

Experiments Control System

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Orchestrating 4th Generation Experiments at MAX IV

Continuous Scans, Multimodal Measurements, and Hardware-Synchronized Data Acquisition

Outline

- Control System and Orchestration
- Tomography case
- Continuous Scans
- Multimodal Experiments

Control System and Orchestration

**Experiment
Orchestration**



**Control
System**



Hardware

Icepap

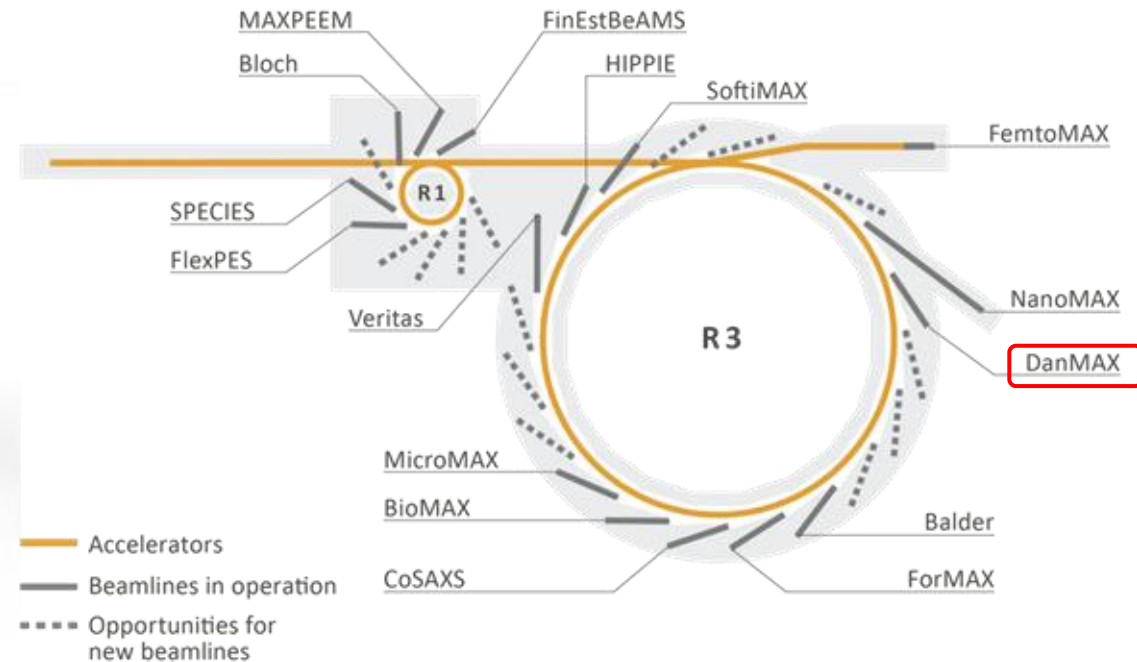
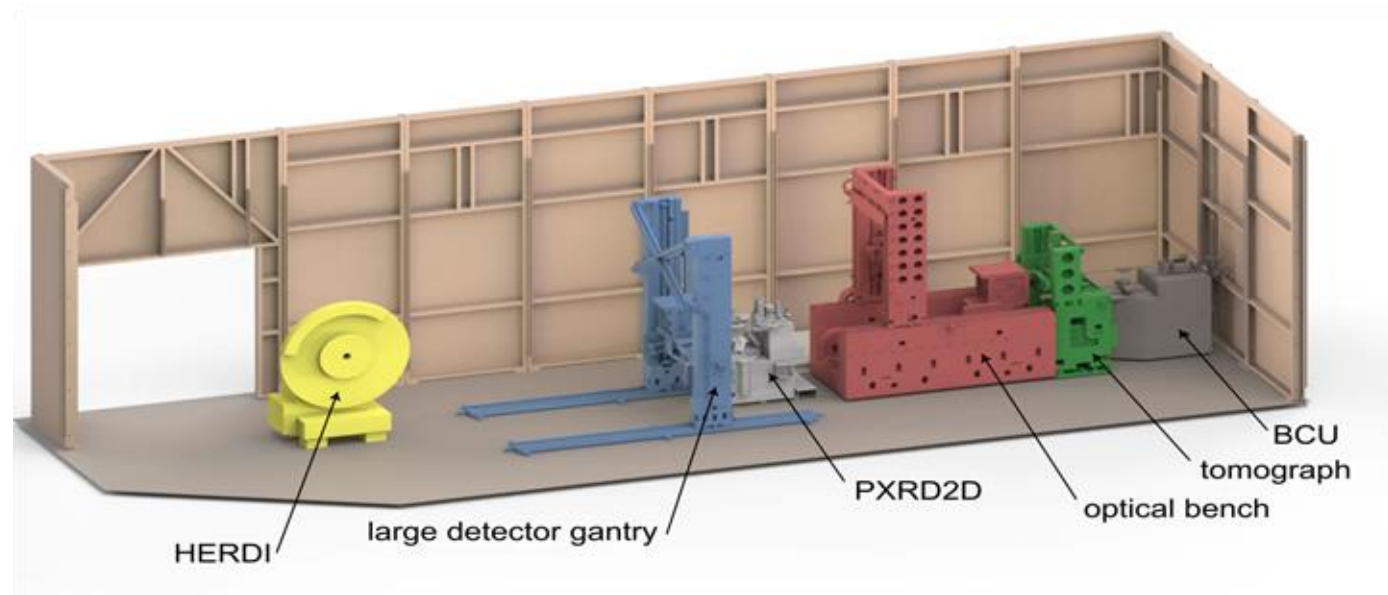


Metadata



Tomography case

- A materials science beamline
- Operates in hard X-ray range 15-35 keV
- Three endstations: full-field imaging, versatile powder diffraction, and high-resolution powder diffraction(ongoing).





- Supports a **wide range of sample types and environments**
- Effective pixel size: 550 nm or 275 nm
- Combines **transmission-based** imaging with **diffraction-based** imaging.

Sample goniometer:

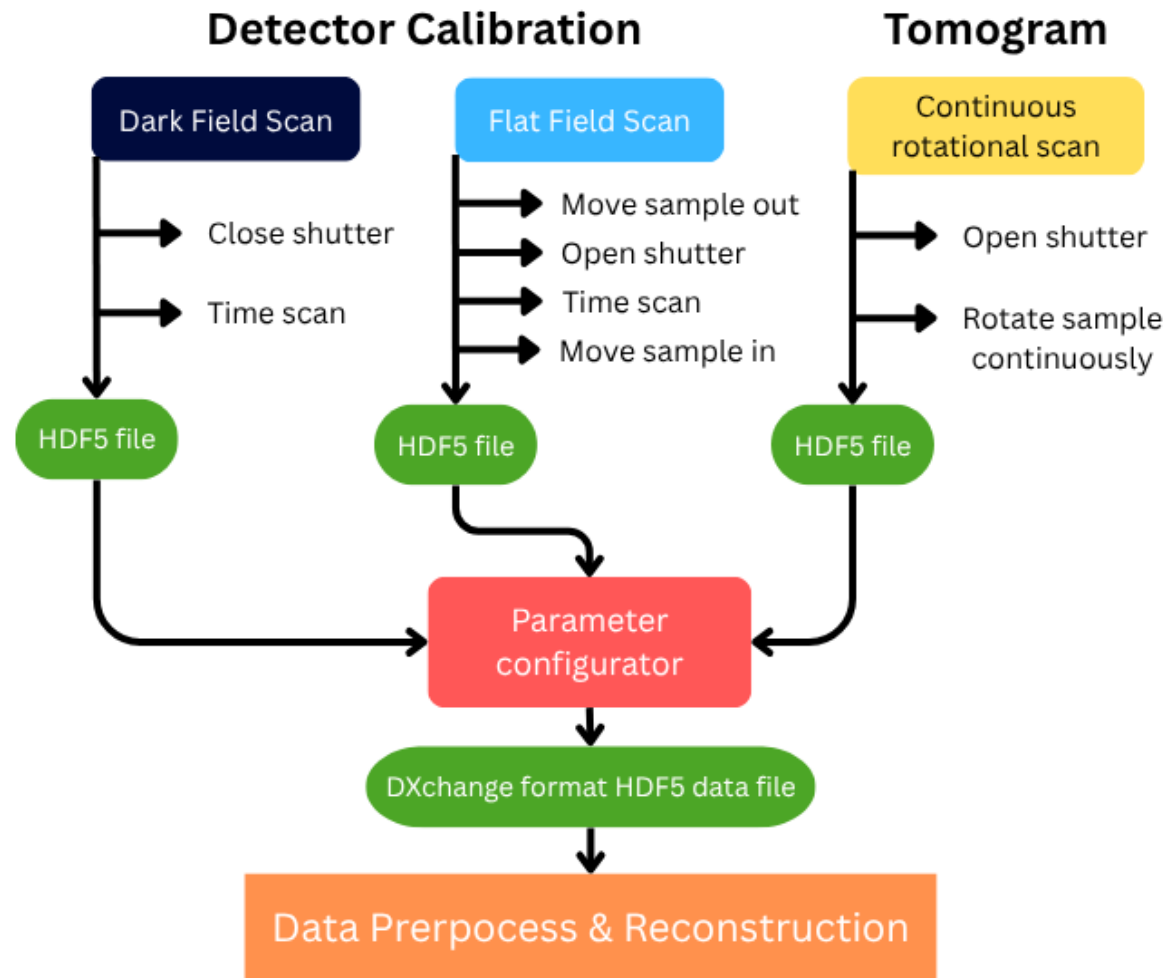
built around two rotary unions controlled by an ACS system.

- Supports the XY alignment stages mounted above it
- Offers 20nm radial and axial error motion.
- Provides essential electrical connections for user-defined sample environments, including small motors, trigger signals, and high-voltage supplies.
- Two additional rotary unions enable high-pressure gas/fluid delivery and vacuum operation.

Measurement time:

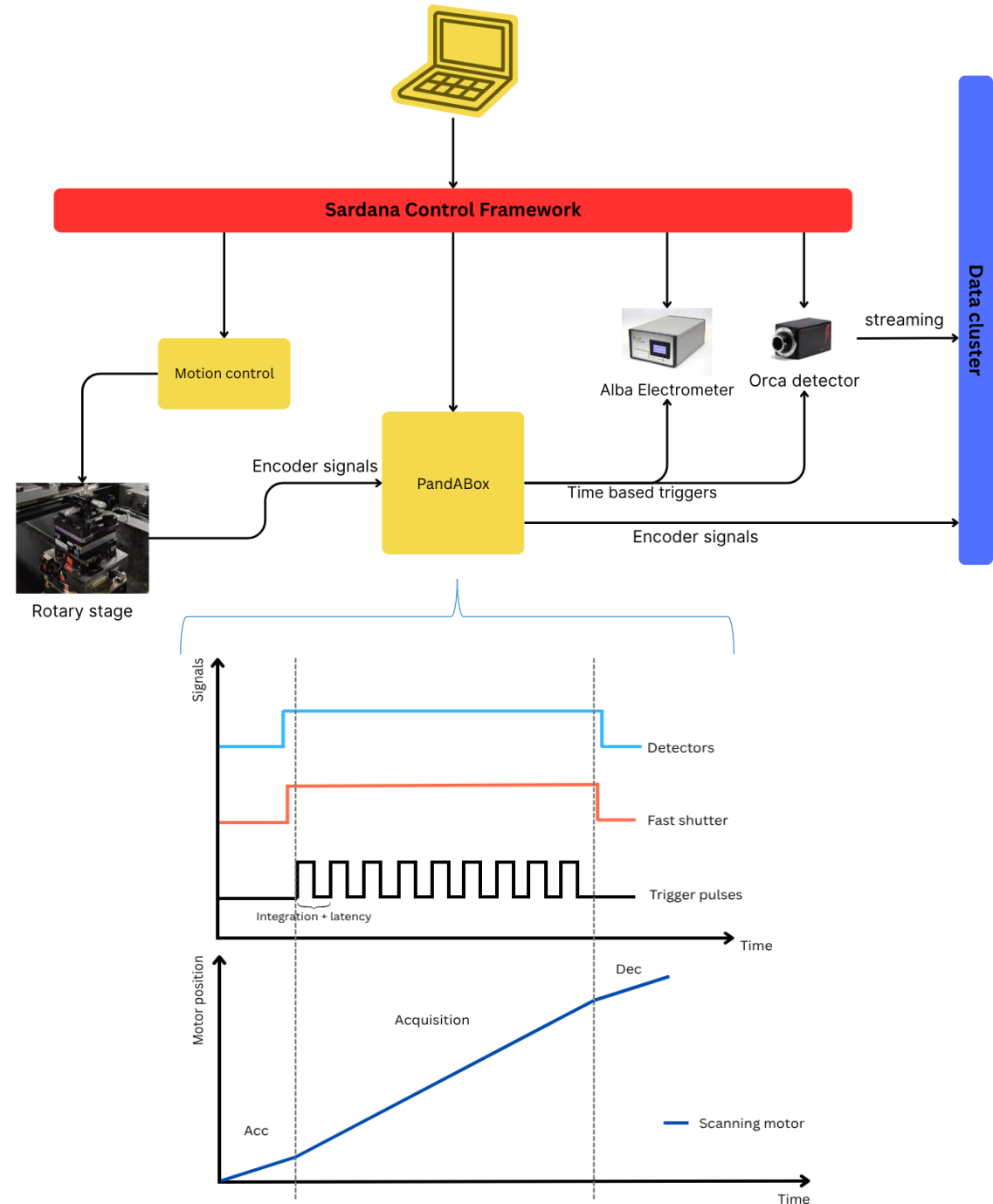
- Single-volume tomographic scan ($\sim 1 \text{ mm}^3$) can be as fast as 1 second.
- Typical scan times: 10–300 seconds per volume
- Scan duration depends on:
 - Exposure settings
 - Detector dynamic range
 - Objective lens used

Experiment Process

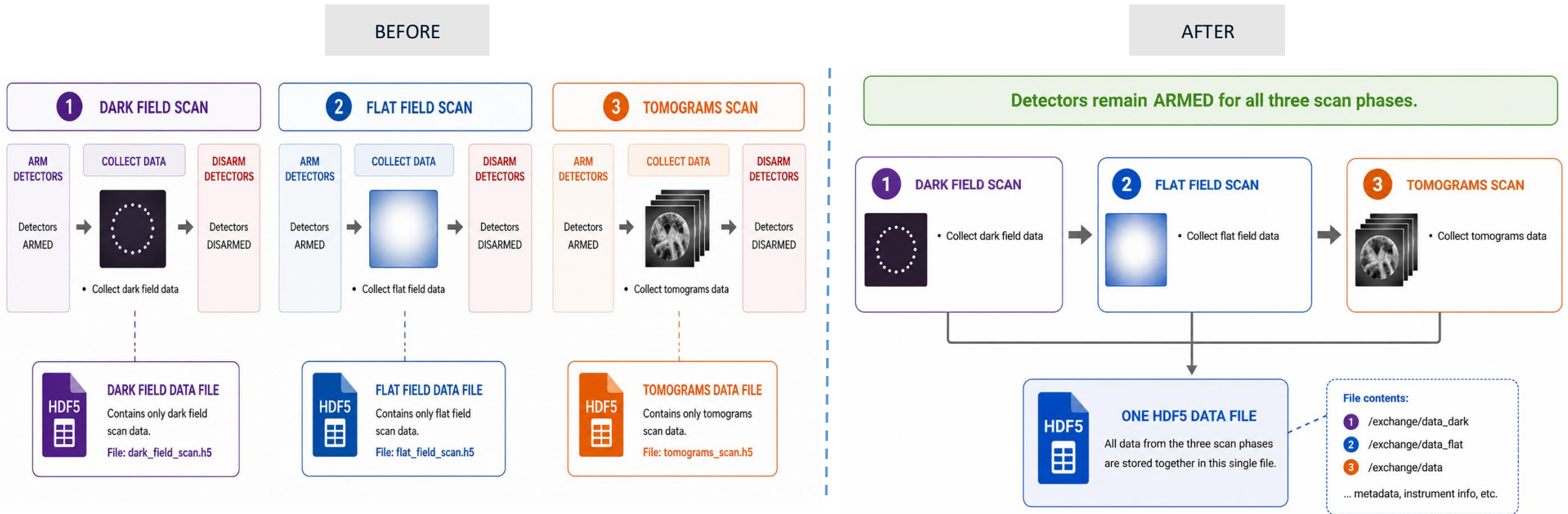


Synchronization

- Sardana handles the software synchronization between the detectors and motor movements.
- PandABox generates the acquisition triggers and ensures that data are acquired at the correct motor positions.
- The acquired data and motor positions are streamed to the cluster in parallel during the scan.



Future Work



Improve efficiency

- Skip disarming the detector for different scanning phases
- Create only 1 data file
- Prepare the tomograms while repositioning the sample during the flat field acquisition phase

Continuous scan

At MAX IV, continuous energy scans are performed through continuous monochromator and undulator motion while data are acquired. This makes better use of the available photon flux while shortening measurement time and improving throughput.

Reference:

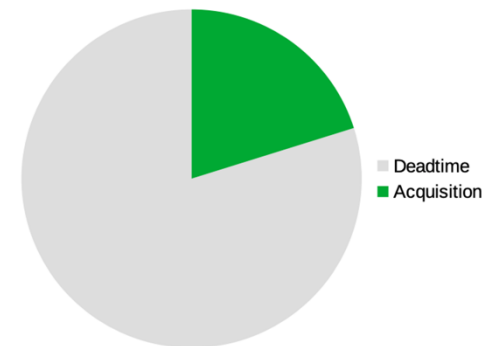
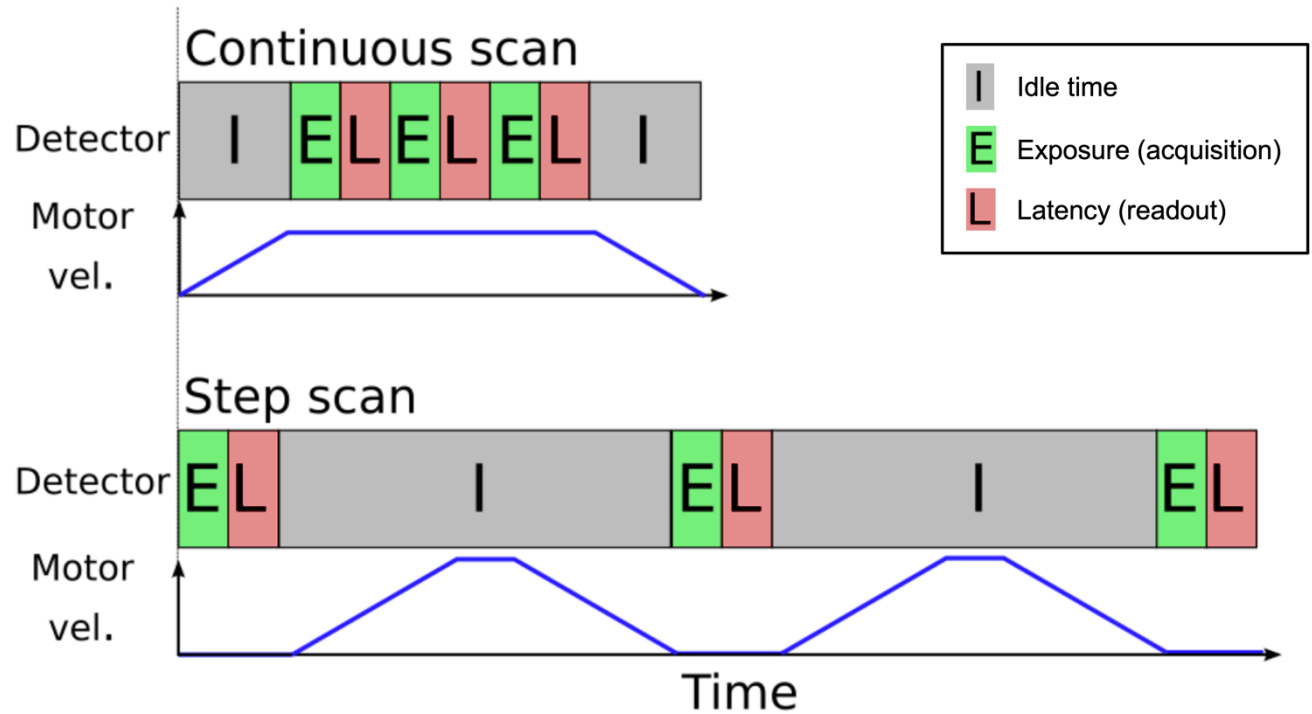
<https://proceedings.jacow.org/icalepcs2025/doi/jacow-icalepcs2025-thag006/>

<https://proceedings.jacow.org/icalepcs2025/pdf/WEAG006.pdf>

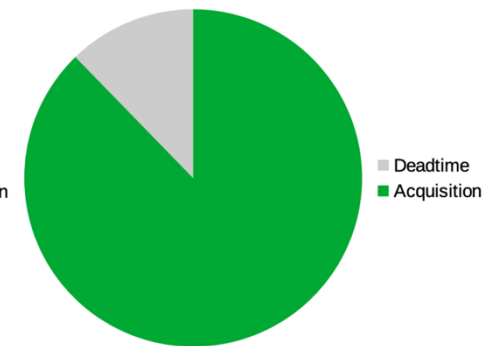
https://proceedings.jacow.org/icalepcs2025/pdf/THAG006_talk.pdf

Faster experiments

- Reduce the duration of experiments or increase the amount of data collected.
- Opposed to step scans, continuous scans acquire data while the motors are continuously moving.
- Measurements are triggered as soon as the correct positions are reached and made while the motor is still moving.
- It is possible with detectors that have short exposure and integration times.



Step scan
248 seconds

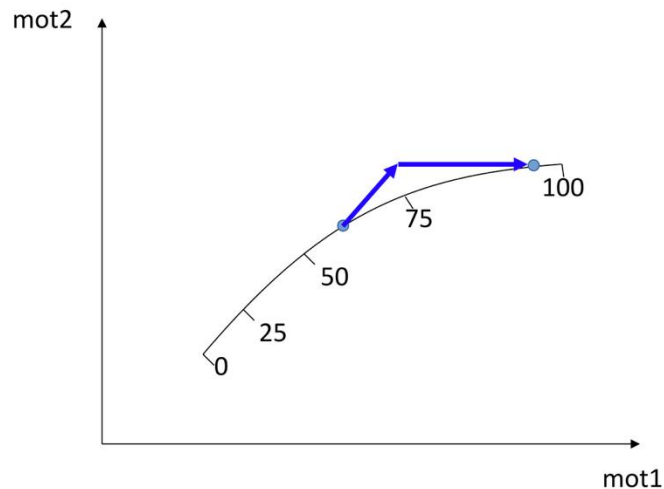


Continuous scan
57 seconds

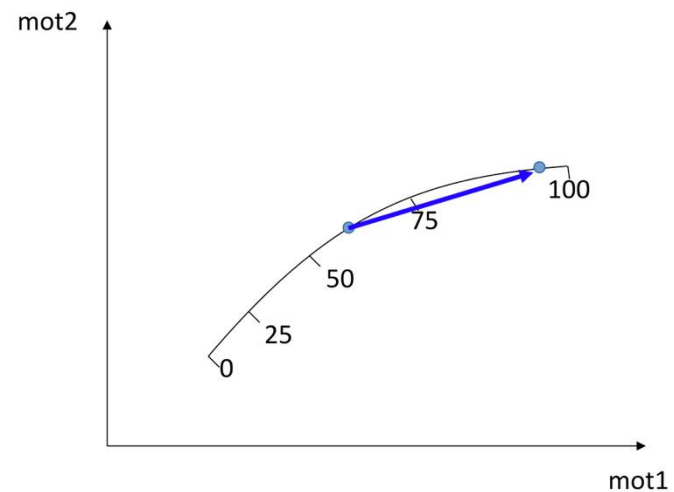
Icepap Parametric Trajectory

- It is possible to make non-linear movements in IcePAP keeping a constant value in eV/s.
- The trajectory tables are calculated by a sardana controller and inserted in the IcePAP driver.
- The IcePAP uses an interpolation method to follow the trajectory.
- Energy range and the number of points in the trajectory table are configurable.

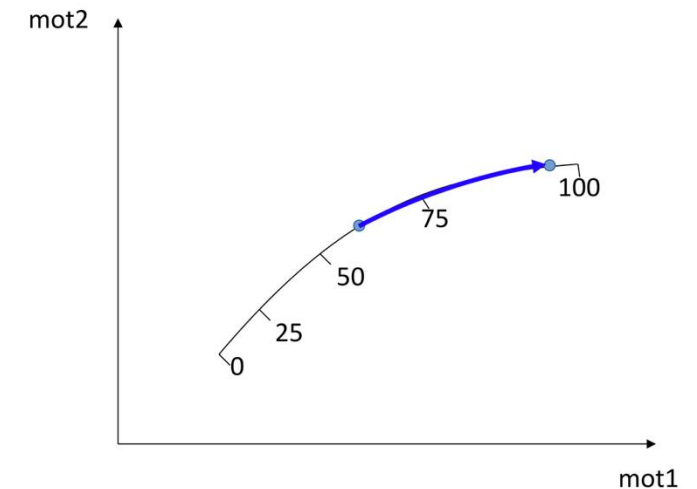
Nominal Velocities



Matched Velocities

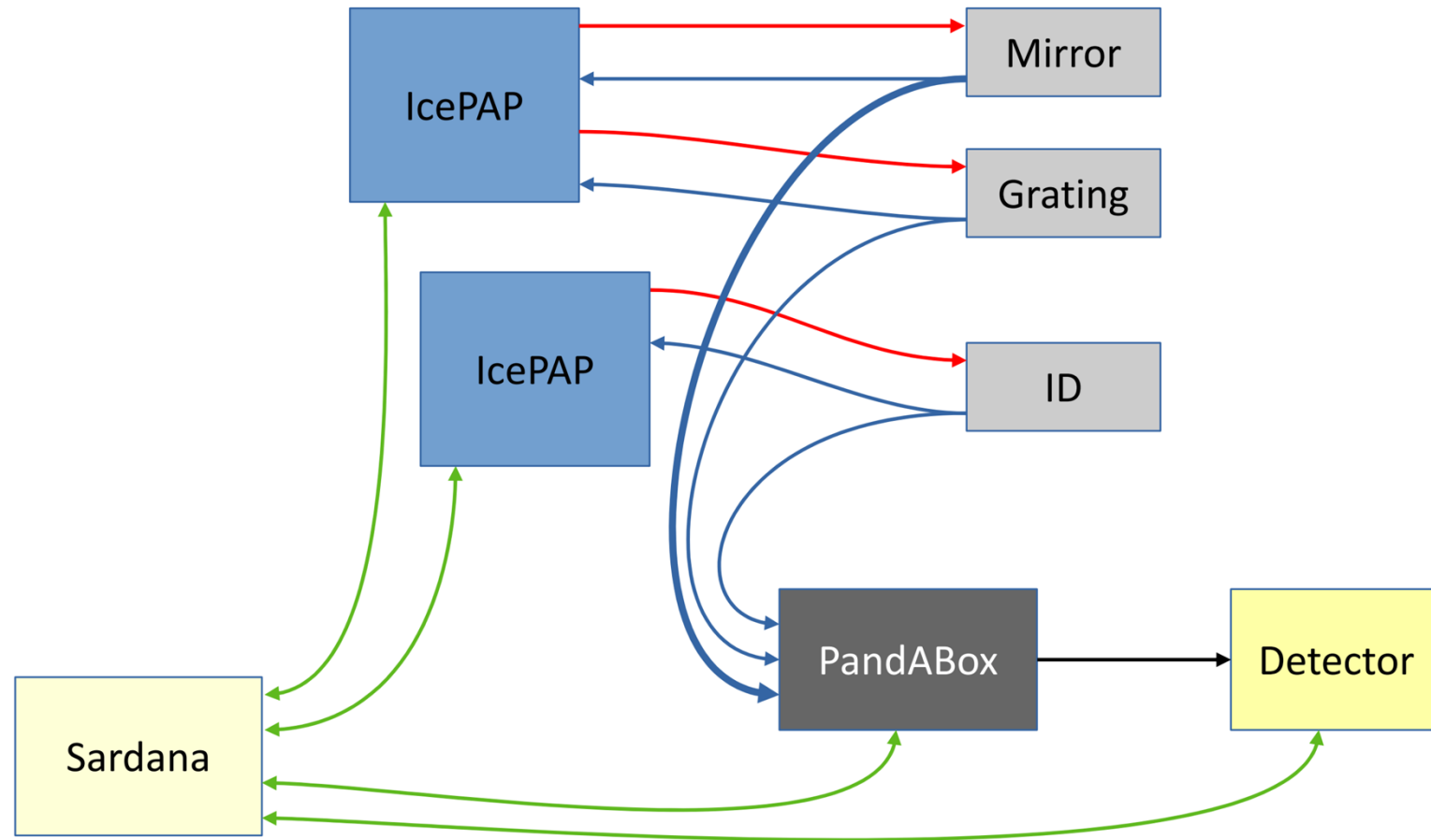


Parametric Trajectory



Synchronization Scheme

- The synchronization is made through hardware using PandABox (FPGA).
- The encoders of the motors are connected to the PandABox.
- The orchestration system (Sardana/Contrast) configures at which positions the detectors should be triggered.
- The detectors are armed by the orchestration system (Sardana/Contrast) in the beginning of the scan.



Implementation at MAX IV Beamlines

- The continuous scan is a long running project on MAX IV, implemented on 8/16 beamlines.
- Each beam line has its own set of requirements, and the implementation of the continuous energy scan needs to be analysed case by case.
- Non-linear gap motion prevents photon flux loss.
- A general architecture based on hardware components enables scalability across different beamlines and control/scanning systems.

Multimodal Experiments at MAX IV

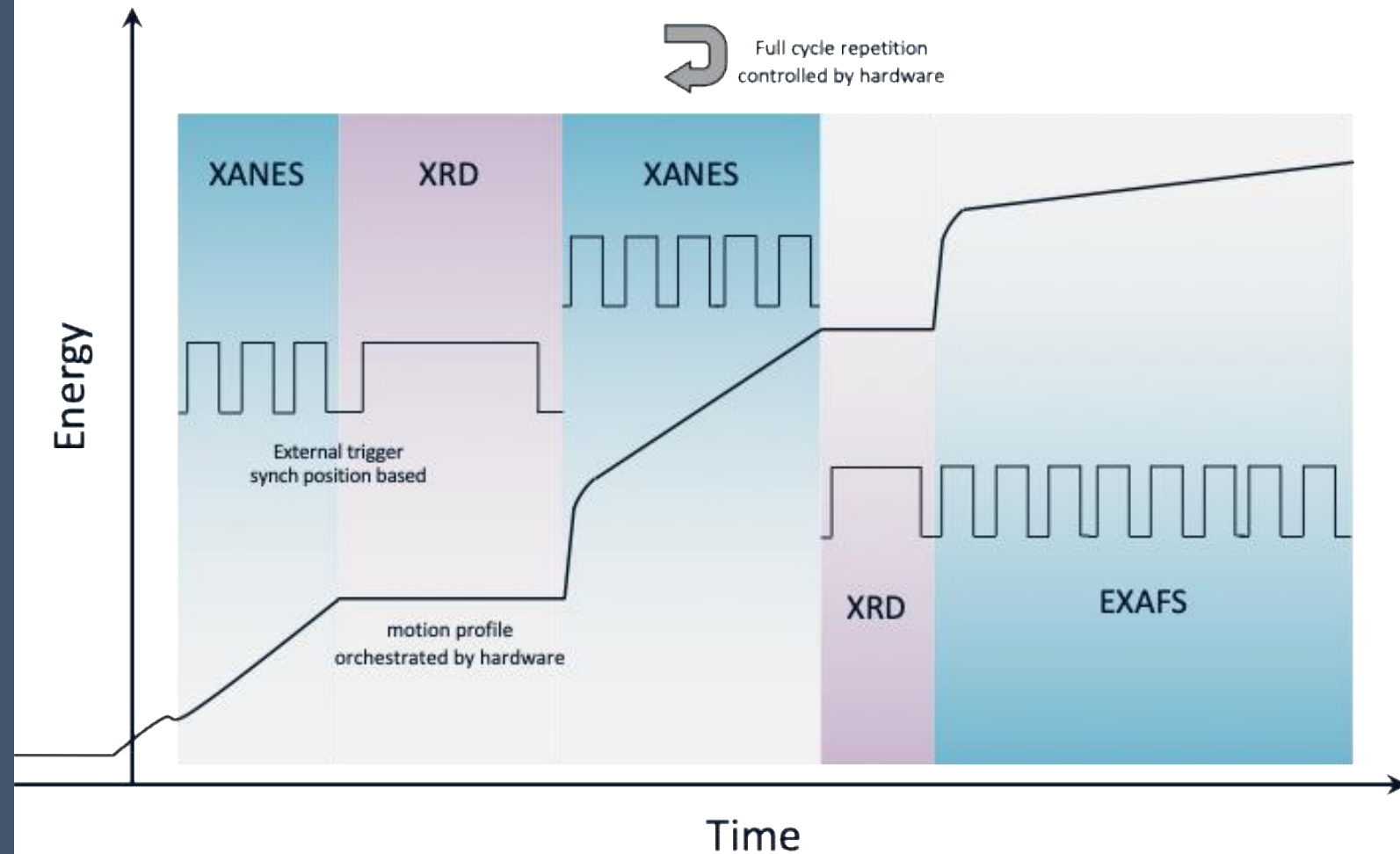
- A combination of complementary techniques within a single synchronized measurement:
 - Correlated observations from the same experimental and sample conditions.
 - Improved overall beamline throughput.
- A combination of measurements made across different beamlines into a single experiment.

Reference:

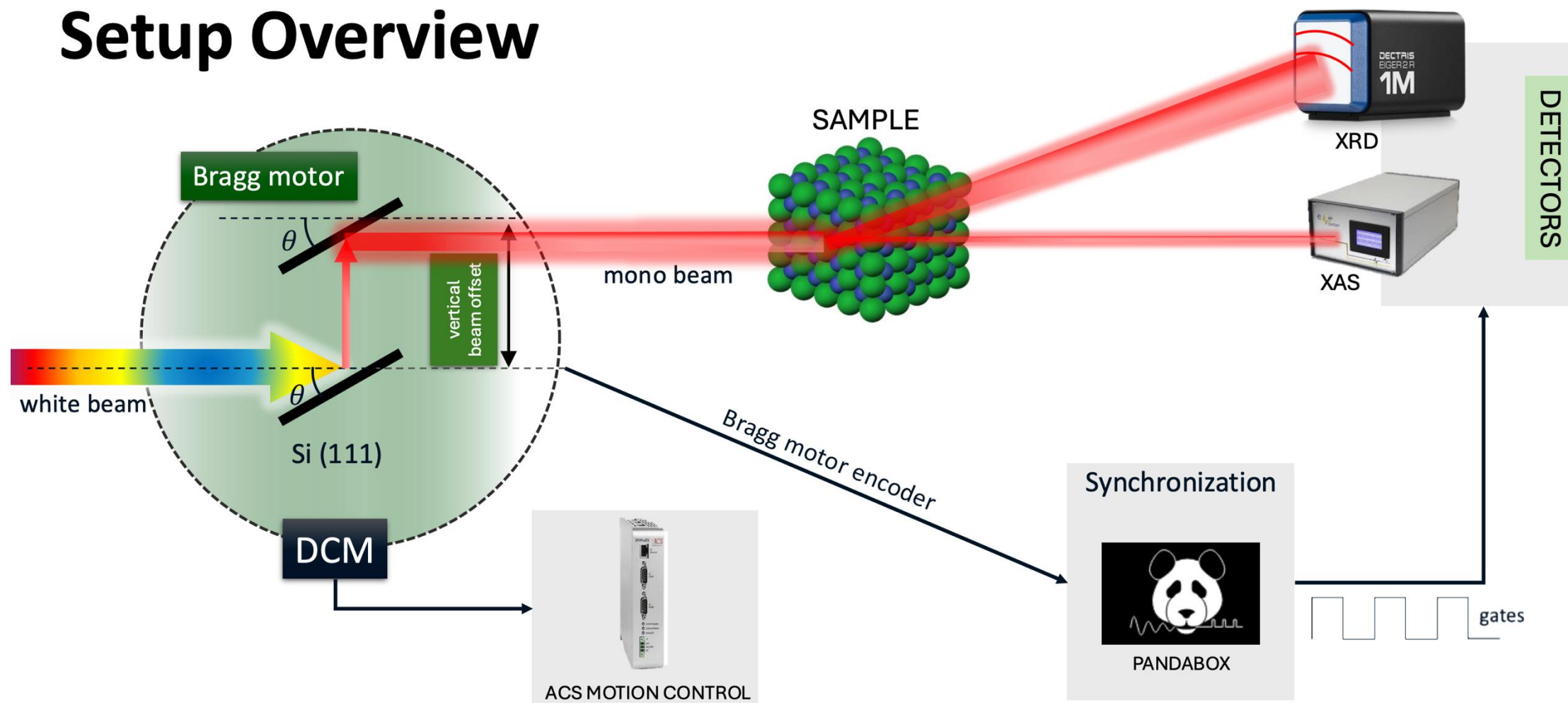
<https://proceedings.jacow.org/icalpcs2025/doi/jacow-icalpcs2025-thag002/>

<https://proceedings.jacow.org/icalpcs2025/pdf/THAG002.pdf>

https://proceedings.jacow.org/icalpcs2025/pdf/THAG002_talk.pdf



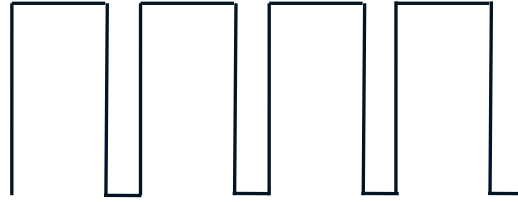
Setup Overview



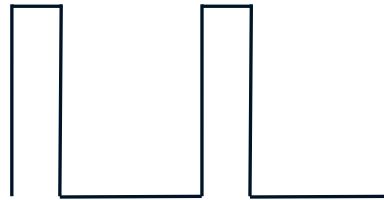
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  "tg01": [
    {
      SynchParam.Delay: {SynchDomain.Time: 0},
      SynchParam.Active: {SynchDomain.Time: 0.2},
      SynchParam.Total: {SynchDomain.Time: 0.3},
      SynchParam.Repeats: 4,
    }
  ],
  "tg02": [
    {
      SynchParam.Delay: {SynchDomain.Time: 0},
      SynchParam.Active: {SynchDomain.Time: 0.1},
      SynchParam.Total: {SynchDomain.Time: 0.5},
      SynchParam.Repeats: 2,
    }
  ]
}
```

tg01: triggergate axis 1



tg02: triggergate axis 2



expconf

Channel	Synchronizer	Synchronization
Albaem-01	tg01	Trigger/Gate
Albaem-02	tg01	Trigger/Gate
Eiger-01	tg01	Trigger/Gate
Eiger-02	tg02	Trigger/Gate
PCAP	tg02	Trigger/Gate

TriggerGate

SynchOne(axis, configuration):

```
if axis == 1:
    configuraton = tg01
if axis == 2:
    configuration = tg02
```

Albaem-01

PrepareOne(axis, 0.2, 4, 0.1, nb_starts)

Eiger-02

PrepareOne(axis, 0.1, 2, 0.4, nb_starts)

Systematic Experiment Description and Triggering

- Experiment descriptions capture orchestration logic in a reusable form, reducing reliance on beamline-specific implementations
- A common triggering model simplifies the integration of new synchronized techniques
- Explicit experiment context ensures consistent data correlation and provenance tracking

Decouple data acquisition from scan execution

