Optical Society of Korea Summer Meeting 2016 @ BEXCO, Busan July 12, 2016
OSK-OSJ Joint Symposium

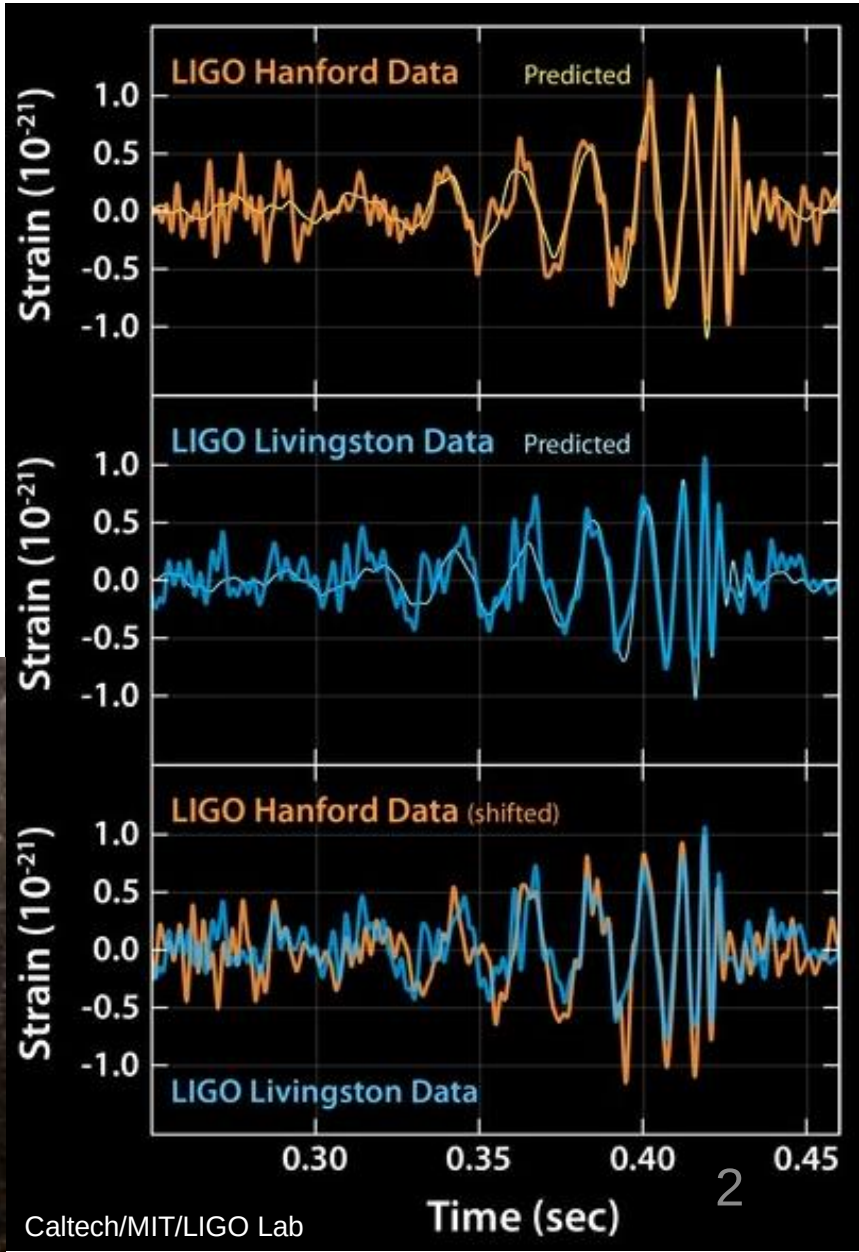
# Recent News and Status of the KAGRA Gravitational Wave Telescope

Yuta Michimura
Department of Physics, University of Tokyo

for the KAGRA Collaboration

# First Detection of GW

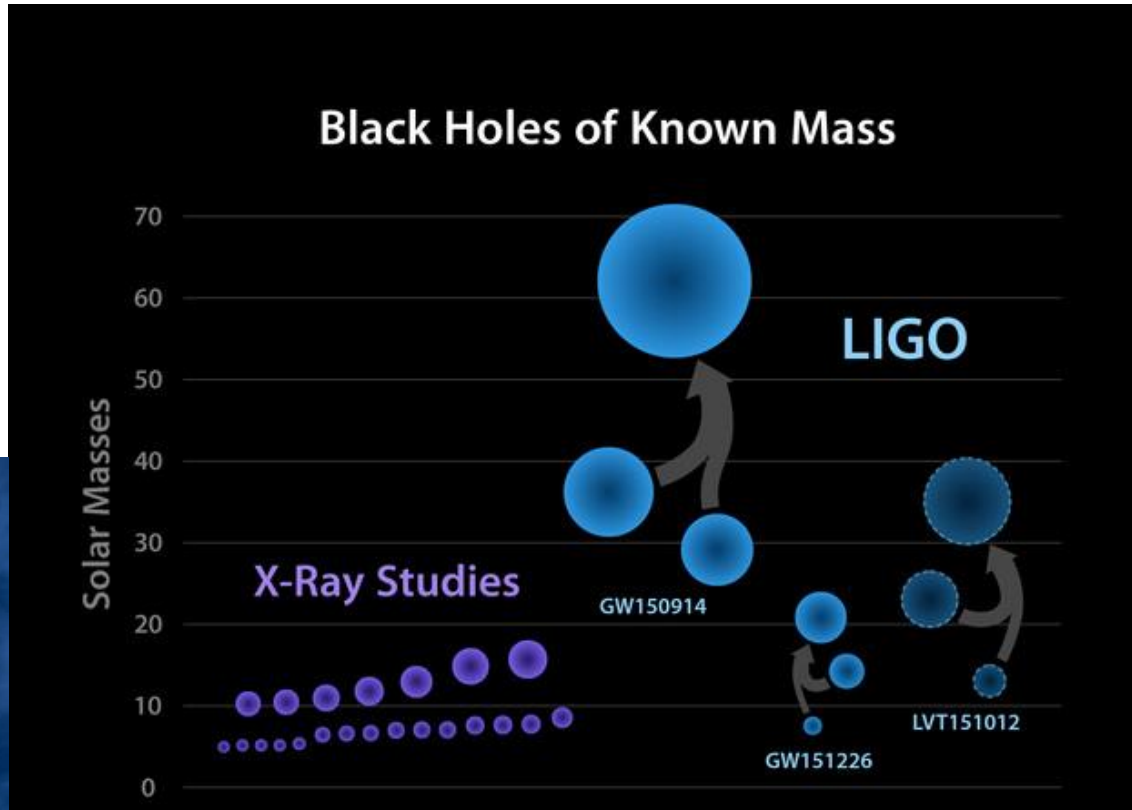
- Advanced LIGO detectors
- binary black hole mergers
  - GW150914
    - 36Msun & 29Msun
  - GW151226
    - 14Msun & 7.5Msun




Caltech/MIT/LIGO Lab

# Where Do BBHs Came From?

- masses were heavier than expected
- usual stars can only be ~10Msun BHs
- still under discussion
  - primordial BHs?
  - from first stars?
  - from globular clusters?
  - etc……

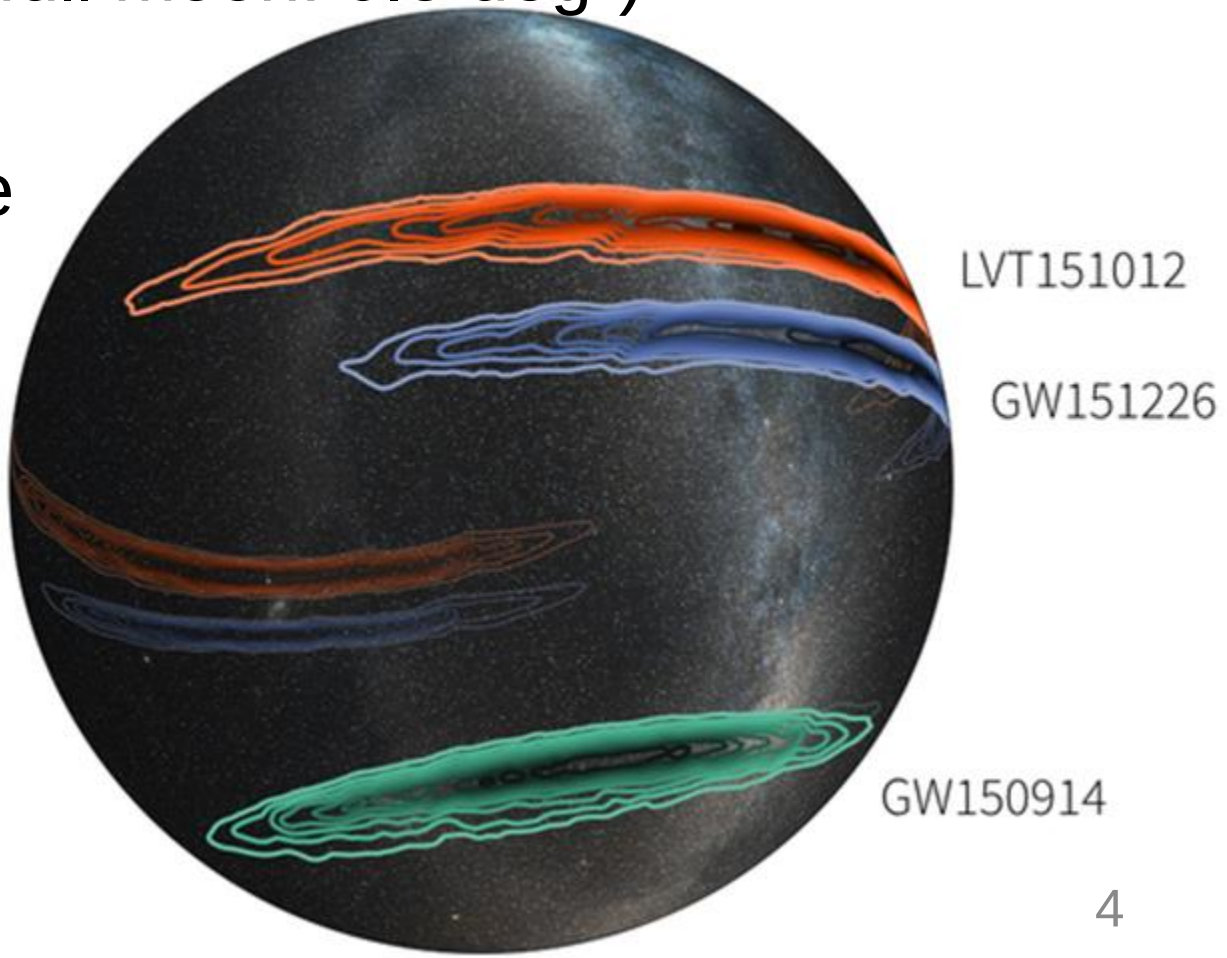



https://www.ligo.caltech.edu/

# Sky Location

- sky location with 2 detectors has limitations
  within ~ hundreds of square-degrees
  (size of the full moon: 0.5 $deg^2$)

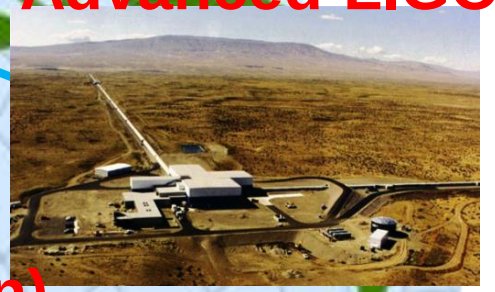
- need 3 or more detectors to localize better



# Global Network of GW Detectors

- upgrade/construction around the world








LIGO-India (approved)

# KAGRA

- Large-scale Cryogenic Gravitational Wave Telescope (Nickname: KAGRA)
- constructed underground in Japan
- 60+ institutes, 200+ collaborators
- project started in 2010

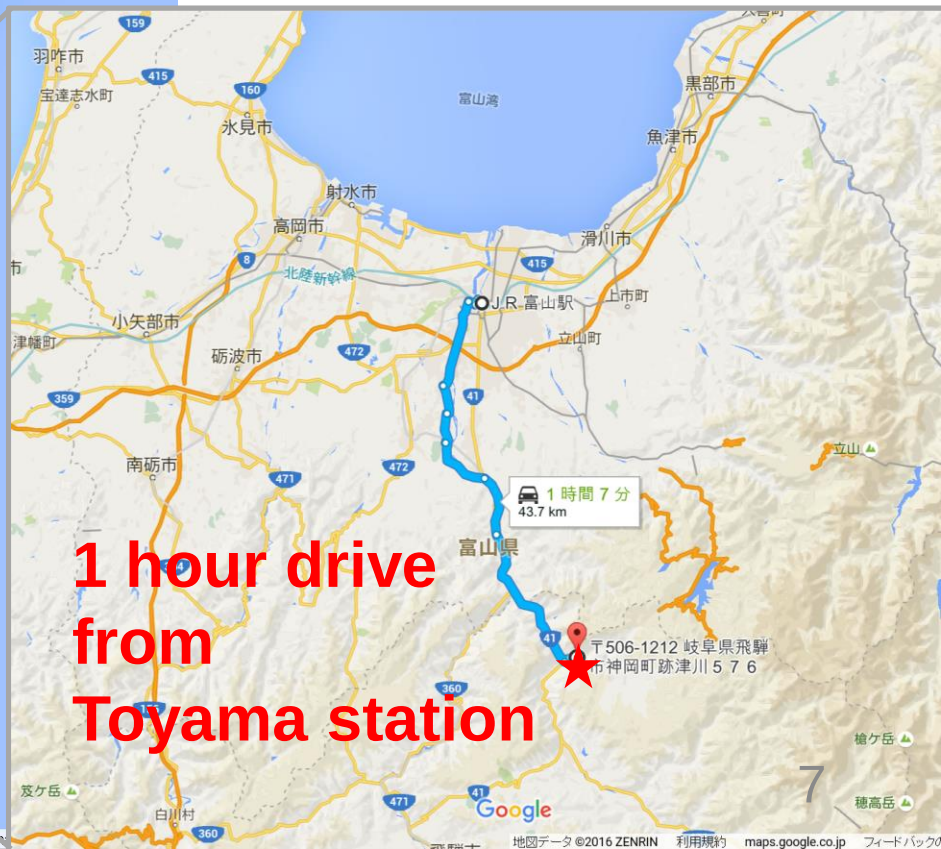

PI:
Takaaki Kajita

and many more...

# Where's KAGRA?

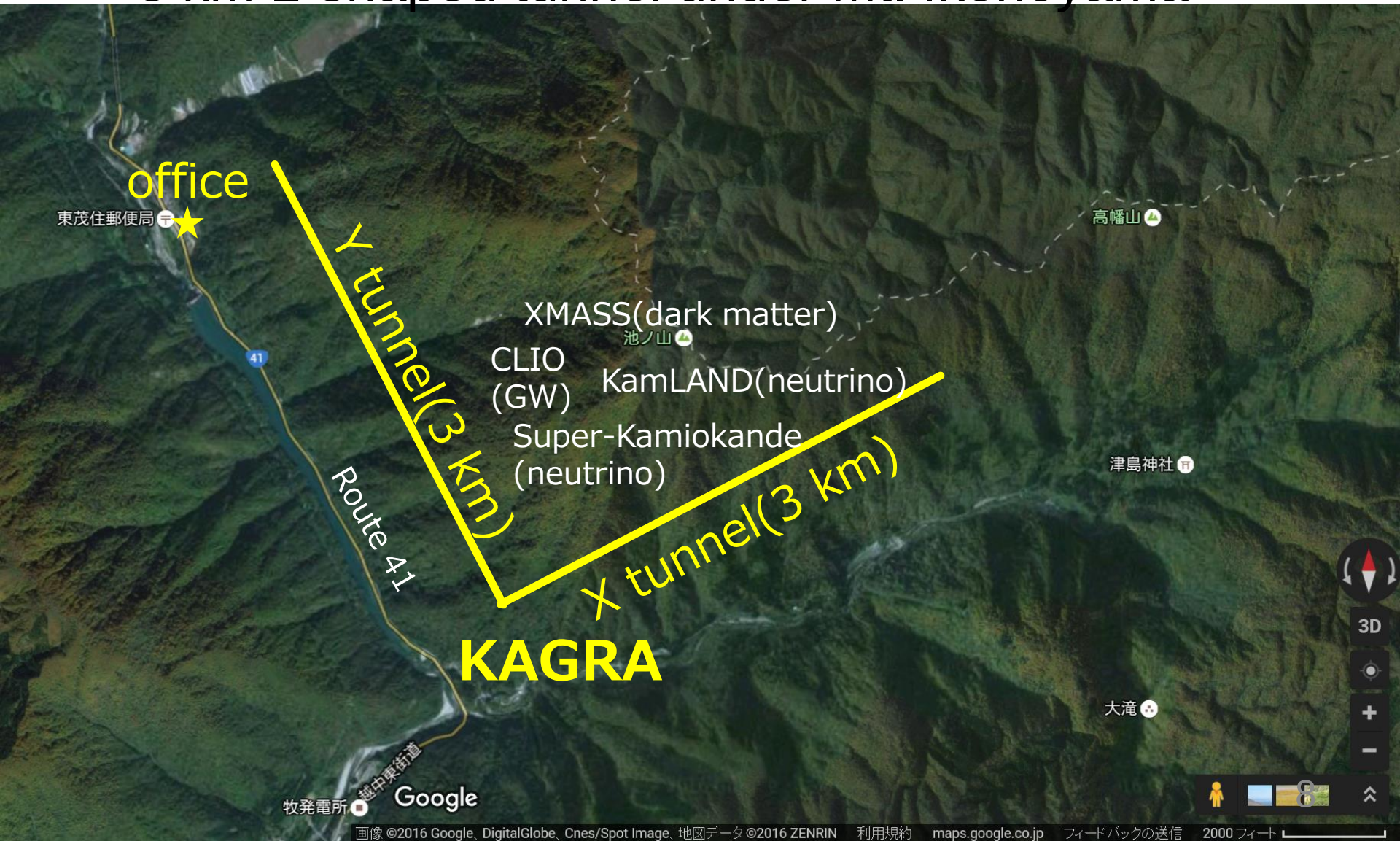
- Kamioka mine, Gifu, Japan

**2.5 hours from Tokyo by Shinkansen**

# Facilities Around Kamioka

- 3 km L-shaped tunnel under Mt. Ikenoyama



# KAGRAトンネル

- 3 km vacuum pipe for each arm (~ 1e-7 Pa)
- laser beam go back and forth

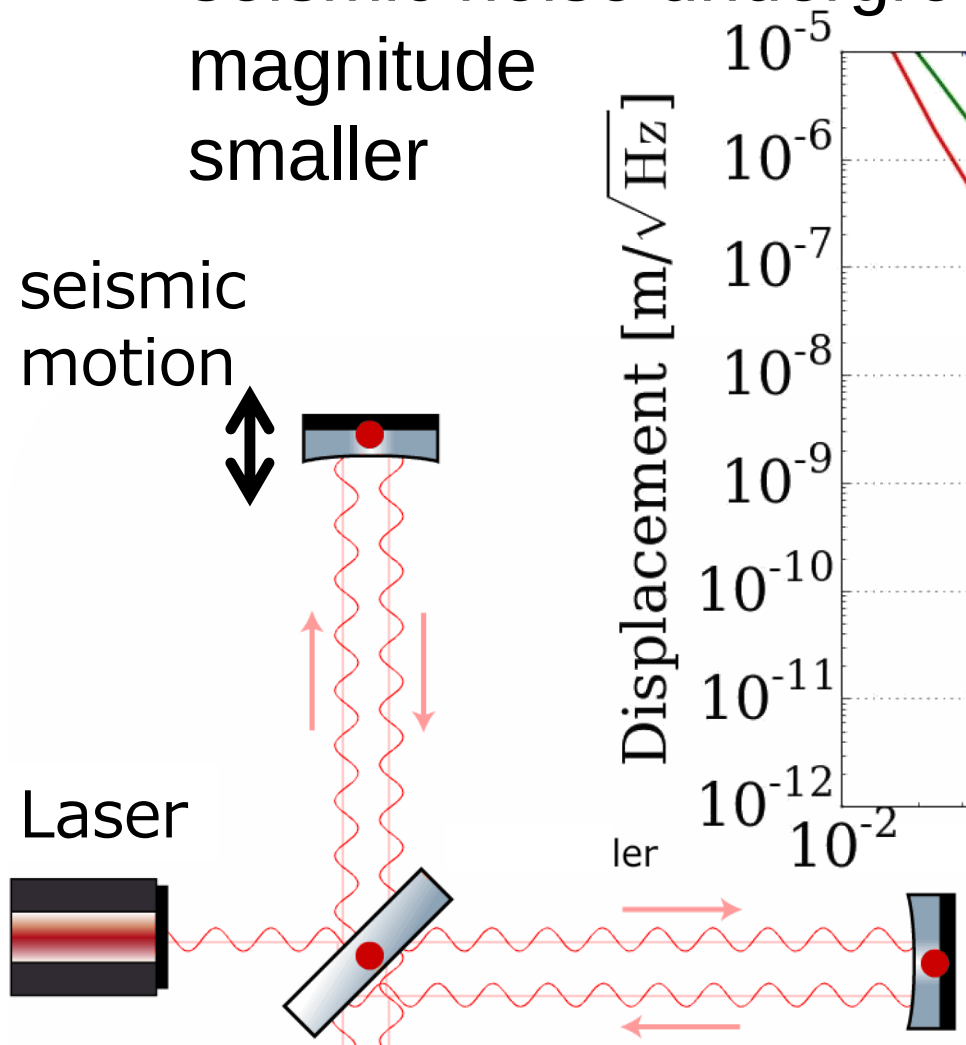
新跡津坑口
(2016.2.8)

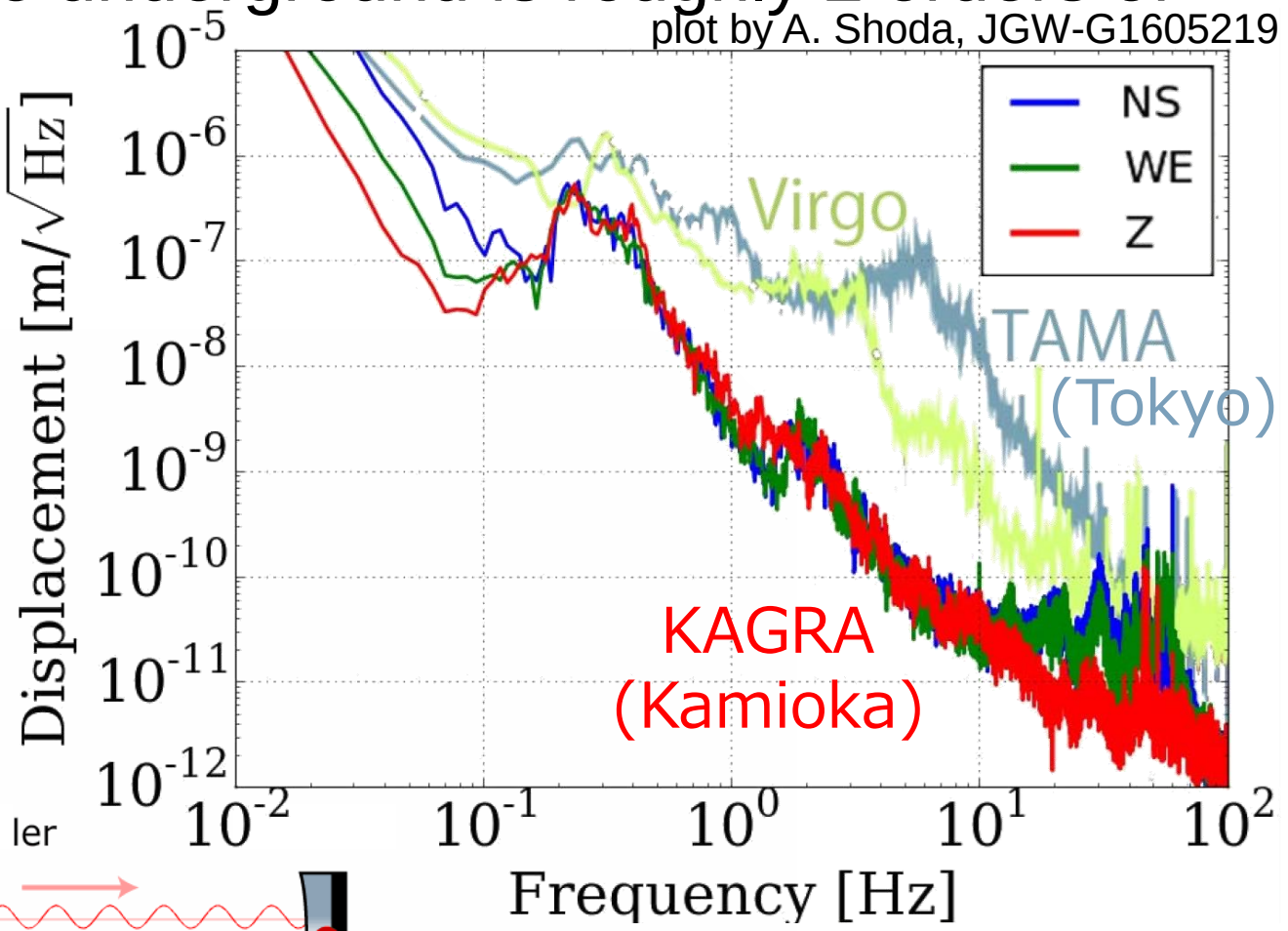
# Working Underground is Tough

- helmet, work clothes, rubber boots, oximeter, electric bicycles, etc

# Why Underground?

- seismic motion of mirrors will be noise source
- seismic noise underground is roughly 2 orders of magnitude smaller

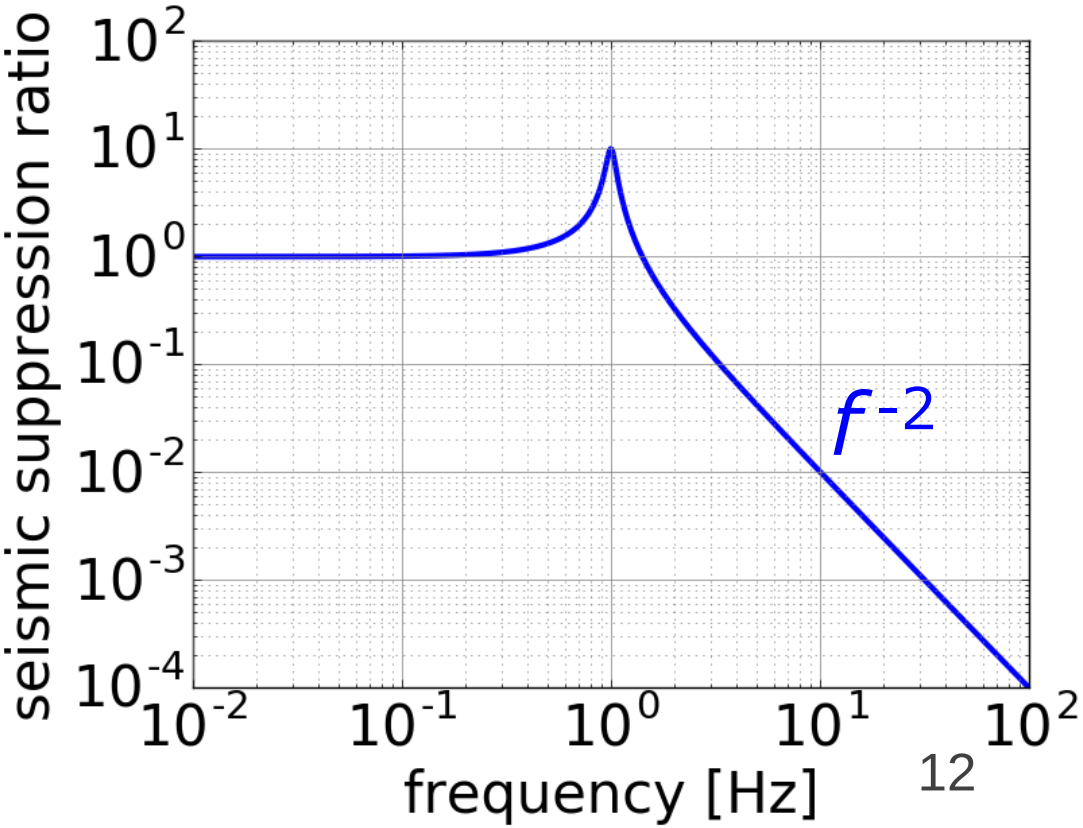


# Suspensions for Seismic Isolation

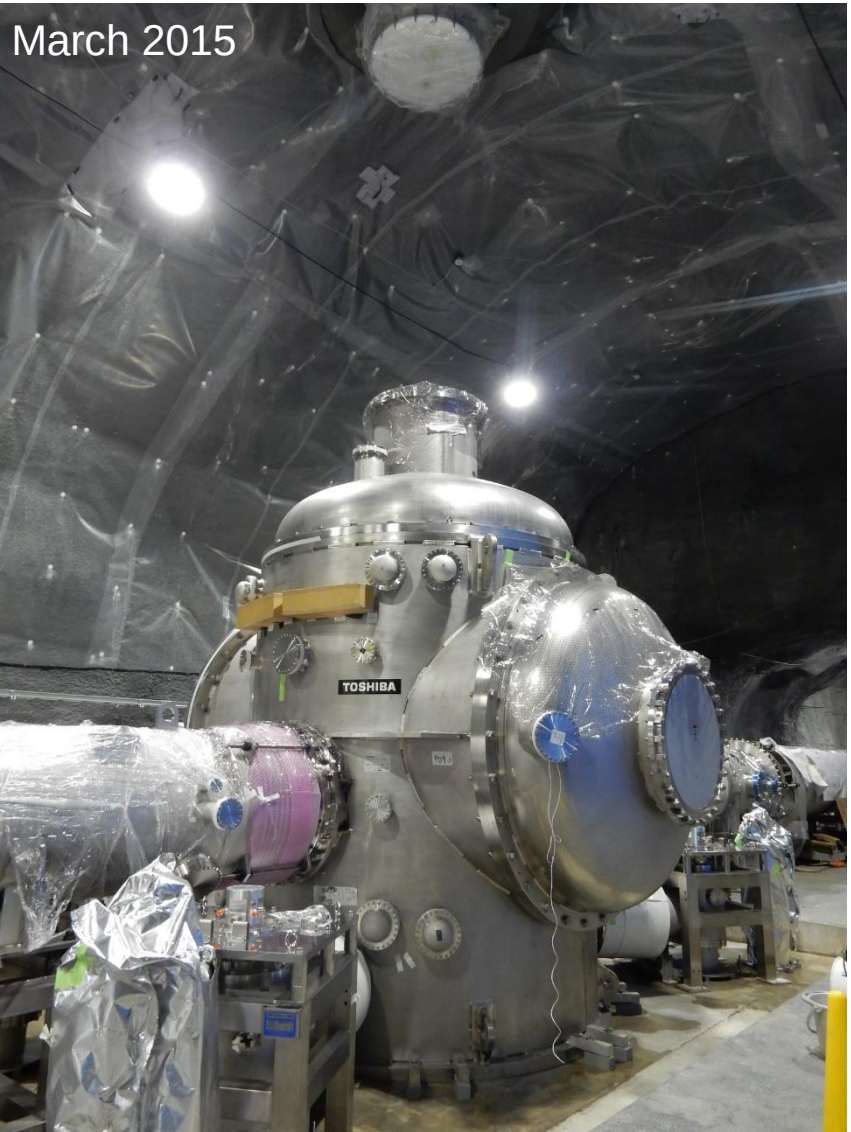
- suspend mirrors to reduce seismic noise

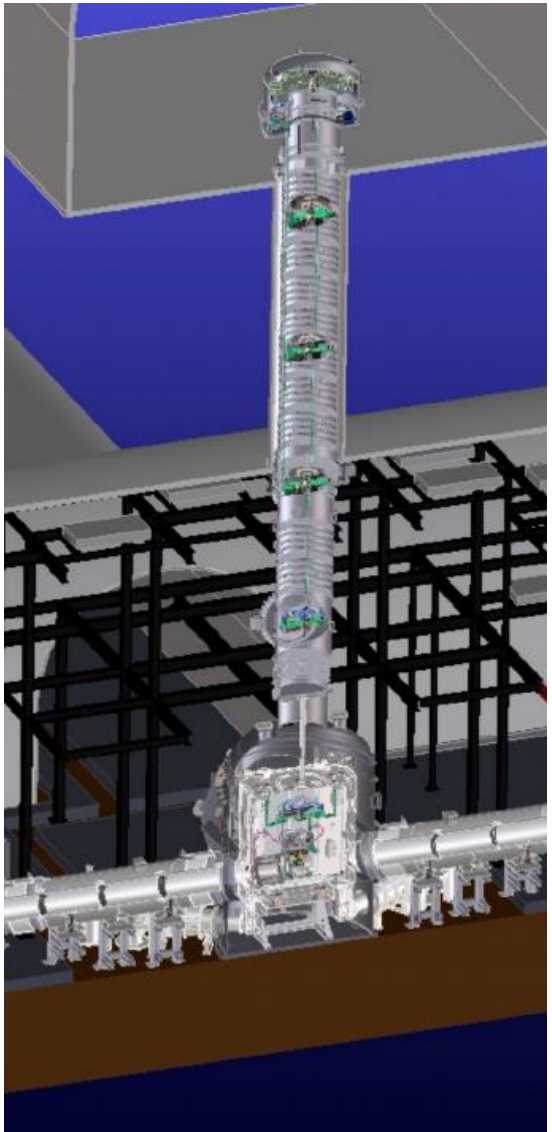


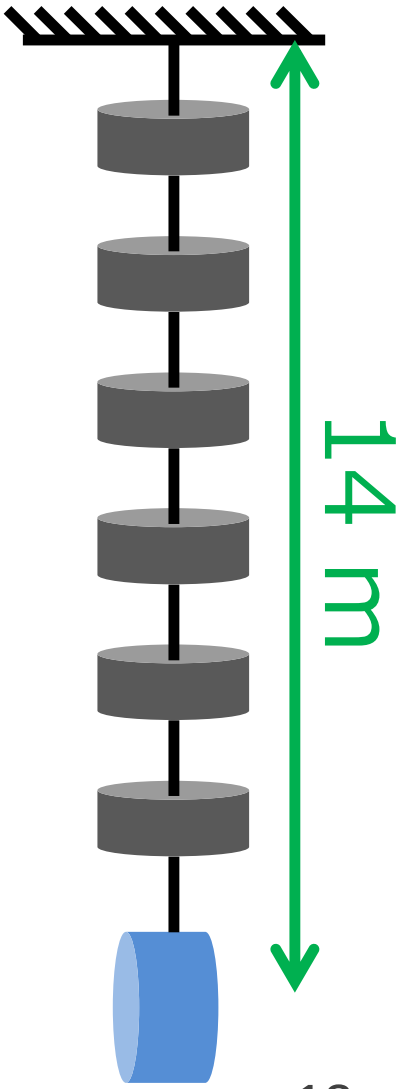



# Vibration Isolation System

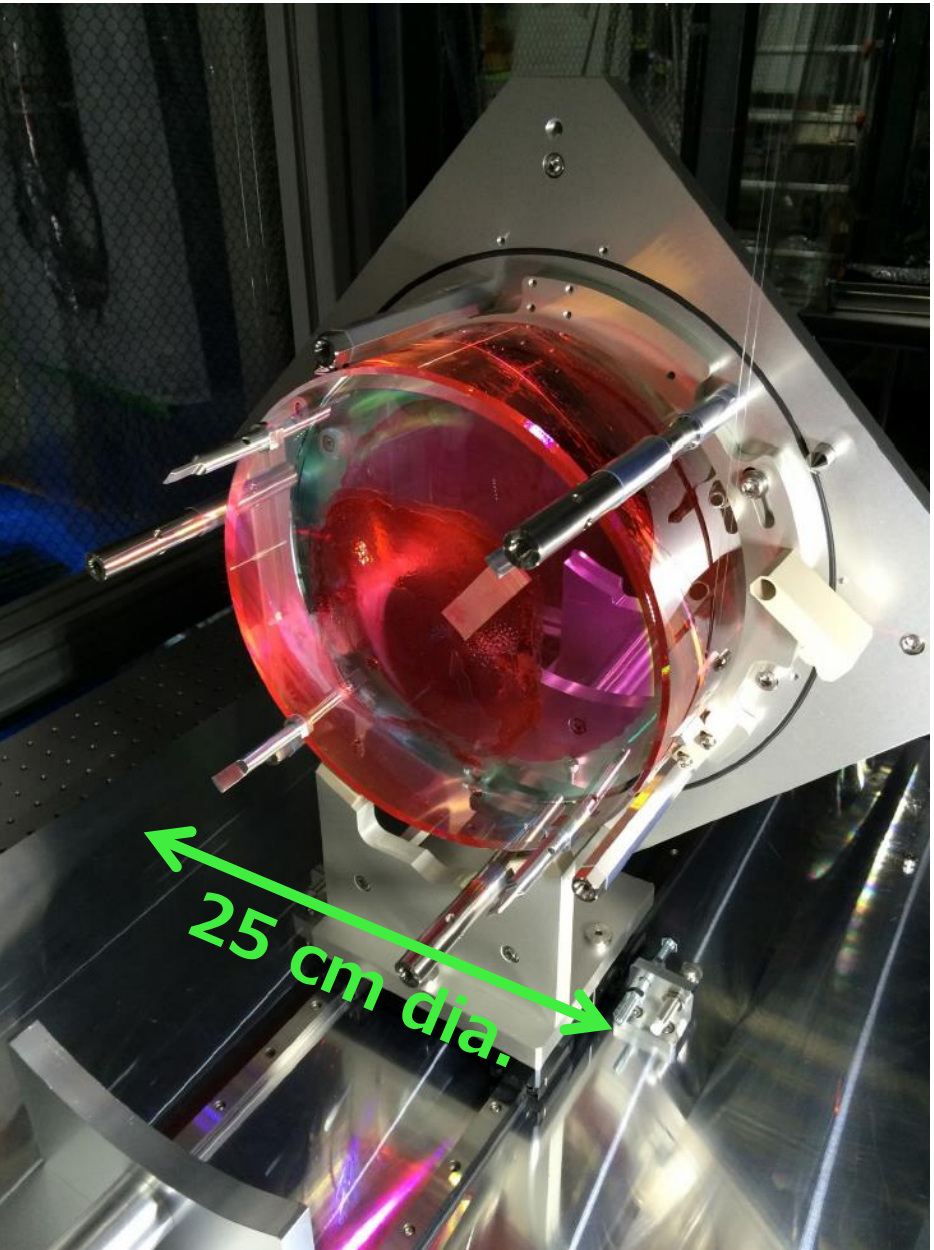
- 7-stage pendulum super attenuators

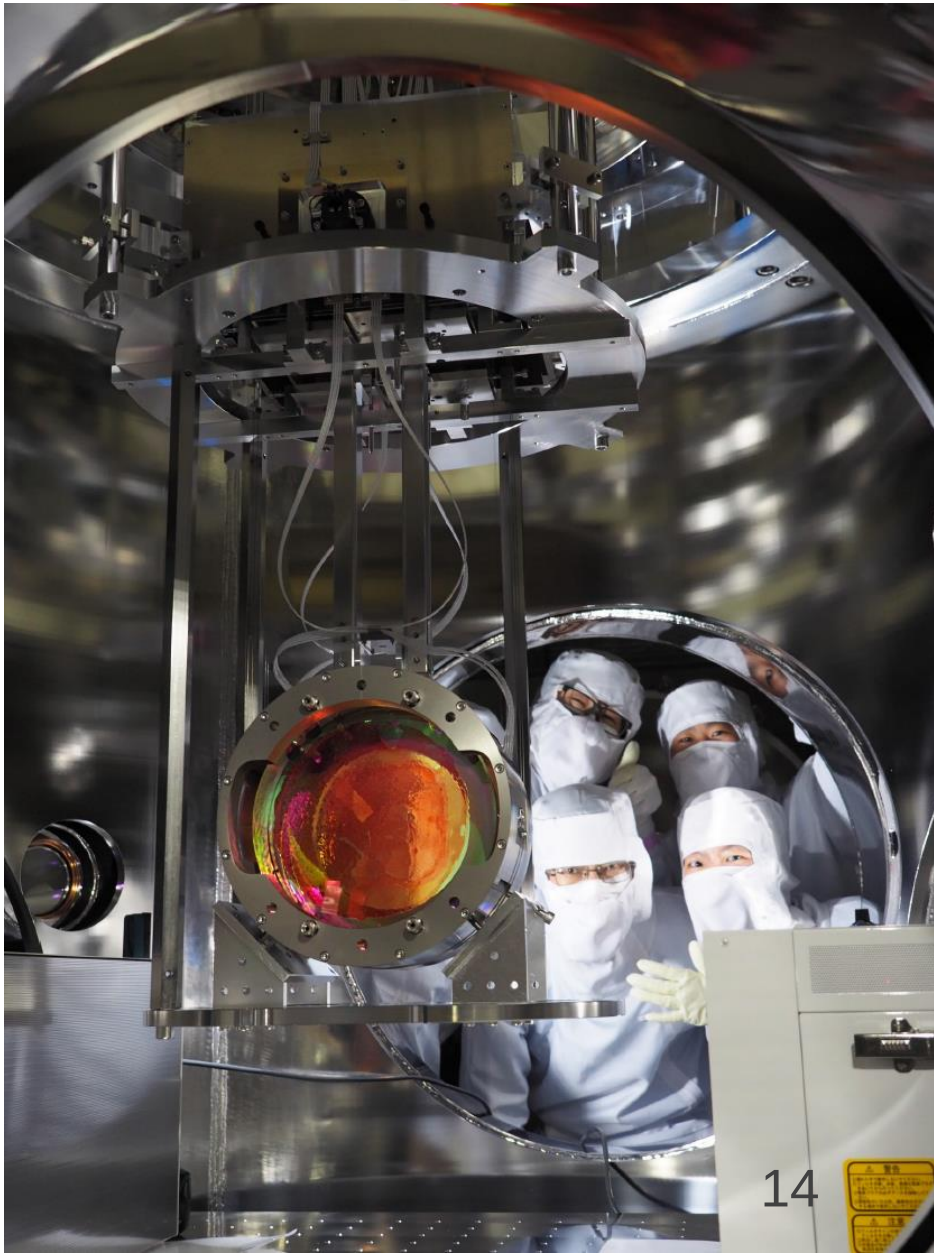




# Room Temperature Suspension

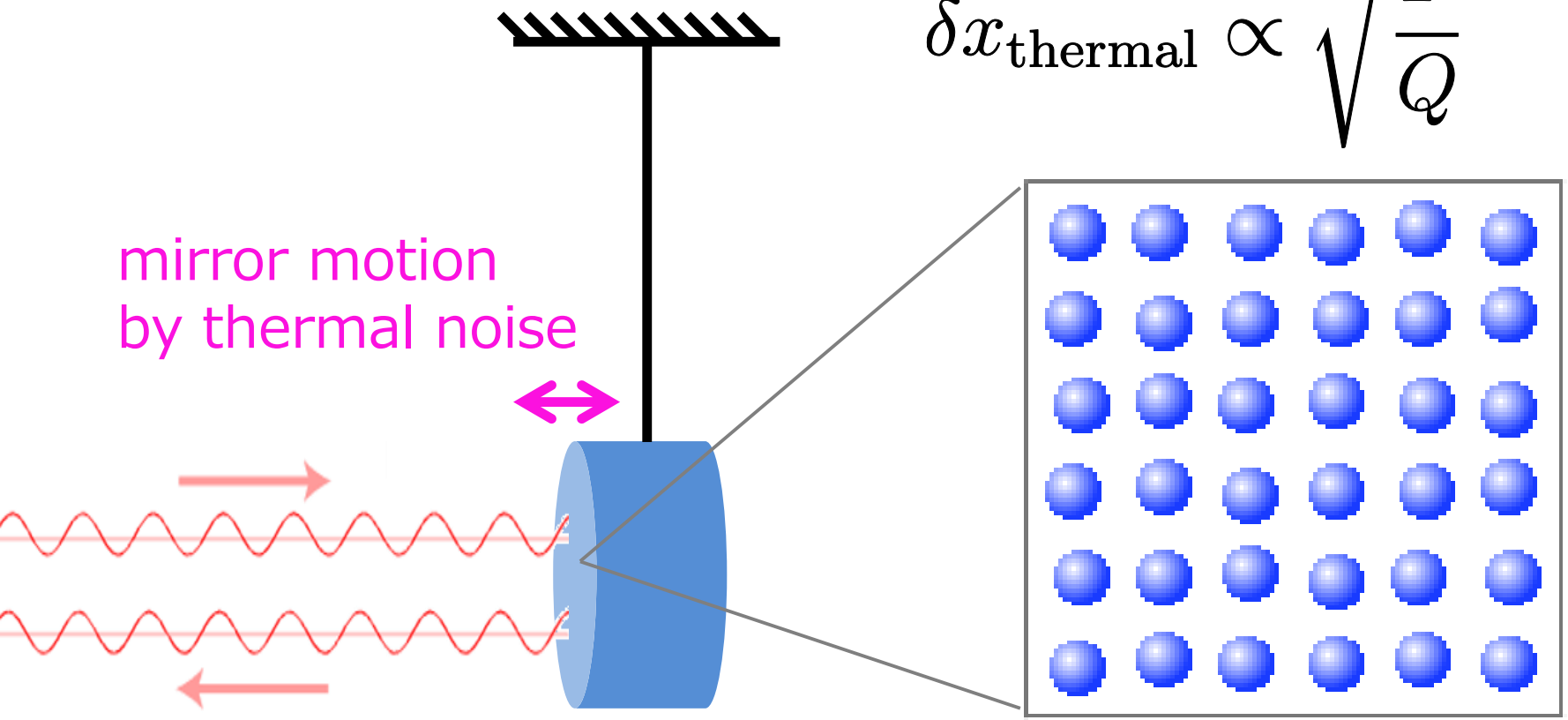


# Thermal Noise

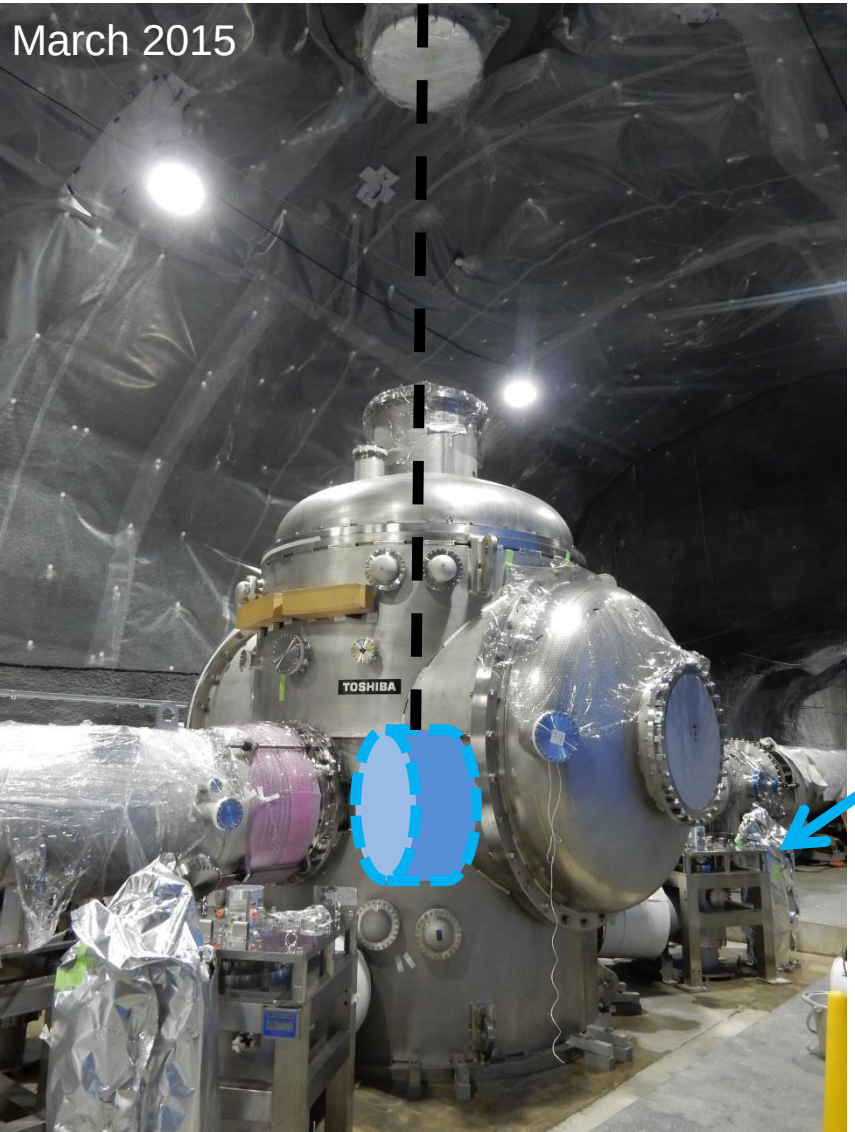
- Brownian motion of atoms creates thermal noise
- cool down mirrors to 20 K to reduce thermal noise

$$\delta x_{\mathrm{thermal}} \propto \sqrt{\frac{T}{Q}}$$



# Cryostat

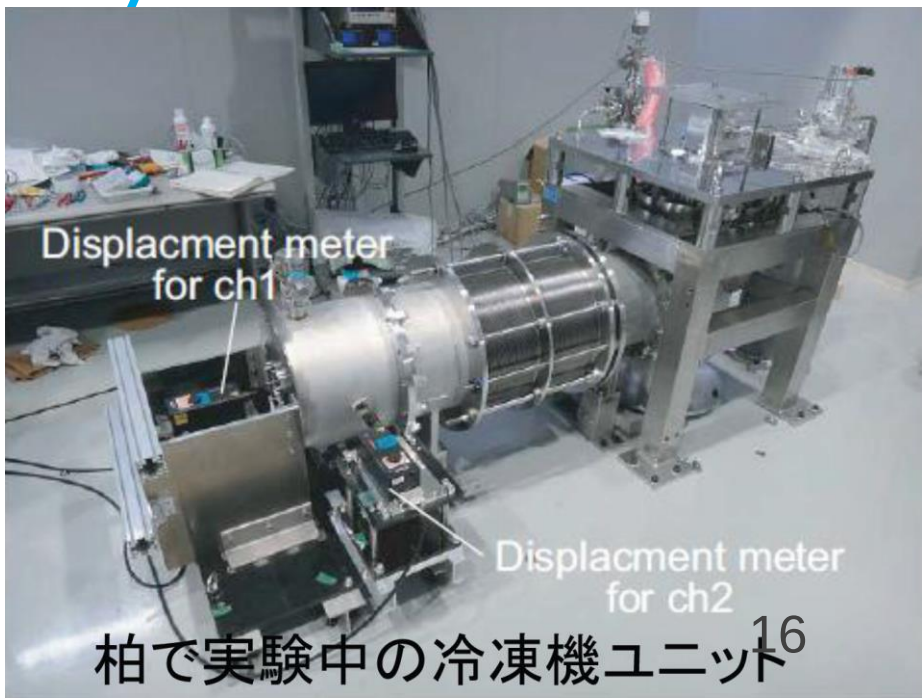
- developed cryocoolers with ultra-low vibration




TOSHIBA
Leading Innovation

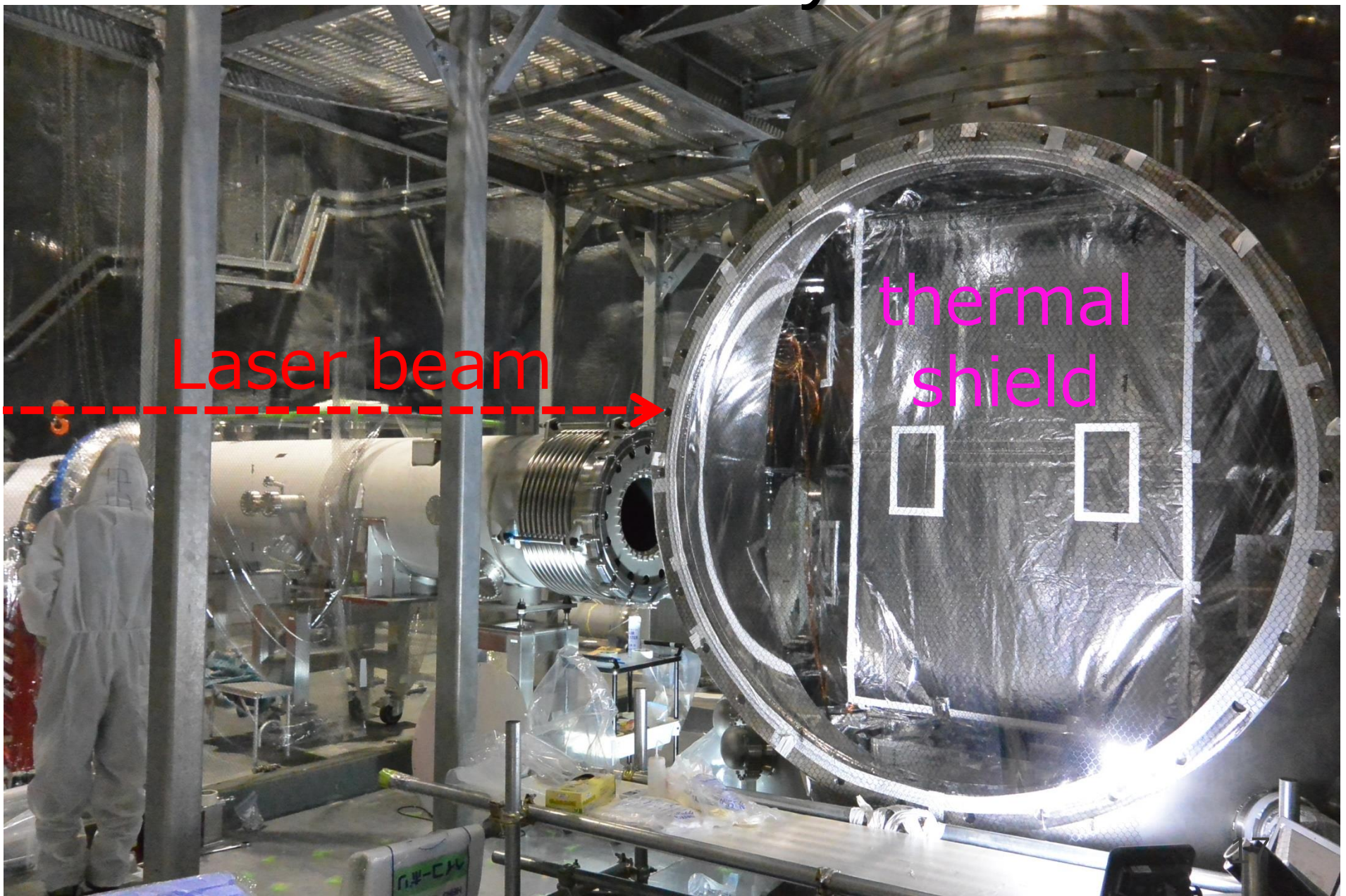
JECC TORISHA Co.,Ltd.

cryocooler




柏で実験中の冷凍機ユニット

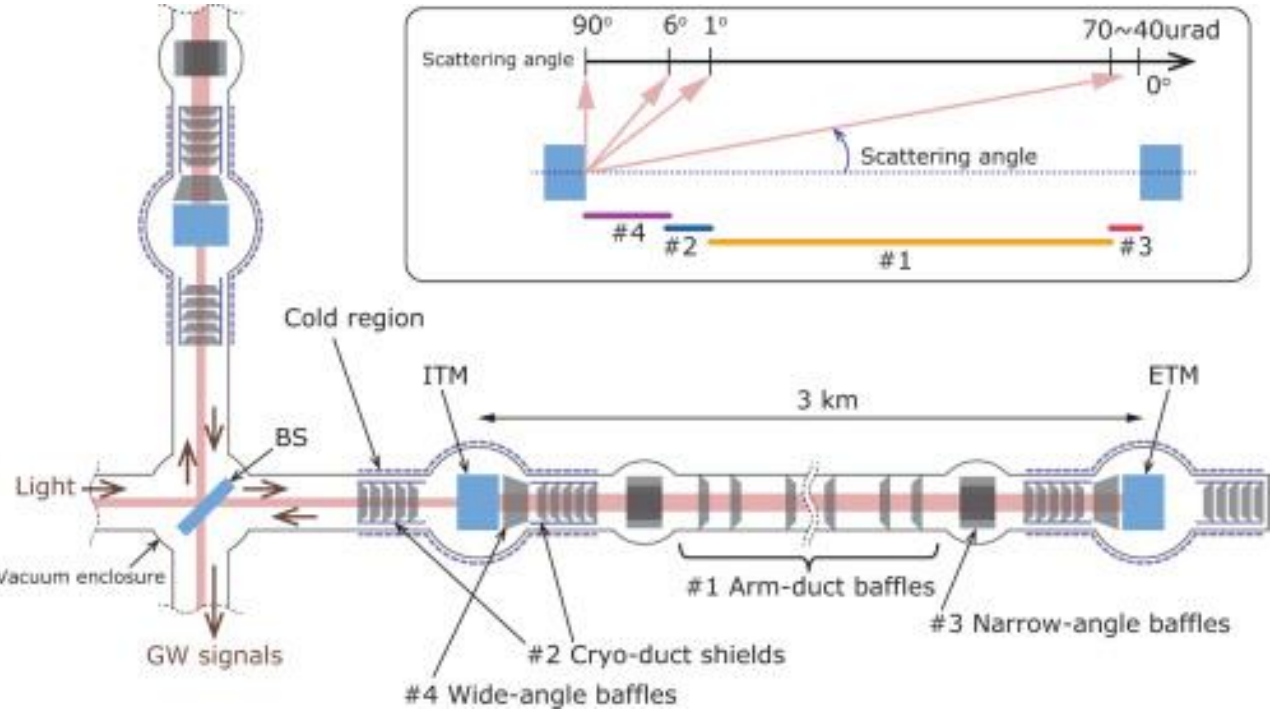
# Inside the Cryostat

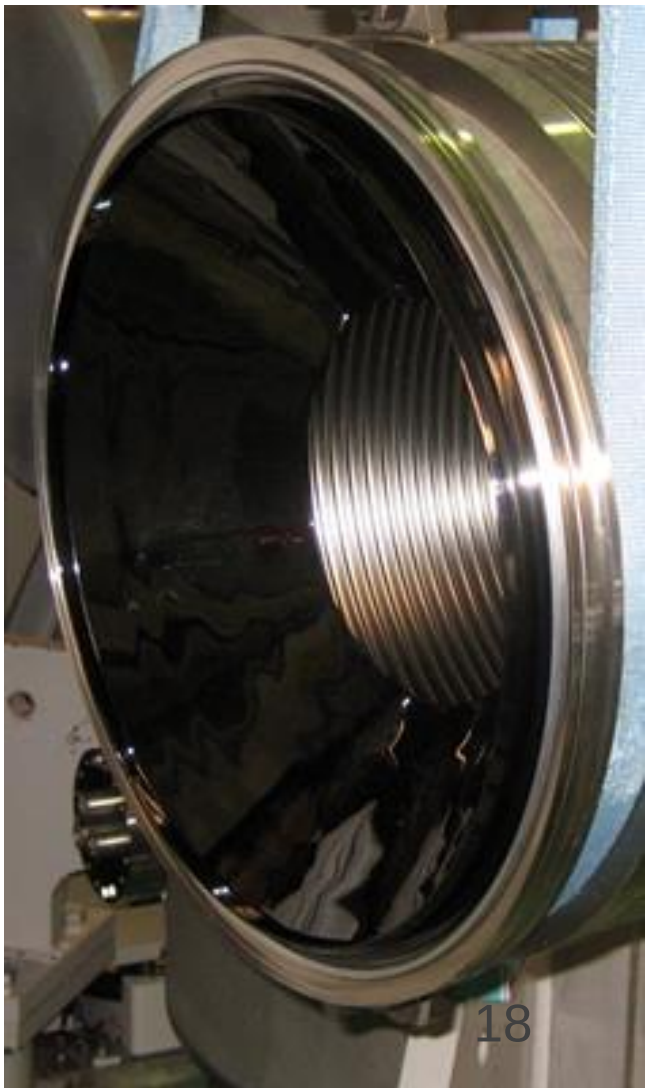


# Optical Baffles

- for absorbing stray light and 300 K thermal radiation
- nickel-phosphorus-tungsten (NiPW) black coating

T. Akutsu+, Optical Materials Express 6, 1613 (2016)

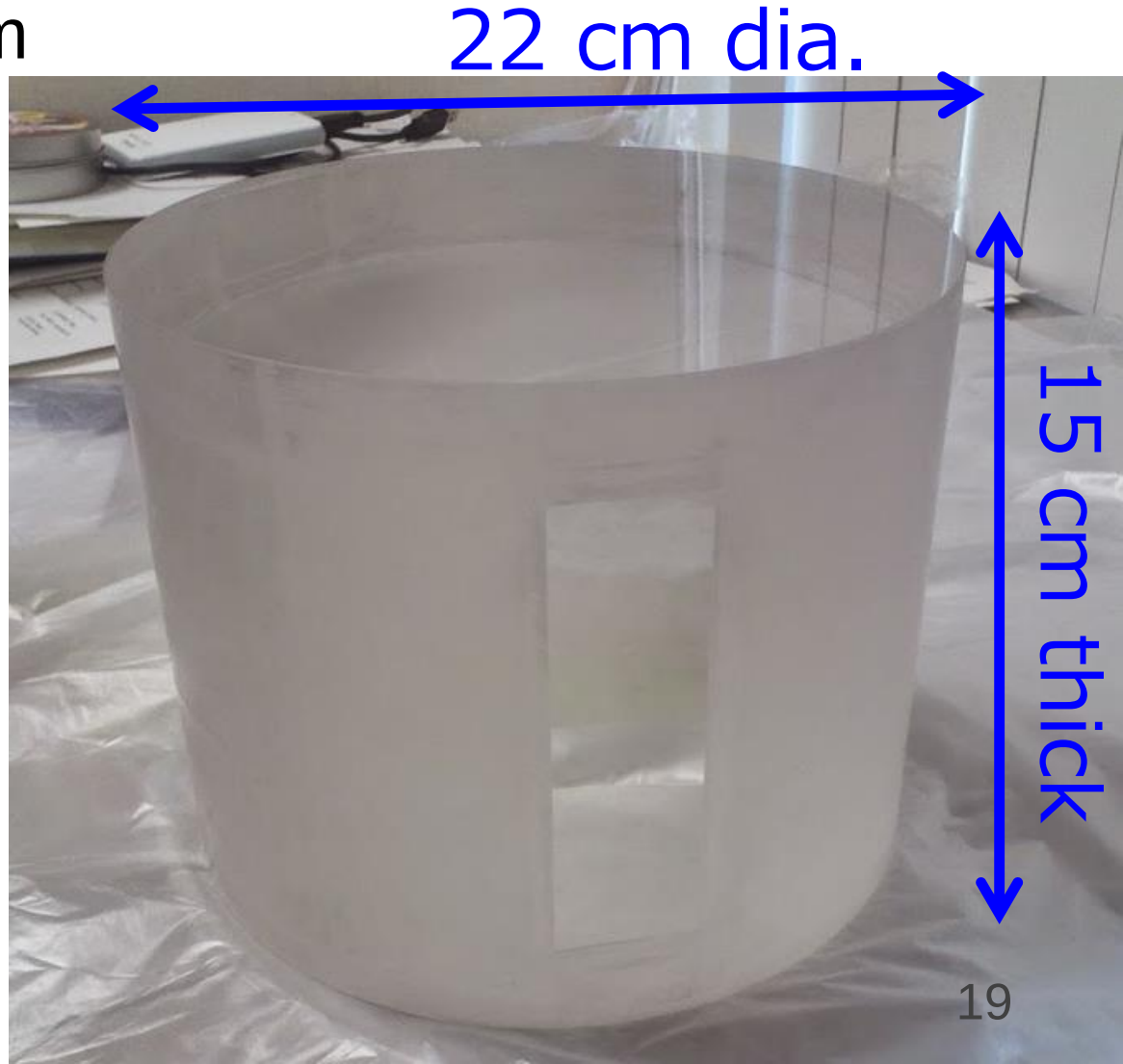


# Sapphire Mirror

- sapphire has high Q-value
- HR loss < 45 ppm
- absorption
  < 50 ppm/cm
- figure error
  < 0.5 nm rms

$$\delta x_{\mathrm{thermal}} \propto \sqrt{\frac{T}{Q}}$$




E. Hirose+,
Phys. Rev. D 89, 062003 (2014)

# Clean Environment

- ISO class 1 super clean booth

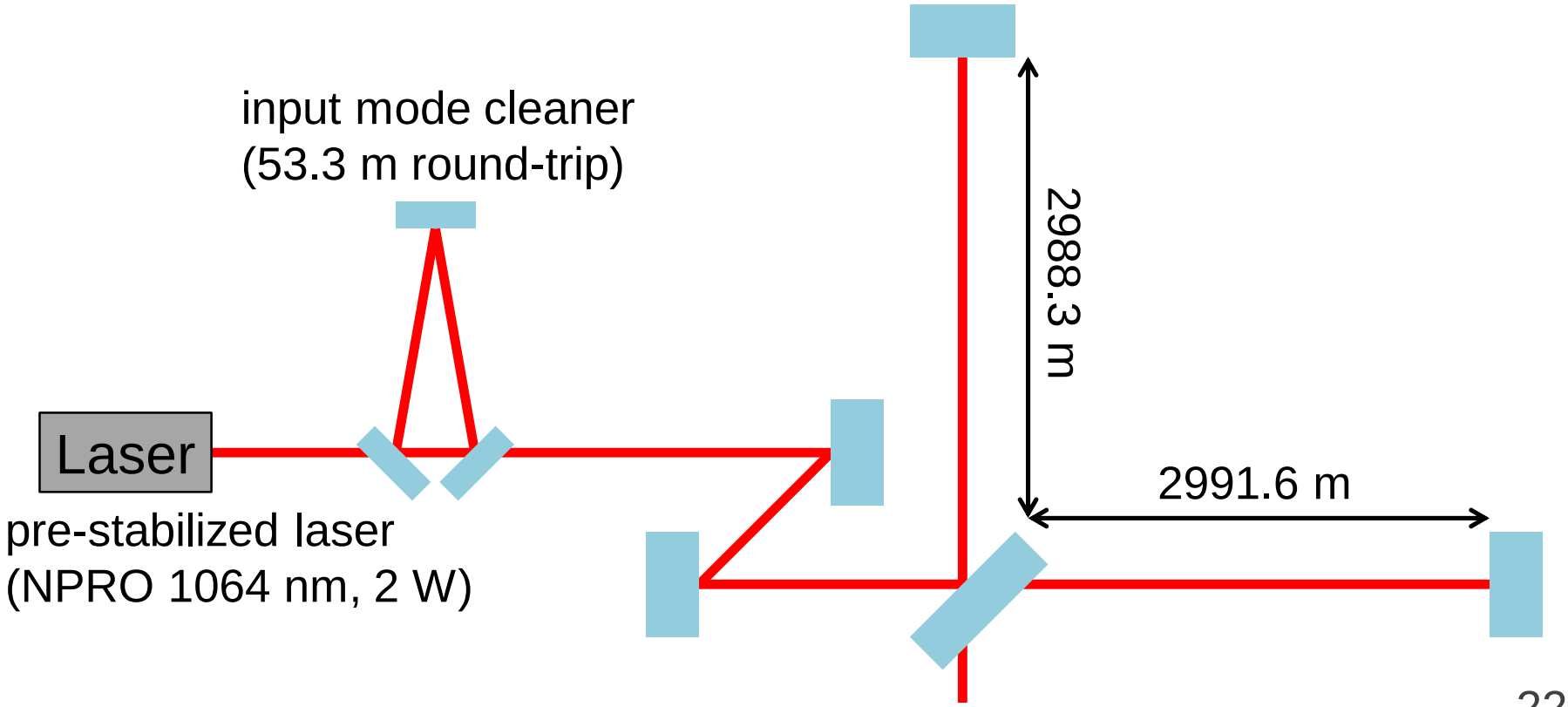
# Recent News

- Nov 2015: inauguration of initial phase facility
- Mar-Apr 2016: First test runs with simplified 3-km Michelson configuration


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

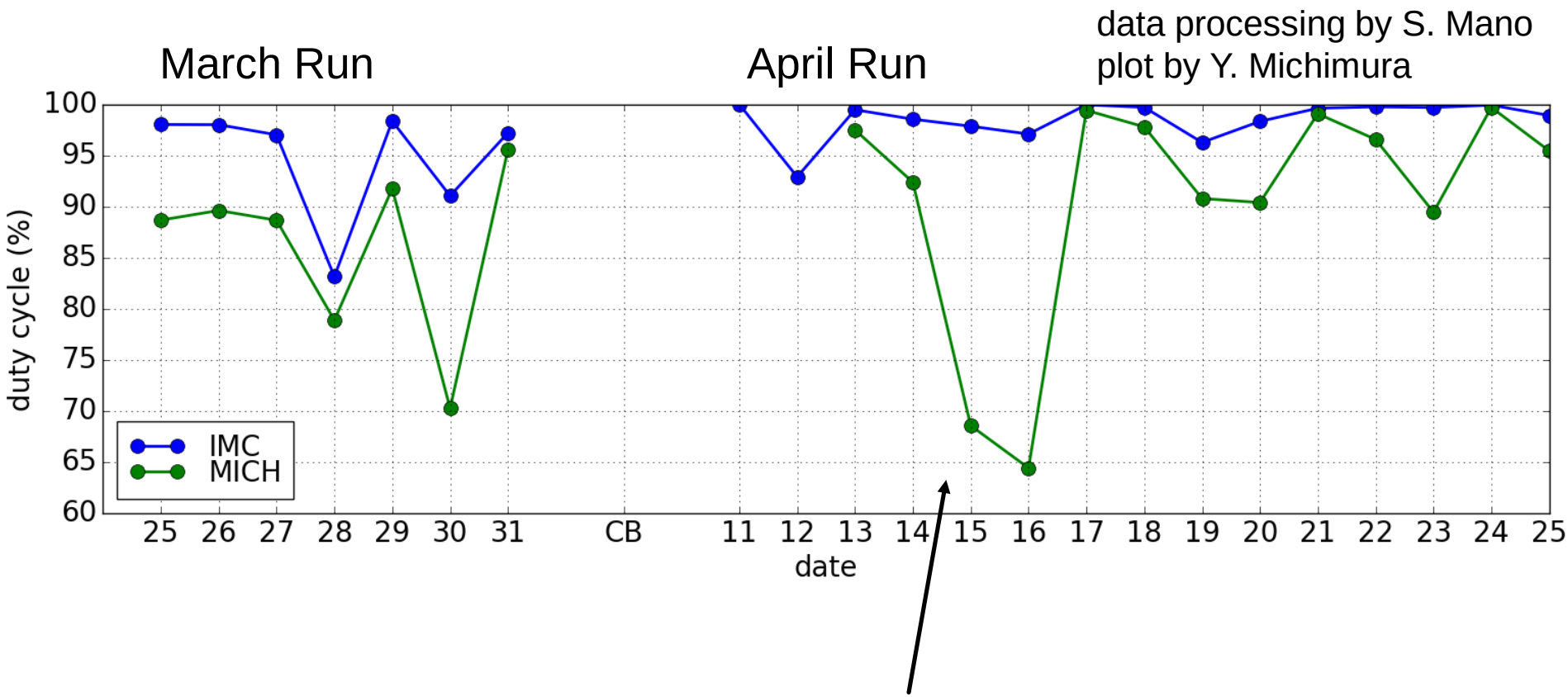
# First Test Runs

- 3-km room temperature Michelson interferometer
- March 25 - 31 and April 11 - 25



# Duty Factor

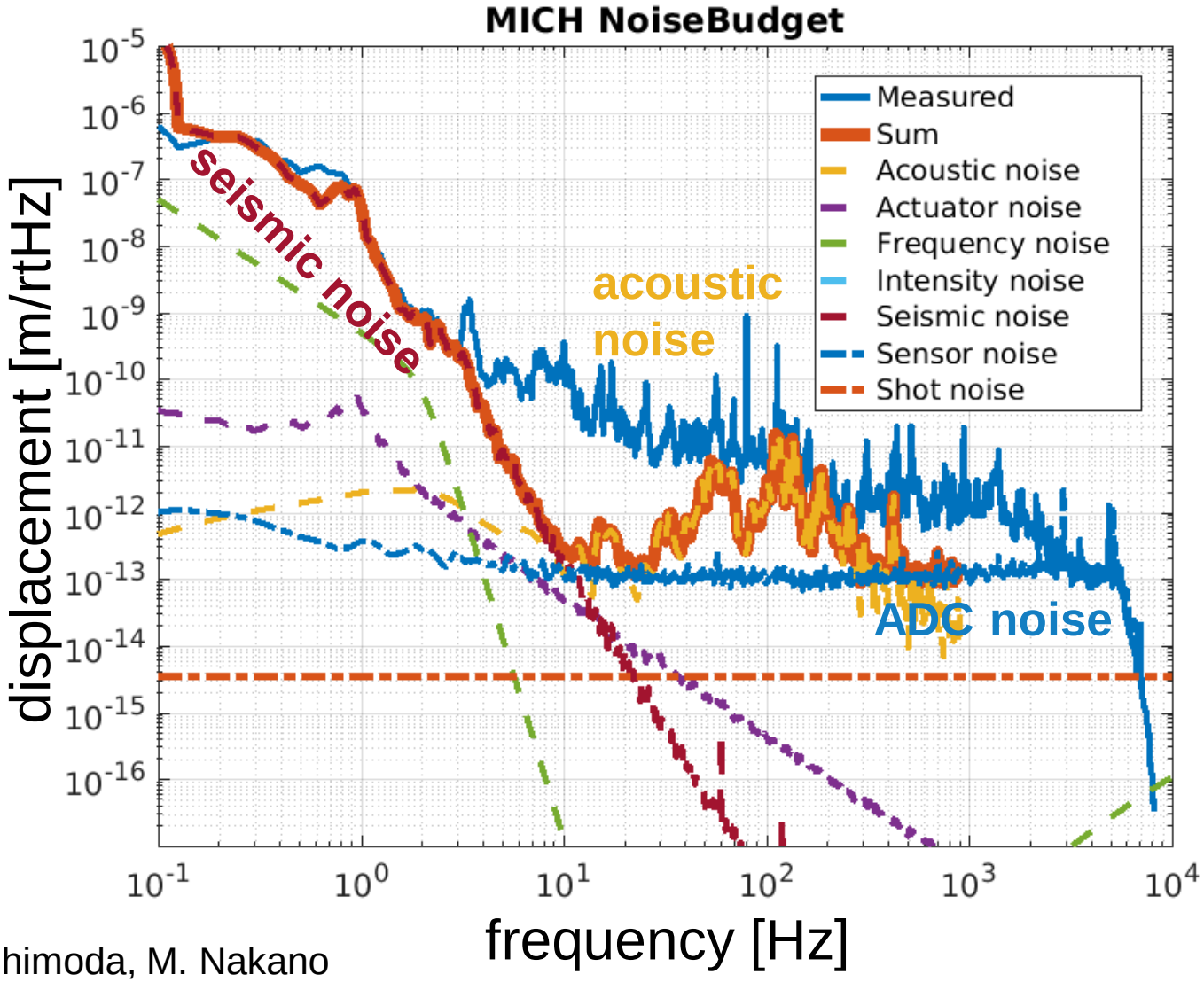
- 85.2 % for March run, 90.4 % for April run




Kumamoto Earthquake (7.0 Mw),
BS went wrong

# Sensitivity

- not good, but the very first result for KAGRA

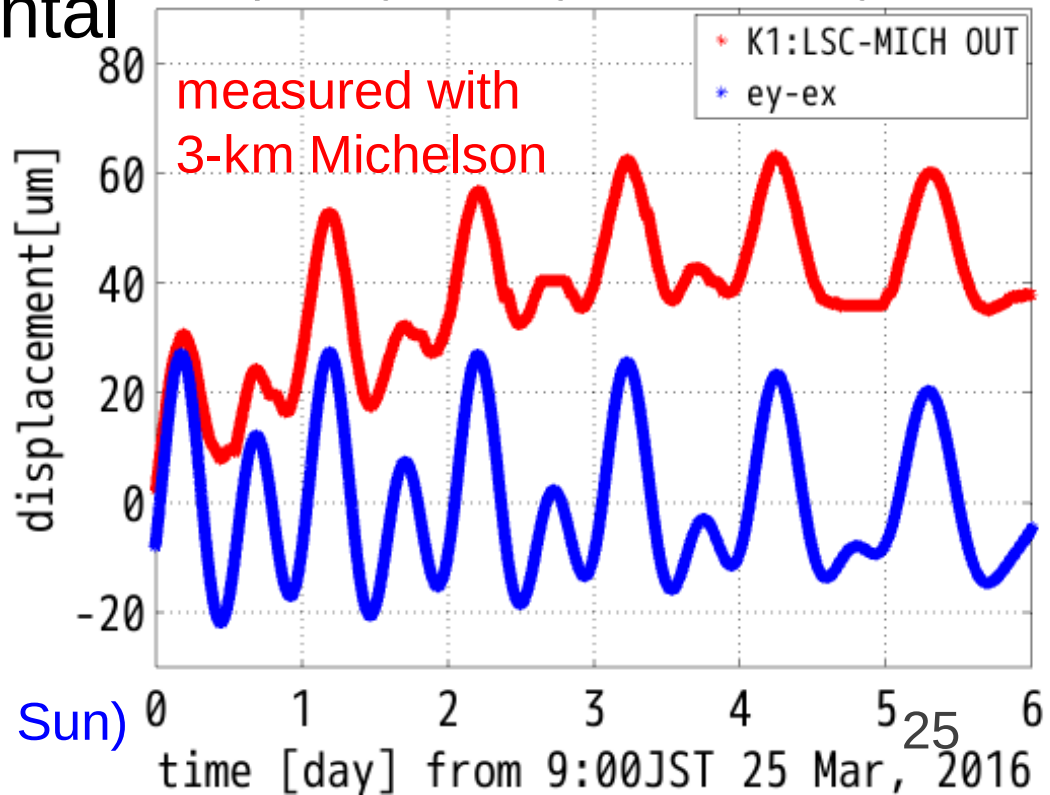



plot by T. Shimoda, M. Nakano

# Test Run Results

- gained experience on 3-km interferometer operation
- observation shift and data transfer/management worked as expected
- acquired environmental data at KAGRA site
  e.g. tidal length change of 3-km arms

plot by K. Hayama, A. Araya *et al.*



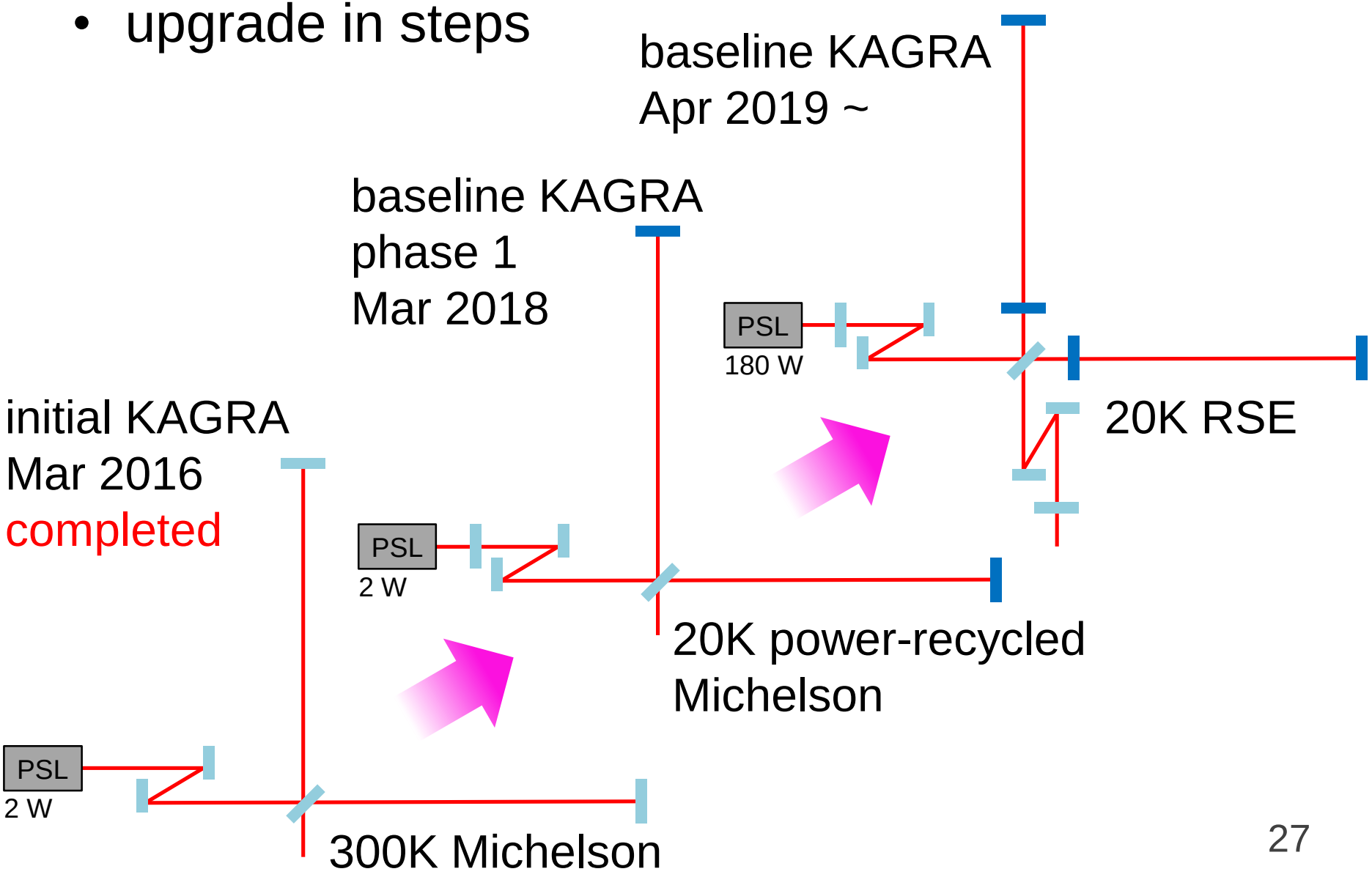

prediction using GOTIC2 model
(tidal effect from the Moon and the Sun)

# Data Transfer and Management

- real time transfer to ICRR Kashiwa and Osaka City Univ.
  (~3 sec latency, ~ 200 MB/sec)
- delayed mirroring at Academia SINICA, Taiwan and KISTI, Daejeon
- 7.5 TB in total

# KAGRA Roadmap

- upgrade in steps



# Recent Progress on Cryogenics

- cryogenic suspensions under development
- cryostat assembly on-going

photos from JGW-G1605315

# Summary

- KAGRA is under construction at Kamioka, Japan
- Key features: underground and cryogenic
- First test runs with room temperature 3-km Michelson interferometer successfully completed on March 2016
- Cryogenic test run expected on March 2018
- Observation runs expected on ~ 2019

# Acknowledgements


- KAGRA is supported by MEXT, JSPS Leading-edge Research Infrastructure Program, JSPS Grant-in-Aid for Specially Promoted Research 26000005, MEXT Grant-in-Aid for Scientific Research on Innovative Areas 24103005, JSPS Core-to-Core Program, A. Advanced Research Networks, and the joint research program of the Institute for Cosmic Ray Research, University of Tokyo.