles on a turn-by-turn basis**

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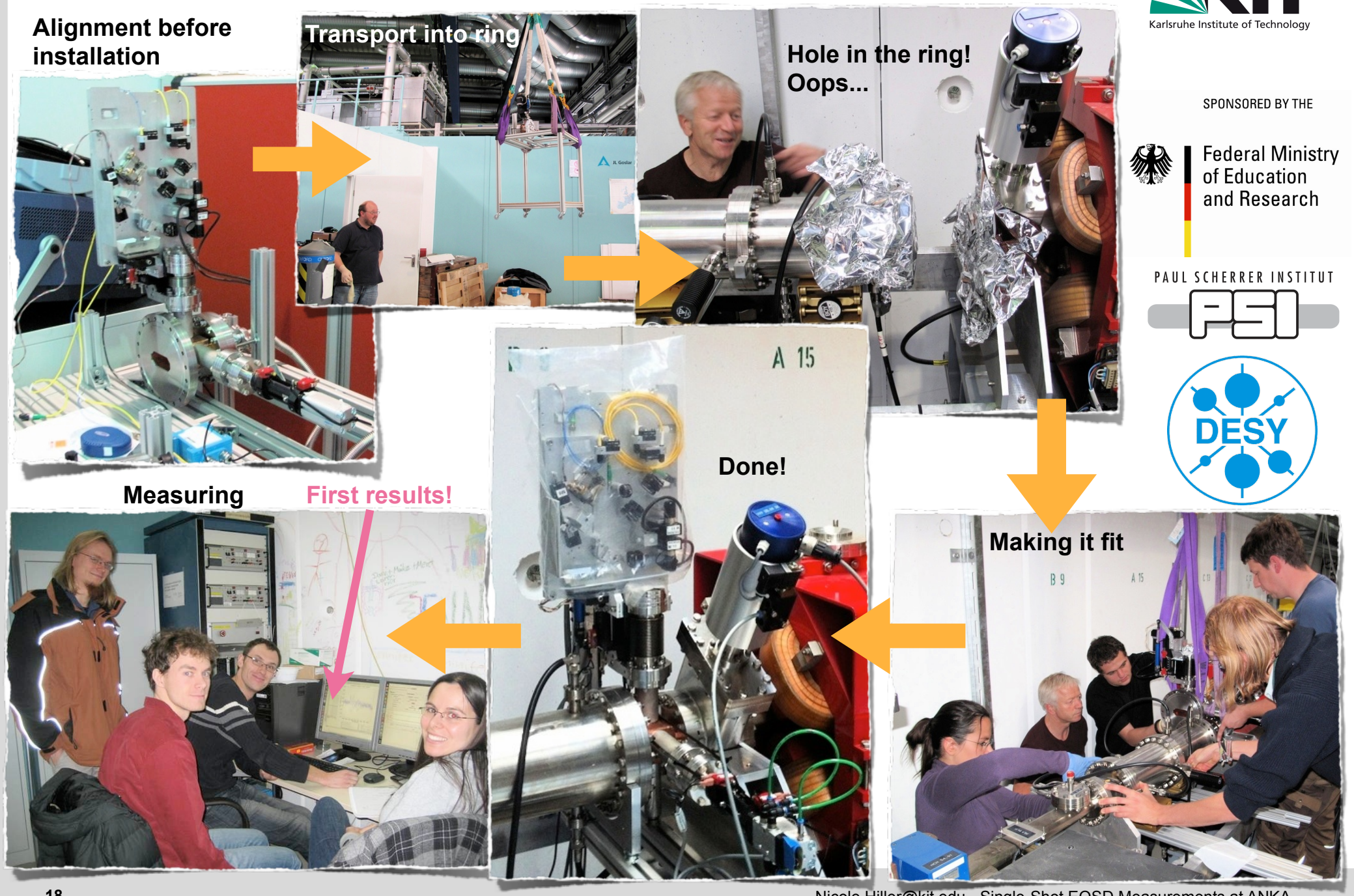
Thank you for your attention/support!



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