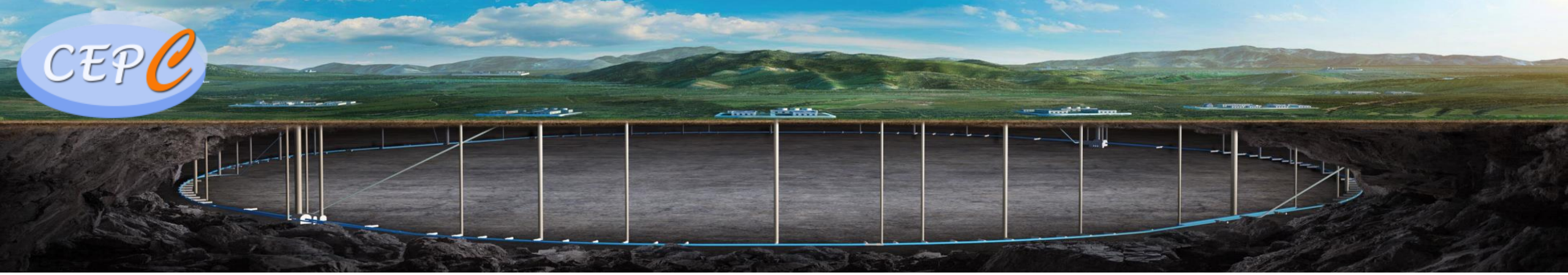

CEPC control designs and studies

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Content

- Scope and Performance of the CEPC control system
- Requirement information of controlled devices
- Control system and sub-system
- Summary

Scope of the Control System

- Global control
  - Center Control System: Control Platform, computers, servers, database, etc
  - Control network System
  - Timing System
  - Machine Protection System
  - Video monitoring system
- Local control
  - Power Supply Control System
  - Vacuum Control System
  - Temperature Monitoring System
  - Linac Control System
- Integration of sub-systems
  - LLRF, Cryogenic system, Injection/Extraction system etc.
- Interface to other systems
  - Detector(Experimental physics), beamline and conventional facility

Performance of the Control System

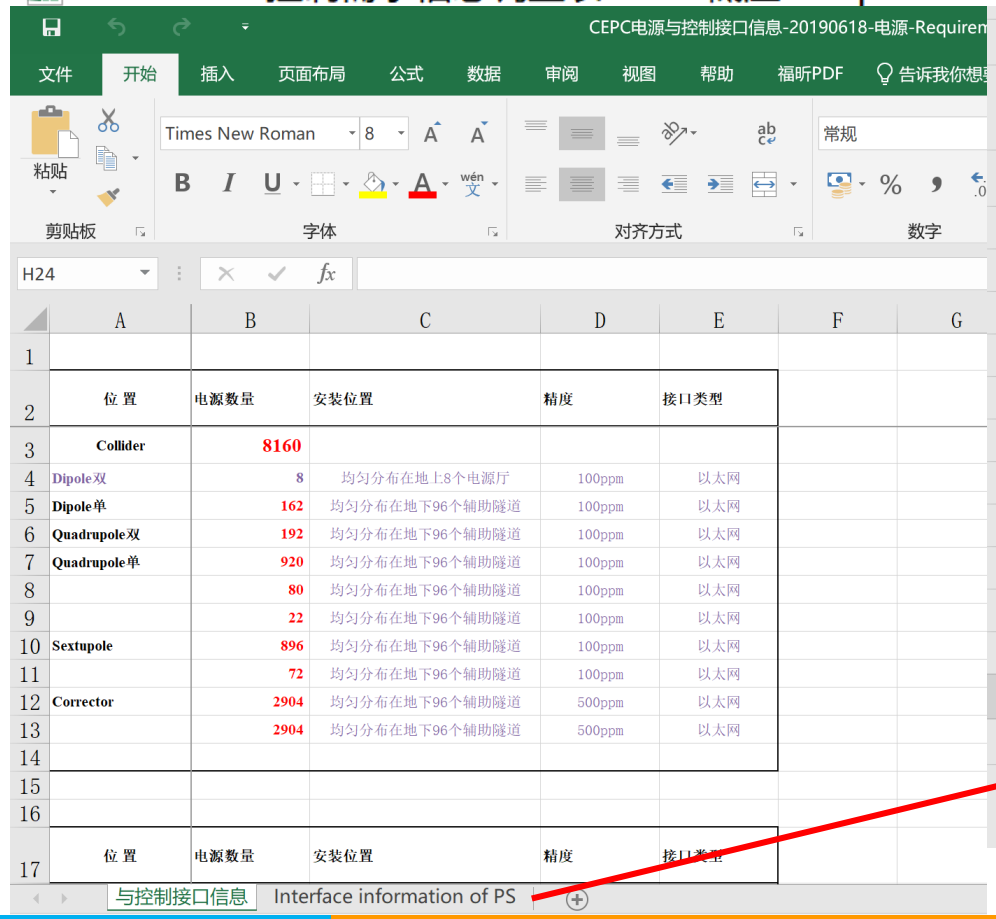
- 5*bility+RT
  - Stability
  - Availability
  - Flexibility
  - Scalability
  - Reliability
  - Real Time

Requirement information of controlled devices

- Bilingual requirement table

CEPC-TDR控制需求信息调查表2018-低温 (2)-Requirement from Cryo.xlsx

CEPC-TDR控制需求信息调查表2018-低温-Requirement from Cryo.xlsx



	位 置	电源数量	安装位置	精度	接口类型
3	Collider	8160			
4	Dipole双	8	均匀分布在地上8个电源厅	100ppm	以太网
5	Dipole单	162	均匀分布在地下96个辅助隧道	100ppm	以太网
6	Quadrupole双	192	均匀分布在地下96个辅助隧道	100ppm	以太网
7	Quadrupole单	920	均匀分布在地下96个辅助隧道	100ppm	以太网
8		80	均匀分布在地下96个辅助隧道	100ppm	以太网
9		22	均匀分布在地下96个辅助隧道	100ppm	以太网
10	Sextupole	896	均匀分布在地下96个辅助隧道	100ppm	以太网
11		72	均匀分布在地下96个辅助隧道	100ppm	以太网
12	Corrector	2904	均匀分布在地下96个辅助隧道	500ppm	以太网
13		2904	均匀分布在地下96个辅助隧道	500ppm	以太网
17	位 置	电源数量	安装位置	精度	接口类型

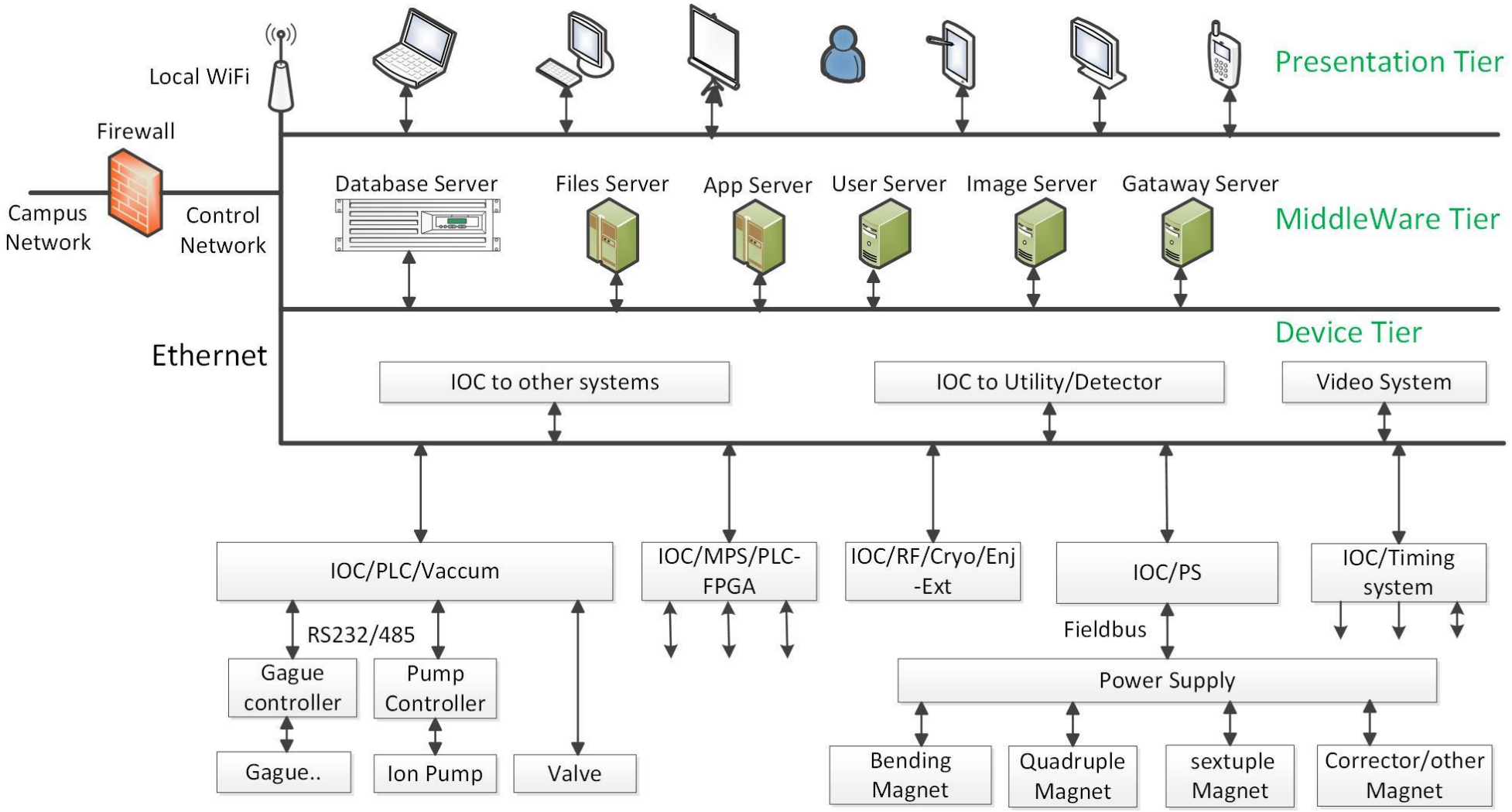
与控制接口信息 Interface information of PS

	Type/Affiliations	Quantity	Location	Precision	Interface
3	Collider	8160			
4	Dipole-Double	8	8 Power Supply Hall	100ppm	以太网
5	Dipole-Singular	162	96 Auxiliary Tunnel unit	100ppm	以太网
6	Quadrupole-Double	192	96 Auxiliary Tunnel unit	100ppm	以太网
7	Quadrupole-Singular	920	96 Auxiliary Tunnel unit	100ppm	以太网
8		80	96 Auxiliary Tunnel unit	100ppm	以太网
9		22	96 Auxiliary Tunnel unit	100ppm	以太网
10	Sextupole	896	96 Auxiliary Tunnel unit	100ppm	以太网
11		72	96 Auxiliary Tunnel unit	100ppm	以太网
12	Corrector	2904	96 Auxiliary Tunnel unit	500ppm	以太网
13		2904	96 Auxiliary Tunnel unit	500ppm	以太网
17	Type/Affiliations	Quantity	Location	Precision	Interface

Characteristic of CEPC

- Super scale
  - Linac: 1.8km
  - Ring: 100km circumference （booster and collider）
- A large number of Controlled Equipments
  - Discrete distributed in the Linac and Ring
- Quantity of PVs
  - Millions of PVs

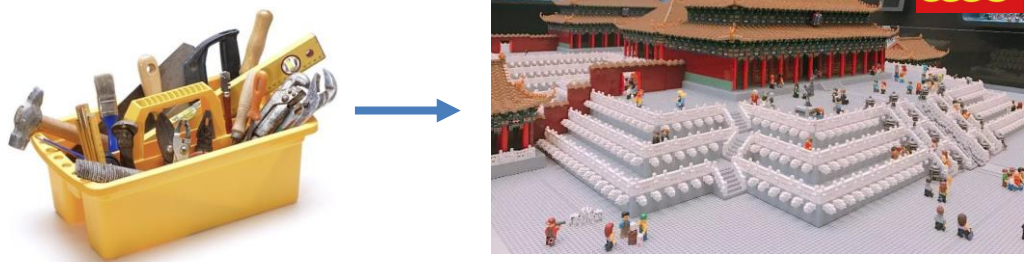
Control System and sub-system



Overall architecture of the CEPC control system

Standardization of CEPC Control system

- Software Platform
  - EPICS： open source, free SCADA/DCS, toolkits
  - Modern industry standards/ technology to manage EPICS (IOC/Driver/GUI)
    - Docker, Kubernetes, and Sumo etc.
- Hardware Platform
  - Standardization, Modularity and COTS （Commercial-Off-the-Shelf)
  - Workstations and servers
  - ATCA/uTCA
  - PLC
  - Motion controller/Driver
  - etc.



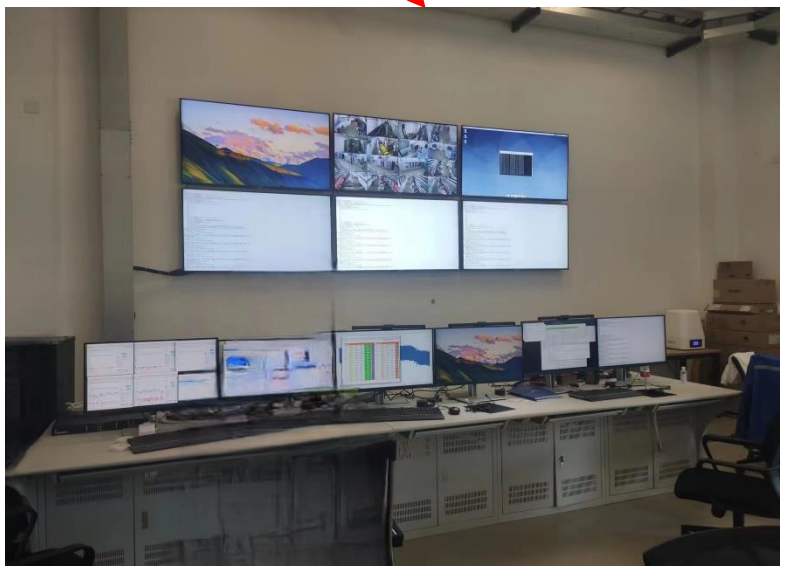
Control System and sub-system: CCS

- Central Control System
  - Control Rooms
  - Management and operation of IOCs/OPIs
  - Server and management of High level software
  - CA/PVA Gateway
  - OPI tools--CSS, caQtDM, PyDM etc
  - Data Archiver
  - Alarming system
  - Elog
  - Issue information of machine via instant message(weChat)
  - Machine status summary on Web
  - Etc

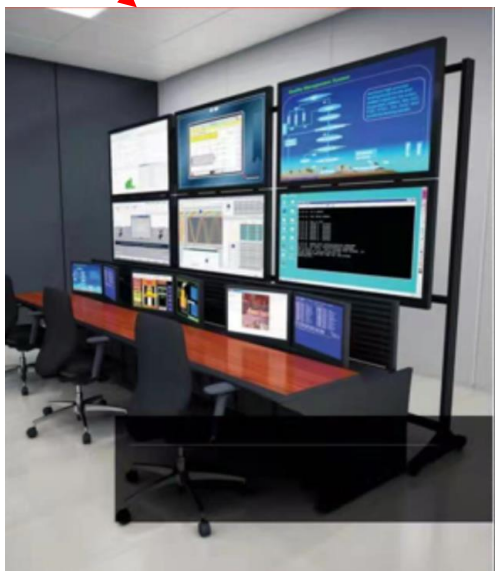
Control System and sub-system: CCS

- Control Rooms(While construction, commissioning at the same time)
  - One central control room for whole CEPC
  - One temporary Linac control room for commissioning at initial stage of CEPC
  - Dozens of local control room （mini console） for the site commissioning

CCR Renderings of CSNS



HEPS-LINAC（Temporary）

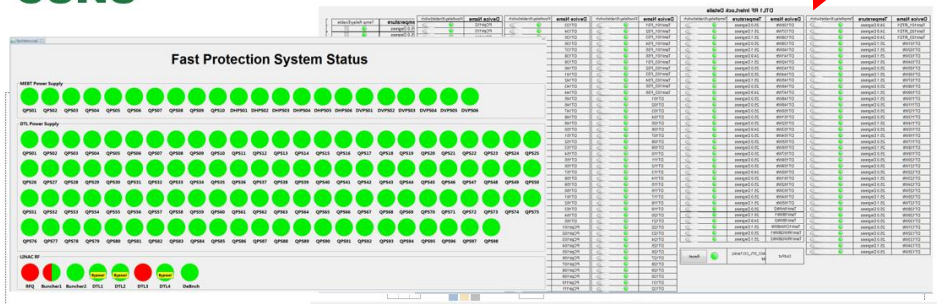


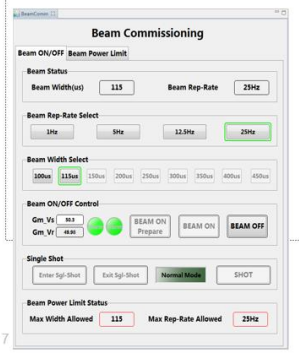
Mini Console

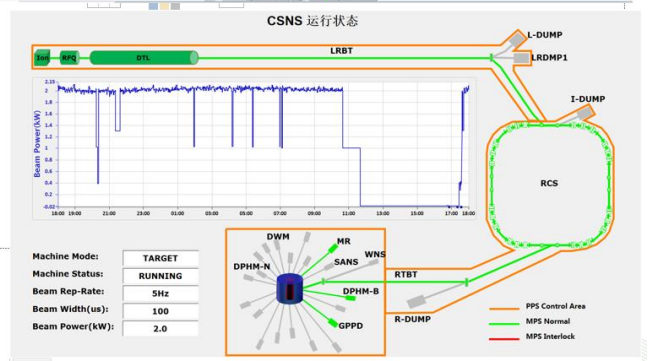
Control System and sub-system: CCS

- OPI/GUI tools
  - ~~edd/dm(2k),medm,edm~~,CSS, caQtDM, PyDM, etc
  - Update, 5~10 years
  - Keep up with OPI technological progress

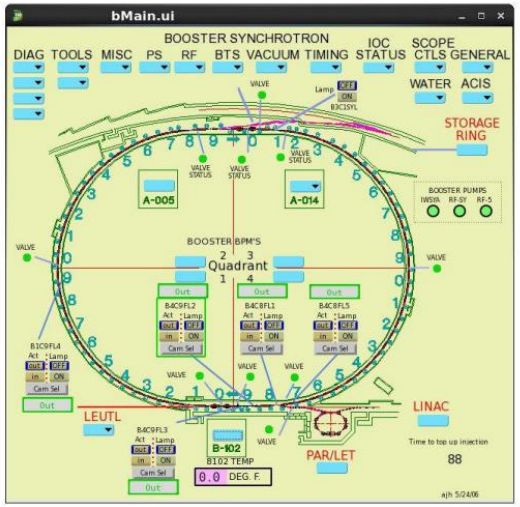
CSNS

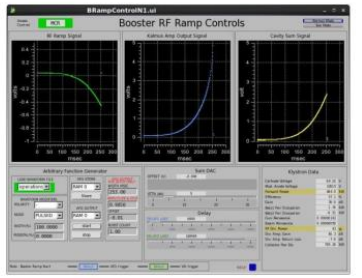


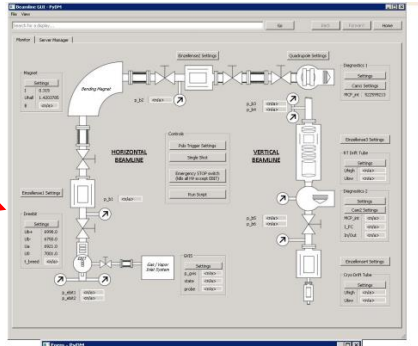


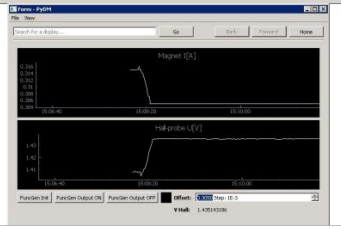


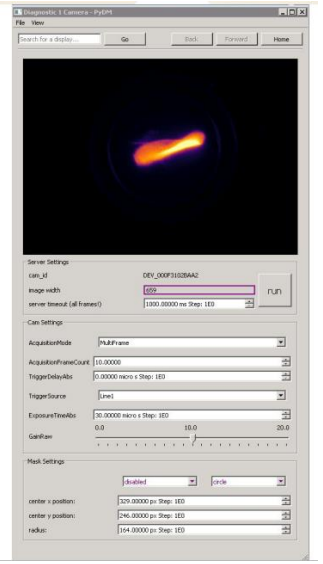
caQtDM Examples





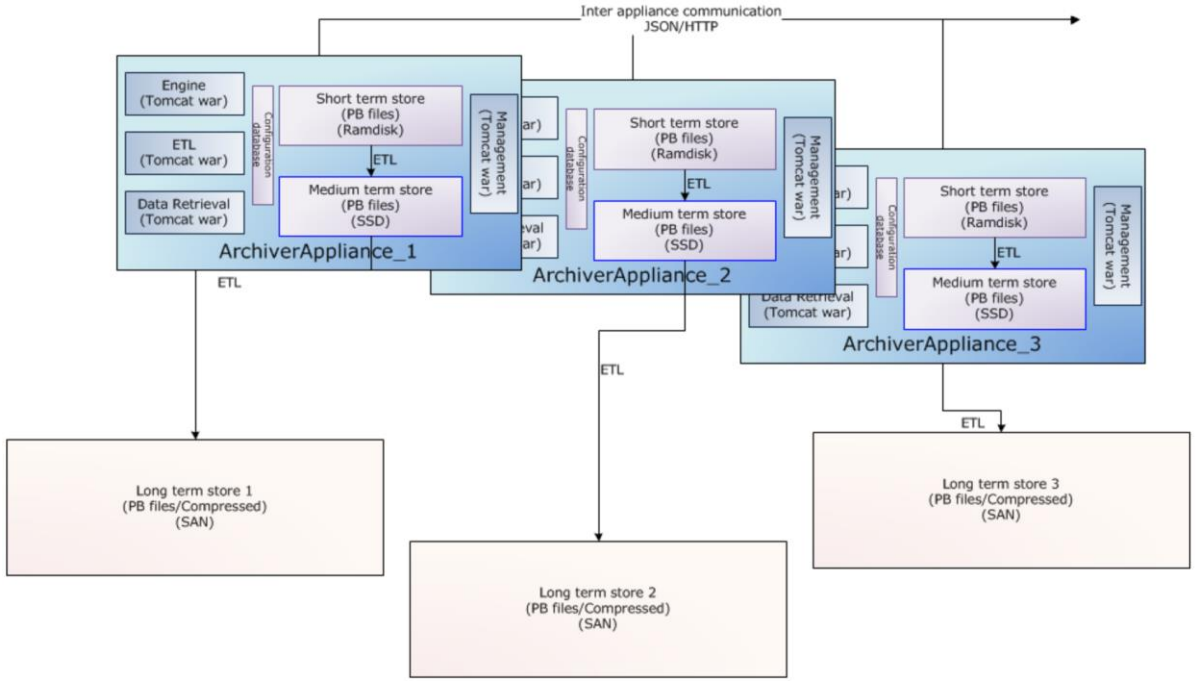




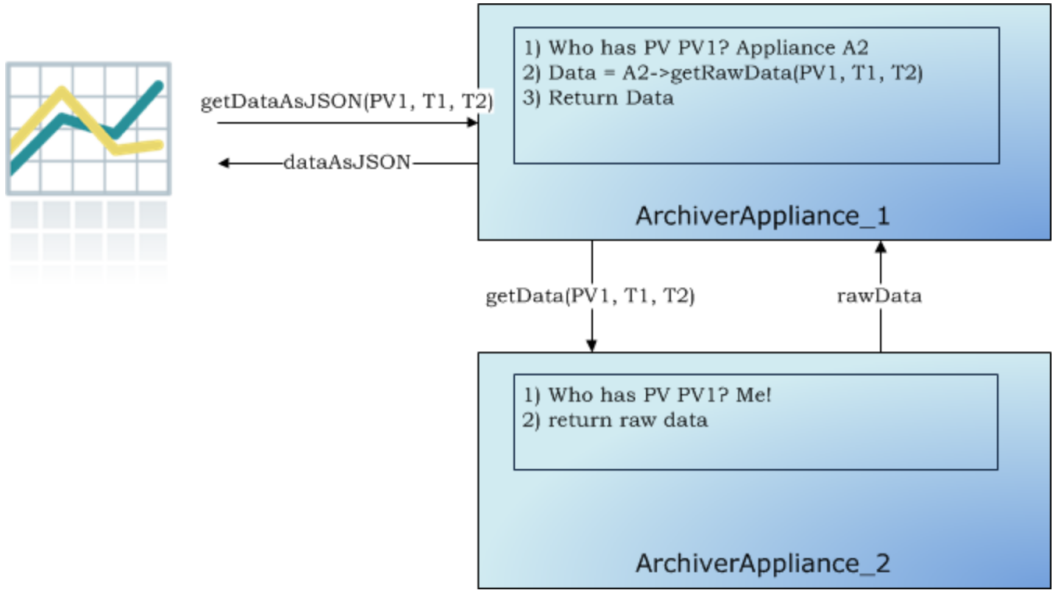


Control System and sub-system: CCS

- Data Archiver -- Archiver Appliance (AA)
  - Archive millions of PVs
  - Cluster



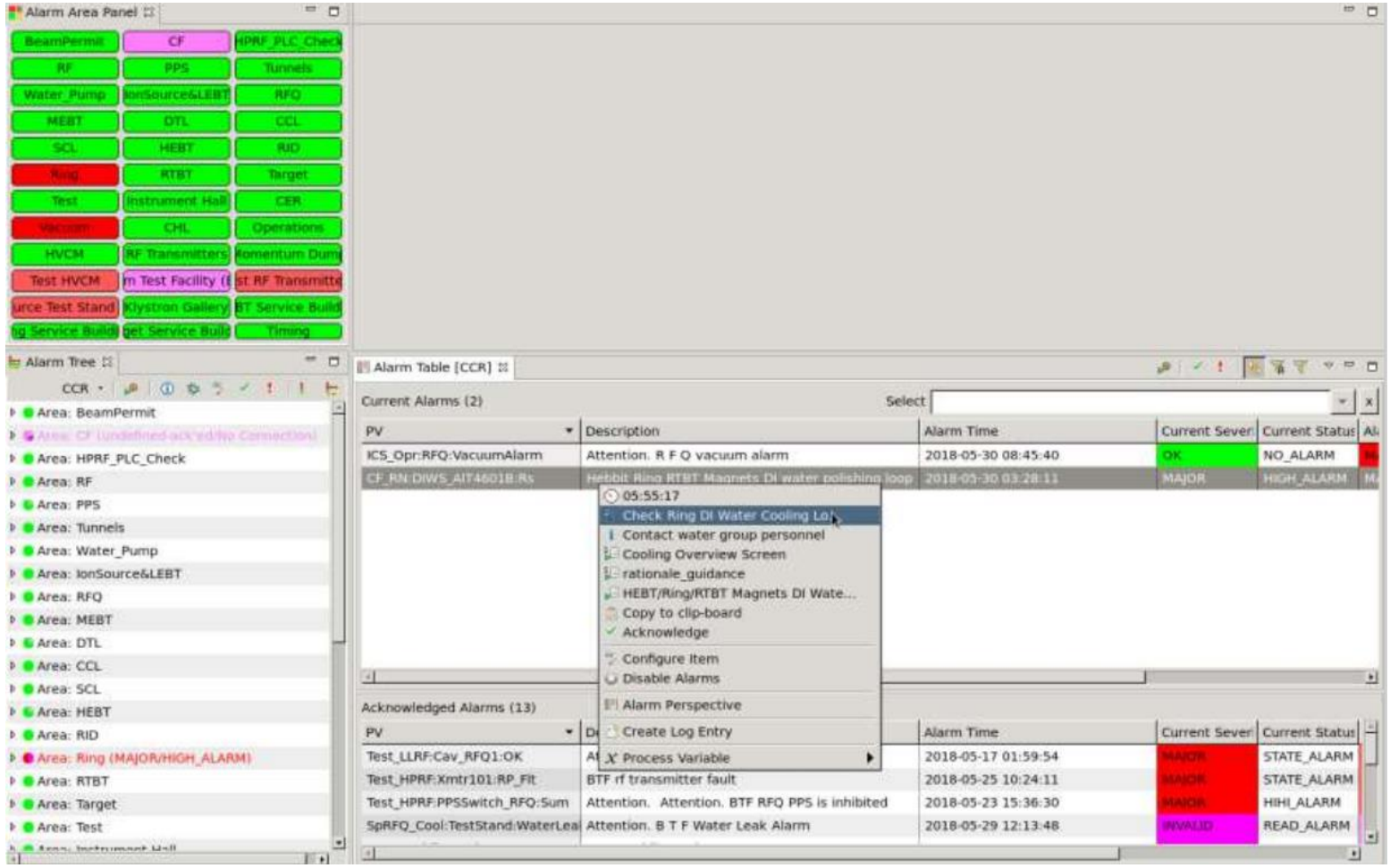
Multiple appliances sending data into different long term stores



Data retrieval request for PV in other appliance

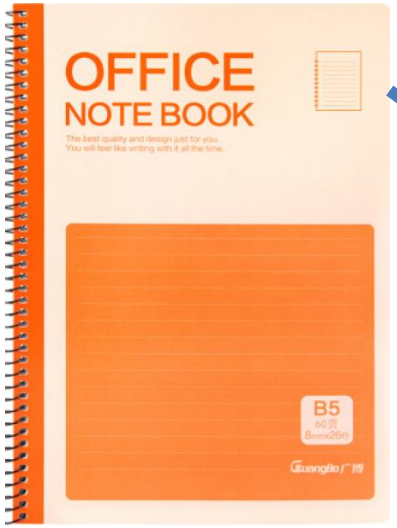
Control System and sub-system: CCS

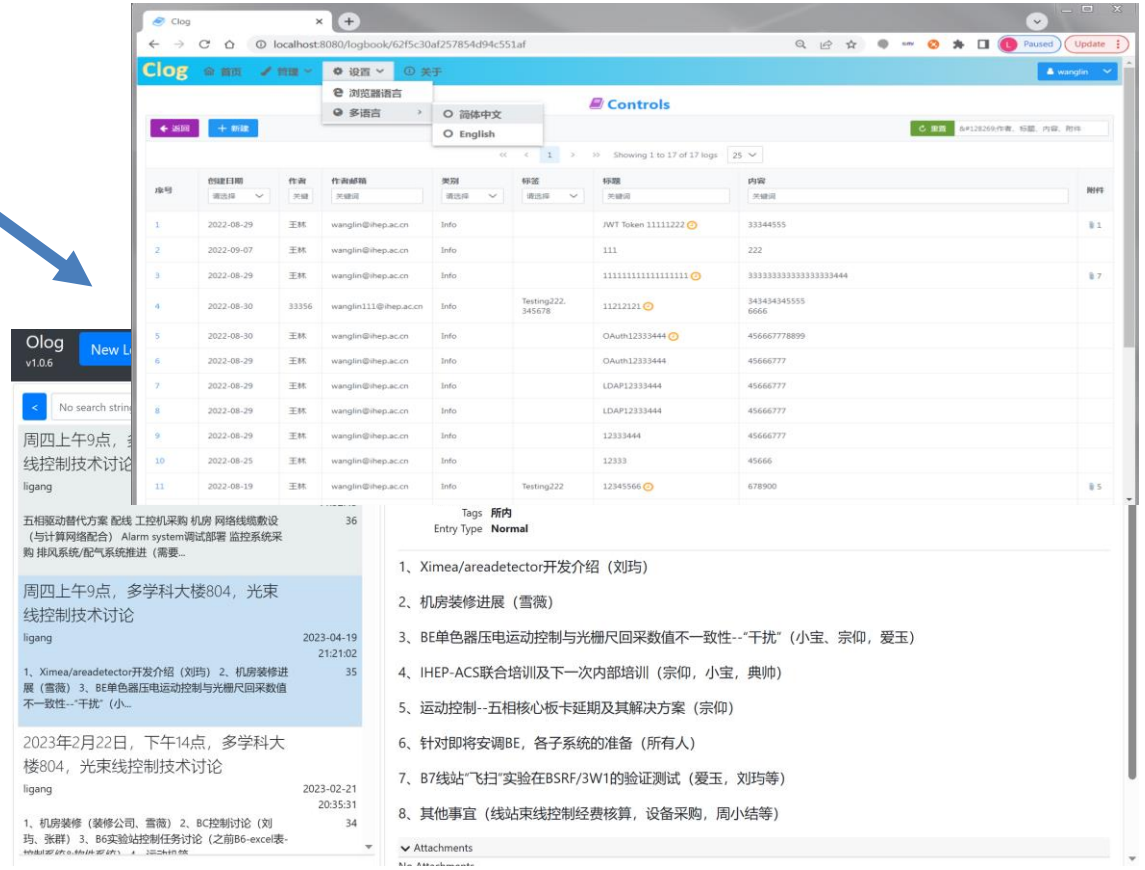
- Alarming system
  - Monitor PVs
  - Track alarms
  - Acknowledgement



Control System and sub-system: CCS

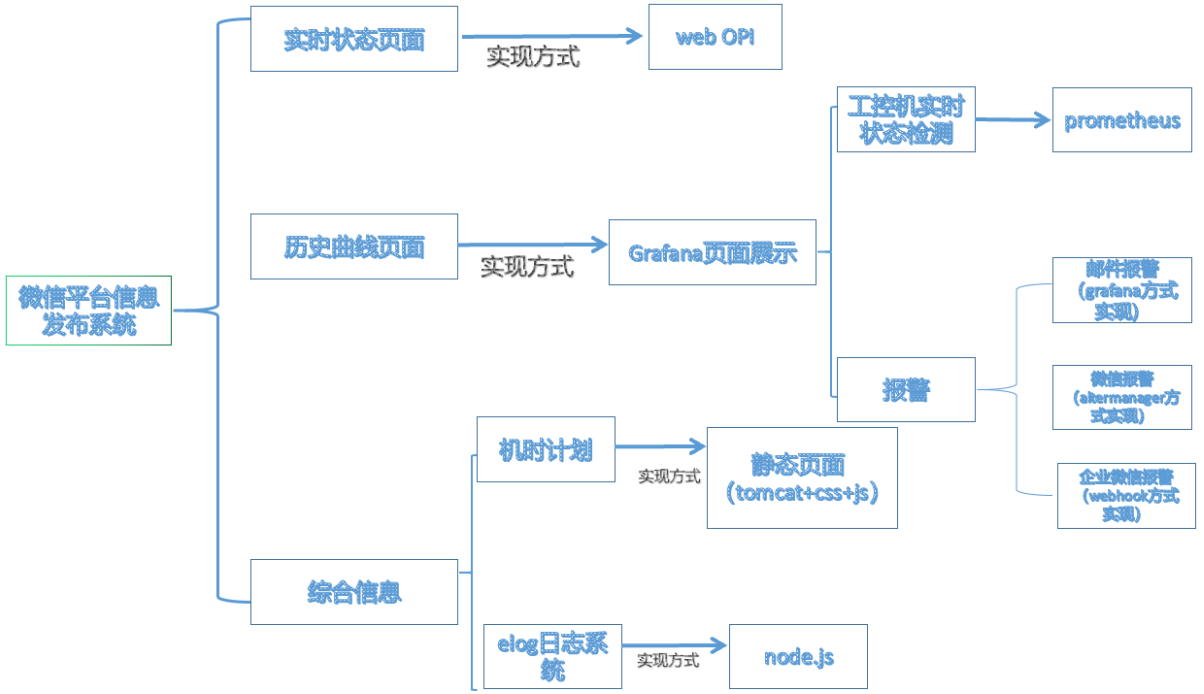
- Electronic log system
  - Server for operators, engineers, and users of large scientific facilities
  - Online digital logbook service
  - Create log entries
    - Meta-data
    - Attachments
  - Search
  - Authentication

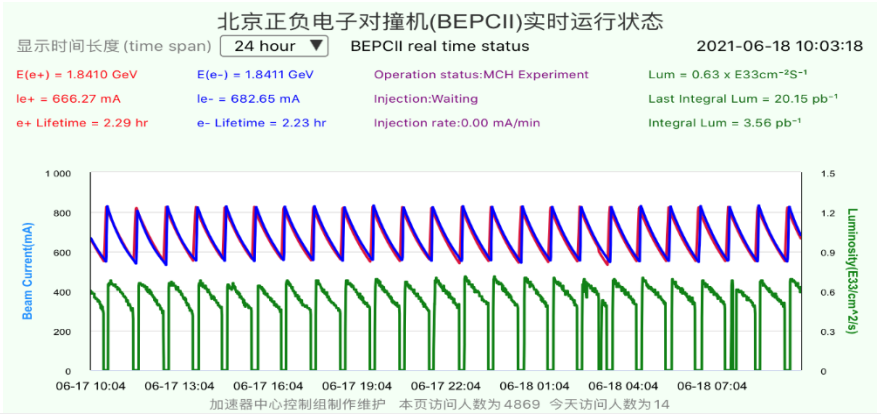


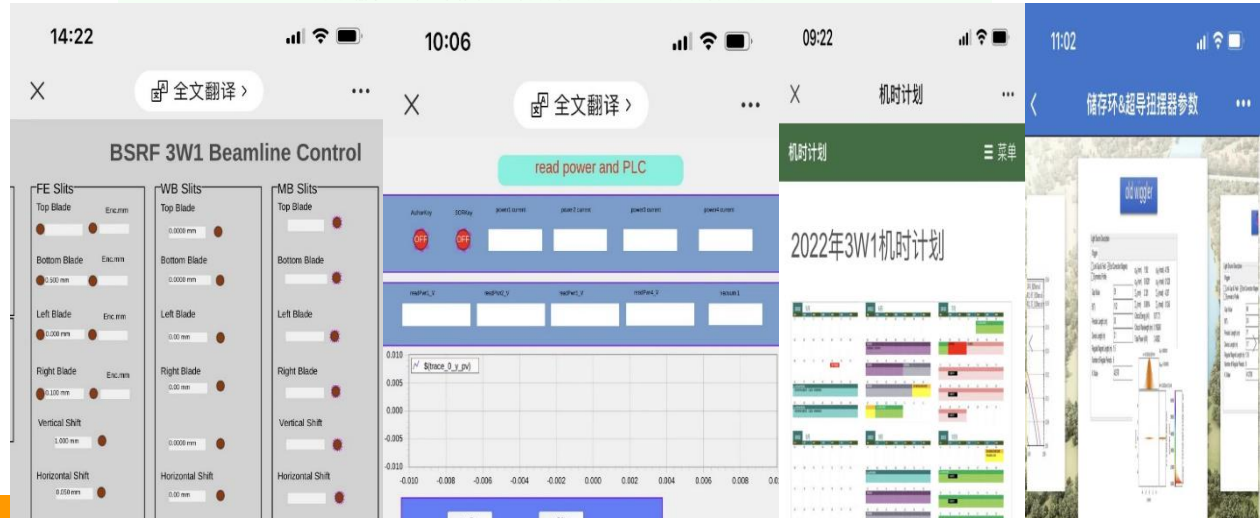


Control System and sub-system: CCS

- Issue information of machine based on weChat or Apps
  - Get to know information of CEPC complex anytime, anywhere
  - PVs and another information



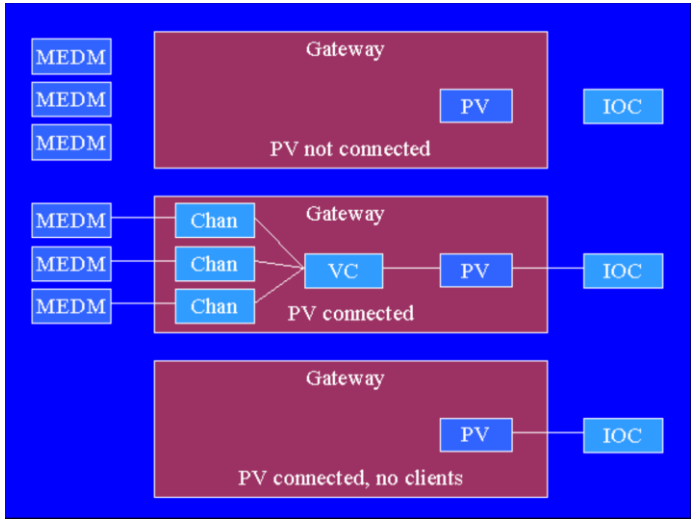




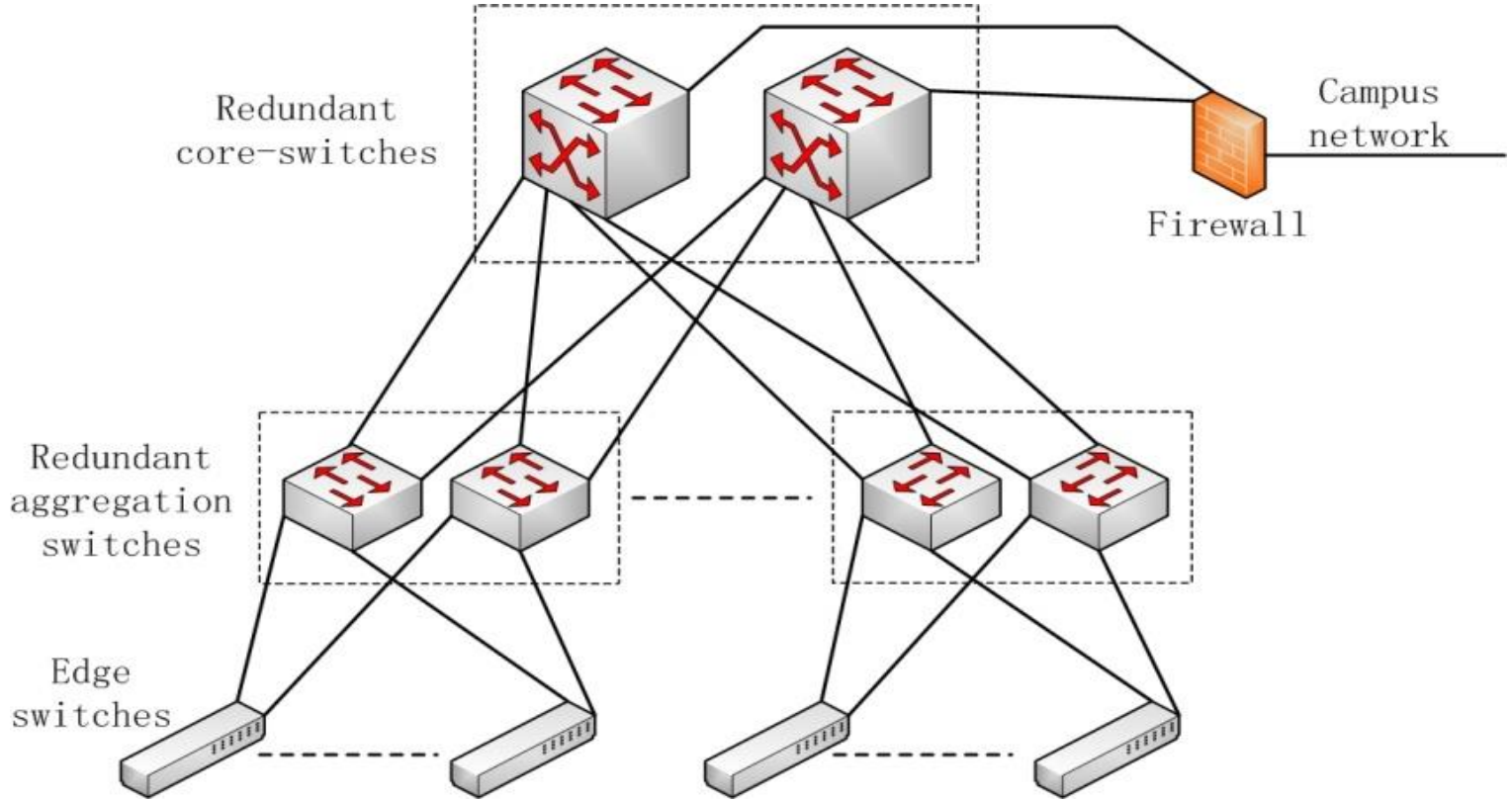
Apps and weChat （iOS and Android）

Control system & sub-system: Control Network

- Data rate/traffic/congestion in the network
  - Low latency switch
  - Vlan Technology
  - PVA/CA Gataway



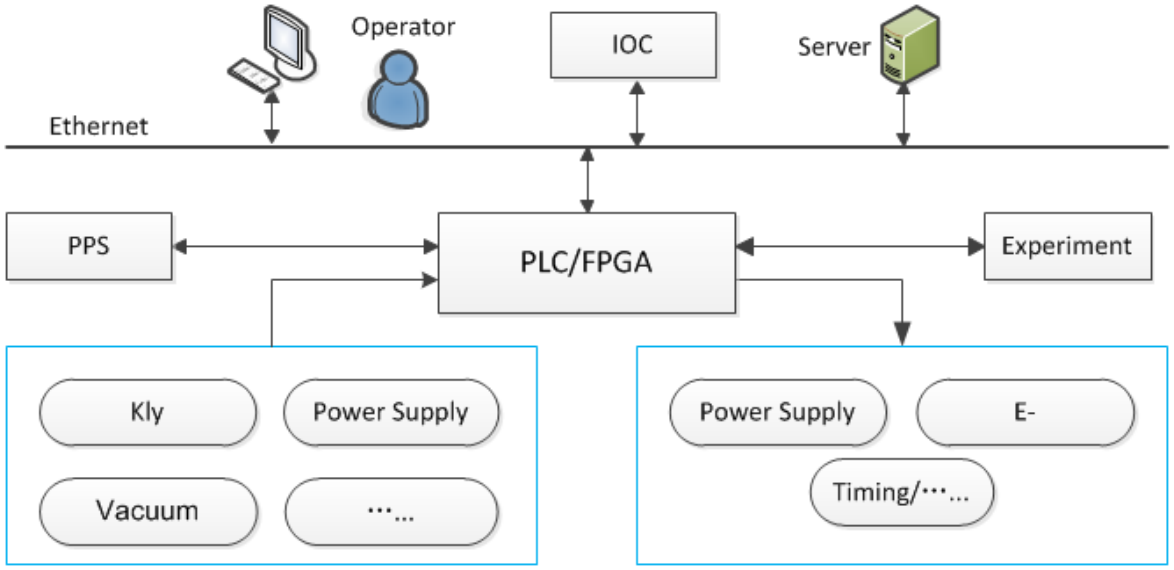
EPICS Gataway



Control Network System: three layers

Control system and sub-system: MPS

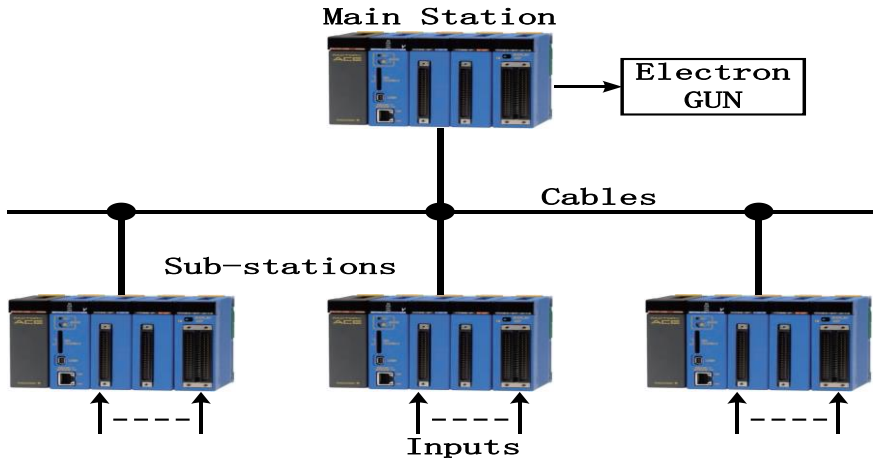
- Machine Protection System （ MPS ）
  - Stop beam or steer beam to dump, when key device or sub-system is a fault or abnormal
  - Tightly related to the accelerator design
- Generally, the structure of MPS=EPS (PLC)+FPS (FPGA)



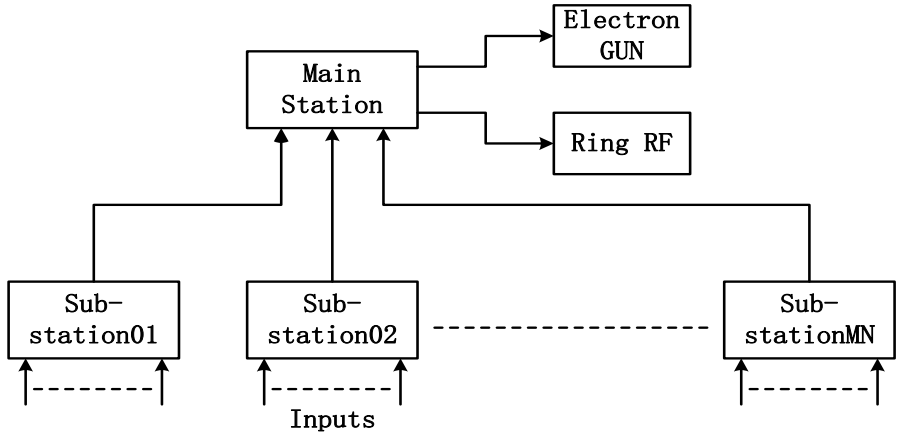
The MPS Architecture of CEPC

Control system and sub-system: MPS

- PLC for slow inputs, a response time of tens of ms is defined
  - The actuators are RF power ramp down and shutdown of electron gun
  - Preliminary name : Equipment Protection System (EPS)
- FPGA for fast inputs, a response time of tens of us is defined
  - The actuators are RF power off and shutdown of electron gun.
  - Preliminary name : Fast Protection System (FPS).
- Individual systems for loose coupling, easy implementation and debug



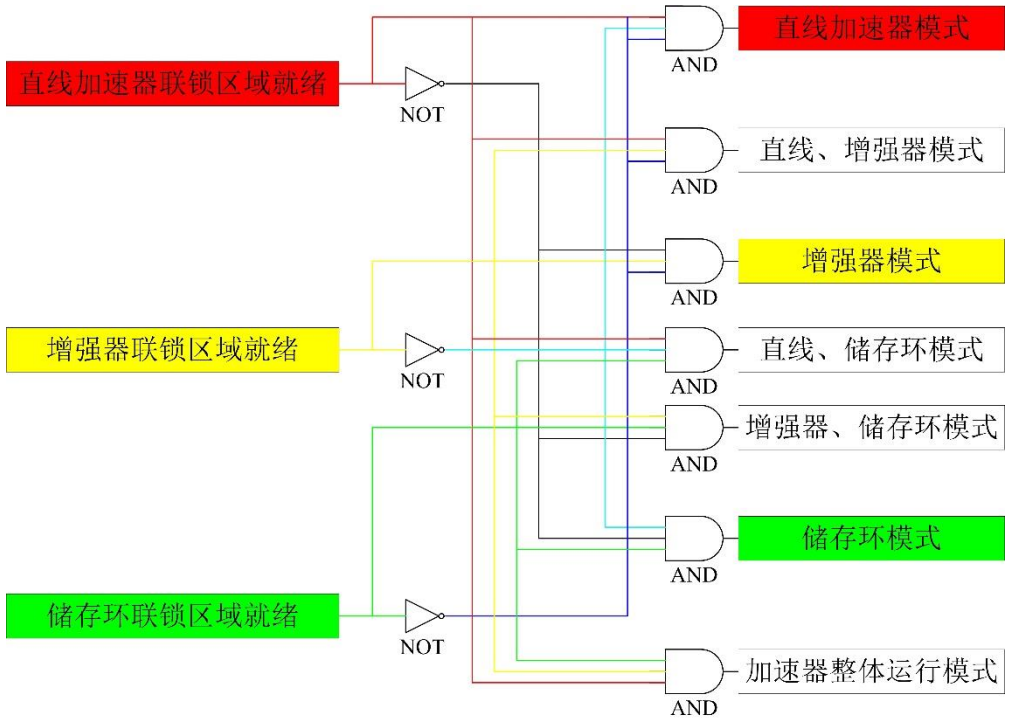
EPS based on PLC



FPS based on FPGA

Control system and sub-system: MPS

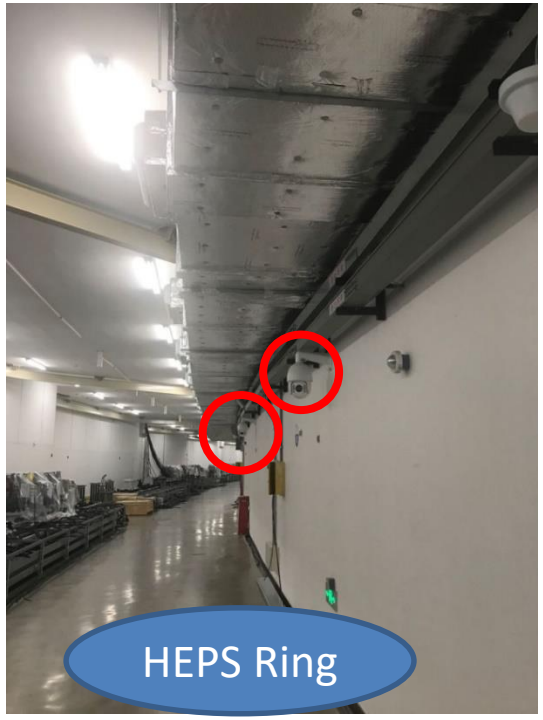
- Example of HEPS' MPS

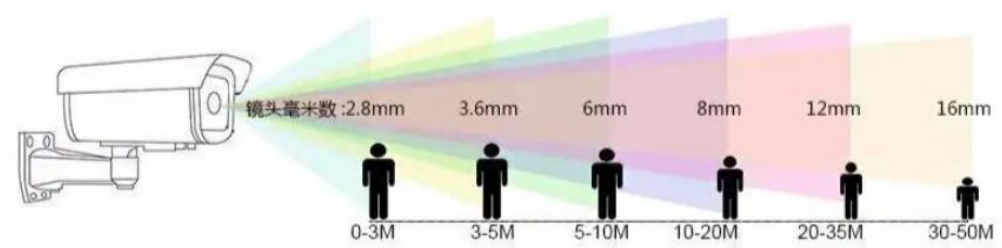


Instance of HEPS' MPS

Control system and sub-system: VSS

- Video Surveillance System
  - Record the device installation process as an image archive
  - Monitoring equipment status and on-site scenarios
  - Fixed-position camera and mobile camera





镜头选配表

镜头毫米数	2.8mm	3.6mm	6mm	8mm	12mm	16mm
建议照射距离	0-5m	0-5m	5-10m	10-20m	20-35m	30-50m
1/3 感光度	85°	75°	50°	38°	26°	20°

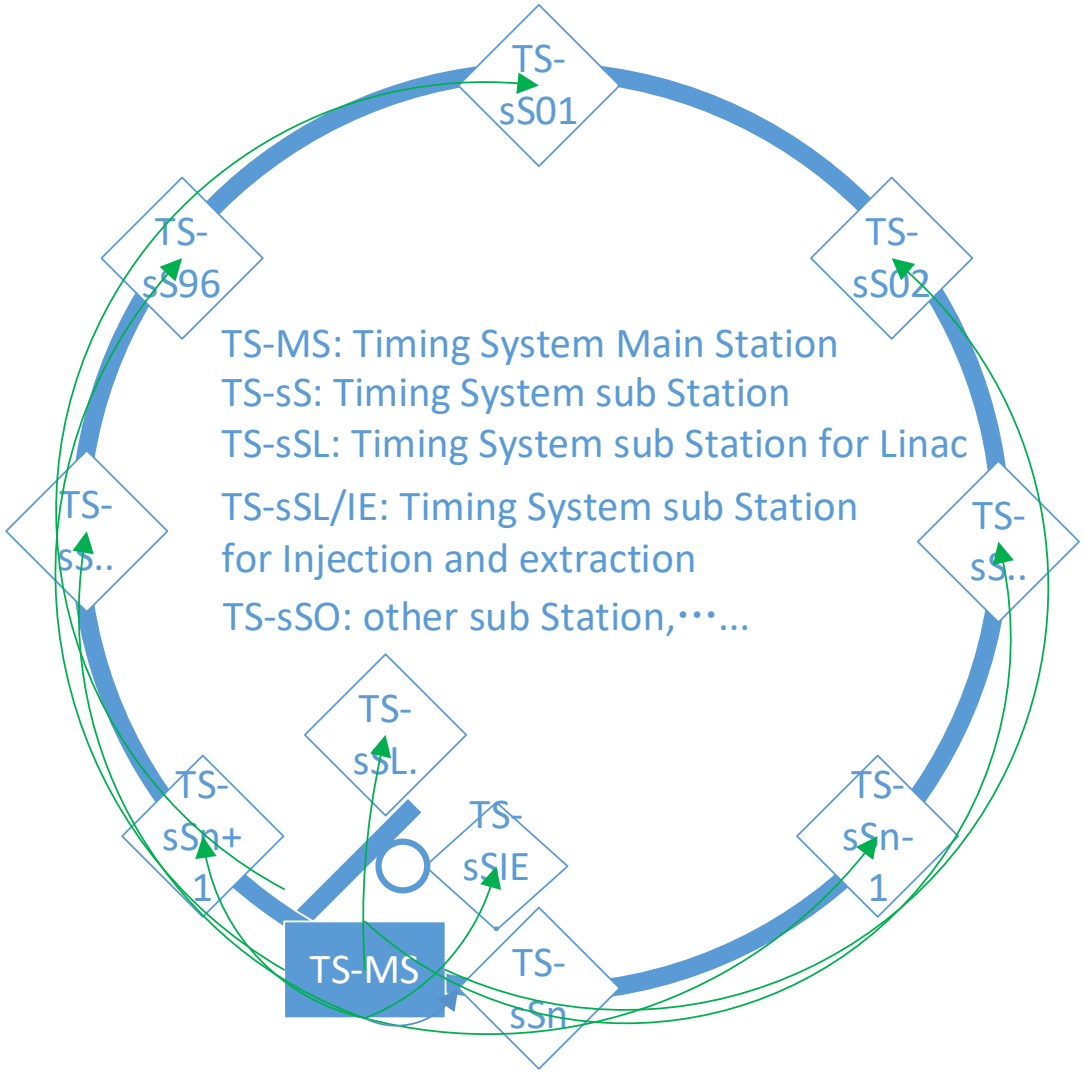
Control system & sub-system: Timing system

- Preliminary timing signal statistics of controlled devices

Destination	Quantity	Specification	Supplementary Notes
BI（TTL信号）	10664	Jitter<50ps	BPM、profile、DCCT、Tuning、BCM and BLM
BI（RF信号）	5030	Jitter<0.5ps, <1ps, <5ps	BPM、Profile、DCCT、Tuning、BCM and BLM
PS	860	Jitter<5ns	Booster 、Dipole、Quadrupole、Sextupole、Corrector and so on
RF	883	Jitter<50fs, <100fs, <50ps	

Control system & sub-system: Timing system

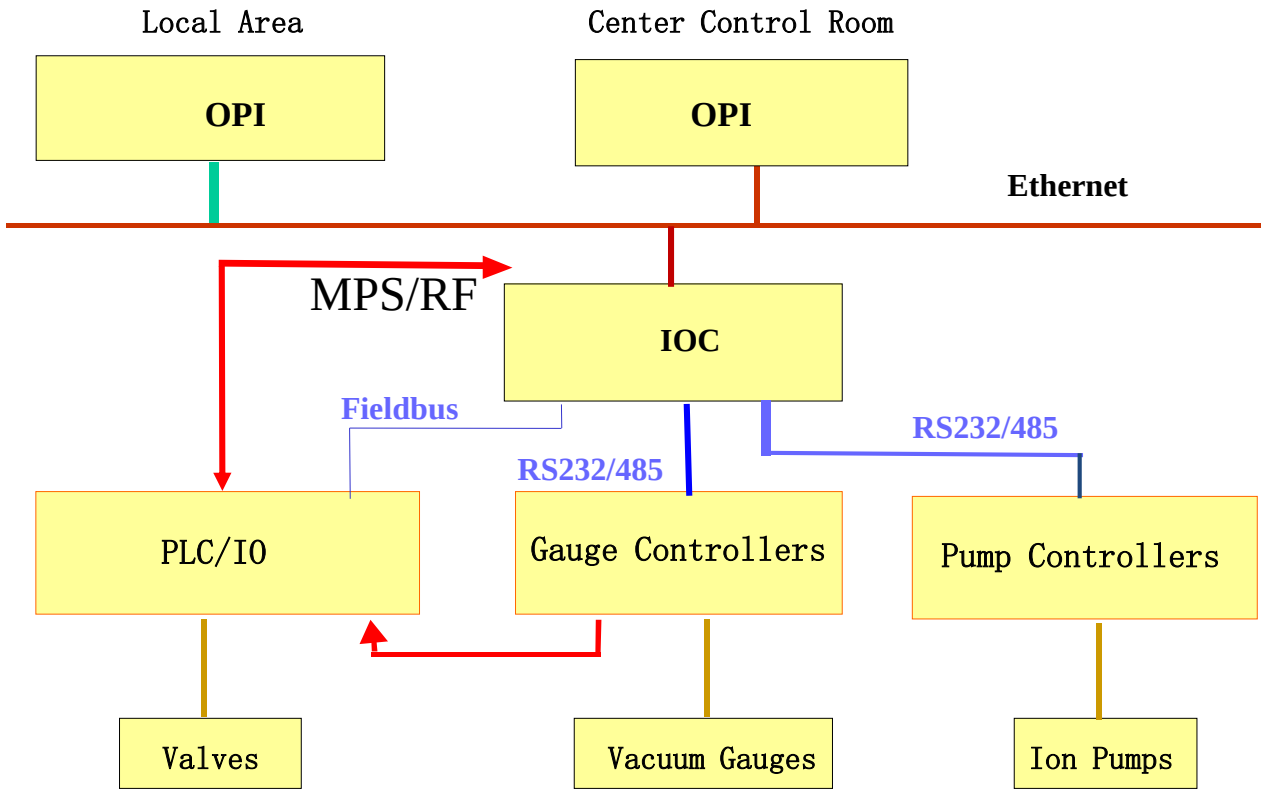
- The basic structure of Timing System
  - Event system and RF transmission system
  - Event system: Trigger signal and Low frequency clock signal
  - RF transmission system: Transmit high stability RF signal



- TS-MS: In CCR or RF-station
- TS-sS: Close to the controlled devices in sub-tunnels or other hall

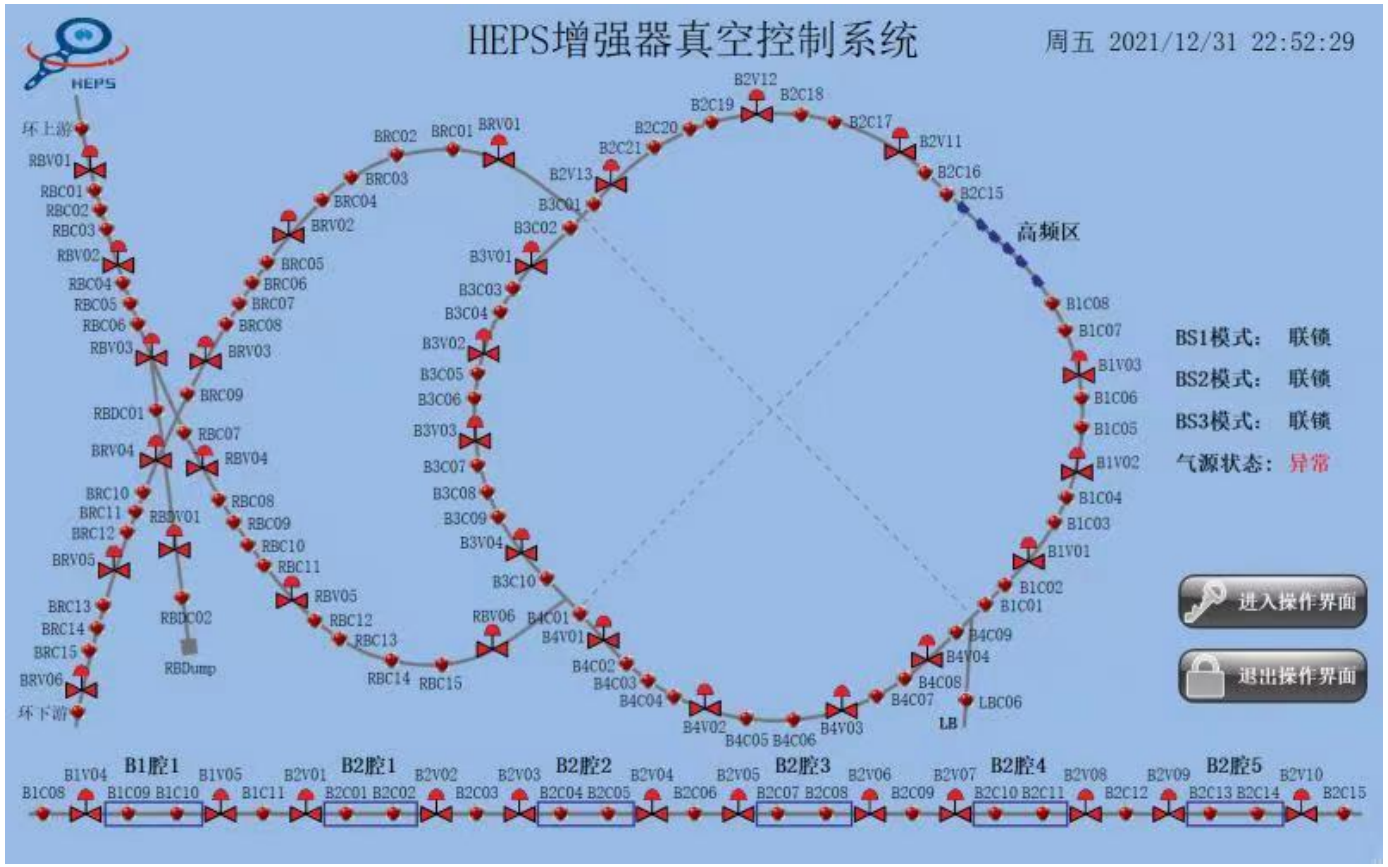
Control system and sub-system: Vacuum CS

- Vacuum equipments
  - Vacuum Gauge：7574
  - Ion pump：22607
  - Valve：1620
- Monitor
- Interlock policy
  - Voting scheme：Close Valve
  - Closed state of NO Contact：OK



Control System and sub-system: Vacuum CS

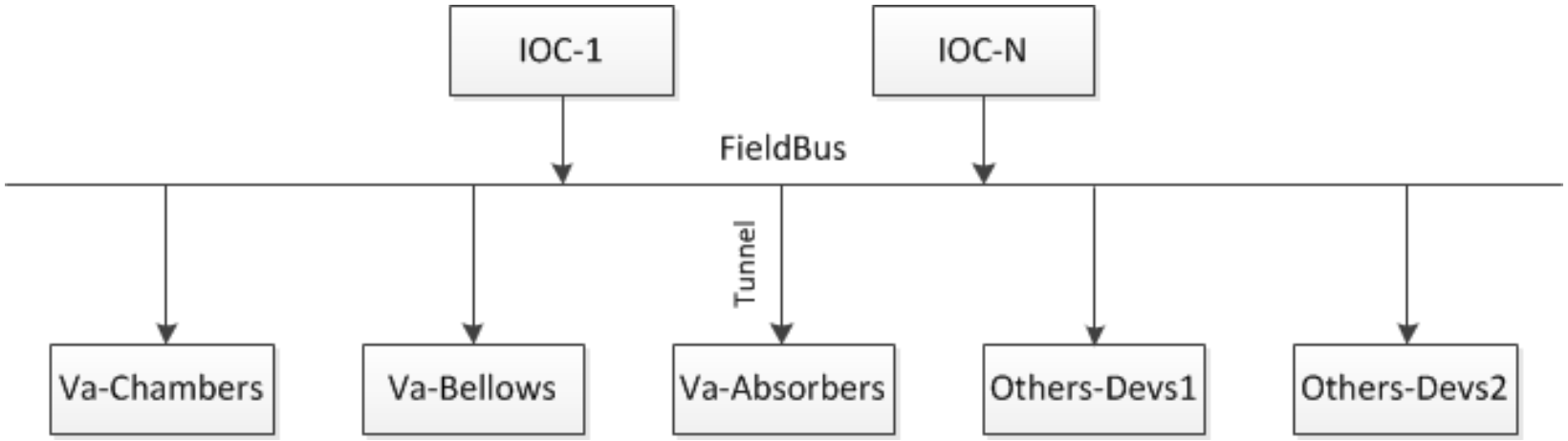
- Example of HEPS' vacuum CS



Instance of HEPS' Vacuum CS

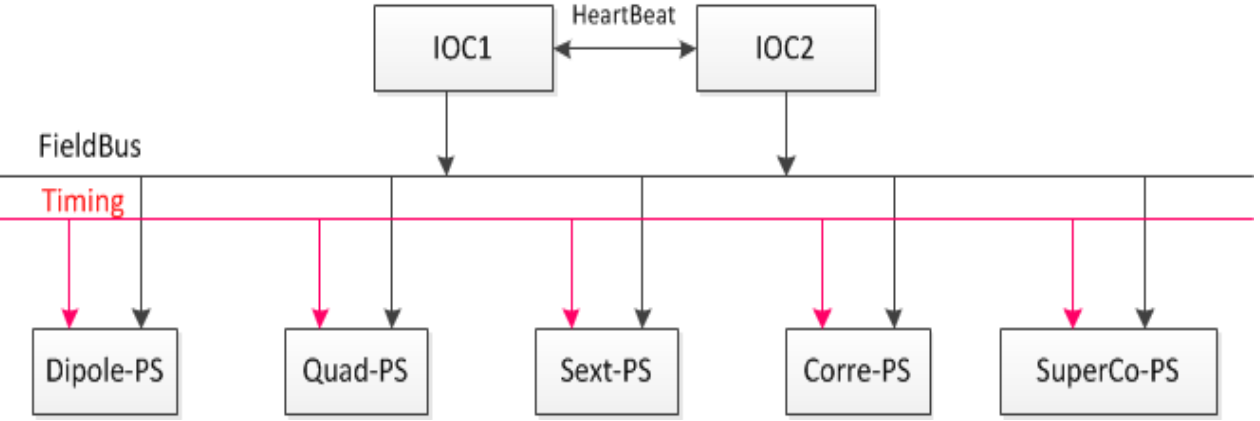
Control system and sub-system: TM

- Temperature Monitoring(TM)
  - Quantity: 100,000+(Vacuum devices)
  - ADAM4015/6015, Temperature paperless recorder
  - Others: … …

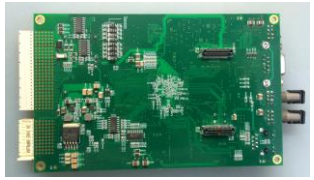


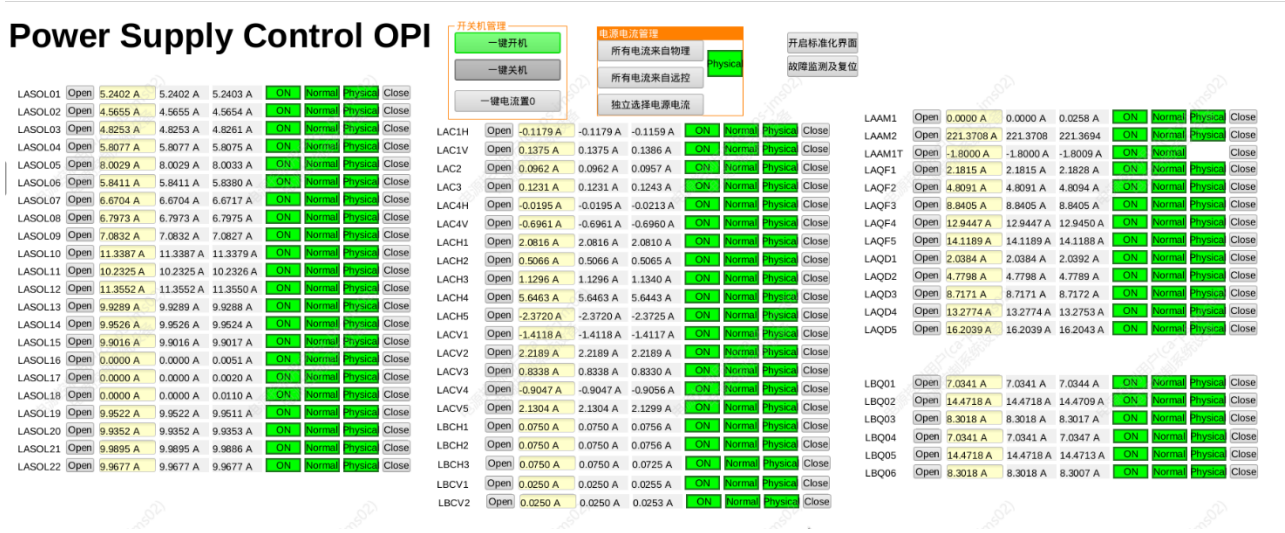
Control System and sub-system: PSCS

- Power Supply control system (PSCS)
  - Accelerate from 30GeV to 120GeV (Linac to Booster ring)
  - Magnets' power supply co-ramping within an accuracy of tens of μs



Redundant IOCs for PSCS – (DPSCM)

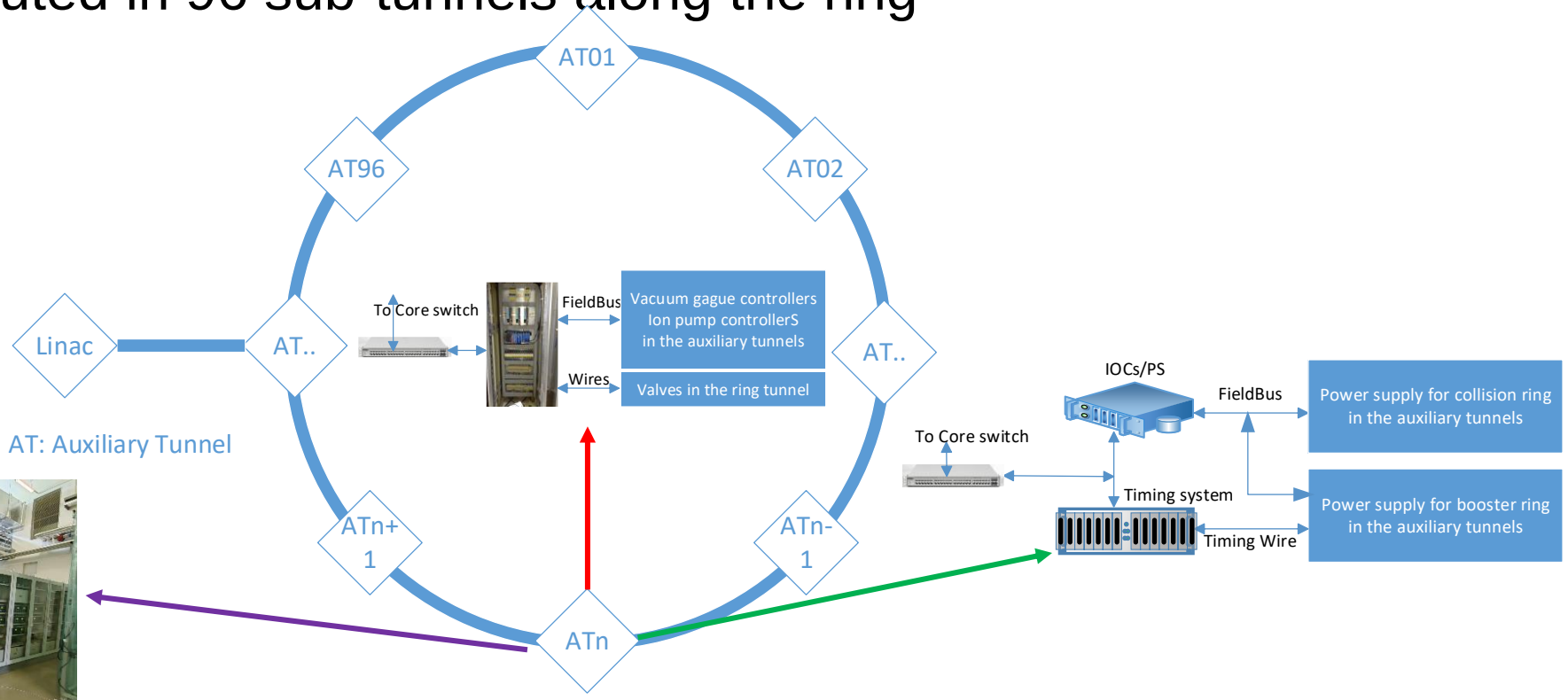




Instance of HEPS' PSCS

Control System & sub-system: Cabinet Layout

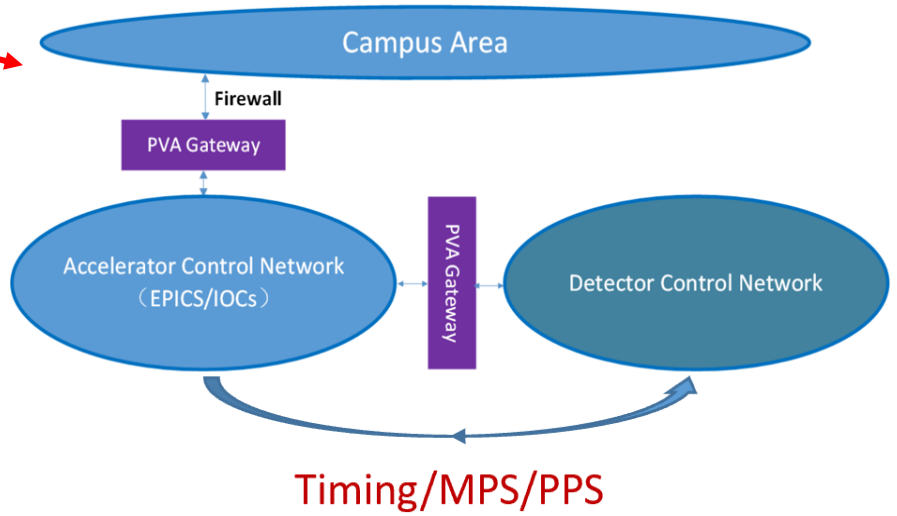
- Control Cabinet layout of Vacuum CS, PSCS, TM, etc
  - Be close to controlled devices(vacuum controller, power supply and so on)
  - Mainly distributed in 96 sub-tunnels along the ring



The layout of control cabinet in sub-tunnels

Control System and sub-system: Integration

- Integration of subsystems and other systems
  - LLRF, Cryogenic system, Injection/Extraction system etc
  - Detector(Experimental physics), beamline and conventional facility
- The following rules must be followed
  - Agree with standards of CEPC control system
  - Consistent with software (EPICS)
  - Unified hardware



Control System and sub-system: DM

- *Database Management of CEPC*

Parameter Database	Naming Convention Database
Magnet Database	MPS and interlock database
Lattice and Model Database	Management of File
Log and trouble tracking	Alignment Database
Management of Cable and device	Alarm database
Configuration of Security database	Etc..

- More and more Database will be designed with the progress of the Project

Next Step--EDR

- Time deterministic system (Timing system and MPS)
  - Build the prototypes
  - Deterministic time
  - Longest transmission distance
- The application of the state-of-art technologies
  - Video Surveillance System: Robot
  - Communication: 5G/6G (~~wire cables/optical fibers~~)
  - Etc
- Optimize the layout of the control local sub-station
  - Balance/compromise: cost, performance and ease of maintenance

Summary

- More detailed requirements should be further clarified, with the progress of CEPC project
- EPICS：Cooperate closely with EPICS community and company
- New technique (IoT/AI/ML, etc) used in control system

Thanks a lot!