17th Biennial International Conference on Accelerator and Large Experimental Physics Control Systems

ICALEPCS 2019

上海同步辐射光源
Shanghai Synchrotron Radiation Facility

COSYLAB
CONTROL SYSTEM LABORATORY

Fast Machine Interlock System and Its Applications

Ming Liu, Chongxian Yin

Electronics Group, Shanghai Synchrotron Radiation Facility, Shanghai

Klemen Erjavec, Uroš Legat

Cosylab, Ljubljana

liuming@zjlab.org.cn

Content

- System design
- Hardware
- Application

Machine Interlock System

- Jointly-developed project by Electronics Group (SSRF) and Cosylab since 2013.
- Experience for architectural design gathered from discussions with different labs.
- Fast and deterministic response time
  - 1μs for local crate
  - 5μs for global network
- Distributed architecture
  - 2.5Gbps fiber optic network

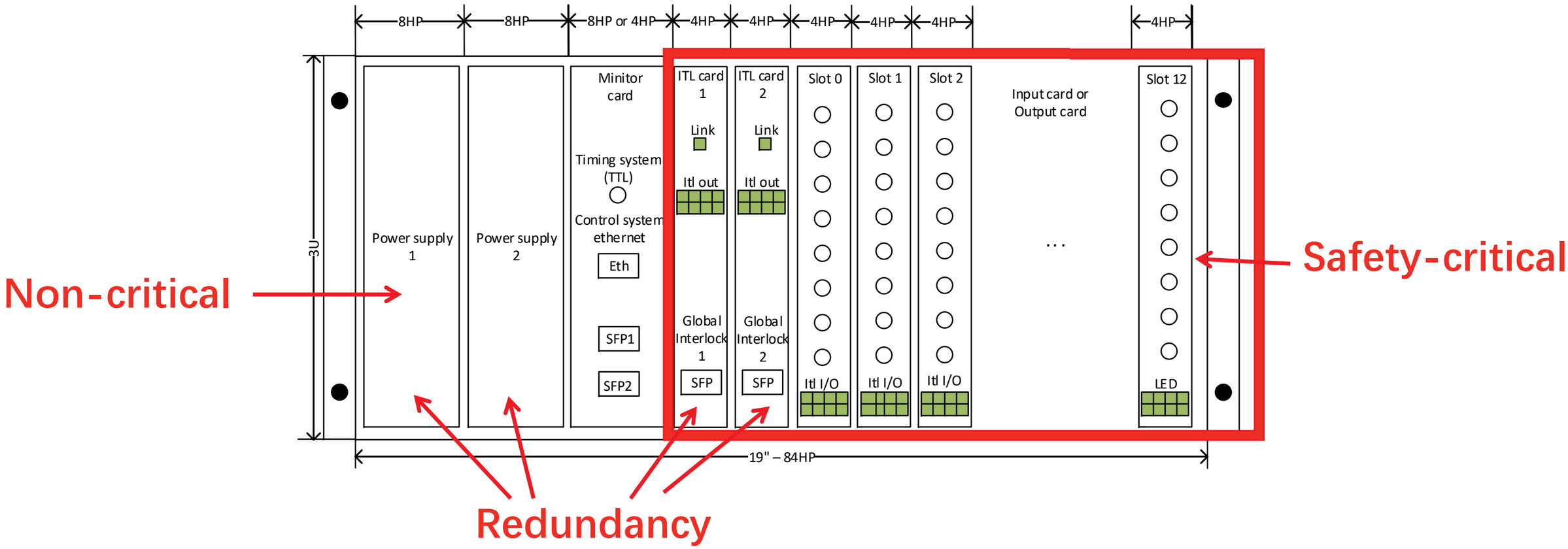
Reliability

- Fault safety design, comply with IEC-61508 standard
- Separation of safety-critical parts from non-critical
- Redundancy of vital functions (power supply and logic)
- Hard-deterministic signal paths
- Detailed system health check available to control system
- Core function implementation by combinational logic but not sequential

Flexibility

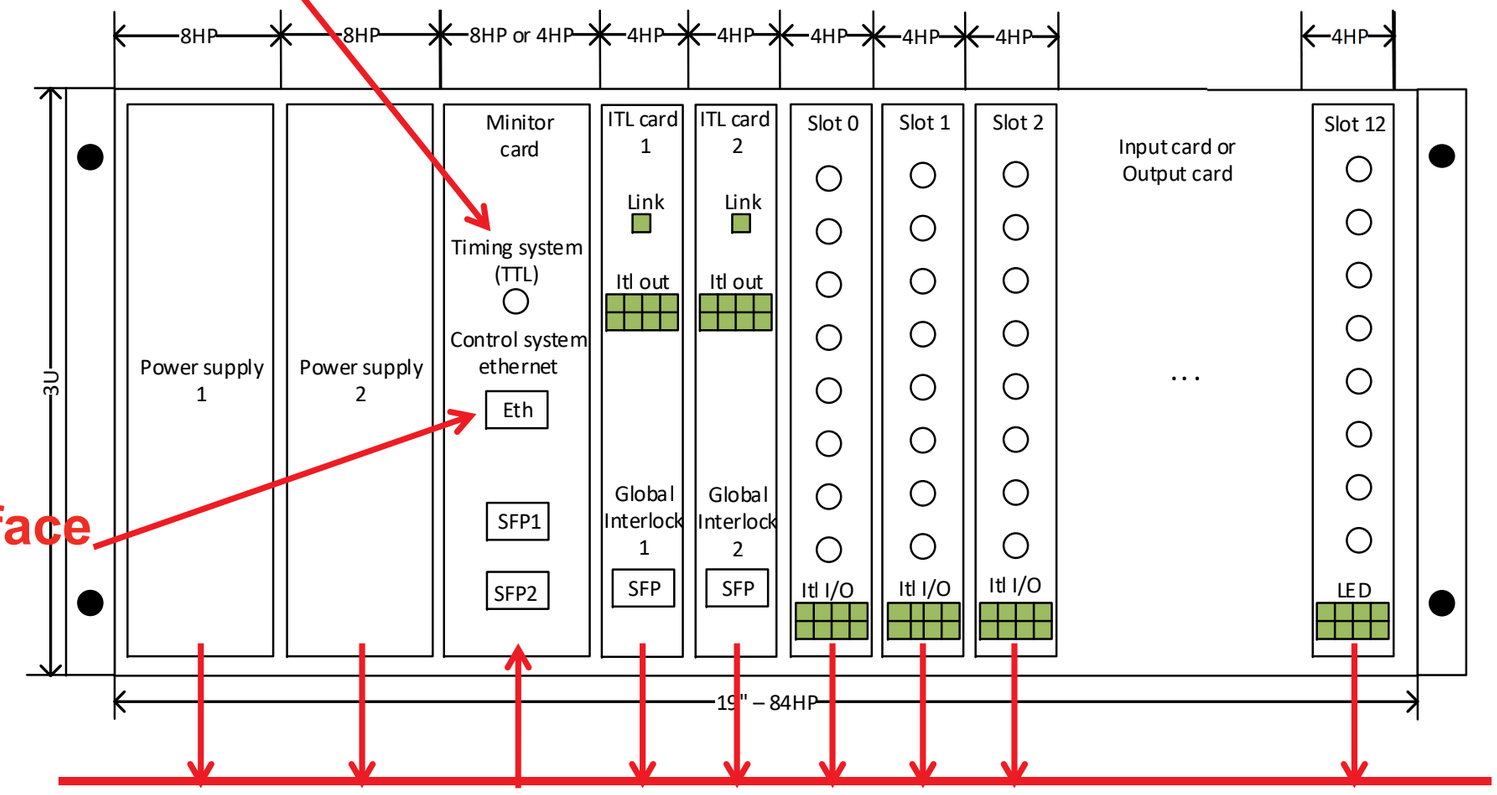
- Fast interlock mode switch
- Configurable interlock logic
- Based on FPGA but not PLC
- BIT function
- Flexible I/O capability (electrical, optical, relay)
- Different interlock response for different machine mode

Hardware Overview



Hardware Overview

Control system Interface
(configuration, SW interlock, monitoring)



Timing System Interface
(timestamping)

Backplane: monitoring and interlock interconnect

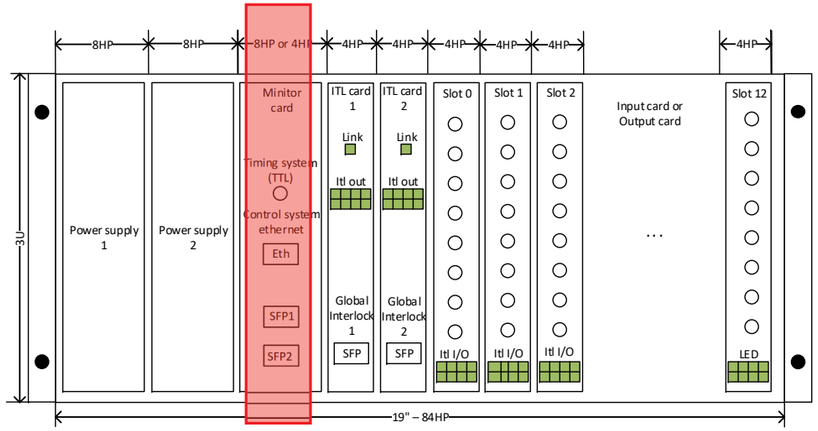
Customized backplane based on cPCI (only mechanical and electrical)

Hardware List

- Monitor Card
- Interlock Card
- Input Card
- Output Card

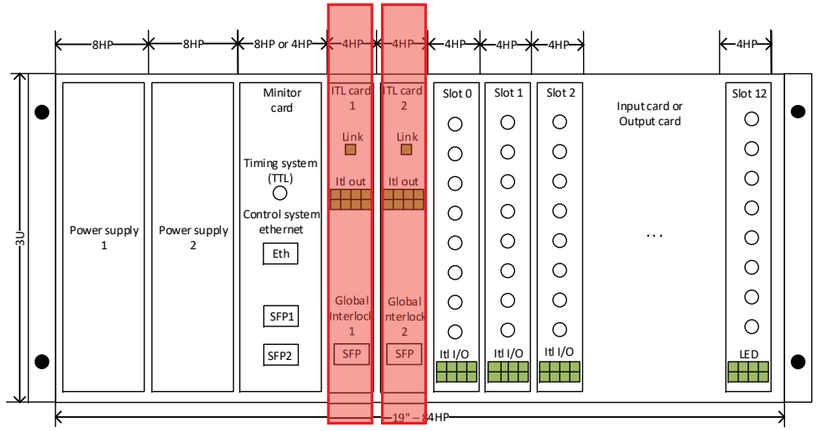
Monitor Card

- Non-safety critical functions
- System monitoring
- Logging for post-mortem
- Connection to Control System
- Trigger software interlock
- Integration with Timing System (timestamping)
- Monitoring the sanity of components (all cards in system)
- Checking the configuration (check if cards in crate match pre-defined configuration)



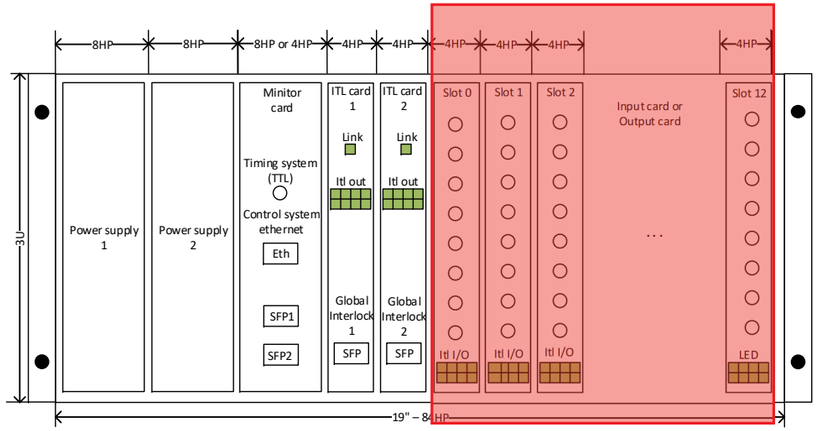
Interlock Card

- Critical interlock logic
- Fixed FPGA firmware
- Logic table configured by software
- 2.5G fiber link (SFP)
- Cascaded fiber networks
- Switched fiber networks
- Redundant fiber networks and Interlock card supported



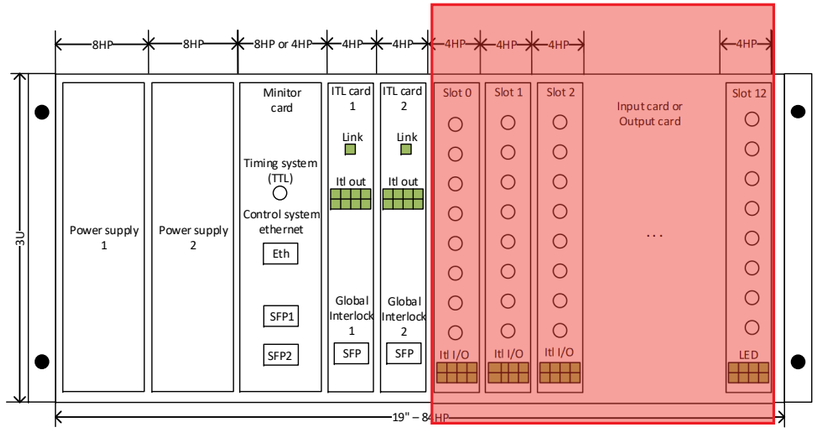
Input Card

- Various input interface supported
  - 8 Channels TTL input
  - 8 relay input
  - 4 optical input
- Debounce function



Output Card

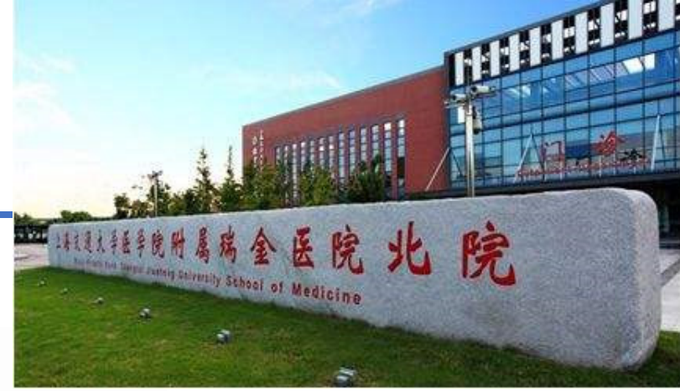
- Various output interface supported
  - 8 channels TTL output
  - 8 relay output
  - 4 optical output
- Failsafe function

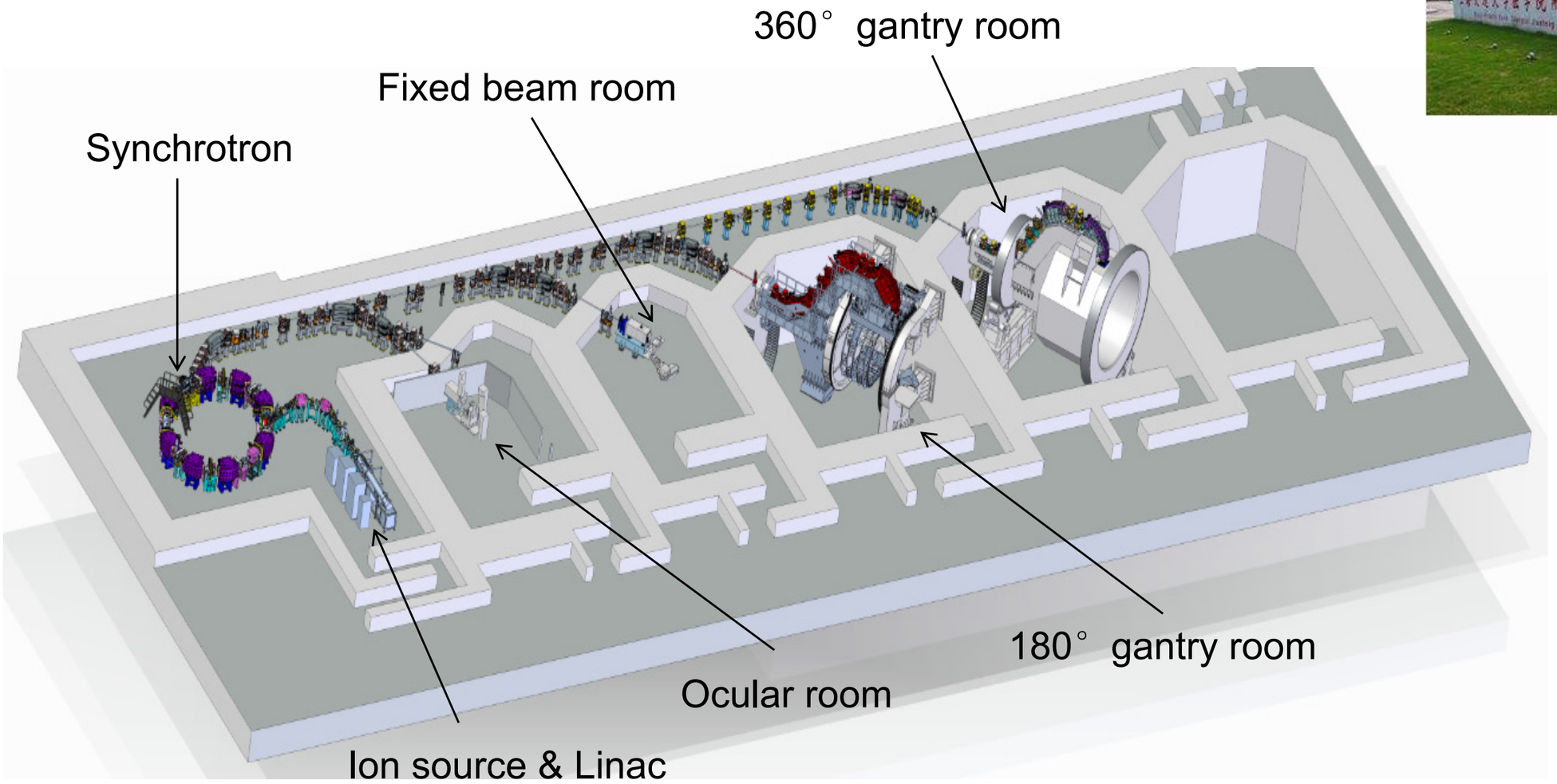


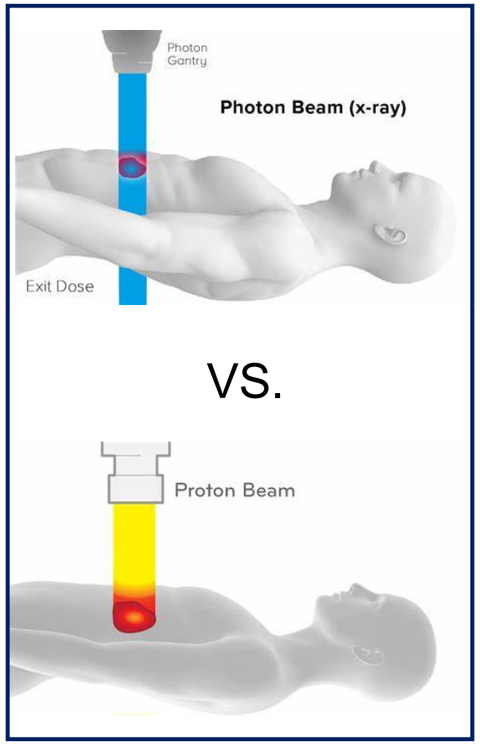
Application Examples

- MIS was adopted for machine protection for large accelerator facilities.
  - Treatment interlock system of Shanghai Proton Therapy Facility (SAPT) in Ruijing Hospital
  - Machine protection system of front-end demo Linac of China initiative Accelerator Driven System (CiADS)

Shanghai Advanced Proton Facility

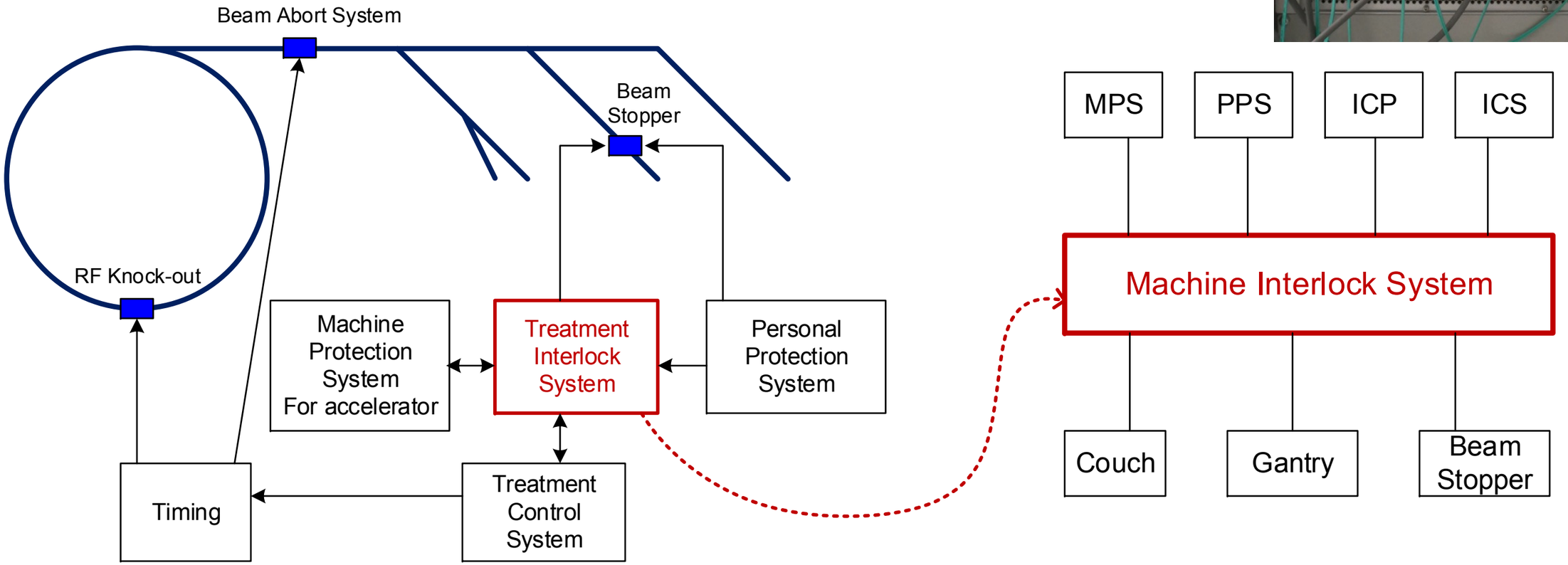






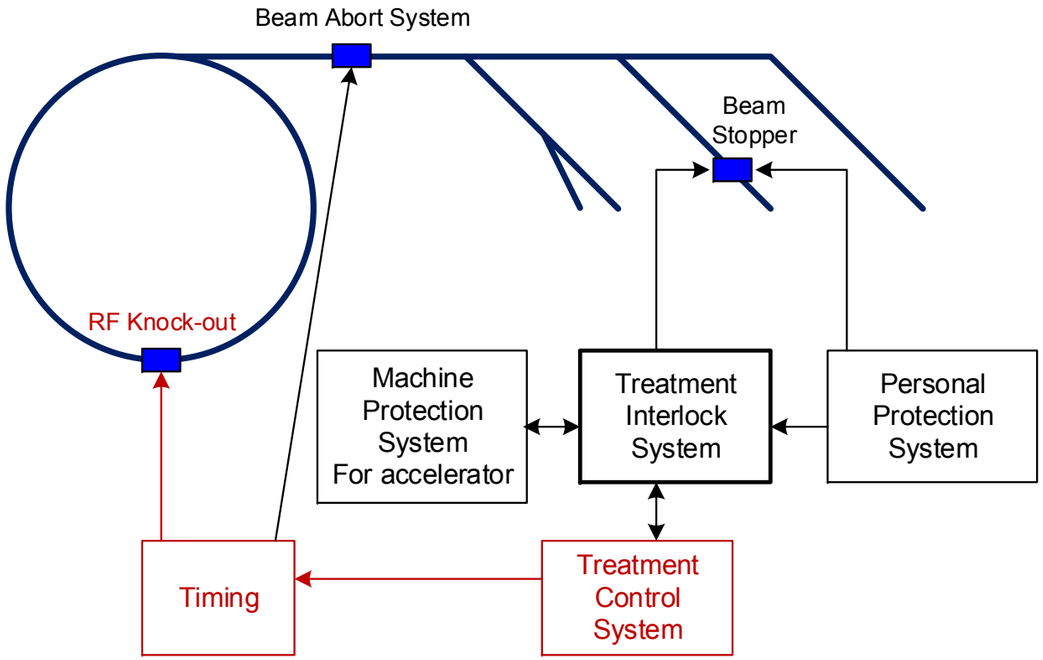
Implementation in Shanghai Advanced Proton Facility

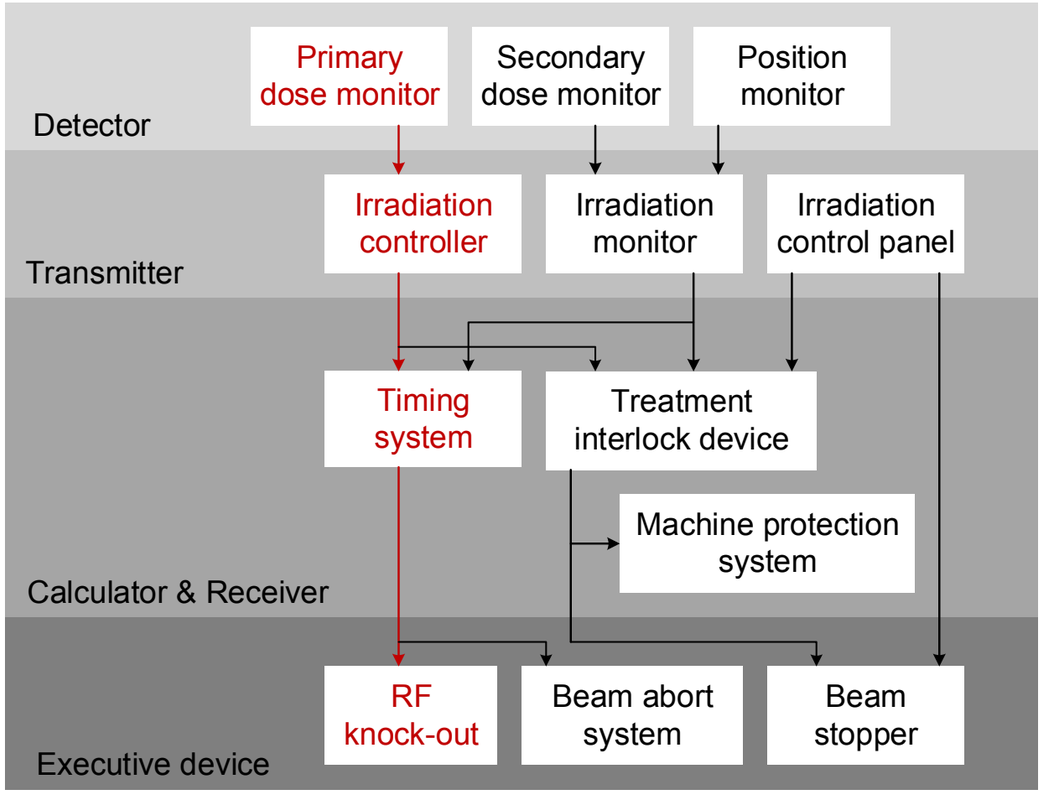
- Based on the fast Machine Interlock System, multi-redundant safety interlock mechanism is developed to protect personnel and machine from hazards.



Treatment Interlock Procedure

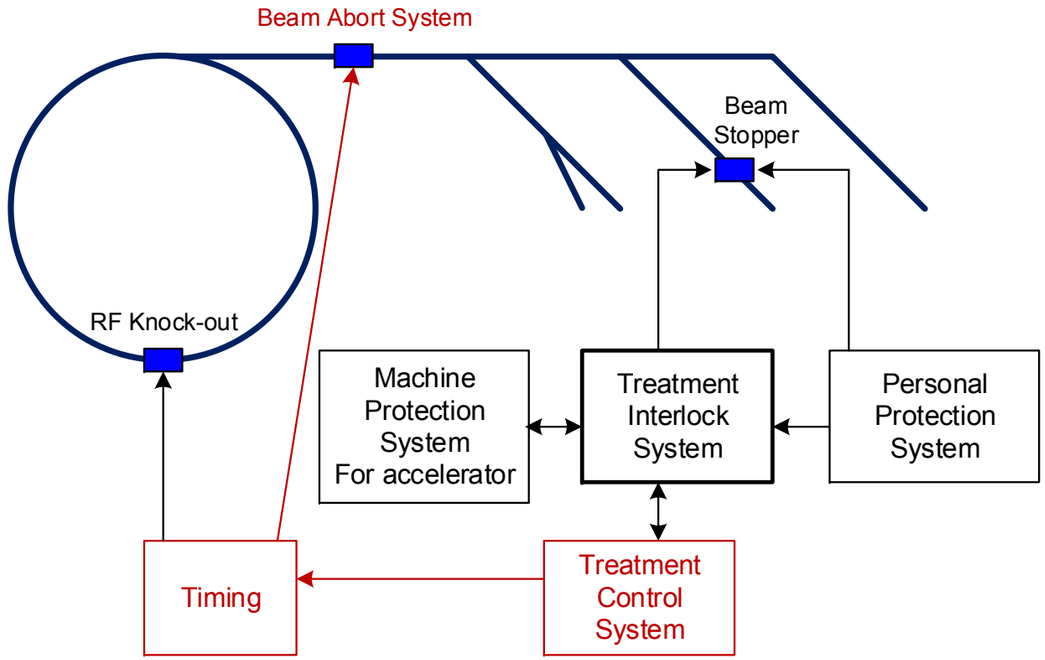
- Normal process

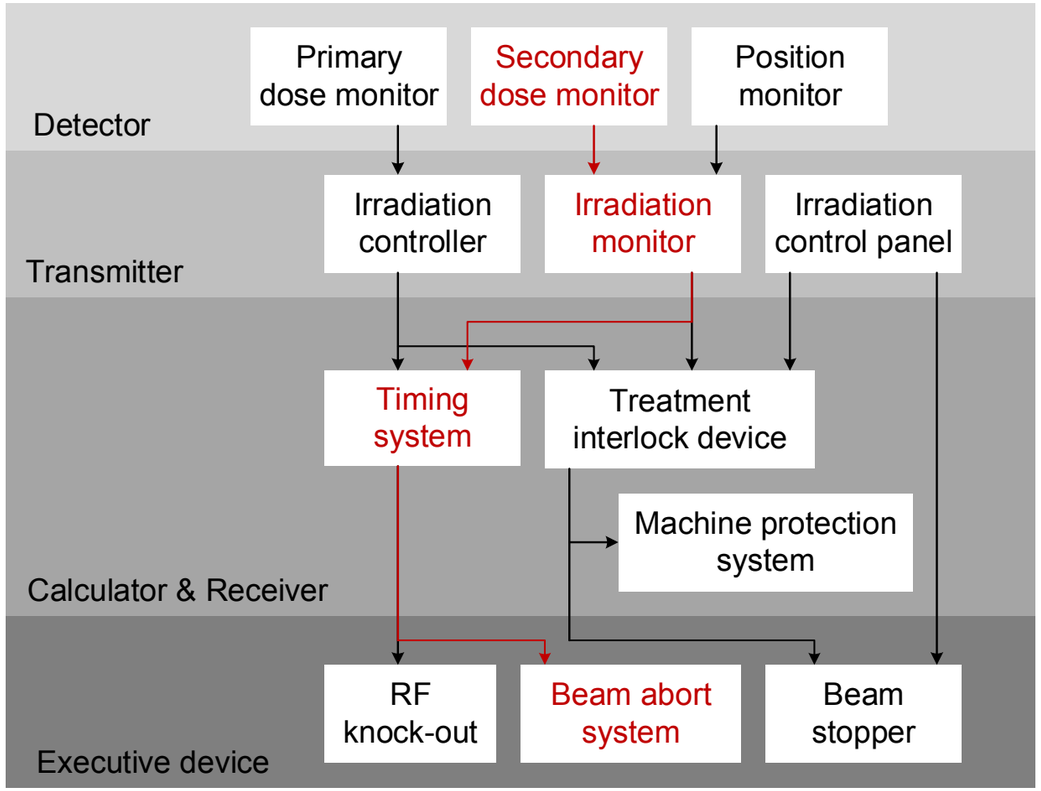




Treatment Interlock Procedure

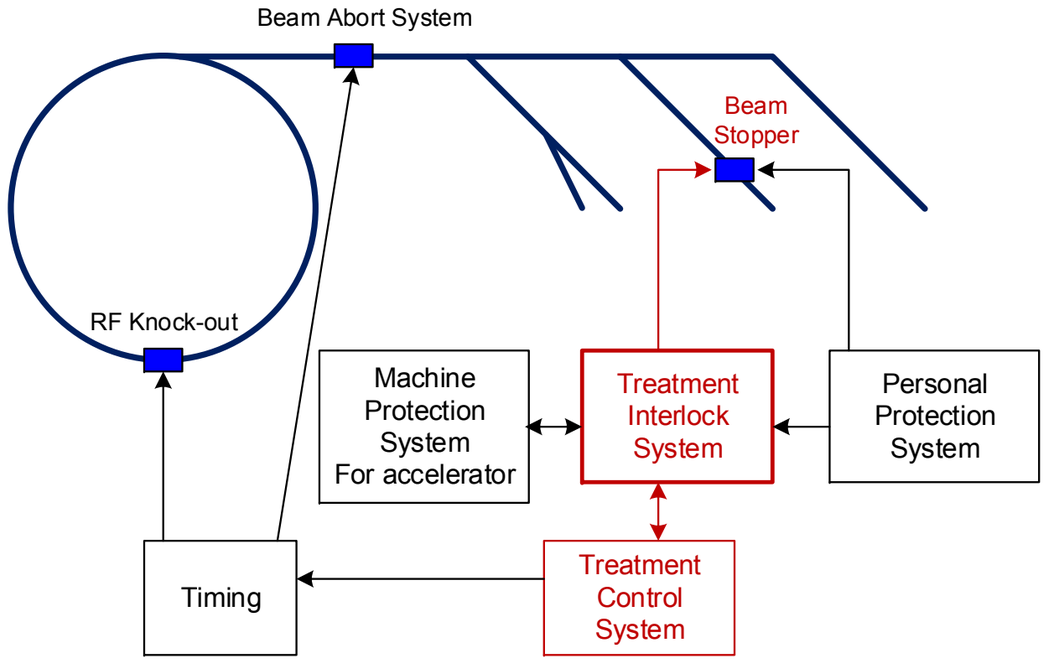
- 120% of spot dose reached, and irradiation terminated automatically.

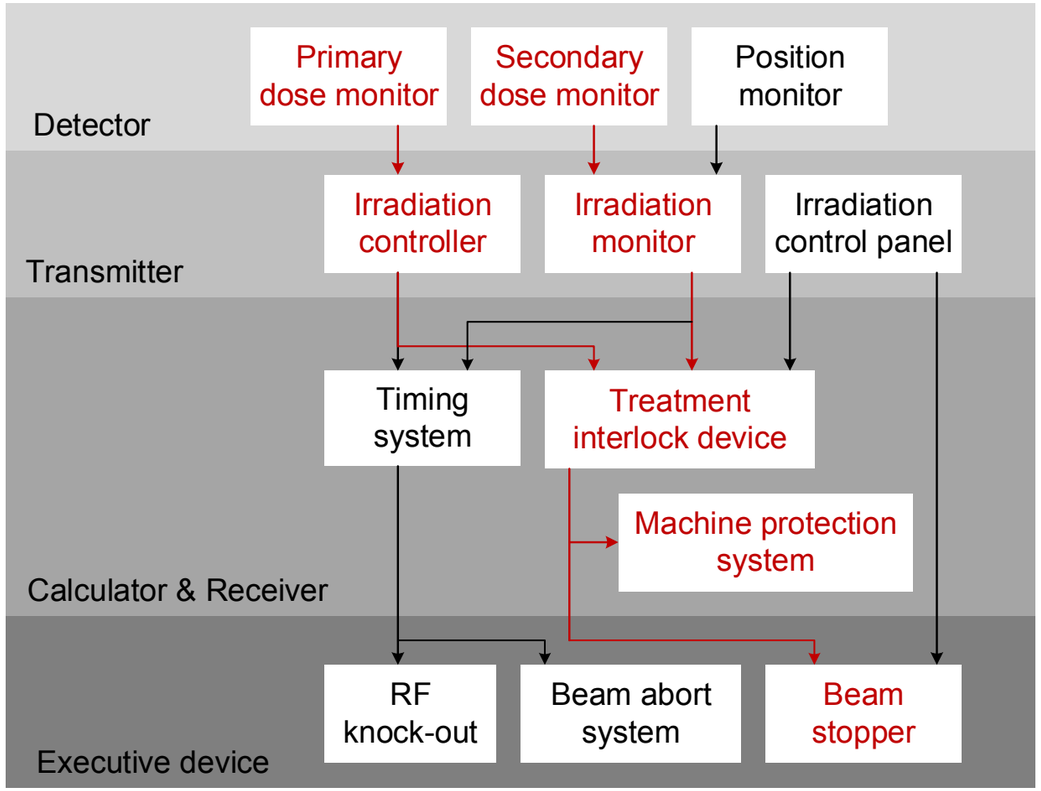




Treatment Interlock Procedure

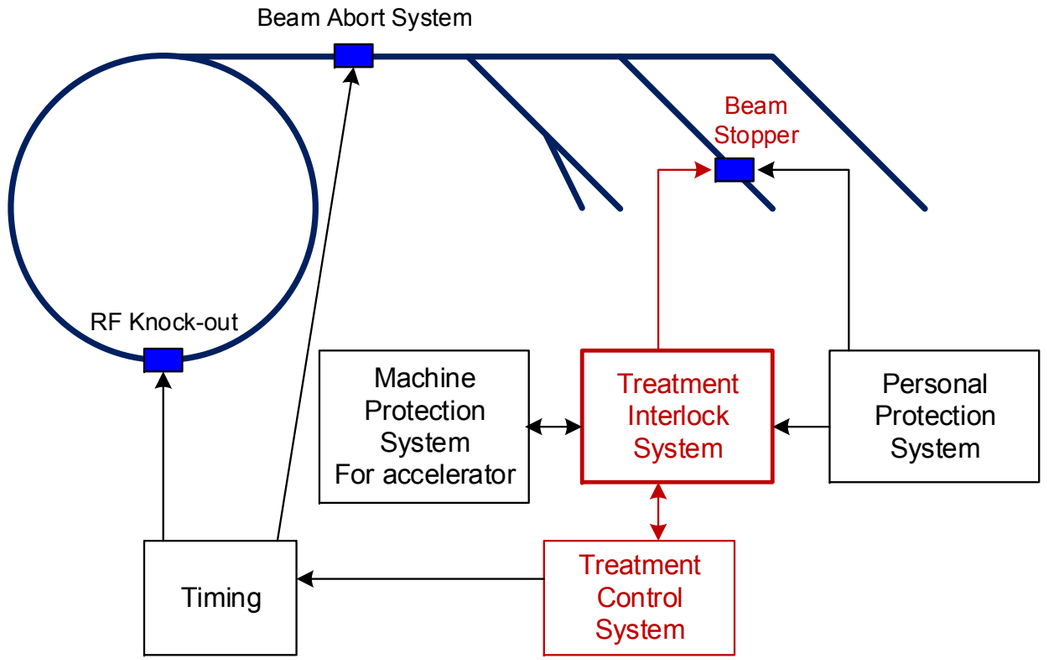
- 150% of spot dose reached, and irradiation terminated automatically.

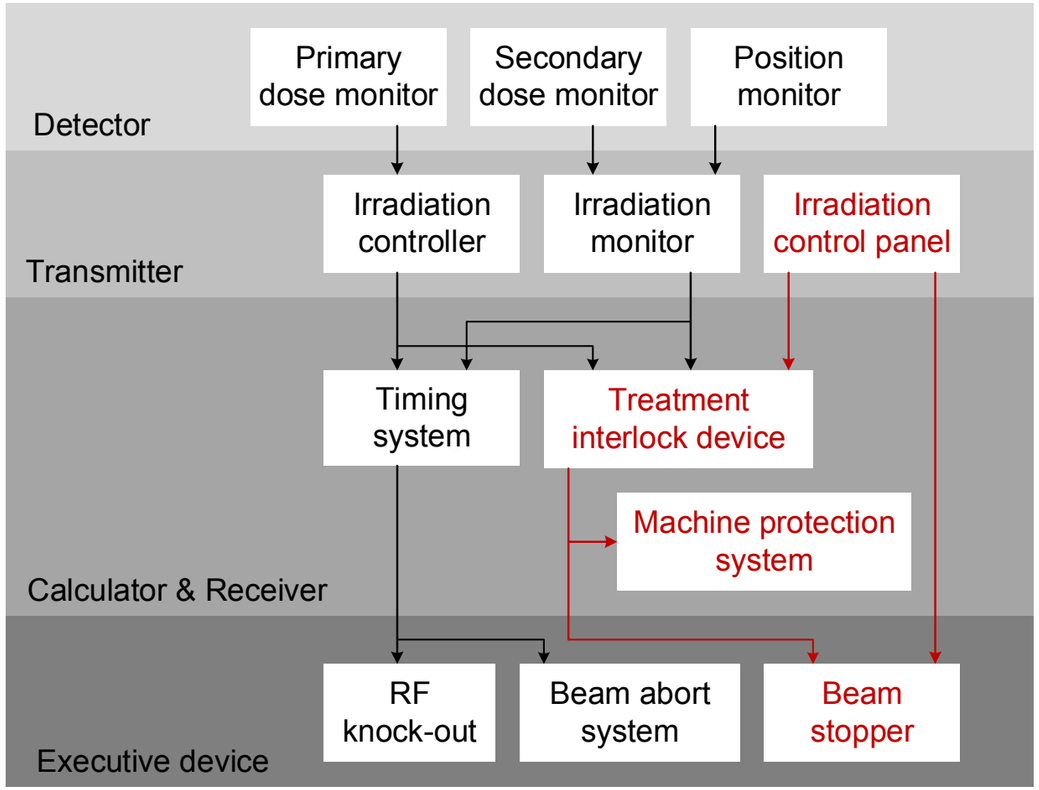




Treatment Interlock Procedure

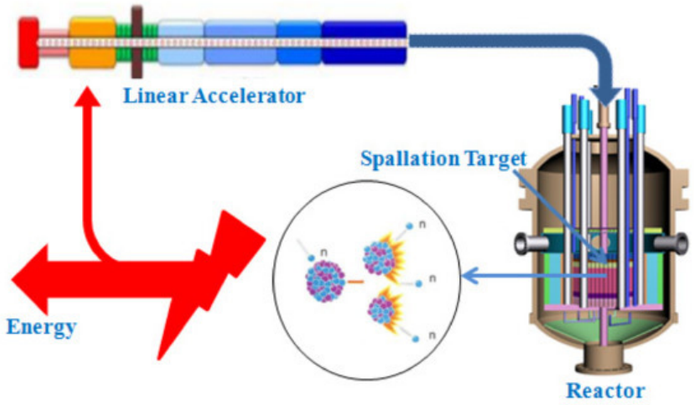
- Irradiation terminated by operator.





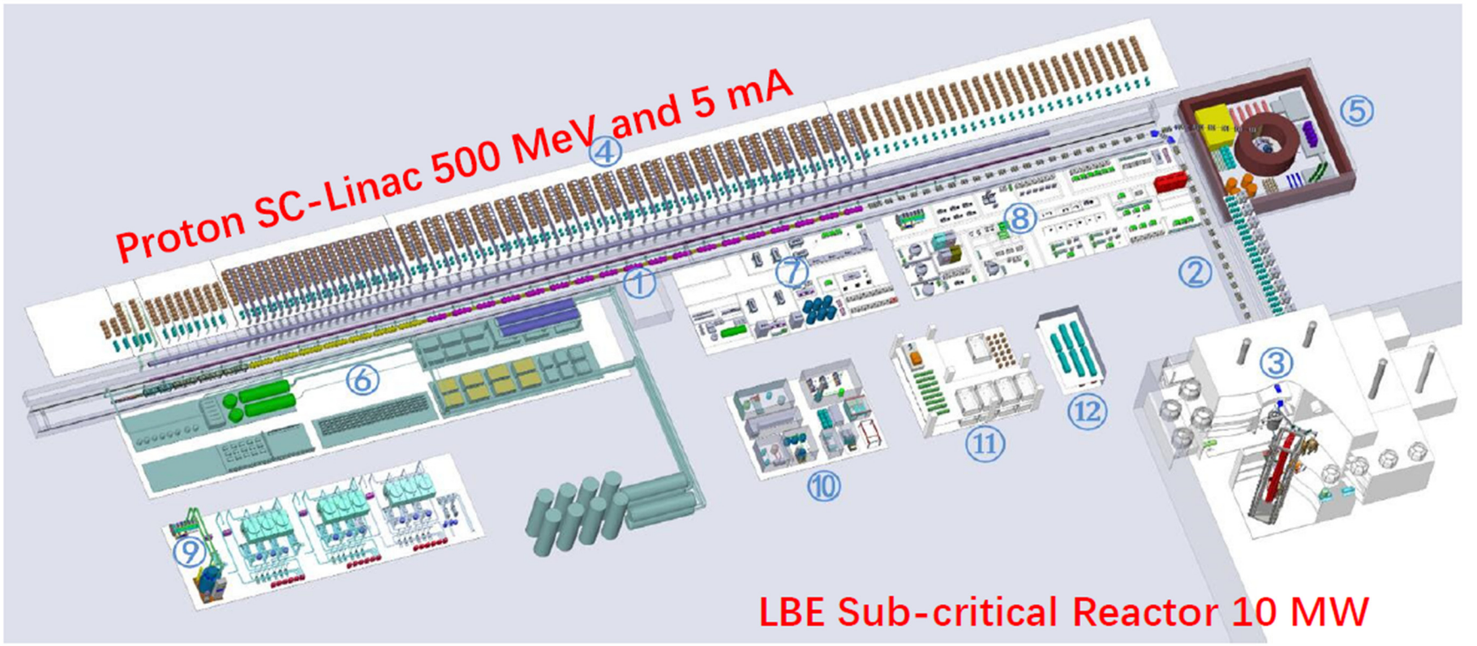
China initiative Accelerator Driven System

- CiADS Project:
  - Huizhou, Guangdong Province
- Front-end Demo Linac:
  - Lanzhou, Gansu Province



Yan X. *et al*, Energies 2017, 10(7), 944

Overview of CiADS

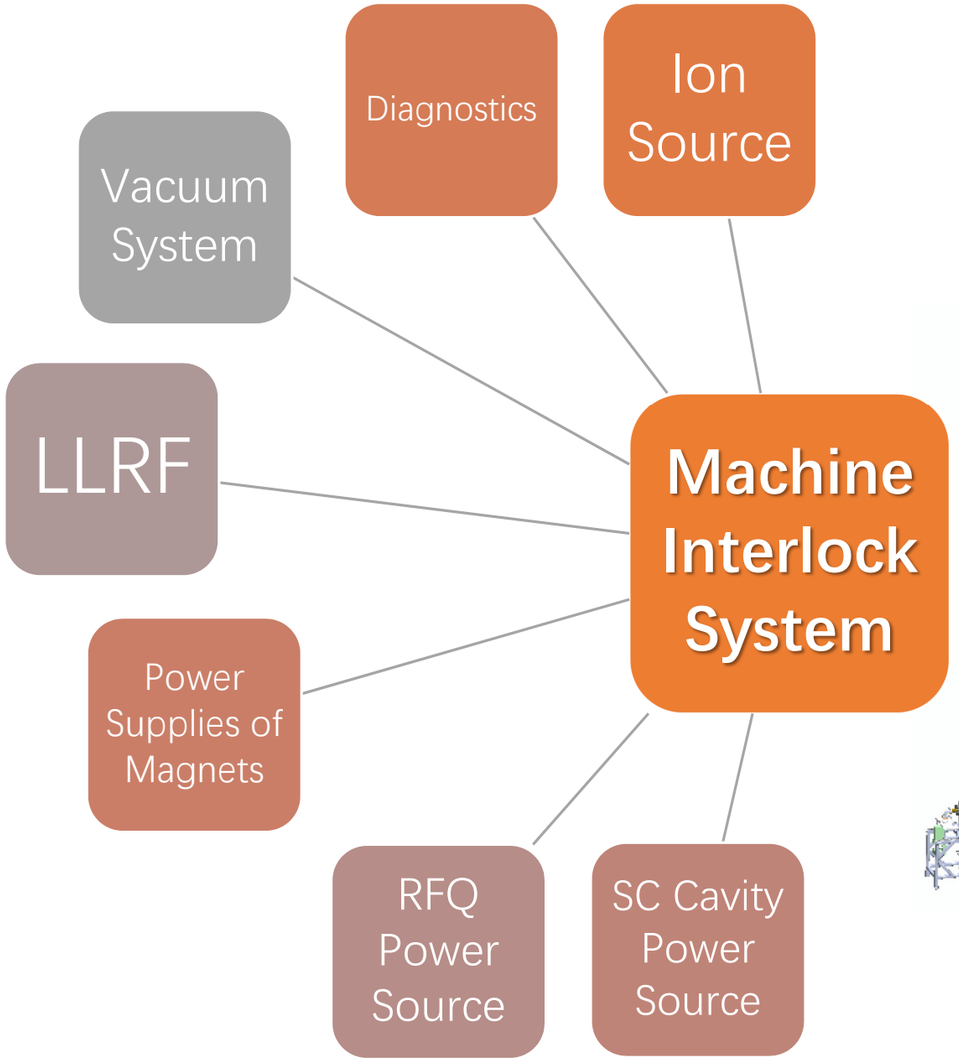


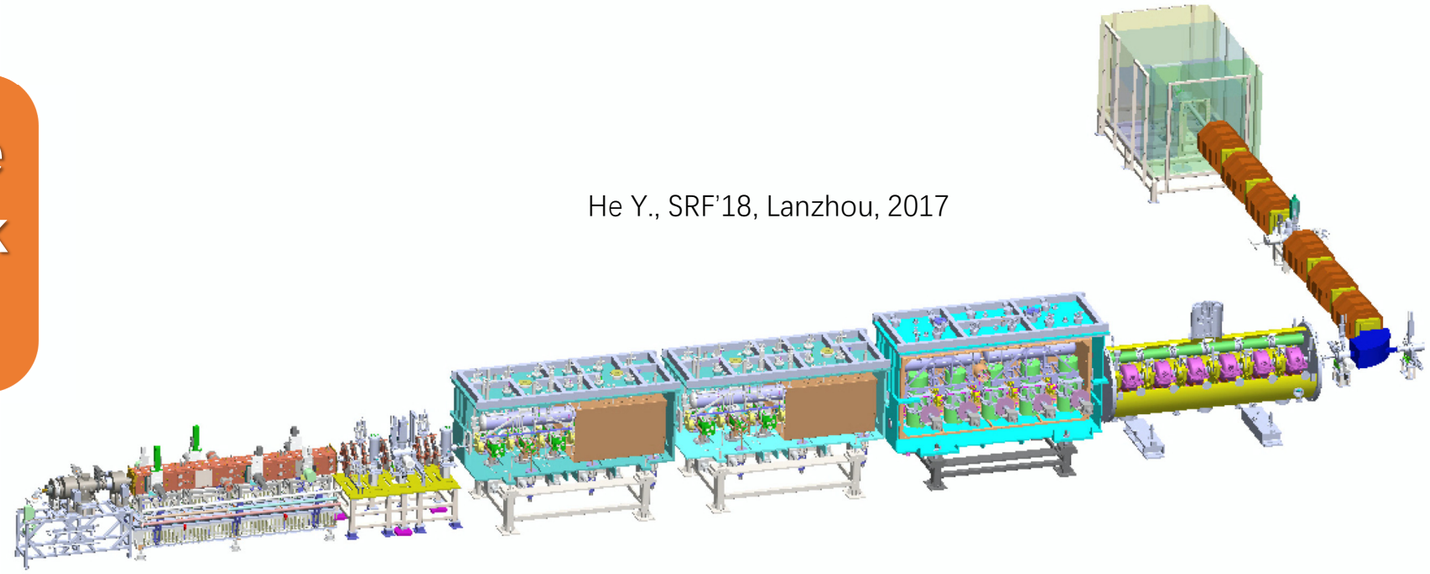
① SC LINAC
② Coupling beam line
③ Reactor Hall
④ RF High power station
⑤ Beam dump and target
⑥ Cryogenic station
⑦ Accelerator assembly Hall
⑧ SRF conditioning hall
⑨ Cooling water station
⑩ Target assembly hall
⑪ Hot cell building
⑫ Central Electric station

He Y., SRF'18, Lanzhou, 2017

5

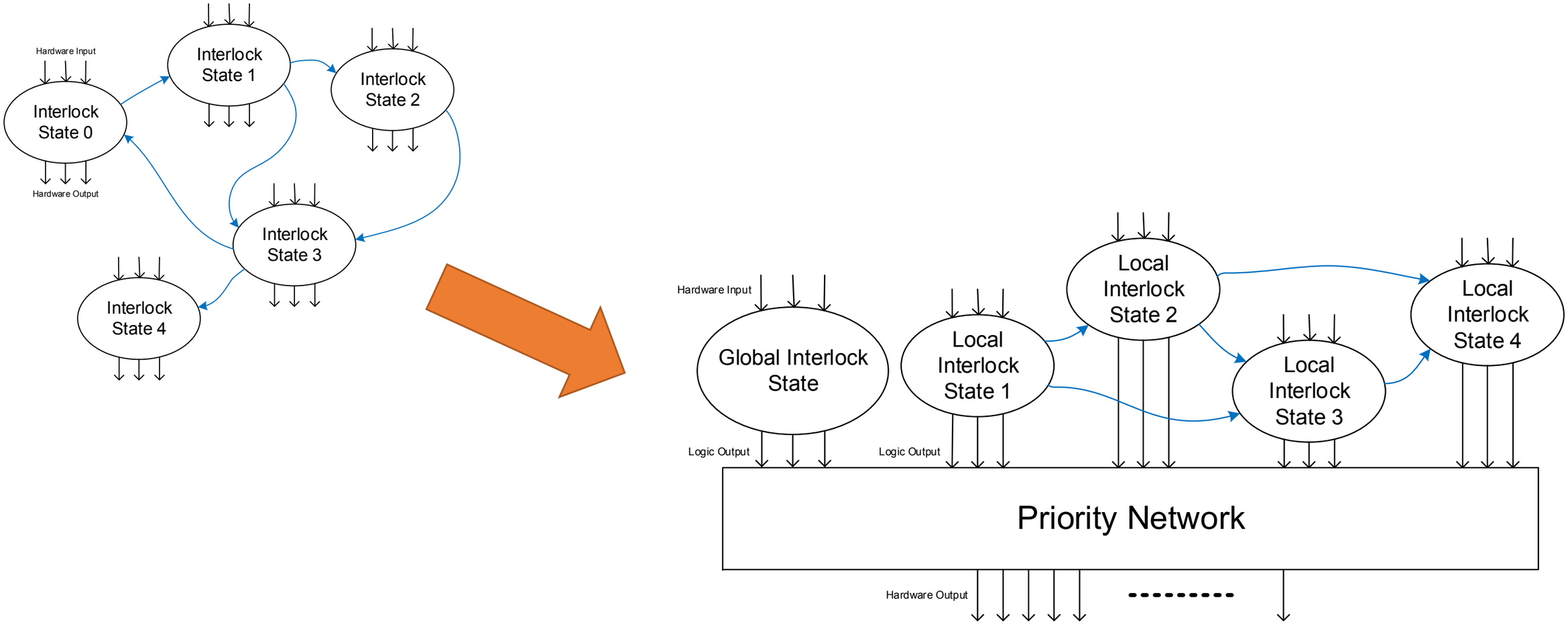
Implementation in Front-end Demo Linac of CiADS





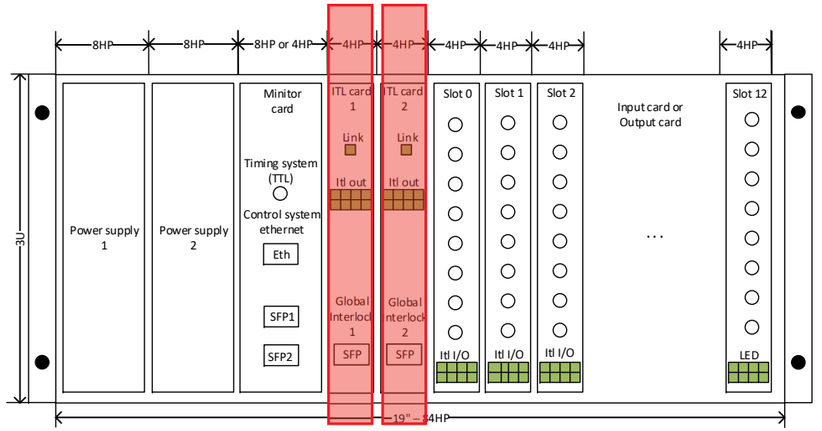
He Y., SRF'18, Lanzhou, 2017

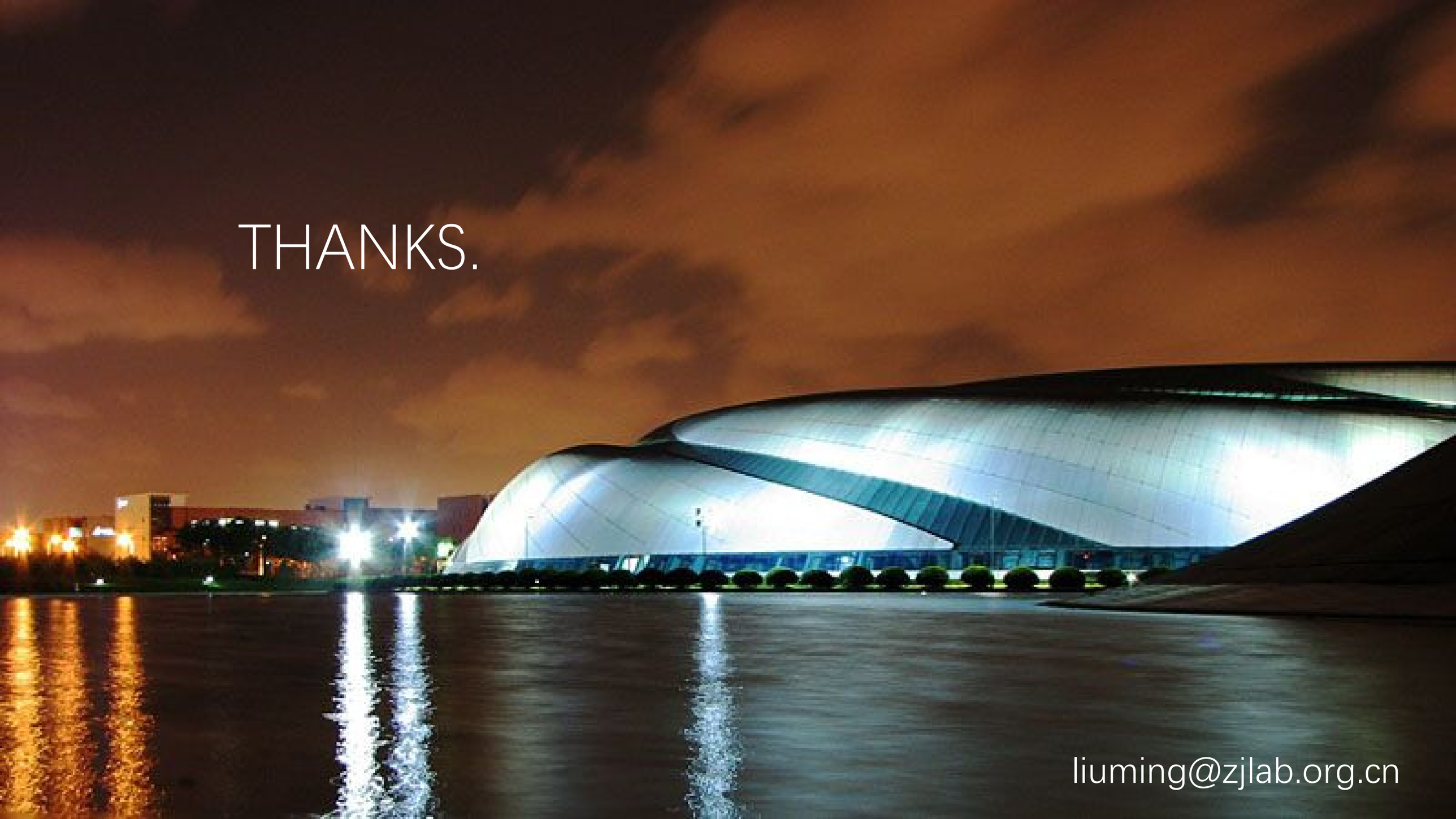
MIS Upgrade Consideration in Future



MIS Upgrade Consideration in Future

- Hardware upgrade of Interlock Card
  - One oscillator -> two oscillators
  - Implementation of mutual monitoring between the two oscillators in firmware, so reliability of sequential logics will be improved.




THANKS.
liuming@zjlab.org.cn