Integrated Detector Control and Calibration Processing at the European XFEL

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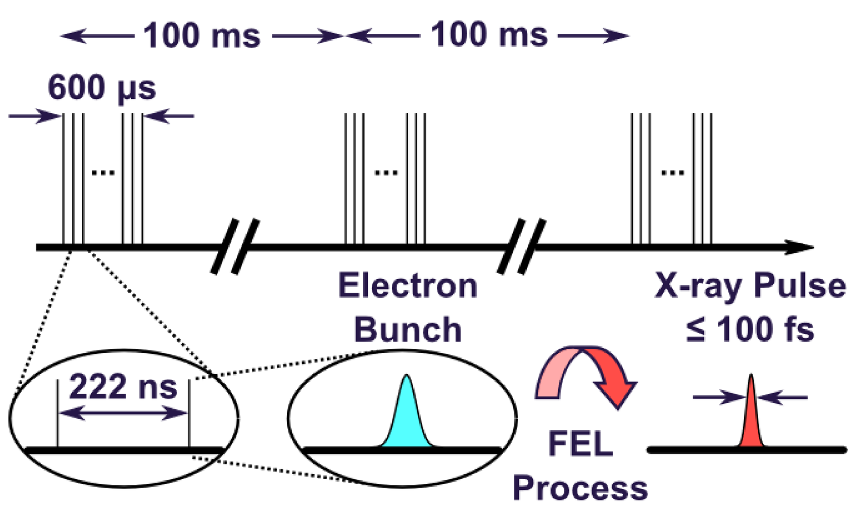
The European XFEL

The European X-ray Free Electron Laser is a high-intensity X-ray light source currently being constructed near Hamburg that will provide spatially coherent X-rays in the energy range between 0.25 keV and 25 keV. The machine will deliver 10 trains/s, consisting of up to 2700 pulses, with a 4.5 MHz repetition rate.

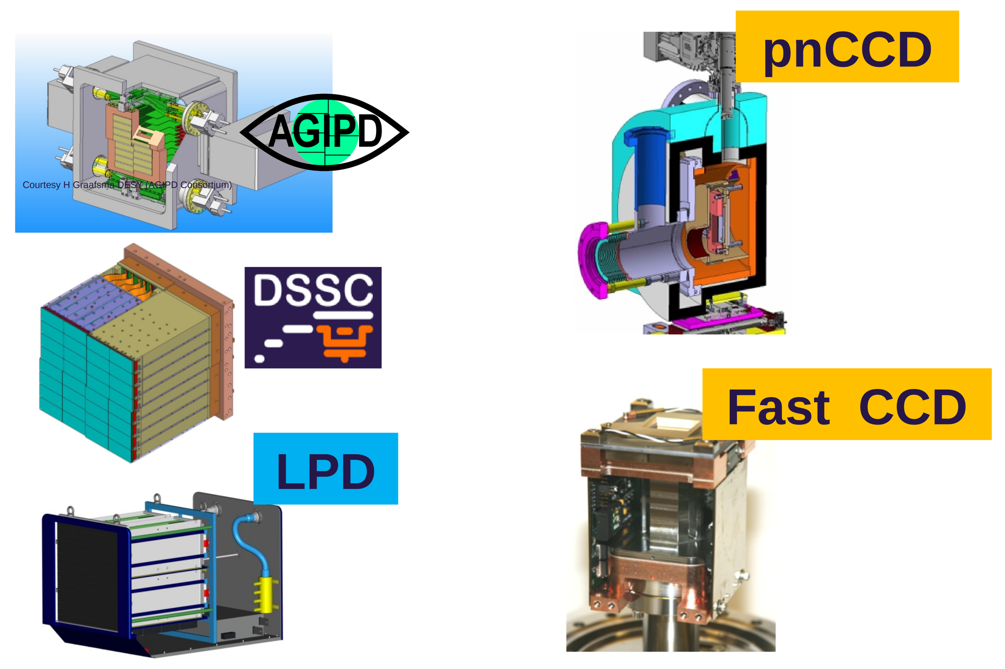


The LPD, DSSC and AGIPD detectors are being developed to provide high dynamic range Mpixel imaging capabilities at the mentioned repetition rates. A consequence of these detector's characteristics is that they generate raw data volumes of up to 12.8 Gbyte/s. In addition the detector's on-sensor memory-cell and multi-/non-linear gain architectures pose unique challenges in data correction and calibration, requiring online access to operating conditions and control settings.

Detectors at the EU.XFEL

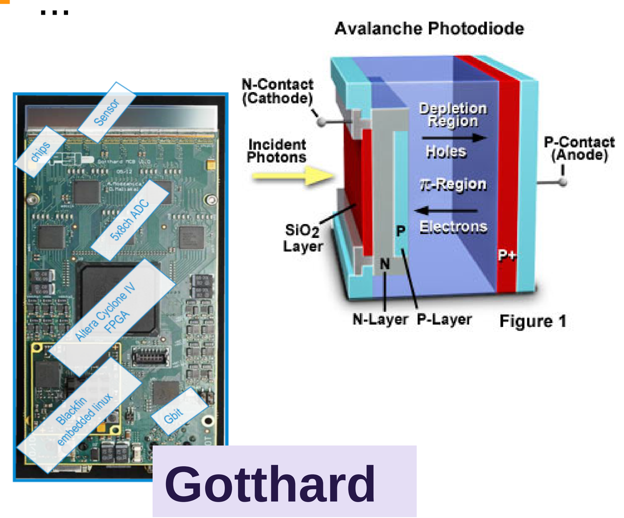
2-D large area X-ray imaging detectors

- High repetition 4.5 MH detectors:
- Low repetition 10 Hz detectors:



...and more to come

- 1D detectors (Gotthard)
- Avalanche Photo Diode (APD)
- Silicon Drift Detector (SDD)
- MCP
- ...



Control Software: Karabo

Karabo will be used to control and manage the photon beamlines at the European XFEL as well as the experiments with associated detectors.
For detector operation we have to control:

- Vacuum systems
- High voltage
- Detector operation
- Data acquisition
- Data correction, calibration and analysis

Fig.1 illustrates the different components of the system. Exemplary, an example of the DAQ-interface of a detector (Fig.4), the control of a full detector setup including its vacuum system (Fig.2) and a composite device to control several devices simultaneously (Fig.3) are presented.

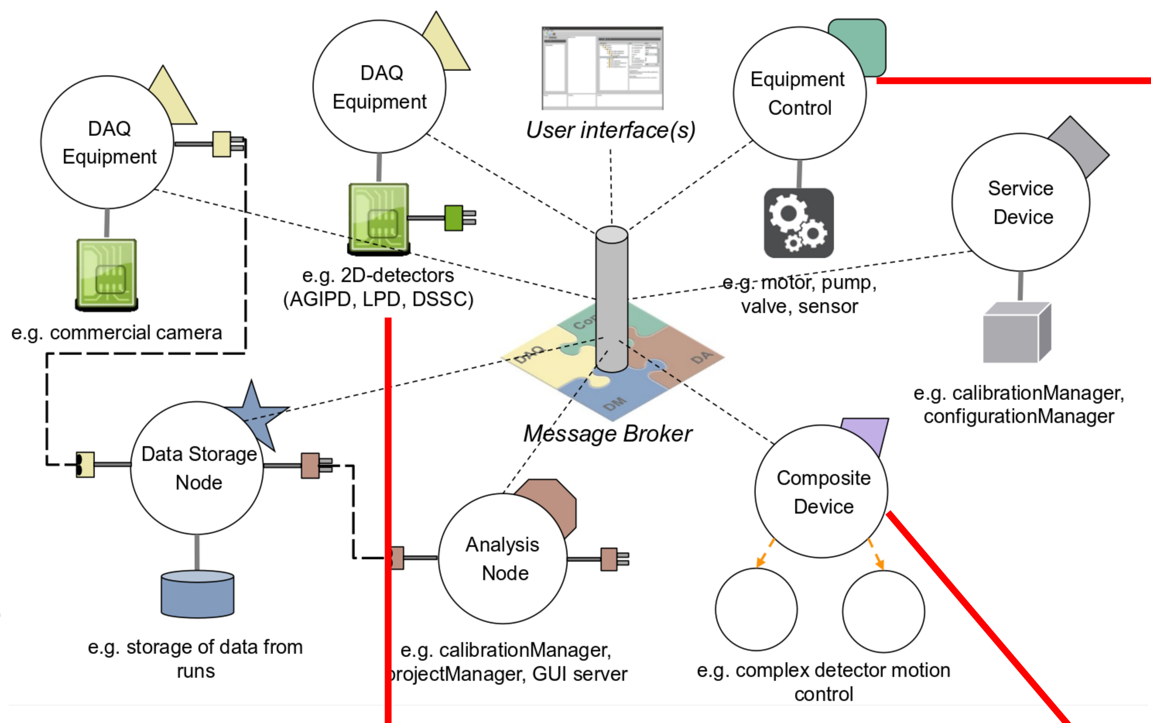


Fig 1: Design concept of the Karabo framework

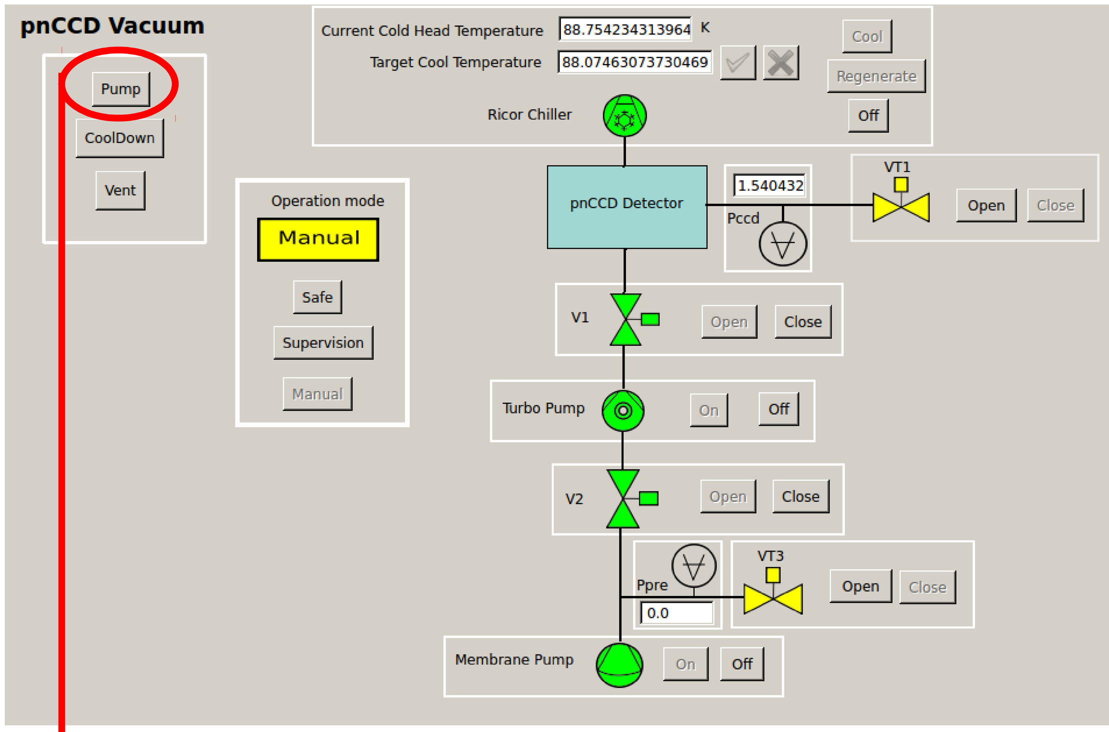


Fig. 2: Control GUI for the vacuum system of a pnCCD detector.

Detector Integration and Data Pipelines

The SDD detector is a 1D silicon drift detector used for source calibration purposes. The communication and readout of the SDD detector has been integrated into Karabo as a device, allowing the SDD to be used in automated procedures via Karabo. The measured spectra can be written into an HDF5 file or passed via a p2p connection to another device for processing. A compute device monitors this output channel and performs:

- Energy calibration
- Peak finding
- Spectrum comparison
- Comparison with energy lines of different elements

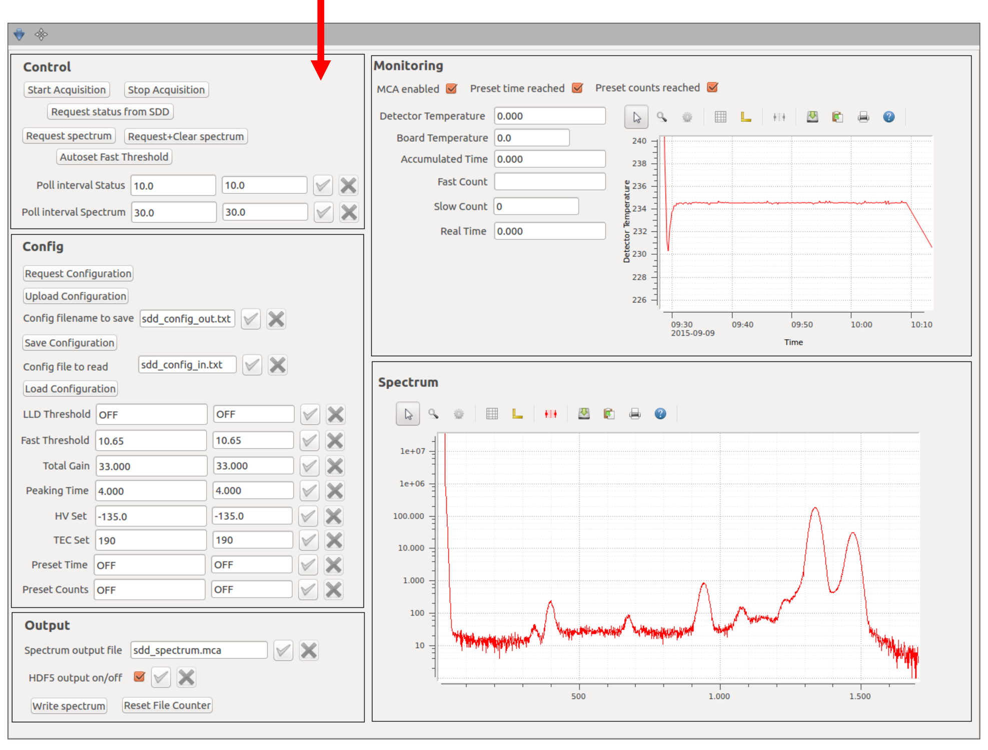


Fig 4: GUI of the SDD detector as integrated in Karabo.

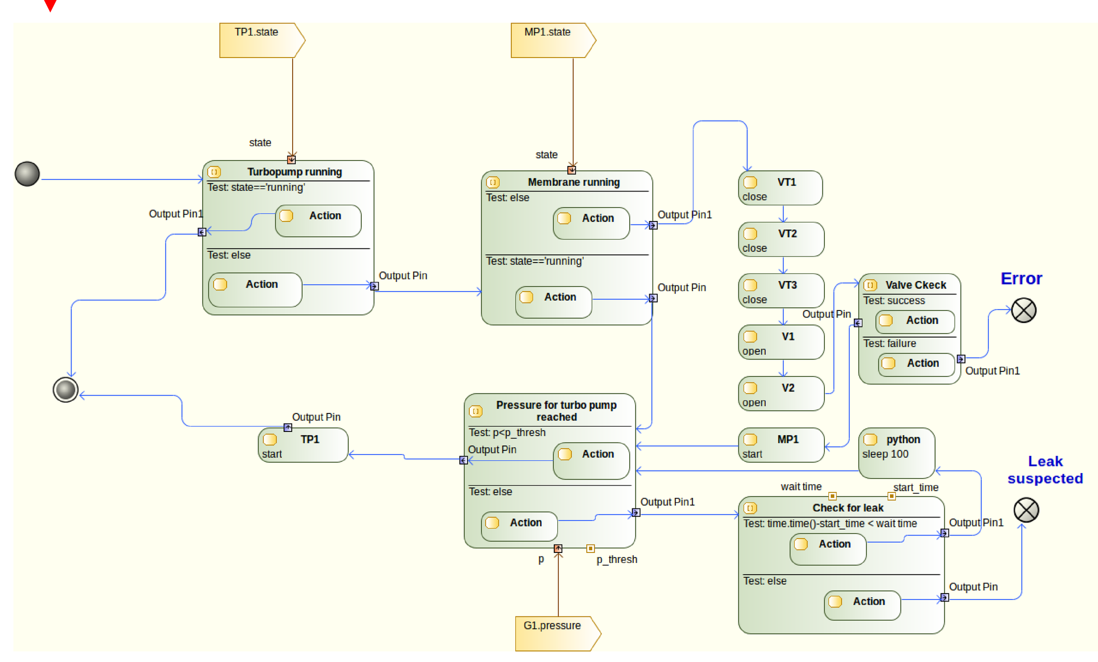


Fig 3: UML activity diagram of the program flow of the pump action as realized as composite device in Karabo.

Python-based Calibration and Data Analysis Suite – Near Real-time Corrections Using GPUs

Common calibration and correction routines for 2D pixel detectors, which can be used both interactively and in an automated, pipelined fashion. Routines included e.g

- Offset correction
- Common-mode correction
- Gain correction
- Pattern classification
- Cluster identification

Raw data | Offset + CM + Gain corrected data | Classified patterns and clusters

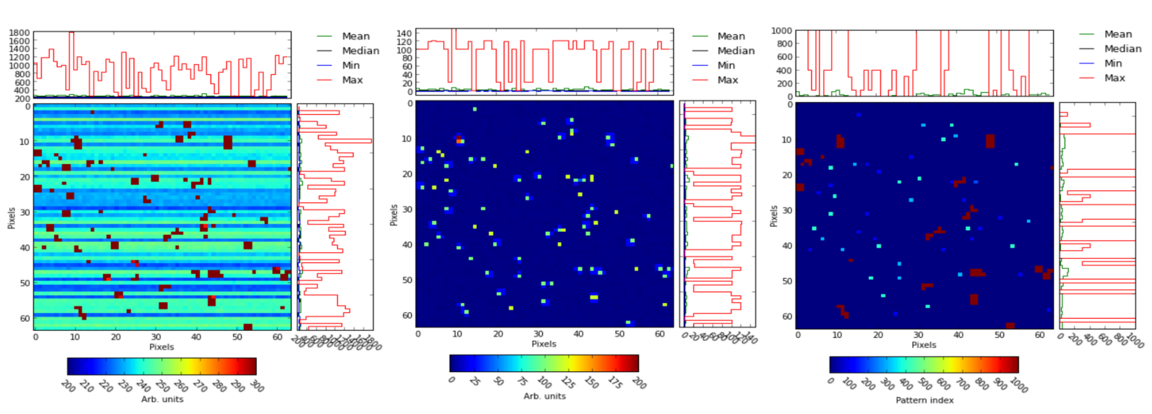


Fig. 7: Examples of GPU-based corrections on test data. The left plot shows the uncorrected data with common mode effects highlighted; the center plot the same data after offset-, common mode- and gain correction have been performed on a per pixel, per-memory cell basis. The right plot shows the identified patterns, indices 100-404, as well as clusters (1000) with higher multiplicities.

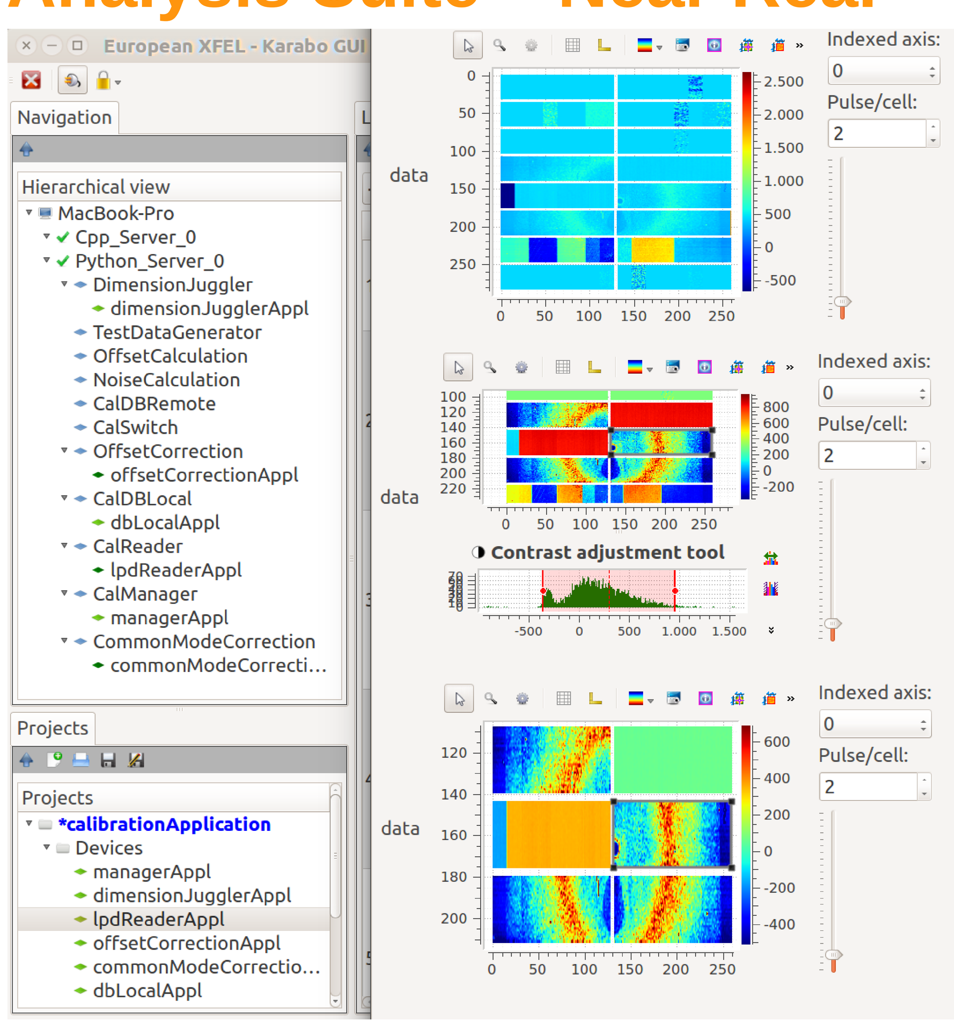


Fig 6: Karabo views of single-shot scattering images of a ferrous solution acquired with an LPD prototype. From top to bottom uncorrected, offset-corrected and common mode-corrected images are shown. Correction constants were provided by a calibration database.

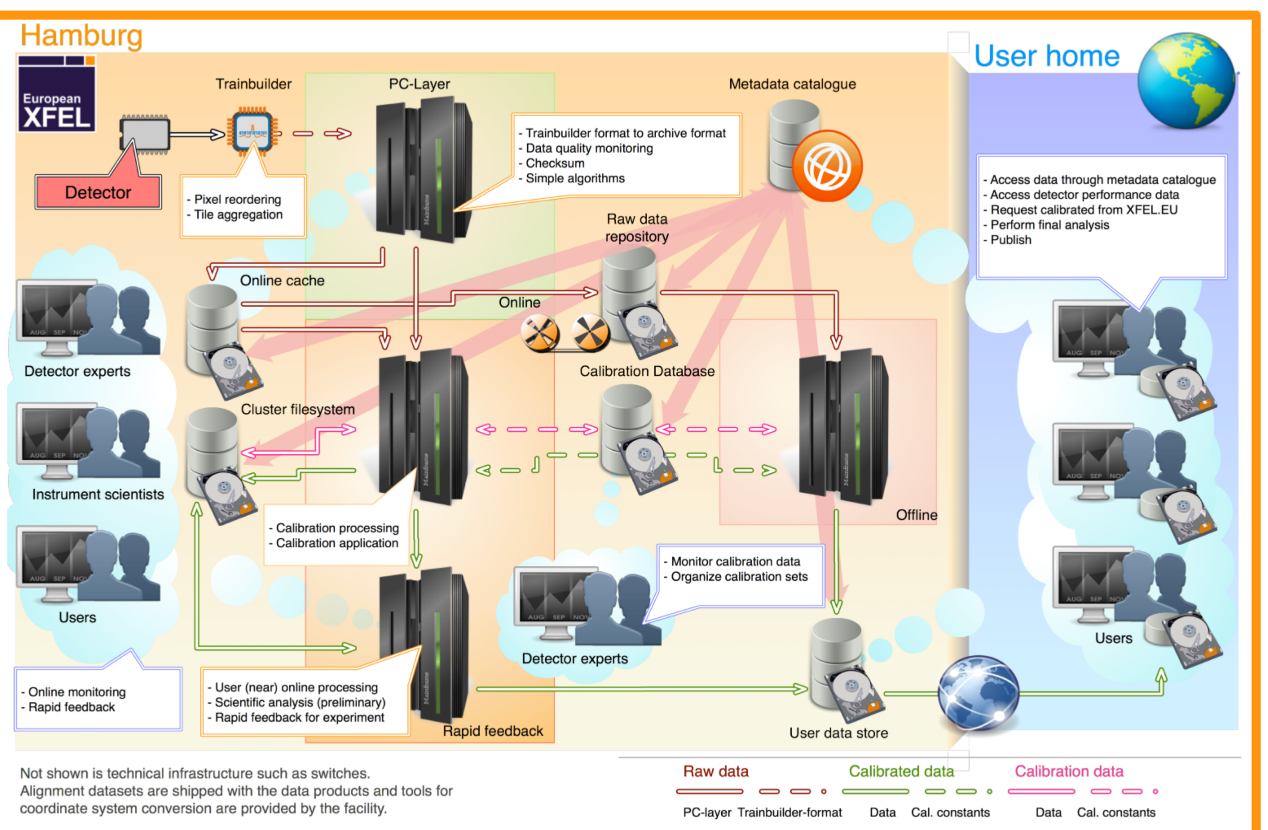


Fig 5: General concept of data-flow at the European XFEL. Users will be provided with corrected and calibrated data only.

Detector (Pixels x mem. cells)	GPU (ms)	CPU (ms)**	Speed-Up
LPD (128x32x512)	**26.5**	3473	~130x
AGIPD (128x512x352)	**344.9**	15394	~45x
DSSC (512x128x512)	**477.4**	38456	~75x
LPD Supermodule (256x256x512)	**466.1**	35796	~75x

Corresponds to one 10G line (DSSC, LPD Supermodule)

** without pattern classification, 6(x2 HT) core XEON W3680@ 3.33Ghz, 24GB RAM

Tab 1: Achievable GPU vs. CPU speed-up of the calibration pipe-line (offset, common-mode correction, event-classification, gain calibration) for data sizes present on a 10G link. Measurements where done on a Nvidia K2200D GPU.

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