JGW-G2012283

Experience from KAGRA
- Site and Infrastructure -

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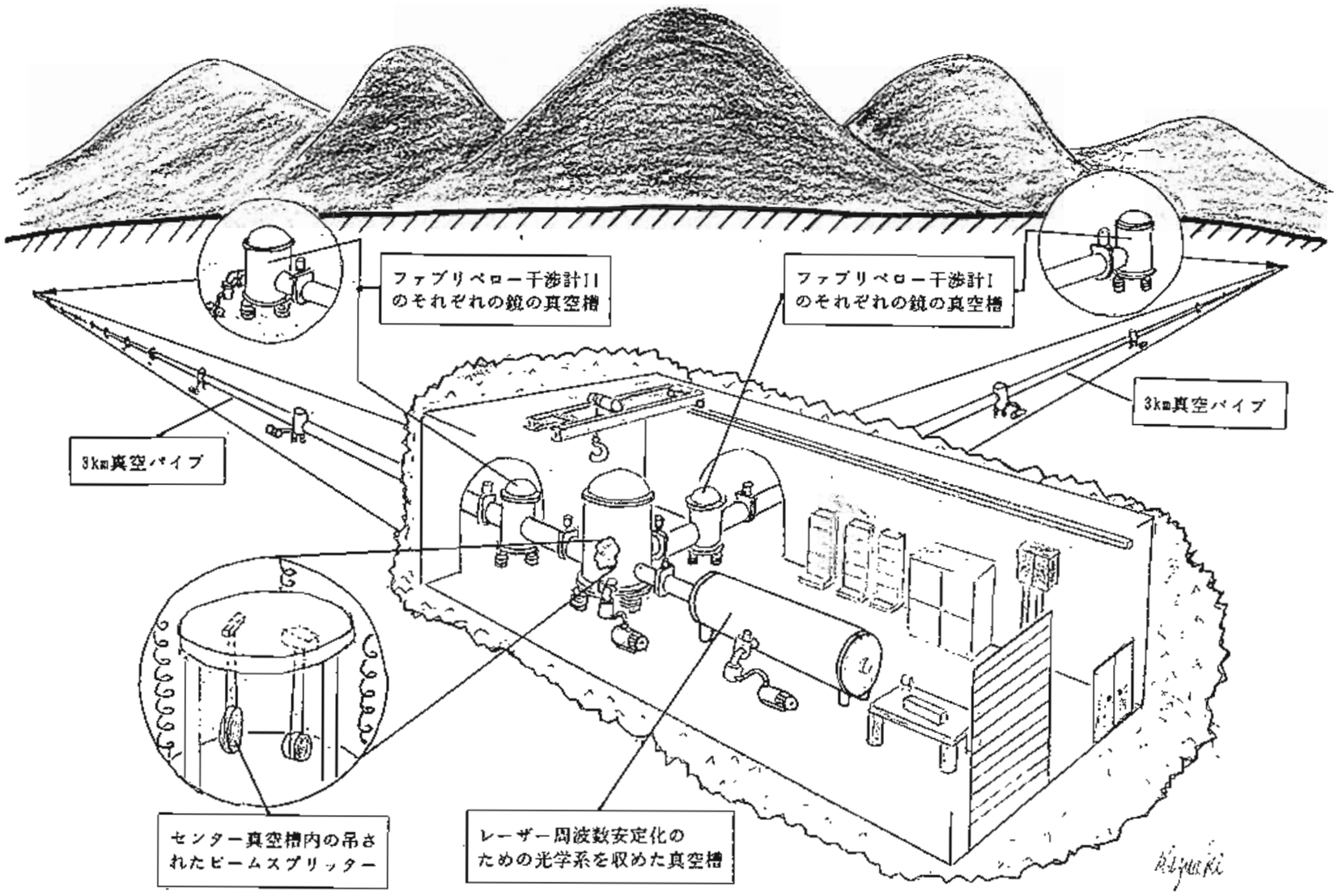
- Tunnel
- Seismic motion in the mine
- Temperature and humidity
- Water issue



レーザー干渉計型重力波検出装置

この装置は、２組の３km共振器長ファブリペロー干渉計Ⅰ、Ⅱからなるレーザー干渉計で、光路を真空に保つための真空パイプと鏡などの光学部品を収める真空槽が示されている。中央の真空槽にはビームスプリッターが、地面の振動を避けるため振子状に吊され、ファブリペロー干渉計のそれぞれの鏡は３km真空パイプ両端の真空槽に吊されている。装置全体は、低周波の振動の少ない地下に設置される予定である。（参考図。編集部挿入）

Schematic figure of a future plan presented in 1993.
The plan had included use of an underground site.

ICRR news　No. 18 1993.9.15

Kamioka mine was chosen as KAGRA site

Kamioka mine

- Good: It is made of old and hard rock of gneiss.
- Good: Scientific facilities existed.
- Bad: Heavy snow and enormous amount of spring water.

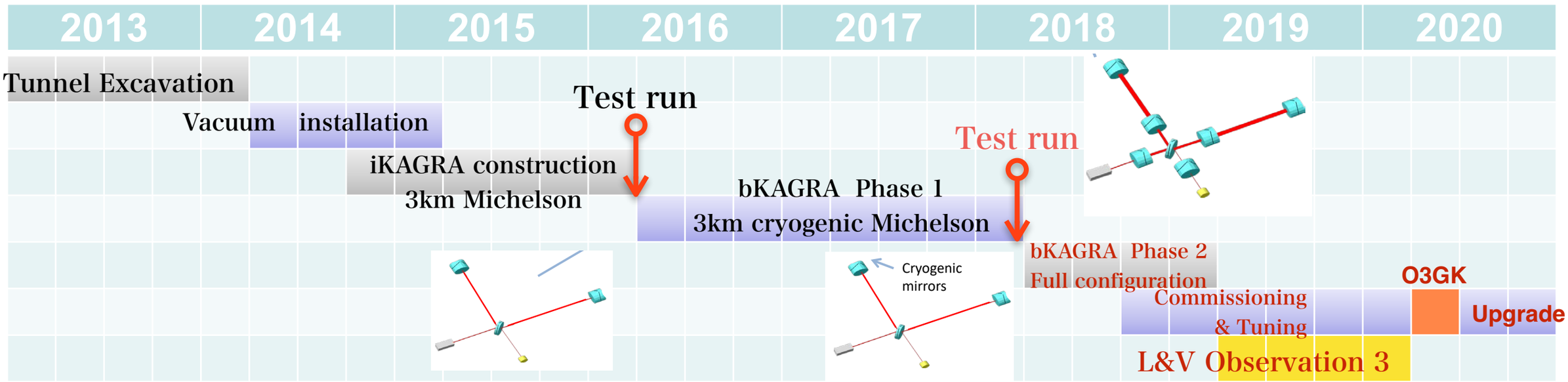
KAGRA

General information

- Laser interferometric gravitational wave detector with 3km arm length.
- Key features of KAGRA
  - KAMIOKA underground site.
  - Use of cryogenic mirrors.
- PI: Prof Kajita
- 400+ collaborators
- 120 groups
- 14 regions
- Project started from 2010.6.

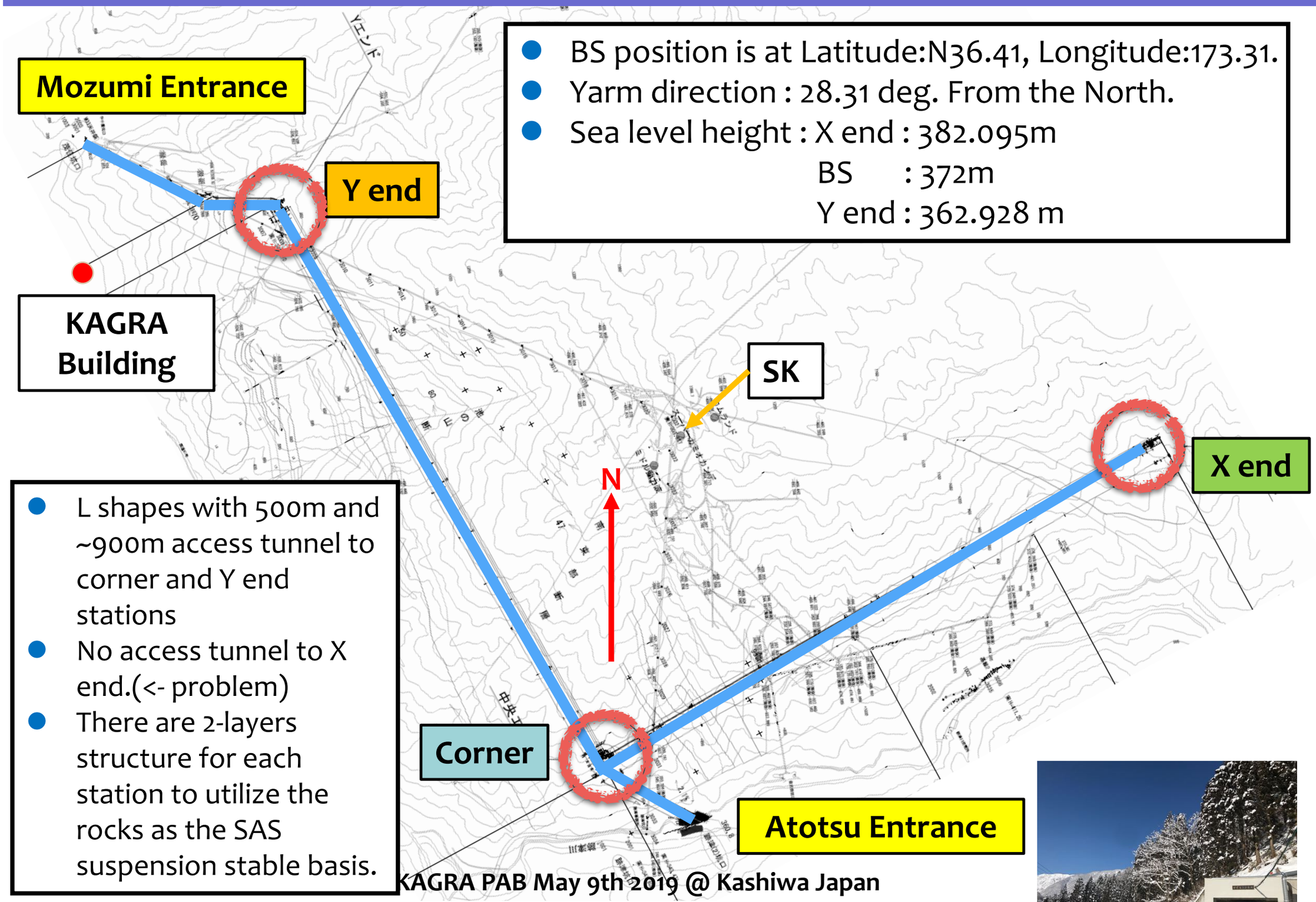
Tunnel excavation

- Site : Kamioka, Hida, Gifu, Japan.
  - 300km north west of Tokyo.
- Excavation : 2012/5-2014/3.
- Total length : 7,694m (Arm tunnels 6,000m, Experiment rooms 817m, Access tunnels 880m).
- Total volume : 146,000m^3.
- Method : NATM(New Austrian Tunneling Method).
- Company : Kajima corporation.



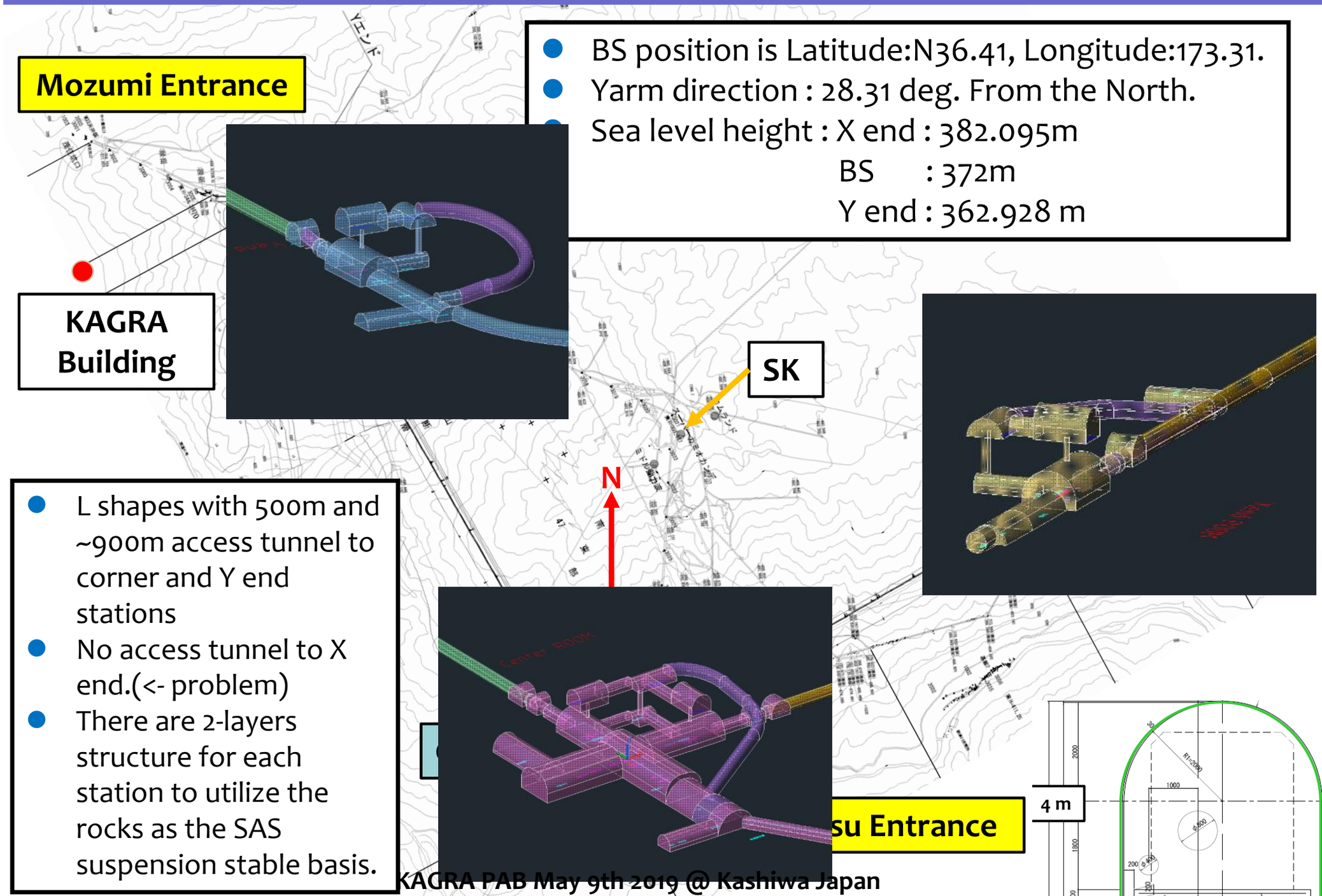
Tunnel Position and Alignment

- BS position is at Latitude:N36.41, Longitude:173.31.
- Yarm direction : 28.31 deg. From the North.
- Sea level height : X end : 382.095m
  BS : 372m
  Y end : 362.928 m



- L shapes with 500m and ~900m access tunnel to corner and Y end stations
- No access tunnel to X end.(<- problem)
- There are 2-layers structure for each station to utilize the rocks as the SAS suspension stable basis.

Tunnel Position and Alignment



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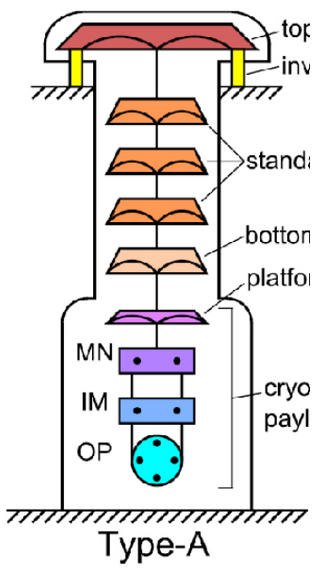


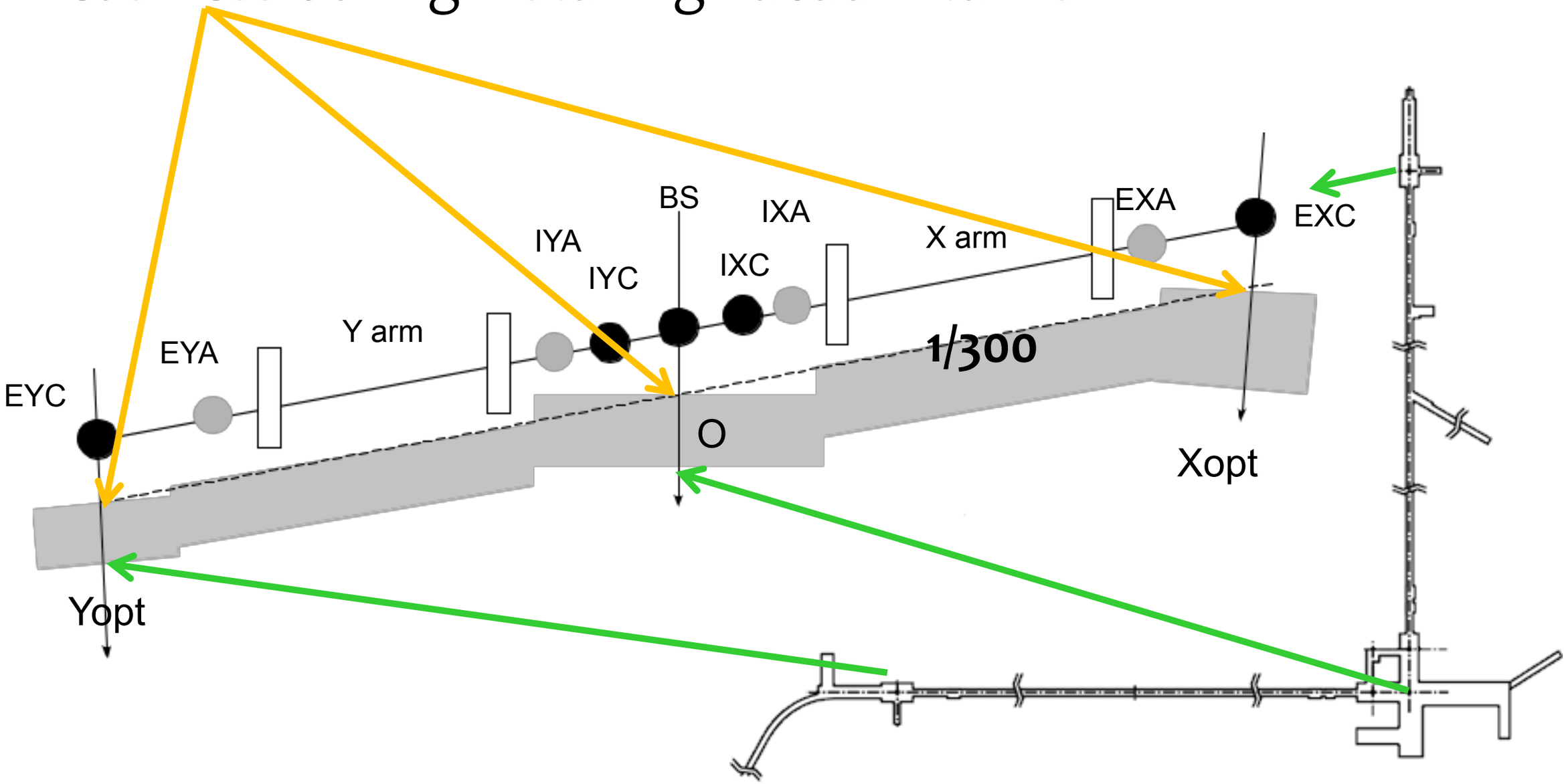
Type-A

- L shapes with 500m and ~900m access tunnel to corner and Y end stations
- No access tunnel to X end.(<- problem)
- There are 2-layers structure for each station to utilize the rocks as the SAS suspension stable basis.

Arm tunnel

Tunnel Slope

- Slope of 1/300 was selected to drain the water to rivers.
- Horizontal planes for each station are prepared for easiness during installing vacuum tanks

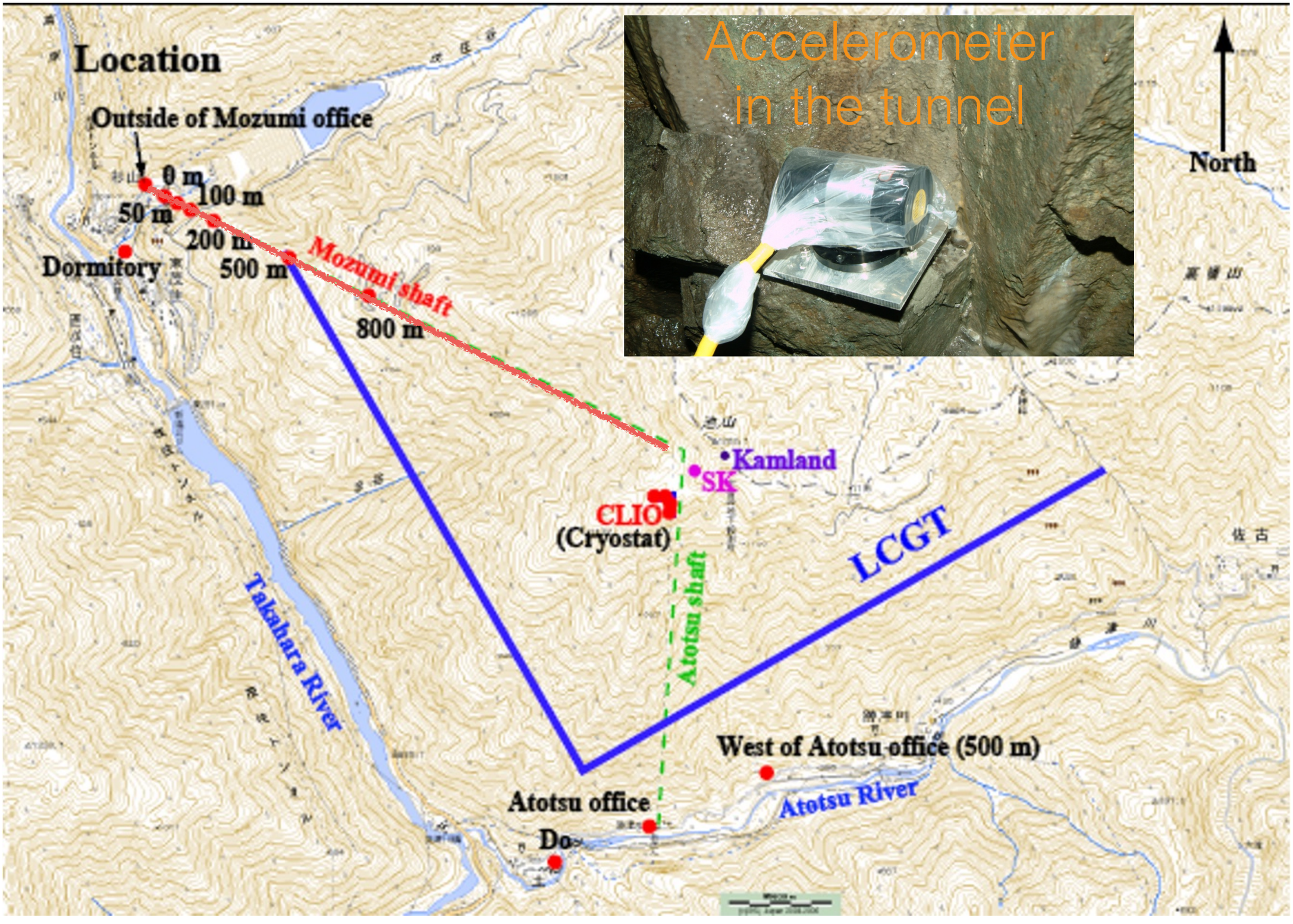


Seismic motion

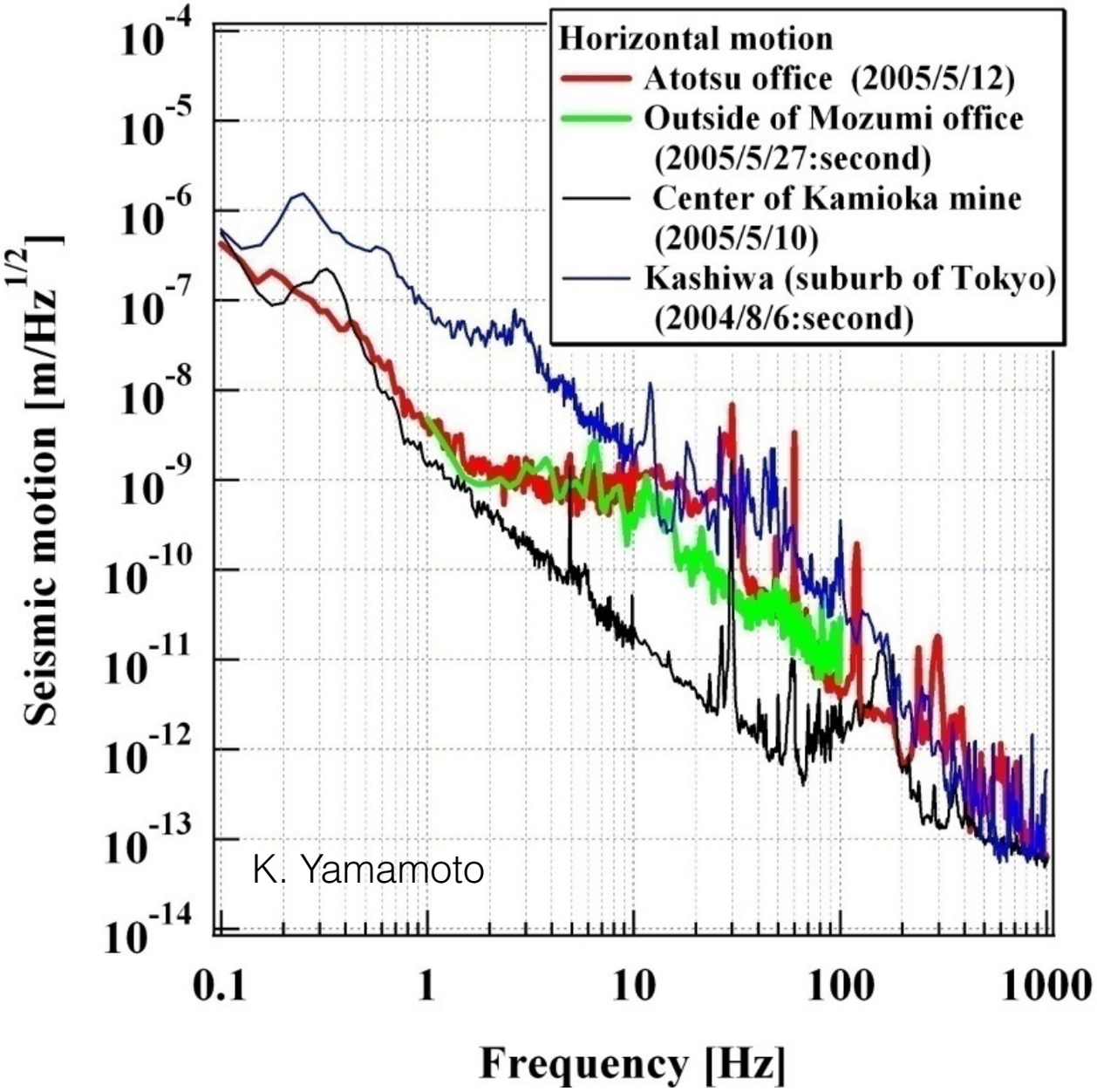
- Small seismic motion is an important reason of constructing KAGRA in the underground site.

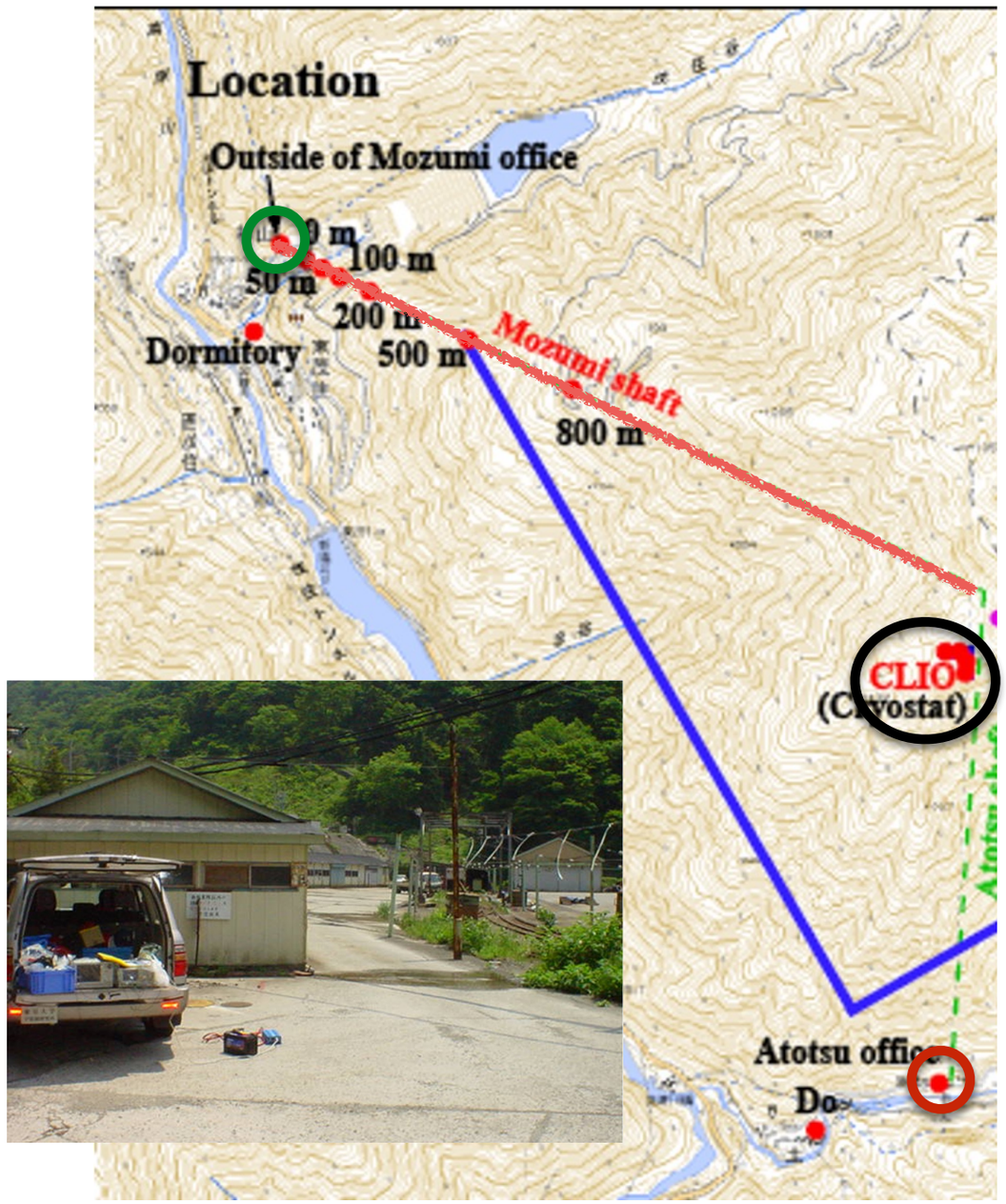
- We investigated how much KAGRA should be made inside in order to obtain small seismic motion as we expected.

We measured seismic motion at several places along the existing tunnel.



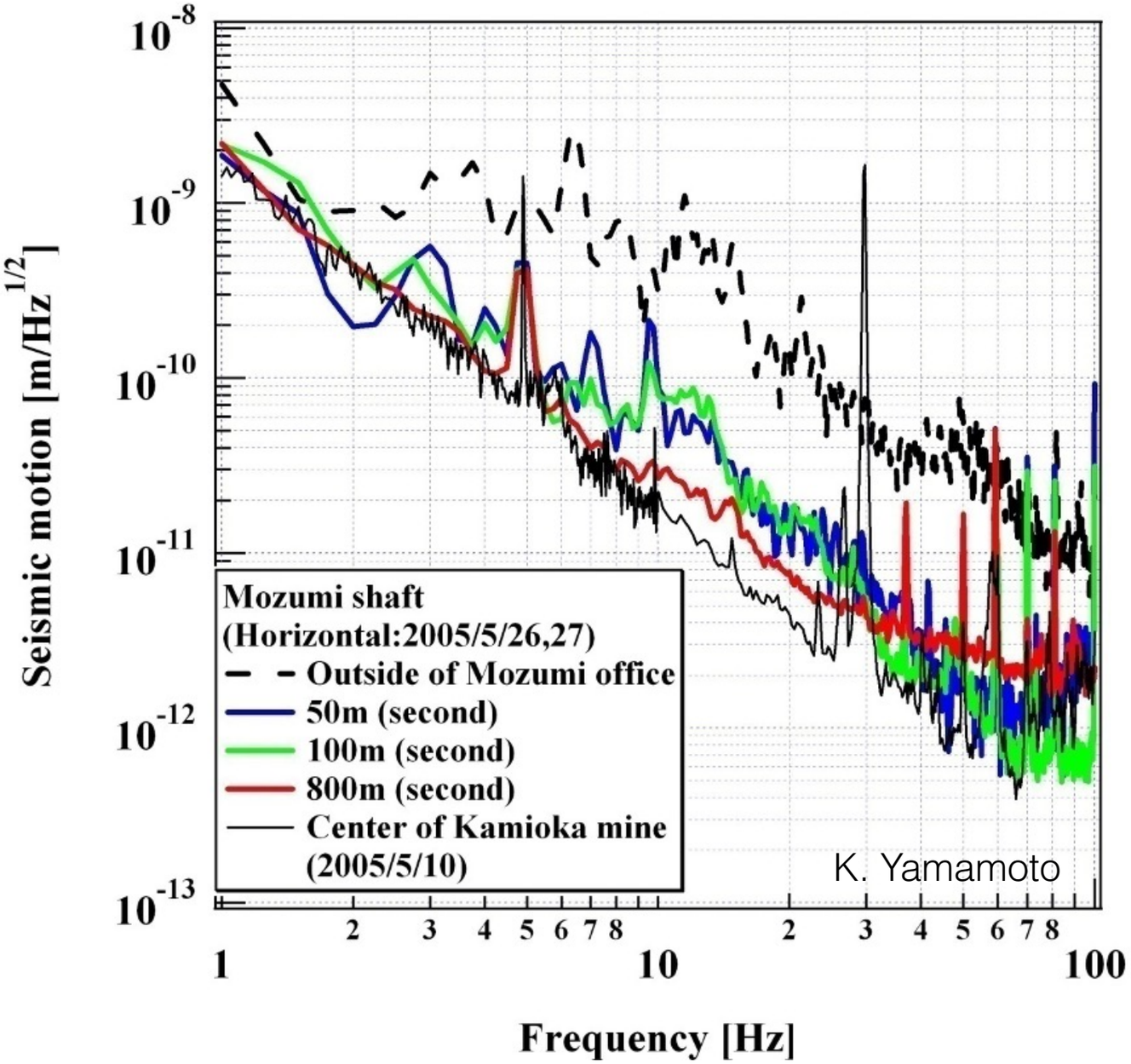
Measurement results of seismic motion at outside

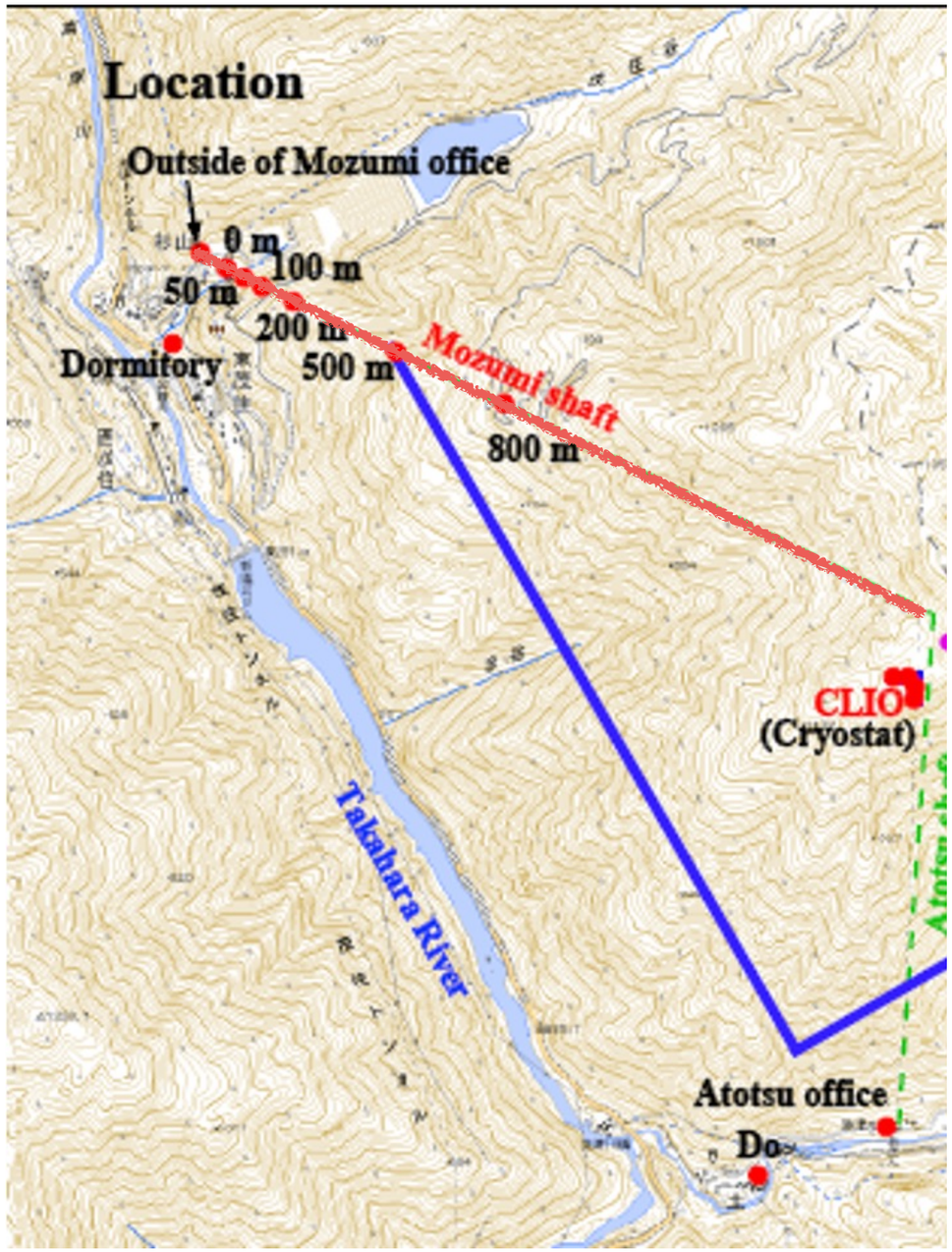




Even in Kamioka, seismic motion at outside is the same level in city area above 10Hz.

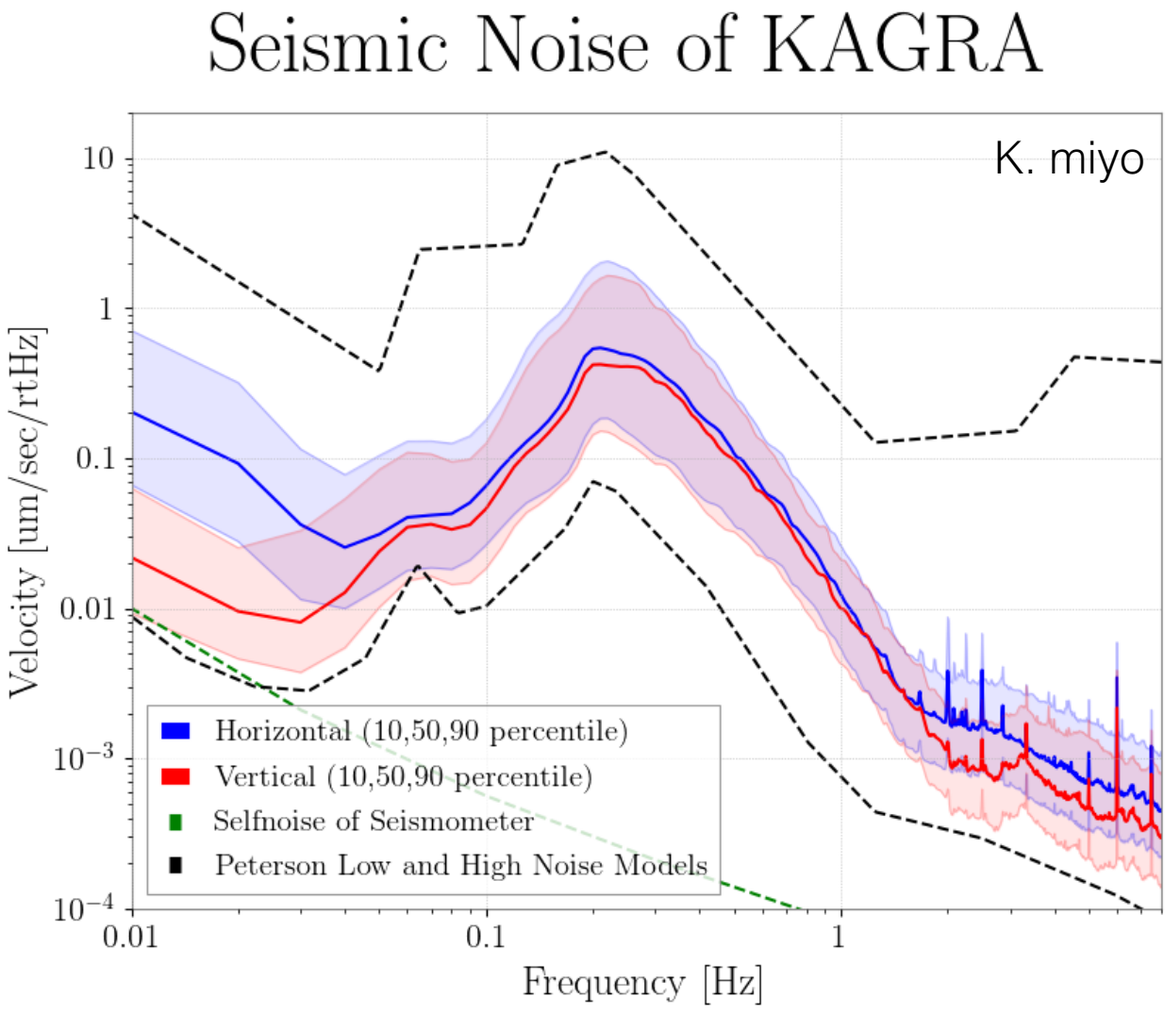
Measurement results of seismic motion in the tunnel

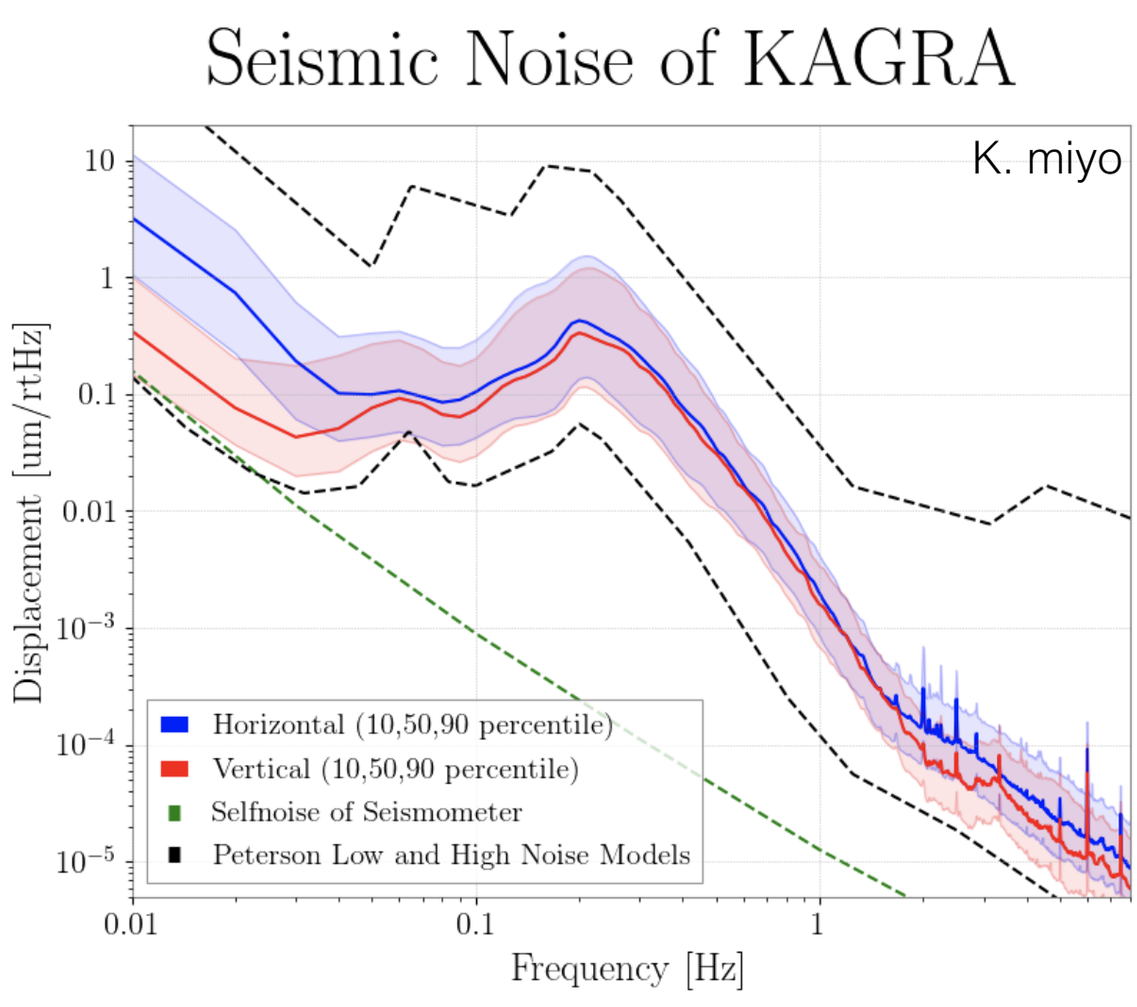




Small seismic motion is available inside 50m or more.
All the experiment rooms of KAGRA are inside 200m or more.

One year measurement results of seismic motion in KAGRA





- 10^{-9}m/rtHz@1Hz is realized.
- Micro-seismic motion around 0.3Hz is terrible for interferometer controls.
  - Excited by intense ocean waves due to bad weather.

Data between Jun 1 2018 to Jun 2 2019
Measurement at EXV (2nd floor in Xend)

Temperature and Humidity Control

Issues:

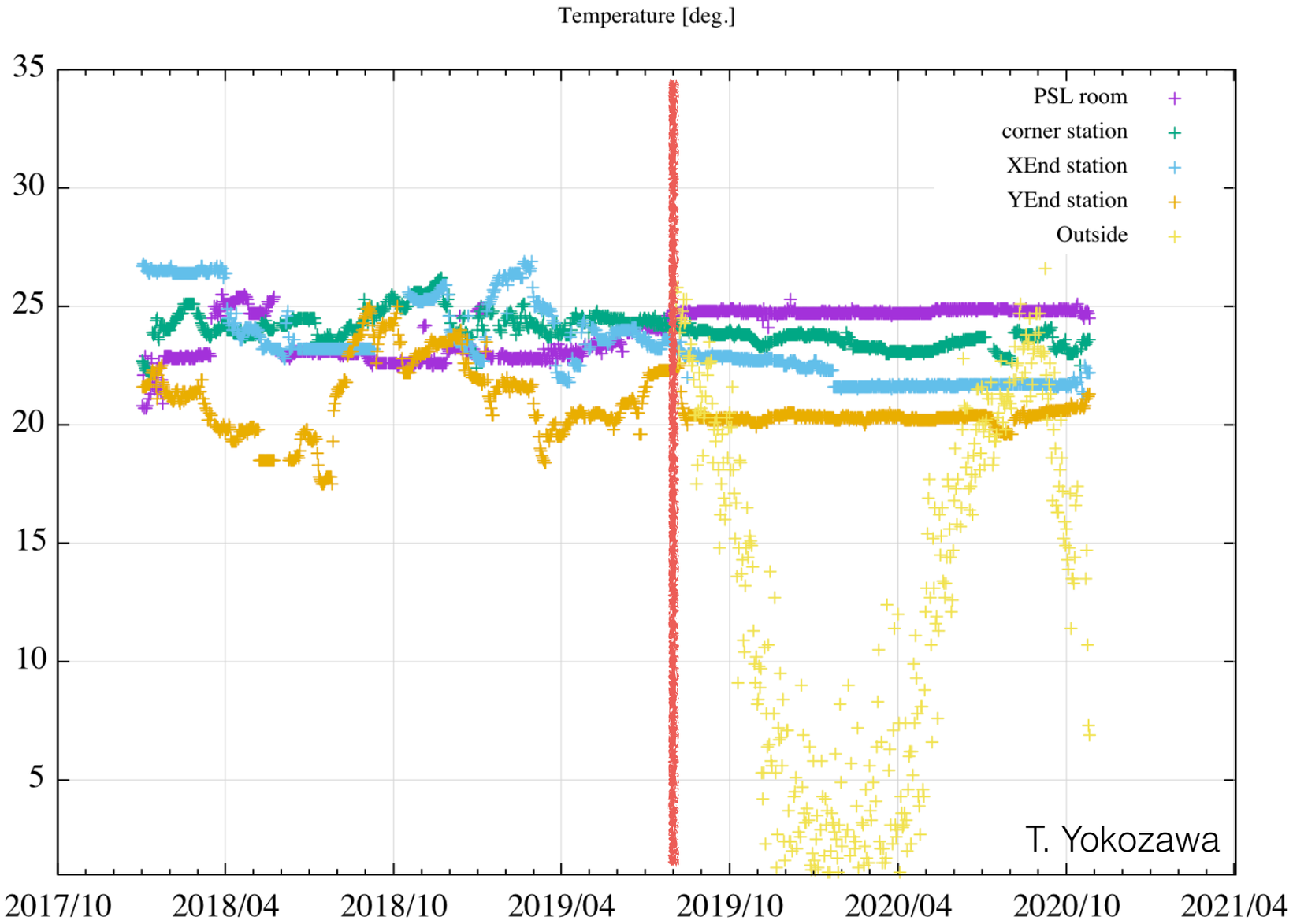
- Temperature change does affect the GAS filters used as seismic noise isolators for BS, PRMs, SRMs, and four sapphire mirrors.
- Humidity control is also important to keep instruments healthy.
- temperature should be most stable in the laser room, keeping cleanness.
- The heat generation is quite different between commissioning time and observation time because of the operation of FFUs that generate clean air in side each station.

Action:

- Dry air (500 m^3/ h for the corner, 200 m^3/h for ends) is injected from outside.
- We equipped two precision air conditioners for the laser room.
- Four 14 kW coolers in the corner station to compensate the heat from ~ 250 FFUs for creating clean air, one 5kW cooler in the X end station, and no in Y end.

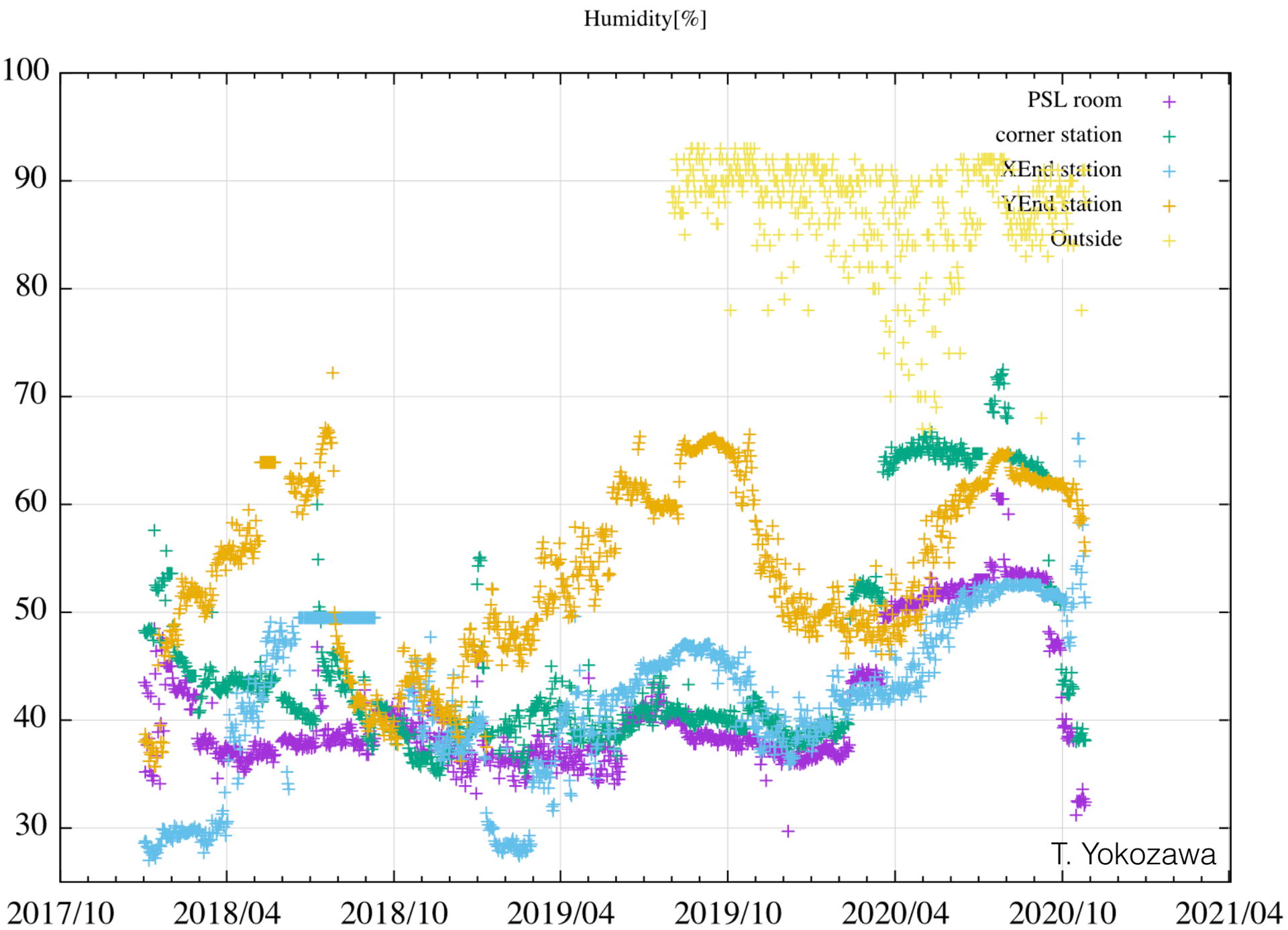
We have to balance heat sources (FFUs, Pumps, PCs, and so on) with cooler.

Temperature changes in KAGRA and at outside



- Temperatures in the experiment rooms were well controlled from August 2019.
- Temperature at outside seems not to affect in KAGRA. -> Merit of underground site.

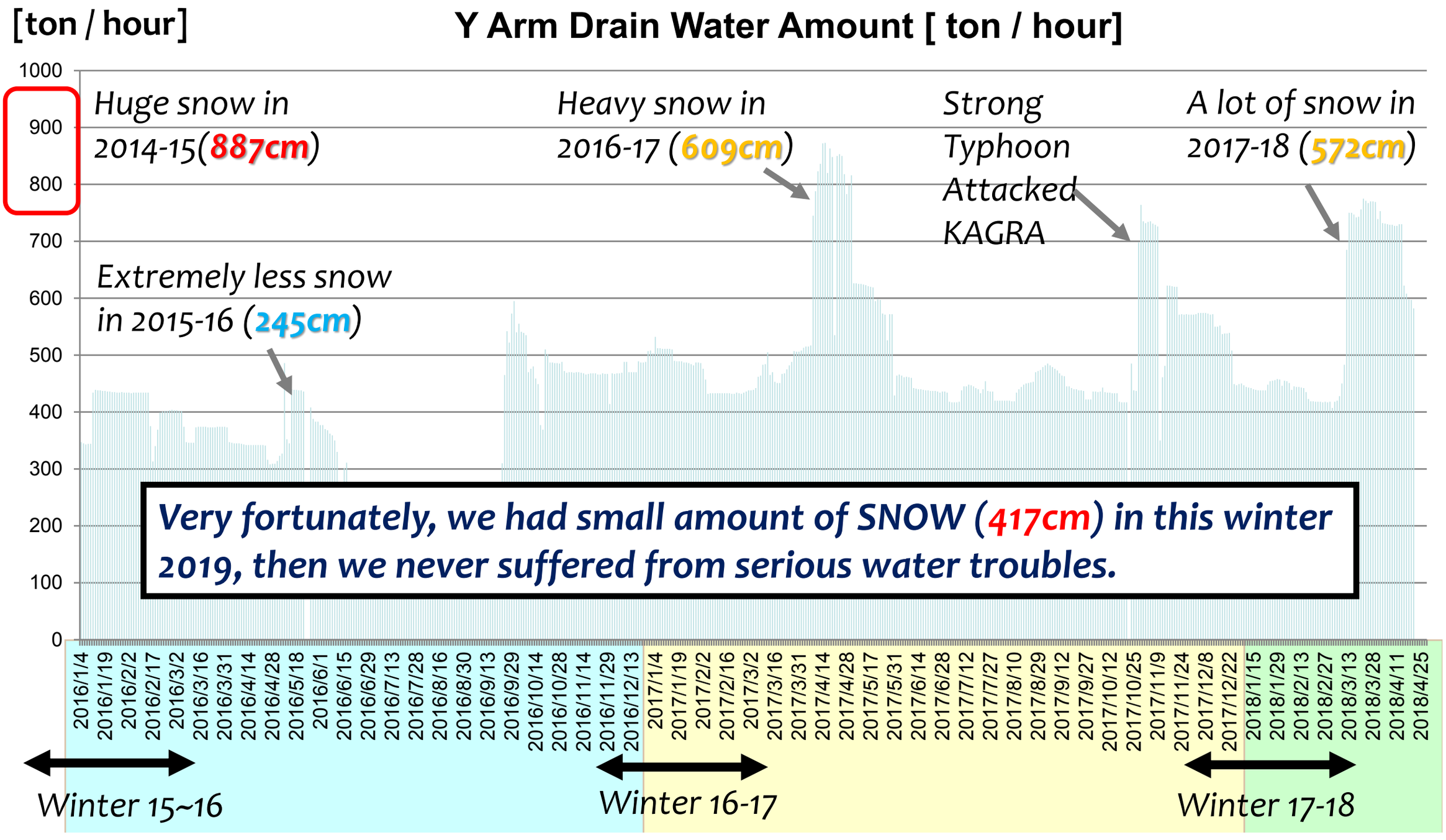
Humidity changes in KAGRA and at outside



Humidity in the experiment rooms were kept less than 70%.

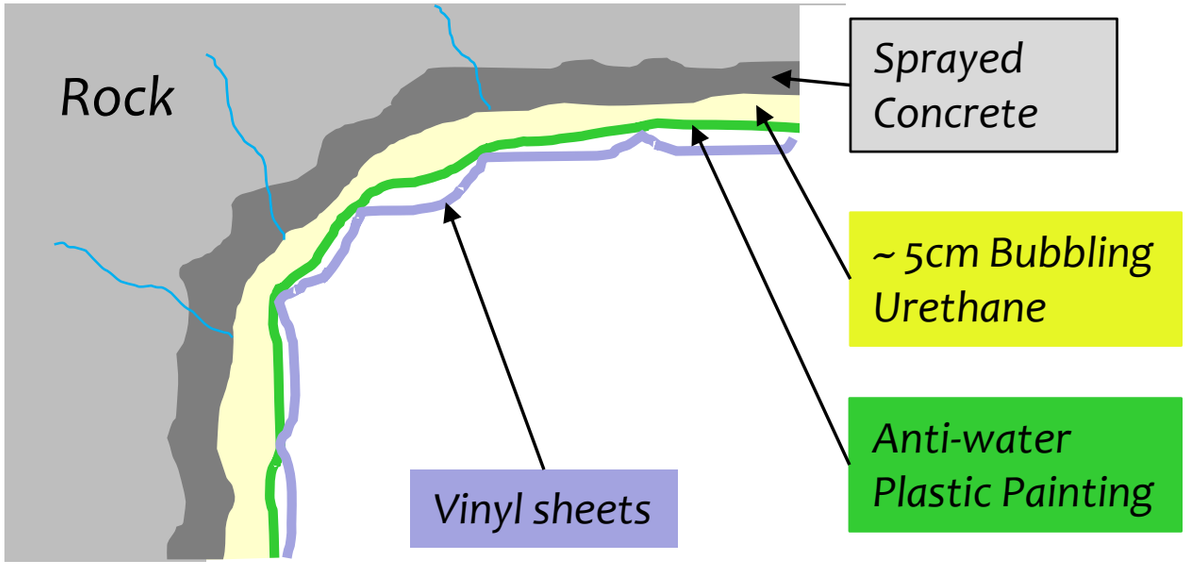
Spring Water Amount Depends on SNOW

- ***Just after finishing excavation, the Y arm water became up to 1250 [ton/hour] (Total 2050 [ton/hour])***



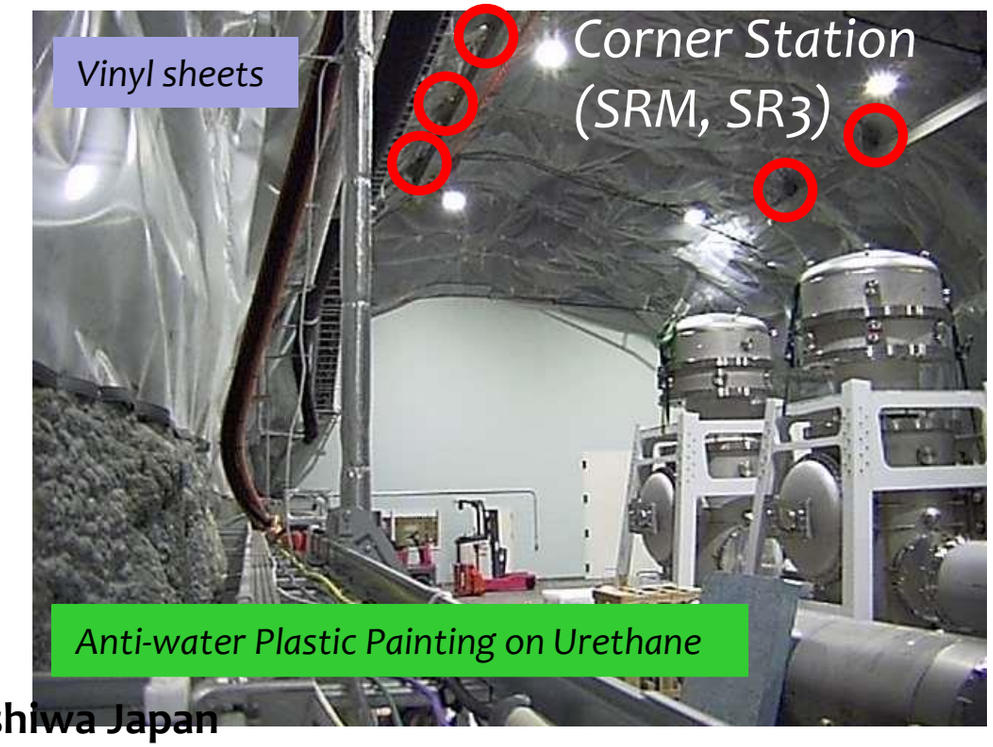
Spring Water Treatment from Walls

(1) Corner and End Stations



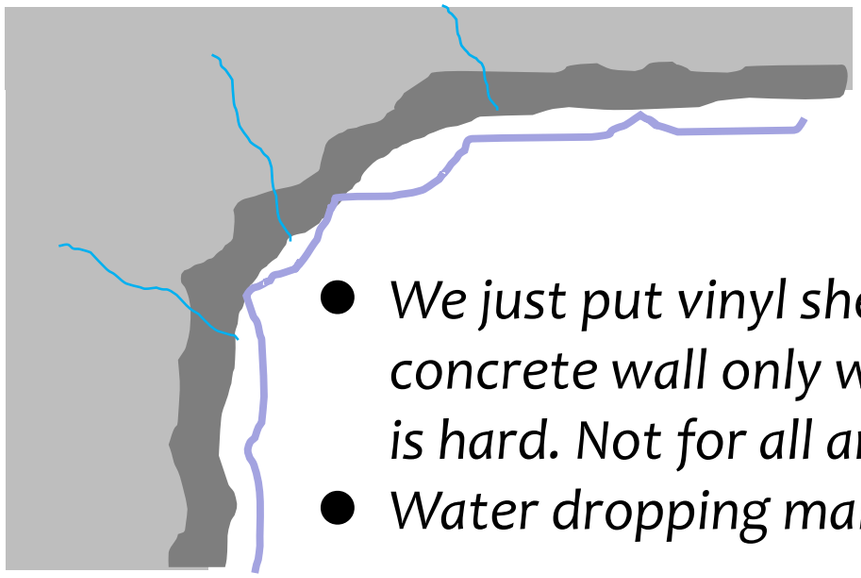
- *The water shielding method using Anti-water plastic layer on the urethane on the wall rock was selected.*
- *However, it didn't work very well. We got many water leak.*
- *We put vinyl sheets on the plastic painting.*
- *However, we could not stop water leak from anchor parts of crane and so on.*

Well designed sheet covering or shaped concrete (like a road tunnel) walls that have water shielding function should be introduced. However it costs higher.

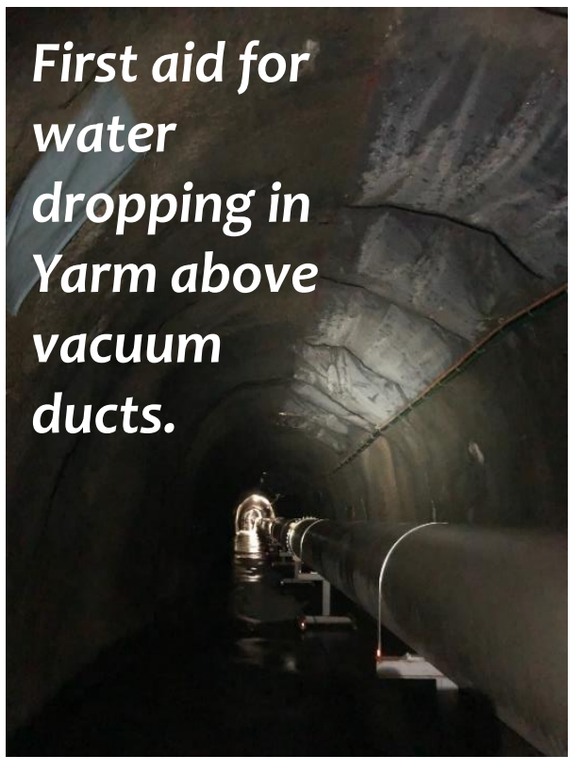


Spring Water Treatment from Walls

(2) Arm Tunnel Area

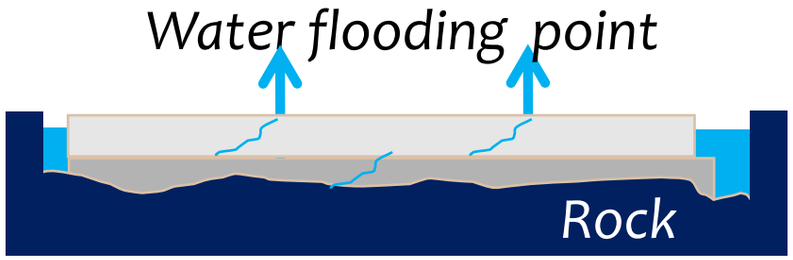


- *We just put vinyl sheets on the concrete wall only where water leak is hard. Not for all area.*
- *Water dropping make noise, maybe.*

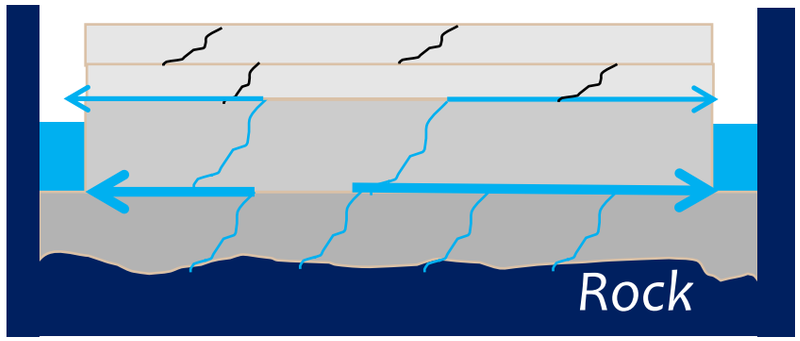


Floor Spring Water Treatment : in Stations

- *We completely missed to estimate the amount of spring water in the tunnel.*
- *Enough layers of concrete floor is necessary to reject water flooding from the floor because the concrete floor inevitably will have cracks.*
- *Deeper ditches are also desired to keep the water level lower than the bottom of the surface concrete.*

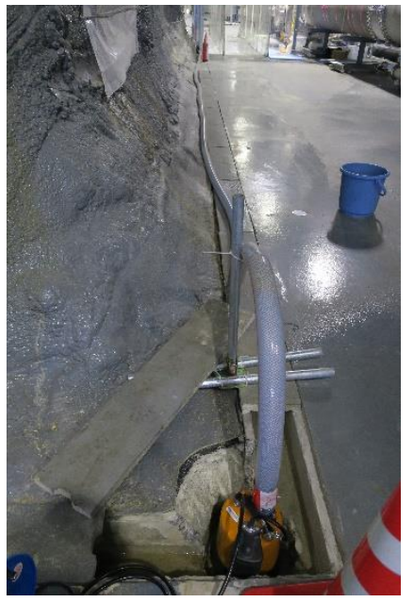


KAGRA Floor Design



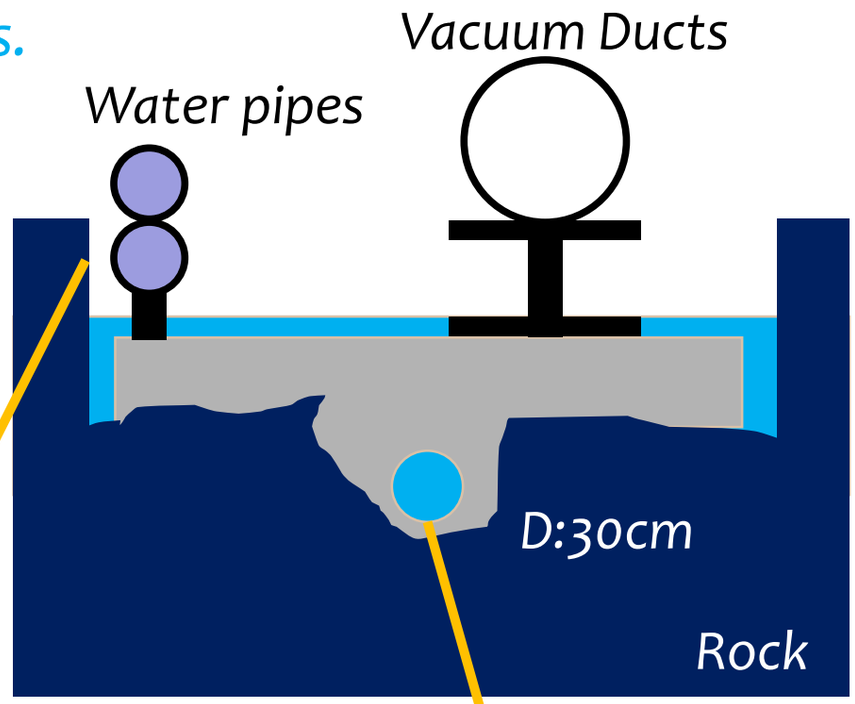
Ideal Floor Design

- *We made several deeper holes to collect waters, and put small water pumps to transfer out side the stations. So, moving pumps might be noise in the future.*

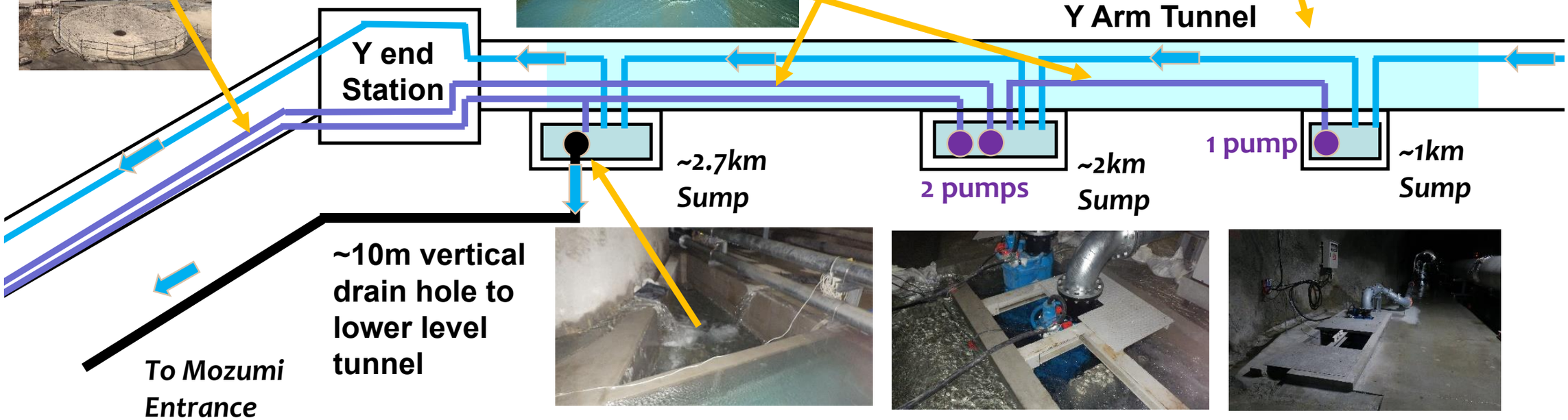


Arm Tunnel Spring Water Treatment

- *Water in the Yarm is a lot because of known faults.*
- *From the end of March to the end of May, the Y-arm central part (1km ~ 2.7km area from the corner station) was covered with water.*
- *To avoid flooding, KAGRA has the drain relays using water pipes (d 150mm), sumps, pumps and vertical drain hole in the only Y arm.*



Y-arm tunnel (firstly excavated)

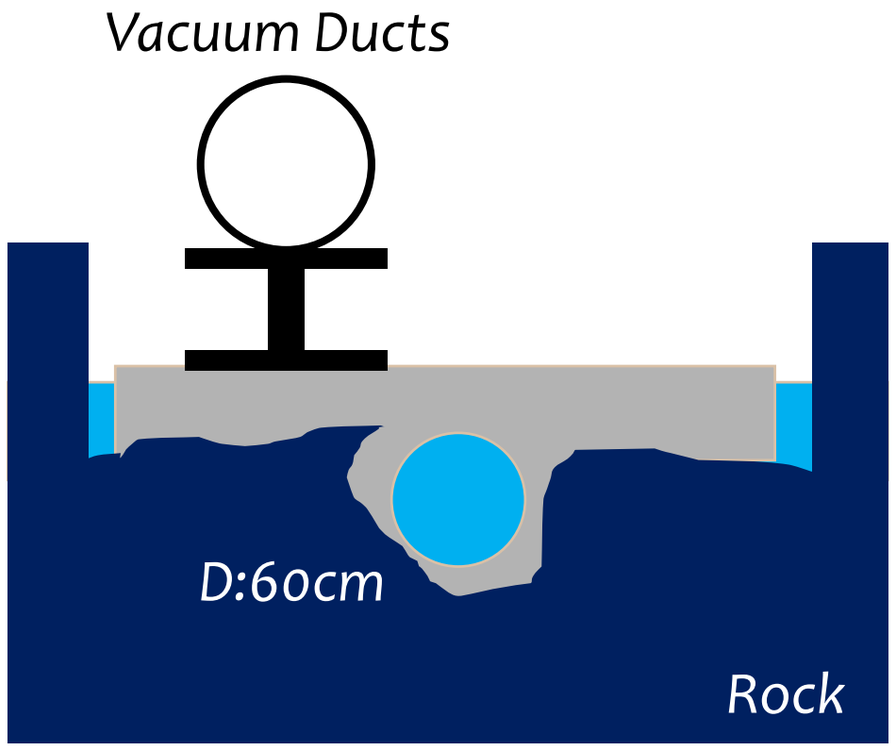


KAGRA PAB May 9th 2019 @ Kashiwa Japan

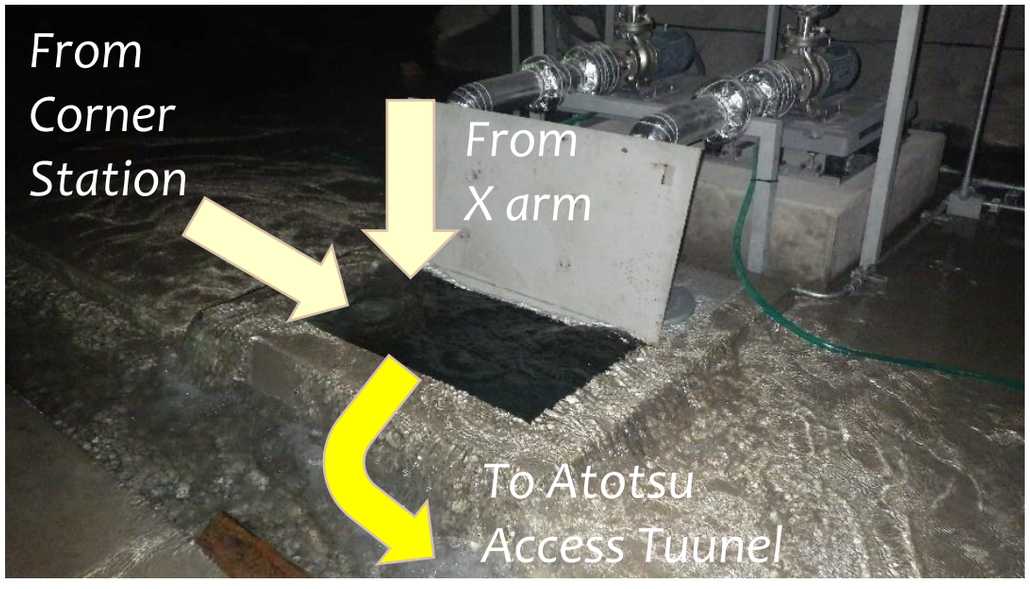
Arm Tunnel Spring Water Treatment

- *In X arm, we put a larger drain pipe under the floor, then we could avoid flooding.*
- *The water from this X arm is transferred to the drain pipe in the Atotsu access tunnel.*
- *Because the drain pipe is insufficient below floors in the access tunnel, there is flooding in the access tunnel.*

It is important to design how to drain water systematically.



X-arm tunnel (Secondly excavated)

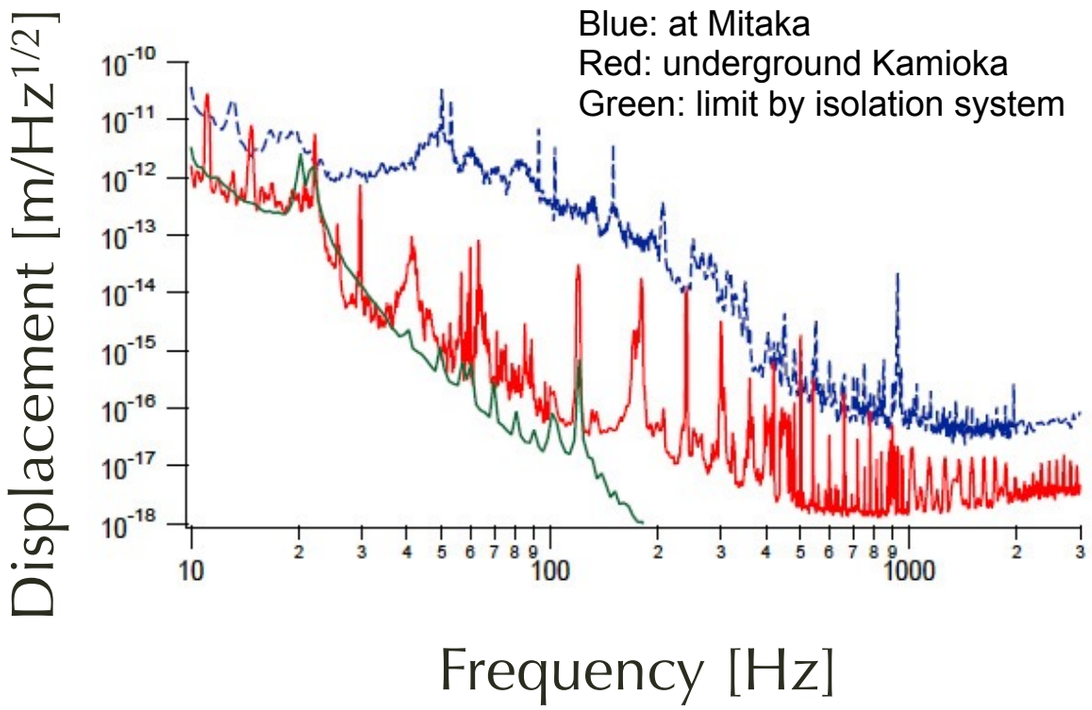


Summary

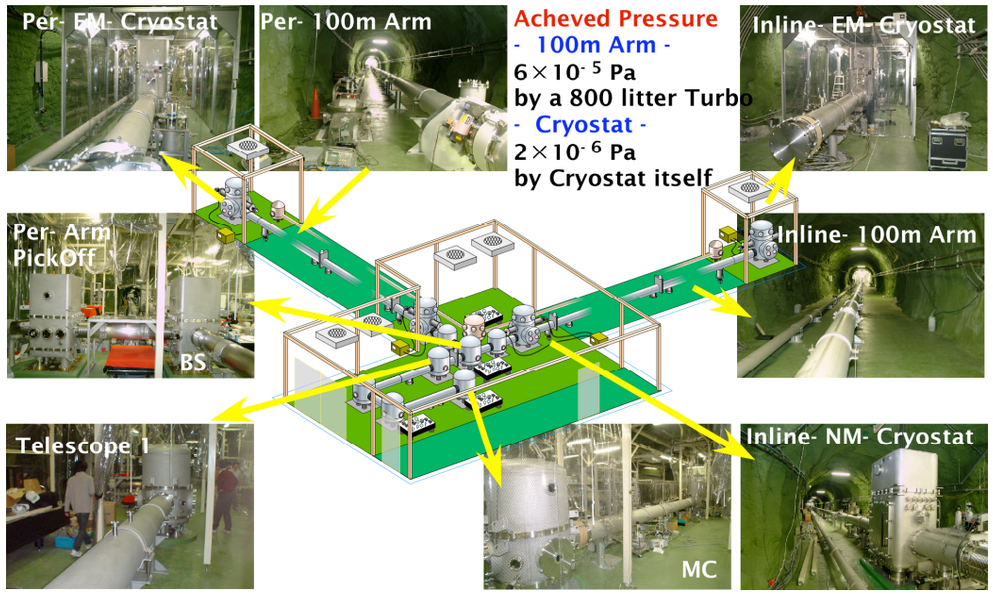
- KAGRA is constructed in the Kamioka mine.
- Small seismic motion is available inside 50m or more.
- Micro-seismic motion caused by intense ocean waves is terrible.
- We have to balance heat sources with cooler to make temperature stable.
- Dry air injection from outside is needed to keep humidity under 70%.
- Systematic design of water drain is important.

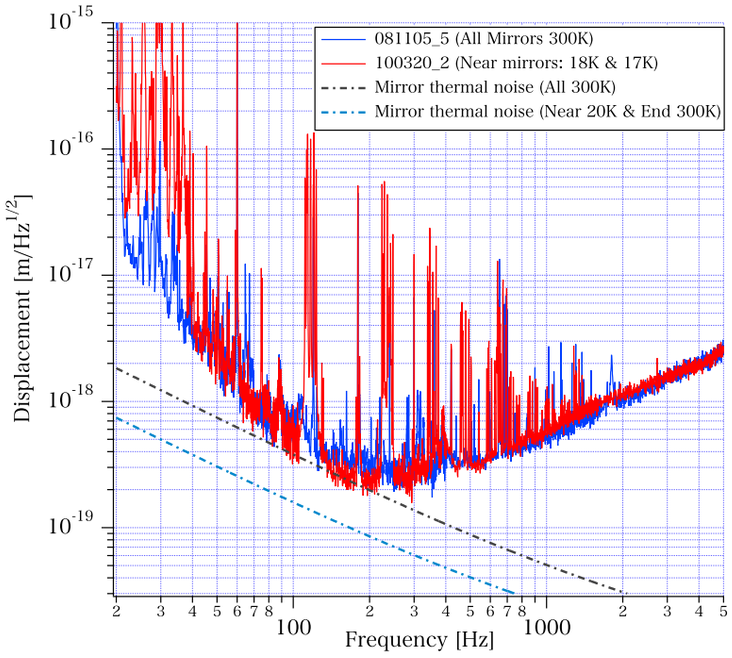
Two prototype interferometers developed in the Kamioka mine

LISM (20m Prototype) 1999-2003



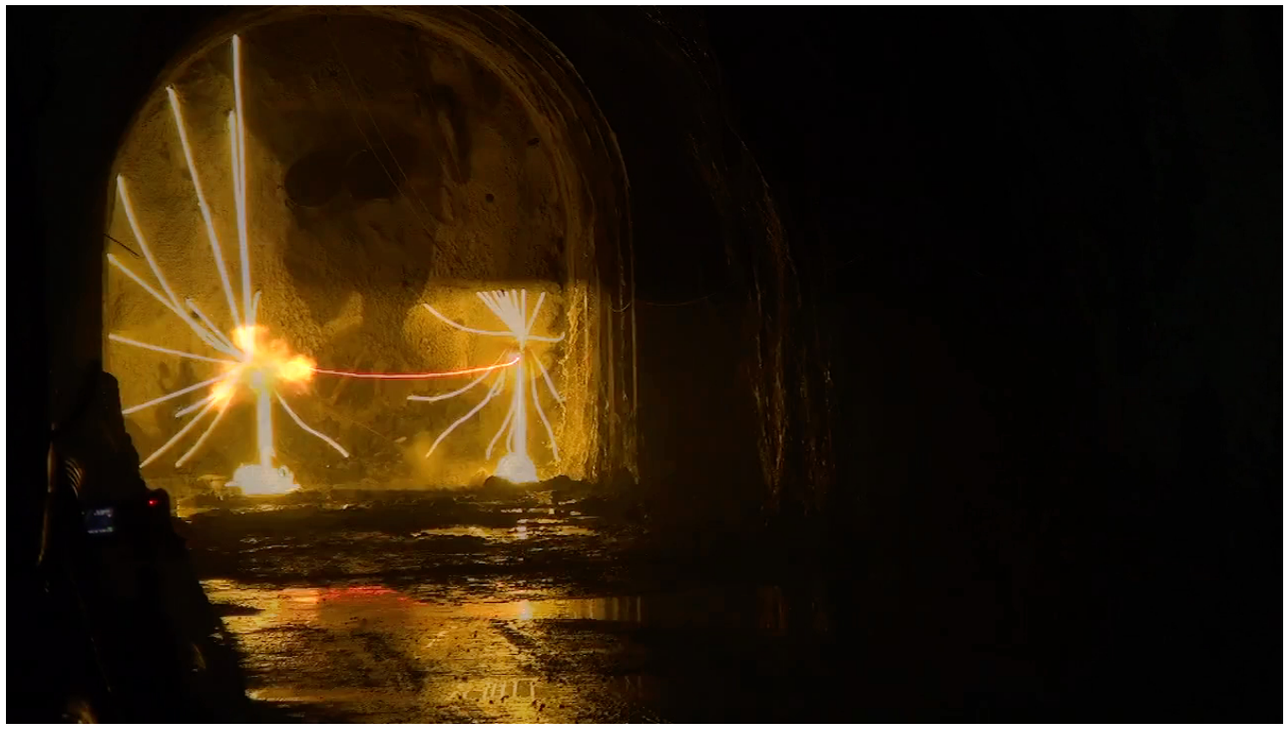
CLIO (100m Cryogenic Prototype) 2002-2010



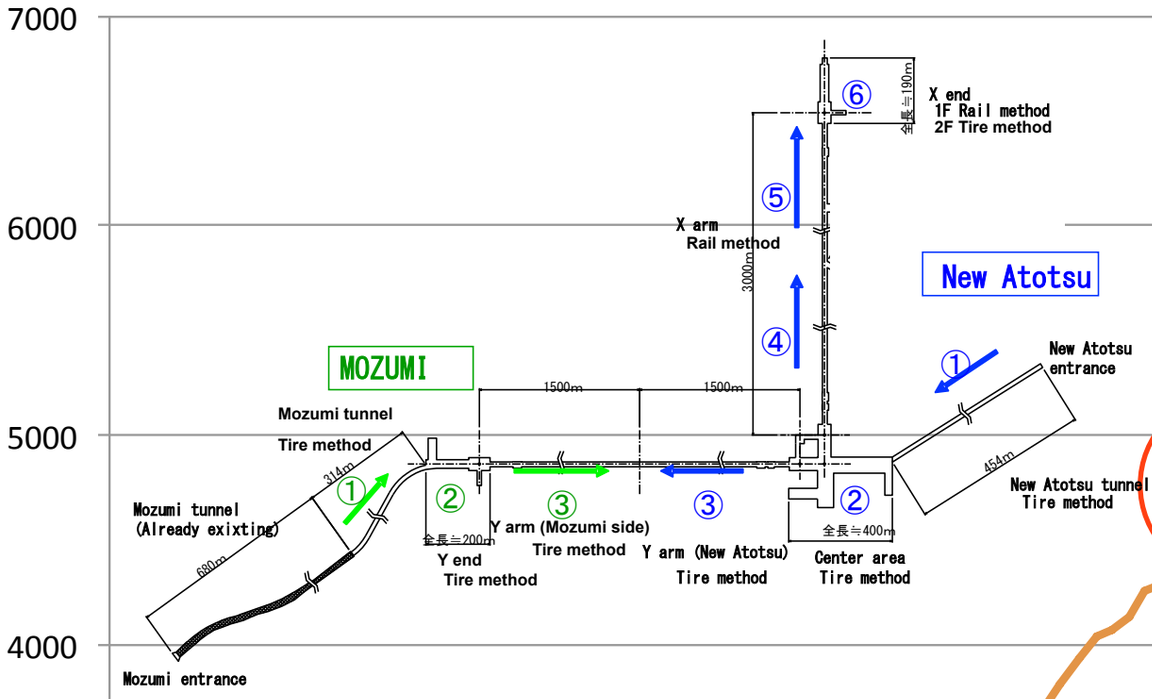


New Austrian Tunneling Method

- Processes
  - Making holes for fire powders.
    - ANFO(Ammonium Nitrate Fuel Oil)
  - Inserting fire powders.
  - Blasting!!
  - Taking away rocks.
  - Spraying concrete to the surfaces to keep inside.
- Key technique.
  - Long hole blasting.
  - usual: 1.2~1.5m per each blasting.
  - KAJIMA corp.: 4m per each.
  - Merit: reduction of time loss due to replace heavy machines. -> Faster excavation.



Blasting



2013/9/1-30
Xarm: 359.4m
Yarm(down slope): 301.2m
Total: 660.6m

Xarm
3000m/14month=210m/month

- Mozumi total [m]
- New Atotsu total [m]
- Yarm (Mozumi) total [m] from Yno. 129+83.5
- Xarm total [m] from Xno. 100+66.5
- Yarm (Atotsu) total [m] from Yno. 100+63.5
- ALL total [m]

Not including experiment rooms.


Yend cryogenic room


Yfront cryogenic room


Xarm tunnel


Xfront cryogenic room

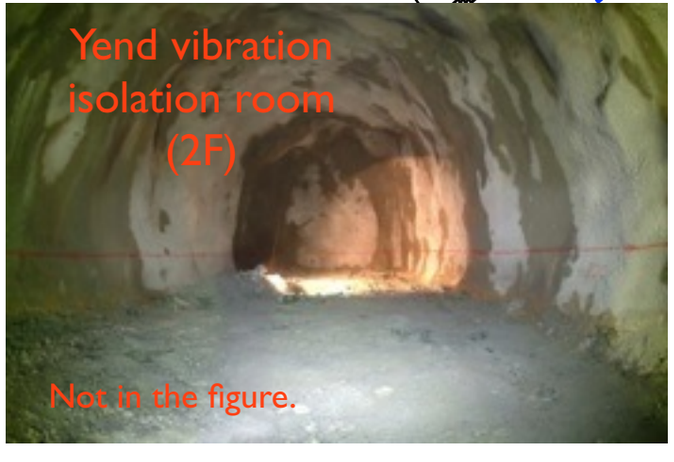

Yarm tunnel


Yend cryogenic room
(reverse angle)


Mine entrance

Yend access tunnel
to the 2nd floor
Not in the figure.


Center area
reverse angle

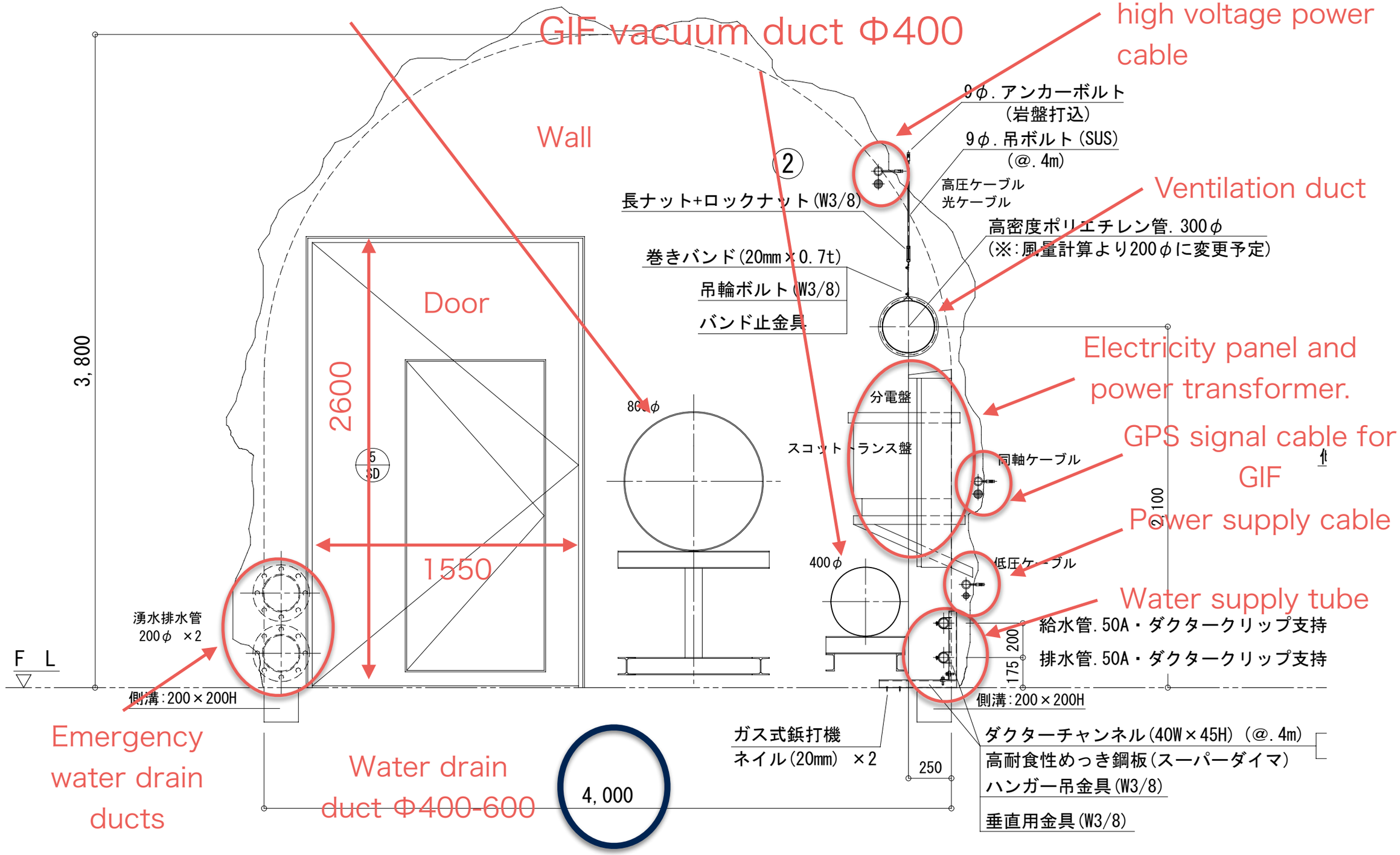

Yend vibration
isolation room
(2F)
Not in the figure.


Break through
blasting of Yarm


Center area
from Laser room


Center area

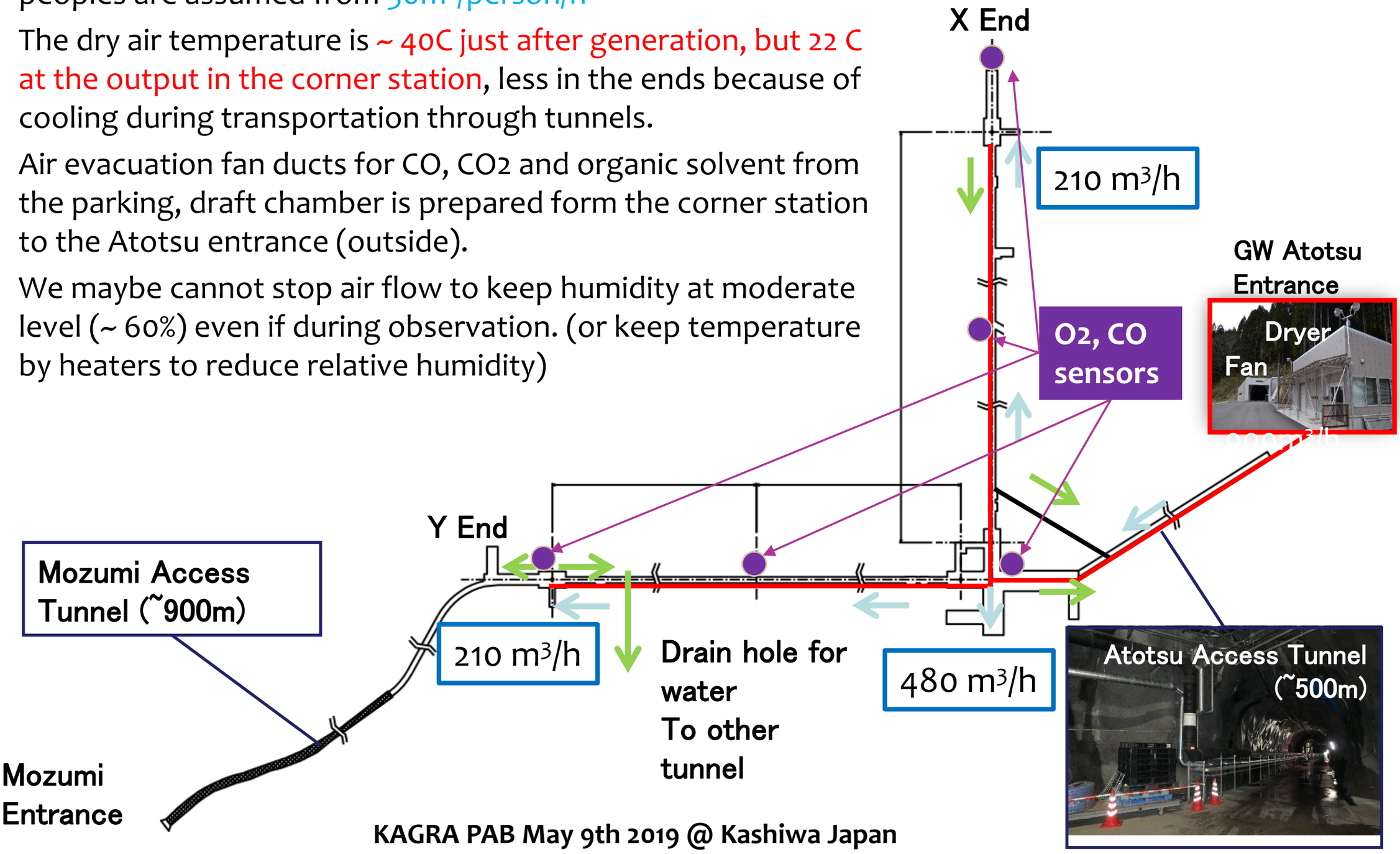
MOZUMI
New Atotsu
⑥
全長≒190m
X end
1F Rail method
2F Tire method
⑤
X arm
Rail method
3000m
④
①
New A
entrance
1500m
1500m
Mozumi tunnel
Tire method
314m
①
②
③
全長≒200m
Y end
Tire method
Y arm (Mozumi side)
Tire method
③
Y arm (New Atotsu)
Tire method
②
全長≒400m
Center area
Tire method
454m
New Atotsu tunnel
Tire method
unnel
exixting)
680m



Example of cross section of arm tunnels to show items to be installed.

Dry Air Injection from Outside

- 900m³/h for all stations (guaranteed at the blowing point by setting the 5kPa pressure at the fan position). 30 working peoples are assumed from 30m³/person/h
- The dry air temperature is ~ 40C just after generation, but 22 C at the output in the corner station, less in the ends because of cooling during transportation through tunnels.
- Air evacuation fan ducts for CO, CO2 and organic solvent from the parking, draft chamber is prepared form the corner station to the Atotsu entrance (outside).
- We maybe cannot stop air flow to keep humidity at moderate level (~ 60%) even if during observation. (or keep temperature by heaters to reduce relative humidity)



Temperature and Humidity Stabilization in Each Station

Action:

- **Basically, we expect the natural cooling effect and temperature stability underground during observation mode.**
- KAGRA has no "precision" air conditioners to stabilize temp in each station, but just have four 14 kW coolers (water cooling type) in the corner station to compensate the heat mainly from ~ 250 FFUs for creating clean air, one 5kW cooler in the X end station, and no in Y end.
  1. **Corner Station :** We have already checked the temperature in the corner station will increase up to 27 C or more even if all ~ 250 FFUs are turned off for observation mode because of other heat sources such as IFO control DGS instruments, vacuum pumps and cryocooler compressors that should be operated. → Consequently, we concluded that one 14 kW cooler should be operated. So we should check the vibration effect on sensitivity in the future. We have put vibration isolator for one cooler. At present, we can keep 23-24 C range at BS, PRMs, SRMs positions.
  2. **Y End Station :** We have already checked the temperature will be stabilized around 20 C because of the balance between dry air injection, heat from instruments and cooling effect of the tunnel surface itself. Actually, the temperature of Y end station is least among three stations.
  3. **X End Station :** We have already checked the temperature will be stabilized around 23~24 C (@ EXC1F) because of the balance between dry air injection, heat from instruments, 5kW cooler cooling effect, and warmer tunnel wall itself. Actually, the temperature of X end station is highest among 3 stations. 5kW cooler (apparently it has low vibration compared with 14 kW water cooling type coolers) might be operated during observation.

Humidity changes at outside of KAGRA in a week

in the arm tunnel
Temperature: 11℃
Humidity: 85%
Stable.