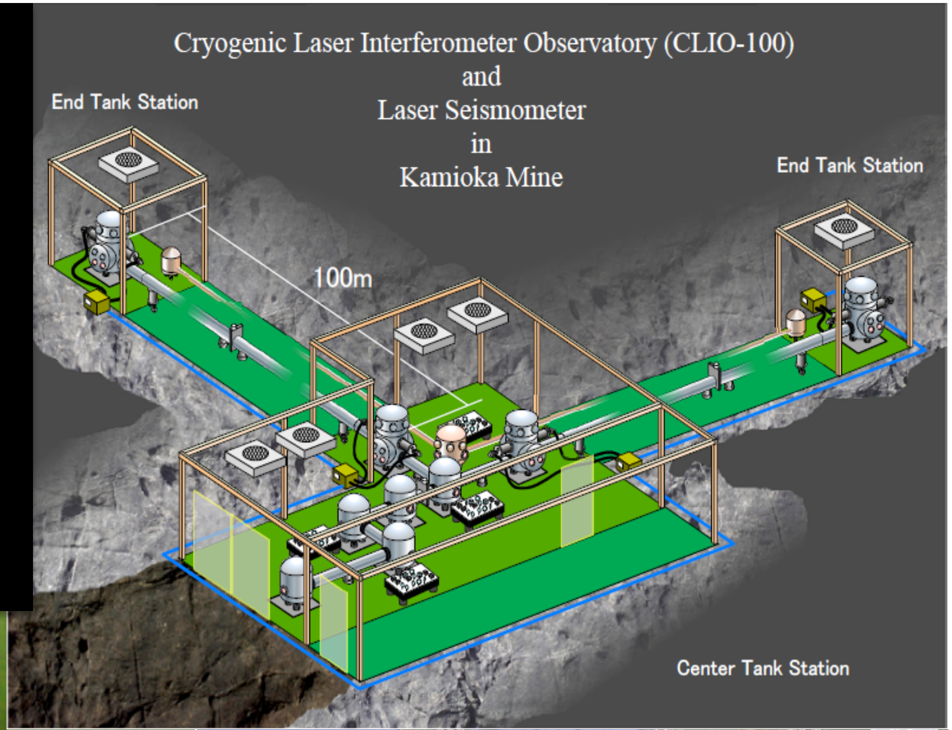
Lessons from commissioning cryogenic systems underground

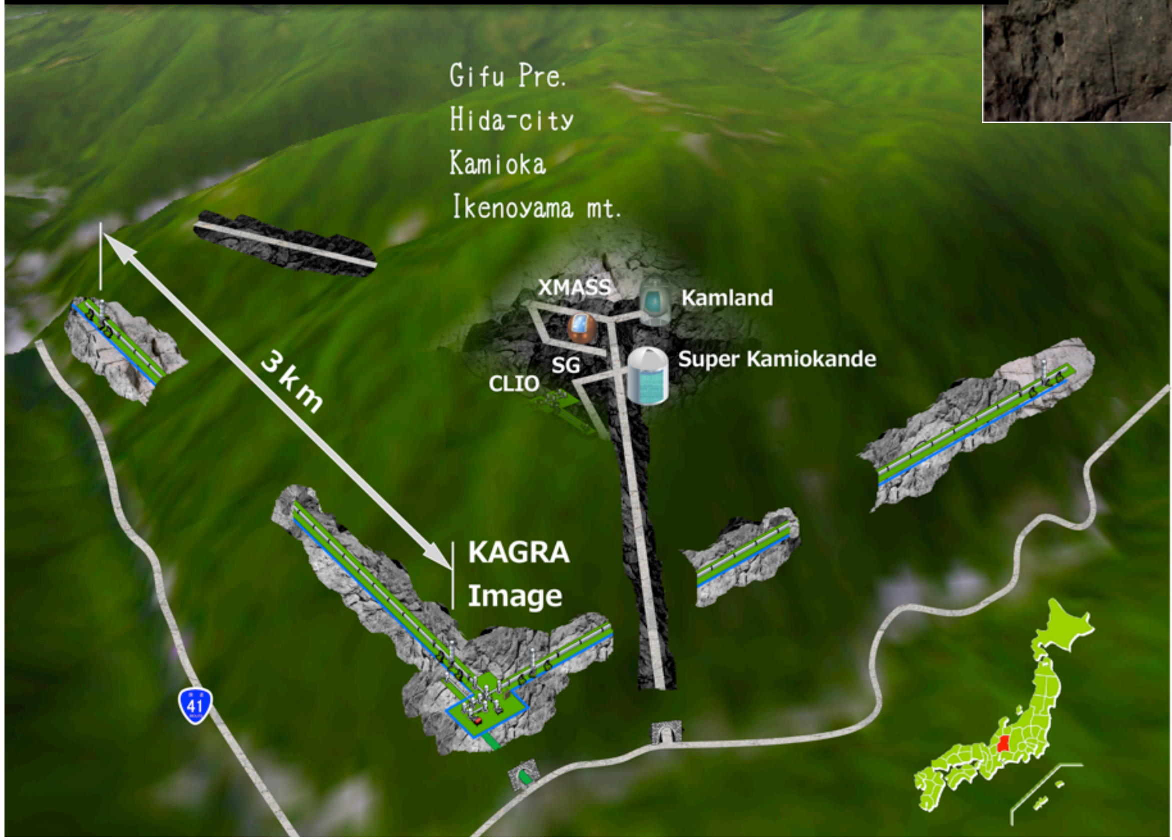
May 20, 2012 GWADW2013 at Elba, Italy

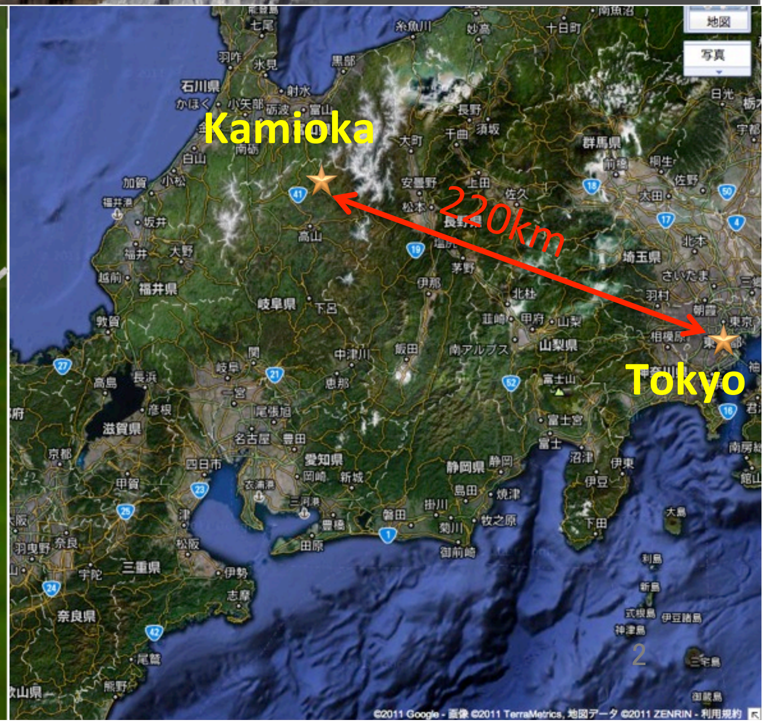
Osamu Miyakawa(ICRR, UTokyo)
and
KAGRA collaboration

Kamioka site

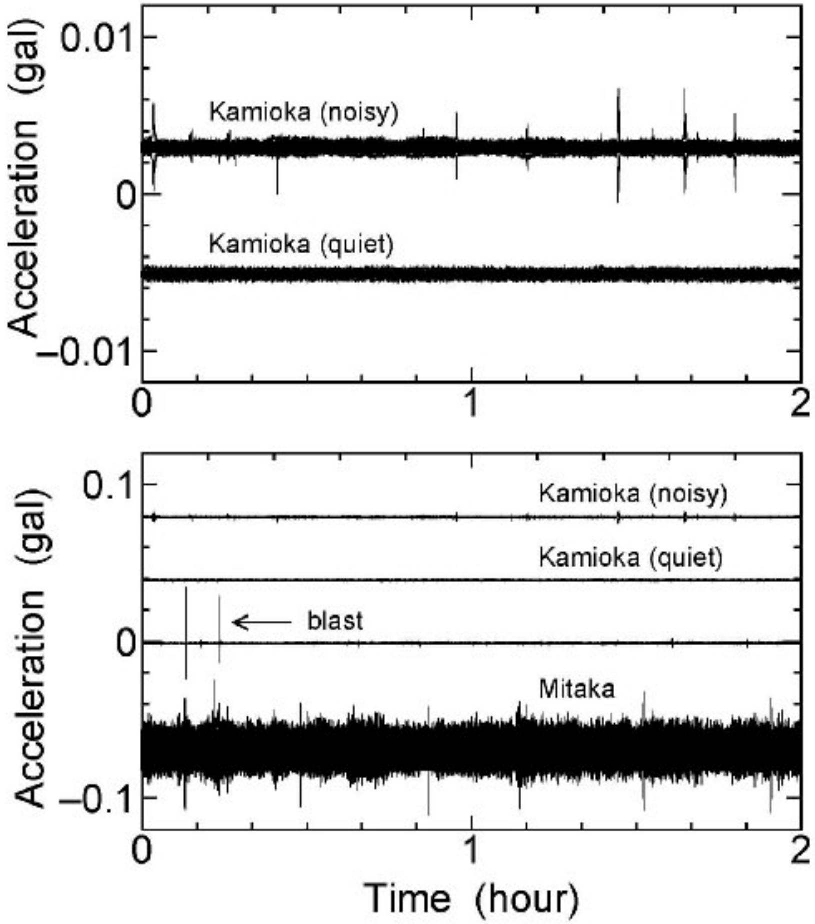
- CLIO and KAGRA are located in Kamioka mine underground
  - Laboratory area with Super Kamiokande, XMASS, Kamland etc.
  - 220km away from Tokyo
  - 360m altitude
- Mountain consists of very hard rock
  - 5 [km/sec] sound speed
  - Low seismic noise environment

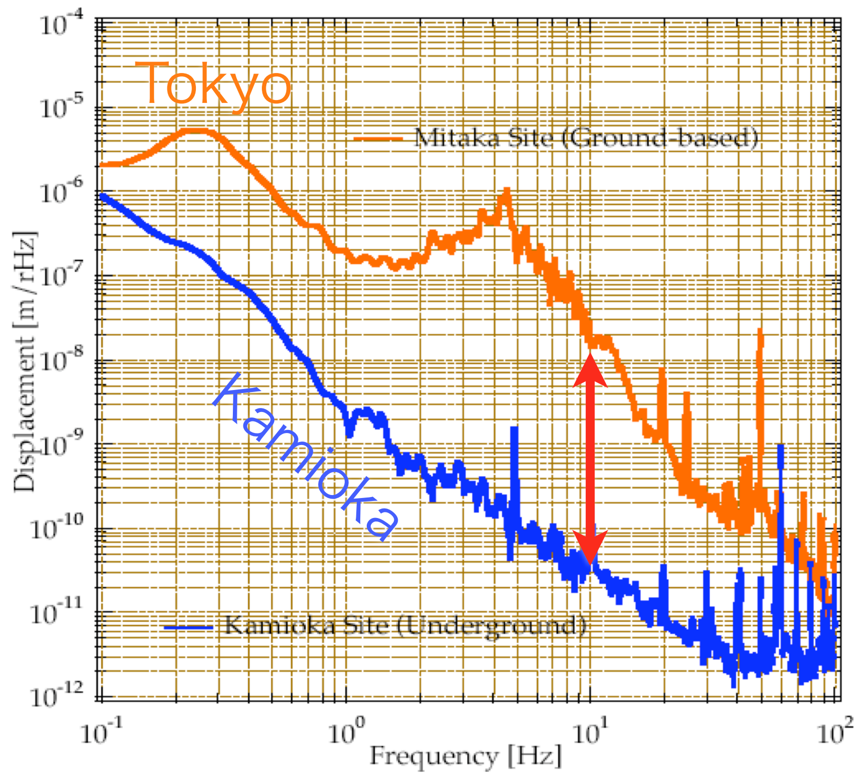






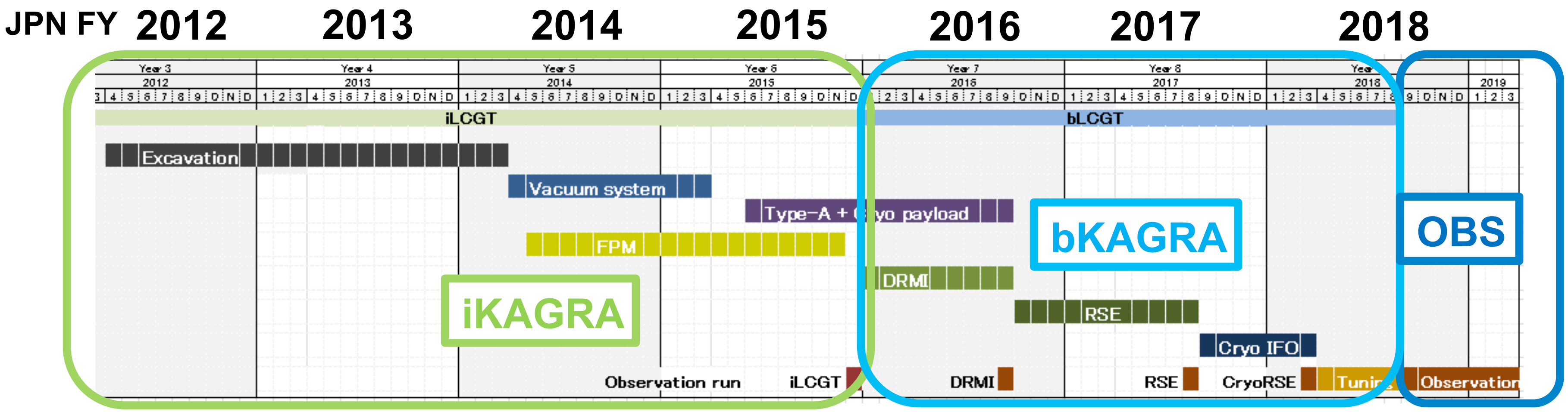
Underground site is QUIET





Amplitude of seismic motion

Schedule



iKAGRA

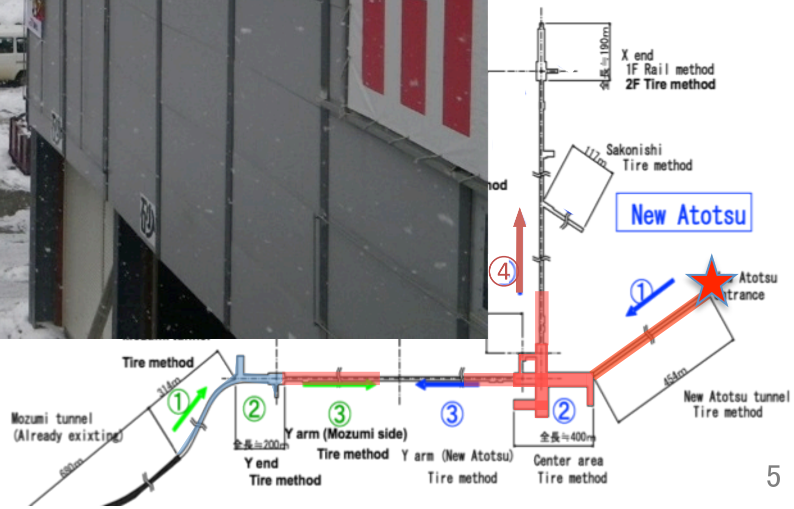
- Room-temp. FPMI
- Low laser power (10W)
- Simple seismic isolation
- 10kg silica TM

bKAGRA

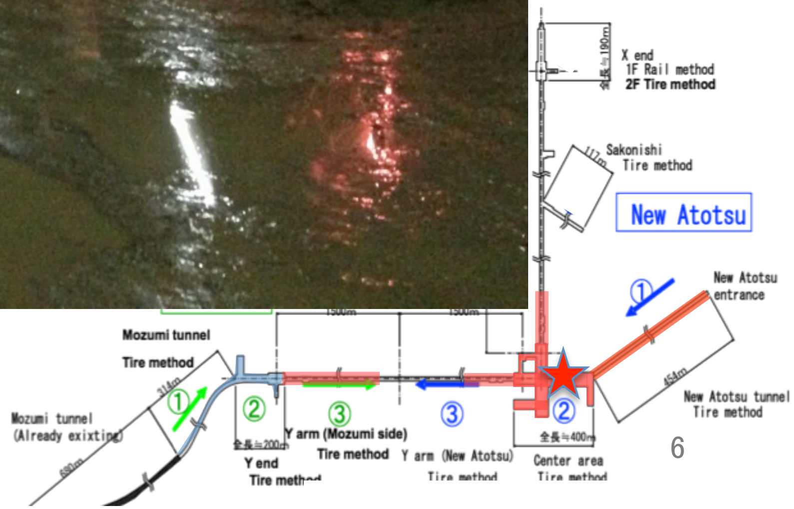
- Cryogenic RSE
- High laser power (180W)
- Low frequency seismic isolation
- 23kg sapphire TM

- The project started in 2010
- Due to the March 11 earthquake (2011), budget implementation was delayed and whole the schedule shifted 1 year behind.
- Construction of tunnels is in progress.
- KAGRA will be in 2 stages: iKAGRA and bKAGRA

KAGRA tunnel entrance (New Atotsu)

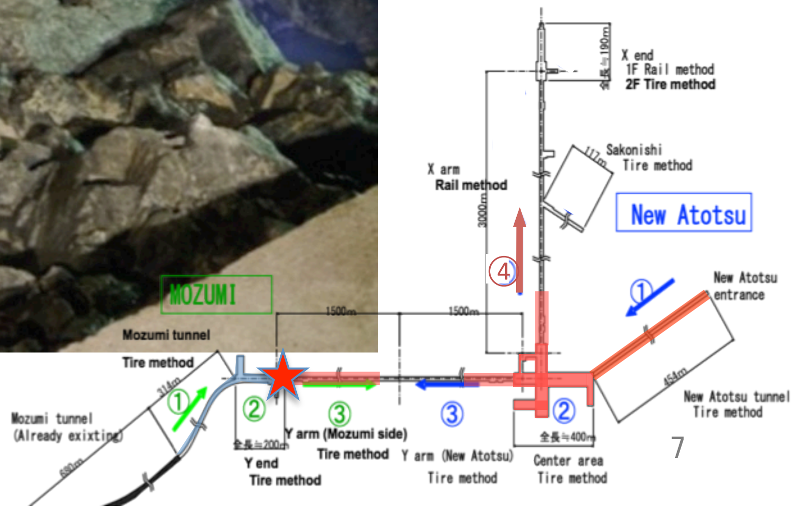



Laser room
X arm
Y arm

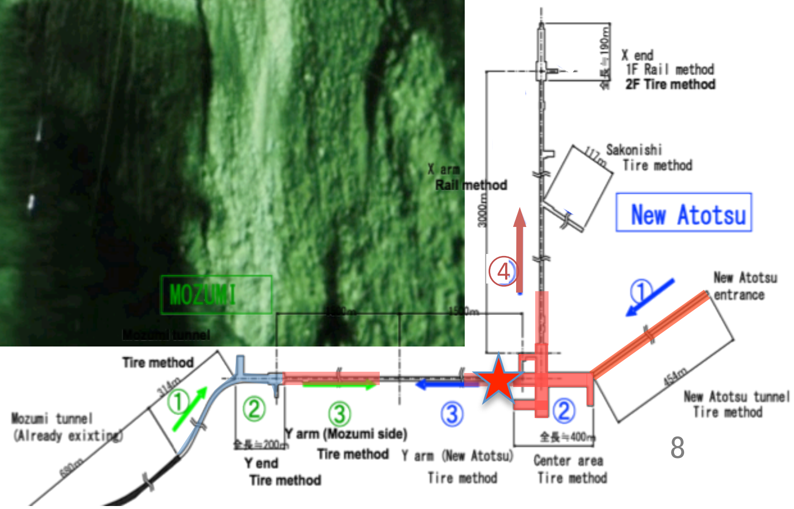

X end
1F Rail method
2F Tire method
Sakonishi
Tire method
New Atotsu
New Atotsu
entrance
Mozumi tunnel
Tire method
Mozumi tunnel
(Already exixting)
Y end
Tire method
Y arm (Mozumi side)
Tire method
Y arm (New Atotsu)
Tire method
Center area
Tire method
New Atotsu tunnel
Tire method

Center room

Y end area for chamber location



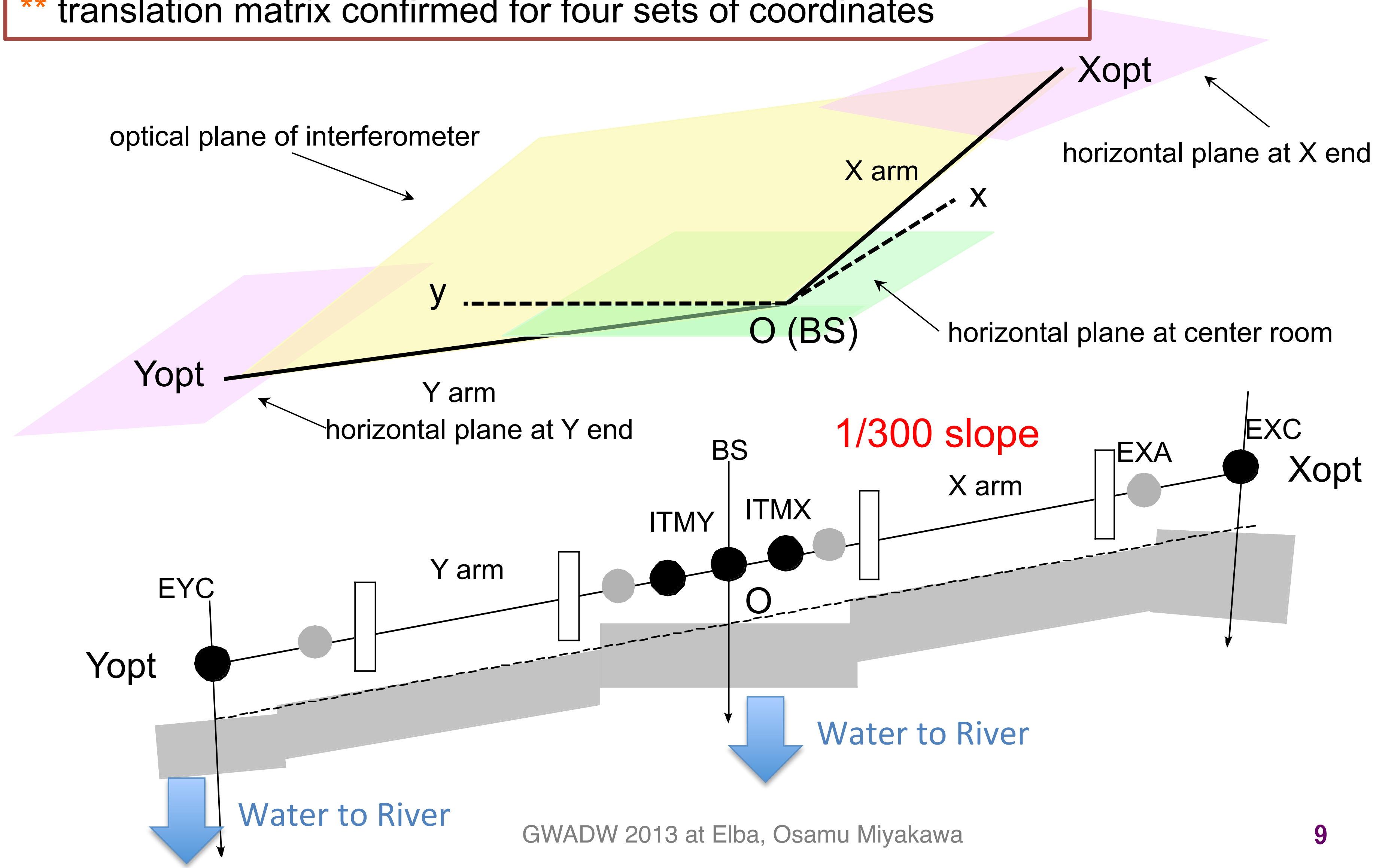
Y arm under water

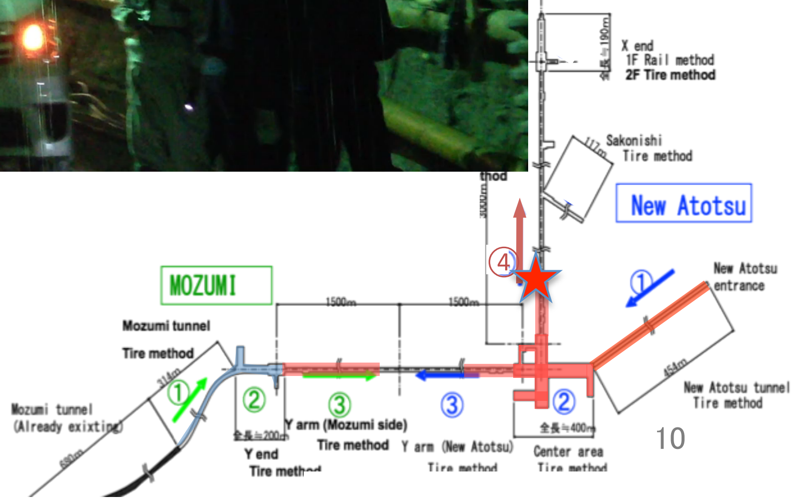


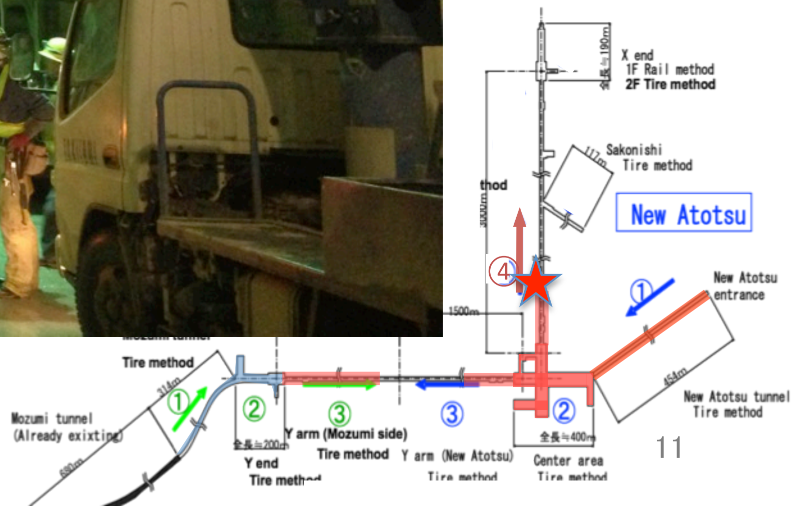
KAGRA Vacuum System

1. Layout (four planes/floors)

** horizontal floors in each room prepared for installing chambers
** translation matrix confirmed for four sets of coordinates




X end
1F Rail method
2F Tire method
全長≒190m
Sakonishi
Tire method
117m
New Atotsu
3000m
④
MOZUMI
1500m
1500m
New Atotsu
entrance
①
Mozumi tunnel
Tire method
314m
①
②
③
③
②
454m
New Atotsu tunnel
Tire method
Mozumi tunnel
(Already exixting)
全長≒200m
Y arm (Mozumi side)
Tire method
Y arm (New Atotsu)
全長≒400m
Center area
Y end
690m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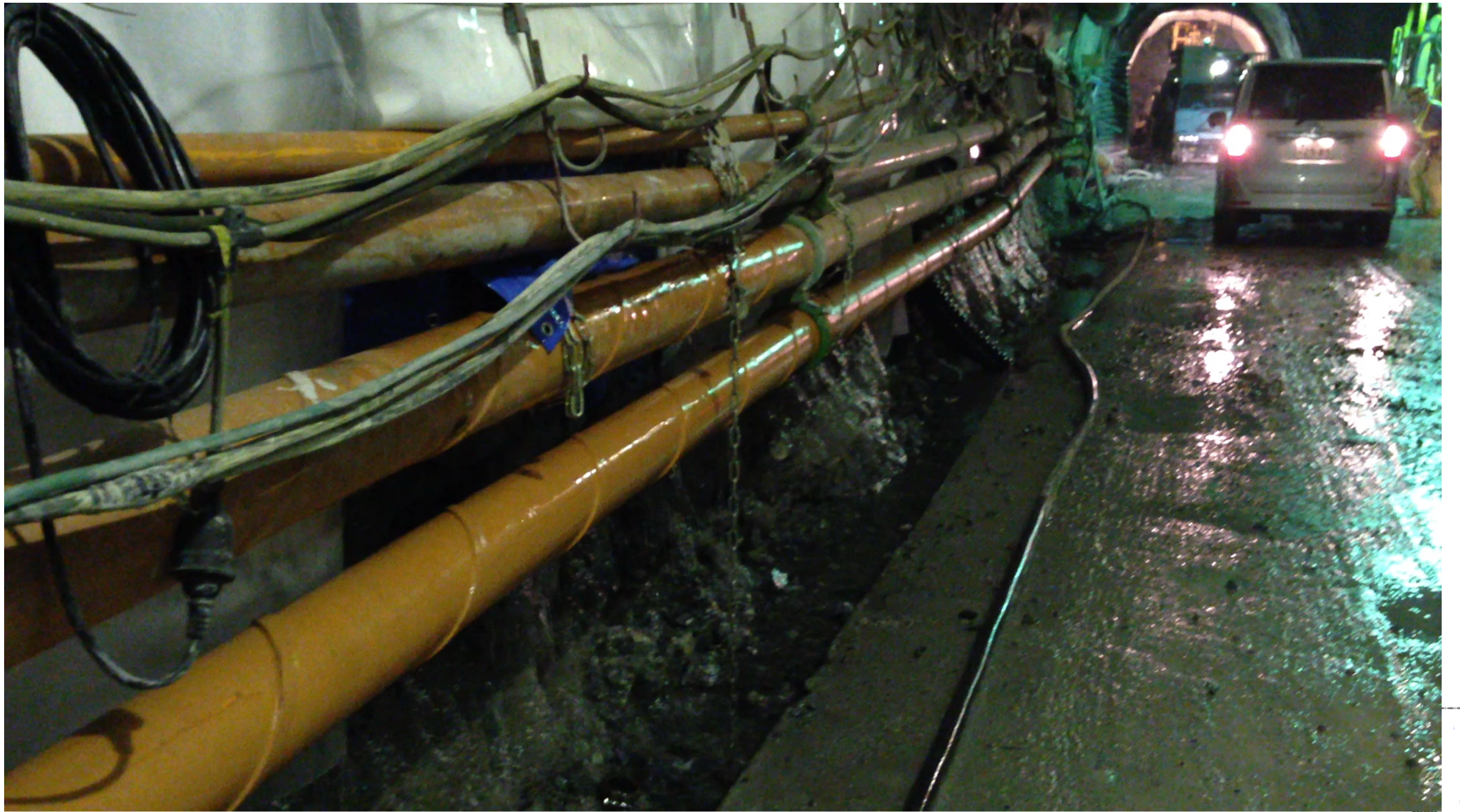

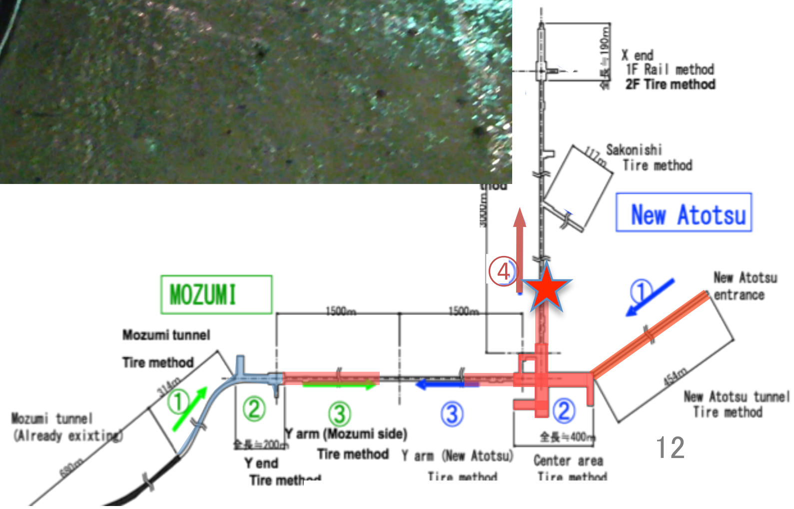
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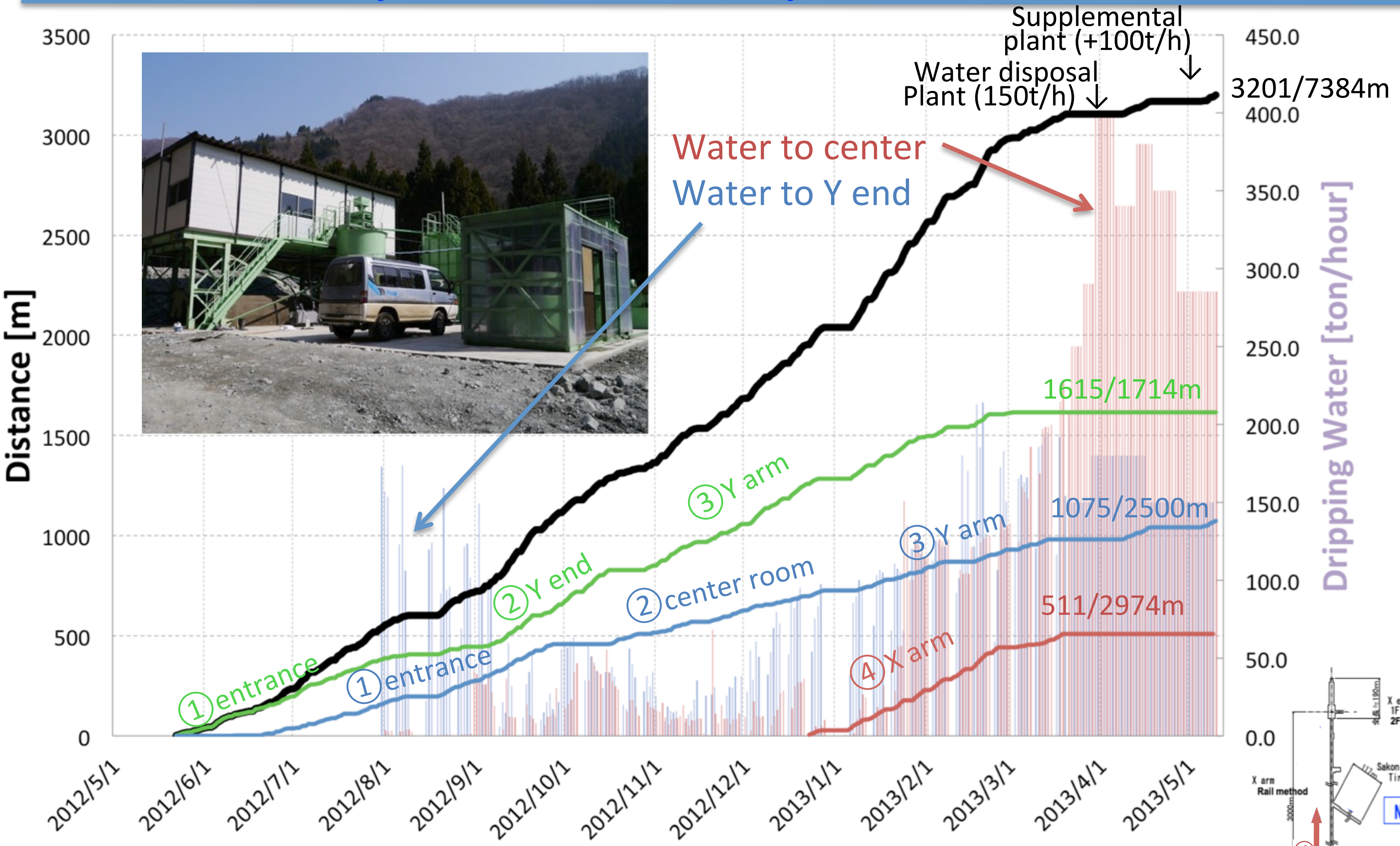
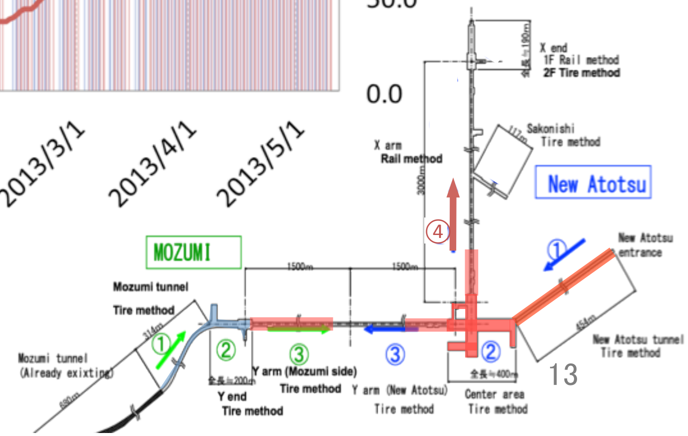
Center area
454m
New Atotsu tunnel
Tire method

KAGRA tunnel distance for May 22, 2012 – May 10, 2013



Distance: 43.4% (3201m/7384m)

Volume: 51.9% ($72000m^3/138700m^3$)



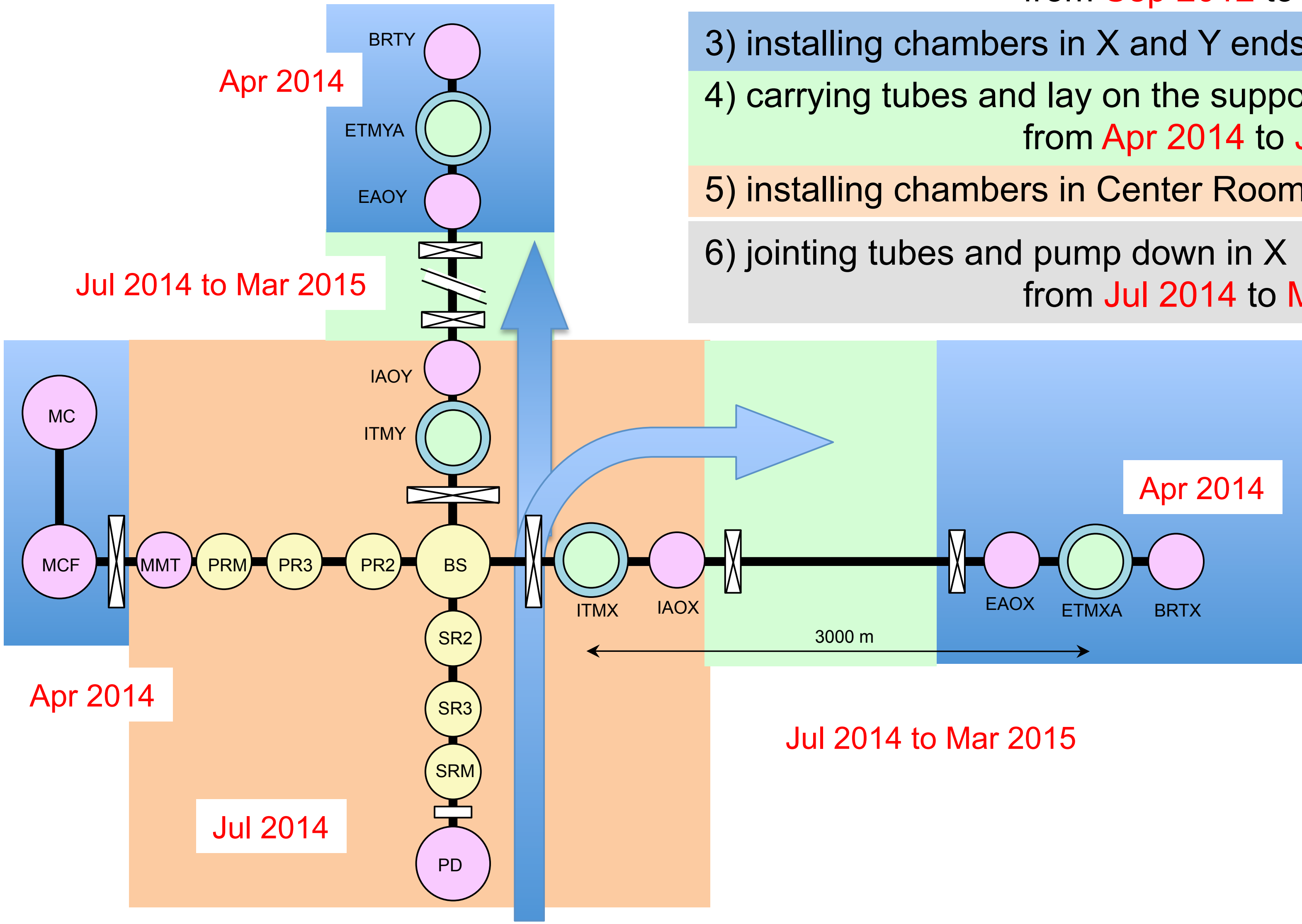
JGW-G130166

KAGRA Vacuum System

Schedule for installing

Finish X-arm at the end of 2014

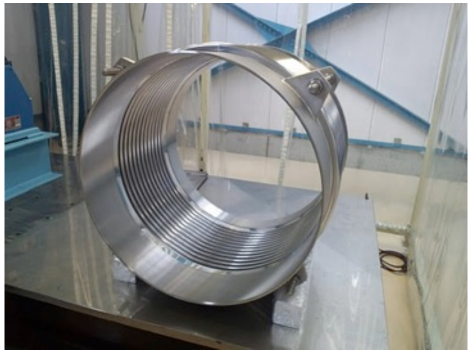
1) manufacturing 478 of tubes;
from Apr 2011 to Mar 2013
2) manufacturing chambers;
from Sep 2012 to Mar 2014
3) installing chambers in X and Y ends; Apr 2014
4) carrying tubes and lay on the supports;
from Apr 2014 to Jun 2014
5) installing chambers in Center Room; Jul 2014
6) jointing tubes and pump down in X and Y arm
from Jul 2014 to Mar 2015



Vacuum tubes

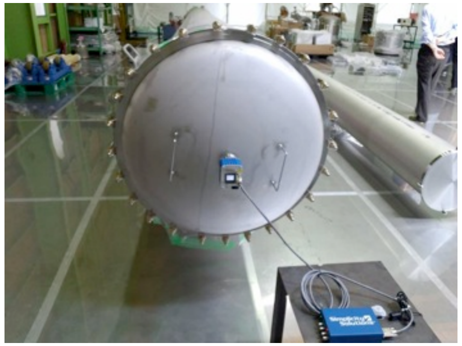
12m, Φ800mm x 478 => 3km x 2

Press to form a duct



Bellows for each duct

Baking at MIRAPRO Co. Noda/MESCO, Kamioka

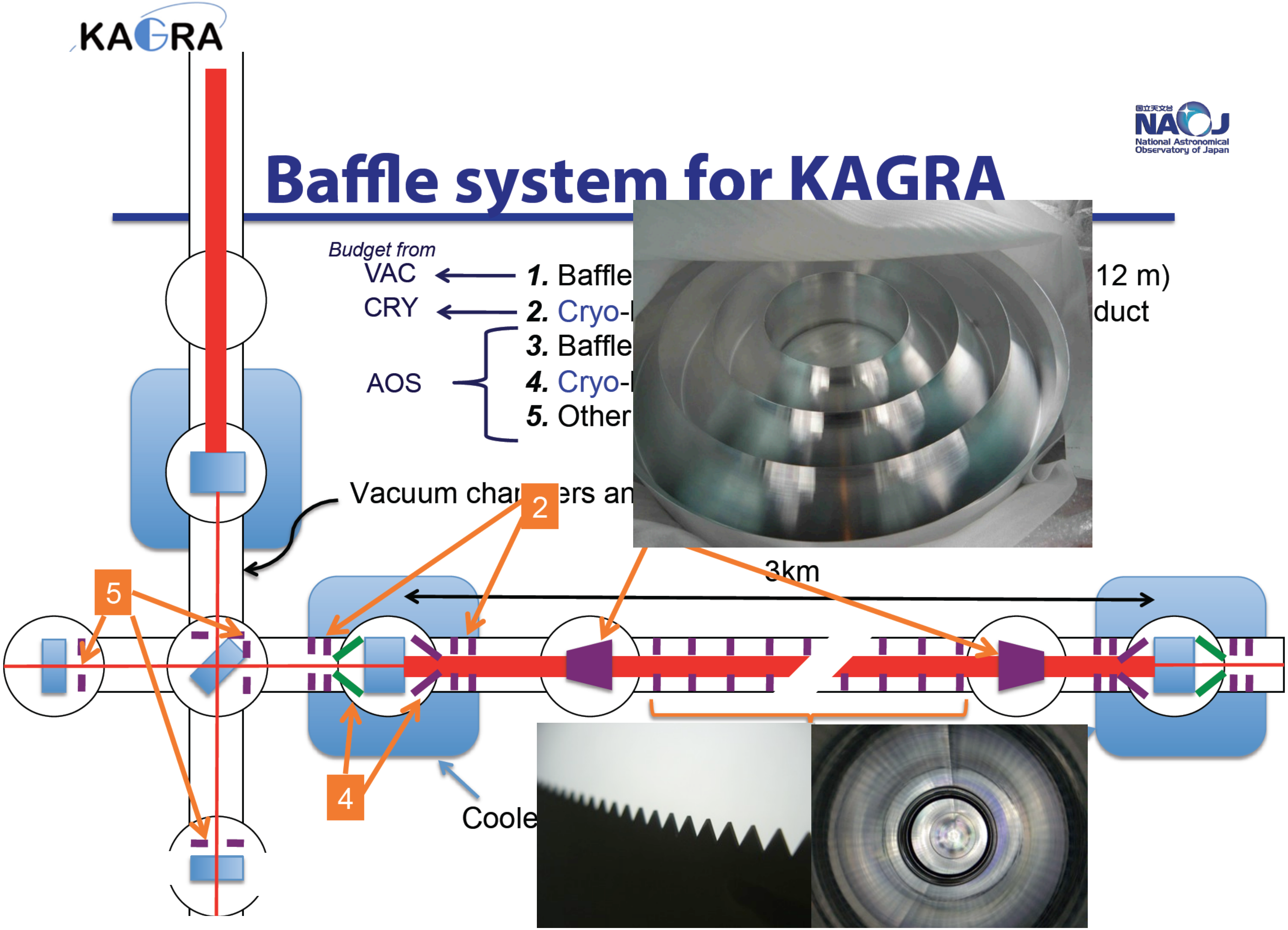


Test at MIRAPRO Co. Noda

Y. Saito JGW-G1200988-v1

JGW-G130166

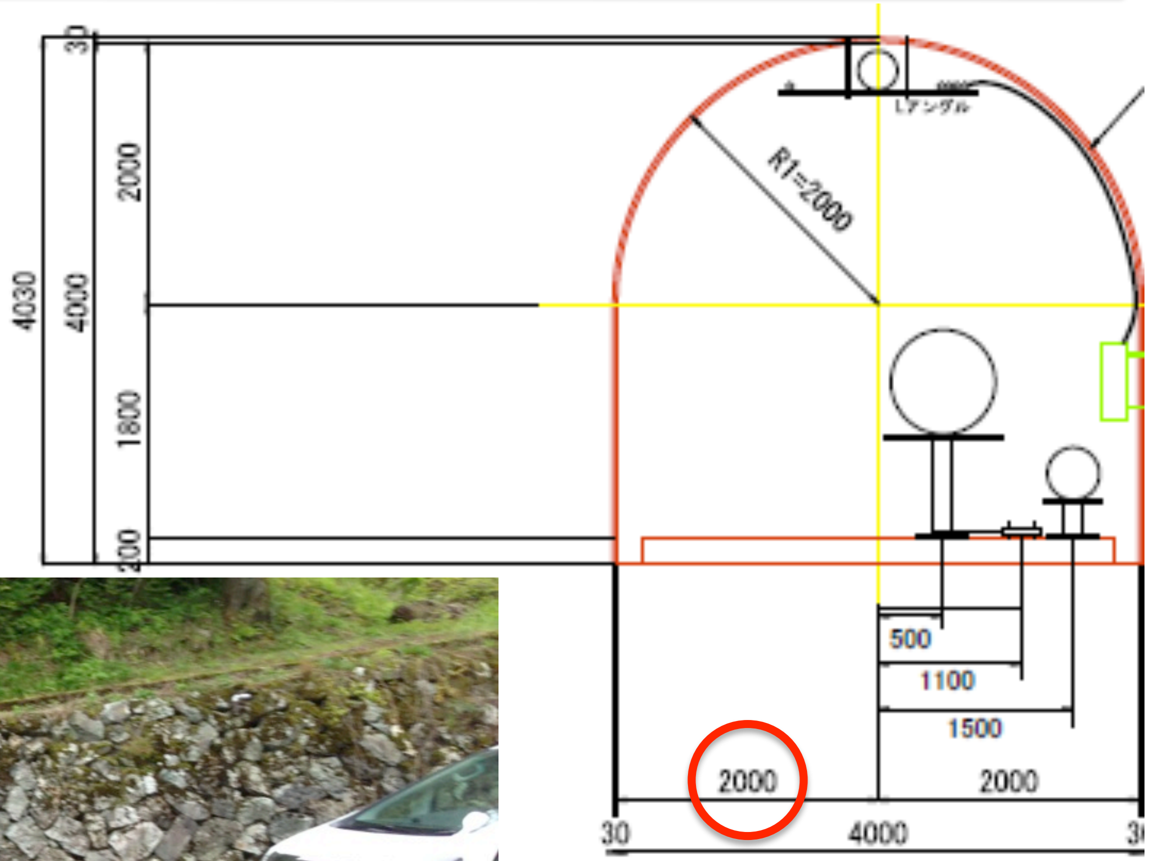
Baffle system for KAGRA



KAGRA

Transportation in arms

- Electric car
- 6hous charge, 70km drive
- Max 60km/h
- Max 12° slope
- ~8000USD

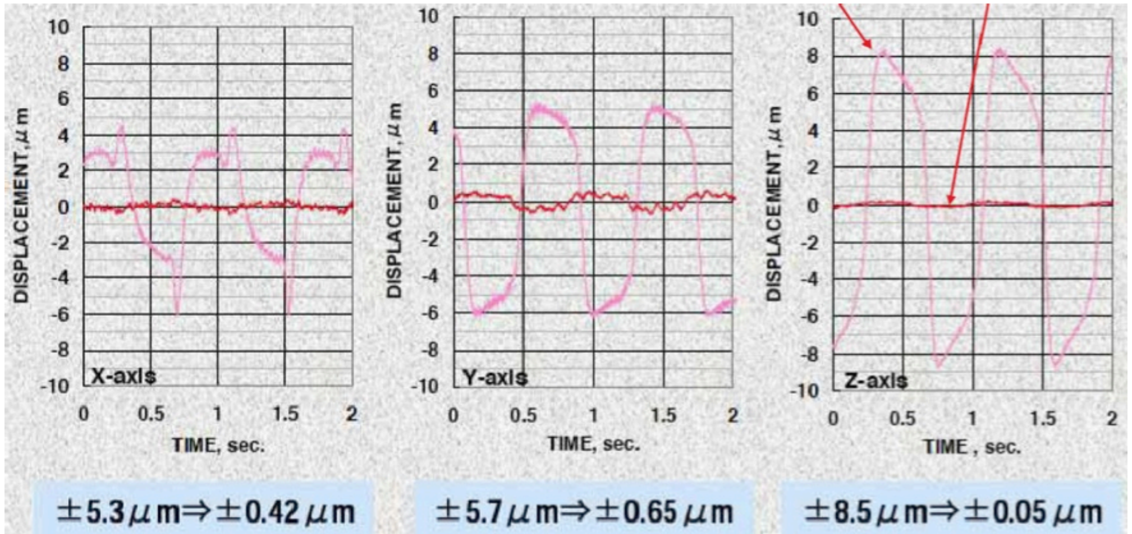


KAGRA Cryostat

Ultra-Low Vibration Refrigerator
- vibration reduction performance

Reduction of the 4K vibration

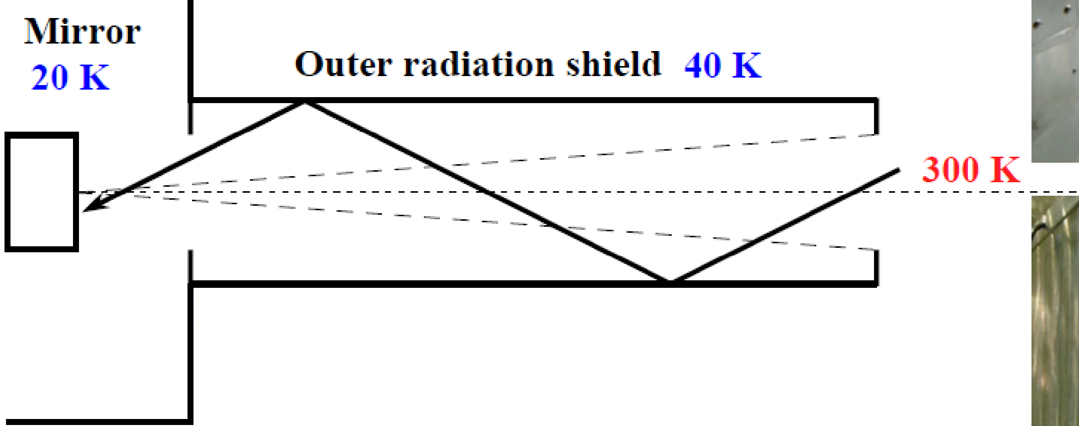
X-axis **Y-axis** **Z-axis**

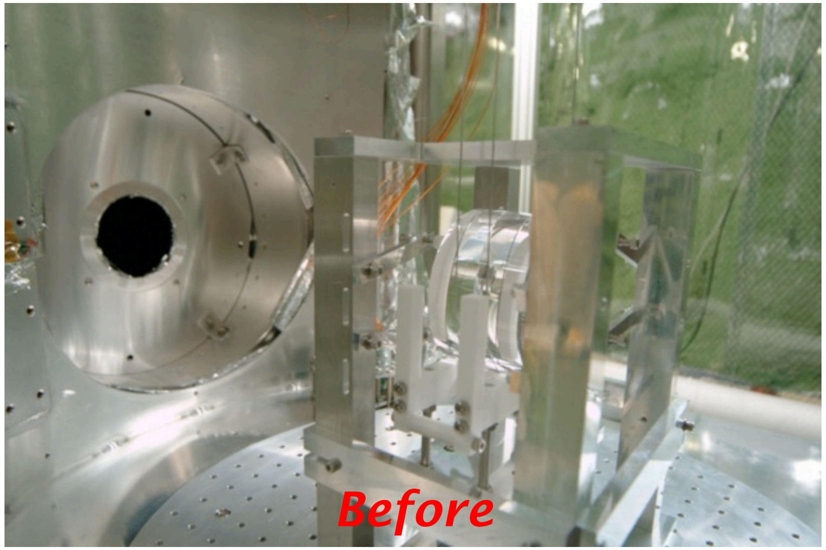


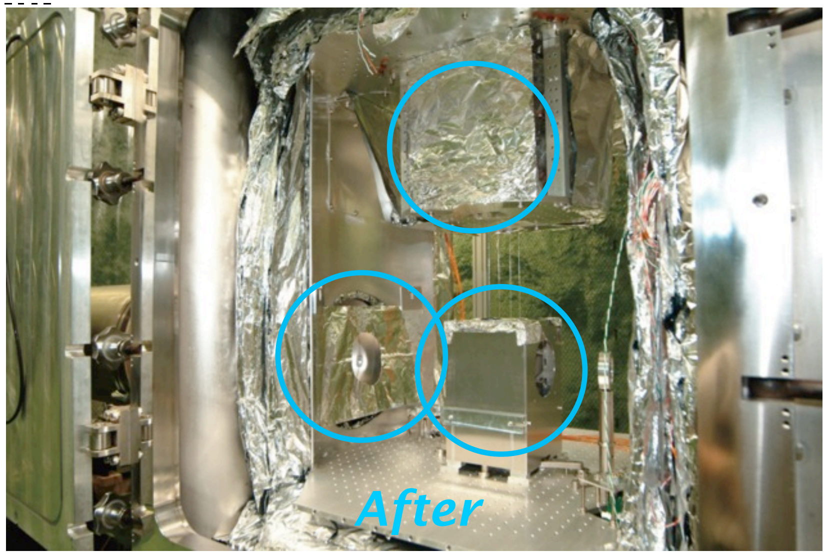
The values show mainly the operation frequency vibration.

Excess Heat Radiation

Indirect radiation from 300K is large.
We neglected it first…







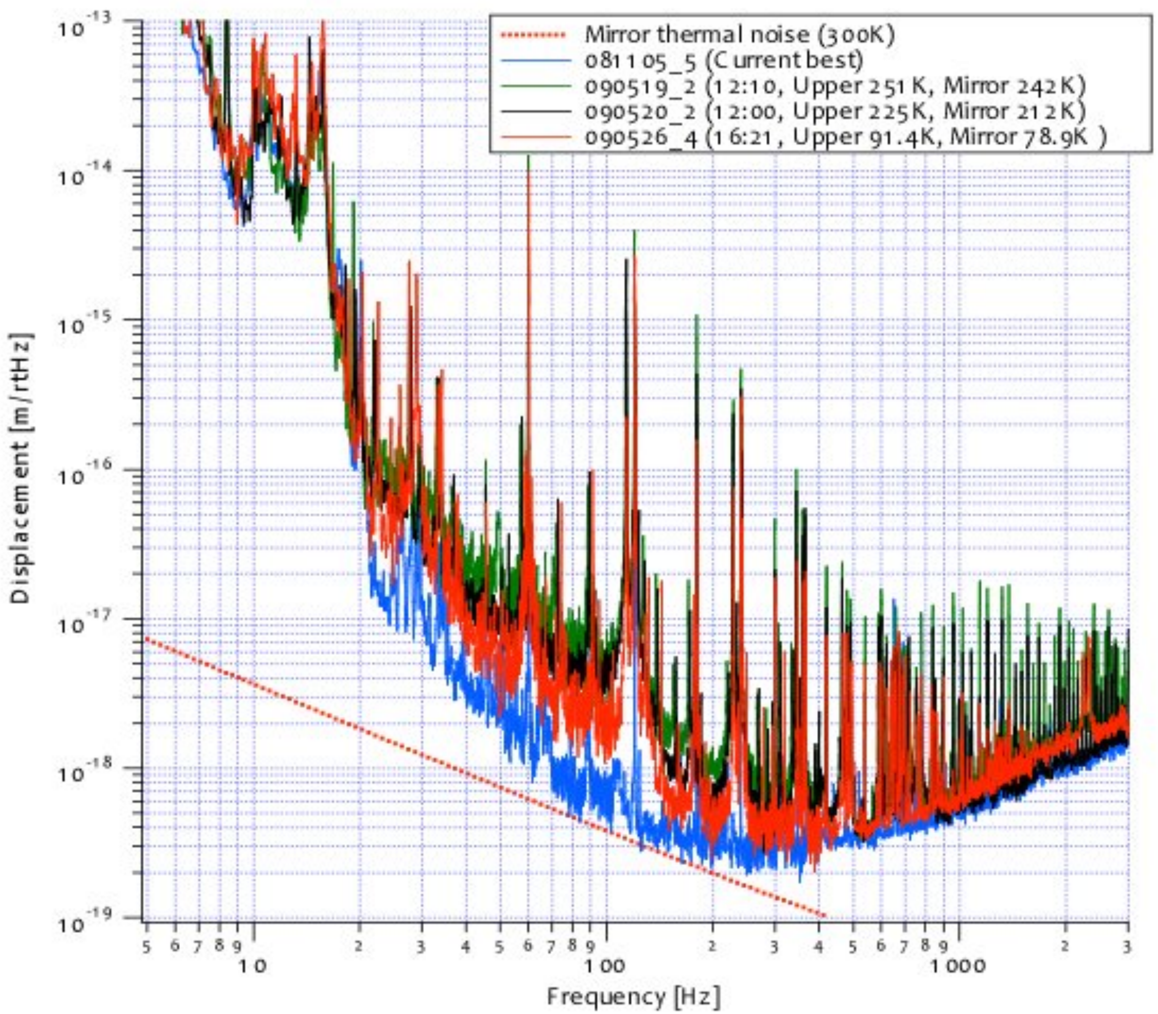
- *We put radiation shields inside the inner shield.*
- *An essential resolution is to have baffles or "black" radiation shield ducts .*

Low temperature experiment

•Suspension thermal noise was reduced, as the aluminum wires were cooled;

1. 242K 5/19/2009
2. 212K 5/20/2009
3. 79K 5/26/2009

•A big jump from 212K to 79K, because of too much creaks when structures were shrinking to measure noise or to keep lock. Creaks vanished below 100K.



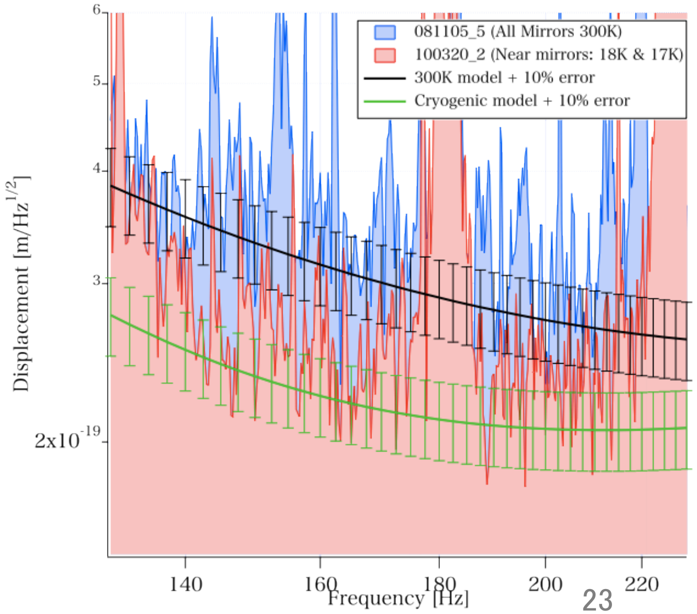
What learned form cryogenic experiences

- Thermal conduction is the only method for cooling.
  - Mirror is always heated by laser.
  - Mirrors are in high vacuum (10^{-5}Pa), so no convection or no radiation works for cooling.
  - Heat on mirror is sucked through wire's conduction.
- Height adjustment
  - Thermal shrink of suspension wires for 2-4 mm.
- Contaminations on the mirror by small leakage shown as change of cavity reflectivity
  - Needed a careful check for O-ring, gate valve with a leak detector
- Eddy current damping force using magnets is too strong in low temperature and the mass will be stuck to outer magnet frame.

trouble, trouble, trouble…

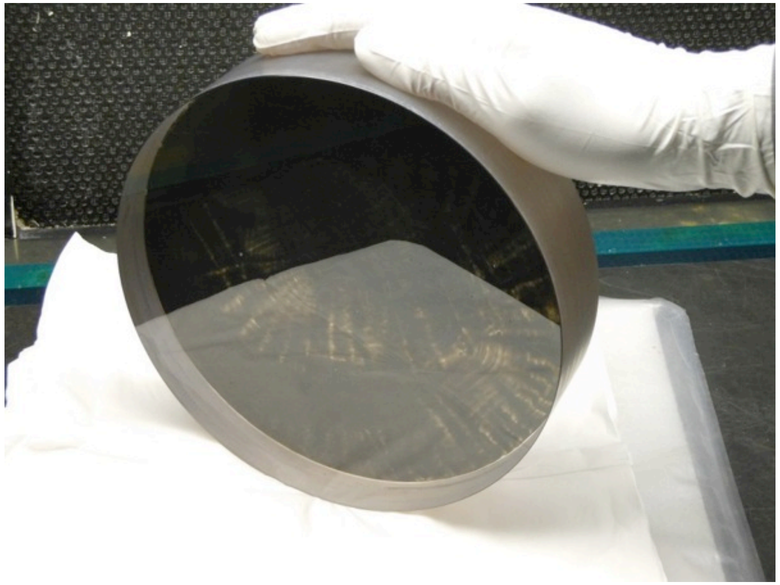
(1) 5/17/2009 - 6/10 : Inline near.reduced pendulum thermal noise, contamination
(2) 6/19 – 9/7 : Inline near 27k, Trouble for a touching mirror
(3) 7/6 – 9/6 : Inline near. 27K.
(4) 7/31 – 9/6 : Per arm near. First cooling, 17K. contamination
(5) 9/11 – 11/21 : Inline near. No coil actuator.
(6) 9/11 – 11/21 : Per arm near. No coil actuator. contamination
(7) 11/27 – 1/17/2010 : Inline near. New coil actuator.
(8) 11/29 – 12/23 : Per arm near. New coil actuator. contamination
(9) 12/28 – 1/17/2010 : Per arm near. Trouble for a touching mirror
(10) 1/22/2010 – : Inline near. New magnet damping. 17K.
(11) 1/22/2010 – : Per arm near. New magnet damping. 16K.

The sensitivity improvement is consistent with thermal noise reduction



Sapphire mirrors

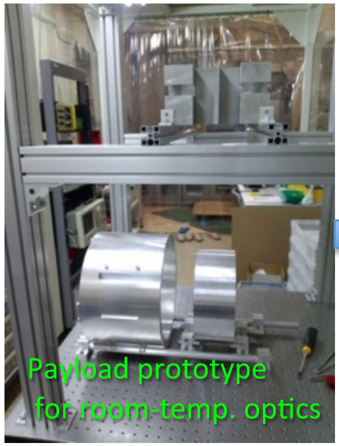
- Pathfinder polish of sapphire has been done.
- The realized surface distortions are 0.34nm/140mm, 0.42nm/180mm; these values are better than our requirement 0.5nm/140mm.
- ROC with 0.15% error over 180mm (2002.98m/2000m)

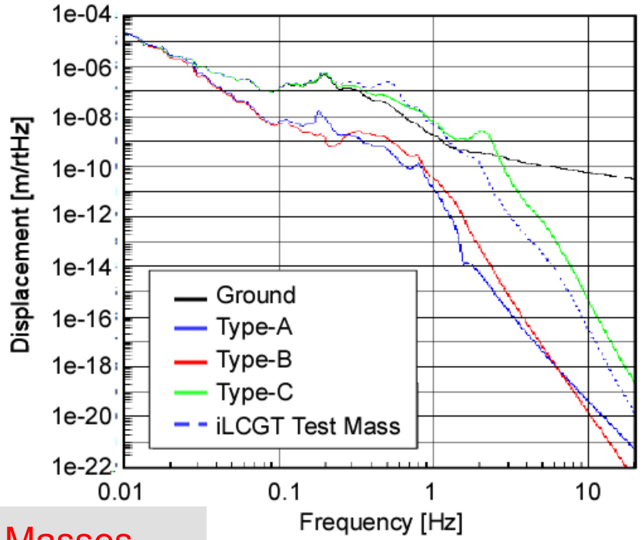


Polished sapphire crystal of 200-mm diameter

Clean room test bench

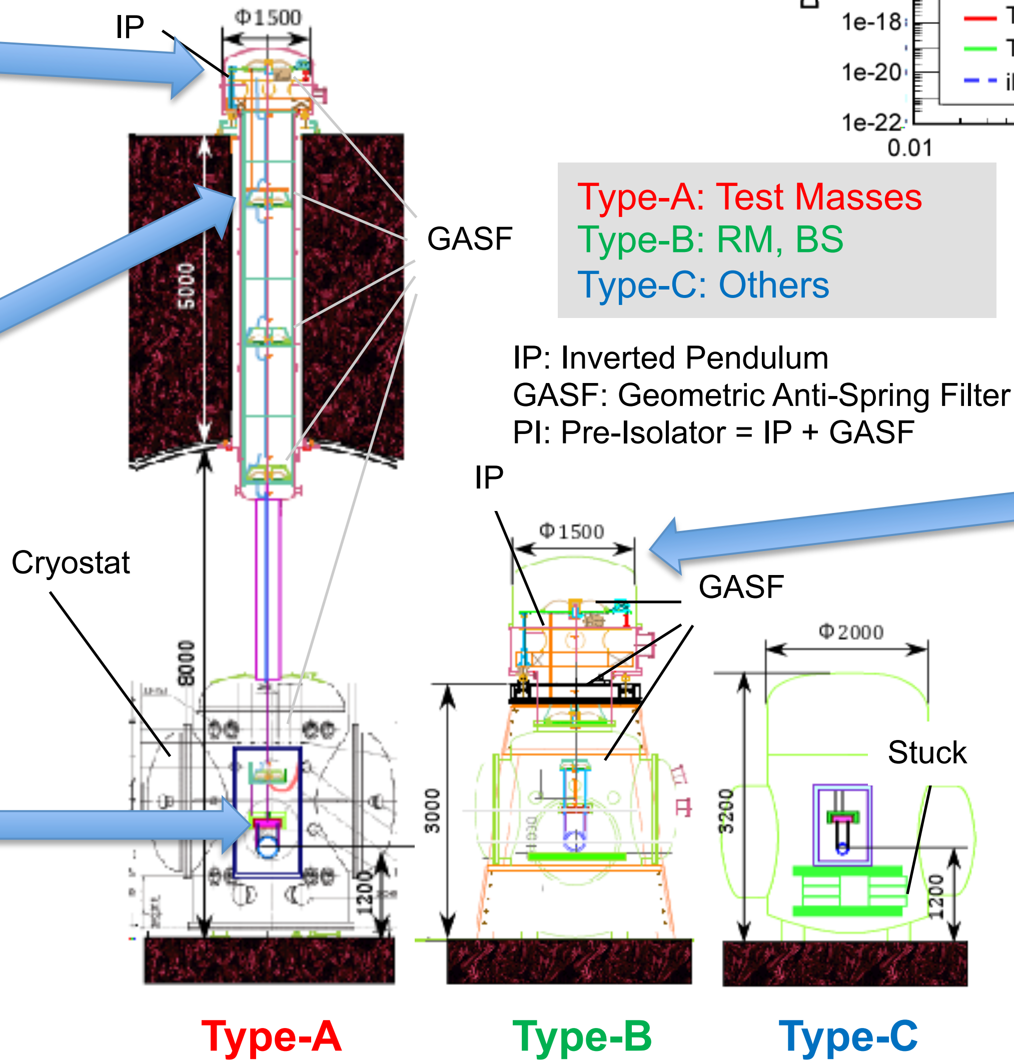
Seismic isolation



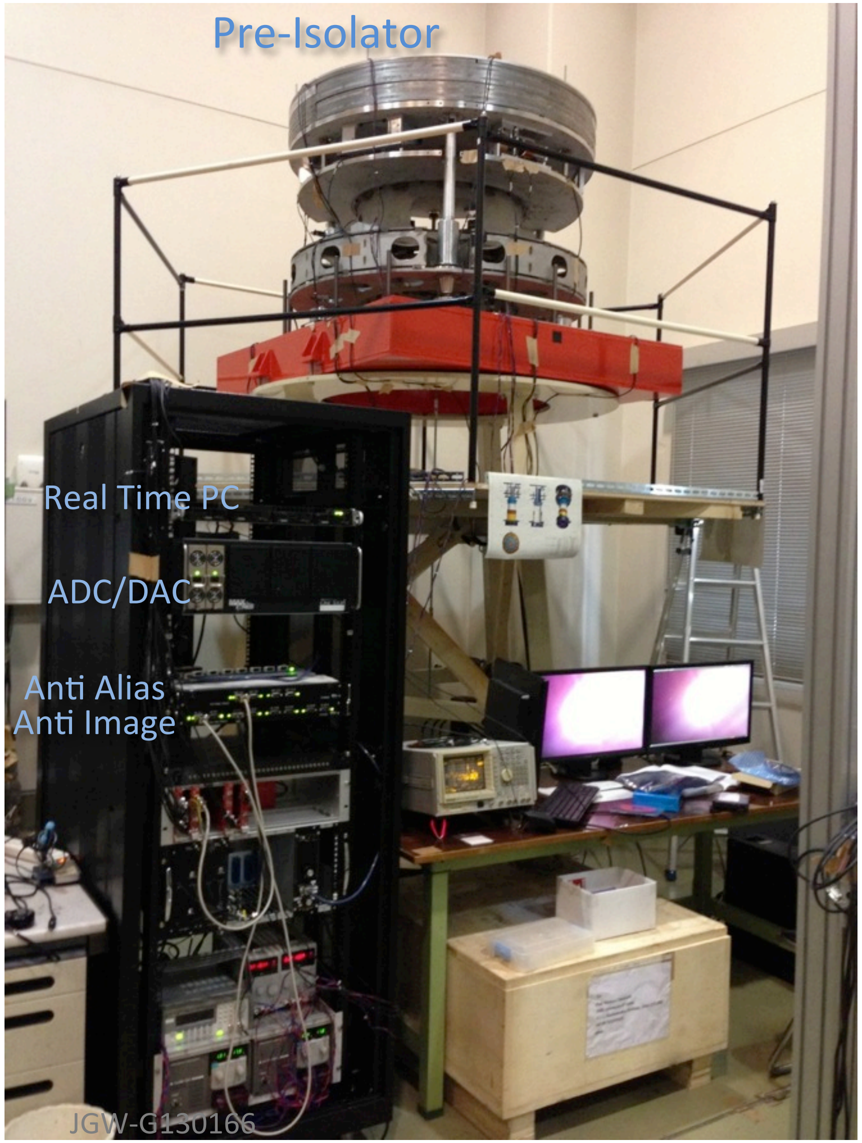


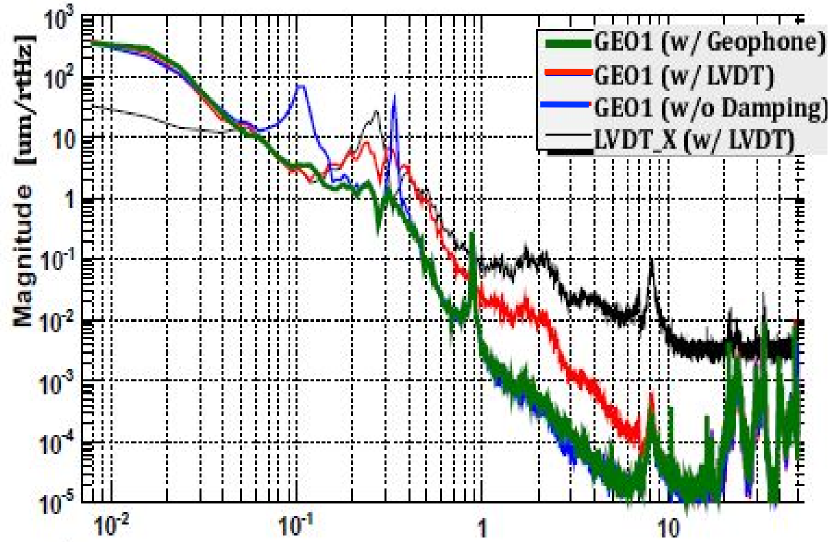
Type-A: Test Masses
Type-B: RM, BS
Type-C: Others

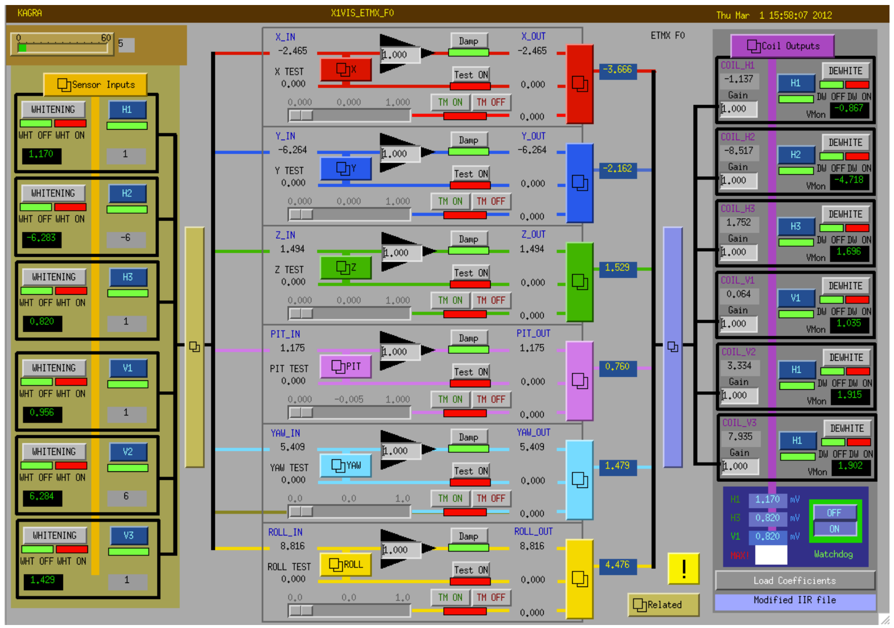
IP: Inverted Pendulum
GASF: Geometric Anti-Spring Filter
PI: Pre-Isolator = IP + GASF



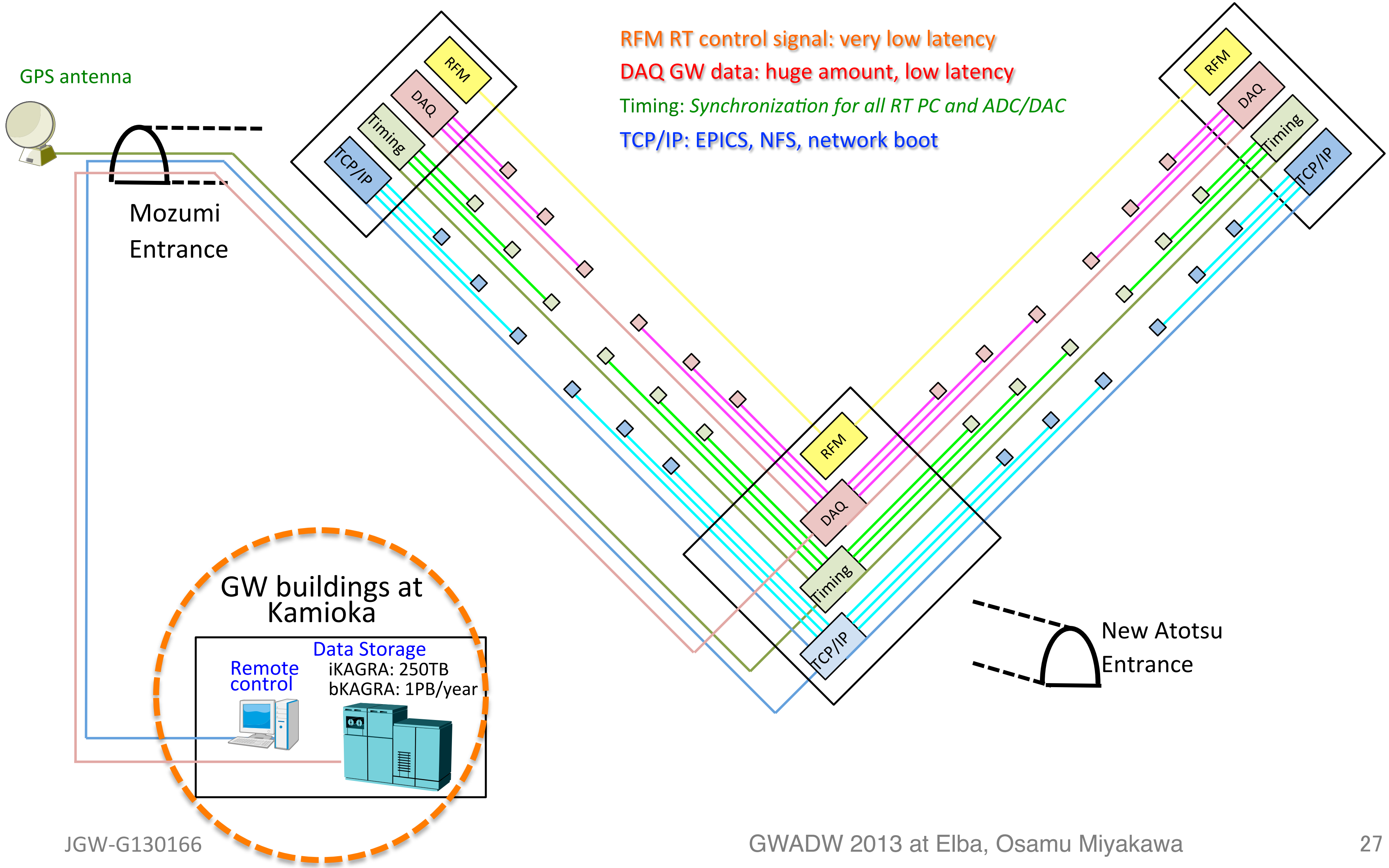
Local control for Pre-Isolator







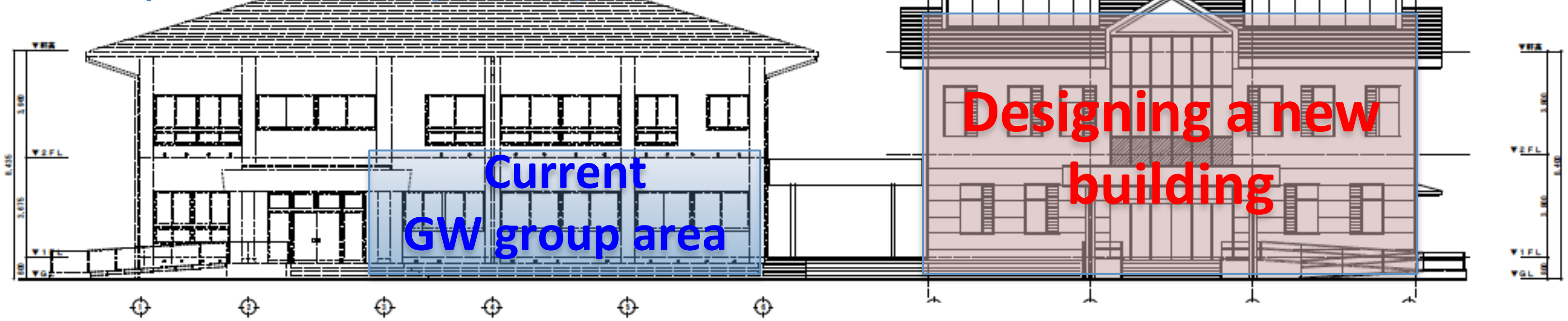
Network design for controls and DAQ

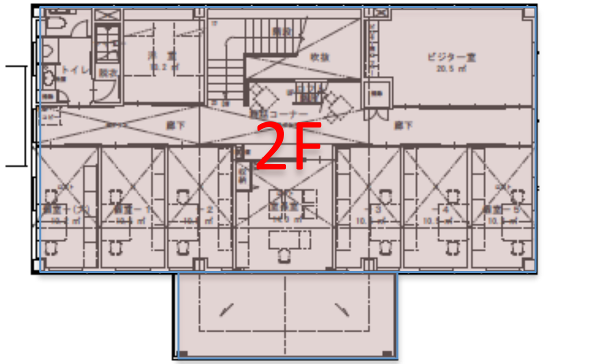


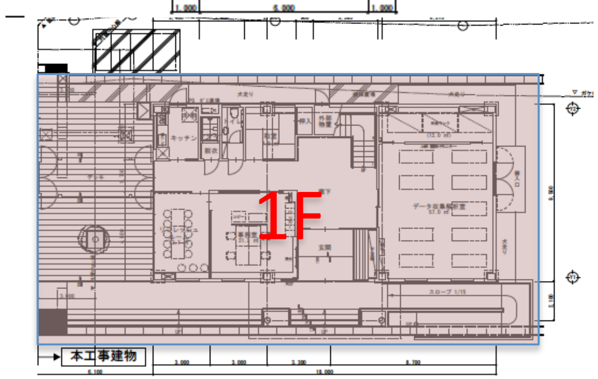
New building at Kamioka

Last year: ~150m^2
(1F of Community center)

This year: 338m^2







History of cryogenic mirrors in Japan

1997 Stating of feasibility study at KEK. Sapphire mirror & fiber suspension.

10cm

7m

2001 CLIK: Control of cryogenic Fabry-Perot cavity at Kashiwa.

2002~ CLIO: Sensitivity Improvement by Thermal noise reduction by cooling.

100m

201? KAGRA: Detection of Gravitational wave.

3000m