

Strategies of radon and cleanliness control at JUNO

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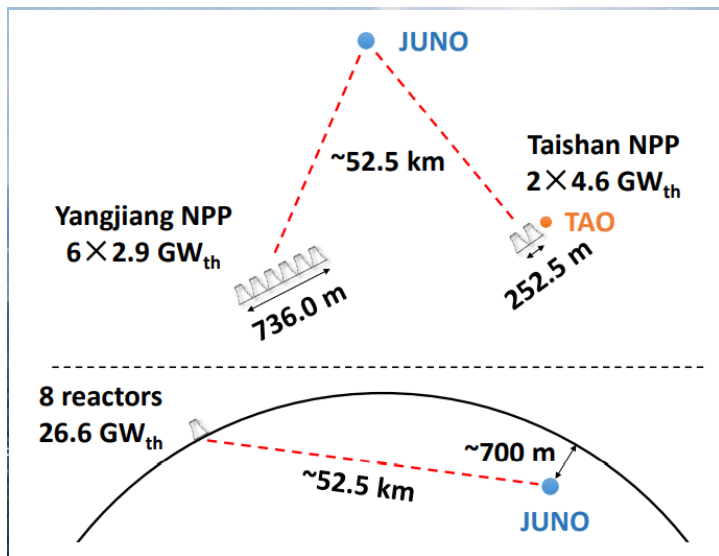
On behalf of the JUNO collaboration



XVIII
International Conference on
Topics in Astroparticle and
Underground Physics 2023

28.08. - 01.09.2023
University of Vienna

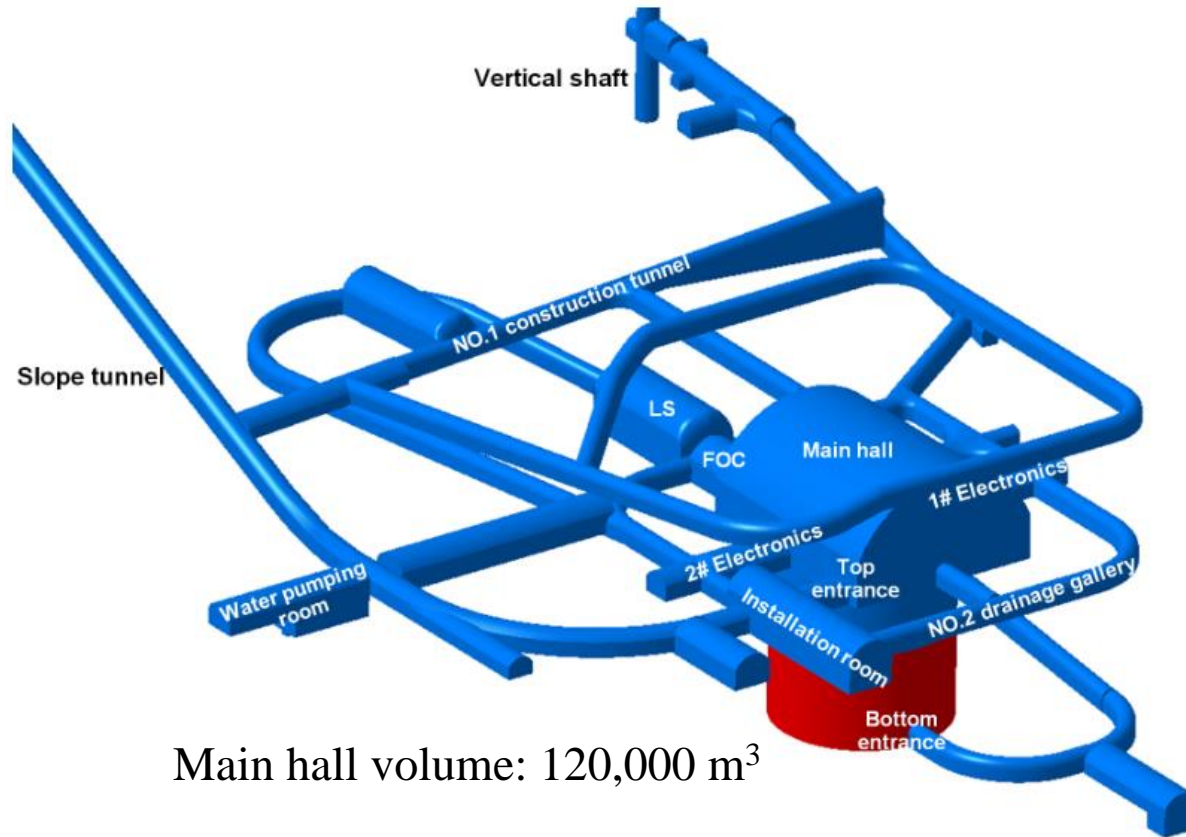
Jiangmen Underground Neutrino Observatory



Layout of the JUNO underground laboratory

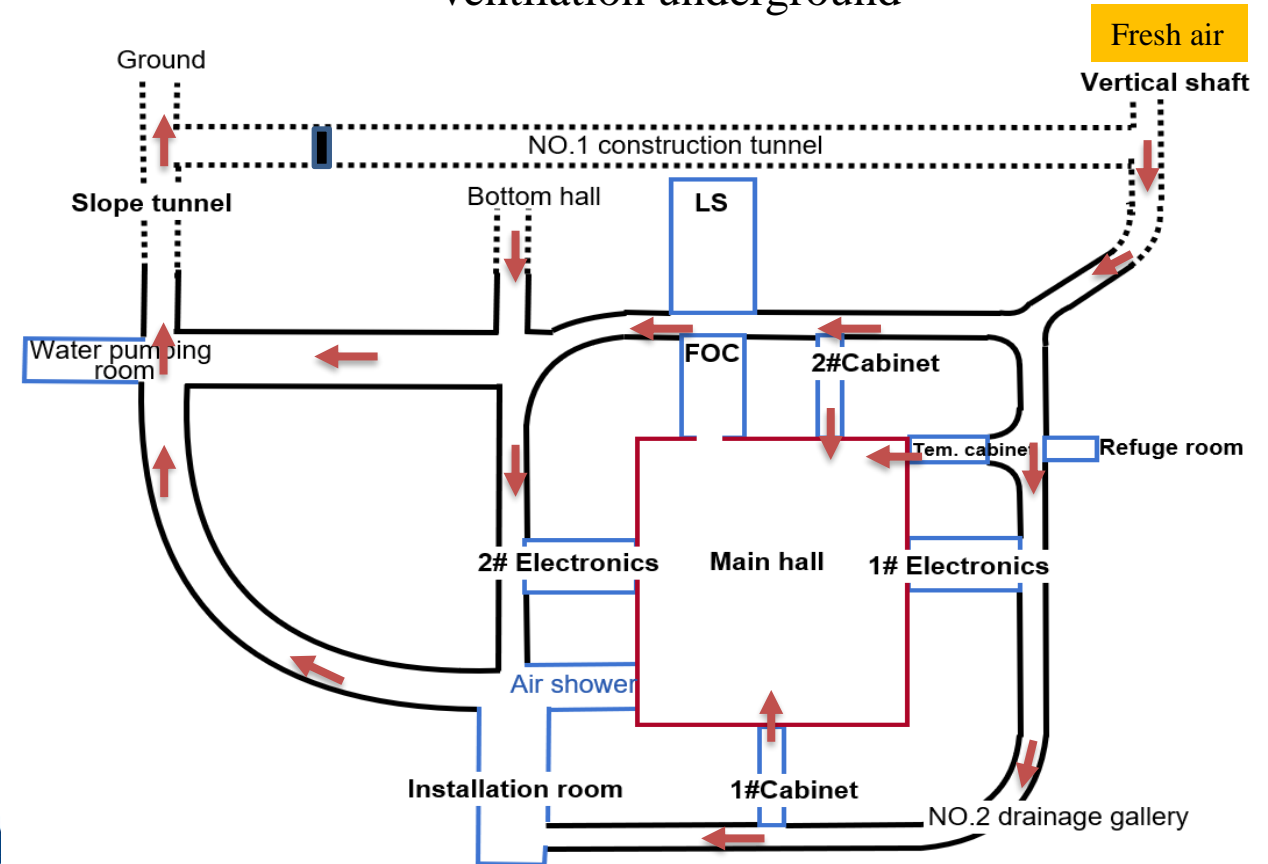


Total underground space: 300,000 m³

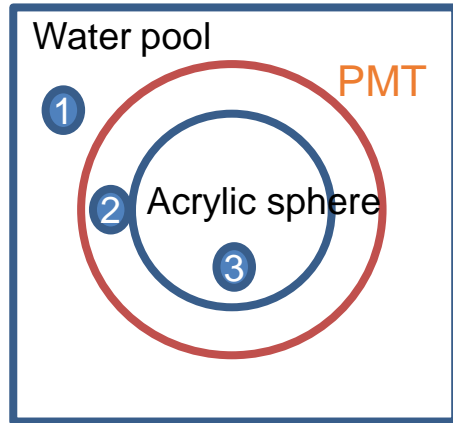


Main hall volume: 120,000 m³

Ventilation underground



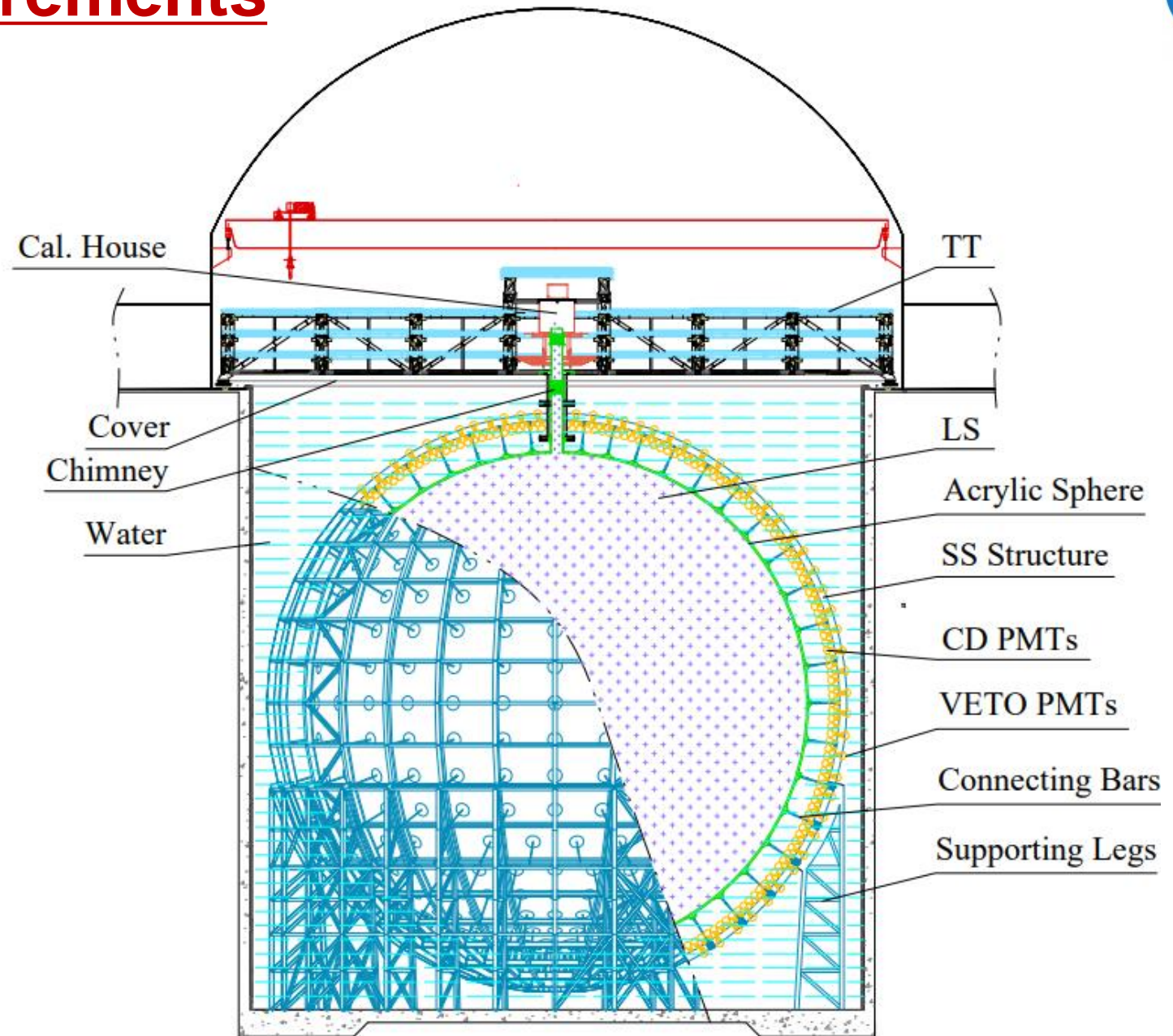
Environment requirements



Region	Level
1	Class 100,000
2	Class 10,000
3	Class 1000

Temperature: $21^{\circ}\text{C} \pm 1^{\circ}\text{C}$

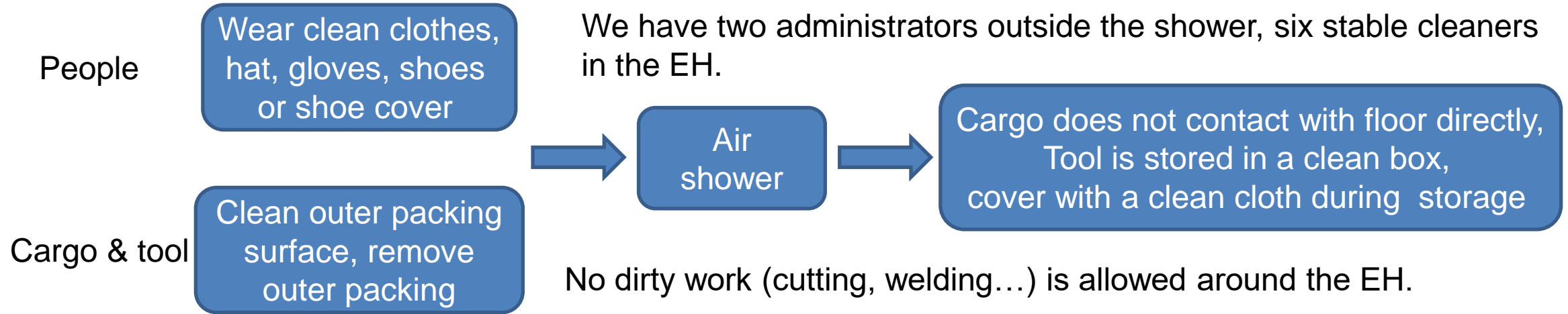
Radon concentration in air: 100 Bq/m^3





Cleanliness control at JUNO site

Basic principle for the Experimental Hall (EH)

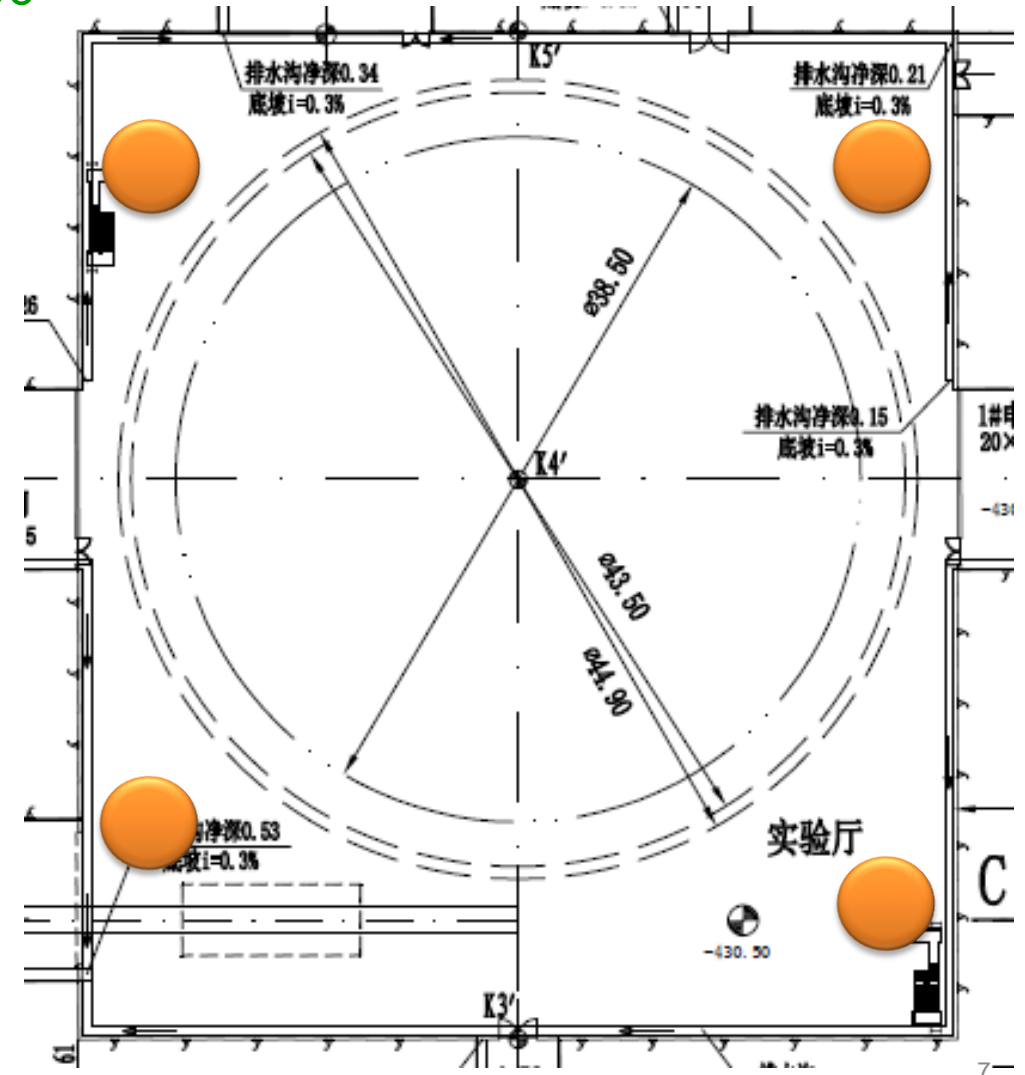


Ventilation inside the EH



■ Four temporary cabinets are installed on the corners of the top hall

- ✓ Three-stage filters → outlet air quality: Class 1000
- ✓ Ventilation speed: 200,000 m³/h



PMT installation



Acrylic installation

■ Installation environment:

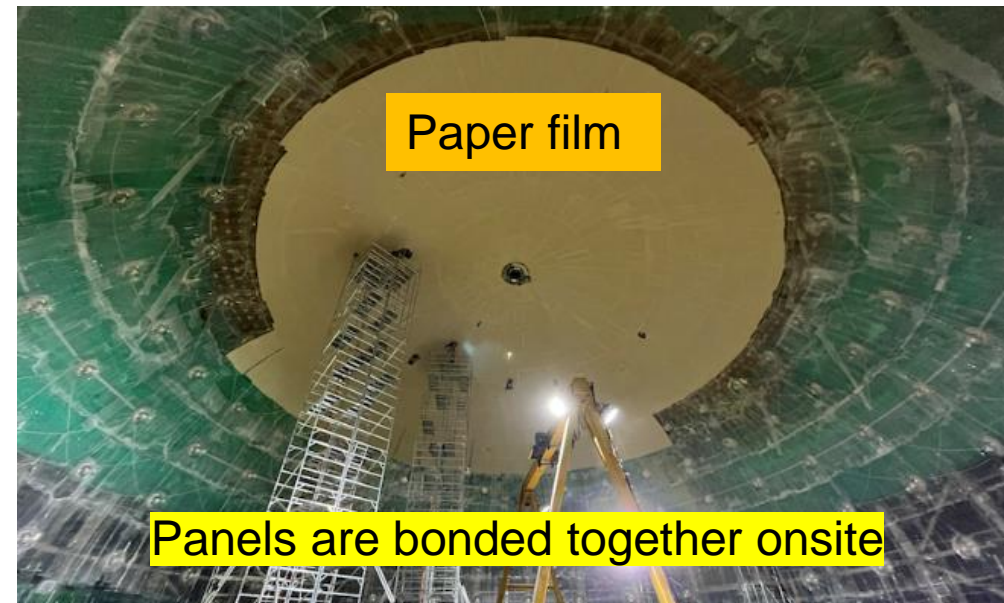
- ✓ A pipe with 0.7m diameter from the cabinet (with three stage filters) outlet to chimney to inlet best air (fewer particles, low temperature)

■ Surface treatment after bonding:

- ✓ Sanding to 3000 mesh + deionised water polishing + deionised water cleaning

■ Protection:

- ✓ Inner surface (Polyethylene → paper with water soluble glue)
- ✓ Outer surface (Polyethylene → removed after equator layer)

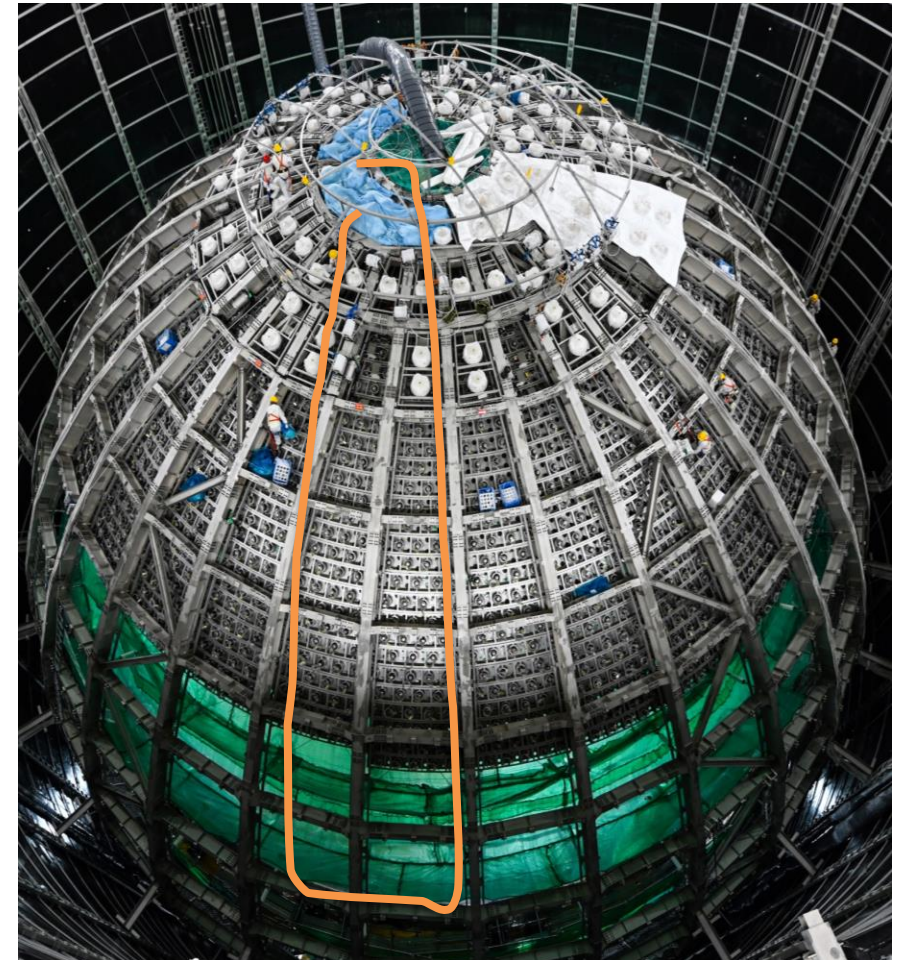
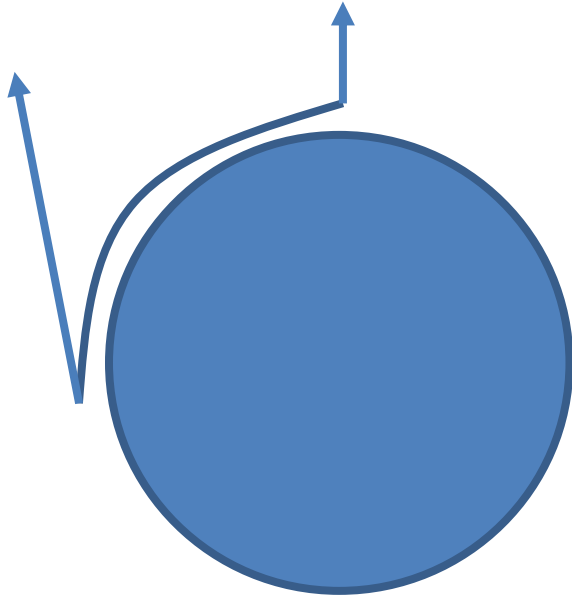


Special protection of installed veto PMTs



■ Veto PMTs will be covered with clean cloths to avoid dust deposition on the surface

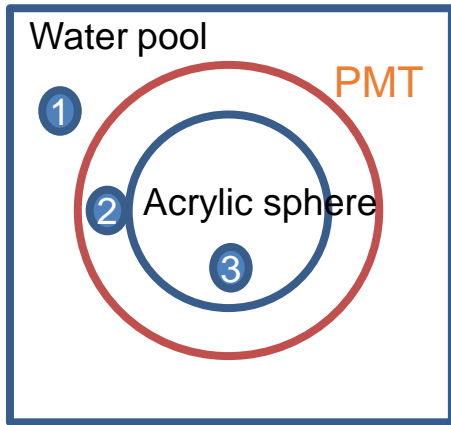
- ✓ Cloth: same with that used in the clean room, about 61 kg
- ✓ Installation: fasten on magnetic field shielding coil, total ten pieces
- ✓ Remove: unravel the rope from north pole by person, lift the cloth by overhead travelling crane, together with some rope



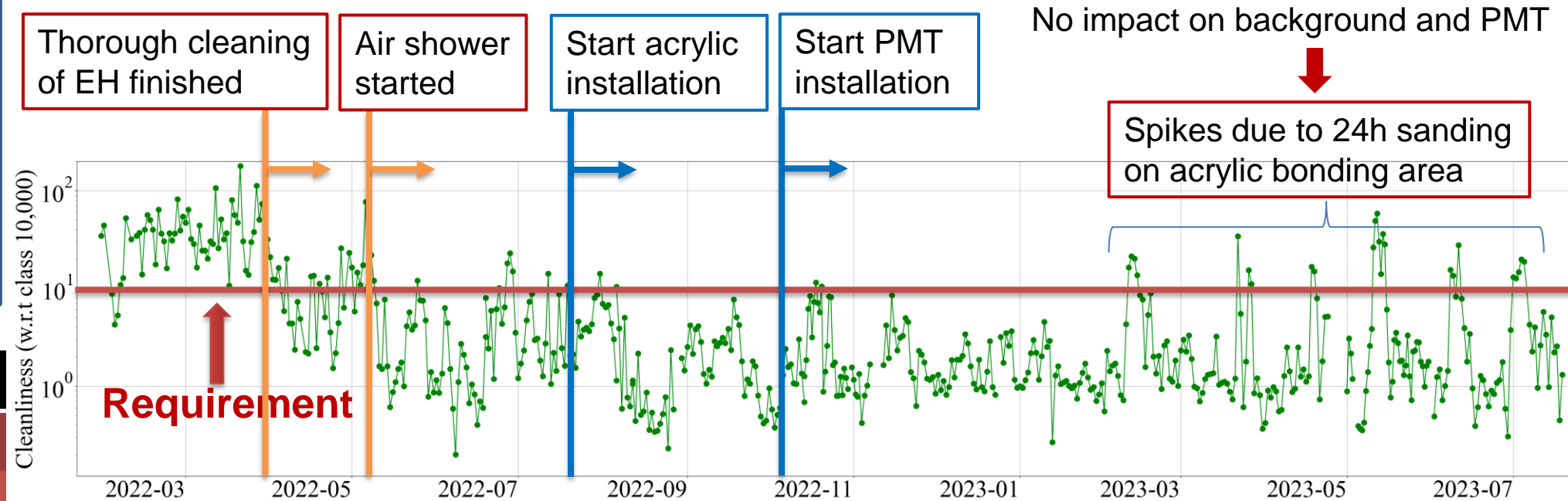
Onsite cleanliness monitoring



■ Region 1



Region	Level
1	Class 100,000
2	Class 10,000
3	Class 1000



Calculation method of cleanliness Y-axis: total volume of real-time monitored particles divided by the Class 10,000 level particles

Temperature: $21^{\circ}\text{C} \pm 1^{\circ}\text{C}$

The overall cleanliness inside the EH have reached our requirement since May 2022.

■ Region 2

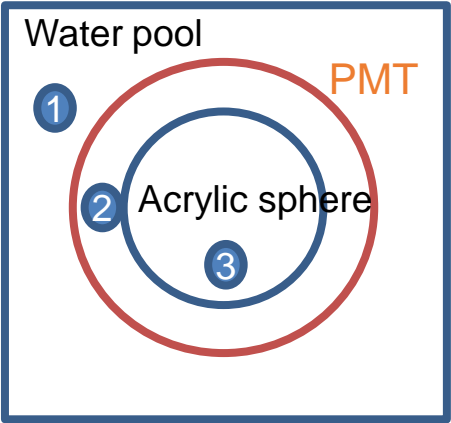
Most of the time, the average dust cleanliness is around Class 10,000, so no special ventilation in the gap between acrylic and PMT modules

Environment inside acrylic



Region 3

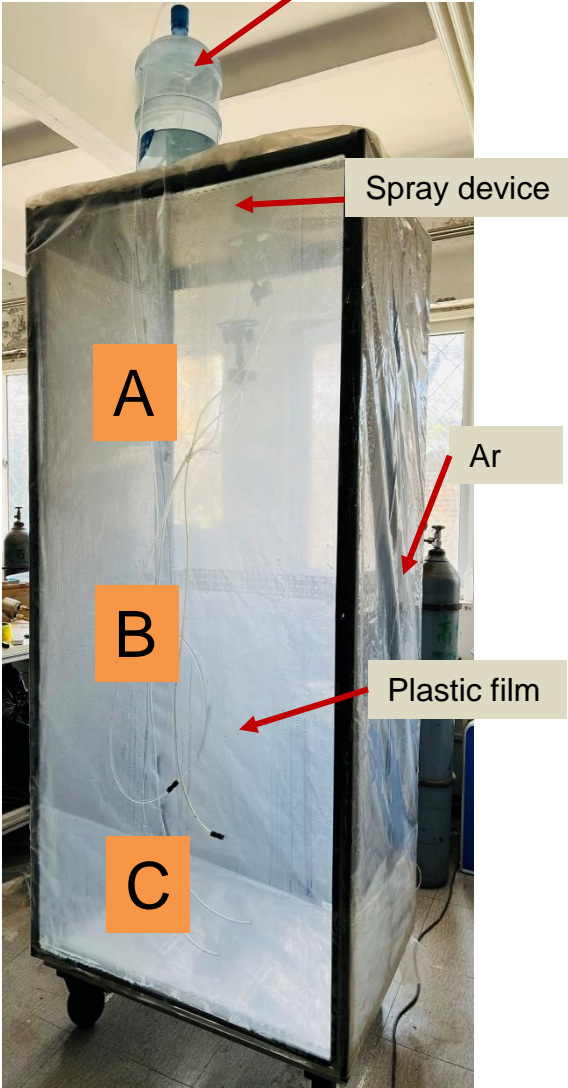
- ✓ After installation: seal the sphere and spray inside the sphere
- ✓ Preliminary result in lab: spray can reduce the particles in air by 2-3 orders
- ✓ Add some anionic surface active agent can increase the agglomeration of dust particles, for example, SDBS



Region	Level
1	Class 100,000
2	Class 10,000
3	Class 1000

Temperature: 21°C±1°C

Particle measurement		Initial status	A	B	C
Particle size (μm)	Number m ³	Number m ³	Number m ³	Number m ³	Number m ³
	Class 1000				
≥0.1	1.00E+06				
≥0.3	1.02E+05	7.2E+7	3.0E+5	1.6E+5	5.8E+4
≥0.5	3.52E+04	2.9E+7	1.0E+5	7.3E+4	3.2E+4
≥1	8.32E+03	1.1E+6	3.2E+3	7.0E+3	1.1E+4
≥3		3.3E+5	0	0	2.8E+3
≥5.0	2.93E+02	5.6E+4	0	0	0
≥10	0	1.6E+4	0	0	0

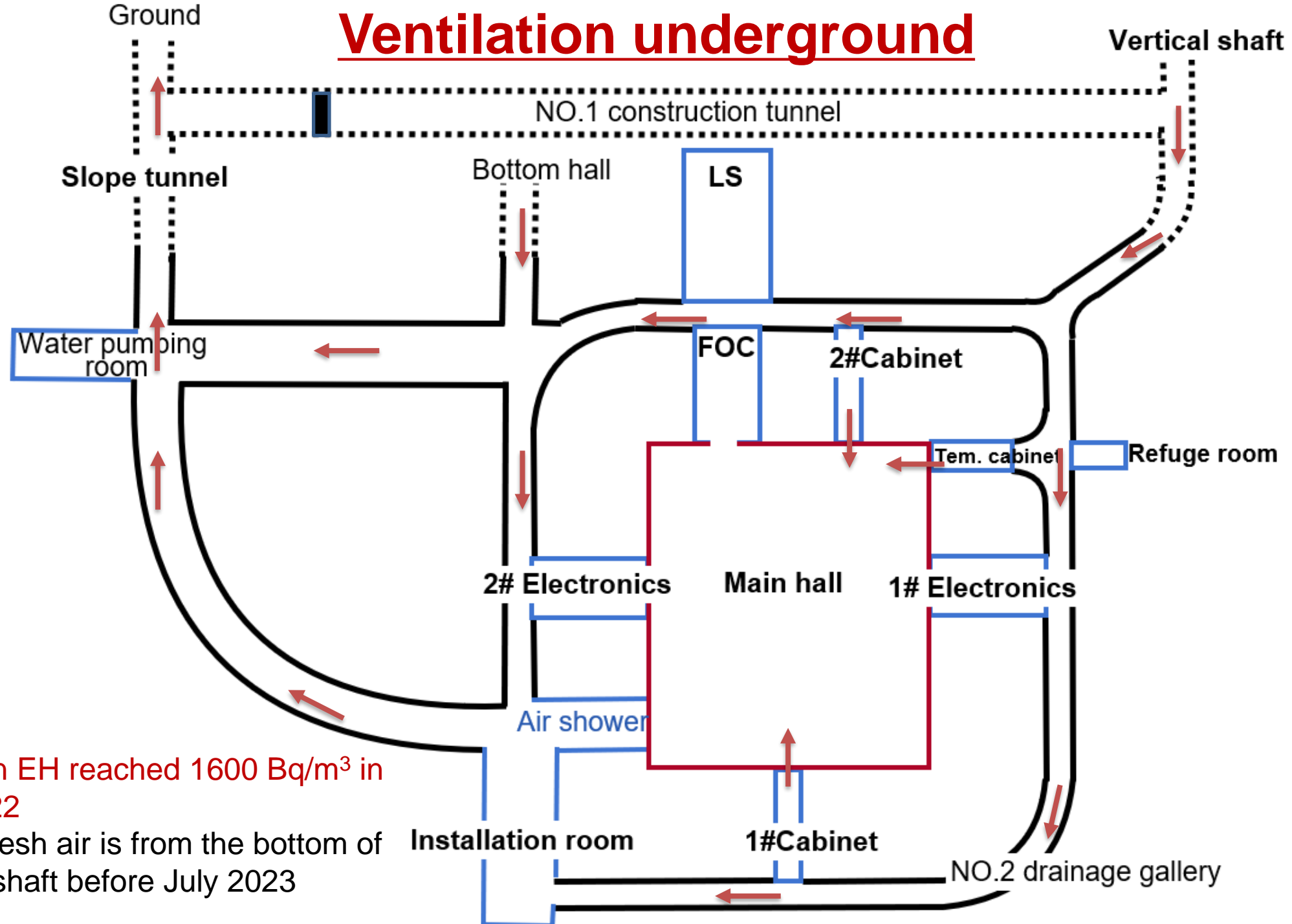


Experimental model



Radon control at JUNO site

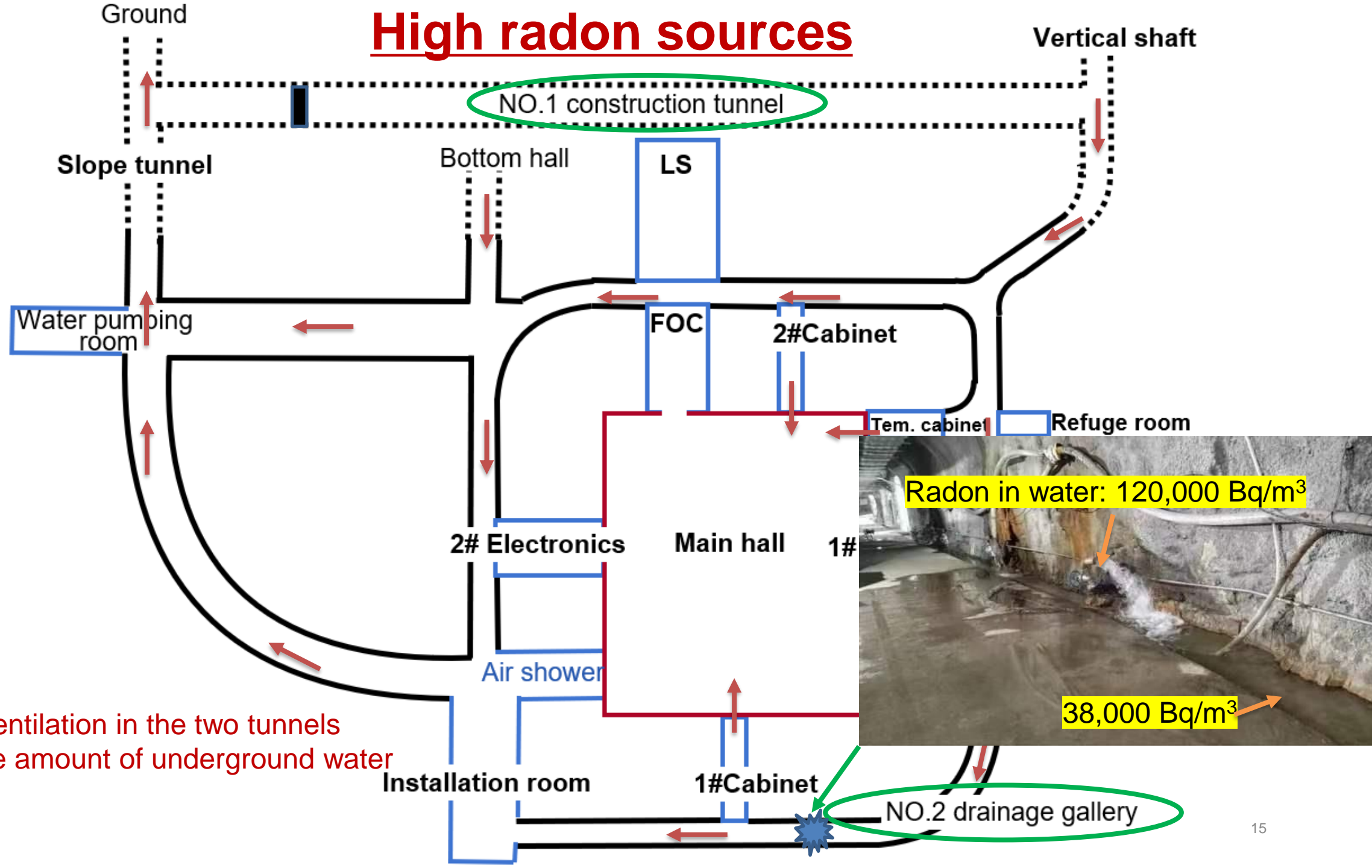
Ventilation underground



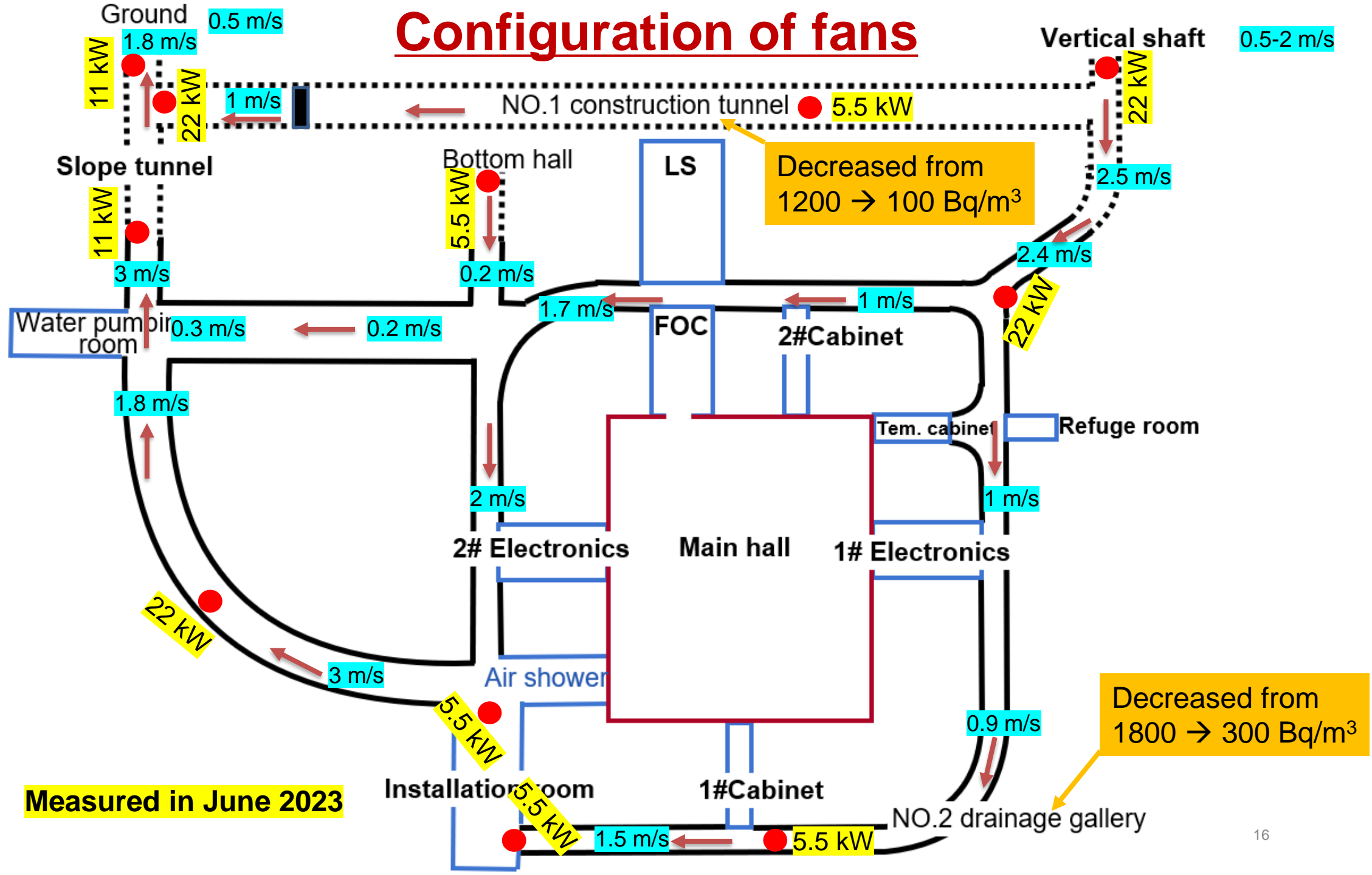
Radon in EH reached 1600 Bq/m³ in May 2022

All the fresh air is from the bottom of vertical shaft before July 2023

High radon sources



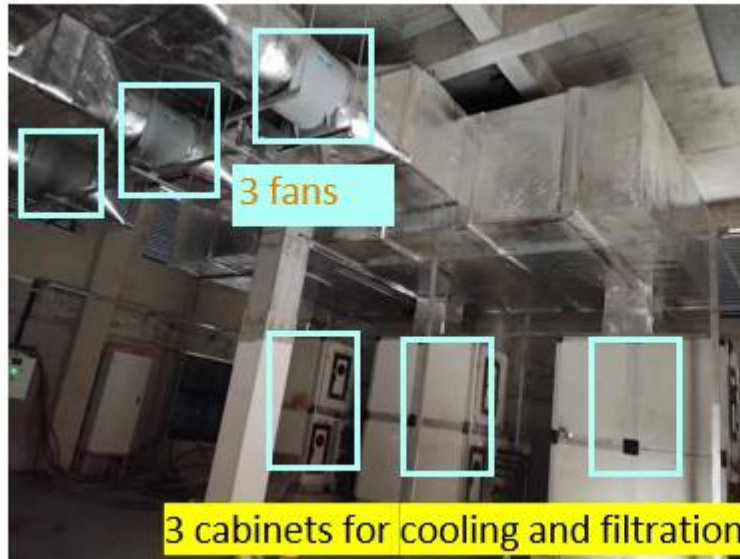
Configuration of fans



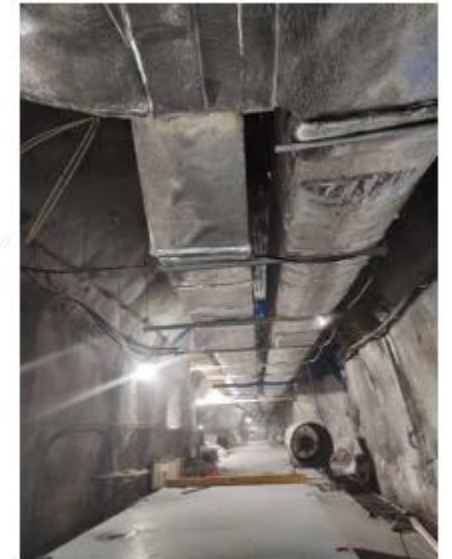
Vertical shaft

■ **Construction time:** from April to June 2023 (~3 months)

1. Added air cabinets on the ground



2. Connected fresh air pipe to EH

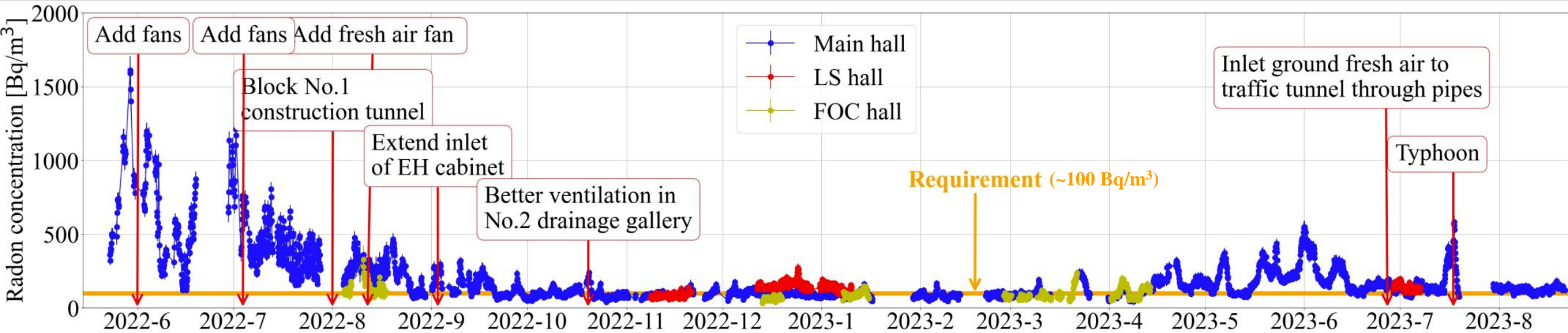


Fresh air from vertical shaft ground (40,000 m³/h) started from June 27

Onsite radon monitoring



- Radon in EH started fluctuation since April, when the room for ground cabinets started installation.
- Radon in EH is more stable since July, except the special period during typhoon



Summary



■ Cleanliness control

- ✓ Clean room management in 120,000 m³ hall: clean clothes, air shower, no dirty work
- ✓ **Cleanliness: equivalent to Class 10,000-100,000**

■ Underground radon control

- ✓ Large amount of underground water at JUNO site: 450 m³/h with 120,000 Bq/m³ radon in water → underground water is a large radon source
- ✓ Ventilation and block of the experimental hall are quite important and effective to decrease radon concentration in underground air
- ✓ **Radon in air: 100-200 Bq/m³**
- ✓ The fresh air from the ground of vertical shaft is ready since July 2023.

Thanks for your attention!