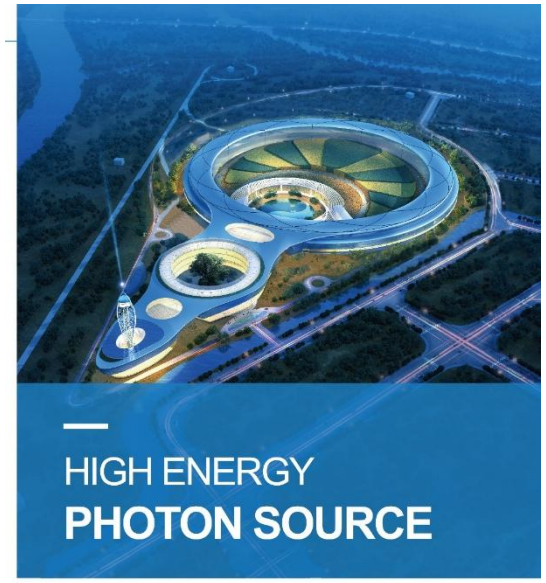
Institute of High Energy Physics

Next-Generation Scientific Software System and AI-Driven Intelligence for Synchrotron Beamlines



MAMBA
Data acquisition software

Yi Zhang

2025/8/13

Outline

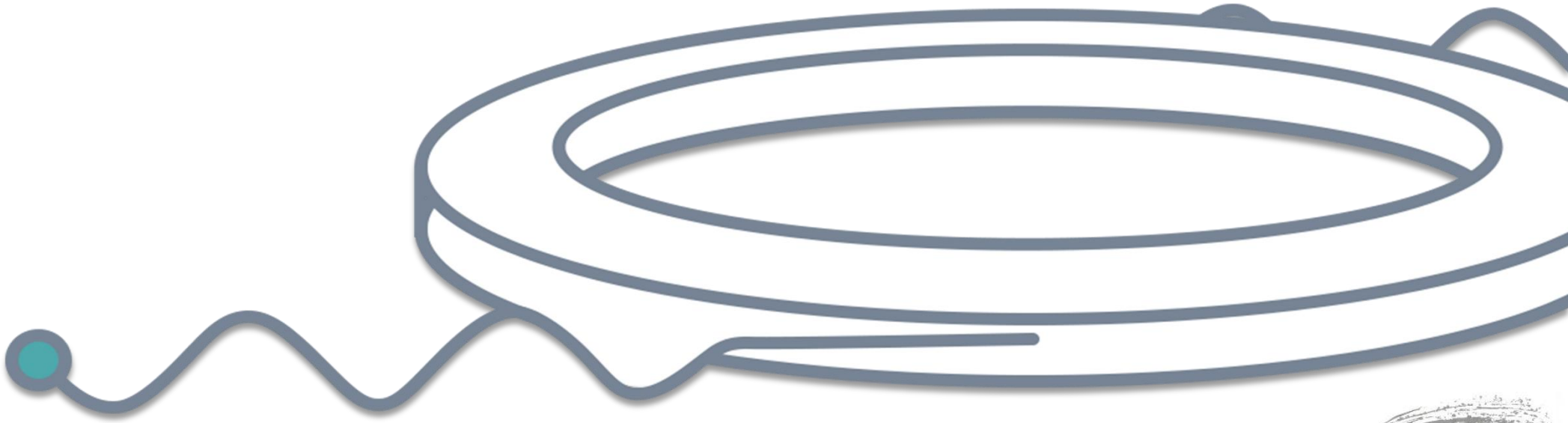
- **The Mamba project**
- **Addressing big data challenge using AI/ML**
- **Collaborative efforts for intelligent light source**

HEPS needs a systematic software solution

- Three dedicated HEPS teams for addressing the challenges in control, scientific software and computing

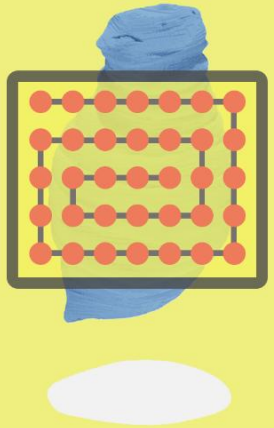
- Develop Control and acquisition software from scratch, no legacy issue
- Founded in 2020, HEPS-SE team are aiming to develop a systematic software solution in control and data acquisition for Phase I beamlines in HEPS

The Mamba Project

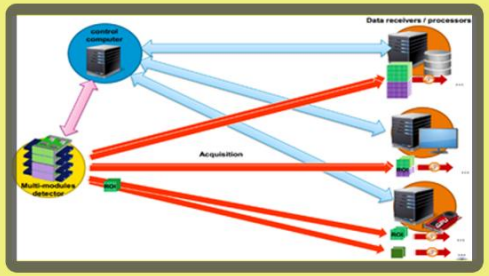


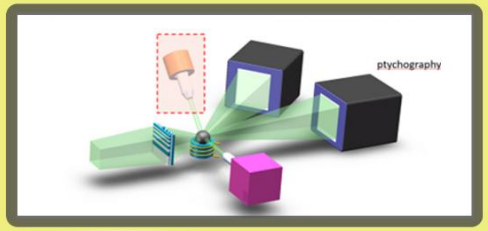
Drastic increase in data and experiment complexity

1 Nano & macro probe

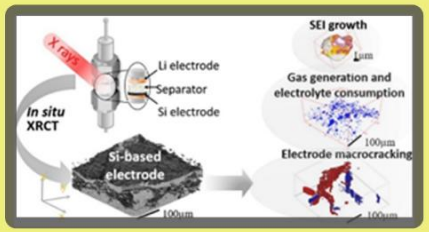


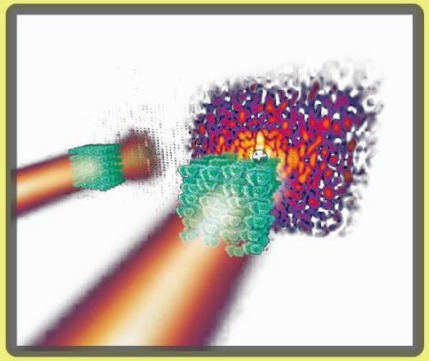
2 High throughput & Multi-modal



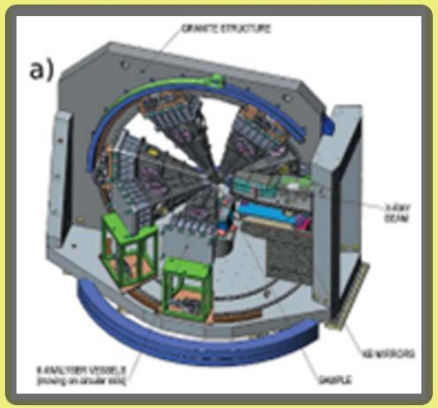


3 In situ & dynamic experiments





4 beamline automation & intelligent control

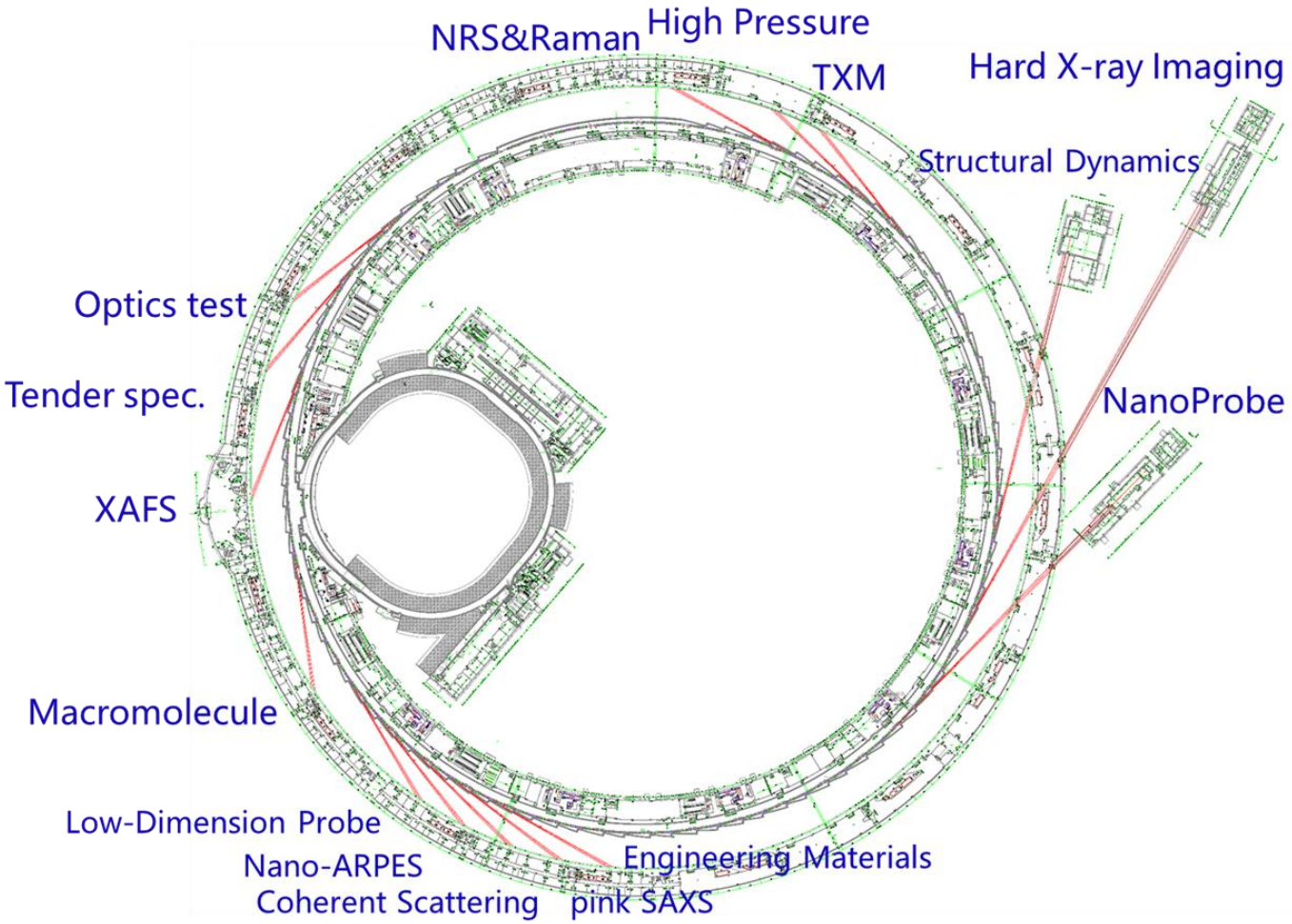


5 National data mangementpolicy

HEPS

- X-ray flux orders of magnitude brighter,
- Detectors are orders of magnitude larger and faster, single beamline generate up to *Pb* /run,
- *In situ* and *dynamic* experiments require real-time feedback and autonomous control,
- Data and software infrastructure for big science project

Heavy task for a young team



- 15 beamlines for Phase I project
- Multiple experimental modes and methods for single beamline
- Up to 30 suites of acquisition software delivered by 2025
- Limited personnel and lack of experience
- A systematic solution for all Phase I and future beamlines

A new generation synchrotron experiment operating software system

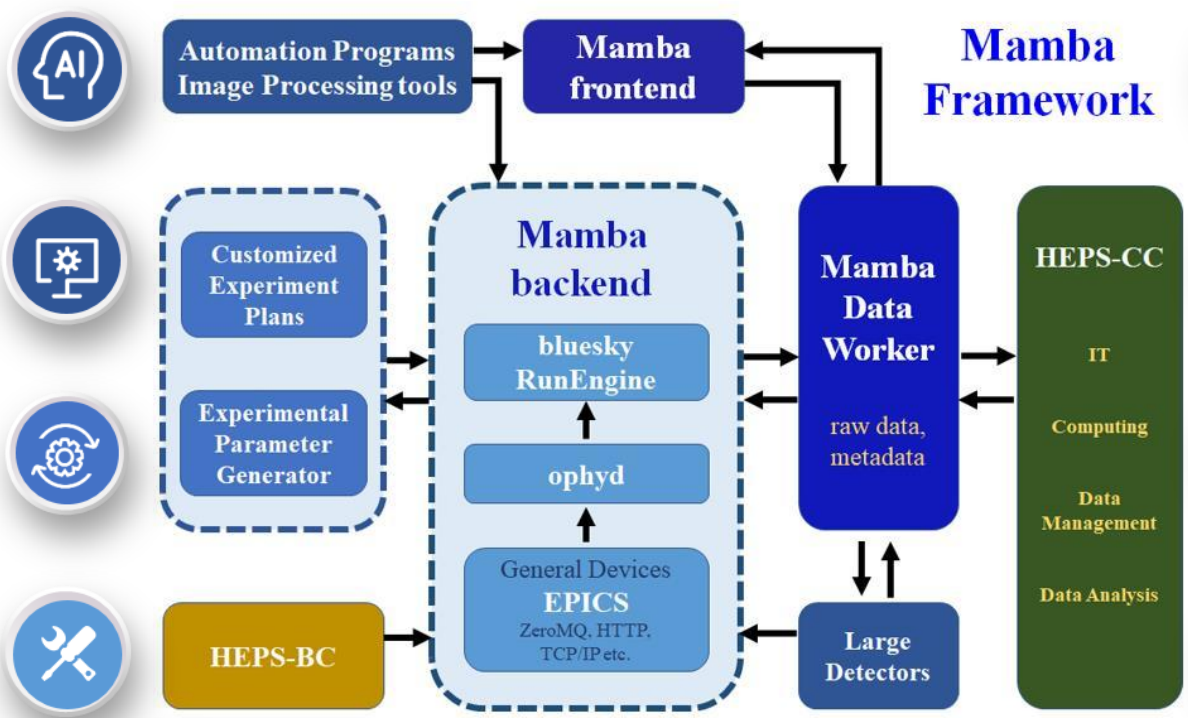
(*Mamba*)

Beamline automation

Real-time feedback and autonomous control

Custom experimental procedures and commands for all experiment methods

Smart *in-situ* experiment



Friendly GUIs

Easy experiment mode switch

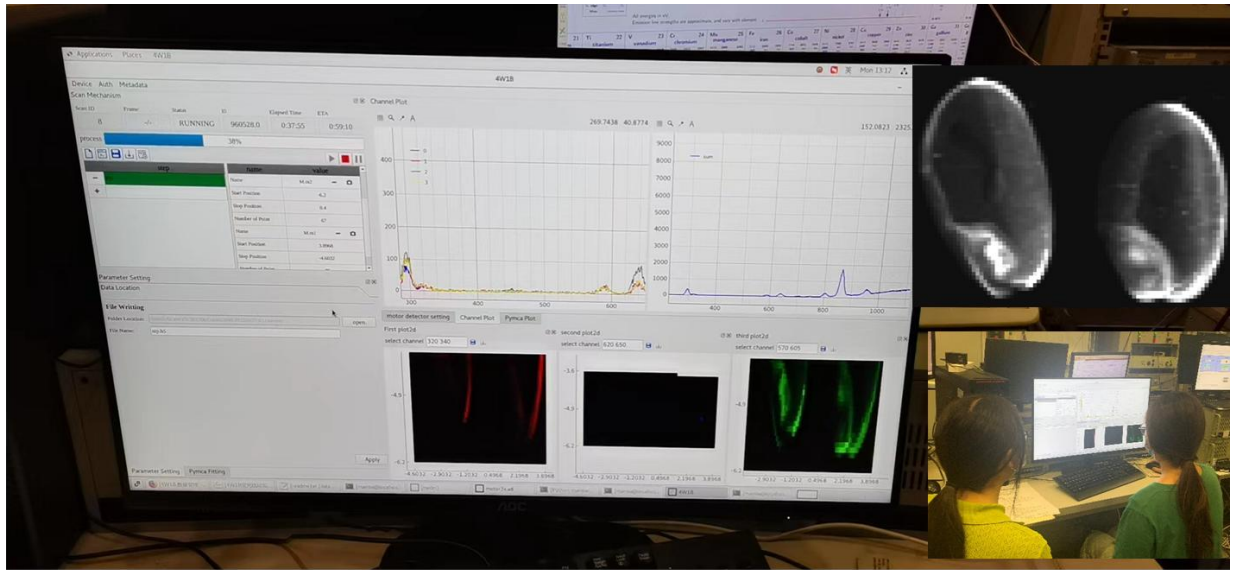
Fast and multi-modal DAQ

Rich metadata, high interoperability

Multi-dimensional, accurate, fast fly scans

Mamba: a systematic software solution for beamline experiments at HEPS. ***Journal of Synchrotron Radiation***, 2022

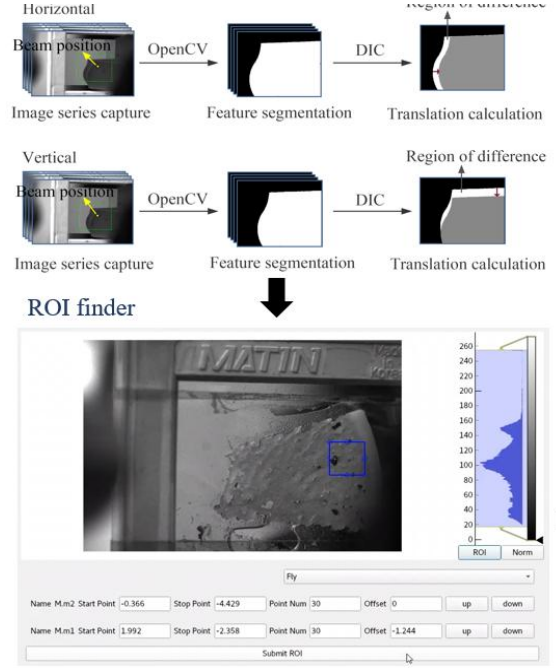
Progress of *Mamba* project

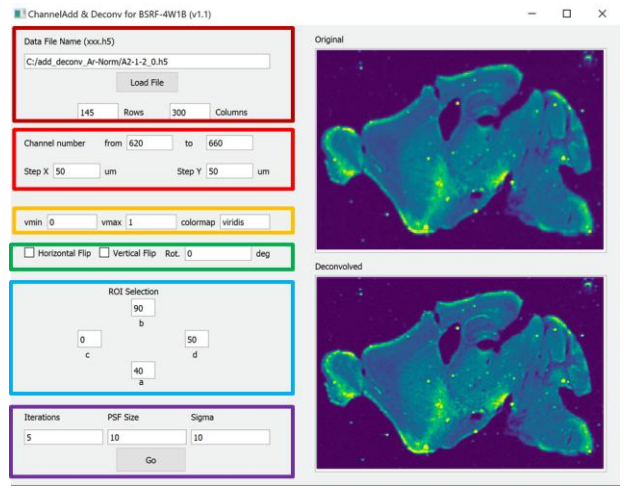


Software development & testing at BSRF

XRF mapping

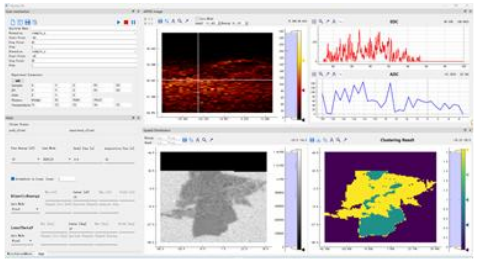
- **Project start from April 2020**
- ***Mamba*** **was officially deployed and open to users at 4W1B beamline in July 2022**



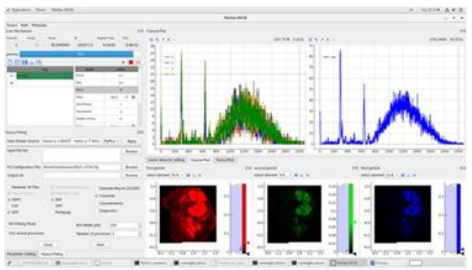


- ☐ **ROI selection & scan sequence modules**
- ☐ **On-the-fly scanning**
- ☐ **One-click data acquisition and real-time analysis**

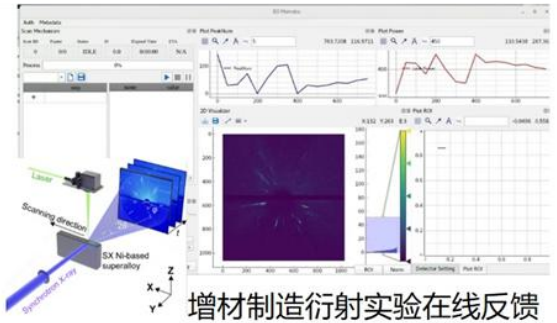
Test and deployment of Mamba at HEPS



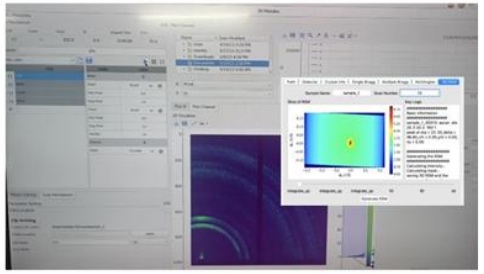
Nano-Arpes



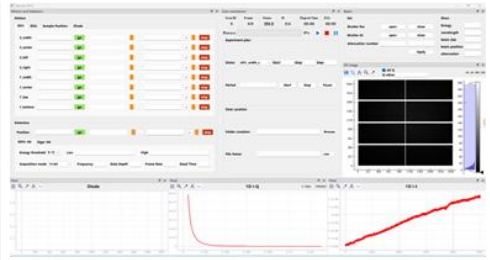
荧光“飞扫”



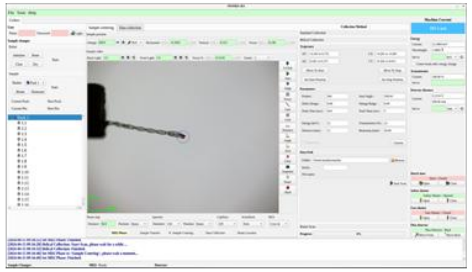
增材制造衍射实验在线反馈



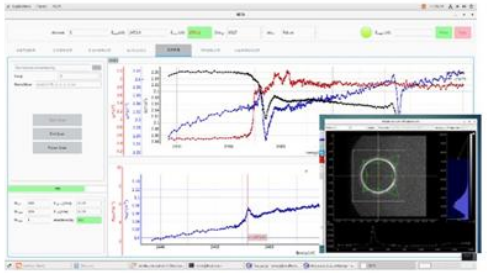
表面衍射



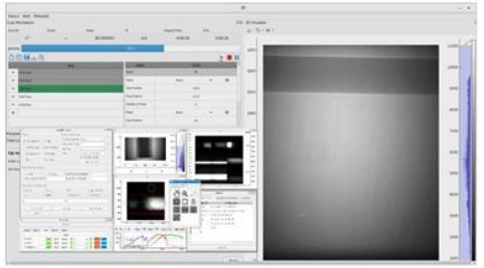
XPCS



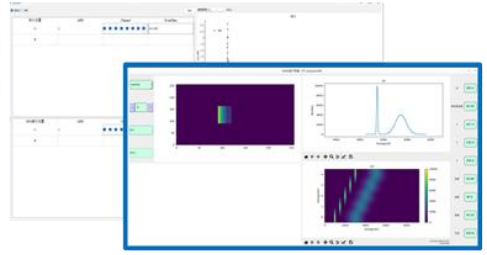
生物大分子



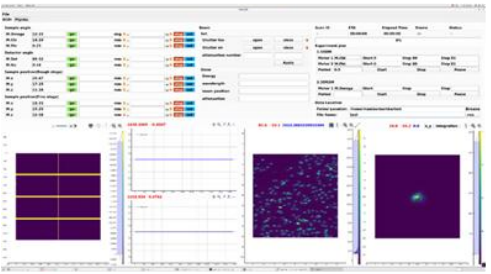
通用吸收谱与发射谱



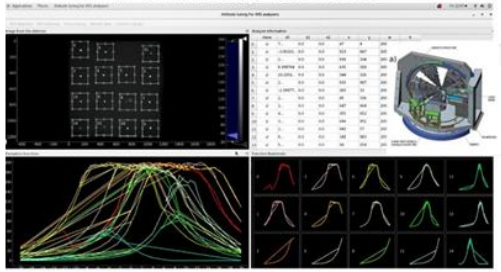
STXM & CT



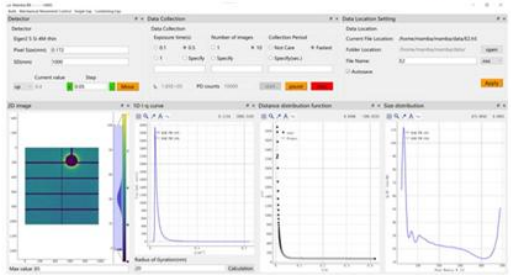
NRS/RIXS



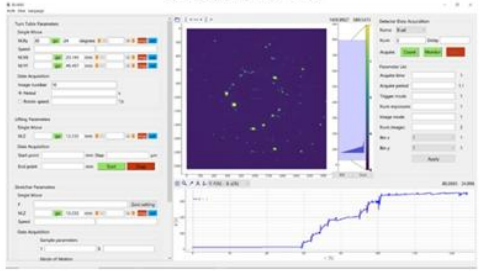
相干衍射成像



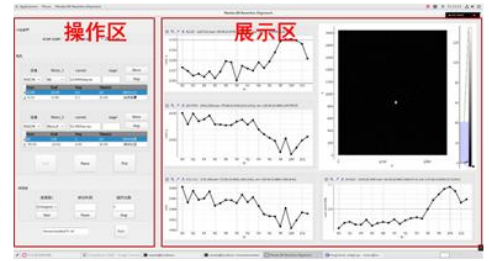
一键式拉曼谱仪调姿



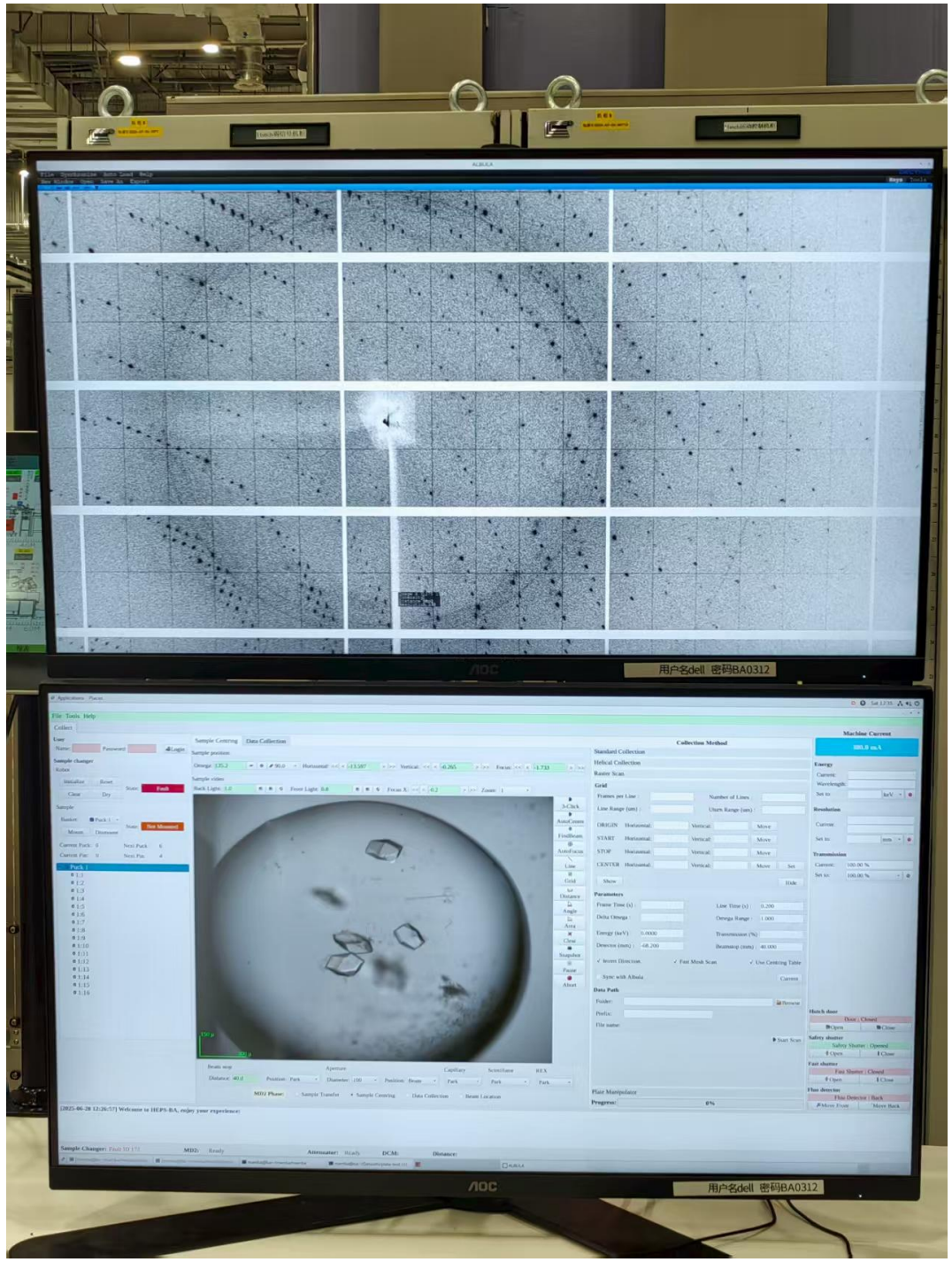
SASX/WAXD联动



原位 3DXRD



束线调光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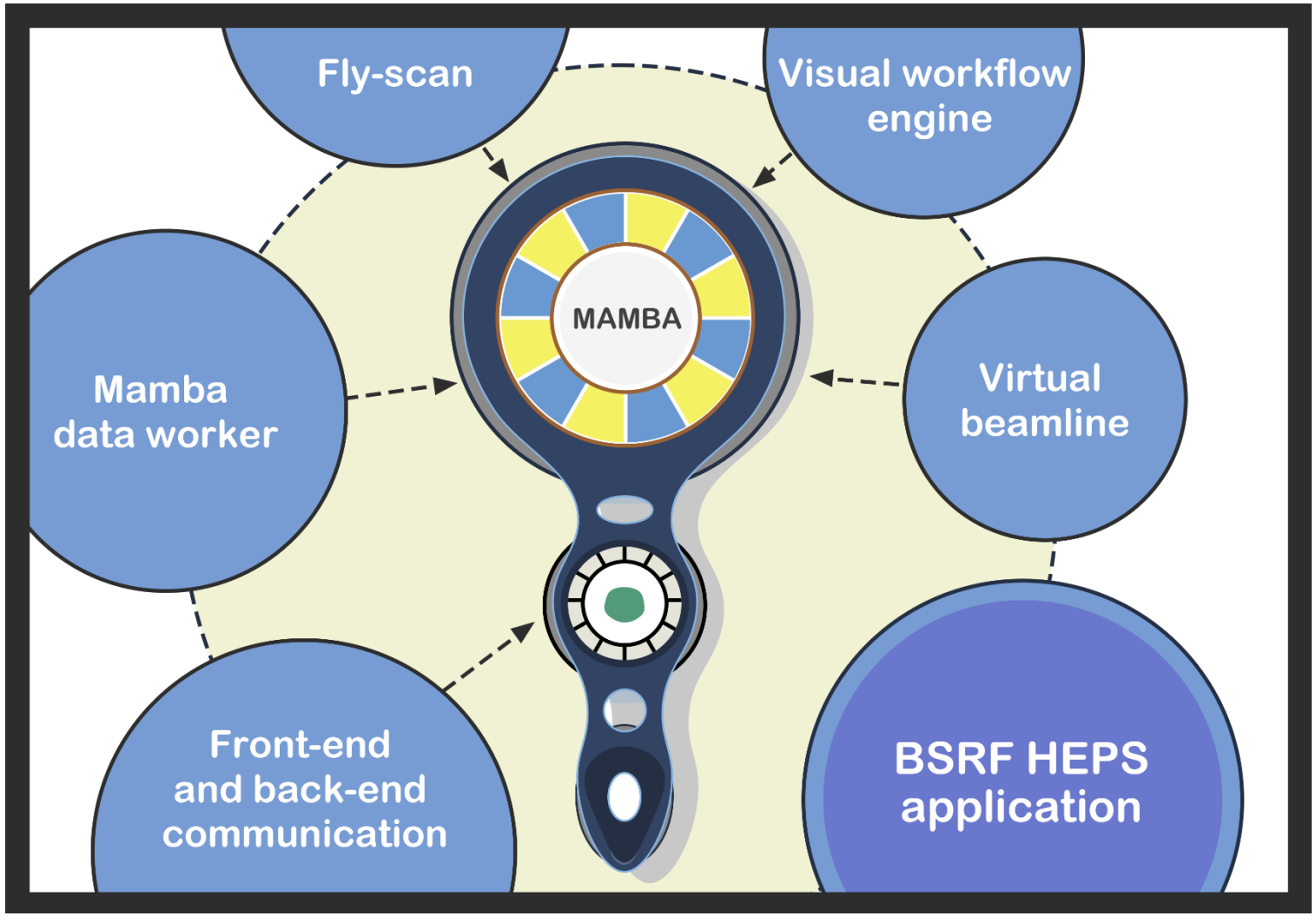
Explore key techniques of new generation control and acquisition system

Already



On going

- Python IOC, Systematic detector integration and High-performance readout
- Beamline and experiment specific plan and GUI library
- Versatile attitude tuning framework and beamline automation
- Closed-loop control based on real-time data analysis
- AI-Enabled experimental control

Liu et al. ***J. of Synchrotron Radiat.*** **29(3)**, (2022) ; Zhang et al. ***J. of Synchrotron Radiat.*** **30(1)**, (2023) ; Li et al. ***J. of Synchrotron Radiat.*** **30(6)**, (2023); Li et al. ***Synchrotron Radiat. News***, (2023); Wang et al. ***J. of Synchrotron Radiat,*** (2024);

A systematic detector integration solution for HEPS

◻ Systematic -- work mainly done by HEPS beamline control team

Centralize management of developing detector IOCs;

EPICS-based integration and an extended ADGenICam;

ihep-pkg packaging system and ~/iocBoot conventions to simplify EPICS deployment and enhance .

Main detector-like devices that need to be integrated

- Devices with *EPICS* IOCs that satisfy current requirements:
  - GenICam (GigE/USB3 Vision) industrial cameras: Hikvision, FLIR *etc*
  - Andor (sCMOS, CCD), marCCD, Merlin, Minipix, PICam, Pilatus
  - Keck-PAD, PCO, Photron, PVCAM; Mythen; Falcon Xn, Xspress 3
- Devices that require self-developed *EPICS* IOCs:
  - Specialized Imaging Kirana, Ximea
  - Self-made APD detector, iRay Mercu
- Devices that require high-performance integration modules:
  - Eiger, Lambda/Sparta, Rigaku XSPA, Hamamatsu
  - Tucsen, self-made Si-pixel detector
  - PandABox, multiple sensors (needing high-speed 0D readout)

◻ High-Performance

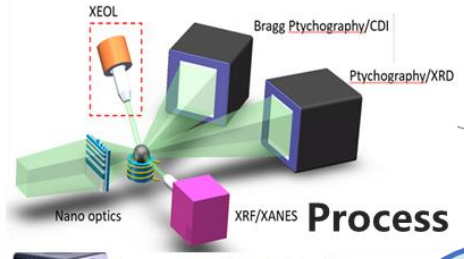
A QueueIOC framework for Python IOCs based on caproto;

Simplify architecture and communition protocols leading to better performance than areaDetector.

All 2D detector can be run in monitor mode

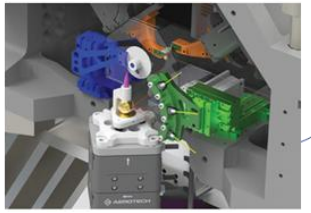
Mamba Data Worker for HEPS phase I experiments

- **Tackles the exascale data acquisition and real-time processing challenge**



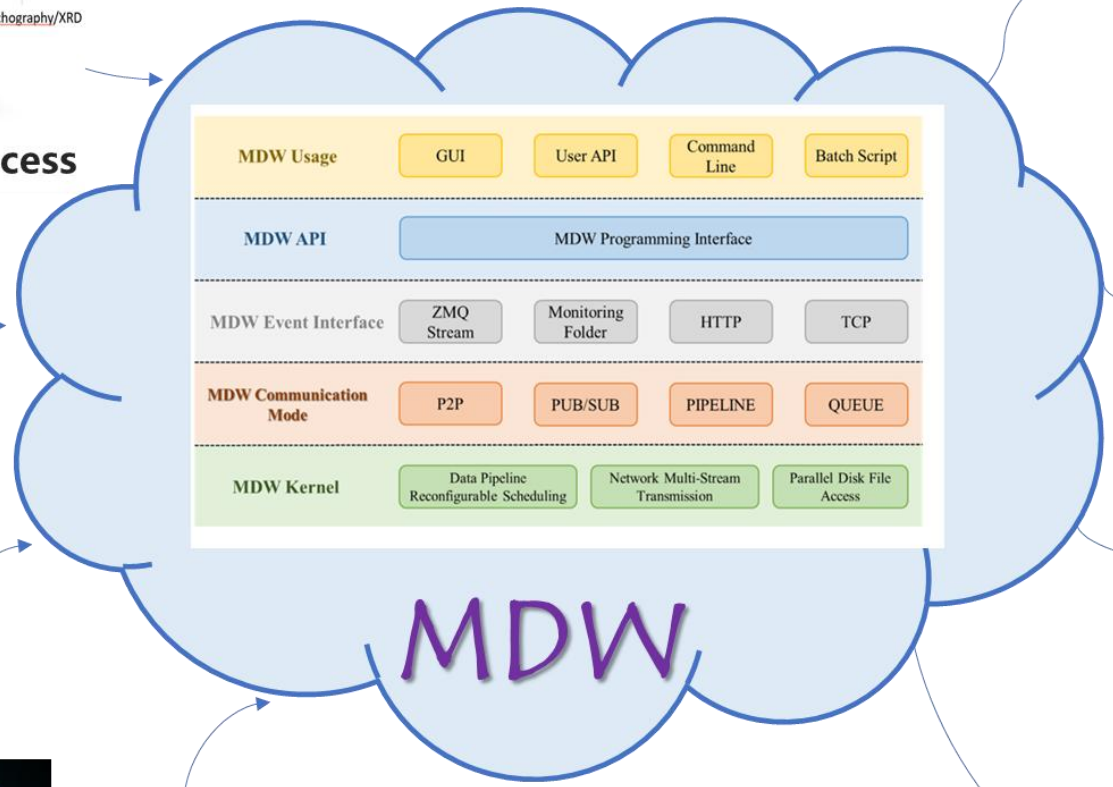
Process

Detectors

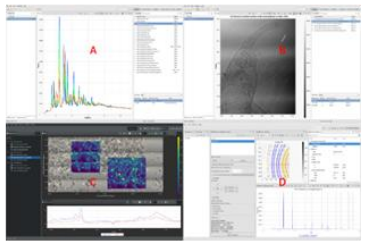


Motion

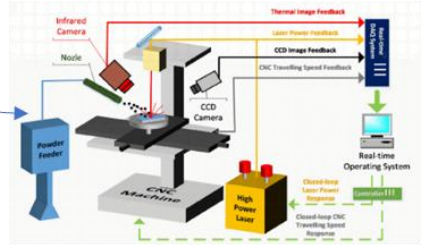
Metadata
(sample, environment etc.)



Scientific database



Data visualization



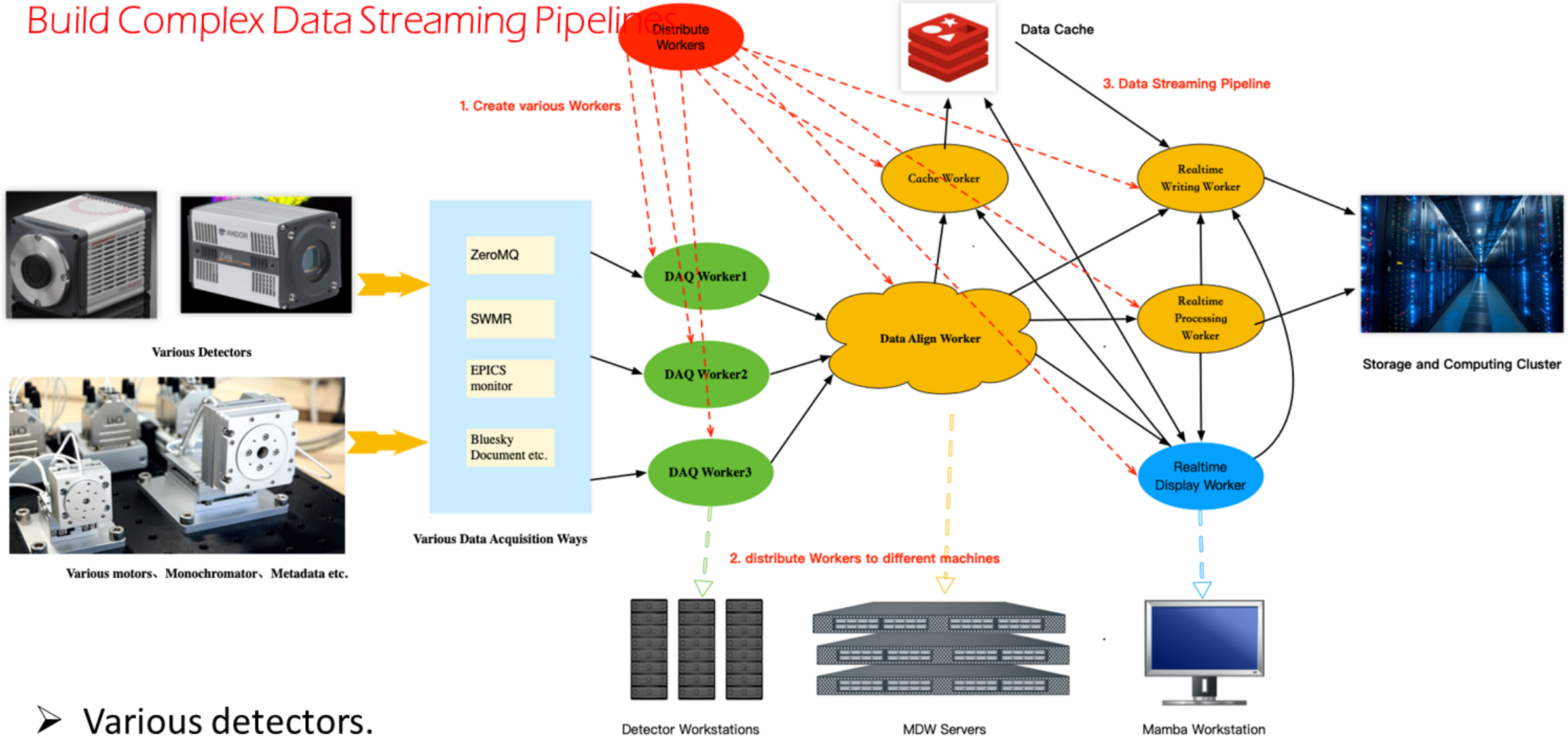
Feedback control

Storage

A High-Throughput Big Data Orchestration and Processing System for High Energy Photon Source. ***Journal of Synchrotron Radiation***, 2023

- DAQ
- Distribution
- Scheduling
- Assembly
- Reduction
- Disk writing
- Visualization

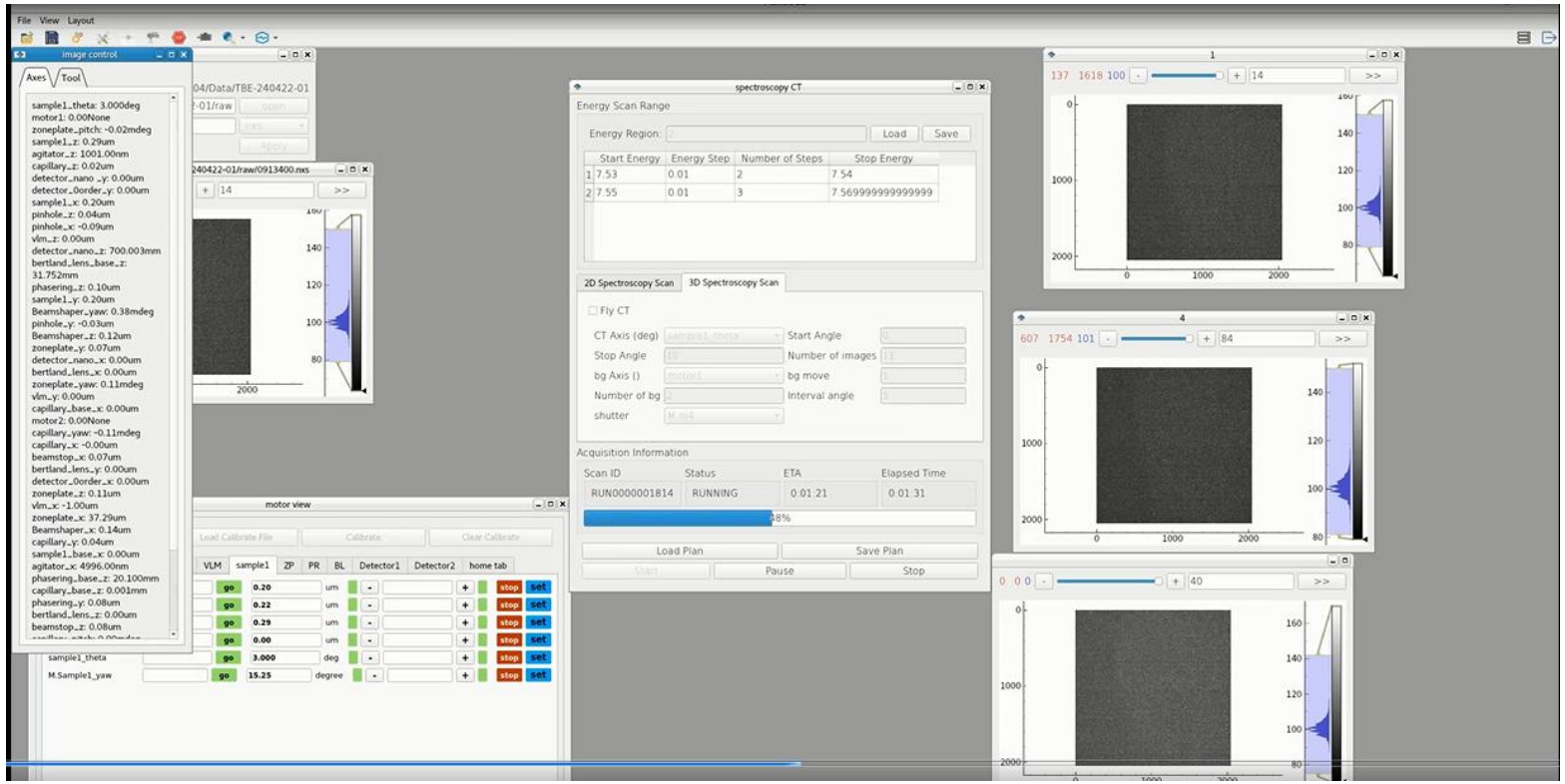
Build Complex Data Streaming Pipelines



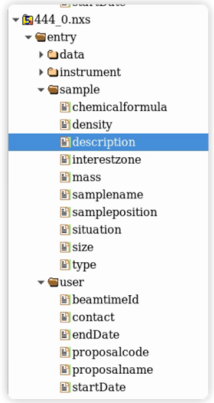
- Various detectors.
- Various scanning methods.
- Various data acquisition methods
- Various machines.
- Various data streaming paths

- Enable collaboration across terminals
- Ease of use

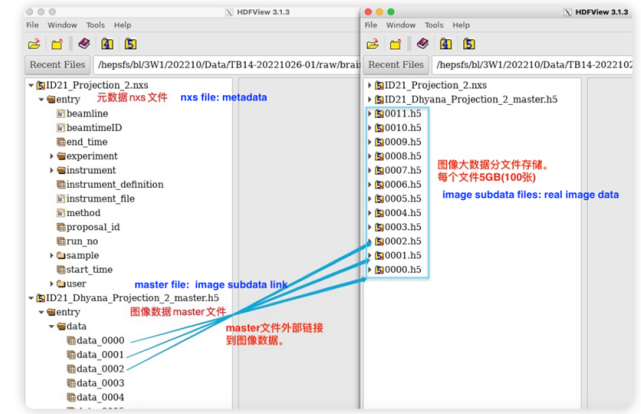
Leading the way in making scientific data FAIR at China.



- 假设每300张（可调）存成一个data文件，
- 文件（1个master文件，10个hdf5文件）
  - ✓ ID21_count(scan)_Dhyana_*RunID*_master.h5
  - ✓ ID21_count(scan)_Dhyana_*RunID_00000*_data.h5
  - ✓ ID21_count(scan)_Dhyana_*RunID_00001*_data.h5
  - ✓ …
  - ✓ ID21_count(scan)_Dhyana_*RunID_00009*_data.h5

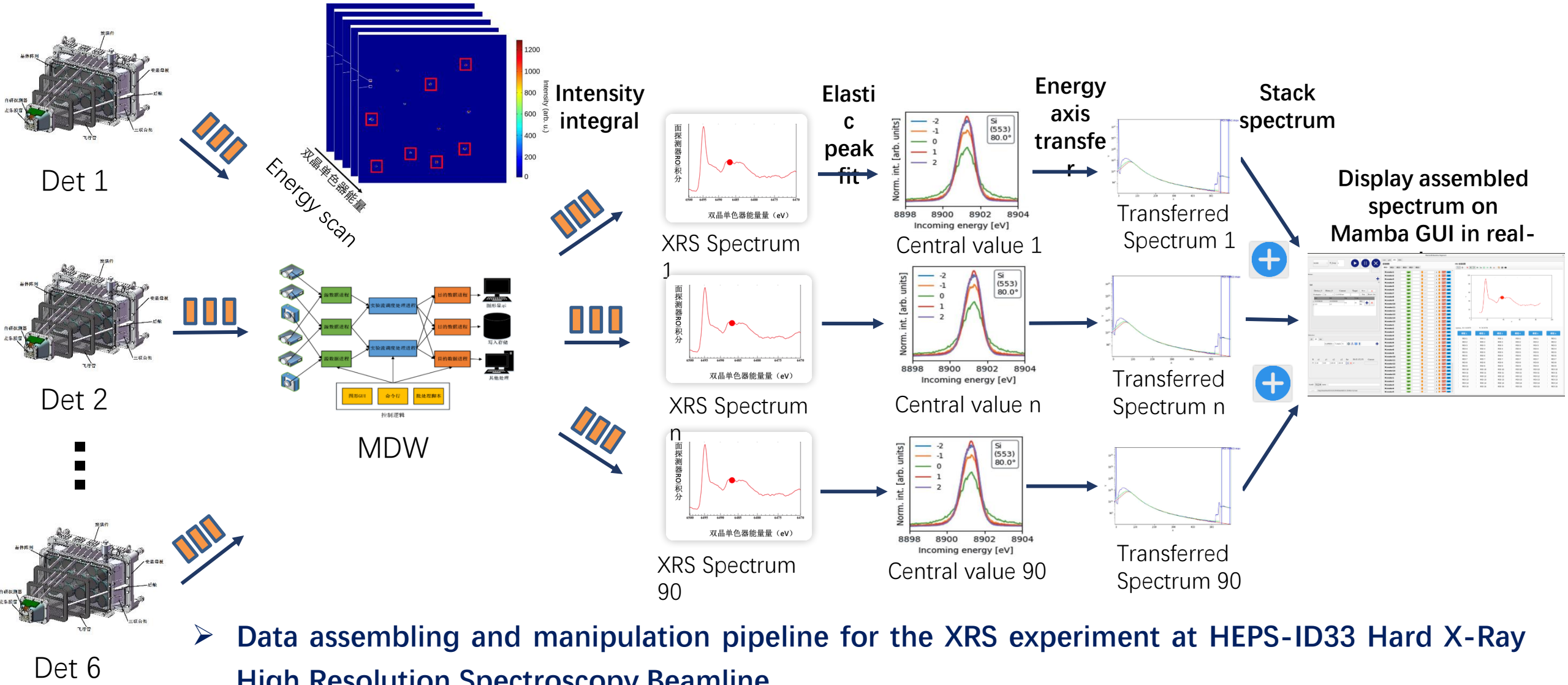


Single nxs file



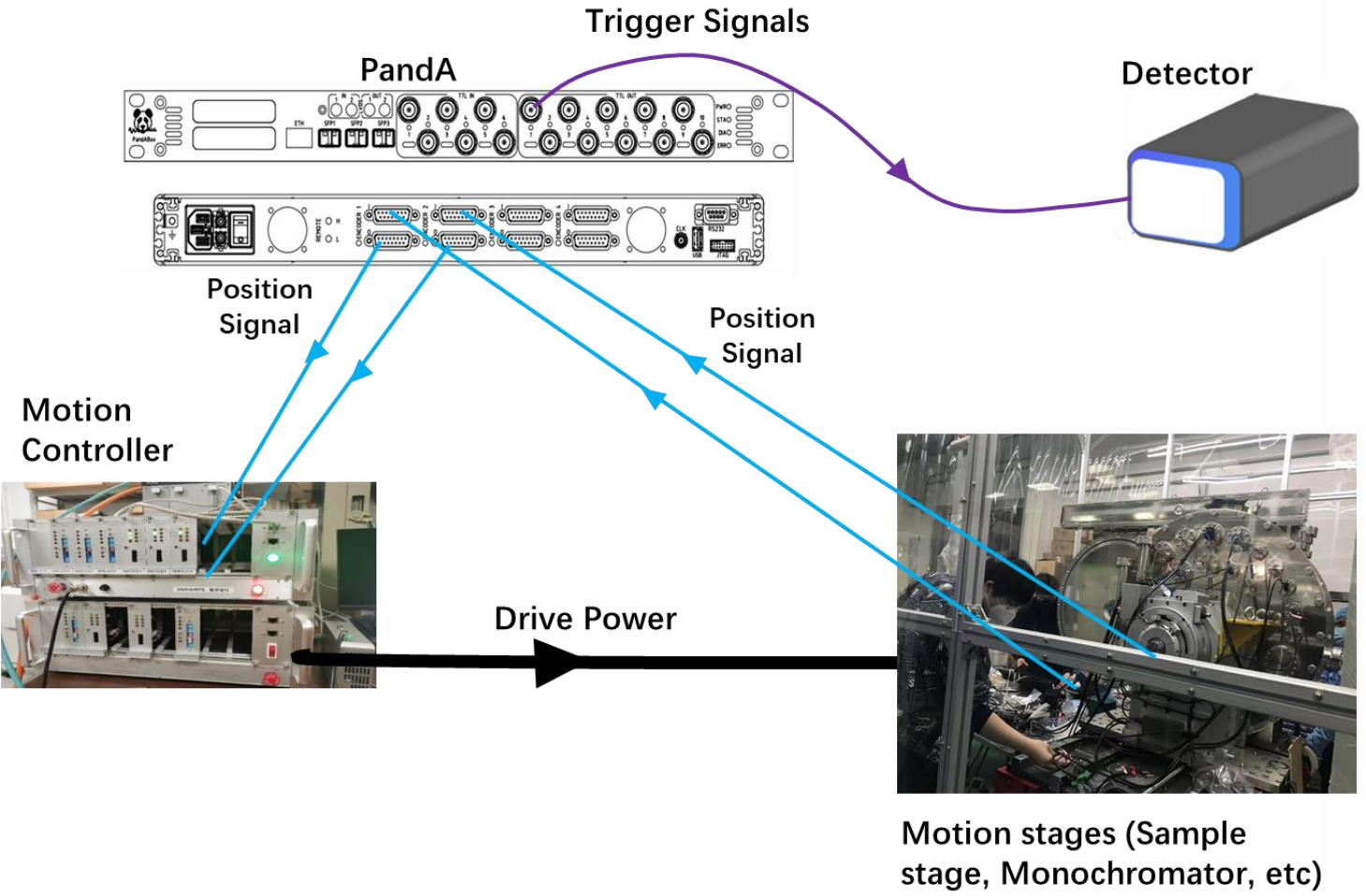
nxs+master+ data0+data1+…

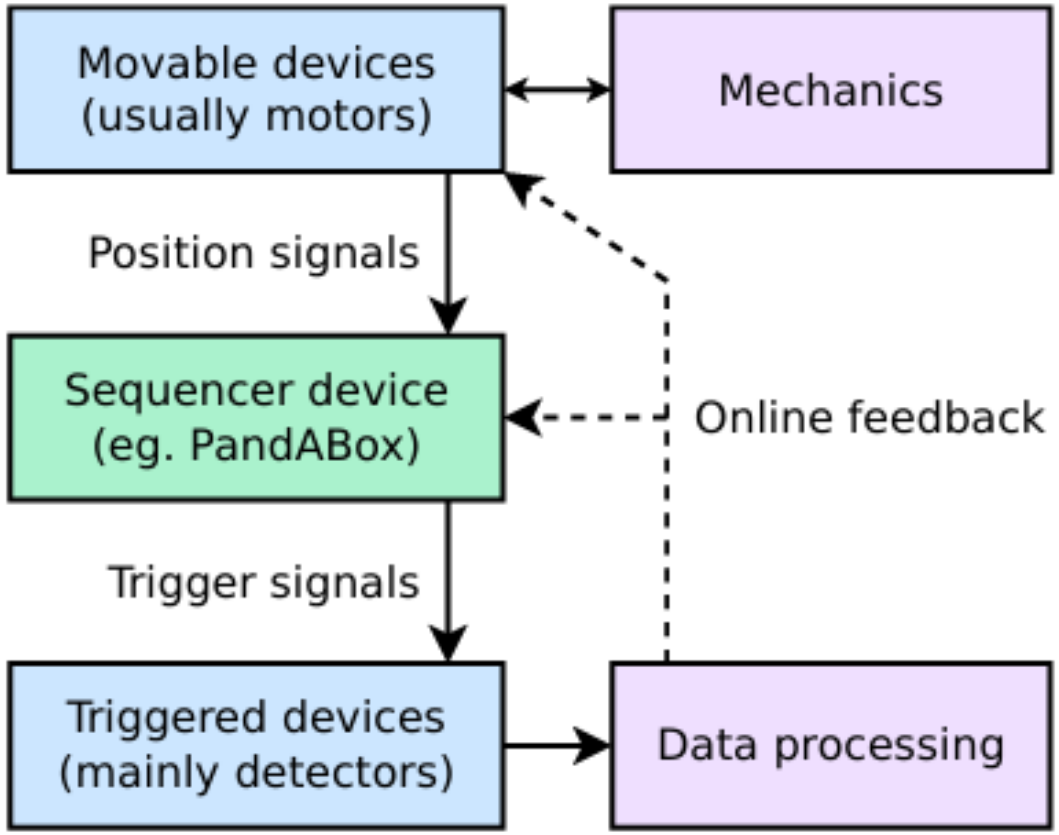
- **Unified data format and standards**
- **Data streaming for multi-modal experiments, easy data access from large dataset**
- **Each image and spectrum contain comprehensive metadata information, a flexible and automatic metadata collection mechanism**



- **Data assembling and manipulation pipeline for the XRS experiment at HEPS-ID33 Hard X-Ray High Resolution Spectroscopy Beamline**
- **We create this pipeline to transfer the images on the Raman spectrometer into 1D spectrum needed by the users, this pipeline includes several processing steps and is not necessarily straightforward to create.**

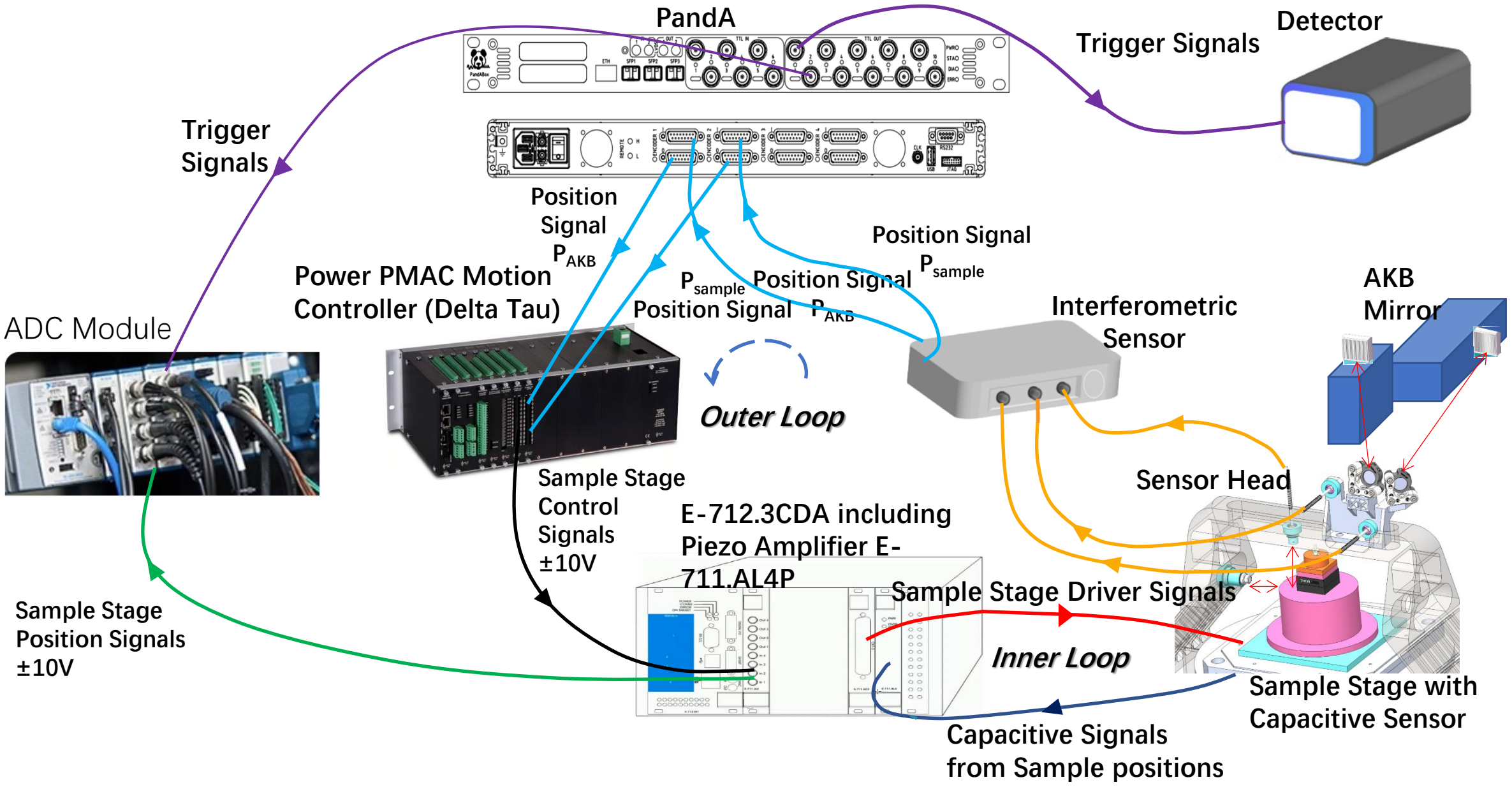
Fly-scan general event structure





P.-C. Li, C.-L. Zhang, ..., Y. Liu*. *Synchrotron Radiat. News*, **2023**, *36*(6): 27–33.

Fly-scan event structure based on Power PMAC

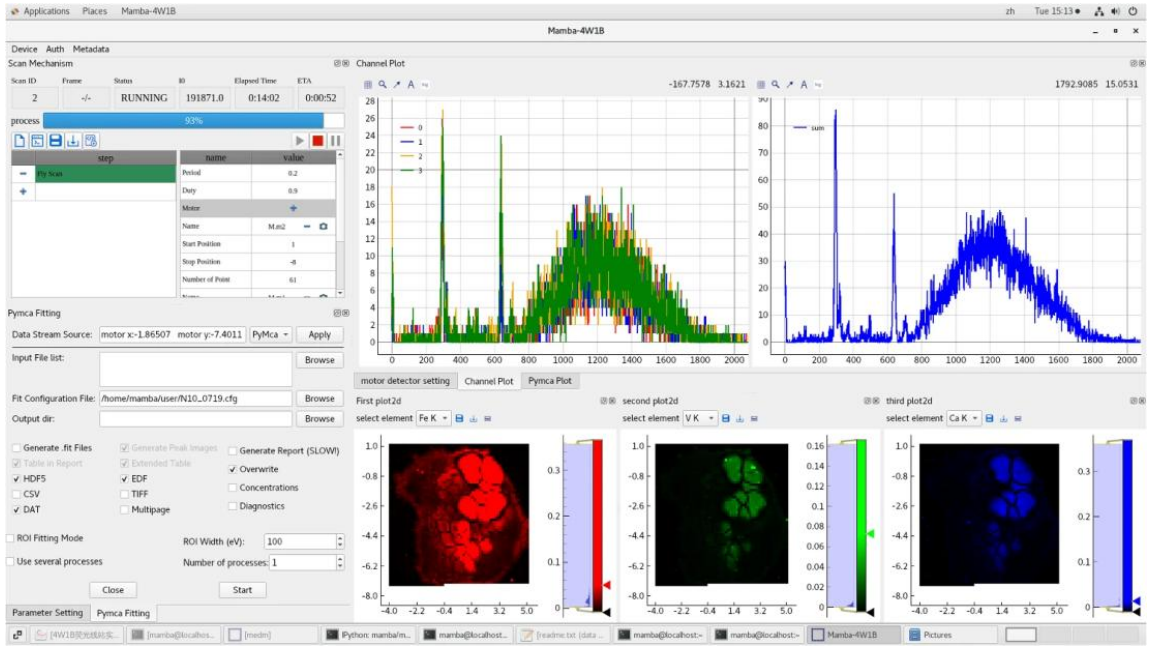


Fly-scan hardware and event orchestrating structure

Scan Mode	Beamlines	Designed Structure
Fly Scan (11/15)	Hard X-ray Nanoprobe Multimodal Imaging Beamline	Structure based on Power PMAC
	Hard X-ray Coherent Scattering Beamline	
	Engineering Materials Beamline	General Structure
	Hard X-ray High Resolution Spectroscopy Beamline	
	High Pressure Beamline	
	Hard X-Ray Imaging Beamline	
	X-ray Absorption Spectroscopy Beamline	
	Low-Dimension Structure Probe Beamline	
	Tender X-ray Beamline	
	Transmission X-ray Microscope Beamline	
Step Scan (4/15)	Hard X-ray Nanoprobe Multimodal Imaging Beamline	Structure Based on PandA Box and GPIO in Power PMAC
	Hard X-ray Coherent Scattering Beamline	
	Hard X-Ray Imaging Beamline	Structure Based on PandA Box
	Pink Beam SAXS Beamline	Structure Based on PandA Box

Fly-scan integration in Bluesky and Mamba

- Position based triggering
- Time based triggering
- Software based fly-scan
- Complex trajectory
- Online tuning fly-scan



(a) *Mamba startup script fragment for PandABox-based fly scans.* `ImagePlanner` *is a specialised MambaPlanner with friendly default settings for image data handling.*

```
U.planner = ImagePlanner(U)
U.planner.extend(PandaPlanner(
```

`D.panda` and `D.adp` are Bluesky encapsulations for the control and data interfaces of PandABox, respectively; the latter is based on the EPICS module ADPandABlocks. `div` *requires a fragment to contain at most 12216 frames of data from Xspress3.* `h5_tols` *requires the HDF5 file acquired from Xspress3 to contain exactly the expected number of frames at the end of each line during a fly scan.*

```
    D.panda, D.adp, divs = {D.xsp3: 12216}, h5_tols = {D.xsp3: 0},
```

`enc_tols` *requires that for every motor involved in a fly scan, the difference between its raw position and its encoder position does not exceed 25 pulses at the beginning of the scan, in order not to disrupt the sequencer program used.*

```
    enc_tols = {m: 25 for m in M.values()},
```

`vbas_ratios` *requires that the speed of a motor to be at least 2 times its starting speed, because otherwise the speed setting would be disregarded by the motion controller (Kohzu ARIES, used at the 4W1B beamline of BSRF).*

```
    vbas_ratios = {m: 2.0 for m in M.values()},
```

`configs` *sets Xspress3 to be triggered by external TTL signals during a fly scan.*

```
    configs = {D.xsp3: {"cam.trigger_mode": 3}}
))
P = U.planner.make_plans()
```

An example for grid fly scans, which intentionally mimics Bluesky's `grid_scan()`.

```
#P.fly_grid([D.xsp3], M.m2, -1, 1, 3, M.m1, -4, 4, 5, duty = 0.5, period = 0.5)
```

(b) *Mamba startup script fragment for Bubo-based software fly scans.*

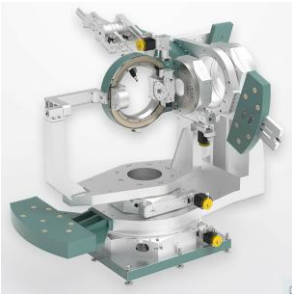
```
U.planner = ImagePlanner(U)
U.planner.extend(BuboPlanner(D.bubo, h5_tols = {D.xsp3: 0}))
```

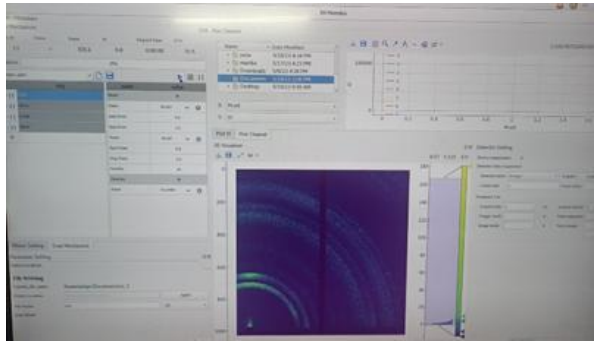
An example for software-based grid fly scans, similar to the PandABox-based interface above.

```
#P.sfly_grid([D.xsp3], M.m2, -1, 1, 3, M.m1, -4, 4, 5, pad = 0.5)
```


P.-C. Li, C.-L. Zhang, ..., Y. Liu*. Synchrotron Radiat. News, 2023
P.-C. Li, C.-L. Zhang, ..., Y. Liu*. Radiat. Detect. Technol. Methods, 2023

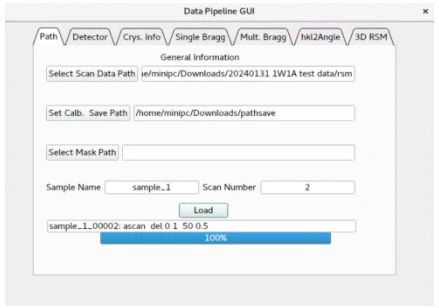
Beamline and experiment specific plan and GUI library

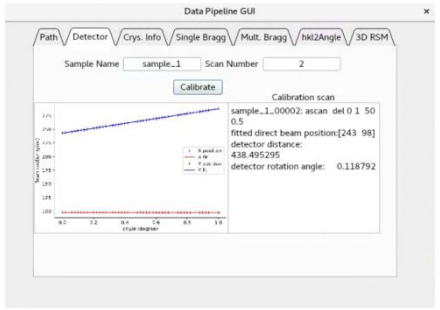


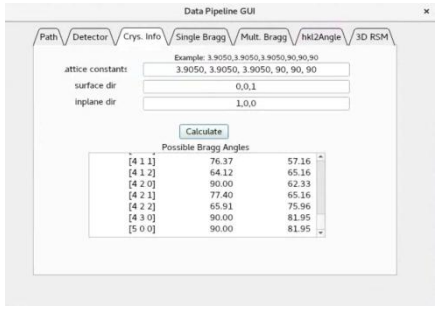


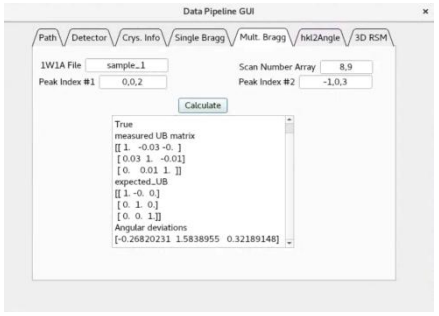
- At HEPS-B9: implemented 6-circle diffractometer control in bluesky

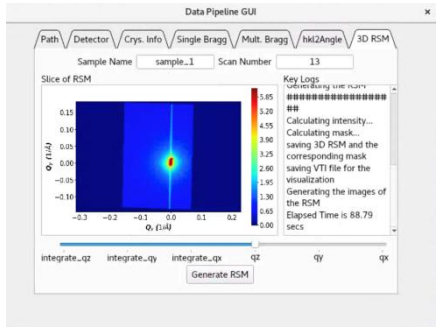
- UB matrix calculation GUI based on PyCXIM (collaboration with Dr. Zhe Ren)





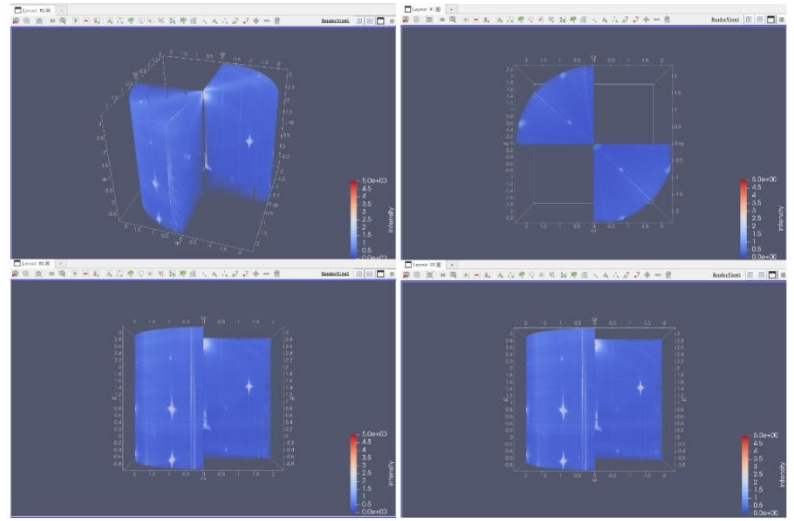




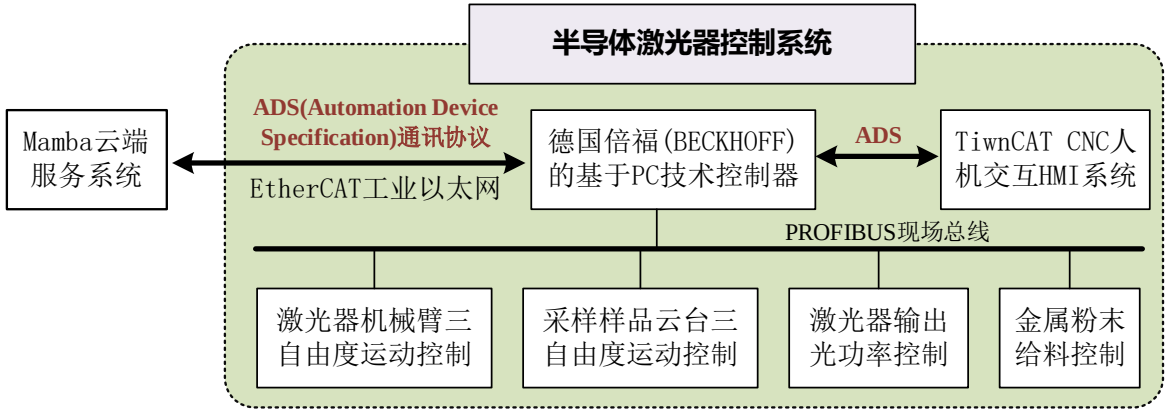


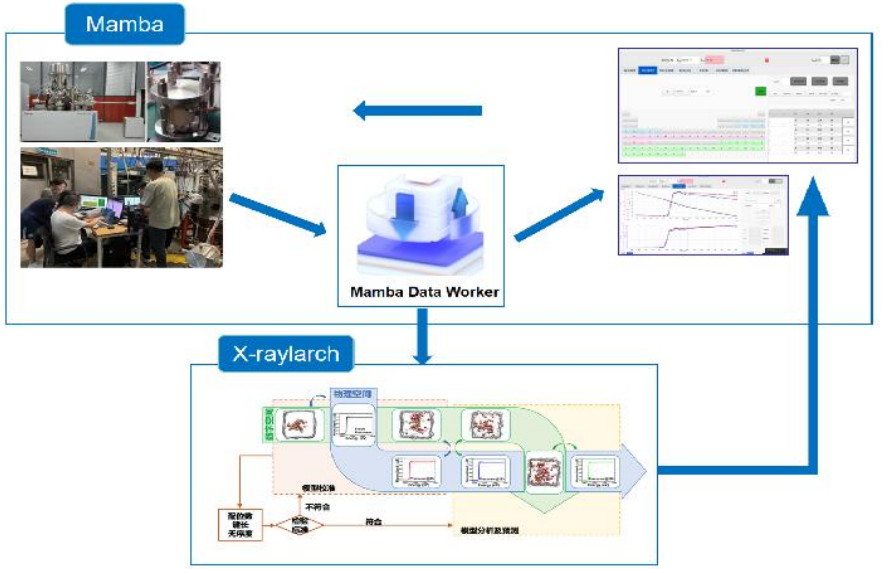
- Integrating the PyCXIM algorithms into the beamline-specific plans of *Mamba*

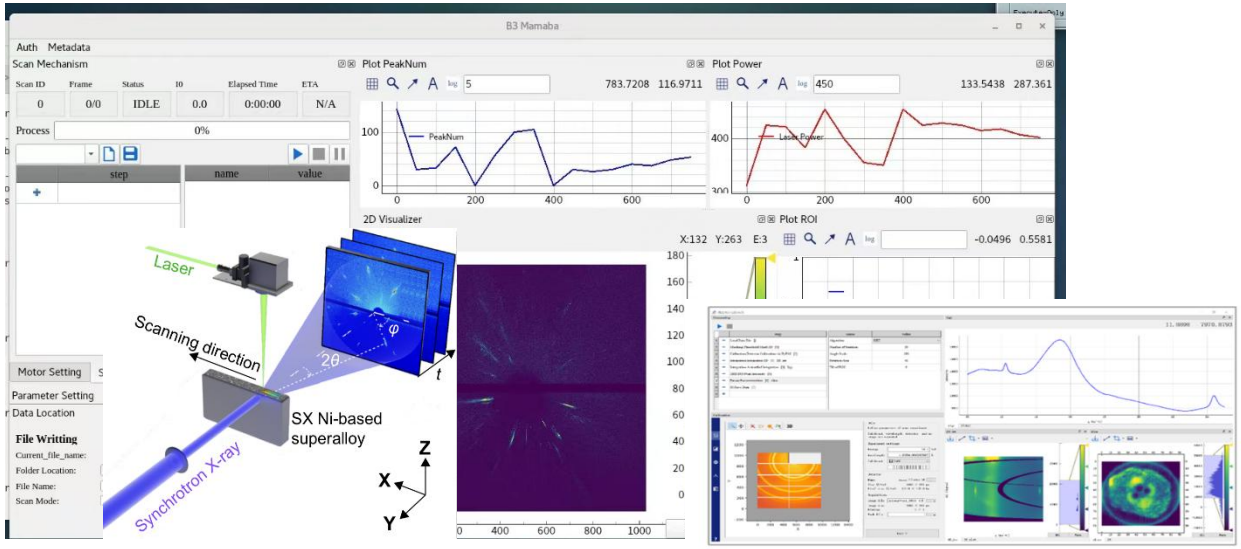
- High-resolution large-scale 3D reciprocal space reconstruction for real- time visualization and analysis

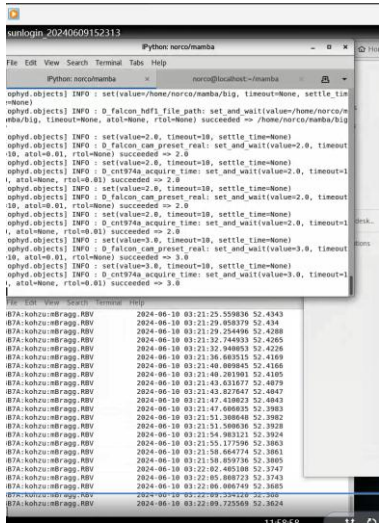


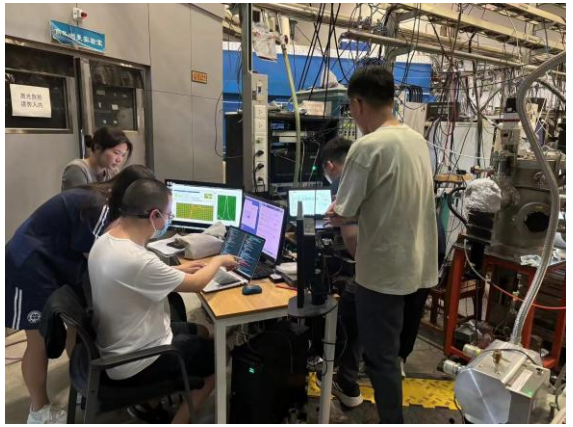
Closed-loop control based on real-time data analysis











- Proof-of-concept test on real-time feedback control technology of metallic additive manufacturing

- Proof-of-concept test on performing digital twin experiments (dynamic XAFS)

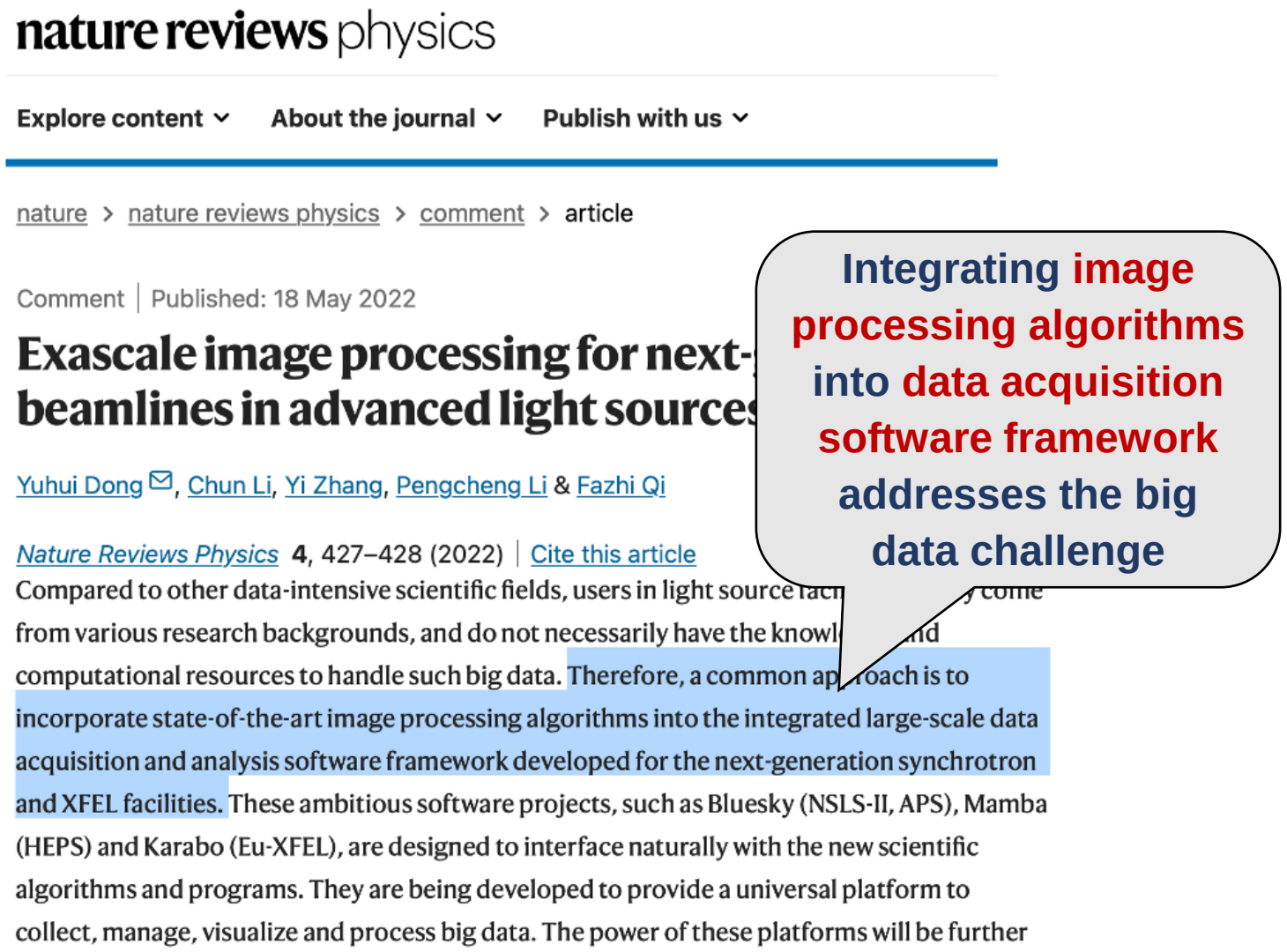
Experimental automation via good software design,

Beamline intelligence empowered by AI/ML .

Addressing big data challenge using AI/ML

A new research paradigm at fourth-generation synchrotron

- **"Large-scale scientific software framework + AI for Science"**



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Exascale image processing for next-[illegible] beamlines in advanced light source[illegible]

Yuhui Dong ✉, Chun Li, Yi Zhang, Pengcheng Li & Fazhi Qi

Nature Reviews Physics **4**, 427–428 (2022) | Cite this article

Compared to other data-intensive scientific fields, users in light source fac[illegible] come from various research backgrounds, and do not necessarily have the knowl[illegible]nd computational resources to handle such big data. Therefore, a common ap[illegible]roach is to incorporate state-of-the-art image processing algorithms into the integrated large-scale data acquisition and analysis software framework developed for the next-generation synchrotron and XFEL facilities. These ambitious software projects, such as Bluesky (NSLS-II, APS), Mamba (HEPS) and Karabo (Eu-XFEL), are designed to interface naturally with the new scientific algorithms and programs. They are being developed to provide a universal platform to collect, manage, visualize and process big data. The power of these platforms will be further

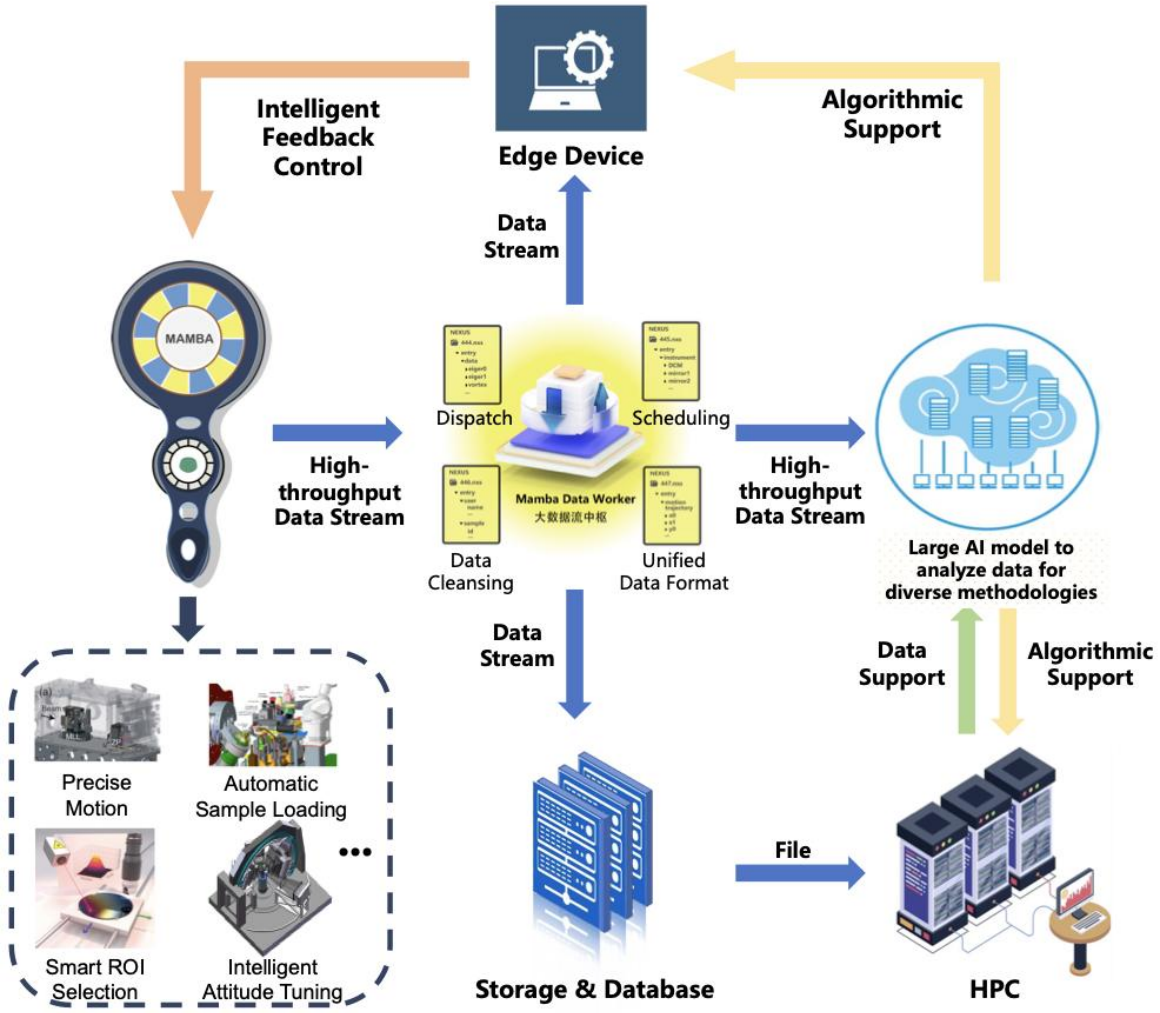
Integrating image processing algorithms into data acquisition software framework addresses the big data challenge

- **Leveraged by the unified software ecosystem, data will flow seamlessly between various application nodes, further empowering algorithms**
- **The software framework will provide a broad stage for the algorithm application at wide range of sciences**

AI facilitated big scientific project at intelligent light source

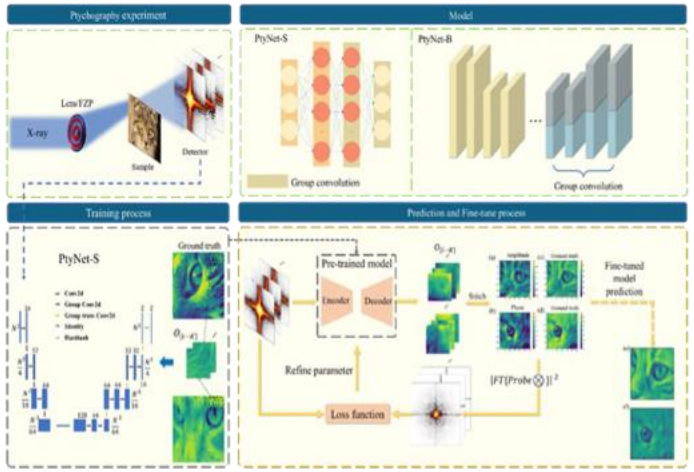
- **The light source is becoming one of the largest scientific data source**

- DL-empowered full-stack DAQ and analysis pipeline for synchrotron experiments
- Mamba data worker for big data science
- Domain specific big AI model
- Intelligent cluster of scientific infrastructures



“AI for Science” applications in diverse methodologies

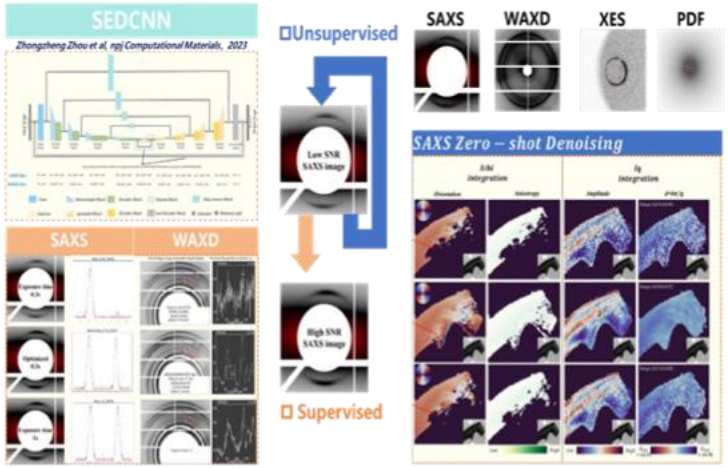
☐ Large AI model solves ptychographic phase retrieval problem



X.Y. Pan et al. ***iScience***, 2023

X.Y. Pan et al. ***Acta Physica Sinica***, 2023

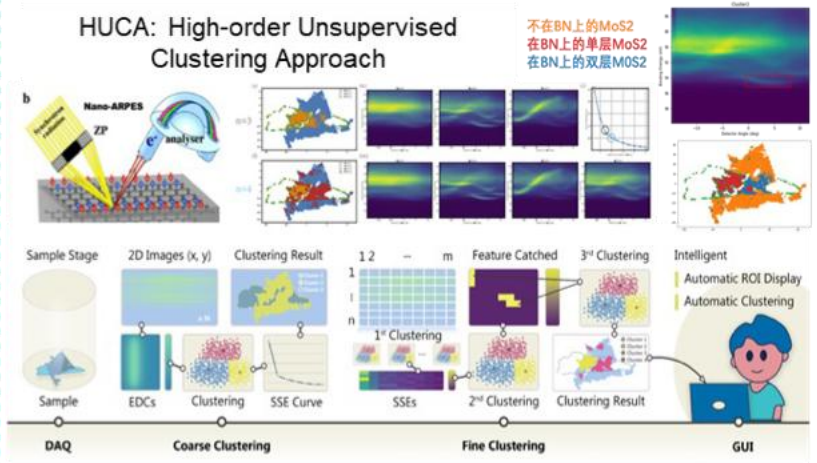
☐ Physics-informed denoising solution



Z.Z. Zhou et al. ***npj Comp. Mater.***, 2023

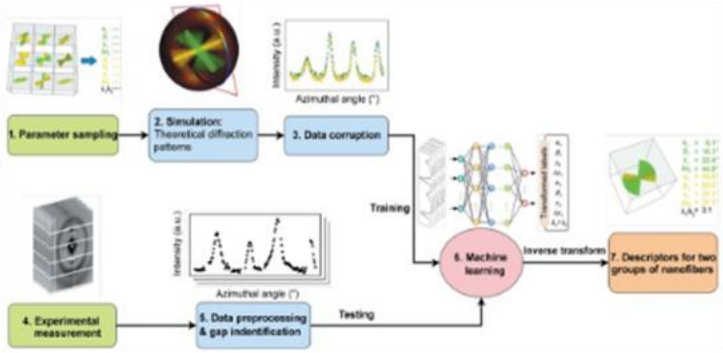
Z.Z. Zhou et al. ***Journal of Appl. Crystallogr.***, accepted

☐ Clustering of Nano-ARPES experimental spectra



L.Z. Bian et al. ***Commun. Phys.***, under review

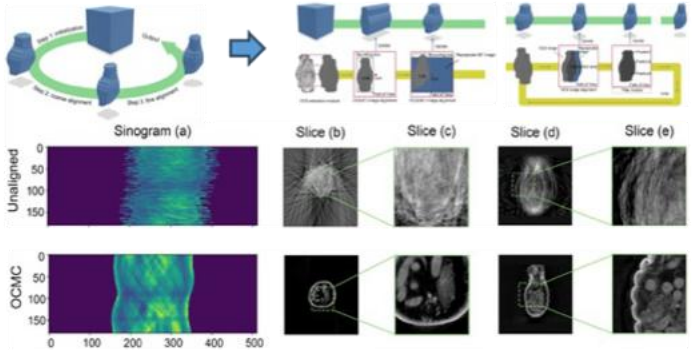
☐ Physical information retrieval from massive diffraction data using machine learning methods



M. Sun et al. ***IUCrJ***, 2023

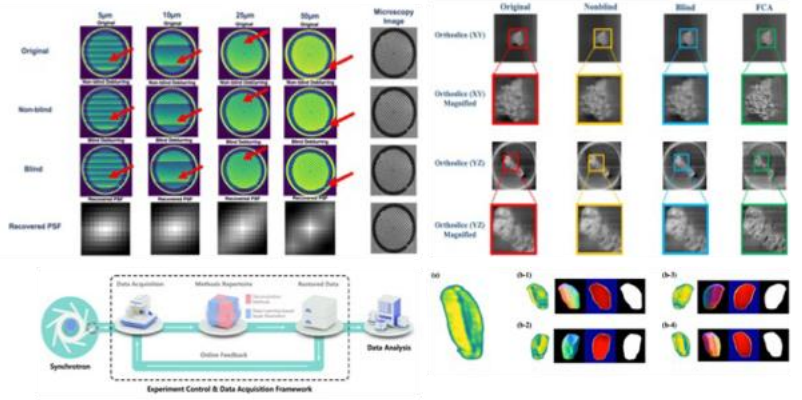
X. Zhao et al. ***IUCrJ***, 2024

☐ End-to-end image misalignment correction method for tomography



Z. Zhang et al. ***iScience***, 2023

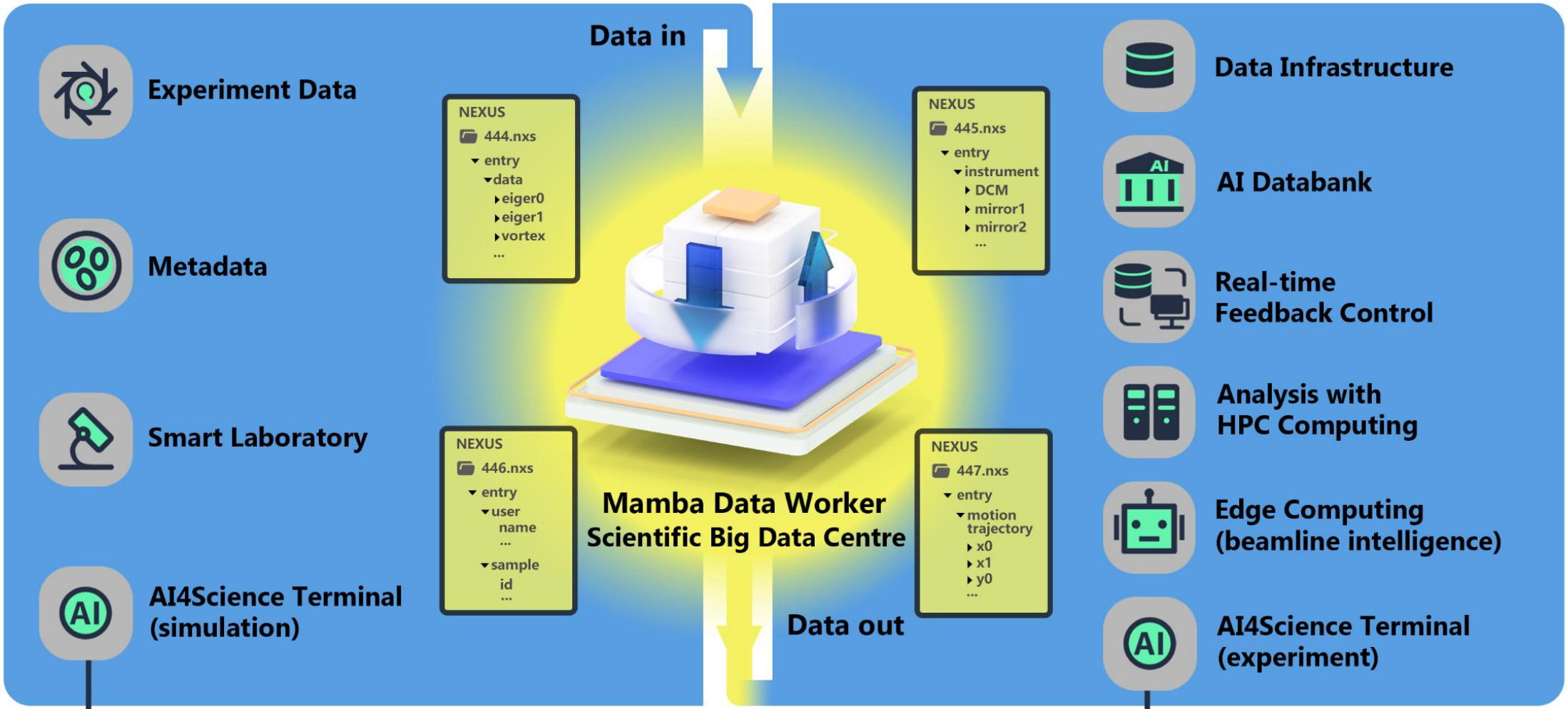
☐ Deconvolution and super-resolution pipeline



C. Li et al. ***Nucl. Sci. Tech.***, accepted

Mamba Data Worker for intelligent light source

- **Enables new scientific opportunities**

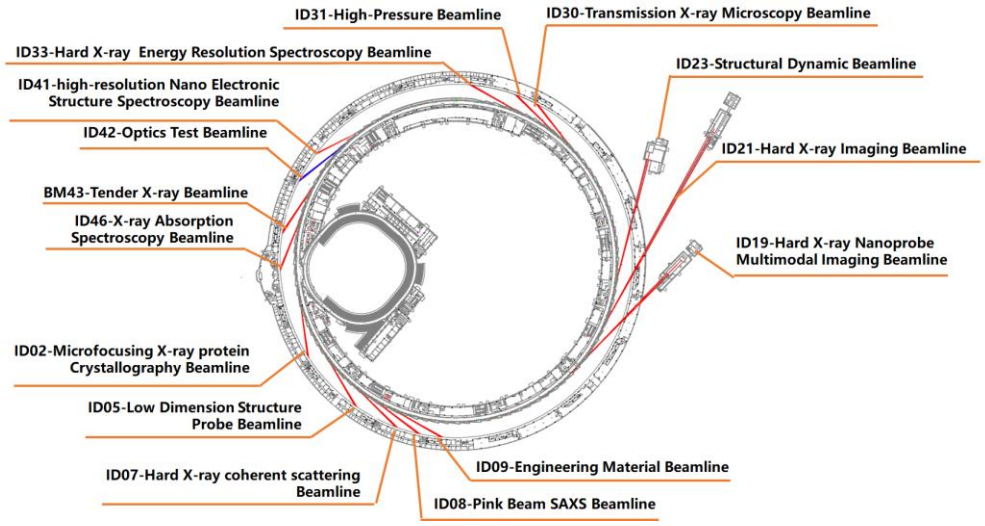


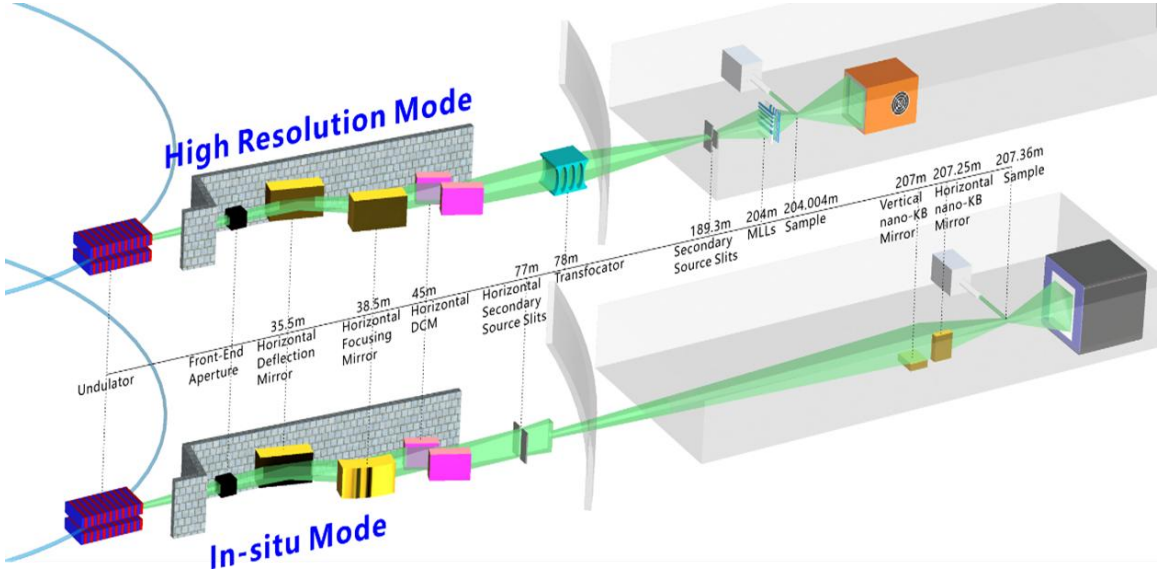
- **Beamline intelligence 束线智能**
- **AI4Science Terminal 智慧终端**

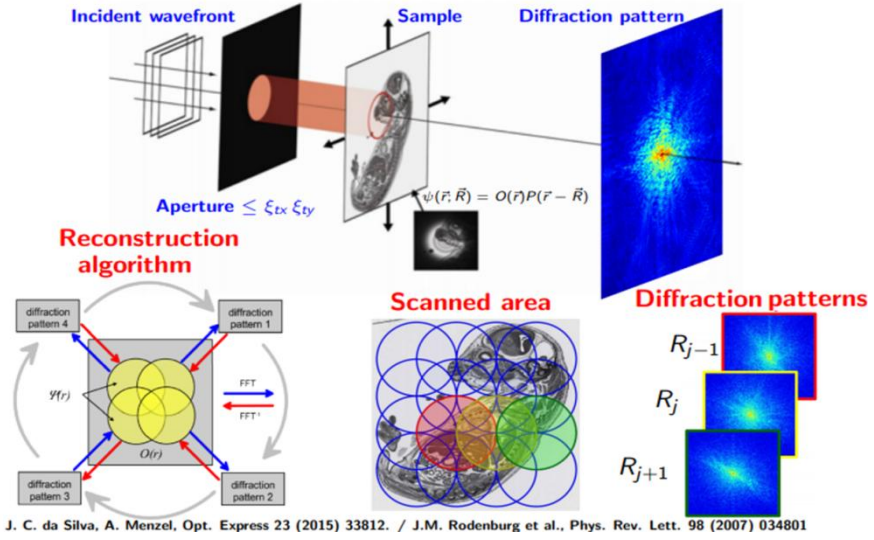
Data-driven beamline intelligence applications : beamline alignment

Requirements Analysis

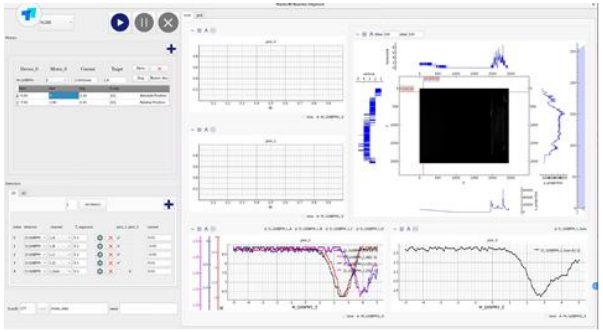
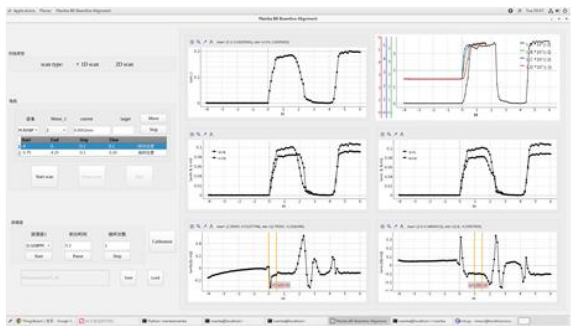
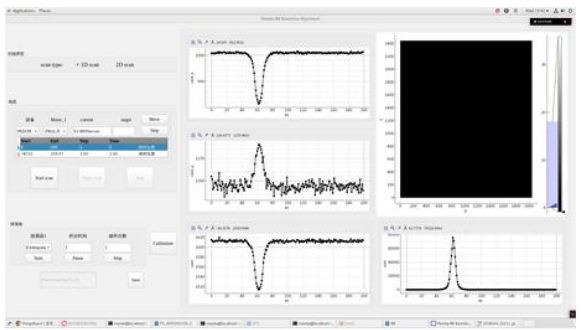
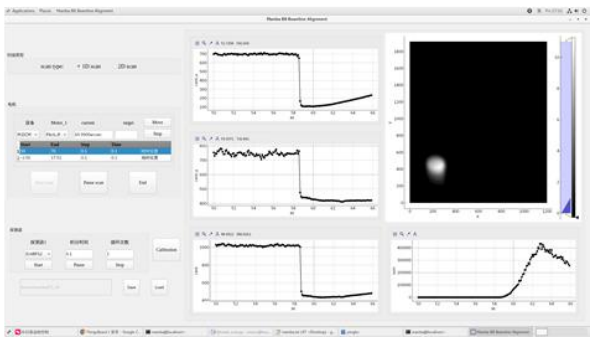
- Many last-minute requests with tight deadlines.
- A large number of micro/nano beamlines.
- The critical dependence of experiments on precise beam alignment.
- The necessity for immediate feedback during operation.
- A strong push towards automating processes.





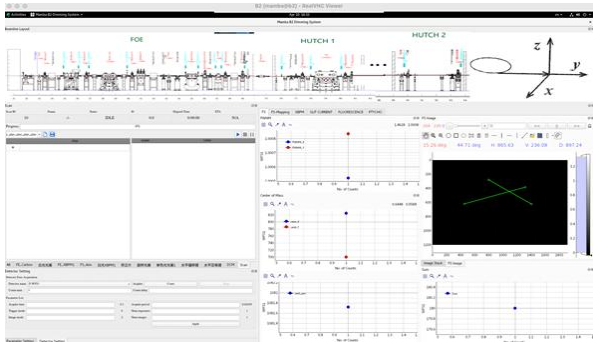


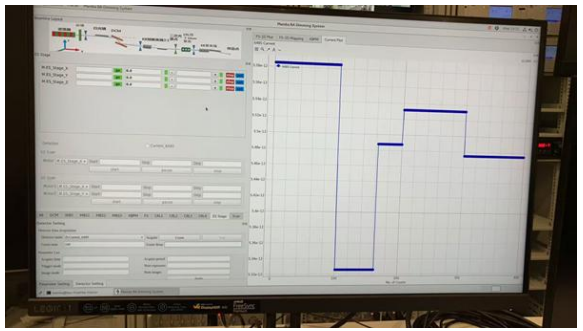
Data-driven beamline intelligence applications : beamline alignment

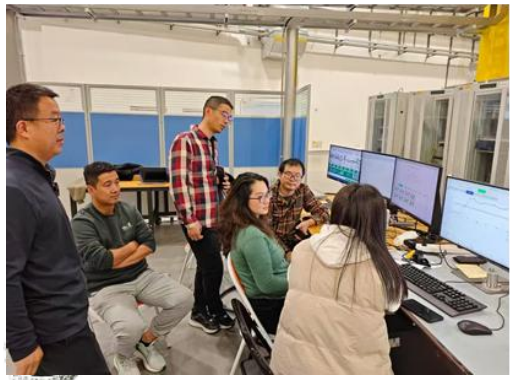





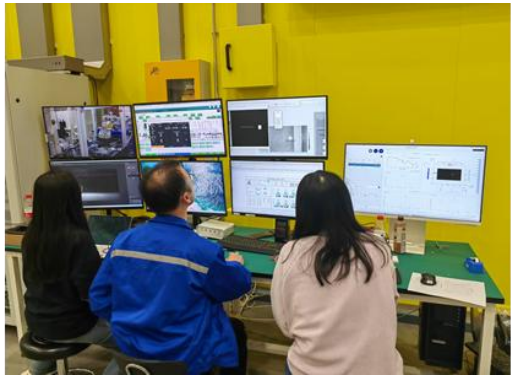
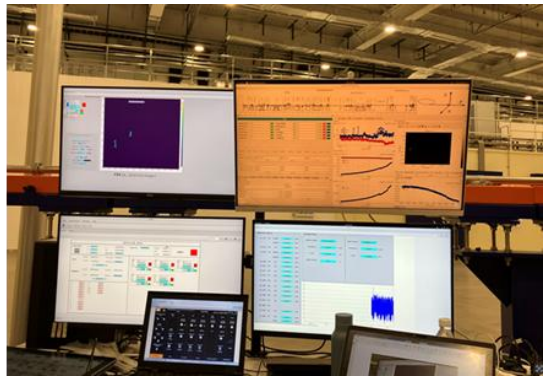
Step1:

Beamline commissioning software



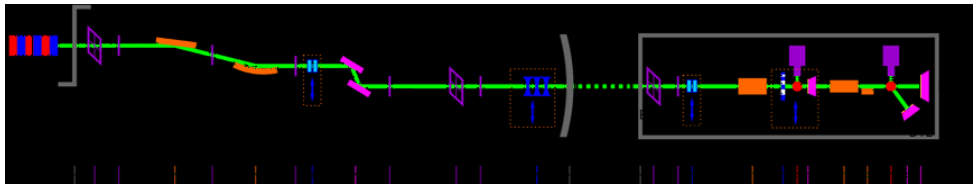


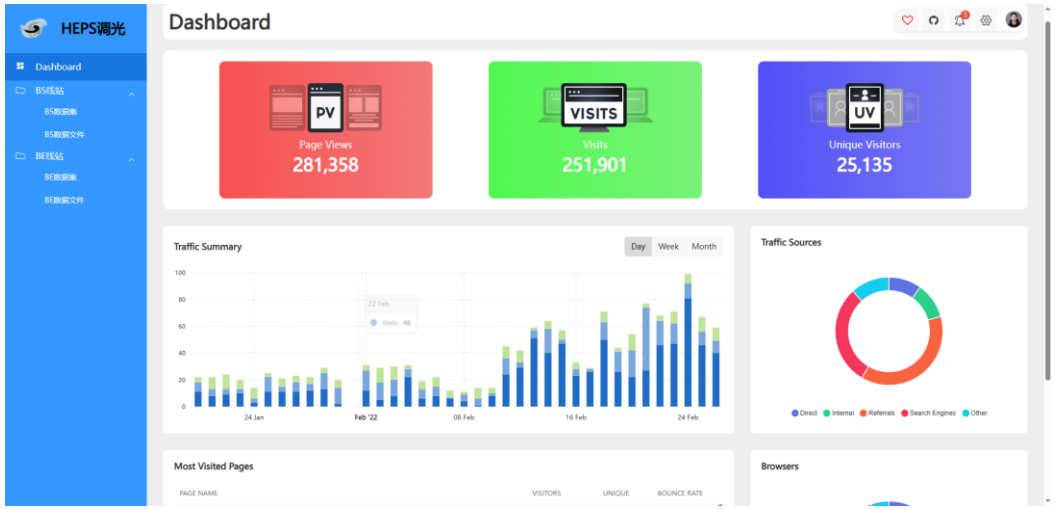



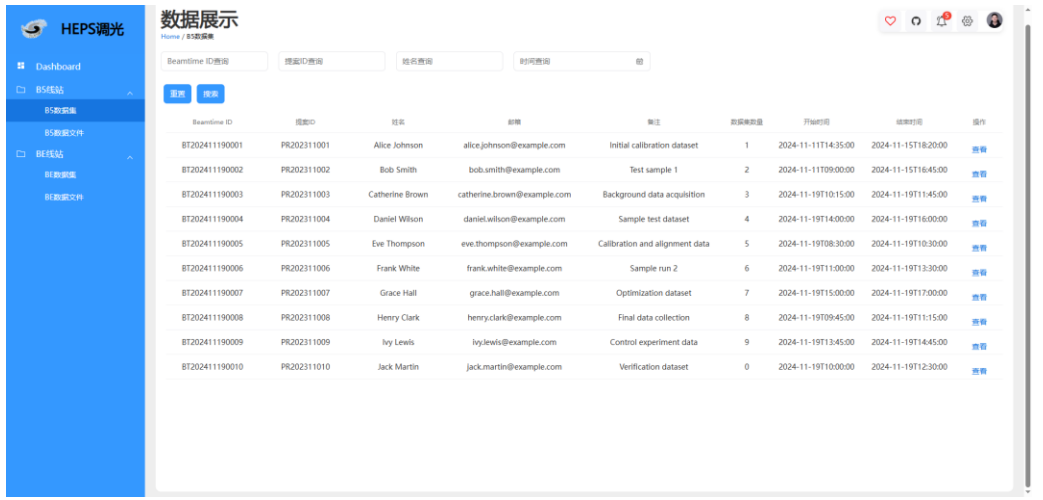




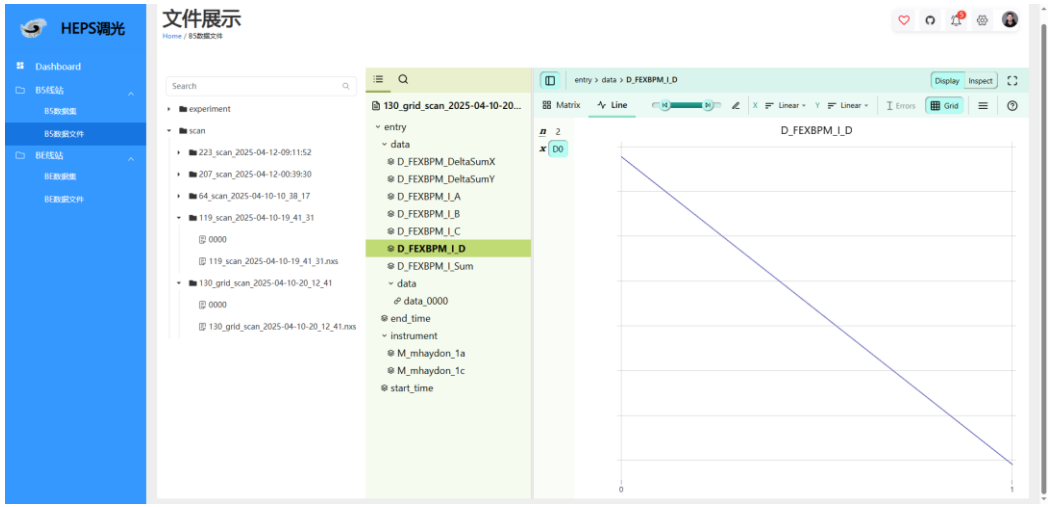
Data-driven beamline intelligence applications : beamline alignment

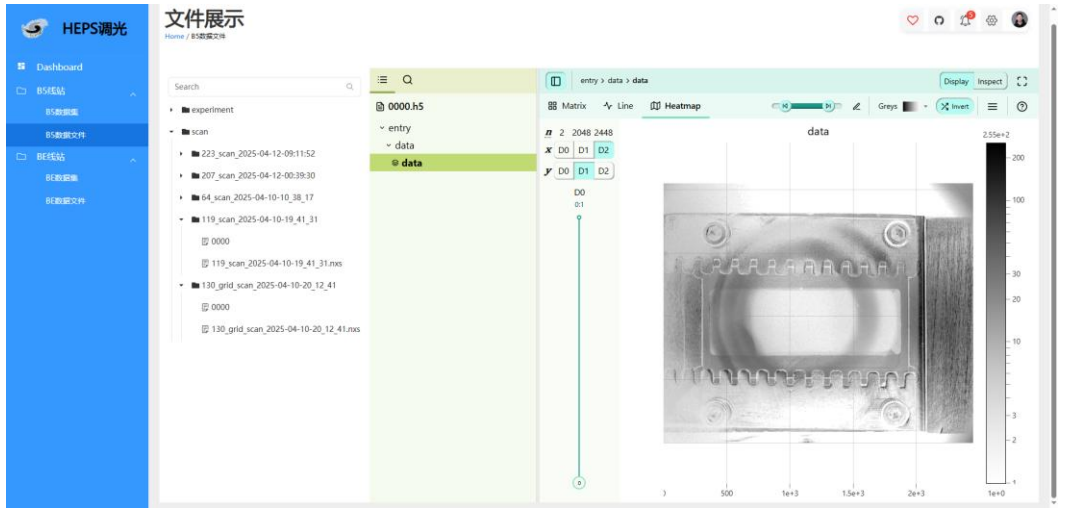
Step2: Collecting Beamline commissioning data



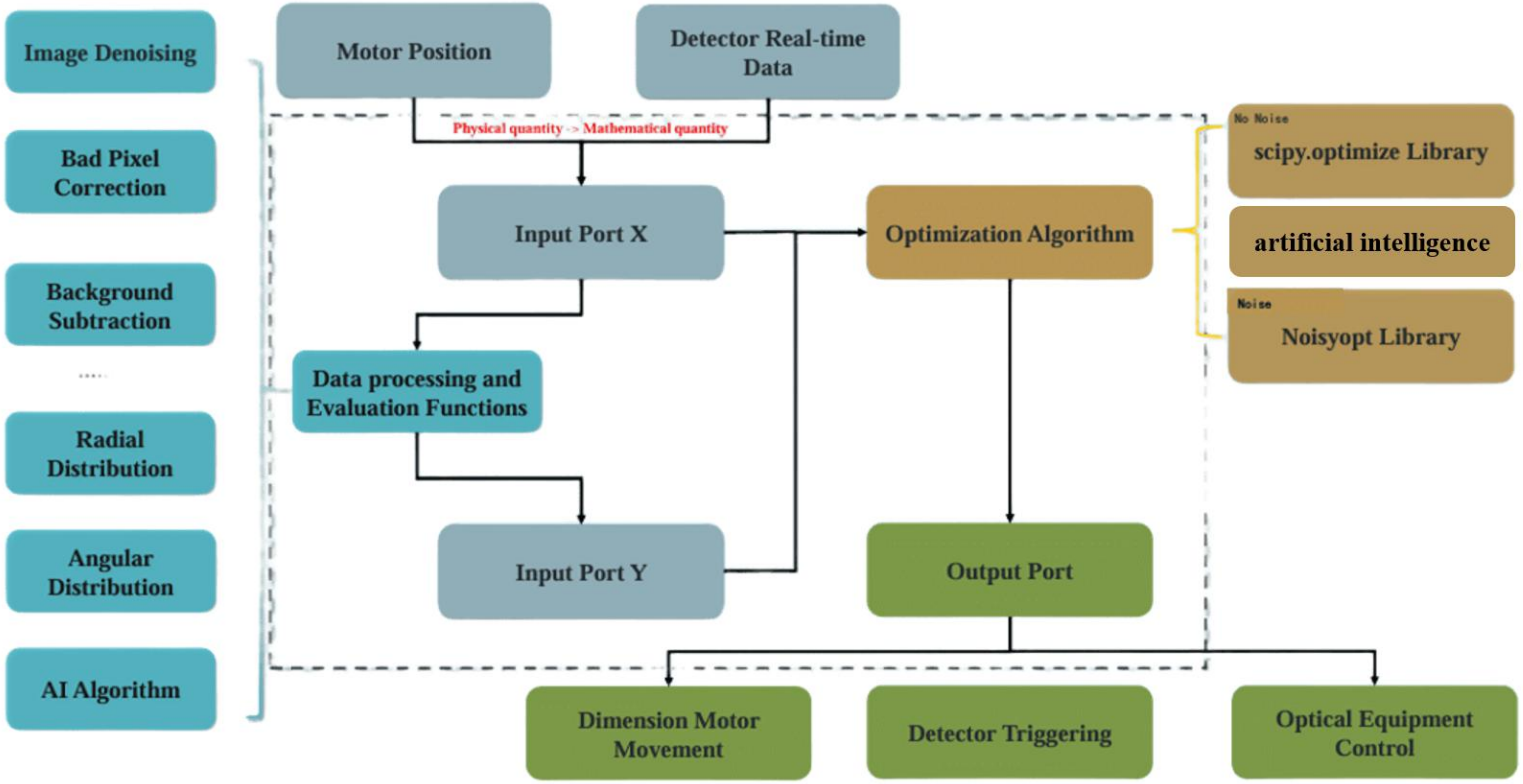








Step3: A Unified Framework for Attitude Tuning



research papers

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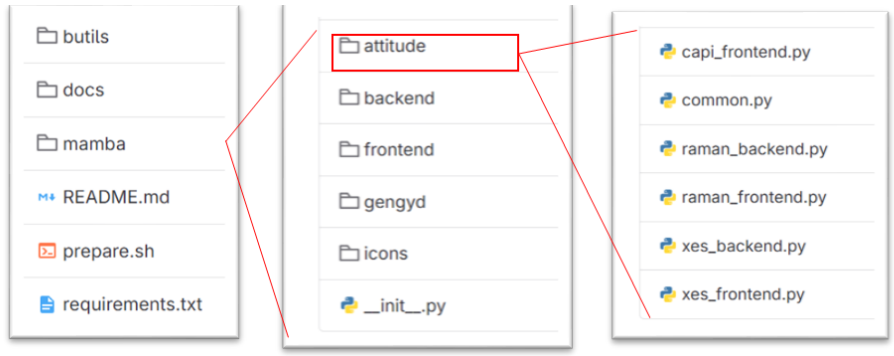
A versatile framework for attitude tuning of beamlines at light source facilities

Peng-Cheng Li,[a,b,c]‡ Xiao-Xue Bi,[b]‡ Zhen Zhang,[a,c] Xiao-Bao Deng,[b] Chun Li,[b] Li-Wen Wang,[b] Gong-Fa Liu,[a,c] Yi Zhang,[b,c] Ai-Yu Zhou[b] and Yu Liu[b]*

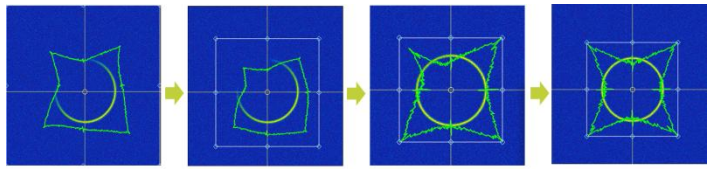
- **Input/Output ports**
  Physical quantity -> Mathematical quantity
- **Data Processing and Evaluation Functions**
  Optional, scalable（Image Denoising、Bad Pixel Correction、 Background Subtraction、Radial Distribution、Angular Distribution and AI .）
- **Optimization Algorithms**
  Feature-rich, widely supported, high maturity



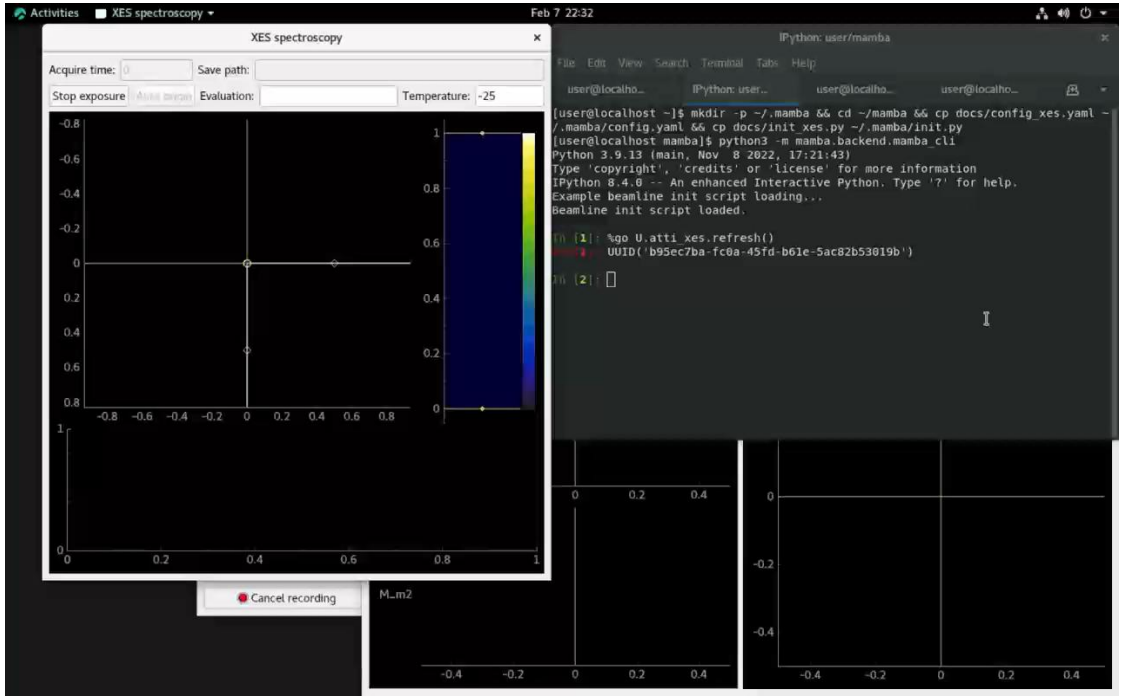
Step3: A Unified Framework for Attitude Tuning

General Attitude Tuning: XES Spectrometer

- Performing Bragg reflection on the analyzer of the vonHamos spectrometer on the 4W1B of BSRF will produce a circular pattern.
  (**pitch/tilt** & **yaw/pan** angles)
- General Attitude Tuning software is used to optimize the shape of the circle.

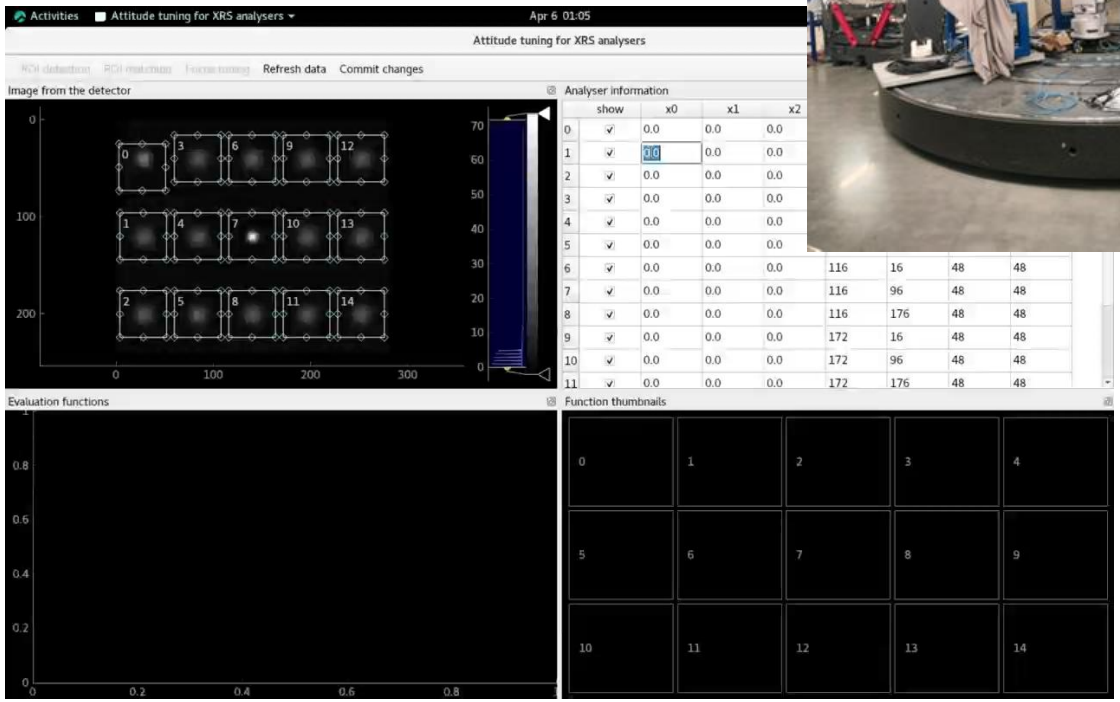


XES Spectrometer Attitude Tuning Process



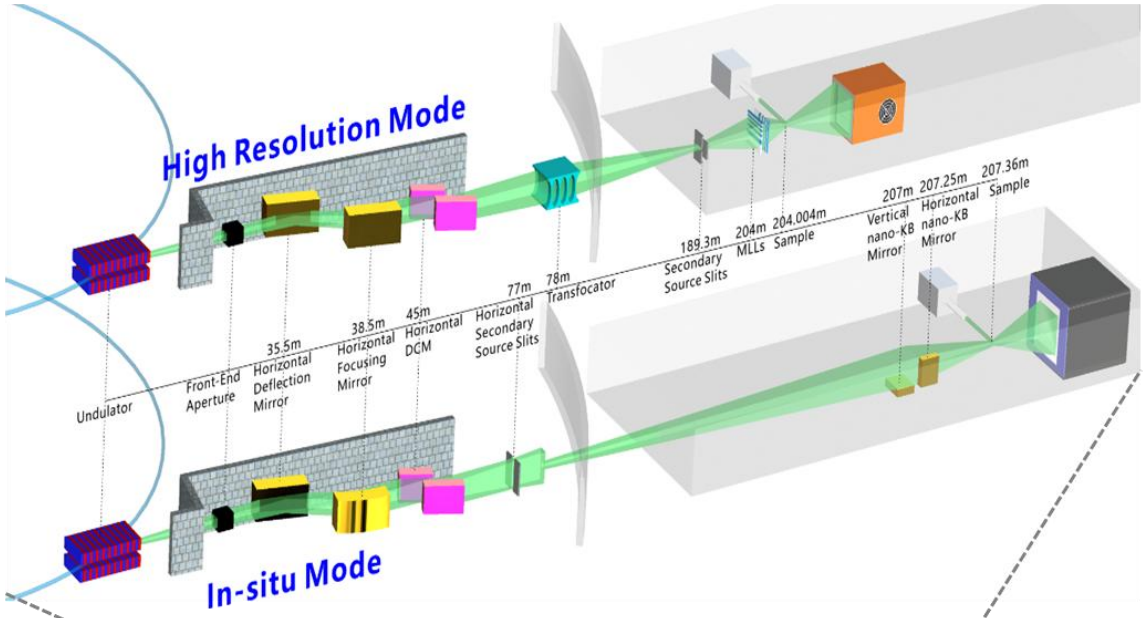
Specialised Attitude Tuning: XRS Spectrometer

- Proof-of-concept test on the automatic attitude tuning of analyzer crystals of HEPS Raman spectrometer.
  (**90** analyzer crystals, **270** motions , and **6** detectors)
- Specialized attitude tuning software is used for spot identification, allocation and focus adjustment.



Step4: algorithm development and deployment

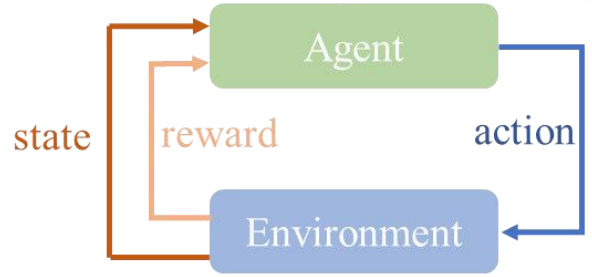
Fast Intelligent Autofocus Alignment Of Digital Twin System For Beamline Stations



Realtime online X-ray focusing system

$$Q(s,a) = Q(s,a) + \alpha(r + \gamma maxQ(s',a') - Q(s,a))$$

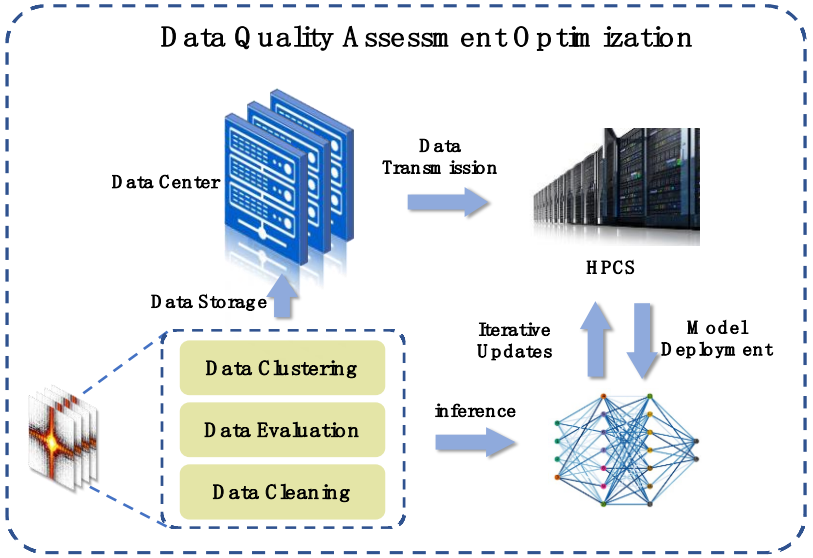
Reinforcement learning network model

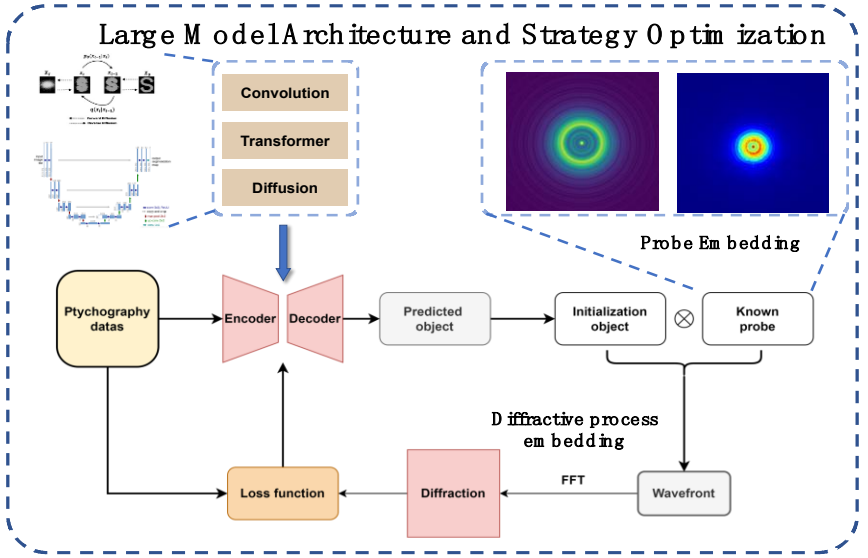


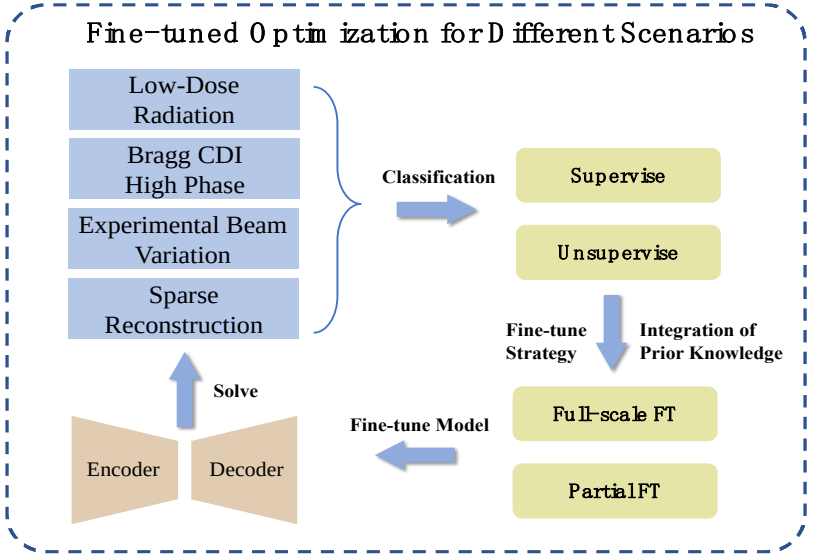
Virtual digital twin system for autofocus alignment

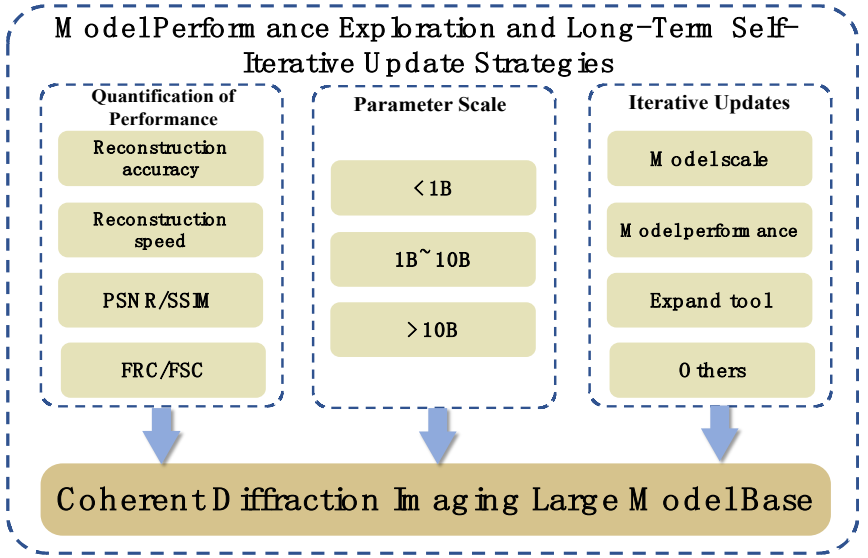
Further optimize training

Step5: Developing Domain specific big AI model

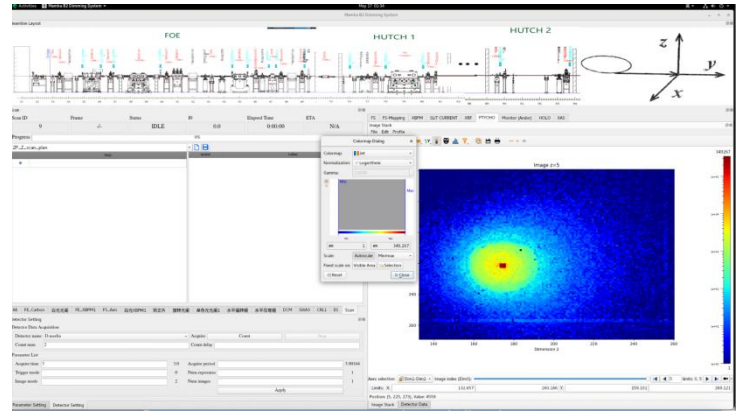




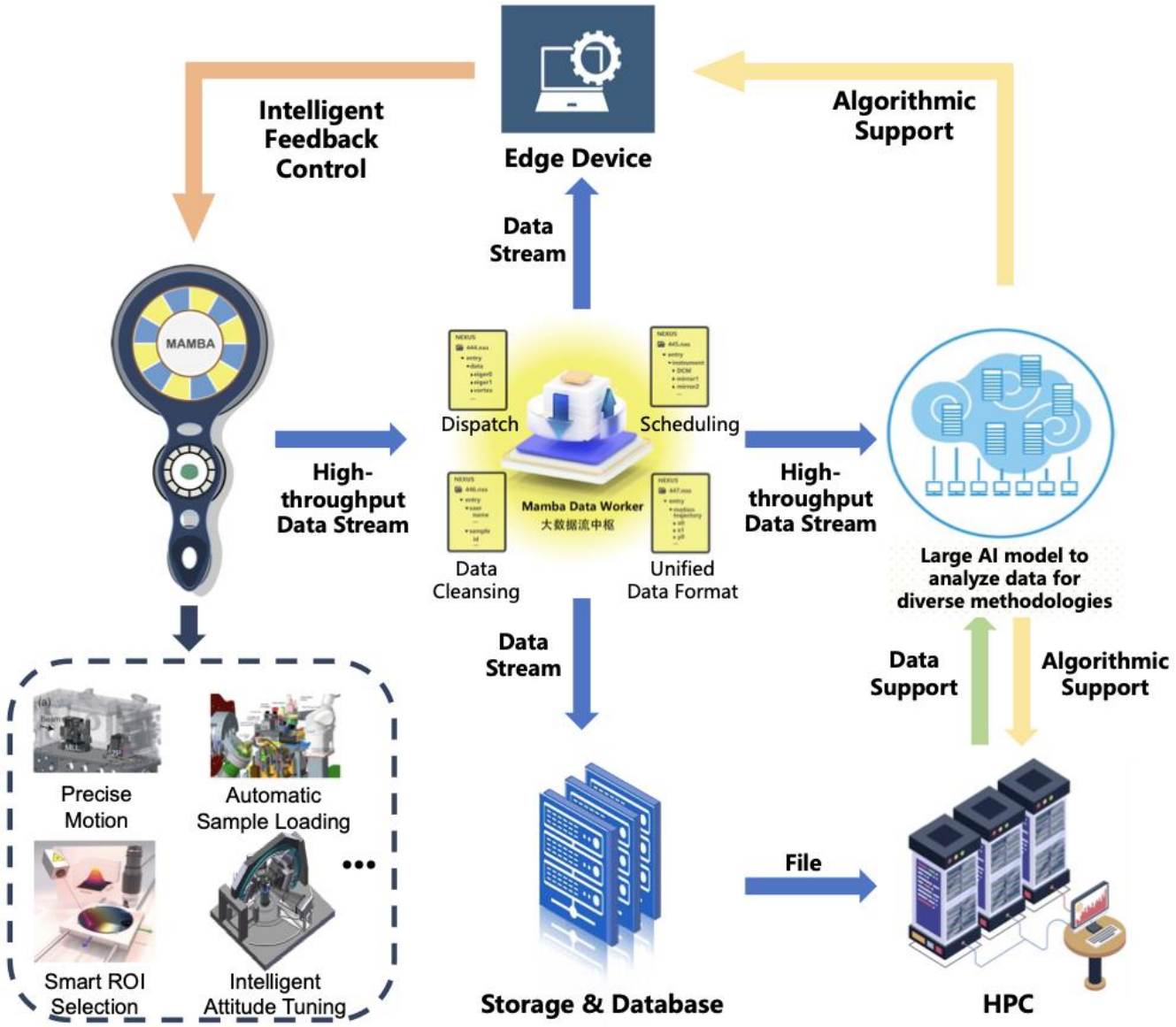


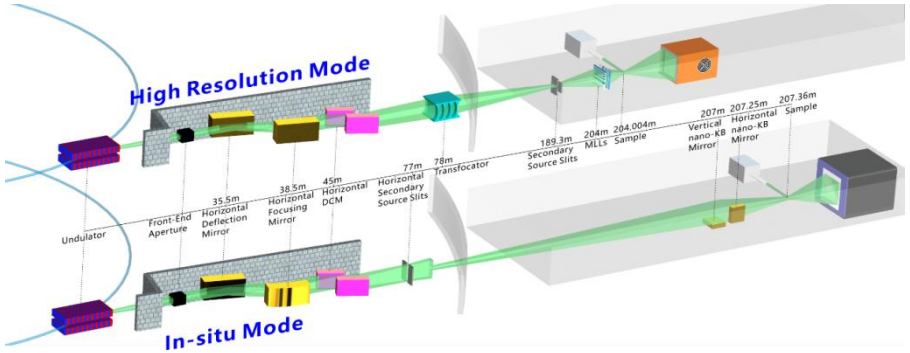


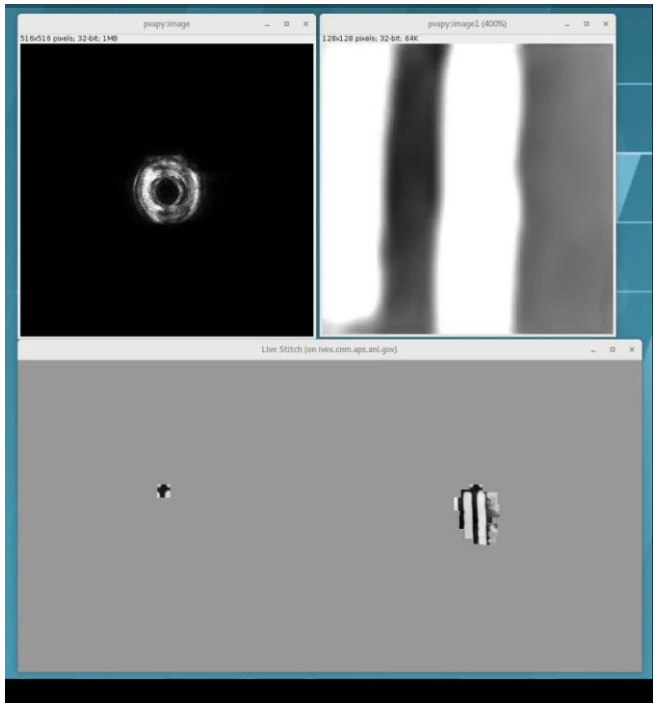
- Real-time data analysis and online feedback control capabilities
- Deployable to edge devices from various beamlines
- Iteratively updated with data accumulating at long-term



Step6: Beamline auto-piloting



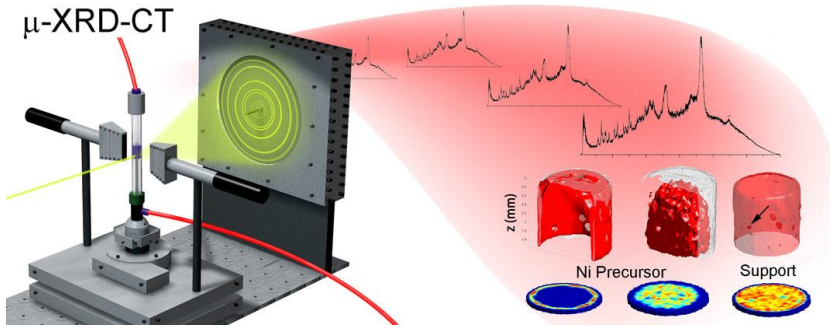




Algorithms-driven SAXS/WAXD technique development

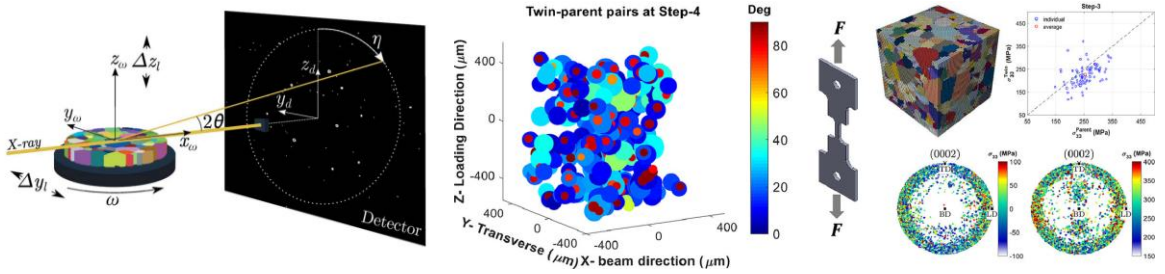
Multidimensional SAXS/WAXD is becoming a routine method

Powder samples (catalysts, rocks, minerals, etc.)



3D XRD

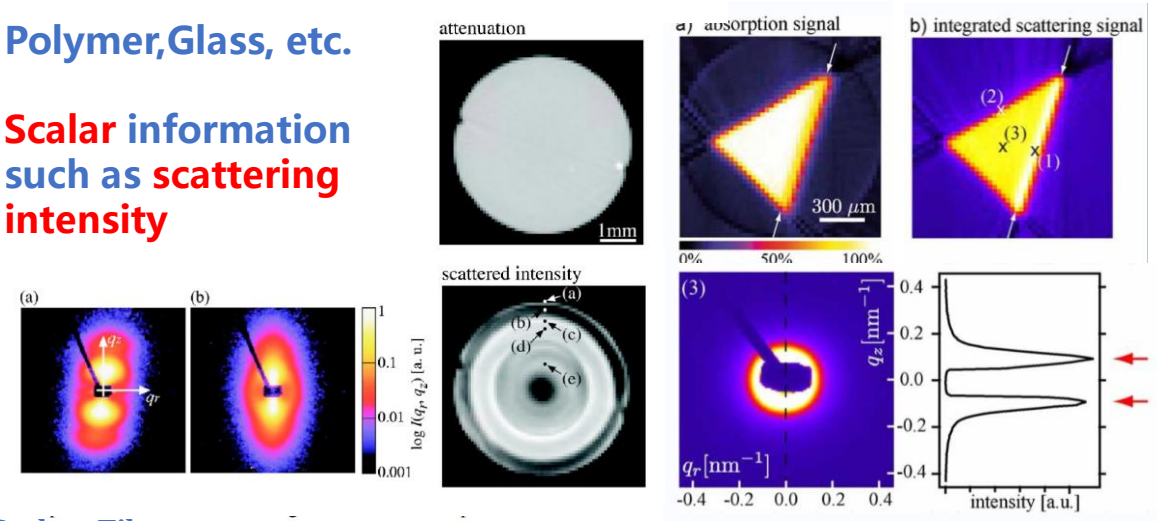
Metal



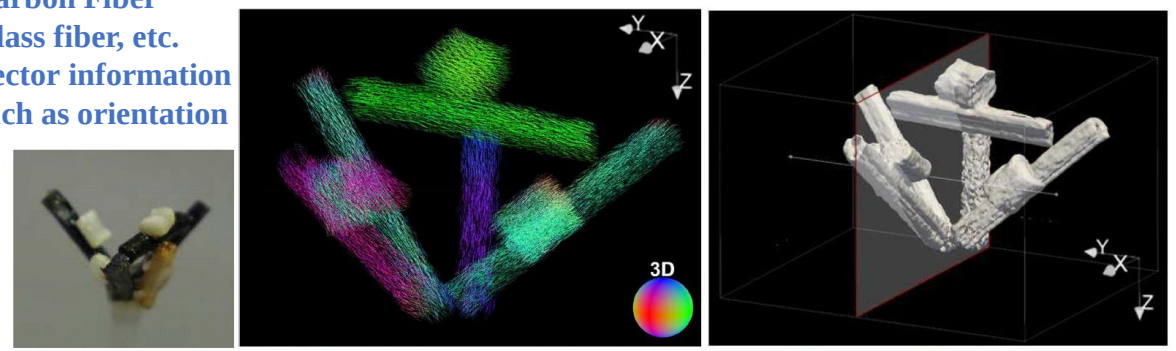
SAXS-CT

Polymer,Glass, etc.

Scalar information such as scattering intensity



Carbon Fiber
Glass fiber, etc.
Vector information such as orientation



(a) Fibre pellet assembly **(b)** Full 3D view of the reconstructed fibre orientations **(c)** Contour and 2D slice selection

N. Axel Henningsson, et al. J. Appl. Cryst., 2020
Hamidreza Abdolvanda , et al. Acta Materialia. 2020

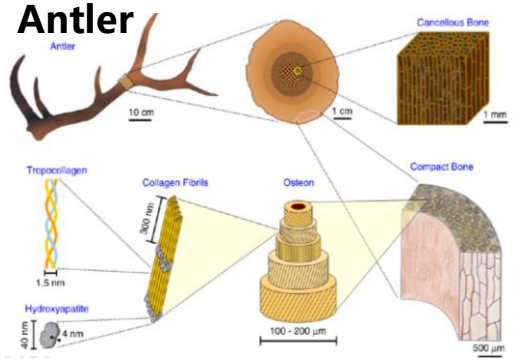
J. M. Feldkamp, et al. Phys. Status Solidi A, 2009
Tao Hu, et al. Macromolecules, 2020
Jisoo Kim, et al. Scientific Reports. 2021

Algorithms-driven SAXS/WAXD technique development

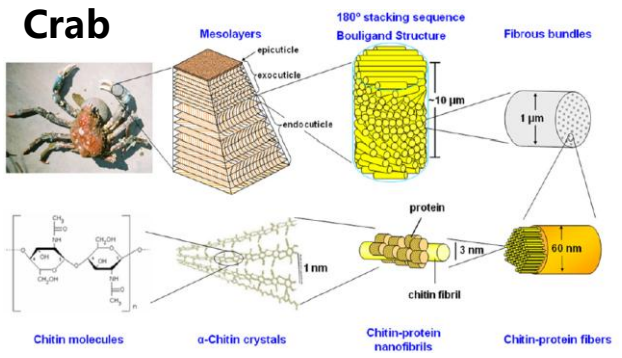
3D characterization of anisotropic fiber orientation

Natural Material

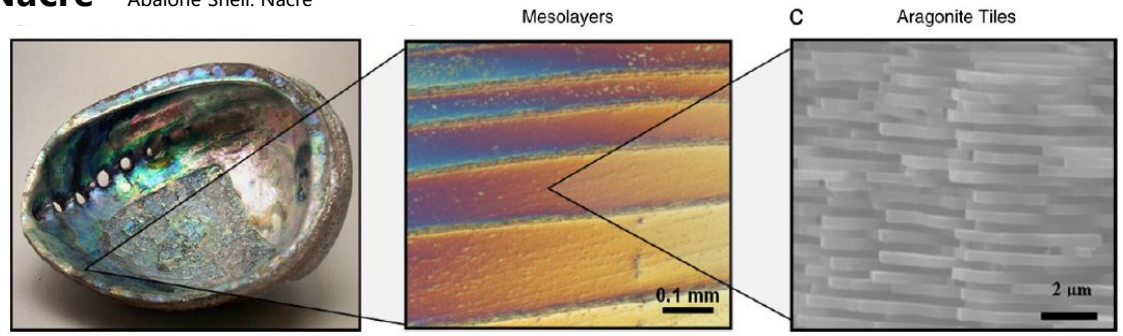
Antler



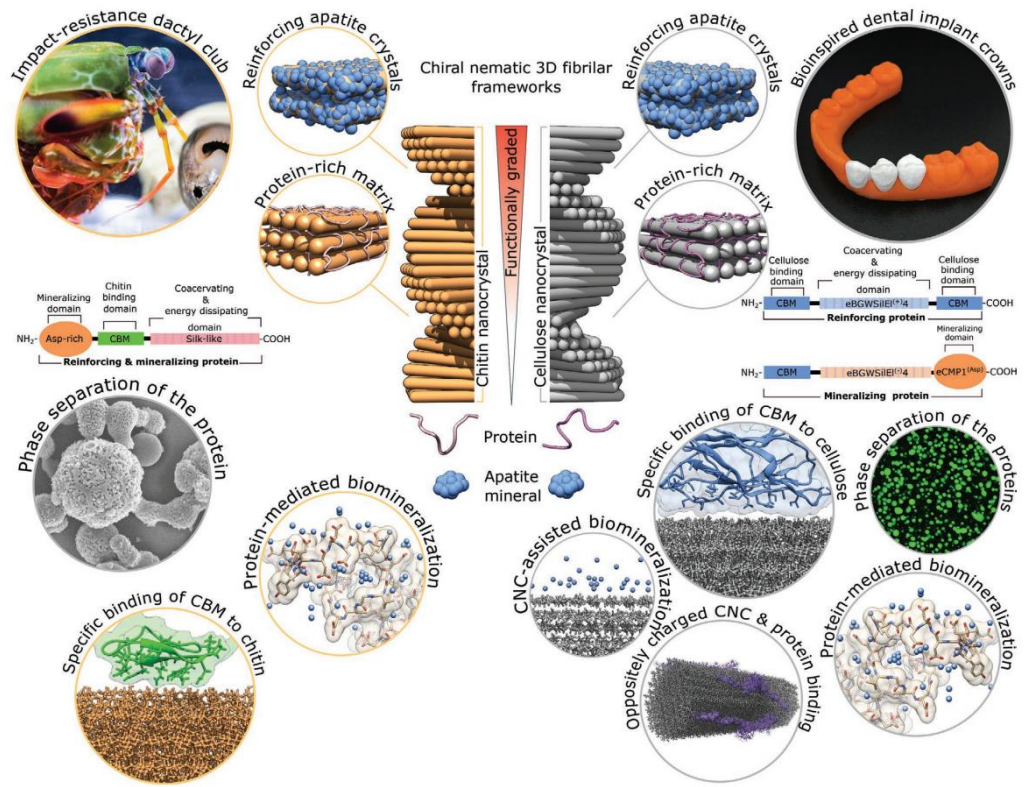
Crab



Nacre Abalone Shell: Nacre



Biomimetic Material

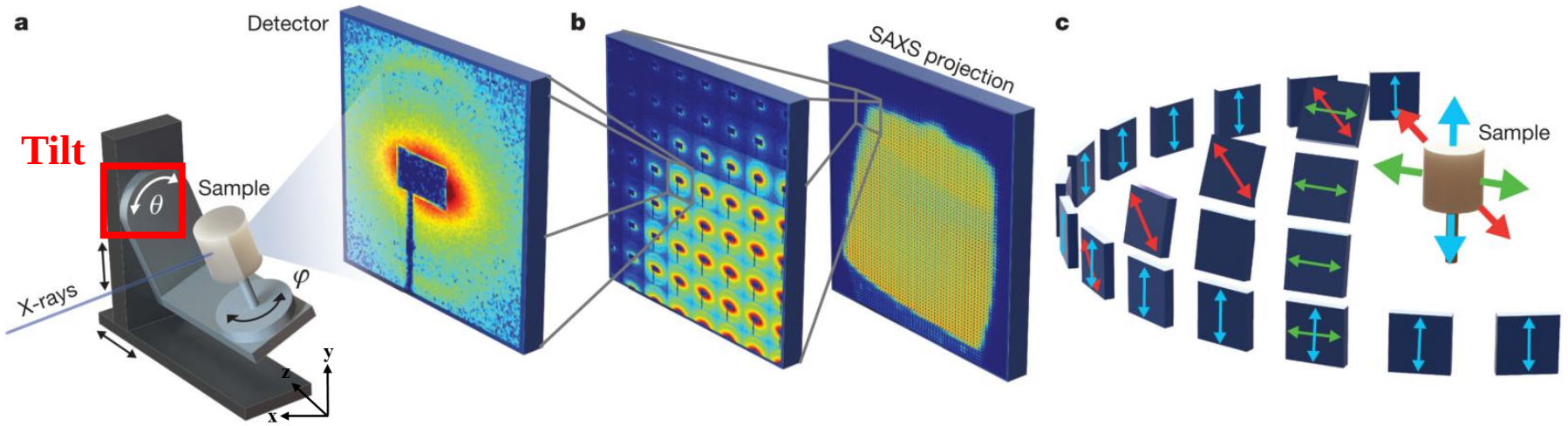


Anisotropic fiber orientation is directly related to the anisotropic mechanical properties of materials, but there is a lack of suitable characterization methods.

Launey, M.E.et al. Adv. Mater. 21(20) (2009) 2103-2110. Ritchie, R.O. Nature Materials. 10(11) (2011) 817-822. Pezhman Mohammadi.et al. Adv. Mater.33(20) (2021)

Algorithms-driven SAXS/WAXD technique development

Bottleneck of 6D SAXS/WAXD : Timeliness of sample scanning



How to avoid time-consuming Tilt angle scanning and directly use 3D scanning data to replace 4D scanning, to achieve 6D SAXS/WAXD tomography:

- Improve the efficiency of 6D SAXS/WAXD experiments and reduce the experimental time by an order of magnitude.
- Reduce the amount of experimental data.
- Implement *in-situ* experiments setup.

For anisotropic materials, SAXS/WAXD tomography does not meet the rotational invariance required for CT reconstruction.

Sample Size： 3*4 mm²

Beam Size: 50*50 um²

Exposure time: 50 ms

Patterns Number：

1,376,352

Time consumption:

40 h

Rotation range: 0-360°

Tilt range: 0--68°
(10 tilt angles)

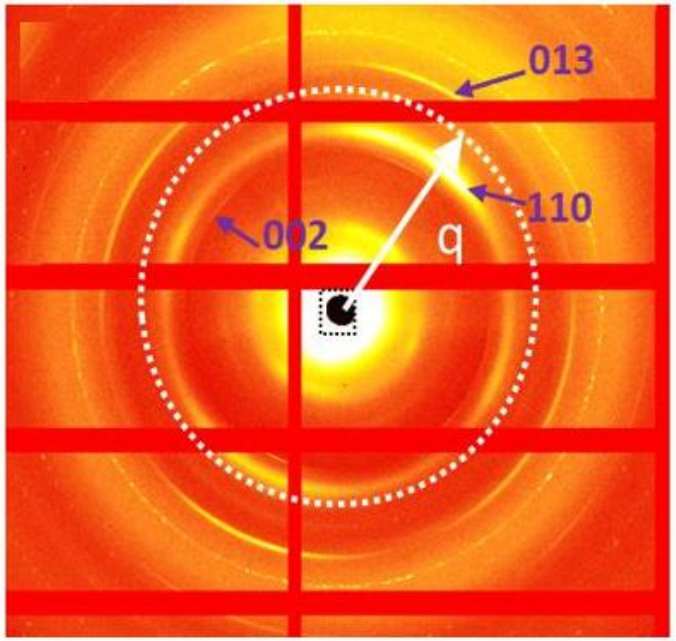
Florian Schaff, Martin Bech, et al. Nature:2015, 527:353-256 Marianne Liebi, et al. Acta Cryst. A74:2018

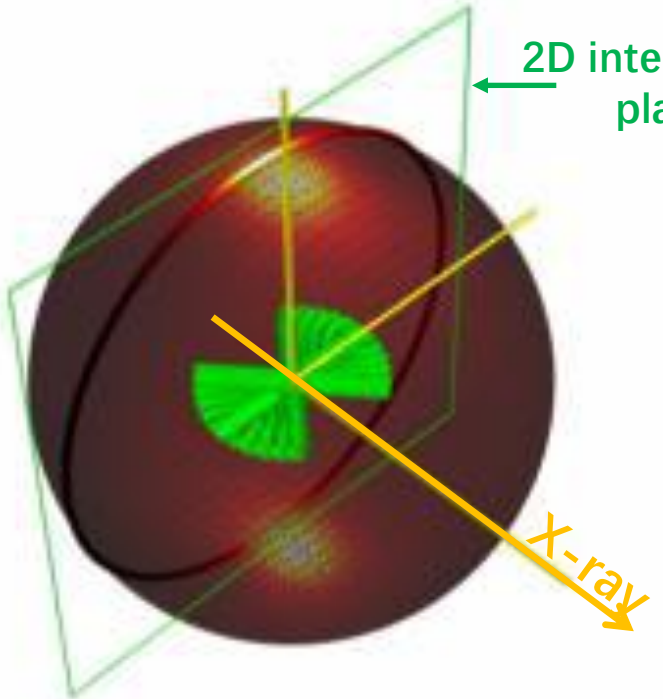
Algorithms-driven SAXS/WAXD technique development

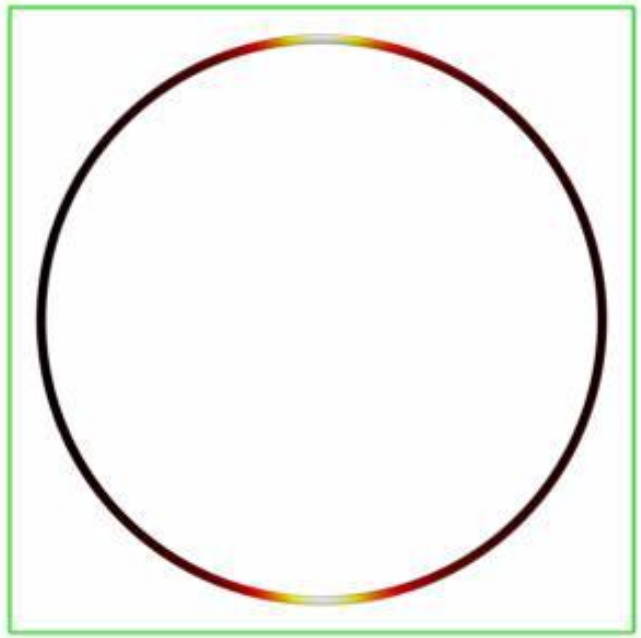
Can the scanning process of reciprocal space be simplified?

Are there 3D information hidden behind 2D WAXD pattern?

The QS(110) change with fibre orientation parameters (γ, Δγ (2D), α, β (3D)) variation







2D WAXD pattern

Intensity distribution changes on QS(110) sphere

2D diffraction ring

Y. Zhang, et al. *Scientific Reports*, 2016

Algorithms-driven SAXS/WAXD technique development

Step 1: Simulating 6D WAXD Tensor Tomography Dataset

Fiber orientation

Spatial intensity distribution of voxel in the sample coordinate system

Intensity Distribution at Any X-ray Incidence Angle

$$I^{L}_{j,\varphi}(q_x, q_y, q_z) = I^{S}_{j}(q_x, q_y, q_z)$$

$$I^{L}_{j,\varphi}(q_x, q_y, q_z) = R_y I^{S}_{j}(q_x, q_y, q_z)$$

Voxels along the X-ray Incidence Path during Sample Movement

From 3D Spatial intensity distribution to 2D diffraction patterns

$$I^{L}_{i,\varphi}(q_x, q_y, q_z) = \sum_{j=1}^{N} \underbrace{w_{ij}}_{\text{Weight Factor Wij}} I^{L}_{j,\varphi}(q_x, q_y, q_z) \underbrace{\exp(-\mu D_{\varphi,ij})}_{\text{Absorption Term}}$$

Step2: From 2D patterns to 3D QS(110)

➢ 3D Inverse Space Prediction and Numerical Optimization of Diffraction Data

Traversal → Basin-hopping Algorithm

Basin-hopping Algorithm:

- Results: Simulation curve and fitting curve with $R^2 = 99.1\%$, correlation coefficient (PCC) between simulated $QS(110)^{L}_{i,\varphi}$ and fitted $QS(110)^{Lf}_{i,\varphi}$ is 0.91
- Advantages: Setting iteration count, callback function, boundary conditions, etc., to accelerate finding the optimal solution of the function.

Fitting 1051 curves
CPU computation: 8220 hours
GPU computation: 160 hours

Step 3: Reconstruction

➢ Tensor Reconstruction :Distributed Reconstruction Strategy

Step 1:Transforming 3D Reciprocal Space from Spherical Coordinate System to Cartesian Coordinate System

Step 2: Point-by-point CT reconstruction

Step 3: Stitching point-by-point to form a three-dimensional voxel space image.

Spherical Coordinate System (r, θ, φ) Cartesian Coordinate System (x, y, z)

The sinogram formed by the intensities at the same position (r_0, c_0) of $I^{sv}_{i,\varphi(r,c)}$ → FBP reconstruction, the intensity of each voxel at the position (r_0, c_0).

Dimensionality Reduction from 3D Reciprocal Space to 2D Tensor

6D reconstruction achieved through CT reconstruction methods.

Step 4: Fiber Orientation Parameter Extraction

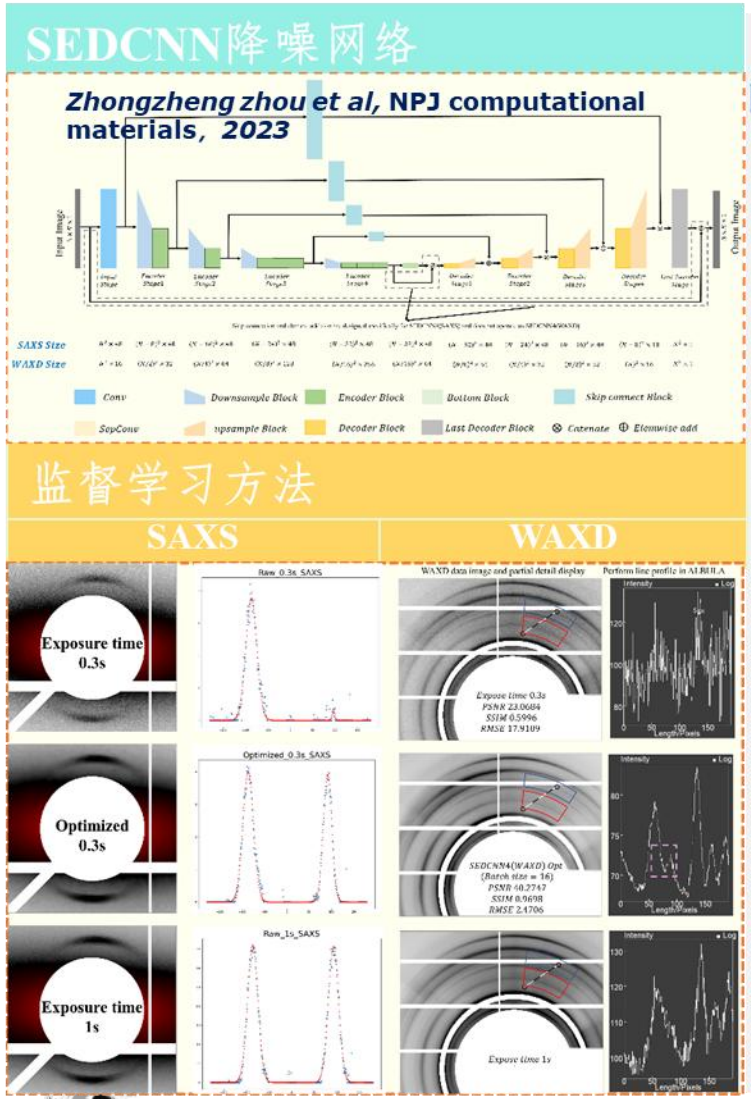
Simulation

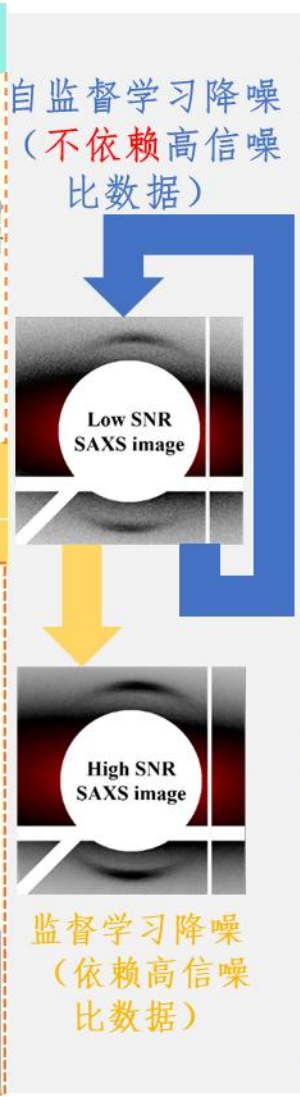
Result

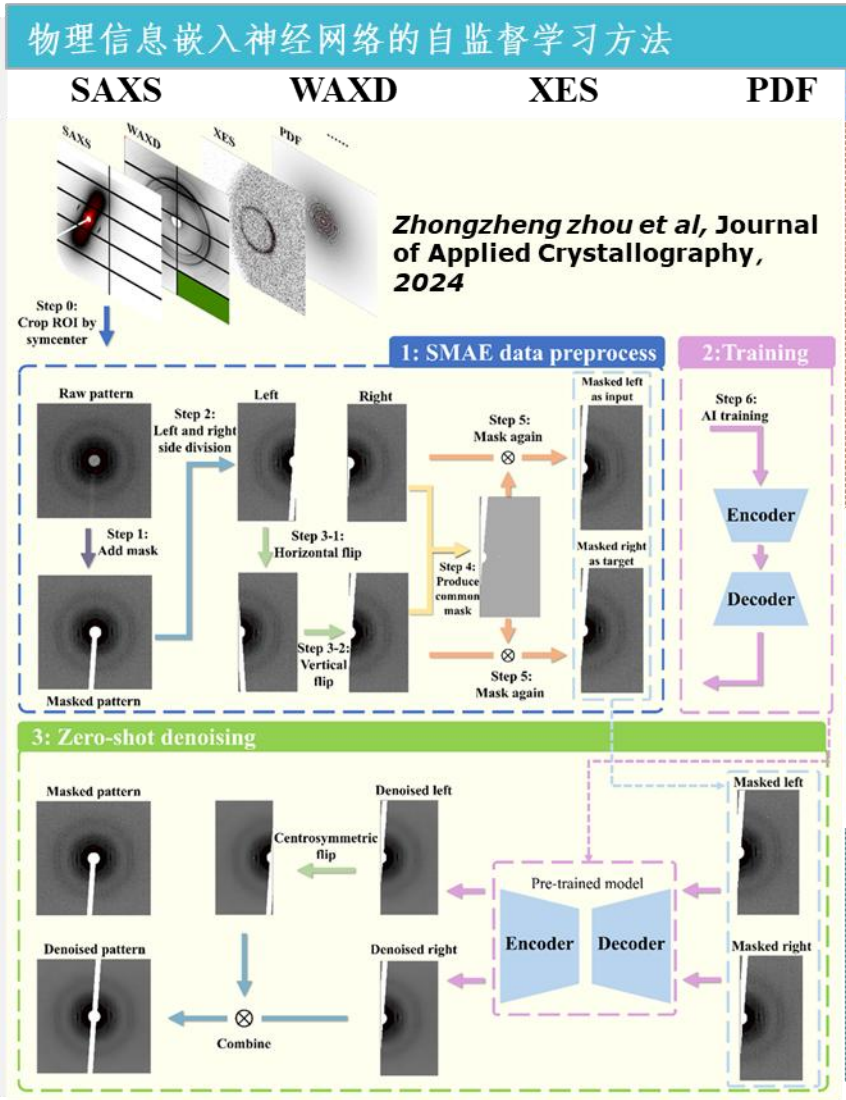
X. Zhao, Z. Dong, C. Zhang, H. Gupta, Z. Wu, W. Hua, J. Zhang, P. Huang, Y. Dong, Y. Zhang, A step towards 6D WAXD tensor tomography, IUCrJ 11(4) (2024) 502-509.

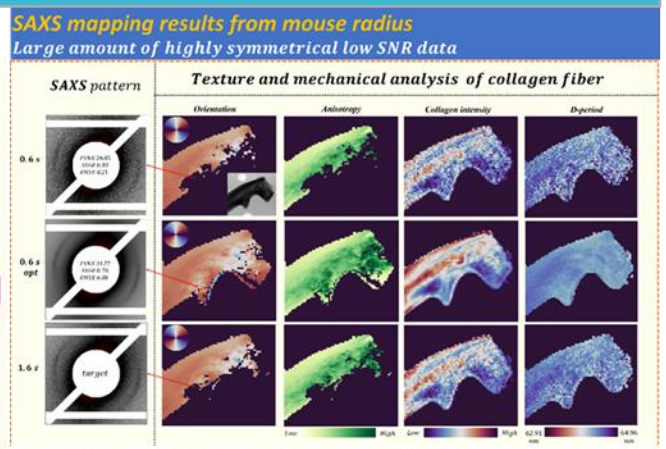
Algorithms-driven SAXS/WAXD technique development

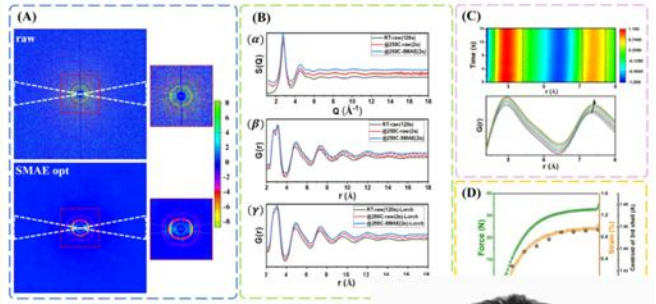
Measure faster by x-ray denoising method









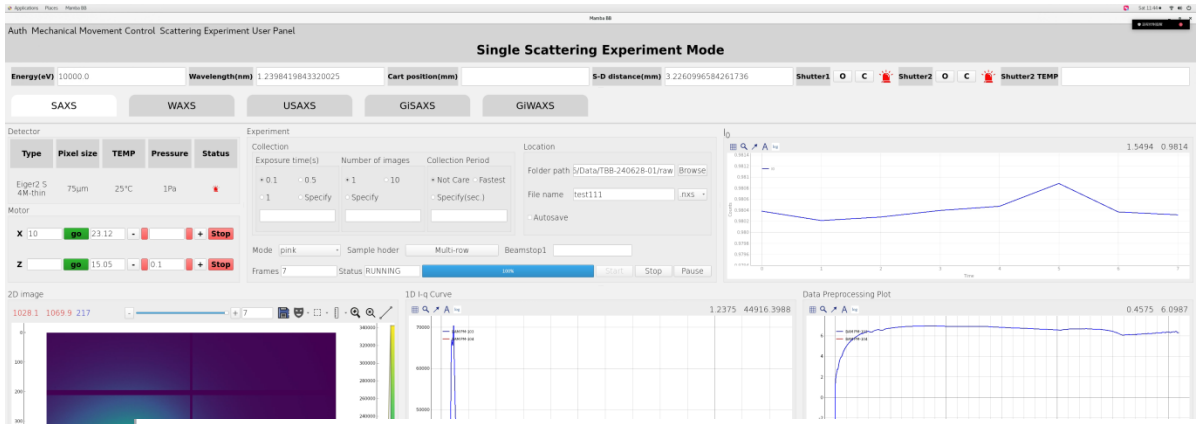


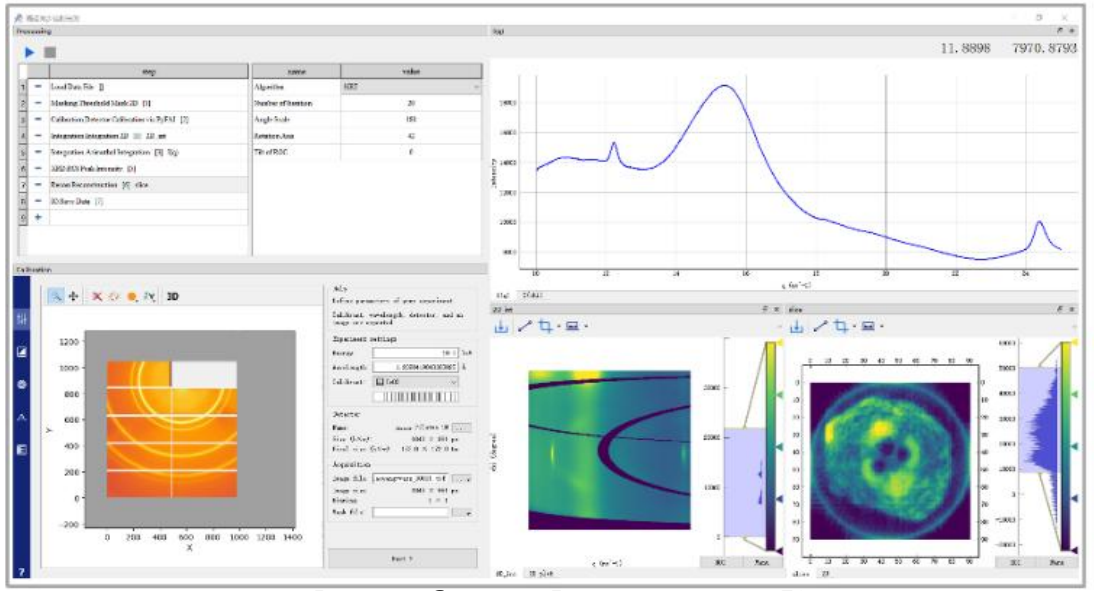
On going: AI 降噪在动态化表征开始做出贡献

李纯

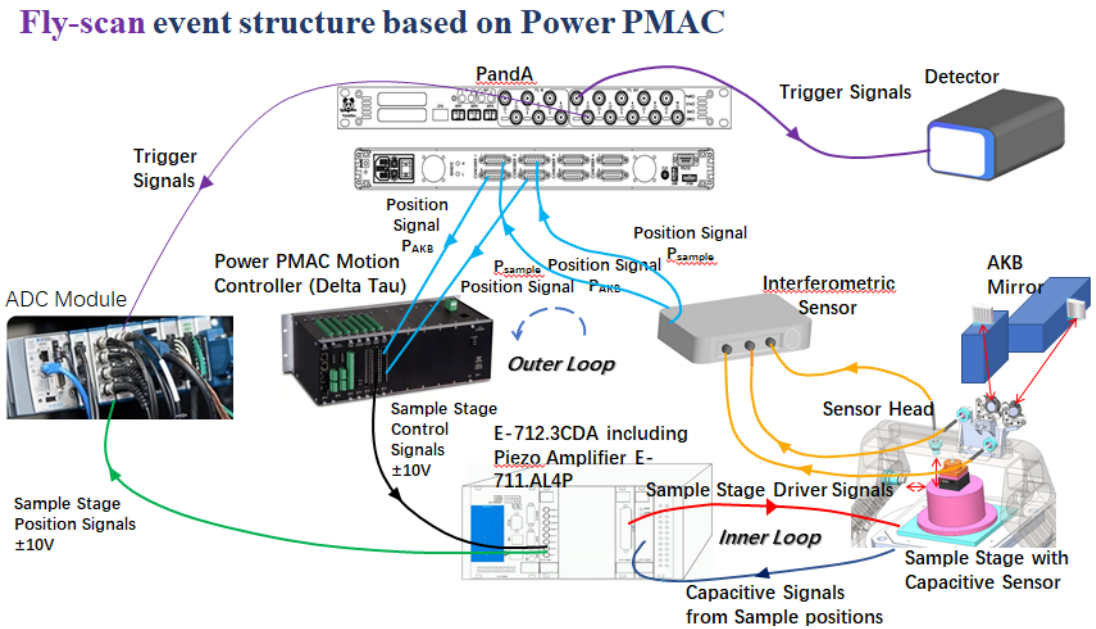
Algorithms-driven SAXS/WAXD technique development

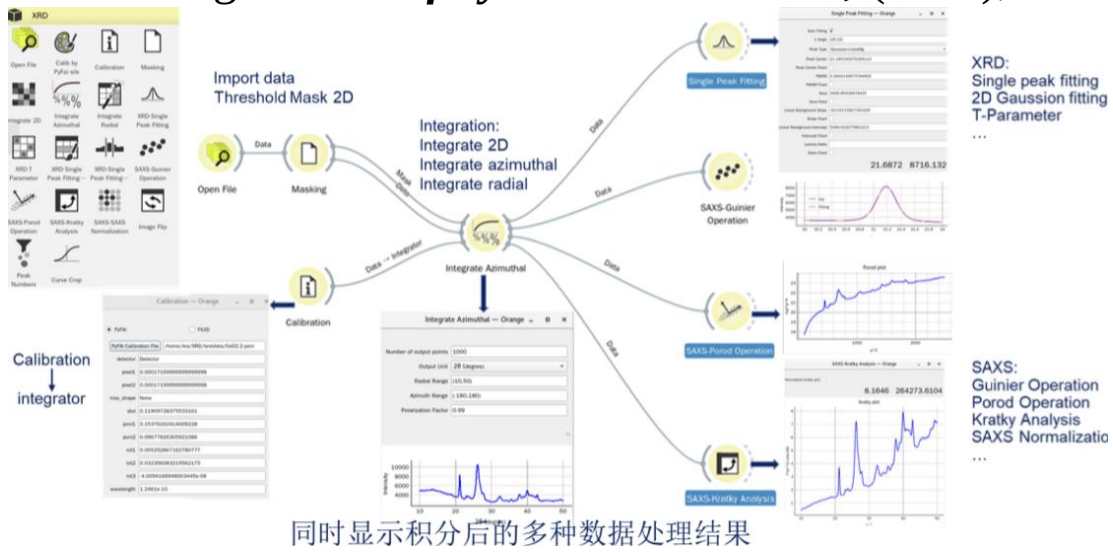
Data quality assurance by Mamba soft





Wang et al. ***J. of Synchrotron Radiat,*** (2024);





同时显示积分后的多种数据处理结果

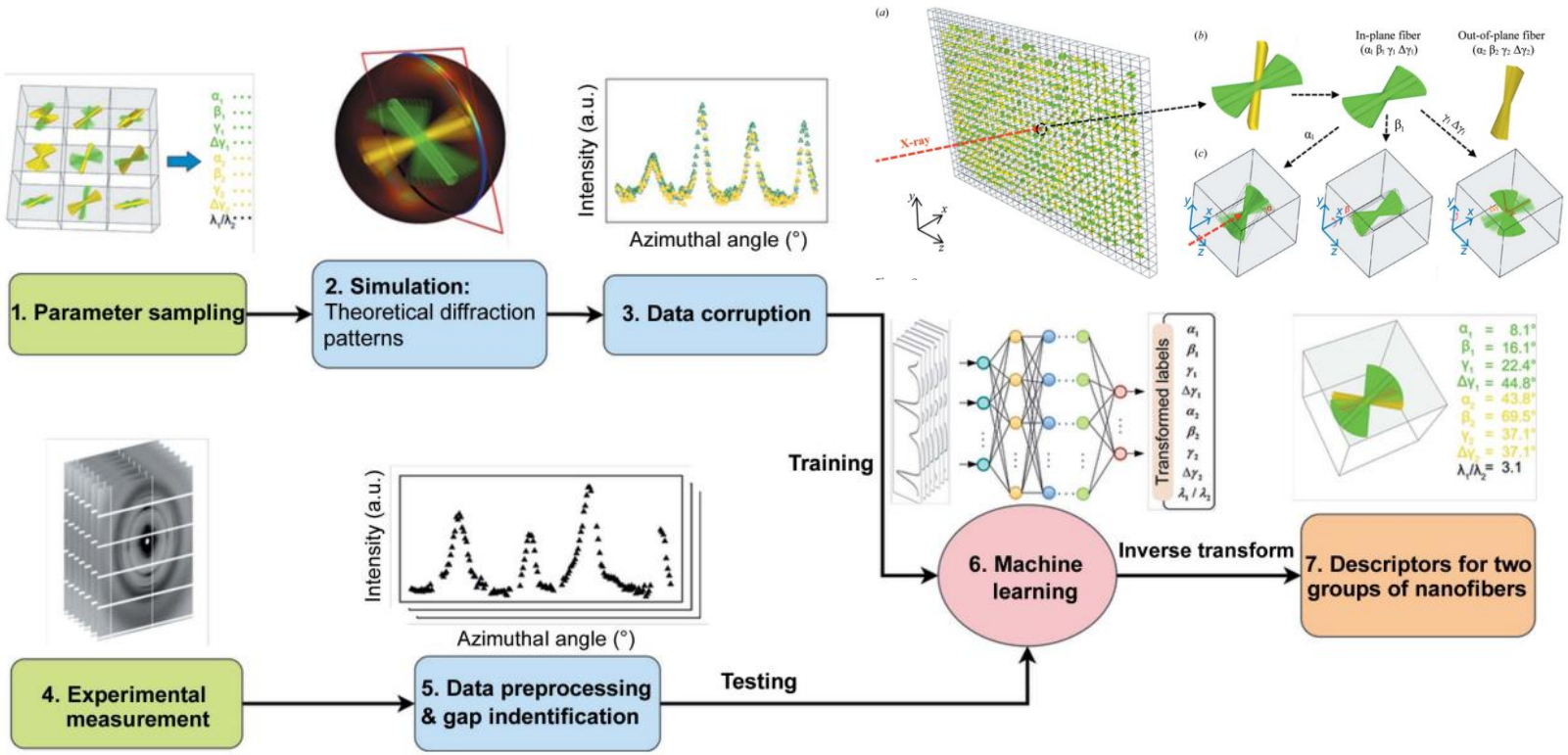
□ Fly-scan

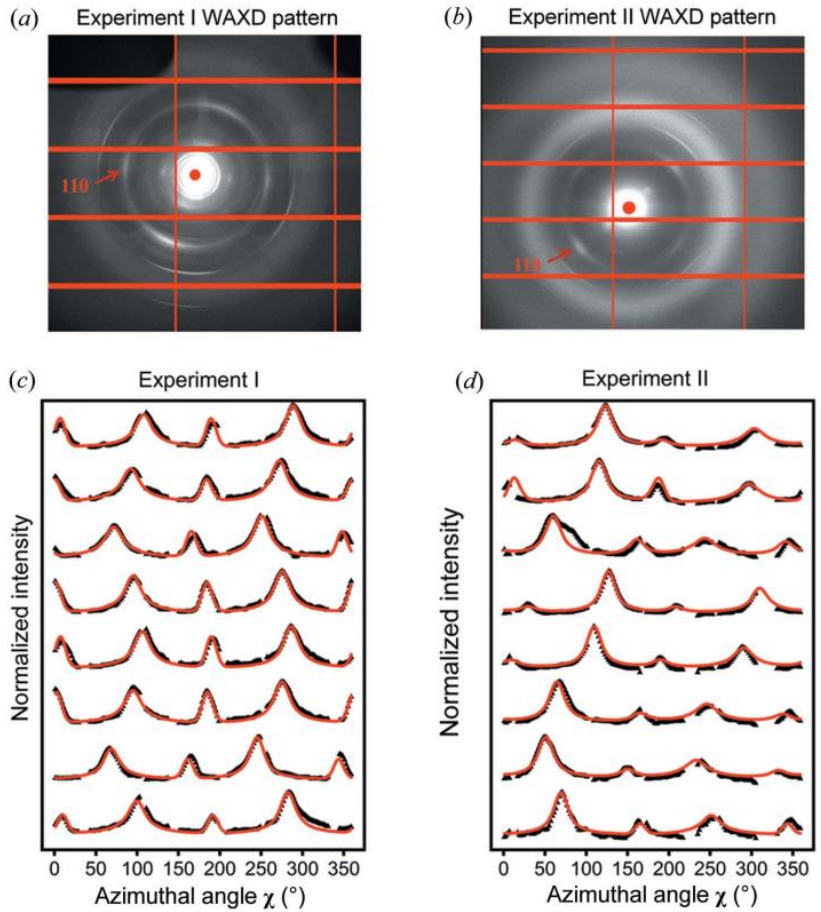
□ Real-time data analysis

Algorithms-driven SAXS/WAXD technique development

Faster data analysis using AI

Learning for Extracting Physical Information from Massive Diffraction Data

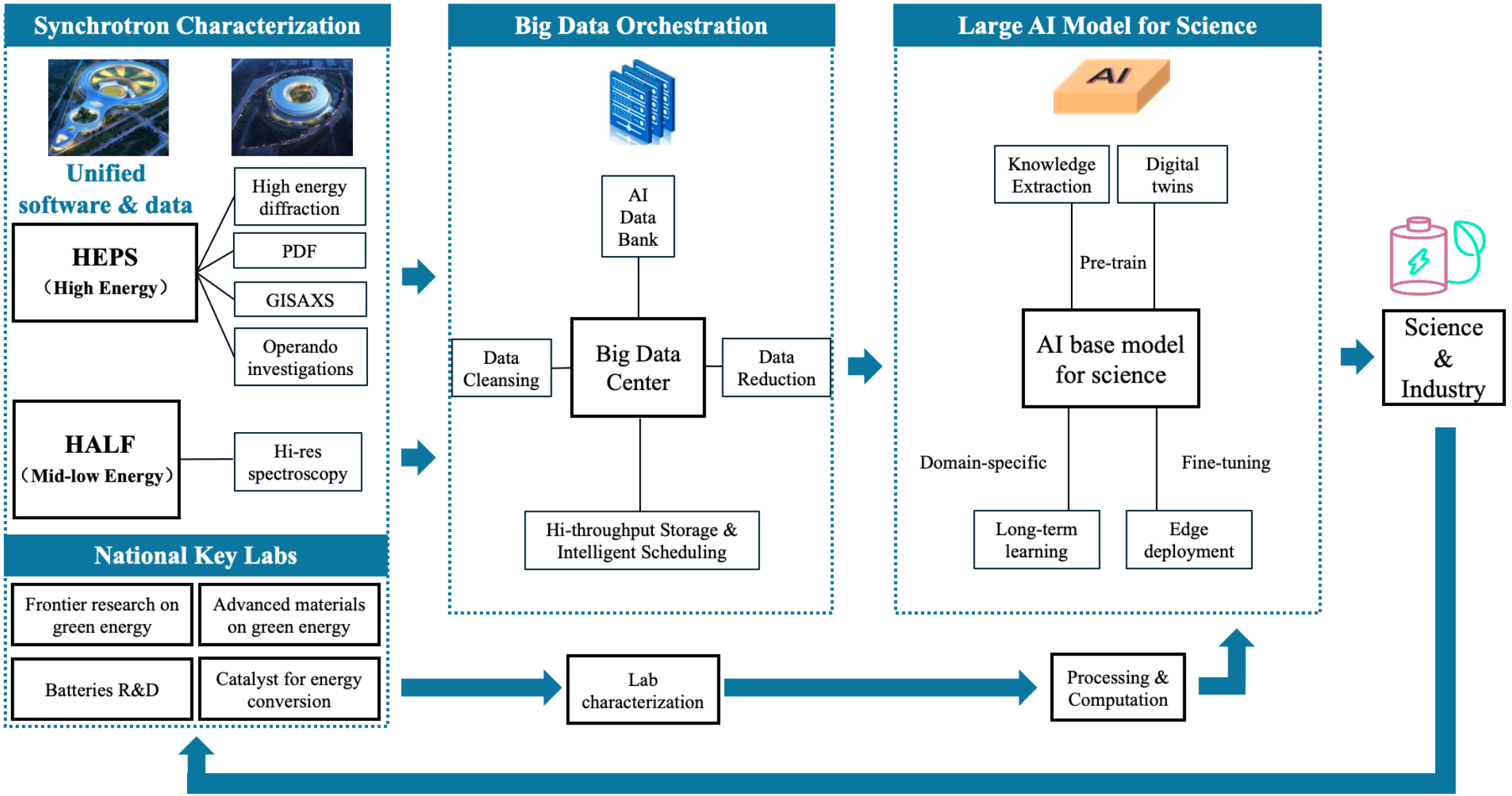




Efficient Data Acquisition Rate of One Million Frames per Hour, with Data Processing Time Less than 10 s.

Sun, M.#, **Zheng Dong**# et al. IUCrJ (2023)

Intelligent cluster of scientific infrastructures



Collaborative efforts for intelligent light source

Our Team

- **Building an all-round scientific software and algorithm development group**


Complex device control


Experiment process control

MAMBA


Area-specific algorithms

Big data acquisition and processing


User client development



Artificial Intelligence

Welcome to join our team

Domestic and international collaboration

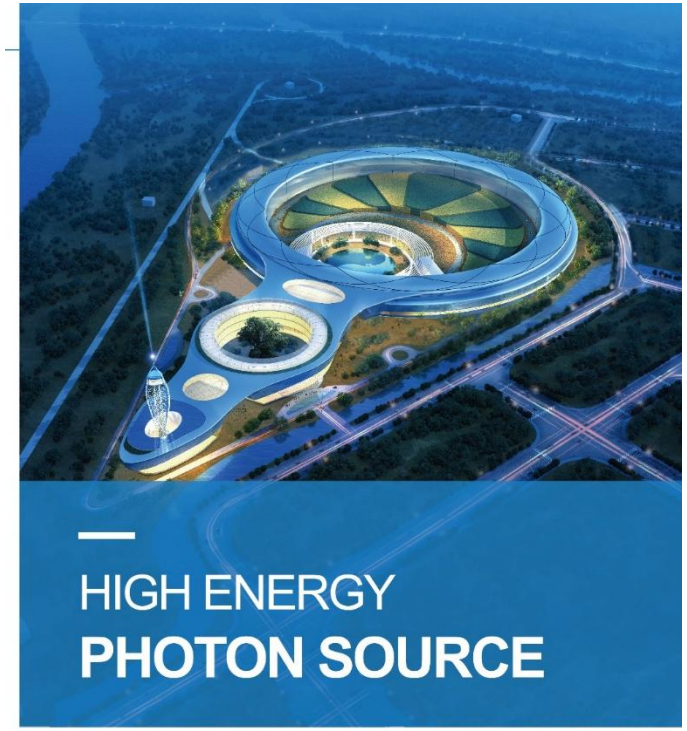
Funding from:

- **National Key Research and Development Project of China;**
- **Chinese Academy of Sciences;**

We are planning to form and develop a nation-wide united scientific software solution in China.

Internationally, we are looking for collaboration from other synchrotron sources.

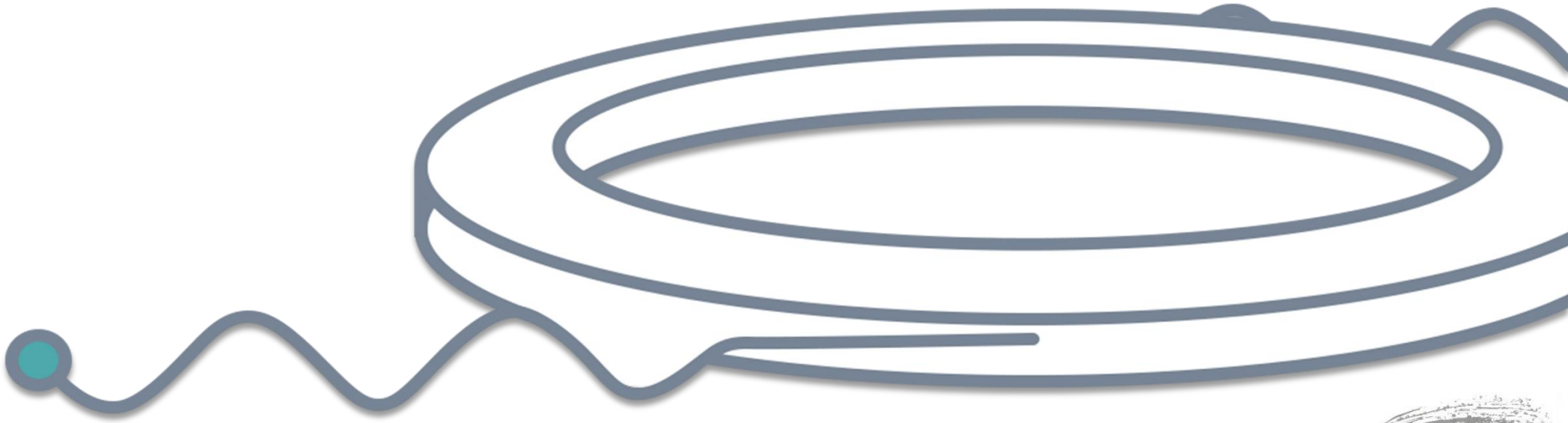
Mamba and *HEPS* Grow together



MAMBA
Data acquisition software

The full potential of the HEPS will be realized by coupling the intrinsic capabilities of the facilities with advanced Mamba system

Device and motion control

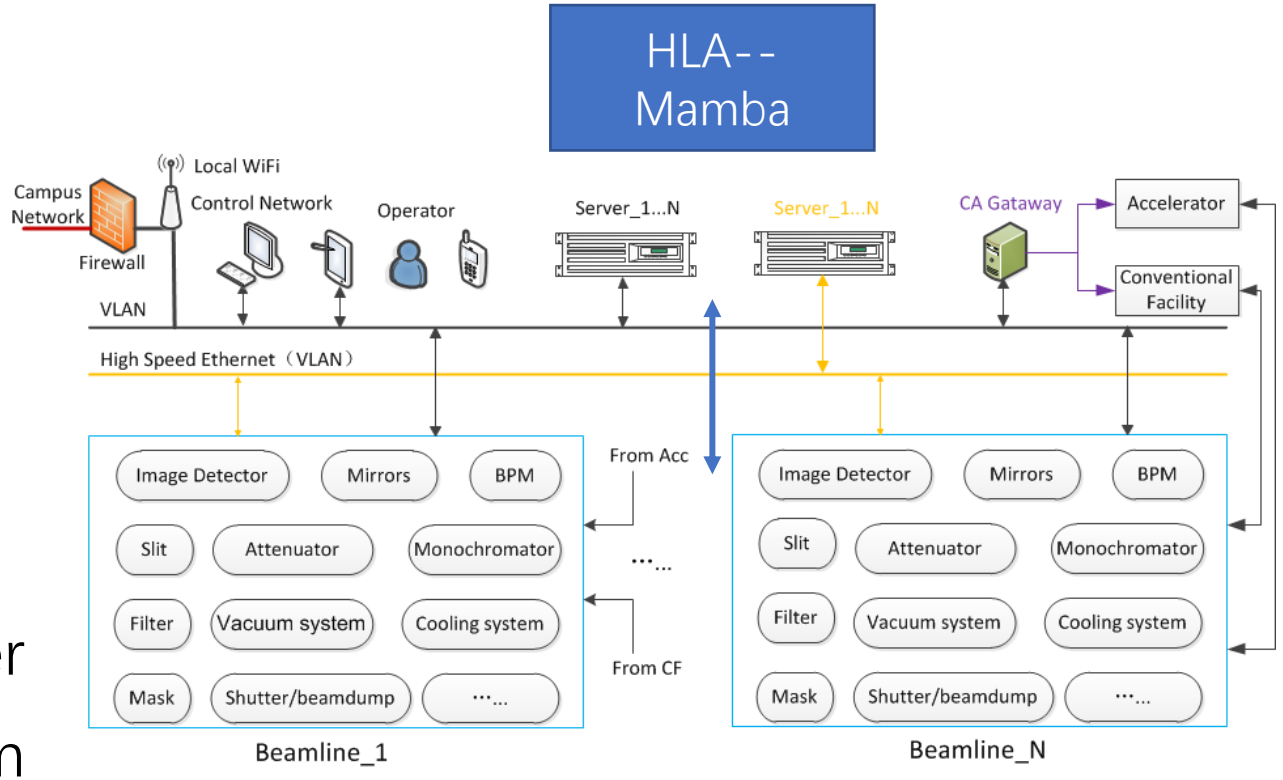


Beamline control system

- Control tasks
  - “14+1”beamlines
  - ➢ Achieve the desired X-ray
  - ➢ Ease the scientist at experimental endstations
  - ➢ Control and monitor all the equipments of beamlines
  - ➢ Detect the position of X-ray beam
  - ➢ Protect the people/equipment from hazard, and send alarm and issue information.
  - ➢ Provide friendly OPIs, robust and efficient communications tools and rich application tools
  - ➢ Archive and retrieve the data of beamline

Beamline control system

- The controlled equipment
  - Mirror and crystal bender
  - Monochromator
  - Beam Position Monitor
  - Image Detector
  - Low current measurement device
  - Slit, Shutter, Mask, Attenuator, Filter
  - Cryo-cooling/water-cooling system
  - Vacuum devices, etc.

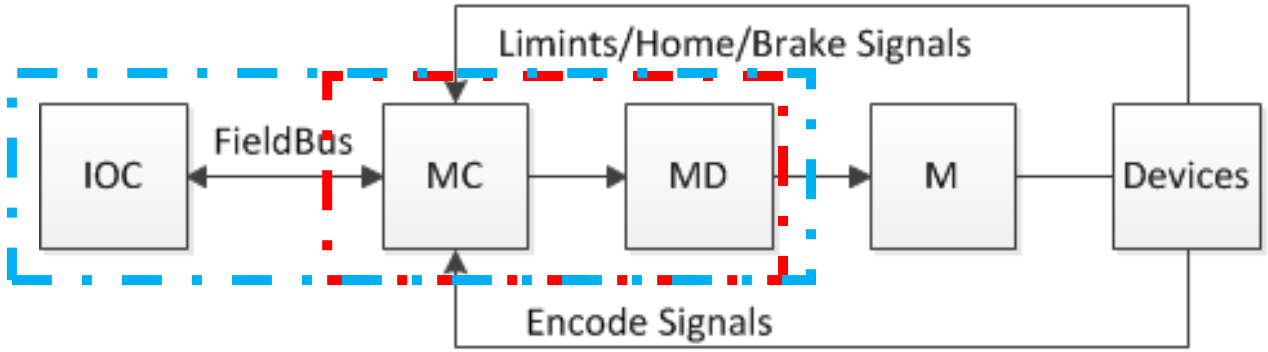


Beamline control system

- Design Principles of the Control System
  - Stability
  - Availability
  - Reliability
  - Flexibility
  - Extendibility
  - Real Time

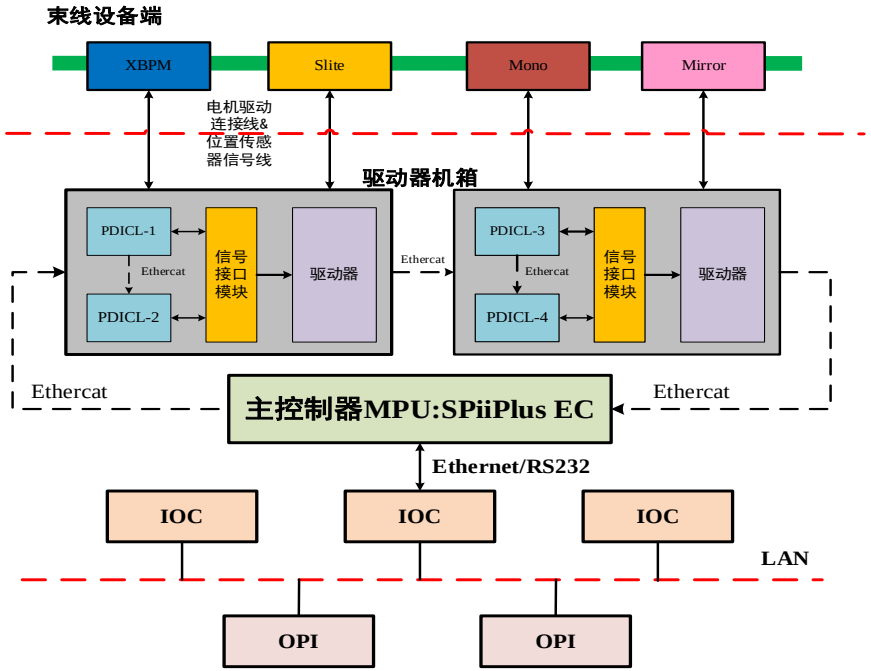
Beamline control system

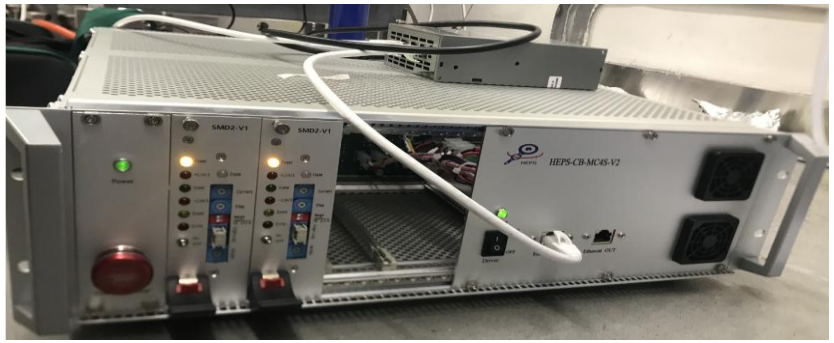
- Motion control system
  - Drive the optical elements (such as mirror, slit, attenuator, monochromator, filter, etc.) to get satisfied X-ray beam.
  - Critical subsystem of the beamline control system
  - Supporting various motor types
    - **step motor**, servo motor, piezo motor and so on



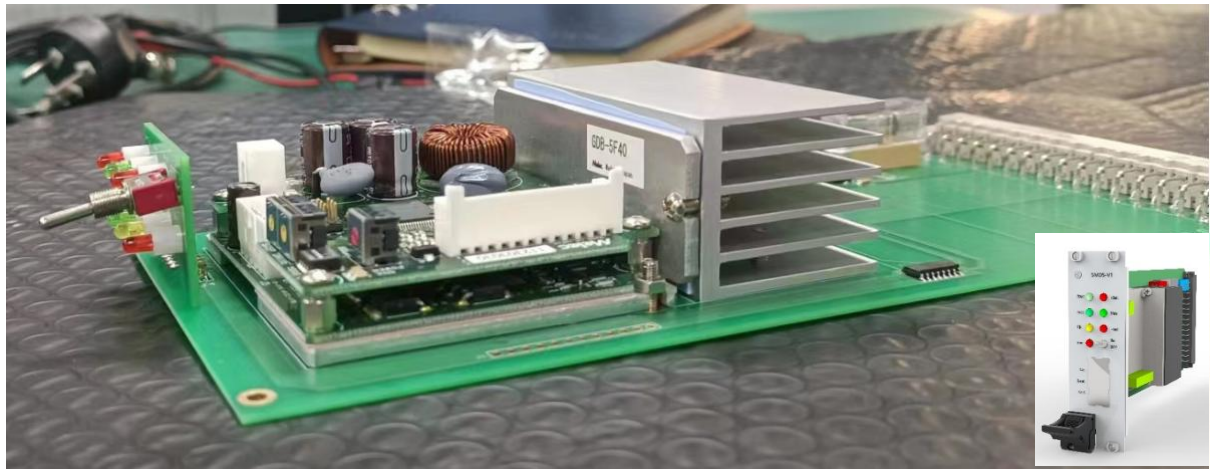
Beamline control system

- Motion control system
  - Self-developed a set of motion control system
  - Drive two-phase and five-phase step motors



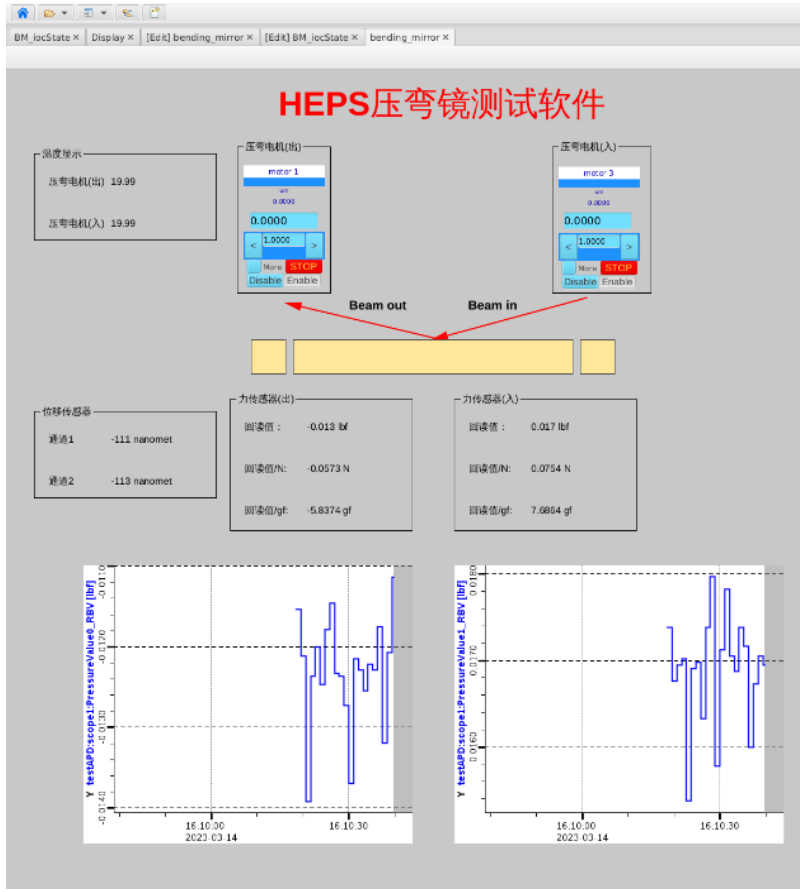


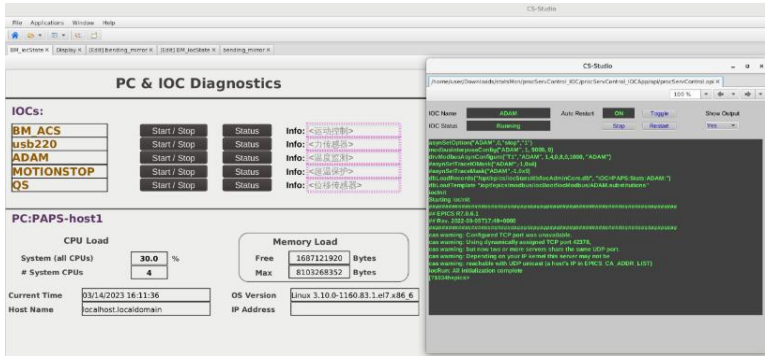
Beamline control system

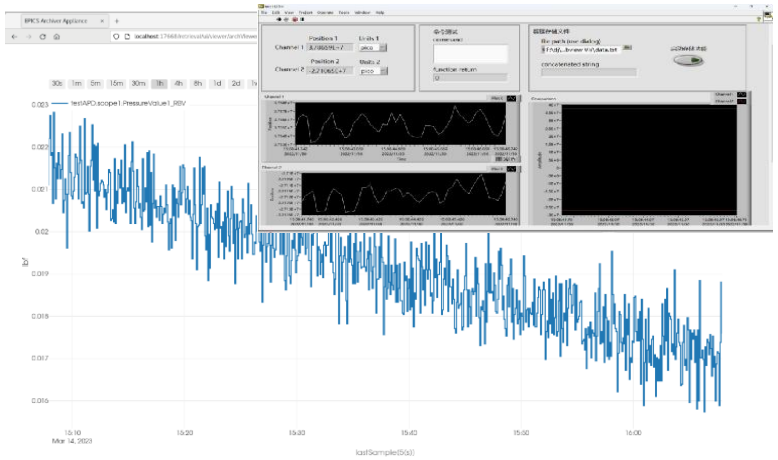


Beamline control system

- Motion control system used at PAPS

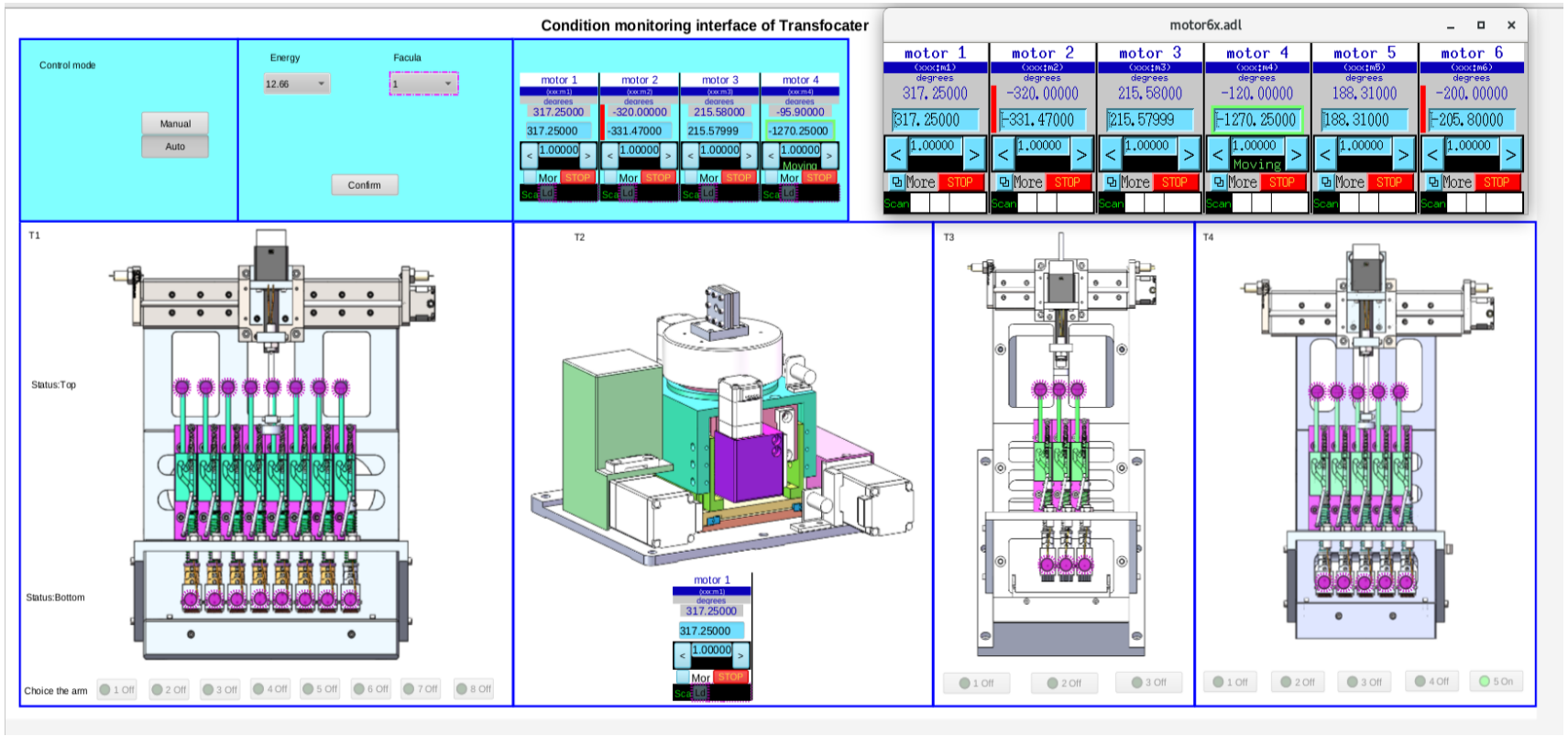


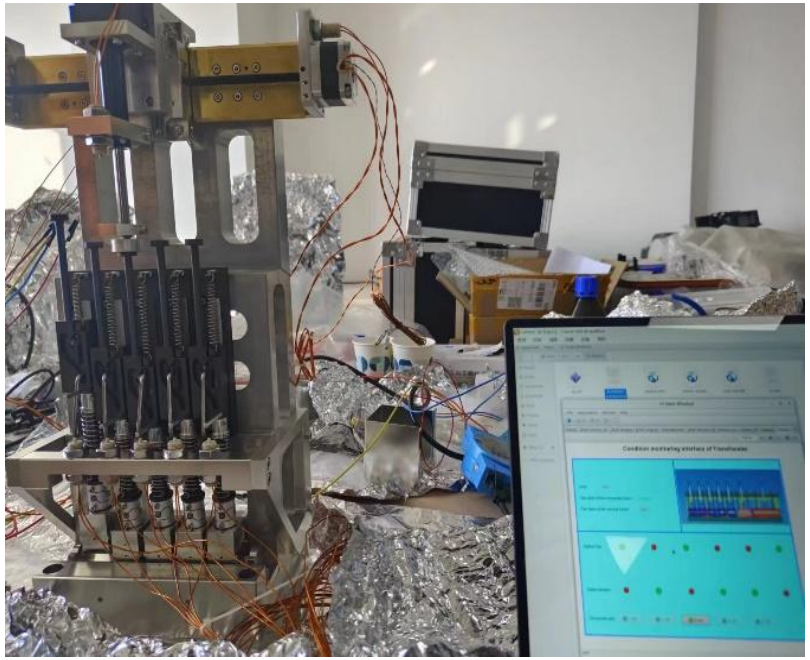




Beamline control system

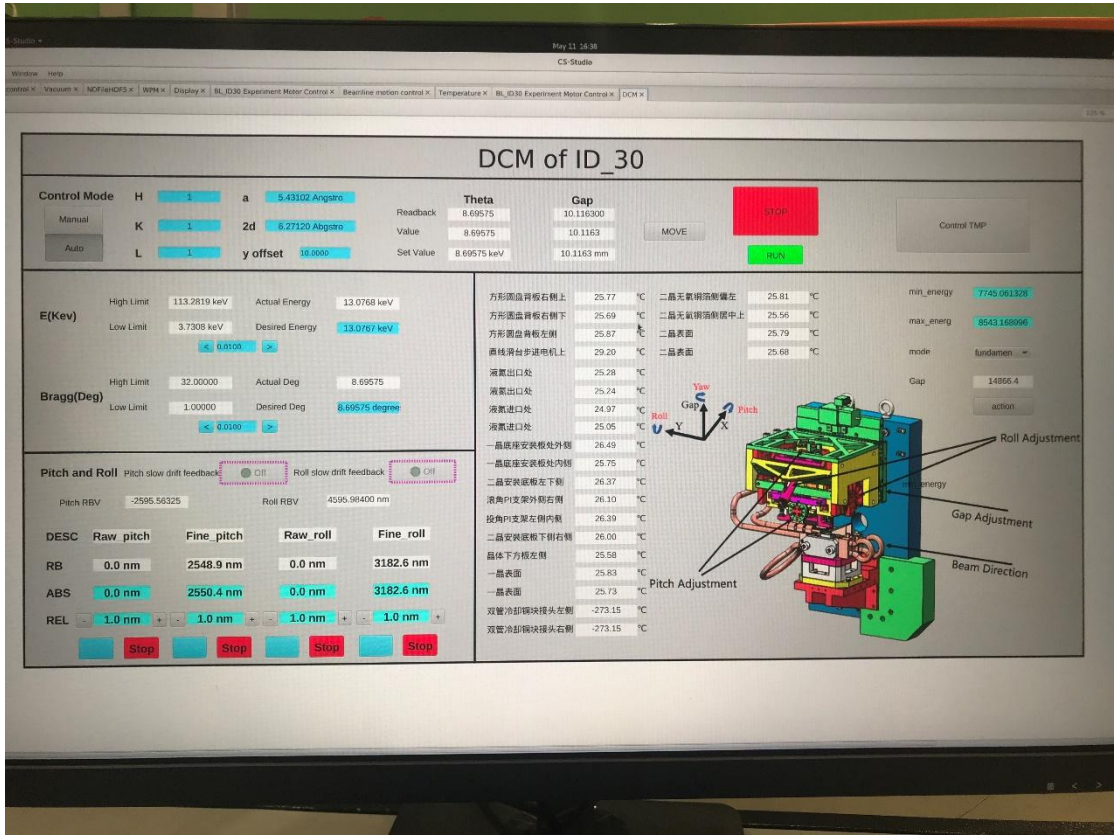
- Transfocator motion control

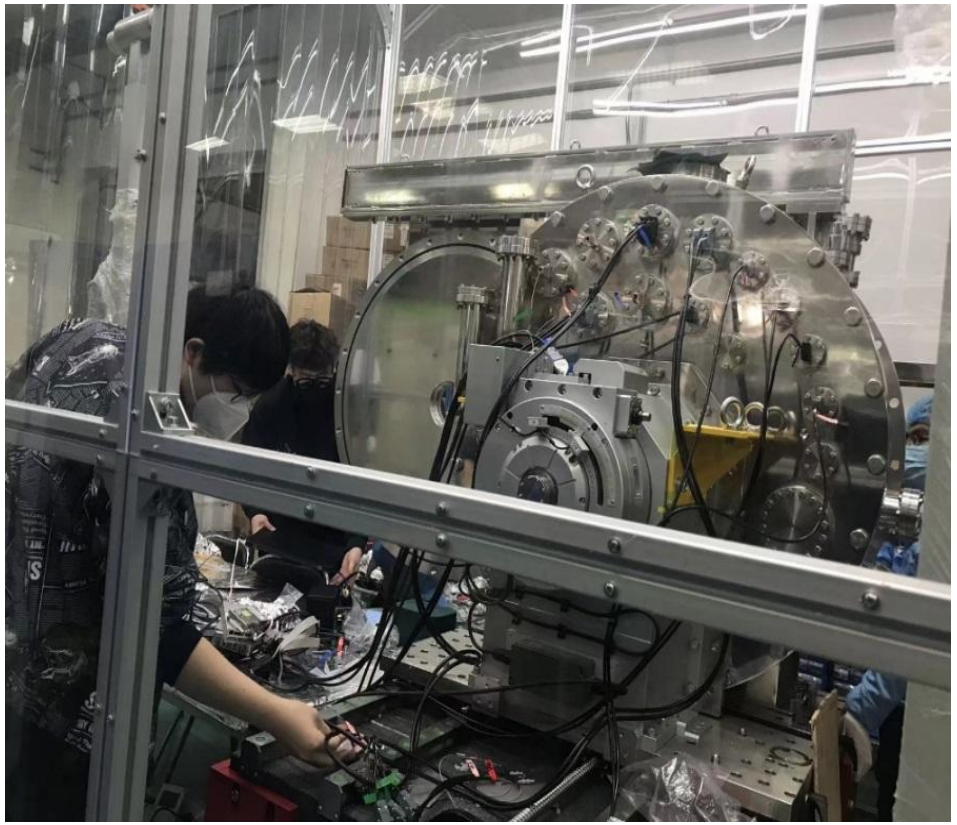




Beamline control system

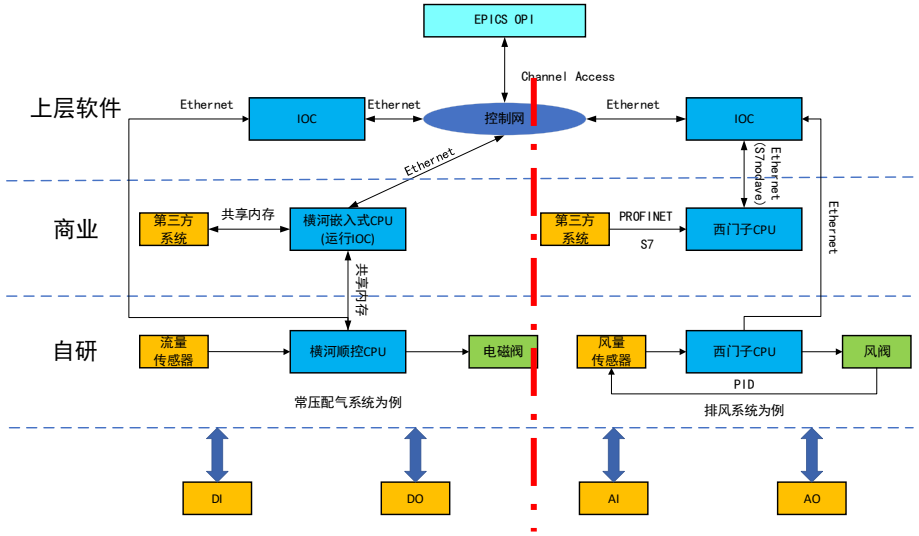
- DCM motion control system



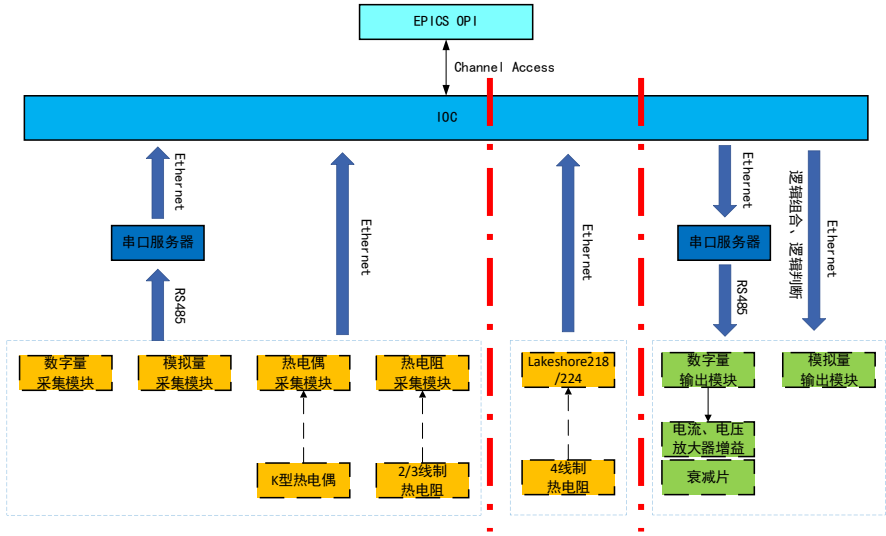


Beamline control system

- Control system based on PLC and intelligent IO module
  - PLC: gas distribution system, hutch exhaust system, etc.
  - Intelligent IO module: temperature, shutter, discrete IO control

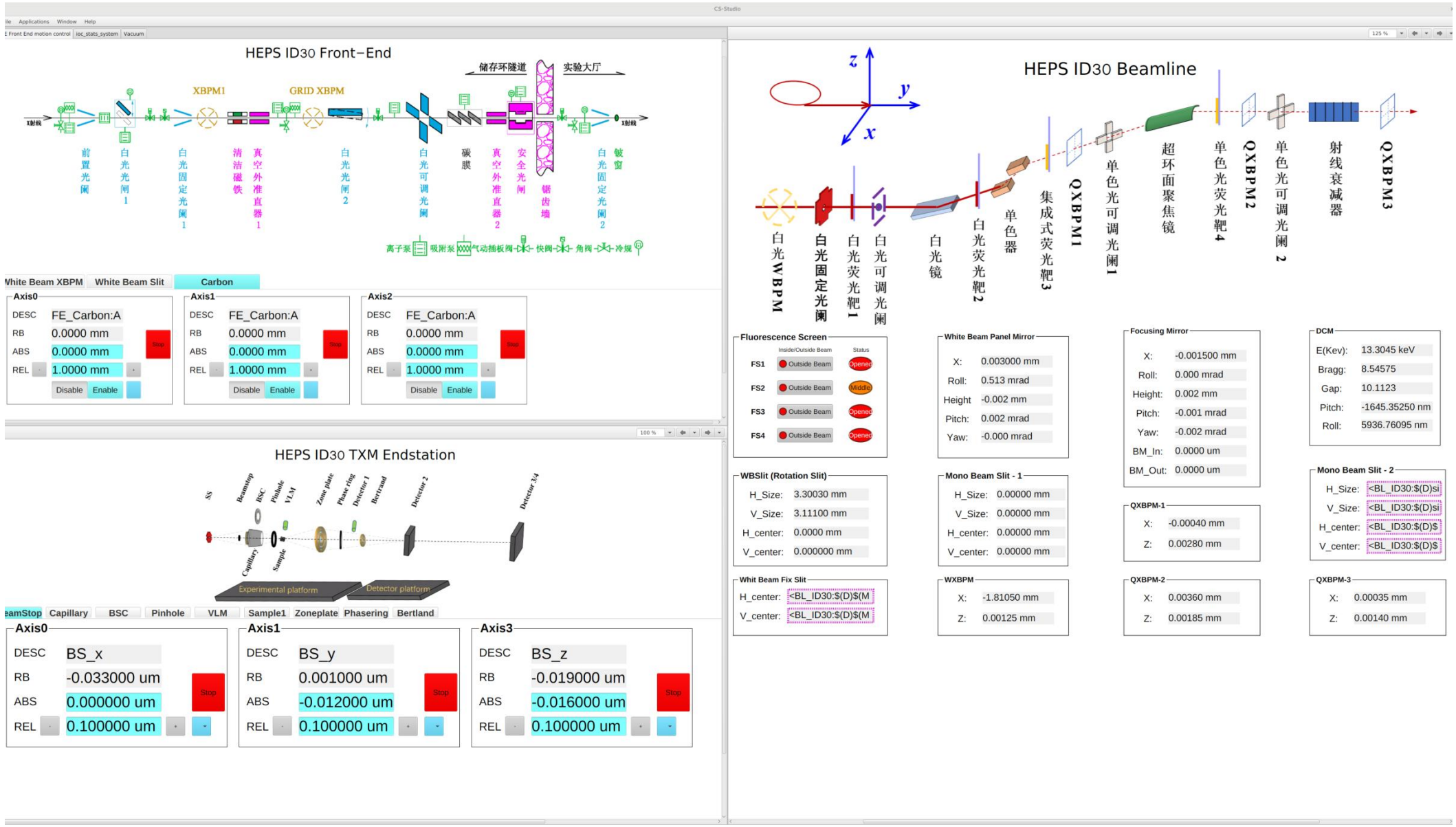


The structure of PLC control system

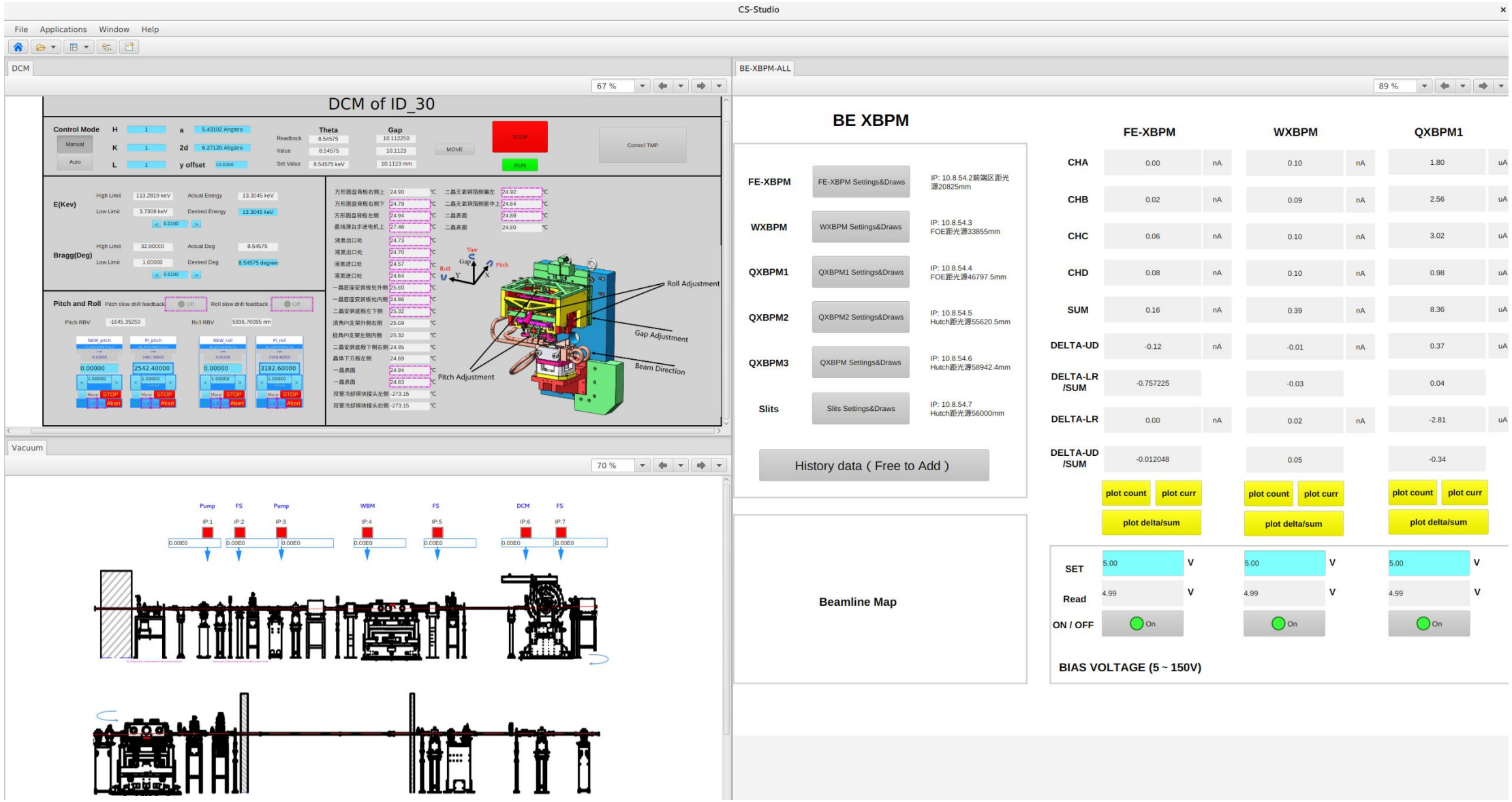


The structure of discrete IO control

BE beamline control system



BE beamline control system

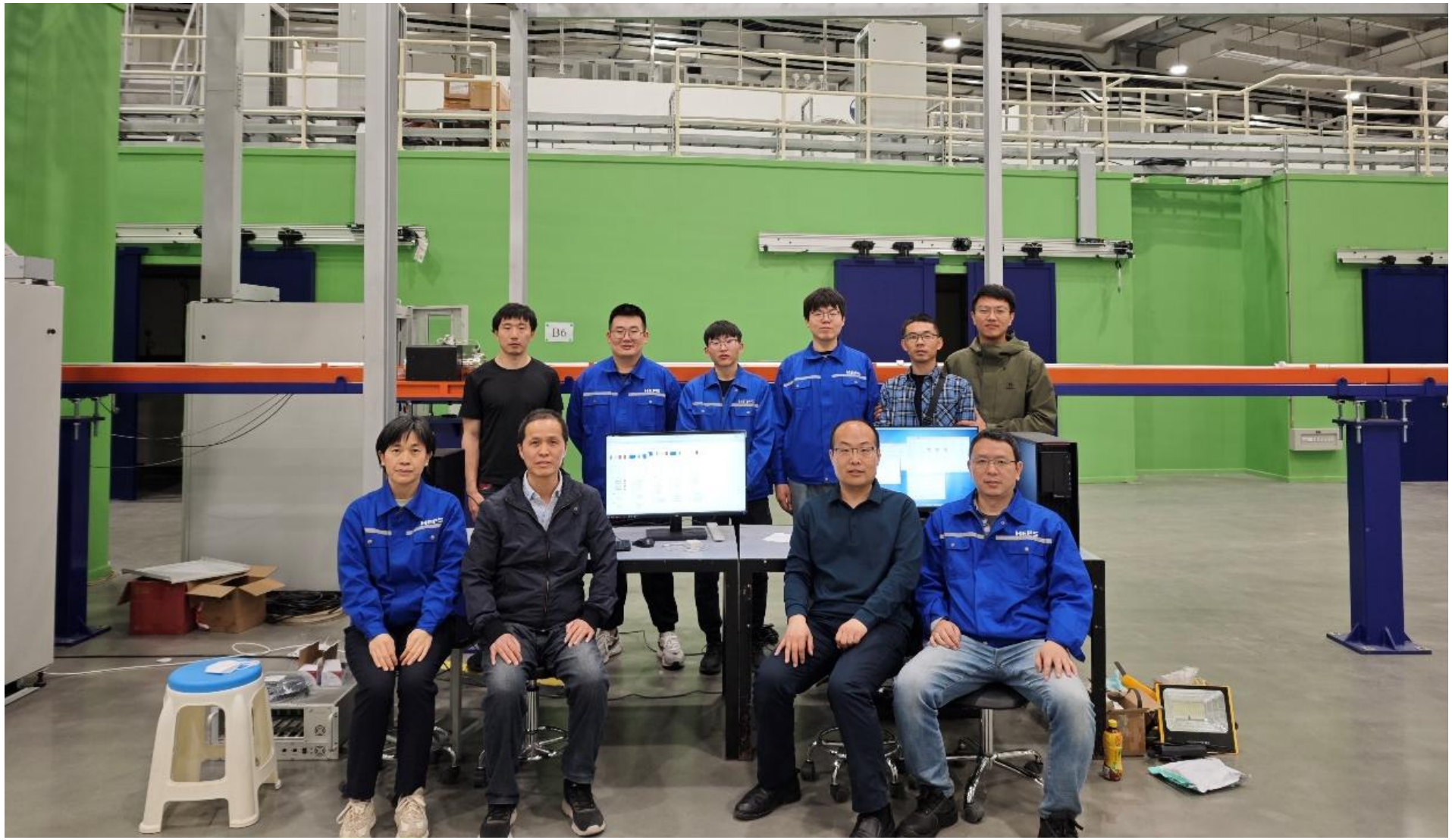


Beamline control system

- 7 beamline control systems have already been delivered
  - BE, BD, B7, B8, BF, BB and B4

	Control subsystem	Mirrors slits	Mono-chromators	Temperature monitoring	FS image	Ion pump data	Weak current acquisition	Devices in experimental area	Exhaust system	3rd party system	Public service	Date of completion	Version upon completion	Notes
	控制子系统	镜箱、狭缝	单色器/Tra	温度监控	荧光靶图像	离子泵数据	弱电流采集	实验区设备	排风系统	第三方系统	公共服务	交付时间	交付版本	备注
	BE	√	√	√	√	√	√	√	√	√	√	2024.05.22	V1.0	4.17, Beta version
	BD	√	√	√	√	√	√	√	√	√	√	2024.09.05	V1.0	Beam dimming, 9.21
	B7	×	×	√	√	√	×	√	√	√	√	2024.10.10	V0.1	Beta, light in experimental area, 10.13
第一批线站	B8	√	√	√	√	√	√	√	√	√	√	2024.10.18	V1.0	10.18 delivered, 10.24 white beam
First batch	BF	√	√	√	√		√	√	√	√	√	2024.10.25	V1.0	10.27 FS with adjustable focus
beamlines	BB	√	√	√	√	√	√	√	√	√	√	2024.12.04	V1.0	
	BA													
	B1													
	B2													
	B3													
第二批线站	B4	√	√	√	√	√	√	√	√	√	√	2024.12.19	V1.0	交付前端区和FOE，供光学系统
Second batch beamlines	B5													
	B6													
	B9													
	BC													

Control Team



Thanks for your attention!