



Machine Protection System for HEPS

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On behalf of Machine Protection System

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Outline

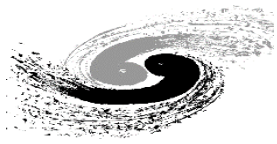
1 Brief introduction of HEPS & MPS

2 Requirments & Design

3 Summary



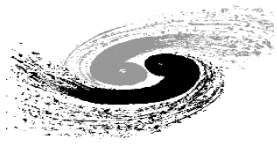
Brief introduction of HEPS & MPS



High Energy Photon Source

Main parameters	Unit	Value
Beam energy	GeV	6
Circumference	m	1360.4
Emittance	pm·rad	34.2
Brightness @20 keV	ph/s/mm ² /mrad ² /0.1%BW	3.2×10^{22} @low- β 0.77×10^{22} @high- β
Beam current	mA	200
Injection		Top-up





Machine Protection System

- The HEPS (High Energy Photon Source) operate with large amount of power and energy stored in beams and superconducting magnets.
- In order to **prevent damage to accelerator components in case of failure**, highly reliable Machine Protection System(MPS) is indispensable.
- MPS equipments are distributed in all the accelerator area. It collect urgent beam dump requests to beam abort devices within Very short time. Input signals from PS, ID, RF, vacuum, beamline, BPMs, BLMs and so on.
- SPS signals: ~ 3200
- FPS signals: ~ 2000



Requirments & Design



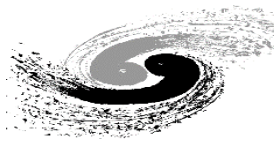
Requirments

Interlock protection requirements based on radiation

Trigger conditions	22kHz data from bpm on both sides of the ID, Horizontal closed orbit >2.8mm or vertical closed orbit >1.5mm	
Interlock protection response time	<0.1ms , the faster the better	
Beam dump method	RF	
Beam dump time	<1ms	
Data preservation time length	Turn by turn BPM data	10 thousand turns pre and post trigger time(~0.9s)
	RF	0.5s data pre and post trigger time

Note :

- 1、 This table is to protect Vacuum components from synchrotron radiation damage, and the integrated interlock protection scheme need Control, Physics and other systems design together.
- 2、 when receiving trigger signal, lock the cache data, and can transmit these data at a slower speed.
- 3、 Personnel safety and machine protection should be considered.



Design

- The MPS consist of Slow Protection System(SPS), Fast Protection System(FPS) and Run Management System(RMS).
 - The SPS is Programmable Logic Controller(PLC) based system which can deliver **less than 20 msec** reaction time.
 - The FPS is Field Programmable Gate Array(FPGA) based system which can deliver **less than 20 μ sec** reaction time.
 - The RMS guarantee HEPS running safely and easy to operate, together with Personnel Protection System(PPS), it can **set the accelerator modes by mechanical key switch**.

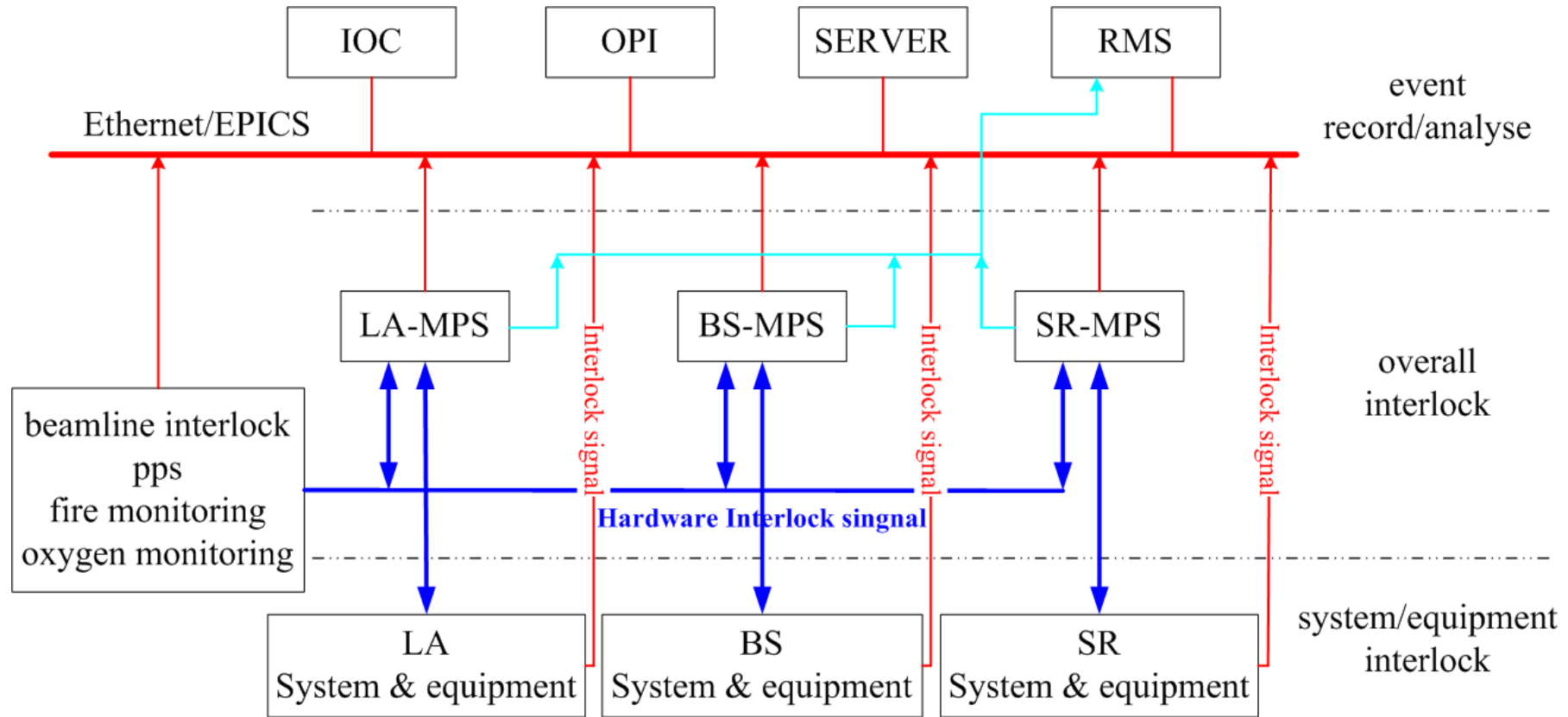


Design Principles

- **Independence:** MPS responsible for the accelerator operation safety, it's just provide interlock signals between related systems, data transfer over a independent network.
- **Redundancy:** critical equipments or signals should be redundant configuration.
- **Fail-safe:** failure in MPS should lead to a safe state automatically according to preset interlock program.
- **Safety, availability and reliability:** self-diagnostic, heartbeat...



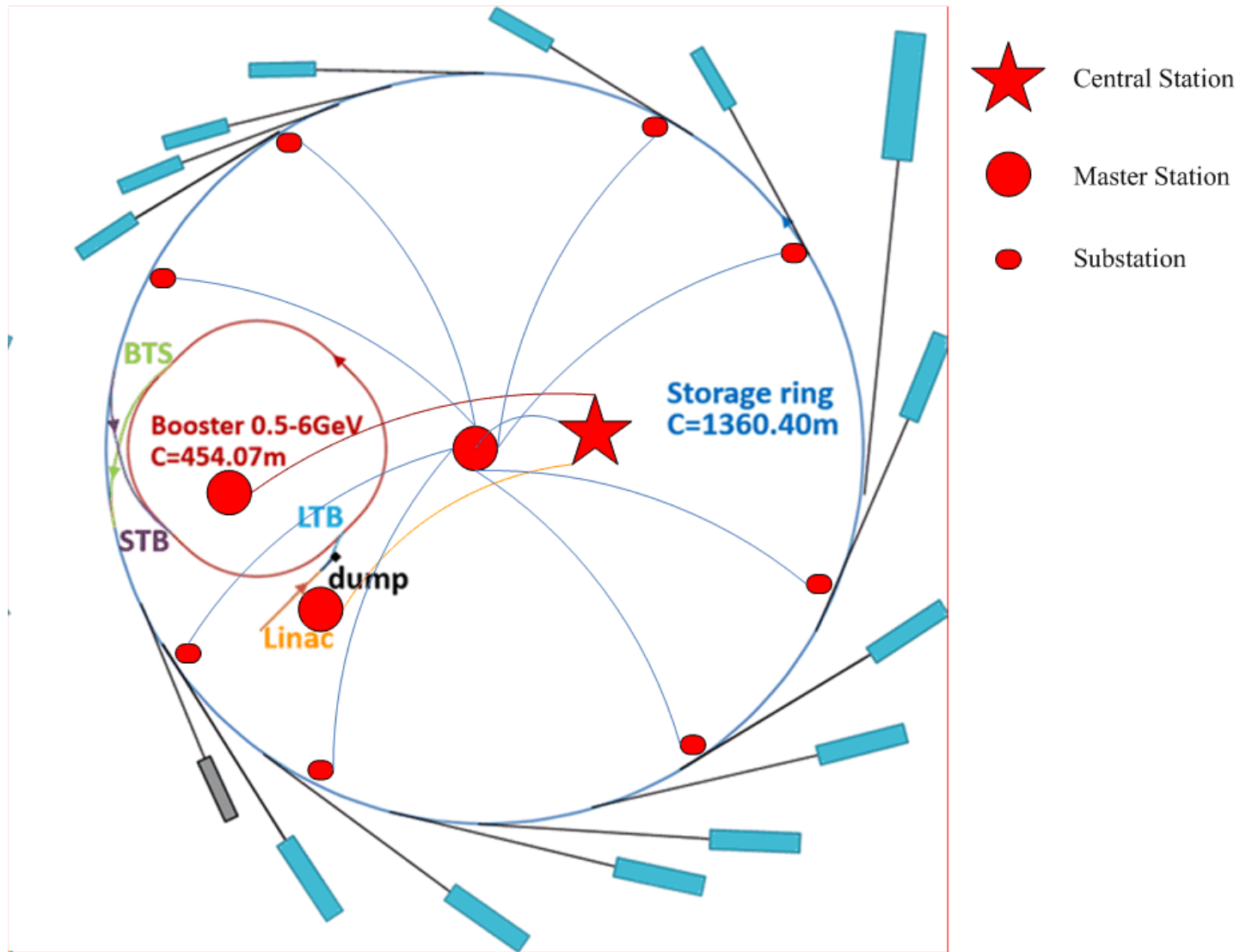
MPS Architecture

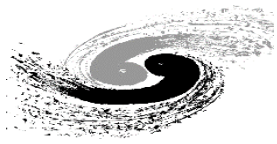


MPS architecture

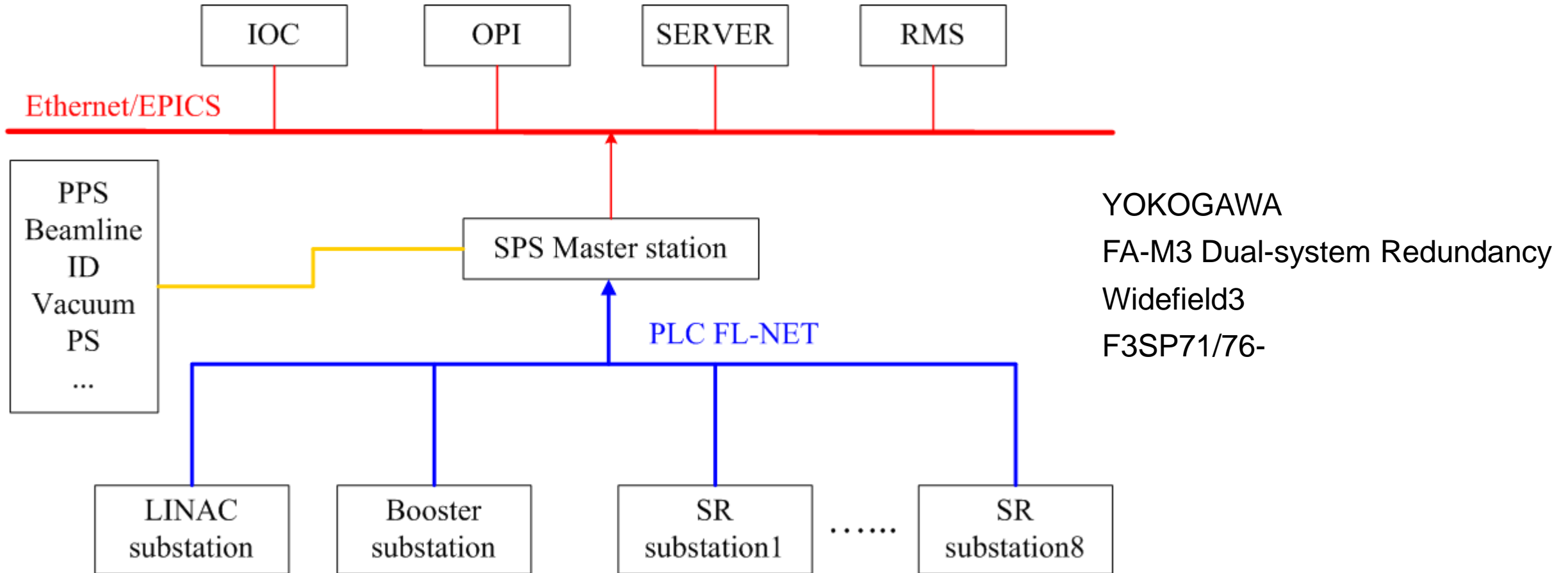


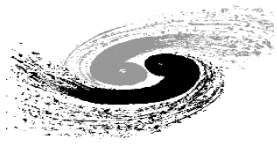
MPS Layout



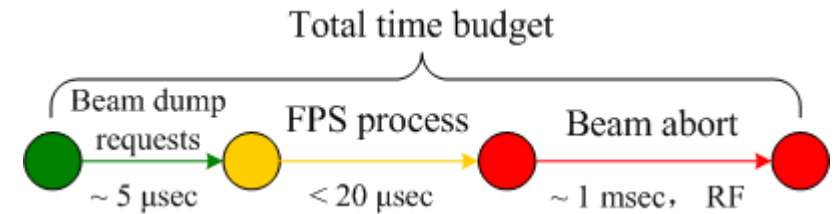


SPS Layout



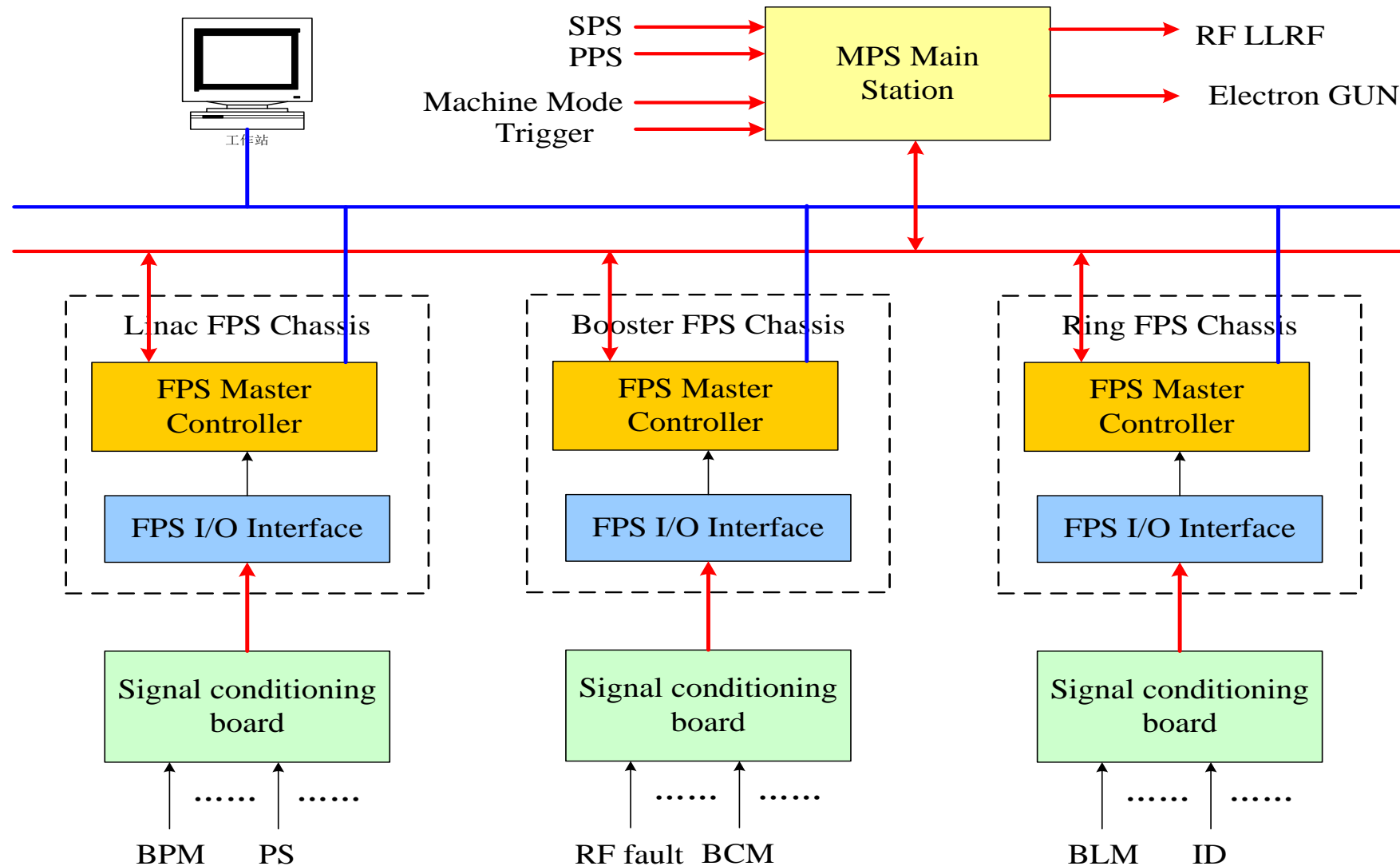


- Work when Device/System fault will cause beam loss
- Response time: less than 20 μsec
- Inputs
 - Beam diagnosis : BPMs, FCs, BLMs...
 - Power supplies
 - RF faults
 - Insertion devices
 - .etc
- Behavior : Injection forbidden, electron gun shutdown, RF power off



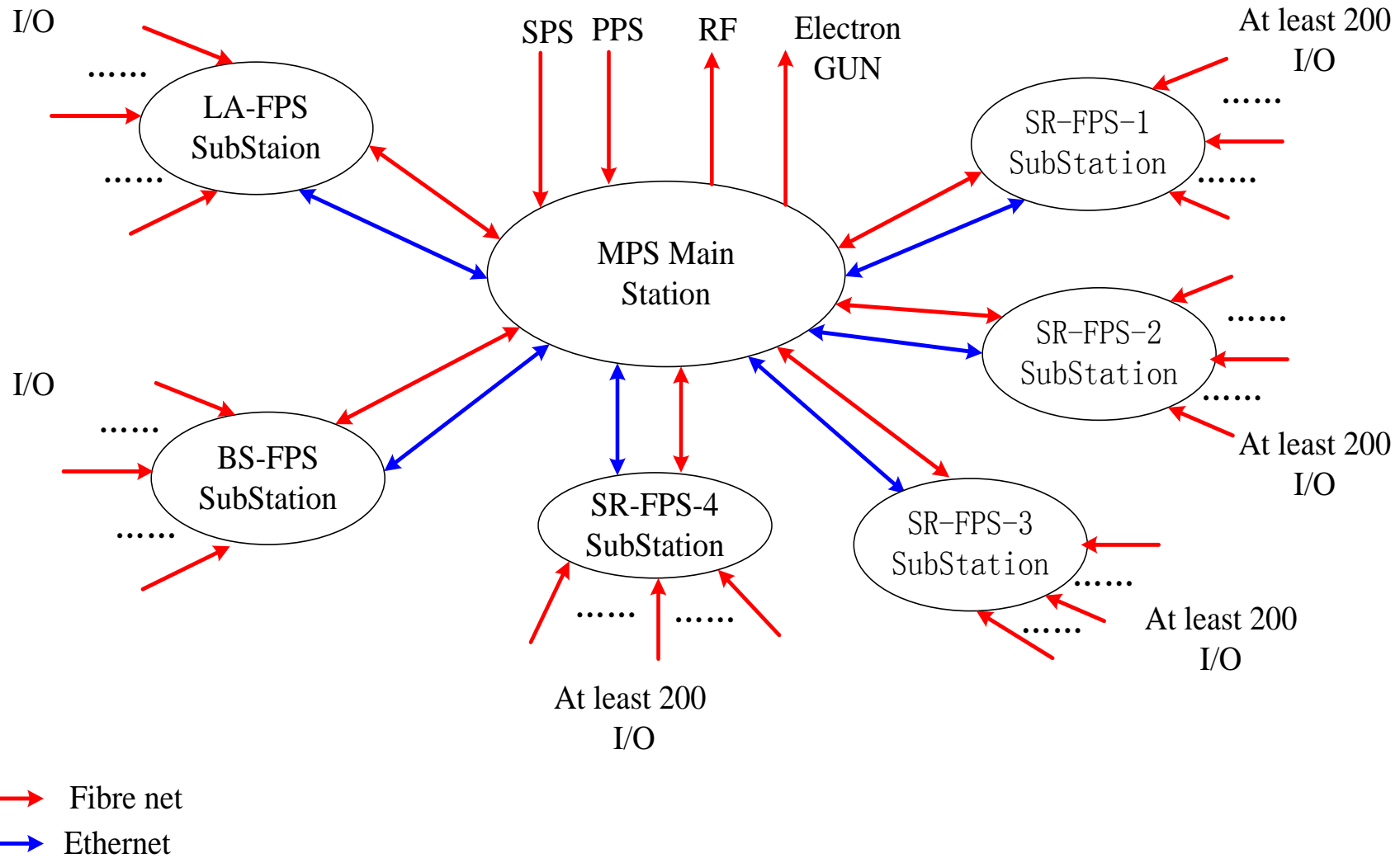


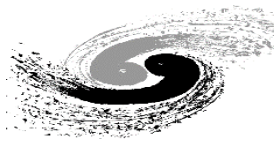
FPS Architecture





FPS Layout

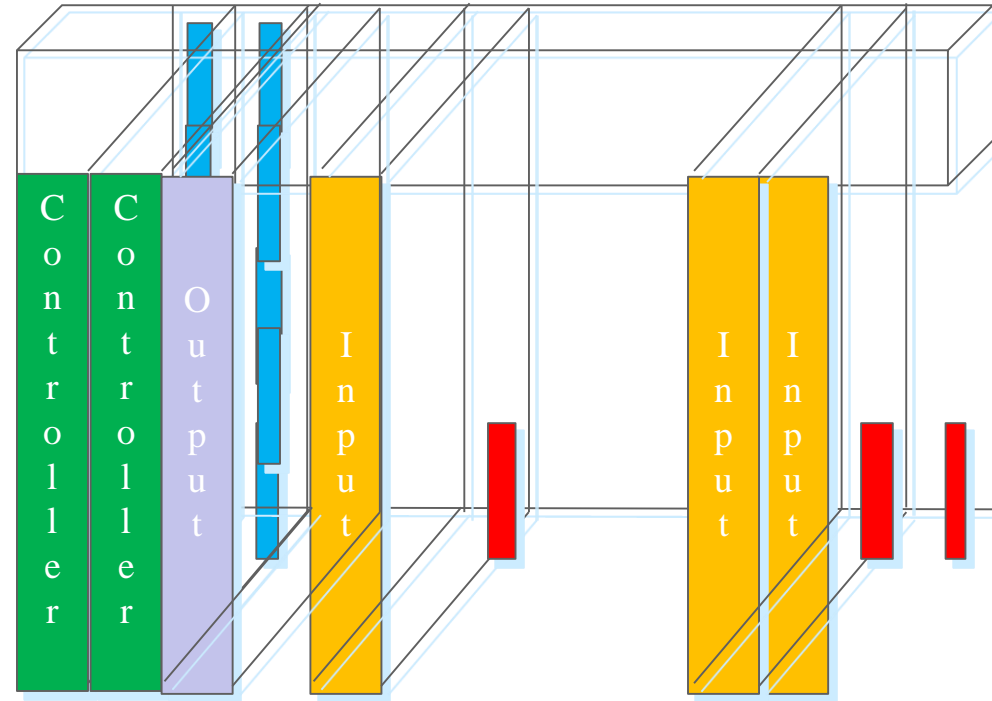




FPS Chassis

● 9U, 21 slots

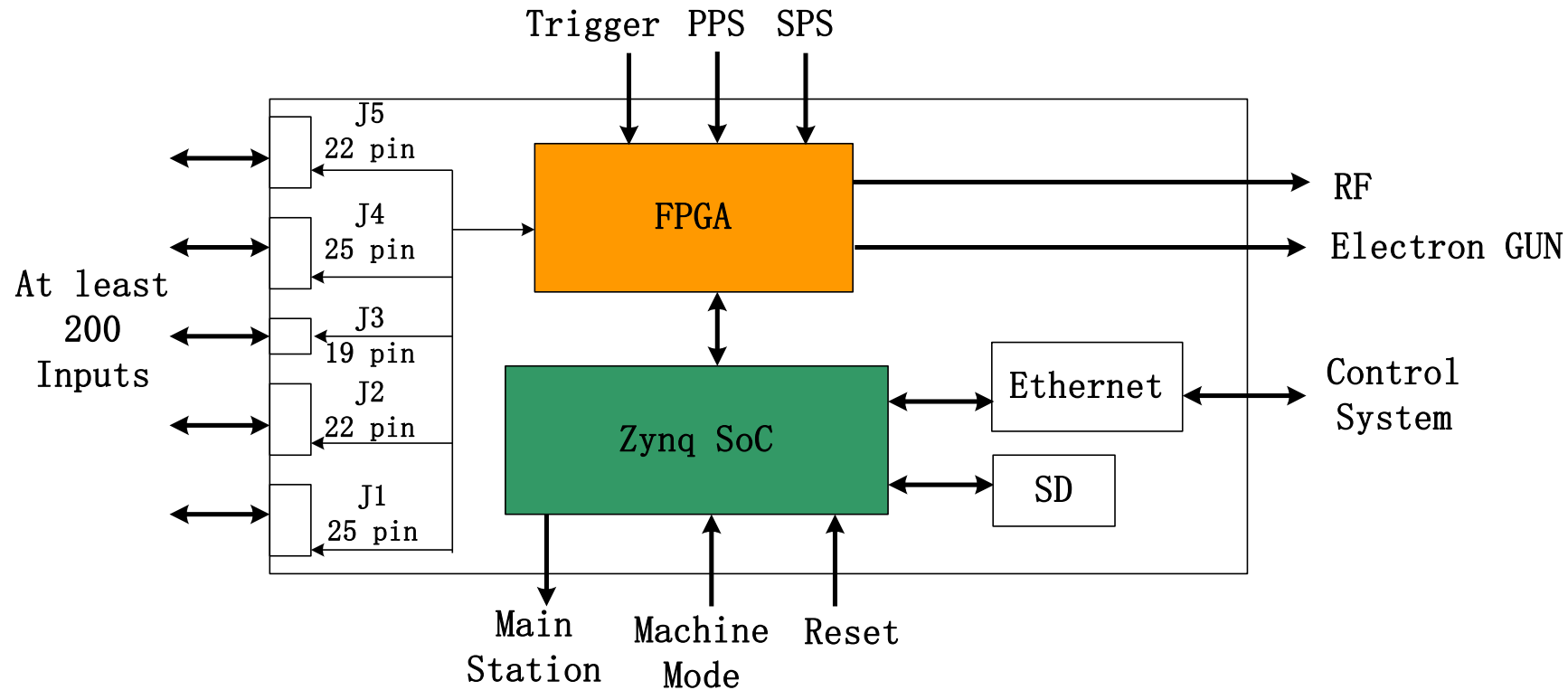
- Slot1-2, Controller
- Slot3-4, Output
- Slot5-6, free for Input
- Slot7-21, Input

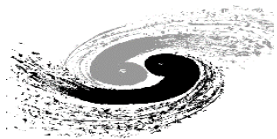




FPS Master Controller

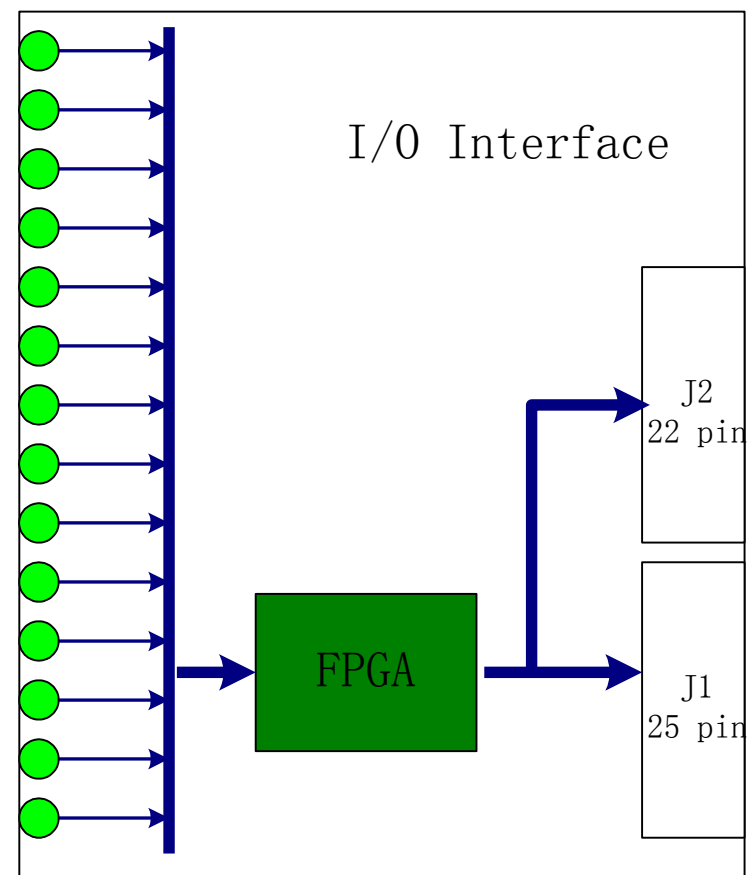
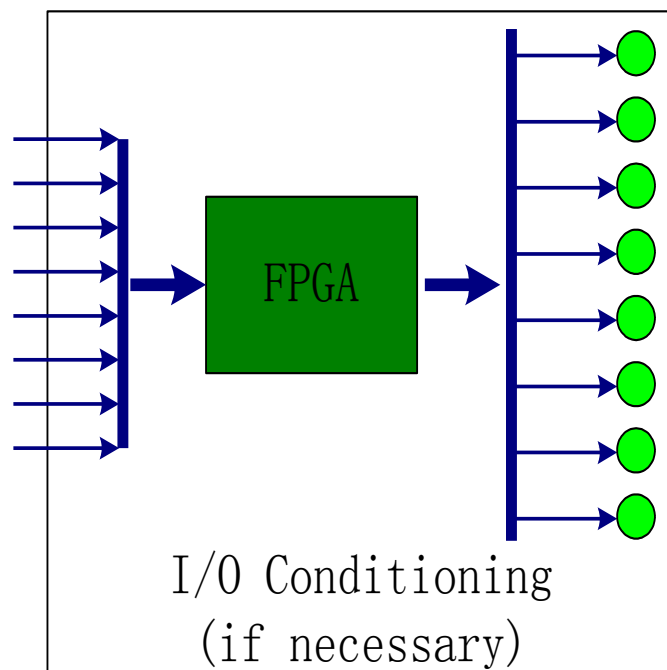
- Xilinx SoC + FPGA
- 6U, Refer to CPCI specification
- J1 to J5 connector used

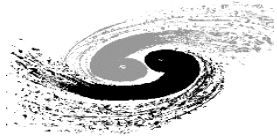




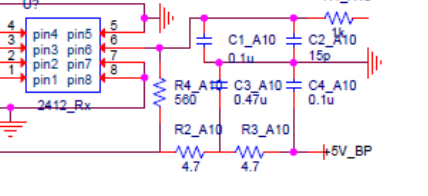
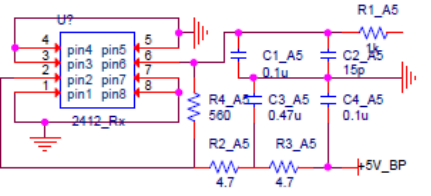
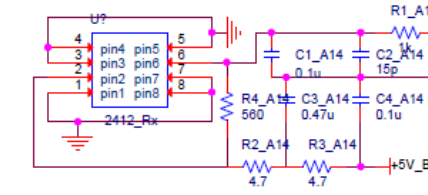
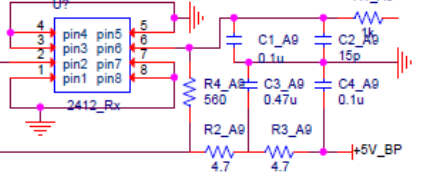
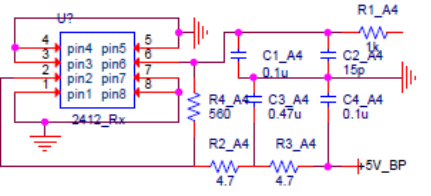
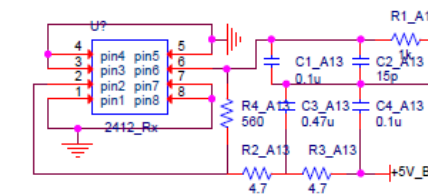
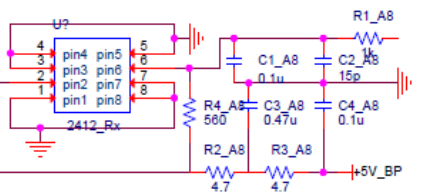
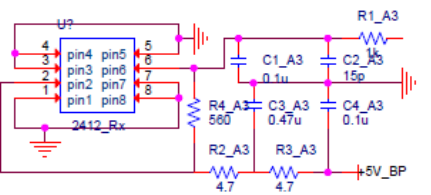
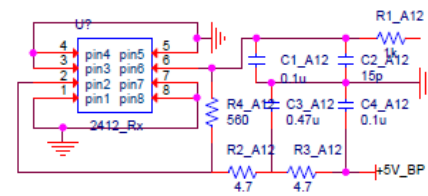
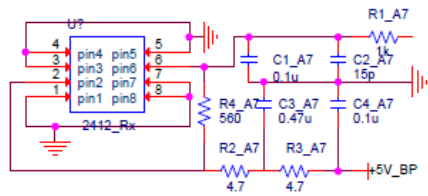
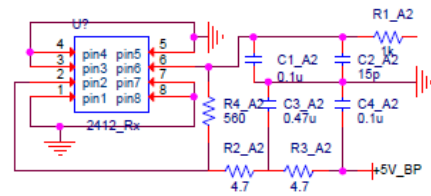
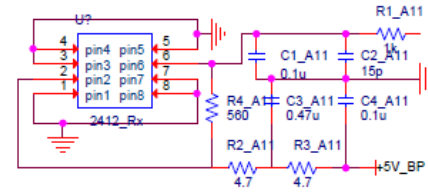
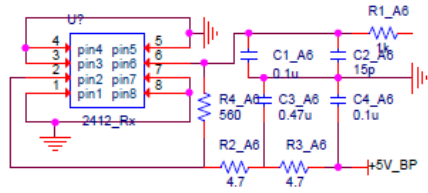
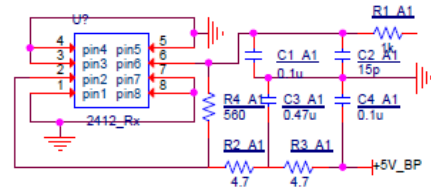
FPS I/O Interface

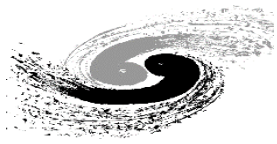
- 14 channel inputs
- 6U, Refer to CPCI specification
- J1 to J2 connector used



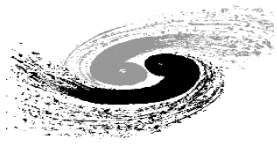


FPS-optical receiver circuit schematic

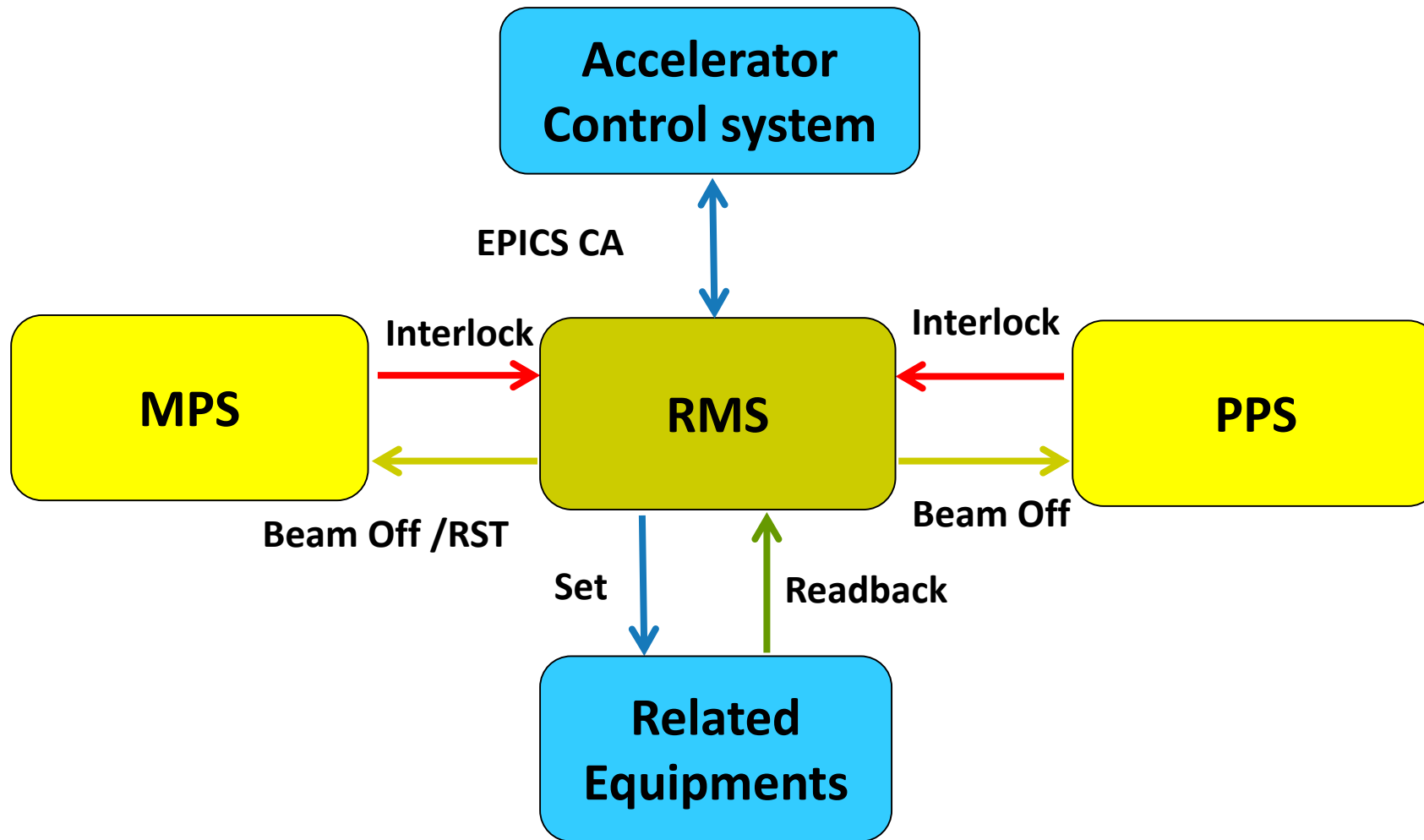




- RMS guarantee the accelerator running safely and easy to operate. Together with PPS, RMS can set and validate machine modes and machine state.
- Global level defined.
- Interface to MPS and PPS through cables, interface to the other system through cables or EPICS CA.
- PLC and industrial computer based.
- Whole system UPS (Uninterruptable Power Supply) powered.



RMS Relationship

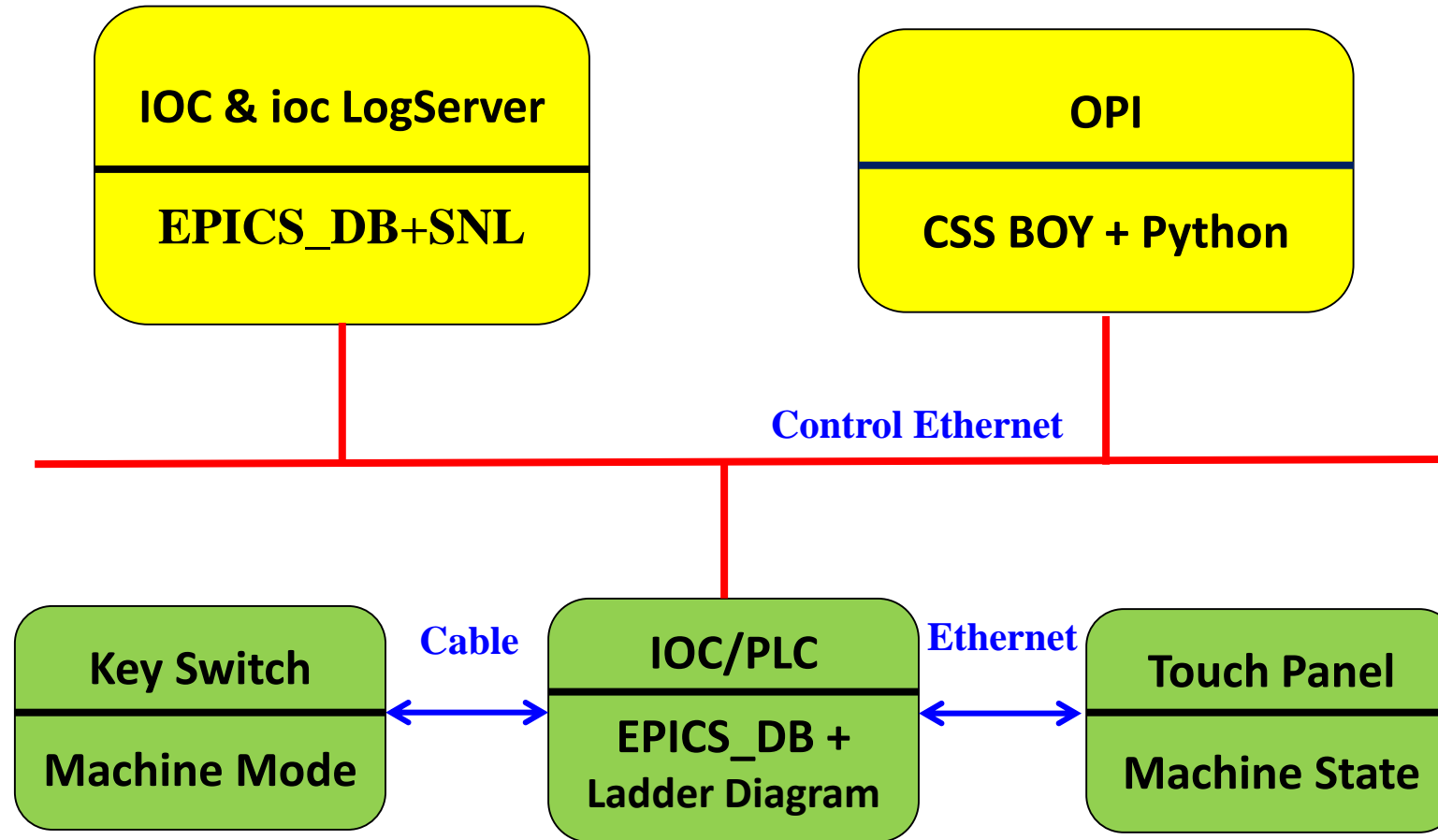


Relationship with related systems and equipments



RMS Layout

Function can be completed through software applications.

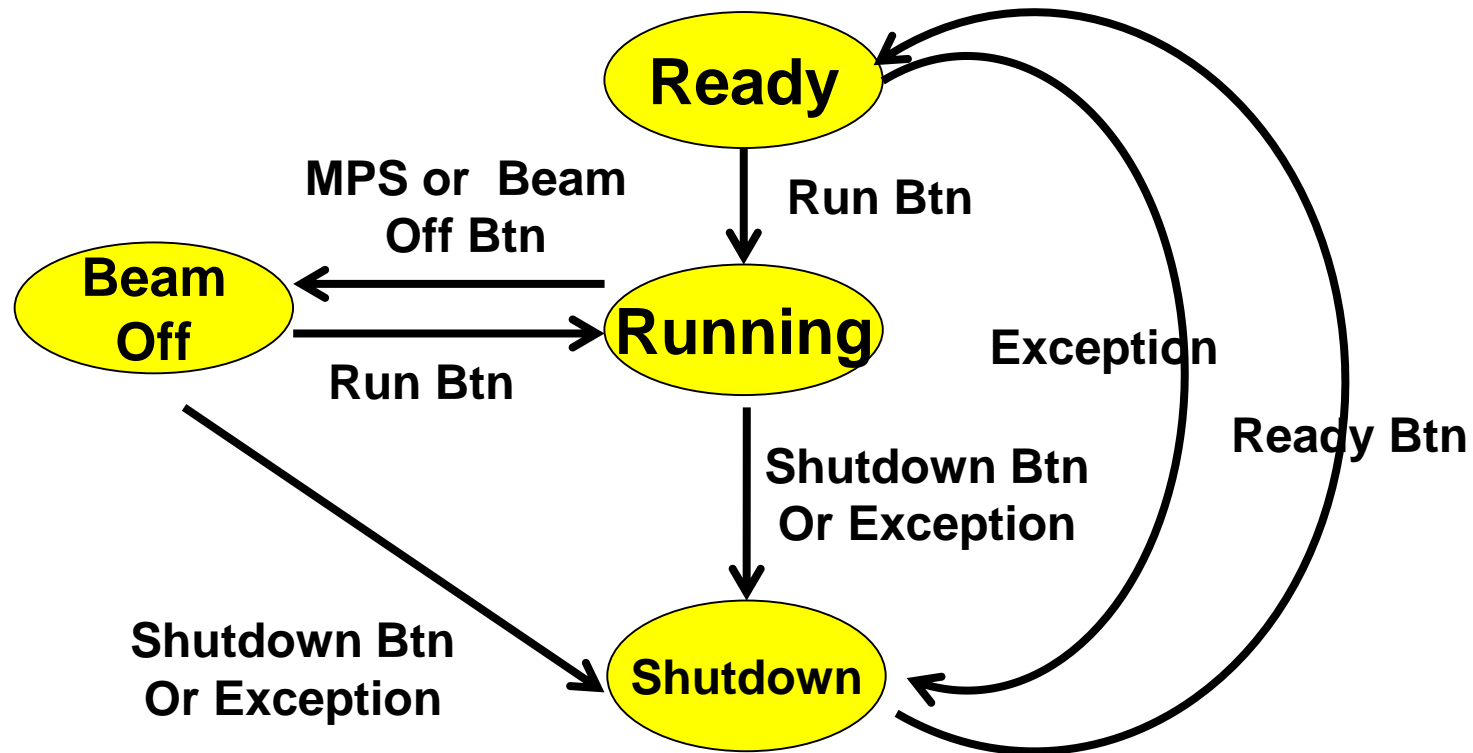


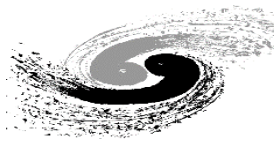
Machine modes selected by key switch and machine state set by touch panel in central control room.



RMS-accelerator state transition diagram

Only in “Running” state, beam can be extracted.





Summary



Summary

- Machine protection is not an objective in itself, it's to maximise operational availability by minimising down-time, and avoid irreparable equipment damage.
- The preliminary design has been done, detailed design (fault classification, operation modes) is on-going.
- R&D platform for MPS will be set up, Prototype will be developed.



Thanks for your attention!