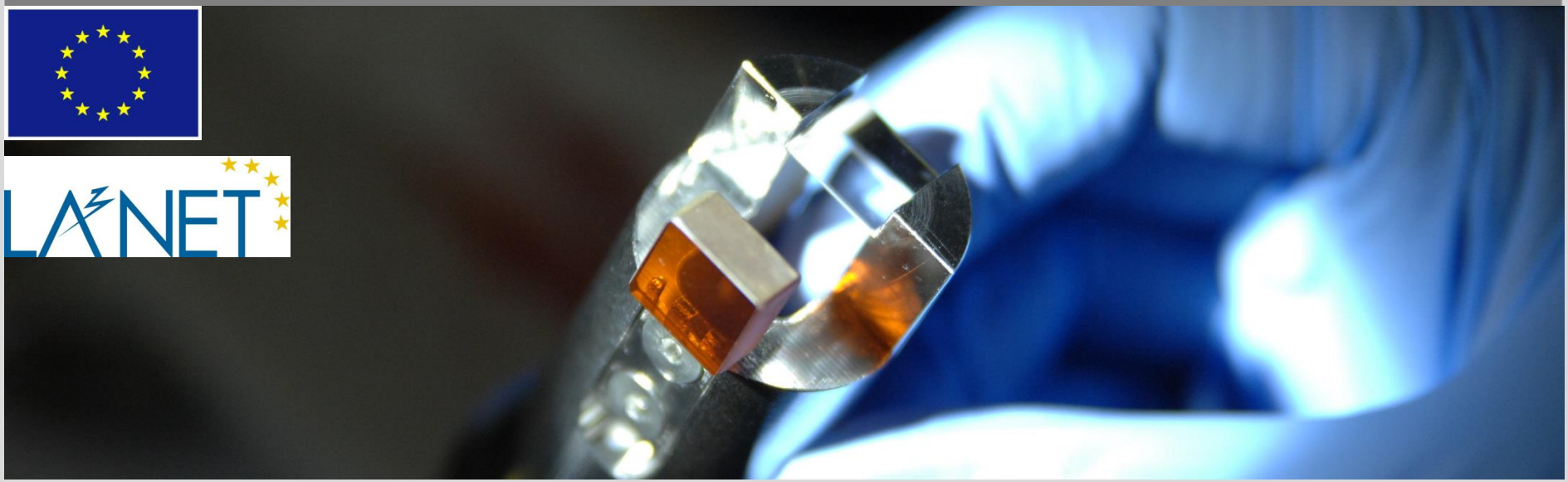
Bunch shape with electro optic technique- measurements on the limits

Andrii Borysenko, Nicole Hiller, Michael J. Nasse, Marcel Schuh and Anke-Susanne Müller.

Karlsruhe Institute of Technology

Institute for Photon Science and Synchrotron Radiation

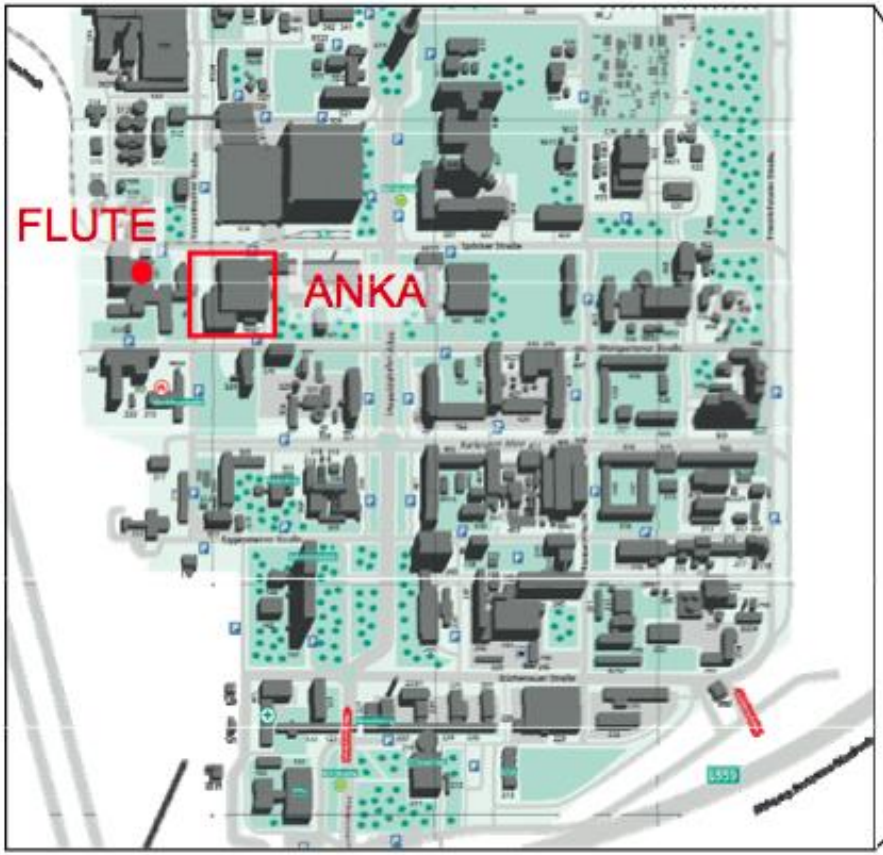


Outline

- What is FLUTE – machine and motivation
- What to use for bunch length measurement?
- Principles of electro-optical bunch length measurements
- Simulations of a bunch length monitor
- Measurements at SwissFEL ITF
- Summary & outlook

Location

KIT Campus North, Karlsruhe, Germany



Motivation

- **F**erninfrarot **L**inac- **U**nd **T**est **E**xperiment
- FLUTE – accelerator test facility at KIT

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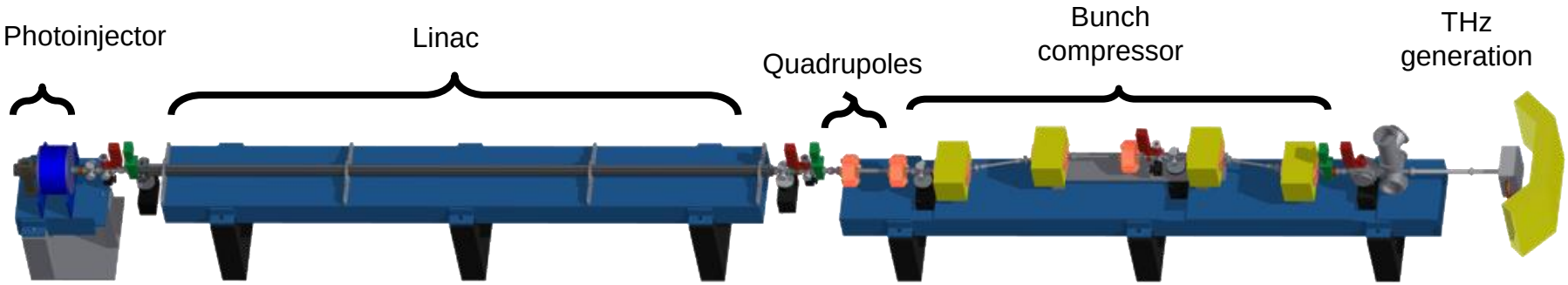
  - Wide range of bunch charges and lengths
  - Different coherent THz radiation generation schemes



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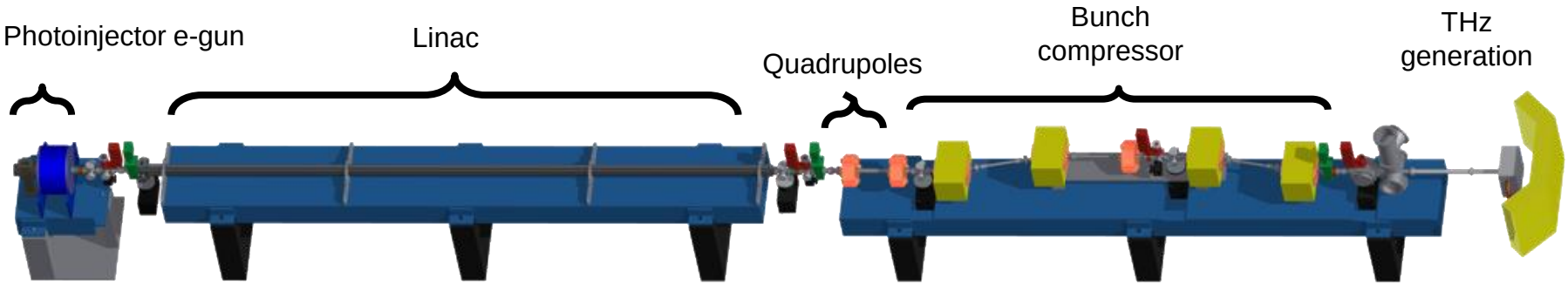
→ Bunch length monitor

→ High dynamic range/adaptive

→ Non-destructive



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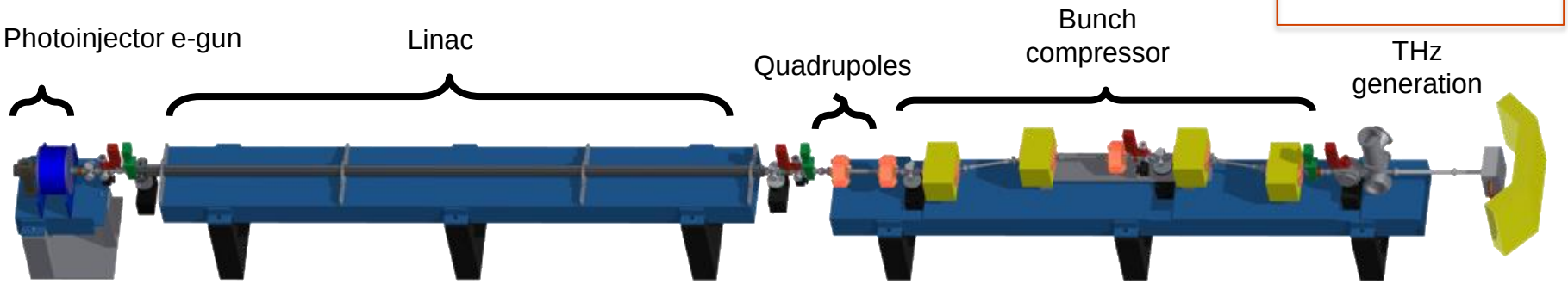
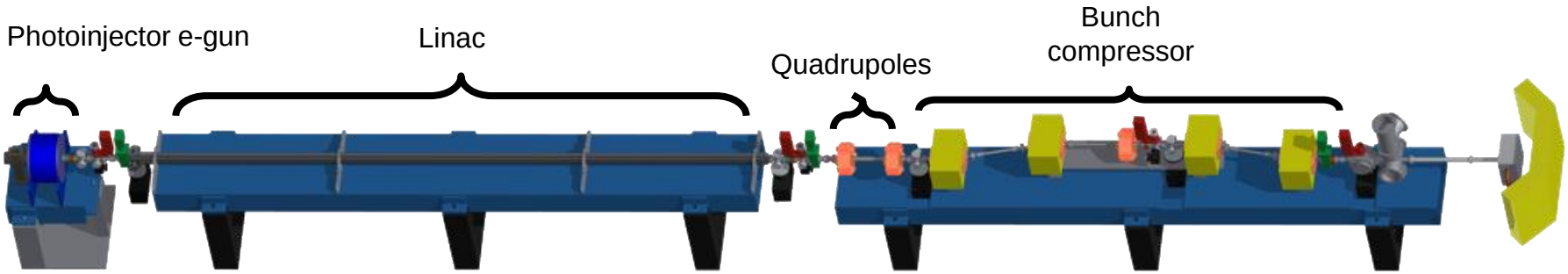
↘ EO-based bunch length monitor



Motivation

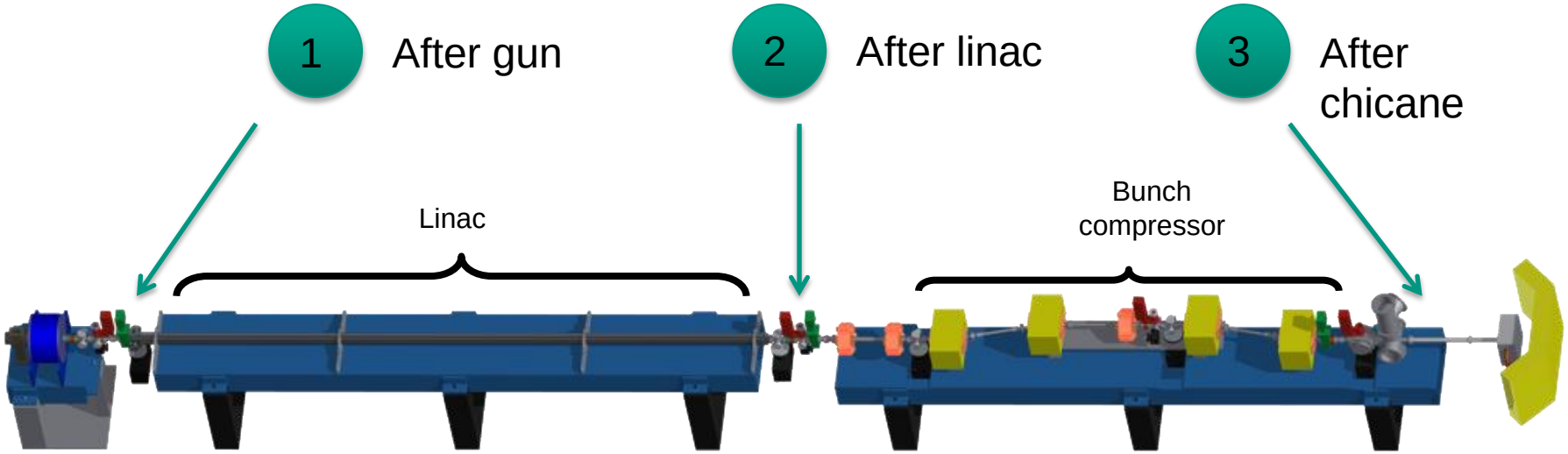
- FLUTE key parameters

Final electron energy	42	MeV
Electron bunch charge	1 - 3000	pC
Electron bunch length	1- 300	fs
Pulse repetition rate	10	Hz
Length	~15	m



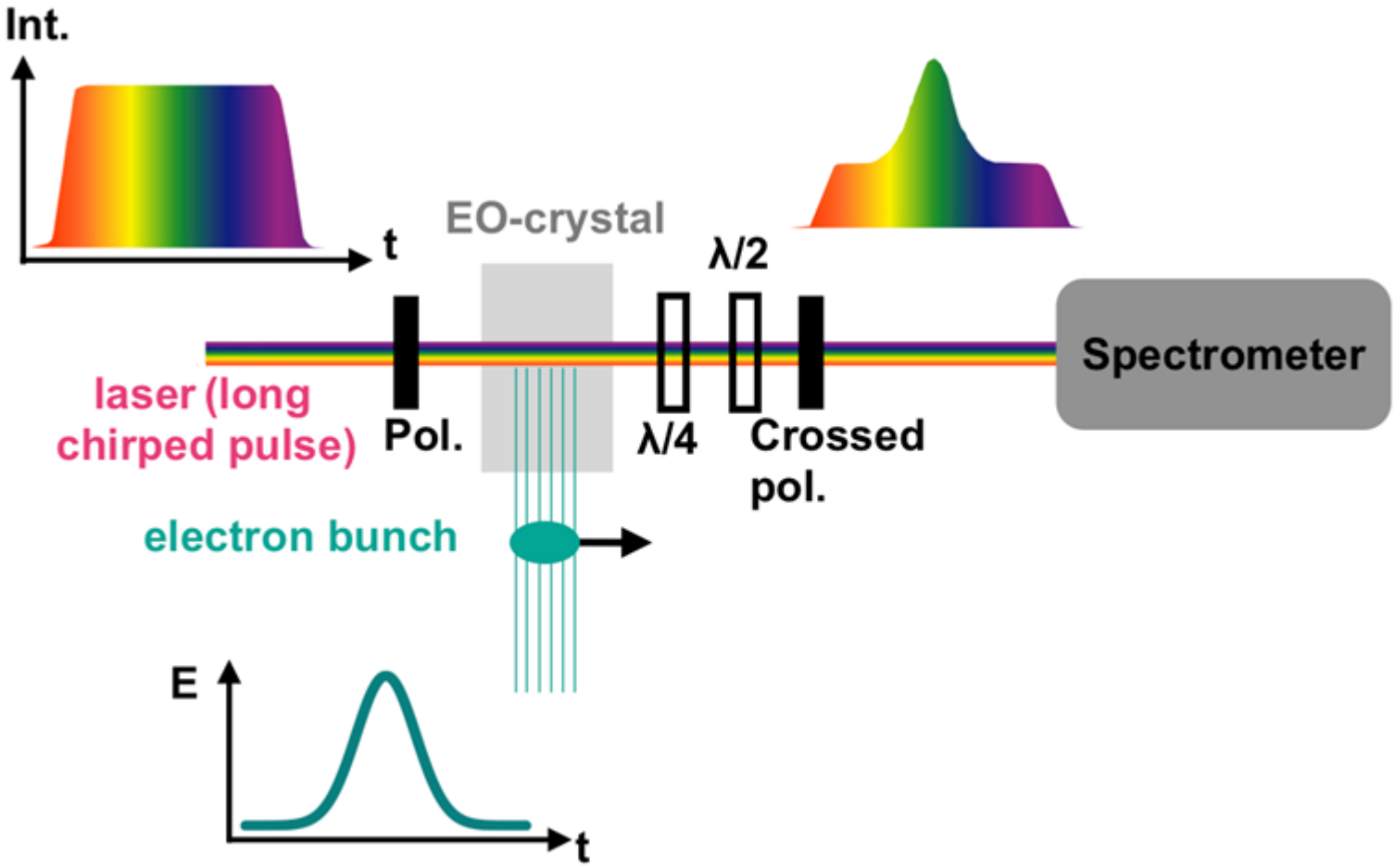
Locations of interest for longitudinal diagnostics

Operation mode	Bunch length (rms), fs		
	Gun	Linac	Chicane
1 pC	520	450	1 - 10
100 pC	1200	1080	67
3000 pC	2500	2300	200
	7 MeV	42 MeV	42 MeV



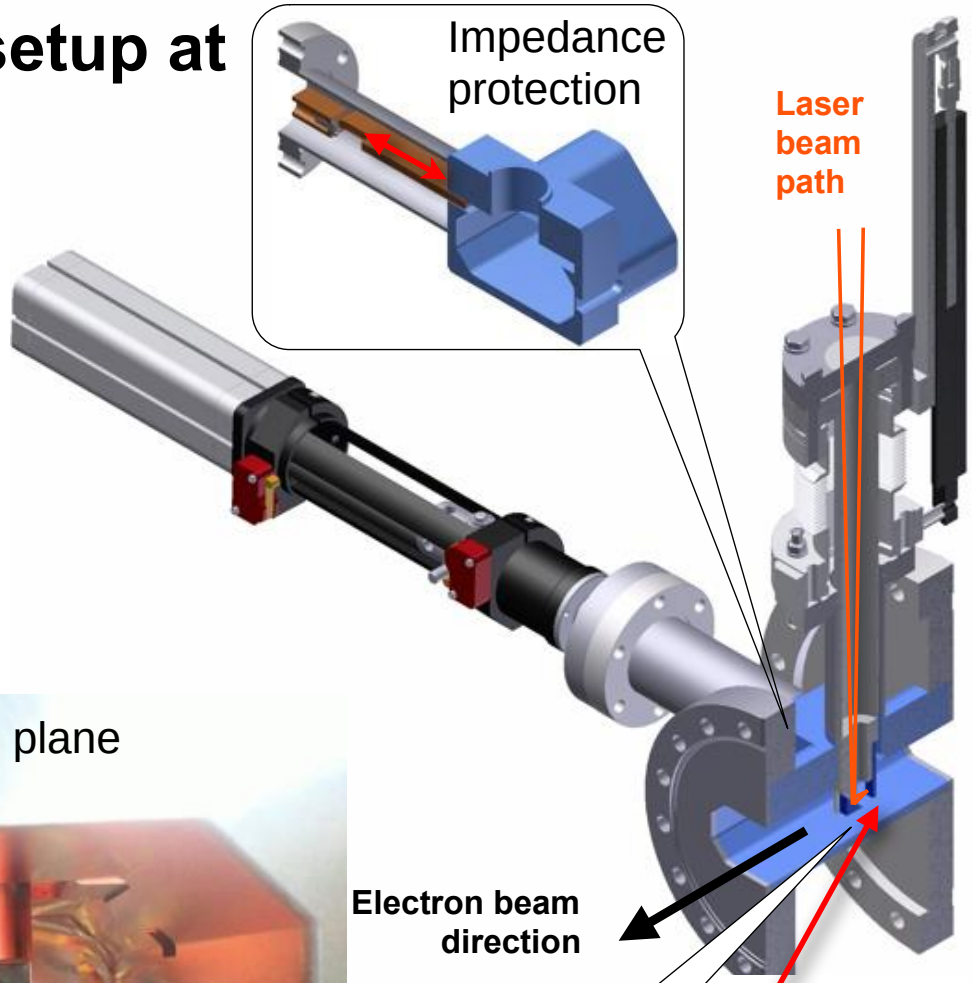
Principles of Electro-Optical Spectral Decoding

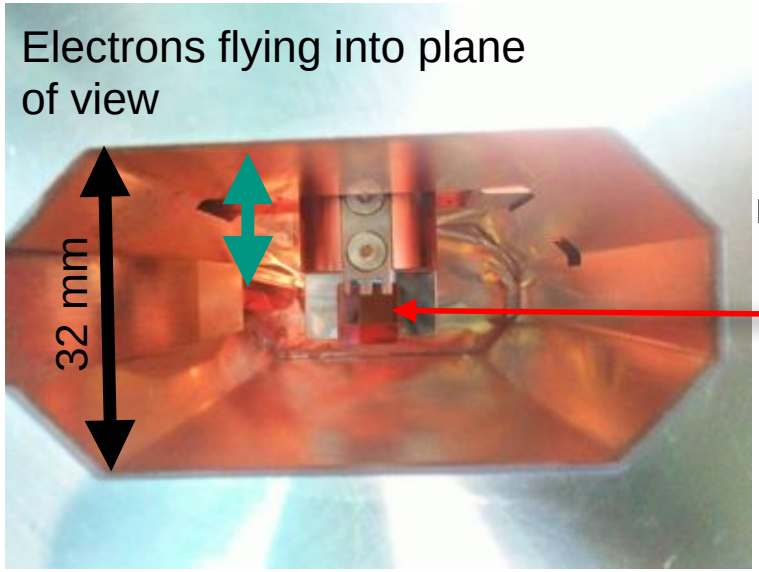
- Single-shot method



Near-Field setup at ANKA: EO-Monitor

*Nicole Hiller, KIT



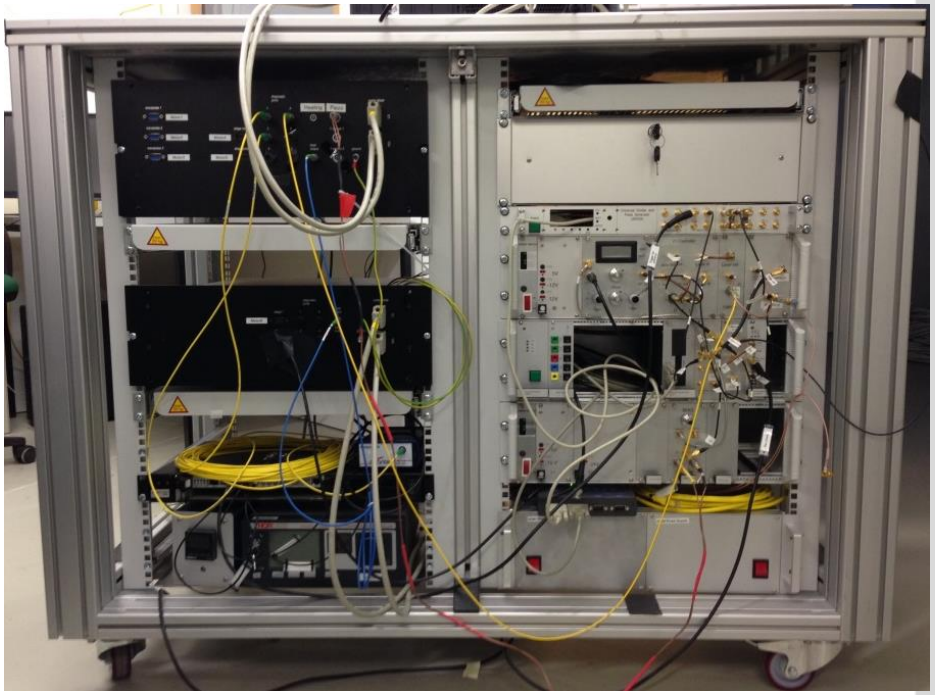


EO monitor with grating compressor and wave plates

Laser System

Yb-doped fiber laser 1030 nm*

EO system installed at ANKA



* Courtesy of Peter Peier, Desy

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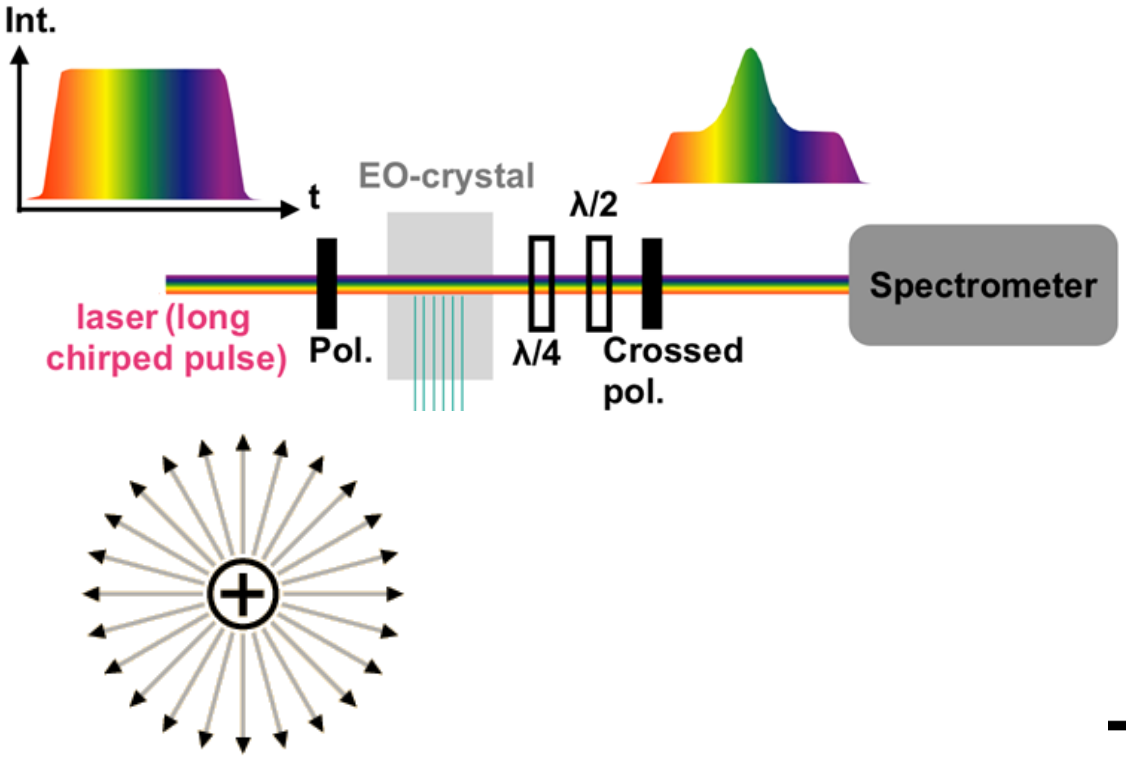

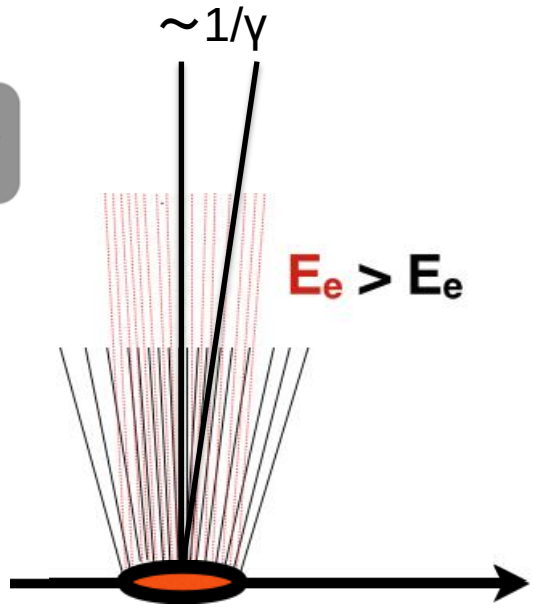

Uncertainty at low beam energy

Principles of Electro-Optical Spectral Decoding

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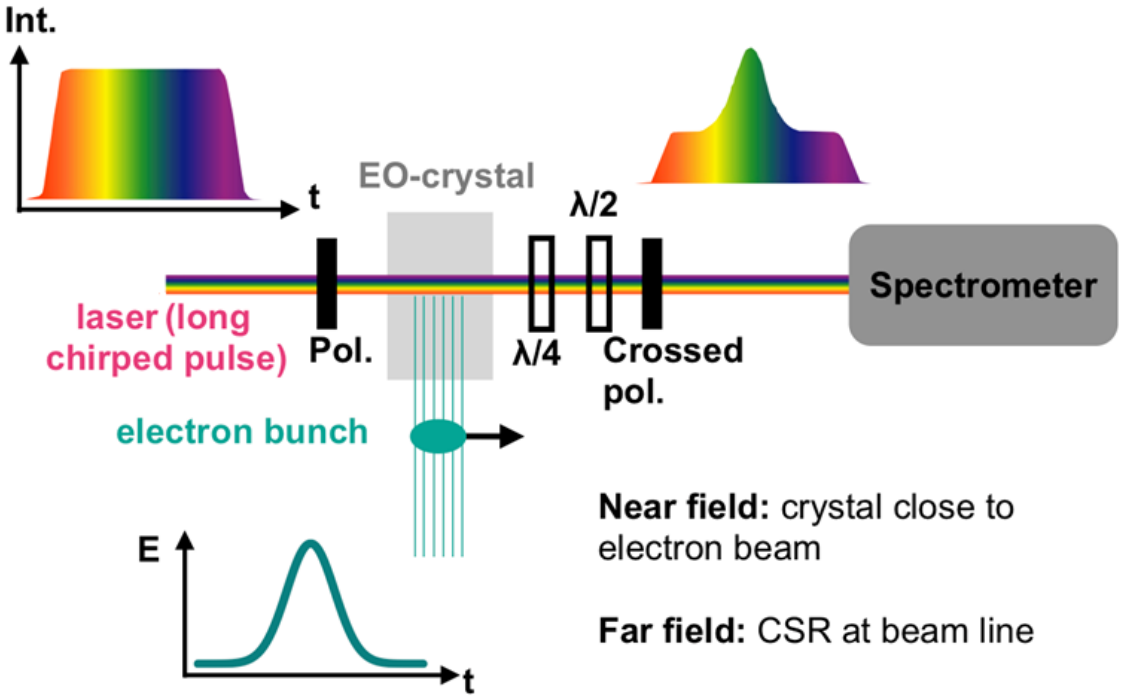

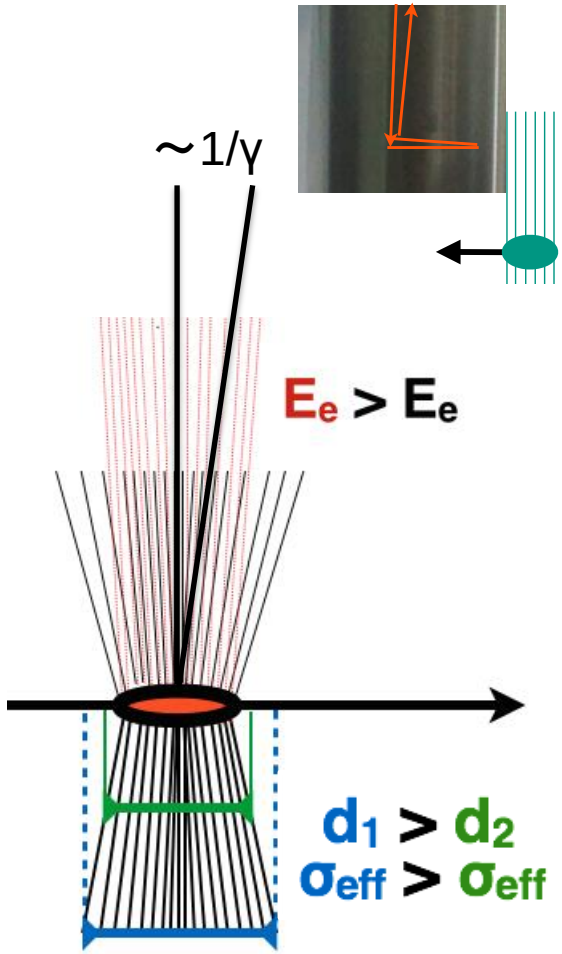

Uncertainty at low beam energy

Simulation

- **Tool**: MATLAB based code – developed by B. Steffen (DESY)
- Main Input parameters:

	Electron Bunch	Laser	Crystal & Detection
Fixed	**γ – energy** (7, 42 MeV)	**σ_λ- spectral width** **λ – wavelength** (1030 nm – Yb-doped)	**Material (GaP)** **Wave-plate settings**
Varied	**Q – charge**		**Distance to e-beam**
	σ_z – length	**σ_T – pulse length**	**Thickness of a crystal**

Aim: Determine optimal settings for bunch-length monitor

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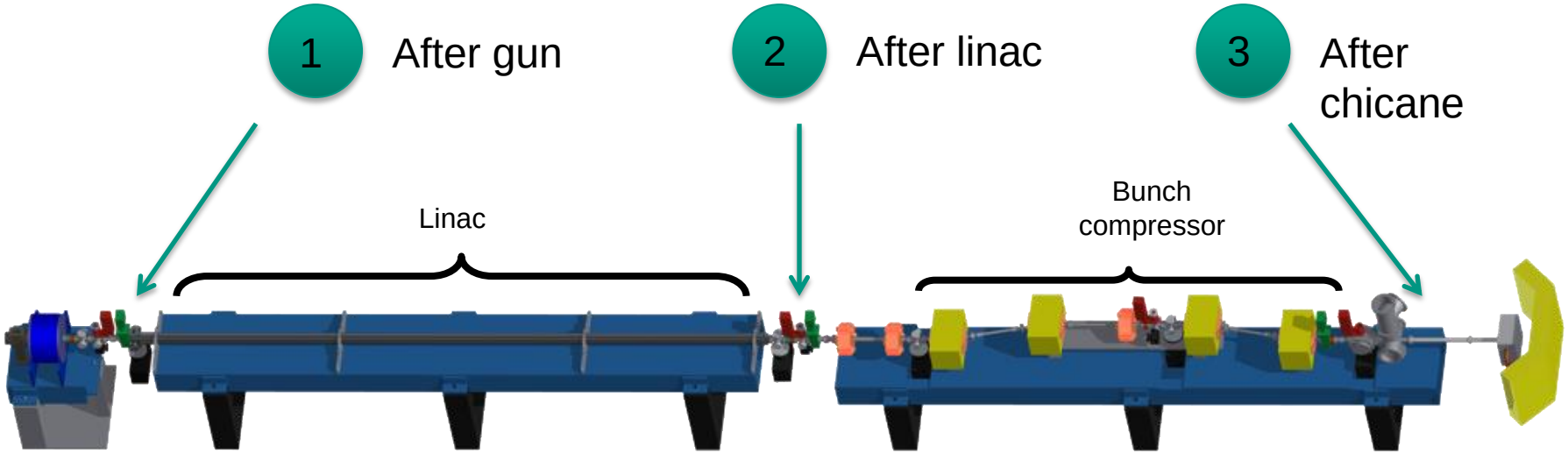
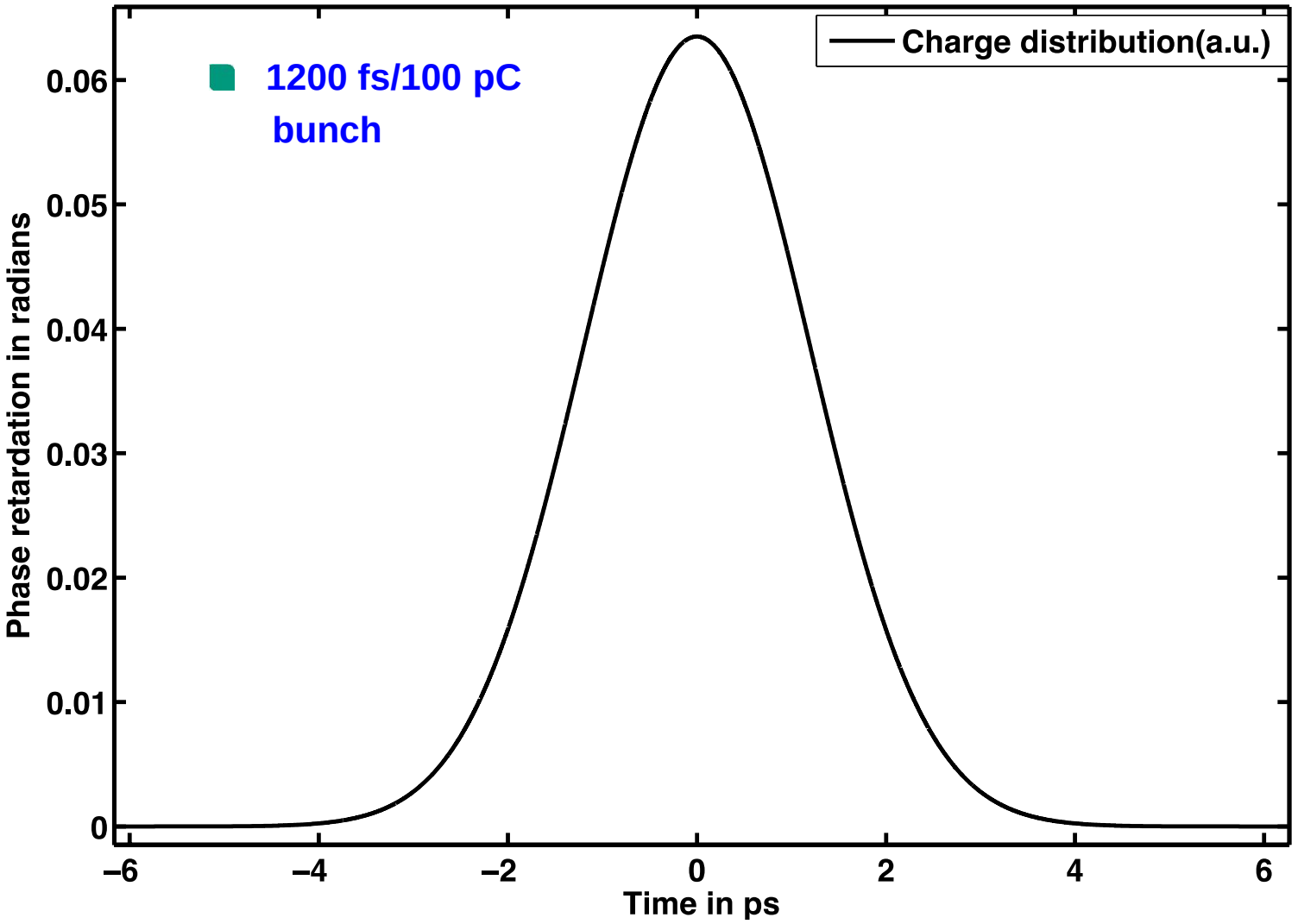


Simulation Results



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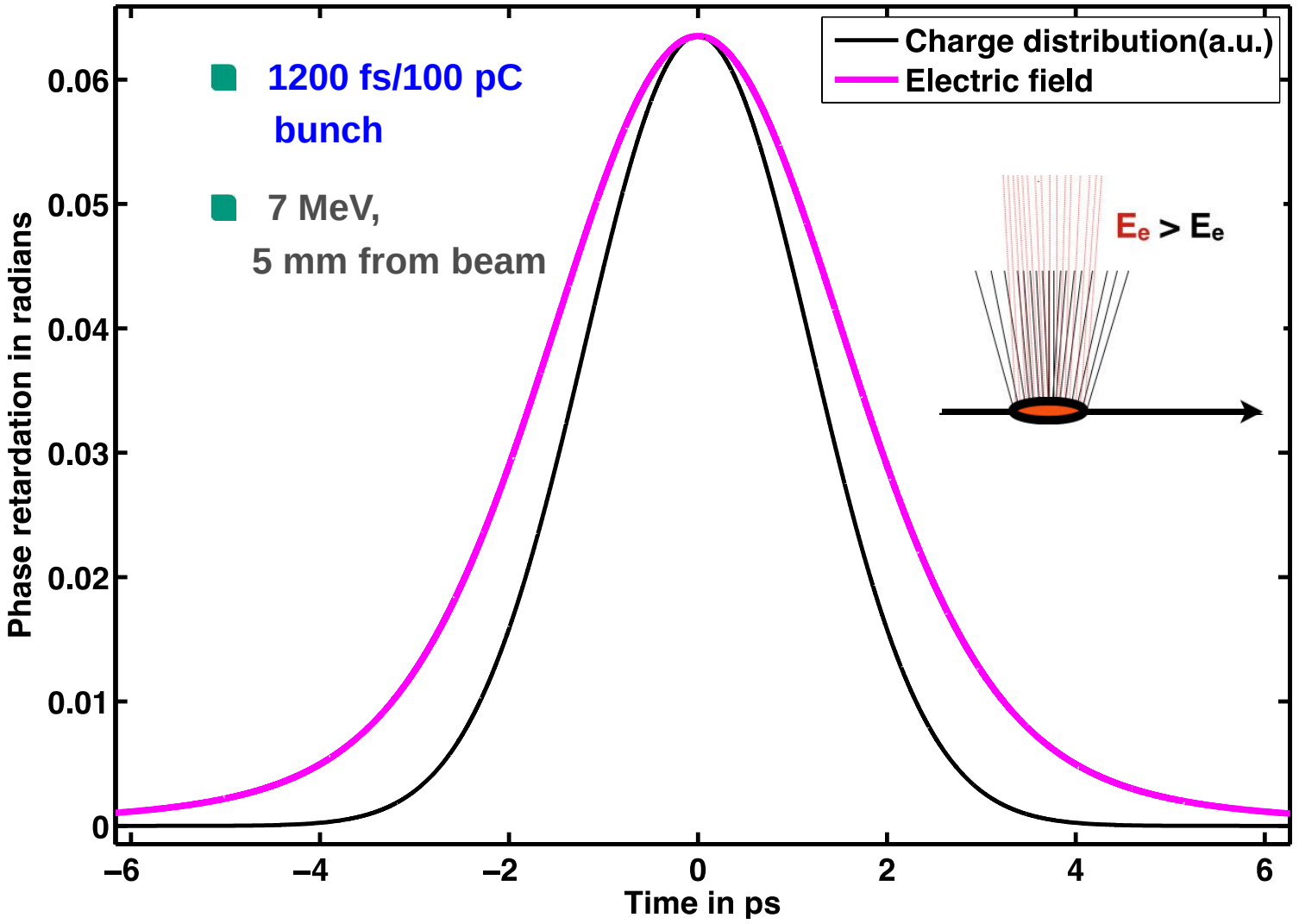

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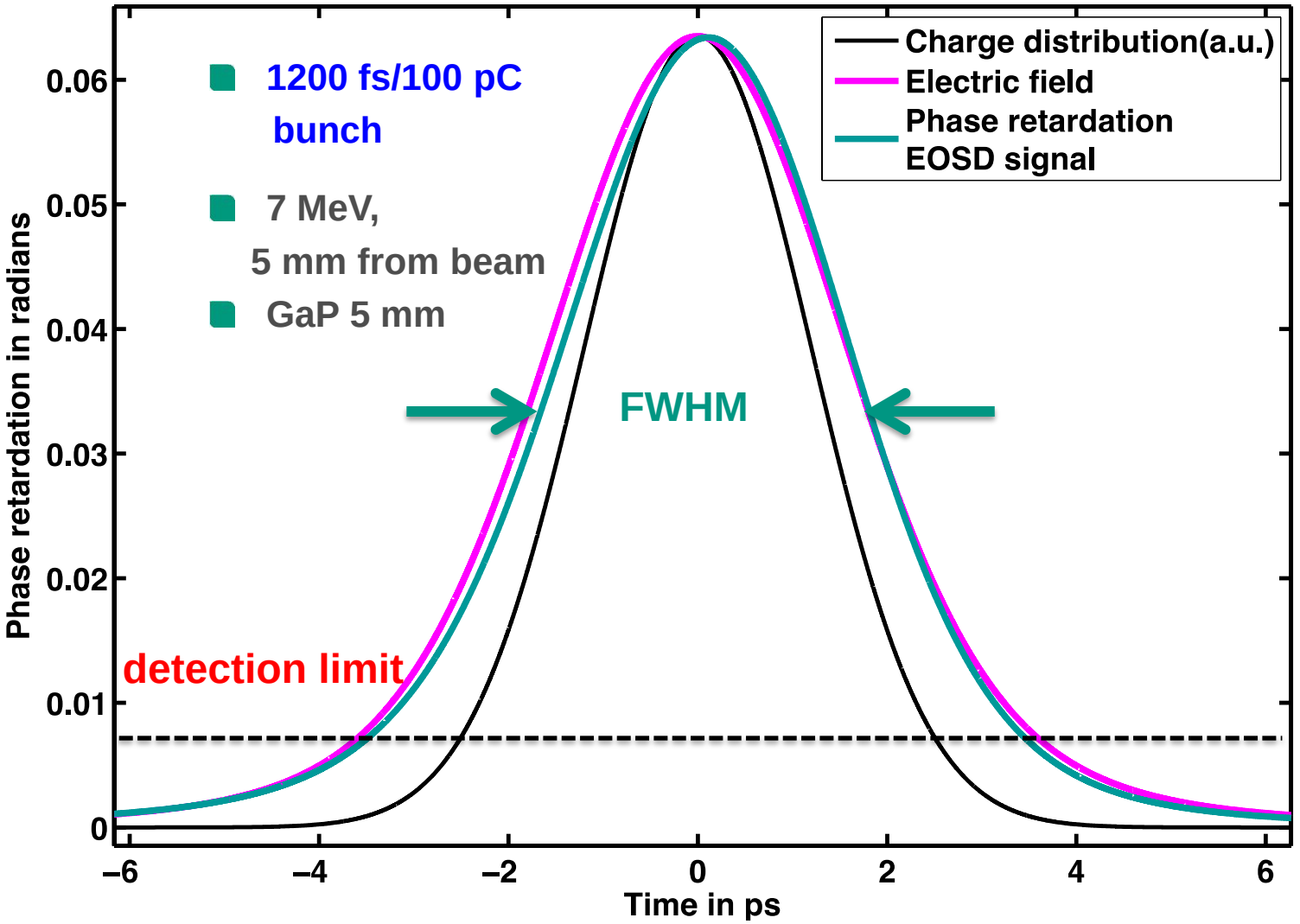
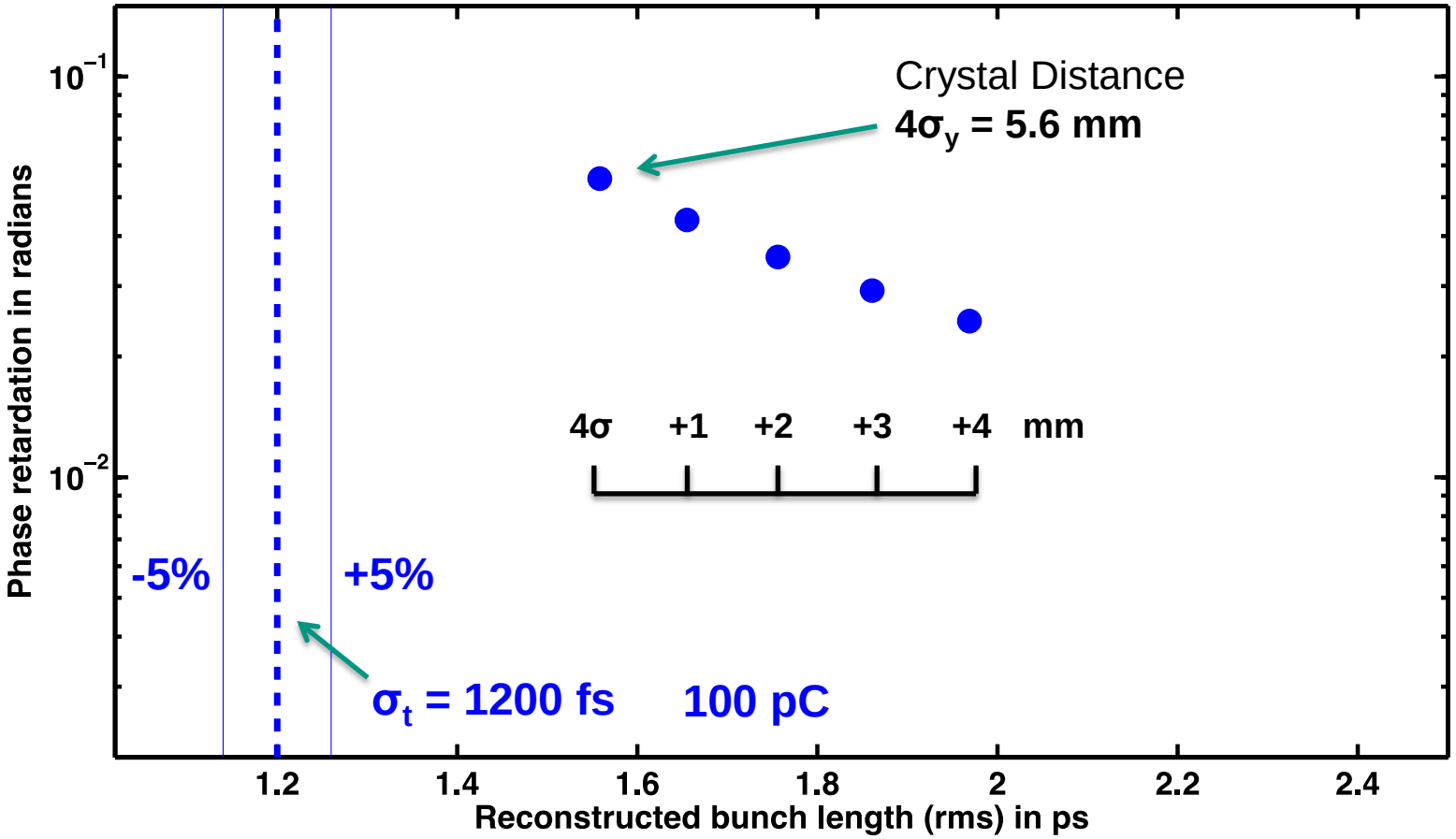


EOSD signal – after Gun (7 MeV)



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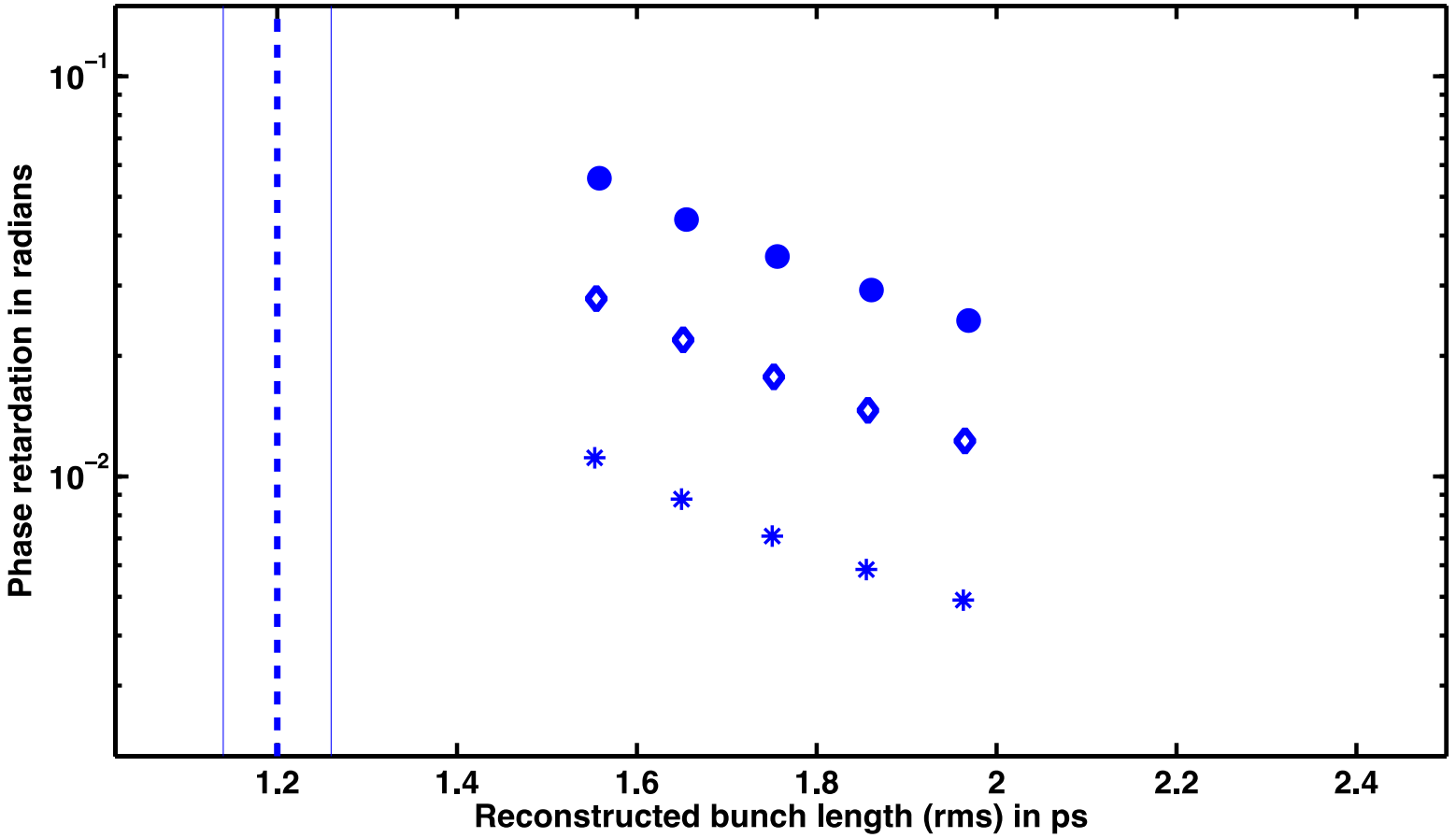

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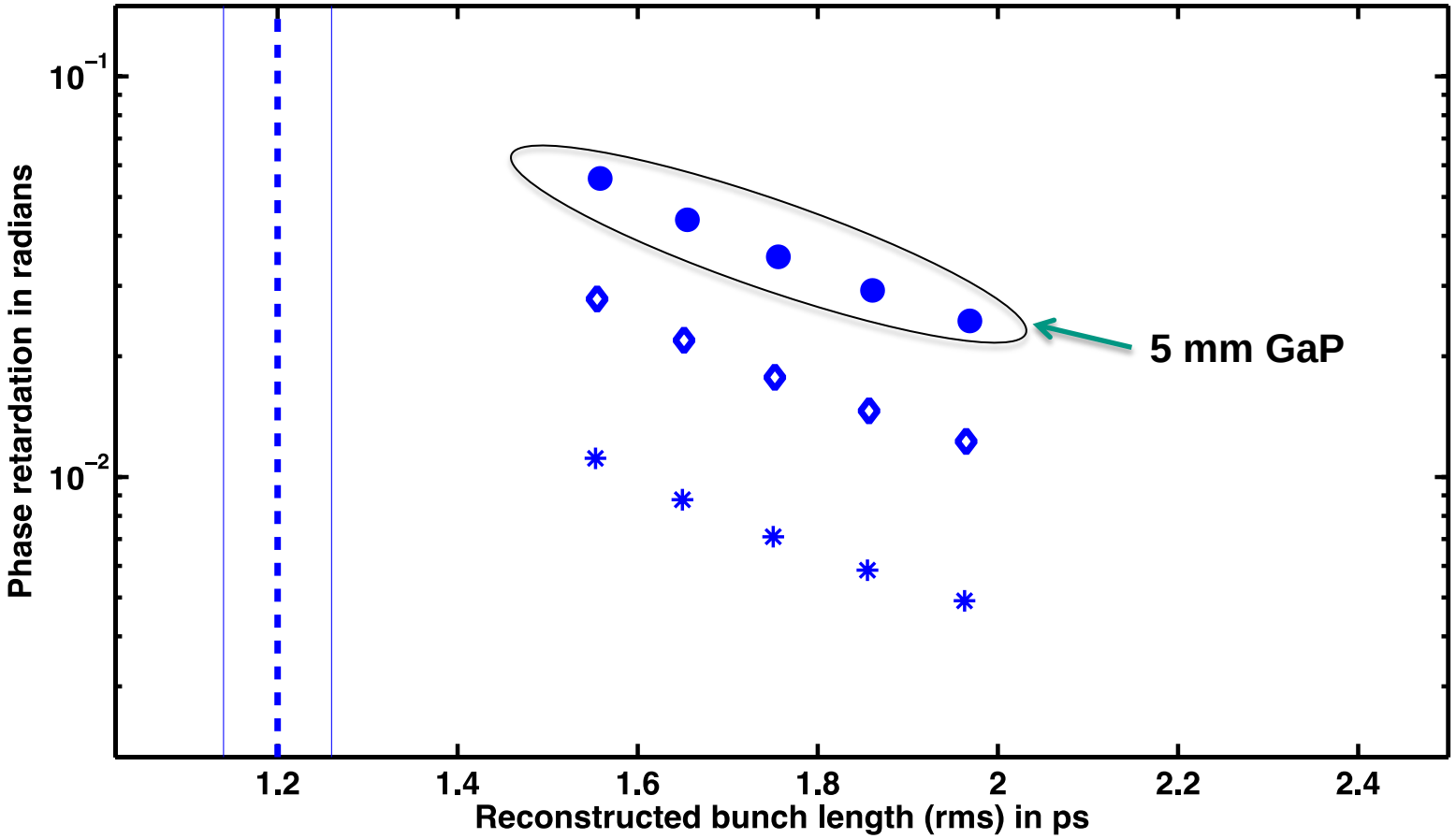

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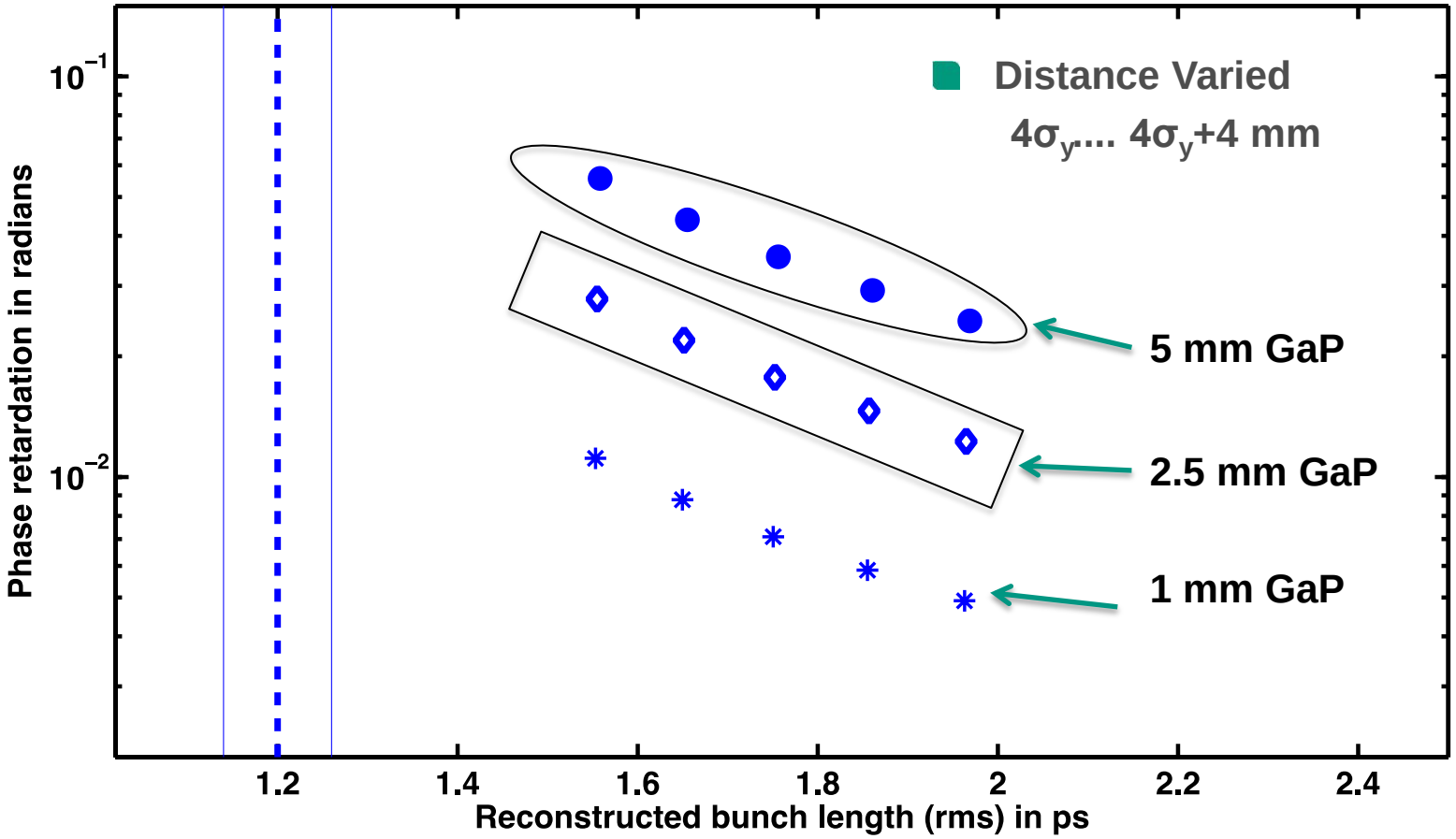

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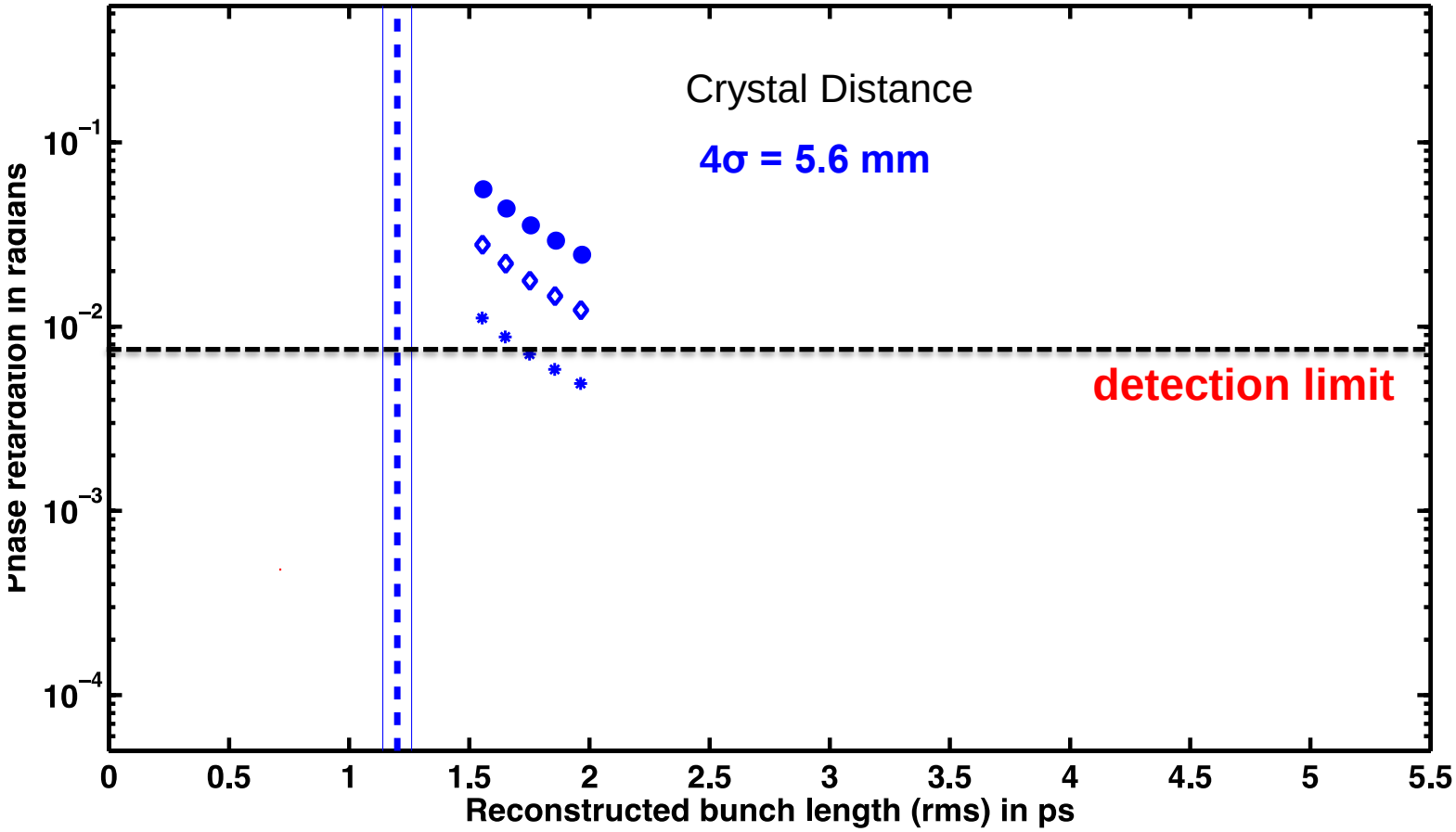

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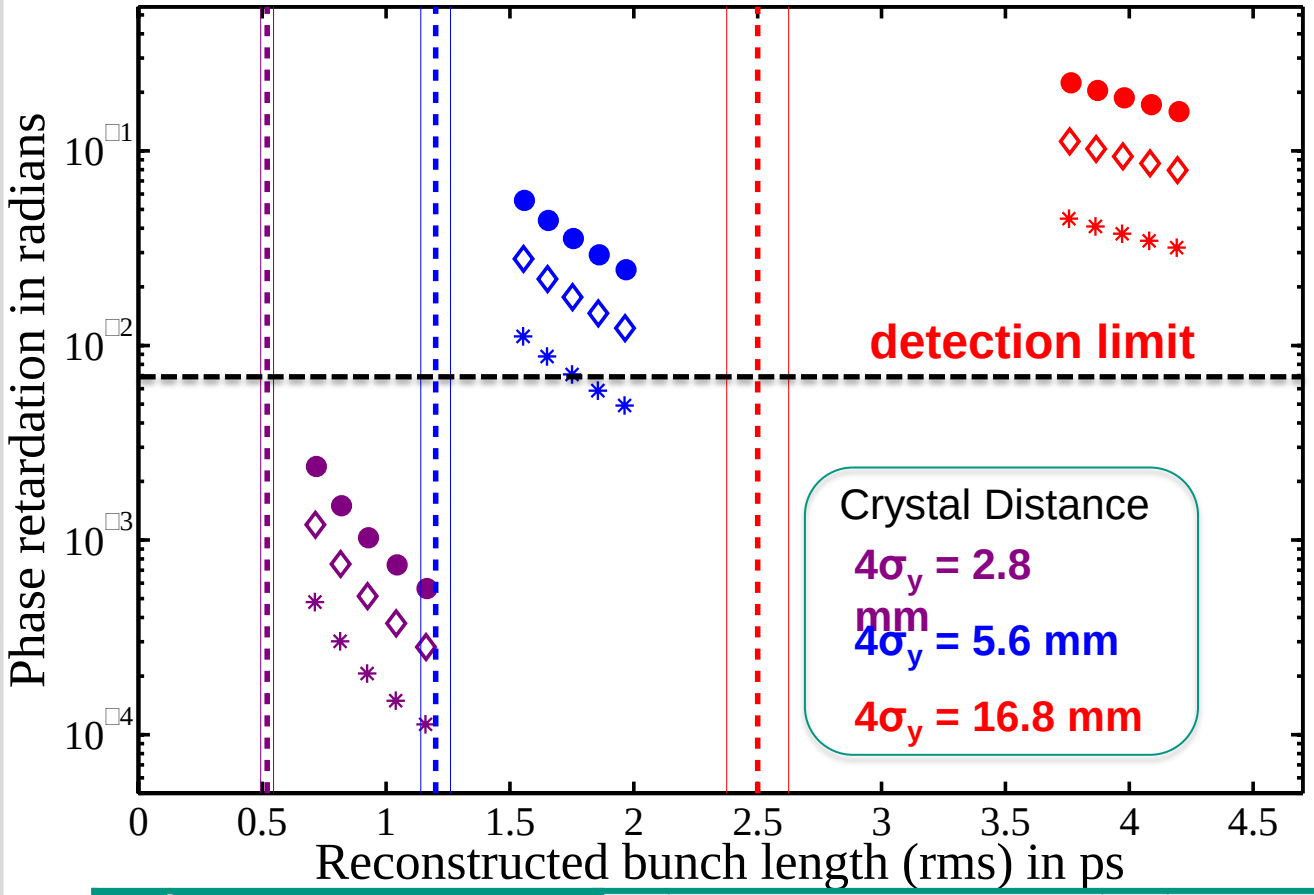
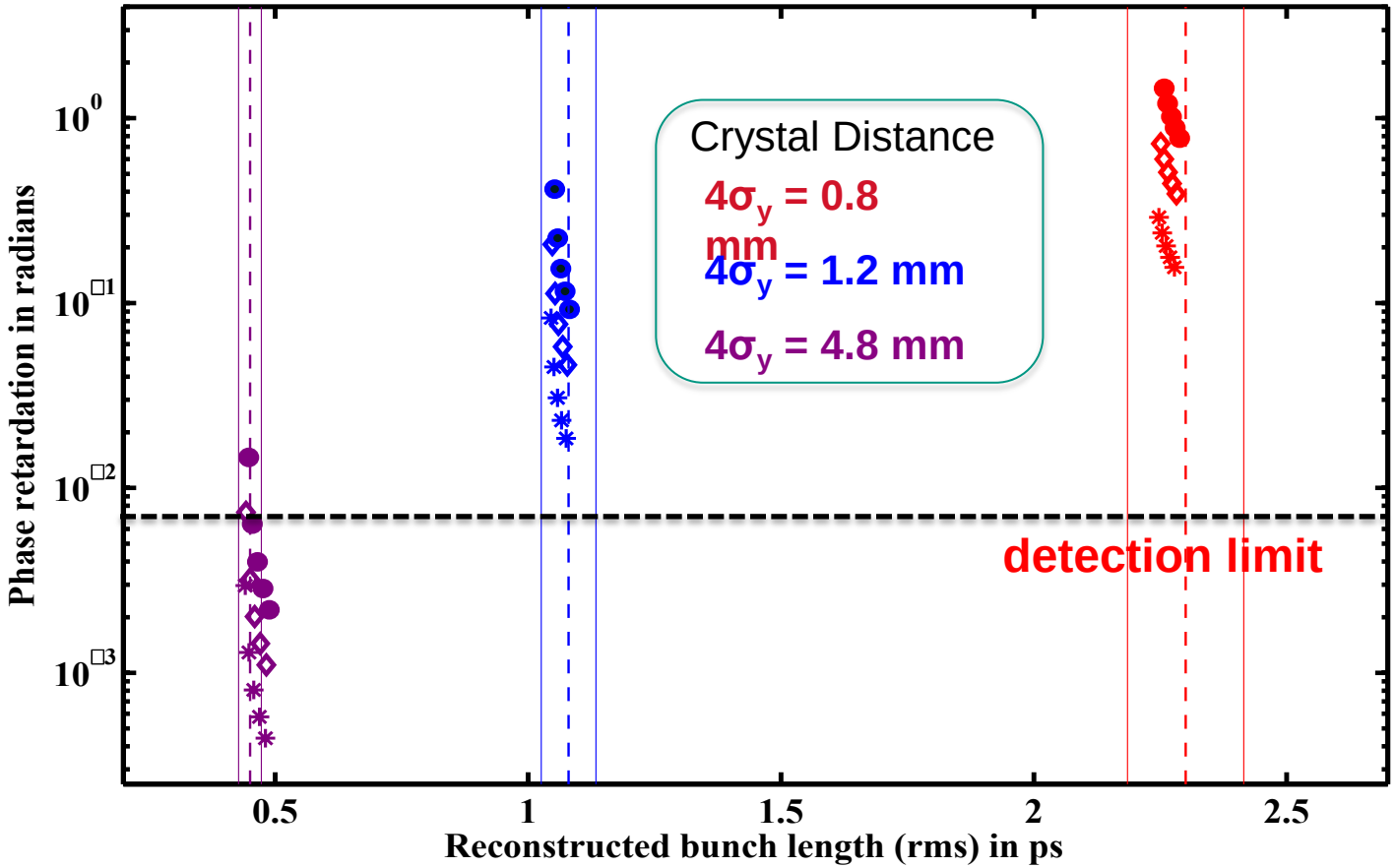


- Challenge – low γ
- Limits – Low charge density
- Conclusion:
  - Thick crystal
  - Bring it close

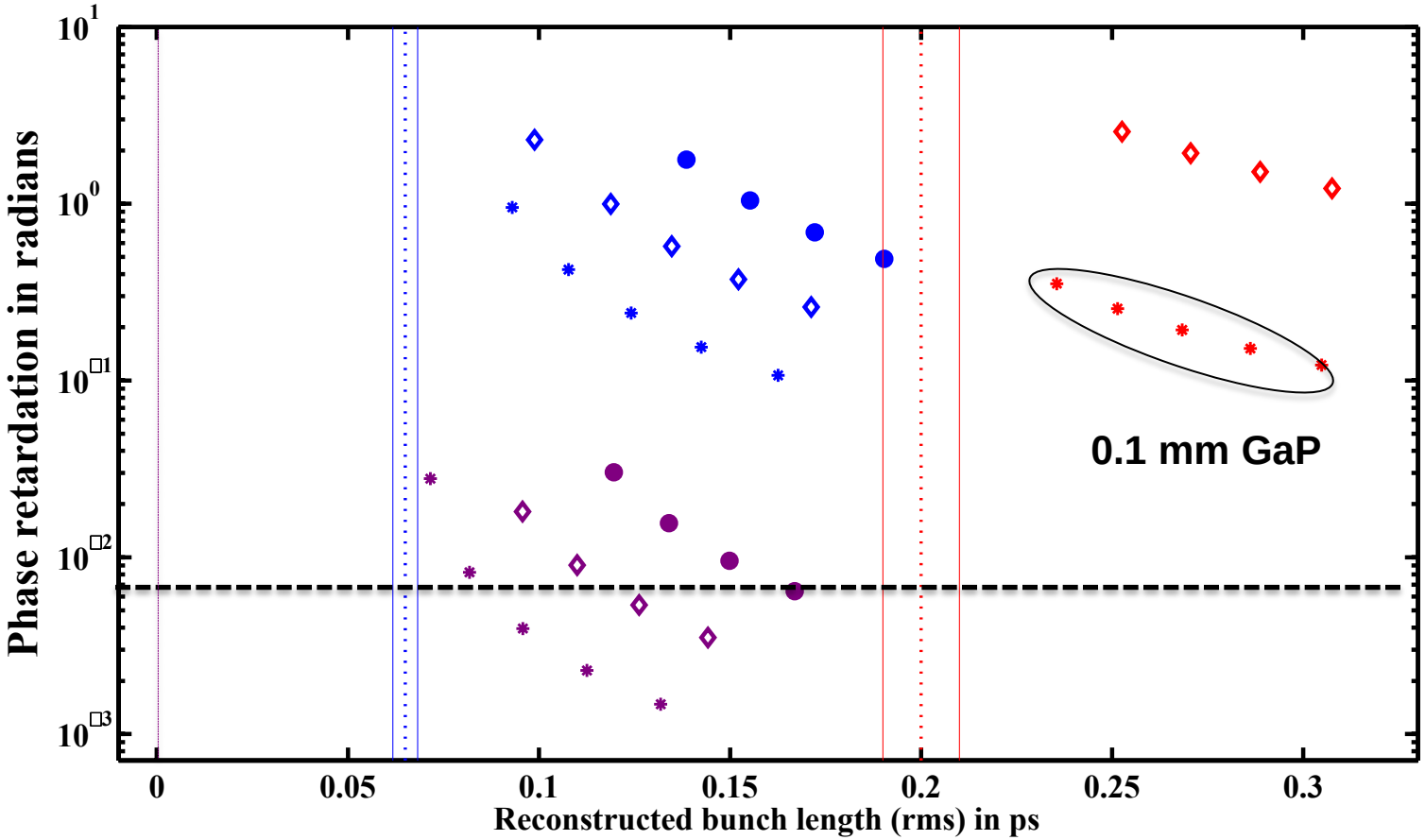
Gun	Linac	Chicane	
520 fs	450 fs	1 fs	1 pC
1200 fs	1080 fs	67 fs	100 pC
2500 fs	2300 fs	200 fs	3000 pC

EOSD signal – after linac (42 MeV)



Gun	Linac	Chicane	
520 fs	450 fs	1 fs	1 pC
1200 fs	1080 fs	67 fs	100 pC
2500 fs	2300 fs	200 fs	3000 pC

EOSD signal – after chicane (42 MeV)



Gun	520 fs	Linac	450 fs	Chicane	1 fs	1 pC
	1200 fs		1080 fs		67 fs	100 pC
	2500 fs		2300 fs		200 fs	3000 pC

Simulation Summary

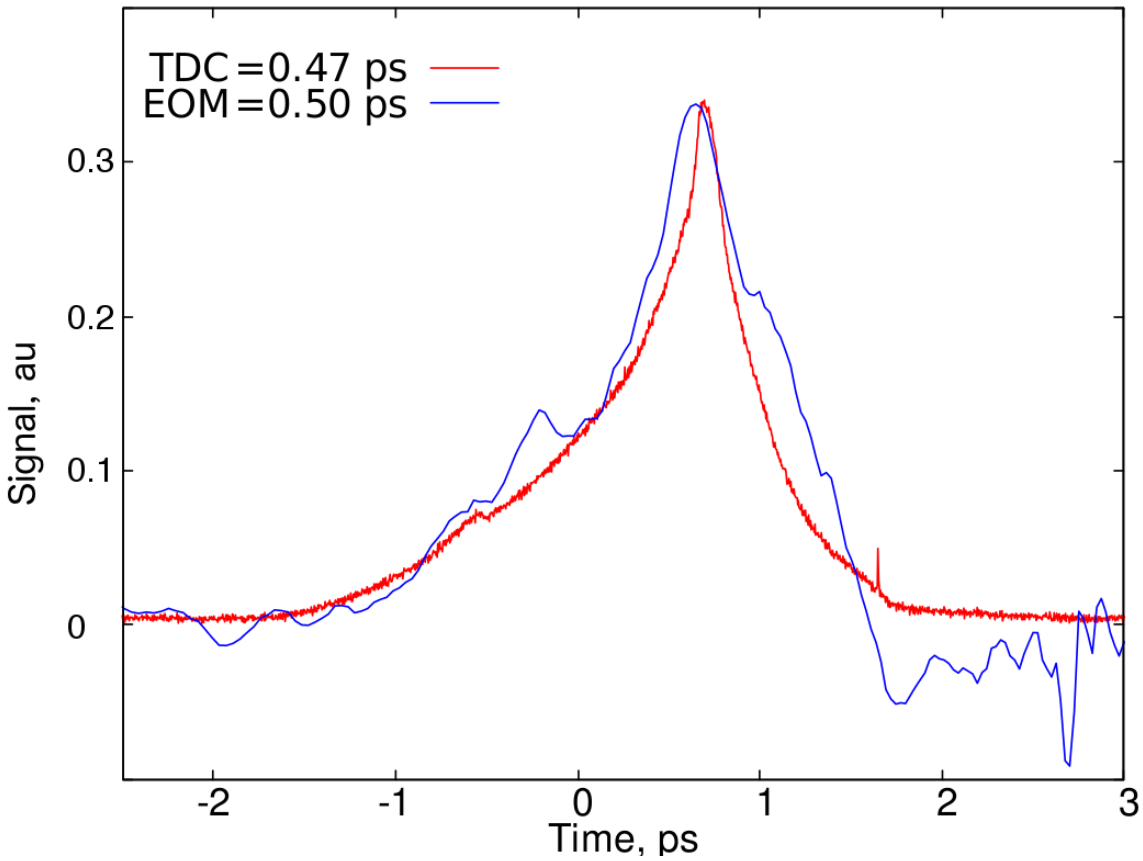
- **Position 1: After Gun**
  - **Challenge – low γ**
  - **Limits – Low charge density**
- **Position 2: After linac**
  - **Measurement conditions reliable**
- **Position 3: After chicane**
  - **Crystal thickness become more important**
  - **Laser pulse length plays stronger role**
  - **Too strong signal**

Conclusion:

- **Thick crystal**
- **Bring it close**
- **Even 1 pC measurable**
- **Thinner crystal**

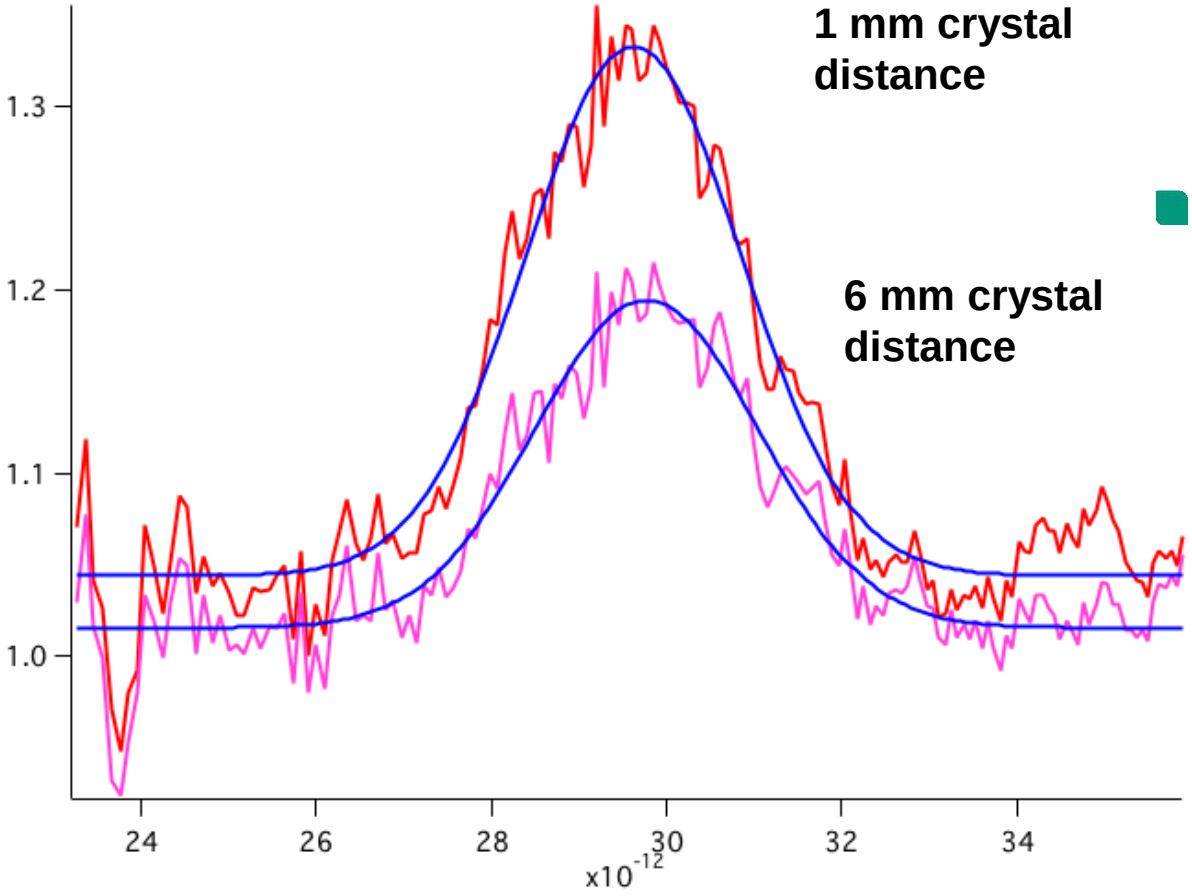
Measurements at Swiss FEL TIF

- EO with TDC
- 100 pC

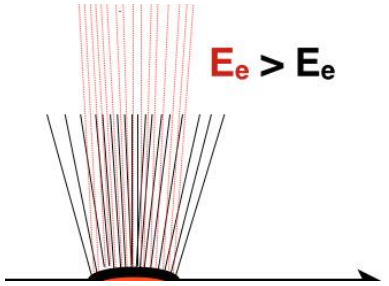


* Courtesy of Yevgeniy Ivanisenko, PSI

Measurements at low energies

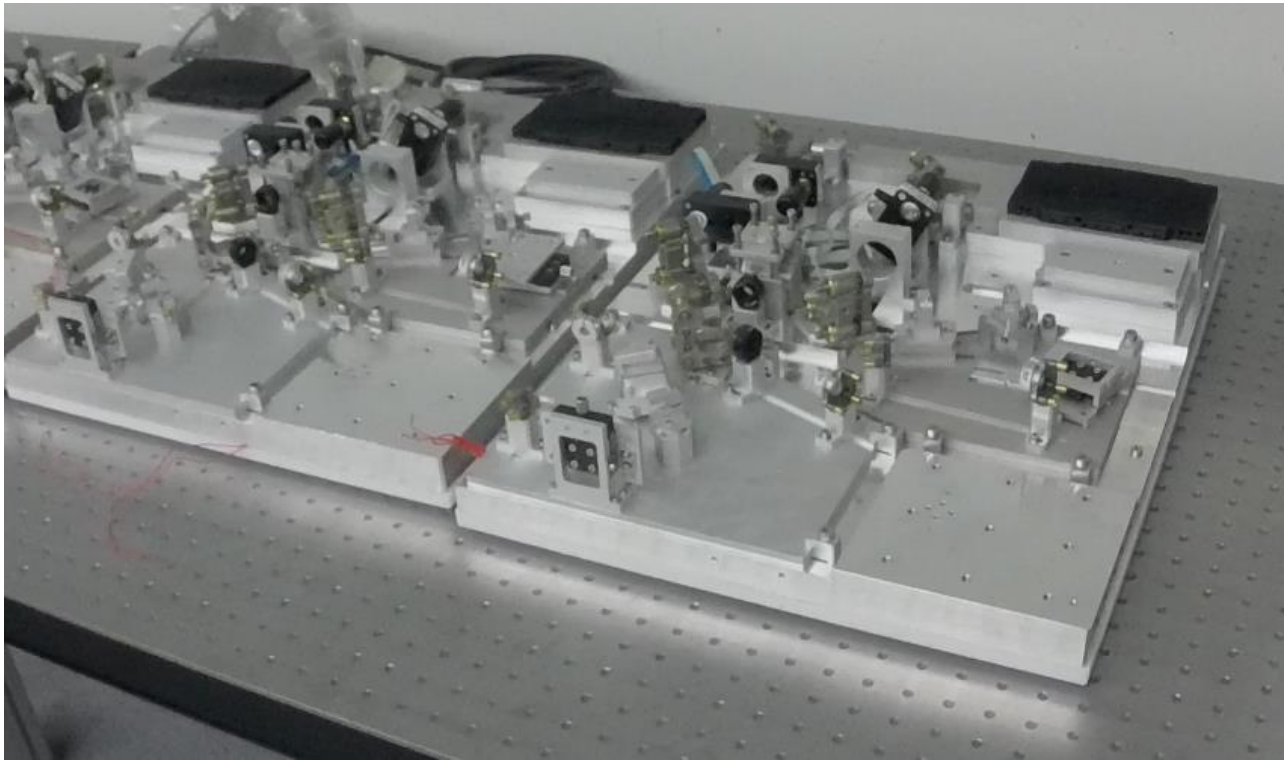


- Crystal position change from 1 mm to 6 mm will gain 80 fs RMS in bunch length measuremrnt



Recent development

- **Laser assembly at DESY**



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PSI: Rasmus Ischebeck, Yevgeniy Ivanisenko

KIT: ANAK THz Group, Nicole Hiller

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