Gravitational wave detection by KAGRA

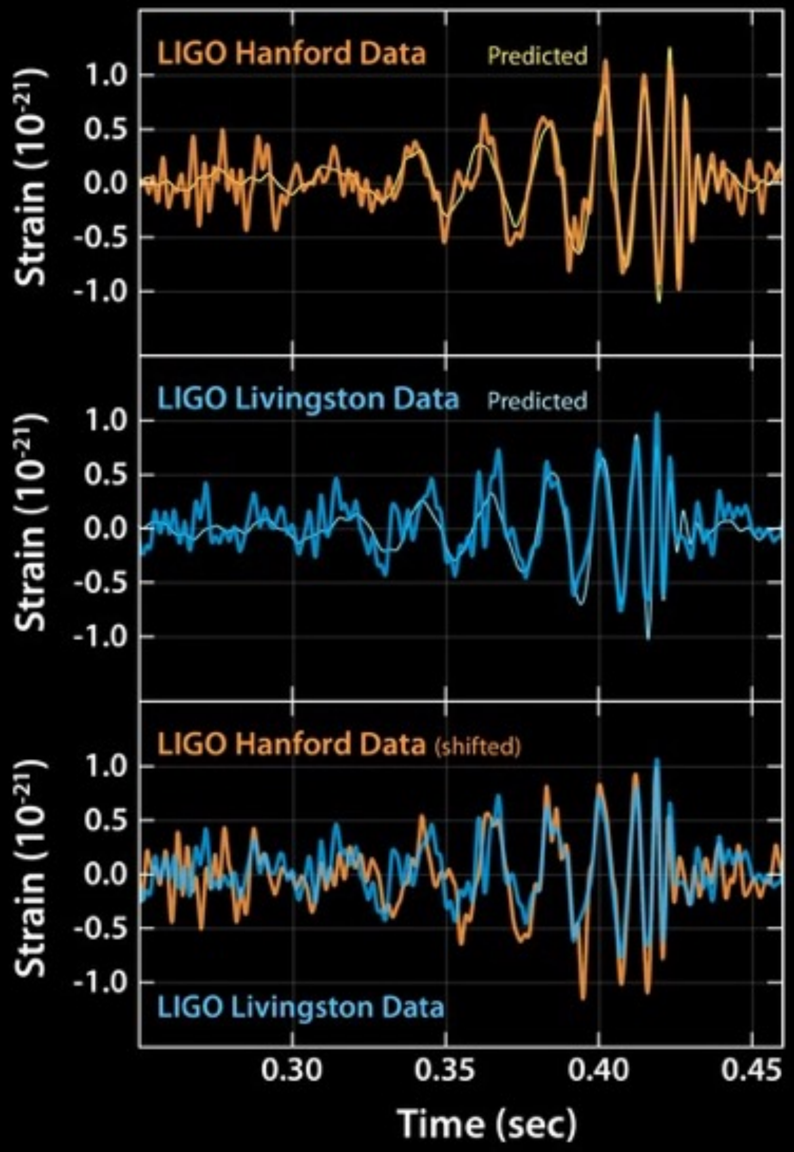
July 6, 2017

Kiso Schmitt Symposium

Osamu Miyakawa, ICRR, UTokyo

Gravitational waves detected by LIGO

What signals were seen?



Waves measured by two LIGO detectors on 2015/9/14

Listening as sound・・

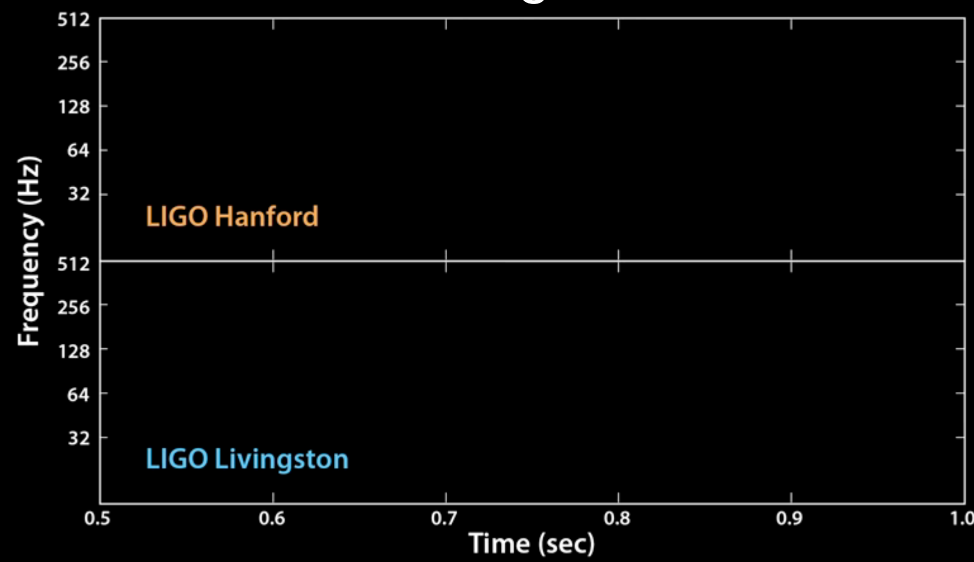


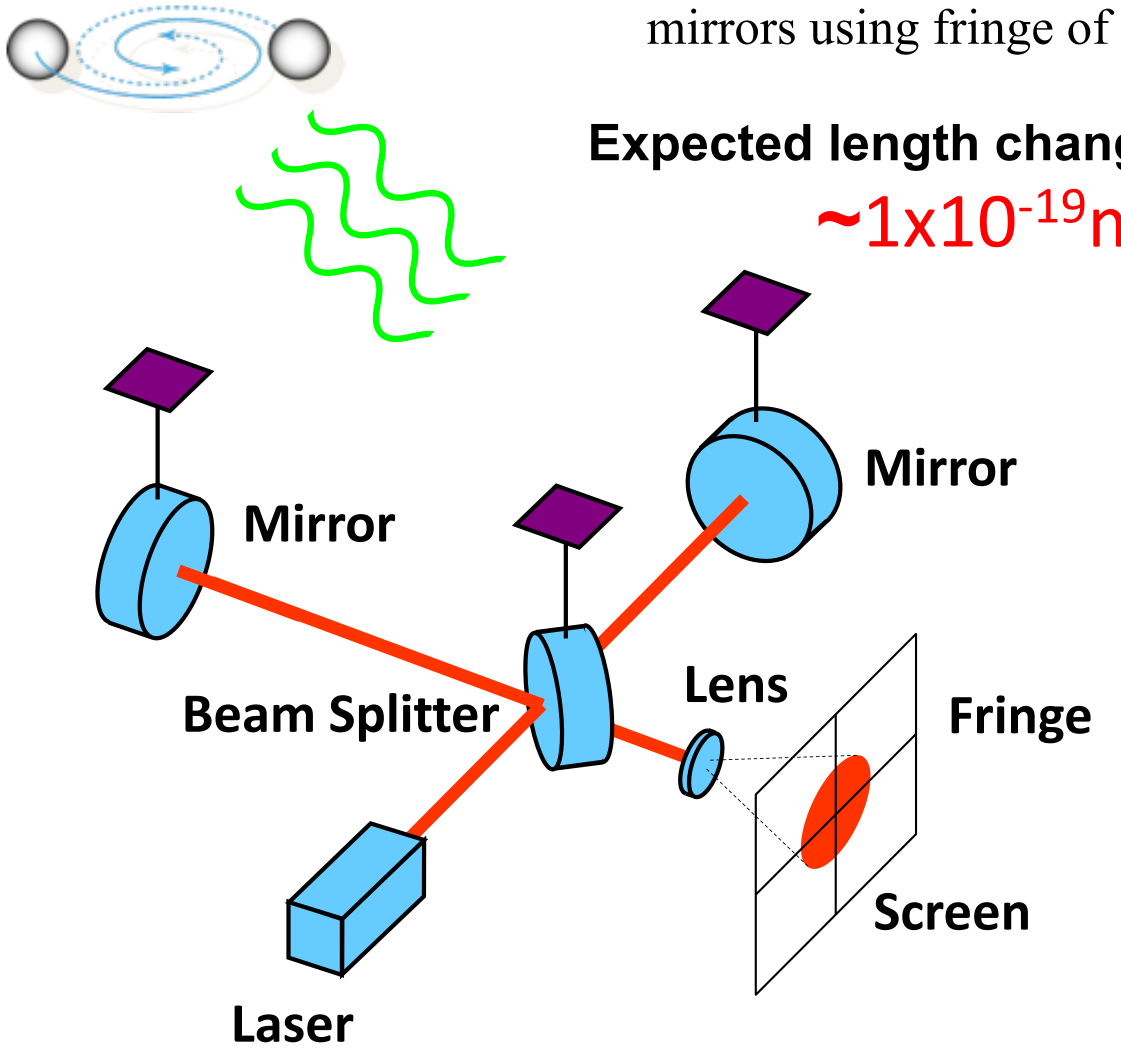
Figure Credit: LIGO Scientific Collaboration

Detection of gravitational wave using laser interferometer

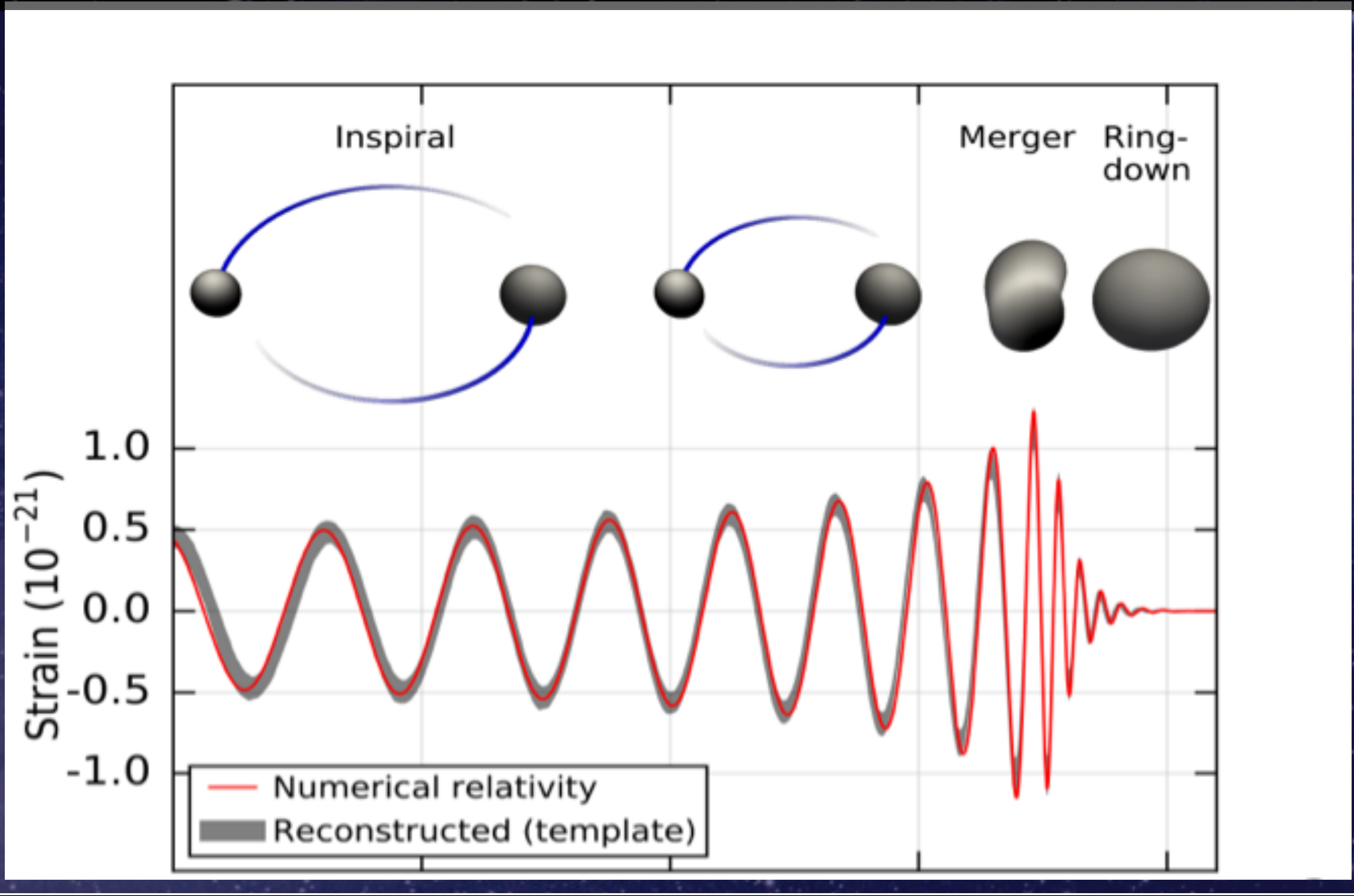
GWs move mirrors differentially.
We measure the distance between mirrors using fringe of light.

Expected length change by GW :

$\sim 1 \times 10^{-19}$ m



What can we know from this detection?



- Signal from binary black holes
- 13 billion yesar ago
- Two black holes merged into one black hole
- 36 solar mass black hole + 29 solar mass black holes make a 29 solar mass black hole

Area of GW sources

- by two LIGOs ~500deg^2
- +VIRGO ~30deg^2
- +KAGRA ~10deg^2

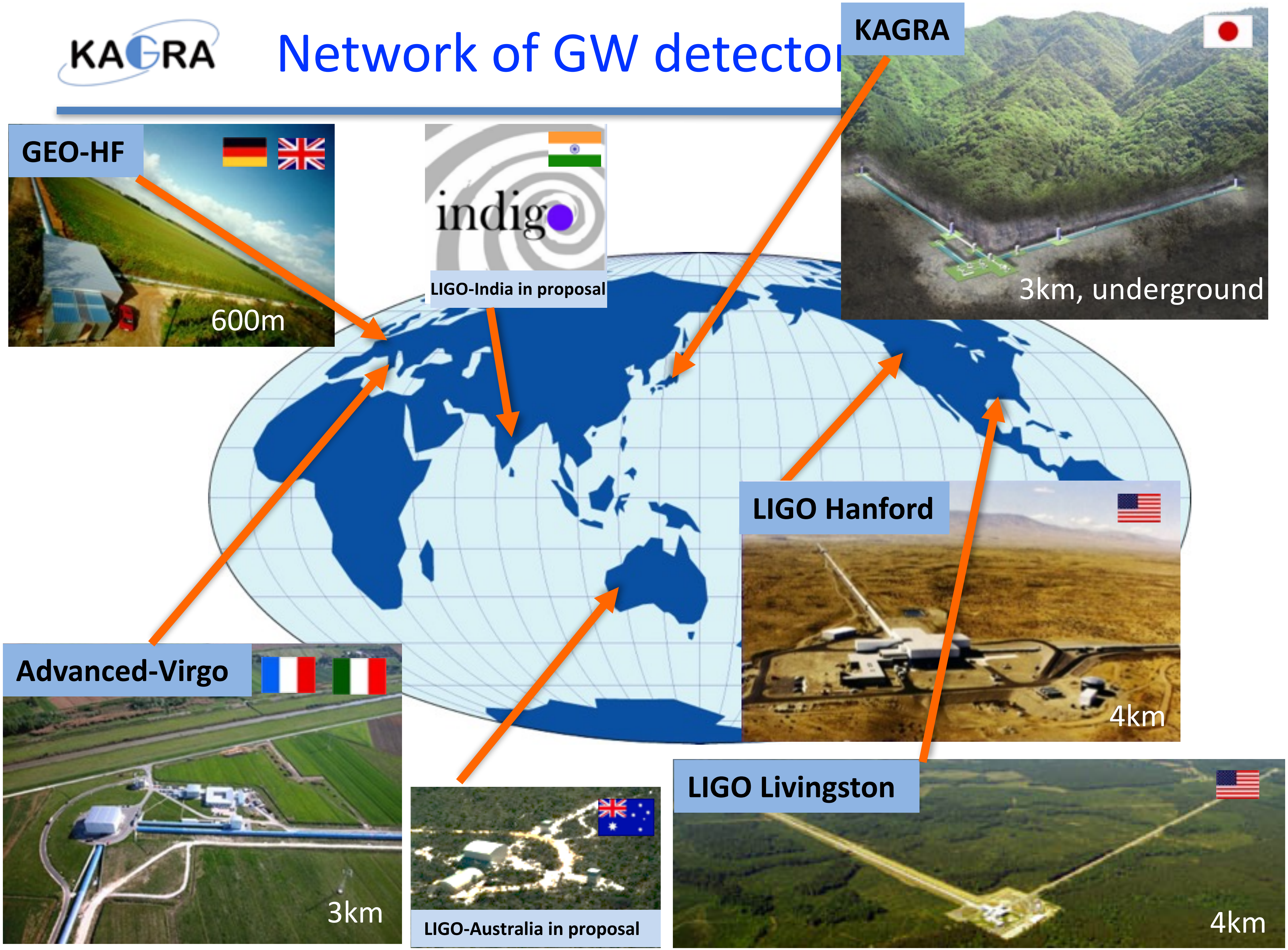
(1.4,1.4)Msun	LHV	LHVK
median of δΩ [Deg^2]	30.25	9.5

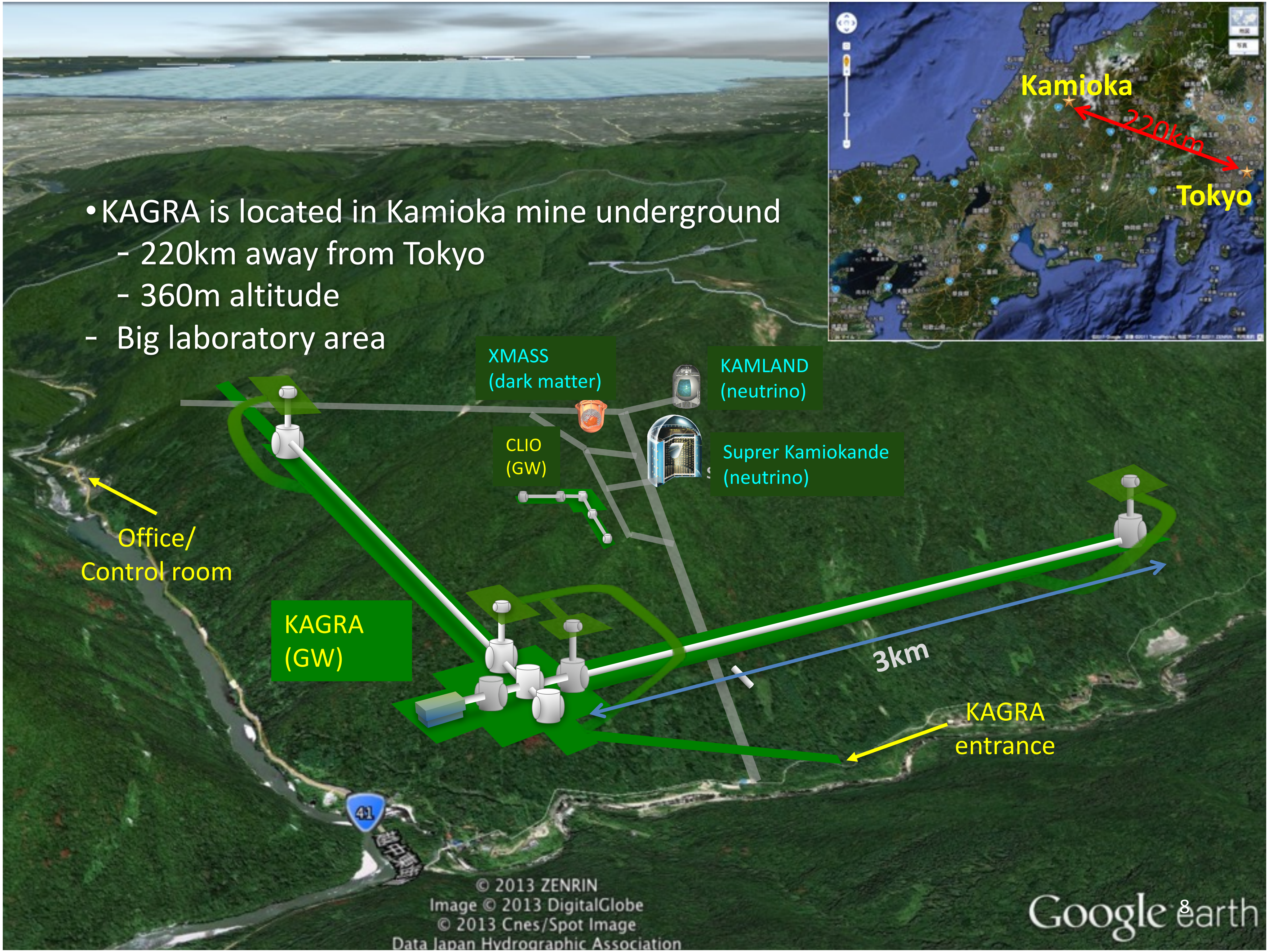
L:LIGO-Livingston
H:LIGO-Hanford
V: Virgo
K: KAGRA

J.Veitch et al., PRD85, 104045 (2012)
(Bayesian inference)
See also Rodriguez et al. 1309.3273

direction, inclination, polarization angle are given randomly

Network of GW detectors




•KAGRA is located in Kamioka mine underground
- 220km away from Tokyo
- 360m altitude
- Big laboratory area
Kamioka
220km
Tokyo
XMASS
(dark matter)
KAMLAND
(neutrino)
CLIO
(GW)
Suprer Kamiokande
(neutrino)
Office/
Control room
KAGRA
(GW)
3km
KAGRA
entrance
41
© 2013 ZENRIN
Image © 2013 DigitalGlobe
© 2013 Cnes/Spot Image
Data Japan Hydrographic Association
Google earth

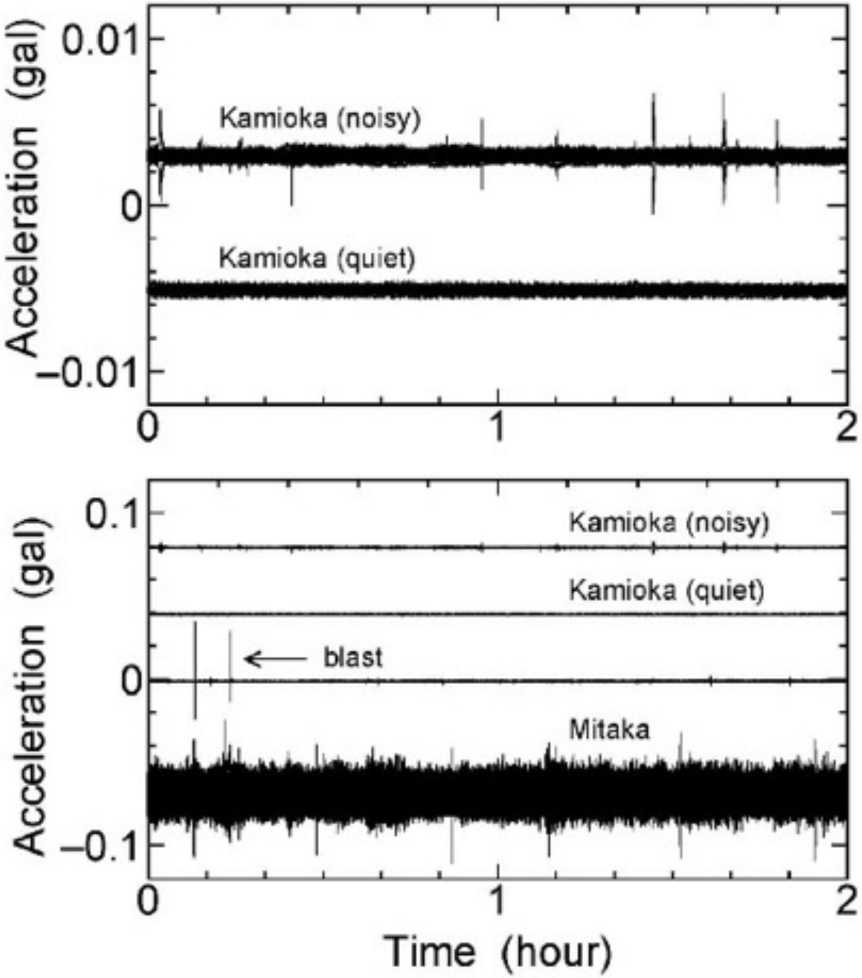
KAGRA Project

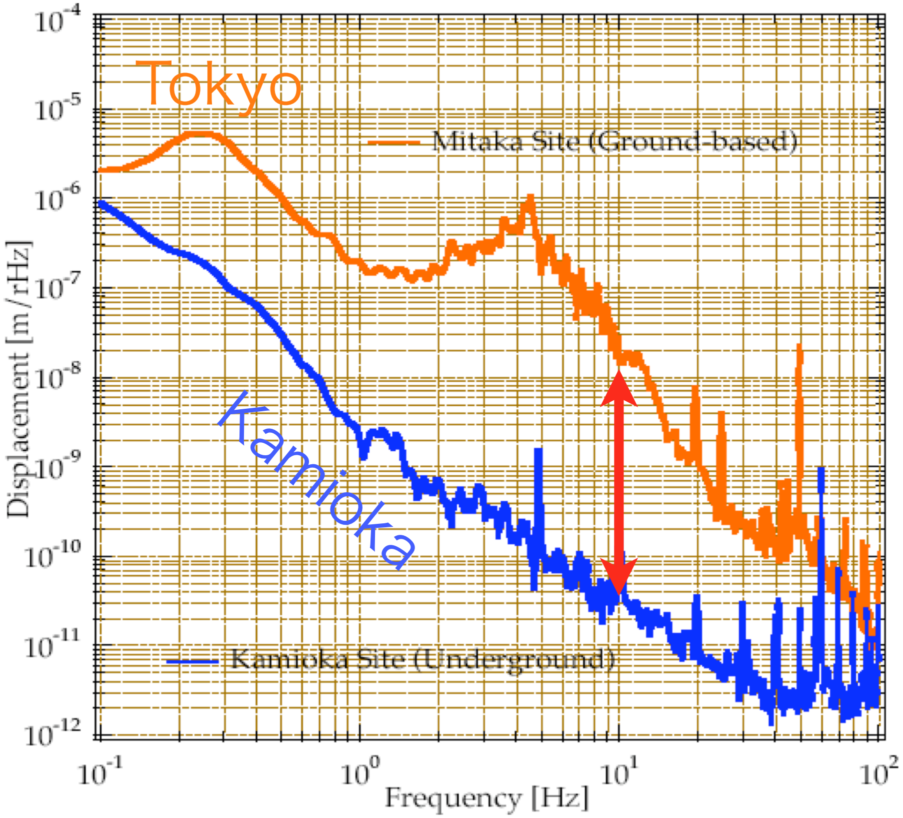
- Host: ICRR Utokyo, Co-host: KEK, NAOJ
- 300+ collaborators from 90+ institutes
- Constructed in Kamioka mine
- Underground and cryogenic

KAGRA

Snow in winter.
Melted snow in April.

Quiet underground site

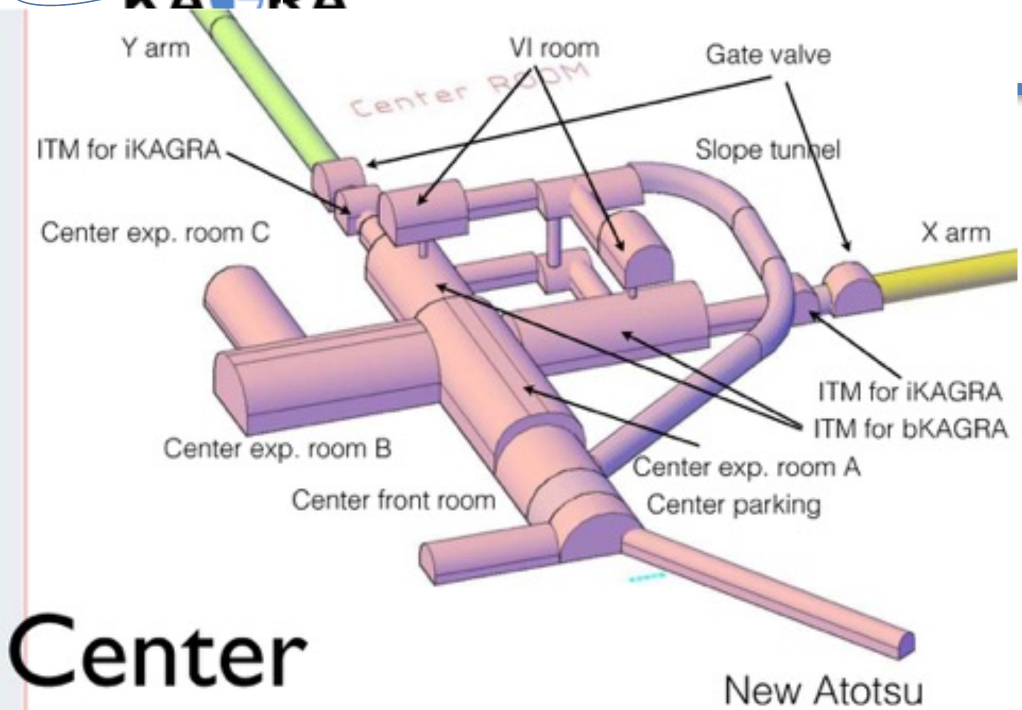




Amplitude of seismic motion

- Surrounded by hard rock (Hida-gneiss)
  - 5 km/sec sound speed

Design and on site pictures



Tilted corridor (1/300) inside Tunnel (X arm)


Entrance of New Atotsu


Center Room

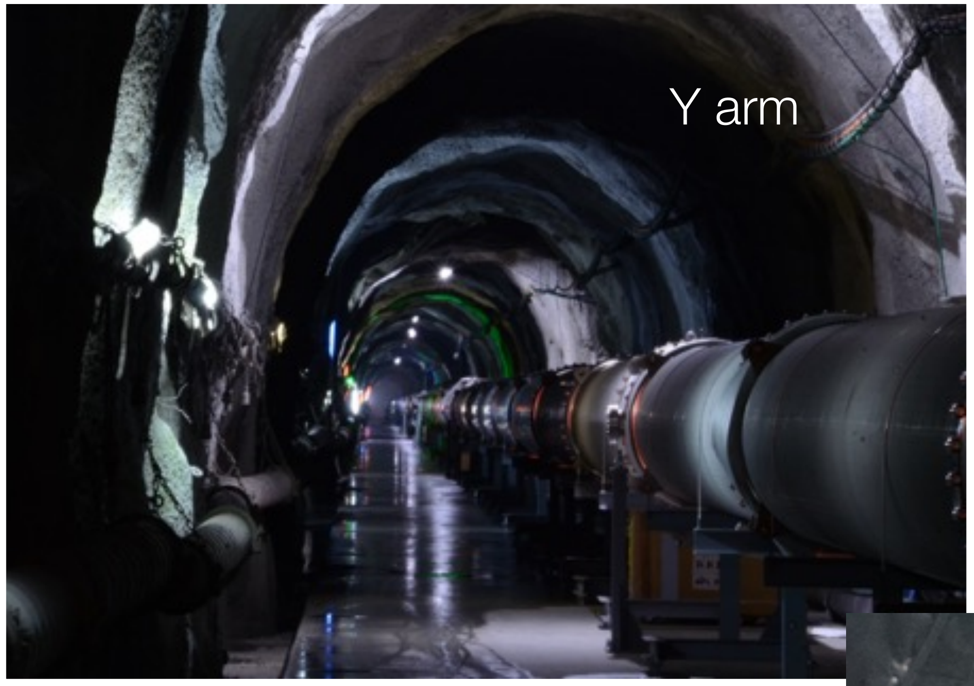
KAGRA pictures

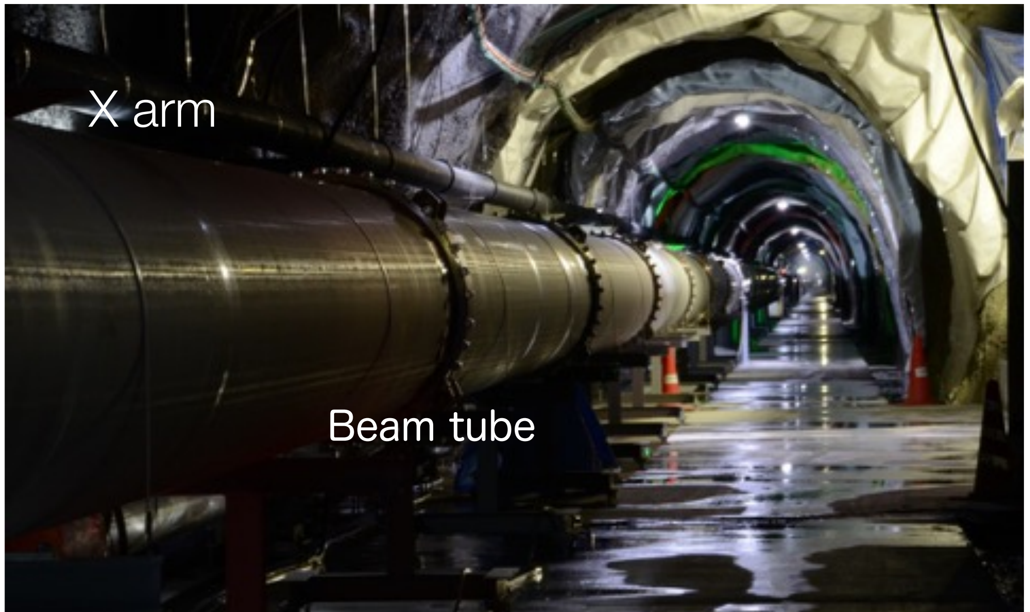
Vacuum chambers

Entrance of KAGRA

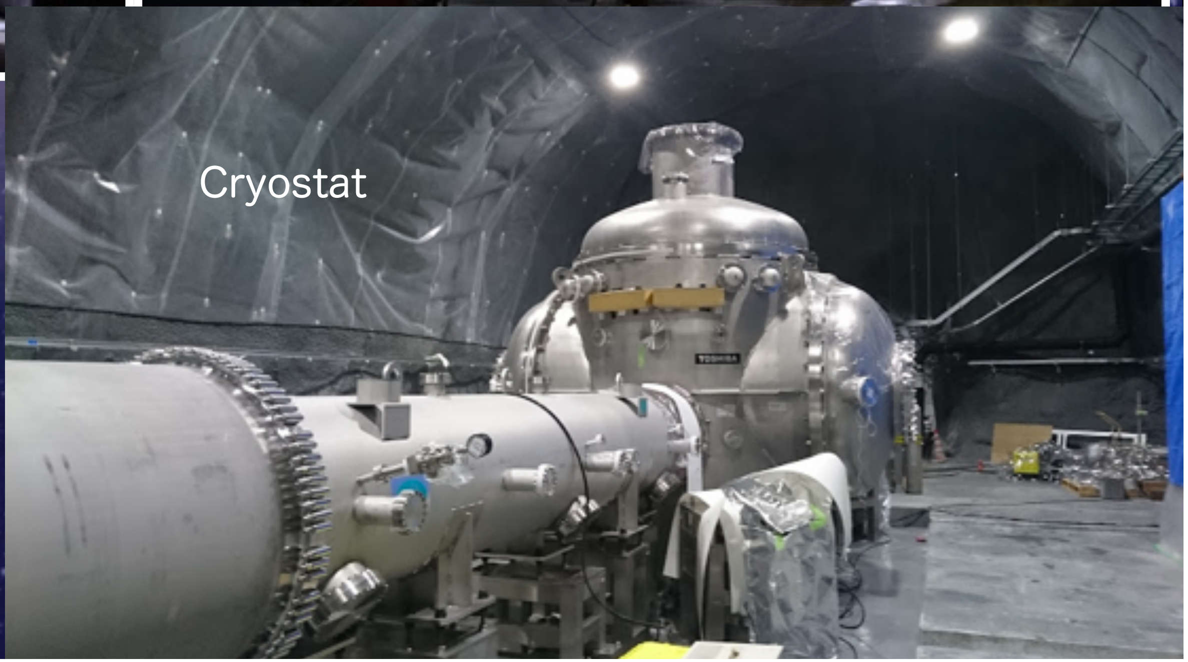
Remote control room

KAGRA pictures

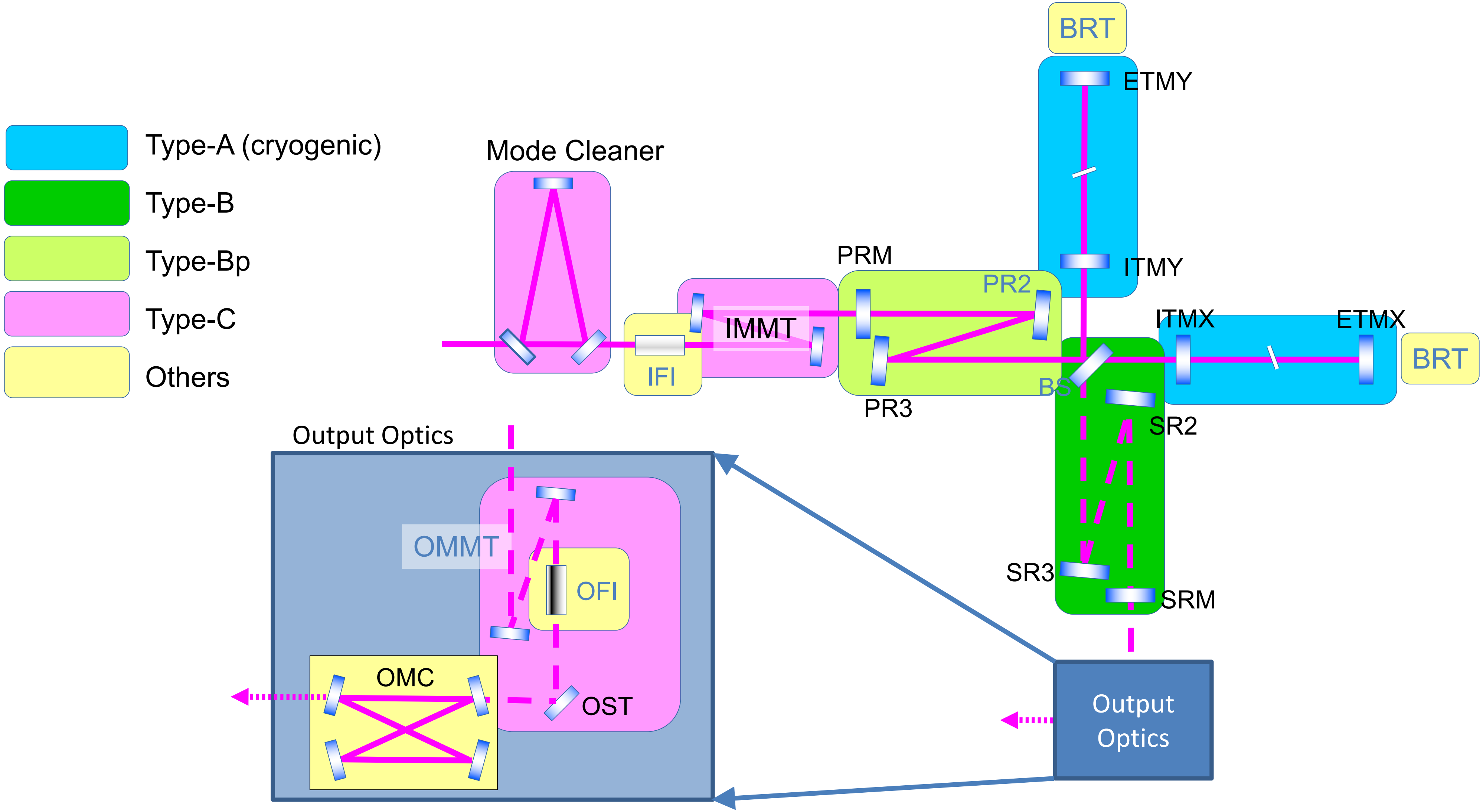




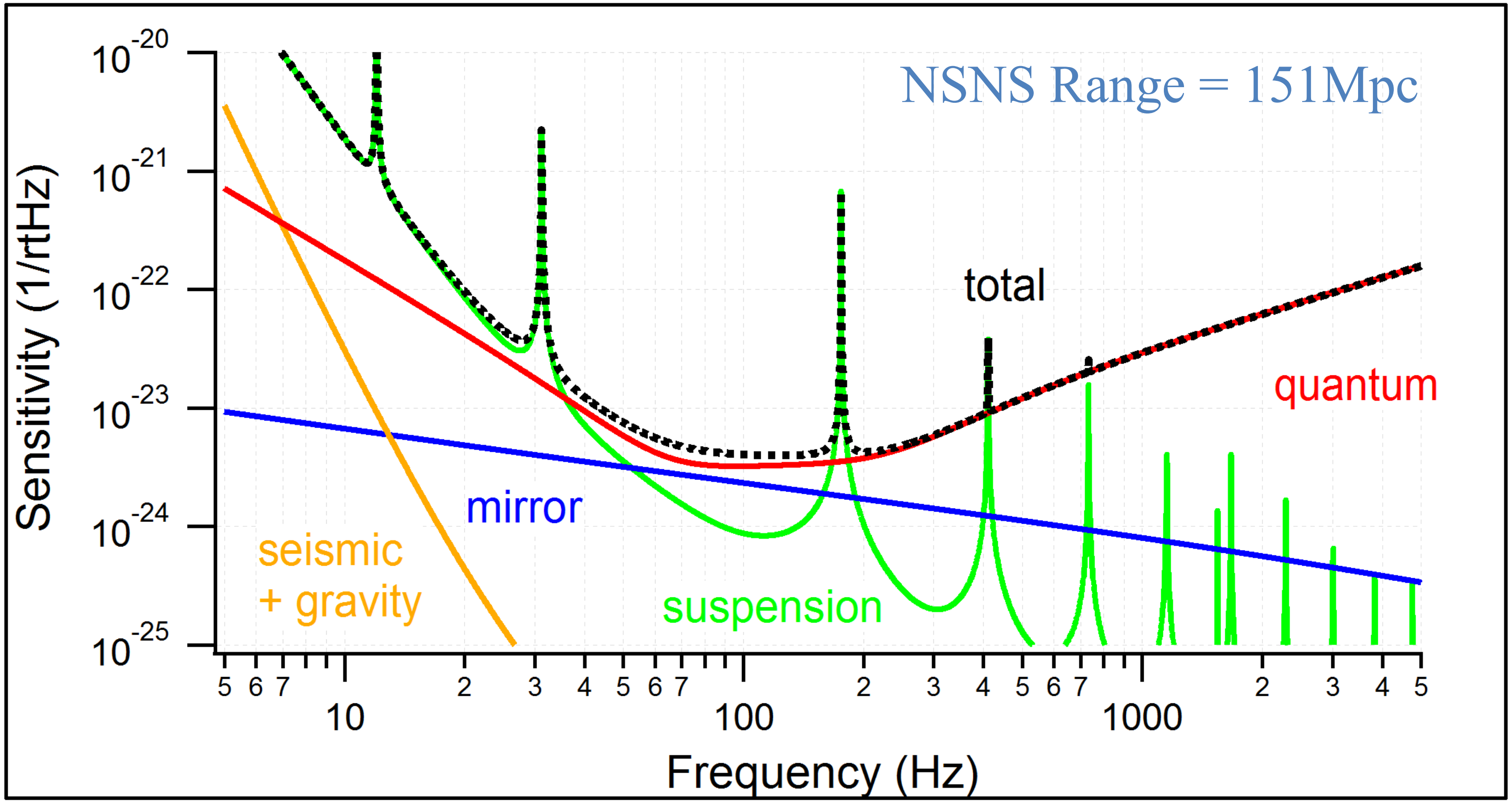
Sapphire mirror



KAGRA Baseline Configuration

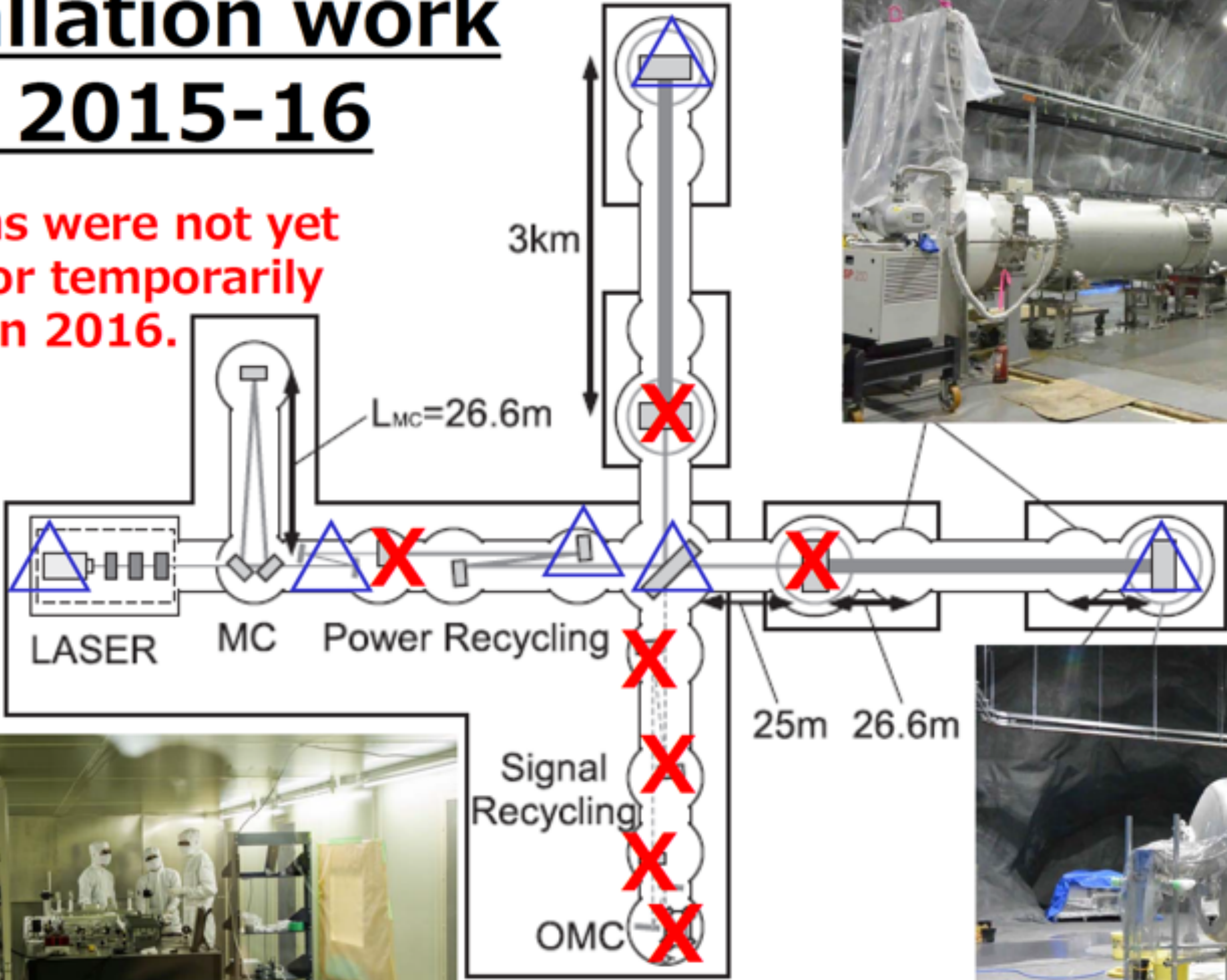


KAGRA Baseline Sensitivity



Installation work in 2015-16

Most items were not yet installed or temporarily installed in 2016.

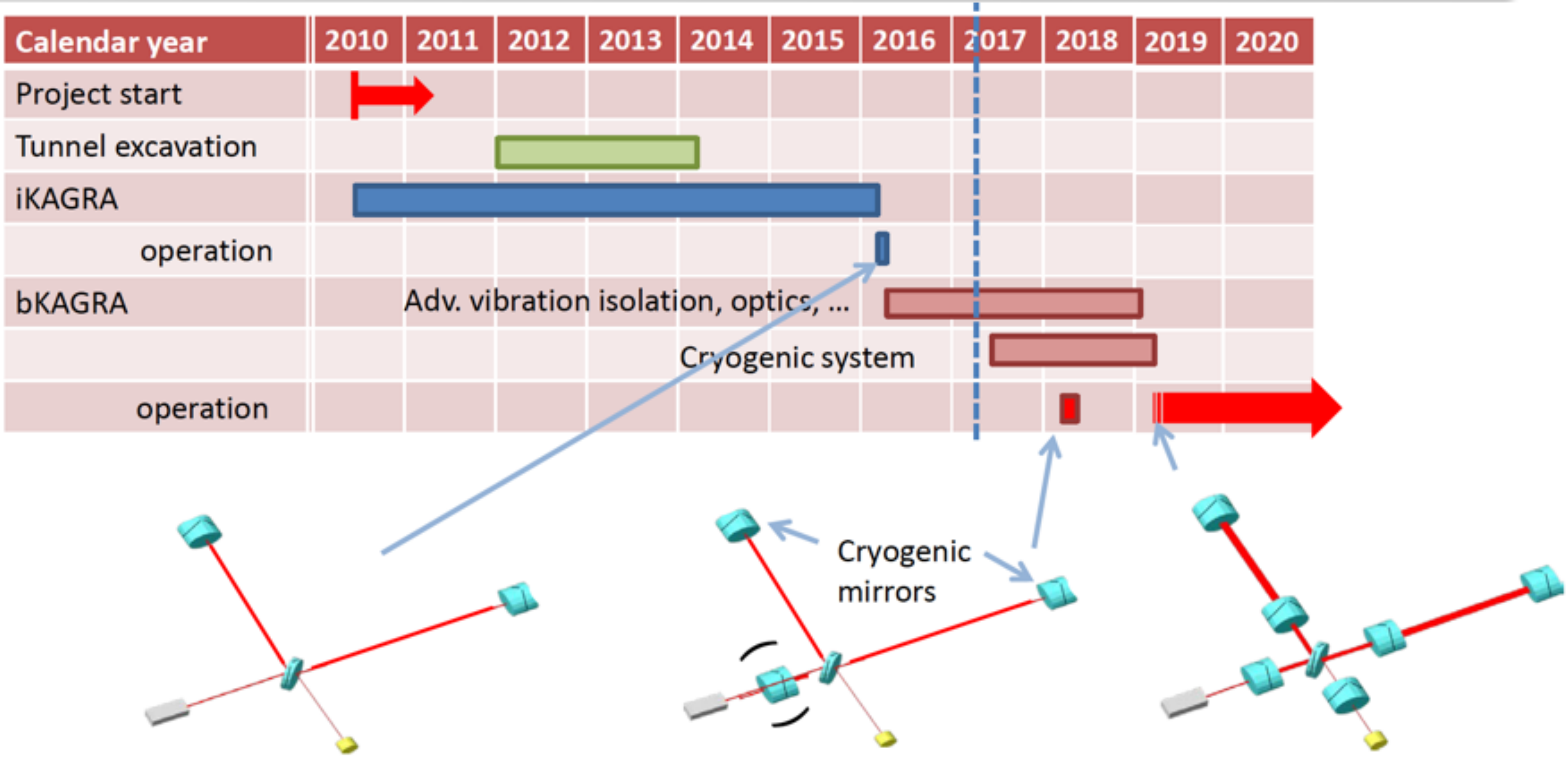


But, facility, digital control system, and infrastructure were installed by 2016.

iKAGRA Test Run in 2016

- Period: March 25 to 31 and April 11 to 25
- To obtain experiences of the management and operation of the km-class interferometer
- For test controls, data transfer, observation shift, etc.

Overall plan



iKAGRA

Initial KAGRA
Michelson at room temp.

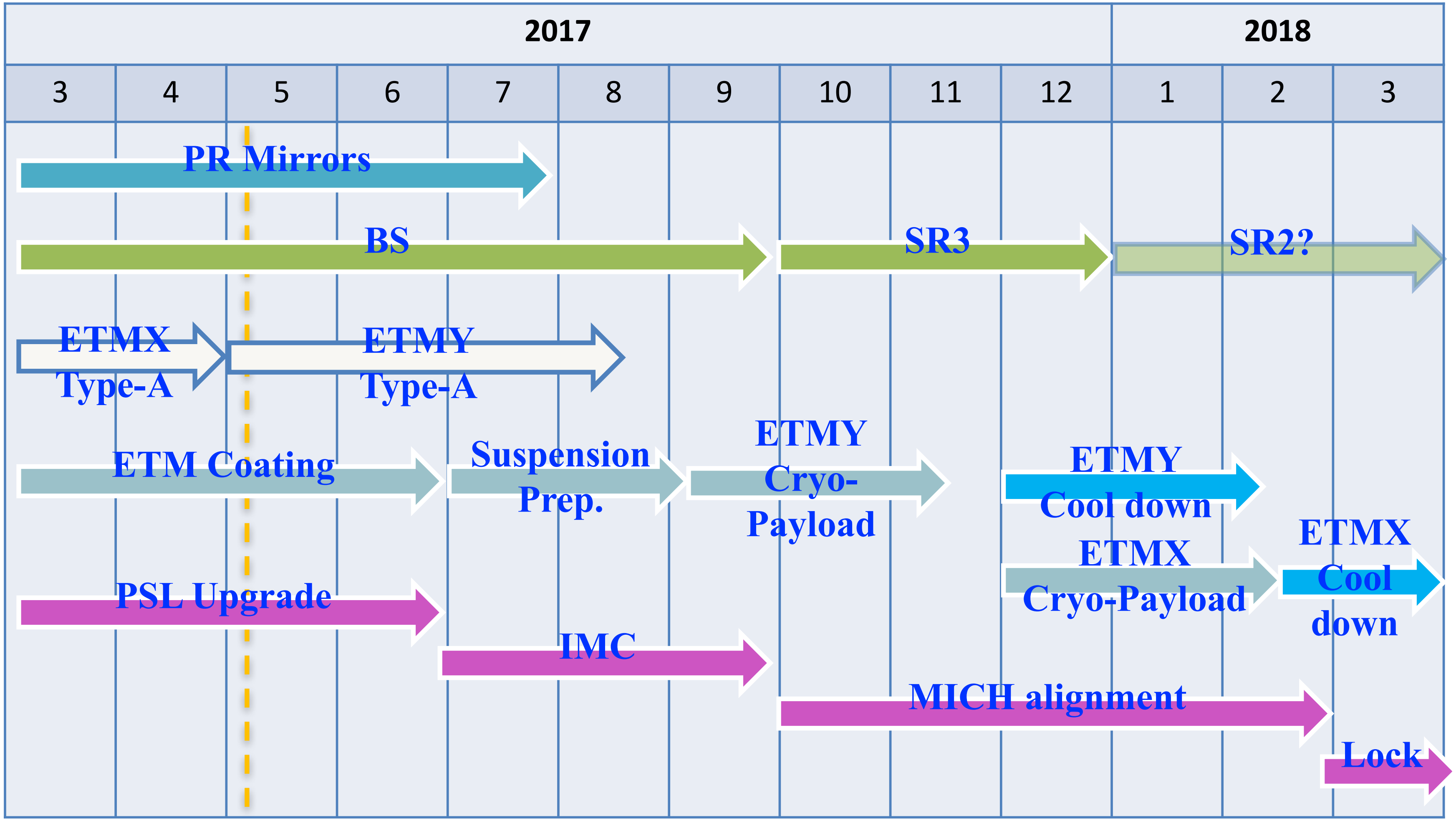
bKAGRA

Phase 1
Michelson with two cryogenic mirrors.

Phase 2
Four cryogenic mirrors.

Phase 3
DRFPMI with four cryogenic mirrors.
Observation run

bKAGRA phase 1 schedule

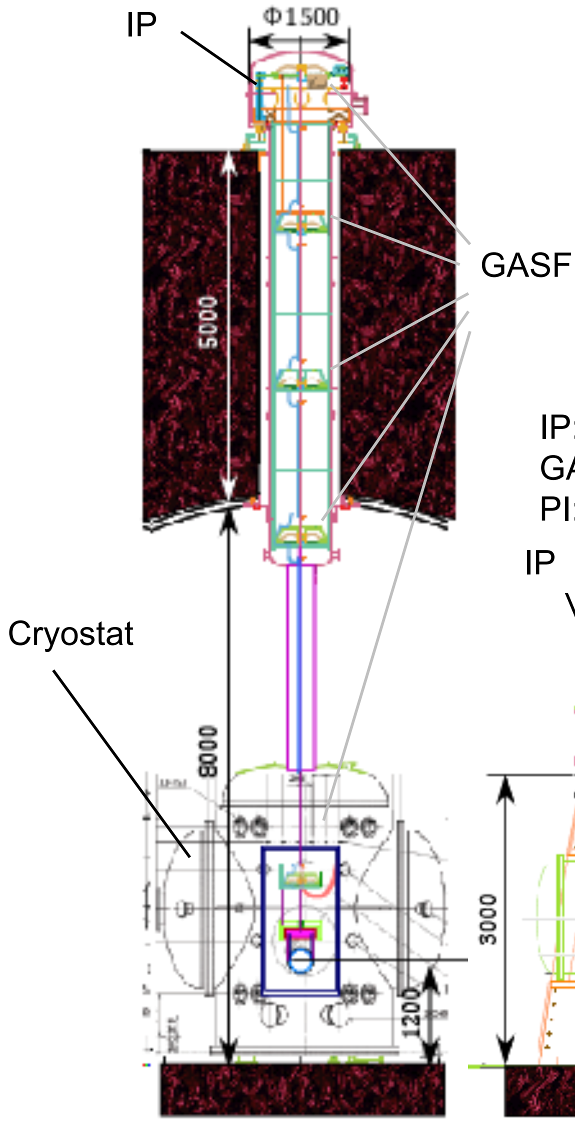


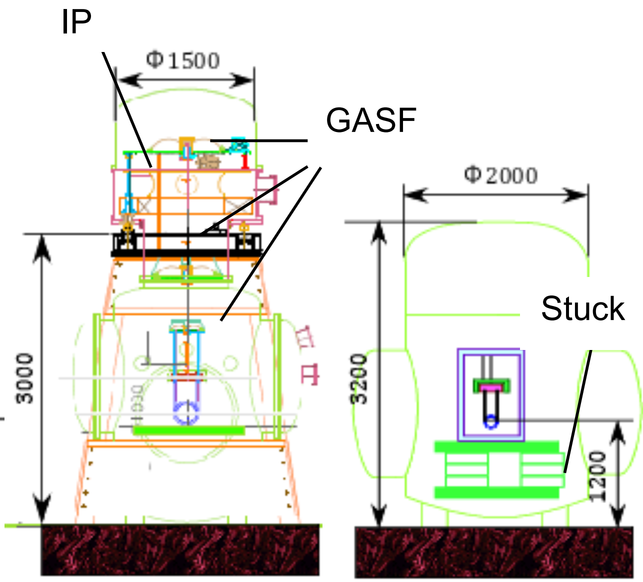
- Schedule is mostly limited by many vibration isolation systems.
  - (PR3), PR2, PRM, BS, SR3, (SR2), ETMX, ETMY
- Low temperature operation is also tight work.

Vibration Isolation System

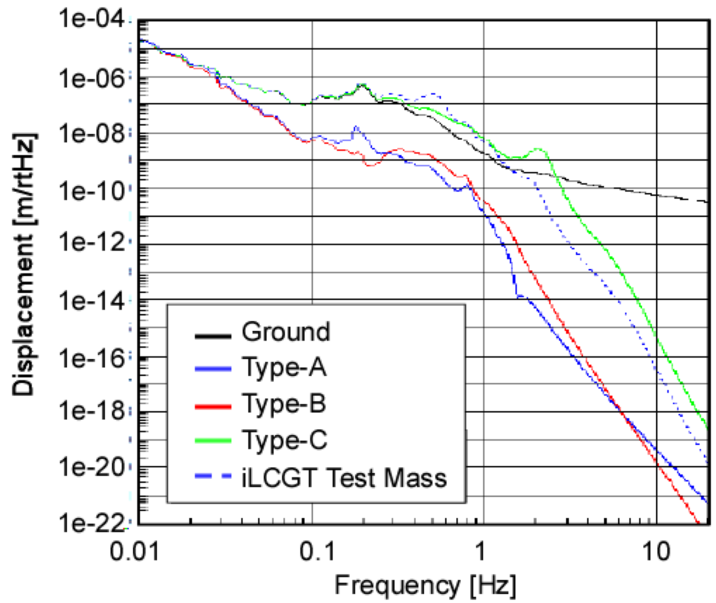
Type-A: Test Masses
Type-B: RM, BS
Type-C: Others

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

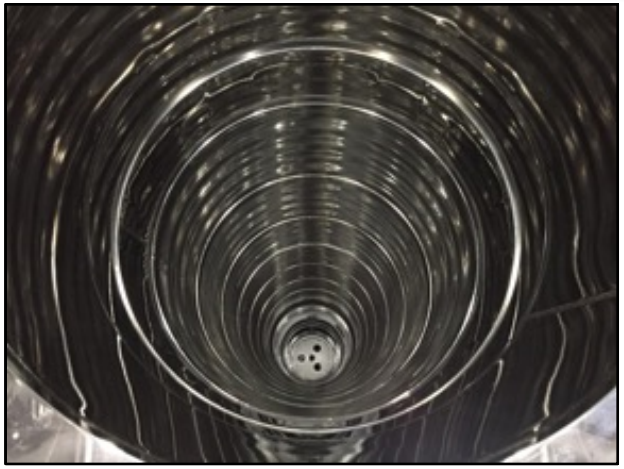


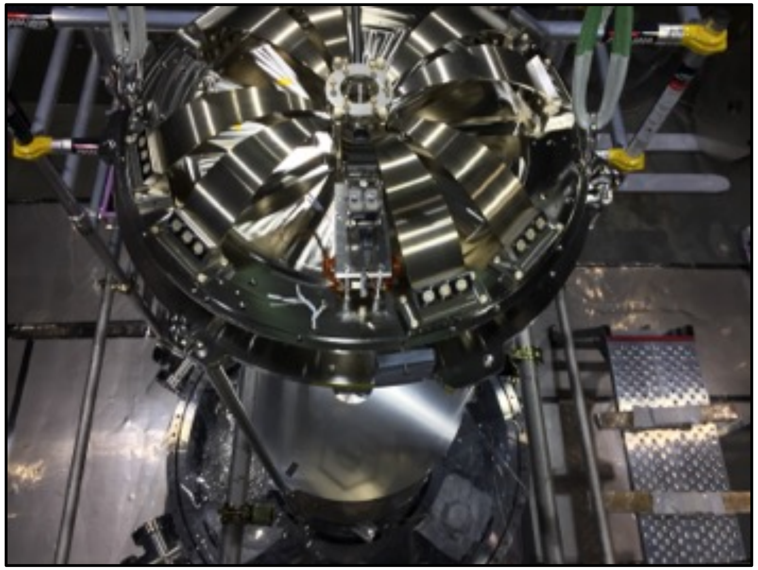


Type-A Type-B Type-C



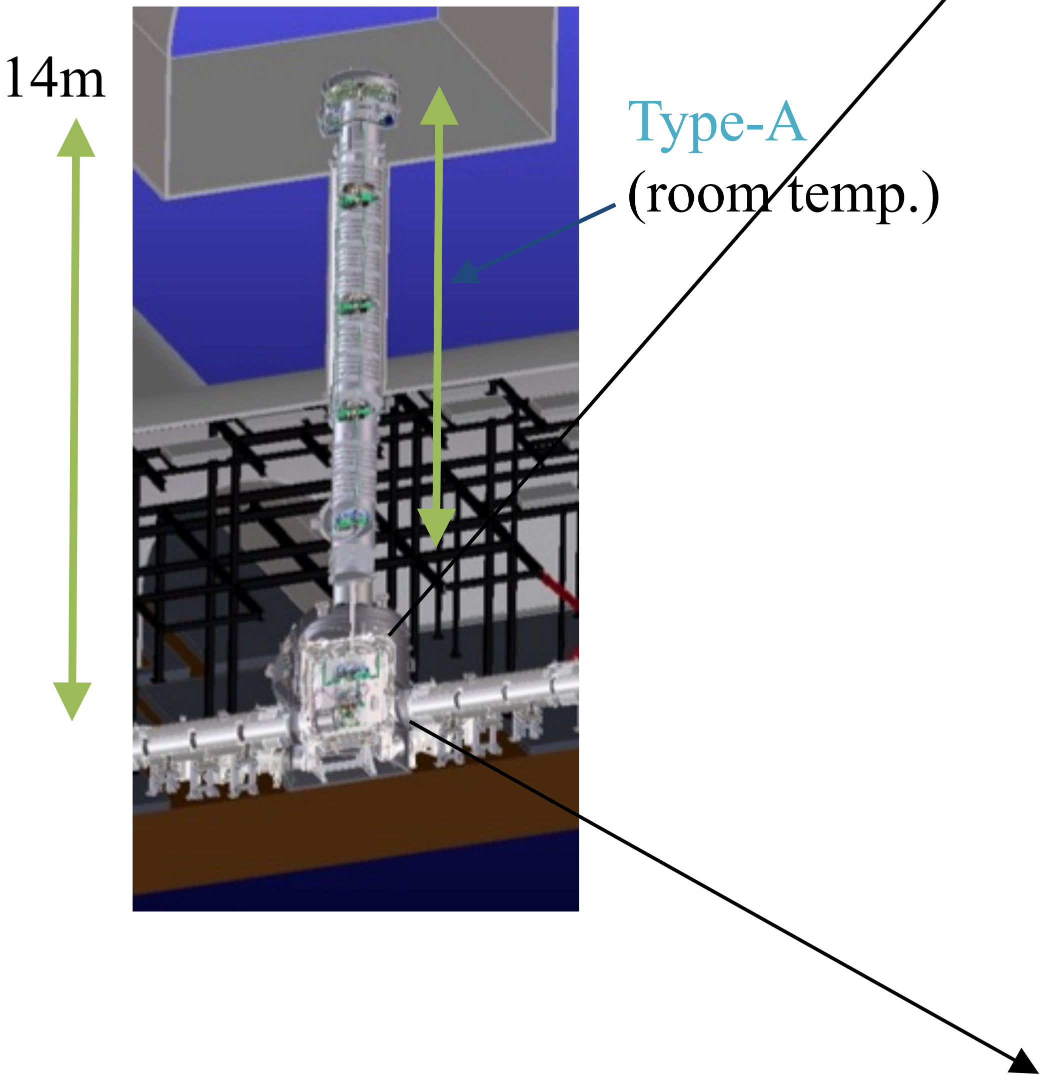
Type-A suspension installation

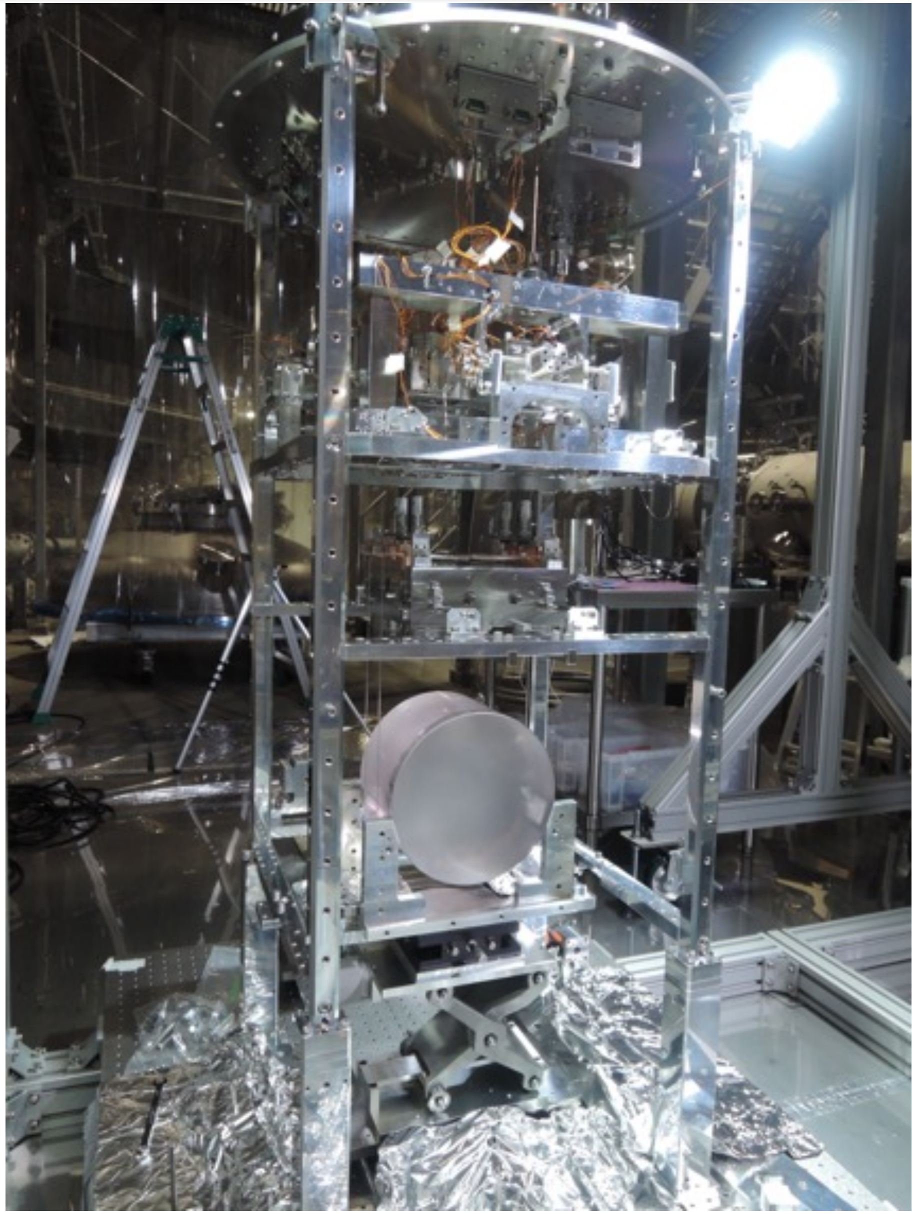




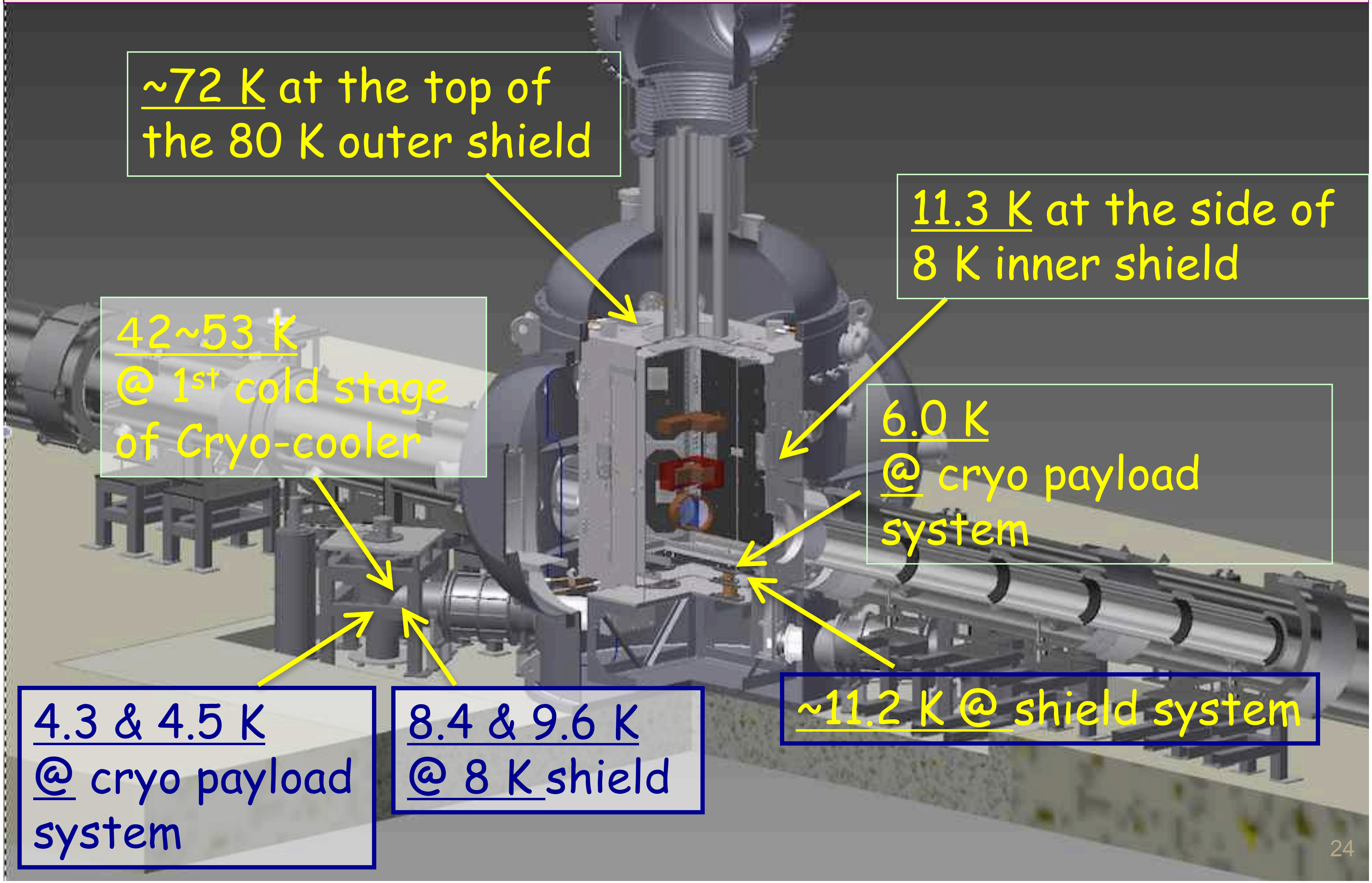
-> Koki Okutomi's talk on Thursday morning
"Controls of the KAGRA cryogenic vibration isolation system"

Type-A + Cryogenic Suspension

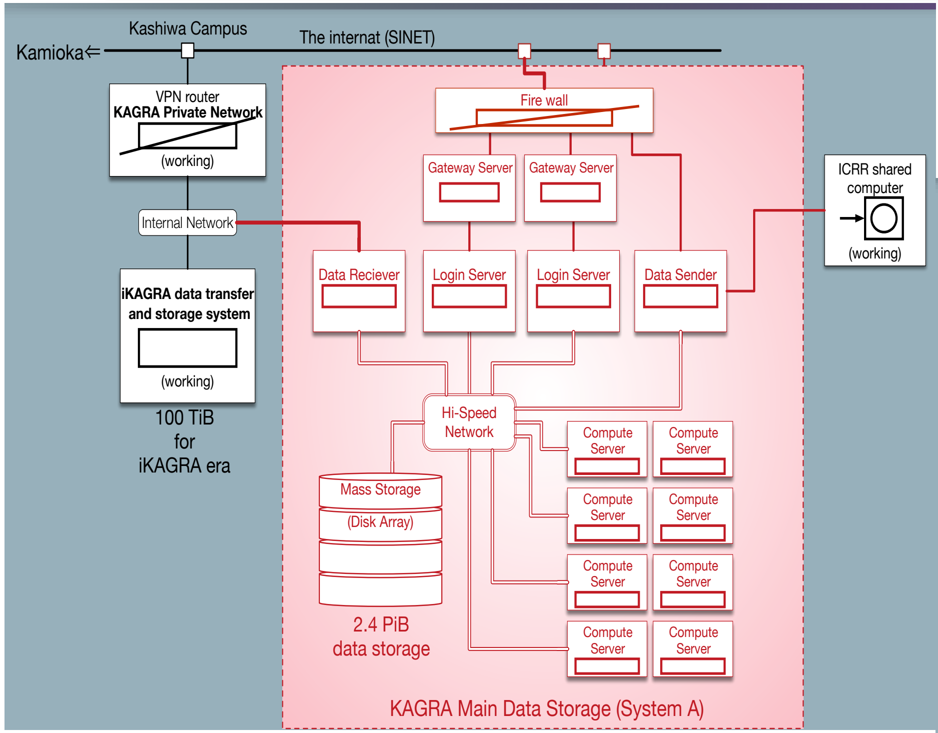




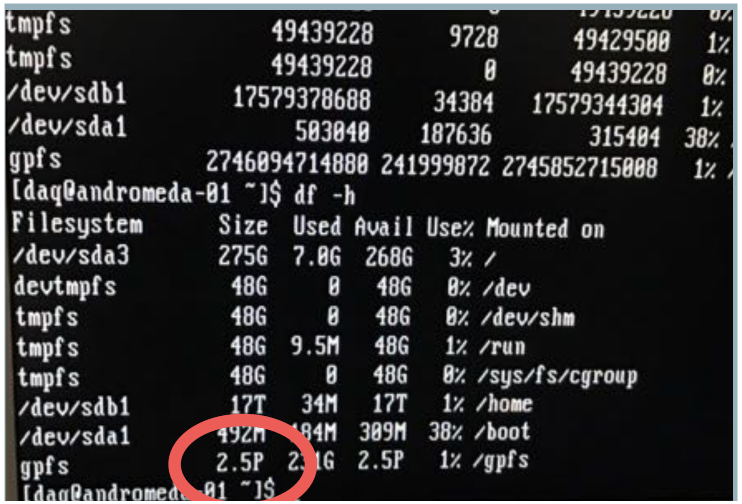
Temperature of main cryostat at X-front
@2017 Mar. 13



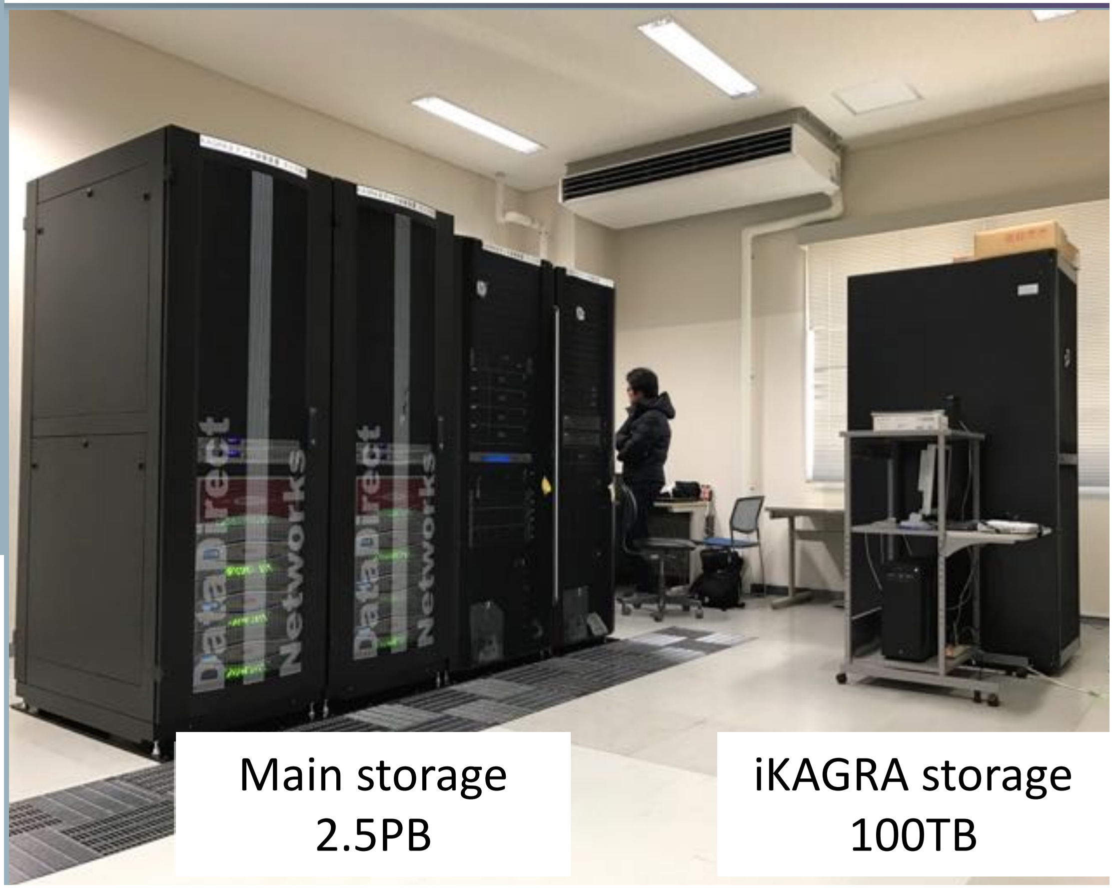
Main Data Storage



Main data storage system



```
tmpfs          49439228       9728    49429500   1%
tmpfs          49439228          0    49439228   0%
/dev/sdb1   17579378688      34384 17579344304   1%
/dev/sda1        503040     187636      315404  38%
gpfs      2746094714880  241999872 2745852715008   1%
[daq@andromeda-01 ~]$ df -h
Filesystem  Size  Used Avail Use% Mounted on
/dev/sda3   275G  7.0G  268G   3% /
devtmpfs     48G     0   48G   0% /dev
tmpfs        48G     0   48G   0% /dev/shm
tmpfs        48G  9.5M   48G   1% /run
tmpfs        48G     0   48G   0% /sys/fs/cgroup
/dev/sdb1    17T   34M   17T   1% /home
/dev/sda1   492M  184M  309M  38% /boot
gpfs        2.5P  2 1G  2.5P   1% /gpfs
[daq@andromeda-01 ~]$
```



Main storage
2.5PB

iKAGRA storage
100TB

Operation of main storage has been started in March 2017.

Viewgraph by M.Yoshida

J-GEM の概要

日本および世界に散らばる日本の望遠鏡群のネットワーク
重力波対応現象の探索

主な観測能力:
- 5 deg² opt. imaging w/ 1m
- 1 deg² NIR imaging w/ 1m
- opt-NIR spectroscopy w/ 1–8m
- opt-NIR polarimetry





- 1m 木曽シュミット望遠鏡（東大）
  超広視野カメラ➔ 36平方度
- 1.5m かなた望遠鏡（広大）
- 2m なゆた望遠鏡（西はりま）
- 50cm MITSuME望遠鏡（国立天文台）
- 91cm 広視野赤外線望遠鏡
  （国立天文台）
- 32m 電波望遠鏡（山口大）

50cm 望遠鏡
(広島大学)

3.8m 望遠鏡
(京都大学)

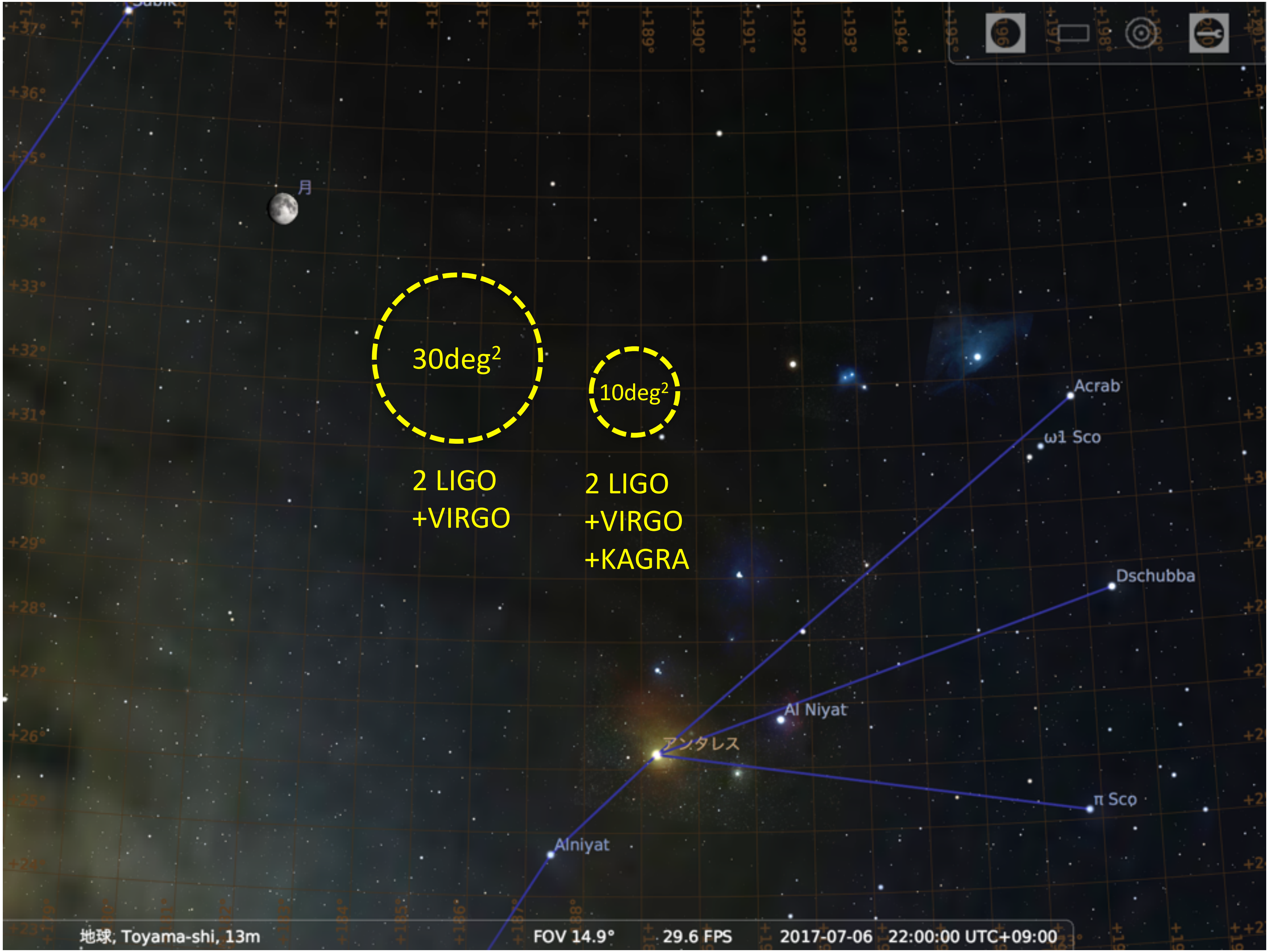
すばる望遠鏡

TAO 望遠鏡
(東京大学)

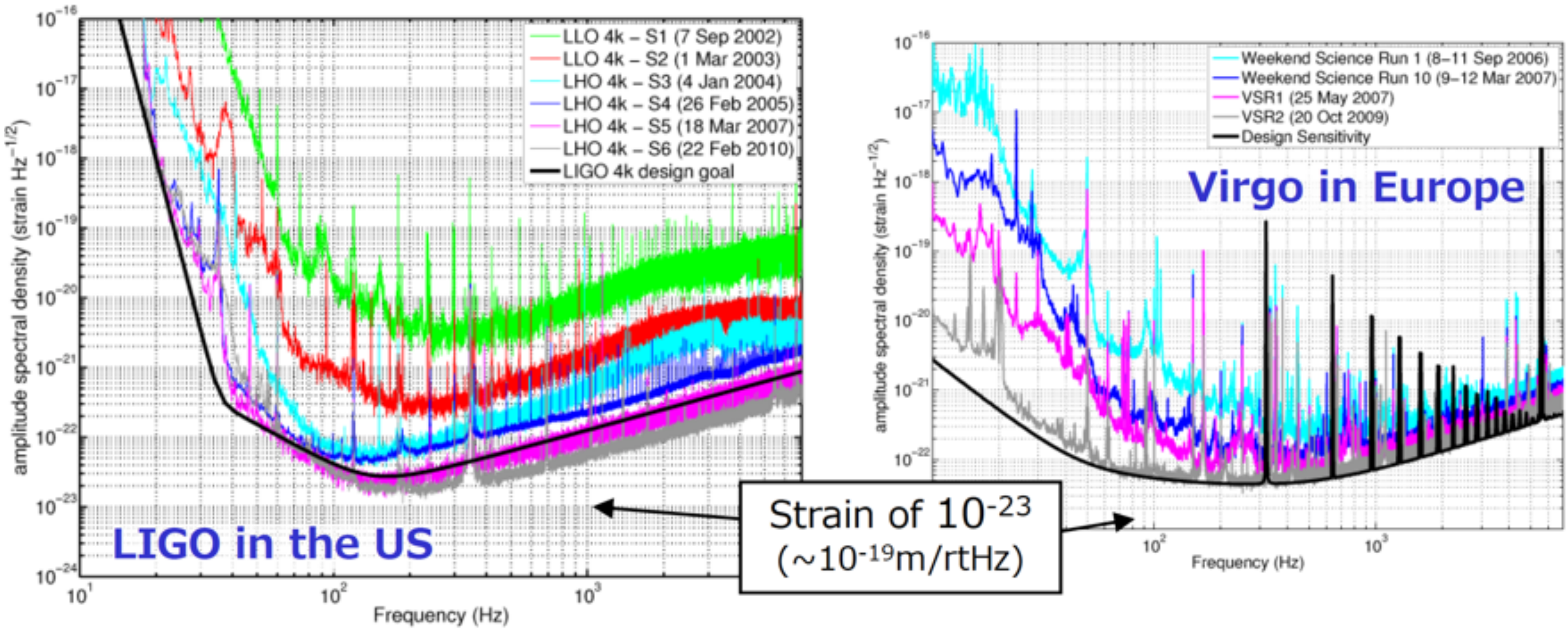
IRSF（名古屋大学）
@ 南アフリカ

MOA-II（名古屋大学）@
ニュージーランド

miniTAO（東京大学）
@ チリ


30deg²
10deg²
2 LIGO
+VIRGO
2 LIGO
+VIRGO
+KAGRA
月
Acrab
ω1 Sco
Dschubba
Al Niyat
アンタレス
π Sco
Alniyat
地球, Toyama-shi, 13m
FOV 14.9°
29.6 FPS
2017-07-06 22:00:00 UTC+09:00

Development of sensitivities



- Generally, it takes ~5years to reach the target sensitivity.