Design of the HALF Control System

Gongfa Liu

NSRL/USTC

11 October 2023

ICALEPCS 2023，9 - 13 October 2023，Cape Town, South Africa

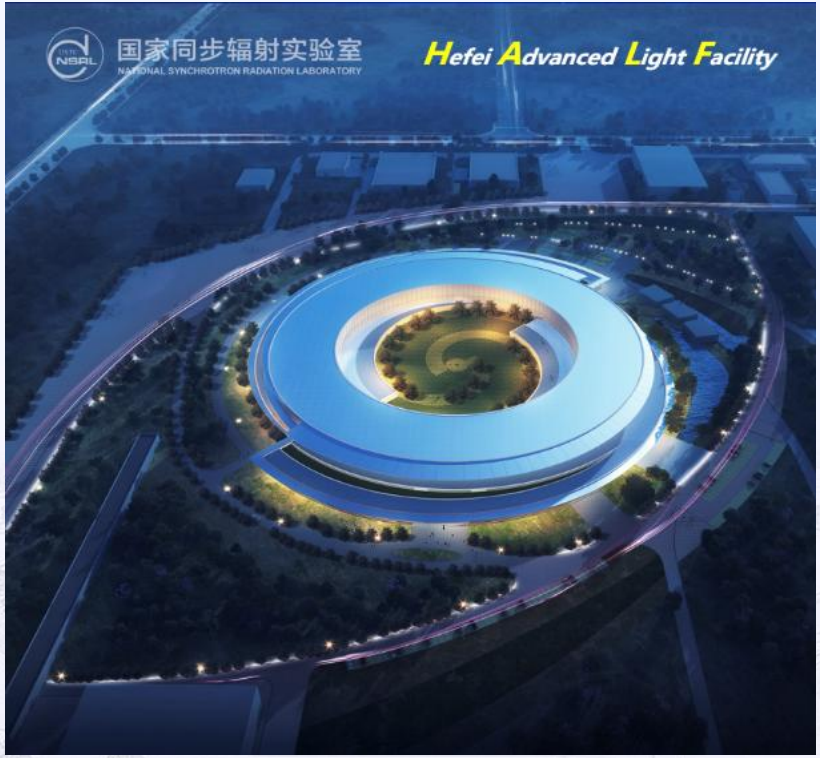
Outline

- Project Introduction
- Control System Overview
- Control System Components
  - Environment
  - Device Control
  - Equipment Protection
  - Timing
  - Network
  - Data Archiving
  - Alarm
- Summary

Project Introduction

- HALF: Hefei Advanced Light Facility
- 4th generation synchrotron light source, 6BA-lattice
- Construction period: Jun. 2023 – Oct. 2028
- Budget: ~400M US$

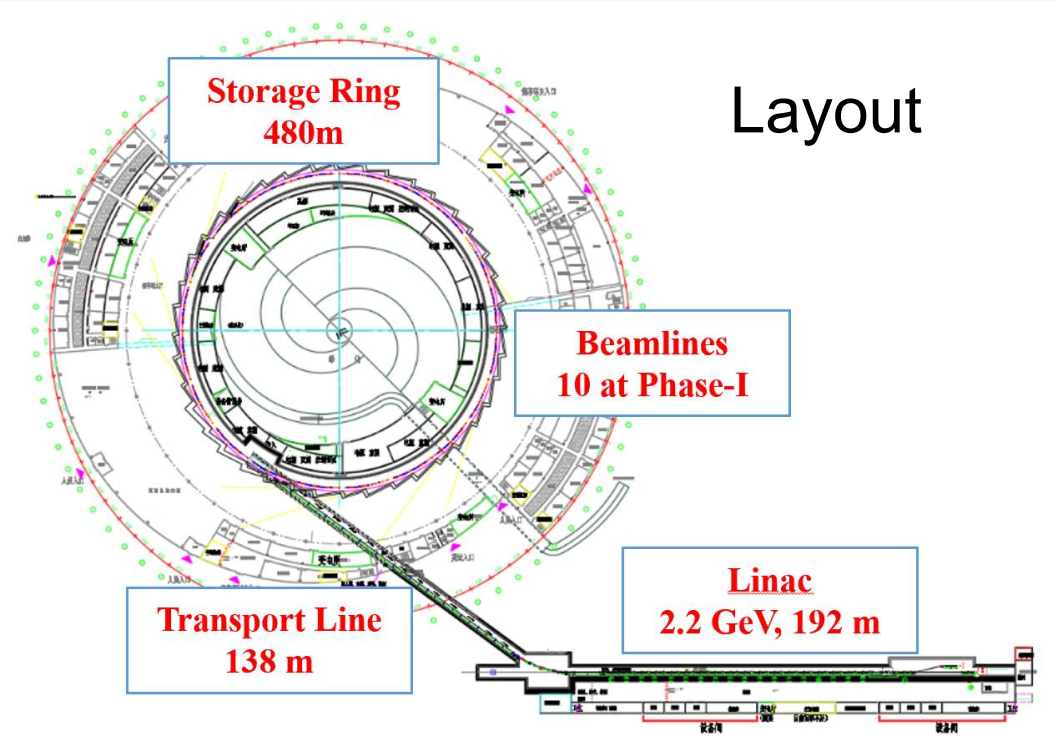
Project Introduction



- Main Parameters of SR
  - Beam Energy: 2.2 GeV
  - Circumference: 480 m
  - Emittance: 86.3 pm·rad
  - Beam current: 350 mA
  - Brightness: 1.15×10^{21} phs/mm^2/mrad2/0.1%BW/s
  - Injection: Full energy, Top-off
  - Lattice: 6BA
  - Straight sections: 20×5.3 m + 20×2.2 m
  - RF: 500 MHz

Project Introduction

- Linac
  - 192 m
  - 2.2 GeV，full energy
- Transport Line
  - 138 m
- Storage Ring
  - 480 m
  - diffraction limited SR
- Beamlines
  - 10@ Phase-I

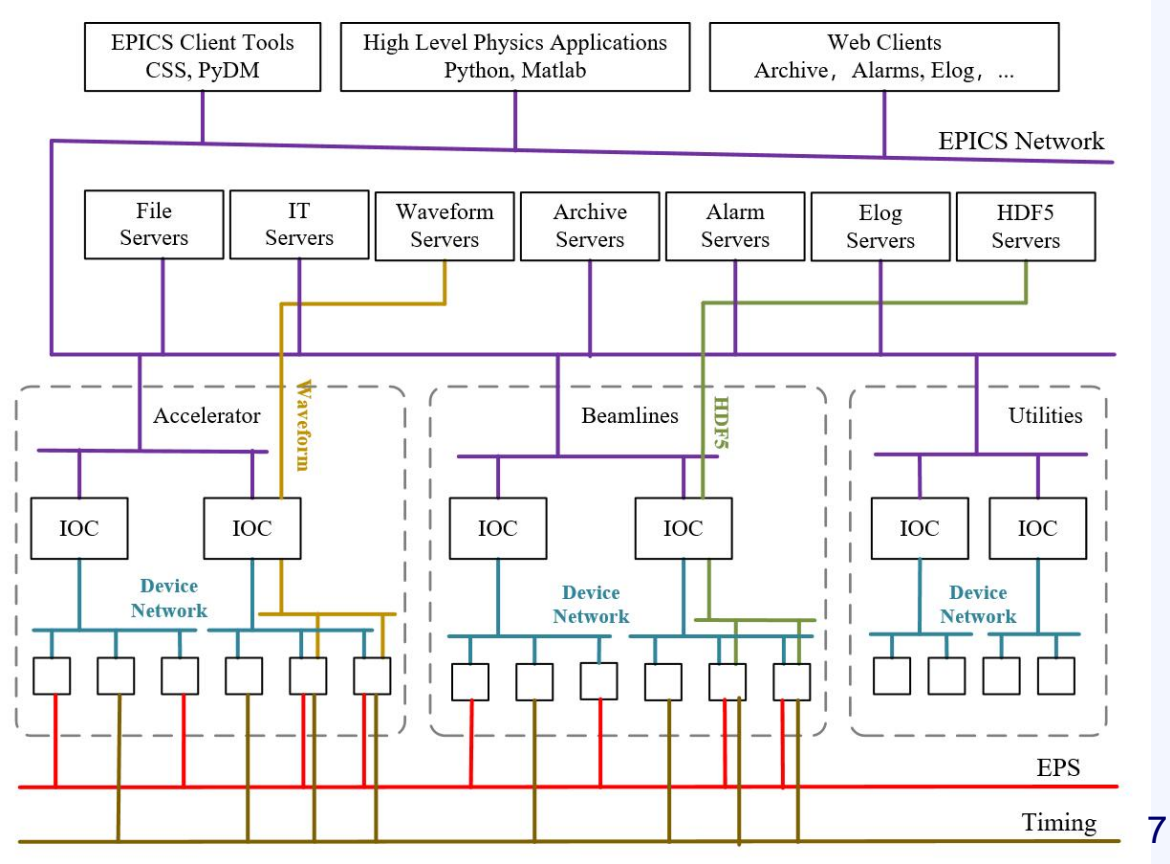


Control System Overview

- The HALF control system serves as the platform for the commissioning and operation of the entire facility.
- A unified architecture is adopted for the accelerator, beamlines, and utilities, thereby addressing the issue of manpower shortage.
- Requirements: high availability, scalability, flexibility, efficiency and security
- Methods: EPICS 7 + Server virtualization + VLAN+ COTS products

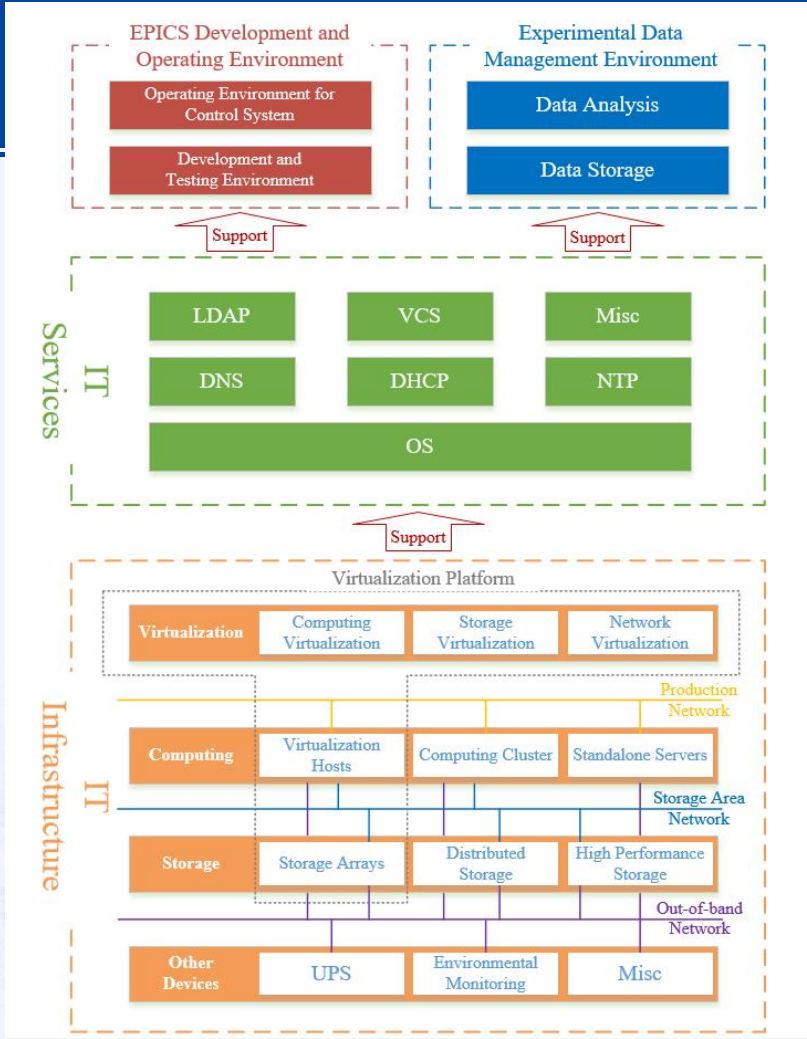
Control System Architecture

- Environment
- Device Control
- Equipment Protection
- Timing
- Network
- Data Archiving
- Alarm



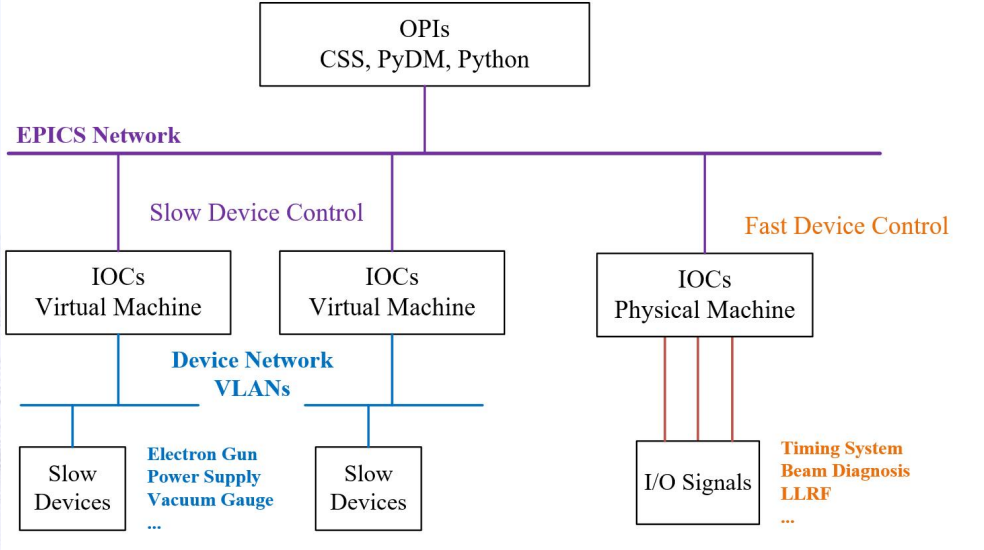
Environment

- IT infrastructure
  - Computing and storage hardware
  - Virtualization technology
- IT services
  - DNS, DHCP, NTP, LADP …
- EPICS development and operating environment
- Experimental data management environment



Device Control

- Device control is the basis of the HALF control system
- Controlled Devices: ~5,000
- Types: slow device control and fast device control
- Fast Device Control
  - IOC on Physical Machine
  - High-speed and low-latency
- Slow Device Control
  - IOC on Virtual Machine
  - Benefits of server virtualization
  - Device network: multiple subnets



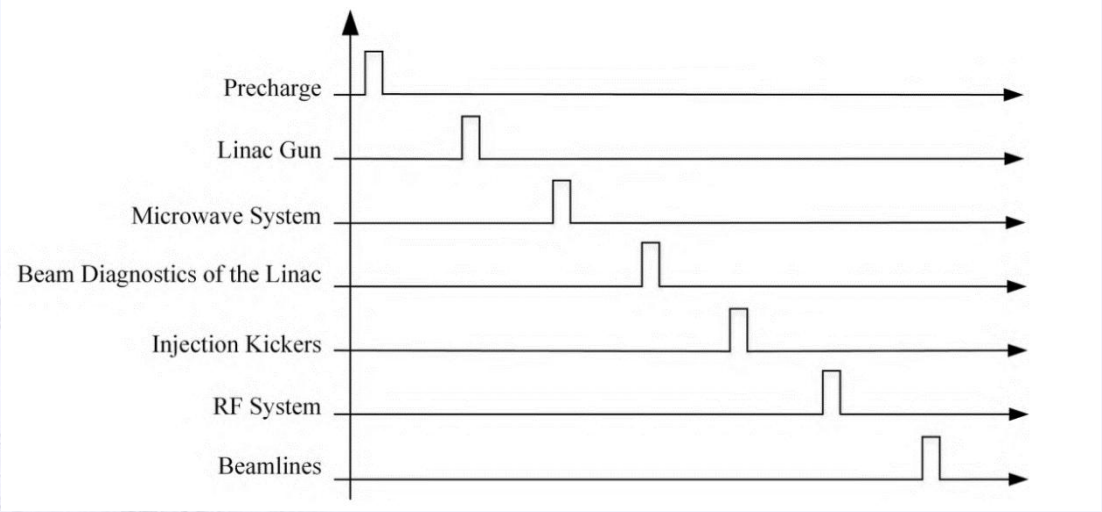
Equipment Protection System(EPS)

- EPS is an dispensable system, it establishes the interlocking protection logic to protect the key equipment from damage in the event of a fault.
- HALF EPS: accelerator EPS + beamline EPS
- Accelerator EPS
  - A main PLC + multiple salve PLCs
  - Response time: <20 ms within PLC, <100 ms between PLCs
- Beamline EPS
  - 10 independent subsystem for 10 beamlines
  - A PLC for each subsystem
  - Functions and interlocking logic of each subsystem are similar
  - Response time: <100 ms

Timing System

- The timing system provides trigger signals for the HALF injector, storage ring and beamlines, coordinates beam injection and measurement, and achieves arbitrary filling pattern.

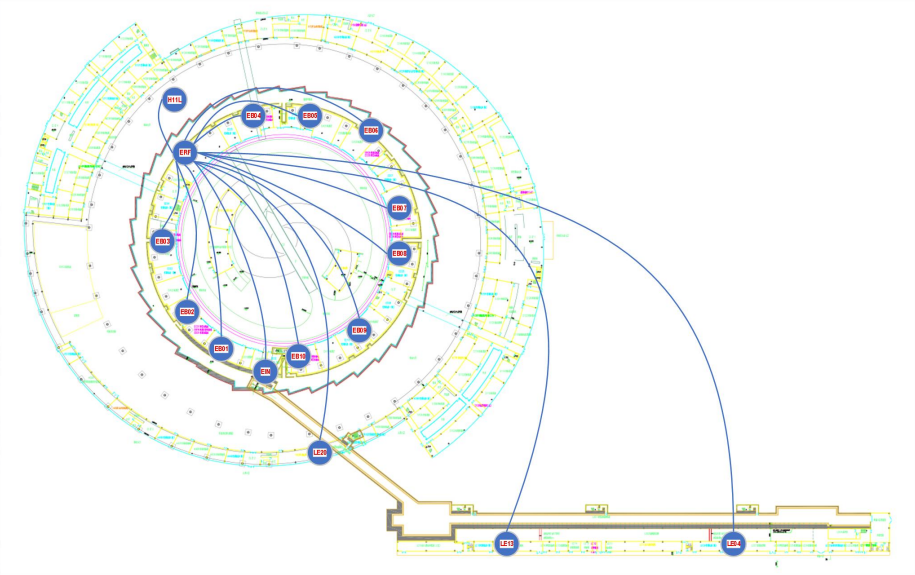
- Repetition freq. of beam injection: 1-10 Hz
- Timing delay: <10 ns (<10 ps for e-gun)
- Jitter: <30 ps
- Delay compensation

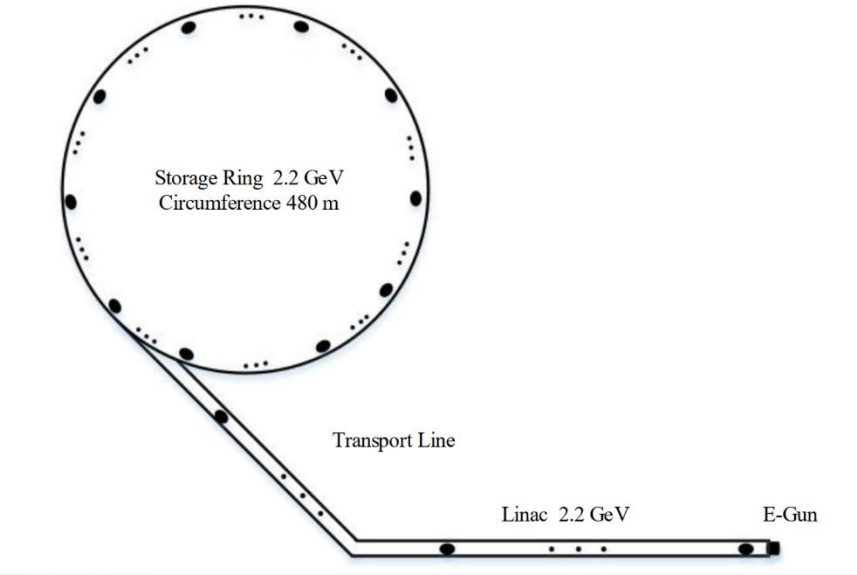


Timing sequence (the horizontal axis only represents the chronological order)

Timing System

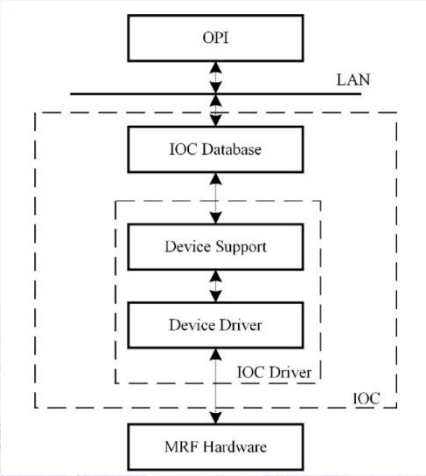
- Event System, MTCA.4
- EVM + 15 EVRs
- Arbitrary filling pattern
- Event Clock: 166.6 MHz (499.8/3)

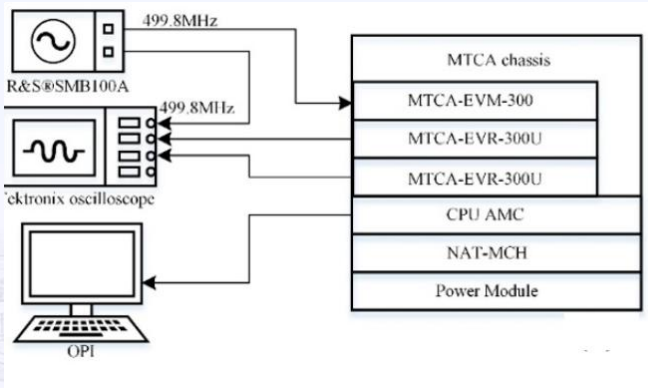




Timing System

- Prototype system*: MTCA.4 + Event System + EPICS
- Software: device & driver support with EPICS general record

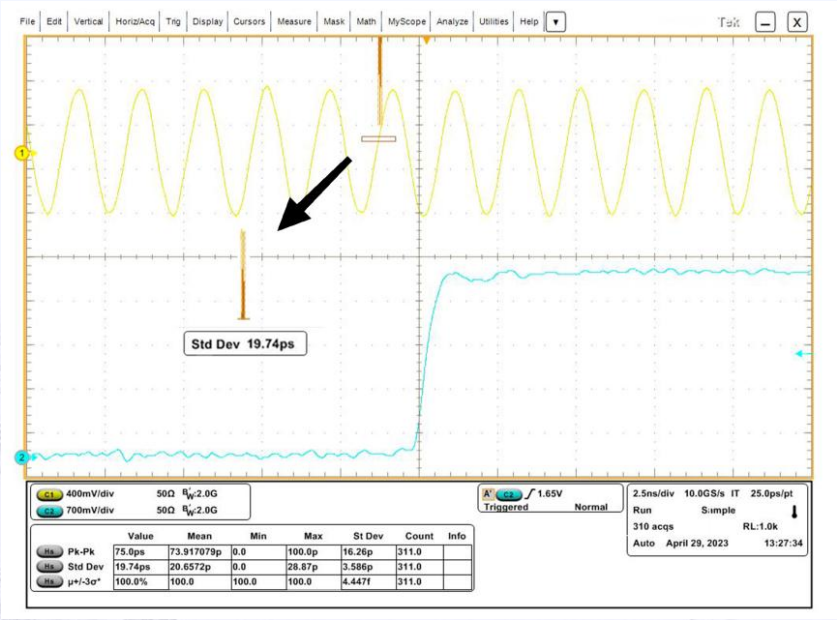


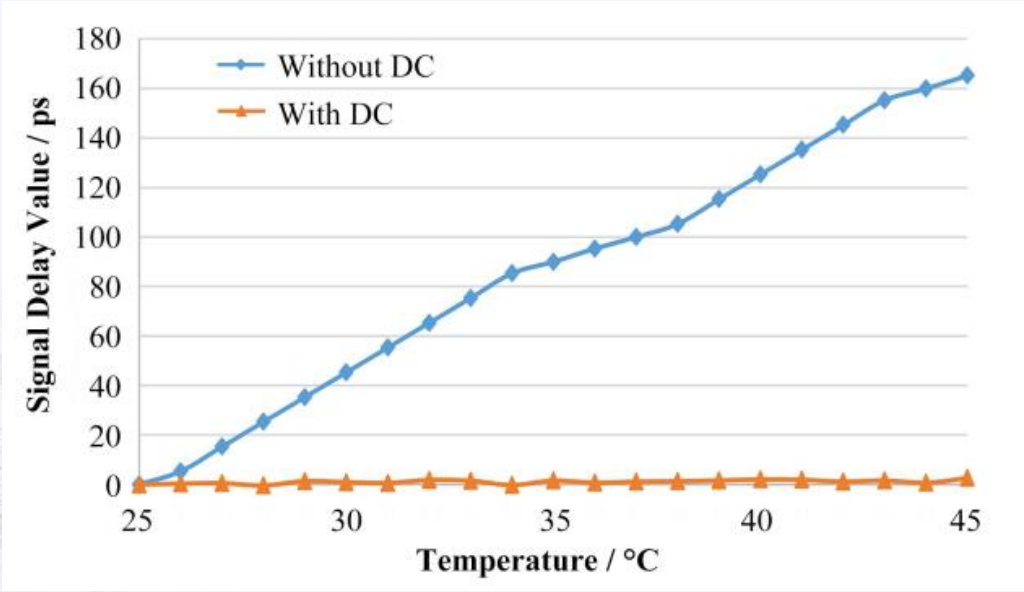


*G. Zhai, X. Sun, K. Xuan, L. Chen, C. Li, and G. Liu, “The design of Hefei advanced light facility timing system”, Nuclear Techniques, vol. 45, no. 12, p. 120102, Dec. 2022. doi: 10.11889/j.0253-3219.2022.hjs.45.120102

Timing System

- Jitter is19.74 ps (<30 ps)
- With Delay Compensation (DC), drift: ~3 ps



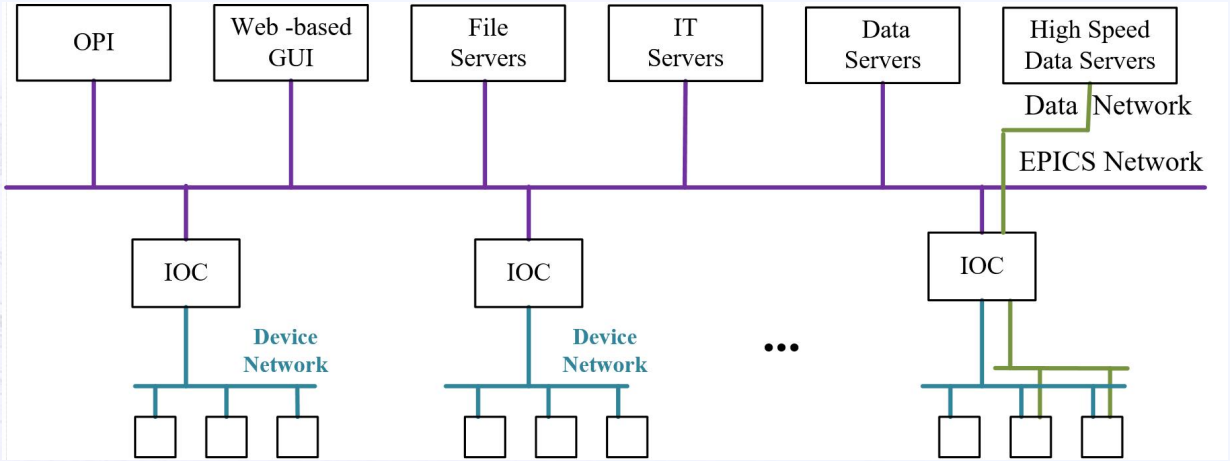


Network

- Network nodes：~4,000，complex
- The stable and reliable operation of the network is critical to HALF availability
- Network composition
  - Communication network
  - Network security system
  - Network status monitoring system

Network

- Communication network
  - Control network + Data network： physically isolated
  - Control network： EPICS network + Device network， VLAN
    - EPICS network
    - Device network: subdivided by VLAN
  - Data network： 10 Gbps (can be expanded to 100 Gbps)



Network

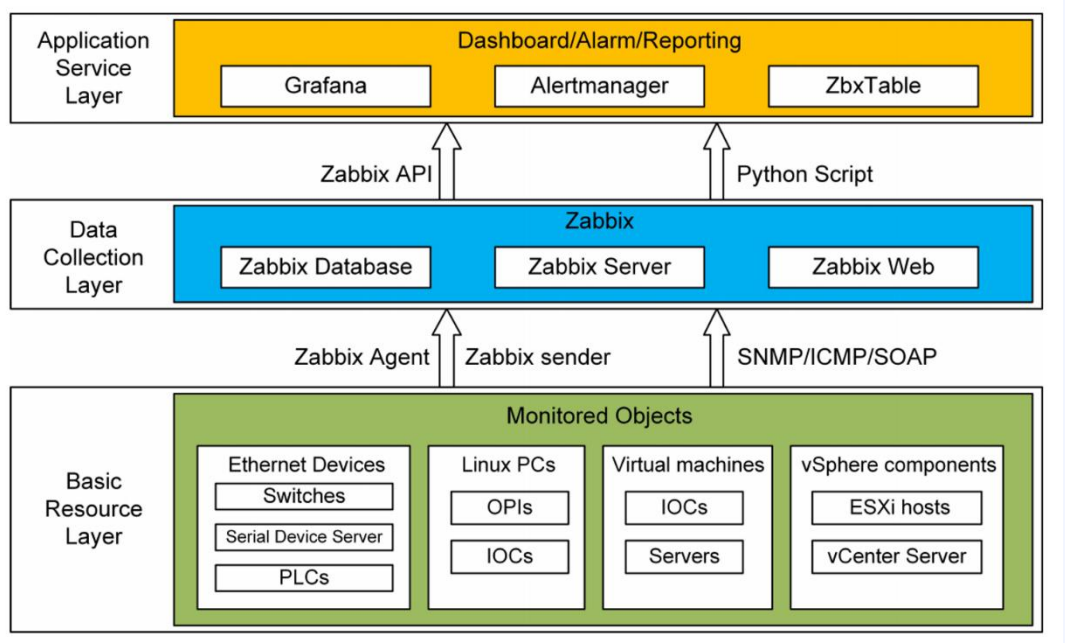
- Network security system
  - Technology: network security tools
    - Firewalls
    - Antivirus
    - Intrusion Detection and Prevention Systems (IDS/IPS)
    - Virtual Private Networks (VPN)
    - …
  - Management
    - Account management
    - Device access rules
    - …

Network

- Network status monitoring system: promptly discover issues such as network failures and degraded performance, improve maintenance efficiency.
- The system is developed with Zabbix.
- Zabbix is a mature and effortless enterprise-class open source monitoring solution for network monitoring and application monitoring of millions of metrics.
- Zabbix s widely used in large scientific facilities, such as SuperKEKB, ALICE, etc.

Network

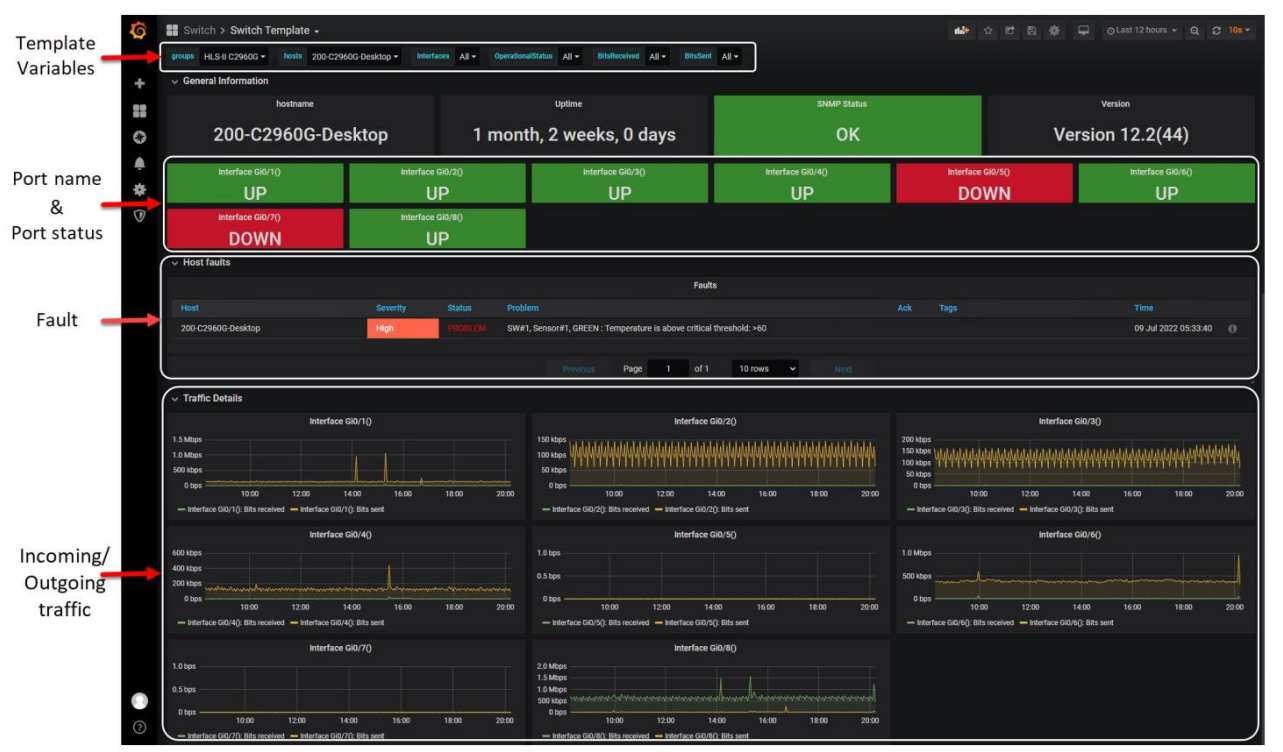
- Architecture of the network status monitoring system*
  - Basic resource layer
  - Data collection layer, collects data through protocols such as Zabbix agent, SNMP, SOAP, etc.
  - Application service layer
    - Dashboard
    - Alarm
    - Reporting



* T. Qin, C. Li and G. Liu, “Control infrastructure monitoring system at the NSRL facility cluster”, Journal of Instrumen-tation, vol. 17, no. 11, p. 11005, Nov. 2022. doi: 10.1088/1748-0221/17/11/P11005

Network

Switch dashboard



Network

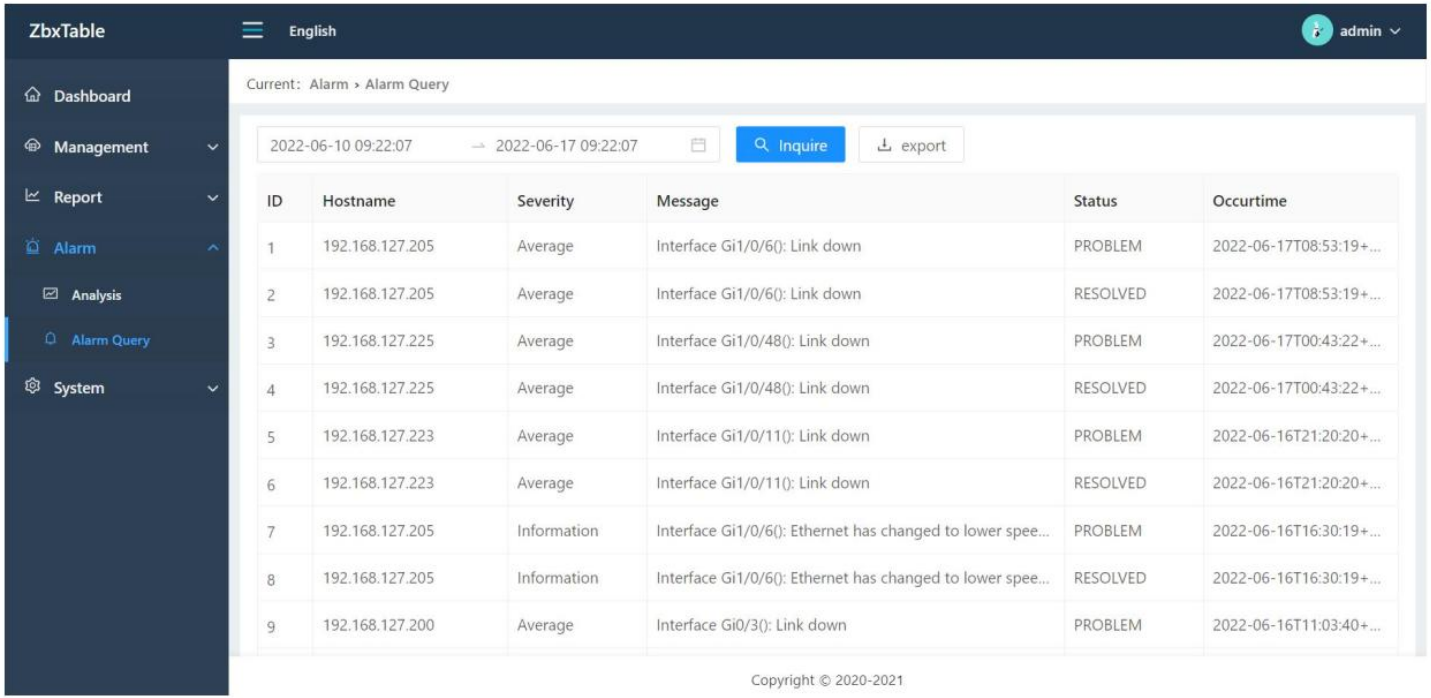
WeChat message of alarm

web-based GUI of alarm

Time	Info	Host	Problem • Severity	Duration	Ack	Actions	Tags
03:35:40 PM		200-C2960G-Desktop	Interface Gi0/3(): Ethernet has changed to lower speed than it was before	47m 55s	No	1	
03:33:23 PM		226-C2960X-IR-TM	Interface Gi1/0/1(): In half-duplex mode	50m 12s	No	2	
03:33:18 PM		203-C2960S-MFR	Interface Gi1/0/12(): In half-duplex mode	50m 17s	No	2	
03:33:18 PM		203-C2960S-MFR	Interface Gi1/0/13(): In half-duplex mode	50m 17s	No	2	
03:33:17 PM		101-C2960X-IR-EXP(N)	Interface Gi1/0/28(): In half-duplex mode	50m 18s	No	2	
Today							
05/31/2022 01:00:42 PM		200-C2960G-Desktop	SW#1, Sensor#1, GREEN : Temperature is above warning threshold: >50	1m 26d 3h	Yes	99+	
05/06/2022 02:12:56 PM		251-C4507R-left	CPU Remote: Temperature is above warning threshold: >50	2m 21d 2h	Yes	5	
05/03/2022 10:16:31 PM		Zabbix server	MySQL: Failed to get items (no data for 30m)	2m 23d 18h	Yes	5	
May							
04/22/2022 01:33:57 PM		252-C4507R-right	CPU Remote: Temperature is above warning threshold: >50	3m 5d 2h	Yes	5	
04/21/2022 12:51:56 PM		251-C4507R-left	IFE Remote: Temperature is above warning threshold: >50	3m 6d 3h	Yes	5	
04/19/2022 09:15:56 AM		251-C4507R-left	XPP Remote: Temperature is above warning threshold: >50	3m 8d 7h	Yes	5	
04/19/2022 09:03:58 AM		252-C4507R-right	IFE Remote: Temperature is above warning threshold: >50	3m 8d 7h	Yes	5	
04/19/2022 09:03:58 AM		252-C4507R-right	XPP Remote: Temperature is above warning threshold: >50	3m 8d 7h	Yes	5	
04/19/2022 09:03:55 AM		250-C4507R-3rd	XPP: Temperature is above critical threshold: >60	3m 8d 7h	Yes	5	
04/19/2022 09:03:55 AM		250-C4507R-3rd	CONAN: Temperature is above warning threshold: >50	3m 8d 7h	Yes	5	

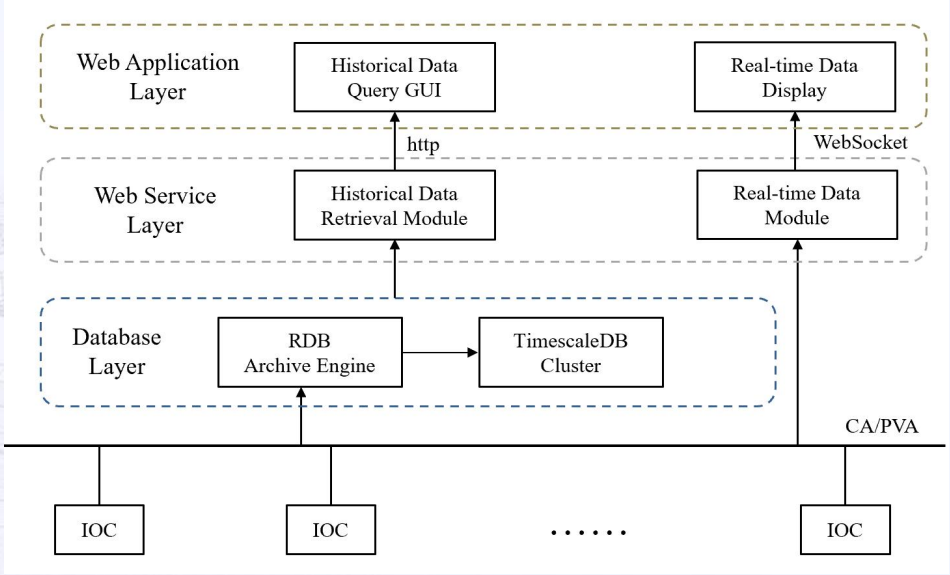
Network

List the raw alarm data within a week



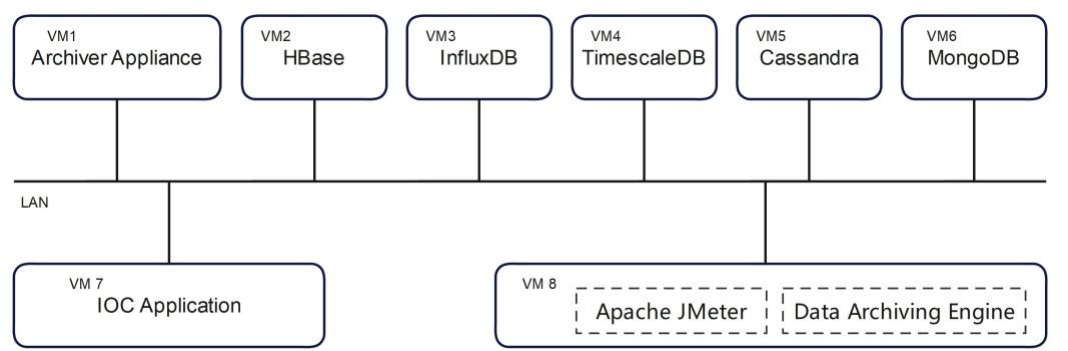
Data Archiving System

- According to the estimation based on the HALF scale, approximately 25,000 EPICS PVs will be stored in the data archiving system.
- RDB Archive Engine + TimescaleDB
- Web-based GUI will be developed for data query and analysis



Data Archiving System

- A fair database test platform is designed and built to evaluate the read-write performance of databases commonly employed in the particle accelerator field.
  - MongoDB, HBase, InfluxDB, TimescaleDB, Cassandra
  - EPICS Archiver Appliance (AA)
- Virtual machines with same hardware configuration: 2 CPU cores，8 GB memory and 500 GB disk
- Performance test tool: Apache JMeter



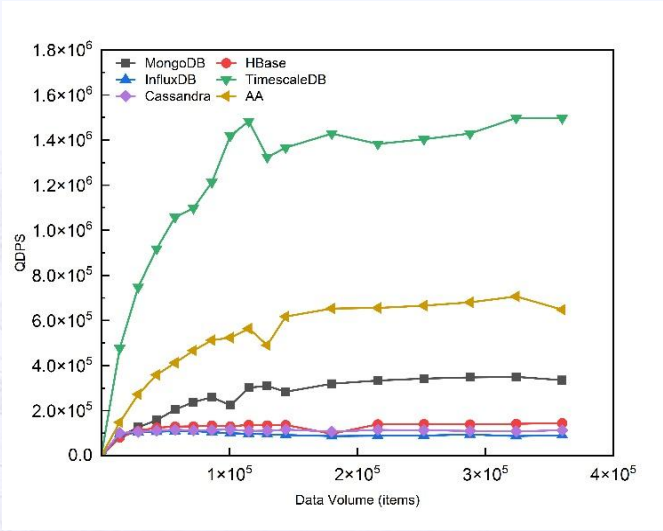
Details in the poster THPDP036

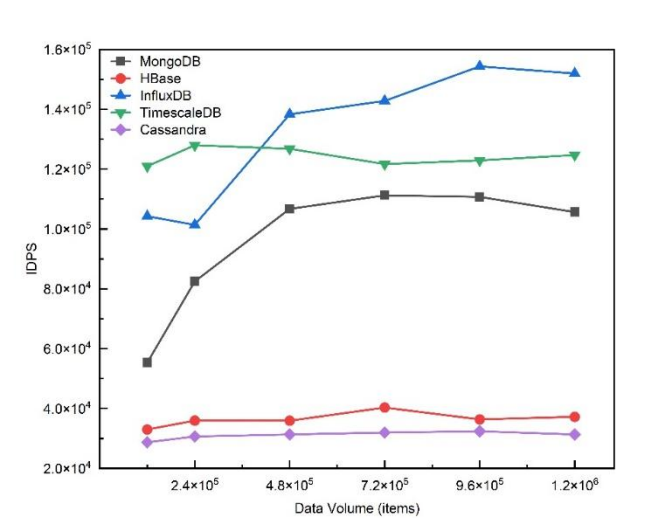
10/12/2023, 16:15-17:45

Hall D

Data Archiving System

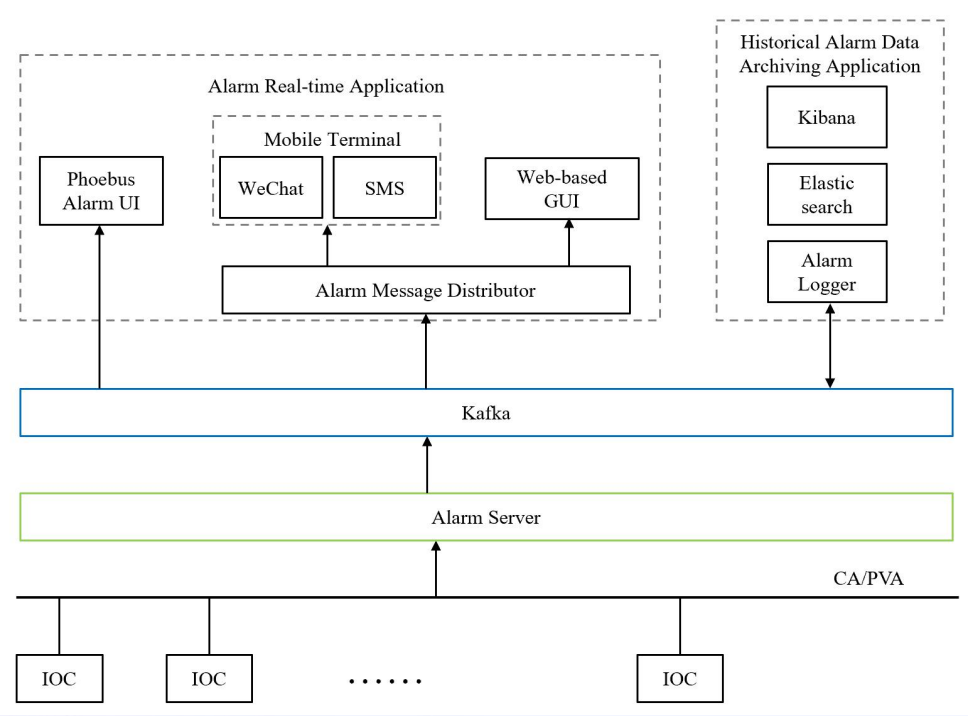
- TimescaleDB read-write performance
  - Read: best (left fig.); Write: second-best (right fig.)
- TimescaleDB supports continuous aggregation, which allows to summarize data at different levels of granularity and form materialized views. Materialized views can significantly improve query performance for long term data.





Alarm System

- Based on Phoebus/Alarms
- 3 ways of alarm message distribution are developed
  - WeChat
  - SMS
  - Web-based GUI



Summary

- The HALF control system is built on EPICS for the entire facility, including accelerator, beamlines, and utilities.
- A unified architecture is adopted, incorporating server virtualization, VLAN and COTS products.
- Some R&D tasks have been started, such as timing system, network status monitoring system, data archiving system and alarm system.
- Collaborations are welcome.

THANKS

USTC
NSRL
国家同步辐射实验室
NATIONAL SYNCHROTRON RADIATION LABORATORY