# Radiation Safety at J-PARC at NSRI, JAEA

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/High Energy Accelerator Research Organization (KEK)
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# Outline of this talk

- What is J-PARC?
  - Safety management system
- Accelerator facilities in laboratory of nuclear facilities
- Zoning and access control to controlled areas
- Confinement of airborne activity
- Radiation monitoring system
  - Threshold determination of warning and alarming of monitors

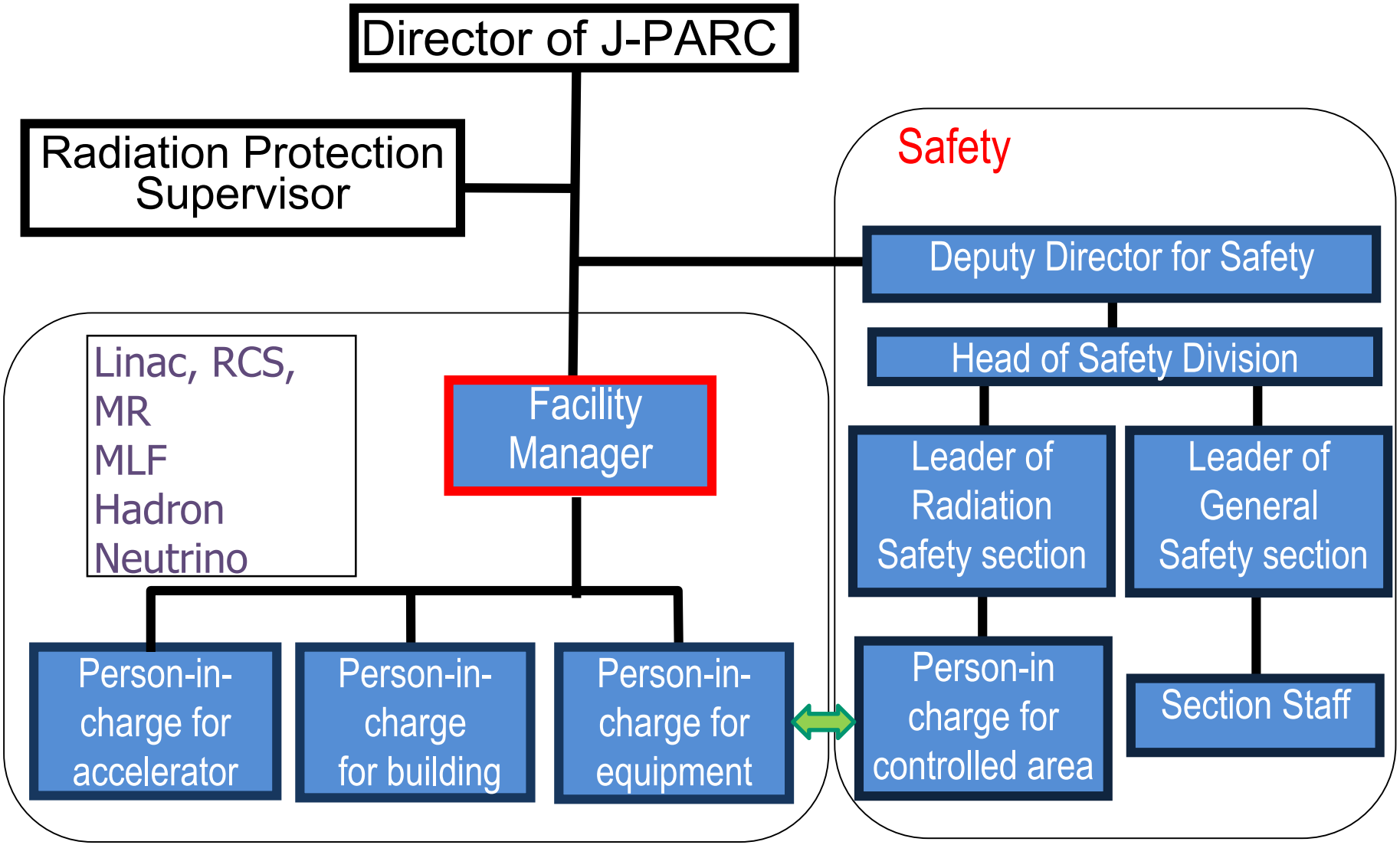
# Japan Proton Accelerator Research Complex (J-PARC)

Jointly operated by JAEA and KEK

- 3 accelerators
  - 400 MeV LINAC
  - 3 GeV RCS
  - 50 GeV MR (30 GeV operation)
- 3 user facilities
  - Materials and Life Science Experimental Facility (MLF)
  - Hadron Experimental Facility (HD)
  - Neutrino Experimental Facility (NU)

# Safety Management System in J-PARC

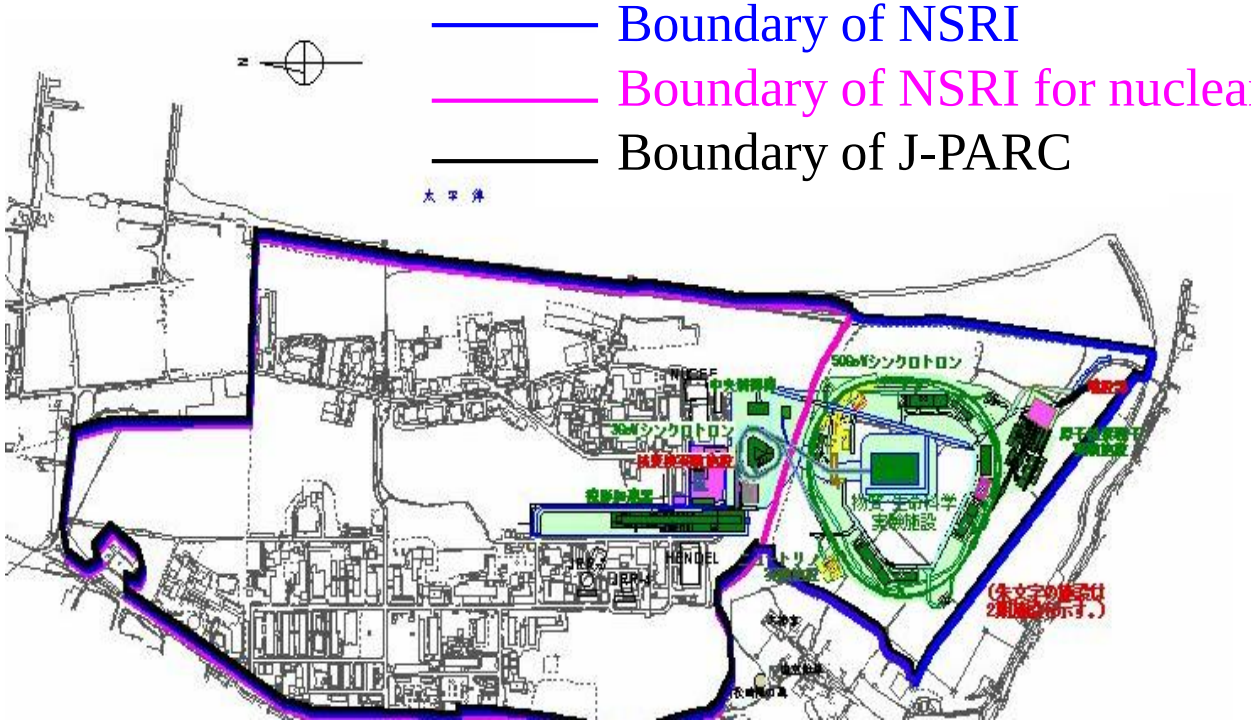
Facility/Division is responsible for the safety of each Facility/division



# J-PARC
# in NSRI, JAEA

# Location of J-PARC

- The boundary of J-PARC is same as that of NSRI(**N**uclear **S**cience **R**esearch **I**nstitute, JAEA).
- Nuclear safety agreement is concluded between the local government and NSRI. J-PARC must act in accordance with this agreement which defines the duty to report in troubles, etc.



# Information Flow in Emergency

*In emergency, J-PARC act under the NSRI, where J-PARC located in.*

JAEA President (Tokyo, Tokai)

KEK Director (Tsukuba ~70km)

Info.

NSRI Local headquarter

NSRI Director General

J-PARC Center Director

➢Leading info. exchange on situations and actions

Notific.

(Ques.)

Local governments

Relevant authority in central governments

Info. summarized

J-PARC

Command post

Facility Manager

➢Analysis of the situation

➢Supervision of the actions

Direction

Reporting Info.

Accidental site

➢Inspection of the trouble

➢Recovering actions

TEL (cellphone)

Teleconference

FAX, TEL

# Zoning, access control

# Requirement on Spatial Dose Rate

Site Boundary : 0.25 mSv / 3 months
(0.115 μSv/h)
3 months => 2,184 h

- Contributions of all facilities in the site, including the research reactors, which are not J-PARC facilities, need to be counted.
- J-PARC contribution should be less than 0.05 mSv/3 month.

Red values: legal limits

Buffer Area Boundary : 20 μSv / 1 week
(0.5 μSv/h)

Controlled Area Boundary : 1.3 mSv / 3 months
(2.6 μSv/h)
3 months => 500 hours

Region of Regular Access: < 1 mSv / week
(25 μSv/h)
1 week => 40 hours

Restriced area: > 25 μSv/h

Forbidden area: > 100 mSv/h

# Criteria for Radiation Controlled Area

Radiation controlled areas are defined as the areas in which radiation levels may exceed the following specified levels:

1. Effective dose
   : 1.3 mSv/3months
2. Average concentration of radioactivity in the air
   : > 1/10 DAC (Derived Air Concentration, legal limit value from inhalation of air with RI)
3. Surface contamination
   : 4 Bq/cm$^2$ for $\gamma$, $\beta$ emitters
   : 0.4 Bq/cm$^2$ for $\alpha$ emitters

# Classification of Controlled Area

## 2nd-Class Controlled Area

External Exposure only

## 1st-Class Controlled Area

External and Internal Exposure
(Surface contamination, air activity or induced radio activity etc.)

# Controlled Area with High Radiation Level

The areas with high radiation levels is classified into the following two types and access to the area is strictly controlled:

## Restricted area

a) spatial dose rate might exceed 25 μSv/h

b) average concentration of radioactivity in the air might exceed 1/10 DAC (Derived Air Concentration)

c) surface contamination might exceed

40 Bq/cm$^2$ for γ, β **emitters**

4 Bq/cm$^2$ for α **emitters**

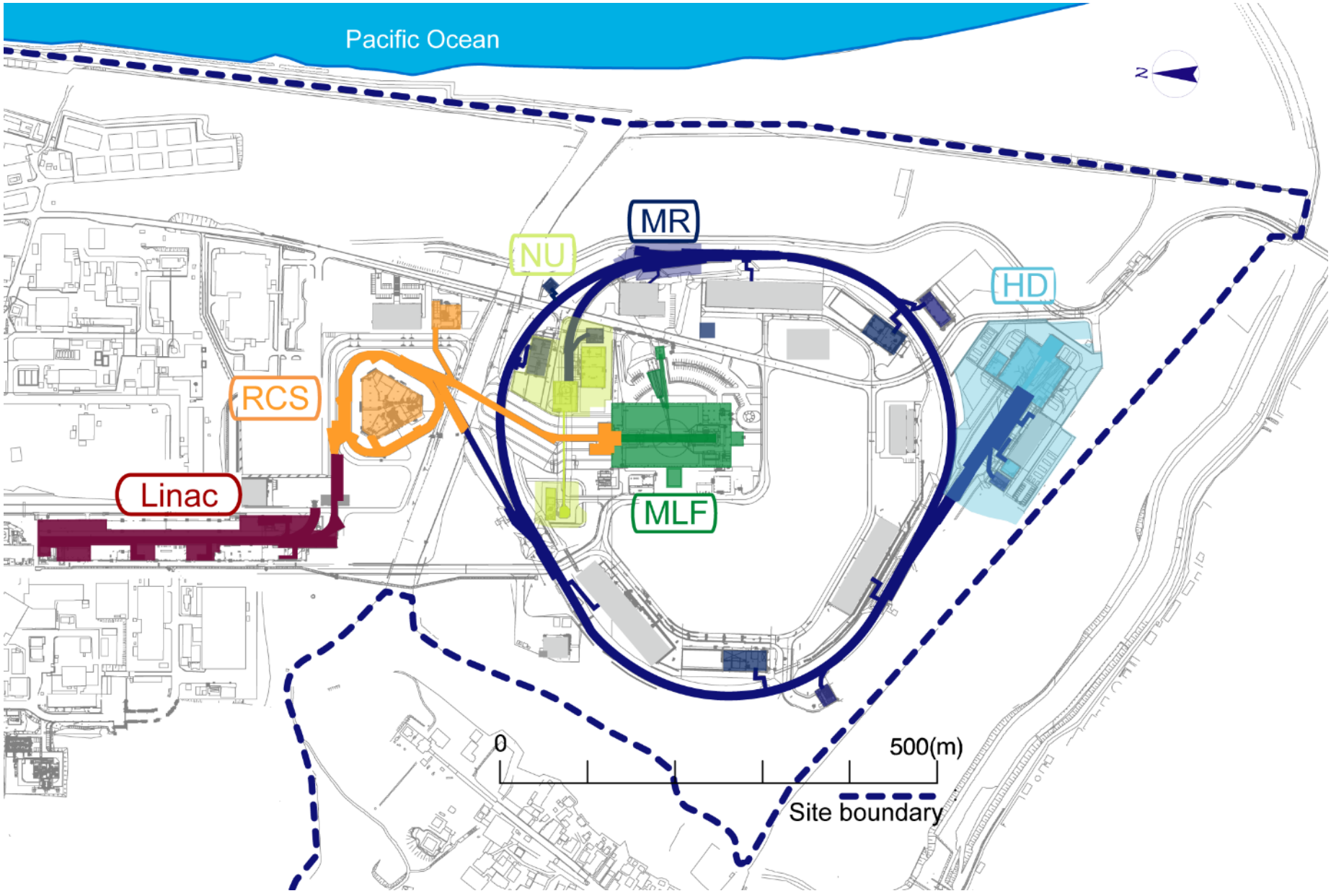
## Forbidden area

spatial dose rate might exceed 100 mSv/h

Interlocked area (restricted or forbidden)

None can access while beam on

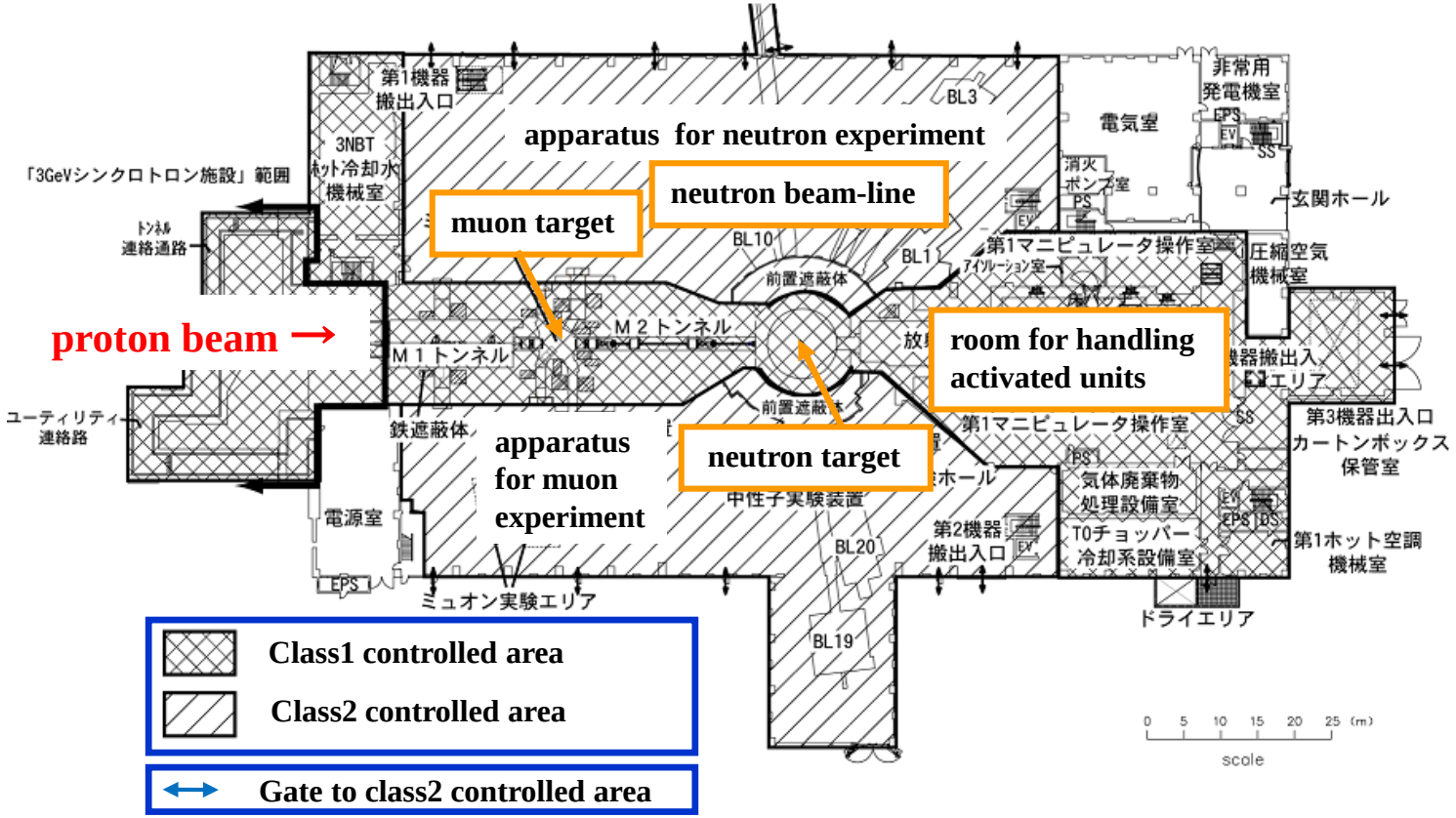
# Radiation Controlled Area @ J-PARC

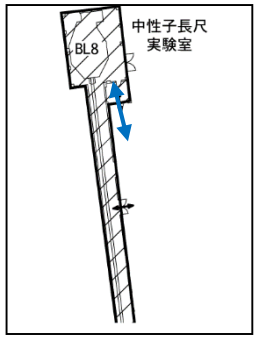


# Zoning at MLF (Low Power Operation)

## Materials and Life Science Experimental Facility
## --- the 1st floor

~ 2016.11.1




As increasing operation power, induced radio-activity of irradiated samples should be considered

# New Zoning Category

| Japanese | English | Sign |  |
|---|---|---|---|
| 1種A | 1st class A | 1種A<br>1st class A | Access to this area is restricted because of high level radiation dose and/or contamination. |
| 1種B | 1st class B | 1種B<br>1st class B | Typical 1st class area<br>(The area except 1st class A or 1st class C) |
| 1種C | 1st class C | 1種C<br>1st class C | Low surface contamination area<br>(In this area, it doesn't allowed to work with the risk of contamination; cutting, welding radioactive materials.) |

# New Zoning Category

When you access to 1st class radiation controlled area, you should ...

1種C
1st class C

1st class C : Exchange shoes.

1種B
1st class B

1st class B

1種A
1st class A

1st class A

Exchange shoes, and put on yellow coat or overall.

When you exit, you should check the contamination on your hands and feet with a hand foot cloth monitor.

# New Zoning Category for High Power

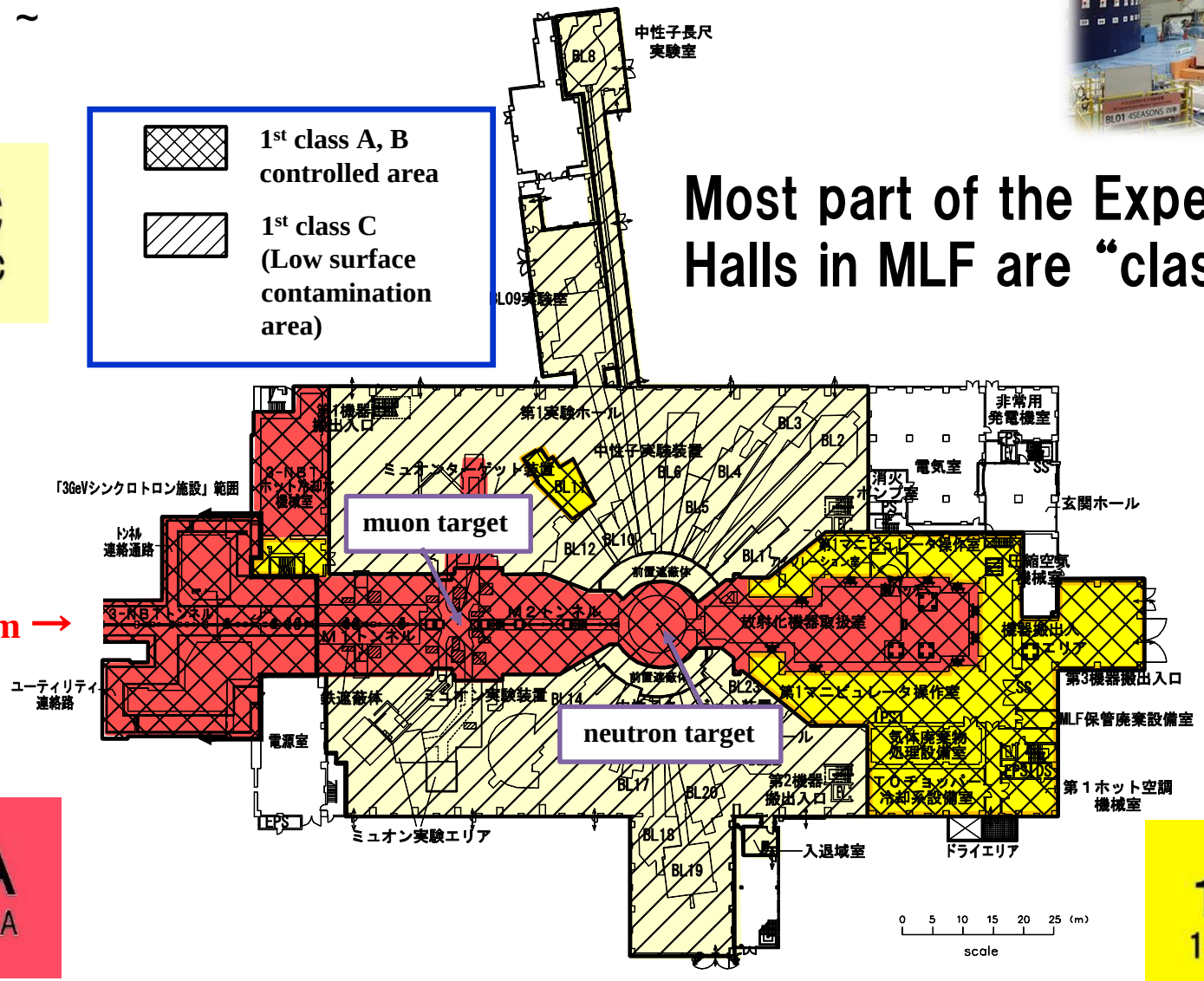
2016.11.1 ~

1種C
1st class C

1st class A, B controlled area

1st class C (Low surface contamination area)

**Most part of the Experimental Halls in MLF are “class C”.**




Plan view of MLF

1種A
1st class A

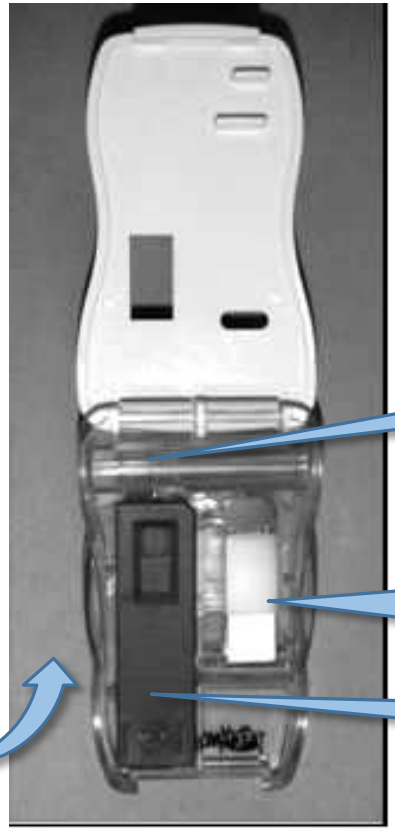
1種B
1st class B

# ID Device for Access Control

ID: RFID transponder
for access control

γ/β: Optically Stimulated Luminescence element

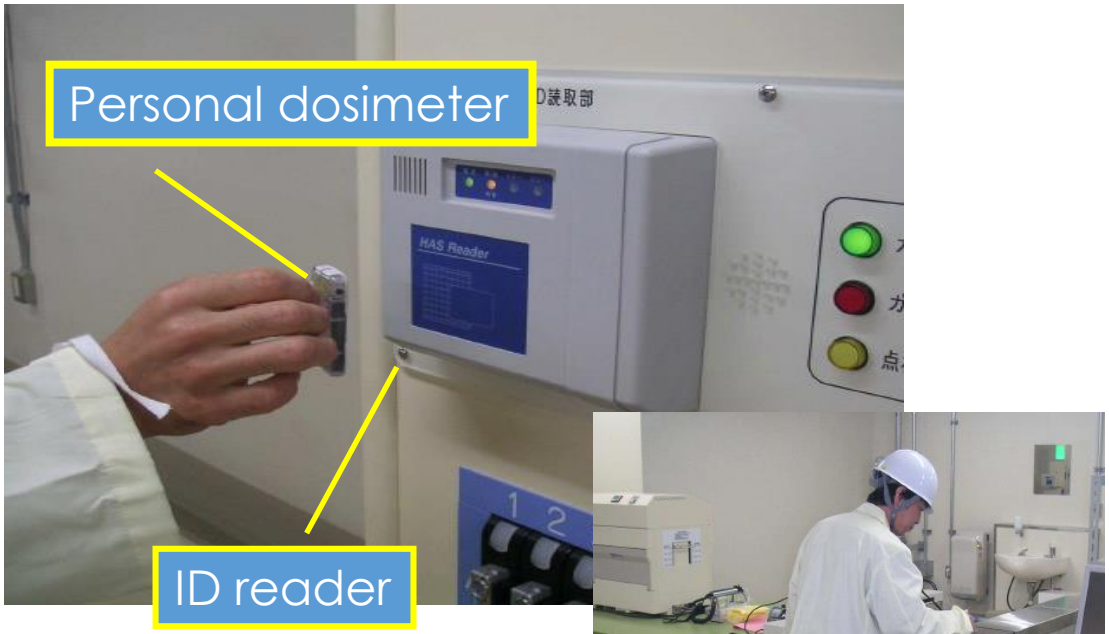
*n*: Plastic Solid State Track detector


ID device is packed inside the personal dosimeter, not to forget to ware own PD

# Access Control (Normal Working Area)

Entrance to controlled area




Exit

Hand foot cloth & Article monitor

# Access Control (High Radiation Area)

Alarm personal dosimeter
and
personal key (beam interlock)


Body surface and article
contamination monitor (exit)

# Personal Dosimetry

## Administrative Dose Limit @J-PARC

| Male | Female |
| --- | --- |
| 7 mSv/y | 5 mSv/y |

For radiation workers

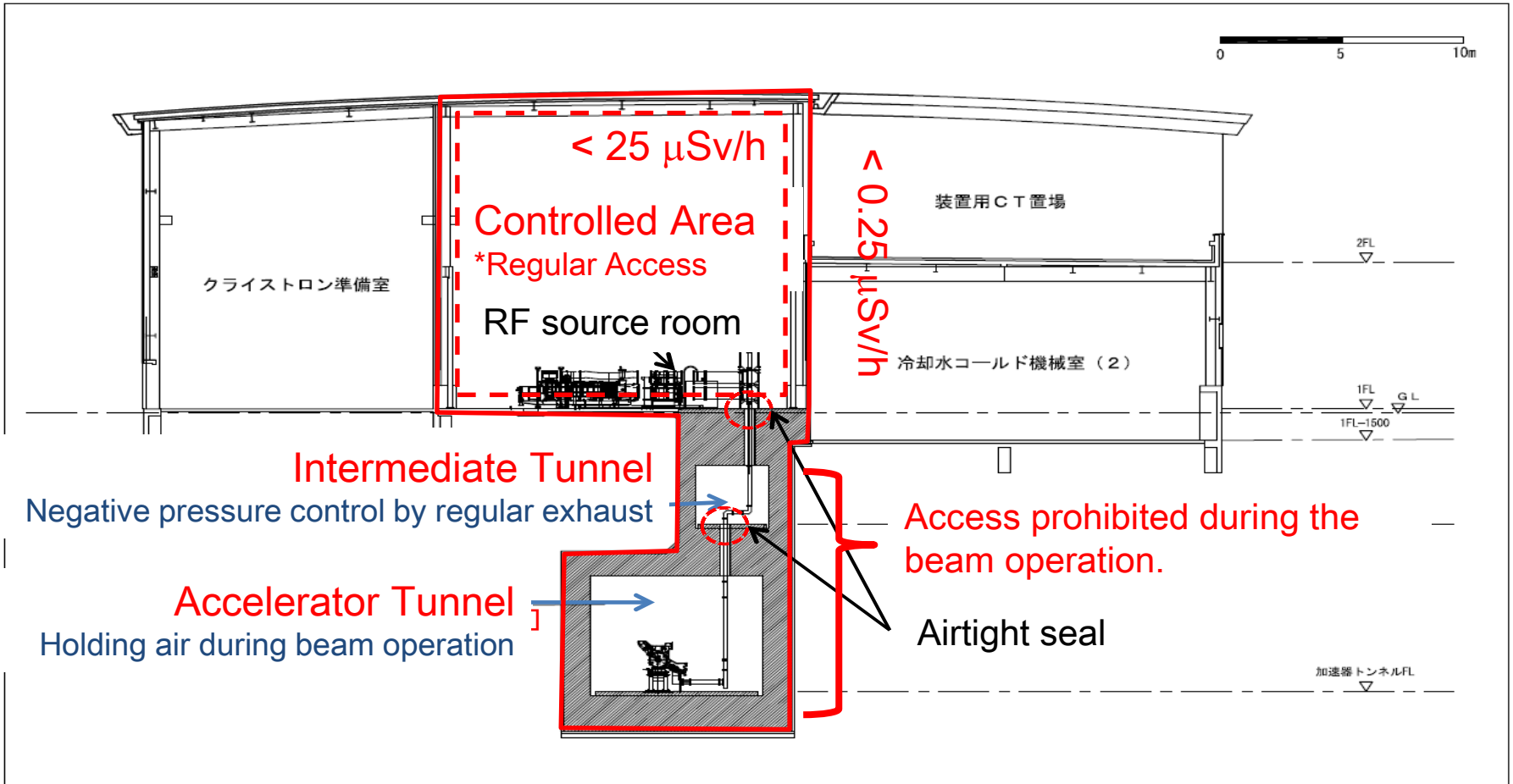
The Legal dose limit of Japan

- 100 mSV/5y and 50 mSv/y
- 5 mSv/3 months for women

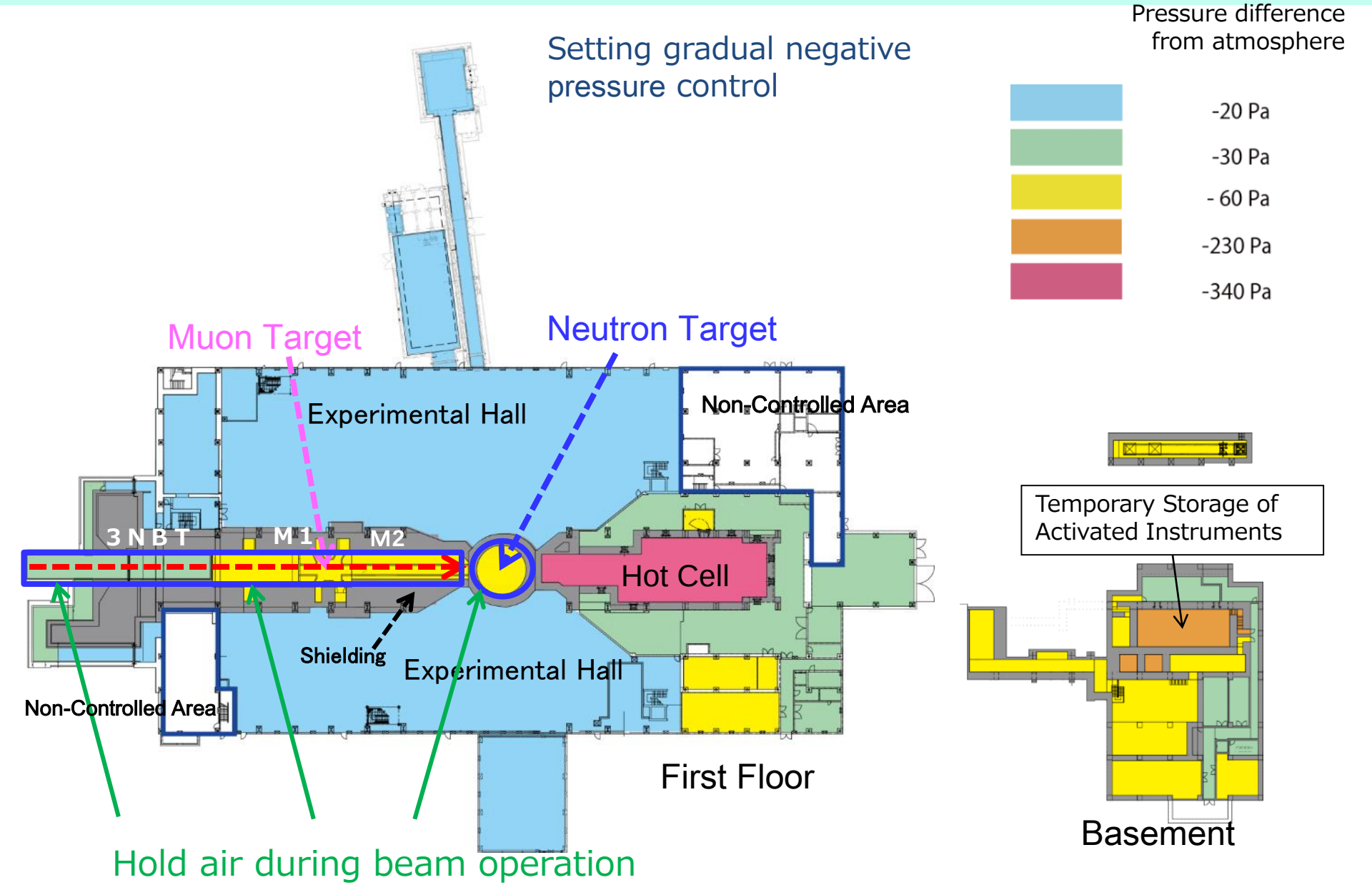
# Confinement of airborne contamination

# Air Controlled Area of the Accelerator

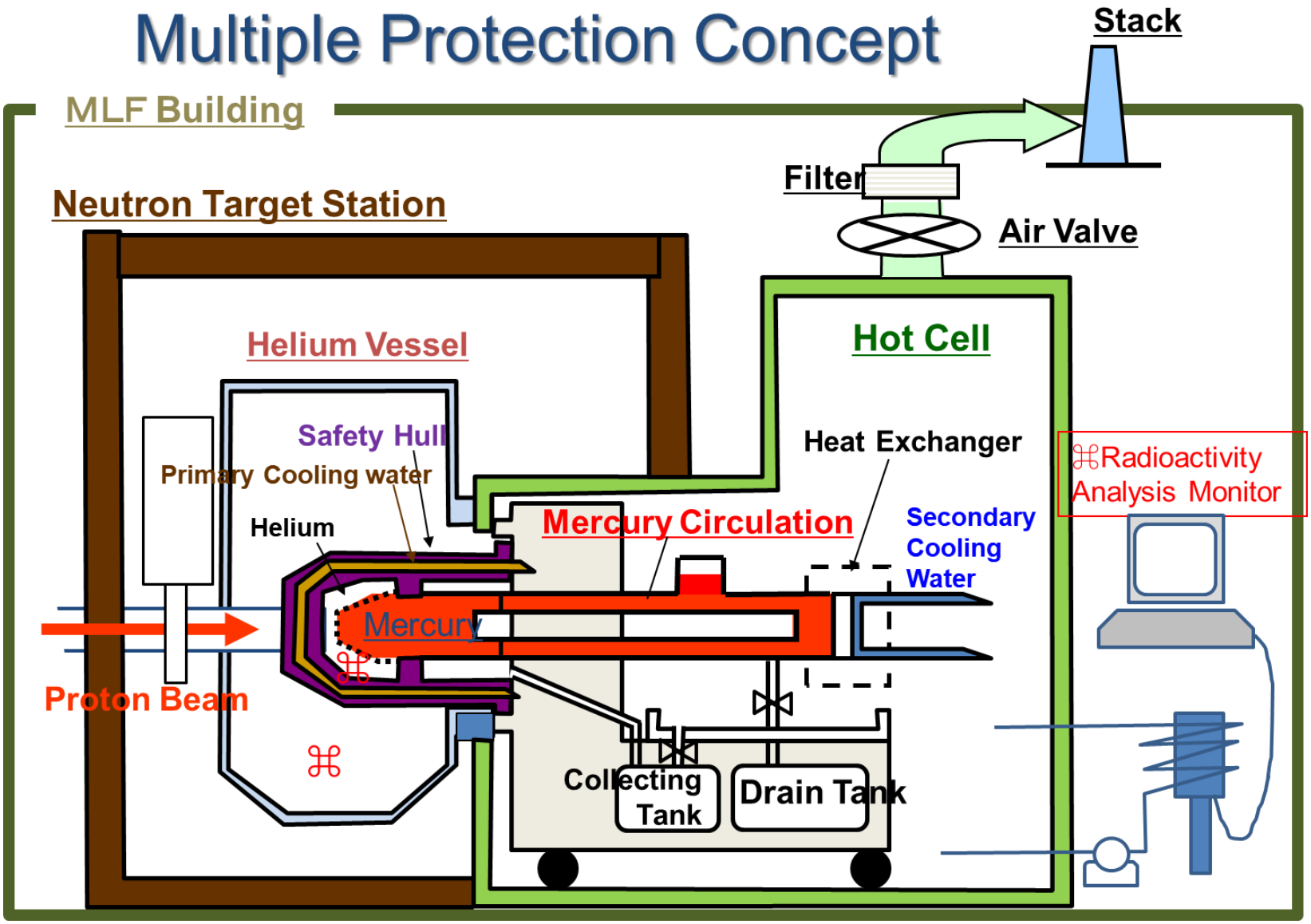
- Unable to exhaust the accelerator tunnel during the beam operation.
  - Radioactive gas products with short half lives are produced, such as $^{15}O$(2.04m), $^{13}N$(9.97m), $^{11}C$(20.4 m), $^{41}Ar$(1.8 h) etc.
  - In order to keep the regulation, cooling time is necessary before exhaust.
- The intermediate tunnels are constructed to prevent direct leakage of radioactive gas from the accelerator tunnels to environment.



# Air Controlled Area of MLF Hall



# Confinement of the mercury oriented RI



# Radiation Monitoring System

# Radiation Monitoring System

- Radiation Monitoring
  - Pulsed gamma (beam oriented)

    Ionization chamber
  - Continuous gamma (induced radioactivity oriented)

    Semi-conductor / NaI(Tl)
  - Neutron

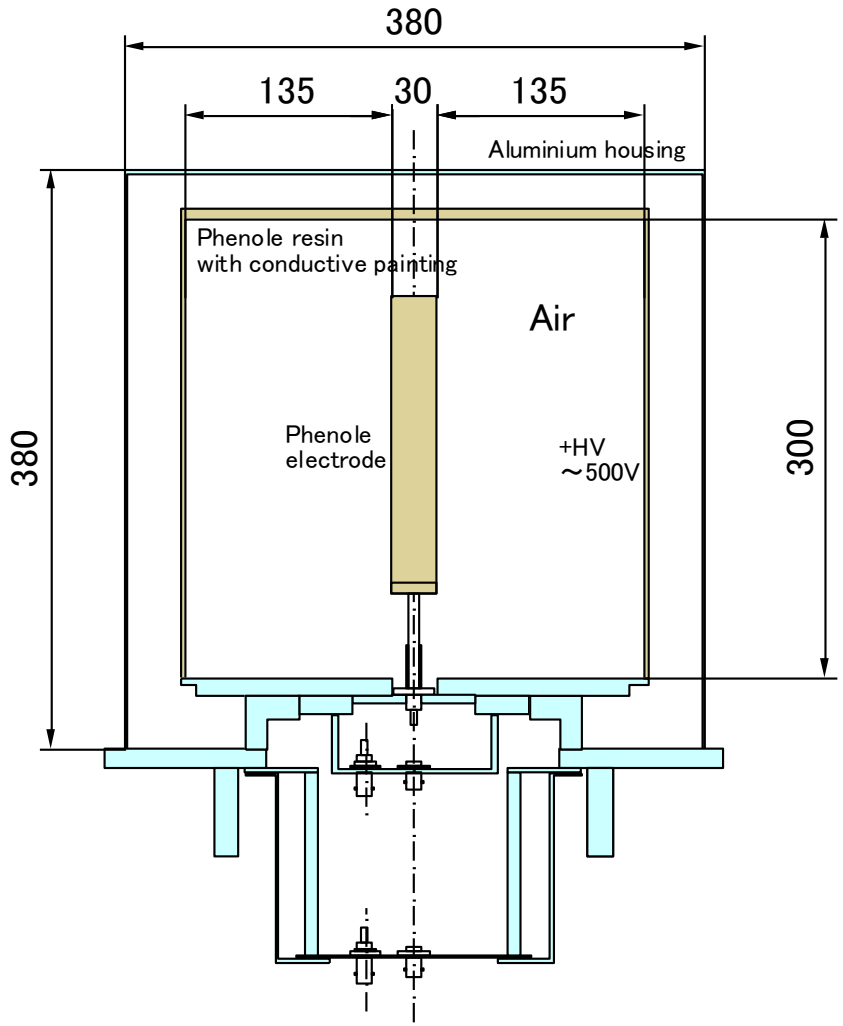
    He-3 proportional chamber with polyethylene moderator
  - High rate neutron

    He-3 proportional chamber with polyethylene moderator, not only counts the number of signals, but also measures the charge integral
  - High energy neutron

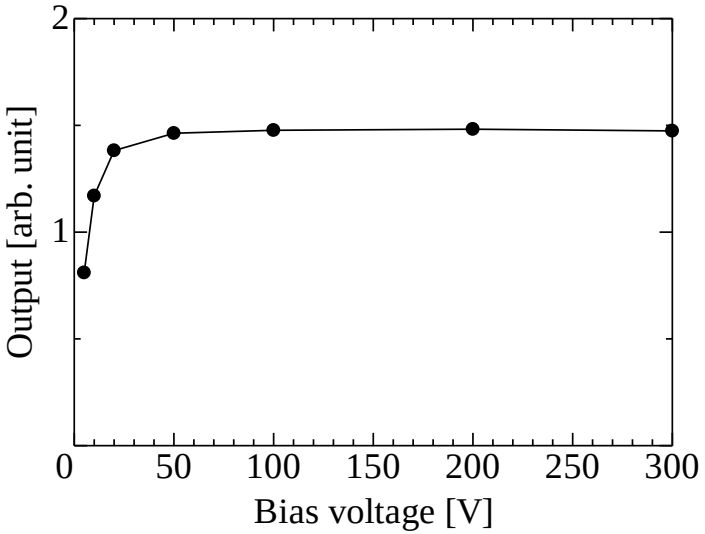
    He-3 proportional chamber with polyethylene/lead moderator

# Radiation Monitor

# X/γ monitor (Area monitor)



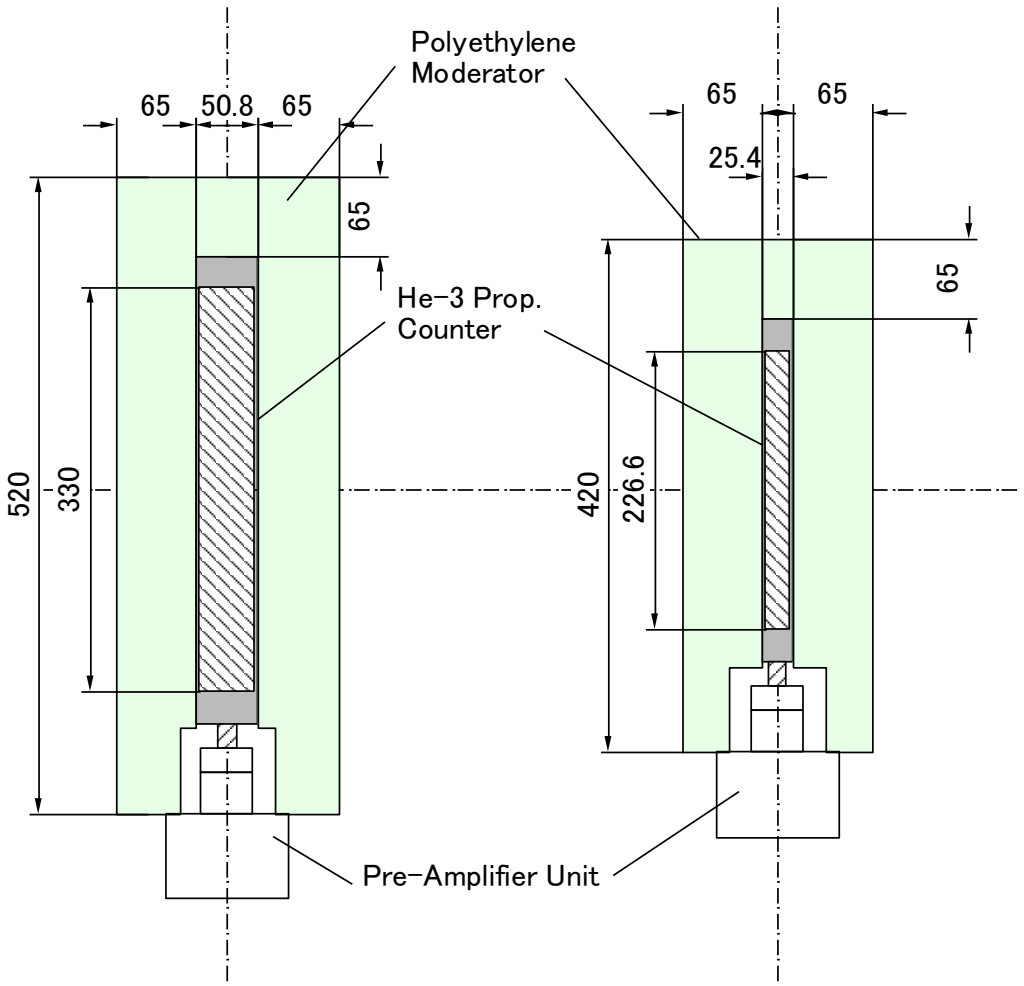

Air filled Ionization Chamber




→ High sensitivity
Count rate for background
20litters : 0.5-1cps
10litters : 0.05-0.1 cps

Others
GM counter (0.5-1cps)
NaI scintillator (2" 3-5cps, 3" 5-10cps)

# Neutron monitor (Area monitor)




- 1" or 2" He-3 Proportional counter
  - 0.95 MPa, 2500volts
- 6.5cm thick polyethylene moderator
  - →A few MeV neutrons mainly
  - → High sensitivity
    Count rate for background
    1inch : 0.2-0.4cps
    2inch : 0.5-1 cps

# Radioactivity Monitoring System

- Airborne activity in exhaust
  - Radioactive gas

    Ionization chamber or Plastic scintillator (J) / NaI(Tl) with Pb shield (K)

    For H-3, silica aerogel traps and liquid scintillator
  - Radioactive dust

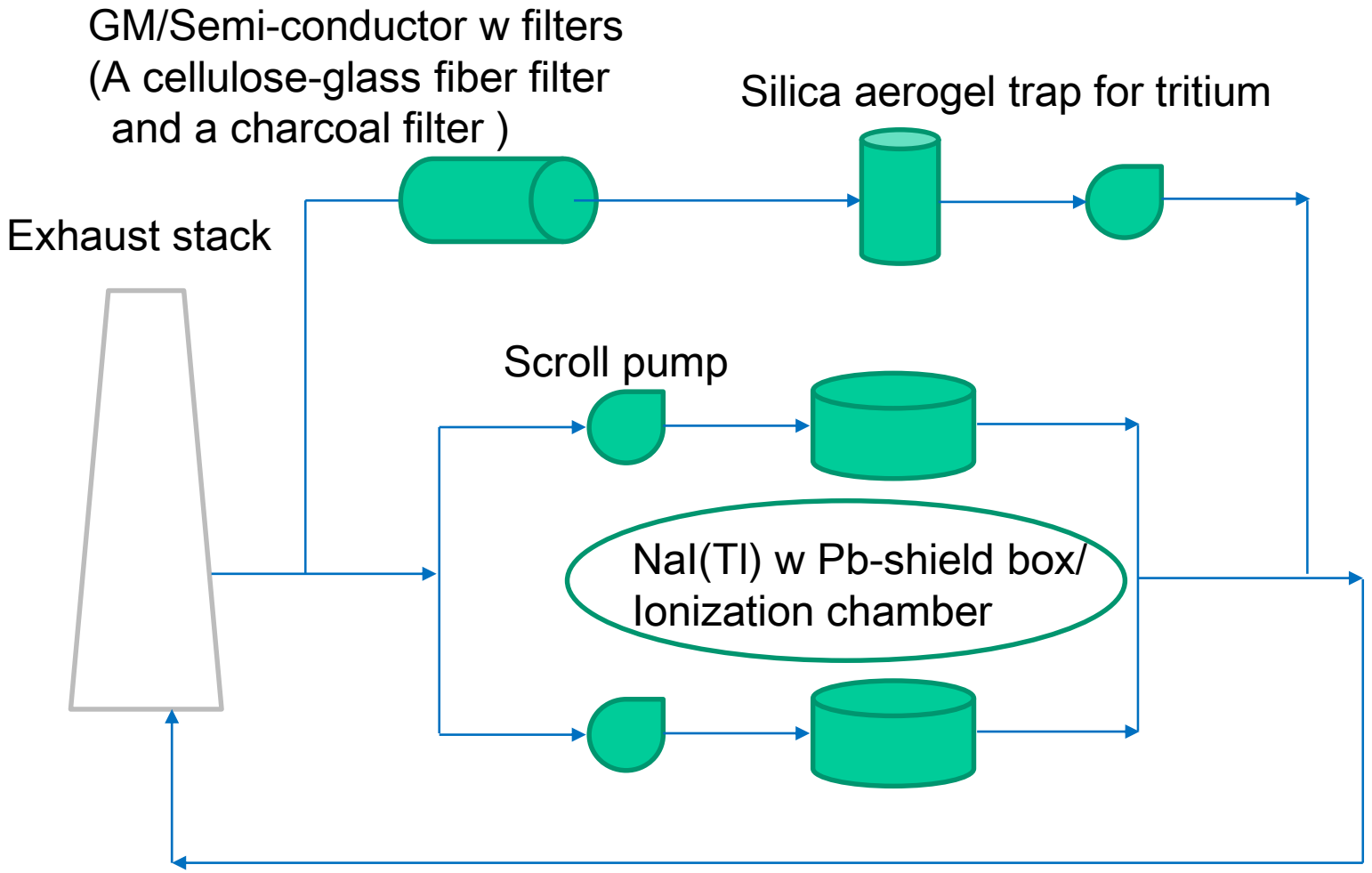
    Semi-conductor (J) / GM or NaI(Tl) (K) with filters

    Filters: A cellulose-glass fiber filter and a charcoal filter (for I, Hg etc.)

    replaced once a week and measured with Ge detector
- Activity in drain
  - Before drainage, radioactivity is measured with liquid scintillator (H-3, C-14) and Ge detector

# Airborne radioactivity monitor

- Radioactive dust and air in exhaust

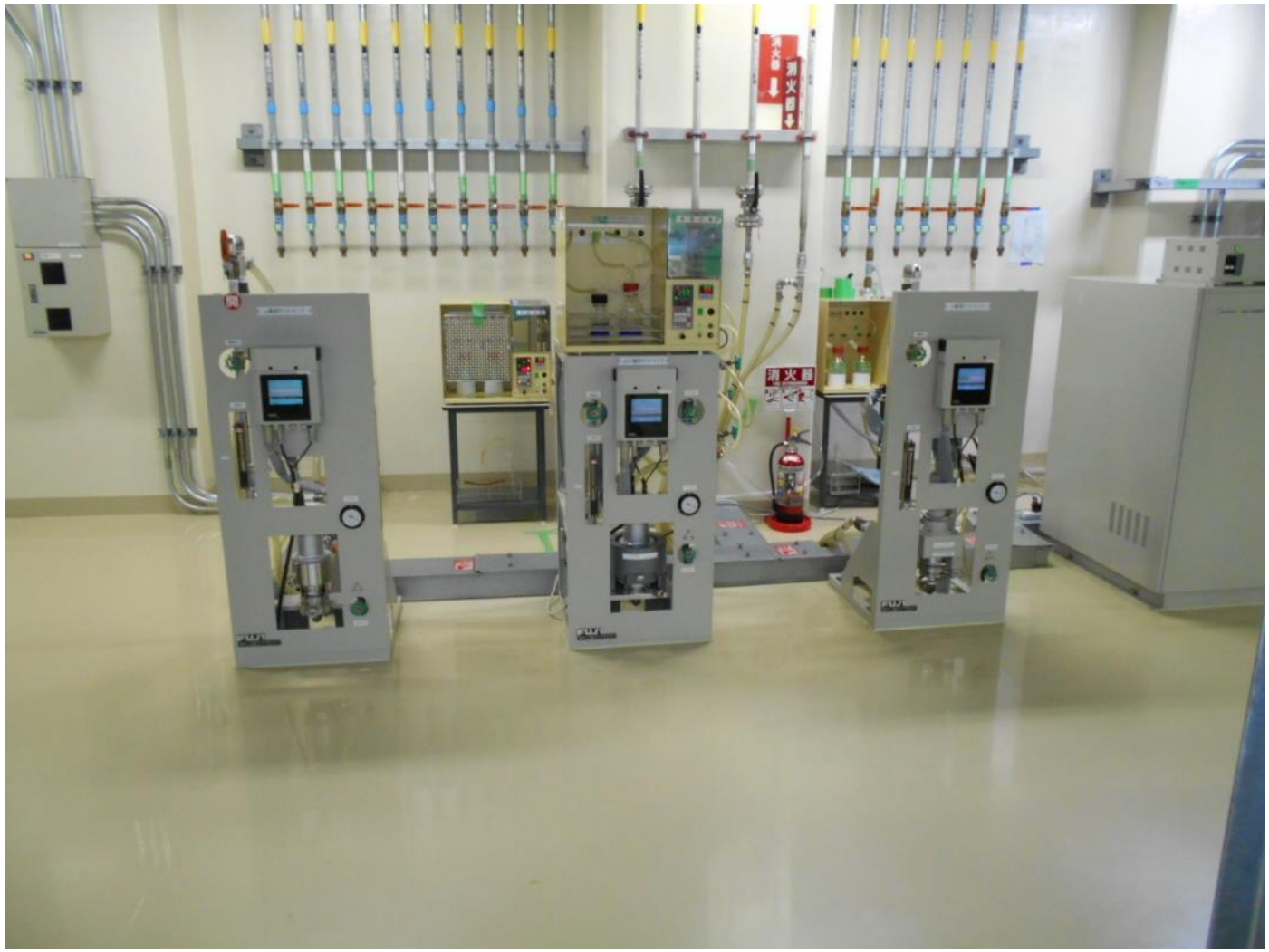



To measure activity without pause, gas monitors are duplicated

# Gas and Dust Monitors

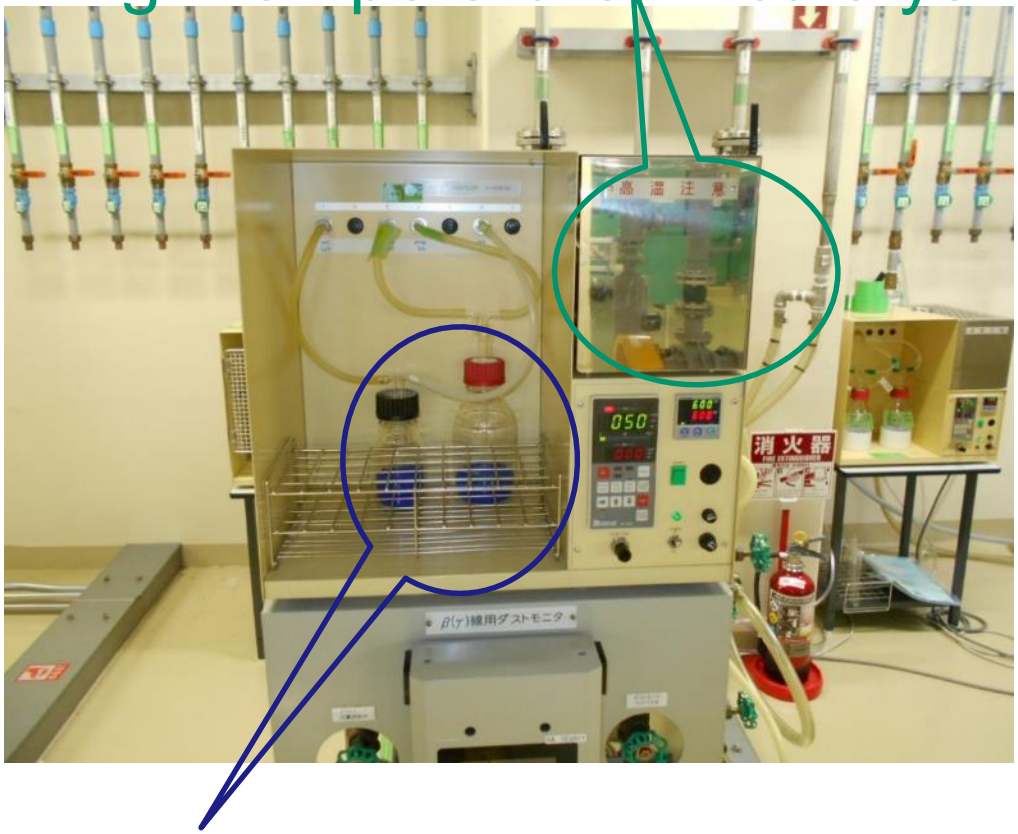
# Exhaust Gas Monitor

# Dust Monitors



# Tritium Collection Device

After trapping HTO, HT is oxidized with high temperature Pt catalyst




Silica-gel bottles are replaced once a month.
After 24 hours leaving in water, water activity is measured with Liq-scintillator

HTO and HT are separately collected in silica aero gel

# Setting Alarm for Radiation

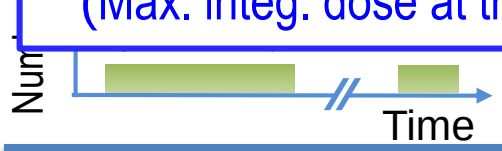
# Threshold Level for Radiation

- Interlock monitor at controlled area boundary
  - 60 min integration of radiation dose
  - If exceeds 0.5 uSv (buffer area criterion), beam acceleration is stopped automatically
- Online monitor: 2 level (warning & alarm) are applied
  - Warning : Normal operation x 2
  - Alarm : Warning x 5 (normal x 10)
- In principle, “warning” means starting investigation, “alarm” means stopping operation.
  But now, if radiation monitor starts to warn, accelerator operator stops beam operation immediately.

# Radioactive Material Leak Incident in 2013

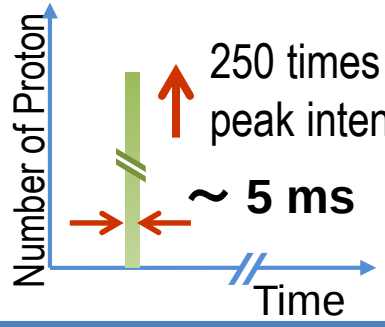
**① Uncontrolled / unconscious release of RI without filter**

(Max. integ. dose at the site boundary : 0.17 μSv)

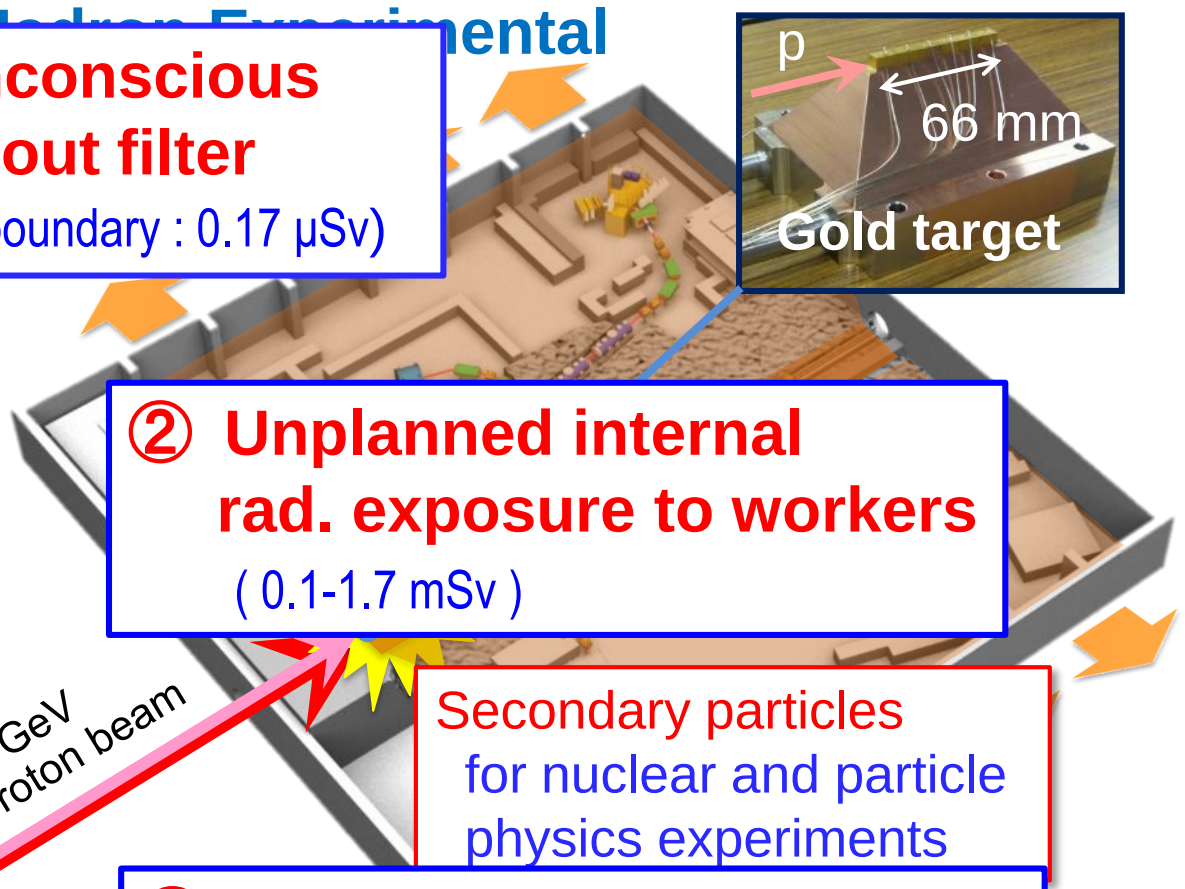



Slow extraction profile
( Normal operation )

March 23, 2013, 11:55




Abnormal beam due to malfunction of the beam extraction system




**② Unplanned internal rad. exposure to workers**

( 0.1-1.7 mSv )

Secondary particles for nuclear and particle physics experiments

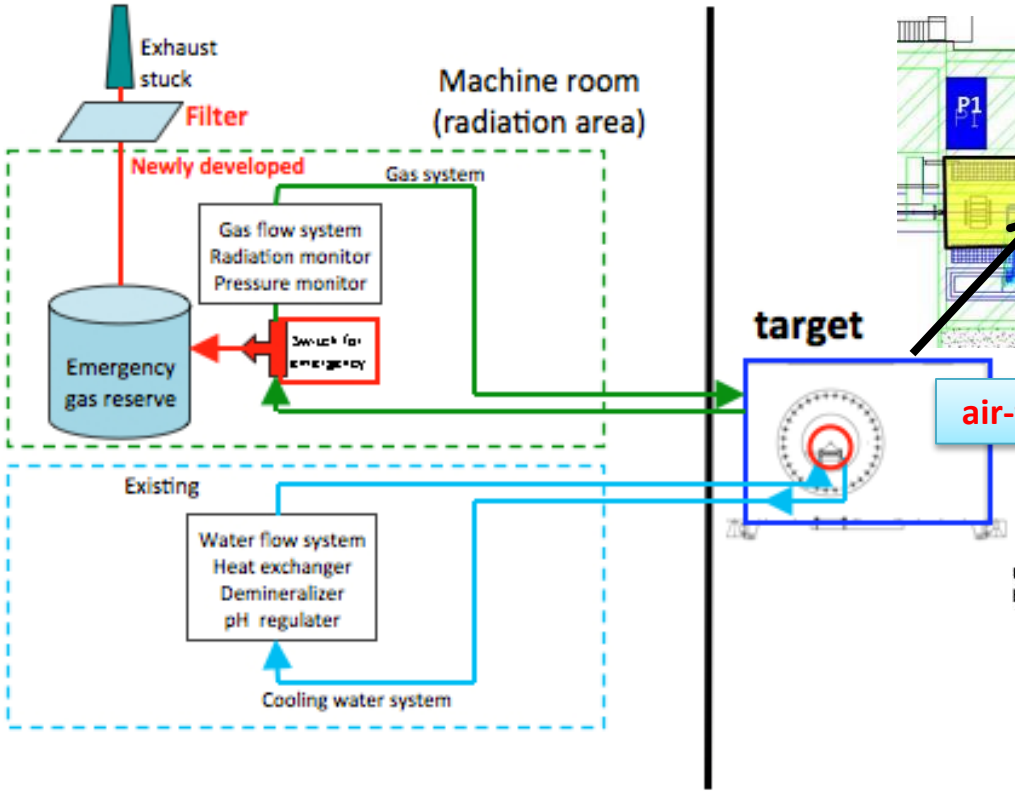
**③ Delay in notification to relevant auth. / local gov.**

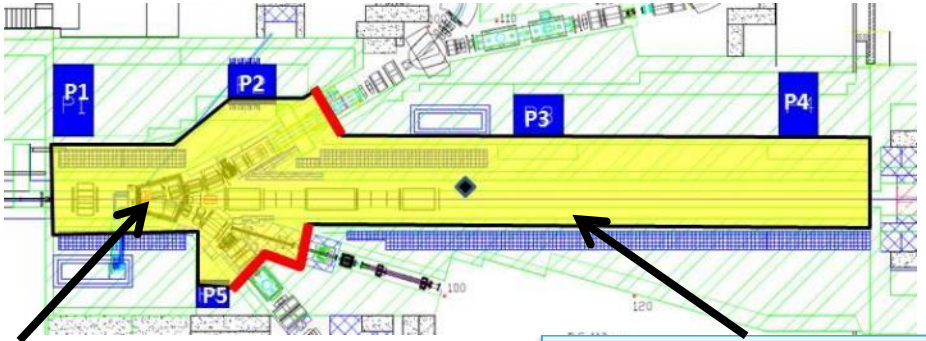
Heating of the Au target to melting / evaporation

Release of radioisotpopes (RI) from the target

Diffusion of RI into the exp. hall ⇨ Environment

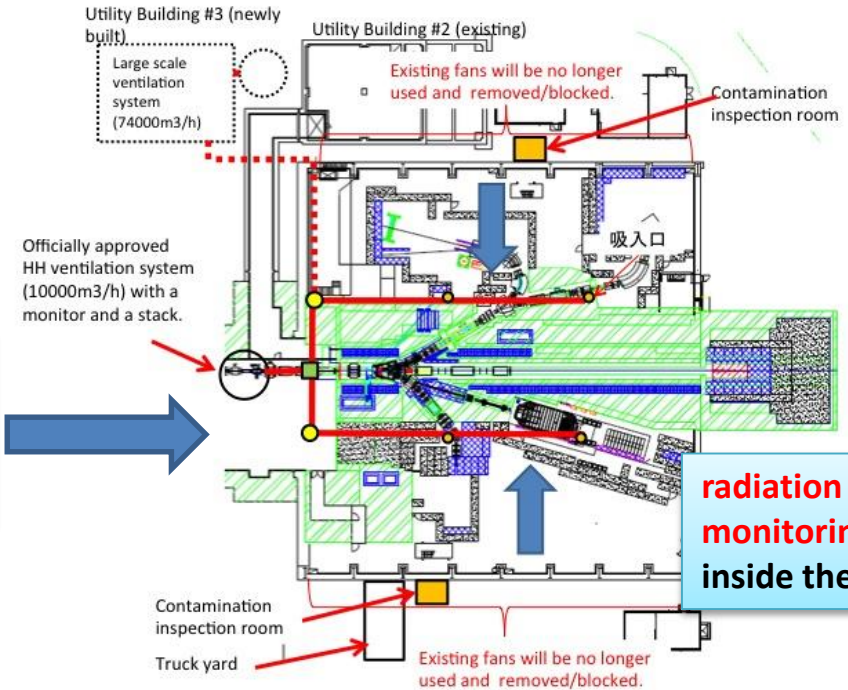
# Hadoron hall improvements




air-tight target chamber

improving air-tightness of Primary Beam Line




**Experimental Hall**

- **Exhaust fans were removed and sealed.**
- **The exhaust is filtered with monitoring.**

**radiation monitoring inside the Hall**

# Setting Alarm for Airborne Activity

# Legal limit for Airborne Activity

- Room gas at working area
  - Threshold airborne activity concentration
    - Corresponds to 1 mSv exposure for 1 week (40 h) inhalation
- Exhaust gas
  - Threshold airborne activity concentration at site boundary

    (Concentration are averaged in 3 month)
    - Corresponds to 1 mSv exposure for 1 year (8760 h) inhalation

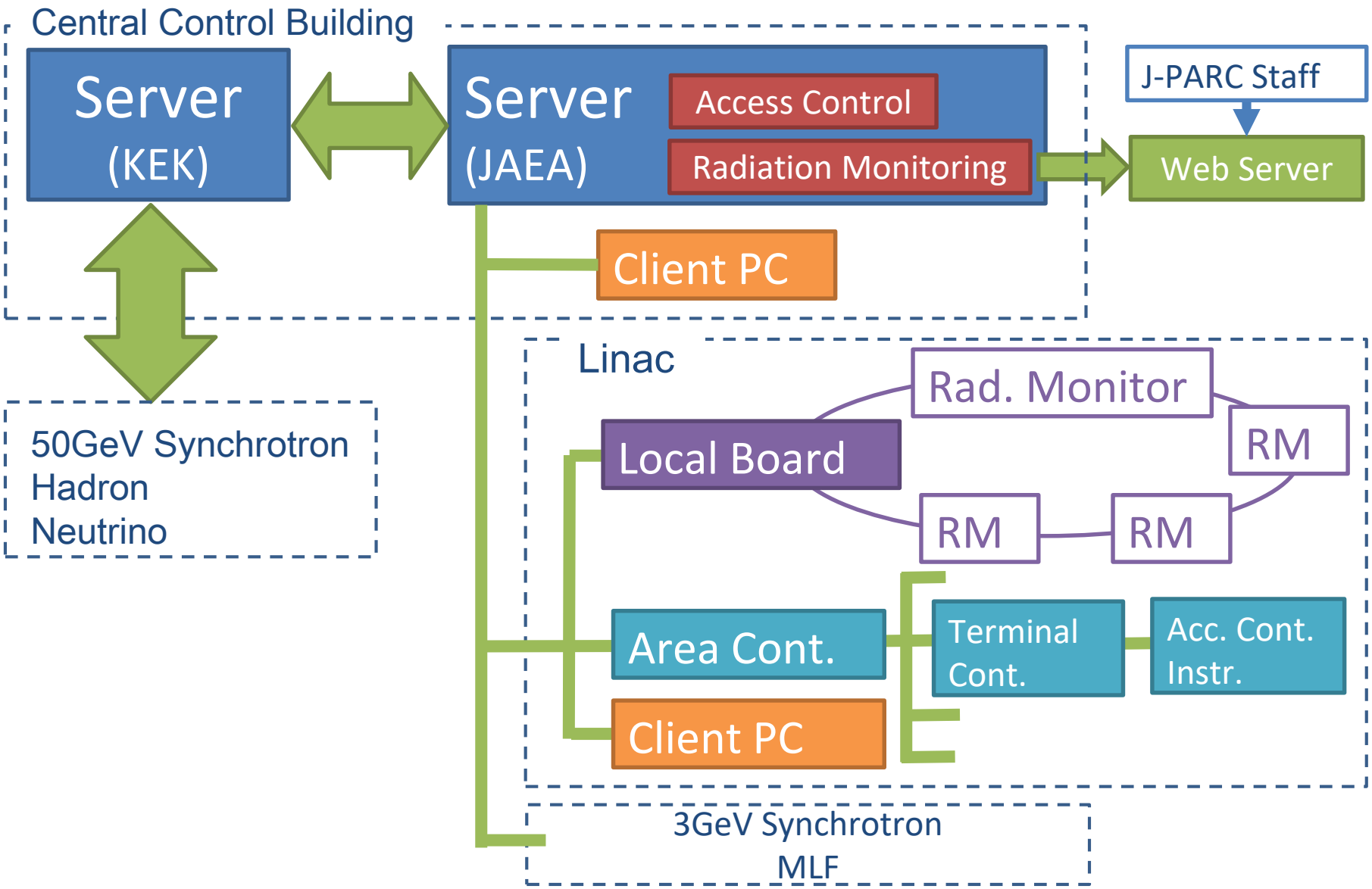
| Nuclide | Form | Concentration Limit for room gas ($Bq/cm^3$) | Concentration Limit for exhaust ($Bq/cm^3$) |
|---|---|---|---|
| Ar-41 | Submersion | $1 \times 10^{-1}$ | $5 \times 10^{-4}$ |

- At J-PARC, 20 uSv / 1 year at site boundary (1/50 legal limit)

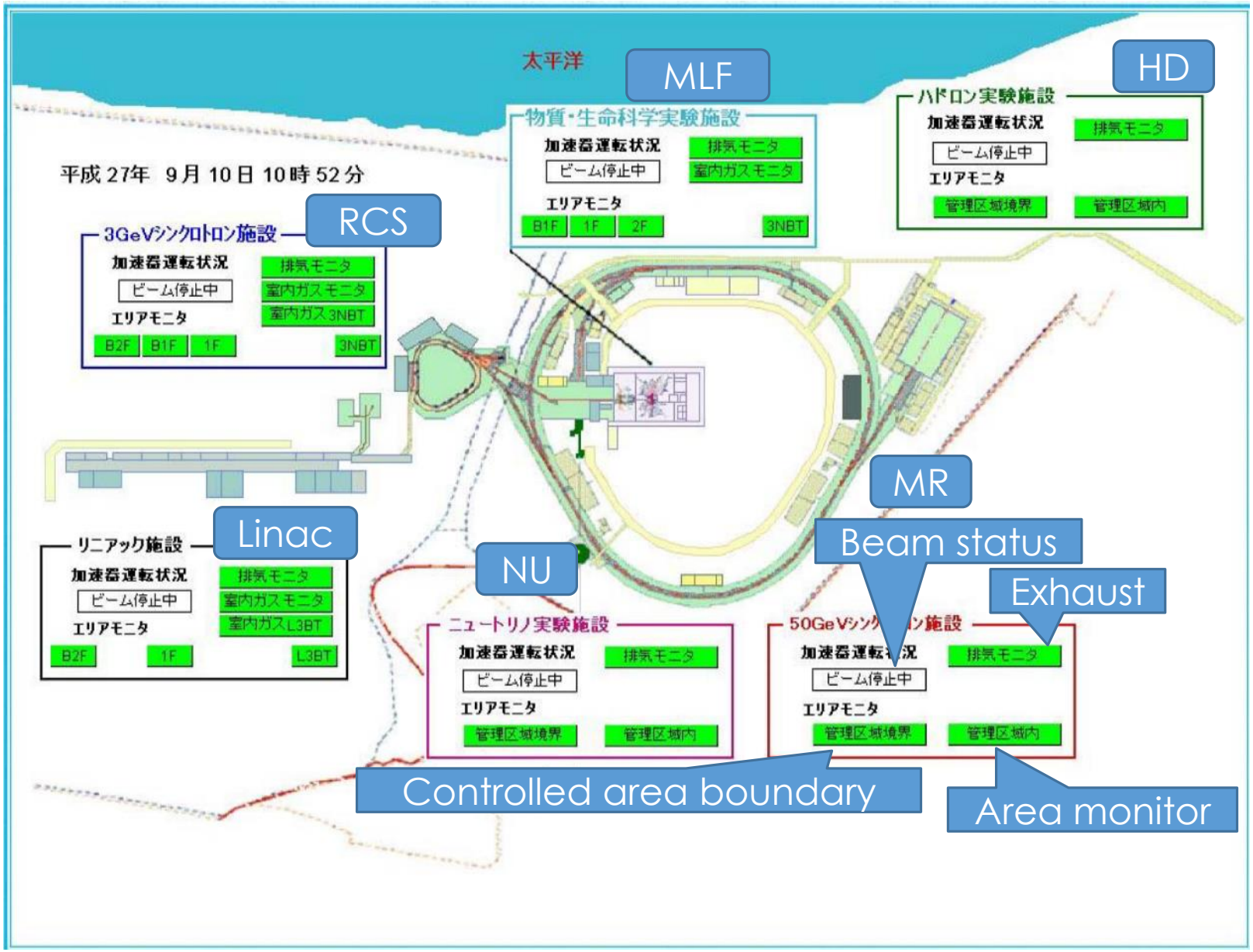
# Threshold Level for Airborne Activity

- Room gas monitor (independent from legal limit)
  - Warning: Normal operation x 2
  - Alarm : Warning x 5 (normal x 10)
- Exhaust gas monitor
  - Warning: J-PARC concentration limit
    - Continuous 3 month exhaust with same concentration exceed J-PARC limit (but still 1/50 legal limit)
  - Alarm : Warning x 10
- Exhaust dust monitor (Trapped on filters)
  - Warning: Normal operation x 2
  - Alarm : Warning x 5 (normal x 10)

# Integrated Monitoring System



# Monitoring and Alarm Display Image



# Summary

- Accelerator facilities in laboratory of nuclear facilities
  - In case of emergency, J-PARC must act as a part of NSRI
- Zoning and access control to controlled areas
  - Criteria in J-PARC are severer than legal limits in Japan
  - As increasing the beam power, zoning have been changed
- Confinement of airborne activity
  - Air is confined in the accelerator tunnel during operation
  - Air in the MLF is maintained by gradual negative pressure management
- Radiation monitoring system
  - Thresholds for alarm are determined in accordance with the center-wide policy