中国科学院近代物理研究所
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Detector Control System for CEE

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Institute of Modern Physics（IMP）

Chongqing 2025.09.17

Contents

- Introduction of CEE & DCS
- Design and implementation of CEE-DCS
  - Network construction
  - Software architecture:EPICS
  - Database
  - Electronics logbook
  - Wechat
- Update and optimization
- Conclusion

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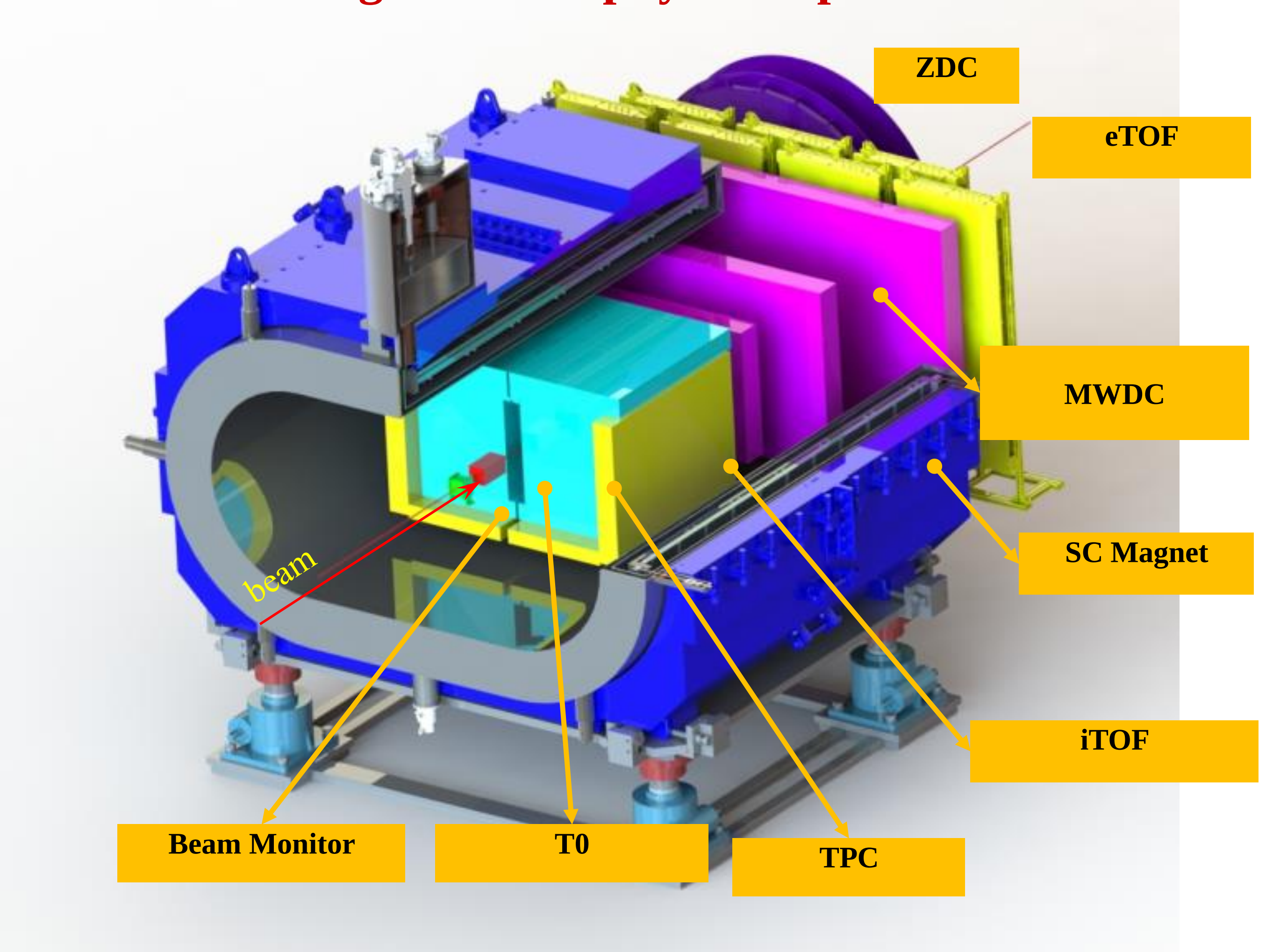
CEE:Backgroud

CEE: CSR External-Target Experiment, it will be the first-large nulclear physics experimental device at HIRFL-CSR, heavy-ion collisions

Physical goals

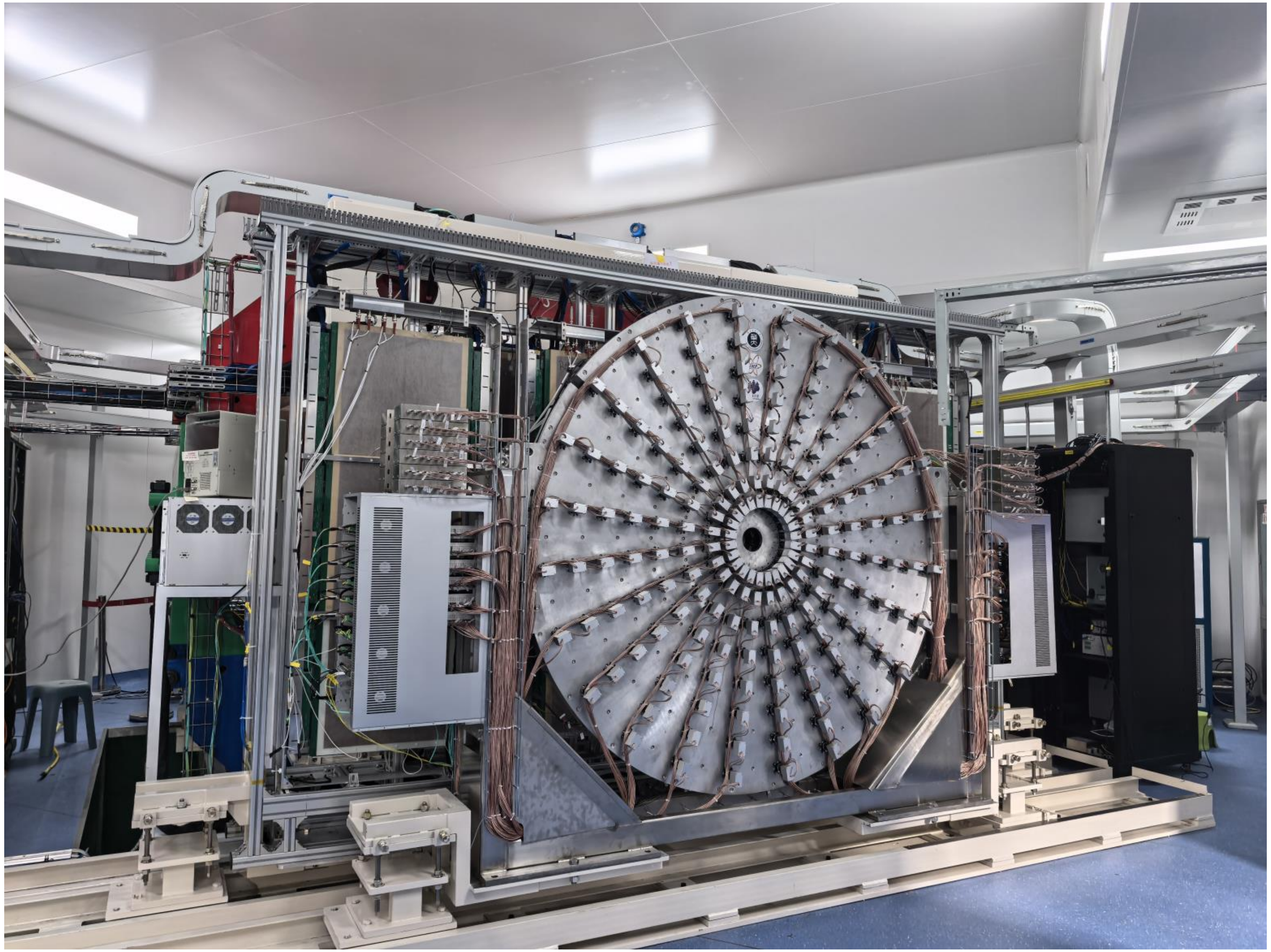
- To study the bulk properties of strongly interacting matter
- To study equation of state high baryon density region
- To understand the quantum chromo dynamics (QCD) phase diagram
- Buget: 74,5241 million



A collaborative project between 8 universities and institutes

CEE subsystems

- Superconducting Magnets
- BM： Beam Monitor
- TPC: Time Projection Chamber
- Starting time detector (T0)
- iTOF: Internal Time-of-Flight
- eTOF: Endcap Time-of-Flight
- MWDC: Multiwire Drift Chamber
- ZDC: Zero Degree Calorimeter
- DAQ: Data Acquisition System
- Trigger
- Technical Support
- **Detector Control System**
- Clocks
- Scientific Applications



Detector control system（DCS）

- Ensure the proper and safe operation of the experiment
- Monitor/control all the critical parameters of the experiment->Interlocks
- Provide necessary information for data corrections
- Collect data from sensors and send them to local database and finally to the centralized database
- Data archival
- Elog
- Design and set up CEE Local Area Network(LAN)
- Develop accelerator event parsing system for trigger system
- Realize the data interaction between accelerator and CEE LAN
- Time synchronization of equipments running in CEE LAN
- … …

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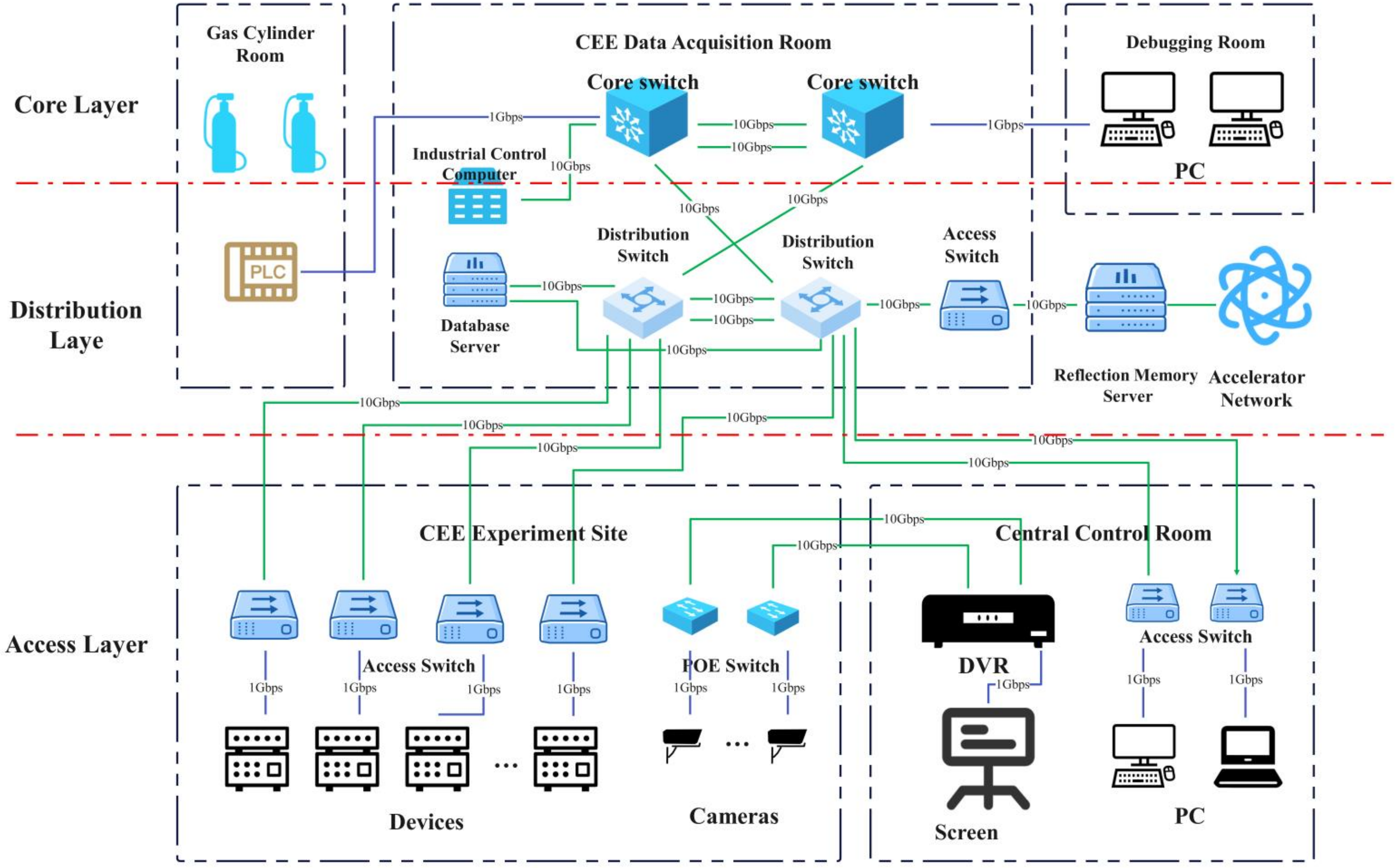
Design and implementation of CEE-DCS

--Network construction

Detector control system（DCS）： Network Construction

- **Three-layer network architecture design：** Core Layer , Distribution Layer , Access Layer
- **Achieving data communication between different networks:** CEE network, accelerator network, surveillance video network, DAQ data transmission network, office network.



- Redundant of two core switches
- Maximum bandwidth of 48 Gbps
- The maximum bandwidth usage is approximately 640 Kbps
- Uplink connection: optic fiber
- Downlink connection: Category 6 shielded twisted pair (STP) cables

Detector control system（DCS）： Network Construction

- **Three-layer network architecture design**： Core Layer , Distribution Layer , Access Layer
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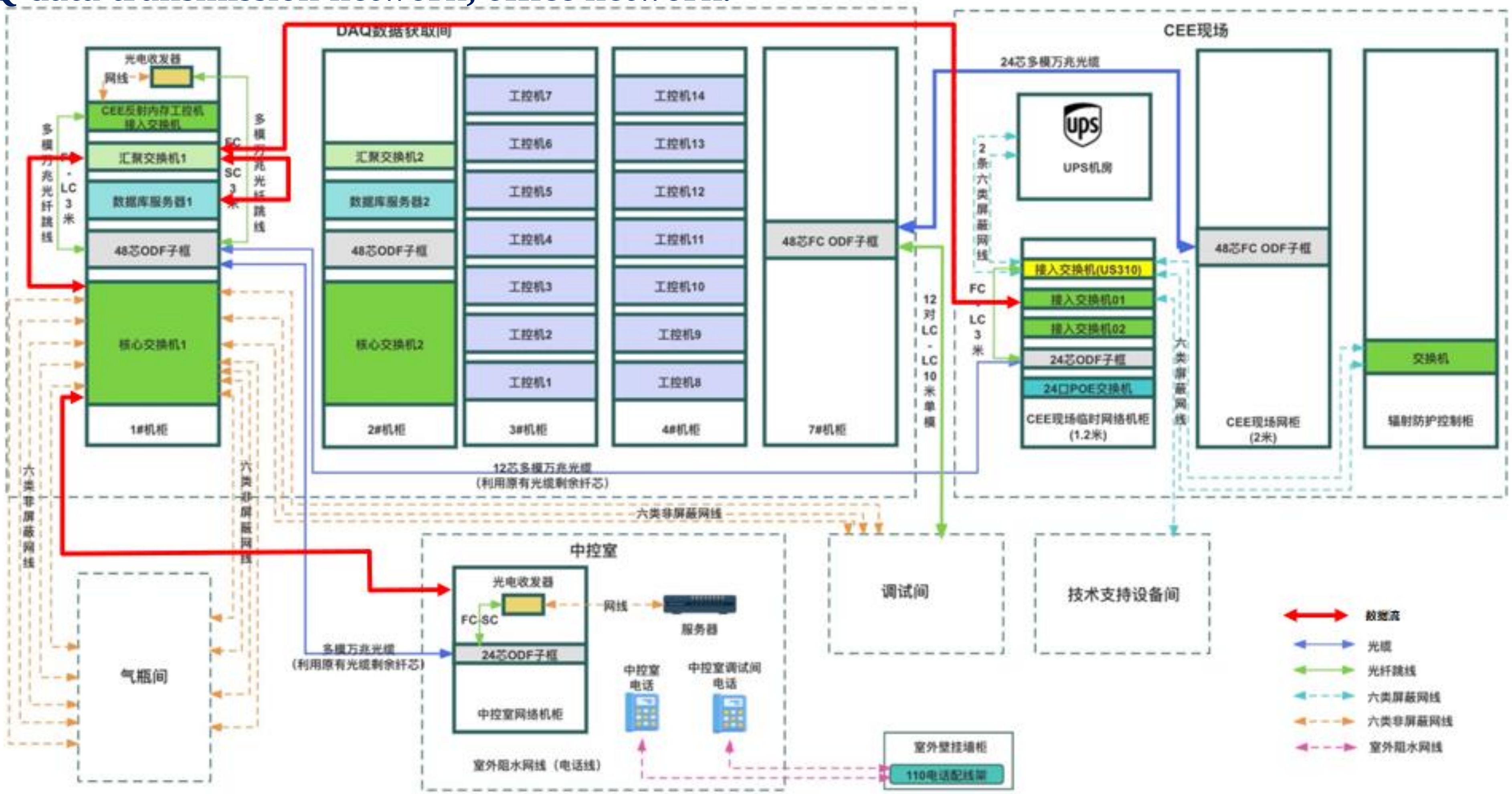
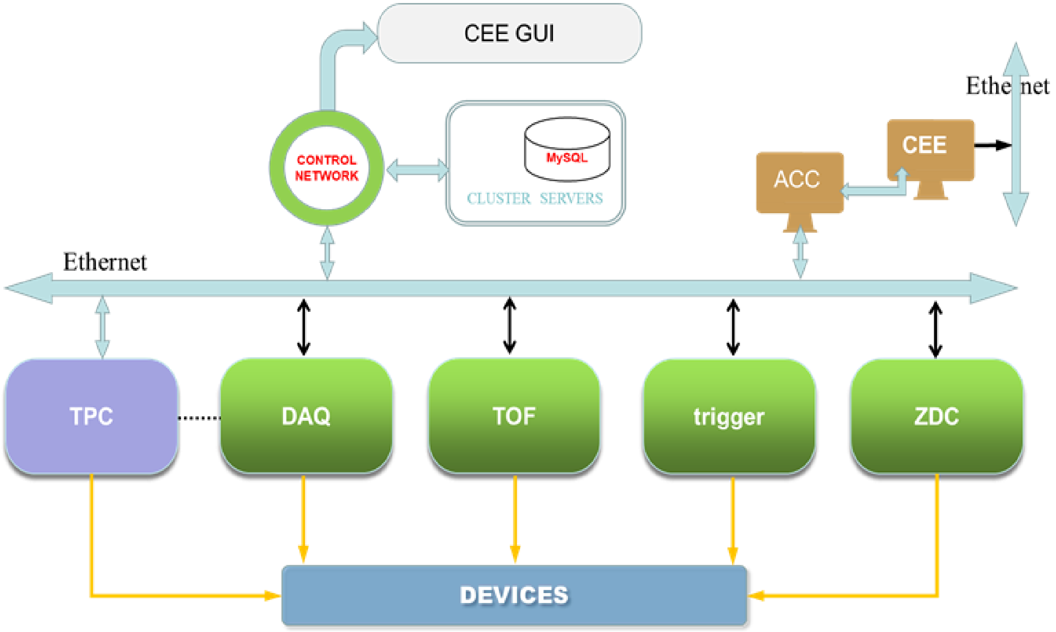


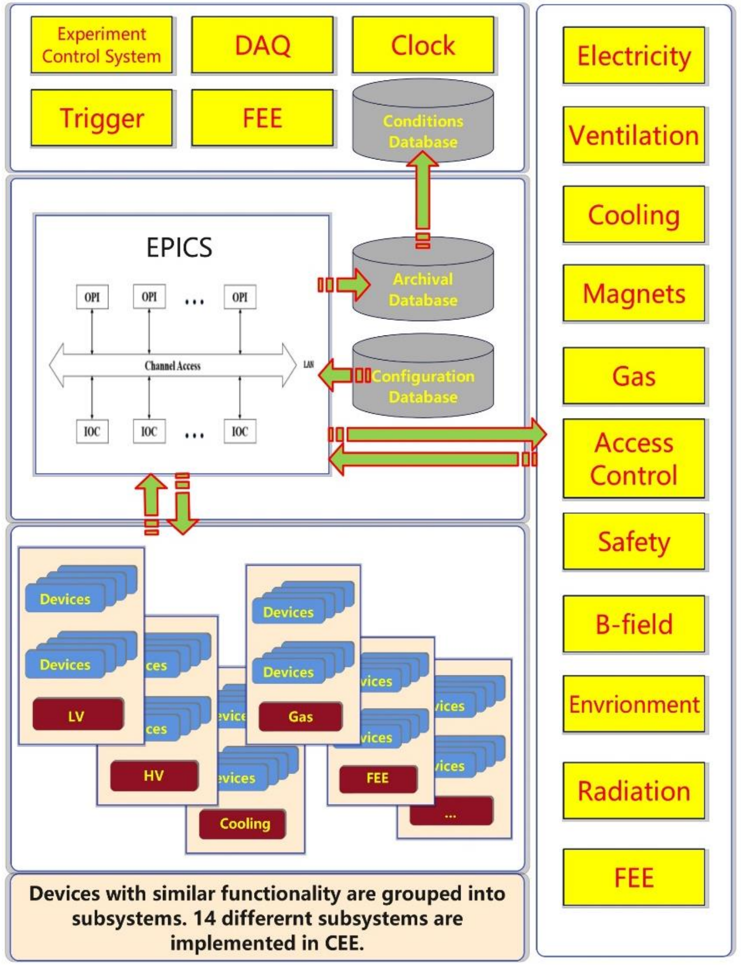
Design and implementation of CEE-DCS

--EPICS Architecture

DCS context and scale

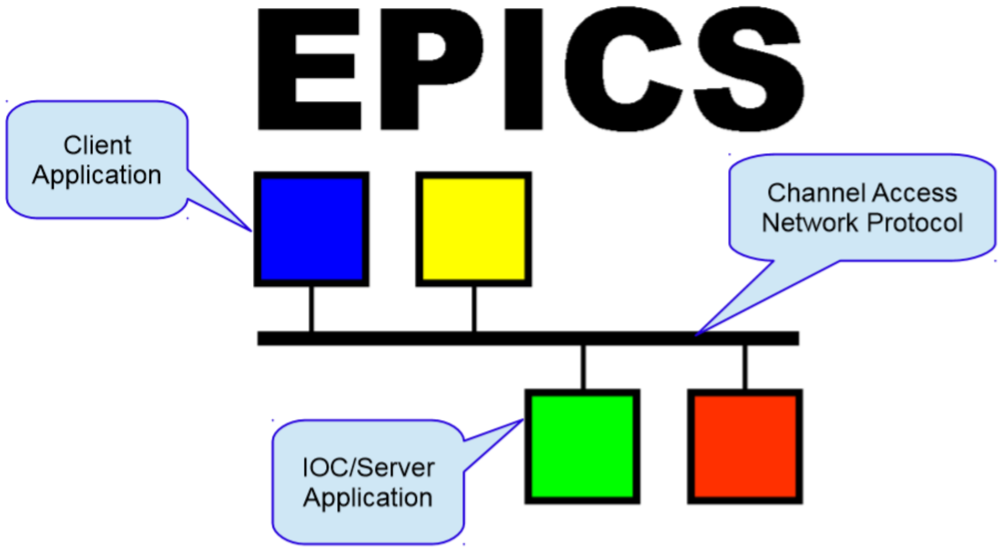
- 3-tiers hardware architecture
- **EPICS-based** architecture
- Open-source software

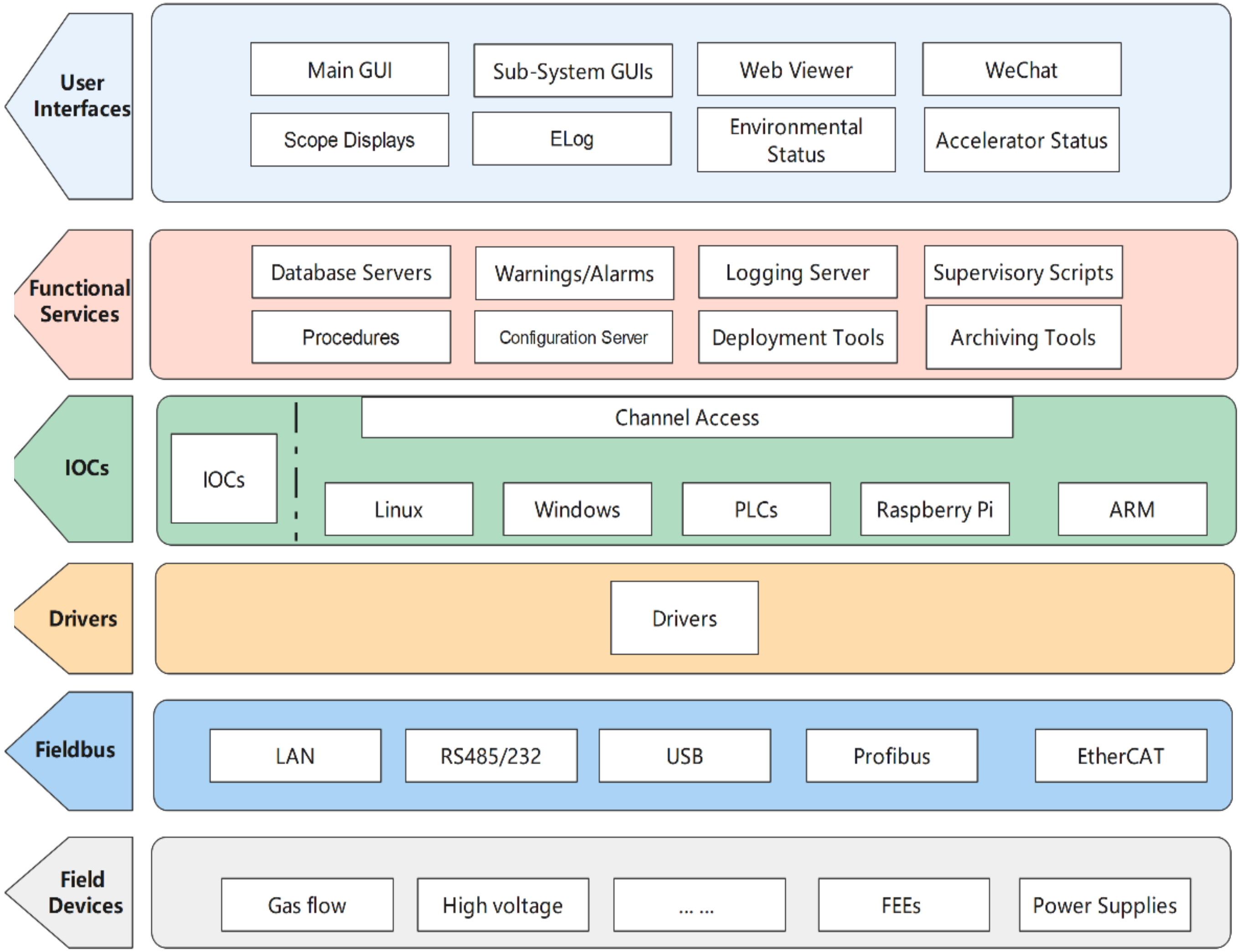




- 7 autonomous detector systems
- Embedded computers
- 14 subsystems
- Control computers
- EPICS
- ~20000 PV items
- ~100 network attached devices
- ~40 kinds of frontend services

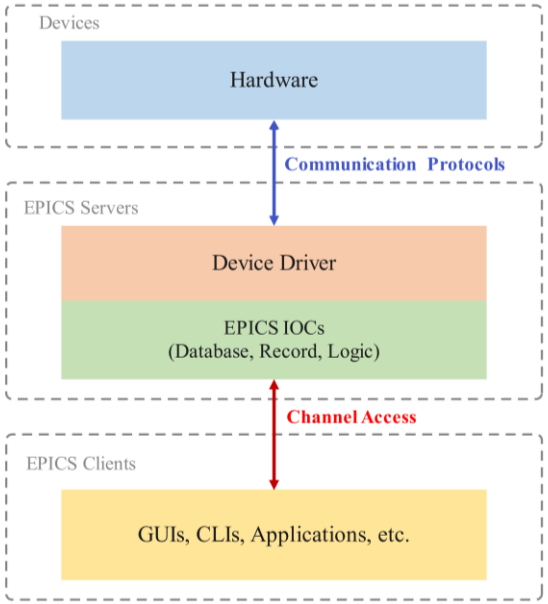
Software Architecure

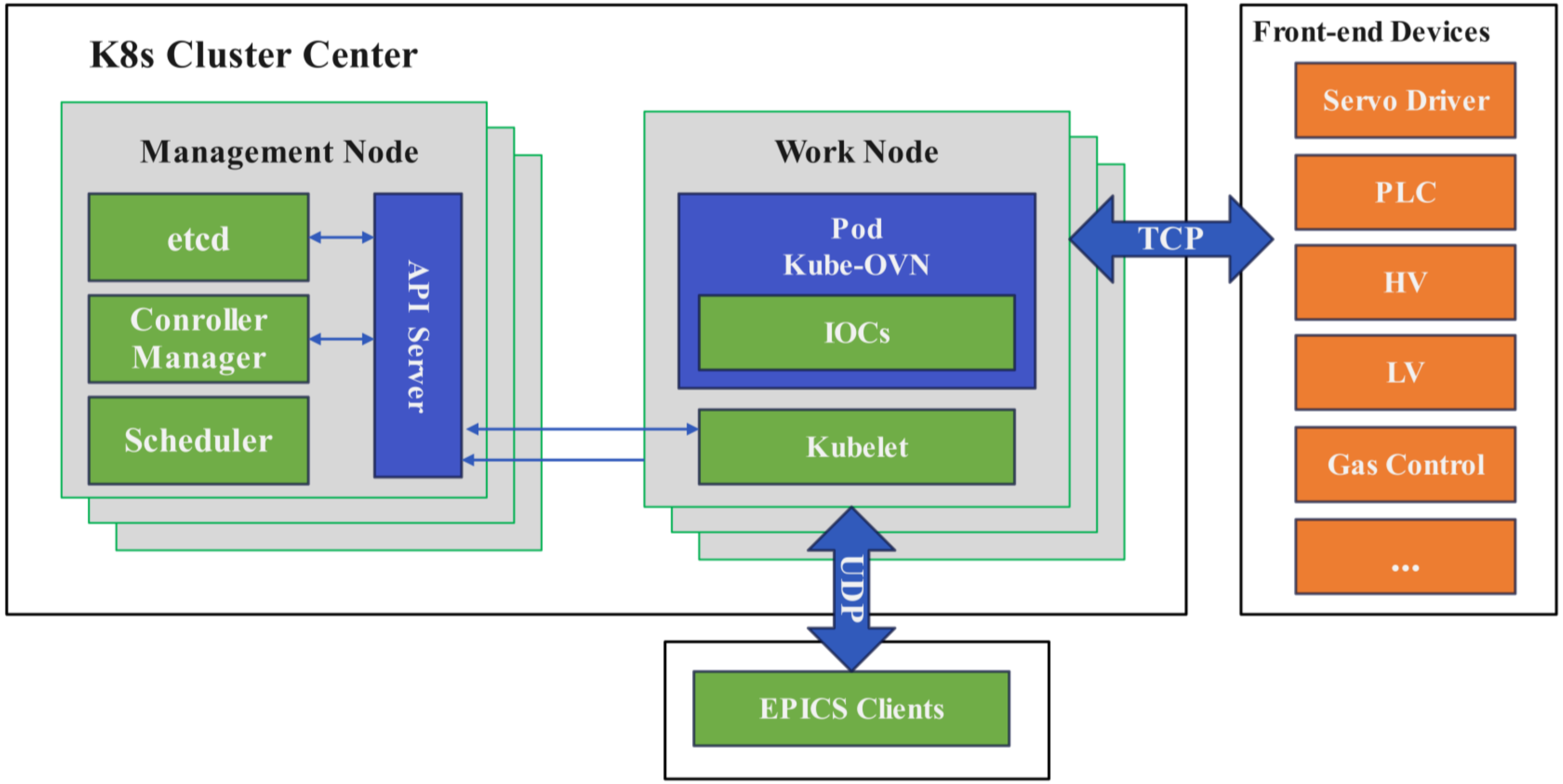




DCS implementation： IOCs

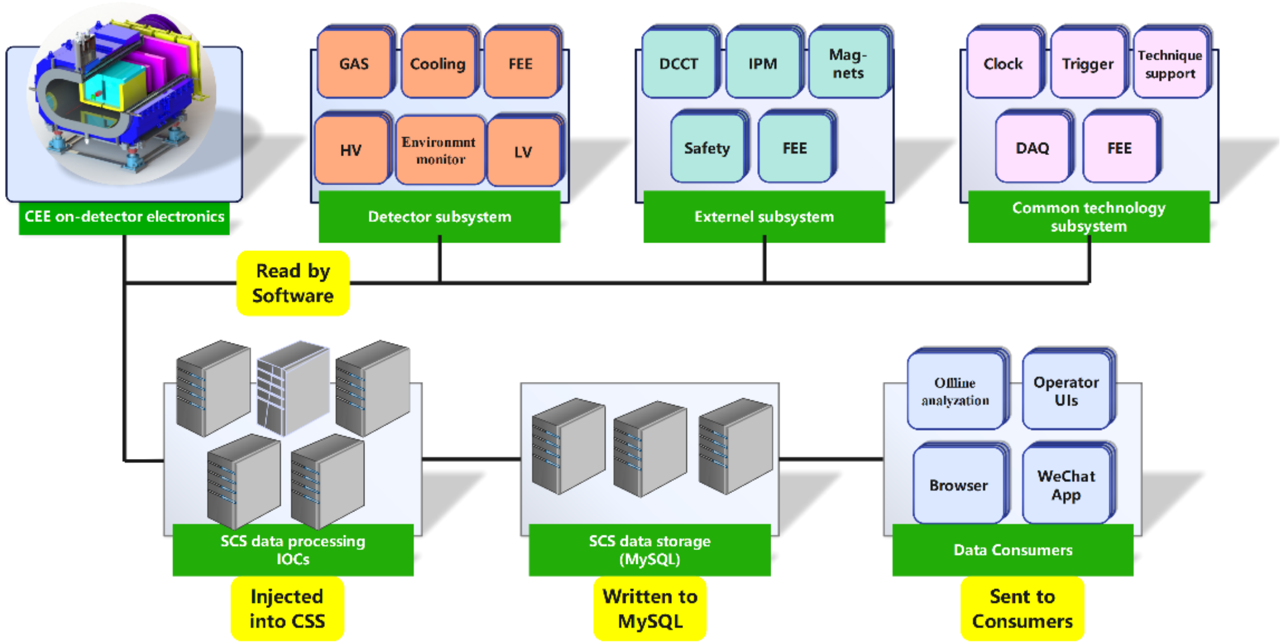
- Each sub-systen has their own IOCs
- Different types of front-end electronics
- High/ low voltages
- Motion control
- Environment variables
- Gas control system
- Water-cooling control sysytem
- ……

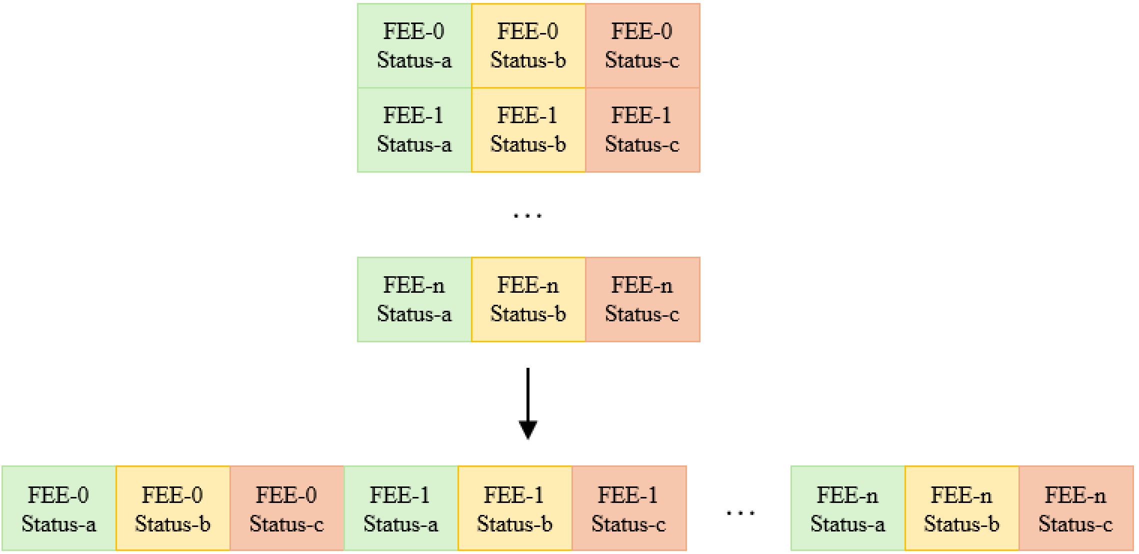




Detector control system （DCS）： Data Flow

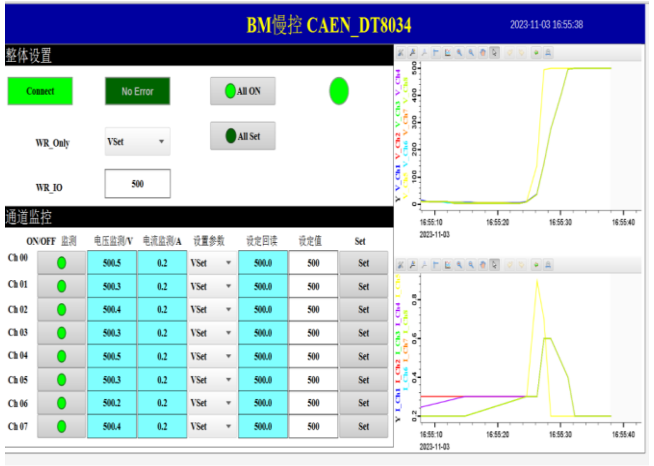
- **Data communication and integration:** CEE DCS communicates with hardware via PVs, integrating them into the IOC of each subsystem.
- **FEE status format:** one-dimensional array, organized according to the FEE pattern. This format is consistent across all detectors.

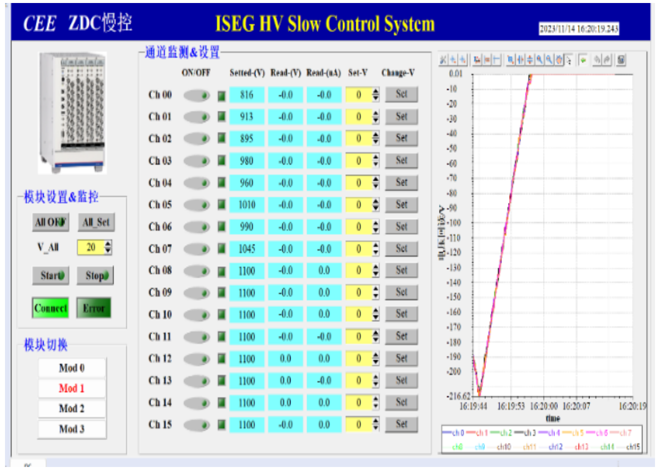


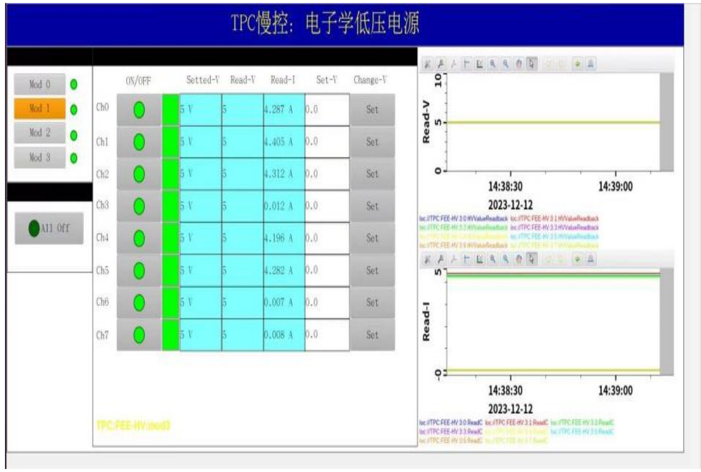


DCS implementation： GUIs

- ➢ **CSS or Phoebus-based**
- ➢ **GUIs development and implementation have been completed**

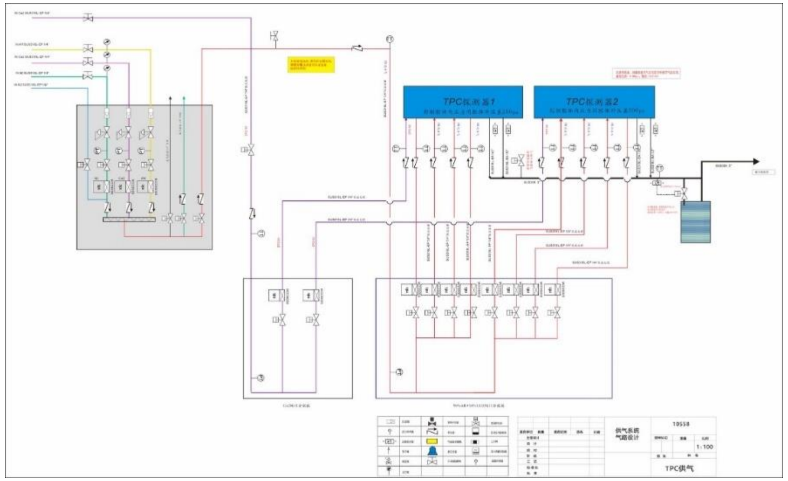


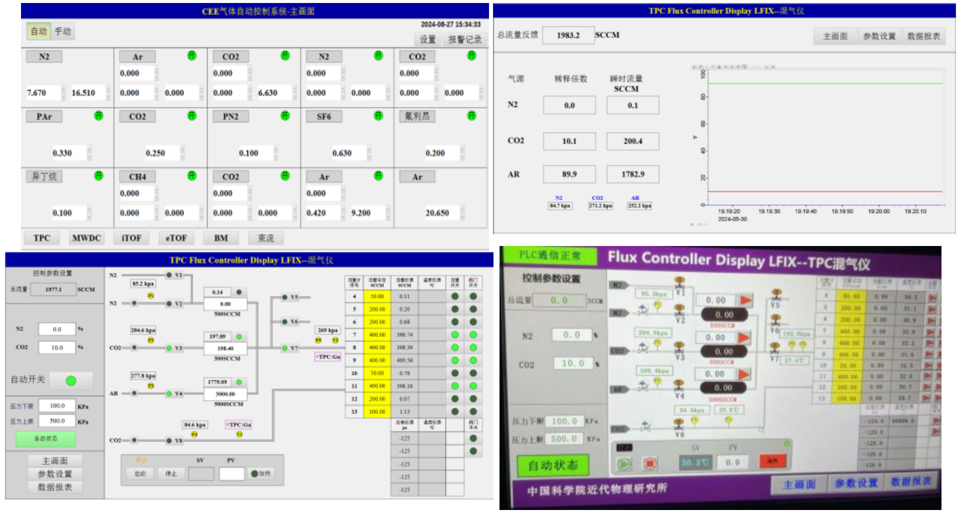




DCS implementation: Gas Control System

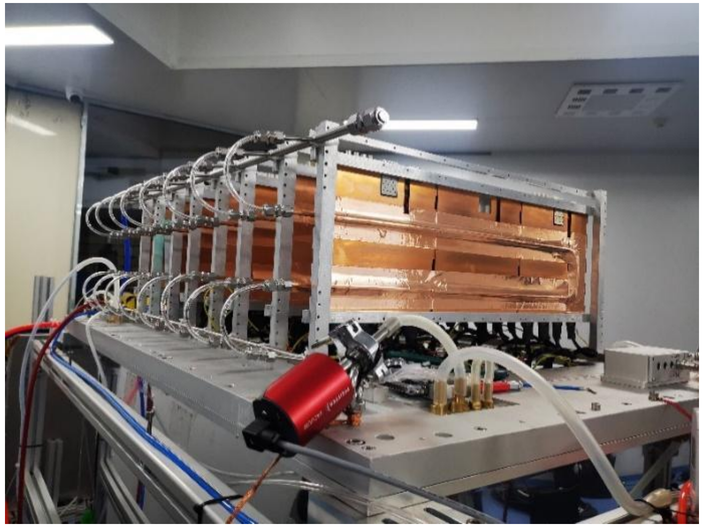
- **Regulating the pressure and composition of the gas**
- **Monitoring gas temperature, O2 and H2O**
- **Data acquisition system based on PLC collects and logs the gas system parameters, controls the purification of the mixture.**
- **A separate alarm and interlock system prevents the detectors from operating under unsafe conditions**

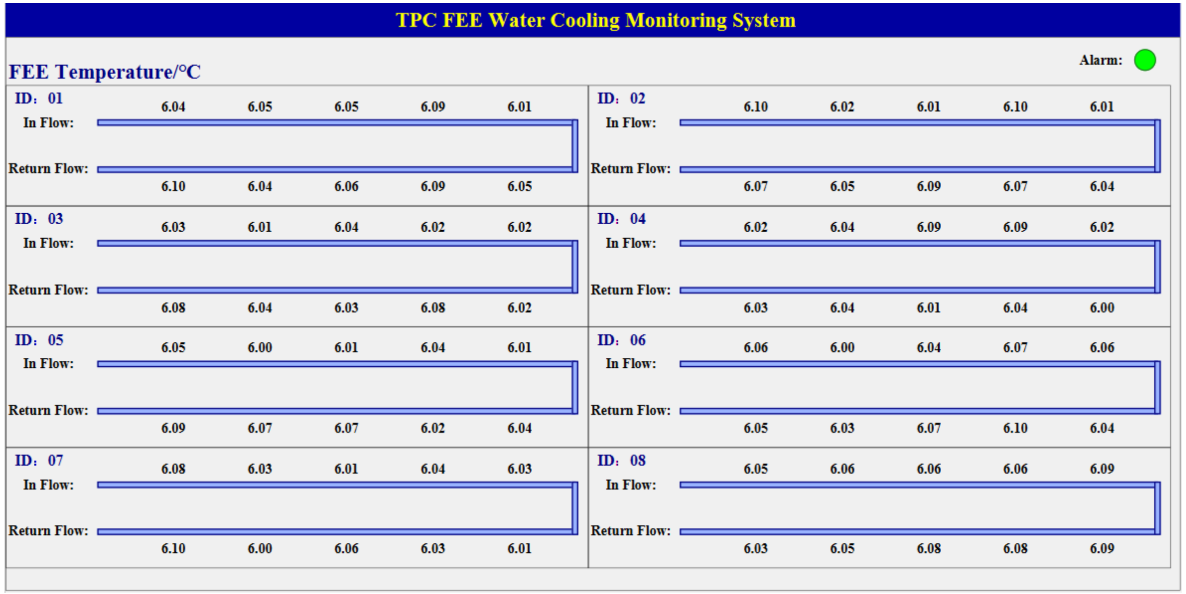


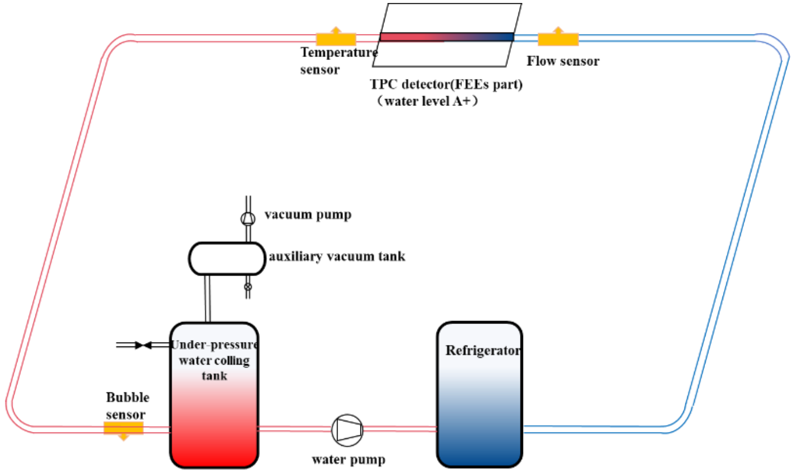


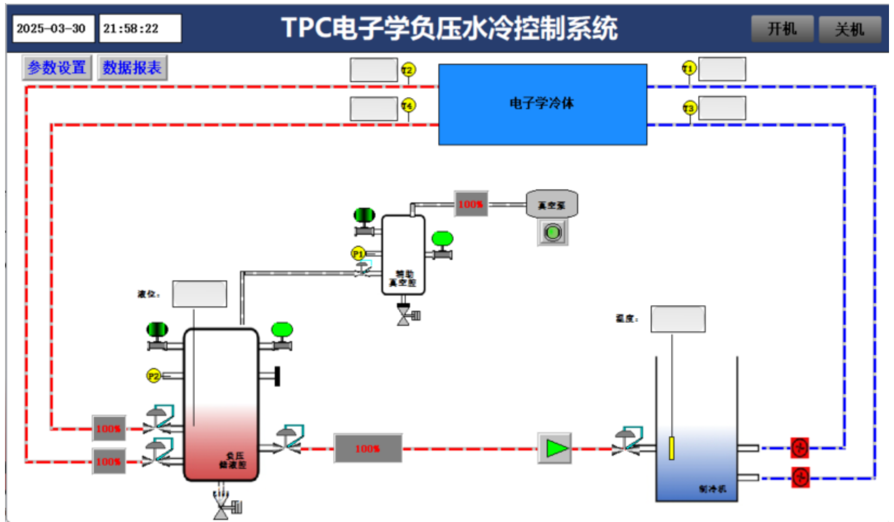
DCS implementation: Water-cooling System

- Water-cooling for Cold bodies of TPC FEEs
- Under-pressure water-cooling(Need to commission)





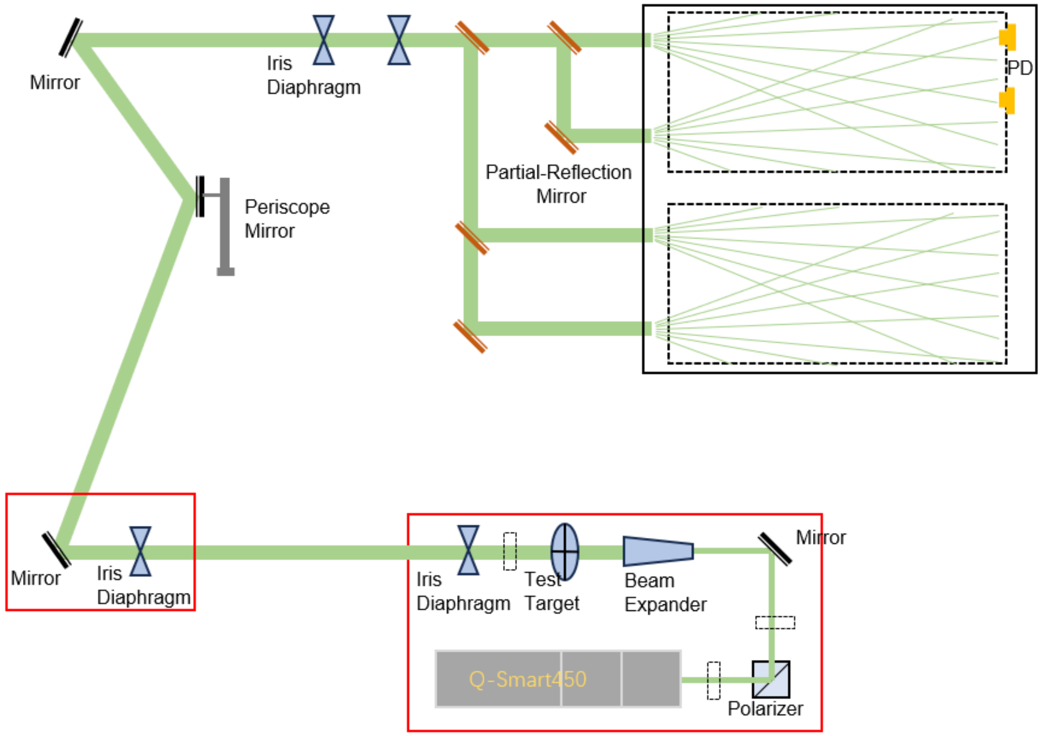


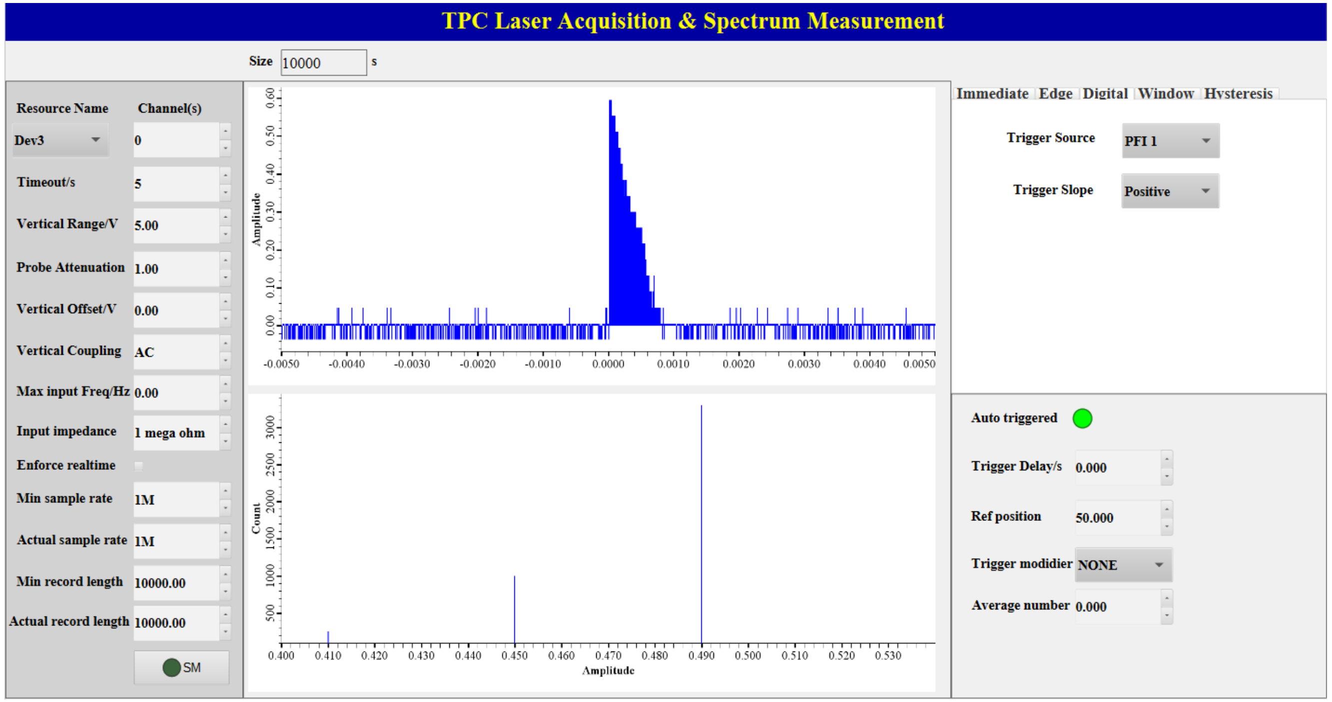


DCS implementation: Laser System

➢ **Beam energy calibration with pulsed ultraviolet beams for TPC**

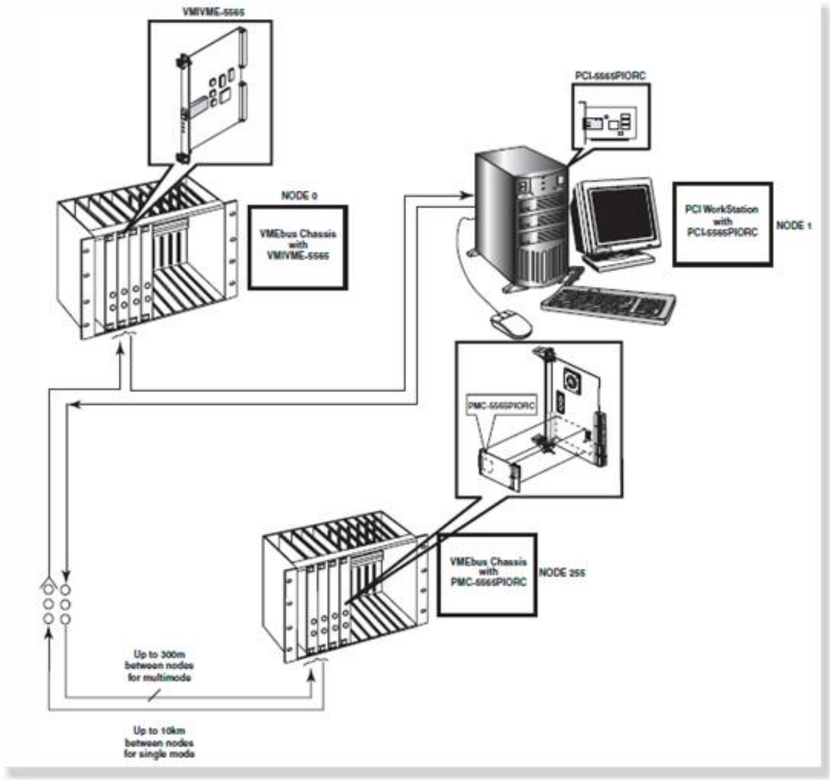
➢ **Monitor the operational state and records beam signals for analyzation**

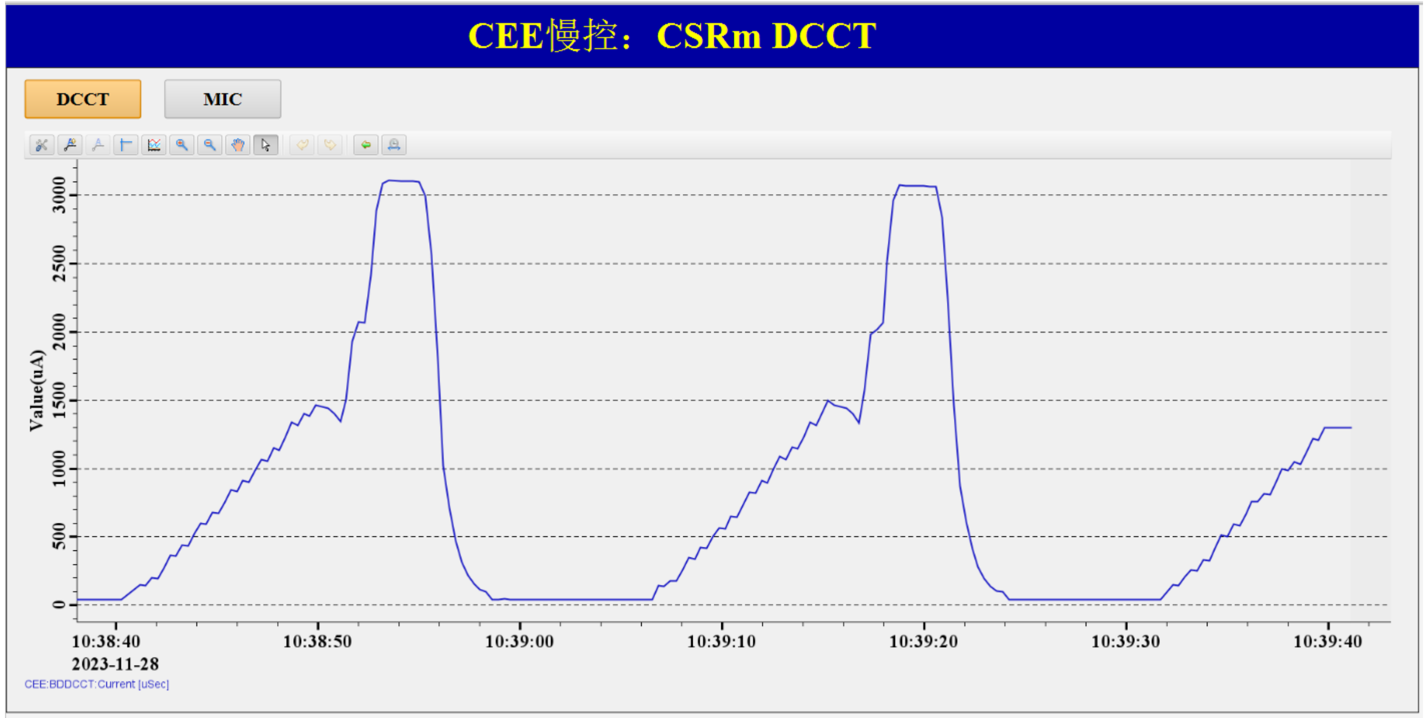




DCS implementation: Reflective Memory Technology

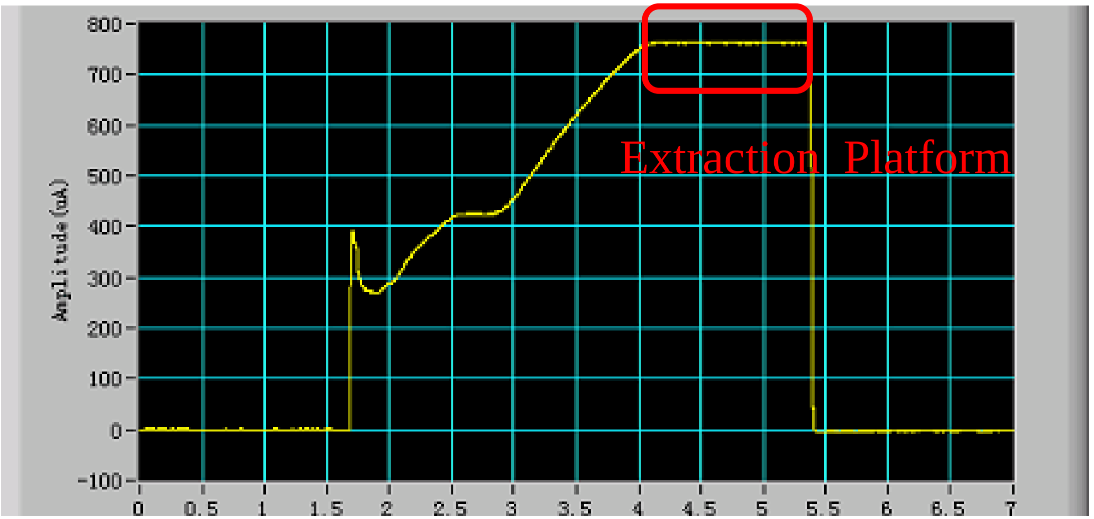
- ➢ **Enable data interaction between the CEE and accelerator networks through optical connection, physical isolation, ensuring CEE network security**
- ➢ **Reflection memory technology for monitoring accelerator parameters: Beam intensity, beam profile…**
- ➢ **Design and implementation of a high real-time, stability, and low-overhead network communication protocol but obsolte**





DCS implementation: Slow Extraction Events parse device

- Parse the accelerator slow extraction events and generate TTL signals related to the accelerator operation cycle for the trigger system, providing trigger signals
- FPGA-based, embedded IOC
- Precise trigger signal generation with adjustable delay (in microseconds)

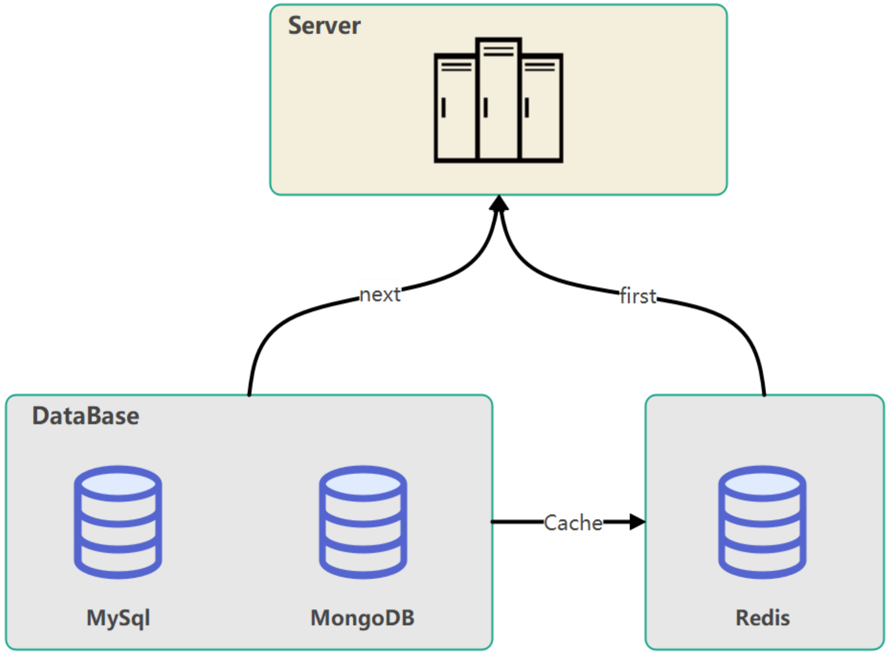


Design and implementation of CEE-DCS

--Databse

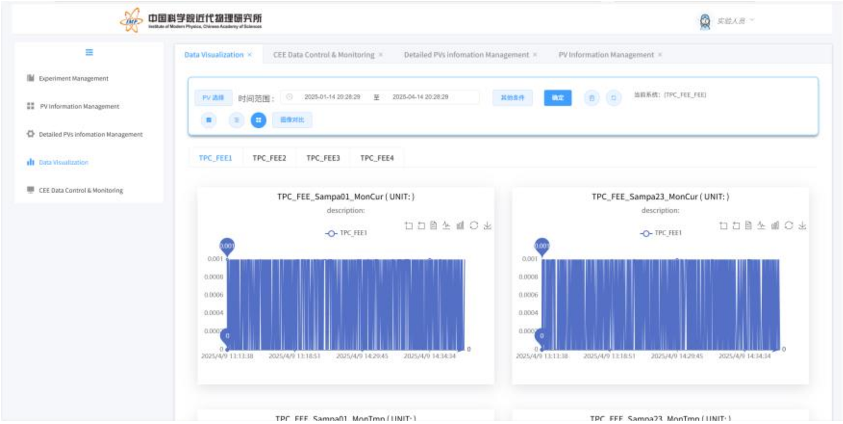
Database design & Implementation

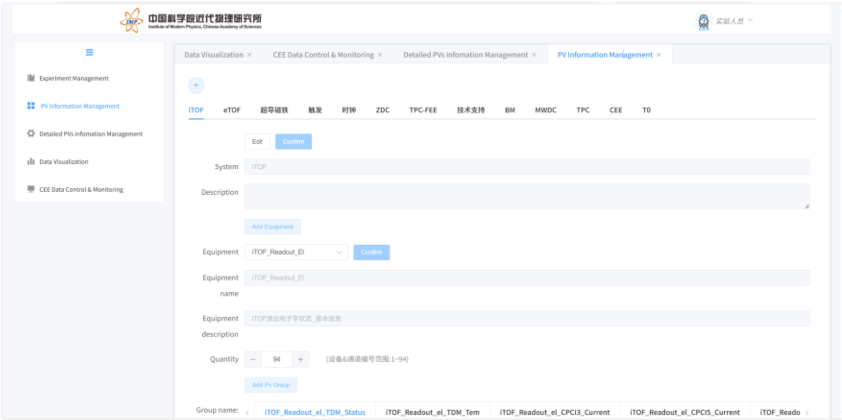
- **Hybrid architecture**
- **MySQL** is used for system data, meta data
- **Redis database**
- **MongoDB** for time-series data
- **Web-based** GUIs

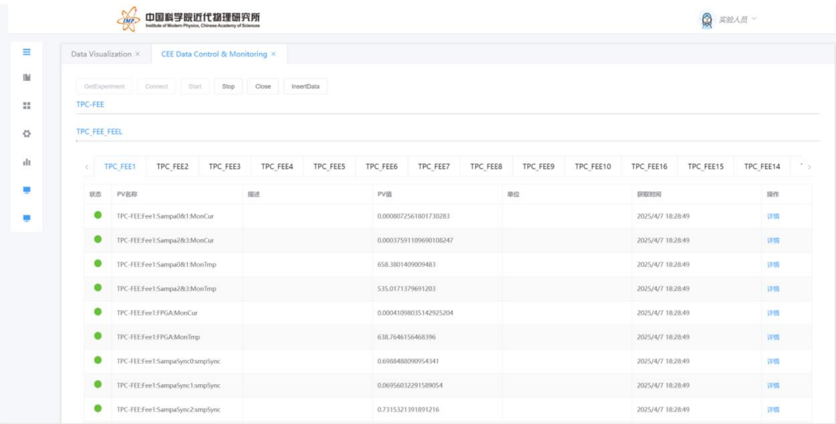


Database design & Implementation: Database GUI

- MySQL
- System Login
- Device, table management
- Data load, data analysis, data export, data selection



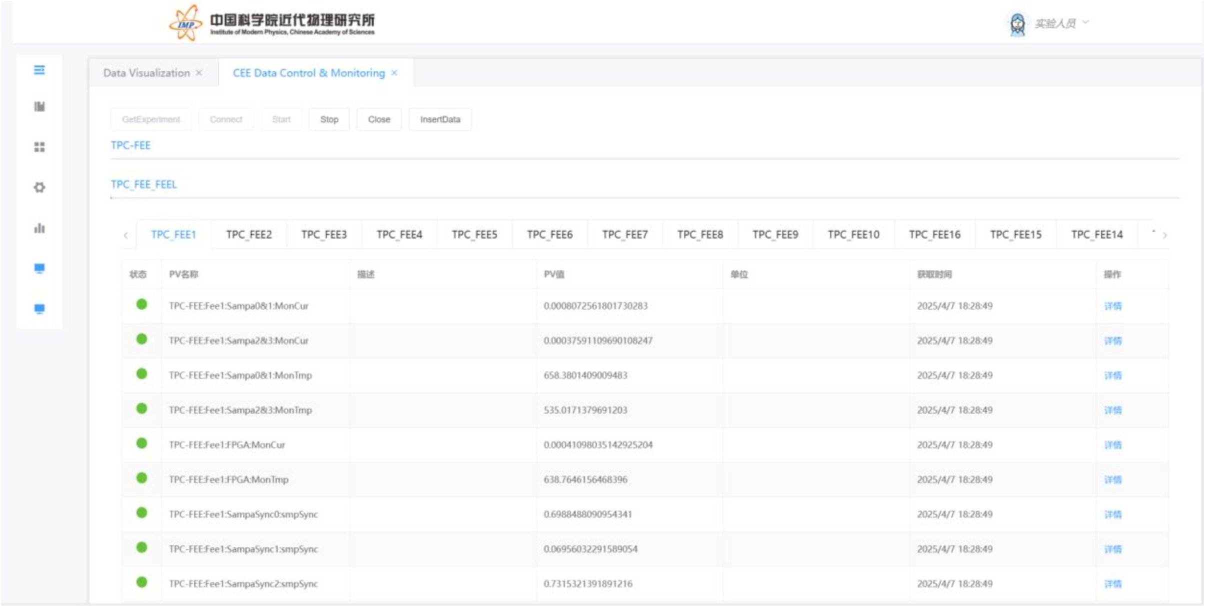




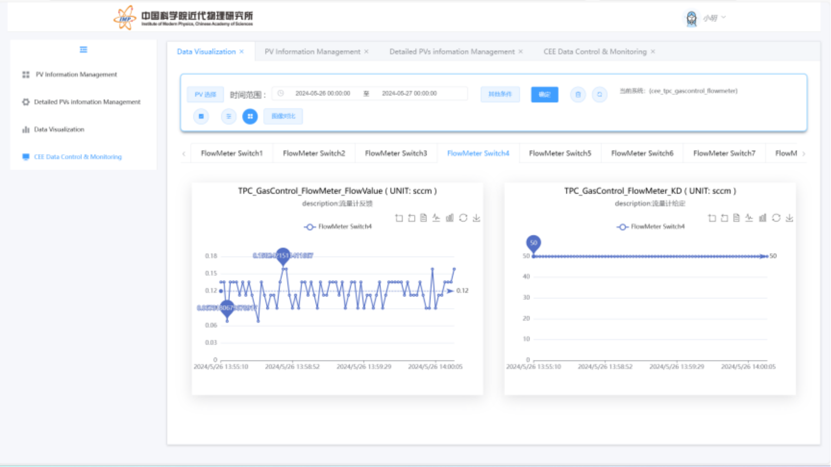
Database operation GUIs specillay designed for users

Database design & Implementation: Web-based Data Visualization

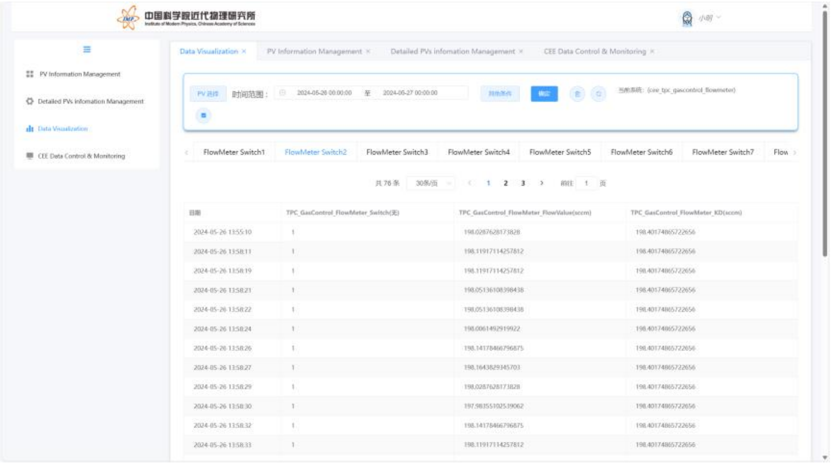
- **PV Variable Monitoring Interface:**



- **Data Visualization Interface (chart):**



- **Data Visualization Interface (lists):**

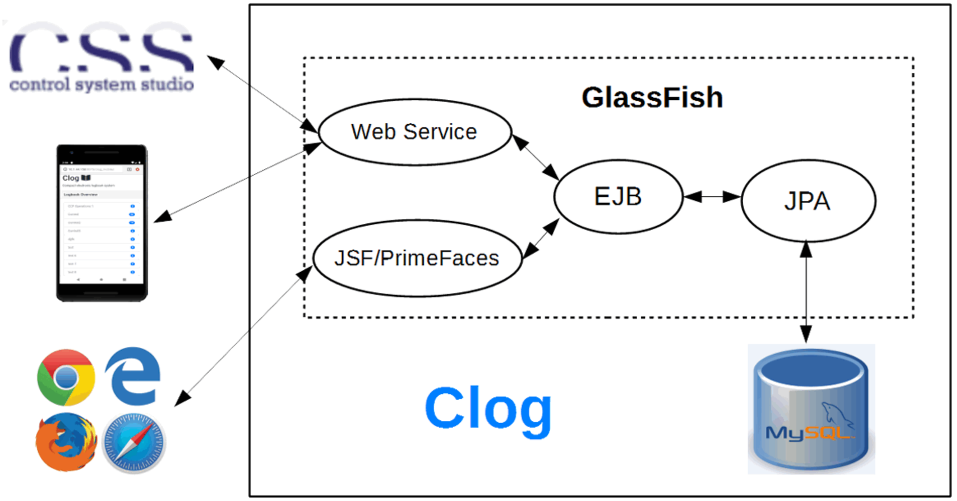


Both monitoring interfaces and database visualization interfaces adhere to minimalist design principles, optimized for experimental personnel's operational efficiency and data accessibility.

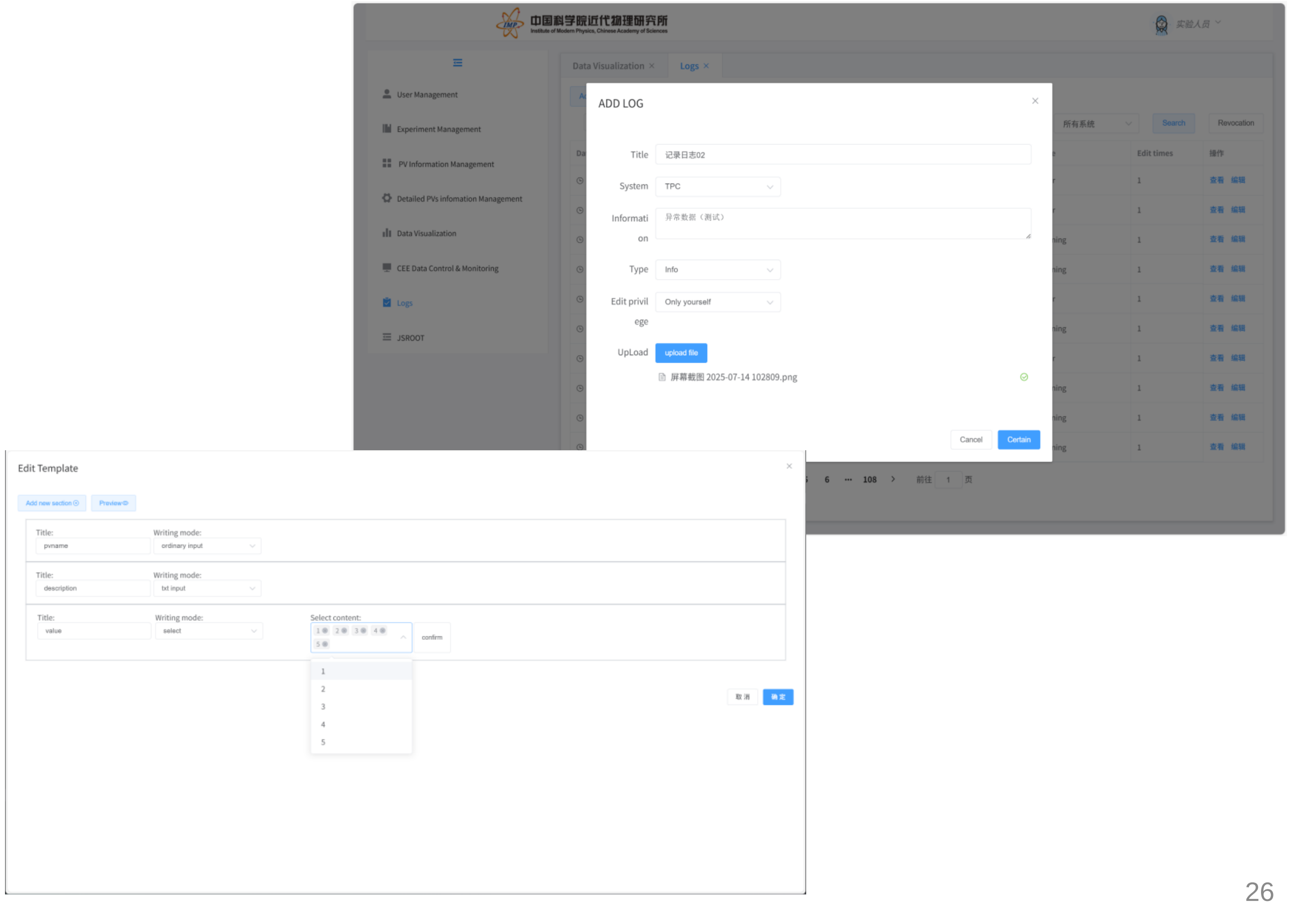
Electronic logbook

- Enables digital recording, secure storage, intelligent analysis, and collaboration tools
- Enhances efficiency and supporting data-driven decisions
- **Developed by our group: data,alarming, video,pictures and so on**

Elog	Olog
Monolithic architecture	Microservices modular design



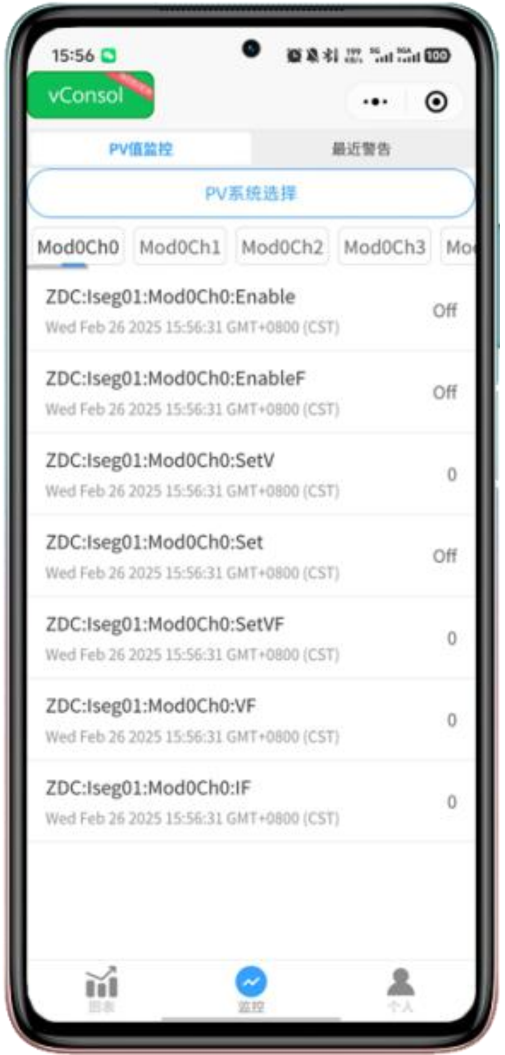
Coutercy by IHEP



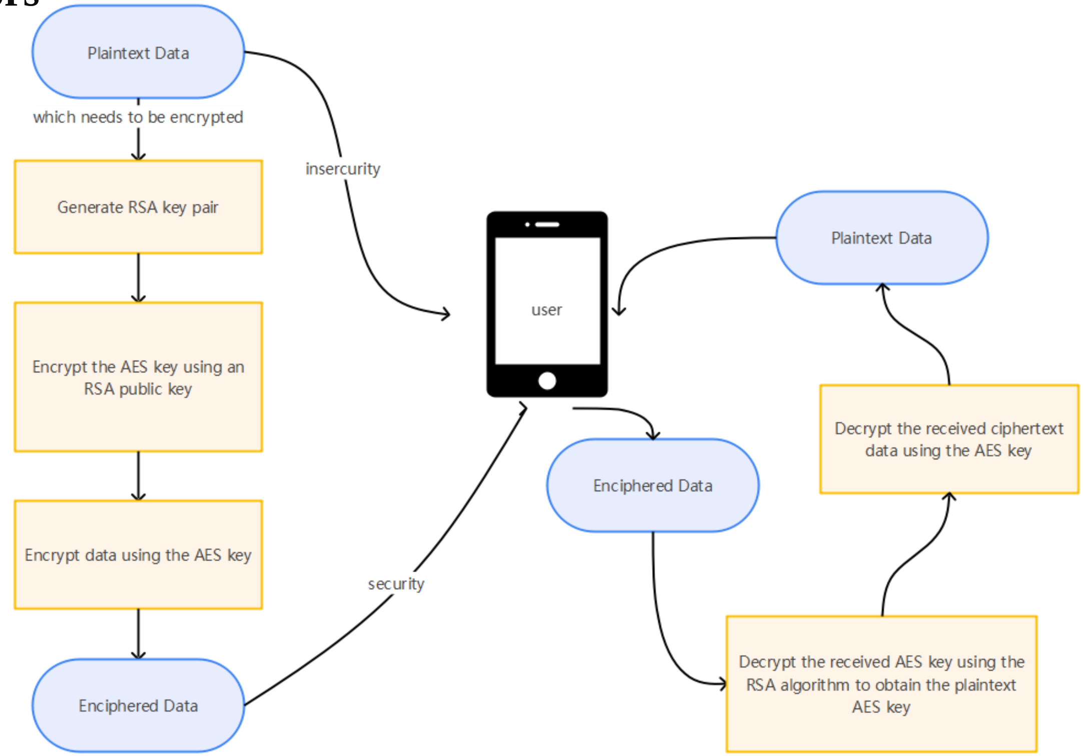
Database design & Implementation: Mobile APP/WeChat Mini Program

Mobile APP/WeChat Mini Program Monitoring Interface

push critical warning or error messages to system administrators



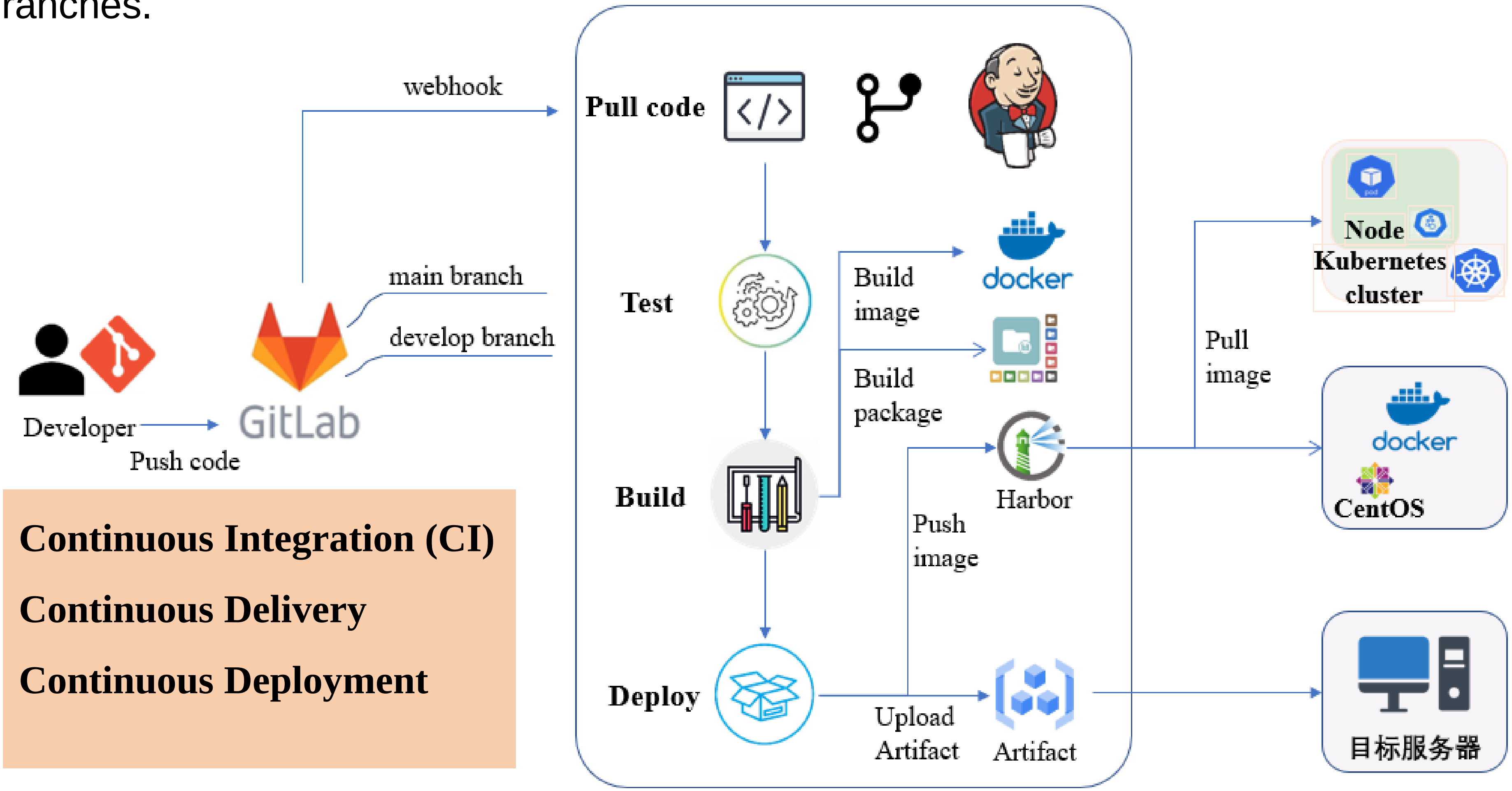
Data Encryption:



Hybrid encryption scheme **employs RSA to encrypt the AES symmetric key** followed by AES directly encrypting the transmission payload.

CI/CD: Workflow diagram

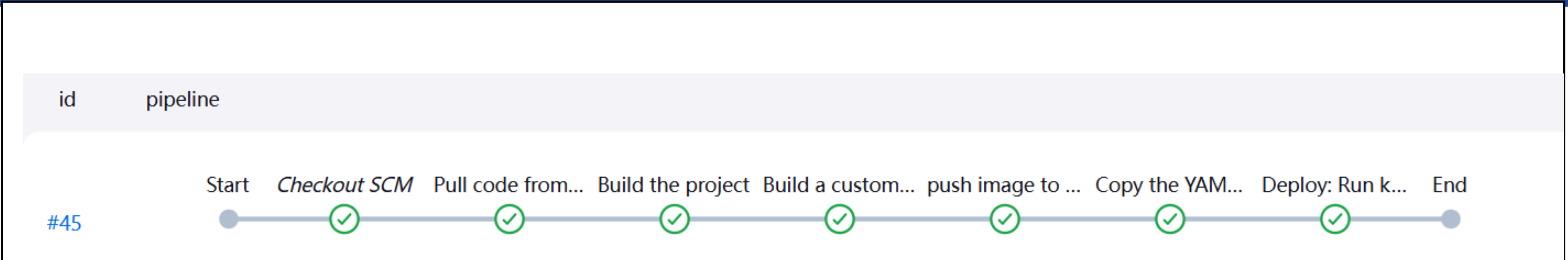
- A method that introduces automation during the application development phase to continuously deliver applications to customers
- Developers submit code to GitLab, triggering automated builds; reviewers assess based on build/test results and merge compliant branches.



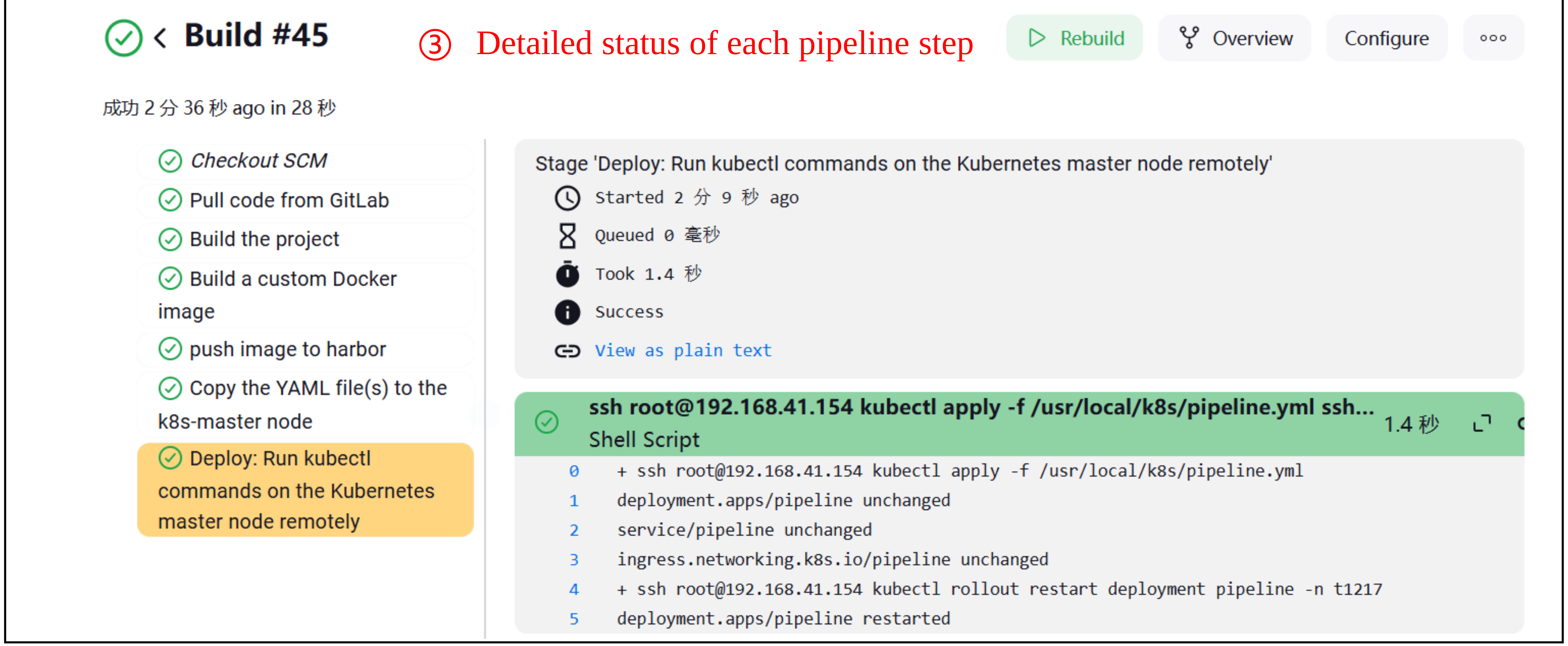
CI/CD workflow diagram

CI/CD: Application Practices

① Trigger a build

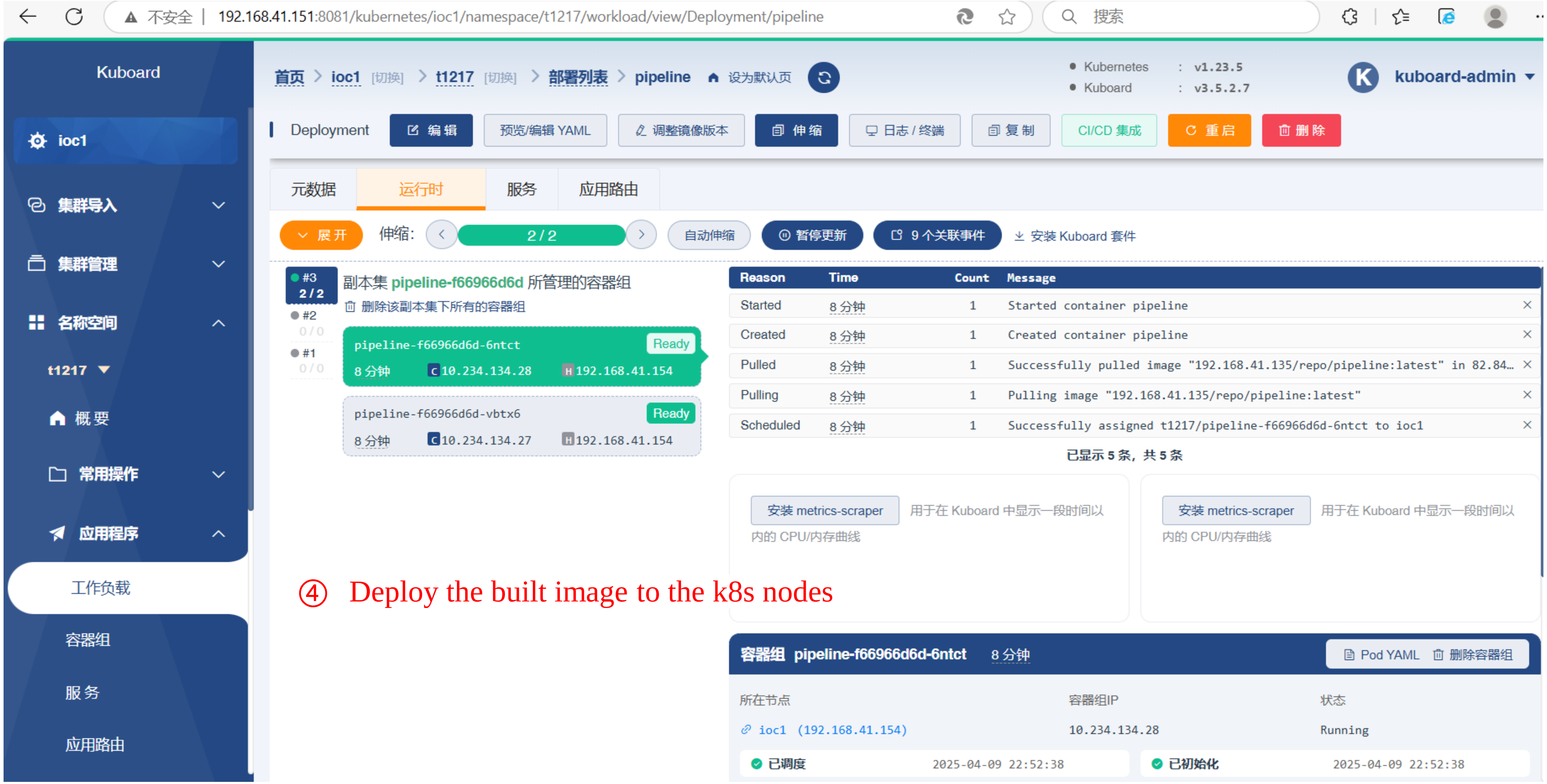


② Pipeline



③ Detailed status of each pipeline step

CI/CD: Application Practices

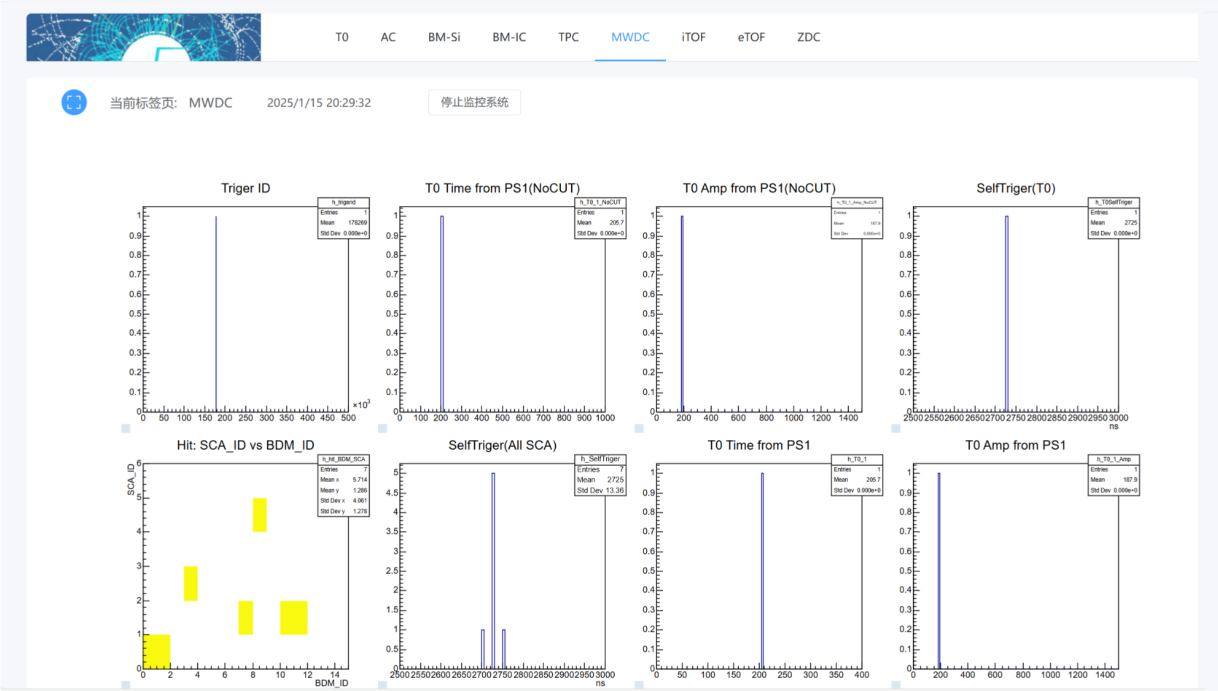


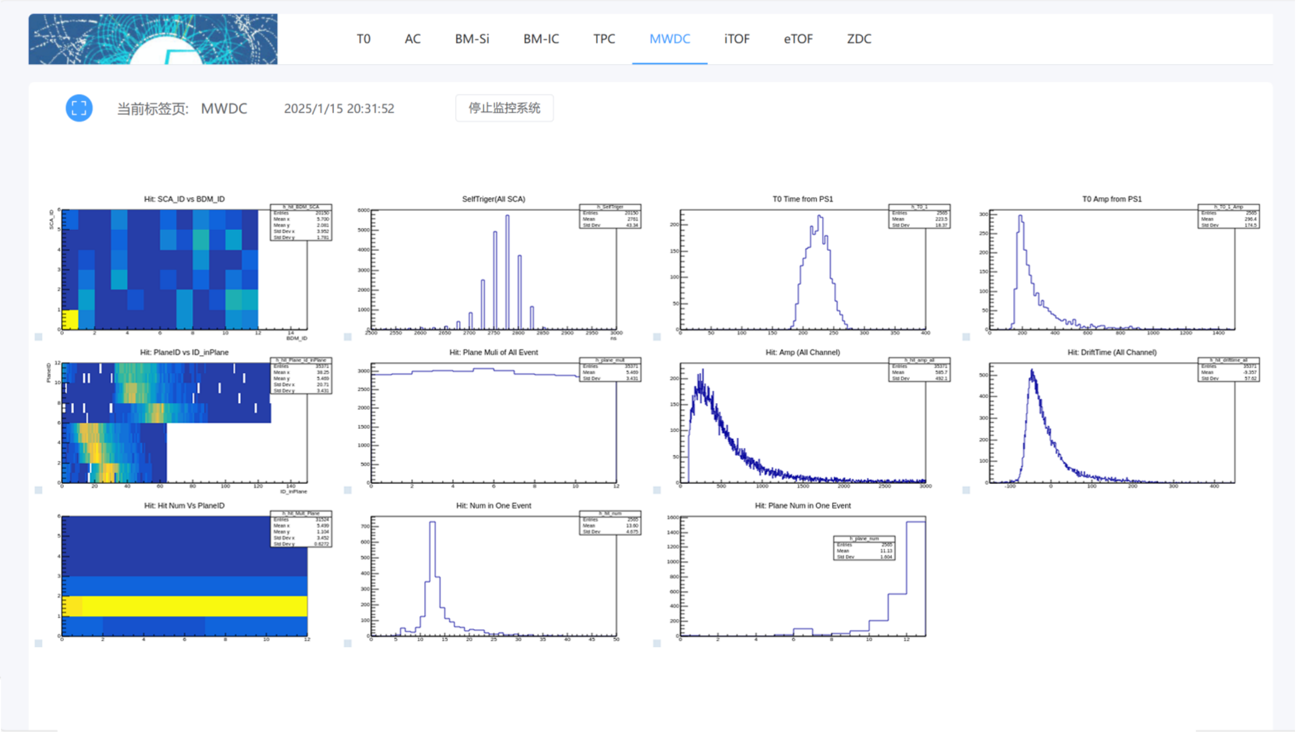
④ Deploy the built image to the k8s nodes

Database Update： RooT-Web Implementation

JSROOT Data Monitoring Interface

- Real-time monitoring(online-data) and graphical rendering of **ROOT data** via **web-based platforms**
- **Automated screenshot capture and archival** upon triggering of data-driven alert thresholds

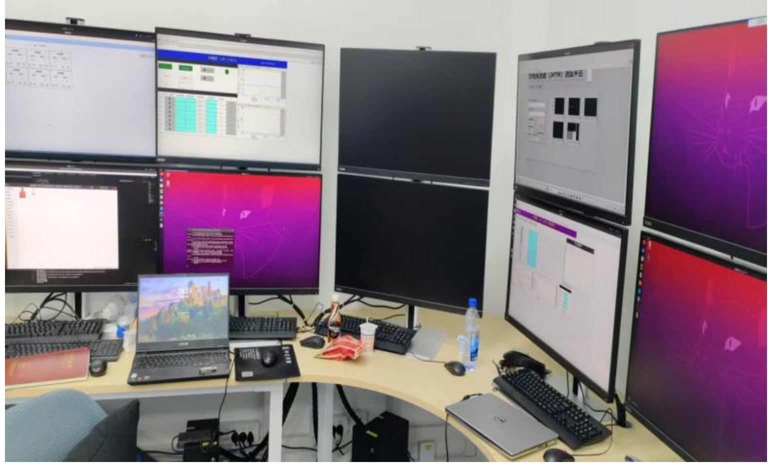


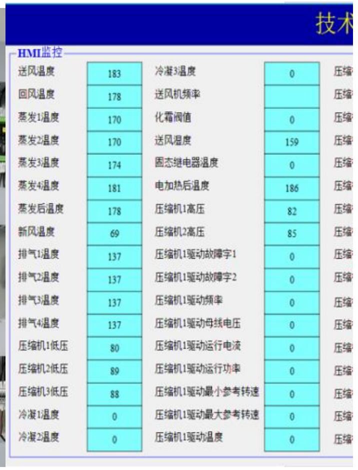


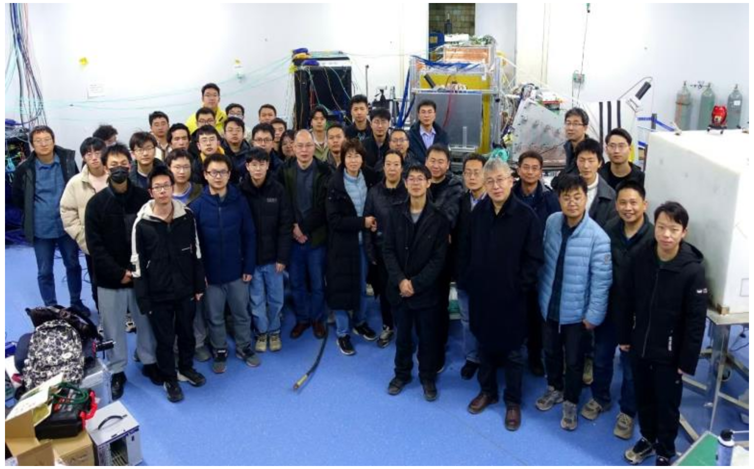
MWDC measurement results with beam

DCS implementation： software tests

➢ **The system has completed the unit tests, integration tests and field tests with beam**







Conclusion

- All the above modules have been developed and tested with beam
- It will be tested with all the other sub-systems in October with beam
- Scalibality

Further system validation

Thank you