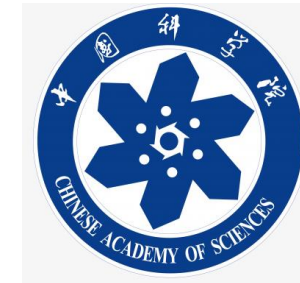




中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences



Detector Control System for CEE

Min LI, on behalf of Detector Control Team

Institute of Modern Physics (IMP)

Chongqing 2025.09.17

Contents

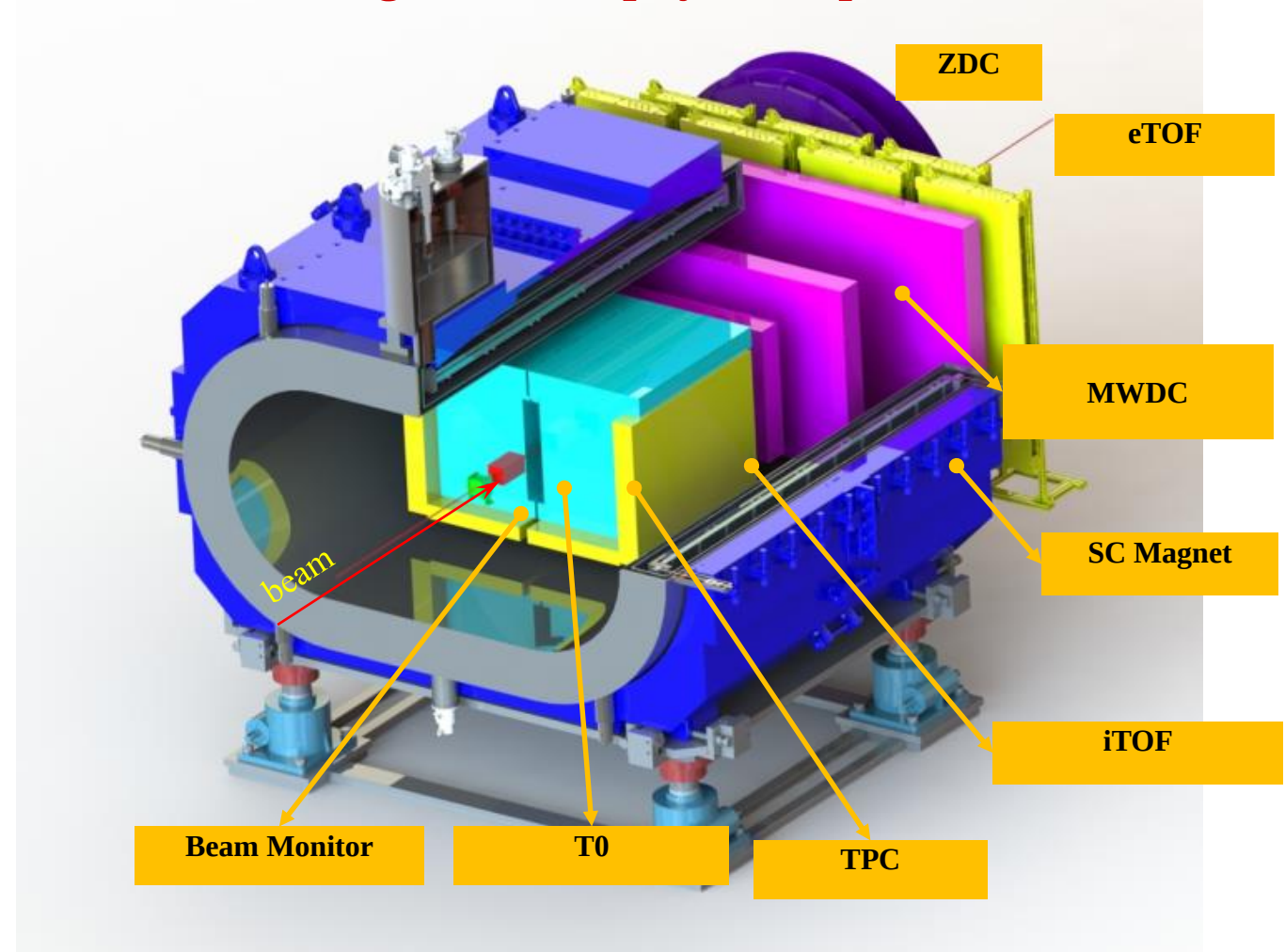
- **Introduction of CEE & DCS**
- **Design and implementation of CEE-DCS**
 - **Network construction**
 - **Software architecture:EPICS**
 - **Database**
 - **Electronics logbook**
 - **Wechat**
- **Update and optimization**
- **Conclusion**

- *Introduction of CEE & DCS*
- **Design and implementation of CEE-DCS**
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CEE: CSR External-Target Experiment, it will be the first-large nuclear physics experimental device at HIRFL-CSR, heavy-ion collisions

Physical goals

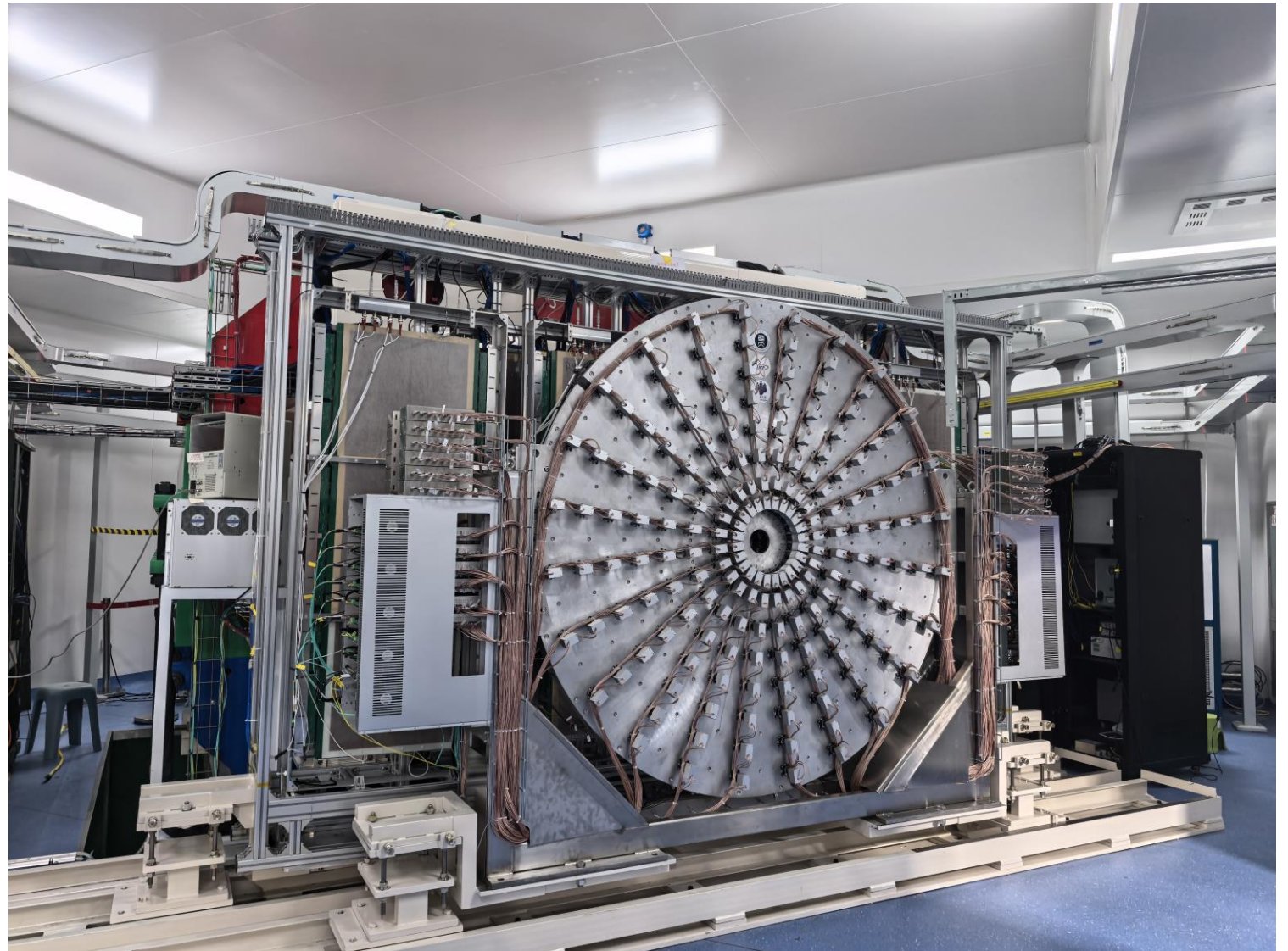
- To study the bulk properties of strongly interacting matter
- To study equation of state high baryon density region
- To understand the quantum chromodynamics (QCD) phase diagram
- Budget: 74,5241 million



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
-

Contents

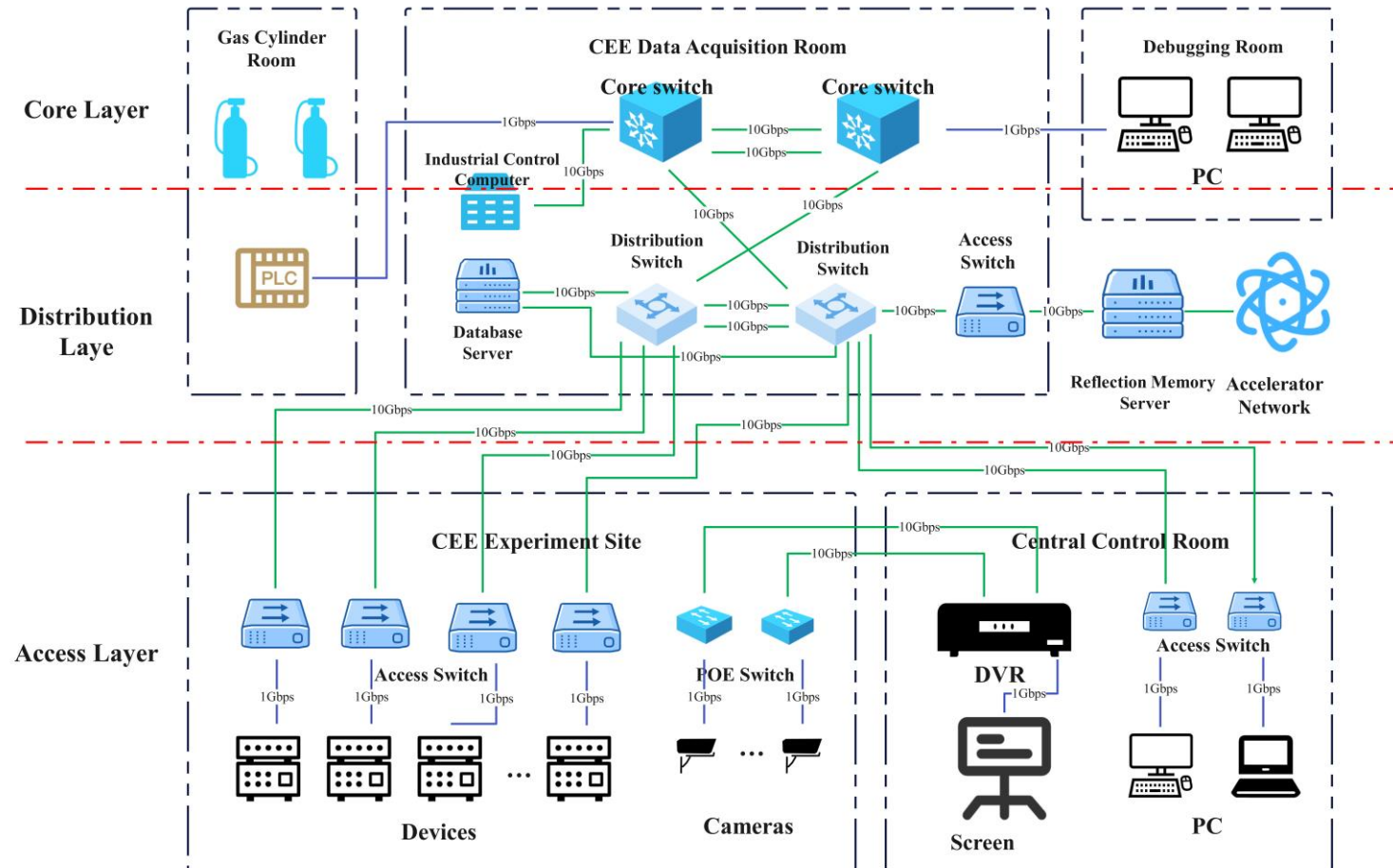
- Introduction of CEE & DCS
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Design and implementation of CEE-DCS

--Network construction

Detector control system (DCS) : Network Construction

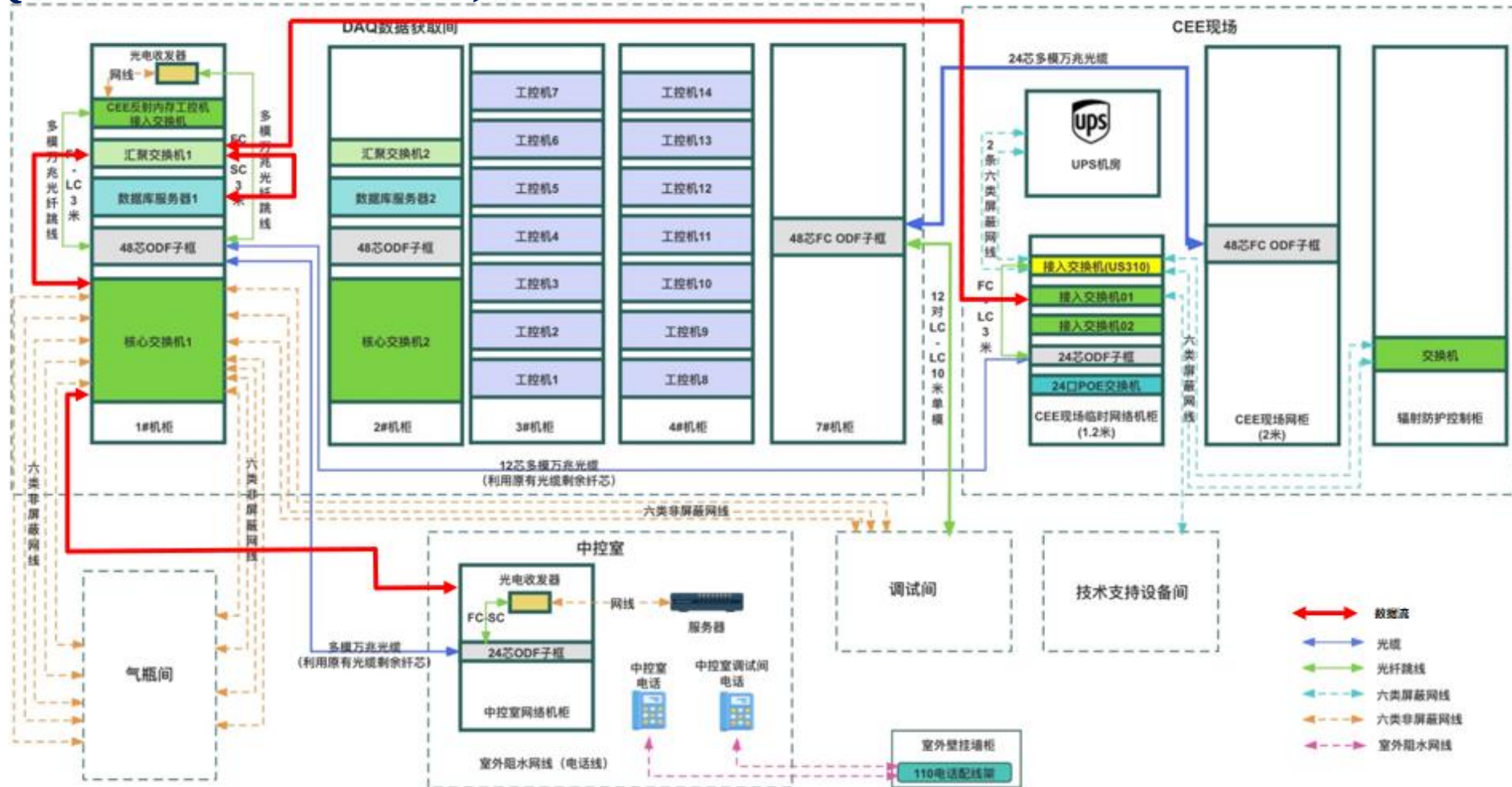
- **Three-layer network architecture design:** Core Layer , Distribution Layer , Access Layer
- **Achieving data communication between different networks:** CEE network, accelerator network, surveillance video network, DAQ data transmission network, office network.



- 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
- **Achieving data communication between different networks:** CEE network, accelerator network, surveillance video network, DAQ data transmission network, office network.

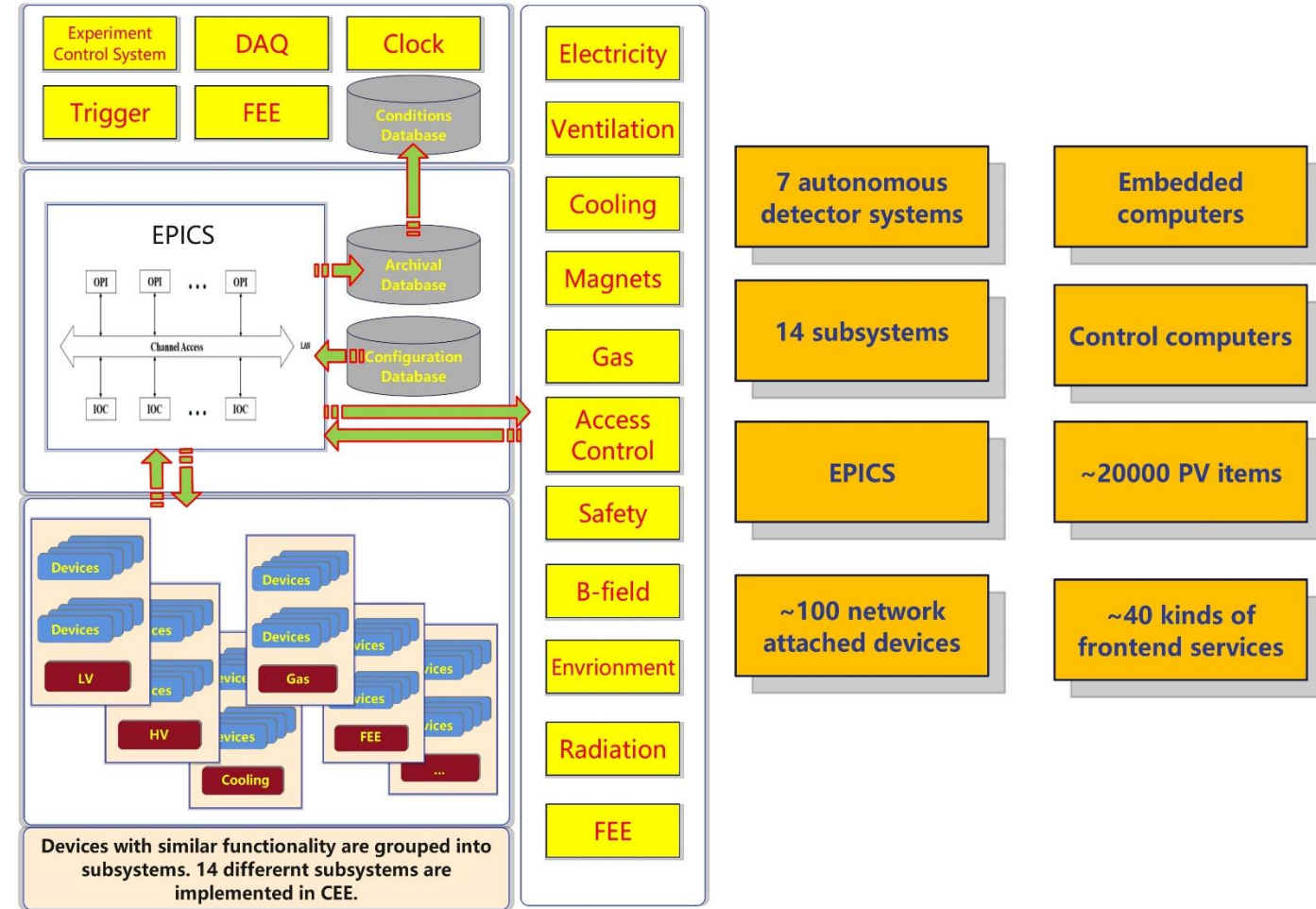
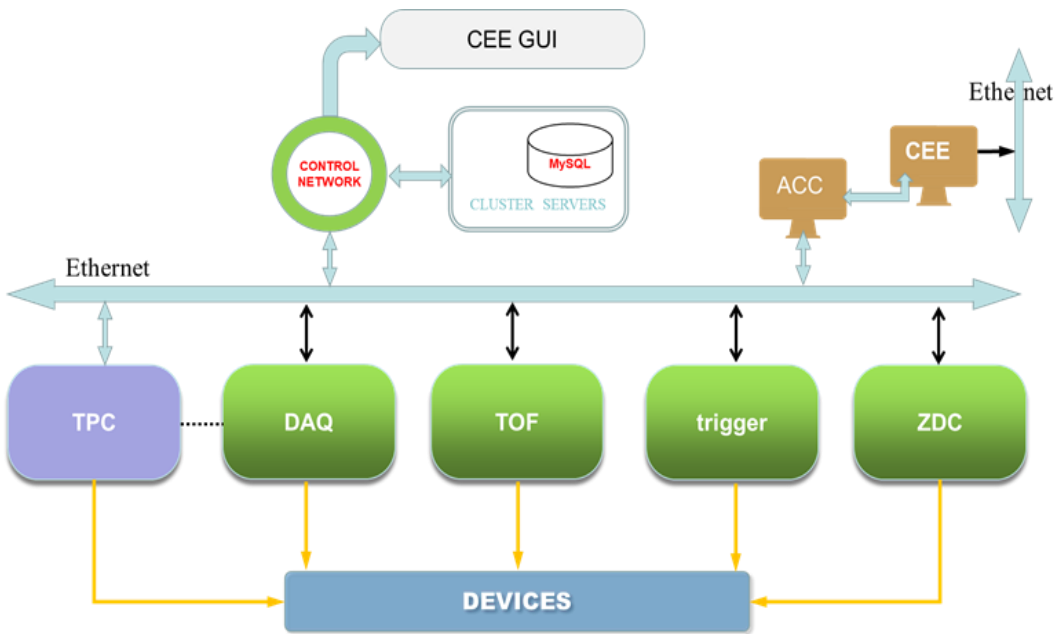


Design and implementation of CEE-DCS

--EPICS Architecture

DCS context and scale

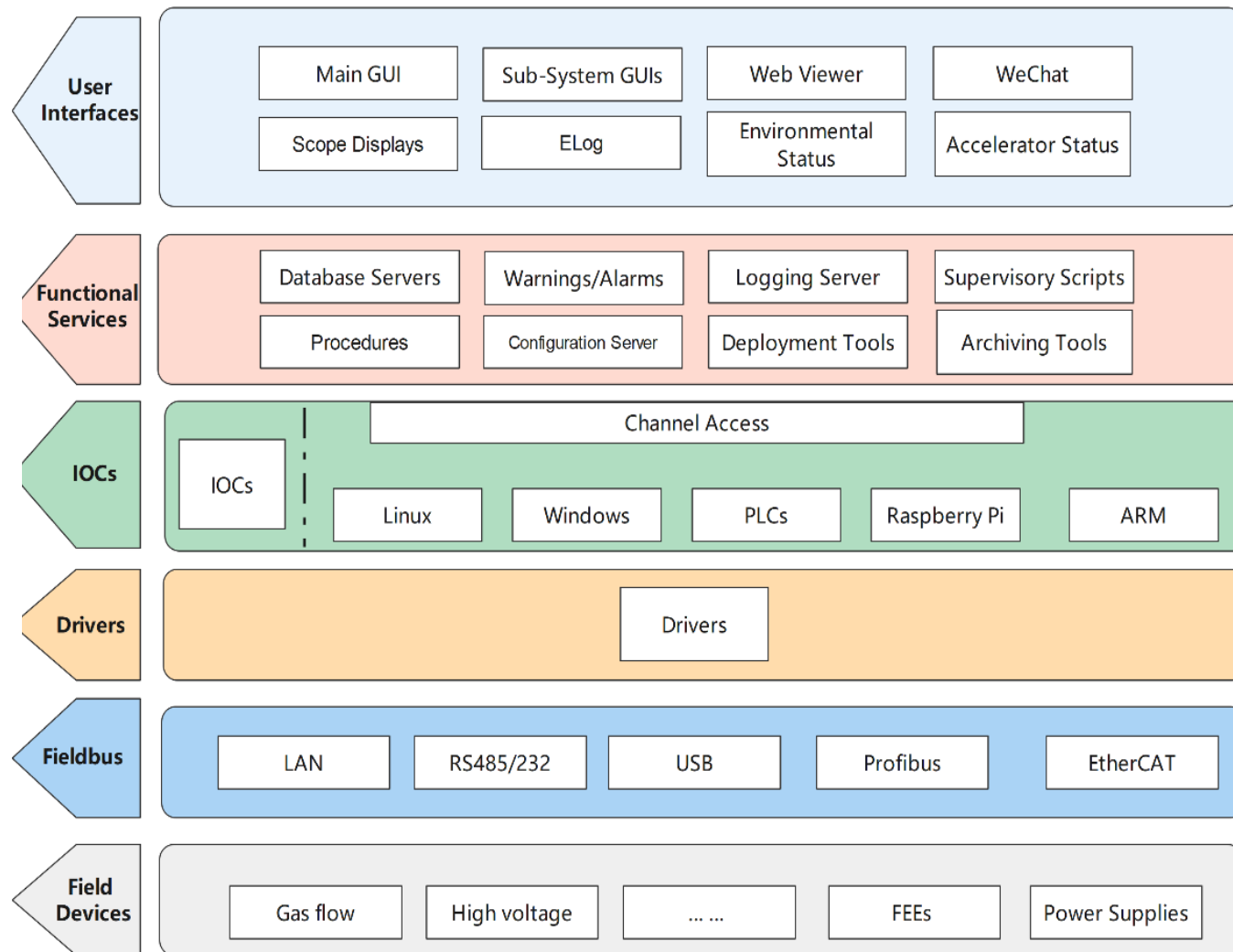
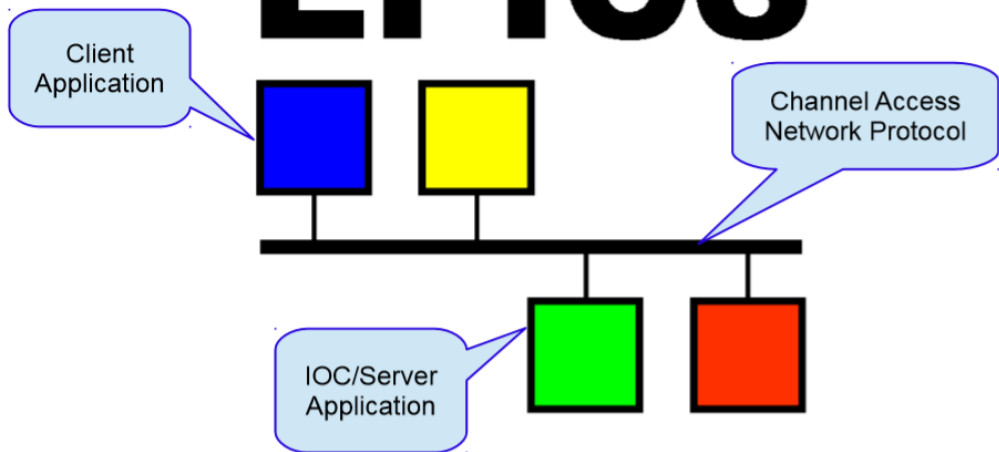
- 3-tiers hardware architecture
- **EPICS-based** architecture
- Open-source software



Software Architecture

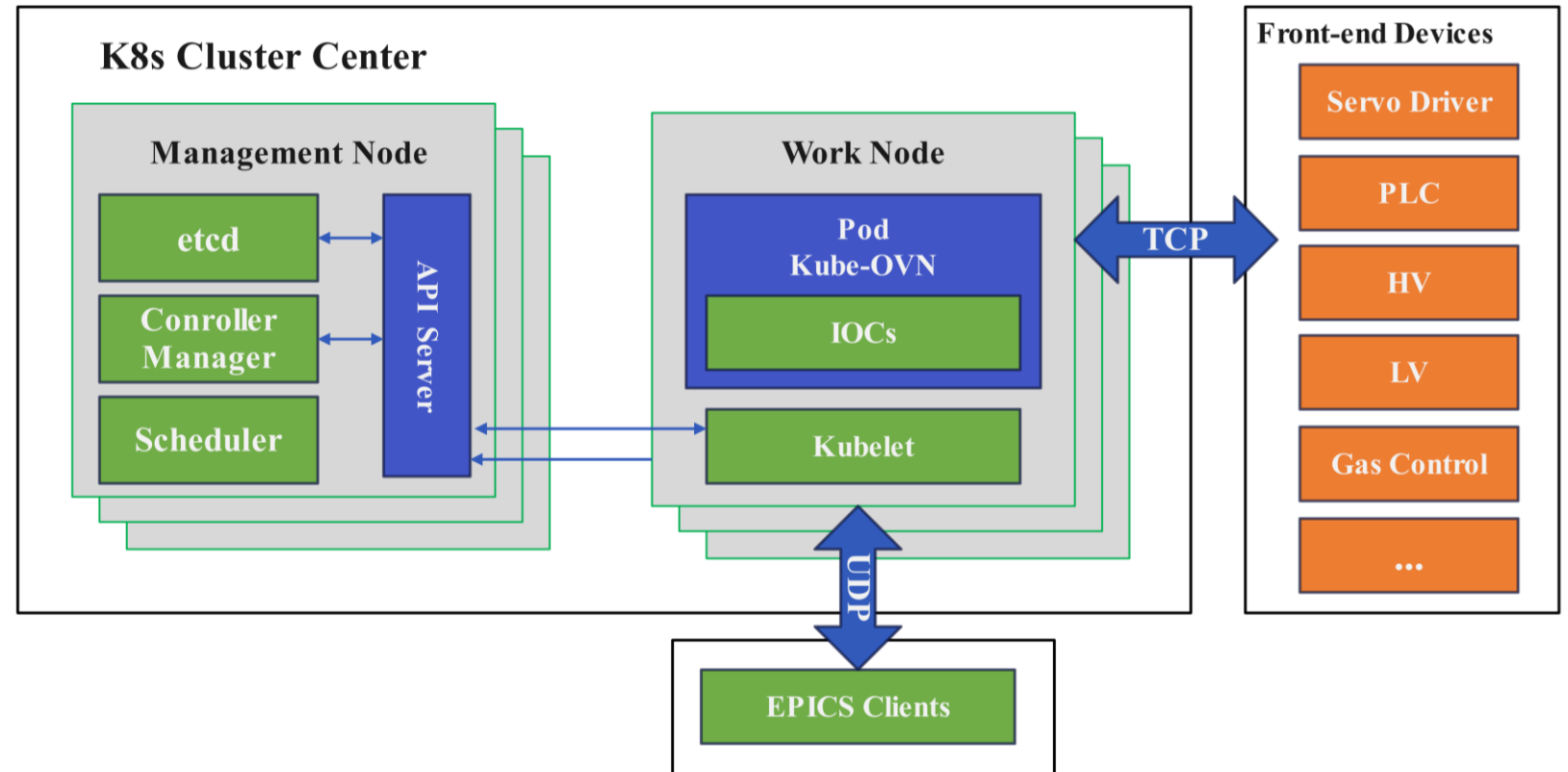
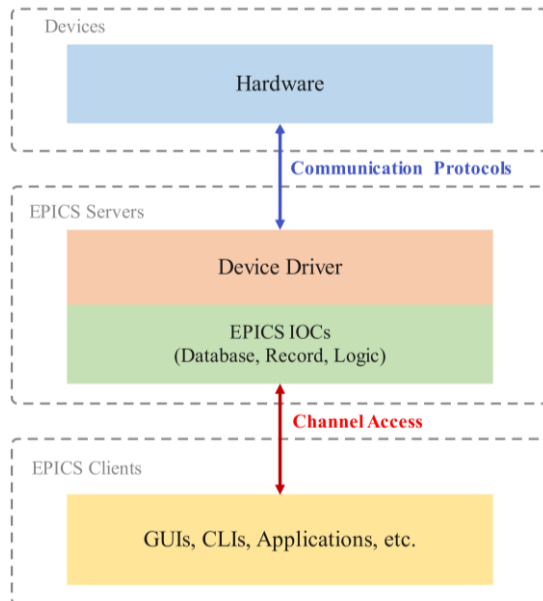


EPICS



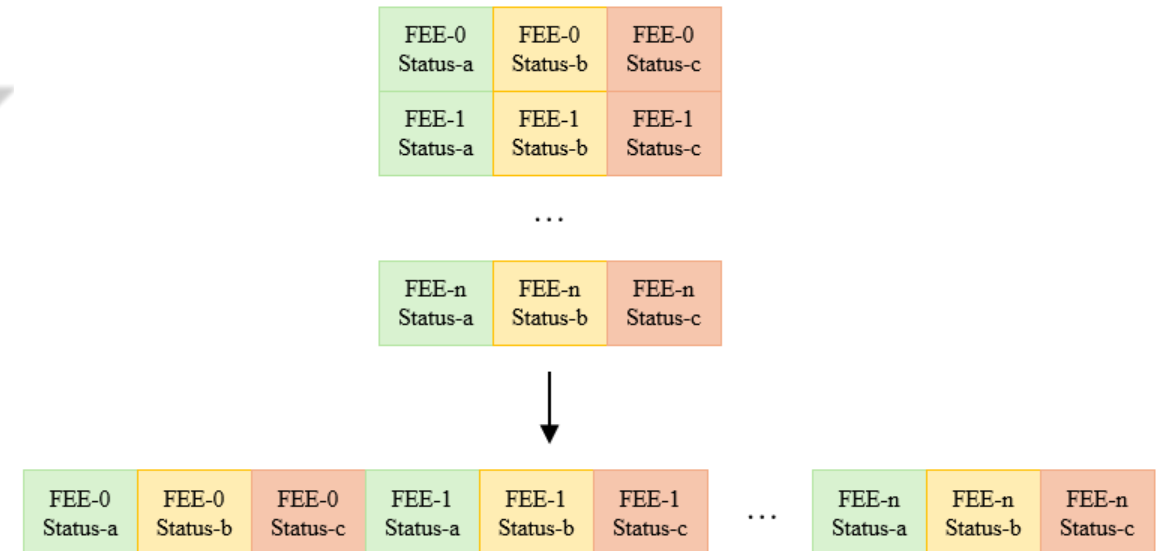
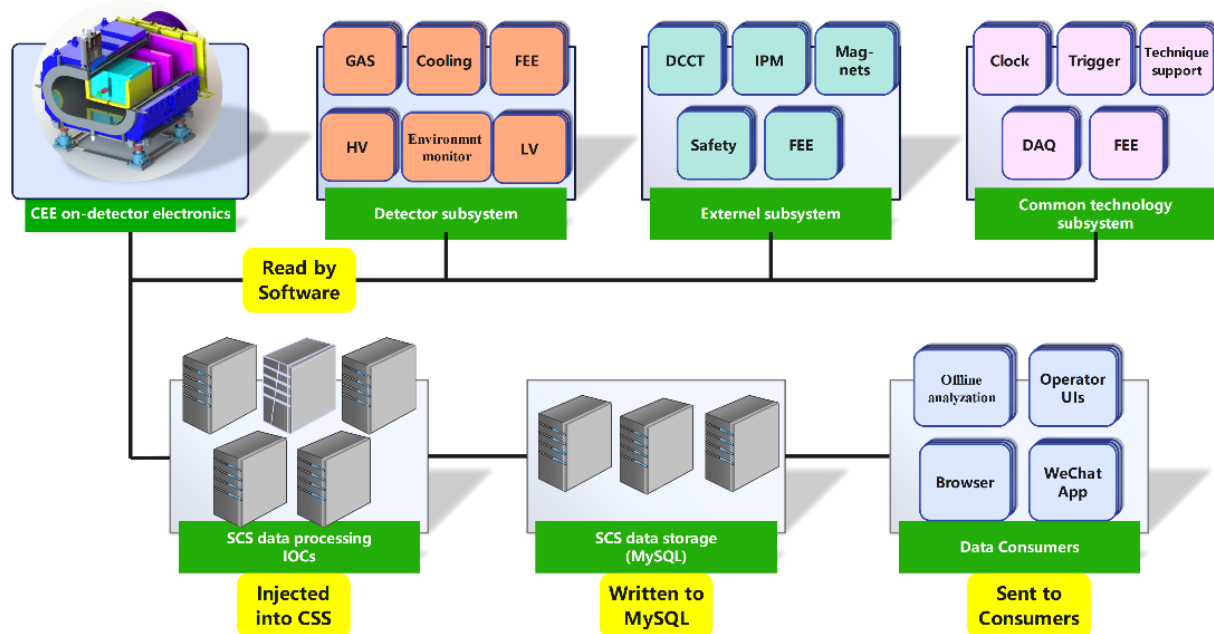
DCS implementation: IOCs

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



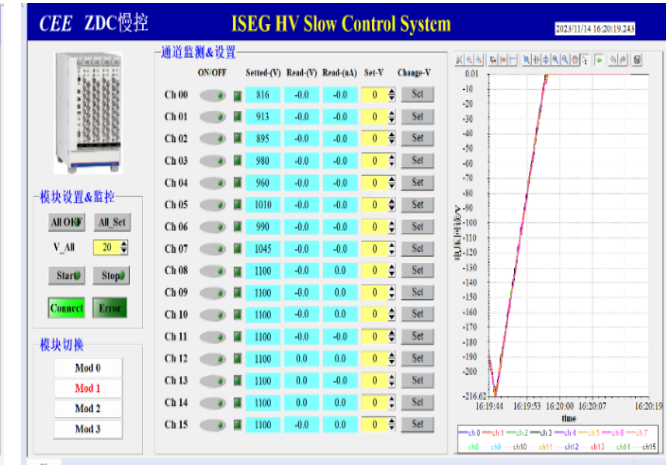
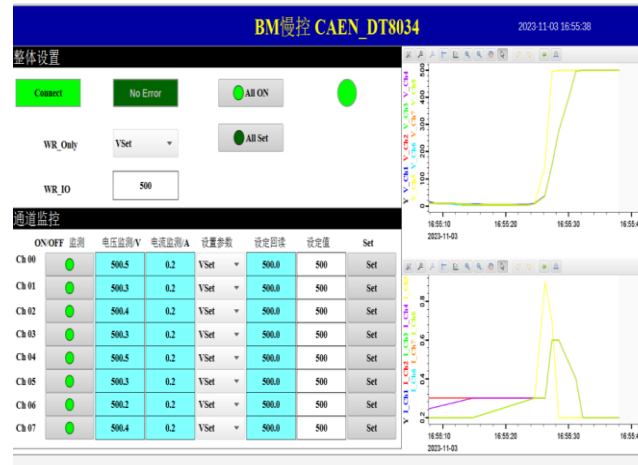
Detector control system (DCS) : Data Flow

- **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

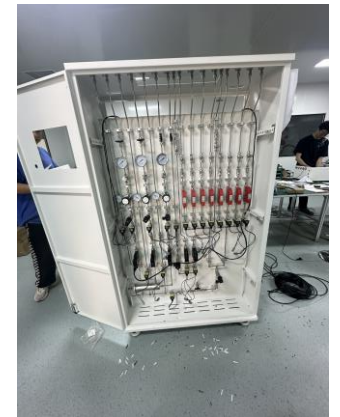
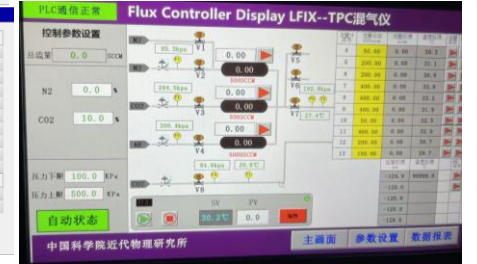
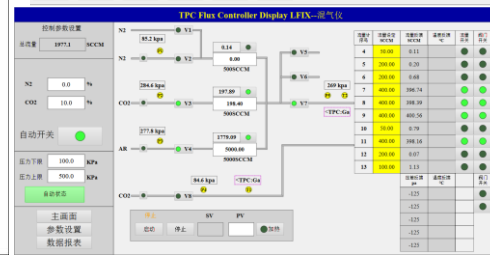
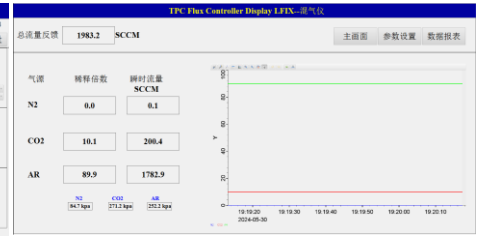
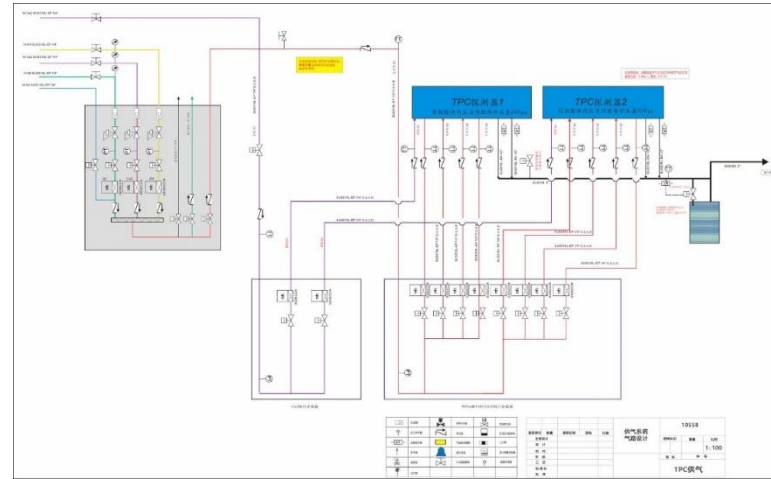
- CSS or Phoebus-based
- GUIs development and implementation have been completed



DCS implementation: Gas Control System

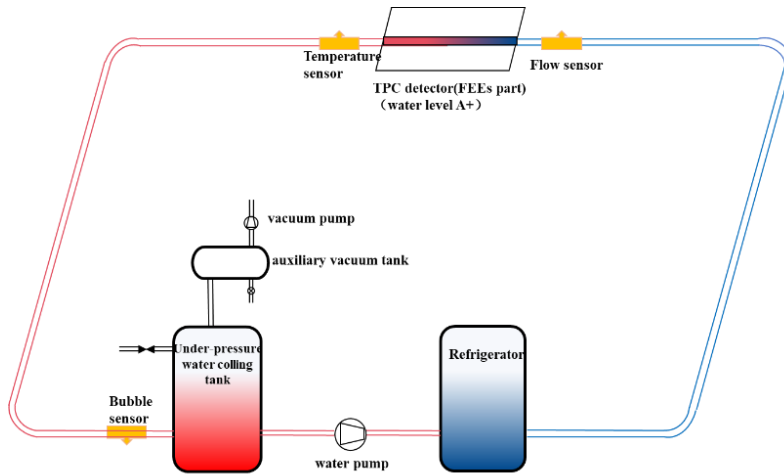


- Regulating the pressure and composition of the gas
- Monitoring gas temperature, O₂ and H₂O
- Data acquisition system based on PLC collects and logs the gas system parameters, controls the purification of the mixture.
- A **separate alarm and interlock system** prevents the detectors from operating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

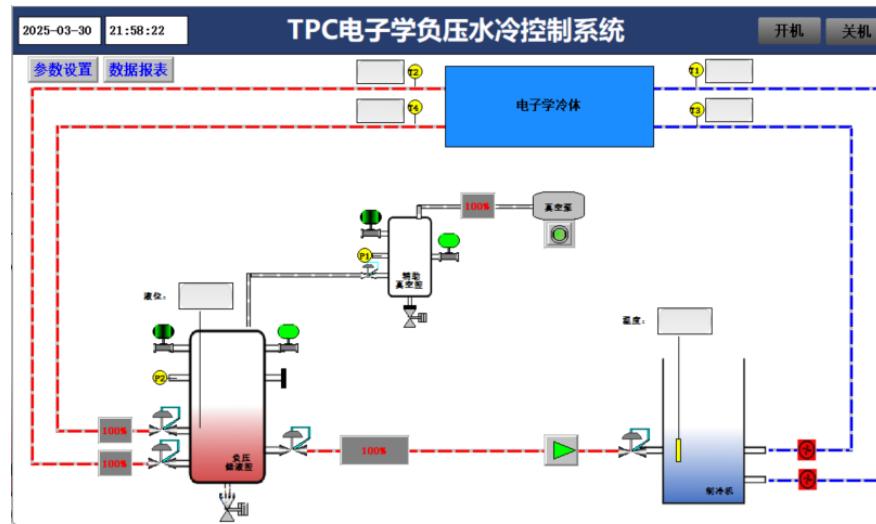


DCS implementation: Water-cooling System

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

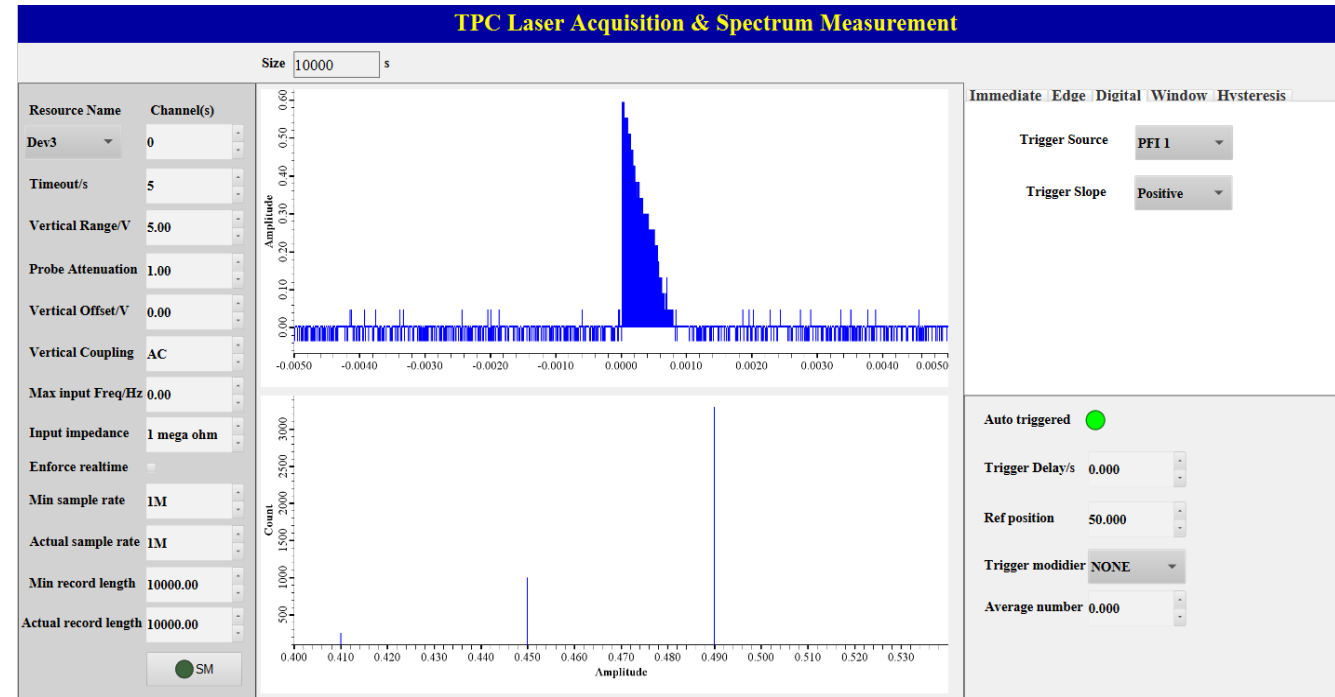
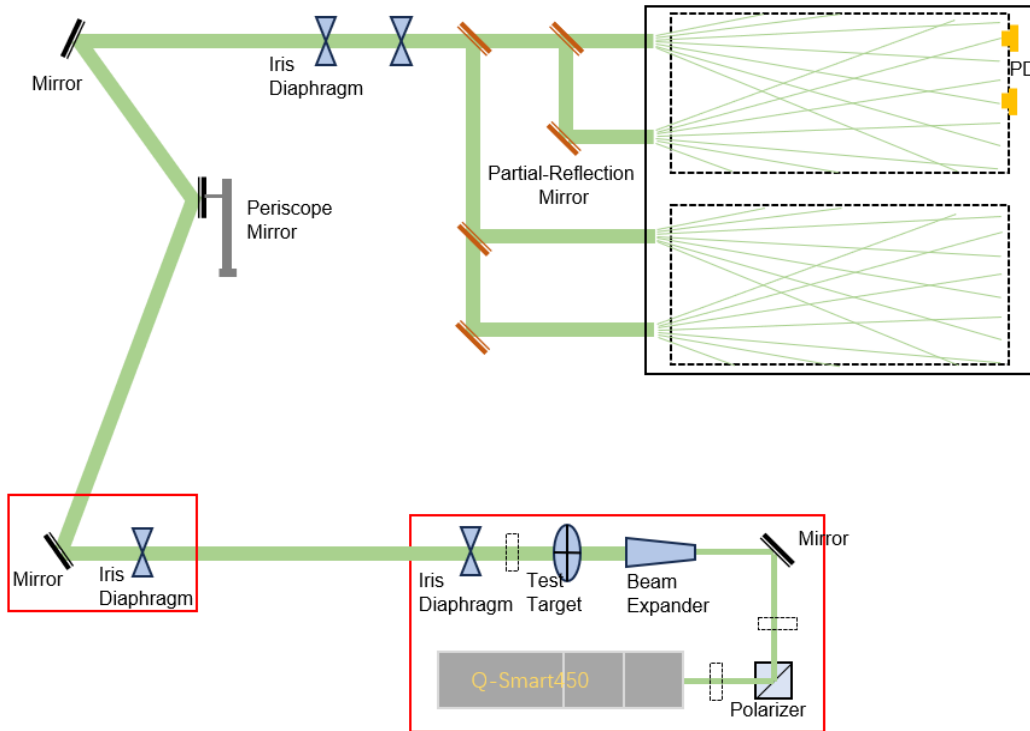


TPC FEE Water Cooling Monitoring System											
FEE Temperature/°C											Alarm:
ID: 01						ID: 02					
In Flow:						In Flow:					
Return Flow:						Return Flow:					
6.046.056.056.096.01						6.106.026.016.106.01					
6.106.046.066.096.05						6.076.056.096.076.04					
ID: 03						ID: 04					
In Flow:						In Flow:					
Return Flow:						Return Flow:					
6.036.016.046.026.02						6.026.046.096.096.02					
6.086.046.036.086.02						6.036.046.016.046.00					
ID: 05						ID: 06					
In Flow:						In Flow:					
Return Flow:						Return Flow:					
6.056.006.016.046.01						6.066.006.046.076.06					
6.096.076.076.026.04						6.056.036.076.106.04					
ID: 07						ID: 08					
In Flow:						In Flow:					
Return Flow:						Return Flow:					
6.086.036.016.046.03						6.056.066.066.066.09					
6.106.006.066.036.01						6.036.056.086.086.09					



DCS implementation: Laser System

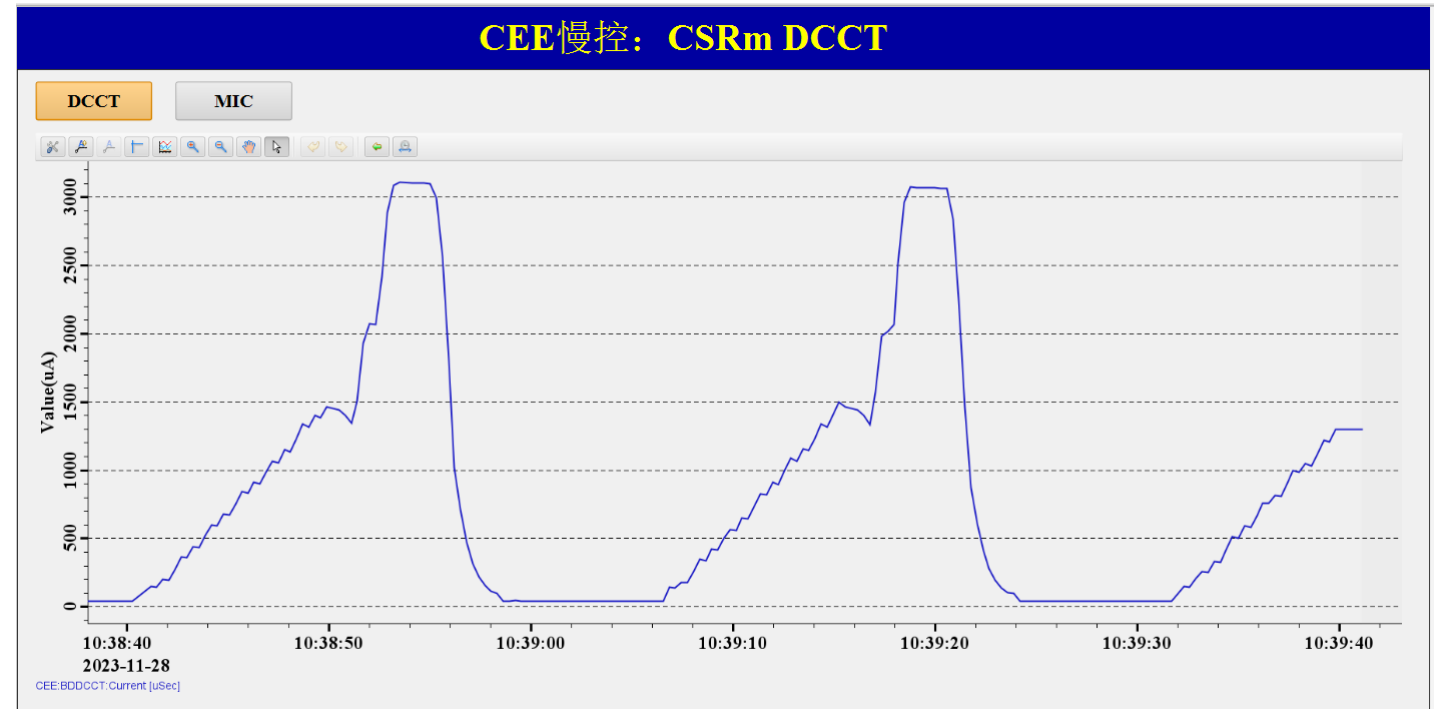
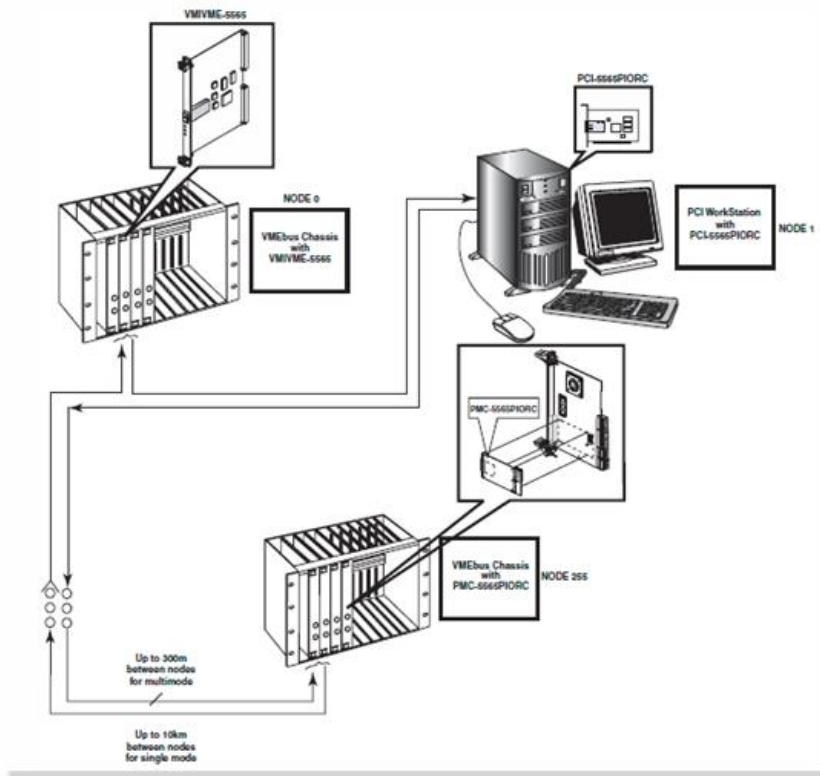
- Beam energy calibration with pulsed ultraviolet beams for TPC
- Monitor the operational state and records beam signals for analyzation



DCS implementation: Reflective Memory Technology



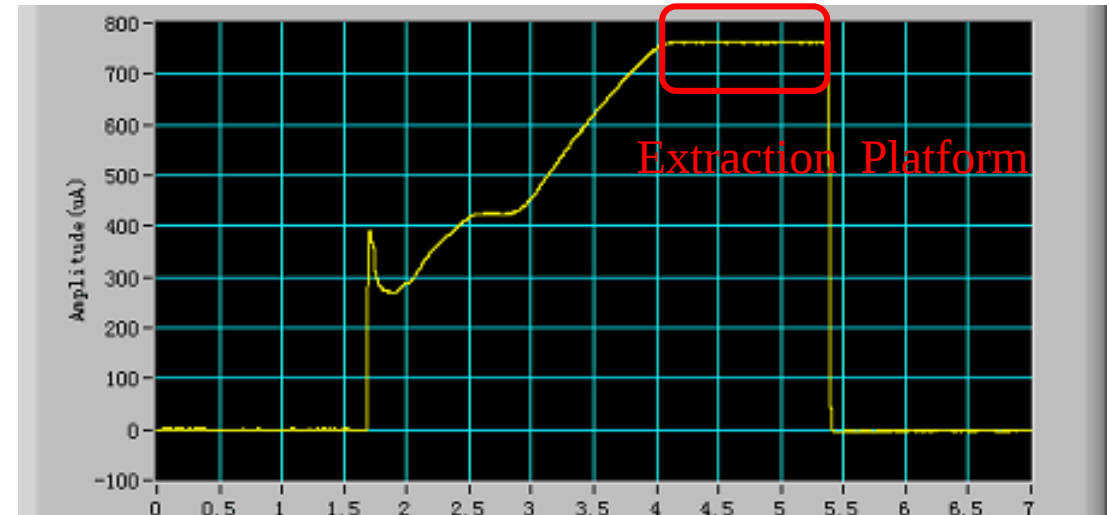
- Enable data interaction between the CEE and accelerator networks through optical connection, physical isolation, ensuring CEE network security
- **Reflection memory technology for monitoring accelerator parameters: Beam intensity, beam profile...**
- Design and implementation of a high real-time, stability,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



DCS implementation: Slow Extraction Events parse device



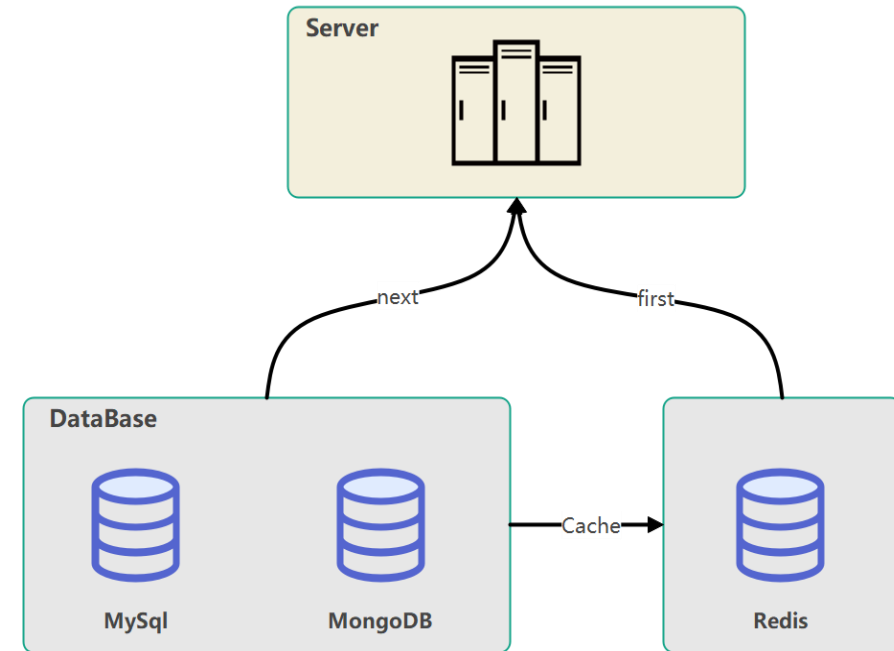
- Parse the accelerator slow extraction events and generate TTL signals related to the accelerator operation cycle for the trigger system, providing trigger signals
- FPGA-based, embedded IOC
- Precise trigger signal generation with adjustable delay (in microseconds)



Design and implementation of CEE-DCS

--Database

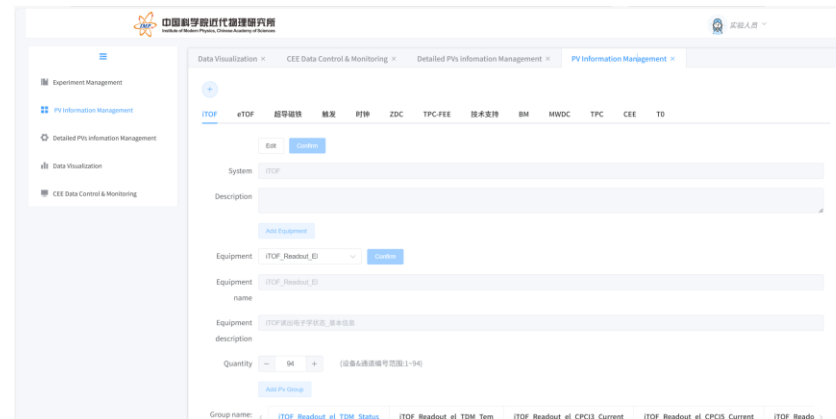
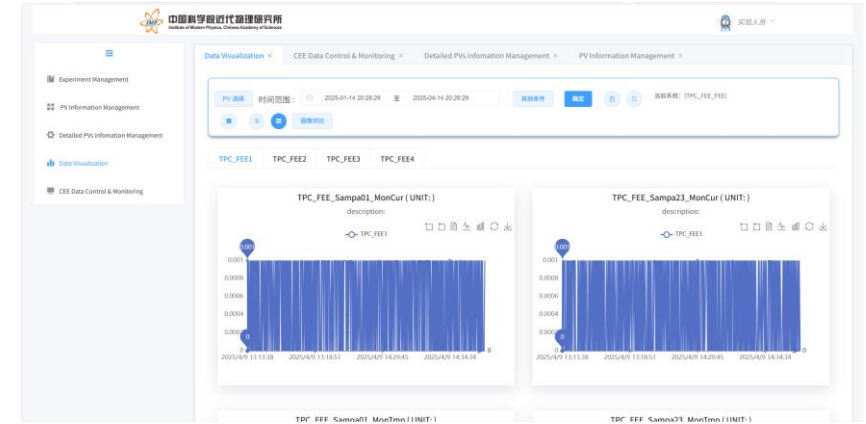
- **Hybrid architecture**
- **MySQL** is used for system data, meta data
- **Redis database**
- **MongoDB** for time-series data
- **Web-based** GUIs



Database design & Implementation: Database GUI



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

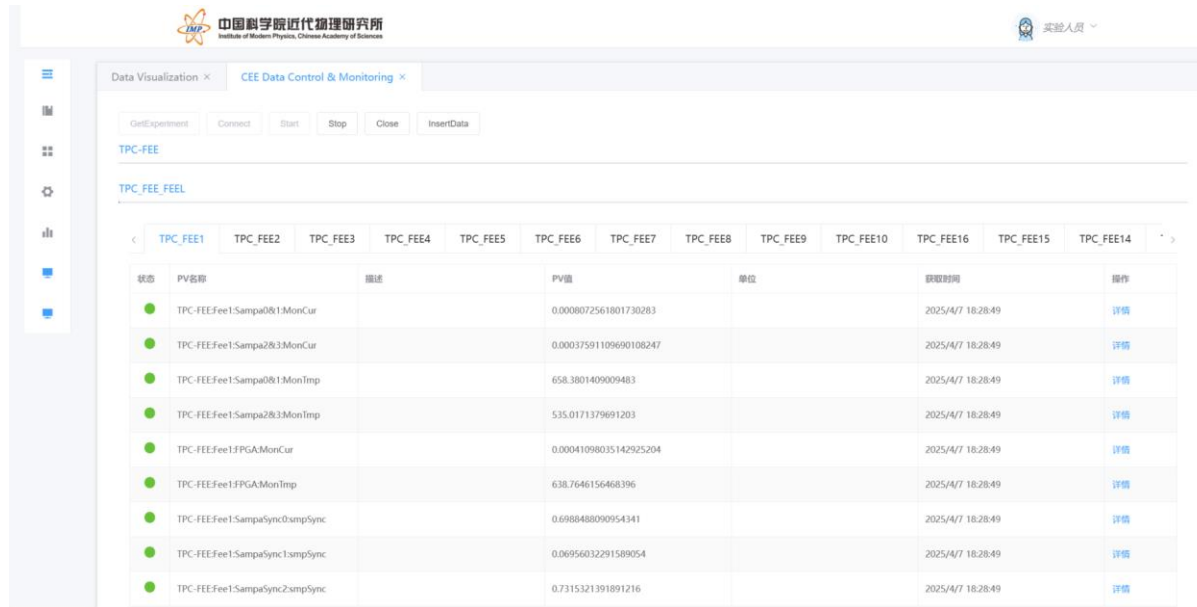


设备	PV名称	描述	PV值	单位	更新时间	操作
TPC_FEE	TPC_FEE_Sampa03_MonCur		0.0000072561801730283		2025/4/7 18:28:49	详情
TPC_FEE	TPC_FEE_Sampa23_MonCur		0.0001719110960108247		2025/4/7 18:28:49	详情
TPC_FEE	TPC_FEE_Sampa03_MonTop		458.3801409009483		2025/4/7 18:28:49	详情
TPC_FEE	TPC_FEE_Sampa23_MonTop		535.01711379691203		2025/4/7 18:28:49	详情
TPC_FEE	TPC_FEE_Sampa03_MonCur		0.00040109803514252504		2025/4/7 18:28:49	详情
TPC_FEE	TPC_FEE_Sampa03_MonTop		638.7648156468396		2025/4/7 18:28:49	详情
TPC_FEE	TPC_FEE_Sampa03_CompSync		0.000488000054541		2025/4/7 18:28:49	详情
TPC_FEE	TPC_FEE_Sampa03_CompSync		0.00056803291589054		2025/4/7 18:28:49	详情
TPC_FEE	TPC_FEE_Sampa03_CompSync		0.7335321391891216		2025/4/7 18:28:49	详情

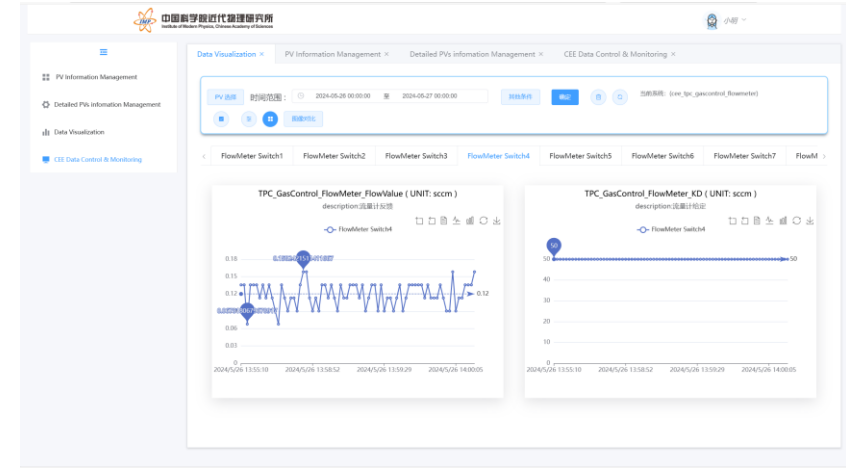
Database operation GUIs specially designed for users

Database design & Implementation: Web-based Data Visualization

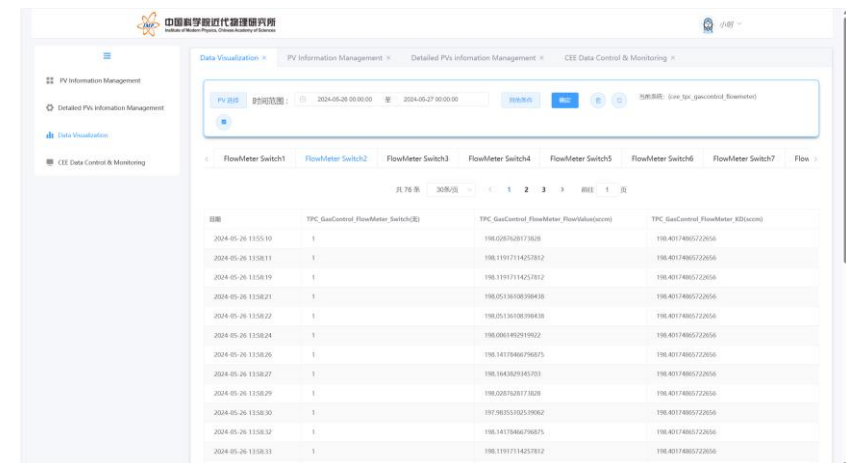
❑ PV Variable **Monitoring** Interface:



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



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

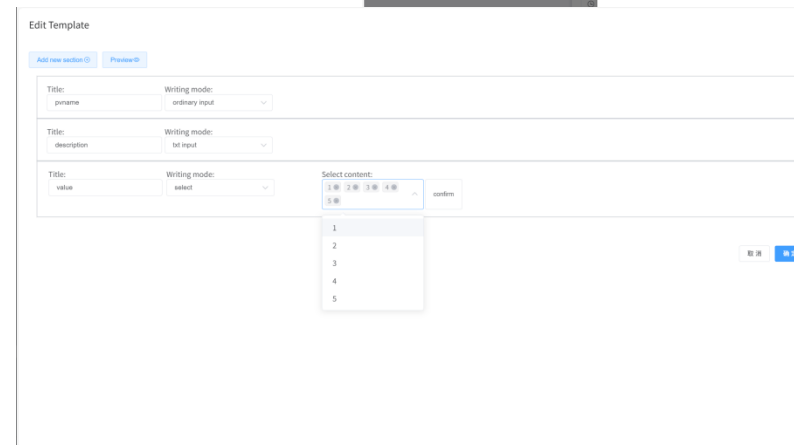
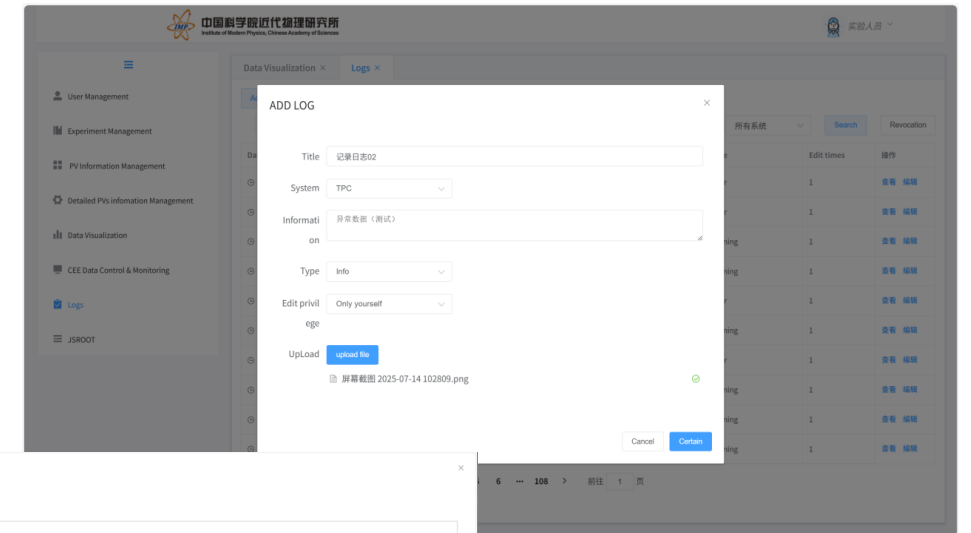
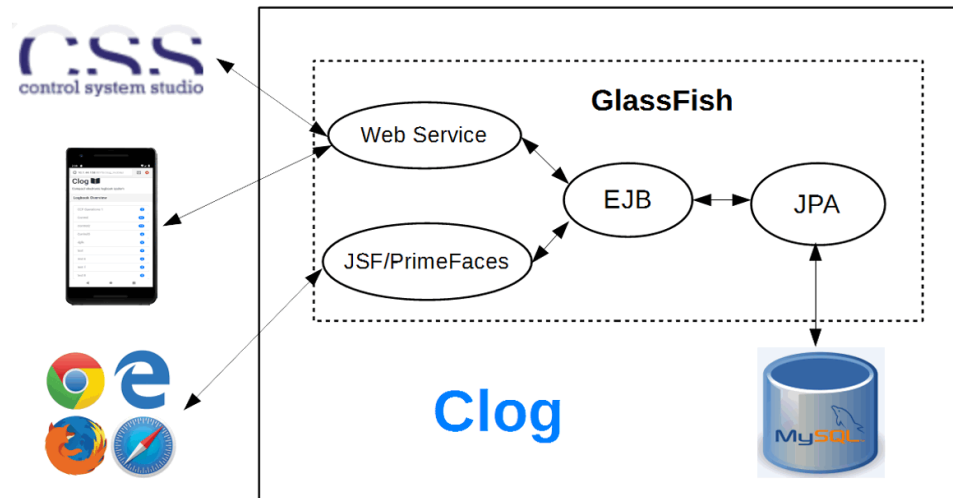


Both monitoring interfaces and database visualization interfaces adhere to minimalist design principles, optimized for experimental personnel's operational efficiency and data accessibility.

Electronic logbook

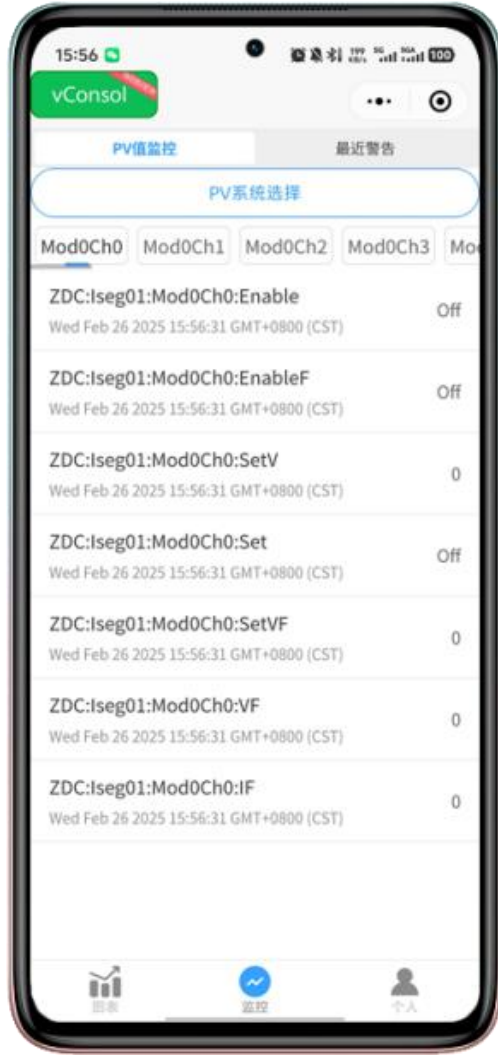
- Enables digital recording, secure storage, intelligent analysis, and collaboration tools
- Enhances efficiency and supporting data-driven decisions
- **Developed by our group: data, alarming, video, pictures and so on**

Elog	Olog
Monolithic architecture	Microservices modular design

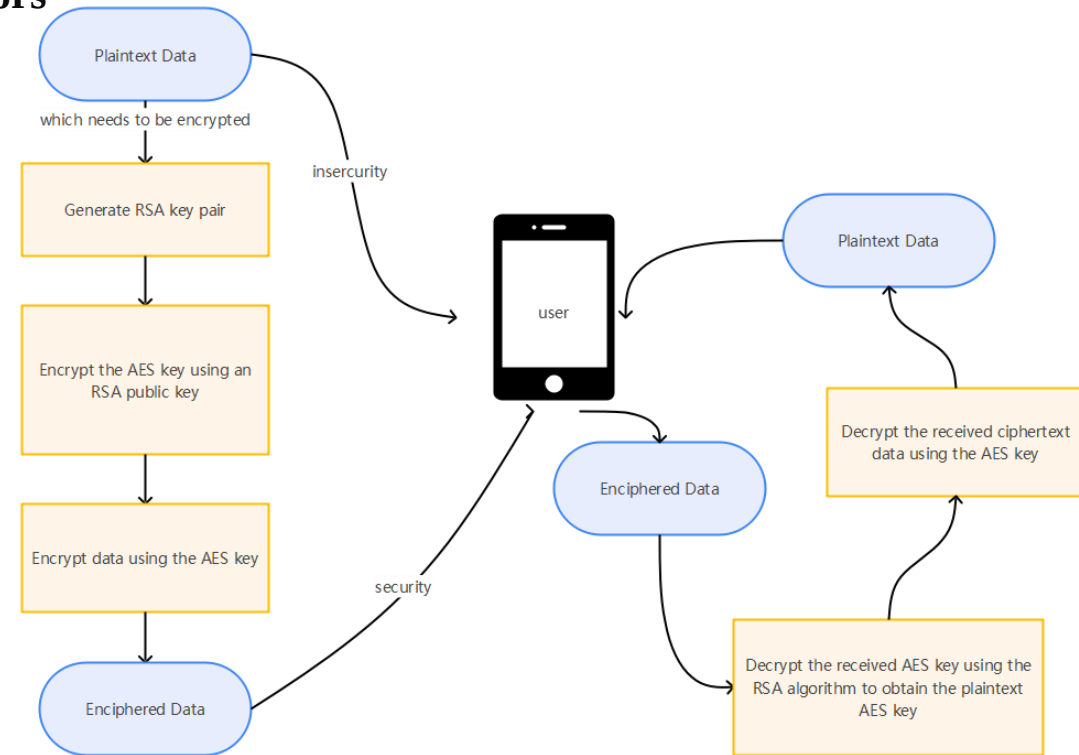


Database design & Implementation: Mobile APP/WeChat Mini Program

- Mobile APP/WeChat Mini Program Monitoring Interface
push **critical warning or error messages** to system administrators



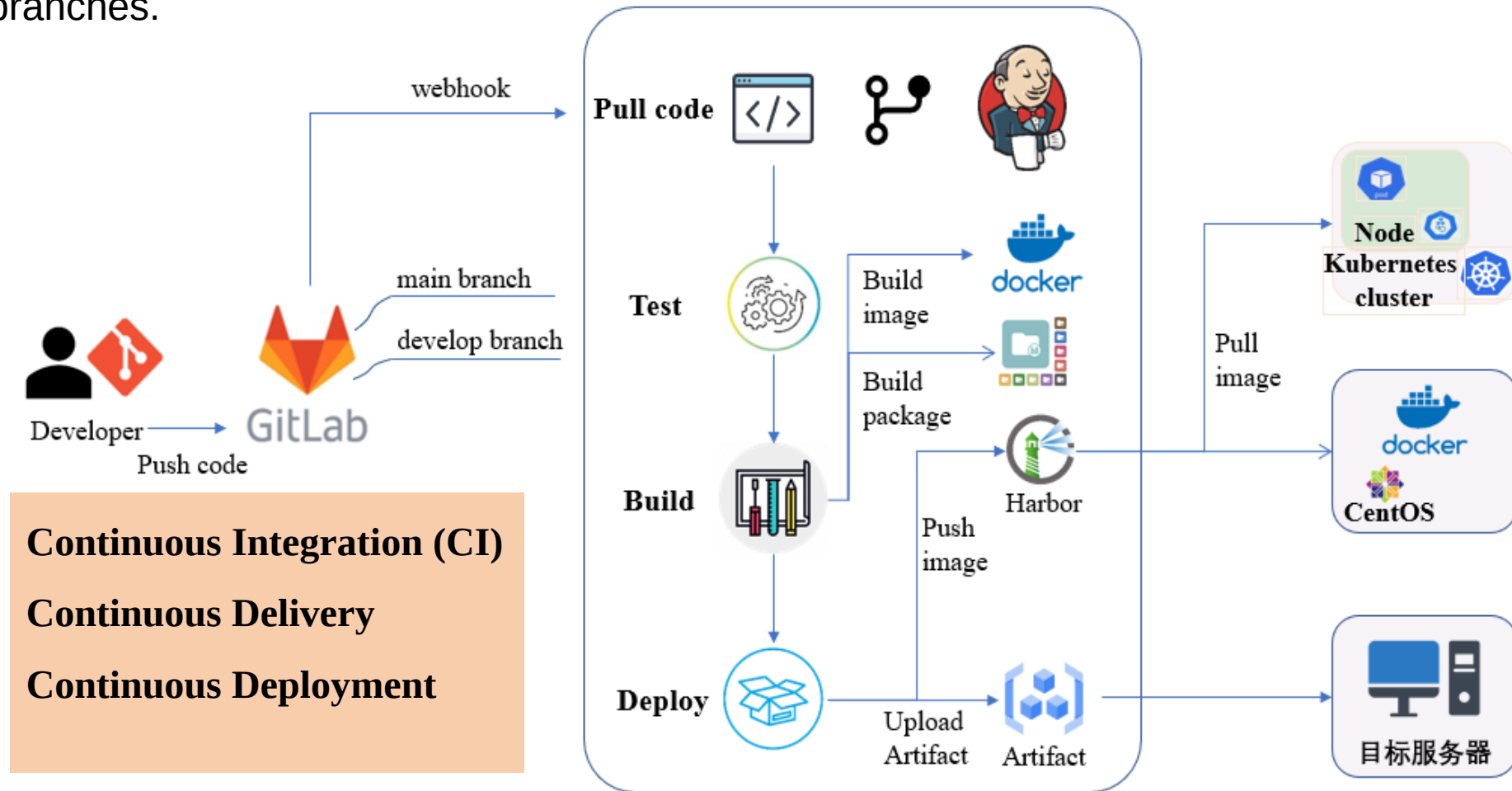
- Data Encryption:



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

Builds

过滤构建...

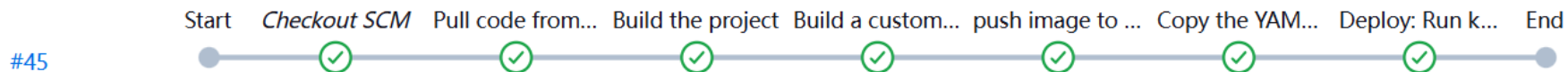
Today

✓ #45 下午2:52
Started by GitLab push by Administrator

✓ #44 下午2:45

① Trigger a build

id pipeline



② Pipeline

✓ < Build #45

③ Detailed status of each pipeline step

▶ Rebuild

🔗 Overview

Configure

⋮

成功 2 分 36 秒 ago in 28 秒

- ✓ Checkout SCM
- ✓ Pull code from GitLab
- ✓ Build the project
- ✓ Build a custom Docker image
- ✓ push image to harbor
- ✓ Copy the YAML file(s) to the k8s-master node
- ✓ Deploy: Run kubectl commands on the Kubernetes master node remotely

Stage 'Deploy: Run kubectl commands on the Kubernetes master node remotely'

🕒 Started 2 分 9 秒 ago

⌚ Queued 0 毫秒

🕒 Took 1.4 秒

🟢 Success

🔗 [View as plain text](#)

✓ **ssh root@192.168.41.154 kubectl apply -f /usr/local/k8s/pipeline.yml ssh...** 1.4 秒

Shell Script

```
0 + ssh root@192.168.41.154 kubectl apply -f /usr/local/k8s/pipeline.yml
1 deployment.apps/pipeline unchanged
2 service/pipeline unchanged
3 ingress.networking.k8s.io/pipeline unchanged
4 + ssh root@192.168.41.154 kubectl rollout restart deployment pipeline -n t1217
5 deployment.apps/pipeline restarted
```

CI/CD: Application Practices

Kuboard

192.168.41.151:8081/kubernetes/ioc1/namespace/t1217/workload/view/Deployment/pipeline

首页 > ioc1 [切换] > t1217 [切换] > 部署列表 > pipeline 设为默认页

Kubernetes : v1.23.5
Kuboard : v3.5.2.7

kuboard-admin

Deployment 编辑 预览/编辑 YAML 调整镜像版本 伸缩 日志/终端 复制 CI/CD 集成 重启 删除

元数据 运行时 服务 应用路由

展开 伸缩: 2 / 2 自动伸缩 暂停更新 9 个关联事件 安装 Kuboard 套件

副本集 pipeline-f66966d6d 所管理的容器组
删除该副本集下所有的容器组

pipeline-f66966d6d-6ntct Ready
8 分钟 10.234.134.28 192.168.41.154

pipeline-f66966d6d-vbt6x6 Ready
8 分钟 10.234.134.27 192.168.41.154

Reason	Time	Count	Message
Started	8 分钟	1	Started container pipeline
Created	8 分钟	1	Created container pipeline
Pulled	8 分钟	1	Successfully pulled image "192.168.41.135/repo/pipeline:latest" in 82.84...
Pulling	8 分钟	1	Pulling image "192.168.41.135/repo/pipeline:latest"
Scheduled	8 分钟	1	Successfully assigned t1217/pipeline-f66966d6d-6ntct to ioc1

已显示 5 条, 共 5 条

安装 metrics-scraper 用于在 Kuboard 中显示一段时间以
内的 CPU/内存曲线

安装 metrics-scraper 用于在 Kuboard 中显示一段时间以
内的 CPU/内存曲线

容器组 pipeline-f66966d6d-6ntct 8 分钟 Pod YAML 删除容器组

所在节点	容器组IP	状态
ioc1 (192.168.41.154)	10.234.134.28	Running

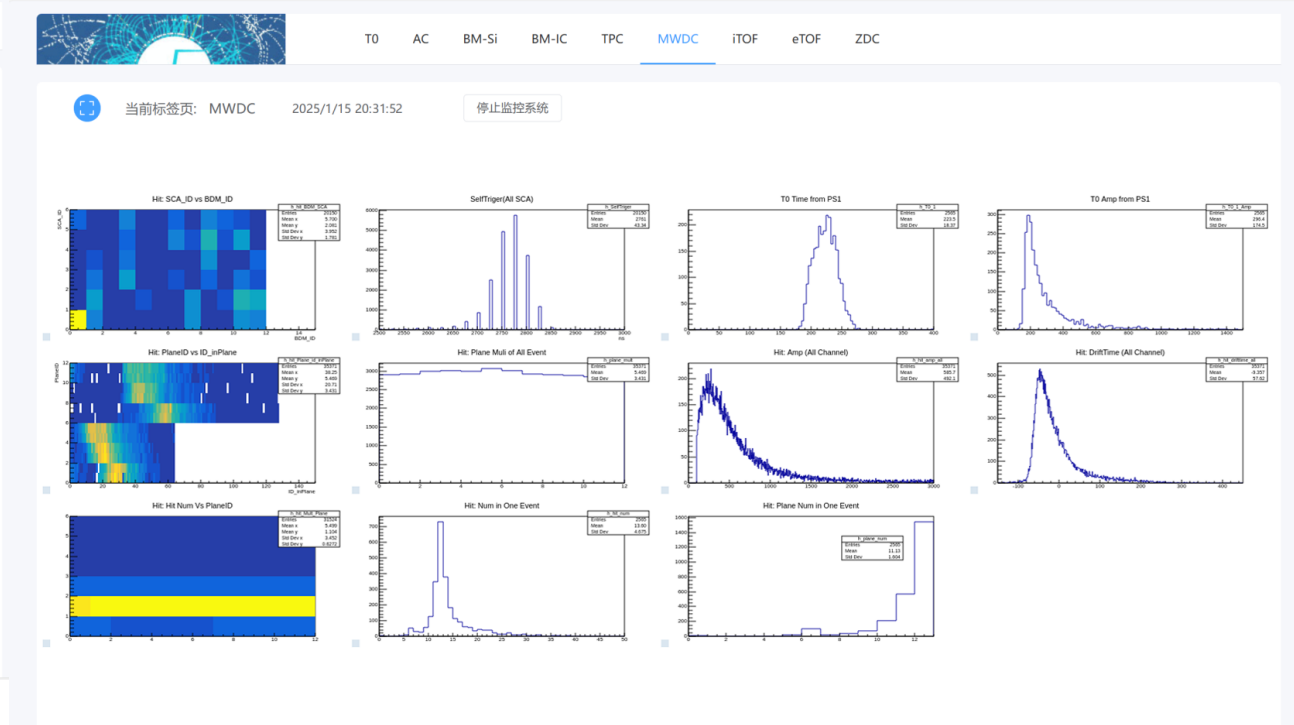
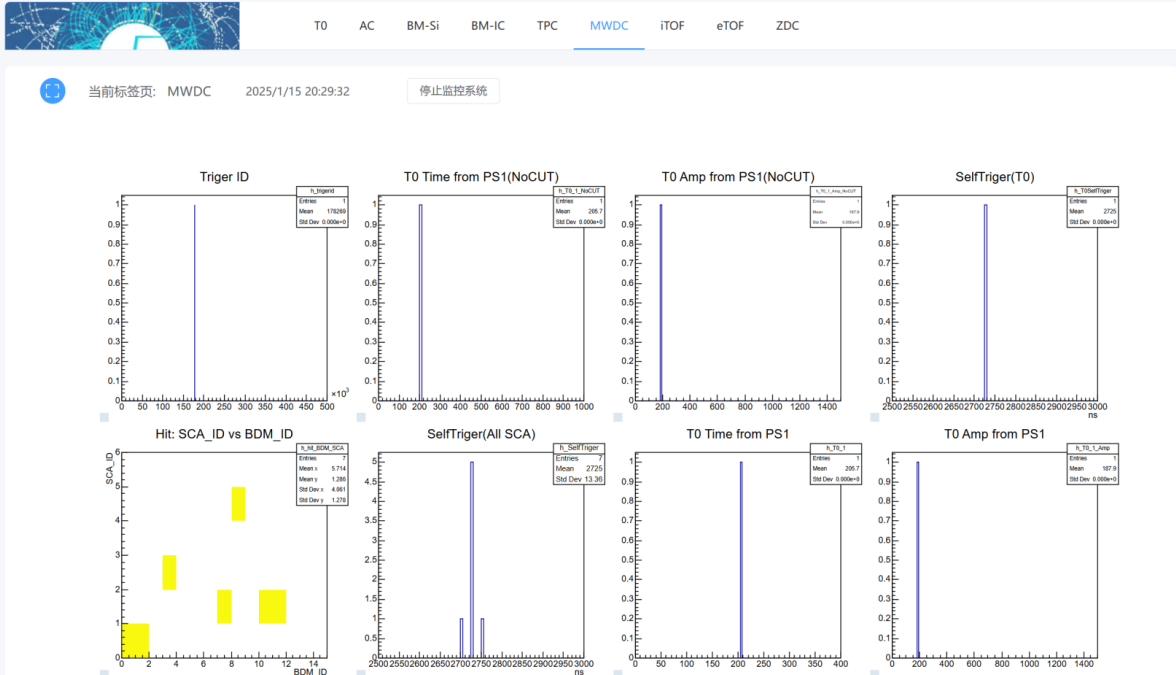
已调度 2025-04-09 22:52:38 已初始化 2025-04-09 22:52:38

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



- 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



中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences



Thank you