Latest Status of KAGRA

- **Underground** and **Cryogenic** interferometric gravitational-wave detector at Kamioka, Japan
- KAGRA finished all the installations by April 2019, and extensively under commissioning.
- **KAGRA plans to join LV Observation Run 3 from the end of 2019.**

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

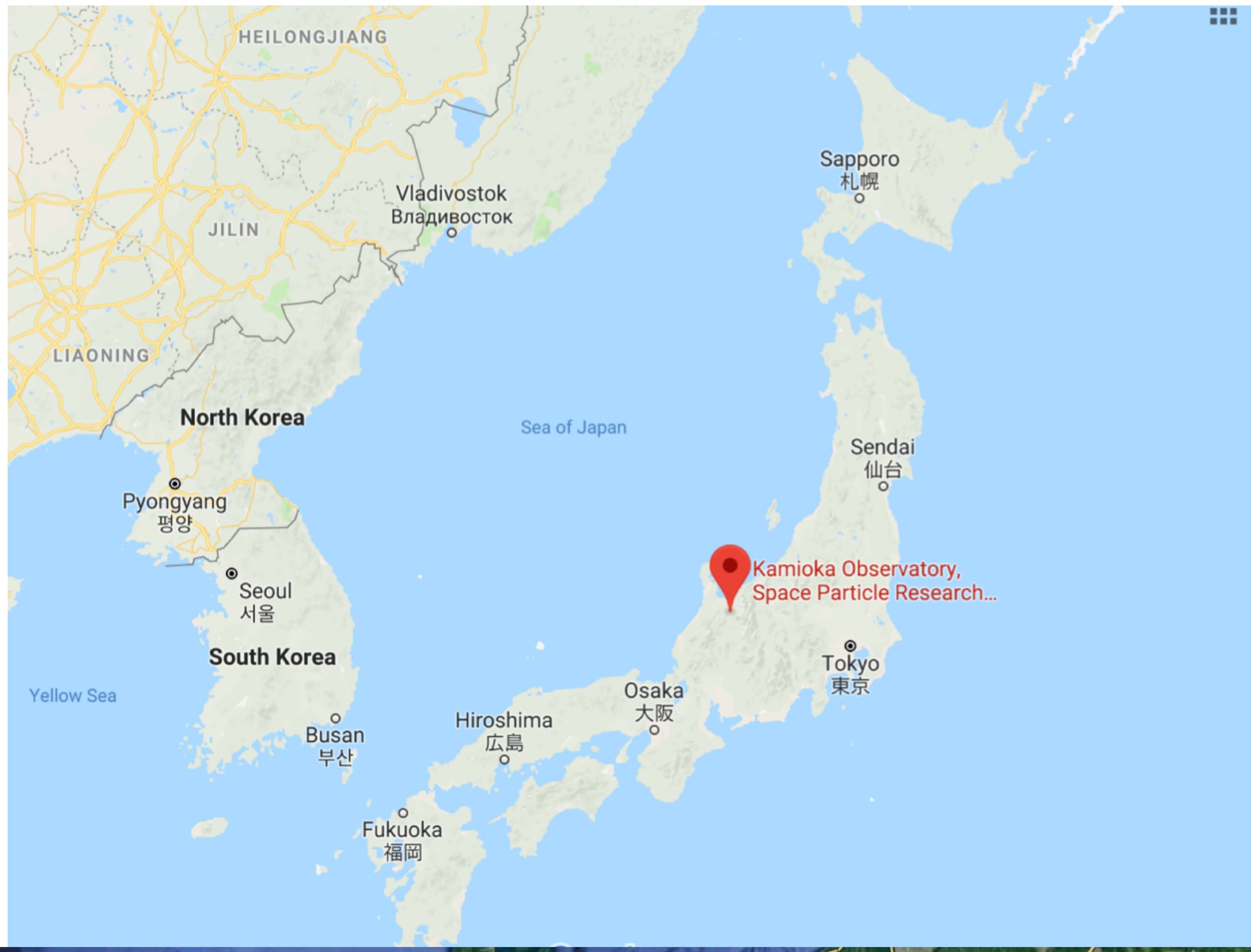
after my talk today,

Takayuki Tomaru
Cryogenic mirror system in KAGRA

Yuta Michimura
Prospects for upgrading the KAGRA gravitational wave telescope

KAGRA (Kamioka GW Observatory)

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



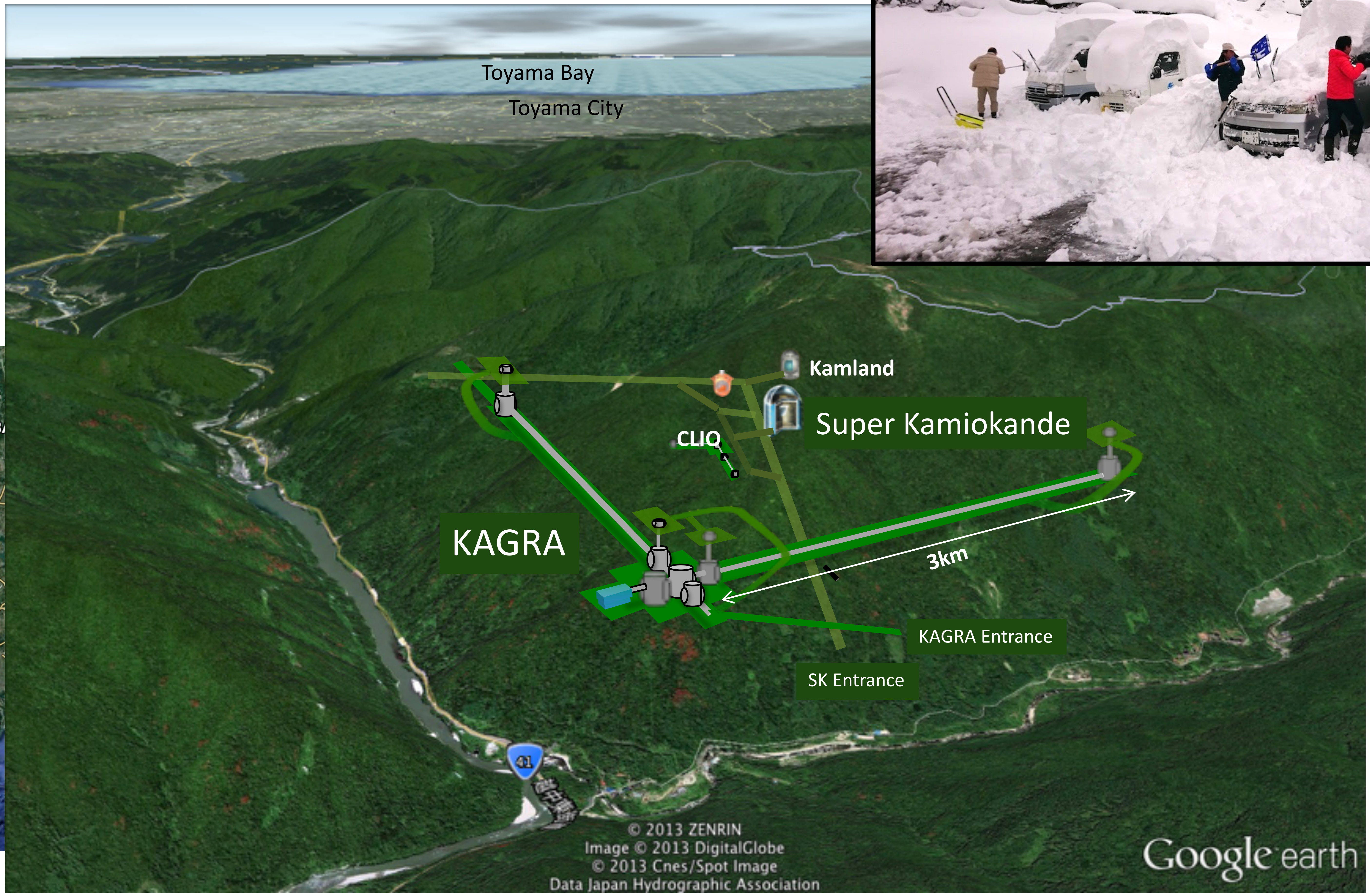


fig. by Keiko Kokeyama

KAGRA collaboration

KAGRA

110 groups, 14 countries
350+ active members

Default-author list 2018 has 200 members.
Obs. shift candidate list has 260 names.

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

F2F Aug. 2019 @ U. Toyama, Japan
F2F December 2019 @ U. Tokyo, Japan

Organize International Workshop
2 times / year

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

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

Organization of KSC (KAGRA Scientific Congress)

KAGRA

Takaakі Kajita (PI)

Masatake Ohashi (vice PI)

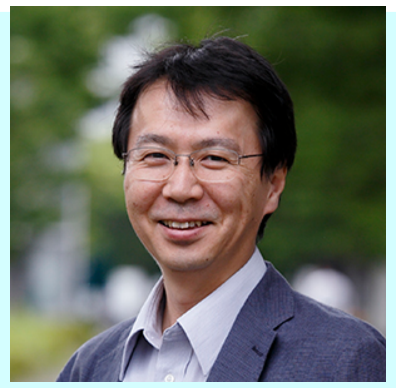
Yoshio Saito (SEO proj. manager)

KAGRA Scientific Congress (KSC) organization chart 2019/May 15

- PI
- EO — sharing information & idea — KSC board
- SEO

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)

Data Analysis Committee (DAC)
- * Hideyuki Tagoshi
- + WGs chairs/vice chairs
- + Hisaaki Shinkai (board)



- Compact Binary Coalescence: * Hideyuki Tagoshi, Kipp Cannon, Hyung-Won Lee, Tjonnie Li
- Continuous Wave: * Yousuke Itoh
- Burst Wave: * Kazuhiro Hayama
- Stochastic Wave: * Guo-Chin Liu, Sachiko Kuroyanagi
- Computing & Software: * Ken-ichi Oohara, Hirotaka Takahashi, Kazuki Sakai
- Calibration: * Yuki Inoue
- Detchar: * Keiko Kokeyama

- 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

KAGRA collaboration papers

PTEP

Prog. Theor. Exp. Phys. 2018, 013F01 (23 pages)
DOI: 10.1093/ptep/ptx180

Construction of KAGRA: an underground gravitational-wave observatory

T. Akutsu[1], M. Ando[1,2,3], S. Araki[4], A. Araya[5], T. Arima[6], N. Aritomi[3], H. Asada[7], Y. Aso[1], S. Atsuta[8], K. Awai[9,10], L. Baiotti[11], M. A. Barton[1], D. Chen[9], K. Cho[12], K. Craig[9], R. DeSalvo[13,14], K. Doi[9,10,15], K. Eda[2,3], Y. Enomoto[9], R. Flaminio[1], S. Fujibayashi[16], Y. Fujii[1], M.-K. Fujimoto[1], M. Fukushima[1], T. Furuhata[15], A. Hagiwara[4], S. Haino[17], S. Harita[8], K. Hasegawa[9], M. Hasegawa[18], K. Hashino[15], K. Hayama[9,10], N. Hirata[1], E. Hirose[9,10], B. Ikenoue[1], Y. Inoue[17], K. Ioka[19], H. Ishizaki[1], Y. Itoh[2,*], D. Jia[18], T. Kagawa[15], T. Kaji[6], T. Kajita[9,10], M. Kakizaki[15], H. Kakuhata[18], M. Kamiizumi[9,10], S. Kanbara[15], N. Kanda[6], S. Kanemura[15], M. Kaneyama[6], J. Kasuya[8], Y. Kataoka[8], K. Kawaguchi[19], N. Kawai[8], S. Kawamura[9,10], F. Kawazoe[20], C. Kim[21,22], J. Kim[23], J. C. Kim[24], W. Kim[25], N. Kimura[4,9], Y. Kitaoka[6], K. Kobayashi[15], Y. Kojima[26], K. Kokeyama[9,10], K. Komori[3], K. Kotake[27], K. Kubo[28], R. Kumar[4], T. Kume[4], K. Kuroda[9], Y. Kuwahara[3], H.-K. Lee[29], H.-W. Lee[24], C.-Y. Lin[30], Y. Liu[9], E. Majorana[31], S. Mano[32], M. Marchio[1], T. Matsui[15], N. Matsumoto[33,34], F. Matsushima[15], Y. Michimura[3], N. Mio[35], O. Miyakawa[9,10], K. Miyake[18], A. Miyamoto[6], T. Miyamoto[9,10], K. Miyo[9], S. Miyoki[9,10], W. Morii[36], S. Morisaki[2,3], Y. Moriwaki[15], Y. Muraki[8], M. Murakoshi[28], M. Musha[37], K. Nagano[9], S. Nagano[38], K. Nakamura[1], T. Nakamura[16], H. Nakano[16], M. Nakano[18], M. Nakano[9,10], H. Nakao[6], K. Nakao[6], T. Narikawa[6], W.-T. Ni[39,40], T. Nonomura[28], Y. Obuchi[1], J. J. Oh[25], S.-H. Oh[25], M. Ohashi[9,10], N. Ohishi[1,10], M. Ohkawa[41], N. Ohmae[35], K. Okino[42], K. Okutomi[43], K. Ono[9], Y. Ono[44], K. Oohara[41], S. Ota[28], J. Park[12], F. E. Peña Arellano[1], I. M. Pinto[13,14], M. Principe[13,14], N. Sago[45], M. Saijo[46], T. Saito[41], Y. Saito[9,10], S. Saitou[1], K. Sakai[47], Y. Sakakibara[9], Y. Sasaki[48], S. Sato[28,†], T. Sato[41], Y. Sato[4], T. Sekiguchi[9,10], Y. Sekiguchi[49], M. Shibata[19], K. Shiga[41], Y. Shikano[50,51], T. Shimoda[3], H. Shinkai[52], A. Shoda[1], N. Someya[28], K. Somiya[8,‡], E. J. Son[25], T. Starecki[53], A. Suemasa[37], Y. Sugimoto[15], Y. Susa[8], H. Suwabe[41], T. Suzuki[4,9], Y. Tachibana[8], H. Tagoshi[6], S. Takada[54], H. Takahashi[48], R. Takahashi[1], A. Takamori[5], H. Takeda[3], H. Tanaka[9,10], K. Tanaka[6], T. Tanaka[16], D. Tatsumi[1], S. Telada[55], T. Tomaru[4,9], K. Tsubono[3], S. Tsuchida[6], L. Tsukada[2,3], T. Tsuzuki[1], N. Uchikata[6], T. Uchiyama[9,10], T. Uehara[56,57], S. Ueki[48], K. Ueno[58], F. Uraguchi[1], T. Ushiba[3], M. H. P. M. van Putten[59,60], S. Wada[3], T. Wakamatsu[41], T. Yaginuma[8], K. Yamamoto[9,10], S. Yamamoto[52], T. Yamamoto[9,10], K. Yano[8], J. Yokoyama[2,3,61], T. Yokozawa[6], T. H. Yoon[62], H. Yuzurihara[6], S. Zeidler[1], Y. Zhao[63], and L. Zheng[64]

(KAGRA Collaboration)

Prog. Theor. Exp. Phys. (2018) 013F01
[arXiv:1712.00148]

Construction & iKAGRA operation (2016)

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

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

introduction & history

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Classical and Quantum Gravity

ACCEPTED MANUSCRIPT

Vibration isolation system with a compact damping system for power recycling mirrors of KAGRA

Ayaka Shoda[1]

Accepted Manuscript online 14 March 2019 • © 2018 IOP Publishing Ltd

What is an Accepted Manuscript?

Class. Quant. Grav. 36 (2019) 095015
[arXiv:1901.03053]

Vibration isolation

arXiv.org > astro-ph > arXiv:1901.03569

Search or Artic
(Help | Advanced s

Astrophysics > Instrumentation and Methods for Astrophysics

First cryogenic test operation of underground km-scale gravitational-wave observatory KAGRA

KAGRA Collaboration: T. Akutsu, M. Ando, K. Arai, Y. Arai, S. Araki, A. Araya, N. Aritomi, H. Asada, Y. Aso, S. Atsuta, K. Awai, S. Bae, L. Baiotti, M. A. Barton, K. Cannon, E. Capocasa, C-S. Chen, T-W. Chiu, K. Cho, Y-K. Chu, K. Craig, W. Creus, K. Doi, K. Eda, Y. Enomoto, R. Flaminio, Y. Fujii, M.-K. Fujimoto, M. Fukunaga, M. Fukushima, T. Furuhata, A. Hagiwara, S. Haino, K. Hasegawa, K.

CQG accepted
[arXiv:1901.03569]

phase-1 operation (2018)

articles on KAGRA / KSC newsletter

KAGRA

NEWS IN FOCUS

PHYSICS Tantalizing signs of superconductivity at near-room temperature **p.12** | **POLITICS** Violence in Nicaragua engulfs scientists **p.11** | **NEW YEAR** Gene-editing, open access and seals with sensors to shape 2019 **p.13** | **MATERIALS** The scramble to understand a twisted form of graphene **p.15**

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 origin 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 ▸

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Nature 565 (2019 Jan) 30

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BY EMILY CONOVER MARCH 08, 2019

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BY MARIA TEMMING MARCH 08, 2019

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BY EMILY CONOVER MARCH 08, 2019

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BY SID PERKINS MARCH 08, 2019

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BY LISA GROSSMAN MARCH 07, 2019

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BY SUJATA GUPTA MARCH 07, 2019

NEWS
How helpful gut microbes send signals that they are friends, not foes

NEWS PHYSICS, ASTRONOMY, GRAVITATIONAL WAVES

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/

linked from

https://gwcenter.icrr.u-tokyo.ac.jp/en/

KAGRA SCIENTIFIC CONGRESS: COLLABORATORS' INFORMATION EXCHANGE 2019/04/18

KSC Newsletter

Issue 4

Einstein Telescope and KAGRA signed agreement
to collaborate on the development of the common technologies

The 5th KAGRA International Workshop (KIW5) was held at Perugia, Italy. The third day of the workshop was named "The first KAGRA-Virgo-3G Detectors Workshop (KV3G)", where we discussed the project of Einstein Telescope (ET), one of the key gravitational-wave observatory plans in the future. The nascent ET collaboration (it will be formulated in April 2019) plans to construct a triangle-shape 10 km-armed laser-interferometer underground, and with cryogenic technology. Its core technologies match with our experiences.

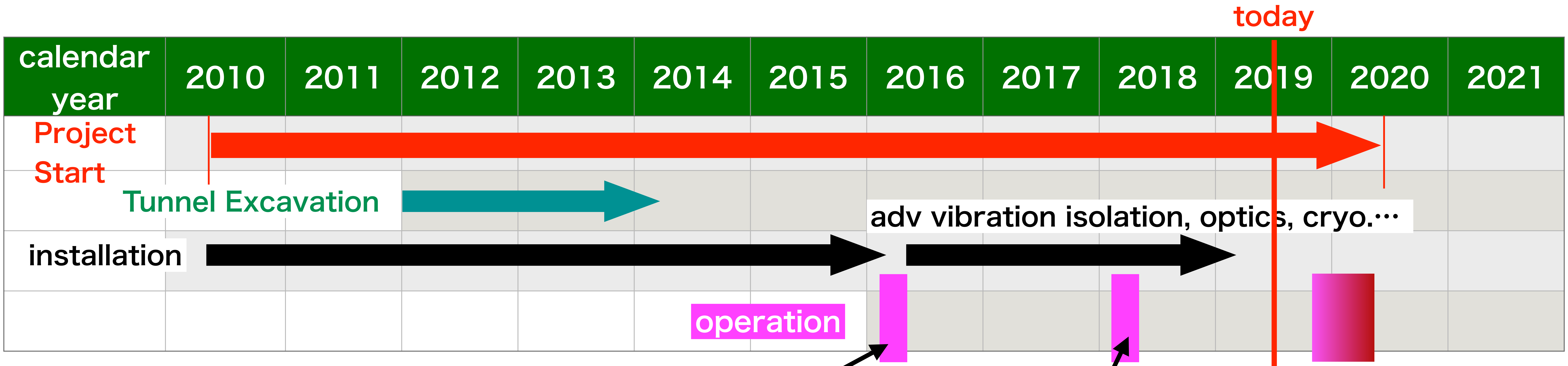
On February 16, 2019, at the gorgeous Sala dei Notari (hall of Notari), our PI, Takaaki Kajita, and the ET steering board chairmen, Michele Punturo and Harald Lück, signed a letter of intent to collaborate on the development of third generation detectors. The scope of the letter is quite general (see JGW-M1909820), but we believe it becomes a certain step forward for both of us.

KIW5 and KV3G workshop had more than a hundred of participants. The meeting continued from the early morning to the late evening, but we enjoyed a small historical old city area, Perugia chocolates, and environment of AC Perugia (Perugia Calcio). We thank LOC members, especially Helios Vocca and Flavio Travasso for giving us this opportunity.

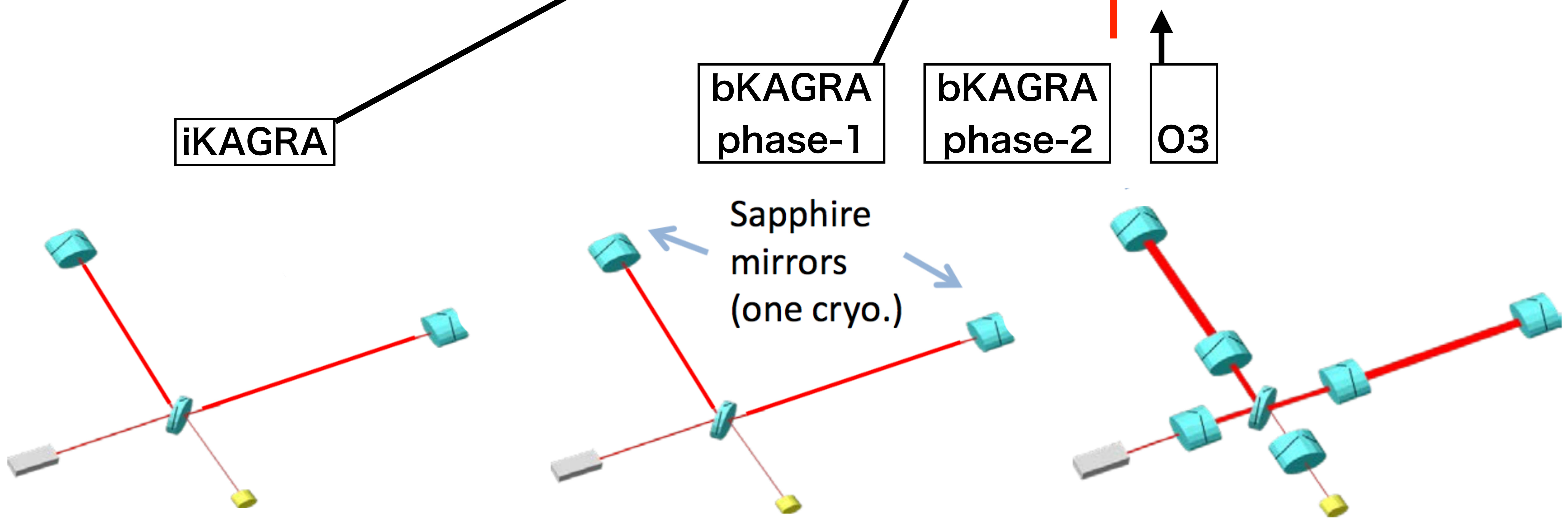
Contents of this issue

1

Brief History of KAGRA

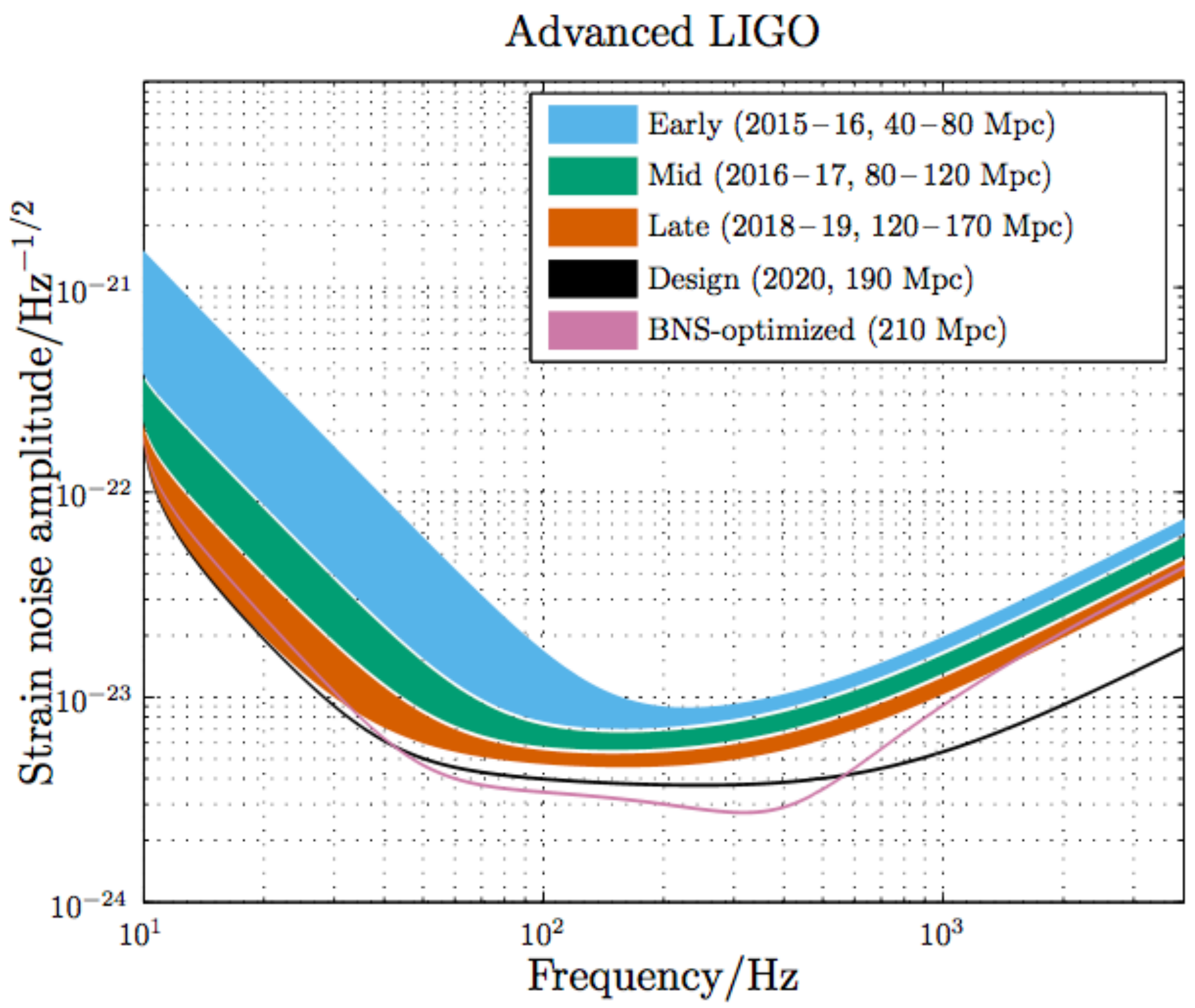


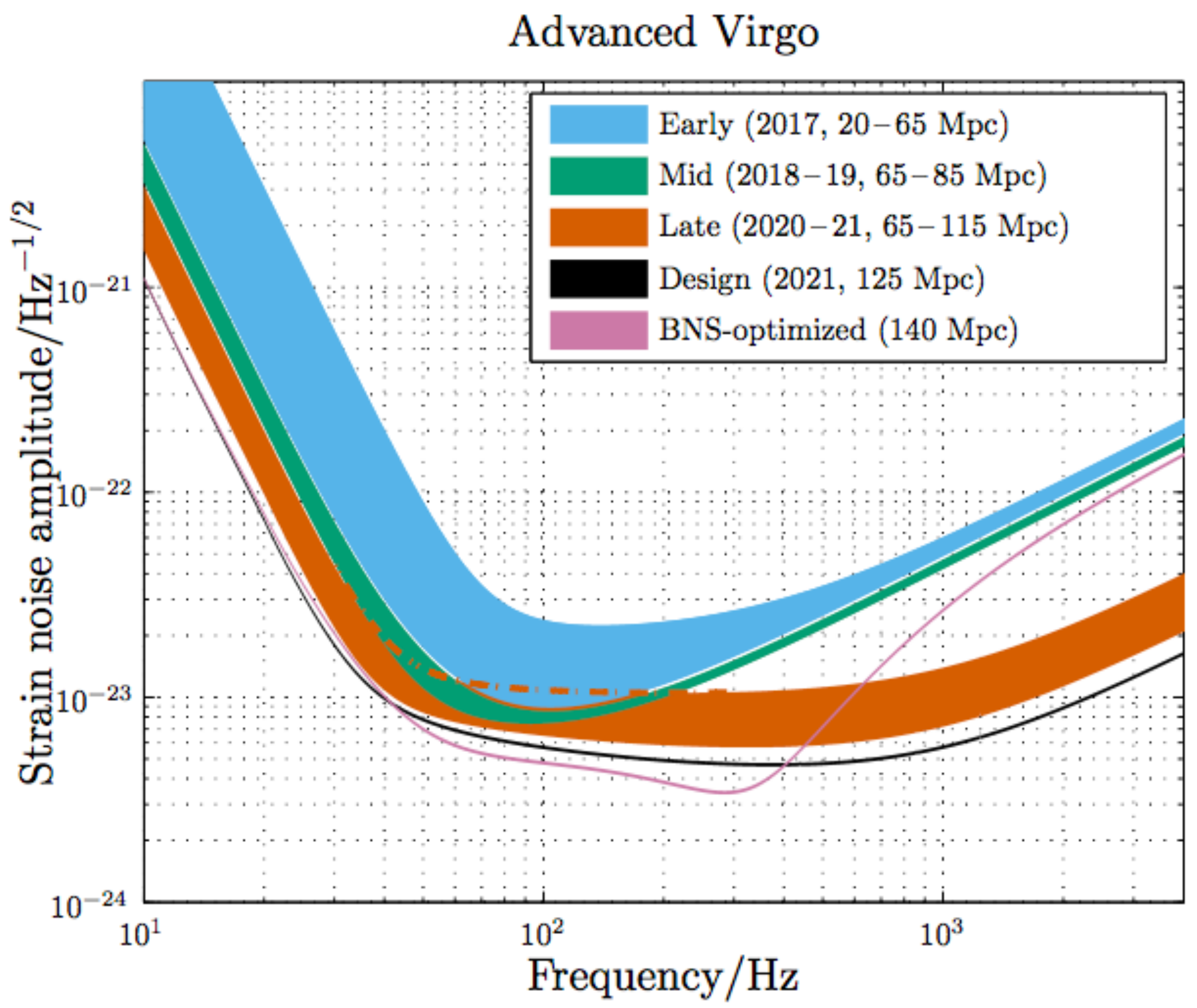
iKAGRA = initial KAGRA
bKAGRA = baseline KAGRA

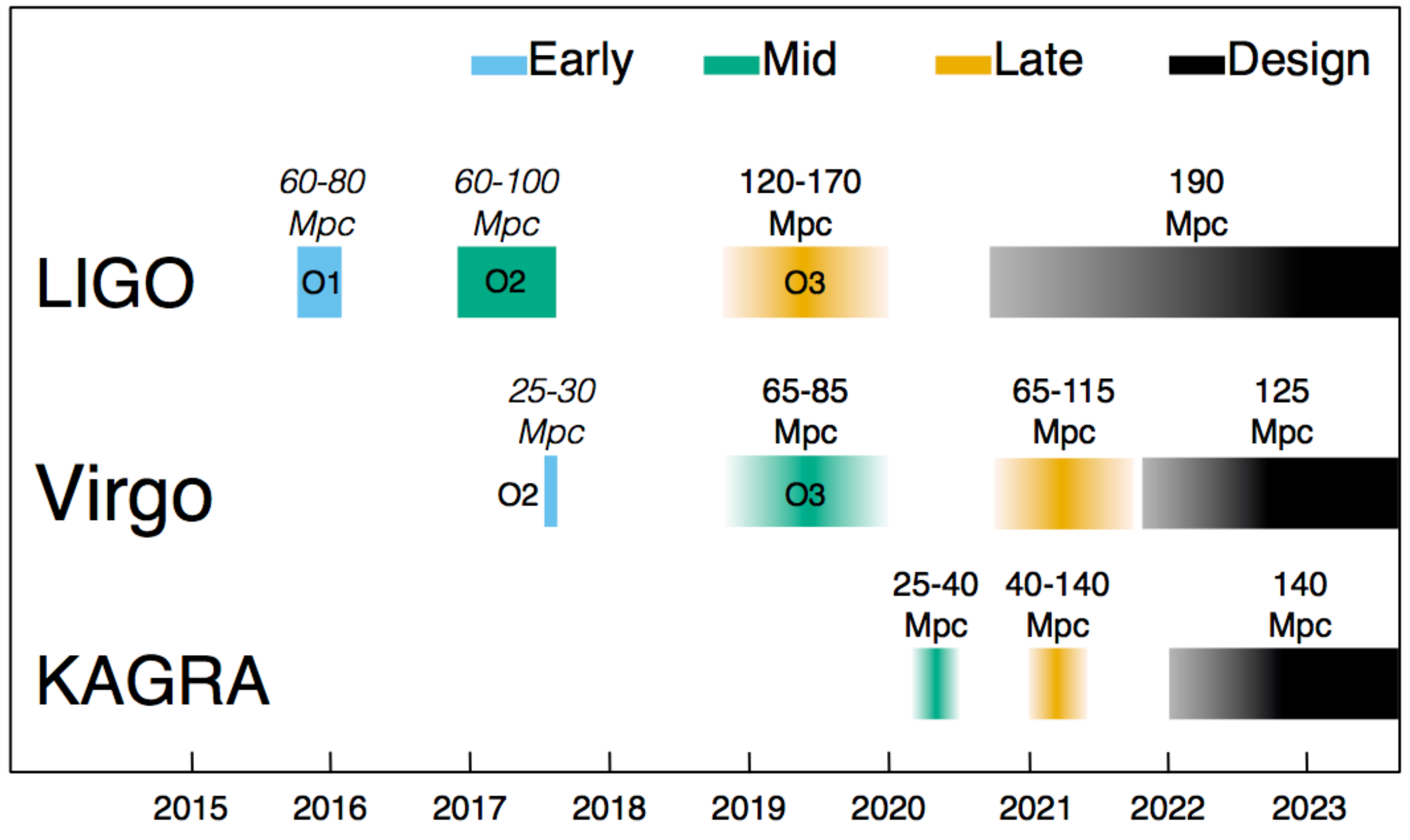


[arXiv:1712.00148]　[arXiv:1901.03569]

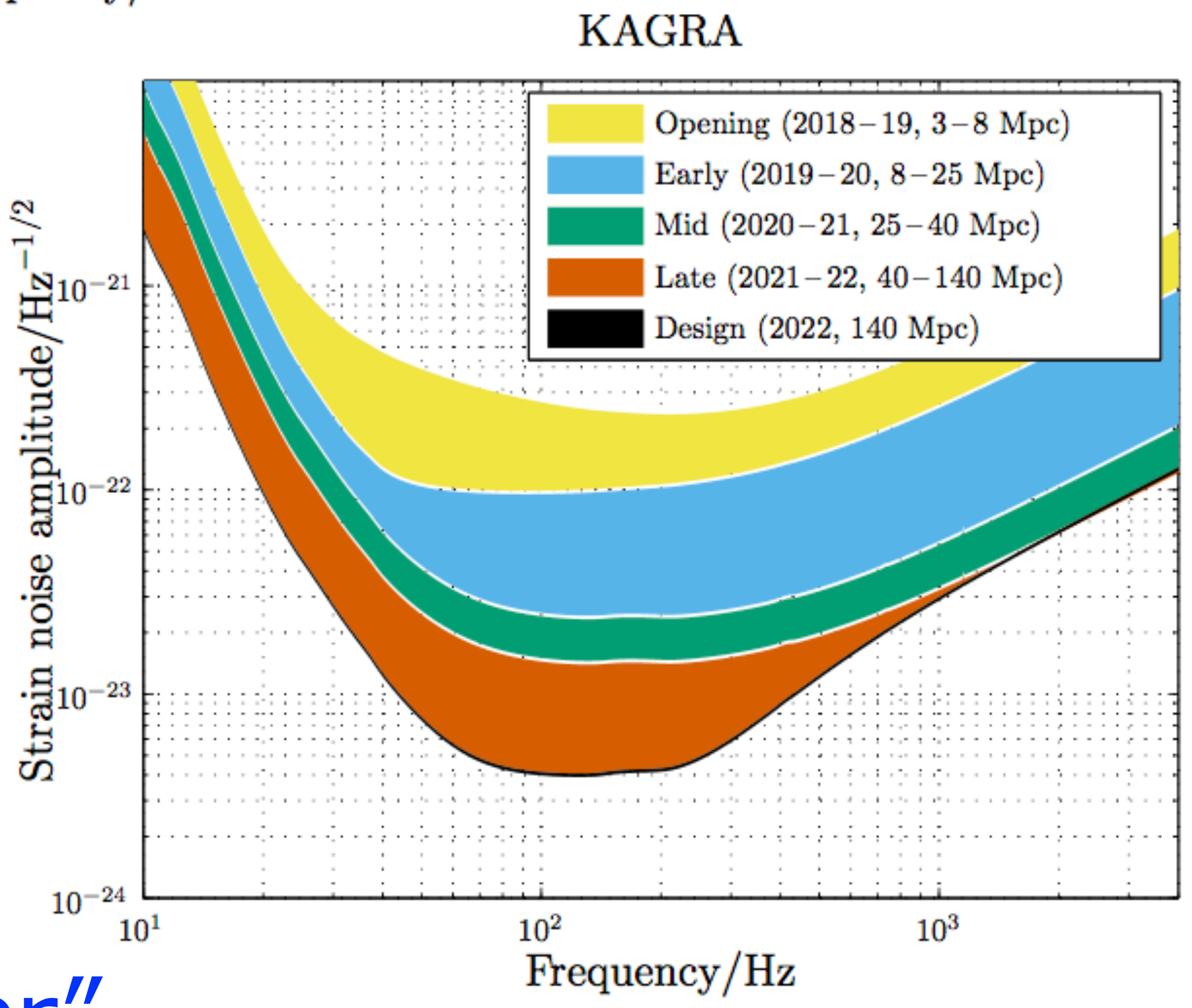
Target Sensitivity & Schedule



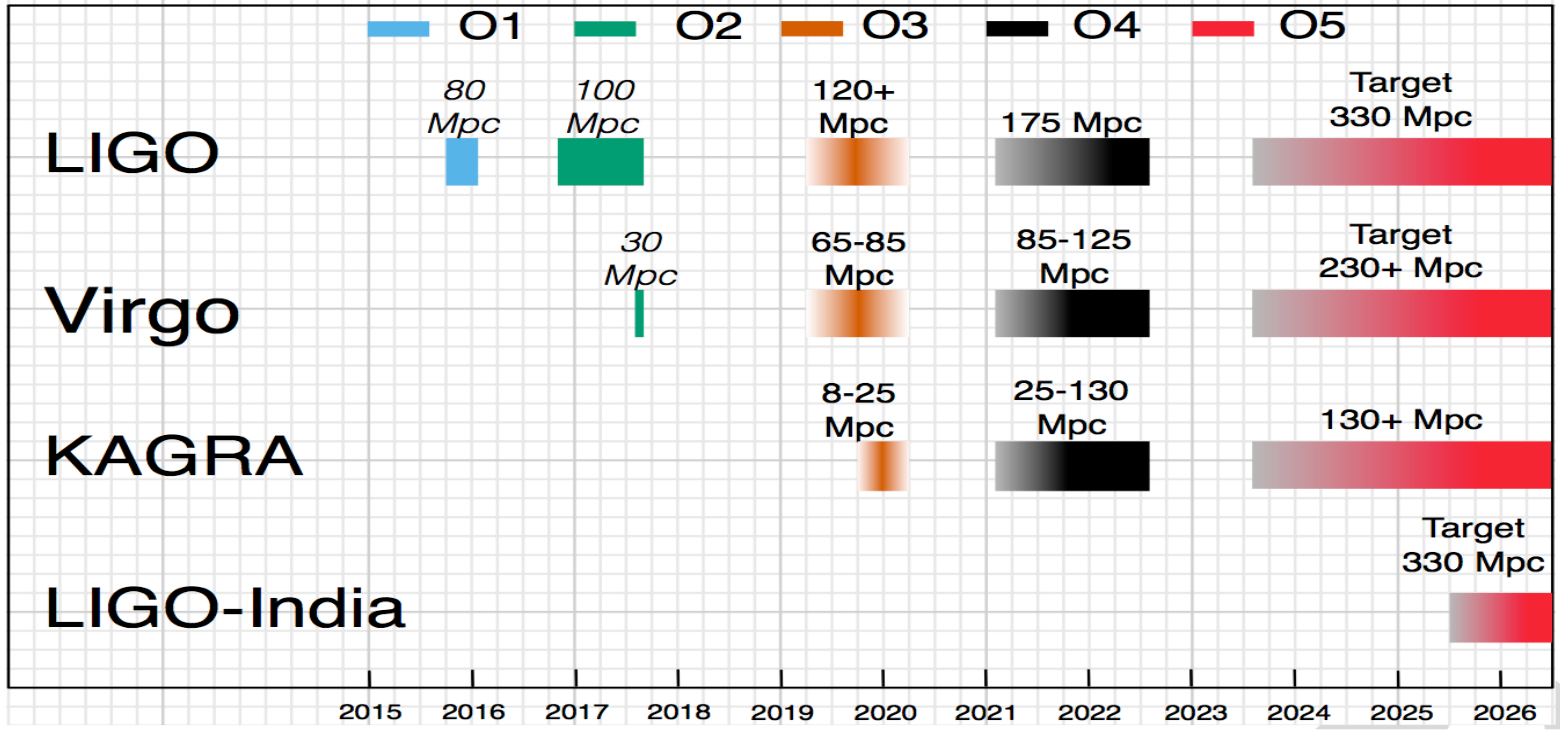




[1304.0670v4]



[draft]



"Scenario Paper"

Living Rev Relativ (2018) 21:3

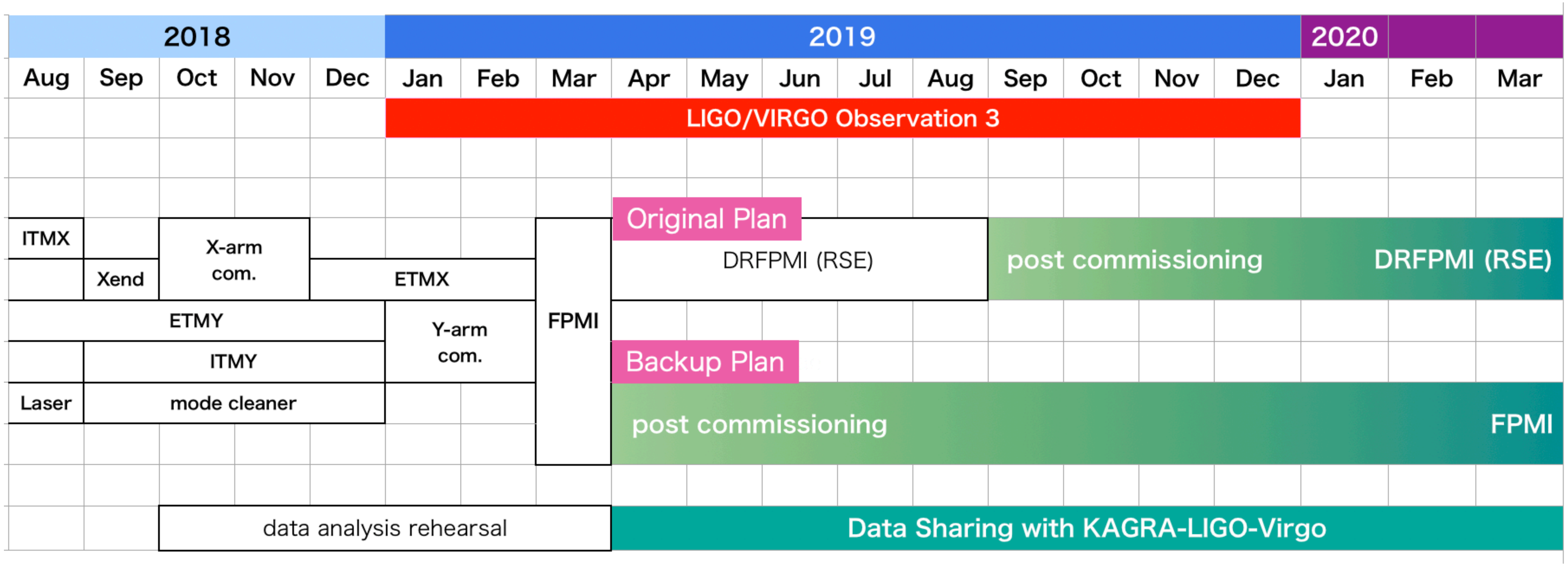
https://doi.org/10.1007/s41114-018-0012-9

[1304.0670v4]

Schedule plan for joining O3 (2018)

In 2018 Feb, KAGRA decided to join O3 by accelerating all the installation.

The plan at 2018 June:



plan A
-25Mpc

plan B
-10Mpc

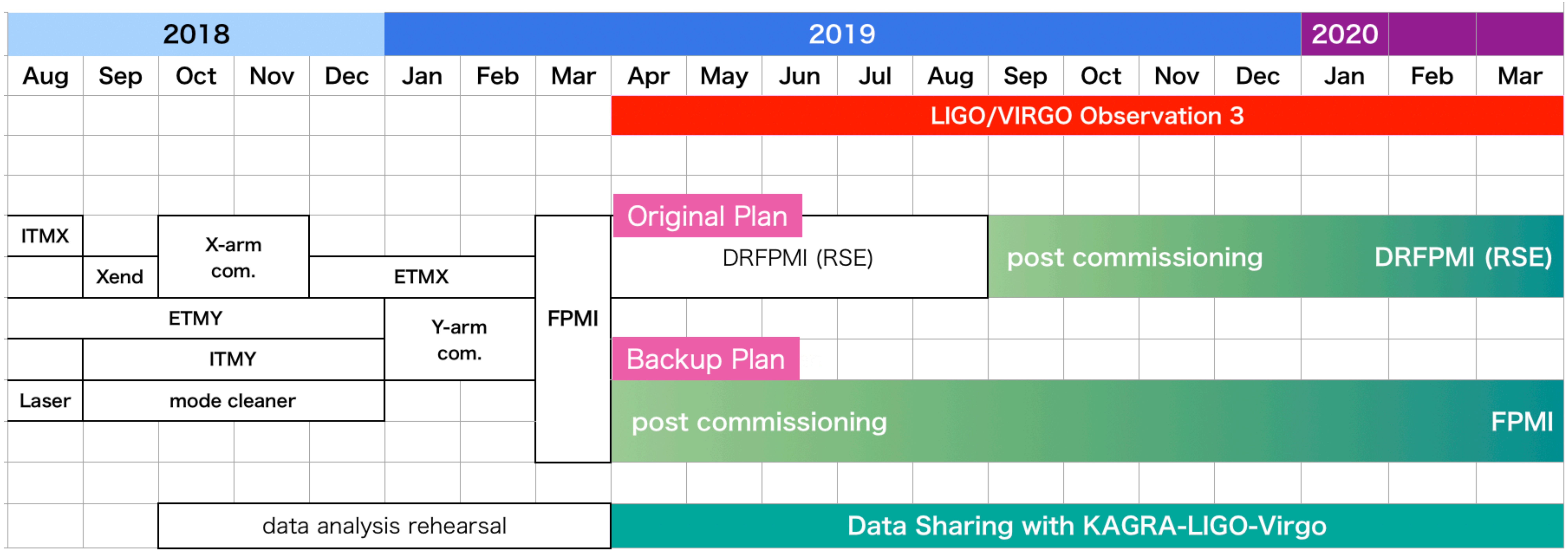
▲ Finish all the installation

Schedule plan for joining O3 (2018)

In 2018 Feb, KAGRA decided to join O3 by accelerating all the installation.

KAGRA finished all the installation by the end of April 2018.

The plan at 2018 June:



plan A
-25Mpc

plan B
-10Mpc

▲
~~Finish all the installation~~

▲
Finish all the installation

Schedule plan for joining O3 (now)

In 2018 Feb, KAGRA decided to join O3 by accelerating all the installation.
KAGRA finished all the installation by the end of April 2018.

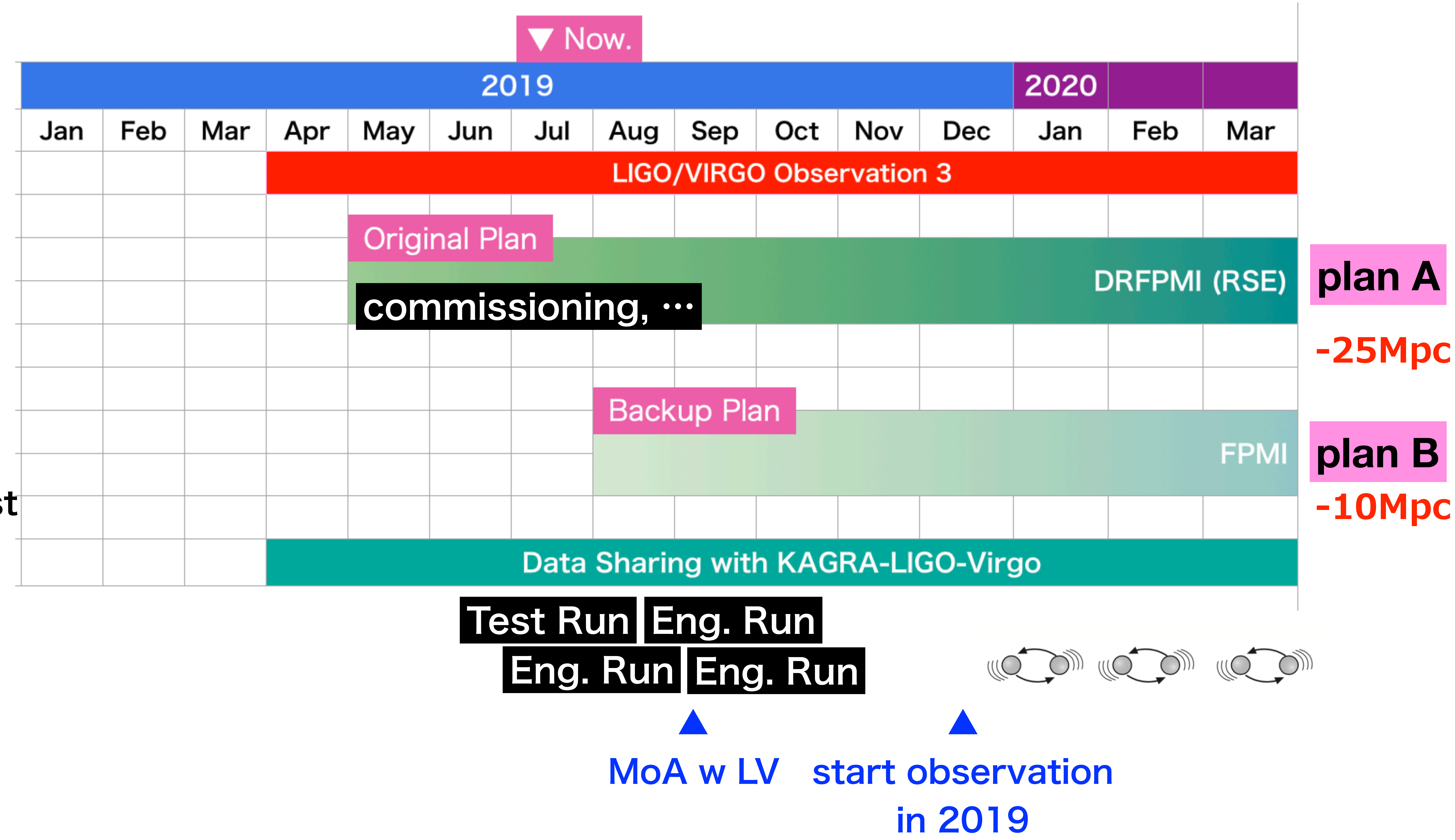
The plan now:

We are commissioning with FPMI with PR & SR.

Test Runs:

June 6 X-arm
June 19 PR, SR

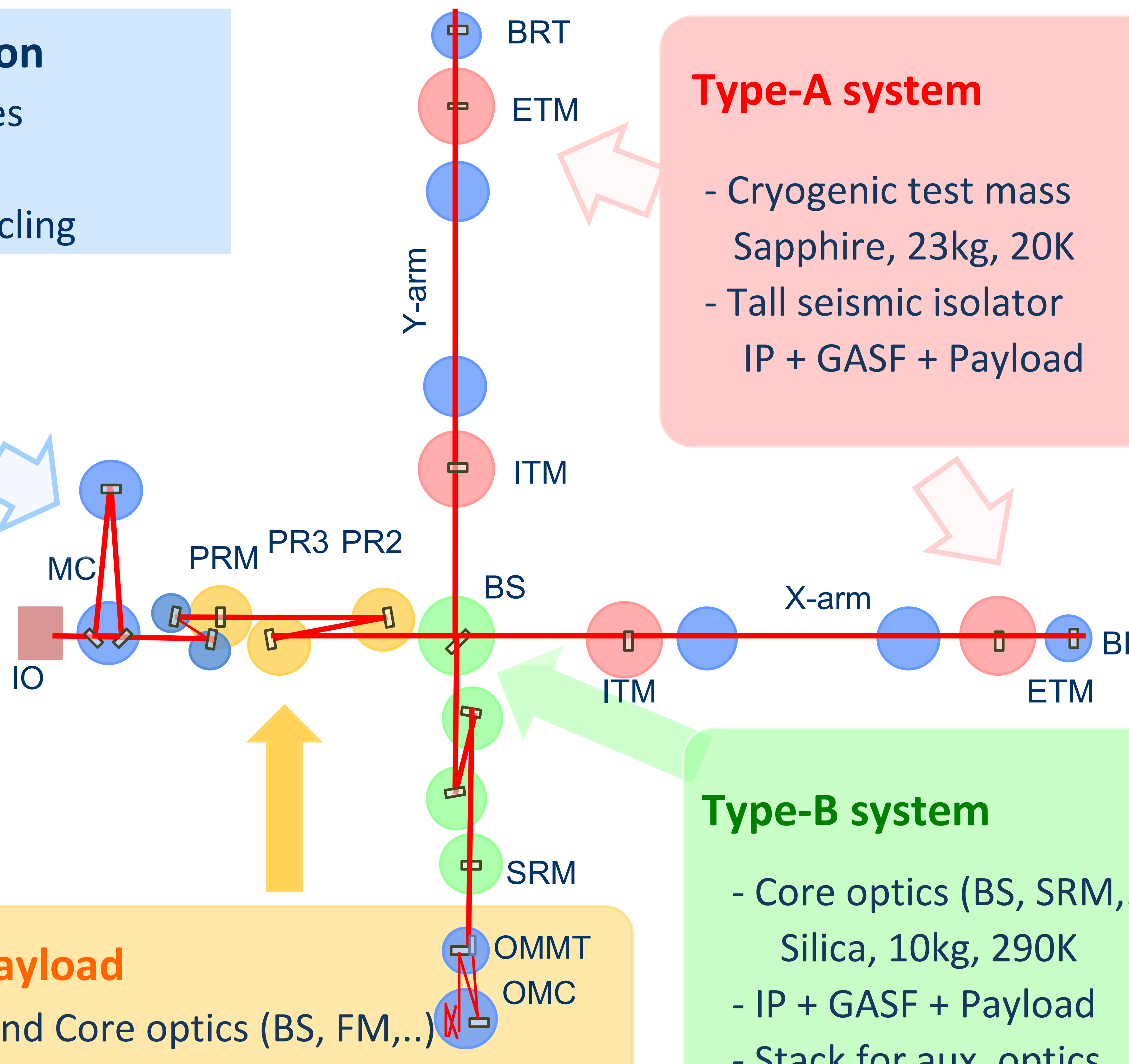
July 13 interferometer test



KAGRA suspension systems

160222_SAITO

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

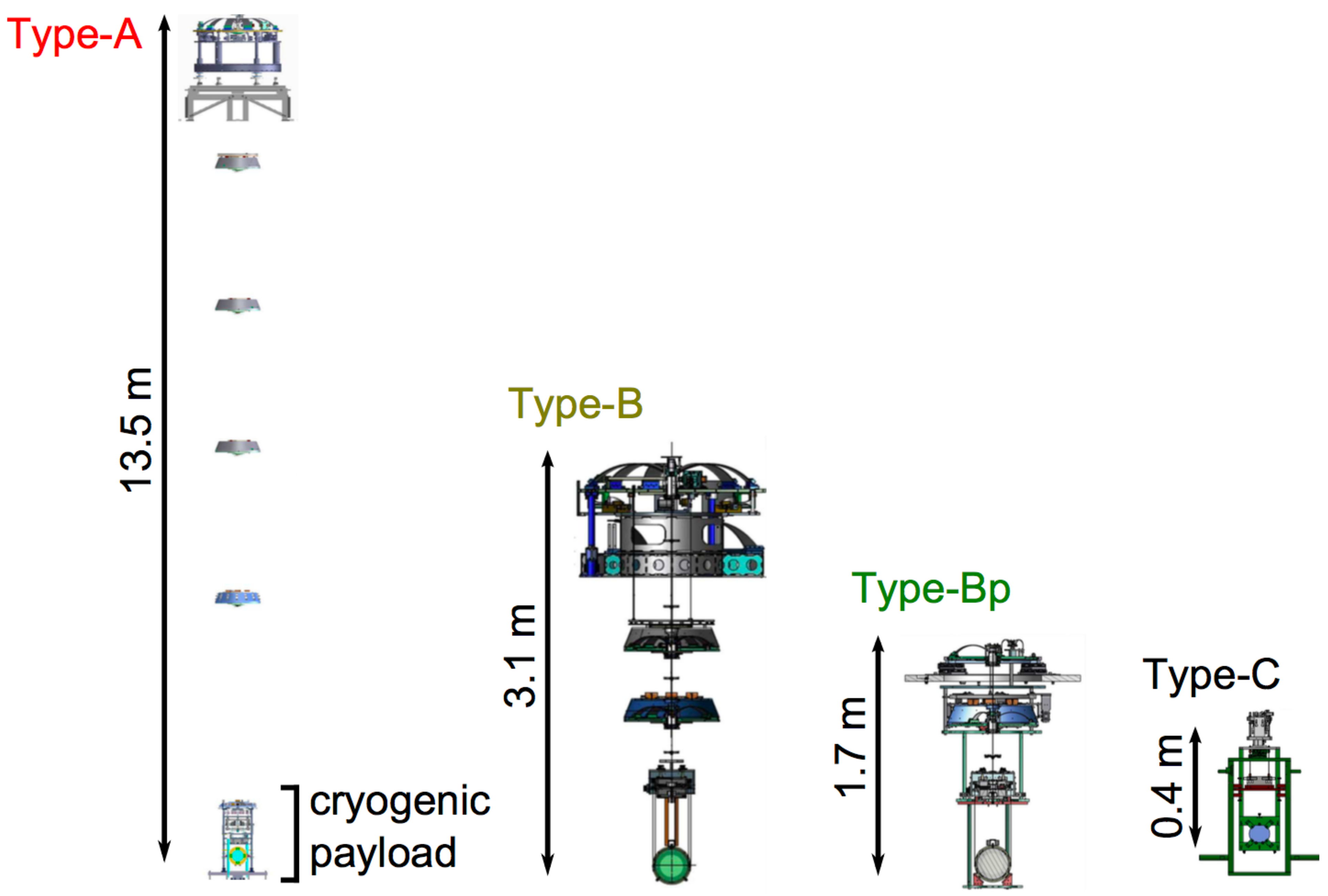


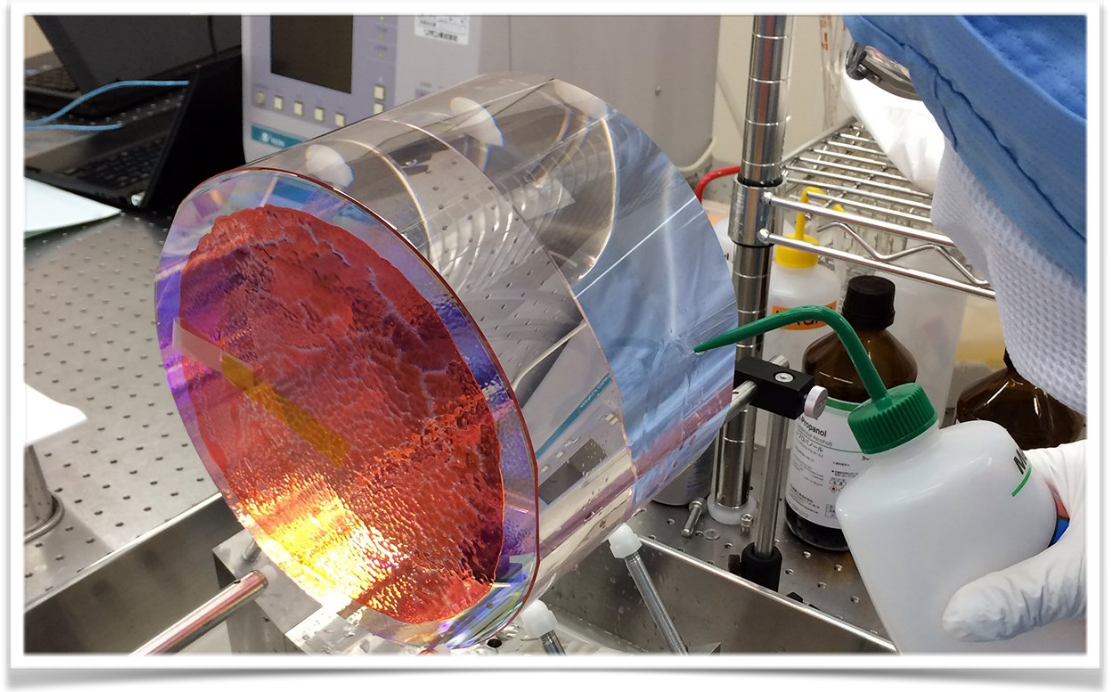
Type-A system
- Cryogenic test mass
  Sapphire, 23kg, 20K
- Tall seismic isolator
  IP + GASF + Payload

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



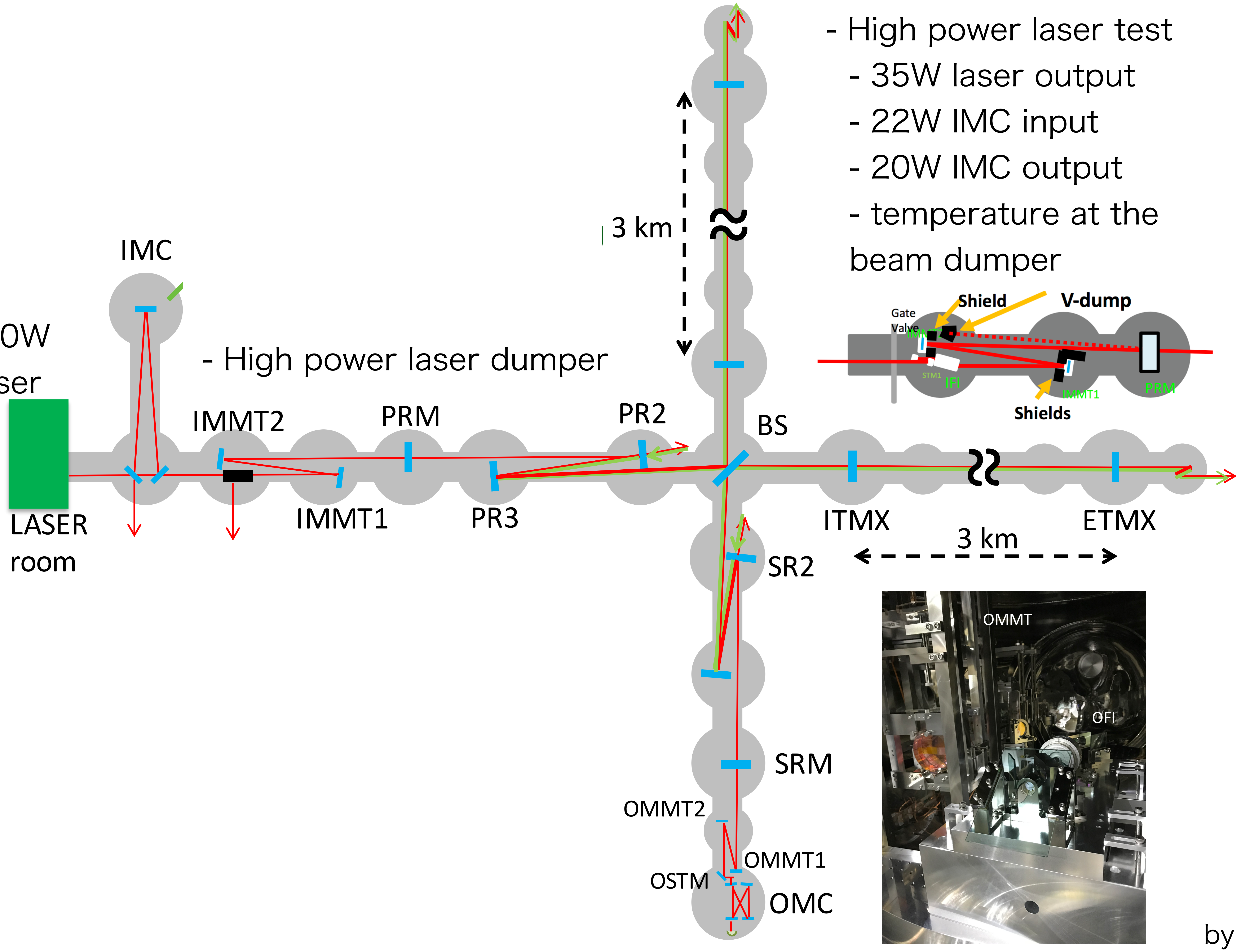


Laser, Input-Output Optics, Auxiliary optics

- 40W Laser

- High power laser dumper

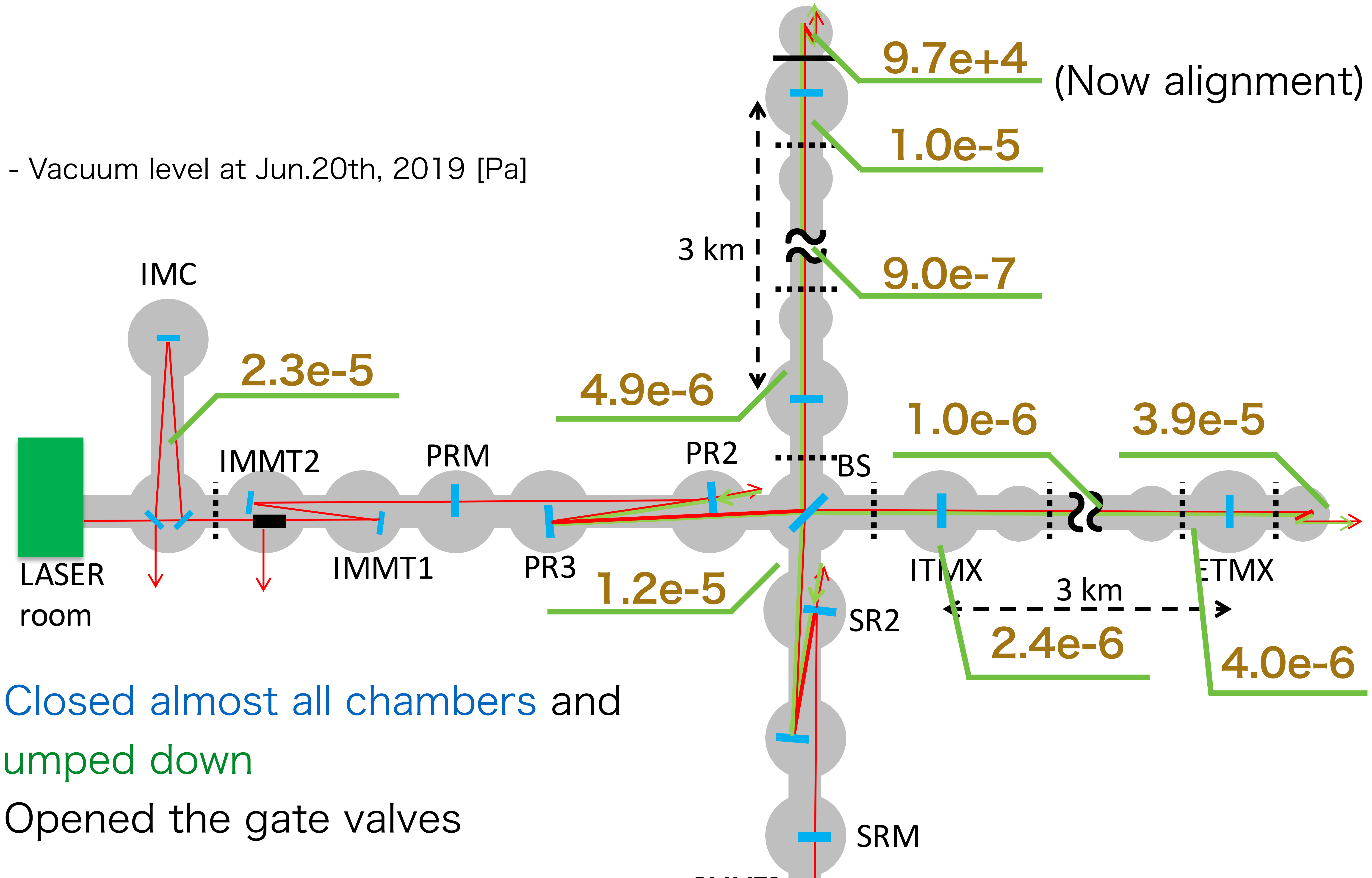
- High power laser test
  - 35W laser output
  - 22W IMC input
  - 20W IMC output
  - temperature at the beam dumper



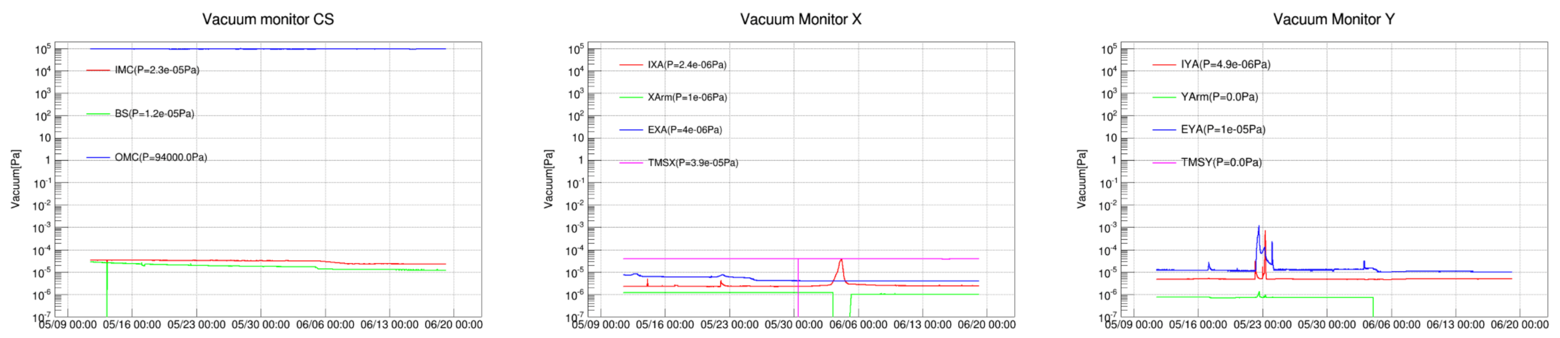
by T. Yokozawa

Vacuum & Facilities

- Vacuum level at Jun.20th, 2019 [Pa]



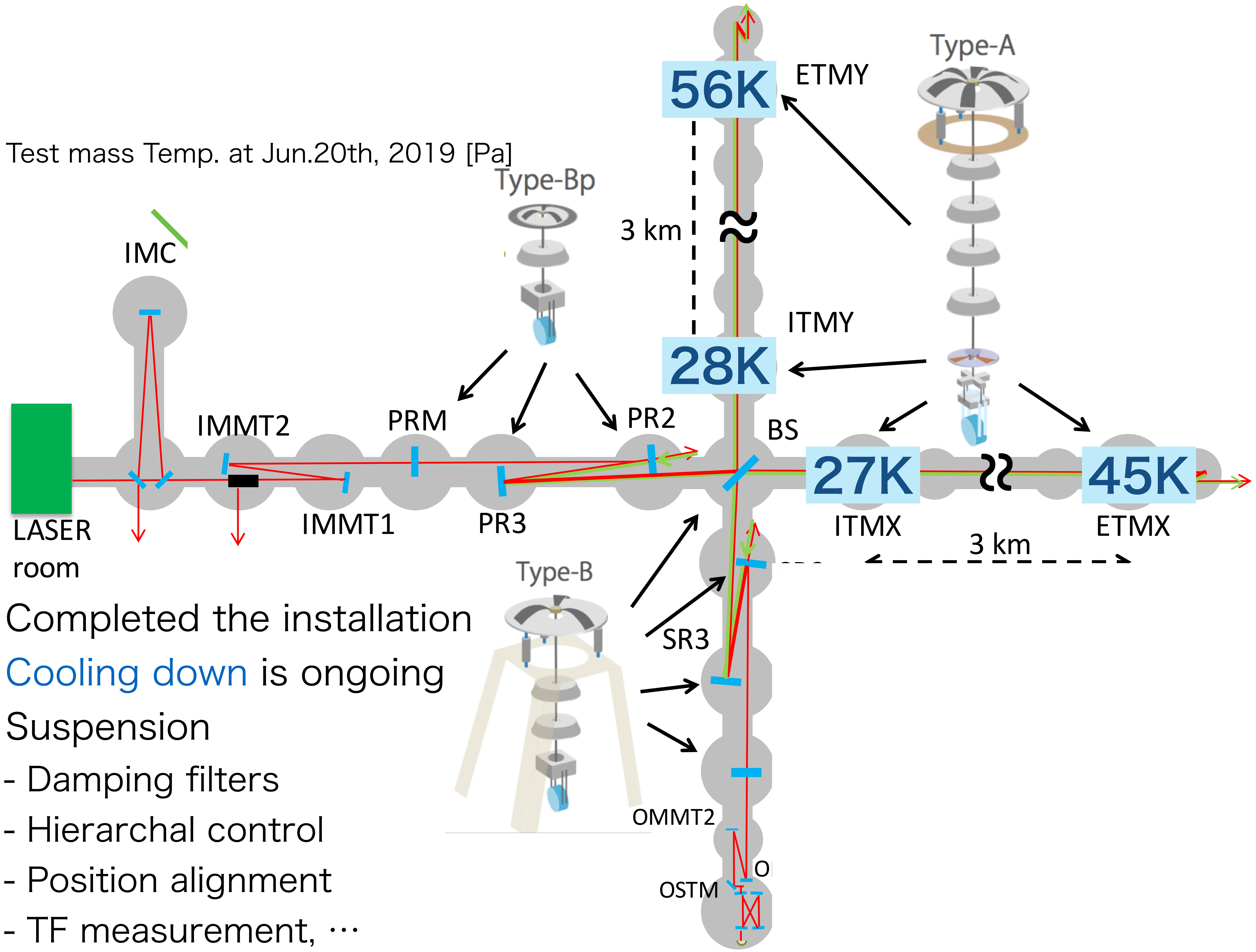
- Closed almost all chambers and pumped down
- Opened the gate valves



by T. Yokozawa

Cryogenic, Vibration Isolation, Mirrors

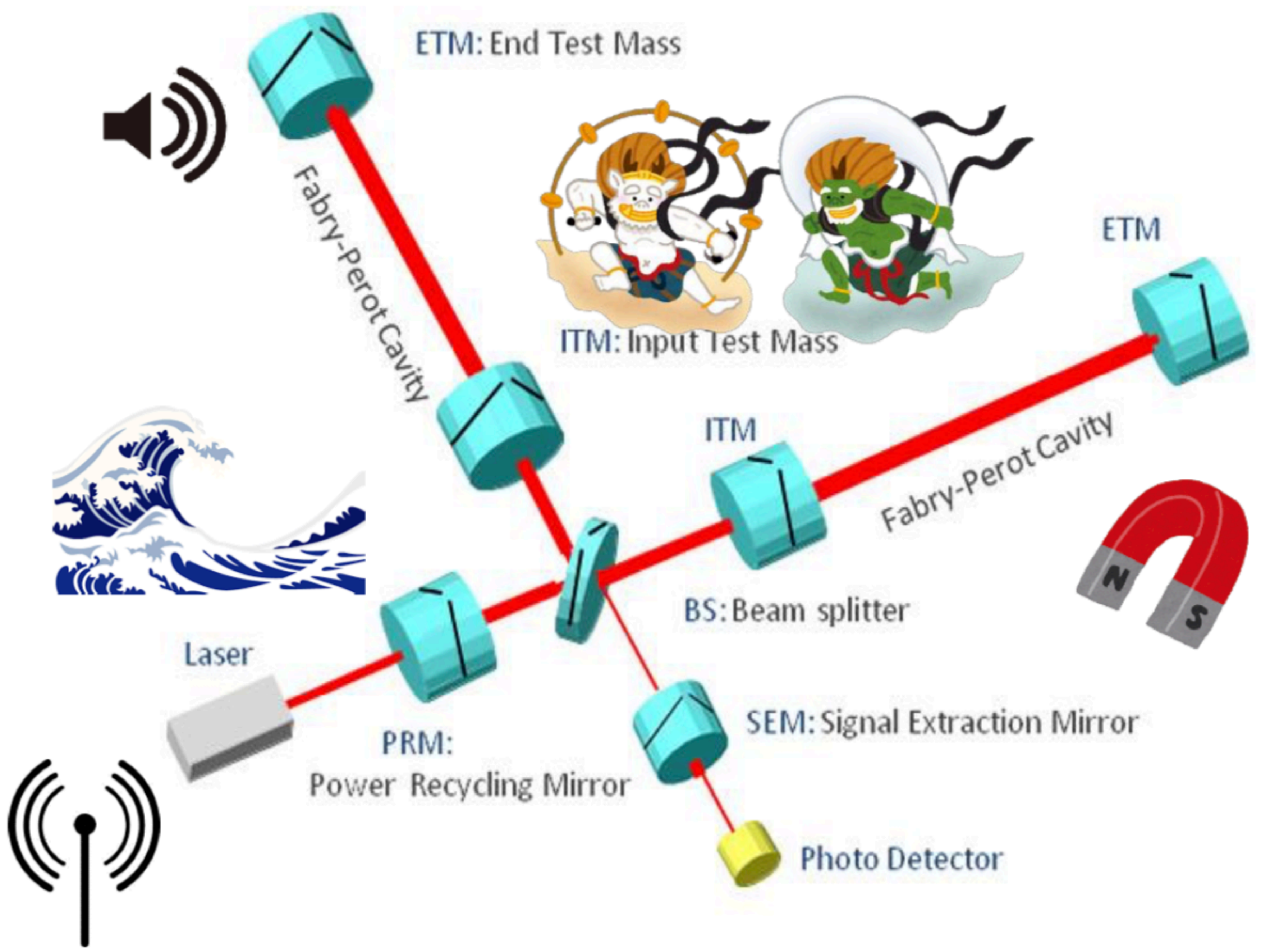
- Test mass Temp. at Jun.20th, 2019 [Pa]

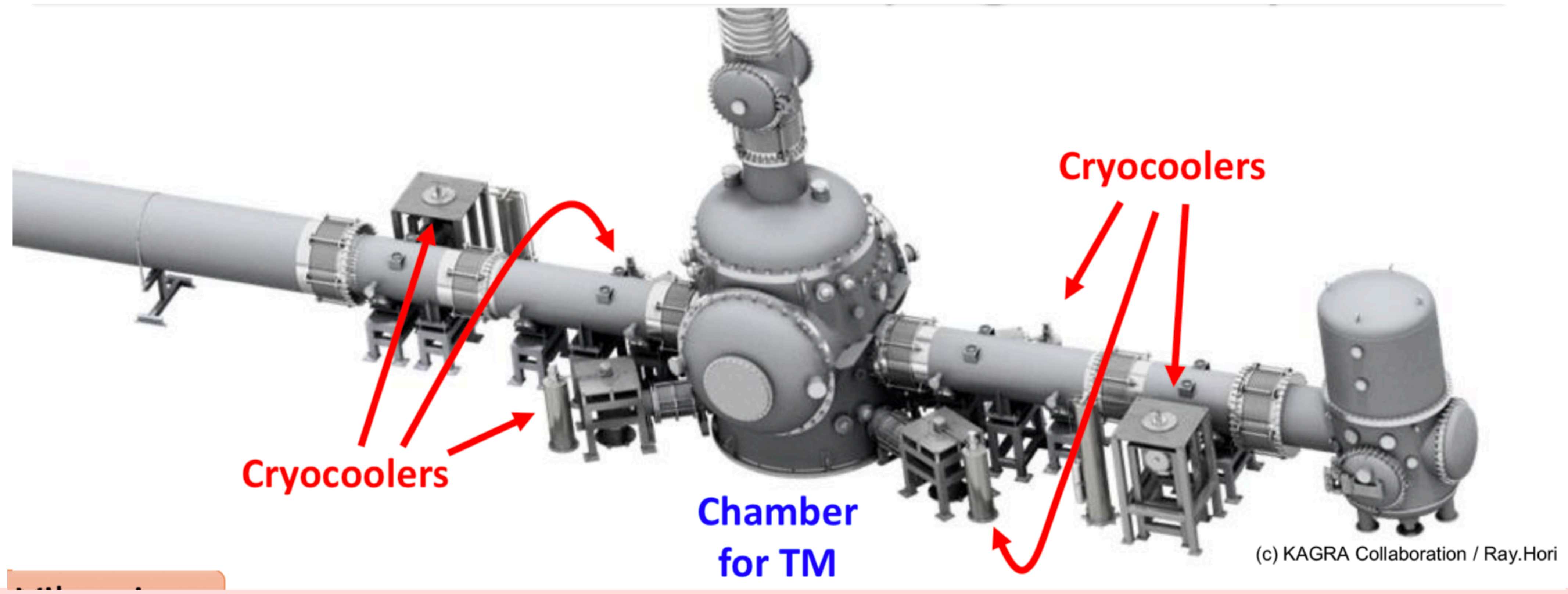


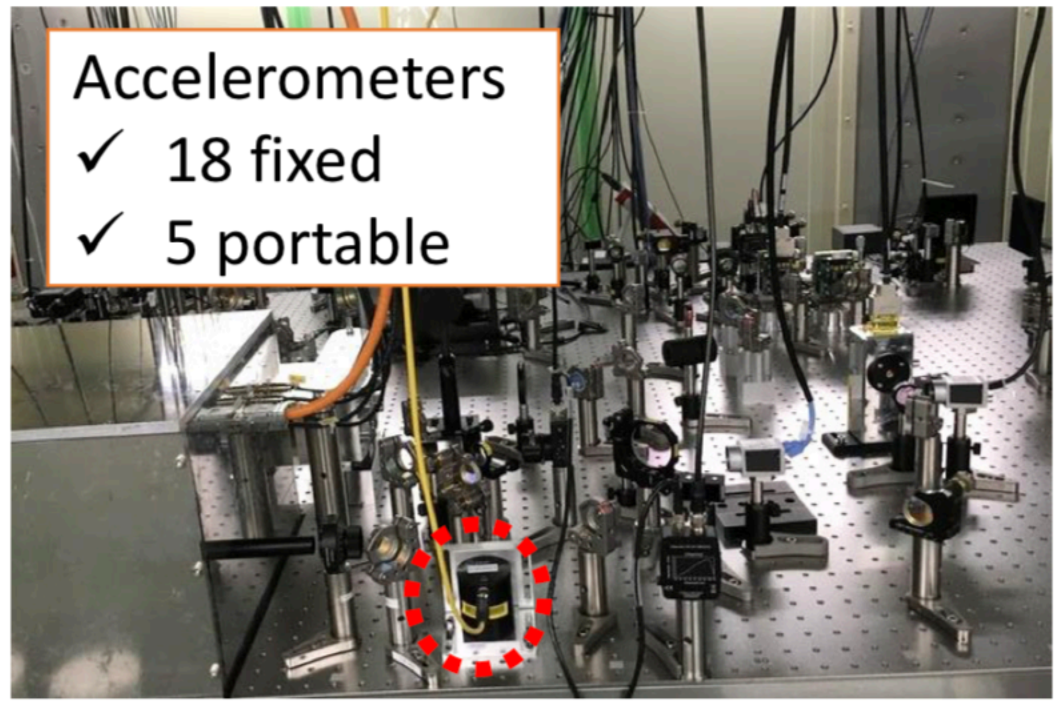
- Completed the installation
- Cooling down is ongoing
- Suspension
  - Damping filters
  - Hierarchal control
  - Position alignment
  - TF measurement, …

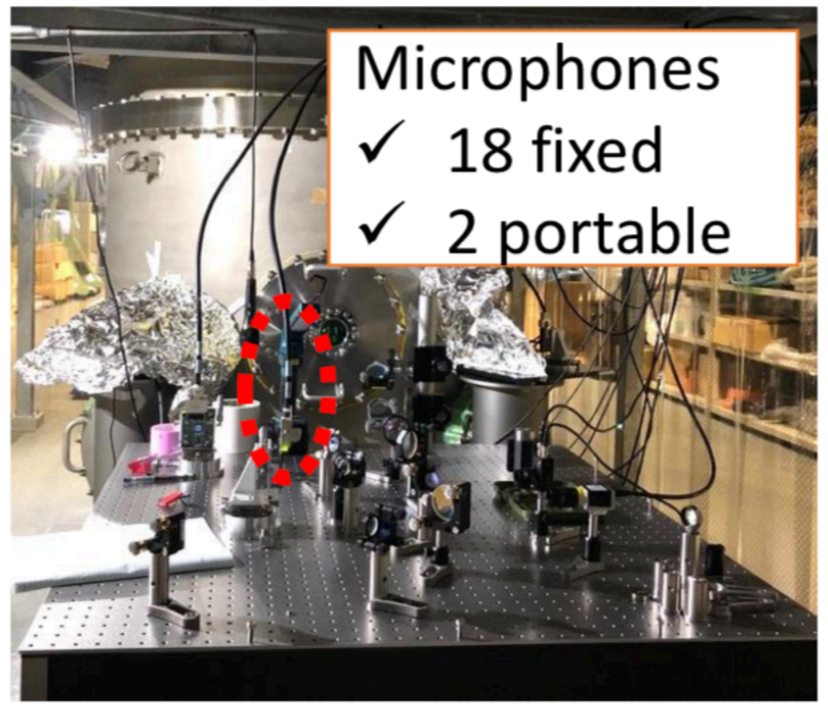
by T. Yokozawa

Physical environment monitors









Magnetometers
✓ 2 fixed
✓ 3 portable

Other sensors :

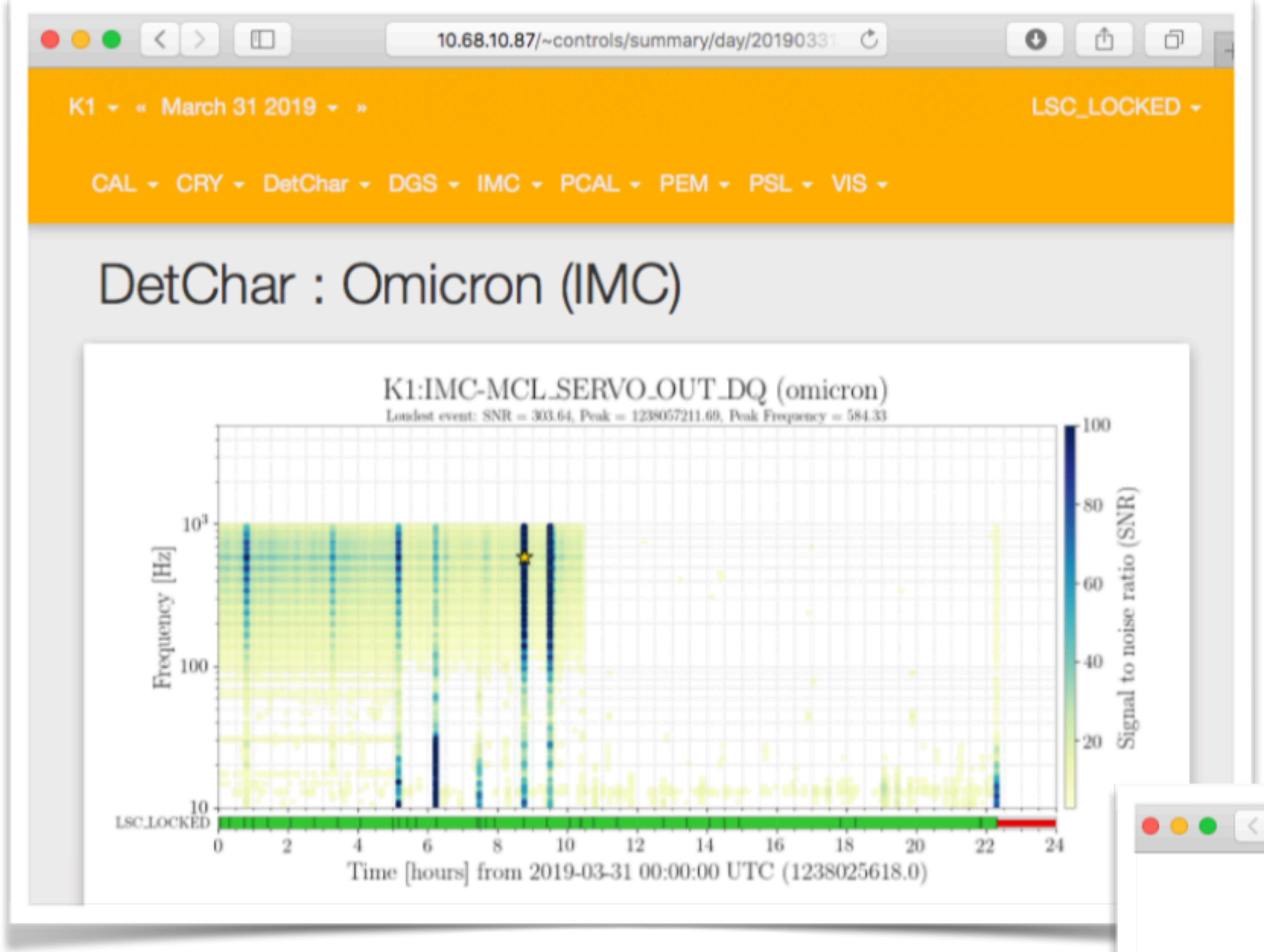
- Radio frequency recover (1)
- DC power monitor (1)
- Temperature & humidity sensors (69)
- Vacuum gauges (11)

by T. Washimi

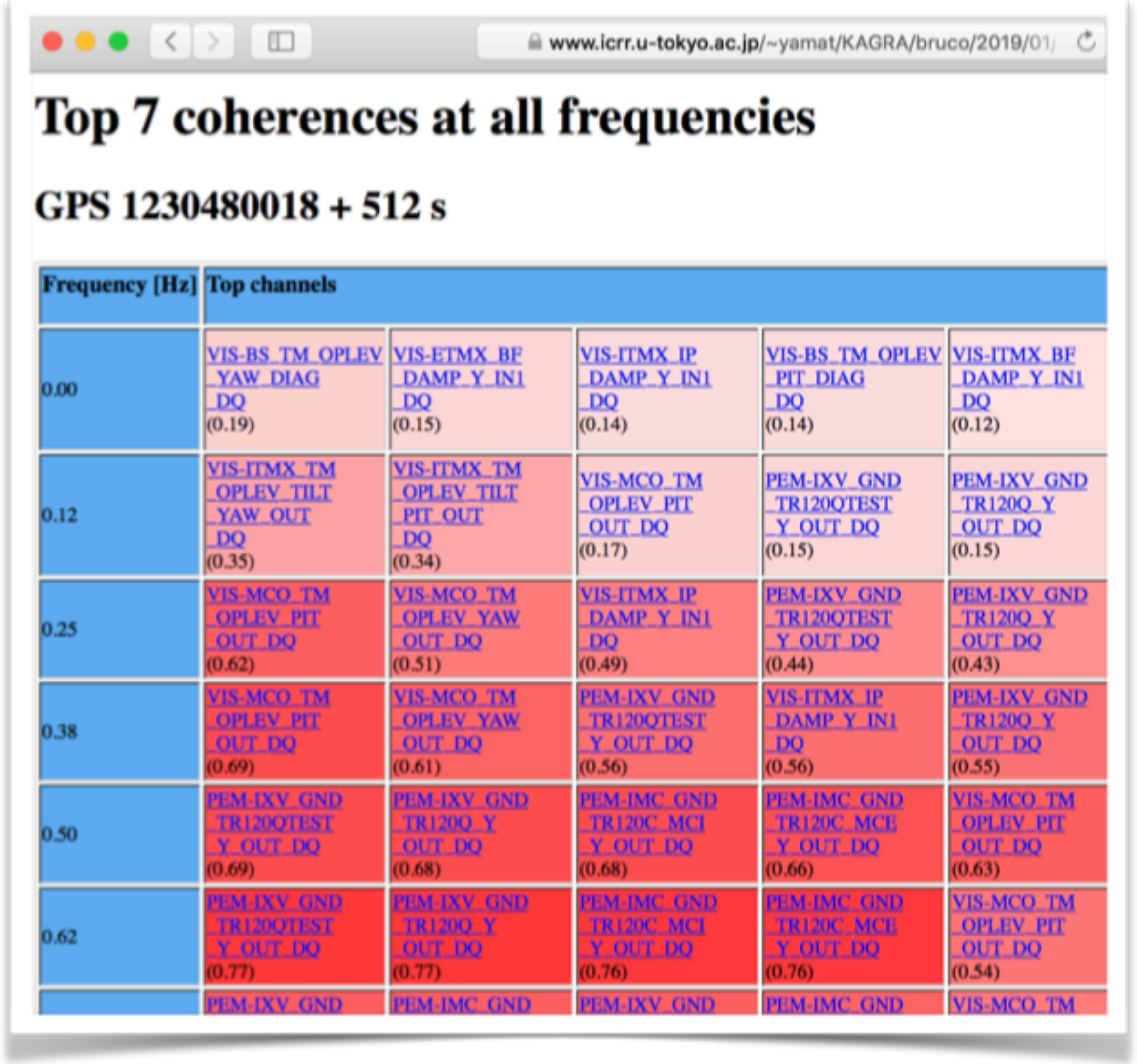
identified 2Hz noise from cryocoolors
noise from fans 13-59 Hz and 1135-2015 Hz
1-3 Hz magnetic field from cryocoolors

Commissioning tools

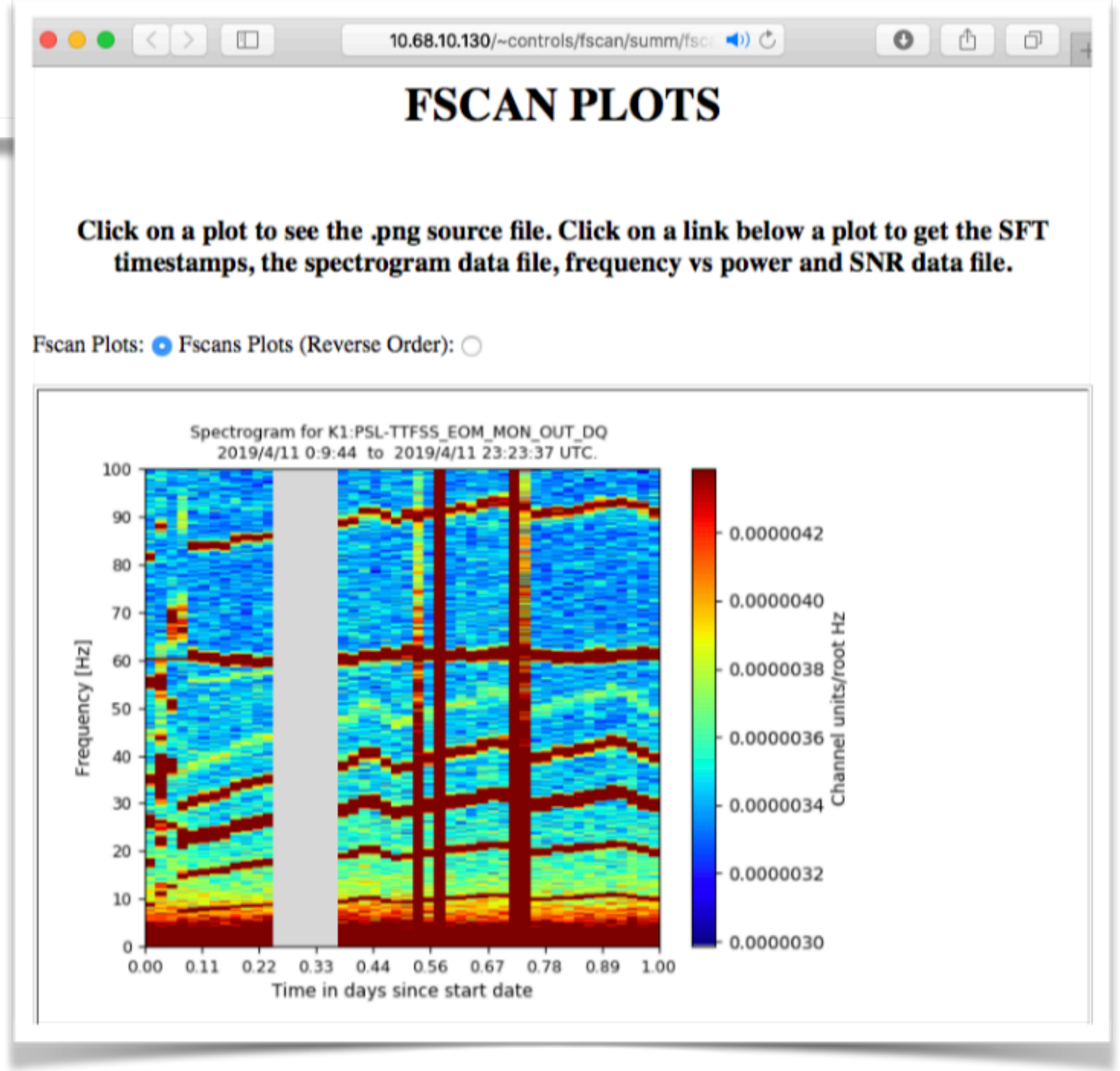
LV DetChar tools



Glitch trigger generation (Omicron)

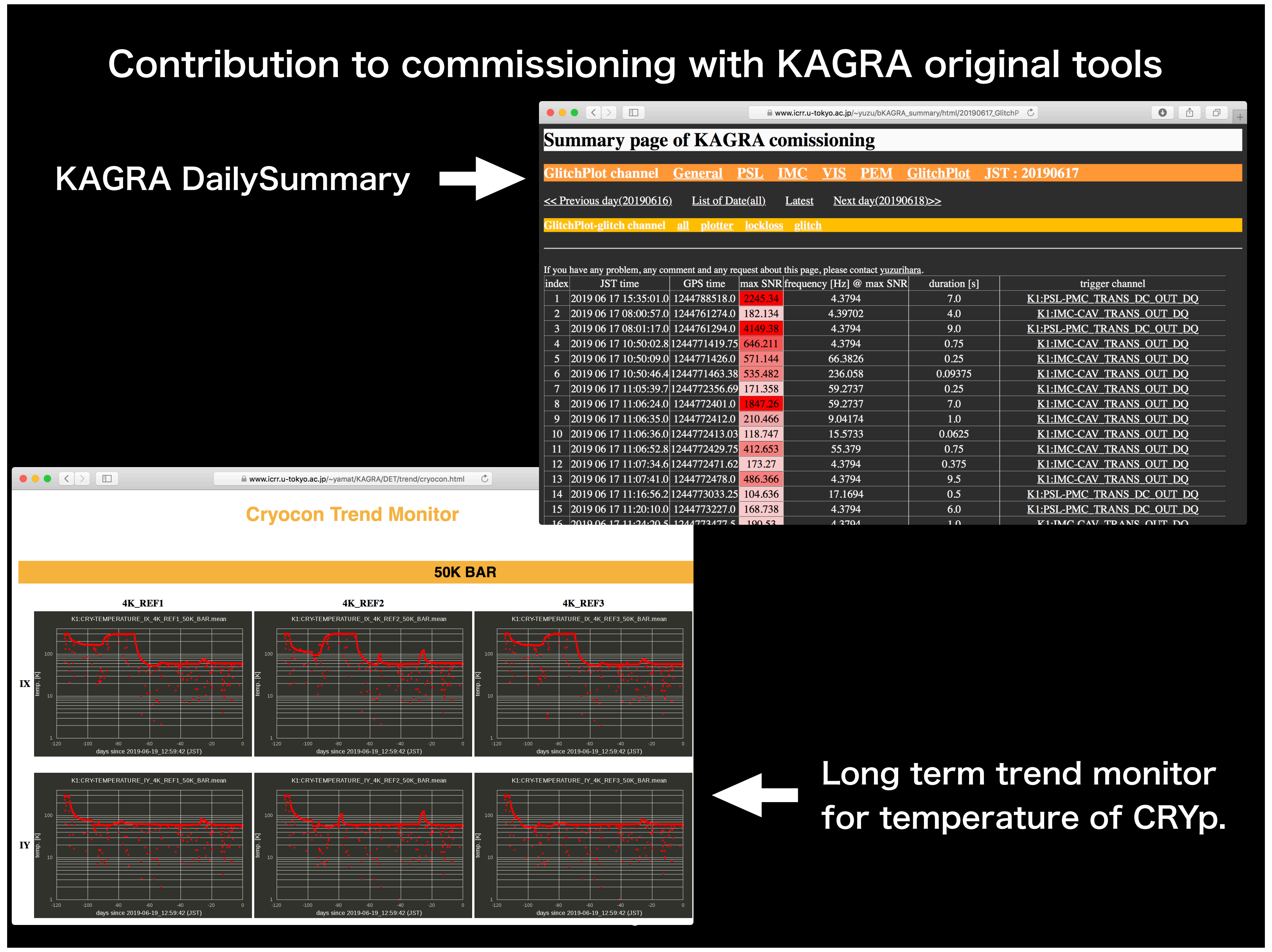


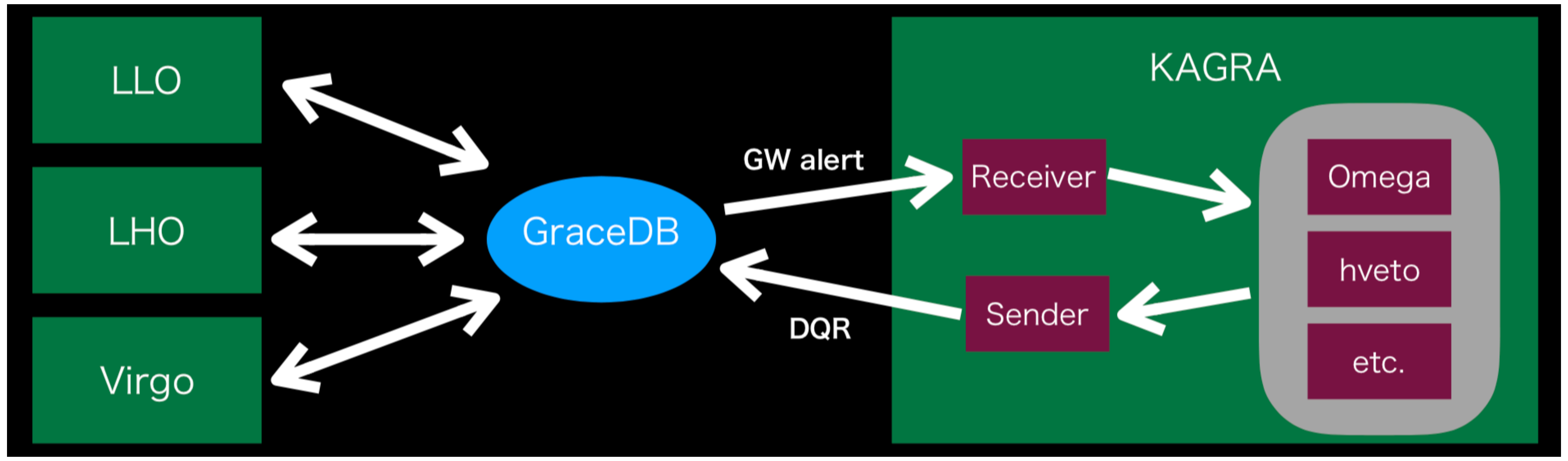
Coherence search (Bruco)



Spectral Line identification (Fscan)

KAGRA original tools





by T. Yamamoto

Data-exchange tests with low latency

Low Latency h(t) transfer

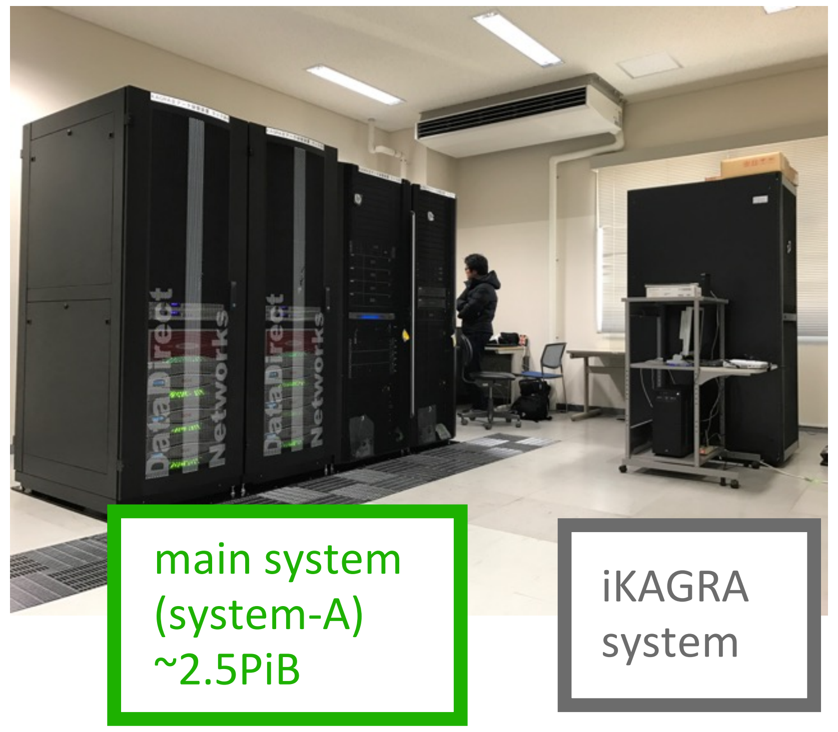
KAGRA tunnel —> the surface —> Kashiwa server : 3 sec

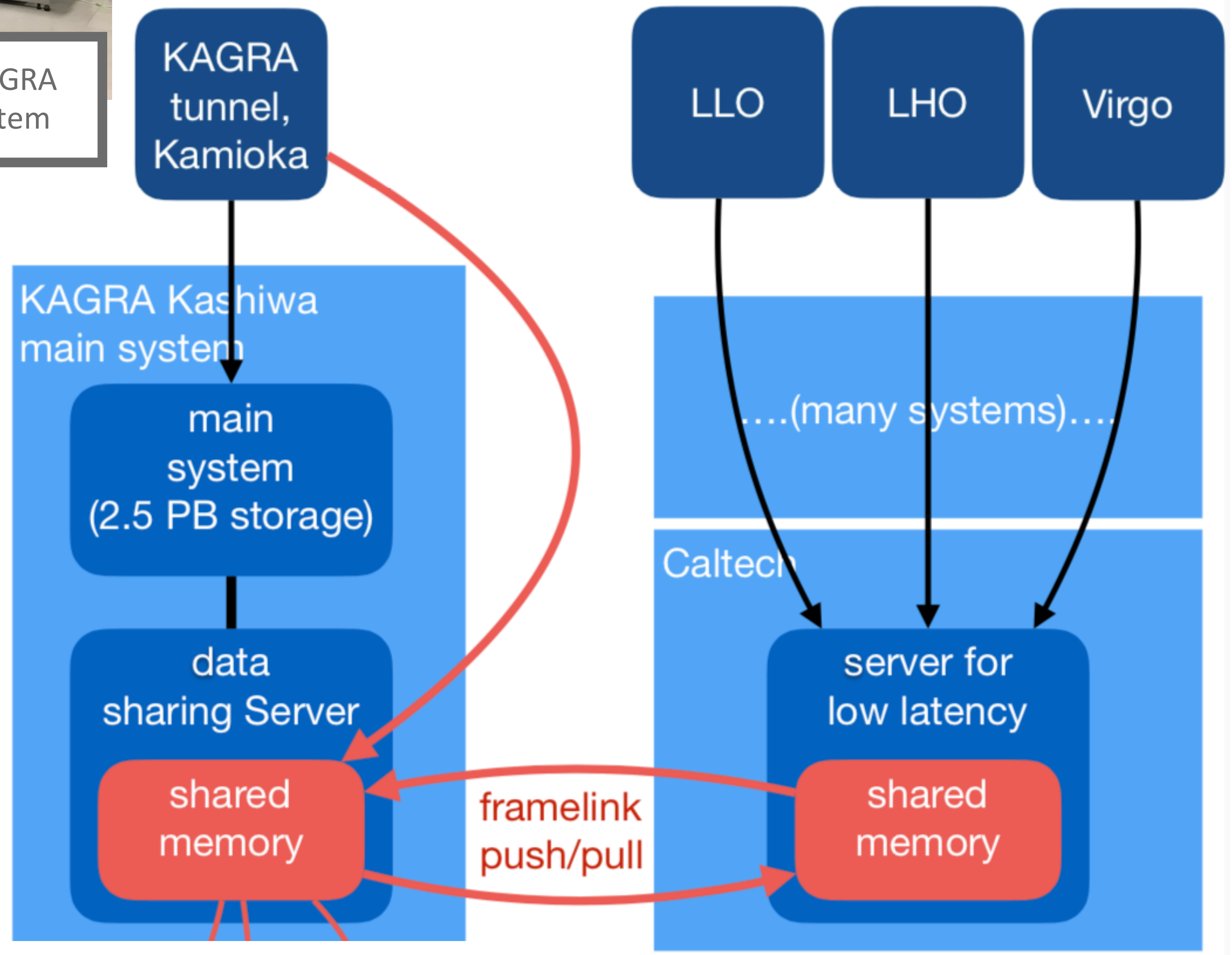
Low Latency connection with LV

LHO/LLO —> Caltech —> Kashiwa : 6-14 sec

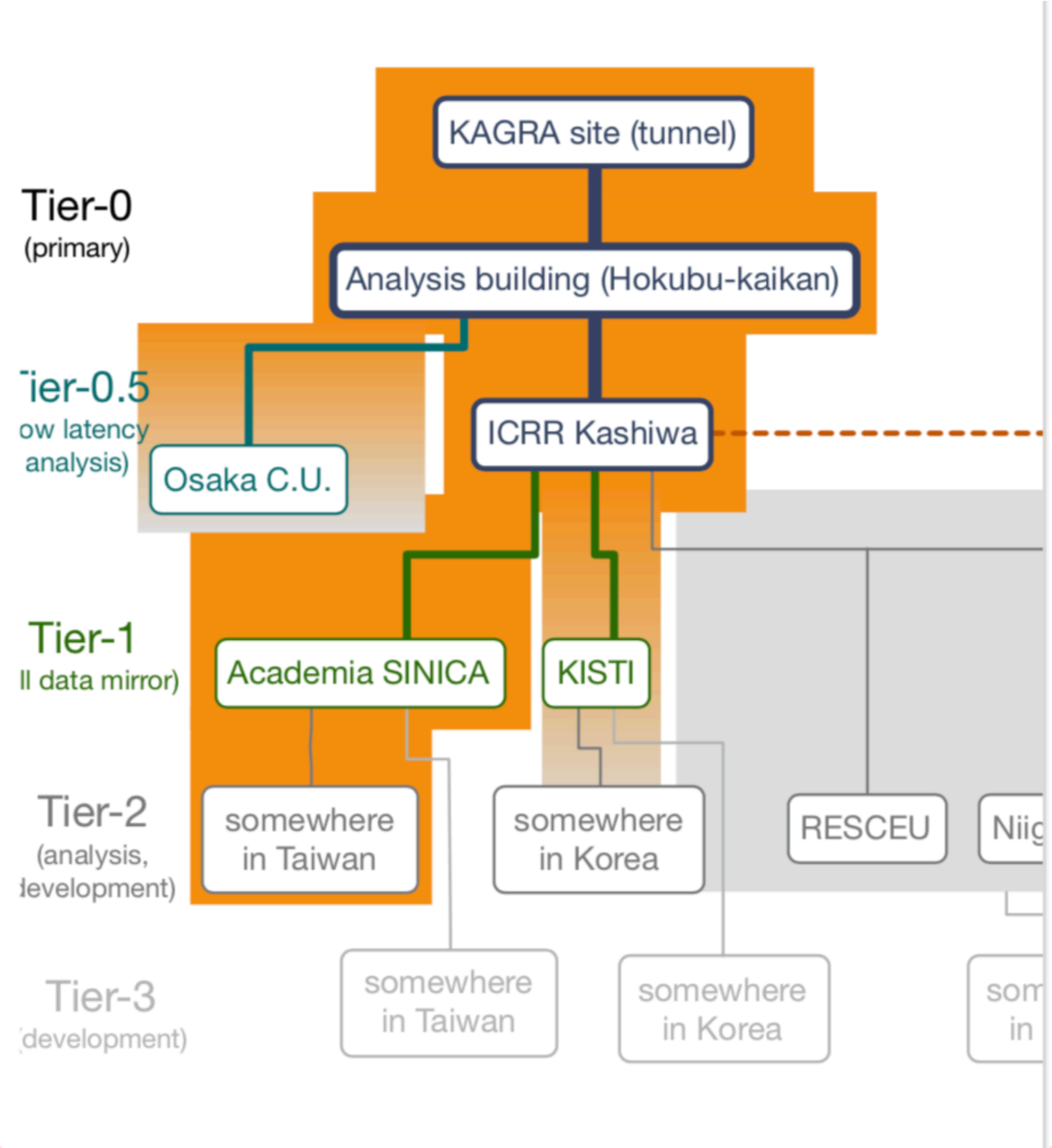
Virgo —> Caltech —> Kashiwa : 10-16 sec

(time includes reconstruction)





by N. Kanda



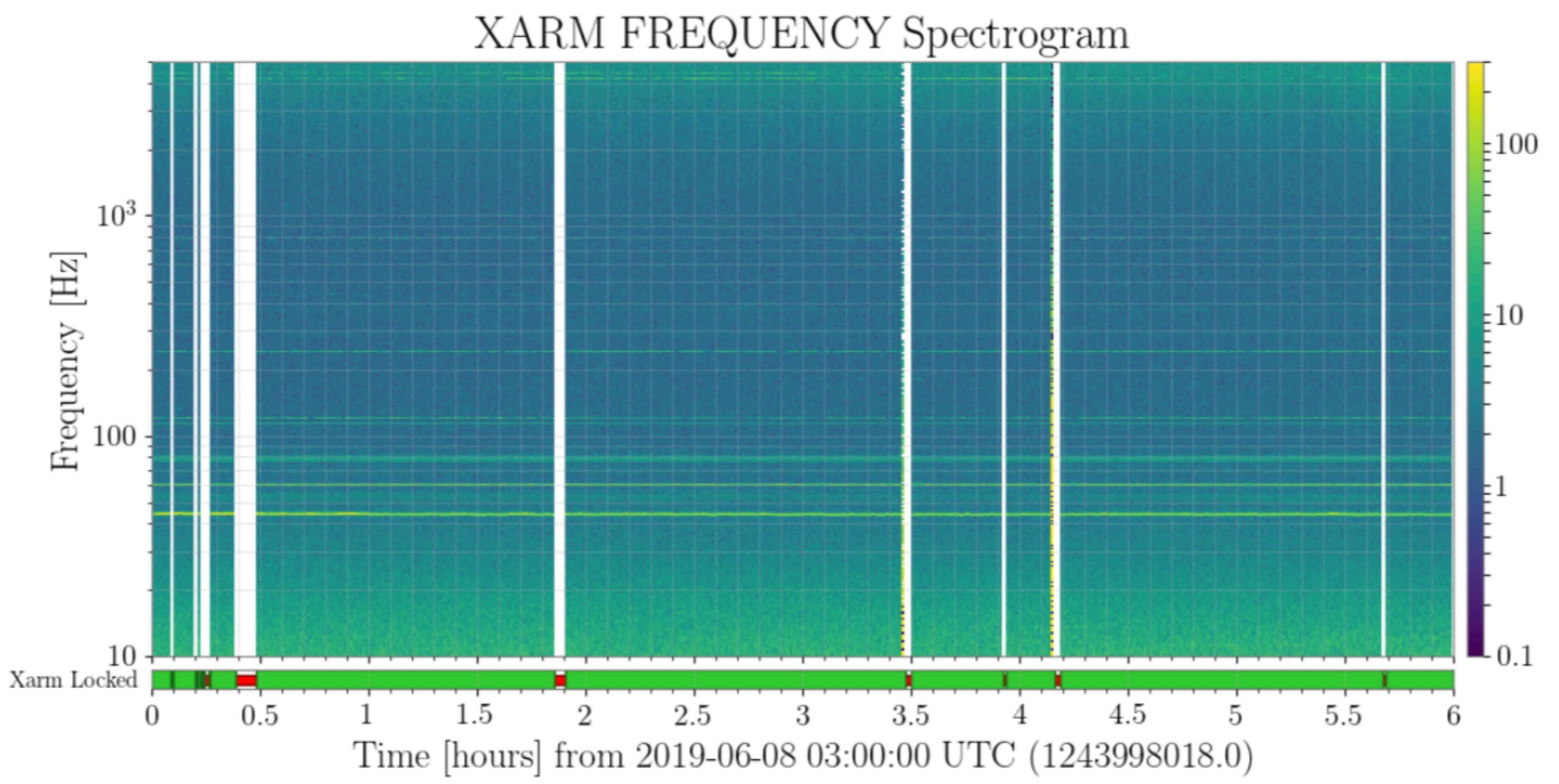
LV data distribution to Tier-x level will be monitored by Tier-site managers.

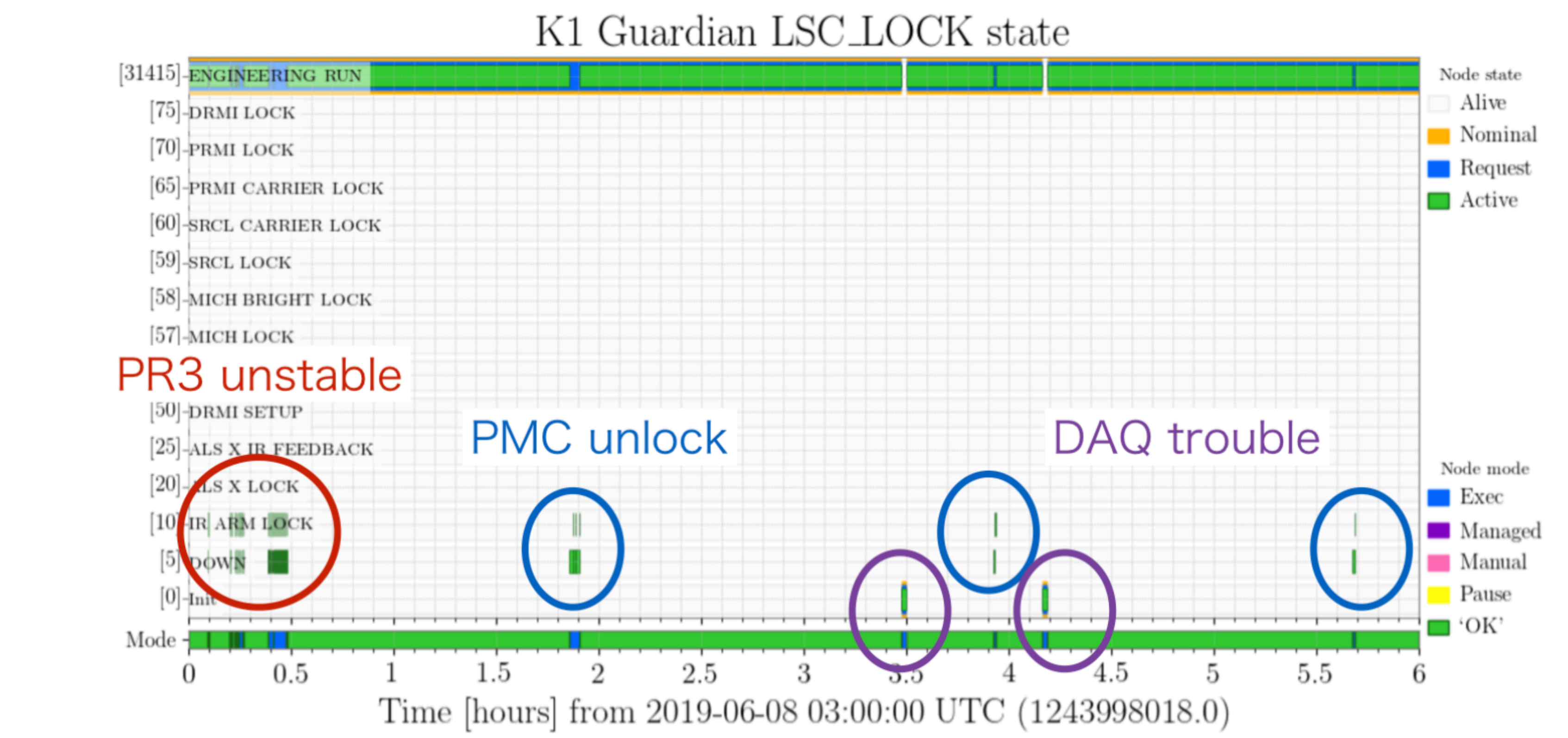
Test runs

June 8, X-arm for 5.5 hrs/6 hrs

We conducted the 1st engineering run at June 8th 12:00-18:00(JST)
- **X arm lock with IR main laser**
- Total duty cycle of the science mode was **94.8%**

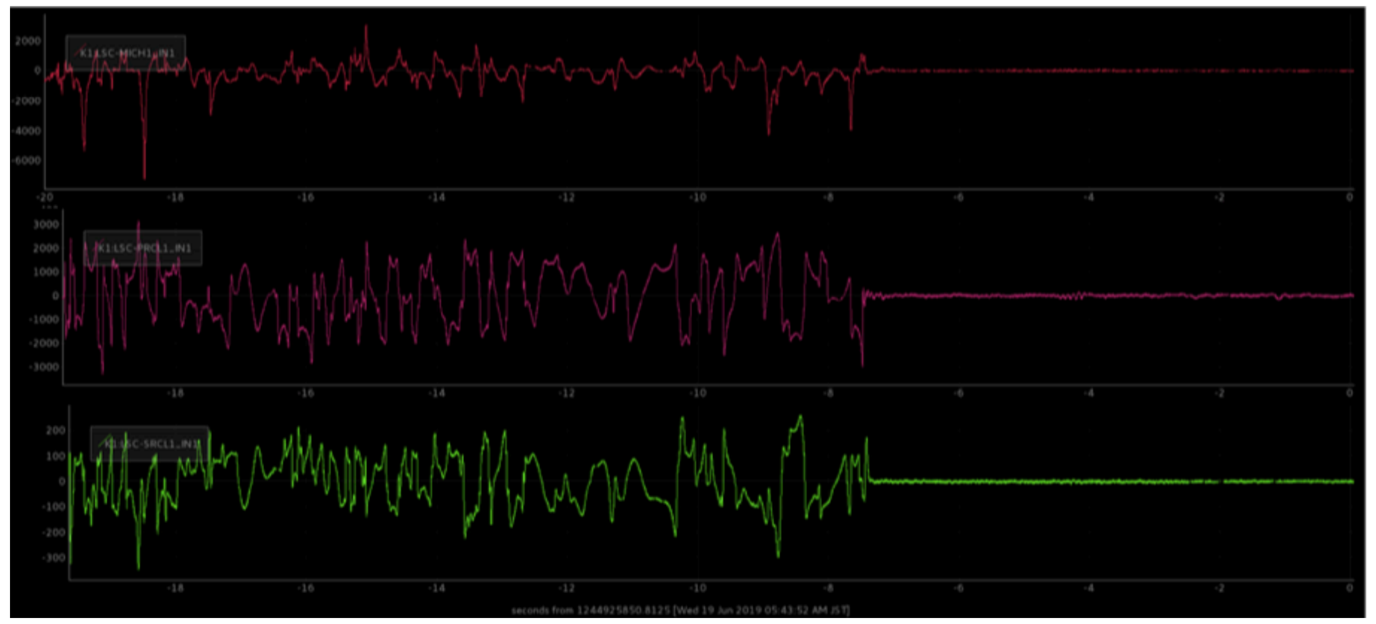
- Transient noise and narrow band frequency(line) noise identification
- Coherent channel search between main channel and PEM/IFO control signals/ instrument signals





June 19, DRMI first locked

- only PR, SR parts were tested.
- locked in 10 sec, locked for a couple of mins
- We began searching the best parameters



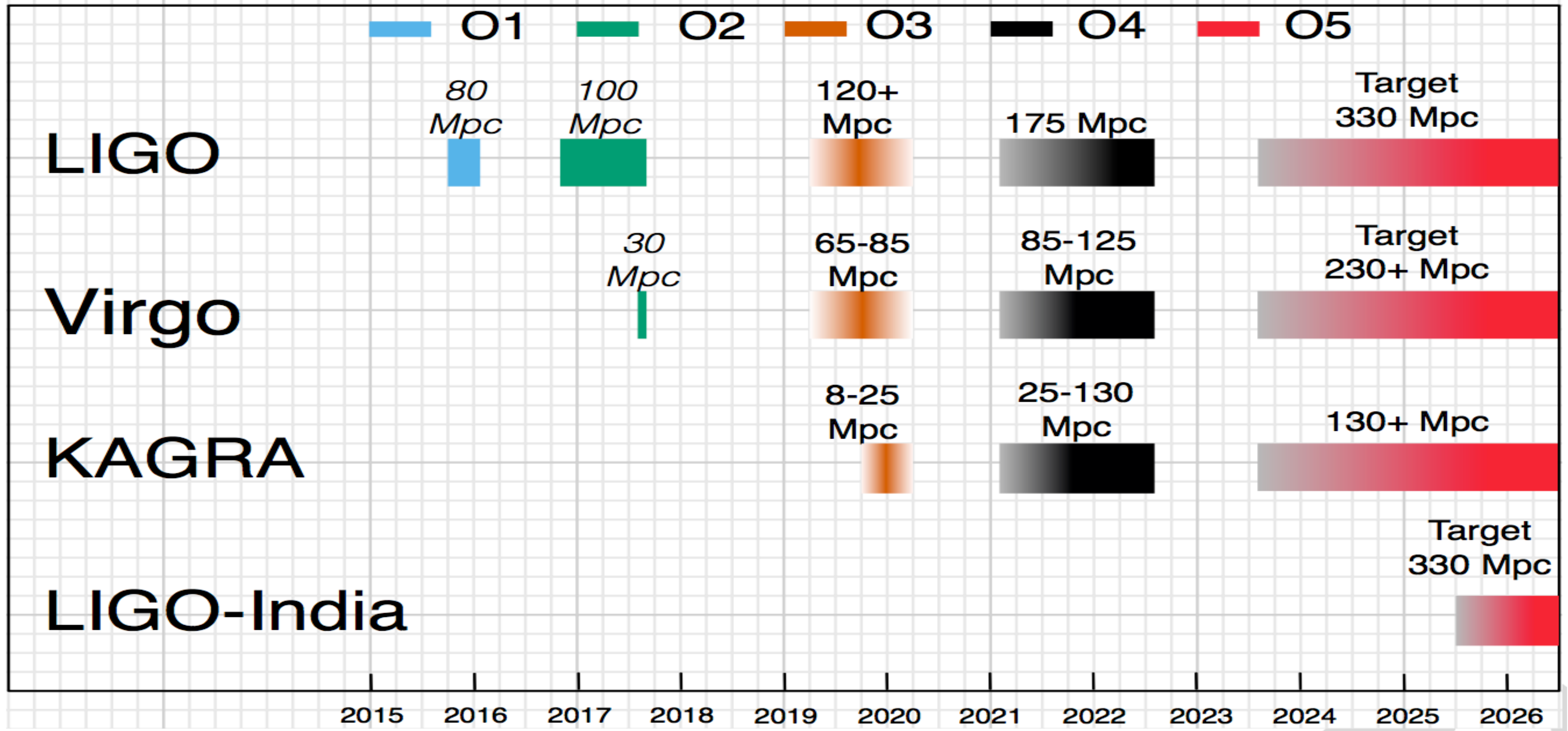
- MICH error signal
- PRCL error signal
- SRCL error signal

July 13, Engineering Run

Interferometer w cryogenic, finally…

Status of KAGRA: Summary

- KAGRA finished all the installations by April 2019, and under extensive commissioning.
- June 8, X-arm locked (d.c. 94.8% of 6 hrs)
- June 19, PR and SR locked in 10 sec, locked for several mins.
- **KAGRA plans to join O3 from the end of 2019.**



- KAGRA-LV data exchange started.
- KAGRA-LV data analysis groups meetings has started.
- KAGRA-LV MOA discussion starts soon.
- KAGRA has joined LV publication plans.

KAGRA appreciates the community's warm welcomes.

- KAGRA plans to join O4 from the beginning.