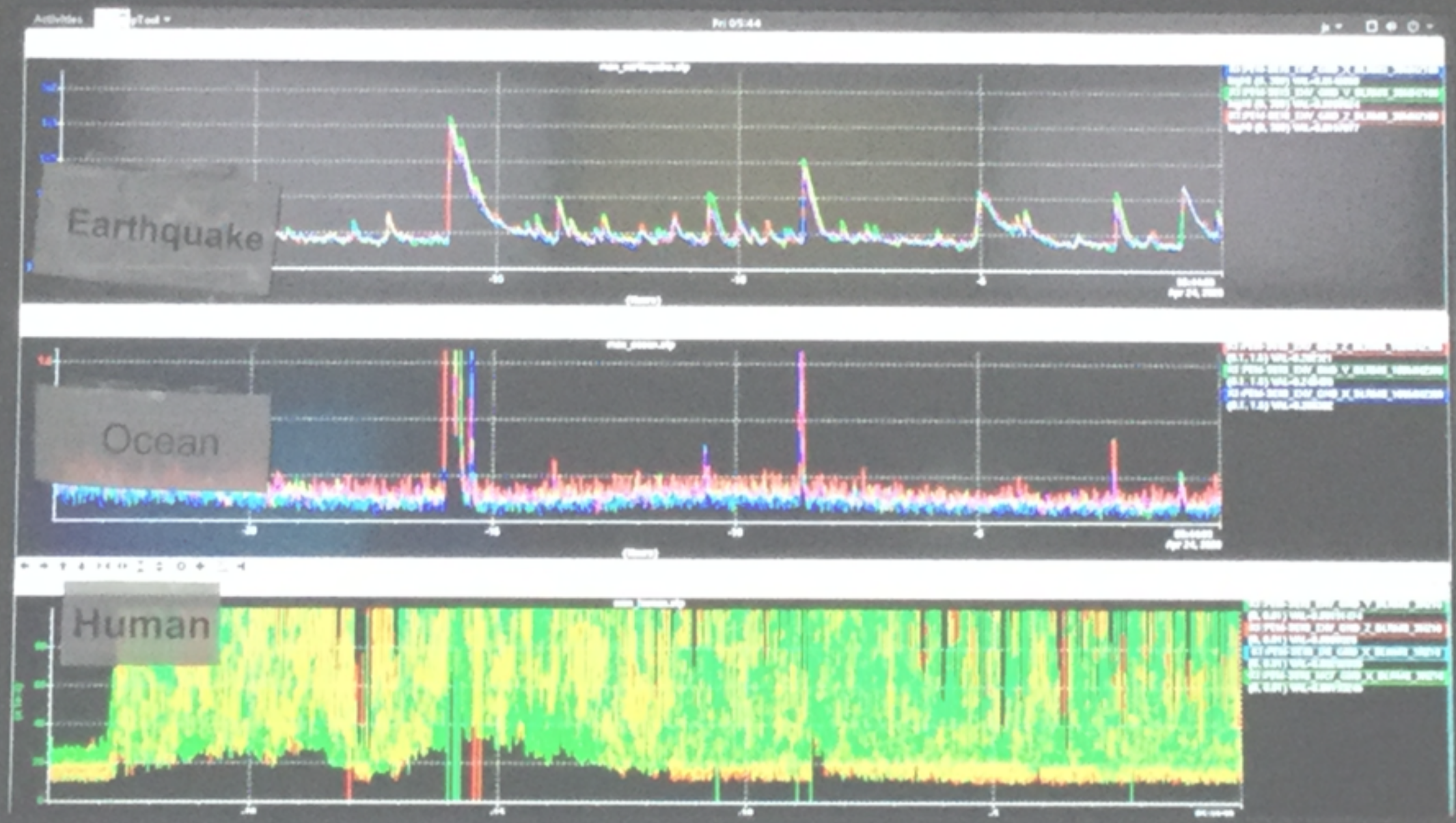
Status of KAGRA PEM



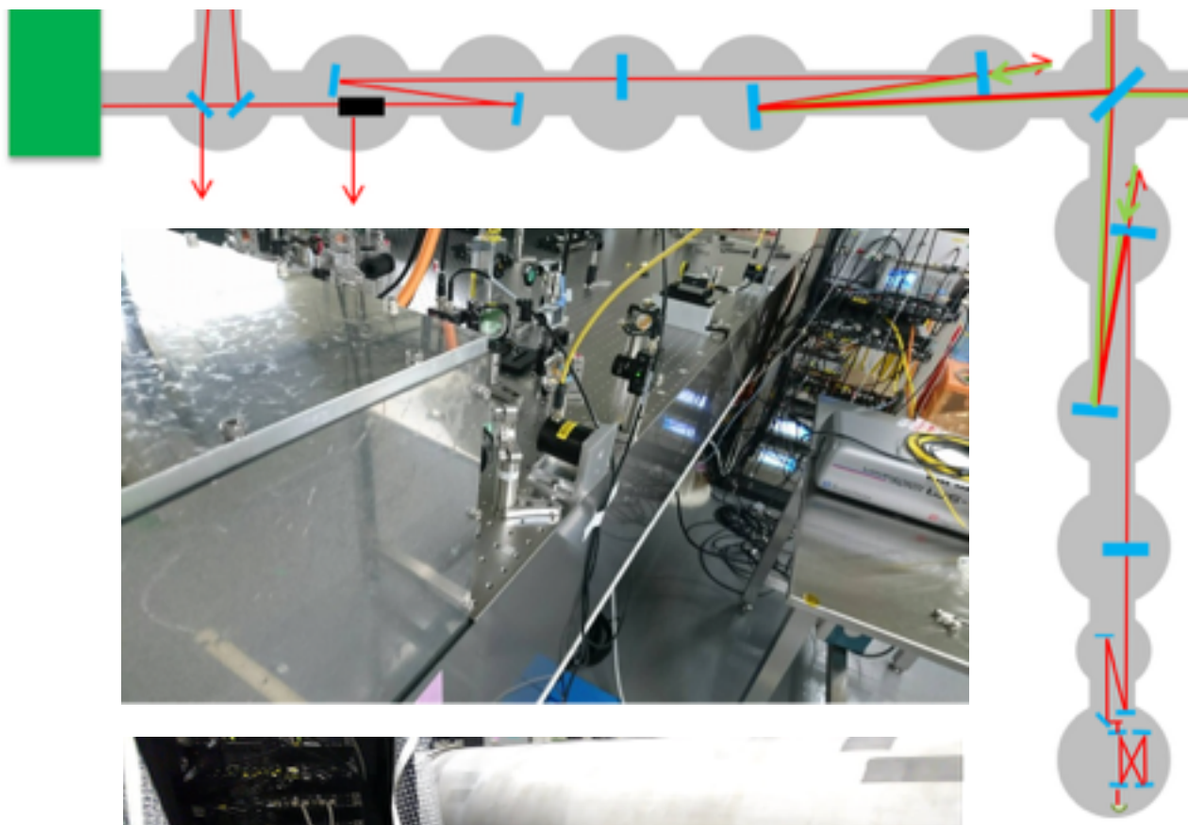
The 7th KAGRA international workshop

Status report session (Parallel session Experiment) 2020/12/19

Takaaki Yokozawa(ICRR)

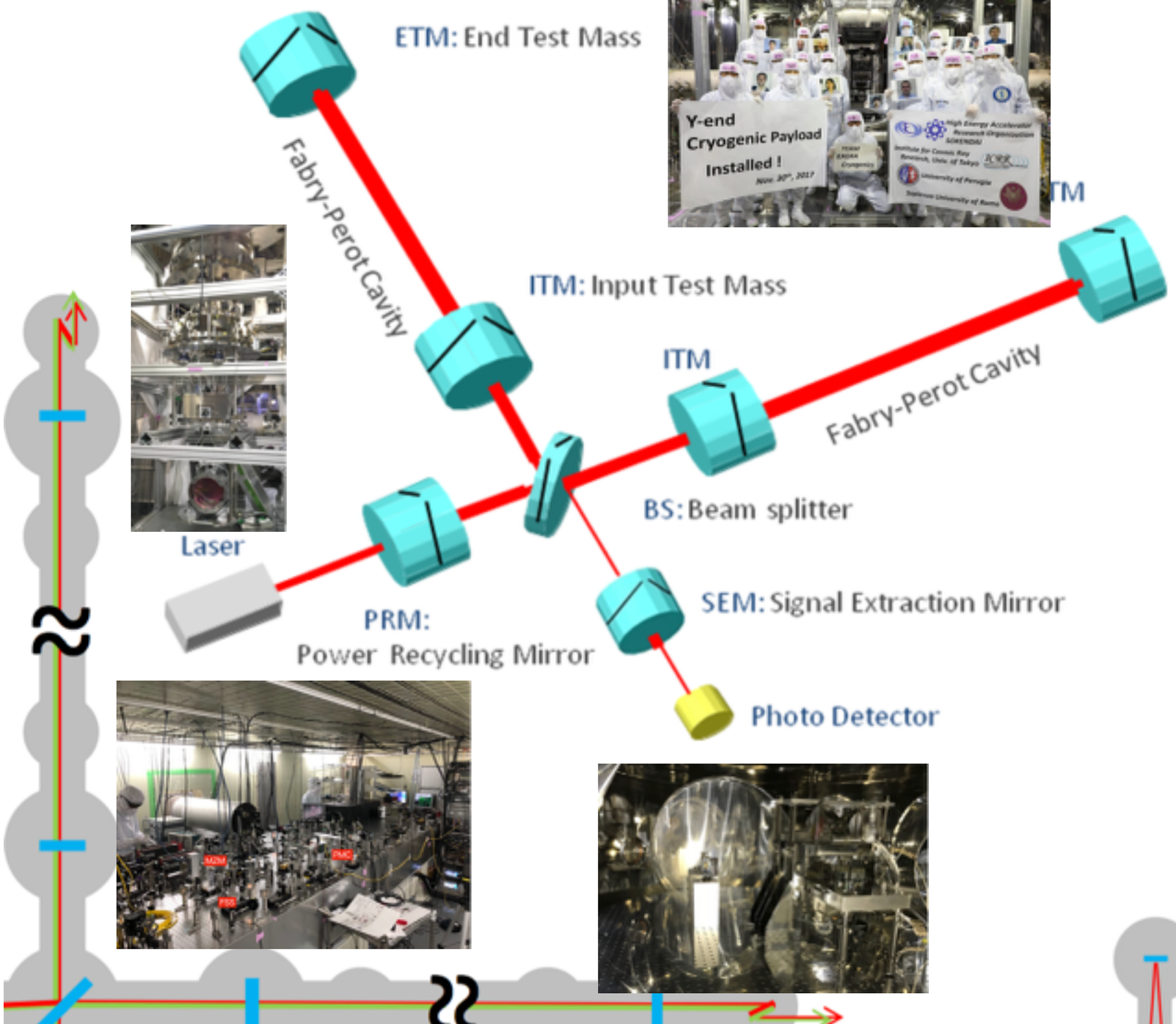
Contents

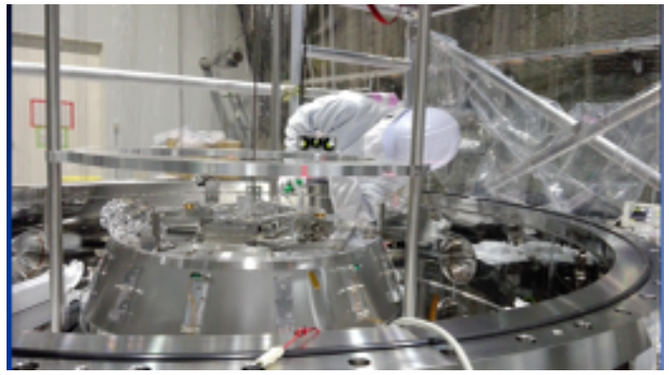
- Progress from last KIW
- Activities toward O3GK
  - Turn on/off instruments
  - Hammering test
  - PEM injection
  - Noise investigation
- Future prospects
- Summary



PEMs

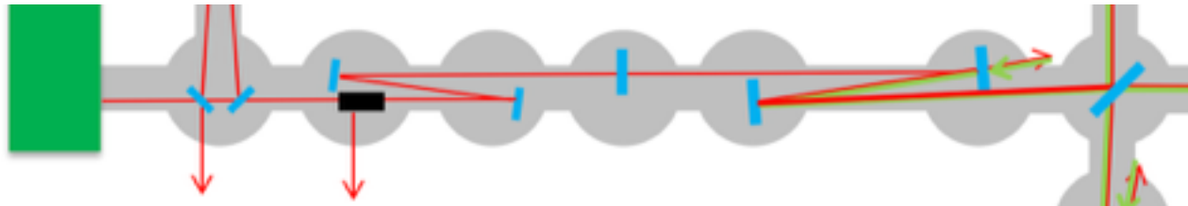
- PEM : Physical Environmental Monitors





- Installation of the Instruments toward O3GK was finished at Apr., 2019
- Interferometer commissioning work
- O3GK international observation at Apr., 2020

PEMs



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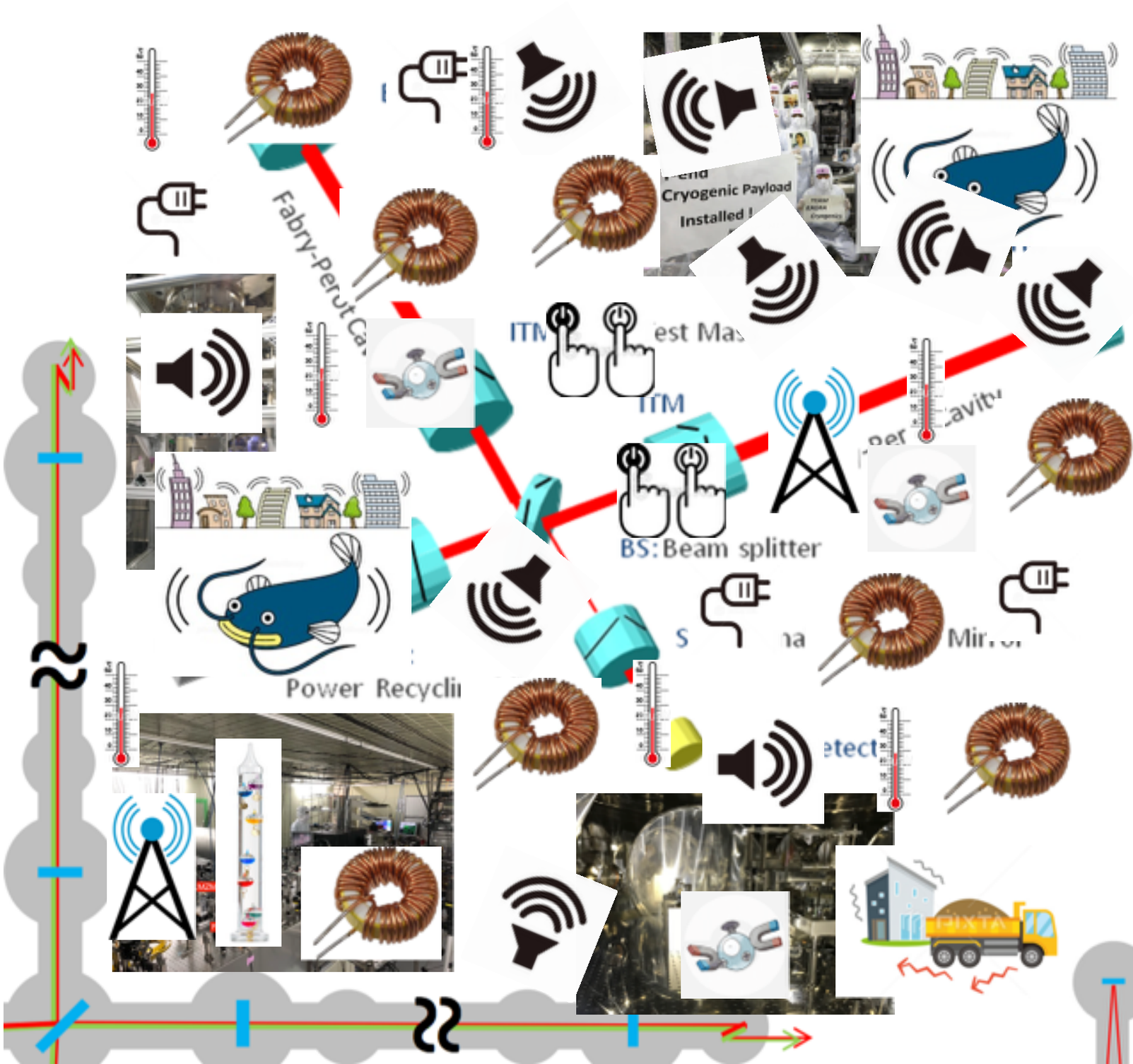
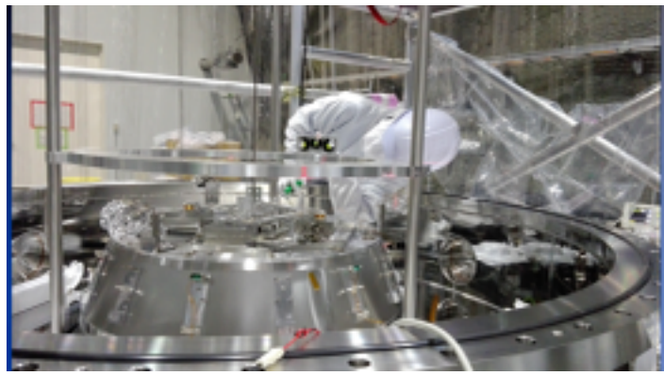




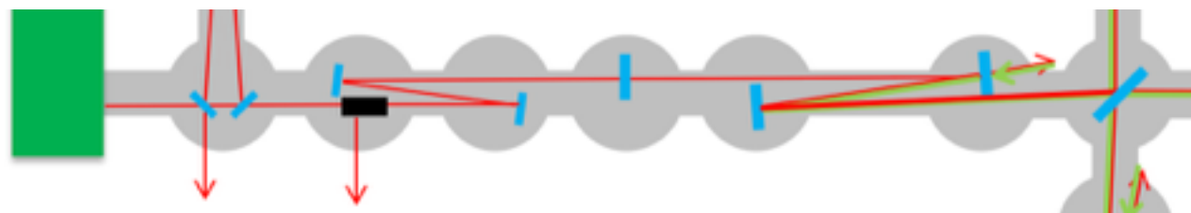
- There are many noises in KAGRA
- Environmental noise will be one of the main noises
- To investigate, remove and reducing them is main task of PEM
- Underground and cryogenic

PEMs

- PEM : Physical Environmental Monitors

- Sound
- Magnetic
- Vibration, seismic
- Radio frequency
- Power
- Weather, temperature
- Cosmic ray
- etc., etc., etc., …

PEMs



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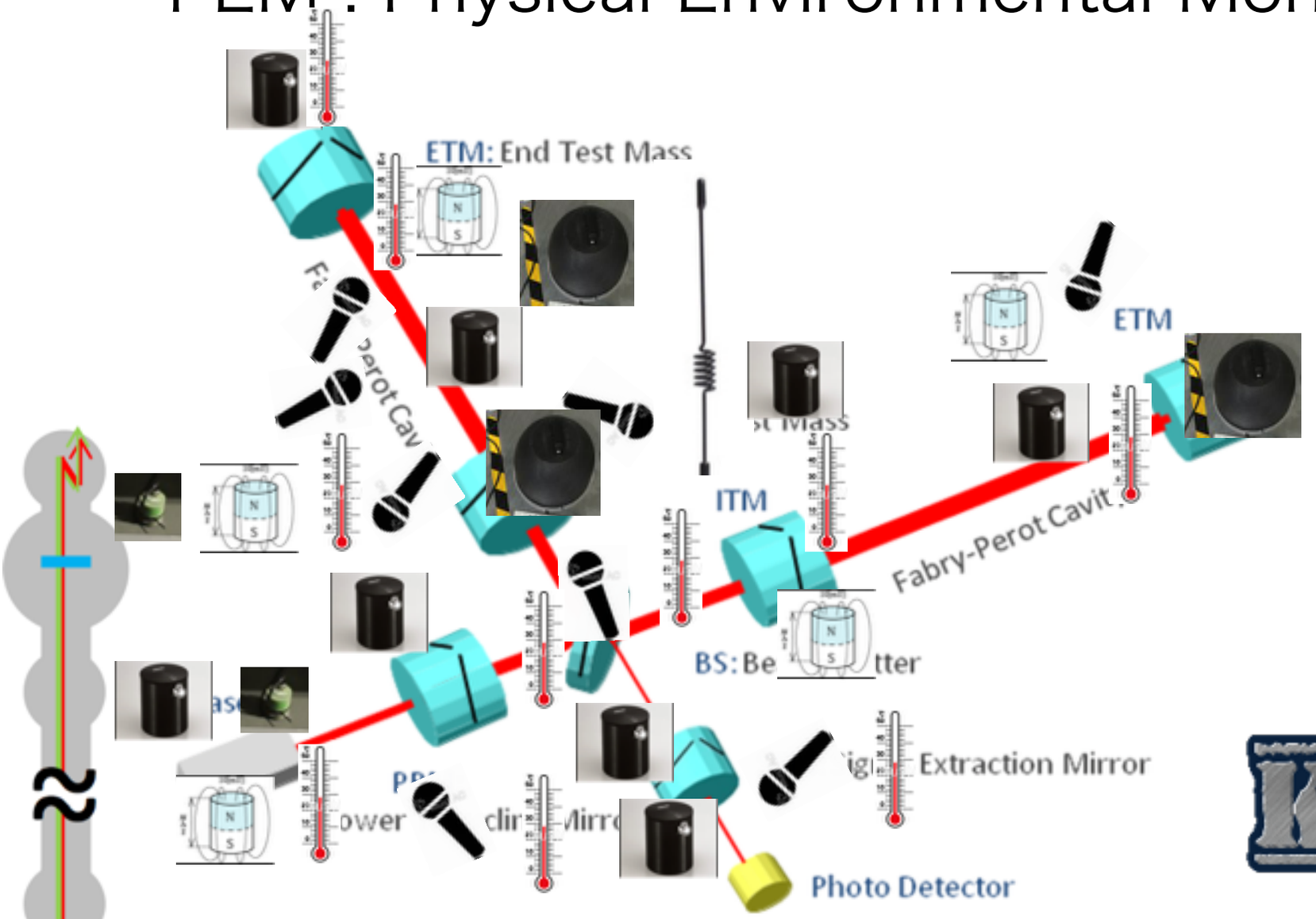
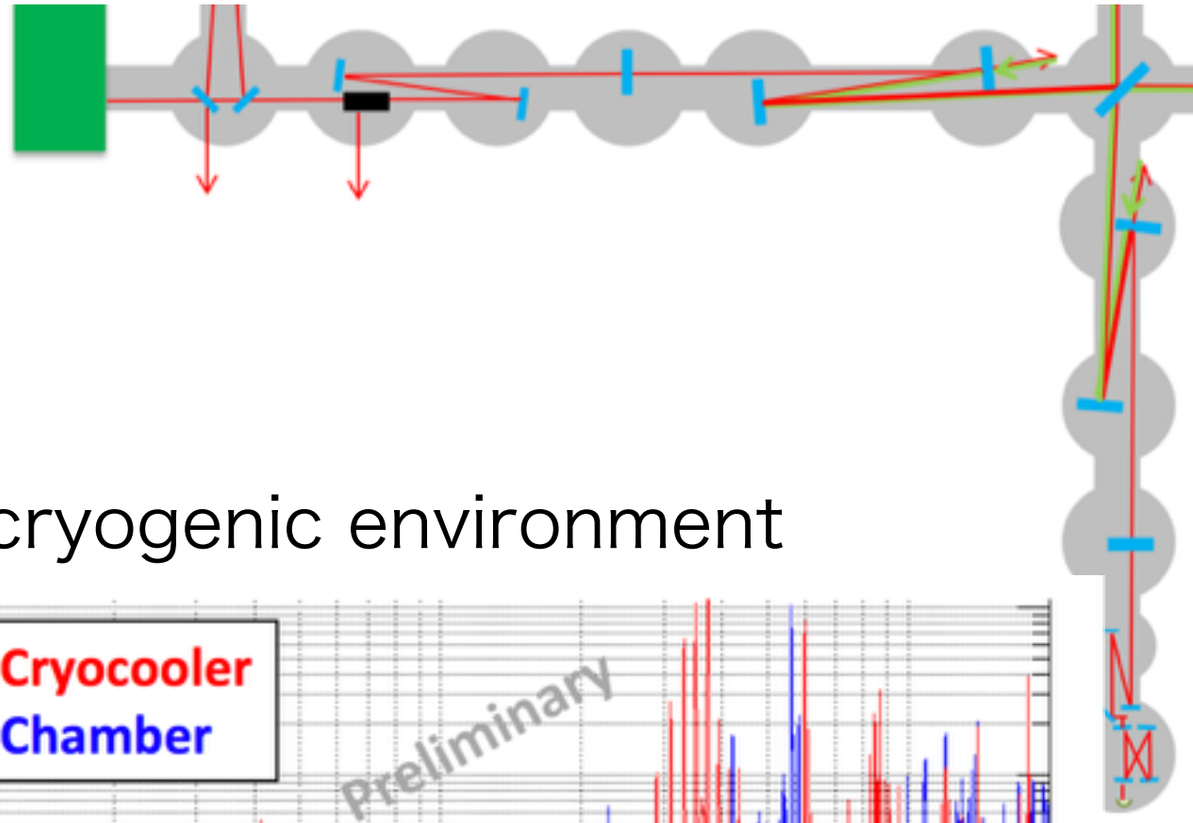


- Sound
- Magnetic
- Vibration, seismic
- Radio frequency
- Power
- Weather, temperature
- Cosmic ray
- etc., etc., etc., …

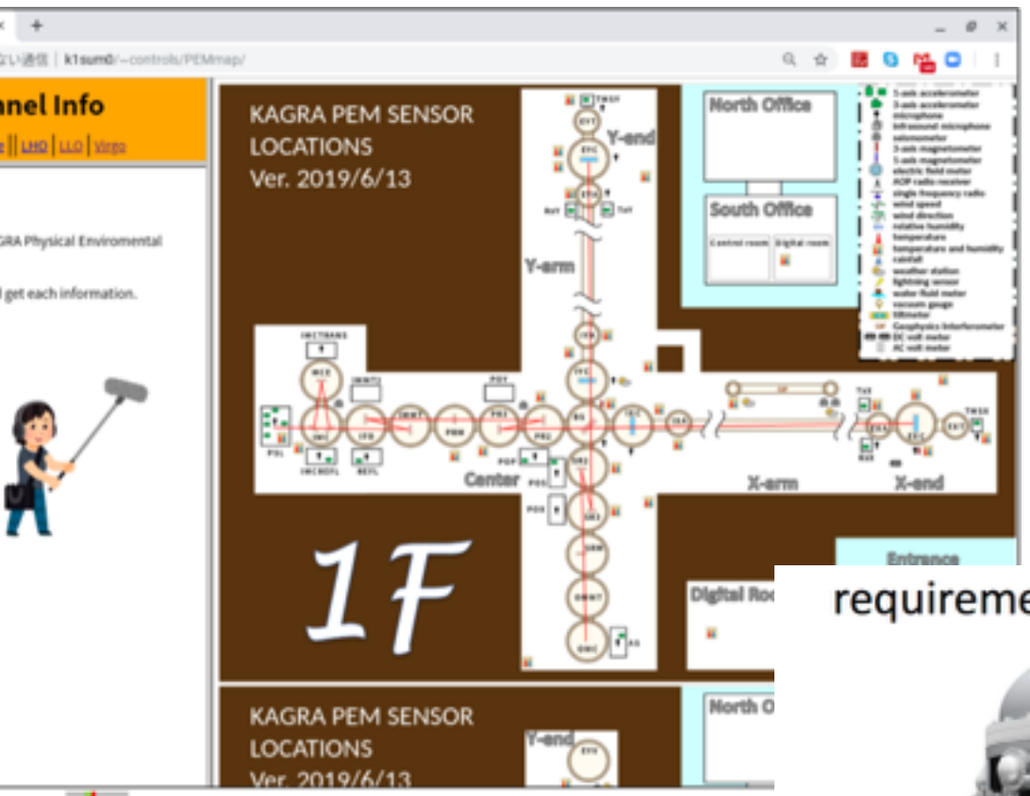
KAGRA PEM

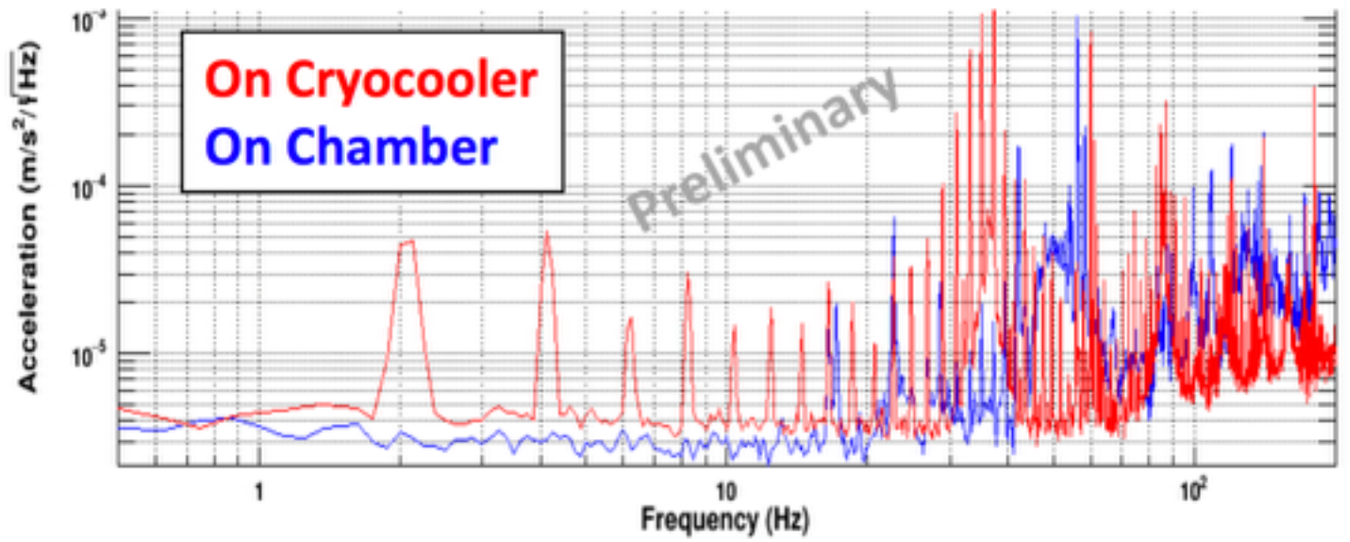
- To access such an environmental noise, PEM is essential
- Install various PEMs for identification and understanding
- Glitch analysis, lock loss study, noise subtraction, …
- Understanding underground and cryogenic features

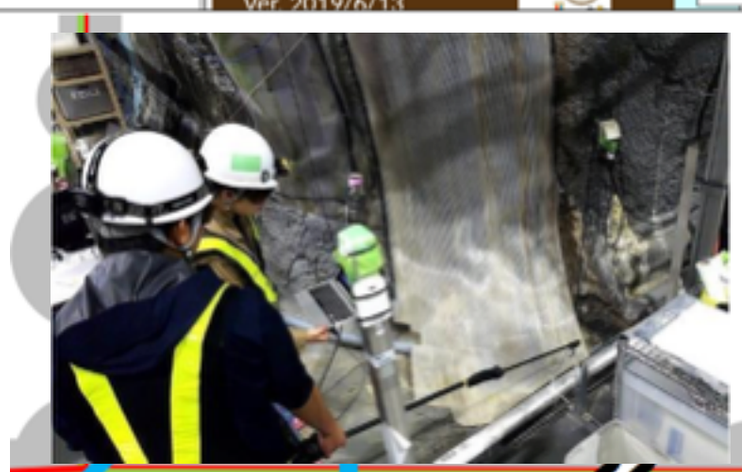
Last KIW report



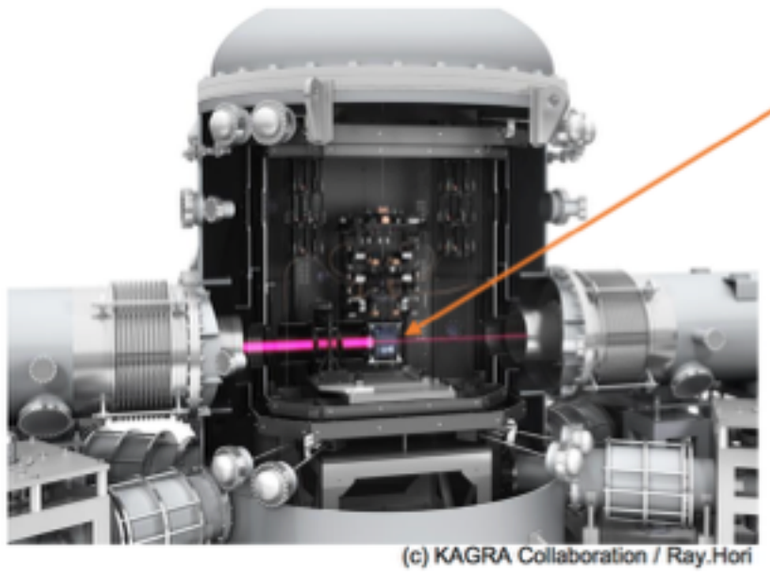
- Report by T.Washimi(Naoj)
  - Installation of PEMs
  - Characterize the underground/cryogenic environment

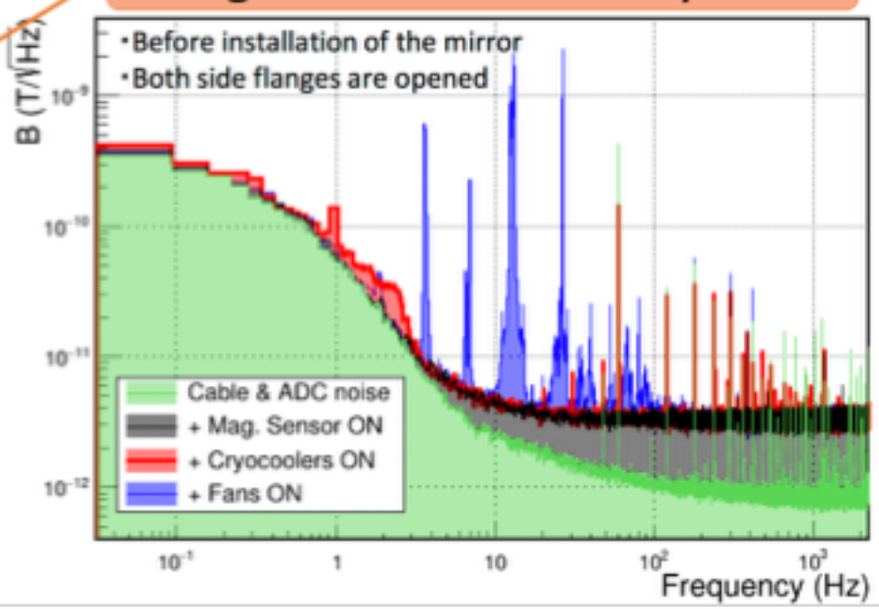






requirement (~10^{-9} T).





PEM installation

- Installed and summarized the PEM channels

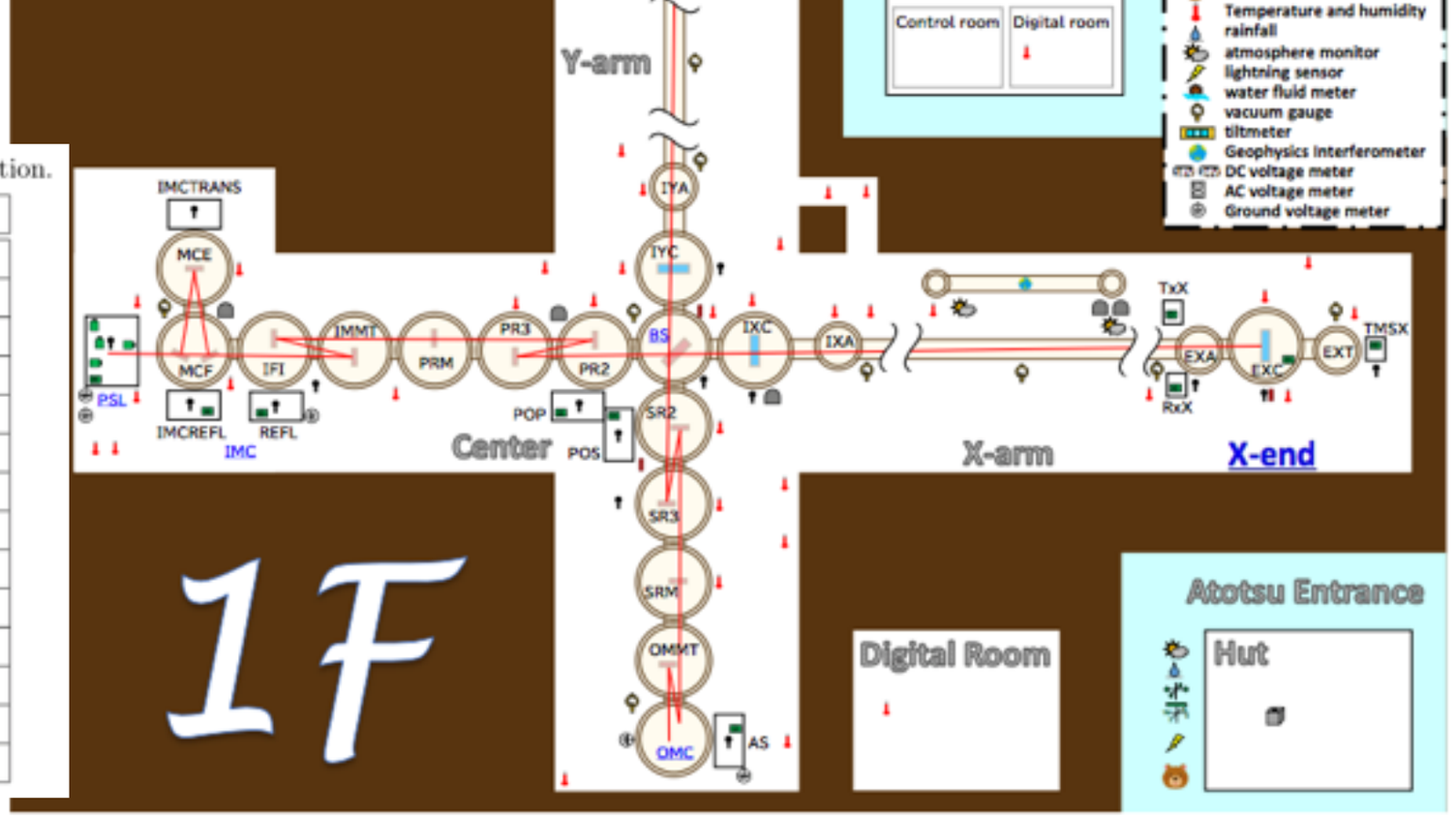
- Final setup
  - https://www.icrr.u-tokyo.ac.jp/~washimi/KAGRA/PEM/PEMmap/archives/O3GK/
- The detail is written in PTEP paper

Overview of KAGRA : (3) Calibration, detector characterization, physical environment, and geophysics interferometer †

https://arxiv.org/abs/2009.09305

Table 2 Summary of the KAGRA PEM sensors installed for the O3GK observation.

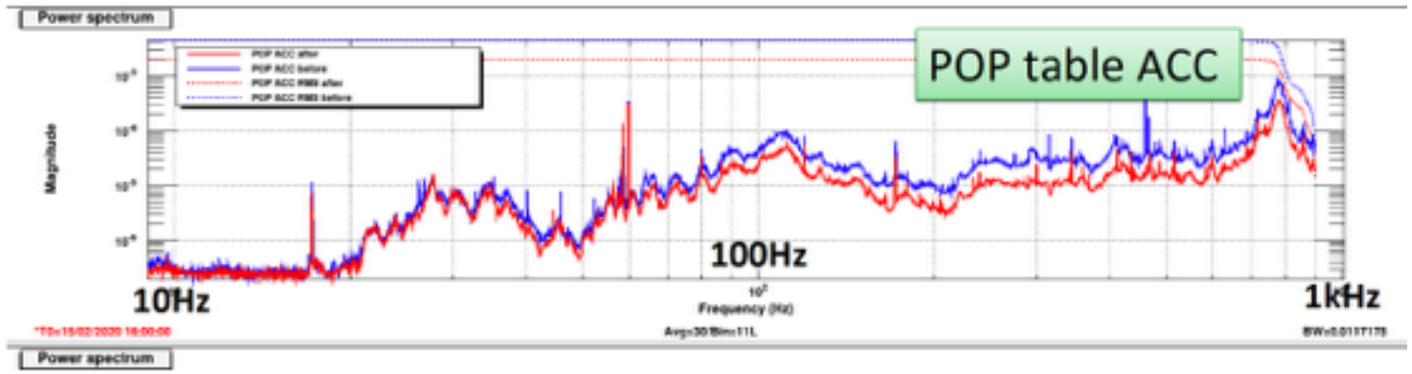
Sensor type	Product name	Operating frequency	Number
Seismometer 1	Trillimu120Q	10 mHz -150 Hz	3
Seismometer 2	Trillium compact	10 mHz -150 Hz	3
Accelerometer 1	TEAC 710	20 mHz - 200 Hz	10
Accelerometer 2	TEAC 706	3 Hz - 14 kHz	6
Accelerometer 3	PCB M601A02	17 mHz - 10 kHz	4
Accelerometer 4	KISTLER 8640A5	0.5 Hz - 3 kHz	4
Microphone 1	B&K 4188-A-021	20 Hz - 12.5 kHz	3
Microphone 2	ACO microphones	20(1) Hz - 20 kHz	17
Microphone 3	Audio-technica AT-VD6	60 Hz - 15 kHz	2
Magnetometer	Bartington Mag-13MCL100	DC - 3 kHz	3
Voltmeter	KAGRA DAC (directly)	DC - 16 kHz	5
Thermometer	T&D RTR-507SL	5 min sampling	77
Weather station	Davis Vantage Pro2 #6152JP	1 min sampling	1
Lightning sensor	Blitzortung System Blue	(triggered time)	1

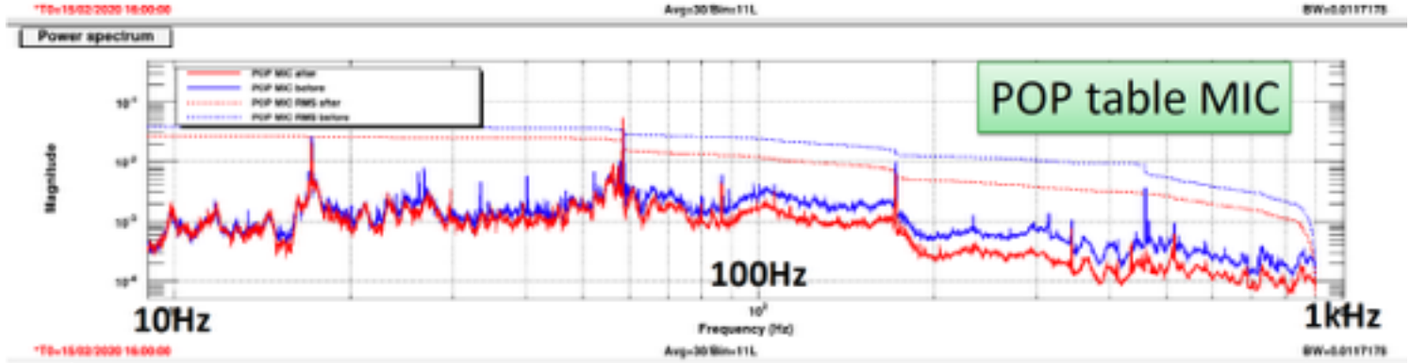


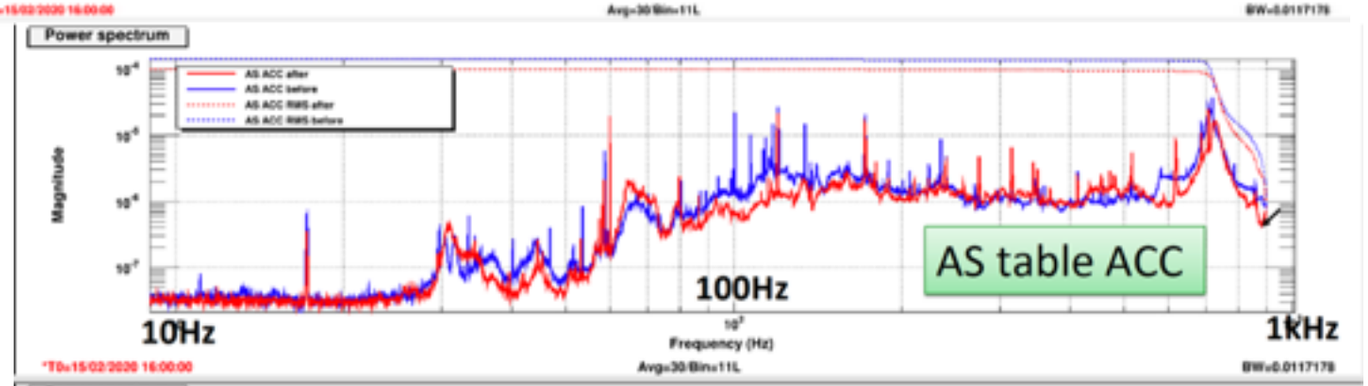
Instrument on/off test

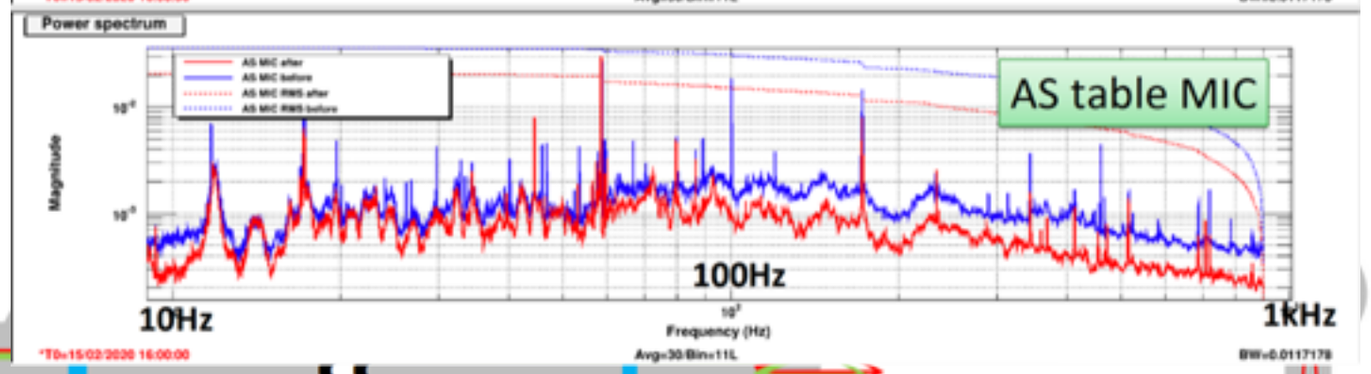
- Turned off FFUs and vacuum pumps

* FFU : Fan Filter Unit





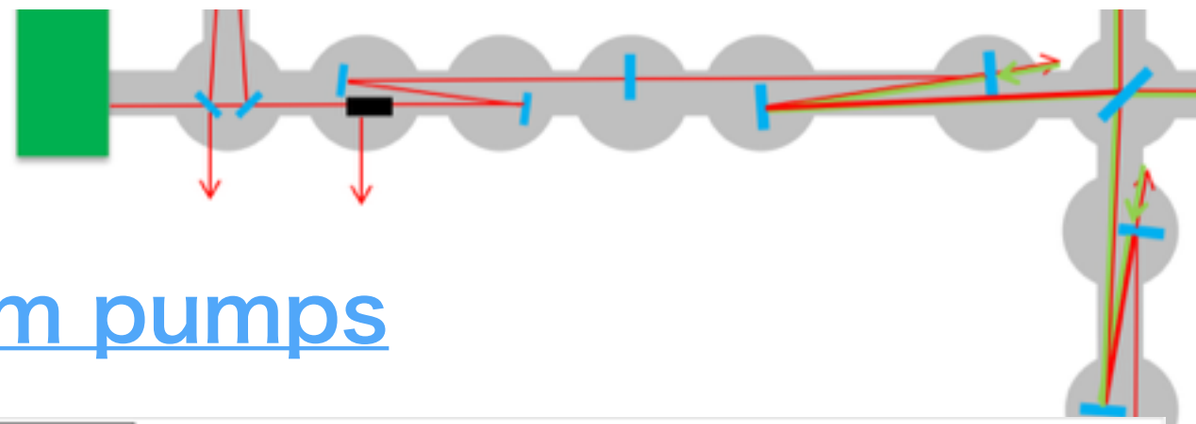




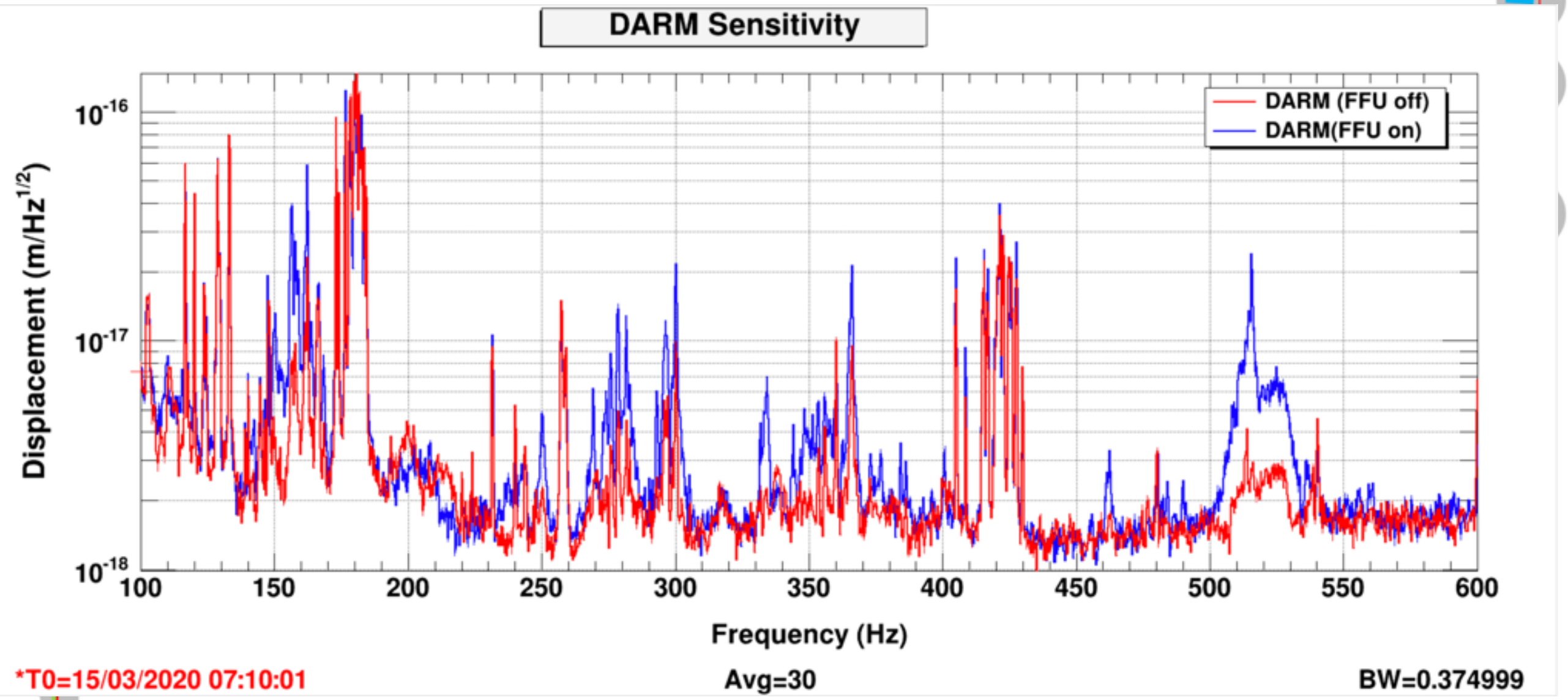
- (Almost) all FFUs, turbo pumps and route pumps were turned off
- Temperature control by heaters

- ON (Jan. 27)
- OFF (Feb. 15)

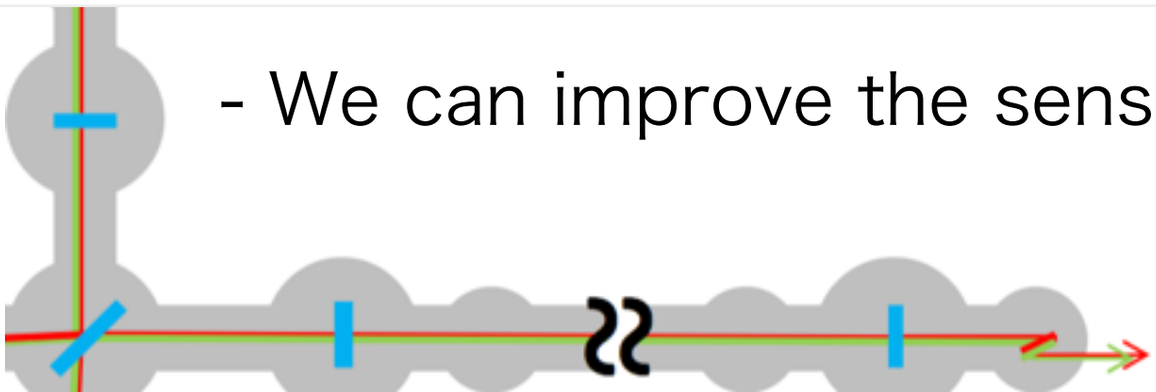
Instrument on/off test

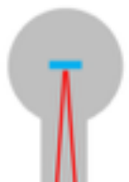


- Turned off FFUs and vacuum pumps



- We can improve the sensitivity by tuning off the FFUs

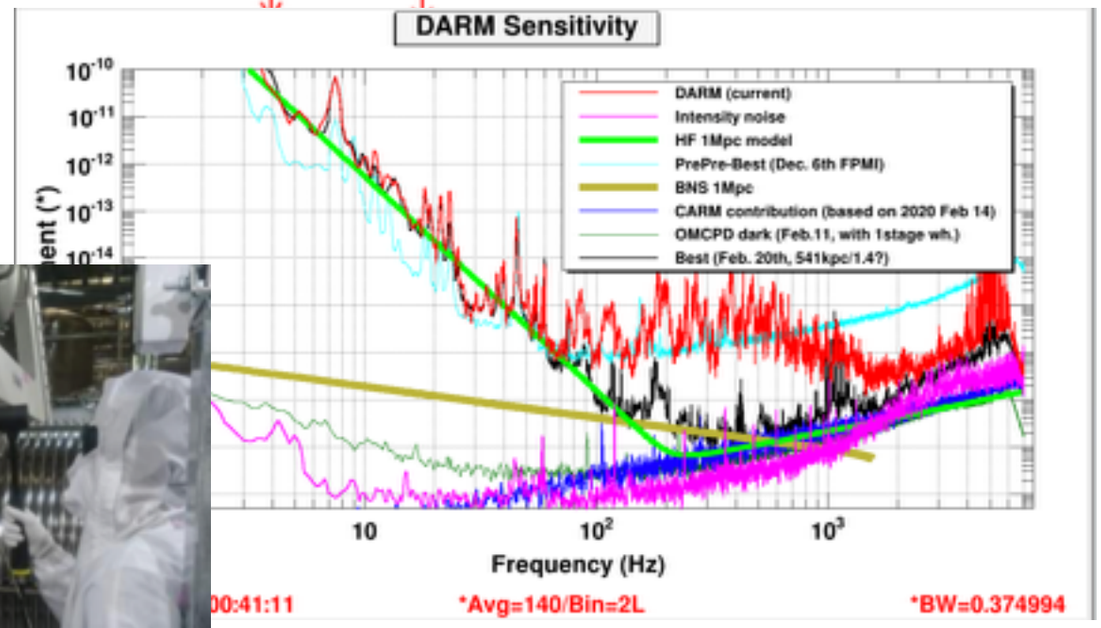


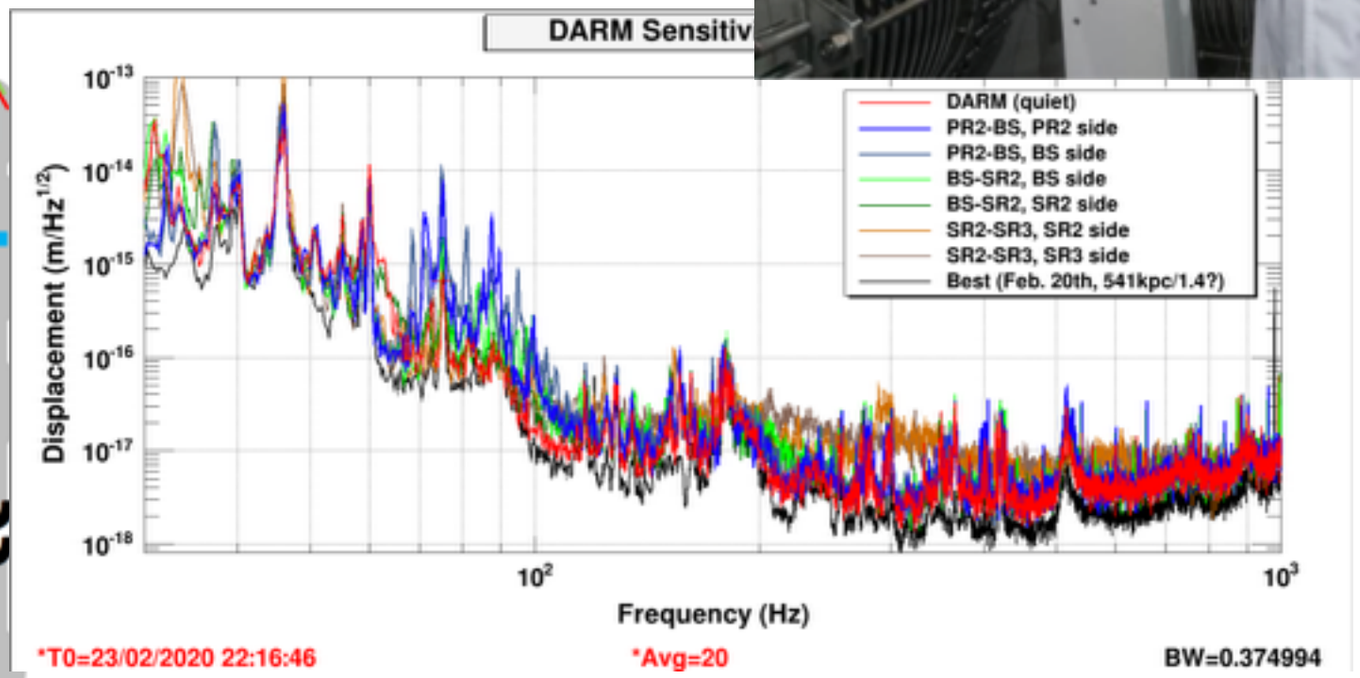


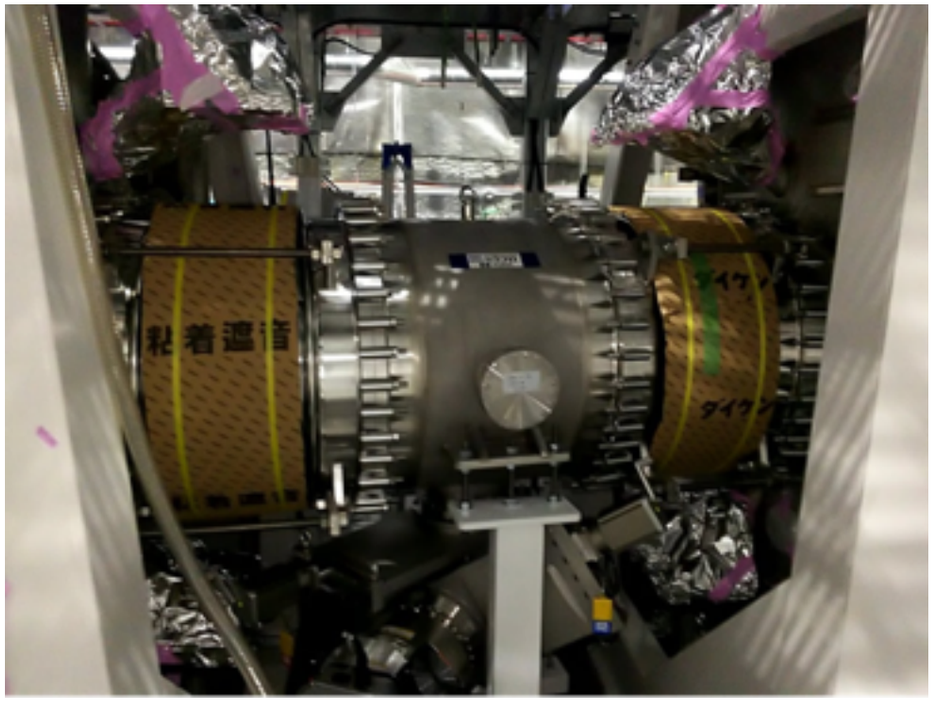
Hammering test

- Hammering test

- OMC leg
- BS/SR area
- IMC/IMM/PR area
- Yend area

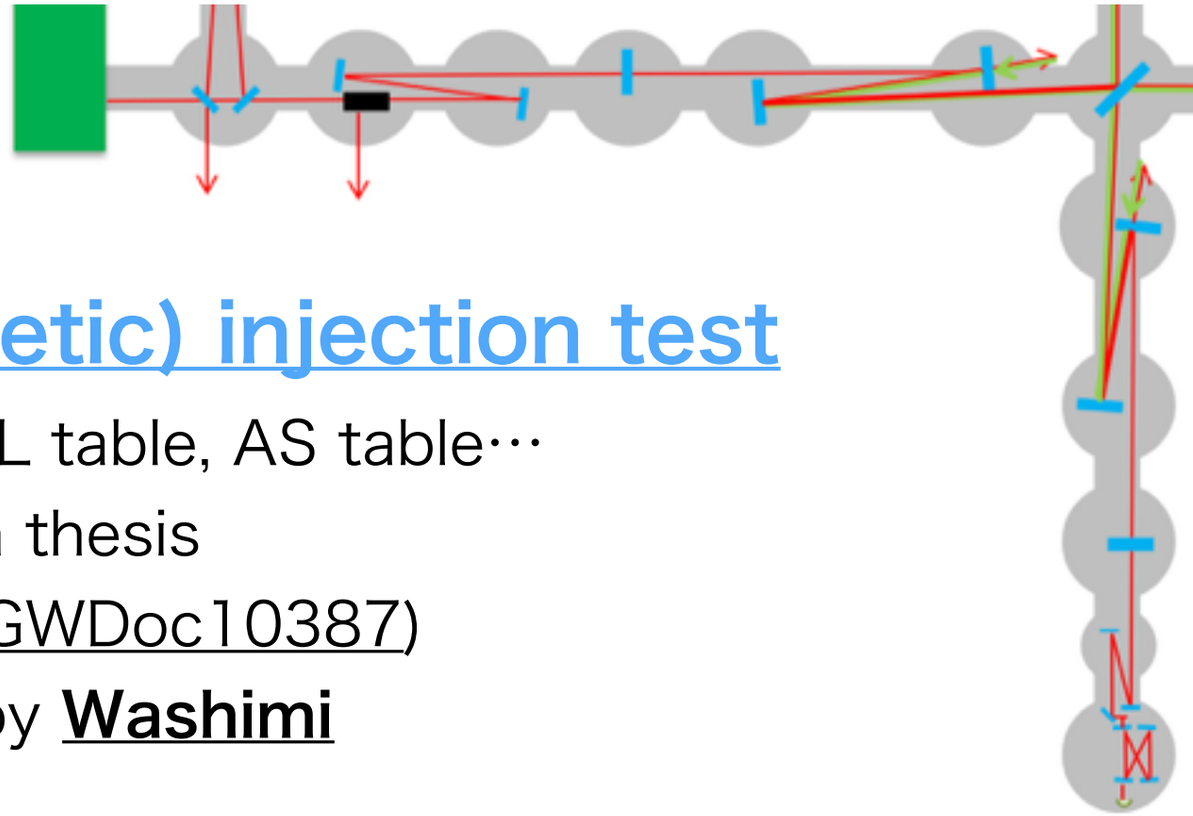






- We found large excess in DARM when hammering the bellows between IMC and IFI chambers -> Acoustic injection

PEM injection

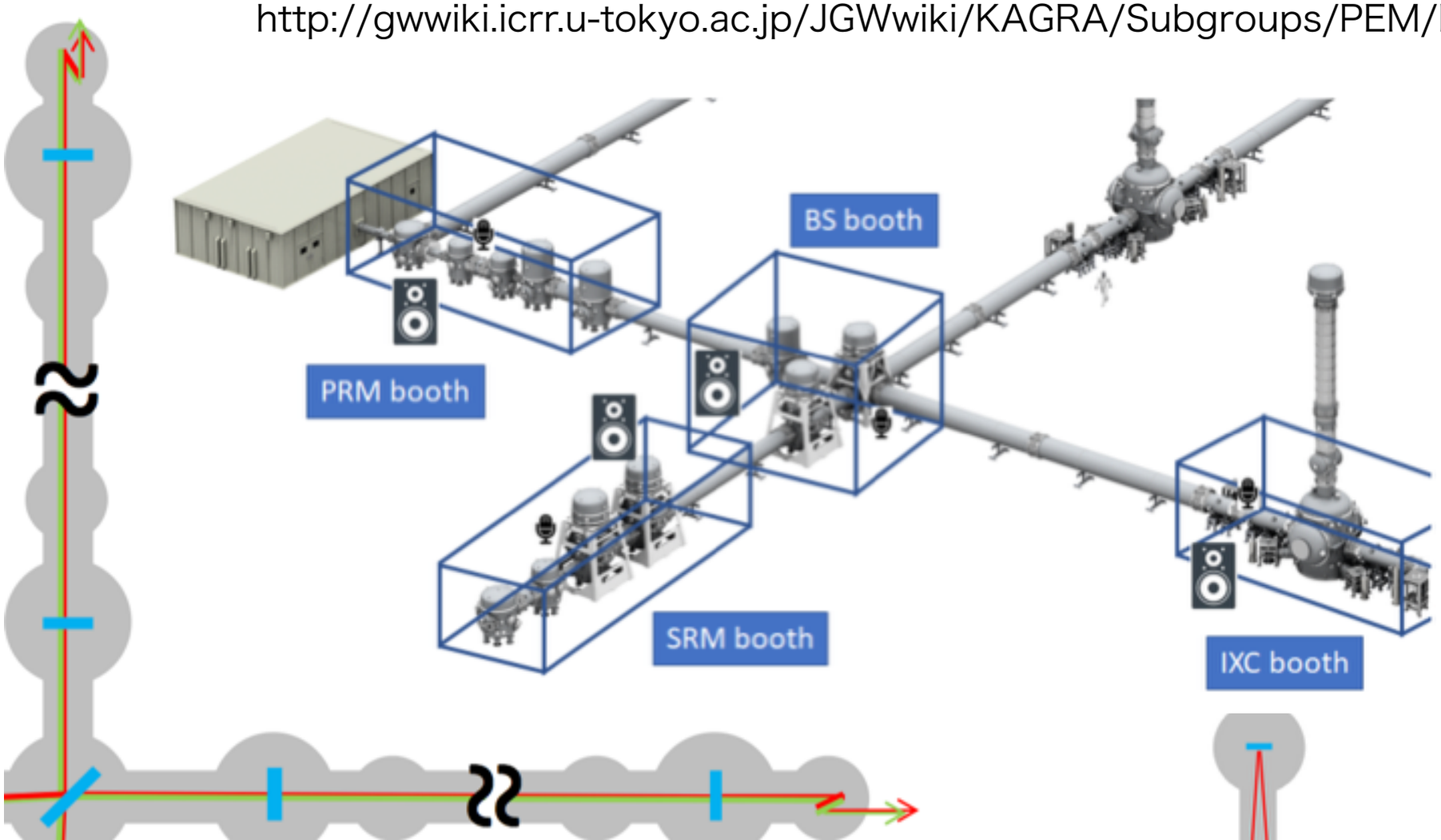


- Acoustic (vibration, magnetic) injection test

- Acoustic injection to PSL room, REFL table, AS table…
- **Takaaki Tanaka**(Niigata) graduation thesis
- **Taiki Tanaka**(ICRR) master thesis(JGWDoc10387)
- Development new analysis method by **Washimi**

https://arxiv.org/abs/2012.09294

http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA/Subgroups/PEM/PEMinjection/O3



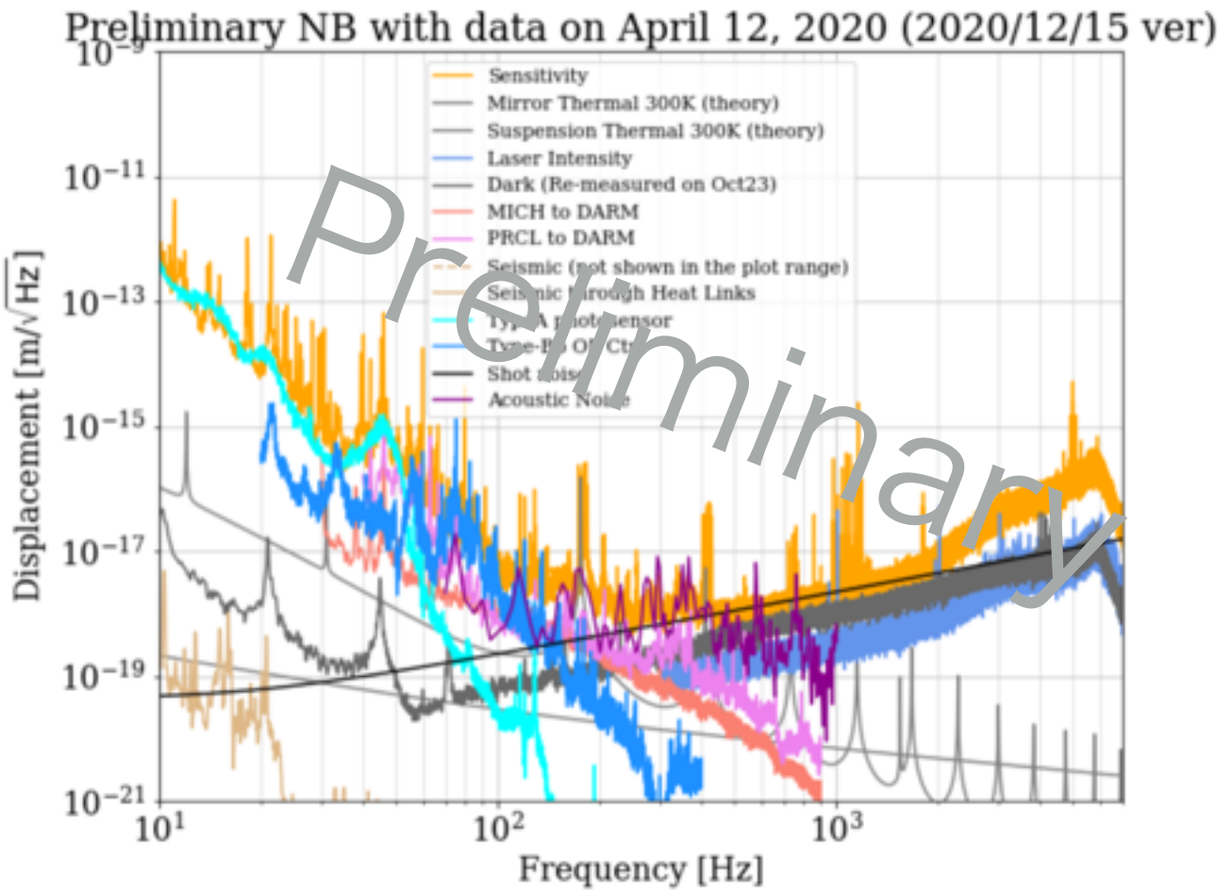
Noise investigation

- Underground environment investigation

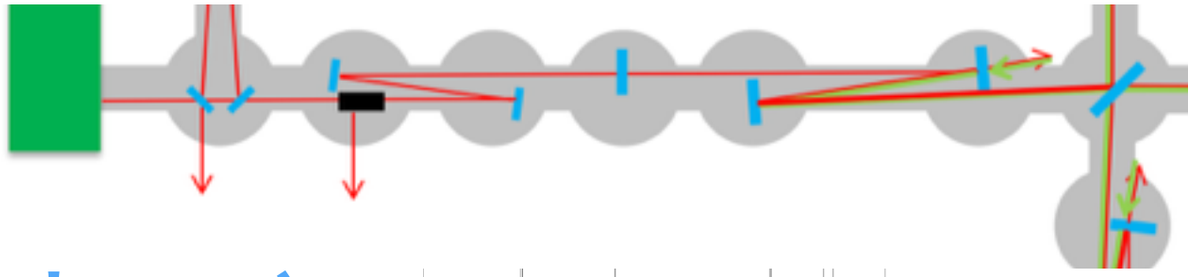
- Temperature control
- Ground motion
- Magnetic field
- etc.

- Interferometer characterize

- noise budget
  - scattered light
  - environment noise
- glitch noise identification
- line noise investigation
- lock loss study
- weather monitor
- mirror surface monitor



Future prospect (1)



- Preparation toward O4(Hardware)

- PEM re-installation

- We are planning to do re-cabling and re-installing
- Water fluid / tiltmeter/ …

- New PEM injection

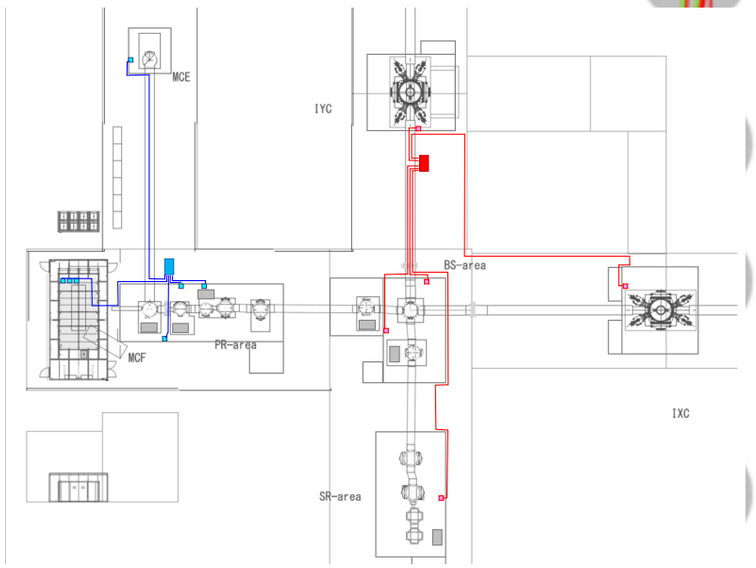
- Set PEM injection to both end station
- Large coil
- New PEM injection idea

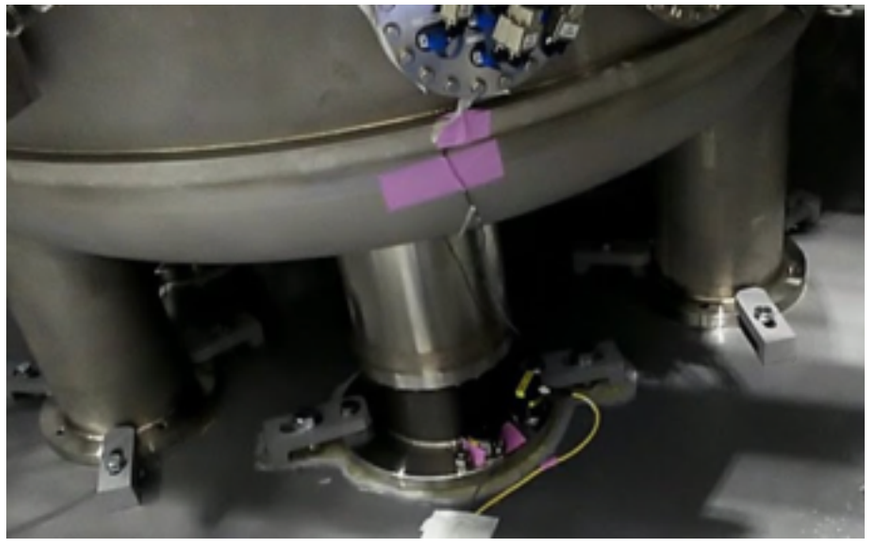
- Transfer function measurement

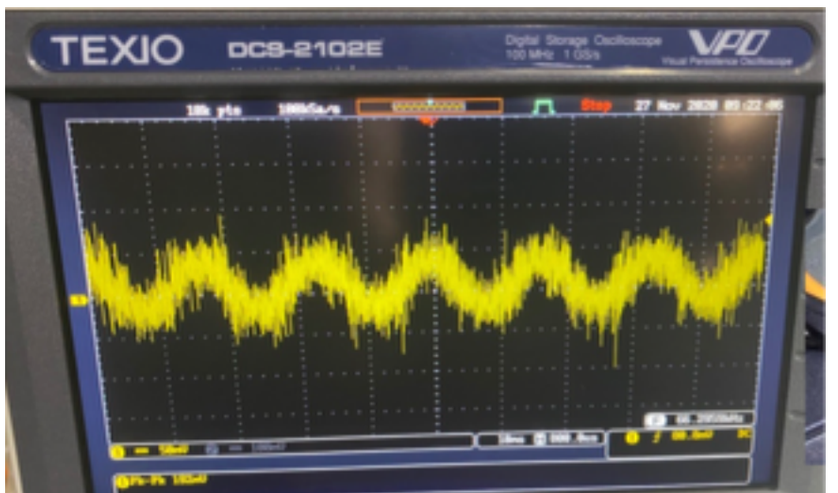
- Chamber leg to chamber table
- Chamber duct/bellows to chamber table
- Optical table to DARM
- Chamber to DARM

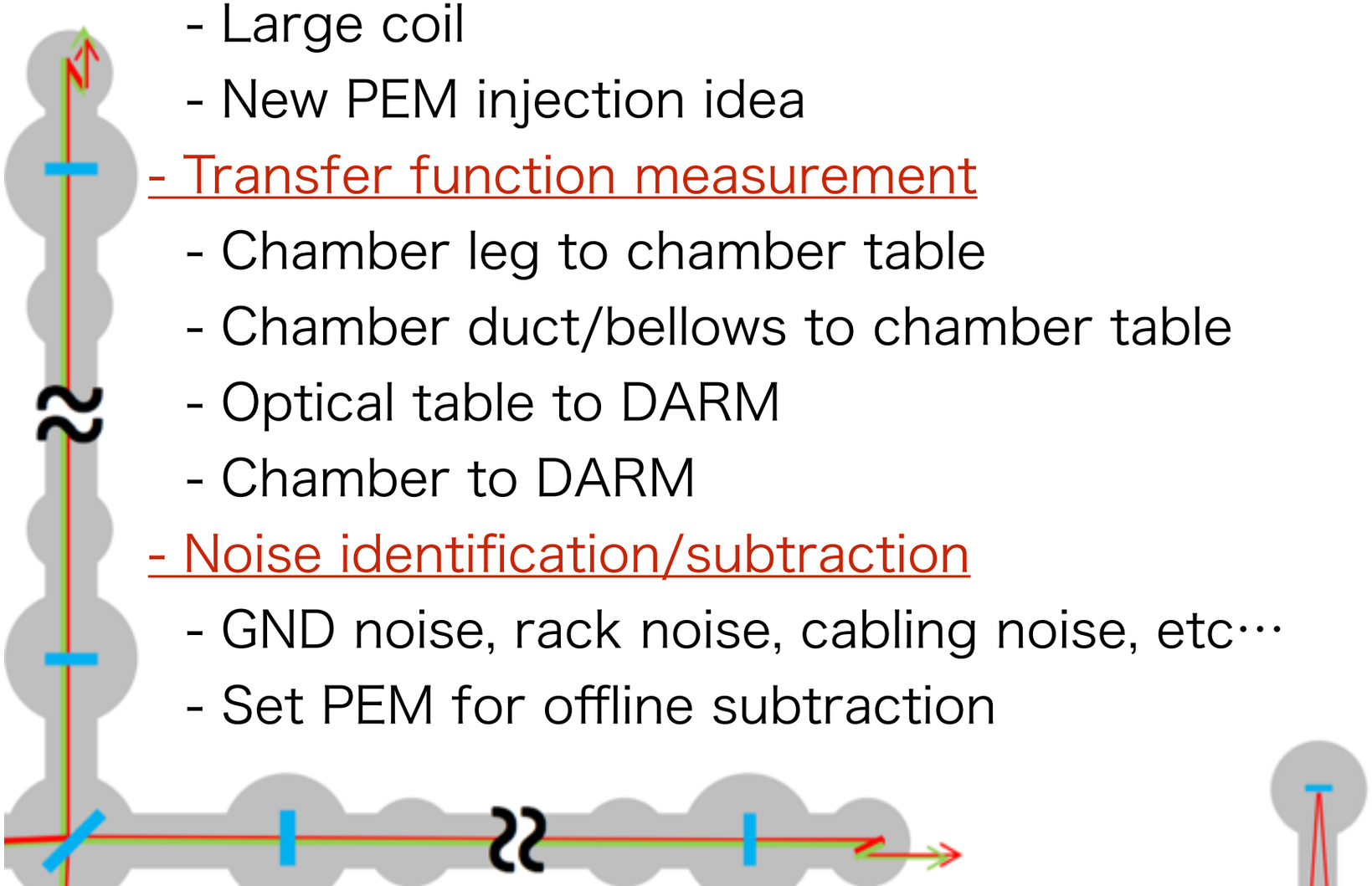
- Noise identification/subtraction

- GND noise, rack noise, cabling noise, etc…
- Set PEM for offline subtraction







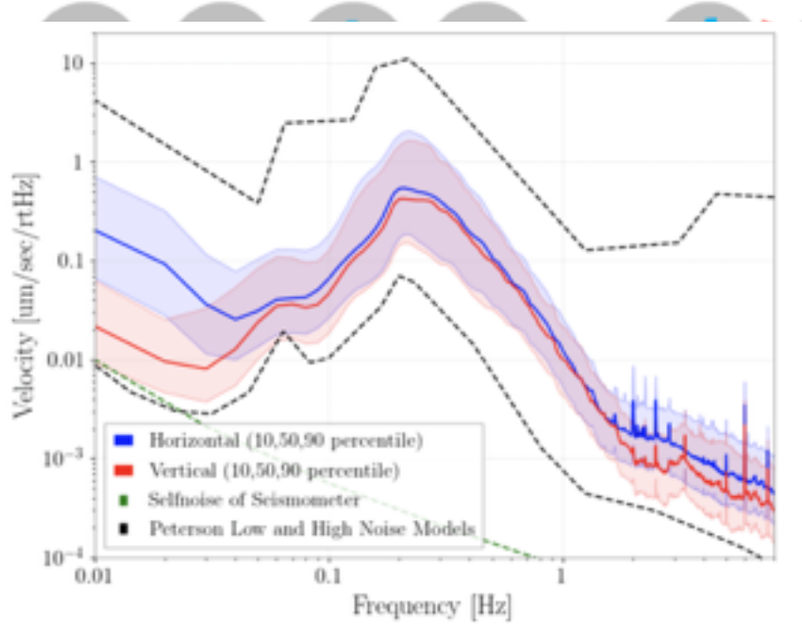


Future prospect (2)

- Preparation toward O4(Software)

- Lock loss study
  - Lock loss investigation by auxiliary channels
  - Prepare the auto analysis tool (aFujiLINCO)
- Offline noise subtraction
  - Power line noise (w/ sideband)
  - Injected line subtraction(ADS, CAL)
  - Using PEM (ex. ICA)
- Characterization of interferometer summary
  - Daily summary page and summary report
  - Weather summary
  - PEM flag and prepare for RRT(Large seismic, lightening, …)
- Plotting tool
  - advanced Pastavi, advanced Ninja(Noise INJection Analysis)
- Investigation of underground/cryogenic environment
  - Next page

Future prospect (3)



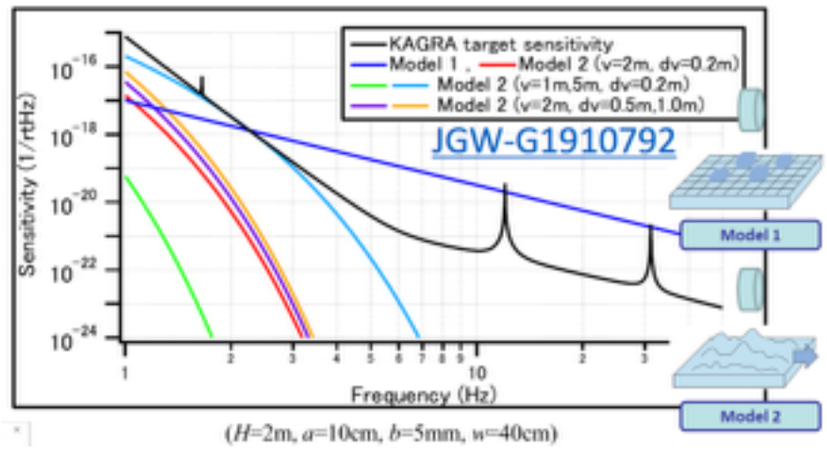
- Environment study

- Investigation of underground environment

- Long term environment analysis
  - Seismic motion, magnetic field, weather
  - Frequency of micro-seismic motion vs. wave map
  - Earthquake(Many earthquakes near KAGRA after O3GK)
  - Lightening, spring water, Schumann resonance, …
  - Vibration/sound/power_noise from instruments

- Investigation of Newtonian noise

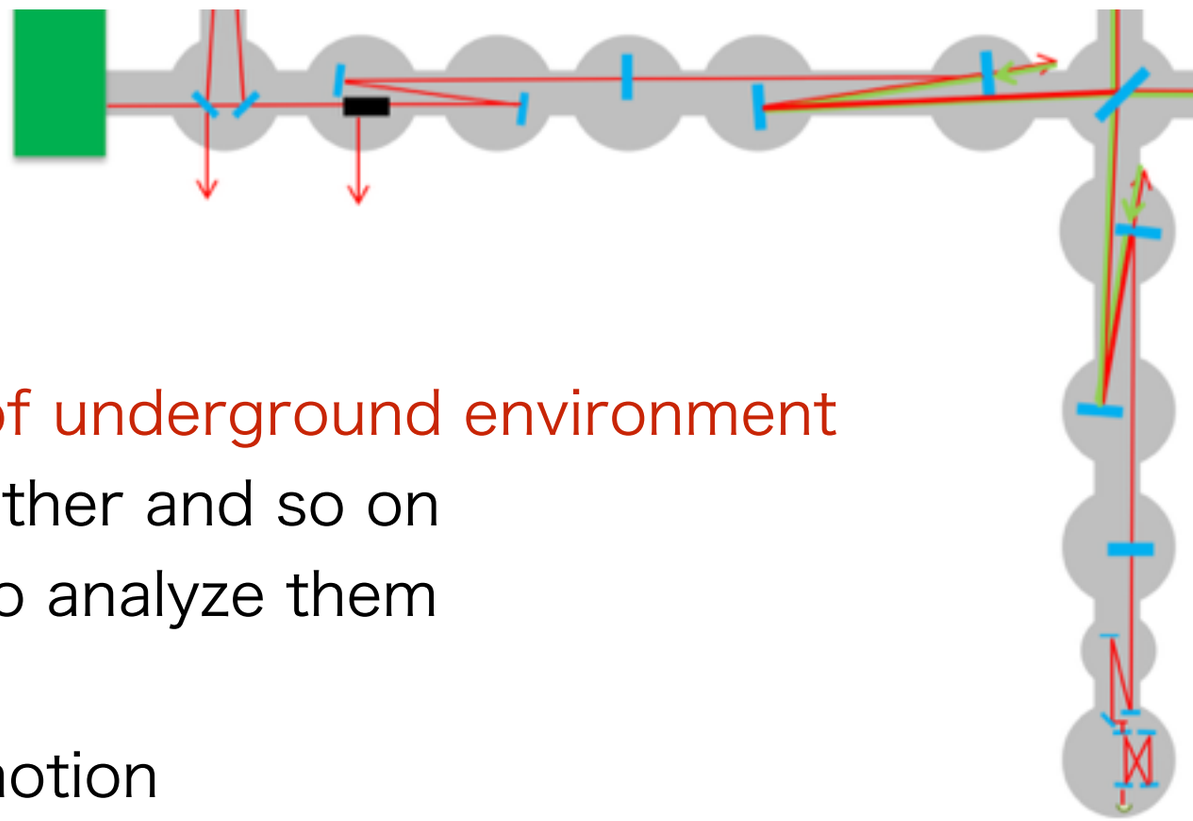
- Model, theory investigation
- Measurement tool, method
  - New measurement detector
  - Water fluid, Surface wave, atmospheric, …
- Analysis



- Investigation of noise from human activity etc.

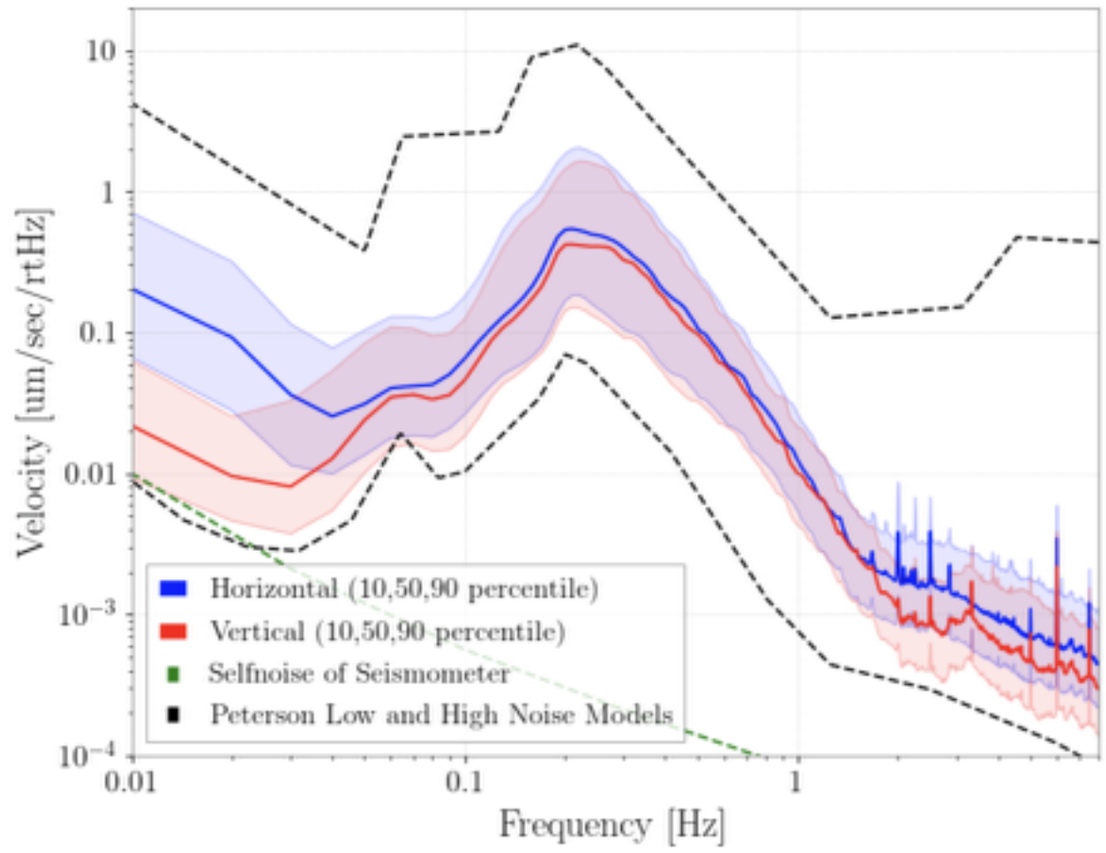
- From heavy traffic, dam, blasting, snow removal, …
- Cooler, vacuum pump, air conditioner, …

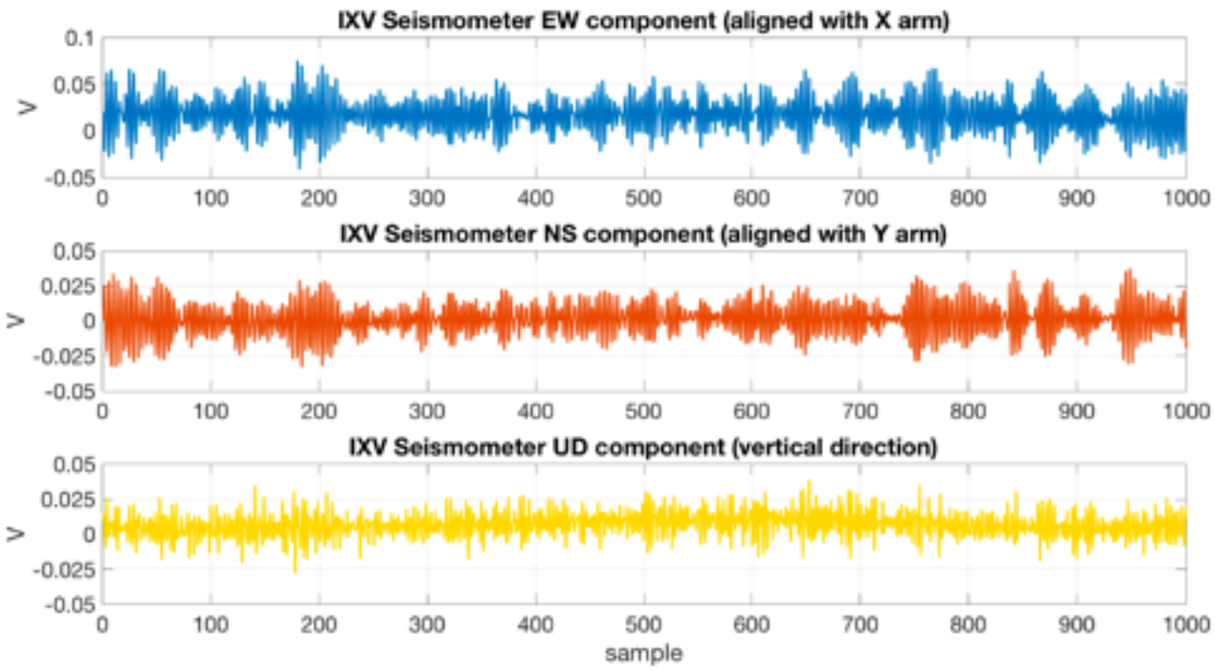
Underground environment



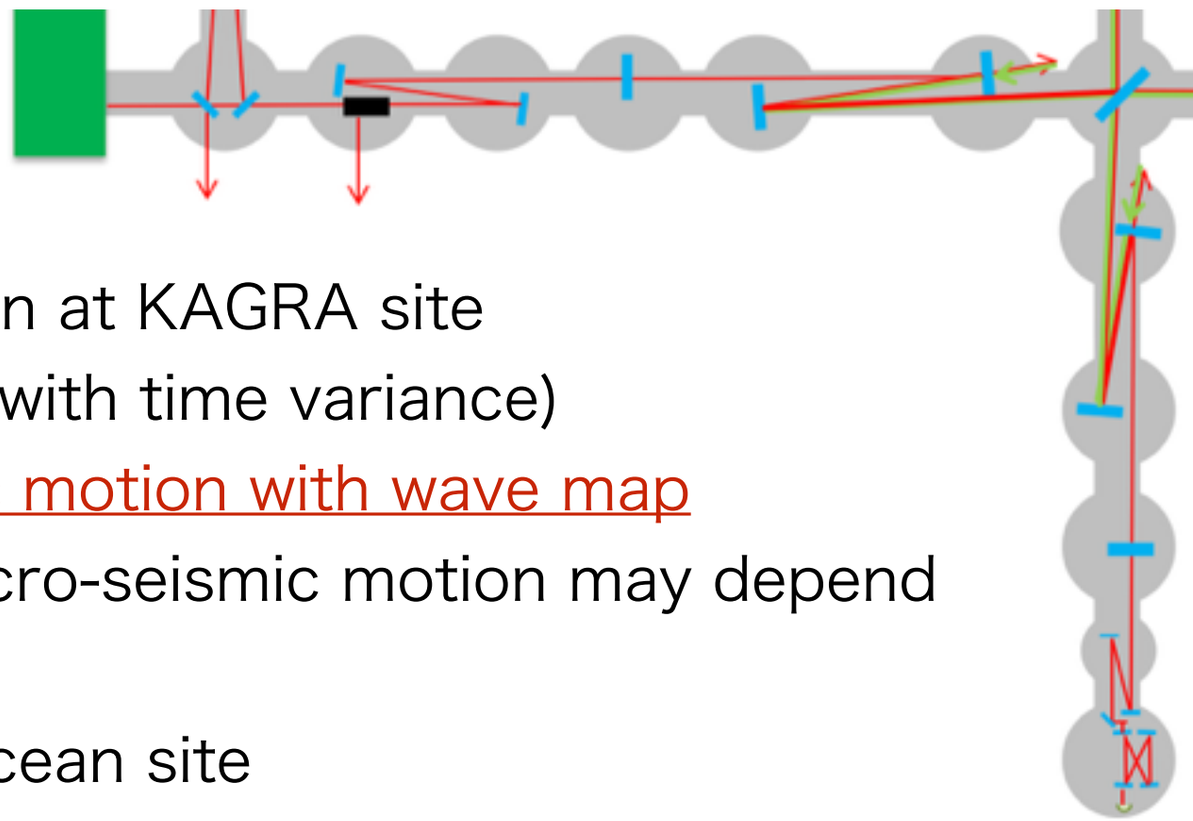
(1) Long term environmental analysis

- We had more than one year data of underground environment
  - Seismometer, magnetic field, weather and so on
- We already started some project to analyze them
  - Seasonal ground motion
  - Characterization of the ground motion
  - Evaluate Newtonian noise



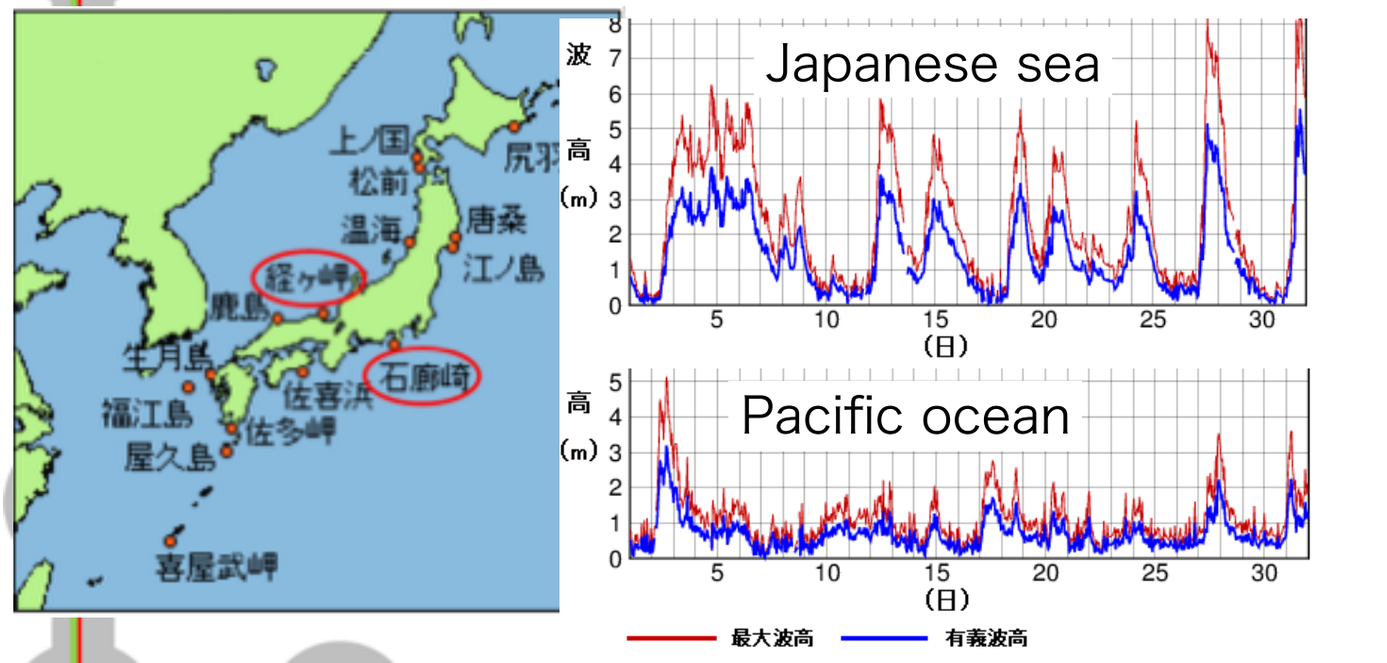


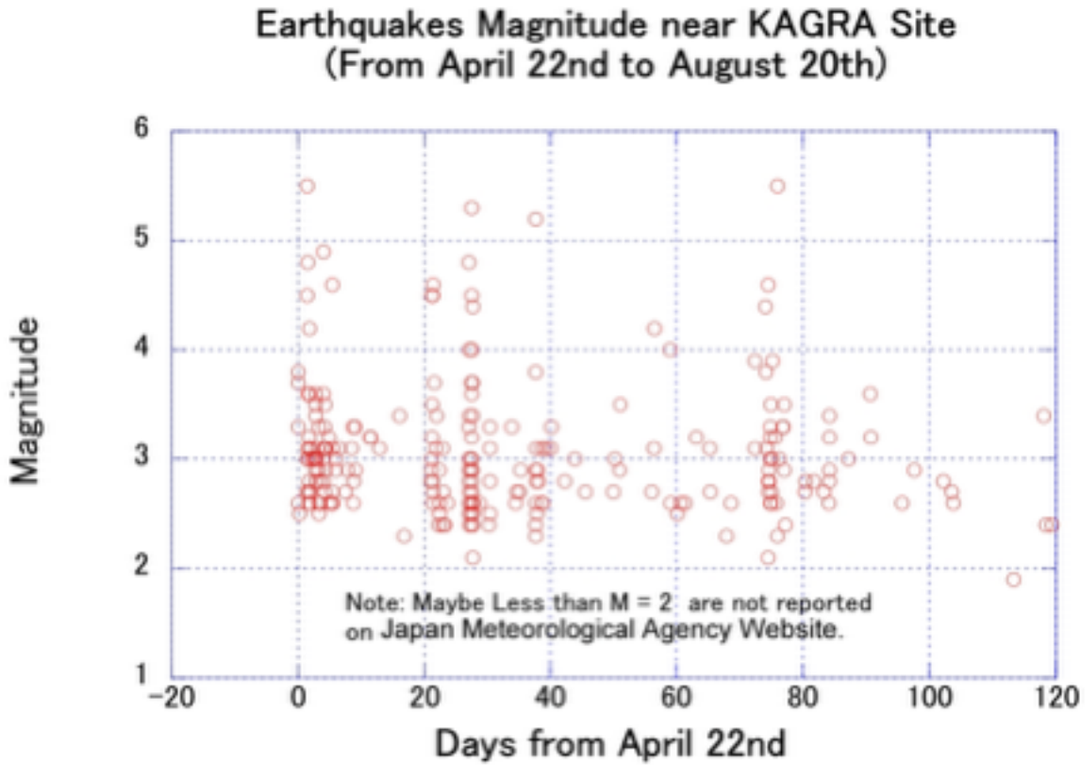
Underground environment



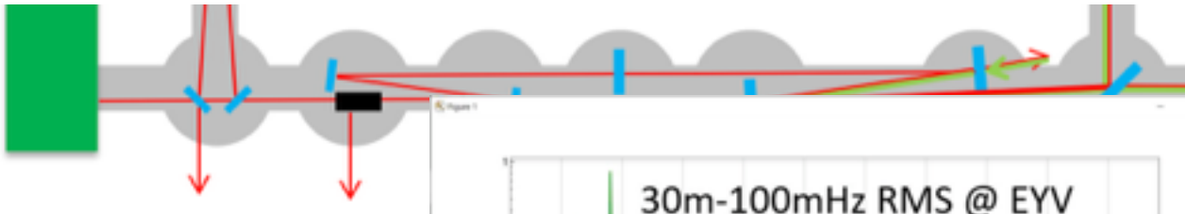
(2) Understanding the seismic motion at KAGRA site

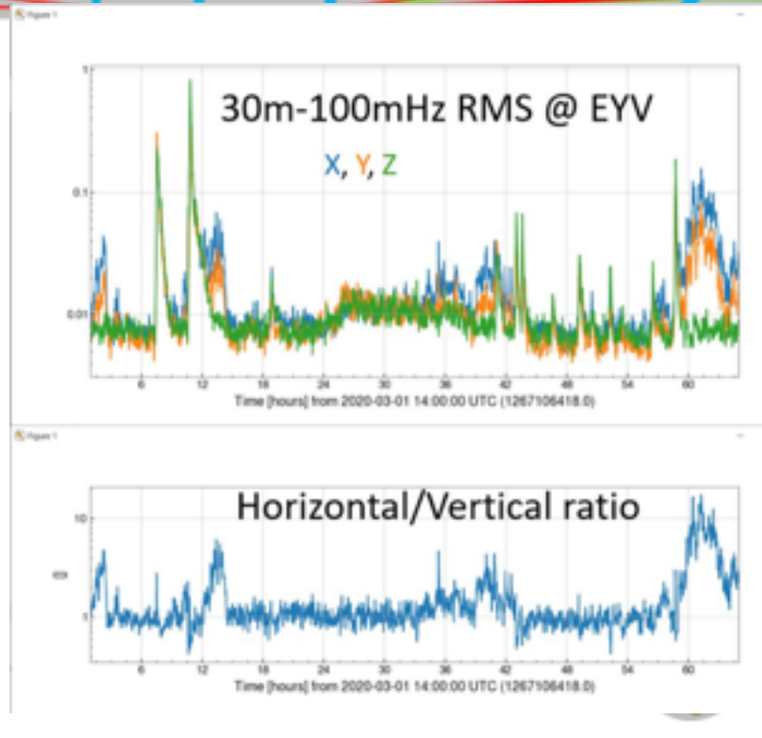
- Spectrum of the seismic motion (with time variance)
- Dependence of the micro-seismic motion with wave map
  - The center frequency of the micro-seismic motion may depend on the position of ocean wave.
    - Japanese sea site or Pacific Ocean site
- Evaluate the earthquake
  - We have interesting data that many earthquake occurred near the KAGRA site Apr. - Aug.





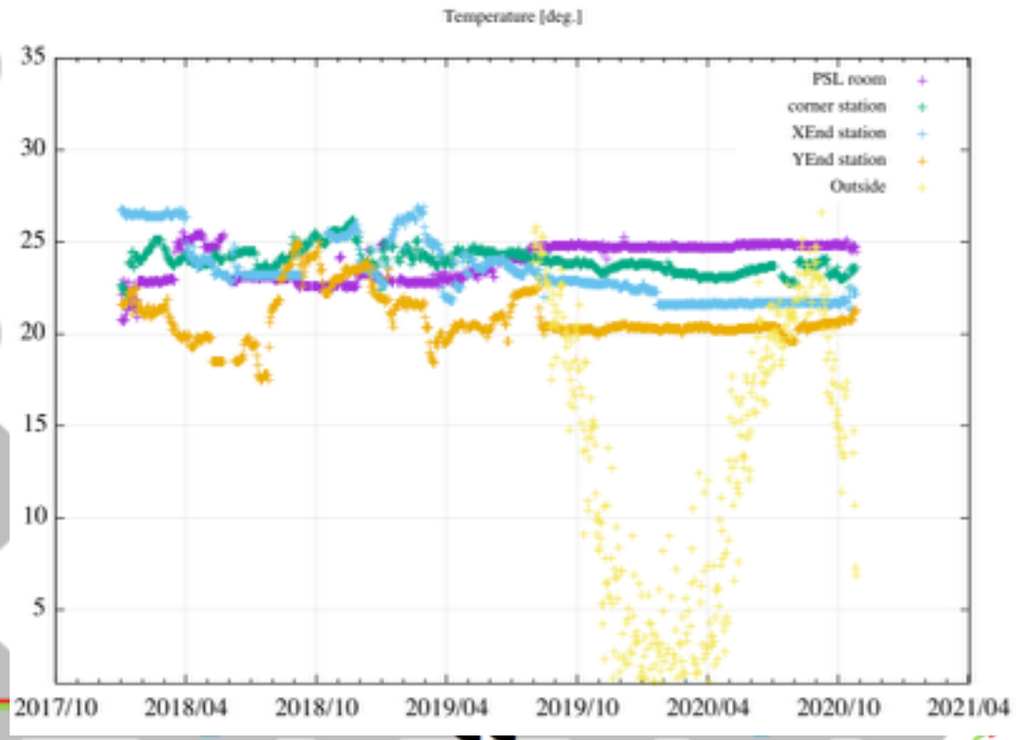
Underground environment

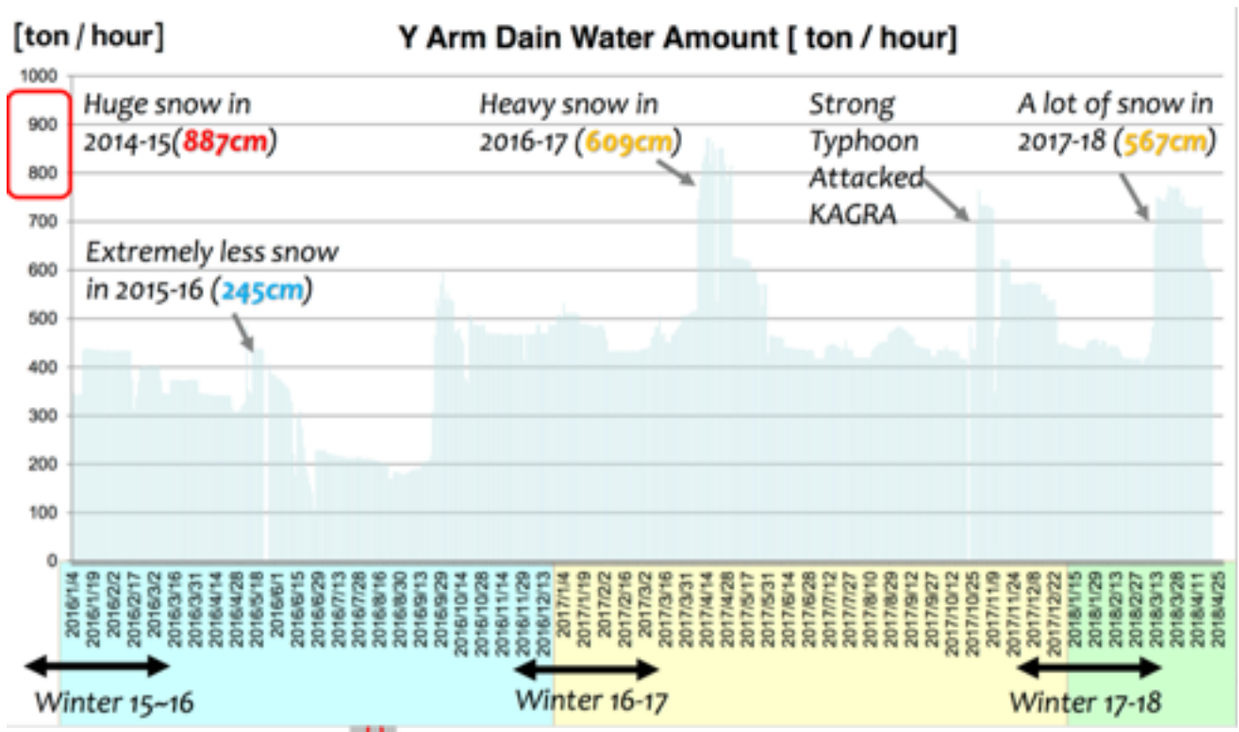




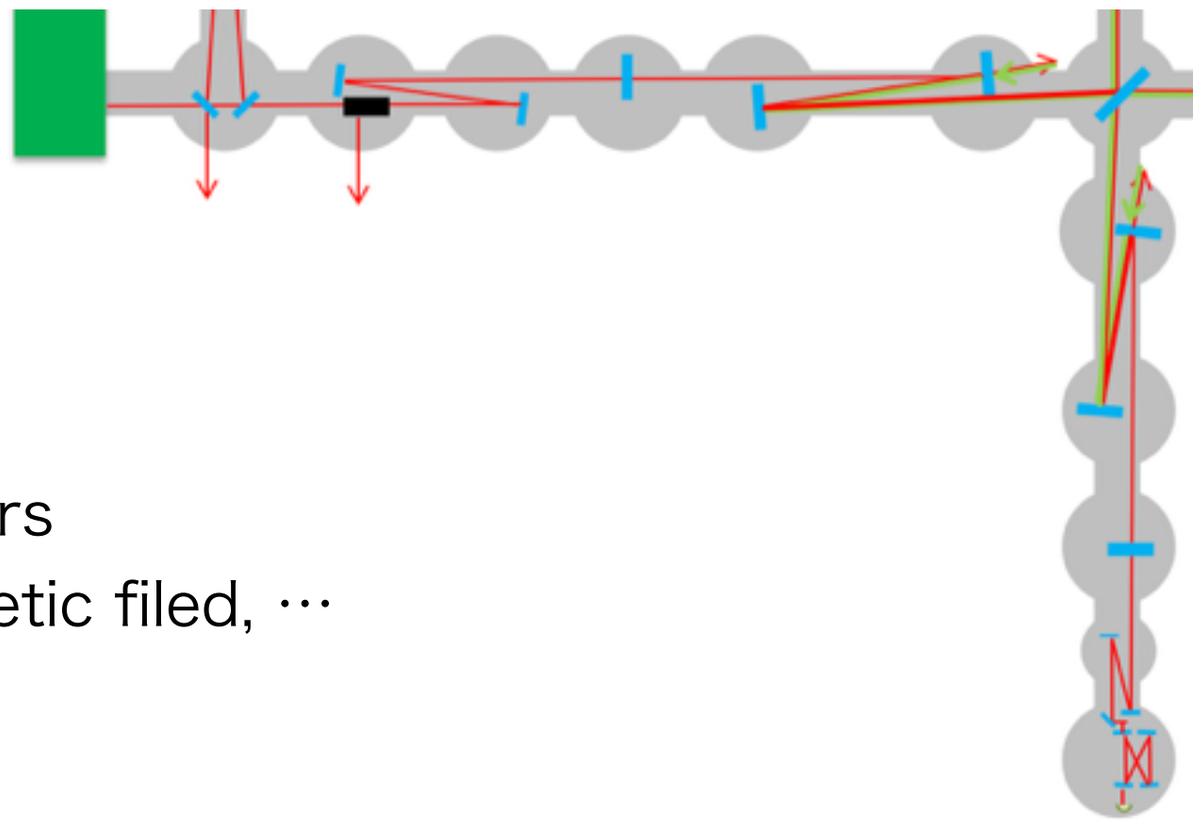
(3) Understanding the underground environment

- Temperature stabilization
- Position dependence of the ground motion
  - Corner station, XY end station
  - Effect of the human activity and water fluid(?)
- Magnetic field
  - Transfer function between outside and inside
  - Evaluate the magnetic filed effect with stochastic analysis group
- Water fluid analysis
  - There is much water in Spring -> Effect to detector





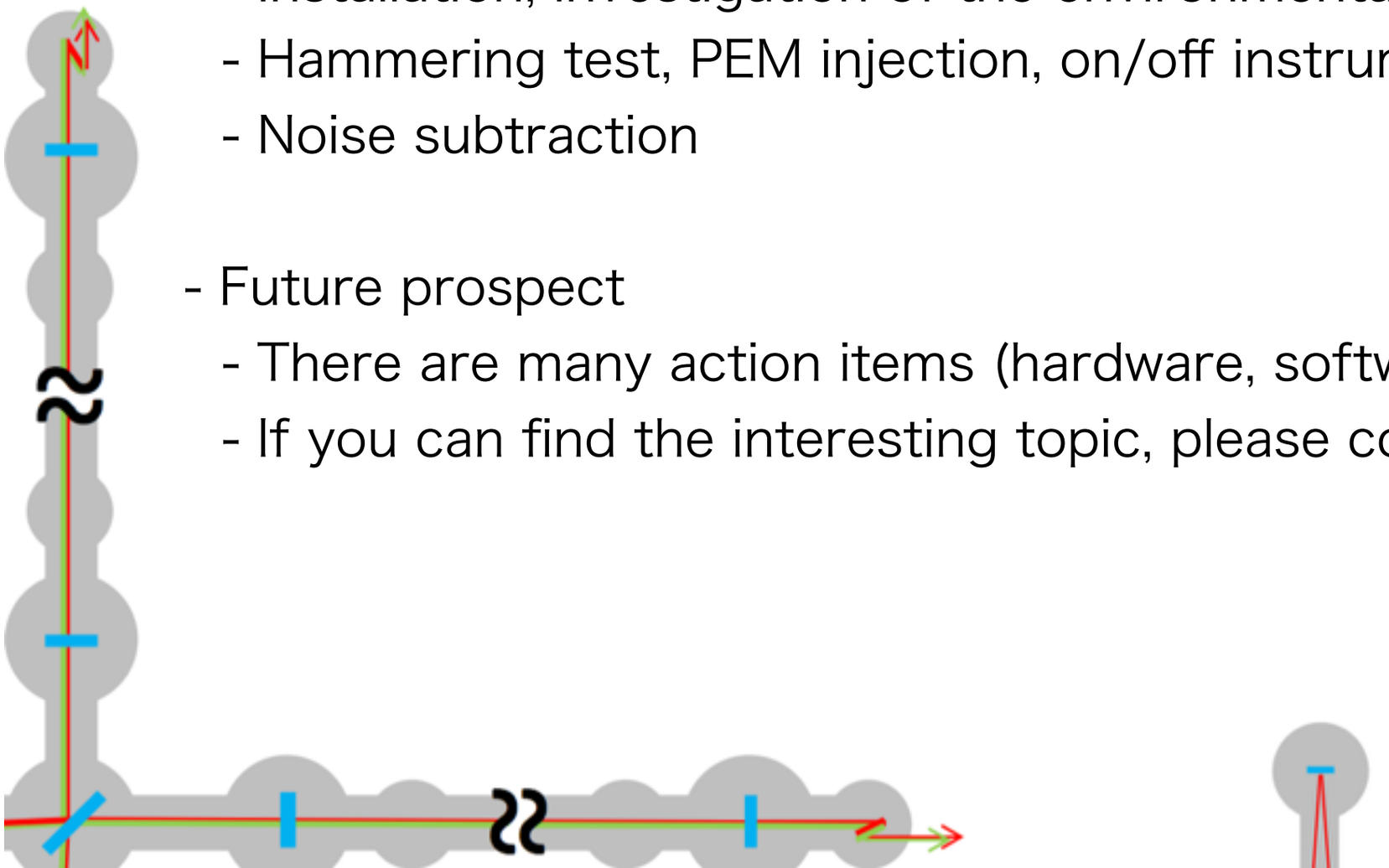
Summary



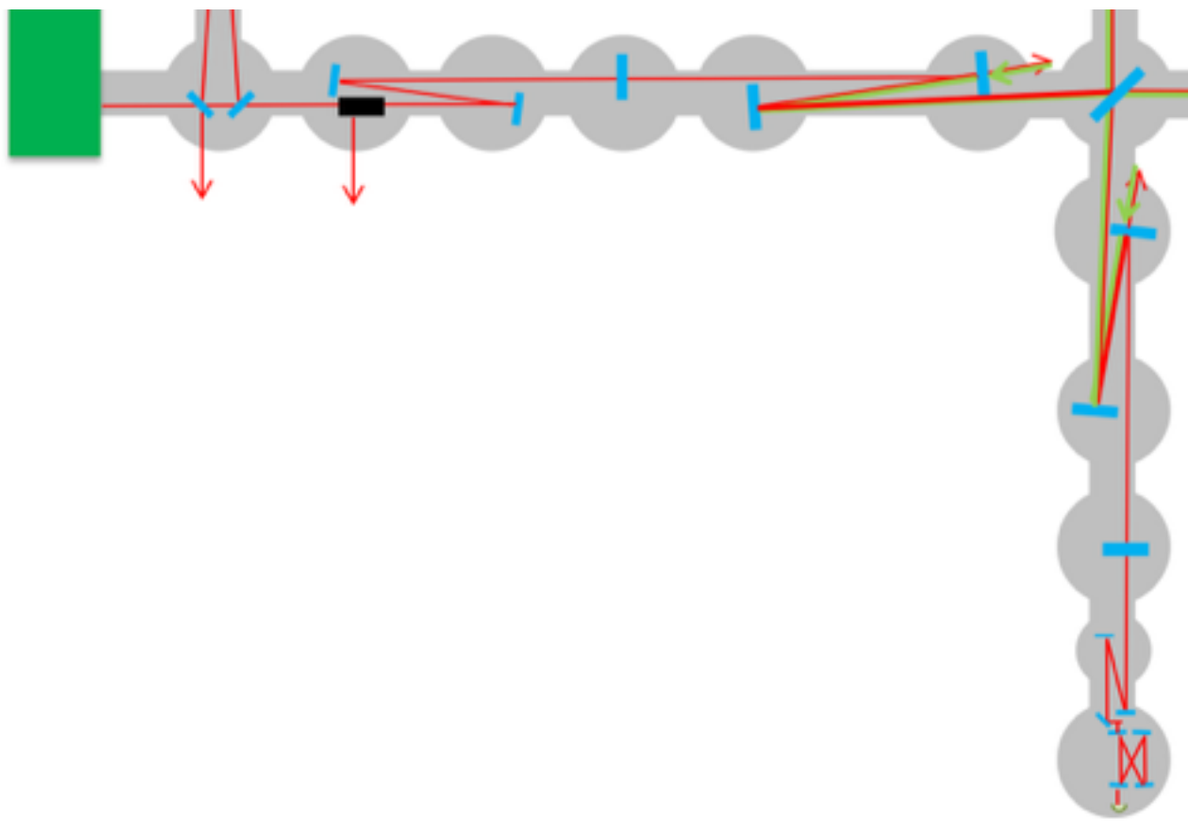
- PEM : Physical Environmental Monitors
  - Monitor the vibration, sound, magnetic filed, …

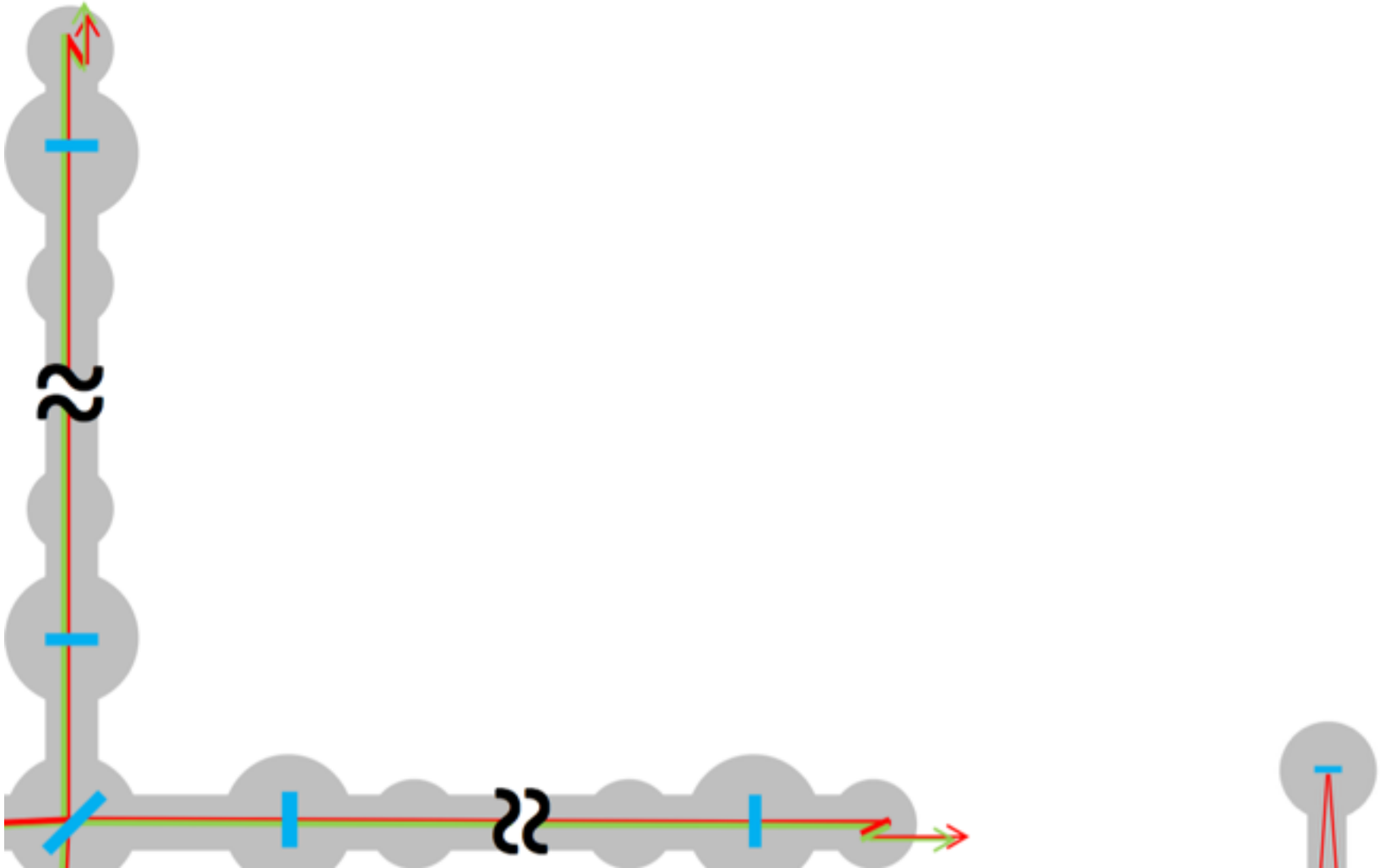
- Towards O3GK
  - Installation, investigation of the environmental noise
  - Hammering test, PEM injection, on/off instruments, …
  - Noise subtraction

- Future prospect
  - There are many action items (hardware, software, environment)
  - If you can find the interesting topic, please contact to us!

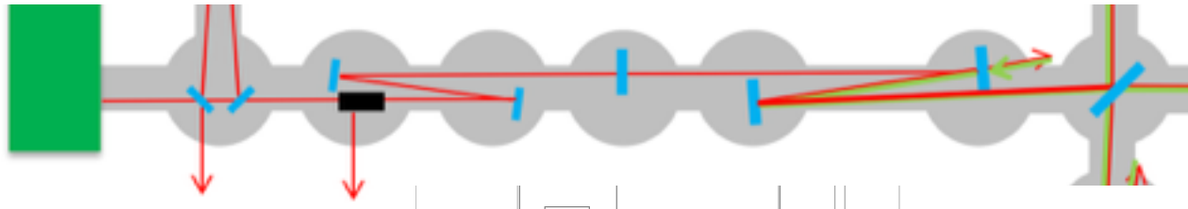


Back ups

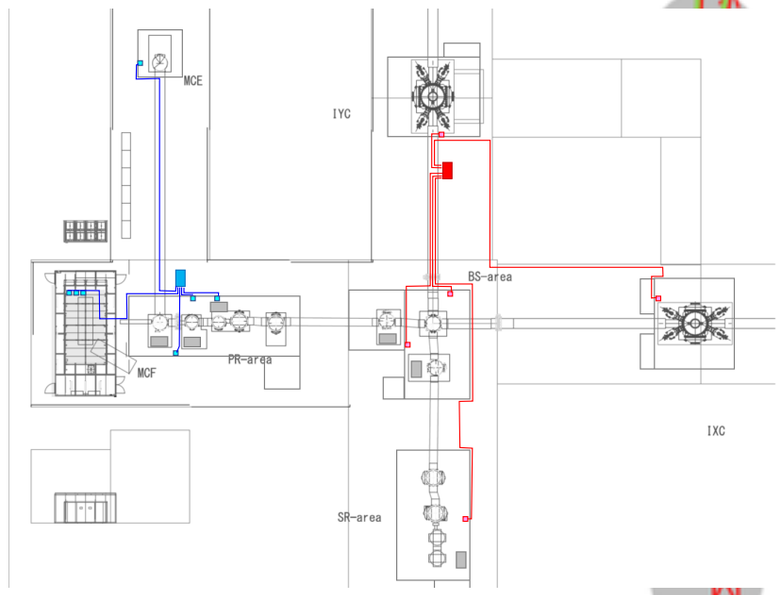




PEM re-installation

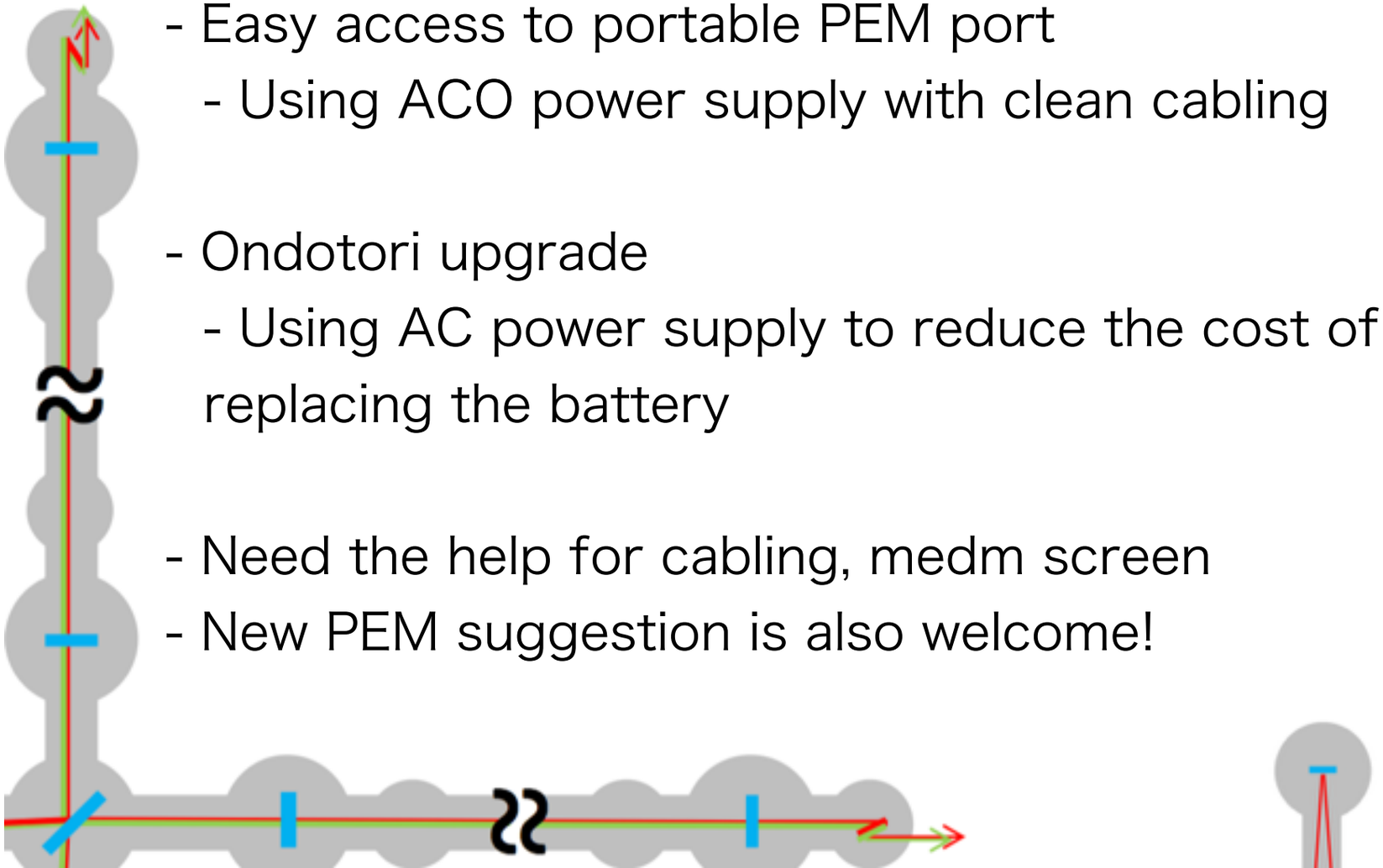


- Now most PEMs were removed.
  - PSL PEM, Seismometers, magnetometers
- Re-cabling for PEM is planned
  - From two racks (around MCF, IY0)
  - No long cabling by BNC -> Dsub
  - Cable rack between IY0 and BS
- Easy access to portable PEM port
  - Using ACO power supply with clean cabling

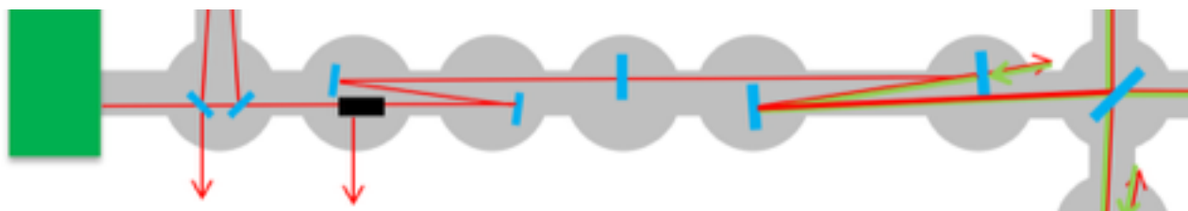


- Ondotori upgrade
  - Using AC power supply to reduce the cost of replacing the battery

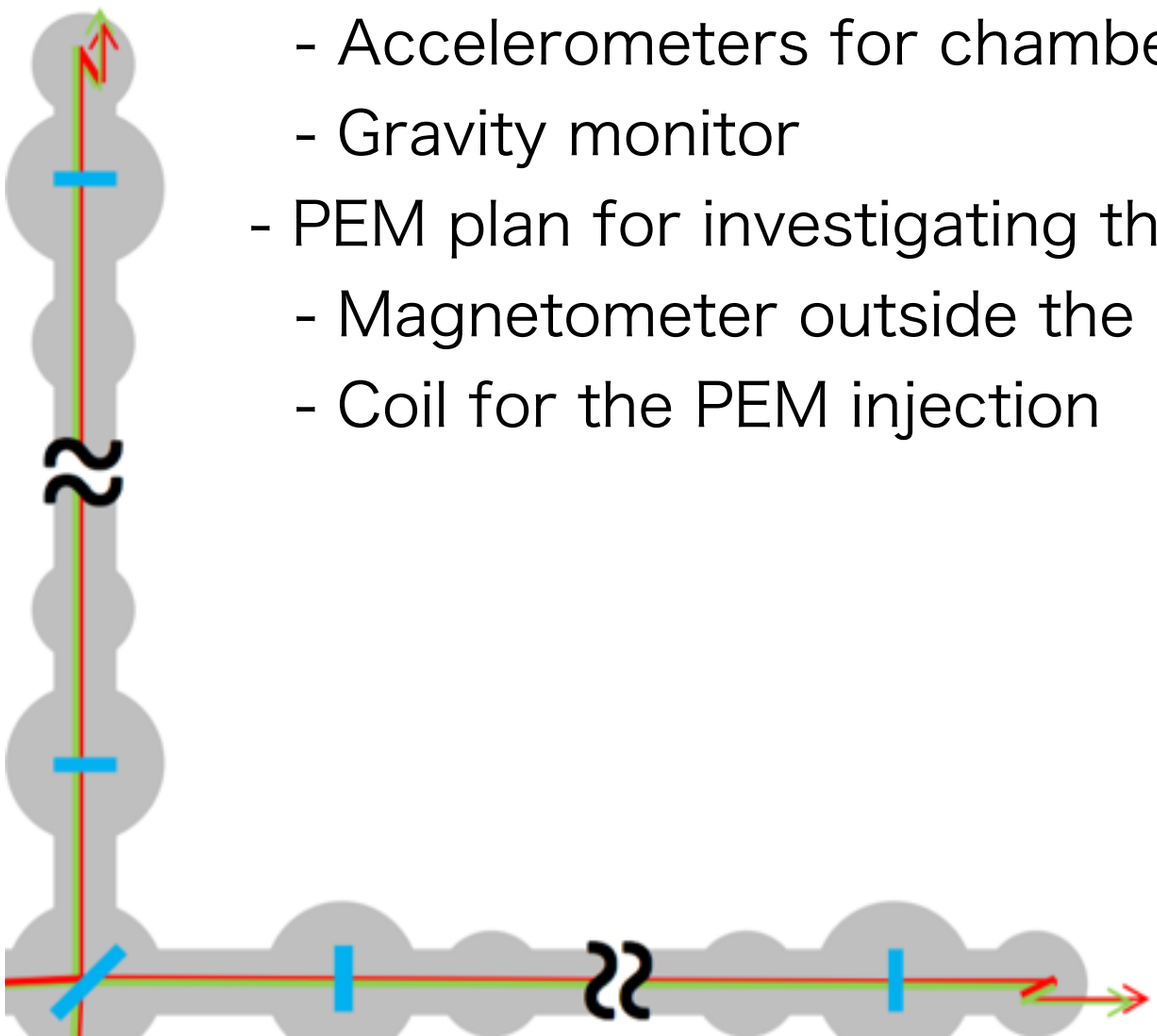
- Need the help for cabling, medm screen
- New PEM suggestion is also welcome!

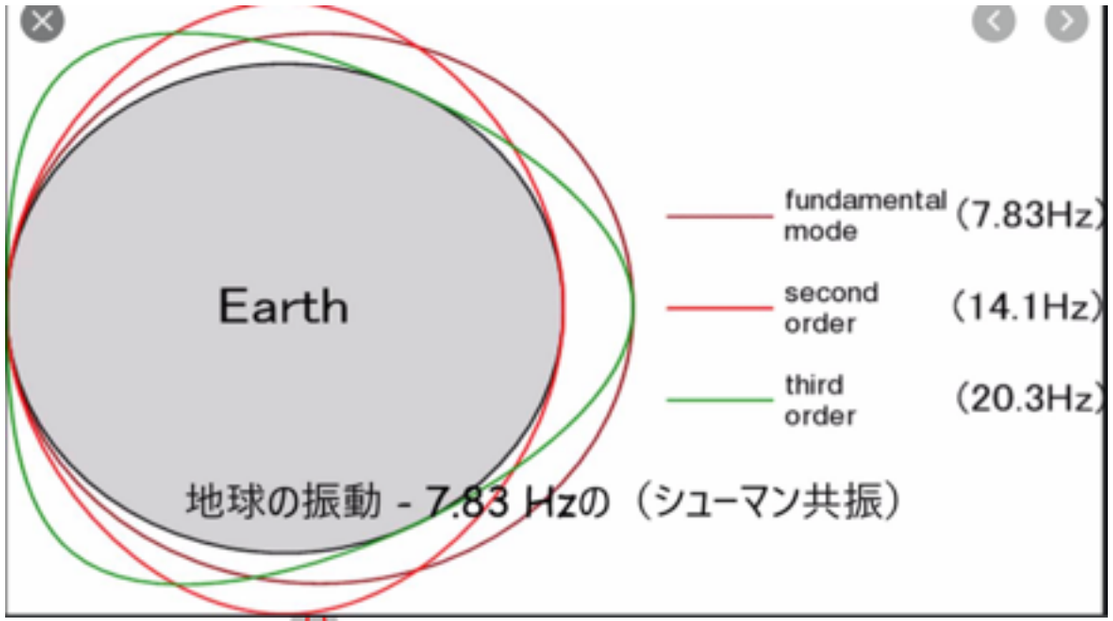


New PEMs

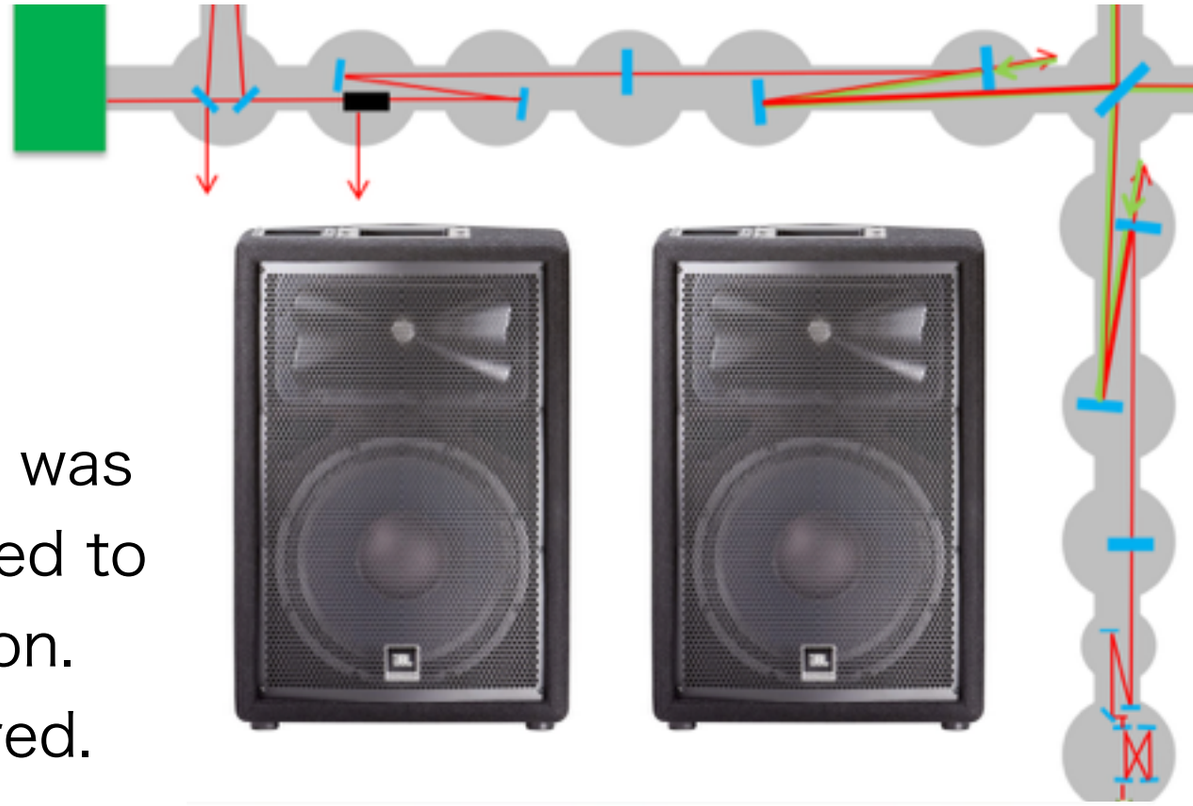


- This is just an idea about new PEMs
  - RF monitor
  - Water fluid
  - infrasound microphone
  - tilt meter
  - Voltage monitor
  - Magnetometer for racks
  - Accelerometers for chambers
  - Gravity monitor
- PEM plan for investigating the stochastic analysis
  - Magnetometer outside the mine
  - Coil for the PEM injection





New PEM injection

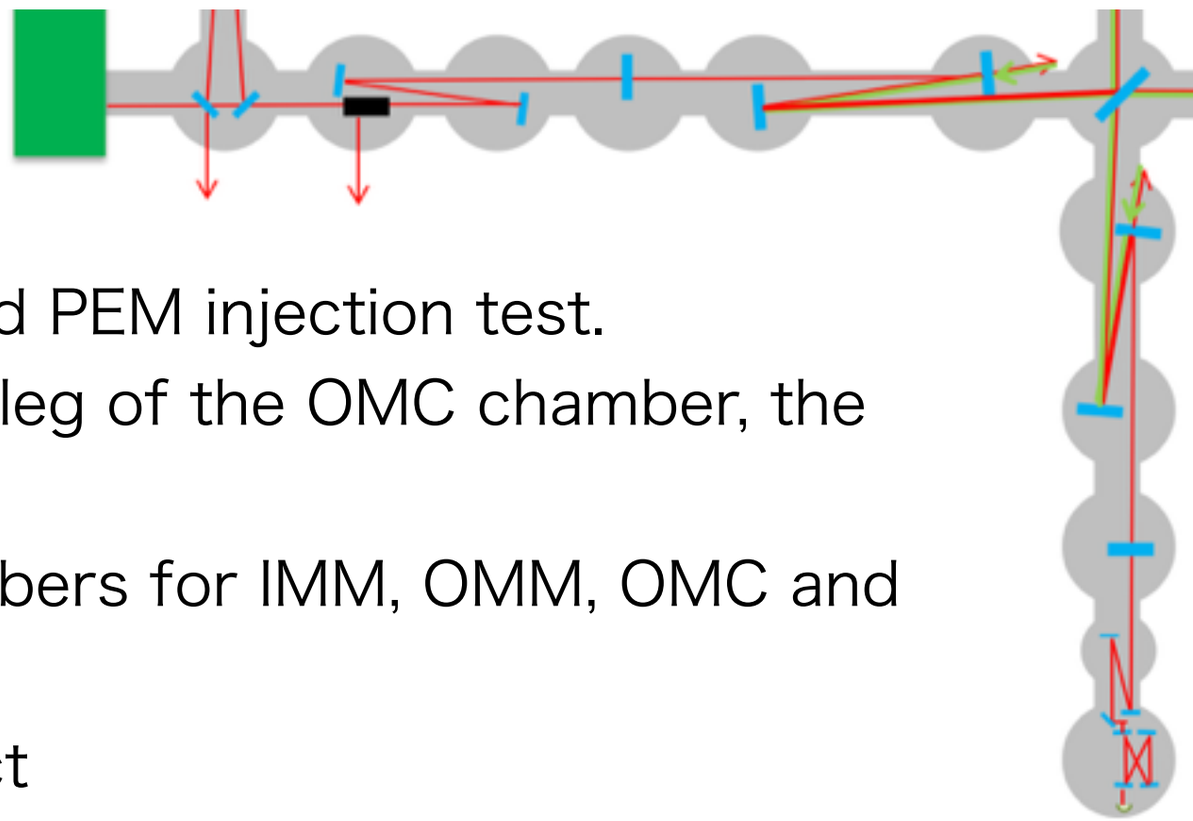


- Now the instruments for PEM injection was prepared only in the center area. We need to prepare similar instruments to end station.
- Speakers and AMP was already prepared.
  - Need coil, DAC and so on

- New PEM injection procedure is welcome
  - Large coil like LIGO and Virgo
  - PEM injection with many PEMs
  - For low frequency vibration

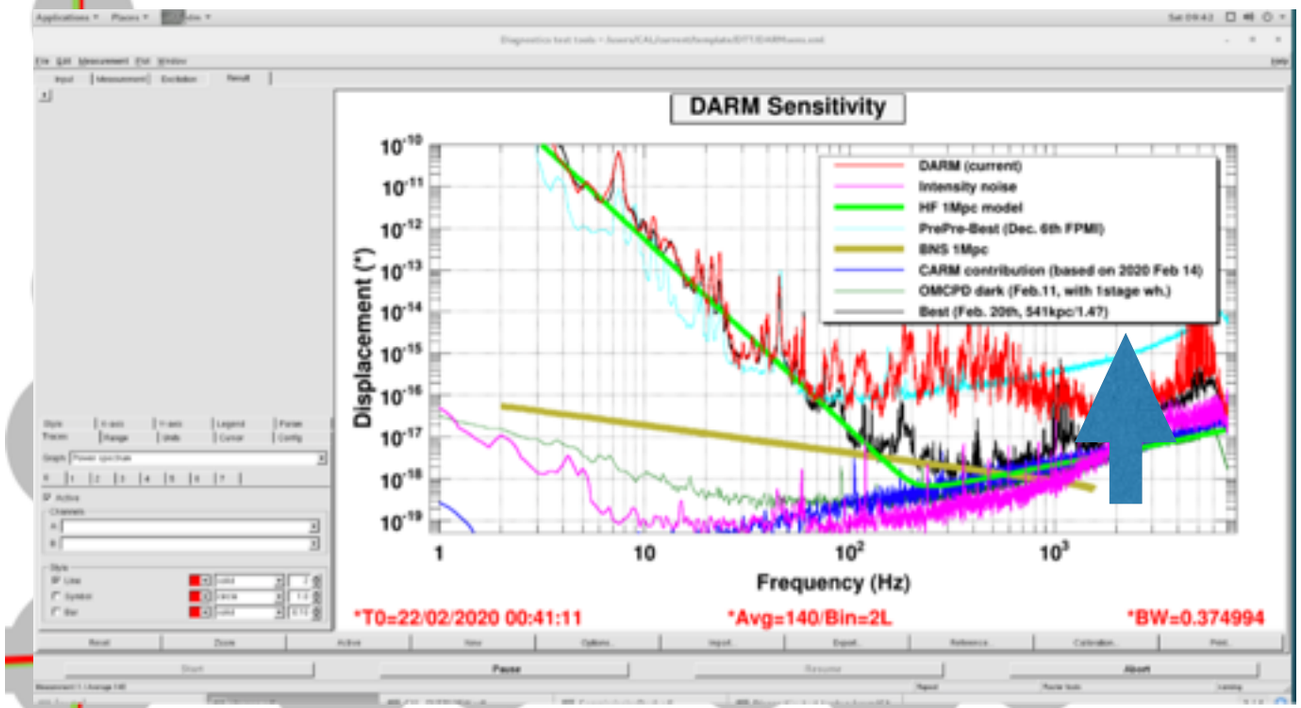
- We need the help for setting to end station
- New idea for PEM injection is also welcome

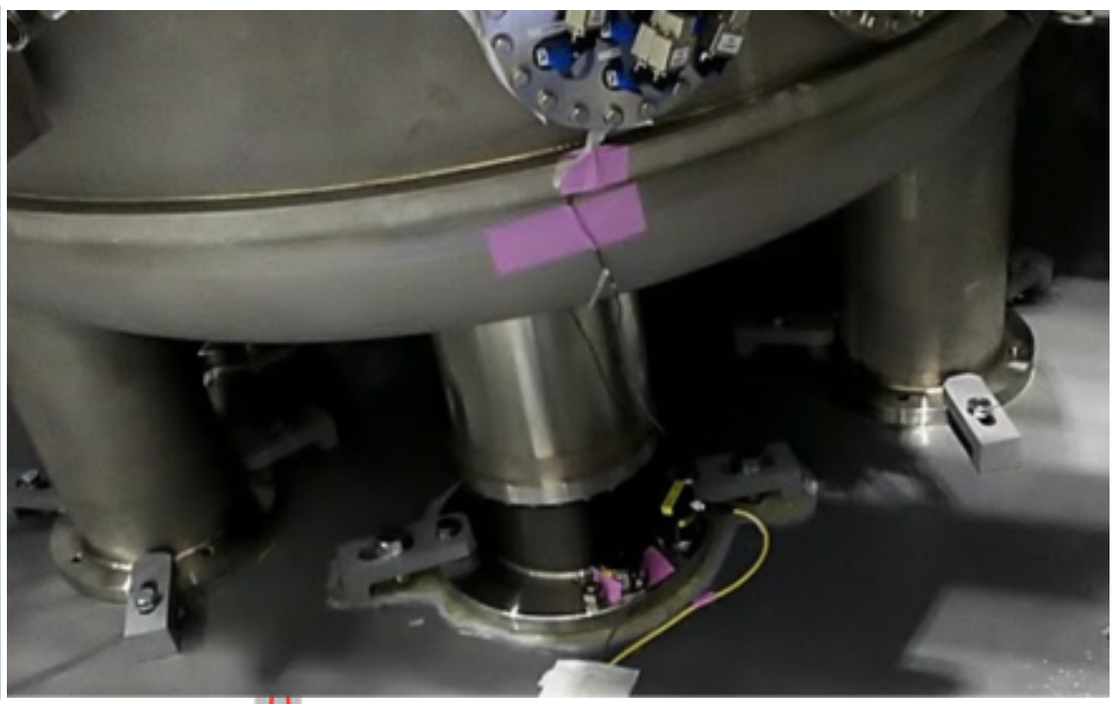
TF measurement



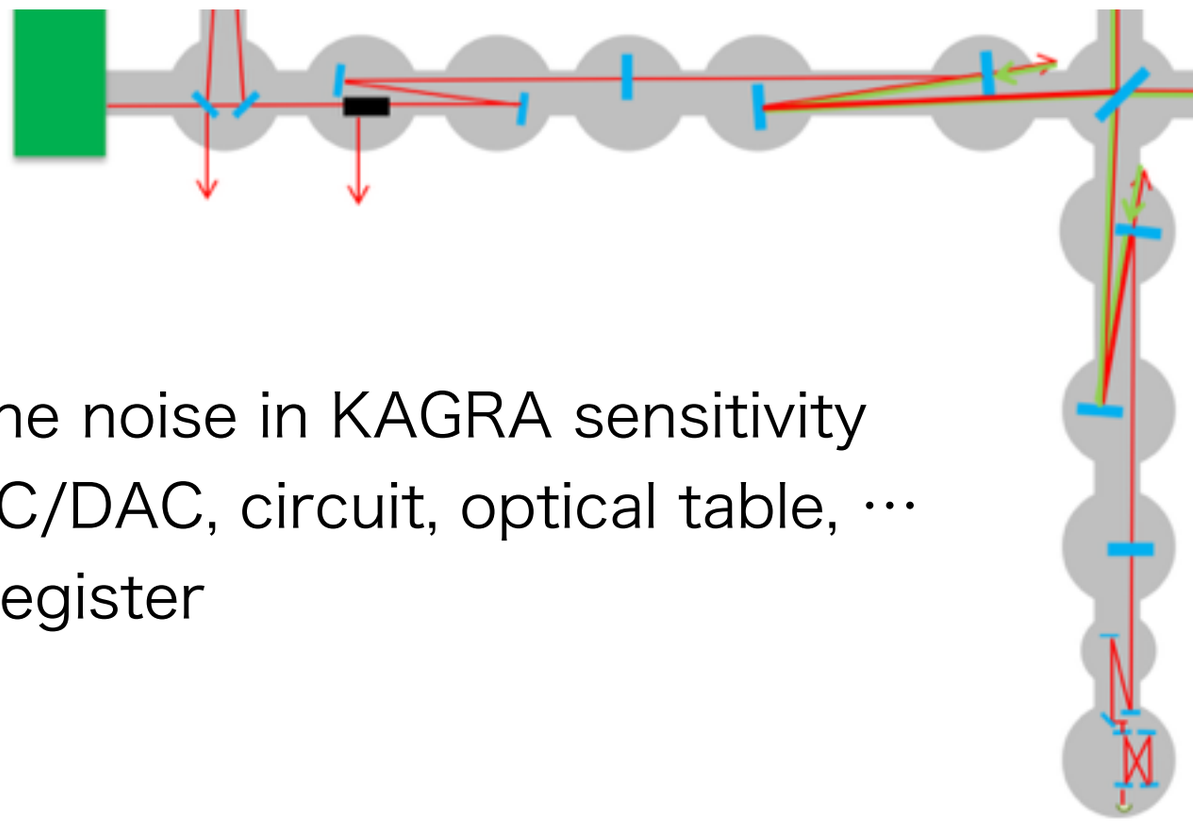
- This is one of the hammering test and PEM injection test.
- We found that when we touched the leg of the OMC chamber, the sensitivity became worse
- So we want to characterize the chambers for IMM, OMM, OMC and so on during opening the chamber.
- It would help the scattered light effect

- We already have accelerometers and vibrator, so we need the help to manage following transfer function measurement.
  - Leg to table, chamber to table, leg to chamber, …

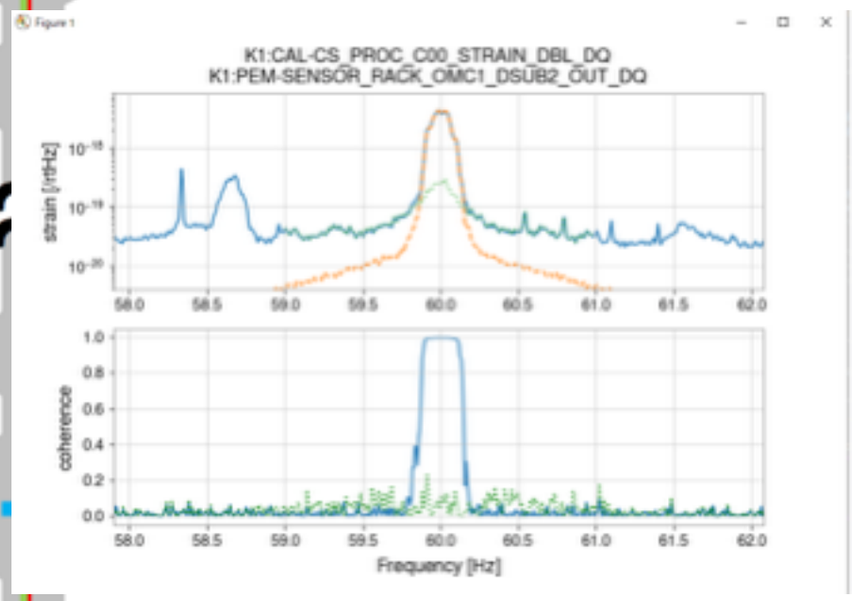


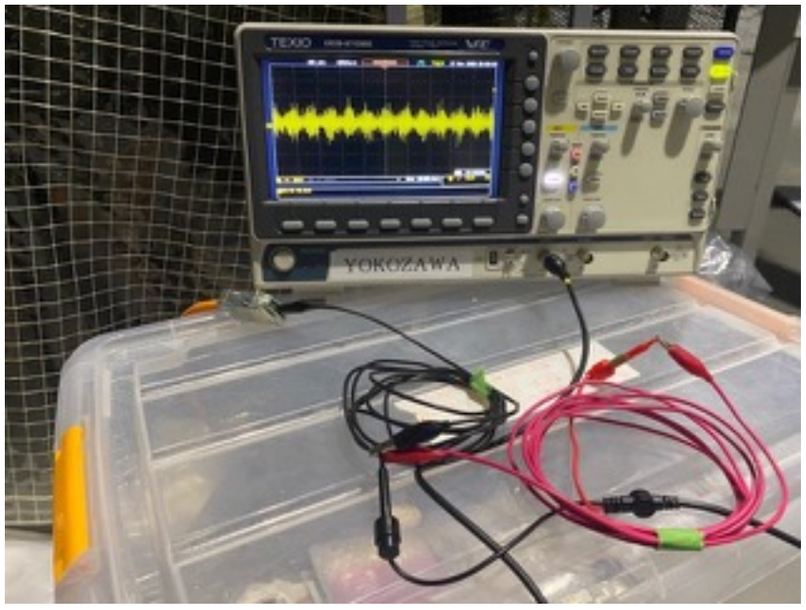


GND noise

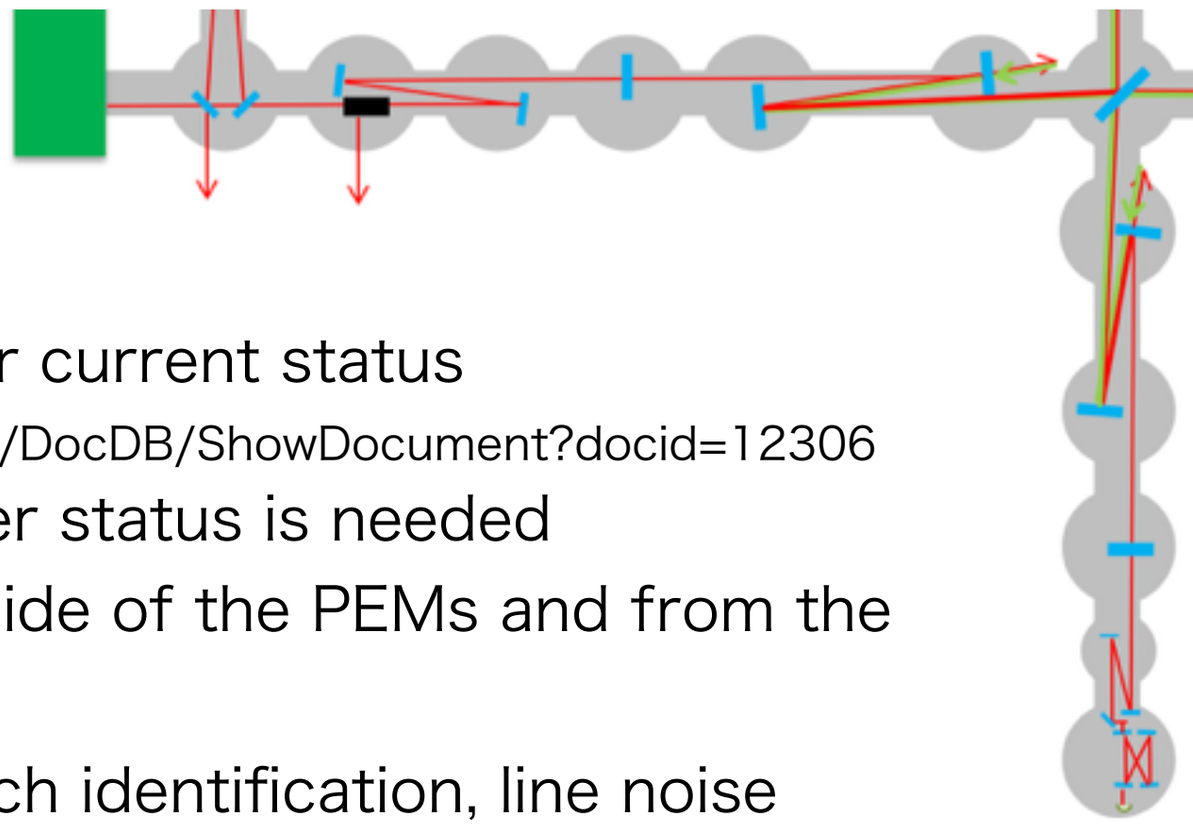


- Evaluate KAGRA GND status
  - There are 60Hz and its harmonic line noise in KAGRA sensitivity
  - Check carefully for GND of the ADC/DAC, circuit, optical table, …
  - Find good GND by measuring the register
- Careful cabling
  - GND connection
  - Potential difference between circuit and chamber/optical table
- Distinguish the cabling for power line cable and signal cable

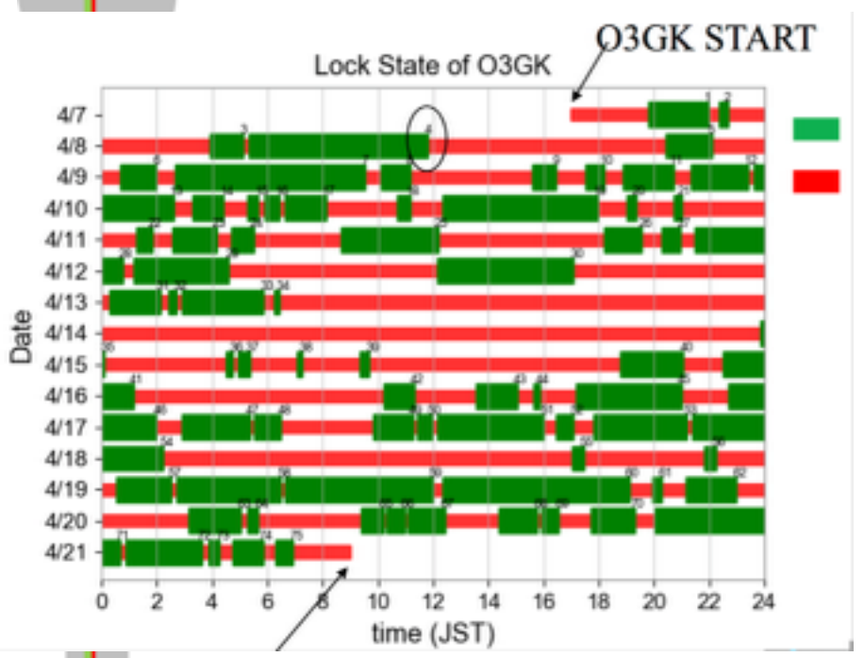


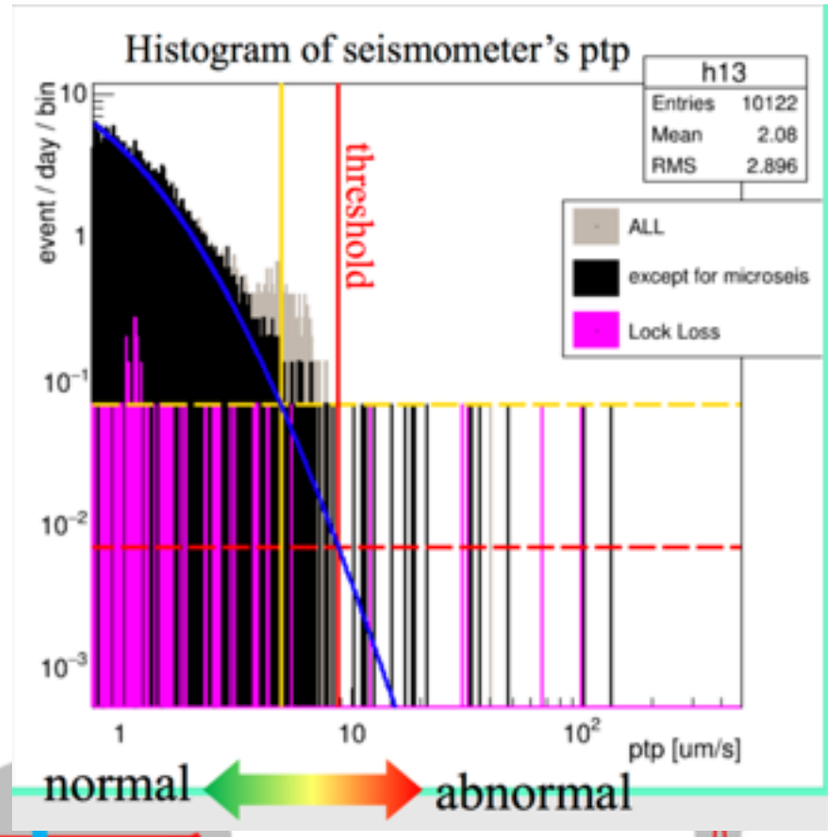


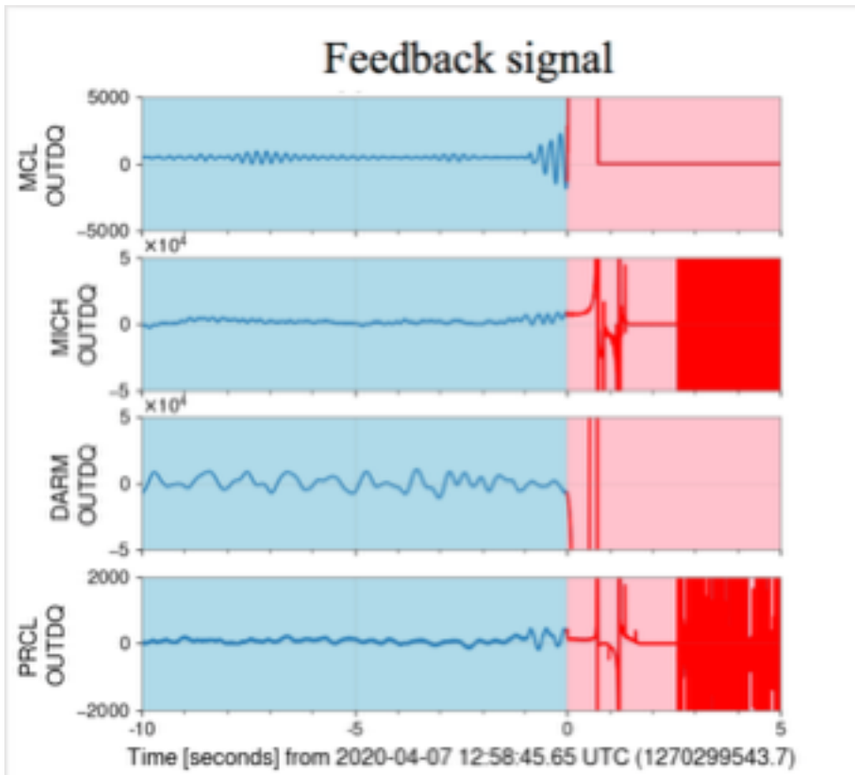
Lock loss study



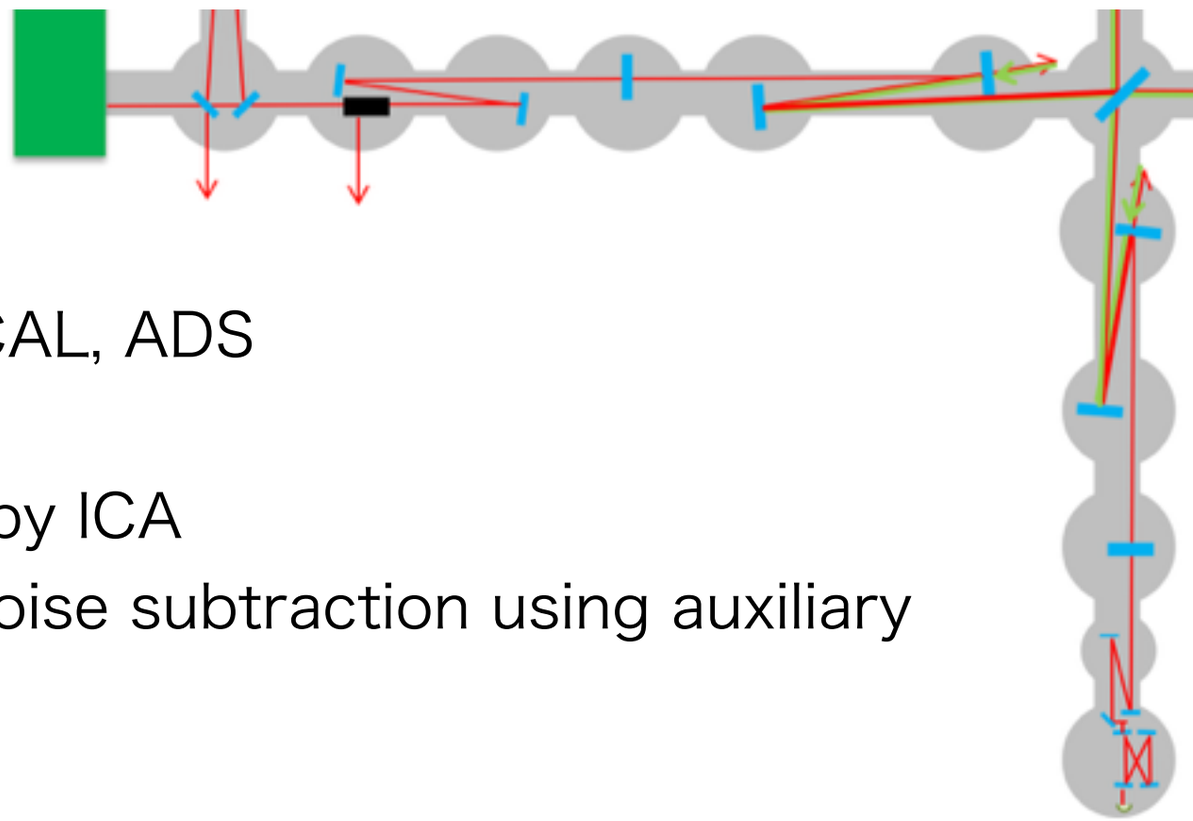
- Please check Fujikawa-san's slide for current status
  - https://gwdoc.icrr.u-tokyo.ac.jp/cgi-bin/private/DocDB/ShowDocument?docid=12306
- Parameter tuning with interferometer status is needed
- Also, we need to check it from the side of the PEMs and from the side of the interferometer control
- Not only the lock loss study, the glitch identification, line noise identification (maybe DetChar part) is essential



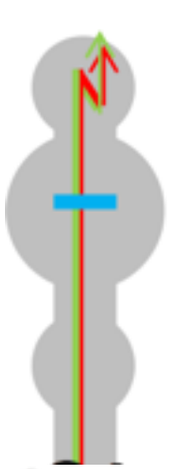


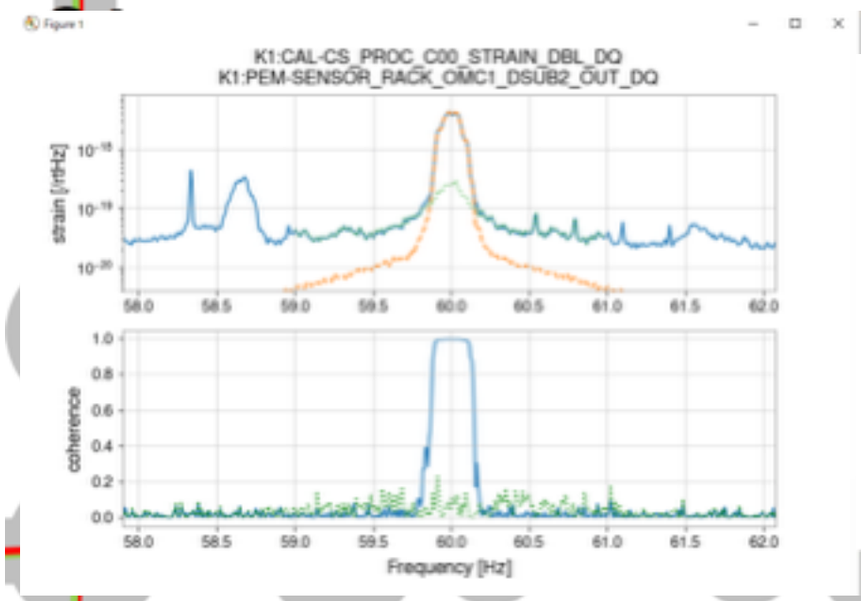


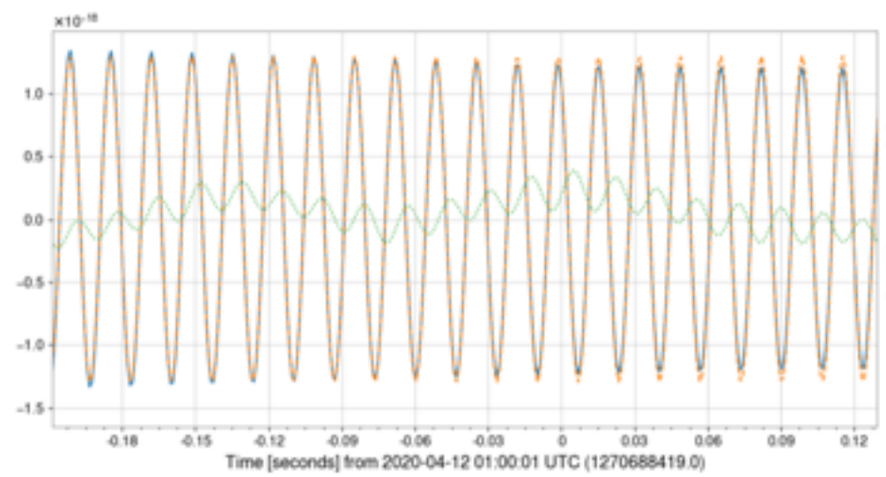
Offline noise subtraction

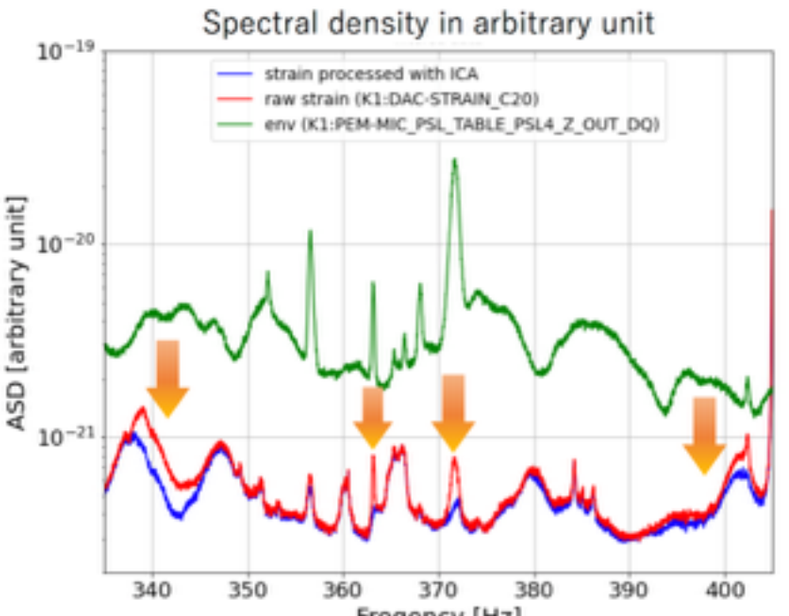


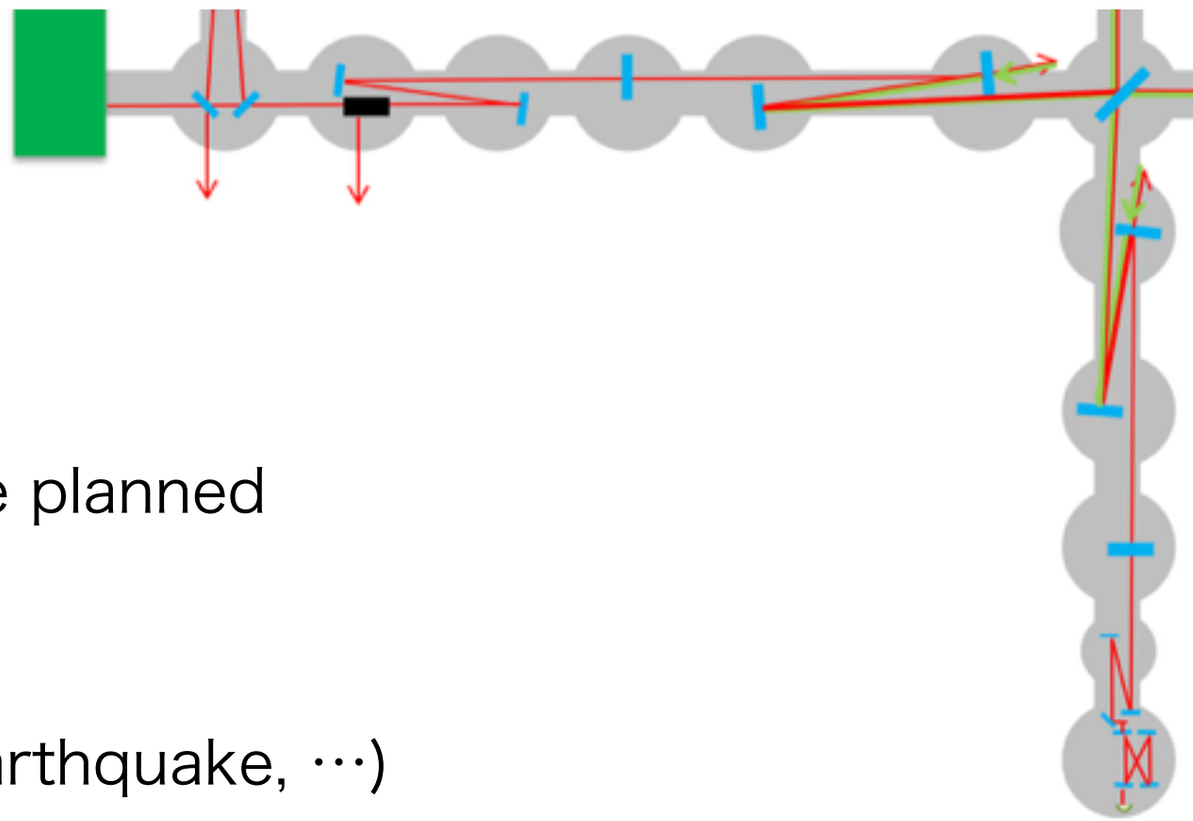
- One demonstration by Washimi-san
  - 60Hz power line, injected line for CAL, ADS
- One demonstration by Kume-san
  - Subtract the acoustic component by ICA
- In LIGO and Virgo, there are many noise subtraction using auxiliary channels (or even DARM signal)
  - Violin mode
  - sideband of power line from some instruments
  - Identified line noise
  - Known glitch(Most famous one is large glitch with GW170817 in Livingston)
- Noise subtraction should also be prepared in KAGRA.





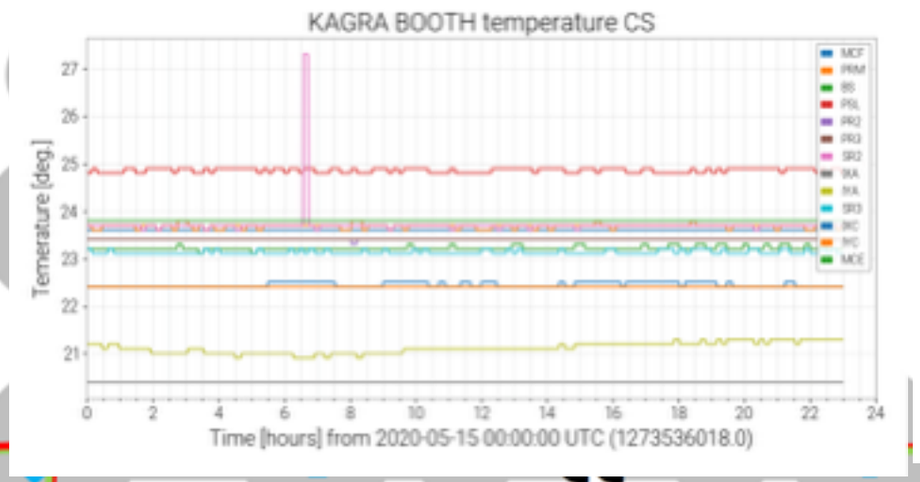


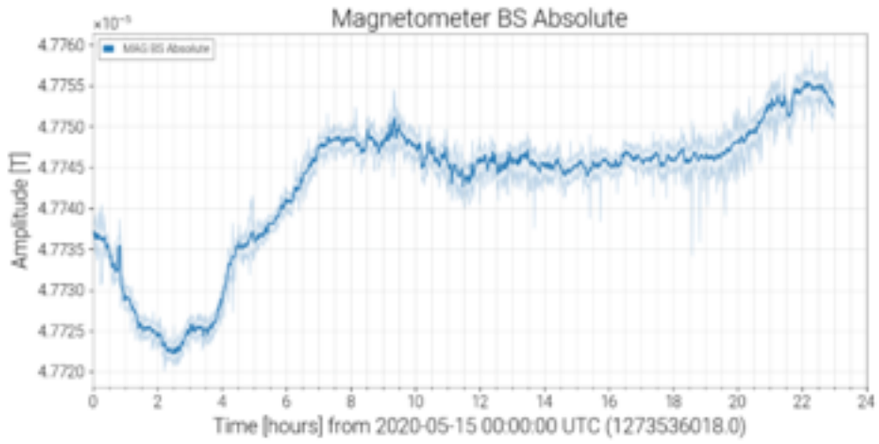


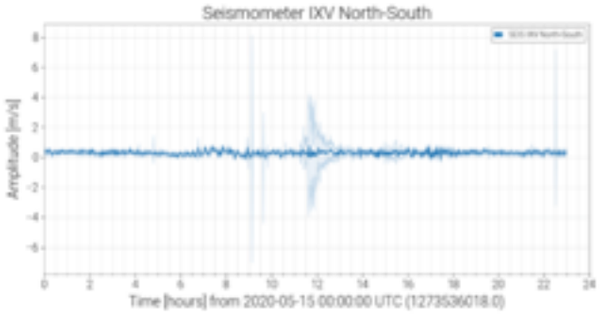


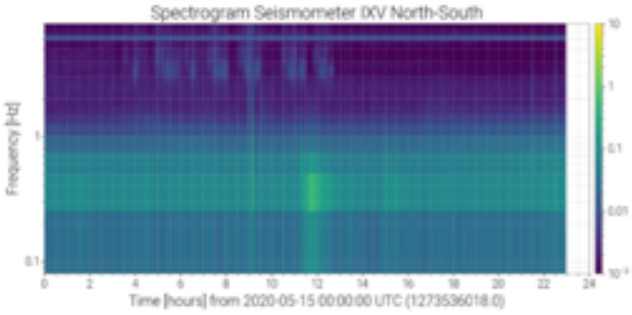
Characterization

- Update the daily summary page
- Weather summary page
  - Whether html or pdf format will be planned
  - Easy access for daily weather
    - Rain, temperature, wind
    - Seismic motion(micro-seismic, earthquake, …)
- PEM flags consideration
  - Candidate of earthquake, noisy microseismic, lightening, laud sound, noisy 60Hz noise, and so on
  - This would help the RRT(Rapid Response Team)
  - Future, we want to leave flags to frame file
    - Realtime analysis or low latency analysis

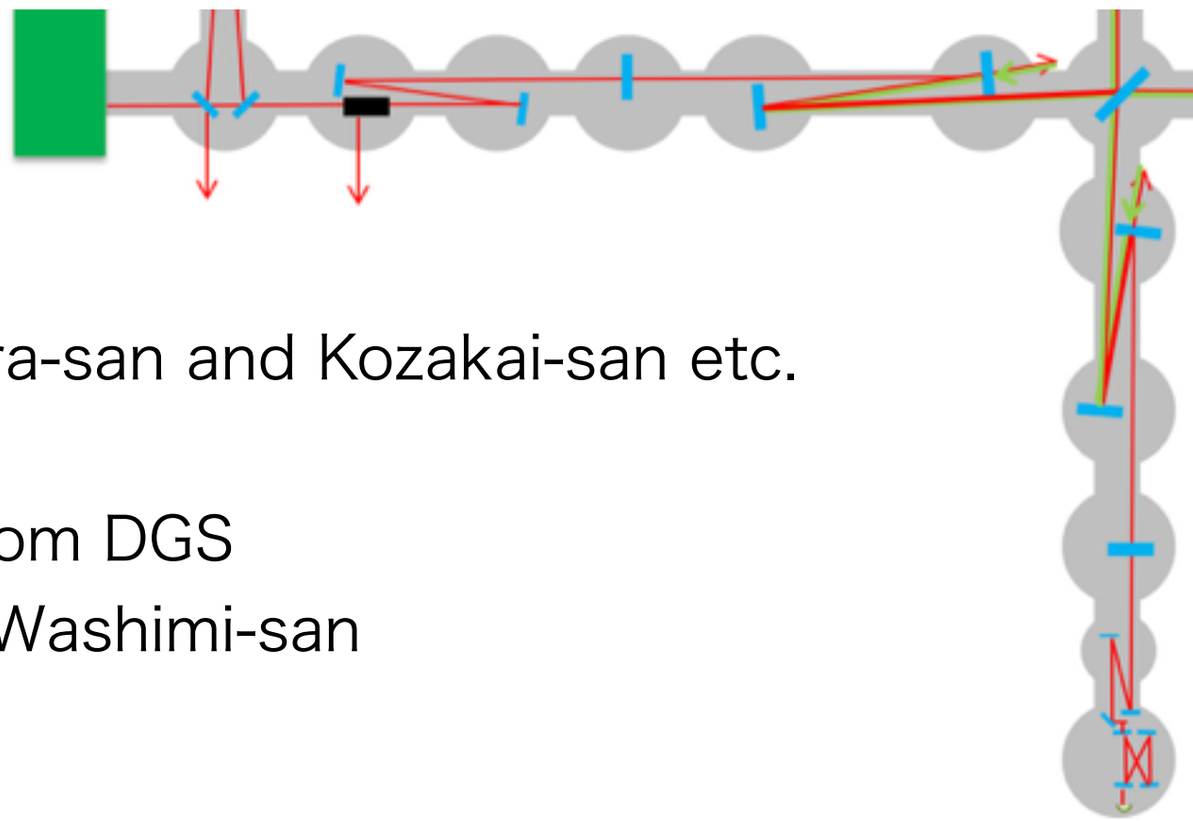






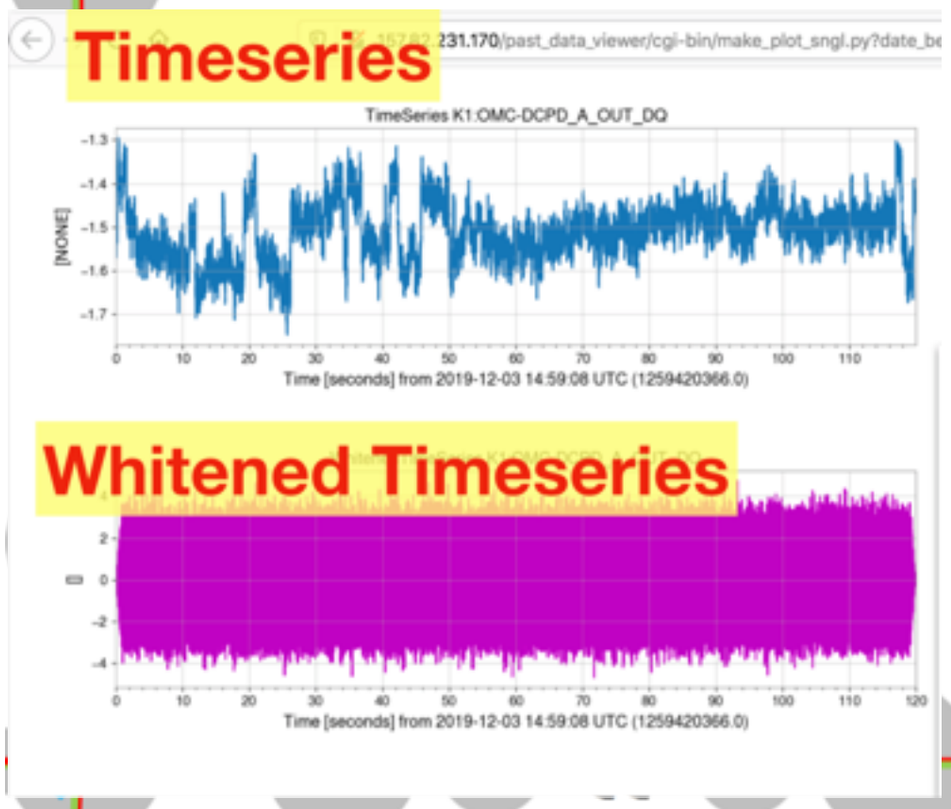


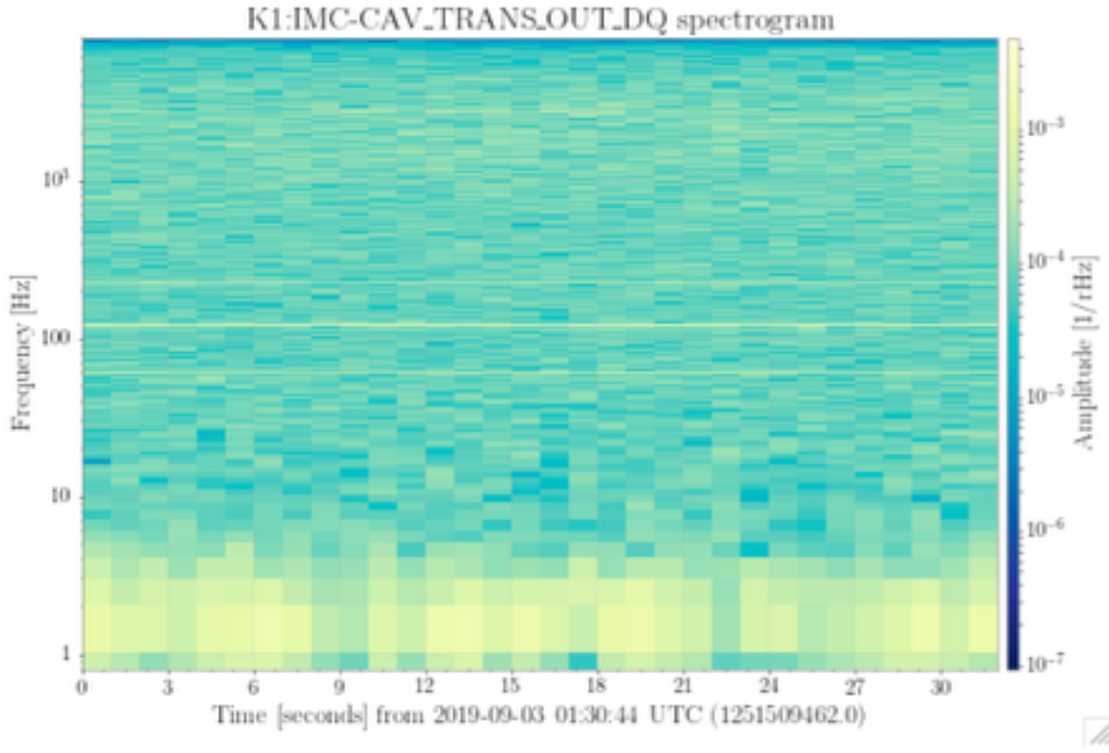
Plotting tool



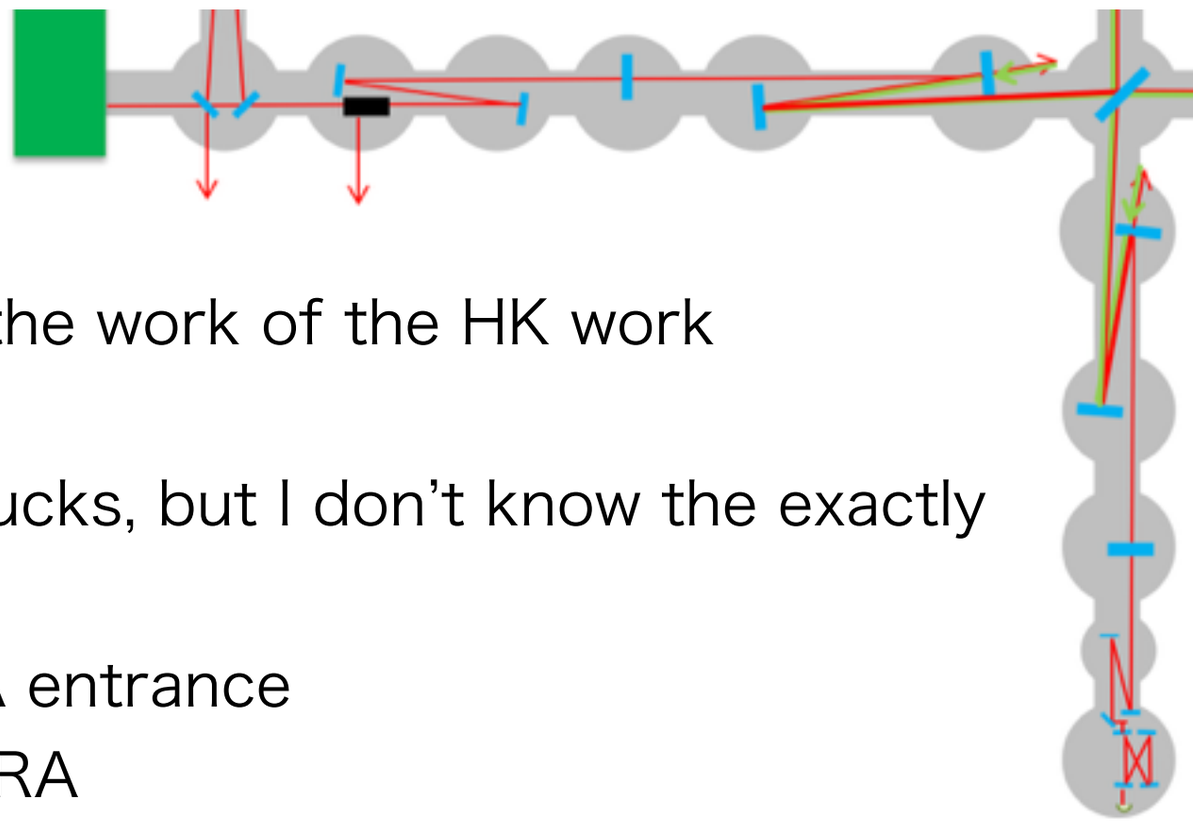
- Very good tools provided by Yuzurihara-san and Kozakai-san etc.
  - Pastavi, iKozapy, …
- Also, diaggui, dataview, ndscope, … from DGS
- SEM(Slow Environmental Monitor) by Washimi-san
- Vacuum monitor

- Prepare the template for making plot and learn GWpy, root would help your researches and KAGRA commissioning





Human activity noise



- One detected the 1-3Hz noise with the work of the HK work
  - 8:00 - 12:00, 13:00 - 17:00
  - We suspect the heavy traffic by trucks, but I don't know the exactly
  - Now we didn't see this behavior
- Snow removal activity at the KAGRA entrance
- Relationship between dam and KAGRA
- Unknown horizontal motion detected at MCF seismometer
  - Water fluid?
- Other activity (Blasting, Construction, water flow, …)