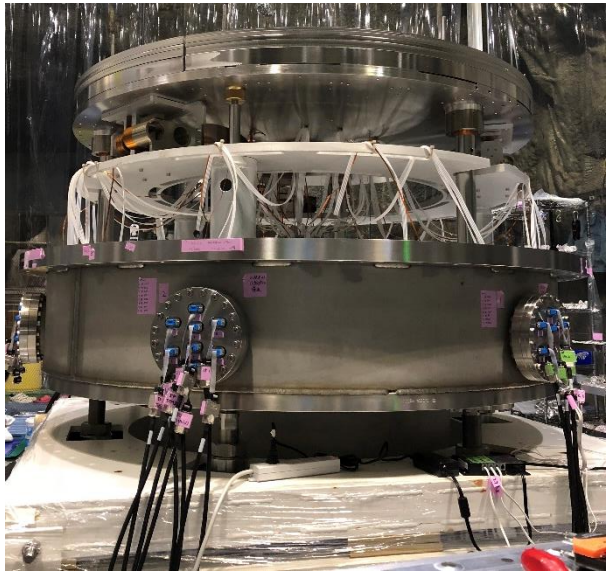
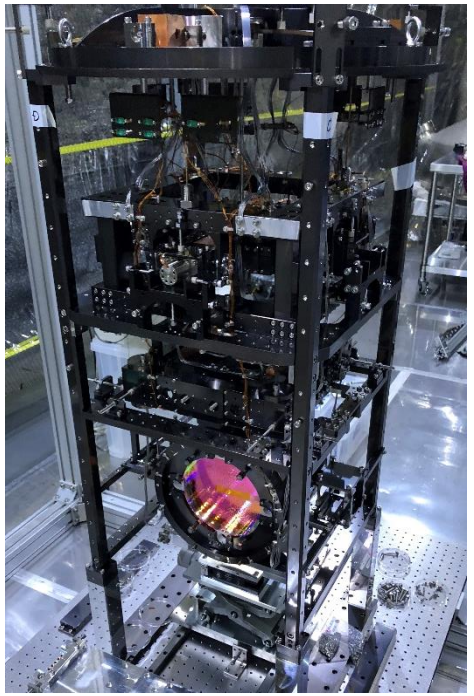
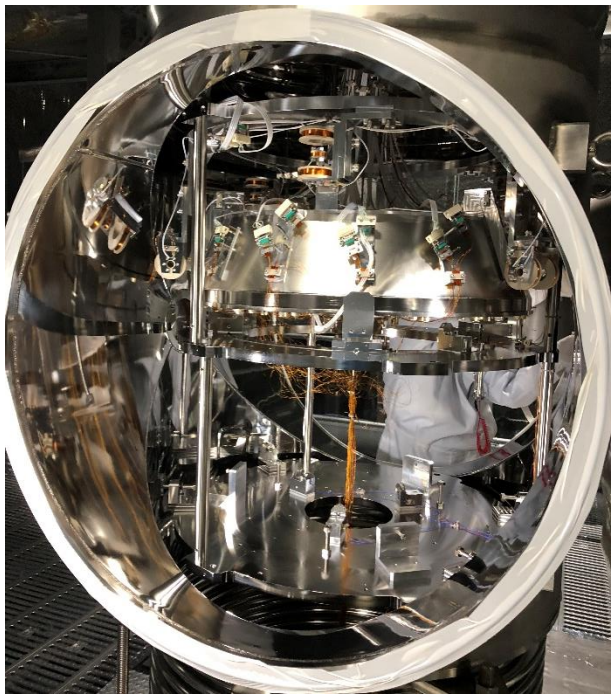
# Status of Type-A suspensions for KAGRA

Yoshinori Fujii
for KAGRA collaboration







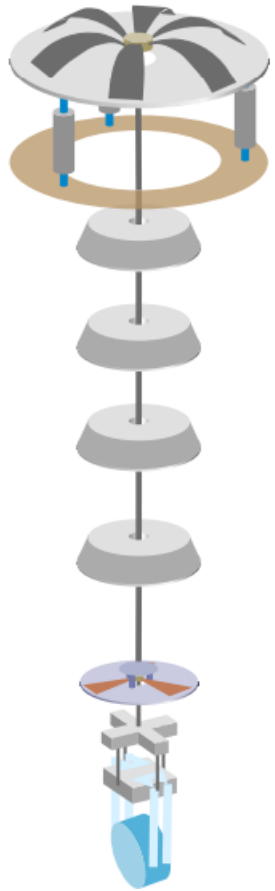
# Status of Type-A suspensions for KAGRA

## What is going on?

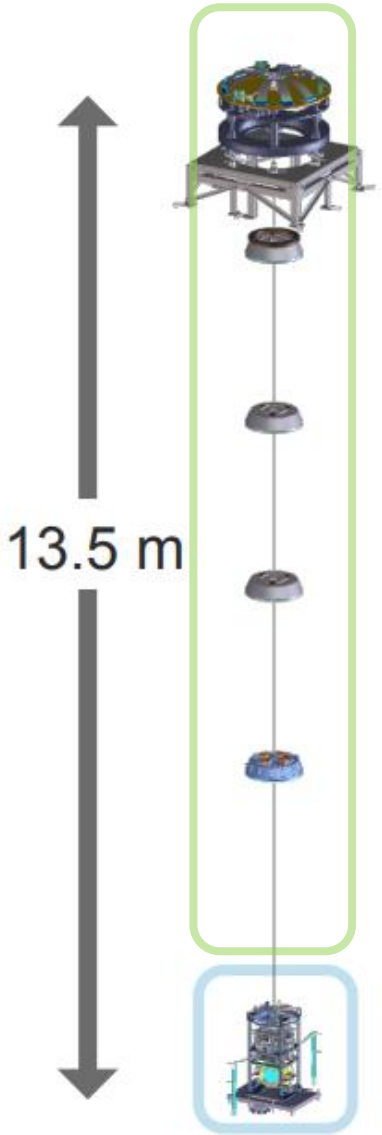
-- Mechanical installation

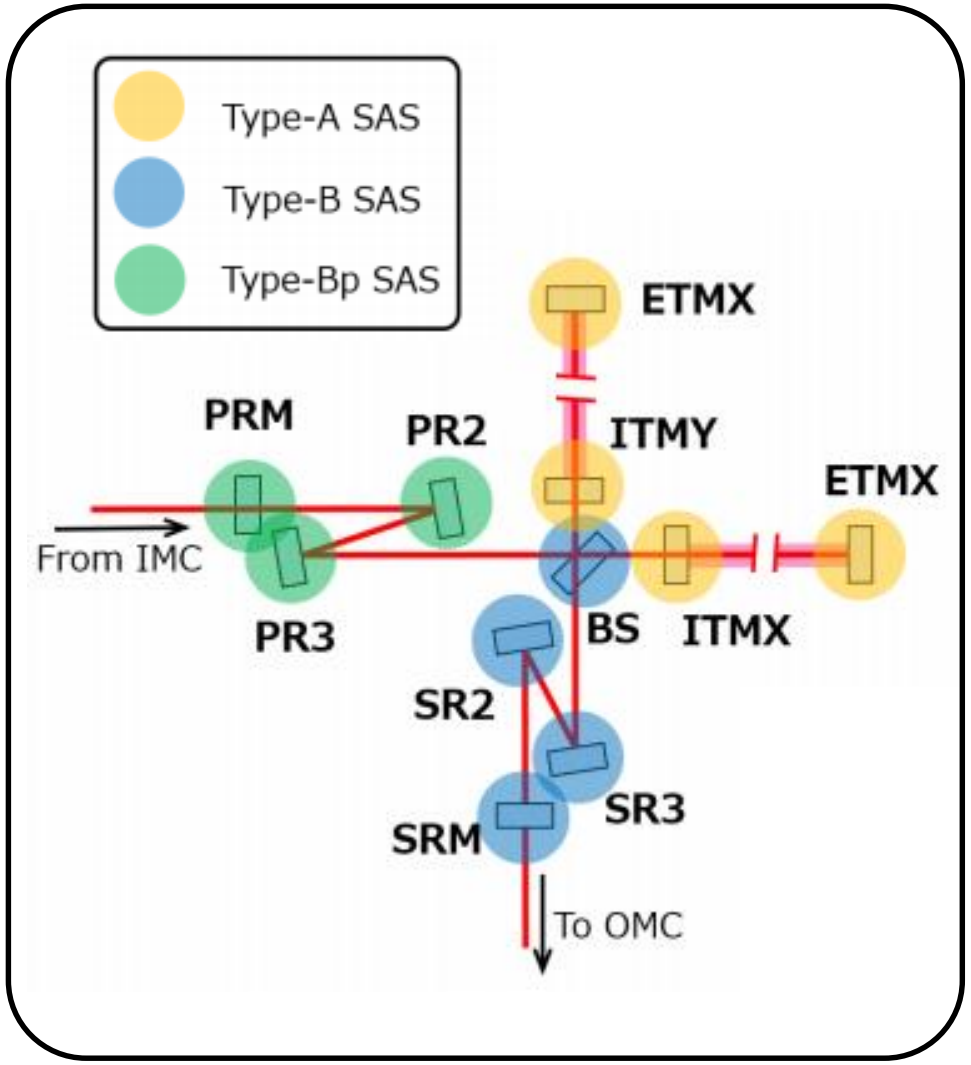
-- Servo filter implementation

-- Verification of suspension performance



# Type-A suspensions?



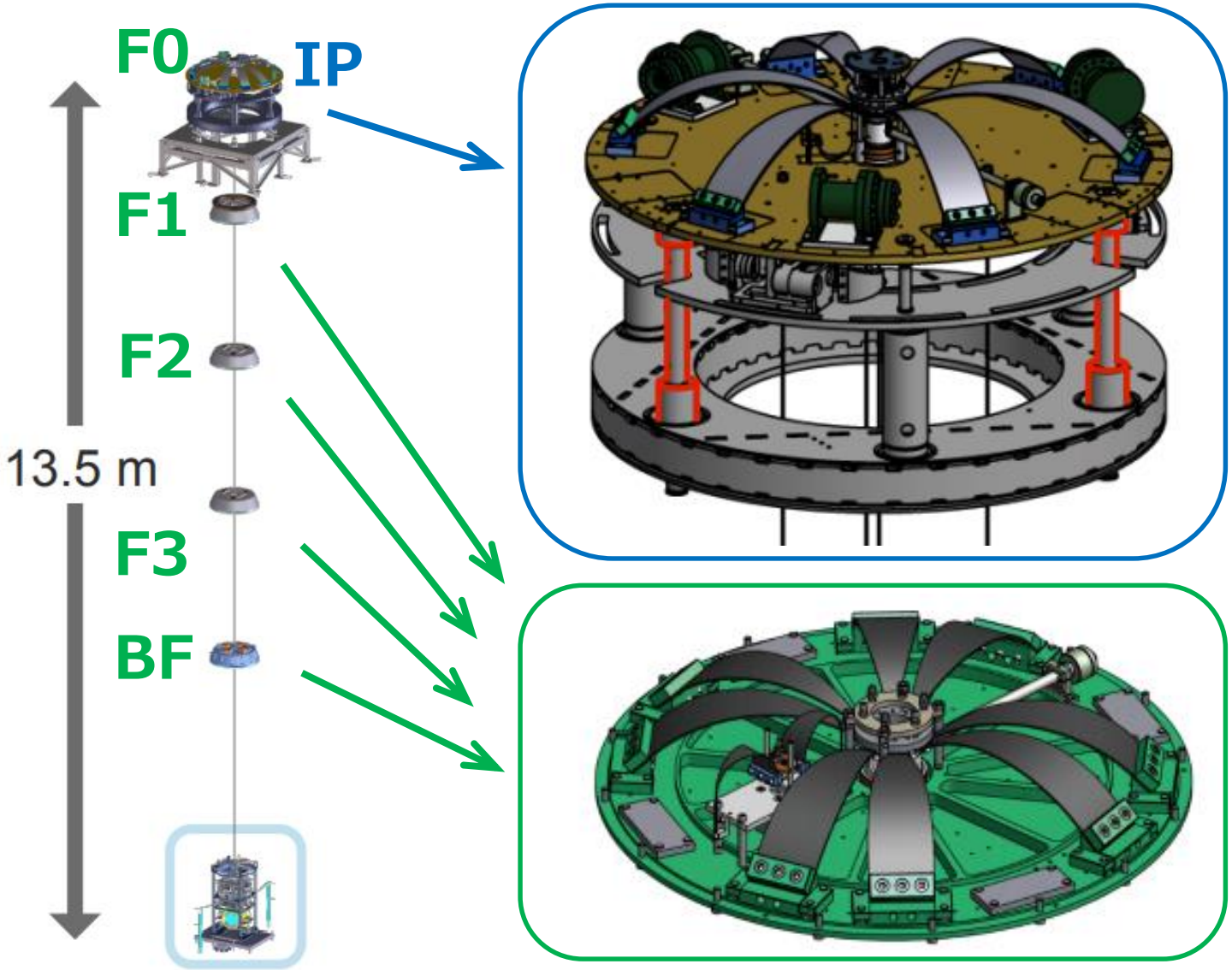




**For the test masses,**

- Upper 5 stages: room-temperature

- Lower 4 stages: cryogenic-temperature

# Type-A suspensions?



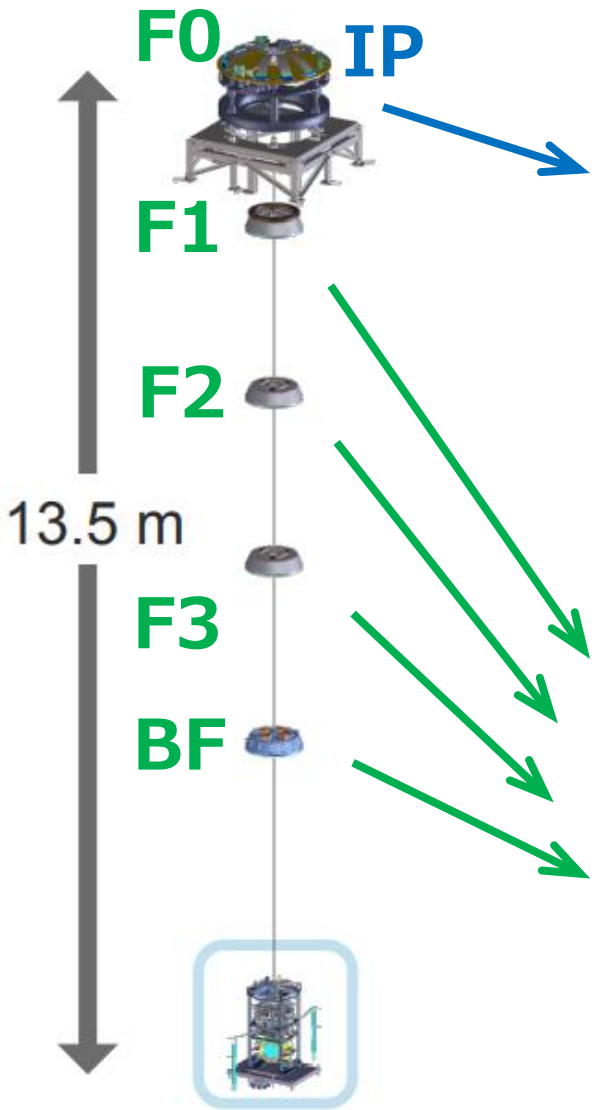


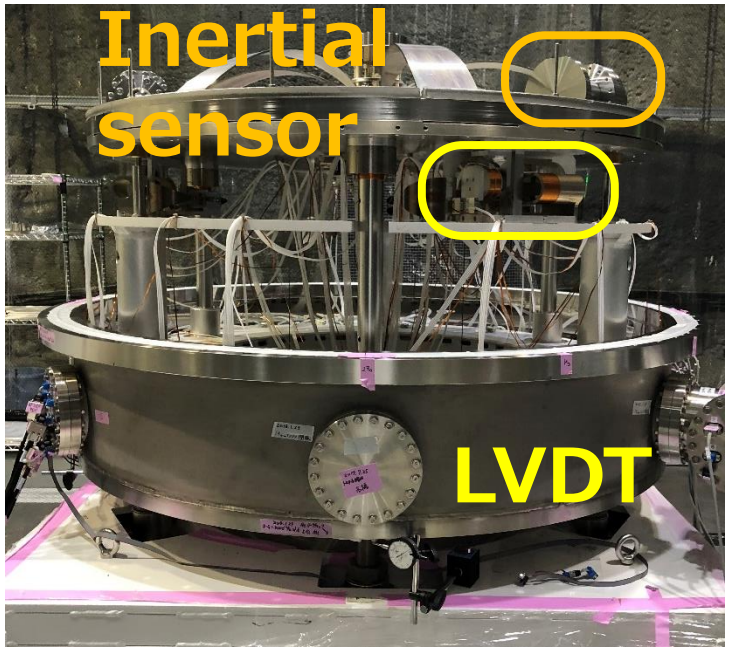

INVERTED PENDULUM
(~ 70 mHz)



GEOMETRIC-ANTI SPRING
(~ 0.4 Hz)

# Type-A suspensions?




## Inverted Pendulum

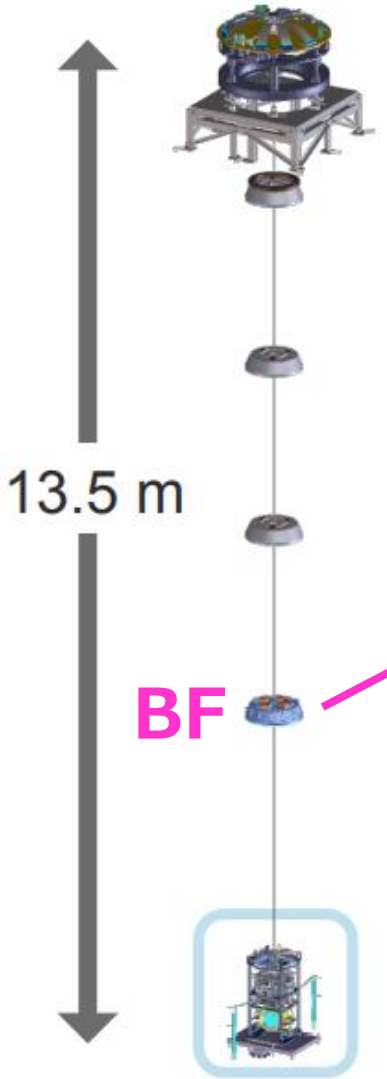
with 3 horizontal
-- LVDT & actuator units
-- inertial sensors


## Geometric-Anti Spring

with 1 vertical
LVDT & actuator unit

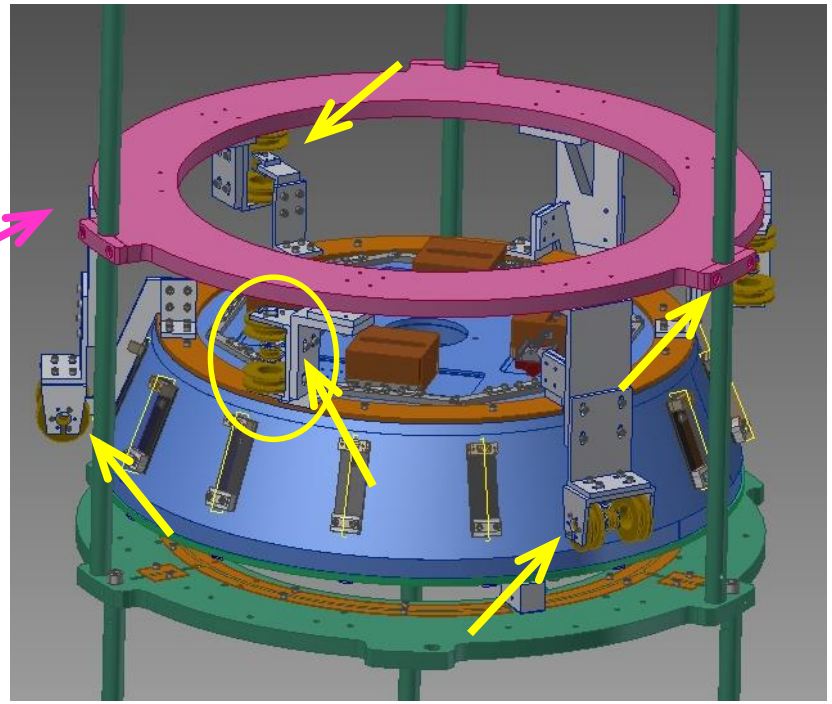
# Type-A suspensions?

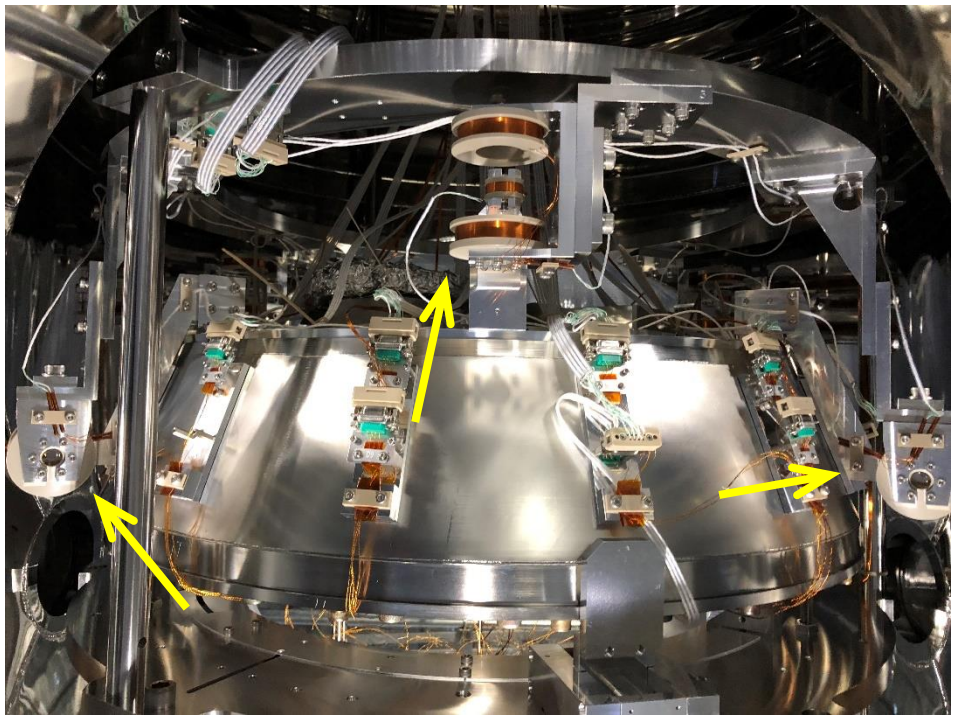
(With collaboration of group in Pisa)




## BOTTOM-FILTER DAMPER

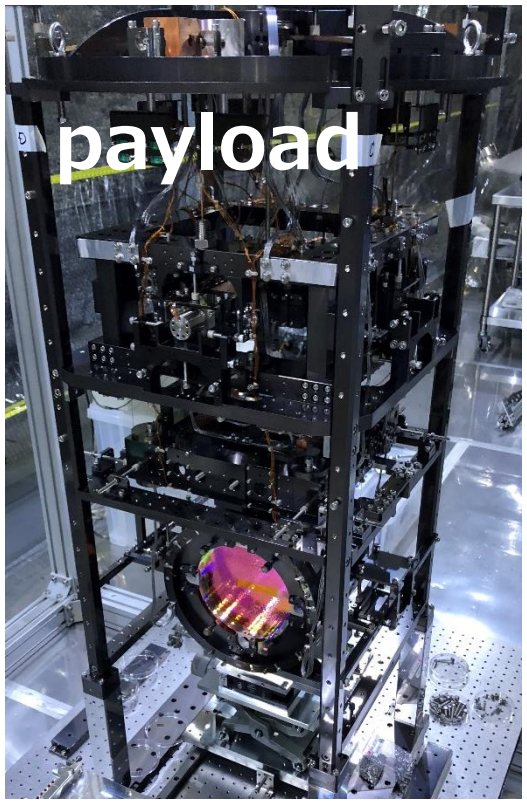
with 3 horizontal & 3 vertical LVDT & actuator units



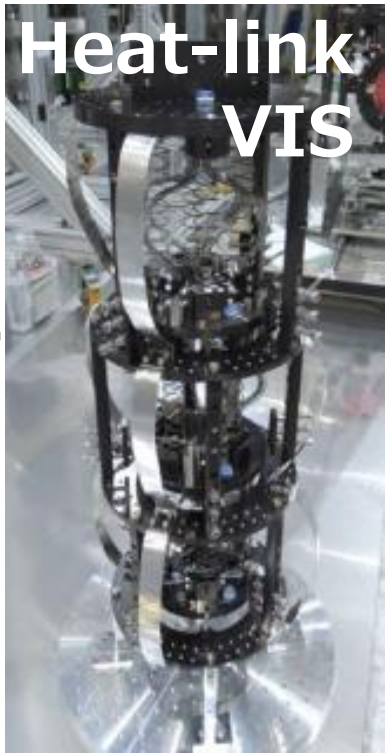


# Type-A suspensions?

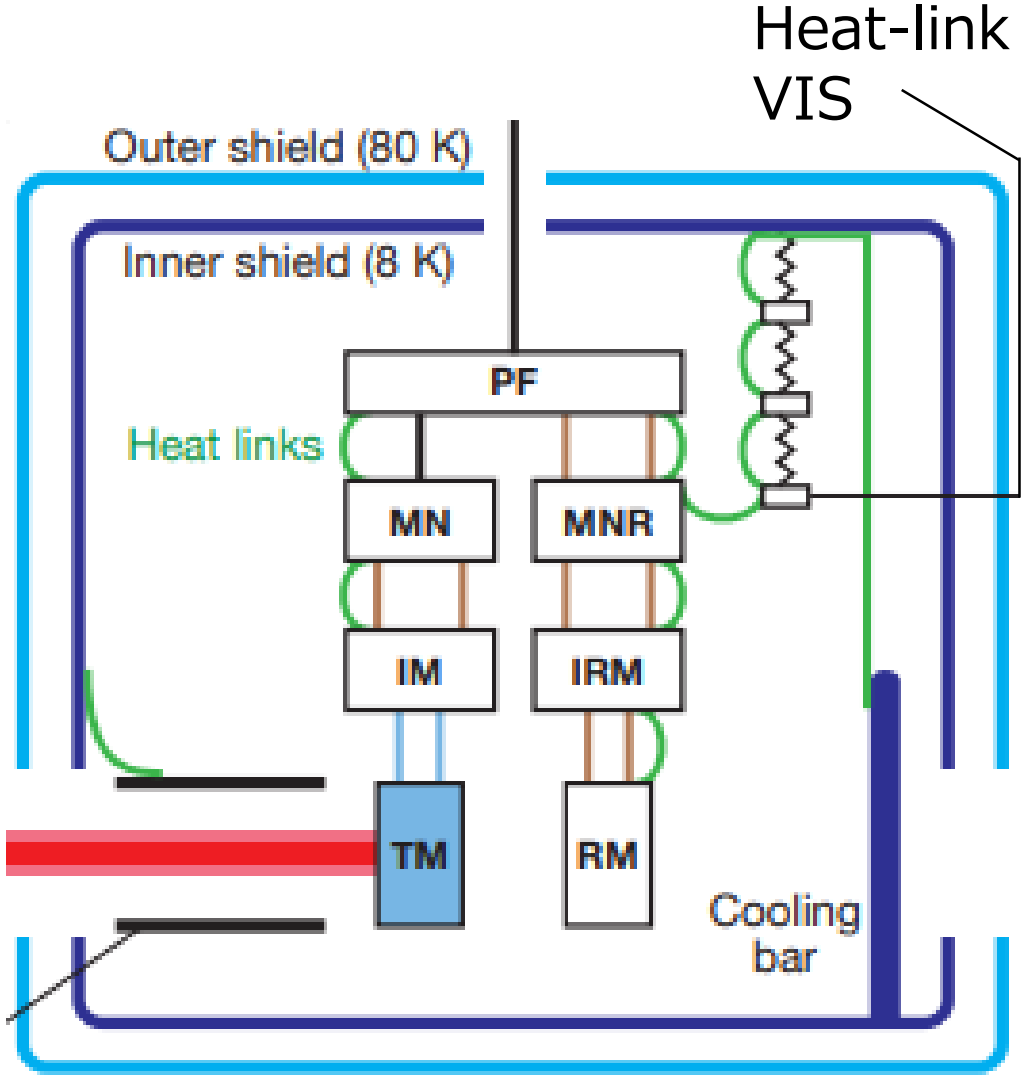

## Inside cryostat




+




(+ Wide-angle baffle)

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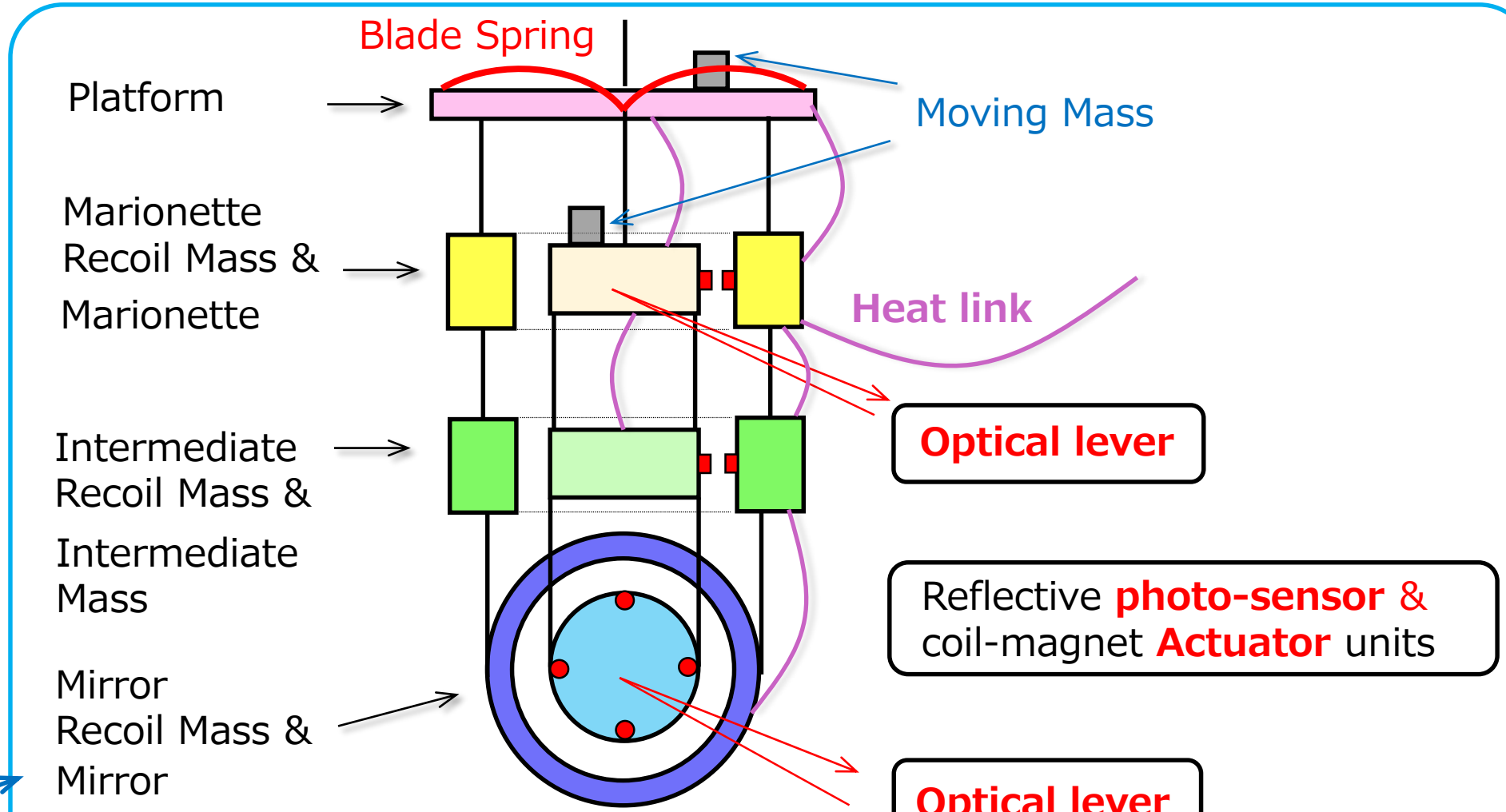
# Type-A suspensions?

Then, mechanical installation status

for O3-observation

# Mechanical installation has done! For all 4 of them!



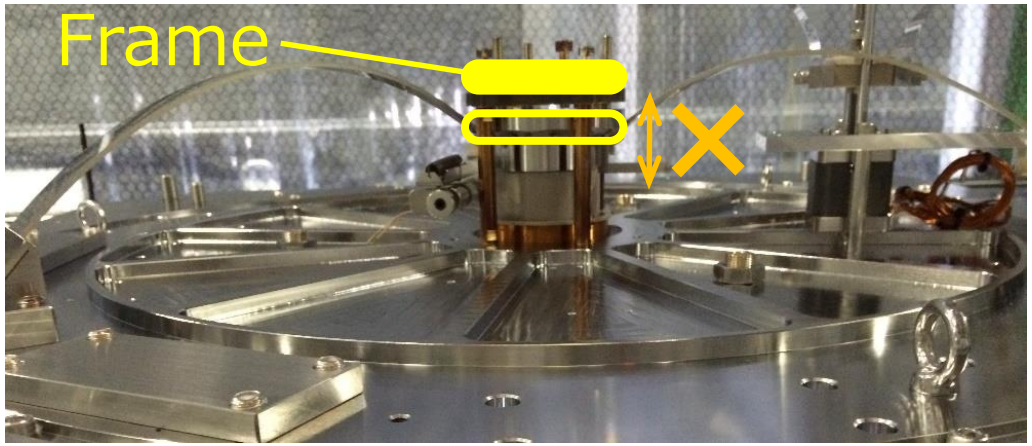
(Still mechanical-wise repairing work exits though..)

# Mechanical installation has done! HOWEVER ..

## ETMX & ETMY:

for ETMX - F2 GAS
for ETMY - F1 & F2 GAS

**Hitting,, ~No oscillation**

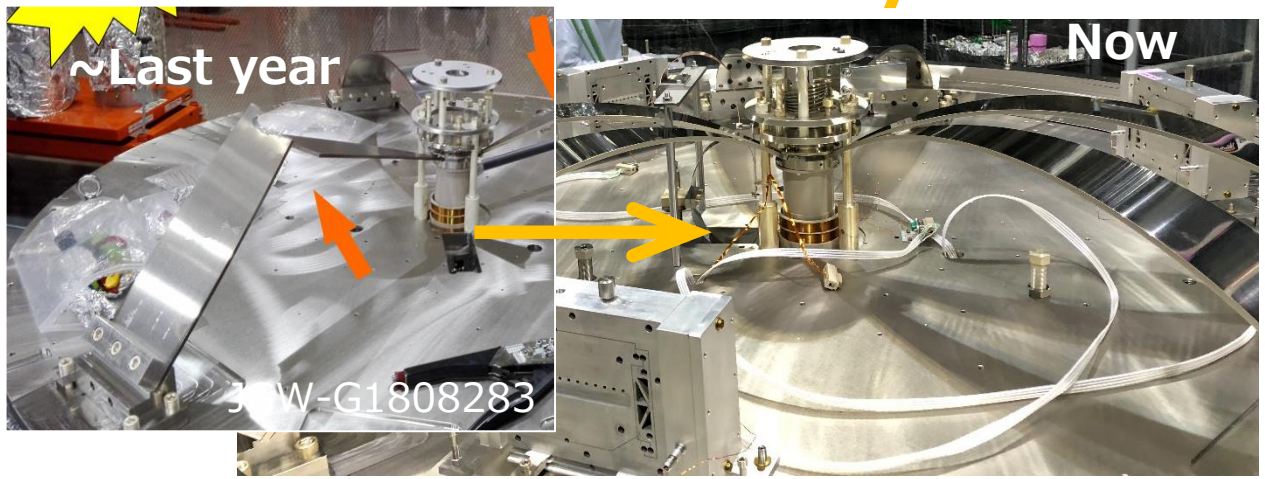



Mass tuning, necessary
but no accessibility.

## ITMX & ITMY:

for ITMX / ITMY – F0 GAS

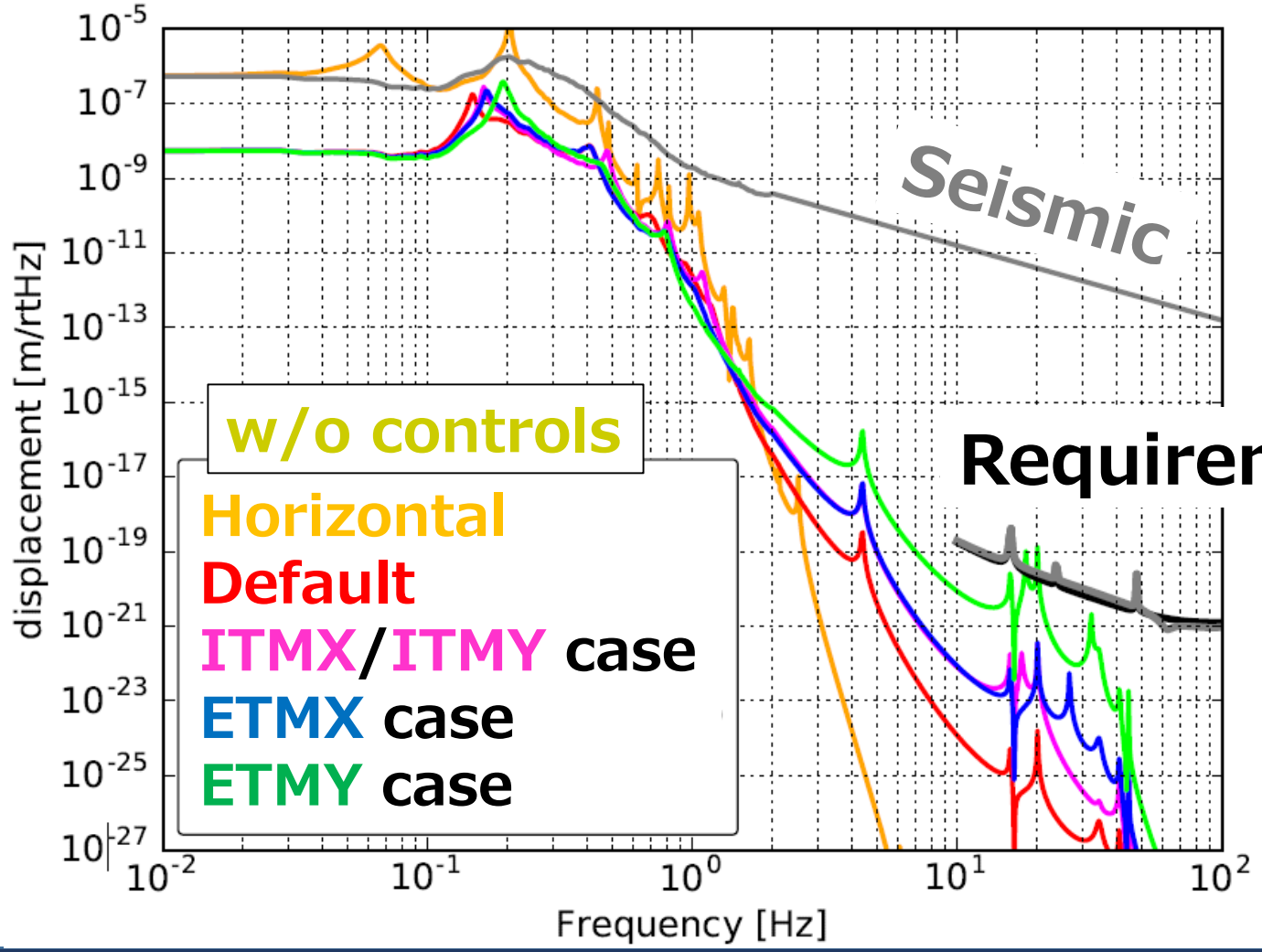
**Newly made blades
could not hold the system..**




Blade replacement, necessary
but time consuming (etc).

# Mechanical installation has done! HOWEVER ..

According to a simulation, assuming 1% coupling,




"acceptable
for the O3-run"

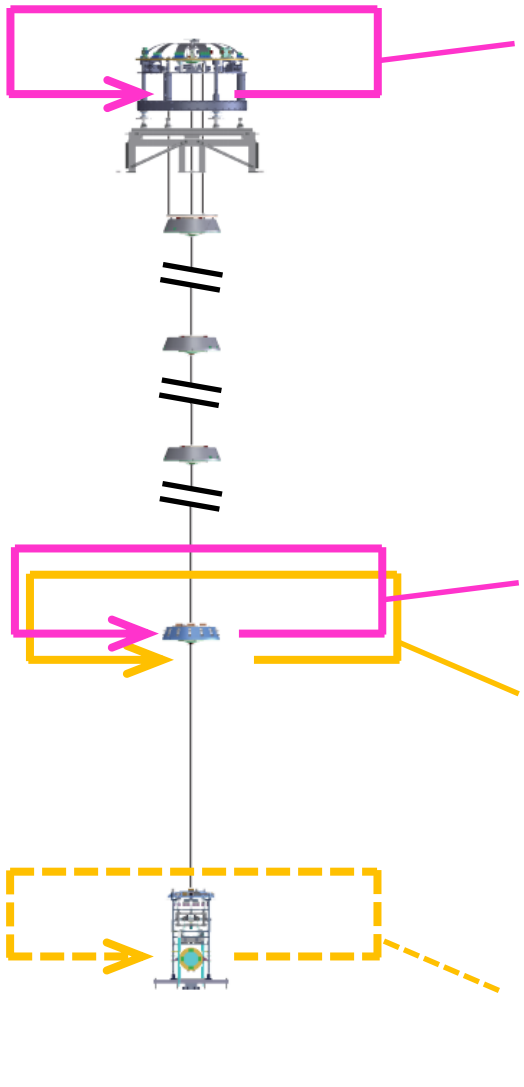
(should be)

Note:
-- Modeled w/o Heat-links
-- params are not tuned.

# Servo filter implementation status

# With displacement sensors, [ for damping ]

**IP**



DC+Damp

For L / T / Yaw

**BF-damper**

DC+Damp

For Yaw

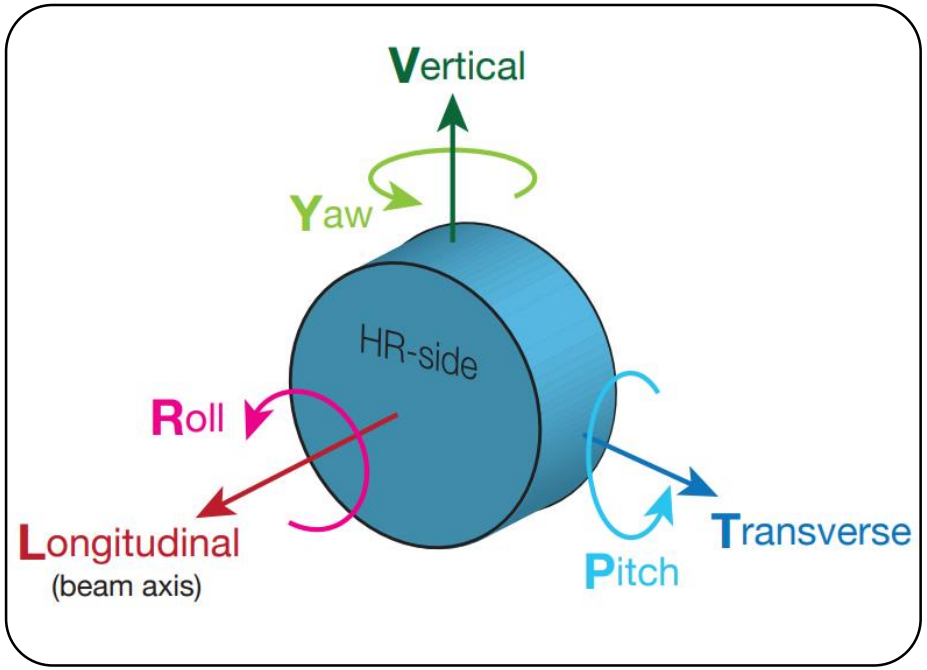
For L / T

Damp

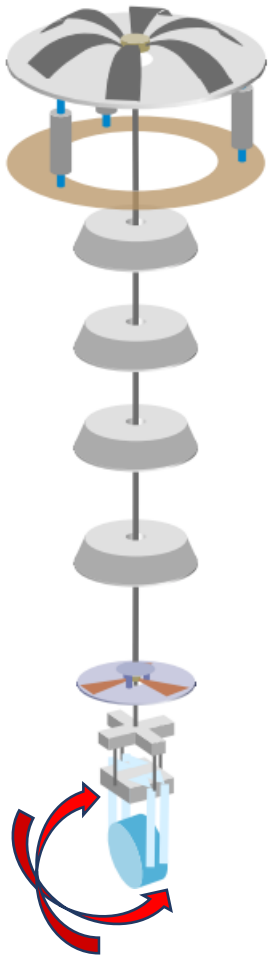
(TMoplev)

Damp

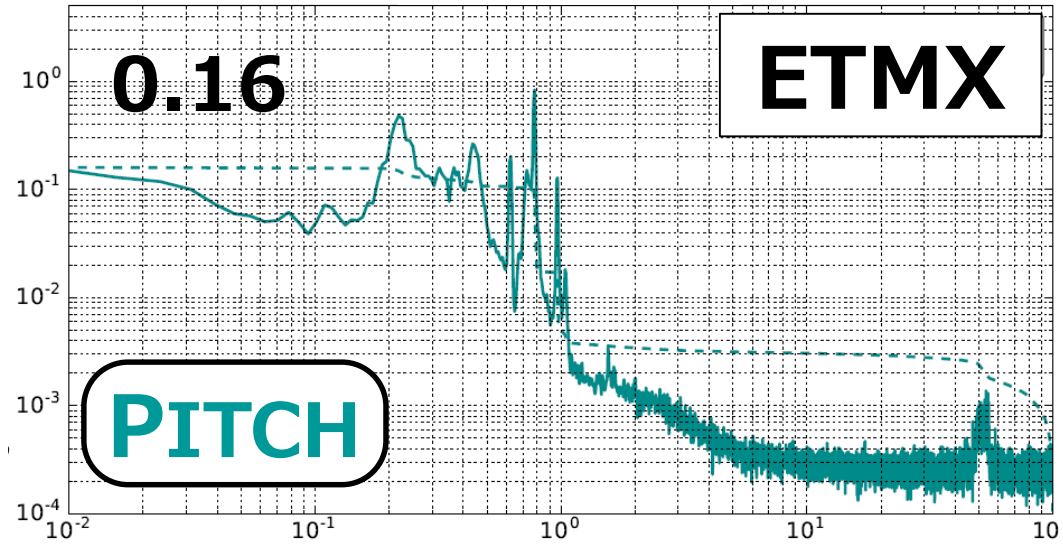
For P / Y

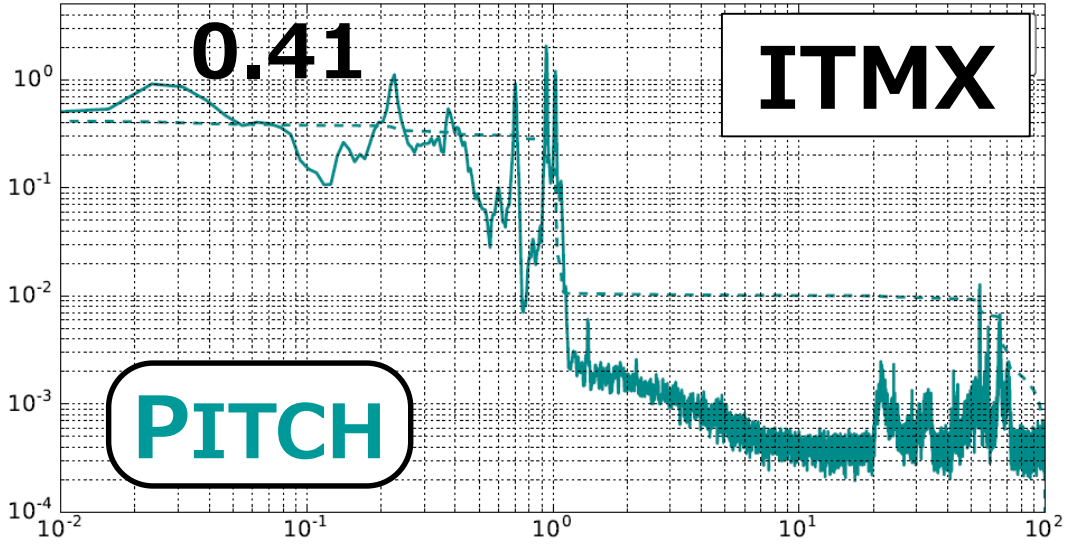


# With displacement sensors, [ residuals ]

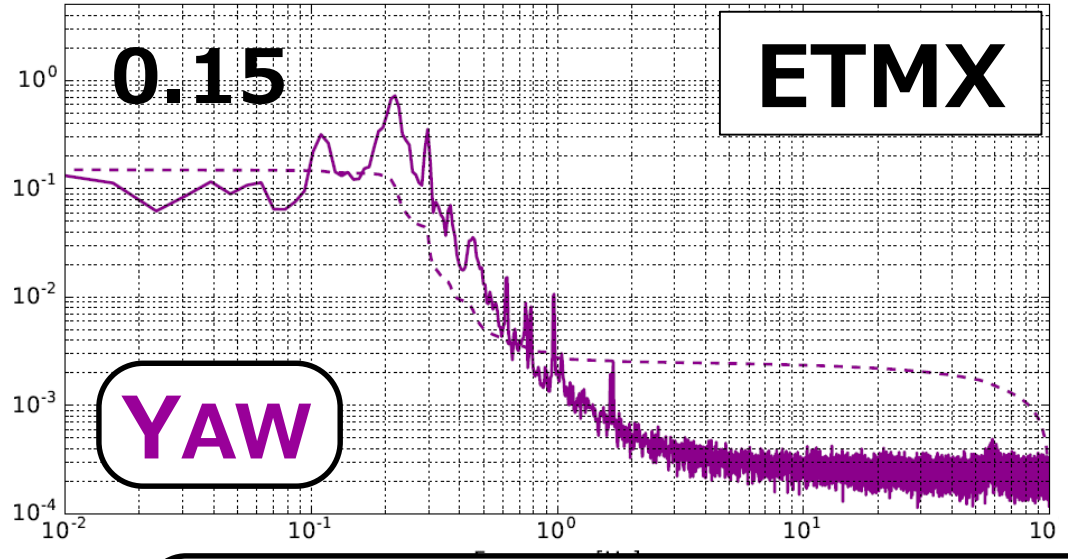


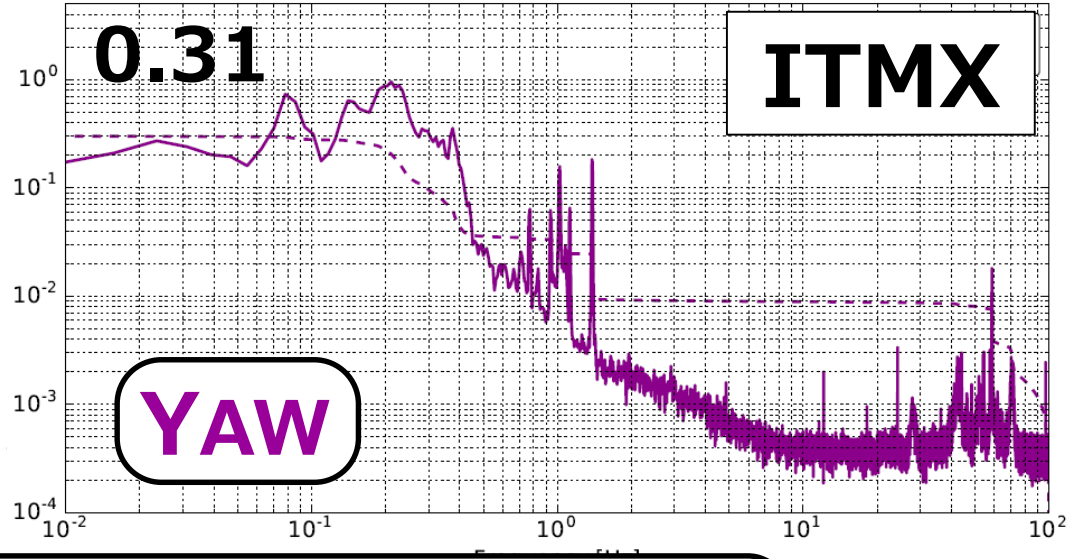
[ urad/rtHz ] or [urad]



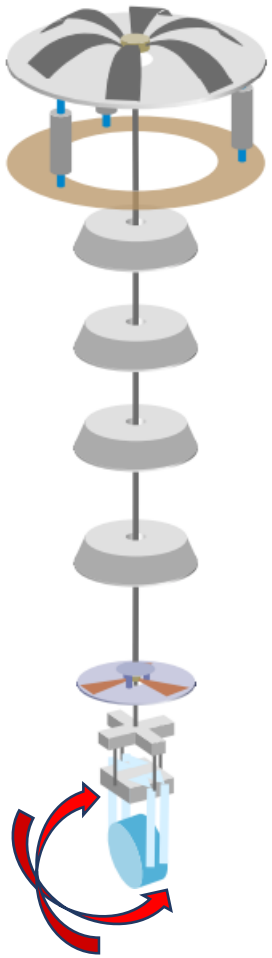

[ urad/rtHz ] or [urad]



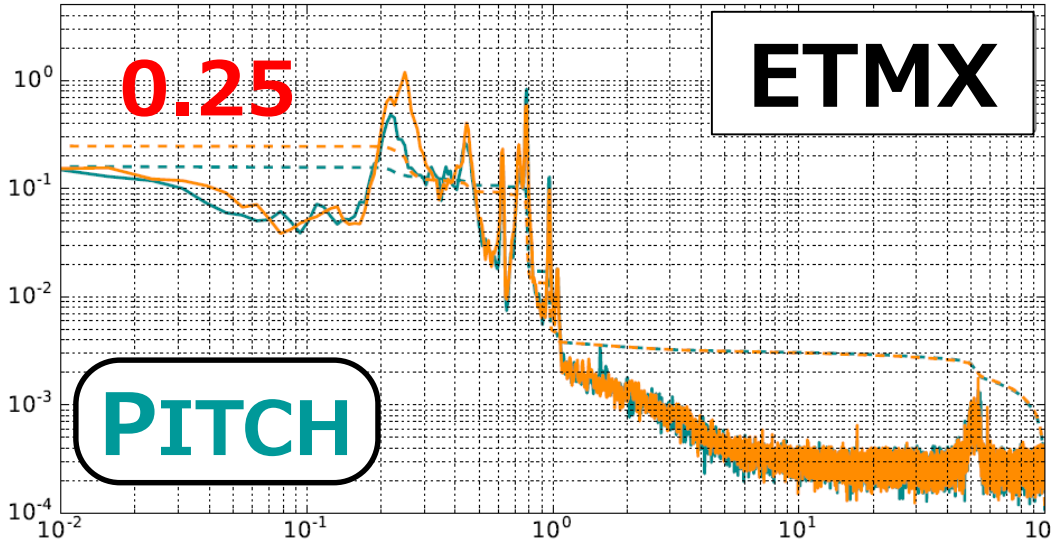



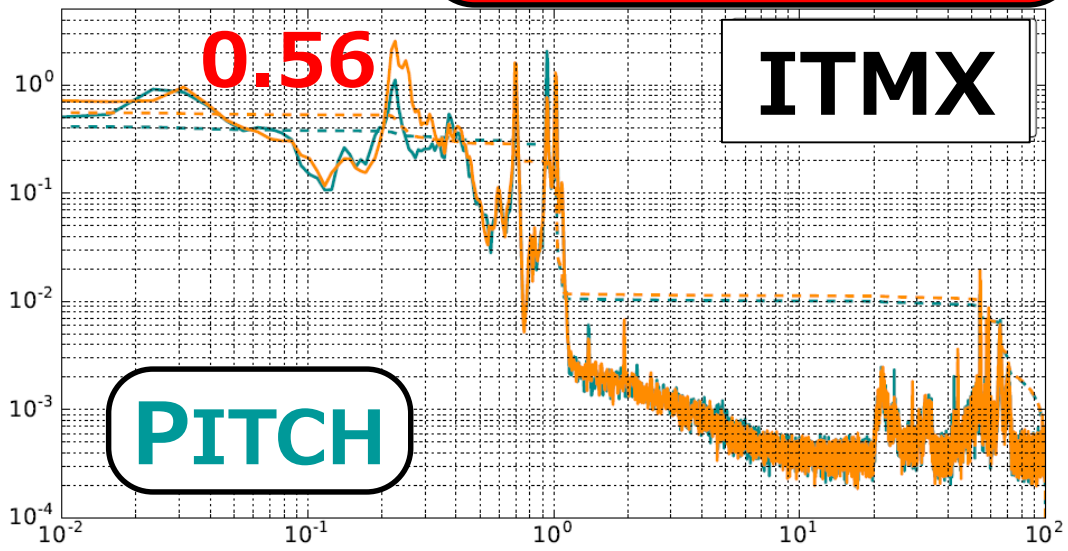

**Locked! Thanks to Kamioka environment.**

# With displacement sensors, [ residuals ] In bad weather

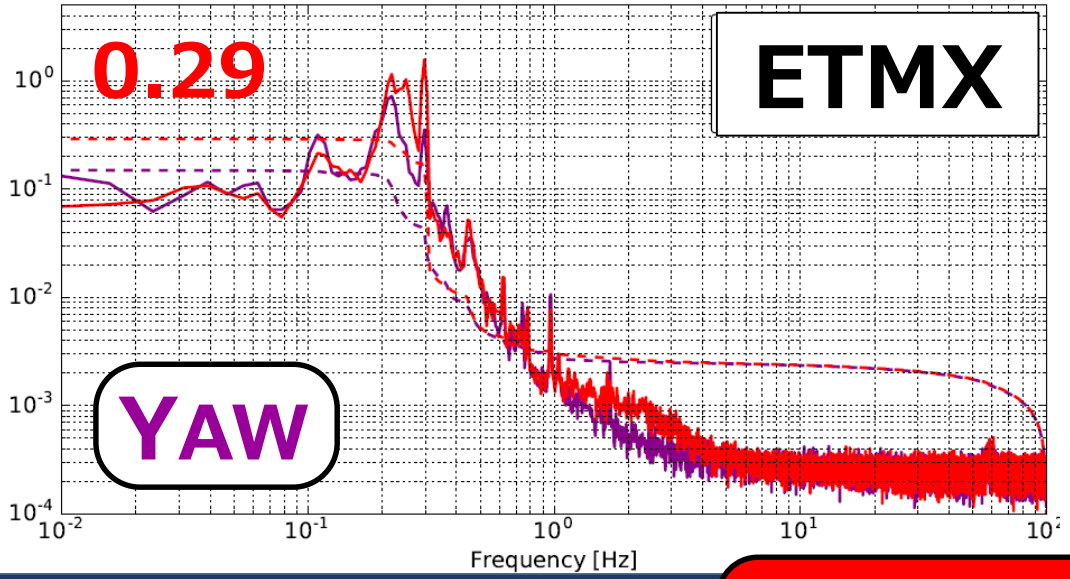


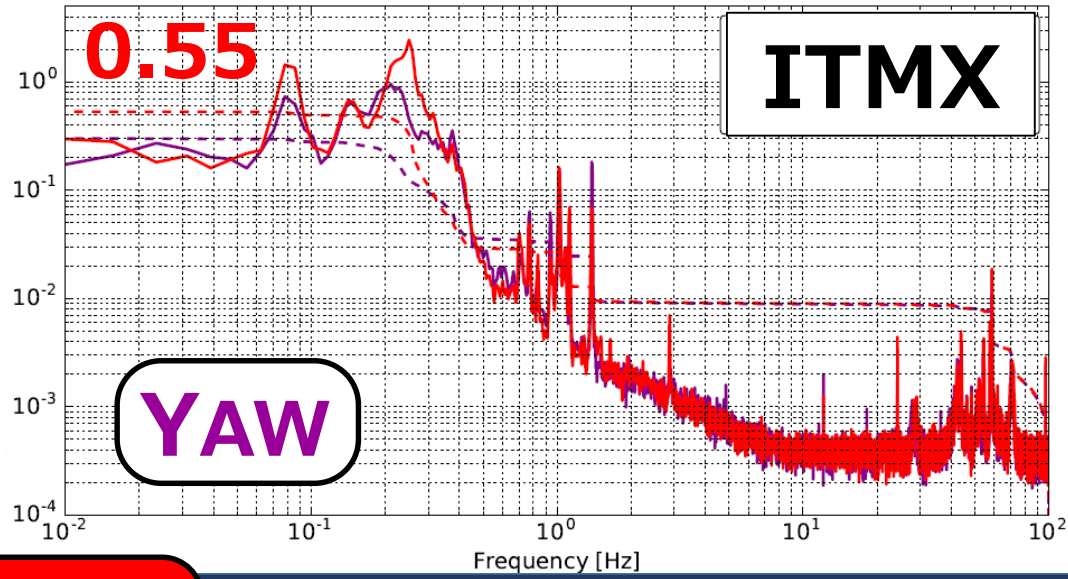
[ urad/rtHz ] or [urad]




[ urad/rtHz ] or [urad]

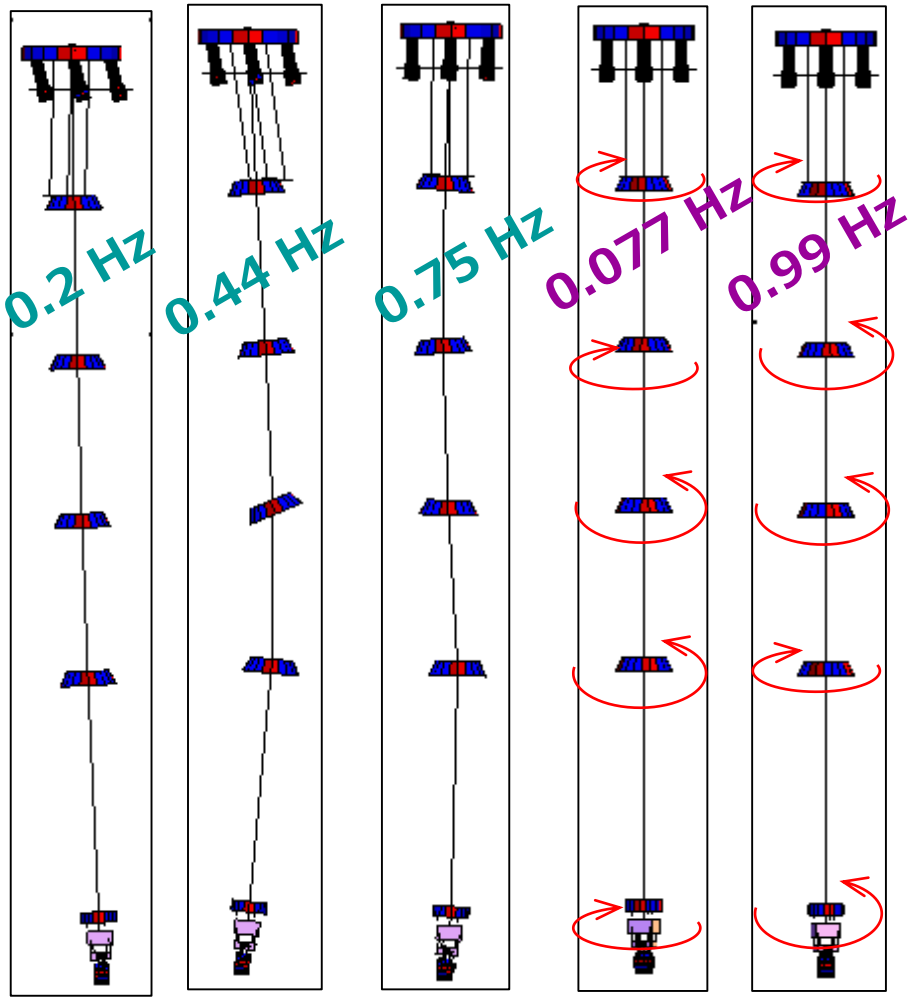


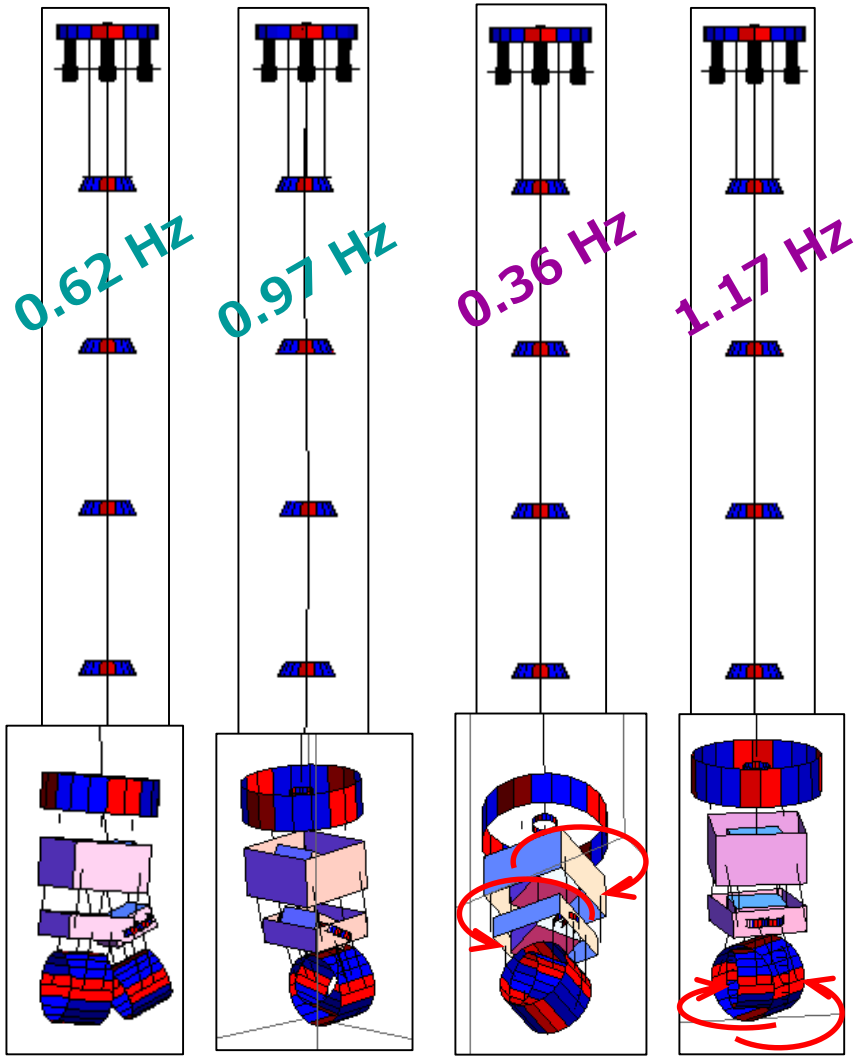

*NOT* locked..

# Candidate (main) resonant modes?

Preliminary




→ Inertial damping at IP
→ damping at tower part

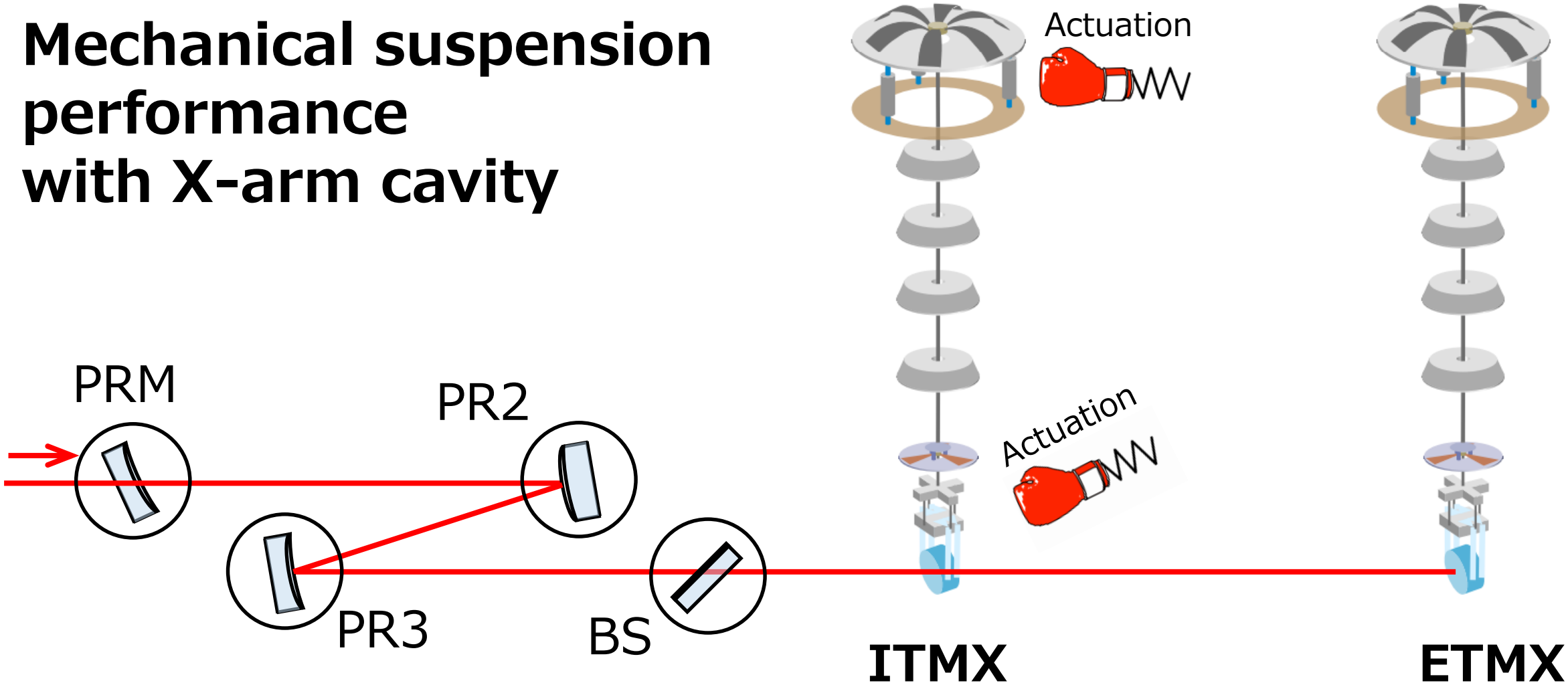



→ damping at payload

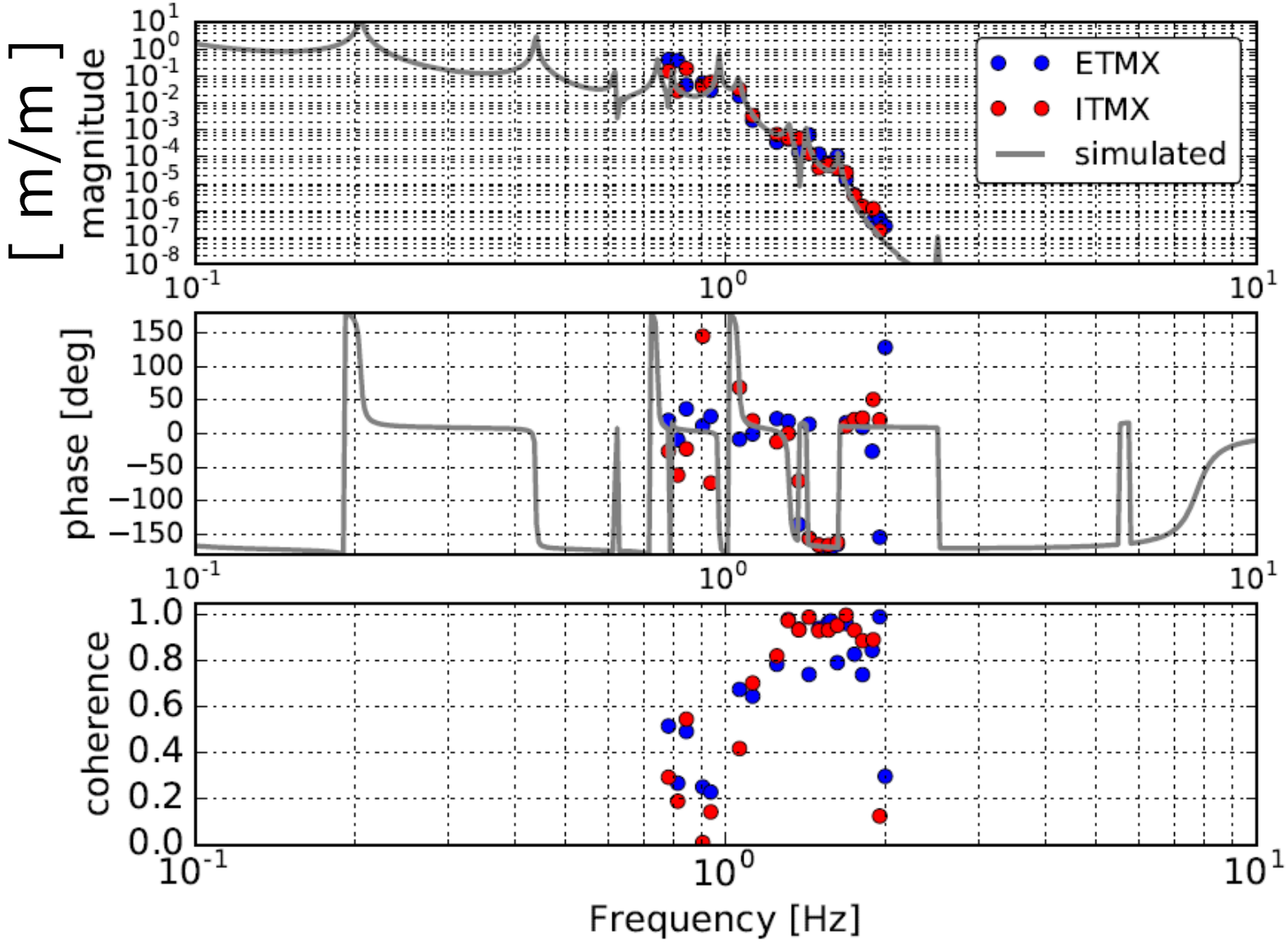
# Verification of suspension performance

# Measurement:

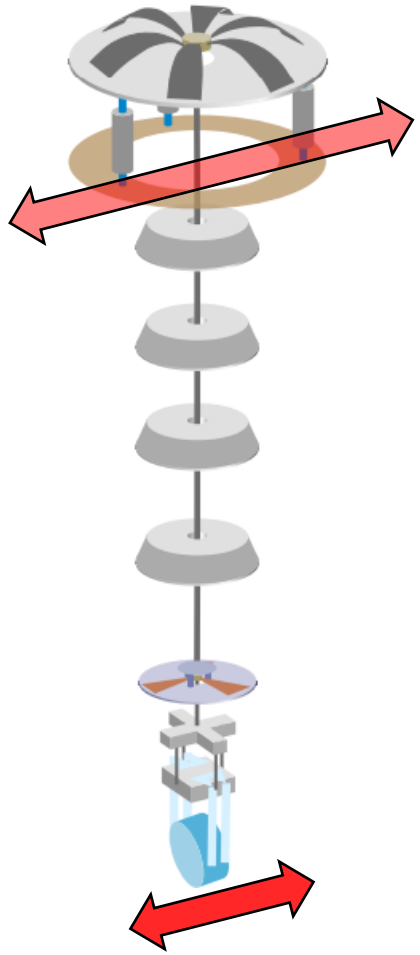
## Mechanical suspension performance with X-arm cavity



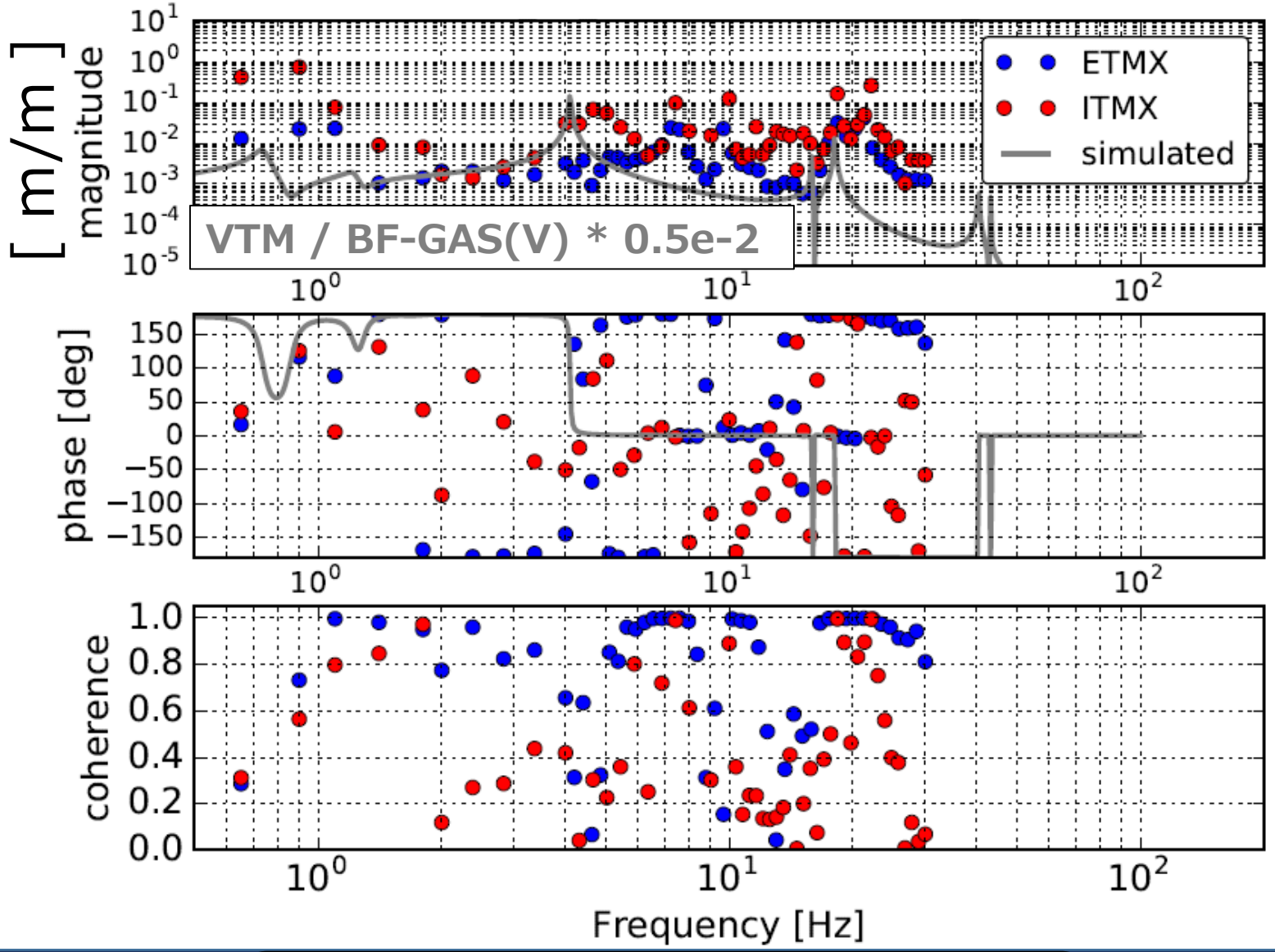
# Vibration isolation ratio, [ Good news! ]



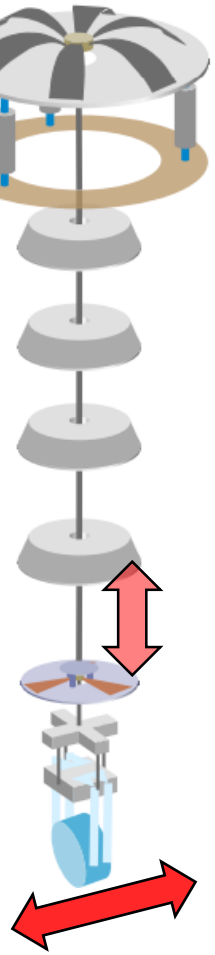

From ground to TM



# V to L coupling, [ System is not yet identified.. ]




From BF-GAS to TM



Real was not so simple..

# Summary:

-- All the Type-A suspensions have been installed.
-- Damping controls are working properly, however, some resonances are not yet damped efficiently.
- ☐ Implement damping controls at payload stages

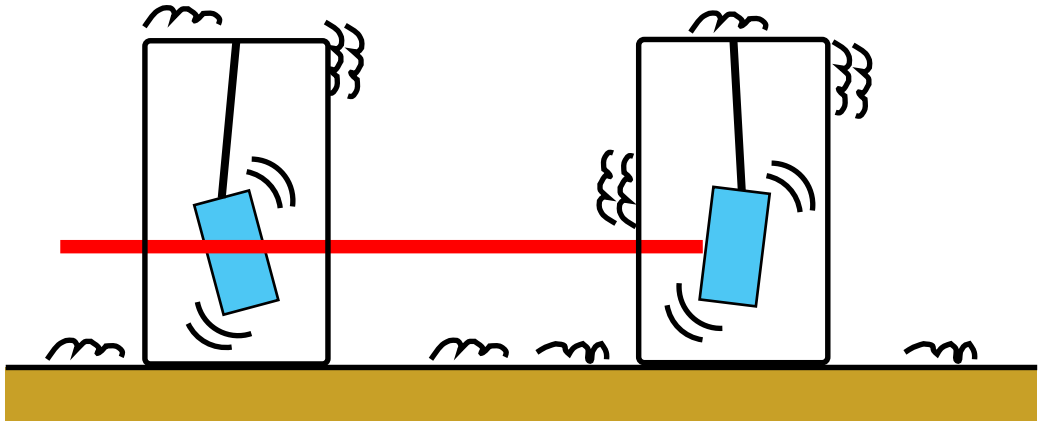
-- Reducing RMS is necessary when the seismic noise is high.
- ☐ Implement inertial damping at IP stage

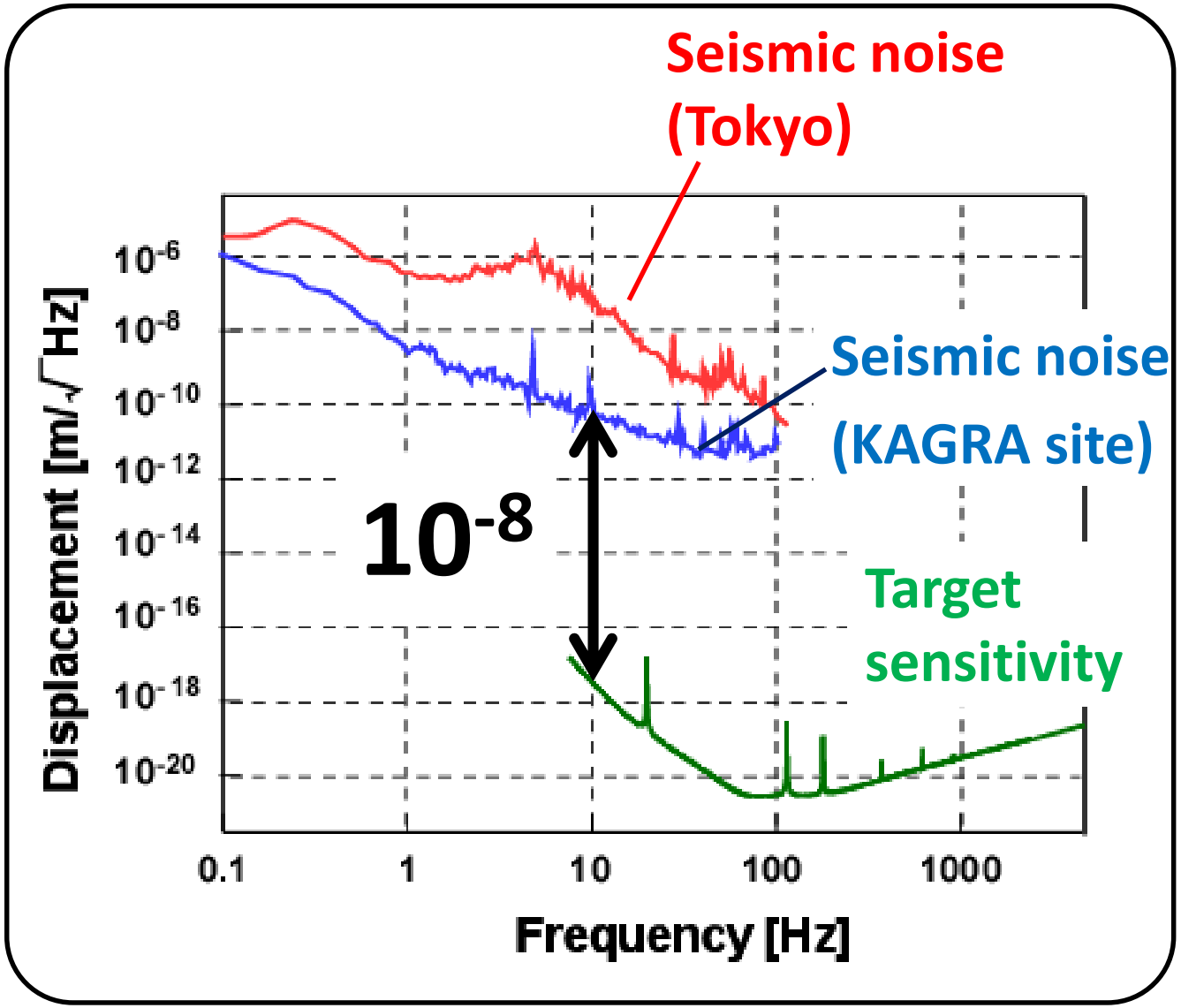
# For soon next:

- ☐ Do mode identification including the heat-link peaks
- ☐ Design the filters in the observation phase.

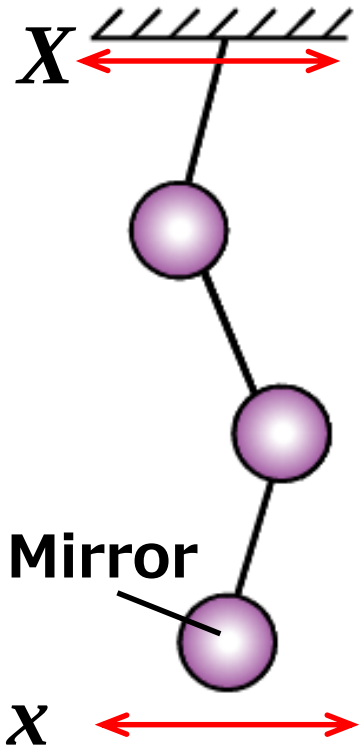
# Backup

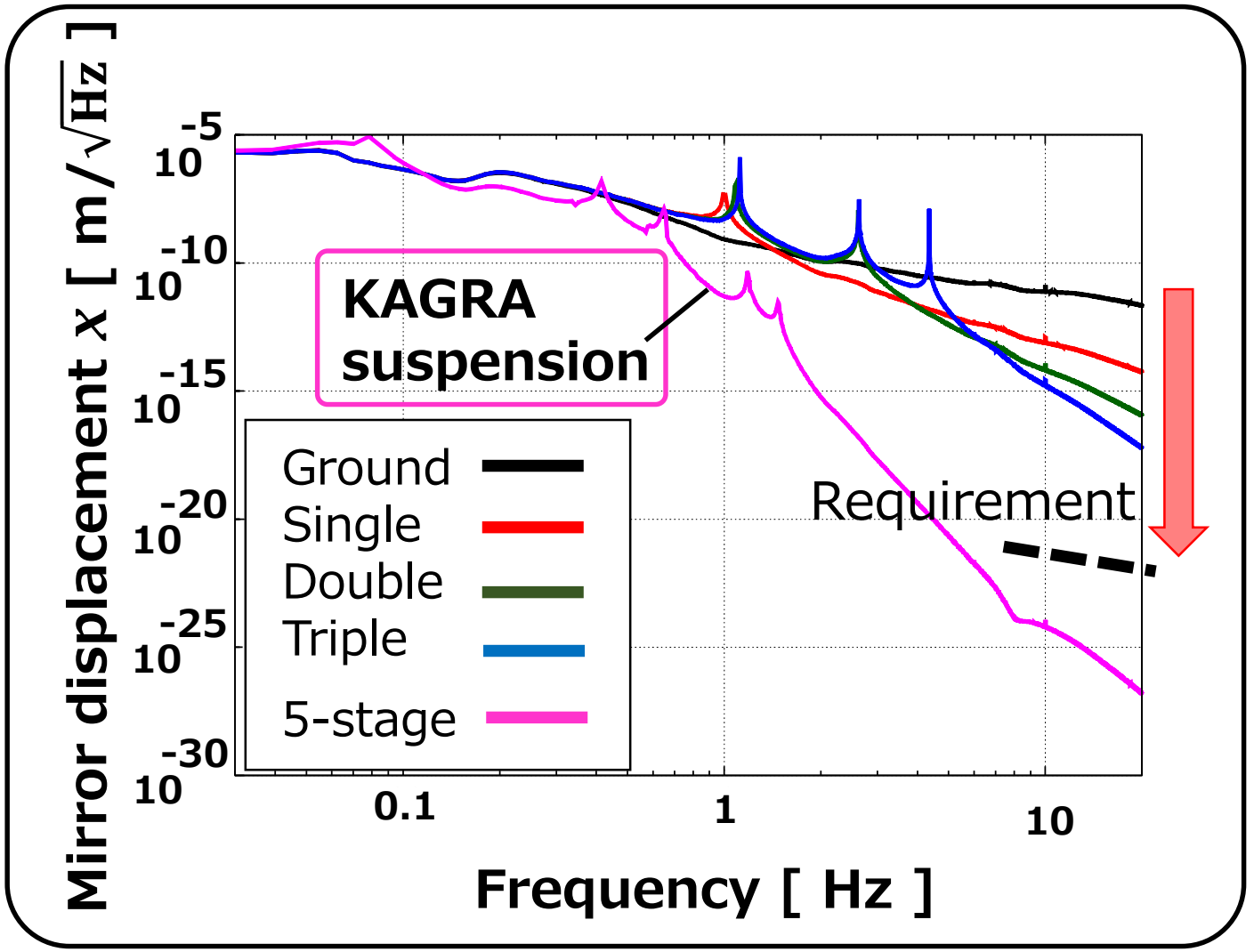
# Seismic noise



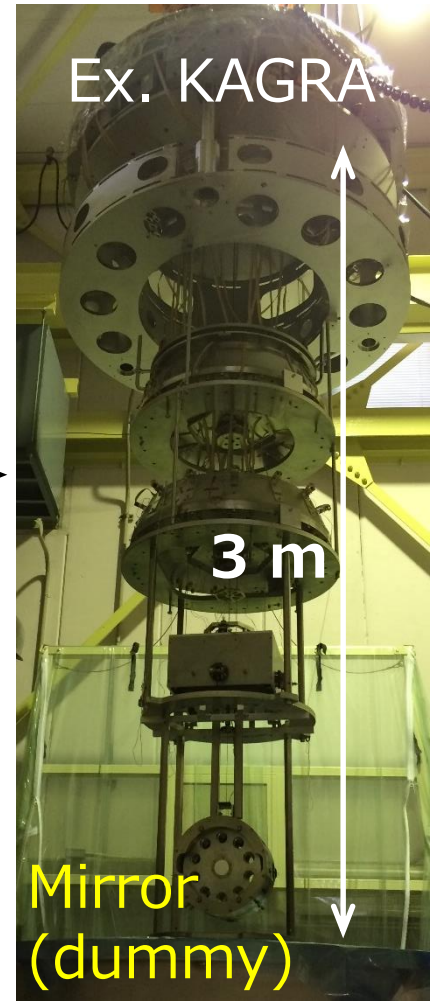


# Seismic attenuation



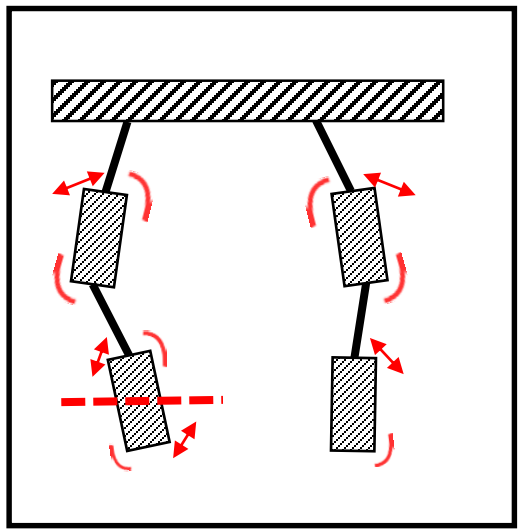




(Type-B suspension case)

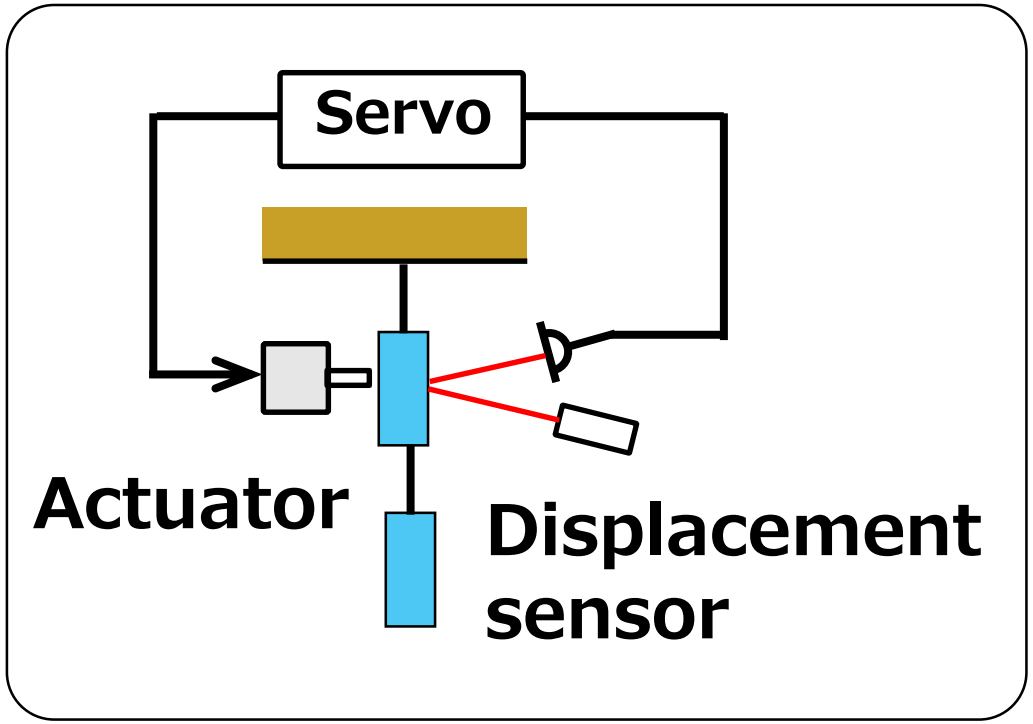


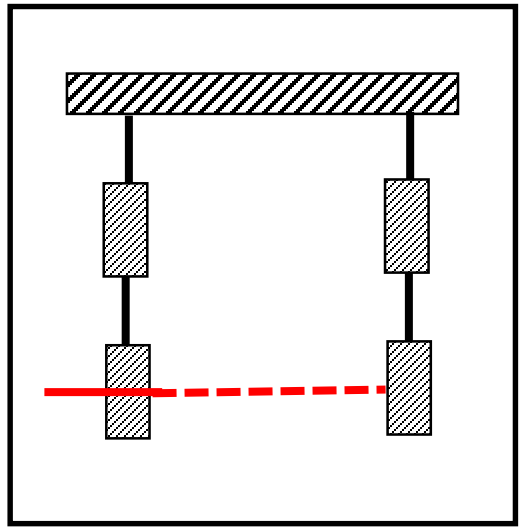
# Resonance damping

→ *Active control*



Starting interferometer operation

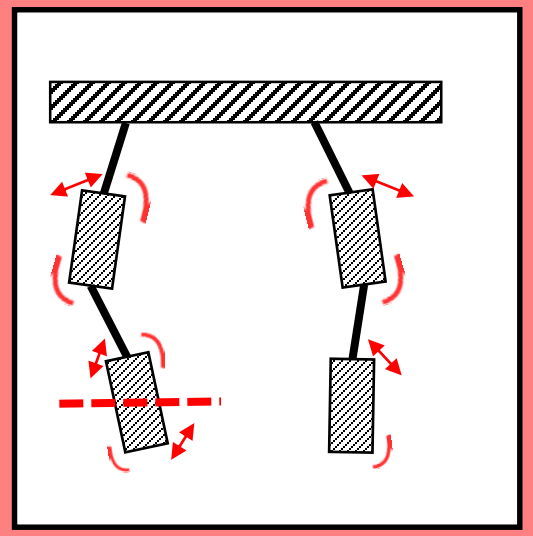


Stable interferometer operation

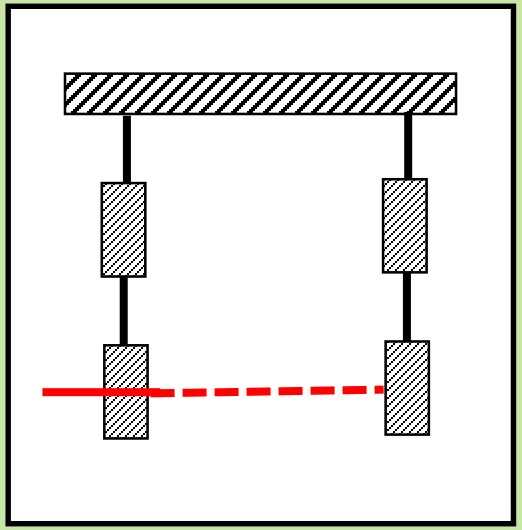
# Designing active control system / Control phase

## 1. Calm-down phase



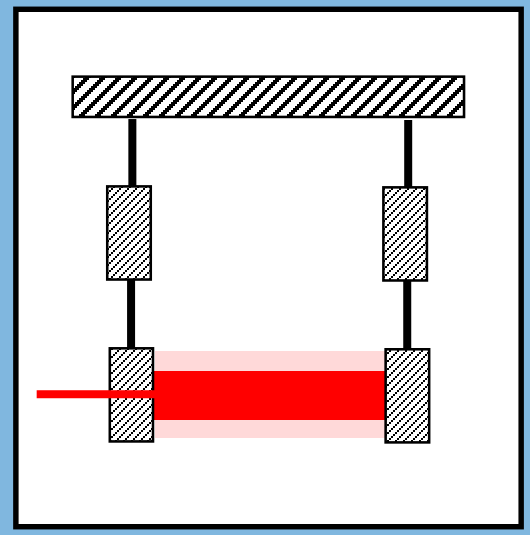
Suppress
large disturbance

## 2. Lock-acquisition phase



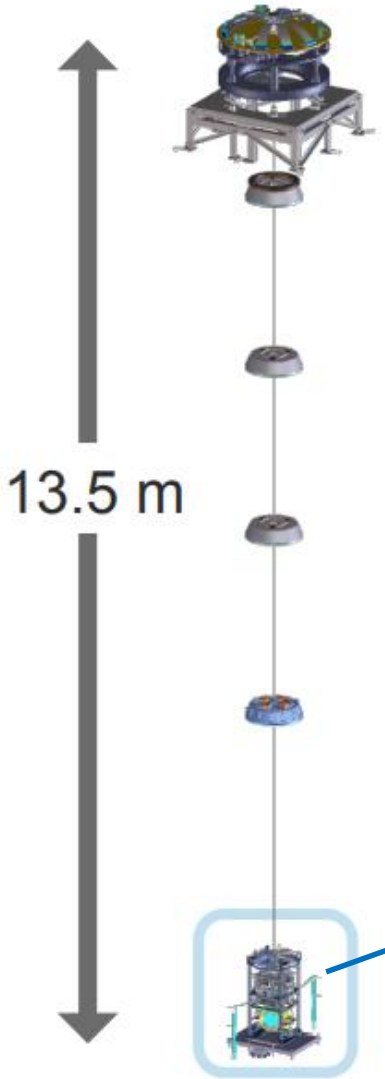
Reduce RMS velocity
RMS angle
(Root-Mean-Square)

## 3. Observation phase

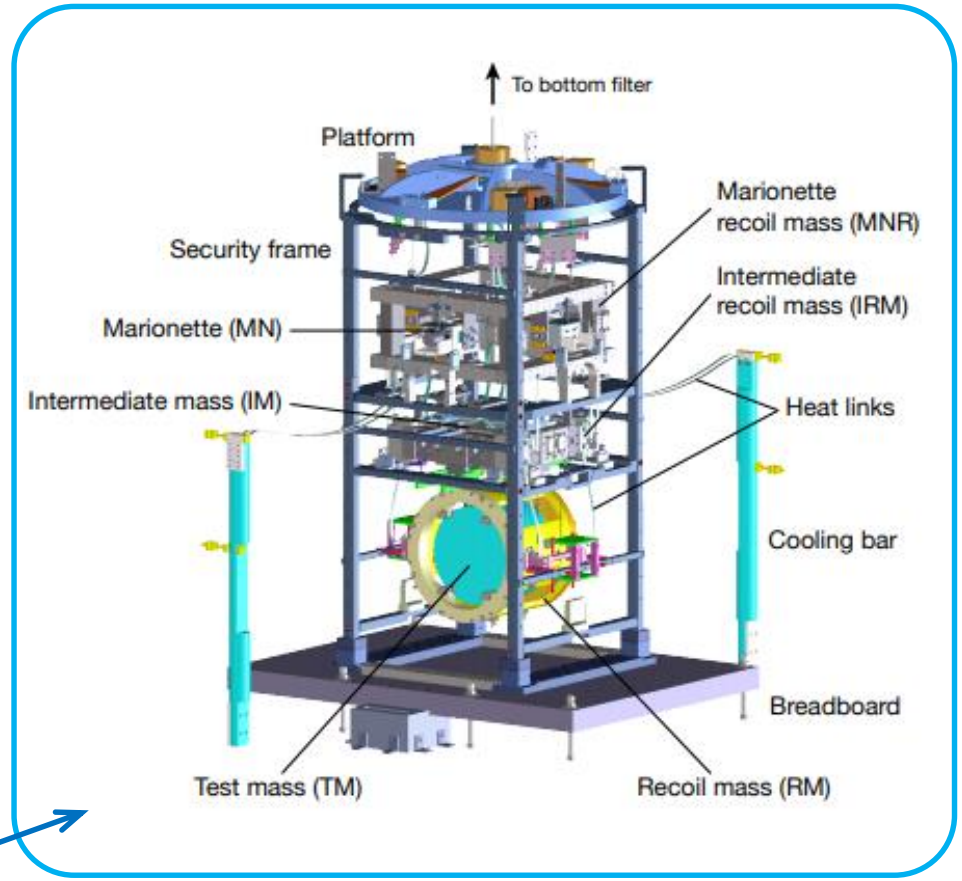


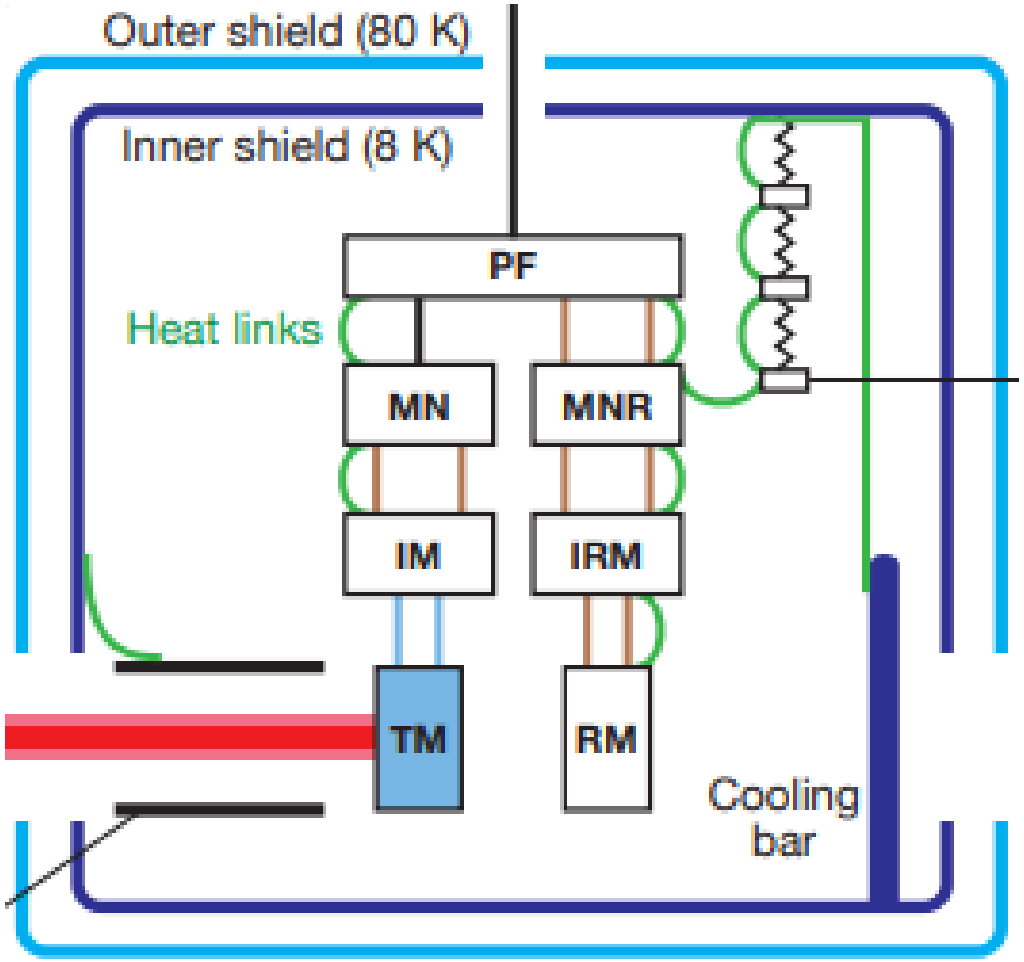
Keep position
with low noise
control

# Type-A suspensions?




## Inside cryostat

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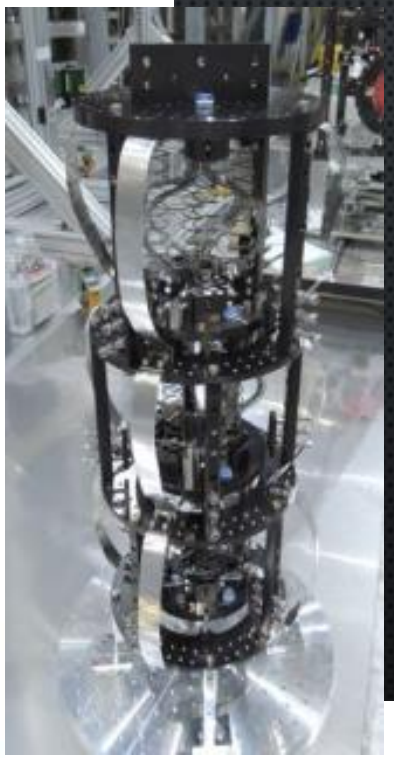
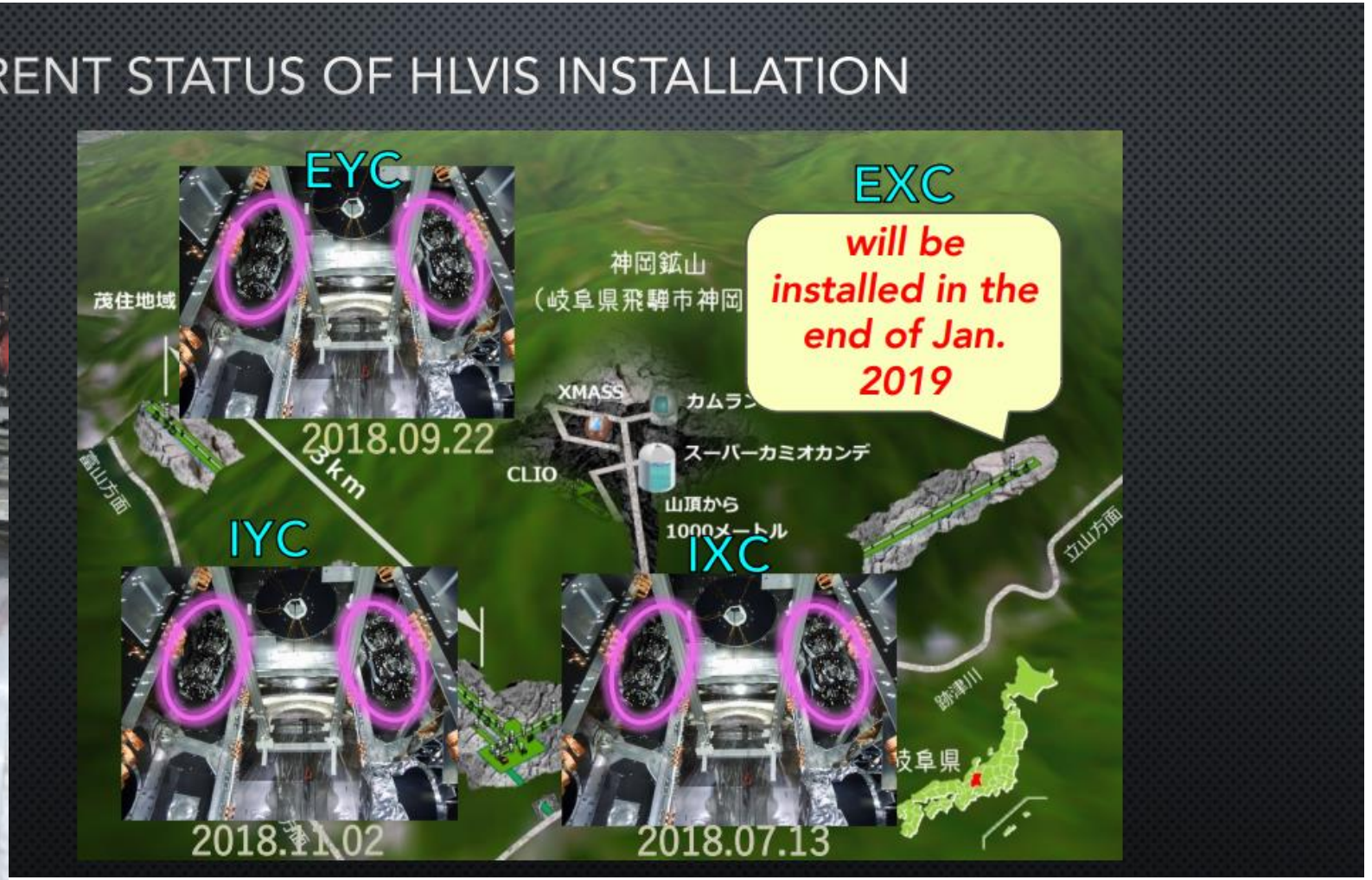
# Type-A suspensions?

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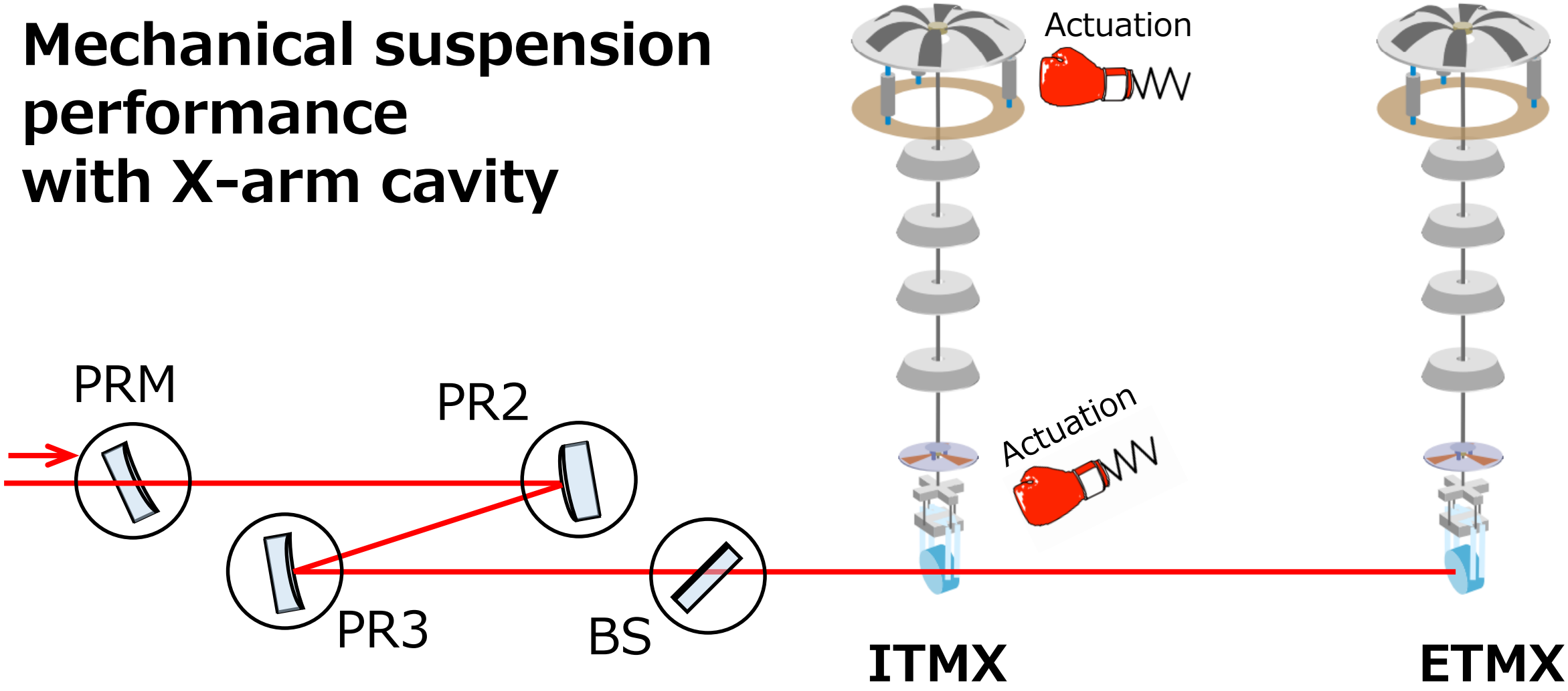
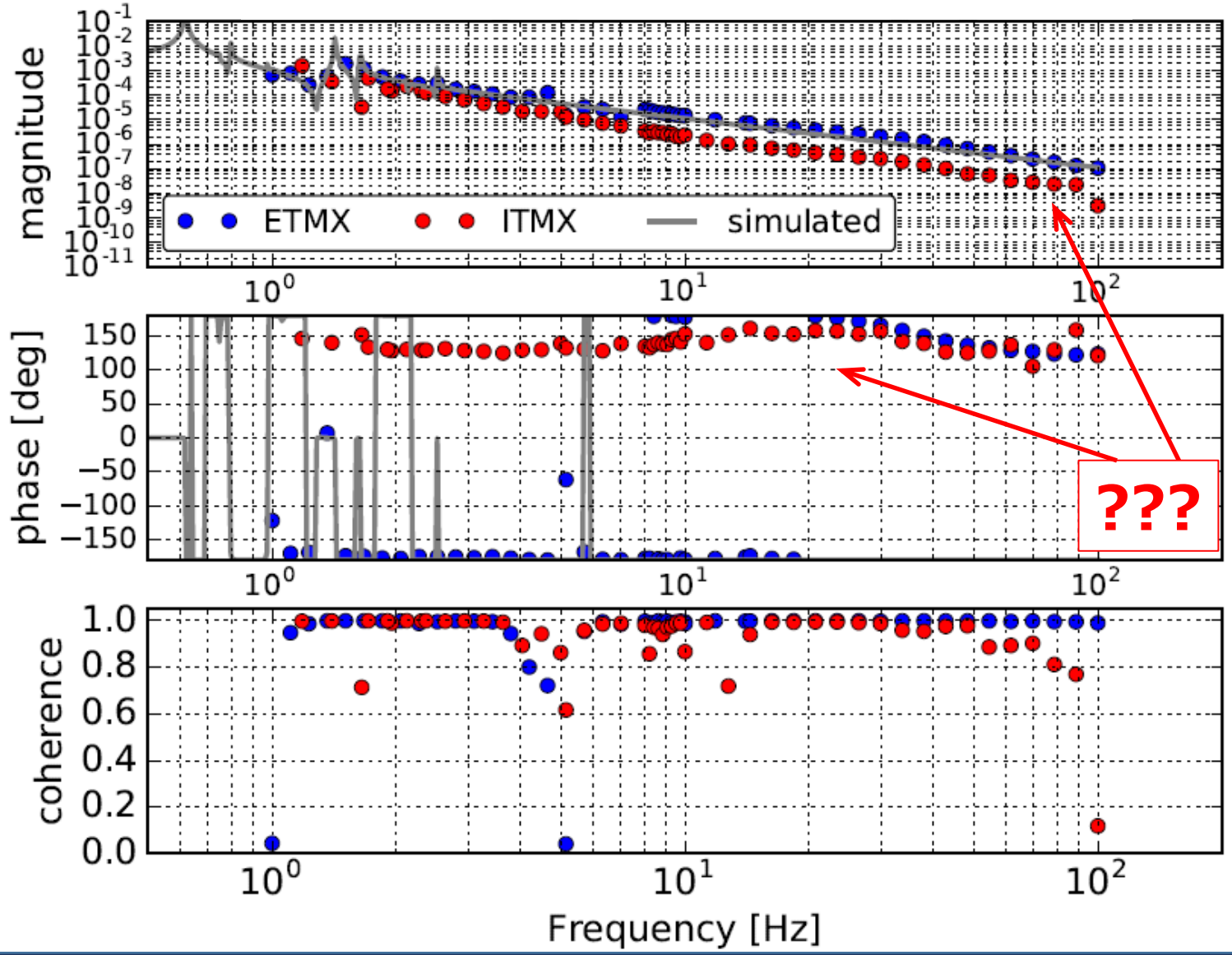
# Measurement:

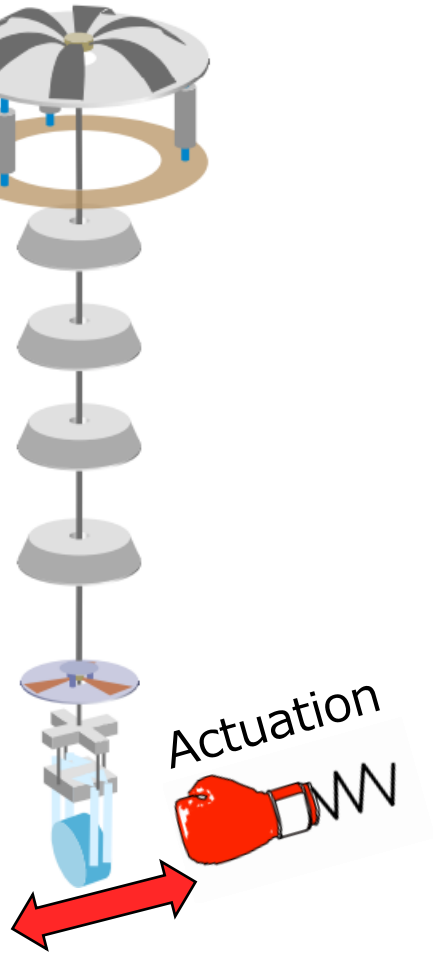
## Mechanical suspension performance with X-arm cavity



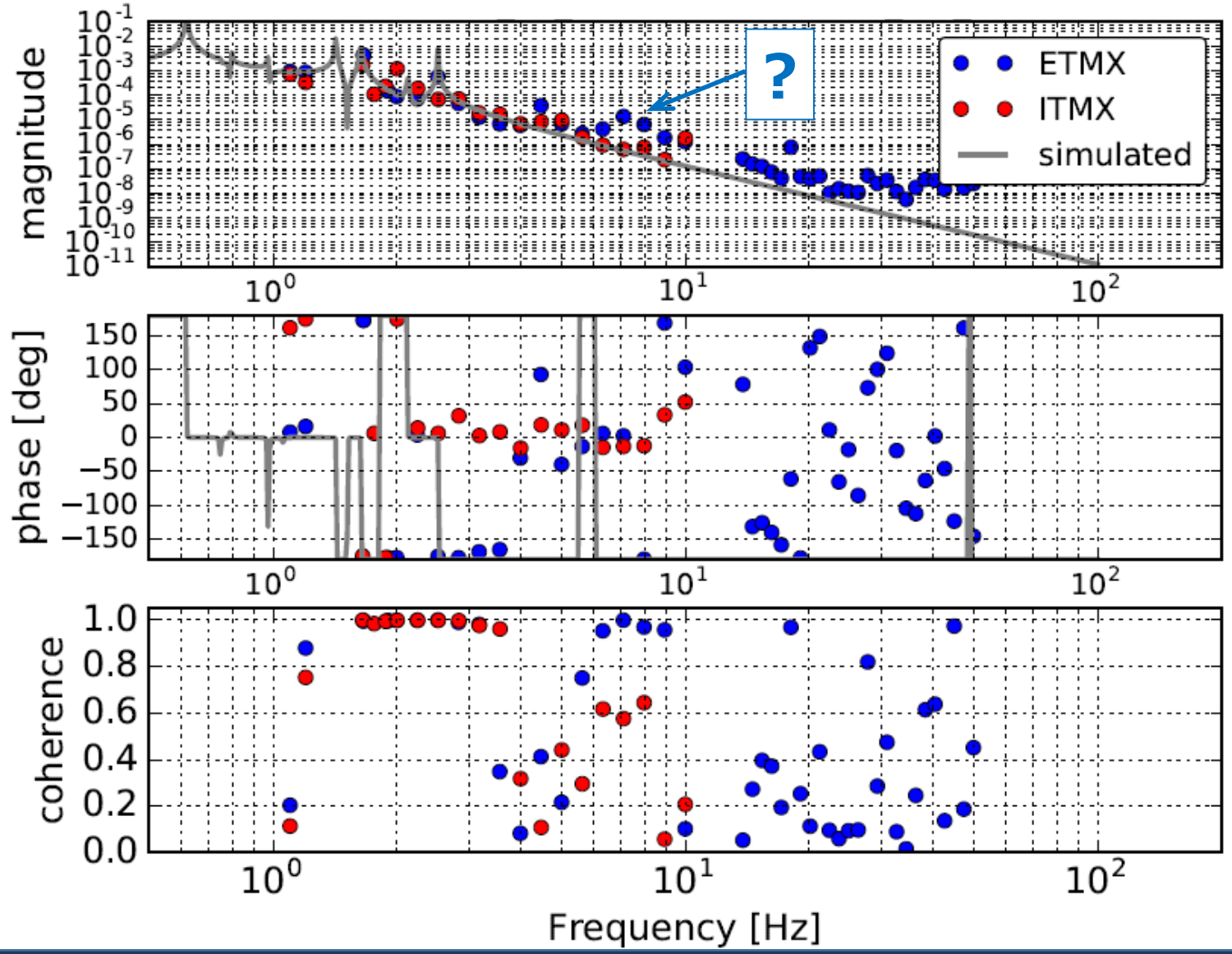
# Force transfer functions



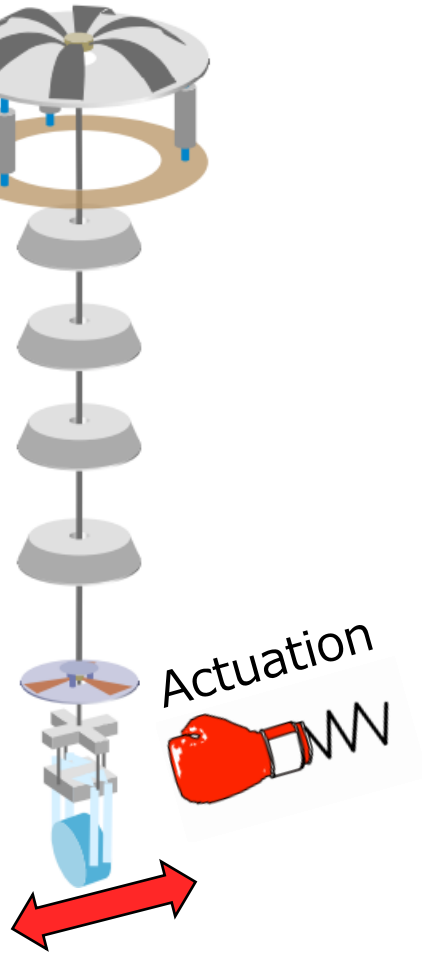

From (TM-RM)-act to TM



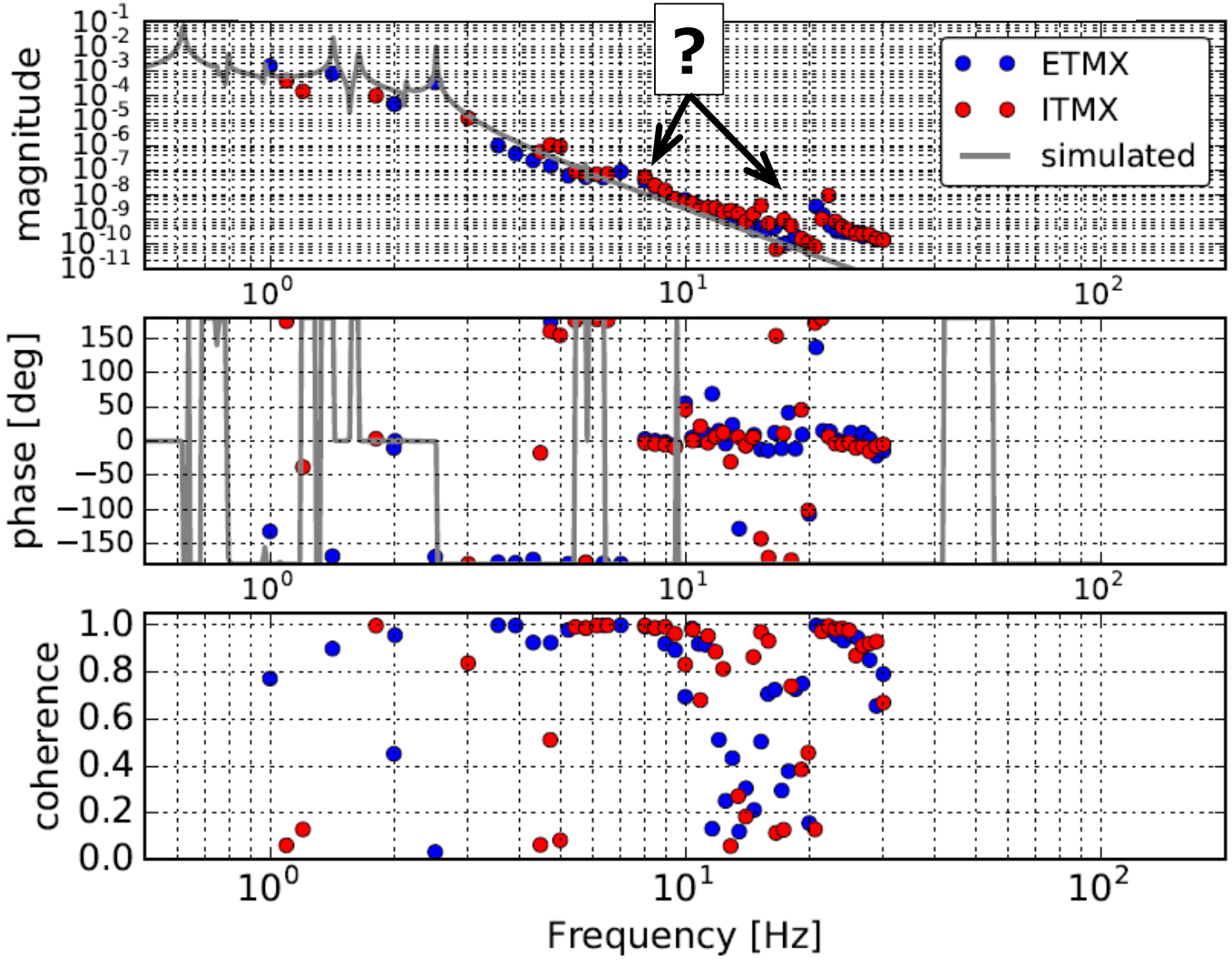
# Force transfer functions



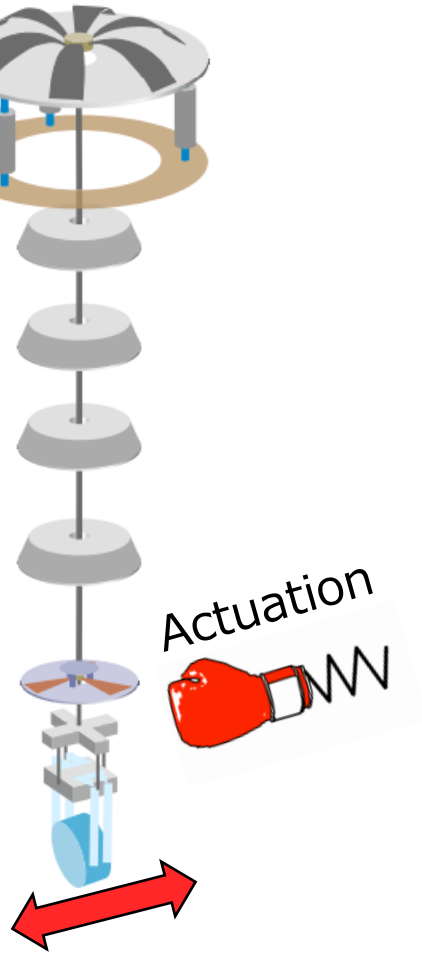

From (IM-IMR)-act to TM



# Force transfer functions




From (MN-MNR)-act to TM



# Note: Measurement of mechanical suspension performance with X-arm cavity

## Excitation point:

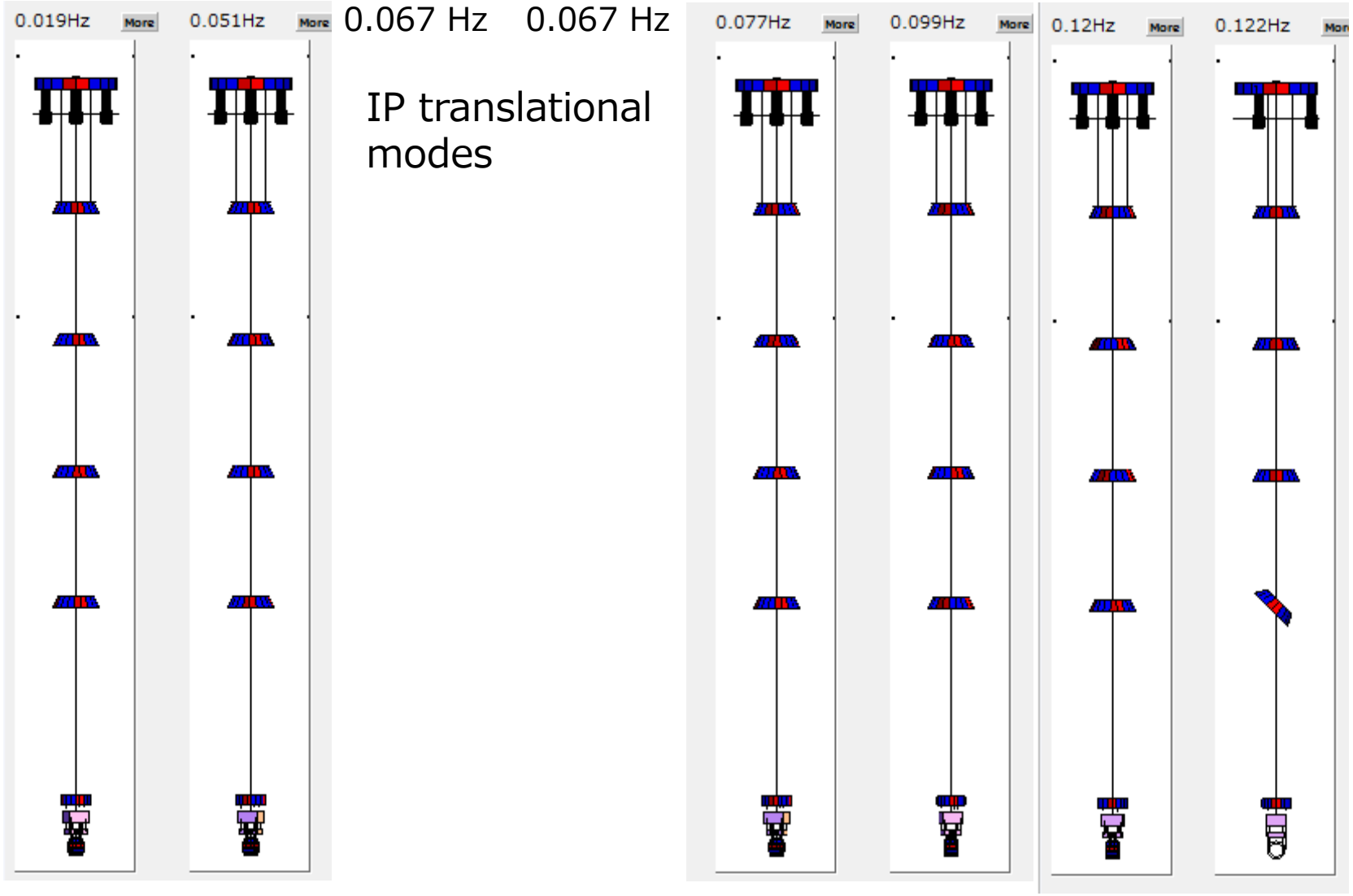
| Excited stage name | Degree of freedom |
|---|---|
| TM | L |
| | P |
| IM | L |
| | V |
| MN | L |
| BF | GAS |
| | (L) |
| IP | L |

## Sensing point:

All the local sensors were working.

(*1) Some resonances have to be identified, as shown in the above.
(*2) measurement files are stored under */users/VISsvn/* though, Not much organized well now.. please let me know if you want to have them ASAP.

#1 #2 #3 #4 #5 #6 #7 #8



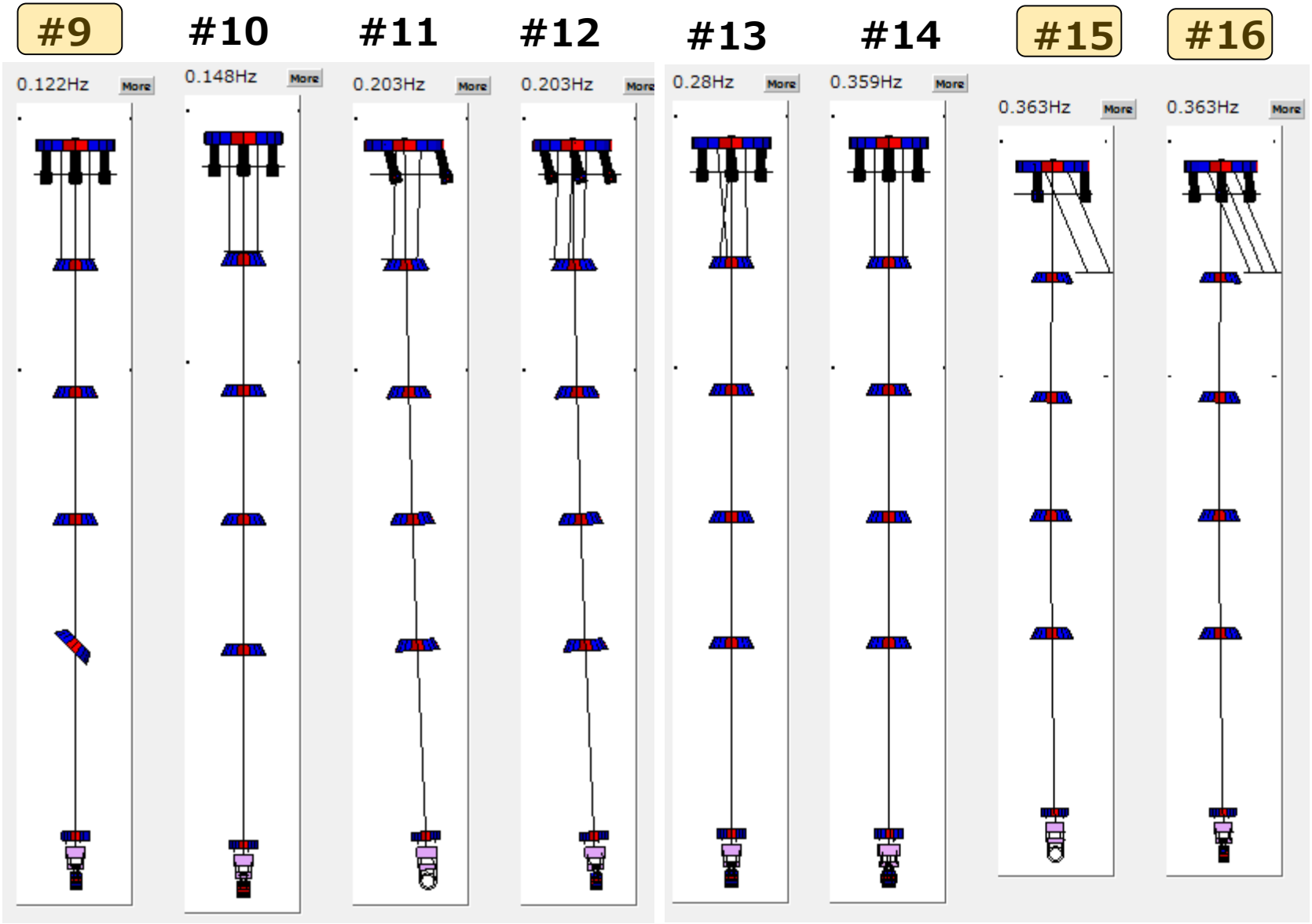

IP translational modes

**Type-A SAS,**

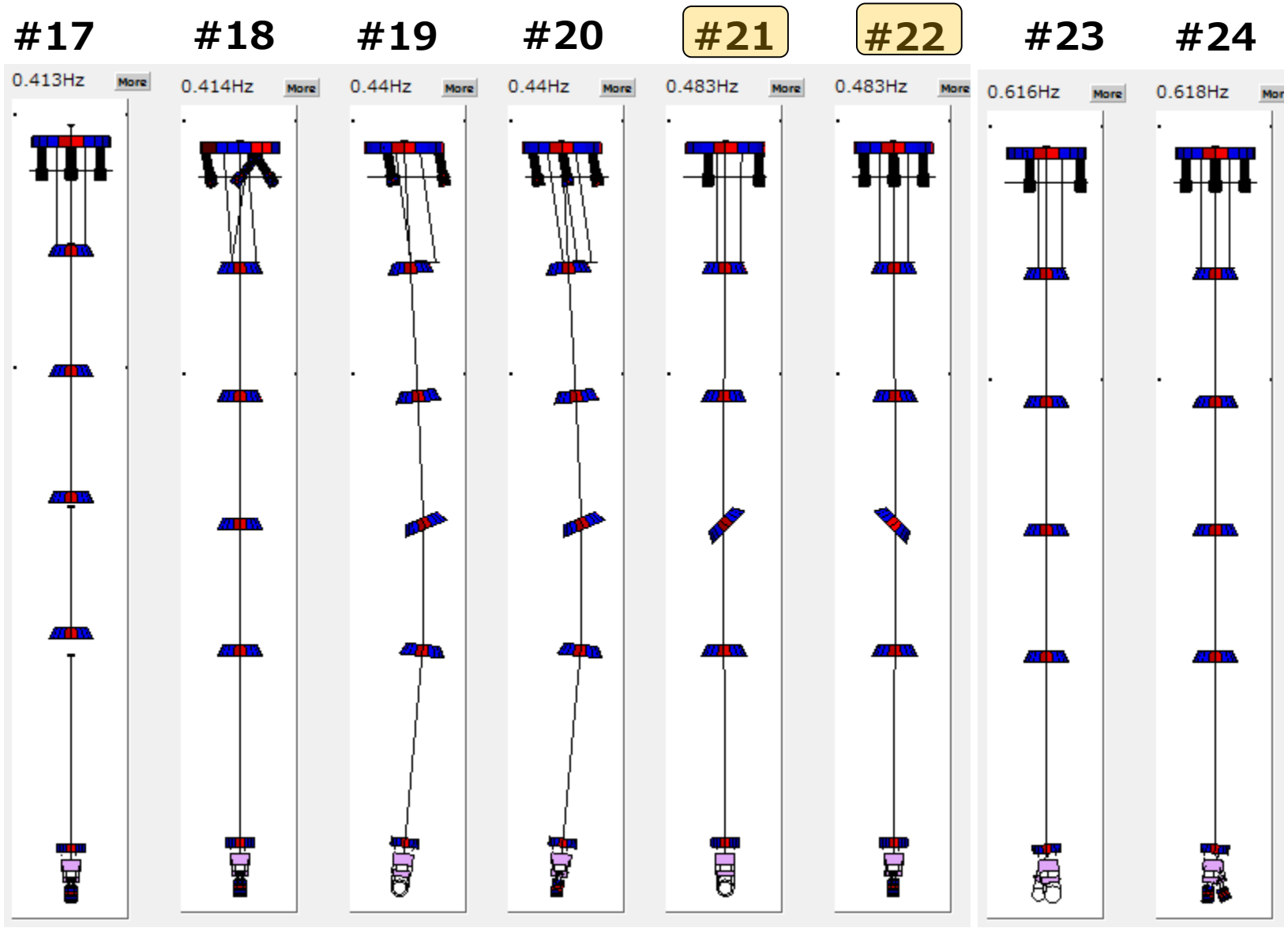
**‘TyrpeA180429_20K’**

**Eigen mode: 75 modes**

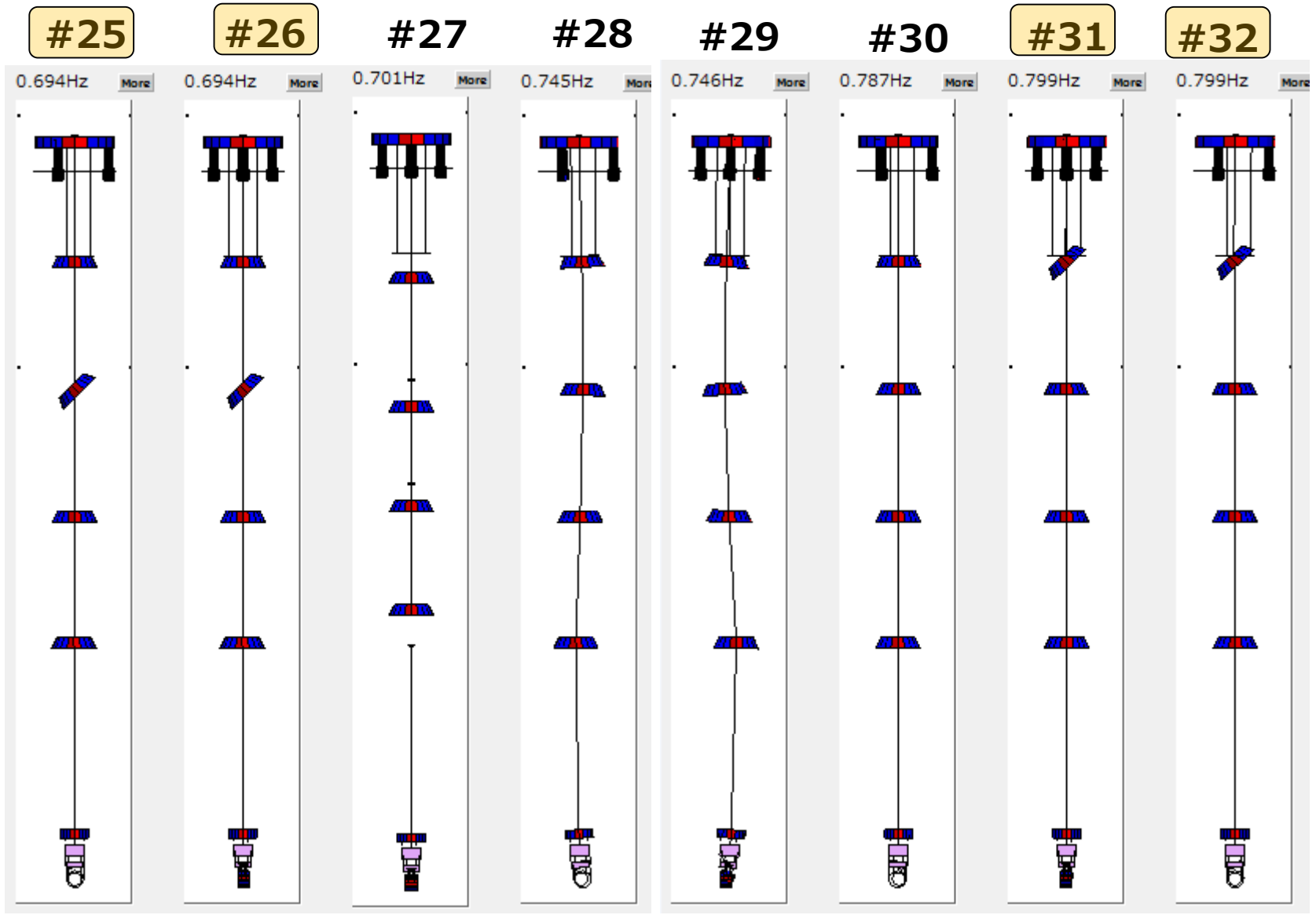
Less interest now



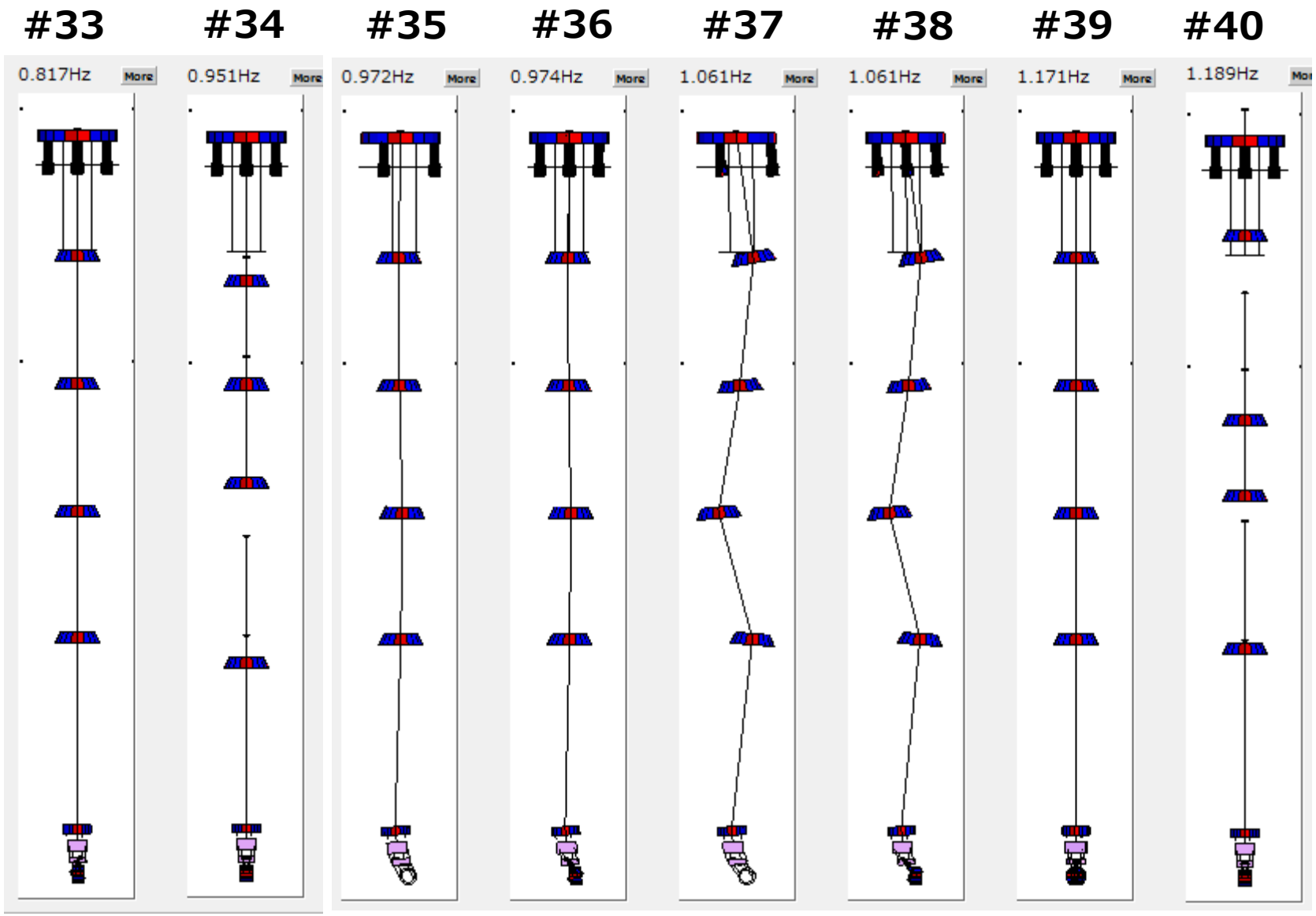

Less interest now



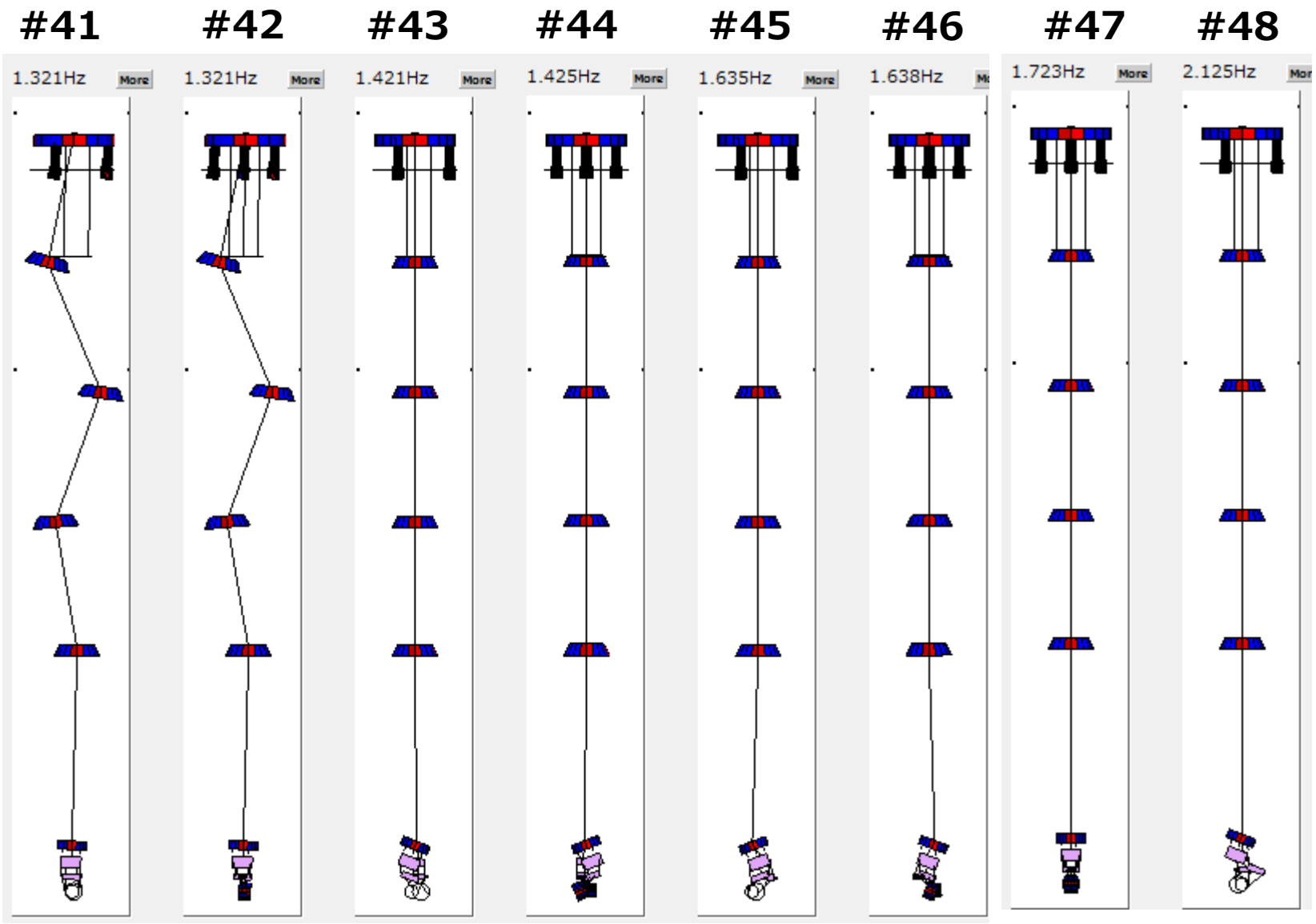

Less interest now



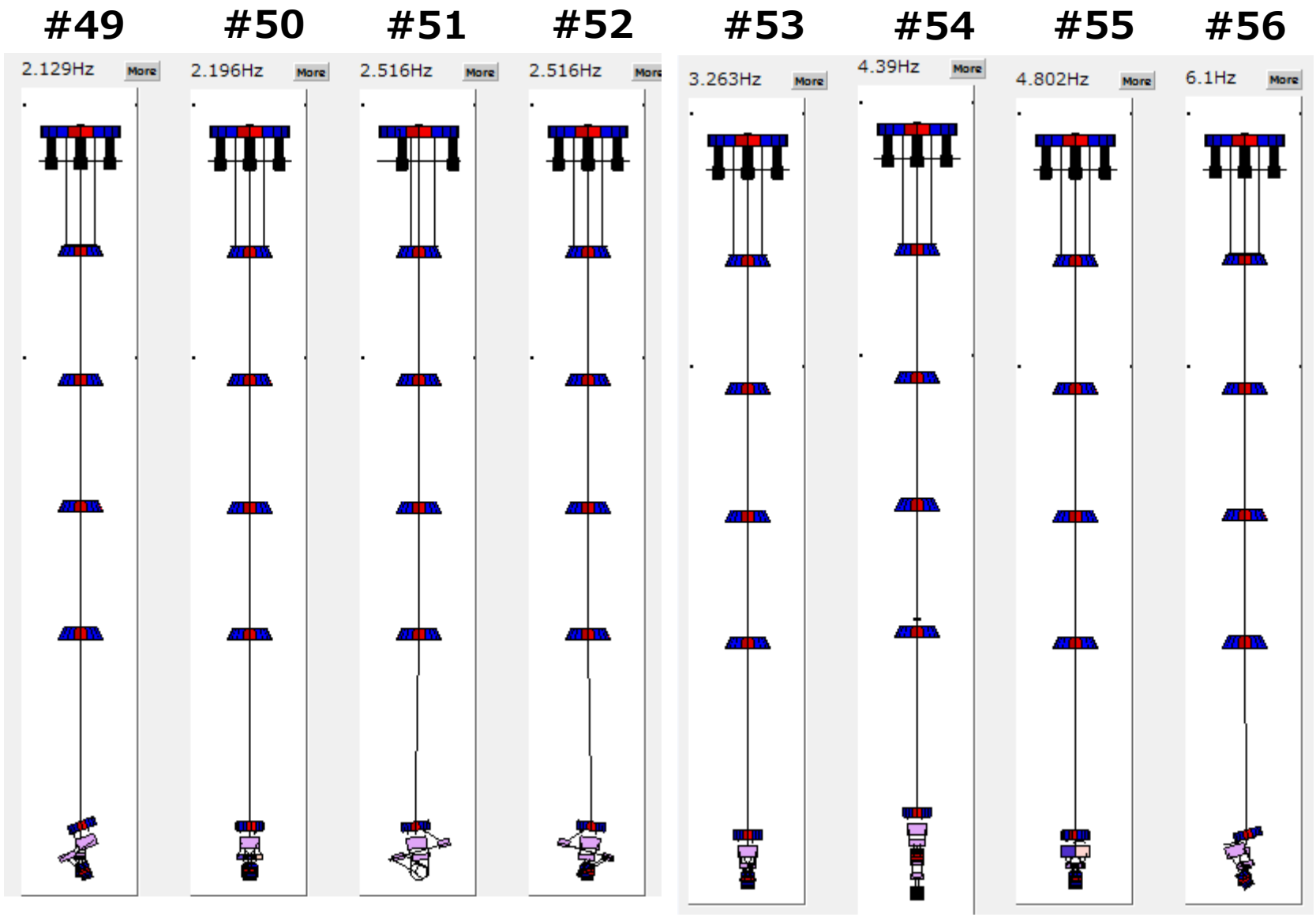

Less interest now



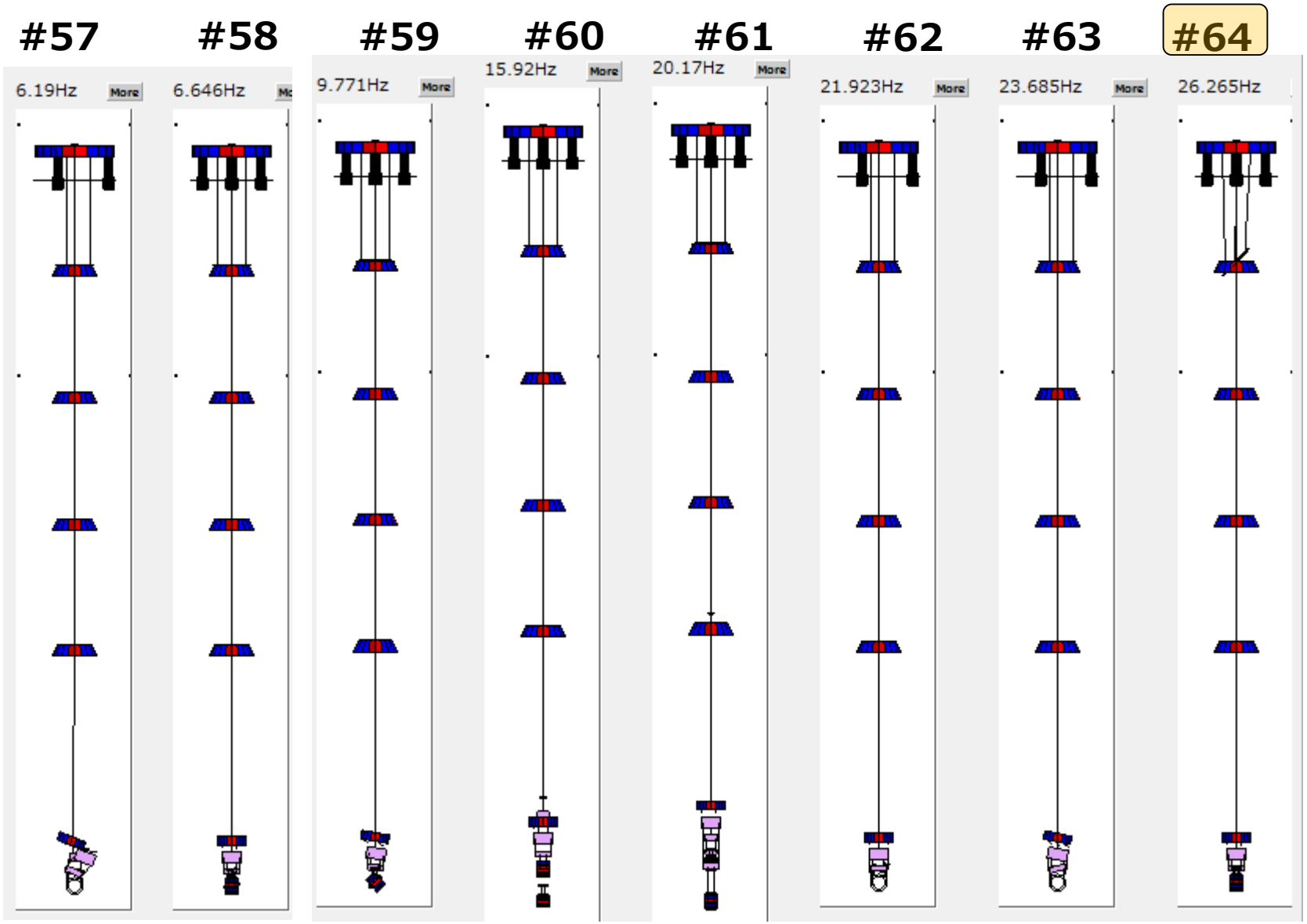

Less interest now



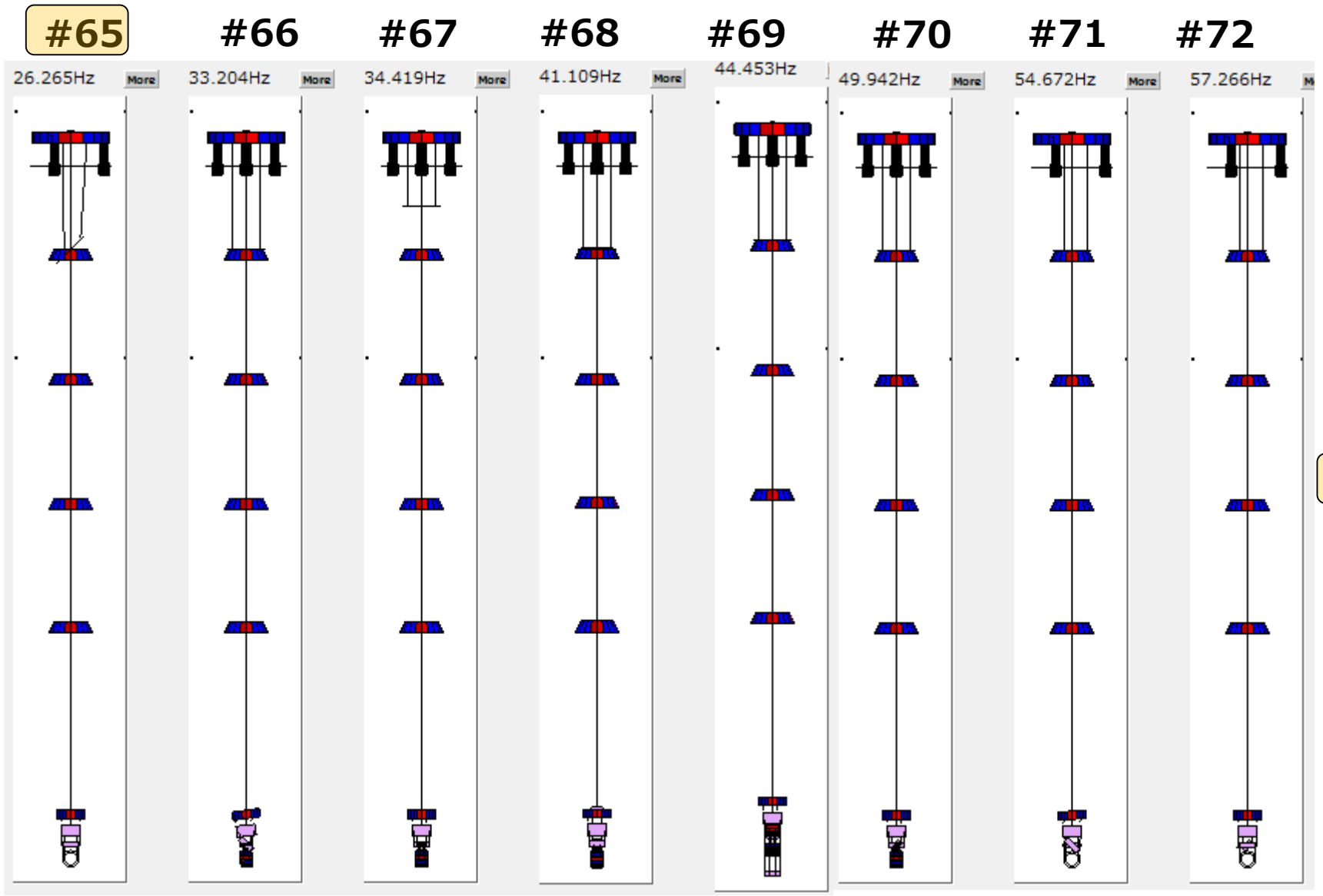

Less interest now



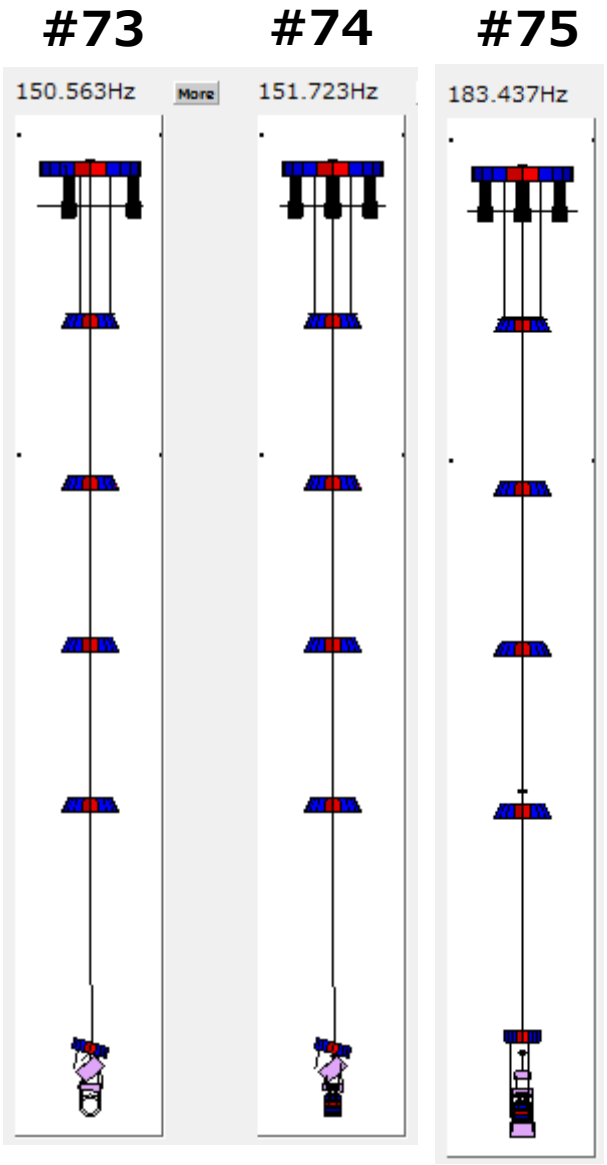

Less interest now




Less interest now



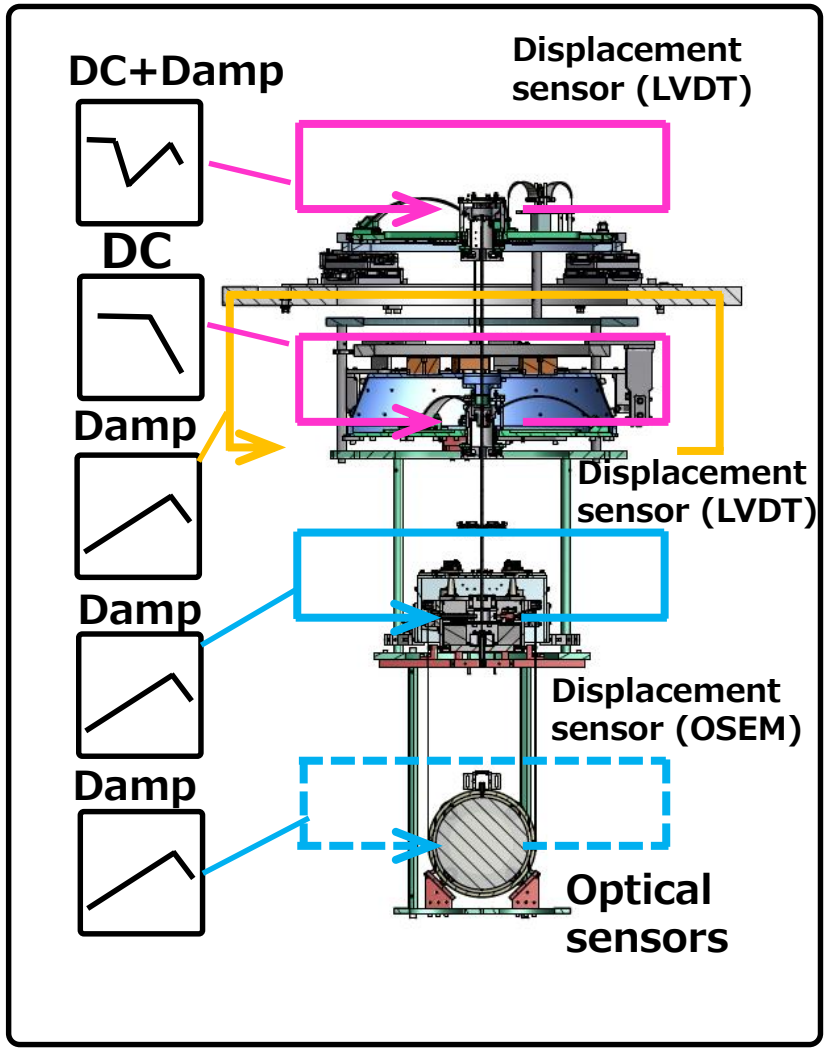

Less interest now



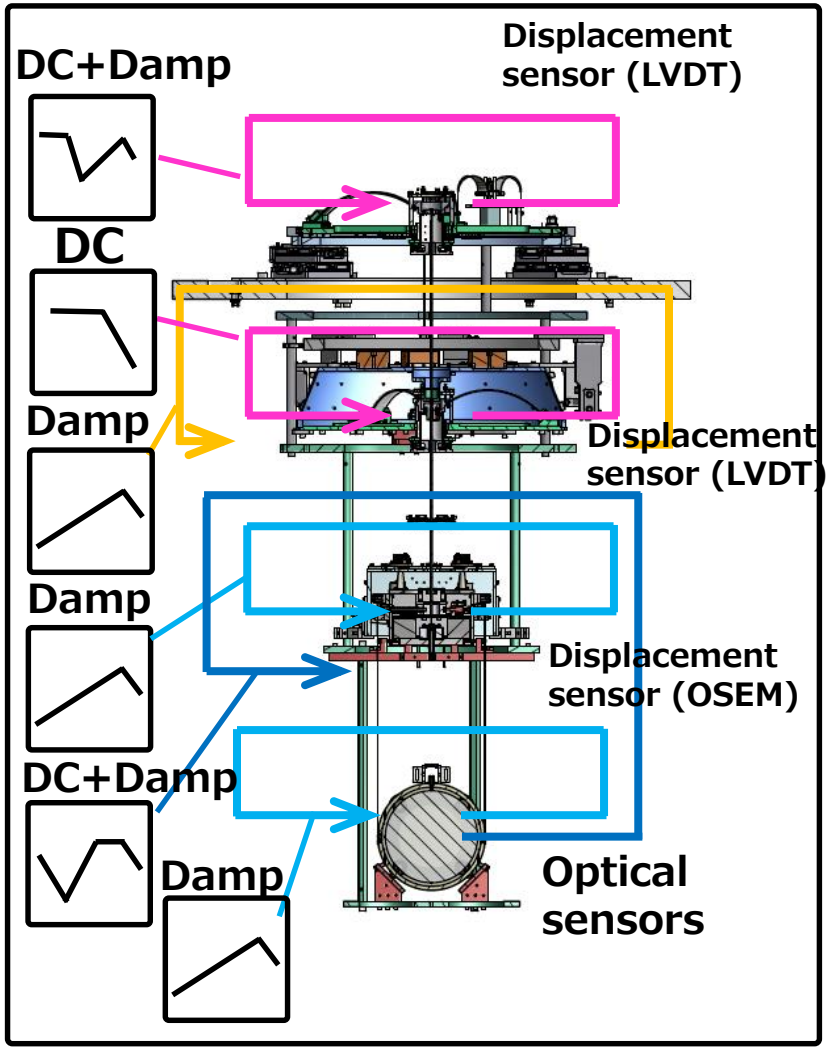

Less interest now

# Designing active control system / ex. Type-Bp SAS

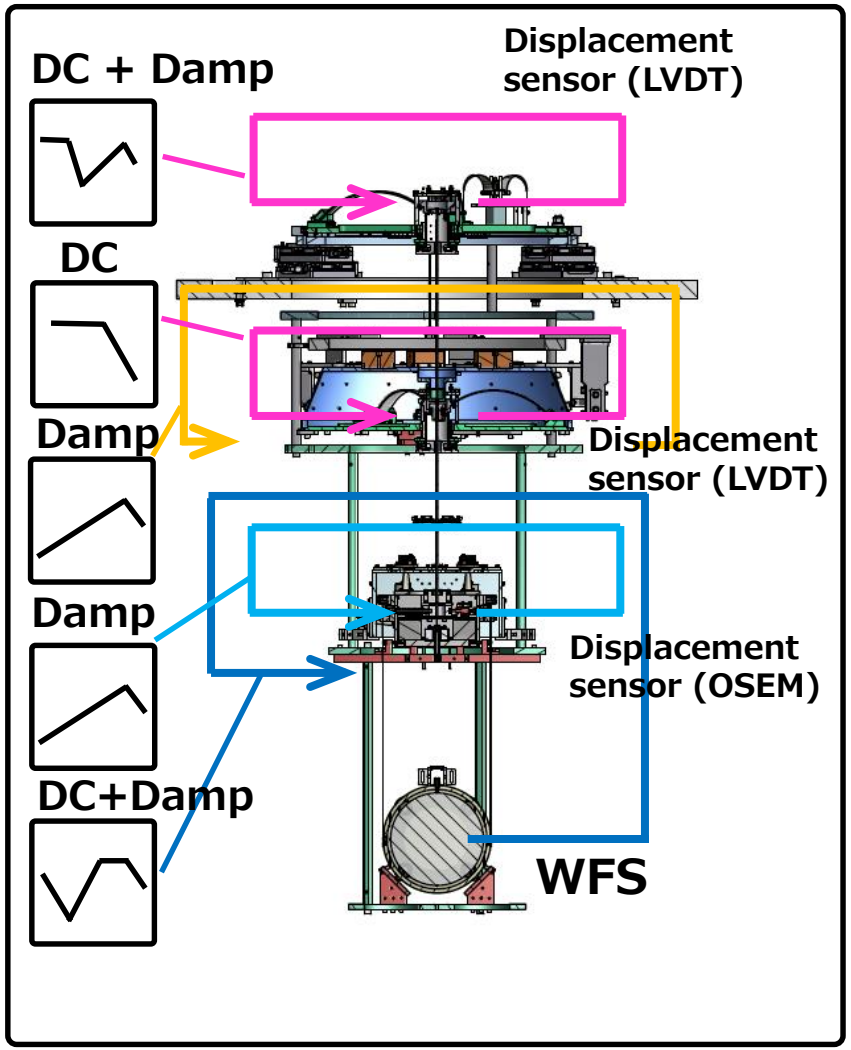
## 1. Calm-down phase




## 2. Lock-acquisition phase

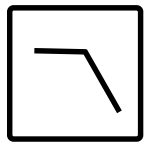



## 3. Observation phase

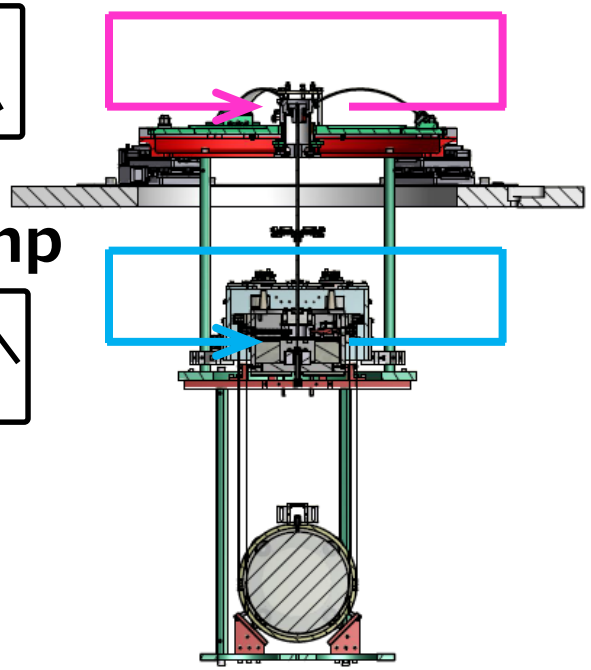


# 2. Decay time measurement

DC

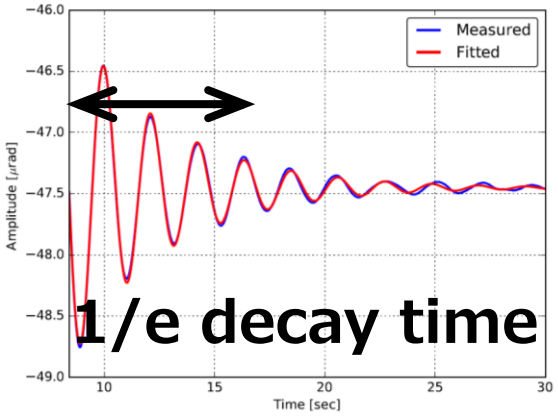


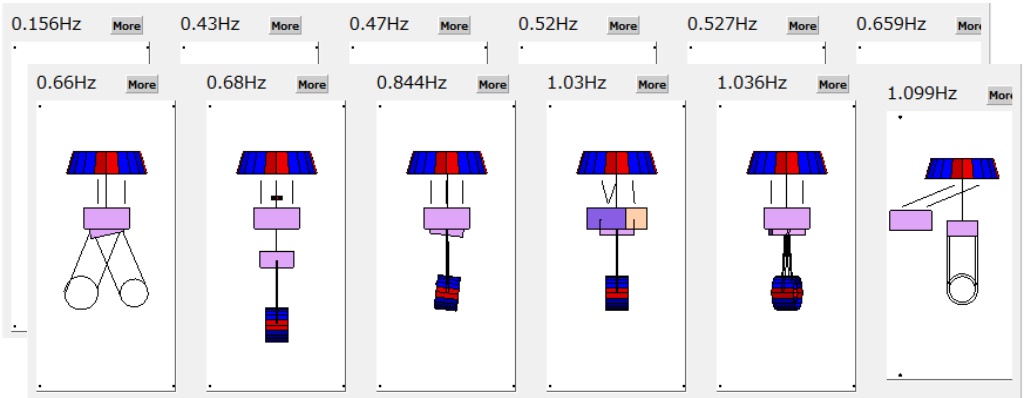
Damp



(Example)

For damping resonances




For the resonant modes
which disturb the lock acquisition.

→ We have to measure the decay time constants
w/ and w/o damping controls,
in order to verify the damping control performance,
FOR ALL THE TYPE-A/B/Bp SUSPENSIONS.