X-ray detectors at the MAX IV synchrotron

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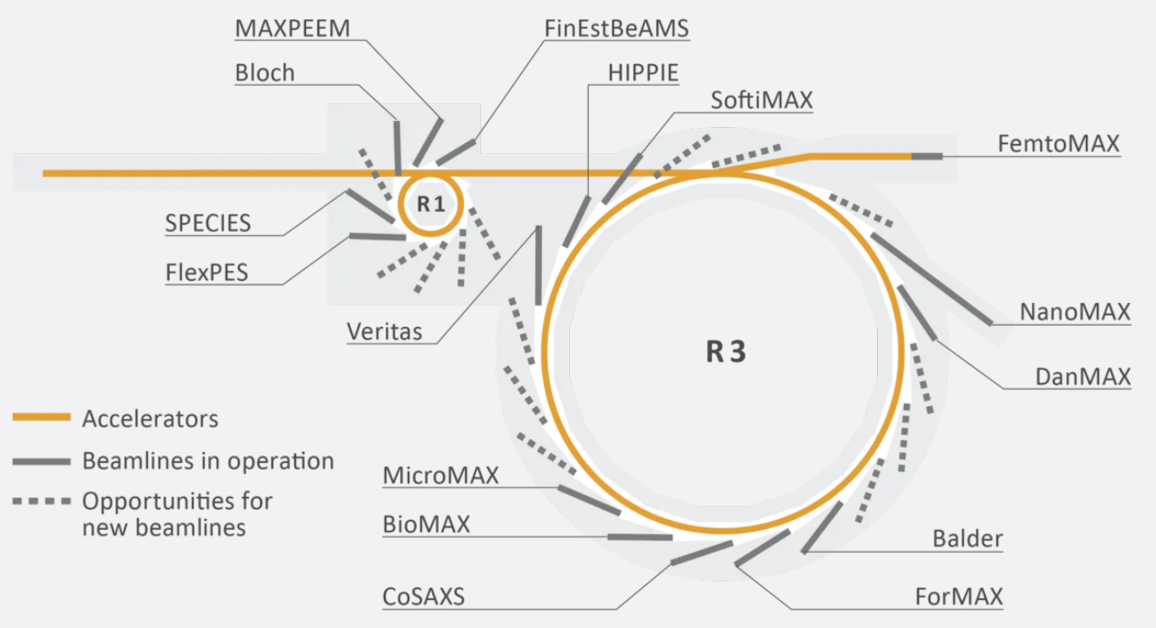
1. MAX IV



MAX IV operates 16 beamlines with space to add more in the future. The experimental stations are situated on the 1.5 GeV (soft X-rays and UV) or 3 GeV (mainly tender and hard X-rays) storage rings or on the Short Pulse Facility at the end of the linear accelerator. These beamlines offer to the facility users a variety of tools, such as spectroscopy, diffraction and scattering, imaging techniques, and more.

1.1 The Scientific Data group

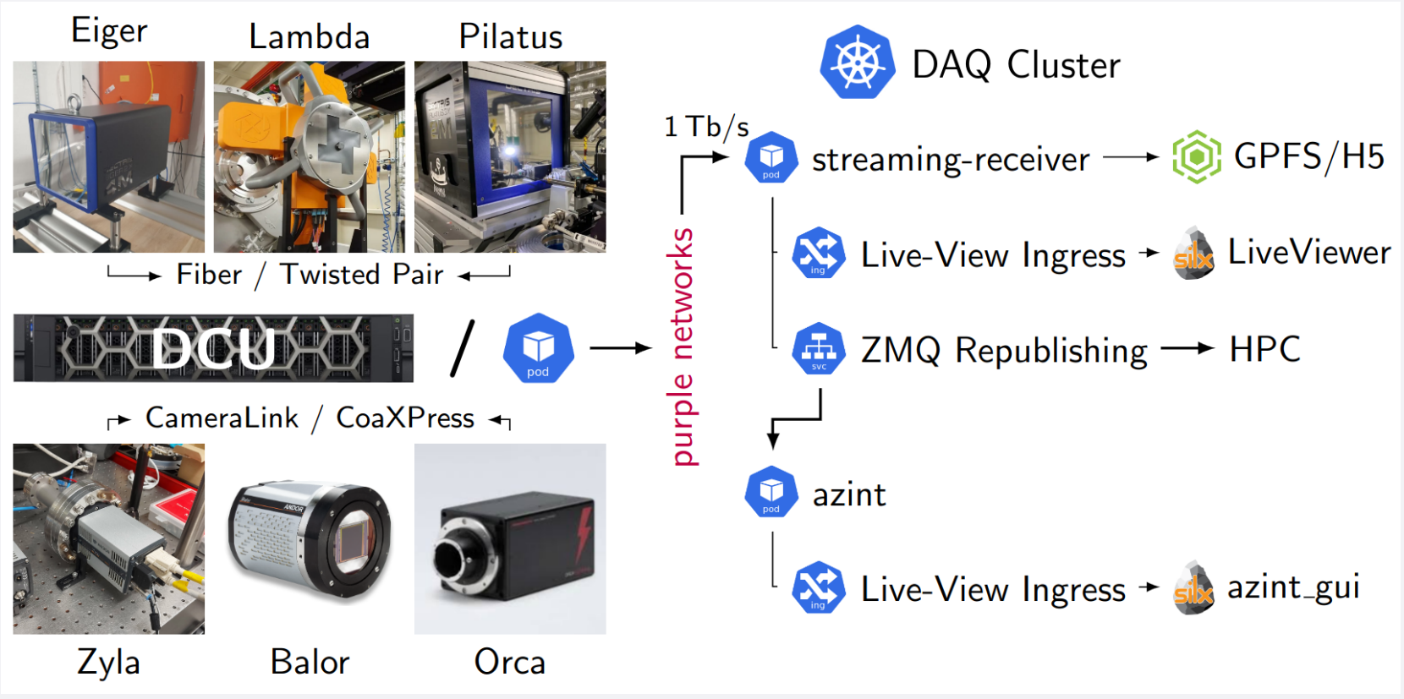
The group takes care of integrating commercial and noncommercial x-ray detectors into the control (Tango) and acquisition systems and supports their operation. The acquisition pipeline also provides associated online visualization and data processing.

We support mostly photon counting, or charge integrating pixel detectors, but we also have some sCMOS and CCD sensors, several Delay Line Detectors, and digital analysers for monolithic semiconductor detectors.

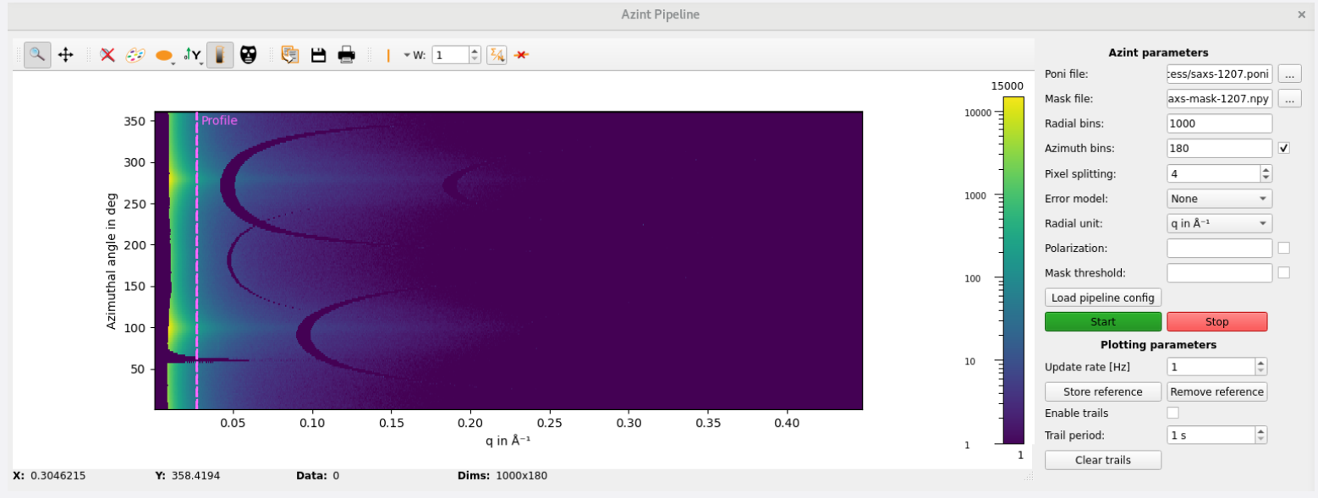
Finally, we build collaborations with both commercial and academic partners to develop new solutions and work together on in-situ test of prototypes.

2. Standardized DAQ and processing scheme

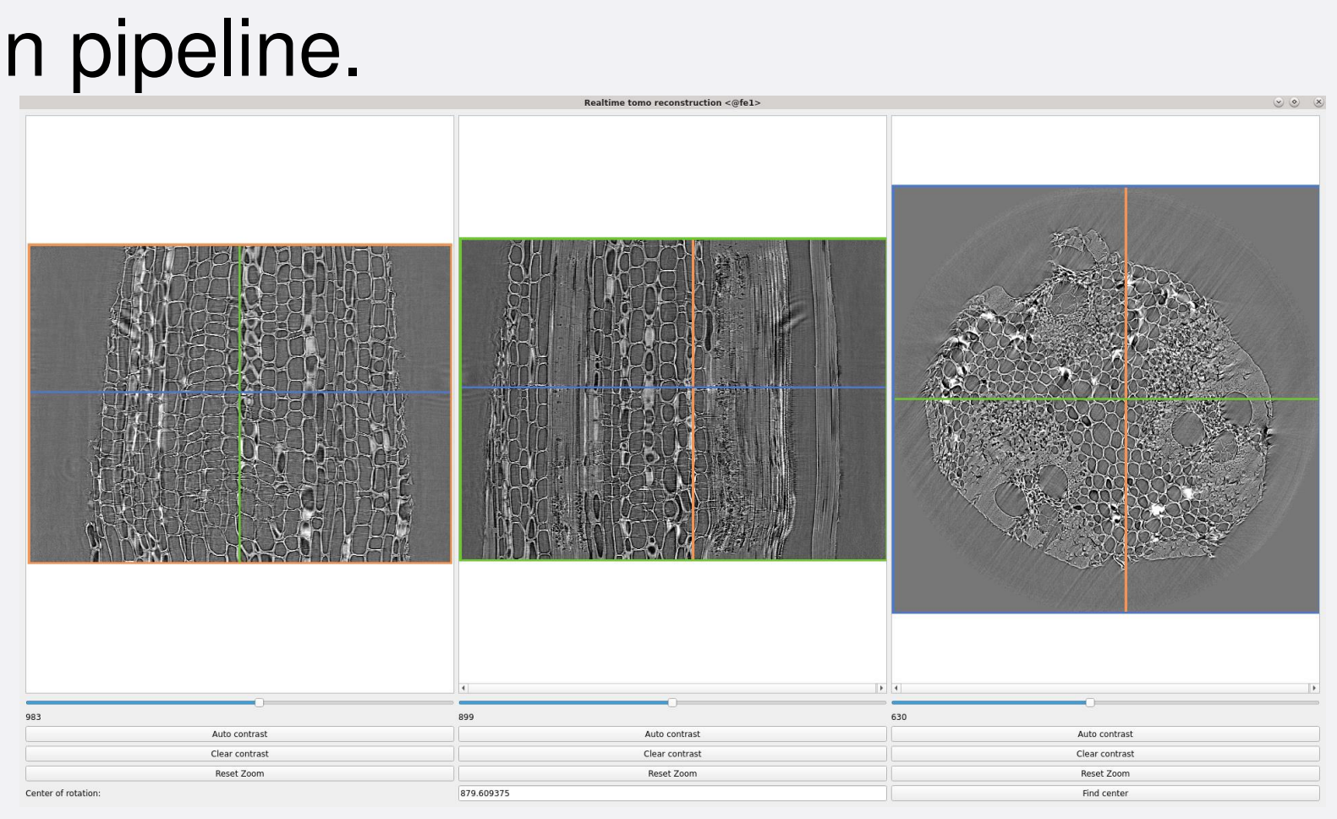
Most detectors and cameras are controlled by a dedicated computer know as Detector Control Unit (DCU).



The DCU usually stream the acquired data to a standard receiver, instances of which are created in the K8s-managed DAQ cluster as required.



The receiver writes the frames as HDF5 files to the GPFS storage, retaining the last processed frame so that it can be served to a standard live viewer. The receiver can also re-stream the data for further online analysis; the most common case being azimuthal integration pipeline.

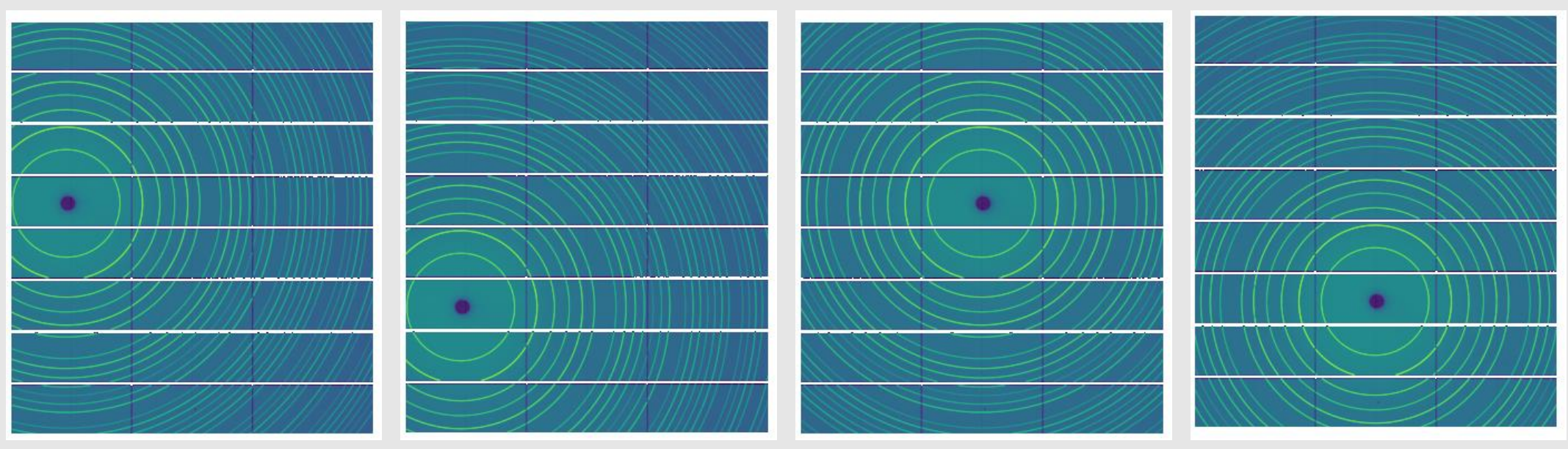


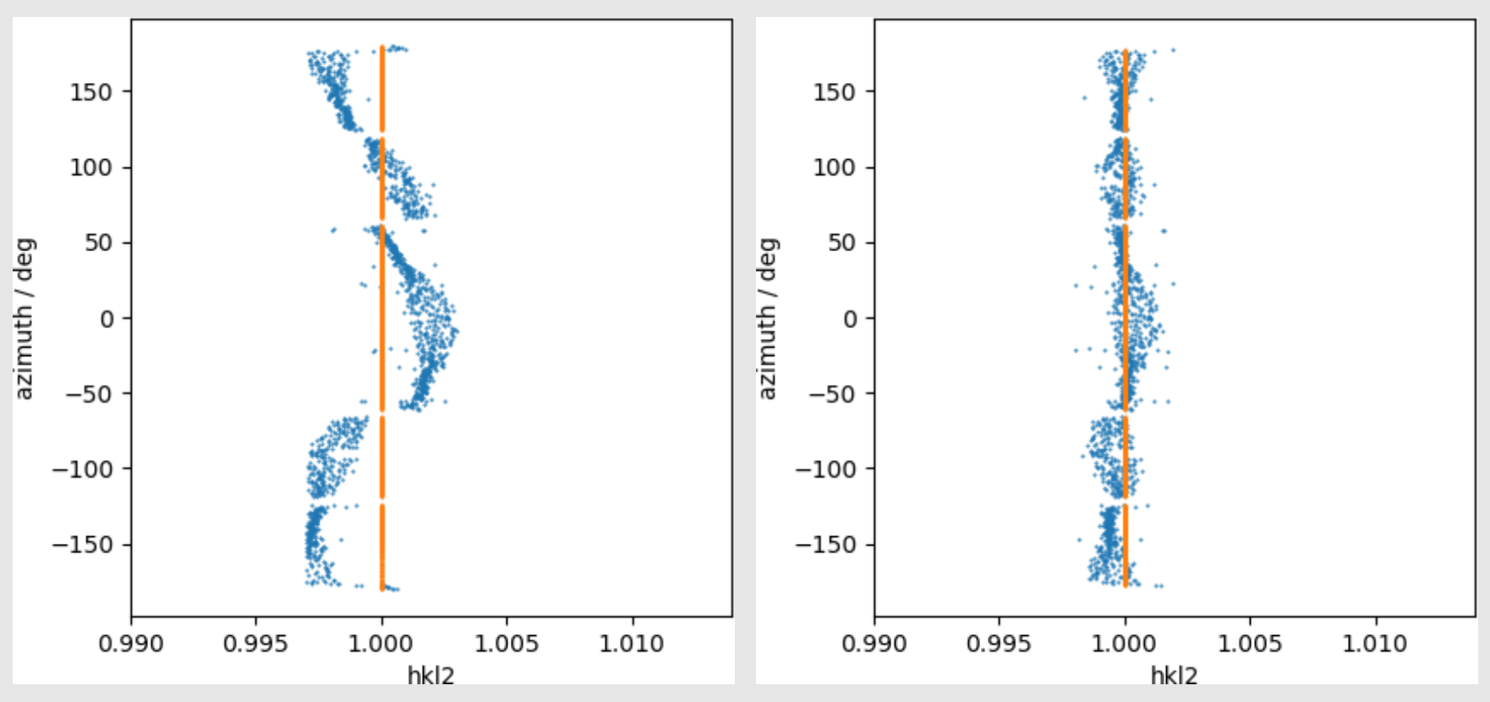
Another possible pipeline is the real time streaming tomography reconstruction based on Filtered Back Projection running on a GPU.

3. Detector characterization and correction

For all our detectors we perform acceptance tests and performance/calibration studies (e.g., module alignment, flat fields).

3.1 Module alignment

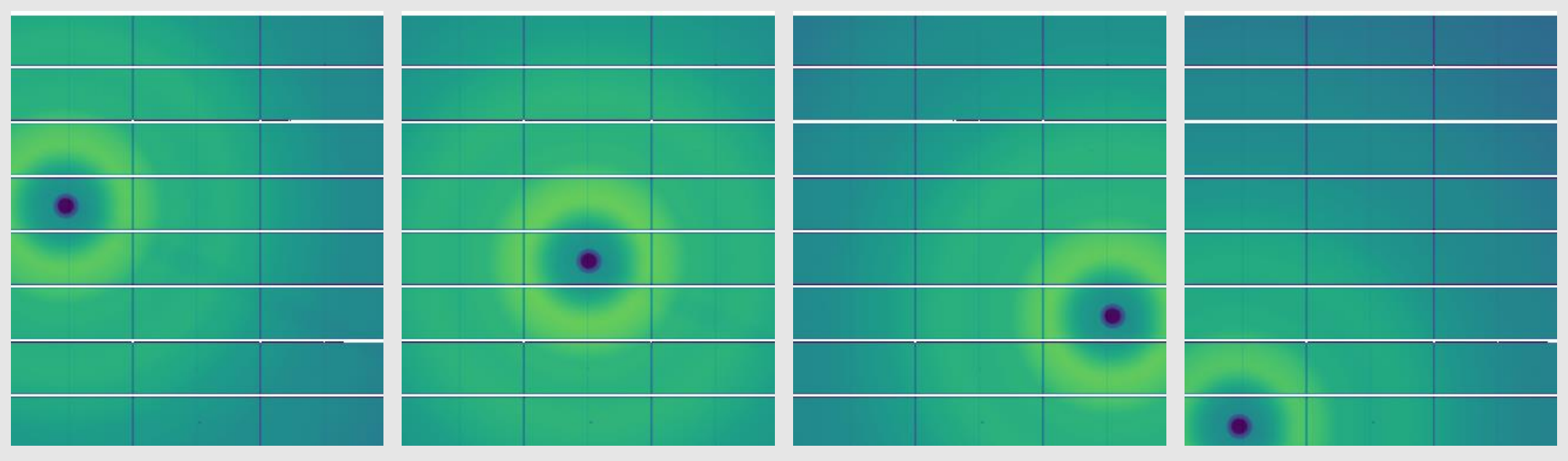


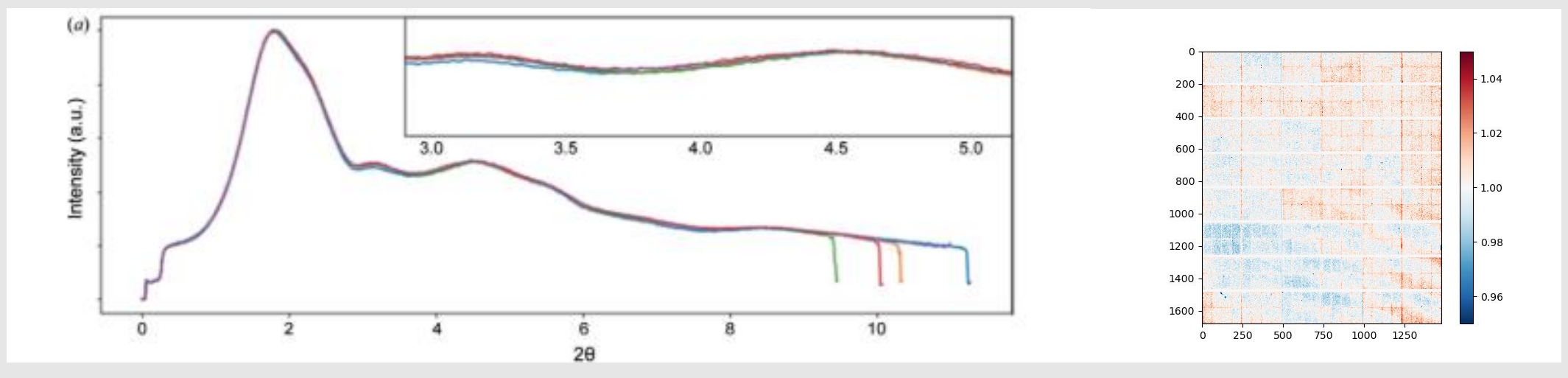


Well known powder diffraction rings with excellent S/N ratio (top) can be used to measure the relative position and orientation of the sub-modules of a large 2D detector, as proposed in [1]. Minimizing with respect to the module displacement the deviations from unity of the sum of the squared Miller indices $hkl2 = h^2 + k^2 + l^2$ for each reconstructed ring (bottom) we obtain sub pixel corrections to the module positions.

These corrections are integrated in the subsequent analyses, e.g. the azimuthal integration.

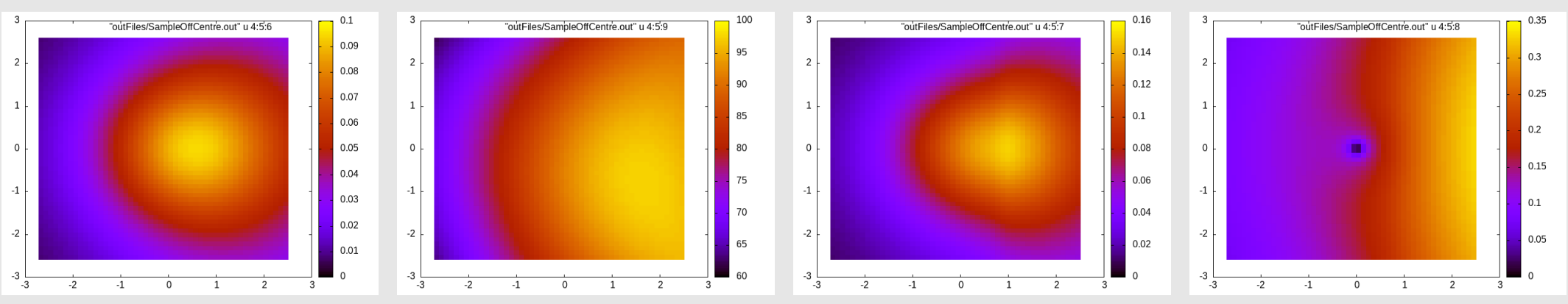
3.2 Flat field corrections





It is sometimes challenging to obtain flat field corrections for some energies and geometries. Following [2] we can generate our flat-field corrections (bottom right) from the deviation from the average (bottom left) of a series of fast scattering measurements from an amorphous scatterer for different beam centers (top).

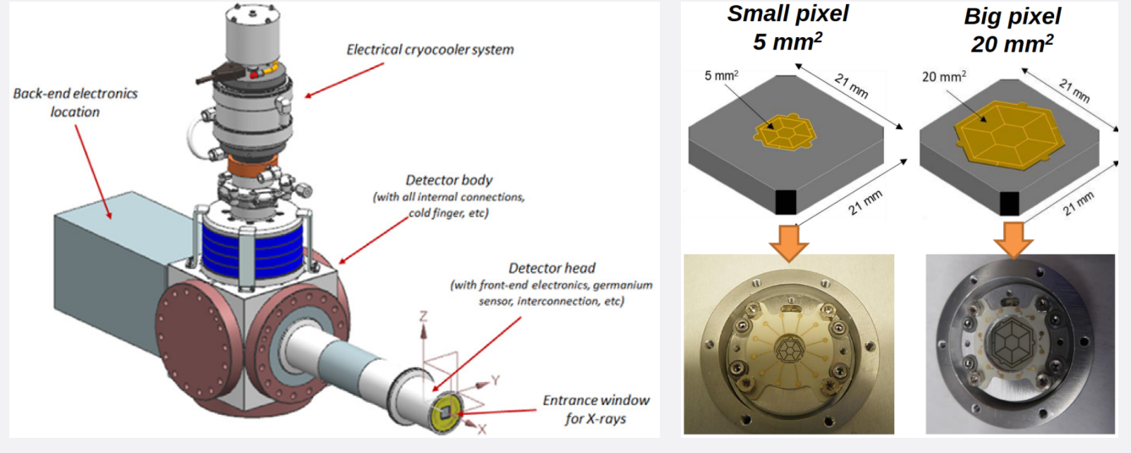
3.3 Multiple scattering corrections



To allow our users to fully exploit the full brilliance of the MAX IV light, we are developing a software toolkit to simulate the different scattering processes off the sample and it vessel [3]. The goal is to extract the elastic scattering from the sample alone by subtracting the other contributions from the measured signal. We show above the simulated elastic and Compton scattering from the sample (left and center left) and of the container's (center right and right) for an off center glass capillary.

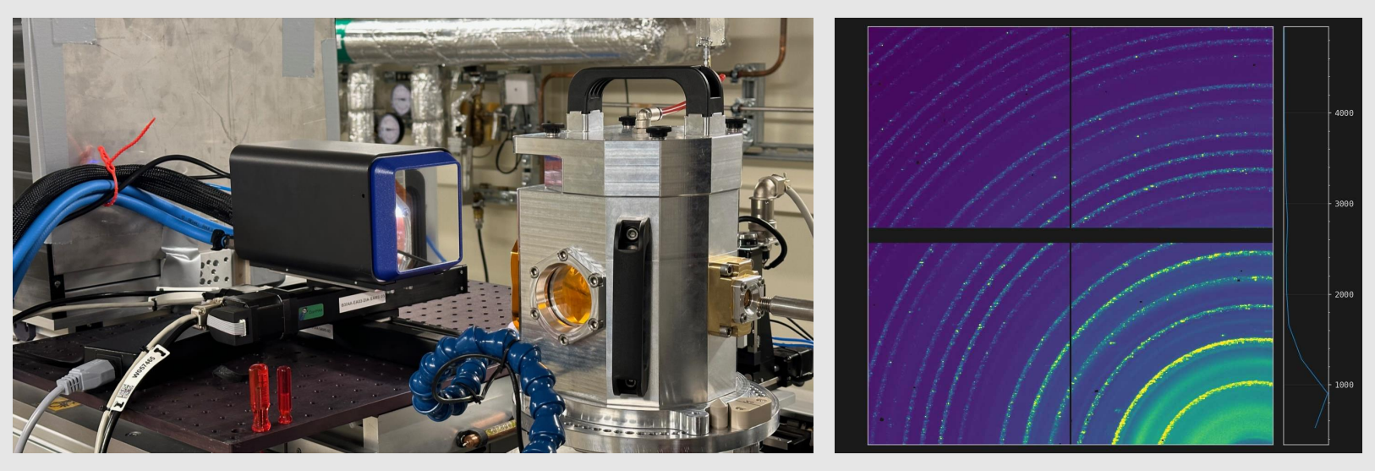
4. New Detectors and Cameras

To allow the MAX IV beamlines to take advantage of the latest advancements in detector technology, the Scientific Data group collaborates with both commercial and research institutions developing new sensors.

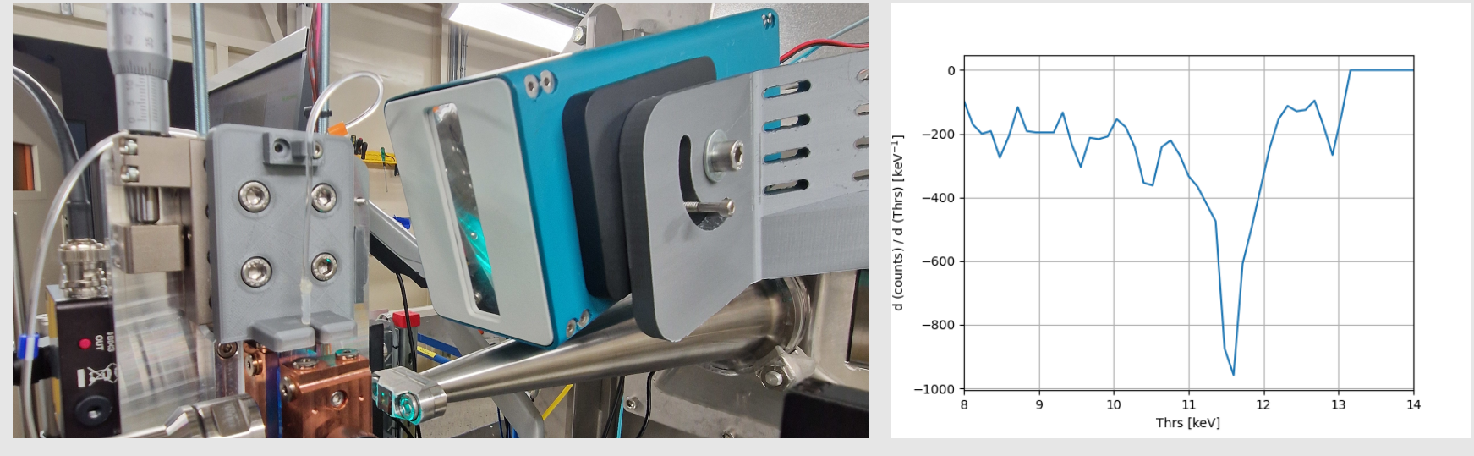


For instance, the group will take part in the test of XAFS-DET, a High Purity Germanium detector (above) developed within LEAPS, the partnerships between industry and European light sources [4].

4.1 Prototype tests

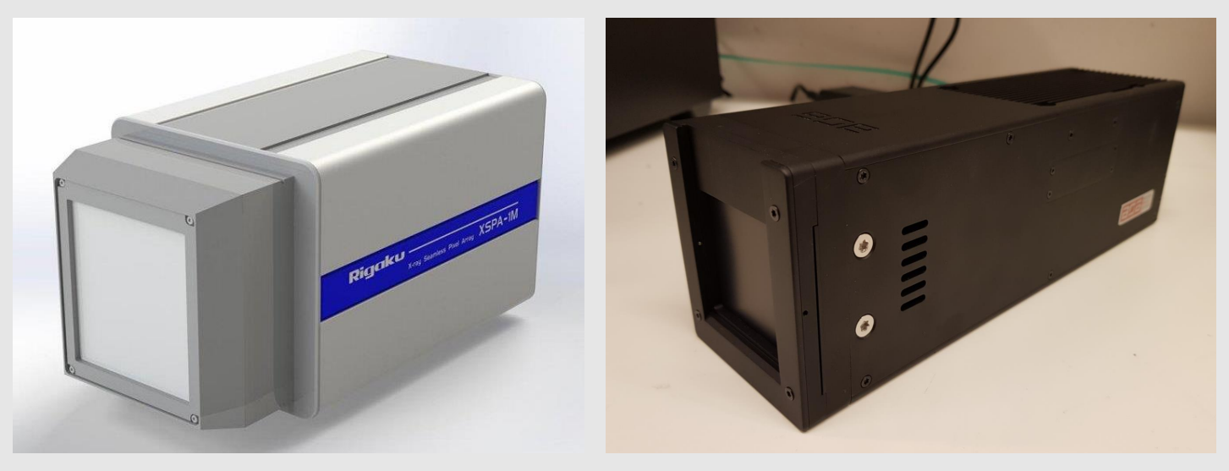


We hosted tests of the Pilatus4 prototype prior to its launch in summer 2023 (left); the diffraction rings of the LaB6 standard inside the ARΩS furnace are pictured above (right).



We recently tested a prototype version of the Medipix based Lumentum rad400 detector (left) as an ultra wide angle detector at the CoSAXS beamline investigating the threshold spread (right) and the linearity.

4.2 Timing resolution



For some techniques, such as X-ray photon correlation spectroscopy (XPCS), timing resolution is of great importance. For this purpose, we have acquired a Rigaku XSPA 1M (right), with 56kHz max frame rate.

Higher time resolutions can be obtained at the price of a lower count rate using a Timepix based sensor, which can measure single photons with sub ns resolution. We are in the process of integrating a Timepix3 based ASI Lynx (left); we will also receive an MCP-Timepix3 detector system from Berkeley Labs through a Röntgen-Ångström Cluster grant.

References

[1] Using Powder Diffraction Patterns to Calibrate the Module Geometry of a Pixel Detector. `https://doi.org/10.3390/cryst12020255`

[2] In situ X-ray area detector flat-field correction at an operating photon energy without flat illumination. `https://doi.org/10.1107/s1600577523001157`

[3] A Monte Carlo study of high-energy photon transport in matter: application for multiple scattering investigation in Compton spectroscopy `https://doi.org/10.1107/S1600577515018603`

[4] XAFS-DET: A new high throughout X-ray spectroscopy detector system developed for synchrotron applications `https://doi.org/10.1016/j.nima.2022.167600`