MTCA for photon diagnostic and user experiments at FLASH

Reliable 24/7 instrumentation

Stefan Düsterer for FS-FLASH, MCS4, MSK (SDiag), …
9th MicroTCA workshop, DESY, 3.12.2020

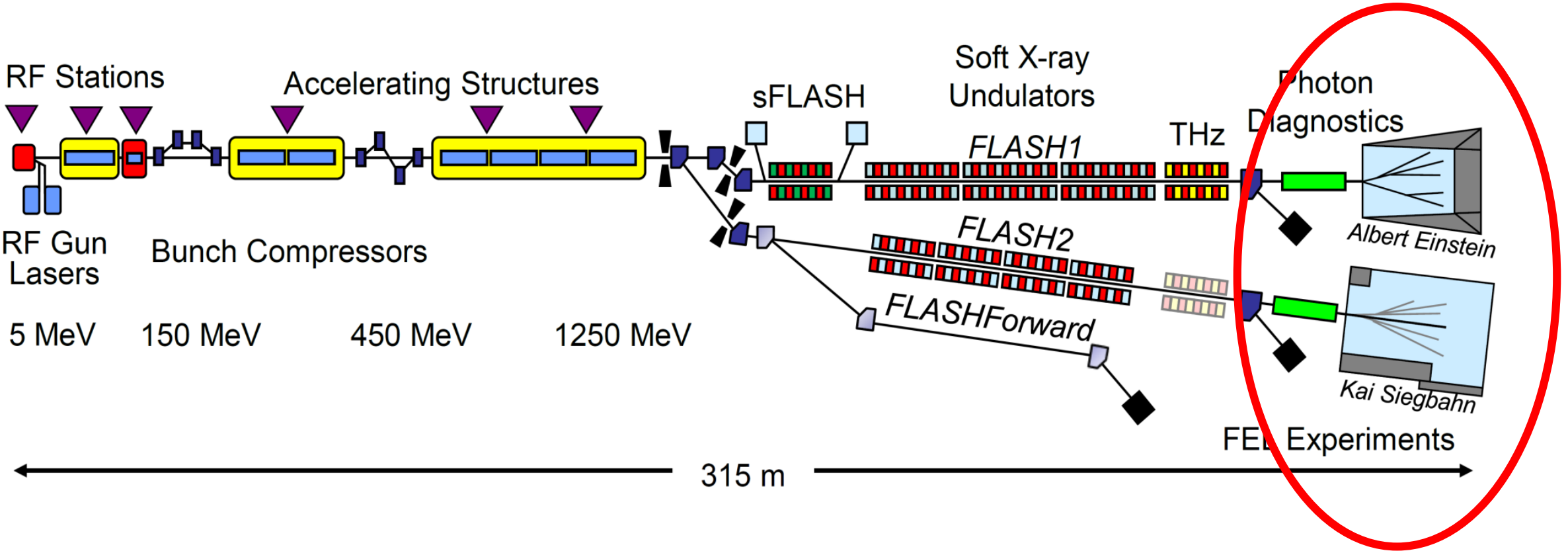
Outline

What am I gonna show …

- What MTCA components do we use for FLASH photon diagnostics / user experiments
- Triggering experiments
- Measuring the wavelength of the FEL
  - Using a MHz line camera (Kalypso)
  - Using photoelectron spectroscopy -> ADC (“OPIS”)
  - AI helps to get information from very noisy signals
- Looking at single-shot photoelectron spectroscopy line shapes (THz streaking)
- What users need …
- Summary

FLASH

Photon diagnostic and experimental halls



MicroTCA @ FLASH

What do we have here ...

Photon Diagnostic: 6 crates

Users: 3 crates

Boards:

- **11x** X2 Timer cards — Triggering User experiments, ADCs, cameras, shutters …
- **14x** ADC: Spdevices ADQ412 (12 bit, 2/4 Gsample) — Recording User signals, photon diagnostic signals
- 8x ADC: Spdevices ADQ108 (8 bit, 7 Gsample) — OPIS spectrometer
- 1x ADC: Spdevices ADQ7 (12 bit, 5/10 Gsample) — Testing …
- 3x ADC: SIS8300 (16 bit, 108 Msample) — integrate diode signals
- 1x FMC Carrier for communication with Kalypso — MHz line camera

Triggers

X2 timer system

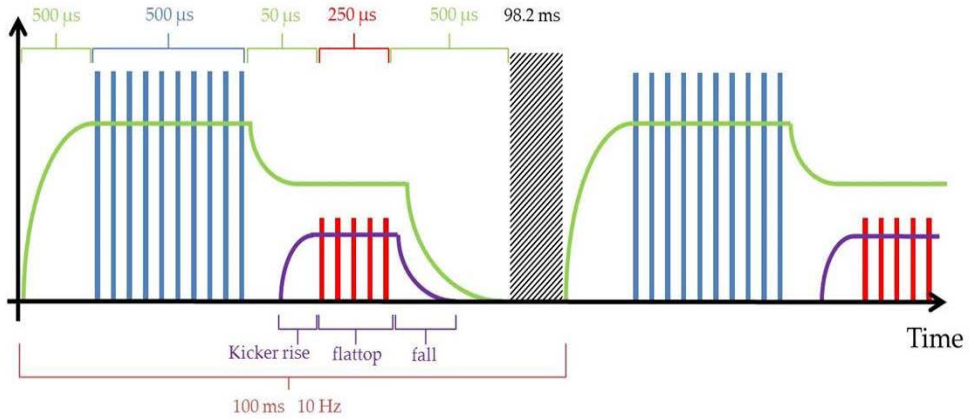
- DESY / XFEL development
- Triggering user devices (cameras, ADCs, scopes,…)
- Triggering ADCs -> up to 10 Gsample -> trigger jitter << 100 ps !

VME trigger system +- 1 ns !

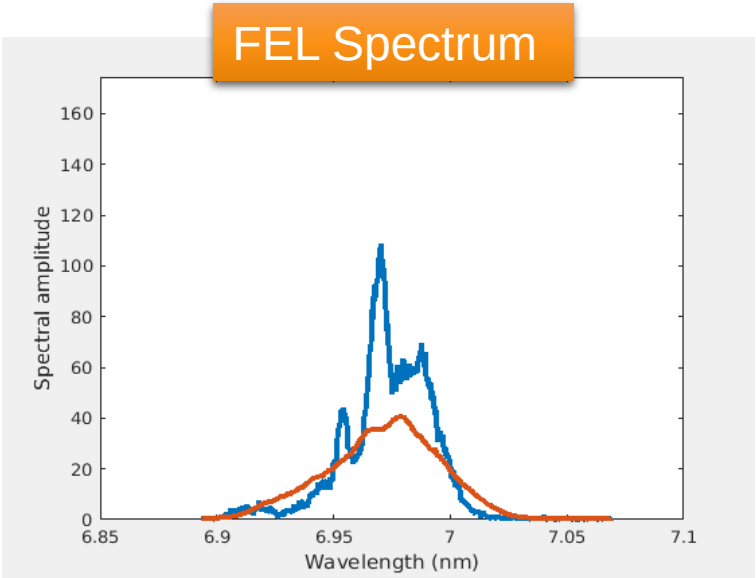
- Very flexible in shifting delays, producing reference frequencies and burst patterns

What is special at FLASH ?

- 10 Hz repetition rate (pulse trains)
- With several 100 pulses per train



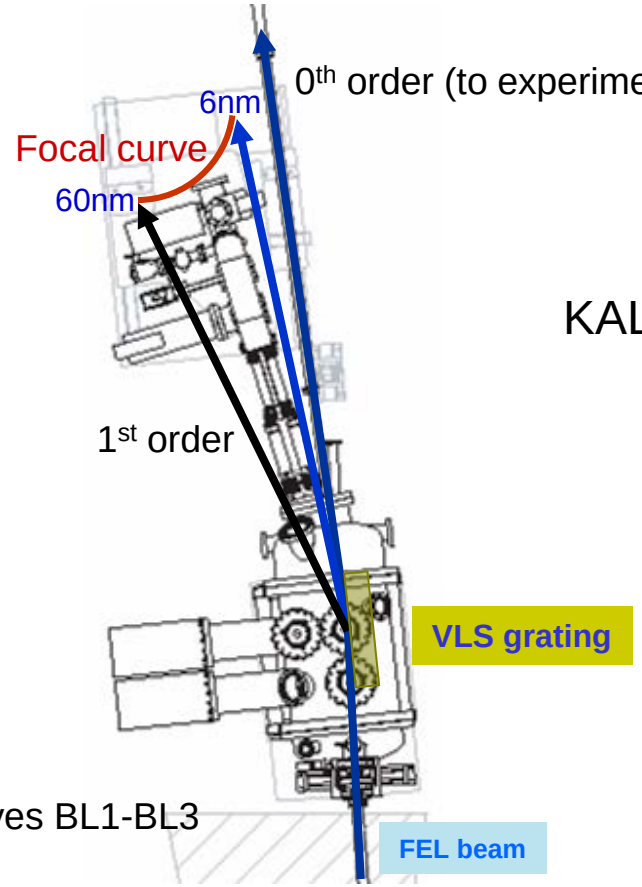
- Each single photon pulse is different (in energy, wavelength, pulse length, arrival time, …)



Spectral distribution of the burst

Working range ……5.8 nm – 60 nm
Efficiency ……1 – 10 %
Resolving power.....~2000-3000

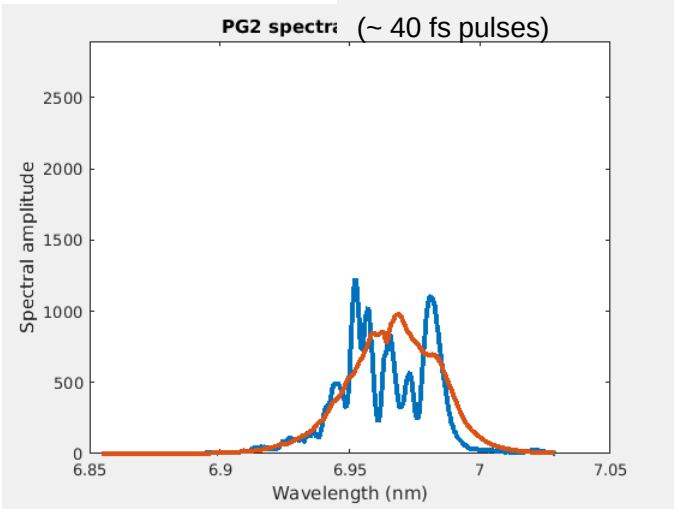
Experiment



Serves BL1-BL3

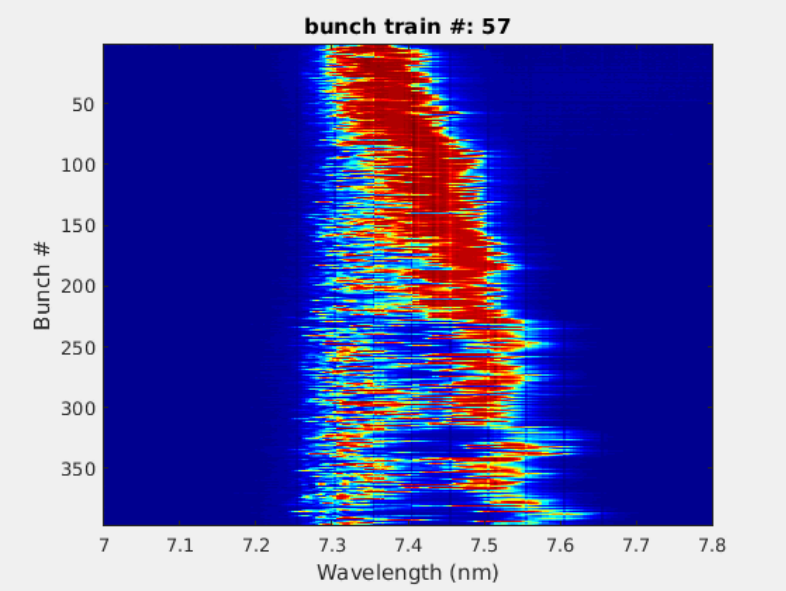
G. Brenner et al.,
Nucl. Instr. and Meth A **635**, 99–103 (2011).

Single shot spectra



PCO camera:
10Hz operation

KALYPSO detector: Shot-to-shot spectra in multibunch mode



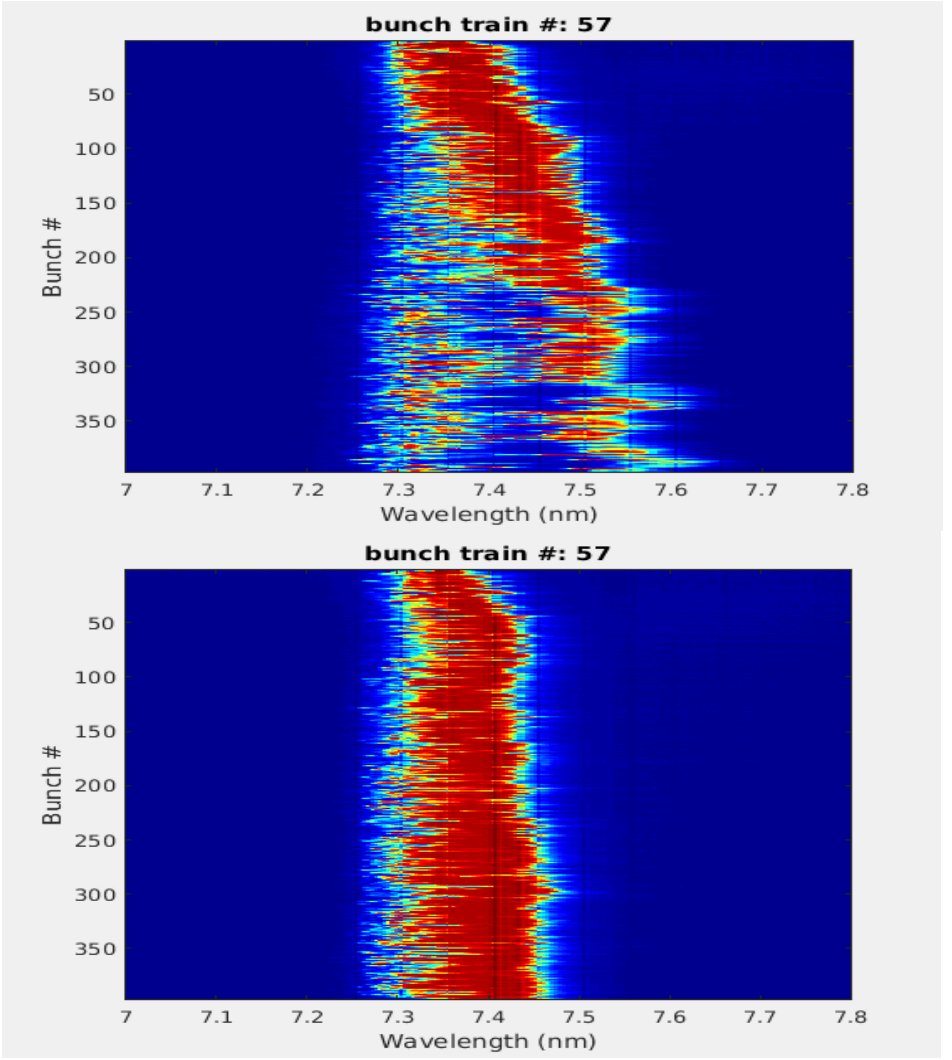
MHz line camera KALYPSO

> KALYPSO:

- Developed within ARD Matter & Technology between KIT, DESY and HZDR
- Low-latency continuous read-out with up to 2.7 MHz rep rate => cw and feedback capability
- Fast data stream-out to MicroTCA.4 developed at MSK in collaboration with University of Lodz
- Integration into DOOCS and DAQ by MCS4
- Currently under development version 3:
  up to 1024 pix, up to 5 MHz, better signal-to-noise

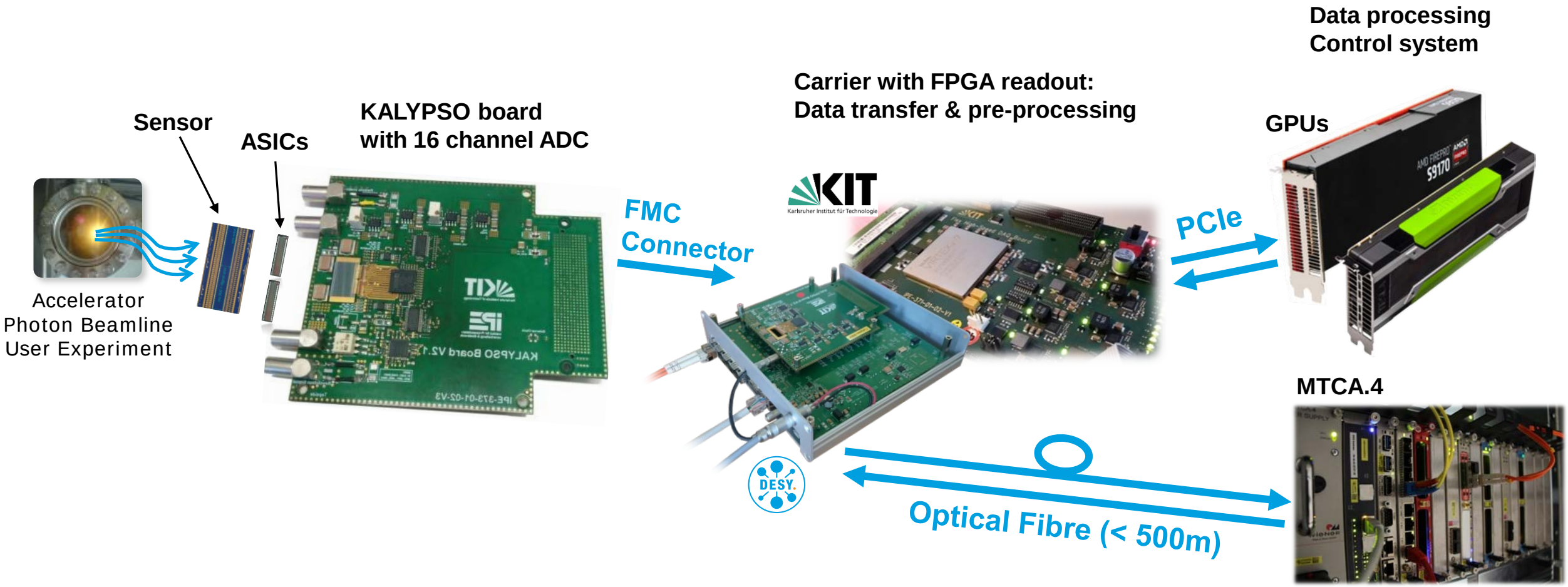
> Parameters for current version 2.1

- 256 pixels, 50 µm pitch
- 14 bit ADC, 2.7 Mfps



KALYPSO

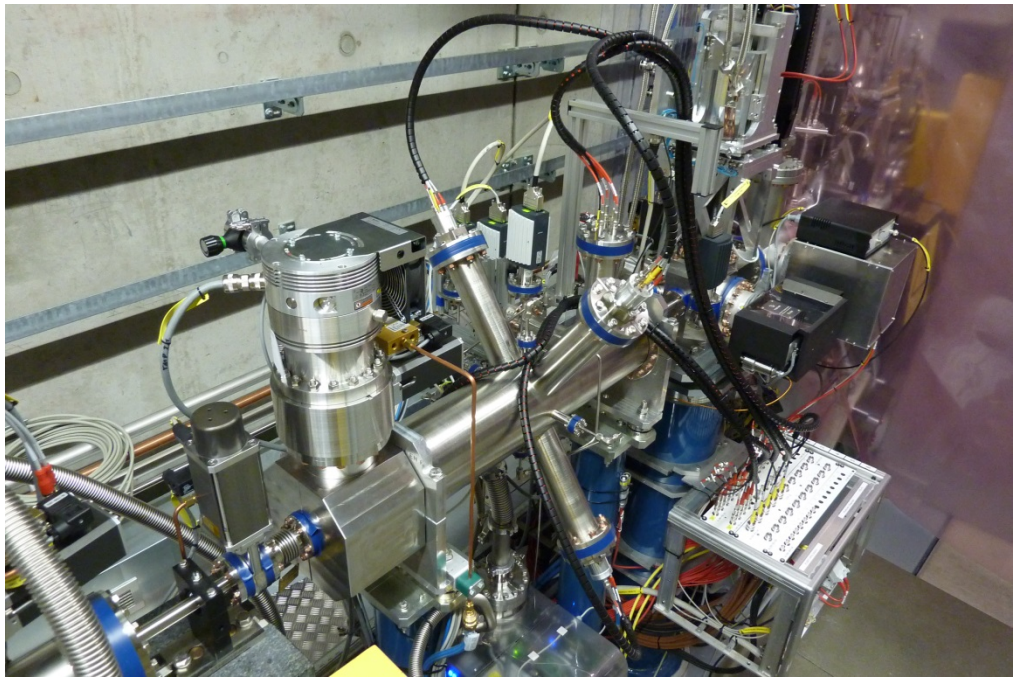
Overview: Building Blocks of the Detector System

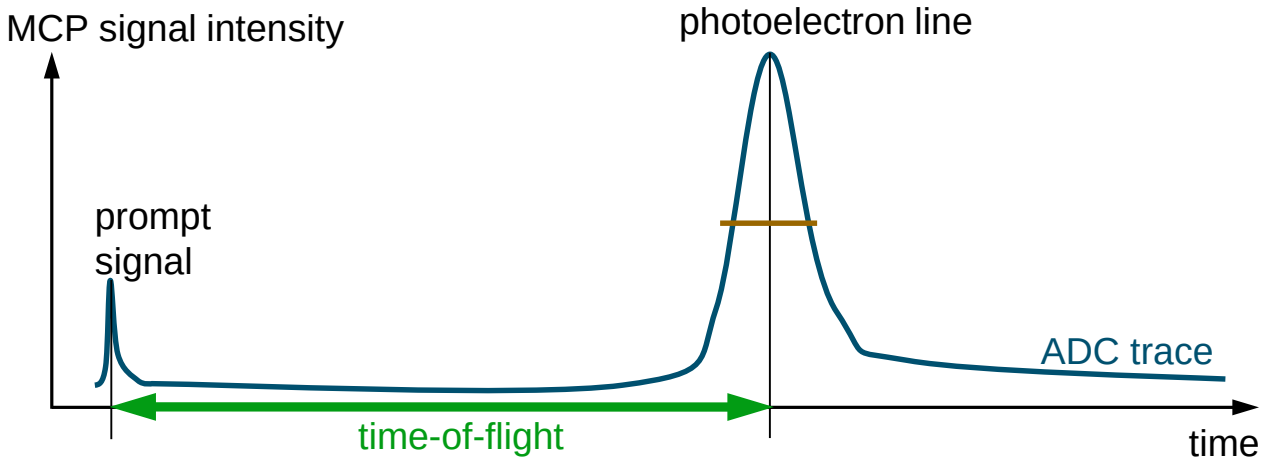


Online Photoionization Spectrometer (OPIS) @ FLASH2.

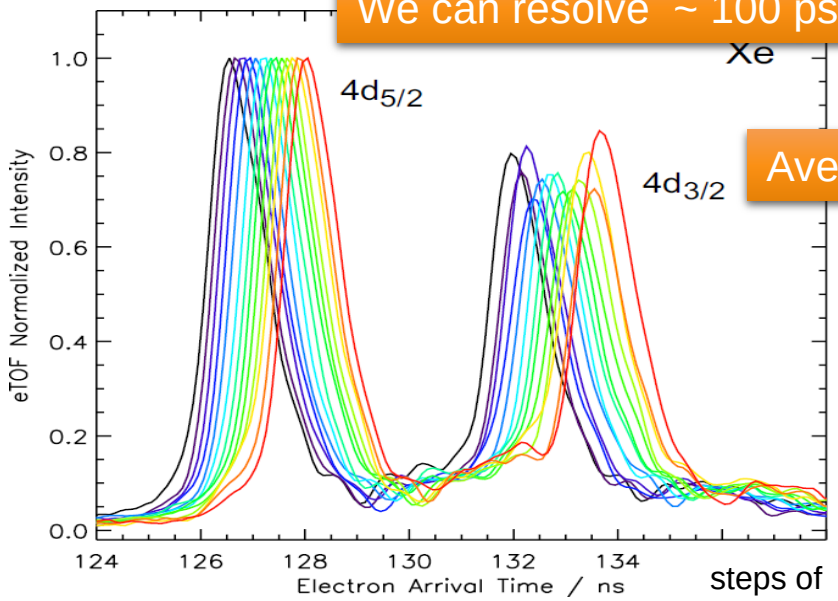
Measure the wavelength with photo electron spectroscopy

- No optical elements which can be damaged or degrade
- Basically 100% transmission
- Self-calibration capability using Auger electrons
- Usage of fast MTCA ADCs → FLASH DAQ storage system





We can resolve ~ 100 ps shift !

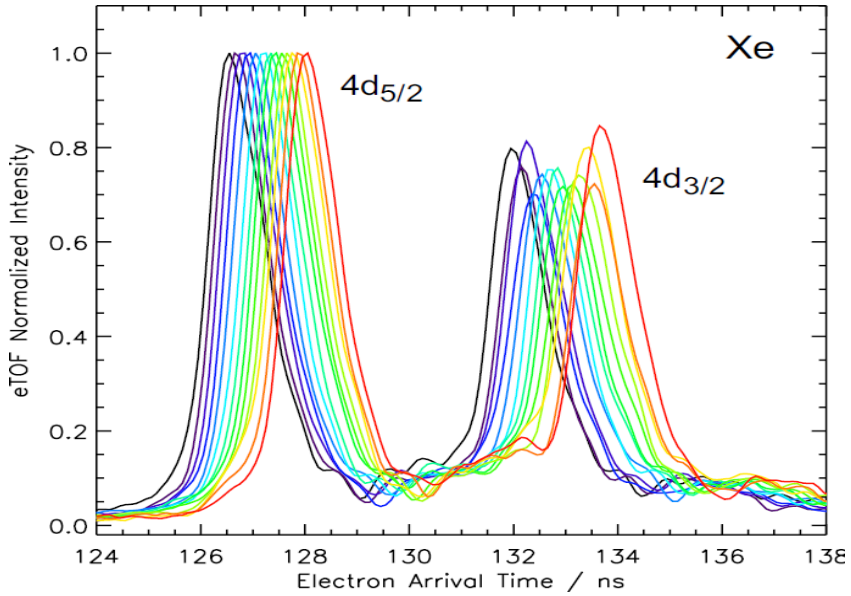


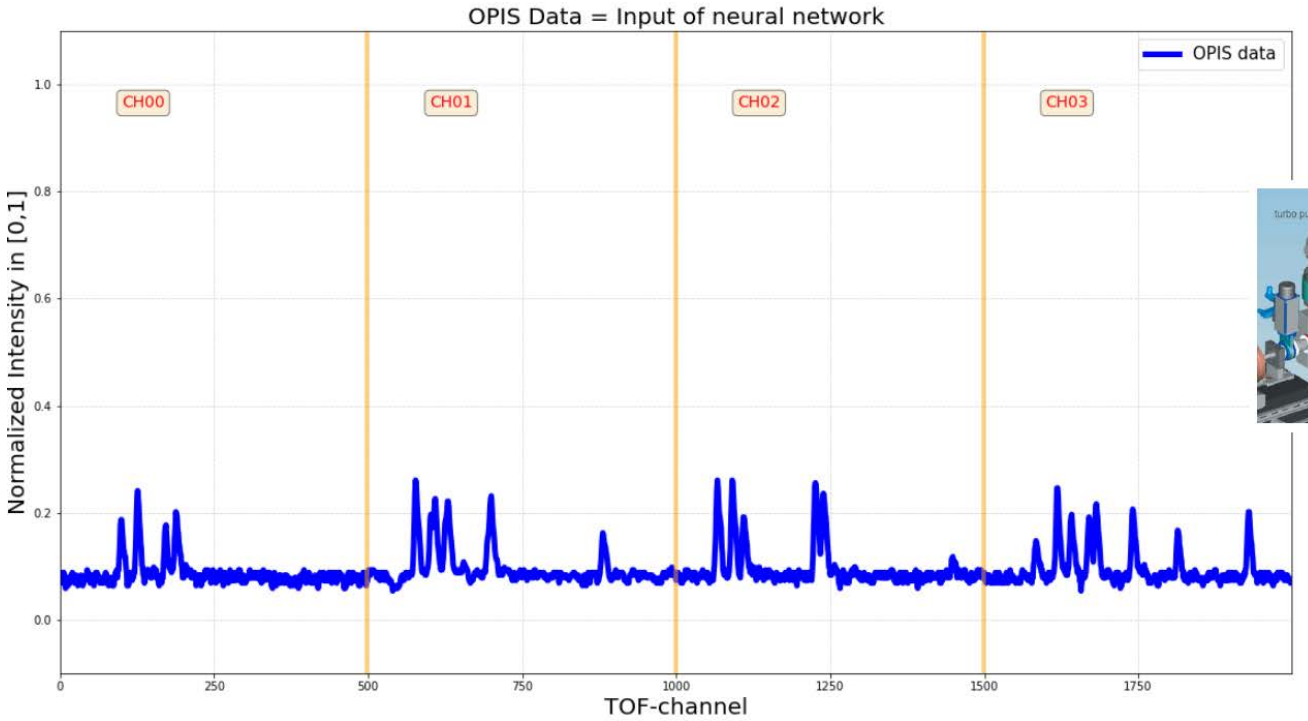
Averaged signals !

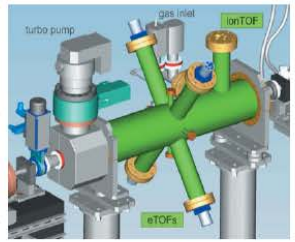
steps of $\Delta h\nu$=0.05 eV

Courtesy M. Braune

Signal from single FEL pulses is very low …



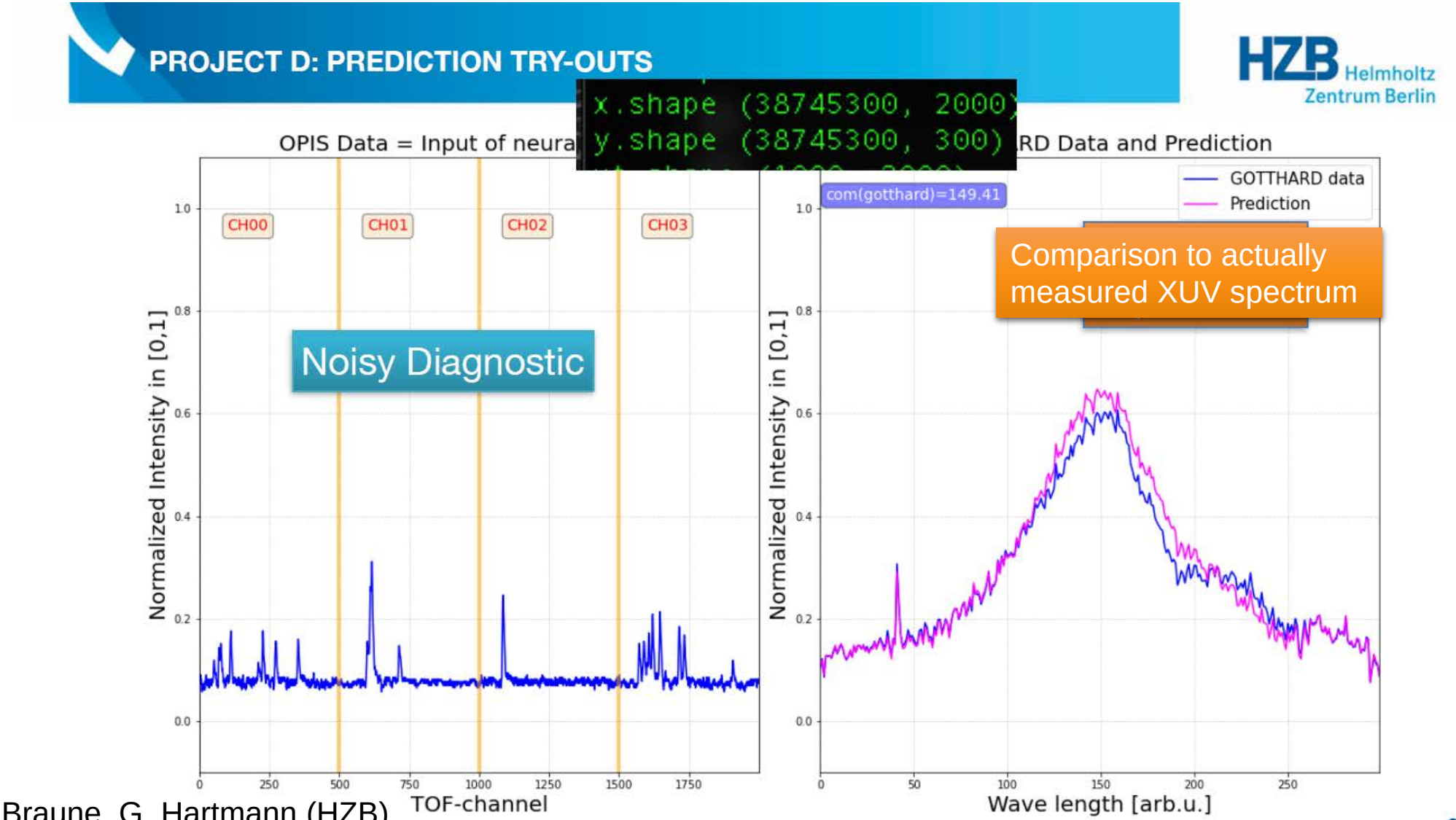




Courtesy M. Braune, G. Hartmann (HZB)

Using artificial intelligence

Comparing AI predictions to measured spectra



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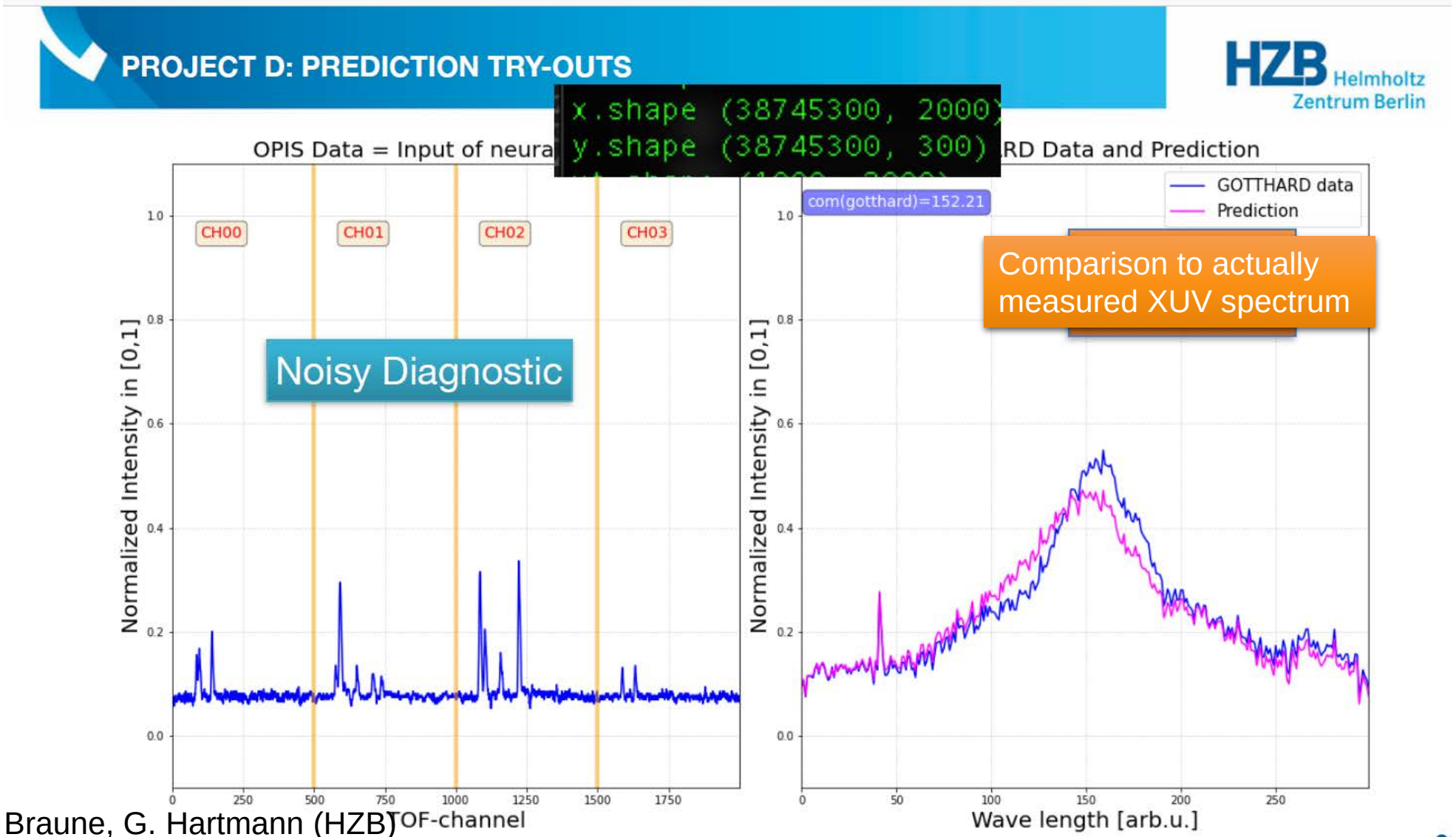

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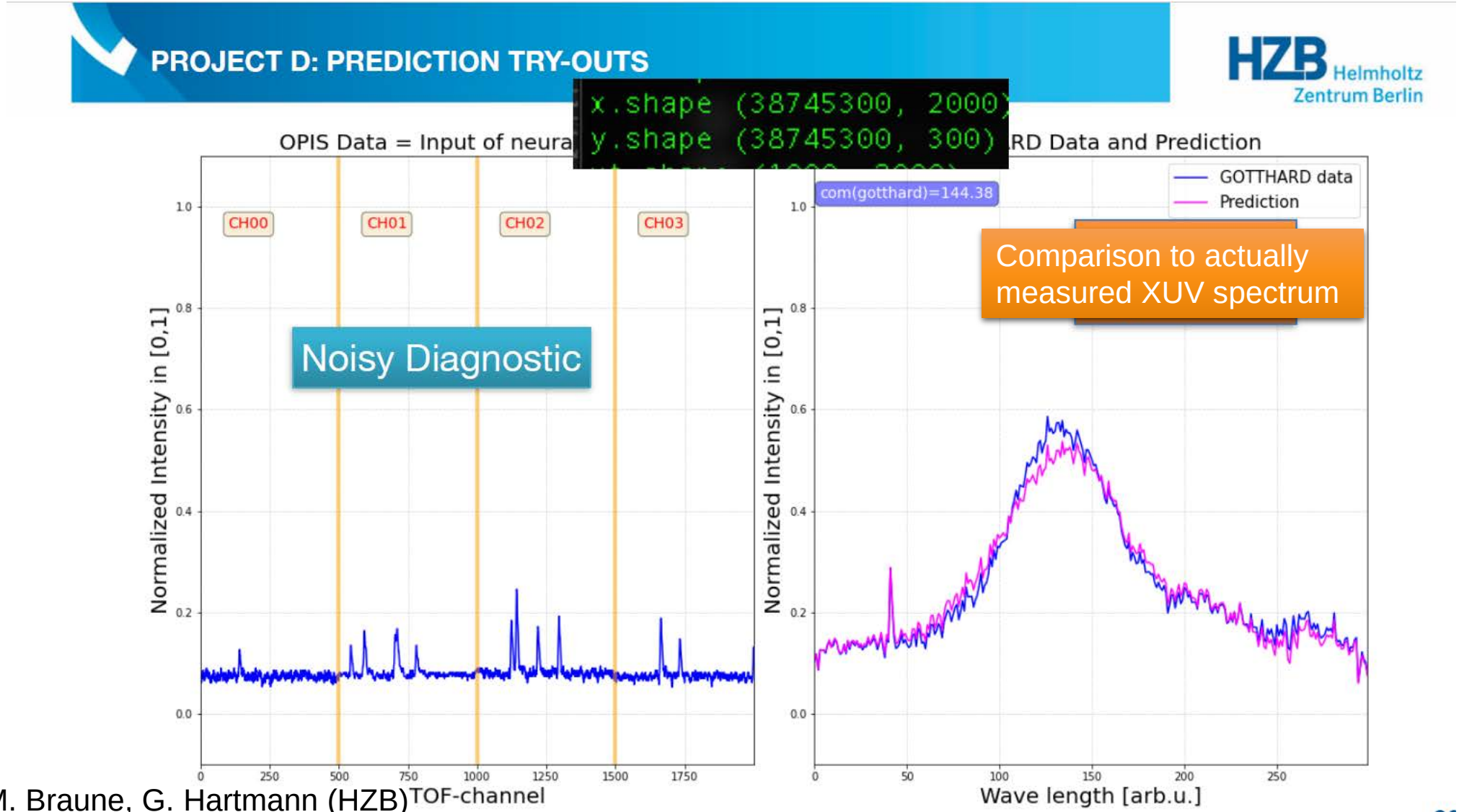

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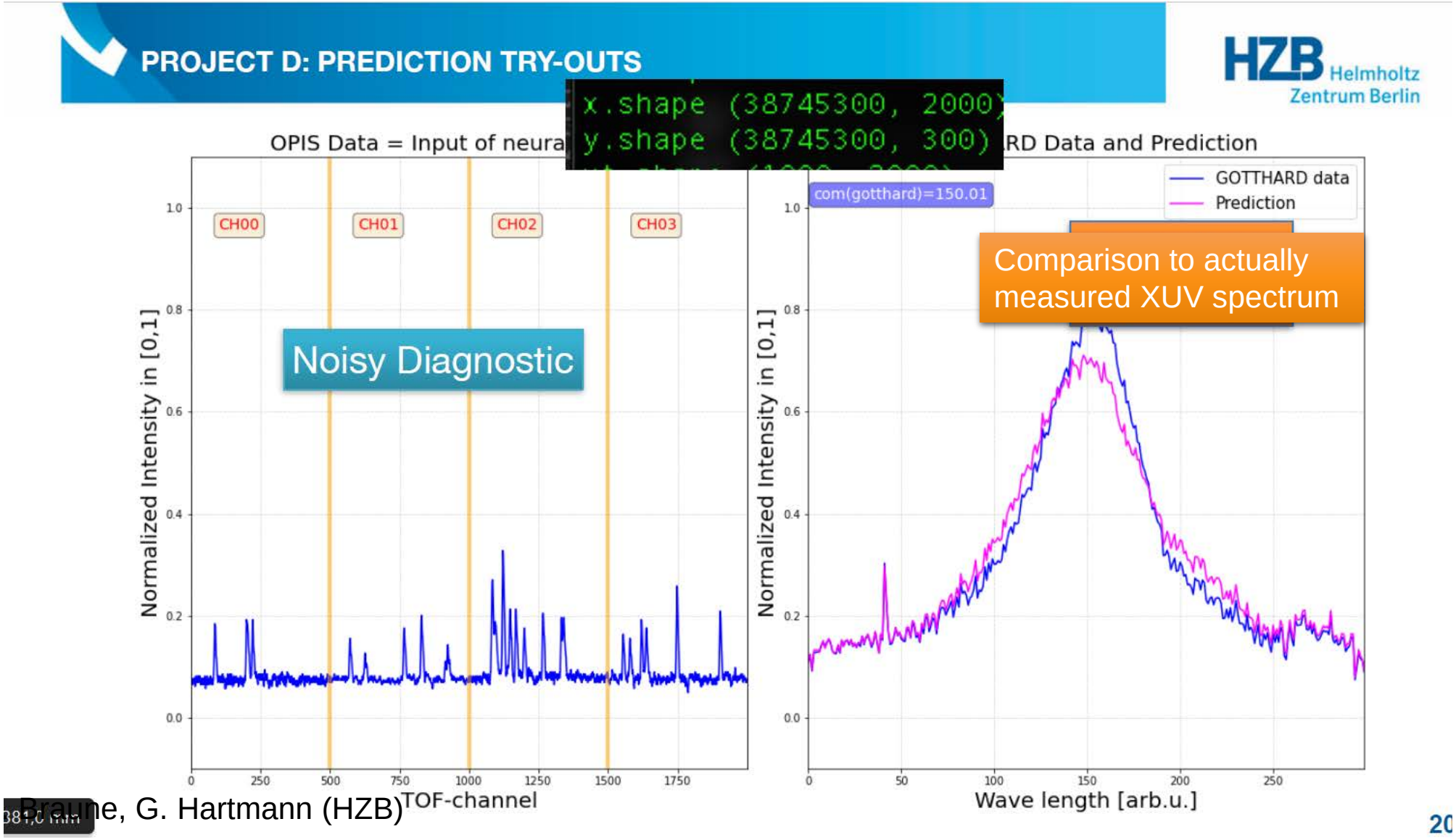

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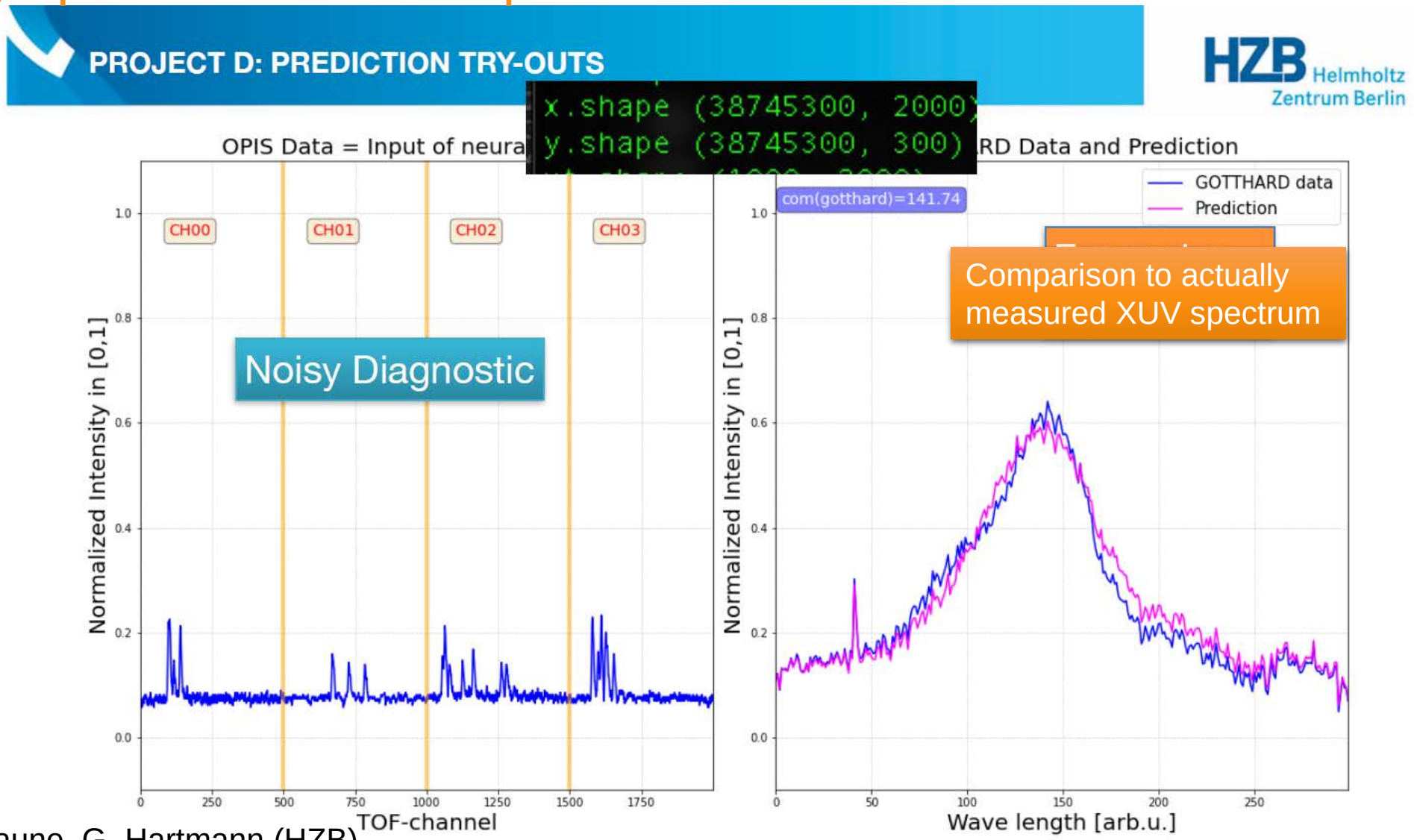

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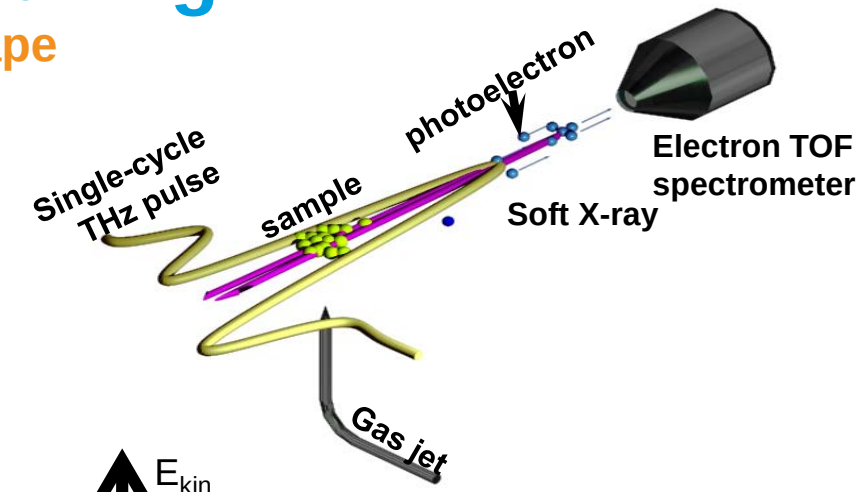
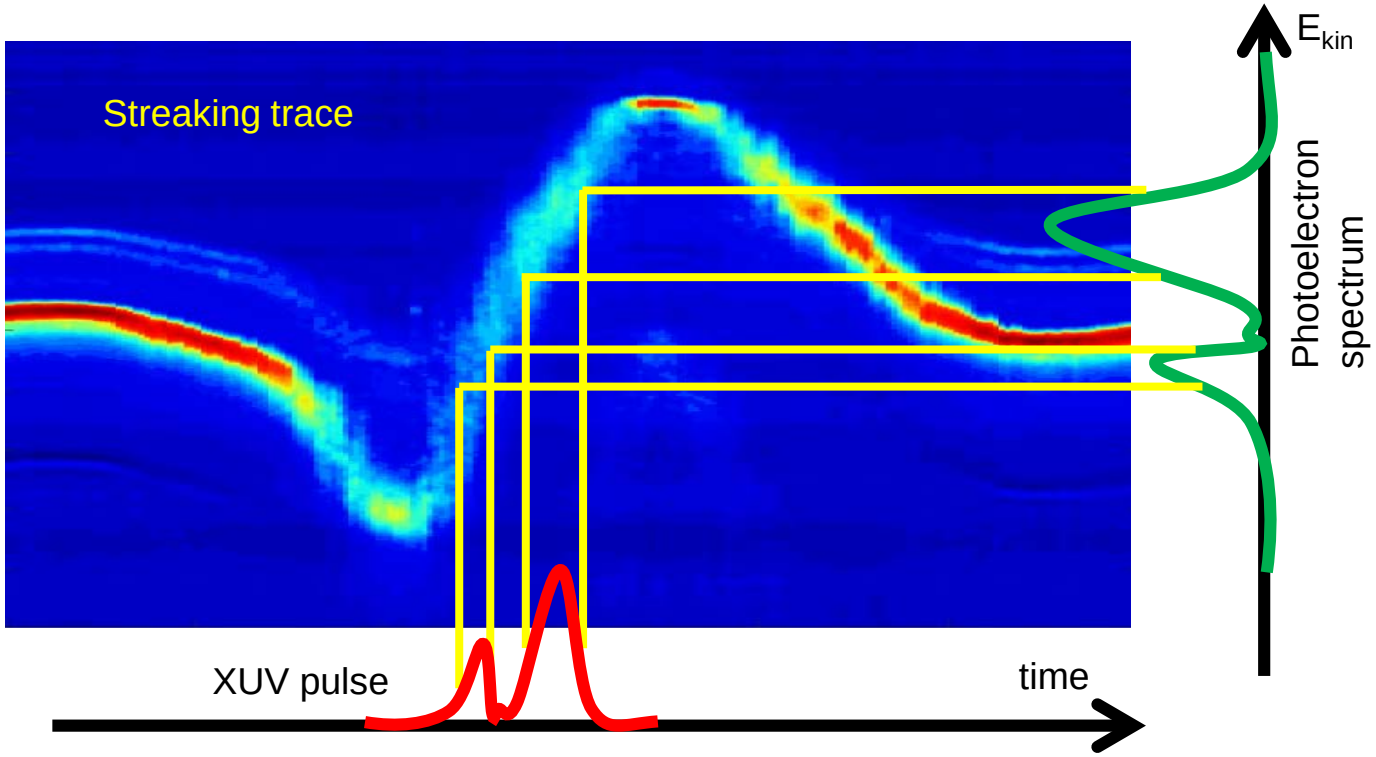
Pulse duration measurement - THz Streaking

Single shot TOF spectroscopy next step … looking at signal shape

Timing jitter > pulse duration -> single shot diagnostic

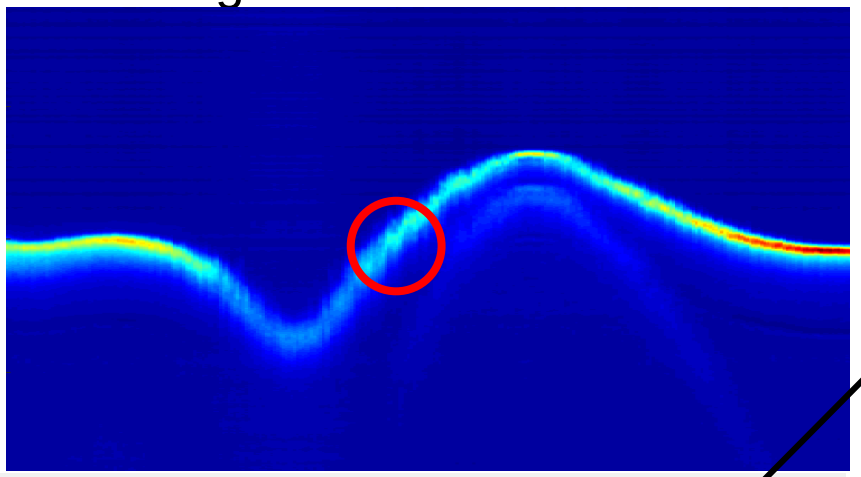


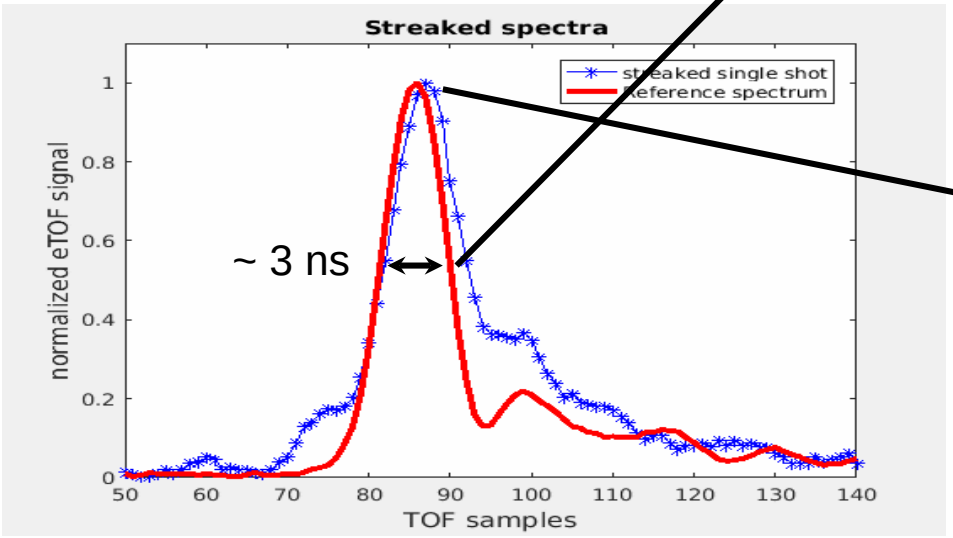


Nat. Photonics **3**, 523 (2009), Nat. Photonics **6**, 852 (2012)

THz Streaking - observables

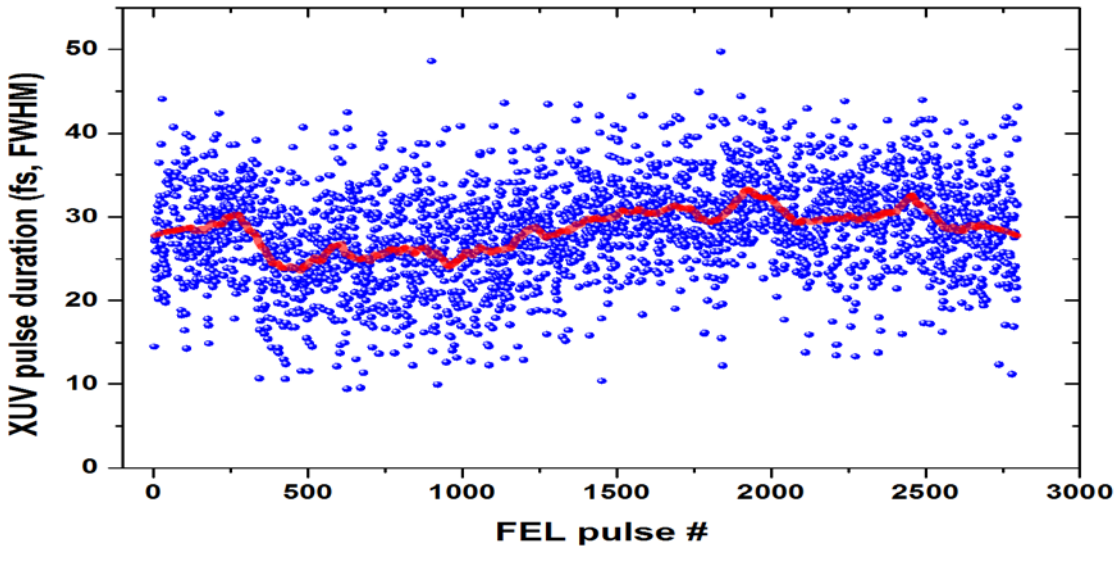
Streaking raw data



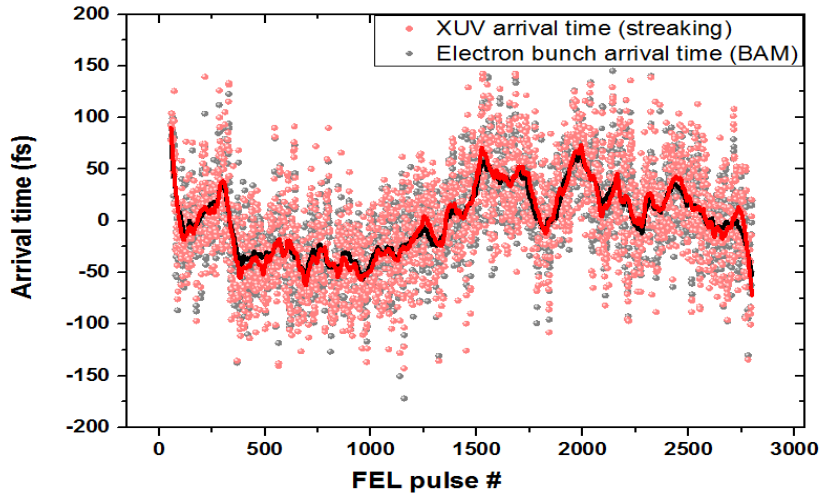


High temporal resolution and high dynamic range

Single shot XUV pulse duration



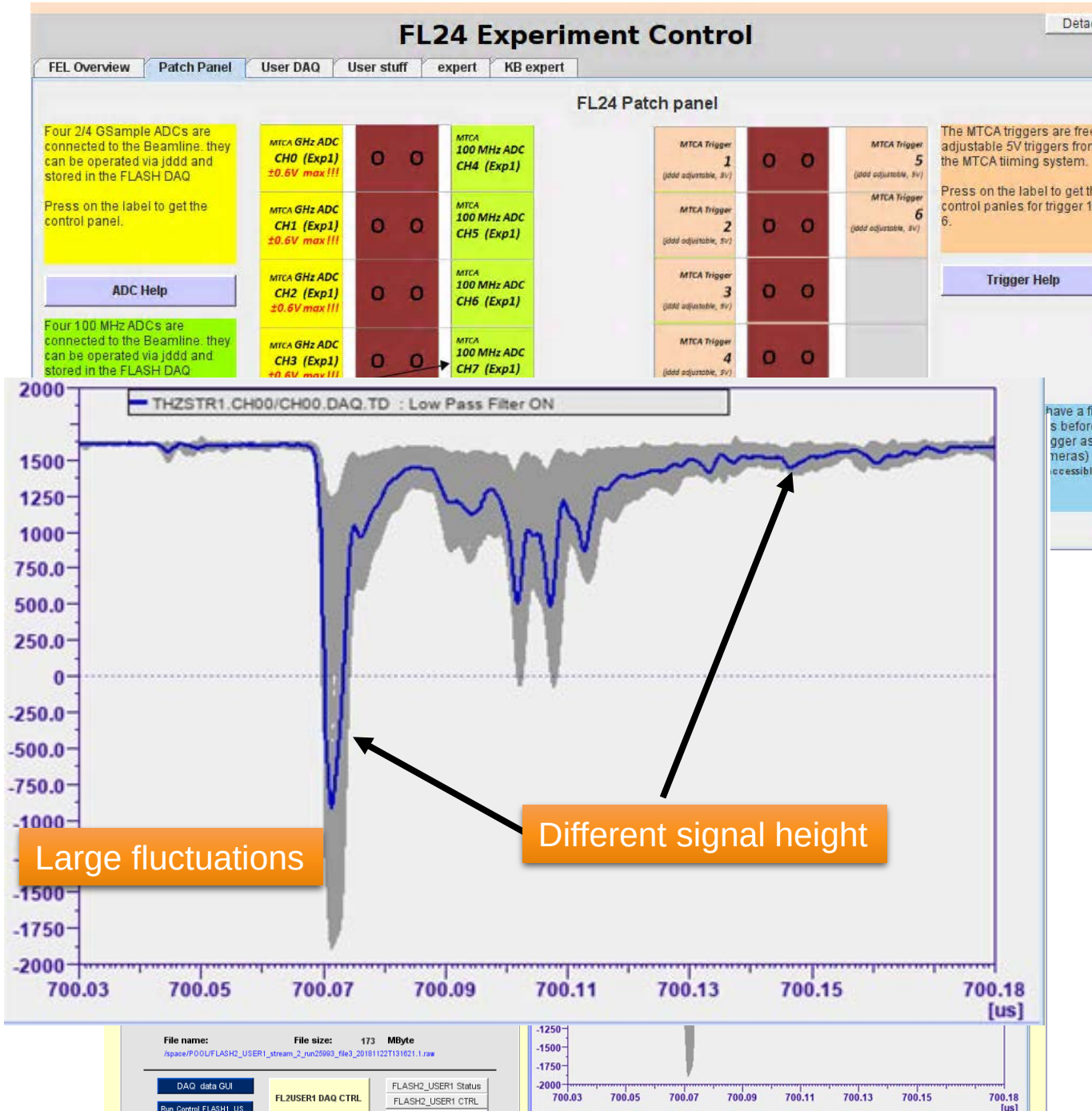
Arrival time



User experiments

- Patch panel at each beamline
  - Trigger
  - 100 MHz ADC (16 bit)
  - 2 / 4 Gsample ADCs (12 bit)

- > 70 % use ADCs
- Pulse height detection -> **dynamic range** / amplitude resolution
- **Spectroscopy -> GHz (4-10 Gsample) + dynamic range**
  - 12 bit o.k. (8 bit definitely not)
  - Signal height adaption with amplifiers **external amplifiers**



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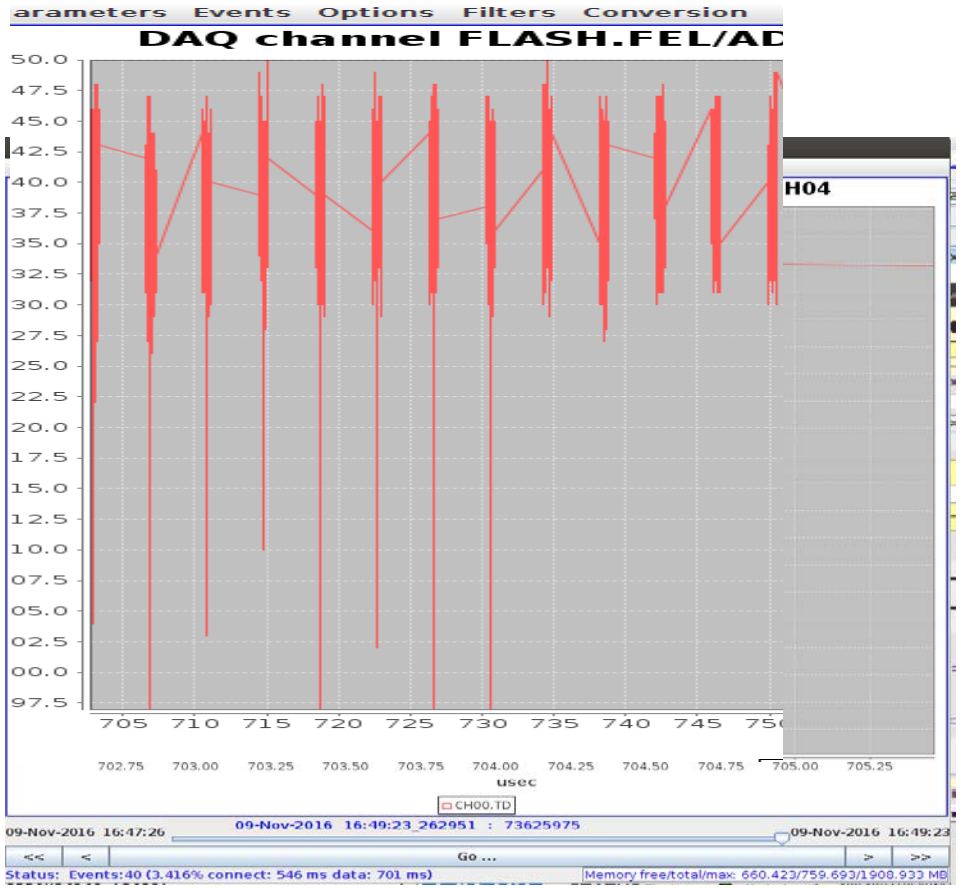
- Data analysis
  - **Pulse synchronous readout** of different channels for online analysis
  - **Data reduction** -> saving only relevant data



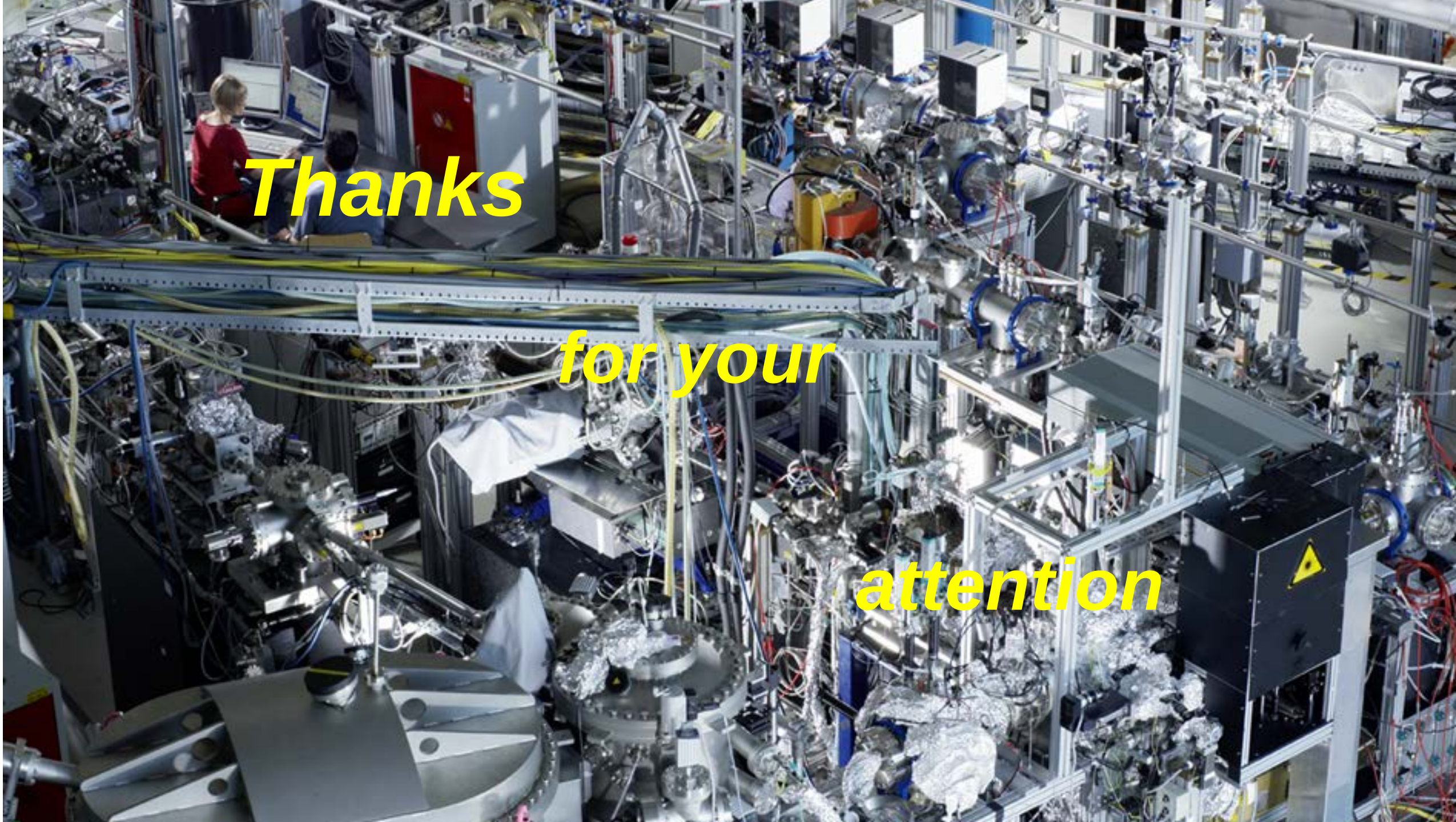
Summary

MTCA in the FLASH experimental halls

- Trigger, line-cameras, ADCs, … fully integrated in the control system
- Easy to operate (dedicated user panels)

- **Reliable – runs 24/7 (with very few problems)**

- ADCs
  - Each experiment is different: different ADC types
  - Time resolution: 2-10 Gsample (>10 gets difficult to transport signals)
  - Dynamic range : 12 bit o.k. 16 bit great (8 bit bad)
  - Adapt signal level by **external** amplifiers -> build in with software switching in would be nicer ☺


Thanks
for your
attention