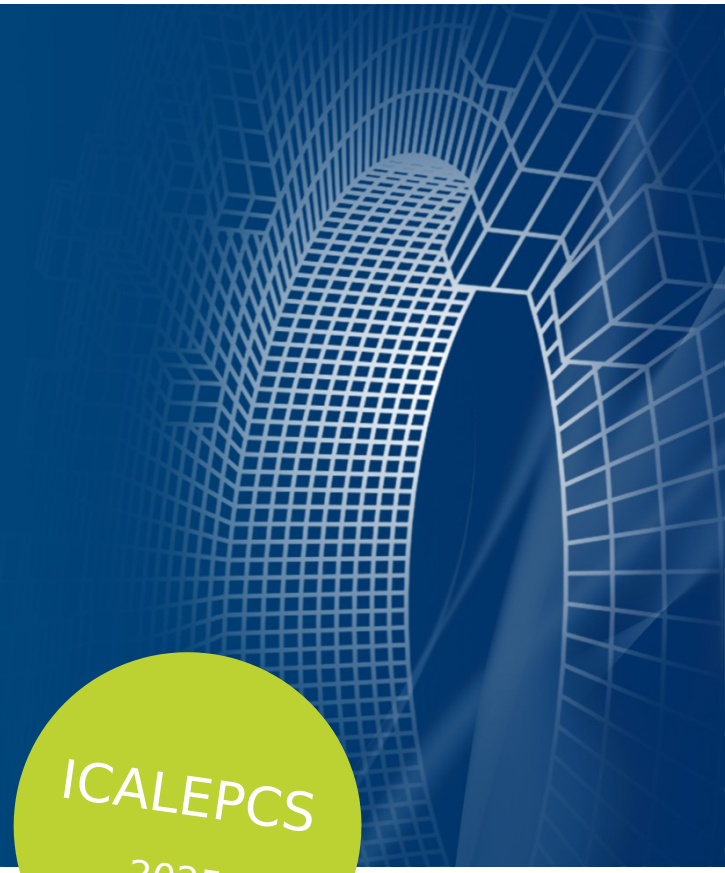
HZB BESSY II Light Source

HASMI: A CONFIGURABLE PYTHON FRAMEWORK FOR AUTOMATED HARMONIC ANALYSIS AND SCAN ORCHESTRATION AT EMIL

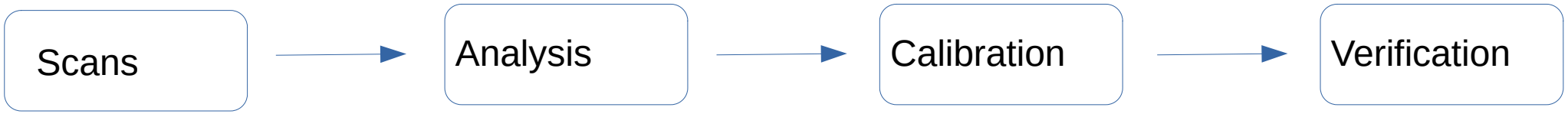
Andreas Balzer
Parvathi Sreelatha Devi
Anna Efimenko
Karsten Holldack



ICALEPCS 2025

Motivation

- Manual optimization is time-consuming & error-prone
- One button workflow
- Required reproducible, fast automation
- Unified approach across across all setups: software, hardware & sequences
- Design to work across all setups:



Automated Fine Tuning

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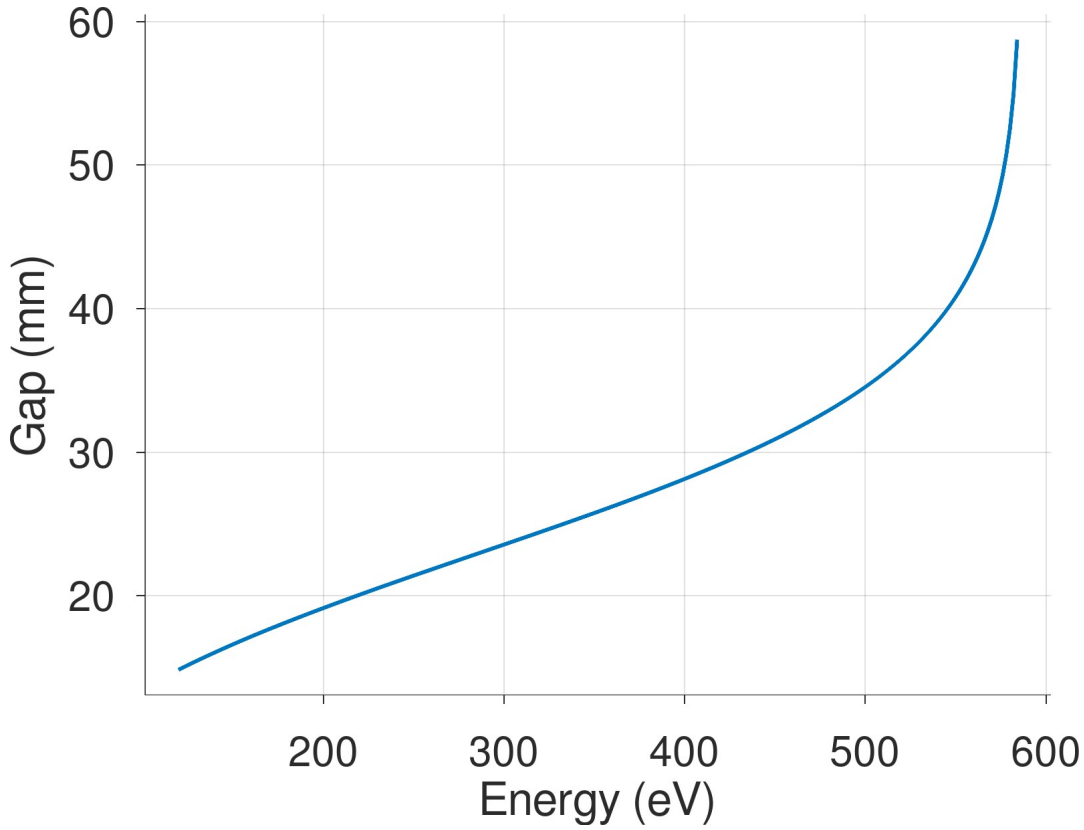
- Fine tuning lookup tables: slope offset correction
- Frequent calibration
- Mapping depends on settings
- (e.g. apertures)
- Two reference scans at start & end of range → update slope/offset.

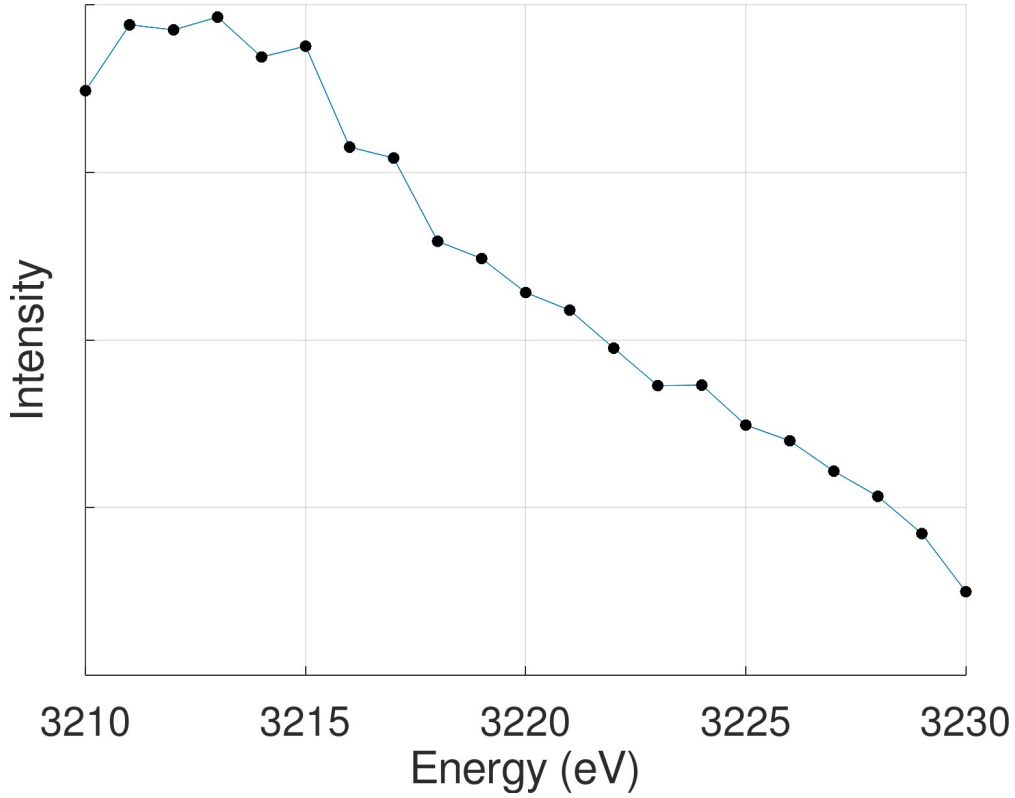
$$\text{gap} = f(\text{slope} \cdot E + \text{offset})$$

$$E = \frac{f^{-1}(gap) - \text{offset}}{\text{slope}}$$

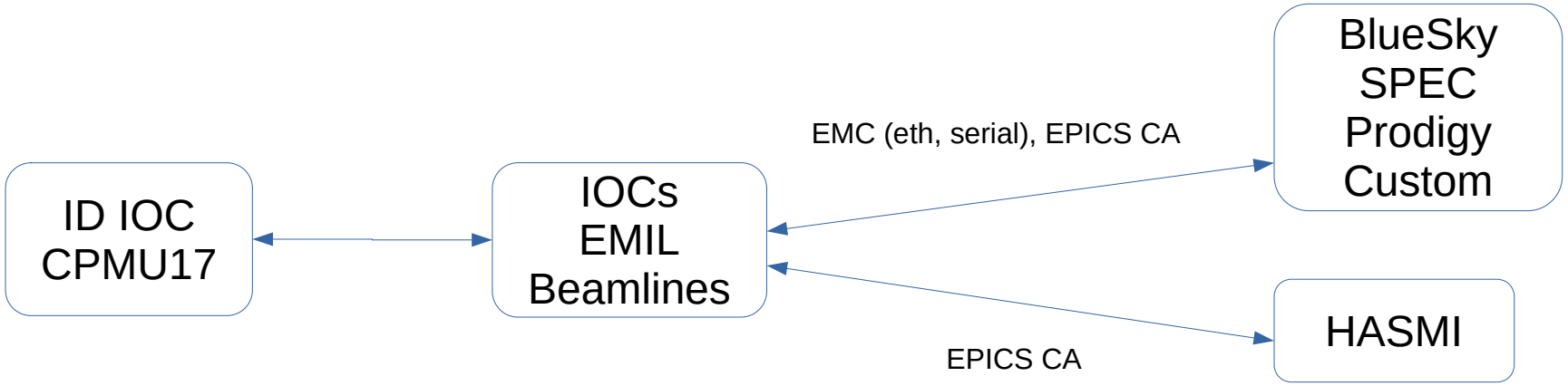


Challenges

- **Reproducibility:** presets & manifest YAML.
- **Orchestration** of different beamline components, data acquisition and scans
- Operator usability
- **Speed**
- Different device types
- **Resolution** and **Noise**
- **Selective peak** finding
- **Integration** into heterogeneous environment: Bluesky, SPEC, Prodigy, Igor Pro, ...



Beamline Integration



- Multiple experimental frameworks / protocols
- Deployed at the CPMU17-DCM Beamlines at EMIL
- Rolled out at UE48 soft branch beamlines at EMIL
- Can be accessed via EPICS CA / Panels / CLI

Software Framework Components

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Interfaces

EPICS PVs

CLI

Core

Application Layer
State Machine

(workflow, slope/offset correction)

Analyzer

(peak detection)

Scheduler

(sequences, presets)

Scan Library

(multi actuator)

Extern

EPICS IOCs

Files

(presets, config, manifest)

State Machine

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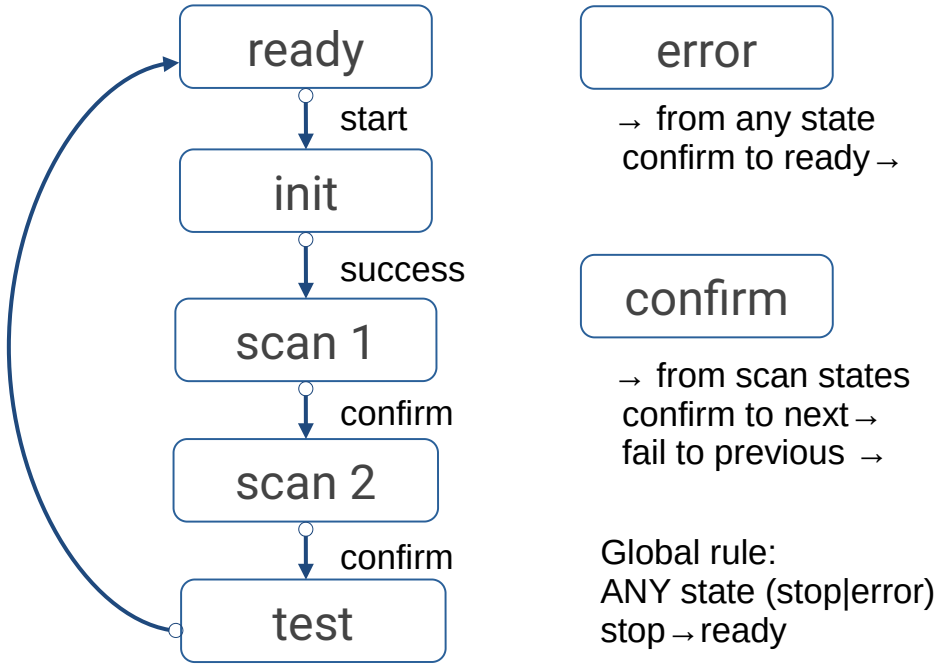
Updates slope & offset correction for undulator lookup tables

- **Loop:** `ready → init → scans → eval → cleanup`
- Confirm & error states
- Keeps track of previous state
- EPICS CA: PvObserver / PvHolder

Workflow

- Scans
- Analysis
- Calibration
- Verification



Test and Automation Framework for Multi-Actuator Scans

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Overview

- Proven Lightweight Testing Tool
- Advanced scanning – stepwise, continuous, multi-dimensional, parallel
- Soft Real-time tools – monitoring, logging, error handling, diagnostics
- Plugins – extend via hooks
- Debug Plots

Design Philosophy:

- Composable architecture – unlimited actuators & plugins
- Developer-oriented

Modules

Scan:
- Abstract Interfaces
- API
- CLI
- Datamodel
- Plotter
- YAML

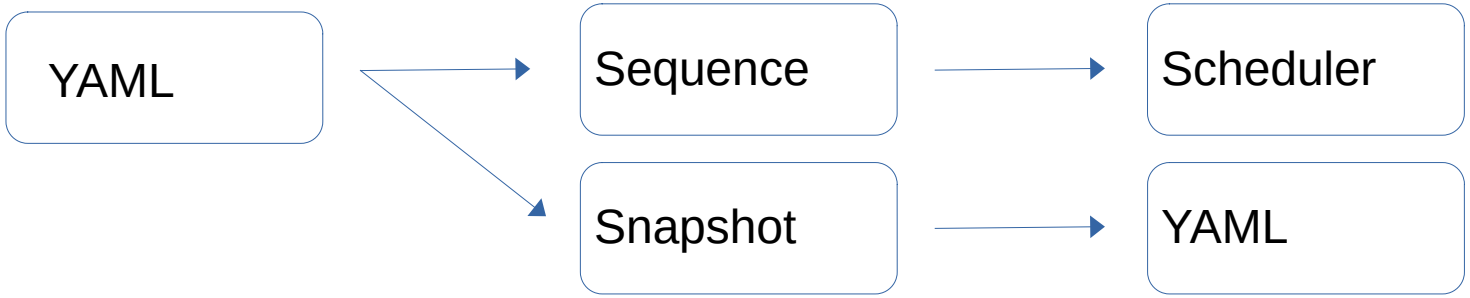
Actuators

Monitors

Plugins

Data

Asyncio Scheduler Framework



Overview

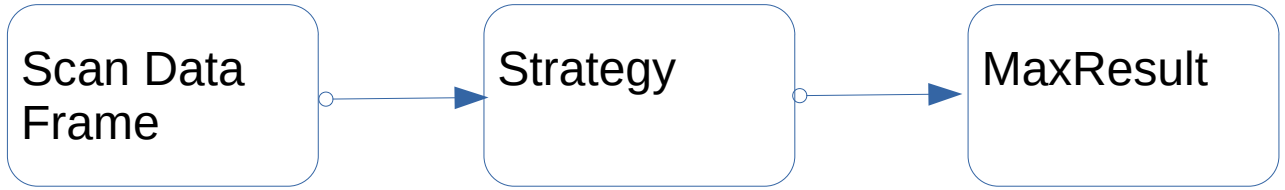
- **Abstract device framework** for diverse hardware/software types
- Async execution (**asyncio**)
- Generates **sequences** from YAML
- **Parallel & serial** execution of motion/automation sequences
- **CLI / API**
- Modular abstractions – factory-pattern devices, extendable capabilities
- Key components – Scheduler, Sequences, **Devices**

Example:
Set PV Sequence to configure beamline
→ Toggle → Aproach Sequence → Scan

Harmonic Analyzer

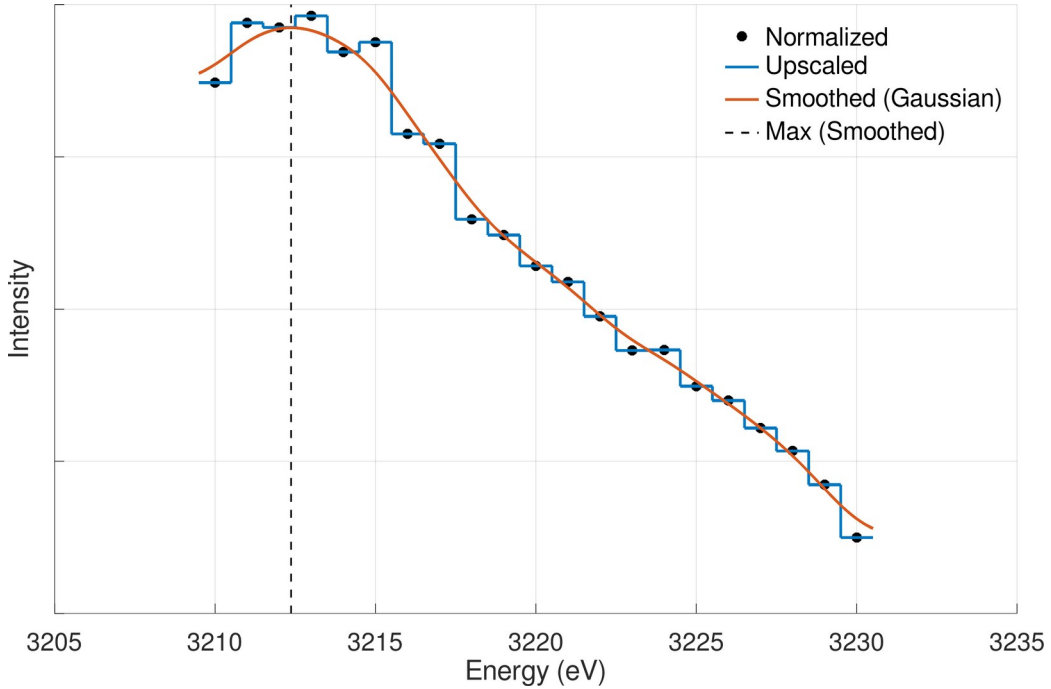
Overview

- Finds harmonic peak positions
- Strategy Pattern for algorithms
  `Argmax, Center of Gravity, Convolution, Autocorr, Crosscorr`



- Preprocessing
- Algorithm
- Kernel Objects

- Gap/Energy
- Fractional index
- Diagnostic



Kernels for Peak Finding

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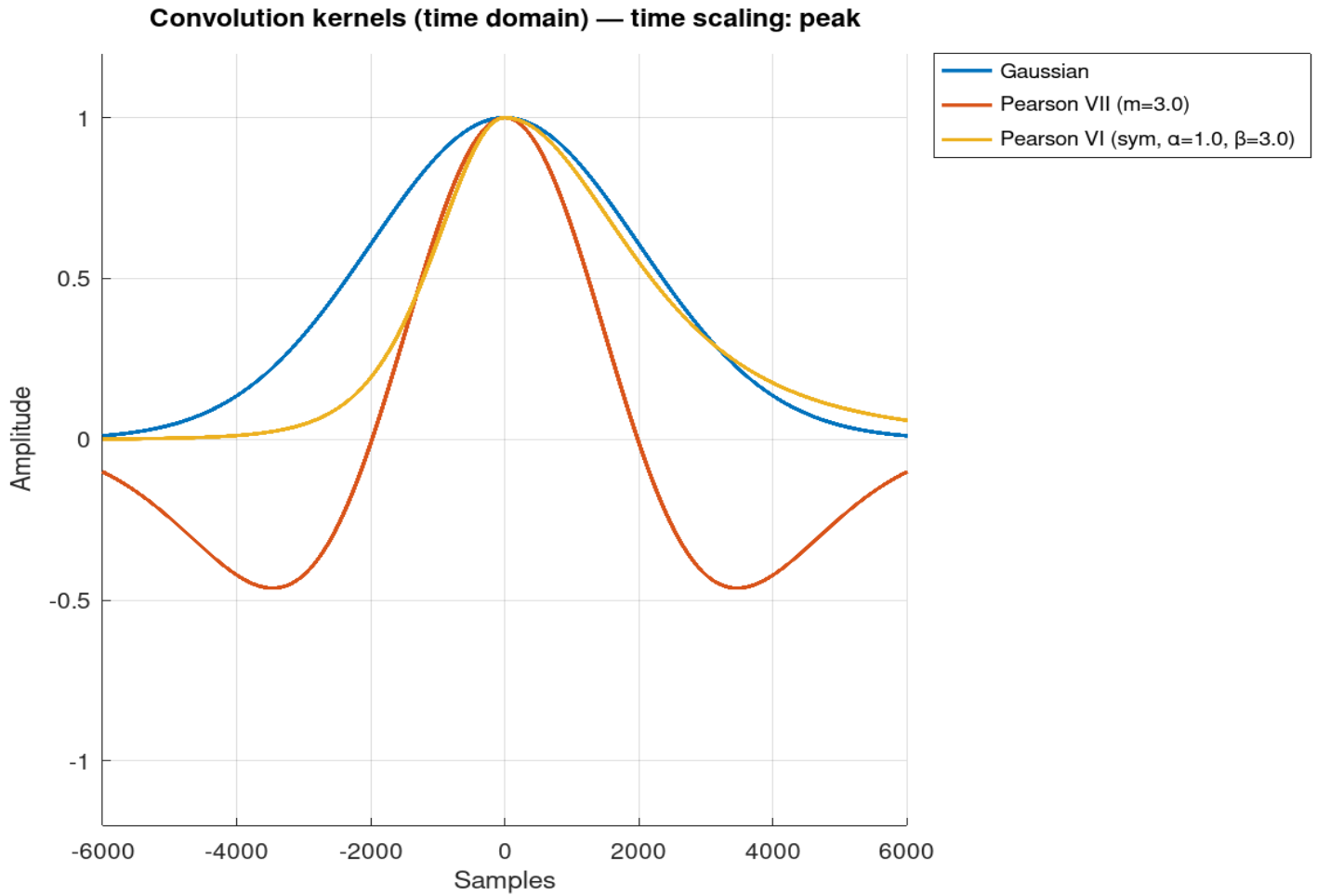
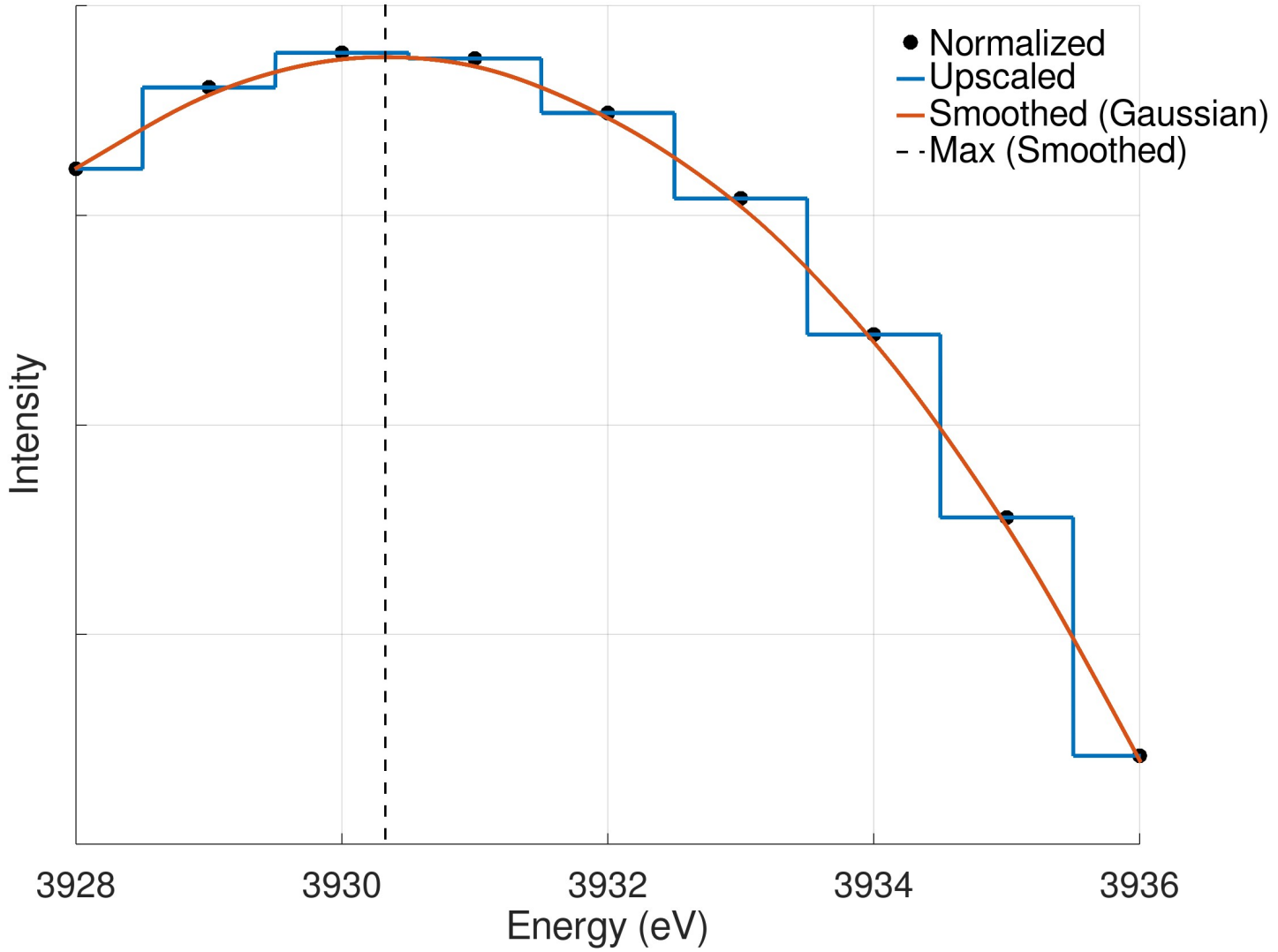
Overview

- Built-in kernels: Gaussian, Mexican Hat, Pearson VI/VII, Rectangle/Boxcar
- Custom kernels supported
- Normalization (L1/L2)
- Translational Offset



Preprocessing

- Ring current normalization
- Detrend (linear)
- Peak window
- Normalization
- Resample (step/hold,interpolated)



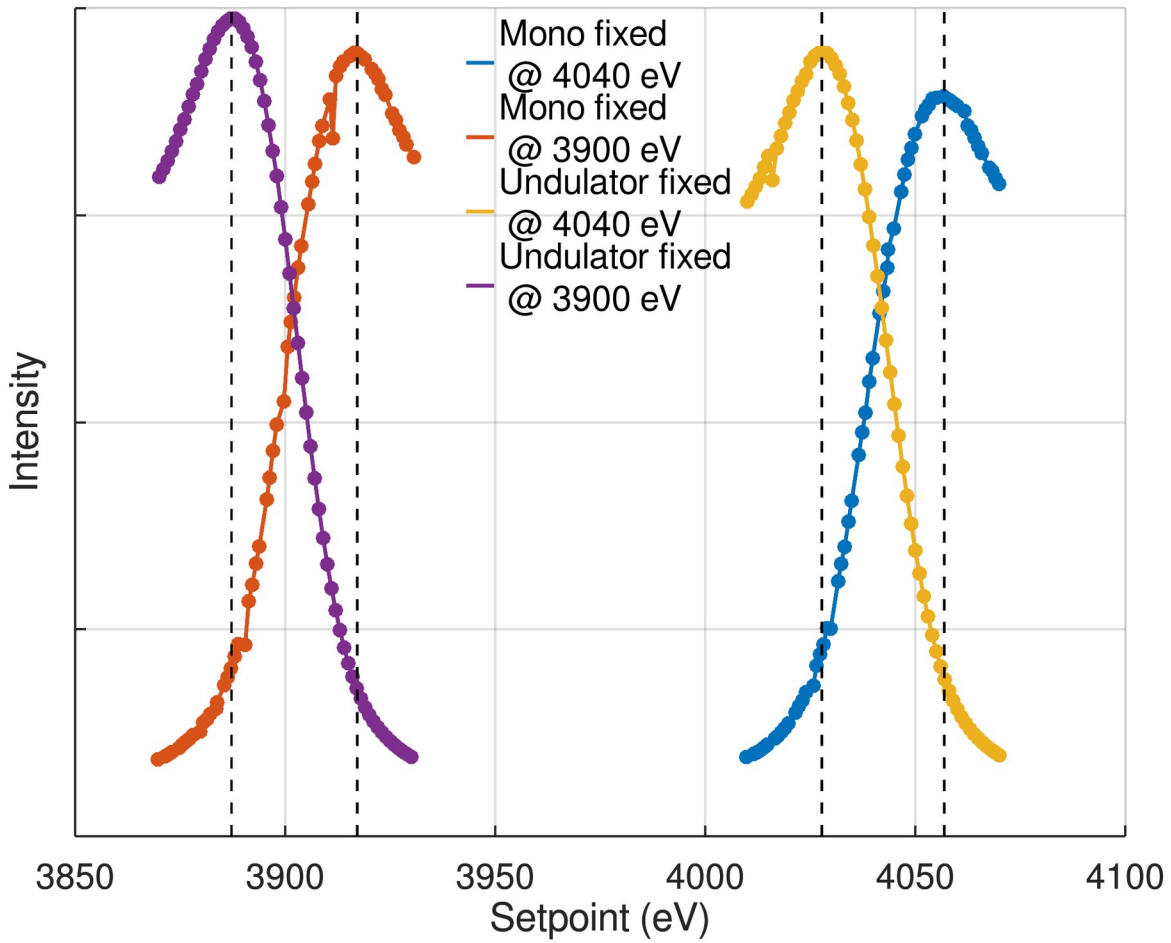
Symmetry

Case 1: Scan monochromator, undulator fixed

Case 2: Scan undulator, monochromator fixed

Symmetry of the Scan Modes

$$(f_1 \circ f_2)(x) = (f_2 \circ f_1)(-x)$$



Post Mortem

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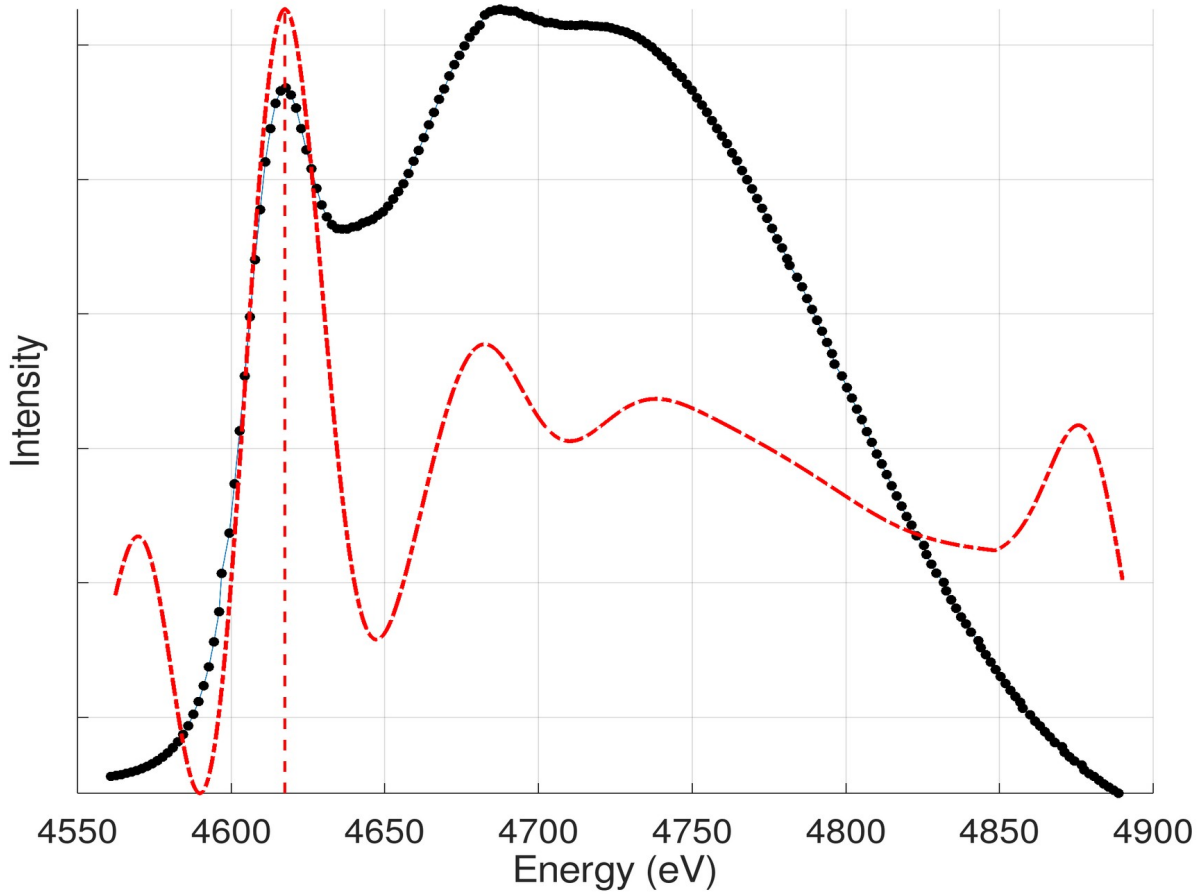
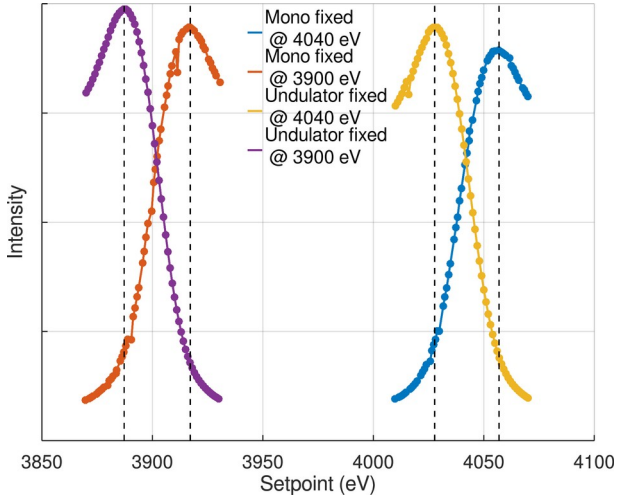
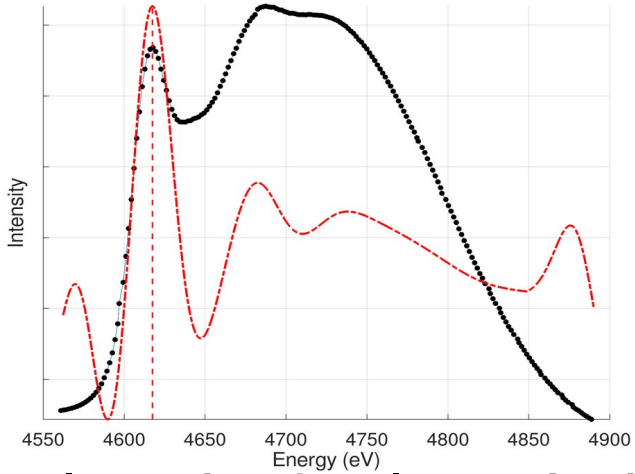
- CLI Tools
- Presets
- Autocompletion
- Usable for non experts



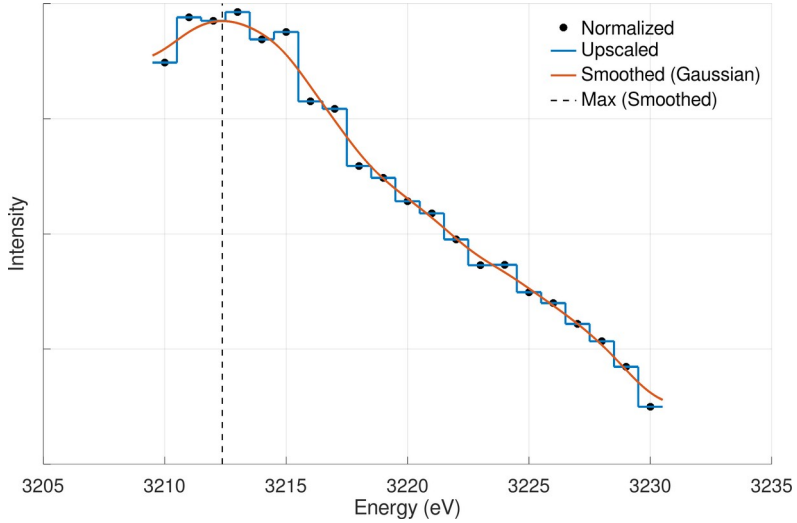
Results



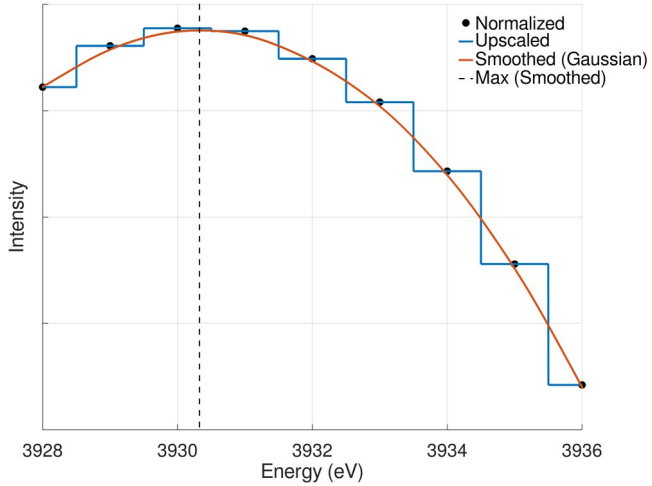
Scan mono or undulator



Local peak of selected width



Noise



Fractional index

Outlook

- Completing deployment on soft branches at EMIL
- Continuous Mode
- Publishing
- Wider deployment

Conclusions

- Modular & extensible
- Declarative YAML / Templates
- Enables „One button operation“
- Integration via CLI, Python import, EPICS CA
- Fully automated
- Robust
- Time saved
- Post mortem / Online

Thank you for your attention.

Now scanning for feedback.