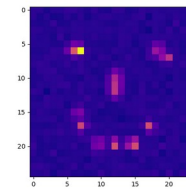
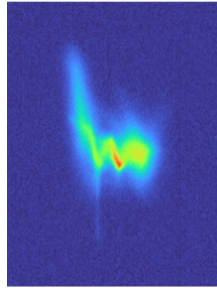
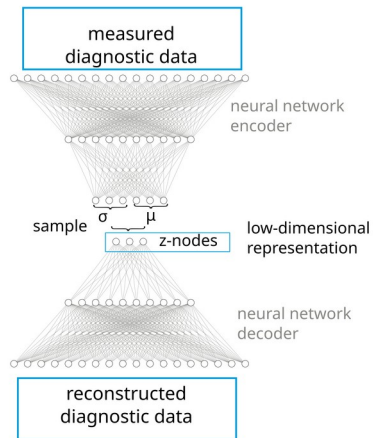


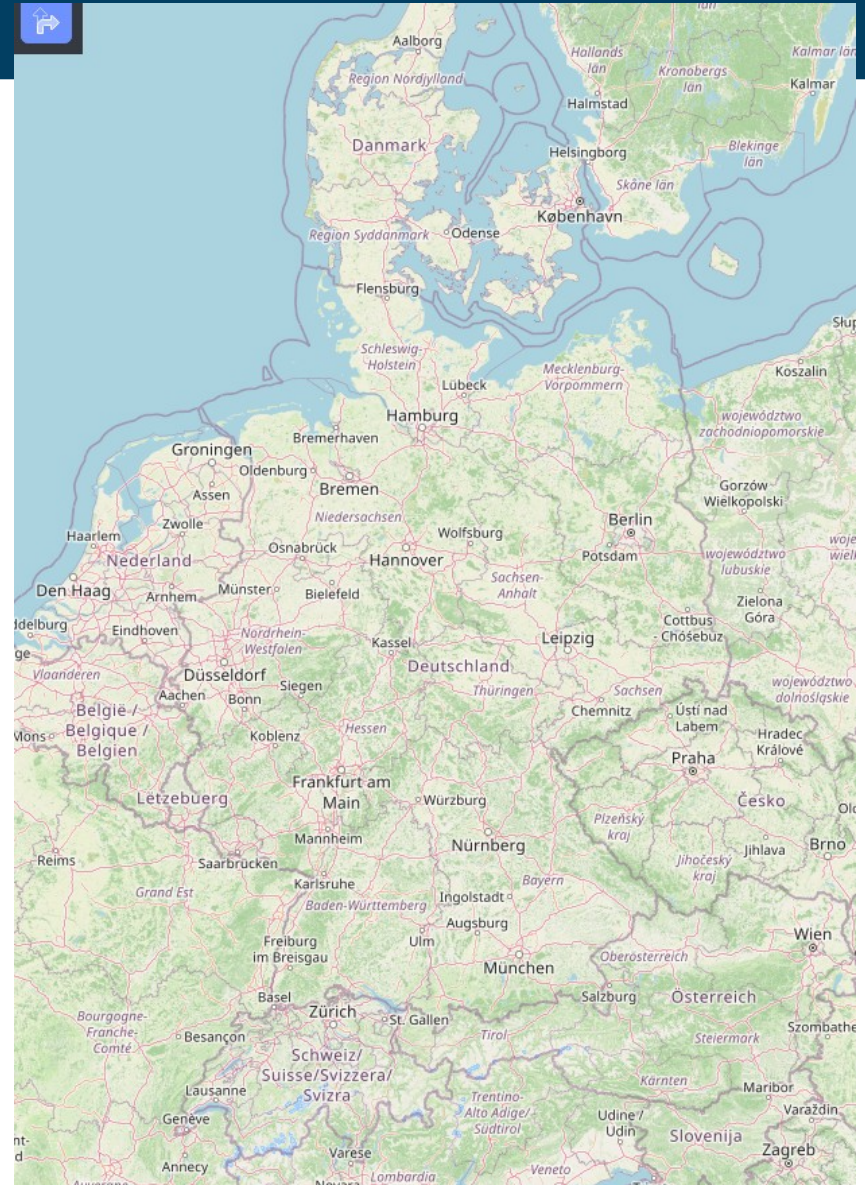
Gesa Goetzke

PEARLS introduction

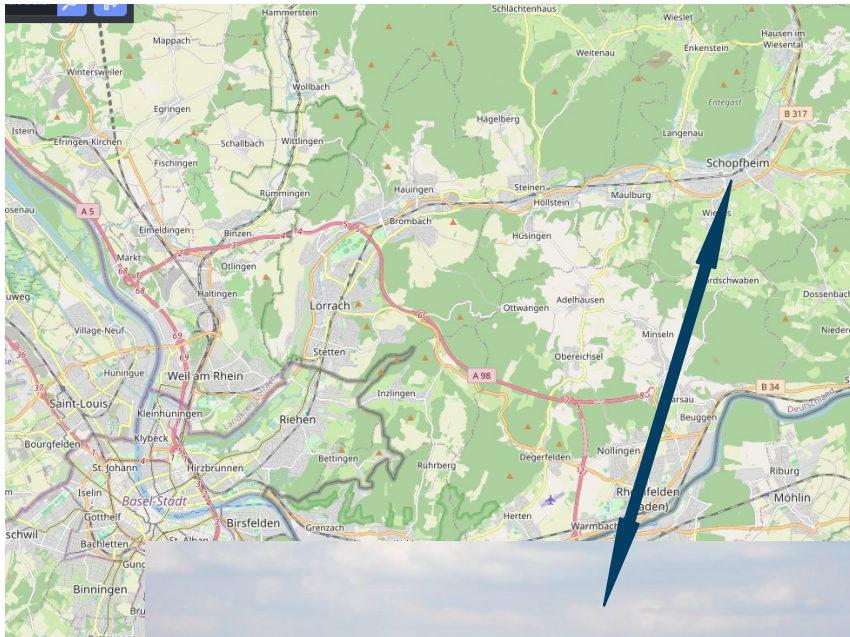


- Early days
- Physics studies at TU Berlin
 - Bachelor Thesis
 - Master Thesis
- Work at DESY
 - Disentangled autoencoders for photon diagnostics
 - U-net based approach for TDS evaluation
- Motivation

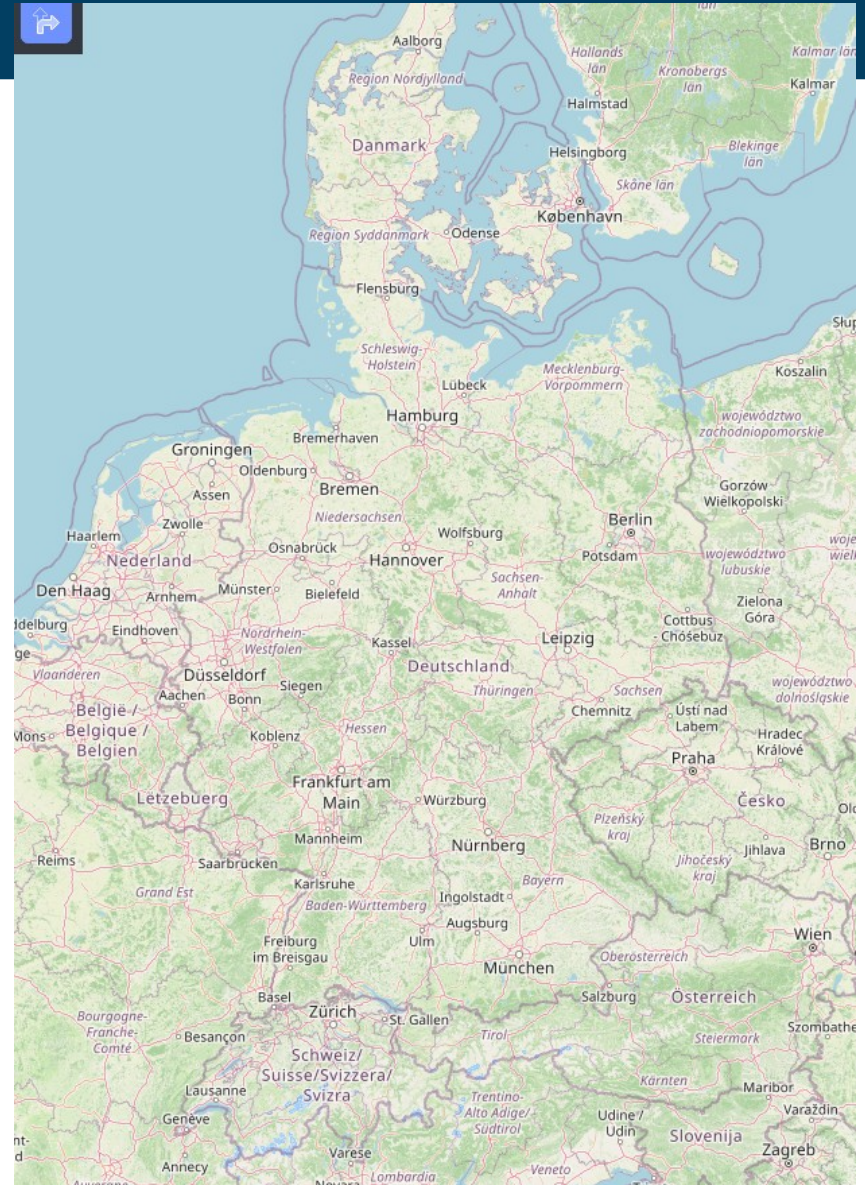
Early days



Early days

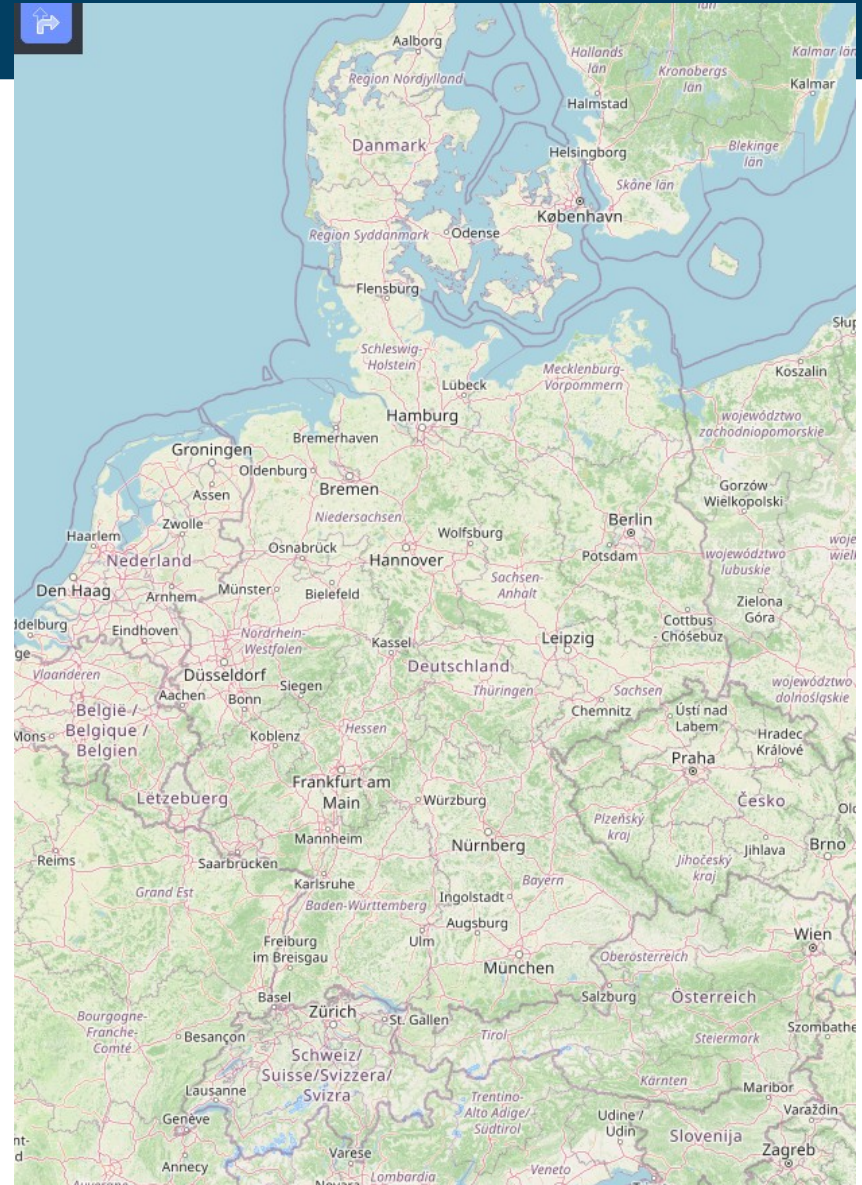


<https://www.alemannische-seiten.de/deutschland/schopfheim.php>



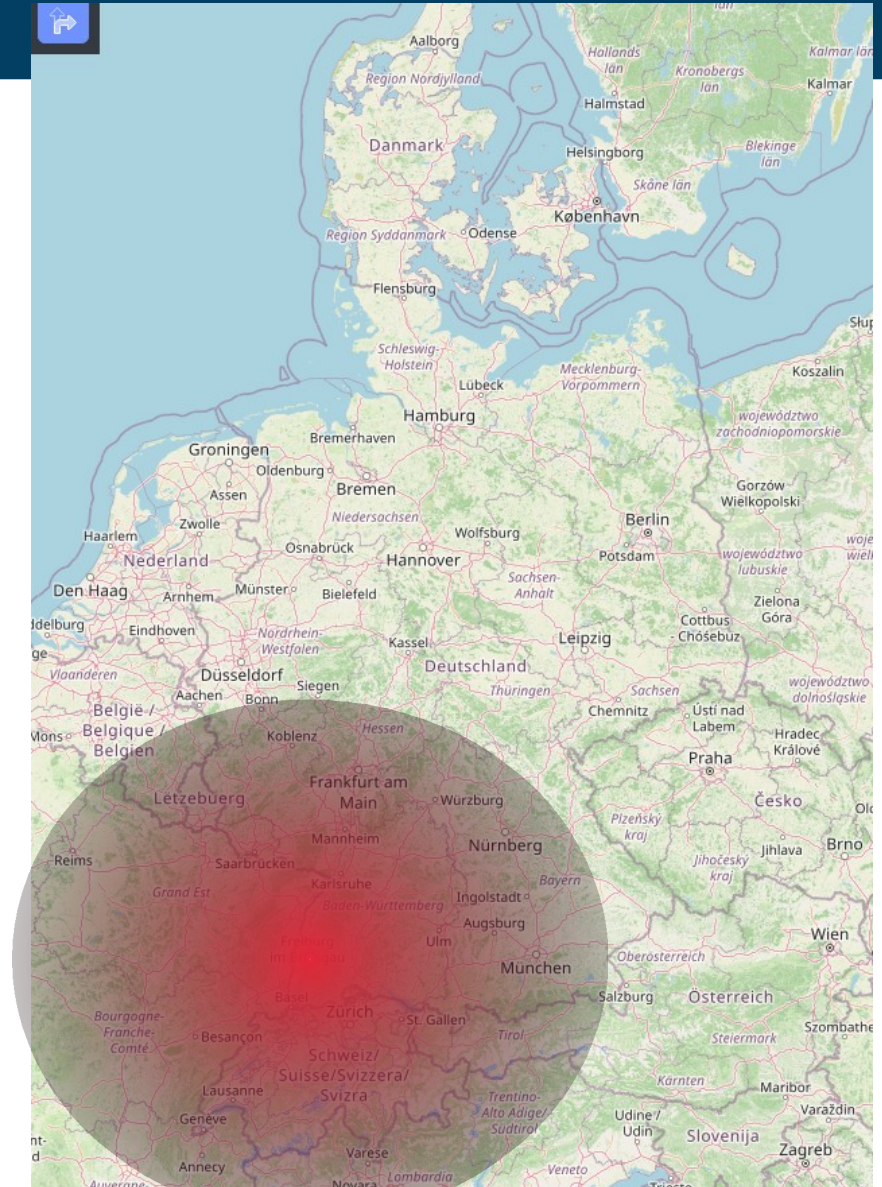
Early days

- Abitur at Theodor Heuss Gymnasium Schopfheim
- major subjects history and physics
- volunteer courses in computer science and astronomy
- What to study: mathematics?, computer science?, physics?

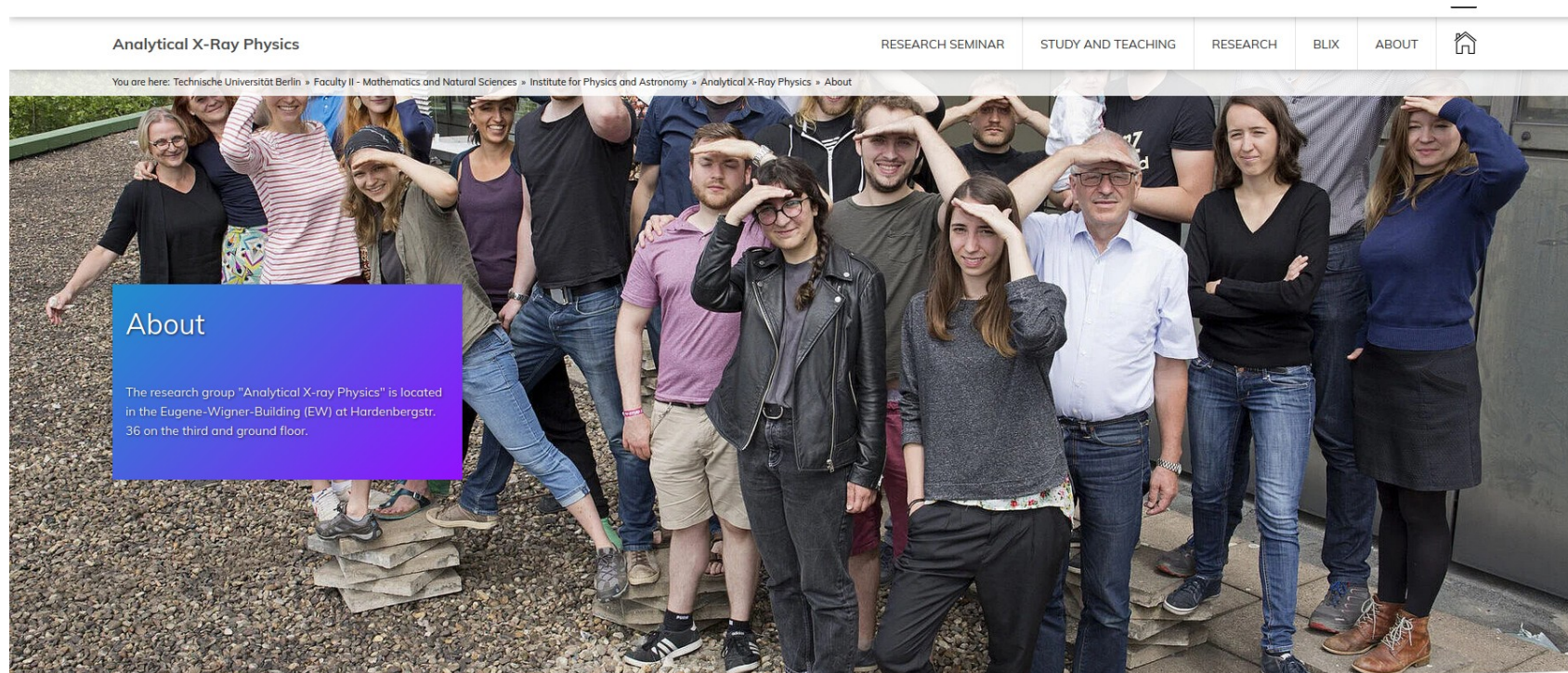


Early days

- Abitur at Theodor Heuss Gymnasium Schopfheim
- major subjects history and physics
- volunteer courses in computer science and astronomy
- What to study: mathematics?, computer science?, physics? => physics!
 - Not within a 'weekend-radius'
 - Significantly larger than Schopfheim



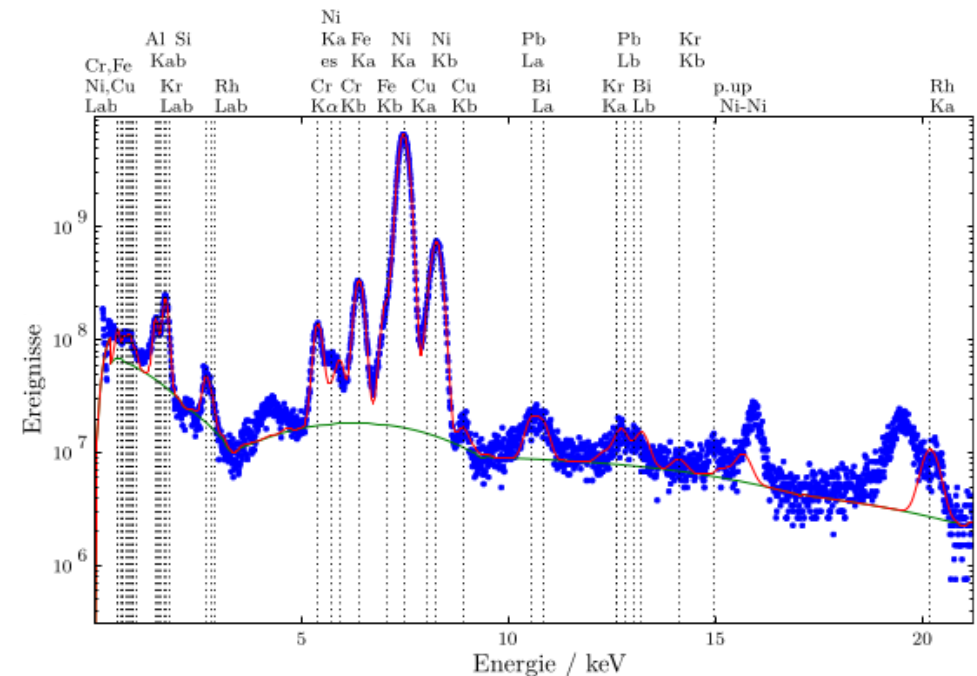
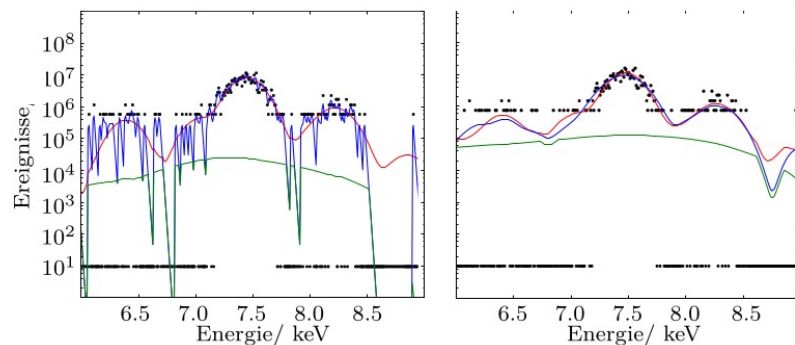
- Join working group: Analytical X-ray physics of Birgit Kanngießer
- X-ray physics I and II, joint lecture by Prof. Dr. Birgit Kanngießer, Prof. Dr. Stefan Eisebitt, Prof. Dr. Thomas Möller



<https://www.tu.berlin/en/axp/about> , Stand: 20.09.2026!

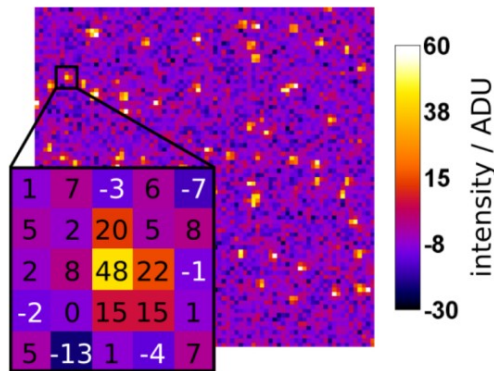
• Bachelor Thesis

- Spektrenentfaltung für winkelaufgelöste Röntgenfluoreszenzanalyse (Spectral deconvolution for angle-resolved X-ray fluorescence analysis)
- Find individual fluorescence lines in noise, overlapping peaks, insufficient statistics, detector artifacts...

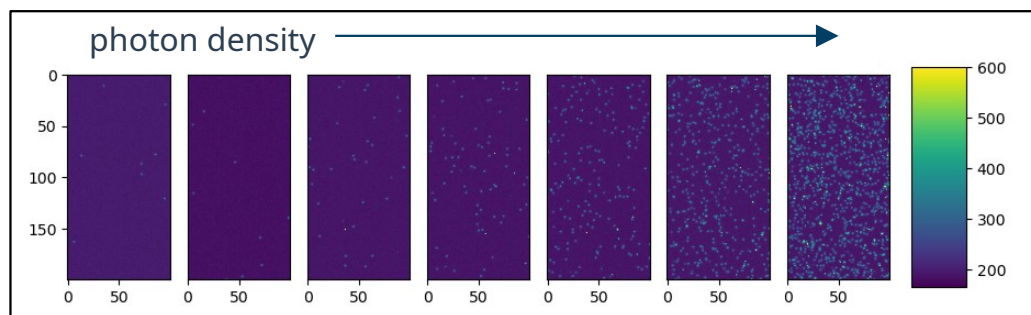
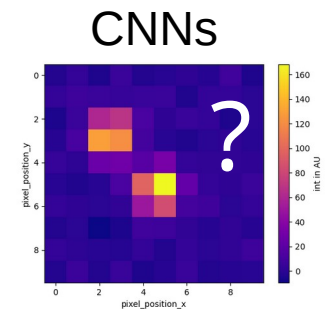
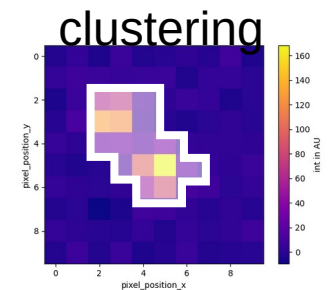
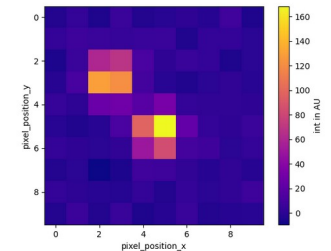
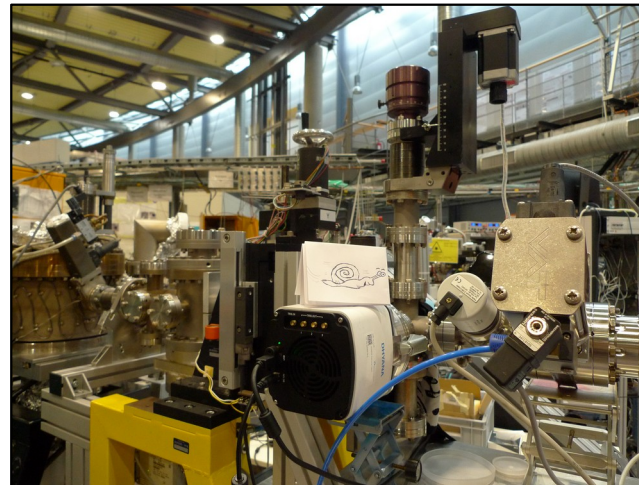


• Master Thesis

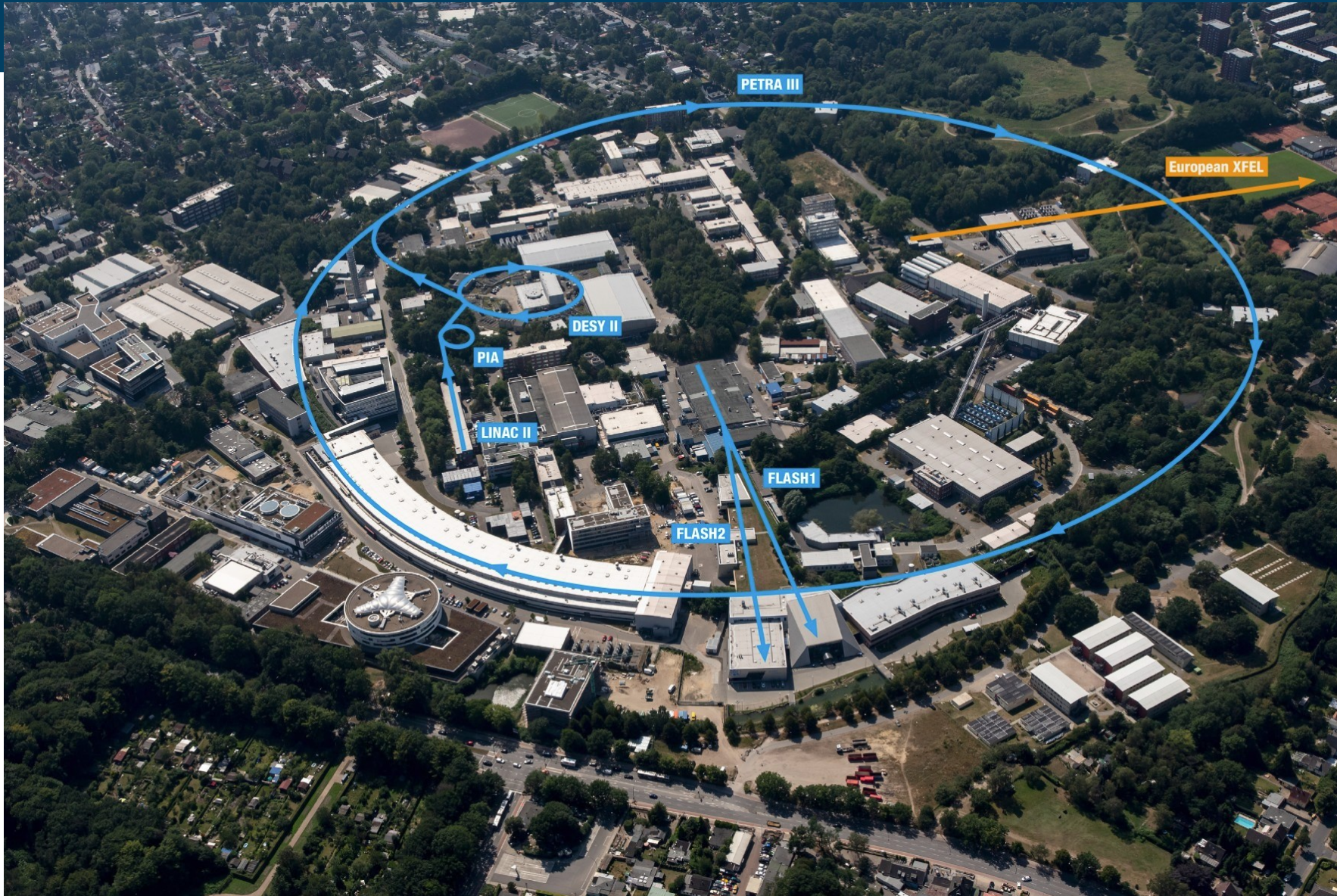
Fast evaluation of single photon events with convolutional neural networks for angle-resolved X-ray fluorescence measurements



J. Baumann Dissertation, TU Berlin, 2017

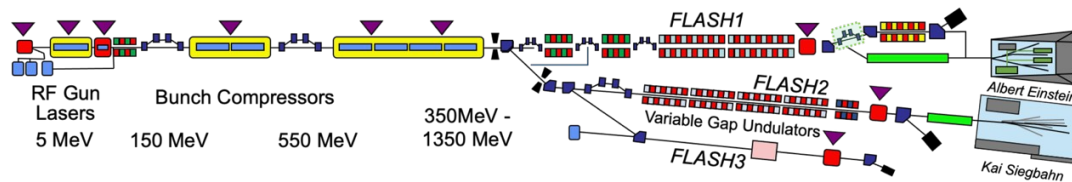


PhD at DESY



<https://photon-science.desy.de/facilities> Stand: 2026-09-21

The Free-Electron Laser FLASH



ultrashort, bright photon pulses that can be used for research on:

- energy transition

Advancements in Liquid Jet Technology and X-ray Spectroscopy for Understanding Energy Conversion Materials during Operation, Acc. Chem. Res. (2023) , DOI: 10.1021/acs.accounts.2c00525

- better electronics

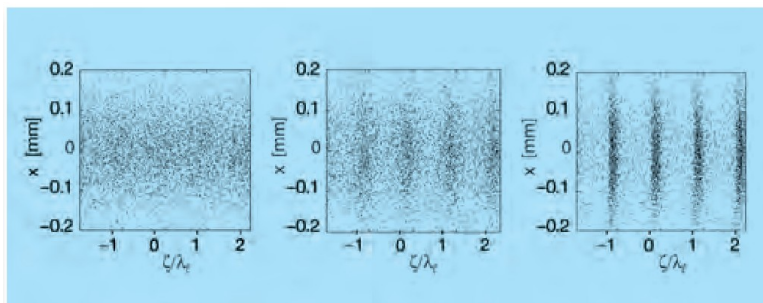
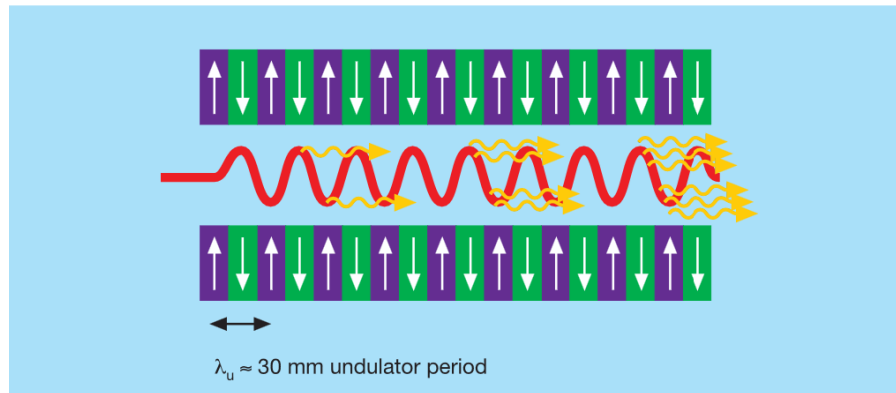
Advancing Energy Materials by In Situ Atomic Scale Methods", Advanced Energy Materials, 2025, DOI: 10.1002/aenm.202404280

- safer drugs

Direct observation of ultrafast symmetry reduction during internal conversion of 2-thiouracil using Coulomb explosion imaging, Nature Communications (2025), DOI: 10.1038/s41467-025-57083-3

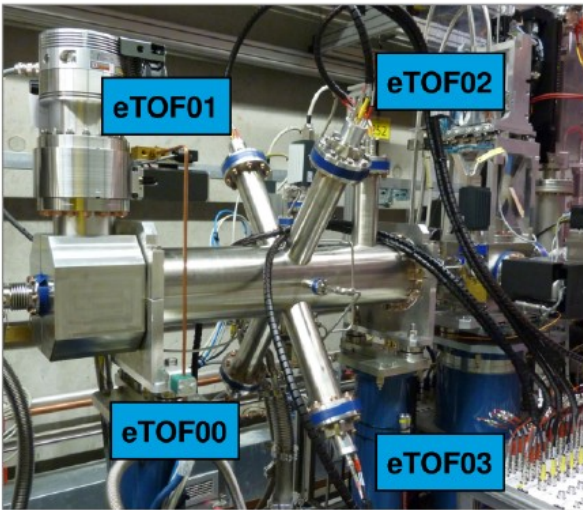
- advanced materials

Melting, Bubblelike Expansion, and Explosion of Superheated Plasmonic Nanoparticles, Phys. Rev. Lett. 134 (2025), DOI: 10.1103/PhysRevLett.134.136101



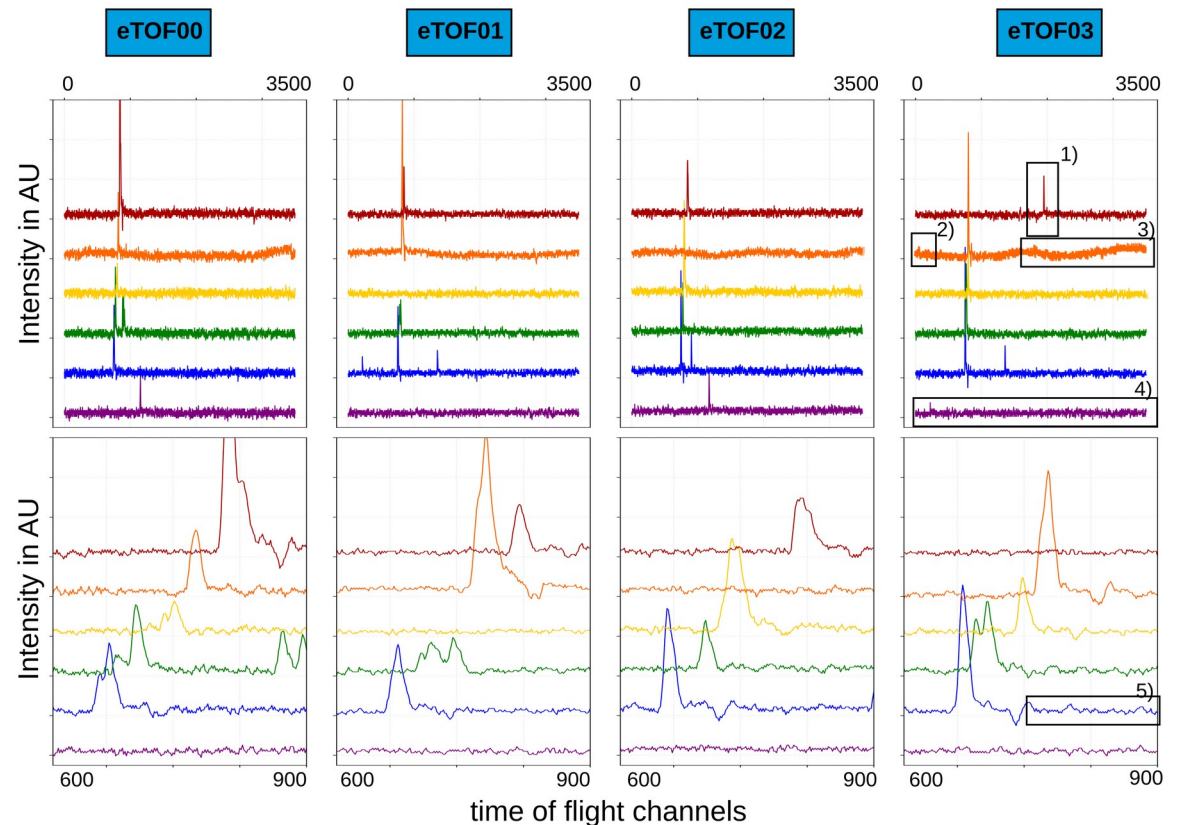
Desy: ML for OPIS

- Joined FLASH Photon Diagnostic in 2021, PhD project under supervision of Gregor Hartmann (HZB)
- First project: ML for **online PhotoIonization Spectrometer (OPIS)**



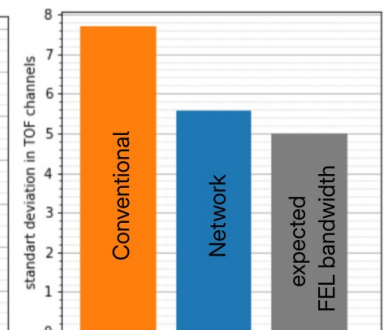
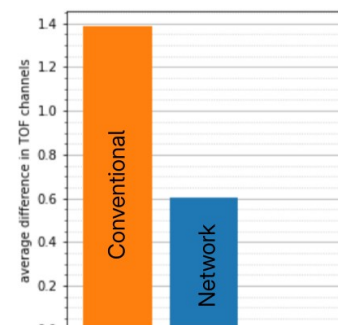
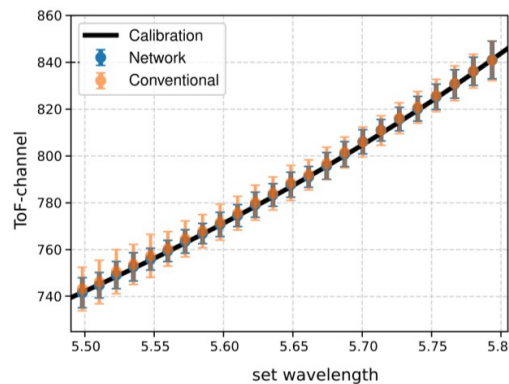
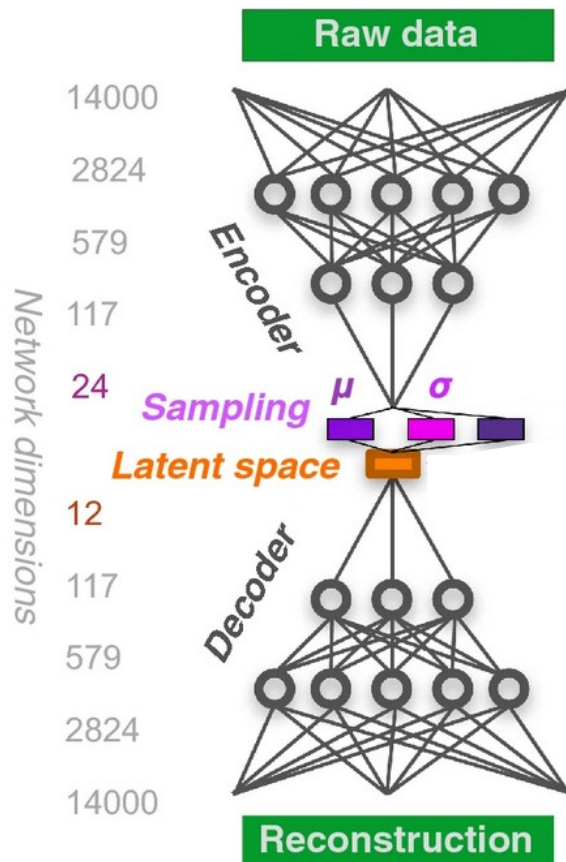
Non-invasive online
wavelength
measurements at
FLASH2 and present
benchmark,
Journal of Synchrotron
Radiation 2018

- 1) random hits
- 2) prompt signal
- 3) baseline disturbance
- 4) trace without signal
- 5) periodic 'zigzag' behavior



Desy: ML for OPIS

- Joined FLASH Photon Diagnostic in 2021
- First project: ML for online **P**hoto**I**onization **S**pectrometer (OPIS)



Article | [Open access](#) | Published: 01 December 2022

Unsupervised real-world knowledge extraction via disentangled variational autoencoders for photon diagnostics

[Gregor Hartmann](#) , [Gesa Goetzke](#), [Stefan Düsterer](#), [Peter Feuer-Forson](#), [Fabiano Lever](#), [David Meier](#), [Felix Möller](#), [Luis Vera Ramirez](#), [Markus Guehr](#), [Kai Tiedtke](#), [Jens Viehhaus](#) & [Markus Braune](#)

[Scientific Reports](#) **12**, Article number: 20783 (2022) | [Cite this article](#)

Pulse length diagnostic: SASE pulses

Needed for temporal diagnostics:

SINGLE SHOT capability

High dynamic range (few fs to ~ 300 fs)

Wavelength independent (VUV to X-rays)

Parasitic / Transparent

*Techniques study: S.Düsterer et al, PRSTAB **17**, 120702 (2014)*

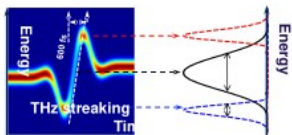
THz Streaking

Measuring the pulse duration and arrival time by means of a single cycle THz streaking field:

- Online monitoring
- Single bunch resolved measurement
- (Almost) non-invasive
- High rep. rate possible

Parameter range

- 20 - 200 fs
- 4 - 40 nm
- 1 - 500 μ J



Frühling et al., Nature Photon 3, 523–528 (2009)
Grguraš et al., Nature Photon 6, 852–857 (2012)

Attosecond- Diagnostics for FLASH 2020+

By means of angular streaking with multi-ToF array

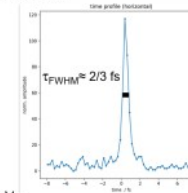
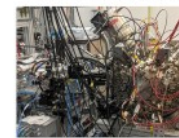


Hartmann et al., Nature Photon 12, 215–220 (2018)

Mapping FEL pulse time structure on the angular coordinate of photoemission („hand of a clock“)

Methodological Kick-Off at European XFEL – SQS (W. Helml/ M. Ilchen)

“Ball”-chamber of M. Braune
(FLASH - DESY) at SQS in June 2022



First isolated sub-fs pulse at 1 keV
photon energy directly measured in
time.

SpeAR Project



Founded by ErUM Pro TRANSALP & SpeAR (M. Ilchen,
W. Helml et al) & FLARE (C. Mai, Ch. Gerth et al)

Pulse length diagnostic: SASE pulses

Needed for temporal diagnostics:

SINGLE SHOT capability

High dynamic range (few fs to ~ 300 fs)

Wavelength independent (VUV to X-rays)

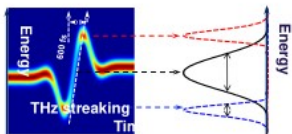
Parasitic / Transparent

Techniques study: S.Düsterer et al, PRSTAB 17, 120702 (2014)

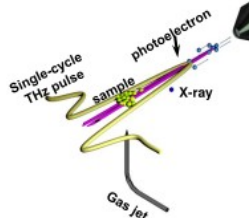
THz Streaking

Measuring the pulse duration and arrival time by means of a single cycle THz streaking field:

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- Single bunch resolved measurement
- (Almost) non-invasive
- High rep. rate possible



Frühling et al., Nature Photon 3, 523–528 (2009)
Grguraš et al., Nature Photon 6, 852–857 (2012)

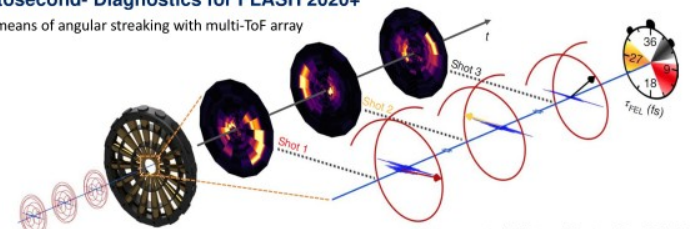


- Pa
- 20
- 4 -
- 1 -

More an experiment
themselves than a 'standard
diagnostic'

Attosecond- Diagnostics for FLASH 2020+

By means of angular streaking with multi-ToF array

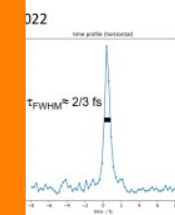


Hartmann et al., Nature Photon 12, 215–220 (2018)

re on the angular coordinate of photoemission („hand of a clock“)

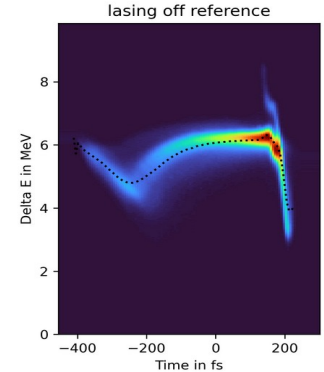
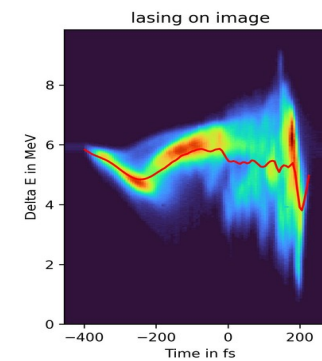
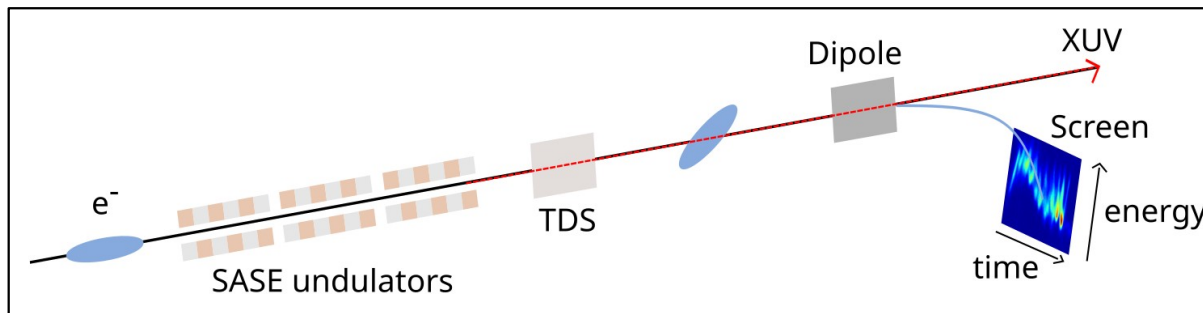
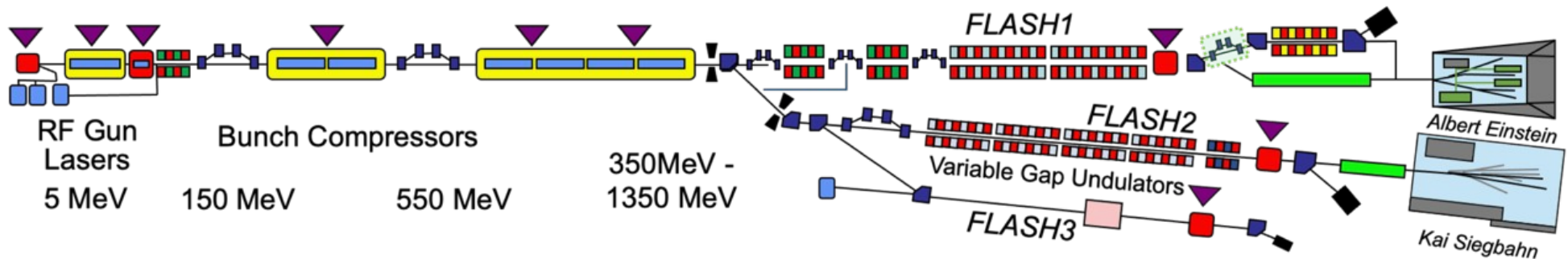
European
achen)

SpeAR Project

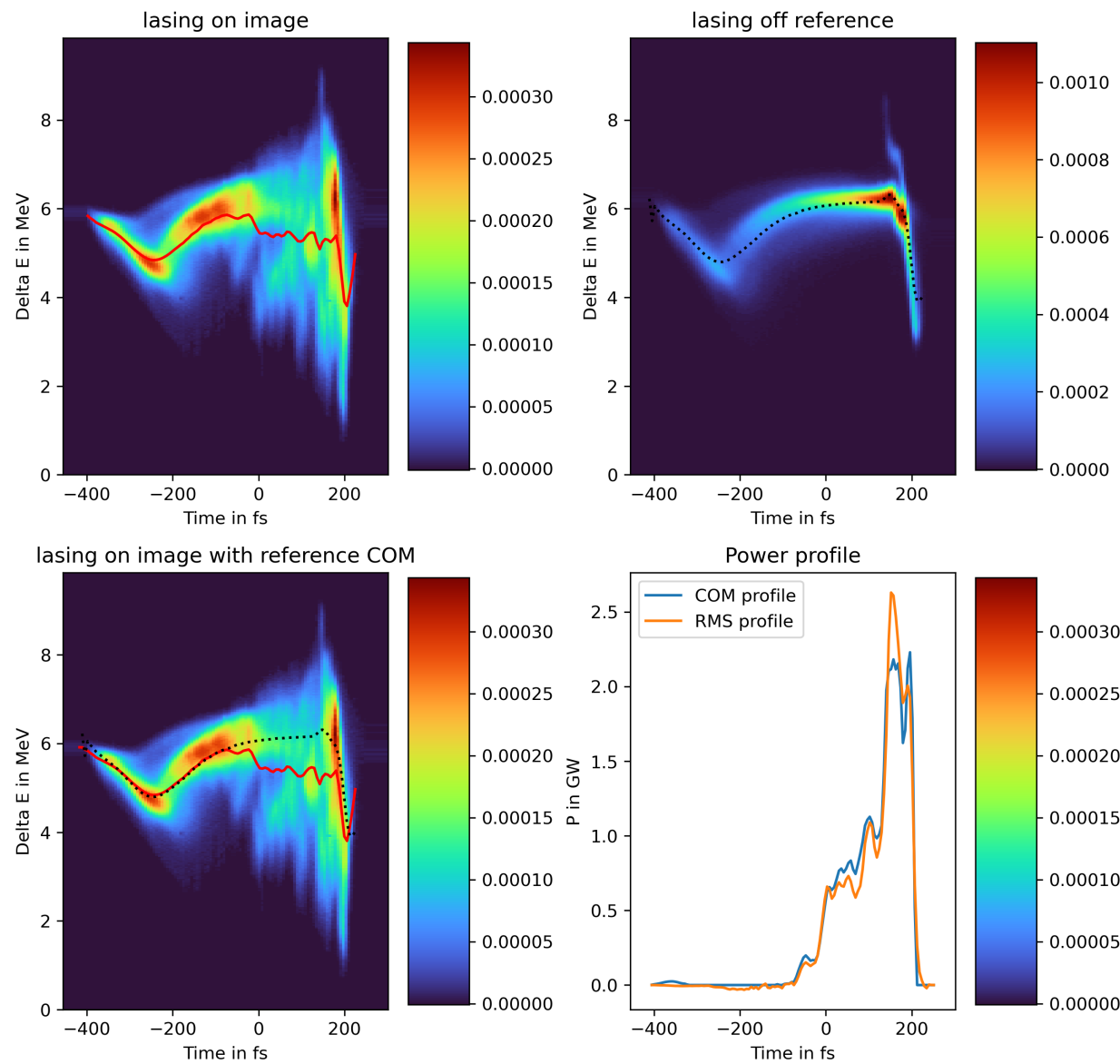


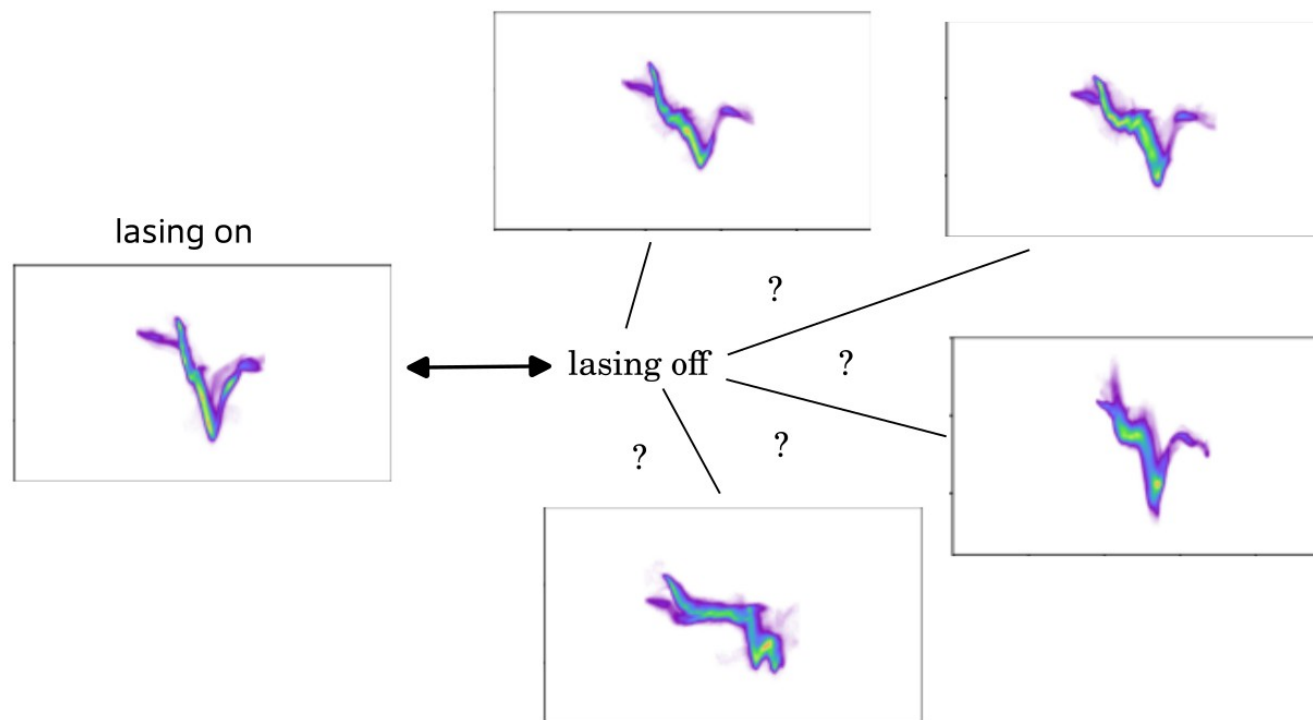
Founded by ErUM Pro TRANSALP & SpeAR (M. Ilchen, W. Helm et al) & FLARE (C. Mai, Ch. Gerth et al)

ML for PolariX TDS

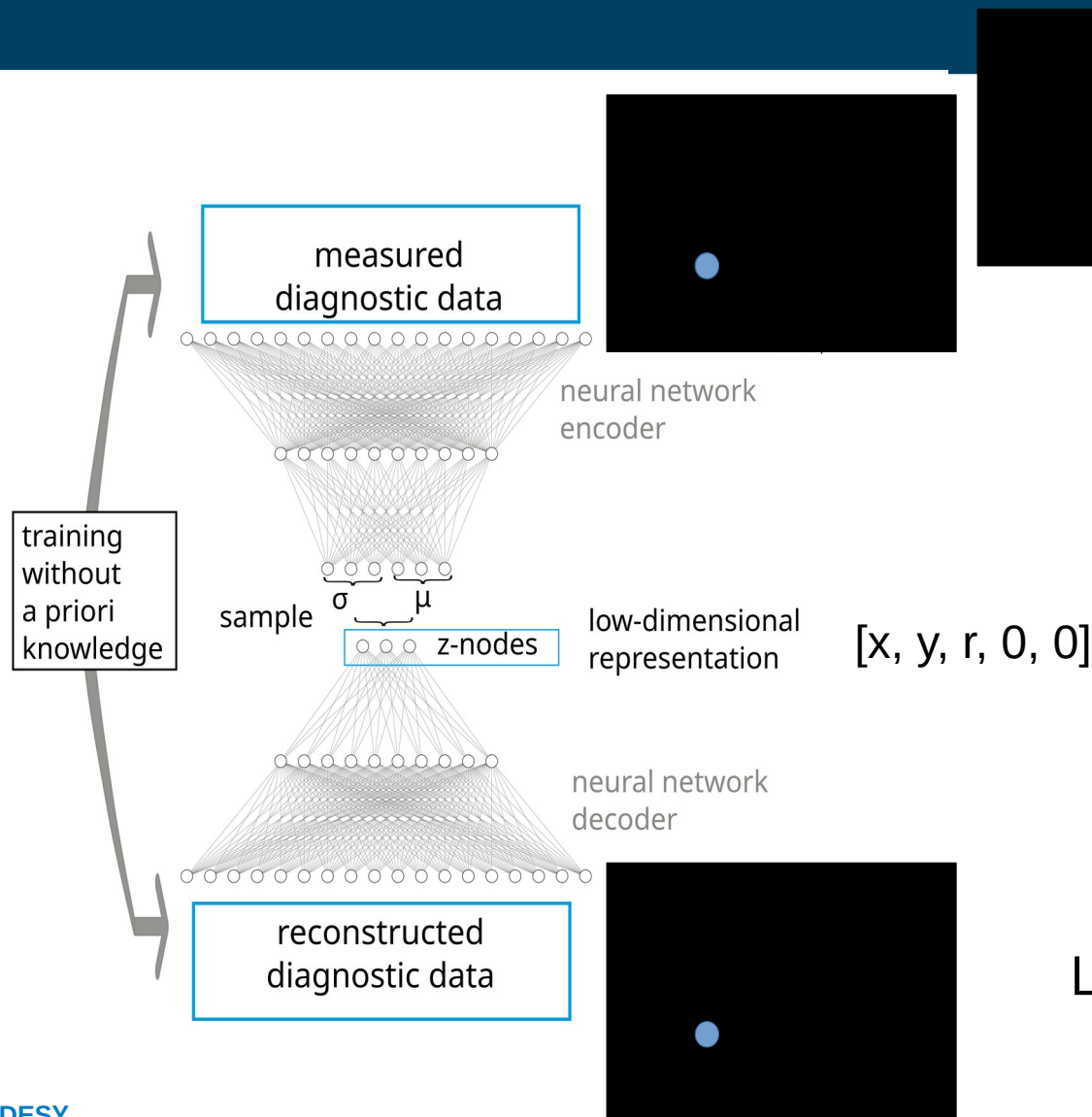


'FLASH2020+ Conceptual Design Report' (CDR) (Jan. 2020, Reference DOI: 10.3204/PUBDB-2020-00465).





disentangled-variational autoencoder



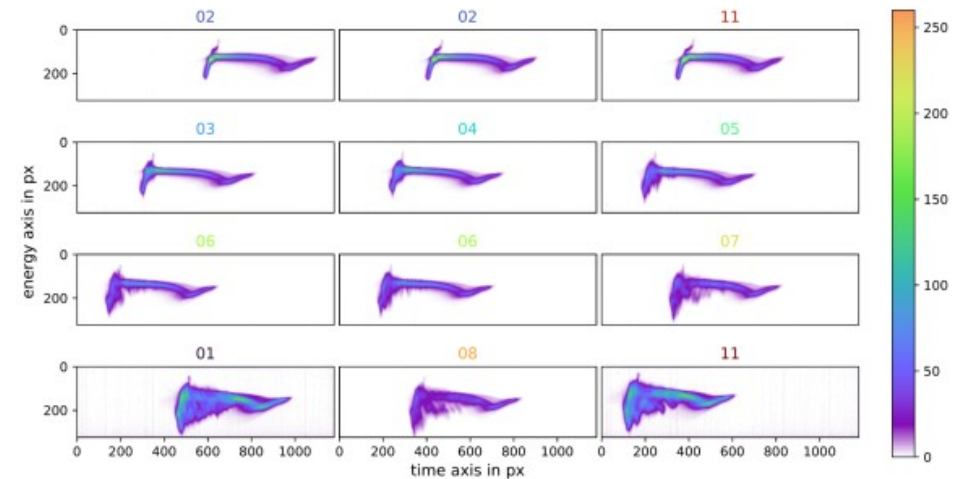
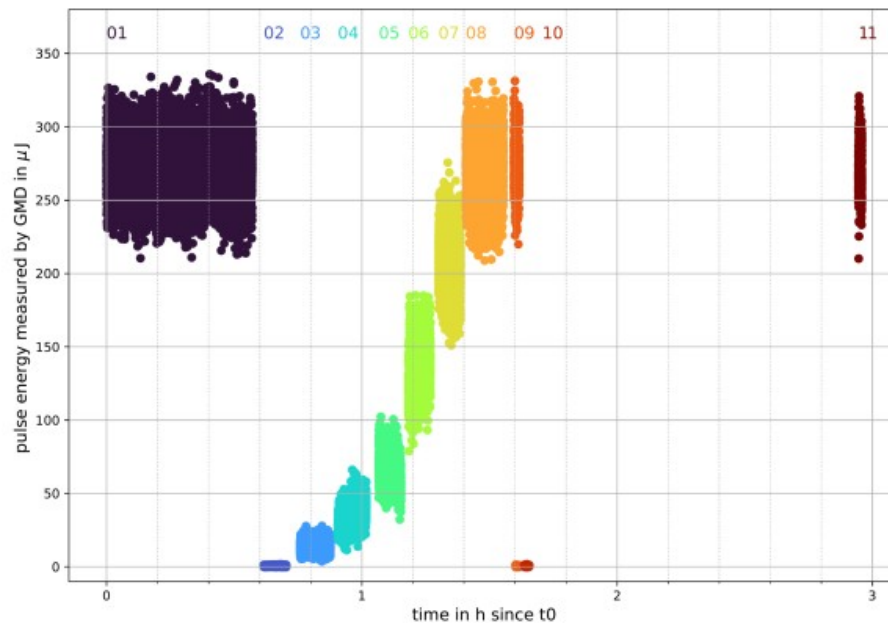
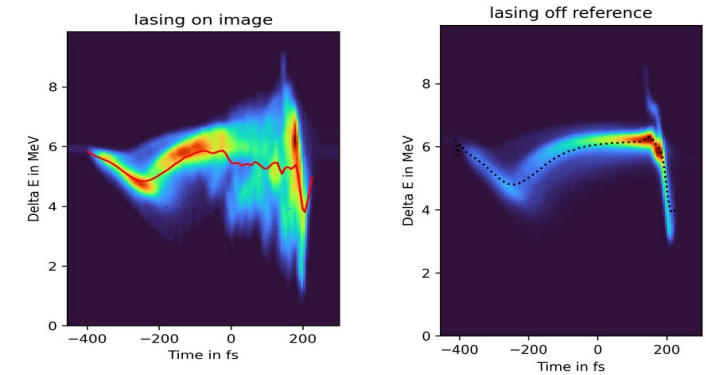
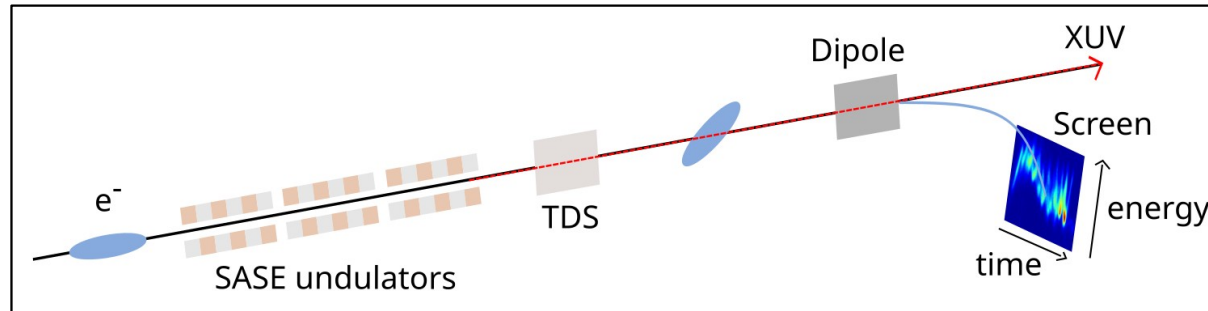
β -VAE: LEARNING BASIC VISUAL CONCEPTS WITH A CONSTRAINED VARIATIONAL FRAMEWORK

Irina Higgins, Loic Matthey, Arka Pal, Christopher Burgess, Xavier Glorot, Matthew Botvinick, Shakir Mohamed, Alexander Lerchner
Google DeepMind
{irinah, lmatthey, arkap, cpburgess, glorotx, botvinick, shakir, lerchner}@google.com

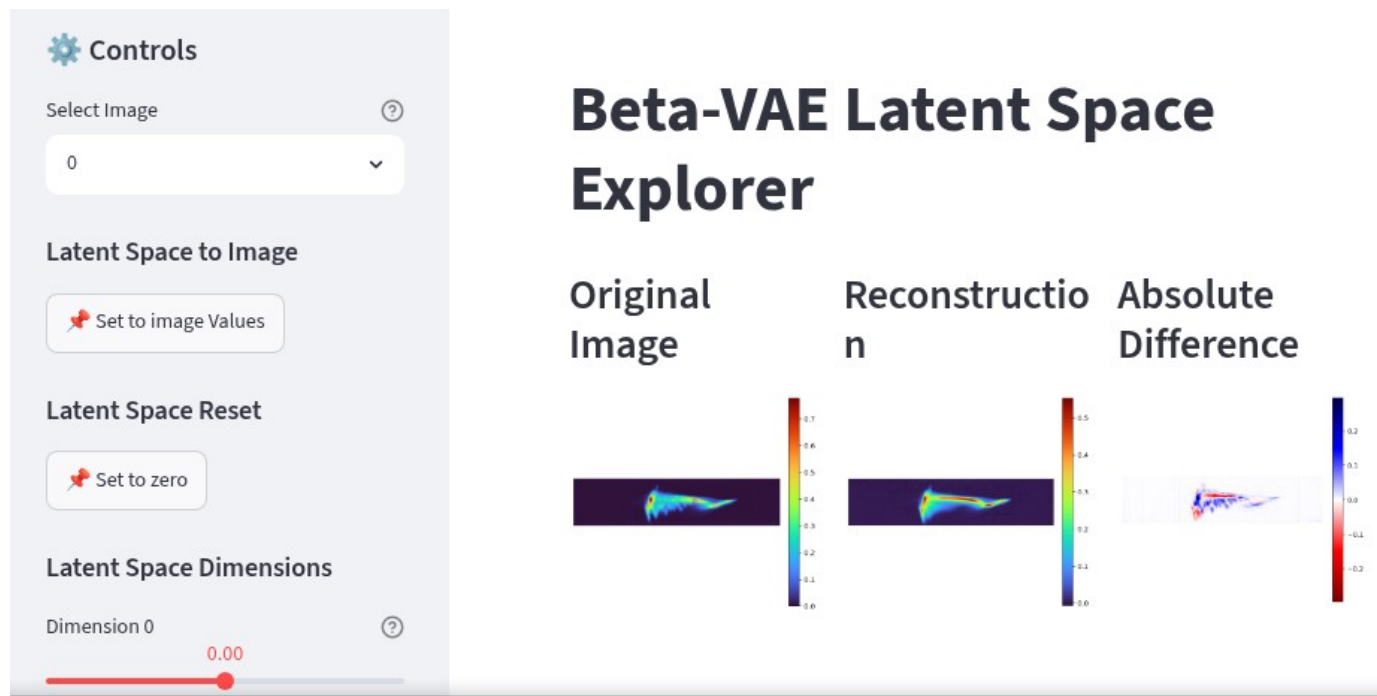


$$L = L_{\text{reconstruction}} + \beta * L_{\text{distribution}}$$

ML for PolariX TDS



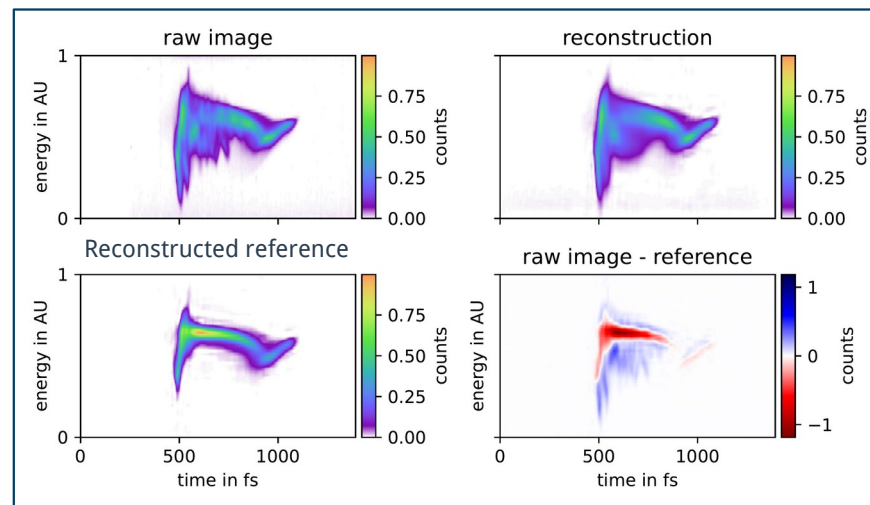
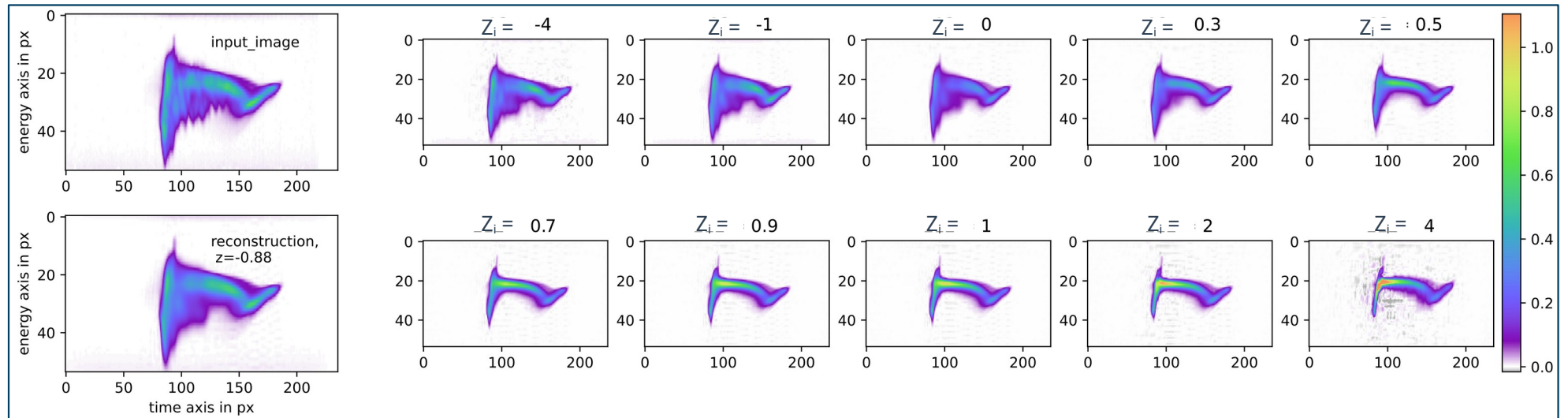
Desy: PolariX TDS



<https://goetzkeg-vaeexplorer-playls-bg188j.streamlit.app/>



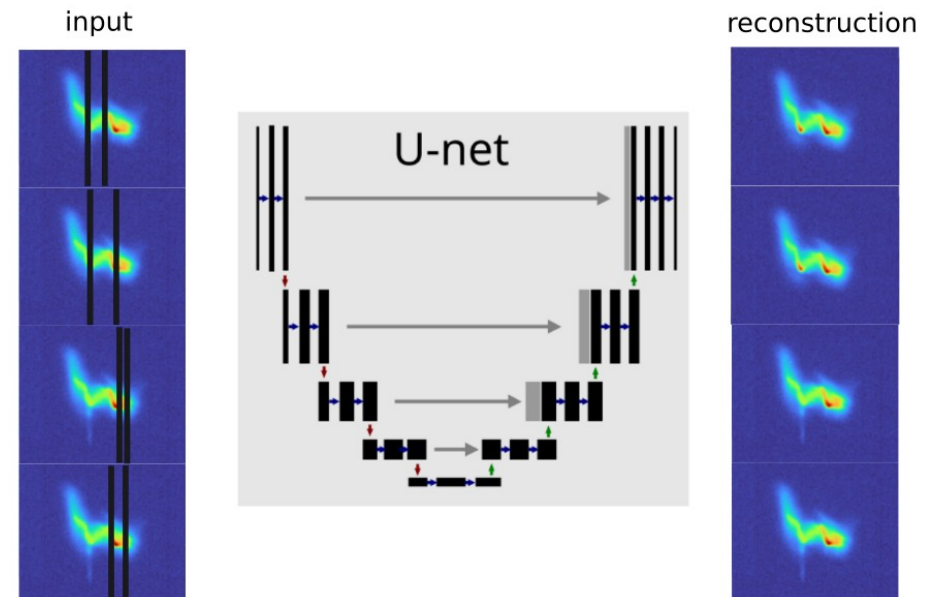
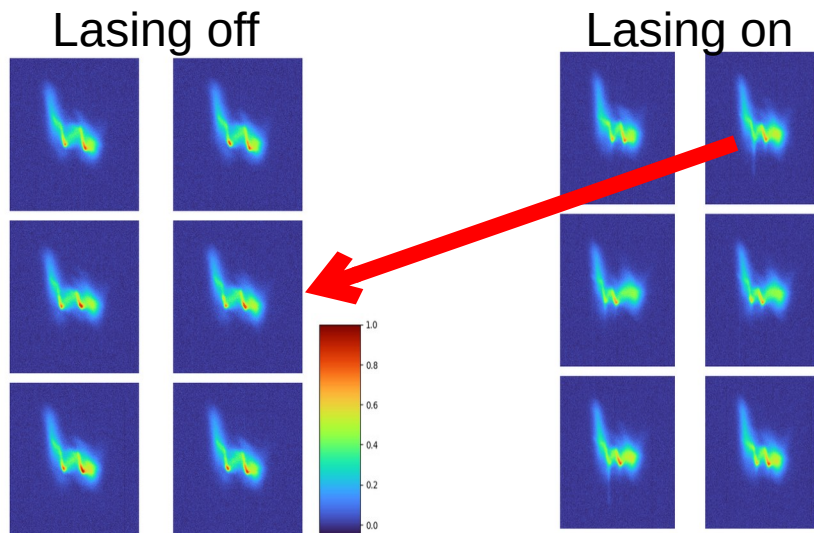
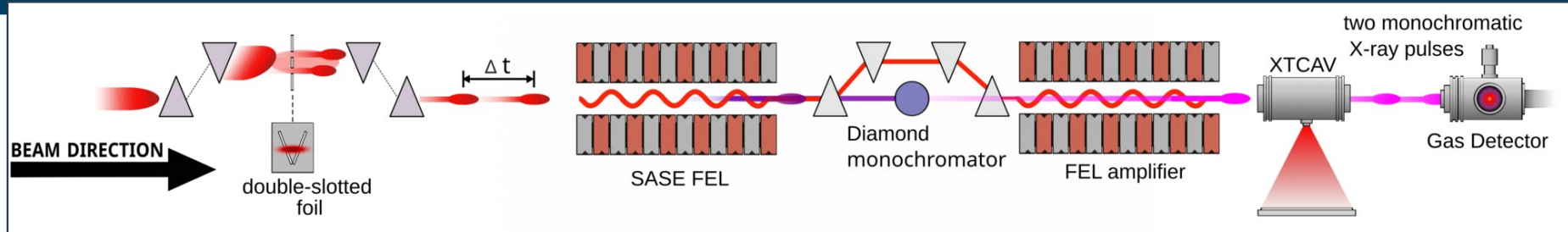
ML for PolariX TDS



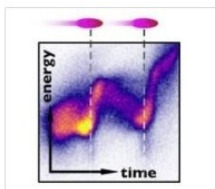
3 Months at SLAC in California



Femto-Pixar



Optics Express Vol. 33, Issue 15, pp. 31235-31243 (2025) · <https://doi.org/10.1364/OE.562798>



femto-PIXAR: a self-supervised neural network method for reconstructing femtosecond X-ray free electron laser pulses

Gesa Goetzke, Rajan Plumley, Gregor Hartmann, Tim Maxwell, Franz-Josef Decker, Alberto Lutman, Mike Dunne, Daniel Ratner, and Joshua J. Turner

Author Information Find other works by these authors



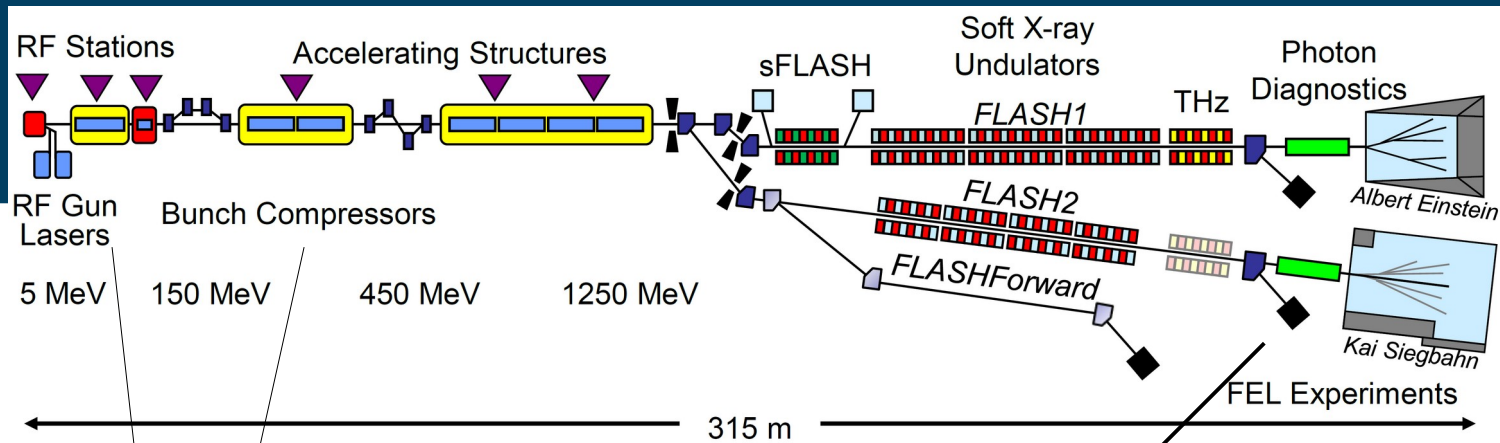
Thesis

Submitted thesis with title:

**“Unsupervised machine learning approaches for
photon pulse diagnostics at free-electron lasers”**

on March 10th





Johan Lundquist

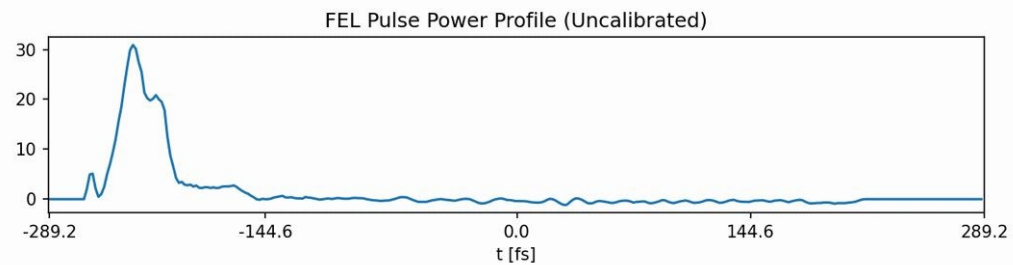
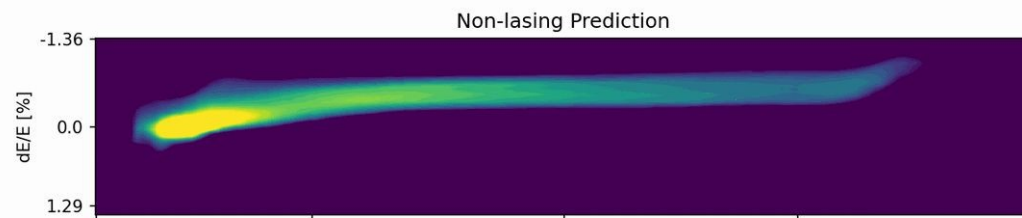
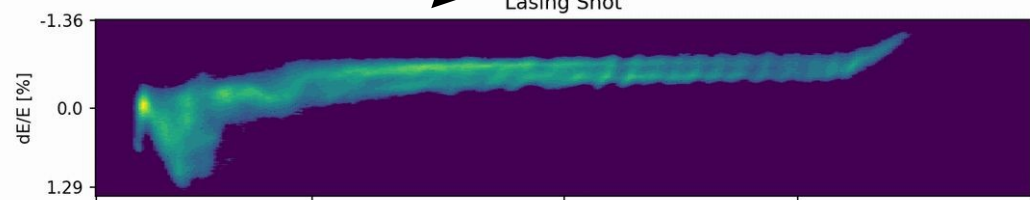


NN

measured

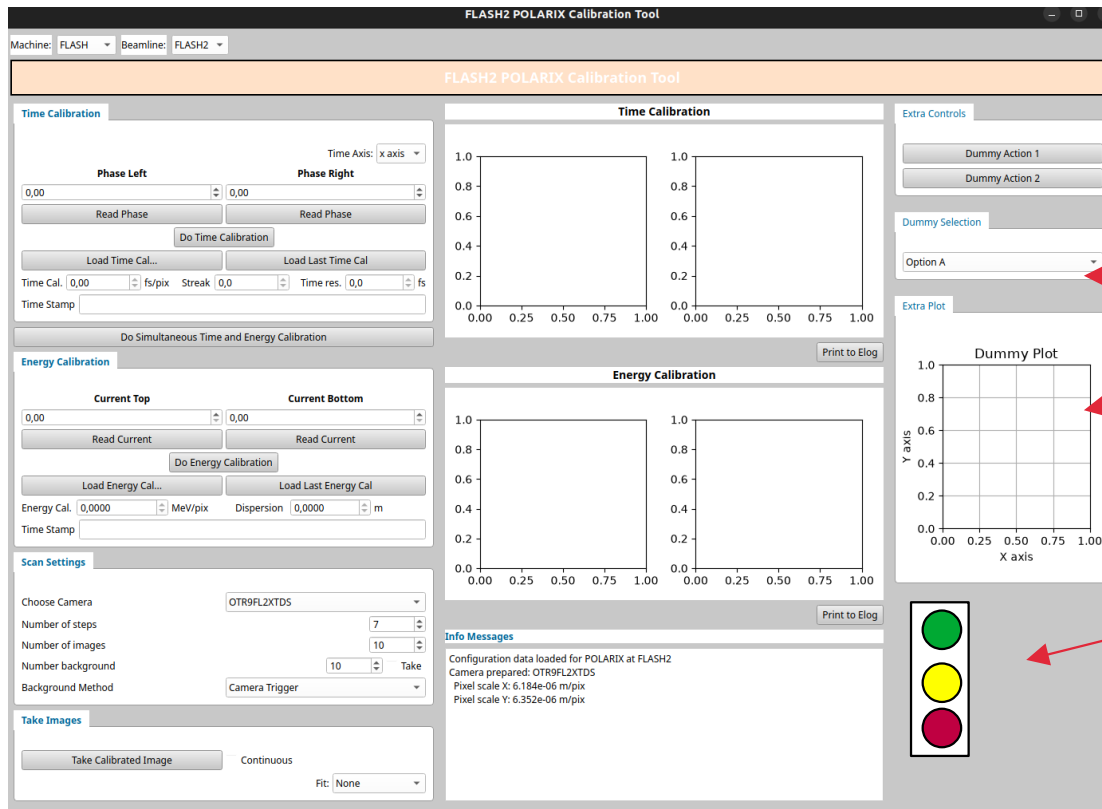
predicted

calculated



What now?

- Transfer all my knowledge about ML and Pulse diagnostic to something usable!
 - build a useful / well documented Tool that each operator can use.
- Started to translate matlab (calibration) tool into python (pyqt5)



Check both phases

Record reference set

Multiple reference finding tools,
With and without ML

Tune lasing off

Status lights –
Red → record new lasing offs

Thanks to:

Gregor Hartmann
Felix Möller
ML Group at HZB



Rajan Plumley
Daniel Ratner
Joshua Turner



Philipp Amstutz

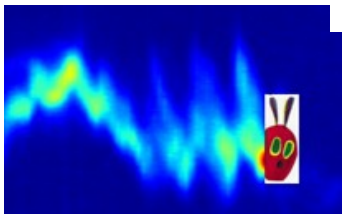
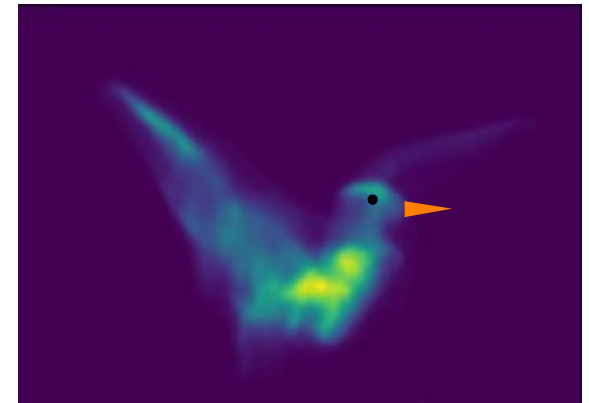
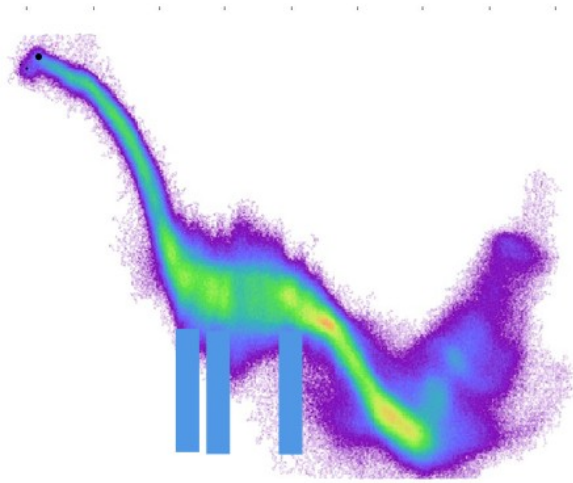


Stefan Düsterer
Kai Tiedtke
Matthias Vogt
Christopher Gerth
Markus Ilchen

The entire FLASH team



Thank You



Questions?

