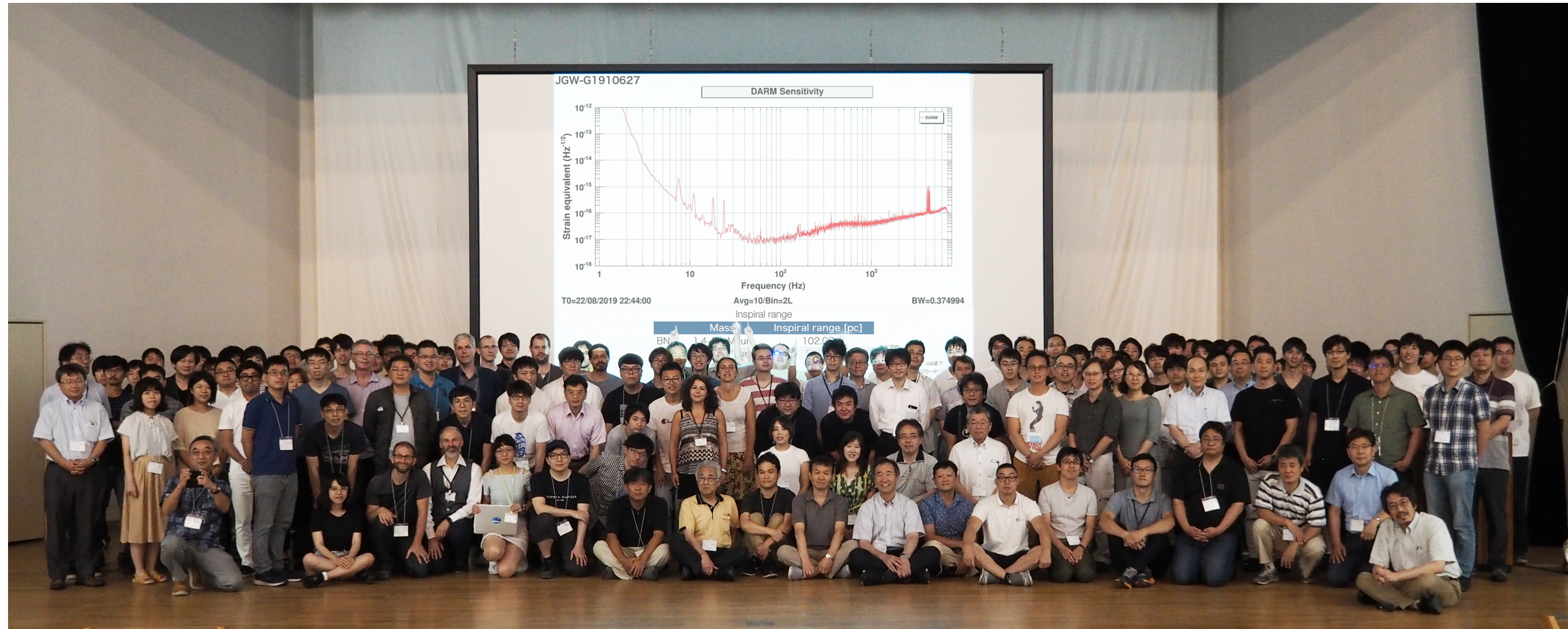


# Status of KAGRA



- ◆ **Underground** and **Cryogenic** interferometric 3 km gravitational-wave detector at Kamioka, Japan
- ◆ KAGRA finished all the installations May 2019, and the first lock of FPMI on Aug 23.
- ◆ Now trials with DRFPMI. Final configuration will be decided in the end of September.
- ◆ **KAGRA plans to join O3 from the end of 2019. (hopefully, someday in Dec.)**



Aug.23 @ KAGRA F2F meeting at Toyama

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



on behalf of the KAGRA collaboration



# KAGRA (Kamioka GW Observatory)

◆ **Underground** and **Cryogenic** interferometric 3 km gravitational-wave detector at Kamioka, Japan

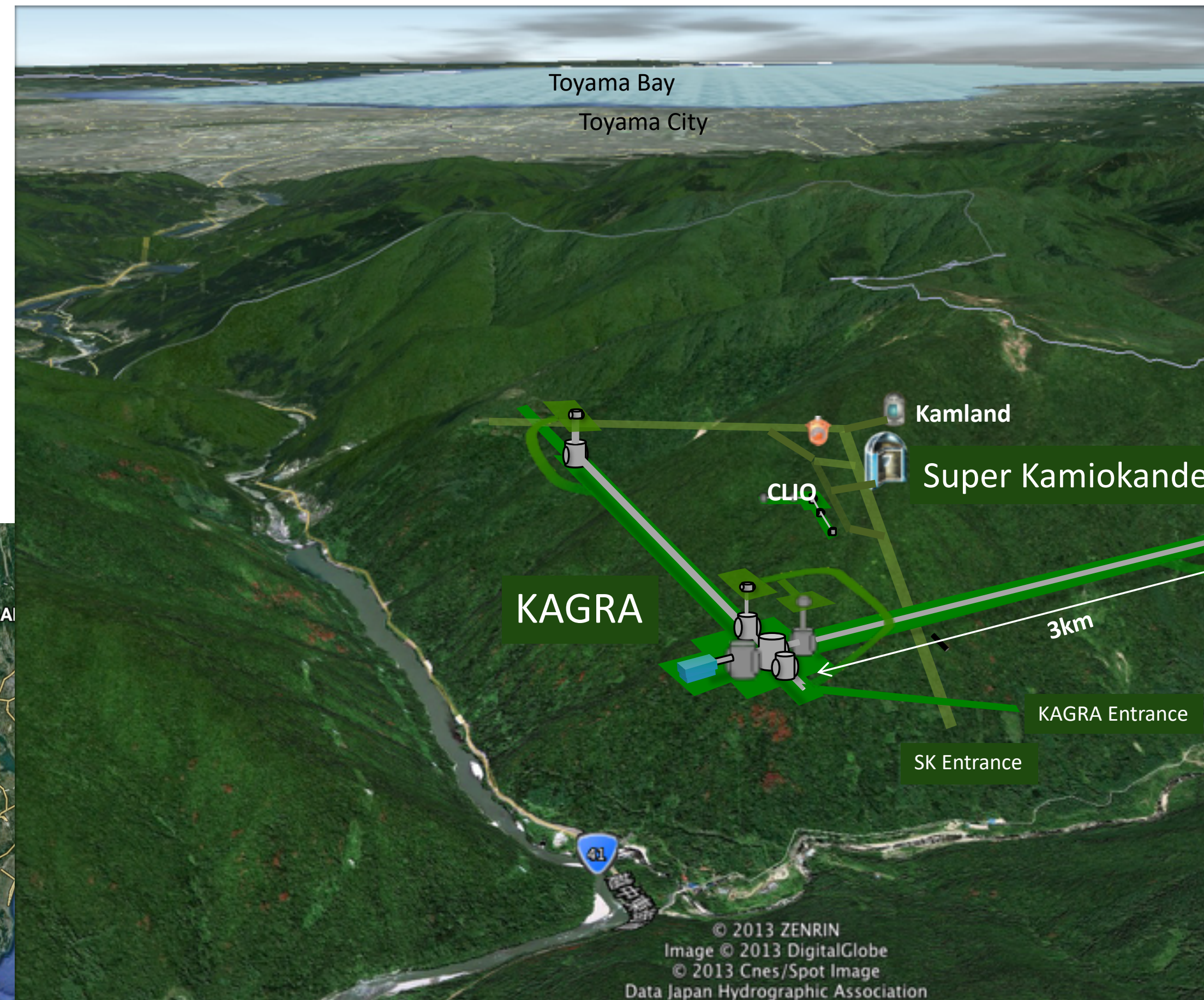


fig. by Keiko Kokeyama



# KAGRA collaboration



110 groups, 14 countries

350+ active members

Default-author list 2018 has 200 members.

Obs. shift candidate list has 260 names.

+60 collaborators in the past 6 months.

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)

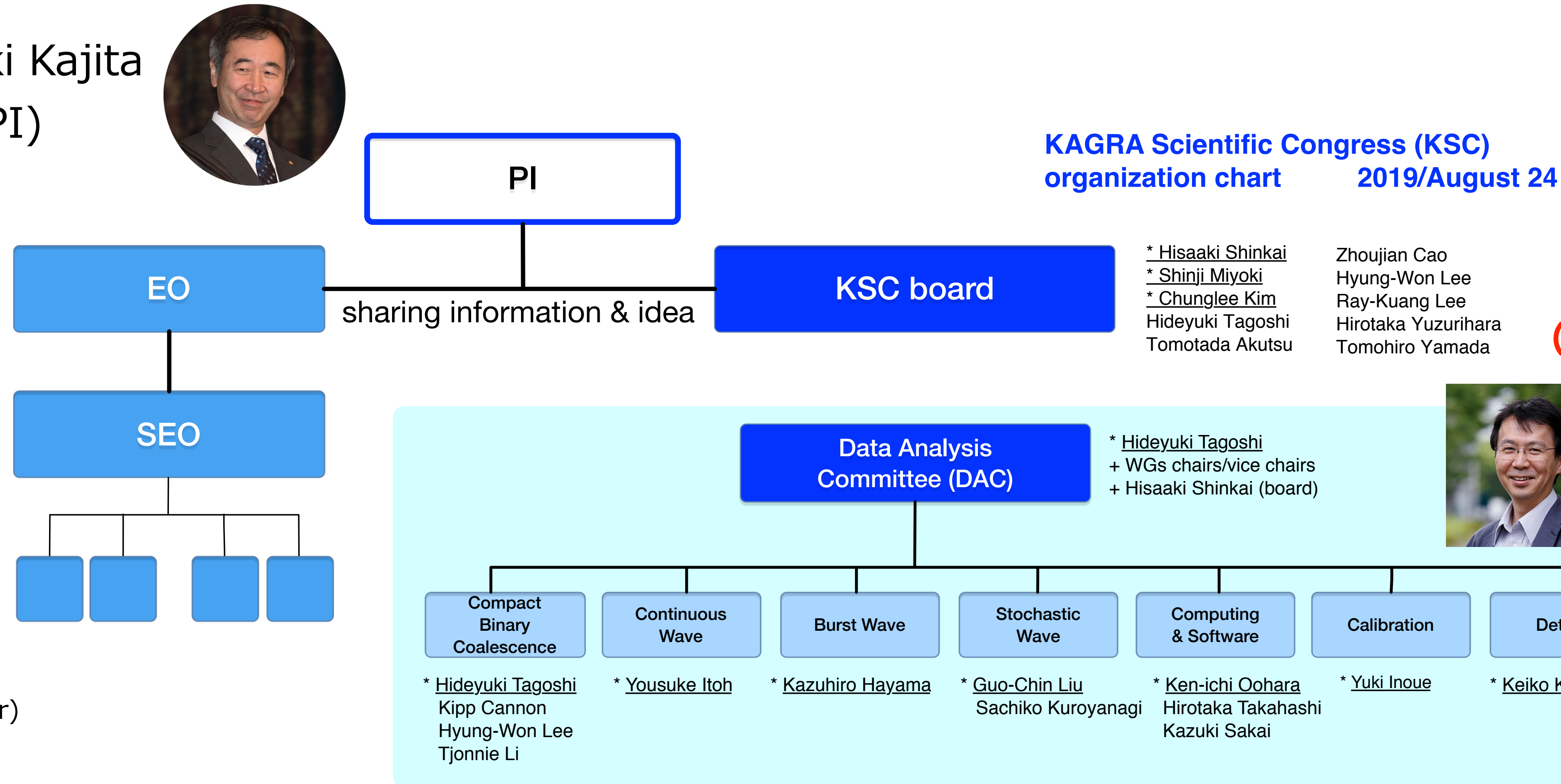
Takaaki Kajita  
(PI)



Masatake Ohashi  
(vice PI)



Yoshio Saito  
(SEO proj. manager)

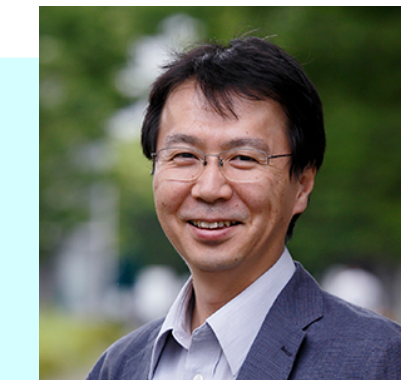


\* Hisaaki Shinkai  
\* Shinji Miyoki  
\* Chunglee Kim  
Hideyuki Tagoshi  
Tomotada Akutsu

Zhoujian Cao  
Hyung-Won Lee  
Ray-Kuang Lee  
Hirotaka Yuzurihara  
Tomohiro Yamada



◀ **New Board**  
**(2019/8-2021/8)**



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



# KAGRA collaboration papers (2019-)



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)<sup>1</sup>. The existence of GWs has been believed since Russel Hulse and Joseph Taylor discovered the binary pulsar PSR B1513 + 16 in 1974 (ref.<sup>2</sup>). 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.<sup>3</sup>). 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

IOP Publishing

Classical and Quantum Gravity

Class. Quantum Grav. **36** (2019) 165008 (22pp)  
<https://doi.org/10.1088/1361-6382/ab28a9>

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

CQG 36 (2019) 165008  
[arXiv:1901.03569]

phase-1 operation (2018)

IOPscience Journals Books Publishing Support Login

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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<sup>1</sup>

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

[What is an Accepted Manuscript?](#)

CQG 36 (2019) 095015  
[arXiv:1901.03053]

Vibration isolation

arXiv.org > astro-ph > arXiv:1908.03013

Search... Help | Adv

Astrophysics > Instrumentation and Methods for Astrophysics

### Application of the independent component analysis to the iKAGRA data

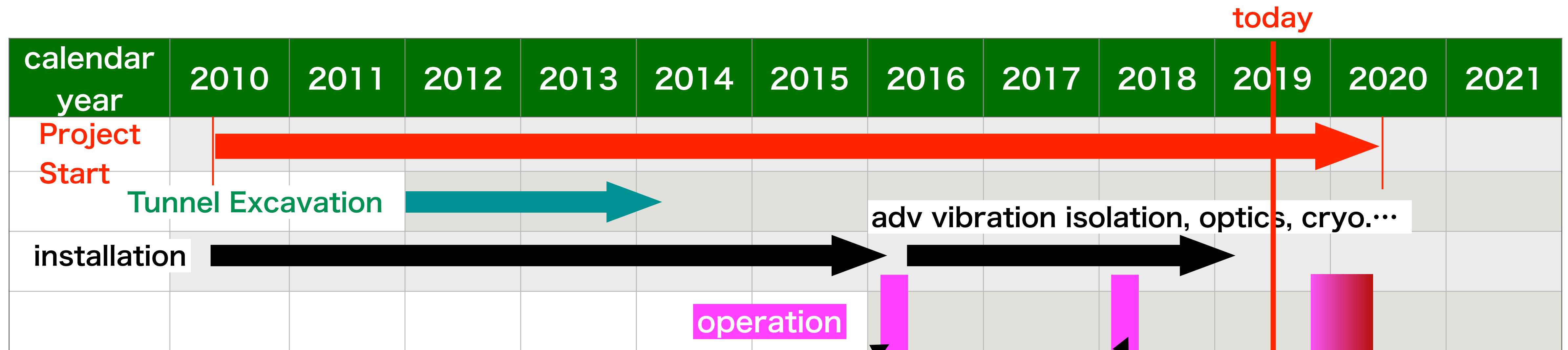
KAGRA Collaboration: T. Akutsu, M. Ando, K. Arai, Y. Arai, S. Araki, A. Araya, N. Aritomi, H. Asada, Y. Aso, S. Atsuta, K. Awai, S. Bae, Y. Bae, L. Baiotti, R. Bajpai, M. A. Barton, K. Cannon, E. Capocasa, M. Chan, C. Chen, K. Chen, Y. Chen, H. Chu, Y.-K. Chu, K. Craig, W. Creus, K. Doi, K. Eda, S. Eguchi, Y. Enomoto, R. Flaminio, Y. Fujii, M.-K. Fujimoto, M. Fukunaga, M. Fukushima, T. Furuhashi, G. Ge, A. Hagiwara, S. Haino, K. Hasegawa, K. Hashino, H. Hayakawa, K. Hayama, Y. Himemoto, Y. Hiranuma, N. Hirata, S. Hirobayashi, E. Hirose, Z. Hong, B. H. Hsieh, G.-Z. Huang, P. Huang, Y. Huang, B. Ikenoue, S. Imam, K. Inayoshi, Y. Inoue, K. Ioka, Y. Itoh, K. Izumi, K. Jung, P. Jung, T. Kaji, T. Kajita, M. Kakizaki, M. Kamiizumi, S. Kanbara, N. Kanda, S. Kanemura, M. Kaneyama, G. Kang, J. Kasuya, Y. Kataoka, K. Kawaguchi, N. Kawai, S. Kawamura, T. Kawasaki, C. Kim, J. C. Kim, W. S. Kim, Y.-M. Kim, N. Kimura, T. Kinugawa, S. Kirii, N. Kita, Y. Kitaoka, H. Kitazawa, Y. Kojima, K. Kokeyama, K. Komori, A. K. H. Kong, K. Kotake, C. Kozakai, R. Kozu, R. Kumar, J. Kume, C. Kuo, H.-S. Kuo, S. Kuroyanagi et al. (152 additional authors not shown)

(Submitted on 8 Aug 2019)

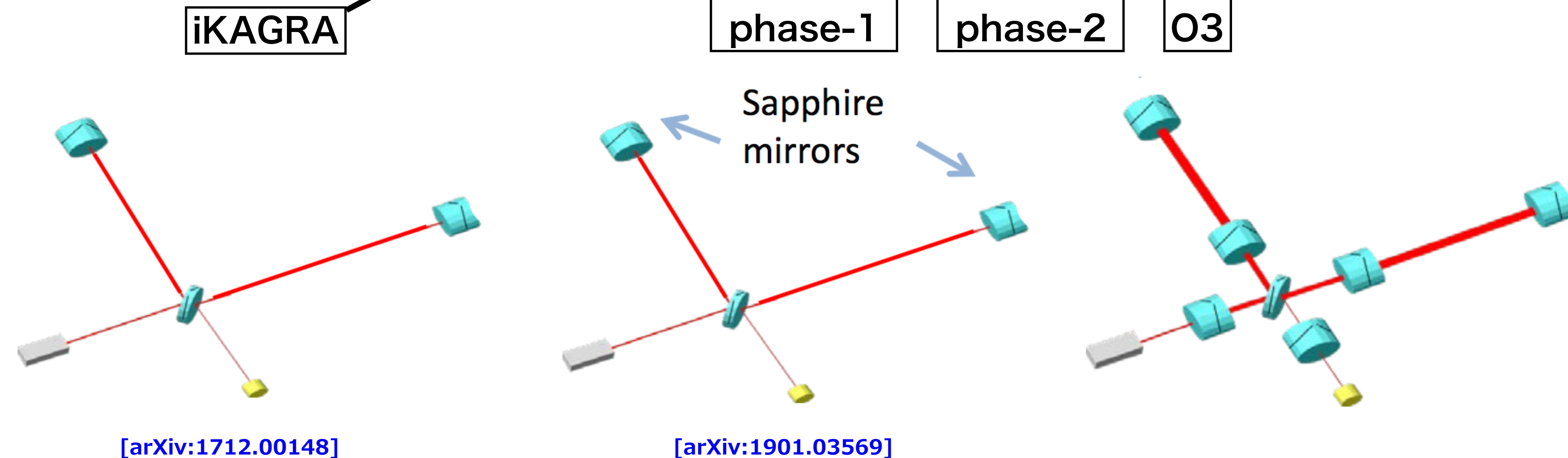
submitted to PTEP [arXiv:1908.03013] [JGW-P1910218]  
iKAGRA data (2016) analysis



# Brief History of KAGRA

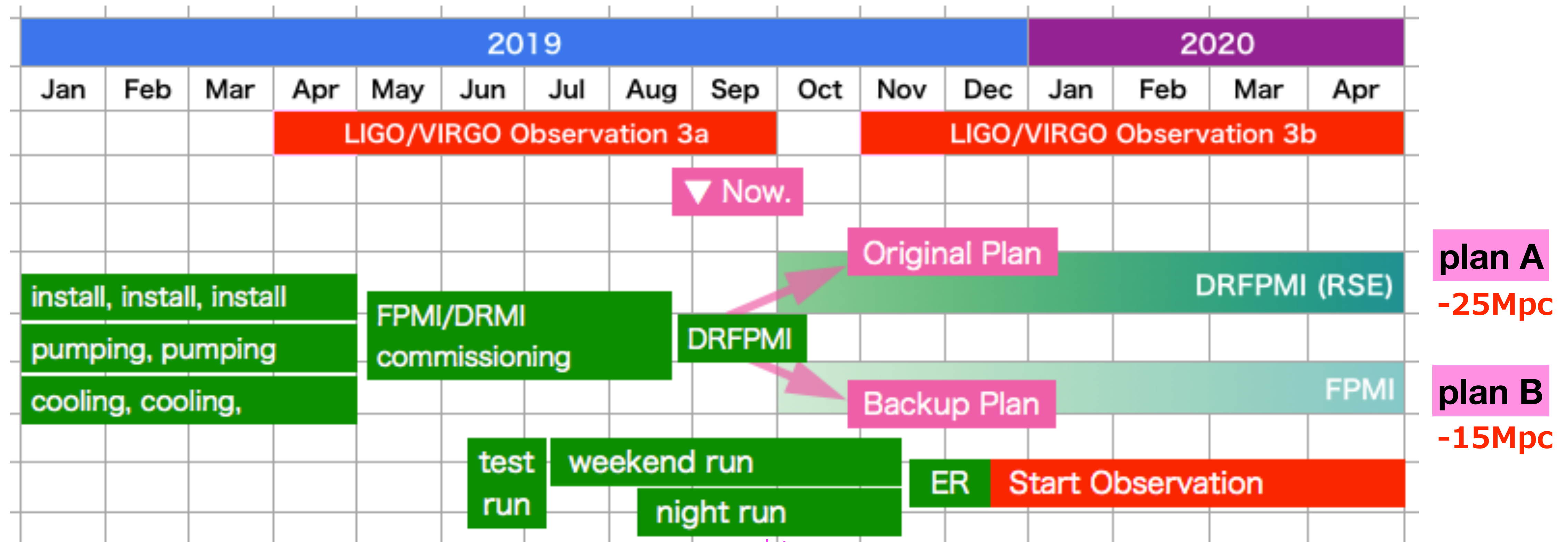


iKAGRA = initial KAGRA  
bKAGRA = baseline KAGRA





# On-going schedule



We are commissioning with FPMI with PR & SR.

Test Runs:

June 6 X-arm

June 19 PR, SR

July 13 short IFO

August 23 First lock of FPMI, 5+ hours, 1 kpc BNS range

**Oct. 4**

Celebration to Commemorate  
the Completion of KAGRA

**End of Sep.**

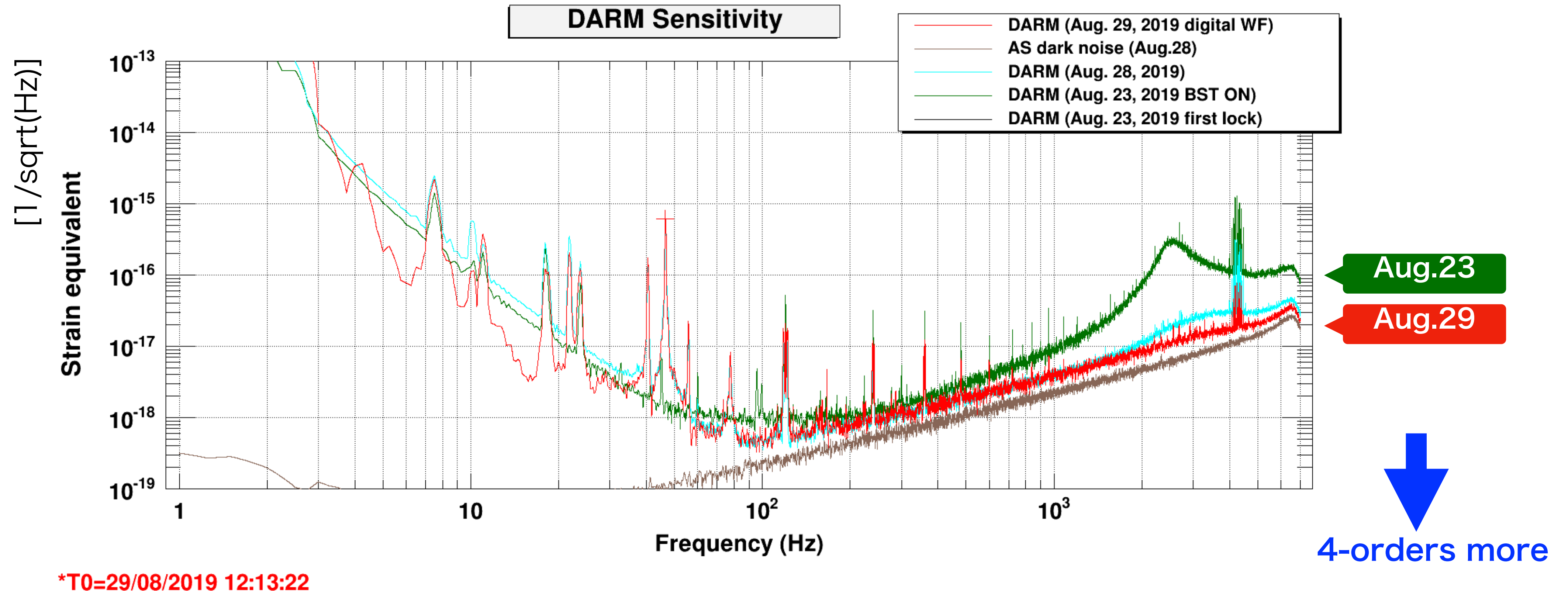
**Final decision of configuration**

if DRFPMI is locked in September, DRFPMI.



**August 23 First lock of FPMI**

automated, 5+ hours, &gt;1 kpc BNS range



We appreciate contributions of **Stefan Ballmer, Valery Frolov, Keita Kawabe** (July & August), **Rana Adhikari, Stefan Ballmer, Jenne Driggers** (September) at KAGRA on-site.



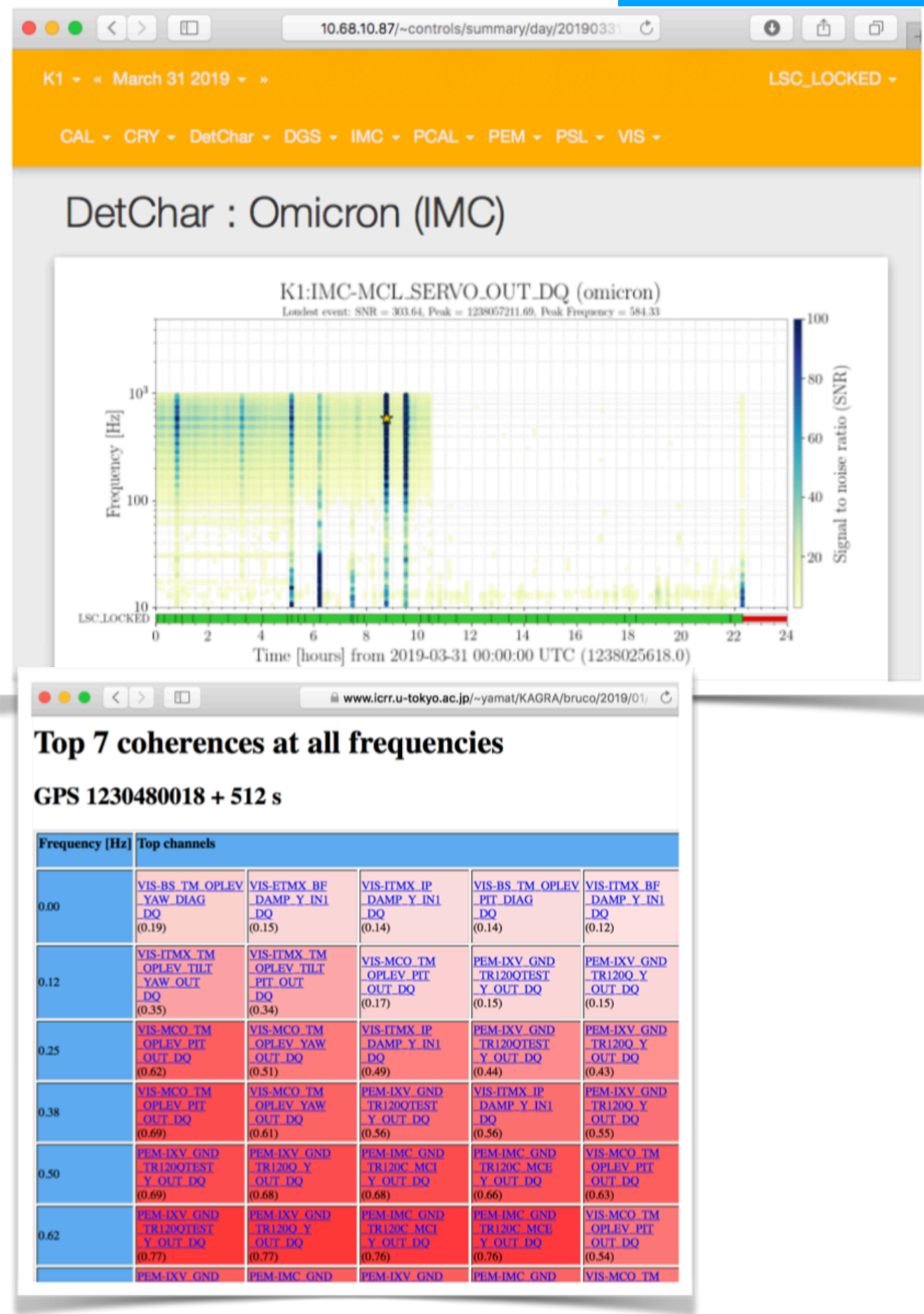
## Current Concerning Issues

- \* **Asymmetry of Finesse** ( $\sim 10\%$ ) due to difference of transmissivity of ITMx & ITMy
  - ➡ OK for O3, to be fixed by O4
- \* **Polarization (sapphire birefringence)** due to inhomogeneity of ITMx & ITMy
  - ➡ low PR & SR gain, no replacements for O3. May be the same in O4.
- \* **Frosting of Mirrors** due to incompleteness of vacuum
  - ➡ re-heat, outgas, and re-cool
- \* **Refrigerator maintenance cycle** (Mean Time Between Failure) is shorter than expected
  - ➡ thermal shield valves, every two weeks, \$ 5K
- \* **Type A Suspensions** (ITMs ETMs) requires stabilazation circuit
  - ➡ requires better damping servos



# Commissioning tools

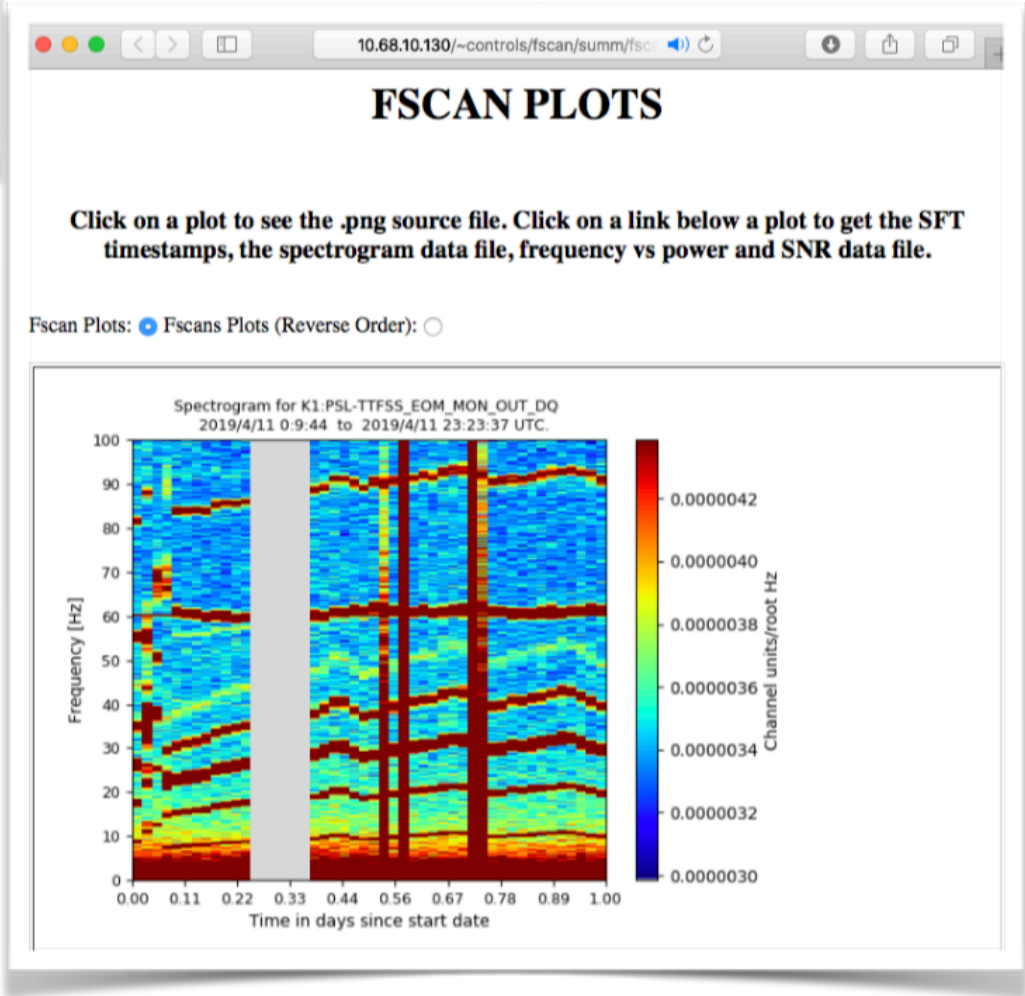
## LV DetChar tools



Coherence search (Bruco)

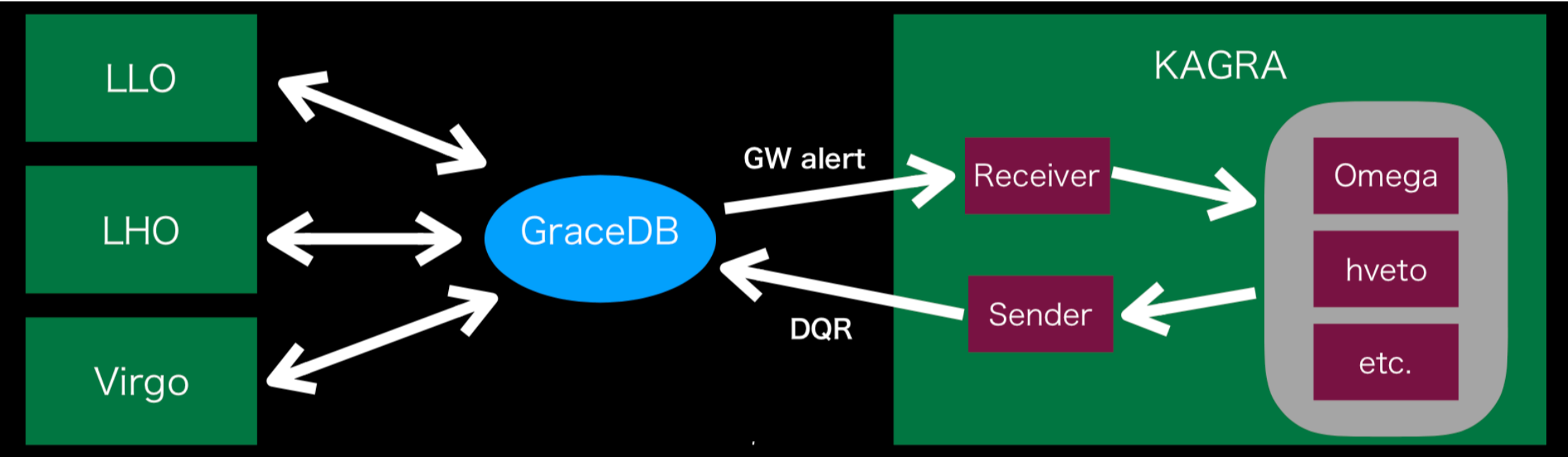
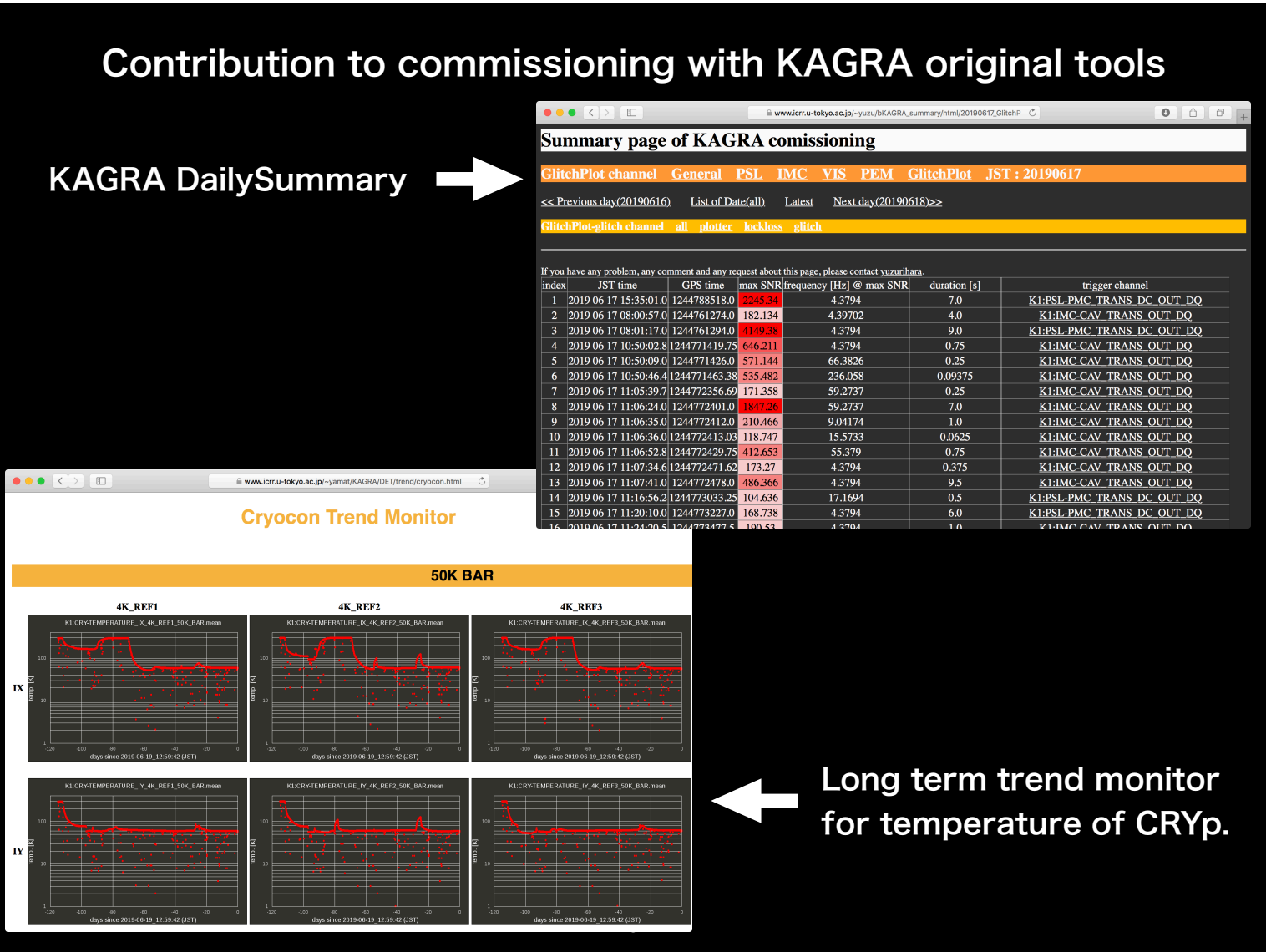
## Glitch trigger generation (Omicron)

## Diagnostics Test Tool (DiagGui)



Spectral Line identification (Fscan)

## KAGRA original tools



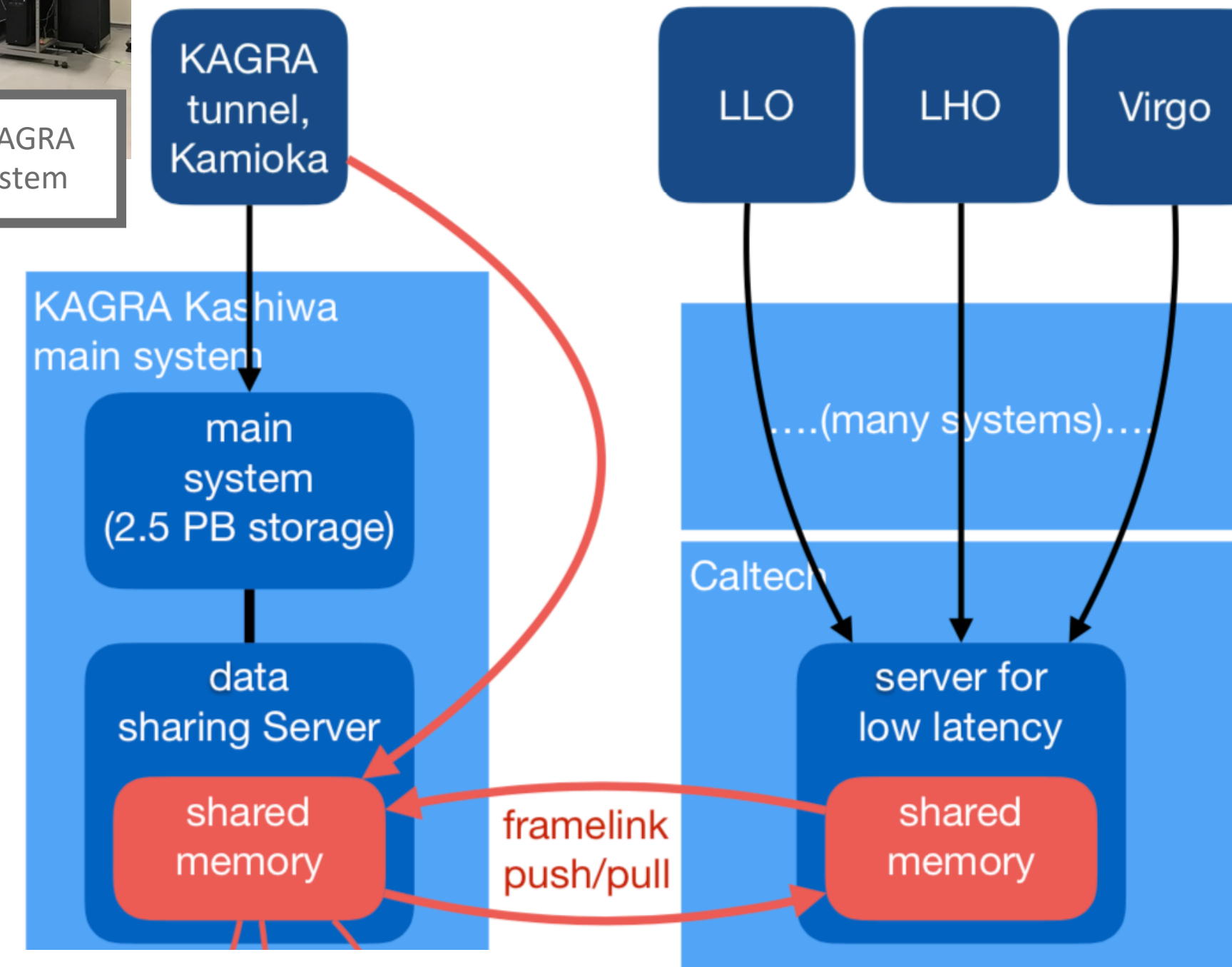
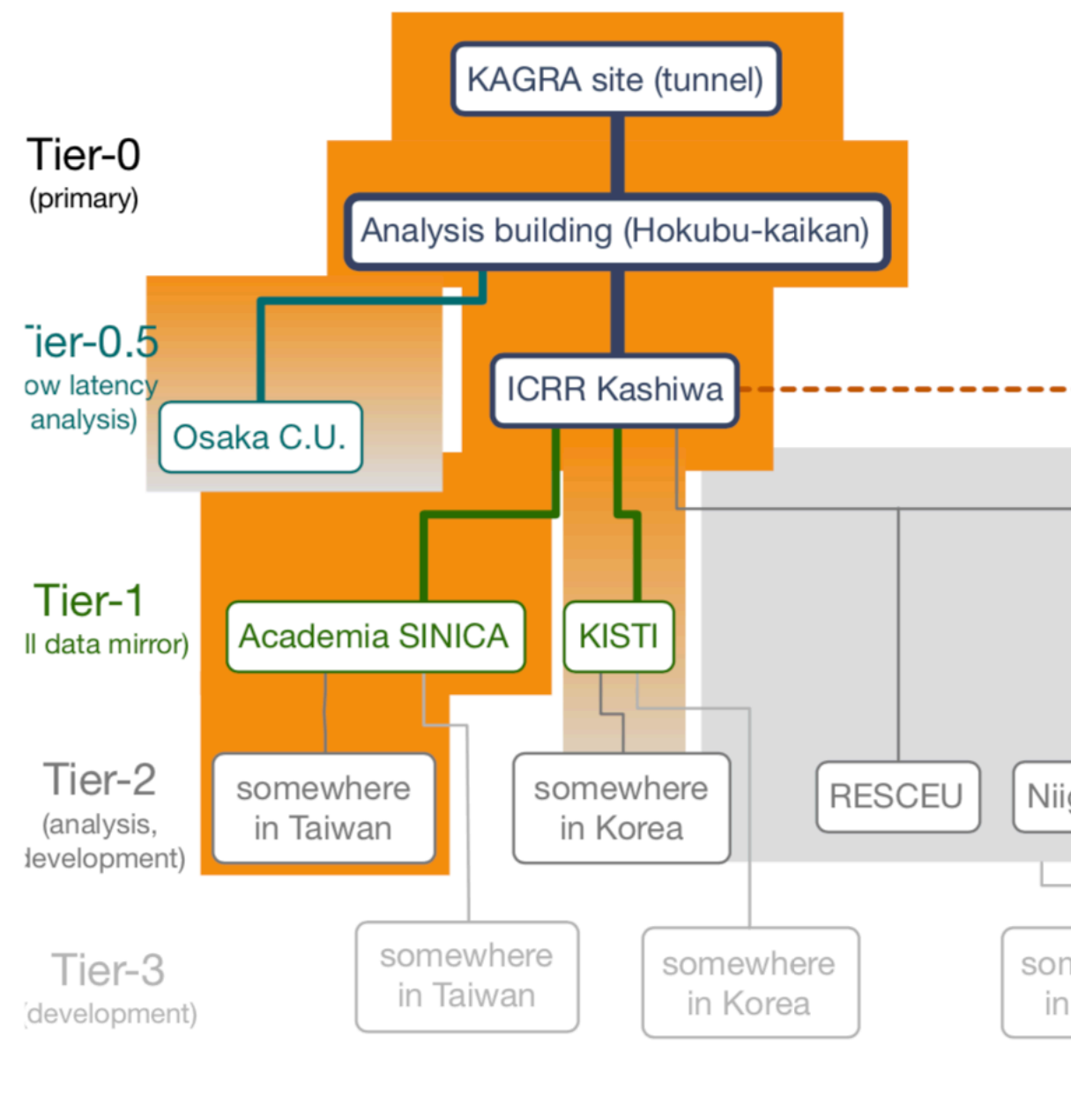
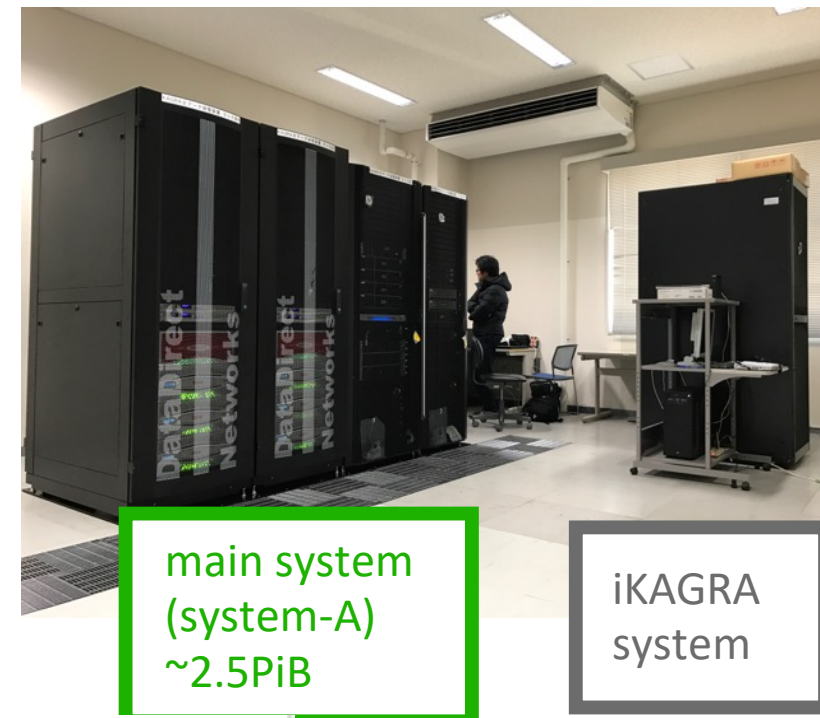
by T. Yamamoto

We appreciate contributions of **Joseph Areeda, Nicolas Arnaud, Andrew Lundgren, Duncan MacLeod, Florent Robinet, Siddharth Soni, Alex Urban** at KAGRA on-site.



# Data-exchange tests with low latency

Exchange (sharing) is already connected and is **working**. *(Thanks for LV's great cooperation!)*



Low Latency h(t) transfer

KAGRA tunnel → Tokyo-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.





KAGRA focused week: June 6 & August 1

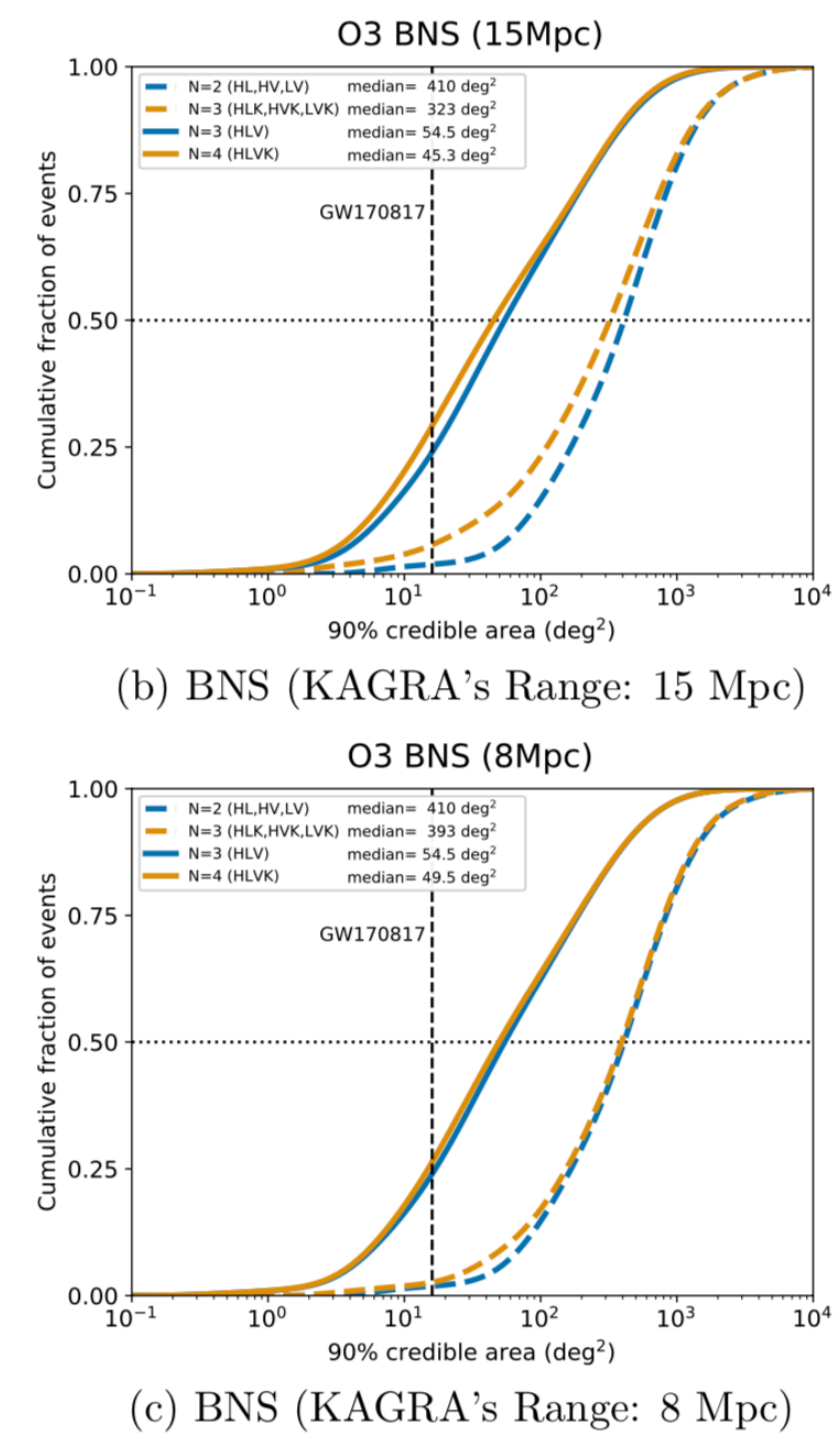
<https://wiki.ligo.org/LSC/JRPCComm/Agenda2019Jun06>  
<https://wiki.ligo.org/LSC/JRPCComm/Agenda2019Aug01>

LVC-KAGRA taskforce term report (draft)

[G1901425](#)  
[JGW-T1910330](#)

LVC-KAGRA taskforce

- Yoshio Saito (KAGRA - leader, project manager)  
Hideyuki Tagoshi (KAGRA - Data analysis)  
Takahiro Yamamoto (KAGRA - Calibration)  
Osamu Miyakawa (KAGRA - commissioning)  
Hisaaki Shinkai (KAGRA - MoU)  
Sadakazu Haino (KAGRA data analysis)
- Steve Fairhurst (LSC)  
Patricia Schmidt (LSC)  
Leo Singer (LSC)  
Marie Anne Bizouard (Virgo)  
Helios Vocca (Virgo)



How much source localization is improved.

(a) KAGRA’s BNS range: 25 Mpc				
Source	(HL, HV, LV)	(HLK, HVK, LVK)	HLV	HLVK
BBH	607	336	79.2	57
NSBH	682	384	90.2	67.9
BNS	410	215	54.5	35.3

(b) KAGRA’s BNS range: 15 Mpc				
Source	(HL, HV, LV)	(HLK, HVK, LVK)	HLV	HLVK
BBH	545	447	68.1	53.8
NSBH	614	482	75.2	60.5
BNS	410	323	54.5	45.3

(c) KAGRA’s BNS range: 8 Mpc				
Source	(HL, HV, LV)	(HLK, HVK, LVK)	HLV	HLVK
BBH	545	525	68.1	65.4
NSBH	614	567	75.2	68.3
BNS	410	393	54.5	49.5

Table 1: The median of the distribution of 90%-credible region of the source localization. All values are in the unit of deg<sup>2</sup>.

How much multi-detector duty-cycle is improved.

Table 4: Observing duty cycles as of July 31, 2019. [5]

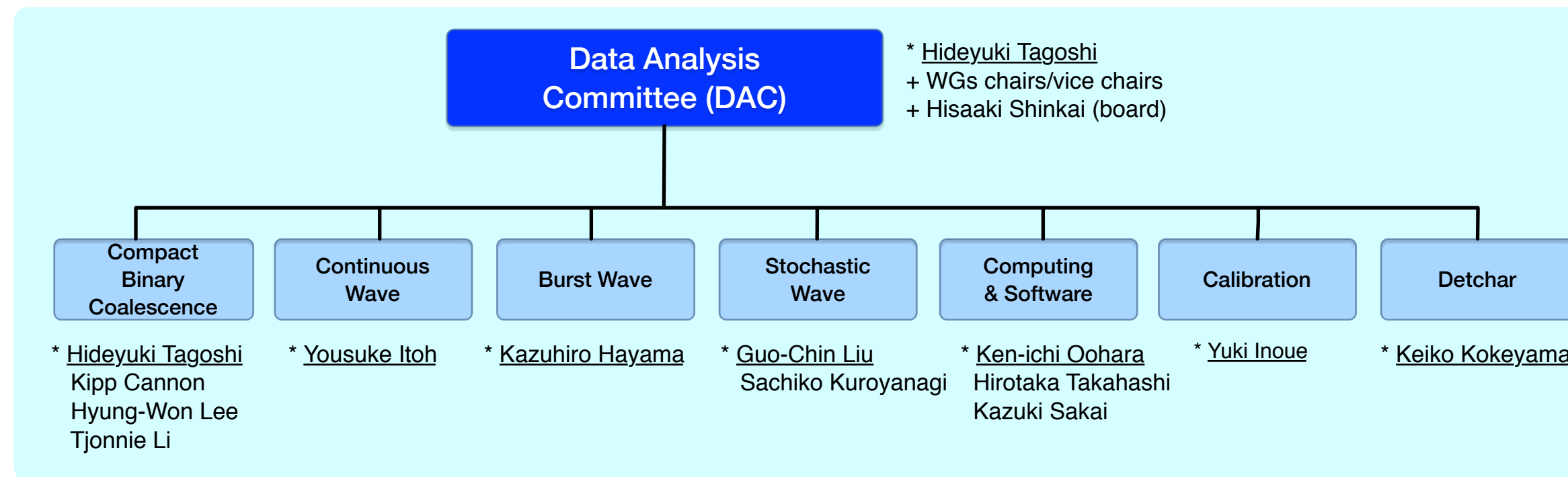
	H1	L1	V1		actual	estimated
Observing	69.7 %	72.9 %	76.4 %	Triple	42.7 %	38.8 %
Ready	0.8 %	0.4 %		Double	37.2 %	45.7 %
Locked	3.3 %	3.7 %	5.7 %	Single	16.2 %	15.9 %
Not locked	26.2 %	23.0 %	17.9 %	No interferometer	3.9 %	1.9 %

probability calculation

Table 5: Estimation of the observing duty cycles for several cases of that of KAGRA ( $P_K$ ), using  $P_H^{O3} = 0.697$ ,  $P_L^{O3} = 0.729$ , and  $P_V^{O3} = 0.764$  (the numbers of H1/L1/V1 of July 31, 2019).

$P_K$	0.4	0.5	0.6	0.7	0.8	0.9
Quadra	15.5 %	19.4 %	23.2 %	27.2 %	31.1 %	34.9 %
Triple	40.6 %	41.1 %	41.5 %	42.0 %	42.4 %	42.9 %
with K	17.3	21.6	26.0	30.3	34.7	39.0
w/o K	23.3	19.4	15.5	11.6	7.8	3.9
Double	32.4 %	29.6 %	26.9 %	24.1 %	21.4 %	18.7 %
with K	6.4	8.0	9.6	11.2	12.8	14.3
w/o K	26.0	21.7	17.3	13.0	8.7	4.3
Single	10.3 %	8.9 %	7.5 %	6.1 %	4.7 %	3.3 %
No interferometer	1.2 %	1.0 %	0.8 %	0.6 %	0.4 %	0.2 %





## LV-DAC white paper 2019

## LV-DAC publication plan O3b

### ◀ at least 3 new proposals from KAGRA-CBC

Ringdown search

BH echo search

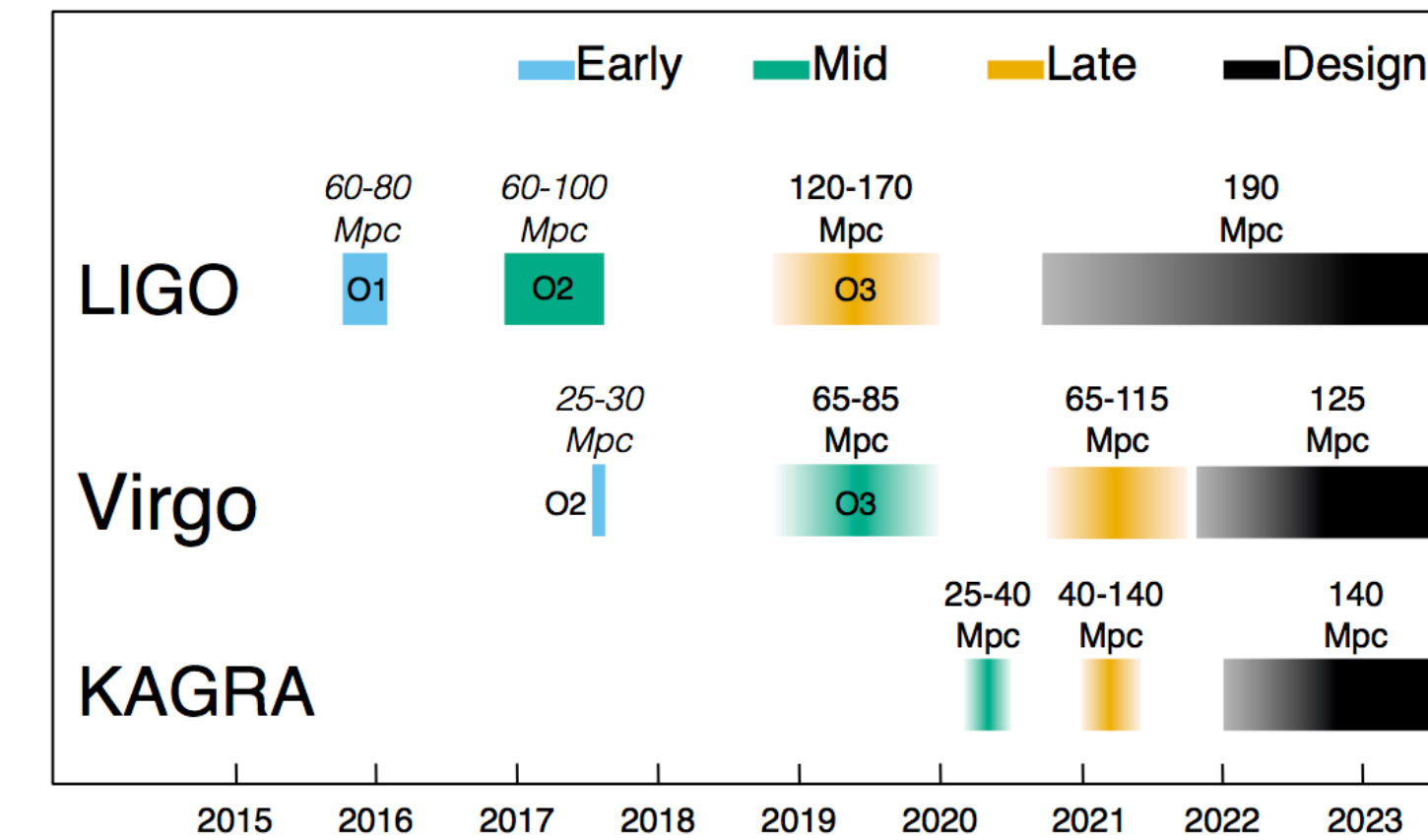
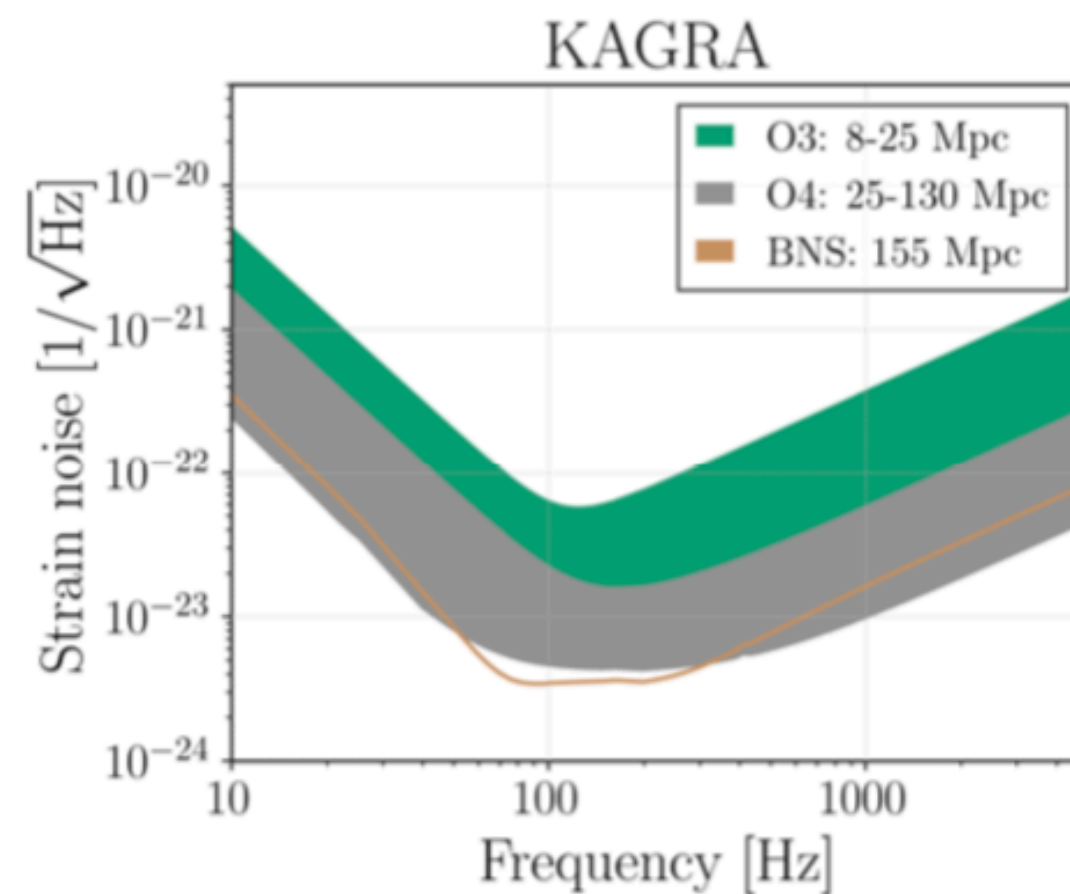
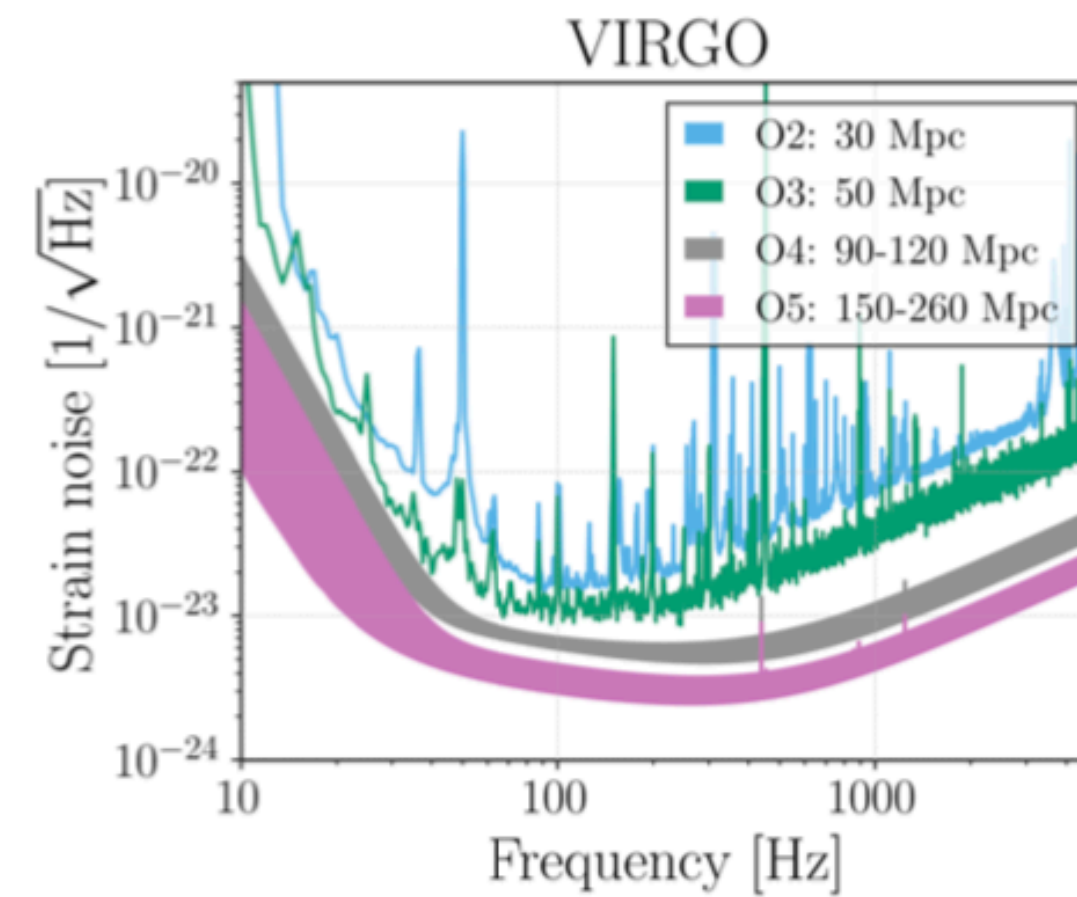
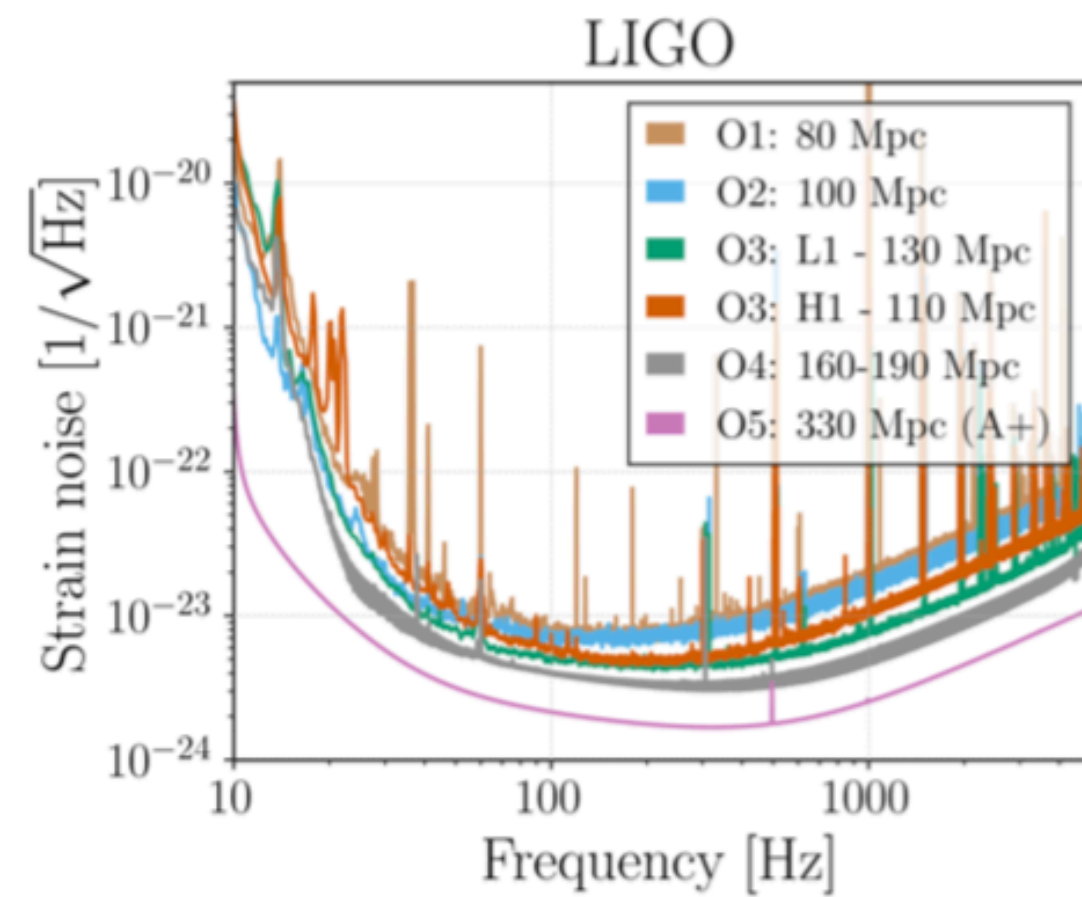
test of massive gravity

### ◀ participating Parameter Estimation ROTation from O3b

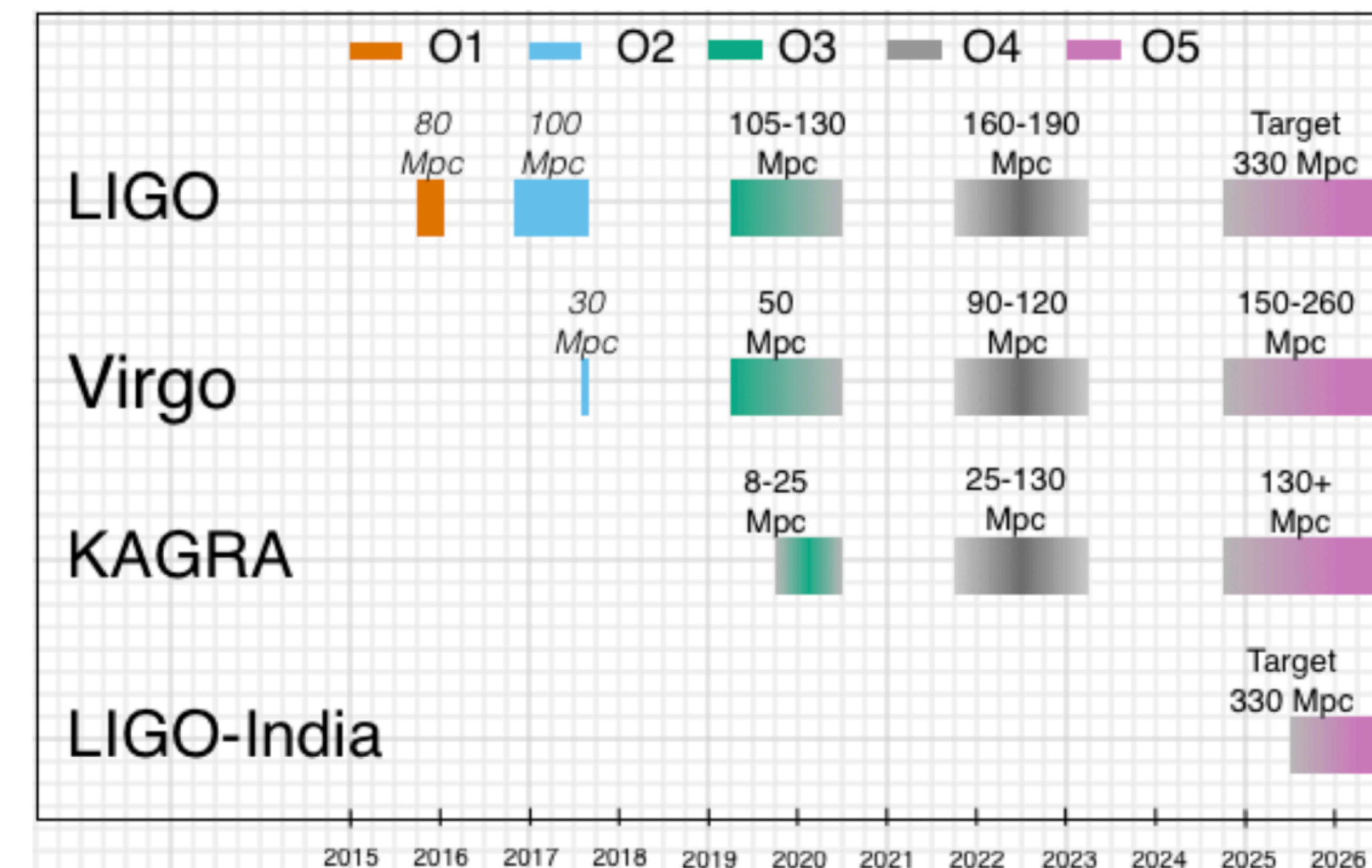
Revision plan of "LVK MoU"	
The LV MoU (March 2019)	The revision plan
<p><b>Memorandum of Agreement</b></p> <p>between</p> <p><b>VIRGO</b></p> <p>and the</p> <p><b>Laser Interferometer Gravitational Wave Observatory (LIGO)</b></p> <p>March 2019</p> <p><b>Purpose of agreement:</b></p> <p>The purpose of this Memorandum of Agreement (MOA) is to establish and define a collaborative relationship between VIRGO and the Laser Interferometer Gravitational Wave Observatory (LIGO) to develop and exploit laser interferometry to measure and study gravitational waves.</p> <p>We enter into this agreement in order to lay the groundwork for decades of world-wide collaboration. We intend to carry out</p>	<p><b>Memorandum of Agreement</b></p> <p>between</p> <p><b>VIRGO,</b></p> <p><b>KAGRA</b></p> <p>and the</p> <p><b>Laser Interferometer Gravitational Wave Observatory (LIGO)</b></p> <p><b>October 2019</b></p> <p><b>Purpose of agreement:</b></p> <p>The purpose of this Memorandum of Agreement (MOA) is to establish and define a collaborative relationship between VIRGO, <b>KAGRA</b> and the Laser Interferometer Gravitational Wave Observatory (LIGO) to develop and exploit laser interferometry to measure and study gravitational waves.</p> <p>We enter into this agreement in order to lay the groundwork for decades of world-wide collaboration. We intend to carry out the</p>



# Target Sensitivity & Schedule



[1304.0670v4]

<https://dcc.ligo.org/LIGO-P1900218/public>


“Scenario Paper”

Living Rev Relativ (2018) 21:3

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

[1304.0670v4]



# Status of KAGRA: Summary



- ◆ KAGRA finished all the installations May 2019, and the first lock of FPMI on Aug 23.
- ◆ Now trials with DRFPMI. Final configuration will be decided in the end of September.
- ◆ **KAGRA plans to join O3 from the end of 2019. (hopefully, someday in Dec.)**
- ◆ KAGRA-LV data exchange started.
- ◆ KAGRA-LV data analysis groups meetings has started.  
(Paper plans, Parameter Estimation ROTA, ...)
- ◆ Towards MoA with LIGO/Virgo, the round-table discussion in this LVC meeting.
- ◆ KAGRA plans to join O4 from the beginning.



KAGRA appreciates the community's warm welcomes.