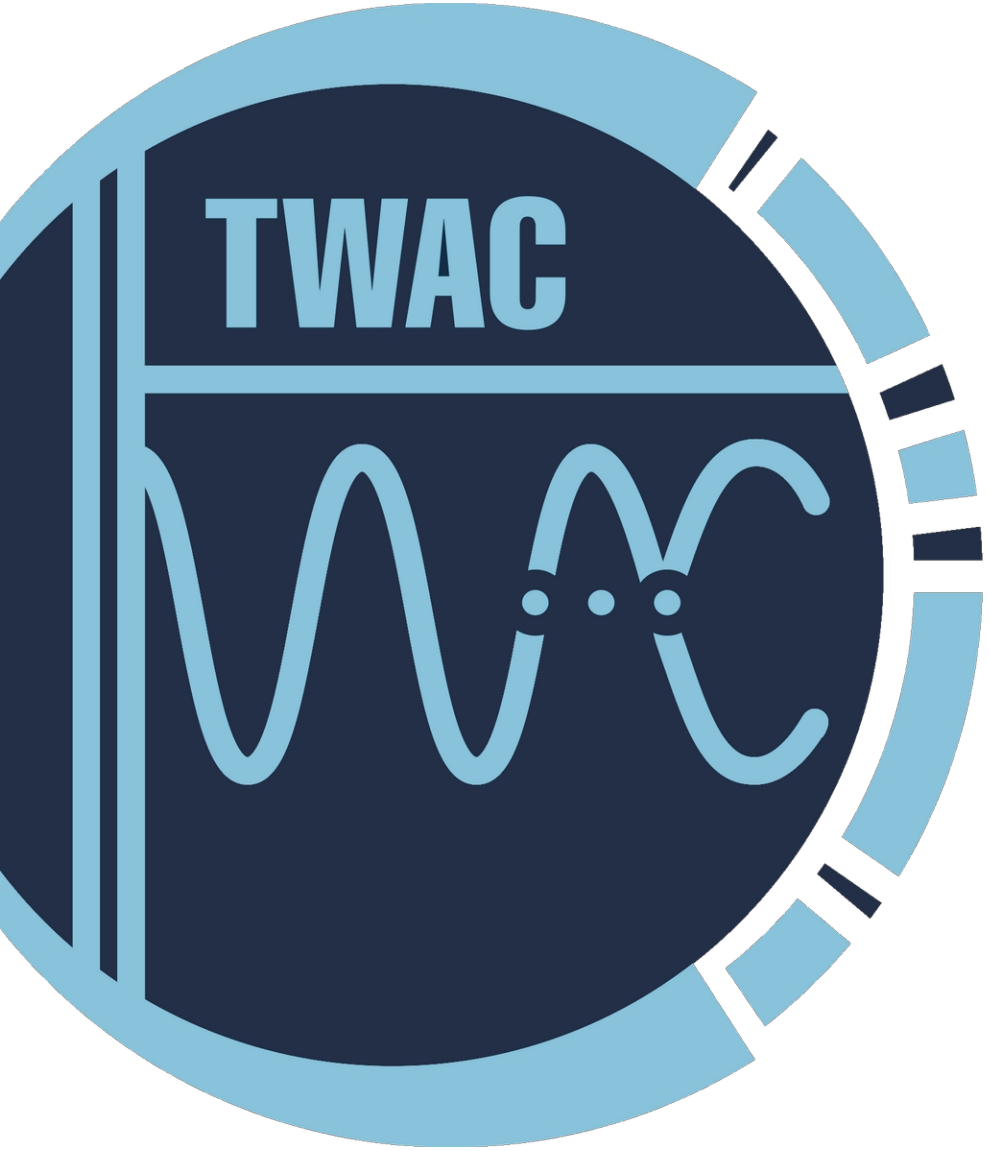
# Speedtalks

1. Coline Gyot
2. Gudrun Niehues
3. J. Michael Klopf
4. Juna Wernsmann
5. Aram Kalaydzhyan
6. Karel Petermans
7. Micha Reissig
8. Andreas Penirschke
9. Quentin Demazeux
10. Siriwan Pakluea
11. Blea Stacey
12. Max Kellermann




# Electron Bunch Compression Measurements on the Compact Electron Accelerator Prototype TWAC

14th Collaboration Workshop on Longitudinal Diagnostics, Sept. 29th-Oct .1st at DESY

Coline Guyot on behalf of TWAC

Funded by the European Union and the Swiss State Secretariat for Education, Research and Innovation (SERI).

# (Future) Electron Bunch Compression Measurements on the Compact Electron Accelerator Prototype TWAC

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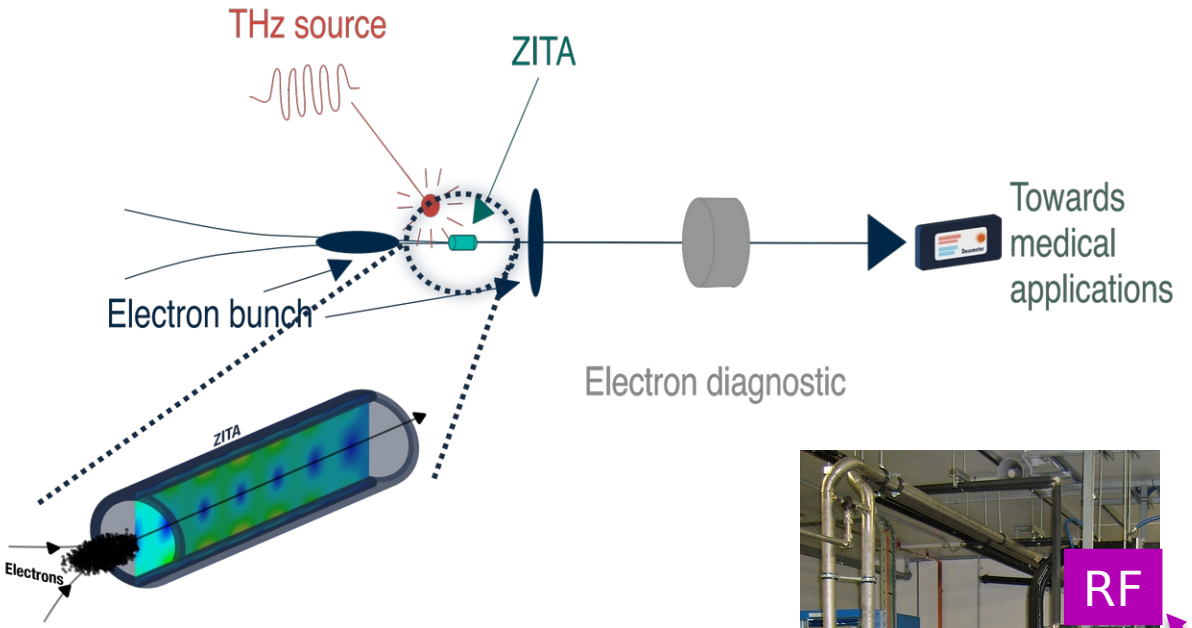
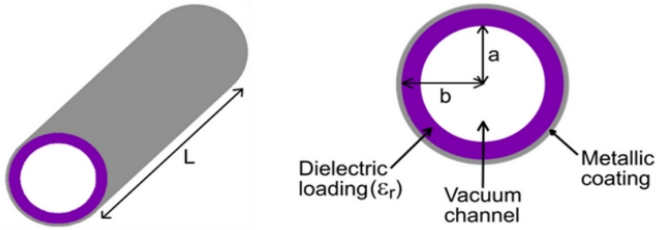
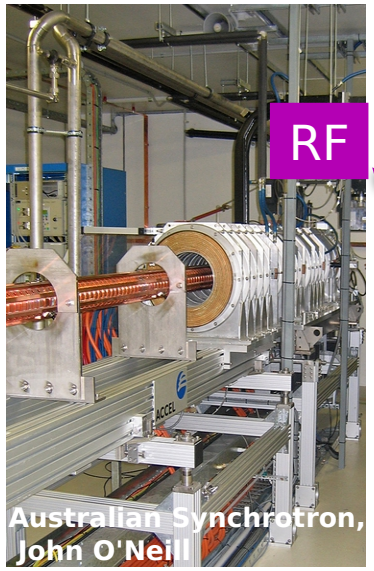
# TWAC: Thz Waveguide Acceleration Project

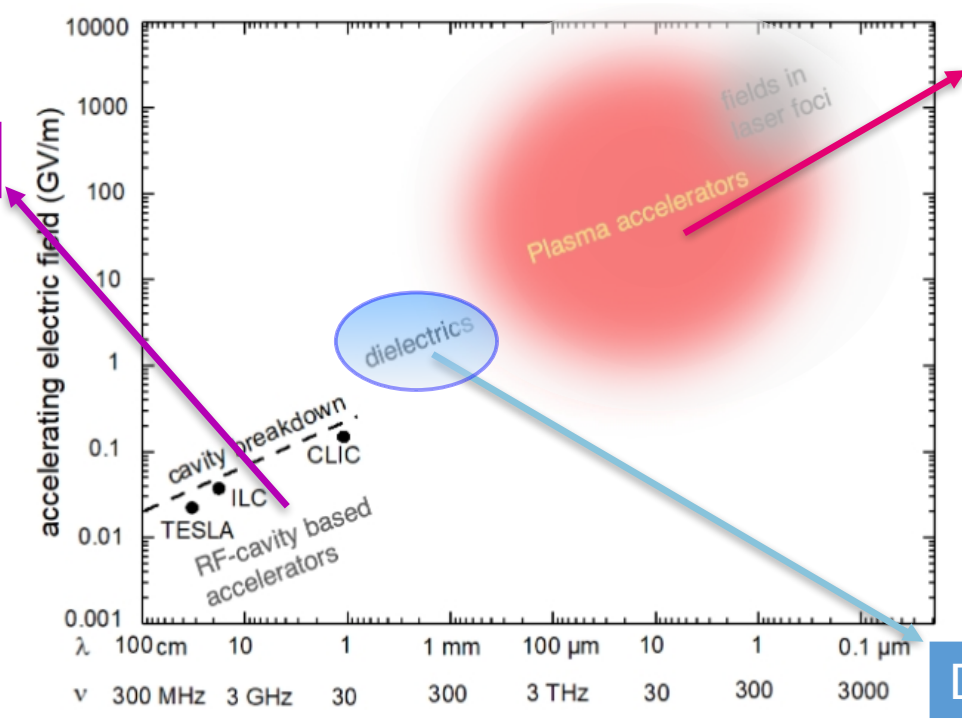



Toward Compact Accelerators with high gradient and high peak current.
First prototype of 1-m scale kA accelerator with high frequency industrial cavity.

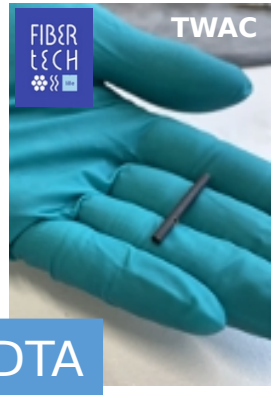
'THz' Accelerating Field
+ Dielectric Waveguide







# Coherent Transition Radiation Diagnostic

[B. Gitter, CAA-TECH-NOTE, 1992]

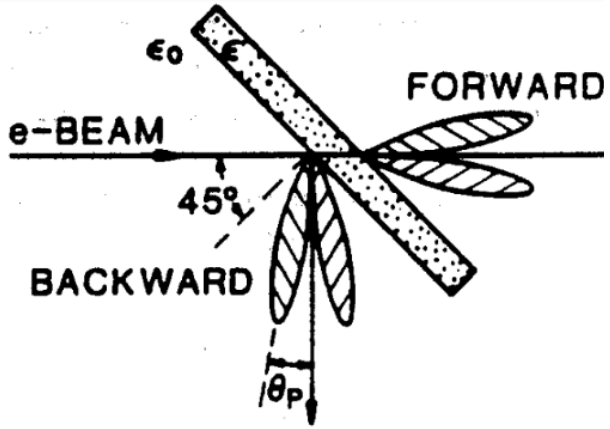
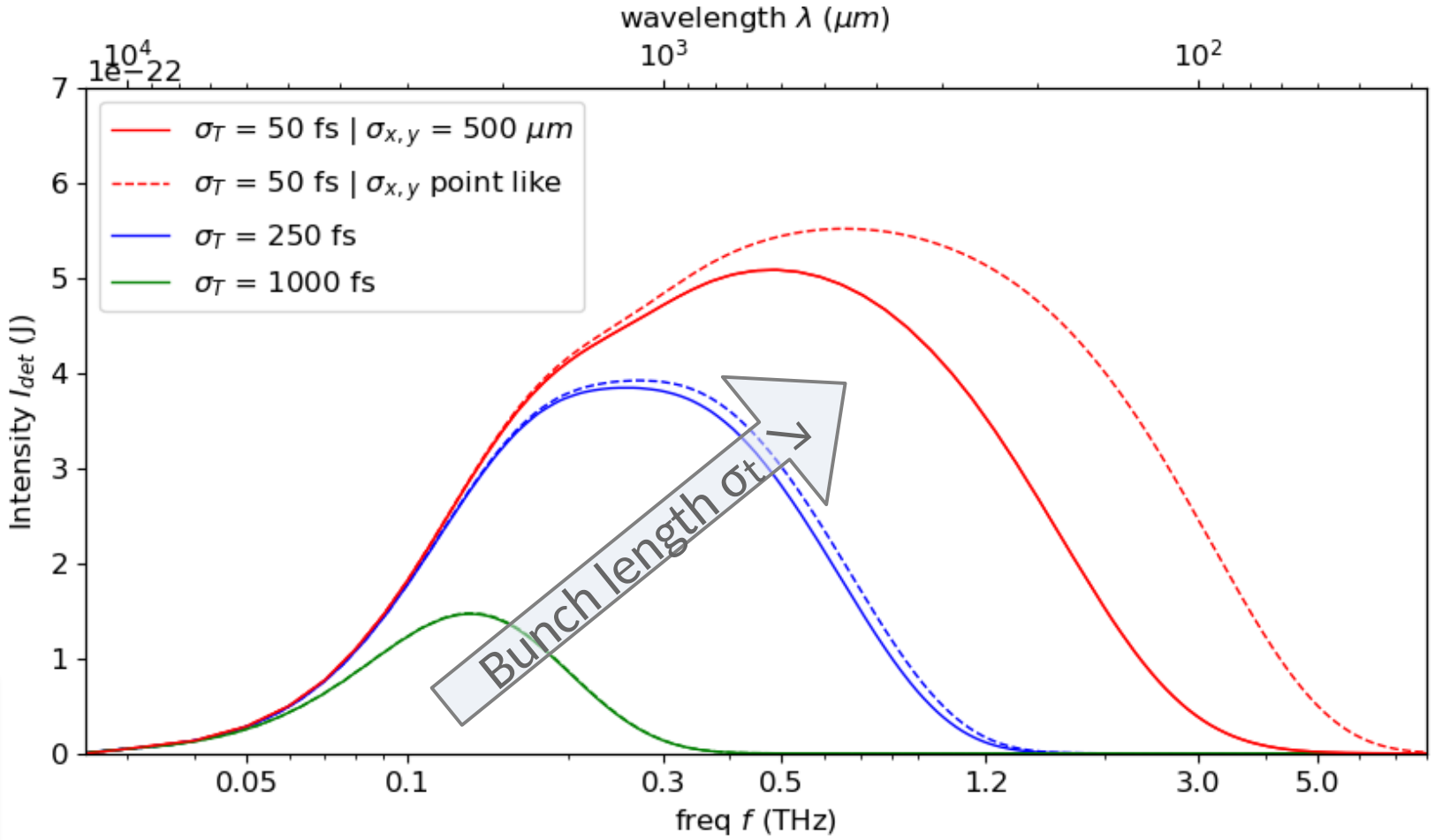



**Figure 6.** Radiation pattern made by a relativistic electron beam passing through a metal foil at an angle of 45° taken from Lumpkin *et al.*[14].




Integrated CTR measures for Bunch Compression Rate for bunch duration ranging from several 100s fs to 10s of fs
Low charge, low energy

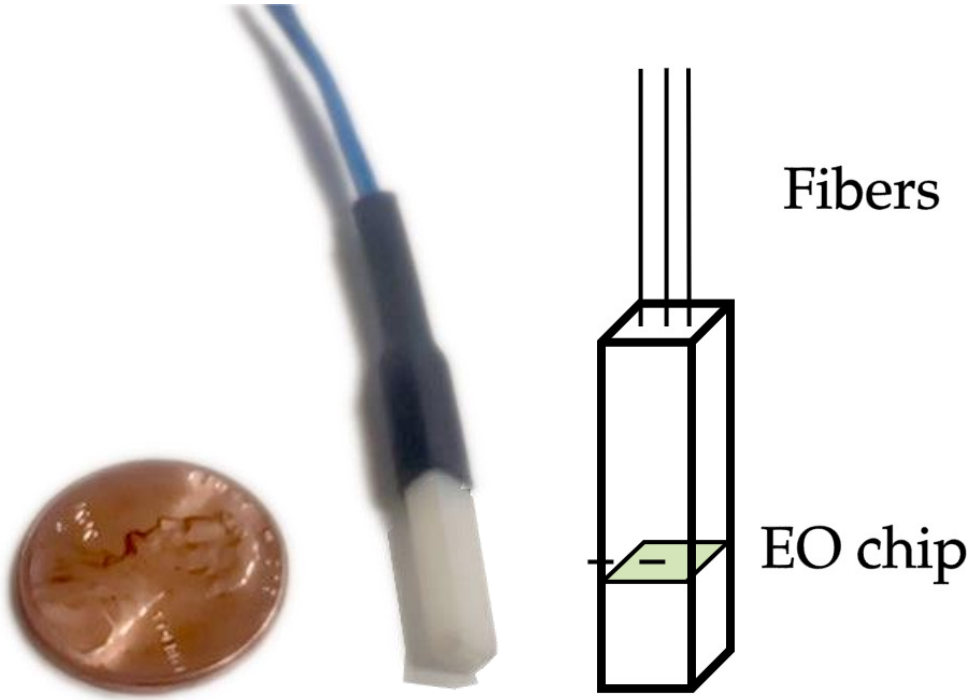
TWAC is funded by :

# Measurements of CSR radiation at KARA using novel thin-film lithium niobate electro-optical sensors

G. Niehues[1], S. Funkner[1], M. Noll[1], J. L. Steinmann[1], P. Rabiei[2], S. Toroghi[2], I. Wilke[3]

[1] Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany.
[2] Rensselaer Polytechnic Institute, Troy, NY 12180, USA.
[3] Partow Technologies LLC, Vista, CA 92081, USA.

14th Collaborative Longitudinal Diagnostics Workshop 2025, DESY, Hamburg

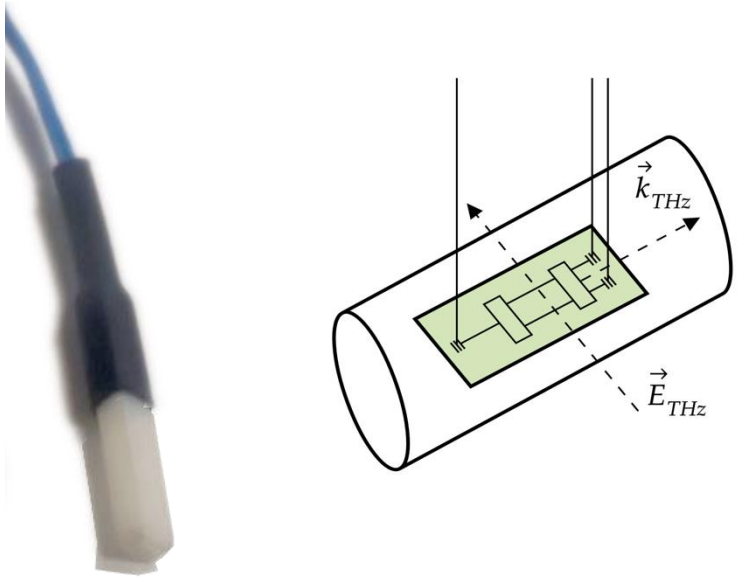



photonic integrated sensor

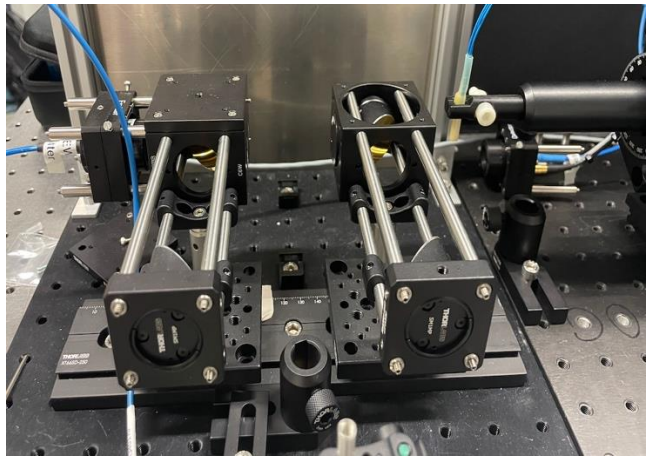
IBPT
Institute for Beam Physics and Technology

# Photonic Integrated Sensor @ KARA:

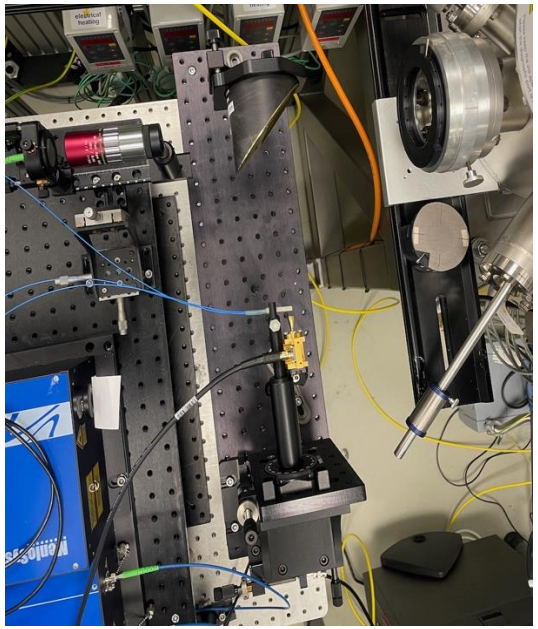
## Sensor Concept




## Characterization Measurements



## CSR Measurements



More at the poster….

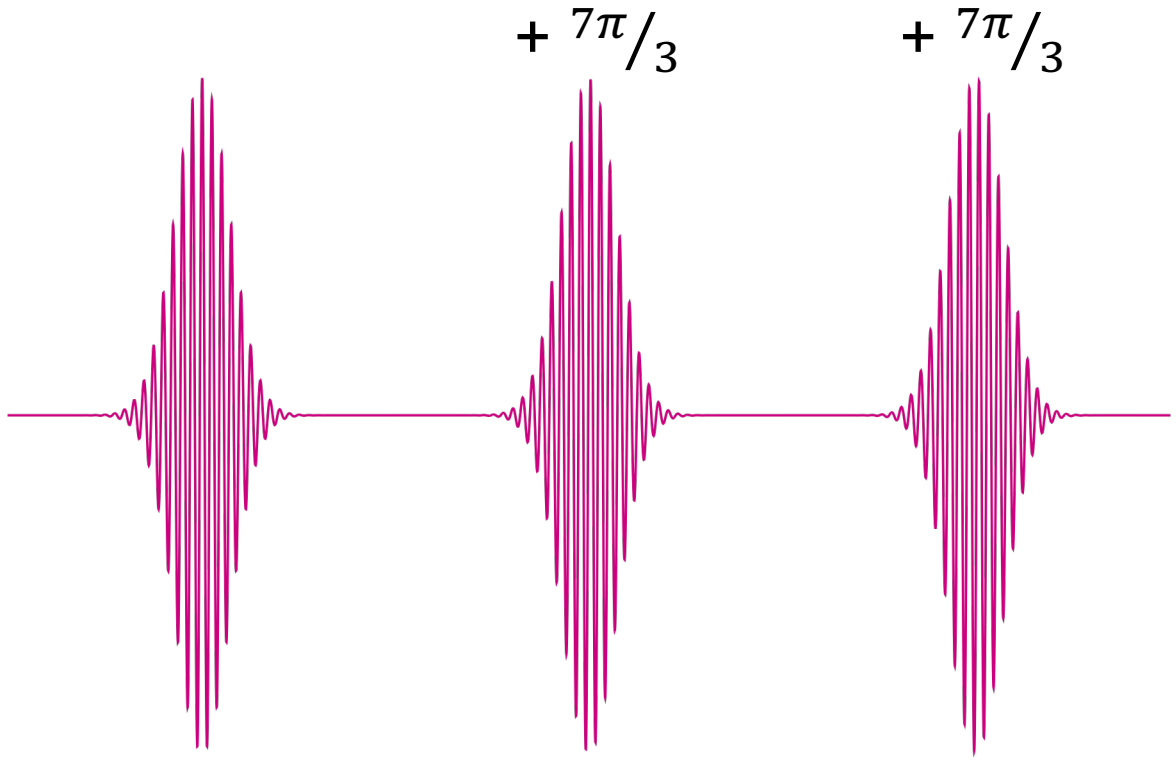
# Simultaneous detection of the magnitude and phase of a THz waveform at high repetition rates

J. Michael Klopf

14th Collaboration Workshop on Longitudinal Diagnostics
*DESY, Hamburg*
*2025.09.30*

# FEL Detuning and CEP Stability

- "*detuning*" of an FEL oscillator refers to shortening the cavity length below "*zero detuning*"
- at *zero detuning* the cavity round trip time matches the rep. rate of the $e^-$ bunches, but the FEL cannot sustain lasing
- detuning causes slippage of the CEP
- CEP stable lasing is possible at detuning of N*λ
- CEP stability is critical for measuring coherent processes – so – **we must find a way to measure it**
- cavity length control based on feedback from measurement of the CEP is a pathway to utilizing THz/IR FELs for driving and measuring coherent dynamics






J. Michael Klopf • klopf@hzdr.de • www.hzdr.de • HZDR

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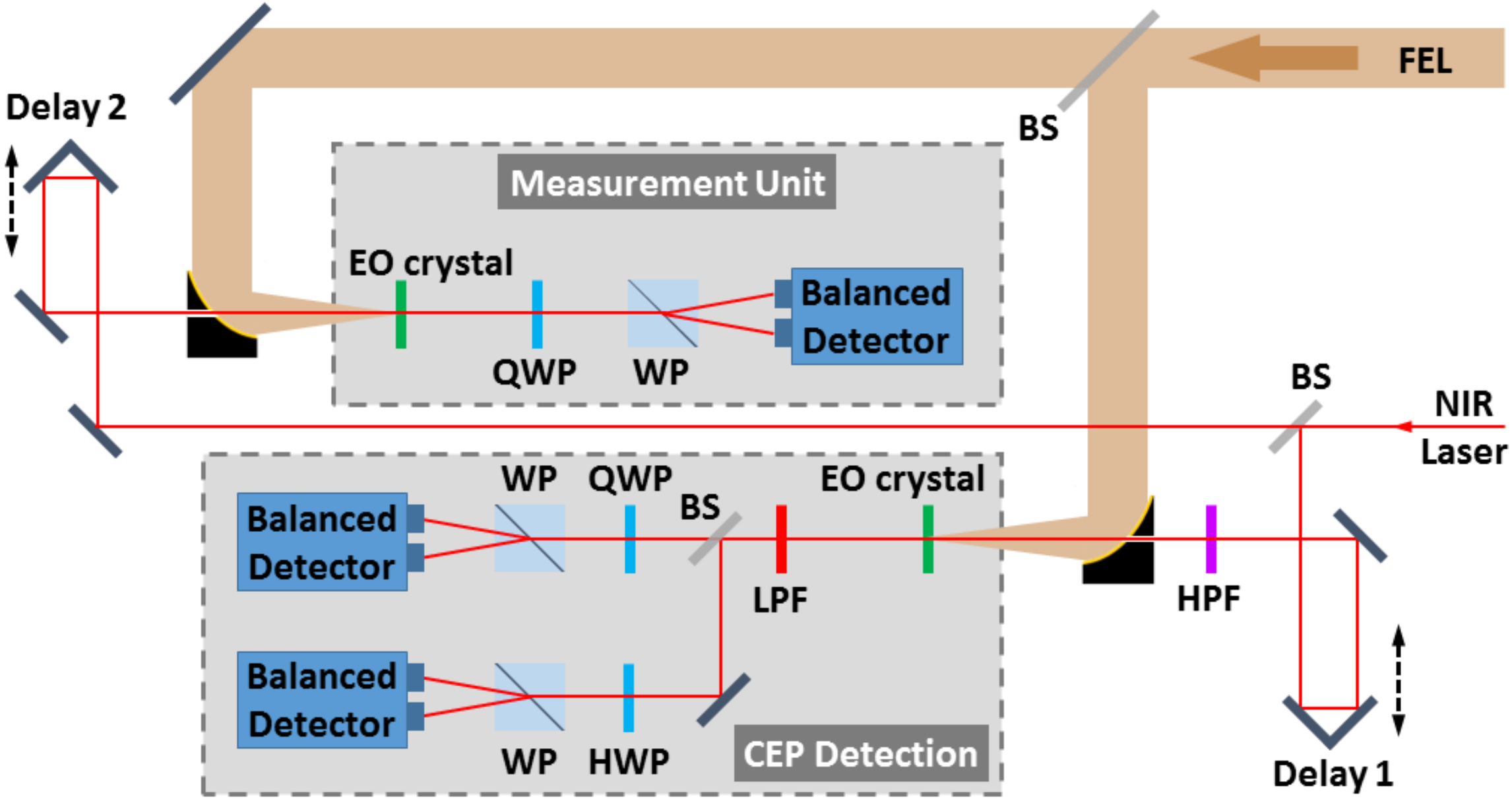
# Layout for Shot-to-Shot CEP Measurement



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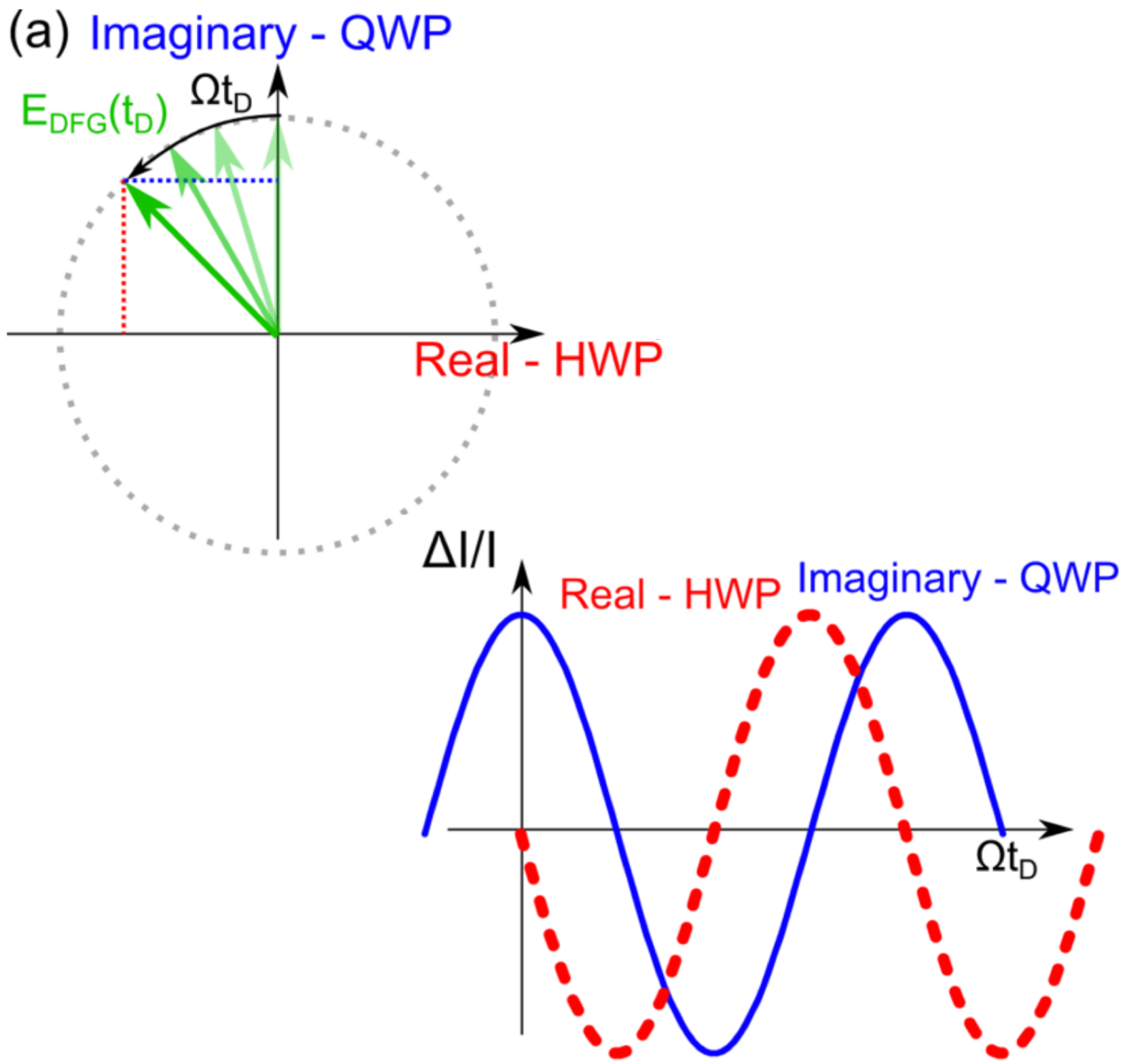
# CEP Measurement Scheme

- to understand the CEP measurement one should consider the EO effect in the frequency domain
- interaction of the instantaneous E field of the THz waveform with the NIR laser pulse creates new photons by **DFG** and **SFG** which are polarized perpendicular to the NIR polarization
- using a thin EO crystal and tilting the crystal slightly to achieve ideal phase matching, the nonlinear interaction generates primarily DFG photons
- use of a low pass filter further enhances the DFG part of the EO signal
- the signals from the HWP and QWP detection are phase shifted by $\pi/2$ (i.e. *Sin* and *Cos*)
- excellent description and analysis by the Leitenstorfer group here




Sulzer, P. et al. Phys. Rev. A **101**, 033821 (2020).



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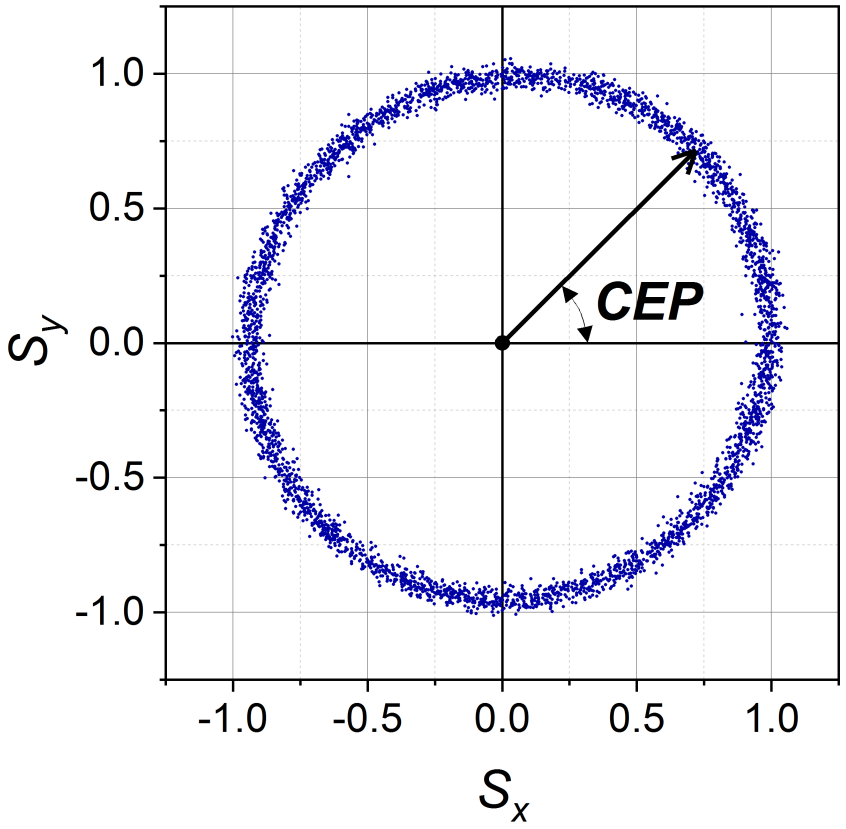
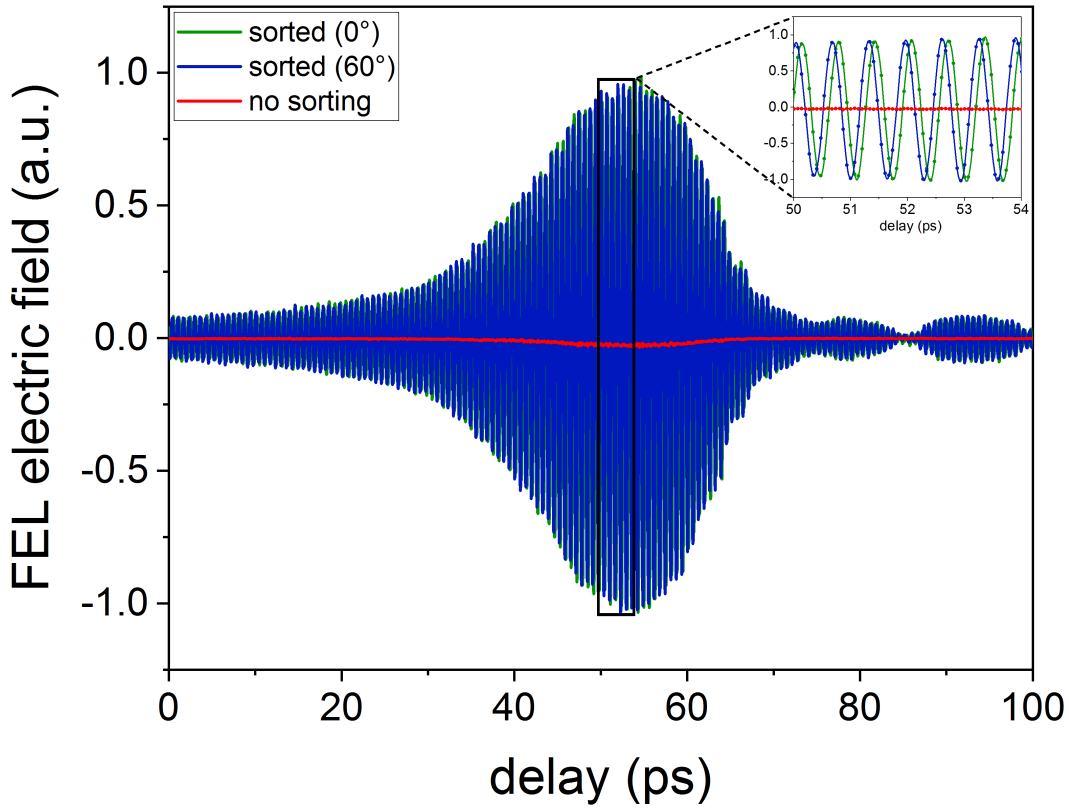
# Shot-to-Shot CEP Measurement




- in polar coordinates, the radius of the plotted signals are proportional to $E_{FEL}$ the angle is the **CEP**
- the spread of the radius provides info on the amplitude stability of the FEL




- standard scanning EOS measurement of FEL waveform averages to zero due to the unstable CEP (**red**)
- binning/sorting by the CEP of each FEL pulse allows recovery of full FEL waveform (**blue** and **green**)



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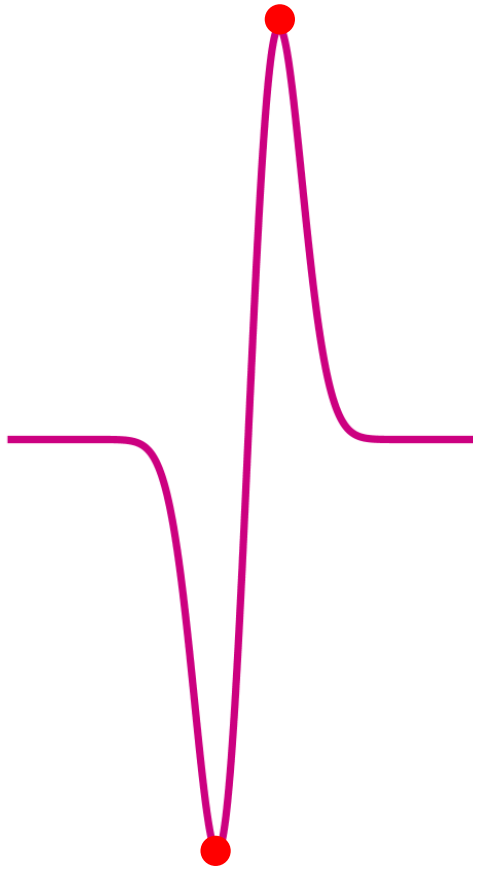
# Potential for Longitudinal Diagnostics

- use two NIR pulses (maybe also a 3rd at zero-crossing)

- set delay of the NIR pulses to the max and min of the CDR pulse







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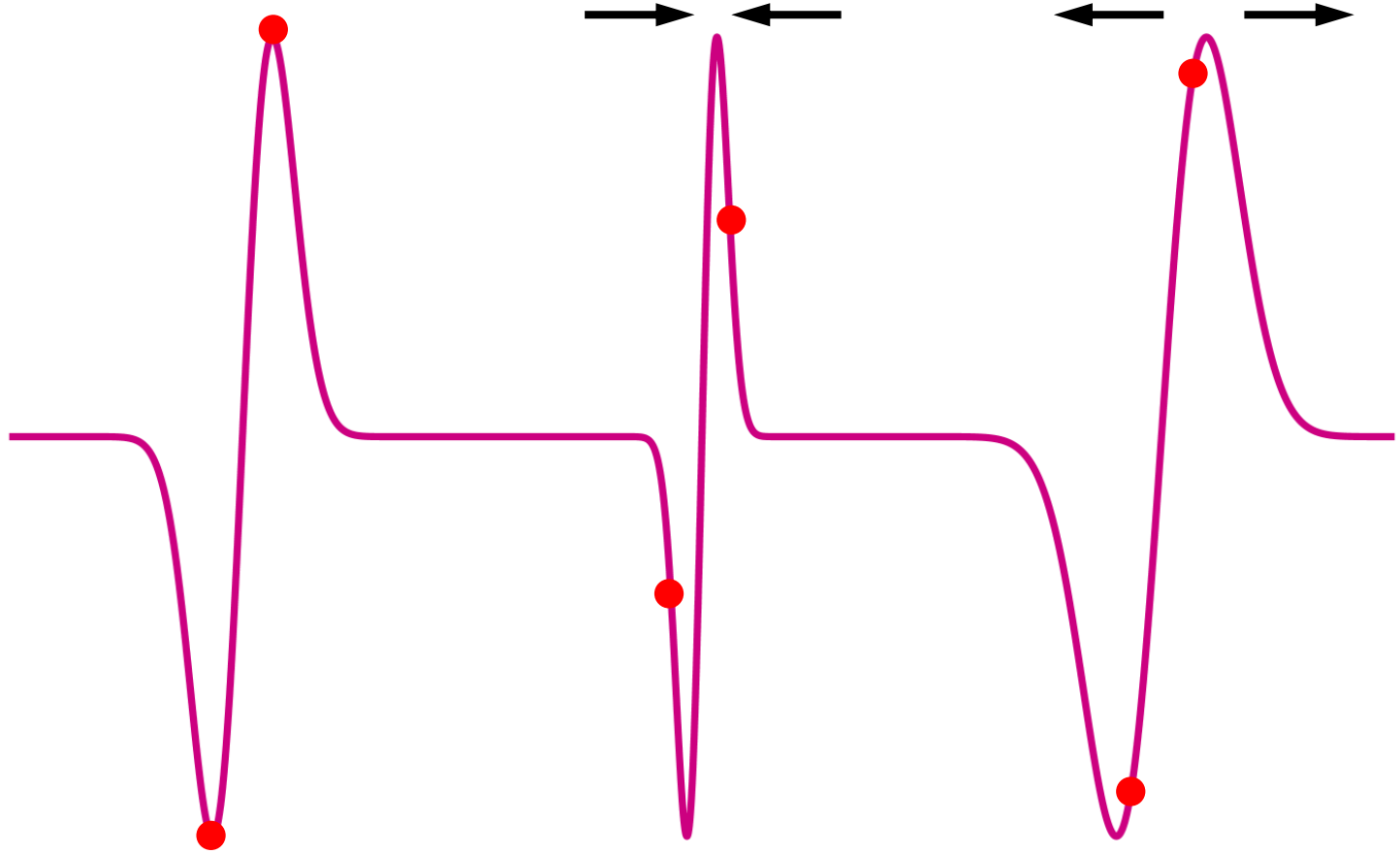
# Potential for Longitudinal Diagnostics

- use two NIR pulses (maybe also a 3rd at zero-crossing)
- set delay of the NIR pulses to the max and min of the CDR pulse
- **change in bunch length**





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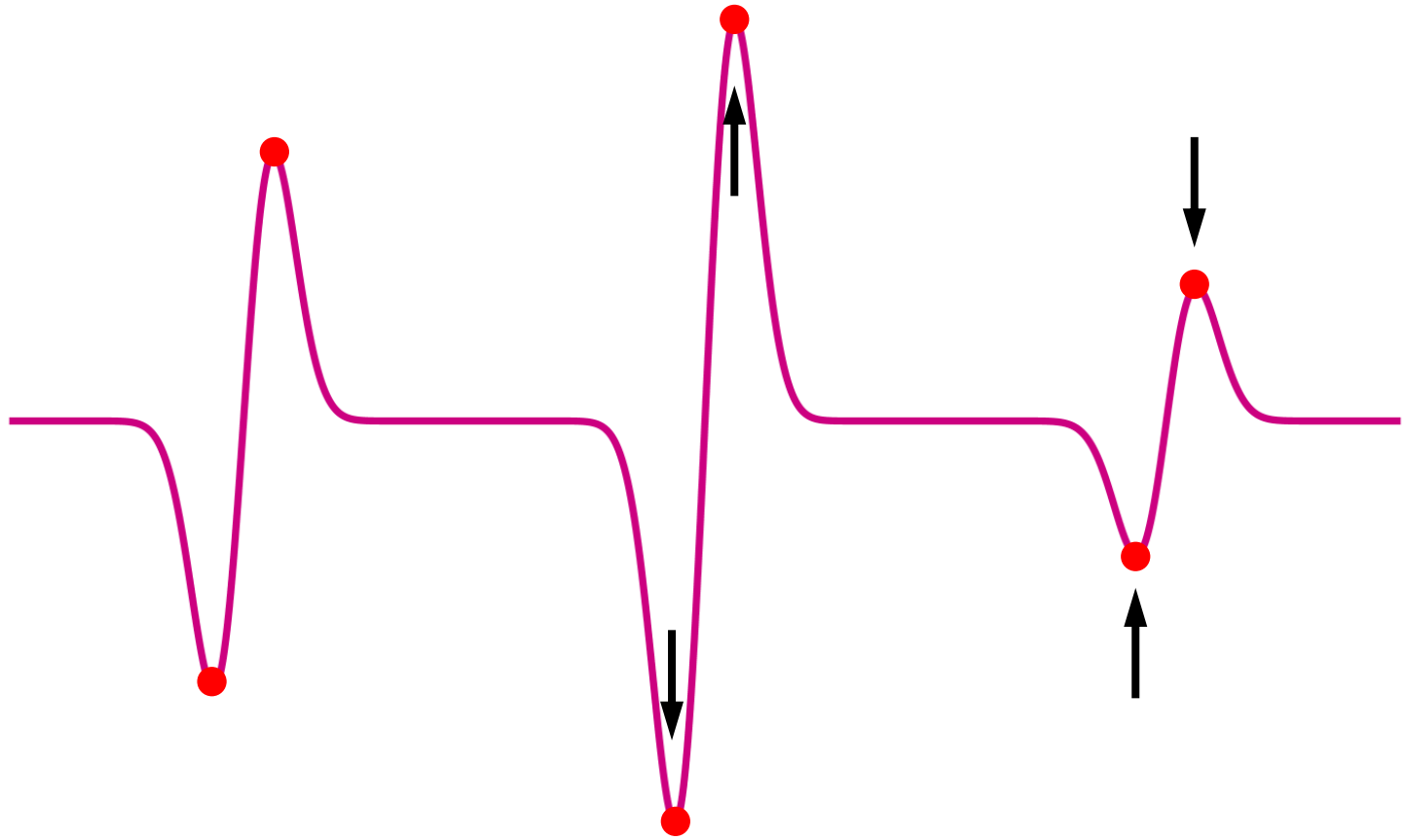
# Potential for Longitudinal Diagnostics

- use two NIR pulses (maybe also a 3rd at zero-crossing)
- set delay of the NIR pulses to the max and min of the CDR pulse
- **change in bunch length**
- **change in bunch charge**





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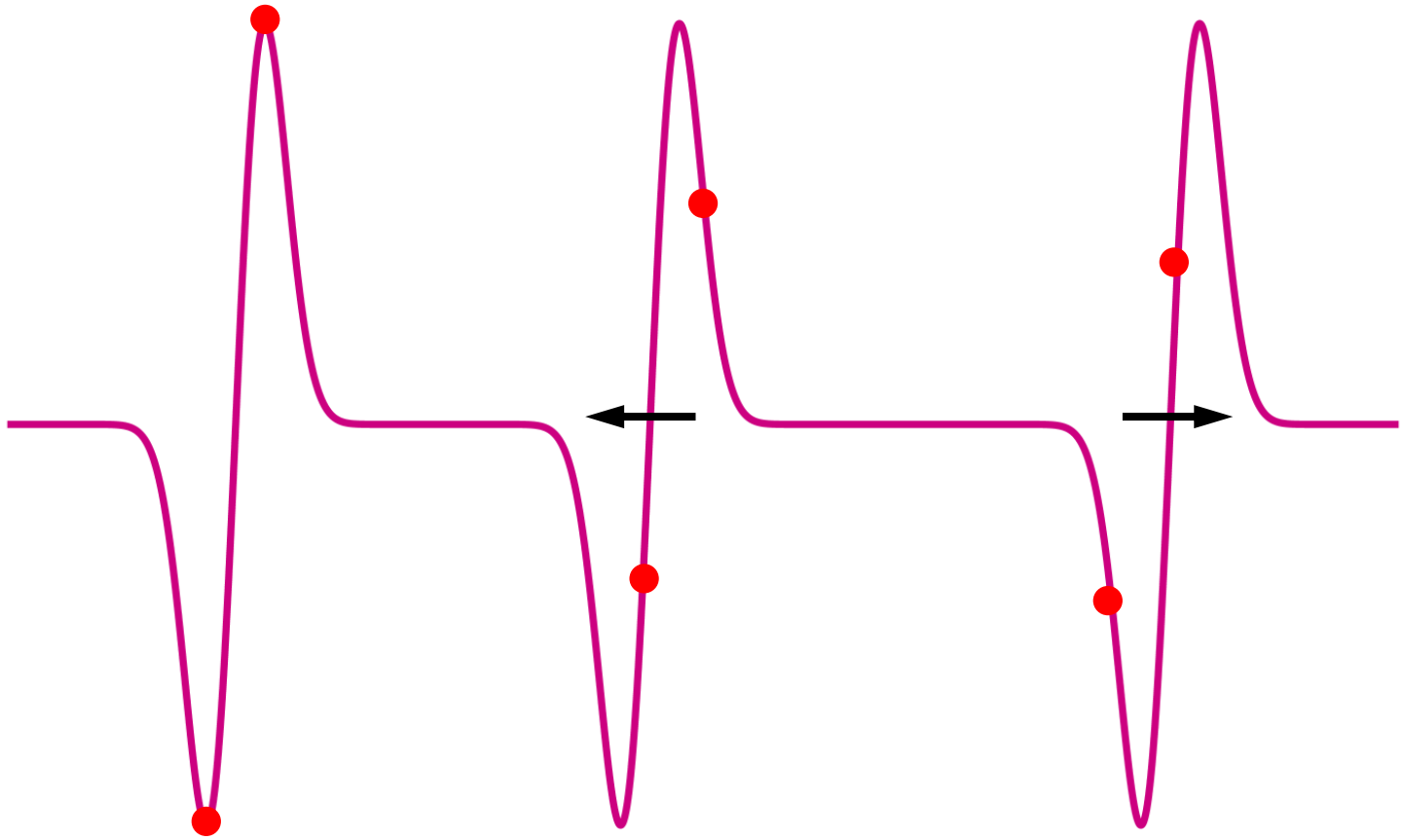
# Potential for Longitudinal Diagnostics

- use two NIR pulses (maybe also a 3rd at zero-crossing)
- set delay of the NIR pulses to the max and min of the CDR pulse
- **change in bunch length**
- **change in bunch charge**
- **change in bunch phase / arrival time**
- **by measuring both magnitude and phase for each NIR laser pulse, possibility to disentangle multiple effects**





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# STERN: SUPERRADIANT THZ RADIATION GENERATION AT EUXFEL

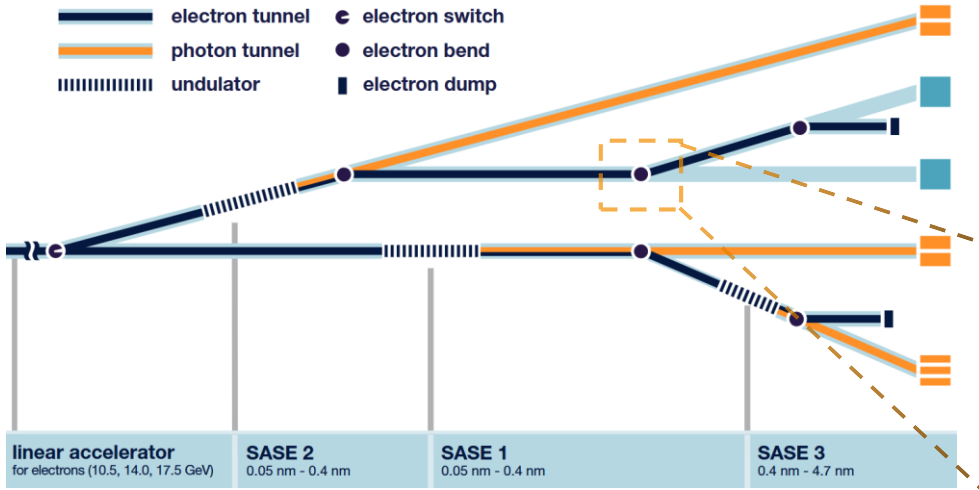
Francois Lemery, Karel Peetermans, Winni Decking, Klaus Floettmann, Nina Golubeva, Nils Lockmann, Bernd Steffen, Marie Kristin Czwalinna, Martin Dohlus, Igor Zagorodnov, Jonah Richards, Torsten Wohlenberg, Lukas Mueller, Daniel Thoden, Lucy Müller, Riko Wichmann, Stuart Walker, Marc Guetg, Shan Liu, Sergey Tomin, Weilun Qin, Tianyun Long, Serge Bielawski, Mikhail Krasilnikov, Gianluca Geloni, Dirk Lipka, Artem Novokshonov, Gero Kube, Ingmar Hartl, Evgeny Negodin, Matthias Scholz

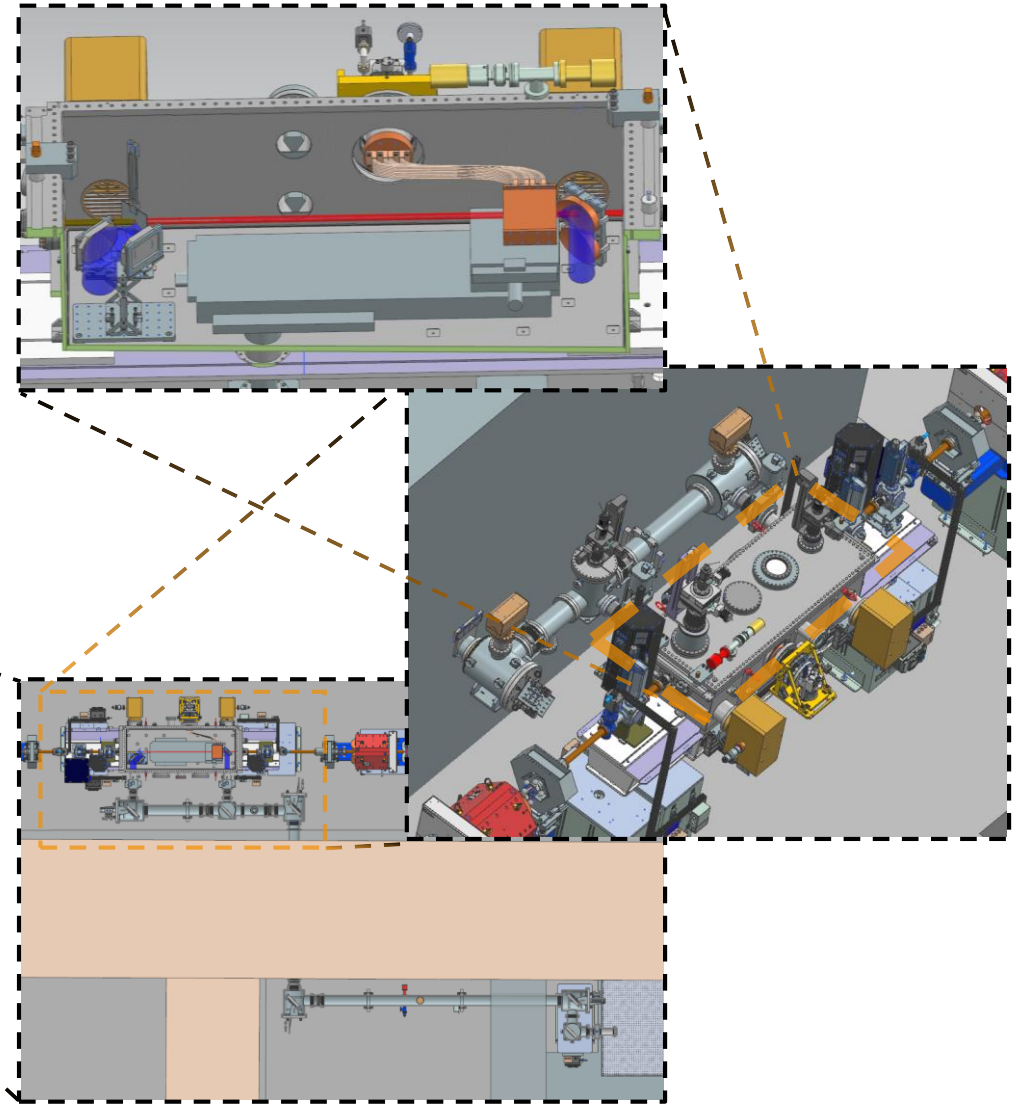
HELMHOLTZ

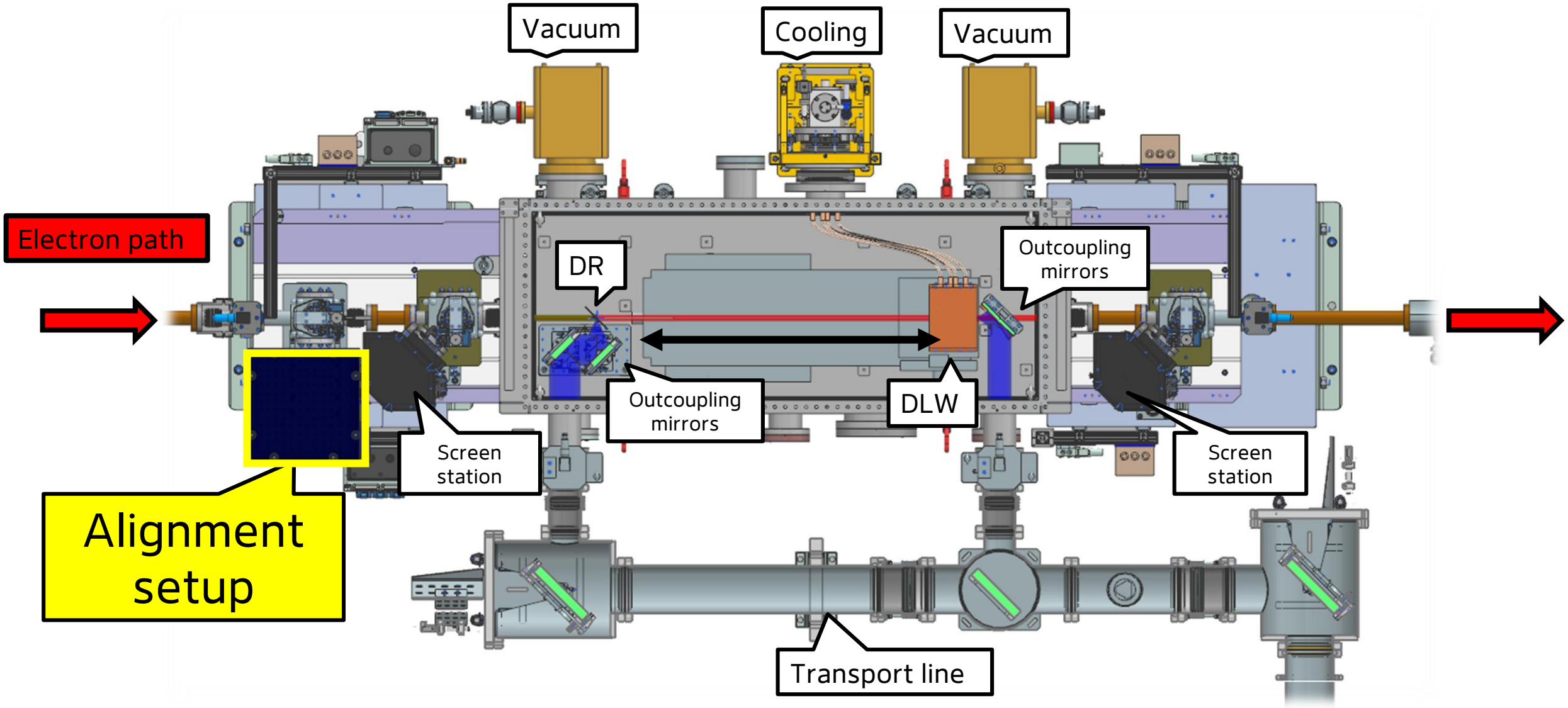
DESY.

# Electron beam based radiation sources

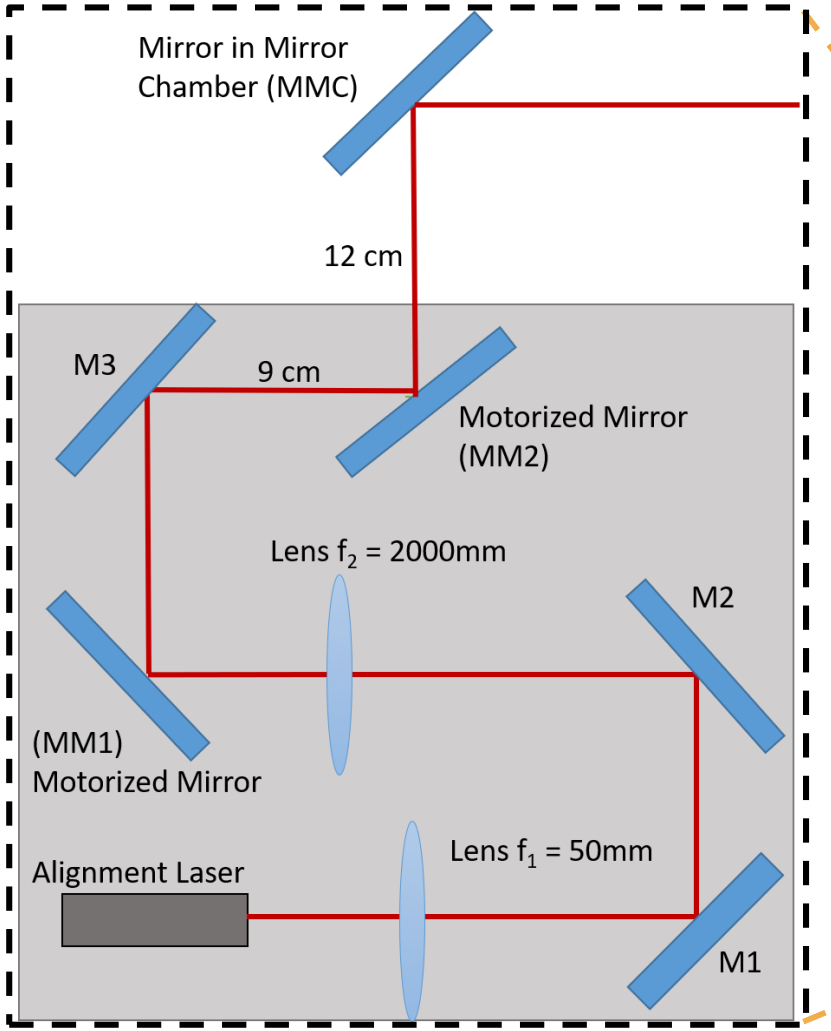
- Located after SASE2
- THz beam transport 10m to diagnostics lab
- Accessible during machine operation



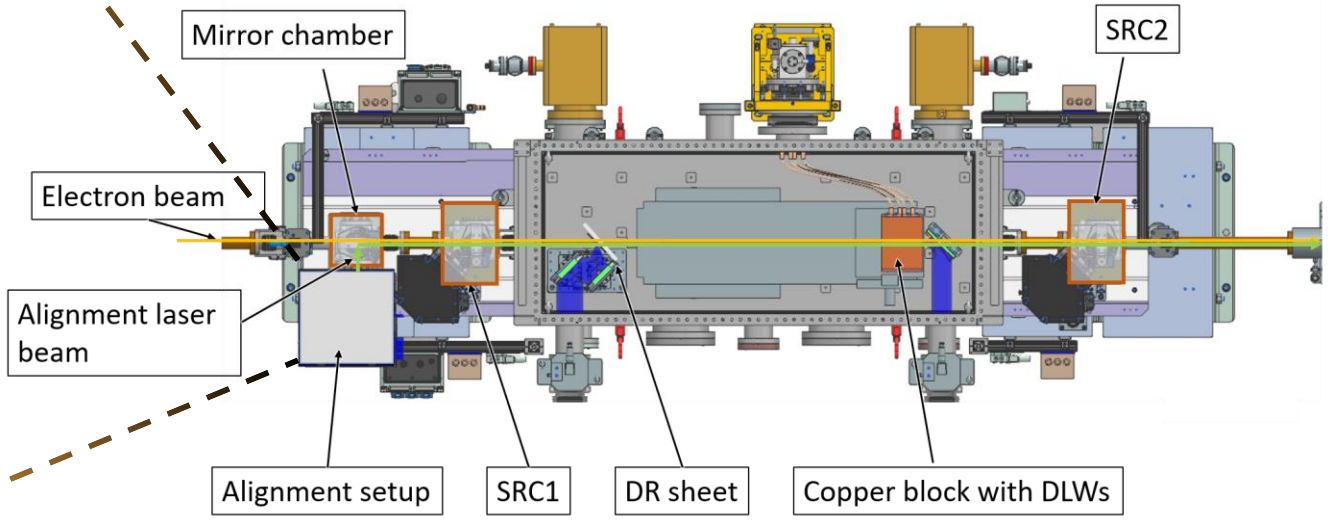




Vacuum
Cooling
Vacuum
Electron path
DR
Outcoupling mirrors
Outcoupling mirrors
DLW
Screen station
Screen station
Alignment setup
Transport line

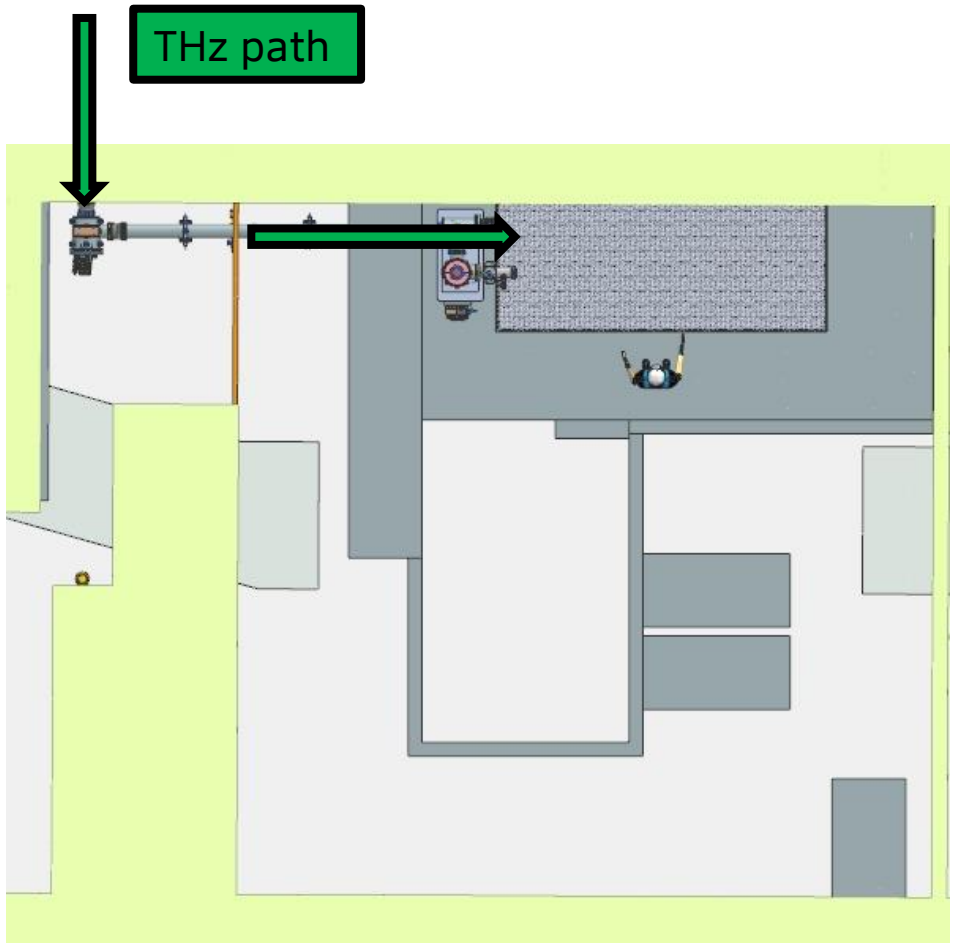
# Alignement Setup




- Fiber coupled 635nm laser for alignment
- Beam waist (expected to be < 0.2 mm) at copper block position
- Laser beam trajectory should correspond to electron beam trajectory



# Lab Area for THz Diagnostics




- THz radiation is brought to safe Diagnostics lab via transport line
- planned **THz Diagnostics**
  - THz camera
  - Autokorrelator for Pulselength
  - Spectrometer (multiple gratings and PyroElectro Optic Sampling, with 1030nm fiber laser
- **Modular Lab Design:** detector)
  - Temporarily extend the lab space into the crane shaft area, easily disassembled
  - false floor for improved working height and cable management

PHOTUR.IS
Research & Engineering Company

**Aram KALAYDZHYAN**

## PHOTUR.IS GmbH:

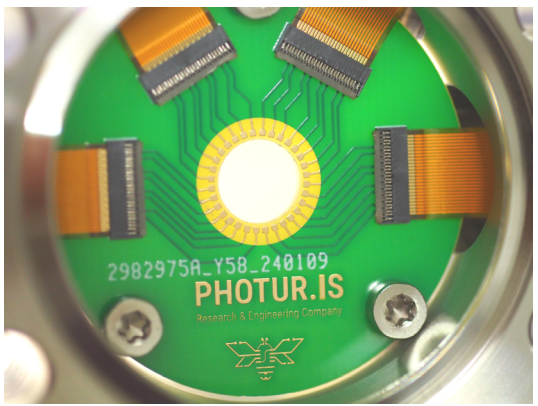
Small team of scientists and engineers from DESY

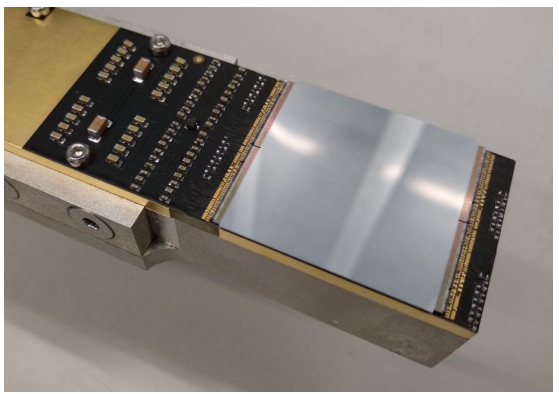
8 years of R&D for academia and innovation companies

Electronics, optics, vacuum systems

# Vacuum-Compatible Electronics for Instrumentation

→ Analog front ends and signal conditioning
→ High density or/and speed interconnection and readout
→ Thermal stabilization and cooling
→ Powering stability
→ Vacuum compatibility & outgassing
→ In-vacuum motion



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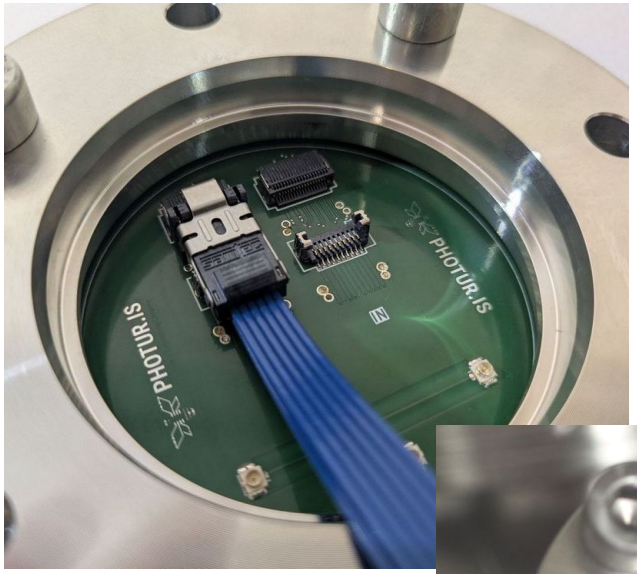
# High-Speed UHV Feedthrough Solutions




→ PCB based, metal-to-metal seal

→ ConFlat flange compatible

→ 120C bakeable

→ Impedance controlled

(e.g. 50Ω single,100Ω pairs)

→ High density

(up to 500 pins per CF63)

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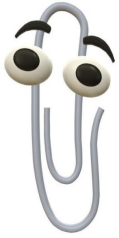
# High Speed Digitizer Platform with 40G QSFP+

- → Cost-effective
- → Modular design
- → 1GS/s 8/10/12bit ADCs
- → 4x10 Gbps via QSFP+
- → Xilinx Zynq 7030/7035
- → 2x4Gb DDR3 SDRAM
- → Open FPGA firmware



Do you need assistance?

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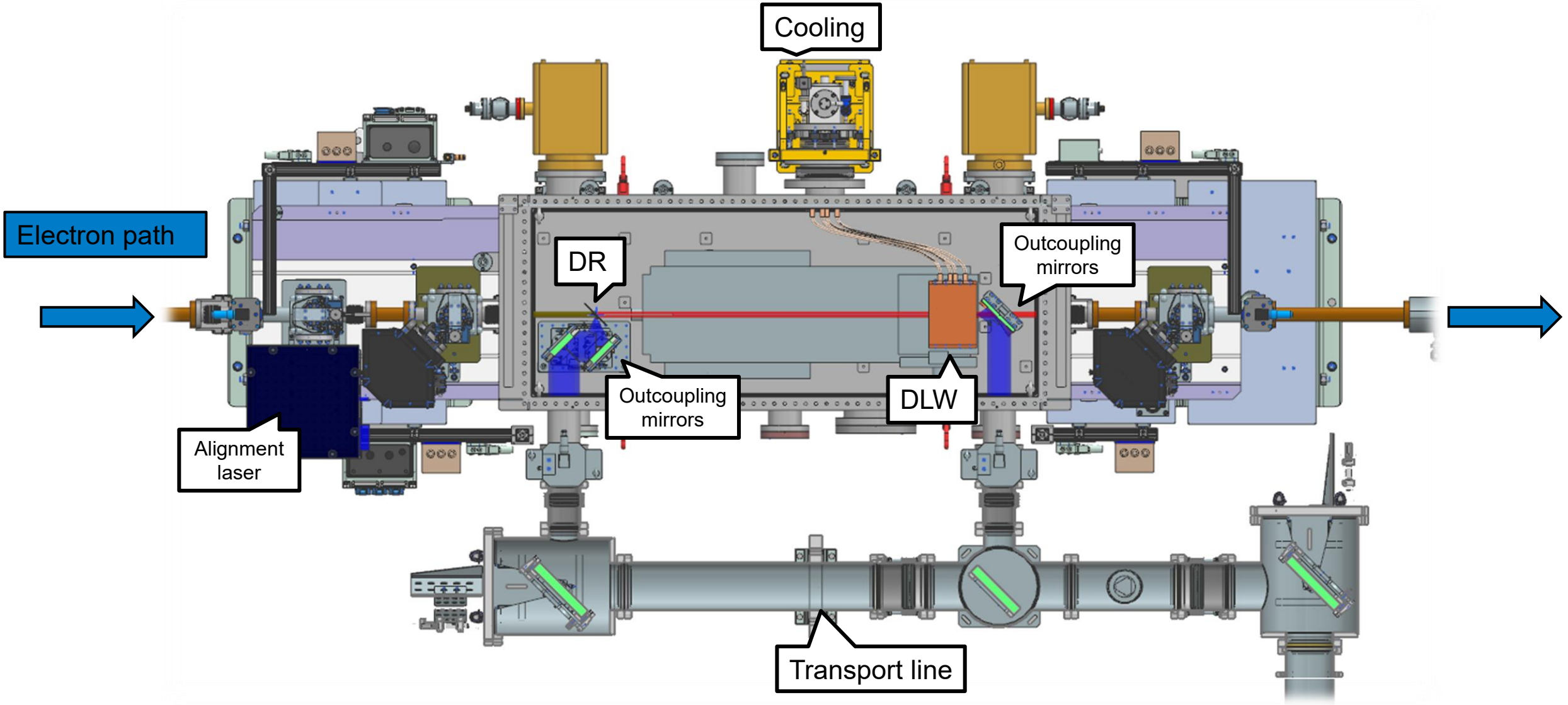
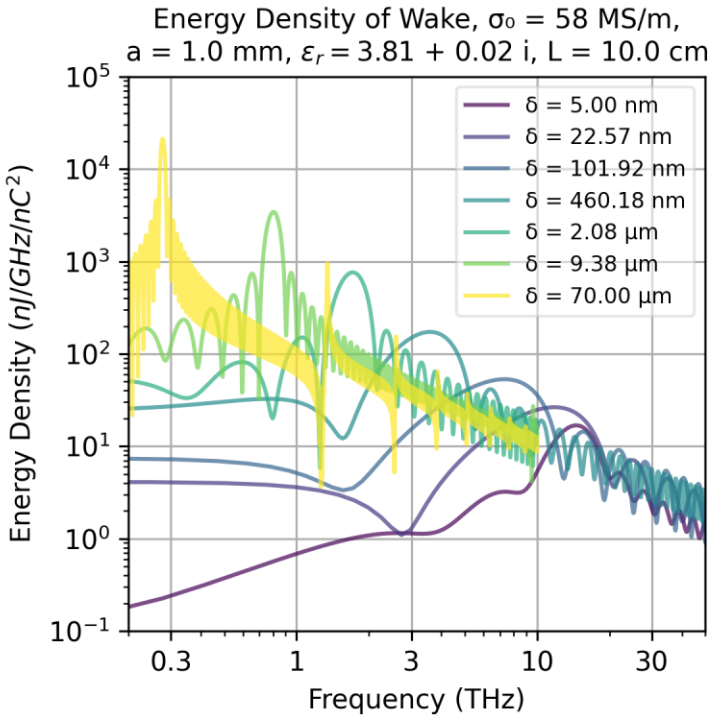
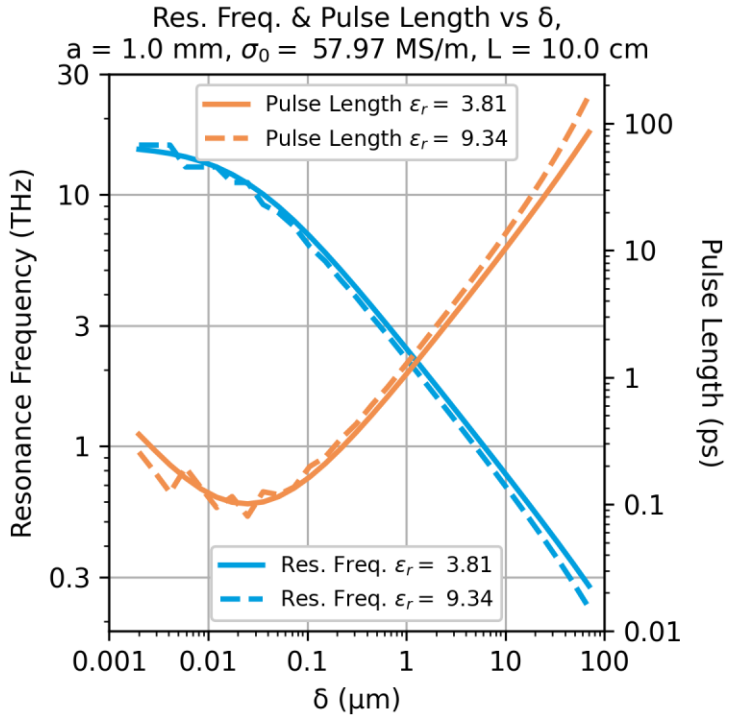
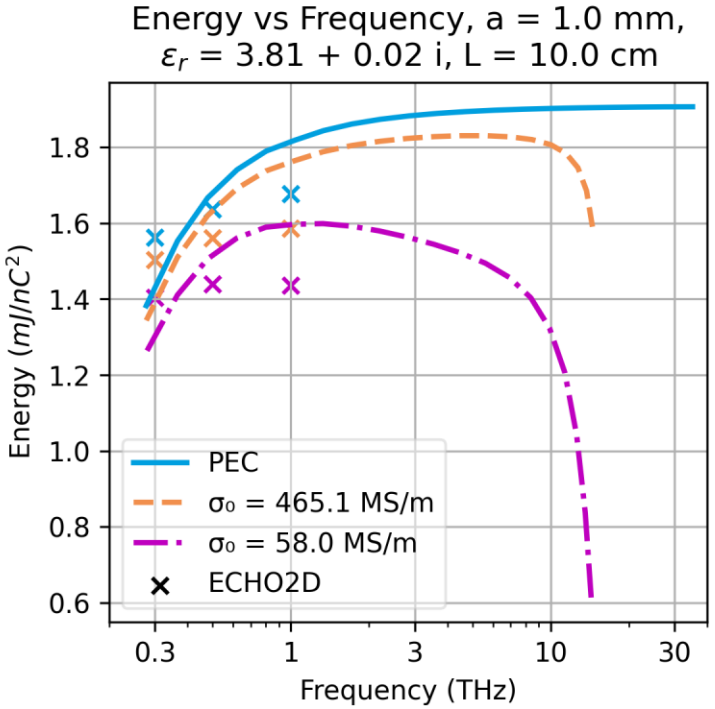



*Filipe Giesteira, Vahit Kalender, Lukas Müller, Torsten Wohlenberg*

# Dielectric lined waveguides

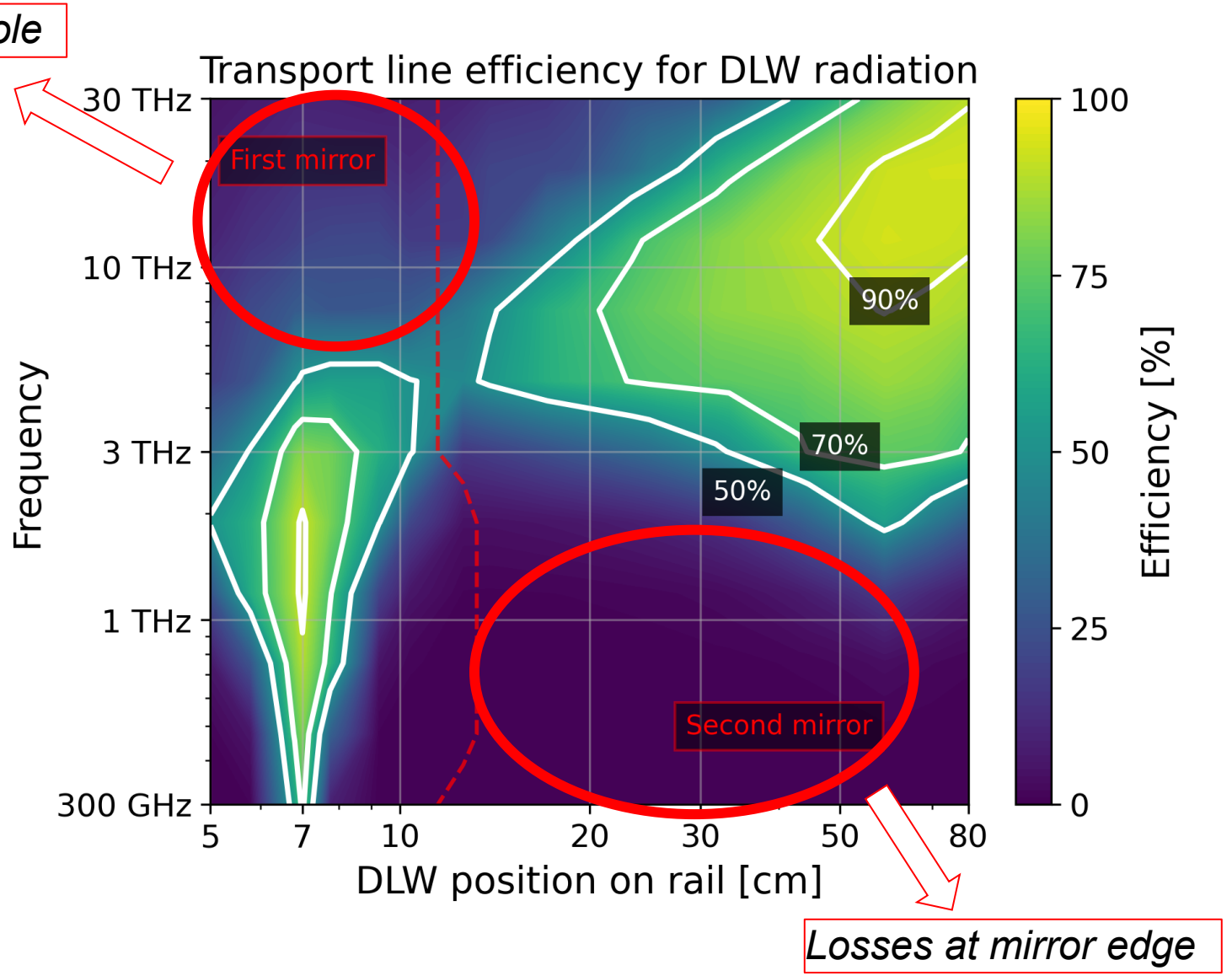


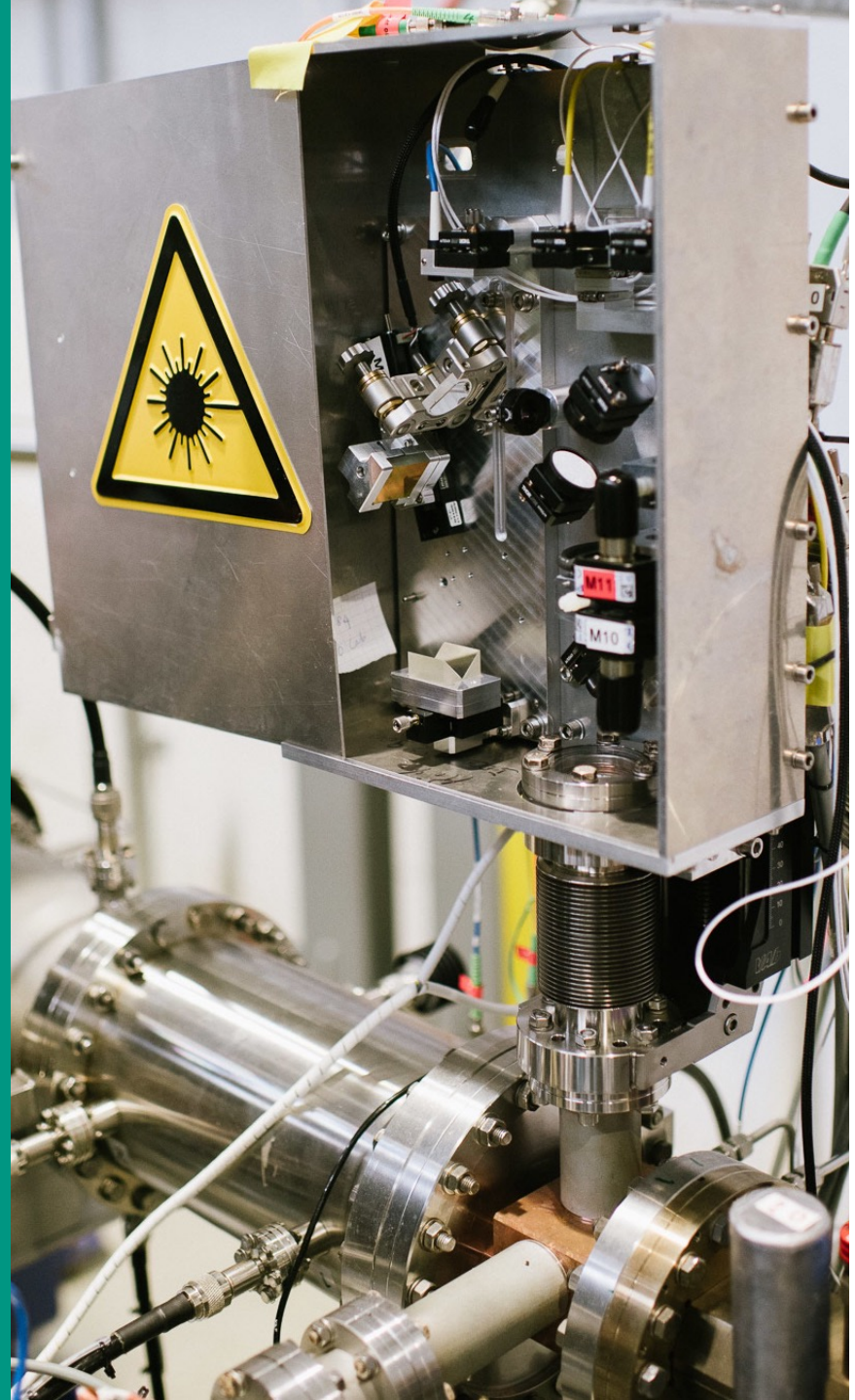



# Transport to diagnostics area

- All frequencies captured and transported at **>70% efficiency**
- Dotted line indicates which mirror transports more
- In practice, working point is experimentally determined



# First prototype measurements with an electro-optical bunch profile monitor for FCC-ee



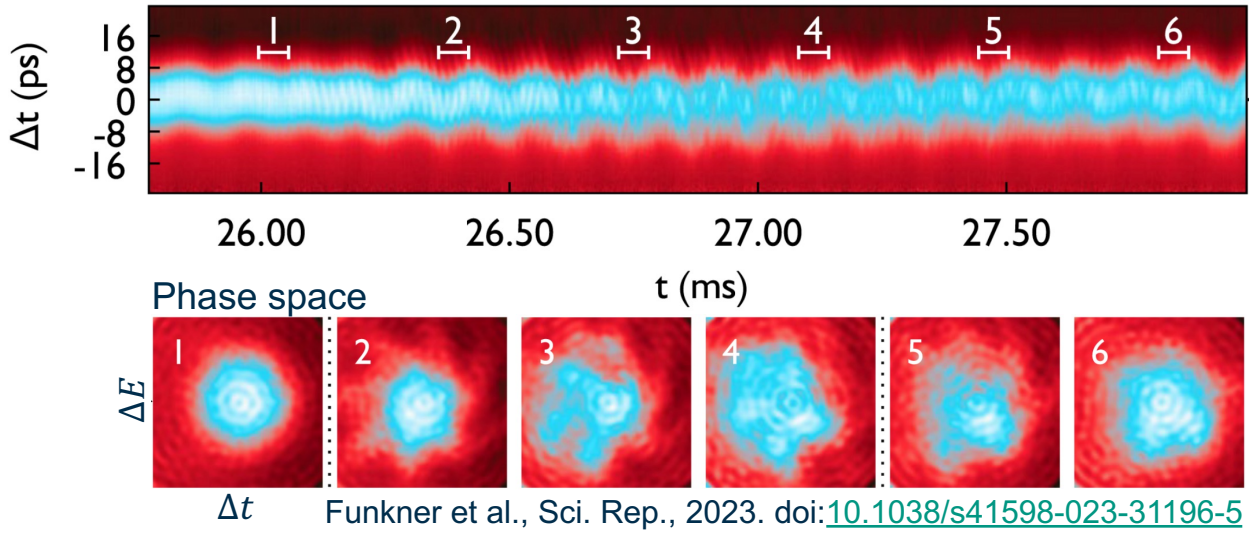

14th Collaboration Workshop on Longitudinal Diagnostics
Micha Reissig et al.
KIT, Karlsruhe, Germany

Institute for Beam Physics and Technology

# First prototype measurements with an electro-optical bunch profile monitor for FCC-ee

**EO system at KARA:**

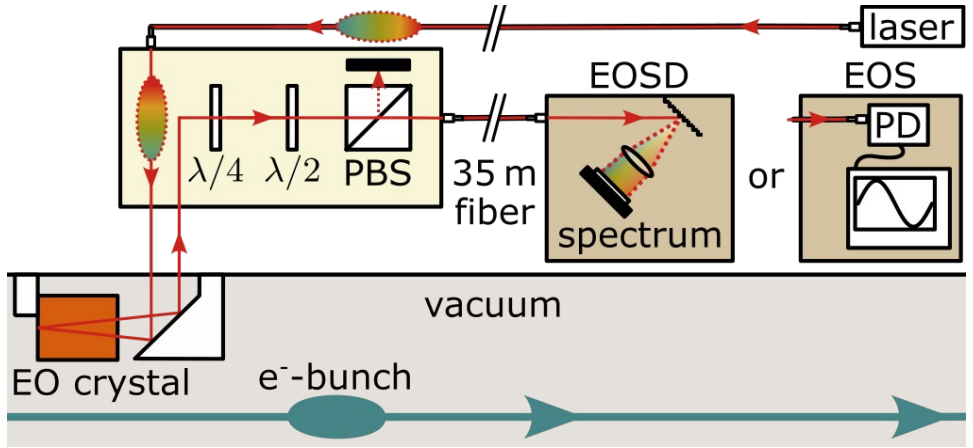
- Single-shot bunch profile measurements
- Turn-by-turn measurements at 2.7 MHz
- Designed for short bunches in the picosecond region
- Allows reconstruction of phase-space dynamics using tomography




Funkner et al., Sci. Rep., 2023. doi:10.1038/s41598-023-31196-5

**Principle of Electro-optical spectral decoding (EOSD)**

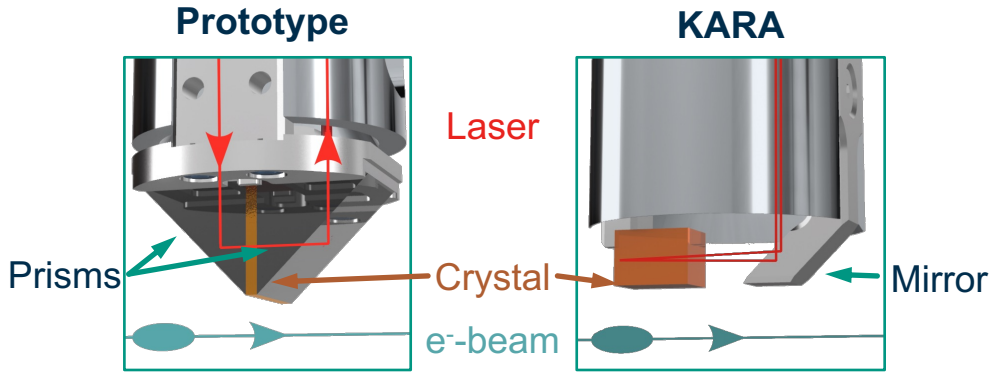
1. Pockels effect to encode bunch profile in polarization of the laser
2. Polarizer to transform into intensity modulation
3. Spectrum of the chirped laser pulse contains longitudinal bunch profile



# First prototype measurements with an electro-optical bunch profile monitor for FCC-ee

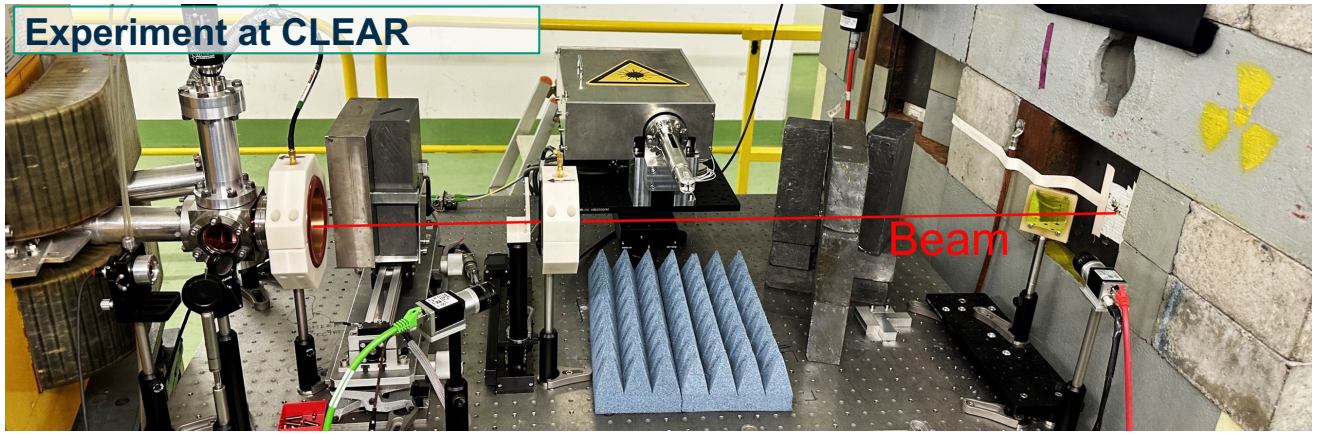
**Novel crystal holder design**

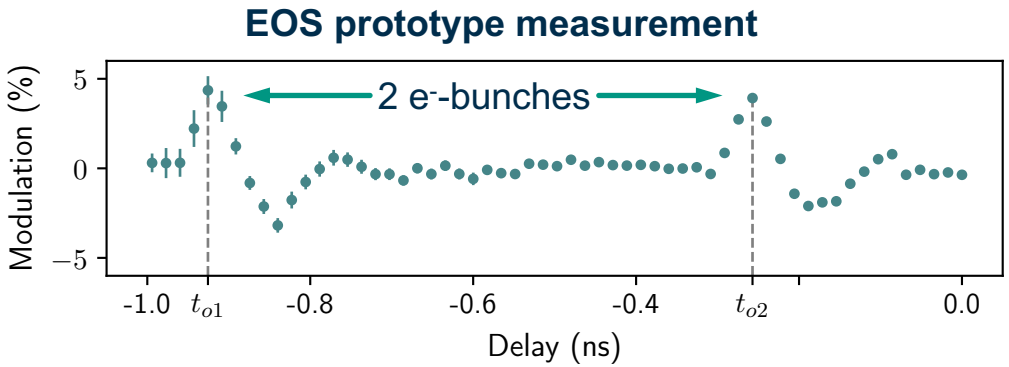
- Suitable for long and short e⁻-bunches
- Prisms instead of mirrors and reflective coatings
- Compact single-pass design → low impedance



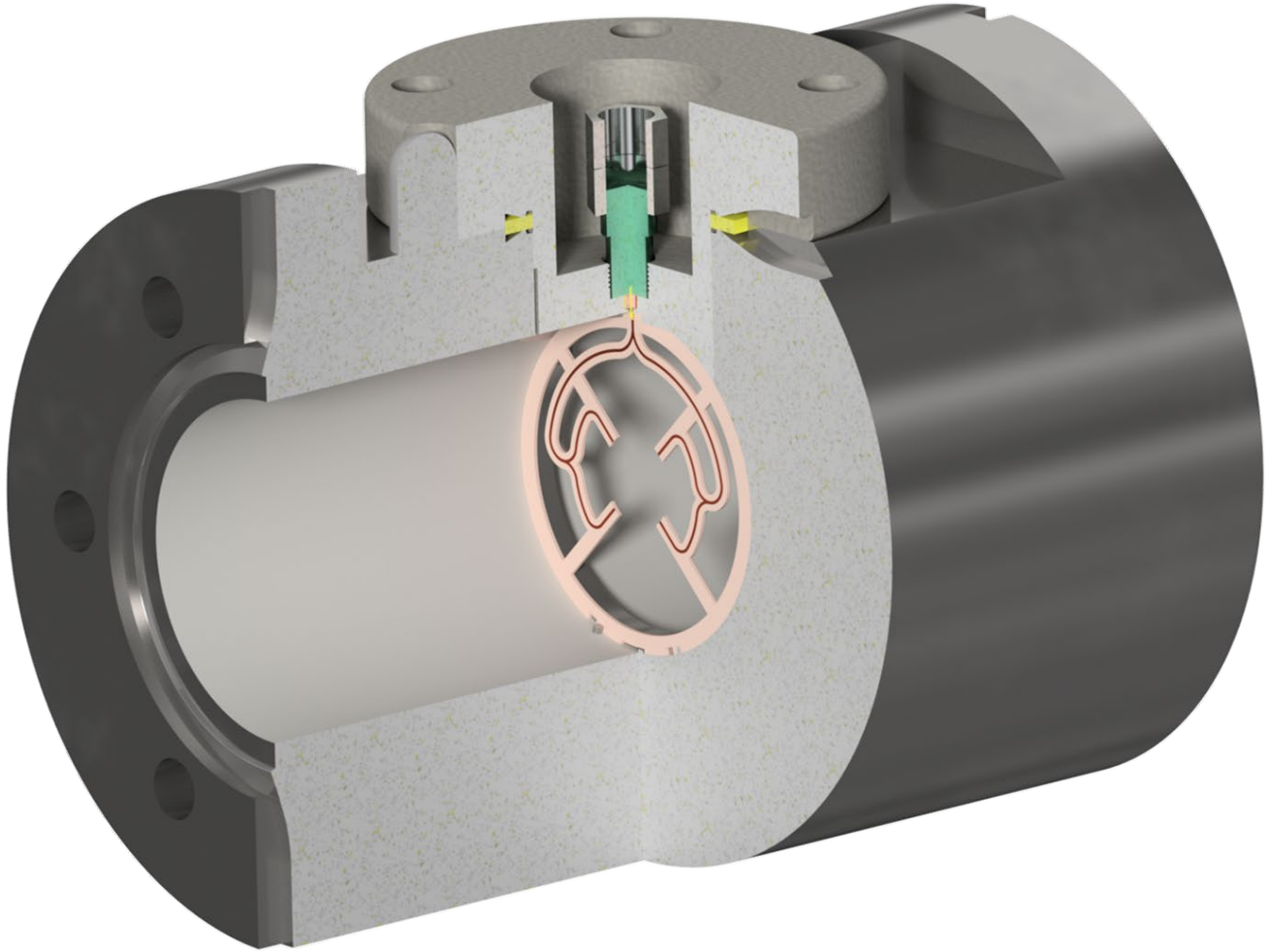

**Proof-of-principle experiment at CLEAR**
(CERN Linear Electron Accelerator for Research)

- Prototype built on basis of the KARA EO monitor
- Successful EO sampling of two consecutive bunches



14th Collaboration Workshop on Longitudinal Diagnostics
28.09.-01.10.2025, DESY, Hamburg



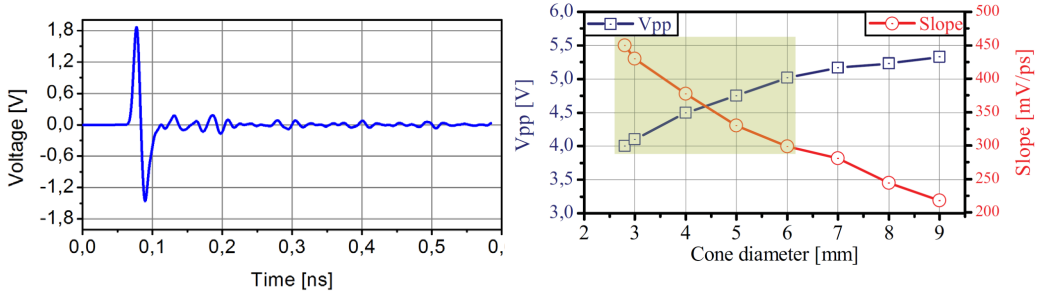
# TEOBAM –
# Innovative mmW pickup structures:
# Development of an ultra-low-charge BAM pickup geometry for fC operation modes

A. Penirschke[1], B. E. J. Scheible[1,2], W. Ackermann[2], M. Kuntzsch[3], M. K. Czwalinna[4], H. De Gersem[2], H. Schlarb[4]

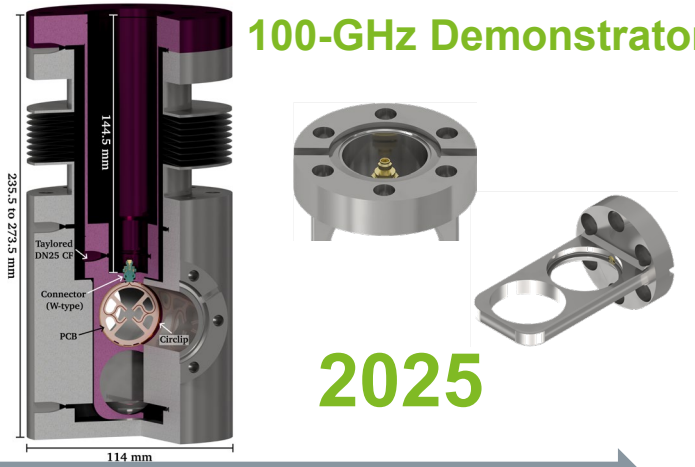
[1]Technische Hochschule Mittelhessen, Wilhelm-Leuschner-Str. 13, 61169 Friedberg
[2]Technische Universität Darmstadt, Schlossgartenstr. 8, 64289 Darmstadt
[3]Helmholtz-Zentrum Dresden Rossendorf HZDR, Bautzner Landstr. 400, 01328 Dresden
[4]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg

Bundesministerium für Forschung, Technologie und Raumfahrt

This work is supported by the German Federal Ministry of Research, Technology and Space (BMFTR) under contract No. 05K25ROA.



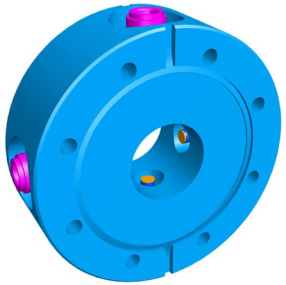

**2009** — **Angelovski** — **2023**




**100-GHz Demonstrator**

**2025**

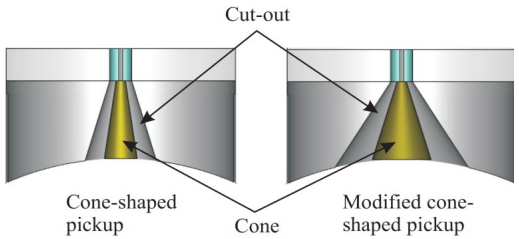
**F. Löhl & K. Hacker**

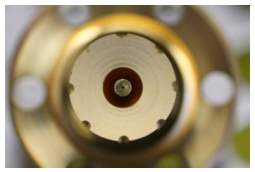


*3D model of the button-type beam pickup designed by K. Hacker and used for the EO-BAM by F. Löhl [Löhl 2009]*

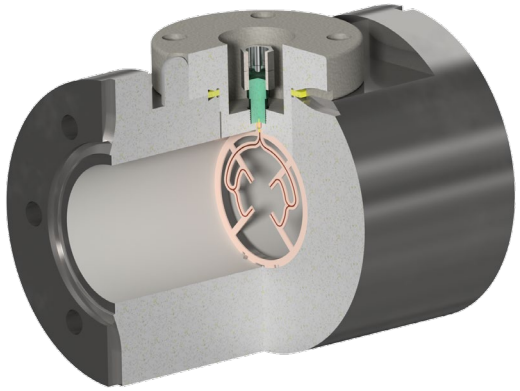
**2011** — 1st gen.

**2013** — 2nd gen.



**Scheible** — **2028**



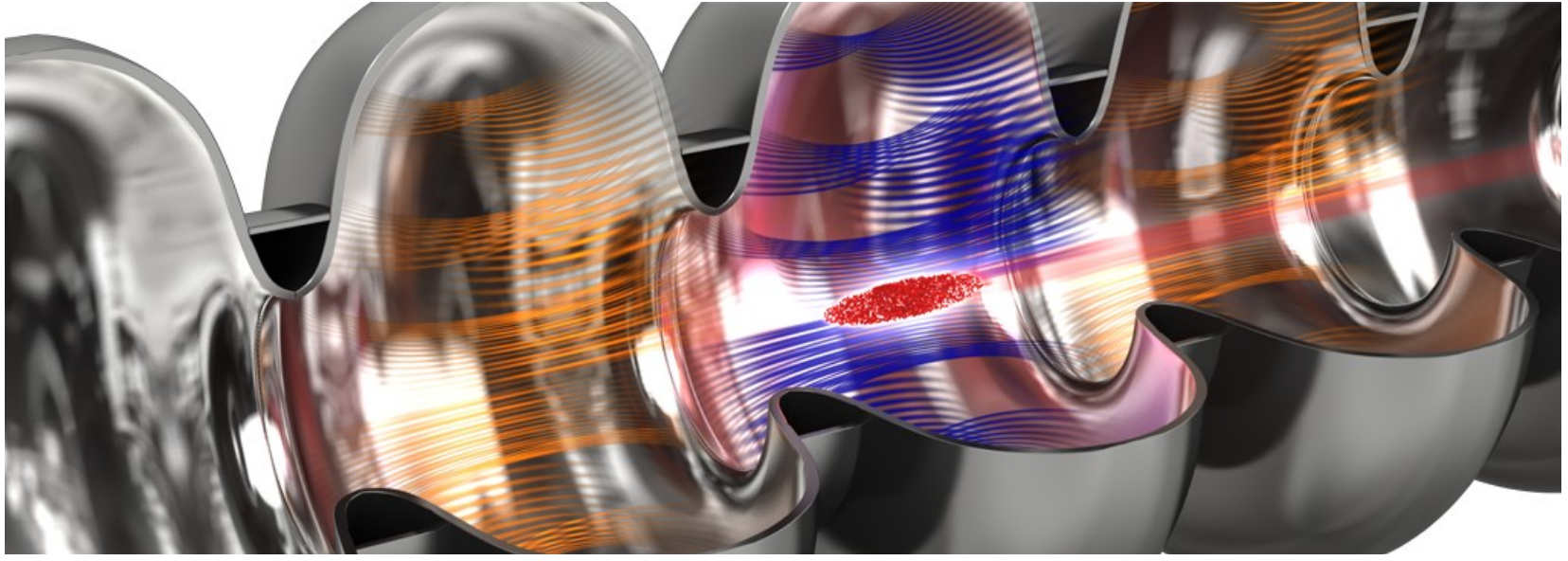
**67-GHz Demonstrator**

Visit my poster

# *Single-shot electro-optic measurement of bunch shapes using diversity schemes at EuXFEL, FLASH and FELBE*

**Quentin Demazeux**, Christophe Szwaj, Eléonore Roussel, Serge Bielawski (PhLAM, France)
Bernd Steffen, Marie Kristin Czwalinna (DESY, Germany)
Michael Klopf (HZDR, Germany)

**14th Workshop longitudinal electron bunch diagnostic, DESY, 2025**

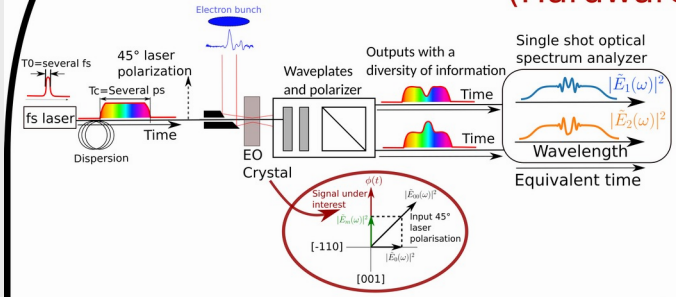


# Principle : Phase diversity technique combined with reconstruction algorithm

Université de Lille

PhLAM

## Diversity Electro-Optic Sampling (DEOS) (Hardware)

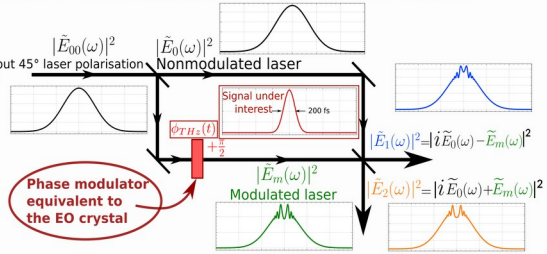



E. Roussel et al.
Phase Diversity Electro-optic Sampling: A new approach to single-shot terahertz waveform recording
*Light: Science & Applications*, January 2022

**The two systems are formally equivalent !**

- **45 degree laser polarization** can be decomposed in **vertical** and **horizontal components**
- **Interference** is produced **inside the PBS**

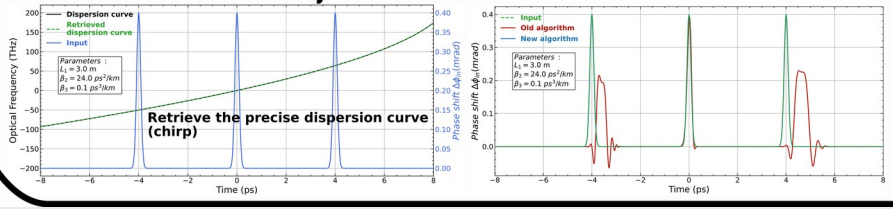
## Mach-Zehnder interferometer with a phase modulator in one arm



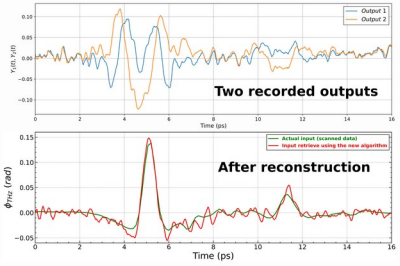

## New reconstruction algorithm : Principle and numerical test (Software)

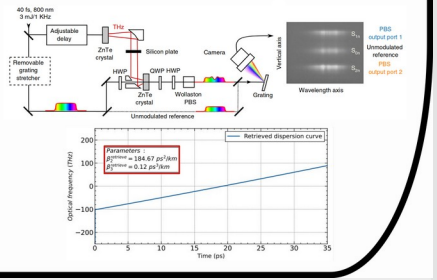
By using :
- The Mach-Zehnder equations
- The two recorded spectra
- The laser spectrum

We are now able to retrieve the dispersion curve and reconstruct our signal without distorsions !




## Table top experimental test at PhLAM Laser based THz source

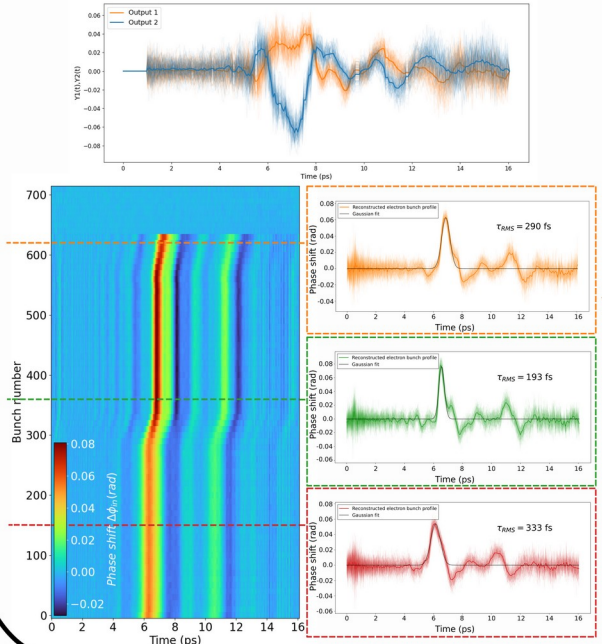


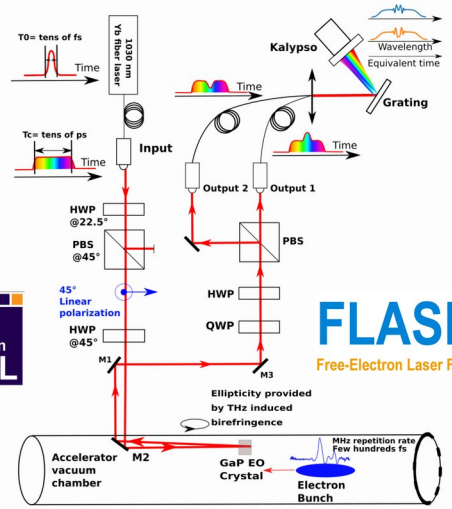
# *Single-shot electron bunch diagnostic at EuXFEL and FLASH*

Single-shot electron bunch diagnostic at EuXFEL and FLASH

DEOS@EuXFEL with the one-channel spectrometer




EuXFEL and FLASH DEOS setup



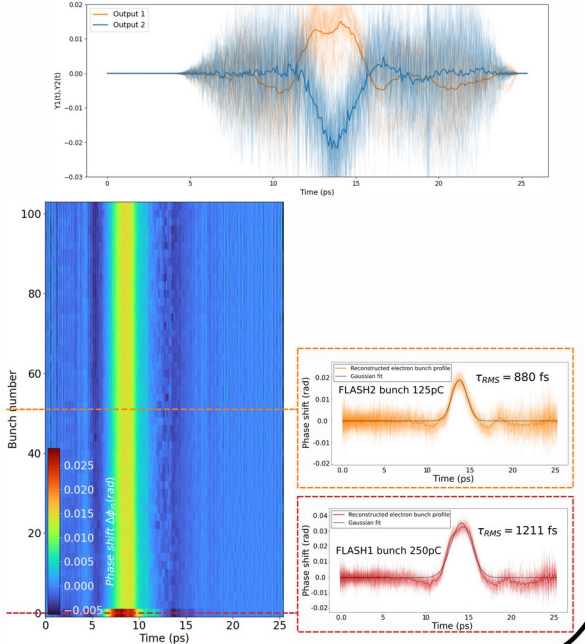

European XFEL

FLASH.
Free-Electron Laser FLASH

More details about FLASH and EuXFEL setup :

B. Steffen et al.
Compact single-shot electro-optic detection system for THz pulses with femtosecond time resolution at MHz repetition rates
Rev. Sci. Instrum. 91, 045123 (2020)

DEOS@FLASH with the two-channel spectrometer

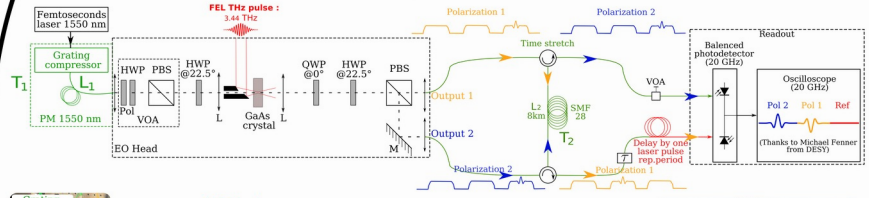


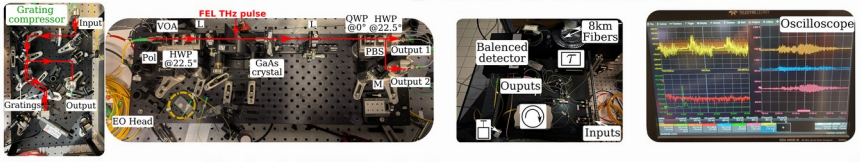
# Carrier envelope phase diagnostic at FELBE

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

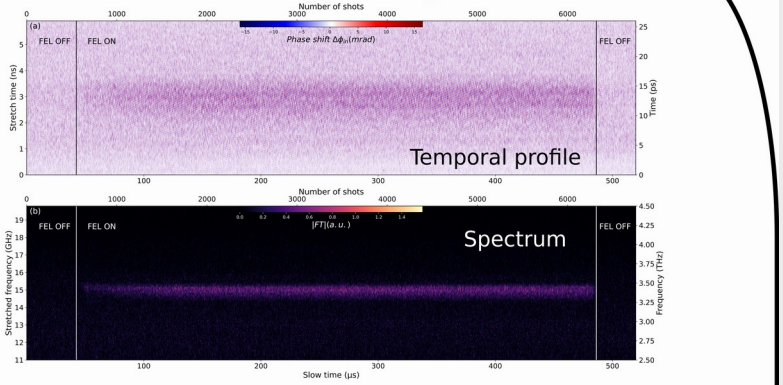
## Carrier Envelope Phase Diagnostic at FELBE

### FELBE DEOS setup

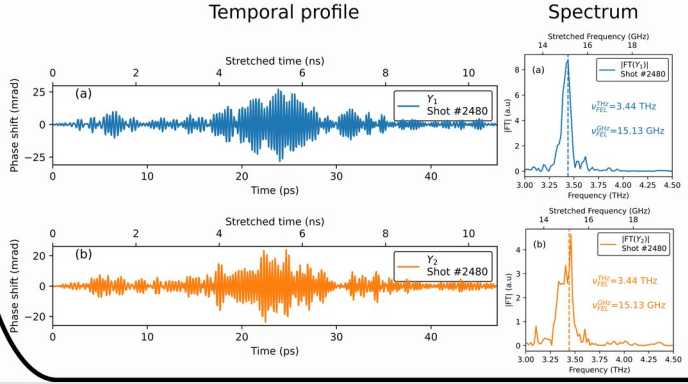


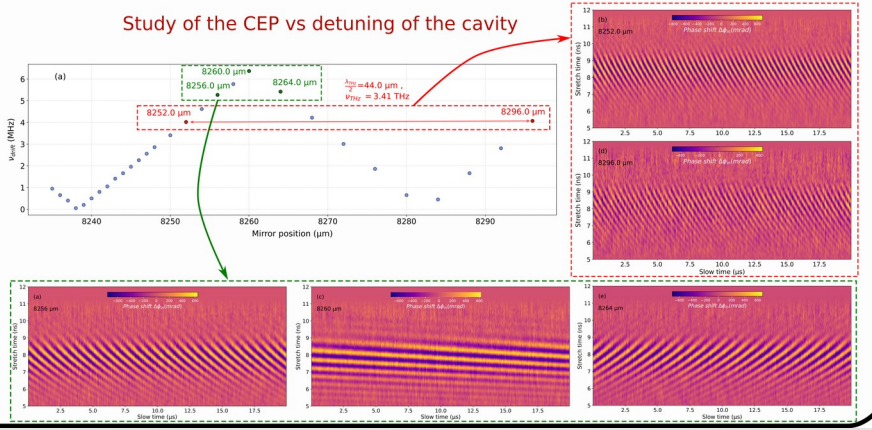

### Entire FEL macropulse in single shot




### Single-shot DEOS outputs

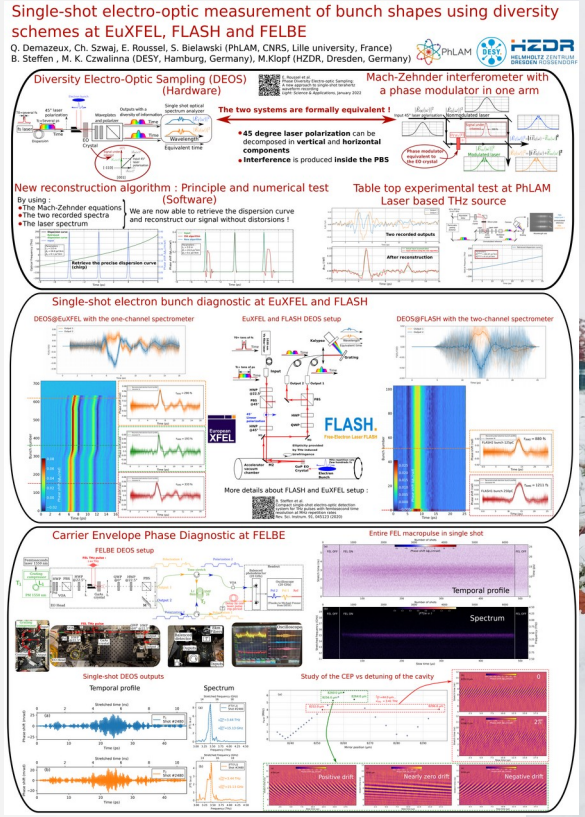



### Study of the CEP vs detuning of the cavity



# Thank you for your attention !

## Photos taken during our winter shift measurement at HZDR Dresden





# DESIGN CONSIDERATIONS FOR ELECTRO-OPTIC SAMPLING AT THZ FEL AT PITZ

Siriwan Pakluea

14th Collaboration Workshop on Longitudinal Diagnostics

30.09.2025

HELMHOLTZ

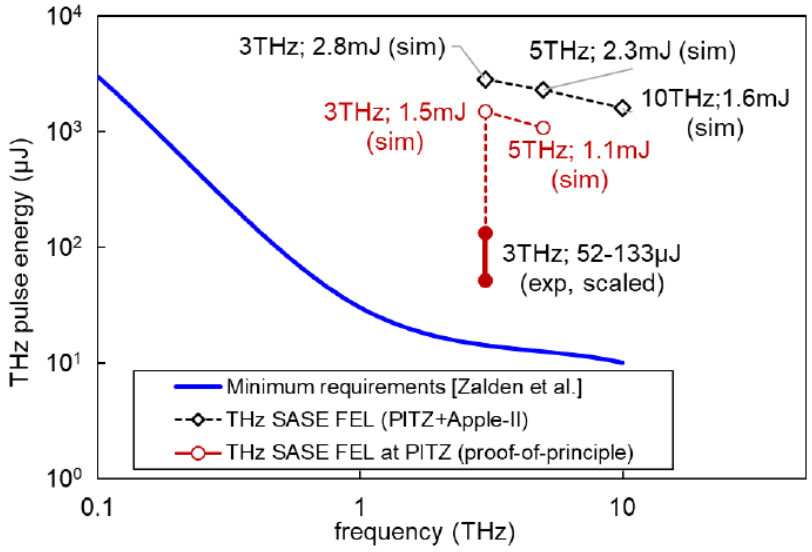
# Motivation for THz at PITZ

## Accelerator based THz source for pump-probe experiments at the European XFEL


*E.A. Schneidmiller, M.V. Yurkov, (DESY, Hamburg), M. Krasilnikov, F. Stephan, (DESY, Zeuthen),*
*"Tunable IR/THz source for pump probe experiments at the European XFEL, Contribution to FEL 2012, Nara, Japan, August 2012*

**THz source requirements**

- Tunable $f$ = 0.1 … 20 $THz$ ($\lambda_{rad}$ = 3$mm$ … 15$\mu m$)
- Time jitter from CEP (few fs) *stable* for field driven to "intensity" driven dynamics
- High pulse energy > 10$\mu J$ ($\mu J$ -hundreds of $\mu J$ -$mJ$ , depending on $f$)
- Repetition rate to follow European XFEL (600$\mu s$ … 900$\mu s$)× (0.1 … 4.5$MHz$) × 10$Hz$ = 27000 … 40500 $pulses/s$



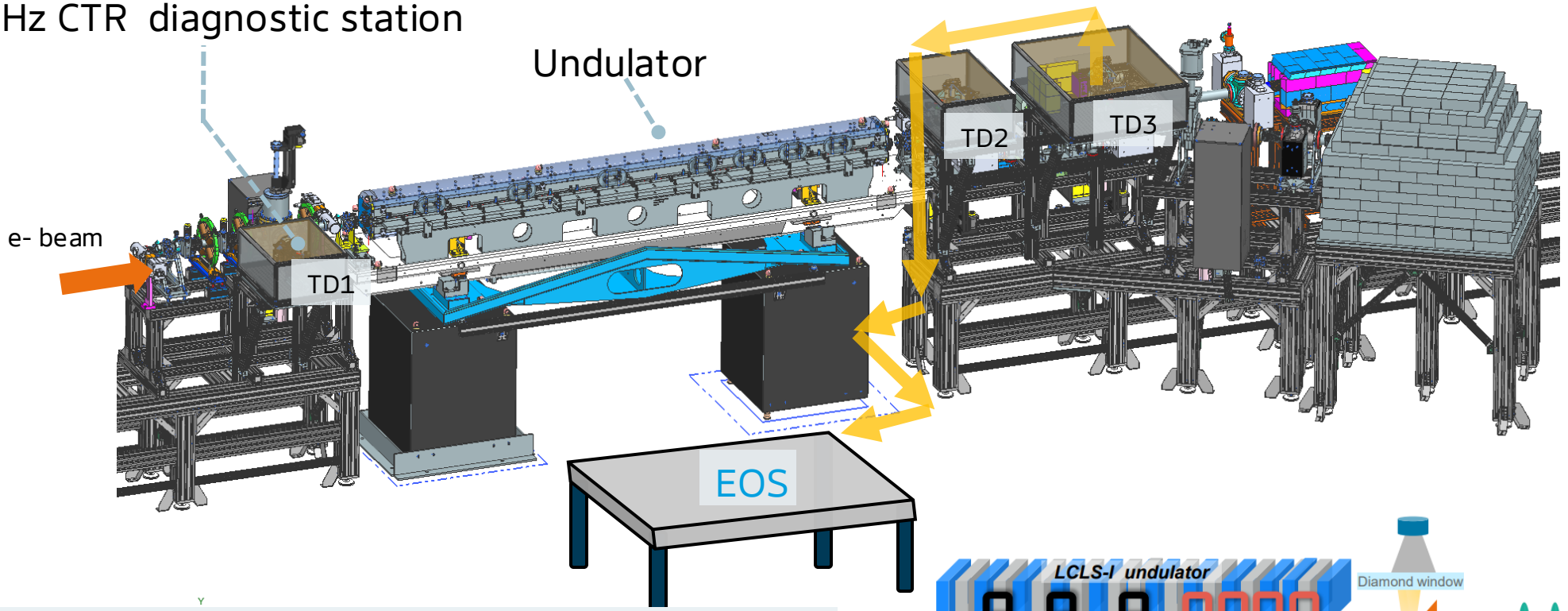

THz pulse energy

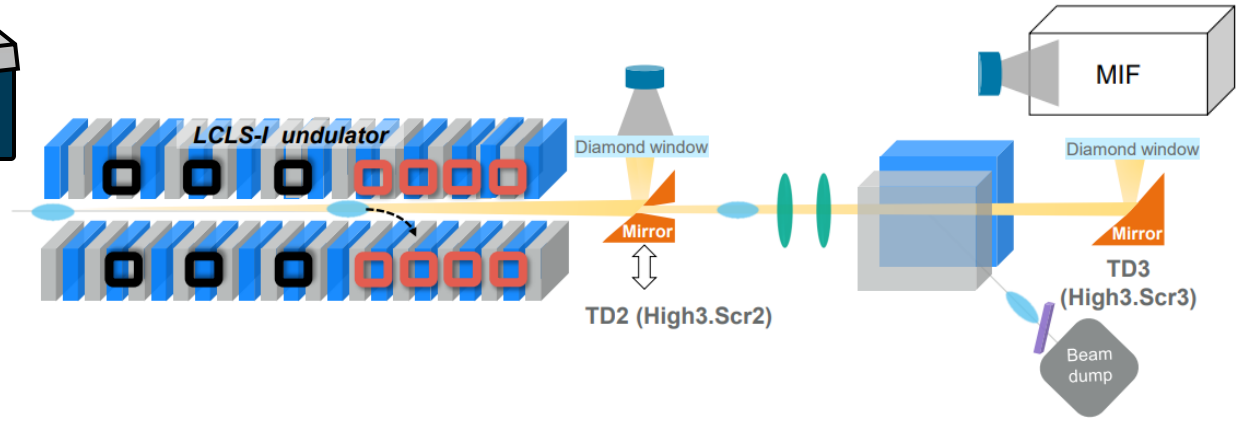
# THz Diagnostics at PITZ

THz FEL diagnostic stations

THz CTR diagnostic station

Undulator




**THz CTR diagnostic**
TD1: Pulse energy and spectrum measurement
**THz FEL diagnostic**
TD2: Pulse Energy measurement
TD3: Beam profile, polarization and spectrum measurement
EOS: Temporal profile measurement

# Design choices and setup considerations for EOS

## Proper design ensures high-resolution, single-shot measurement

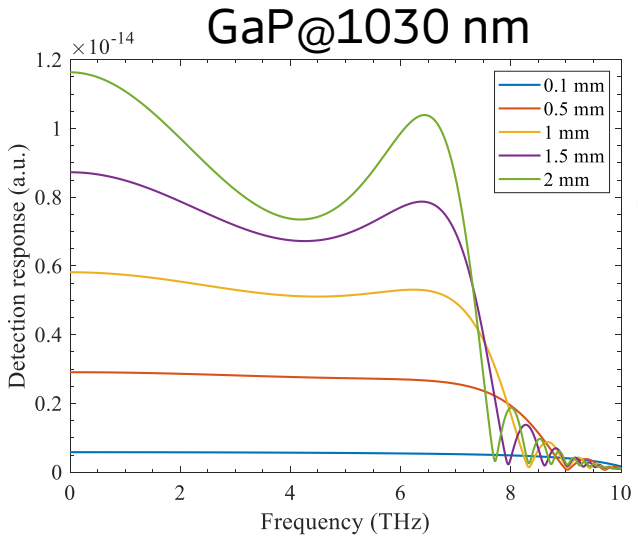
**THz FEL characteristics and laser at PITZ**

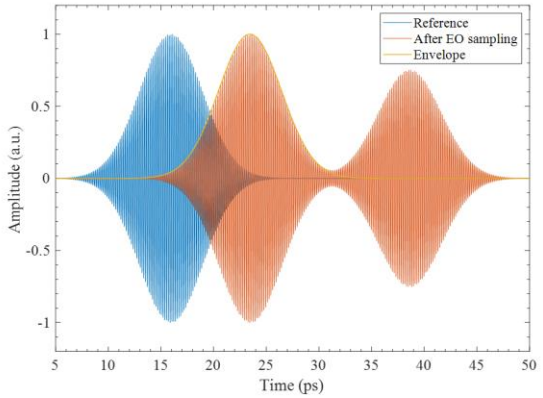
- THz frequency: tunable narrow band 1-5 THz
- Pulse duration: ~20 ps (full width)

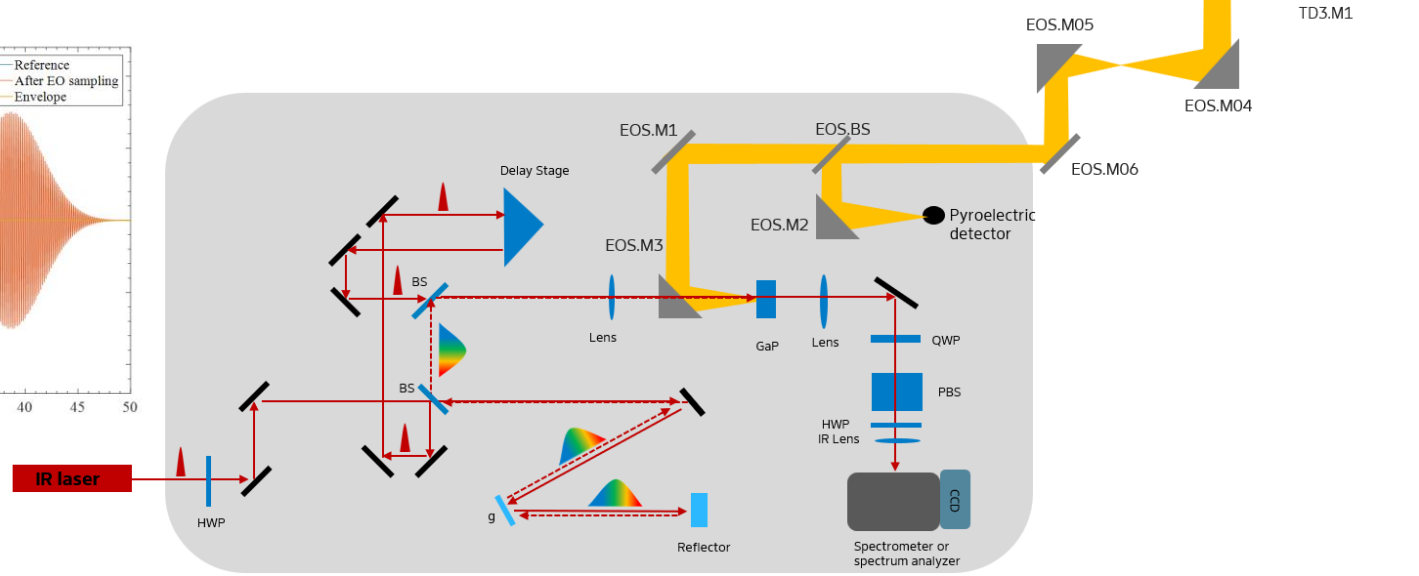
**Calculation of EO process**

- Phase matching and detection response of crystal
- Multiple reflection in the EO crystal

| Parameter | PHAROS | | NEPAL-P | |
|---|---|---|---|---|
| | OSC | PA | OSC | PA |
| Wavelength | 1030 nm | 1030 nm | 1030 nm | 1030 nm |
| Pulse length | 80 fs | 254 fs | 300 fs | 1 ps |
| Bandwidth | 18 nm | 5 nm | 5 nm | 2.5 nm |
| Pulse energy | 4 nJ | 20 µJ | 2 nJ | 40 µJ |
| Rep.rate | 72 MHz | 1 MHz | 54 MHz | 4.5 MHz |
| Expected time resolution | - Step scan: 80 fs<br>- Spectral encoding: 1.5 ps<br>- Amplitude encoding: 80 fs | - Step scan: no<br>- Spectral encoding: 2.76 ps<br>- Amplitude encoding: 254 fs | - Step scan: no<br>- Spectral encoding : 3 ps<br>- Amplitude encoding: 300 fs | no |



# Thank you

# Smith-Purcell and Transition Radiation Based Charged Particle Beam Diagnostics for the Femtosecond-Range

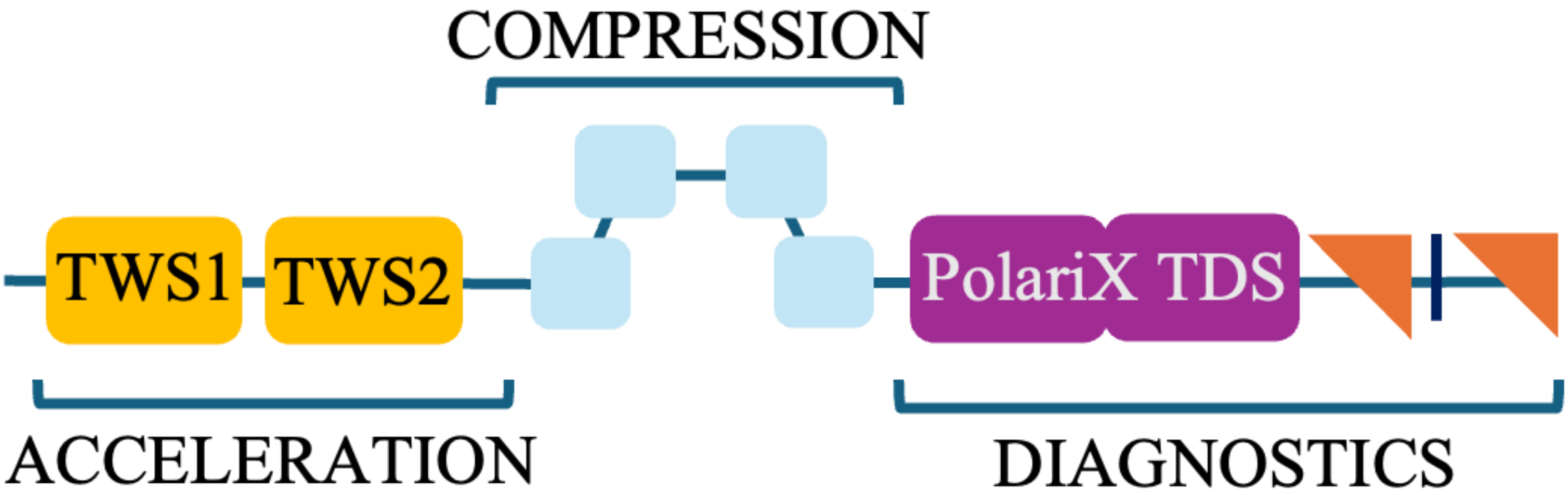
B. Stacey, W. Hillert, W. Kuropka, T. Vinatier

HELMHOLTZ

Deutsches Elektronen-Synchrotron DESY
Ein Forschungszentrum der Helmholtz-Gemeinschaft

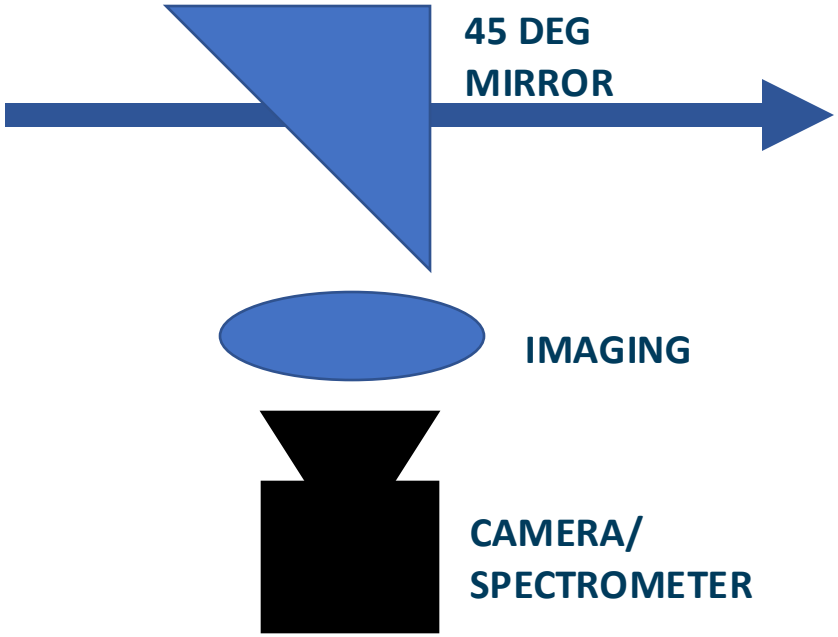
# ARES Layout

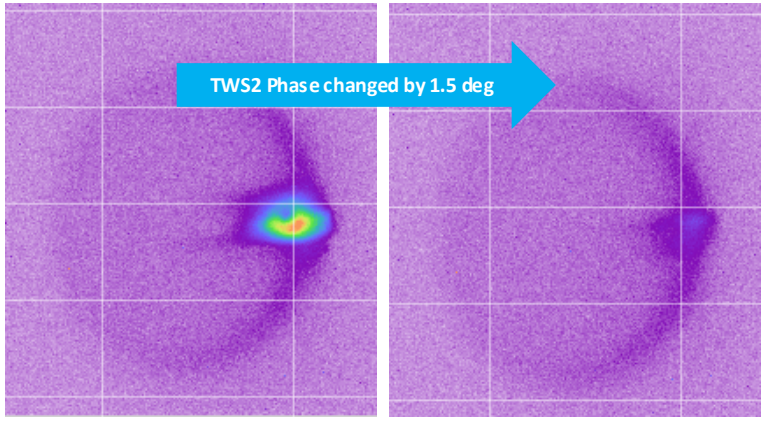
## Accelerator Research Experiment at SINBAD

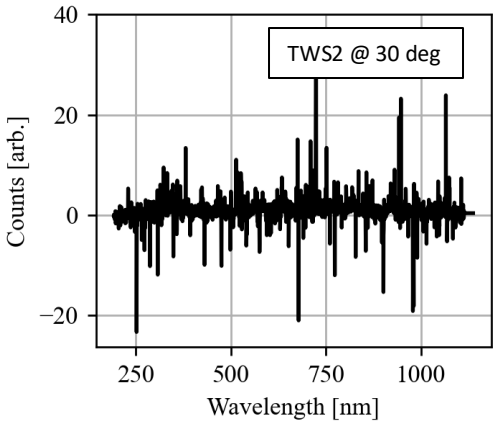


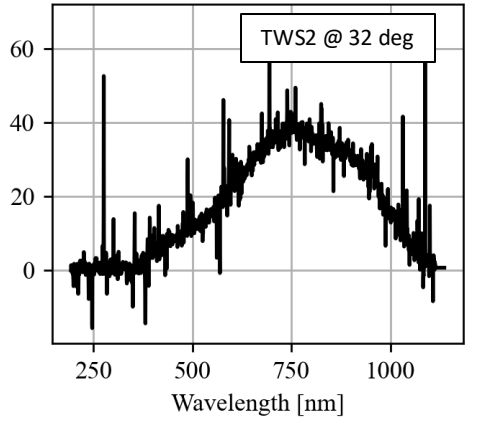
# In-Vacuum TR Bunch Compression Monitor

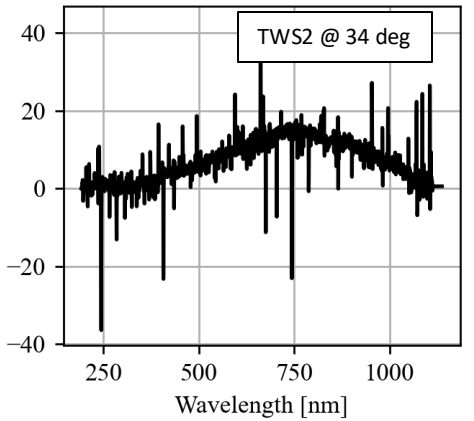
## Coherent and resonant transition radiation as bunch compression monitors towards Smith-Purcell studies



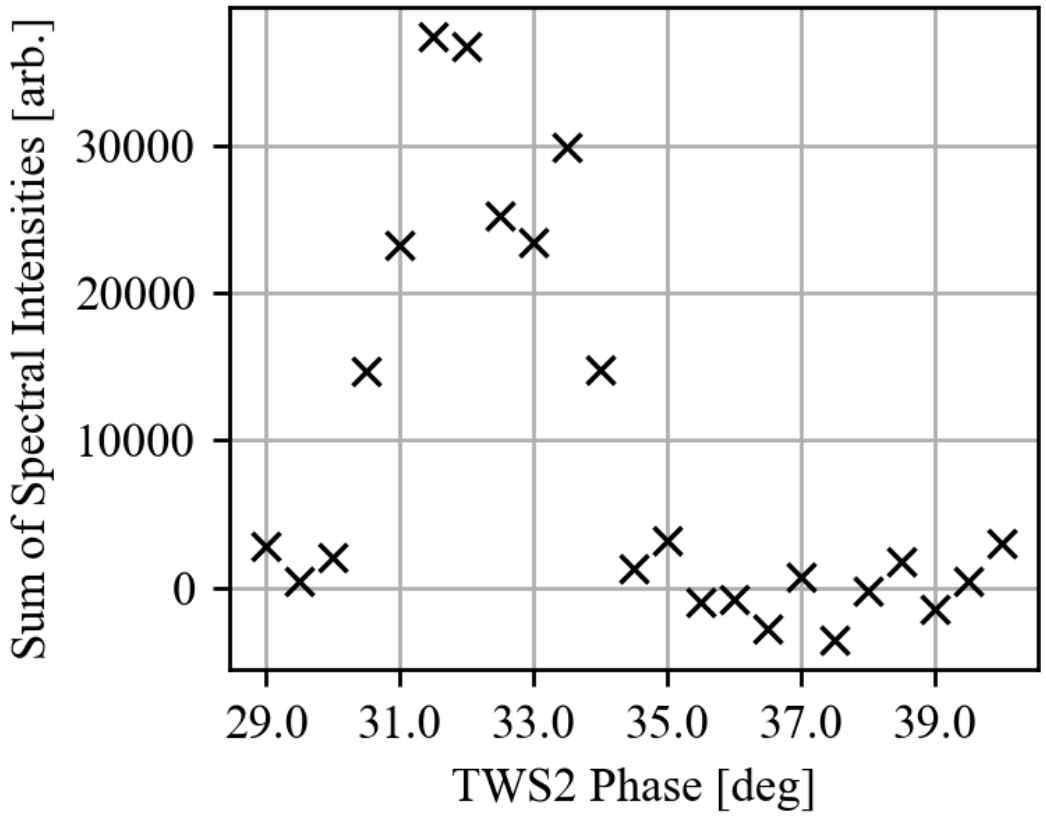



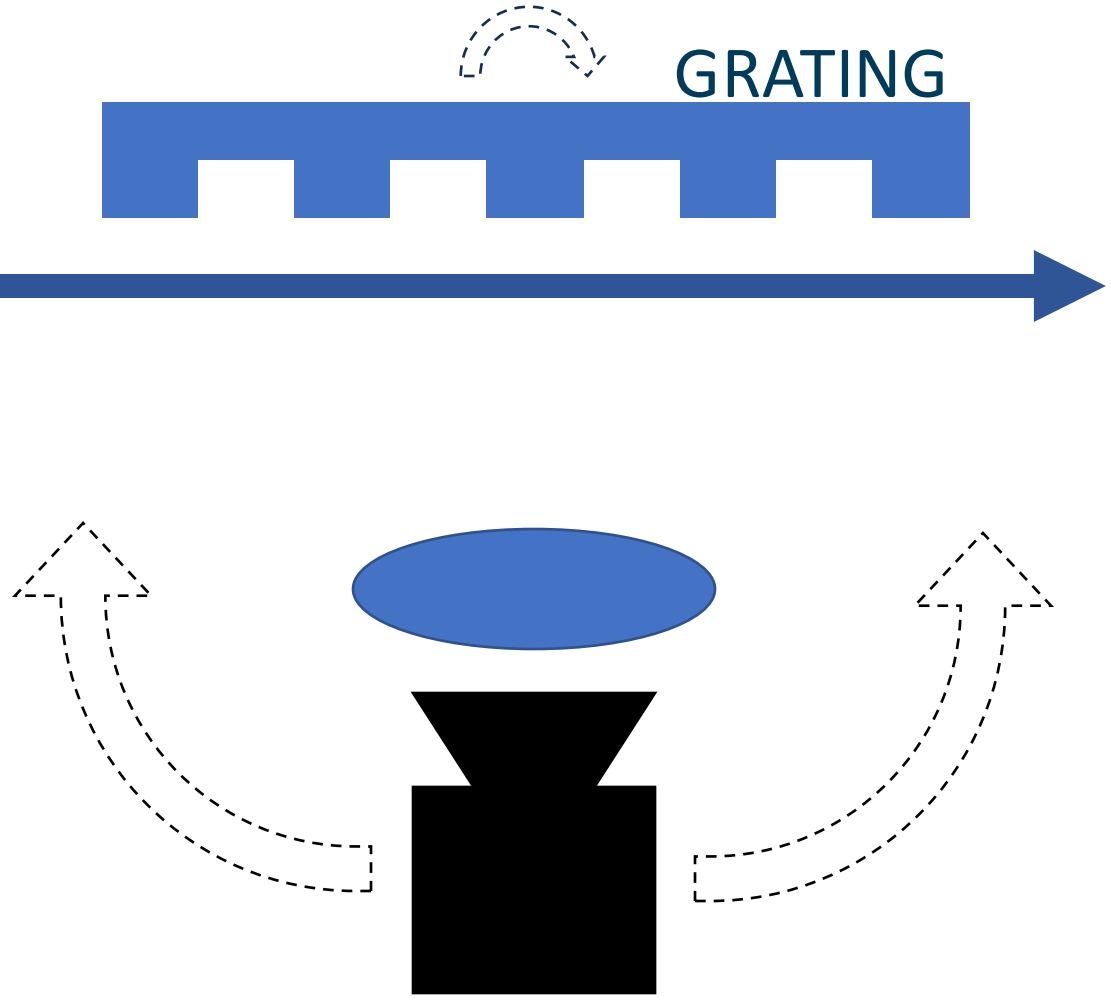
# In-Vacuum TR Bunch Compression Monitor

## Coherent and resonant transition radiation as bunch compression monitors towards Smith-Purcell studies



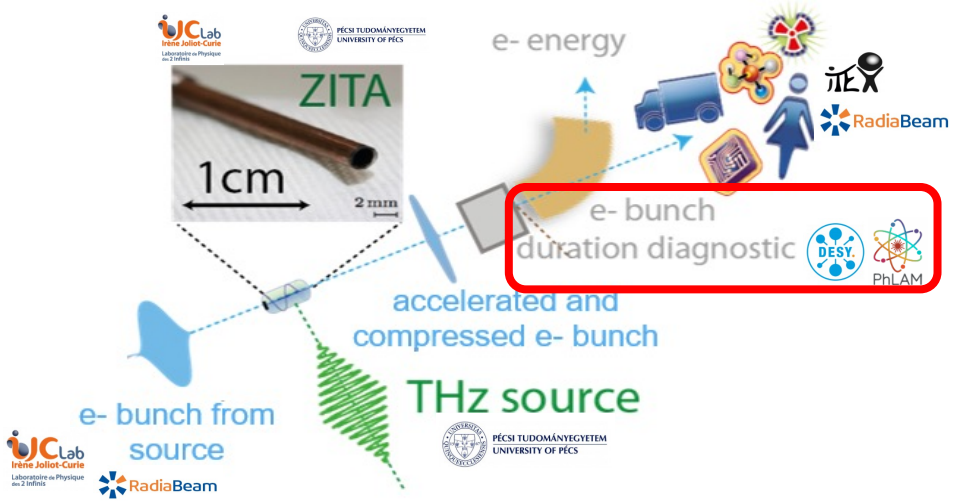
# Smith-Purcell Longitudinal Diagnostic

## Coherent and resonant transition radiation as bunch compression monitors towards Smith-Purcell studies

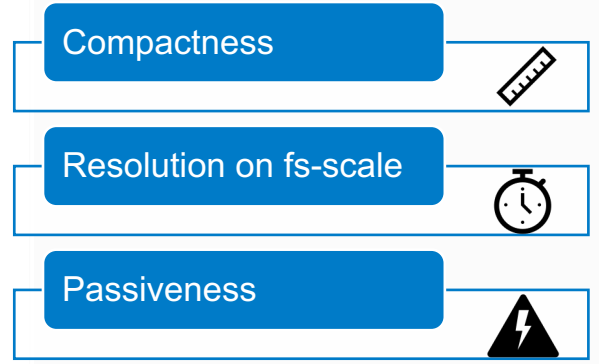


# Current Profile Reconstruction of Low Energy Beams by Passive Streaking

## Wakefield-based bunch duration diagnostics with dielectric capillaries at ARES for the TWAC project




Goal: low-energy, high peak current compact accelerators leveraged by THz-driven acceleration & compression







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**M. Kellermeier**, T. Vinatier,
F. Burkart, H. Dinter, S. Jaster-Merz, W. Kuropka, F. Mayet, B. Stacey

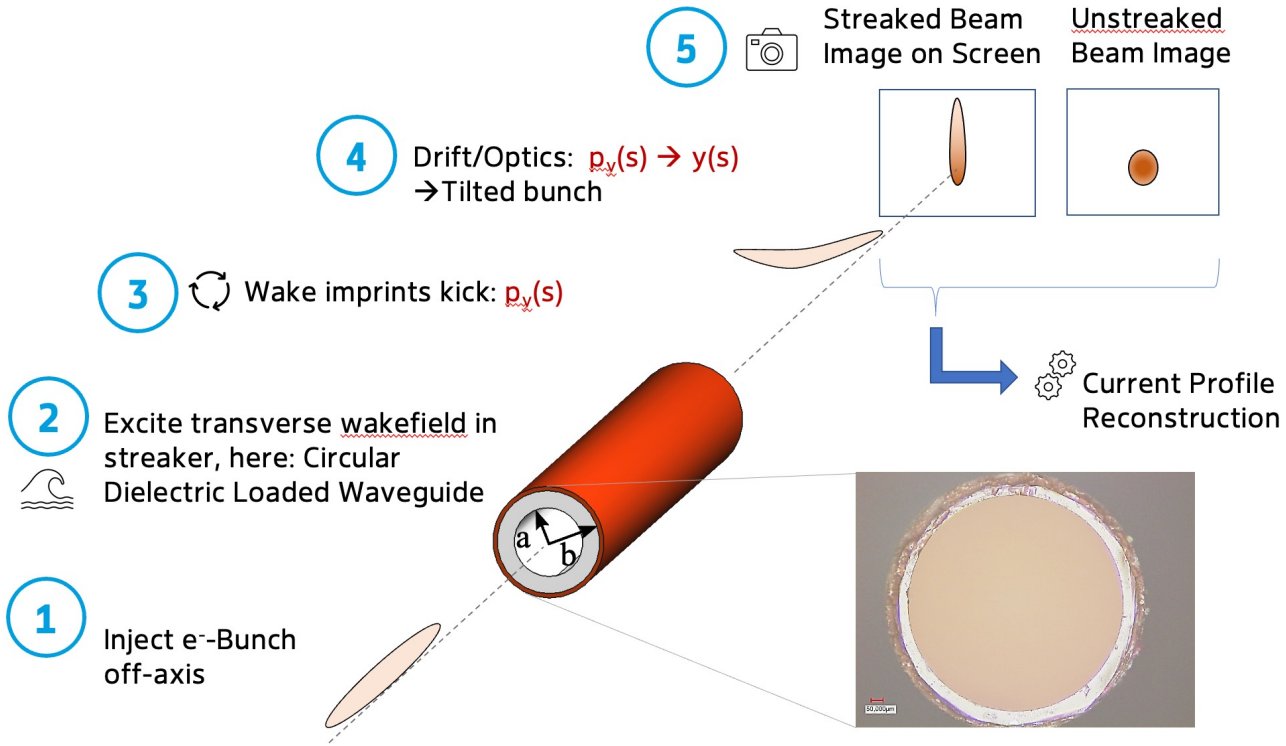
30.09.2025, Hamburg

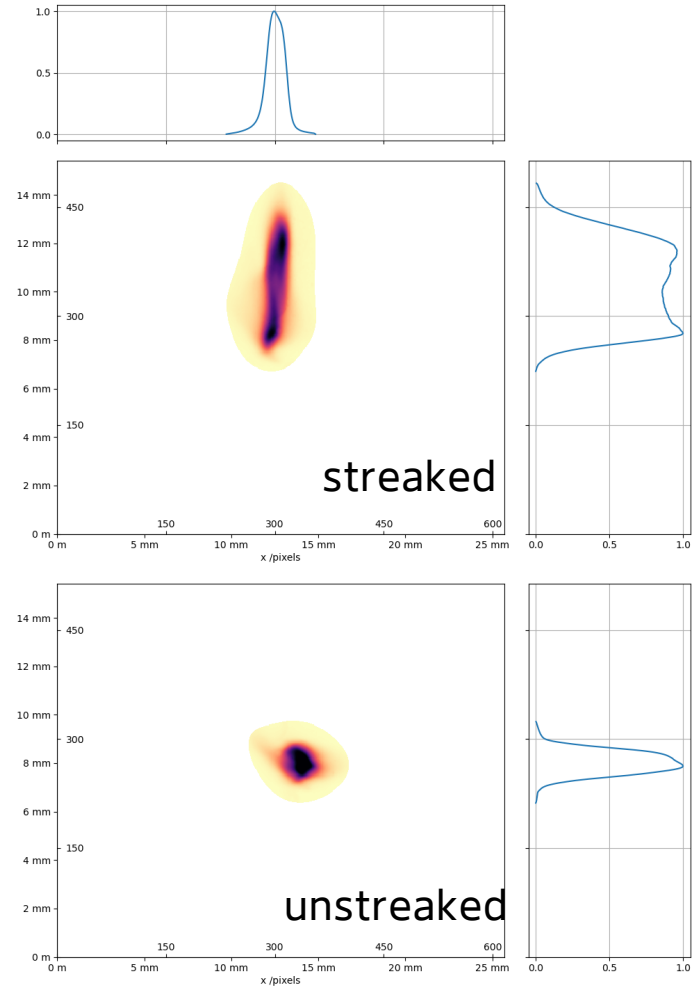
Funded by the European Union

TERAHERTZ WAVE ACCELERATING CAVITY

DESY.

# Concept and Beam Images from Experiments



# Developed Reconstruction Methods

## Passive Streaking

### Quasi-0D

- Applies 2D distribution
- Assumes Gaussian with long.-trans. correlation
- Least Squares Fitting of statistical parameters (deflection & streaking)

### 1D-Reconstruction

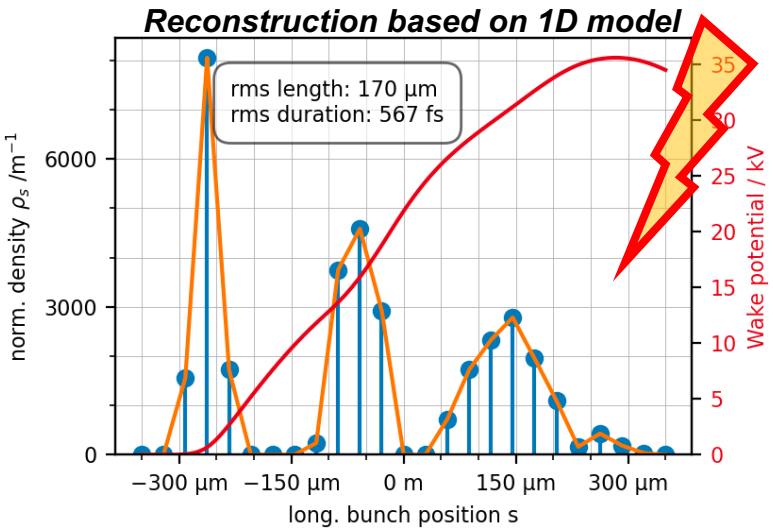
- Assumes no correlation
- streaked image: conv. of unstreaked real beam & streaked line charge density
- Forward Propagation
- Least Squares of streaked distributions

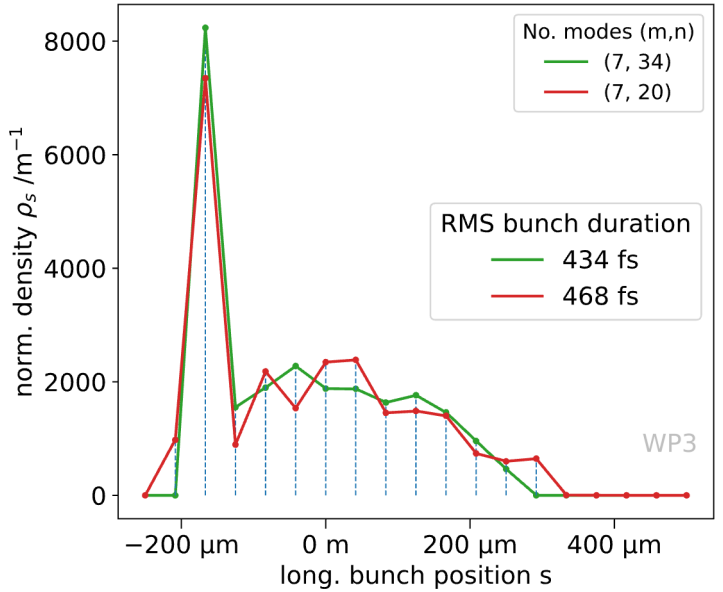
### 2D-Reconstruction

- Arbitrary 2D distribution
- Backward propagation
- Iterated Truncated SVD

# Y-Z correlation as Challenge for Reconstruction

## Glimpse on experimental data analysis

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