

Data Infrastructure and Data Management for Beamlines and Endstations

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On behalf of Data Management Group

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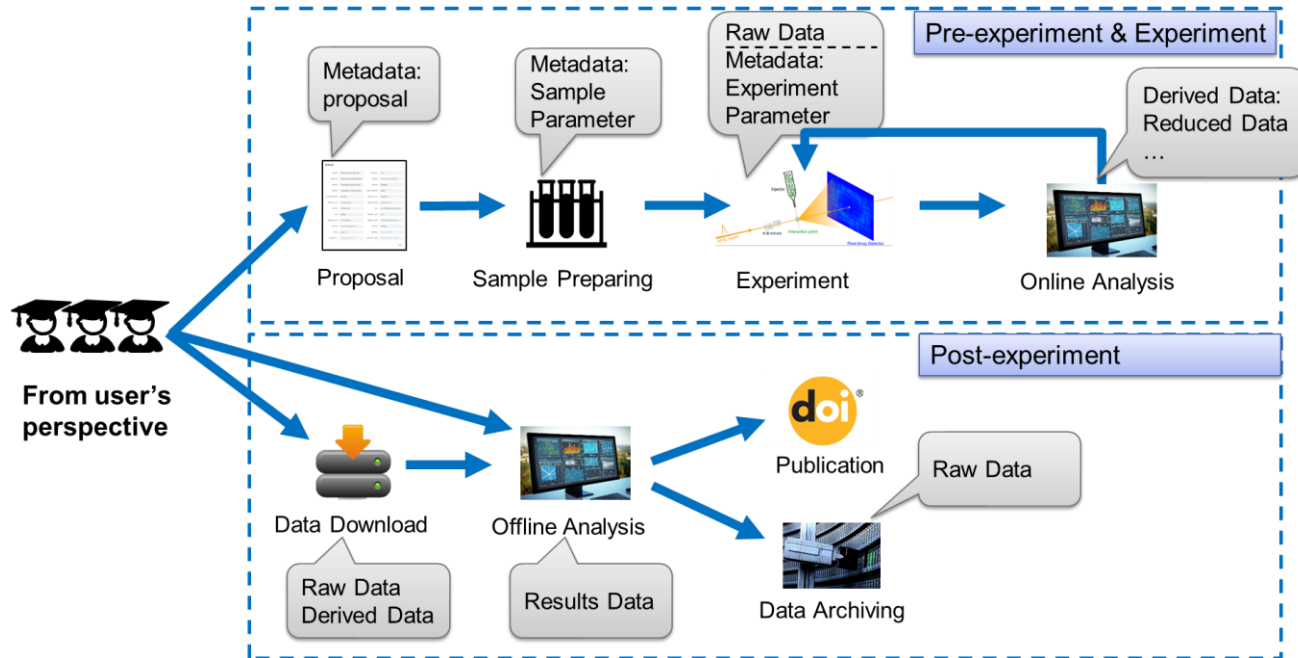
Outlines

- Overview of SHINE data system
- Progress of data infrastructure
- Progress of data management
- Plan and schedule
- Summary

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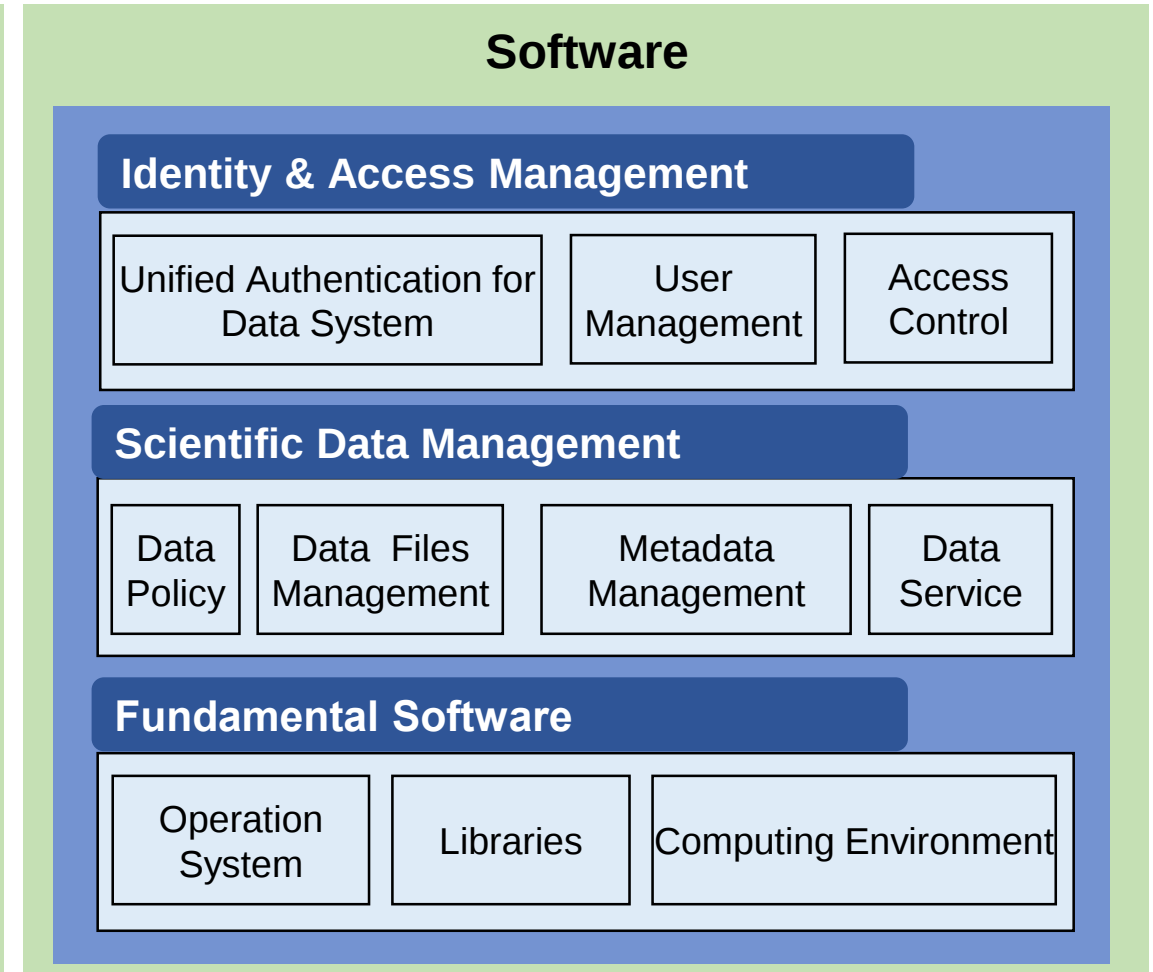
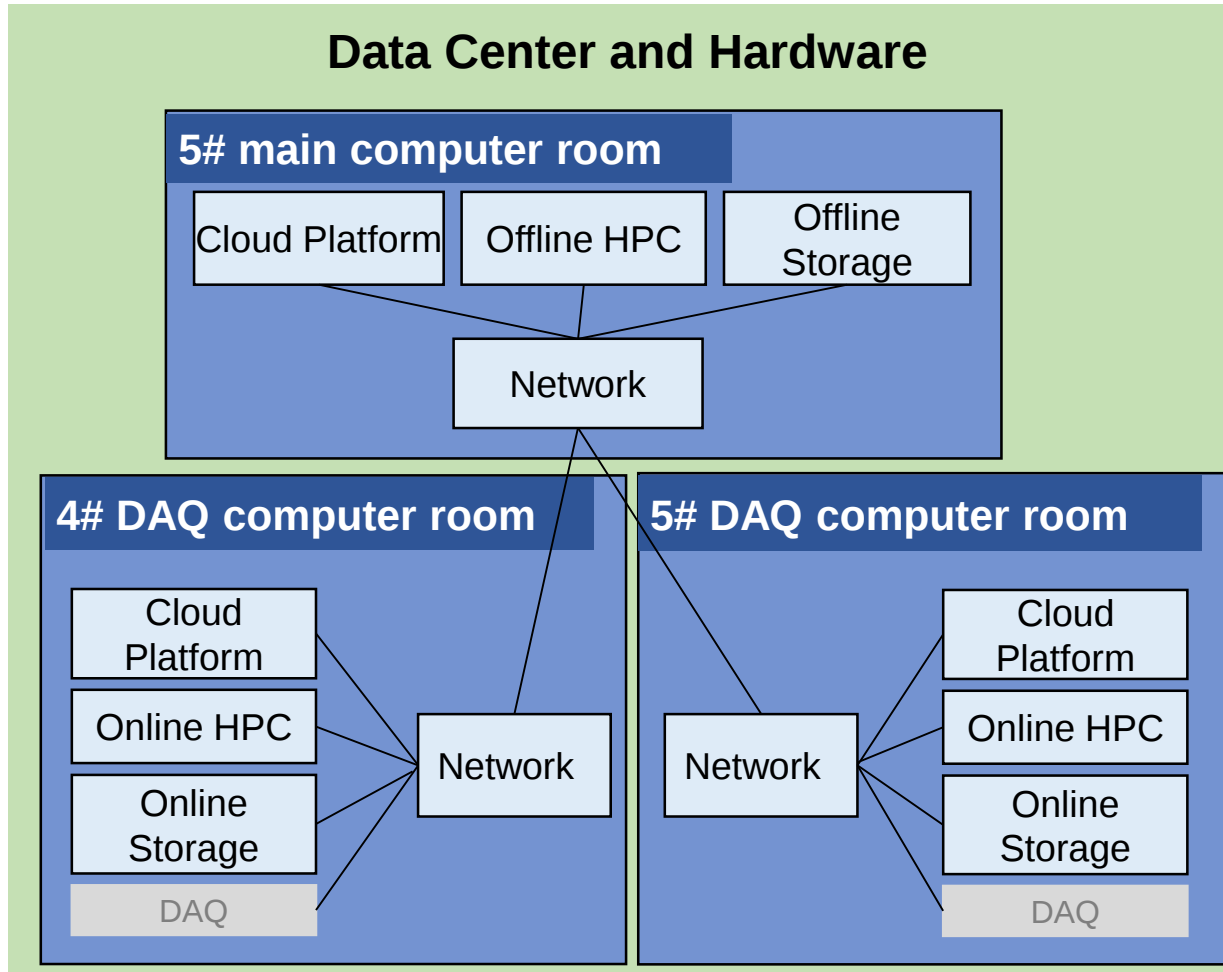
Requirements



Detector	Size	Frame Rate	Interface Type	Data Throughput
JUNGFRAU	2048×2048	2.2kHz	MPO	18.4GB/s
STARLIGHT (in progress)	1024×1024	10kHz	MPO	~20GB/s
CMOS Pixel Detector	2048×2048×2	70Hz	LC	~1.1GB/s
fADC	10GSPS×4×2	100kHz	LC	~4GB/s
ML camera	16k×4×2	100kHz	LC	~9.6GB/s

High-throughput data generated by various detectors requires a reliable, high-speed **network**, along with efficient **storage** and **computing resources** to support fast feedback, rapid data access, long-term data archiving, and robust data processing.

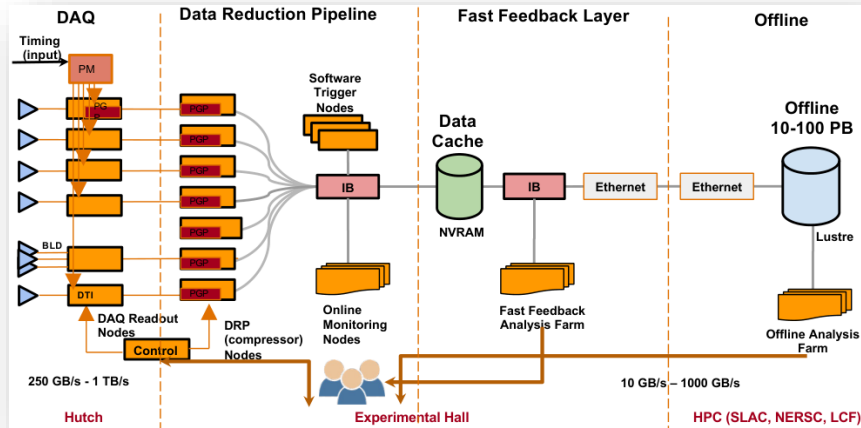
Missions and Services



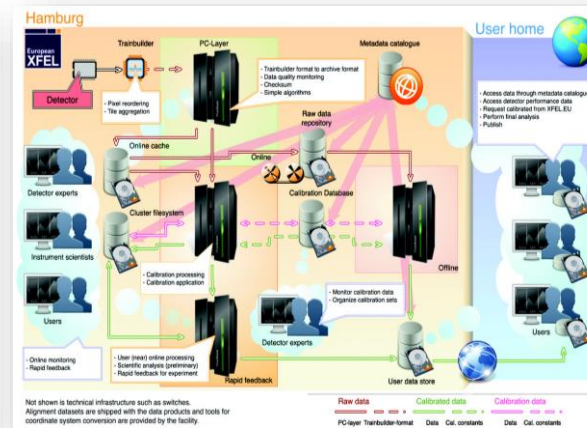
- ❑ Hardware: storage, computing resources, network.
- ❑ Software: scientific data management, identify & access management, etc.

Overview of Data Flow

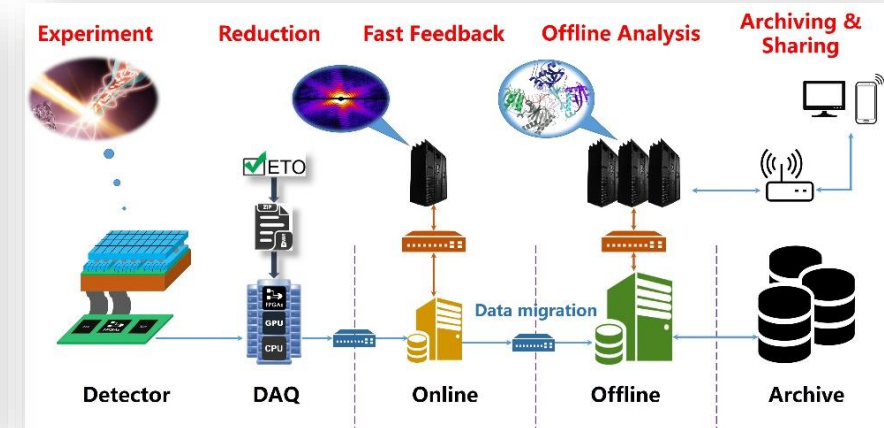
LCLS-II



European XFEL

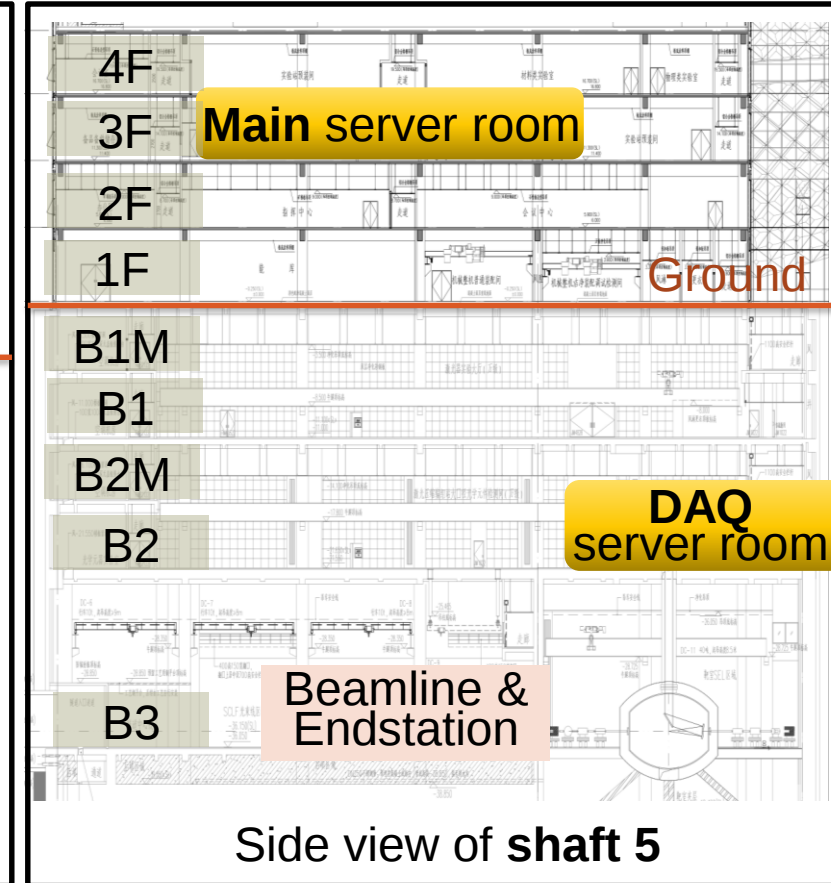
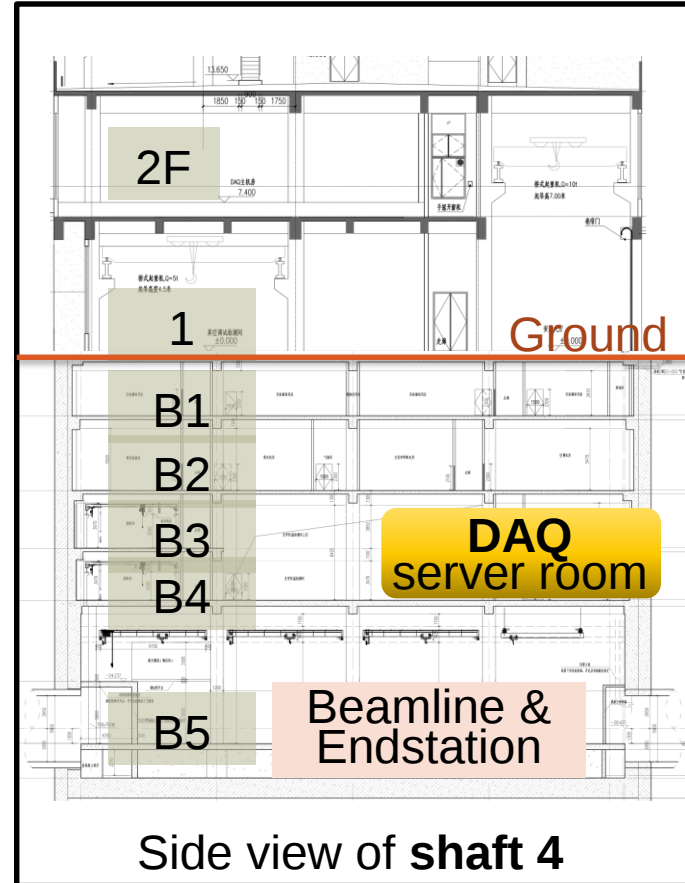
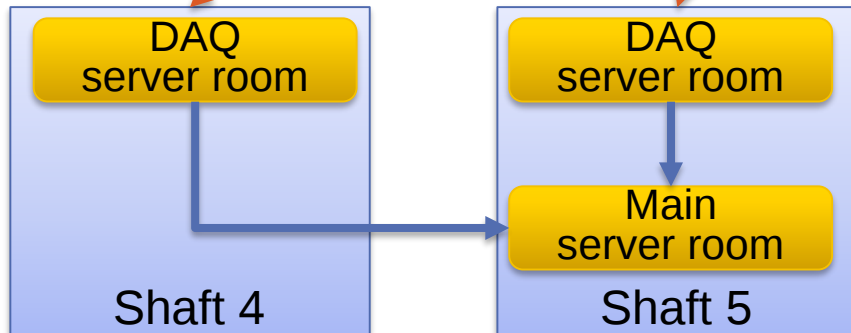


SHINE



- ❑ Data will be cached in online fast storage and analyzed by online high-performance computing (HPC) to provide fast feedback.
- ❑ Data will be migrated from online fast storage to offline massive storage, where it will be analyzed by offline HPC to obtain the final results.
- ❑ Data will be moved to archival storage for long-term preservation and future sharing.

Overview of Data Center Infrastructure



The data center consists of three server rooms:

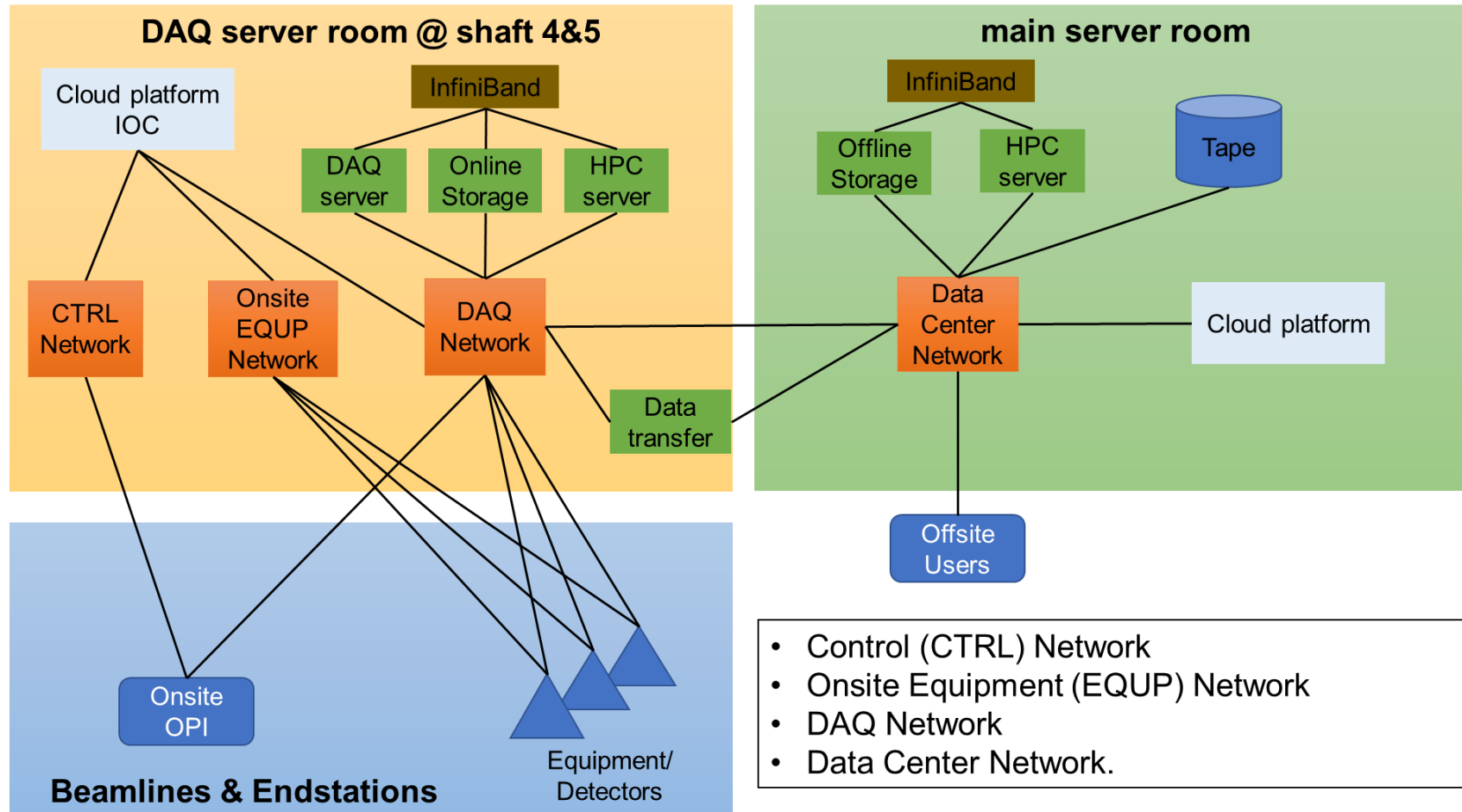
- Two **DAQ server rooms** (DAQ SR) located at shafts 4 and 5, which provide data caching and online analysis for fast feedback.
- One **main server room** (Main SR) at shaft 5, responsible for long-term storage, offline analysis, data archiving, and data sharing.

Overview of Data Policies

- ❑ Follow the **FAIR**(Findable, Accessible, Interoperable, and Reusable) guiding principles.
- ❑ Cached data from the DAQ system will be retained in **online storage** for less than **7 days**.
- ❑ Data migrated from online storage will be preserved in **offline storage** for up to **6 months**.
- ❑ Archived raw data will be stored for more than **10 years** to ensure long-term availability.
- ❑ All data will be made **publicly accessible** after the embargo period.

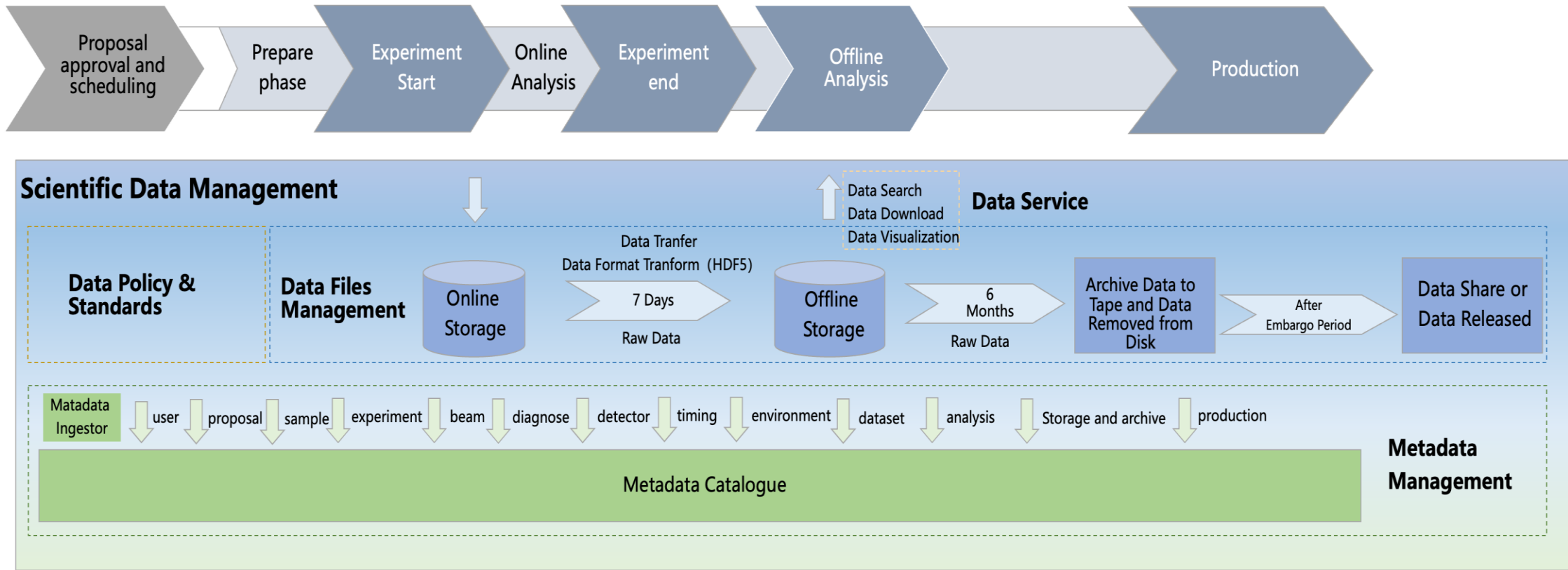
Raw data	Reserved (PB)	Day one (PB)	Duration	Storage medium
Online storage	10	2	<7days	SSD
Offline storage	100	8	6 months	HDD
Archiving storage	500	10	>10 years	Tape

Overview of Hardware Infrastructure



Switches, computing servers, storages, and equipment at beamlines and endstations are interconnected via high-speed Ethernet.

Overview of the Life-Cycle Data Management



Data management is through the entire life-cycle of scientific data, including data policy, data files management, metadata management, and data service.

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Progress of Server Rooms

DAQ server room at shaft 4



14 racks
120kW power supply

DAQ server room at shaft 5



14 racks
120kW power supply

Main server room at shaft 5

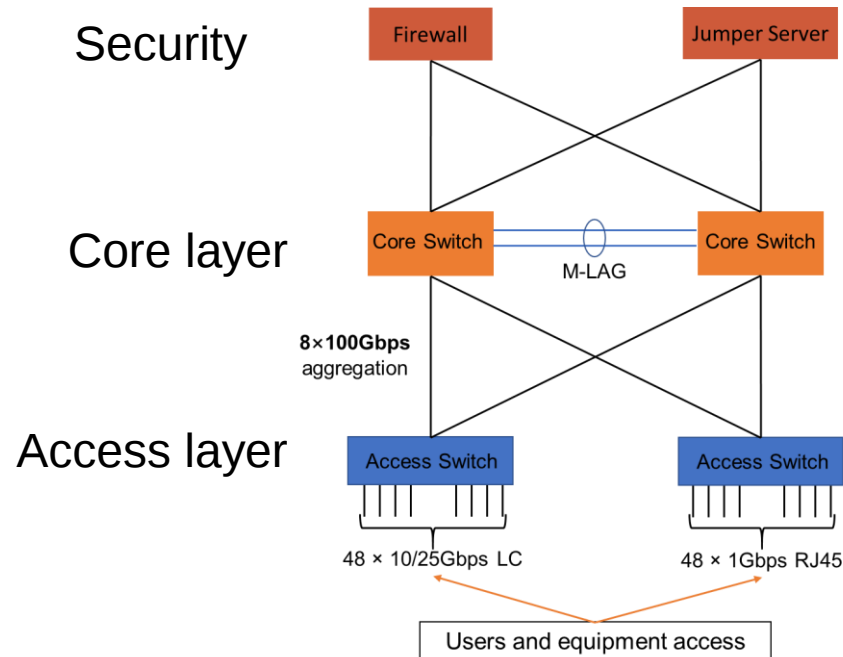


42 of 84 racks
2000kW power supply

All server rooms are ready at the end of July 2025.

Network Topology and Cyber Security

- ❑ 2-tier architecture (Core layer + Access layer) with redundancy core switches for each network.
- ❑ Up to **400/800Gbps** bandwidth (DAQ network) from each endstation.
- ❑ Using the bypass firewall, jumper server and other security devices to ensure the cyber security.
- ❑ **The link speeds and type fully meet the requirements of BE.**



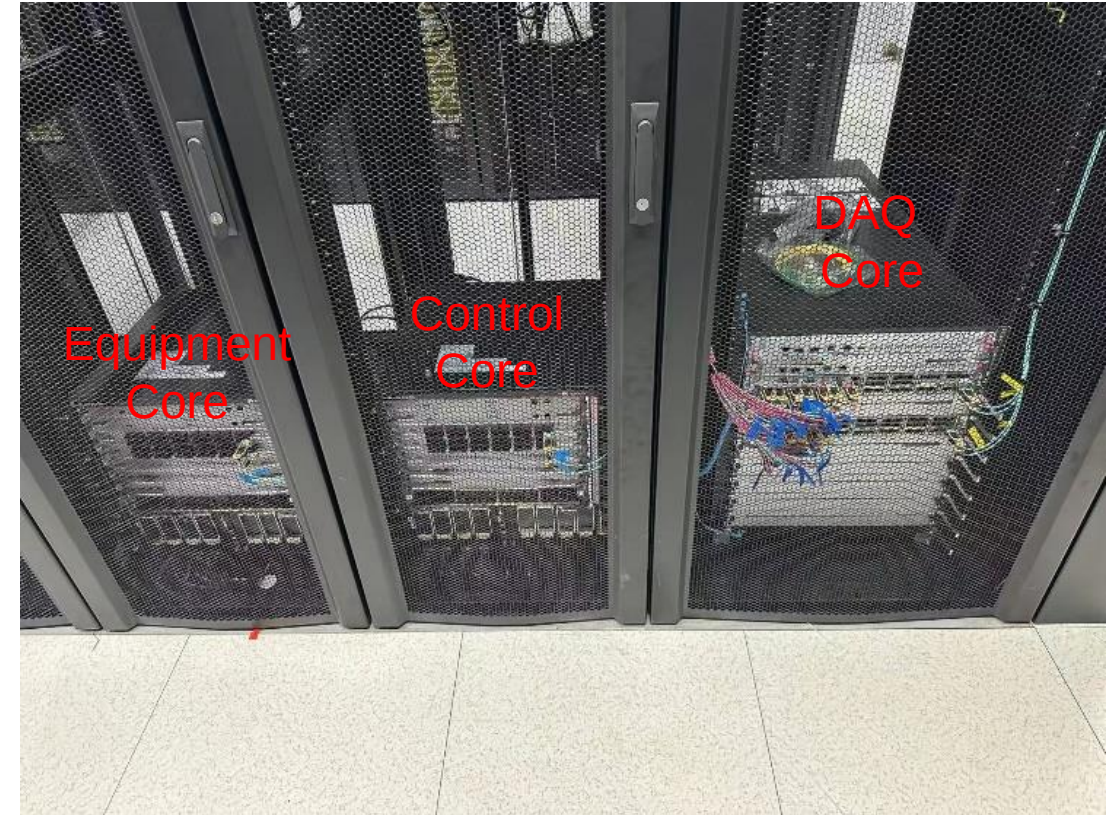
- ❑ Access control
- ❑ Operation Auditing
- ❑ Session Monitoring & Termination
- ❑ Security Isolation
- ❑ Network segmentation
- ❑ Firewall
- ❑ Intrusion detection and prevention

Progress of Network @ Shaft 4

Access Switches @ DAQ server room



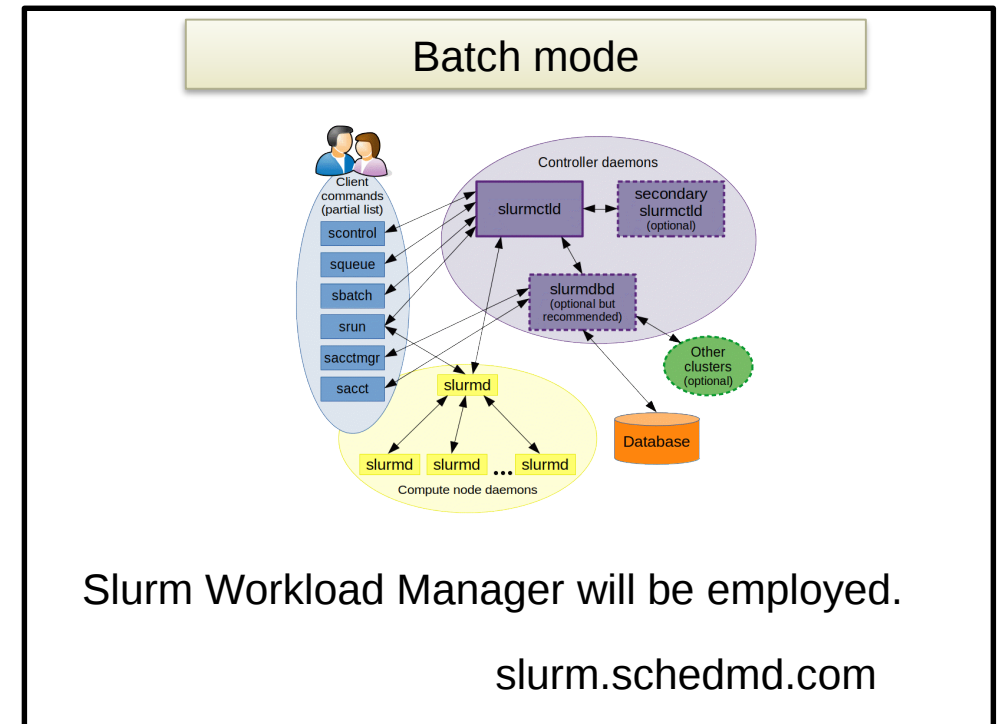
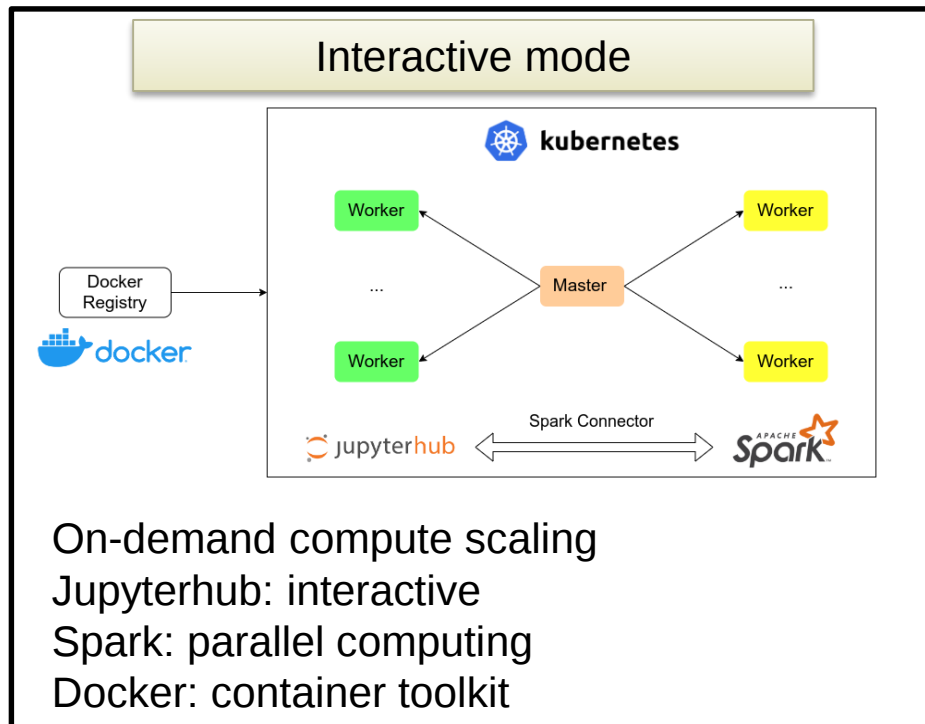
Core Switches @ DAQ server room



The switches are ready at the end of June 2025.

Online Storage and HPC Server @ Shaft 4

- ❑ **Online fast storage:** 6*nodes with 96 NVME disks, 1PB, r/w speed $\geq 100\text{GB/s}$.
- ❑ **File system:** IBM Spectrum Scale (GPFS).
- ❑ **Online CPU:** 10*CPU nodes, 2* Intel Xeon Gold 6542Y 24C 2.9GHz, 512GB RAM (44TFlops).
- ❑ **Online GPU:** 1*GPU node, 512GB RAM, 6*GPU cards ($\geq 100\text{TFlops}$).

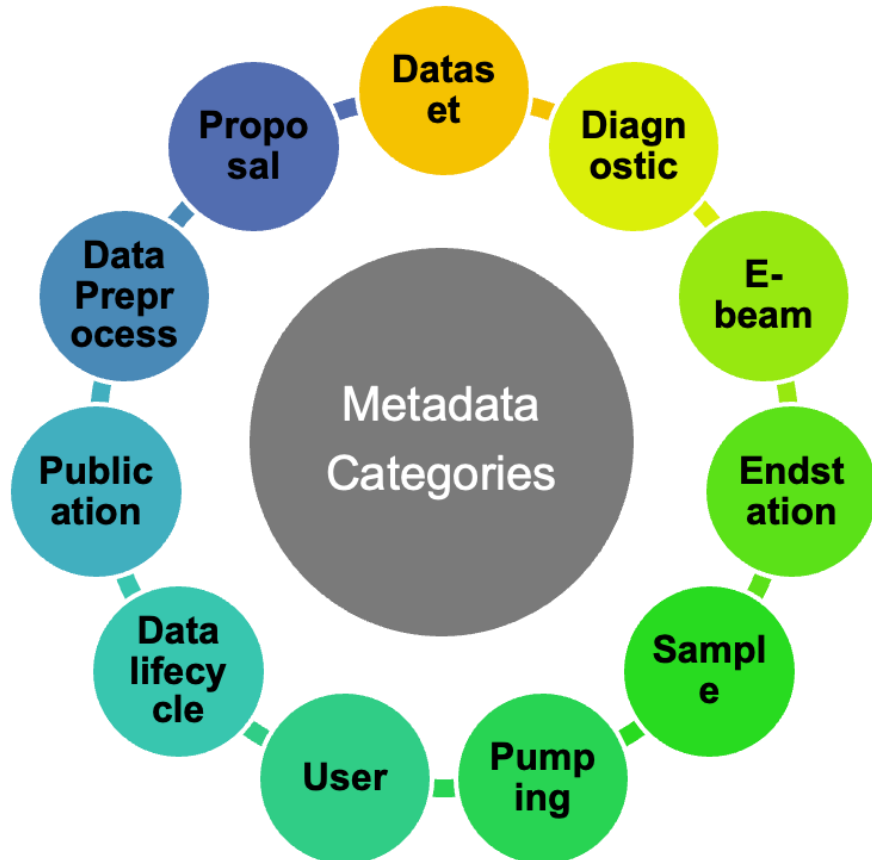


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Metadata Catalogue

- ❑ For the entire lifecycle of scientific data, the **metadata catalogue** was used to manage data files.
- ❑ **Metadata Types: Administrative Metadata and Scientific Metadata (read from the data files or receive from the message from DAQ system via Kafka).**
- ❑ For SHINE, the metadata categories and scientific metadata list are as following.



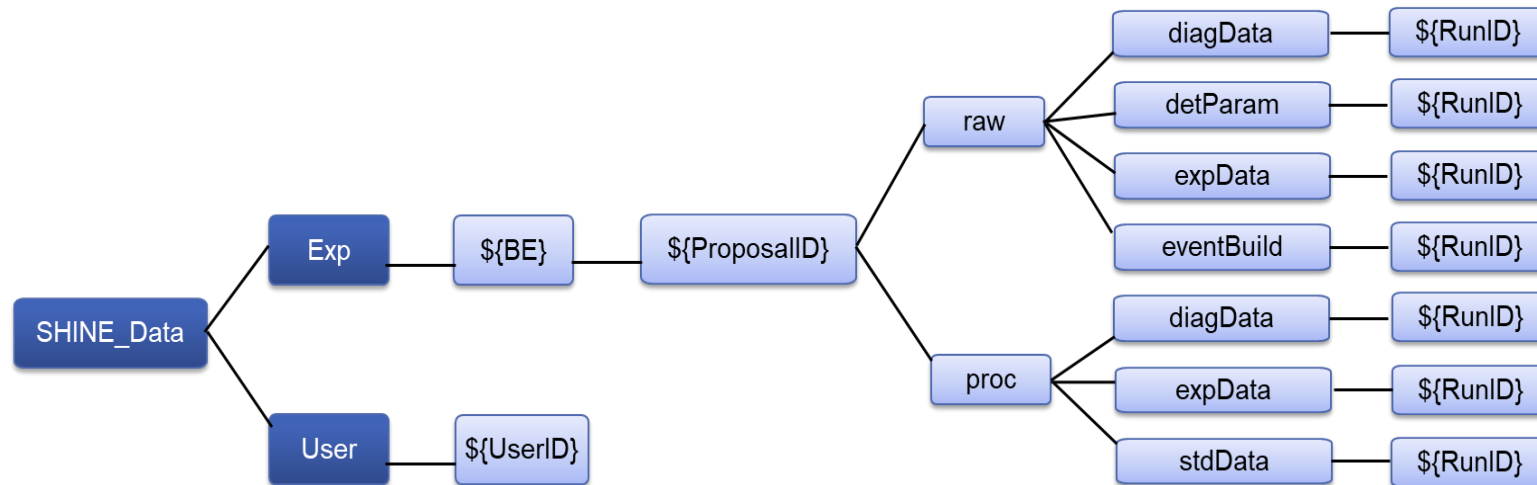
Dataset	RUNID	RUNTYPE	FILELIST	EVENTSNUM	FILESNUM	SIZE	ORIGDATABLOCK
Diagnostic	BLM-1	GMD	HAMPS-1	IMAGER-13	PAM-2	PAM-4	PAM-RESULT
E-beam	AVE-POWER	ENERGY	FREQUENCY	PULSE-LOSS	PULSE-Q	UNDULATOR-GAP	UNDULATOR-VAC
Endstation	FEL	ENDSTATION	KB-PARAMETERS	DETECTOR-VOL	CURRENT	EXTRAFIELD-VOL	
Sample	DESCRIPTION	NAME	SIZE	TYPE			
Pumping	PUMPING-DELAY	PUMPING-ENERGY	PUMPING-SHIFT				

Scientific Metadata for FEL-II

Enough for data analysis?

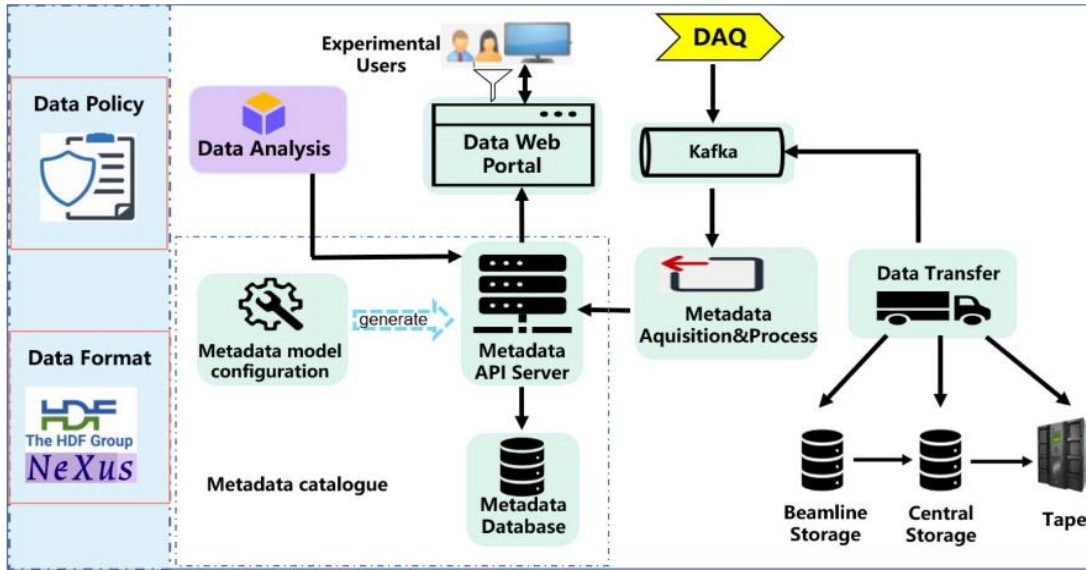
Dataset and Directory

- ❑ The experimental data is stored in a **predefined directory structure**: /SHINE_data/Exp/\${BE}/\${ProposalID}, and a **predefined file name**: \${RAW/CORR/PROC}-\${RunID}-\${DeviceName}-\${FileIndex},
e.g. RAW-R0001-JUNGFRAU00-S00001.h5
- ❑ All data files generated from each run constitute a dataset, and each dataset is associated with a corresponding set of metadata.
- ❑ Once a run has completed data acquisition, the experimental data can be **transferred** to offline storage.
- ❑ File access permission control is based on ACL permission control.



Data Management Software

- In cooperation with the Institute of High Energy Physics (IHEP), we have customized and developed data management software based on the Data Organization, Management, and Access System (DOMAS) framework.



□ Key Modules:

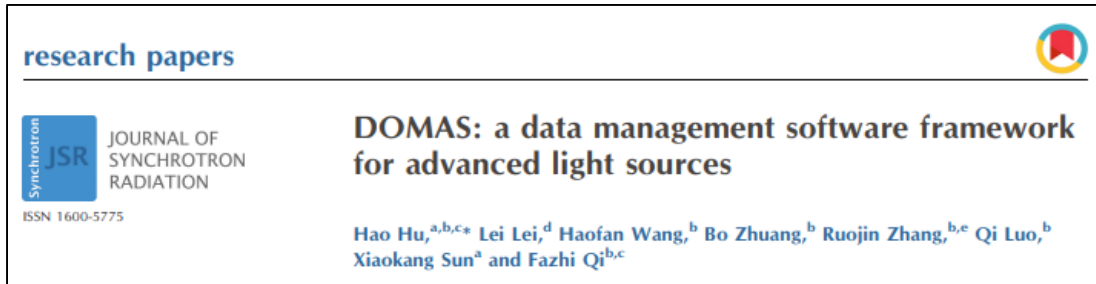
- metadata catalogue, metadata acquisition, data transfer, and data service

□ Technology Stack:

- Spring Boot, MybatisPlus, Kafka, RabbitMQ, Redis, MongoDB, MySQL, Vue, ElementUI, Layui

□ Compared to SciCAT and ICAT:

- configurable metadata model management
- integrated workflow module
- configurable data transfer management
- API authorization control



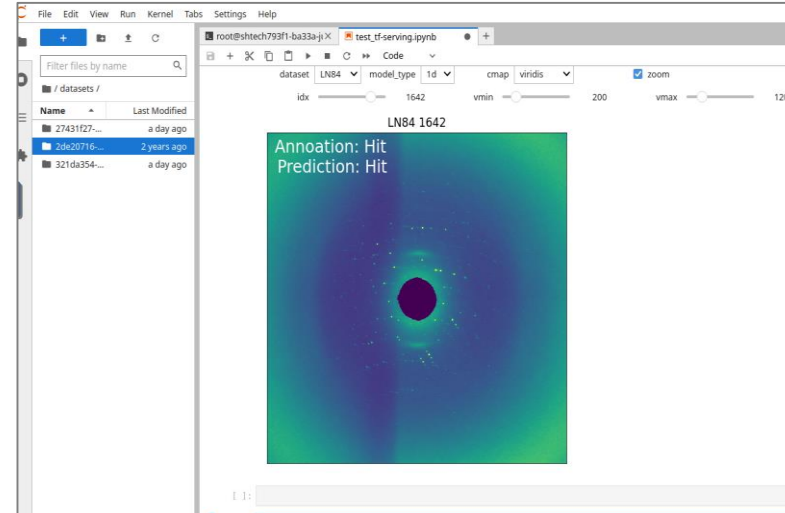
Remote Access

❑ Three methods are provided for data access and analysis:

- SSH → Direct access to the HPC cluster for large-scale data analysis.
- JupyterHub → An interactive analysis environment for data exploration and visualization.
- Data Web Portal → A web-based interface for managing datasets and their associated metadata.

```
[root@dataserver SHINE-data-online]# tree
├── exp
│   └── AMO
│       └── 2025-SHINE-AMO-000002
│           └── raw
│               └── diagData
│                   └── 0001
│                       ├── RAW-R0001-PAM1-ML-BunchID-S00001.h5
│                       ├── RAW-R0001-PAM1-ML-BunchID-S00002.h5
│                       ├── RAW-R0001-PAM1-ML-S00001.h5
│                       ├── RAW-R0001-PAM1-ML-S00002.h5
│                       ├── RAW-R0001-PAM1-ML-S00003.h5
│                       ├── RAW-R0001-PAM1-ML-S00004.h5
│                       ├── RAW-R0001-PAM1-ML-S00005.h5
│                       ├── RAW-R0001-PAM1-ML-S00006.h5
│                       └── RAW-R0001-PAM1-ML-S00007.h5
│               └── eventBuild
│                   └── RAW-R0001-JUNGFRAU00-master.h5
│               └── expData
│                   └── 0001
```

SSH



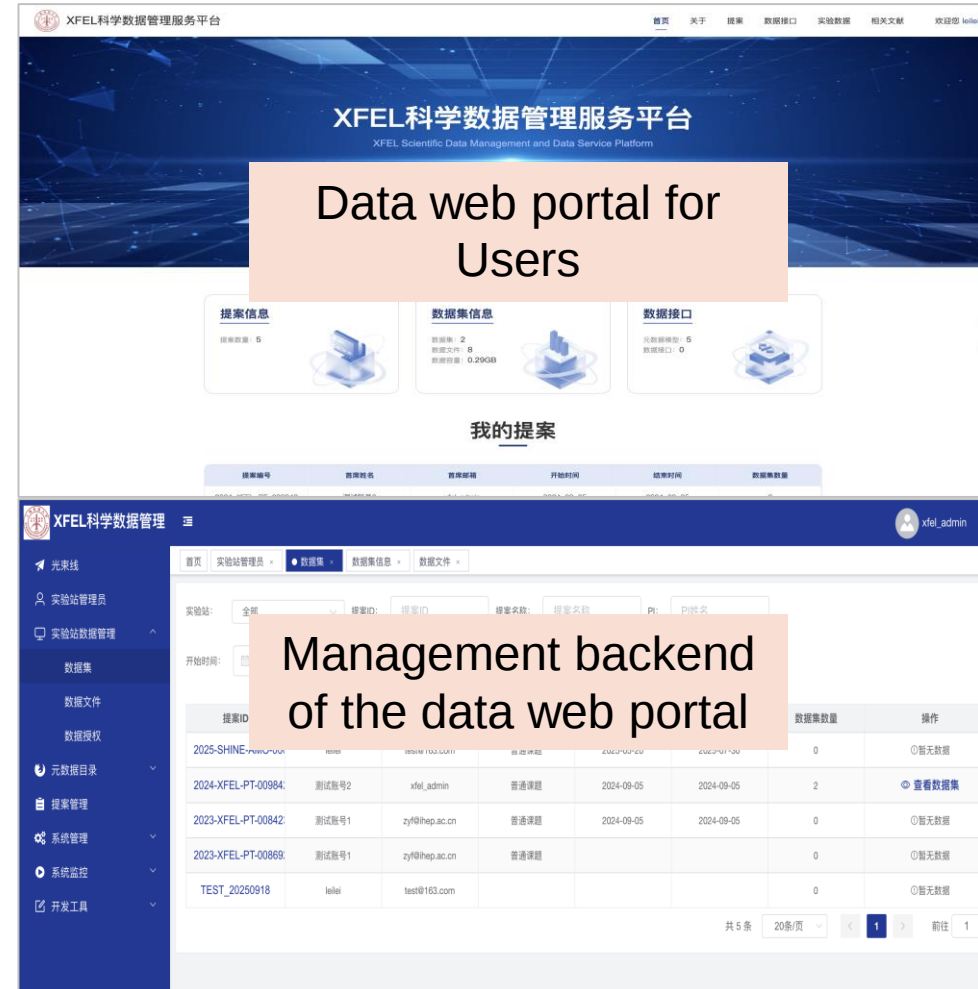
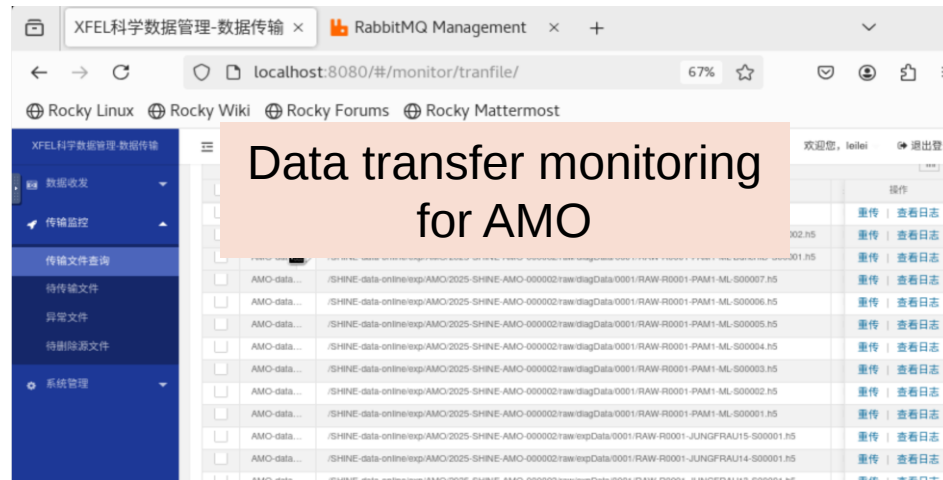
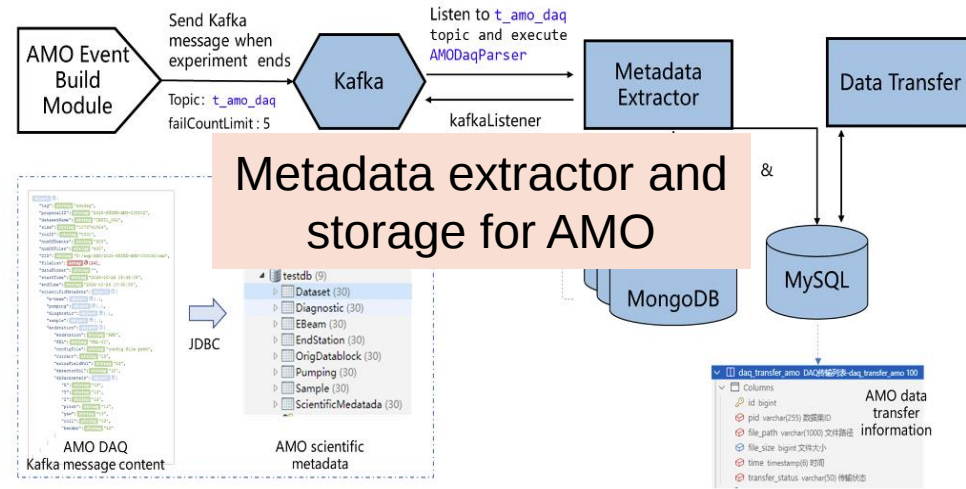
Jupyterhub



Data web portal

Progress of Data Management Software

- Each sub-module of the AMO data management system has been developed and deployed. Joint debugging and testing with the AMO DAQ software are expected to be completed within one month.



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Plan and Schedule

		2025												2026												2027															
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12				
data center infrastructure	Data center	in constructing and commsioning							ready for joint commissioning																																
	Optical fiber @shaft4								in constructing			ready for joint commissioning																													
	Optical fiber @shaft5															in constructing		ready for joint commissioning																							
Hardware	Network @ shaft 4	in constructing and commsioning							ready for joint commissioning																																
	DAQ server @shaft 4						in constructing and commsioning					ready for joint commissioning																													
	Online HPC @shaft 4						in constructing and commsioning					ready for joint commissioning																													
	Online Storage @shaft 4						in constructing and commsioning					ready for joint commissioning																													
	Network @shaft 5								in constructing and commsioning				ready for joint commissioning																												
	DAQ server @shaft 5													in constructing and commsioning				ready for joint commissioning																							
	Online HPC @shaft 5													in constructing and commsioning				ready for joint commissionin																							
	Online Storage @shaft 5													in constructing and commsioning				ready for joint commissioning																							
	Offline HPC													in constructing and commsioning				ready for joint commissioning																							
	Offline Storage													in constructing and commsioning				ready for joint commissioning																							
	Archive Storage													in constructing and commsioning				ready for joint commissioning																							
Data management software	AMO					in constructing						commsioning				ready for joint commissioning																									
	SES												in constructing						commsioning		ready for joint commissioning																				
	SSS															in constructing				commsioning		ready for joint commissioning																			
	HSS															in constructing				commsioning		ready for joint commissioning																			
	CDS																		in constructing				commsioning		ready for joint commissioning																
Cyber security	Cyber security	designing												in constructing												commsioning												completed			

All services are scheduled to be fully operational prior to the commissioning of the beamline and endstations.

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- The Data Management Group is responsible for overseeing the entire lifecycle of scientific data.
- This includes building and maintaining the infrastructure for data acquisition, transfer, online and offline storage, online and offline analysis, archiving, and overall data management.
- All services are scheduled to be fully operational prior to the commissioning of the beamline and endstations.

Questions - from Scientists' Perspective

- ❑ What metadata is essential for scientific data analysis and should be presented to users through the data web portal?
- ❑ In addition to JupyterHub and Slurm, what supplementary services should be provided to users, particularly during experimental operations?
- ❑ What key features and functionalities should users expect from the data management software?
- ❑ What preparations should be made to support future AI-related research and applications?



Thank you for your attention!

