中国科学院上海应用物理研究所
Shanghai Institute of Applied Physics, Chinese Academy of Sciences

Development and implementation of the treatment control system in Shanghai Proton Therapy Facility

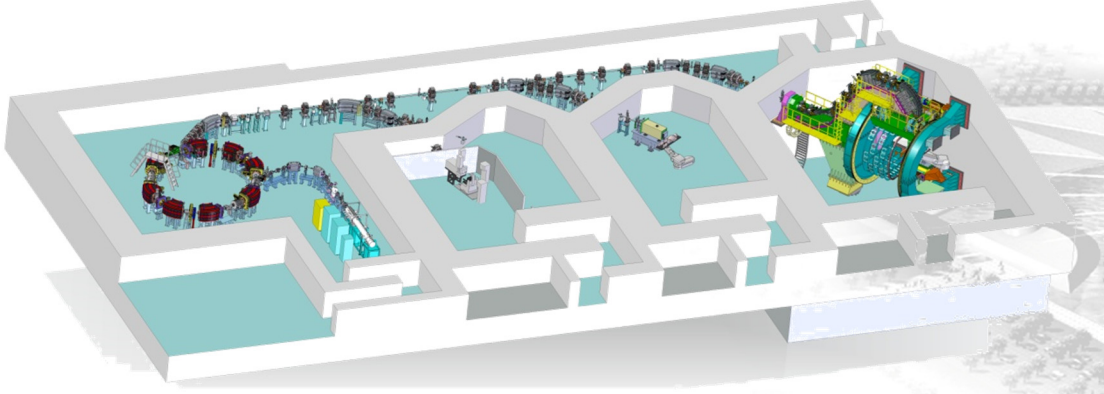
Ming Liu
Electronics Group, Division of Beam Diagnostics & Control Technology
Shanghai Synchrotron Radiation Facility

Outline

- System structure
- Hardware modules
- System implementation

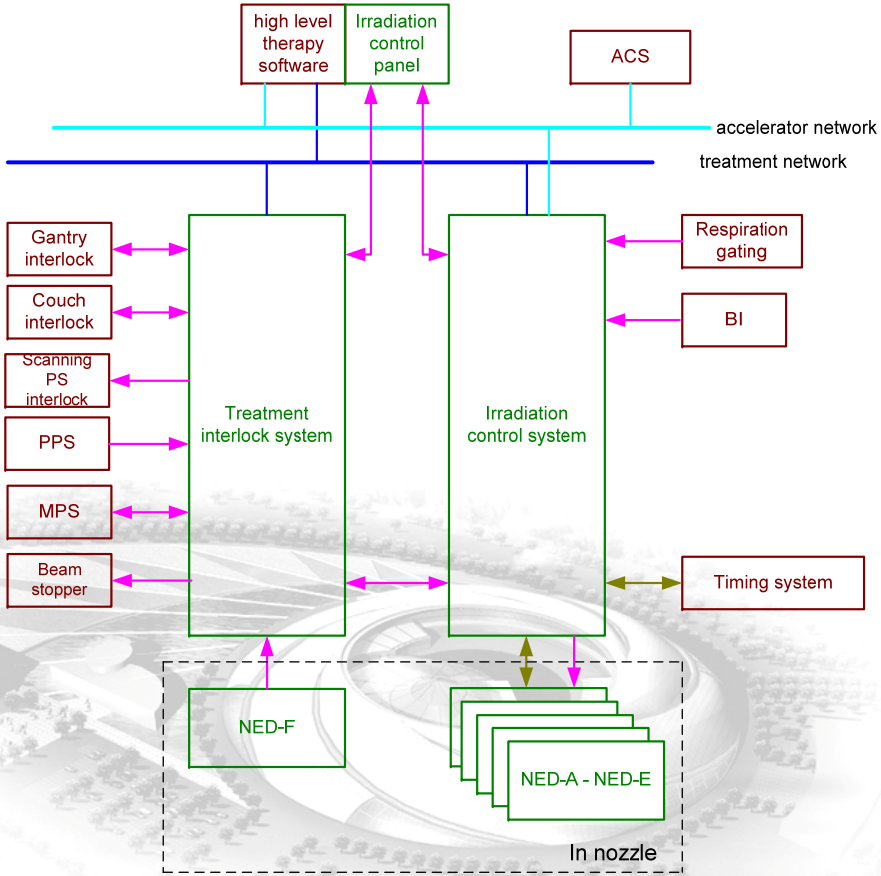
Shanghai Proton Therapy Facility

- Ruijing Hospital North



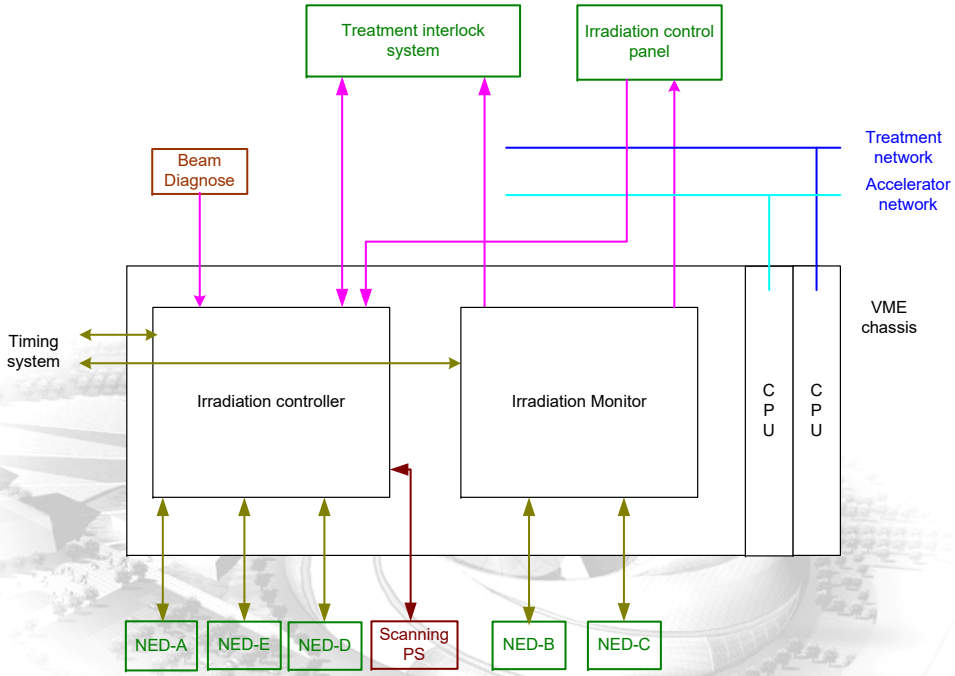
System structure

- Irradiation control sub-system
  - Execute the irradiation procedure
  - Verify treatment parameters
- Treatment interlock sub-system
  - Enable / inhibit treatment relevant equipment and devices
  - Send / receive interlock signals to / from MPS
- Nozzle Electronic Devices (NED)
  - NED-A: primary dose collector
  - NED-B: secondary dose collector
  - NED-C: position data collector
  - NED-D: scanning magnet field data collector
  - NED-E: snout motion control module
  - NED-F: treatment head interlock module



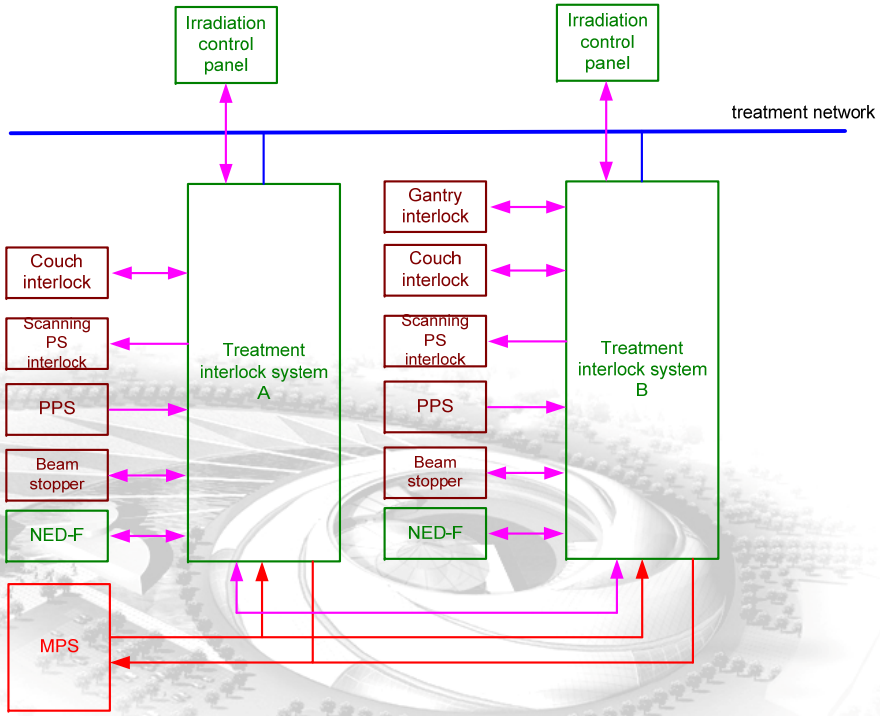
System structure – irradiation control

- The structure of irradiation control sub-system was simplified by separating critical data processing and non-critical data transfer.
  - Critical data processing (beam operation)
    - Dose, position, scanning magnet field, beam on/off, scanning magnet PS etc.
    - By hardware (FPGA, hardwire, optical fiber)
    - In real time
  - Non-critical data transfering
    - Accelerator parameters
    - By EPICS & Ethernet
    - In non-real time



System structure – treatment interlock

- Each treatment room has its own interlock sub-system
  - Guarantee personal safety and machine safety in treatment room;
  - All by hardware

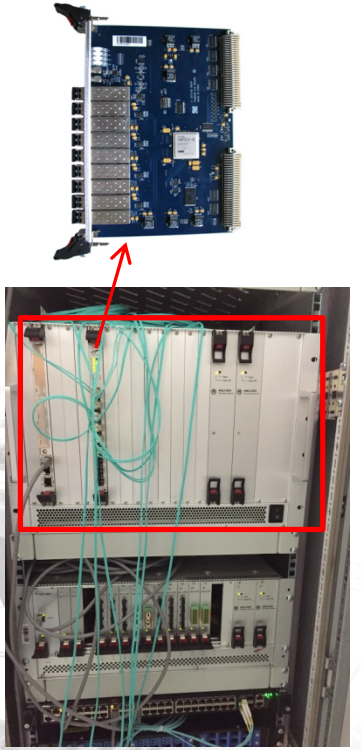


System structure – NEDs

Module	Description
NED-A	Receive data from main-dose monitor including dose, ambient parameters in the monitor, high-voltage readback.
NED-B	Receive data from sub-dose monitor including dose and high-voltage readback; Send high-voltage interlock signals to dose monitors and position monitors.
NED-C	Receive data from position monitors including position data and high-voltage readback.
NED-D	Receive data from hall sensors in the scanning magnet field.
NED-E	Send snout movement orders and receive snout position data.
NED-F	Process local input/output interlock signals in nozzle.

Irradiation controller & irradiation monitor

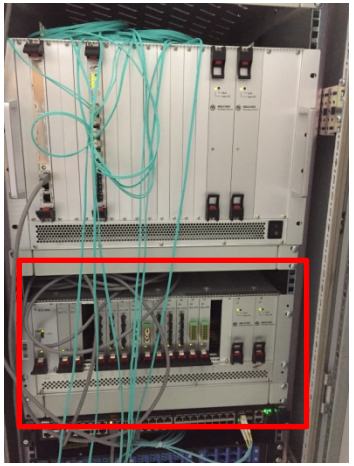
- Both of irradiation controller and irradiation monitor are event timing module EVO designed by ourselves.
  - Control timing sequence by interconnect timing network in uplink port;
  - Receive data from NEDs and send commands to NEDs by peer-to-peer fiber connection in 8 downlink ports;
  - Process data and do calculation in FPGA;
  - Send accelerator parameters and receive accelerator readback status by EPICS & Ethernet;
  - Control scanning PS through transition board by plastic fibers;
  - Interconnect treatment interlock sub-system through transition board by plastic fibers;
  - Interconnect irradiation control panel through transition board by plastic fibers.



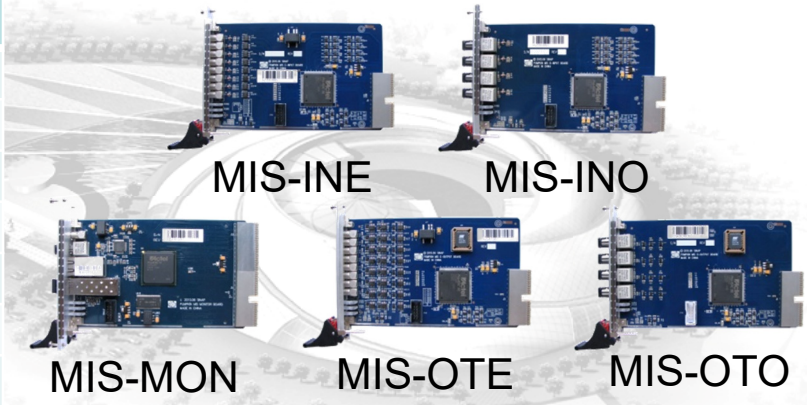
Treatment interlock sub-system

- Co-design with Cosylab;
- Compatible with cPCI 3U mechanical standard;
- Customized backplane bus definition;
- Embedded IOC in the mounted XportPRO;
- Full hardware implementation.

COSYLAB
CONTROL SYSTEM LABORATORY

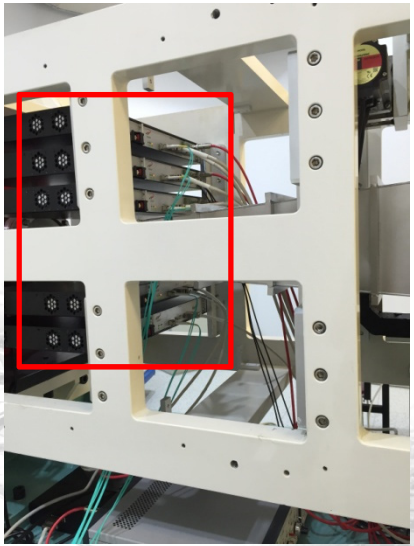


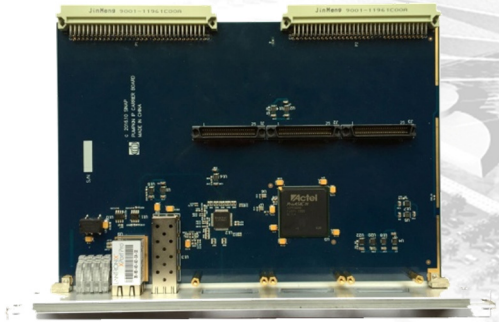
Module	Description
MIS-MON	Monitor and controller of the interlock chassis
MIS-ITL	Interlock logic calculation
MIS-INE	8 electric inputs
MIS-INO	4 optic(2412) inputs
MIS-INR	8 relay inputs
MIS-OTE	8 electric outputs
MIS-OTO	4 optic(1414) outputs
MIS-OTR	8 relay outputs



Nozzle electric devices (NED)

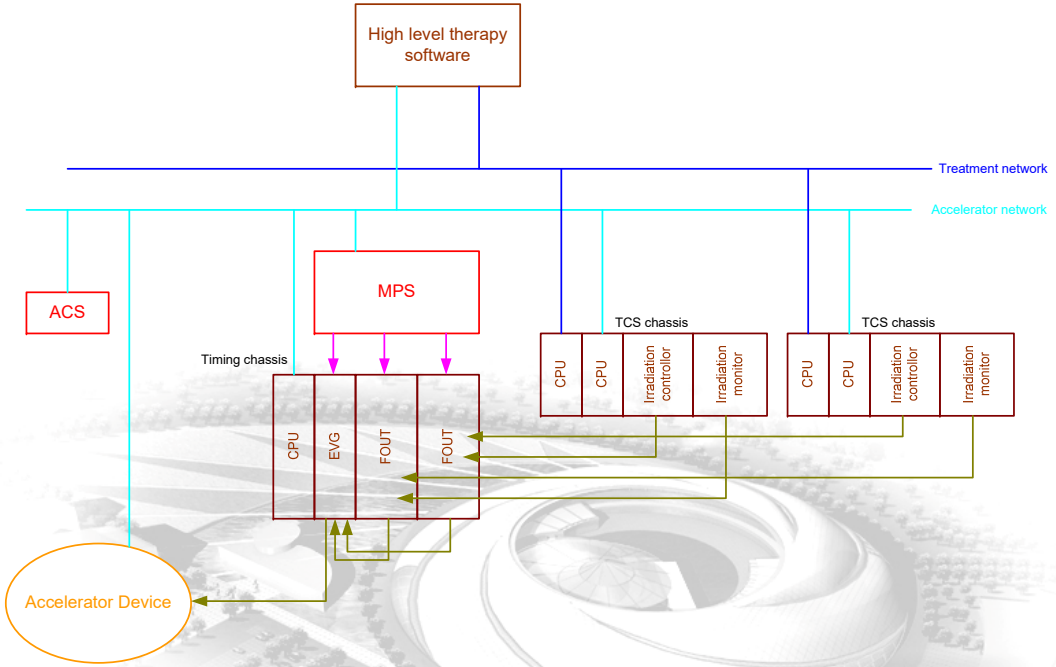
- Standalone modules installed in nozzle;
- Each NED carries 3 modules with IP mechanical standard;
- Radiation hardened FPGA;
- SFP sends and receives data;





System implementation

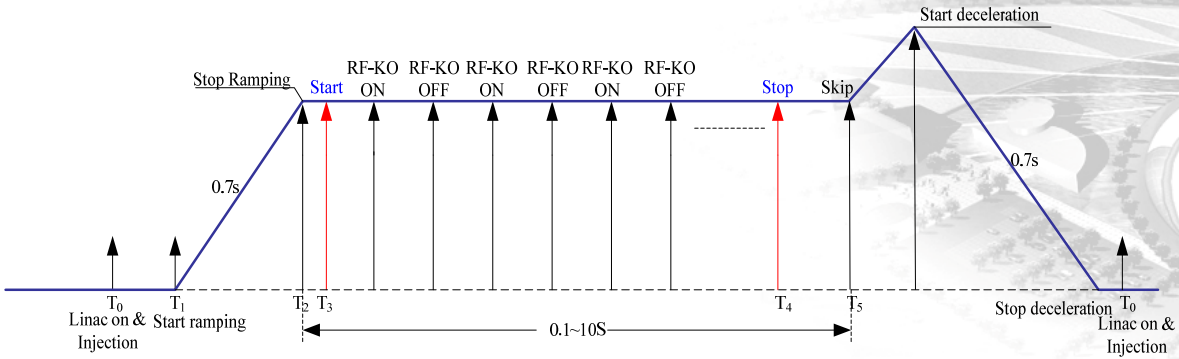
- The irradiation controller and irradiation monitor are integrated into the main timing system, and send events to upstream EVG to turn ON/OFF the beam in real time.
- The transmission of treatment data is through the treatment network.(EPICS/Ethernet)
- The transmission of accelerator parameters is through the accelerator network.(EPICS/Ethernet)

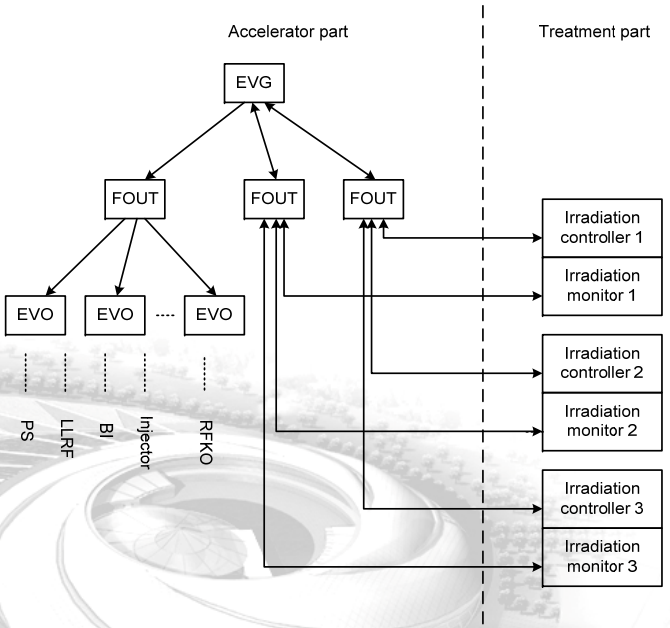


System implementation

▲ triggered by irradiation controller
● triggered by timing system

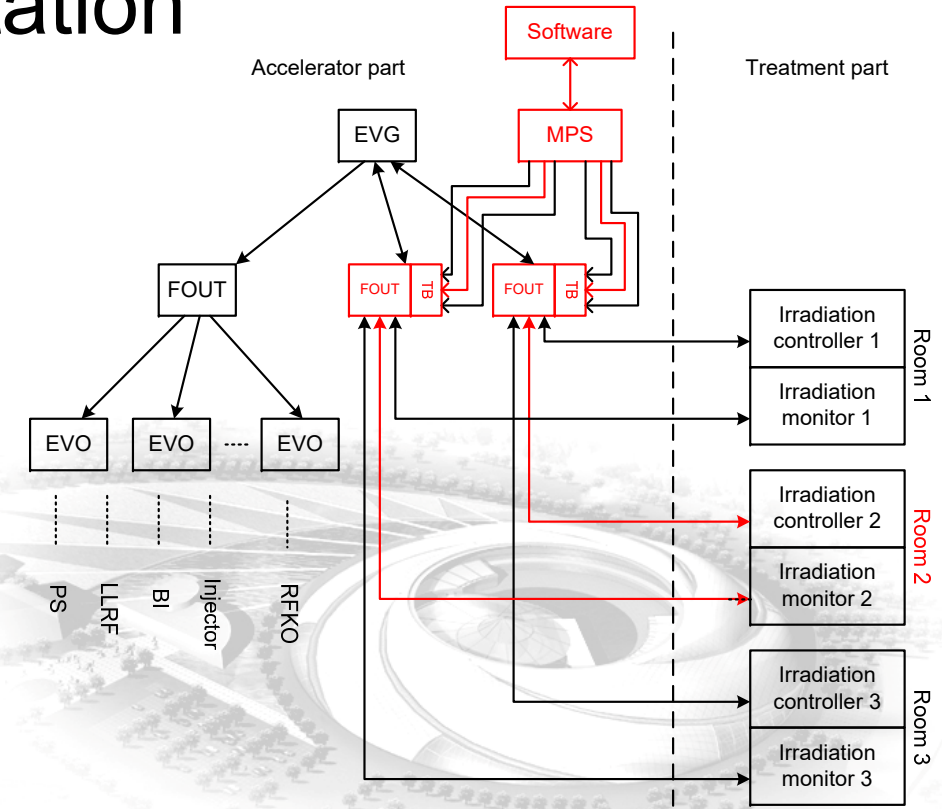
- Accelerating sequences
  - ▲ T_0 : Initialization begins. Irradiation controller sends parameters for 1st layer.
  - ● T_1 : Ramping begins.
  - ● T_2 : Ramping stops. Expected energy achieved.
  - ▲ T_3 : Irradiation controller reads and verifies the status of accelerator.
  - ▲ RF-KO turns ON and OFF to execute spot scanning.
  - ▲ T_4 : Irradiation controller sends parameters for the next layer.
  - ● T_5 : Accelerator continues to go on ramping and then starts deceleration at the highest energy.





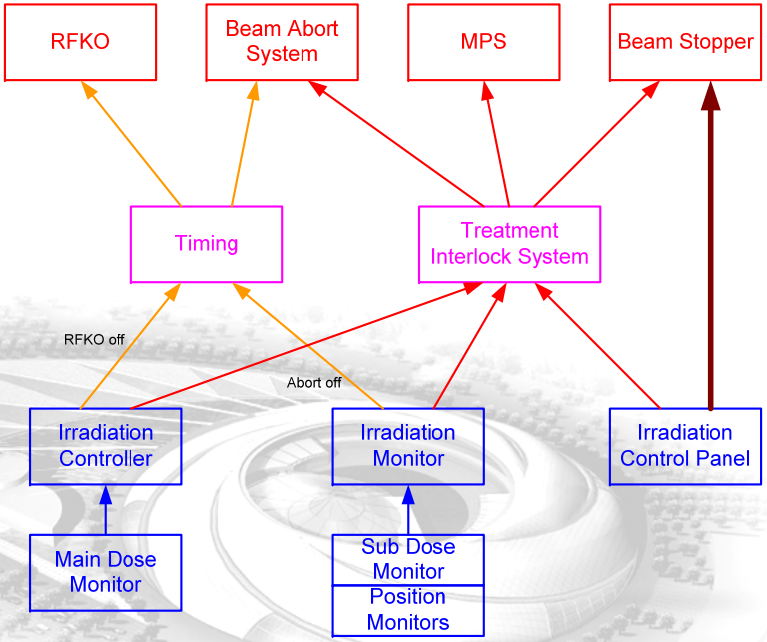
System implementation

- Treatment room switching
  - Up layer software sends room-switching command;
  - MPS selects corresponding channel in transition boards of FOUT through hardwire;
  - FOUT receives the timing sequence only from the irradiation controller & monitor of the selected room.



System implementation

- Multi-redundant safety interlock mechanism
  - Initiator
    - irradiation controller
    - irradiation monitor
    - irradiation control panel
  - Executive devices
    - RFKO
    - Beam abort system (steering magnet)
    - MPS
    - Beam stopper



Recent progress


THANKS.
liuming@sinap.ac.cn