



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

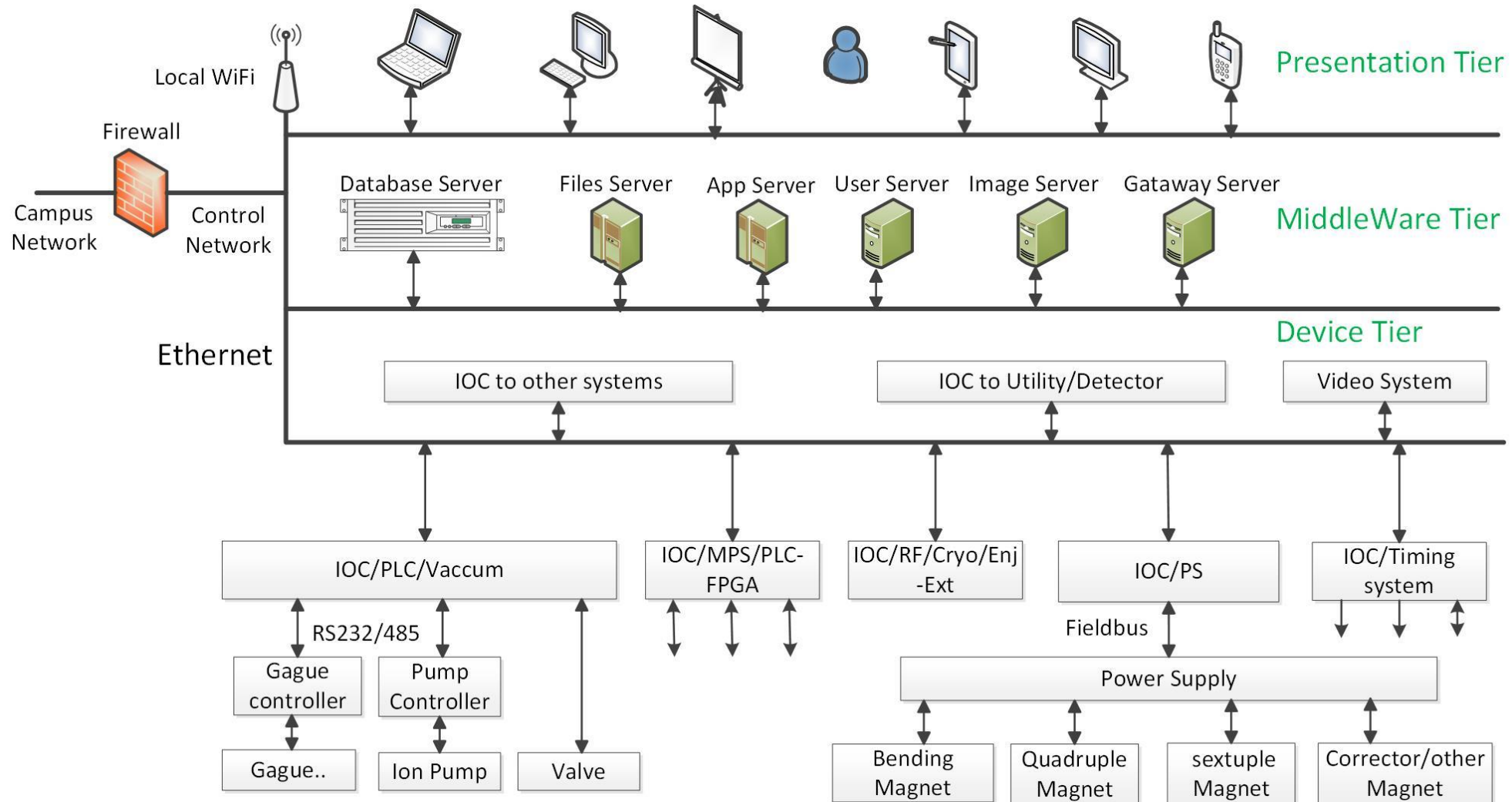
CEPC-TDR控制需求信息调查表2018-低温-Requirement from Cryo.xlsx

CEPC电源与控制接口信息-20190618-电源-Requirement						1					
文件 开始 插入 页面布局 公式 数据 审阅 视图 帮助 福昕PDF 告诉我你想要						2	Type/Affiliations	Quantity	Location	Precision	Interface
Times New Roman 8 A A 常规						3	Collider	8160			
B I U 字体 对齐方式 数字						4	Dipole-Double	8	8 Power Supply Hall	100ppm	以太网
H24 X ✓ fx						5	Dipole-Singular	162	96 Auxiliary Tunnel unit	100ppm	以太网
A B C D E F G						6	Quadrupole-Double	192	96 Auxiliary Tunnel unit	100ppm	以太网
1						7	Quadrupole-Singular	920	96 Auxiliary Tunnel unit	100ppm	以太网
2	位置	电源数量	安装位置	精度	接口类型	8		80	96 Auxiliary Tunnel unit	100ppm	以太网
3	Collider	8160				9		22	96 Auxiliary Tunnel unit	100ppm	以太网
4	Dipole双	8	均匀分布在地上8个电源厅	100ppm	以太网	10	Sextupole	896	96 Auxiliary Tunnel unit	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	11		72	96 Auxiliary Tunnel unit	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	12	Corrector	2904	96 Auxiliary Tunnel unit	500ppm	以太网
7	Quadrupole单	920	均匀分布在地下96个辅助隧道	100ppm	以太网	13		2904	96 Auxiliary Tunnel unit	500ppm	以太网
8		80	均匀分布在地下96个辅助隧道	100ppm	以太网	14					
9		22	均匀分布在地下96个辅助隧道	100ppm	以太网	15					
10	Sextupole	896	均匀分布在地下96个辅助隧道	100ppm	以太网	16					
11		72	均匀分布在地下96个辅助隧道	100ppm	以太网	17	Type/Affiliations	Quantity	Location	Precision	Interface
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						
14											
15											
16											
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											

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

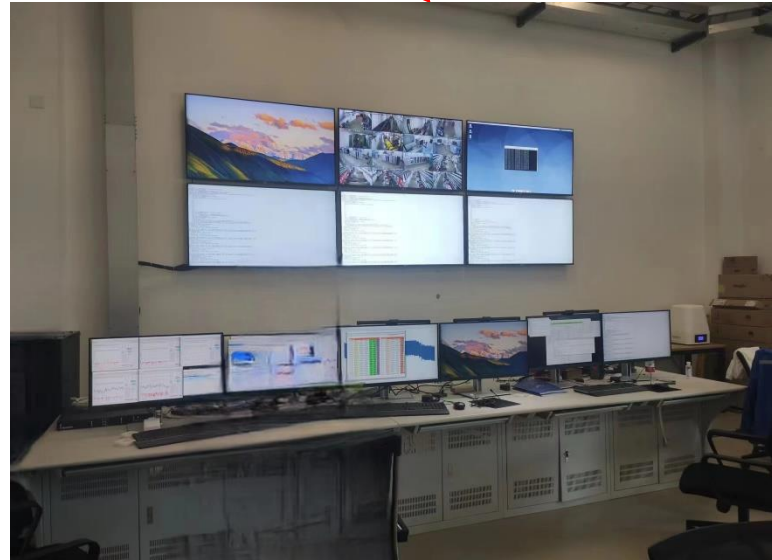
- Control Rooms
- Management and operation of IOCs/OPIs
- Server and management of High level software
- CA/PVA Gateway
- OPI tools--CSS, caQtDM, PyDM etc
- Data Archiver
- Alarming system
- Elog
- Issue information of machine via instant message(weChat)
- Machine status summary on Web
- Etc

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)



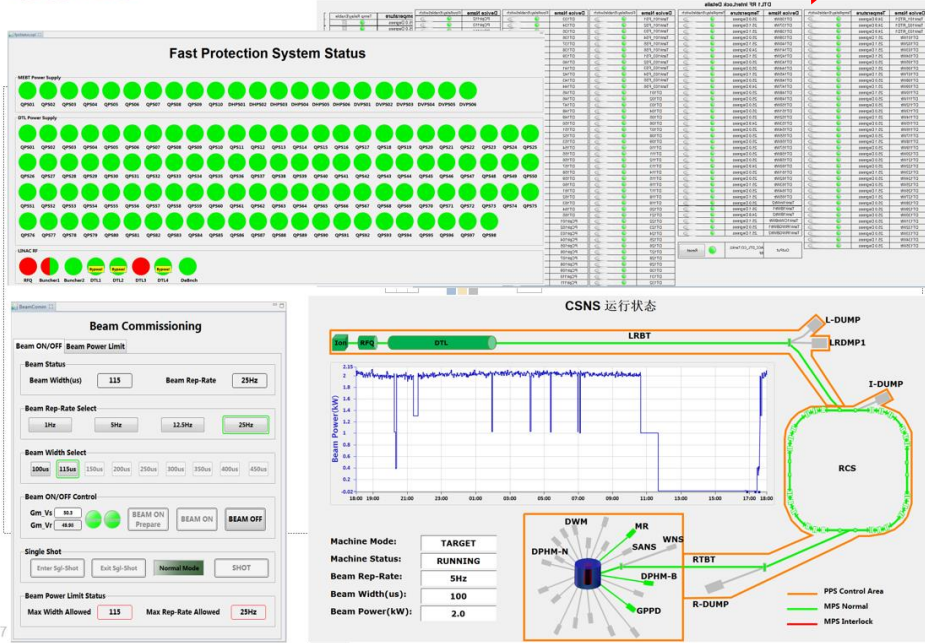
Mini Console

Control System and sub-system: CCS

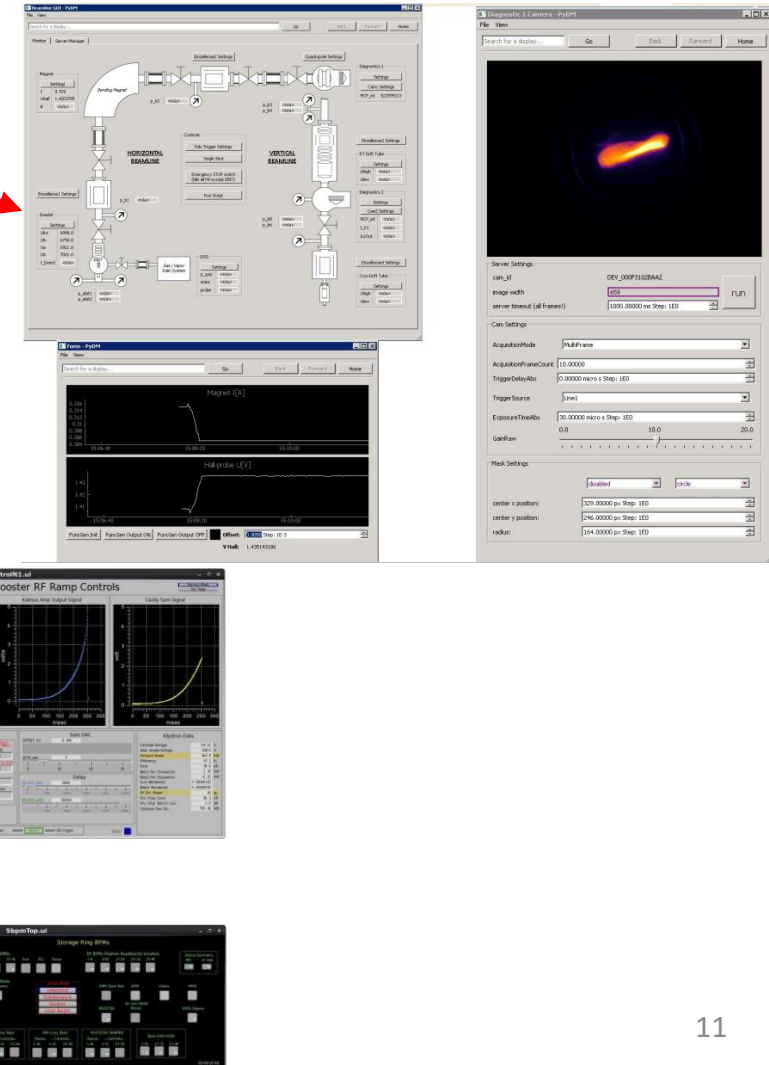
- OPI/GUI tools

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

CSNS



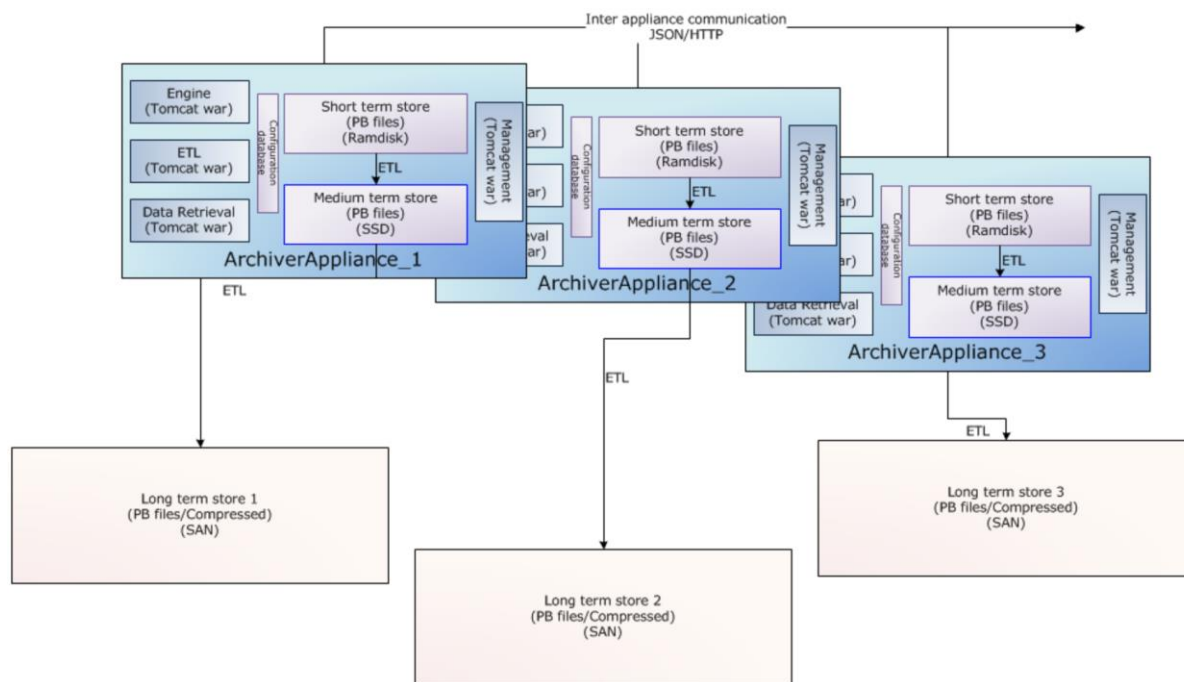
caQtDM Examples



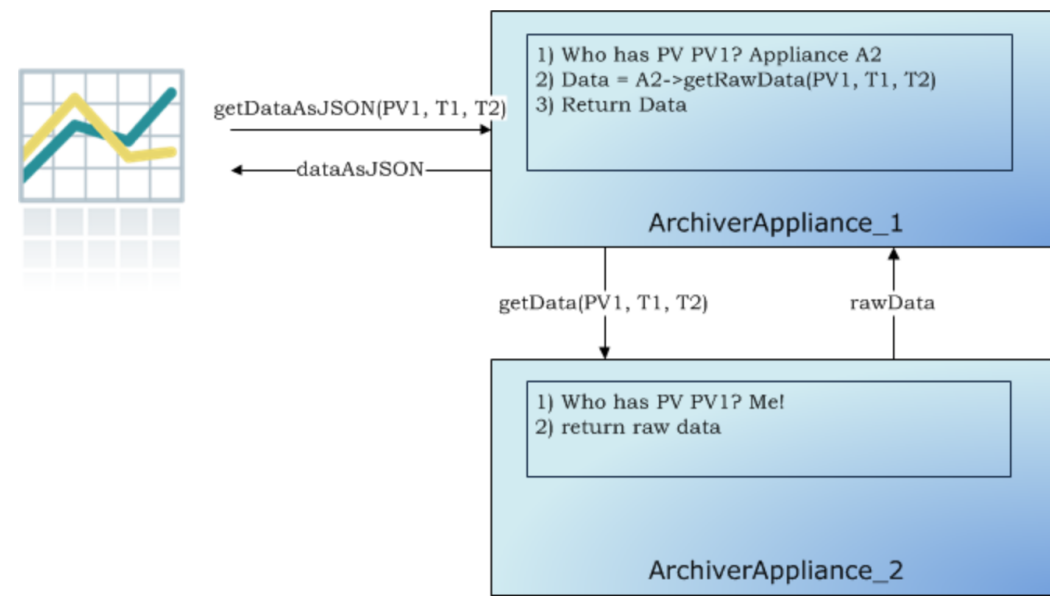
Control System and sub-system: CCS

■ 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

The screenshot displays the CCS Alarming system interface. It features a grid of PVs (Process Variables) at the top, an Alarm Tree on the left, and an Alarm Table (CCR) on the right. The Alarm Table shows current and acknowledged alarms with details such as PV, Description, Alarm Time, Current Severity, and Current Status.

Alarm Table [CCR]

PV	Description	Alarm Time	Current Severity	Current Status	Alarm
ICS_Opr:RFQ:VacuumAlarm	Attention: R F Q vacuum alarm	2018-05-30 08:45:40	OK	NO_ALARM	ALARM
CF_RN:DIWS_AIT4601B:Rs	Hebbitt Ring RTBT Magnets DI water polishing loop	2018-05-30 03:28:11	MAJOR	HIGH_ALARM	ALARM

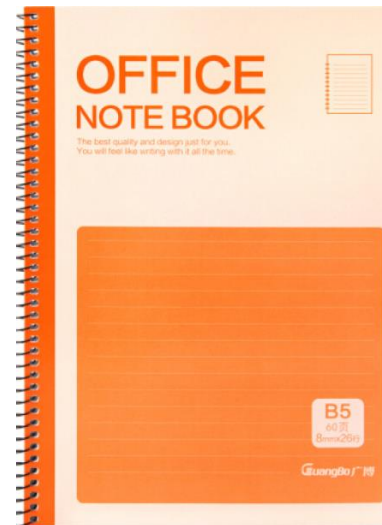
Acknowledged Alarms (13)

PV	Description	Alarm Time	Current Severity	Current Status	Alarm
Test_LLRF:Cav_RFQ1:OK	Attention: Process Variable	2018-05-17 01:59:54	MAJOR	STATE_ALARM	ALARM
Test_HPRF:Xmtr101:RP_Fit	BTTF rf transmitter fault	2018-05-25 10:24:11	MAJOR	STATE_ALARM	ALARM
Test_HPRF:PPSSwitch_RFQ:Sum	Attention: Attention. BTTF RFQ PPS is inhibited	2018-05-23 15:36:30	MAJOR	HIHI_ALARM	ALARM
SpRFQ_Cool:TestStand:WaterLea	Attention: B T F Water Leak Alarm	2018-05-29 12:13:48	INVALID	READ_ALARM	ALARM

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



Olog v1.0.6

Search: No search string

Tags: 所内, Entry Type: Normal

1. Ximea/areadetector开发介绍 (刘琦)

2. 机房装修进展 (雪薇)

3. BE单色器压电运动控制与光栅尺回来数值不一致性--“干扰” (小宝, 宗仰, 爱玉)

4. IHEP-ACS联合培训及下一次内部培训 (宗仰, 小宝, 典帅)

5. 运动控制--五相核心板卡延期及其解决方案 (宗仰)

6. 针对即将安调BE, 各子系统的准备 (所有人)

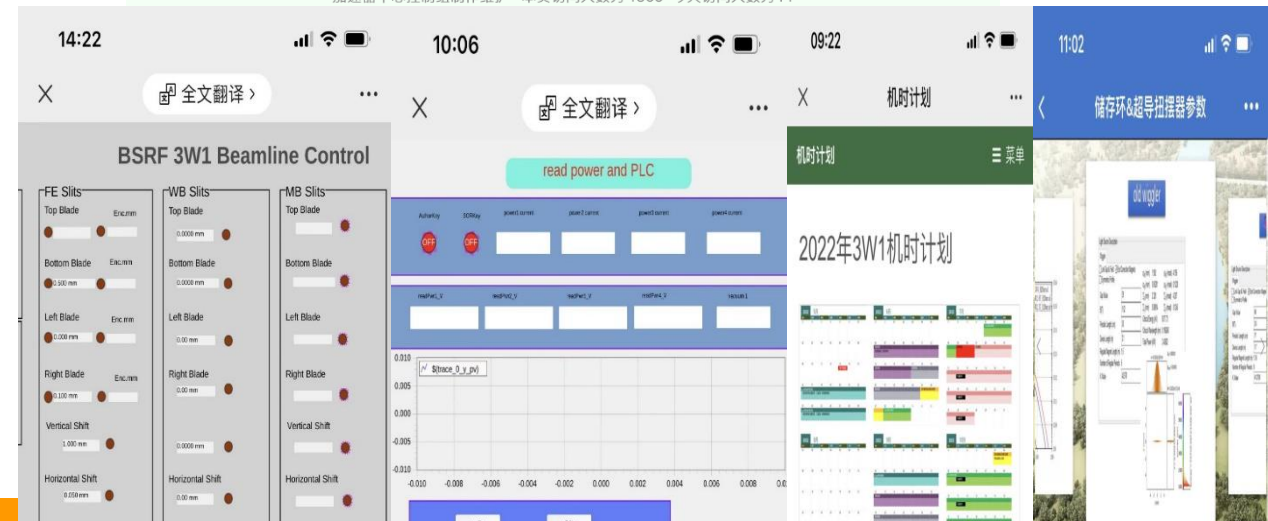
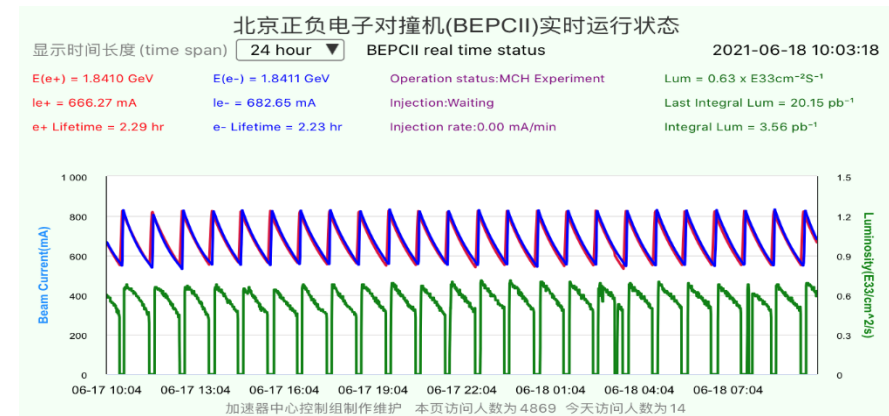
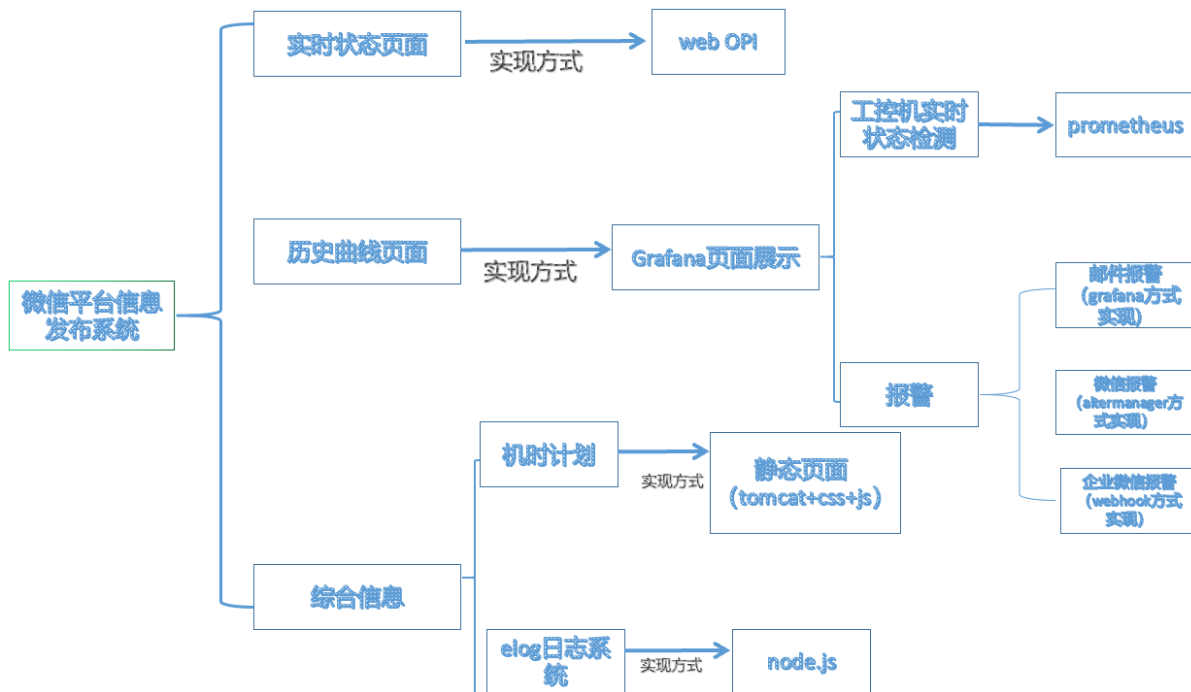
7. B7线站“飞扫”实验在BSRF/3W1的验证测试 (爱玉, 刘琦等)

8. 其他事宜 (线站束线控制经费核算, 设备采购, 周小结等)

Attachments

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

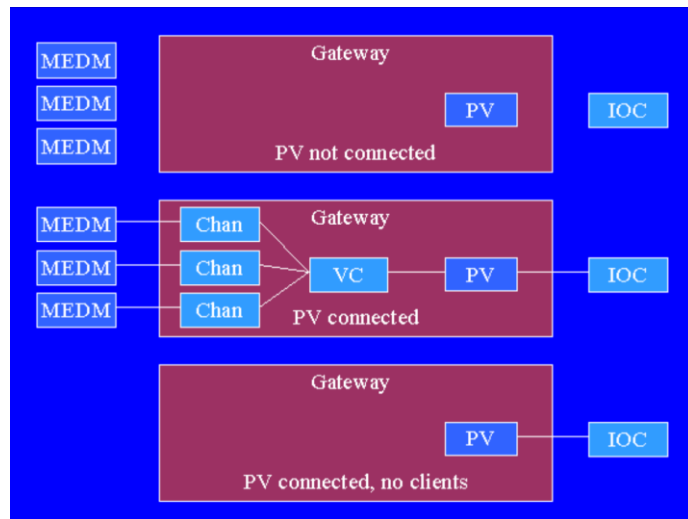


Apps and weChat (iOS and Android)

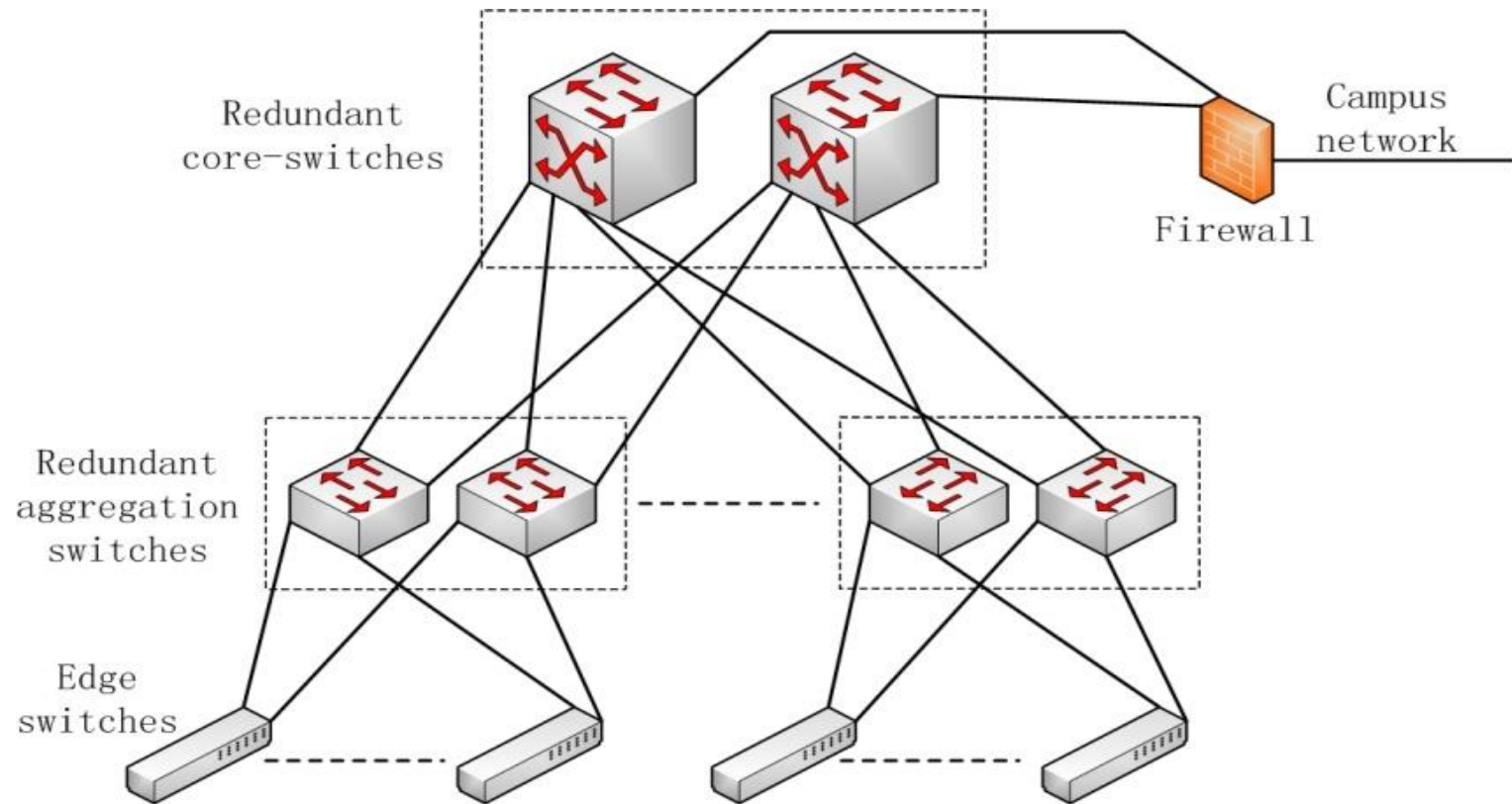
Control system & sub-system: Control Network

■ Data rate/traffic/congestion in the network

- Low latency switch
- Vlan Technology
- PVA/CA Gateway



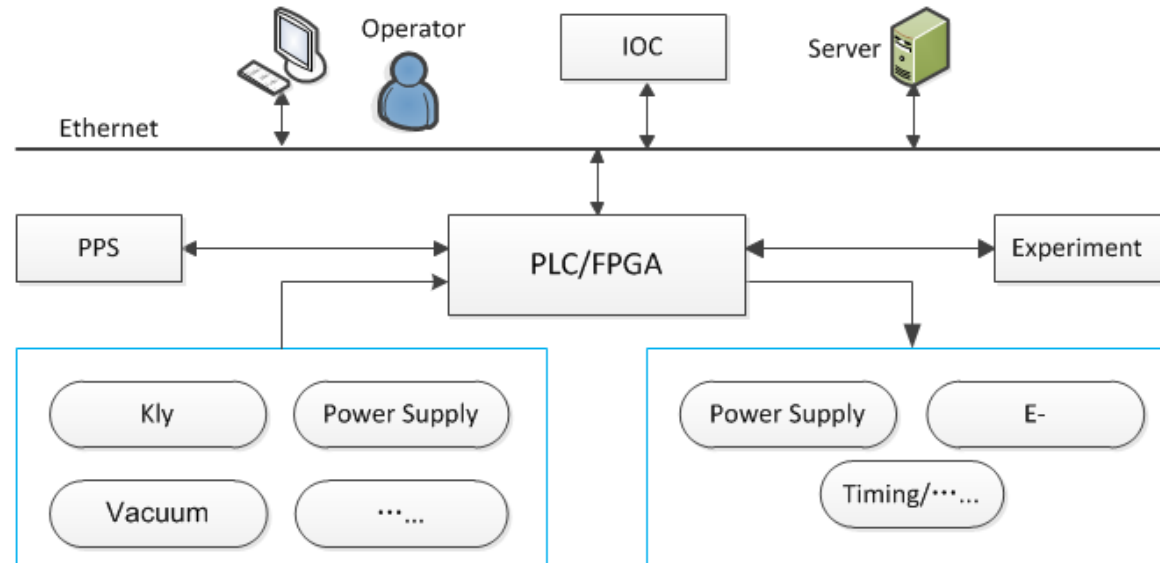
EPICS Gateway



Control Network System: three layers

Control system and sub-system: MPS

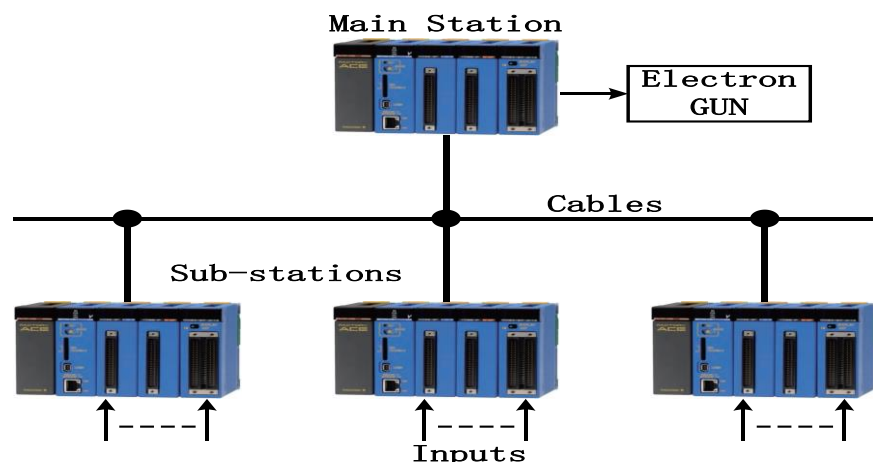
- Machine Protection System (MPS)
 - Stop beam or steer beam to dump, when key device or sub-system is a fault or abnormal
 - Tightly related to the accelerator design
- Generally, the structure of MPS=EPS (PLC)+FPS (FPGA)



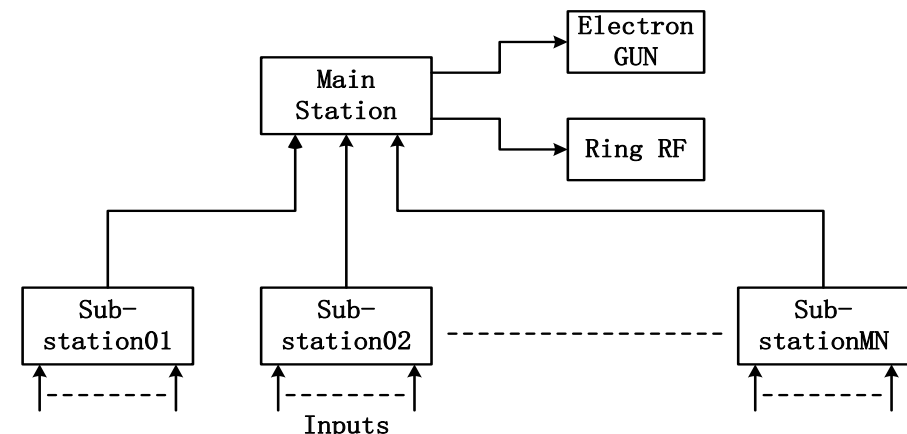
The MPS Architecture of CEPC

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



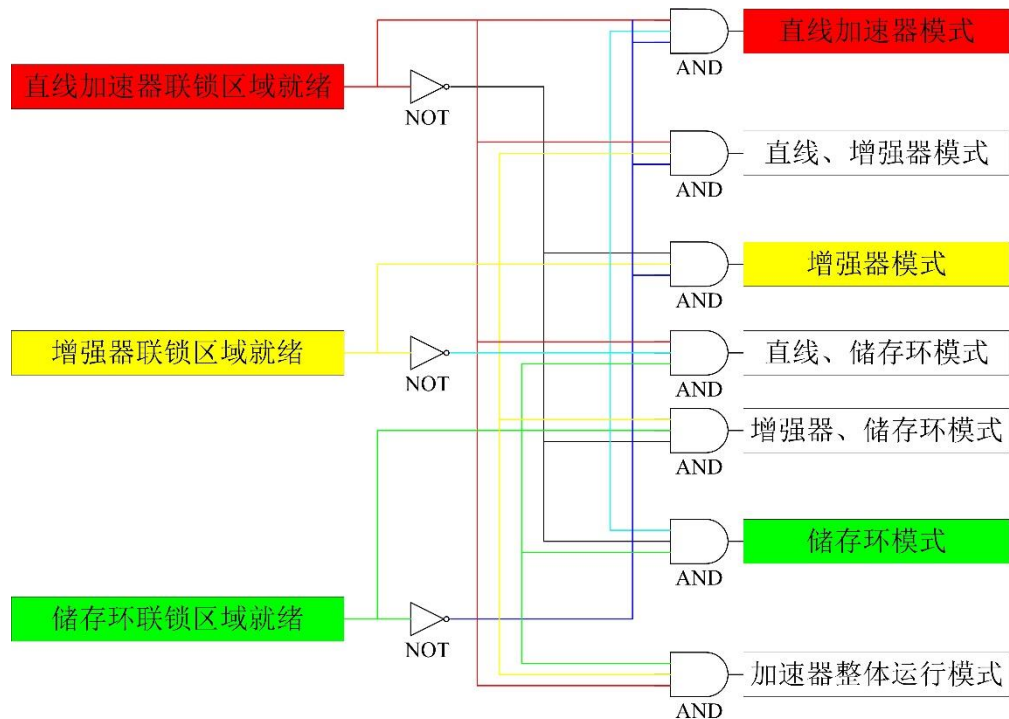
EPS based on PLC



FPS based on FPGA

Control system and sub-system: MPS

■ Example of HEPS' MPS

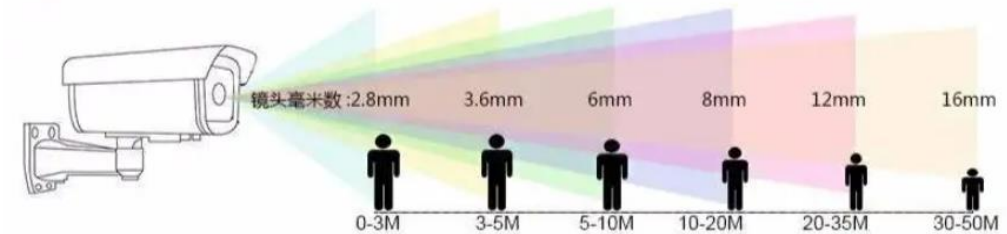
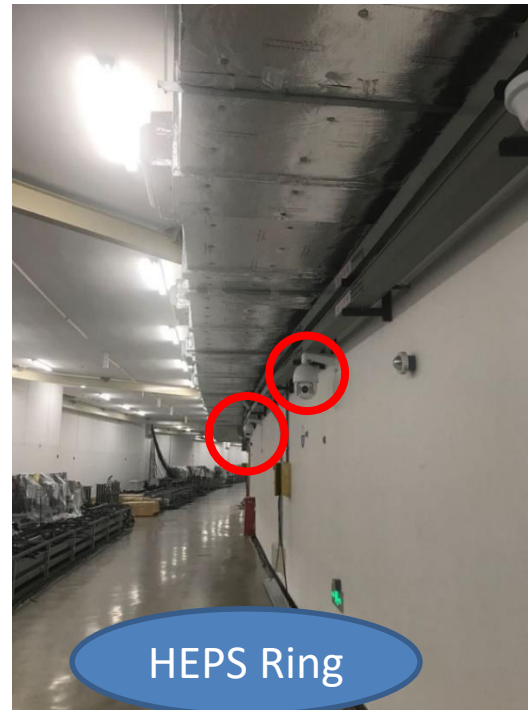


Instance of HEPS' MPS

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

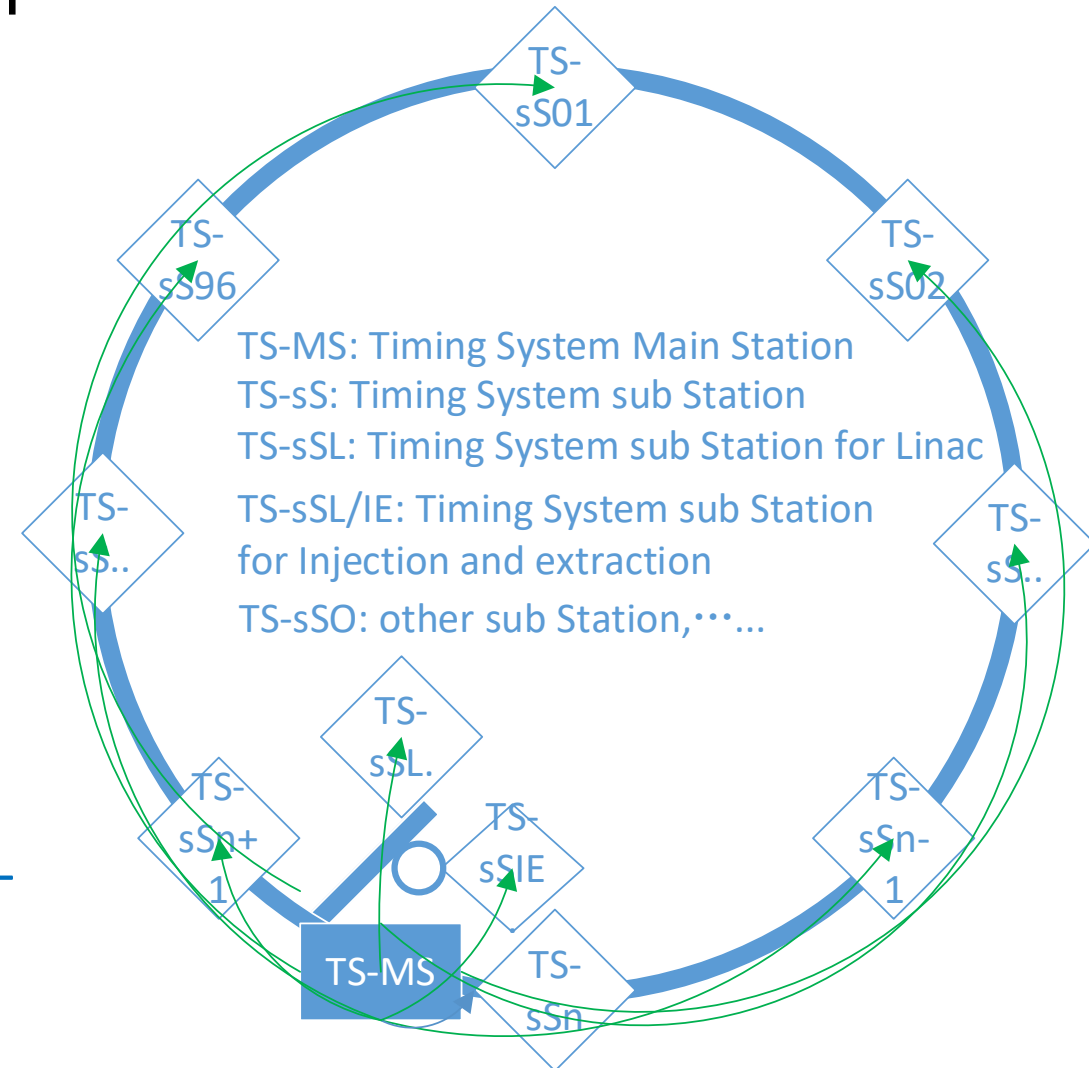
Destination	Quantity	Specification	Supplementary Notes
BI (TTL信号)	10664	Jitter<50ps	BPM、profile、DCCT、Tuning、BCM and BLM
BI (RF信号)	5030	Jitter<0.5ps, <1ps, <5ps	BPM、Profile、DCCT、Tuning、BCM and BLM
PS	860	Jitter<5ns	Booster、Dipole、Quadrupole、Sextupole、Corrector and so on
RF	883	Jitter<50fs, <100fs, <50ps	

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

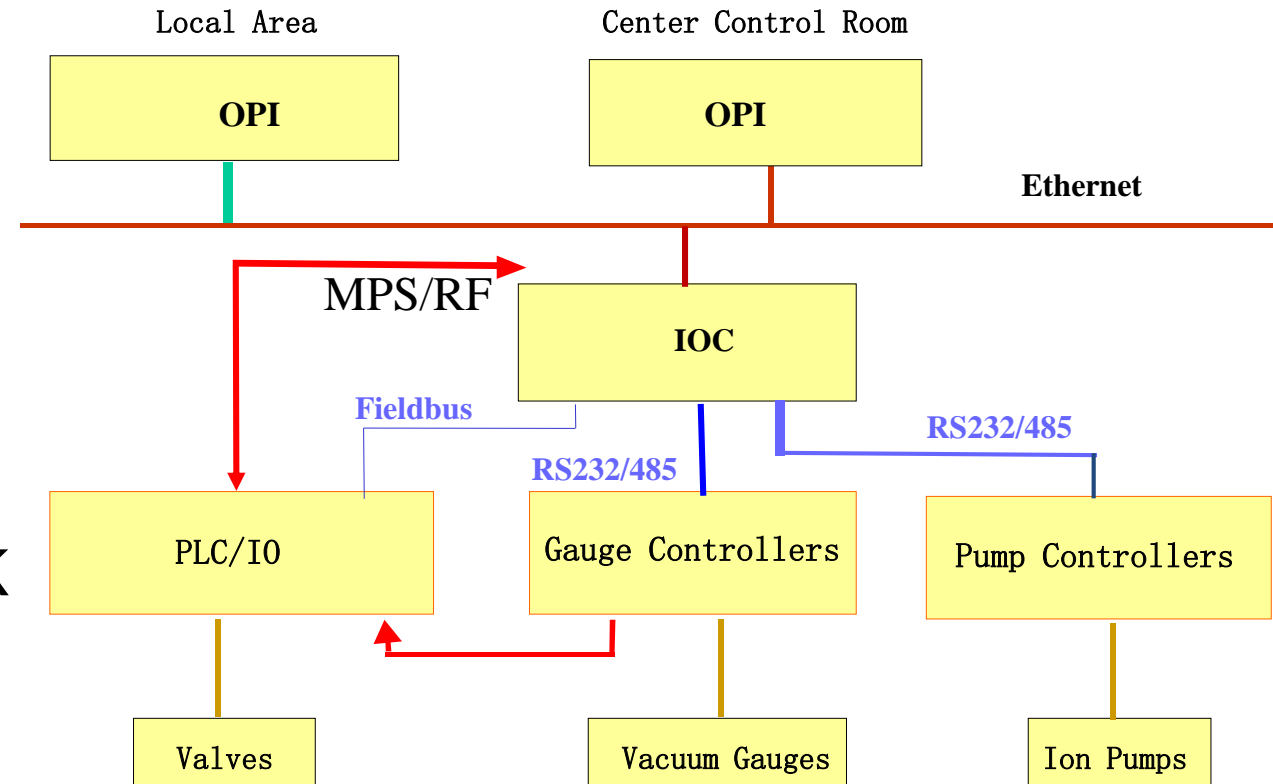
■ Vacuum equipments

- Vacuum Gauge: 7574
- Ion pump: 22607
- Valve: 1620

■ Monitor

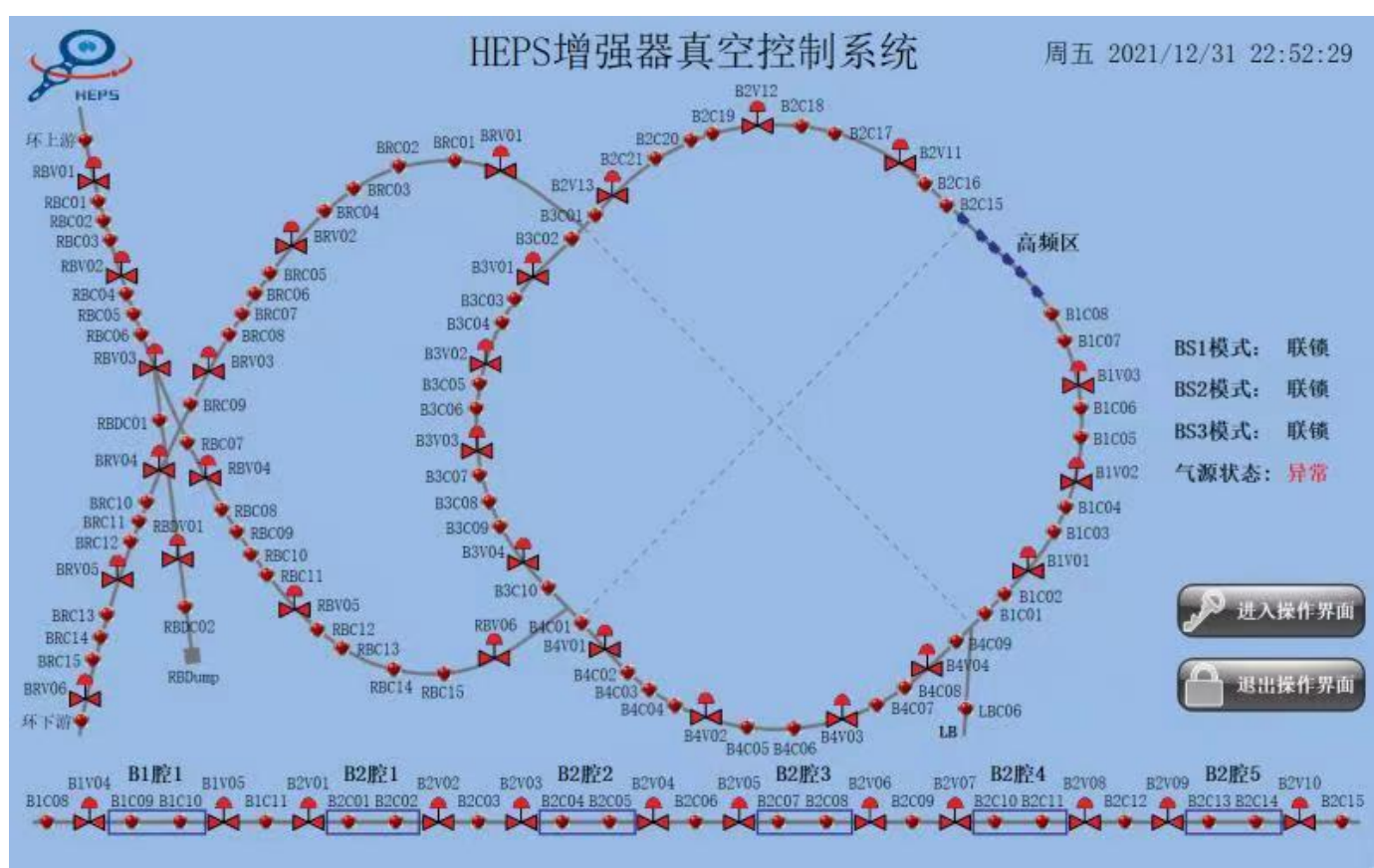
■ Interlock policy

- Voting scheme: Close Valve
- Closed state of NO Contact: OK



Control System and sub-system: Vacuum CS

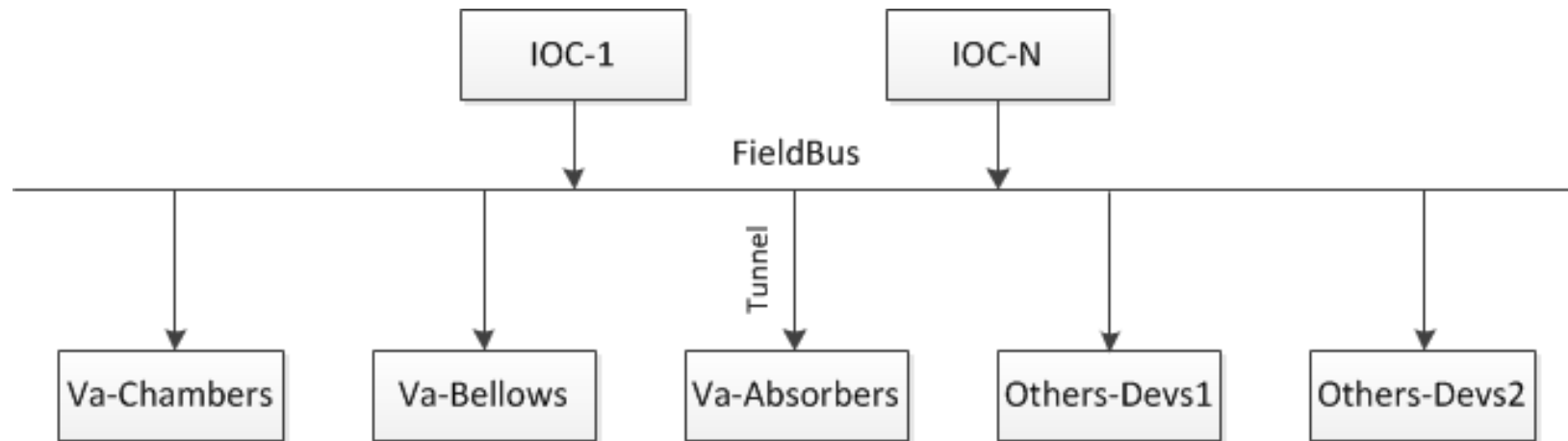
■ Example of HEPS' vacuum CS



Instance of HEPS' Vacuum CS

Control system and sub-system: TM

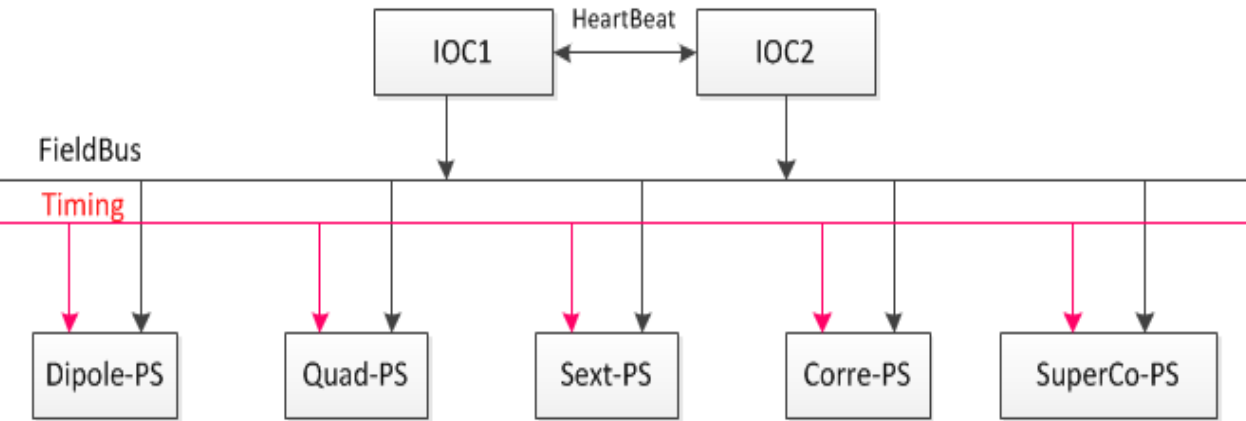
- Temperature Monitoring(TM)
 - Quantity: 100,000+(Vacuum devices)
 - ADAM4015/6015, Temperature paperless recorder
 - Others:



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



Power Supply Control OPI

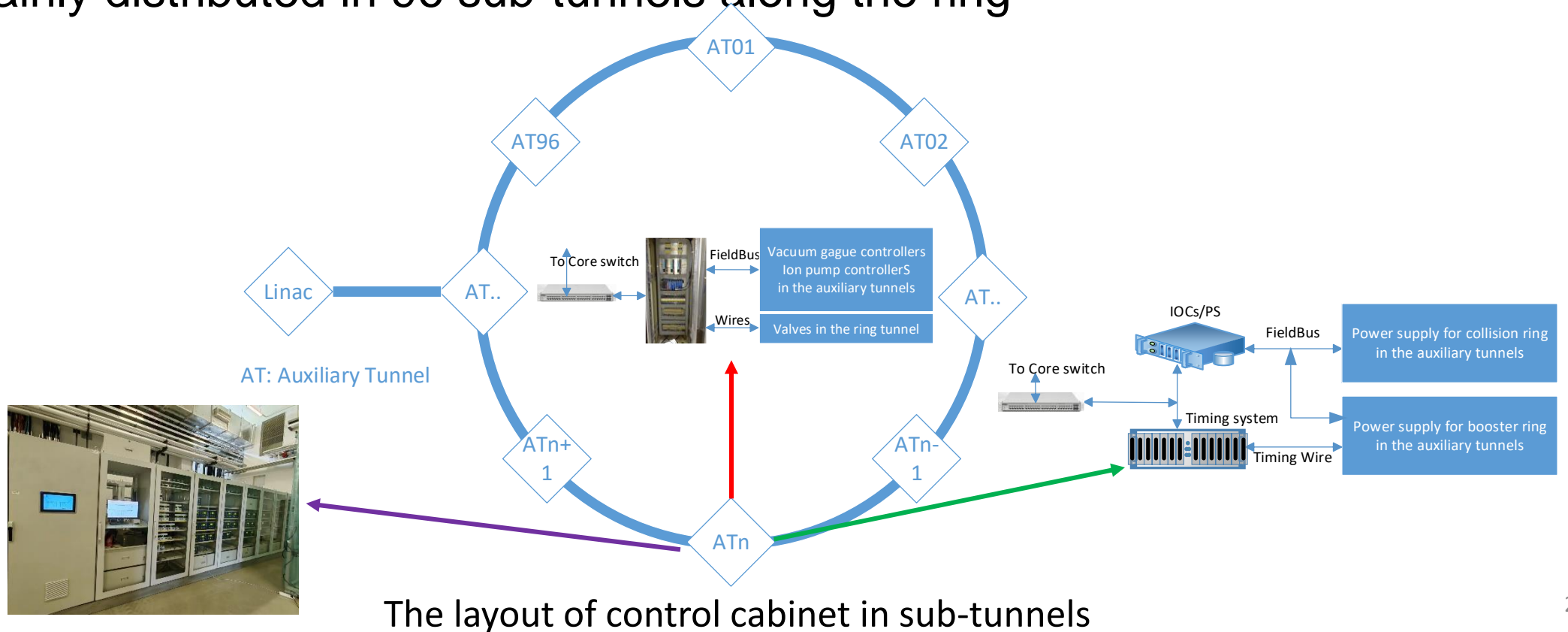
开关机管理										电源电流管理										故障监测及复位									
一键关机										所有电流来自遥控										故障监测及复位									
一键电流置0										独立选择电源电流																			
LASOL01	Open	5.2402 A	5.2402 A	5.2403 A	ON	Normal	Phys	Close		LAC1H	Open	-0.1179 A	-0.1179 A	-0.1159 A	ON	Normal	Phys	Close		LAAM1	Open	0.0000 A	0.0000 A	0.0258 A	ON	Normal	Phys	Close	
LASOL02	Open	4.5655 A	4.5655 A	4.5654 A	ON	Normal	Phys	Close		LAC1V	Open	0.1375 A	0.1375 A	0.1386 A	ON	Normal	Phys	Close		LAAM2	Open	221.3708 A	221.3708 A	221.3694 A	ON	Normal	Phys	Close	
LASOL03	Open	4.8253 A	4.8253 A	4.8261 A	ON	Normal	Phys	Close		LAC2	Open	0.0962 A	0.0962 A	0.0957 A	ON	Normal	Phys	Close		LAAM1T	Open	-1.8000 A	-1.8000 A	-1.8009 A	ON	Normal	Phys	Close	
LASOL04	Open	5.8077 A	5.8077 A	5.8075 A	ON	Normal	Phys	Close		LAC3	Open	0.1231 A	0.1231 A	0.1243 A	ON	Normal	Phys	Close		LAQF1	Open	2.1815 A	2.1815 A	2.1828 A	ON	Normal	Phys	Close	
LASOL05	Open	8.0029 A	8.0029 A	8.0033 A	ON	Normal	Phys	Close		LAC4H	Open	-0.0195 A	-0.0195 A	-0.0213 A	ON	Normal	Phys	Close		LAQF2	Open	4.8091 A	4.8091 A	4.8094 A	ON	Normal	Phys	Close	
LASOL06	Open	5.8411 A	5.8411 A	5.8380 A	ON	Normal	Phys	Close		LAC4V	Open	-0.6961 A	-0.6961 A	-0.6960 A	ON	Normal	Phys	Close		LAQF3	Open	8.8405 A	8.8405 A	8.8405 A	ON	Normal	Phys	Close	
LASOL07	Open	6.6704 A	6.6704 A	6.6717 A	ON	Normal	Phys	Close		LAC1	Open	2.0816 A	2.0816 A	2.0810 A	ON	Normal	Phys	Close		LAQF4	Open	12.9447 A	12.9447 A	12.9450 A	ON	Normal	Phys	Close	
LASOL08	Open	6.7973 A	6.7973 A	6.7975 A	ON	Normal	Phys	Close		LAC2	Open	0.5066 A	0.5066 A	0.5065 A	ON	Normal	Phys	Close		LAQF5	Open	14.1189 A	14.1189 A	14.1188 A	ON	Normal	Phys	Close	
LASOL09	Open	7.0832 A	7.0832 A	7.0827 A	ON	Normal	Phys	Close		LAC3	Open	1.1296 A	1.1296 A	1.1340 A	ON	Normal	Phys	Close		LAQD1	Open	2.0384 A	2.0384 A	2.0392 A	ON	Normal	Phys	Close	
LASOL10	Open	11.3387 A	11.3387 A	11.3379 A	ON	Normal	Phys	Close		LAC4	Open	5.6463 A	5.6463 A	5.6443 A	ON	Normal	Phys	Close		LAQD2	Open	4.7798 A	4.7798 A	4.7789 A	ON	Normal	Phys	Close	
LASOL11	Open	10.2325 A	10.2325 A	10.2326 A	ON	Normal	Phys	Close		LACV1	Open	-1.4118 A	-1.4118 A	-1.4117 A	ON	Normal	Phys	Close		LAQD3	Open	8.7171 A	8.7171 A	8.7172 A	ON	Normal	Phys	Close	
LASOL12	Open	11.3552 A	11.3552 A	11.3550 A	ON	Normal	Phys	Close		LACV2	Open	2.2189 A	2.2189 A	2.2189 A	ON	Normal	Phys	Close		LAQD4	Open	13.2774 A	13.2774 A	13.2753 A	ON	Normal	Phys	Close	
LASOL13	Open	9.9289 A	9.9289 A	9.9288 A	ON	Normal	Phys	Close		LACV3	Open	0.8338 A	0.8338 A	0.8330 A	ON	Normal	Phys	Close		LAQD5	Open	16.2039 A	16.2039 A	16.2043 A	ON	Normal	Phys	Close	
LASOL14	Open	9.9526 A	9.9526 A	9.9524 A	ON	Normal	Phys	Close		LACV4	Open	-0.9047 A	-0.9047 A	-0.9056 A	ON	Normal	Phys	Close		LBO01	Open	7.0341 A	7.0341 A	7.0344 A	ON	Normal	Phys	Close	
LASOL15	Open	9.9016 A	9.9016 A	9.9017 A	ON	Normal	Phys	Close		LACV5	Open	2.1304 A	2.1304 A	2.1299 A	ON	Normal	Phys	Close		LBO02	Open	14.4718 A	14.4718 A	14.4709 A	ON	Normal	Phys	Close	
LASOL16	Open	0.0000 A	0.0000 A	0.0051 A	ON	Normal	Phys	Close		LBC1H	Open	0.0750 A	0.0750 A	0.0756 A	ON	Normal	Phys	Close		LBO03	Open	8.3018 A	8.3018 A	8.3017 A	ON	Normal	Phys	Close	
LASOL17	Open	0.0000 A	0.0000 A	0.0020 A	ON	Normal	Phys	Close		LBC1V	Open	0.0750 A	0.0750 A	0.0756 A	ON	Normal	Phys	Close		LBO04	Open	7.0341 A	7.0341 A	7.0347 A	ON	Normal	Phys	Close	
LASOL18	Open	0.0000 A	0.0000 A	0.0110 A	ON	Normal	Phys	Close		LBC3H	Open	0.0750 A	0.0750 A	0.0725 A	ON	Normal	Phys	Close		LBO05	Open	14.4718 A	14.4718 A	14.4713 A	ON	Normal	Phys	Close	
LASOL19	Open	9.9522 A	9.9522 A	9.9511 A	ON	Normal	Phys	Close		LBCV1	Open	0.0250 A	0.0250 A	0.0255 A	ON	Normal	Phys	Close		LBO06	Open	8.3018 A	8.3018 A	8.3007 A	ON	Normal	Phys	Close	
LASOL20	Open	9.9352 A	9.9352 A	9.9353 A	ON	Normal	Phys	Close		LBCV2	Open	0.0250 A	0.0250 A	0.0253 A	ON	Normal	Phys	Close											
LASOL21	Open	9.9895 A	9.9895 A	9.9886 A	ON	Normal	Phys	Close																					
LASOL22	Open	9.9677 A	9.9677 A	9.9677 A	ON	Normal	Phys	Close																					



Instance of HEPS' PSCS

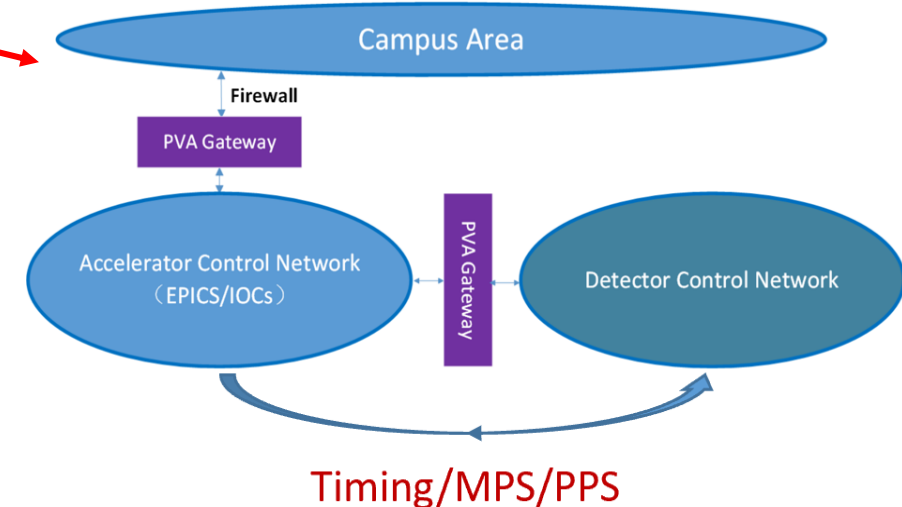
Control System & sub-system: Cabinet Layout

- 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



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

Magnet Database

Lattice and Model Database

Log and trouble tracking

Management of Cable and device

Configuration of Security database

Naming Convention Database

MPS and interlock database

Management of File

Alignment Database

Alarm 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!