Karlsruhe Institute of Technology

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ANKA THZ GROUP

EO measurements at KIT

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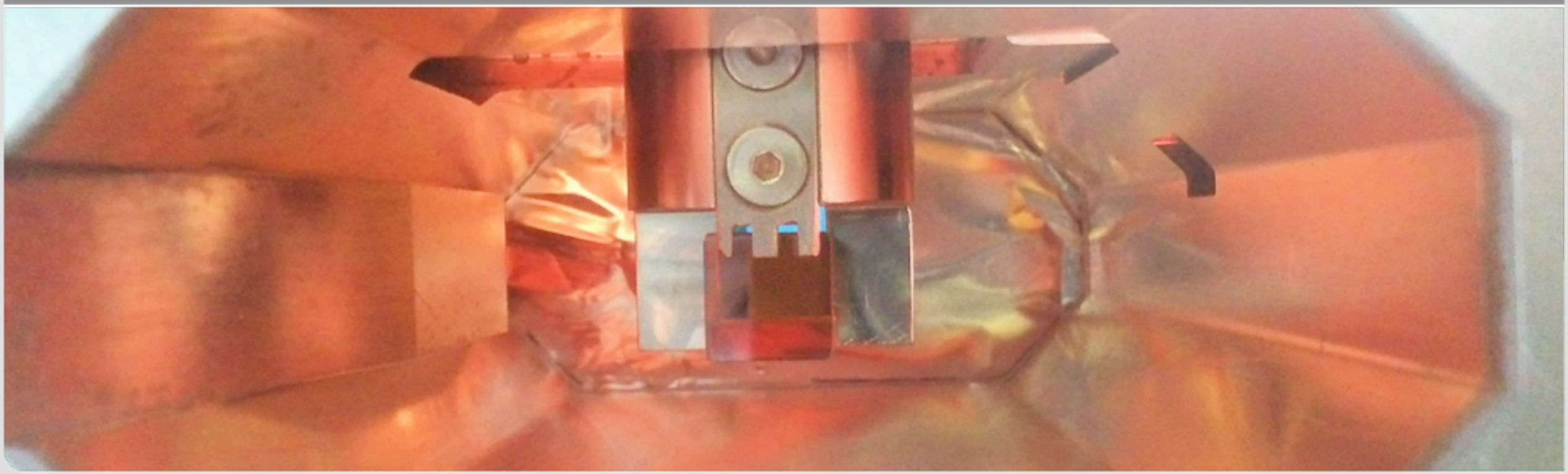
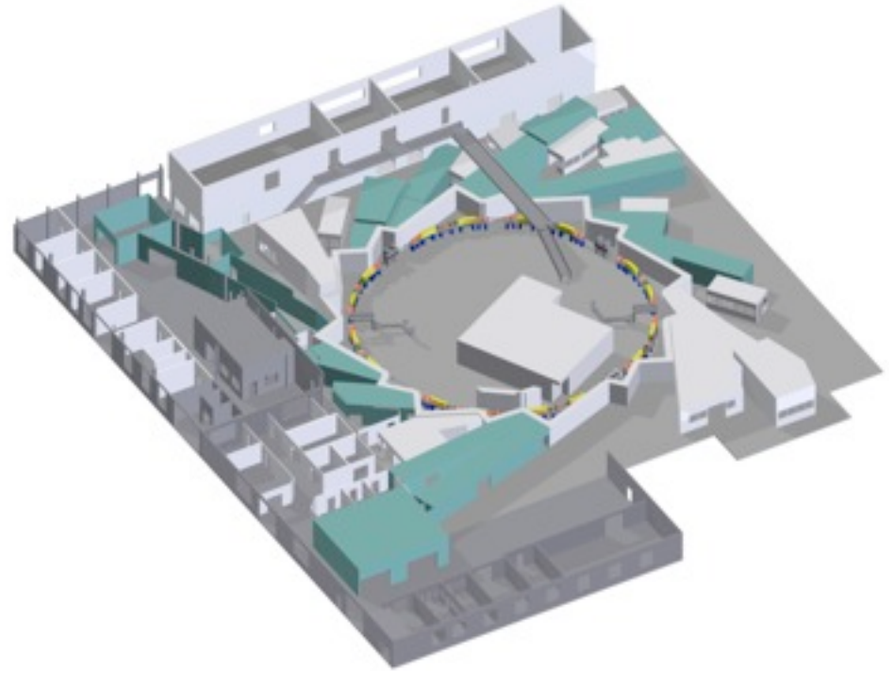
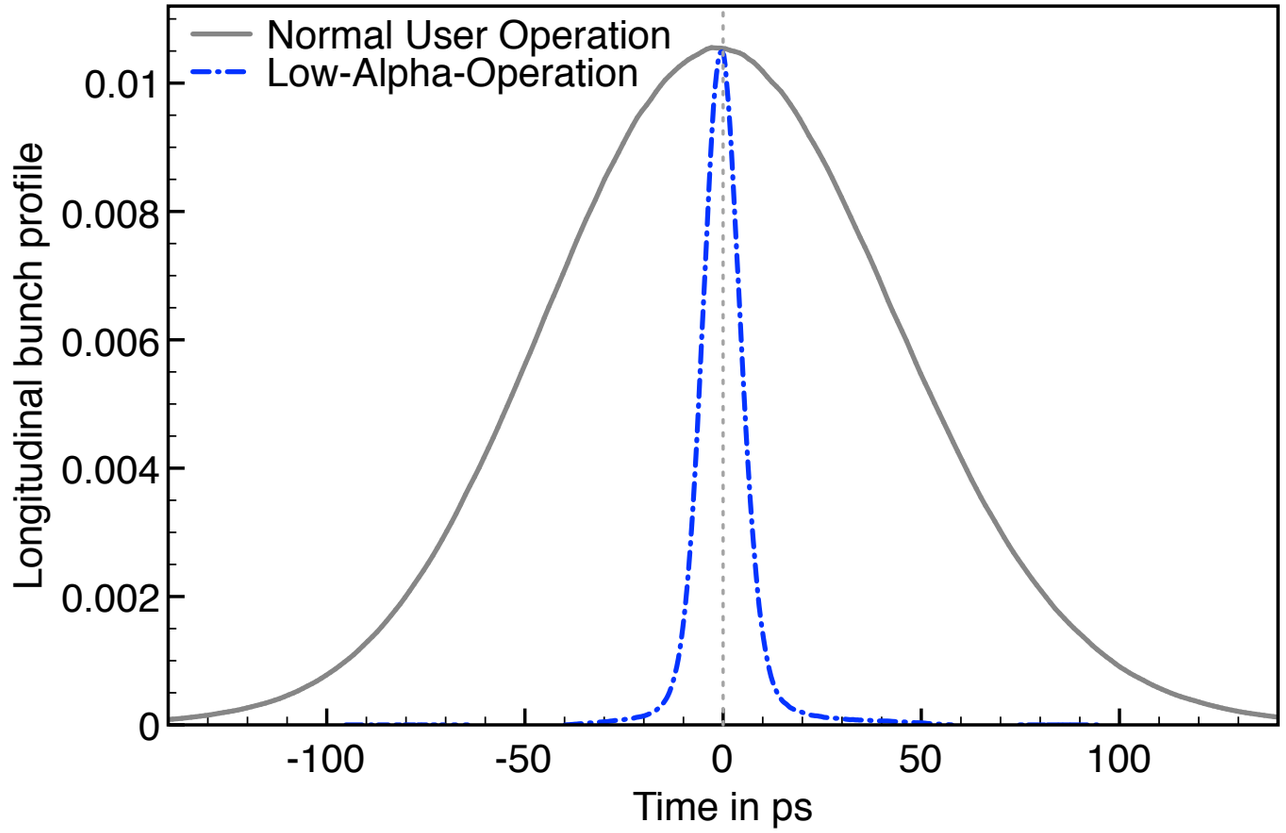
Institute for Photon Science and Synchrotron Radiation (IPS) / Laboratory for the Applications of Synchrotron Radiation (LAS)



Introduction: The ANKA storage ring

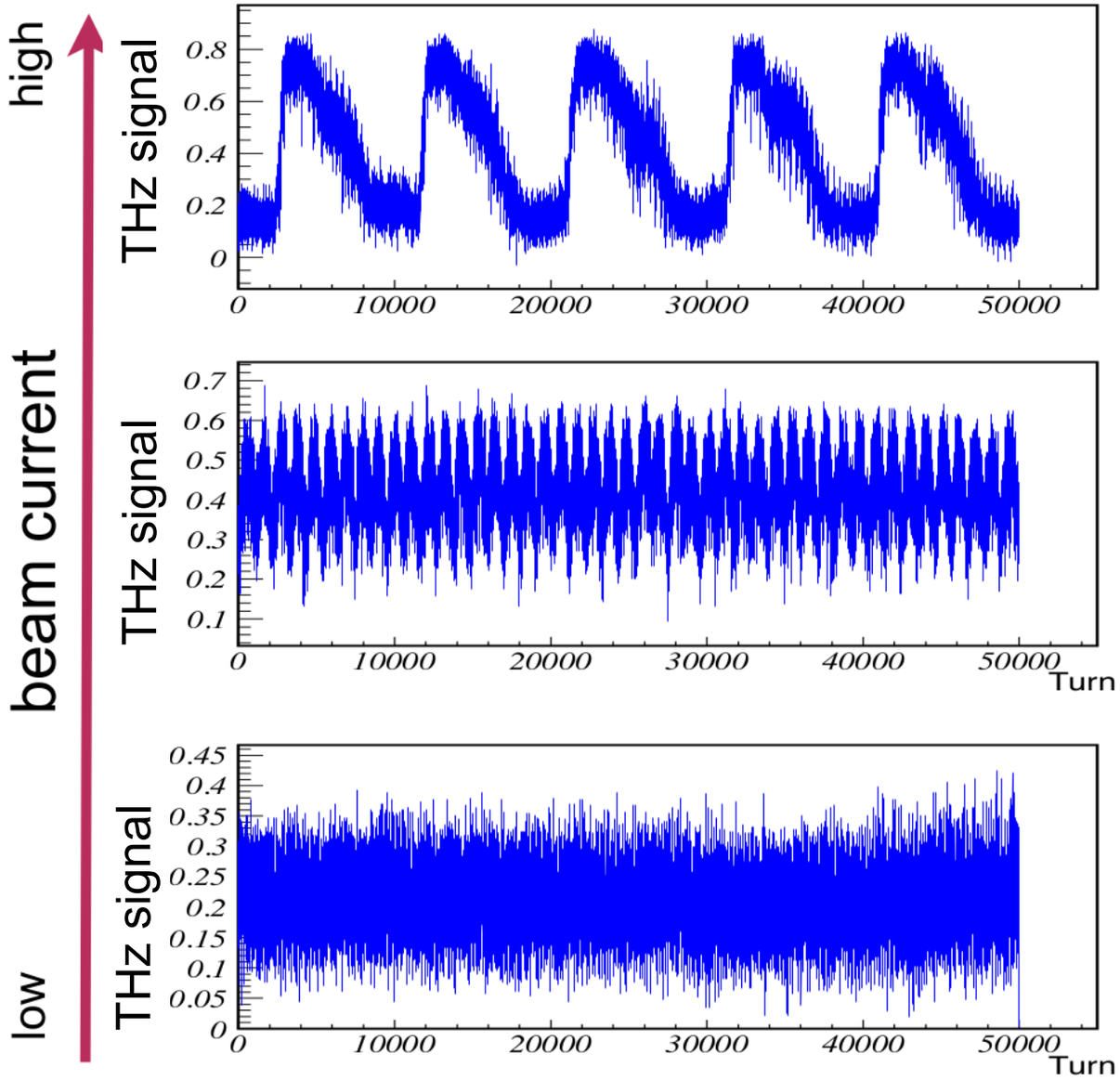
- Circumference 110.4 m
- f_{rev} = 2.715 MHz
- f_{RF} = 499.69 MHz
- Energy 0.5 - 2.5 GeV (0.8 - 1.6 GeV during low-α_c-mode)
- RMS bunch length 45 ps (for 2.5 GeV), down to 1-2 ps (for 1.3 GeV)
- Filling pattern: single- or multi-bunch (min. bunch spacing 2 ns)





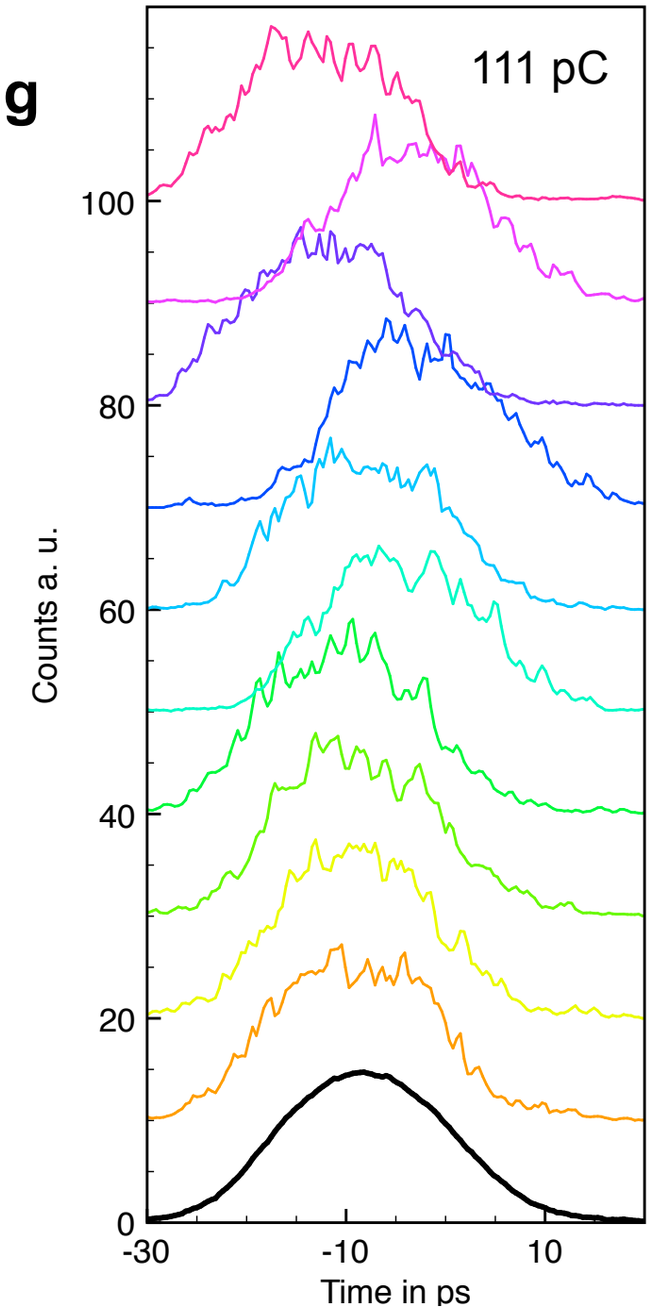
Motivation for single-shot EO measurements at ANKA

Bursting behavior of CSR → microbunching



50k turns = 18.4 ms

Streak Camera single-shot capabilities limited



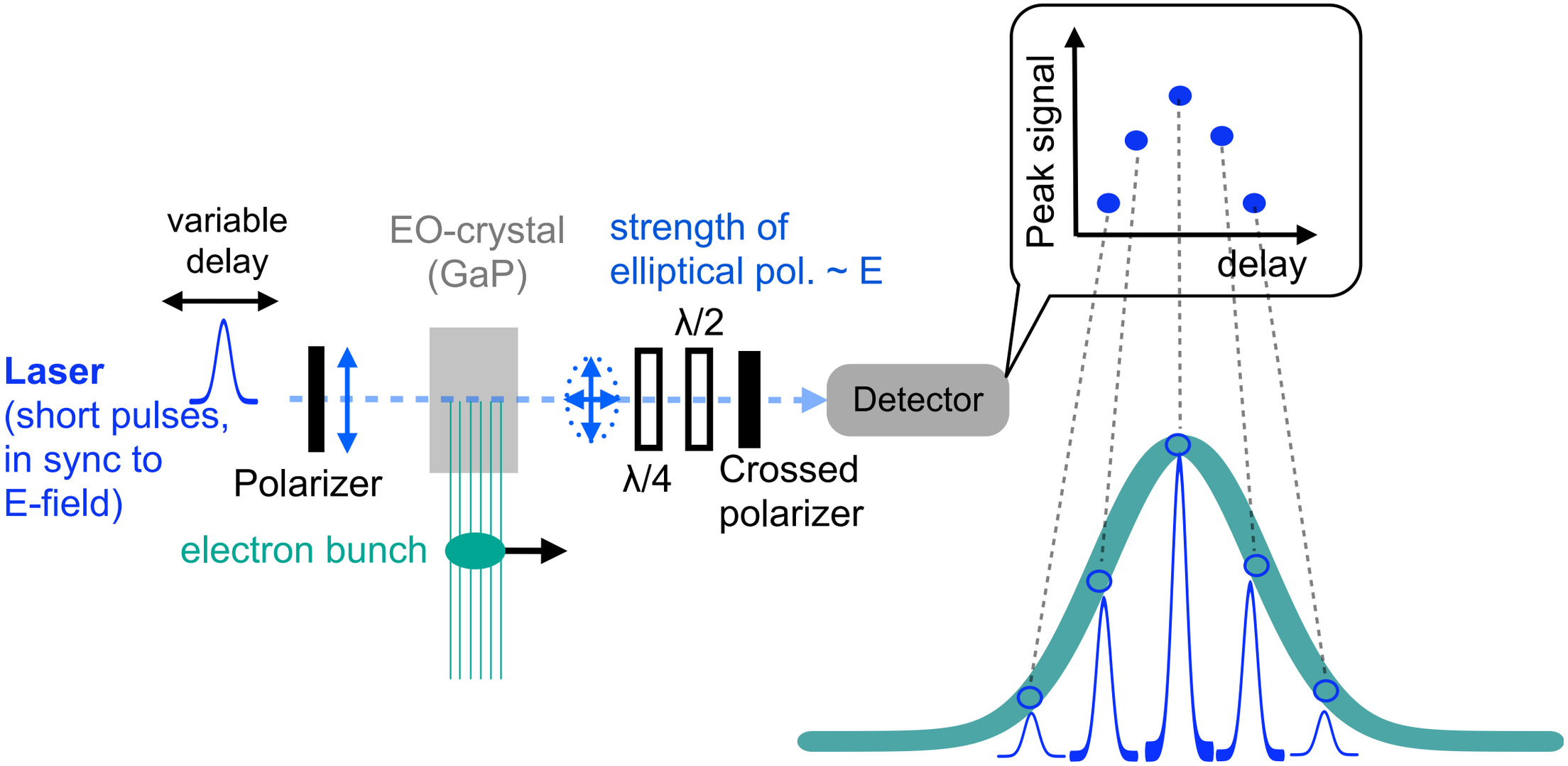
Without filters;
v-slit fully opened

Dominated by shot-noise

We want: Single-shot measurements to study bursting behavior!

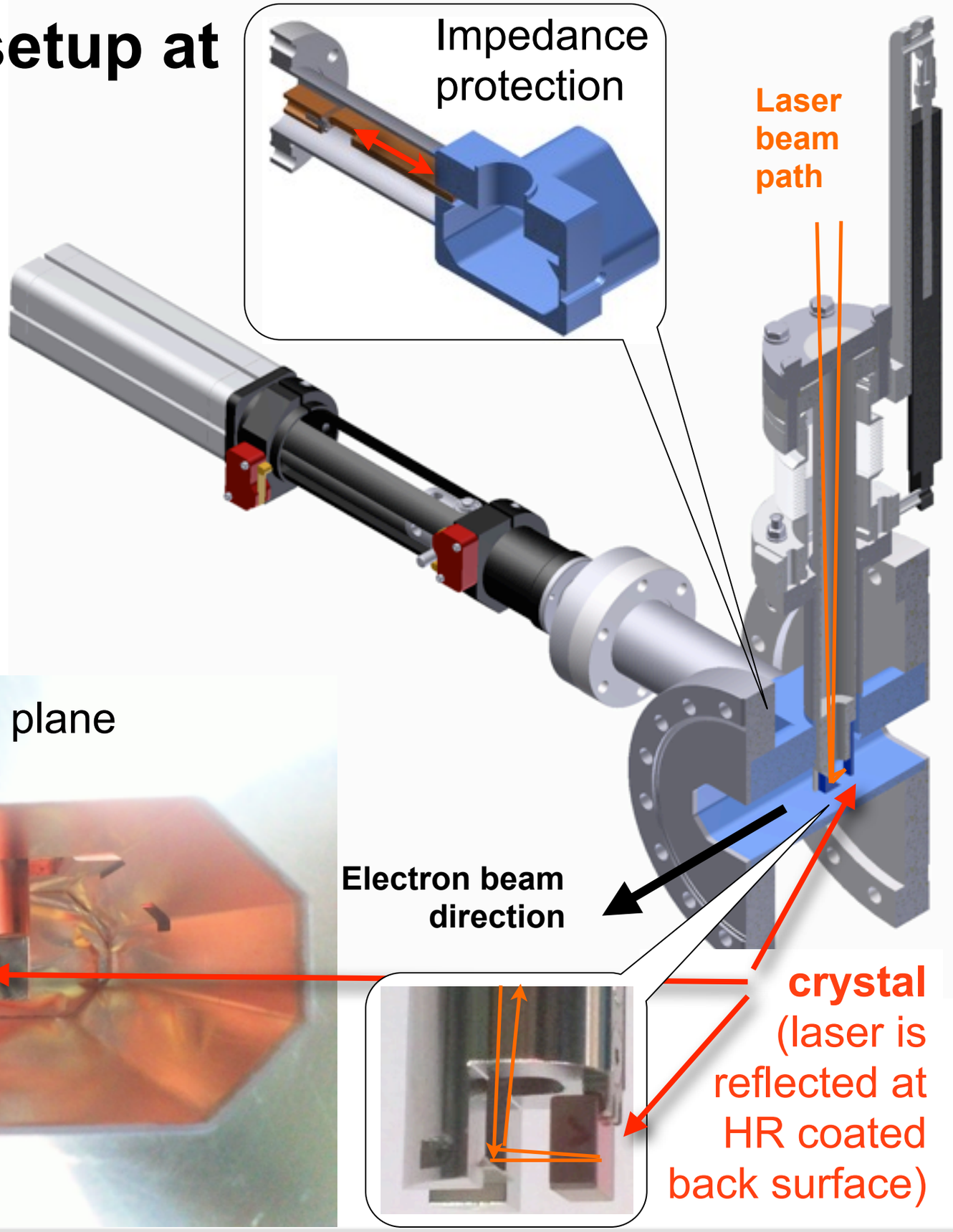
Electro-optical sampling (EOS)

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

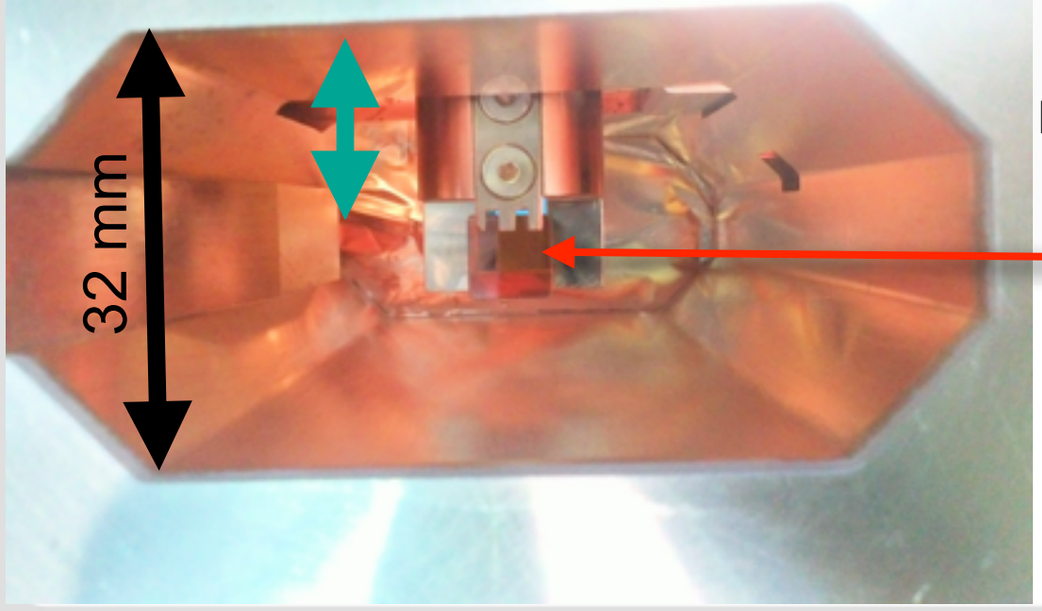


best S/N ratio for nearly crossed polarizer and analyzer angles

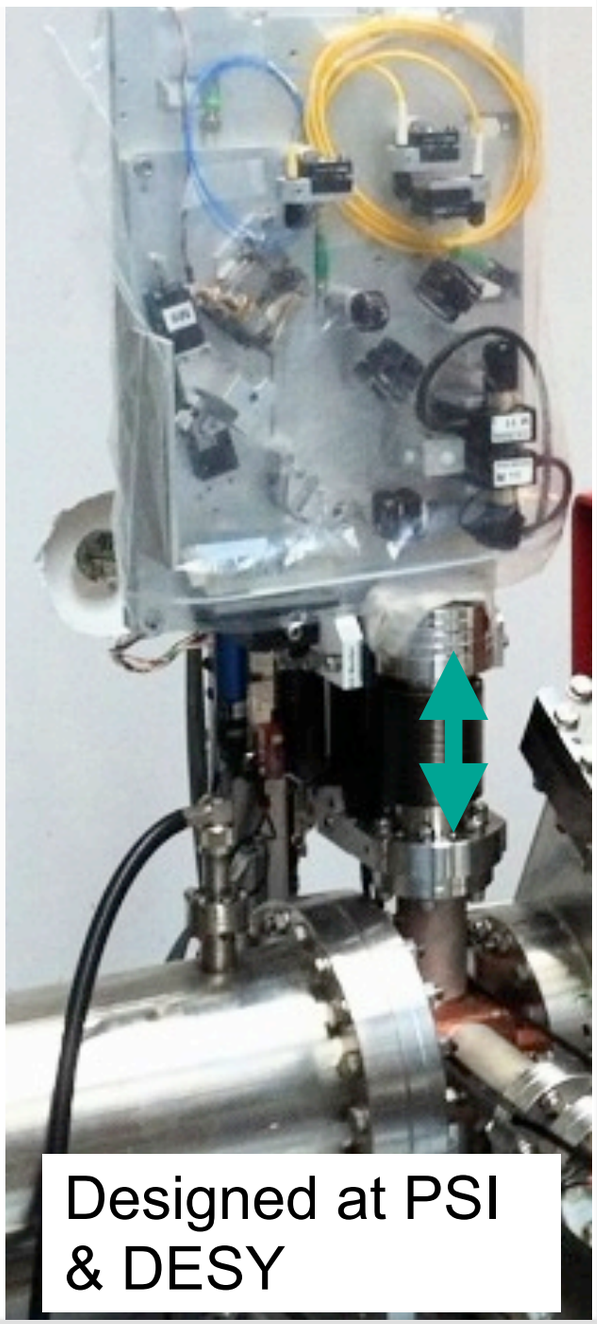
Near-Field setup at ANKA: EO-Monitor



Electrons flying into plane of view

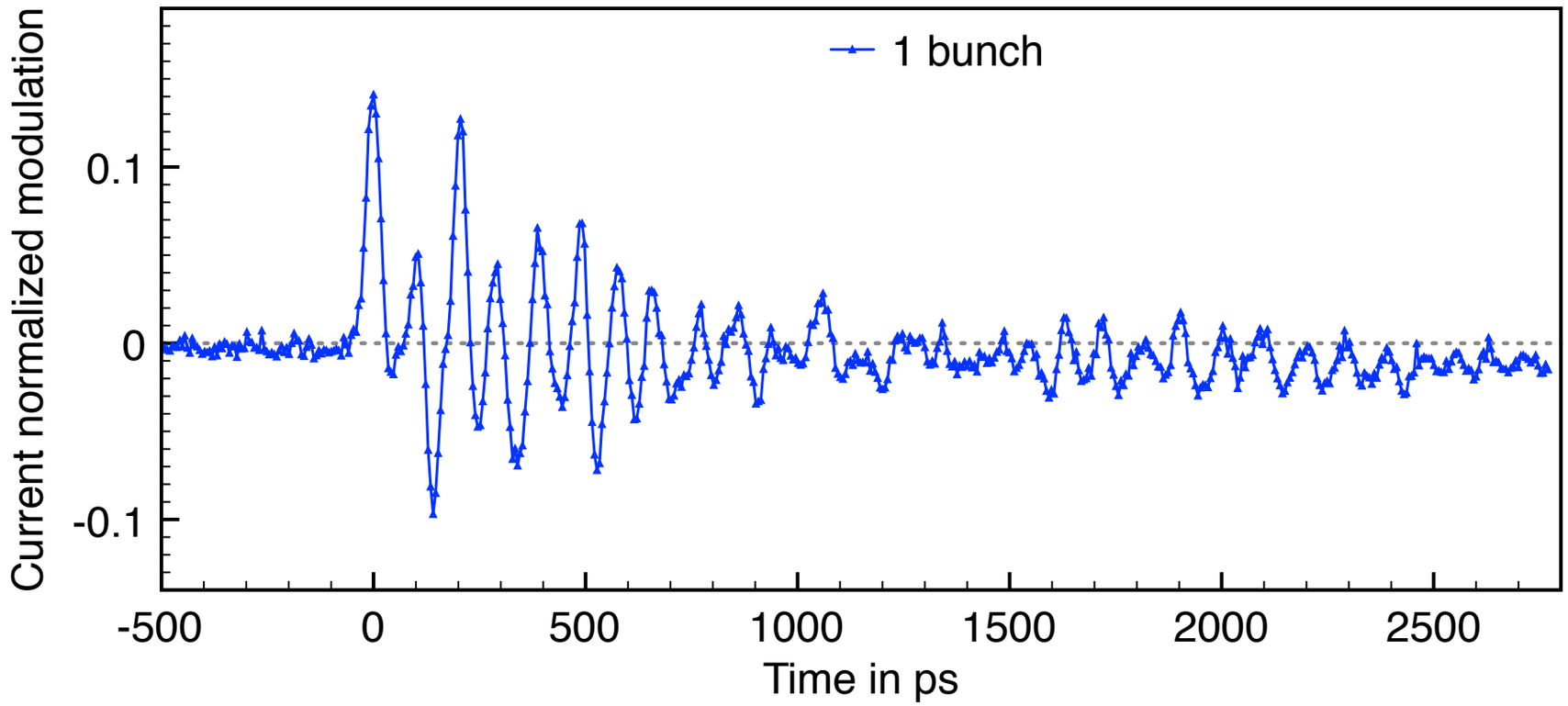


EO monitor with grating compressor and wave plates



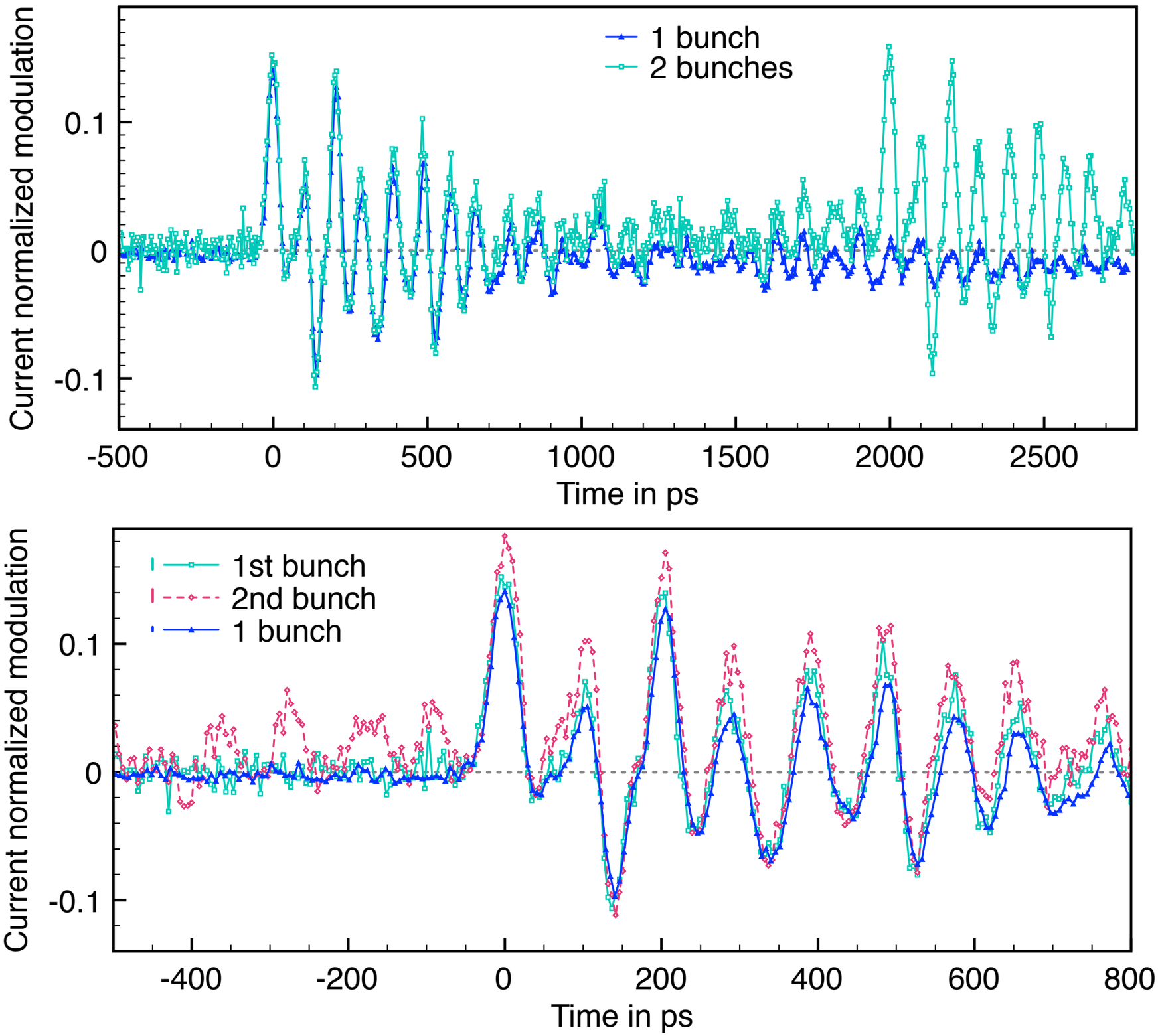
Designed at PSI & DESY

Long-Range Wake-Fields



Bunch spacing 2 ns

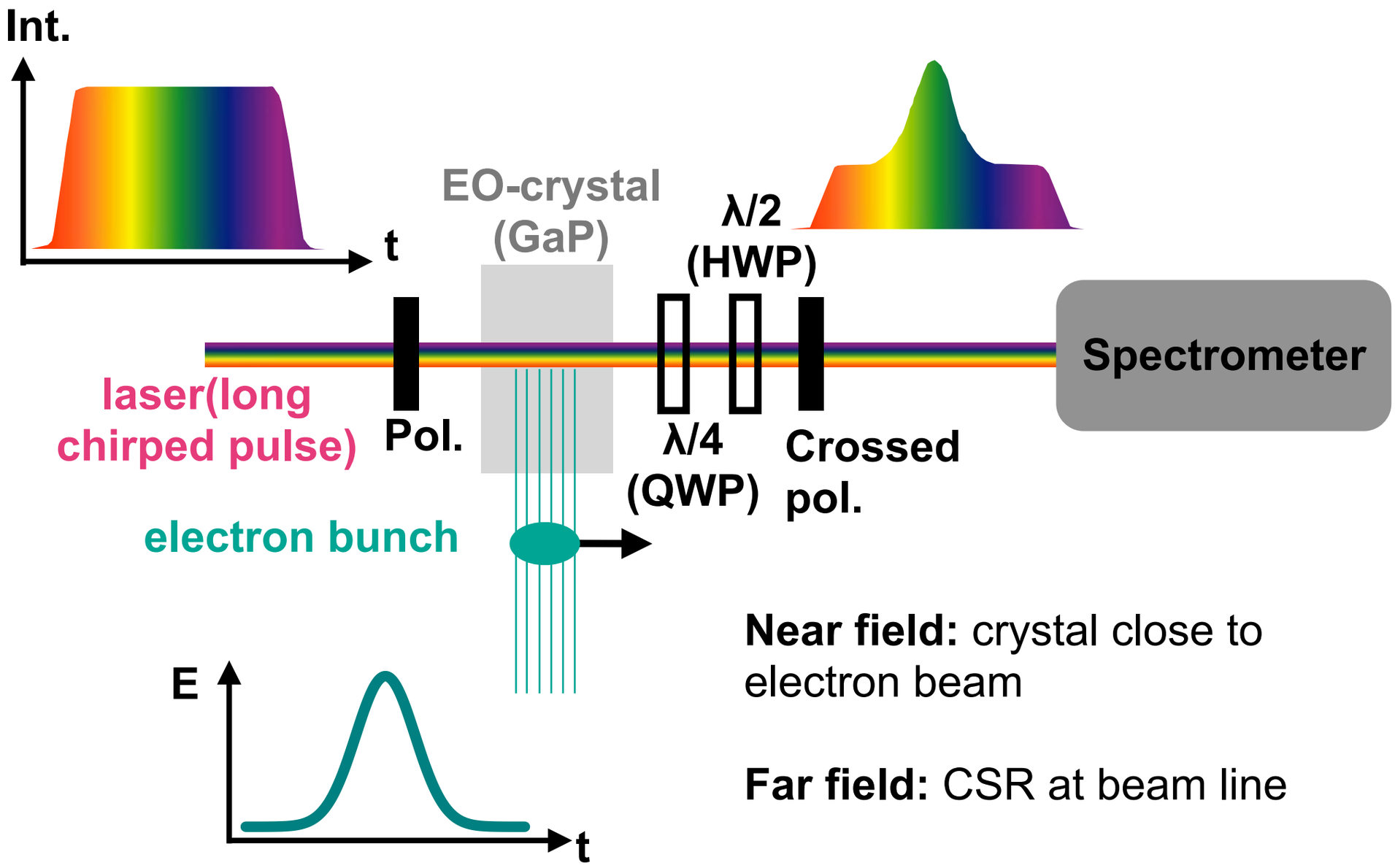
Long-Range Wake-Fields



Bunch spacing 2 ns

Signal of 2nd bunch higher!

Spectral decoding (single shot) - EOSD

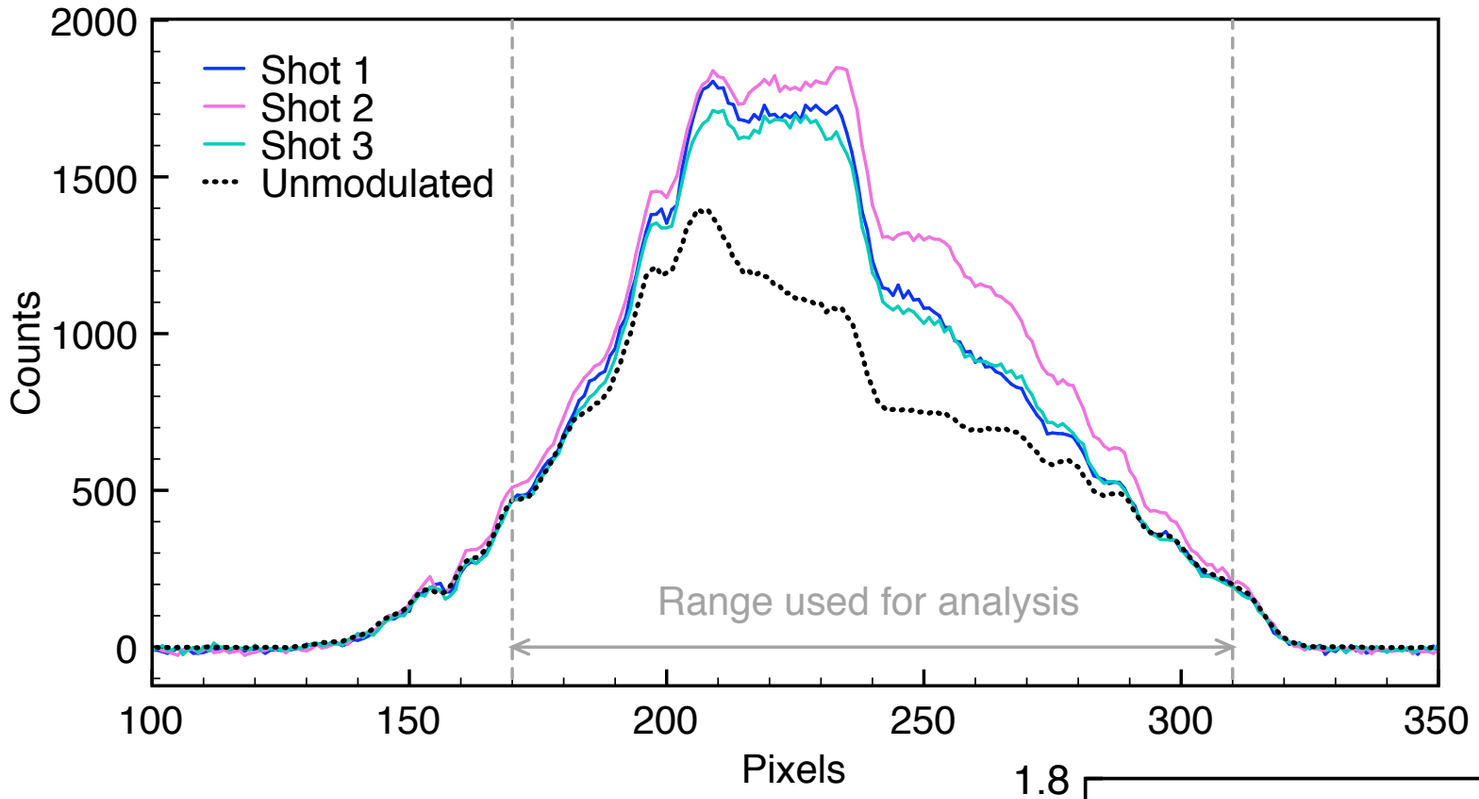


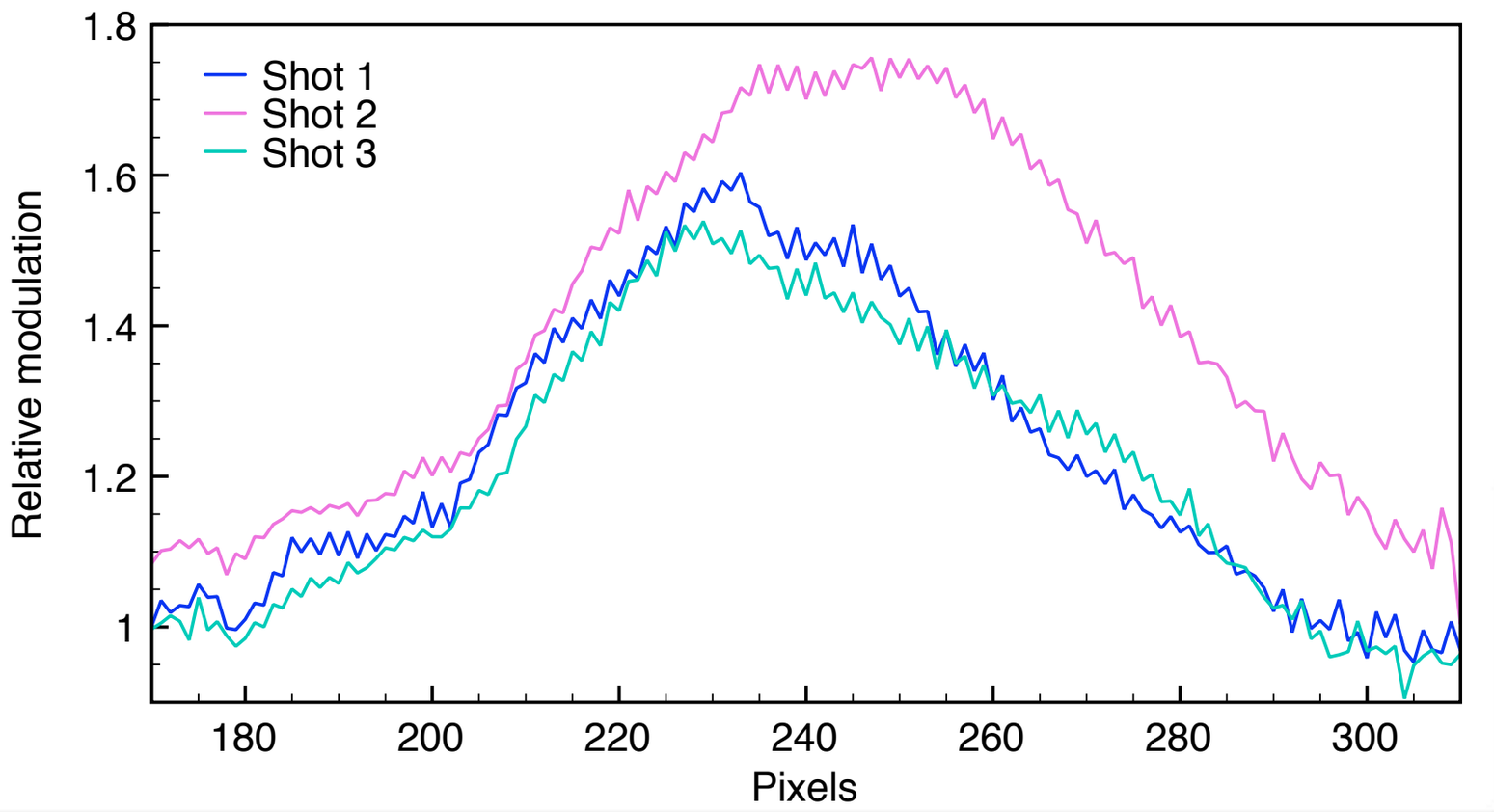
Near field: crystal close to electron beam

Far field: CSR at beam line

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

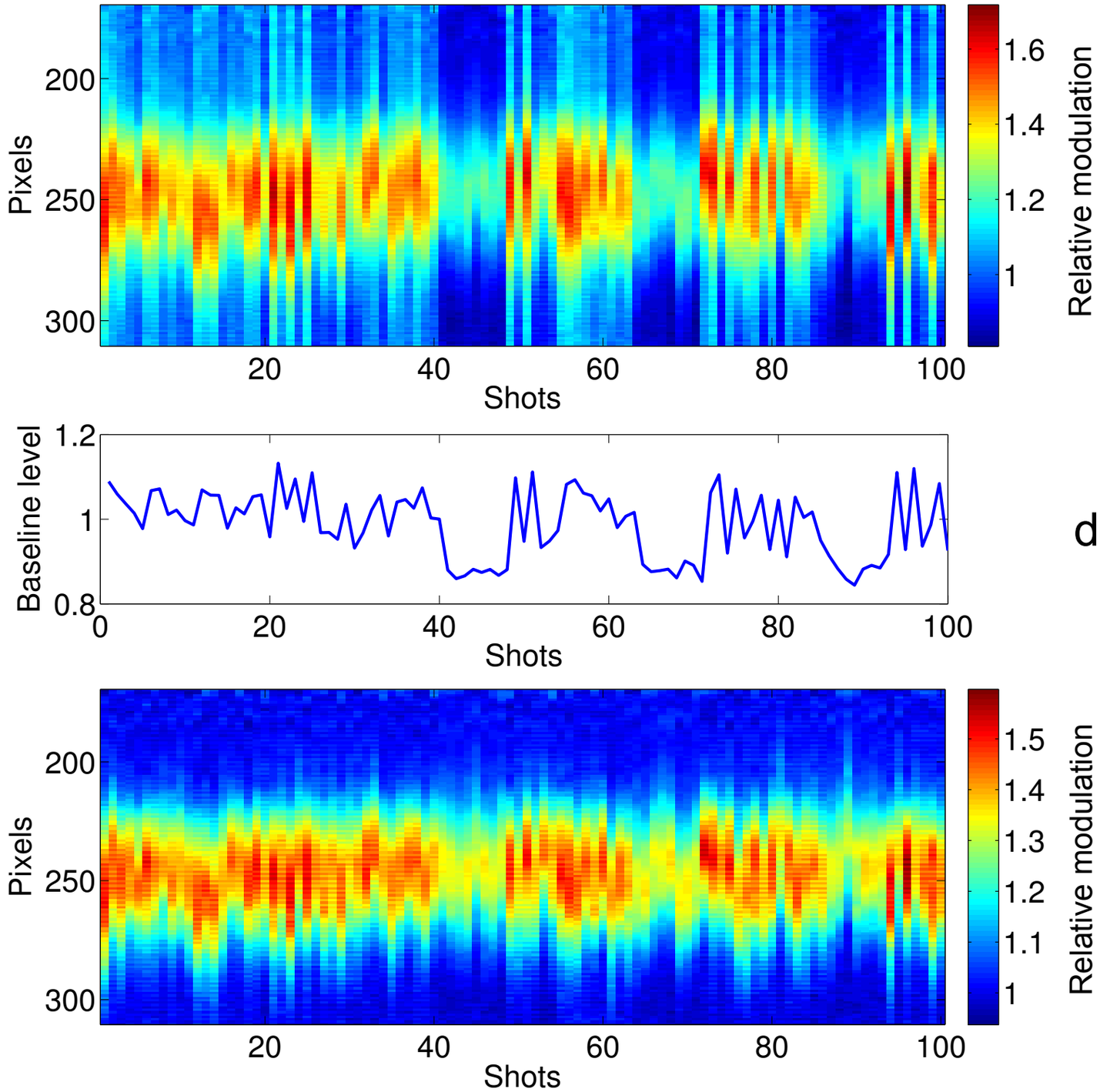
Spectral modulation





Intensity correction

Required because of spectrometer acquisition jitter



determined by Gaussian fits

Still considerable fluctuations.
Beam position fluctuations?

Phase Calibration

HWP angle

$$\frac{I_{det}}{I_{det}(\Gamma = 0)} = \frac{1}{2} \cdot (1 - \cos(\Gamma + 4 \cdot \Theta))$$

$$\Gamma = \frac{\omega d}{c} n_0^3 r_{41} E$$

Relative modulation

Ideally (for small angles): $\frac{I_{det}}{I_{det}(\Gamma = 0)} \propto \Gamma$

Phase Calibration

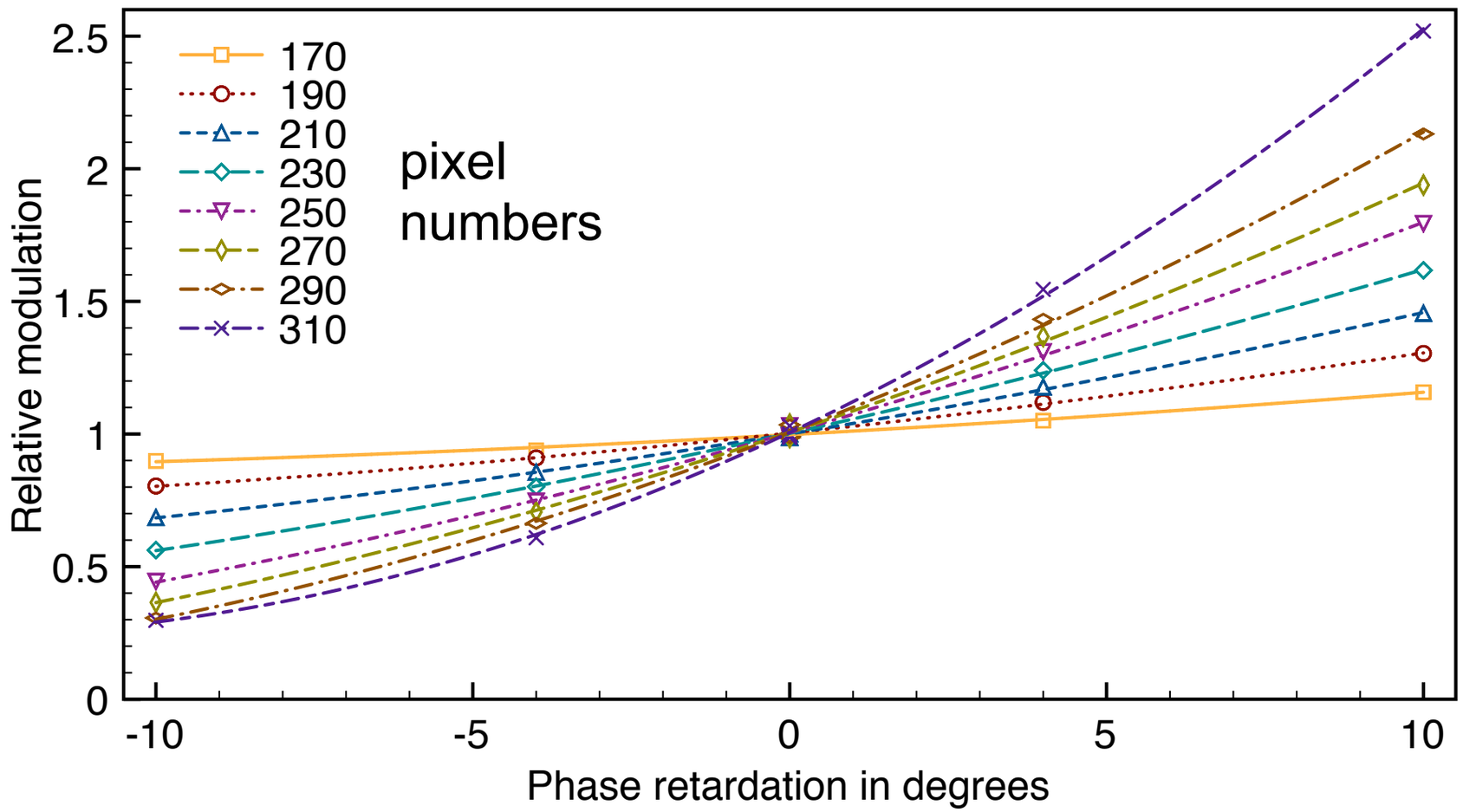
HWP angle

$$\frac{I_{det}}{I_{det}(\Gamma = 0)} = \frac{1}{2} \cdot (1 - \cos(\Gamma + 4 \cdot \Theta))$$

$$\Gamma = \frac{\omega d}{c} n_0^3 r_{41} E$$

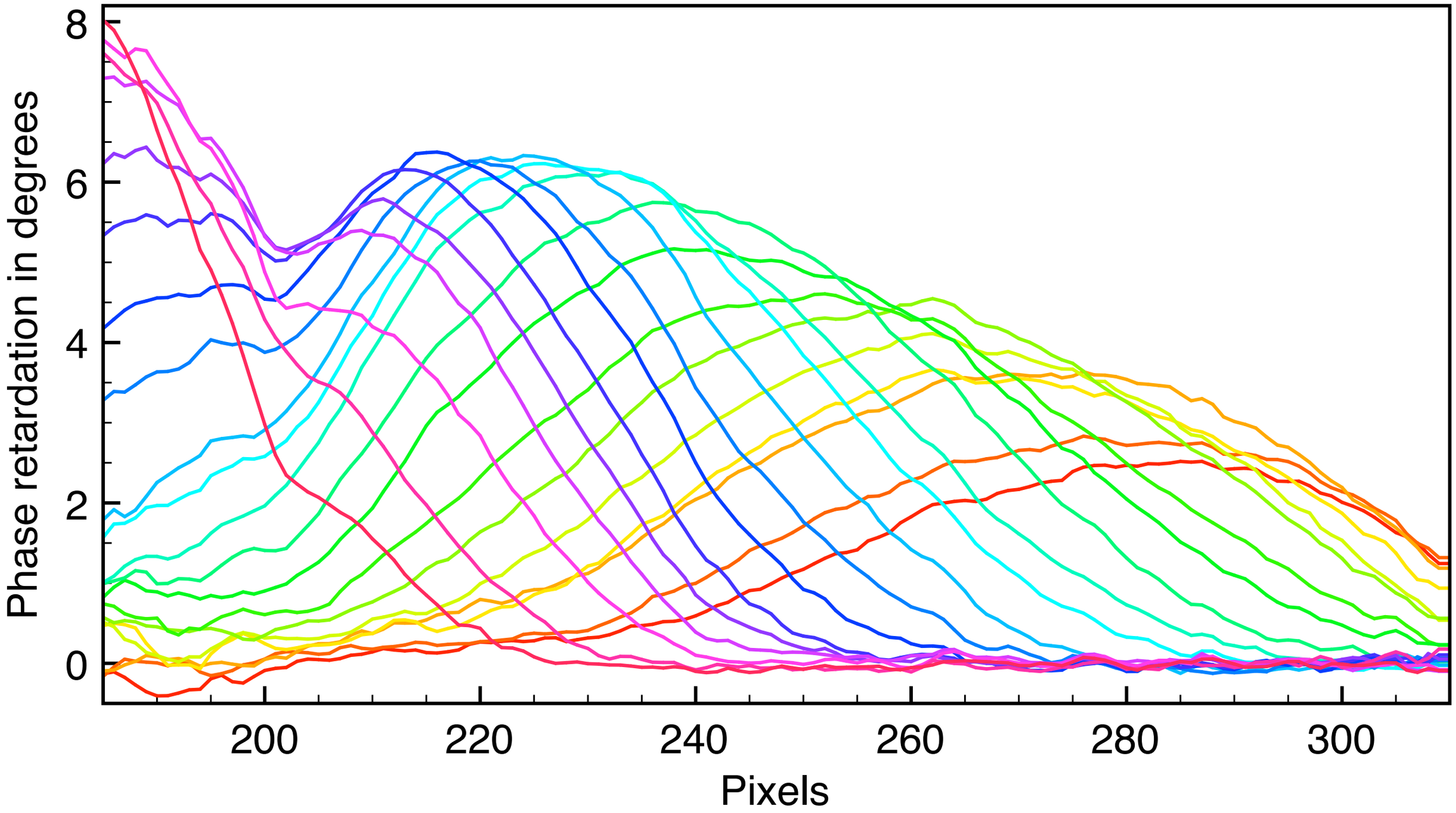
Measurement: Rotate HWP and measure relative change in laser intensity

Problem: Different slopes for different pixels → Calibration for every pixel separately.



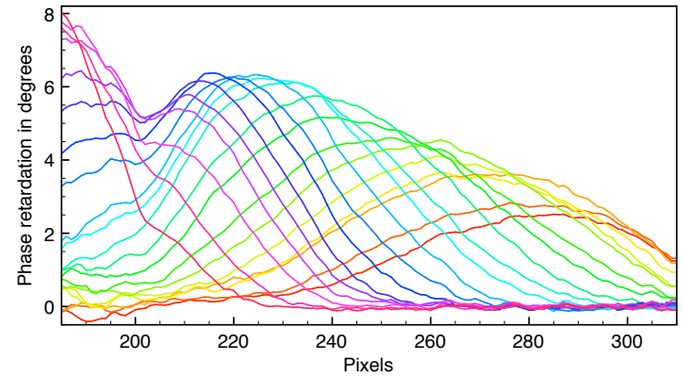
Time Calibration Measurements

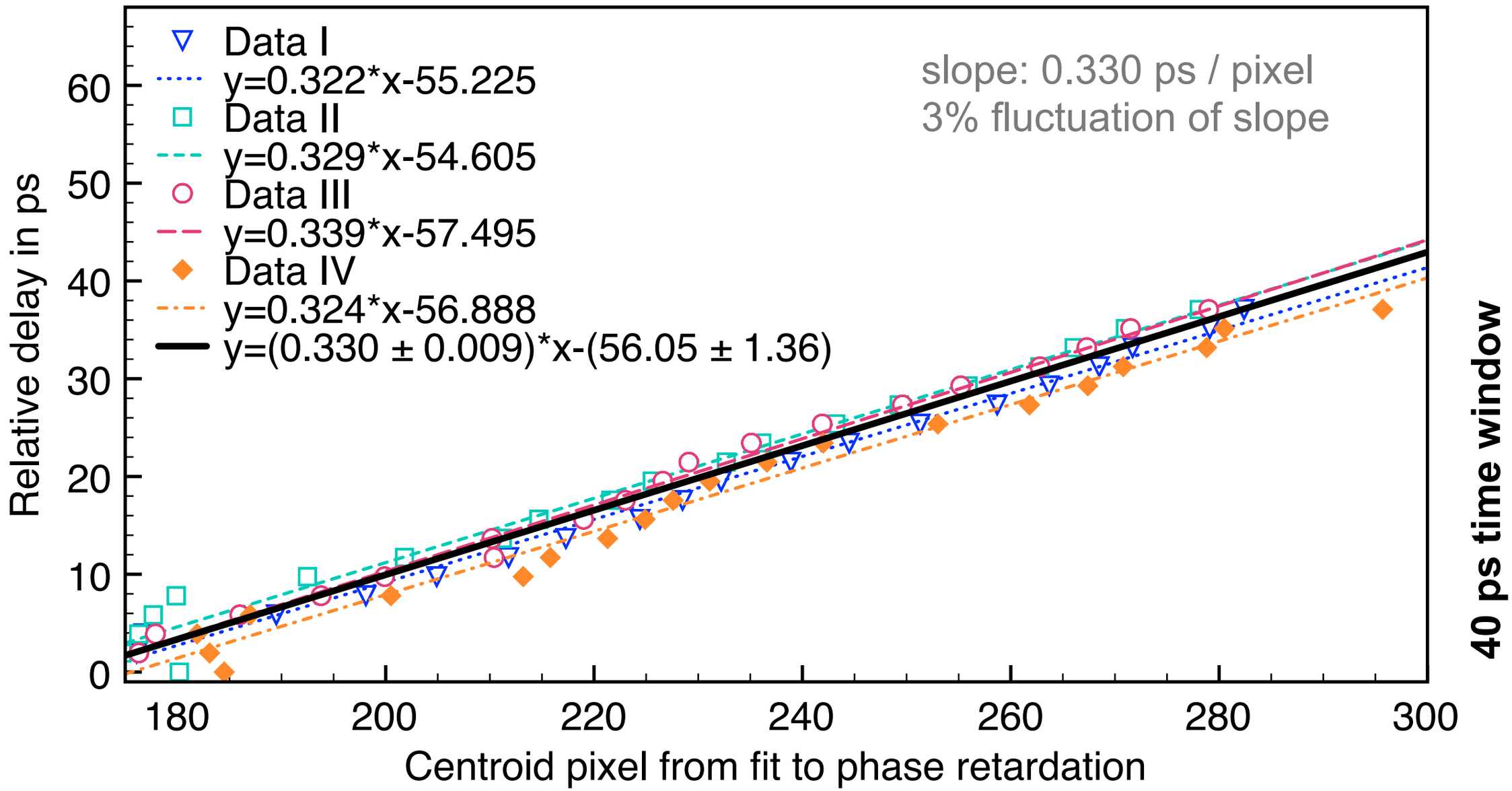
Changing delay between laser and bunch to calibrate:
pixels ➔ time



Time Calibration Measurements

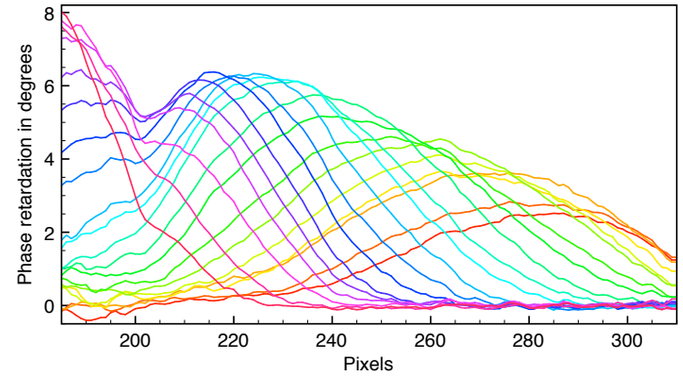
pixels ➔ time





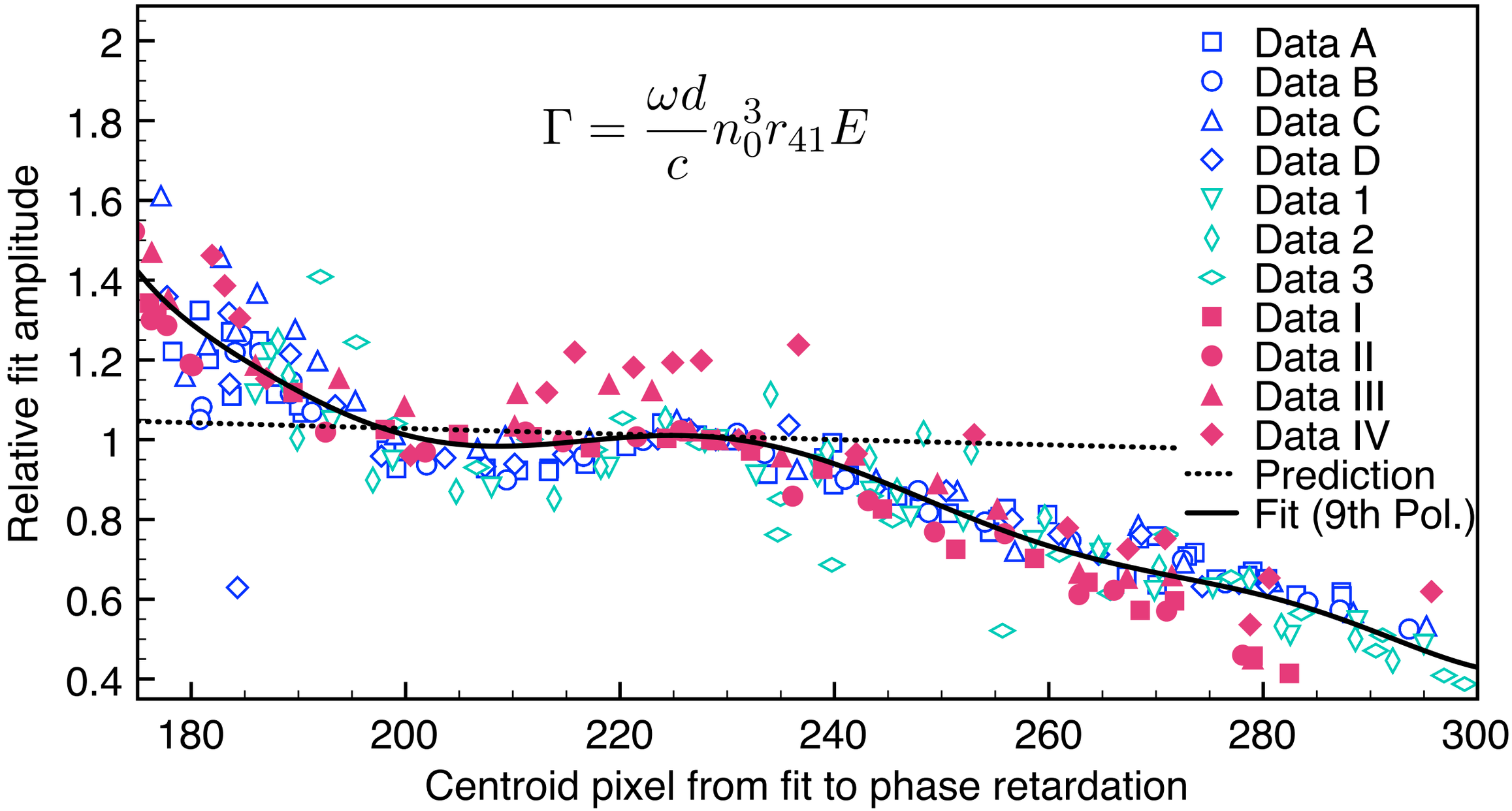
20 shot average, total acquisition time: 65 s

Systematic effects: Amplitude decrease

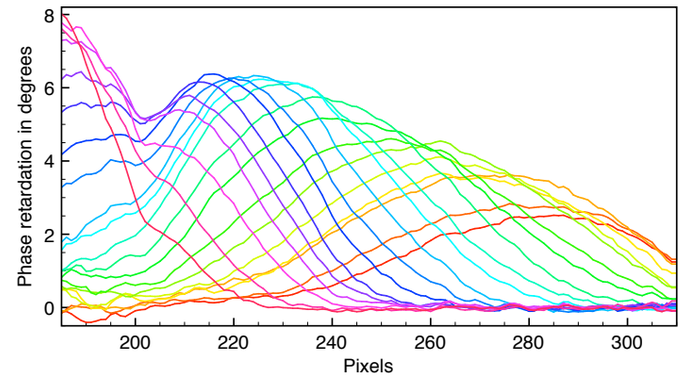


Amplitudes

$$\Gamma = \frac{\omega d}{c} n_0^3 r_{41} E$$



Systematic effects: Bunch length



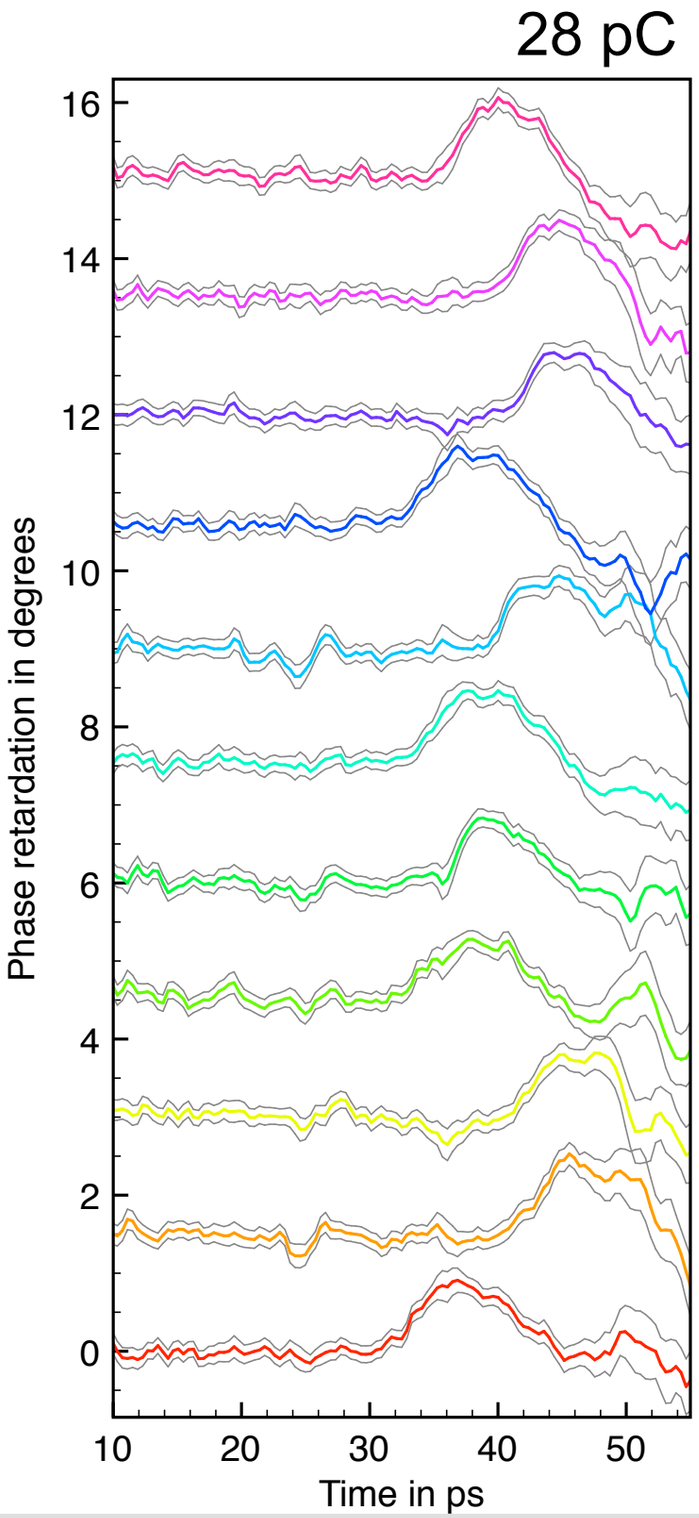
Widths

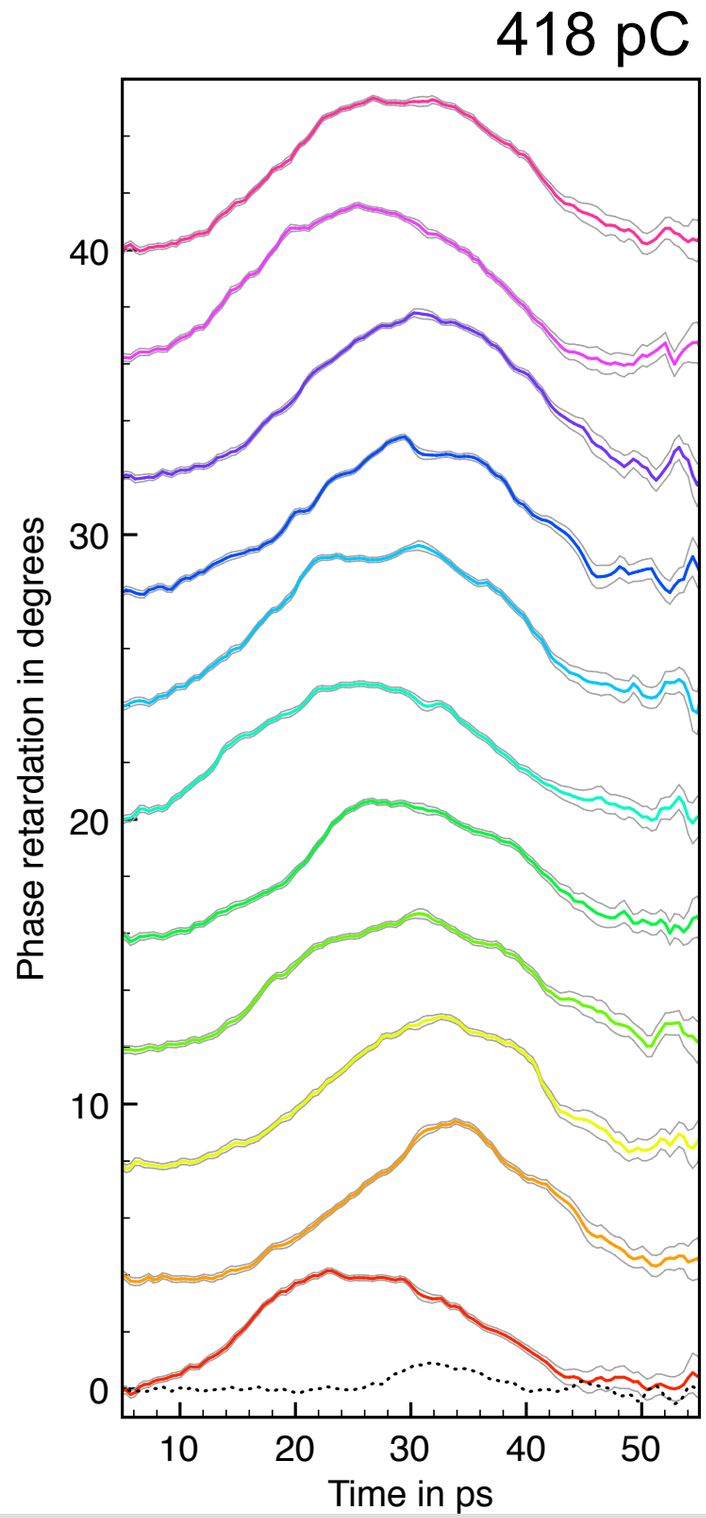
Bunch length from fit in pixels

Centroid pixel from fit to phase retardation

Normal measurement range

EOSD - Single-Shots - Sensitivity

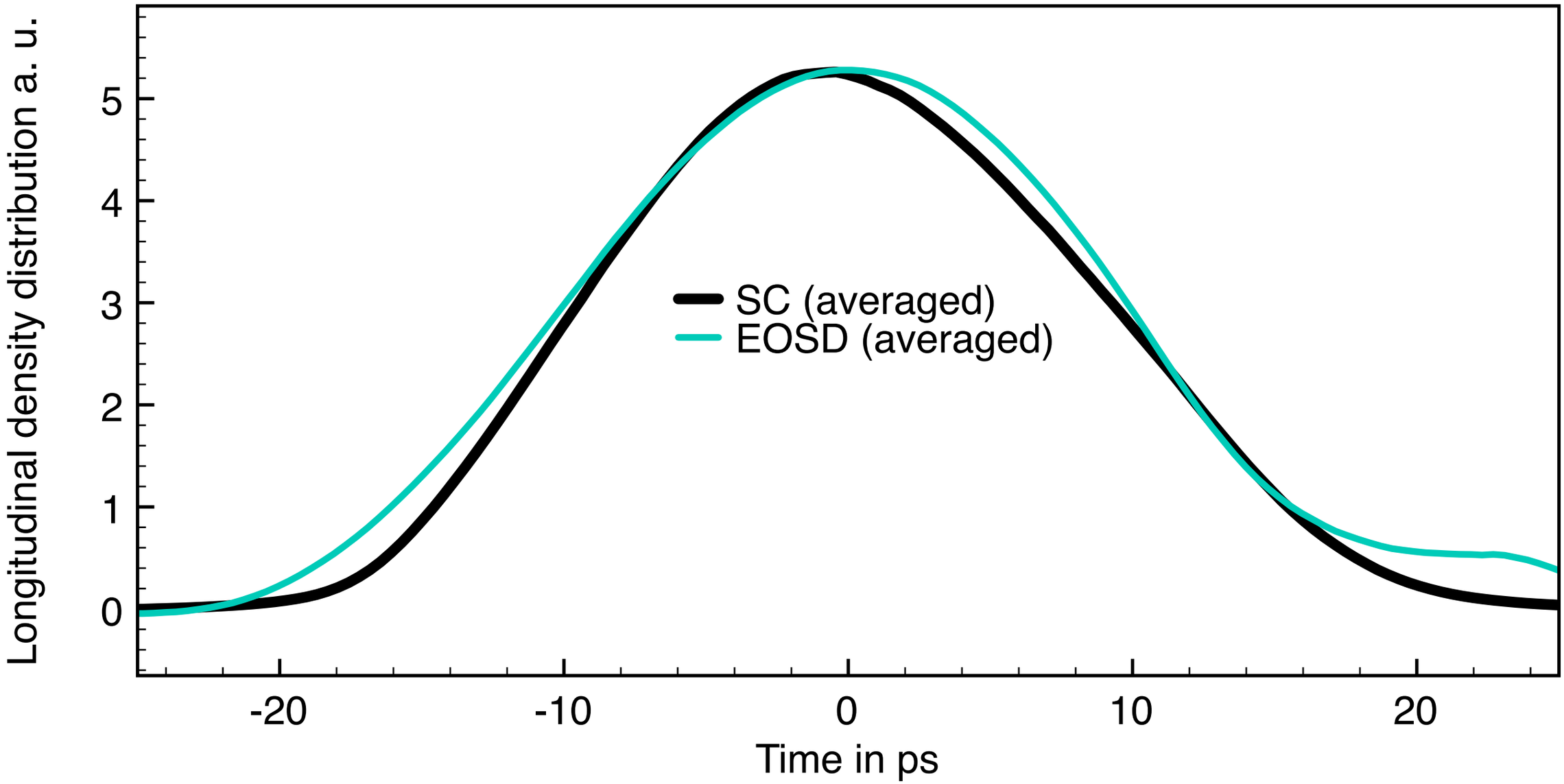




Delay within acquisition window not ideal.

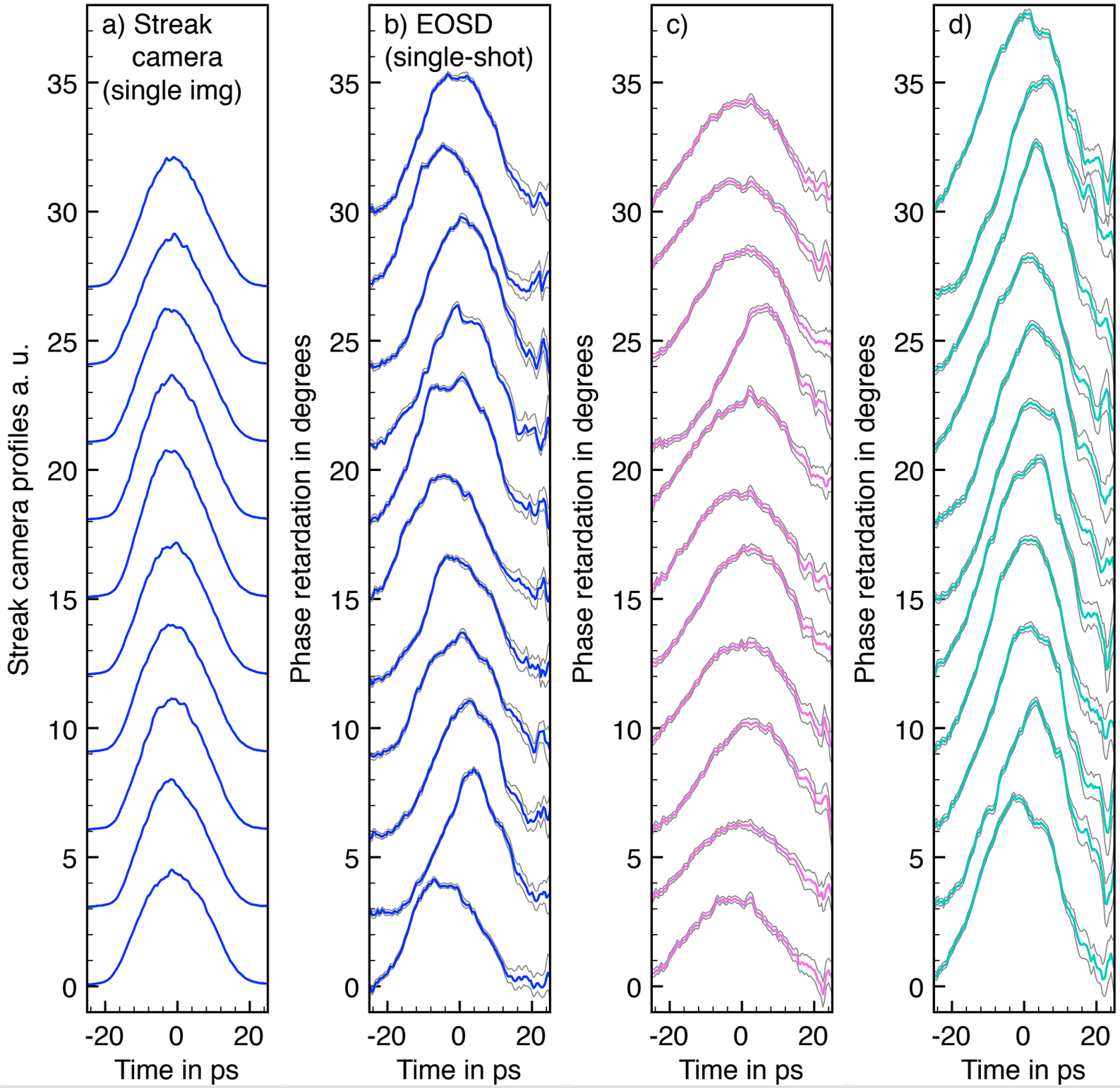
± 1σ error bands from background fluctuation measurements

Comparison with Streak Camera



Length agrees well, deformation shows systematic differences.

Single-shot bunch profiles for different beam parameters



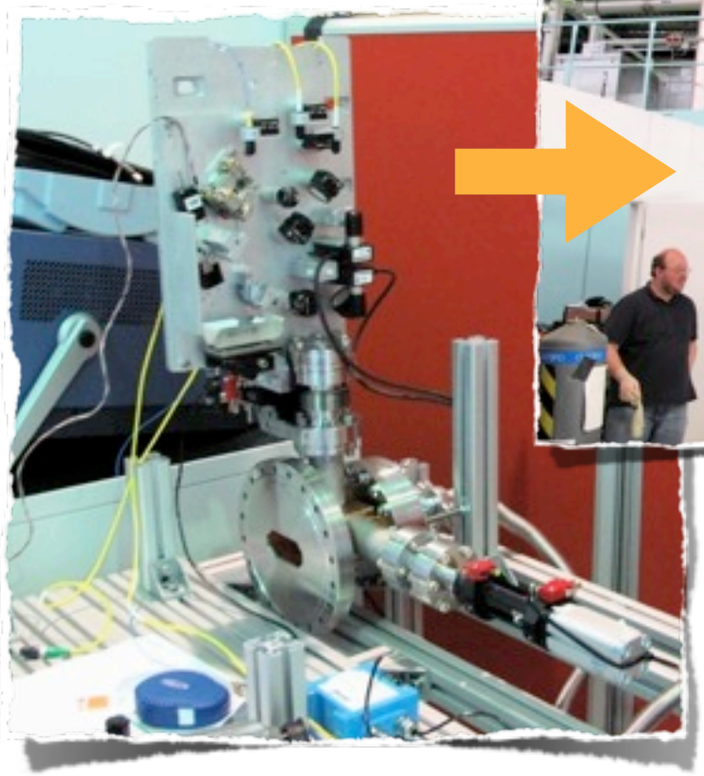
a) + b) 418 pC fully compressed e-beam

c) 422 pC only slight bunch compression

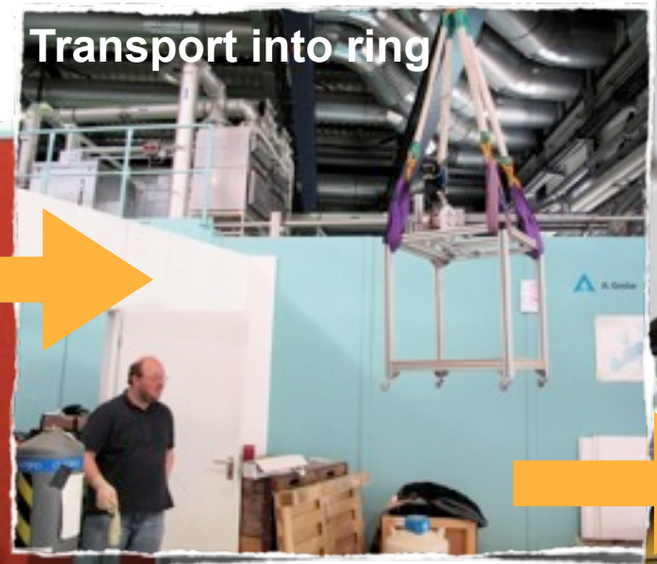
d) 648 pC intermediate compression

Thank you for your attention/support!

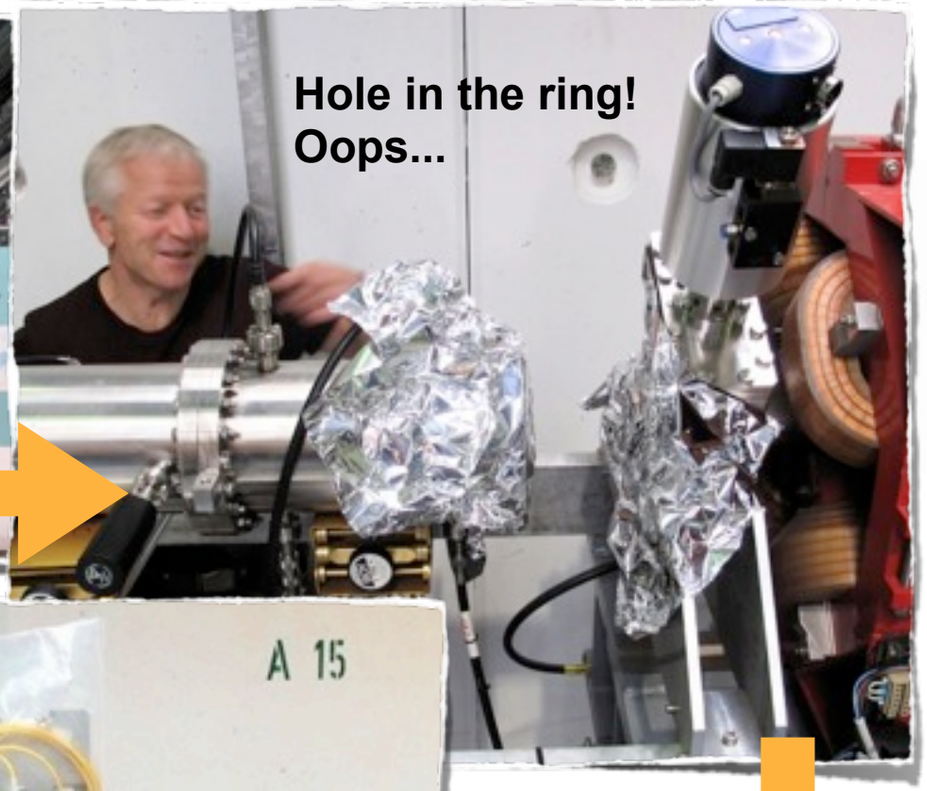
Alignment before installation



Transport into ring



Hole in the ring! Oops...

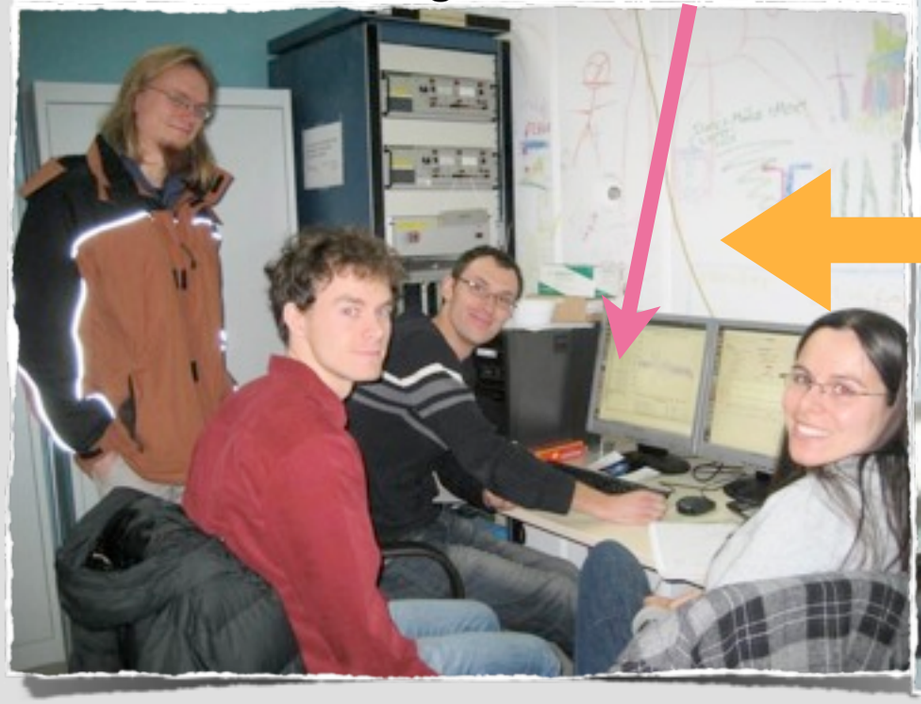


Done!

Making it fit

Measuring

First results!



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DESY

Backup Slides

Near-field EO set up at ANKA

Radiation protection wall

5. Single shot spectrometer / PD / Scope

4. long SM fiber (25 m) to transport signal back

Detection

EO-Laser

1. Yb doped fiber laser
+ single pass fiber amplifier with pulse picker

long cable (26 m) to get BPM signal

Beam position monitor for timing

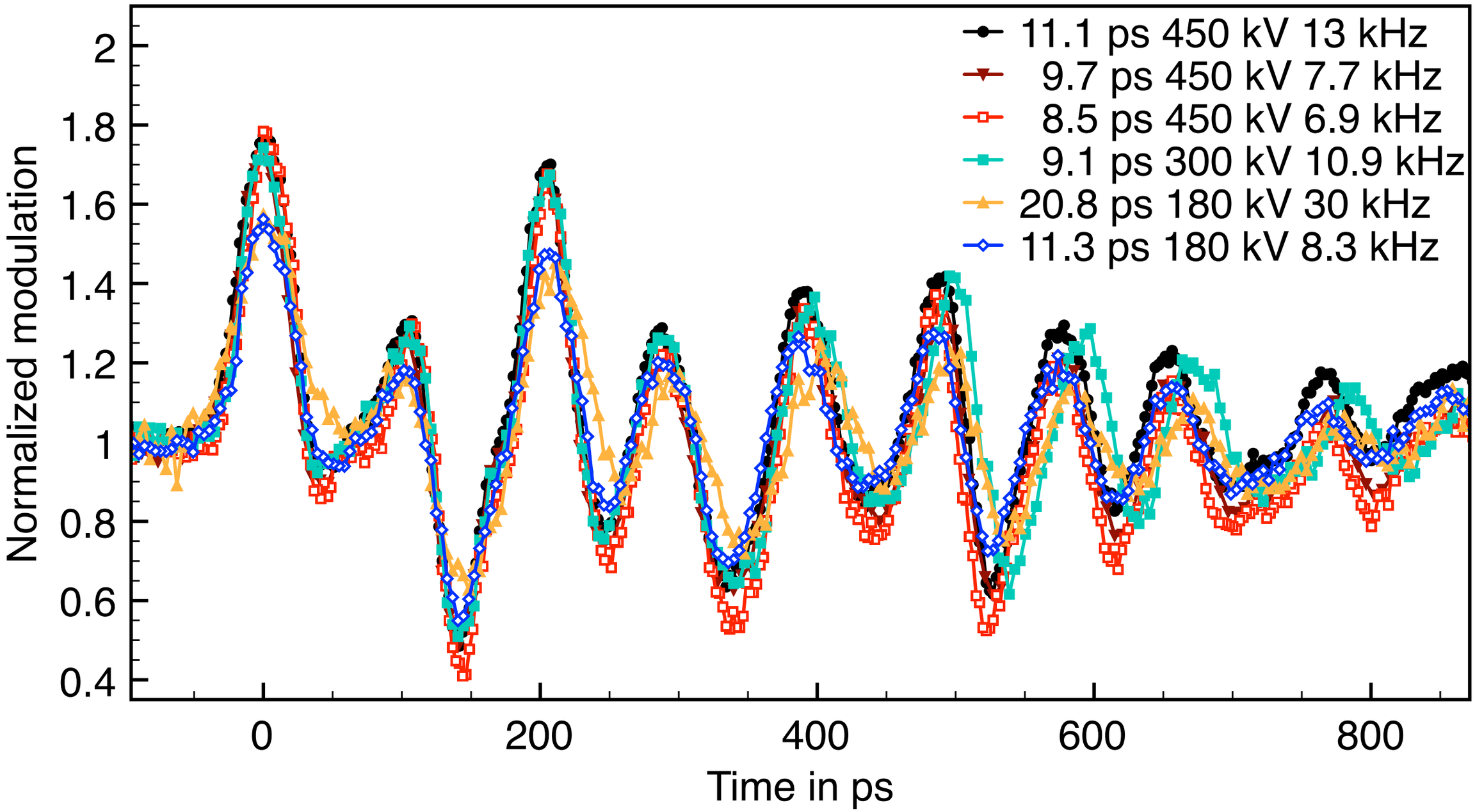
2. long PM fiber (35 m) to stretch pulses

BPM

EOM position

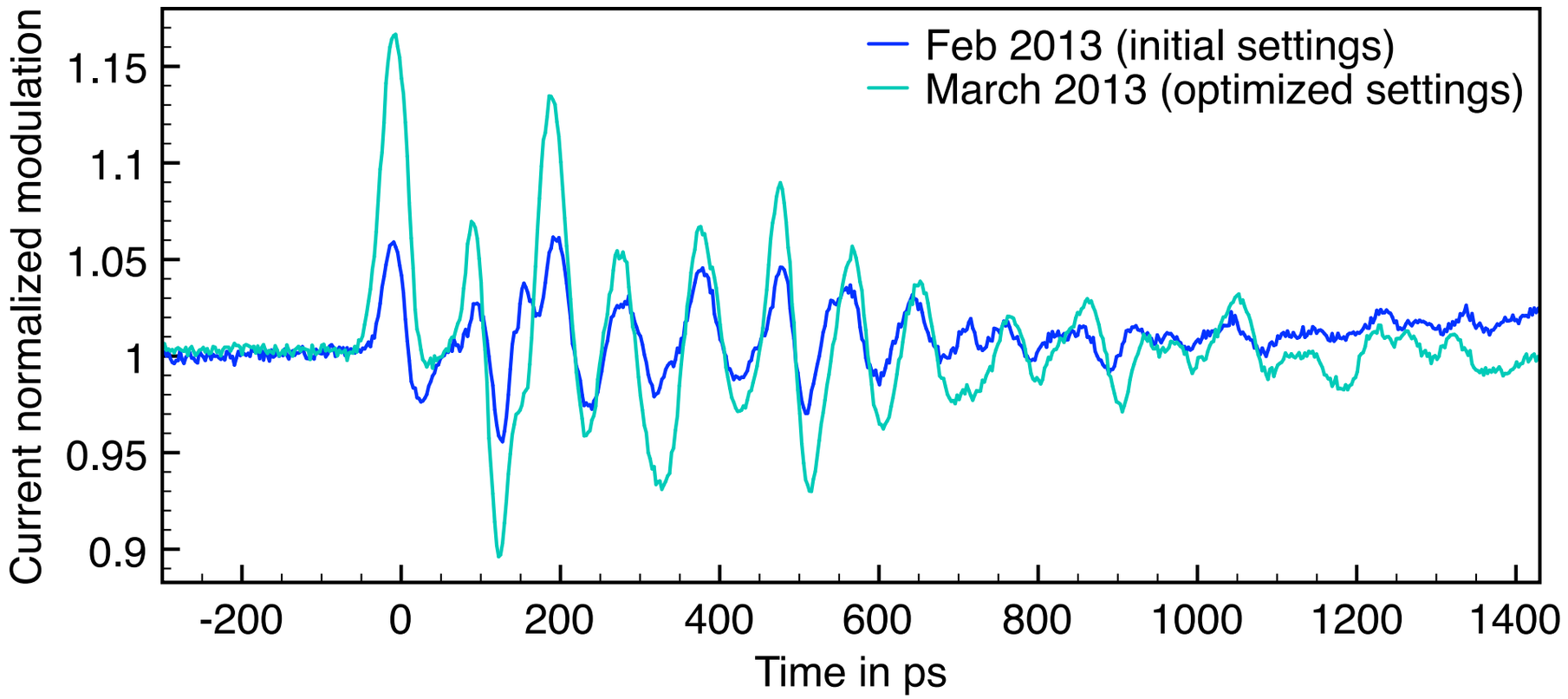
3. pulse compressor + EO monitor

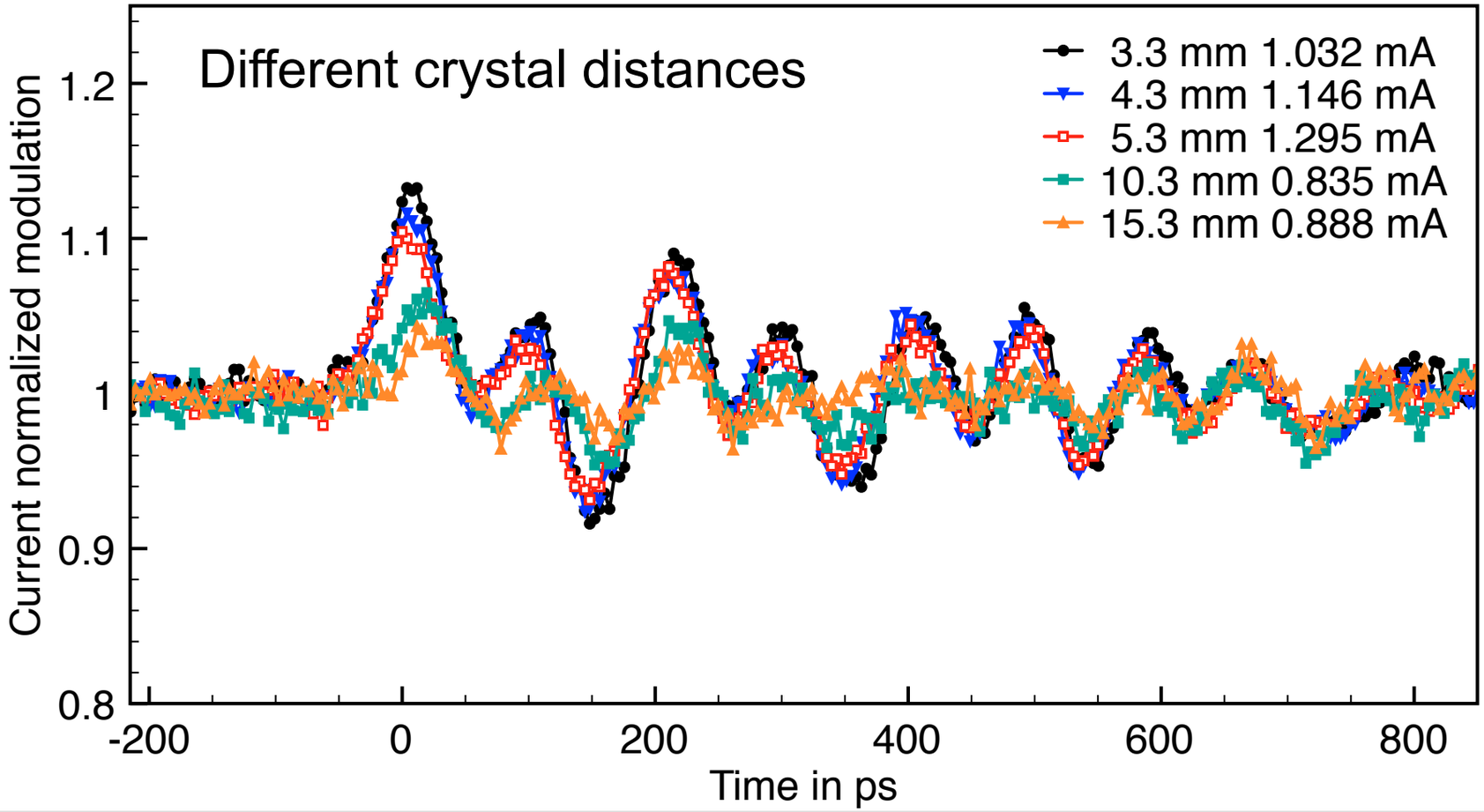
EOS for different machine settings



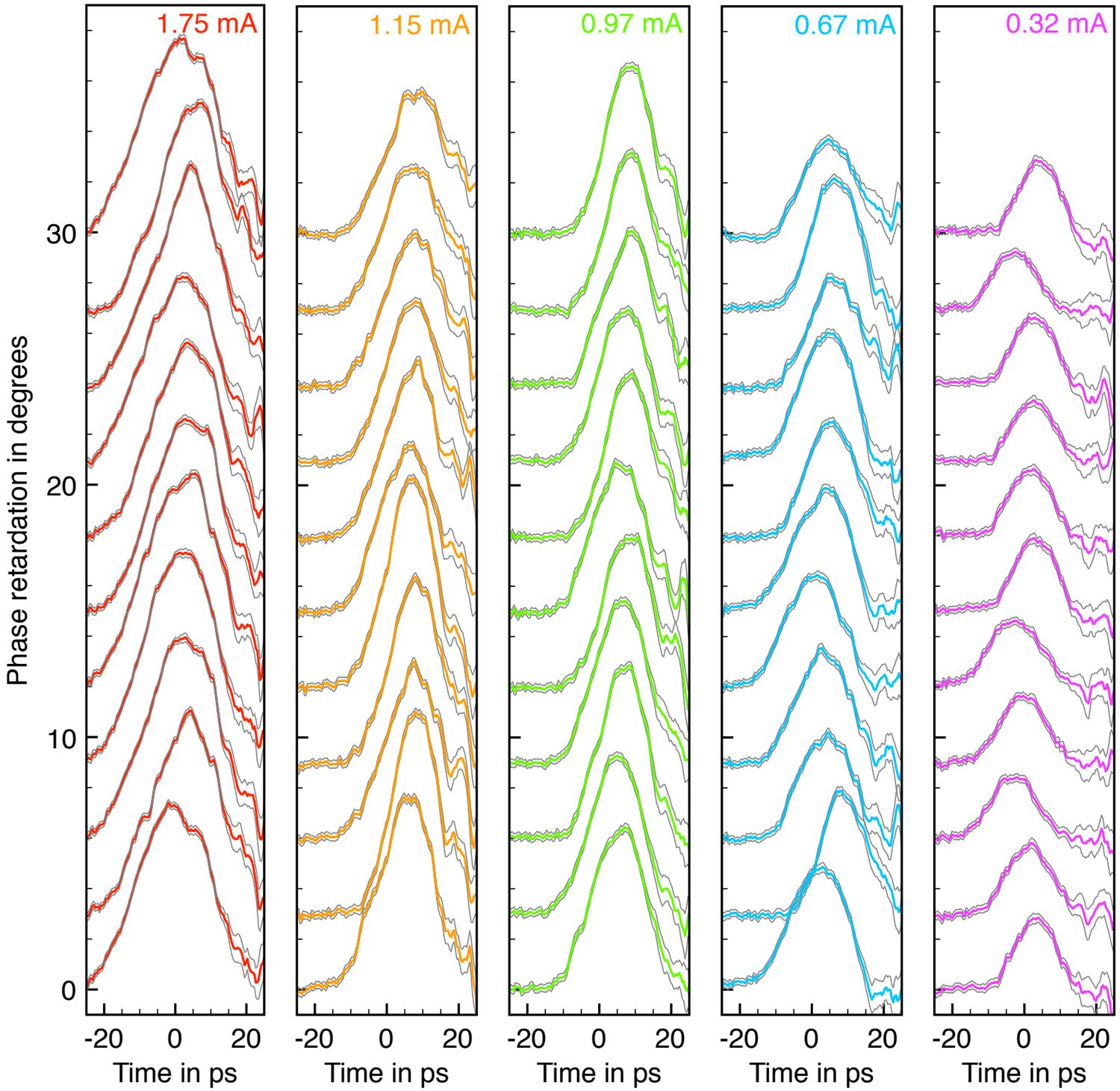
EOS

Long tail of wake-fields.





EOSD for different beam currents



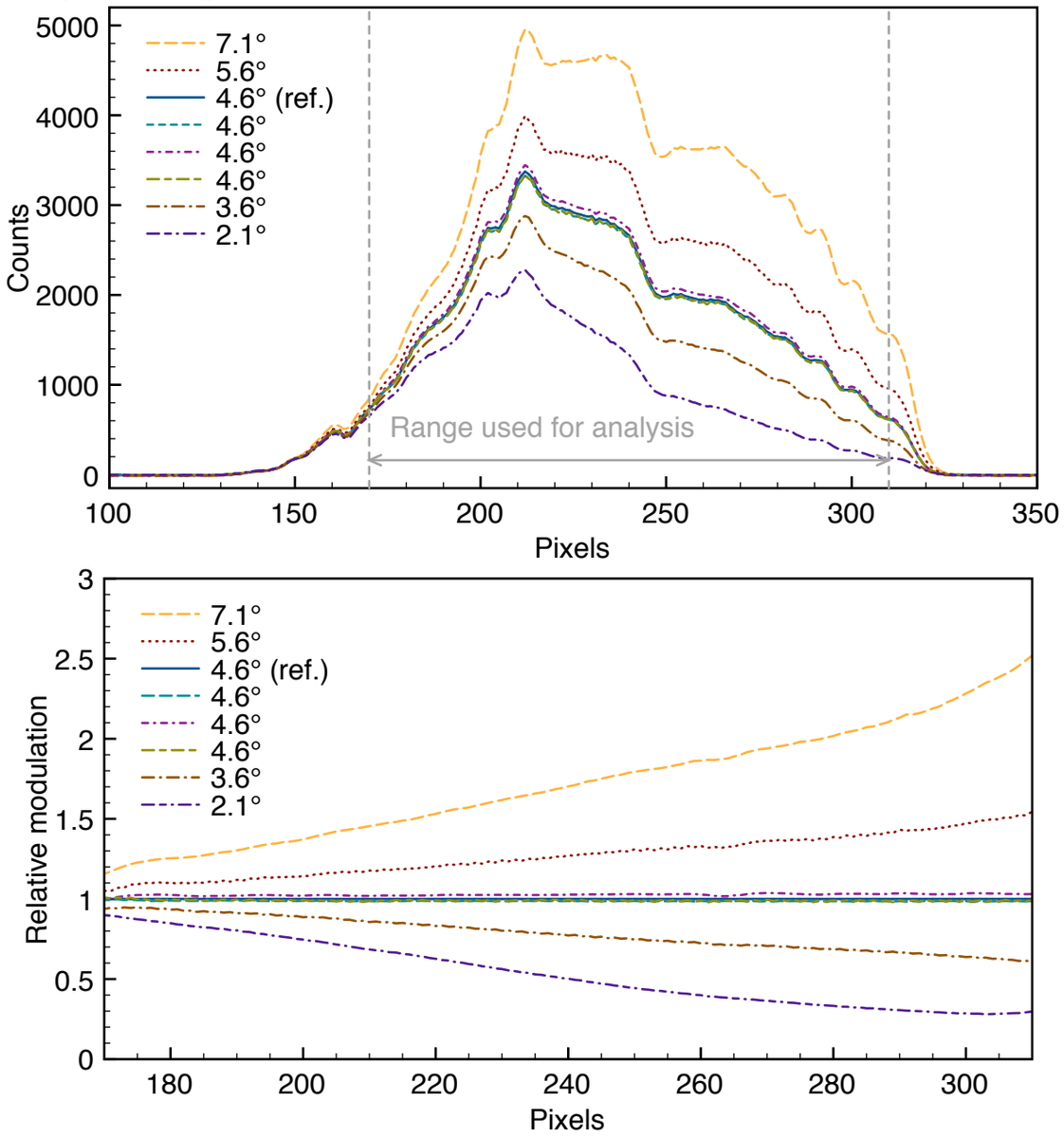
Phase-Calibration

$$I_{\text{final}} = \frac{1}{2} I_{\text{laser}} \left(1 - \cos\left(\Gamma - 4\Theta\right)\right)$$

HWP angle

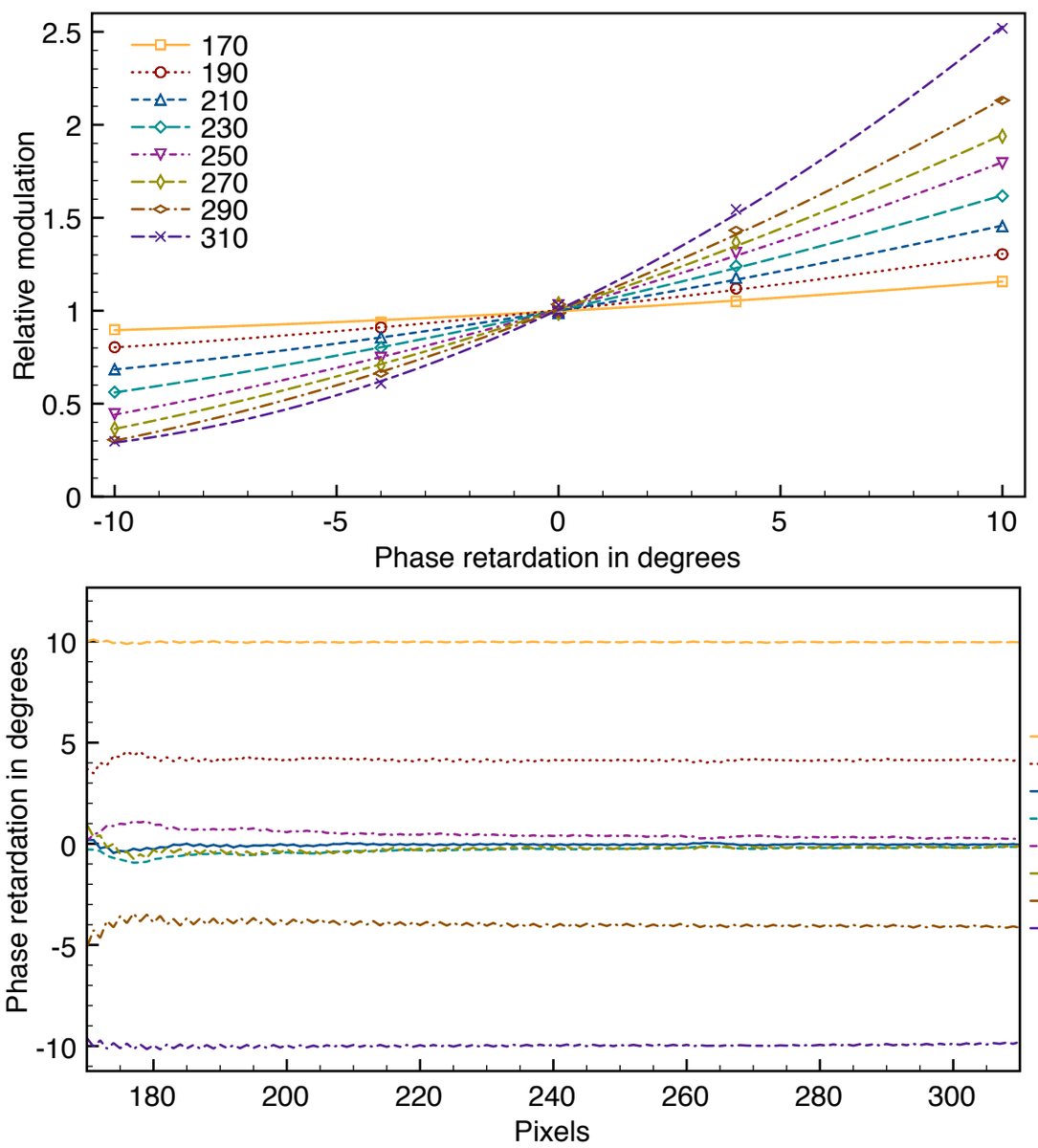
$$\Gamma = \frac{\omega d}{c} n_0^3 r_{41} E$$

Unmodulated laser spectra for different angles of the half-wave-plate (HWP)



Relative modulation dependent on pixel number

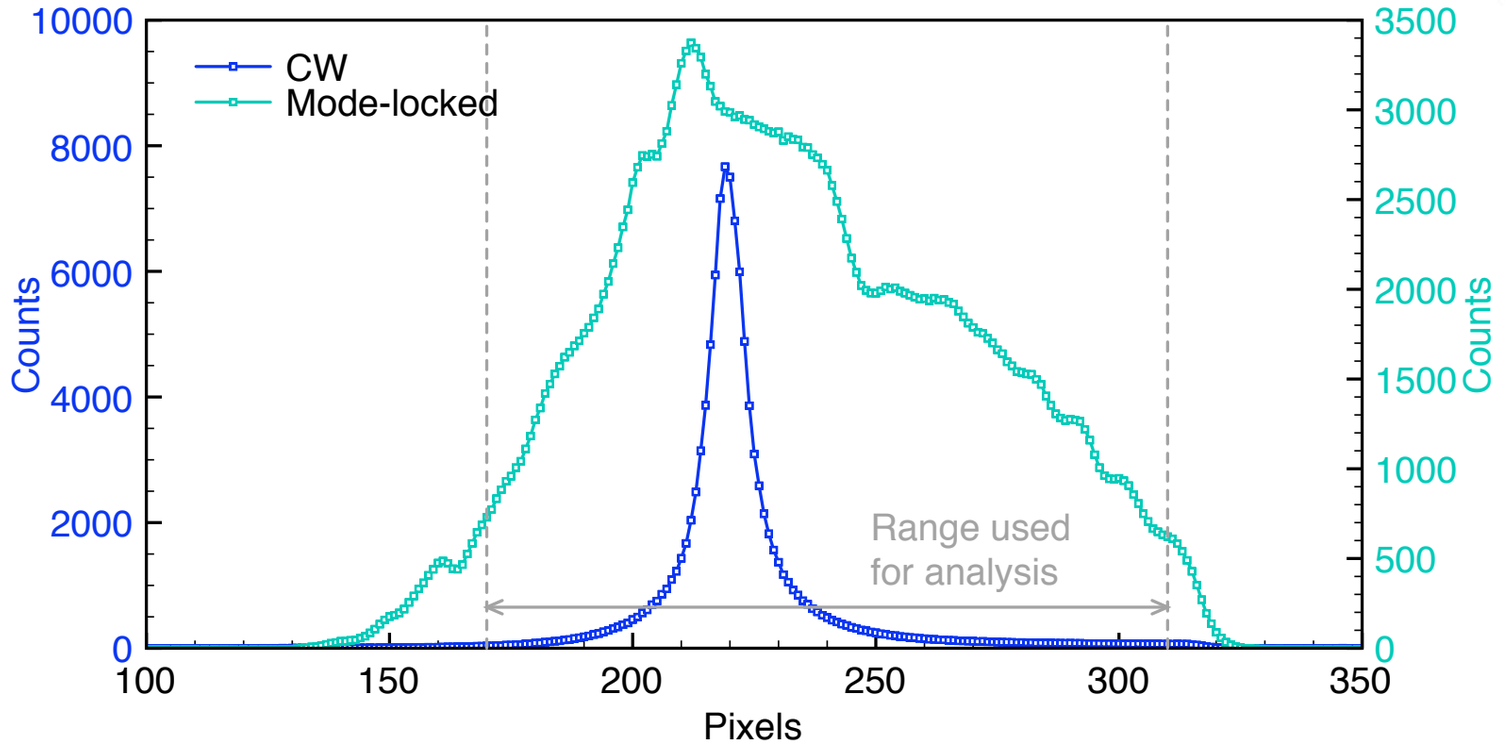
Fits to data

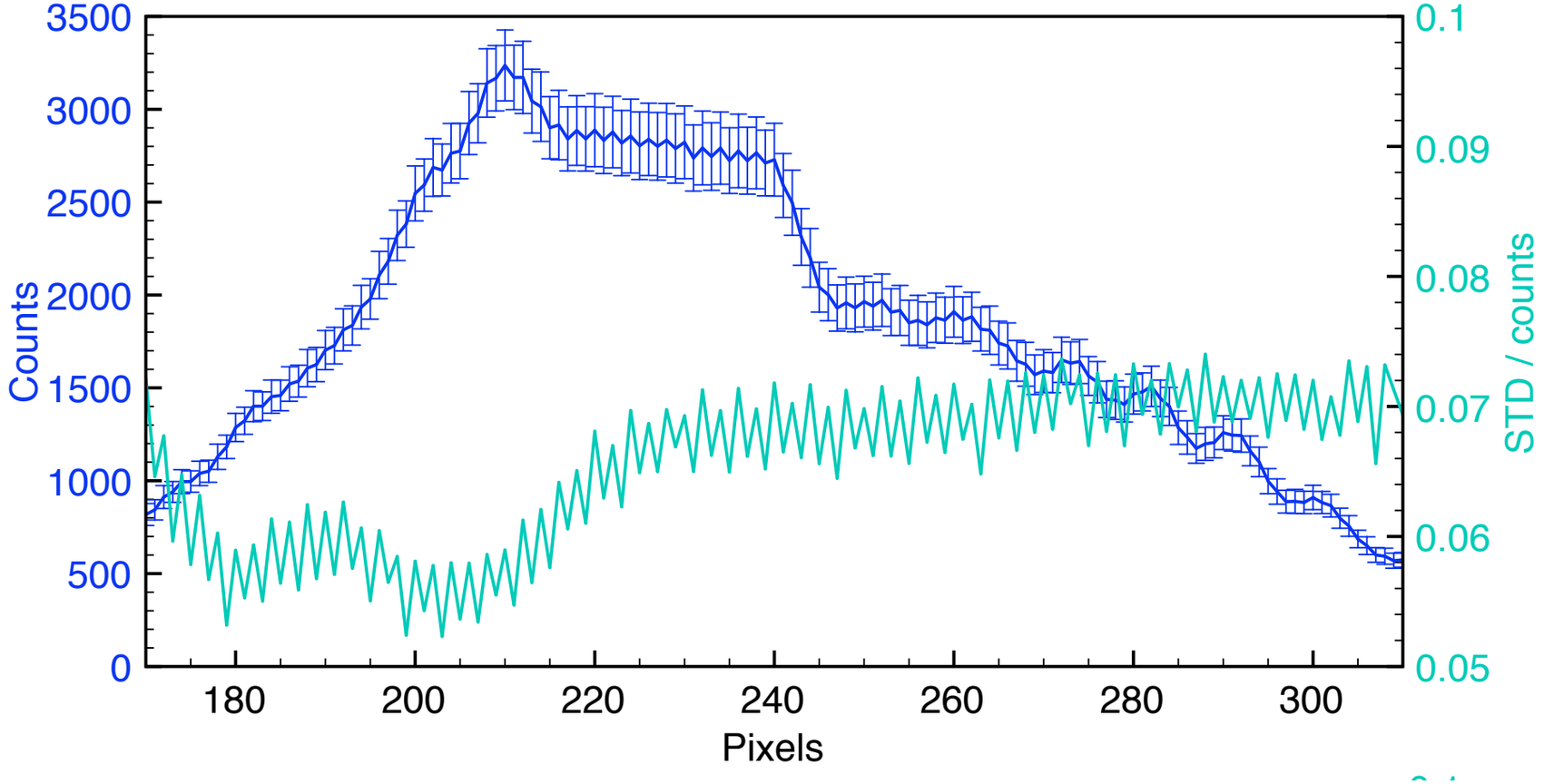


Calibrated data

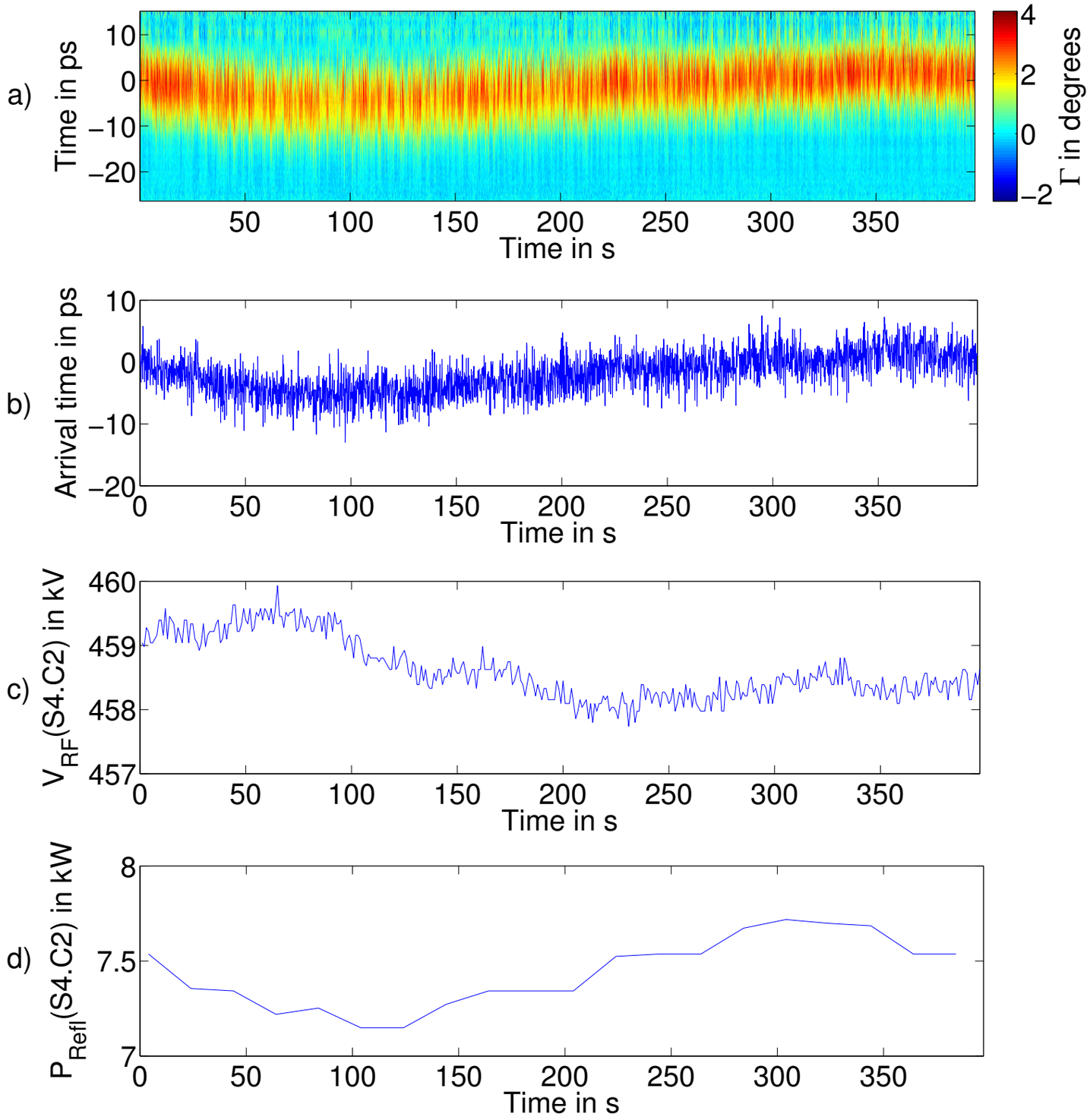
Hopefully just a problem with cheap wave-plates!

Resolution & Spectral fluctuations





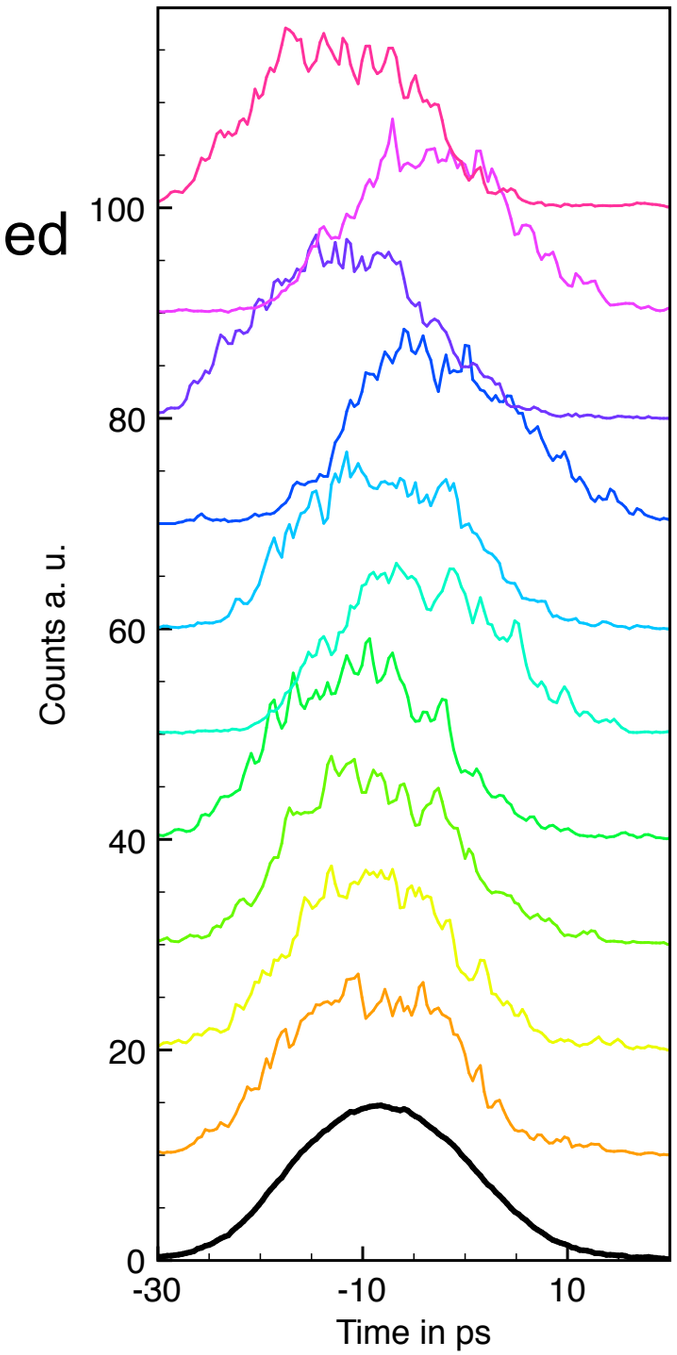
EOSD as arrival time monitor to identify cavity cooling loop troubles

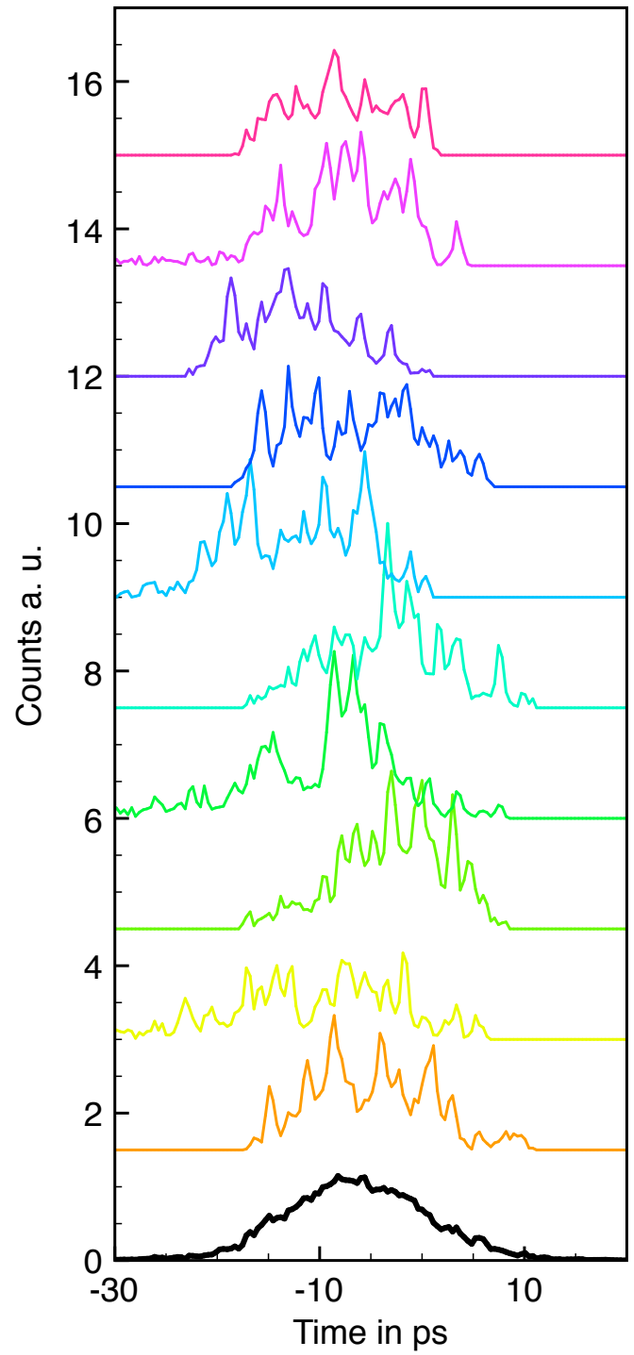


Streak Camera single-shot measurements

Without filters;
v-slit fully opened

111 pC

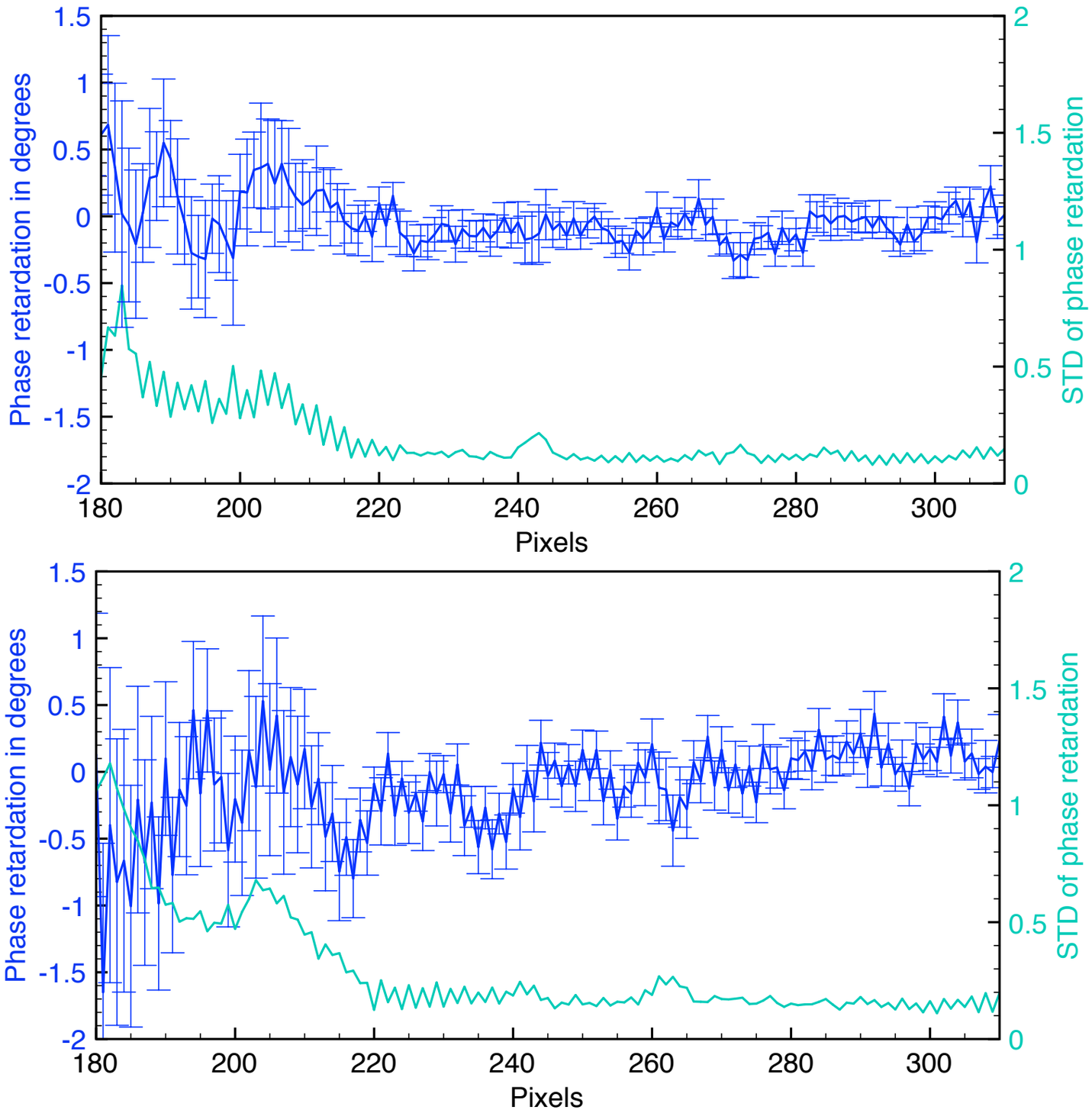




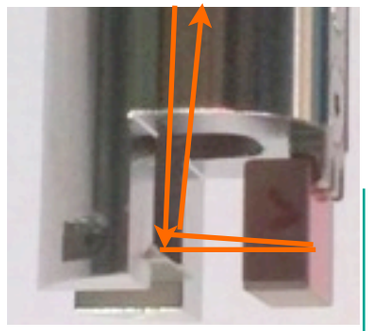
550 nm optical bandpass filter; v-slit fully opened

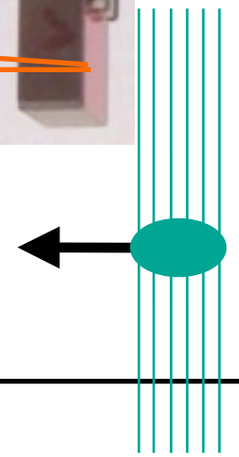
Dominated by shot-noise

Background fluctuations

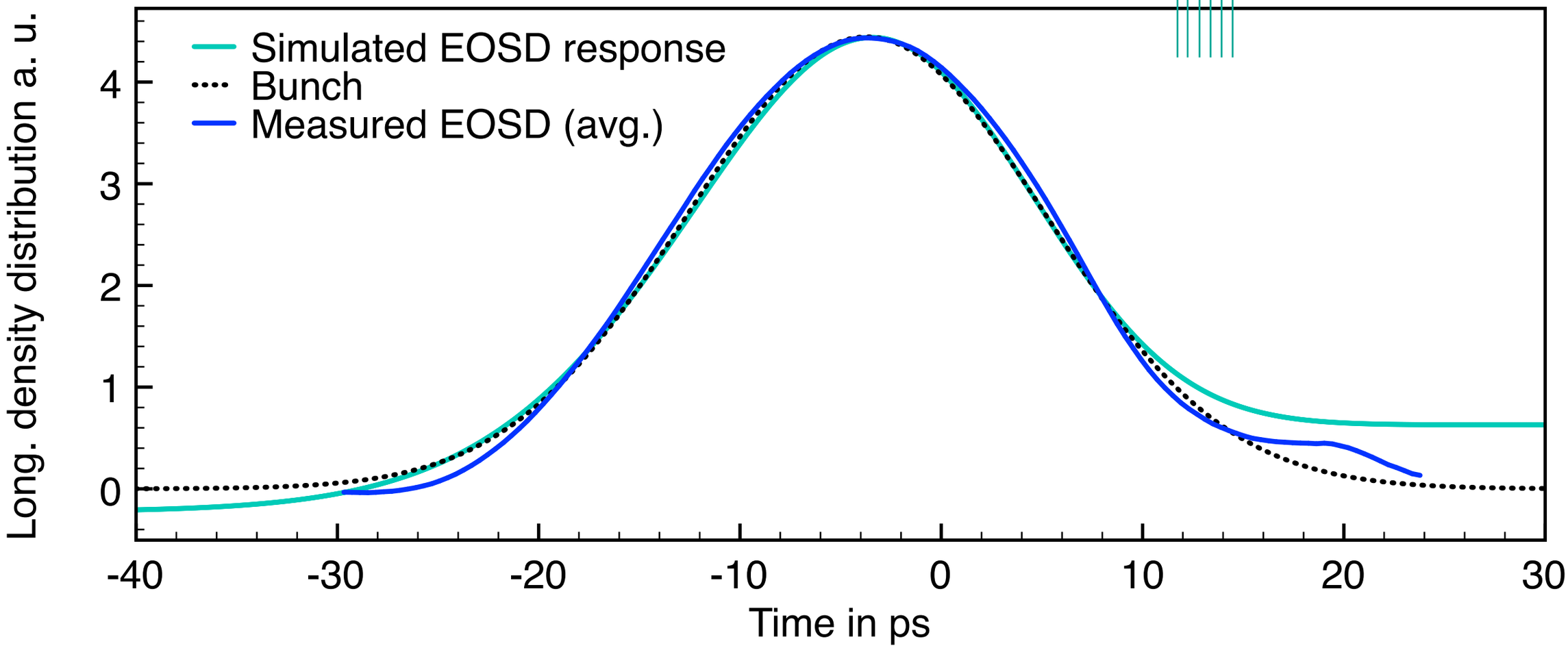


Simulated and measured EOSD response due to compact setup

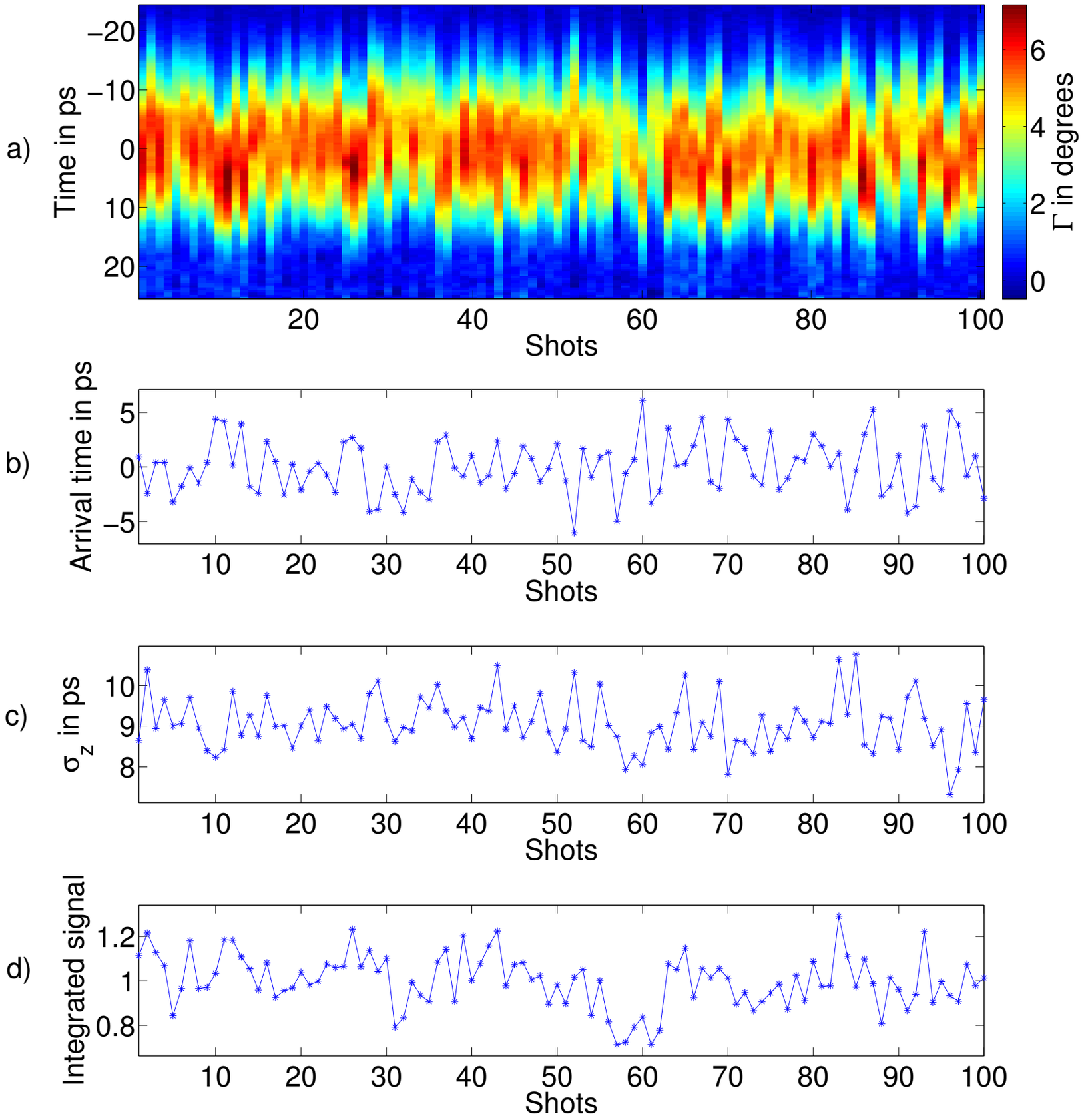




electron bunch



Fluctuations



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