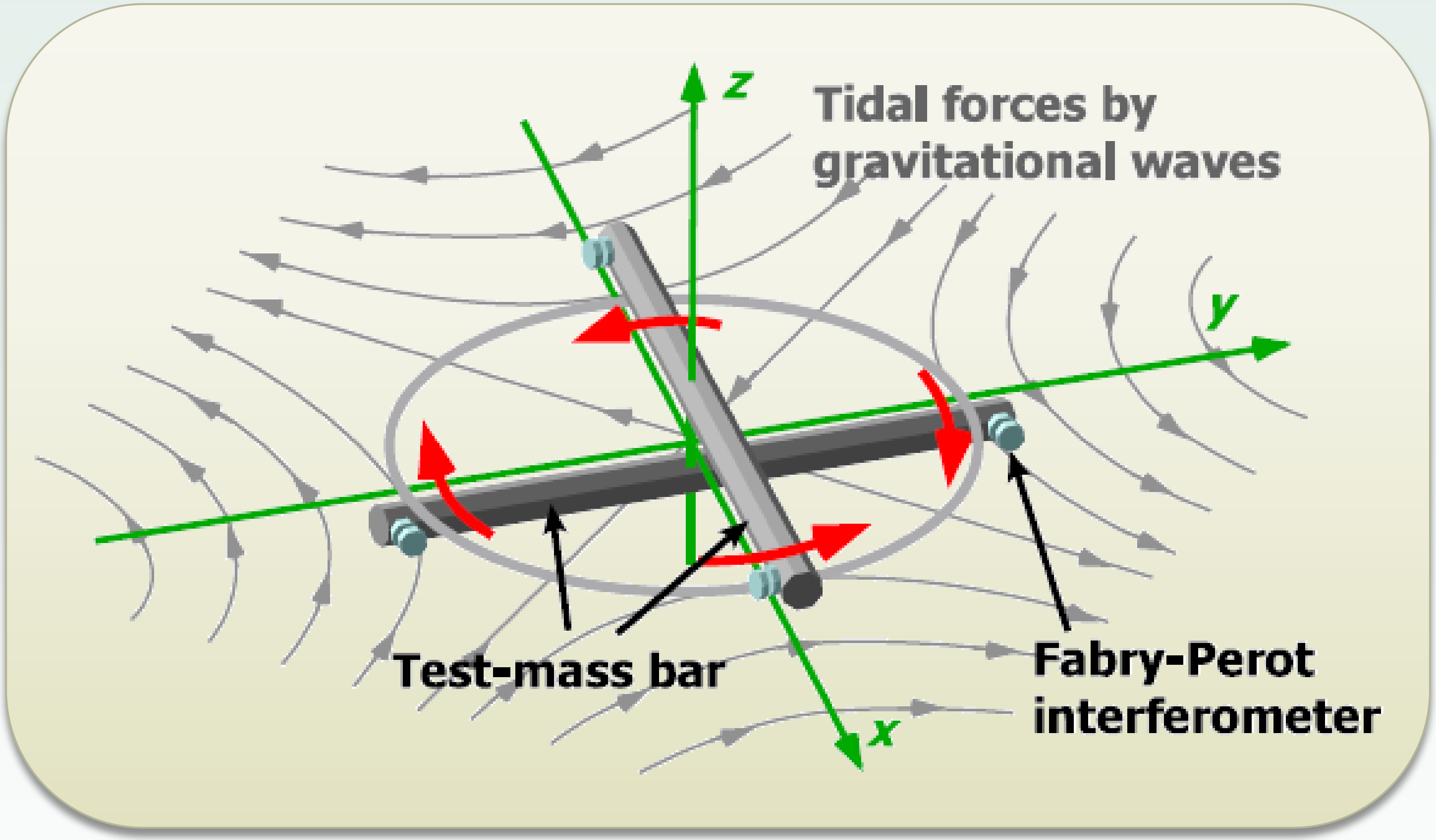
Torsion-bar Antenna for low-frequency GW detection

Ayaka Shoda,
K. Eda[A], K. Tejima[B], Y. Kuwahara, K. Komori, Y. Aso[C], M. Ando

Univ. of Tokyo, RESCEU[A], ICRR[B], NAOJ[C]

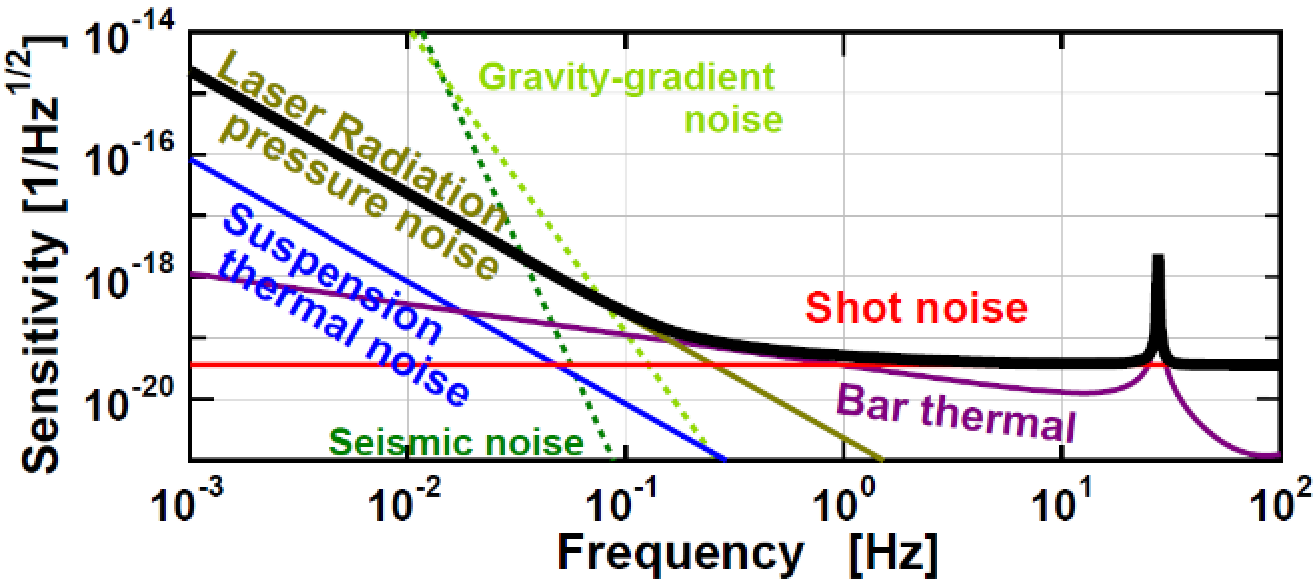
TOBA

Torsion-bar Antenna



$$h(f) \propto \theta(f)$$

Example Sensitivity

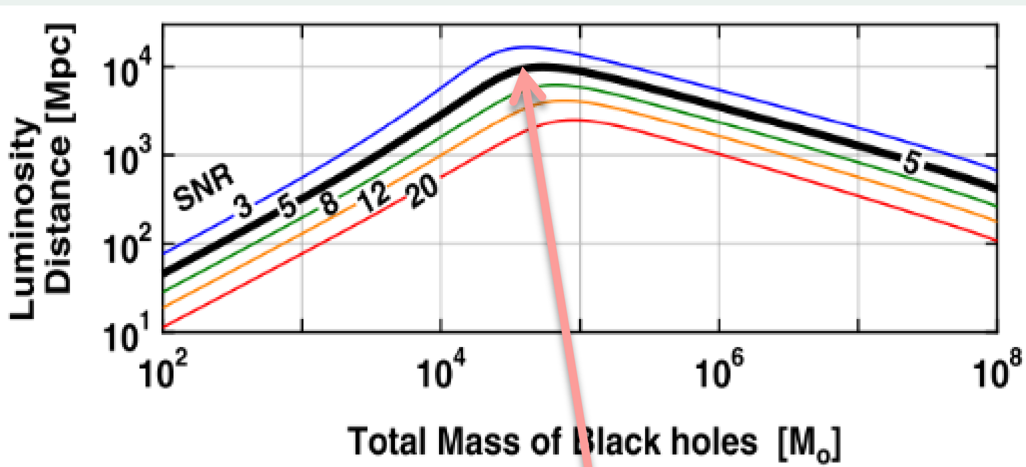


bar length: 10 m, bar temperature: 4K
Laser power: 10 W

Sensitive to low-freq. GWs even on the ground

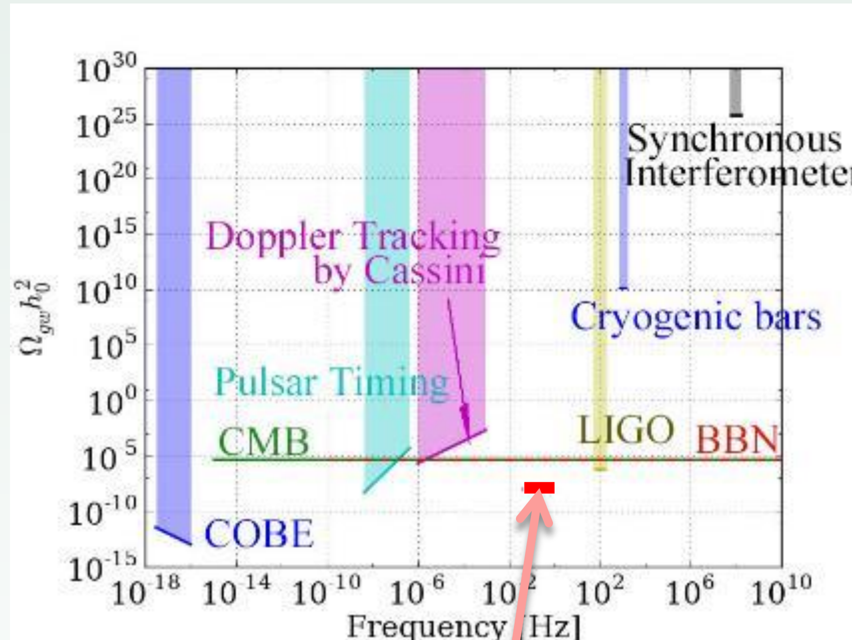
Targets

IMBH mergers



Almost all of the universe

A stochastic GW background



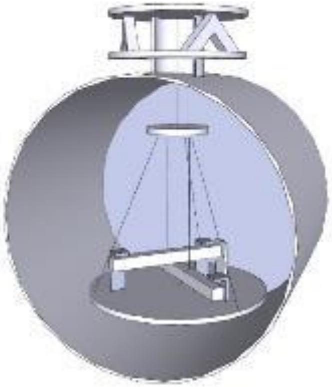
Simultaneous obs. for 1 yr.

Road Map

Phase-I

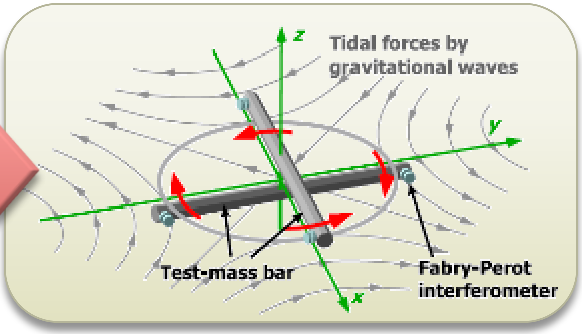
20-cm test mass (single)
300K test mass
Levitated by pinning effect
Michelson interferometer
$h \sim 10^{-8}$ @ 1Hz
Principle test
First observation

Phase-II



25-cm test mass
common mode noise rejection
Cryogenic
Wire suspension
Michelson interferometer
Vibration isolation system
$h \sim 10^{-15}$ @ 1Hz
Newtonian noise
Multi-direction observation

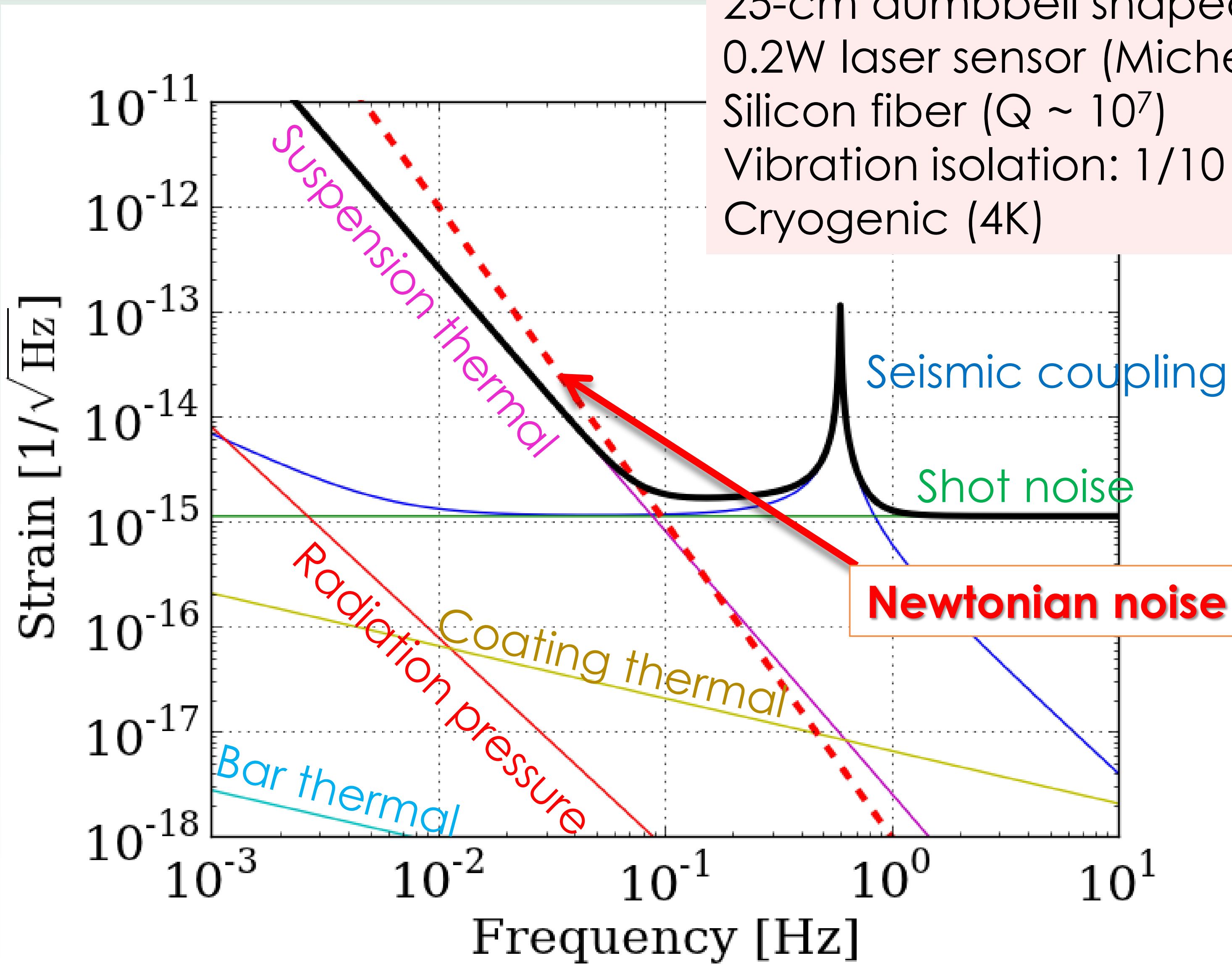
Final



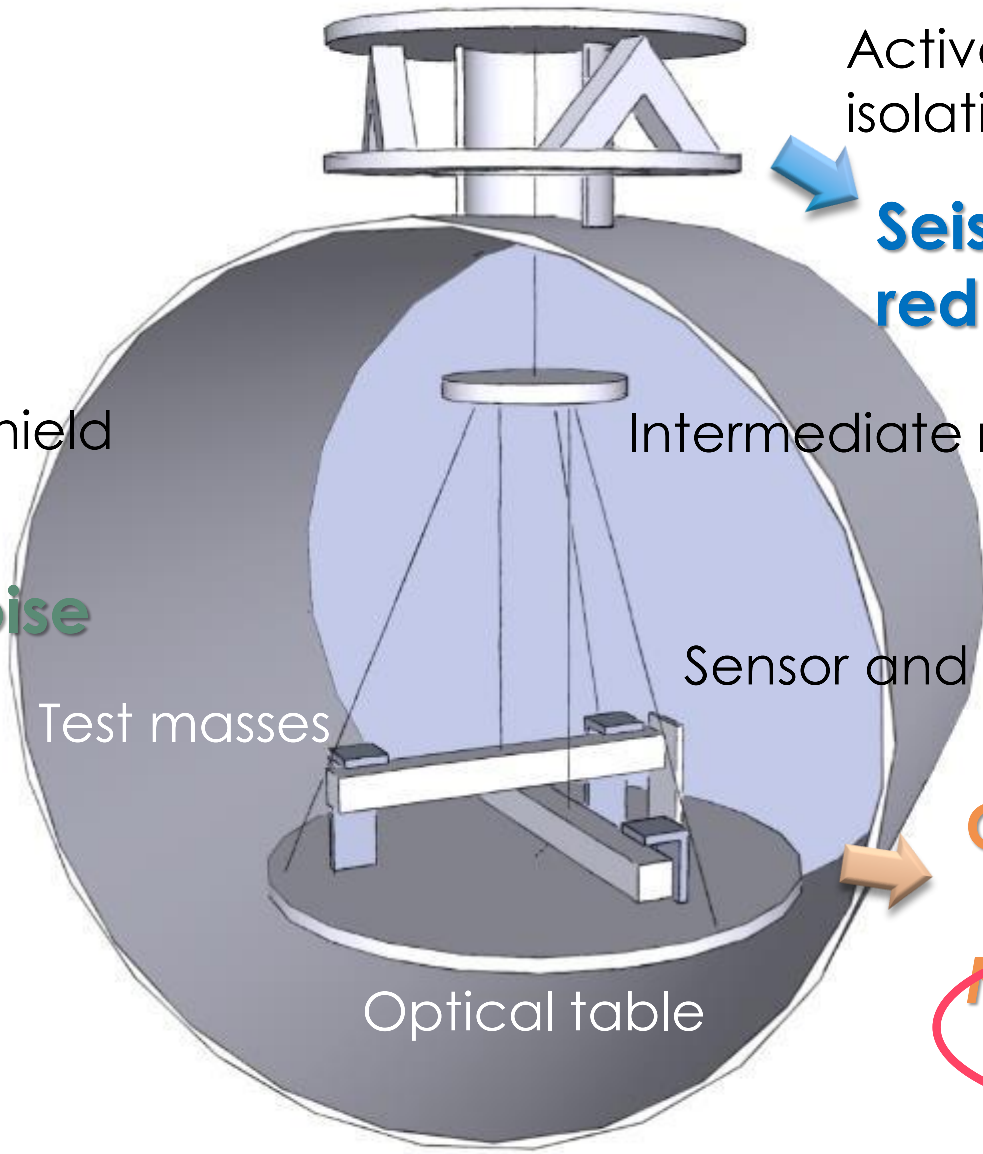
10-m test mass
common mode noise rejection
Cryogenic
High-Q wire/test-mass
Fabry-Perot
Environment noise reduction
$h \sim 10^{-19}$ @ 1Hz
IMBH merger
SGWB search

Design Sensitivity of Phase-II TOBA

25-cm dumbbell shaped bar
0.2W laser sensor (Michelson)
Silicon fiber ($Q \sim 10^7$)
Vibration isolation: 1/10
Cryogenic (4K)



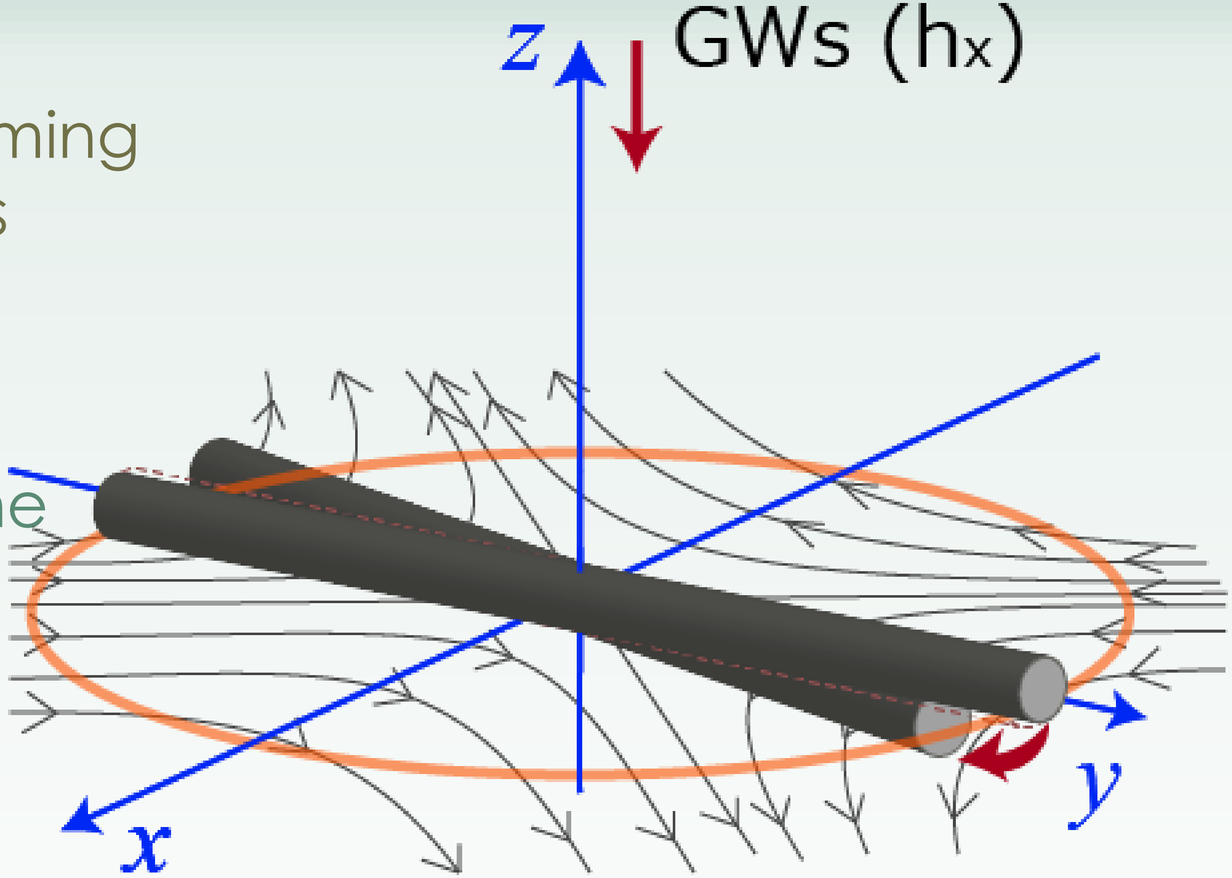
Schematic View



New Observation Method

GWs incoming from z-axis

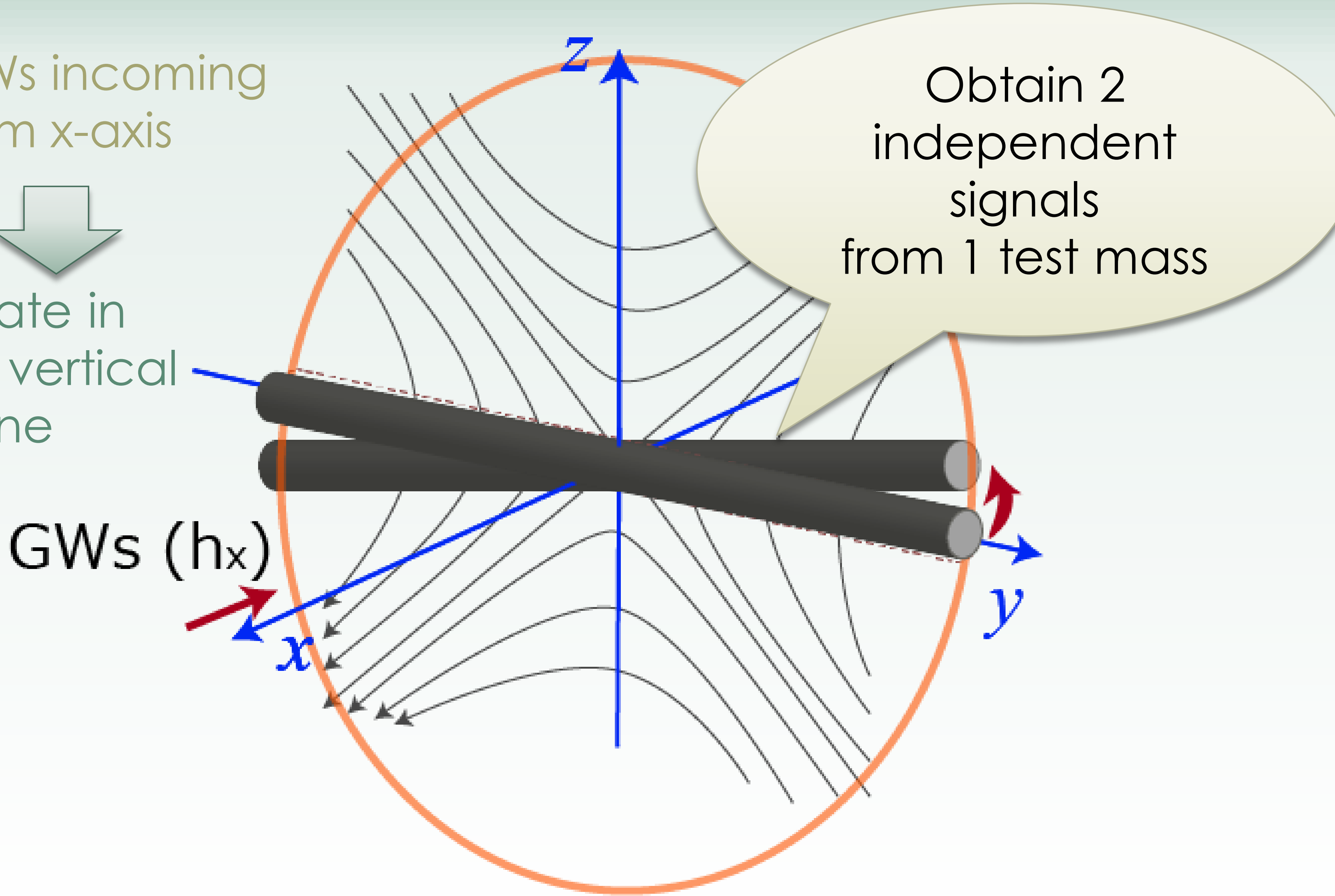
Rotate in the horizontal plane



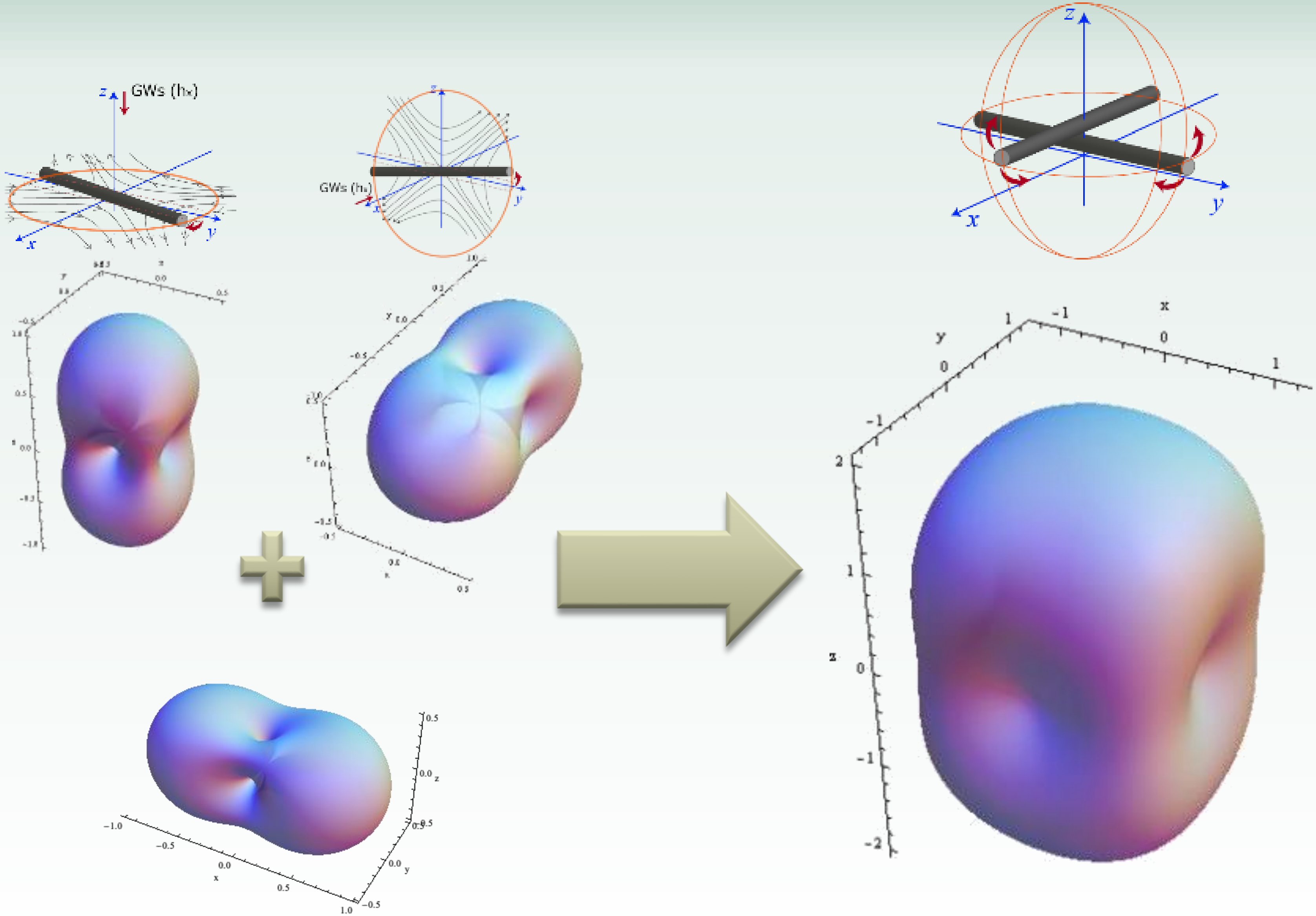
New Observation Method

GWs incoming from x-axis

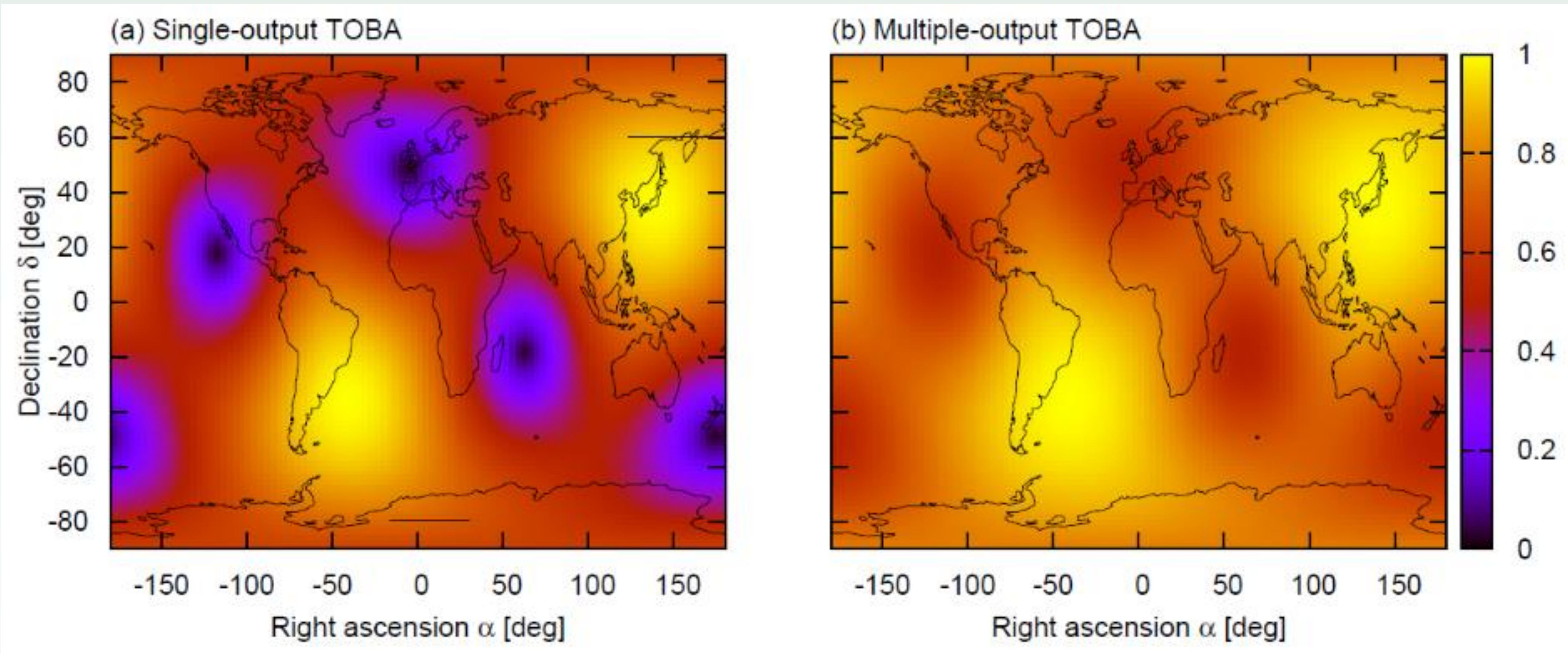
Rotate in the vertical plane



Antenna Pattern Function

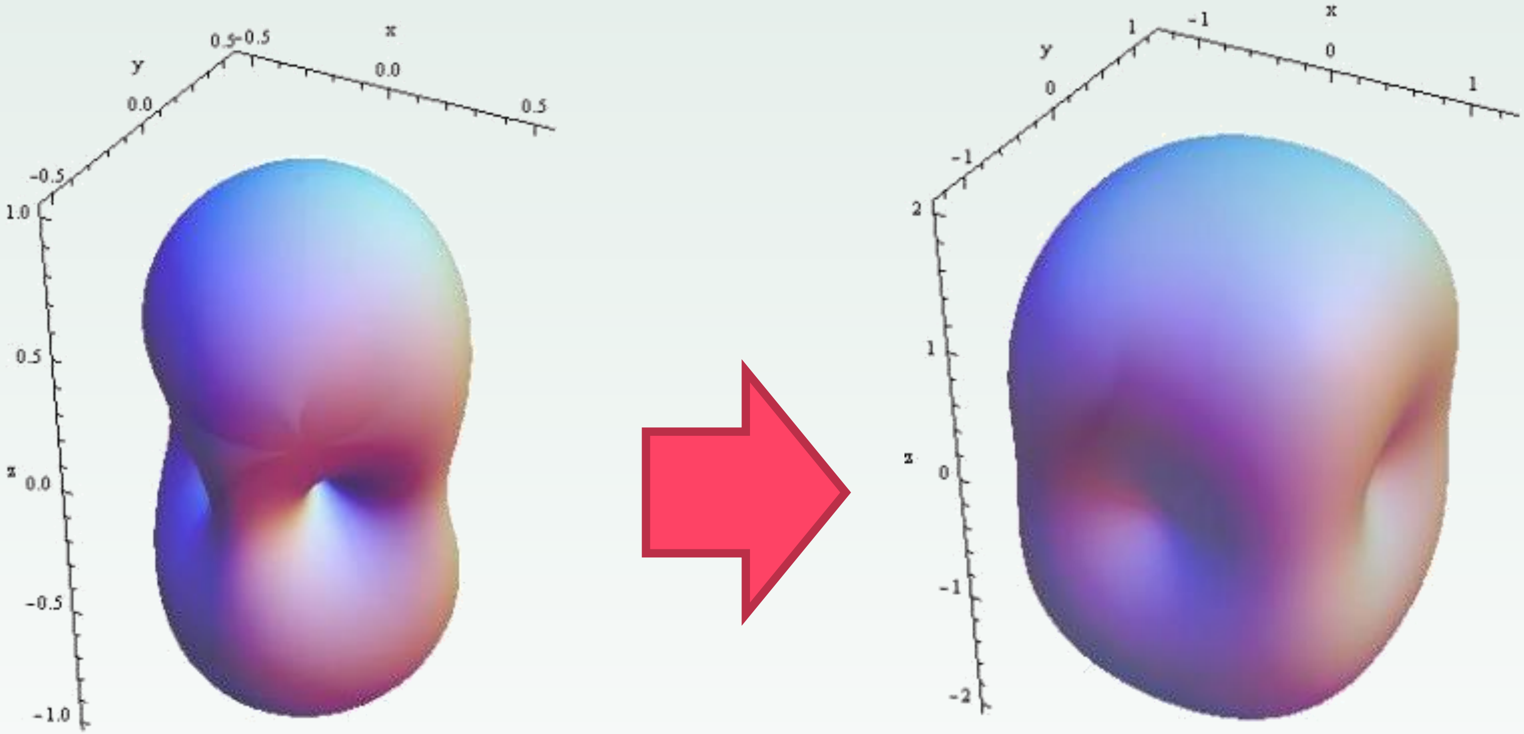


Antenna Pattern Function



TOBA is set at TAMA300 cite

Event Rate



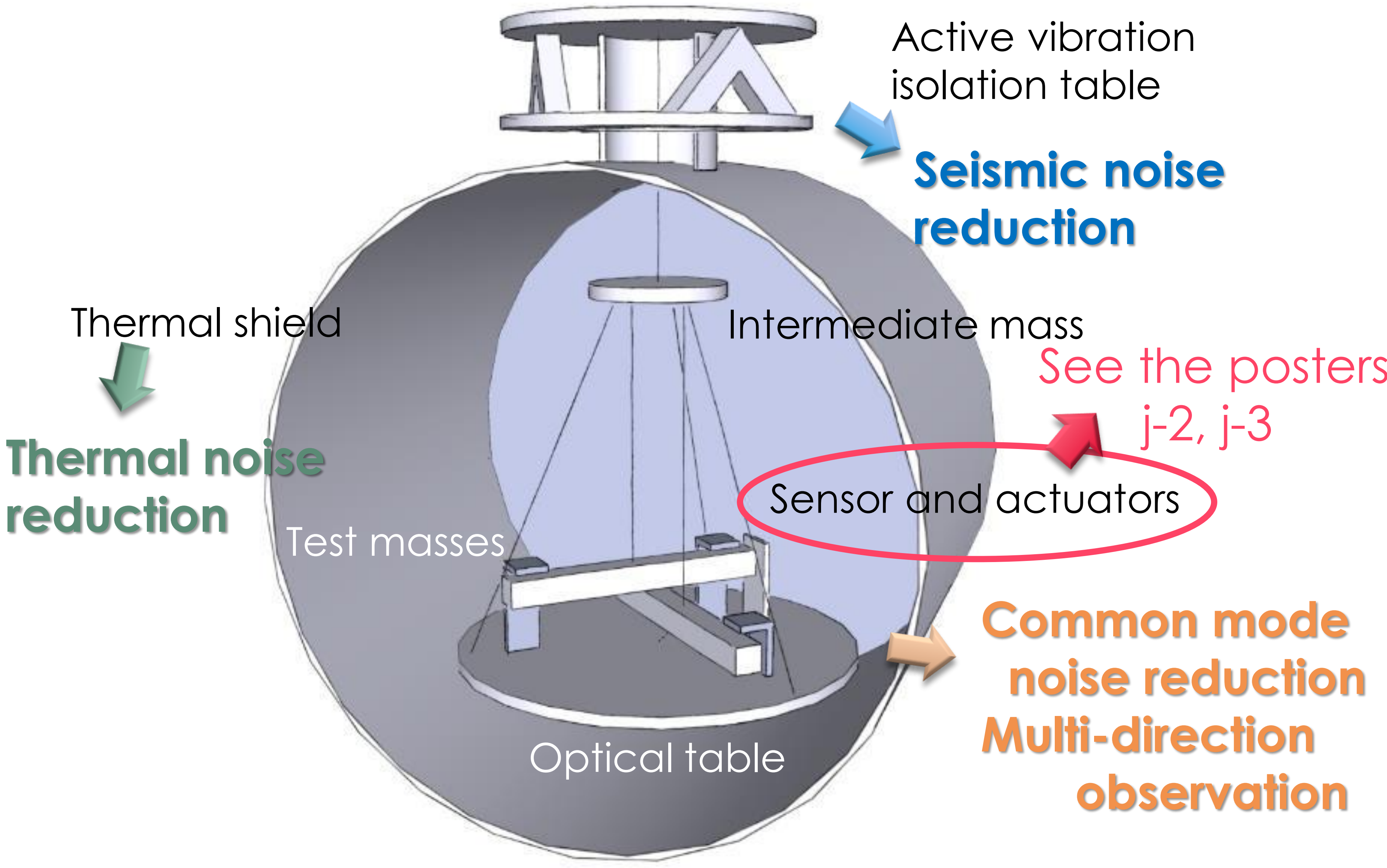
The detection volume
$\propto$ the event rate
$\times$ 1.7

Parameter Estimation (CBC)

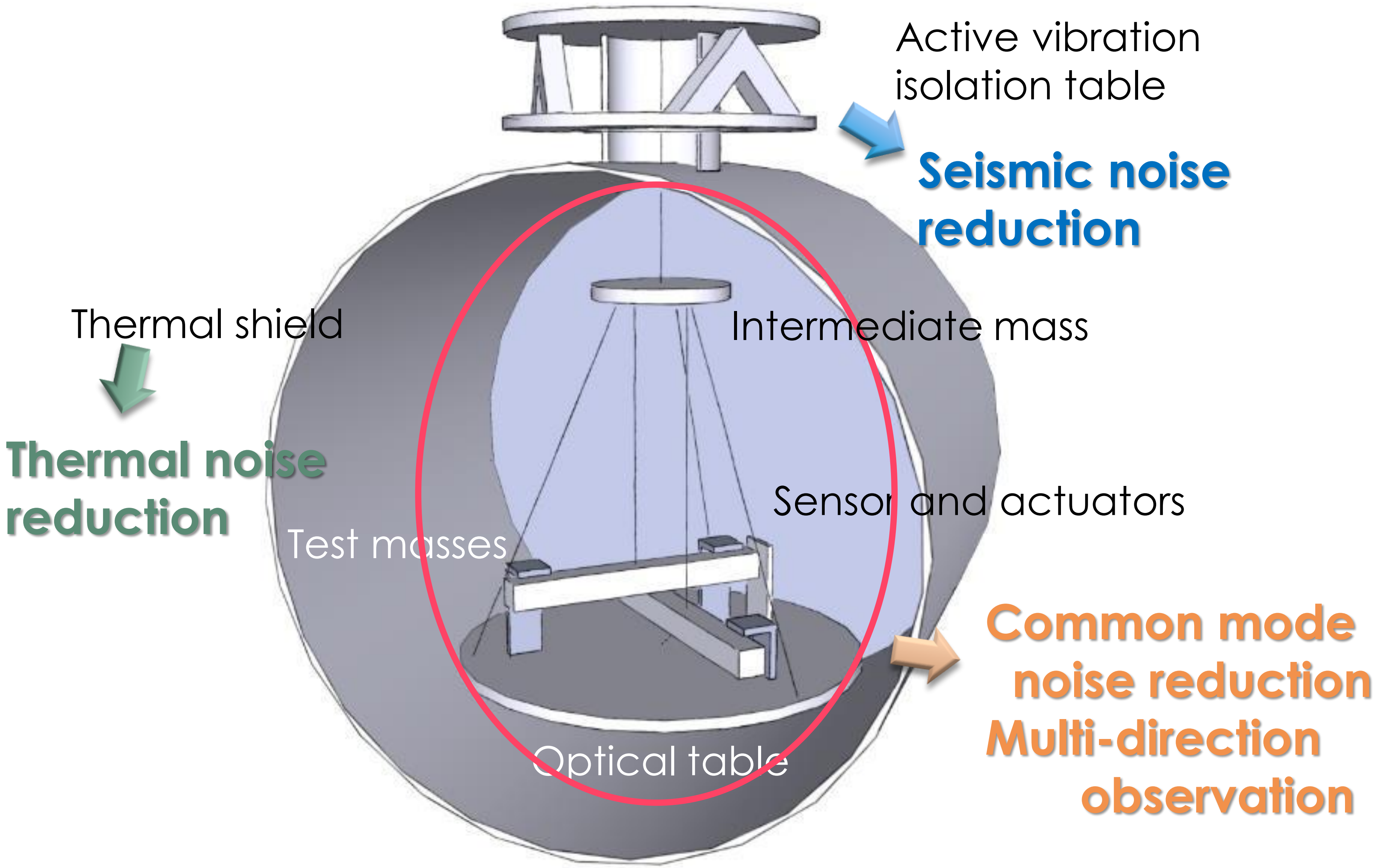
Single-output Multi-output

m_1 $[M_\odot]$	m_2 $[M_\odot]$	α [rad]	δ [rad]	ι [rad]	ψ [rad]	$(S/N)_{\rm I}$	S/N	$\Delta\Omega_{\rm I}$ [sr]	$\Delta\Omega$ [sr]
10^4	10^4	1.0	1.0	1.0	1.0	29.9	35.3	4.02	0.0253
		2.0	−1.0	0.5	3.0	46.1	54.3	2.70	0.0207
		1.0	−1.5	0.5	4.0	40.1	50.6	23.2	0.258
		−3.0	0.5	1.0	0.0	25.0	32.2	0.765	0.0265
		3.0	1.5	1.0	2.0	23.4	31.9	47.2	0.348
		−1.0	1.0	0.5	6.0	48.6	55.8	2.90	0.0188
		−2.0	−0.5	1.0	5.0	26.8	34.4	1.47	0.0757

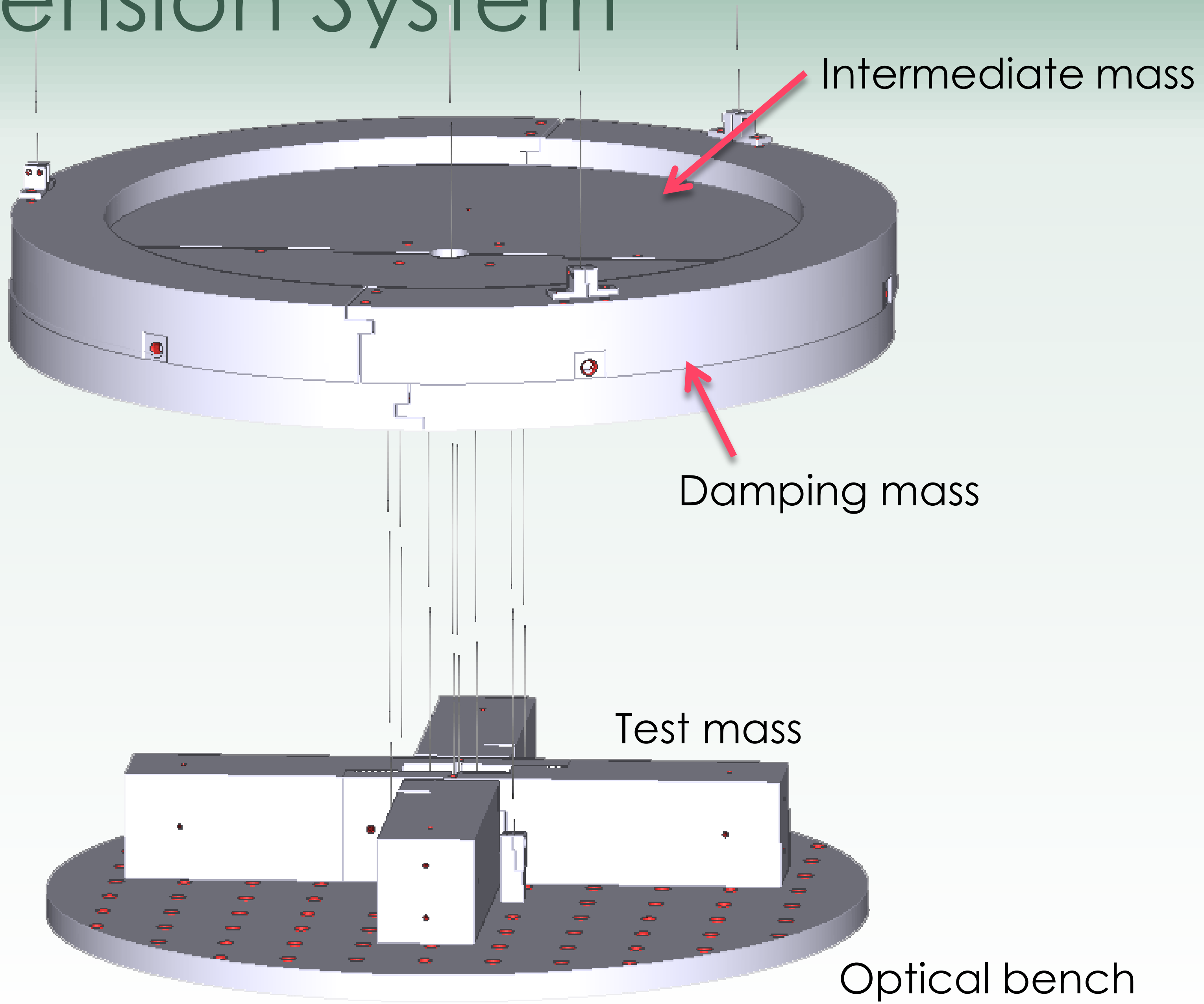
Schematic View

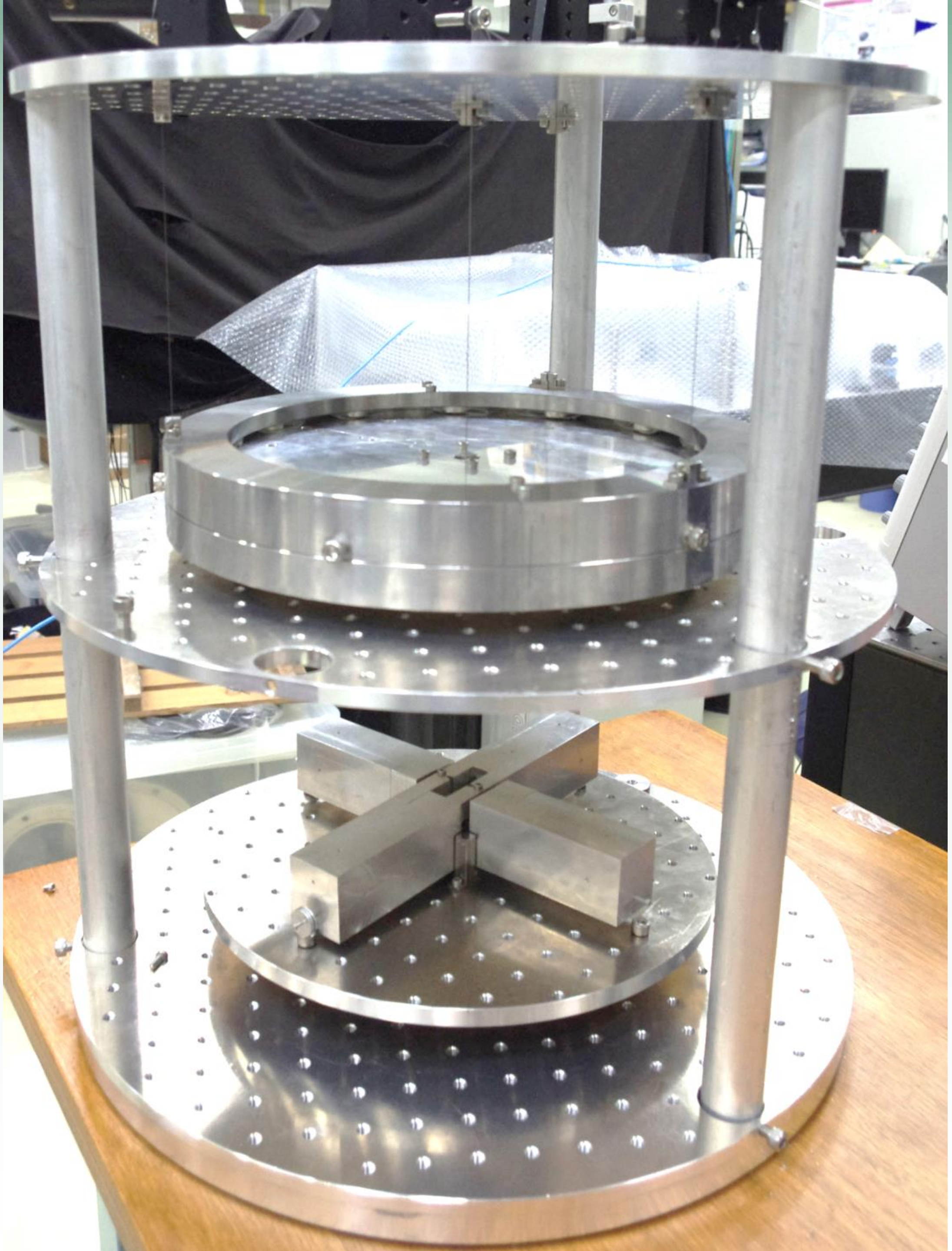


Schematic View



Suspension System

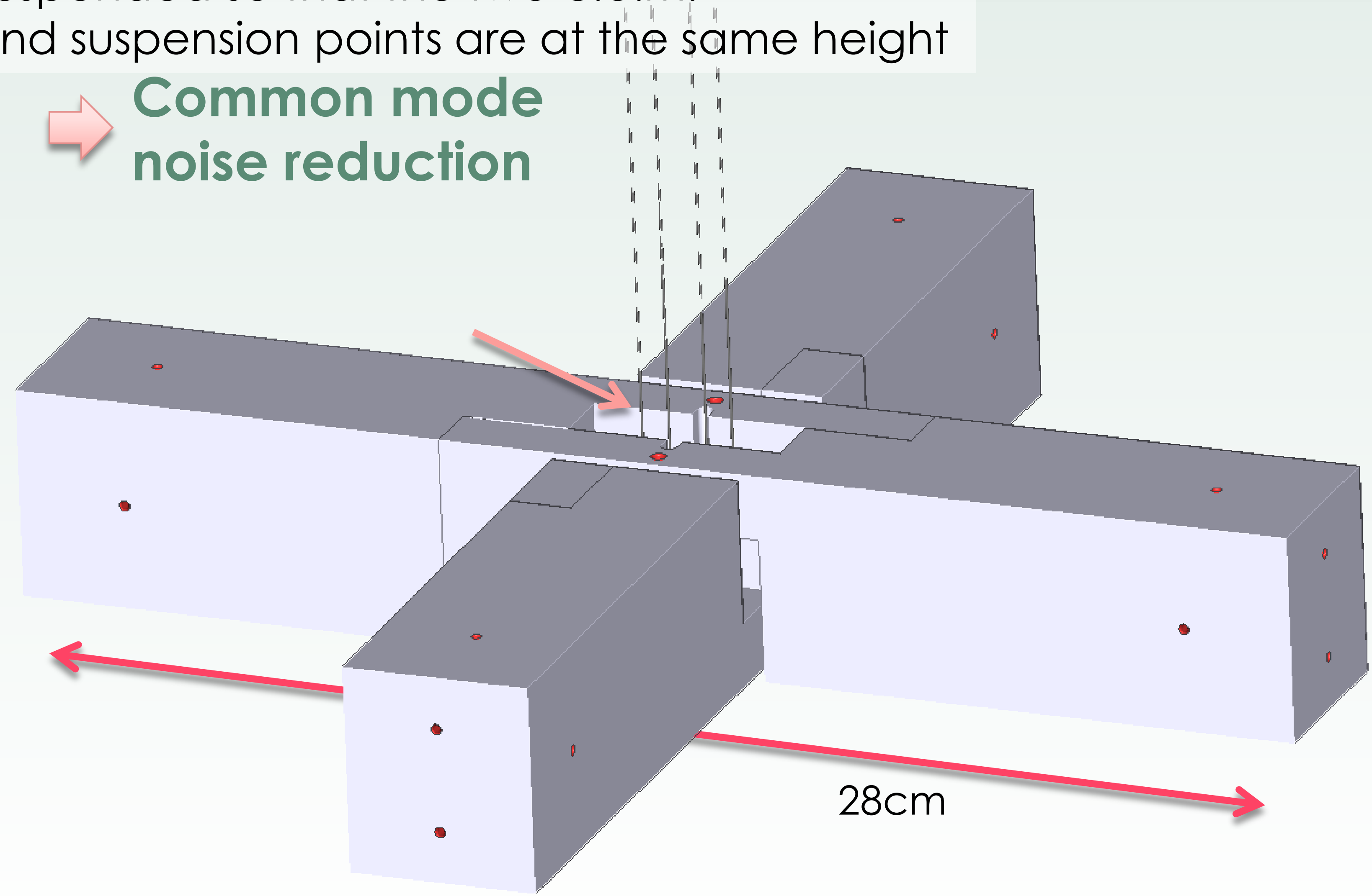


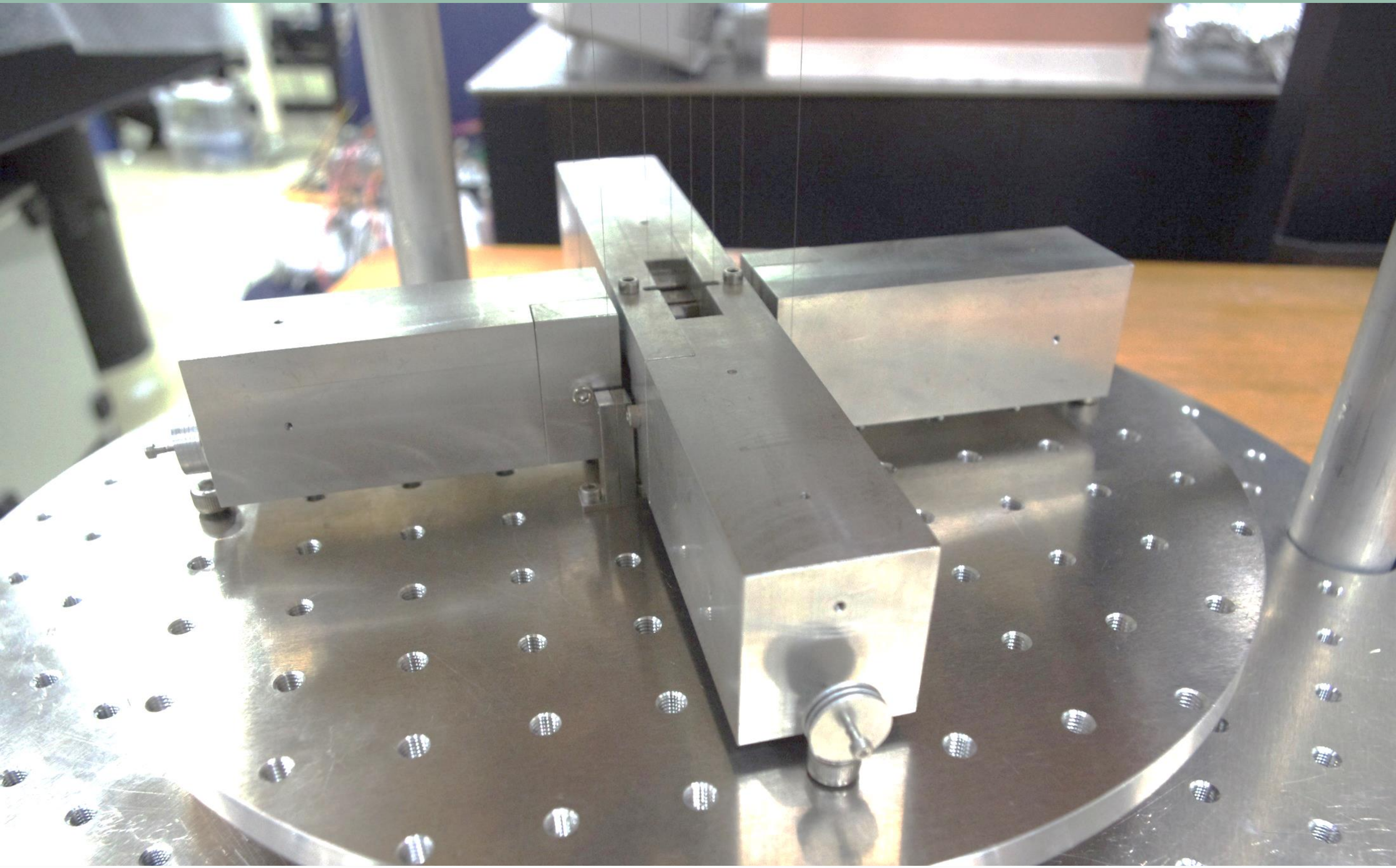


Test Mass

Suspended so that the two c.o.m.
and suspension points are at the same height

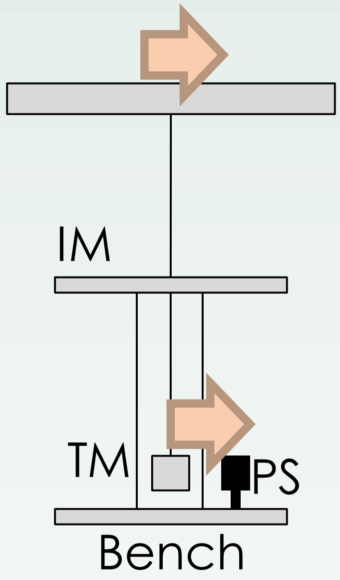
Common mode noise reduction

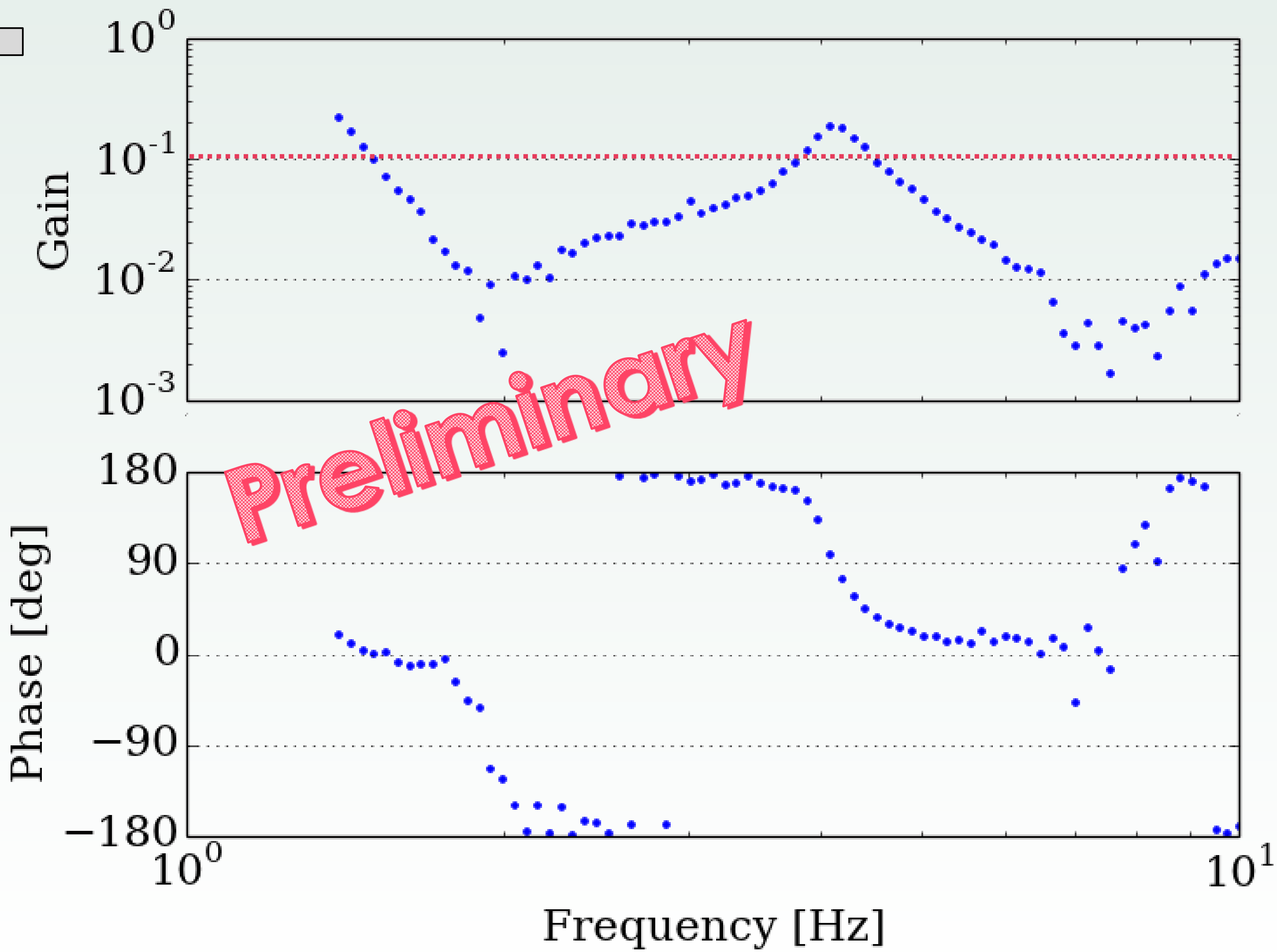




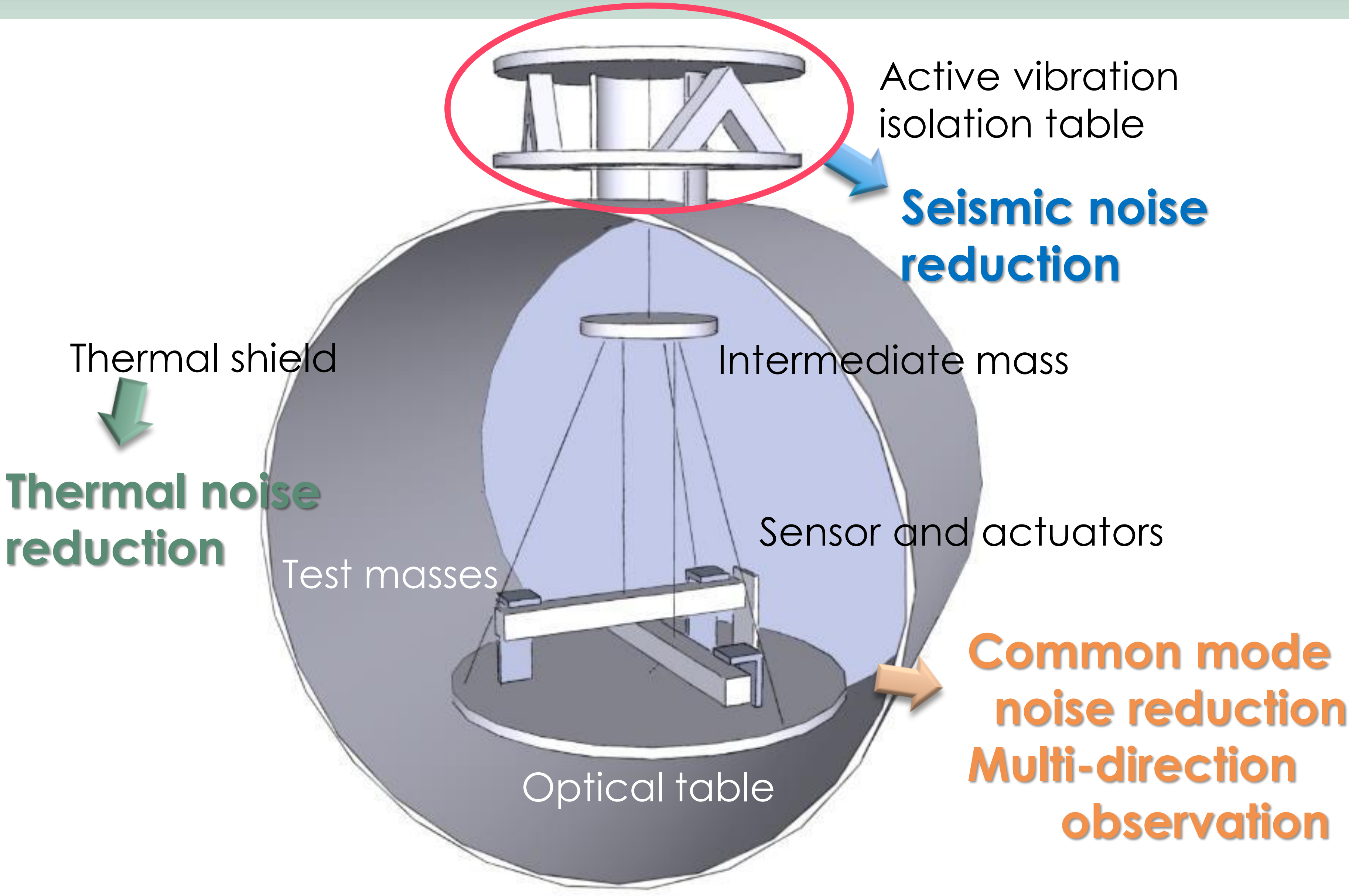
Res. Freq. in horizontal plane = 0.18 Hz
Res. Freq. in vertical plane = 0.13 Hz → **Multi-signal observation**

Vibration Isolation Rate





Schematic View



Vibration Isolation Table

- Translational motion couples to rotation monitor
- Asymmetry excites rotational vibration

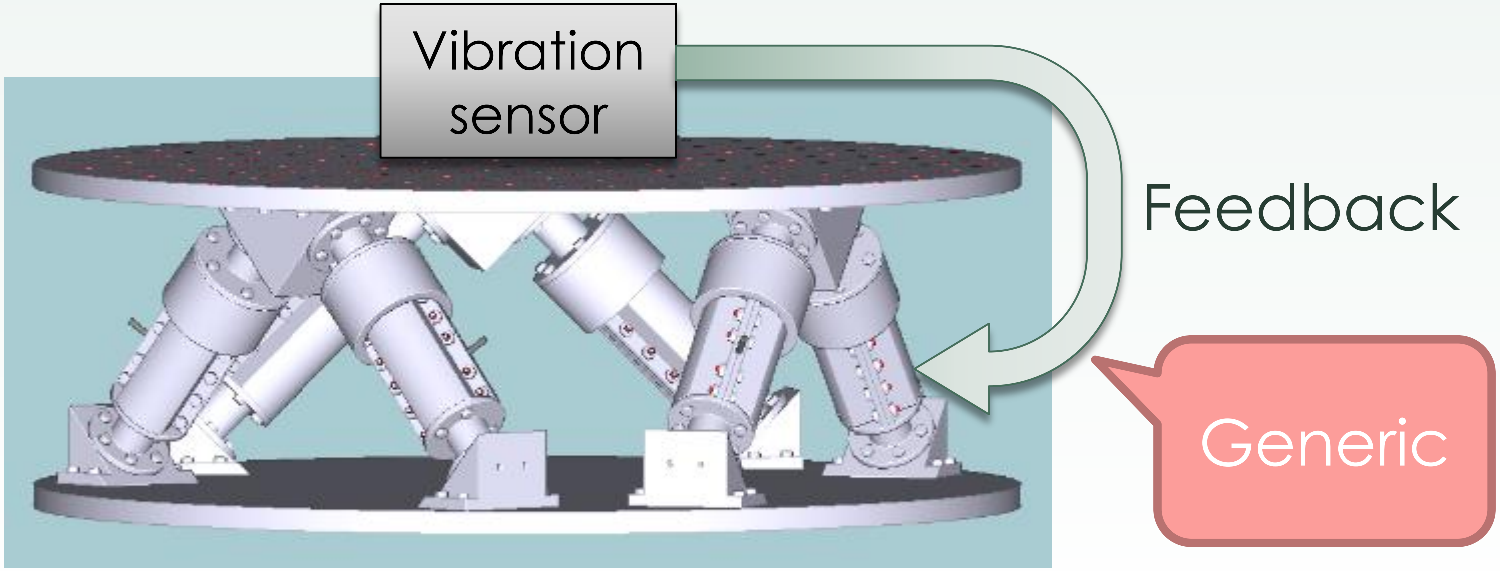
Vibration isolation at low freqs is necessary

goal : Reduction rate: 1/10 @ 0.1-10Hz

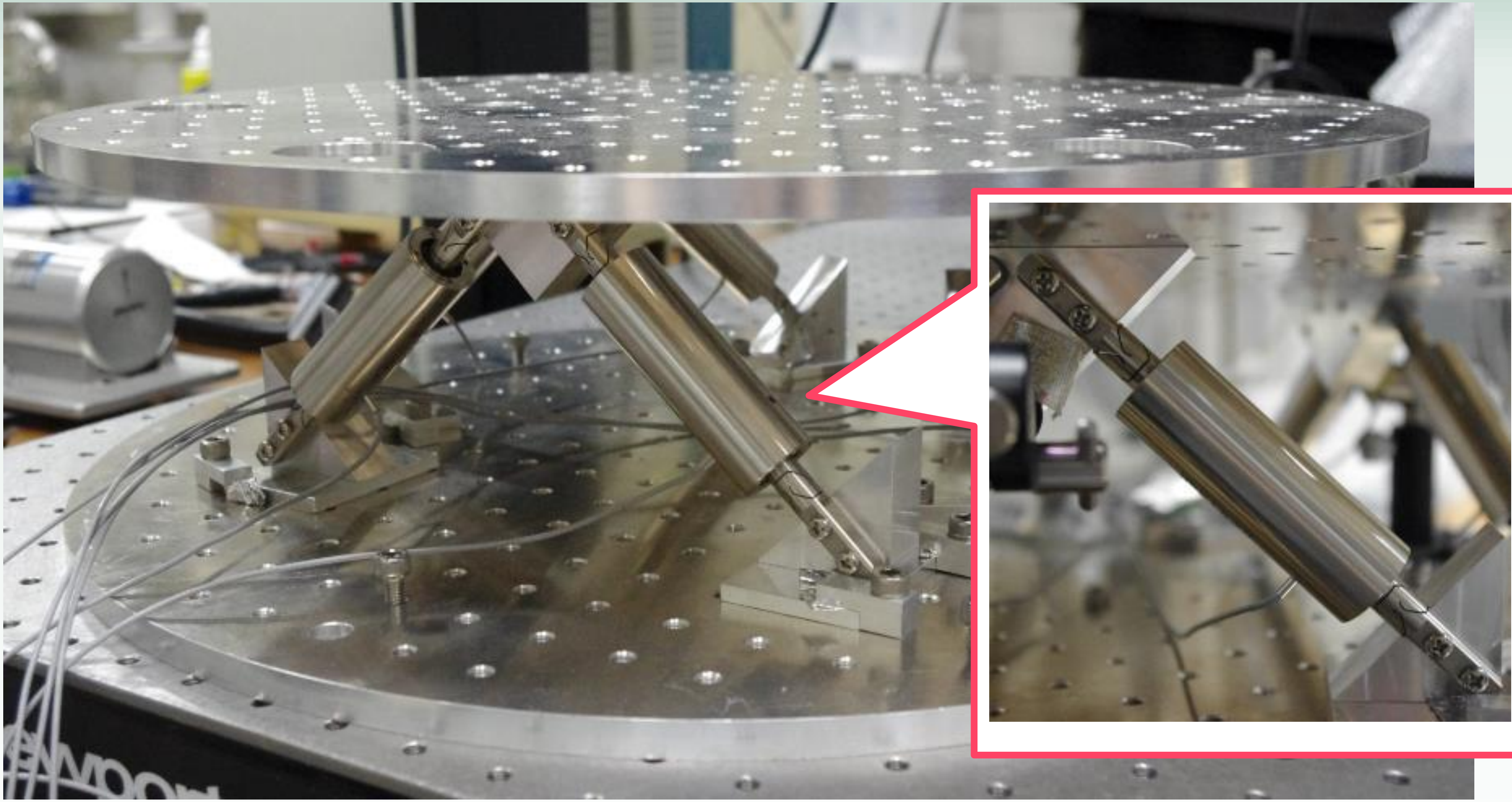
(offline decoupling rate : 1/100)

Active vibration isolation (Hexapod)

Compact, low freq. vibration isolation

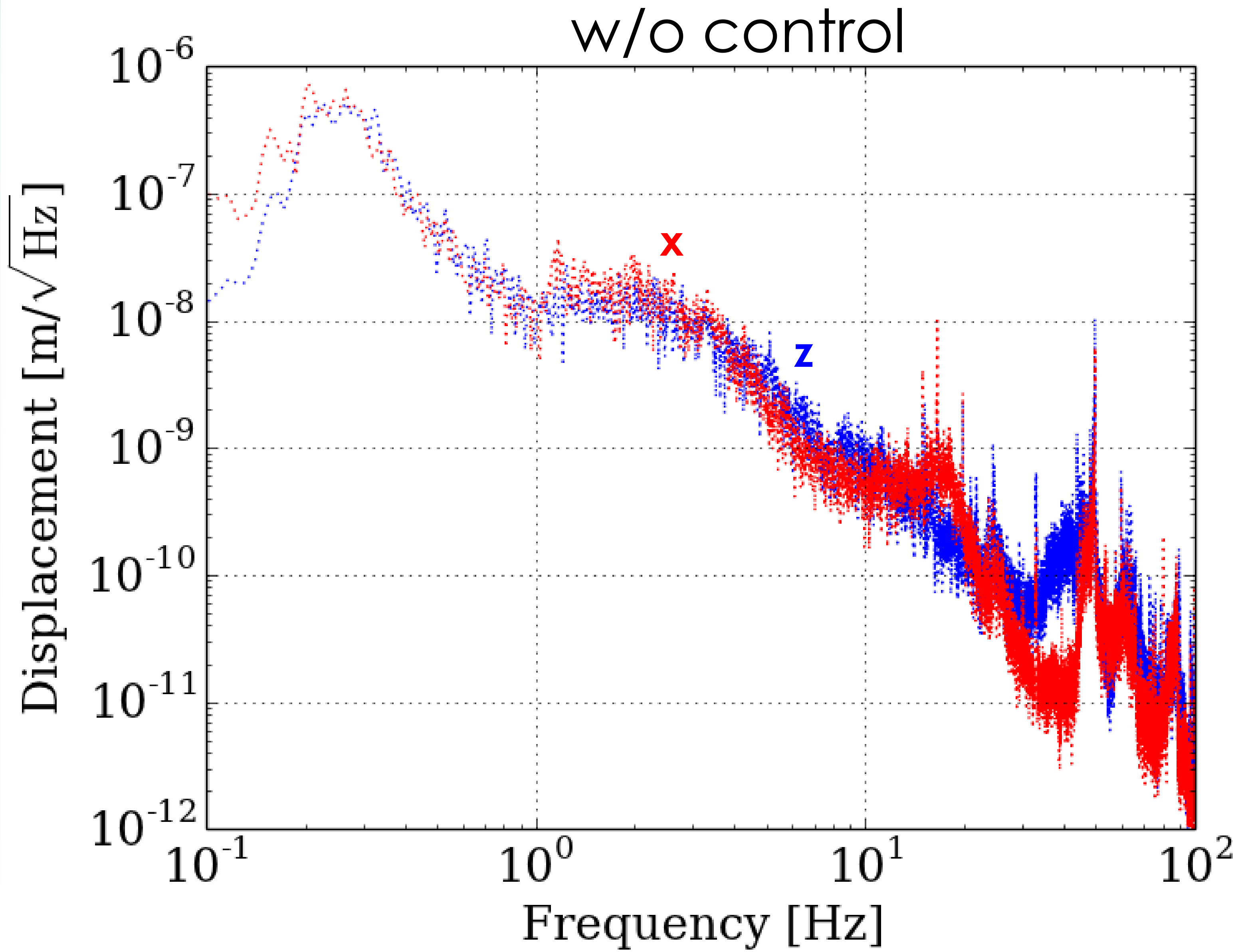


Hexapod

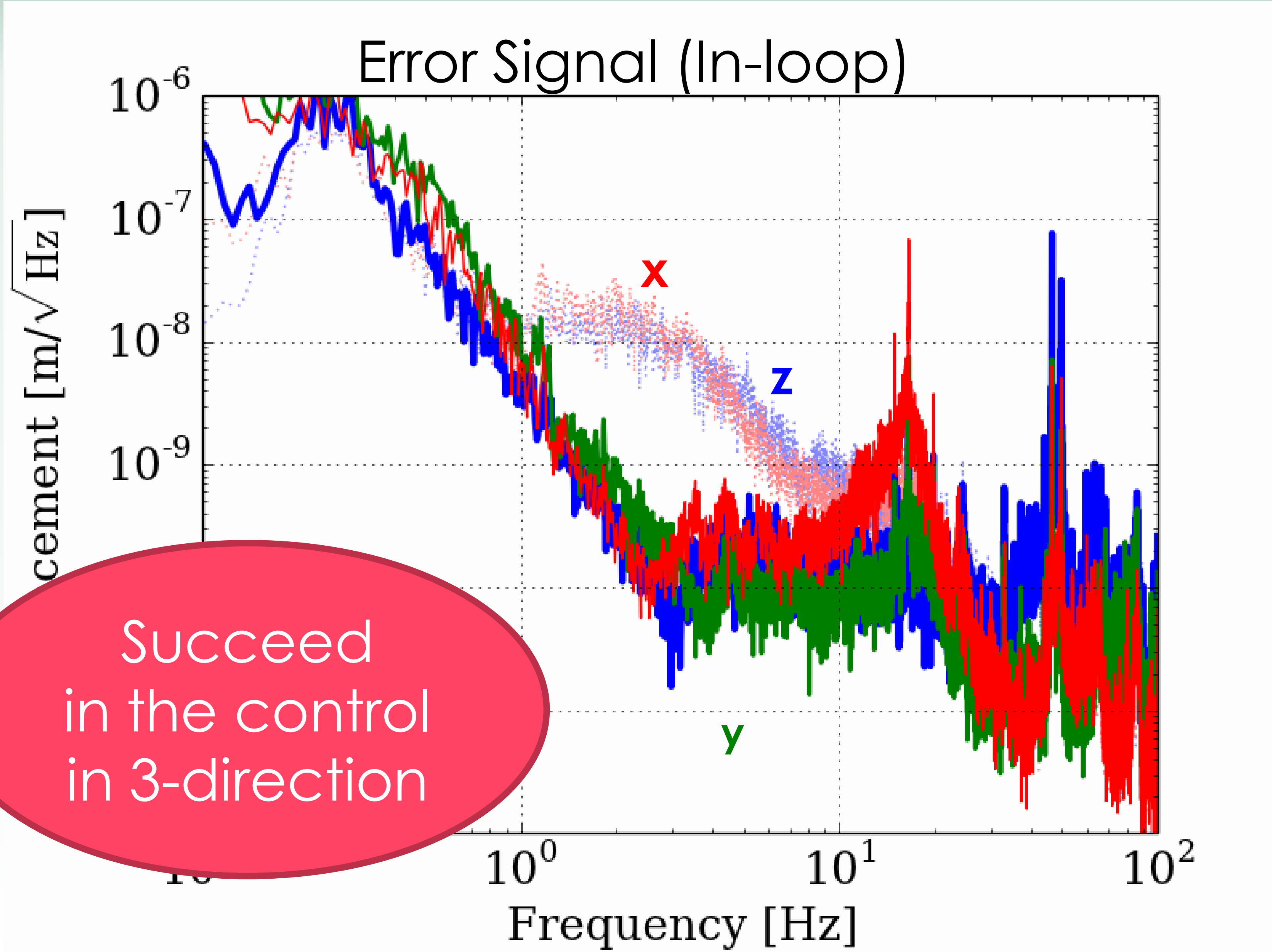


45cm

Vibration Isolation Rate

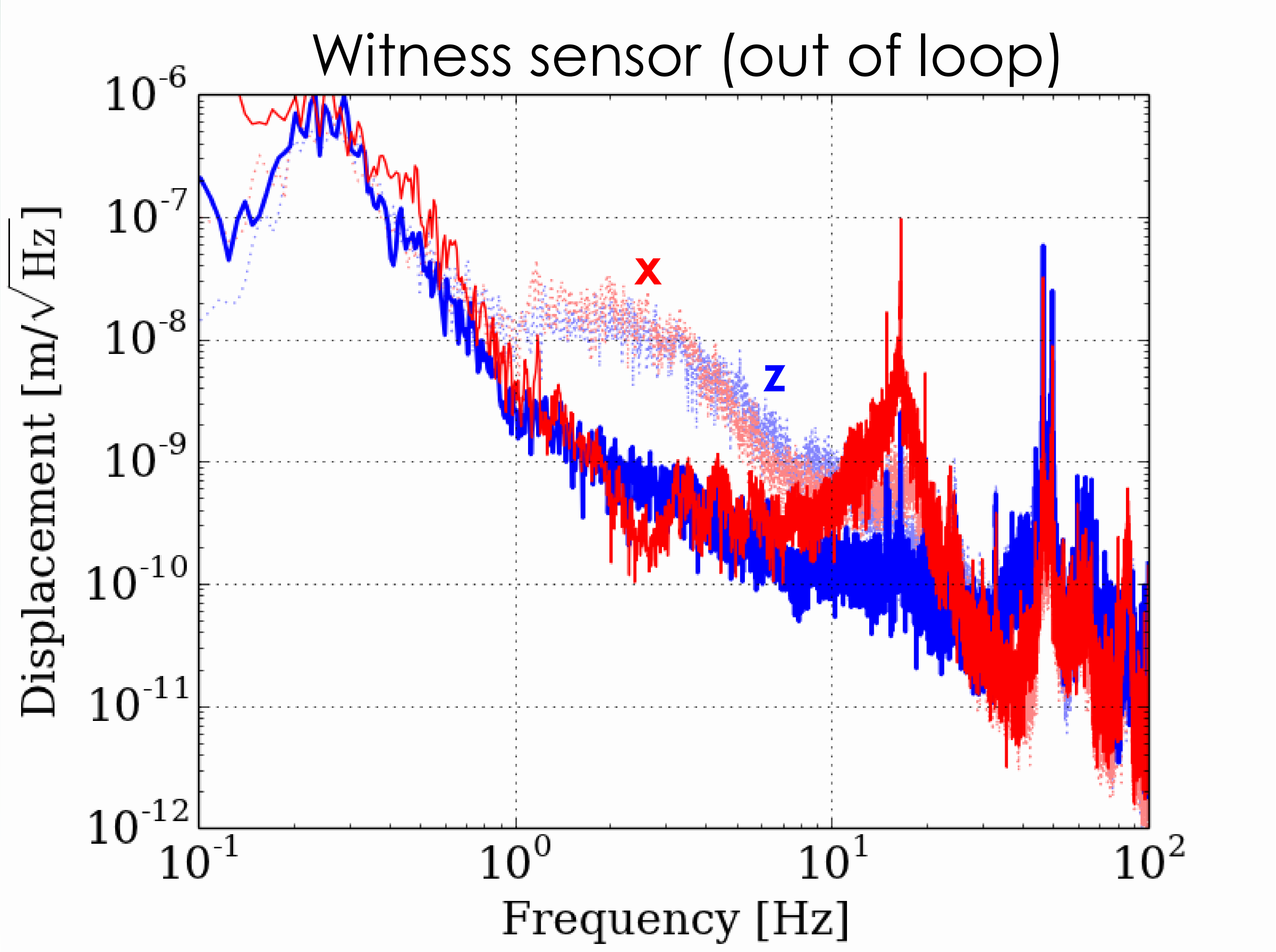


Vibration Isolation Rate

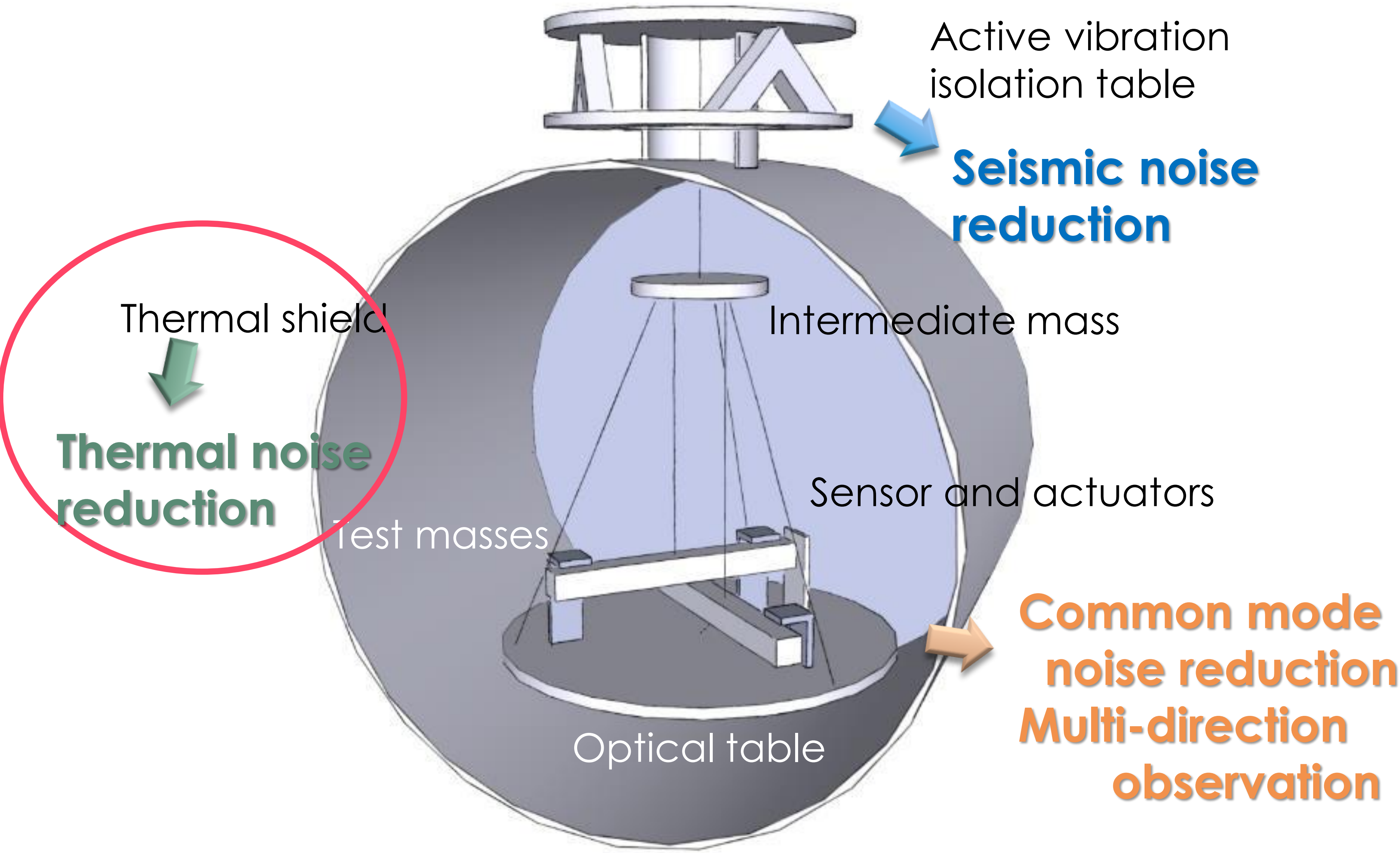


Succeed
in the control
in 3-direction

Vibration Isolation Rate

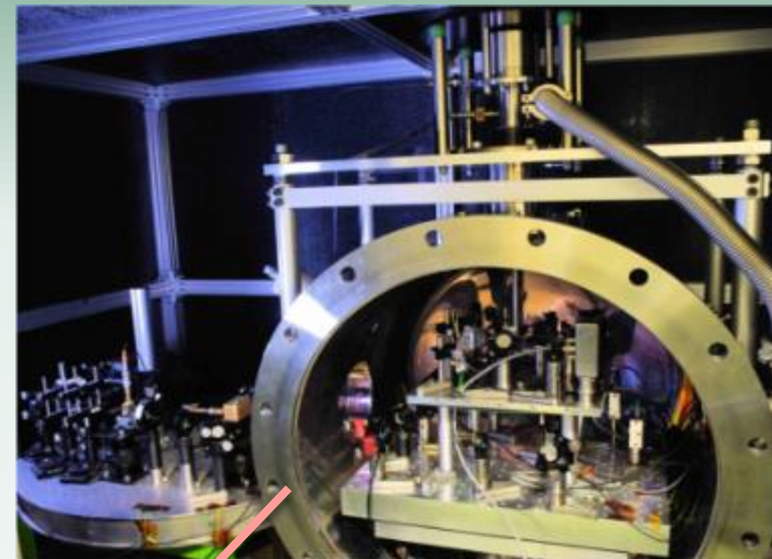


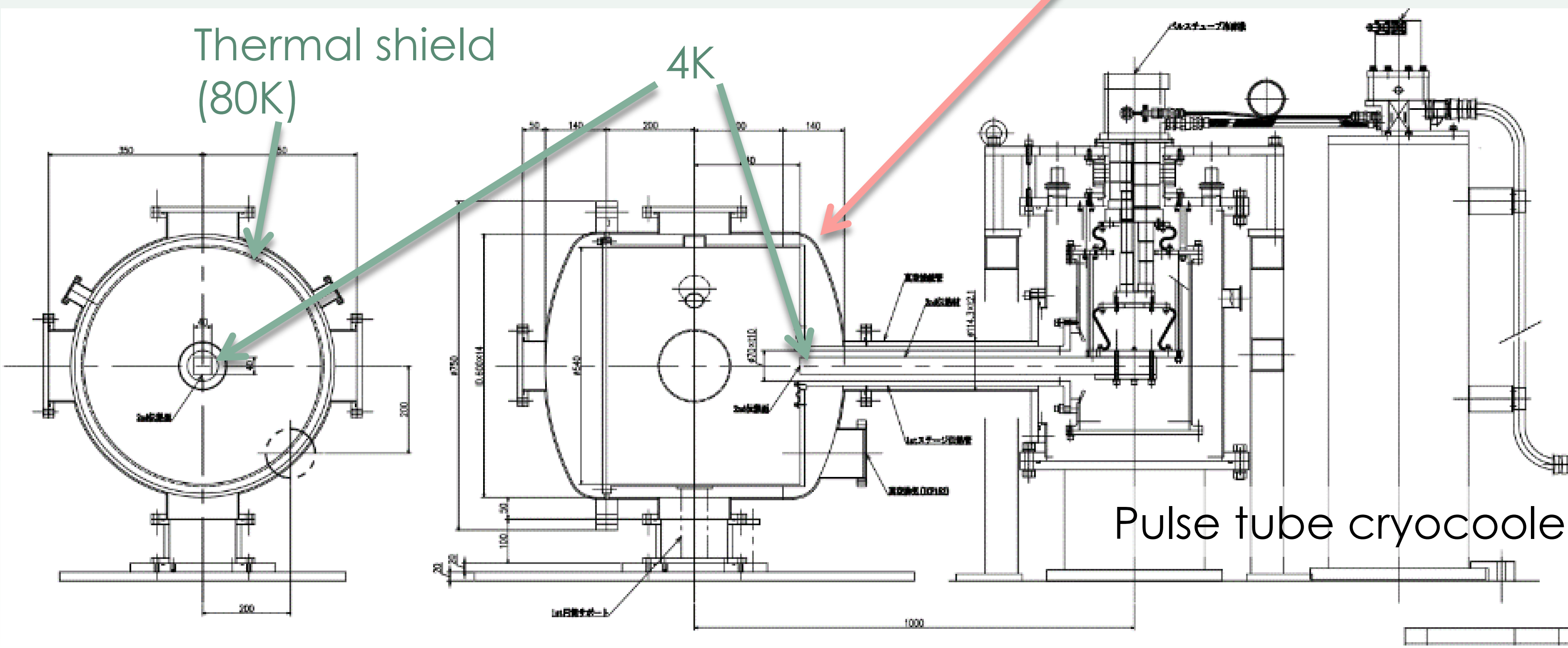
Schematic View

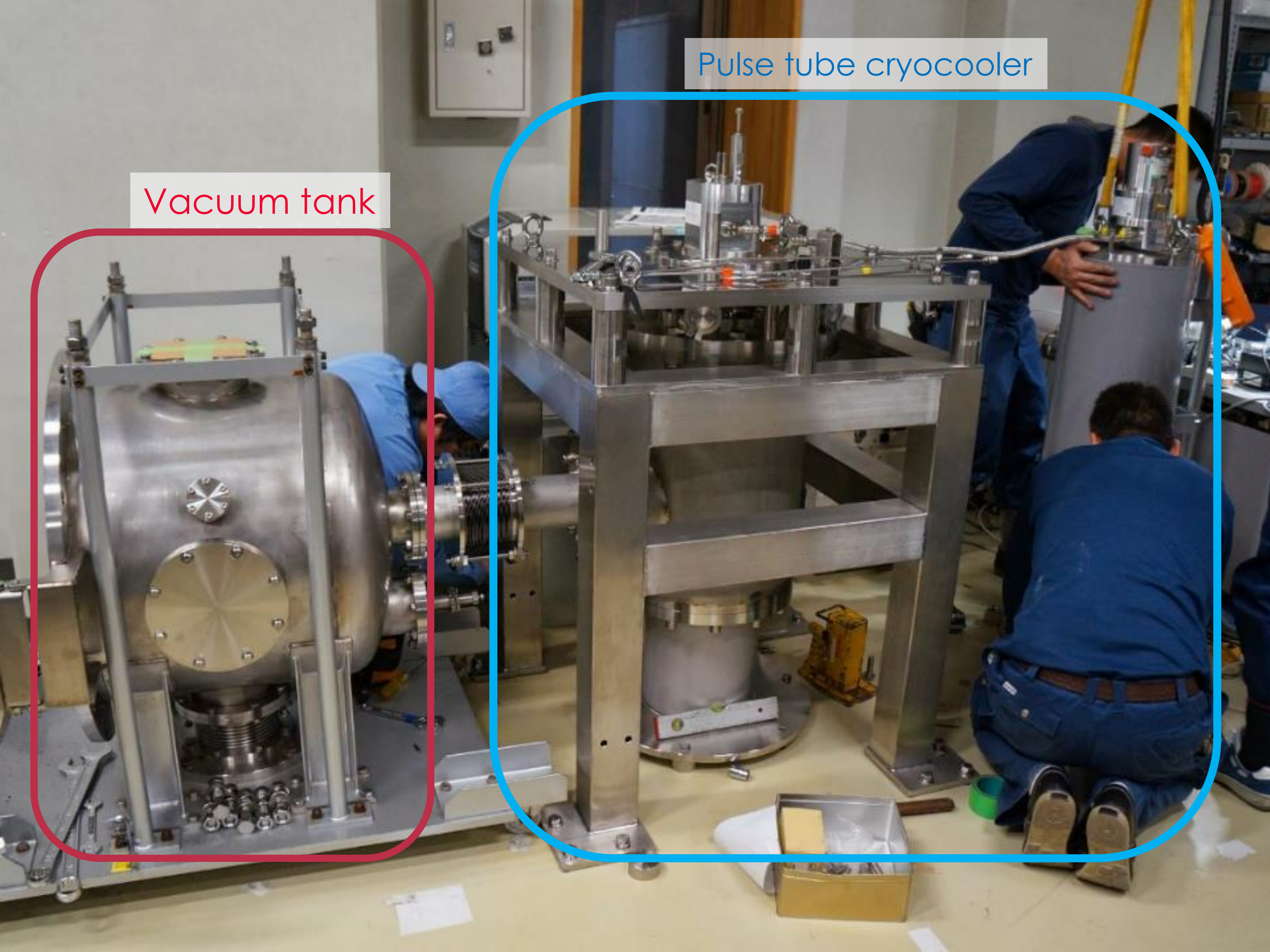


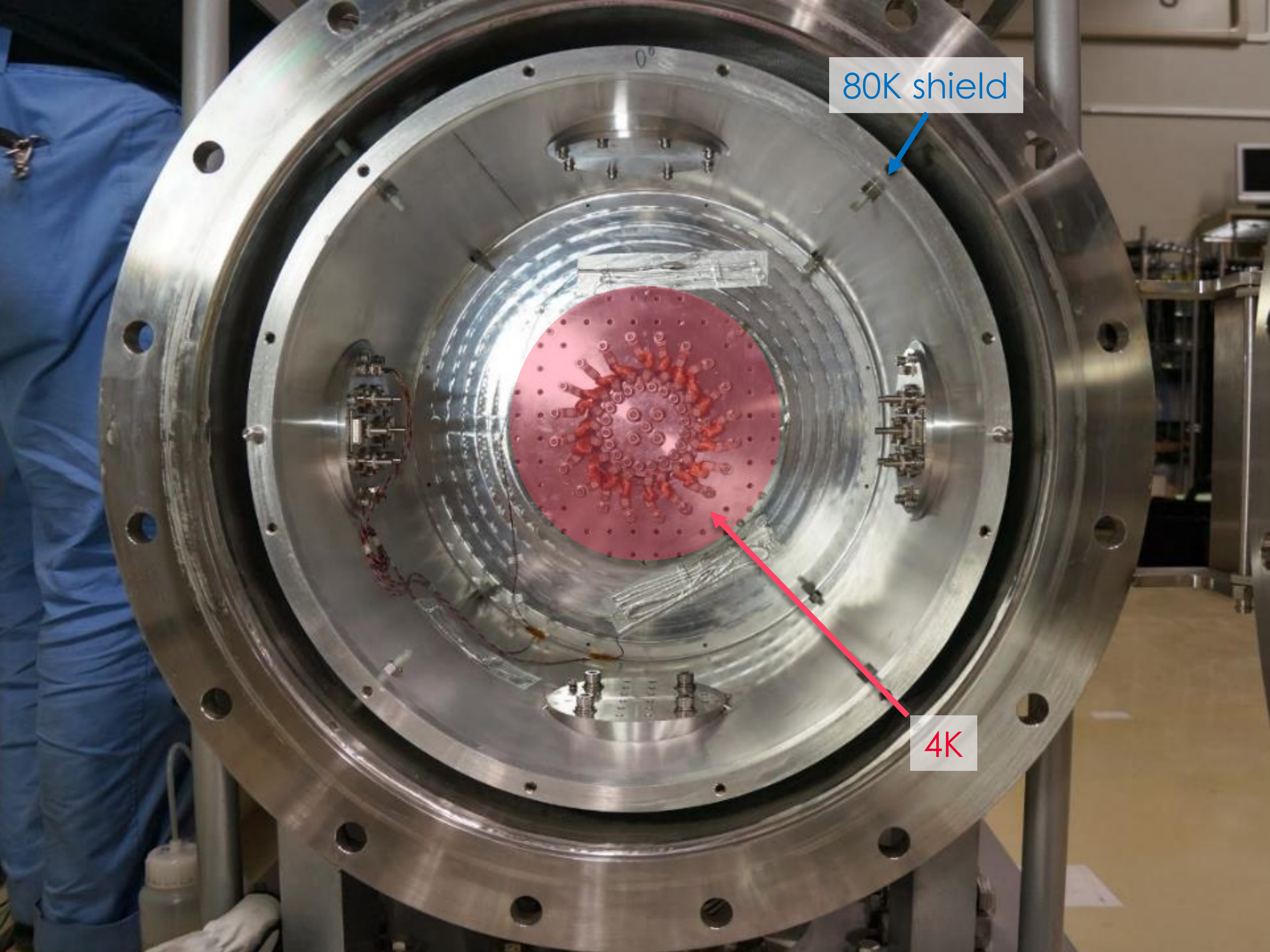
Cryostat

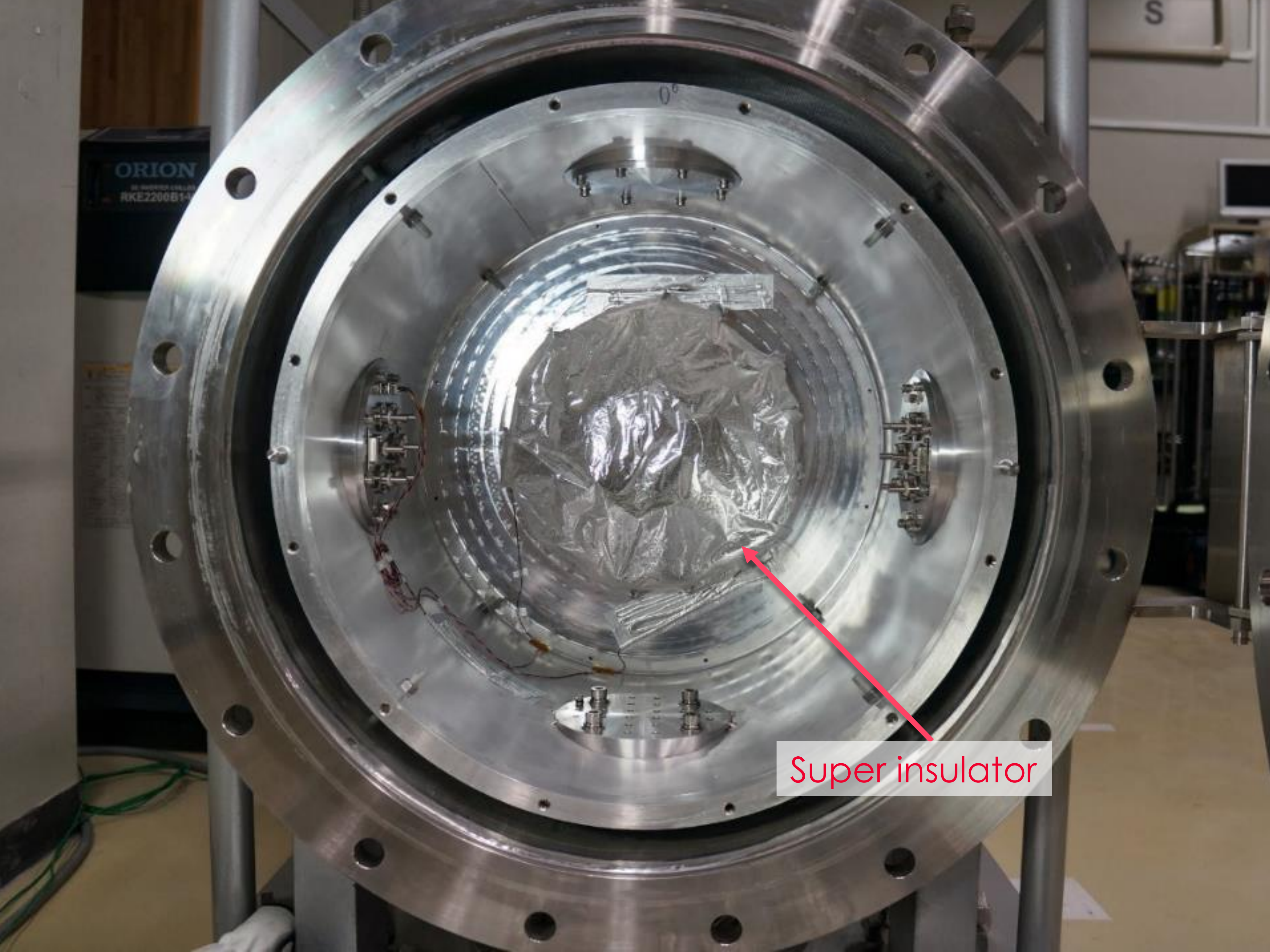
Remake the vacuum tank used with the first prototype

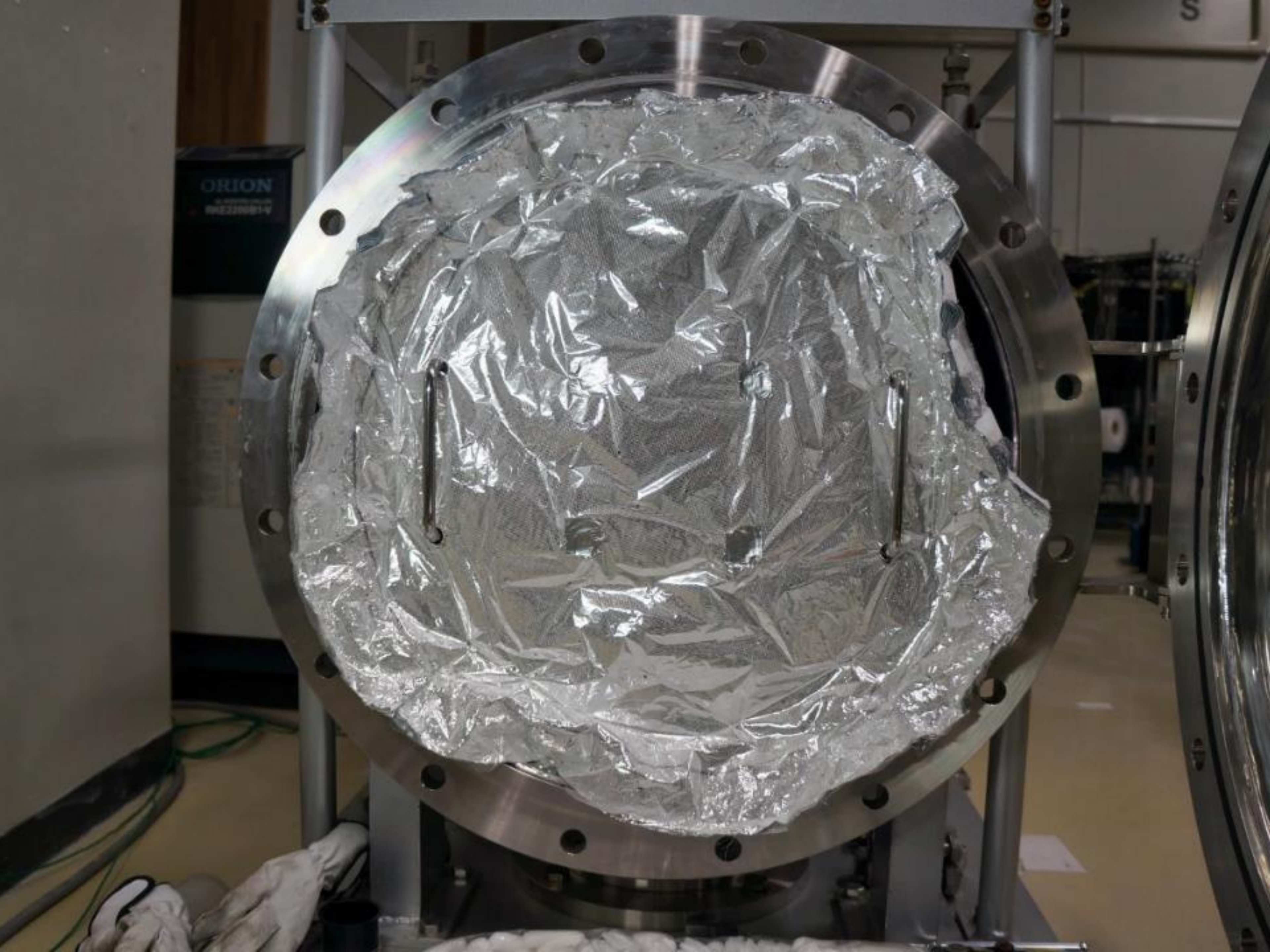





Pulse tube cryocooler
Vacuum tank

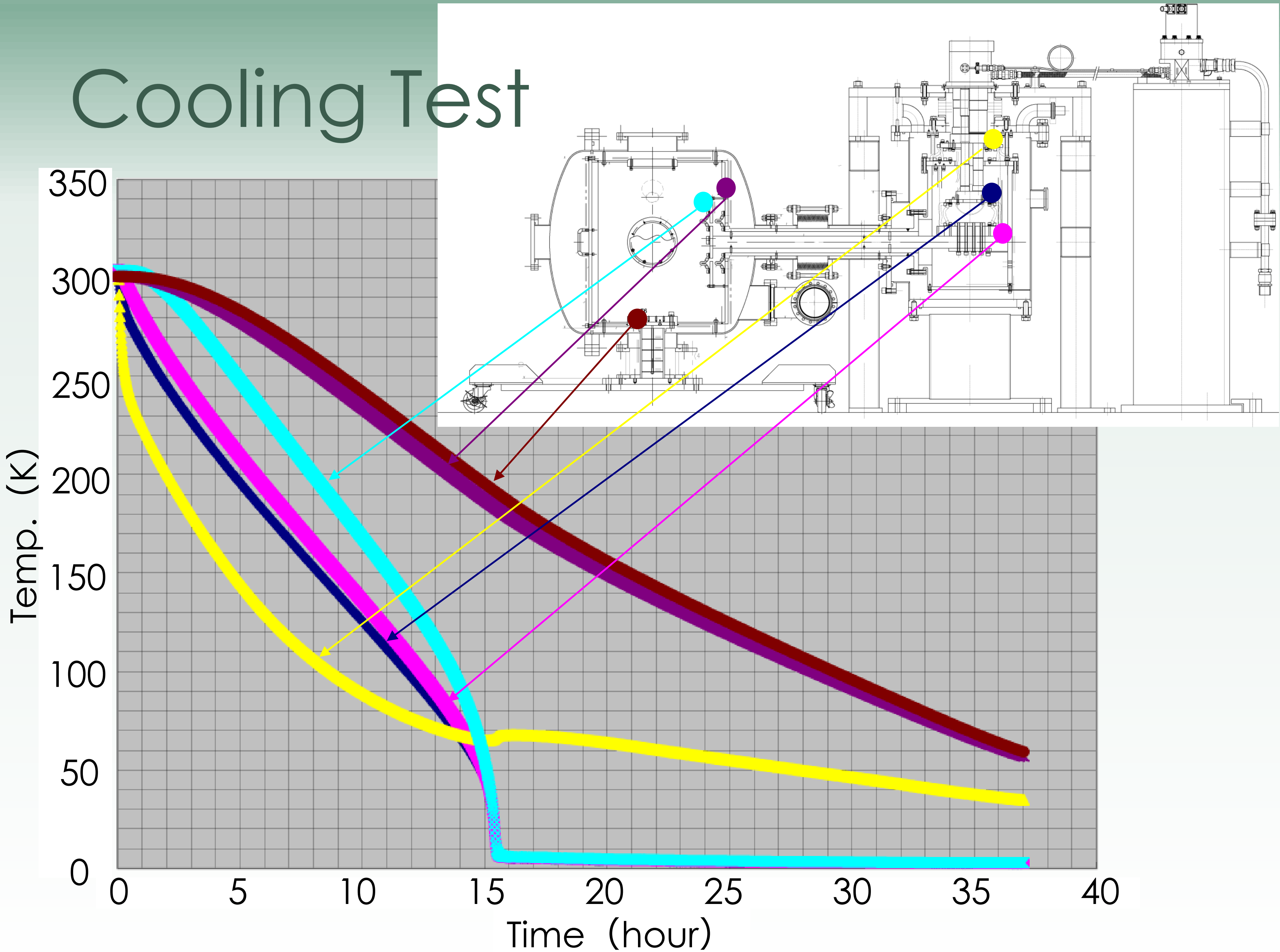

80K shield
4K


ORION
Super insulator


ORION


S
ORION
RKE2200B1-V

Cooling Test



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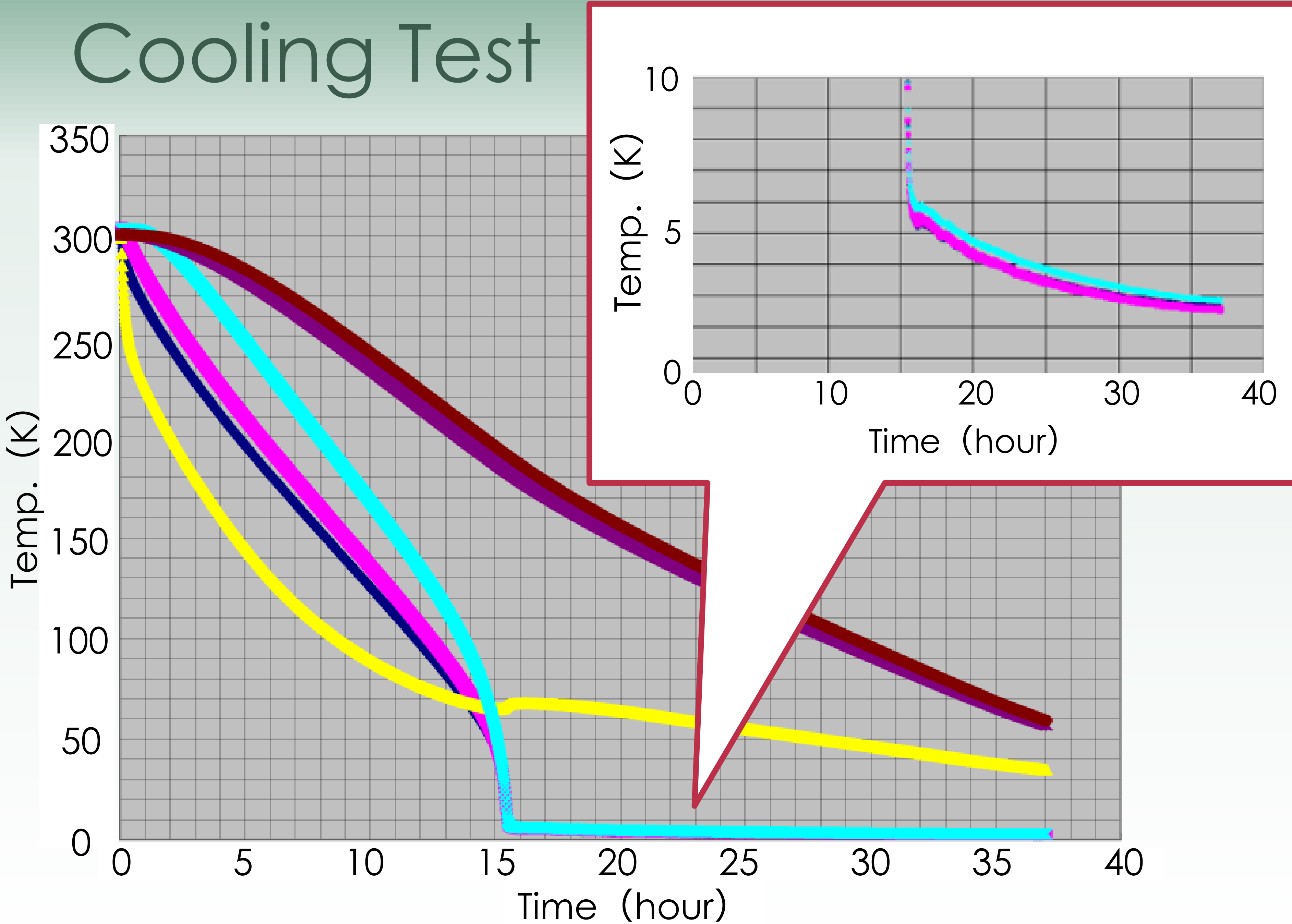

Summary and Future Plan

			2014. Jun.			Sep.				
suspension	Design, Construction, TF evaluation	Combined								
Hexapod	Development, Vibration isolation in 3-direction									
sensor & actuator	Development, Evaluation									
cryogenic	Construction, First cooling test									

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Combined

Further TF evaluation
Vibration isolation

Built at 300K
Seismic noise reduction

Evaluation at 4K
Noise Hunting

Evaluation at 4K

observation
analysis