Overview, experience and first results of MTCA applications at European XFEL Experiments

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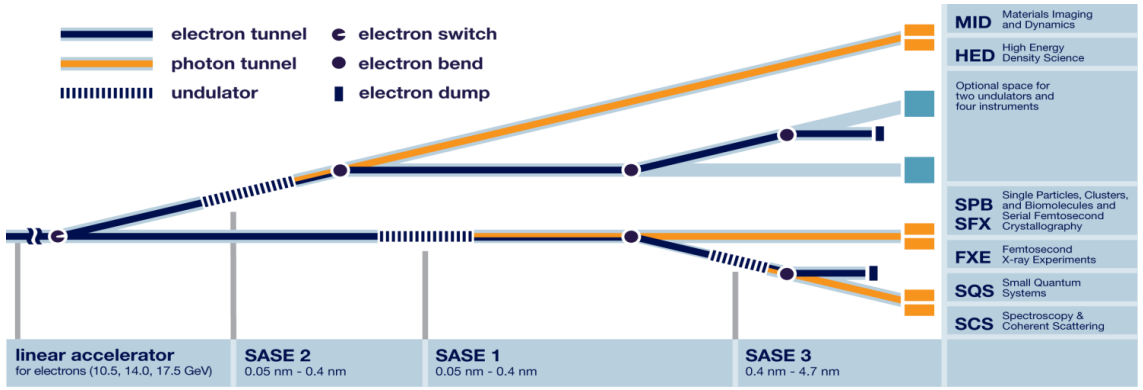
Advanced Electronics

Hamburg, 6 December 2018

XFEL Overview



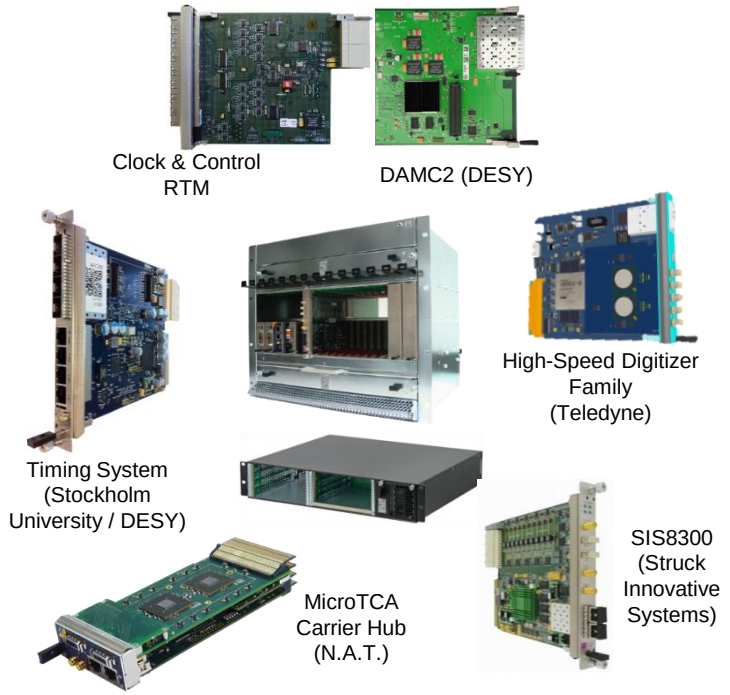
- The European XFEL generates up to 2700 X-Ray pulses
  - Inter pulse separation of 220 ns
  - Train repetition of 10 Hz
- First user operation started in September 2017

Lasing in all three Undulators simultaneously

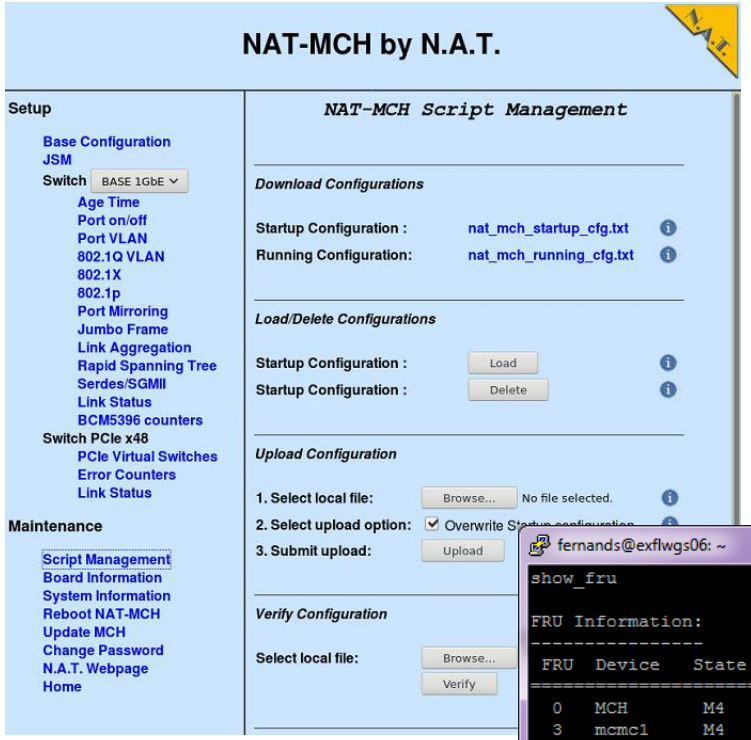
Installation went smoothly

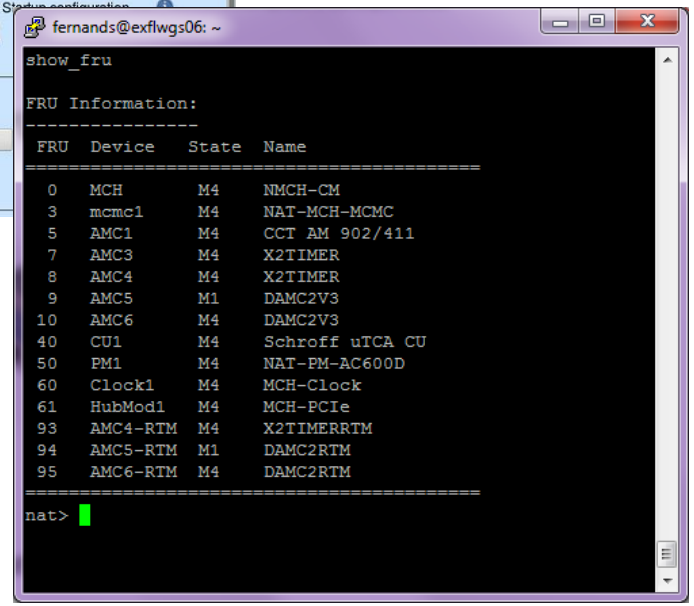
- At photon beam lines, experiments and related laboratories at XFEL are **34 MicroTCA crates**
  - A lot of challenges had to be overcome and we are still learning
- MicroTCA platform is **the key component** for
  - Timing distribution (both in and outside the crate)
  - Digitizer raw and process data
  - Detector triggering and synchronization
- As such we must have
  - Workflows for installation, monitoring and diagnostics
  - Tools that allow us to quickly identify and solve problems

    ► and also show that "**MicroTCA is not the issue**"



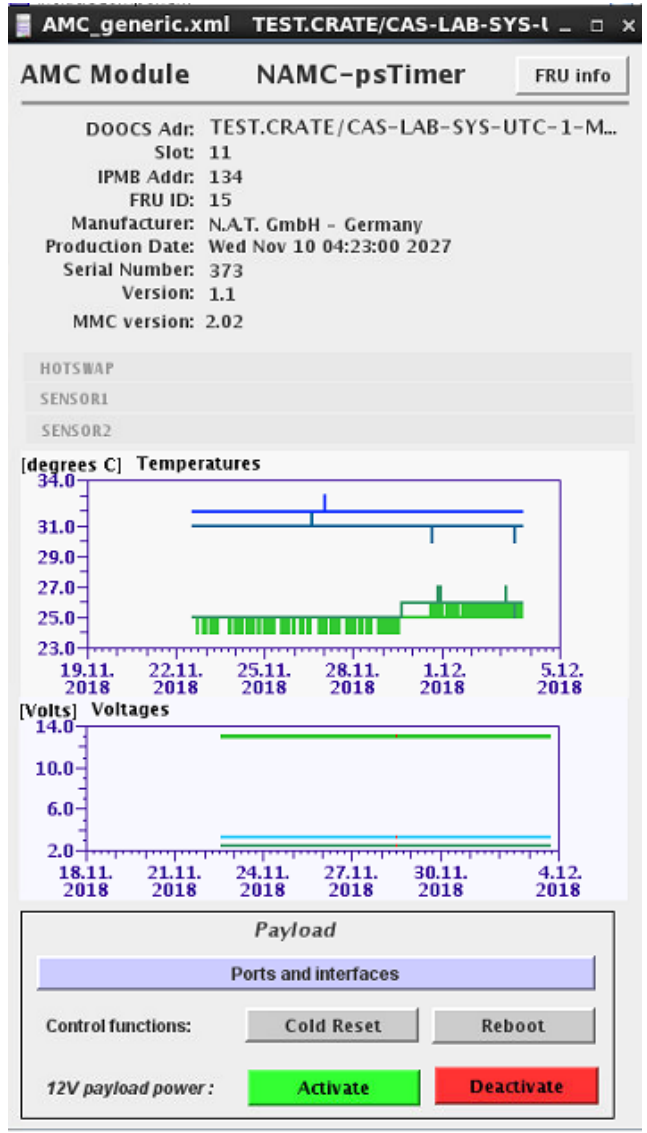
MCH Boards





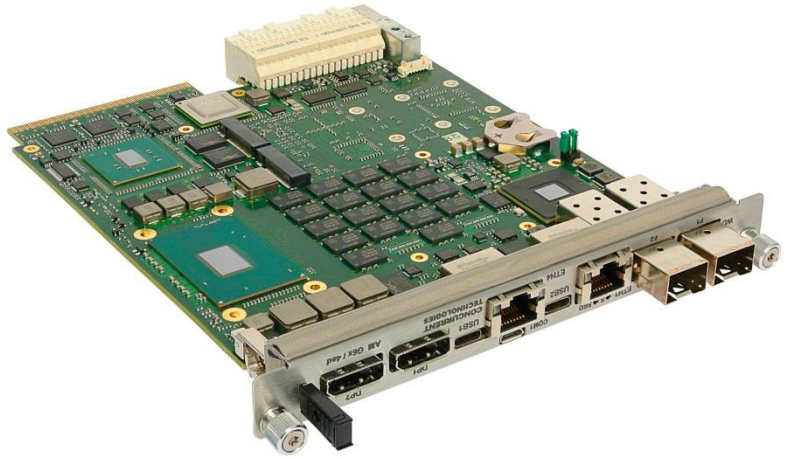
- MCHs use configuration files uploaded via browser interface
  - Most common options are covered by this procedure
  - Remote access via ssh, telnet and browser

Remote crate management



- jDDD Panels to quickly verify content of crate and board sensors
- Quick access to certain functions
  - Control Fans, reboot boards, control payload power…

CPU installation with Foreman and Puppet



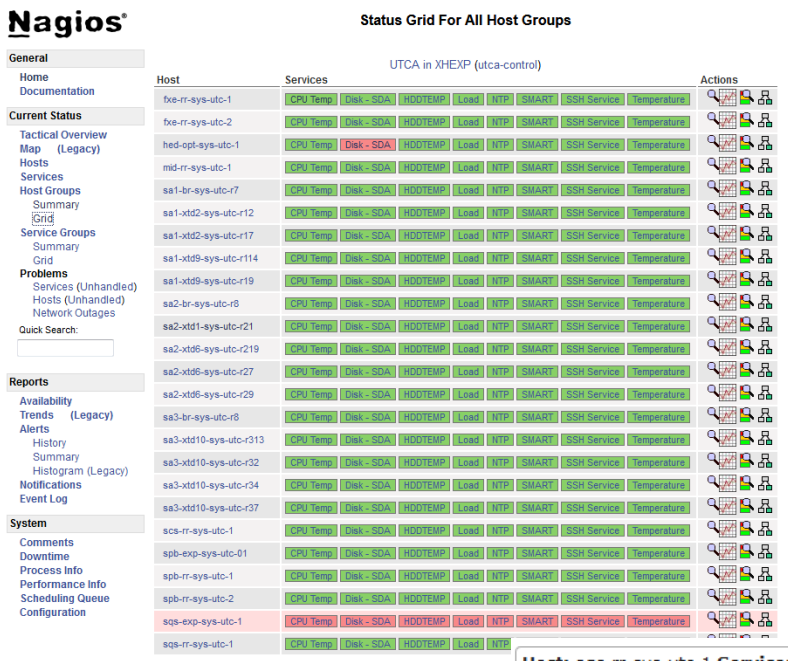
- OS installation + Puppet **via network**
  - New CPU shows up on Network
    - ► Foreman install OS and configures target Puppet Manifest
  - Monitor Host resources

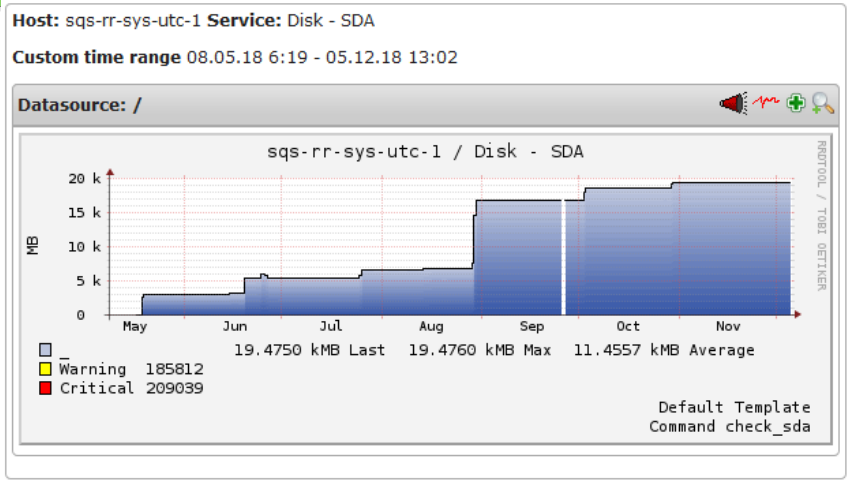
- Software, drivers, repositories, users, groups, permissions, network, etc.
- Different system types – tunnel, laboratories, rack room, development, instruments….

Nagios monitoring

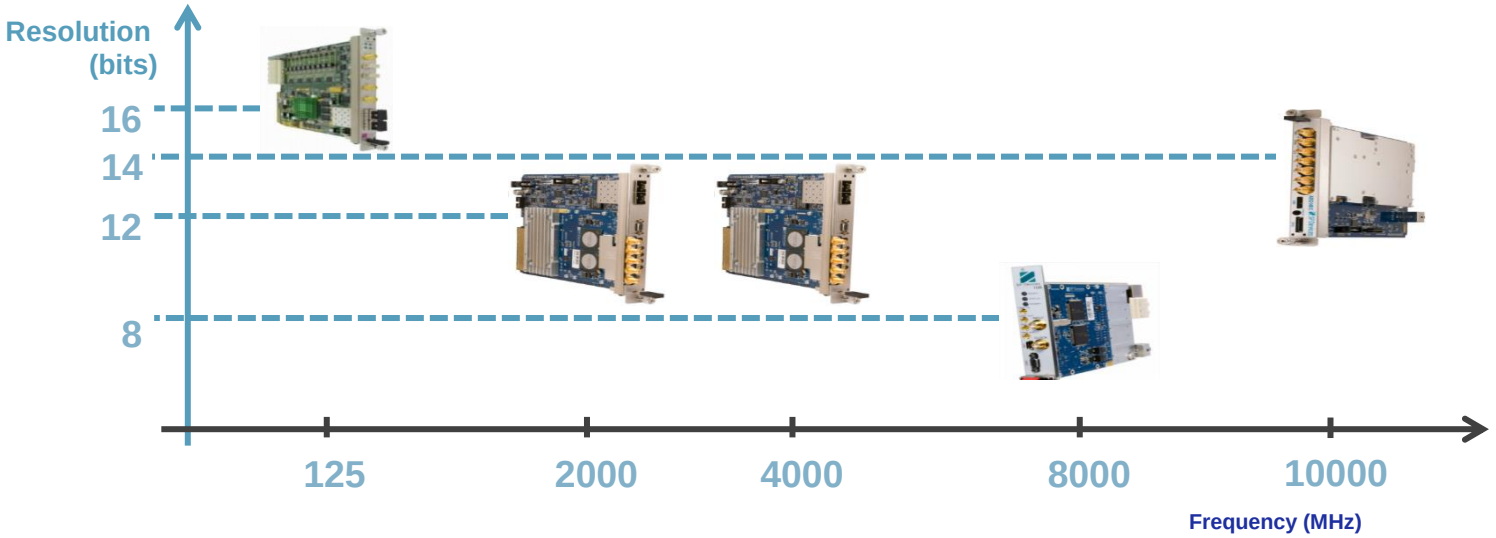
- Automatically send emails for the following situations:
  - CPU/MCH down
  - CPU Temperature/Sensors at critical level
  - Hard disk almost full /Temperature
  - NTP service running
  - SSH service running

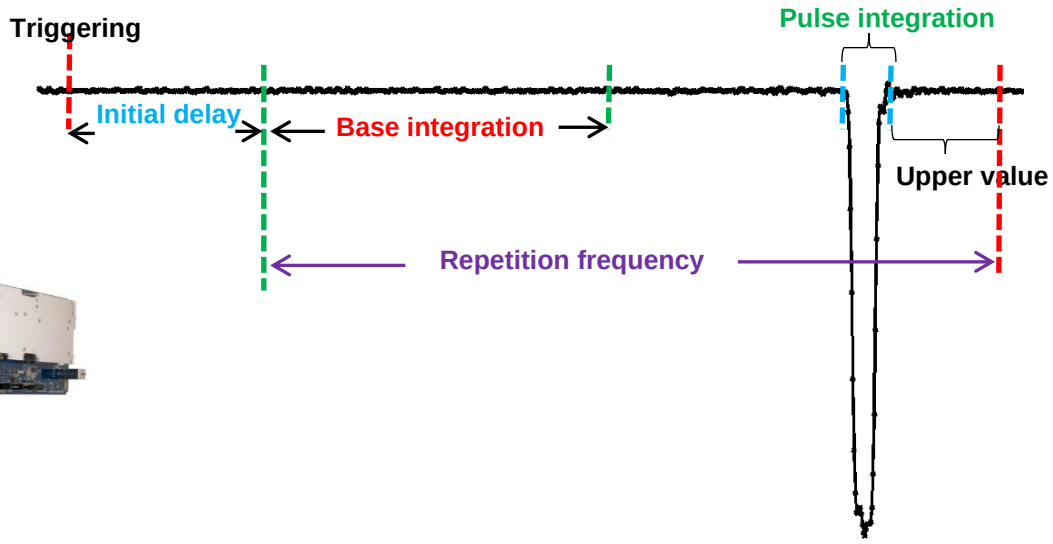
- SMS sent to On call Duty phones
  - Immediate reaction to problems

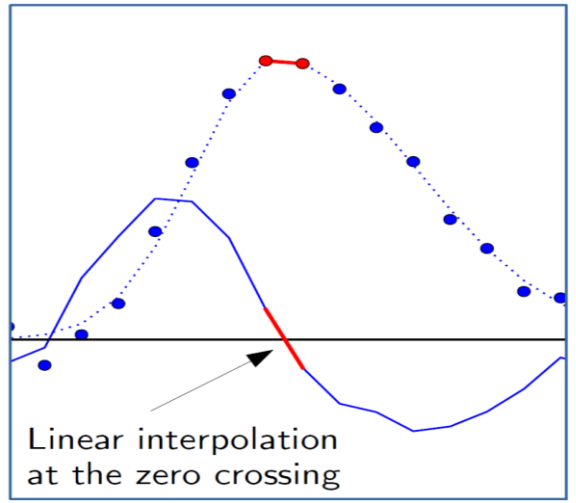




FPGA Digitizers



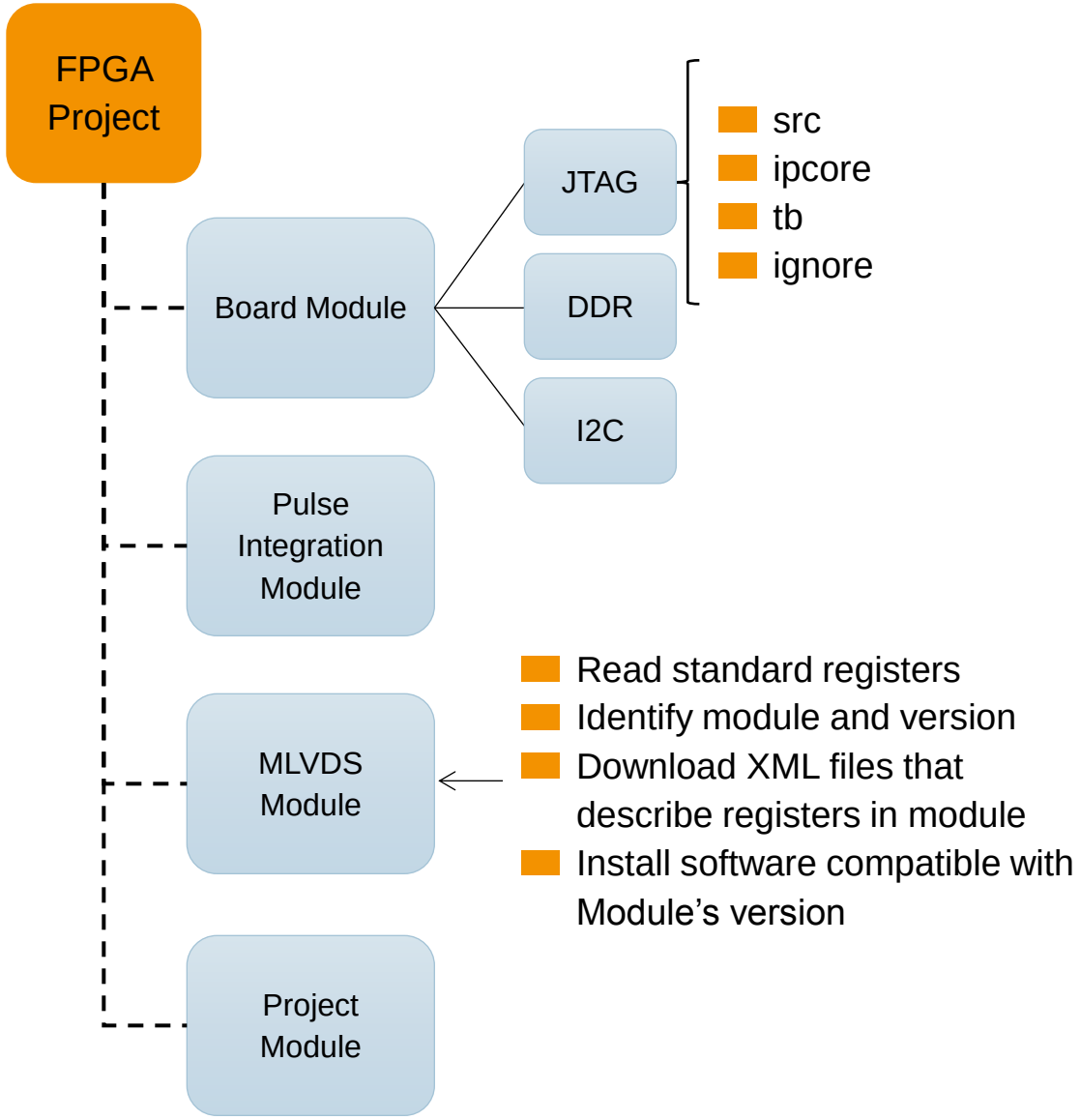




- Hardware Signal Processing
  - Most colleagues are right now interested in the **raw data**
  - **Peak Integration**, **Peak Detection** , Zero Surpression

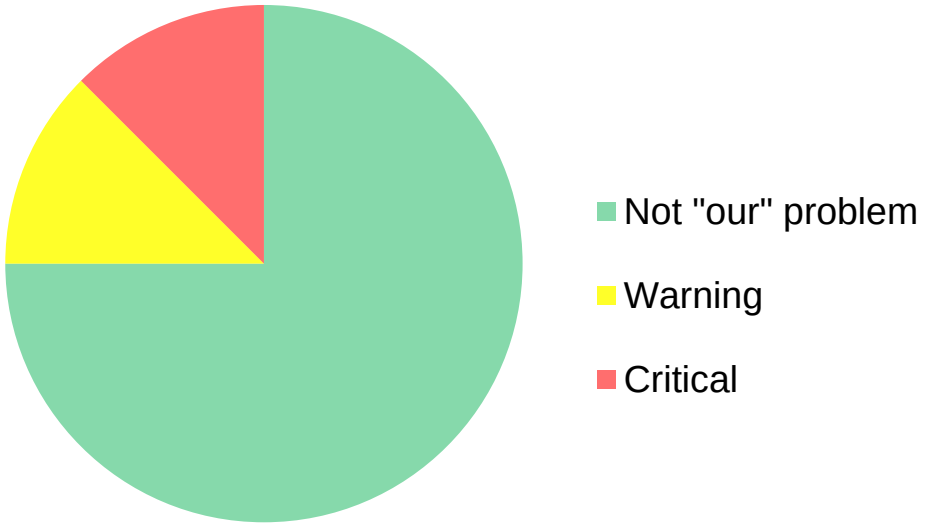
FPGA Development

- FPGA development will increase in the near future as colleagues get more and more familiar with the data
  - Specialized FPGA projects per instrument group/experience
- Process of migration to GIT
  - Standard folder structure for both Modules and Board projects
    - ► Scripts to automatize generation of FPGA configuration files depending on requirements
  - Use of GIT submodules for FPGA modules
- Standard Structure of FPGA projects
  - Automatic installation of software devices to communicate with the hardware and its modules



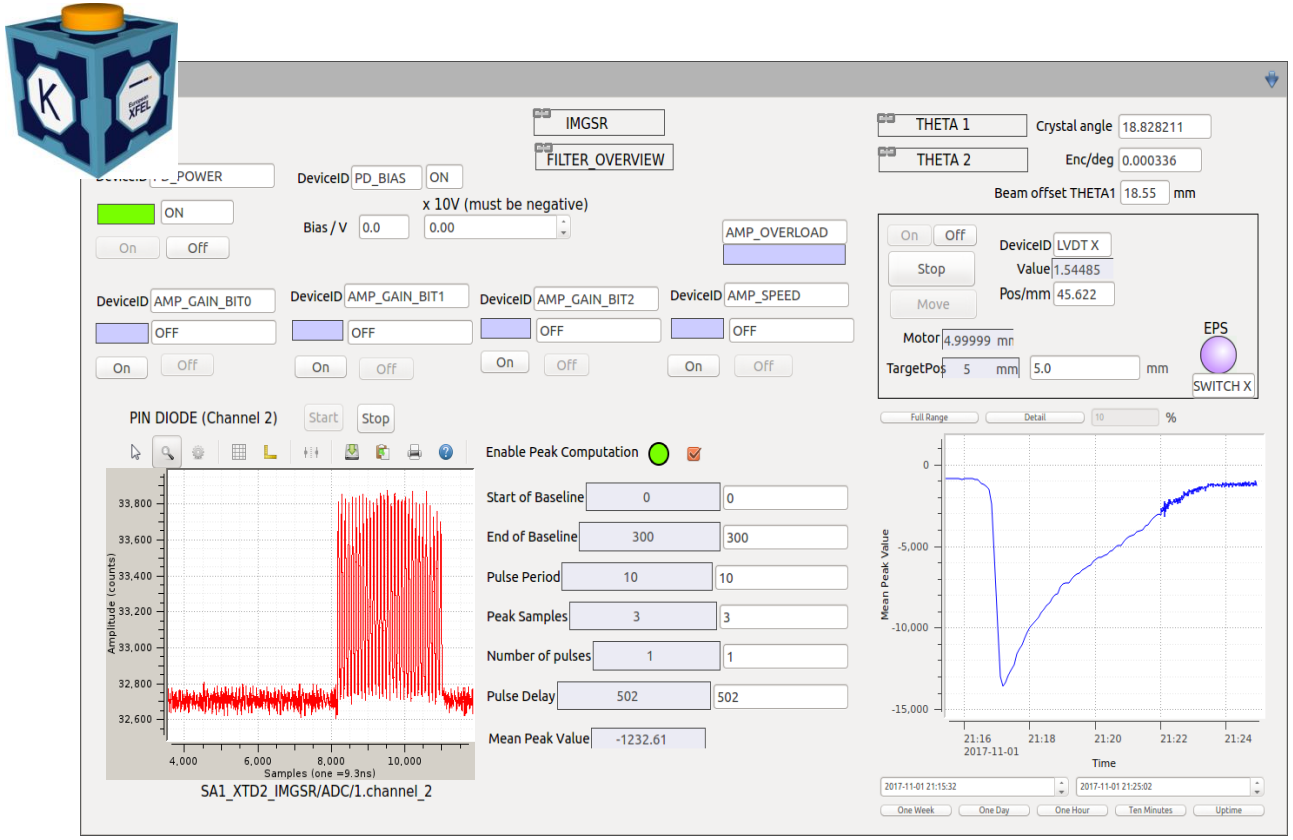
One year in operation

- The MicroTCA On Call duty has significant **low activity** when compared to other XFEL groups
  - In total there were **8 calls** made to our group first year of operation
  - Stability of MicroTCA and XFEL's FPGA solutions

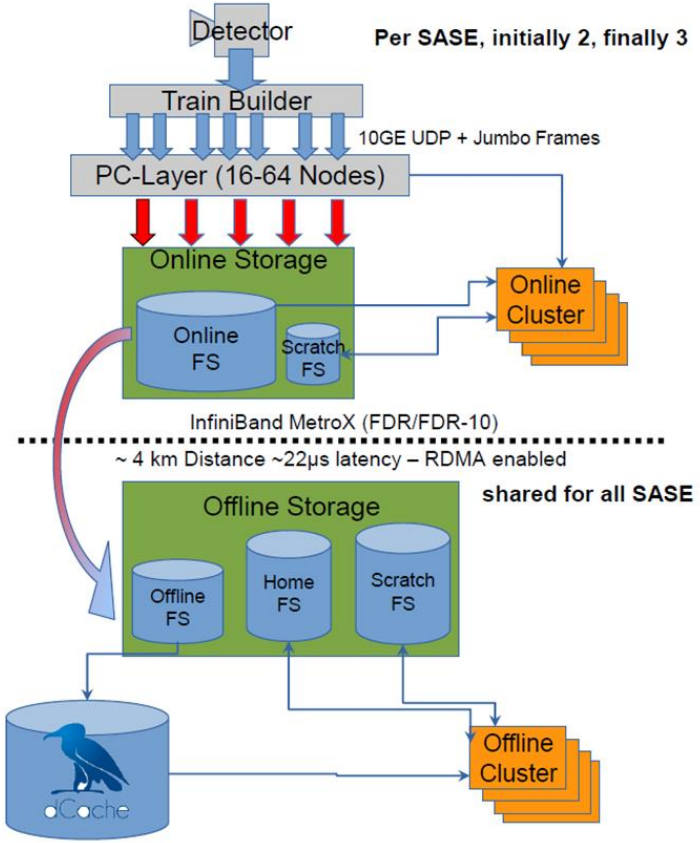


XFEL Applications

Karabo integration

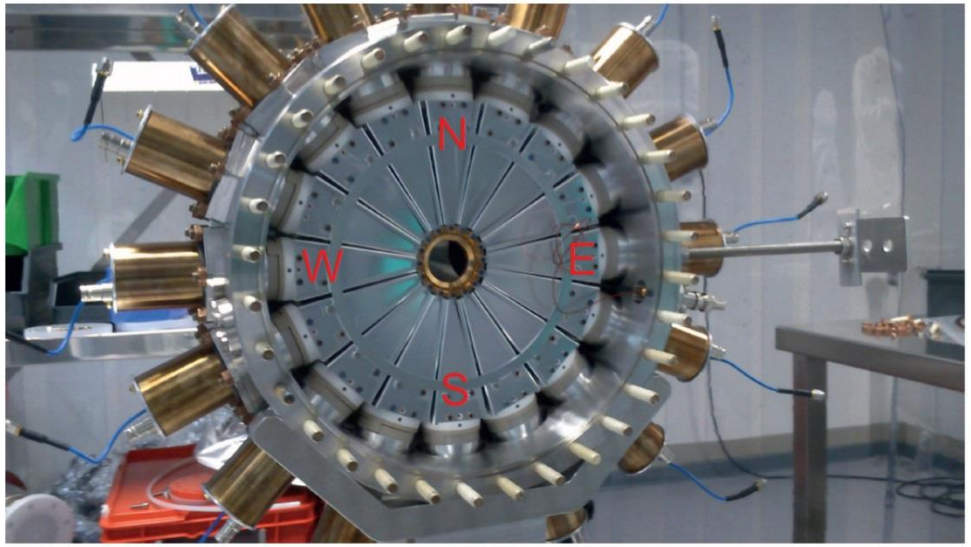


- **Data storage via XFEL DAQ System**
  Digitizer data from SQS group
  - Commissioning: **8020.78 GB** (few months)
  - First user beam time: **5139.58 GB** (5 shifts)



Diagnostics Group - PES

- Photo-Electron Spectrometer (PES): Pulse resolve information
  - Spectral distribution and (Horizontal) Polarization
  - On each Dirfttube (N, NNE, NE, E…) a voltage is applied
  - Target gas is injected, an X-Ray pulse ionizes it and photo electrons are ejected anisotropically
    ► Small fraction are register by the detectors
  - Based on time of flight, time difference between ionization to detection – related kinetic energy of particle



Diagnostics Group - PES

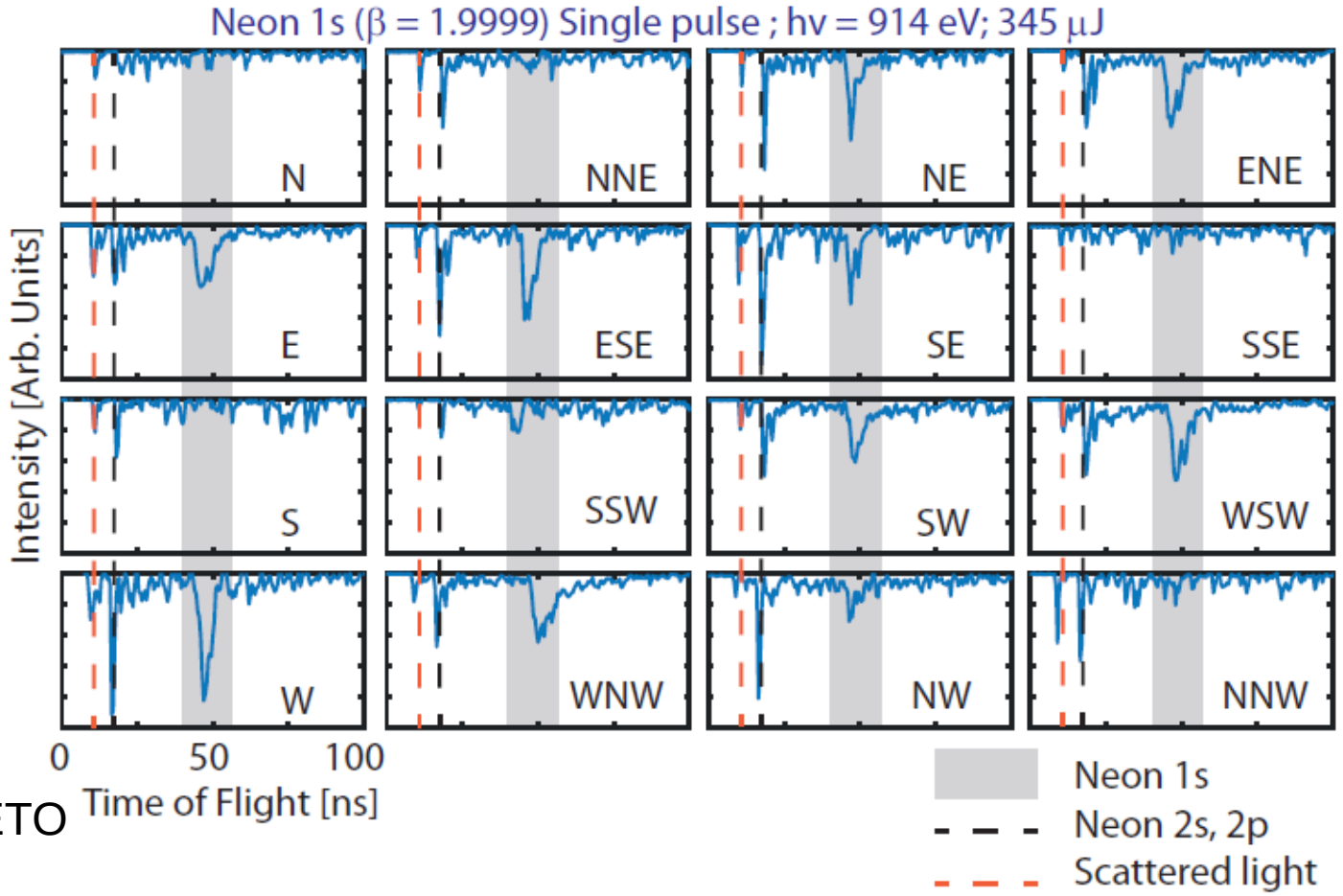
- Polarimetry
  - Accomplish with Auger Lines
  - Data collected from single bunch mode
  - Polarization P is given by

$$P(\theta) = 1 + \frac{\beta}{4}(1 + 3P_{Lin}\cos(2(\theta - \psi))).$$

Perfect horizontal :

$P_{Lin} = 1$ and $\Psi = 0$

  - Integral after background subtraction of Neon 1s is marked in a polar plot
  - This information could also be use for VETO systems



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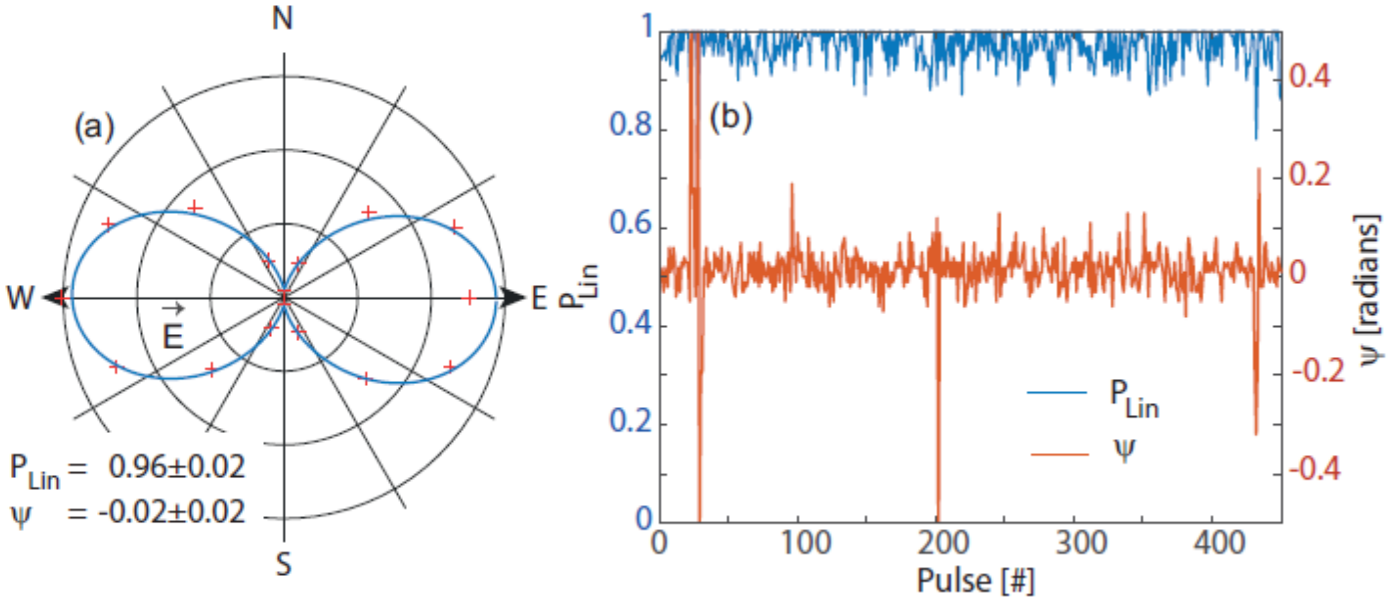

Thanks for the attention

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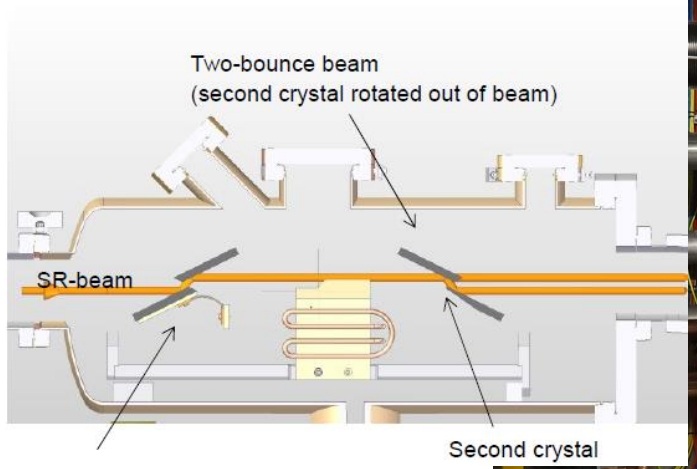
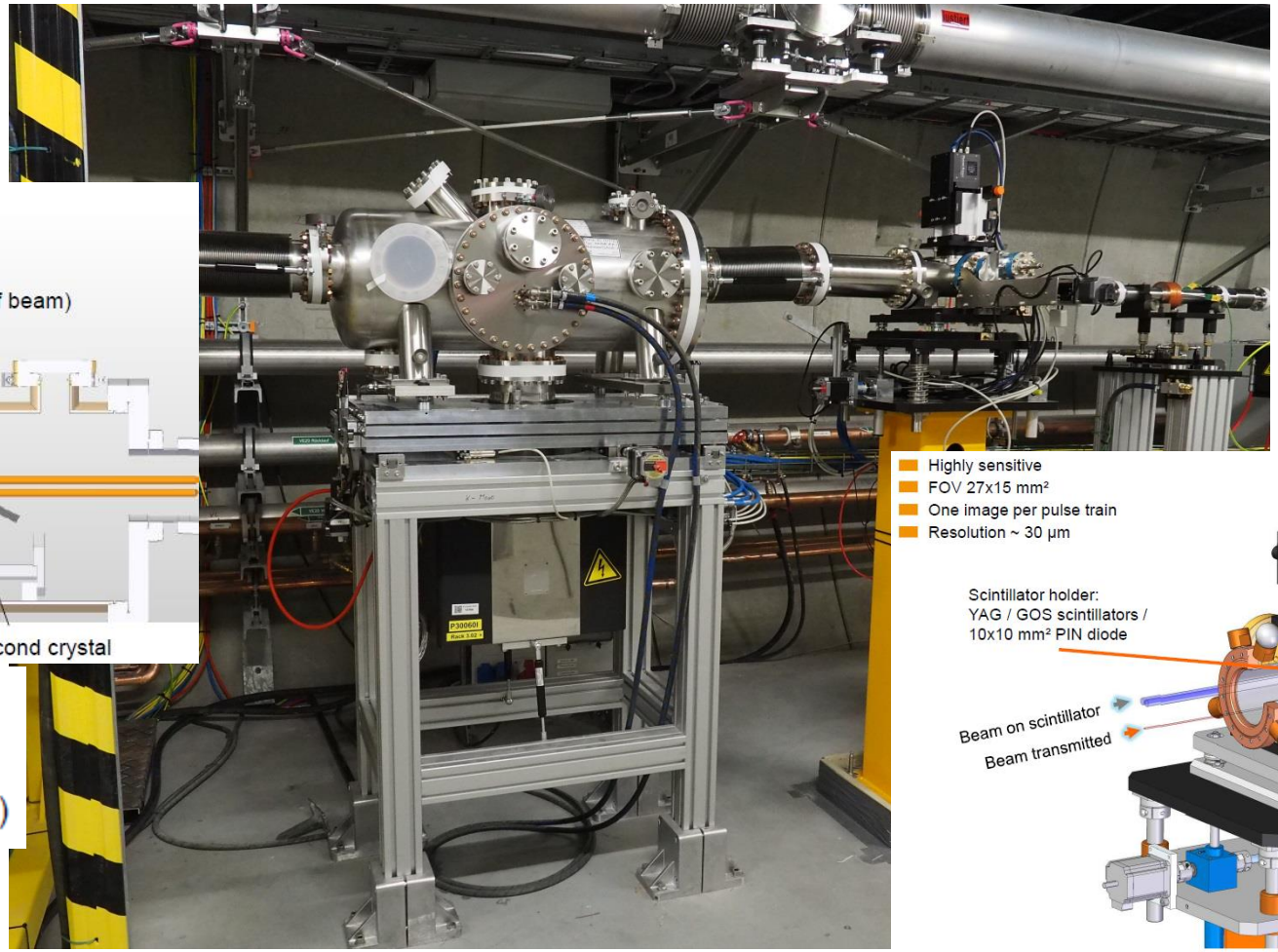
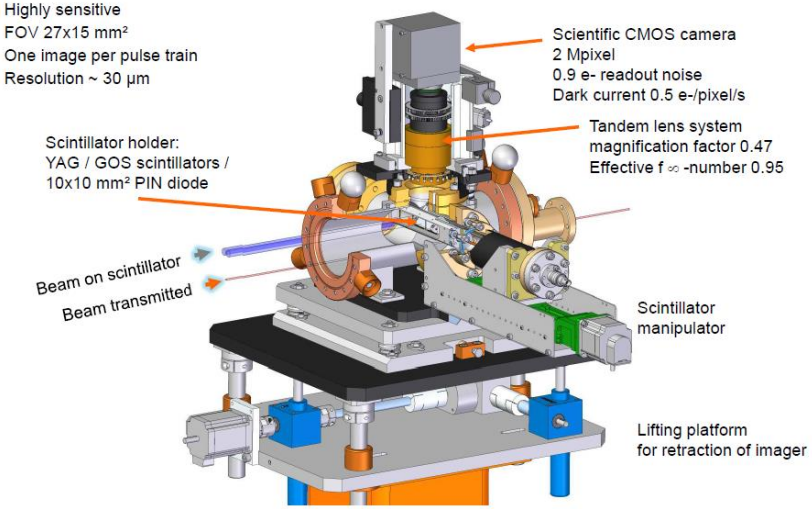
Diagnostics Group – K-Monochromator



First channel-cut crystal
(Huber goniometer,
Renishaw absolute encoder)



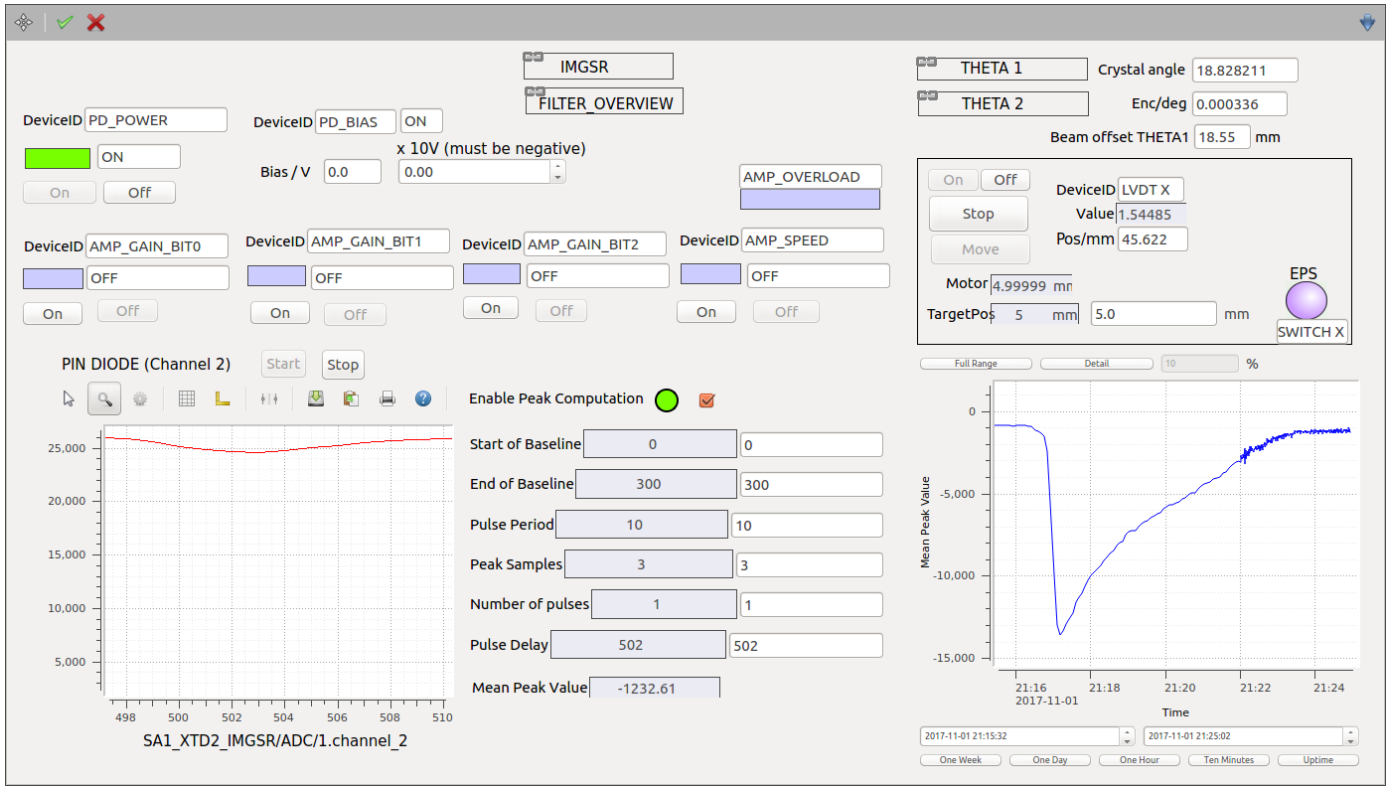
- Highly sensitive
- FOV 27x15 mm²
- One image per pulse train
- Resolution ~ 30 µm



Diagnostics Group – K-Monochromator

Gap tuning method or the relative adjustment of undulator segments: measure photon energy of spontaneous radiation **of each undulator segment**, to calculate and adjust the K-parameters within an accuracy required for FEL operation

- Monochromatized beam detection
- Scan perform “on the fly”: goniometer is moving continuously
  - For each pulse Train, data is stored
- Spectral Shape → information about the homogeneity of magnetic structure



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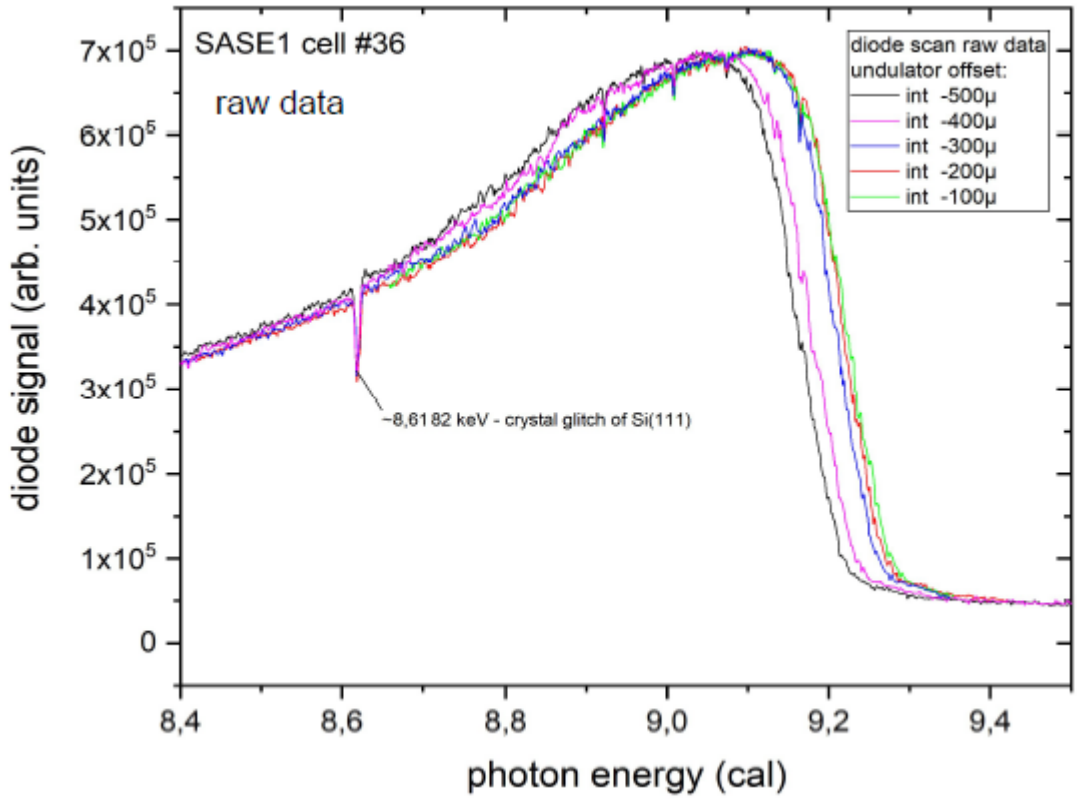
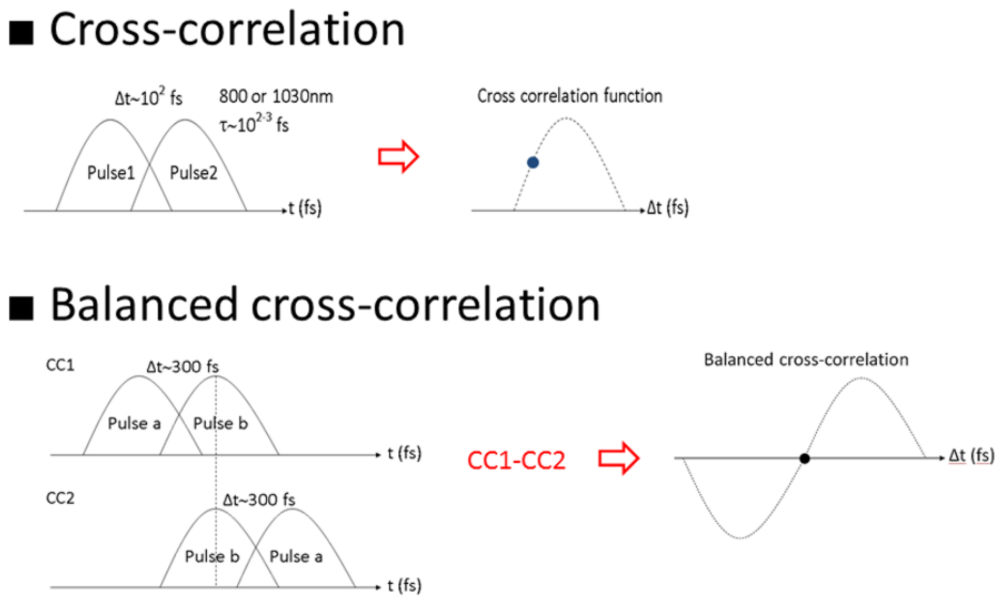


Optical Laser Group – Timing drift/jitter compensation

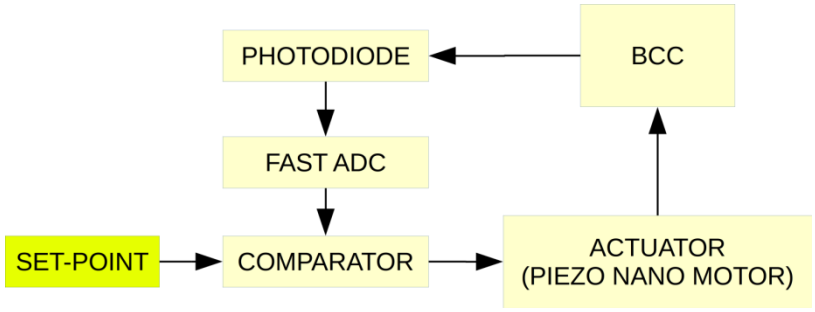
- Balanced Cross-Correlation
  - two cross correlators (CCs), with the same configuration
  - Used for compensation of Timing drift/jitter
- In both CCs, the temporal delays, and the amplitudes of signals are adjusted equally.
- The **timing error signal is the subtraction of the signals from CC1 and CC2**.
- The **error signal is proportional to the timing drift**.

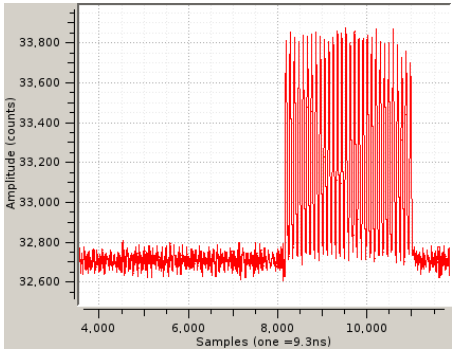


Optical Laser Laboratory

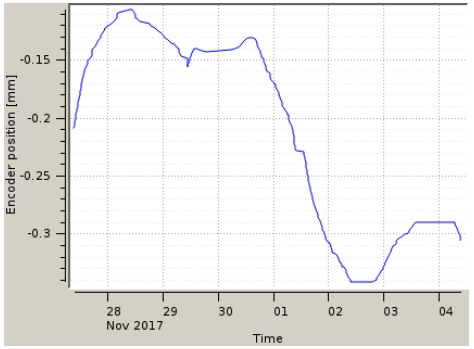
Input parameters to the (DM) BCC at SASE 1:

- XF1: 10Hz, 27us, 1.1MHz, ~ 900fs, 7nJ/p;
- XF2: 20Hz, 5.94ms, 4.5MHz, ~ 300fs, 1nJ/p.

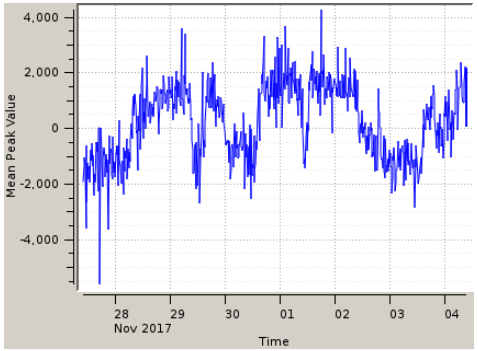




Error signal from the DM-BCC



Mean peak value of error signal

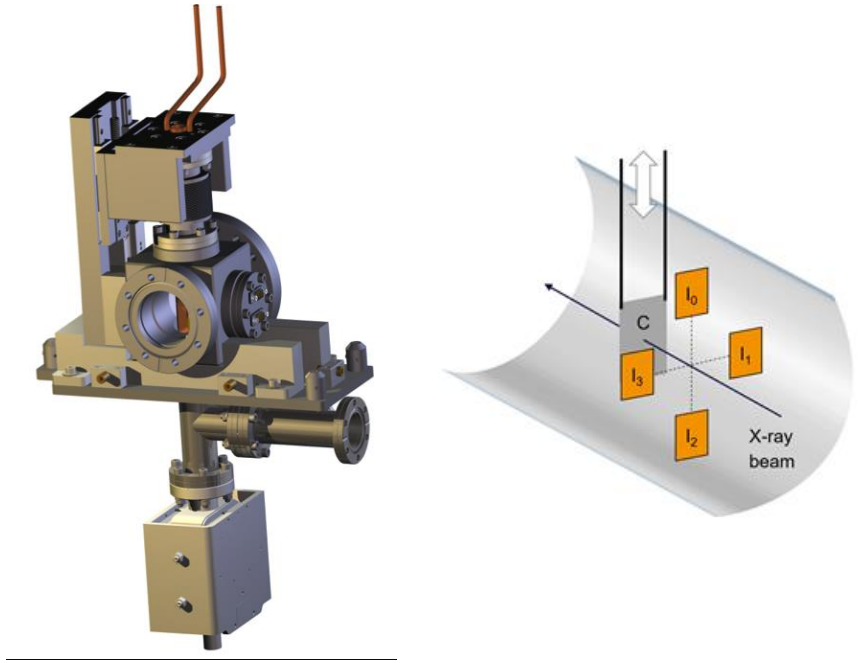


Encoder position of comp.stage

- The pump probe laser in SASE1 is already equipped with one CM- and two DM-BCCs. The operation was successful.
- Slow timing drifts are well measured and compensated, like thermal expansion, humidity change, etc. with **an accuracy of ~ fs**

FXE Group – Intensity Monitor (IPM)

- Measurement of **integrated intensity** of the beam and the corresponding **centre of mass position**
  - relies on the efficient detection of backscattered X-ray photons from a very thin foil of CVD diamond material
  - the detection of the backscattered X-ray photons is realized using 4 photodiodes (PD)
  - All four PDs collect the backscattered radiation from the foil and yield the integrated incident intensity by integrating the output current from the detectors
  - comparing the difference of the individual signals from each diode, one can obtain the position of the beam in the plane perpendicular to the beam direction
- Measurements use ADQ412 from SP Devices



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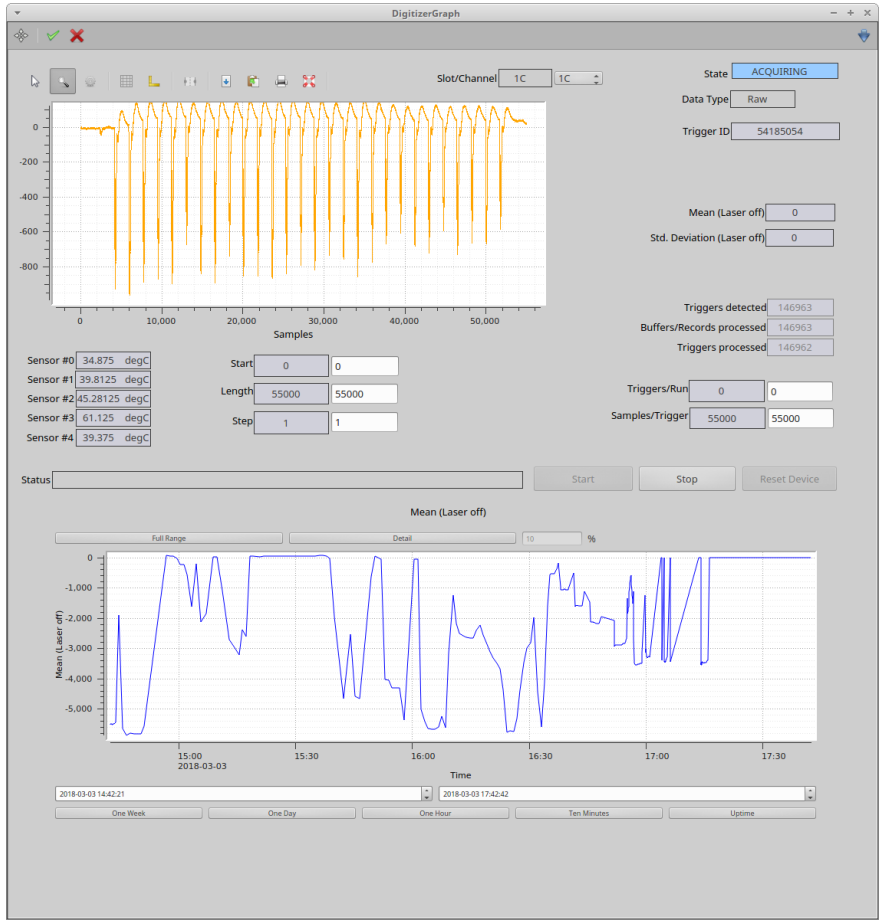

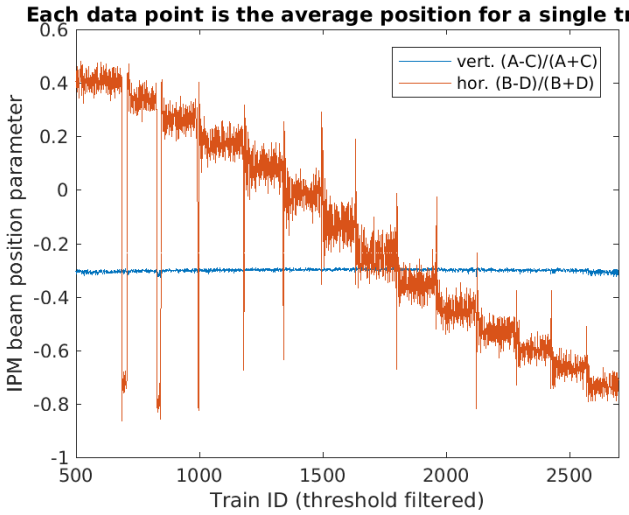

the vertical position does not change, while the beam is moved horizontally with M3 pitch, giving a continuously decreasing value on the IPM. Spikes in the horizontal position are due to the backlash correction.

train-to-train beam position comparison **of each pulse within the train**. It is clear to see that the first few pulses are much more jittering than the later ones