TAUP2017 @ Laurentian University

Jul 26, 2017

# The Status of KAGRA Underground Cryogenic Gravitational Wave Telescope

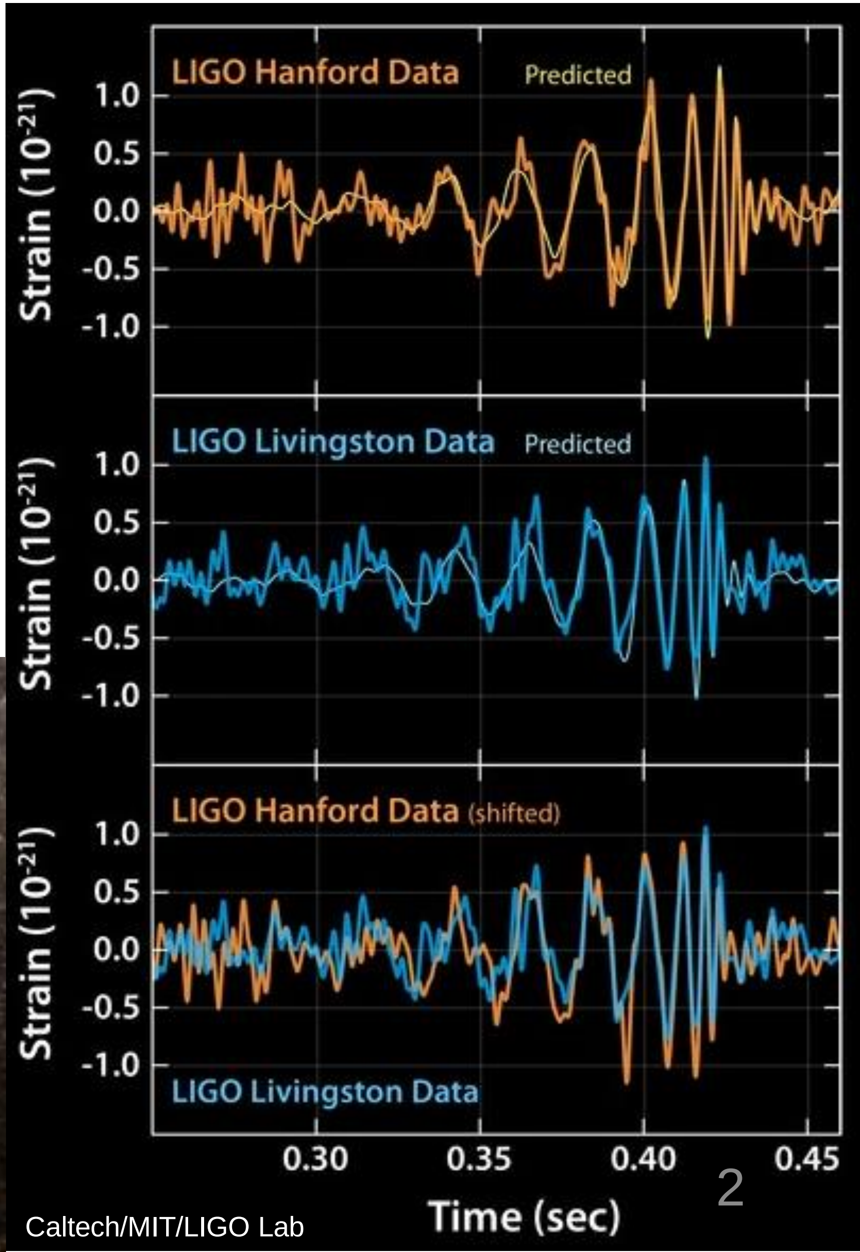
Yuta Michimura

Department of Physics, University of Tokyo

on behalf of the KAGRA Collaboration

# First Detection of GW

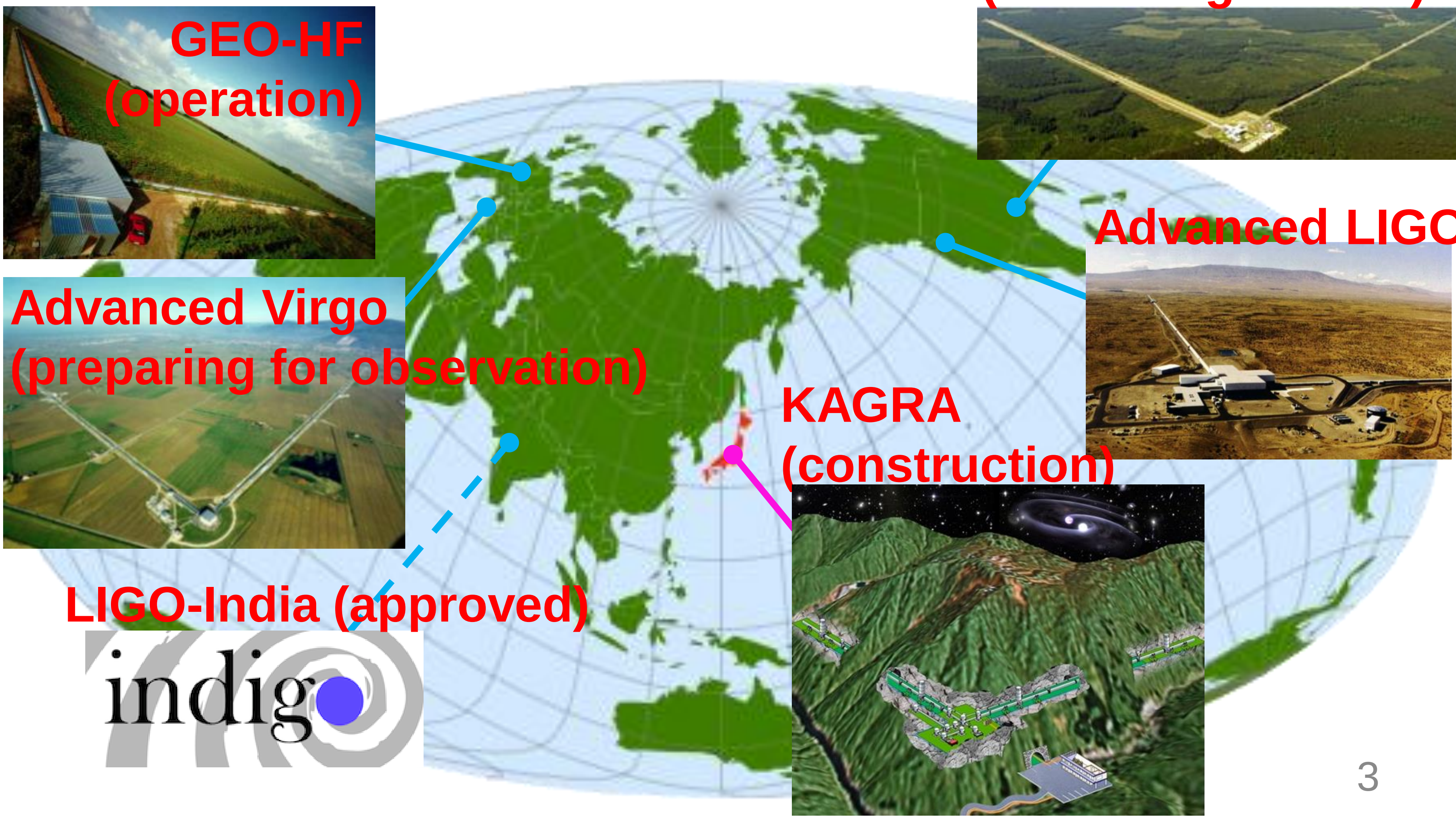
- Advanced LIGO detectors
- Binary black hole mergers
  GW150914
  GW151226
  GW170104
- “heavy” BHs




Caltech/MIT/LIGO Lab

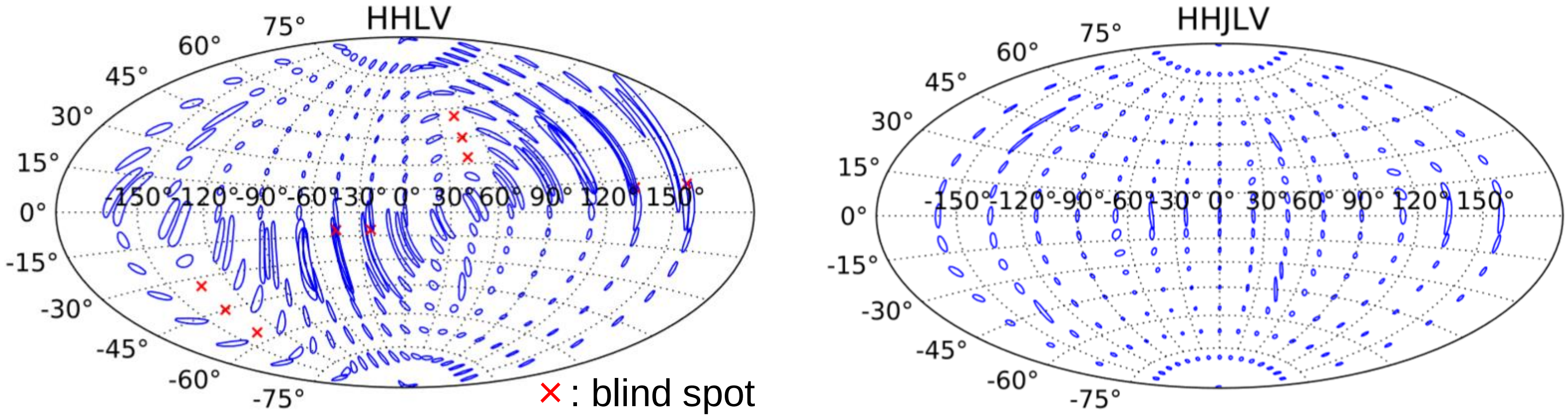
# Global Network of GW Detectors

- enhancing GW astronomy



# GW Astronomy (~5years)

- better sky localization & coverage
  (<10 $deg^2$ and 100 % with LHVK)
- better parameter estimation (spin, distance, etc.)

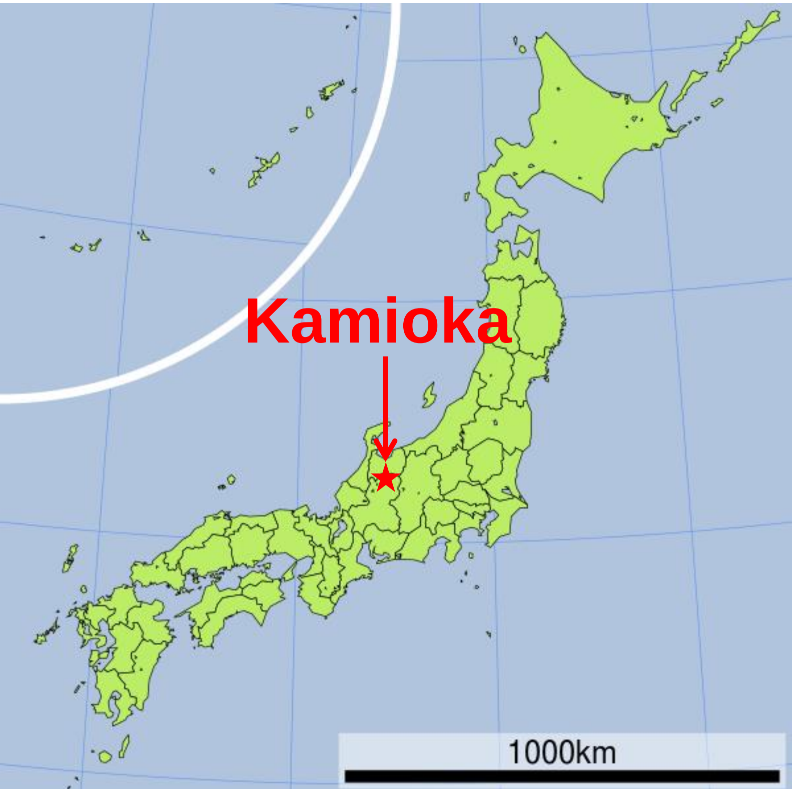



S. Fairhurst, CQG 28, 105021 (2011)

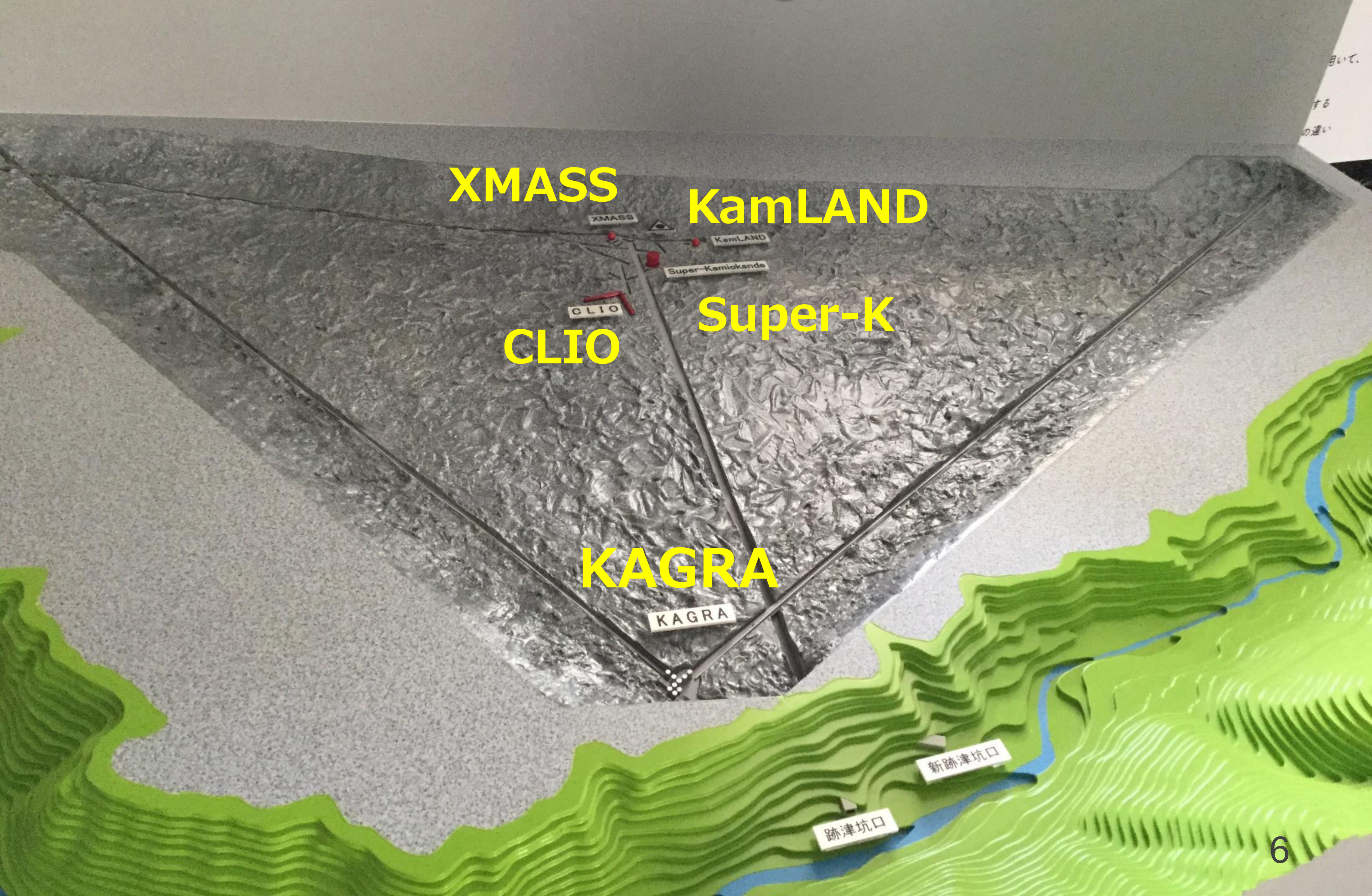
- more BH-BH mergers
  origin of ~30 Msun BH, test of general relativity
- first detection of BH-NS merger, NS-NS merger
  NS equation of state
  origin of short gamma ray burst?

# GW Telescope in Japan: KAGRA

- under construction in Kamioka mine, Japan
- project approved in 2010
- 60+ institutes, 200+ collaborators
- 3-km interferometric GW telescope

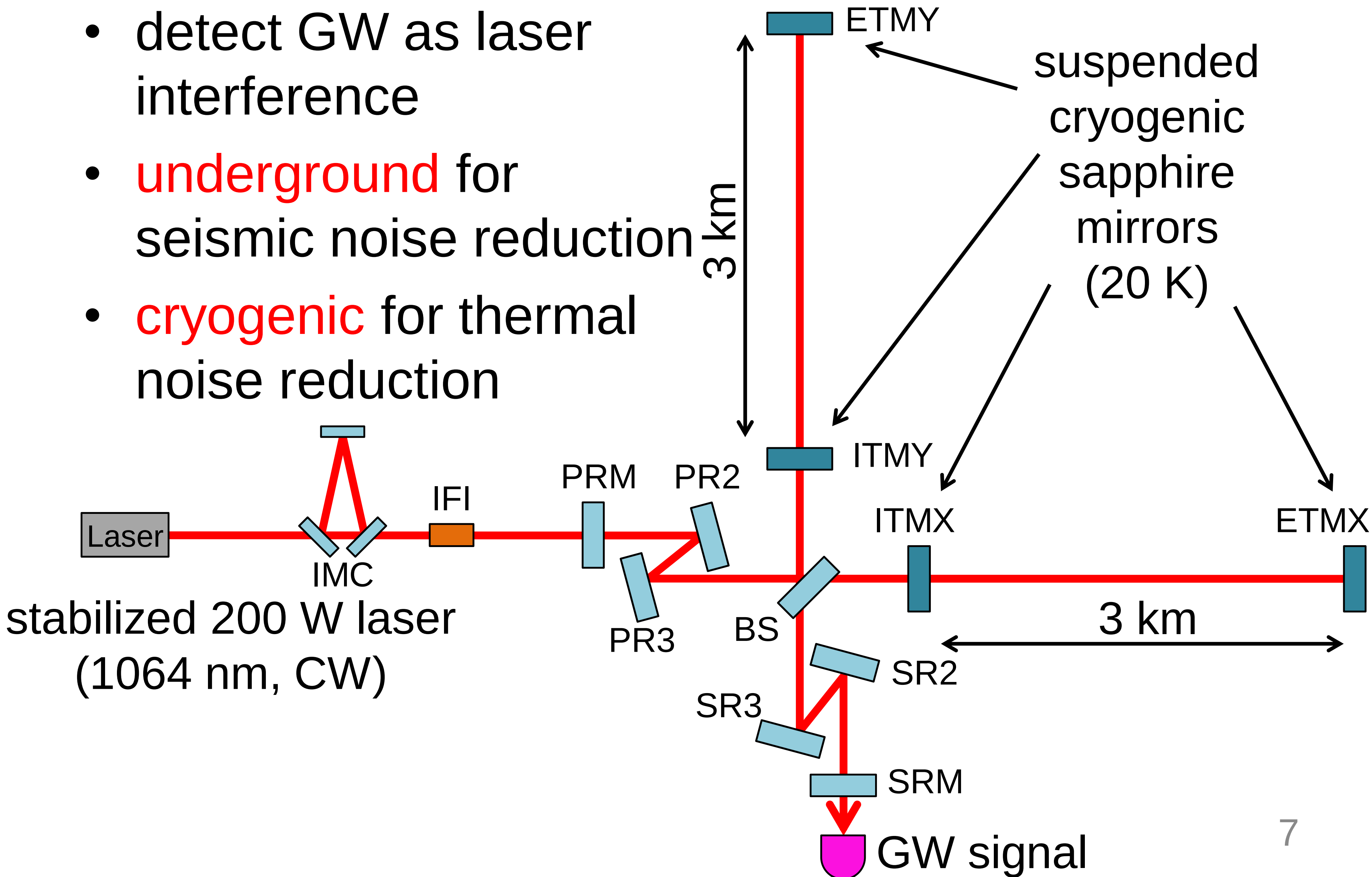



# Kamioka Underground Site



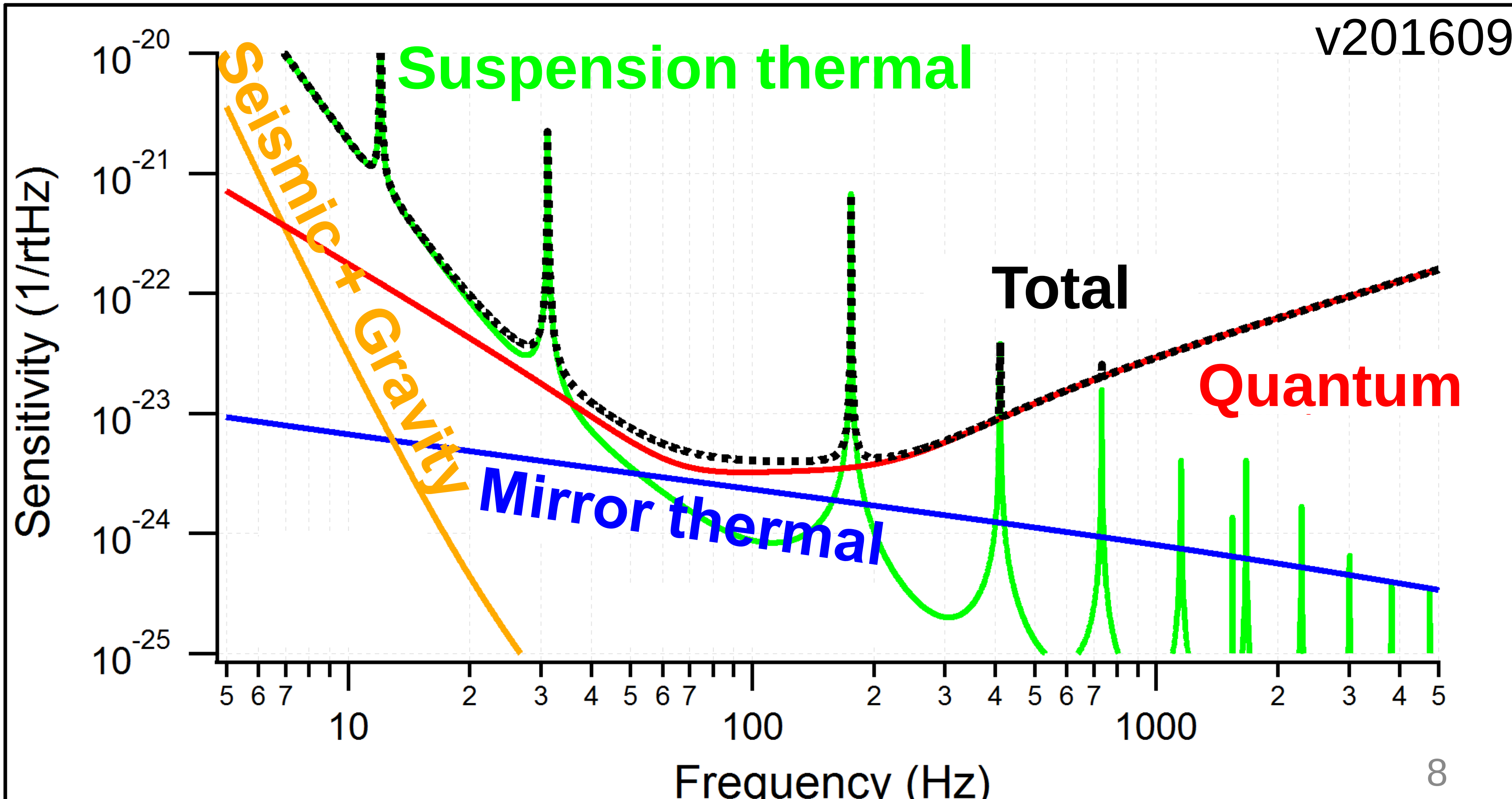
# Interferometer Configuration

- detect GW as laser interference
- underground for seismic noise reduction
- cryogenic for thermal noise reduction

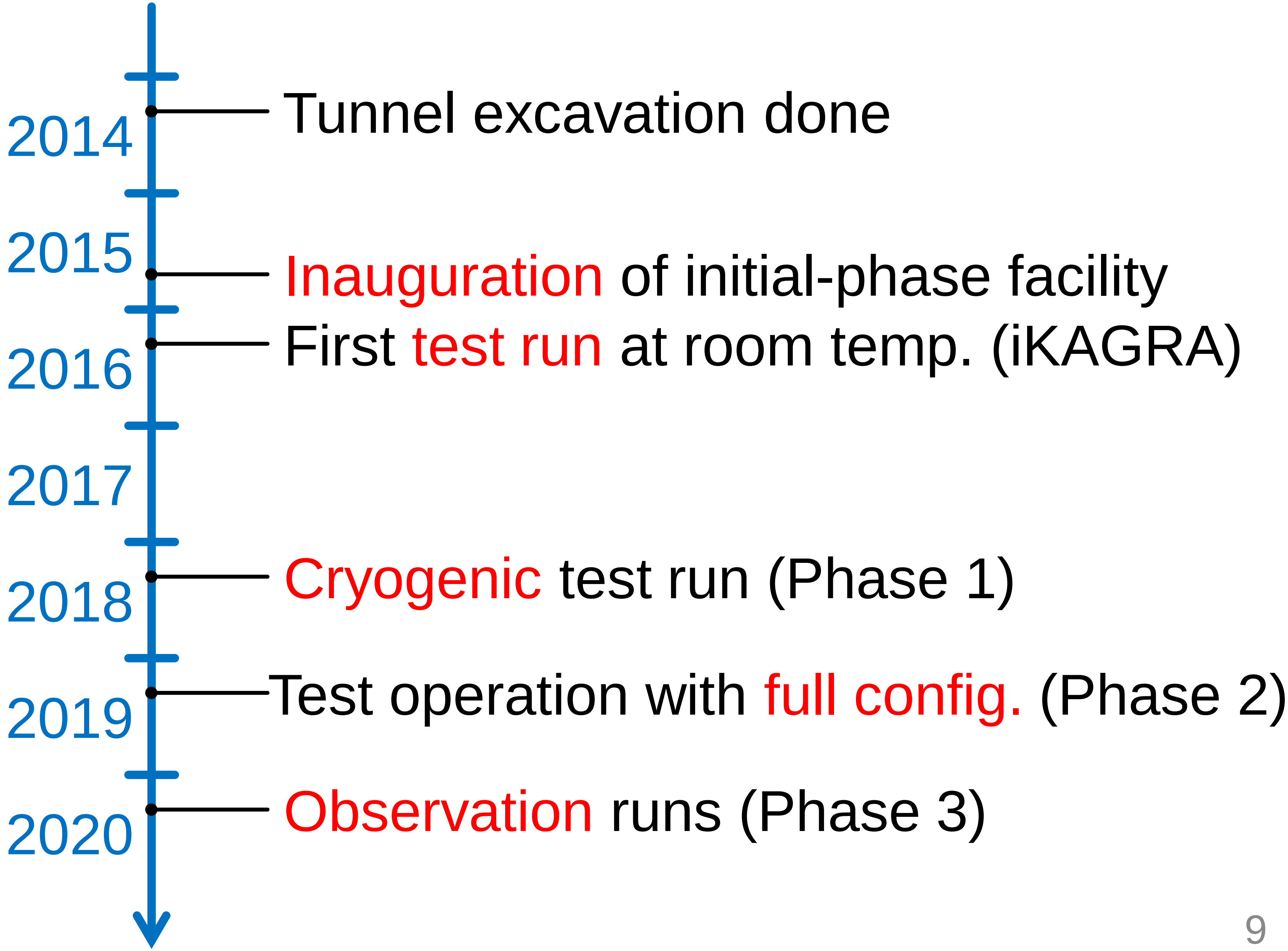


# KAGRA Estimated Sensitivity

- NS-NS 152 Mpc, BH-BH 1.2 Gpc, SN ~$10^2$ kpc
  (1.4-1.4 Msun) (30-30 Msun)

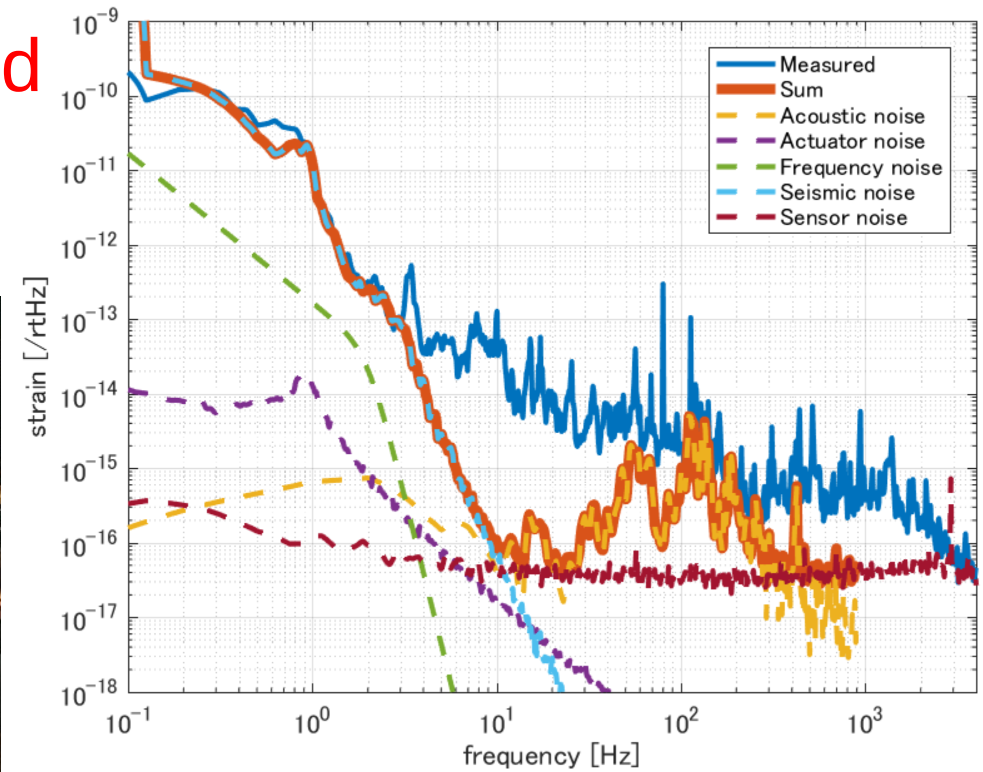


# KAGRA Timeline



# Current Status of KAGRA

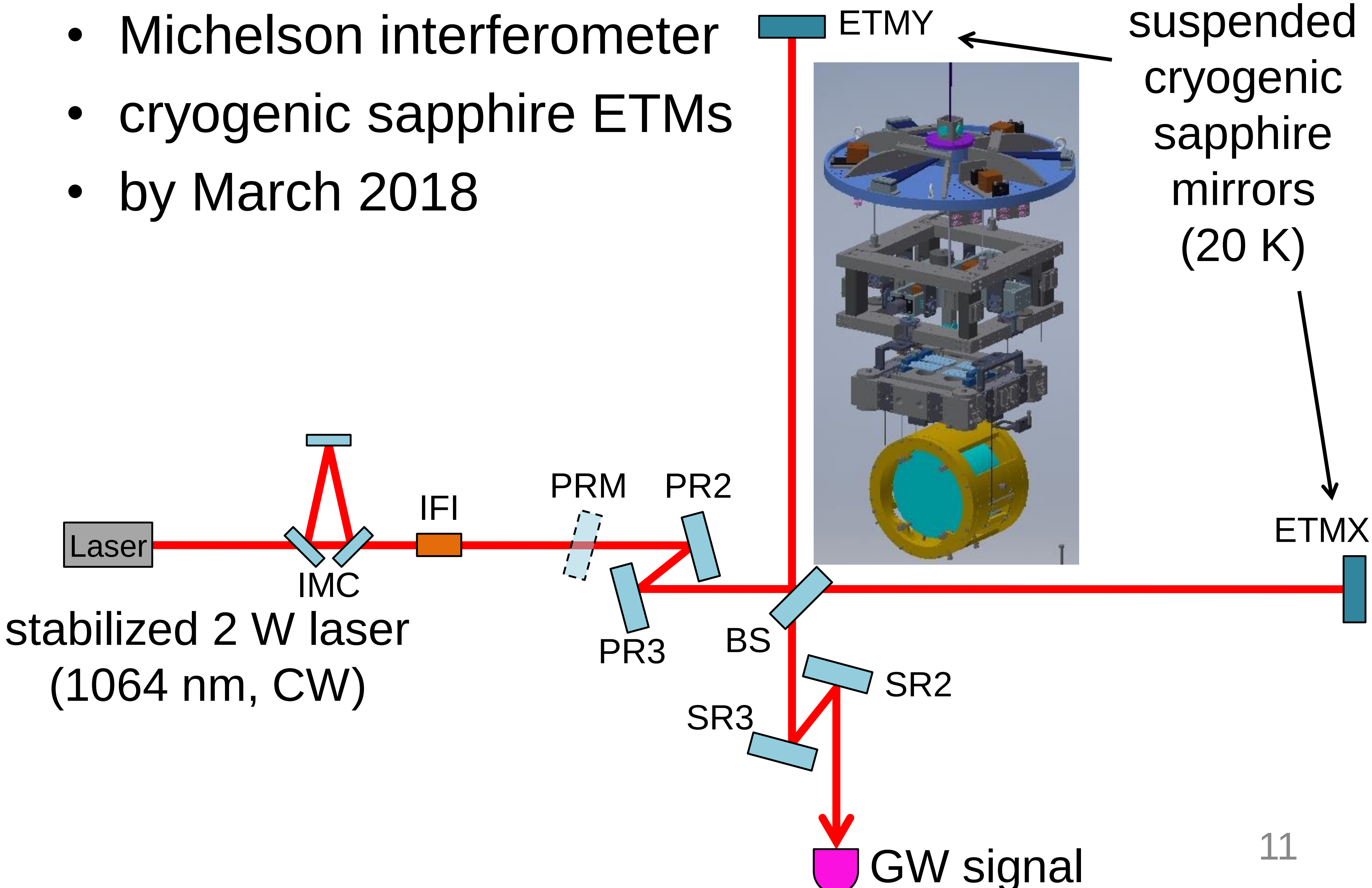
- successfully completed the first test run at room temperature

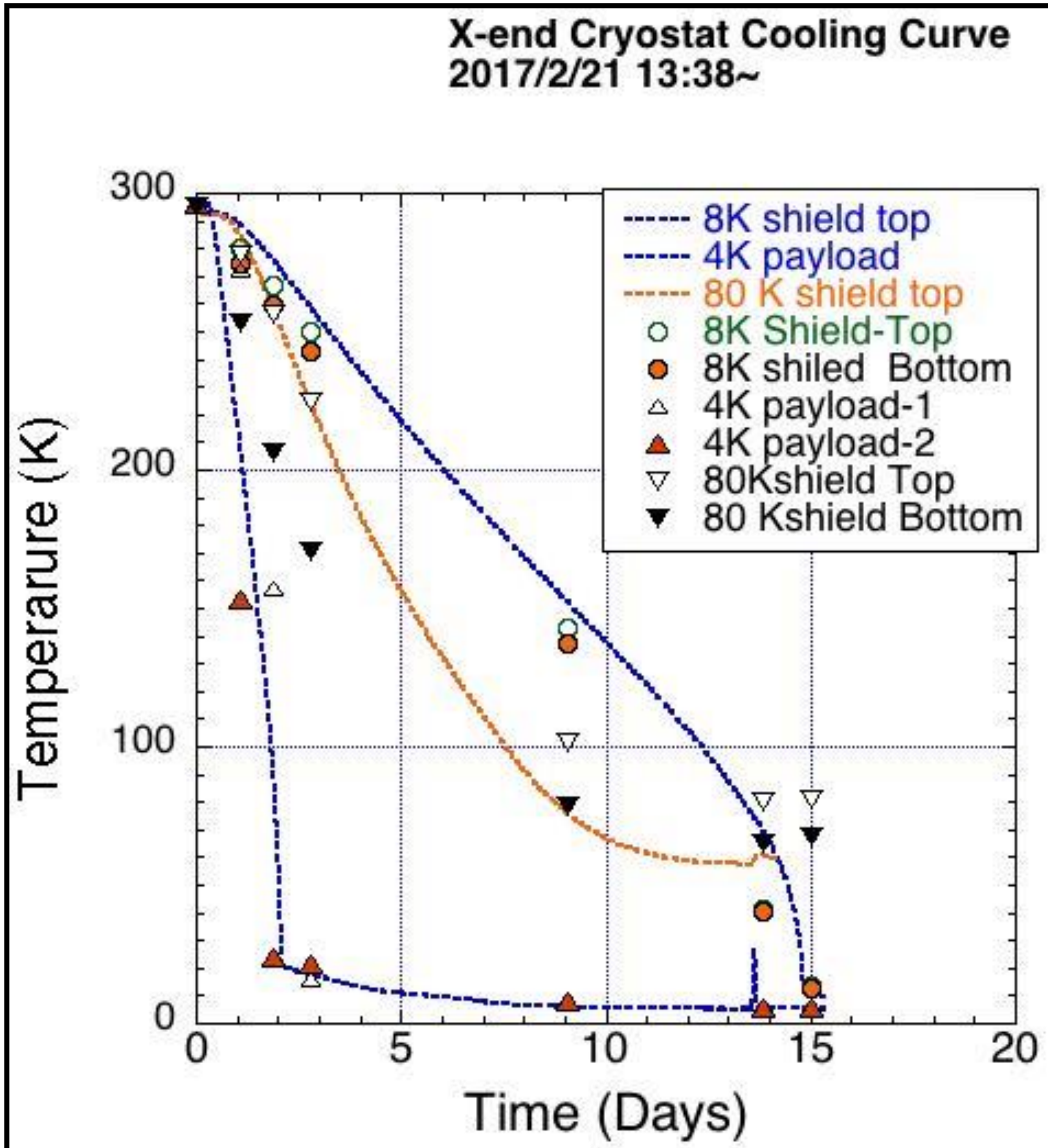

- working for the first cryogenic test run by March 2018 (Phase 1)
  - cryogenic sapphire mirror suspensions
  - room temperature mirror suspensions
  - pre-stabilized laser upgrade

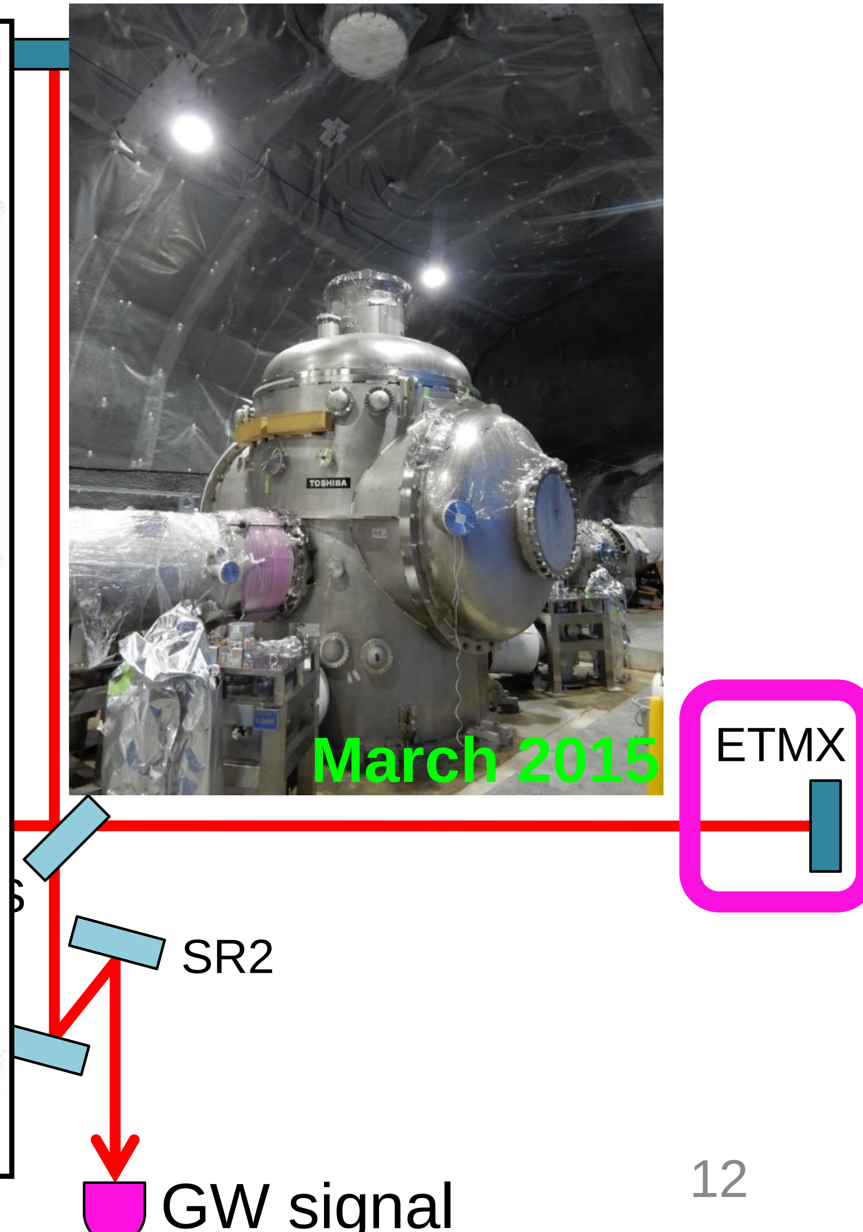
# Phase 1 Configuration

- Michelson interferometer
- cryogenic sapphire ETMs
- by March 2018

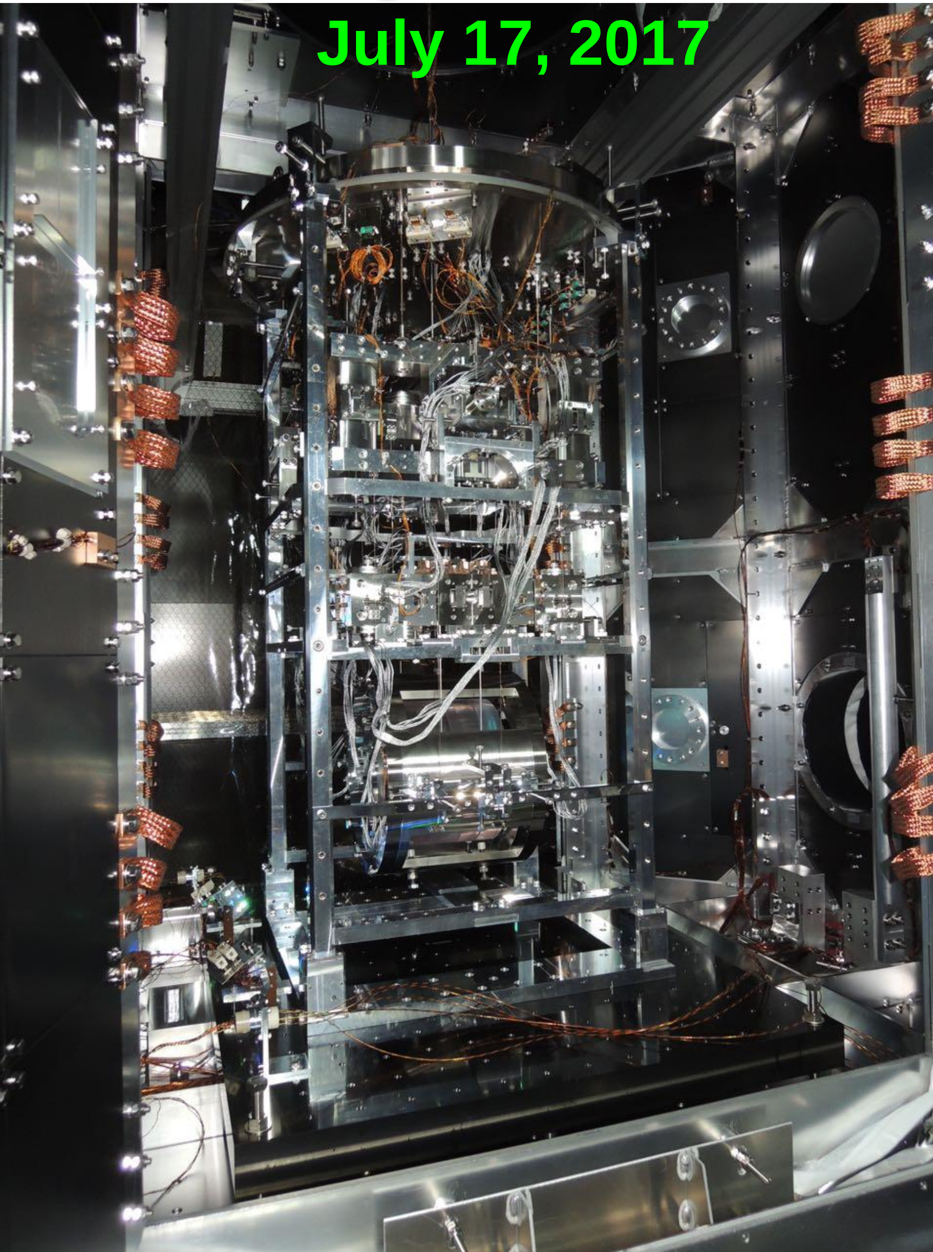


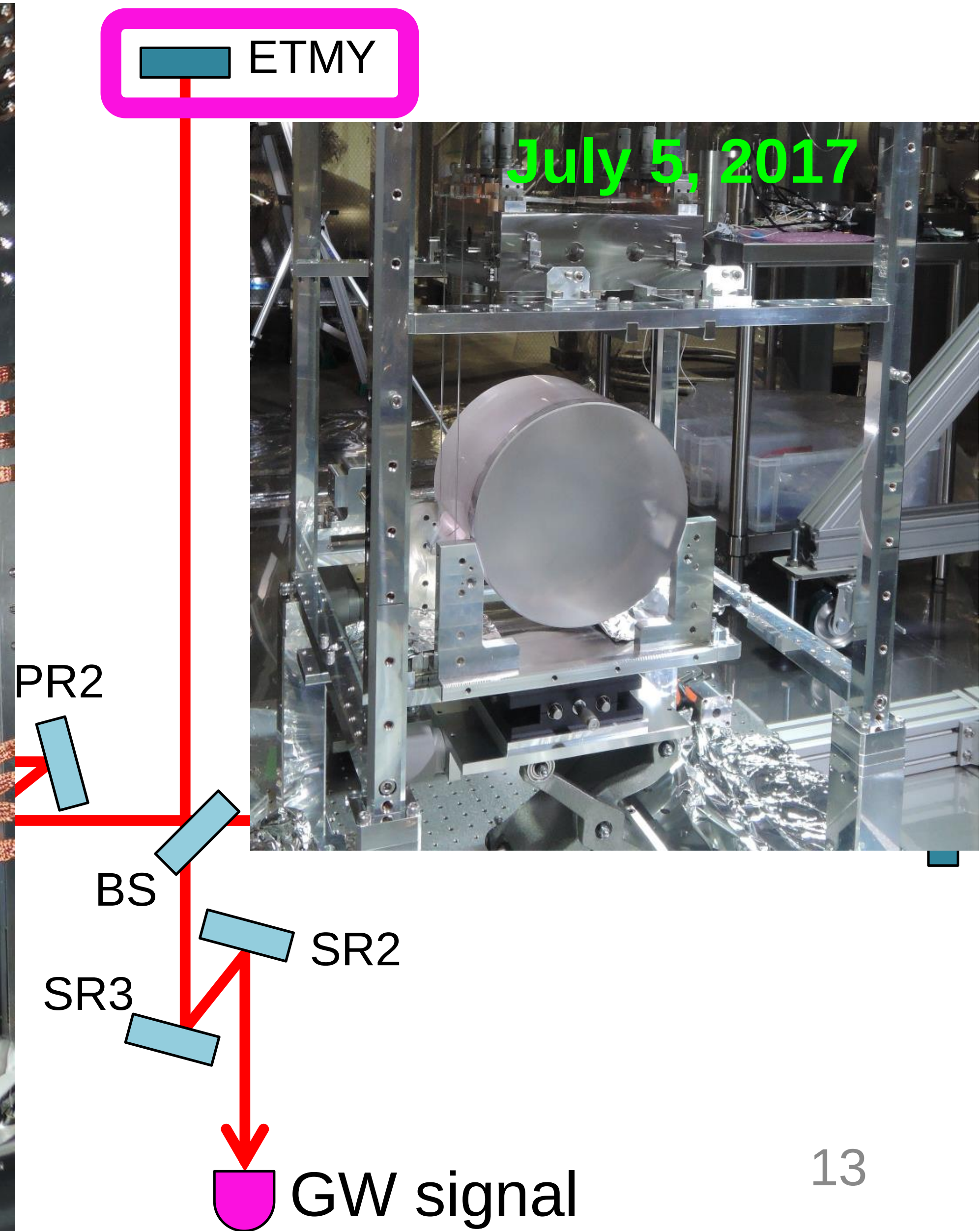
# Cryostat Cooling Test



# Cryogenic Mirror Test Installation

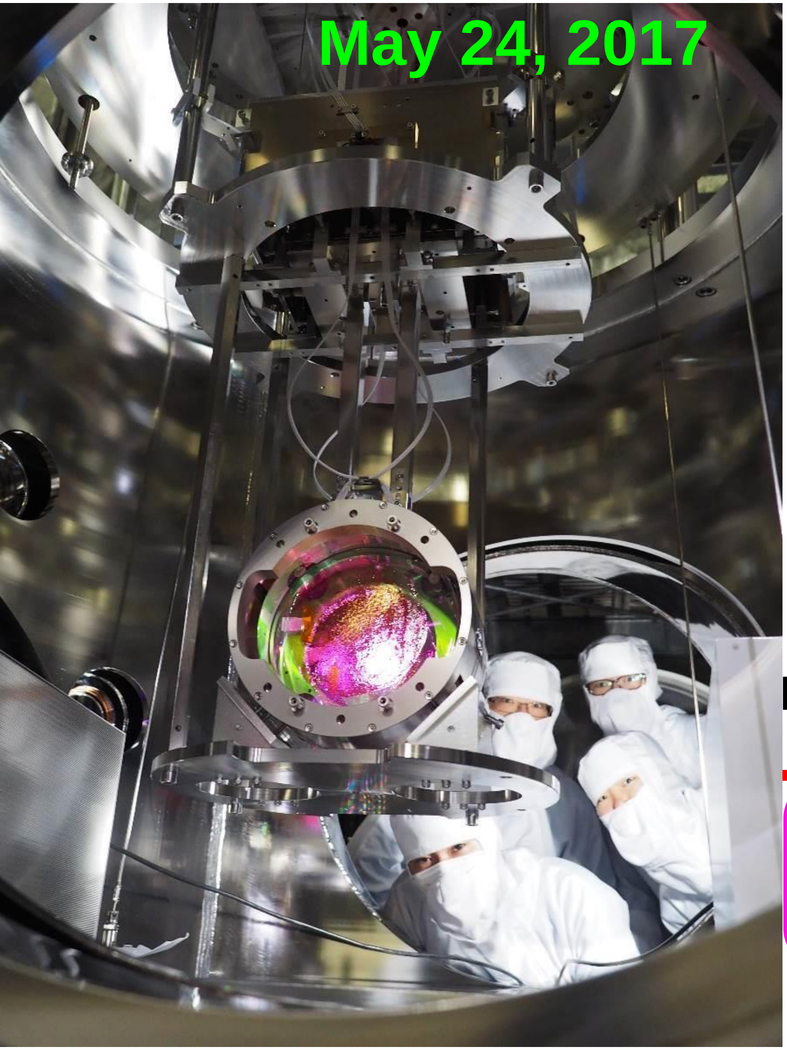


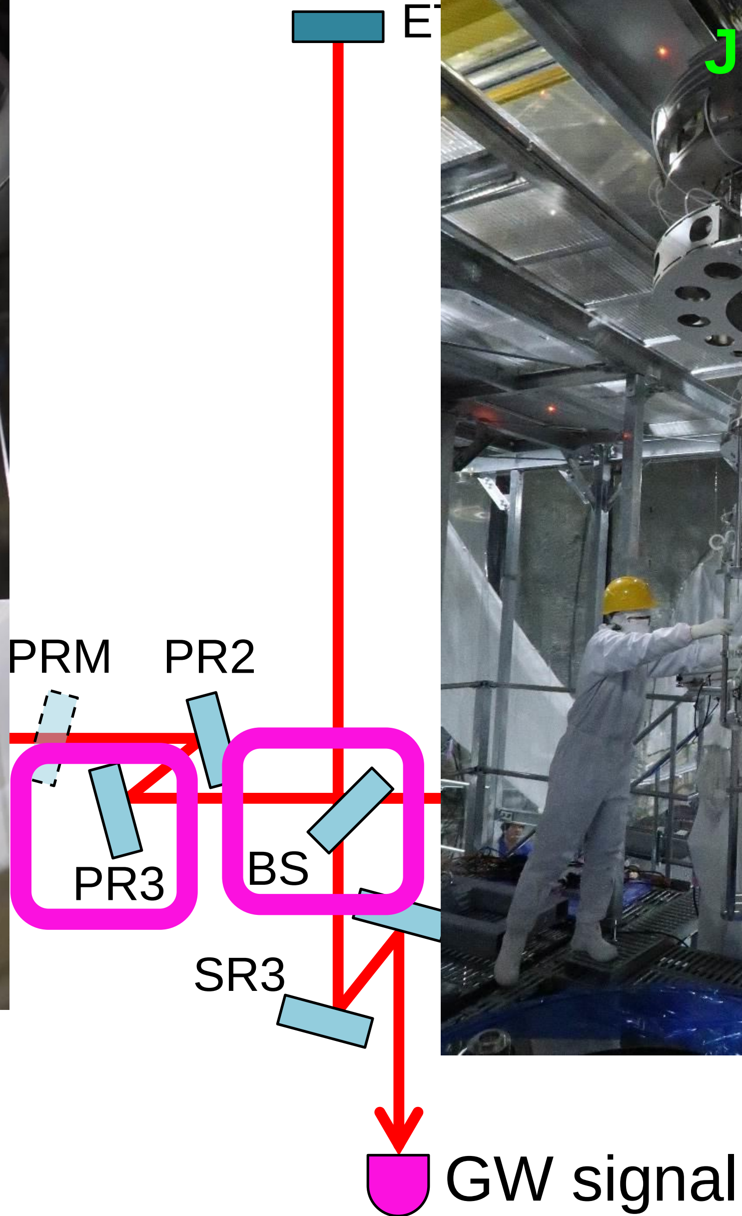



# Cryogenic Mirror Vibration Isolation

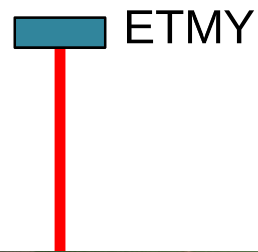
ETMY

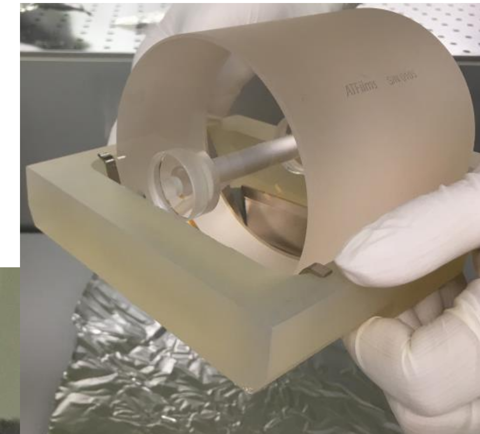

# Room Temp. Mirror Installation

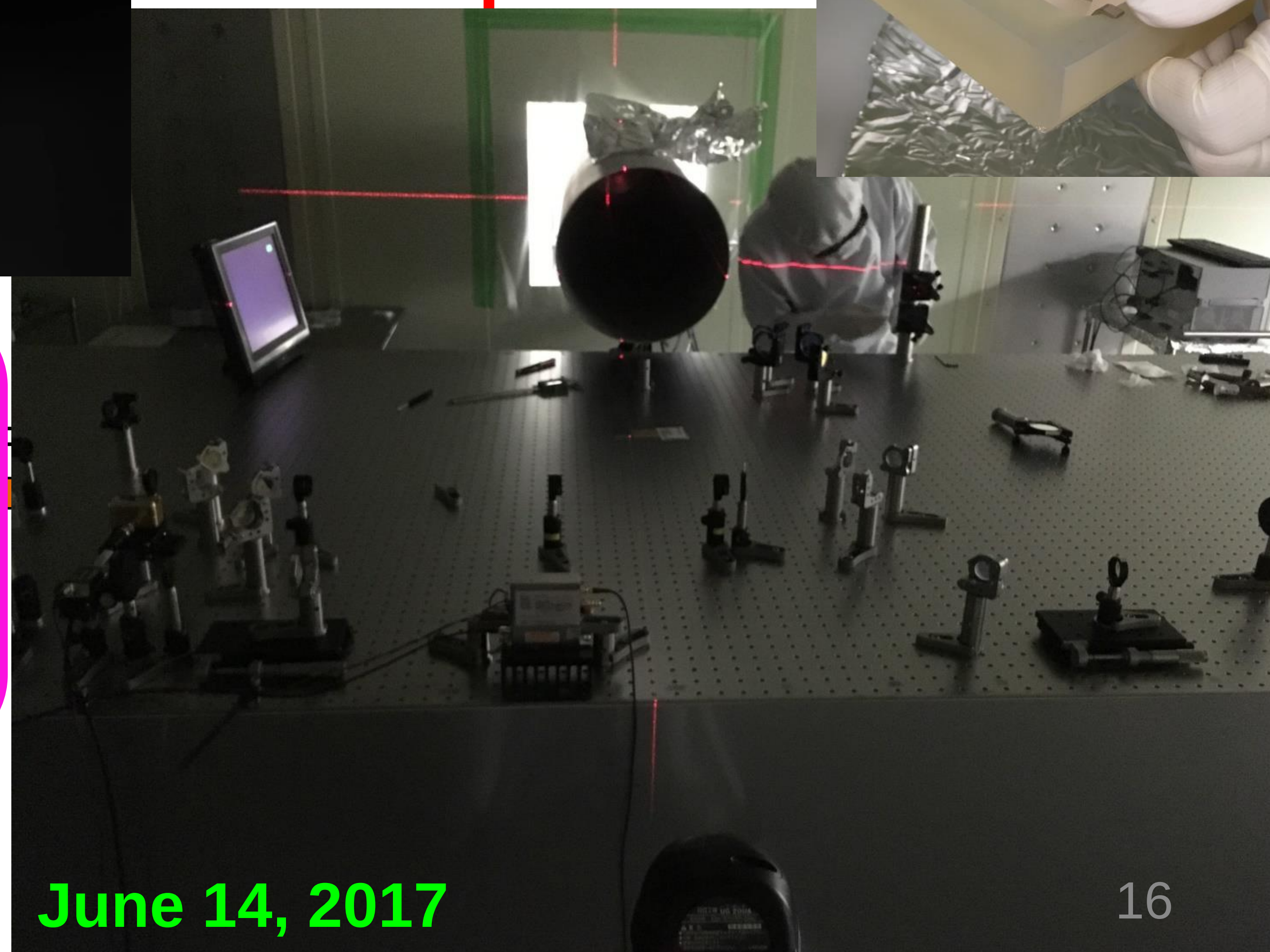


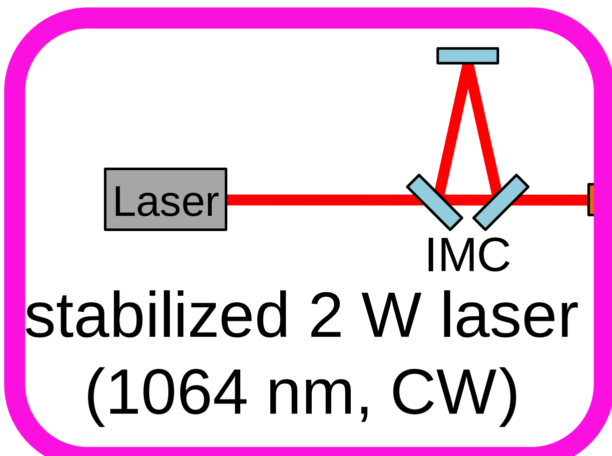




# Pre-stabilized Laser Upgrade

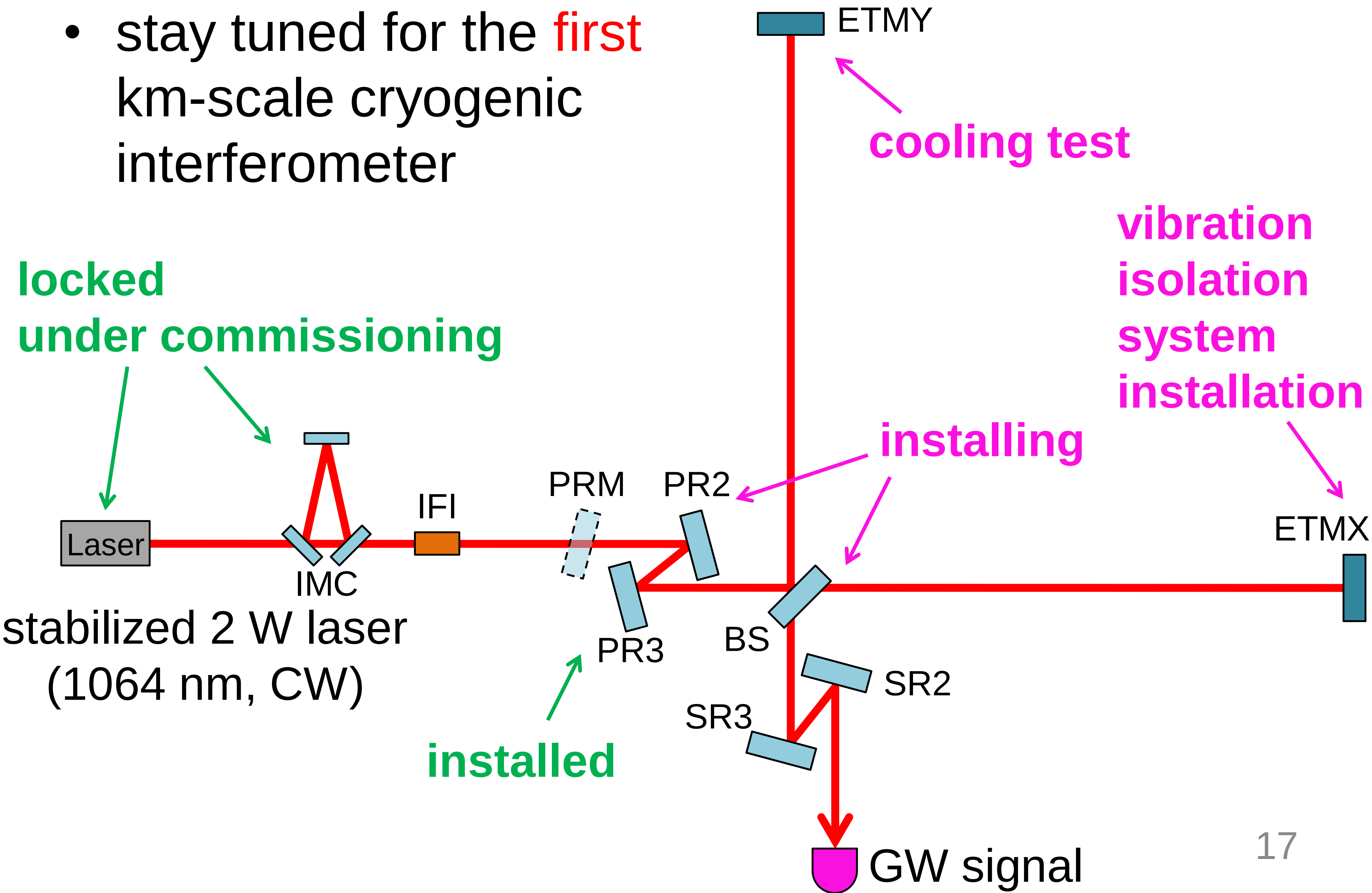





# Phase 1 Installation On Going

- stay tuned for the first km-scale cryogenic interferometer



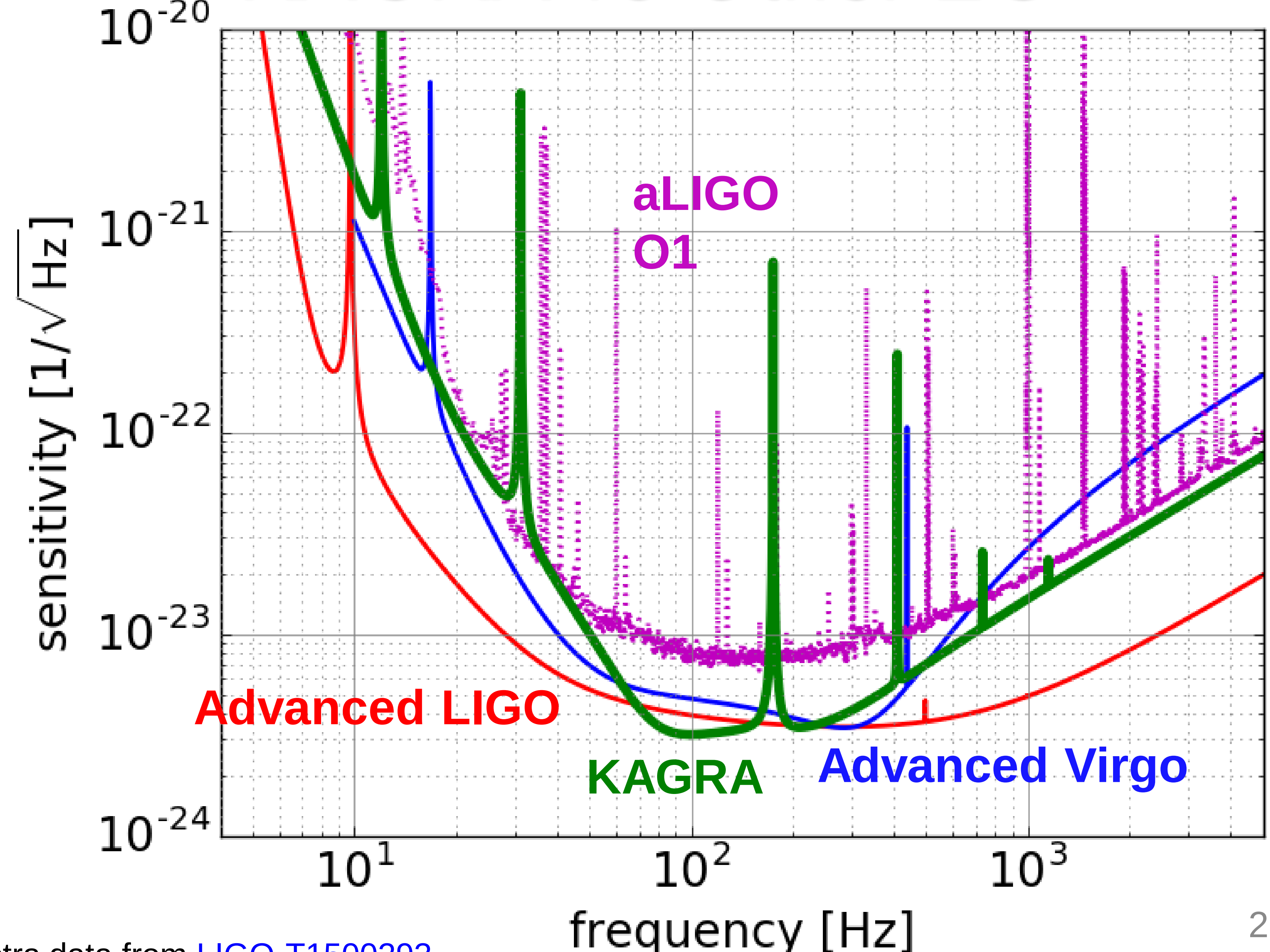

stabilized 2 W laser (1064 nm, CW)

# Summary

- The era of gravitational wave astronomy has begun
- Fruitful science with global network
  - better sky localization, sky coverage, parameter estimation
  - origin of heavy stellar-mass black holes
  - NS-NS, NS-BH binaries
  - multi-messenger astronomy
- GW telescope in Japan: KAGRA
  - unique features: underground and cryogenic
  - completed initial-phase test run
  - first cryogenic test run in March 2018
  - observing runs by ~2020

# Supplementary Slides

# KAGRA vs Other 2G




Spectra data from [LIGO-T1500293]

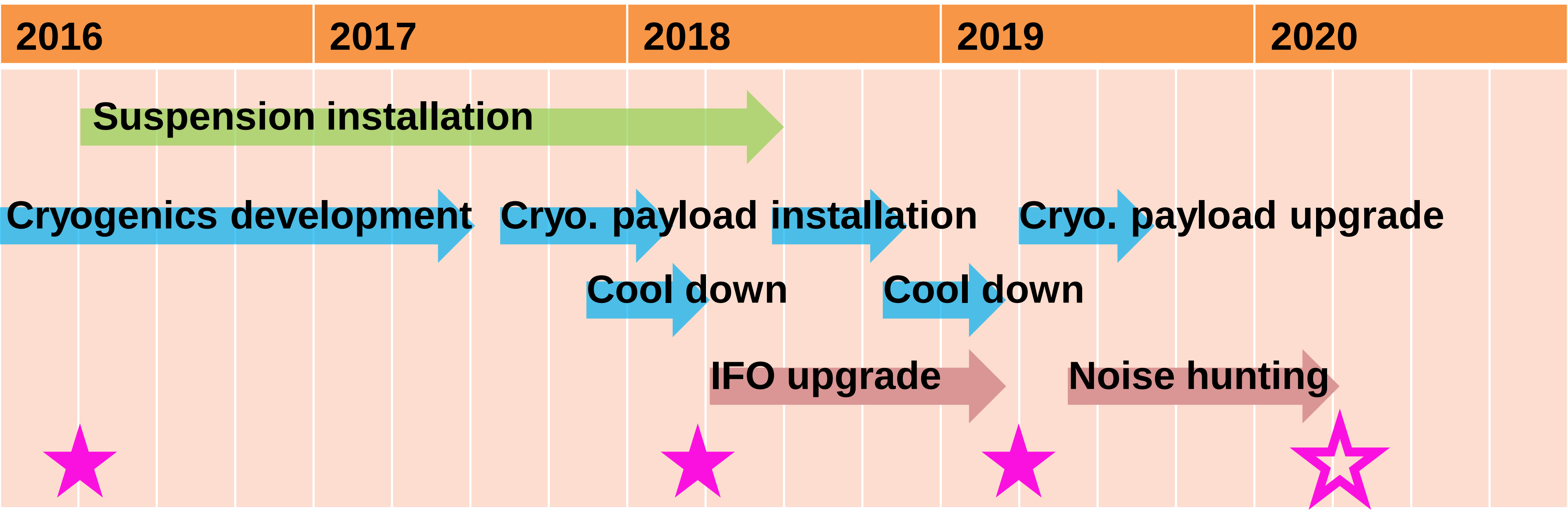
# 2G/2G+ Parameter Comparison

| | KAGRA | AdVirgo | aLIGO | A+ | Voyager |
|---|---|---|---|---|---|
| Arm length [km] | 3 | 3 | 4 | 4 | 4 |
| Mirror mass [kg] | 23 | 42 | 40 | 80 | 200 |
| Mirror material | Sapphire | Silica | Silica | Silica | Silicon |
| Mirror temp [K] | 23 | 295 | 295 | 295 | 123 |
| Sus fiber | 35cm Sap. | 70cm $SiO_2$ | 60cm $SiO_2$ | 60cm $SiO_2$ | 60cm Si |
| Fiber type | Fiber | Fiber | Fiber | Fiber | Ribbon |
| Input power [W] | 78 | 125 | 125 | 125 | 140 |
| Arm power [kW] | 280 | 700 | 710 | 1150 | 3000 |
| Wavelength [nm] | 1064 | 1064 | 1064 | 1064 | 2000 |
| Beam size [cm] | 3.5 / 3.5 | 4.9 / 5.8 | 5.5 / 6.2 | 5.5 / 6.2 | 5.8 / 6.2 |
| SQZ factor | 0 | 0 | 0 | 6 | 8 |
| F. C. length [m] | none | none | none | 16 | 300 |

LIGO parameters from LIGO-T1600119, AdVirgo parameters from JPCS 610, 01201 (2015)
KAGEA parameters are v201609

# Roadmap of KAGRA

- Completed first test run at room temperature. Working for cryogenic test run.
- Baseline KAGRA (bKAGRA) in 3 phases.




**Initial KAGRA**
Michelson at room temp.
Test run

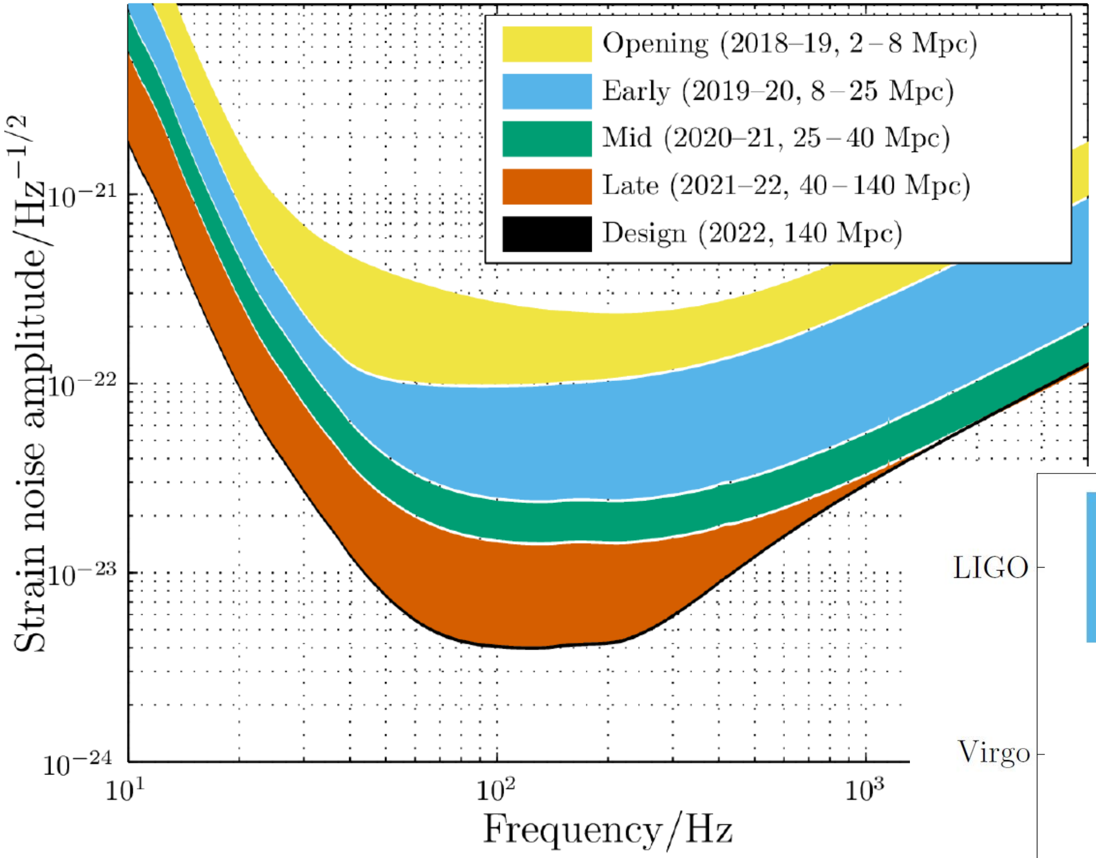
**Phase 1**
Michelson at cryogenic temp.
Test run

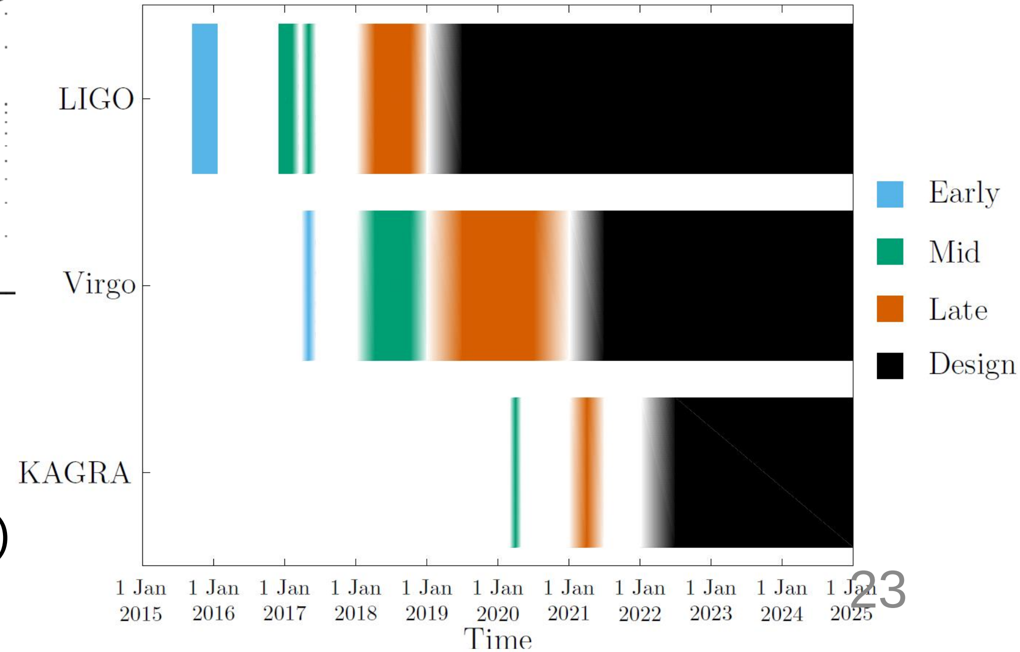
**Phase 2**
RSE at cryogenic temp.
Test run

**Phase 3**
RSE at cryogenic temp.
Observation run

# Observation Scenario

- With 25-40 Mpc in 2020, 40-140 Mpc in 2021

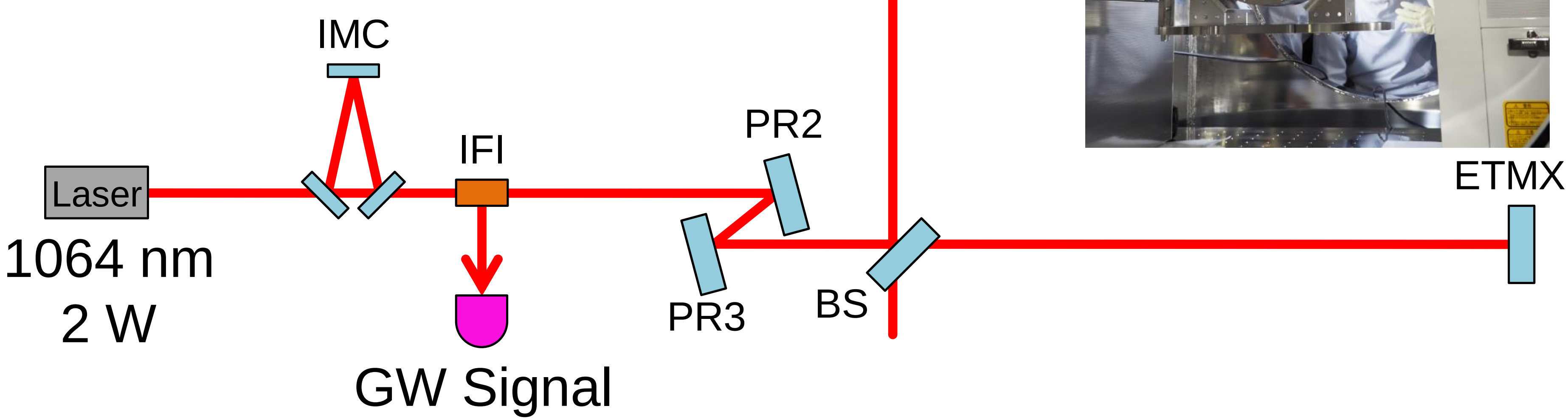



Living Reviews in Relativity 19, 1 (2016)
to be updated

# Initial KAGRA Configuration

- 3 km Michelson
  at room temperature
- Low power
- Simplified suspension
- At air pressure





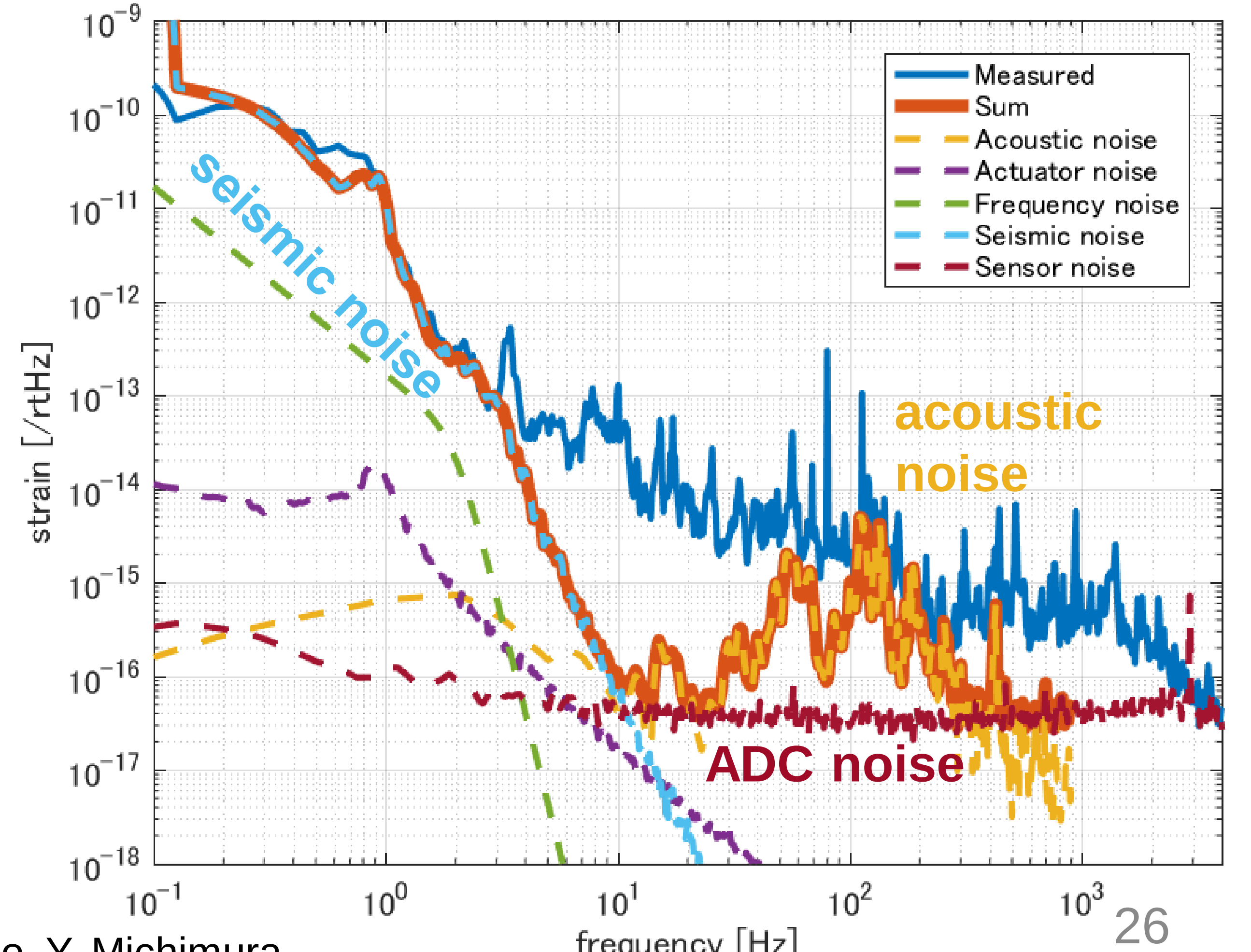
# iKAGRA Test Run in 2016


- Period
  - March 25 to 31
  - April 11 to 25
- Purpose
  - confirm layout of the 3 km vacuum ducts
  - test controls, data transfer, observation shift, etc.
  - get environmental data
  - obtain experiences of the management and operation of the km-class interferometer

http://kyodonews.net/news/2016/03/25/54510

# iKAGRA Sensitivity

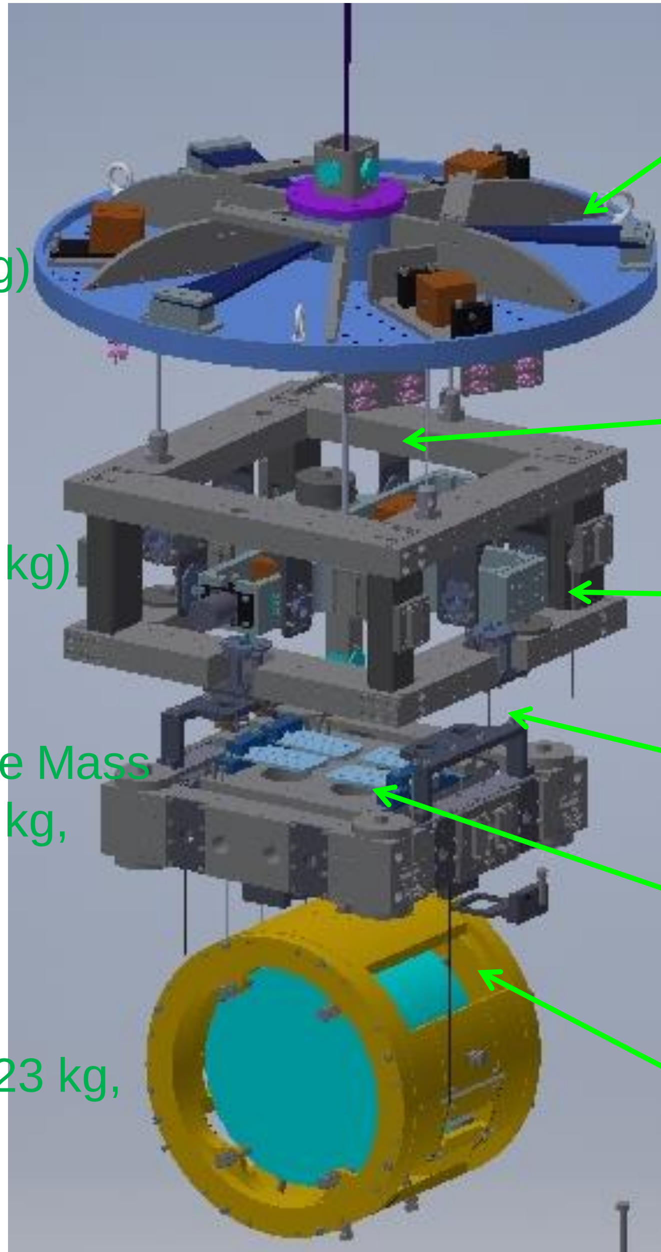
- ~3e-15 /rtHz @ 100 Hz
- Limited by seismic noise, acoustic noise and ADC noise
- Reduction possible in bKAGRA




plot by T. Shimoda, M. Nakano, Y. Michimura

# KAGRA Cryopayload

Provided by T. Ushiba and T. Miyamoto



Platform
(SUS, 65 kg)

Marionette
(SUS, 22.5 kg)

Intermediate Mass
(SUS, 20.1 kg,
16.3 K)

Test Mass
(Sapphire, 23 kg,
21.5 K)

3 CuBe blade springs

MN suspended by 1 Maraging steel fiber
(35 cm long, 2-7mm dia.)
MRM suspended by 3 CuBe fibers

Heat link attached to MN

IM suspended by 4 CuBe fibers
(24 cm long, 0.6 mm dia)
IRM suspended by 4 CuBe fibers

4 sapphire blades

TM suspended by 4 sapphire fibers
(35 cm long, 1.6 mm dia.)
RM suspended by 4 CuBe fibers