



中国科学院高能物理研究所

Institute of High Energy Physics, Chinese Academy of Sciences

The Design and Progress of the Network and Computing System for HEPS

**Hao Hu, on behalf of HEPSCC
IHEP CC/HEPS CC
Institute of High Energy Physics, CAS**

Nov 8, 2023

1. About HEPS & HEPS CC
2. Challenge and Missions for HEPSCC
3. System Design and Progress
4. Summary & Plan

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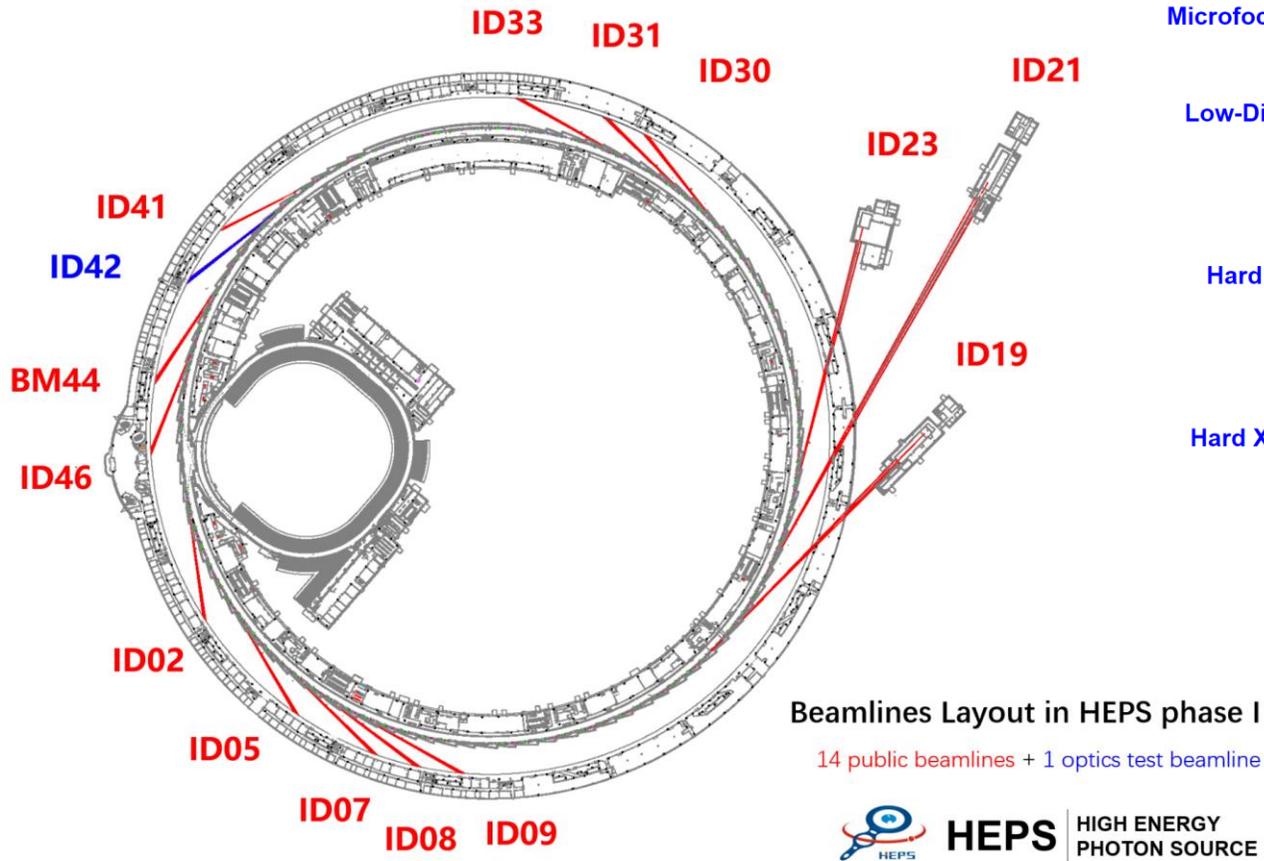
High Energy Photon Source (HEPS)

- The fourth generation light source in China — High energy, high brightness
- Located in Beijing - about 80KM from IHEP
- Officially approved in Dec. 2017, started in 2018
- The whole project will be finished in mid-2025
- The construction of the civil structure is completed

Main parameters	Unit	Value
Beam energy	GeV	6
Circumference	m	1360.4
Emittance	pm·rad	< 60
Brightness	phs/s/mm ² /mrad ² /0.1%BW	>1x10 ²²
Beam current	mA	200
Injection		Top-up



HEPS Beamlines in phase I



Microfocusing X-Ray Protein Crystallography-ID02 Beamline

Low-Dimensional Structure Probe Beamline-ID05

Engineering Materials Beamline-ID07

Hard X-Ray Coherent Scattering Beamline-ID09

Pink Beam SAXS Beamline-ID08

Hard X-Ray Nanoprobe Multimodal Imaging-ID19 Beamline

Hard X-Ray Imaging Beamline-ID21

Structural Dynamics Beamline-ID23

ID30-Transmission X-Ray Microscopic Beamline

ID31-High Pressure Beamline

ID33-Hard X-Ray High Resolution Spectroscopy Beamline

BM44-Tender X-Ray Beamline

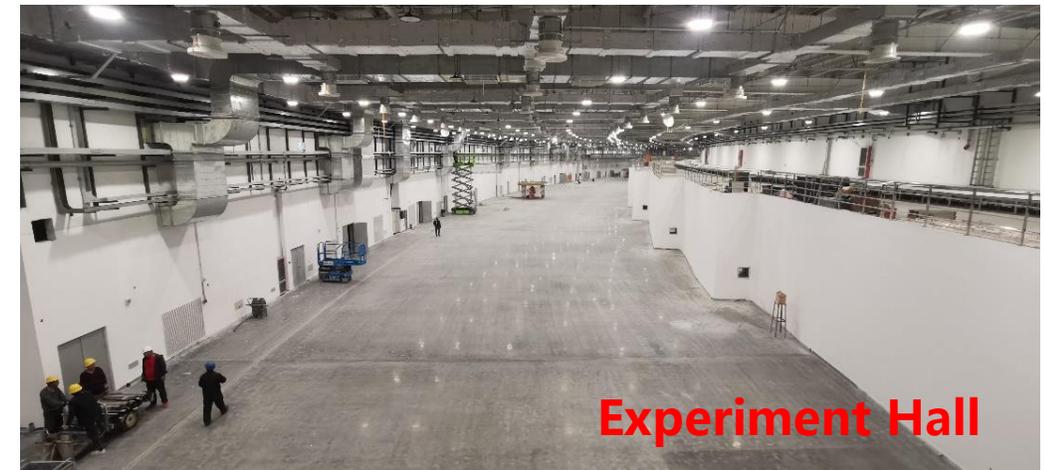
ID41-High Resolution Nanoscale Electronic Structure Spectroscopy Beamline

ID42-Optics Test Beamline

ID46-X-Ray Absorption Spectroscopy Beamline

14 public beamlines + 1 optics test beamline in Phase I

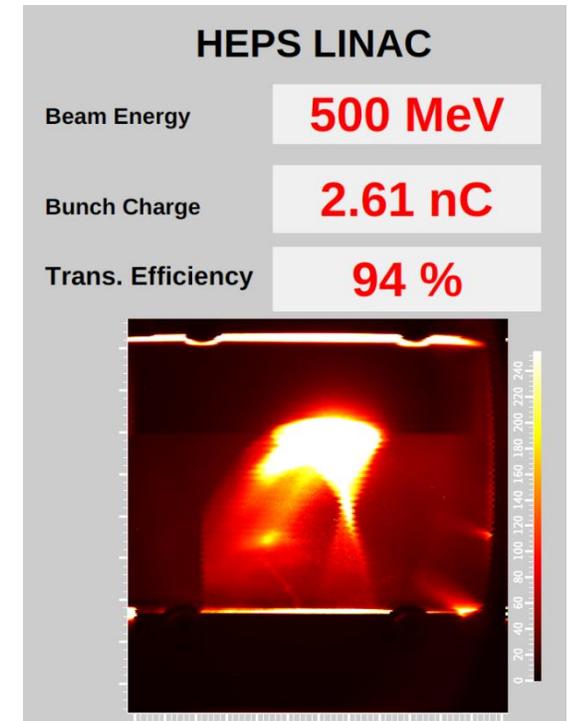
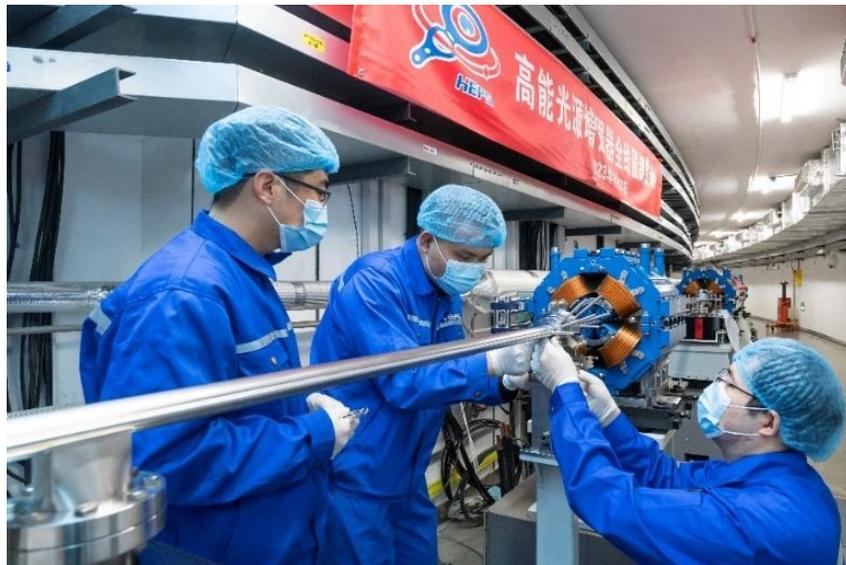
Can accommodate over 90 beamlines in total



Progress of the HEPS project



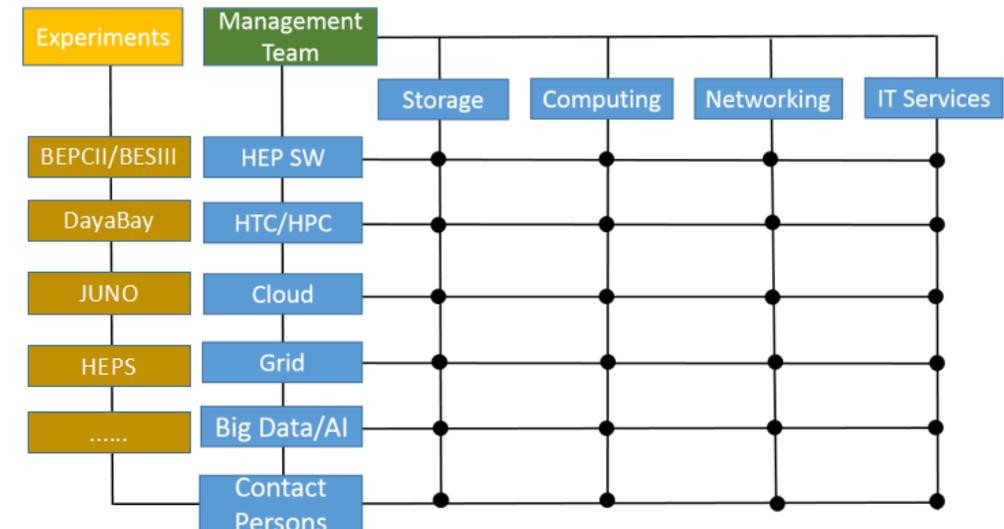
- Now at the stage of equipment installation
- 2023.01, HEPS booster installation completed
- 2023.02, Start installation of storage ring
- 2023.03, HEPS achieved the first electron beam accelerated to 500 MeV
- First batch of beamlines began to install and debug equipment



HEPS CC: the Computing & Communication System for HEPS



- **30+ members**
 - Matrix management, share the talents and knowledge with other experiments
 - Most of the members are coming from IHEP Computing Center (IHEP CC)
 - 3 from CSNS/Computing and Software group, 1 from Beamline
- **7 work groups**
 - Infrastructure , Network, Computing & Storage
 - Scientific Software, Database & Public Service , Monitoring, Security

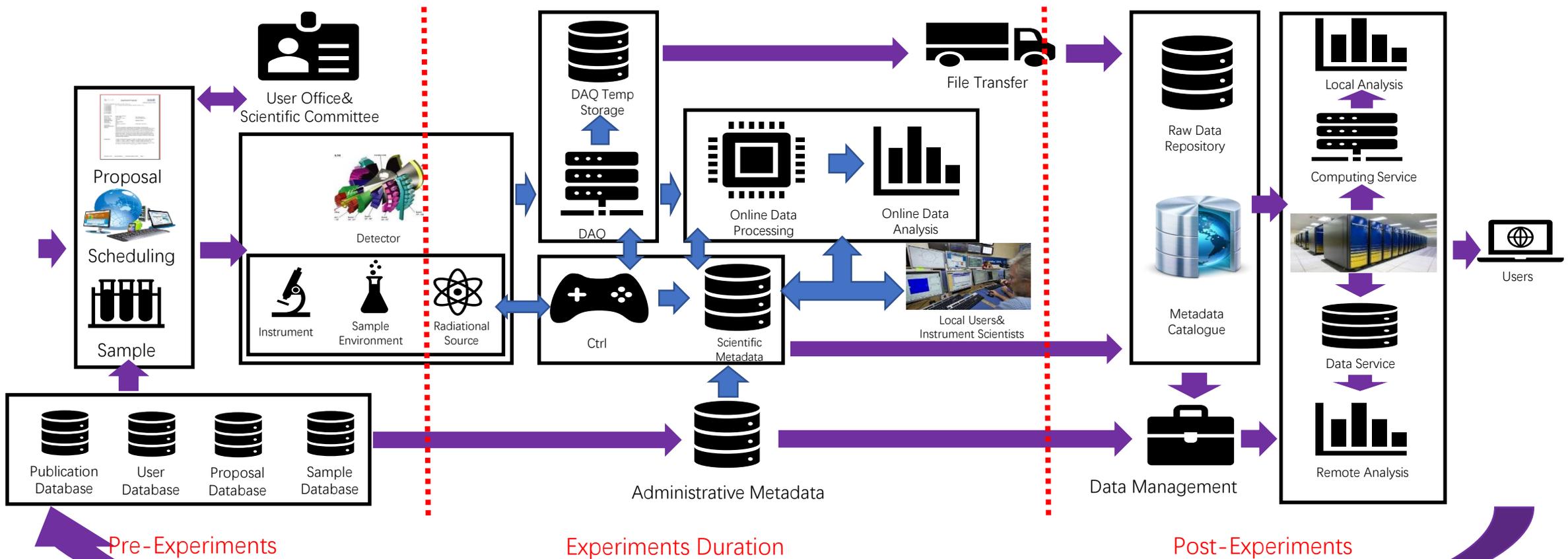


Outline



1. About HEPS & HEPS CC
2. Challenge and Missions for HEPSCC
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IT services for Beamline experiments



IT services are needed during the whole life-cycle of the Beamline experiments

HEPS CC Missions



■ Provision of scientific data and user services for HEPS

- Infrastructure
 - Network
 - Computing
 - Storage
 - Data Management
 - Scientific Software
 - Public Software and Services
- ## ■ Research on open IT technologies related to HEPS



Data Challenges



- ❑ Increased source brightness, X-ray detector capabilities have been continuously improving
- ❑ **More than 24PB raw data will produced per month**

Beamlines	Burst output(Byte/day)	Average output(Byte/day)
B1 Engineering Materials Beamline	600TB	200TB
B2 Hard X-ray Multi-analytical Nanoprobe (HXMAN) Beamline	500TB	200TB
B3 Structural Dynamics Beamline (SDB)	8TB	3TB
B4 Hard X-ray Coherent Scattering Beamline	10TB	3TB
B5 Hard X-ray High Energy Resolution Spectroscopy Beamline	10TB	1TB
B6 High Pressure Beamline	2TB	1TB
B7 Hard X-Ray Imaging Beamline	1000TB	250TB
B8 X-ray Absorption Spectroscopy Beamline	80TB	10TB
B9 Low-Dimension Structure Probe (LODISP) Beamline	20TB	5TB
BA Biological Macromolecule Microfocus Beamline	35TB	10TB
BB pink SAXS	400TB	50TB
BC High Res. Nanoscale Electronic Structure Spectroscopy Beamline	1TB	0.2TB
BD Tender X-ray beamline	10TB	1TB
BE Transmission X-ray Microscope Beamline	25TB	11.2TB
BF Test beamline	1000TB	60TB
Total average:		805.4TB/day, 24.16PB/month

Estimated data volume of HEPS at Phase I

Huge amount of data is a big challenge for data management and processing

Challenges for HEPSCC



■ Large volume of Data

- High I/O throughput and speed: read(max: 6.94GB/s) & write speed(max:15GB/s)
- Hierarchical storage: **Beamline Disk**→ **Central Disk**→ **Tape**
- High capability: **Long-term data preservation**

■ Big Data Management

- Metadata Catalogue
- The organization and retrieval of data

■ Fast Data Analysis

- Online / real-time analysis and fast feedback
- Offline / Data Reconstruction, Analysis ...
- Capability / **The more the better / At least meet the requirements for beamlines**

■ Scientific software

- Scientific Software Framework
- Layered and modularized software platform for data processing
- Build a self-sustaining software ecosystem

■ Public & Data Service

- User management and authentication
- Experiment process management / services
- User interface for experiments, data access/sharing and analysis

1. About HEPS & HEPS CC
2. Challenge and Missions for HEPSCC
3. **System Design and Progress**
4. The Overall Progress
5. Summary & Plan

Machine Room



- About **800m²**: Main Room(520m²), UPS Room, Tape library
- 47 cabinets, reserve space for future expansion
- Electric power
 - Total capacity is **2,500KVA**
 - UPS capacity is 800KVA, 1/2 hour backup
 - 15kW/cabinet for storage, 30kW/cabinet for computing
 - Provide dual power supply
- Use Row-Air conditioning with natural cooling
- Progress
 - Micromodule、Electric power and Refrigeration system have been completed
 - Provide the operation environment for IT equipment

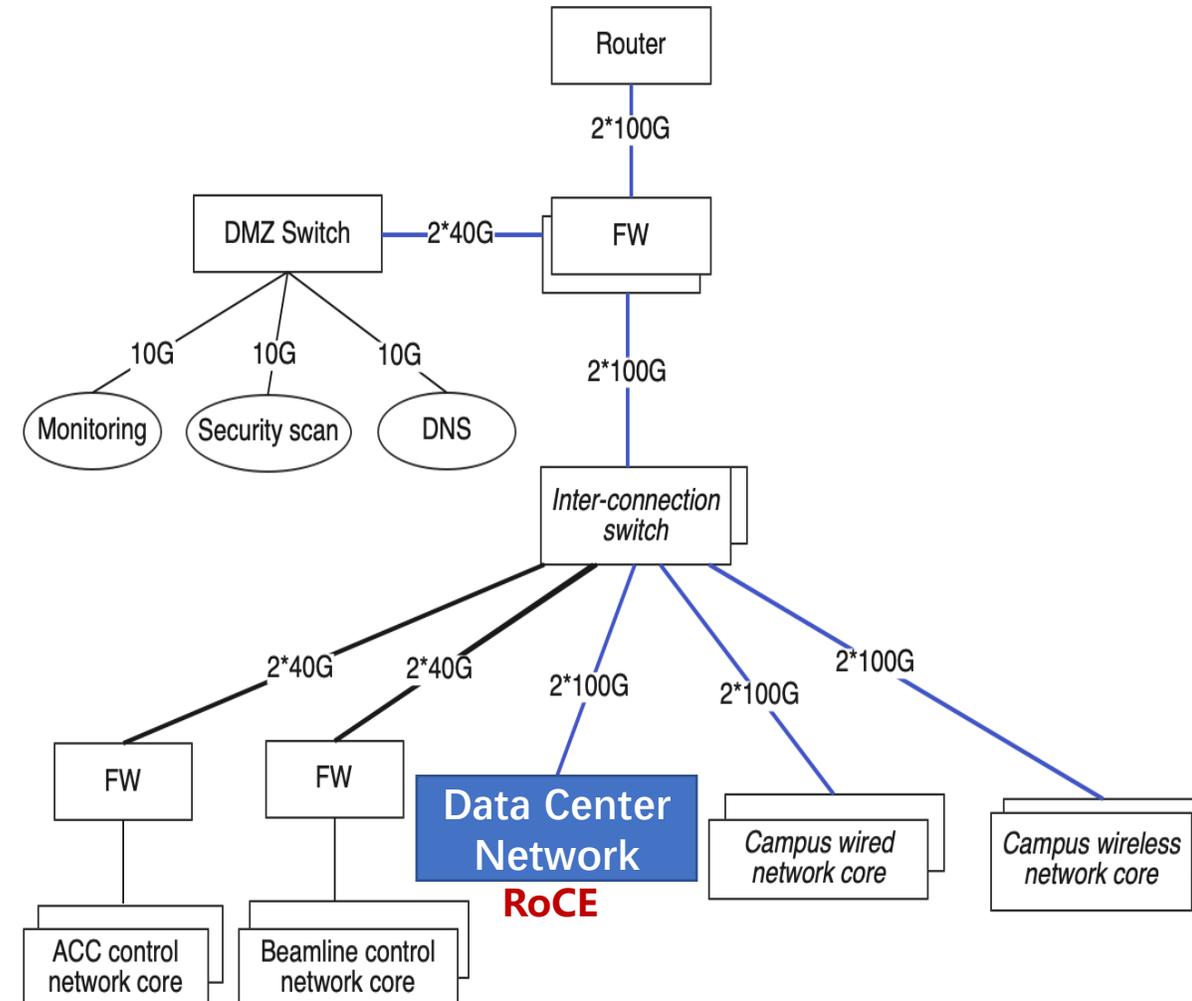


Network



Extensible and high performance network infrastructure

- Core network bandwidth: **200Gbps**
- Data center bandwidth: **200Gbps**
- Both campus wired network and wireless network are followed the same management rules in IHEP
- **RoCE**(RDMA over Converge Ethernet) is supported to provide high performance and lossless network for data center
- Firewalls are used to provide secure environments for both Accelerator Control Network and Beamline Control Network
- Core network and data center network are almost ready at HEP5 Campus



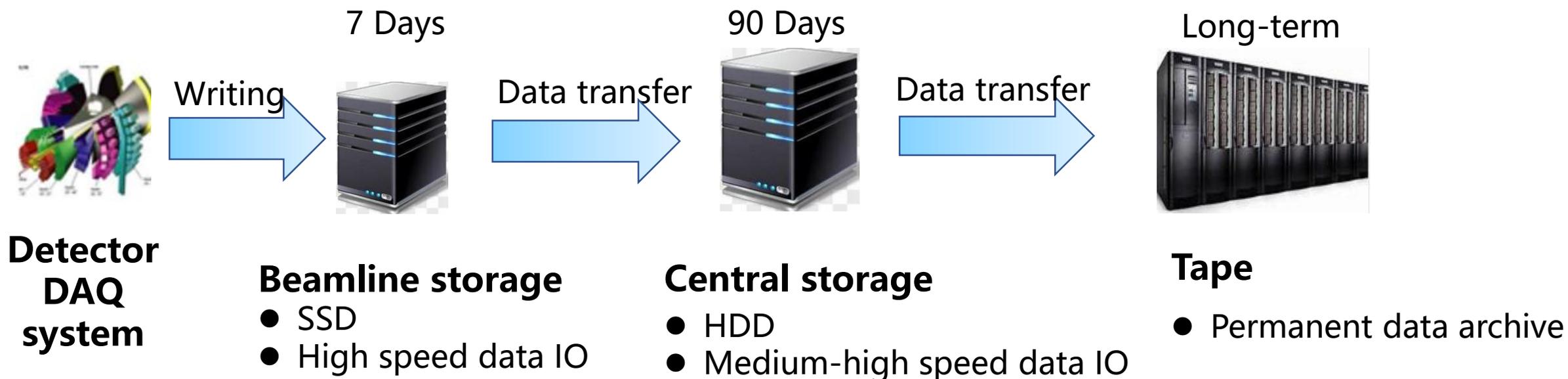
Storage policy for scientific data



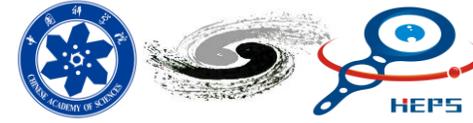
HEPS uses 3-tiered storage architecture

- ① Raw data/processed data are kept on beamline storage for a maximum of **7 days**
- ② Raw data/processed data are kept on central storage for a maximum of **90 days**
- ③ Raw data are archived to the tape for Long-term storage, although No budget for tape

Data storage policy will be adjusted according to the actual data volume and funding situation



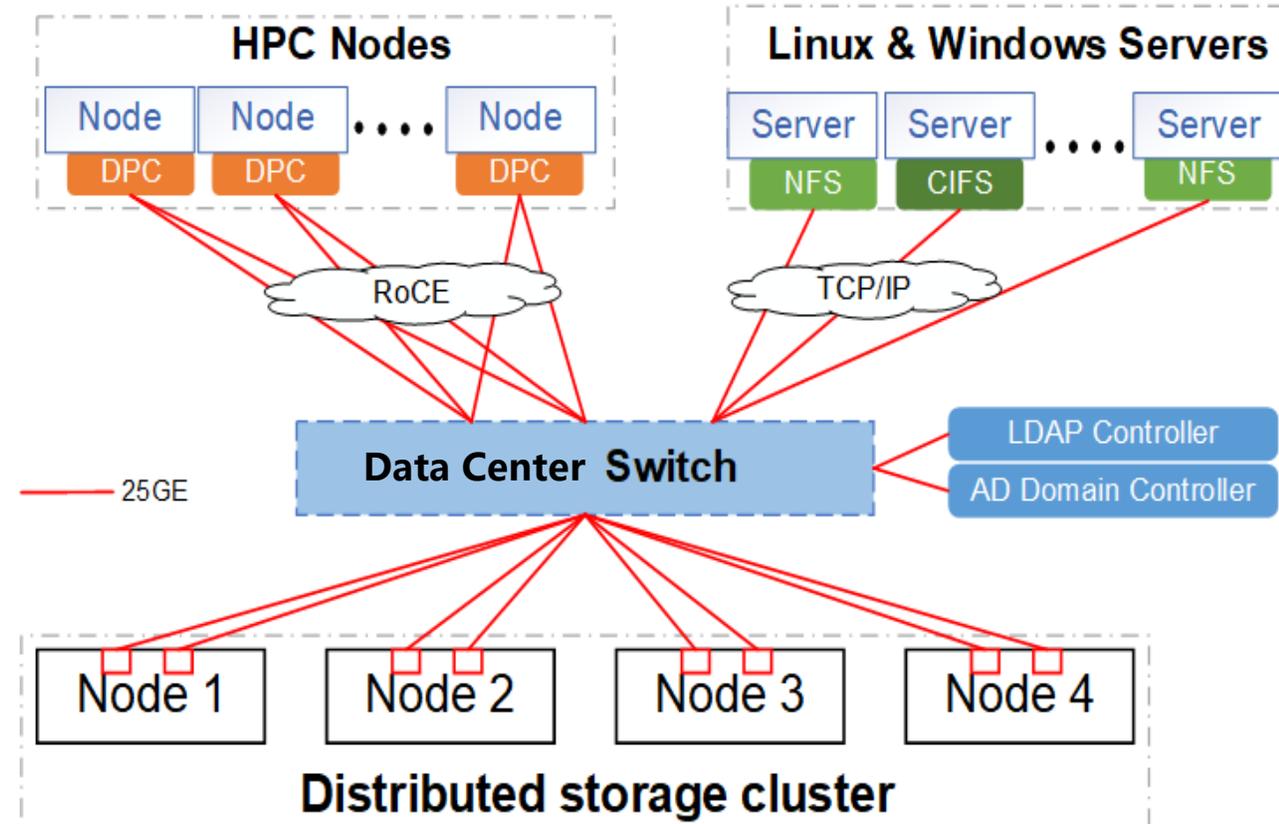
Storage



- **Beamline storage**, **capacity: 800TB**, distributed all-flash SSD arrays
Huawei OceanStor 9950, 100 TB (currently available), read 60GB/s, write 40GB/s
- **Central storage**, **capacity: 30PB**, distributed high-density storage
Huawei OceanStor 9550, 2.4 PB (currently available), read 16GB/s, write 12GB/s
- **Tape storage**: Compliant with the LTO9 standard
THE TLi6000, 2 drives and 2 PB tapes

Features

- **Data center network: 200Gbps**
- **DPC Private Client**
 - A single client can connect to multiple storage nodes
 - Support POSIX and MPI-IO for HPC
 - Use RDMA(RoCE)
- **User Permission, mapping local AD domain with LDAP@IHEP**



Computing

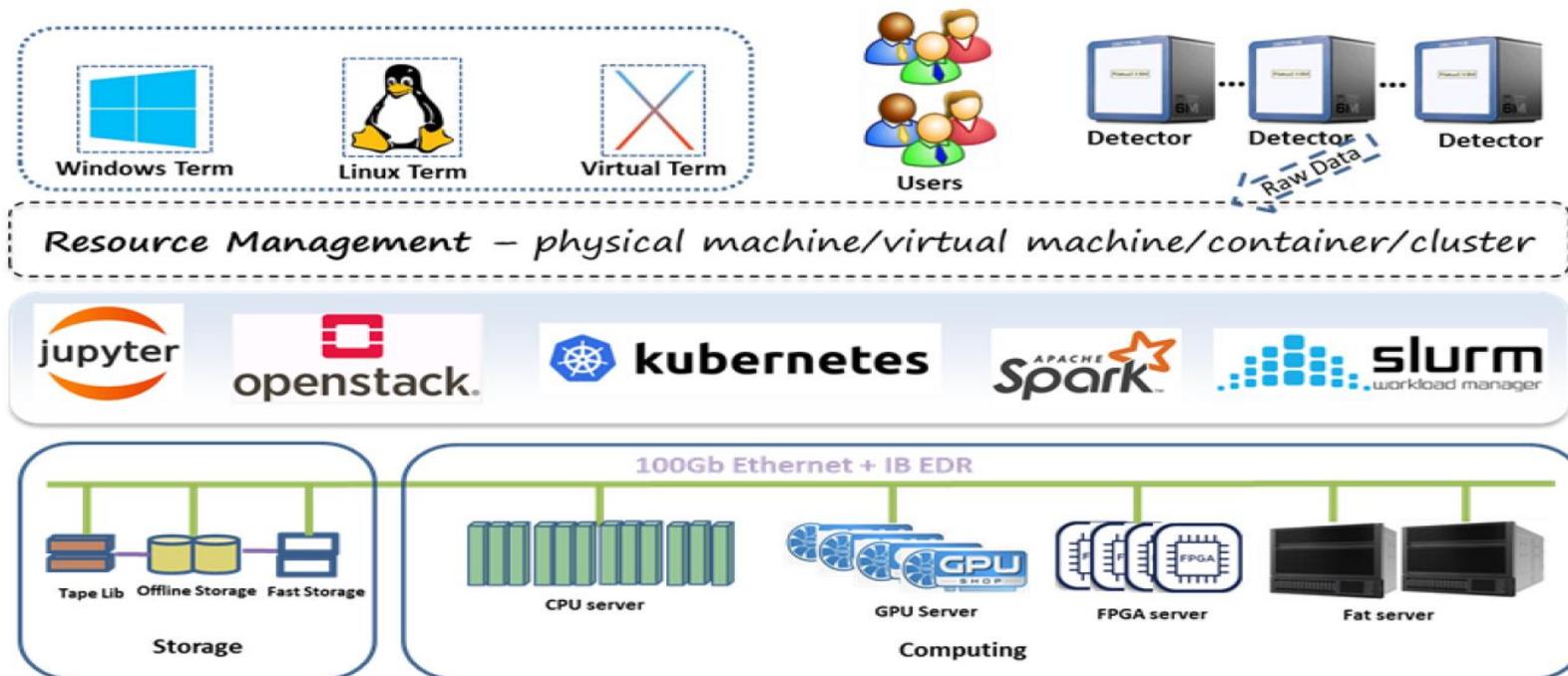


- **Computing Resources**

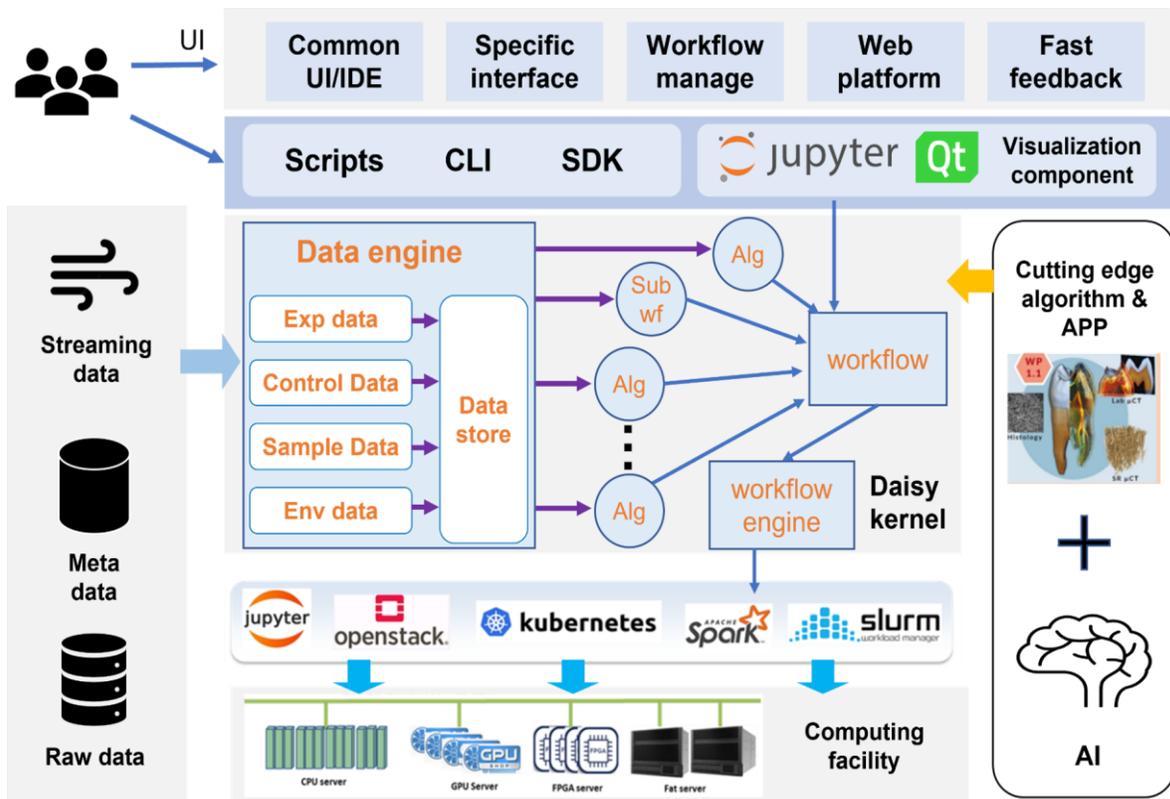
- First stage, 2400 CPU cores ≥ 120 TFLOPS , 30 GPU cards ≥ 360 TFLOPS
- **Far from enough, need more funding support**

- **Unified resource management and scheduling**

- scalable architecture, provide computing resources with necessary software and services
- Resource pool: heterogeneous resources(CPU, GPU, DCU...), image repositories, software and so on
- Resource management middleware: K8S, Slurm, Openstack...
- HPC cluster, real-time data processing farm, cloud-based analysis and web-based analysis



Data analysis software(1)

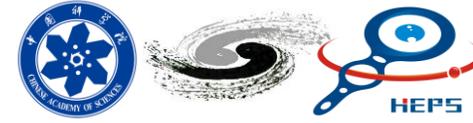


Daisy framework

Data Analysis Integrated Software sYstem(Daisy)

- Basic, common, scalable framework
 - Data engine for high-throughput, multimodal, and multi-source data access
 - Computing engine for low latency data processing with different scales, throughputs via heterogeneous computing power
 - Interface and developing environment for scientific software development
- To establish a software ecosystem for data processing and analyzing for big science
- The basic framework of Daisy has been released
<https://daisy.ihep.ac.cn/>

Data analysis software(2)

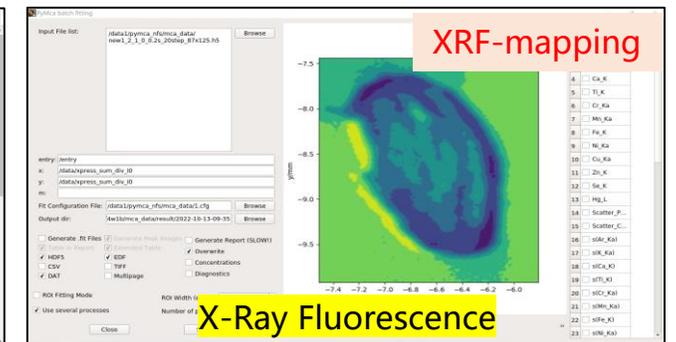
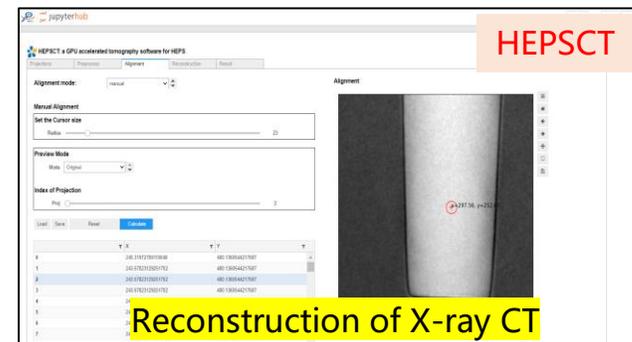
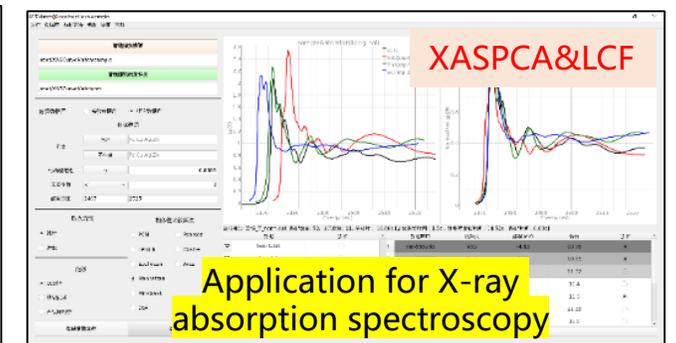
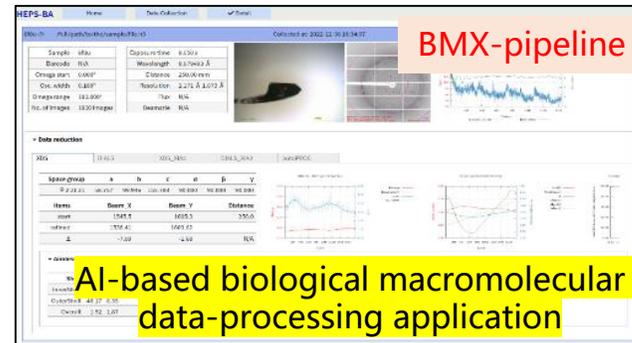
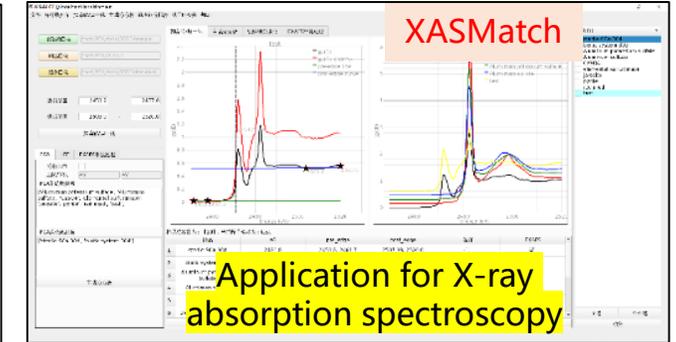
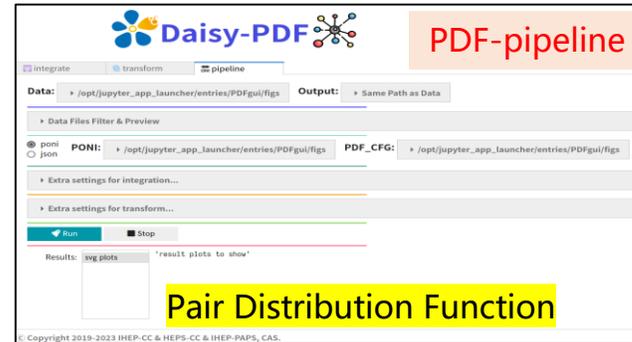


Scientific software

- More than 30 scientific algorithms and tools have been integrated or developed
- PDF, Daisy-BMX, XASMatch, XASPCA&LCF, HEPST, XRF-mapping...

Scientific data processing service

- Automatic pipelines from raw data to get the predicted structure
- Remote large volume data access
- Applied to other scientific area, such as space science



Released scientific software in Daisy

Data management



■ Data Policy for HEPS

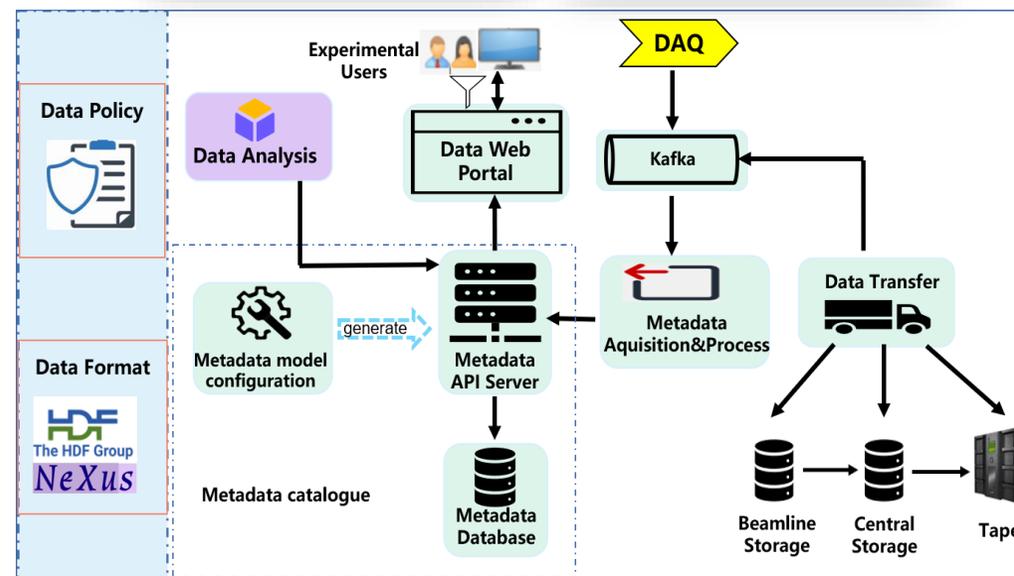
- The ownership, curation, archiving and access to scientific data and metadata

■ Data management software, DOMAS

- Metadata catalogue
- metadata acquisition
- data transfer
- data service
- Track and manage data throughout its entire lifecycle

■ Data format

- Use HDF5 data format, follow the Nexus conventions
- Design HDF5 data format for beamlines
- Promote the standardization of the data format
 - Spectroscopy, imaging, diffraction scattering



User web portal

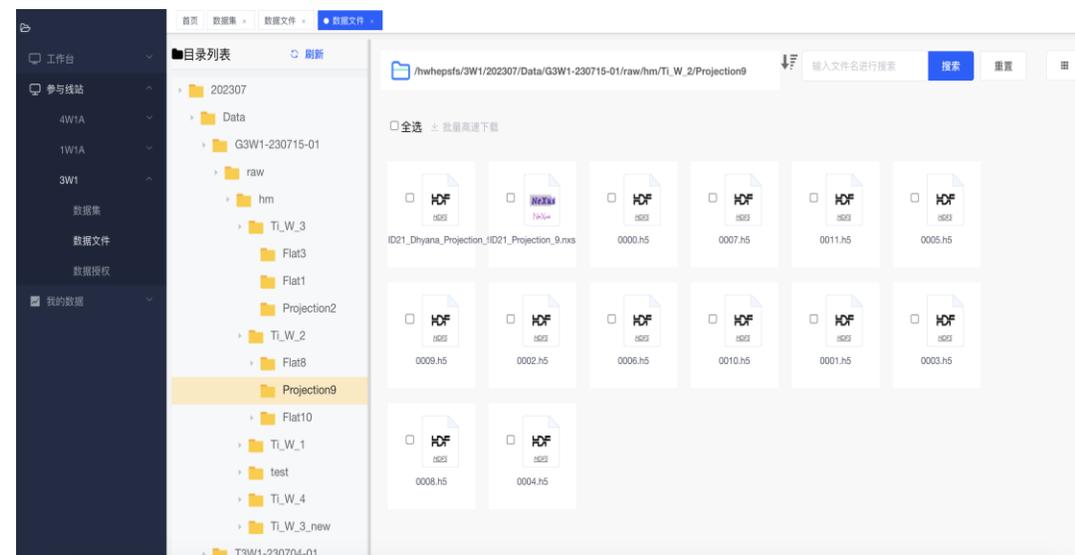
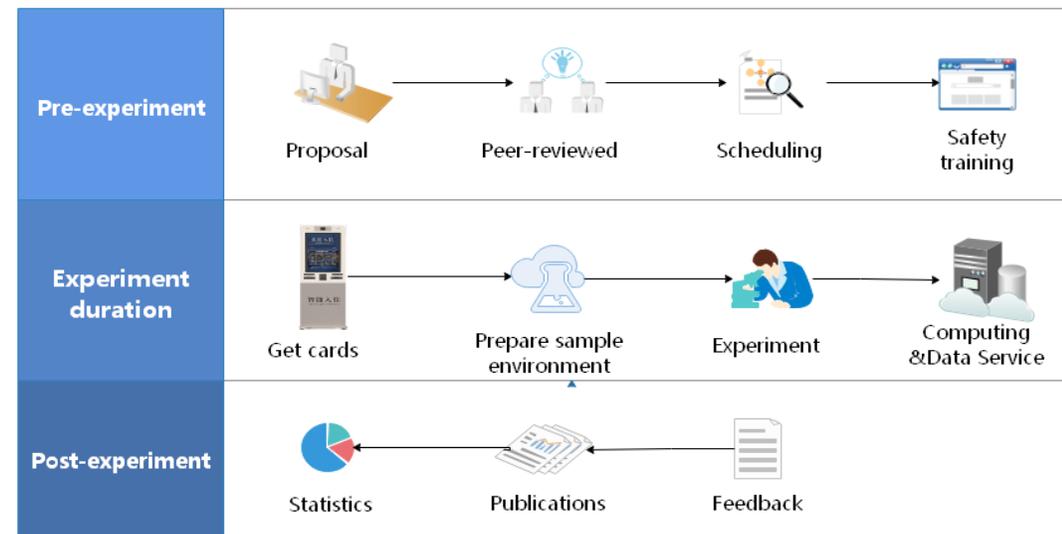


■ User service

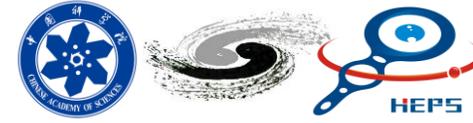
- Provide services for the entire process of user experiment
- Proposal submission, safety training, beam time allocation, experiment management, visiting services and data services...
- Roles: users, beamline administrators, user office, experts...
- User Authentication: Single-Sign-On account

■ Data service

- Data search, download, access, analysis
- HDF5 web viewer, client for downloading
- Provide data analysis service via virtual cloud desktop and JupyterLab



HEPS CC System Integration/Test bed/Production



Set up testbed at BSRF to integrate software systems to verify interfaces and process.

HEPS CC system has been tested in the real experimental environment, moved to production gradually.

1

Oct, 2020, BSRF 1W1A

Simple verification of the data management system

- Network bandwidth is 1Gb/s
- Beamline storage: **2TB** NAS, Dell EMC NX3240, NFS file system
- Central storage: **80TB** disk array, Lustre file system
- Metadata ingest, catalogue, data transfer, data service

2

July, 2021, BSRF-3W1 test beamline

- Network bandwidth updated to 10Gb/s
- Beamline storage & Central storage: **80TB** disk array, Lustre file system
- Integrate **MAMBA, DMS, Daisy**, computing system

3

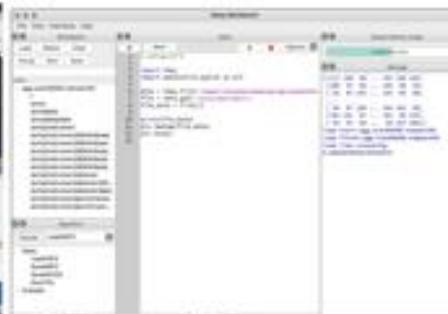
2022-2023, BSRF 4W1B/1W1A/4W1A

Running in production environment

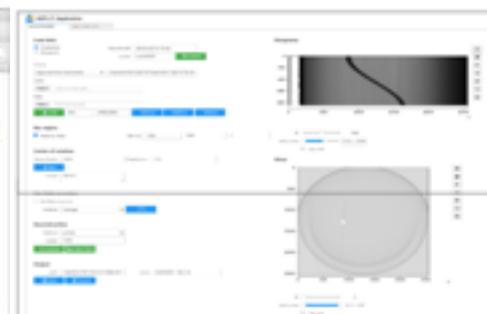
- Network bandwidth updated to 25Gb/s
- Beamline storage: Huawei Ocean Store 9950
- Central storage: 80TB disk array, Lustre file system
- **Follow real experiment process, provide Pymca to do analyzing at 4W1B**



Data acquisition



Analysis framework Interface

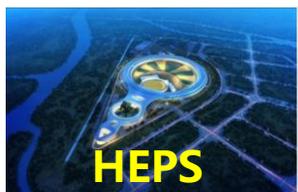


CT reconstruction



Integration test at BSRF

Photon/Neutron Source Facility Alliance for data and software



HEPS



SSRF



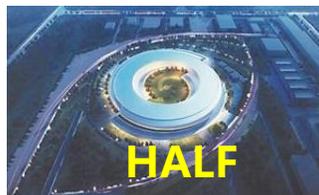
SHINE



CSNS



BEP-II



HALF

Alliance founding members

- HEPS (High Energy Photon Source)
- SHINE (Shanghai High repetition rate XFEL and Extreme light facility)
- SSRF (Shanghai Synchrotron Radiation Facility)
- HALF (Hefei Advanced Light Facility)
- CSNS (China Spallation Neutron Source)

Collaborate to address data and software challenges

- Establish common scientific data management policy
- Develop metadata standard
- R&D of data management and analysis software framework
- Develop disciplinary algorithm and software
- Build software ecosystem

第三届先进光源中子源科学数据及软件研讨会 2023.3.16



Conference of Advanced Photon/neutron Source
Data And Software(CAPSDAS)
Mar, 2023 • BEIJING

Summary & Plan



- The design of HEPSCC system has been thoroughly verified
- HEPSCC has enter the phase of equipment installation and debugging
- Meet the requirements of the first stage
- Need more financial support
 - Permanent storage, computing resources
- Keep collaborating with other photon/neutron source facilities
 - to address challenges of data and software
 - HEP5, CSNS, SHINE, SSRF, HALF...

An aerial photograph of a large, modern stadium with a retractable roof, surrounded by parking lots and roads. The stadium is illuminated with warm lights, and the surrounding area is dimly lit. The text "Thank you for your attention!" is overlaid in the center of the image.

Thank you for your attention!