Radiation Protection at J-PARC Neutrino Experimental Facility and Lessons Learnt

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Radiation Protection:

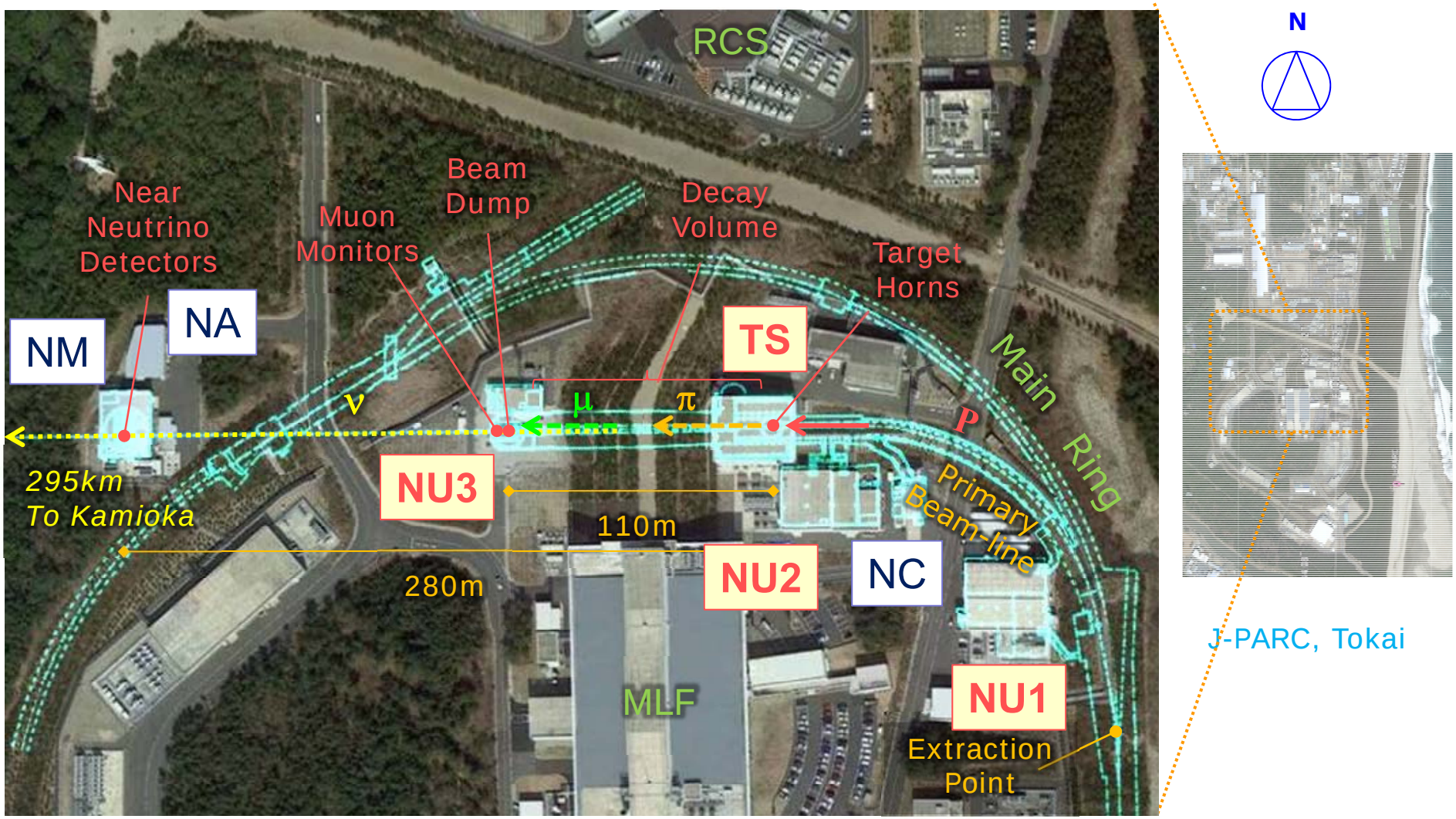
Critical Limiting Factor on HPT Facility Operation

- On the way of designing J-PARC neutrino facility, we thought capacity of beam intercepting devices - target, beam window, electromagnetic horns and beam dump - will limit the acceptable beam power and operation.
- However in reality, radiation protection / safety issues become comparable or even severer limiting factors.
- As examples I will describe tough lessons learnt at J-PARC neutrino facility:

Radioactive air ventilation/exhaust

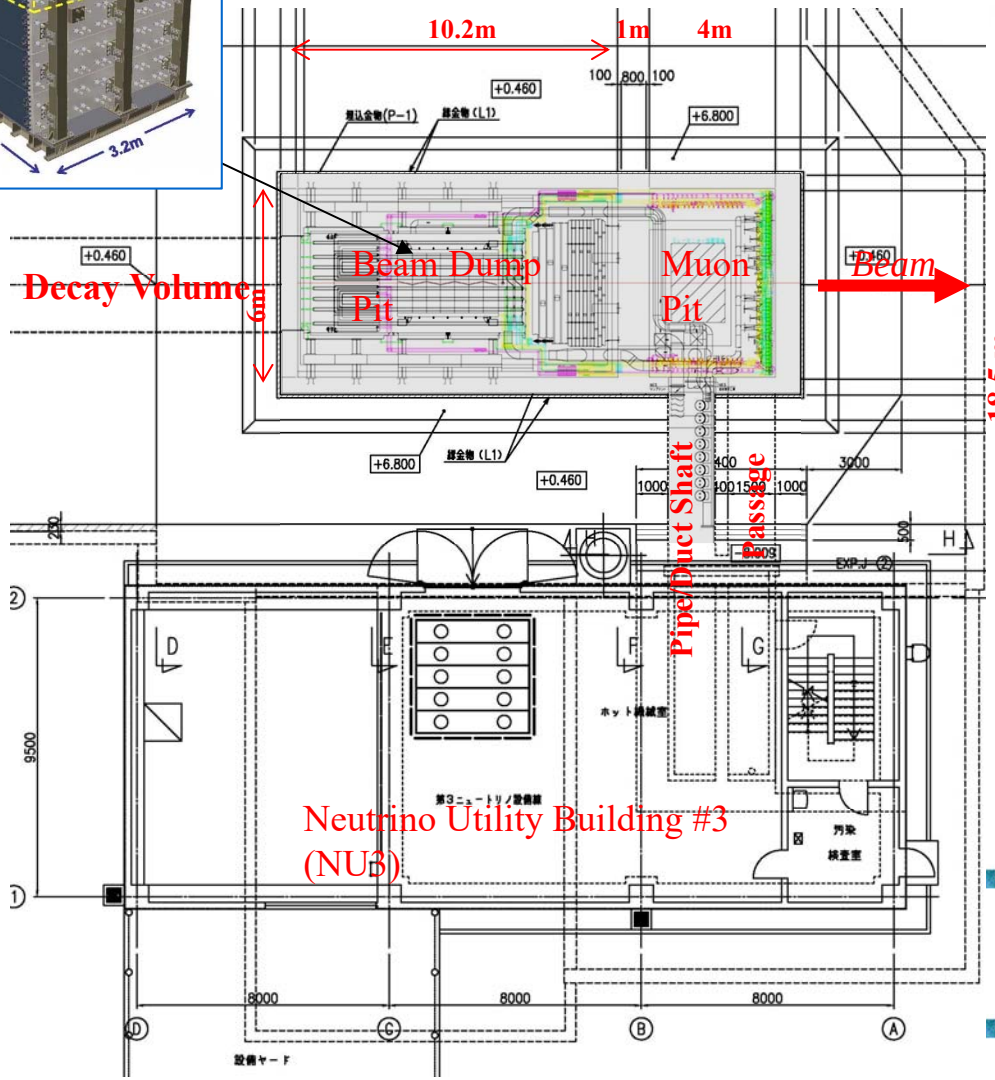
Disposal of tritiated cooling water

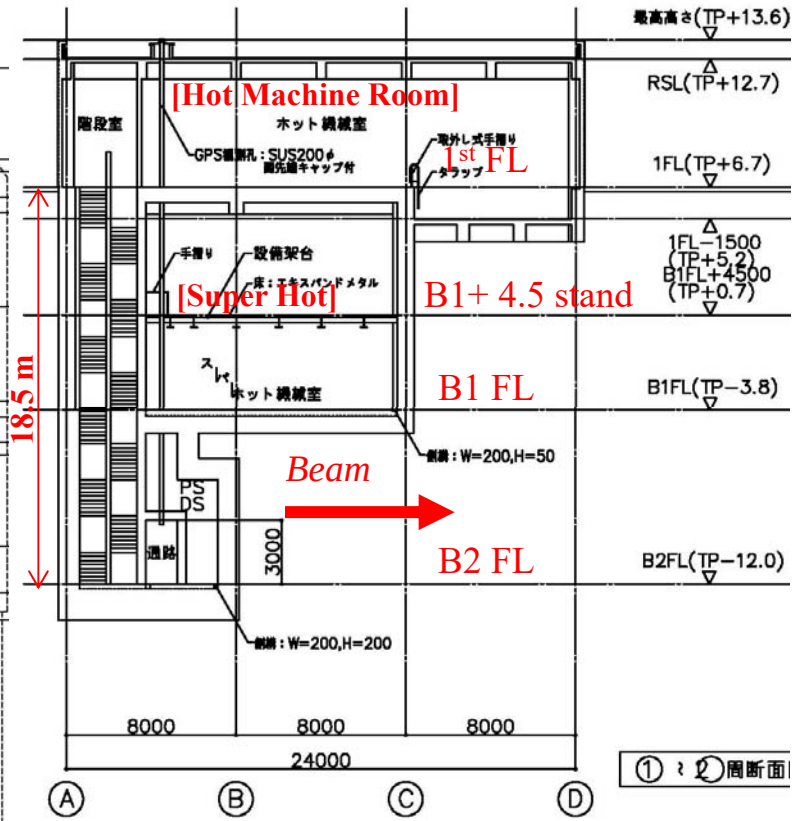
J-PARC Neutrino Experimental Facility



- **TS: Targt Station, NU: Neutrino Utility building**

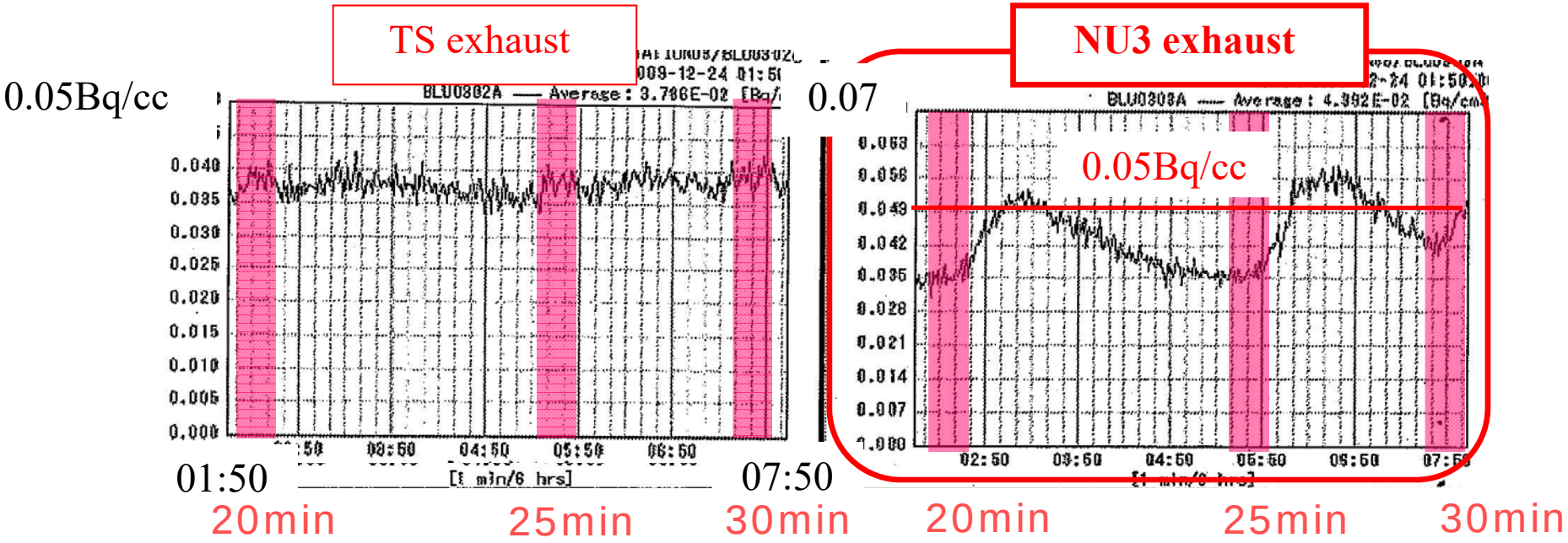
NU3: Neutrino Utility Building #3





- Water circulation system for downstream half of DV and BD [B1]
- Air circulation system for BD / MuPit [B1+4.5]

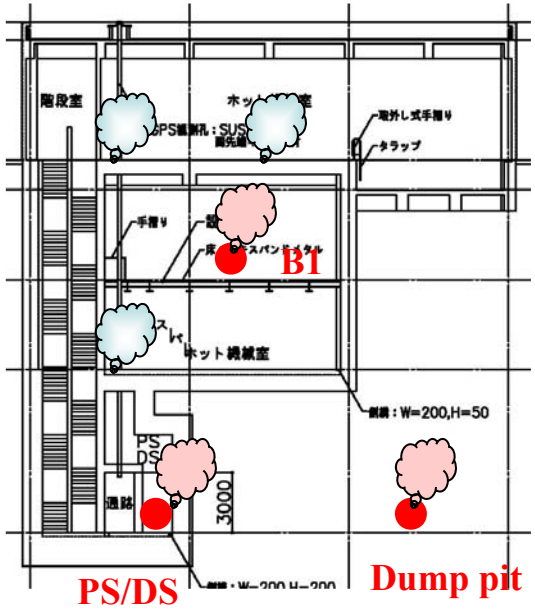
Exhaust monitor signal (Dec.24, 2009)



- The first continuous (only 20kW) beam
- NU3 exhaust signal: Alert level= 0.05Bq/cc(Raw data) ⇔ Observed 0.06 Bq/cc
  - **Beam operation was limited within only ~30min due to the radiation in the exhaust air.**

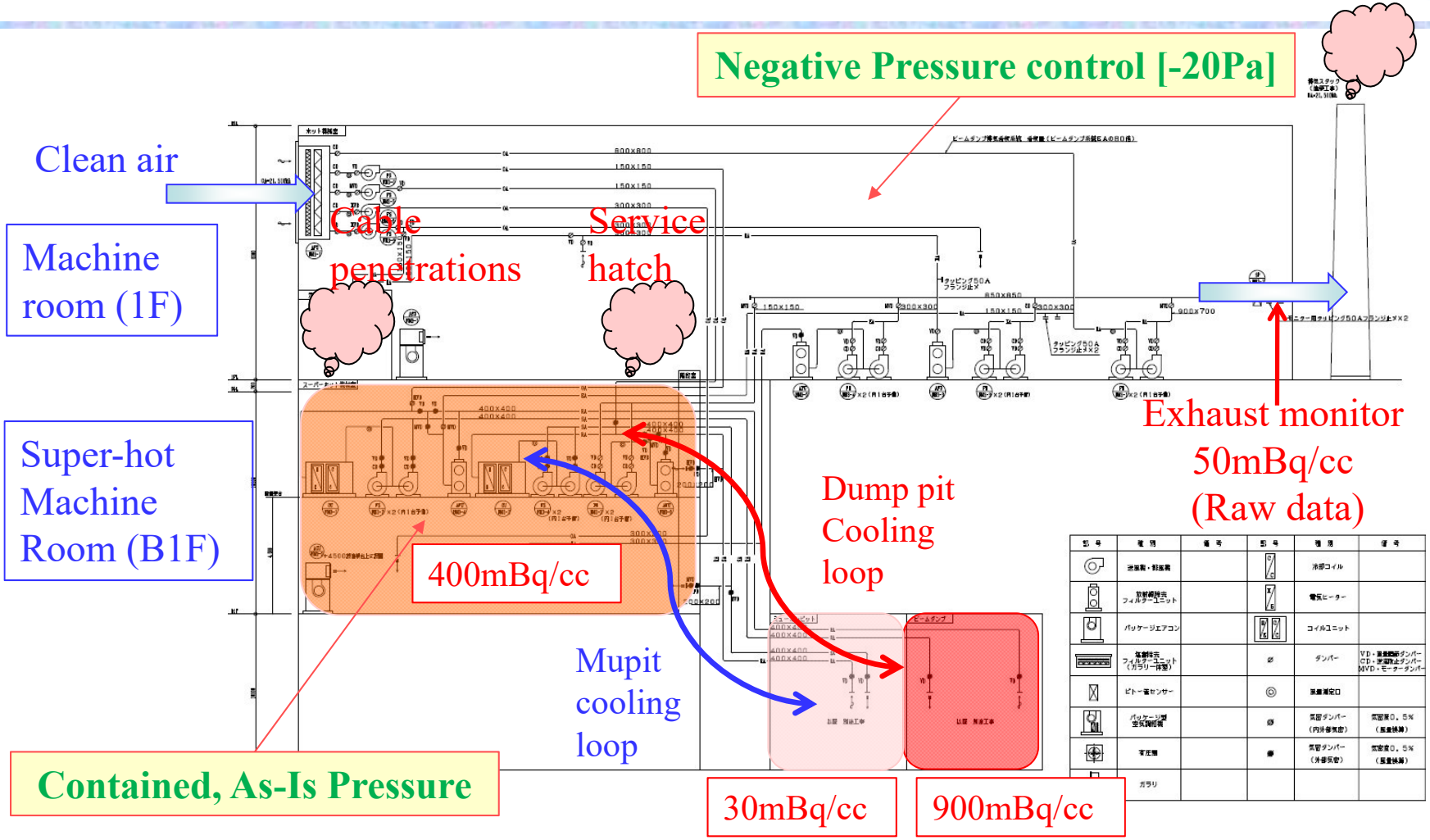
Smoke Test

- Test with a smoke machine, normally used for theater plays !



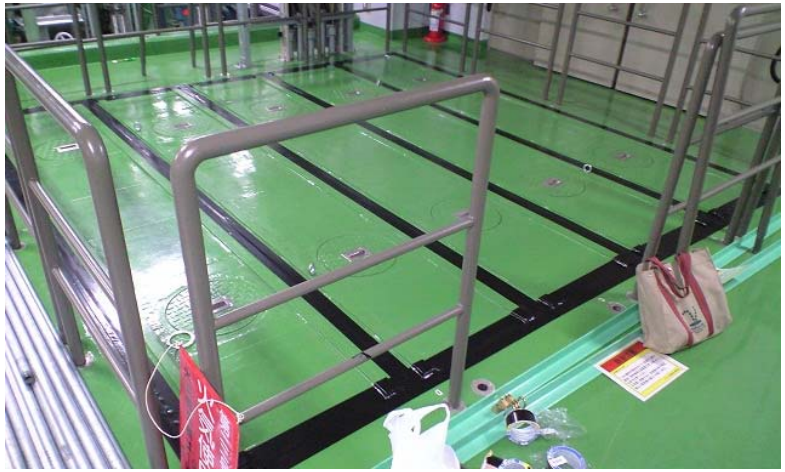
- B2 PS/DS ⇒ smoke around heat-retention of square-ducts / penetration of cable bundles
- B1 ⇒ around service hatch / penetration of cable bundles

Flow of the Irradiated Air at NU3



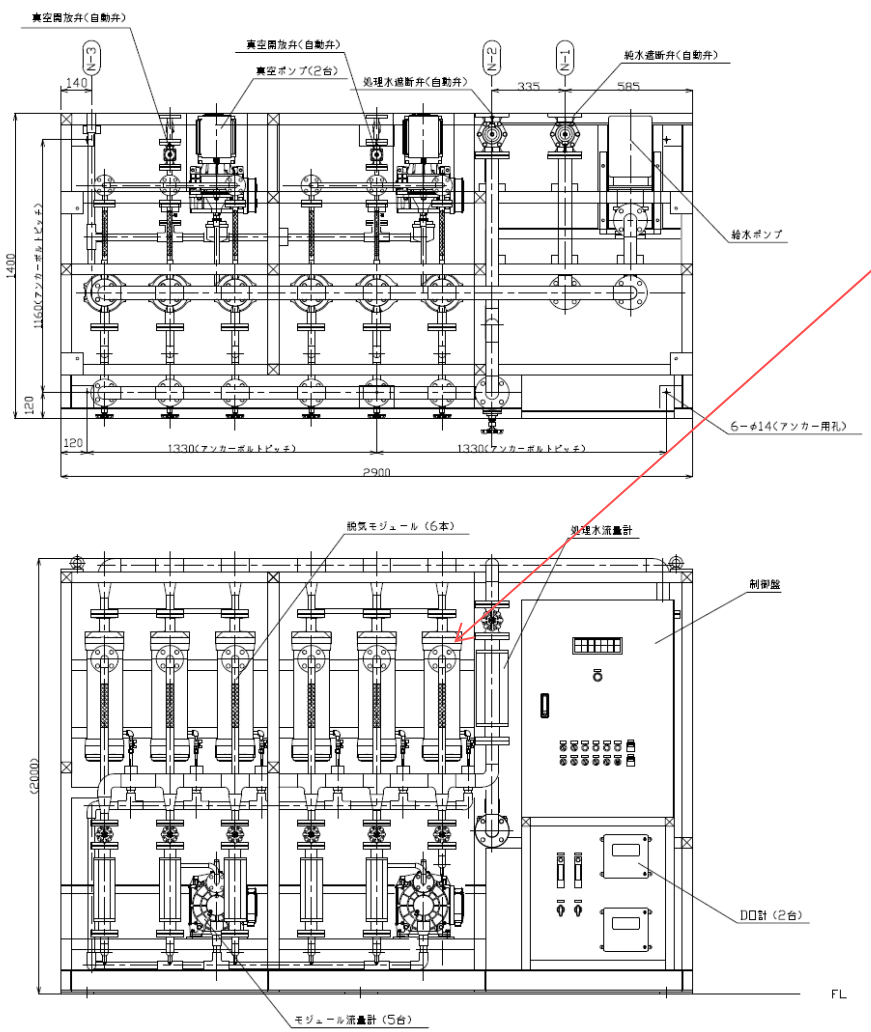
- Environment air monitor suggests that irradiated air was leaked into super-hot machine room from ~~(air-tightened) dump pit cooling loop~~.
- [Most probably from degasifier of radioactive cooling water]
- The air is going into 1F through service hatch and cable penetrations

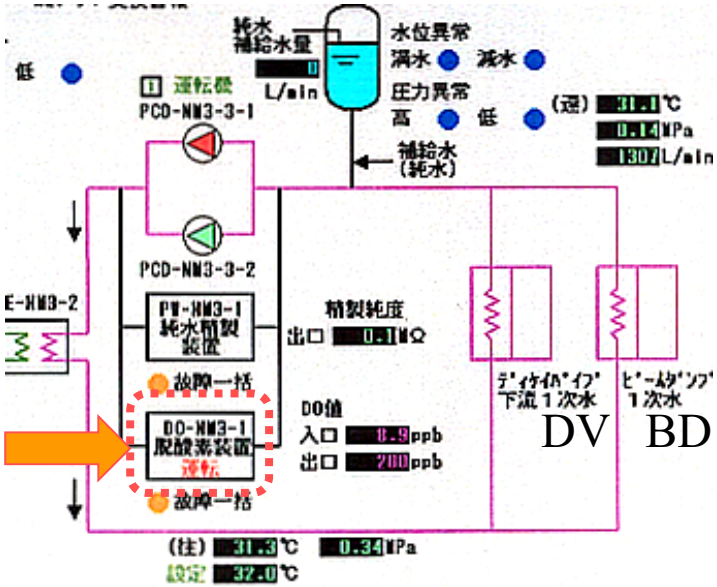
Air tightening (NU3)



- Remove insulation around ducts → seal with thin iron plates and caulking
- Liquid silicone glue for the cable penetrations
- Seal edges of concrete blocks at the delivery entrance to downstairs
- Doors sealed with tape, repeat smoke tests to find remaining leaks

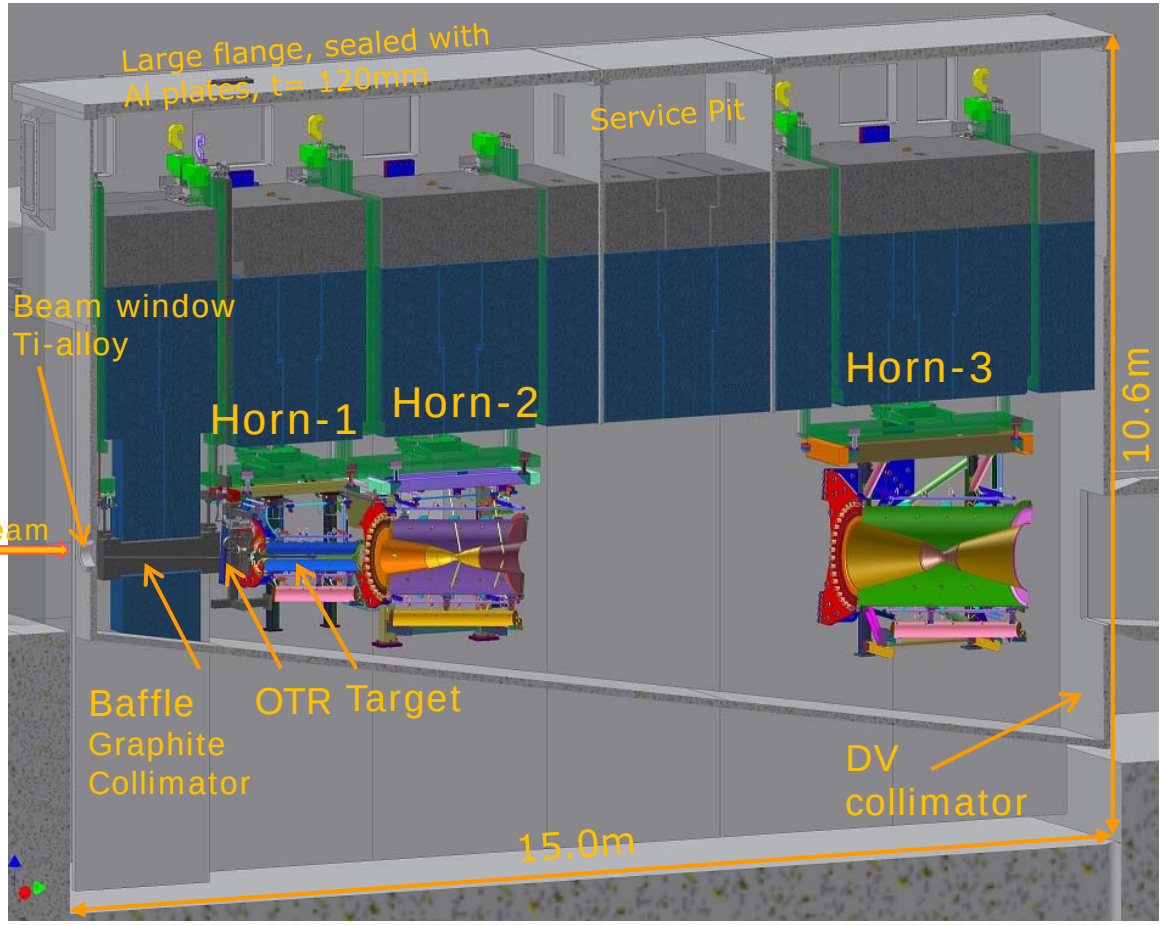
Degasifier in BD/DV cooling water circuit

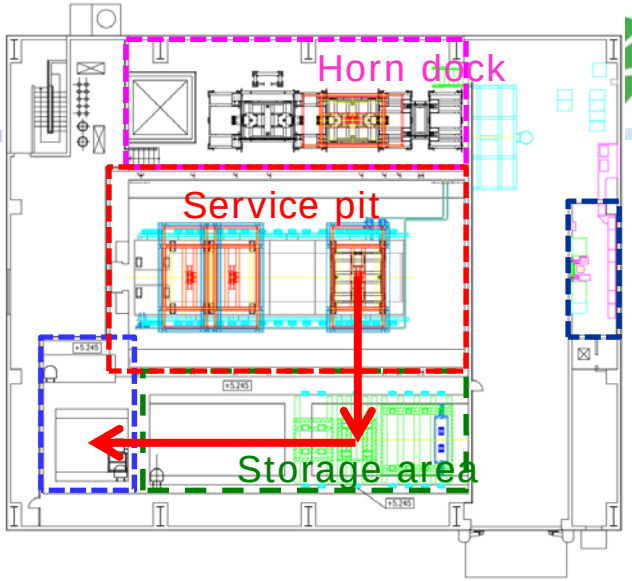


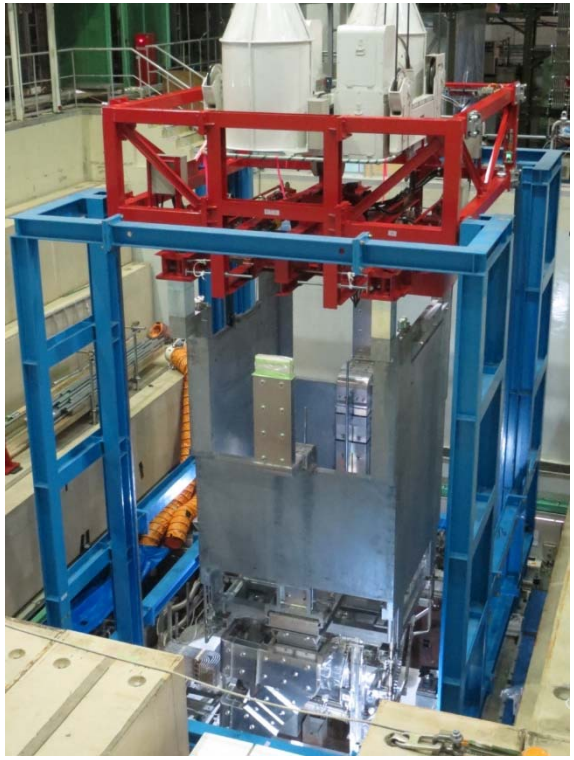


- **Guess: Exhaust from pumps (evacuating hollow fiber membrane filters) may contain radioactive gas from cooling water**

Target Station (TS)





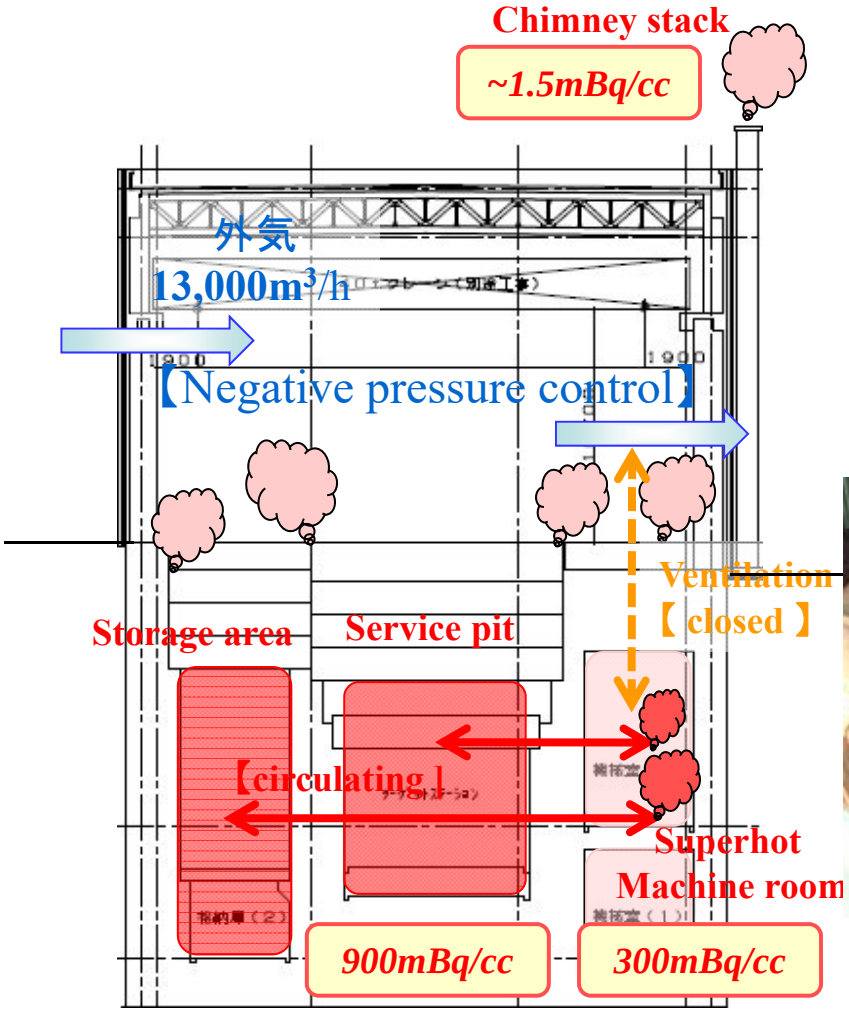


- 3 electromagnetic horns / a baffle are supported from the wall of vessel by support modules.
- Apparatus on the beam-line are highly irradiated after beam. Remote maintenance is the key issue.

Flow of the Irradiated Air at Target Station

Jan. 2010 20kW beam

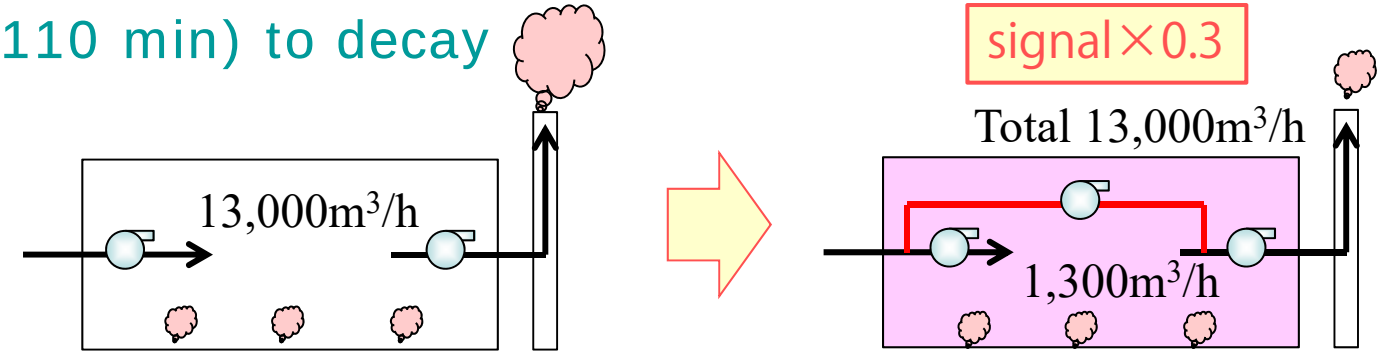
⇔ law : *0.5mBq/cc*
[3month average]

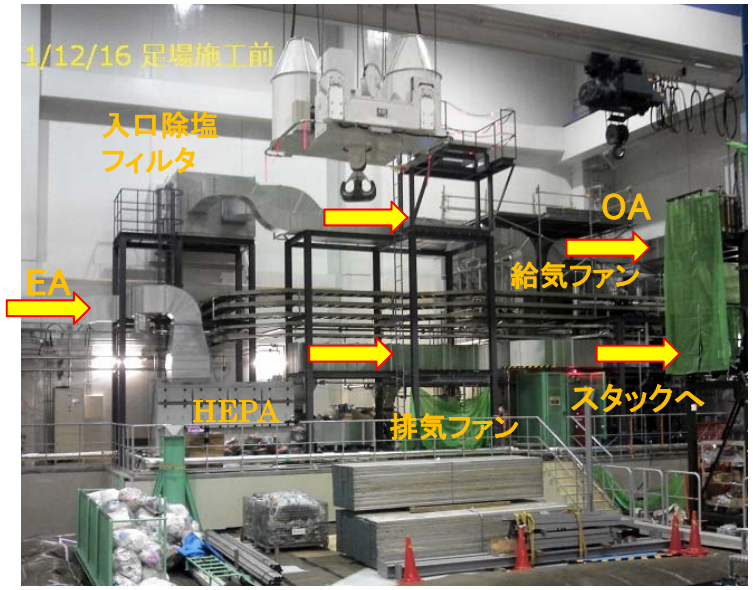


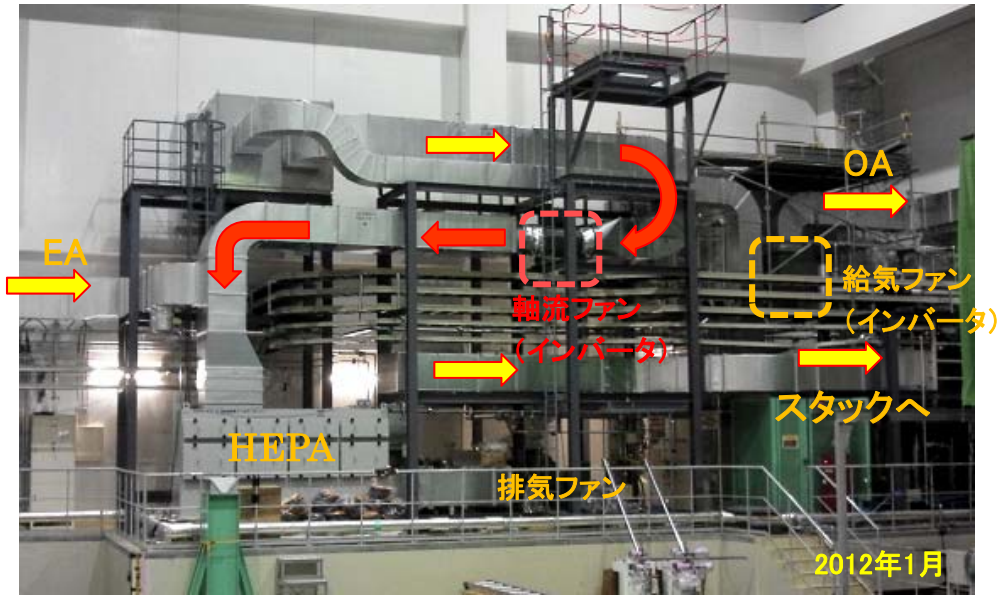
TS 1F Bypass Ventilation

- Reduce ventilation flow to 10% w/o changing total flow

⇒^{41}Ar (110 min) to decay

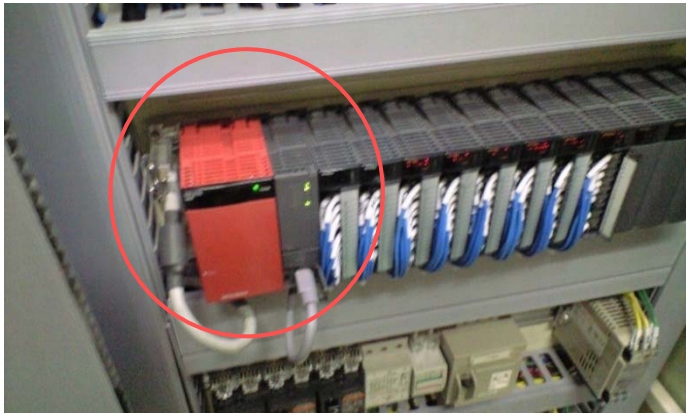


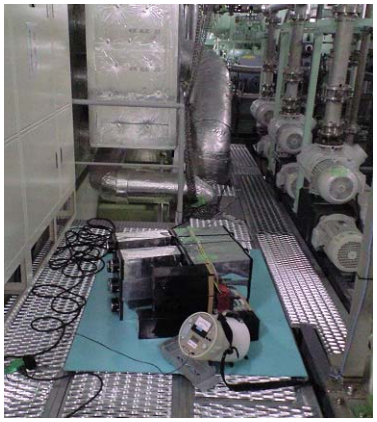


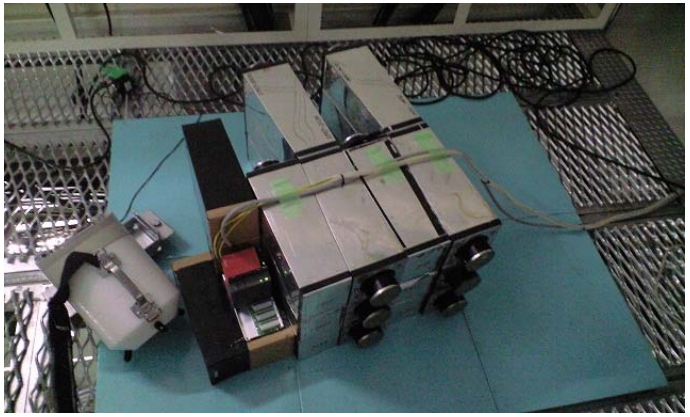


- Exhaust signal　：0.4mBq/cc@130 kW ⇒ 0.13mBq/cc
- 0.1mBq/cc(190kW)　⇒ 950kW acceptable !

Stop of ventilation system by single event upset (2010 April)

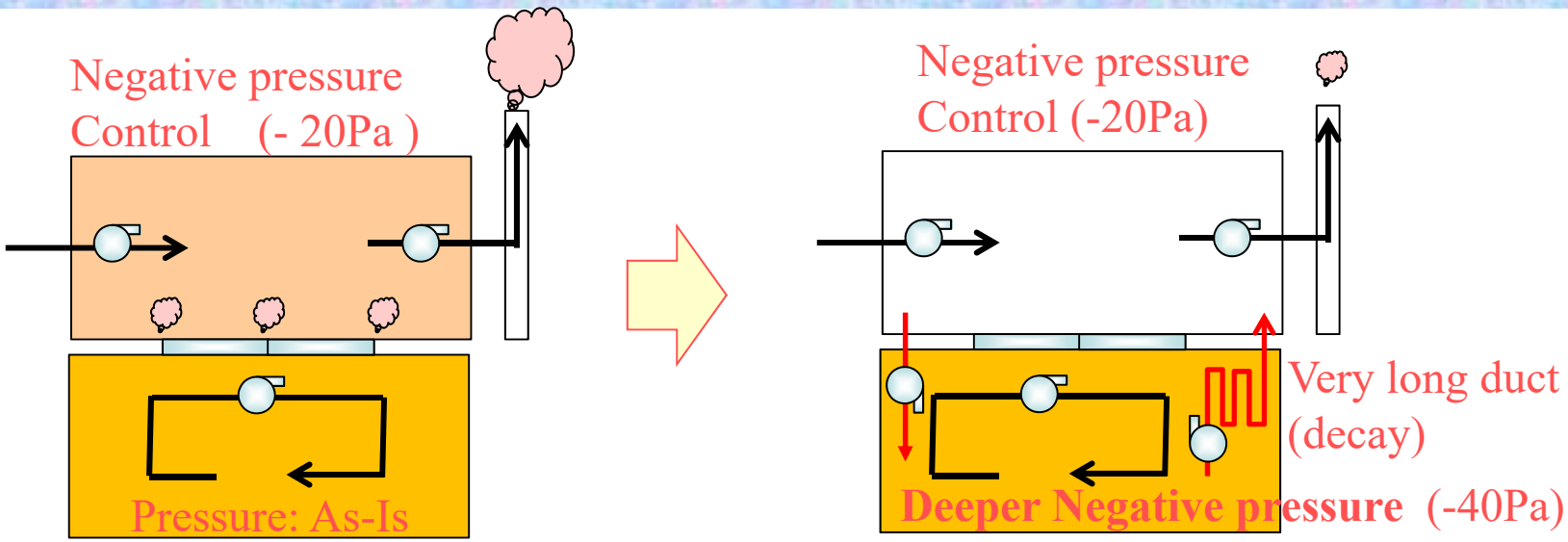


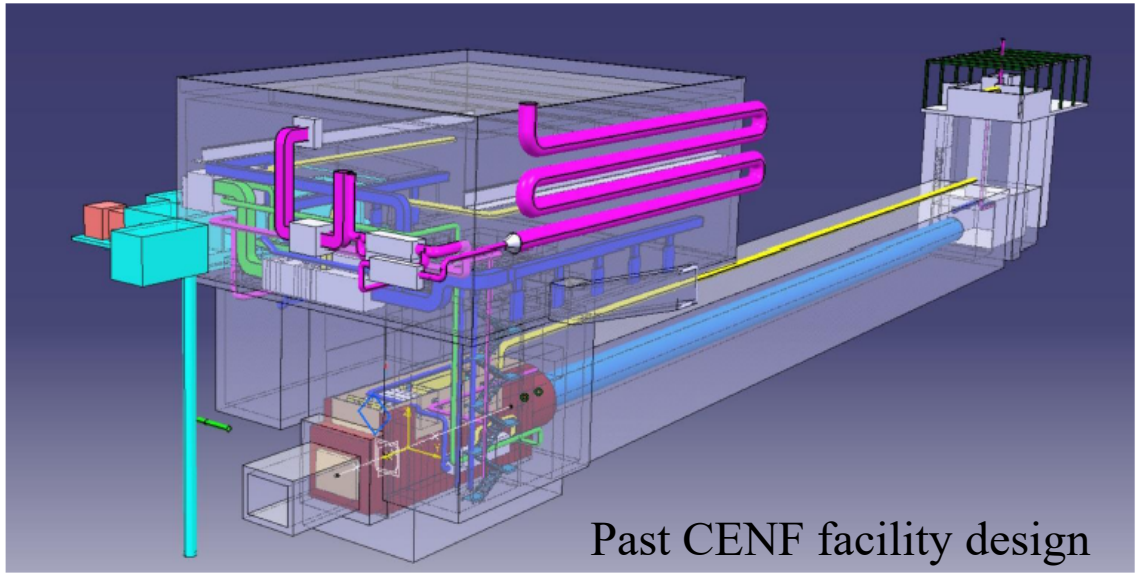




- The control panel was located in B1F machine room, since limitation of 1F floor space. (Later we noticed it was around the level of target..)
- "Single event upset" on a CPU unit of the PLC by beam-induced fast neutrons.
- As temporary fix during Run-1, extract / relocate the CPU unit by 10m to area with less neutrons, then covered with LG blocks.
- Whole control panels of air-conditioning/cooling water at TS moved to the ground floor in 2010, summer.

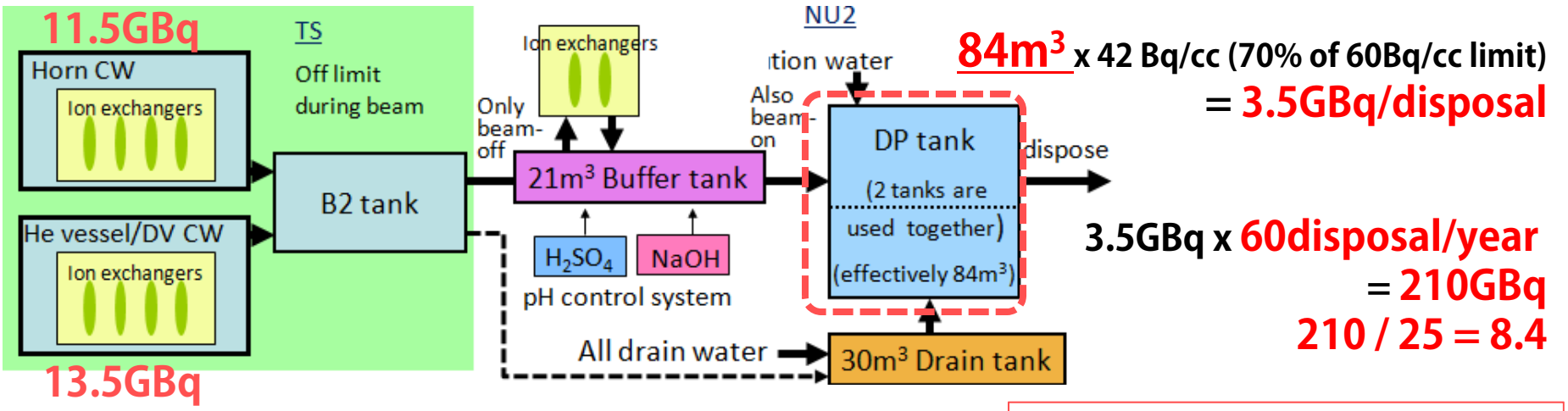
Nested negative pressure control





- It can be very standard idea at reactor facilities (JAEA ?)
- Worth to introduce to J-PARC

Radioactive cooling water drainage @ NU2



84m³ x 42 Bq/cc (70% of 60Bq/cc limit)
= **3.5GBq/disposal**

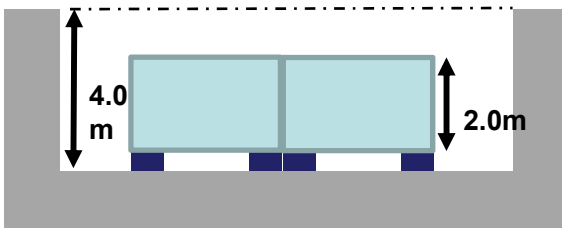
3.5GBq x **60disposal/year**
= **210GBq**
210 / 25 = 8.4

25GBq HTO produced per 1x10²⁰POT
In Horn/TS He Vessel/Decay Volume Cooling Water

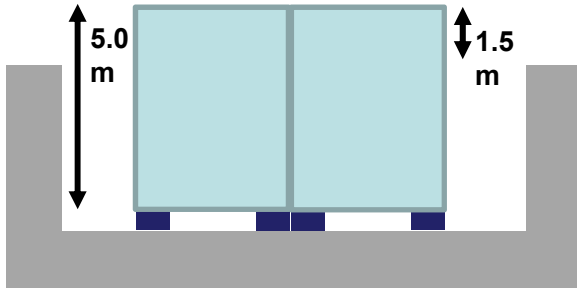
8.4x10²⁰ pot / year
(400kW x 10⁷sec)

- **Although radioactive nuclear ions (7Be..) can be removed using ion-exchange resins, there is no way to extract tritiated water (HTO) .**
- **Disposal after dilution under control of Radiation Hazard Prevention Act**
- **Based on the working procedures by current drainage system, it is very hard to deal tritiated water from 750kW operation within the same year.**
  - **750kW x 10⁷sec (116 days) = 15.6x10²⁰pot → 390GBq**
  - **x ~2 larger than current capability**

Radioactive cooling water drainage@ NU2



(5m x 5m x 2m) x 2tanks



(5m x 5m x 5m) x 2tanks

- **Upgrade water dilution tanks to x ~3 larger volume (84m^3→234m^3)**
  - **Piles of the building are not strong enough.**
  - **New facility building with larger tanks ?**
- **3 urgent improvements:**
  1. **Frequency of drainage (every 3d/ 60 times → 2d/90 : 600kWx10^{7}s)**
  2. **Takeover by tank truck (+150kWx 10^{7}s)**
  3. **Shortcut in the circulation system and apply partial dilution**

Rehearsal of tank-truck takeover at NU3.

(Dec. 2015)

1st real takeover took place on Jan. 2016

Summary

- For J-PARC neutrino facility, currently most severe limiting factor on beam power (400kW x 107sec/year) is from limitation on total amount of tritiated water drainage.
  - Improvement scenario is under consideration, which will count for > 700kW operation.
  - In the future MW operation we need new facility building with larger tank.
  - Or, to carry forward (part of) tritiated water to following years by keeping them in the system (risk when water leak happens)
- Radioactive exhaust air is another limiting factor (upgrade successful to accept ~1MW beam)
  - Nested negative pressure control may solve the problem.
- It should be worth to emphasize that facility design wrt. radiation protection, safety, and waste treatment are of vital importance to maximize the benefit of high power target facility.