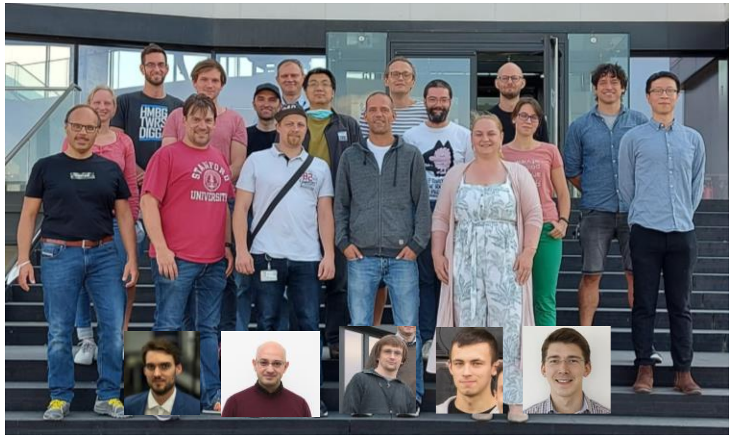
Data @ MID

Corrections, analysis, …

Overview

- General remarks
  - Data sources
  - Karabo
- Corrections and analysis
  - Online
  - Offline
- AGIPD
  - Single photon sensitivity / sparse data
  - Dynamic range / gain switching
  - future operation scenarios

EuXFEL data department



+

Detectors

Electrical Eng. & Electronics

Controls

IT & Data Mngt.

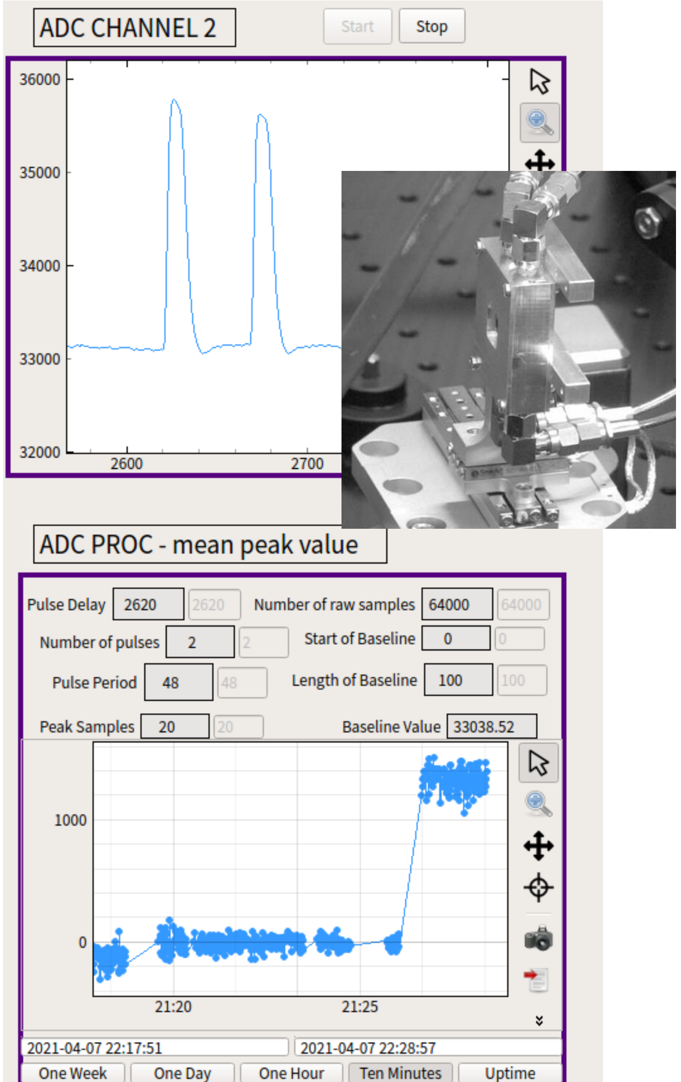
Data Analysis

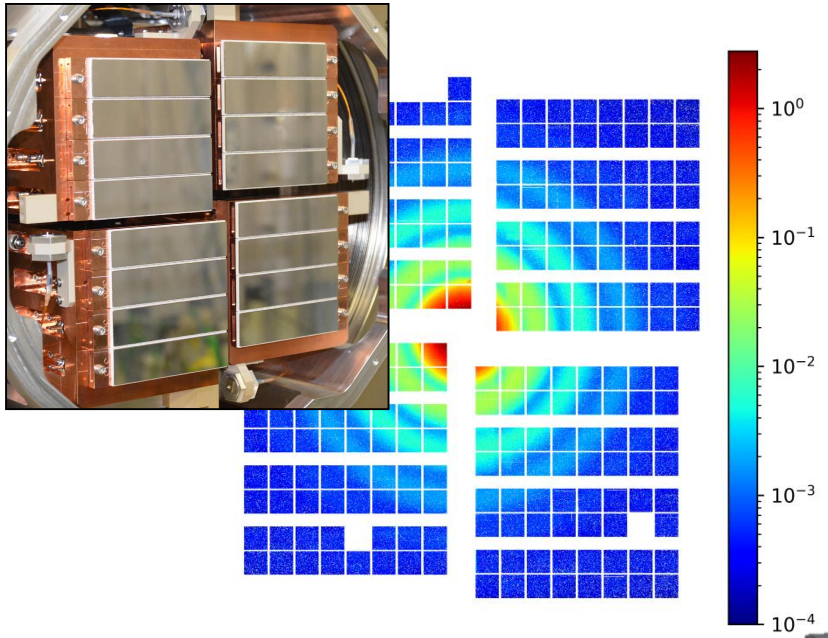
Roman Shayduk,
Markus Scholz
MID detector scientist

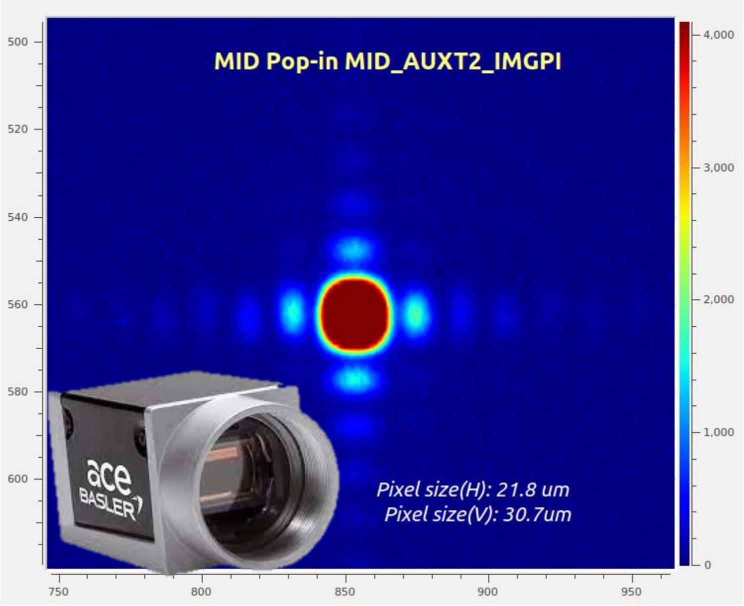
Andrea Parenti,
Riccardo Fabbri,
Robert Schaffer,
controls

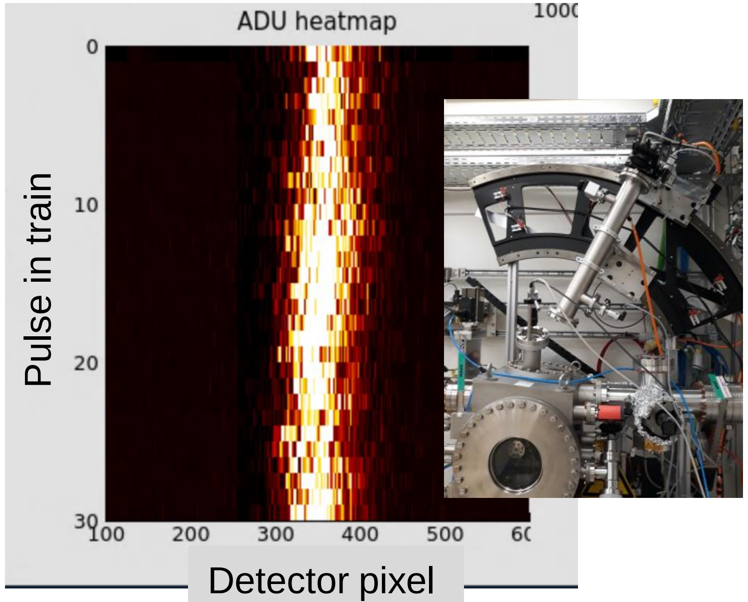
James Wrigley,
Fabio Dall'Antonia
data analysis

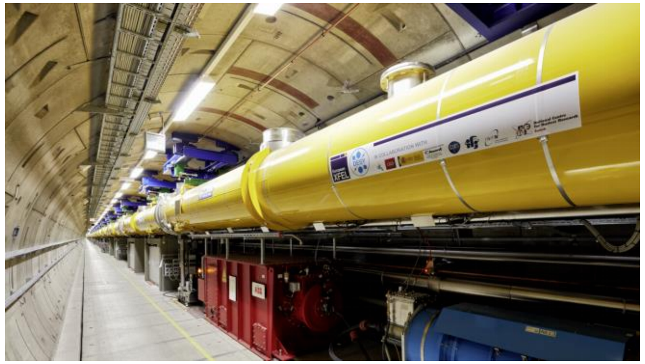
Data sources



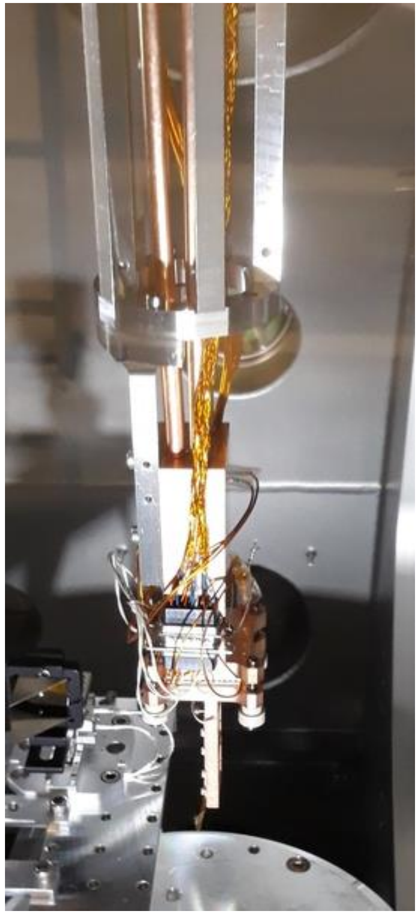


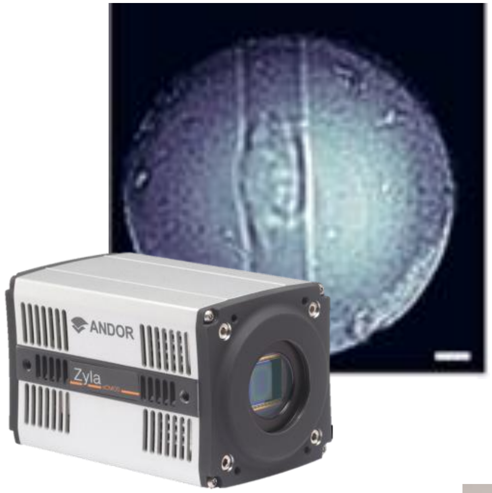


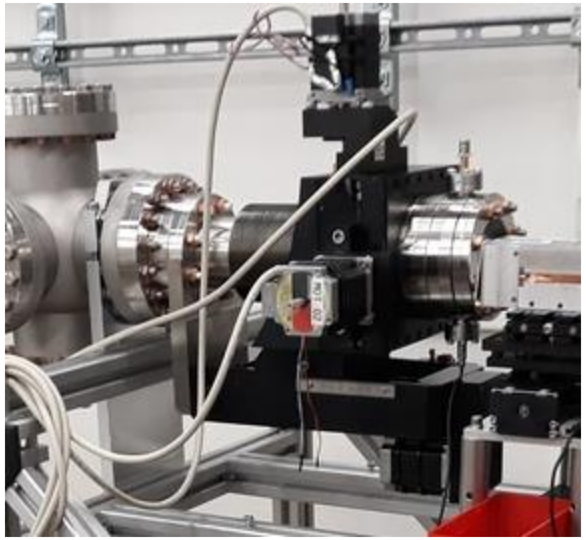


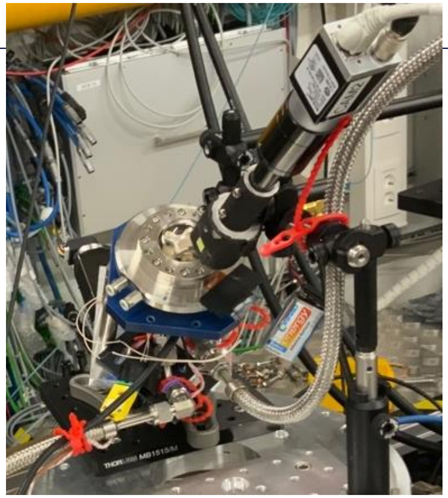


User equipment



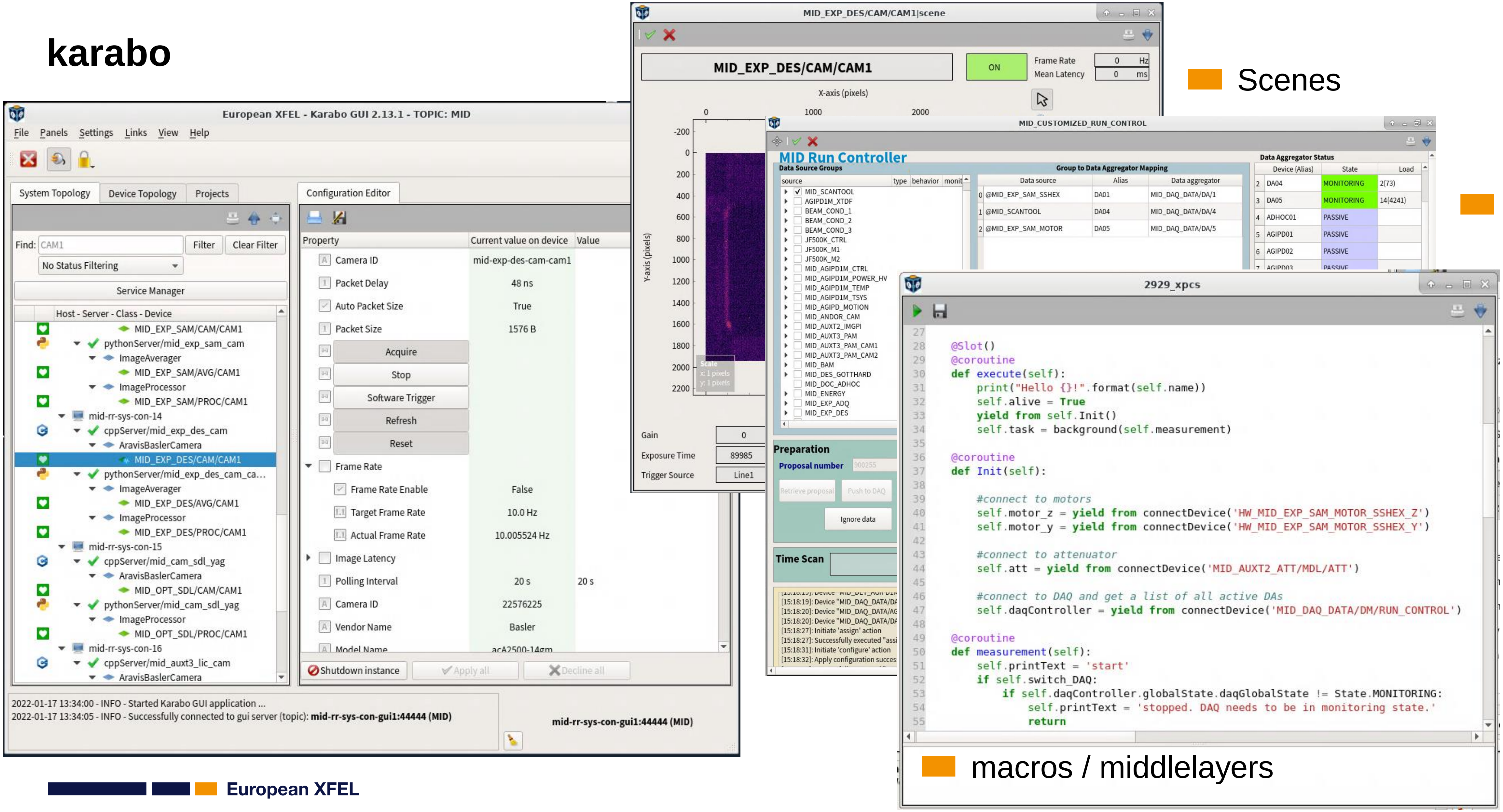






- User Patch Panel (UPP)
  - motor control
  - pump control
  - pressure gauges
  - temperature readout
  - …
- Digitzers
- Detectors / cameras

karabo

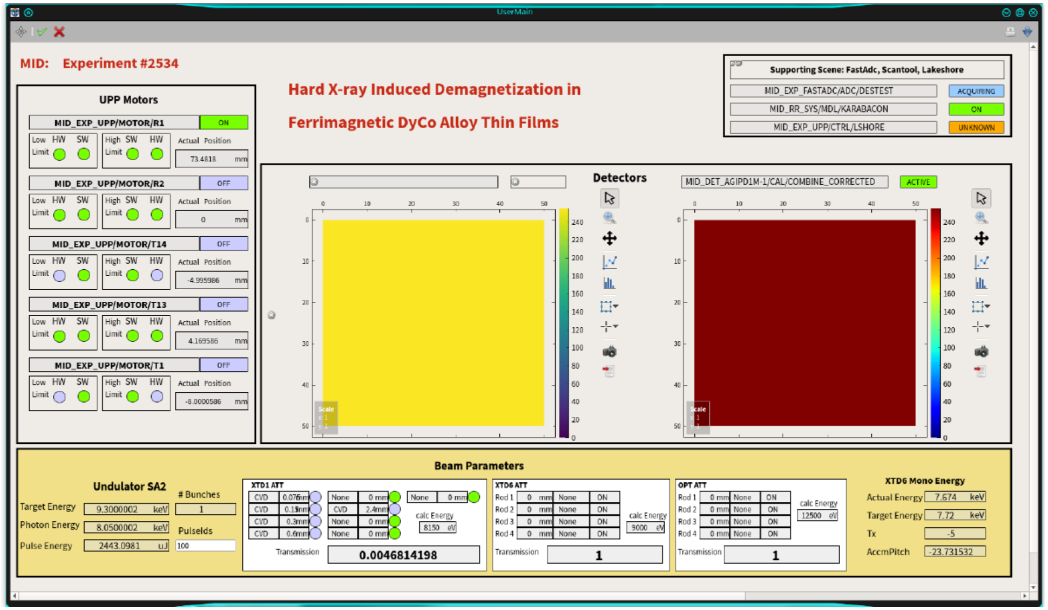


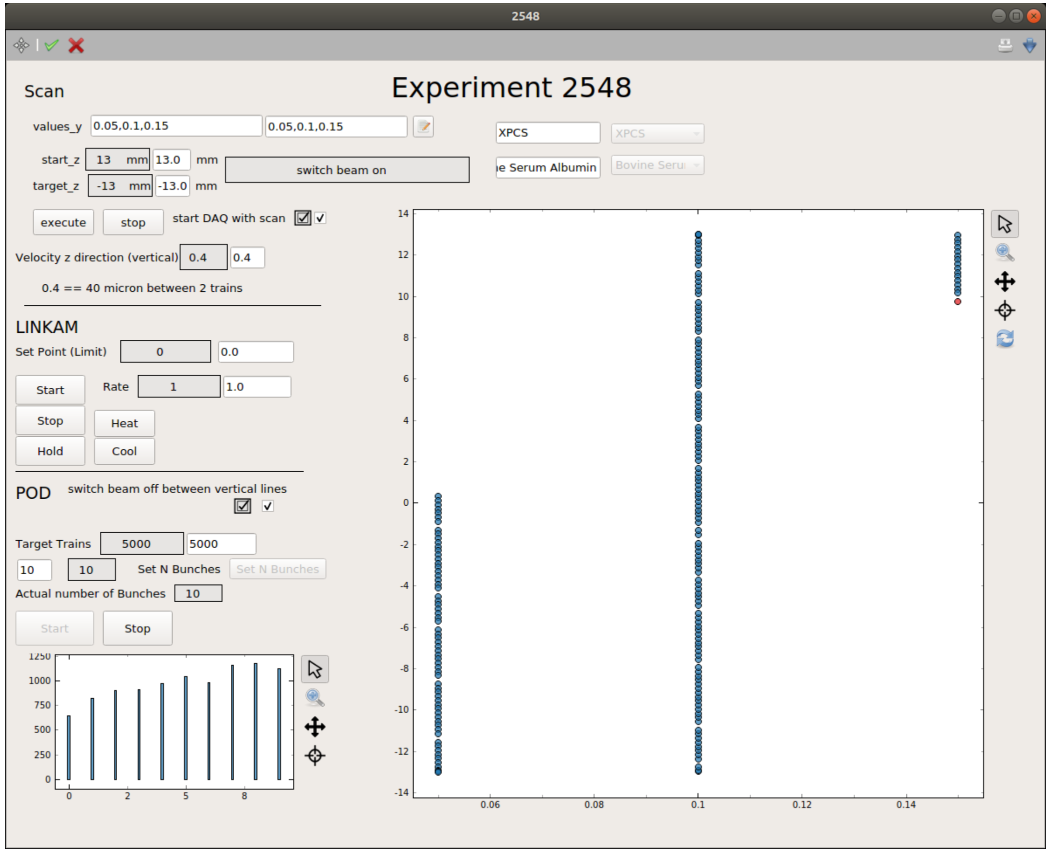
Scenes

DAQ

macros / middlelayers

Customized scenes & macros





- Customized user scenes
  - Visualization of experiment
  - Remote access

- Integrated equipment can be implemented in dedicated macros

- Talk to your local contact!

Corrections & Analysis

➡ **Detectors at the European XFEL**

January 24, 2021, 14:00 CET
Virtual Meeting (Zoom)

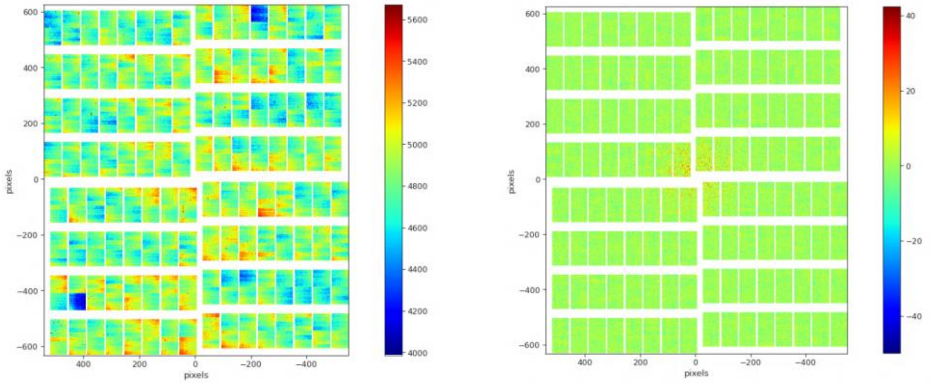
➡ **Data analysis at the European XFEL**

Tuesday, 25 January 2022
Virtual Meeting (Zoom)

https://rtd.xfel.eu/docs/data-analysis-user-documentation/en/latest/index.html

Offline Calibration Pipeline

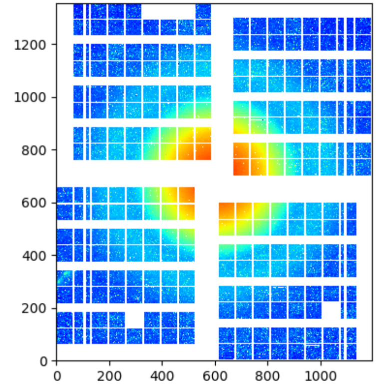
- Many 2D detectors require corrections to process “raw” detector data into analysis-ready “proc”
- Raw data processing (calibration request through myMdC (metadata catalogue, in.xfel.eu/metadata)
- XFEL offline calibration (xfel-calibrate) runs on DESY HPC cluster (Maxwell), jobs are distributed across nodes using SLURM



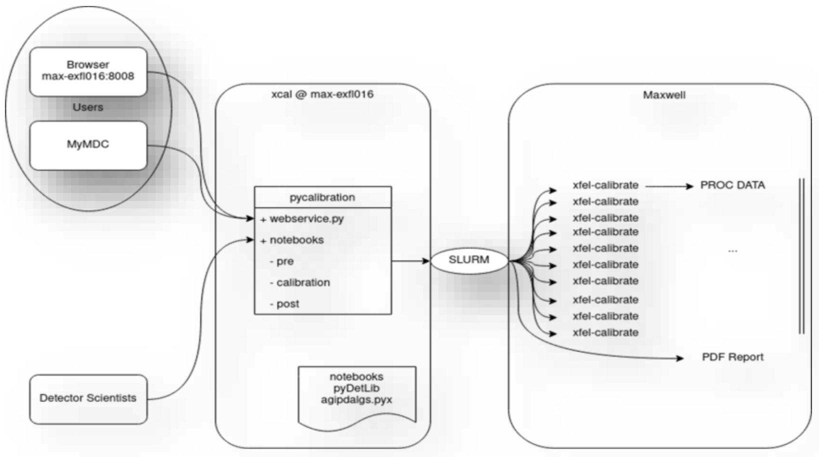
raw

proc

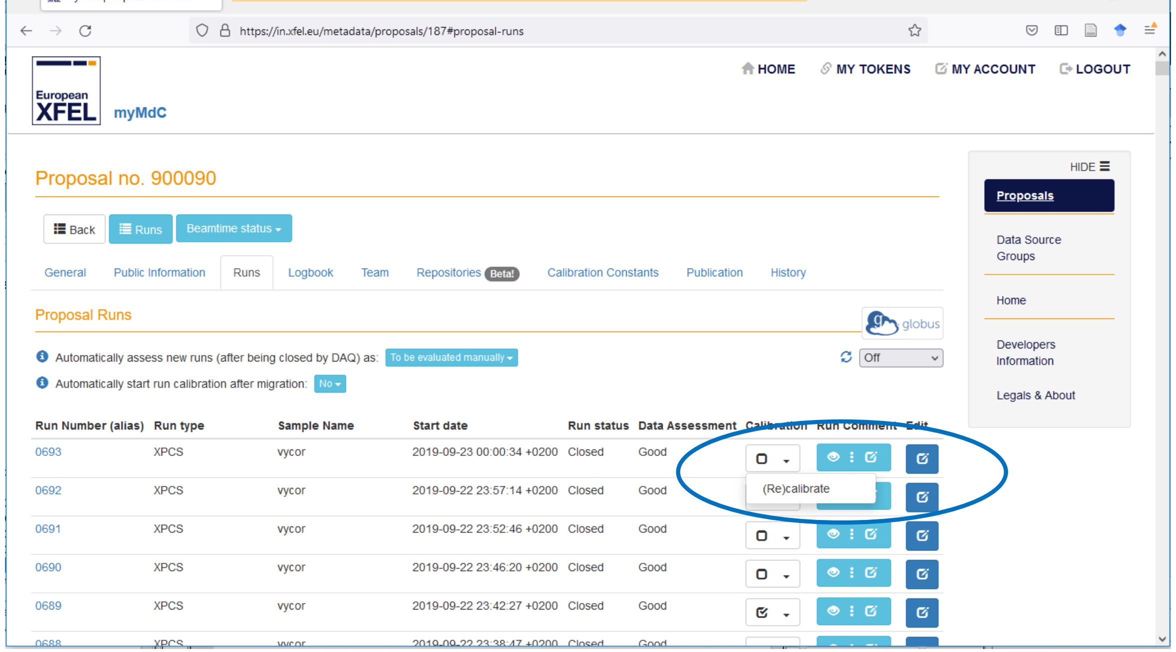
single shot



averaged



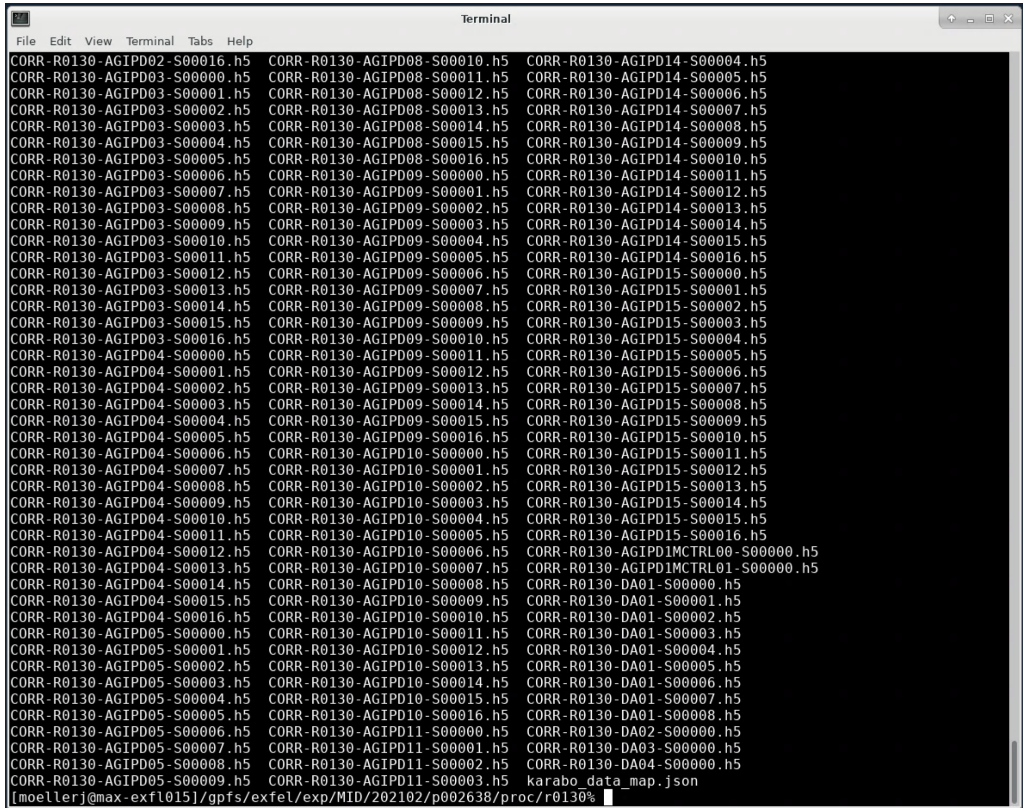
myMdC interface for raw data processing

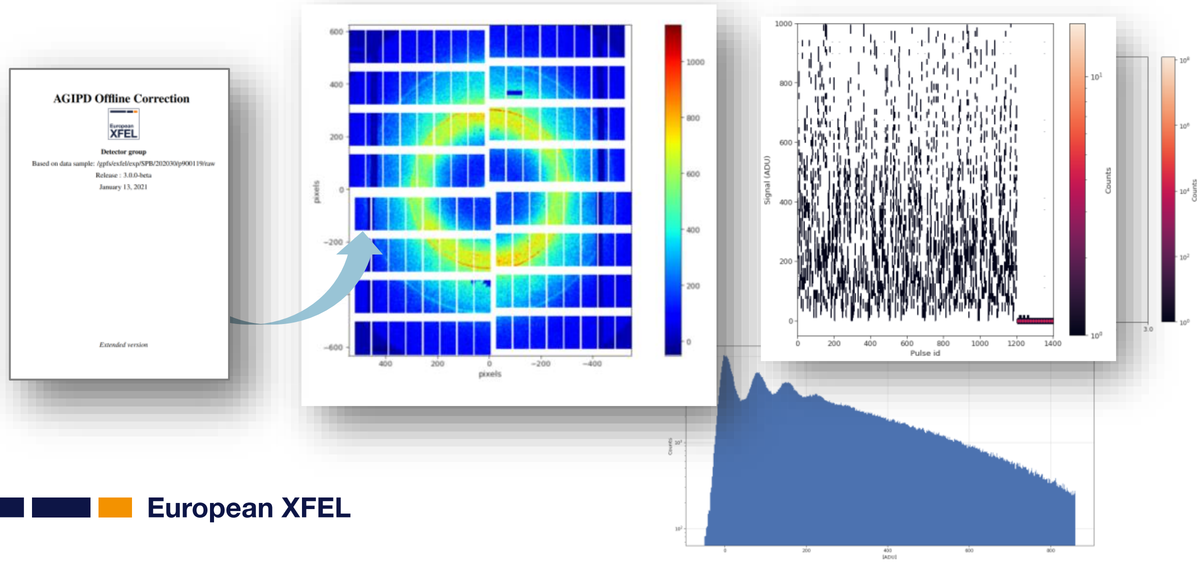


Offline Calibration Pipeline

- Processed data (.h5) and .yml file with calibration metadata is stored in proc/ folder of the proposal

- Automatically generated reports are available for each run in usr/Report folder:
  - Control plots to validate image quality
  - Information about configuration, used calibration constants
  - Configuration of offline corrections is not yet exposed to Users
  - If you spot inconsistencies or you have doubts about the settings: Talk to your local contact!!





EXtra-data

extra-data.readthedocs.io

github.com/european-xfel/extra-data

- Python library for *offline* analysis, designed to give easy access to saved data in runs.
- Opening a run:

```
import extra_data

run = extra_data.open_run(proposal=900193, run=39)
```

- Iterate over all trains in a run as Numpy arrays:

```
agipd = run.select("MID_DET_AGIPD1M-1/DET/*CH0:xtdf", "image.data")
for train_id, data in agipd.trains():
    # Read AGIPD data into a numpy array of shape (pulses, modules, x, y)
    agipd_train = extra_data.stack_detector_data(data, "image.data")
```

- Also supports Pandas and xarray.

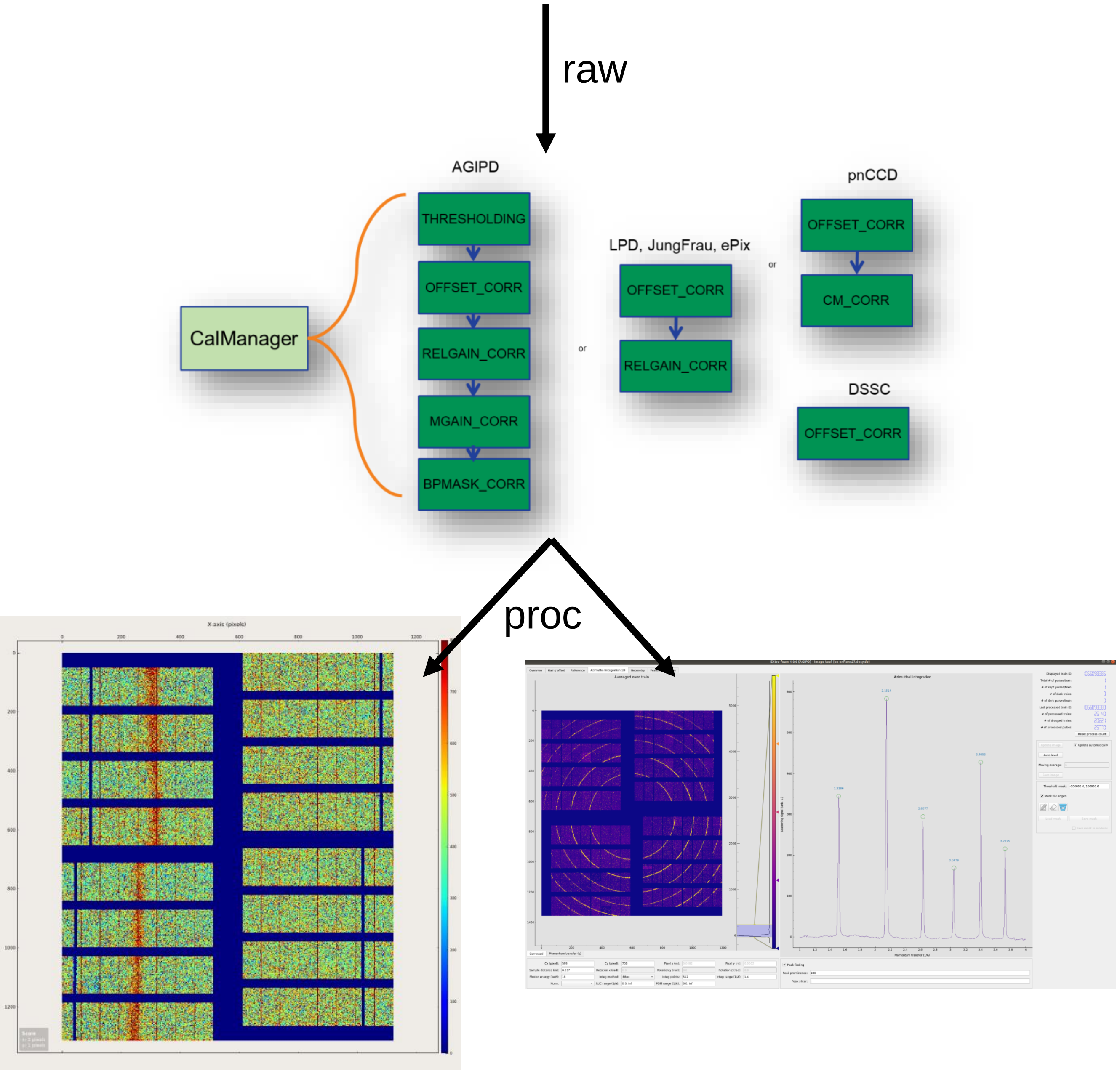
data analysis on the maxwell HPC cluster: https://max-jhub.desy.de

```
In [1]: import extra_data

        run = extra_data.open_run(proposal=2638,run = 130)
        run.info()
```

```
# of trains:    4147
Duration:       0:06:54.7
First train ID: 1166809705
Last train ID:  1166813851

16 detector modules (MID_DET_AGIPD1M-1)
  e.g. module MID_DET_AGIPD1M-1 0 : 512 x 128 pixels
  MID_DET_AGIPD1M-1/DET/0CH0:xtdf
  64 frames per train, up to 265408 frames total

3 instrument sources (excluding detectors):
  - MID_EXP_FASTADC/ADC/DESTEST:channel_3.output
  - MID_RR_SYS/MDL/KARABACON:output
  - SA2_XTD1_XGM/XGM/DOOCS:output

53 control sources:
  - MID_AUXT2_ATT/MDL/ATT
  - MID_AUXT2_ATT/MOTOR/ROD1_IN_OUT
  - MID_AUXT2_ATT/MOTOR/ROD2_IN_OUT
  - MID_AUXT2_ATT/MOTOR/ROD3_IN_OUT
  - MID_AUXT2_ATT/MOTOR/ROD4_IN_OUT
  - MID_DET_AGIPD1M/CC/MON_0
  - MID_EXP_AGIPD1M/GAUGE/PG1
  - MID_EXP_AGIPD1M/MOTOR/Q1M1
  - MID_EXP_AGIPD1M/MOTOR/Q1M2
  - MID_EXP_AGIPD1M/MOTOR/Q2M1
  - MID_EXP_AGIPD1M/MOTOR/Q2M2
  - MID_EXP_AGIPD1M/MOTOR/Q3M1
  - MID_EXP_AGIPD1M/MOTOR/Q3M2
  - MID_EXP_AGIPD1M/MOTOR/Q4M1
  - MID_EXP_AGIPD1M/MOTOR/Q4M2
  - MID_EXP_AGIPD1M/PSC/HV
  - MID_EXP_AGIPD1M/TSENS/H1_T_EXTHOUS
  - MID_EXP_AGIPD1M/TSENS/H2_T_EXTHOUS
  - MID_EXP_AGIPD1M/TSENS/Q1_T_BLOCK
  - MID_EXP_AGIPD1M/TSENS/Q2_T_BLOCK
  - MID_EXP_AGIPD1M/TSENS/Q3_T_BLOCK
  - MID_EXP_AGIPD1M/TSENS/Q4_T_BLOCK
  - MID_EXP_AGIPD1M1/CTRL/MC1
  - MID_EXP_AGIPD1M1/CTRL/MC2
  - MID_EXP_AGIPD1M1/FPGA/MASTER_H1
  - MID_EXP_AGIPD1M1/FPGA/MASTER_H2
  - MID_EXP_AGIPD1M1/MDL/FPGA_COMP
  - MID_EXP_FASTADC/ADC/DESTEST
  - MID_EXP_KEITHLEY/CTRL/KEITHLEY_2611
  - MID_EXP_SYS/TSYS/UTC-2-S4
  - MID_EXP_UPP/CTRL/LSHORE
  - MID_EXP_UPP/MOTOR/R7
```

Online Calibration Pipeline

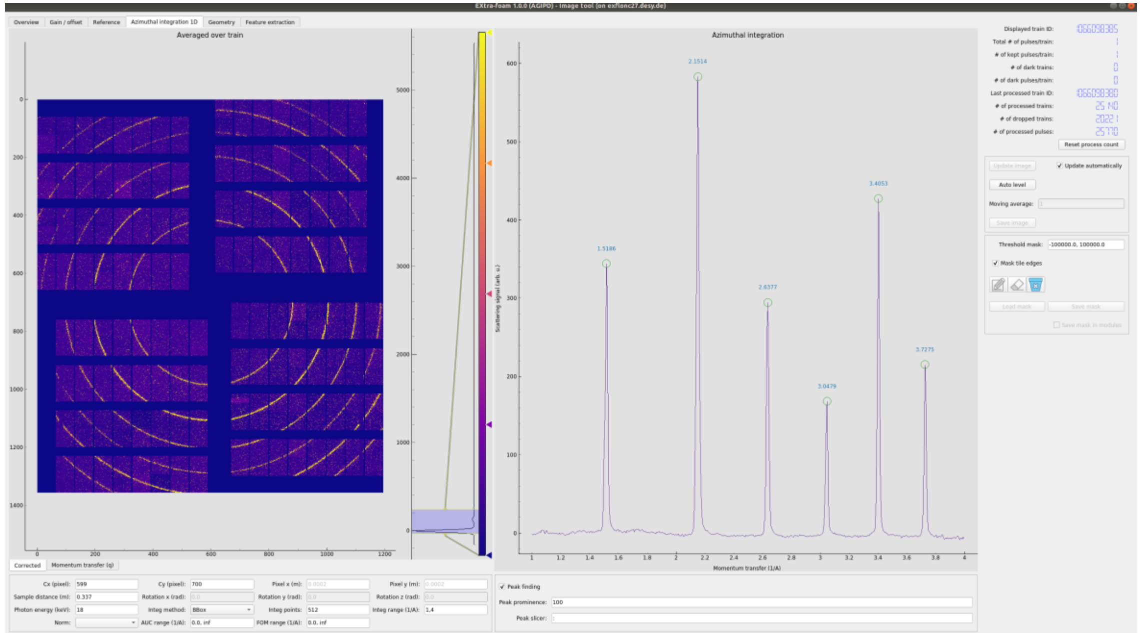
- Online calibration:
  - Correction of data “on-the-fly” with limited number of corrections
  - Possibility to interface external analysis tool via Karabo bridge
  - Next generation pipeline with improved performance in development
  - For analysis during the experiment only
    - ▶ No files saved
    - ▶ Offline calibration



EXtra-foam

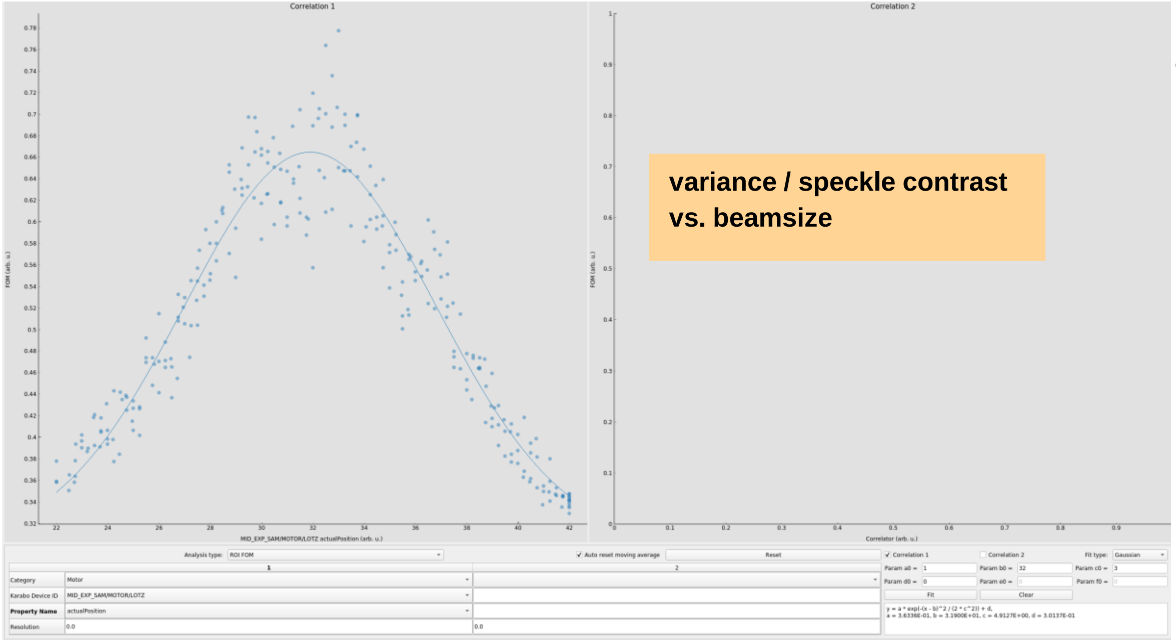
`extra-foam.readthedocs.io`

`github.com/european-xfel/extra-foam`

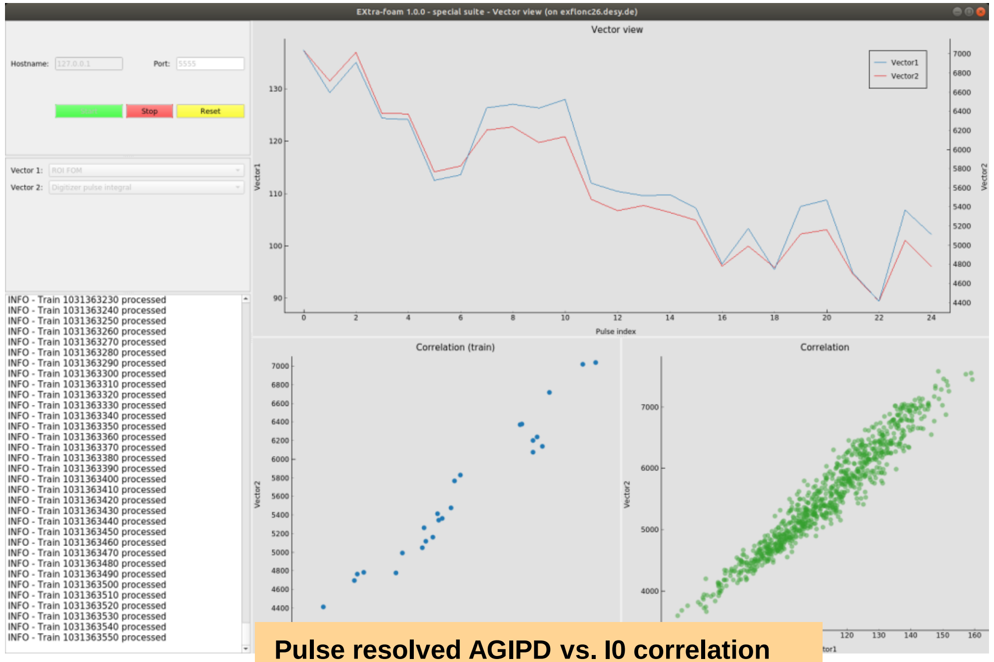


- **F**ast **O**nline **A**nalysis **M**onitor
- Graphical program for *online* analysis.
- Supports features such as:
  - Azimuthal integration
  - ROI analysis (histogramming, correlations, normalization)
  - Feature extraction (concentric rings, edge detection)
- Good for commonly used kinds of analysis.

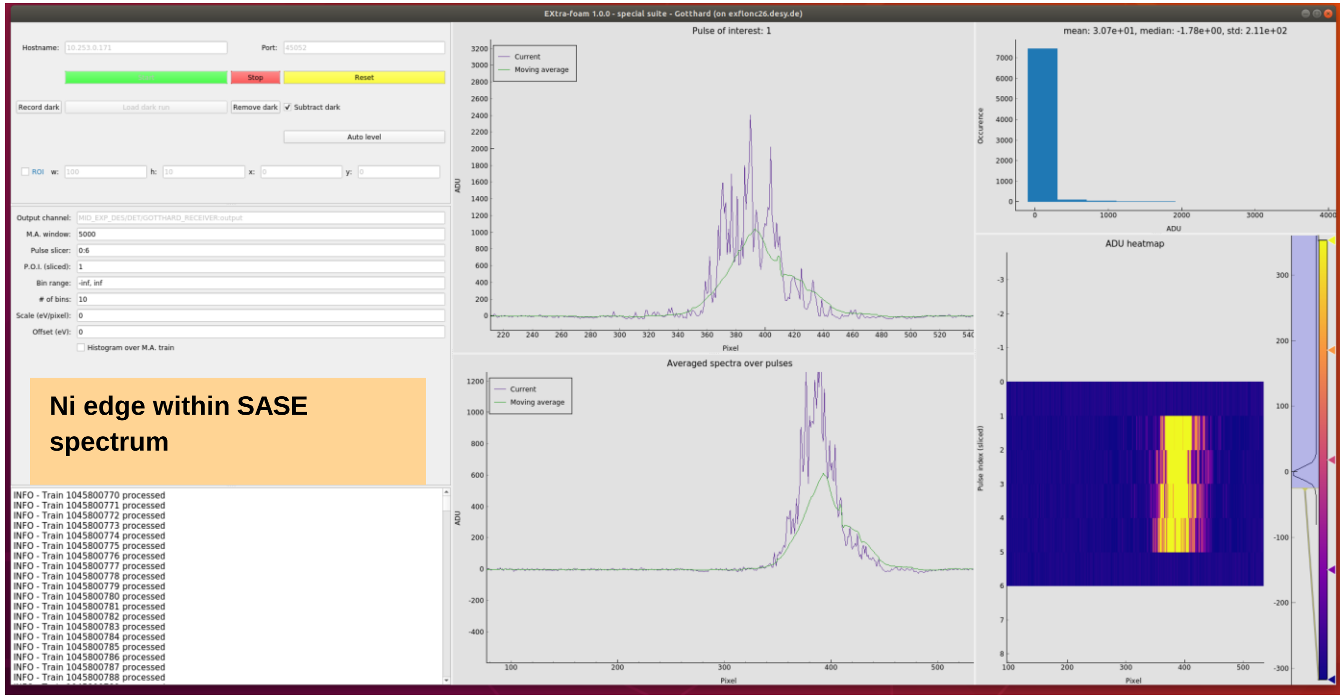
some examples



variance / speckle contrast vs. beamsize



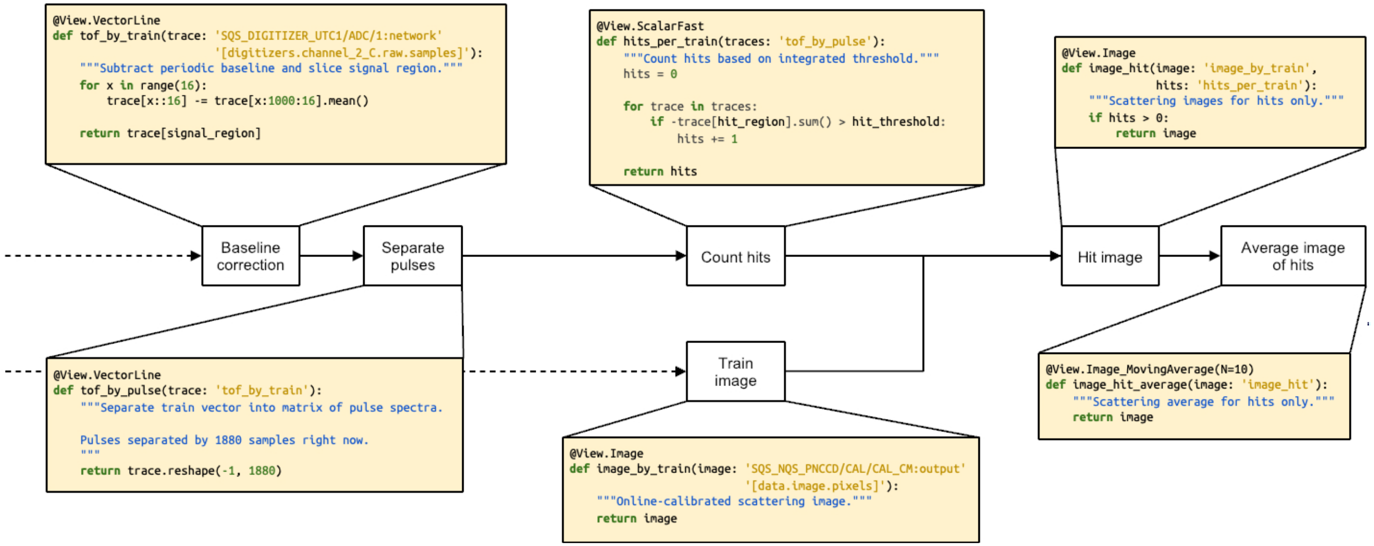
Pulse resolved AGIPD vs. I0 correlation



Ni edge within SASE spectrum

EXtra-metro

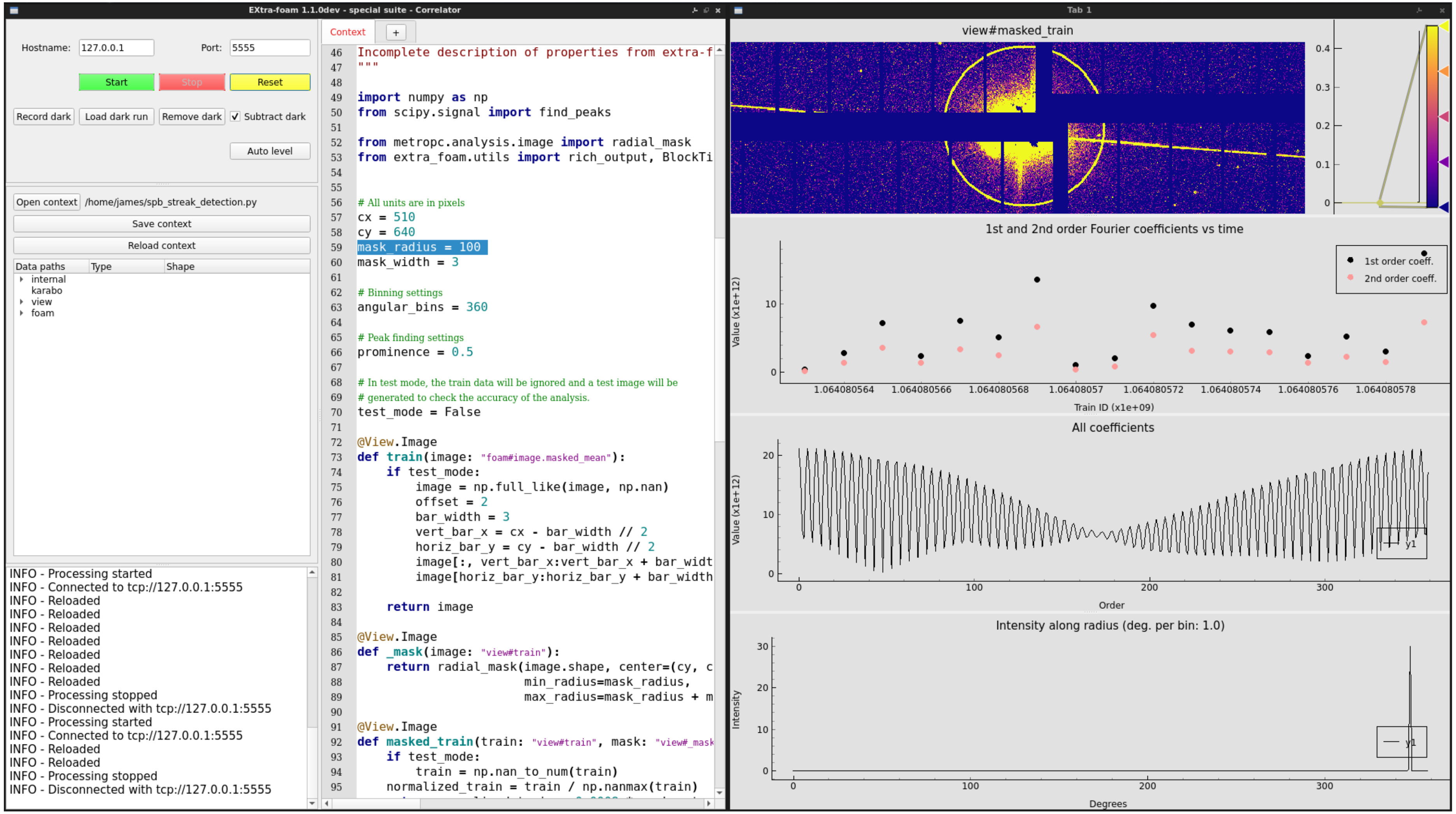
https://desy.de/~schmidtp/metropc-docs



- Processing framework for *online* analysis, not a GUI program.
- Very flexible, all pipelines are written as Python scripts and may be reloaded on-the-fly.
- Well suited for specialized analysis.
- Integrated in Karabo and EXtra-foam for control and visualization.

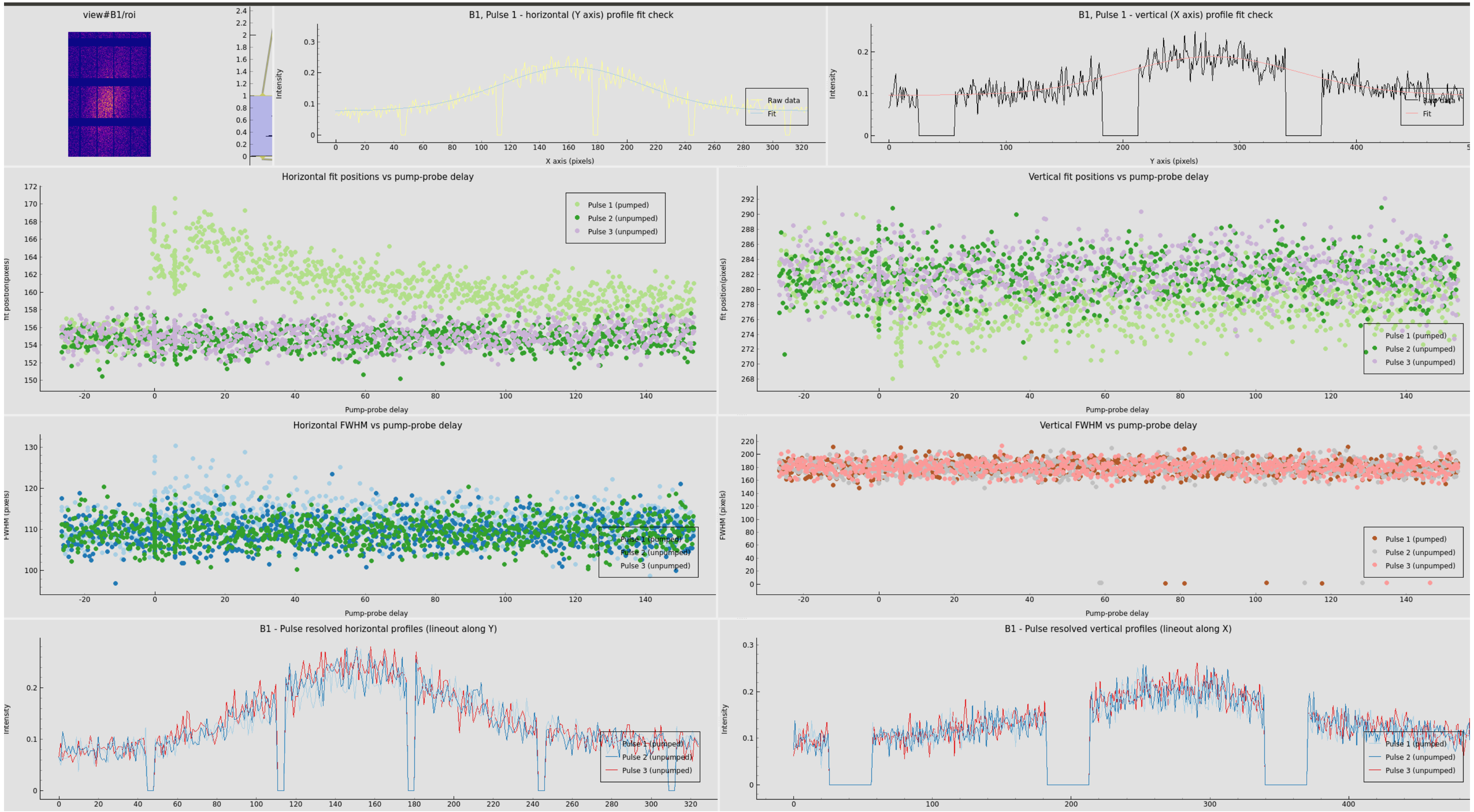
EXtra-metro + EXtra-foam

- Combining GUI interfaces for visualization, masking, ROI definition, …
  - + flexibility of customizable, simple analysis code
- Customizable GUI windows for display of results



One example

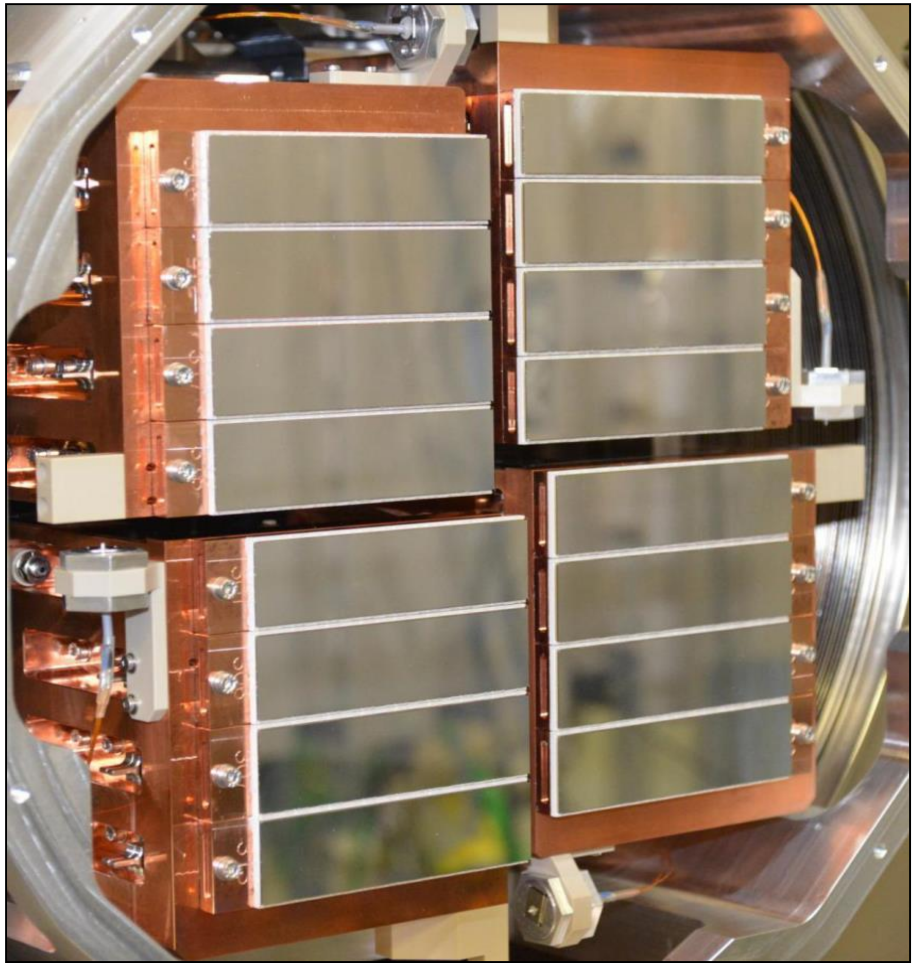
- Pulse resolved, pump-probe Bragg peak analysis



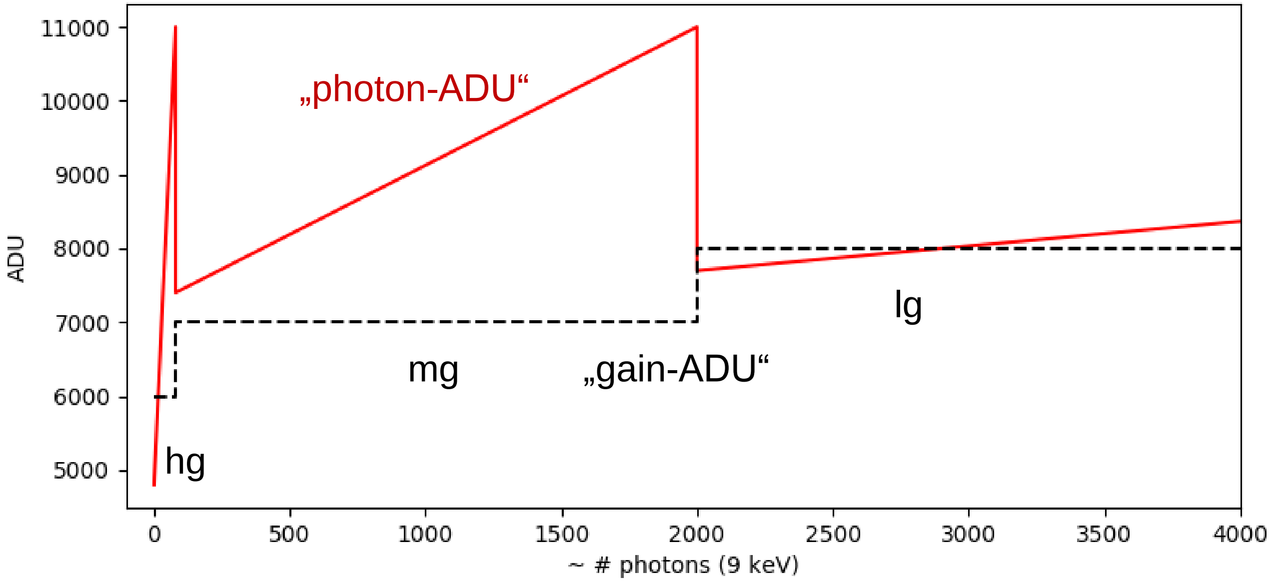
12:30 Thursday,
Plenary session,
A. Stierle (DESY)

AGIPD

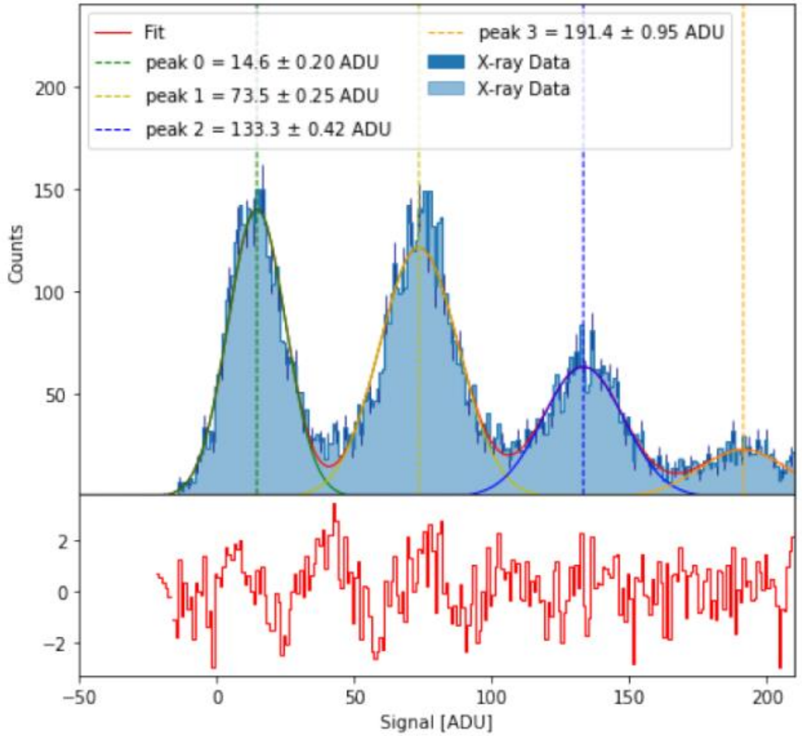
Adaptive Gain Integration Pixel Detector AGIPD



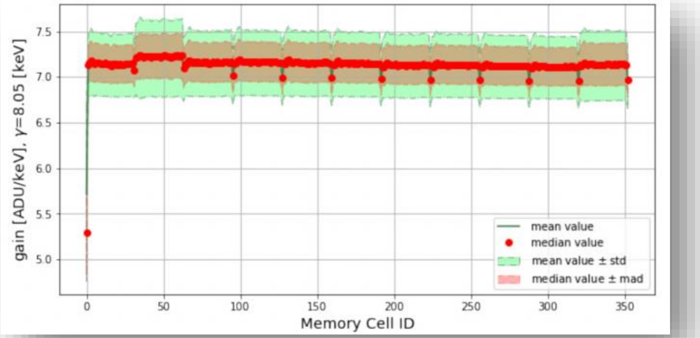
- 1M Pixel
- pixel size 200x200um^2
- Capable of 4.5MHz
- 352 storage cells (352 images/train)
- Single photon sensitive
- Up to 10^4 photons/pixel with 3 gain

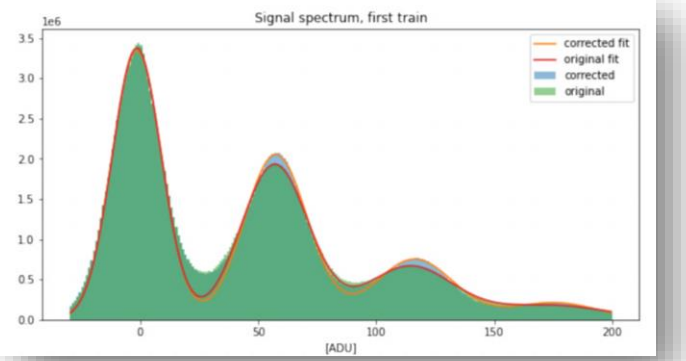


Flatfields

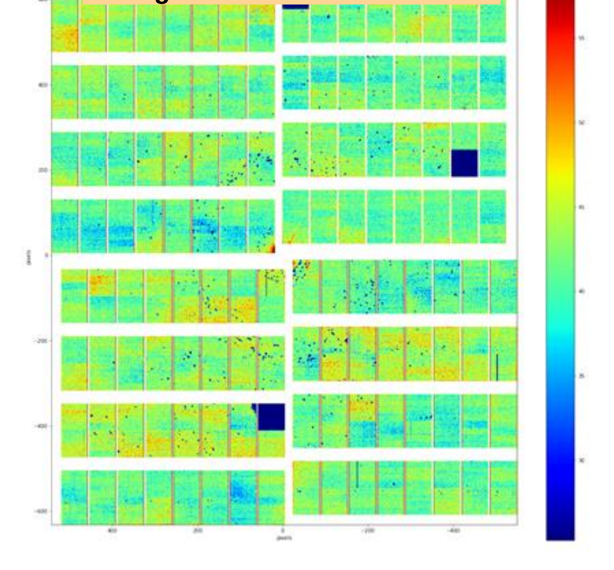


Gain values vs. mem.cell

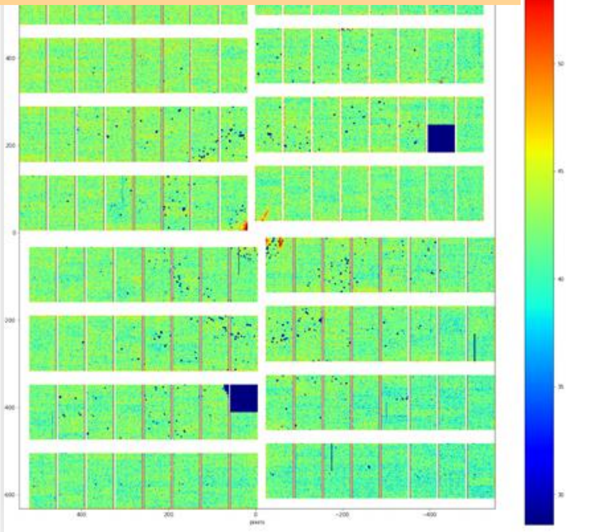




Average img. from one train w/o gain corrections



Average img. from one train with gain corrections

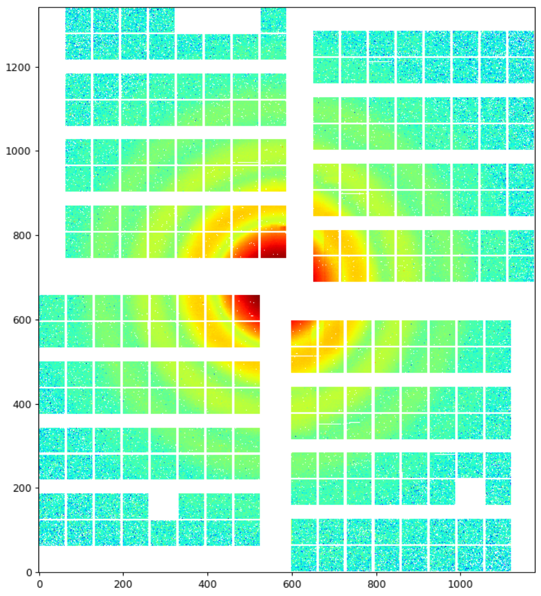


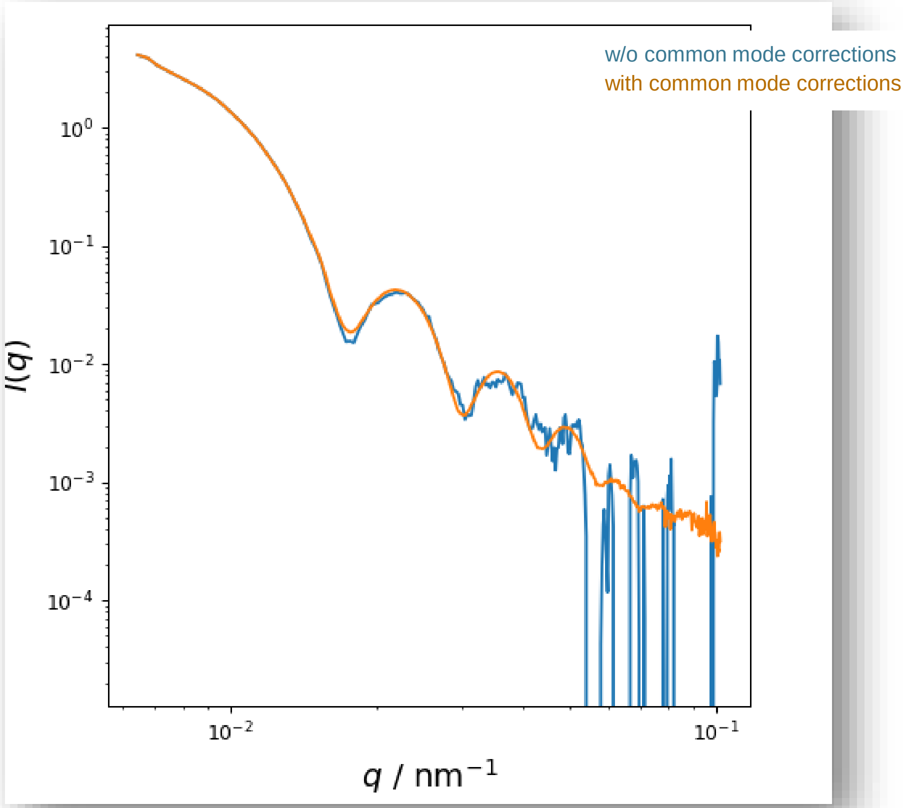
- Development and validation of high gain calibration with single photon peaks (gain maps per pixel and mem. cell)

Common mode

- Pedestals can fluctuate, drift and jump on various timescales
  - Single shot <-> hours
  - Deviations from “dark constant”
    - ► Non-zero contribution of dark pixels

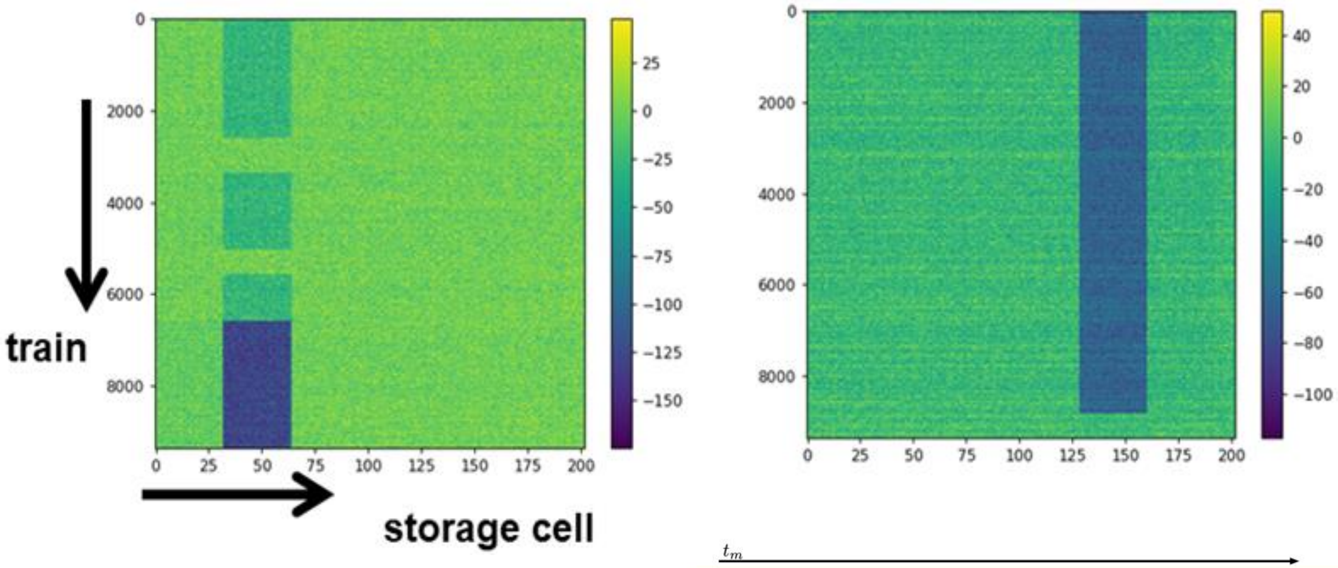
- AGIPD common mode correction
  - More precise pedestal subtraction
  - Identifies empty pixel within single ASIC and empty storage cells within one pixel
  - Subtraction of mean

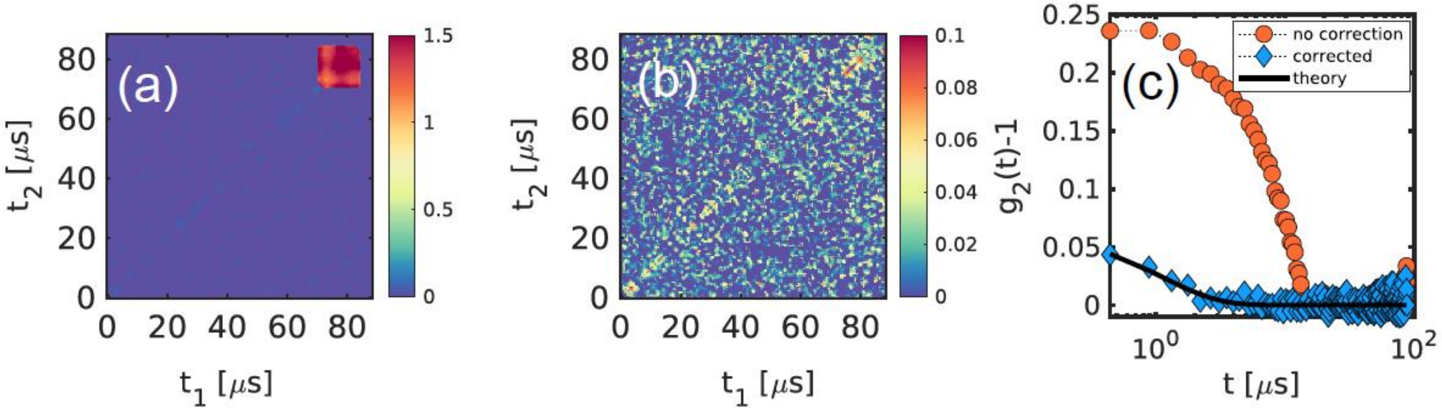


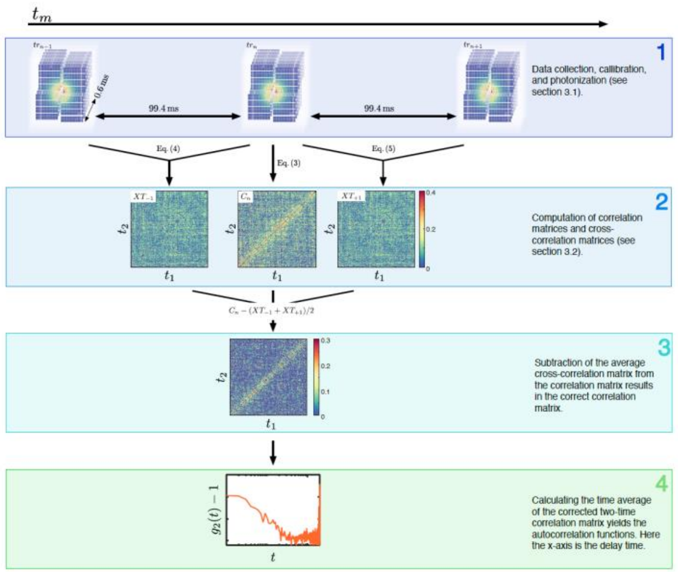


Jumping pixels and XPCS

- Pedestals can fluctuate, drift and jump on various timescales
  - Jumps are rare but correlated
  - Amplitude of jump: up to 1 photon
    - ► Negligible for most analysis
    - ► Serious artifact for XPCS
      - • Remove by intra-train cross correlation





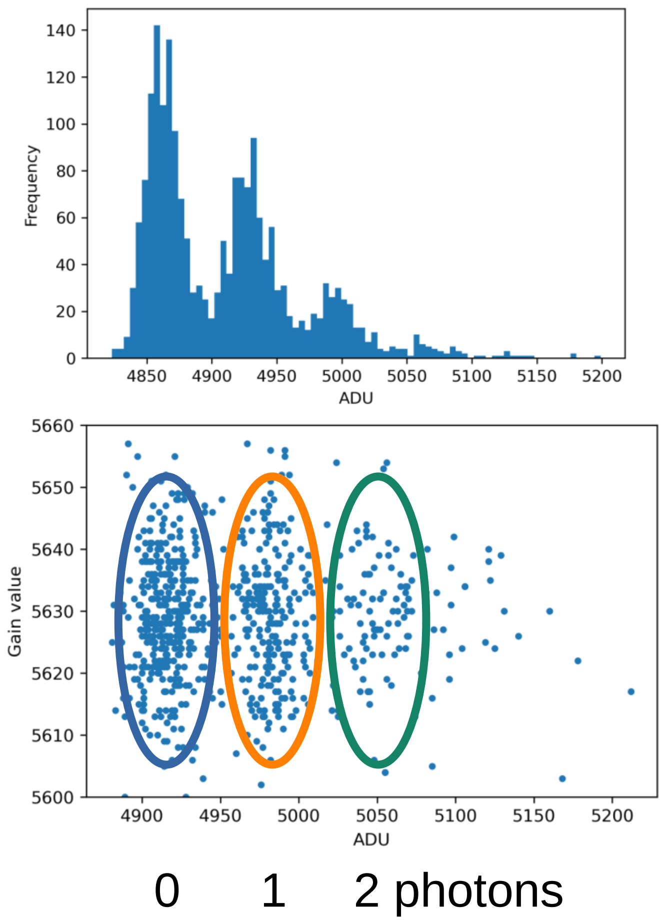


11:15 F. Dallari
11:45 M. Reiser

Dallari, Reiser, et al., (2021) *Appl Sci*, **11**, 8037

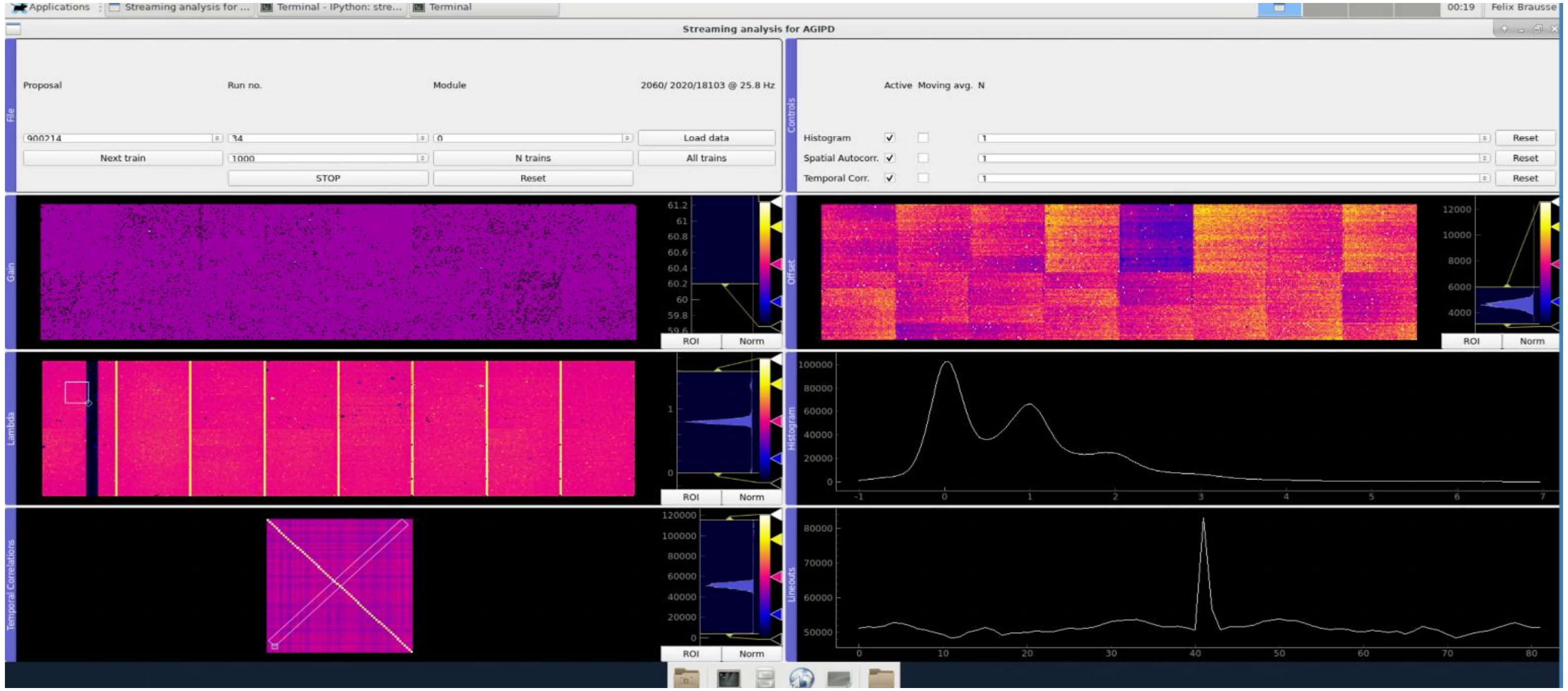
R&D Project GOAST: GPU-Computing for calibration & online analysis

- Online analysis of AGIPD data requires very efficient algorithms, especially when temporal or spatial correlations are desired due to the enormous amount of data per second
- We are exploring GPU-based **streaming algorithms,** which incrementally update calibration constants and analysis results with every processed image → ideal for live operation
- Online calibration is based on **on-the-fly fitting** of a pixel's histogram (zero- and one-photon peak)
- At low count rates (<<1 phot/pix/pulse), we can use the GPU to remove all zero counts (saves storage on the order 1 minus count rate!)



Tuesday 14:00,
DA workshop,
F. Brauße

R&D Project GOAST: GPU-Computing for calibration & online analysis



Tuesday 14:00,
DA workshop,
F. Brauße

- Prototype of a streaming algorithm for calibration and online analysis under development together w/ experimental GUI for processing stored data
- Photon statistics, temporal correlations (XPCS) and spatial correlations (speckle analysis) implemented
- Processing rate > 100 Hz for 1 module, 352 memory cells (planned to run on GPU cluster to process all 16 modules)
- First live tests planned for spring

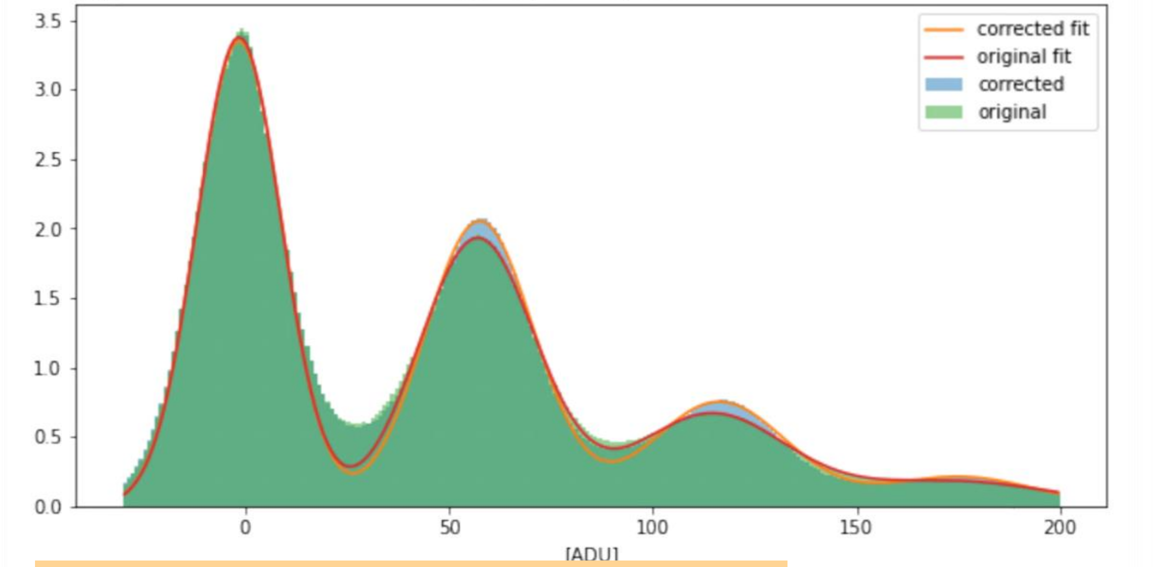
High-high gain mode

- two possible settings of the CDS stage
  - normal CDS – high CDS
  - Correlated double sampling buffer
  - U. Trunk et al., Proc. of SPIE, 10328, 1032805-1

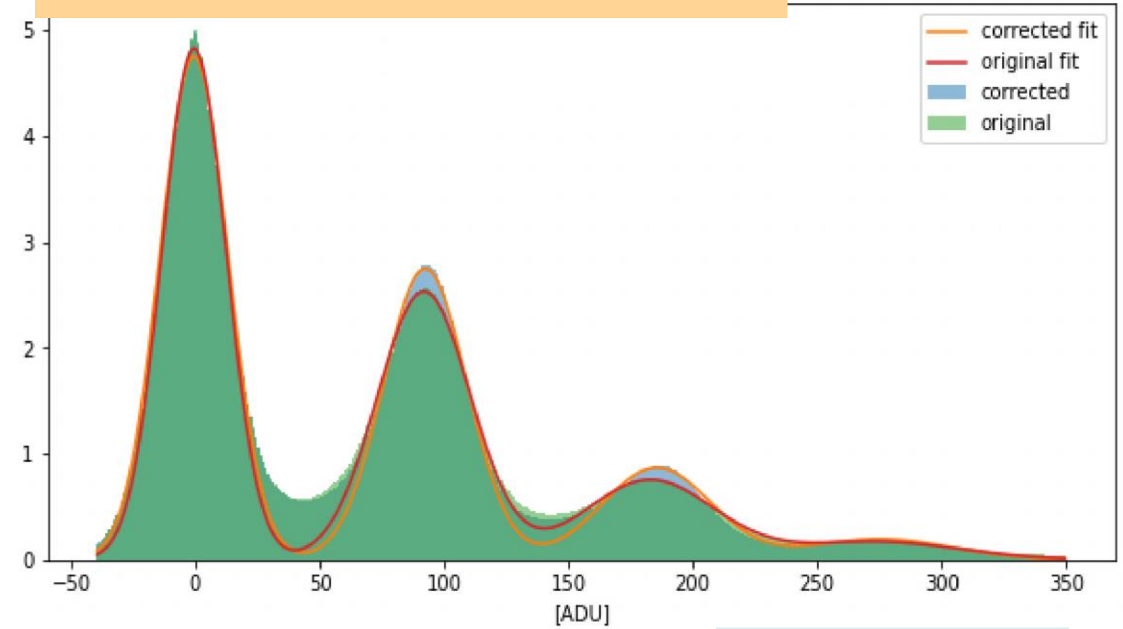
- normal CDS mode used as default so far
  - high CDS
    - ► Higher gain
    - ► Earlier (less photons required) gain switching
    - ► Less noise (1.3 keV → ~0.9 keV)

- Fixed gain mode for further reduced noise to be commissioned in the future

Cu fluorescence in default-high gain mode



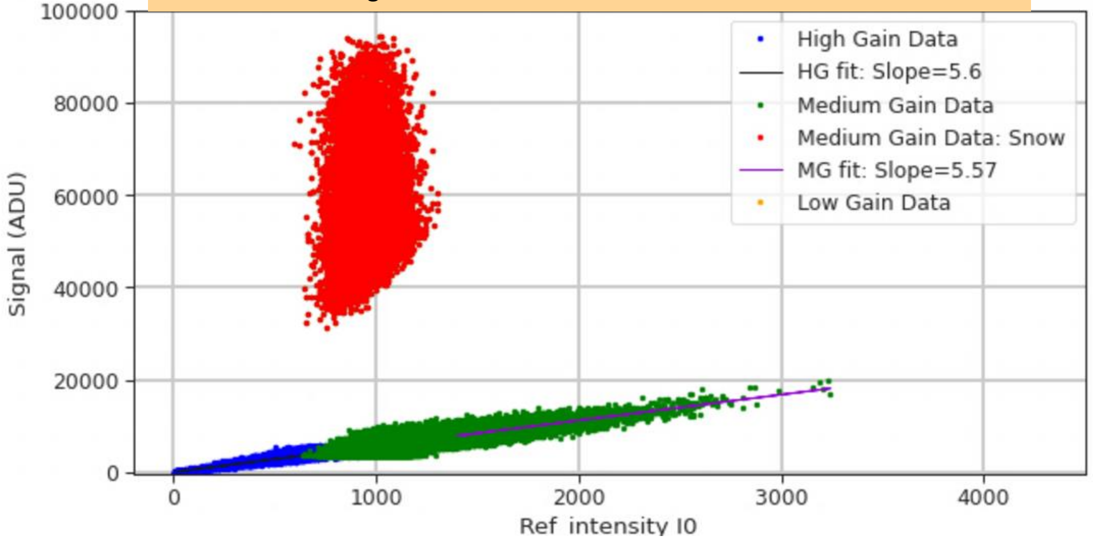
Cu fluorescence in high-high gain mode



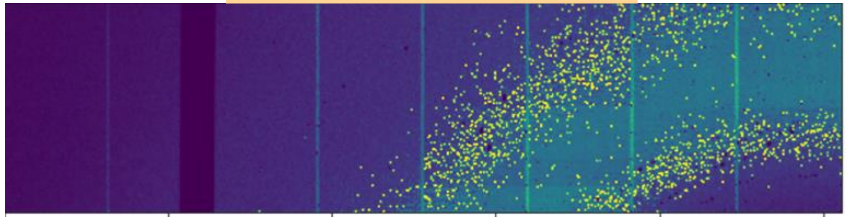
→ 10:45 F. Trost

HG-MG gain switching

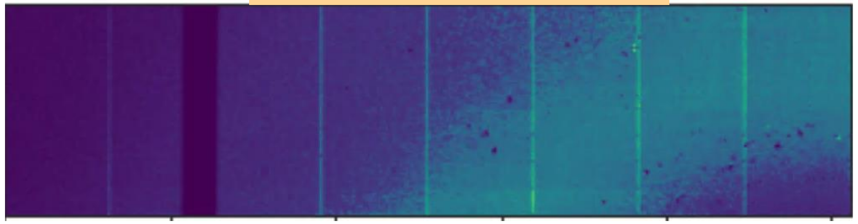
Intensity scan (single pixel, all mem. cells) – 'default' operation with 120 ns integration time

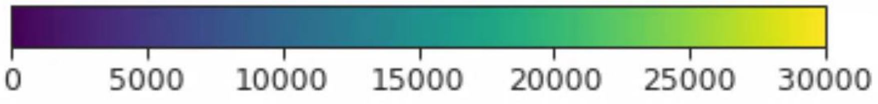


Water ring - 120 ns int. time



Water ring - 200 ns int. time





- Measured intensity close the switching point between HG and MG
  - Artificially high intensities (so called snowy pixels)
  - Intensity discontinuity
- Work on understanding and the transition region is ongoing:
  - Longer integration time for operation below 4.5 MHz
  - X-ray data collected at SPB/SFX (water jet ring) → reduction of "snowy pixels" by two orders of magnitude
  - Noise increase by 3-4 %data (collected in August)

Future operation scenarios for AGIPD

- High-high gain operation
  - ▶ High-CDS mode
  - ▶ default integration time 120 ns
  - Reduced noise (1.3 keV → ~0.9 keV)
  - For data below < 20-30 ph/pix/shot
  - up to 4.5 MHz

- Large dynamic range mode
  - ▶ Normal-CDS setting
  - ▶ increased integration time 200 ns
  - Less “snowy” pixel during gain switching
  - Increased noise (3-4%)
  - <u>Only up to 2.2 MHz</u>

Thank you for your attention!

- https://www.xfel.eu/facility/instruments/mid/index_eng.html
  - Mid-info@xfel.eu

- https://rtd.xfel.eu/docs/data-analysis-user-documentation/en/latest/index.html