Environmental radioactive background control at JUNO

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1, Introduction

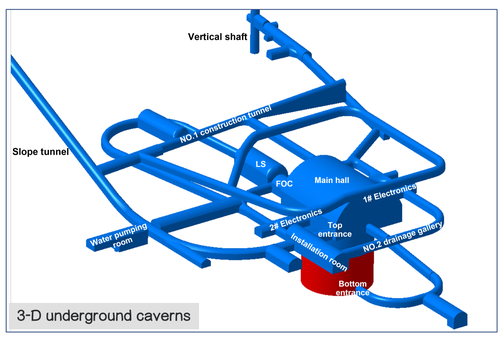
The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kt liquid scintillator (LS) detector for studies of various neutrino physics topics. The level of radioactivity background is an essential factor for the sensitivities.

■ JUNO environment requirements

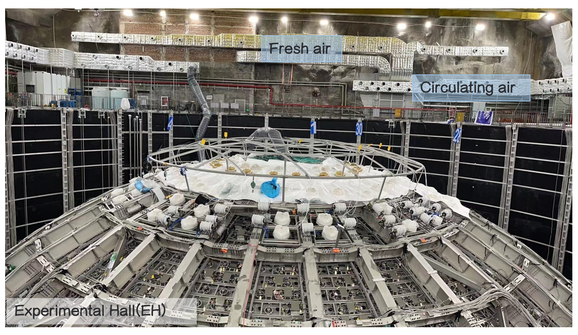
- Physics requirement:
  In LS, ^{238}U , ^{232}Th~10^{-17} g/g , ^{40}K~10^{-18} g/g,^{222}Rn < 0.1 μBq/m^3
- Dust is rich in ^{238}U, ^{232}Th and ^{40}K (can reach 10^{-5} g/g)
  Installation environment: air Cleanliness Class 100 000 (in mass)
- Radon and its daughters can attach to the surface of the detector.
  Radon in air: ~100 Bq/m^3

■ JUNO underground working conditions

- A 564 m deep vertical shaft, and a 1266 m long slope tunnel
- Total underground space ~300,000 m^3
  experimental hall (EH) volume ~120,000 m^3
- Also has a number of attached halls, such as liquid scintillator (LS) room and filling-overflow-circulation (FOC) room



3-D underground caverns

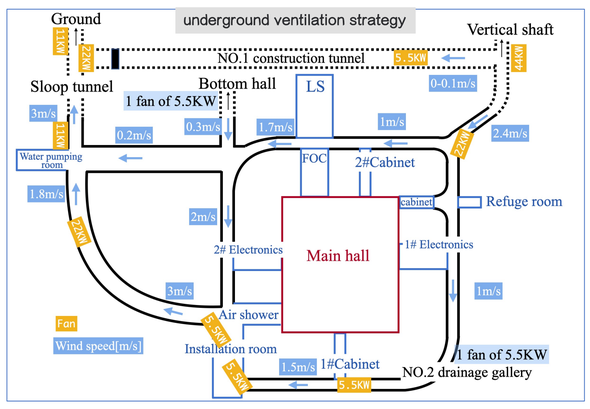


Experimental Hall(EH)

2, Underground ventilation design

☐ Rock and abundant groundwater can produce large amounts of radon gas, and the best way to deal with radon in underground air is good ventilation design

☐ Radon concentration in ambient air is about 10 Bq/m^3. The general ventilation strategies are shown below:



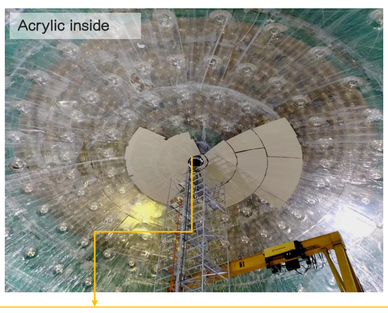
➢ Ventilation in traffic tunnel:
fresh air inlet: vertical shaft
air outlet: slope tunnel

➢ Ventilation in the EH:
fresh air + circulation with filters

- Fresh air (50,000 m^3/h)
  keep low radon level
- Circulation with filters (200,000 m^3/h)
  reduce particles to improve the cleanliness

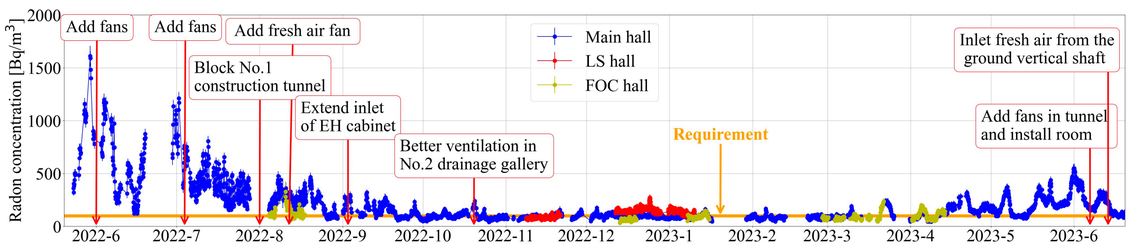

Fresh air inlet
Fan and filter


Ventilation in tunnel
Fan


Acrylic inside

Especially, we supply Class 1000 air from circulation cabinet to acrylic inner surface through chimney(The LS will be fill in the acrylic vessel)

3, Long time monitoring



➢2022-6,7, added fans in the tunnel, increased the wind speed underground
➢2022-8, blocked the No.1 tunnel, and there is a large radon pollution in it
➢2022-9, extended inlet of EH cabinet to the tunnel to improve the air quality
➢2022-10, improved the ventilation in the NO.2 drainage gallery, and there is a large amount of underground water and high radon in it
➢2023-6, added more fans in tunnel and installation room
➢The vertical shaft fresh air system is currently being commissioned ～ will be finished in July

Radon in EH: 1600 Bq/m^3 → 100 Bq/m^3
Radon in the installation room: 1600 Bq/m^3 → 300 Bq/m^3

4, Study of underground radon sources

☐ Motivation:

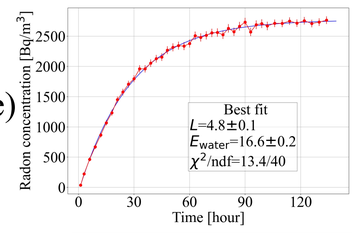
1. Quantitative study of the influence factor of radon in air
2. Optimize the ventilation of EH

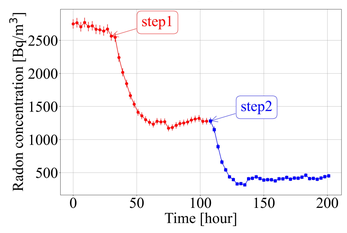
☐ Model: considering the radon emanated, the fresh air and the air leakage, air radon concentration as a function of t [hour] can be expressed as:

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

- C_0: initial radon concentration
- E: radon emanation rate [kBq/h]
- Φ: fresh air volume [m^3/h]
- L: radon net diffusion rate [m^3/h]
- λ: the decay constant of radon [h^{-1}]

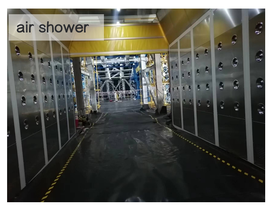
☐ Experimental method
➢ Closed door and monitored radon rise (fit the up curve)
➢ After establishment:
- Step1: opening a crack on the door
- Step2: exhausting the water from one point





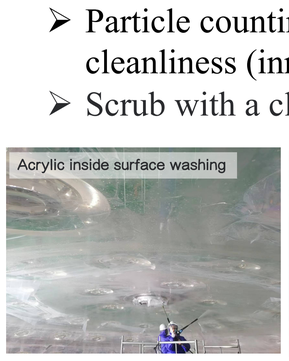
☐ Result:
➢ Radon emanated from underground water dominates the contribution to radon in air
➢ Air leakage contribution: 300 m^3/h/m^2

5, Cleanliness management

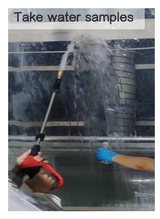

air shower

☐ Isolate the EH to the tunnel:
➢ people wear cleanroom suit
➢ clean goods before entering EH
➢ air shower before entering EH

☐ Acrylic surface treatment
➢ Using high pressure pure water jet (inner surface)
➢ Particle counting for water samples to ensure cleanliness (inner surface)
➢ Scrub with a clean cloth (outer surface)


Acrylic inside surface washing


Acrylic out surface Scrub


Take water samples

☐ Others

Goods covered with clean cloth


LPMT module

Small Goods put in the material bin


sPMT

Cartons forbidden

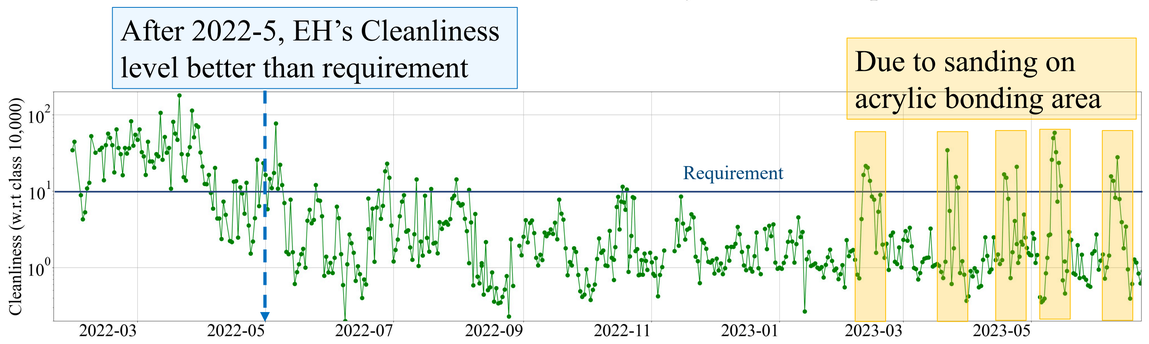

Forbidden

Wear gloves during installation


Wear gloves

6, Cleanliness monitoring

☐ **Cleanliness calculation:** total dust mass divided by Class 10 000 particles mass

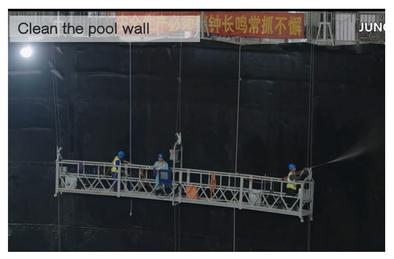


☐ Thorough cleaning


Clean the EH wall

☛ 2022-4 , Cleaned the experimental top hall wall

2022-5 , Washed the wall of the WP install air shower room ☛


Clean the pool wall


Clean the SS structure

☛ 2022-12, Cleaned the SS(stainless steel) main structure