Environmental radioactivity background control at JUNO

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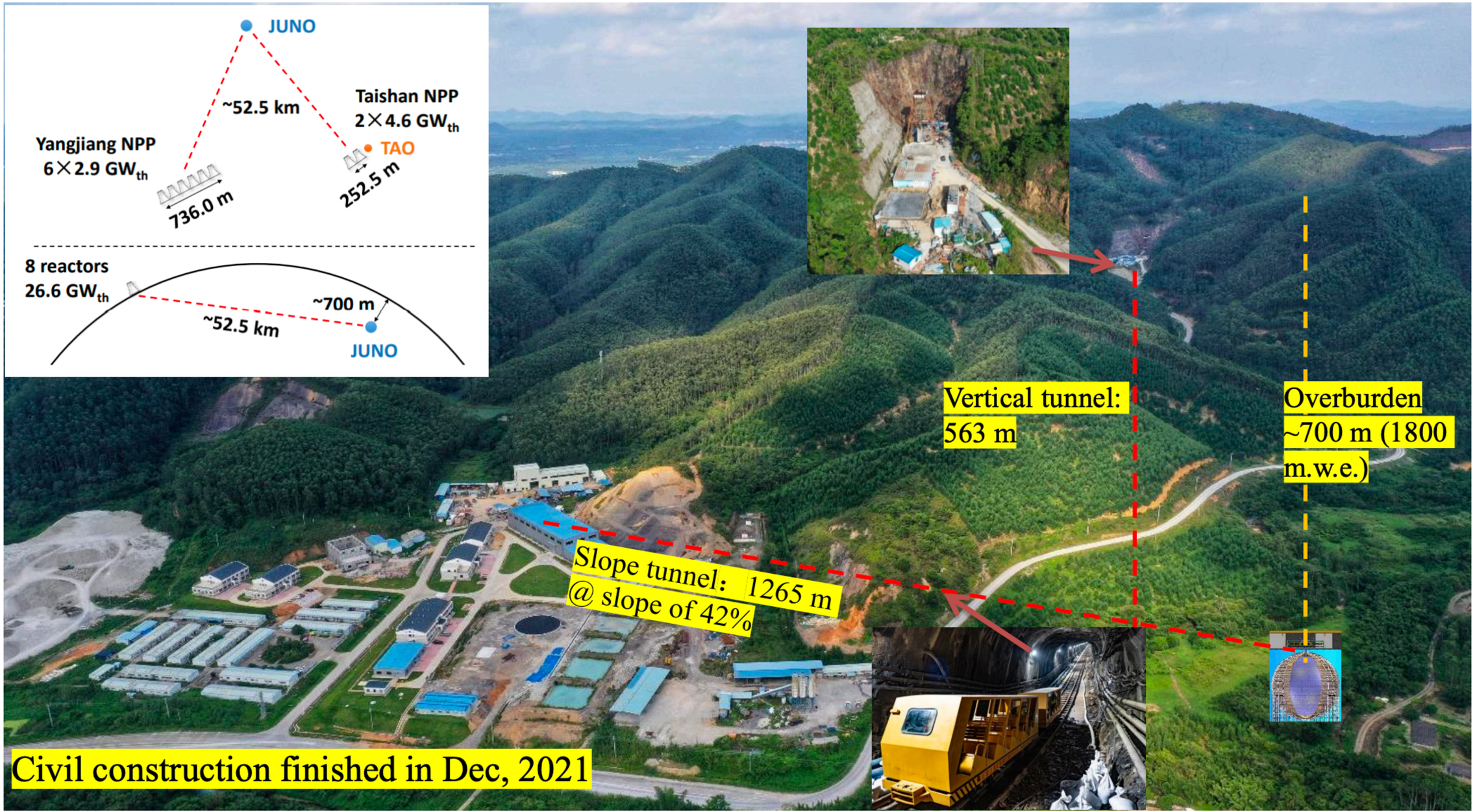
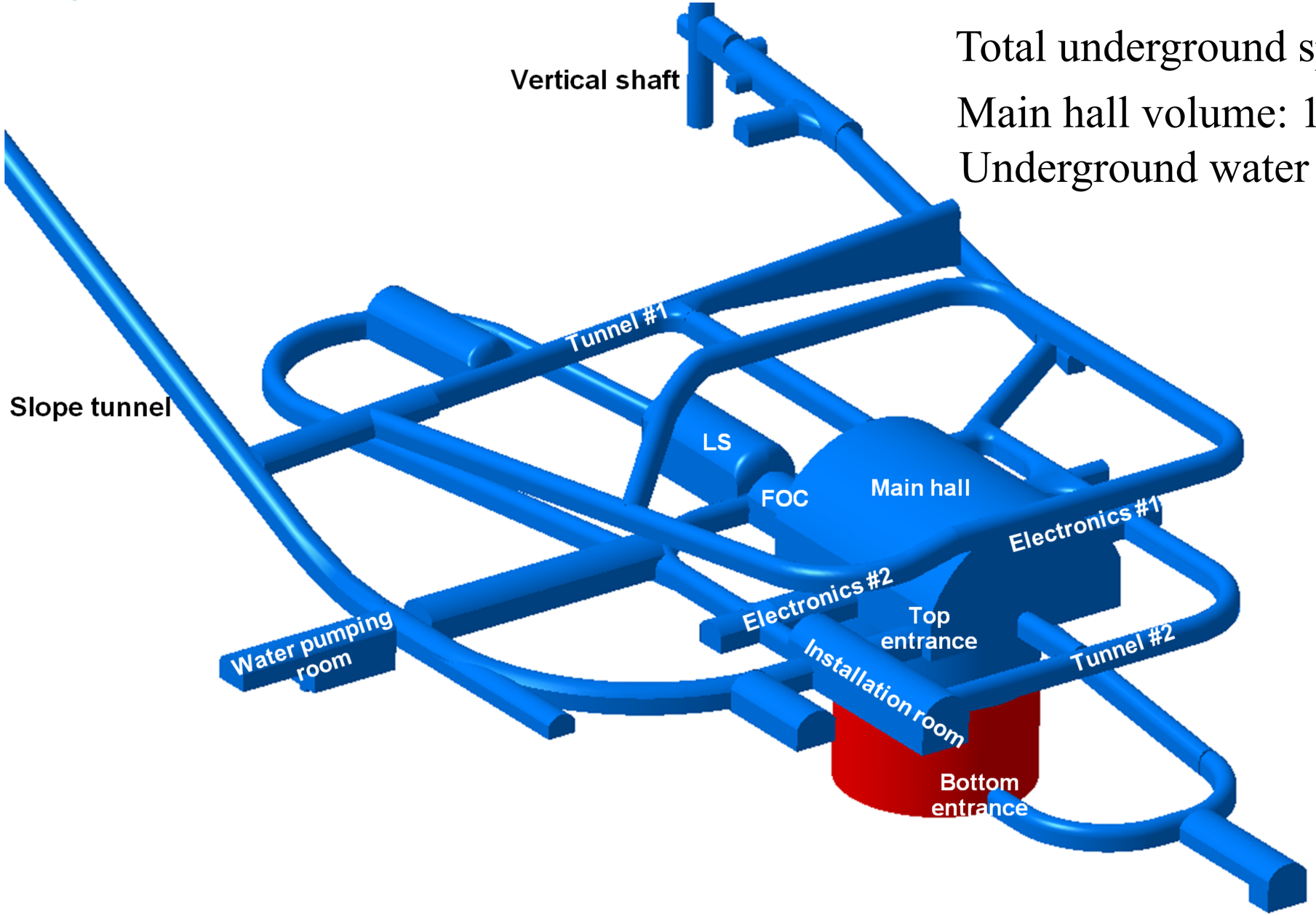
Jiangmen Underground Neutrino Observatory



Underground chambers and tunnels

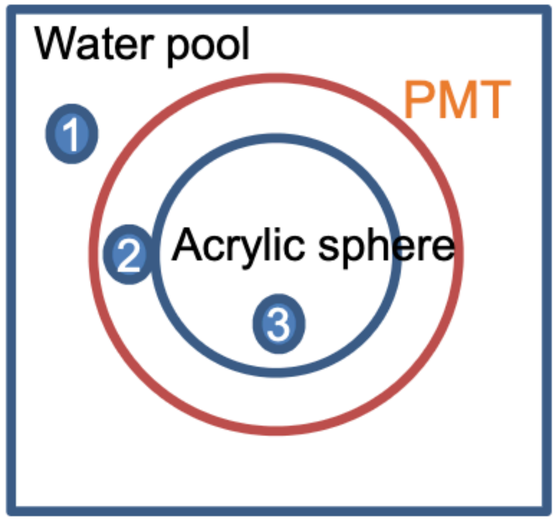


Total underground space: 300,000 m^3

Main hall volume: 120,000 m^3

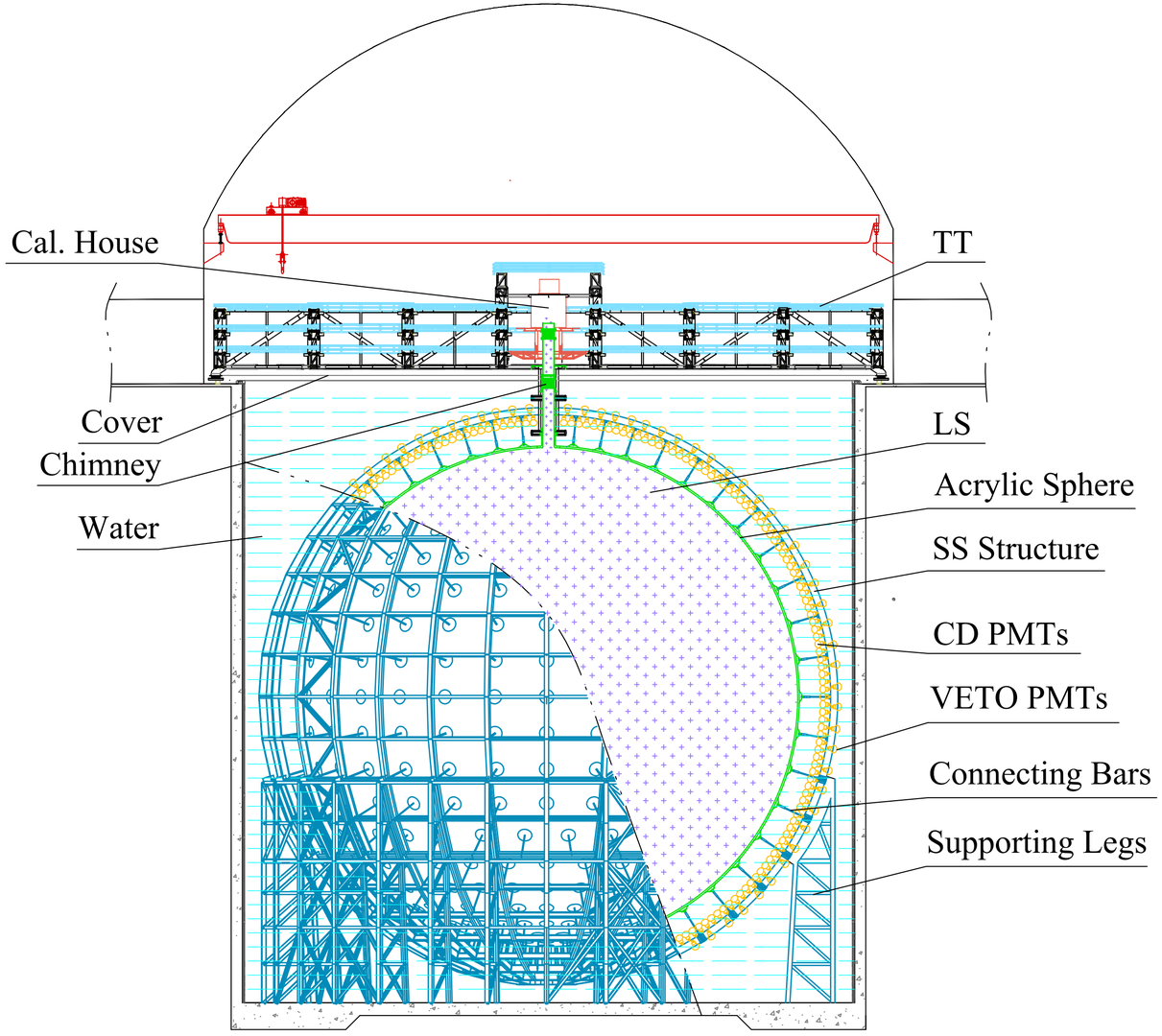
Underground water outflow: 450m^3/h

Environment requirements



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

Temperature: 21℃±1℃

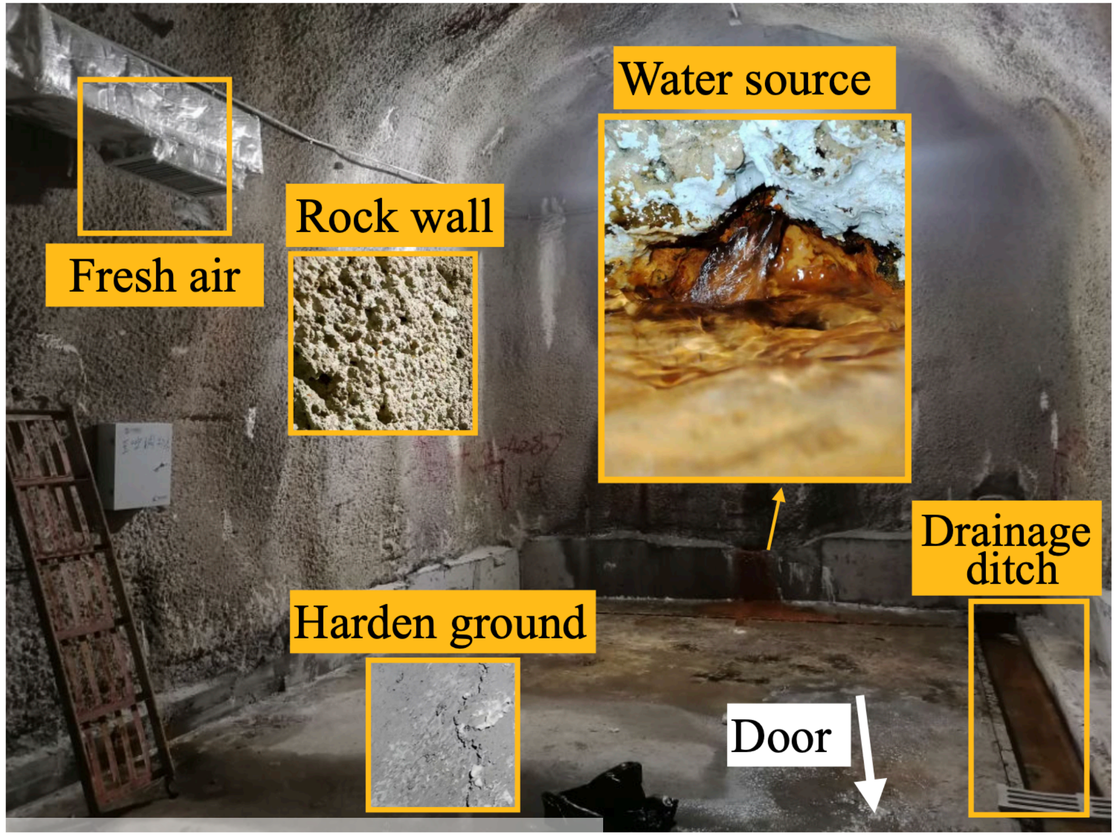


Rn requirement: <200Bq/m^3

Onsite radon control

Study of underground radon sources

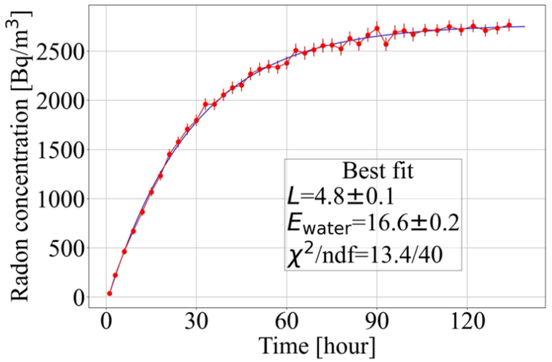
Set up an experiment in an underground chamber to study radon sources

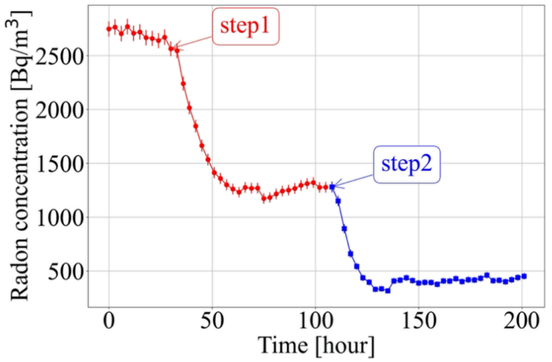


Ref: Eur. Phys. J. C. 2024. 84: 120

Establish a model to extract Rn emanation rate E and diffusion rate L:

$$C_{\text{air}}(t) = \frac{E(1-e^{-\lambda_e t})}{V\lambda_e} + C_0 e^{-\lambda_e t}, \lambda_e = \frac{L+\Phi}{V} + \lambda.$$





Step1: opening a crack on the bottom of the door

Step2: exhausting the water outflow from one point

Result →

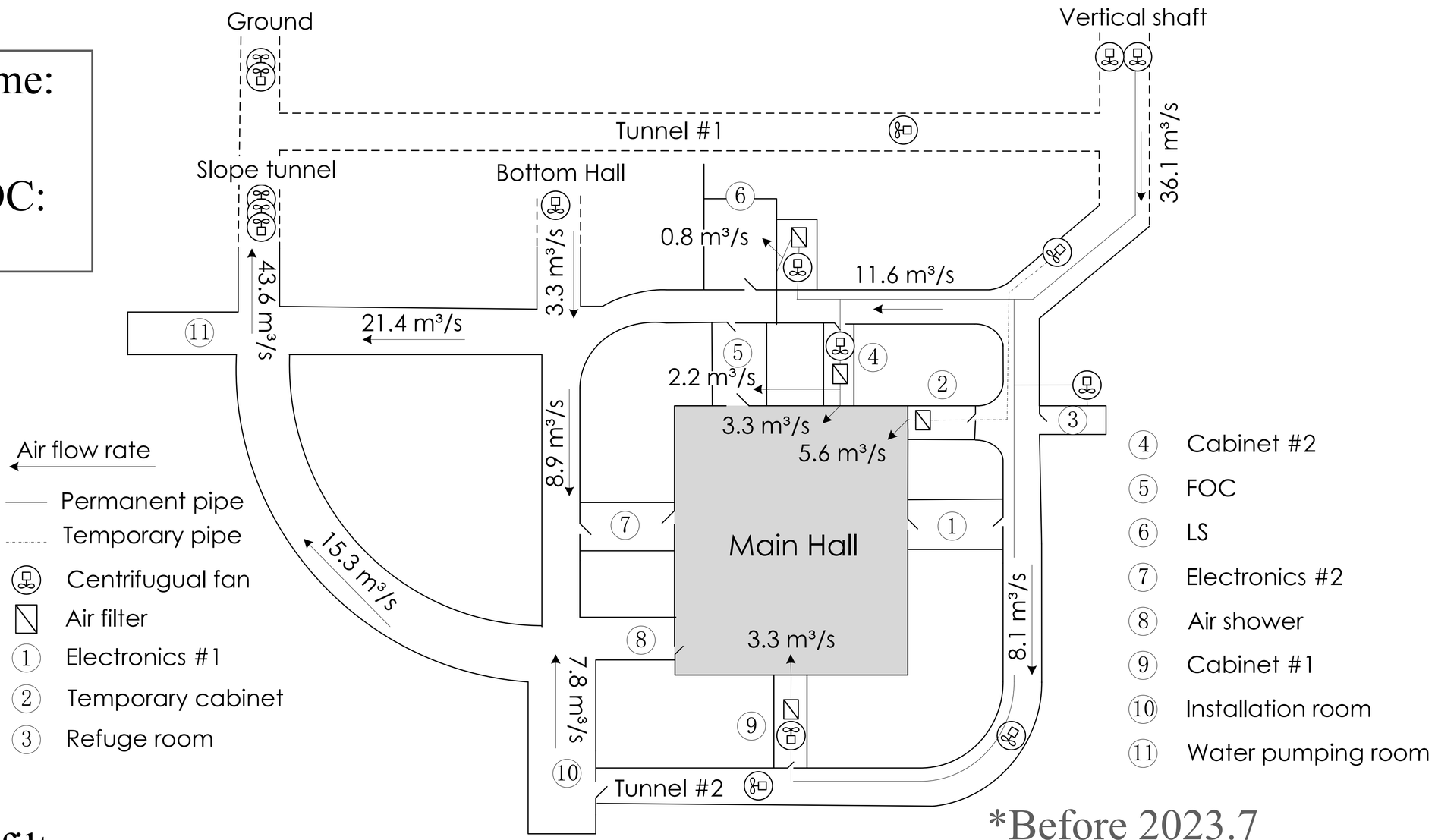
Radon emanated from the water was a main radon source

It is difficult to seal completely, small gaps are very significant for radon diffusion.

Underground ventilation design -- Fresh air flow

Tunnel fresh air volume:
129 600m^3/h

Main hall, LS and FOC:
54 000m^3/h

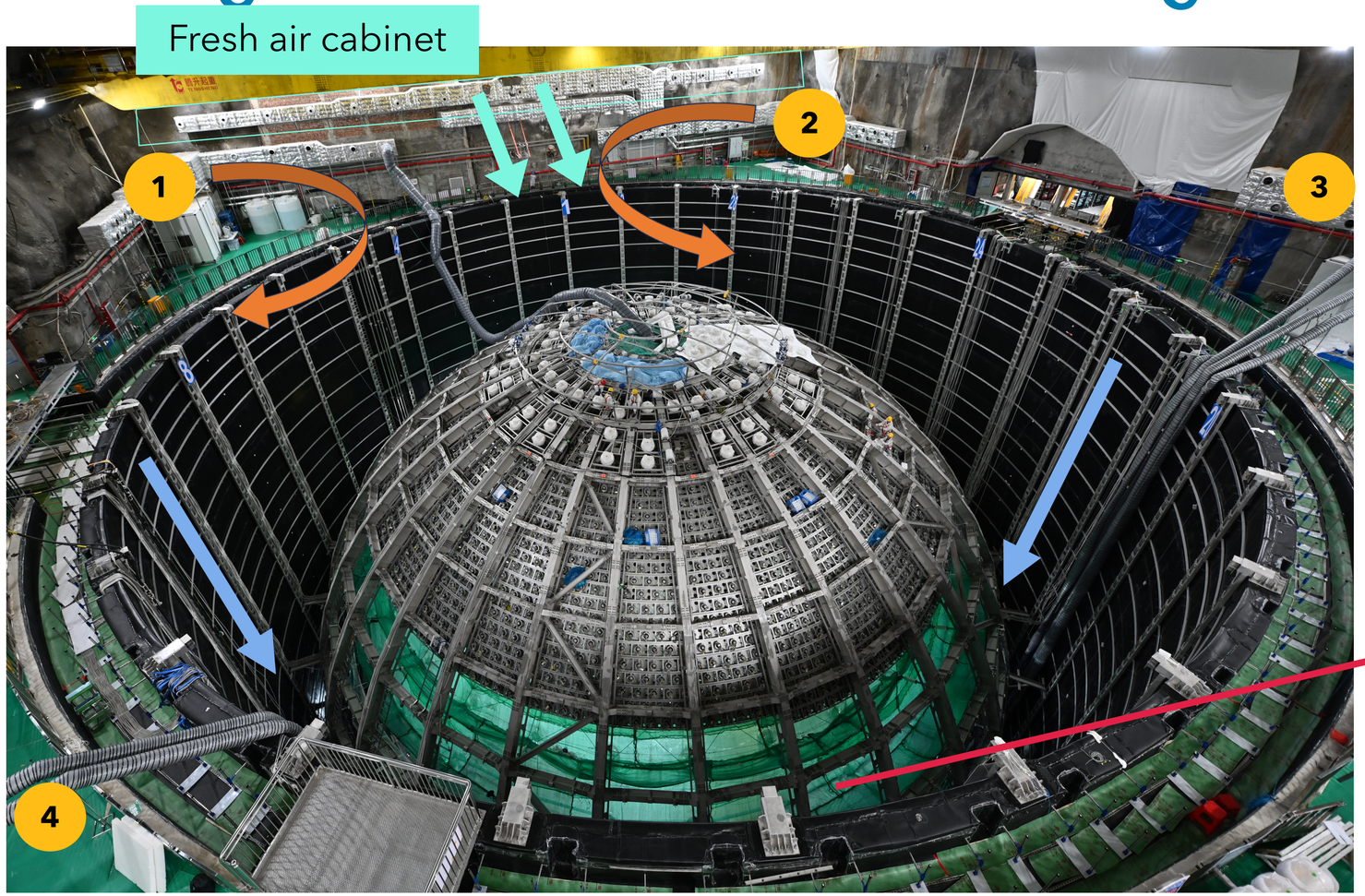


*Before 2023.7

- Tunnel: Fans;
- Main hall:

  Fans, cabinet and filter

Underground ventilation design -- Ventilation in the main hall



Bottom of the water pool:

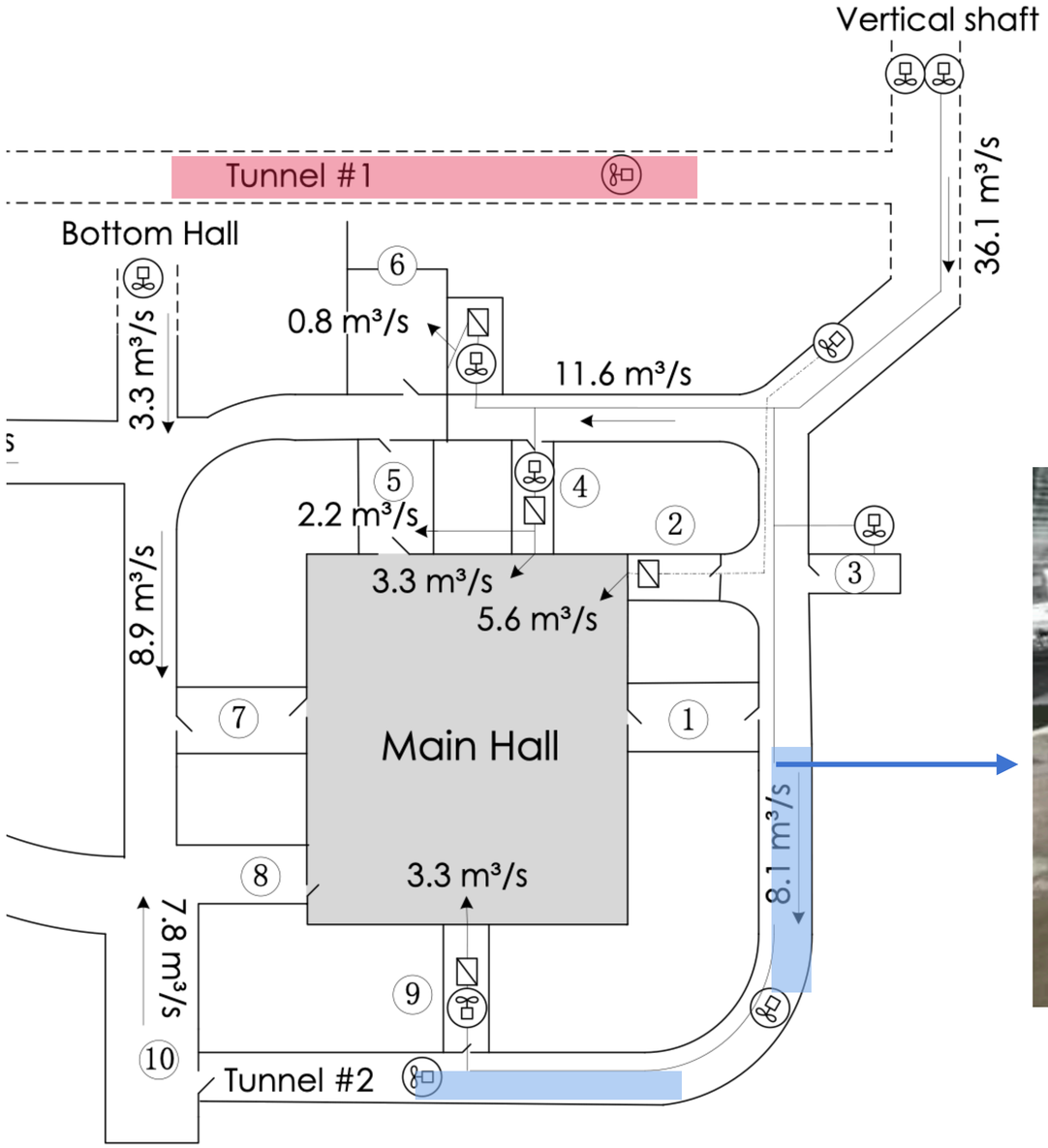
Some points have 70 m^3/h underground water

Set fans out of the bottom help the air exhaust from the main hall, 22,000 m^3/h

Symmetrically, we have 2 fresh air cabinets, and 4 circulation cabinets

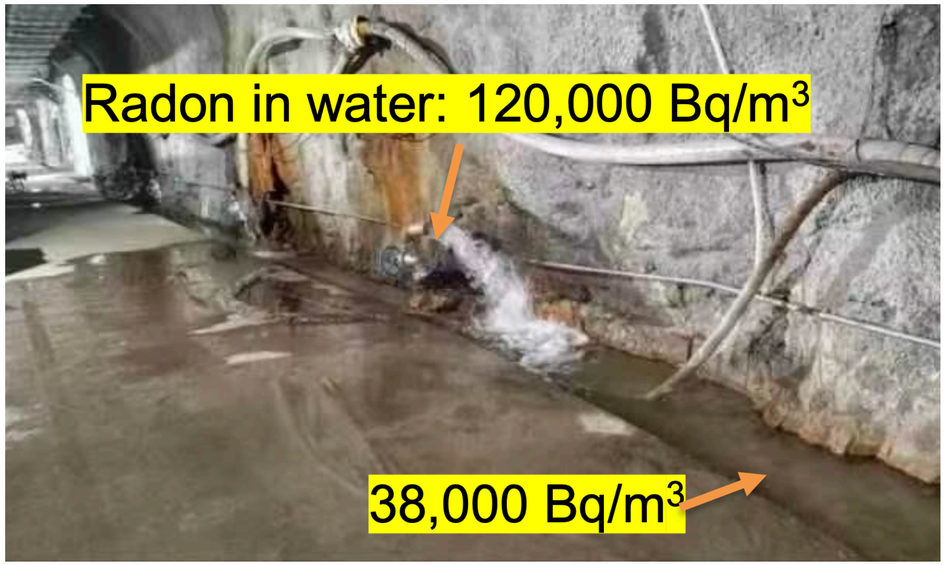
Important strategy

1, High radon source: Tunnel #2 and Tunnel #1



Tunnel #1: no ventilation;
Located upstream of the fresh air

Tunnel #2: no ventilation; close to main hall; Large amount of water



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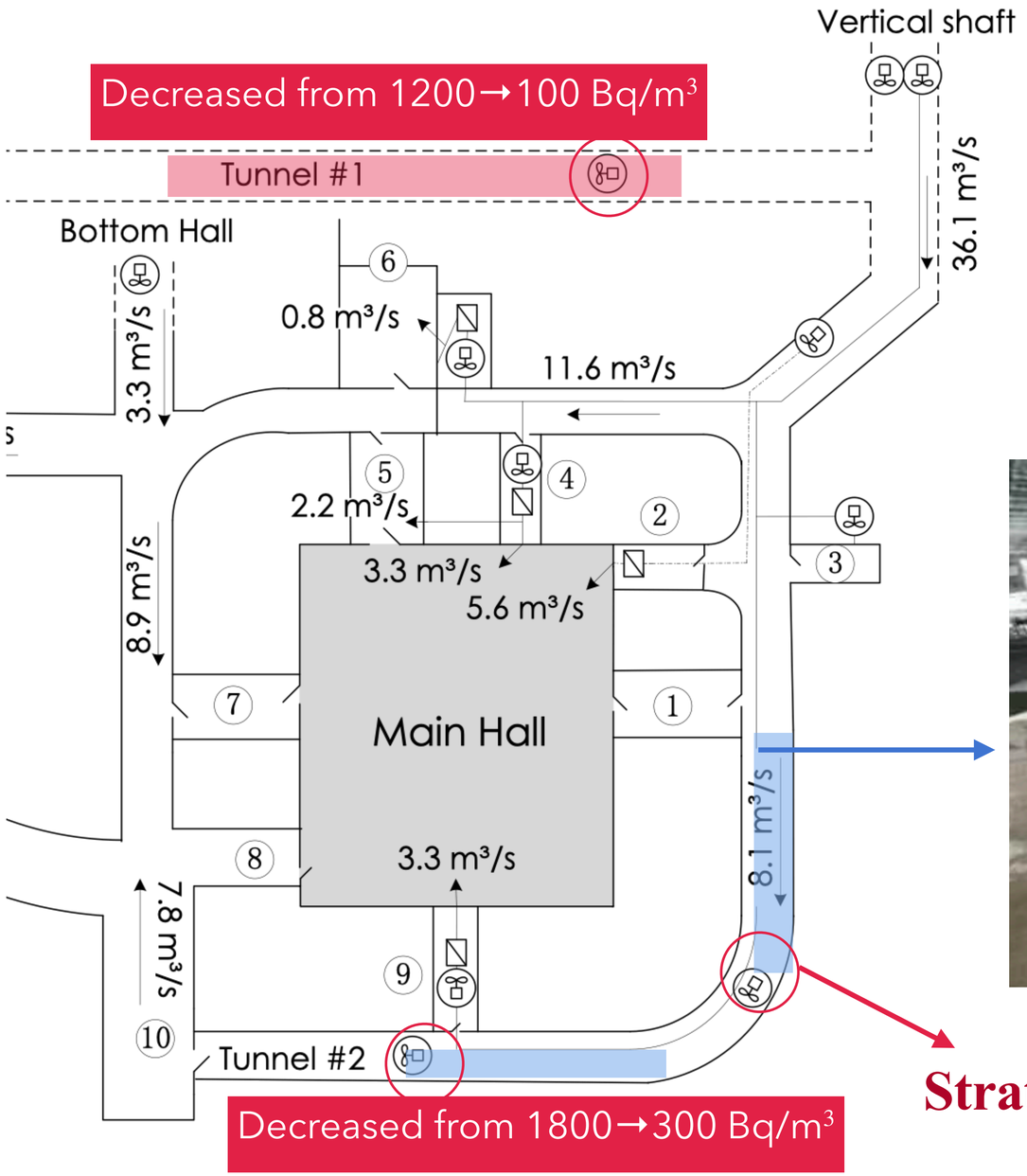

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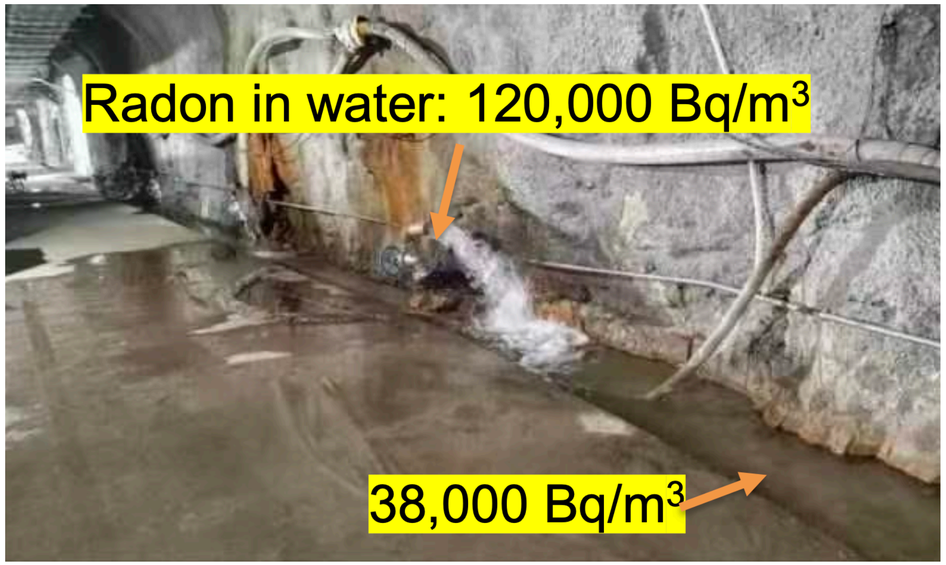
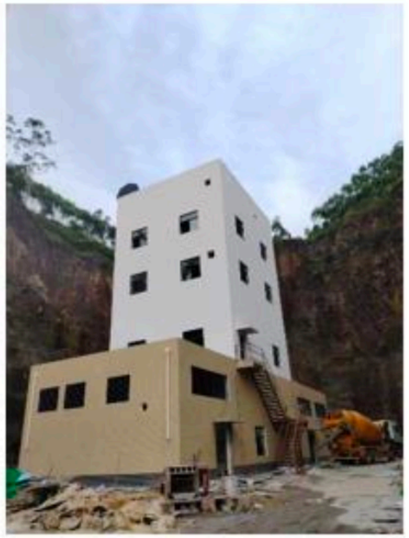


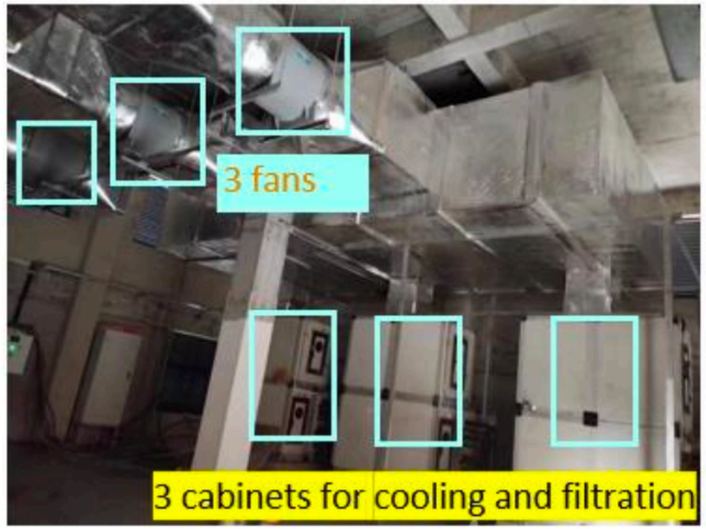
Strategy: better ventilation of the two tunnels

Important strategy 2, Vertical shaft

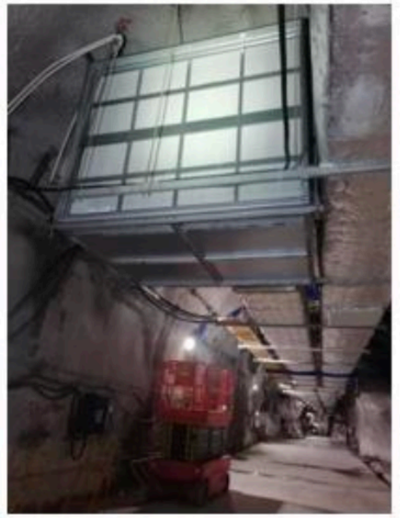
Construction time: from April to June 2023 (~3 months)

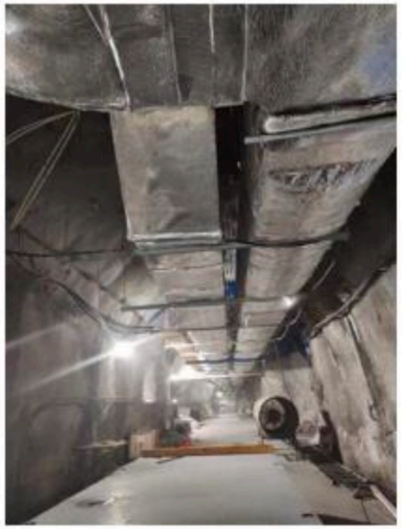
1. Added air cabinets on the ground





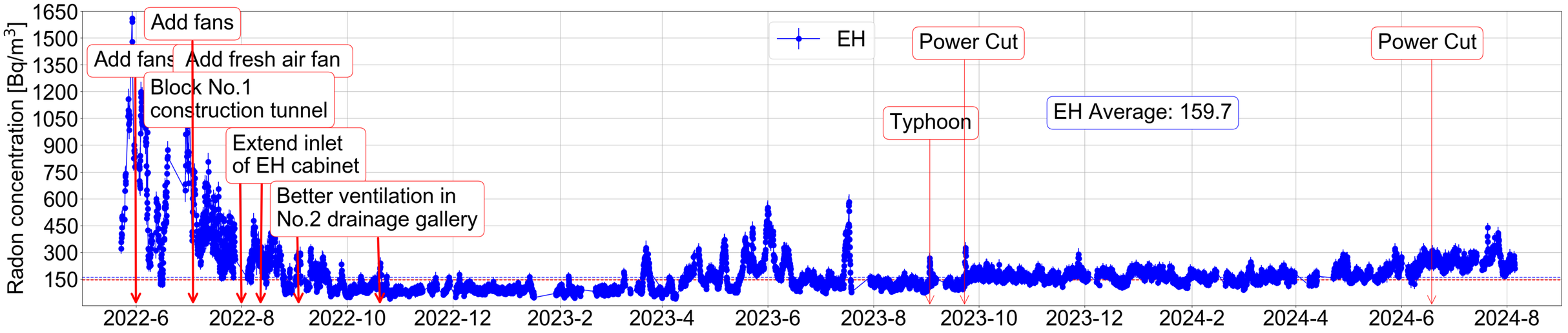
2. Connected fresh air pipe to EH





Fresh air from vertical shaft ground (40,000 m^3/h) started from June 27

Rn long time monitoring



Radon in EH started fluctuation since April, when the room for ground cabinets started installation

Radon in EH is more stable since July 2023, except the special period during typhoon

Environment radon inside the experimental hall below 200Bq/m^3 on average

Cleanliness control

Basic principle for the Experimental Hall (EH)

People

Wear clean clothes, hat, gloves, shoes or shoe cover

We have two administrators outside the shower, six stable cleaners in the EH.

Cargo & tool

Clean outer packing surface, remove outer packing

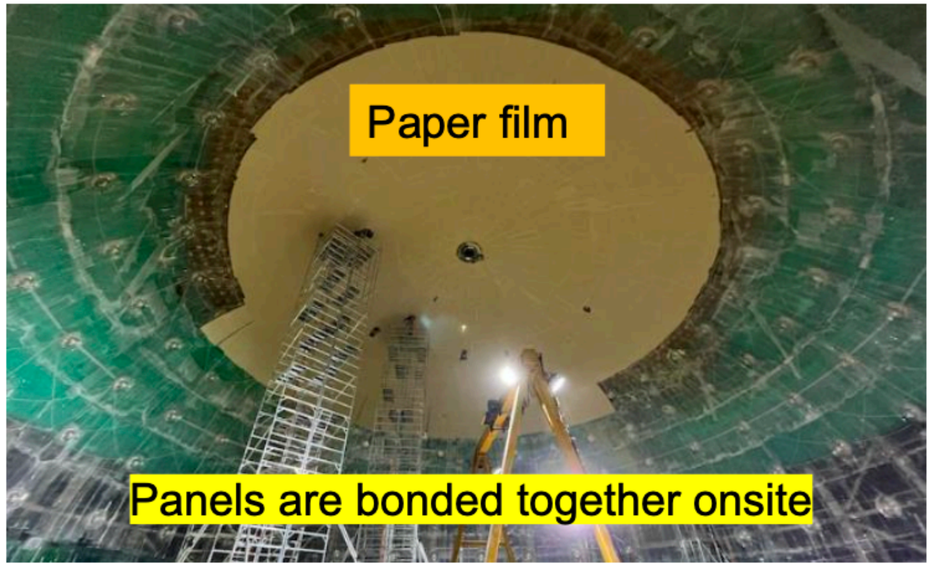
Air shower

Cargo does not contact with floor directly, Tool is stored in a clean box, cover with a clean cloth during storage

No dirty work (cutting, welding…) is allowed around the EH.

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)



PMT installation

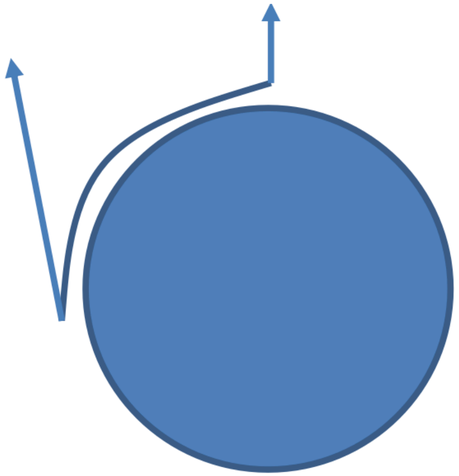
Special protection of installed veto PMTs

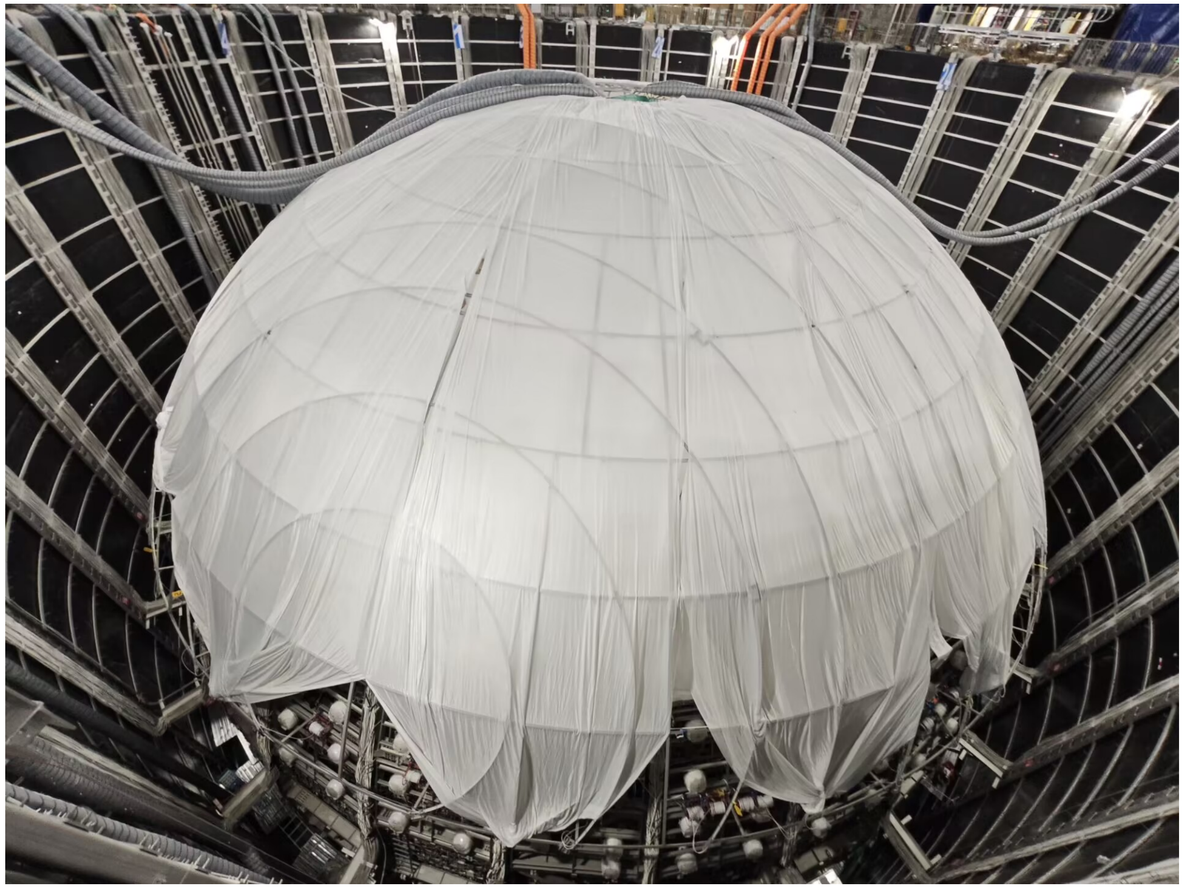
Veto PMTs are covered with clean cloth to avoid dust fallout on the surface

✓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





SS structure cleaning

2 round full cleaning

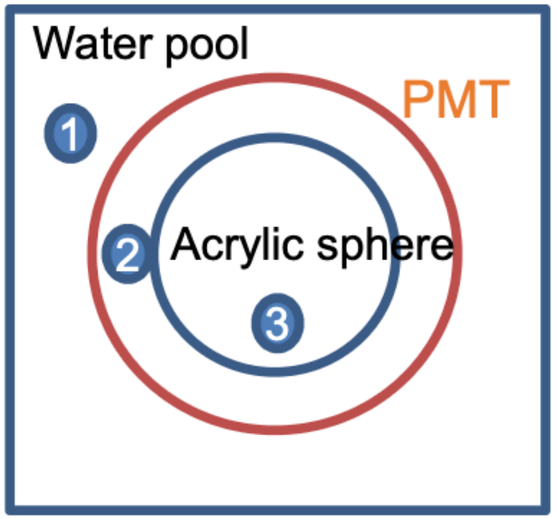
1, Before acrylic instillation: 2022-6, 7

2, Before PMT instillation: 2022-12

PMT instillation period

Before the CD PMT and after the electronics box cleaning layer by layer

Onsite cleanliness monitoring



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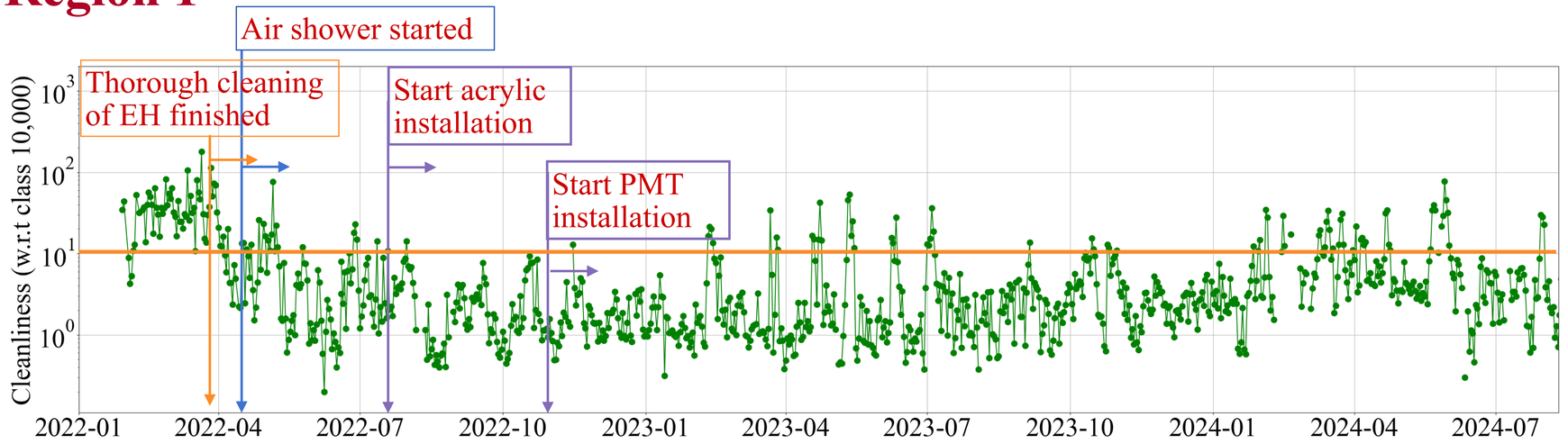
2	Class 10,000
3	Class 1000

Temperature: 21℃±1℃

Region 1



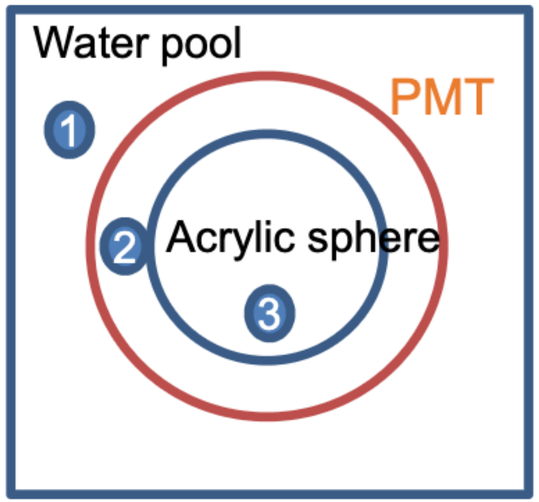
* Calculation method of cleanliness Y-axis: total volume of real-time monitored particles divided by the Class 10,000 level particles

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	Level
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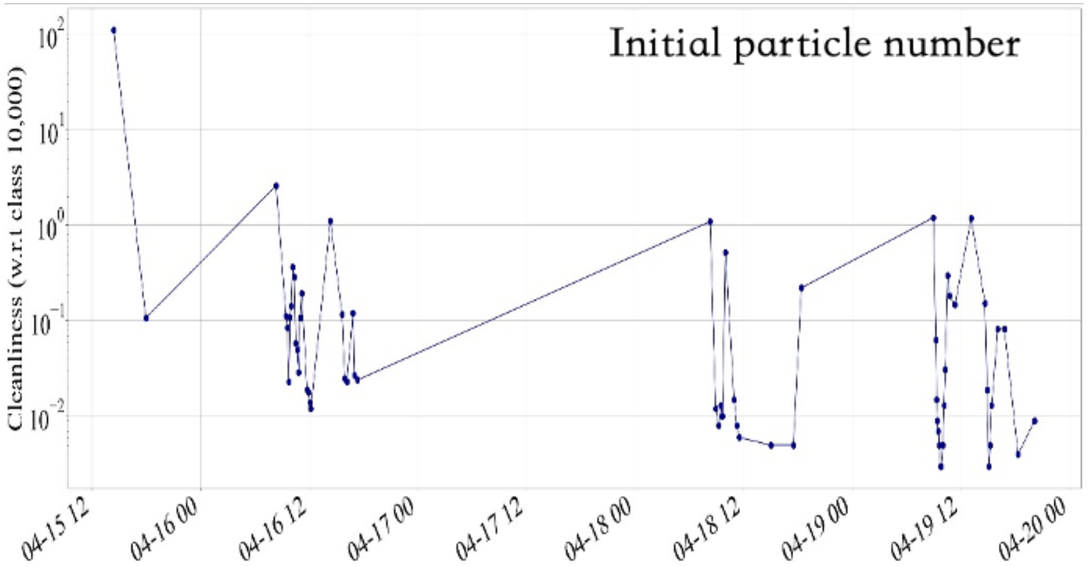
2	Class 10,000
3	Class 1000

Temperature: 21℃±1℃

✓After installation: seal the sphere and spray inside the sphere

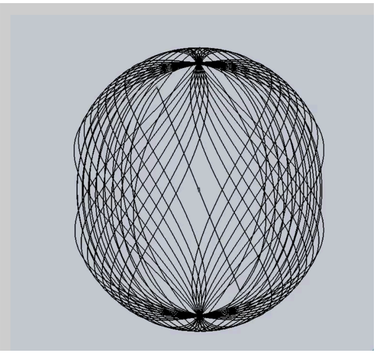
✓Preliminary result in 10m hemisphere: spray can reach to Class 1000, but wide range of variation

✓And then use the 3D rotation nozzle to remove water soluble paper



3D rotating nozzle

track



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
- The fresh air from the ground of vertical shaft is ready since July 2023.
- Environment radon inside the experimental hall below 200Bq/m^3 on average

Paper: https://link.springer.com/article/10.1140/epjc/s10052-024-12474-6

NIKON Z7ii

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Thank you for attention

谢谢！

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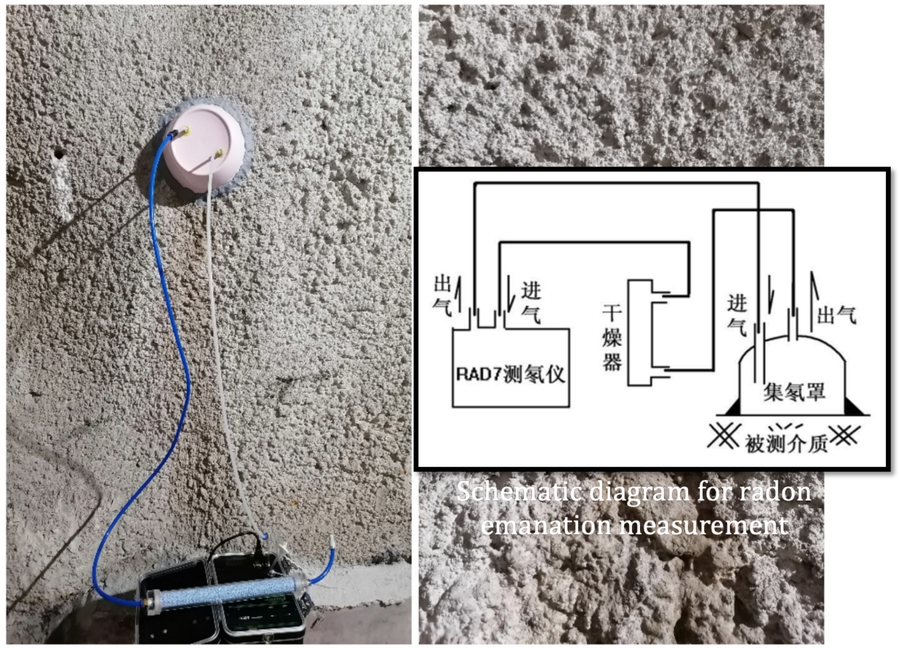
Radon exhalation rate test in walls

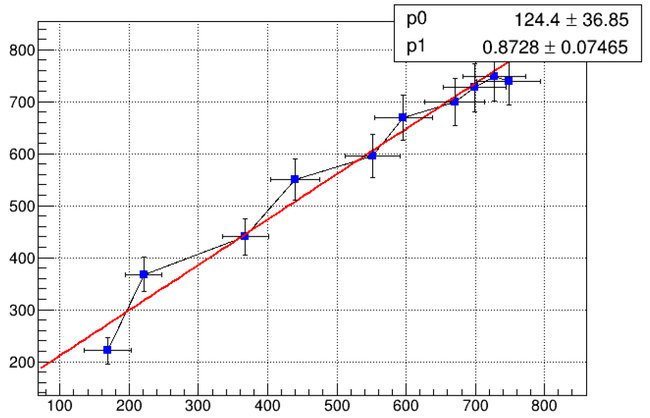
$$\lambda_e = -(\ln b)/T \qquad J = \frac{\lambda_e V}{S(1-e^{-\lambda_e t})}(C - C_0 e^{-\lambda_e t})$$



避难室墙壁

氡析出率：*J= 3.37±0.72 Bq*m^{-2}*h^{-1}*

10.25-1



λ_e = 0.0680

C0 = 169±34.3
C = 739±45.8

b = 0.8728;（拟合斜率）

T=2h（测试时间间隔）

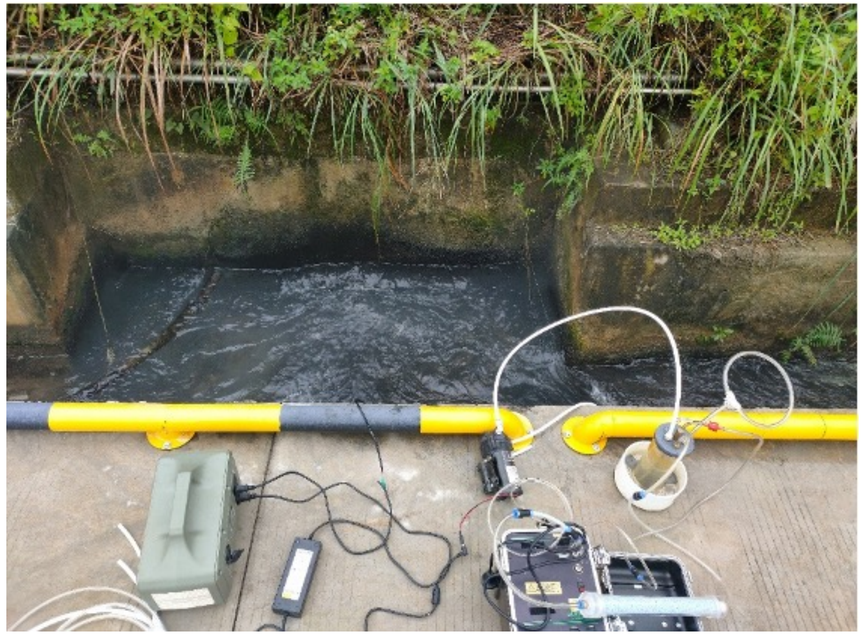
V=2.2*10^{-3}m^3;（集氡罩体积）2.2L

S=4.155*10^{-2}m^2;（集氡罩底面积）d=23cm

t= 20h;（集氡时间）

2

Water radon measurement



Water pump+ atomizer+ rad7