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Control System of Cryomodule Test Facilities for SHINE

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SHINE

Outline

- **SHINE Project Introduce**
- **Cryomodule Test Facilities**
- **Crontrol System**
  - Temperature
  - Pressure
  - Cryogenic Valve
  - Liquid Level
  - Heater Power
  - Vacuum
  - Functional Safety
  - IOC, OPI, AA
- **Conclusion**

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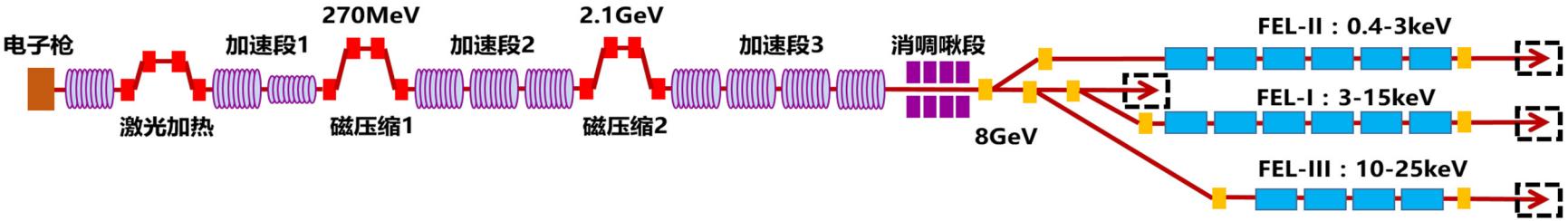
SHINE Project

- Shanghai HighRepetition-Rate XFEL and Extreme Light Facility (SHINE)
- First hard X-ray FEL facility in China

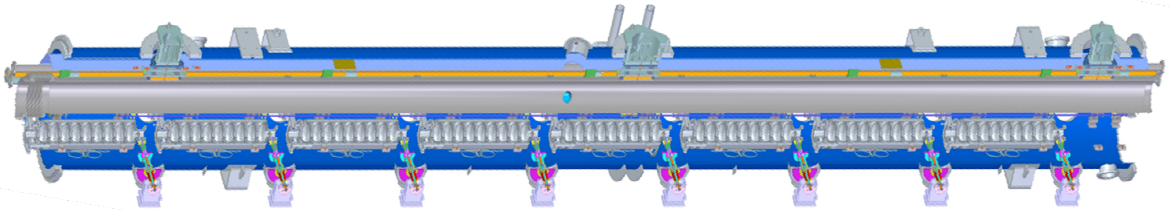


e-beam : 8 GeV	Photon Energy : 0.4 - 25 keV
Pulse duration : 1 - 100 fs	Repetition : 1.0030864 MHz
Total length : 3.1 km	Underground : ~ 29m

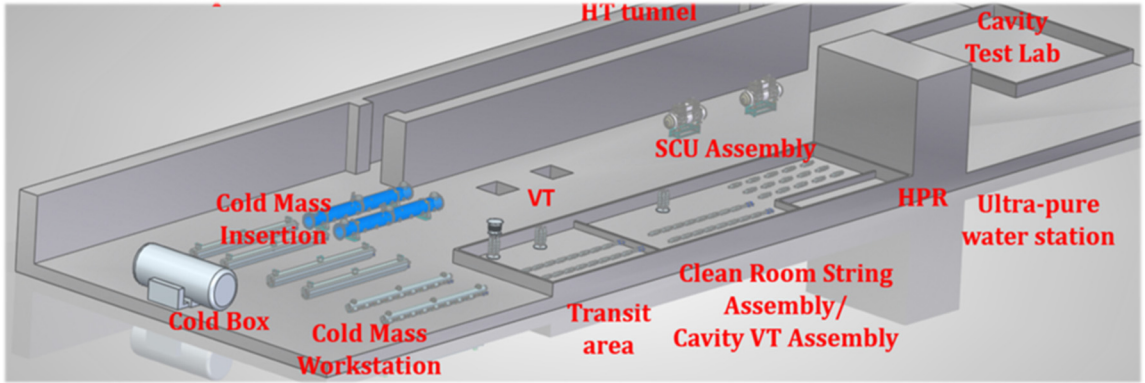

SSRF
SXFEL
SHINE
Injector
SC Linac
Undulators
Beamlines
Near Exp. Hall
Beamlines
Far Exp. Hall

Cryomodule Test Facilities

- 1.3GHz Cryomodules (75)
- 3.9GHz Cryomodules (2)



- Cryogenic component multi-functional test facility (1)
- Superconducting cavity vertical test facility (2)
- Superconducting cavity horizontal test facility (2)



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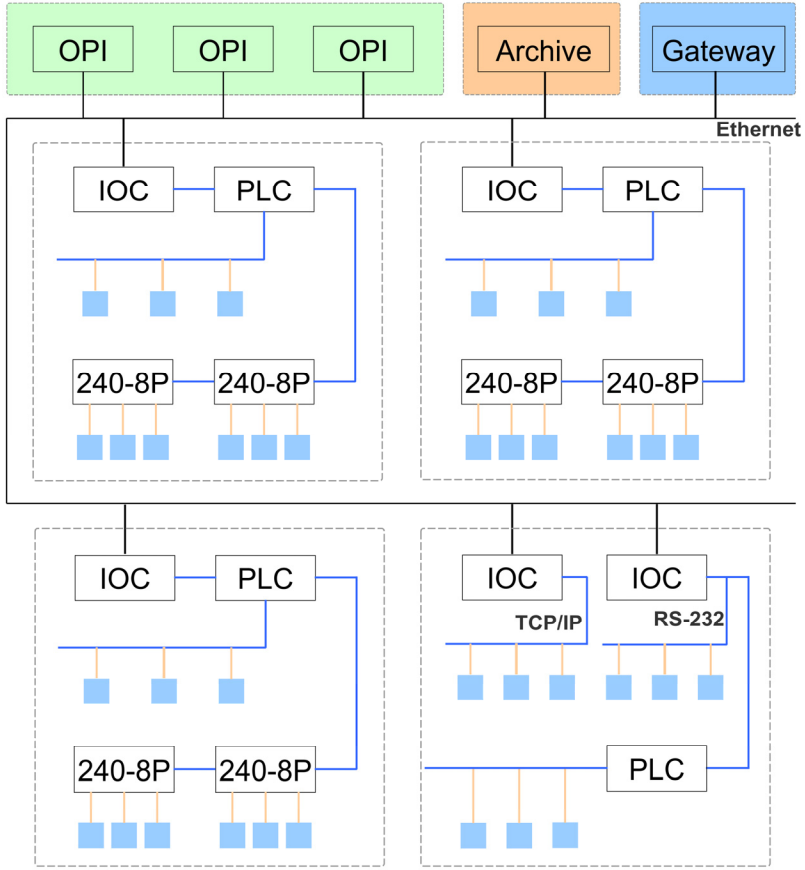
Crontrol System

- The control system will provide operators and engineers with a comprehensive and easy-to-use tool to control and monitor the components.
- Device control : pressure, temperature, liquid level, cryogenic valve, vacuum signal, etc.
- Integration : control network, server cluster, data storage, user interface, high level software and central control room.



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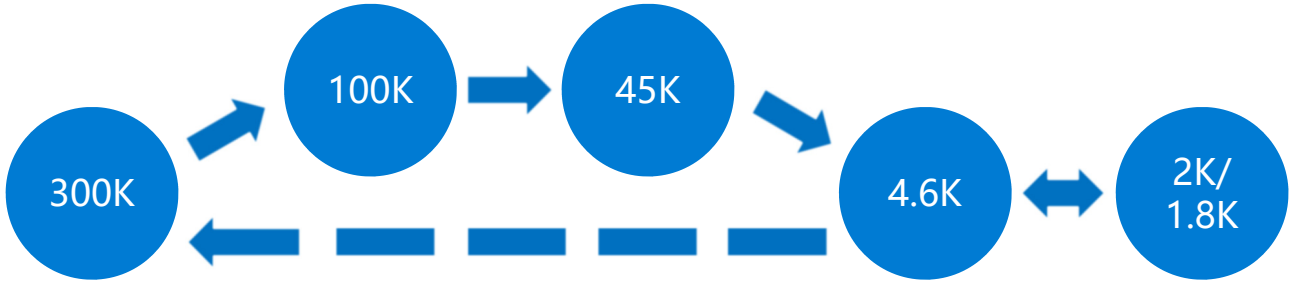
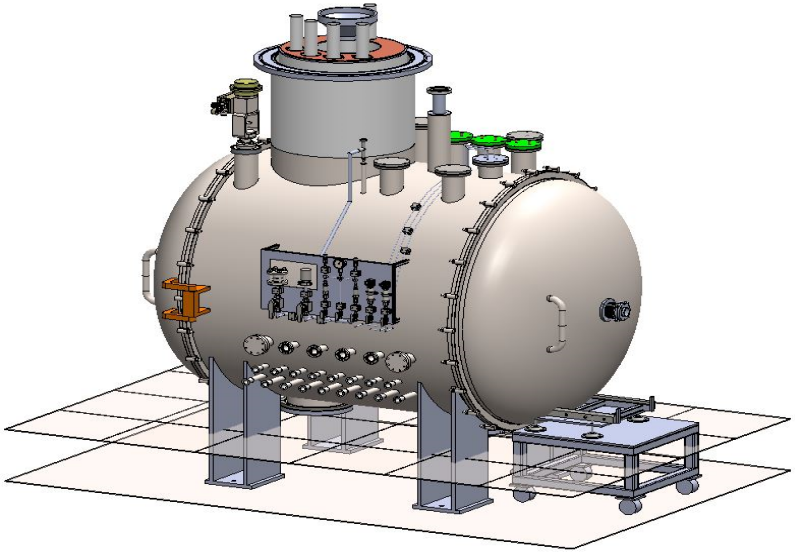
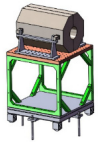
Crontrol System

- Monitor and control the pressure, temperature, liquid level, vacuum signal, etc.
- Adjust the heater power according to the RF signal to stabilize the load of the cryomodule.
- Adjust the J-T valve opening through stabilizing the liquid helium level.
- Manual or automatic control the cryogenic valve for different processes.
- Functional safety systems, including the signal of cryogenic factory and LLRF.
- Data exchange with the cryogenic factory control system.

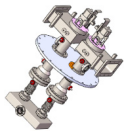


Multi-functional test facility

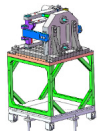




Superconducting Magnets



Coupler

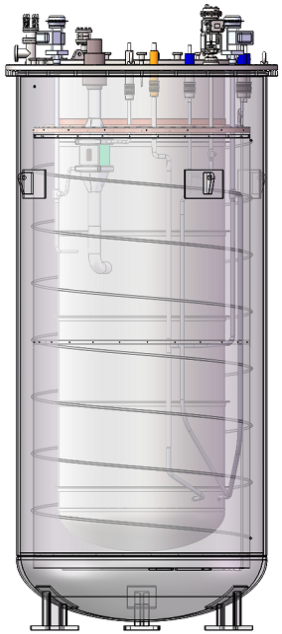


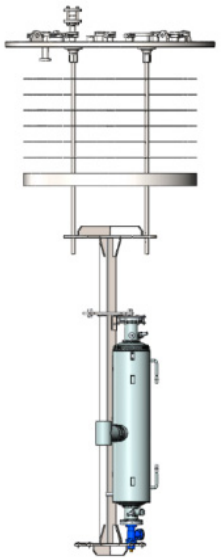
Cold-BPM

Signal	Qty	I/O	Type
Temperature	24	Input	CX-1030-CU-HT
Pressure	5	Input	Analog
Liquid Level	1	Input	Analog
Cryogenic valve	2	Input	Analog
Cryogenic valve	2	Output	Analog, PID
Interlock	4	Input/Output	Digital
Heater Power Supply	4	Input/Output	Analog,Digital
Vacuum Gauge	6	Input	Serial port

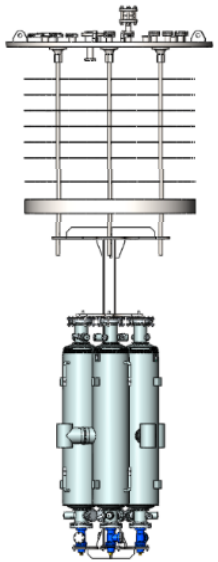
Vertical Test facility

Signal	Qty	I/O	Type
Temperature	47	Input	CX-1030-CU-HT
Pressure	5	Input	Analog
Liquid Level	1	Input	Analog
Cryogenic valve	4	Input	Analog
Cryogenic valve	4	Output	Analog, PID
Interlock	4	Input/Output	Digital
Heater Power Supply	16	Input/Output	Analog,Digital
Vacuum Gauge	6	Input	Serial port





1 Cavity



4 Cavities

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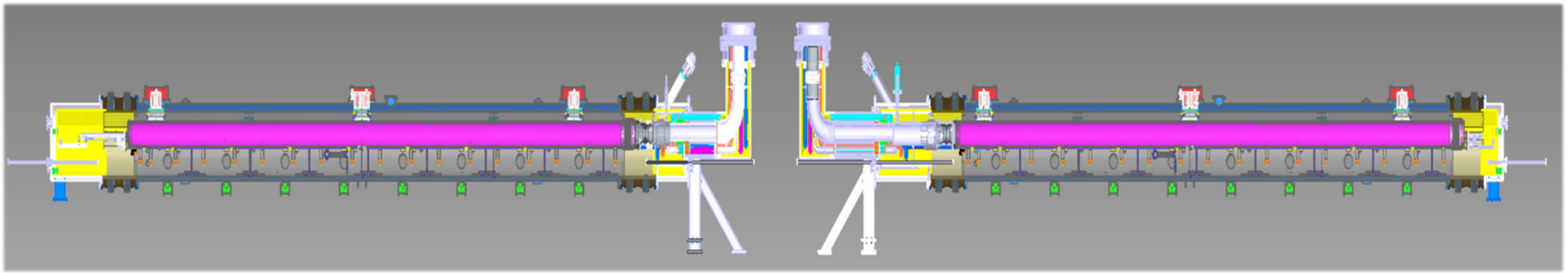
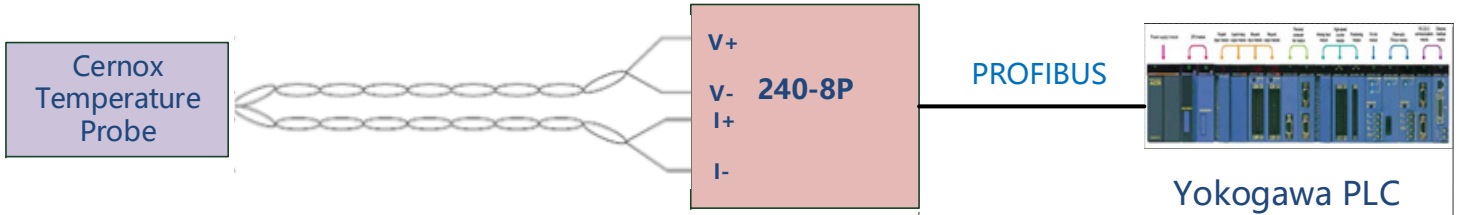
Horizontal Test facility

- Facility 1
  - prototype cryomodules
  - mass production cryomodules
- Facility 2
  - mass production cryomodules

Signal	Qty	I/O	Type
Temperature	120	Input	CX-1030-CU-HT
Pressure	2	Input	Analog
Liquid Level	3	Input	Analog
Cryogenic valve	4	Input	Analog
Cryogenic valve	4	Output	Analog, PID
Interlock	14	Input/Output	Digital
Heater Power Supply	16	Input/Output	Analog, Digital
Vacuum Gauge	3	Input	Serial port
Ion Pump	3	Input	Serial port
Magnet Power Supply	3	Input	Ethernet



Temperature

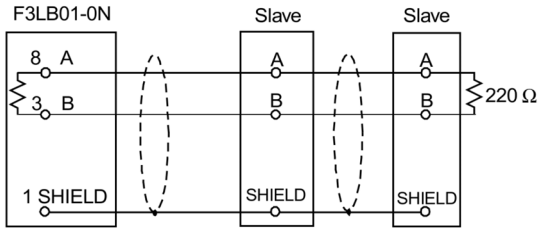


LakeShore Model 240-8P Cryogenic temperature input module

8 inputs compatible with both resistive and diode temperature devices

PROFIBUS-DP network communications

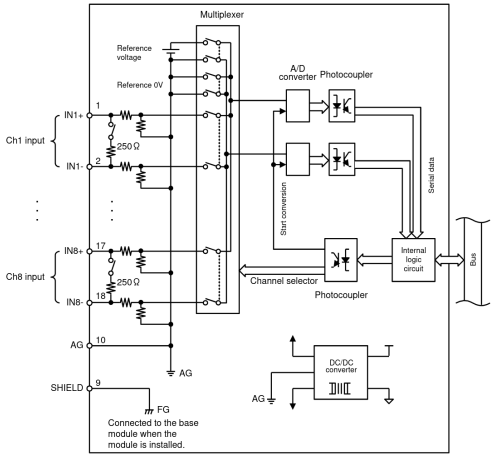
PROFIBUS-DP master control and communicate with the sensors.



Pressure

- KELLER PAA-41X
  - 0...100mbar
- KELLER PAA-33X
  - 0...1600mbar
  - 0...3000mbar

- F3AD08-4R
  - 8 channels
  - 4-20mA

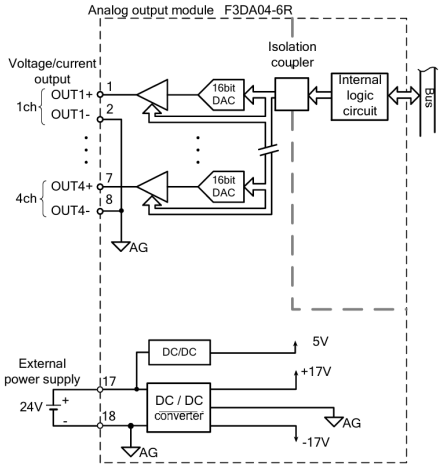


Cryogenic Valve

- Toko Valex T-8800

- Electropneumatic Positioner
  - SAMSON 3730-2

- F3AD08-4R
- F3DA04-6R

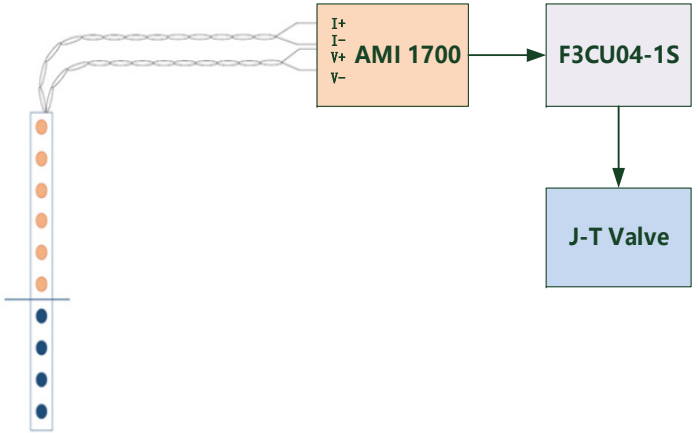


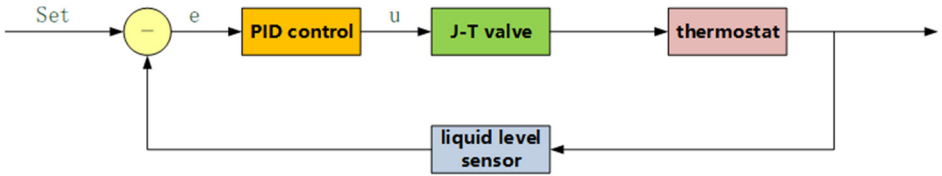
Liquid Level

- Liquid level monitor and stability control

- AMI 2K level probe
- AMI 1700-2K level gauge
- Yokogawa F3CU04-1S PID module

- Manual control the cryogenic valve opening
- PID closed-loop control of the 2K liquid helium level





$$u(t) = K_P[e(t) + \frac{1}{T_I}\int_{s=0}^{t} e(s)\mathrm{d}s + T_D\frac{\mathrm{d}(e(t))}{\mathrm{d}t}]$$

Heater Power

- Cryomodule heating and compensation of total thermal load power
- Heater : Omega KH-112/10 50W
- Power supply : TDK Z60-3.5-C
- Yokogawa PLC
  - F3XD16-3F，digital input, power supply status
  - F3YC08-0C，relay output, power supply control
  - F3AD08-5R，analog input, current readback
  - F3DA08-5R，analog output, current setting
- Manually control the heater current
- Closed-loop control of the total thermal load power

Cavity dynamic load

+

Heater Power

||

Cryomodule Total Power

(constant)

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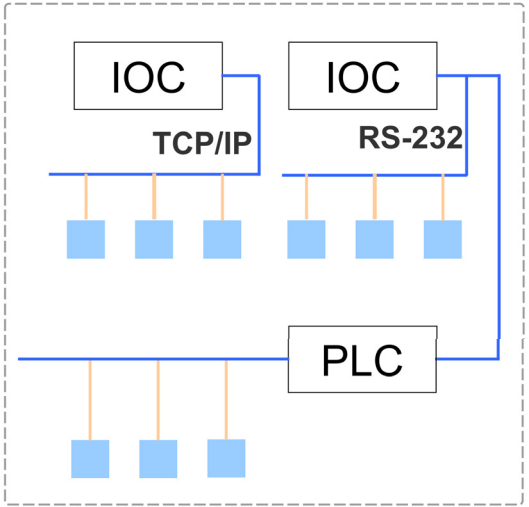
Magnet PS

- Superconducting Magnet
- SSRF power supply controllers
- EPICS streamDevice/asynDriver IOC
  - Power switch control
  - Load current monitor
  - Reference current monitor
  - Current slope control
  - Power supply status monitor

Vacuum

- Agilent XGS600 gauge controller
- Zhenghua gauge controllers
- Zhenghua ion pump power controllers
- EPICS streamDevice/asynDriver IOC



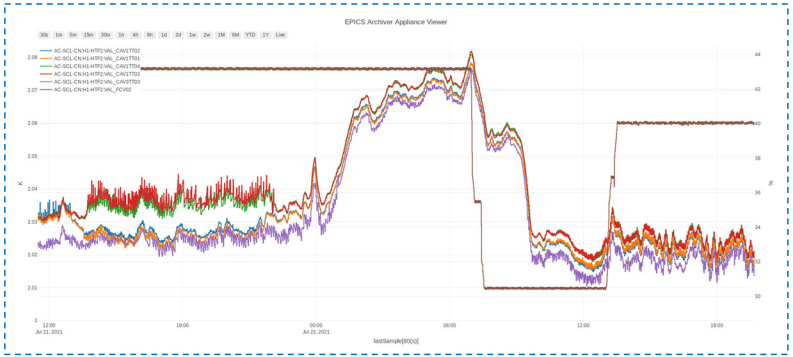
Functional Safety

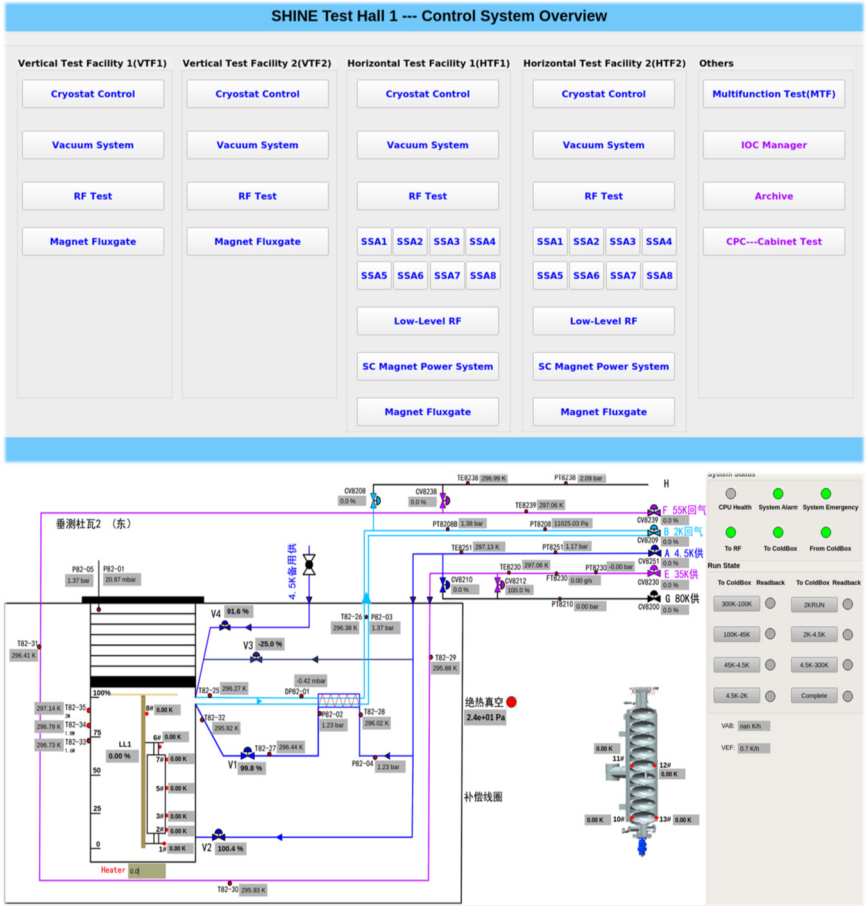
- Protect the important components of the facility
- Report the fault information to the control system

- Latch: save the signal alarm state
- Reset: release the alarm latch
- Bypass: temporarily release the interlock response to the signal from the software

IOC - OPI - AA

- IOC：MOXA DA-682B
- OPI：PyDM
- Archive Appliance





Conclusion

- Multiple facilities have been built for SHINE cryomodule and superconducting cavity test.
- The local control systems are all based on Yokogawa PLC, which monitors and controls the process variables such as temperature, pressure, liquid level and power of the heater.
- PID and other algorithms are used to keep liquid level and power balanced.
- EPICS is adopted to integrate these facilities along with vacuum devices, solid state amplifiers, LLRF and RF measurement system, etc.
- The system development and debugging have been completed, and it has operated stably for several months.

Thanks for your attention !

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