KAGRA STATUS

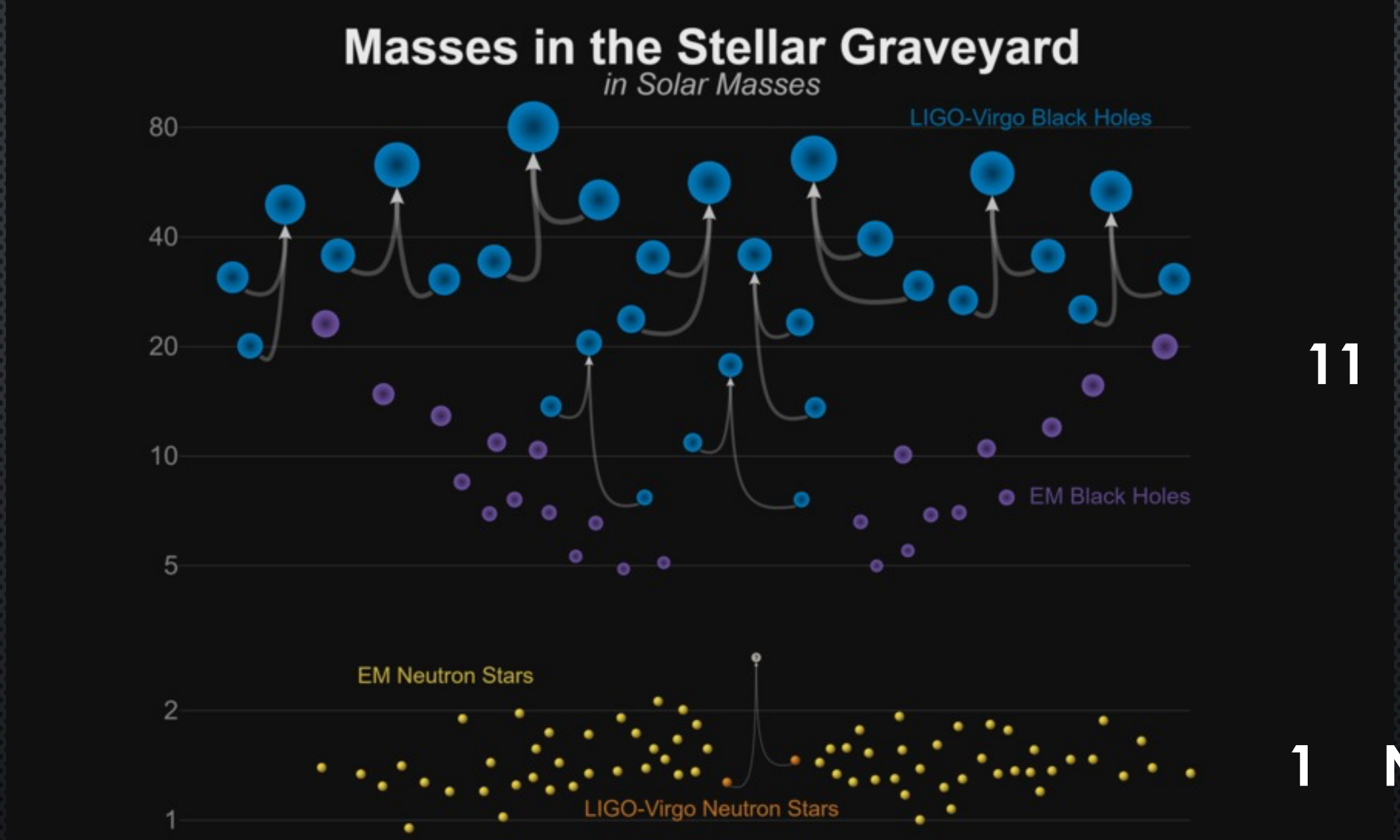
-GRAVITATIONAL-WAVE TELESCOPE IN JAPAN-

29, Apr., 2019

@ Vacuum Fluctuation at Nanoscale and Gravitation conference

Takayuki TOMARU on behalf of KAGRA

National Astronomical Observatory of Japan



11 BH-BH

1 NS-NS

LIGO-VIRGO Observation 3 has been started.
New 4 BH-BH events have been detected.

Observation Network for Gravitational Wave

aLIGO (Hanford), 4km
70-80Mpc for NS-NS

LIGO India
will start from
2025

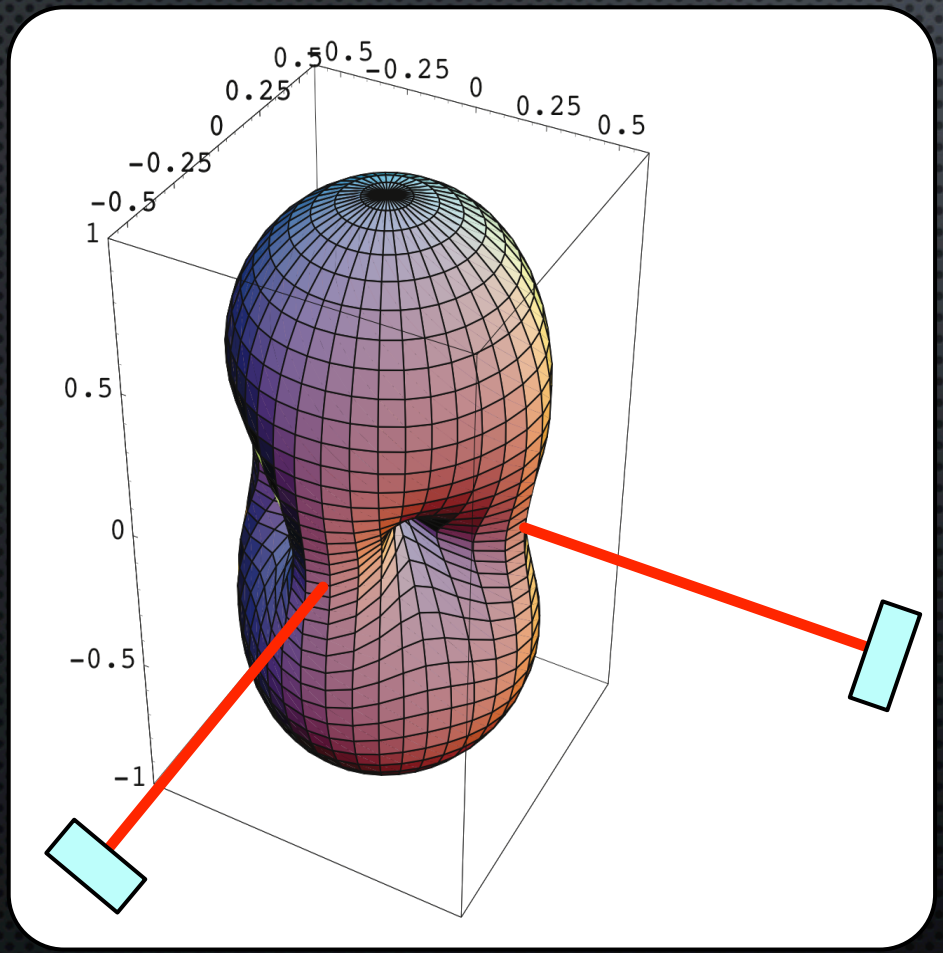
aVIRGO (Pisa), 3km
~55Mpc

KAGRA (Kamioka), 3km
will start from 2019

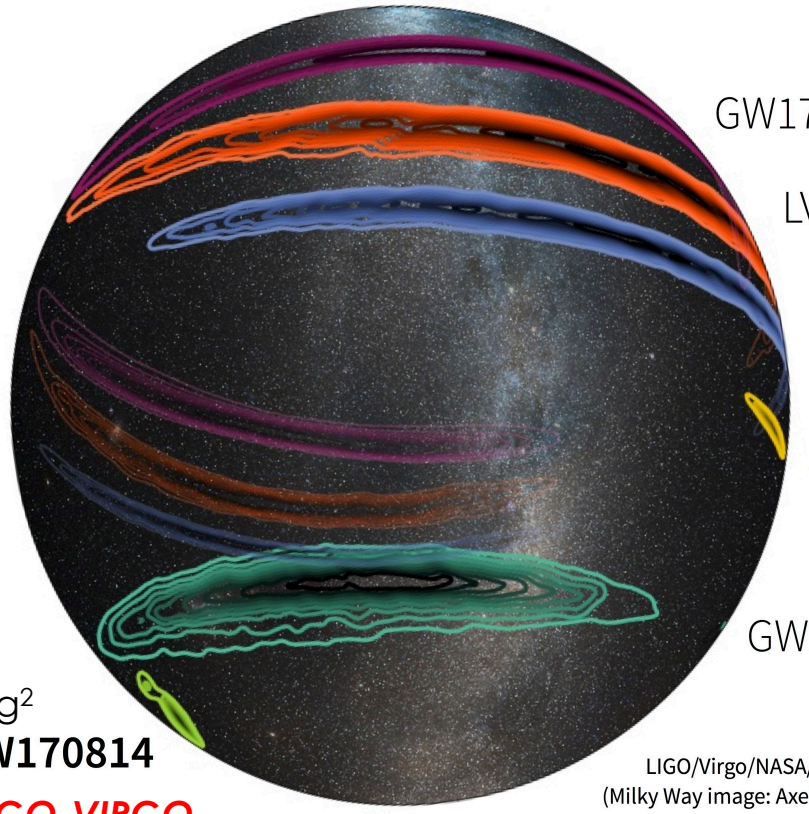
aLIGO
(Livingston), 4km
120-130Mpc

Why do we need KAGRA?

Antenna Pattern of Interferometric Gravitational Wave Detector



Identified Localization of GW Events



GW170104 1200 deg^2

LVT151012

GW151226 850 deg^2

GW170817
28 deg^2
by LIGO-VIRGO

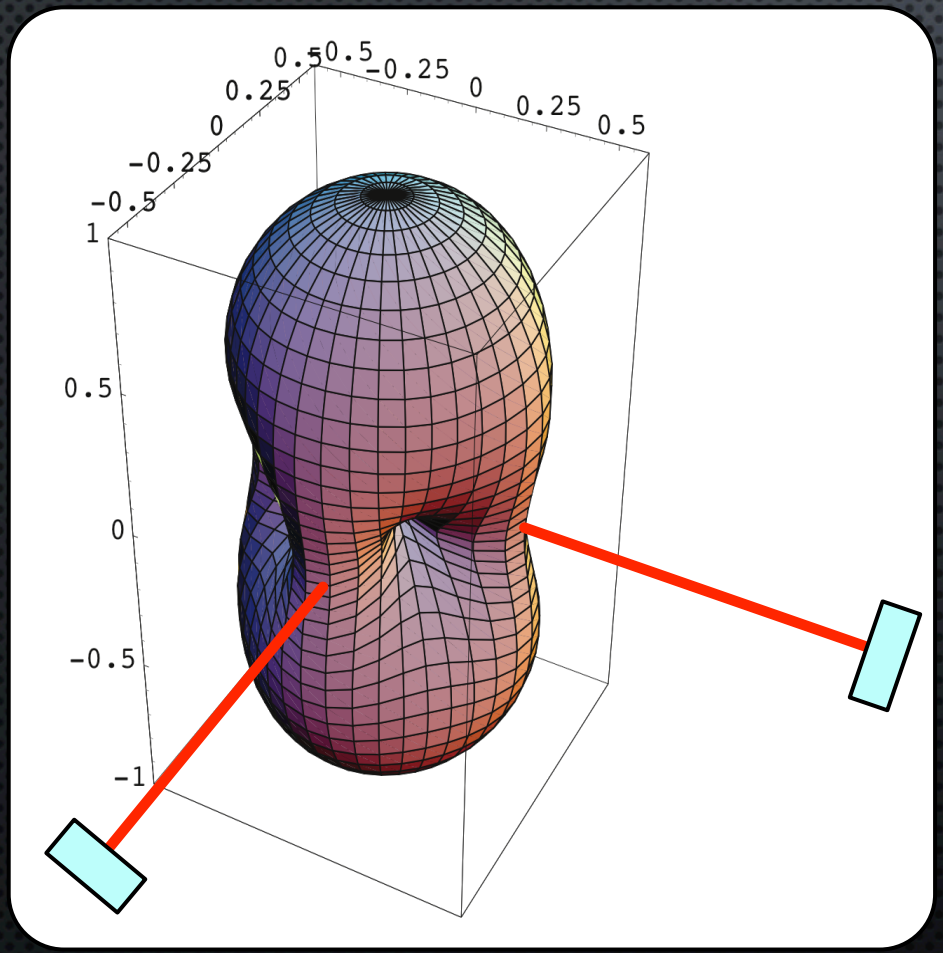
GW150914 600 deg^2

60 deg^2
GW170814
by LIGO-VIRGO

LIGO/Virgo/NASA/Leo Singer
(Milky Way image: Axel Mellinger)

Why do we need KAGRA?

Antenna Pattern of Interferometric Gravitational Wave Detector

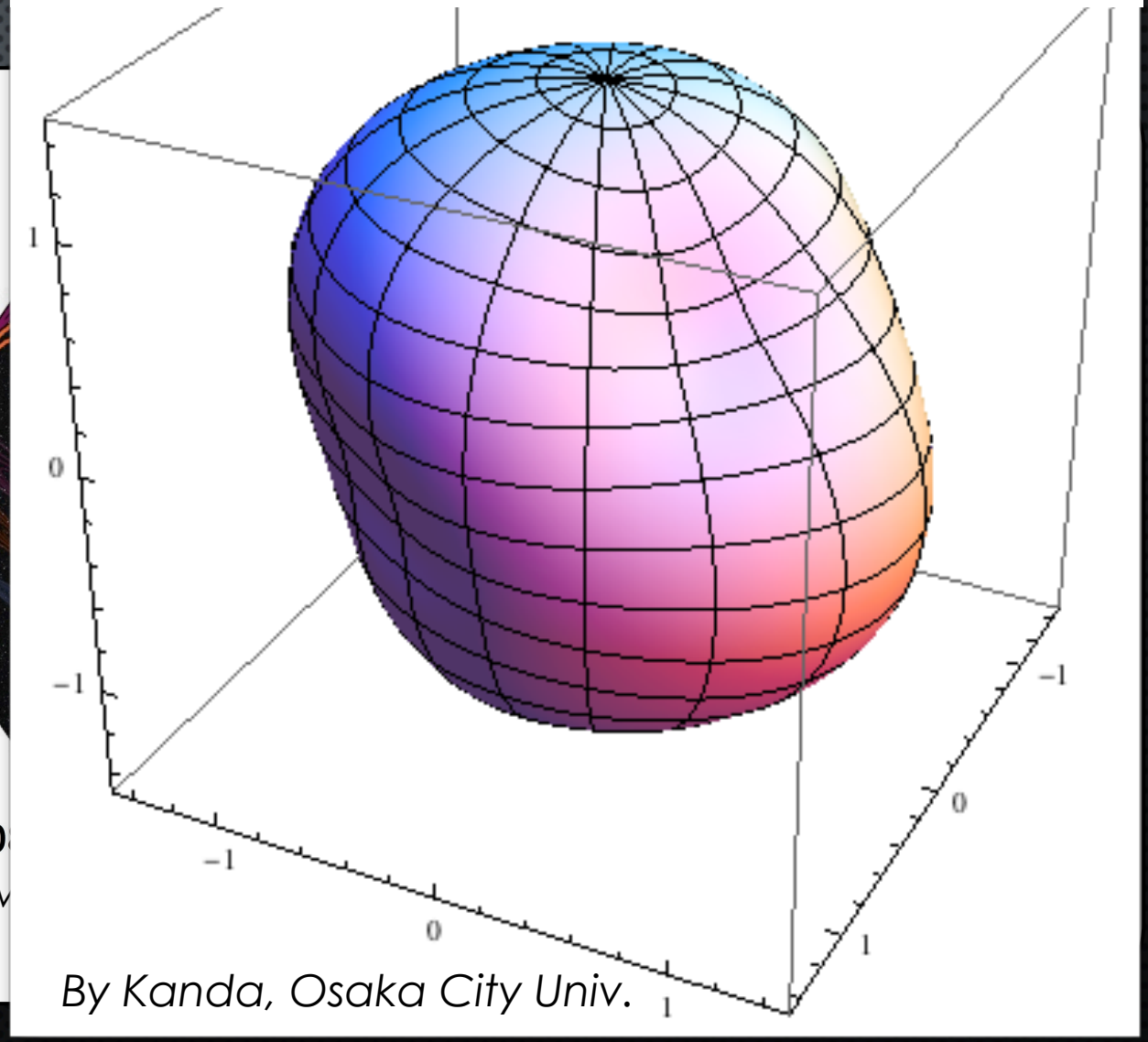


60 deg²

GW170

by LIGO-V

KAGRA + LIGO x2 + VIRGO



By Kanda, Osaka City Univ.

Cryogenic Mirror System

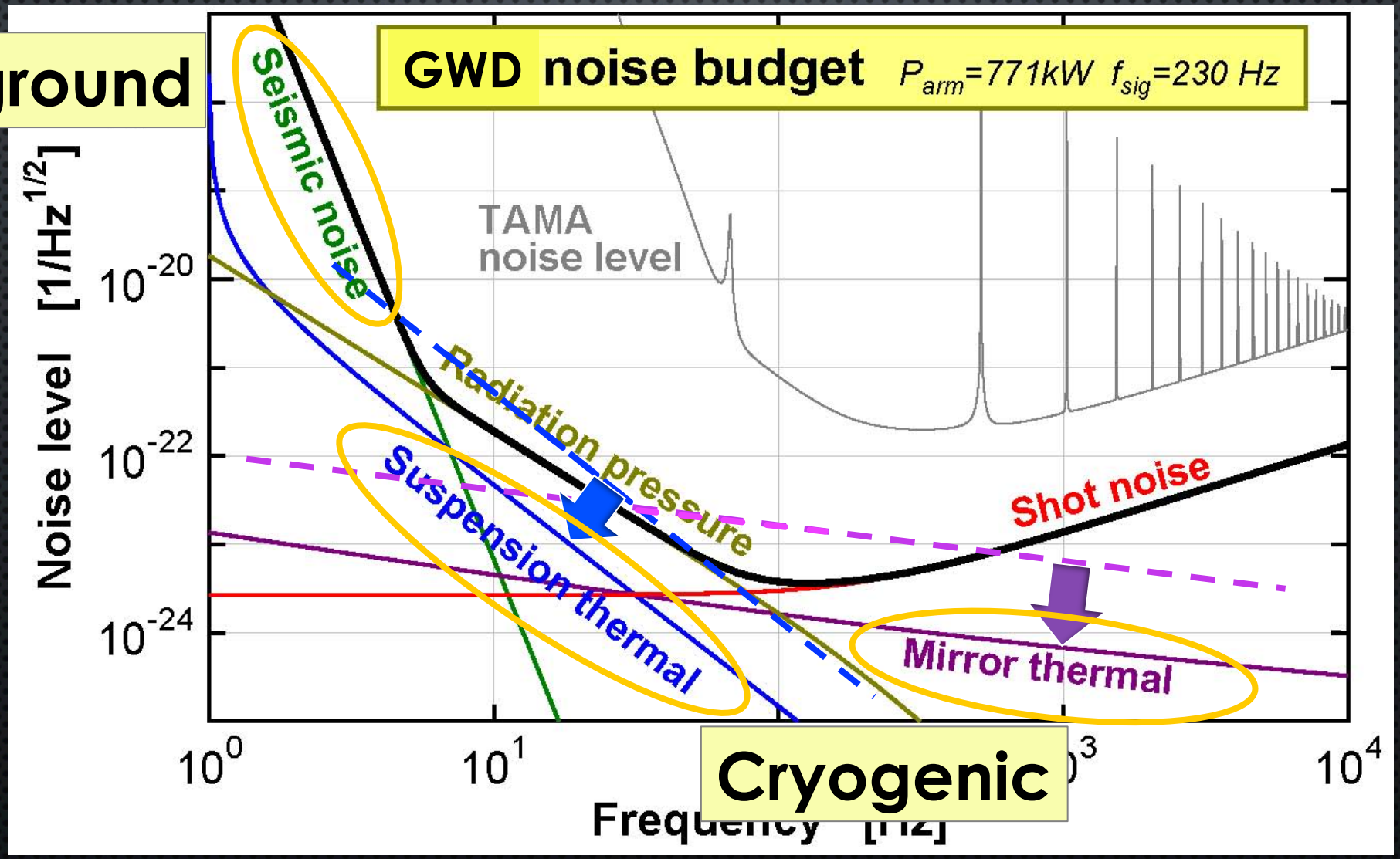
KAGRA

2.5nd Generation GW detector in Japan

Underground

Why Underground? Why Cryogenic?

Underground



Cryogenic

KAGRA LOCATION

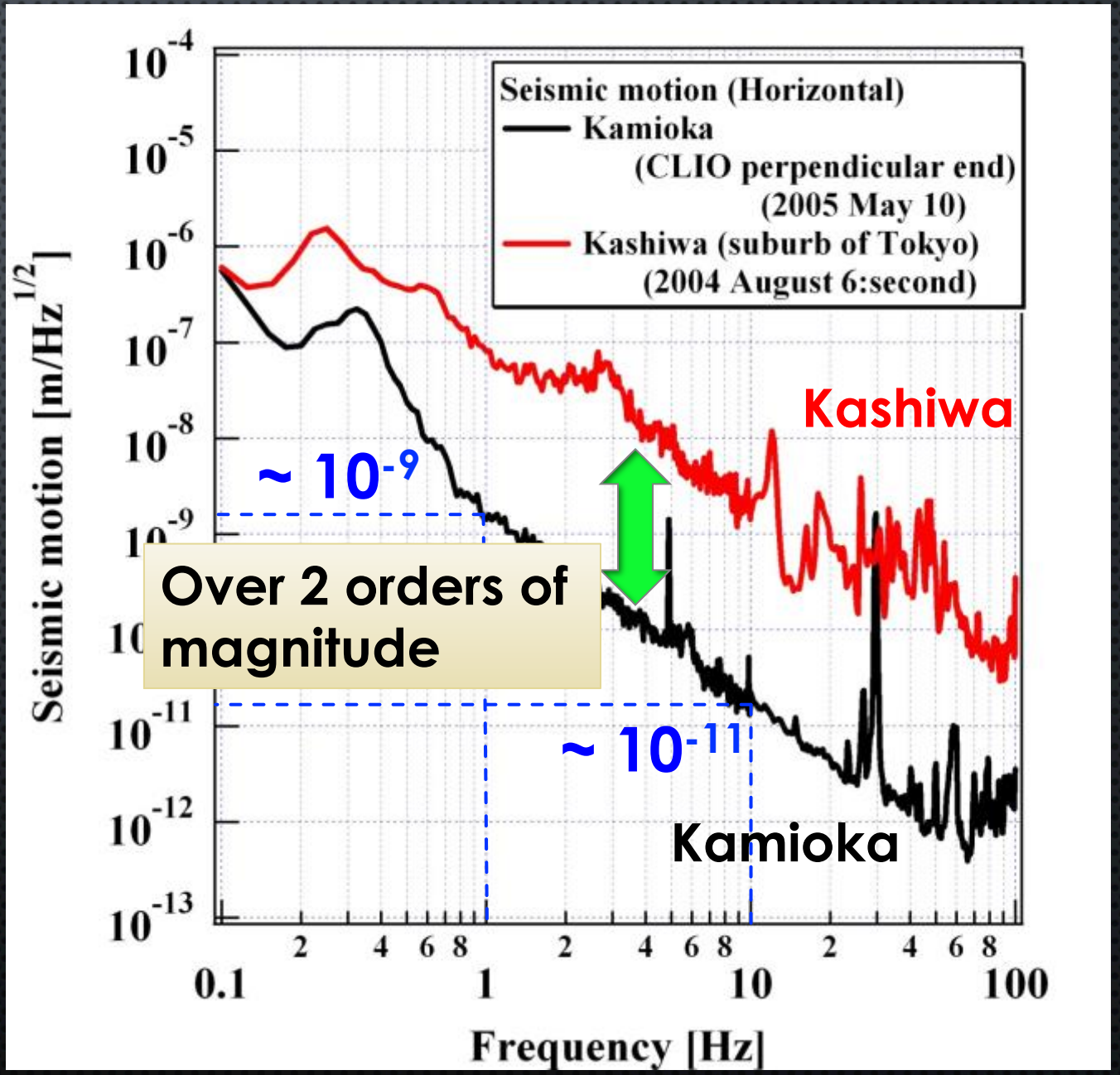
200m underground

Kamioka Underground

Seismic Vibration

We found that underground where is deeper than 100m from surface has drastically smaller seismic vibration level.
In Kamioka underground, seismic vibration level is about 2 or three orders of magnitude Smaller than that at typical urban area.

And seismic vibration level in Kamioka underground is about one order of magnitude smaller than LIGO site.



Water!

Water!!

Water!!!

Water!!!!

Cryogenic Sapphire Mirror and Suspension

(1) Thermal Noise Reduction

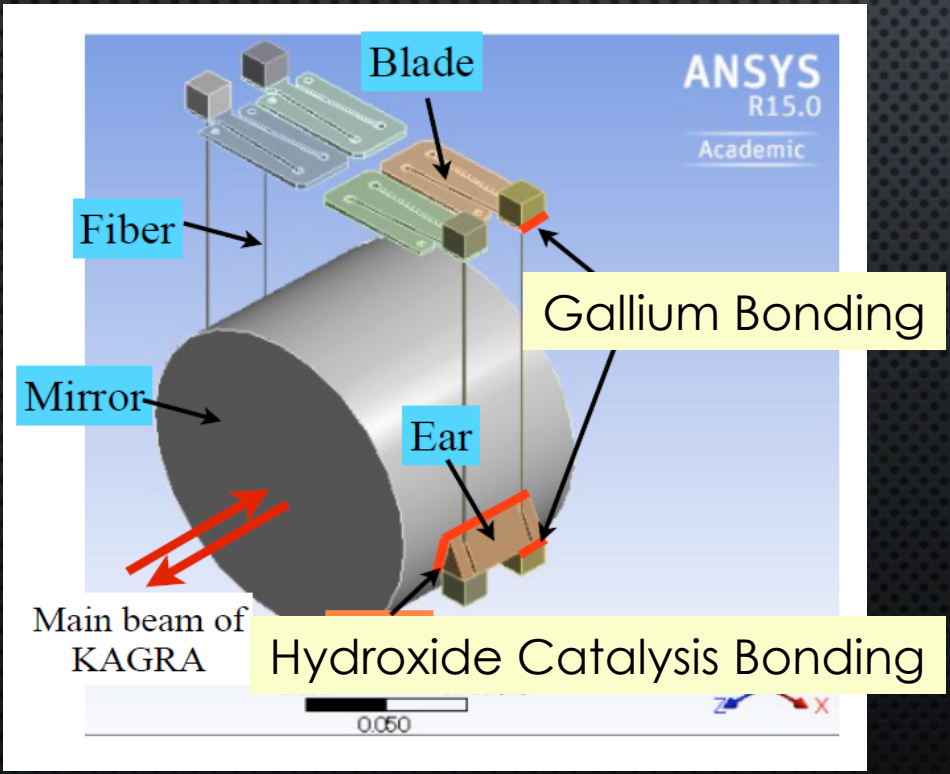
Thermal Noise Amplitude

$$\sqrt{x(\omega)^2} \propto \sqrt{T\,\phi}$$

Moreover **Sapphire @ 20K**

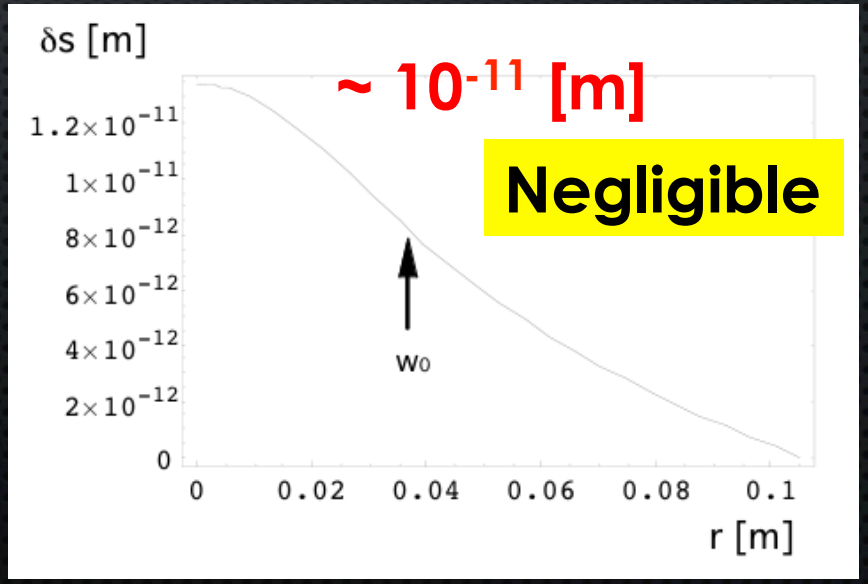
$$\phi = 5 \times 10^{-9} \quad \text{(bulk)}$$
$$\phi = 1 \times 10^{-7} \quad \text{(fiber)}$$

Typical Φ of sapphire at room temperature is ~10^{-6}

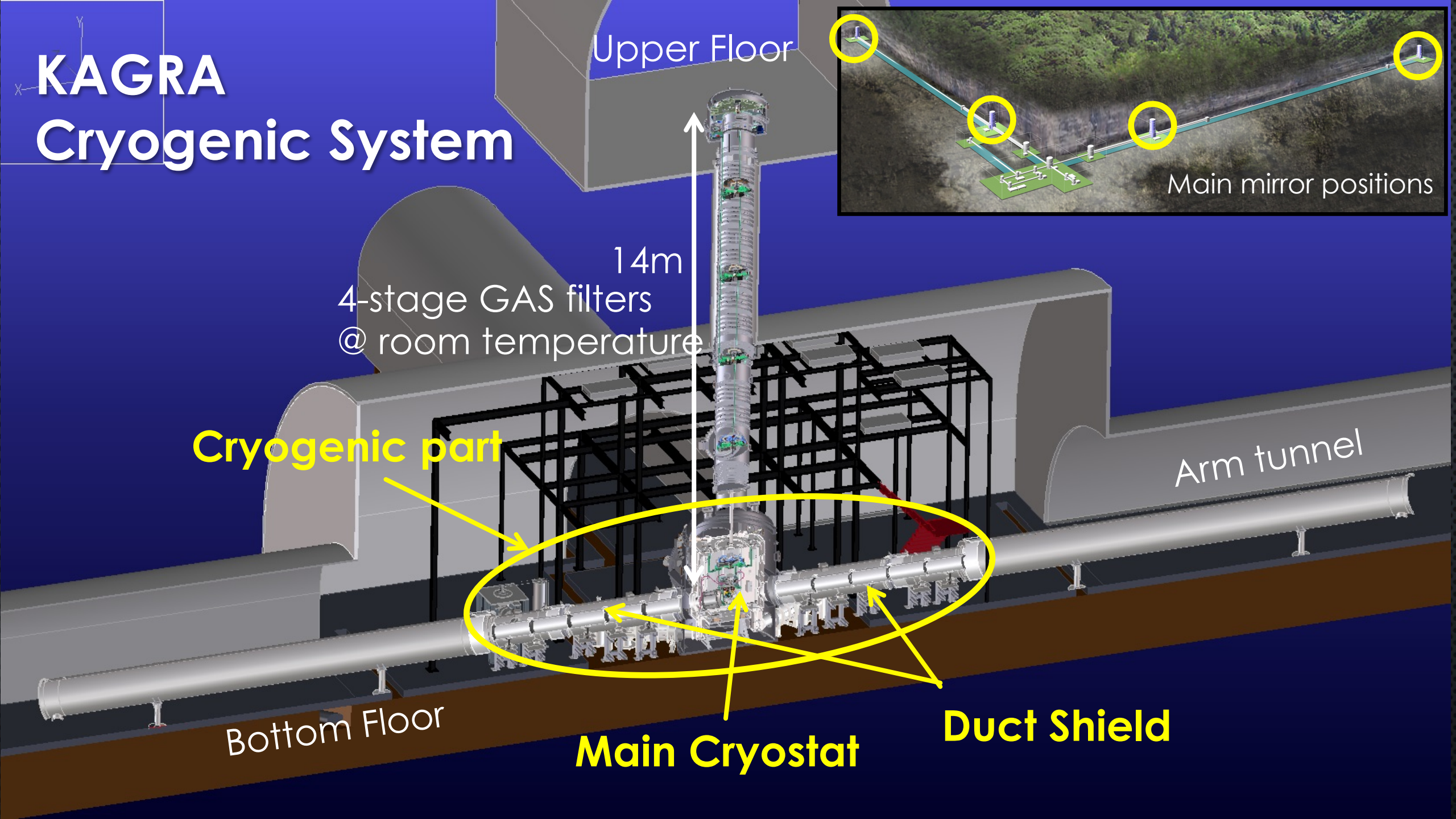


(2) Thermal Lensing

Wave-front distortion at input mirror at 20K

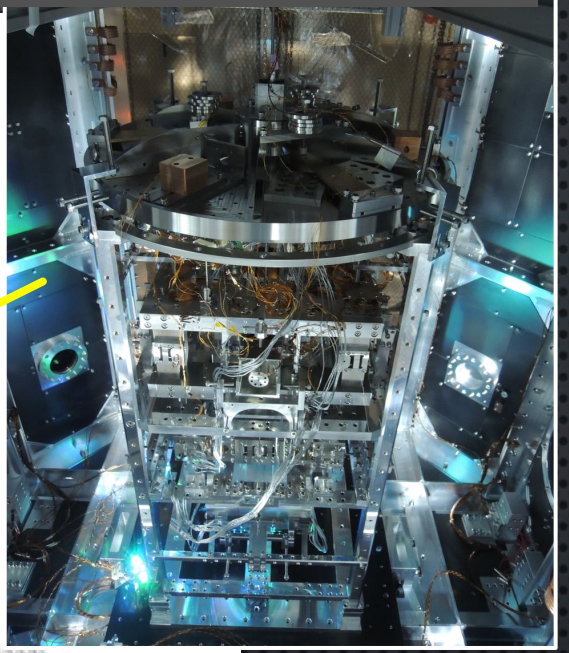


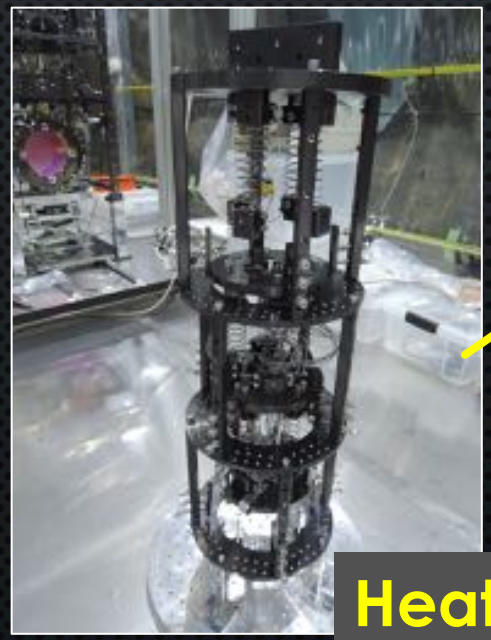
KAGRA
Cryogenic System

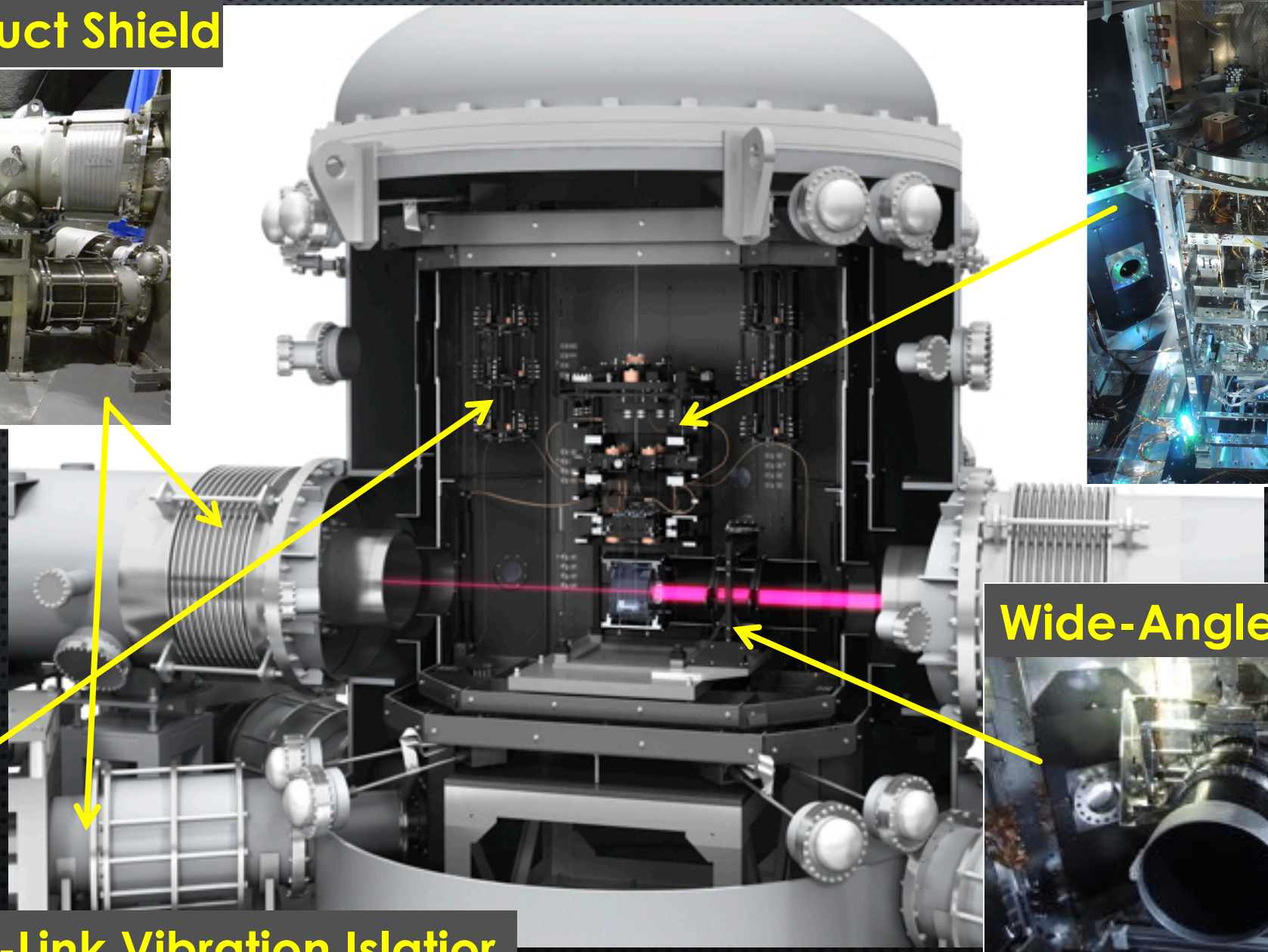


Ultra-small Vibration Cryocooler & Duct Shield

Cryogenic Payload





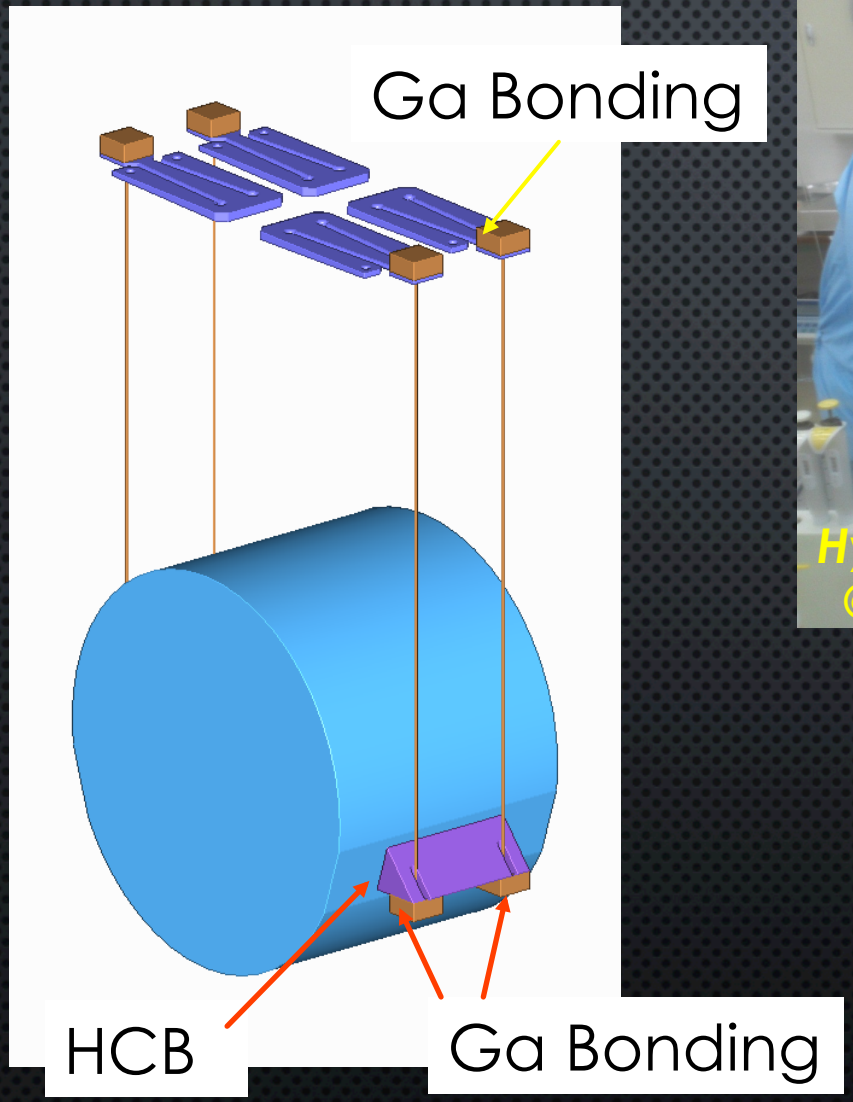


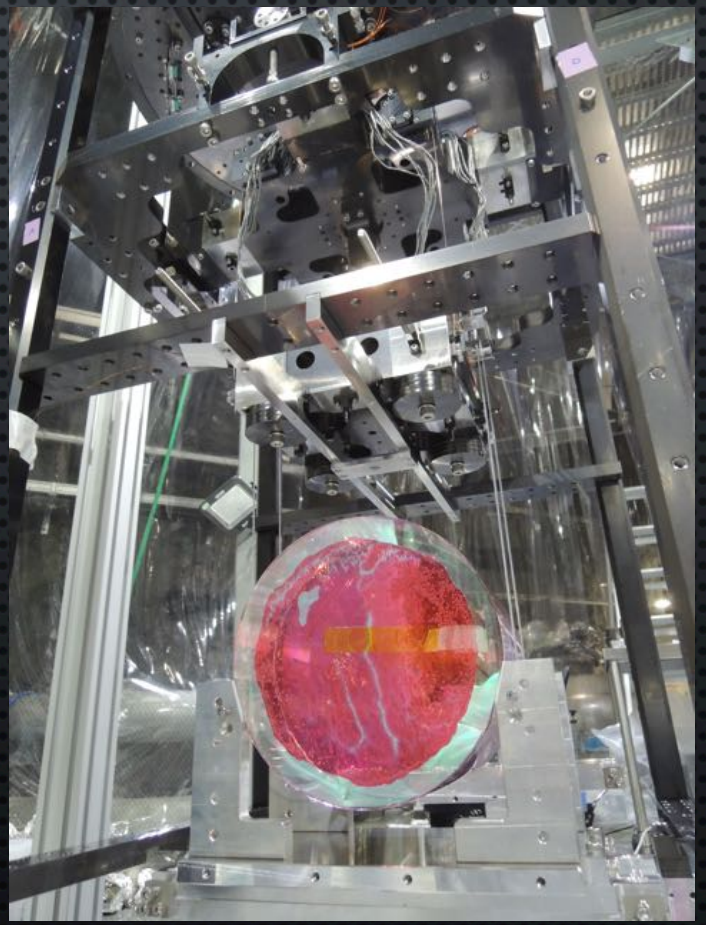
Wide-Angle Baffle

Heat-Link Vibration Islatior

Sapphire Crystal Bonding

These bonding studies were carried on the Basis of collaboration work btw Japan and Europe (ELiTES program)

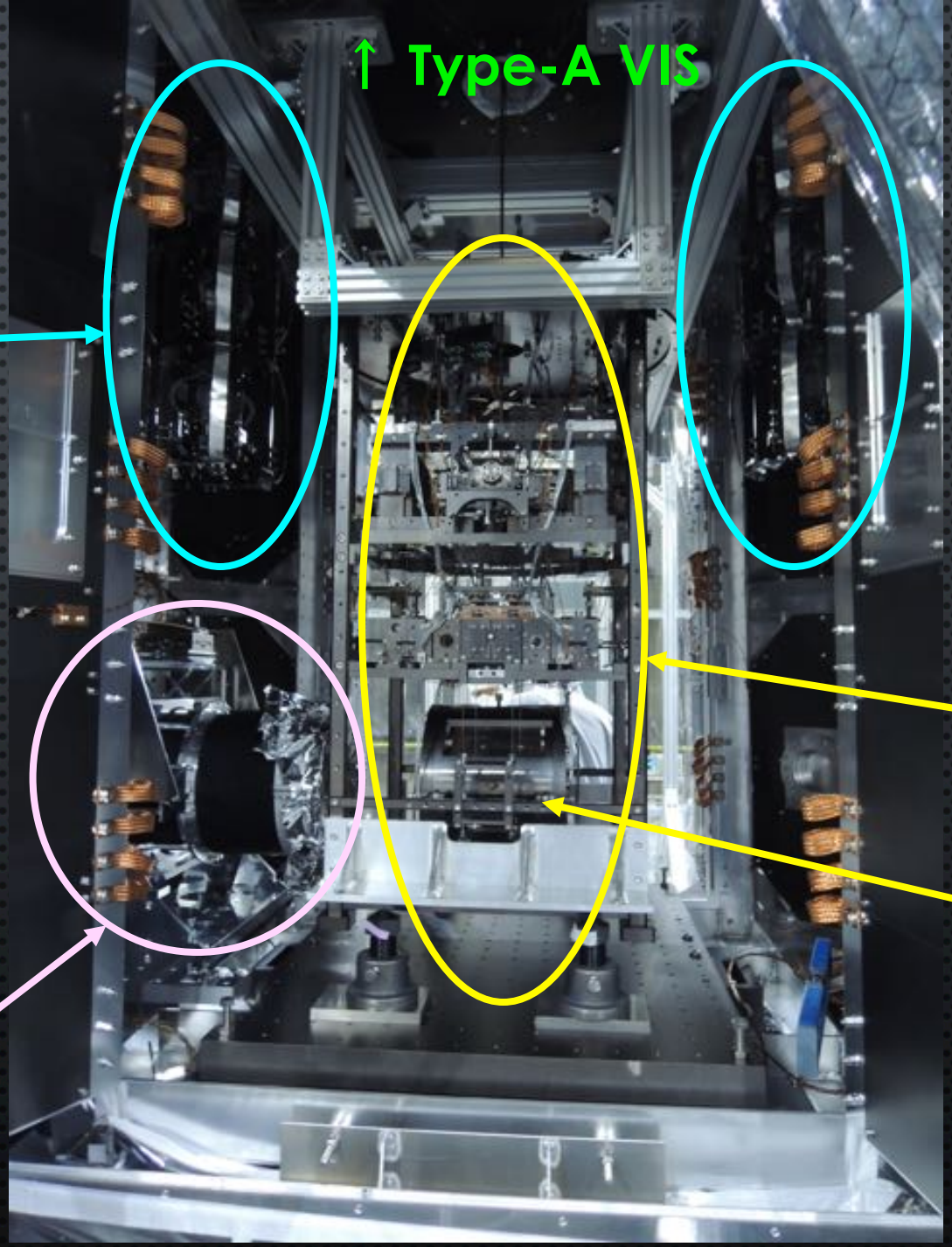





Y-end
Cryogenic Payload
Installed !
Nov. 30th, 2017
TEAM
KAGRA
Cryogenics
High Energy Accelerator
Research Organization
SOKENDAI
Institute for Cosmic Ray
Research, Univ. of Tokyo
ICRR
Institute for Cosmic Ray Research
University of Tokyo
University of Perugia
Sapienza University of Rome

Full Configulation in Cryostat

Heat Link Vibration Isolation System

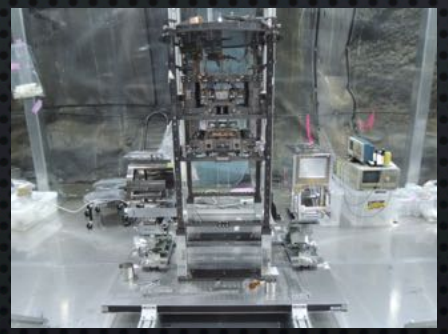


All of Cryogenic Systems have bee installed.

EYC

EITMY: 110K

Started cooling-down from Apr. 10th



IYC

Started cooling-down from Feb 22nd

ITMY: 22K

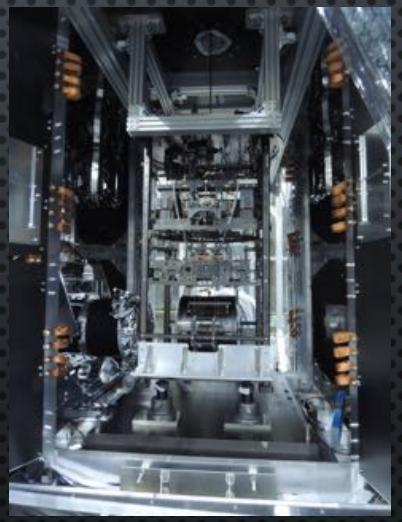
Laser

BS

IXC

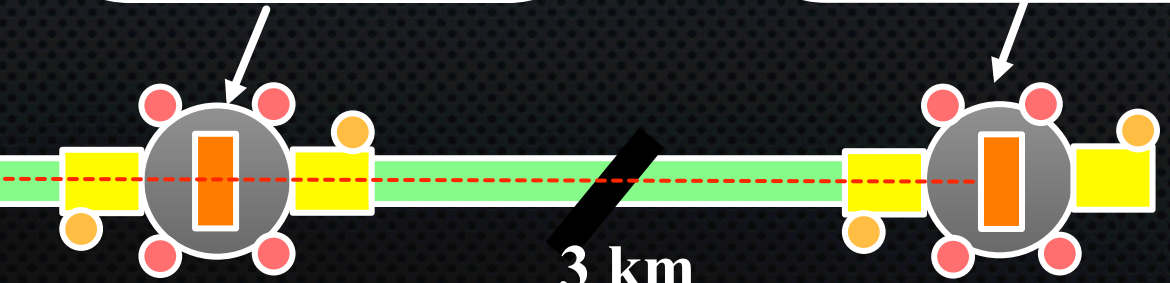
ITMY: 113K

Started cooling-down from Apr. 10th

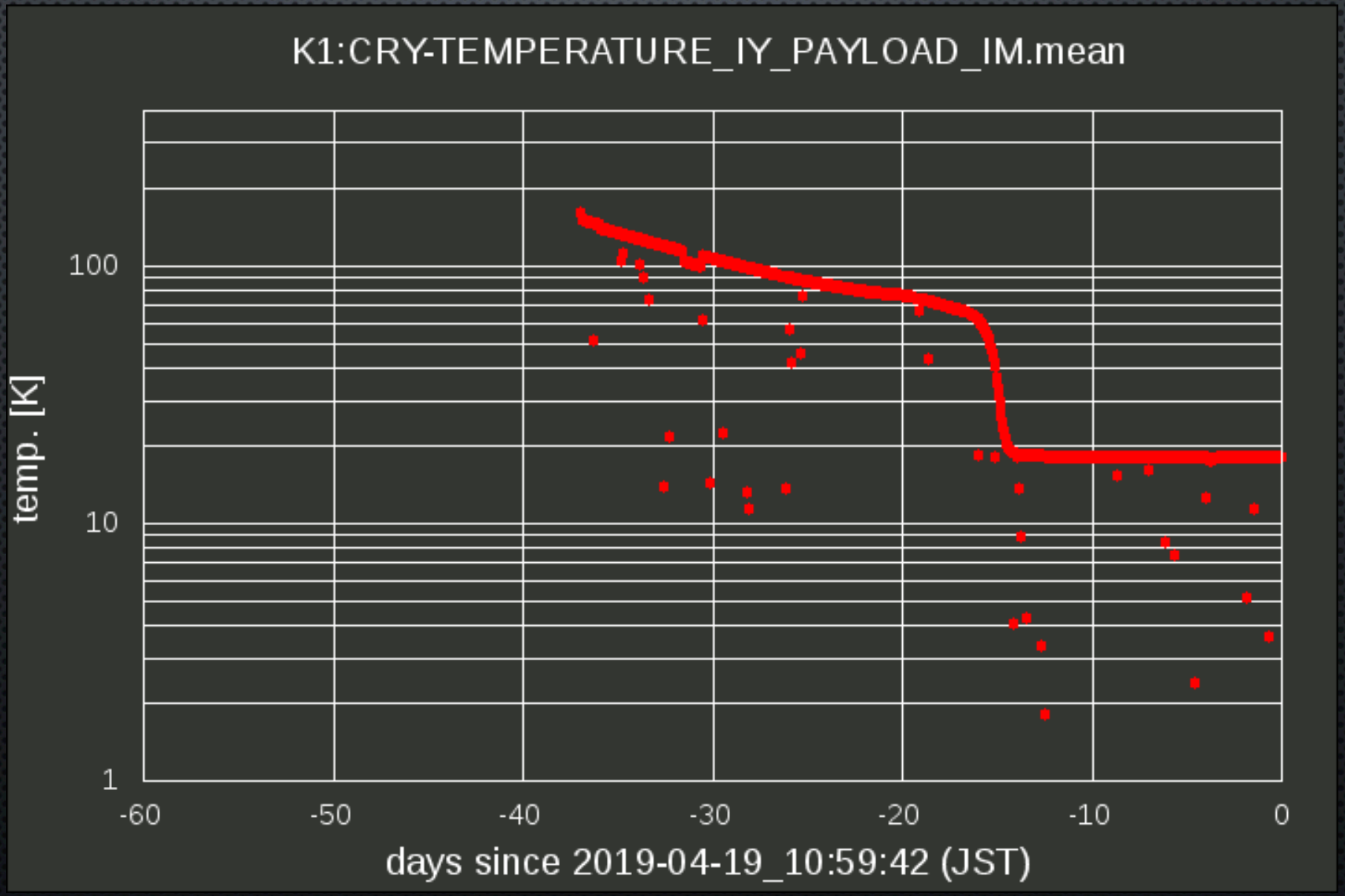


EXC

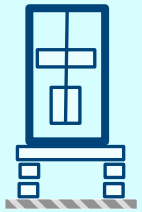
Will start cooling-down from May 1st



Cooling Curve of ITMY



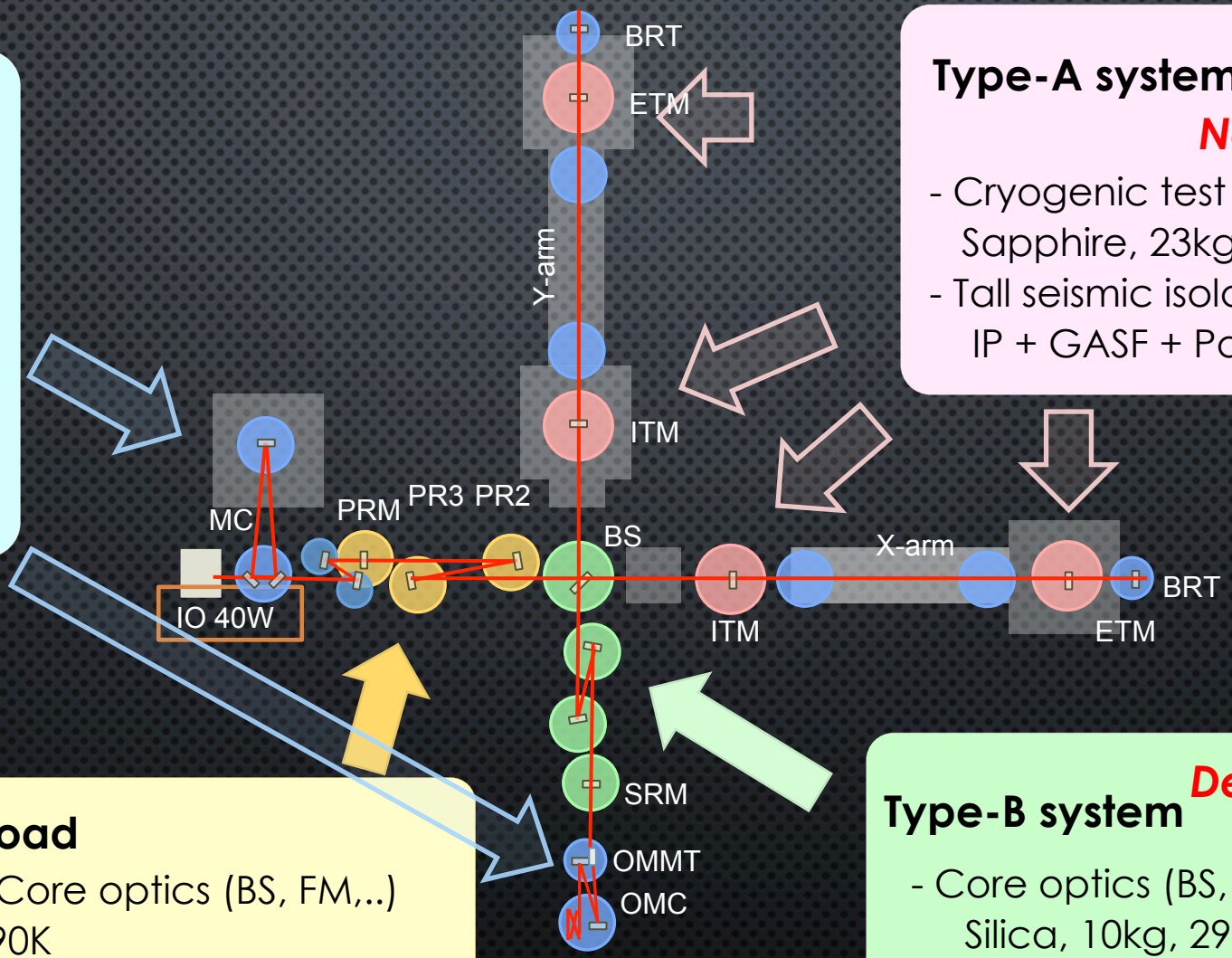
bKAGRA phase-2 (full configuration)



Nov. 30

Type-C system

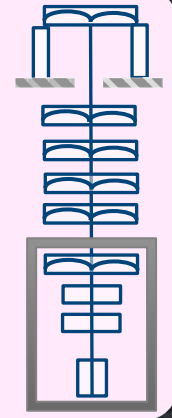
- Mode cleaner
  Silica, 0.5kg, 290K
- Stack + Payload

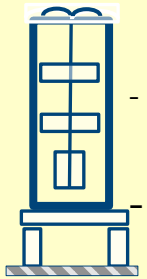


Type-A system

Nov. 9

- Cryogenic test mass
  Sapphire, 23kg, 20K
- Tall seismic isolator
  IP + GASF + Payload



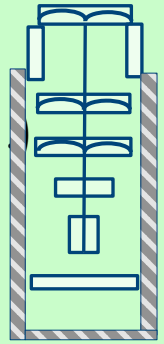


Type-Bp payload

- Test mass and Core optics (BS, FM,..)
  Silica, 10kg, 290K
- Seismic isolator
  Table + GASF + Type-B Payload

Type-B system **Dec. 10**

- Core optics (BS, SRM,..)
  Silica, 10kg, 290K
- IP + GASF + Payload
- Stack for aux. optics



Interferometer Commissioning

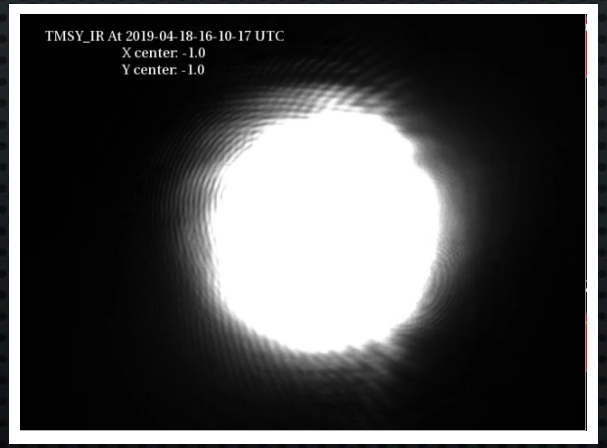
(1) X-arm Commissioning: Dec. 2018 (Done, at room temperature)

- Success full cavity lock <- fine beam alignment was done.
- Cavity length: 2999.992(3) m
- Mode matching: 91%
- Round-trip optical loss: 86ppm

X-arm commissioning with full cryogenic systems was started, and auxiliary green lase lock was done in 17th Apr.

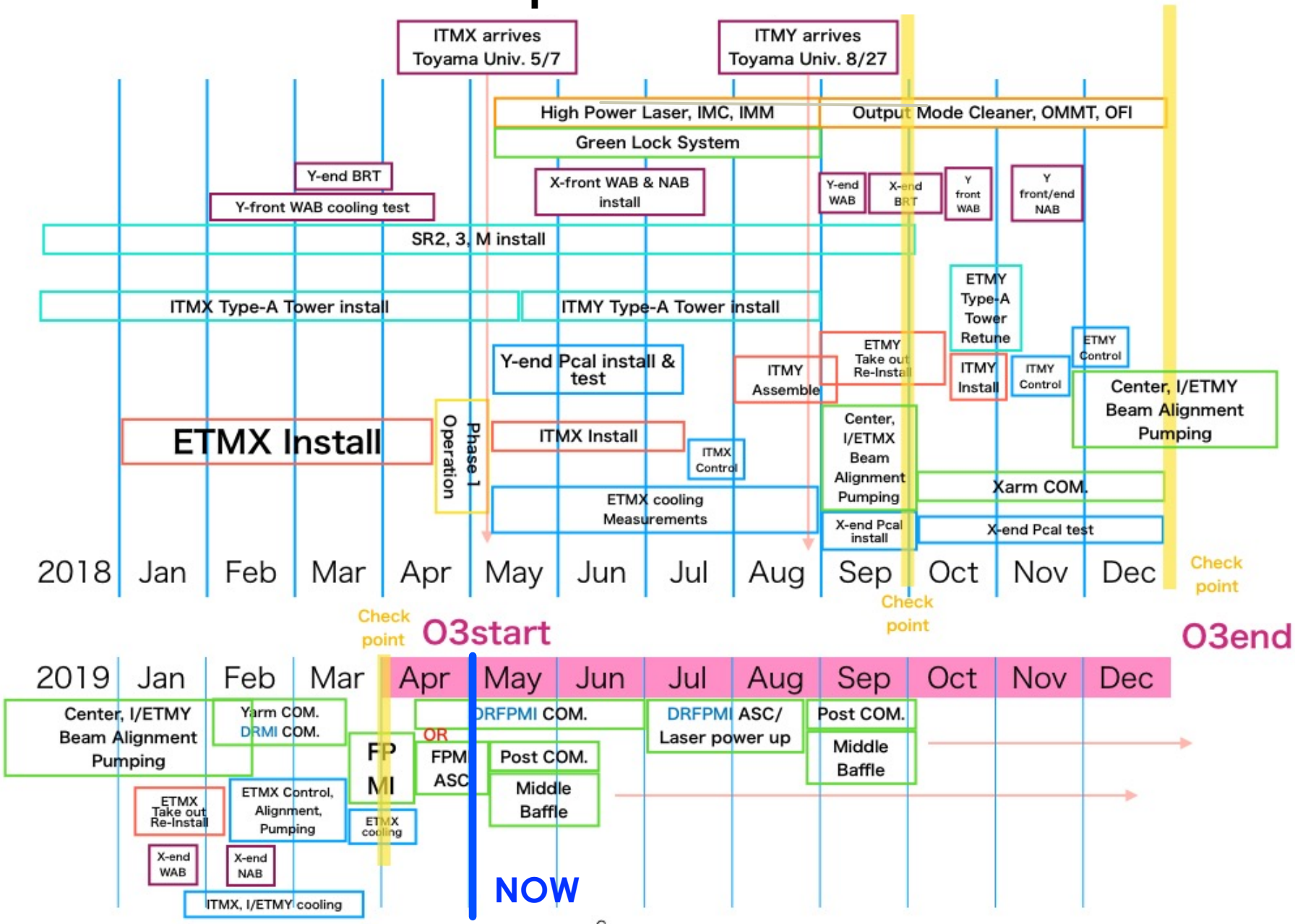
(2) Y-arm Commissioning: from Apr. 2019 (on going, at cryogenic temperature)

- Y-arm cavity lock was achieved on 18th Apr. by using auxiliary green laser and on 28th by IR laser. ITMY was stable temperature of 22K but ETMY was transient state of cooling down of about 110K.



bKAGRA phase-2 schedule

2019/04/09

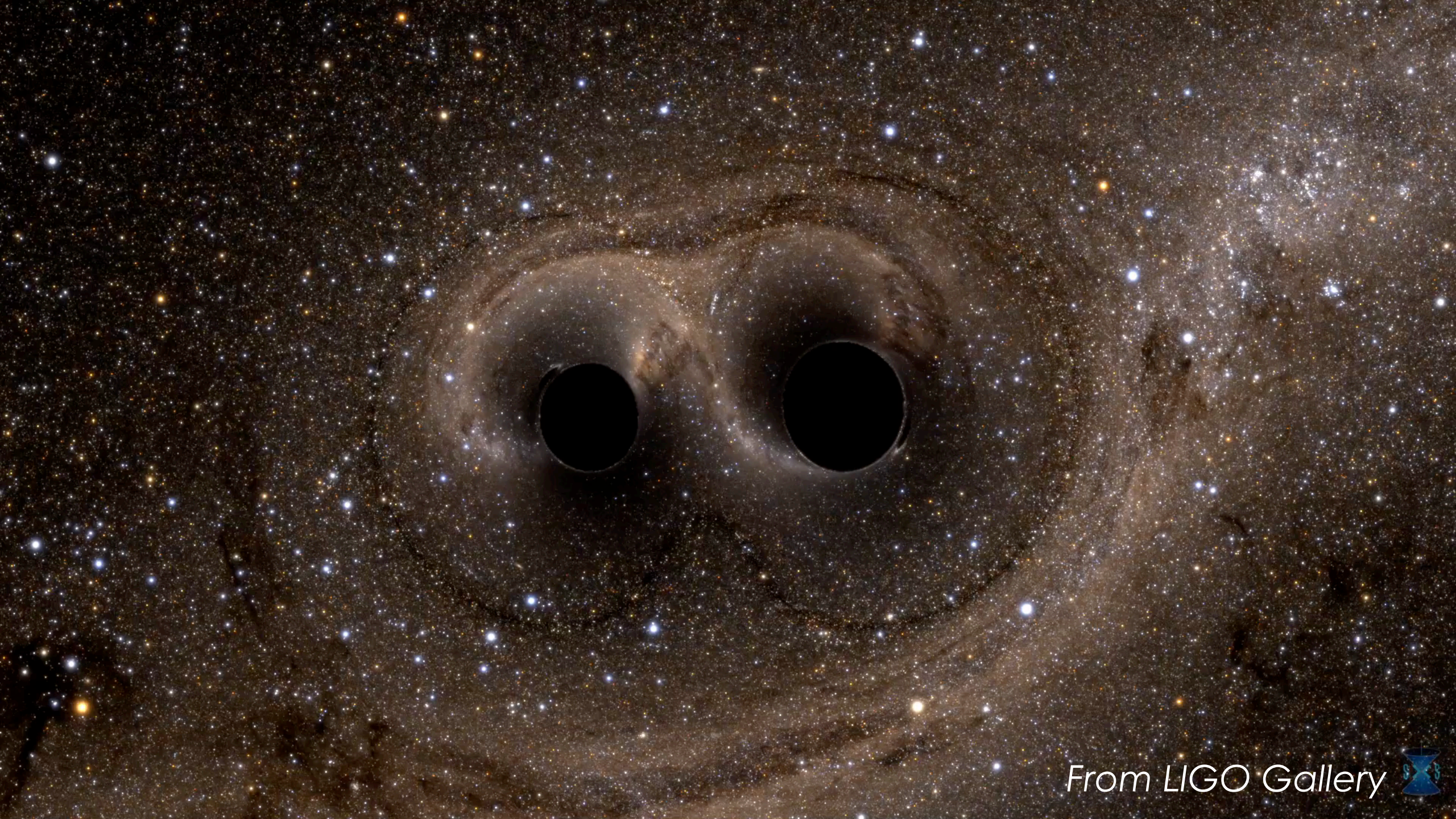


Major Schedule

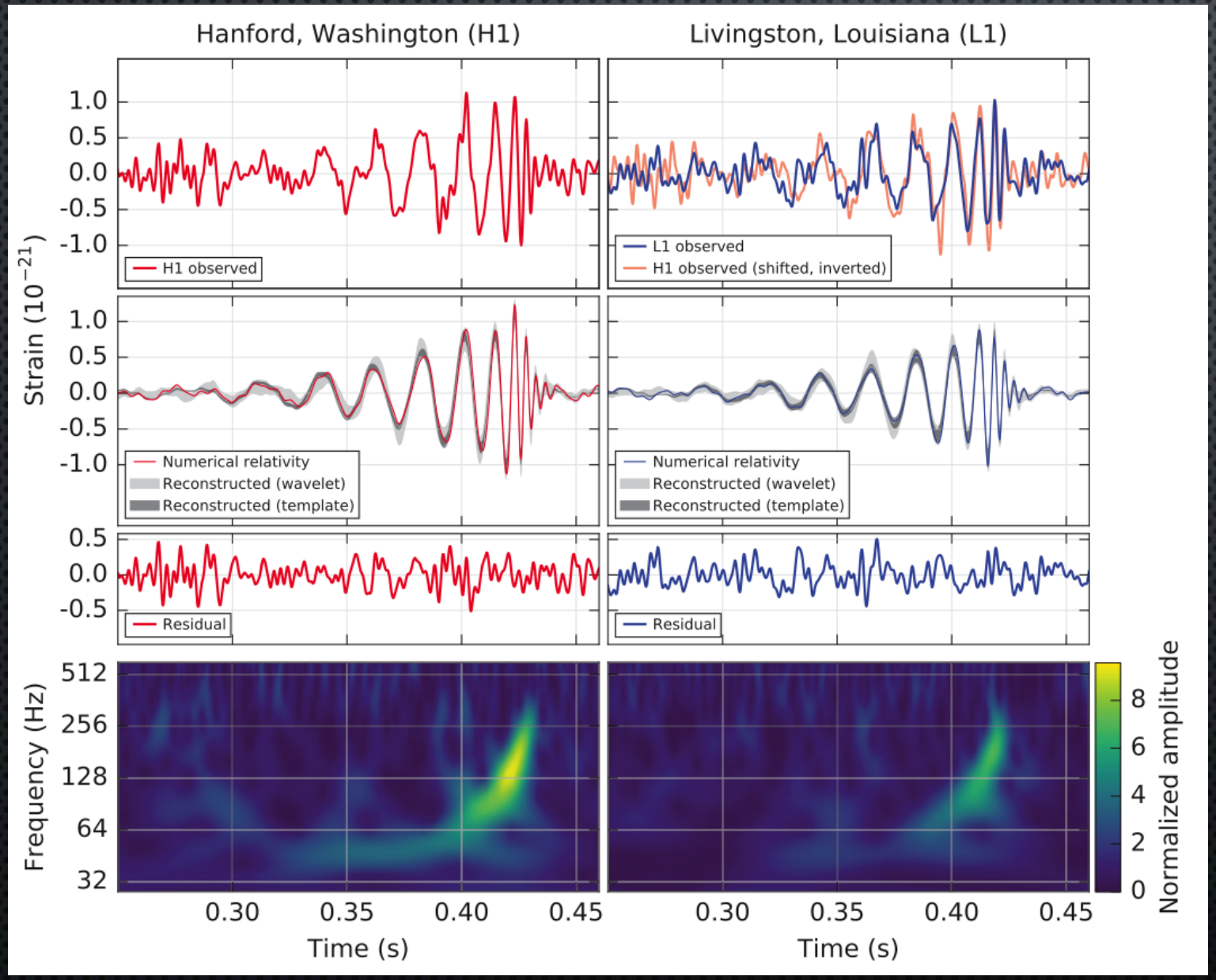
- May, 2019: Y-arm lock by IR laser
- End of May: Fabry-Perot Michelson interferometer
- June: Dual-Recycled Michelson
  Start Dual-Recycled Fabry-Perot Michelson interferometer
  Engineering Runs
- Summer: DRFPMI lock
- Early Winter: Join O3 with >10 Mpc sensitivity for NS-NS event


KAGRA will join O3
in 2019.

Back Up


From LIGO Gallery

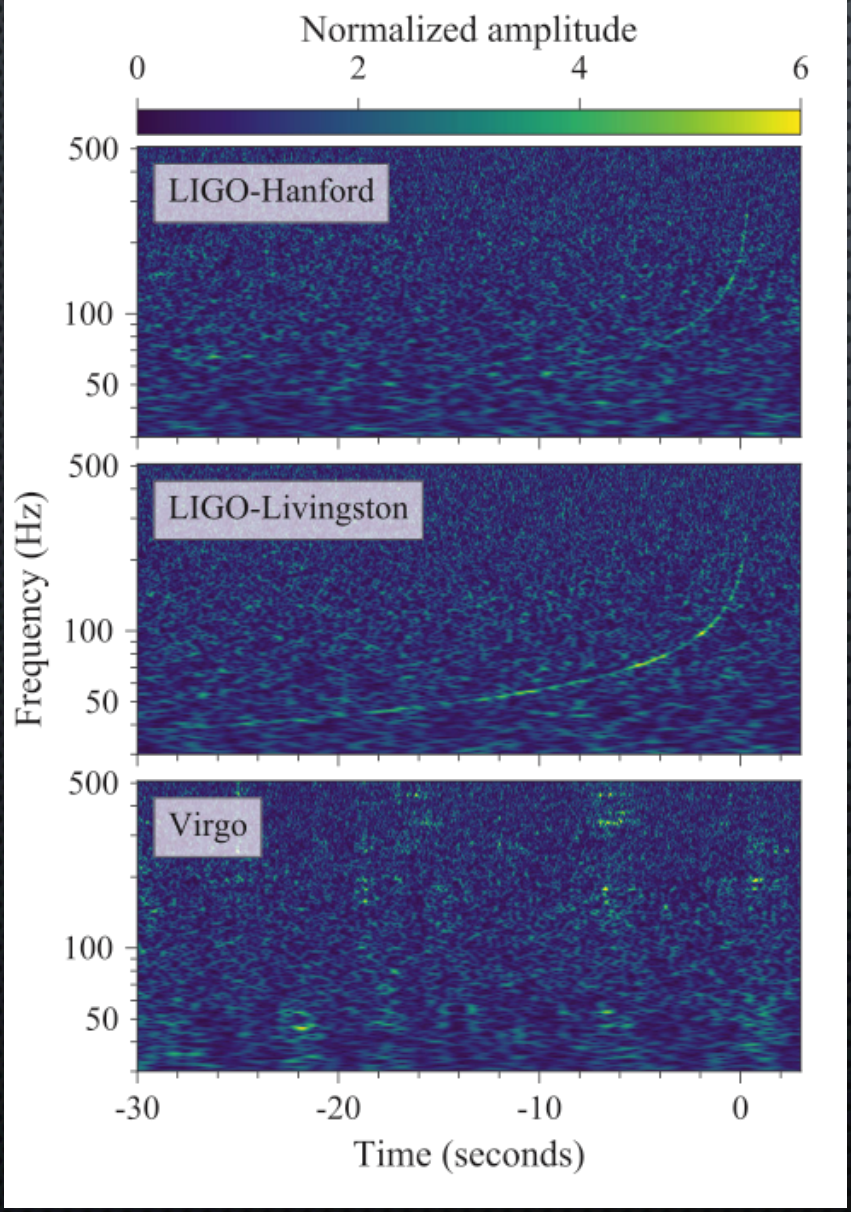
advanced LIGO detected Gravitational Wave



GW150914

Primary Mass:
36.2 (+5.2 -3.8) M_{sun}
Secondary Mass:
29.1 (+3.7 -4.4) M_{sun}
Radiated Energy:
3.0 (+0.5 -0.4) M_{sun}
Luminosity Distance:
420 (+150 -180) Mpc

First observed binary neutron star **GW170817**



Primary Mass: 1.36 – 2.26 M_{sun}
Secondary Mass: 0.86 – 1.36 M_{sun}
Radiated Energy: > 0.025 M_{sun}
Luminosity Distance: 40 (+8 -14) Mpc

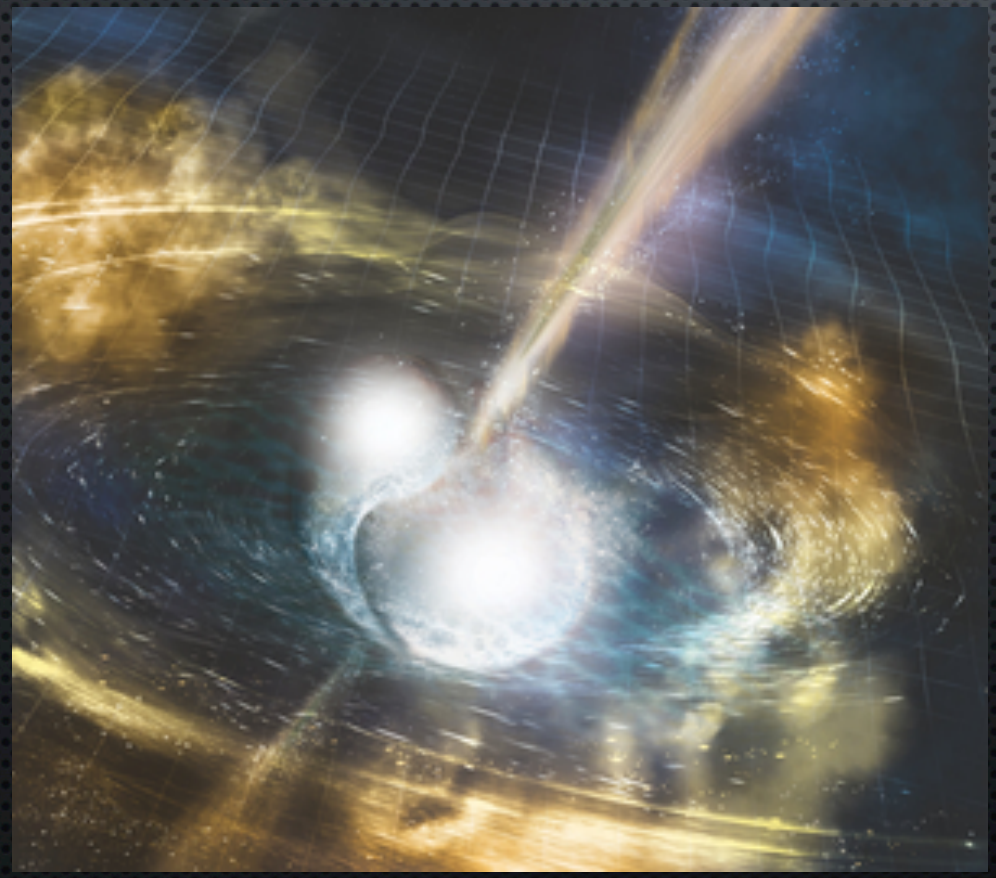
Fermi-GBM detected short gamma -ray burst GRB170817A 1.7s after GW170817.

This is first evidence to connect between binary neutron star merger and short gamma-ray burst

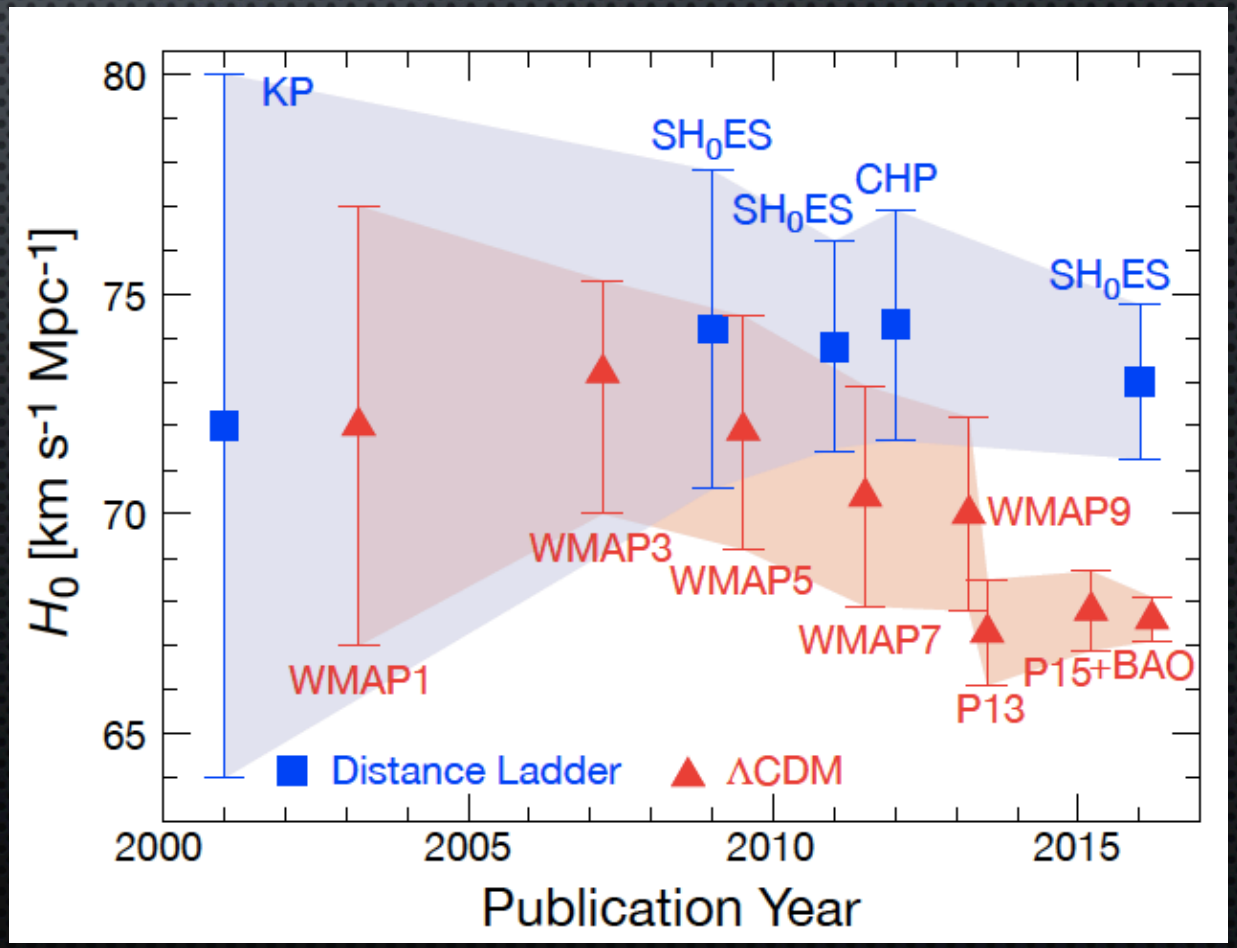
Inclination Angle of Binary System can be derived from GW Polarization

←To obtain both localization and Polarization, we need four detectors at least.

Jet for Gamma-Ray Burst



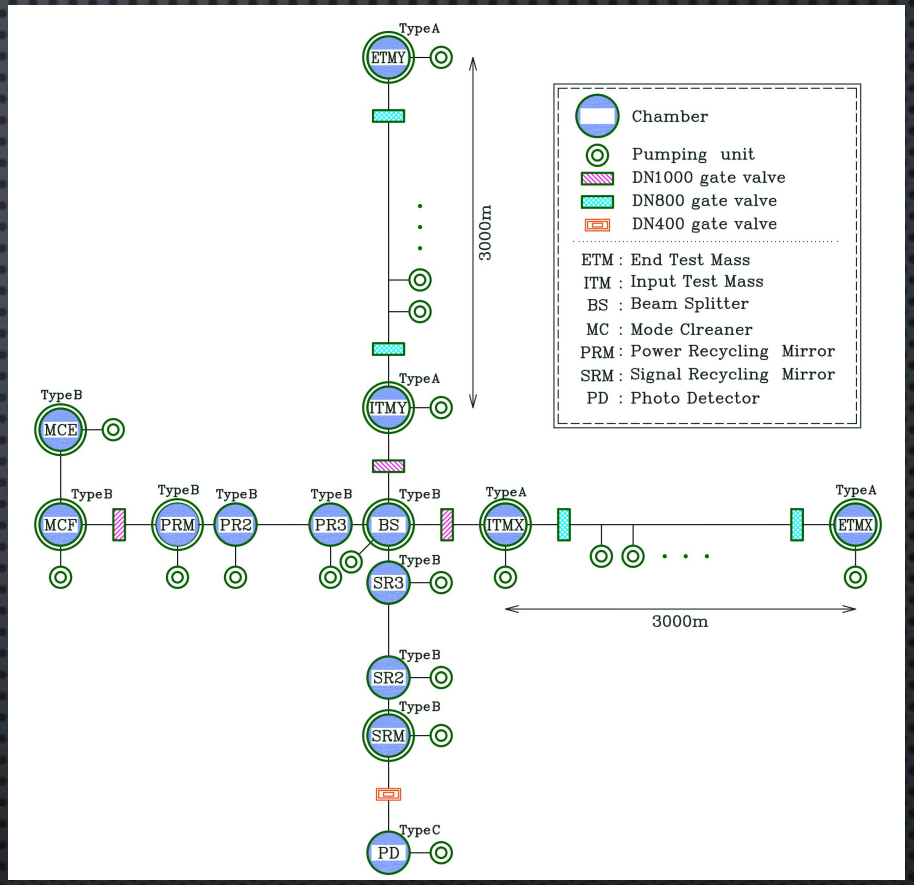
Hubble Tension



Vacuum System

To have sufficiently small laser-beam fluctuation by residual gas, we need ultra-high vacuum of 10^{-7} Pa.

- 3km x 2 Beam Tubes,
  Φ800mm x L12m, 500 tubes
- 10 Major Vacuum Tanks
- 4㏊ Main Cryostats



Inner Volume : ~ 3000 m^3
Surface Area : ~ 15,000 m^2

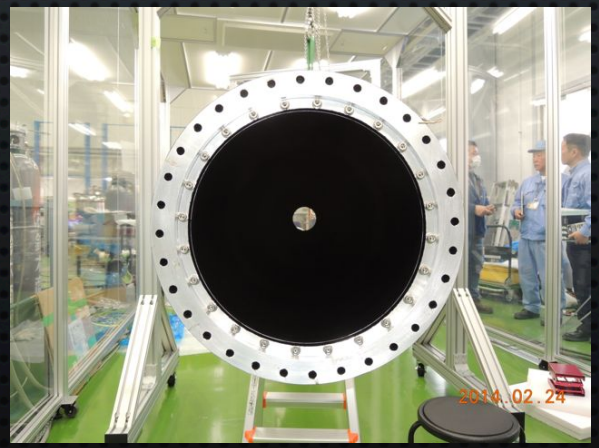
Largest Vacuum System in Japan
(3rd Largest in the World)

Ultra-Small Outgas Vacuum Tubes

Vacuum Baking

Mechanical & Electric Polishing

Black Coating



Outgassing Ratio