# Status of KAGRA

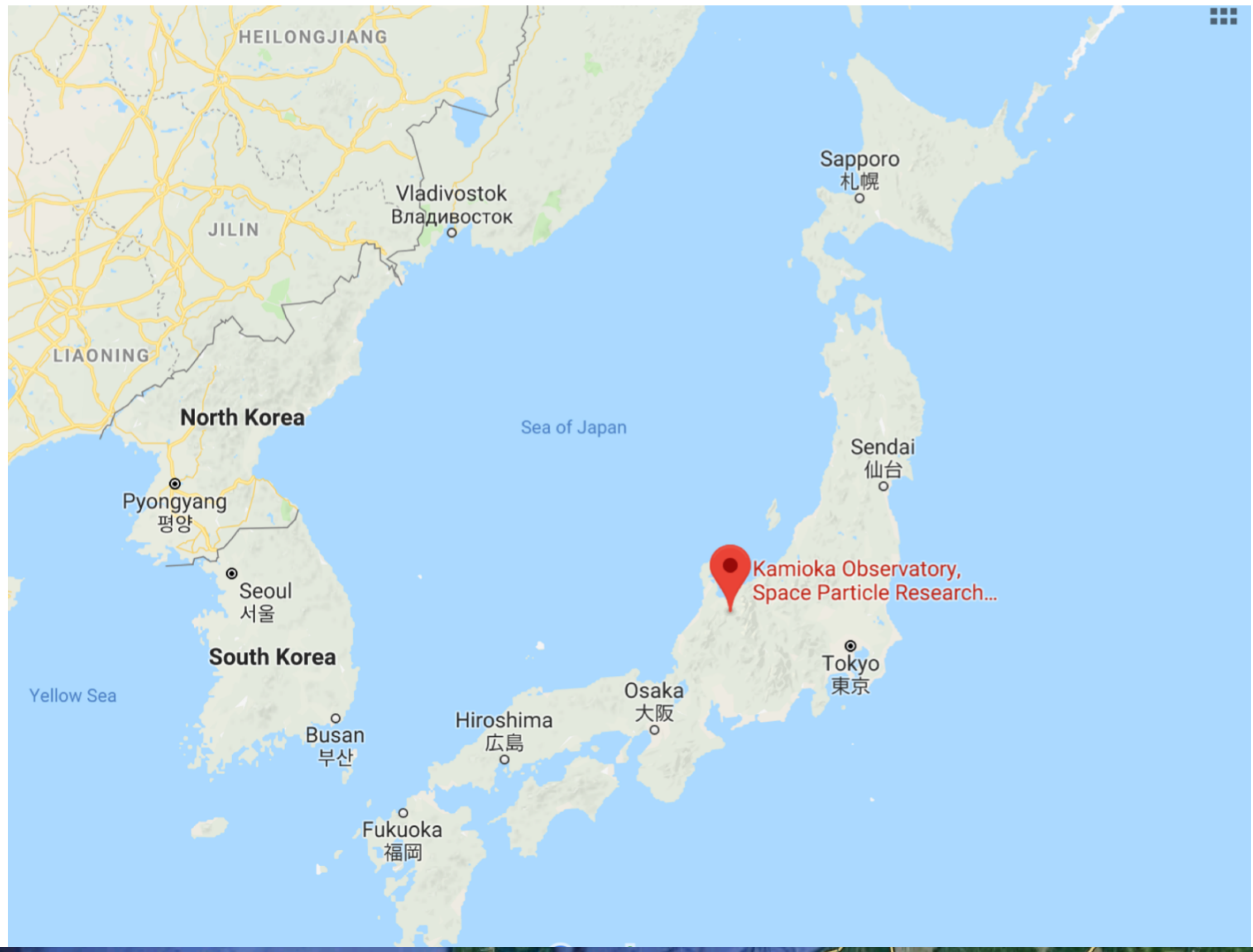
KAGRA

- **Underground** and **Cryogenic** interferometric gravitational-wave detector at Kamioka, Japan
- KAGRA plans to finish all the installations by ~~the end of March~~, 2019.
  at least 2-week delay
- **KAGRA plans to join LV Observation Run 3 from fall 2019.**

Hisaaki Shinkai (Osaka Inst. Tech.)
KAGRA Scientific Congress, board chair

# KAGRA (Kamioka GW Observatory)

◆ **Underground** and **Cryogenic** interferometric gravitational-wave detector at Kamioka, Japan





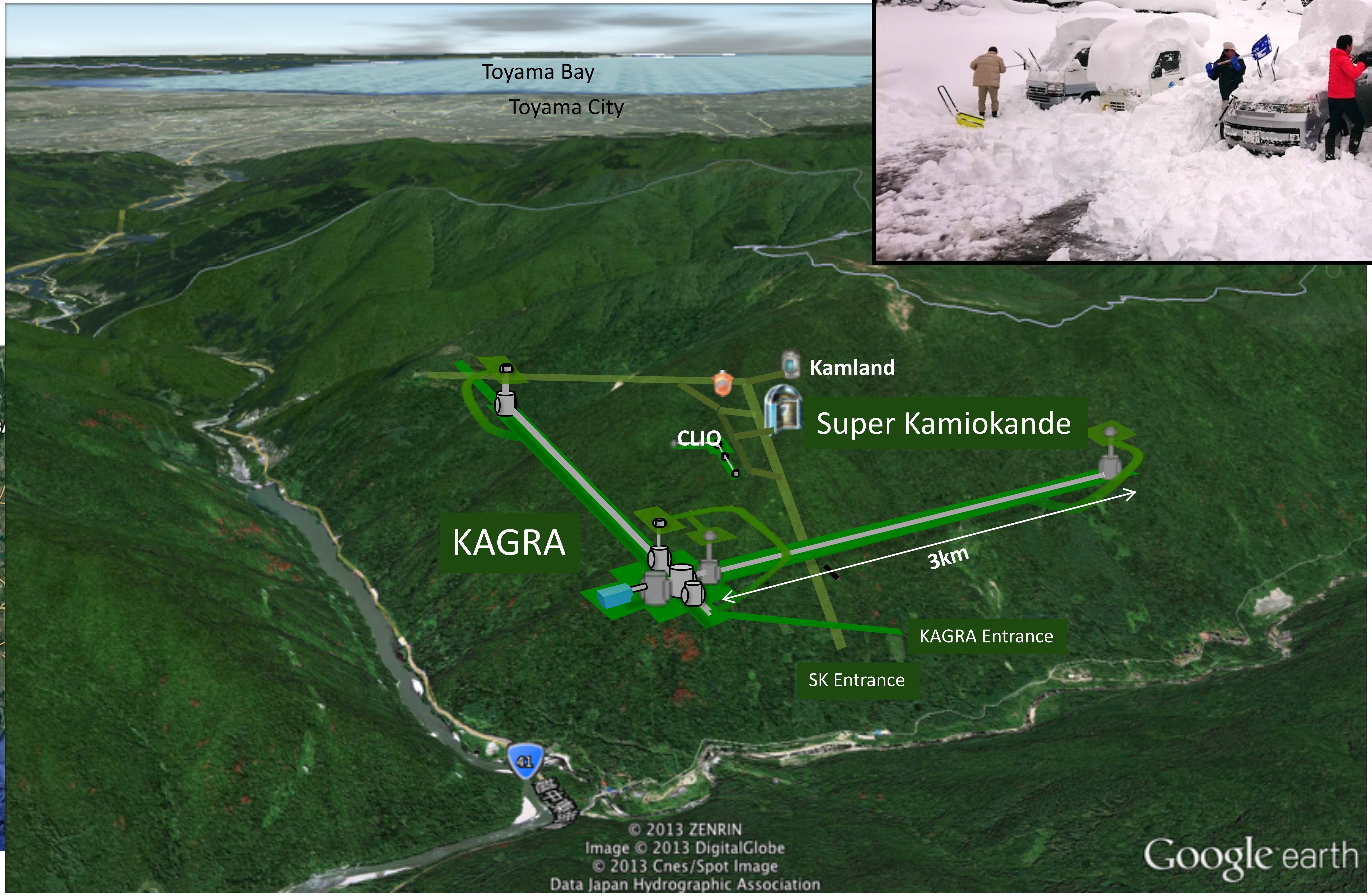



fig. by Keiko Kokeyama

# KAGRA (Kamioka GW Observatory)

KAGRA

Nature Astronomy, 3 (2019) 35.
[arXiv:1811.08079]

nature astronomy
PERSPECTIVE
https://doi.org/10.1038/s41550-018-0658-y

## KAGRA: 2.5 generation interferometric gravitational wave detector

KAGRA collaboration

**The recent detections of gravitational waves (GWs) reported by the LIGO and Virgo collaborations have made a significant impact on physics and astronomy. A global network of GW detectors will play a key role in uncovering the unknown nature of the sources in coordinated observations with astronomical telescopes and detectors. Here we introduce KAGRA, a new GW detector with two 3 km baseline arms arranged in an 'L' shape. KAGRA's design is similar to the second generations of Advanced LIGO and Advanced Virgo, but it will be operating at cryogenic temperatures with sapphire mirrors. This low-temperature feature is advantageous for improving the sensitivity around 100 Hz and is considered to be an important feature for the third-generation GW detector concept (for example, the Einstein Telescope of Europe or the Cosmic Explorer of the United States). Hence, KAGRA is often called a 2.5-generation GW detector based on laser interferometry. KAGRA's first observation run is scheduled in late 2019, aiming to join the third observation run of the advanced LIGO–Virgo network. When operating along with the existing GW detectors, KAGRA will be helpful in locating GW sources more accurately and determining the source parameters with higher precision, providing information for follow-up observations of GW trigger candidates.**

Seeing is believing. We were reminded of this proverb when we received the news of the discovery of GW150914, the first direct detection of gravitational waves (GWs)[1]. The existence of GWs has been believed since Russel Hulse and Joseph Taylor discovered the binary pulsar PSR B1913 + 16 in 1974 (ref. [2]). The long-term radio observation of this system has shown that the observed orbital decay is well described by the energy/angular momentum loss due to GW emission as predicted by Einstein in 1915 (ref. [3]).

Figure 1 shows the location of KAGRA in Kamioka, Japan. The interferometer shares the area with the well-known neutrino detectors Super-Kamiokande and KamLAND. Kamioka is a small town located 1.5 hour driving distance from the city of Toyama, with its biggest claim to fame being an old mine.

Compared with existing laser interferometers, KAGRA is technologically unique in two features. Firstly, it is located in an underground site to reduce seismic noise. Secondly, KAGRA's test masses

# NEWS IN FOCUS



THE ASAHI SHIMBUN VIA GETTY

Japan's Kamioka Gravitational Wave Detector is scheduled to start up in 2019, joining a global network of interferometers.

PHYSICS

## Japan to begin pioneering hunt for gravitational waves

*The underground KAGRA detector will deploy ambitious technology to improve sensitivity.*

BY DAVIDE CASTELVECCHI

Inside a house-sized scaffolding wrapped in thick plastic sheets, Takayuki Tomaru is in full clean-room attire. The physicist, who works at the High Energy Accelerator Research Organization (KEK) in Tsukuba, Japan, is performing one of the most delicate and crucial tasks in the construction of a gravitational-wave observatory: installing one of the machine's four mirrors, each a 23-kilogram cylinder of solid sapphire known as a test mass.

When operations begin later this year, their job will be to bounce infrared laser beams back and forth along two 3-kilometre, high-vacuum pipes, ready to sense the passage of gravitational waves (see 'Japan's wave hunter').

The ¥16.4-billion (US$148-million) observatory — Japan's Kamioka Gravitational Wave Detector (KAGRA) — will work on the same principle as the two detectors of the Laser Interferometer Gravitational-Wave Observatory (LIGO) in the United States and the Virgo solo machine in Italy. In the past few years, these machines have begun to detect gravitational waves — long-sought ripples in the fabric of space-time, created by cataclysmic cosmic events such as the merging of two black holes or the collision of two neutron stars.

With the addition of KAGRA, the growing global network of detectors will enable astrophysicists to locate the position of these feeble cosmic signals in the sky with greatly increased precision. They will be able to dissect the waves' properties, such as how they are ▸

3 JANUARY 2019 | VOL 565 | NATURE | 9



Nature 565 (2019 Jan ) 30

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## A new gravitational wave detector is almost ready to join the search

Japan's KAGRA experiment tests new techniques for spotting ripples in spacetime

BY EMILY CONOVER 7:00AM, JANUARY 18, 2019

**DEEP AND COLD** Chilled mirrors and an underground hideout (shown) should help the KAGRA experiment in its upcoming search for gravitational waves.

ICRR, UNIV. OF TOKYO

Magazine issue: Vol. 195, No. 3, February 16, 2019, p. 8

Science News 195 (2019 Feb) 8

https://www.sciencenews.org/

# KAGRA collaboration

98 groups, 15 countries
250+ active members

**Latest paper has 197 authors.**
**227 members applied for authorlist 2018**

Organize Face-to-Face meeting
3 times (April/August/Dec) / year

**F2F April 2019 @ U. Tokyo, Japan**
**F2F Aug. 2019 @ U. Toyama, Japan**

Organize International Workshop
2 times / year

**KIW5 Feb. 2019 @ Perugia, Italy**
**KIW6 June 2019 @ Wuhan, China**
**KIW7 April 2020 @ NCU, Taiwan**

http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA

# Organization of KSC (KAGRA Scientific Congress)

KAGRA

**KAGRA Scientific Congress (KSC) organization chart 2019/March 10**

Takaaki Kajita

PI

EO

sharing information & idea

KSC board

* Hisaaki Shinkai
* Chunglee Kim
Sadakazu Haino
Yuta Michimura
Nobuyuki Kanda (EO)

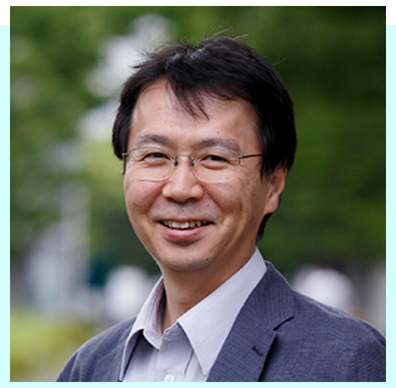
Takahiro Yamamoto (PD)
Koji Nagano (Student)
Zong-Hong Zhu (region)
Hyung-Won Lee (region)
Ray-Kuang Lee (region)

Yoshio Saito

SEO

Data Analysis Committee (DAC)

* Hideyuki Tagoshi
+ WGs chairs/vice chairs
+ Hisaaki Shinkai (board)



| Compact Binary Coalescence | Continuous Wave | Burst Wave | Stochastic Wave | Computing & Software | Calibration | Detchar |
|---|---|---|---|---|---|---|
| * Hideyuki Tagoshi<br>Kipp Cannon<br>Hyung-Won Lee<br>Tjonnie Li | * Yousuke Itoh | * Kazuhiro Hayama | * Guo-Chin Liu<br>Sachiko Kuroyanagi | * Ken-ichi Ohara<br>Kazuki Sakai | * Yuki Inoue | * TBD |

**Joint Editorial board**
* TBD

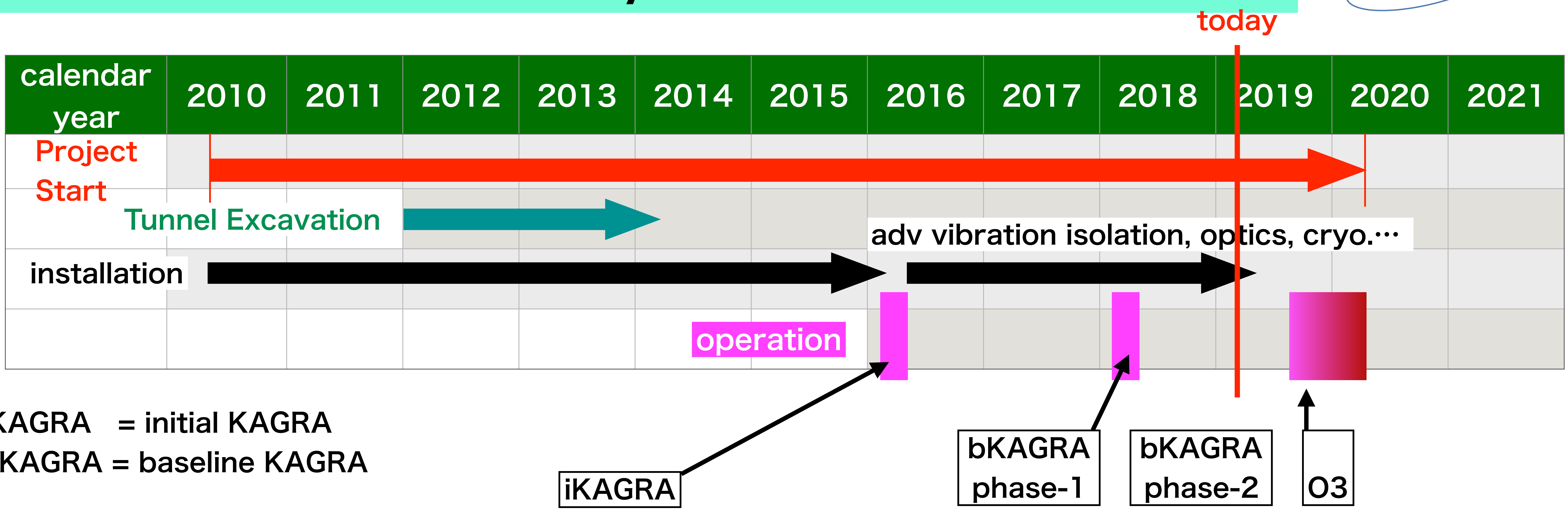
**Joint Run Planning Committee**
Yousuke Itoh
Shinji Miyoki

**LVC-KAGRA taskforce**
Yoshio Saito (leader, project manager)
Hideyuki Tagoshi (Data analysis)
Takahiro Yamamoto (Calibration)
Osamu Miyakawa (commissioning)
Hisaaki Shinkai (MoU)

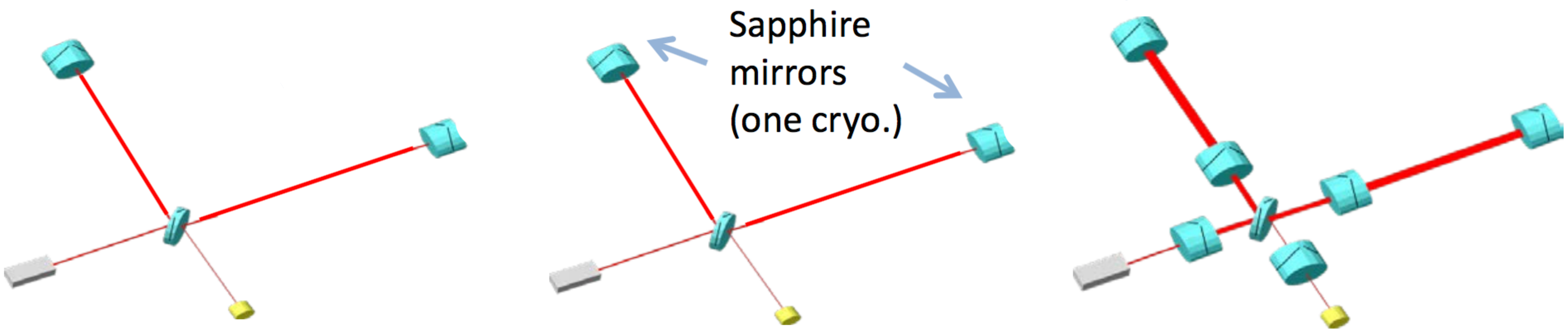
**Joint Meeting Committee**
* TBD

**Joint Detection Committee**
* TBD

# Brief History of KAGRA



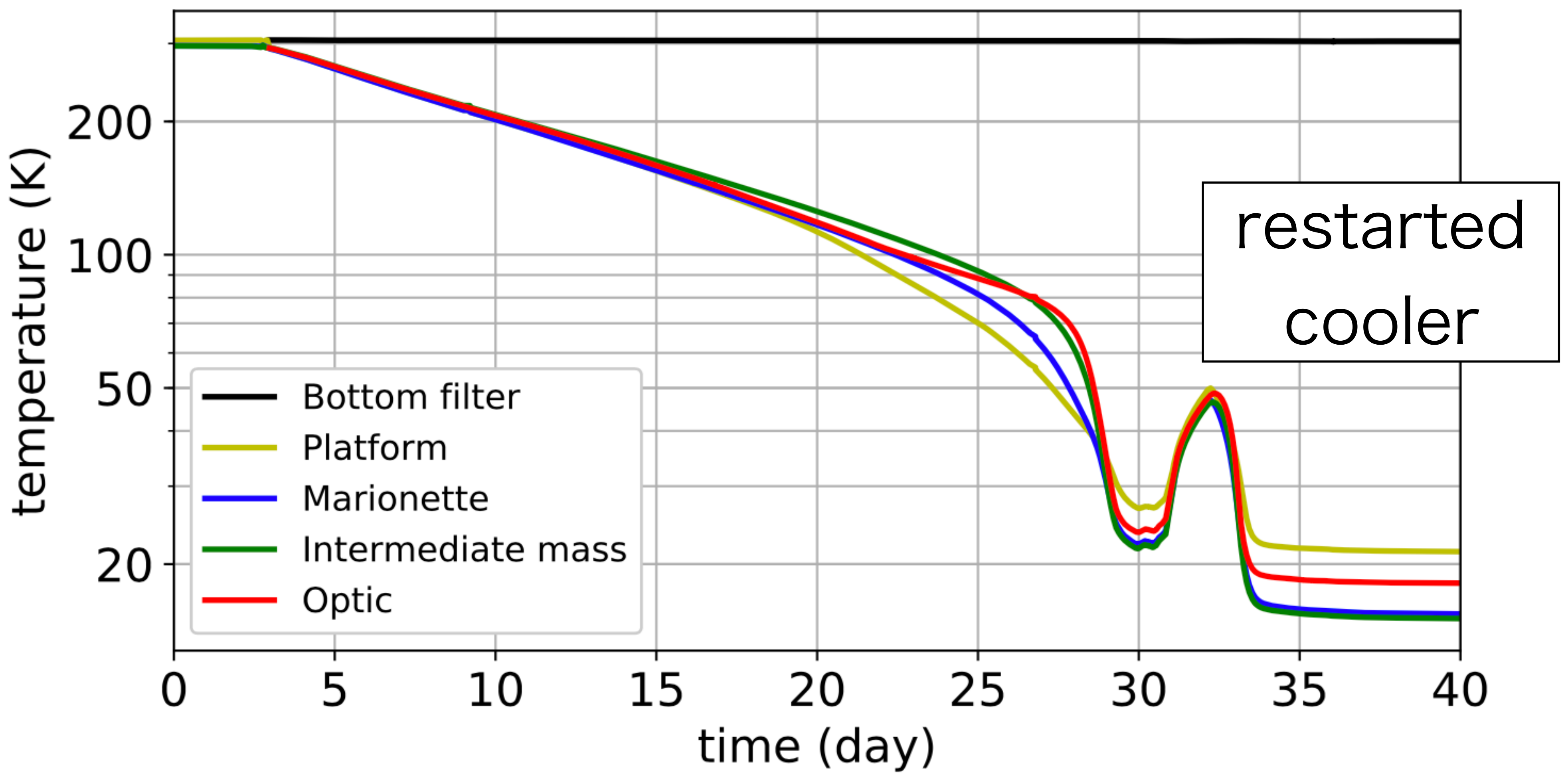

iKAGRA = initial KAGRA
bKAGRA = baseline KAGRA

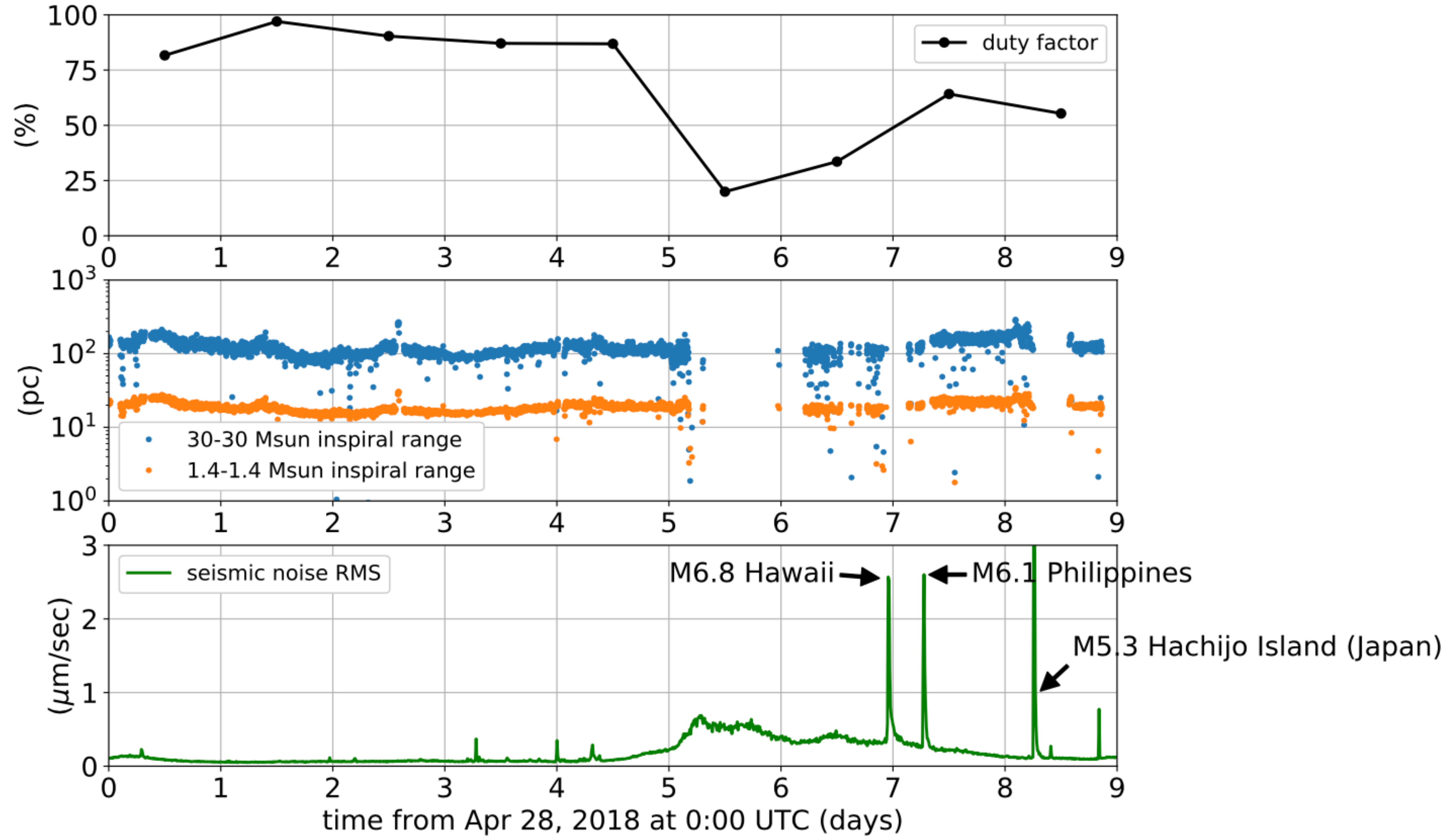


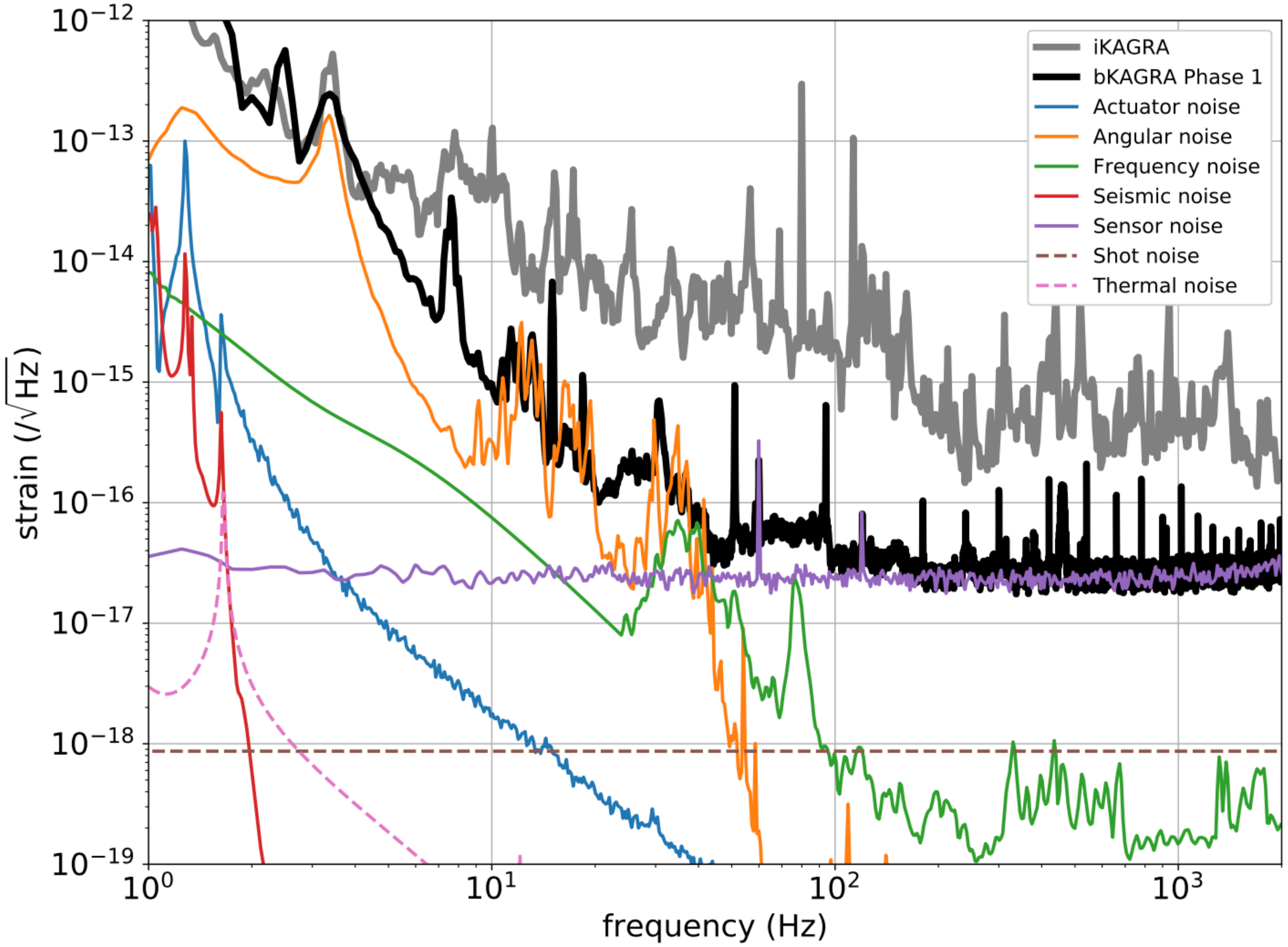

[arXiv:1712.00148] [arXiv:1901.03569]

# bKAGRA phase-1 operation (April & May 2018)

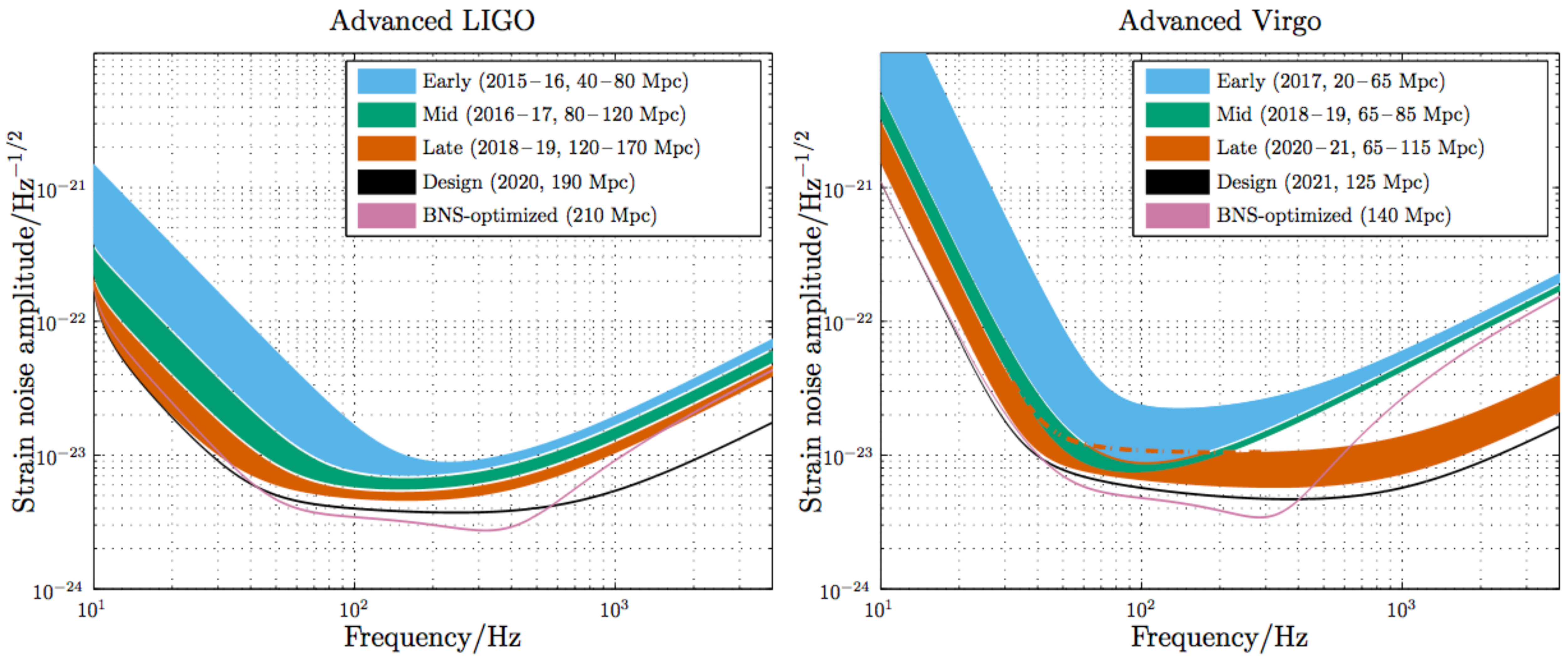
[arXiv:1901.03569]

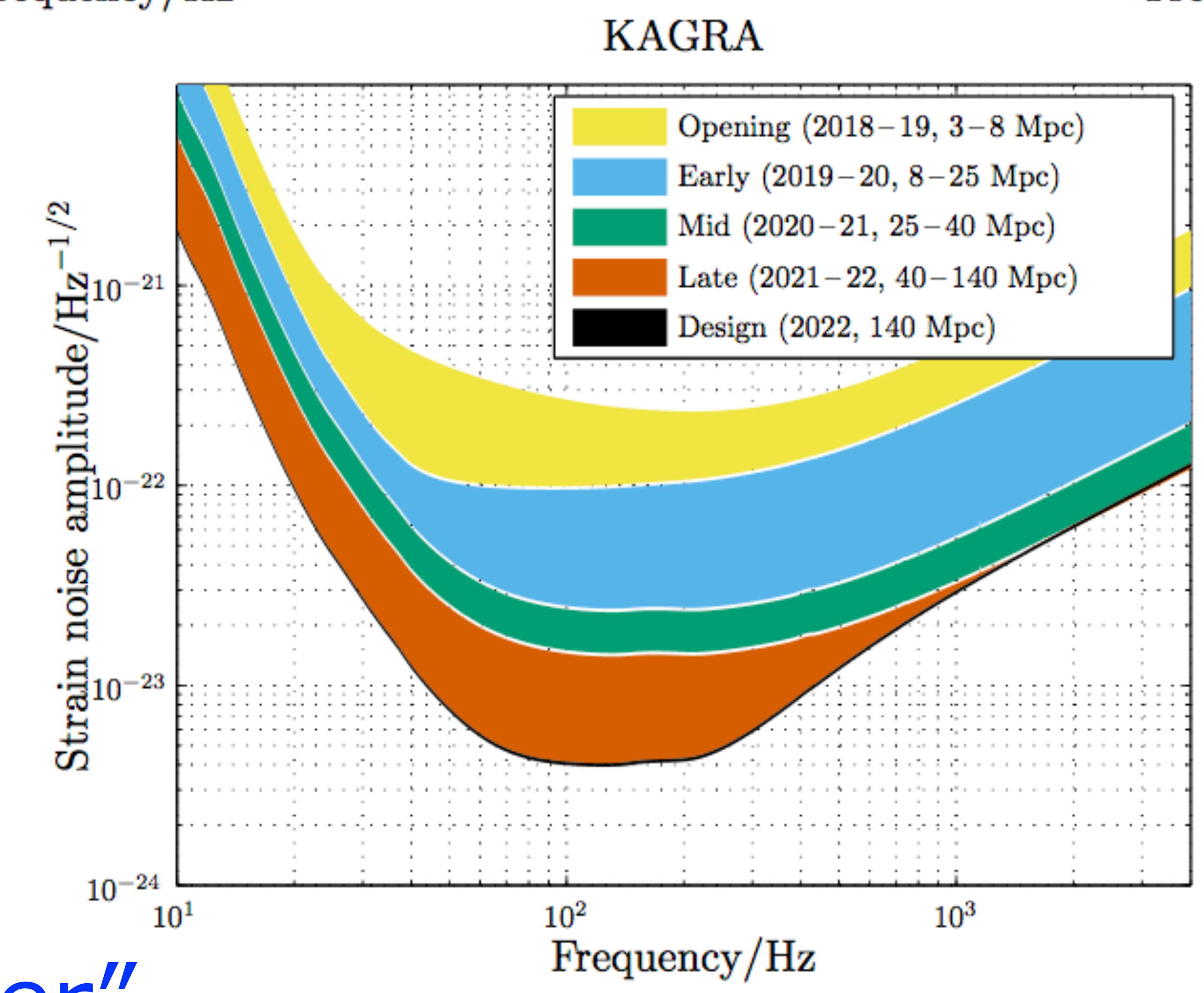


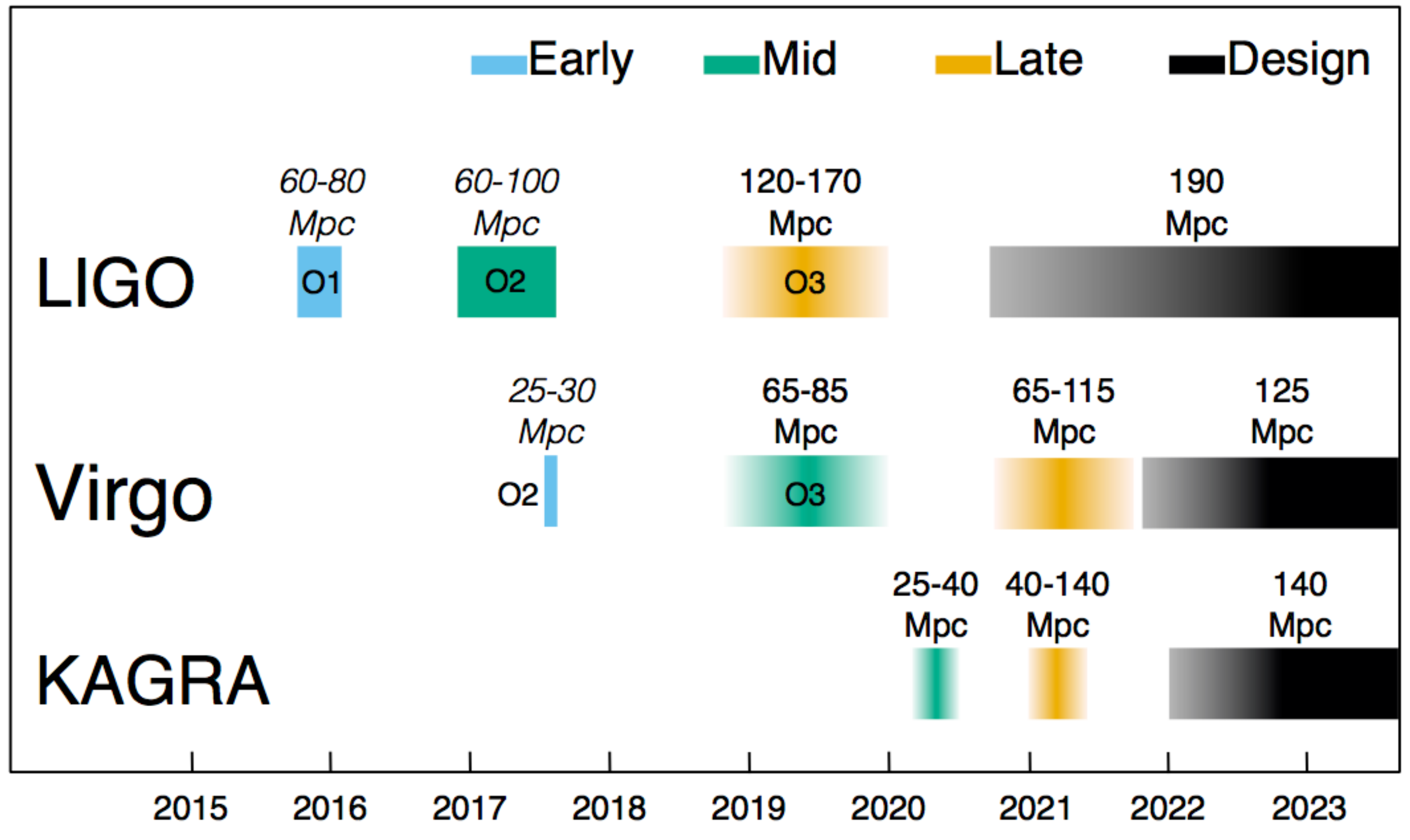



# Target Sensitivity & Schedule

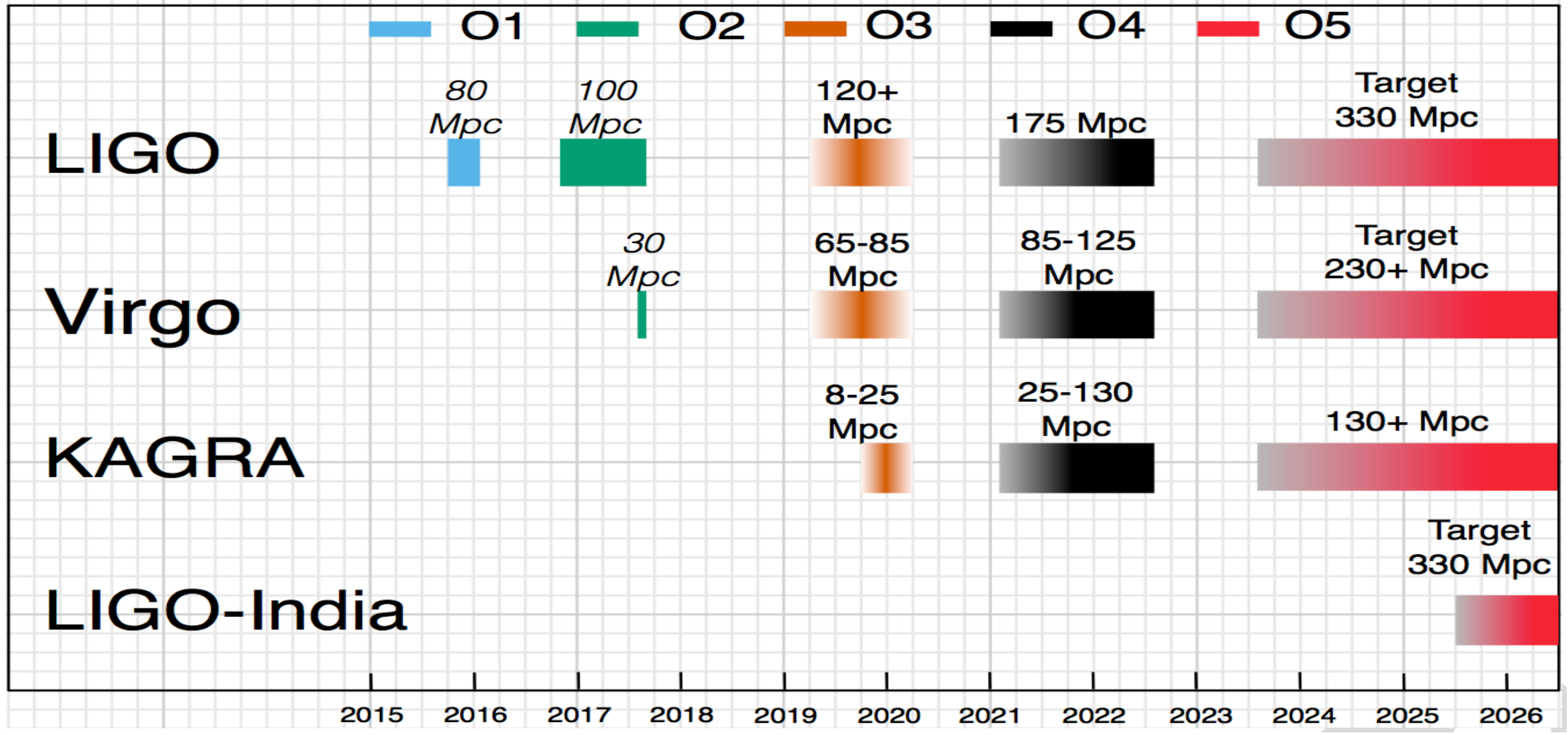



[1304.0670v4]

[draft]



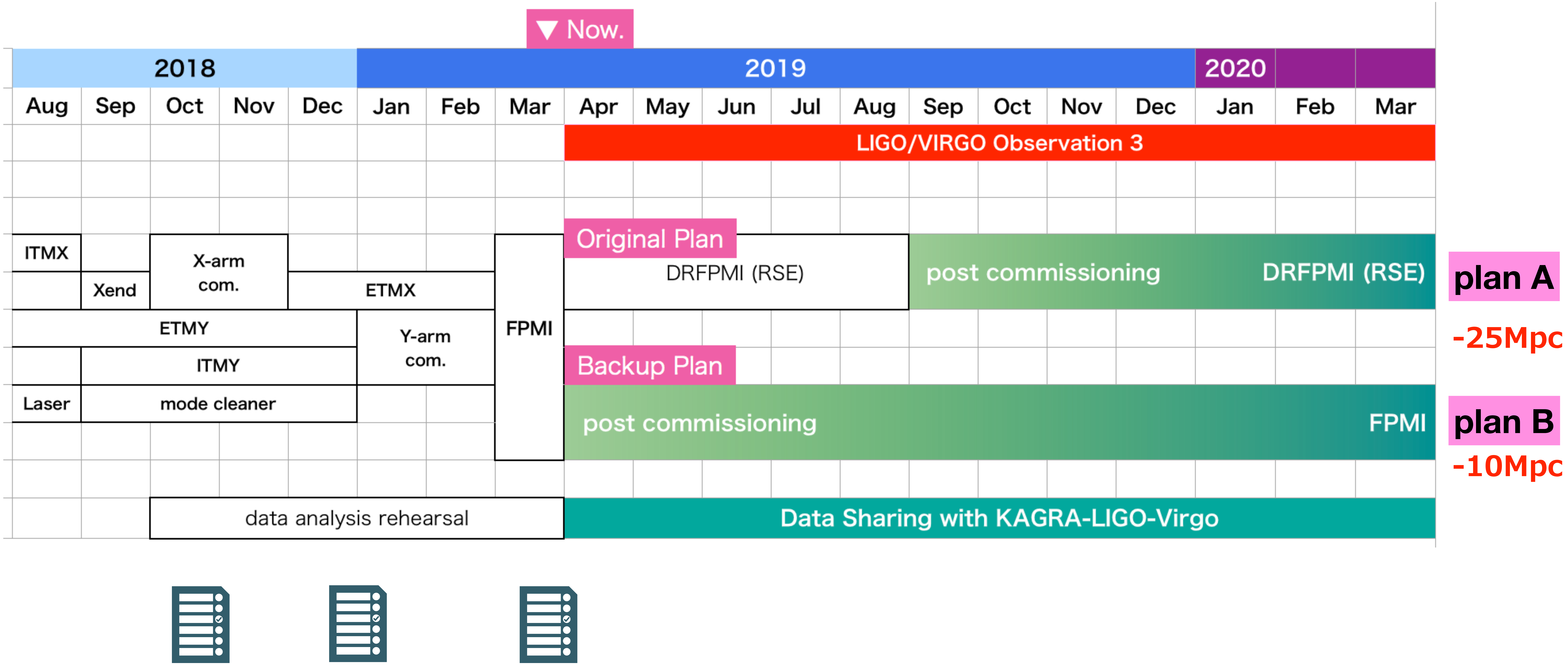

"Scenario Paper"

Living Rev Relativ (2018) 21:3

https://doi.org/10.1007/s41114-018-0012-9

[1304.0670v4]

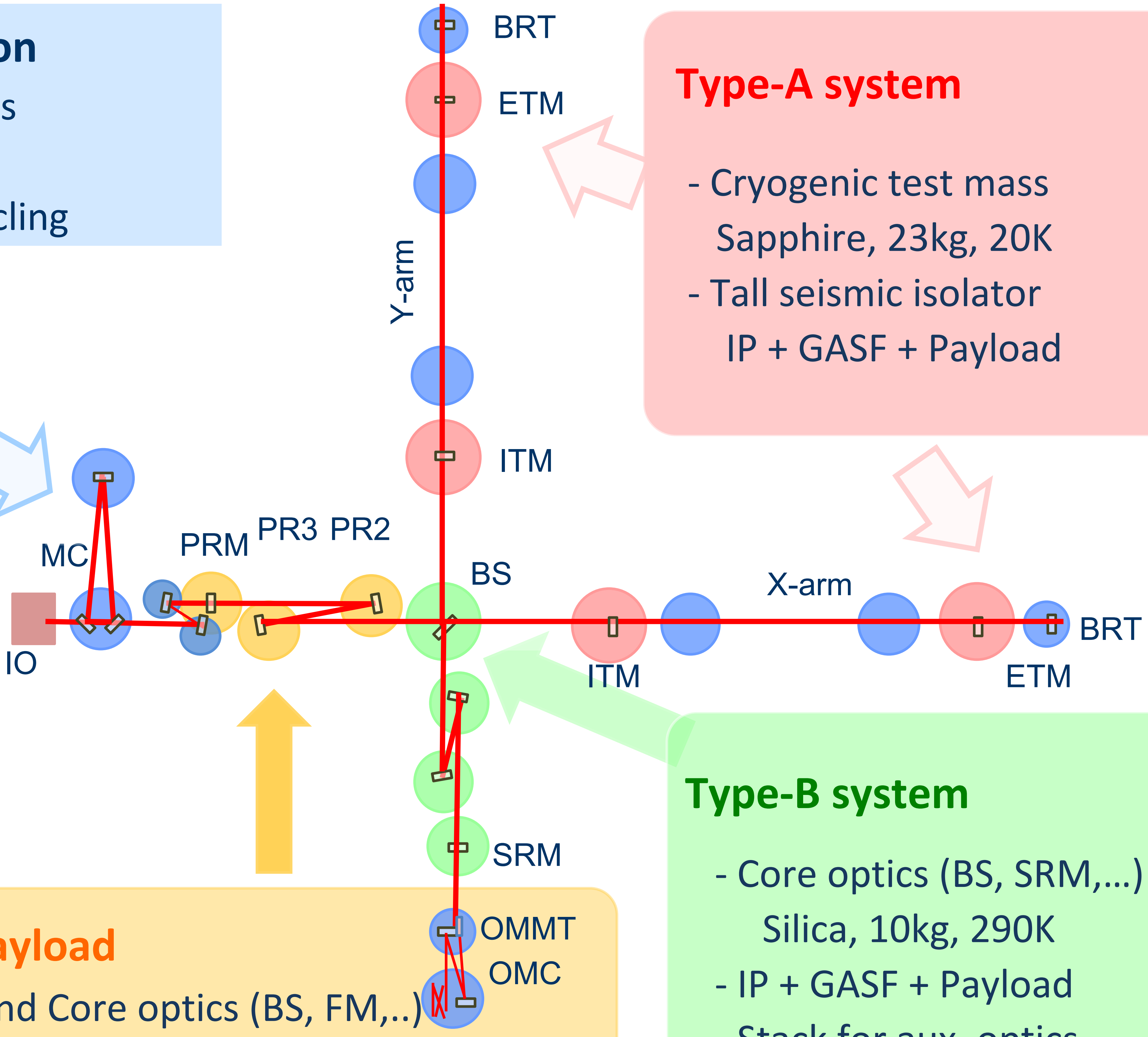
# Roadmap to join O3: Plan A & B

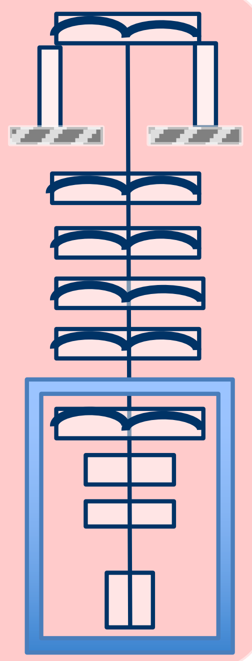



**— either DRFPMI(RSE) (-25Mpc, Oct?) or FPMI (-10Mpc, June?)**
**checking points: Sep/2018, Dec/2018 and Mar/2019**

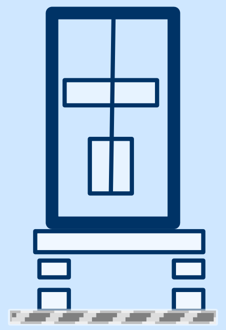
# bKAGRA configuration & installation 2018-2019

## bKAGRA configuration
- Cryogenic test masses
- 3 km arm cavities
- RSE with power recycling

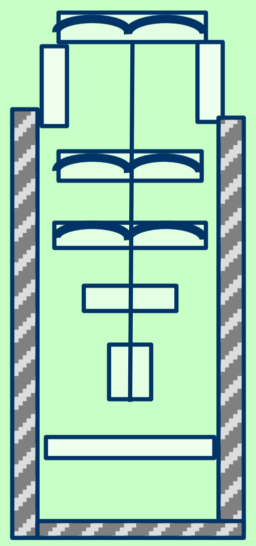


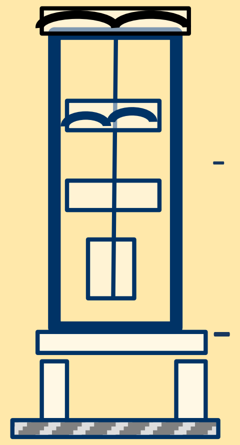
## Type-A system
- Cryogenic test mass
  Sapphire, 23kg, 20K
- Tall seismic isolator
  IP + GASF + Payload



## Type-C system
- Mode cleaner
  Silica, 0.5kg, 290K
- Stack + Payload

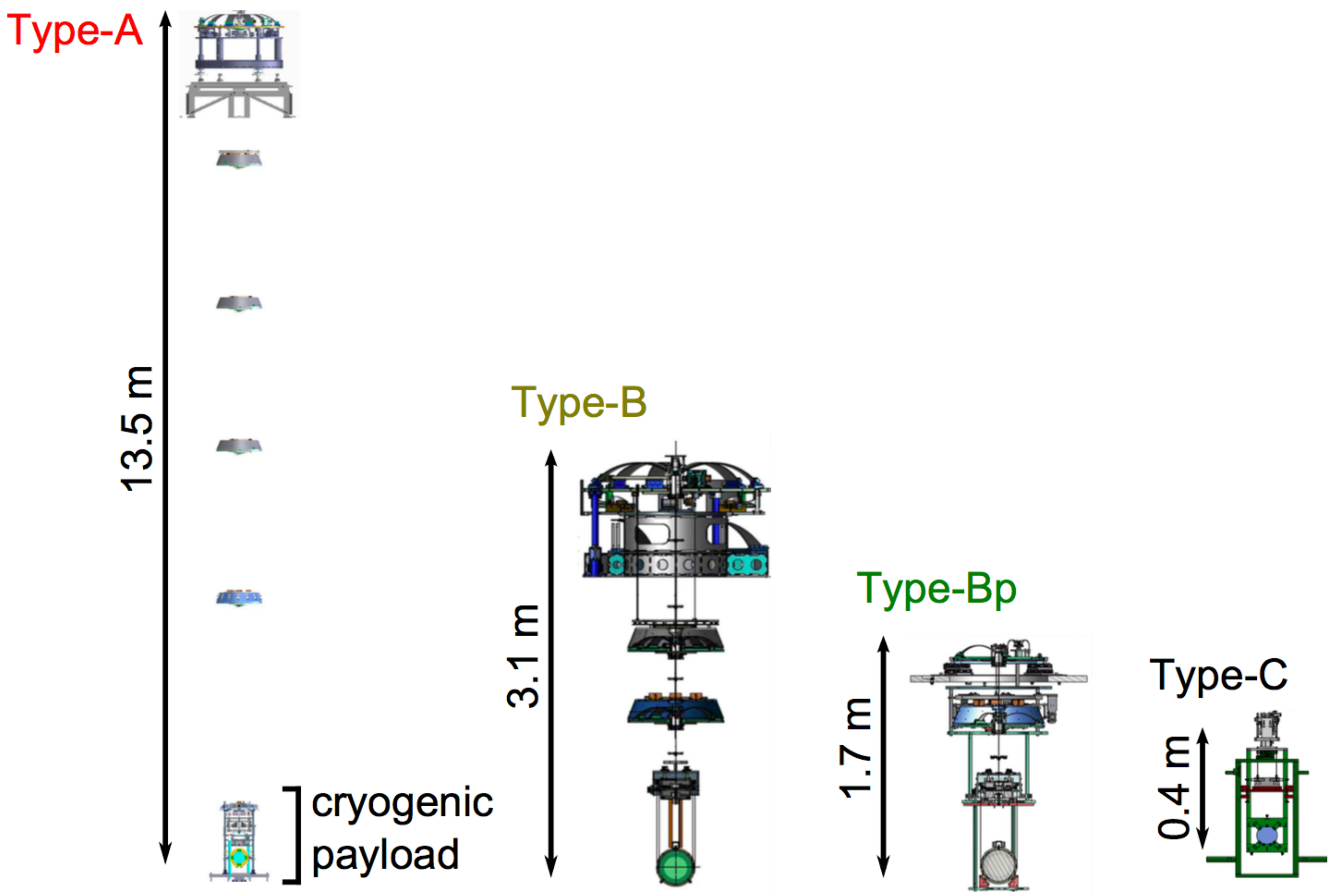


## Type-B system
- Core optics (BS, SRM,…)
  Silica, 10kg, 290K
- IP + GASF + Payload
- Stack for aux. optics

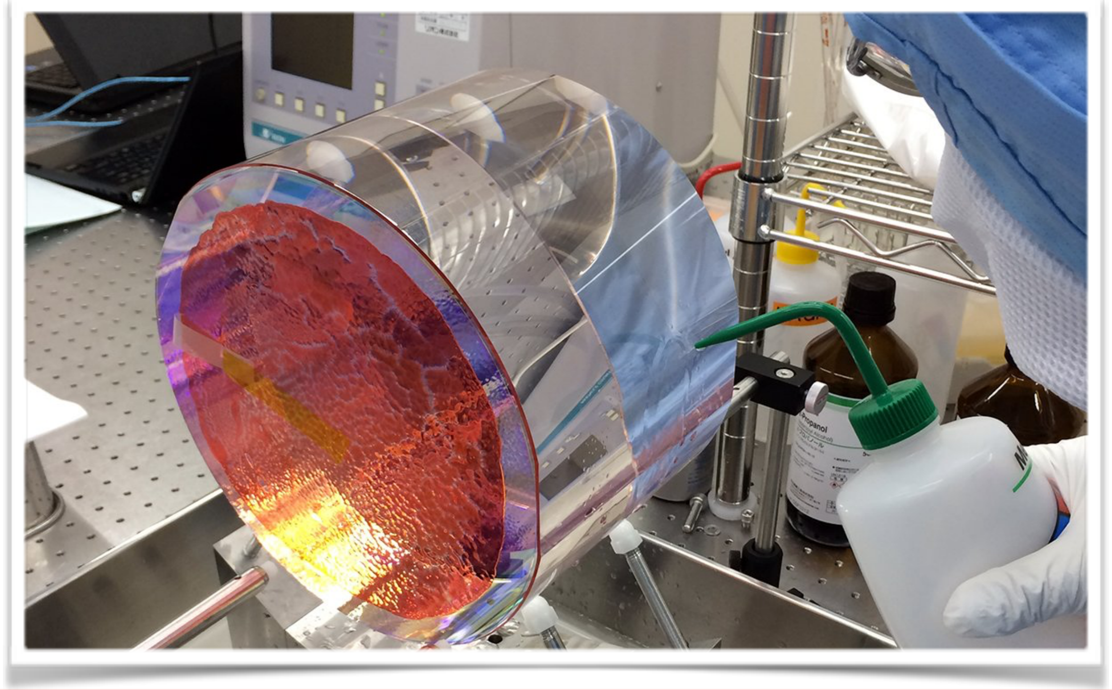


## Type-Bp payload
- Test mass and Core optics (BS, FM,..)
  Silica, 10kg, 290K
- Seismic isolator
  Table + GASF + Type-B Payload

## 【VIS】
**ALL the large suspensions have been installed!**
**Tunings are ongoing along with the alignment.**

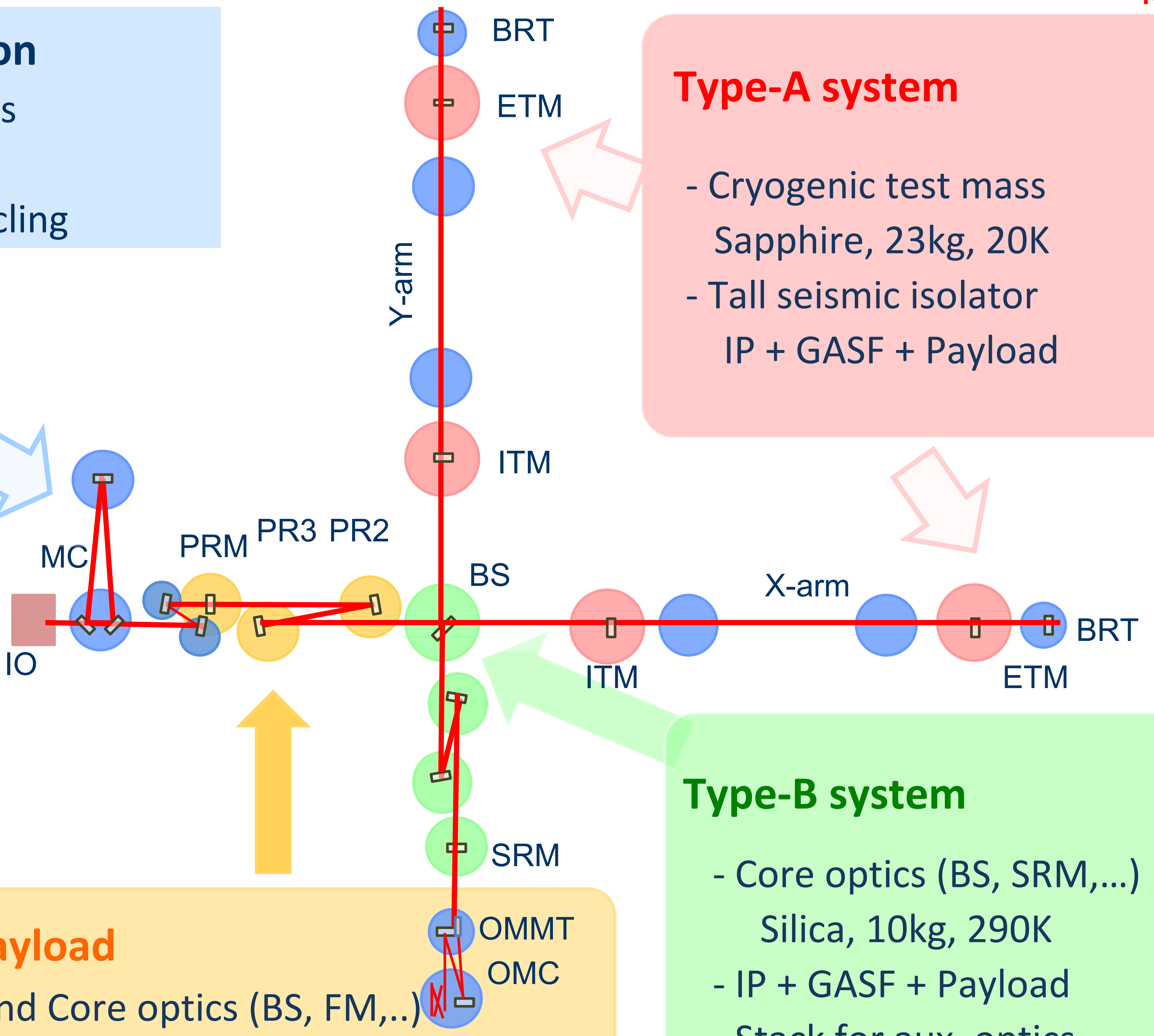


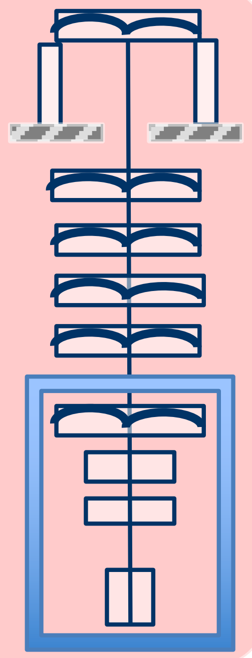

## 【Mirror】
**ALL Sapphire mirrors are installed.**



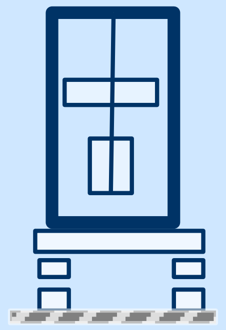
# bKAGRA configuration & installation 2018-2019

**bKAGRA configuration**
- Cryogenic test masses
- 3 km arm cavities
- RSE with power recycling

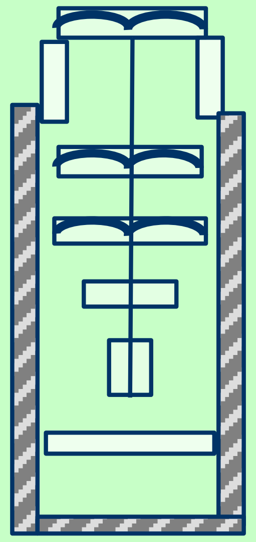


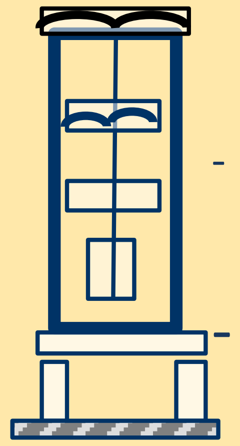
**Type-A system**
- Cryogenic test mass
  Sapphire, 23kg, 20K
- Tall seismic isolator
  IP + GASF + Payload



**Type-C system**
- Mode cleaner
  Silica, 0.5kg, 290K
- Stack + Payload



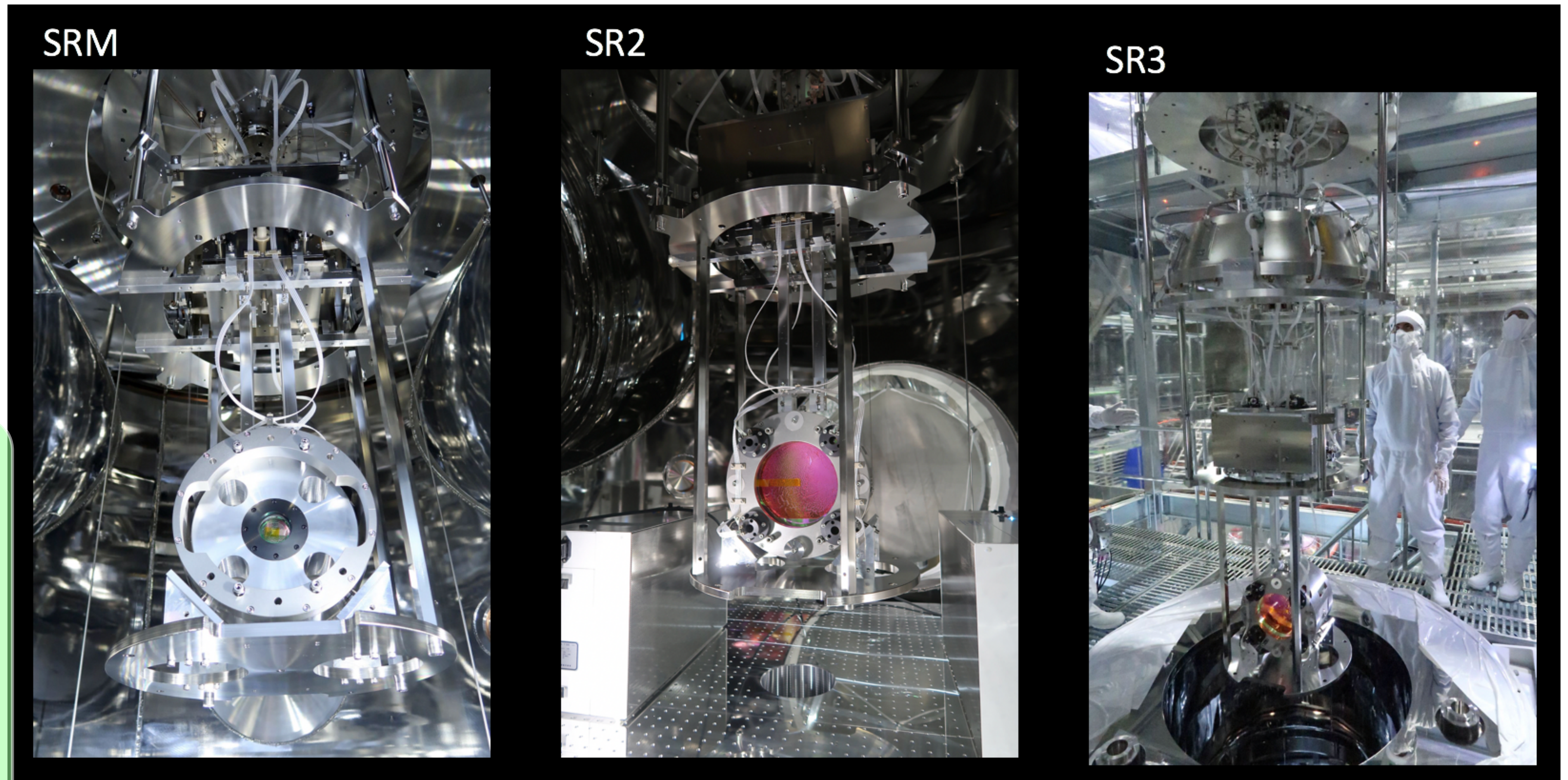
**Type-B system**
- Core optics (BS, SRM,…)
  Silica, 10kg, 290K
- IP + GASF + Payload
- Stack for aux. optics



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

**【VIS】**
**ALL the large suspensions have been installed!**
**Tunings are ongoing along with the alignment.**

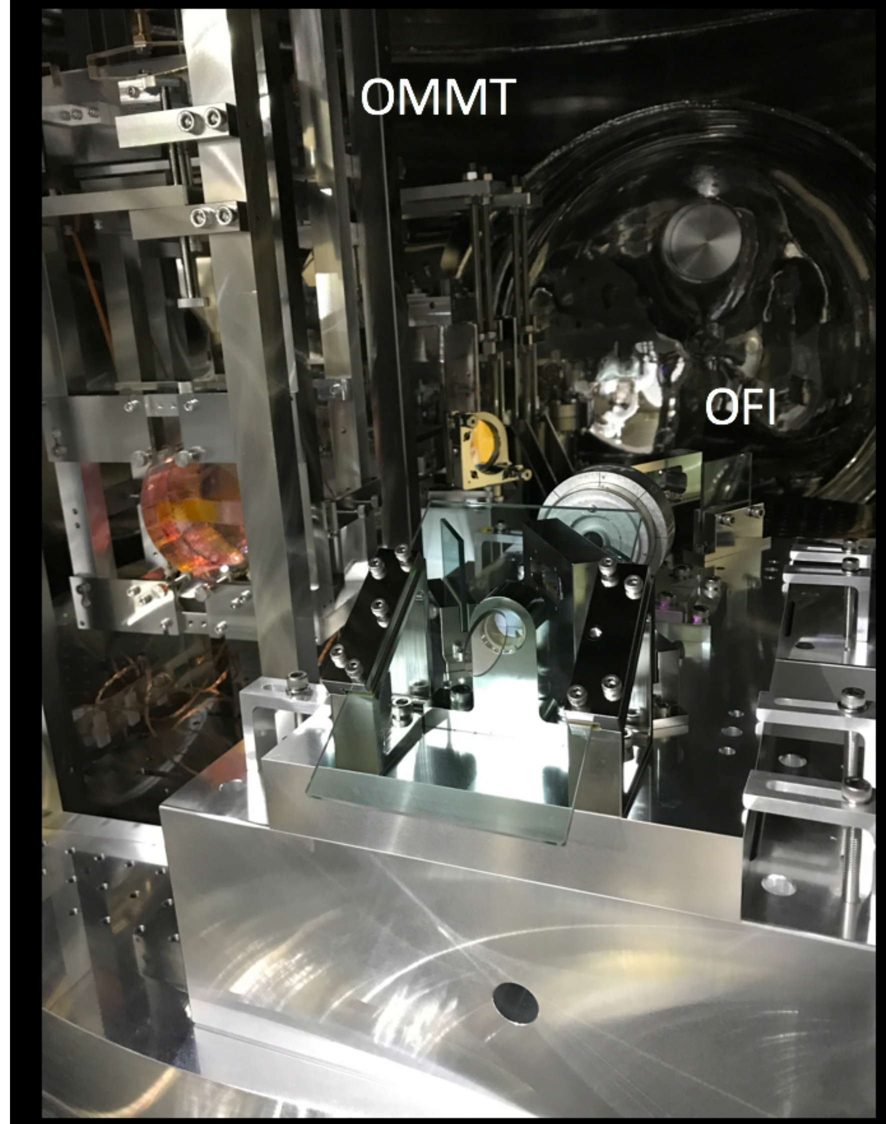
**In Feb., all SRs has been installed!**



* SRM has a temporary 2-inch mirror

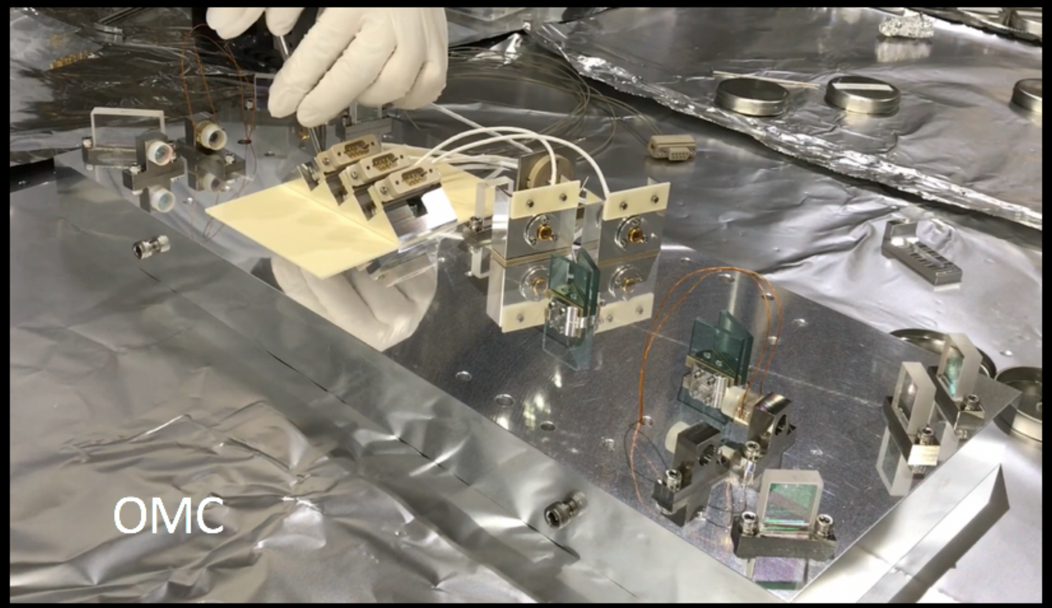
**【Mirror, CRYO】**
**ALL Sapphire mirrors are installed.**

# bKAGRA configuration & installation 2018-2019



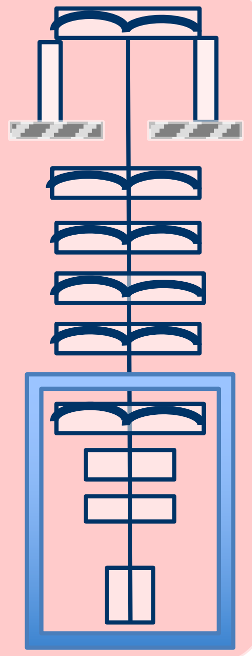

- Output mode cleaner (OMC)
- Output Faraday Isolator (OFI)
- Output mode-matching telescopes (OMMTs) installed!

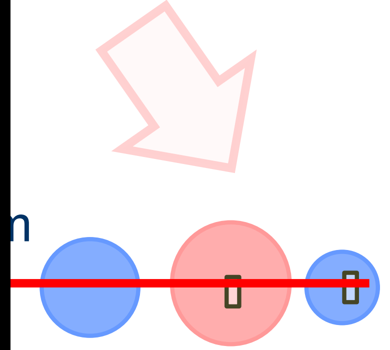
Nov-Dec 2018




ystem

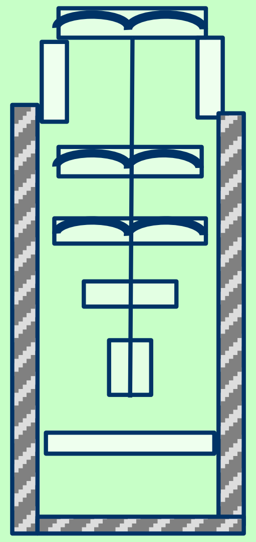
nic test mass
re, 23kg, 20K
mic isolator
ASF + Payload

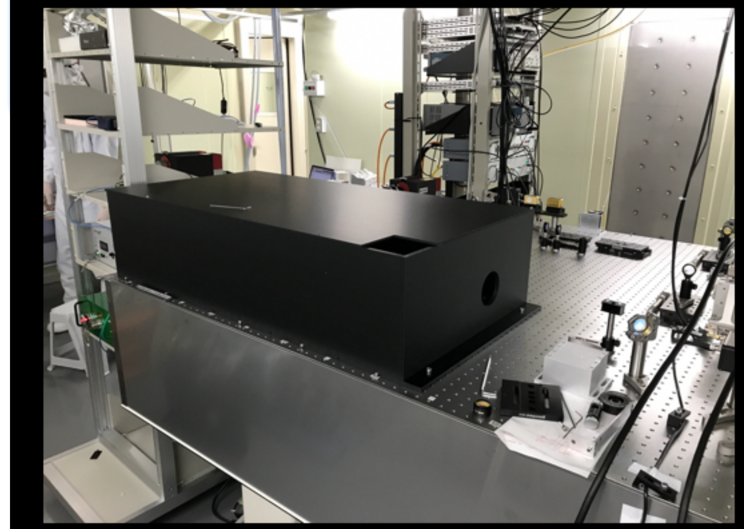


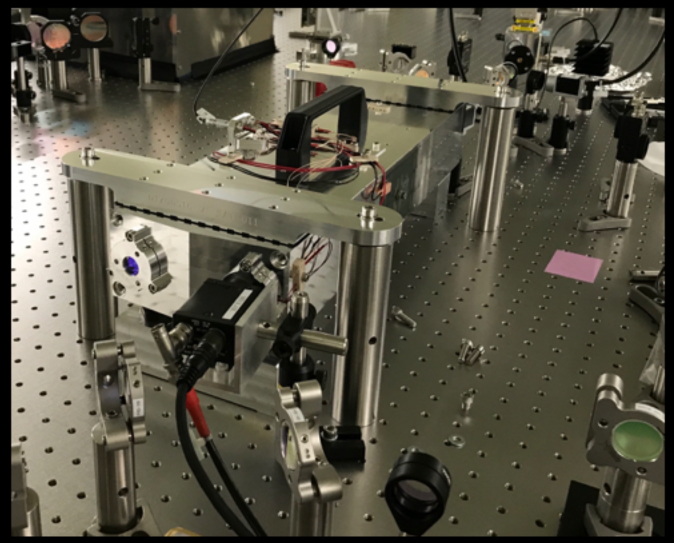


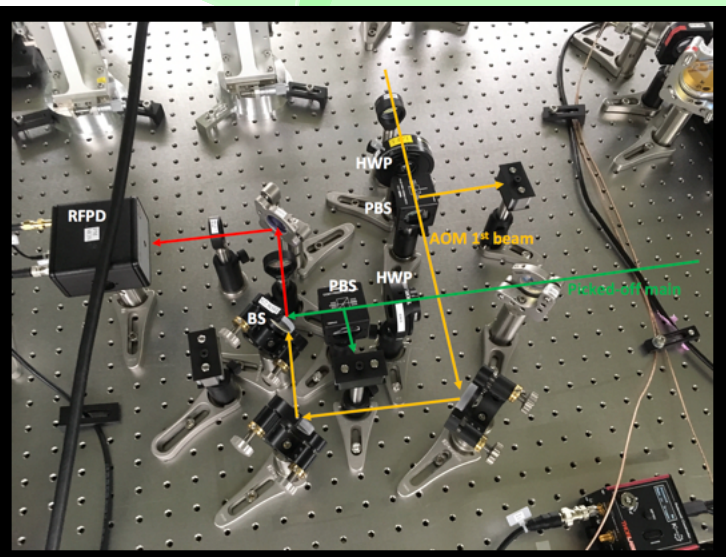

m

(BS, SRM,...)
, 290K
Payload
x. optics









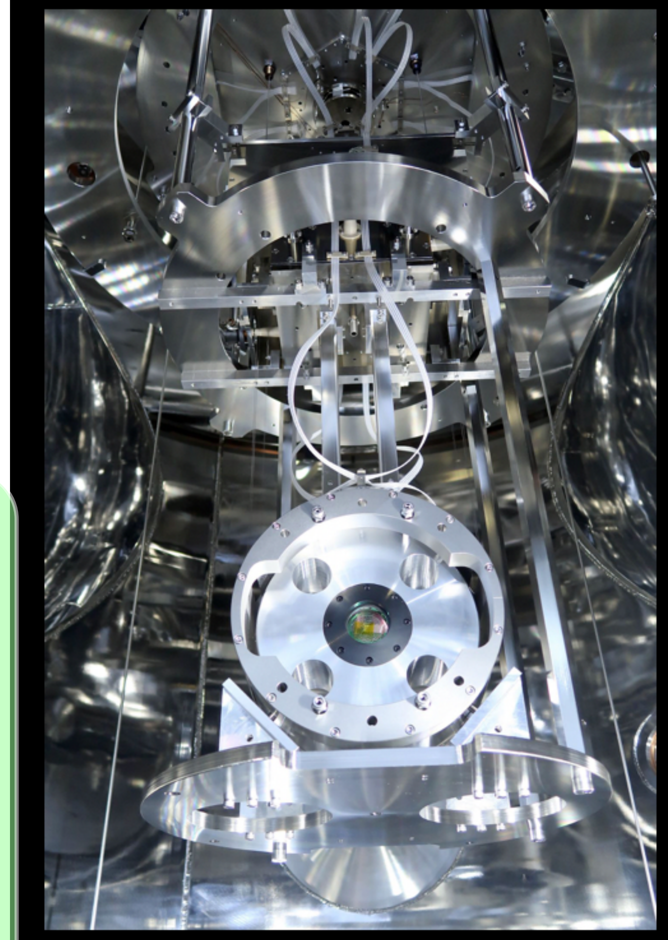
- Input mode cleaner was tested with 10W
- Intensity stabilization is being commissioned
- Frequency stabilization (mode cleaner & reference cavity) has been operating since phase1

**【VIS】**

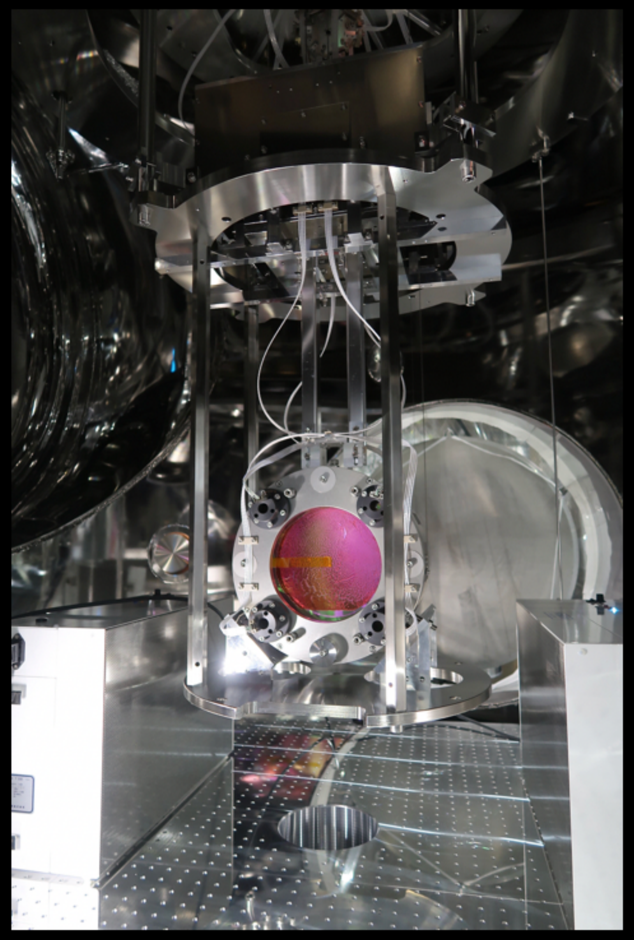
**ALL the large suspensions have been installed!**
**Tunings are ongoing along with the alignment.**

**In Feb., all SRs has been installed!**

SRM



SR2



SR3

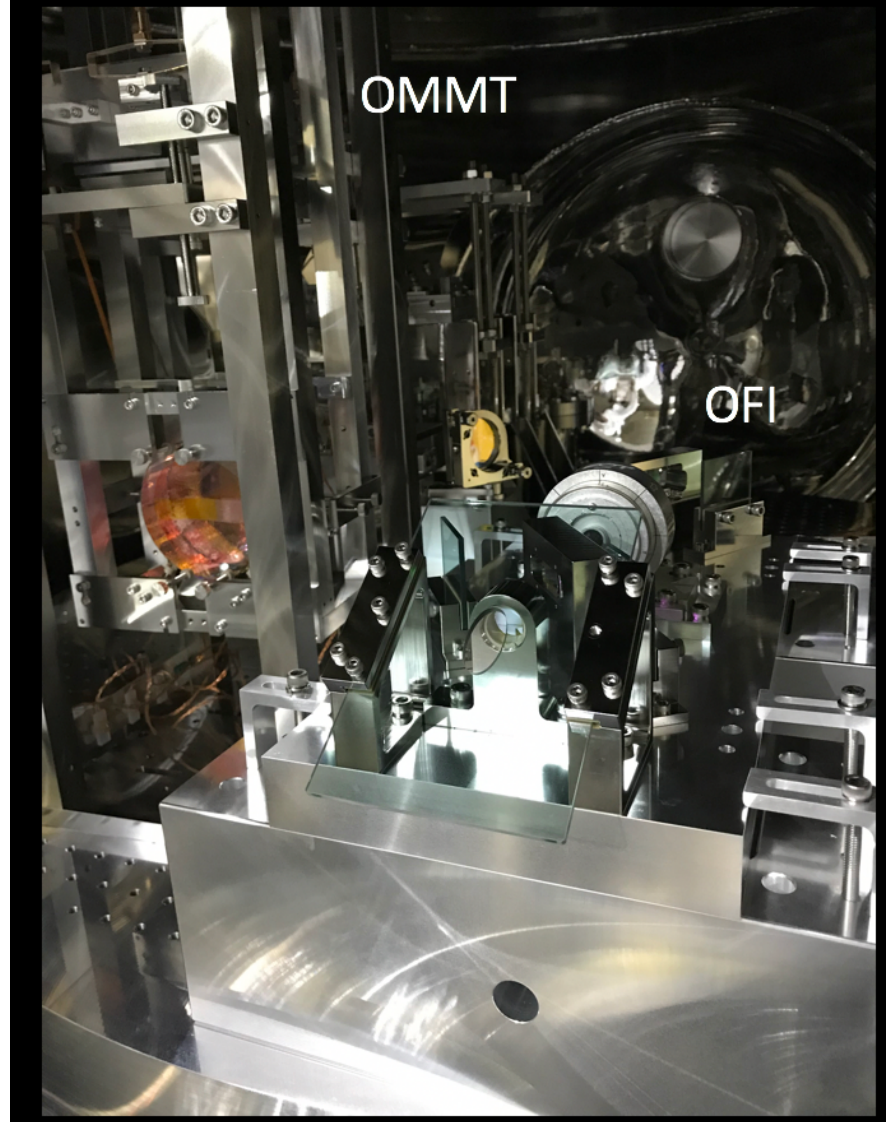
* SRM has a temporary 2-inch mirror

**【Mirror, CRYO】**

**ALL Sapphire mirrors are installed.**

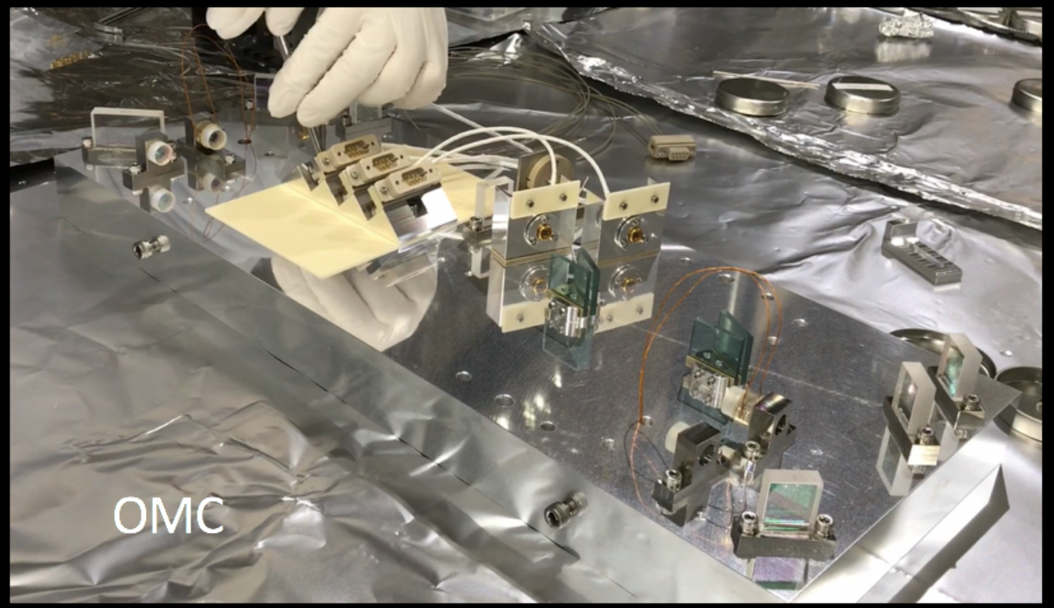
**【Input Optics】 40W laser, PMC, Mach-Zehnder type modulation system, PM&AM monitor system are installed.**
**【Output Optics】 Mode cleaner, Faraday isolater, mode-matching telescopes are installed.**

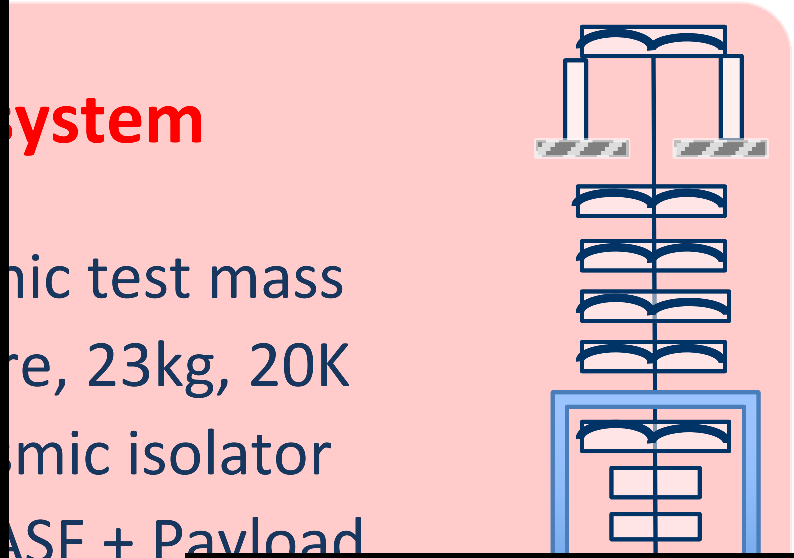
# bKAGRA configuration & installation 2018-2019




- Output mode cleaner (OMC)
- Output Faraday Isolator (OFI)
- Output mode-matching telescopes (OMMTs) installed!

Nov-Dec 2018



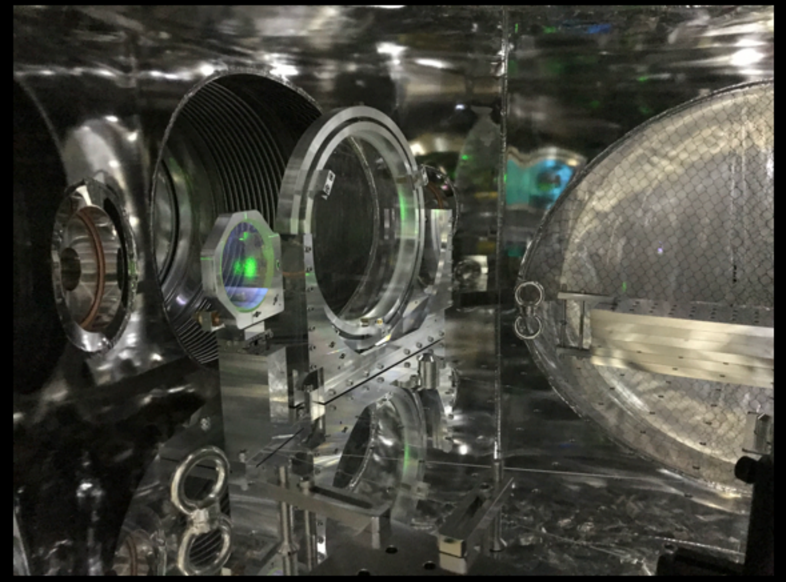




【VIS】
**ALL the large suspensions have been installed!**
**Tunings are ongoing along with the alignment.**

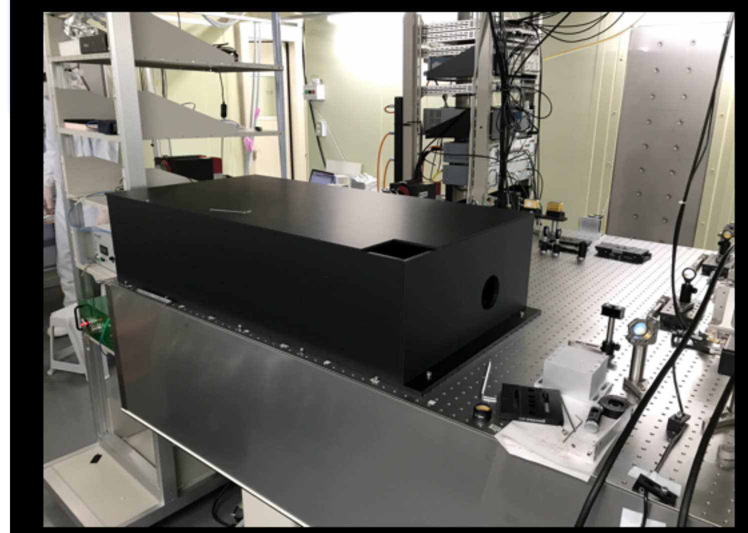
**In Feb., all SRs has been installed!**

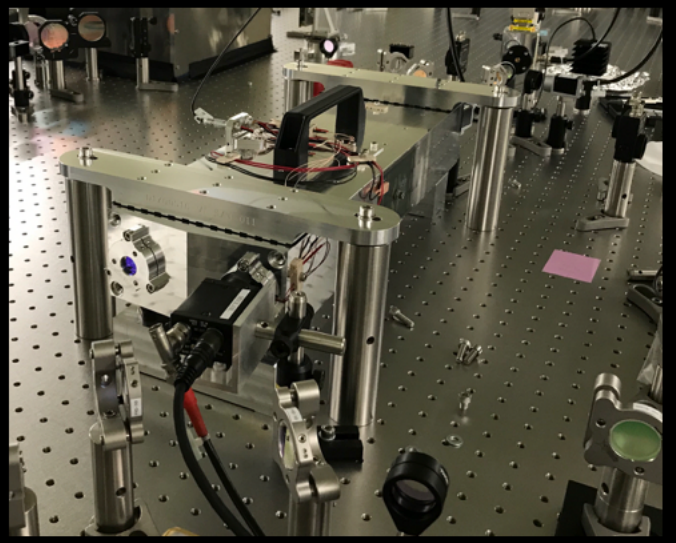
WAB EX

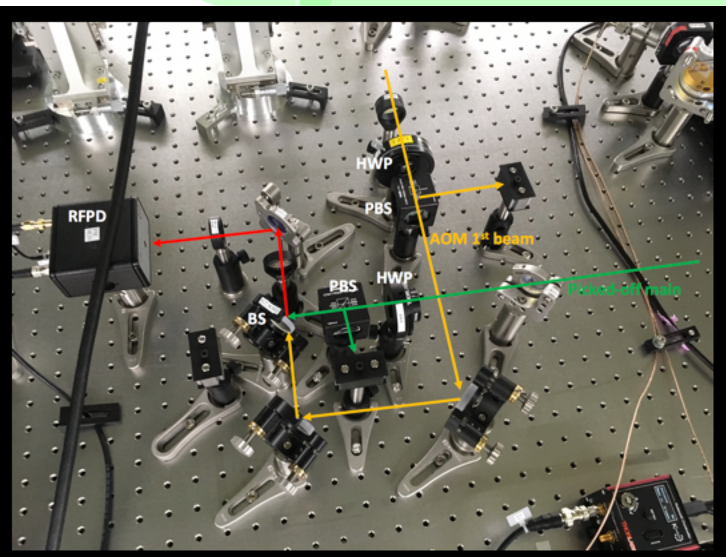
Transmon EX



NAB IY







- Input mode cleaner was tested with 10W
- Intensity stabilization is being commissioned
- Frequency stabilization (mode cleaner & reference cavity) has been operating since phase1

**【Auxiliary Optics】All system finally installed.**

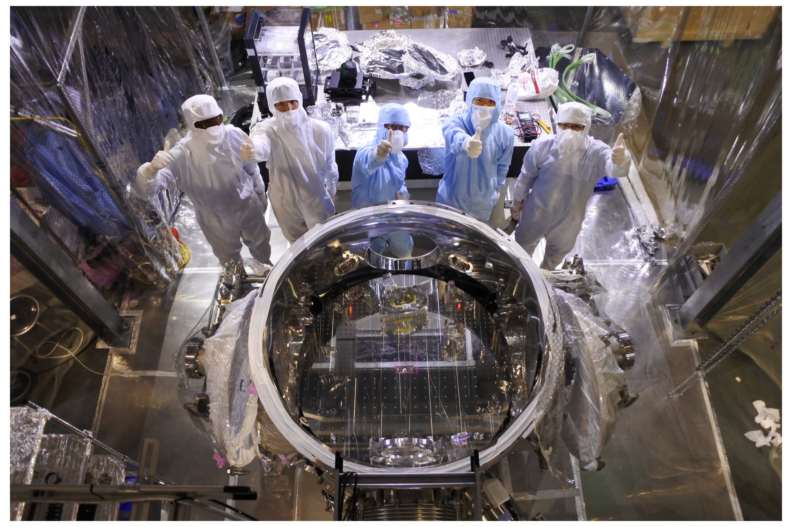
**【Mirror, CRYO】**
**ALL Sapphire mirrors are installed.**

**【Input Optics】40W laser, PMC, Mach-Zehnder type modulation system, PM&AM monitor system are installed.**
**【Output Optics】Mode cleaner, Faraday isolater, mode-matching telescopes are installed.**

# bKAGRA configuration & installation 2018-2019

KAGRA Scientific Congress Newsletter No. 3 2018/12/01

(Right) Photon Calibrator X-end installation completed. July 25. [JGW-G1809009]
In photo, Takaaki Yokozawa, Yuki Inoue, Takahiro Yamamoto, and Chihiro Kozakai.



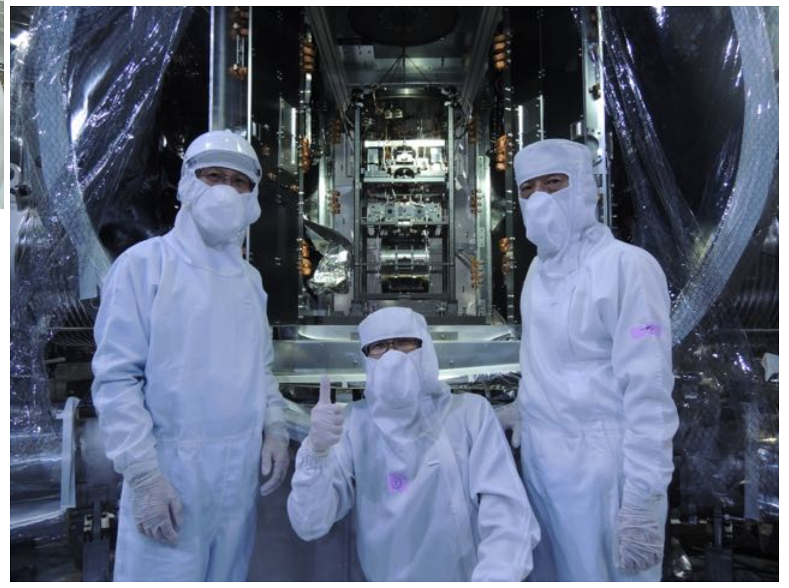
(Left) Installed the BRT part on the TMS-VIS in the EXT chamber at the X-end! [klog 06342].
In photo, Fumihiro Uraguchi, Koji Nagano, Kunihiko Hasegawa, Kenta Tanaka, Naoki Kita, and Tomotada Akutsu.

**We did it! in 2018**

(Right) SR3 Installation, July 20. [klog 05569]
Panwei Huang, Naoatsu Hirata, Terrence Tsang, Fabian Peña, Mark Barton, Ryohei Kozu, and Enzo Tapia. (plus Guiguo observing)

(Above) OMC installation succeeded, October 18. [klog 06612]
In photo, Sotatsu Otabe, Kohei Kusayanagi, Hiraku Sasaki, and Kentaro Somiya.

(Right) Nov. 9, the last installation of cryogenic payload was completed. The photo at Y-front was distributed in [kagra 02500].
In photo, Masahiro Takahashi, Takayuki Tomaru and Sakae Araki.



KSC newsletter (2018 Dec.)

【CAL】

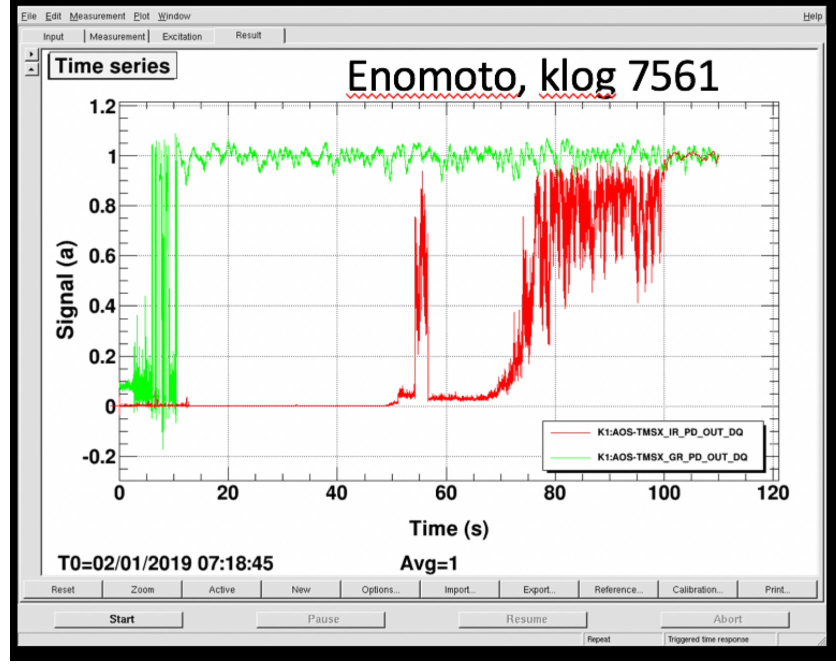
**Photon calibrator modules installed at the both ends**
**Calibration pipelines are being constructed**

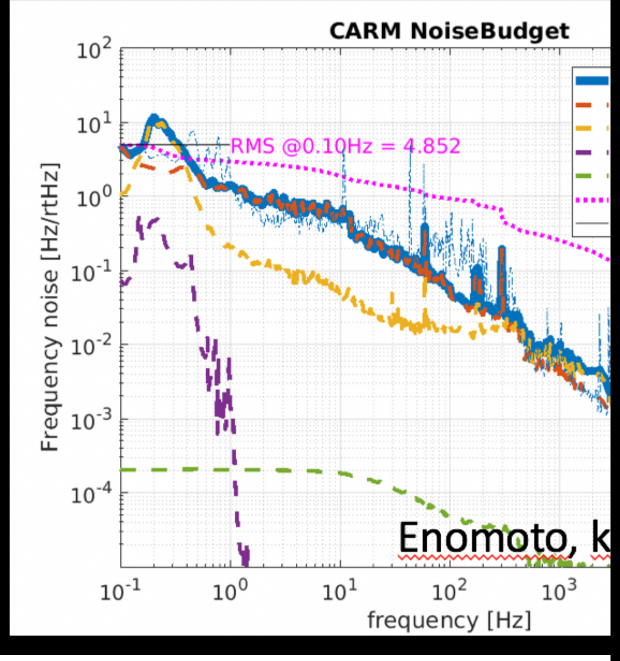
【Mirror】

**Many mirrors were cleaned before starting the DRMI commissioning.**

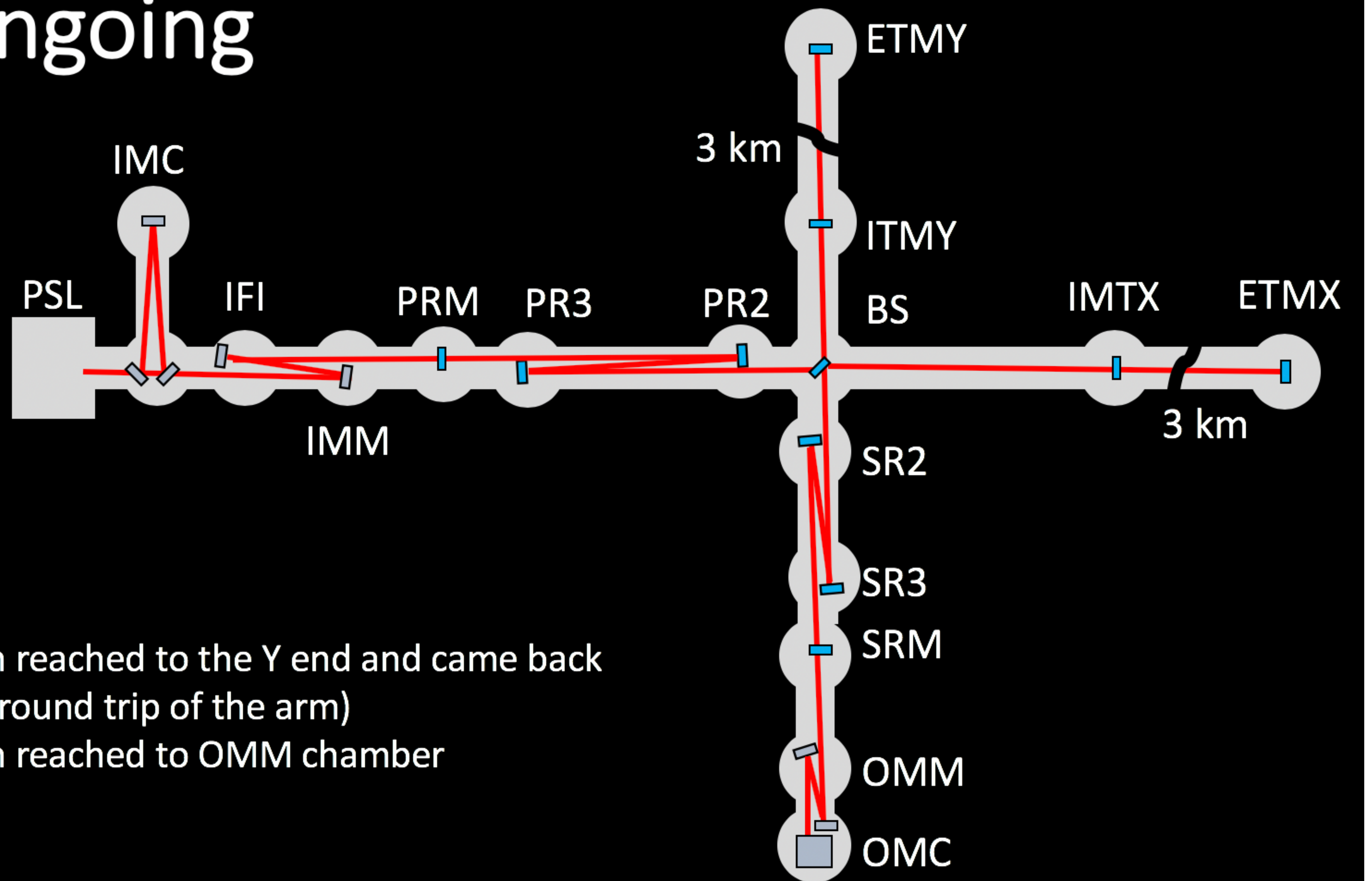
## X-arm Locking Test

- X-arm test has completed
  - X-arm locked with the axillary (green) laser, then successfully handed off to the IR laser
  - Noise budgeting



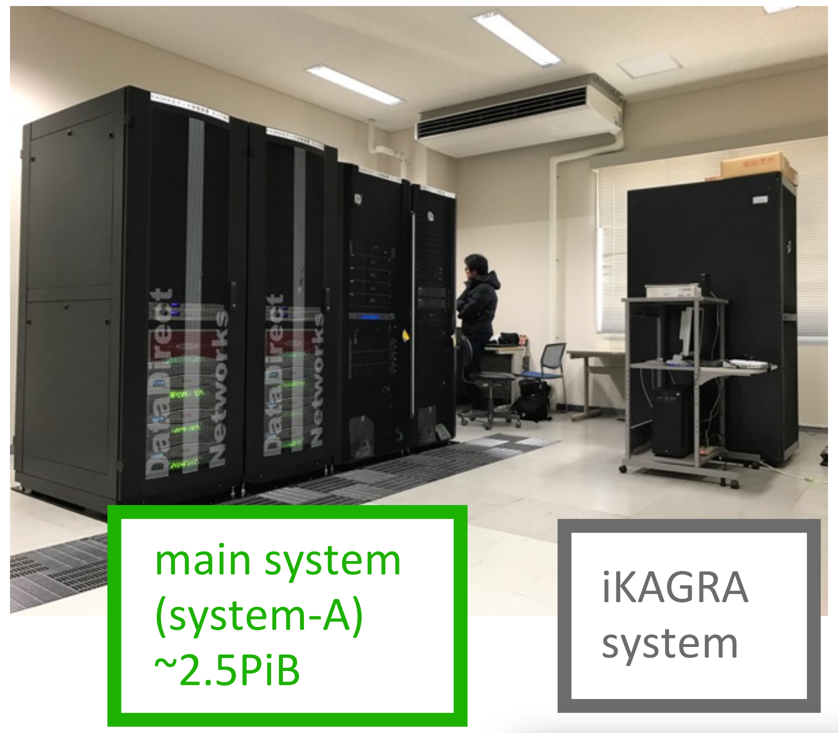



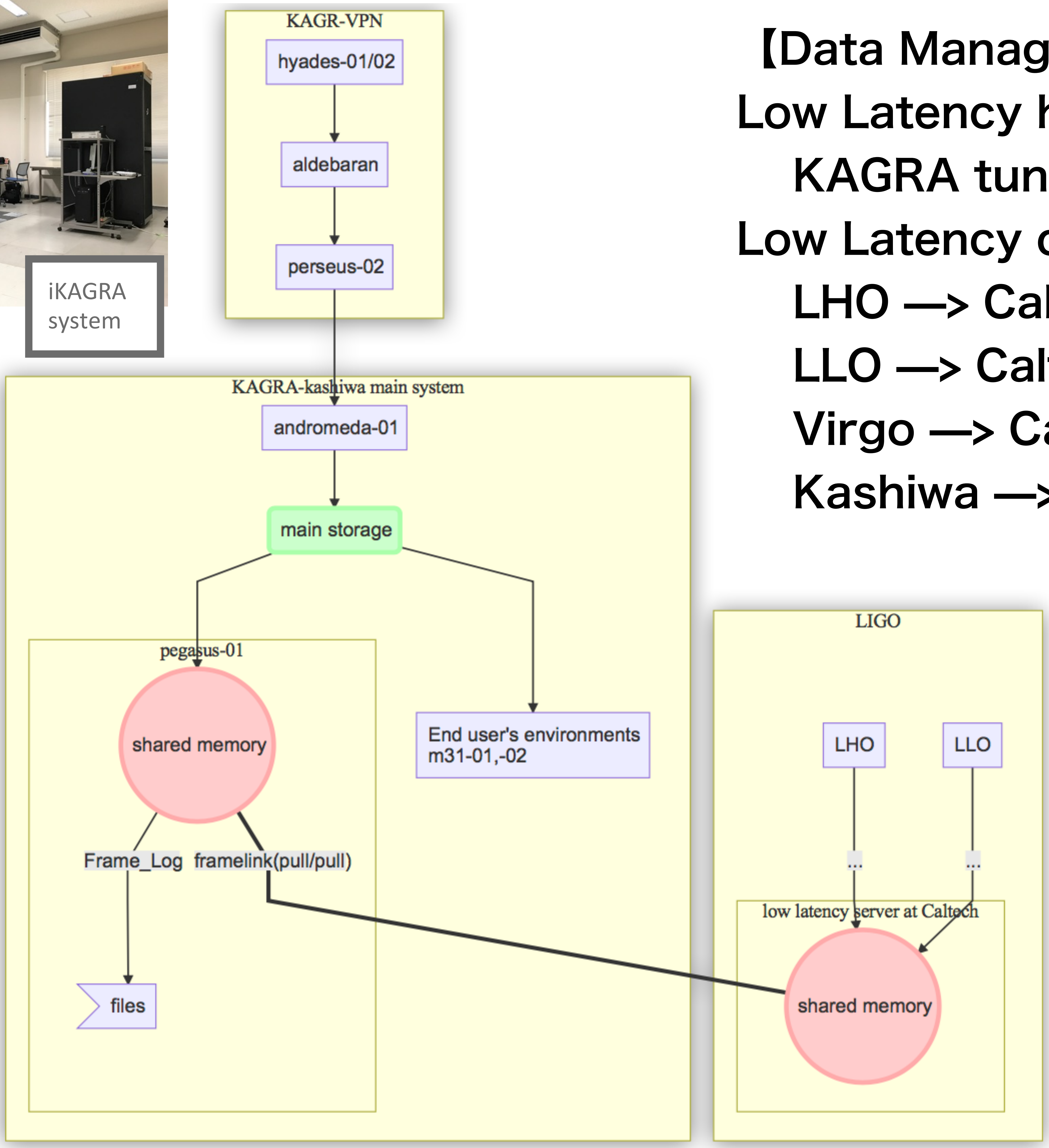

## Interferometer Initial Alignment Ongoing




Beam reached to the Y end and came back (one round trip of the arm)
Beam reached to OMM chamber

# Data-exchange tests with low latency




【Data Management】

Low Latency h(t) transfer

KAGRA tunnel —> the surface —> Kashiwa server : 1.3 sec

Low Latency connection with LV (in Feb. 2019)

LHO —> Caltech —> Kashiwa : 6.4 sec

LLO —> Caltech —> Kashiwa : 9.6 sec

Virgo —> Caltech —> Kashiwa : ? sec

Kashiwa —> Caltech: ? sec

◆ KAGRA-LV data exchange will start in April.

**(MOU between K-LV 2012, attachment B)**

For KAGRA members, LV data access account will be issued only whom filed his/her signed "**O3 commitment form**" and applied for. (declare ethical statement on confidential issues).

# Roadmap to join O3: Plan A & B

KAGRA

▼ Now.

2018: Aug, Sep, Oct, Nov, Dec
2019: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec
2020: Jan, Feb, Mar

LIGO/VIRGO Observation 3

Jan 6: X-arm commissioning was finished.
Feb 11: Y-arm alignment was finished.
Feb 12-15: all the chambers in the central area were pump-downed.
Feb 18: DRMI commissioning (ITMs) was started
Feb 26: cool-down of ITMs was started
<troubles at BS, suspension, cryo>
Mar 25: FPMI commissioning will be started.

Original Plan
Apr19
DRFPMI (RSE)
post commissioning DRFPMI (RSE)
**plan A**
-25Mpc

Backup Plan
Apr5
post commissioning FPMI
**plan B**
-10Mpc

data analysis rehearsal
Data Sharing with KAGRA-LIGO-Virgo

ER? ER? ER?

**— either DRFPMI(RSE) (-25Mpc, Oct?) or FPMI (-10Mpc, June?)**
**checking points: Sep/2018, Dec/2018 and Mar/2019**

# Links to Physics and Astronomy people (in Japan)

KAGRA

## KAGRA collaboration

Takahiro Tanaka

Grant-in-Aid for Scientific Research on Innovative Areas

Michitoshi Yoshida

Japanese Collaboration for GW Electro-Magnetic Follow-up

## GW physics and astronomy: Genesis

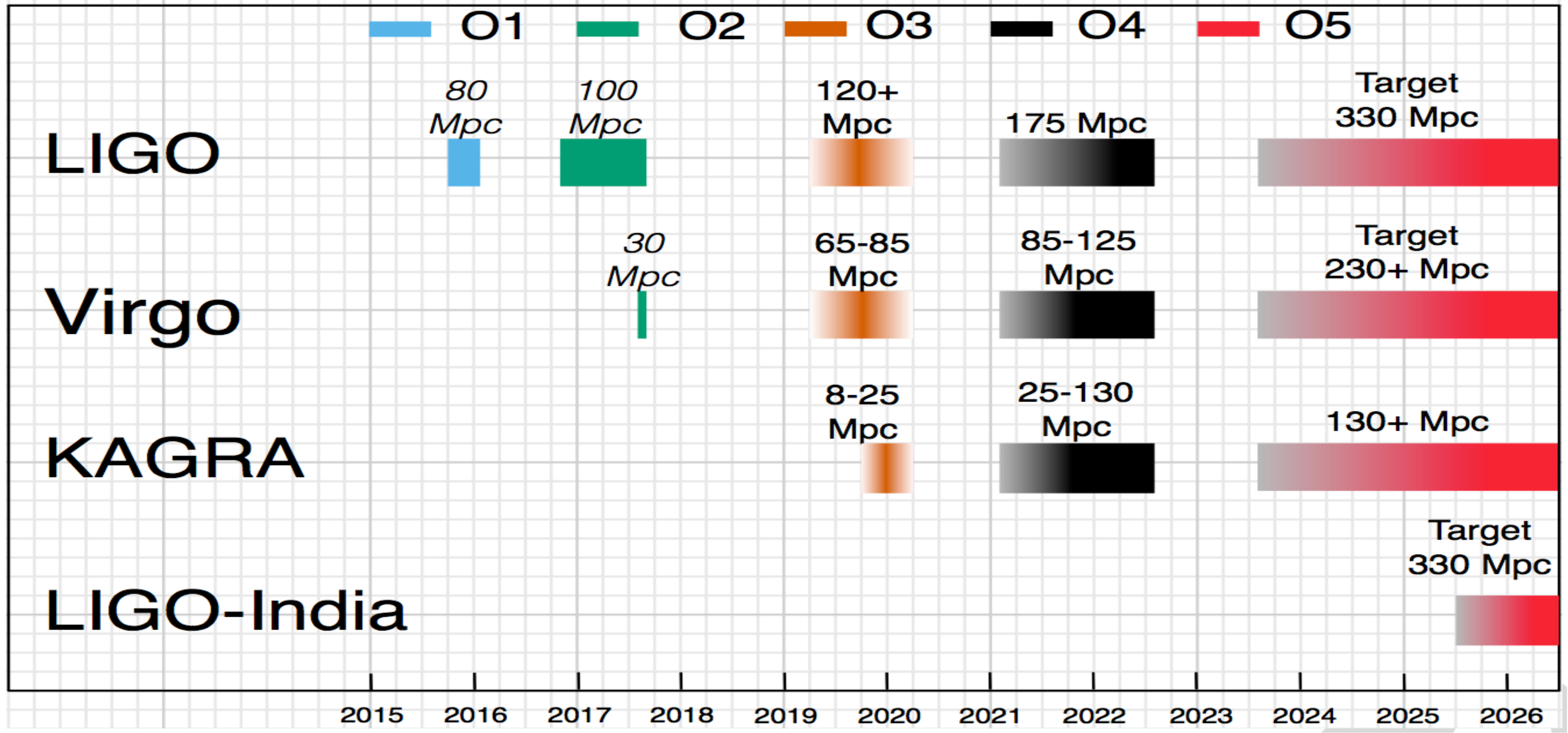
- A01 Testing GR
- A02 Gravity theories
- A03 Study on binary BH formation
- B01 GWs from NS-NS/BH-NS, Pulsars and Magnetars
- B02 Sources probed with High Energy Observations
- B03 Nucleosynthesis with follow-up observations
- C01 Physics of Core-Collapse SN
- C02 SN explosions via their neutrino emissions

## J-GEM collaboration

1. Katana Telescope 1.5m optical-infrared telescope of Hiroshima Univ. Japan
2. Mini-TAO Telescope 1m optical-infrared telescope of Univ. of Tokyo. & Atacam
3. Kiso Schmidt Telescope 1.05m Schmidt telescope of Univ. of Tokyo. & Kiso, Ja
4. OAO-WFC 0.9m infrared telescope of NAOJ. & Okayama, Japan
5. MITSuME Telescopes 0.5m optical telescopes of NAOJ and TITech. & Okayama
6. IRSF 1.4m infrared telescope of Nagoya Univ. & South Africa
7. Yamaguchi 32m Radio Telescope, Yamaguchi Univ. & Yamaguchi, Japan
8. Kyoto 3.8m Telescope, 3.8m optical-infrared telescope of Kyoto Univ. & Okaya
9. Hinotori Telescope 0.5m optical telescope of Hiroshima Univ. & Tibet, China.
10. MOA-II 1.8m optical telescope of MOA collaboration. & New Zealand
11. Subaru Telescope 8.2m optical infrared telescope of NAOJ & Hawaii, USA.

# Status of KAGRA: Summary

- ◆ KAGRA will finish all the installations by middle of April, 2019. (at least2-week delay from the plan a year ago).
- ◆ Our test run begins in early June.
- ◆ **KAGRA plans to join Observation Run 3 from fall 2019.**




- ◆ KAGRA-LV data exchange will start in April.
- ◆ KAGRA-LV MOU discussion will be started soon.
- ◆ KAGRA CBC members are waiting to have access to LV wiki.

- ◆ KAGRA plans to join O4 from the beginning.
- ◆ Regarding future plans, please check out Haino's talk yesterday.