Construction of the New Safety Interlock System for SPring-8 Accelerator

C. Saji, H. Hanaki, S. Hashimoto, Y. Hashimoto, M. Kago,K. Kawata,
T. Masuda, T. Matsushita, S. Miyamoto, T. Nagaoka, N. Nariyama,
H. Ohkuma, K. Soutome, S. Suzuki, M. Takao, R. Tanaka, M. Toko,
Y. Tsuzuki, A. Yamashita, H. Yonehara

Japan Synchrotron Radiation Research Institute(JASRI/SPring-8)

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Contents

- Motivation
- Introduction
  - Accelerator
  - Accelerator Safety Interlock System
- Requirement
- New conceptual design
- Construction
- Summary

Motivation

- Current safety interlock system for SPring-8 accelerator has complicated safety logic and equipment components.
  - Problems:
    - Take many cost (person, time) for safety inspection
    - Very difficult to expand the system for additional accelerator

      etc..

- Construction of new safety system is difficult
  - Tight schedule for short shutdown time
  - Should continue accelerator operation between each construction

    etc..

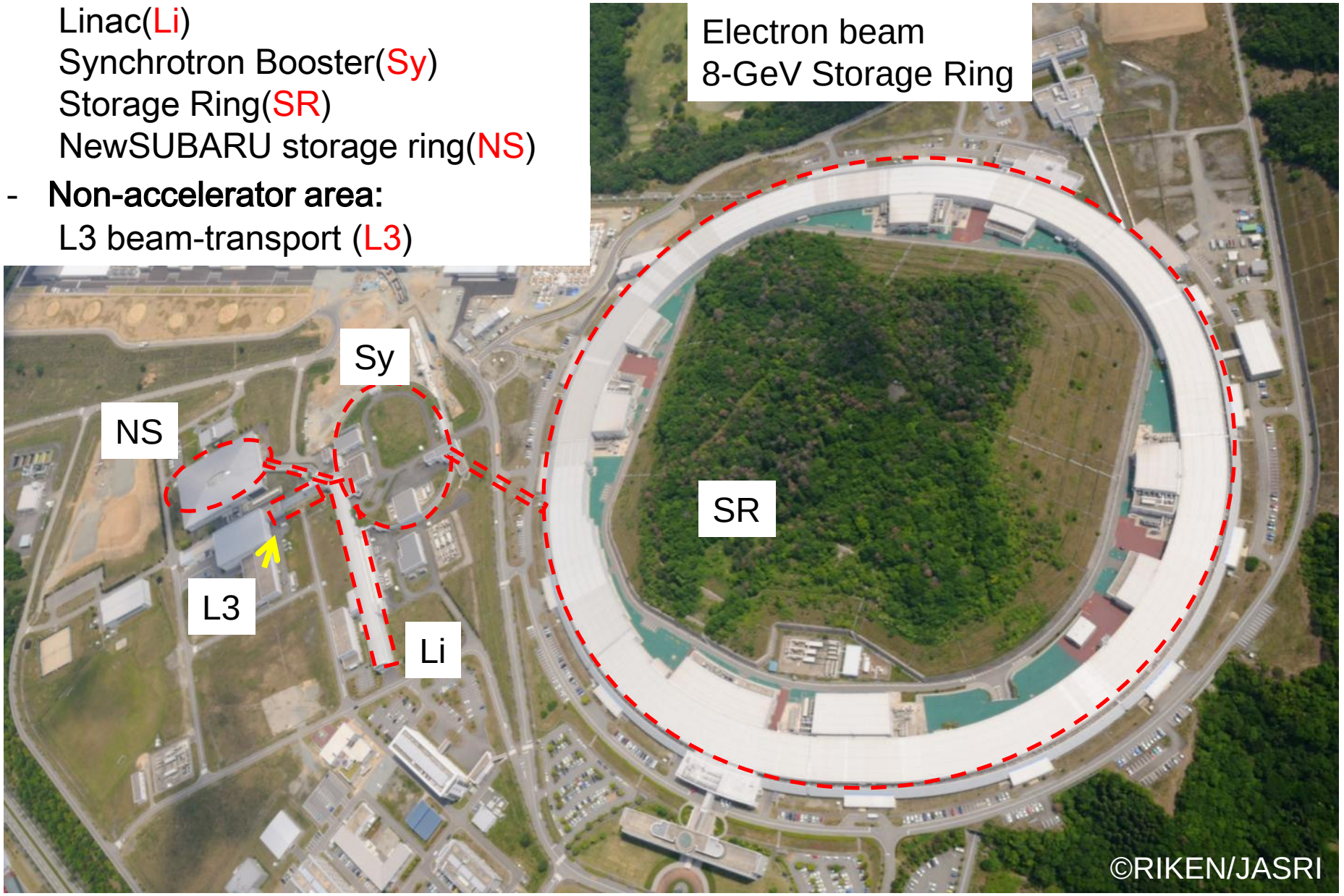
But…

- We will change conceptual design of safety system .

Introduction

- **Accelerator components**
  - Linac(Li)
  - Synchrotron Booster(Sy)
  - Storage Ring(SR)
  - NewSUBARU storage ring(NS)
- **Non-accelerator area:**
  - L3 beam-transport (L3)

SPring-8:

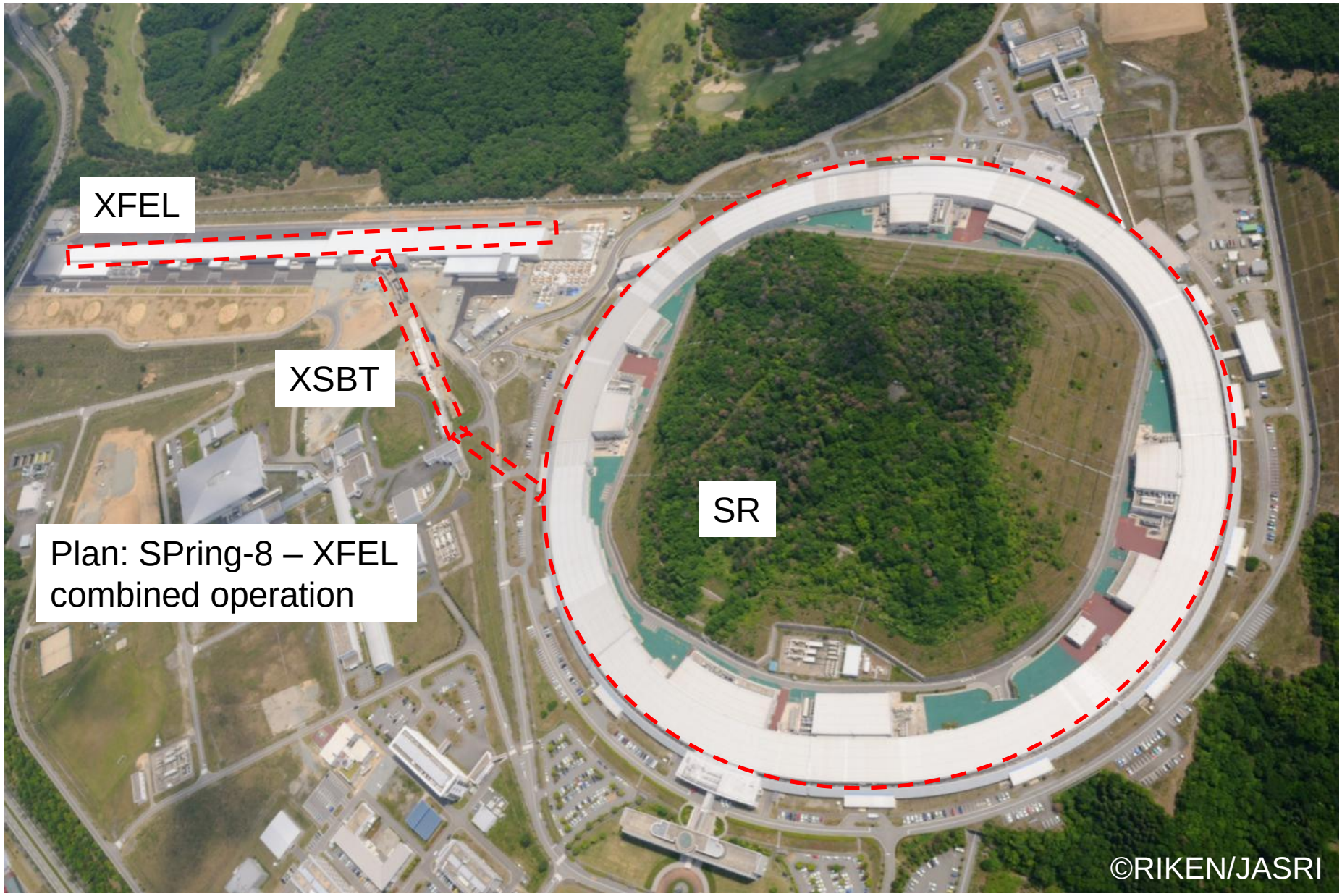


Introduction

- New Accelerator, XFEL/SPring-8:

Introduction

- New Accelerator, XFEL/SPring-8:

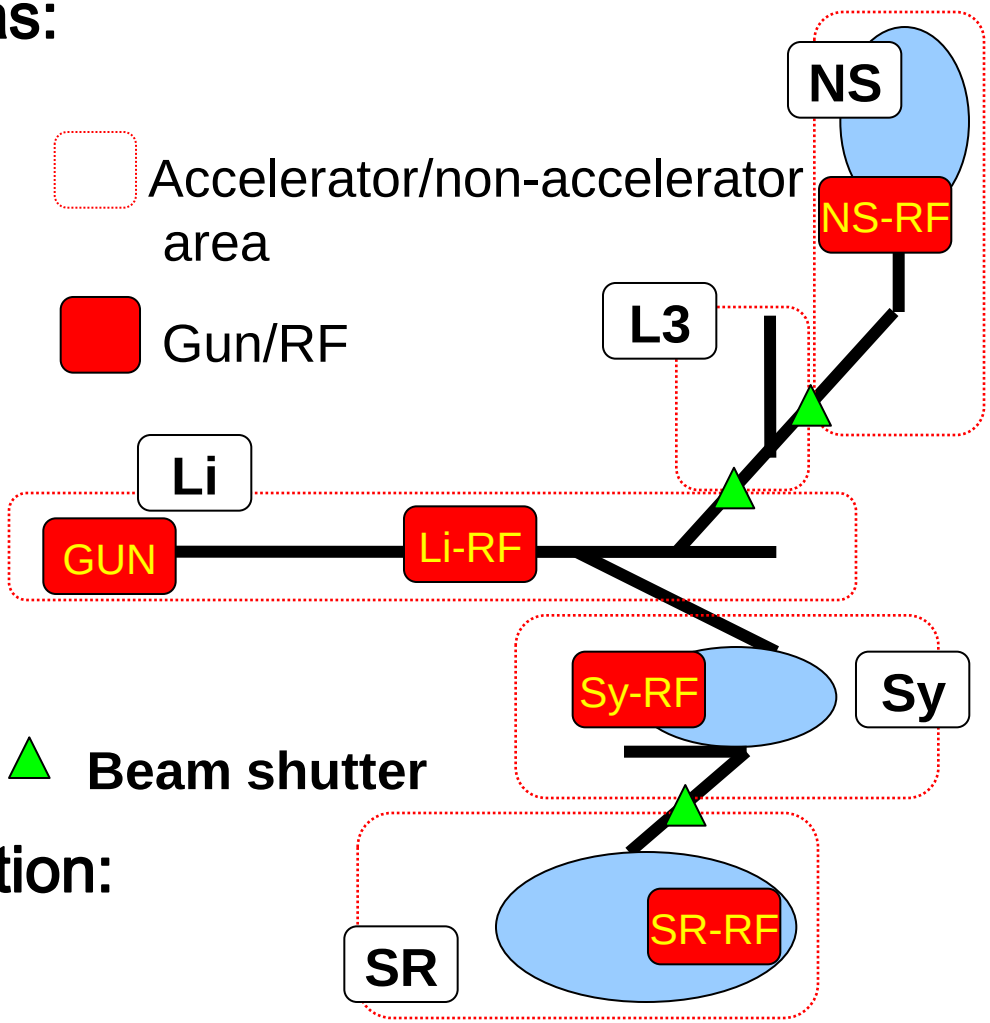


Accelerator Components

- **Five access controlled areas:**
  Linac(Li)
  Synchrotron Booster(Sy)
  Storage Ring(SR)
  L3 beam-transport (L3)
  NewSUBARU storage ring(NS)

- **Division of area:**
  Beam shutters

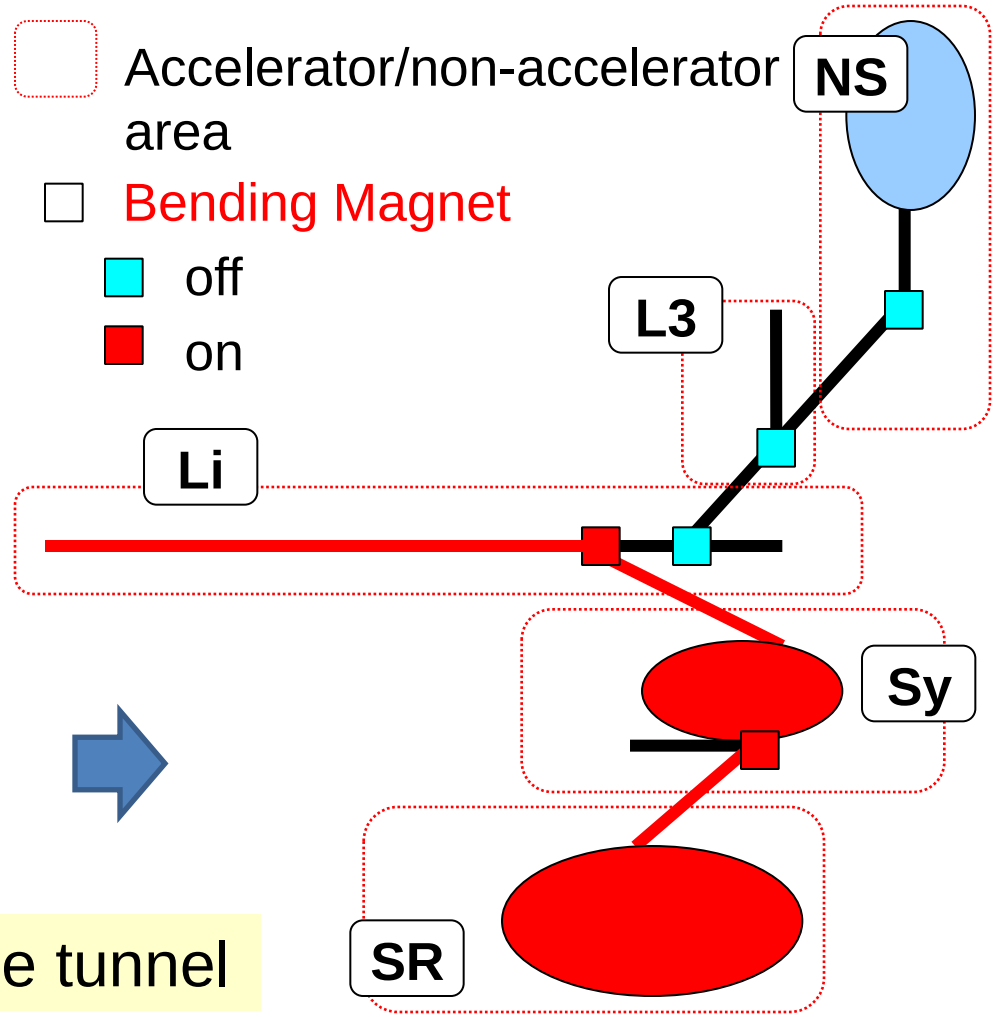
- **Beam generation/acceleration:**
  - One electron gun (GUN)
  - Four acceleration RFs.



SPring-8 Accelerator Components

Various Accelerator Operations (1)

- **Beam transportation route:**
  → Bending Magnets(BM)



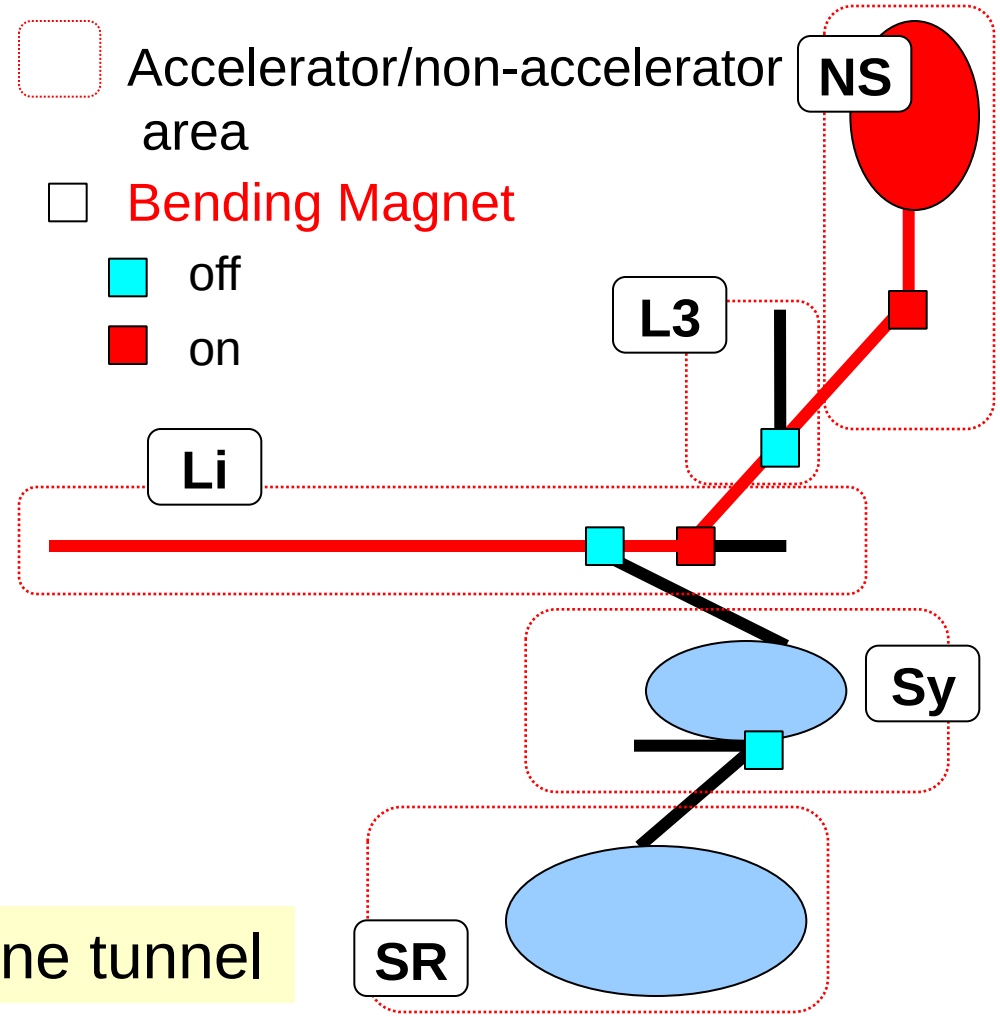
SPring-8 Accelerator Components

SR injection operation

Possible to enter NS machine tunnel

Various Accelerator Operations (2)

NS injection operation



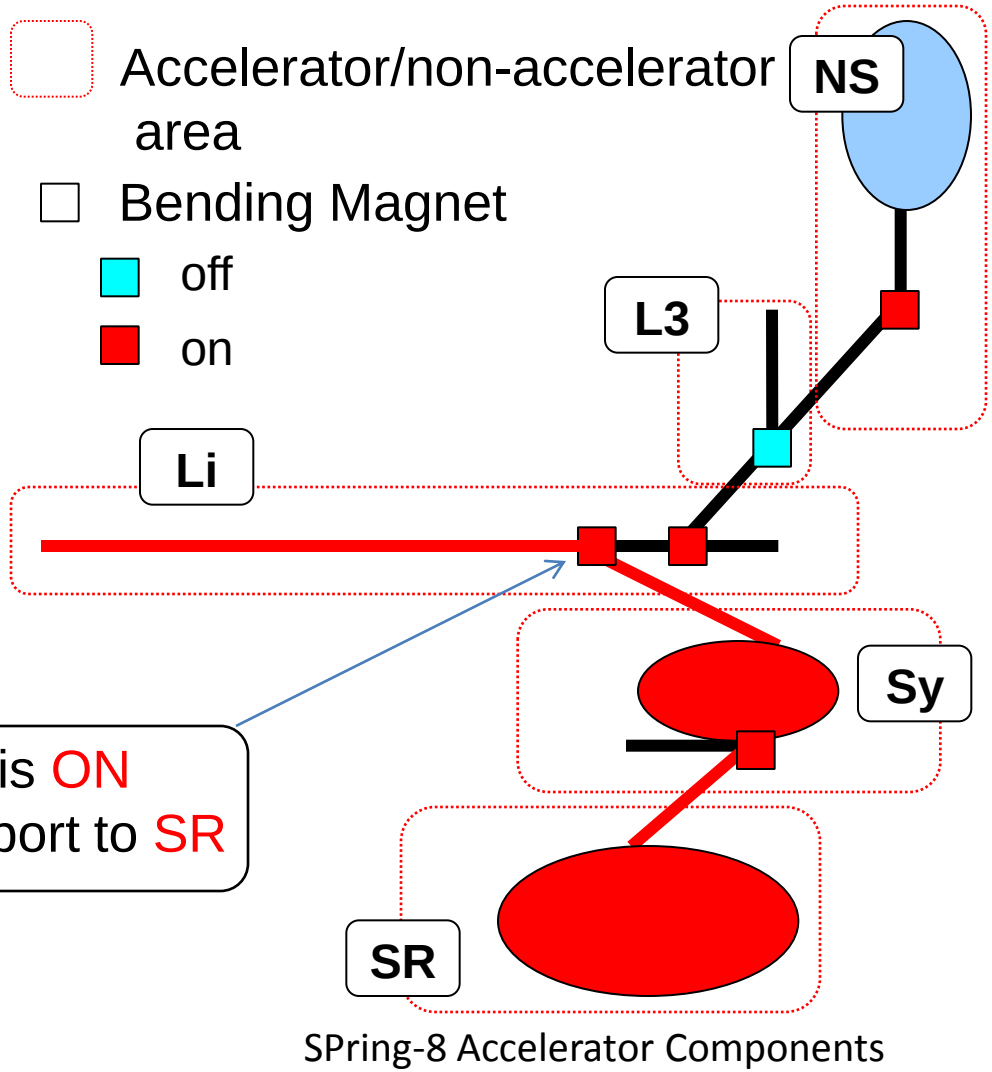
SPring-8 Accelerator Components

Possible to enter SR machine tunnel

Various Accelerator Operations (3)

SR/NS injection
switching operation

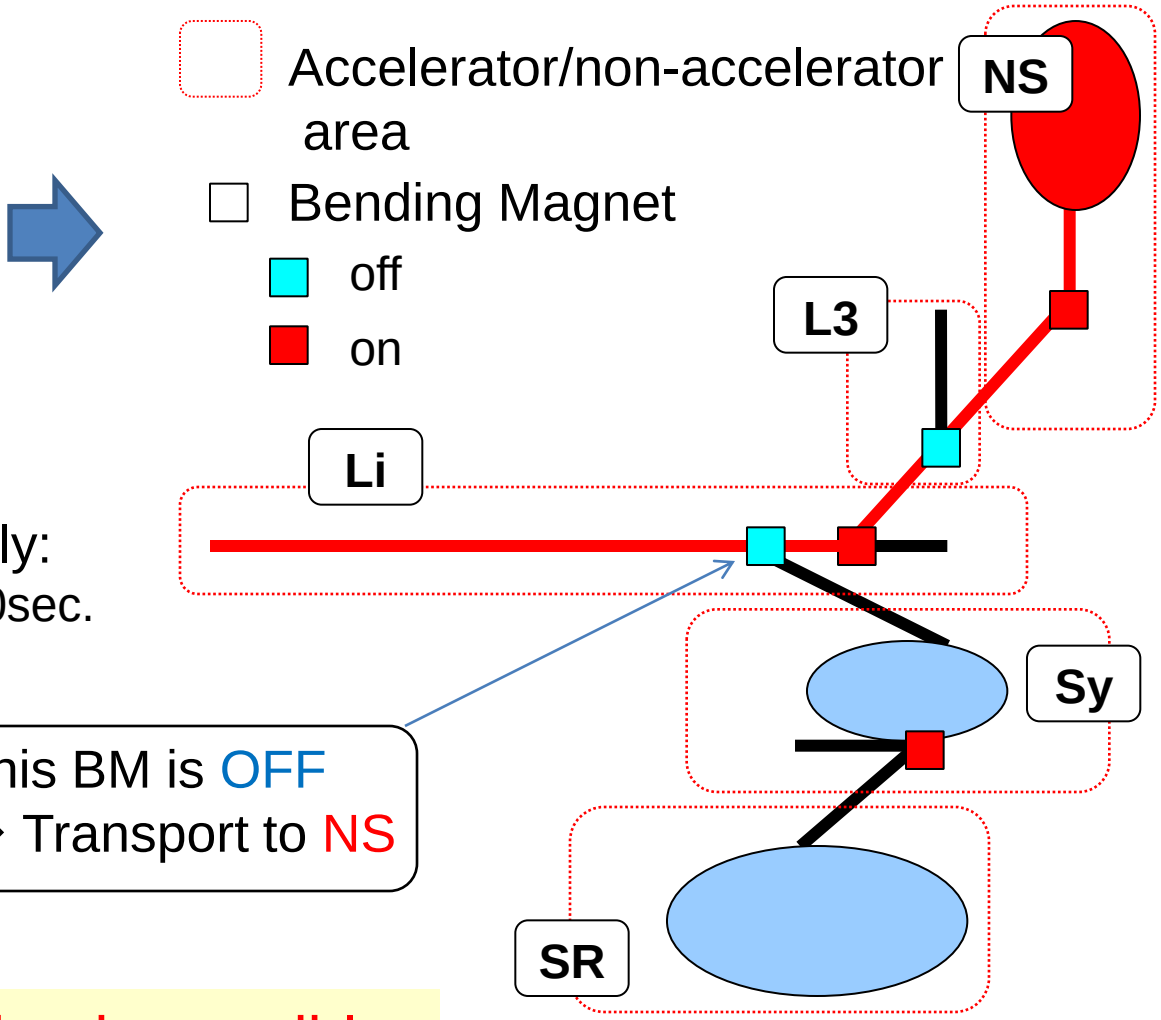
Destination is switched
by changing
one Bending Magnet status



SPring-8 Accelerator Components

Various Accelerator Operations (3)

SR/NS injection switching operation



SPring-8 Accelerator Components

Feature of Operation:

Switch a destination frequently:
Automatically switching every 20sec.

Top-up operation:
continual injection

→ Complex operation is possible

Accelerator Safety Interlock System

Safety Interlock System (= Personnel Safety System)

Purpose:

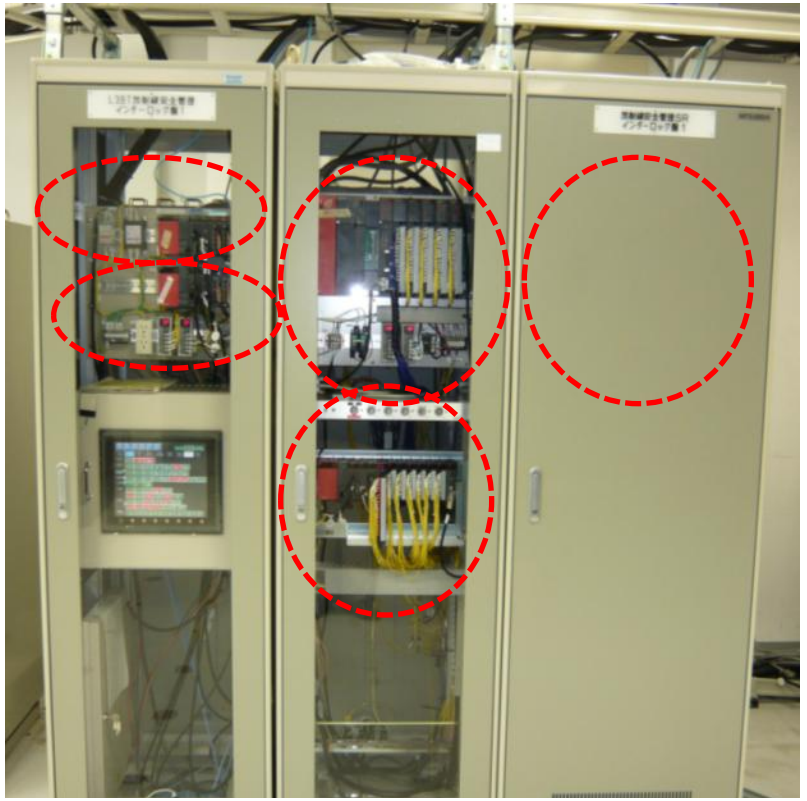
Protect persons from radiation hazard
induced by electron beams and synchrotron radiation

Basic Function:

- Monitoring safety equipment:
  radiation monitor etc..
- Access control:
  manage permission for entering
  radiation-controlled areas
- Control electron beam :
  manage permission of GUN and RF
  as safety conditions

System:

- Programmable Logic Controller (PLC)
  based system
- Consist of several PLC systems

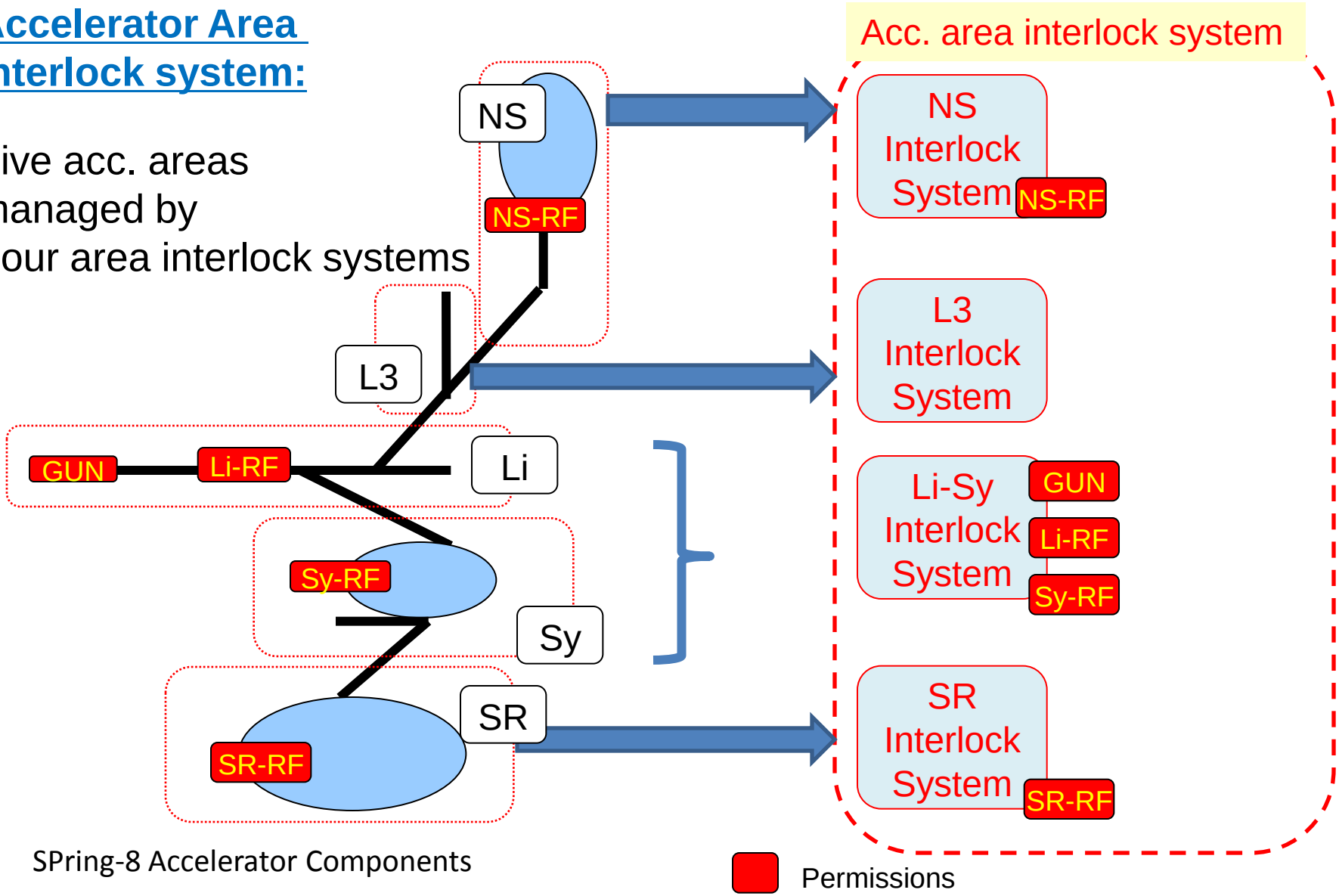


Accelerator safety interlock system
Main racks

Current Accelerator Safety Interlock System (1)

Accelerator Area Interlock system:

Five acc. areas
managed by
Four area interlock systems



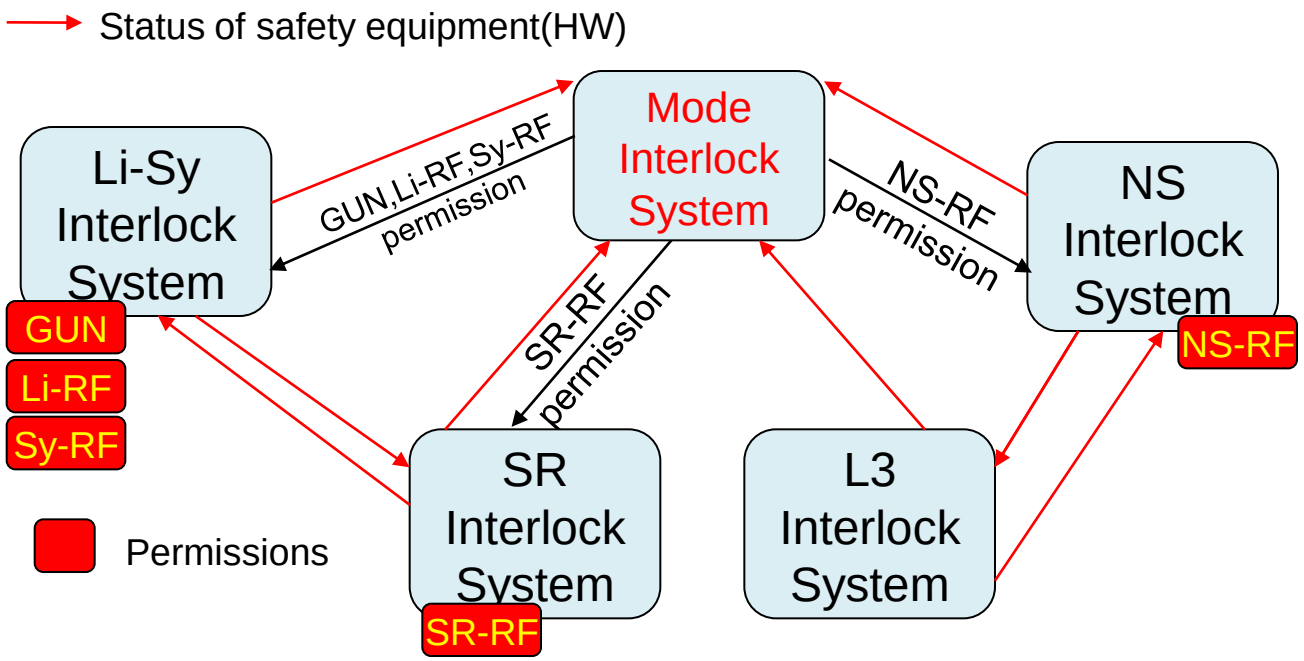
Current Accelerator Safety Interlock System (2)

Operation Mode Interlock System:

→manage combination of areas

• Area system information integrated to MODE interlock system

• MODE judges safety of area combination and give permissions.



Current Accelerator Safety Interlock System

Operation Mode management system

→

Complicated safety Logic
Lower independency of acc. areas
→ Hard to maintain, modify and troubleshoot

Current Accelerator Safety Interlock System (3)

The number of Operation mode (MODE)

At the beginning (1997~),
Accelerator components were
Li, Sy and SR.

- The number of MODE has increased as accelerator upgrade
  - L3 beam-transport added
  - NS storage-ring added
  - Topup operation started
  - Destination switching operation started

→The number of MODEs drastically increased

- Complicated operation
- Very difficult to upgrade system (for additional accelerator)

Safety interlock has MODEs explicitly

List of operation mode (part)

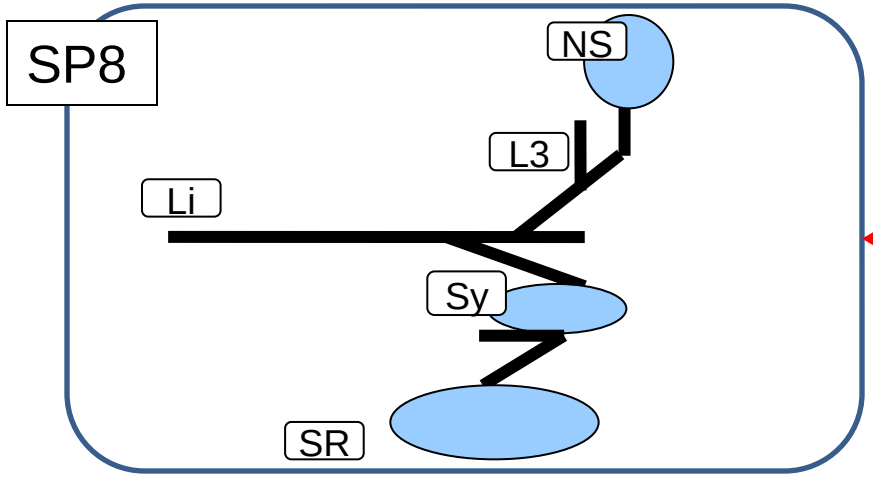
- READY Mode
- L2 Mode
- Sy-injection Mode
- SR-injection Mode
- SR-storage Mode
- L3 Mode
- Topup Mode
- NS-injection Mode
- NS-storage Mode
- Sy・NS-injection Mode
- SR・NS-injection Mode
- Topup・NS-injection Mode
- L2 + Sy-storage Mode
- L2 + Sy-storage + SR-storage Mode
- L2 + Sy-storage + NS-storage Mode
- L2 + Sy-storage + SR-storage + NS-storage Mode
- Sy-injection + SR-storage + NS-storage Mode
- Topup + NS-storage Mode
- NS-injection + Sy-storage + SR-storage Mode
- SR-storage + NS-storage Mode
- L3 + Sy-storage Mode
- L3 + Sy-storage + SR-storage Mode

Around 60 modes

⋮

Requirements for new system

- Easy maintenance
  Many MODEs → internal safety inspection(twice in a year)
  ~20 person x 5 days x 2 times
- Easy modification
  Local modification can affects all of system.
- Simple/easy operation
  Many MODEs and complicated safety logic
  can cause operation mistake
- High extendibility



Plan: SPring-8 and XFEL
Combined operation

XFEL

~60 MODEs → ~120 MODEs?? for additional accelerator.

Need new conceptual design

New conceptual design

A change of safety Interlock conceptual design affects to various division.
→need cooperation of several division

New task force formed:

- Experts in each division was gathered,
  Accelerator Interlock system
  Accelerator operation
  Safety office
  and discussed various issue (2005 ~)

New Conceptual design

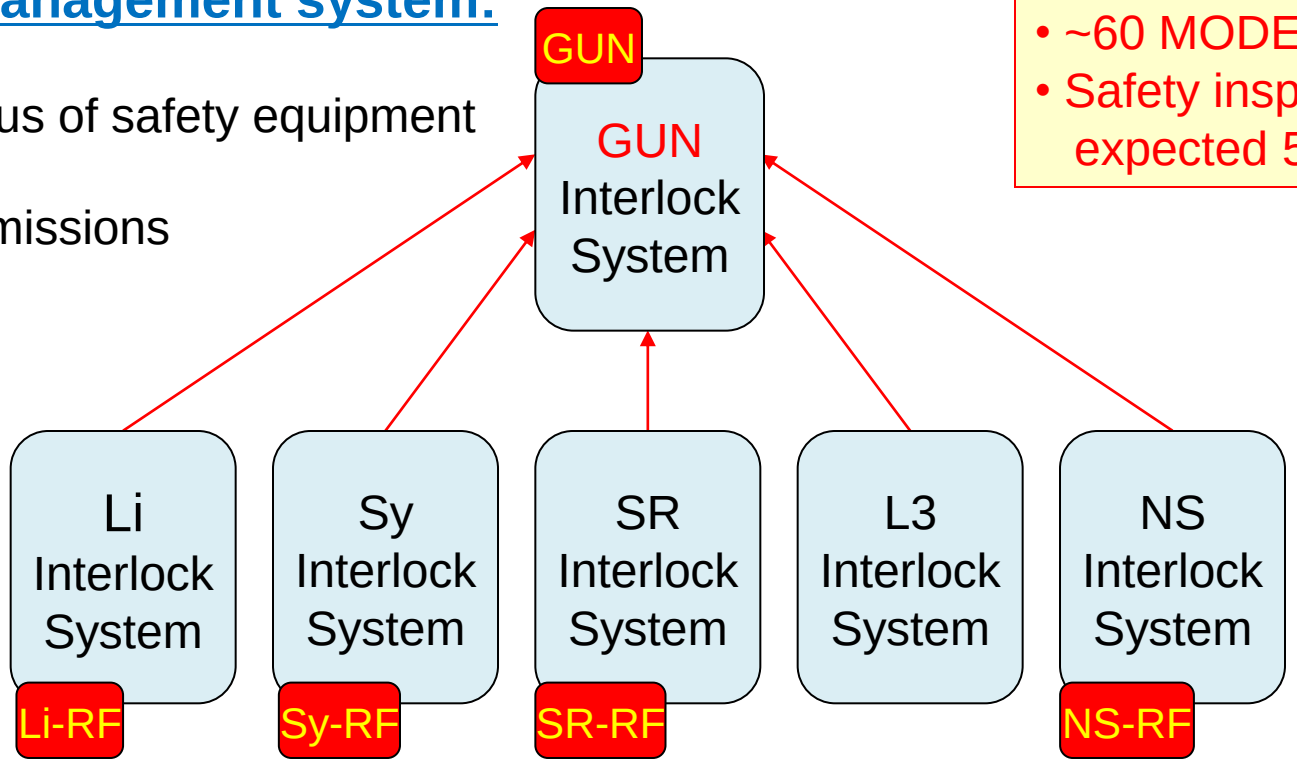
Area management system

New accelerator safety interlock system

Area management system:

→ Status of safety equipment

Permissions

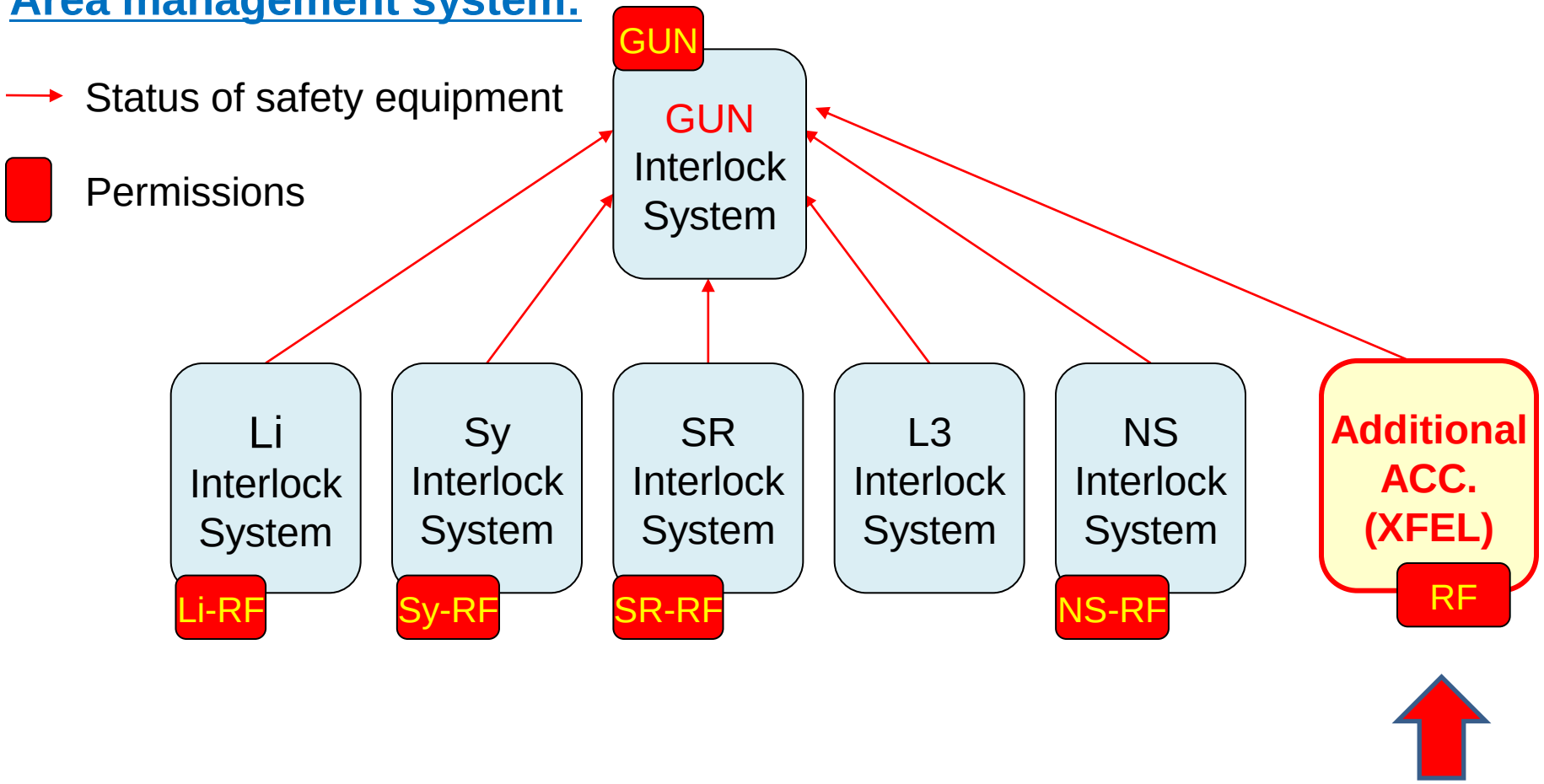


- ~60 MODEs → 0 MODE
- Safety inspection: expected 5days → 3days

- Acc. area managed by Independent system.
  → Li-Sy system divided to three system (GUN, Li, Sy)
- Permissions (GUN/RF) managed by independent system.
- Acc. area system only communicates with GUN system.
- Communication signal will be one way direction from acc. system to GUN system.

New accelerator safety interlock system

Area management system:



- easy to expand for an additional accelerator

Construction (1)

What should we do:

Construction

- Make/settle additional safety equipment
- Make new safety logic and their software for PLCs (for 6 systems)
- Status monitoring/display system
- Wiring/Re-wiring (Signal/Power/Network)
- Rack replacement

For starting accelerator operation

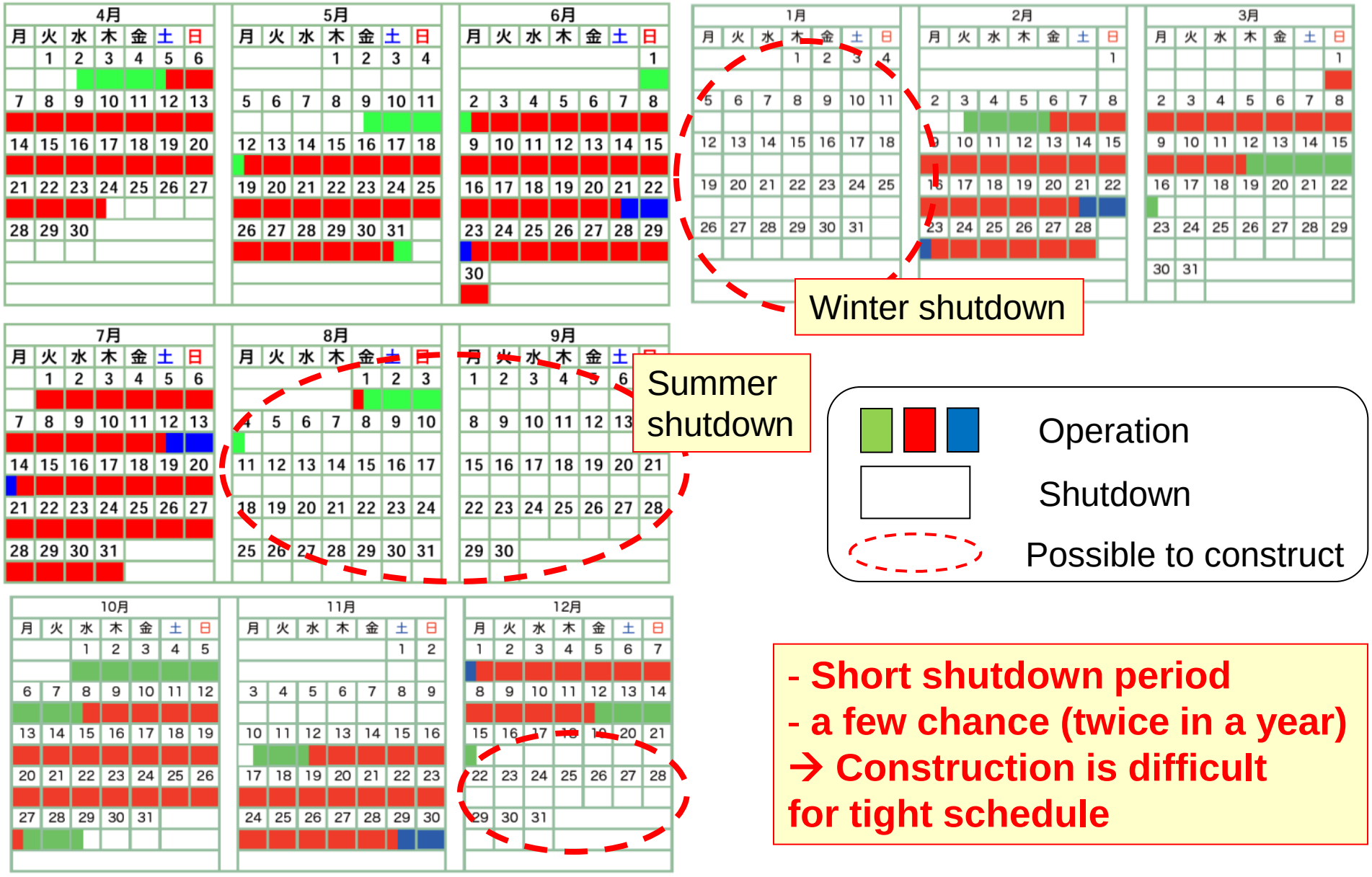
- Internal safety inspection.
- Official safety inspection (with external inspectors)
  → should be passed

- Many things to do
(SPring-8 has large and many facilities)

Construction (2)

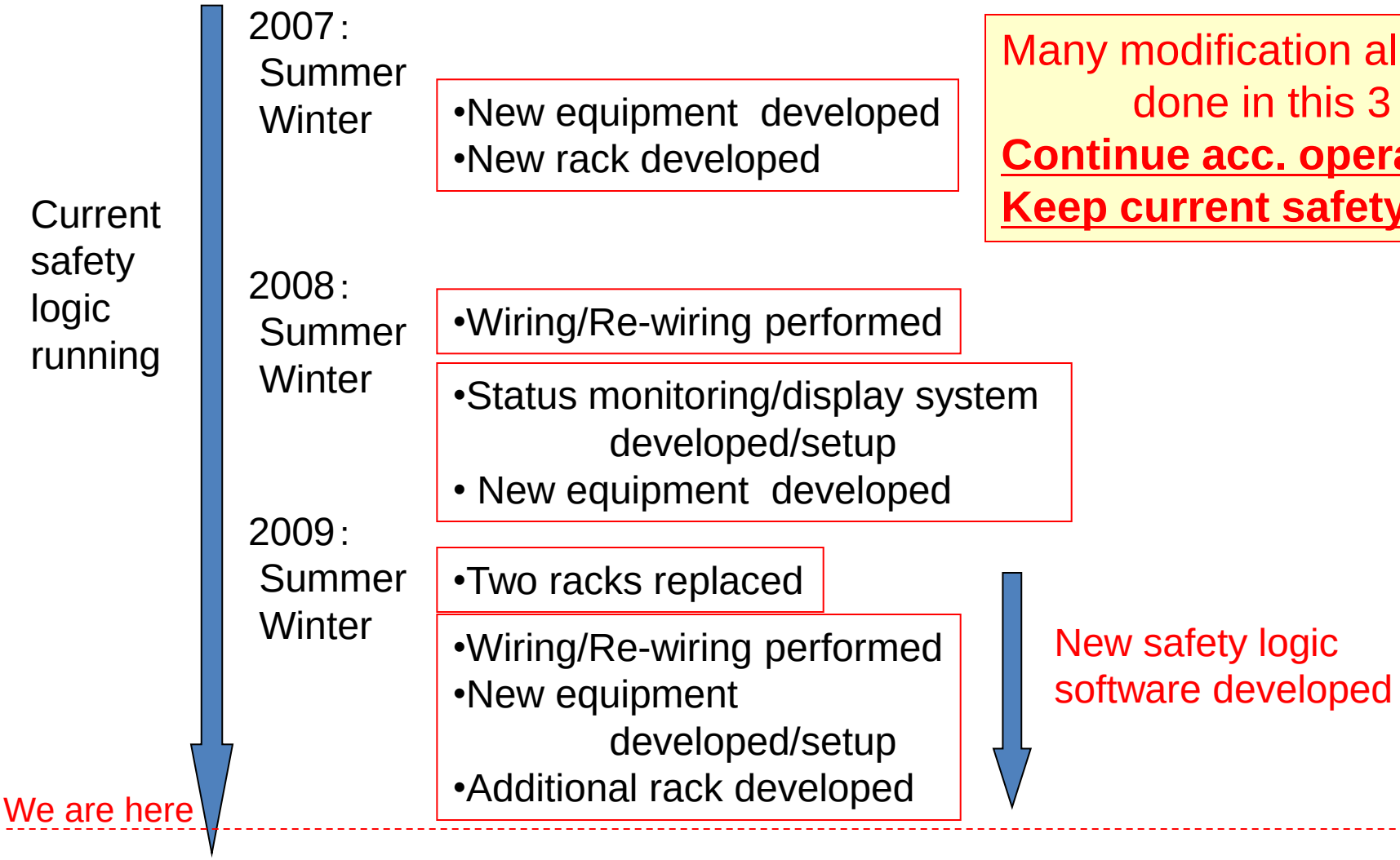
(e.g. 2008FY)

Typical Schedule of Accelerator Operation



- Short shutdown period
- a few chance (twice in a year)
→ Construction is difficult for tight schedule

Construction schedule in the past and future



Construction schedule in the past and future

Current safety logic running

2007:
Summer
Winter

- New equipment developed
- New rack developed

Many modification already done in this 3 years.
Keep current safety logic
Continue acc. operation.

2008:
Summer
Winter

- Wiring/Re-wiring performed
- Status monitoring/display system developed/setup
- New equipment developed

2009:
Summer
Winter

- Two racks replaced
- Wiring/Re-wiring performed
- New equipment developed/setup
- Additional rack developed

New safety logic software developed

We are here

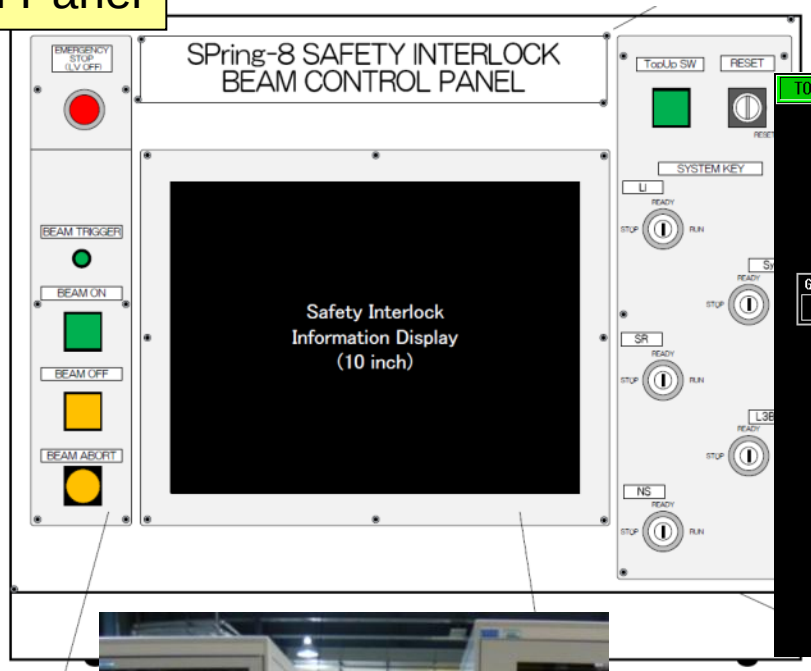
New safety logic

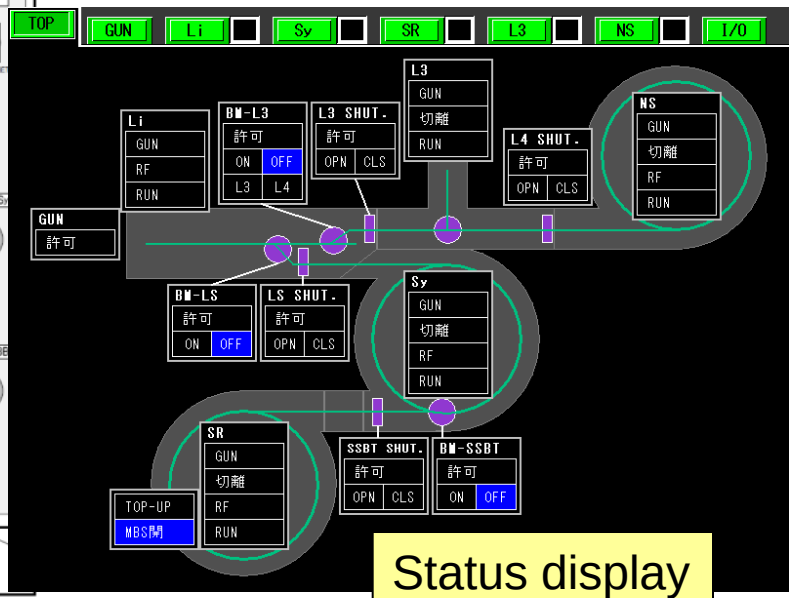
2010:
Summer

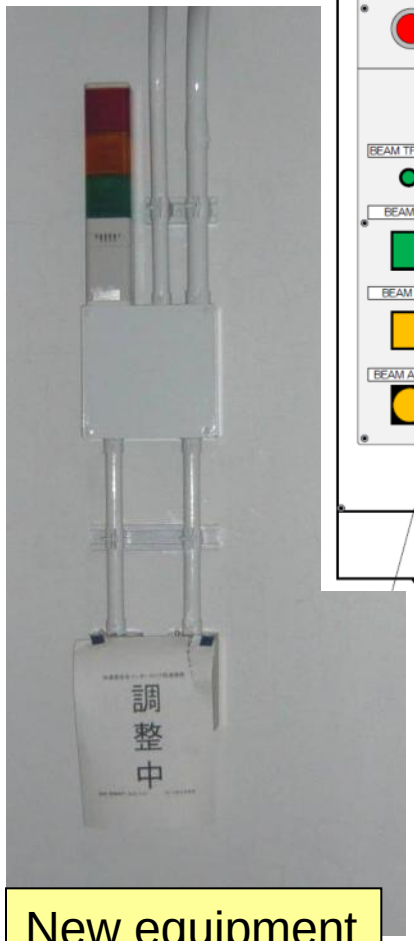
- Replace Main two rack and final wiring
- Remove MODE system
- Install new safety logic, safety inspections

Items already prepared

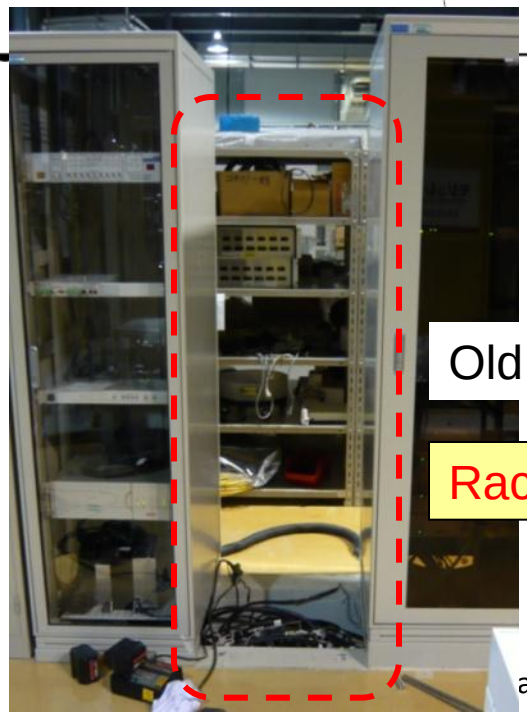
New Control Panel







New equipment

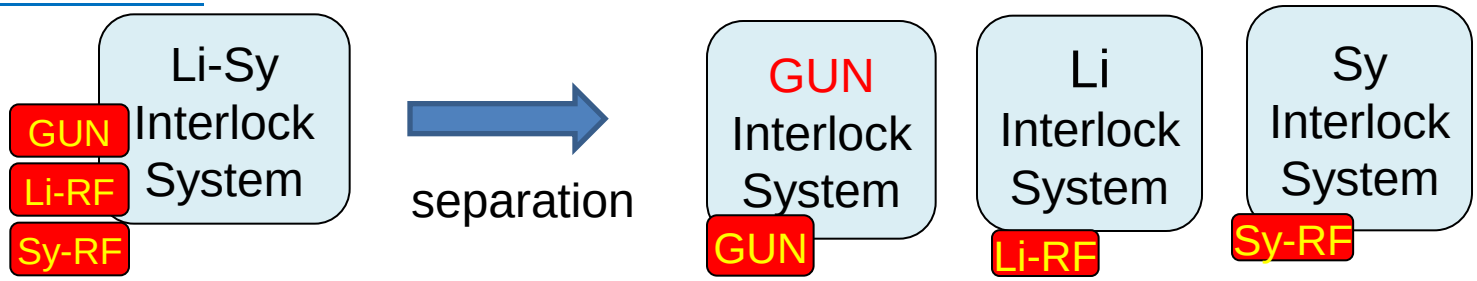


Old → New

Rack replacement

Rack replacement (1) – Motivation -

Motivation:



Current system:

PLC system:
- Li-Sy (one system)

Signal Cable/terminal-block:
- Mixture of Li, Sy, GUN

New system:

PLC system:
- GUN, Li, Sy (3 system)

Signal Cable/terminal-block:
- Independent of Li, Sy, GUN

What to do:
- More rack space
- Replace and rewiring
  - Cables
  - Terminal blocks

Rack replacement (2) – Procedure-

Current safety logic

New safety logic

DIO module

PLC

Terminal block

~2009

Li-Sy

Old rack

External cable

New rack

Li-Sy

• New rack prepared
• Additional 2 PLC space
• Reassign PLC module

Removed

Installed

~2009 Summer

Li-Sy

External cable rewired

We are here

~2010 Summer

GUN

Li

Sy

• 2 PLCs added
• Only modules reassigned
• Quickly modification
• New safety logic

Mixture of GUN, Li, Sy

GUN

Li

Sy

• 3 step procedure has done
• This procedure has been applied to many modification.

Simulator

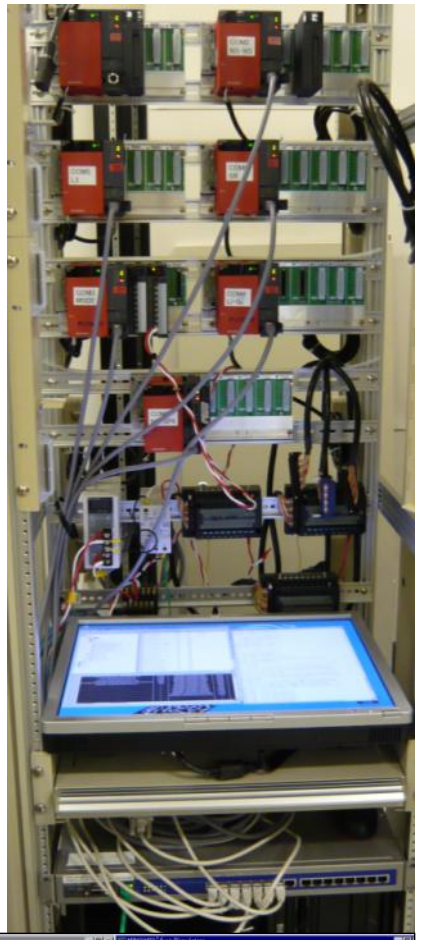
Motivation:

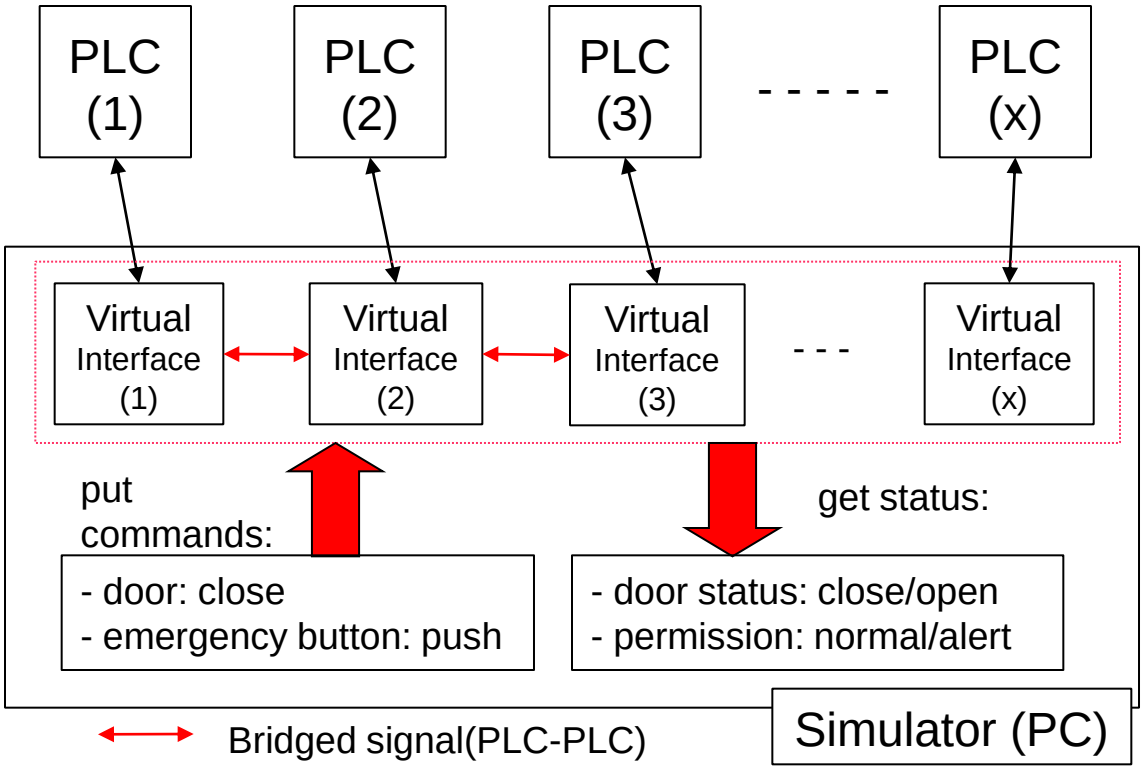
Efficient and precise confirmation of
safety logic programs in a local environment

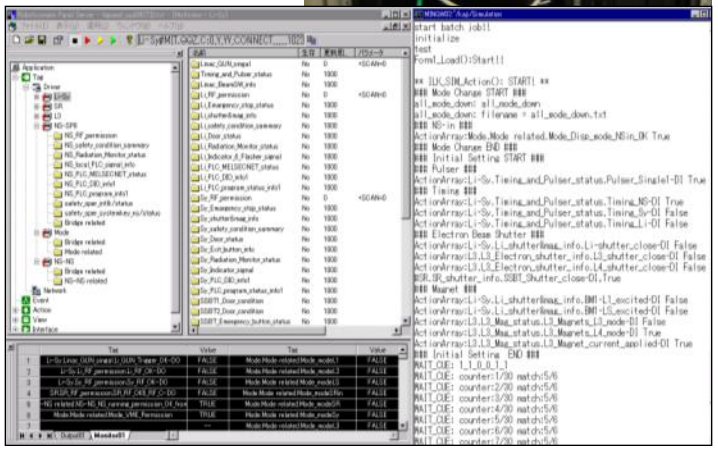
System: PLCs and PC

→Programmatically control PLC signal (put/get)

We are testing new safety logic.







Summary

- Current accelerator safety interlock system is complicated.
- Difficult to upgrade interlock system for additional accelerator area.

- New conceptual design was settled on.
  → based on Area management system
- A part of construction was already finalized with keeping current safety logic.

- New system will be ready in this end of September and operation will be started.

→ also ready for expand of an additional accelerator area.

Supplement

Introduction

- Accelerator components for SPring-8:

Interlock System	Covered Area	Related Permission
Mode	-	GUN, Li-RF, Sy-RF, SR-RF, NS-RF
Li-Sy	Li, Sy	GUN, Li-RF, Sy-RF, SR-RF
L3	L3	GUN, NS-RF
SR	SR	GUN, SR-RF, Sy-RF
NS	NS	GUN, NS-RF

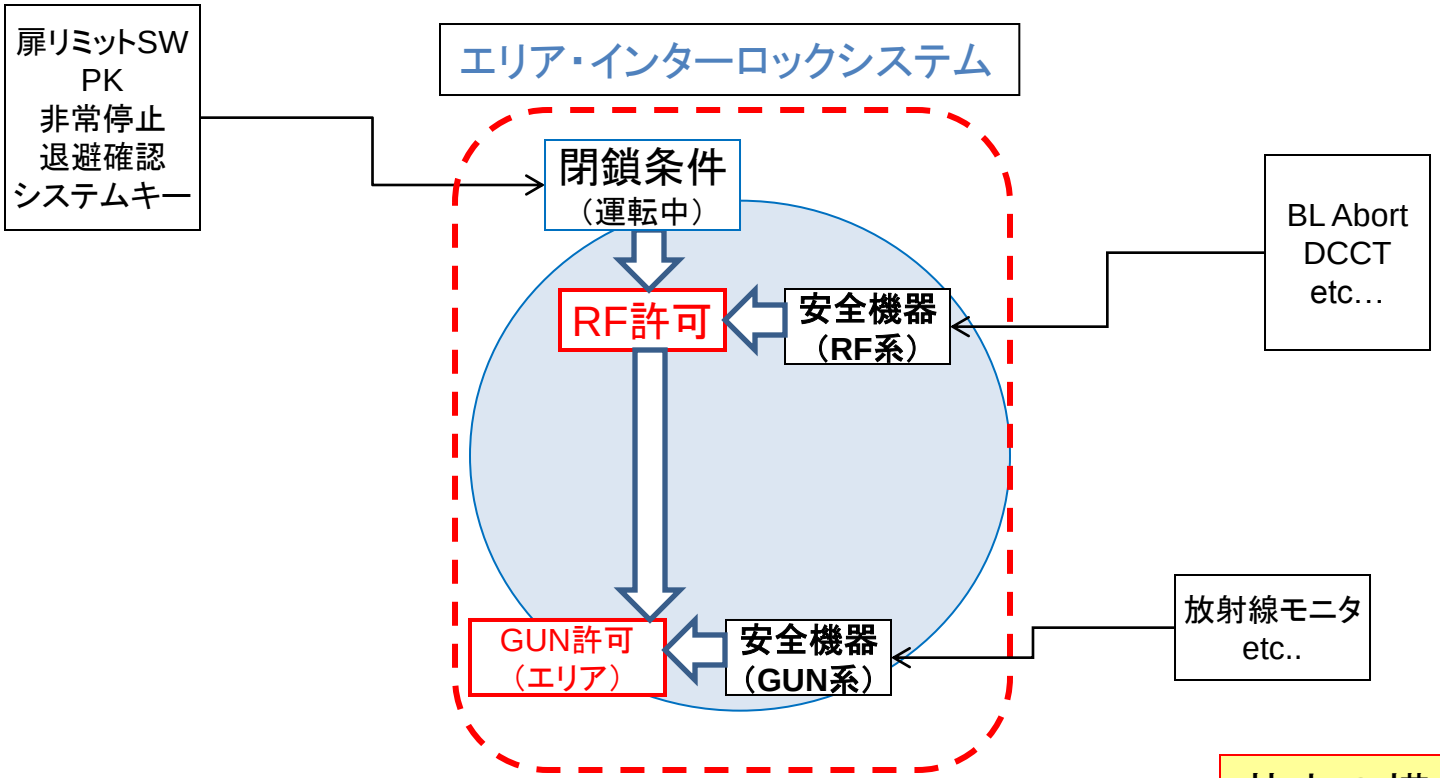
Covered area and related permission of Current Accelerator Safety Interlock System

Interlock System	Covered Area	Related Permission
Gun	-	GUN
Li	Li	GUN, Li-RF
Sy	Sy	GUN, Sy-RF
L3	L3	GUN
SR	SR	GUN, SR-RF
NS	NS	GUN, NS-RF

Covered area and related permission of New Accelerator Safety Interlock System
(Covered areas and related permissions is independently managed by each interlock systems)

エリア管理(1)

ー エリア・インターロックシステム ー



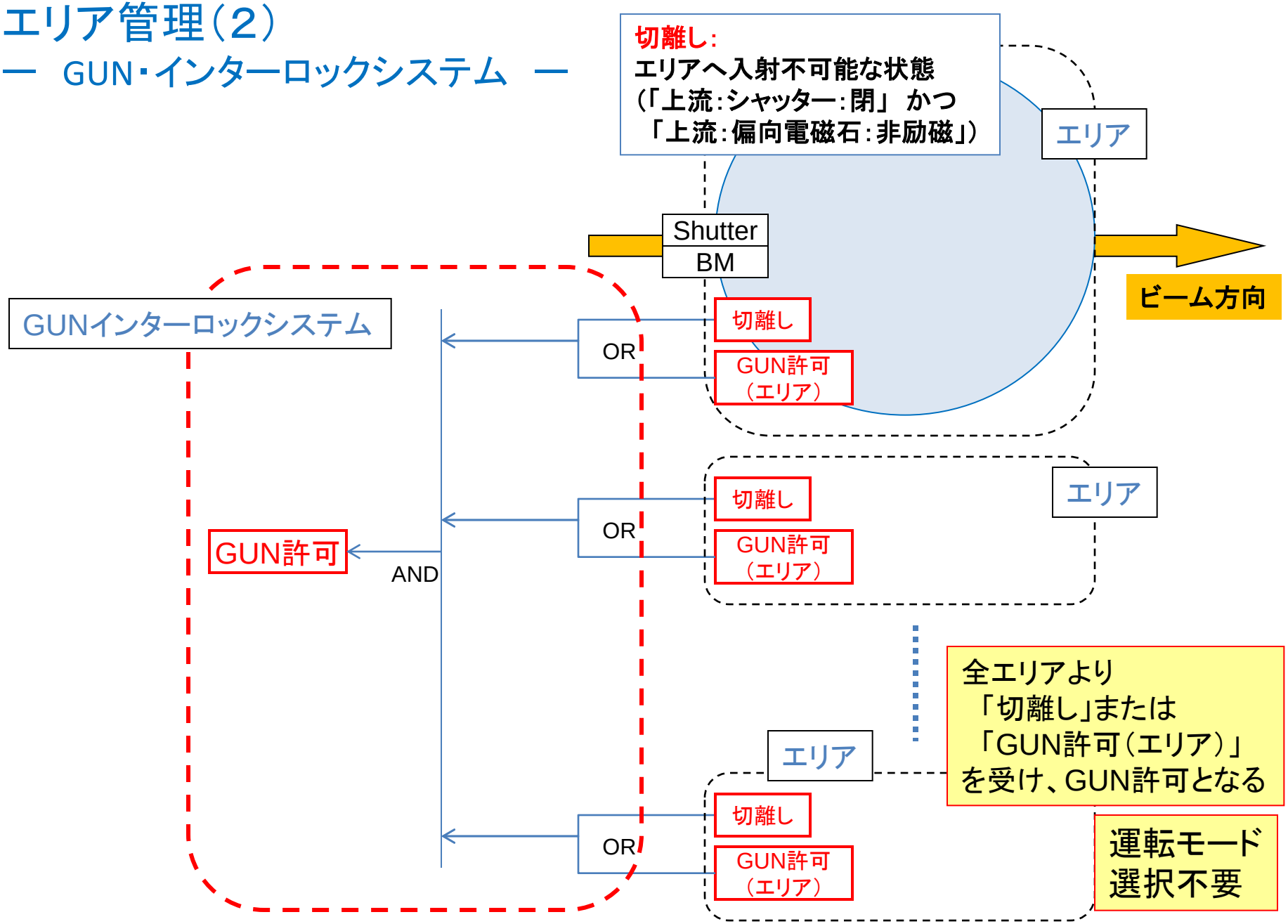
基本の構成・動作は
全エリア同様

運転モード
選択不要

RF許可: RF運転許可(蓄積可能)

GUN許可(エリア): エリアへの入射許可

エリア管理（2）
― GUN・インターロックシステム ―

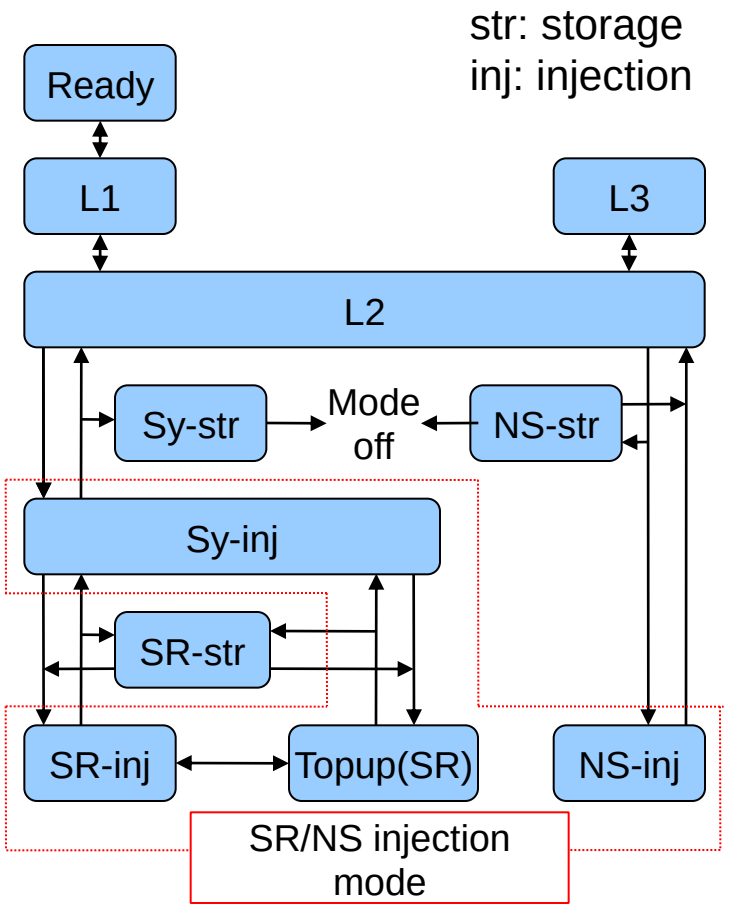


Accelerator Safety Interlock System (3)

Operation mode(MODE)

- For accelerator operation , appropriate MODE should be selected.
- Several MODEs can be selected
- A MODE including combination of some areas

- MODE transition procedure is complicated.



Operation mode transition

(Red region shows Mode with switching a destination)