Yemilab construction and radiation environment

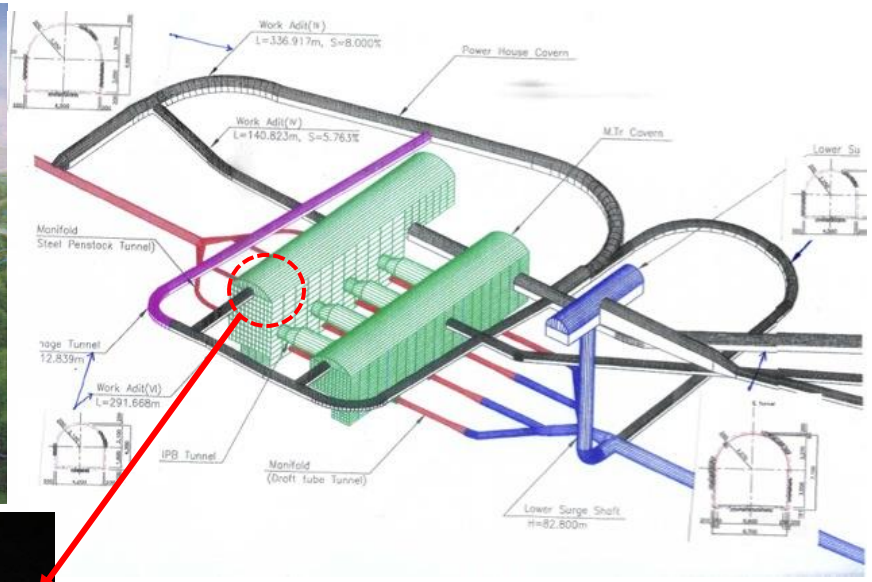
Yemilab

EST. 2022

Less Muon

Better Flavor

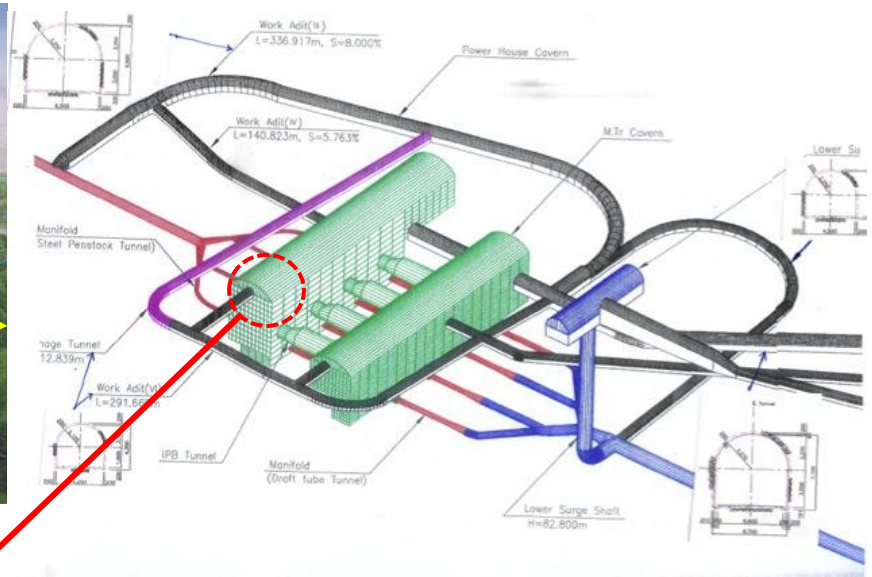
20 years history
(Yangyang underground lab, Y2L)



Y2L phase 1 (A6 tunnel)

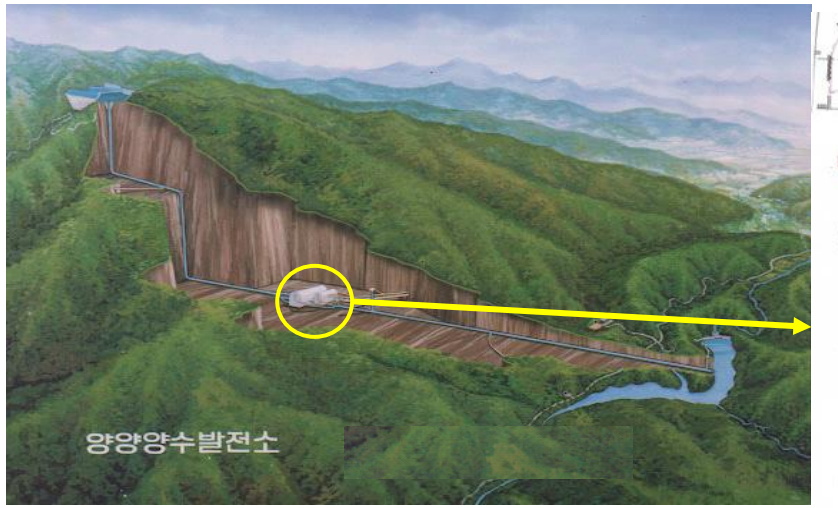
- Since 2003~
- 600m overburden
- Access by car for 2km
- 100m^2 area

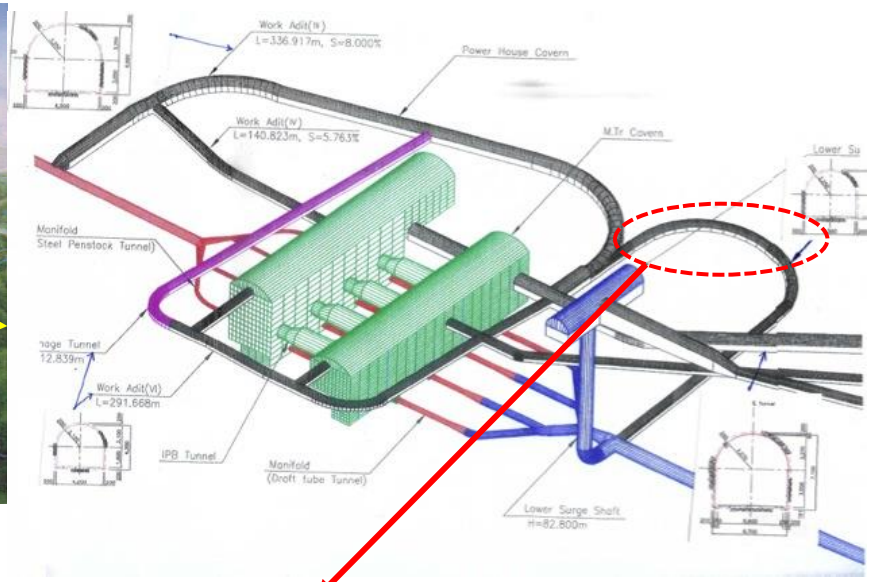
20 years history
(Yangyang underground lab, Y2L)

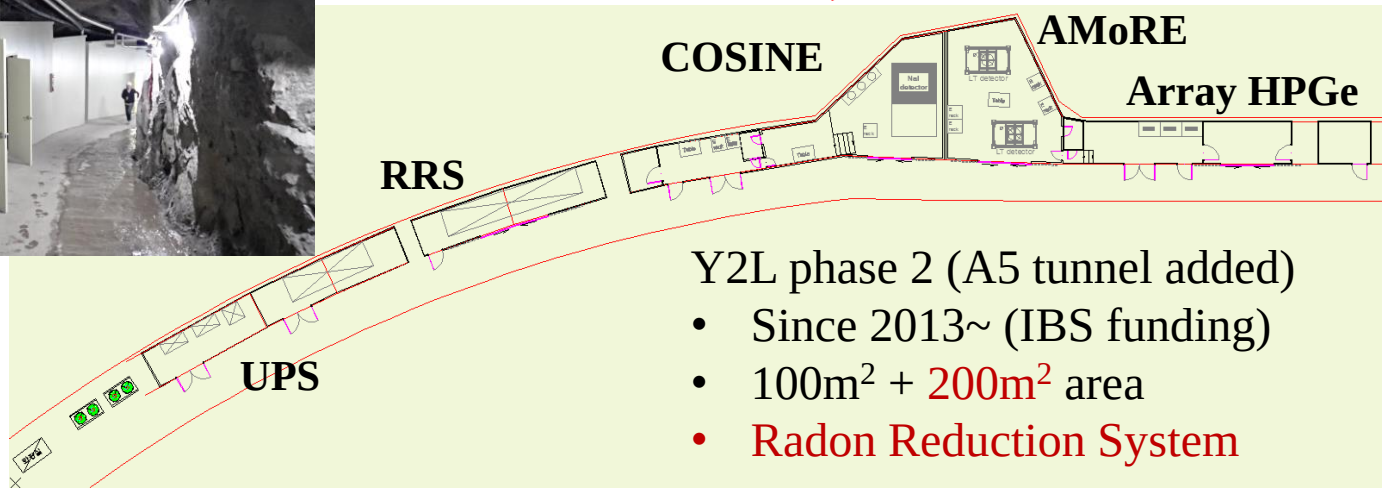


- KIMS experiment start.
  - CsI(Tl) scintillator
- HPGe for radio-assay
- $CaMoO_4$ crystal R&D

20 years history
(Yangyang underground lab, Y2L)



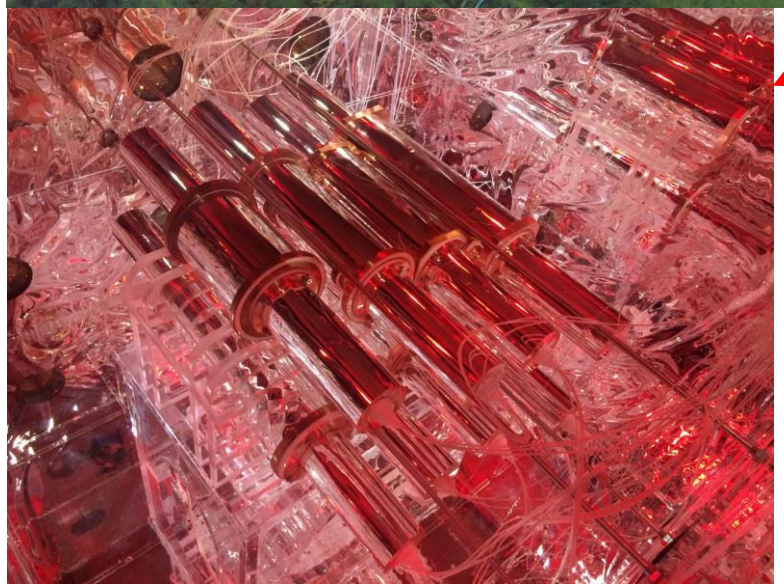


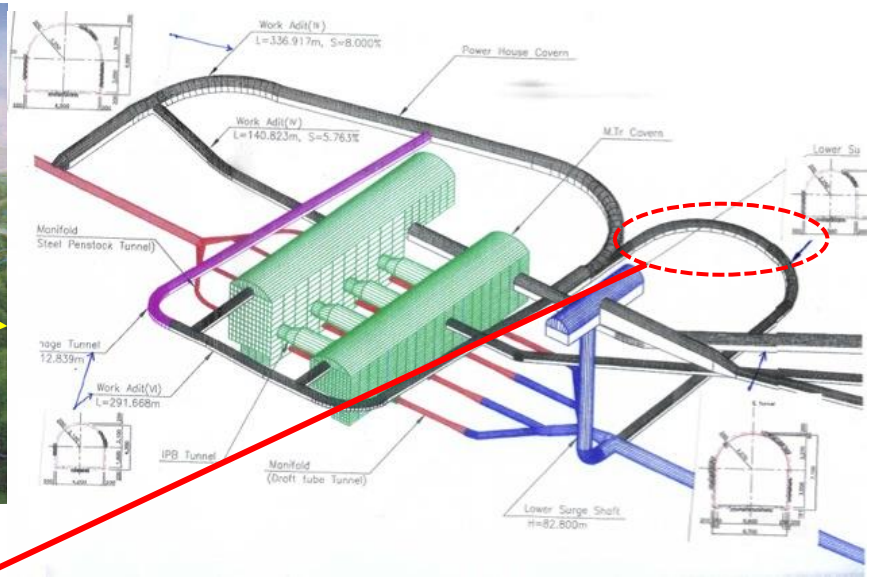


Y2L phase 2 (A5 tunnel added)

- Since 2013~ (IBS funding)
- 100m^2 + 200m^2 area
- Radon Reduction System

20 years history
(Yangyang underground lab, Y2L)

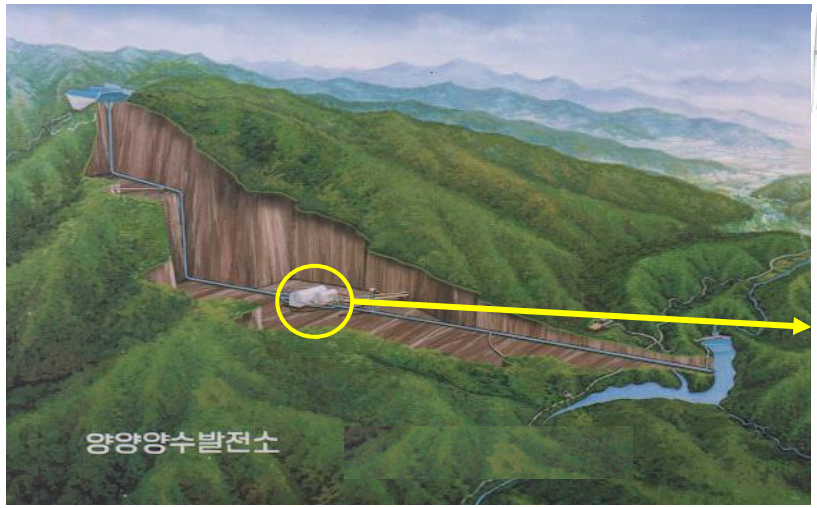


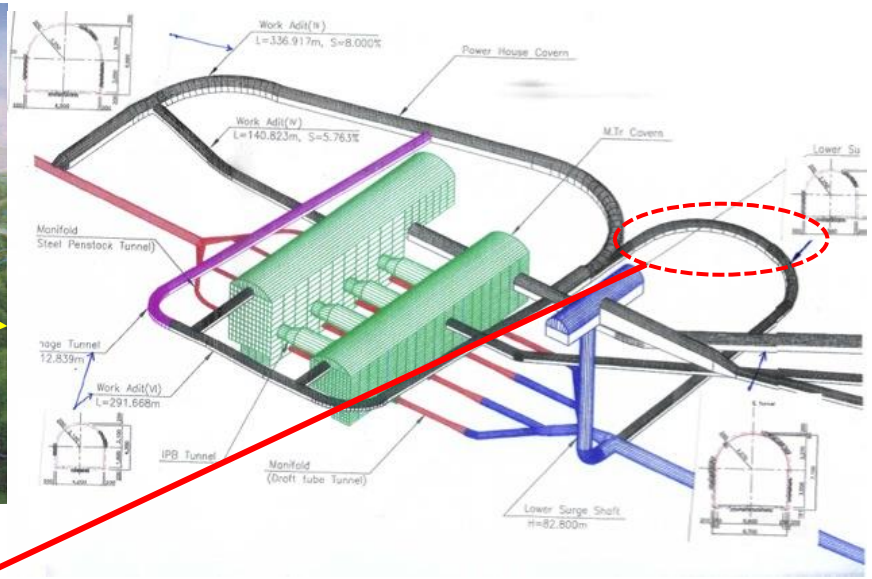


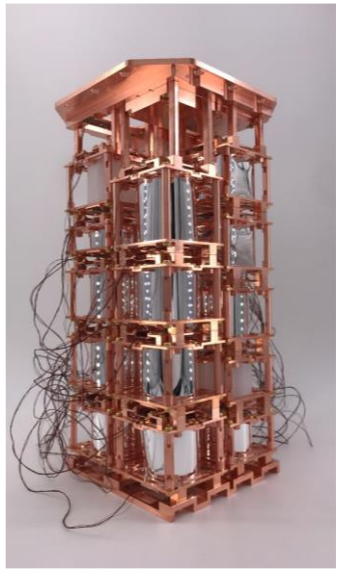
Y2L phase 2 (A5 tunnel added)

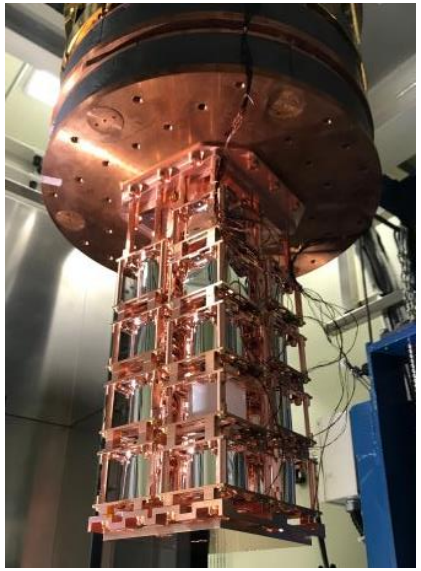
- Since 2013~ (IBS funding)
- 100m^2 + 200m^2 area
- Radon Reduction System
- COSINE experiment start.
  - NaI(Tl) scintillation crystal

20 years history
(Yangyang underground lab, Y2L)





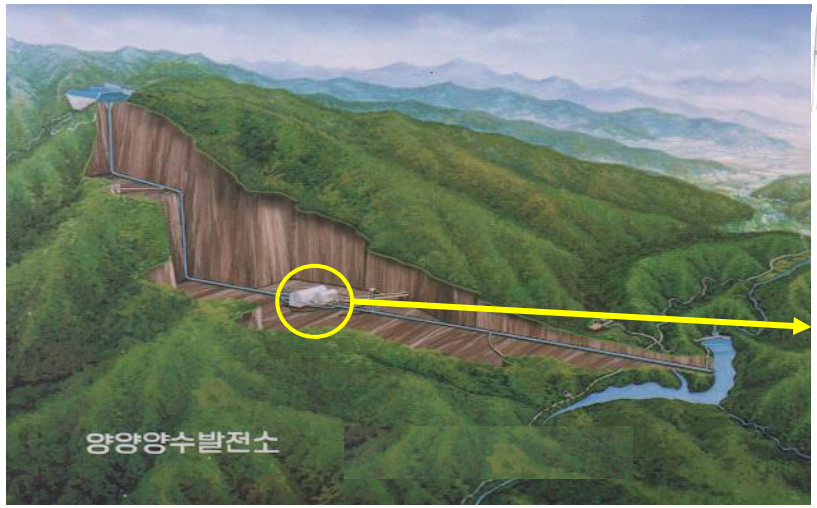


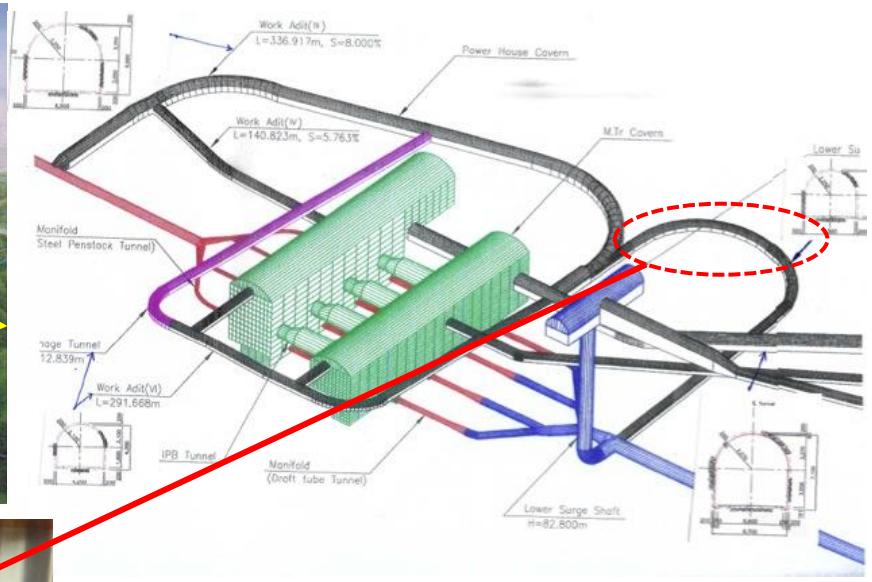


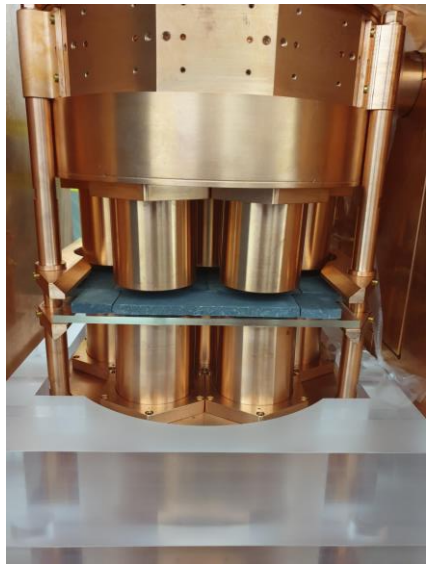
Y2L phase 2 (A5 tunnel added)

- Since 2013~ (IBS funding)
- 100m^2 + 200m^2 area
- Radon Reduction System
- COSINE experiment start.
  - NaI(Tl) scintillator
- AMoRE pilot, phase I

20 years history
(Yangyang underground lab, Y2L)





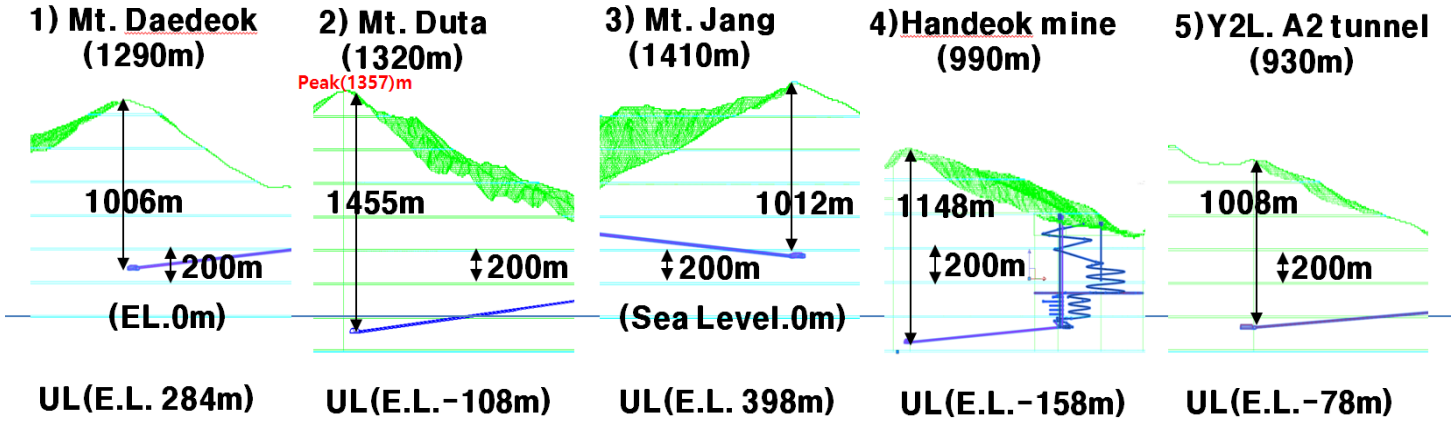


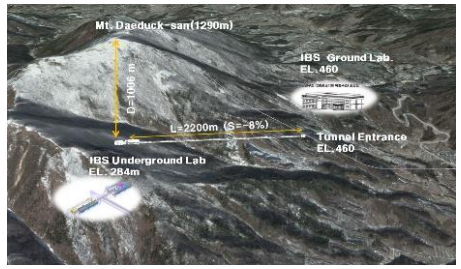
Y2L phase 2 (A5 tunnel added)

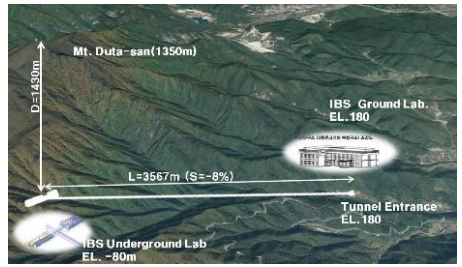
- Since 2013~ (IBS funding)
- 100m^2 + 200m^2 area
- Radon Reduction System
- COSINE experiment start.
  - NaI(Tl) scintillator
- AMoRE pilot, phase I
- 14ch array HPGe

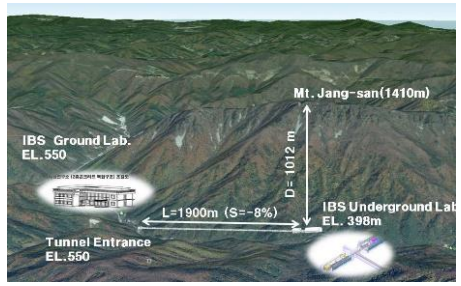
A new underground laboratory

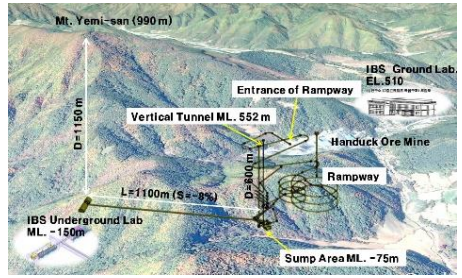
- Larger! Deeper! and Cost effective!

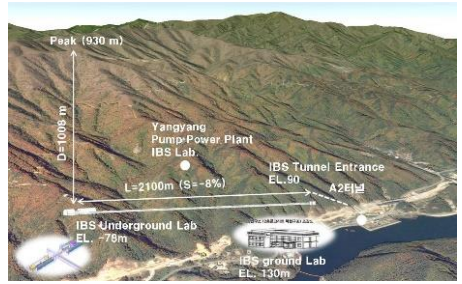






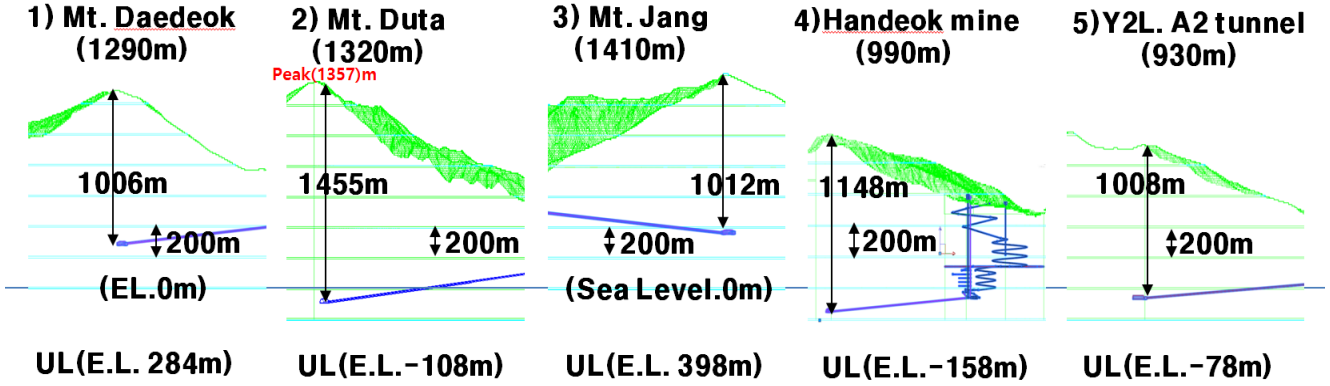


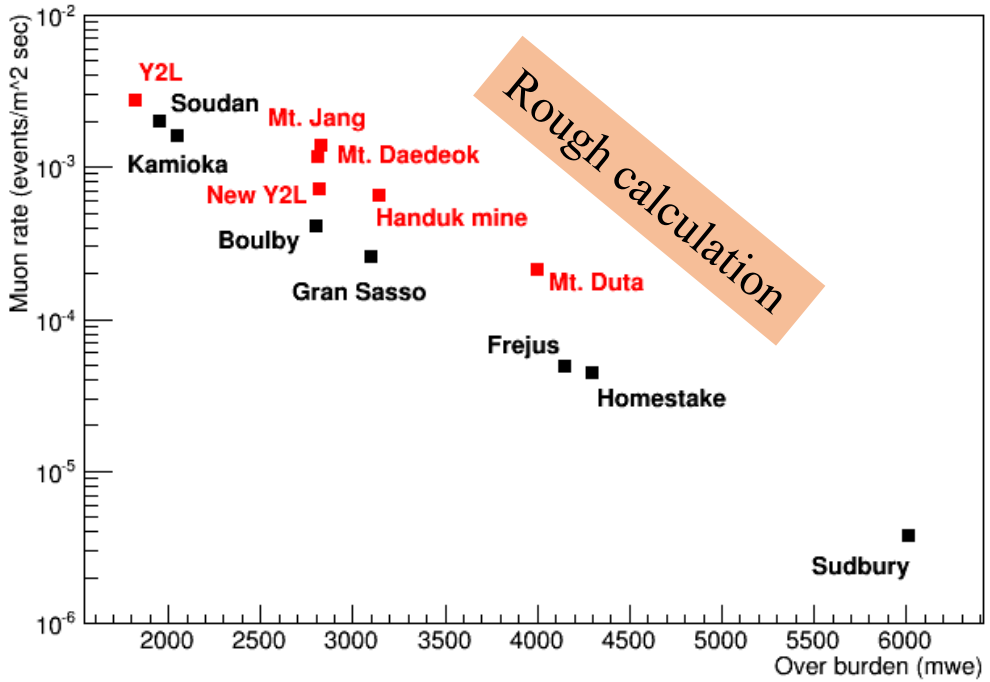


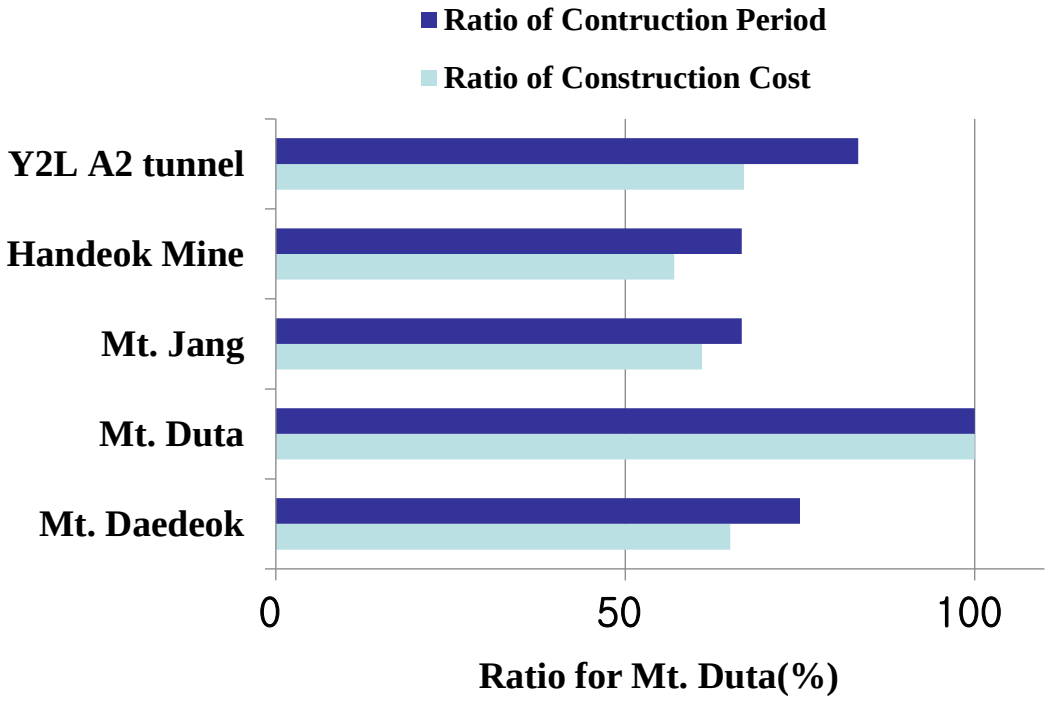


Candidates		H. of Peak	EL. of Entrance	Tunnel Length	Depth of 8%	Overburden	EL. of UL	Muon rate
		(m)	(m)	(m)	(m)	(m)	(m)	Event
1	Mt. Daedeok	1290	460	2200	176	1006	284	857
2	Mt. Duta	1350	180	3570	285.6	1455.6	-105.6	180
3	Mt. Jang	1410	550	1900	152	1012	398	877
4	Handeok mine	990	-70	1100	88	1148	-158	403
5	Y2L A2 tunnel	930	90	2100	168	1008	-78	547

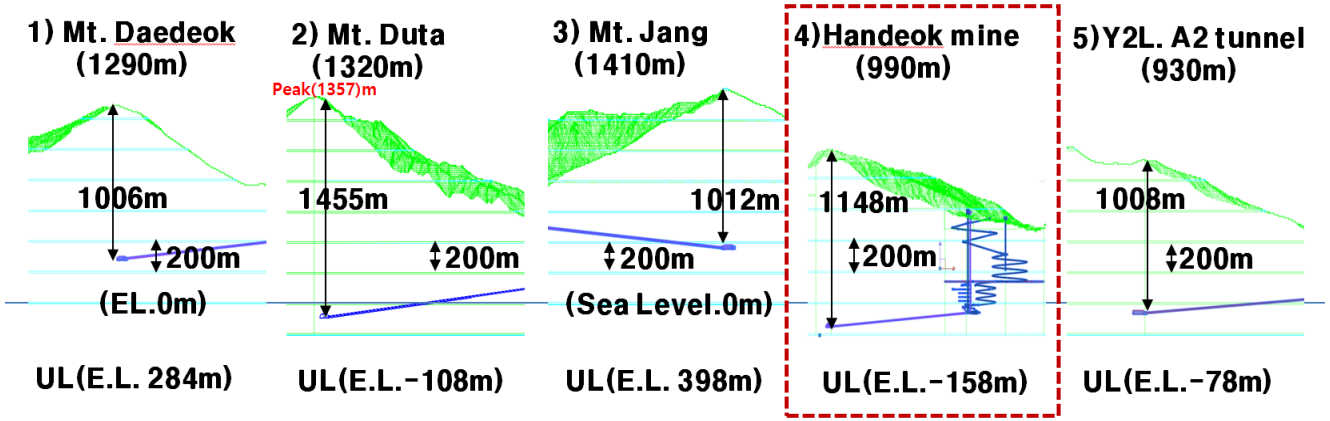
A new underground laboratory

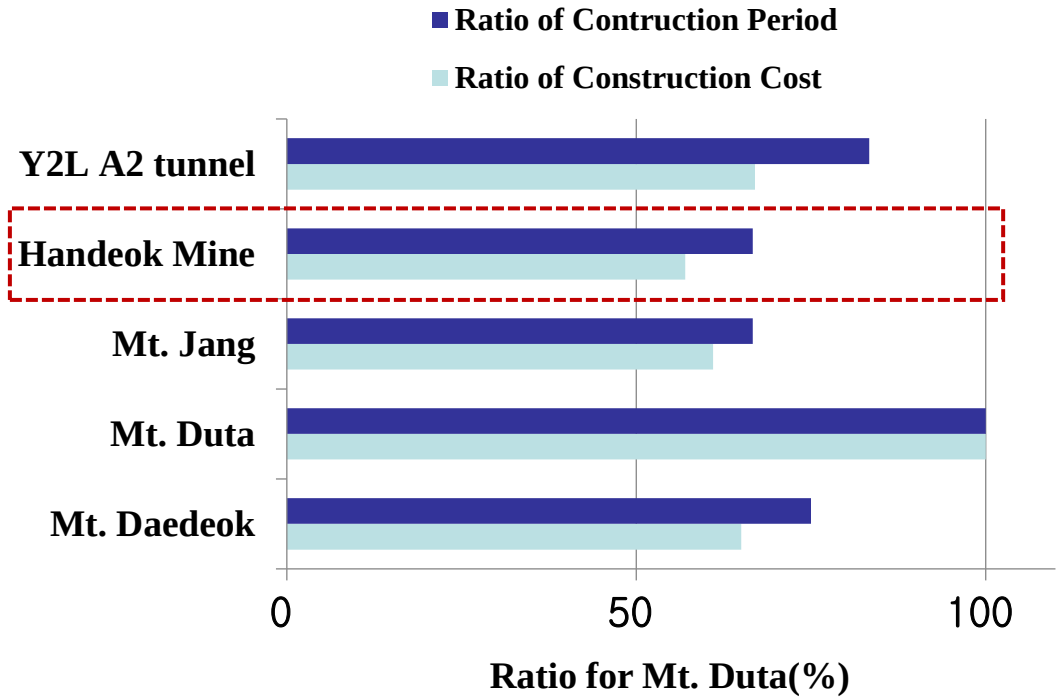


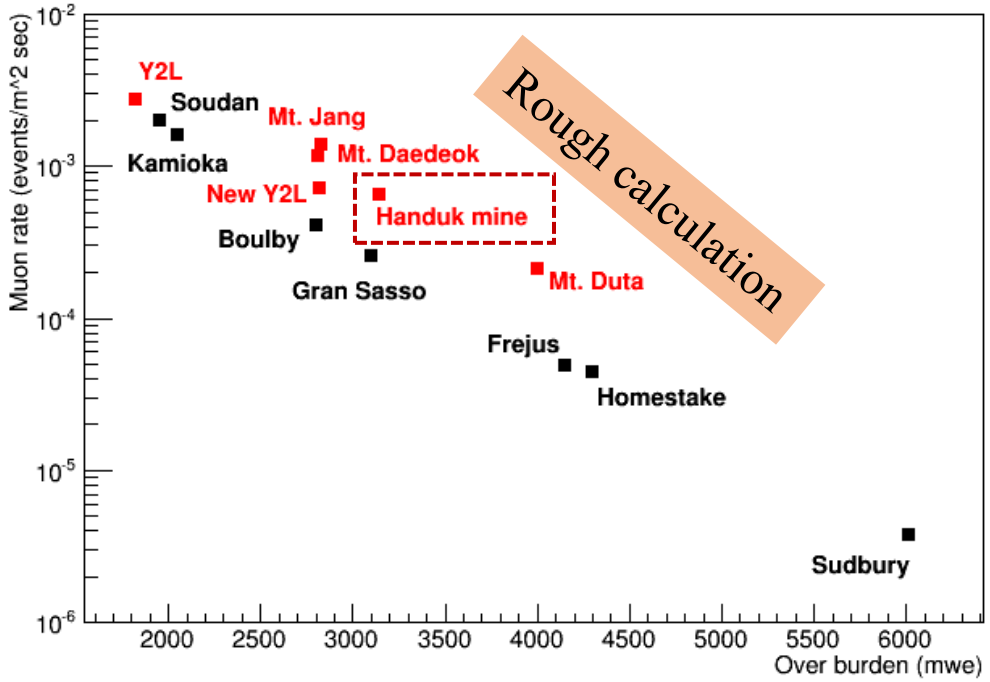




A new underground laboratory







The Handuk mine

1. **Cost effectiveness**
2. **Acceptable overburden**
3. **Limestone for less radioactivity**

Construction of the Yemilab

❖ **Milestones**

2015. New underground facility site chosen as Handuk iron mine

2016.12 Agreement signed with Handuk for the establishment and utilization of Yemilab within Handuk mine

2017.09 – 2018.12 Building the human riding cage

2018.12 – 2020.08 The 1st construction for excavation of the main tunnels

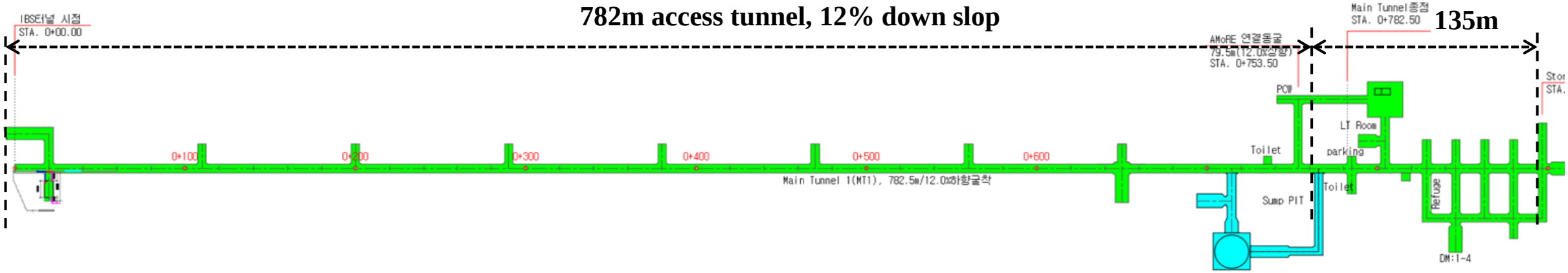
2021.06 – 2023.07 The 2nd construction for LSC & electricity, machinery etc..

2022.10 Renovation of the ground office

2022.10.05 The construction completion ceremony

2023.08 – 2024.09 Y2L relocation to Yemilab

Construction of the Yemilab



- The 1st phase construction
  - Period : 2017. July ~ 2020. August
  - Cage installation in the shaft
  - 1st phase Excavation : 2000m^2 (lab. area)

- The 2nd phase construction
  - Period : 2021. May ~ 2022. July
  - 2nd phase excavation : 1000m^2
  - Electricity and machinery
  - Ground office renovation

Image records of the construction

Ground office

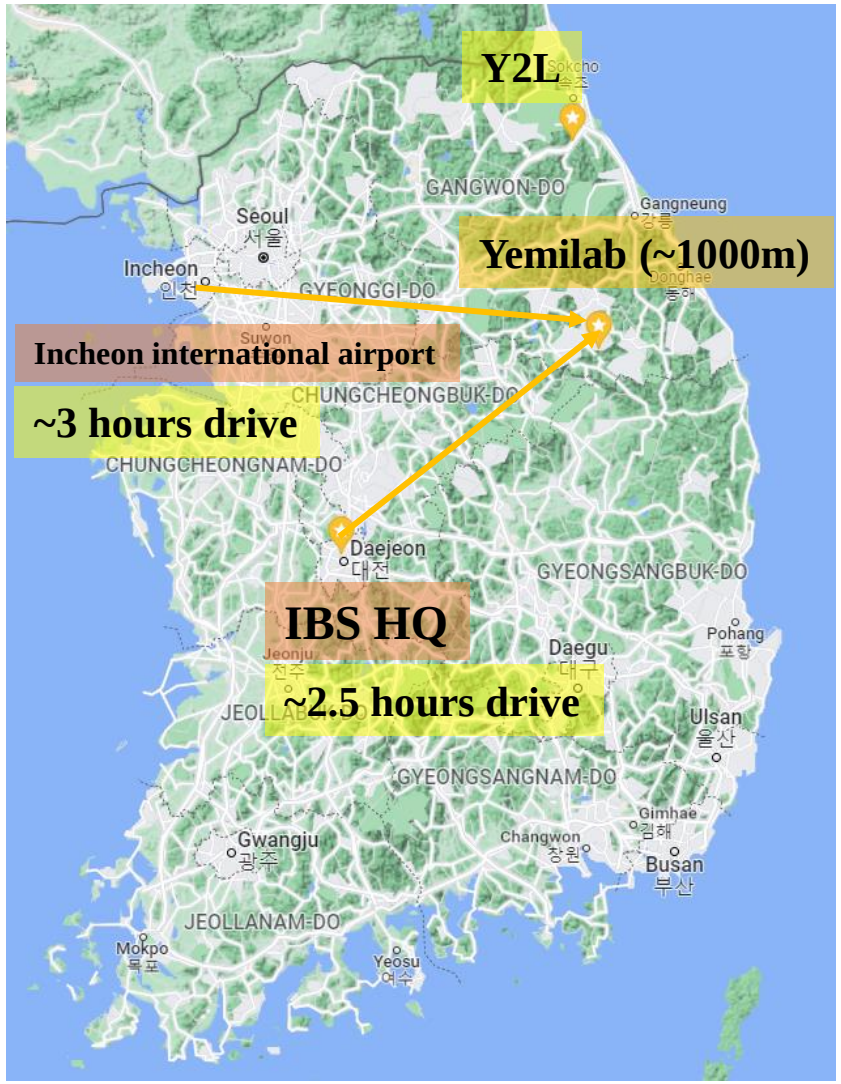
AMoRE cavern

Image records of the construction

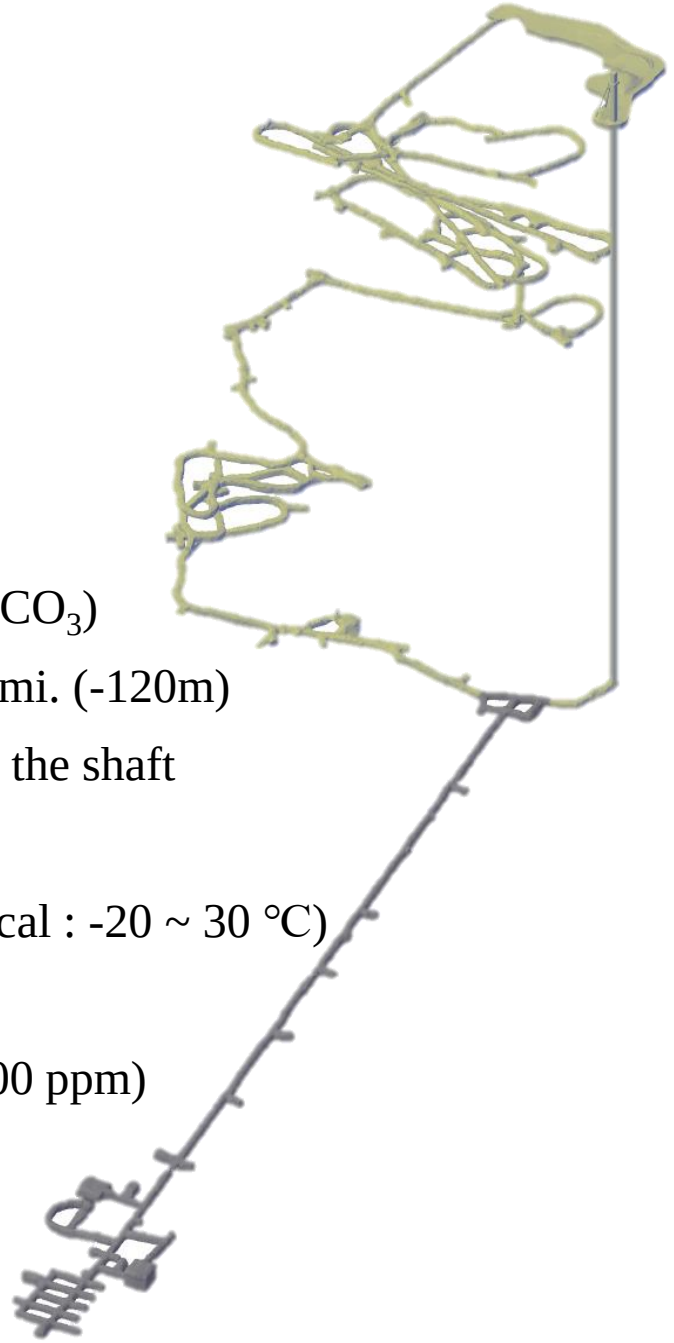
Ground office

AMoRE cavern

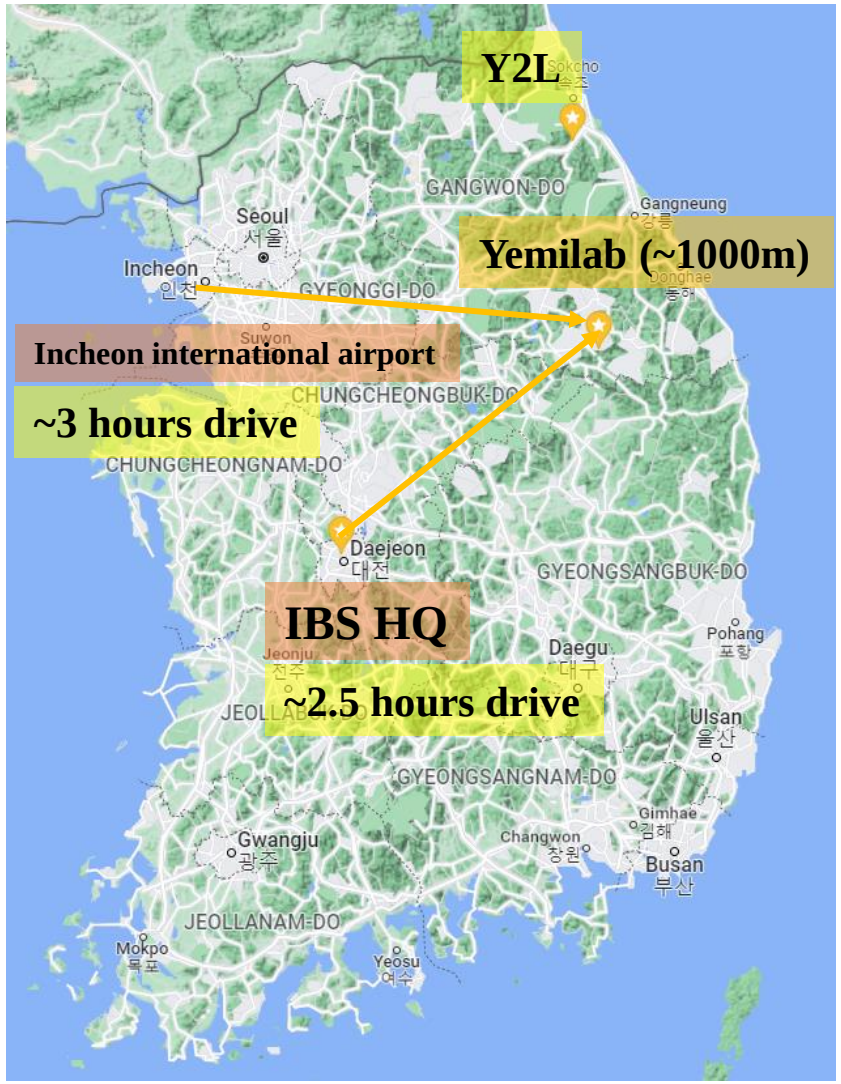
New history (Yemilab)



- Rock composition : Limestone ($CaCO_3$ and $MgCO_3$)
- Overburden : 1009m from the top of the Mt. Yemi. (-120m)
- Air circulation: 39,000 m^3/hour from the end of the shaft
- Electricity : 2MW
- Temperature : 25 ~ 29 ℃ at AMoRE cavern (local : -20 ~ 30 ℃)
- Humidity : 25 ~ 60 % at AMoRE cavern
- Airborne chemical : CO (< 10 ppm), CO_2(<1,500 ppm)

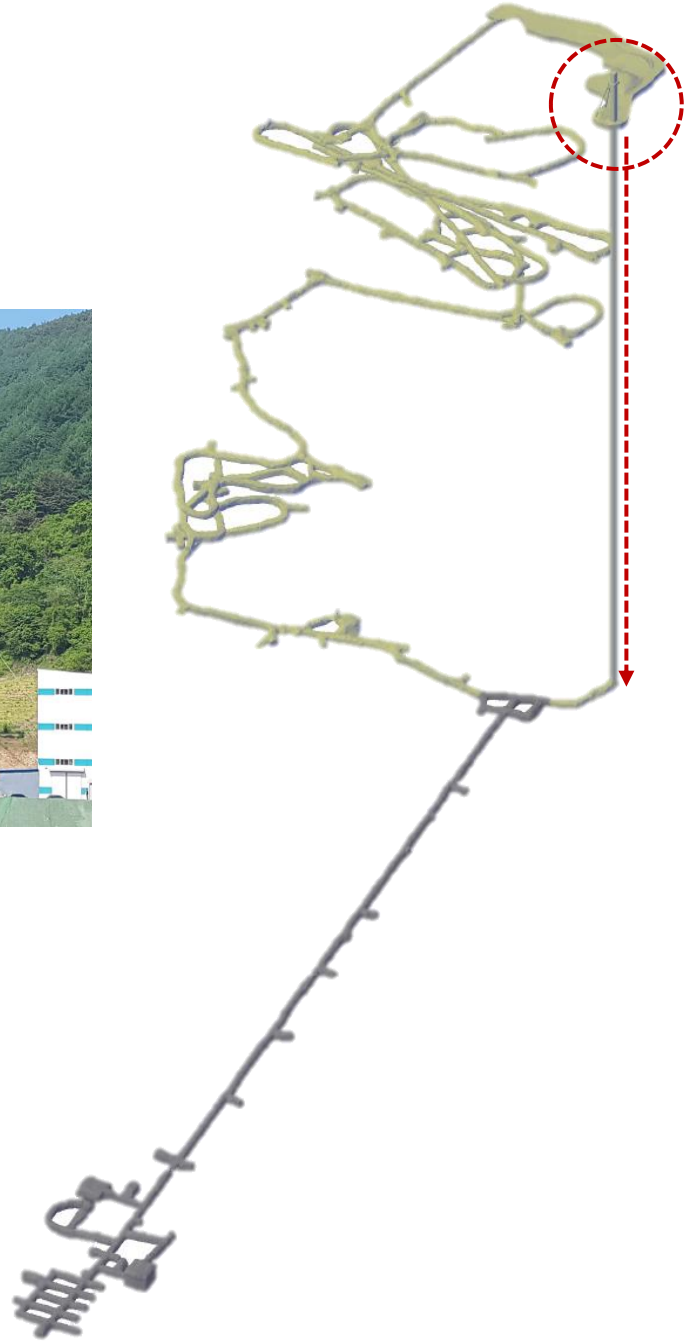


Access to Yemilab (Cage)

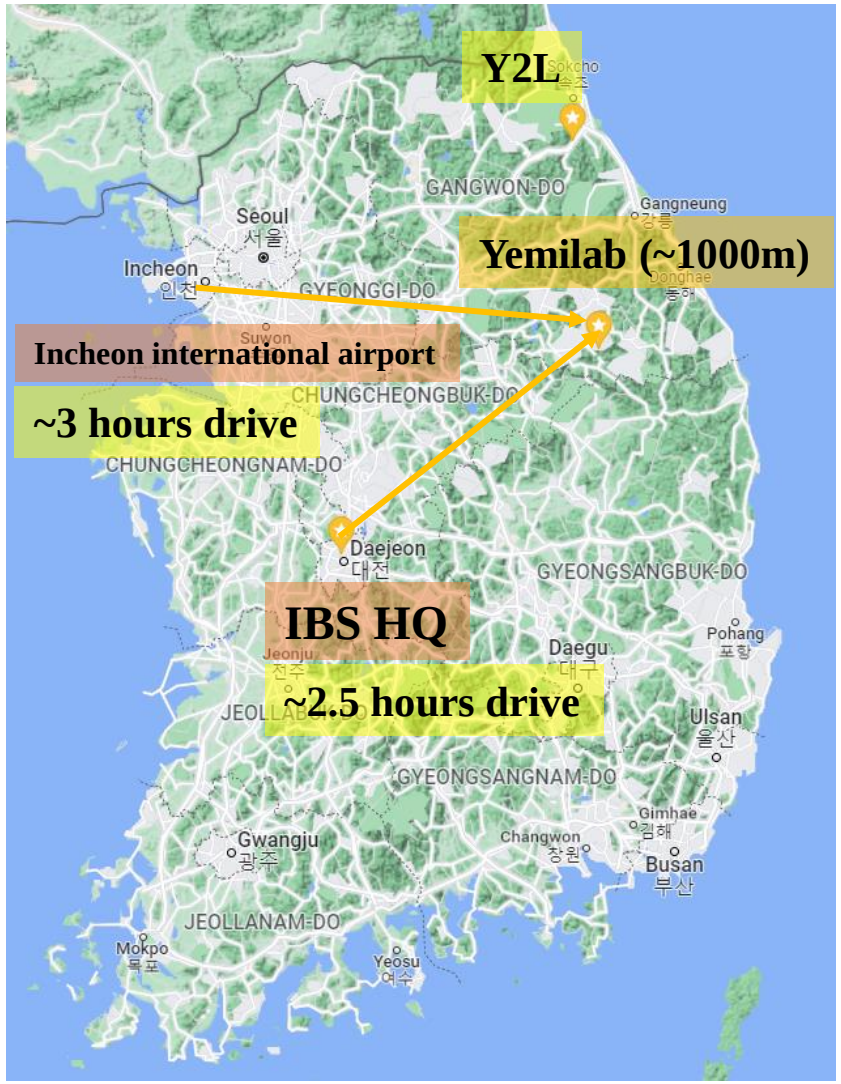


Cage for people

- Manufactured by SIEMAG
- Capacity : ~ 8 people, 1.5 tons
- Speed : 4 m/sec, 2.5 min
- 600m length of shaft

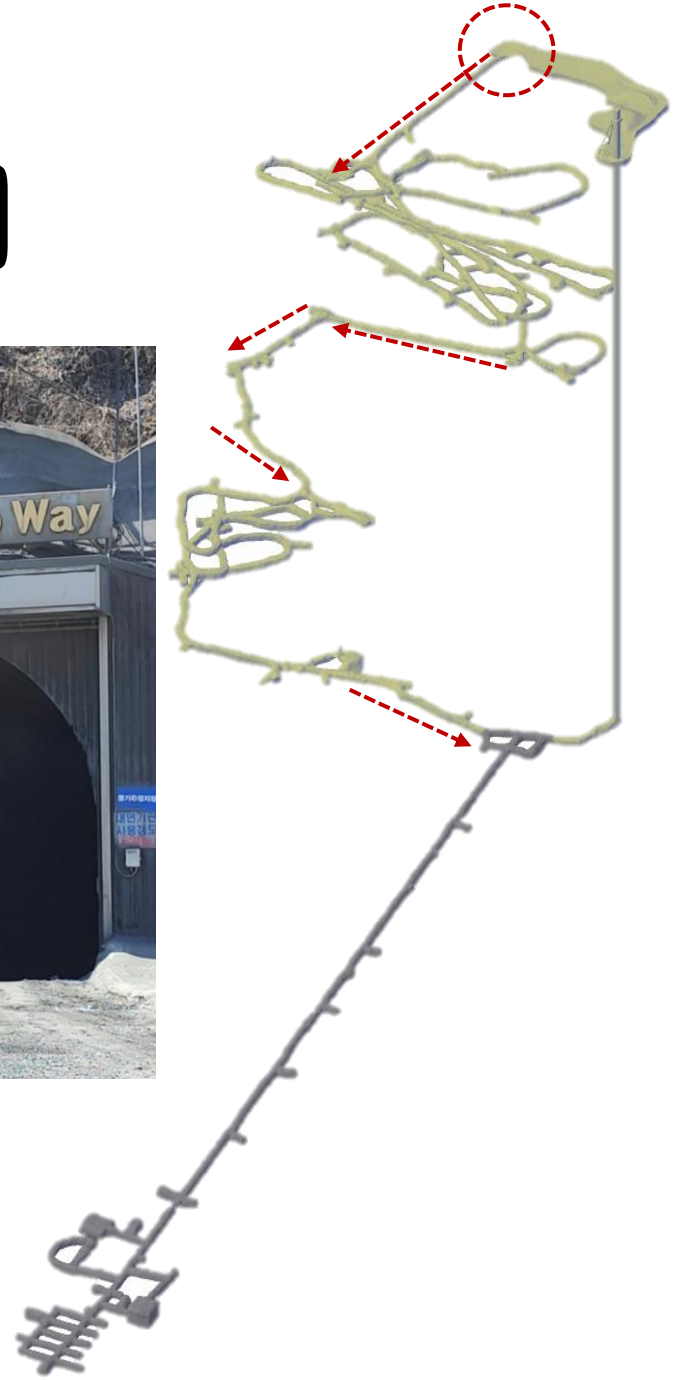


Access to Yemilab (Rampway)



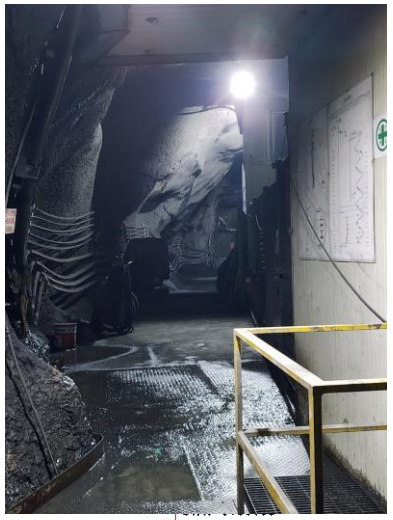
Rampway for cargo

- ~ 6 km unpaved road
- 5m × 5m tunnel
- Radio communication



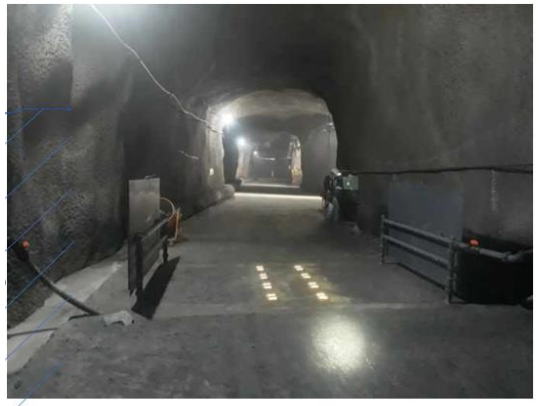
Access to Yemilab

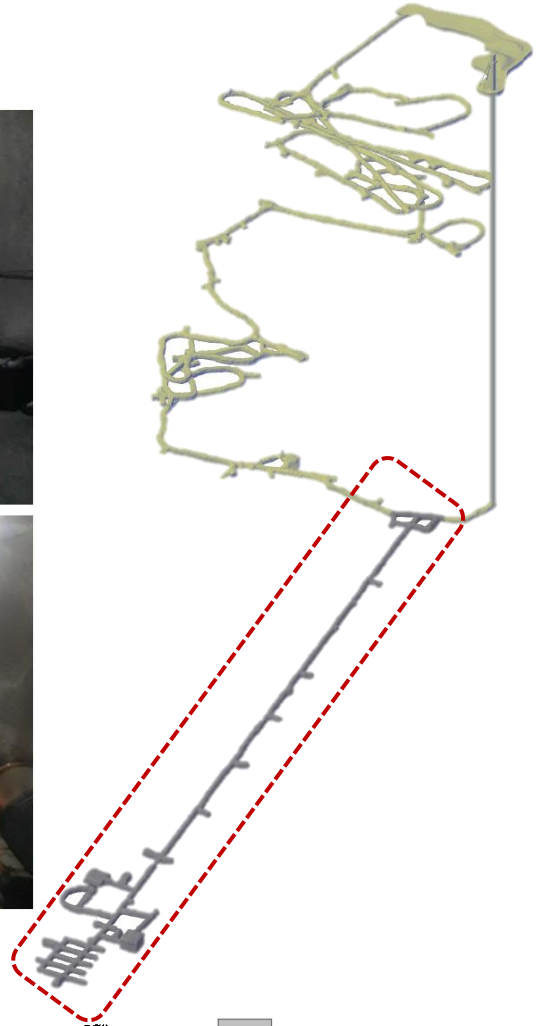
Cage stop

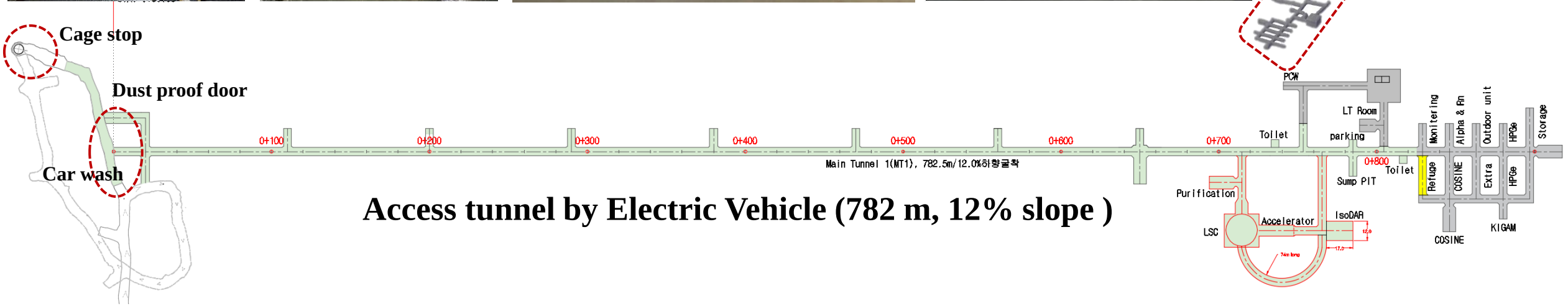


Dust proof door

Car wash





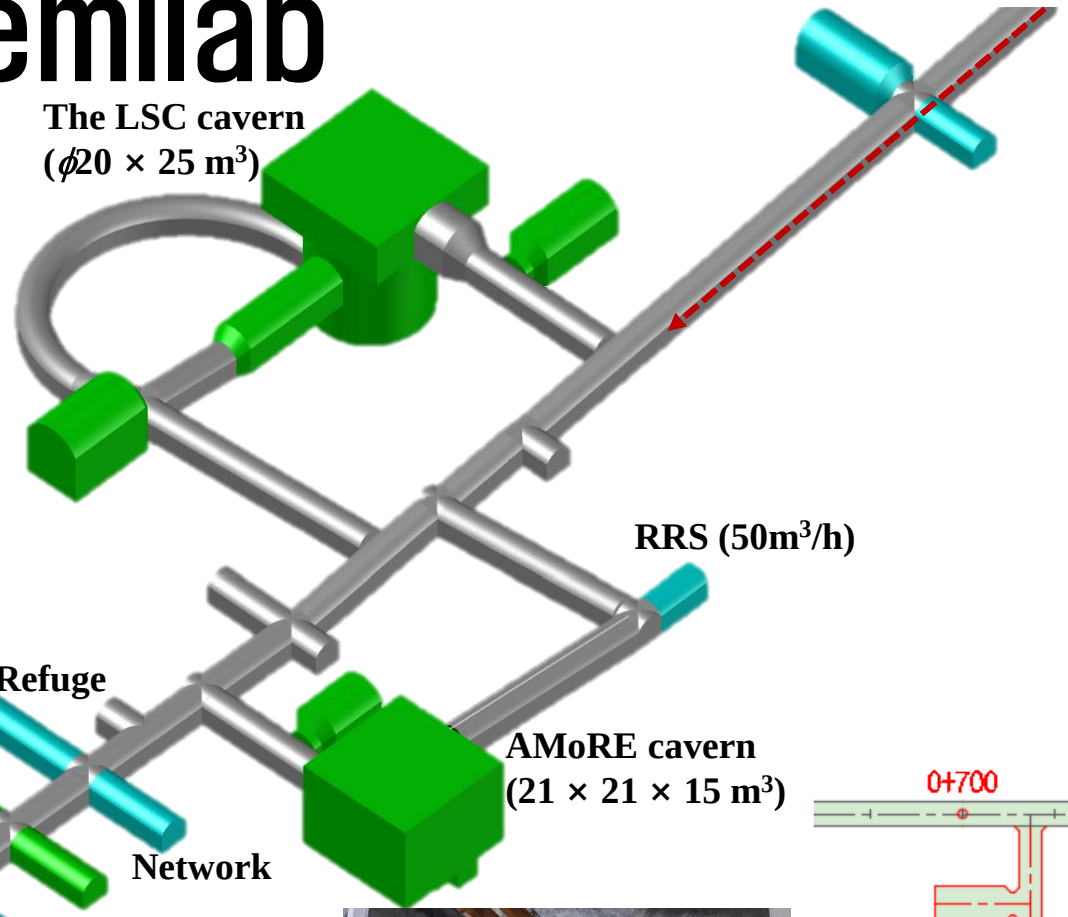


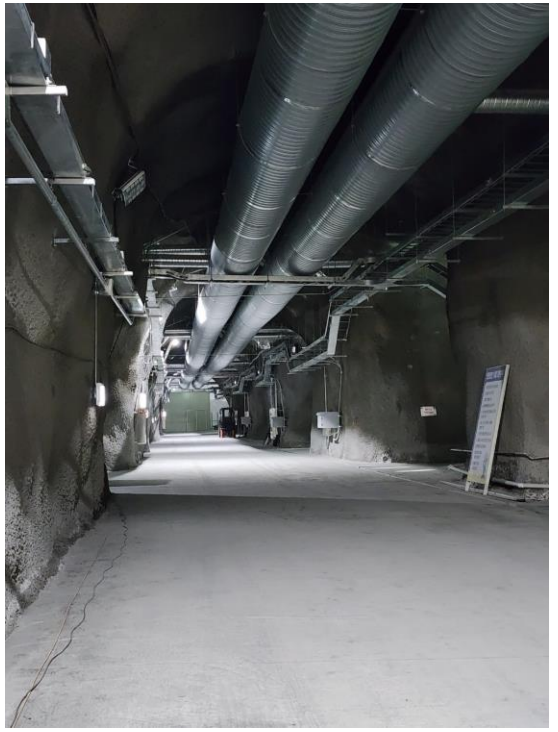
Access tunnel by Electric Vehicle (782 m, 12% slope)

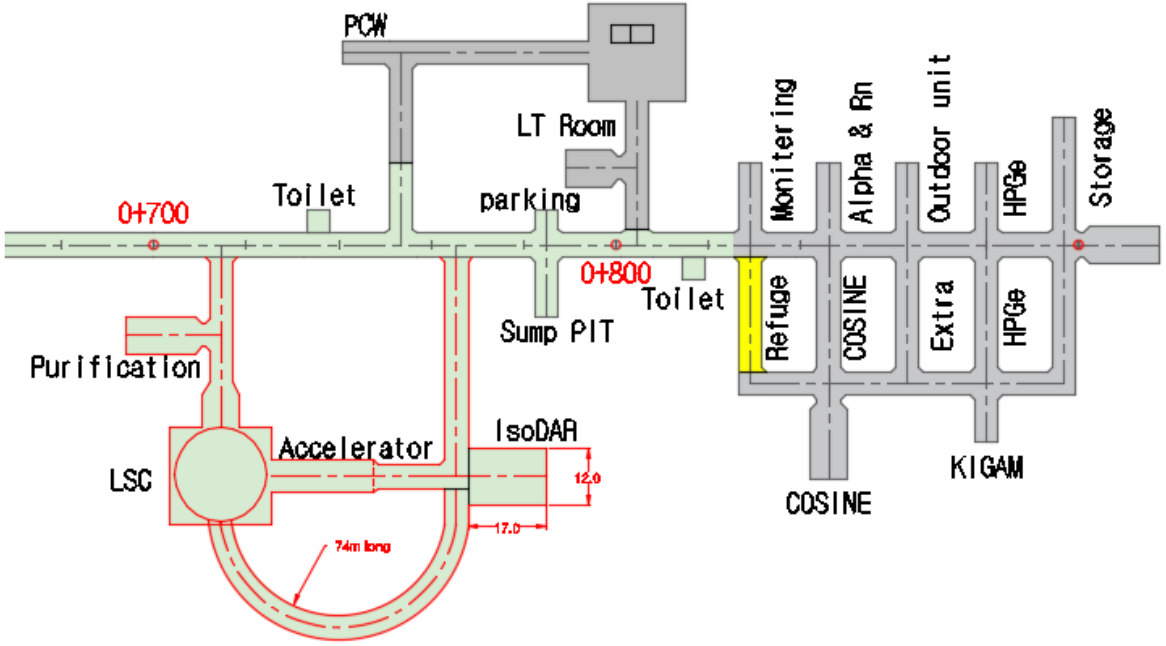
Infrastructures

- Full mobile communication (LTE)
  - Temporary network provision for online monitoring
- Network connection (coming soon)
- Radon reduction system (50 m^3/h, goal: 1/1,000 reduction)
  - 200m^3/h RRS is under consideration.
- LN2 generators for cryostats and HPGe
- Dust proof doors
- Electric vehicles for dust proof area
- Cranes for the large caverns (for large construction)
- Refuge (40 people for 72 hours, Dried food, water, air, UPS and so on)
- **Toilets**

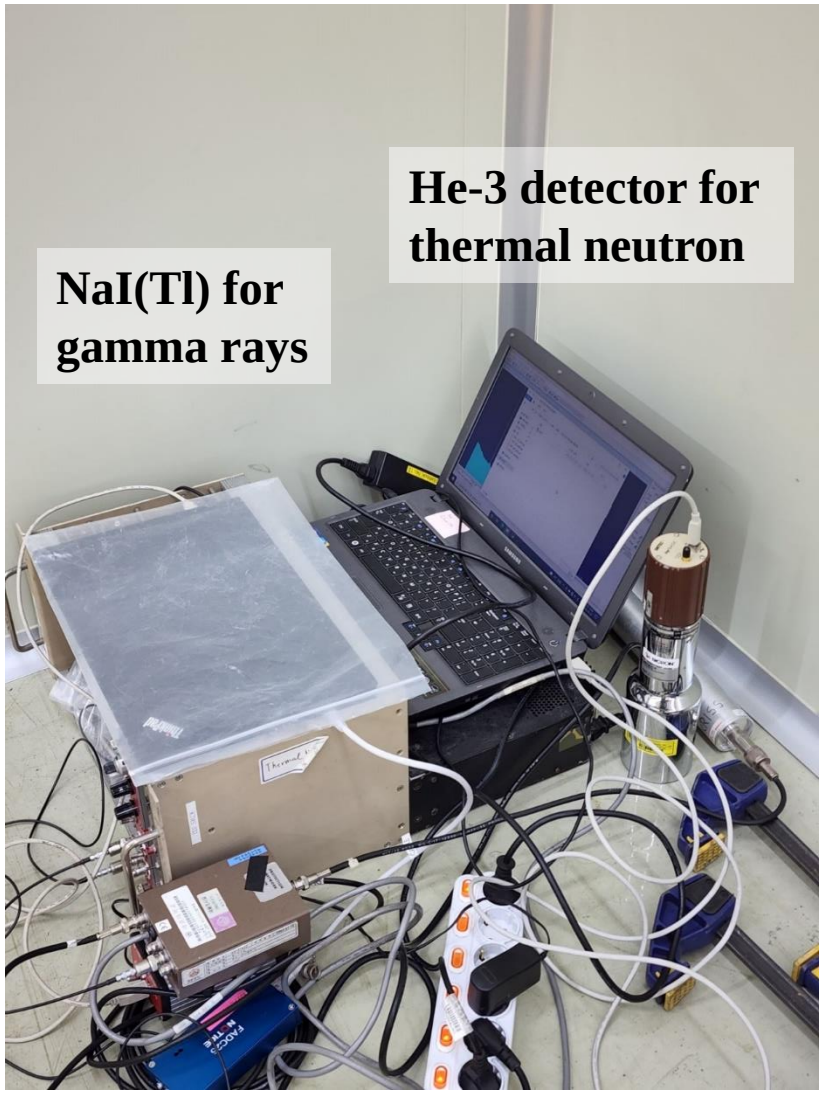
The Yemilab


Access by EV
The LSC cavern
(ϕ20 × 25 m³)
RRS (50m³/h)
AMoRE cavern
(21 × 21 × 15 m³)
COSINE (future)
Refuge
COSINE
HPGe
Network
O.D.U.
KNU cavern
(8 × 8 × 12 m³)



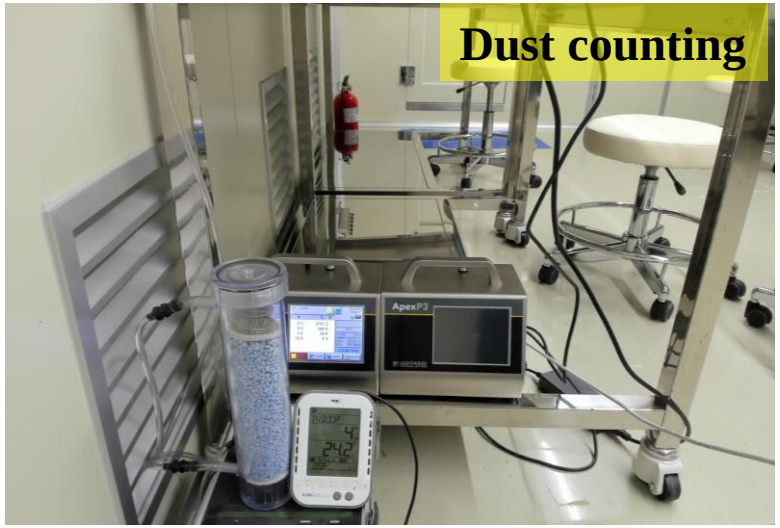

PCW
LT Room
Toilet
parking
0+700
0+800
Toilet
Sump PIT
Purification
LSC
Accelerator
IsoDAR
12.0
17.0
74m long
Monitering
Alpha & Rn
Outdoor unit
HPGe
Storage
Refuge
COSINE
Extra
HPGe
COSINE
KIGAM

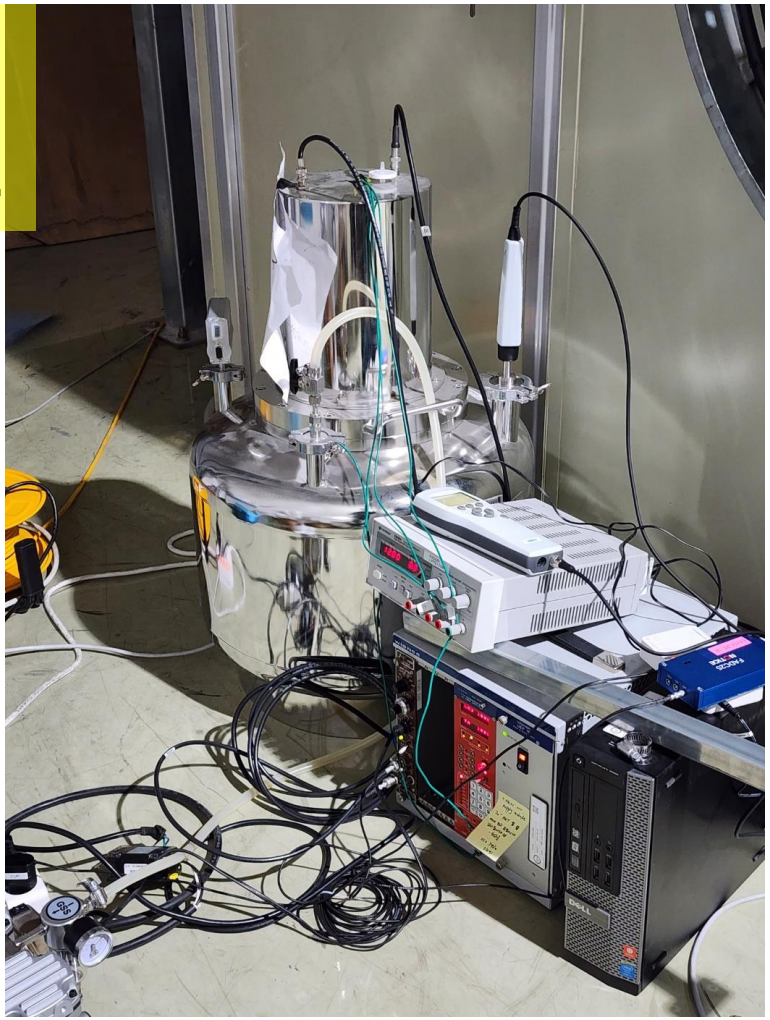
Radiation measurements



RAD7 for low level
RS9A for high level

Rn monitor for Rn free air





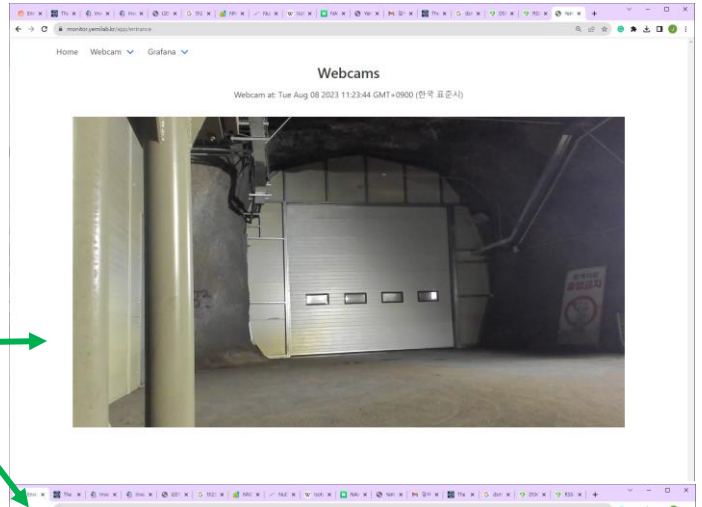
Raspberry Pi based monitoring system

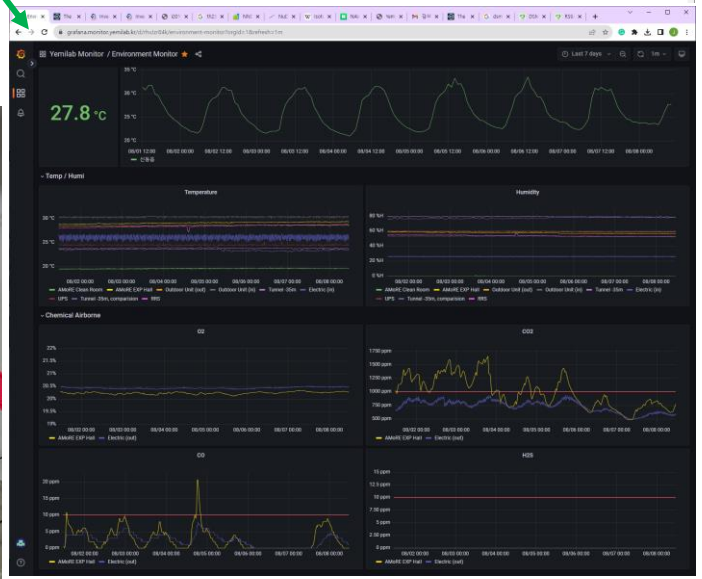
UA10
Calibration software
Temp. : -40 ~ 80 ℃
Humidity : 5 ~ 95 %

DSM101
PM1.0 / PM2.5 / PM10
1~1,000 μg/m^3

USB connection

Router (LTE)





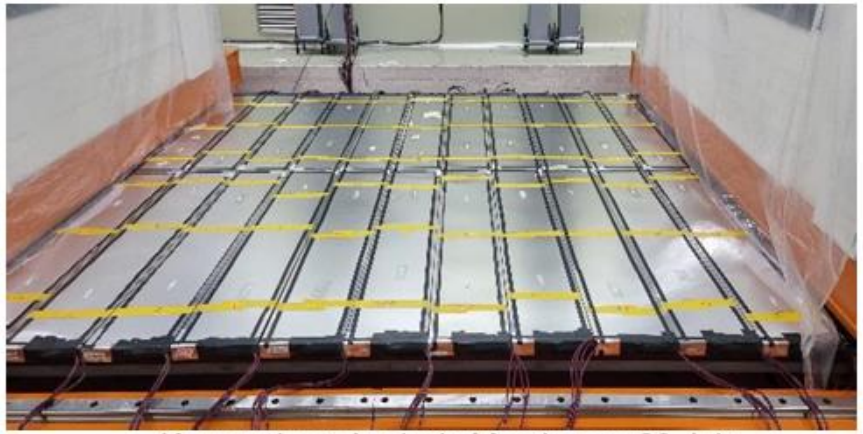
Raspberry Pi-3

UA58-KFG-U
CO (~ 1,000 ppm)
CO_2 (400 ~ 10,000 ppm)
O_2 (0 ~ 25%)
H_2S (0 ~100 ppm)

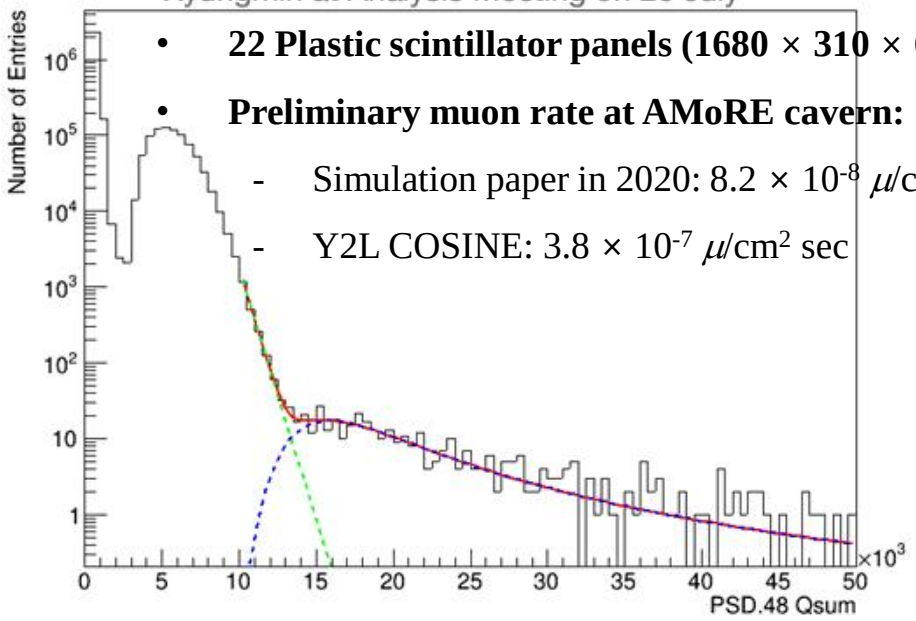
RS9A
7 ~ 3700 Bq/m^3
±15% accuracy

Webcam
1 picture / min

Muon reduction

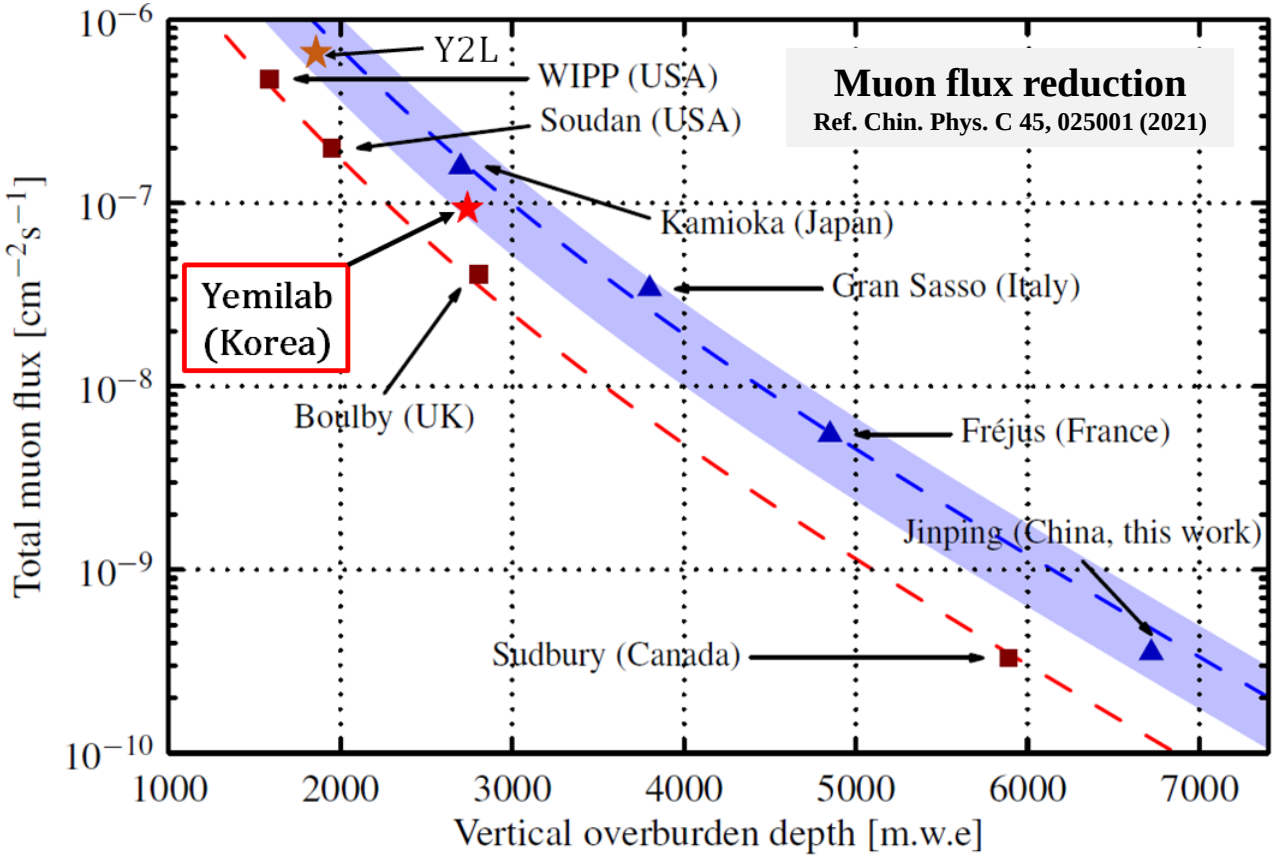


Kyungmin at Analysis Meeting on 20 July



- **22 Plastic scintillator panels (1680 × 310 × 61 mm³ each)**
- **Preliminary muon rate at AMoRE cavern: 1.0 × 10^{-7} μ/cm² sec**
  - Simulation paper in 2020: 8.2 × 10^{-8} μ/cm² sec
  - Y2L COSINE: 3.8 × 10^{-7} μ/cm² sec

U.L.	Gran Sasso	SNO lab	SURF	Kamioka	Boulby	Yemilab
Depth (mwe)	**3,800**	**6,000**	**4,300**	**2,700**	**2,850**	**2,500**
Volume (m^3)	180,000	37,000	7,800	56,500	14,000	25,000



Radioactive background assay

HPGe

Bq/kg	^{226}Ra	^{40}K	^{228}Ac	^{228}Th	^{210}Pb	^{54}Mn
Rock	58.0±5.2	1,161±232.3	52.6±7.5	50.7±5.1	N. A.	N. A.
Cement	26.0±1.3	216.3±10.9	24.0±1.2	21.5±1.1	N. A.	0.36±0.02
Sand	24.6±1.2	848.9±42.5	57.0±2.9	53.5±2.7	N. A.	0.81±0.05
Stone	8.9±0.5	54.8±2.8	9.9±0.5	8.9±0.5	N. A.	0.13±0.01

ICP-MS

			^{238}U	^{232}Th	^{40}K	Sample location
2020.08.19.	Handuk limestone A	KIGAM	1.17	3.43	11400	@ AMoRE Cavern top
	Handuk limestone B	KIGAM	0.68	3.50	13800	@ AMoRE Cavern left
	Handuk limestone C	KIGAM	0.66	2.87	10200	@ AMoRE Cavern right
average			**0.84 (10.4 Bq/kg)**	**3.27 (13.3 Bq/kg)**	**11800 (365.8 Bq/kg)**	

CMD424.1 Dust near Yemi cage 220802

Mass: 1.45 kg , M. day : 1 day CC1

^{226}Ra(^{238}U)	^{234}Th	^{40}K	^{228}Ac	^{228}Th	^{210}Pb
24.61 ± 1.23 Bq/kg	28.12 ± 1.46 Bq/kg	226.08 ± 11.33 Bq/kg	15.21 ± 0.77 Bq/kg	13.61 ± 0.68 Bq/kg	17.82 ± 2.31 Bq/kg

CMD424.2 Dust near AMoRE PCW 220803

Mass: 0.083 kg , M. day : 3 day CC1

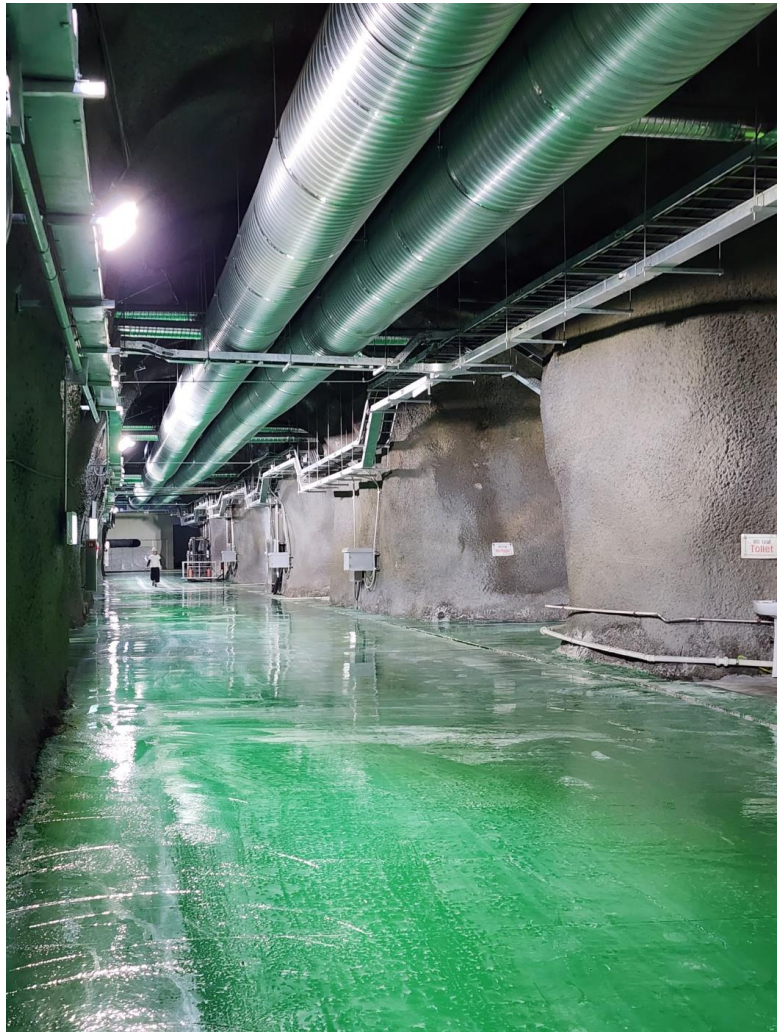
^{226}Ra(^{238}U)	^{234}Th	^{40}K	^{228}Ac	^{228}Th	^{210}Pb	^{54}Mn
24.99 ± 1.26 Bq/kg	39.62 ± 2.15 Bq/kg	407.21 ± 20.52 Bq/kg	22.88 ± 1.18 Bq/kg	23.07 ± 1.16 Bq/kg	164.78 ± 9.17 Bq/kg	0.33 ± 0.04 Bq/kg

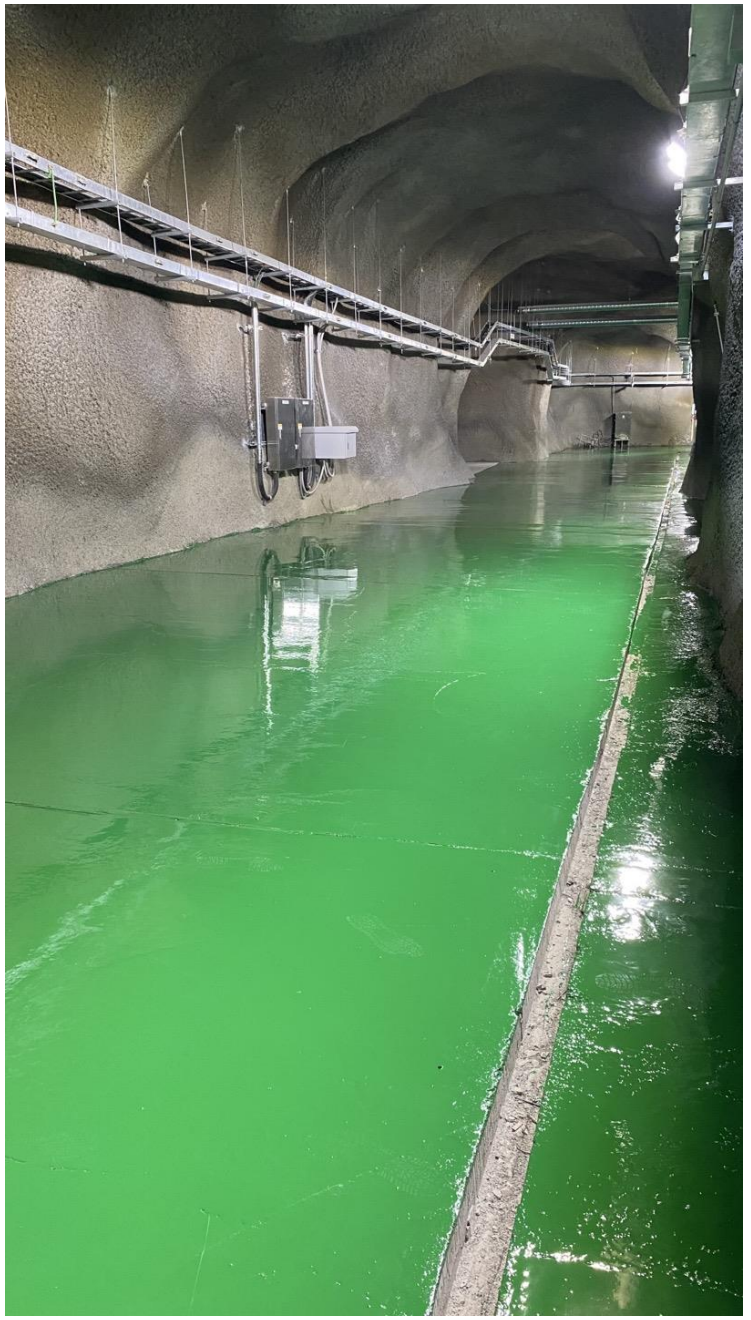
Radio activity of the dust

- 24.99 nBq/μg of ^{226}Ra
- 23.07 nBq/μg of ^{228}Th
- 407.21 nBq/μg of ^{40}K

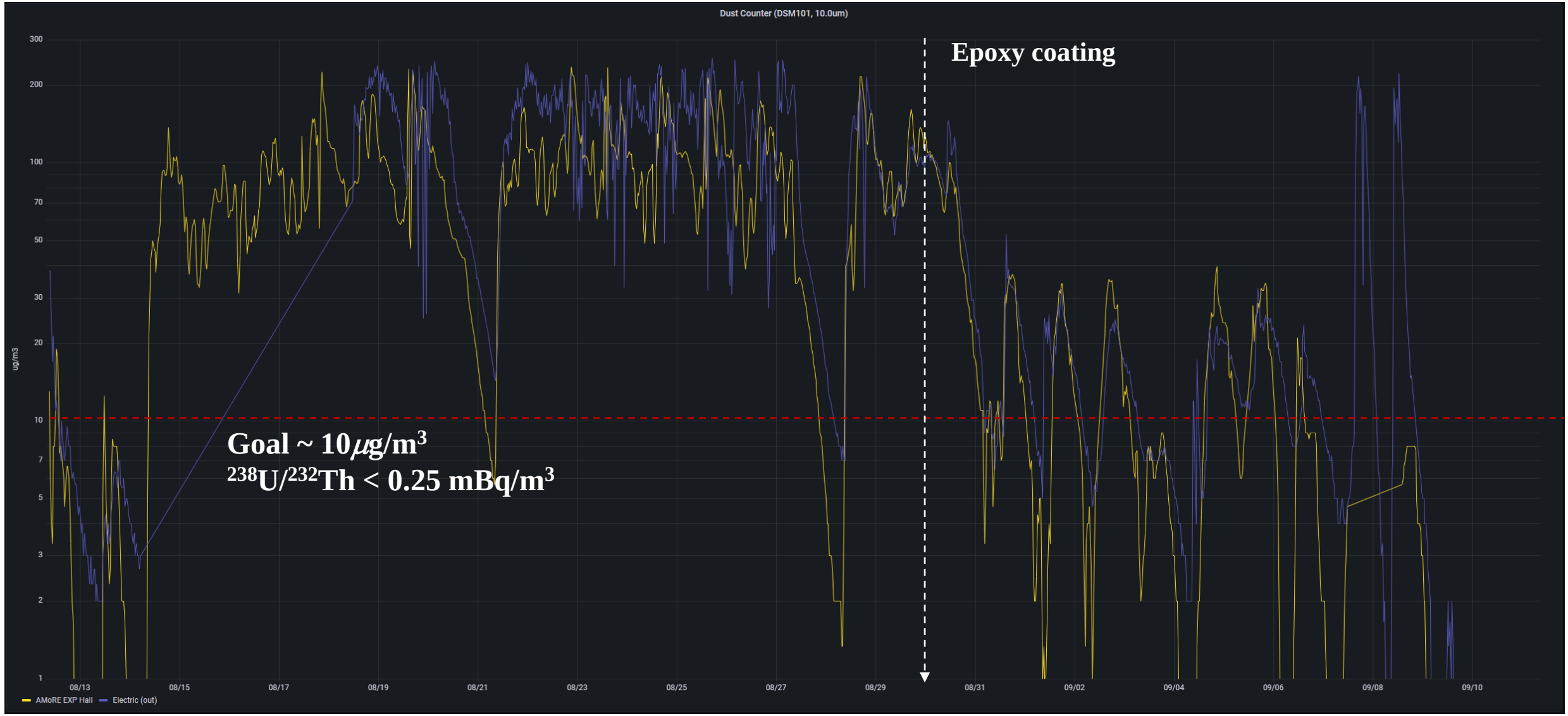
Dust requirement ~ 10 μg/m^3

Epoxy coating (30th Aug.)





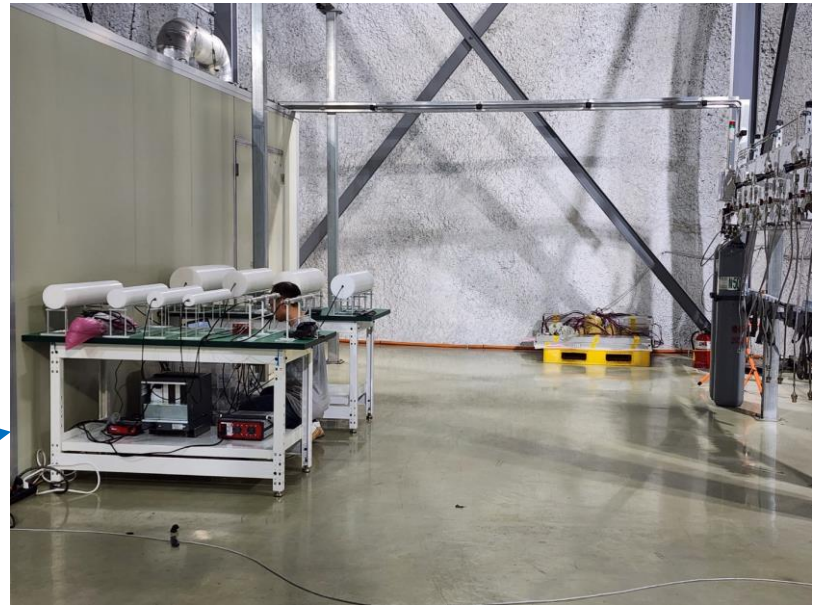
Dust control (epoxy coating)

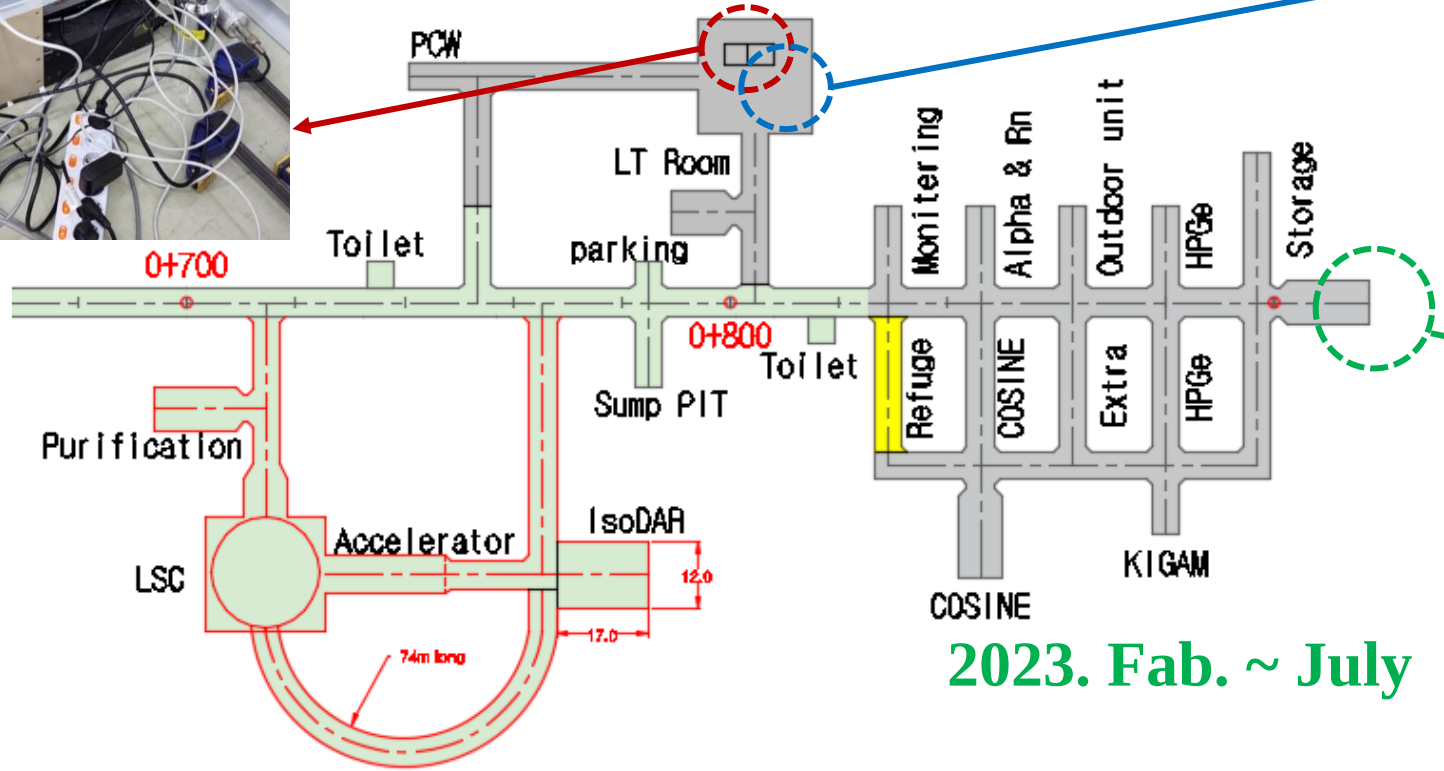


Neutron flux

2022. May ~ 2023. Fab.

2023. July ~

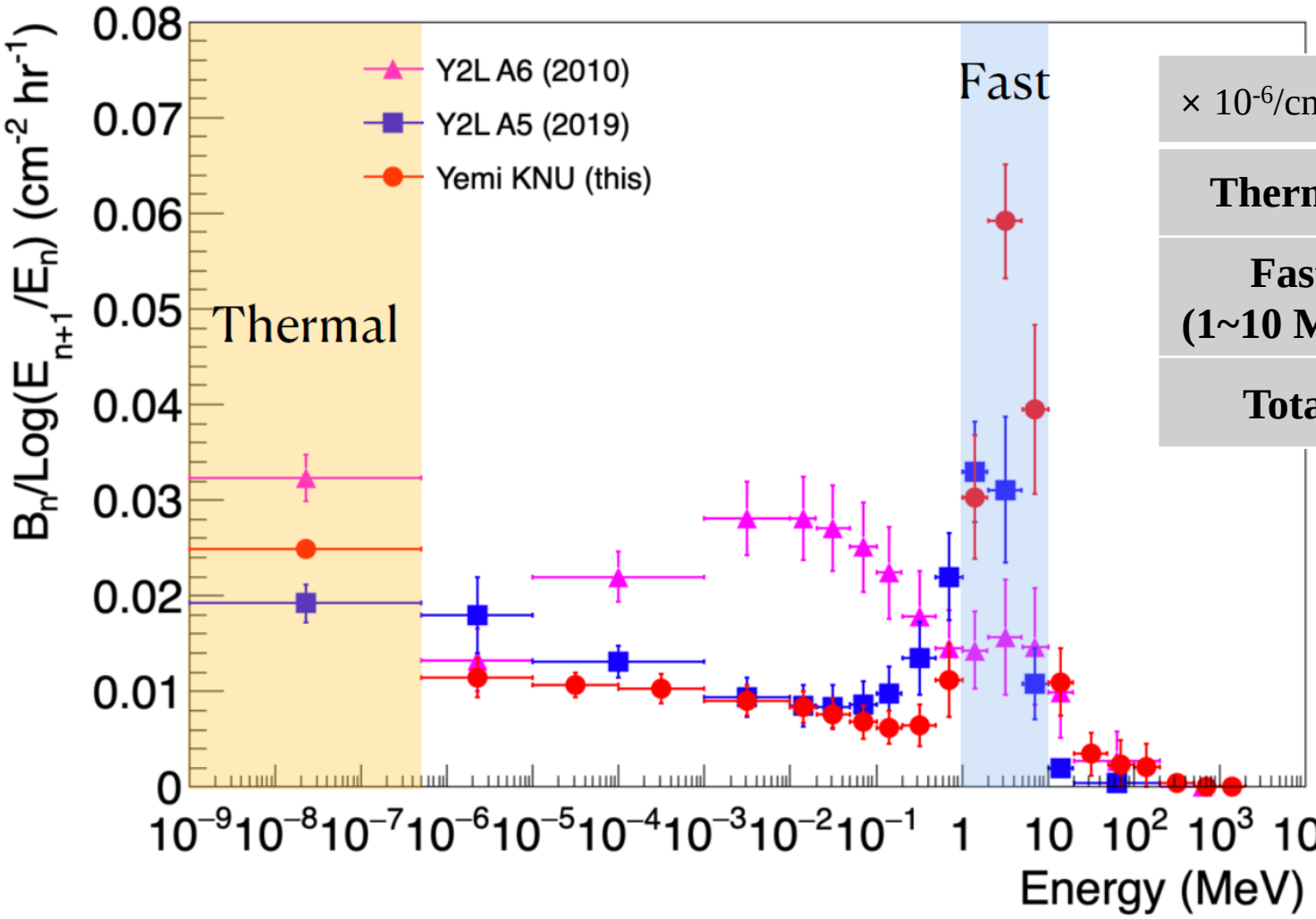




2023. Fab. ~ July

Neutron flux

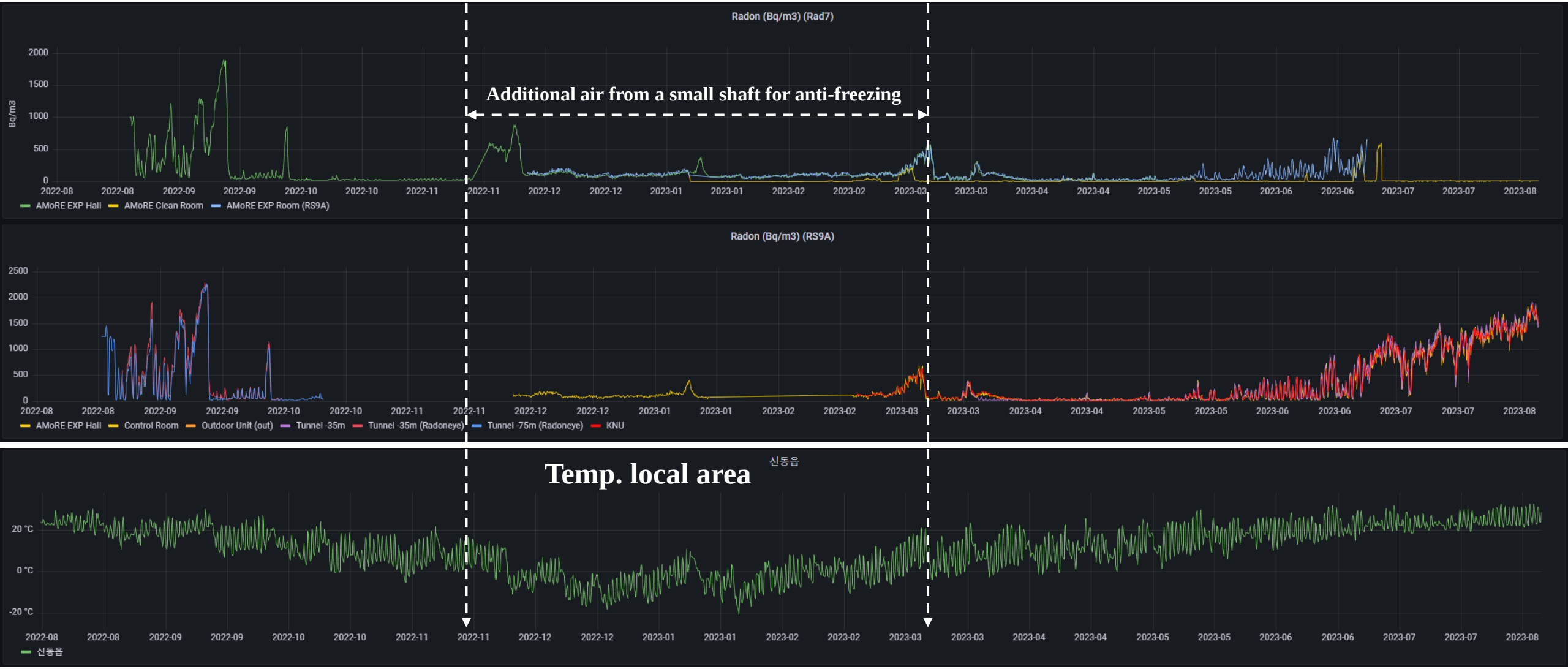
Measured by KRISS



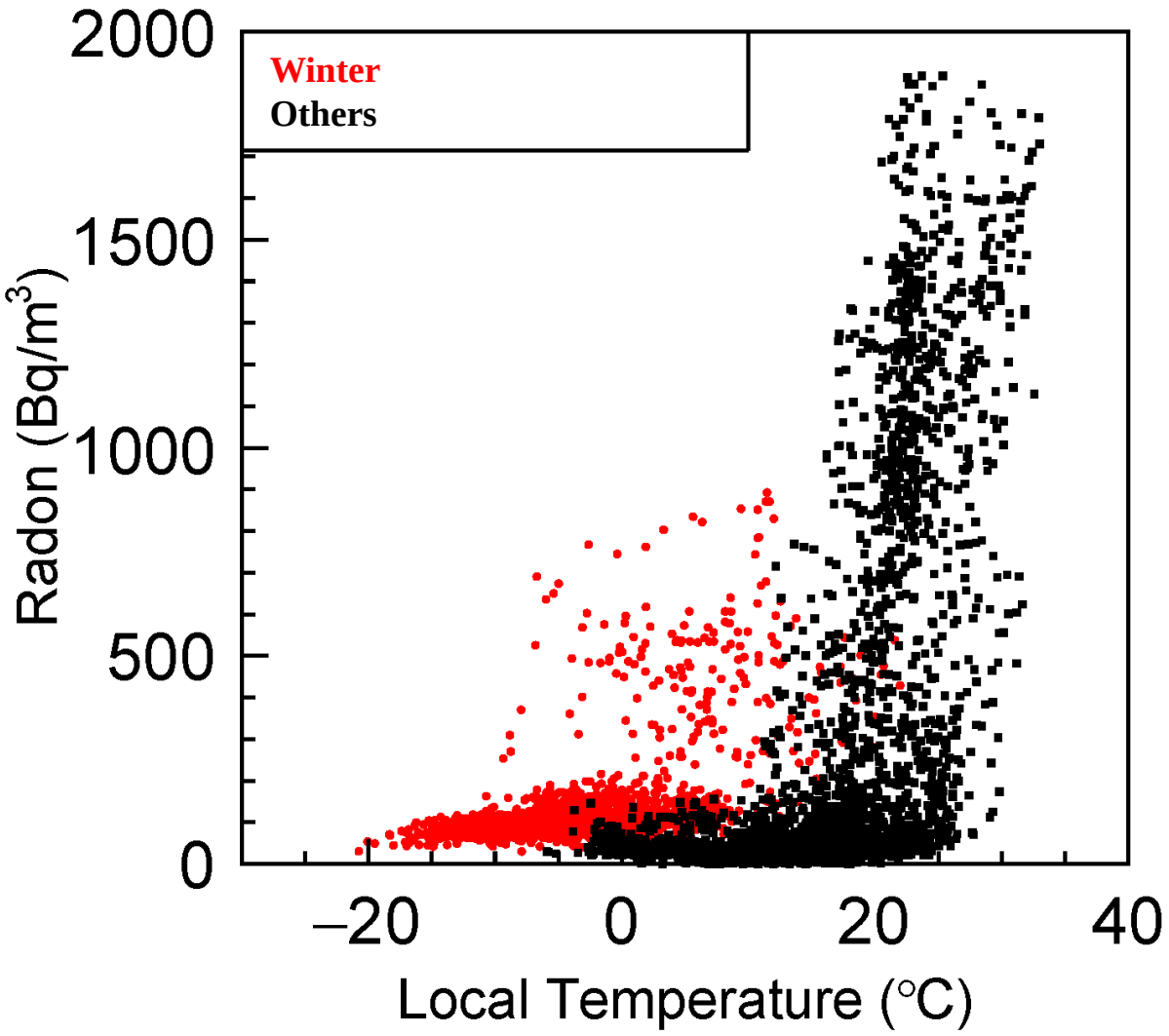
× 10^{-6}/cm_2 sec	Y2L A6	Y2L A5	Yemilab
Thermal	24.2 ± 1.8	14.4 ± 1.5	**18.6 ± 0.8**
Fast (1~10 MeV)	4.2 ± 0.9	7.1 ± 1.0	**12.4 ± 1.1**
Total	67.2 ± 2.2	44.6 ± 6.6	**49.5 ± 1.8**

- **Y2L : More moderation by equipment**
- **Yemilab : A few hundreds of tons Shotcrete**
  - ~ 180 tons on AMoRE cavern
- **Non-shotcrete measurement**
- **Si containment in Rock**

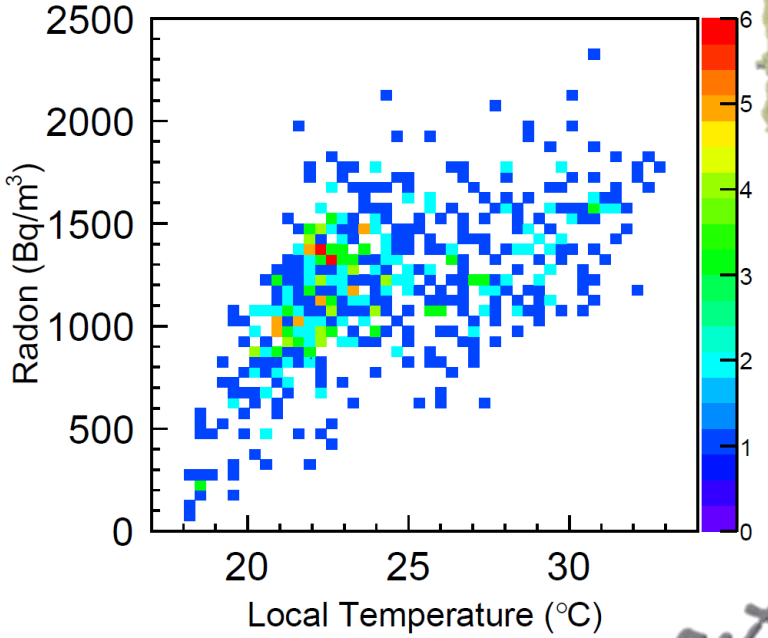
Radon level in Yemilab (1 year cycle)

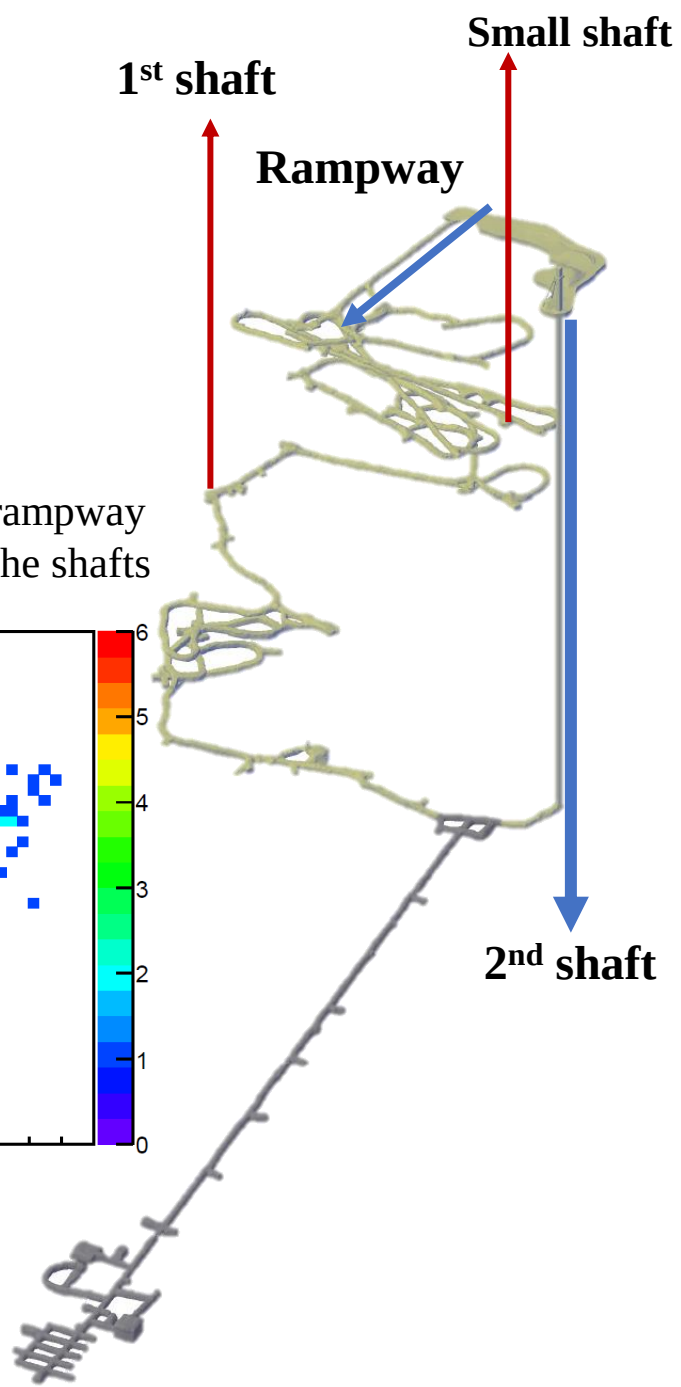


Rn level (Summer)

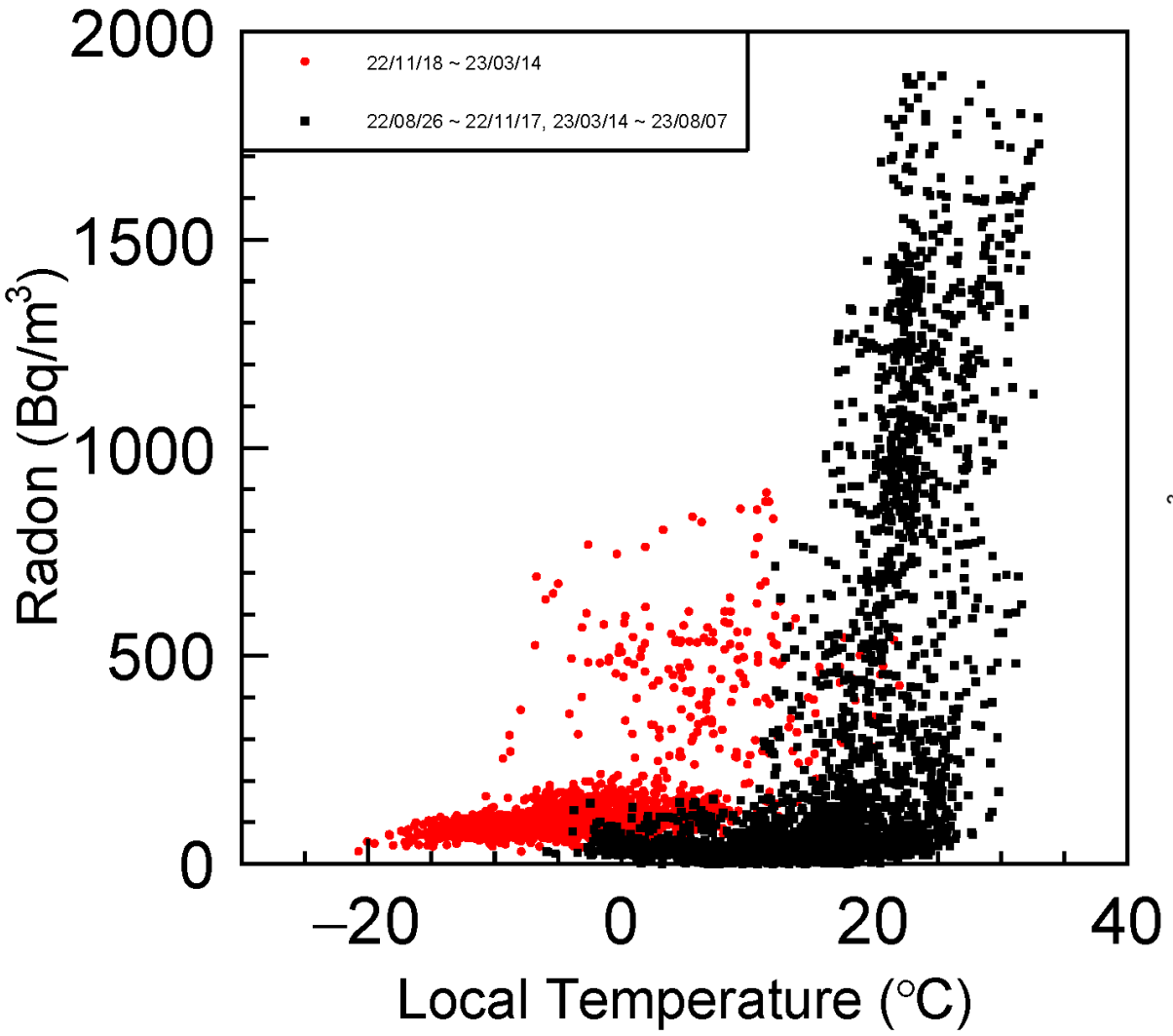


- Large air frictions through the rampway
- Inefficient ventilation through the shafts

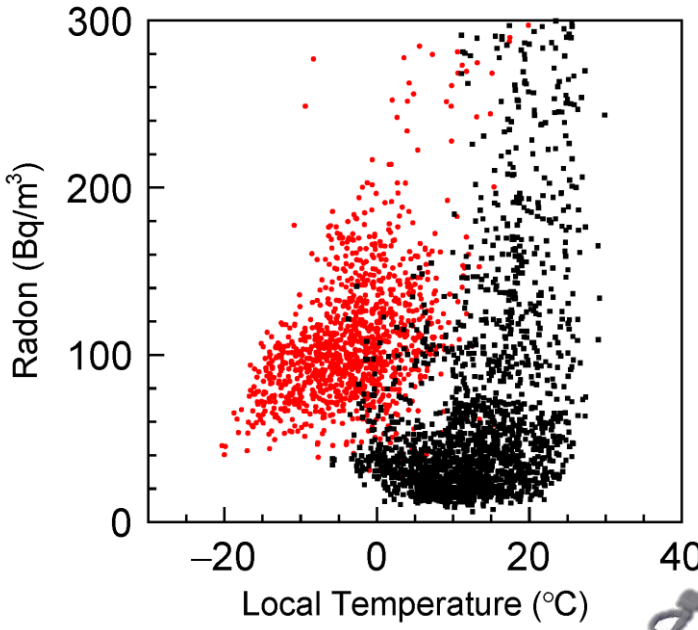


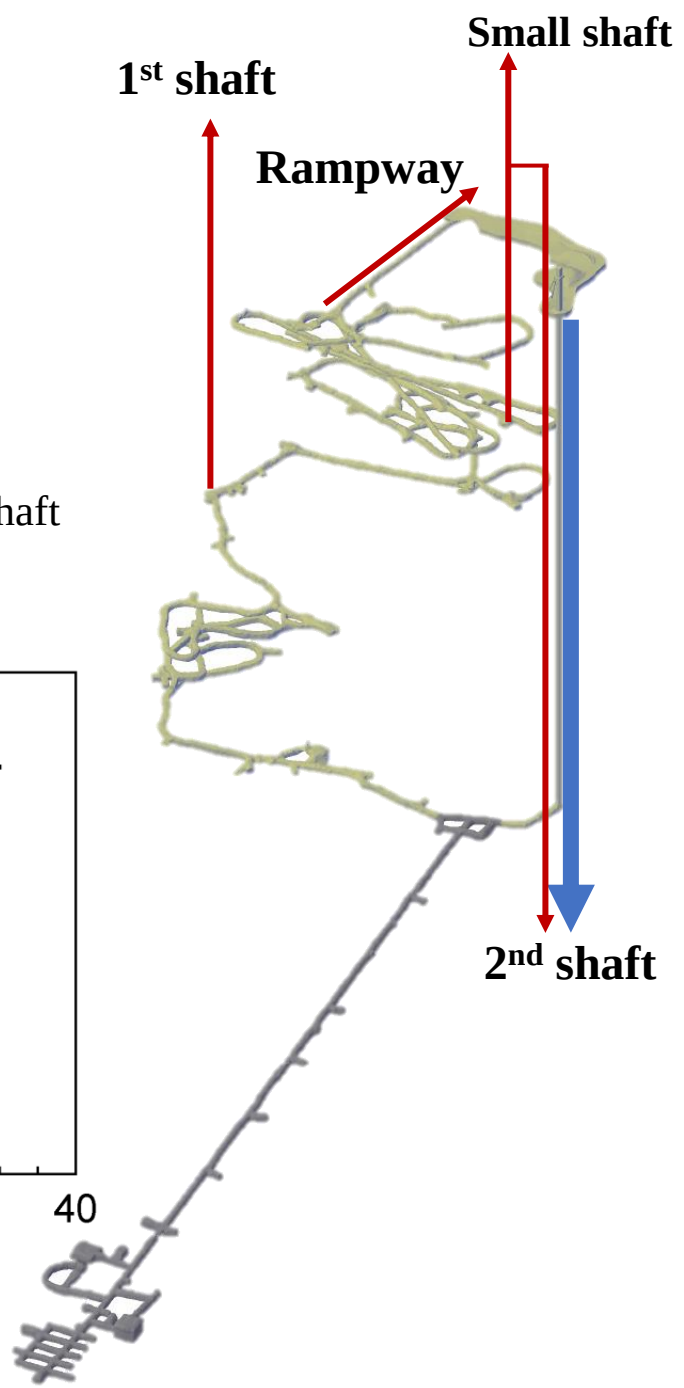


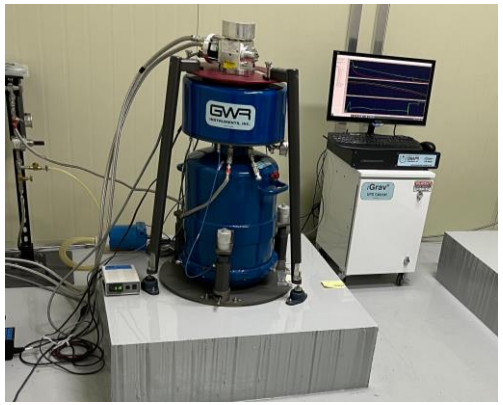
Rn level (winter)



- Additional air from the small shaft
  - Anti-freezing for the cage
- ~20% of the total supply

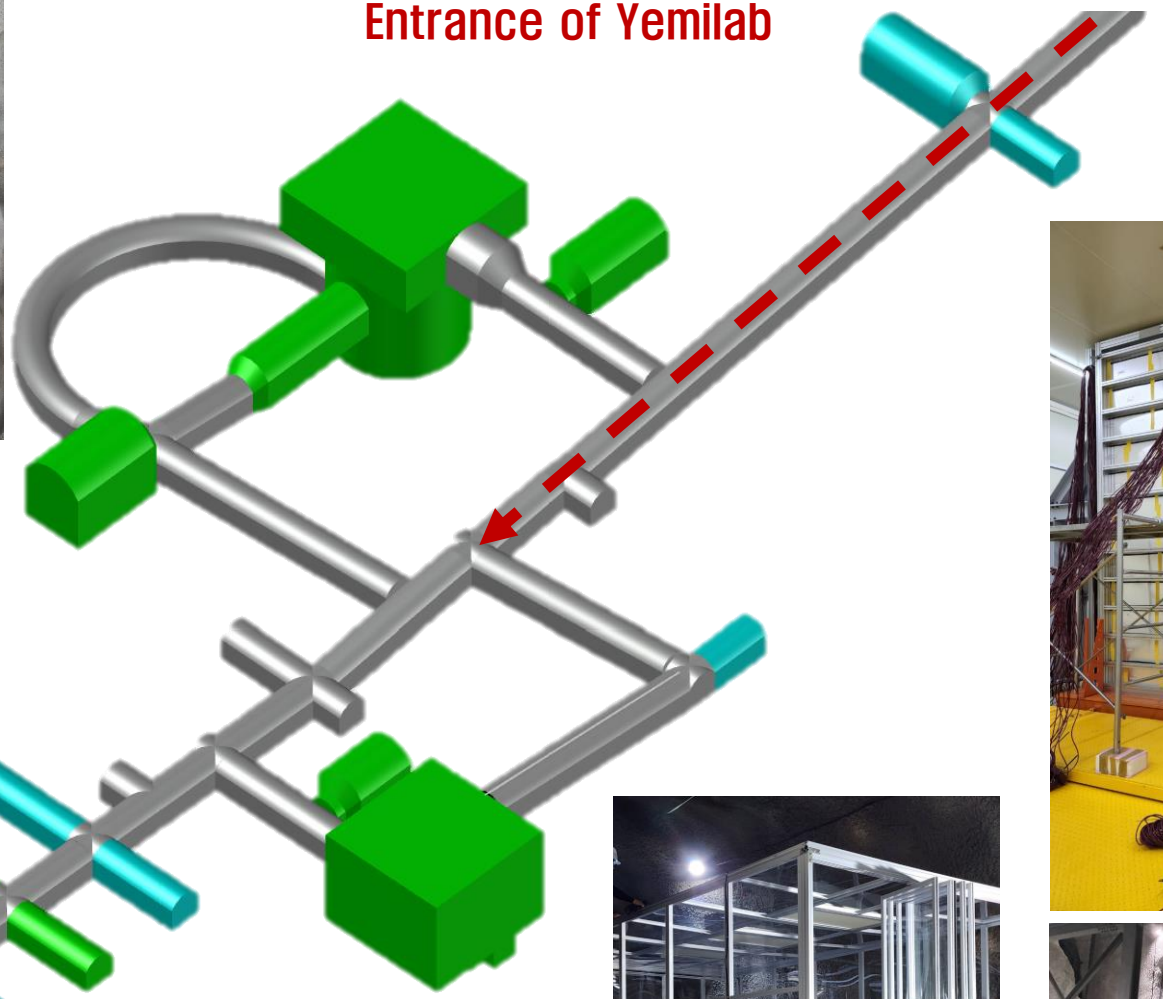


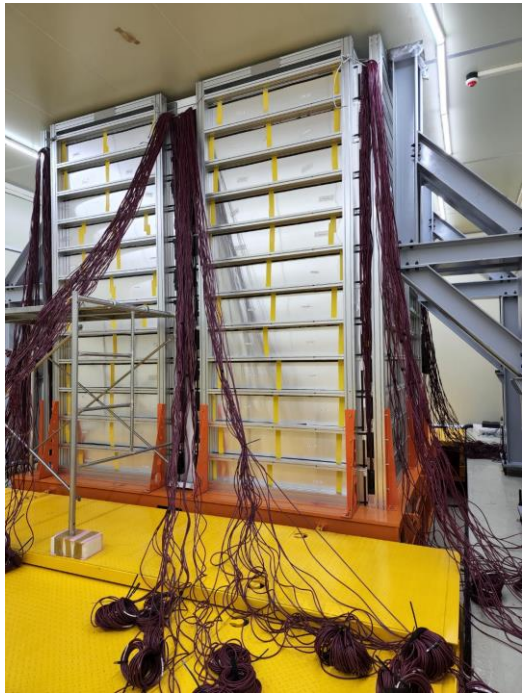




Meteorology
Entrance of Yemilab

Space medicine
(Zero gravity)
Vertical shaft

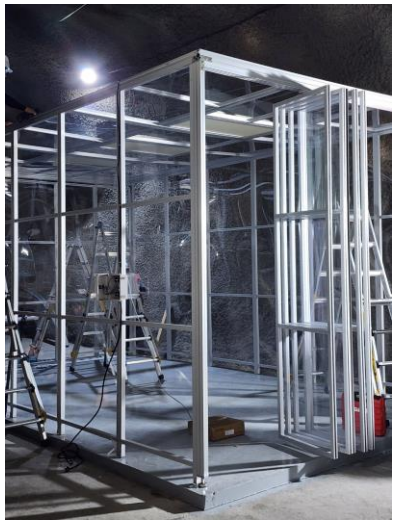




μGravity observation

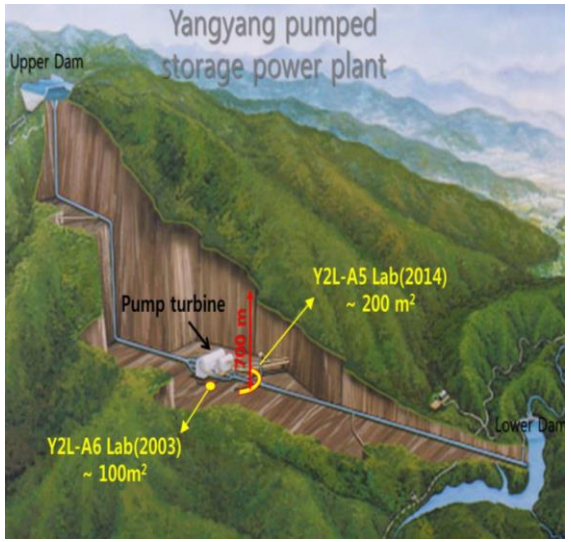
Geology

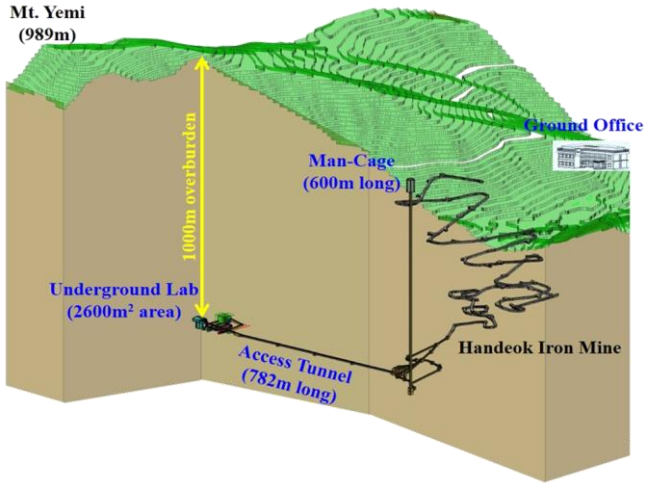
Environment radiation (2024)

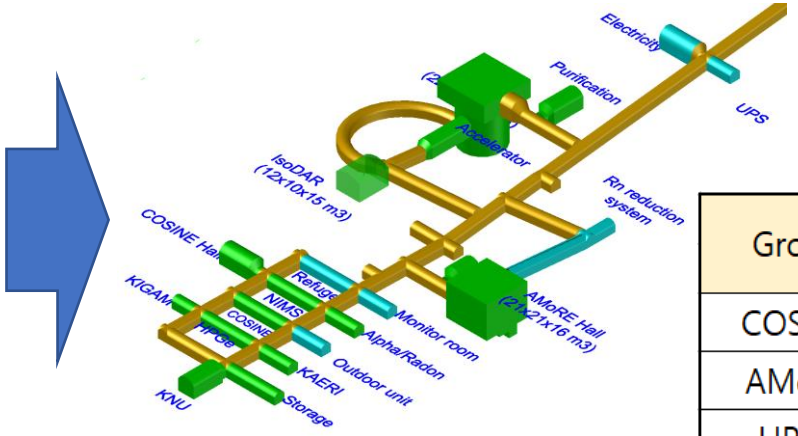


Physics department (KNU)

Transfer plan from Y2L to Yemilab







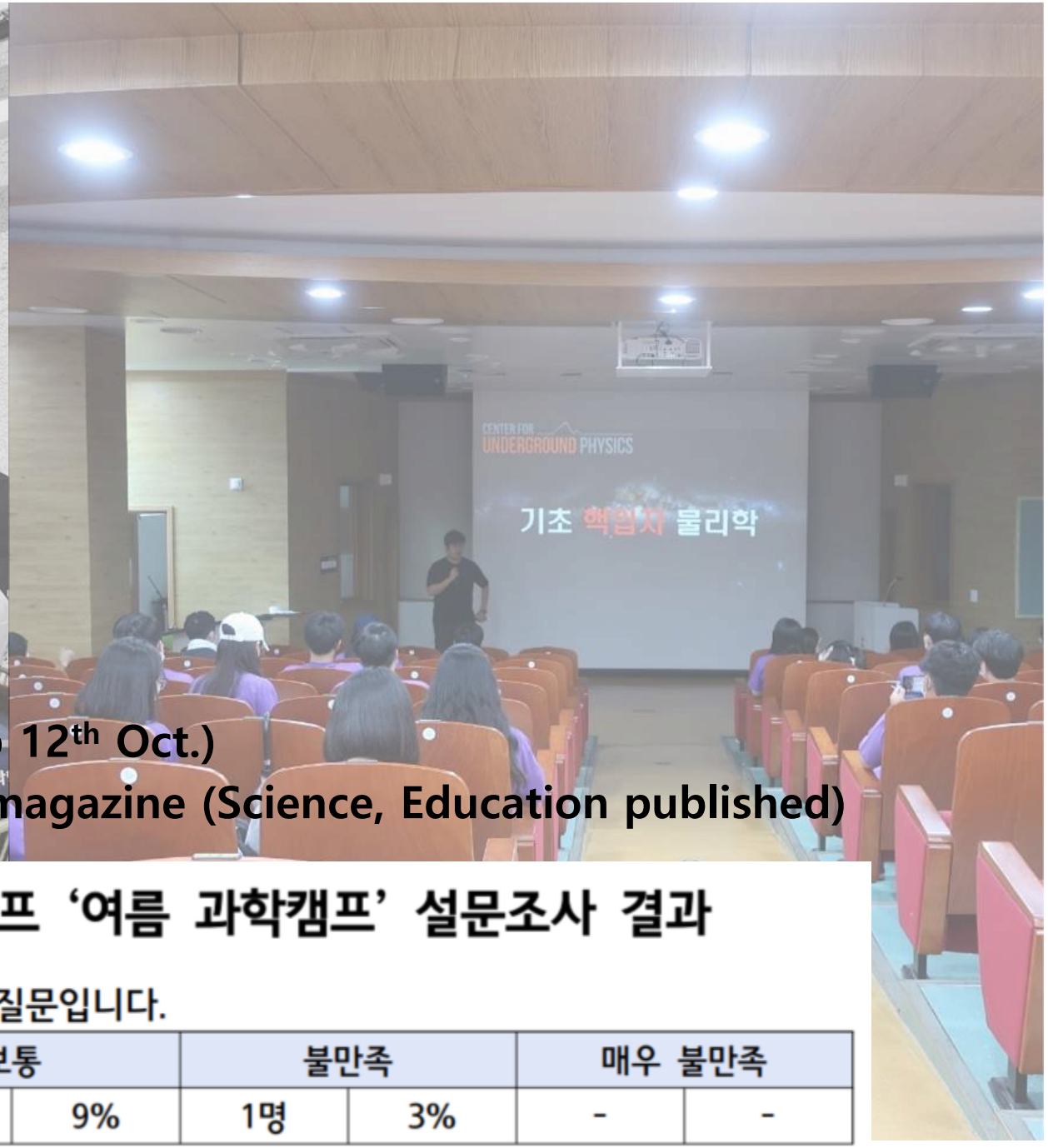
- Relocation will take place over two years, 2023 ~ 2024, this year 70%, next year 30%
- It would be challenging business

The time schedule for Y2L relocation

Group	2023									2024					
	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
COSINE															
AMoRE															
HPGe															
Misc															

Education

- Public Colloquium
- Scientific programs
  - Science drawing contest (coming up 12th Oct.)
  - Yemilab report on Jeongseon local magazine (Science, Education published)



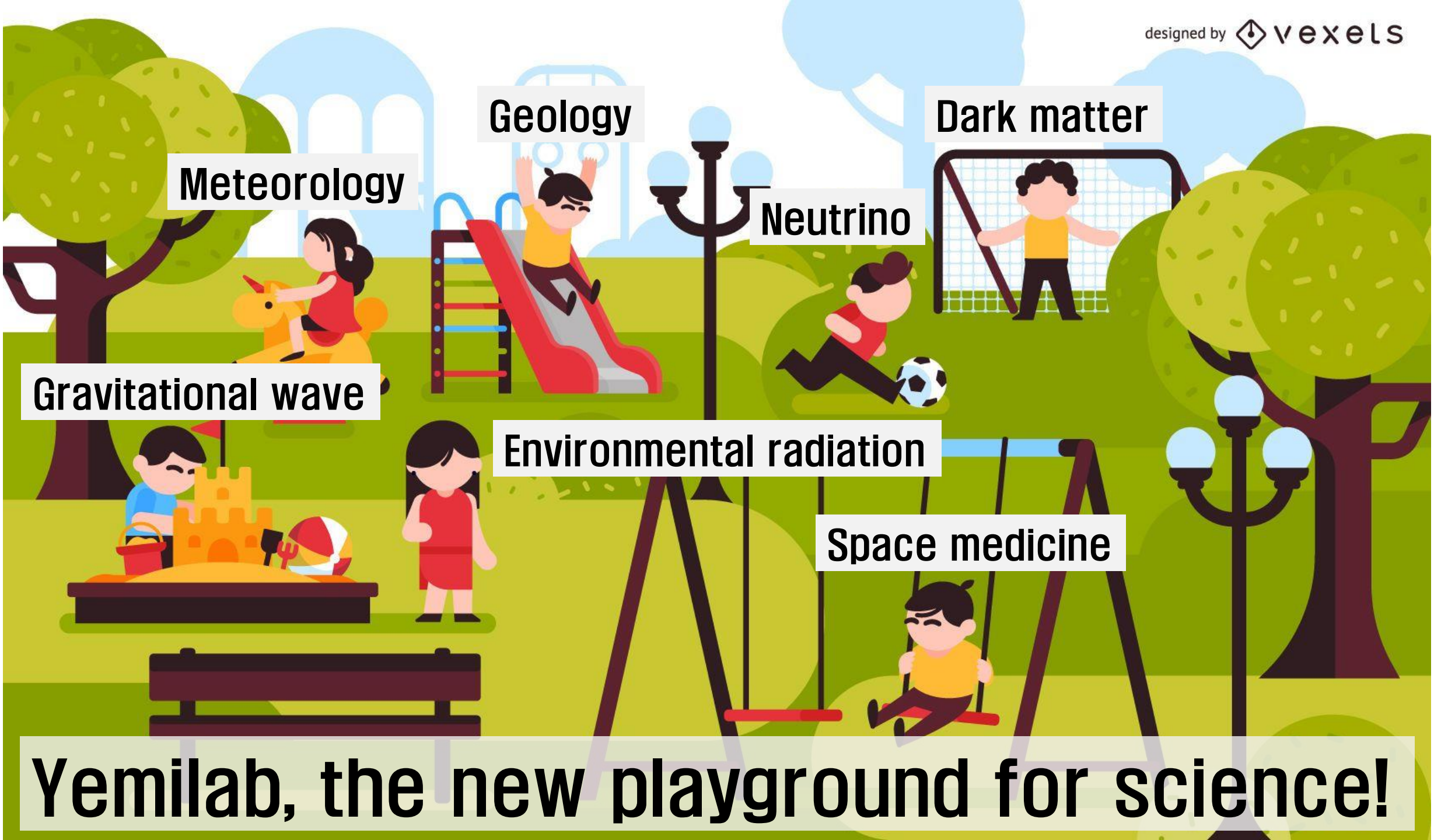
2022년 정선 심화과학반 연합캠프 '여름 과학캠프' 설문조사 결과

1. 다음은 참여한 사업 전반에 대한 만족도에 관한 질문입니다.

매우 만족		만족		보통		불만족		매우 불만족	
18명	51%	13명	37%	3명	9%	1명	3%	-	-

Cultural

- Science culture center at Yemilab
- Y2L 20 years record publication
- KIMS detector exhibition
- Detector working


designed by vexels
Geology
Dark matter
Meteorology
Neutrino
Gravitational wave
Environmental radiation
Space medicine
Yemilab, the new playground for science!