LCGT and CLIO

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(Department of Physics, Kyoto University)

On behalf of the CLIO team and the LCGT Collaboration

Materials by T.Uchiyama, S.Miyoki, O.Miyakawa, A.Araya

GWADW2011 (23 May 2011 La Biodola, Isola d'Elba, Italy)

1. Introduction : LCGT
2. CLIO
3. Earthquake
4. LCGT Schedule and Status
5. Summary

LCGT

LCGT

LCGT (Large-scale Cryogenic Gravitational-wave Telescope)

Next-generation GW detector in Japan

Large-scale Detector
- Baseline length: 3km
- High-power Interferometer

Cryogenic interferometer
- Mirror temperature: 20K

Underground site
- Kamioka mine,
  1000m underground

Start of LCGT project

LCGT project was selected by the 'Facility for the advanced researches' program of MEXT (June 2010).

Construction cost is partially approved:
9.8 BYen for first 3-year construction.
(Original request: 15.5 BYen for 7 years.)

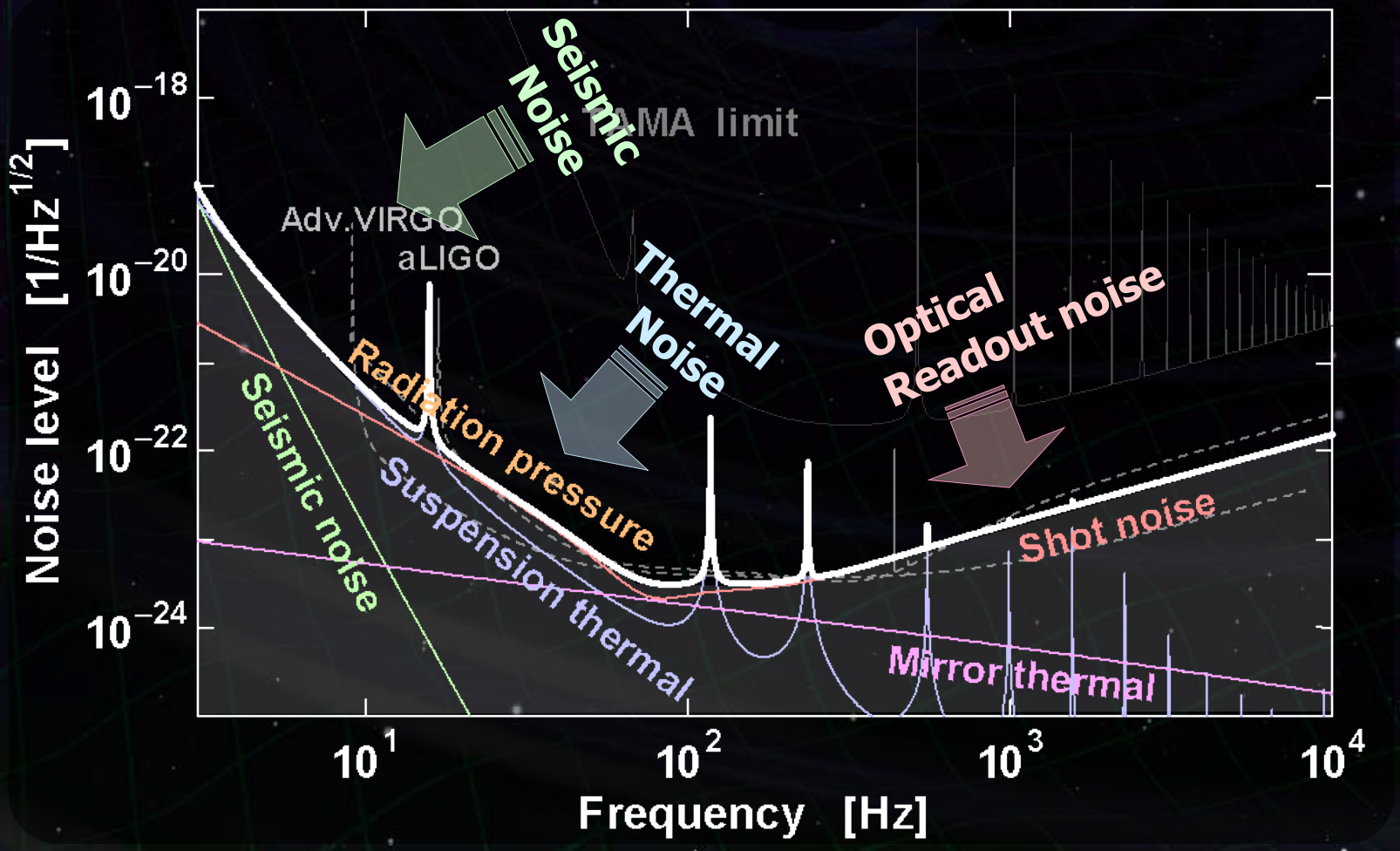
In addition, request for excavation cost has been approved.

Baseline design is not changed:
Requesting the additional cost for full construction of LCGT.

Sensitivity Curve

Comparable with aLIGO Ad.VIRGO

→ Global observation network



Developments for LCGT

High freq. : Shot noise
- Optical config. of RSE
- High-power laser source
- Low-loss optics

Mid. freq. : Thermal noise
- Cryogenic
- Sapphire
- Suspension design

Low freq. : Seismic noise
- Quiet site of Kamioka
- Seismic attenuator

- **Prototypes (NAOJ, Caltech)**
- **Detector design**
  → Talk by K.Somiya
- **100-W laser (Kashiwa)**
  → Talk by N.Ohmae
- **CLIO (ICRR, Kamioka)**
  → This talk
- **Cryostat design (KEK)**
  →Talk by Y.Sakakibara and N.Kimura
- **SAS in TAMA300 (NAOJ)**
- **Attenuator design**
  → Talk by R.DeSalvo

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CLIO

(Cryogenic Laser Interferometer Observatory)

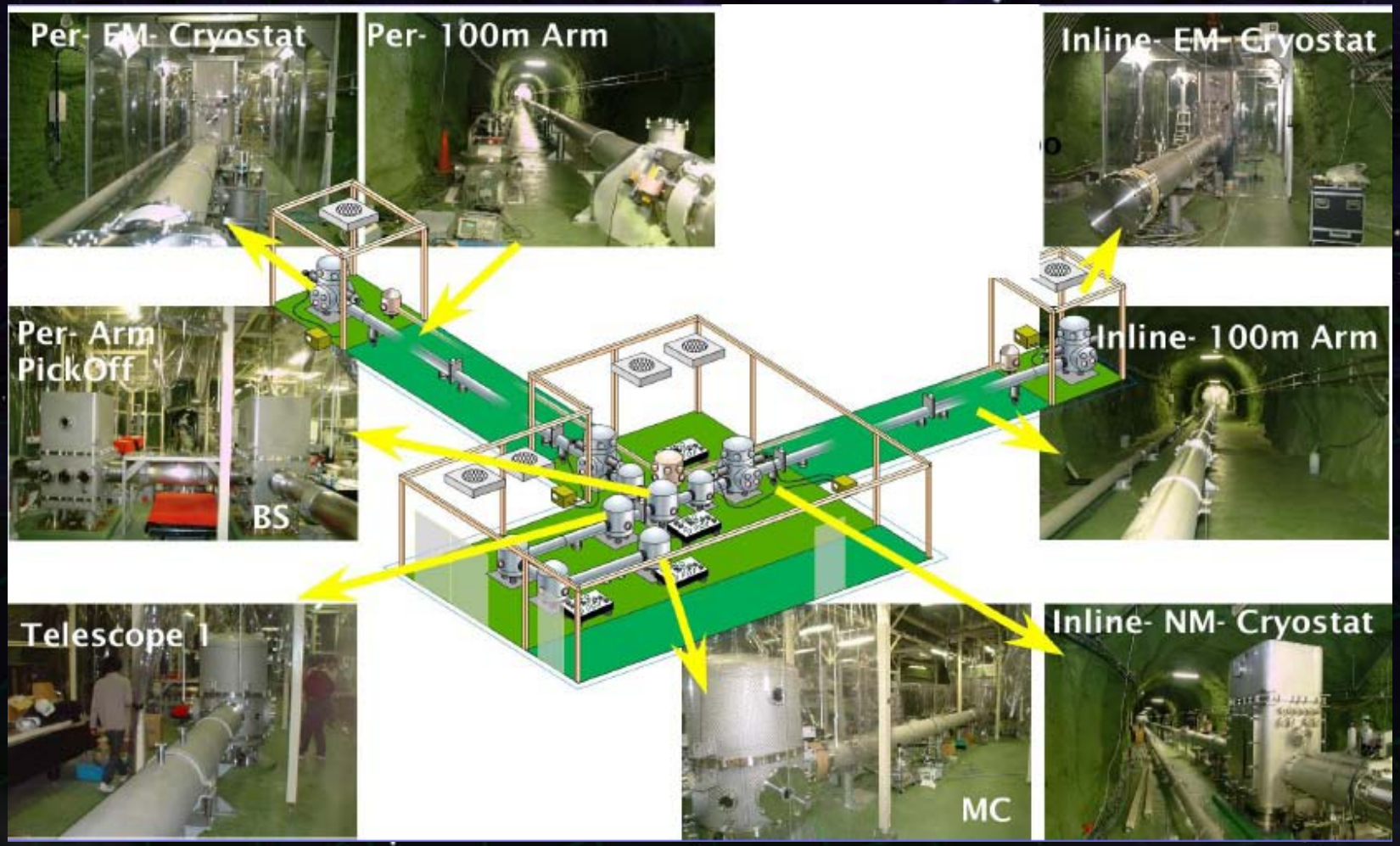
※ **Most of the materials were prepared by …**

S. Miyoki, T. Uchiyama, O.Miyakawa

CLIO

Locked-Fabry-Perot interferometer

Cryogenic Sapphire TM , underground ,baseline length of 100m



CLIO site

Same site as LCGT: Kamioka underground site

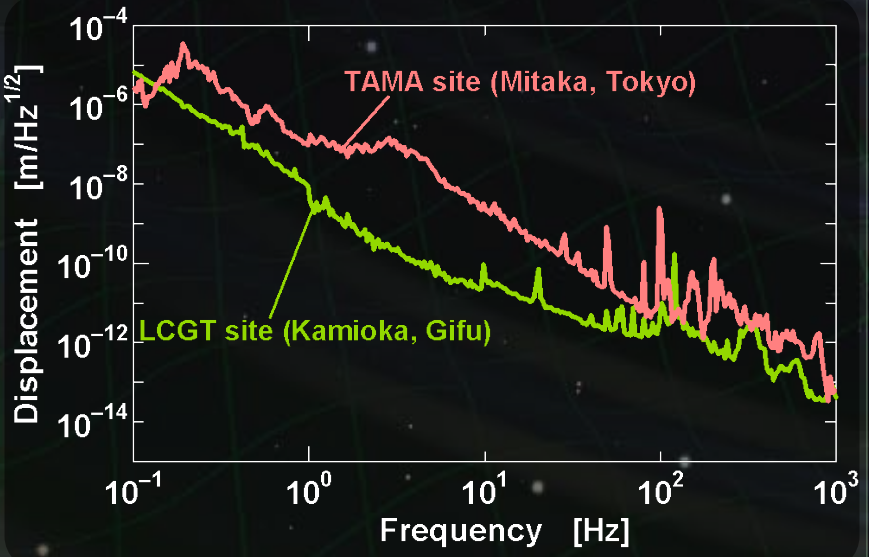
- 220km away from Tokyo
- 1000m underground from the top of the mountain. (Near Super Kamiokande)
- 360m altitude
- Hard rock of Hida gneiss (5 [km/sec] sound speed)

CLIO environment (1/2)

Stable environment for long-term operation
Small seismic disturbance for low-freq. sensitivity

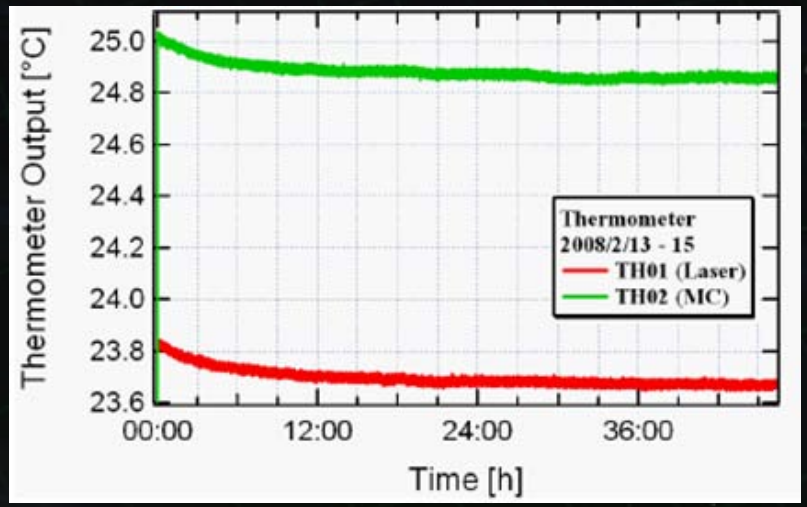
Seismic disturbance

Kamioka underground site
(~1000km underground)
Lower than TAMA300 site
by 2-3 orders



Temperature

Temp. fluctuation < 0.2 degree
for about 2 days



CLIO environment (2/2)

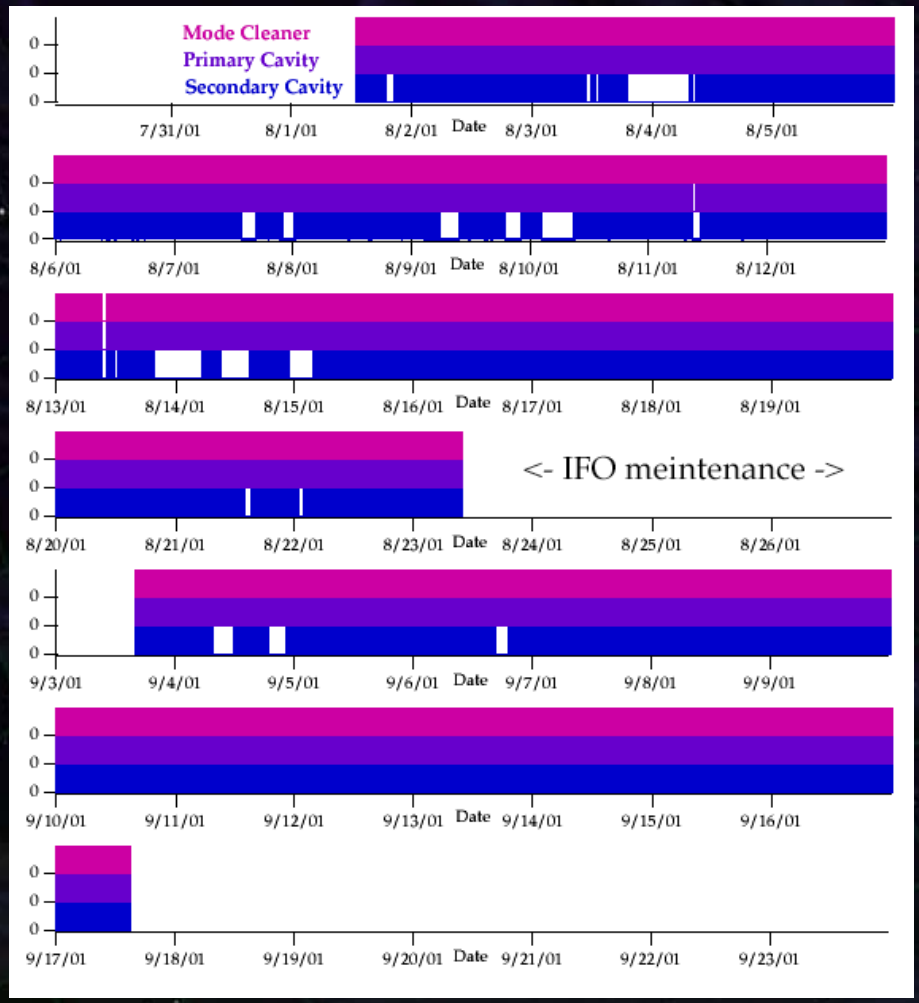
Long-term run at Kamioka site

LISM interferometer

- **Baseline : 20m**
- **Suspended test masses**
- **Locked-FP config.**
- **No global alignment ctrl.**

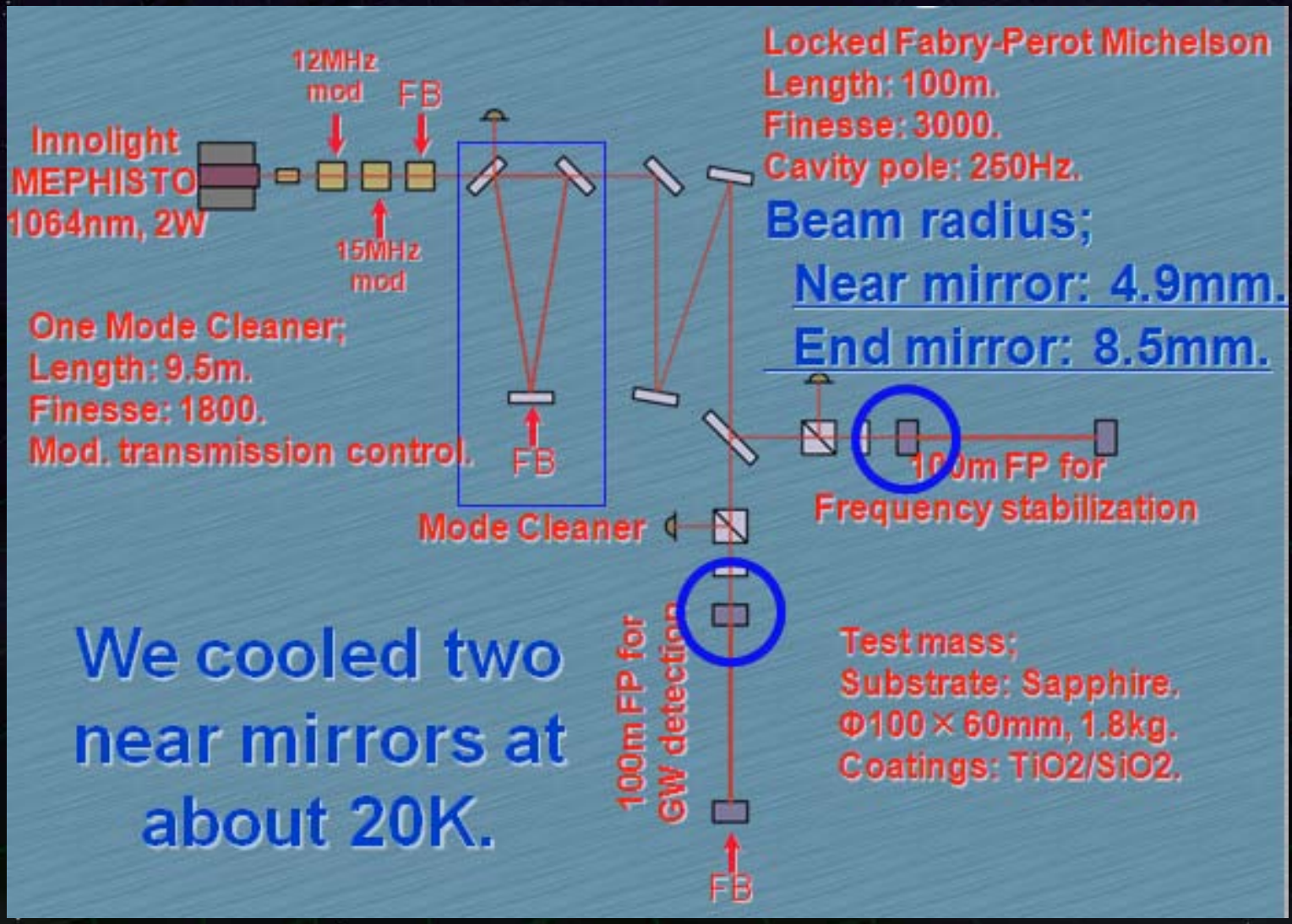
- Observation period :
  8/1-8/23, 9/3-9/17 (2002)
- Total observation time : 862h
- Total lock : 786h
- Longest stretch of lock : 72h

Live rate : 91%
(99.8% for last 1week)



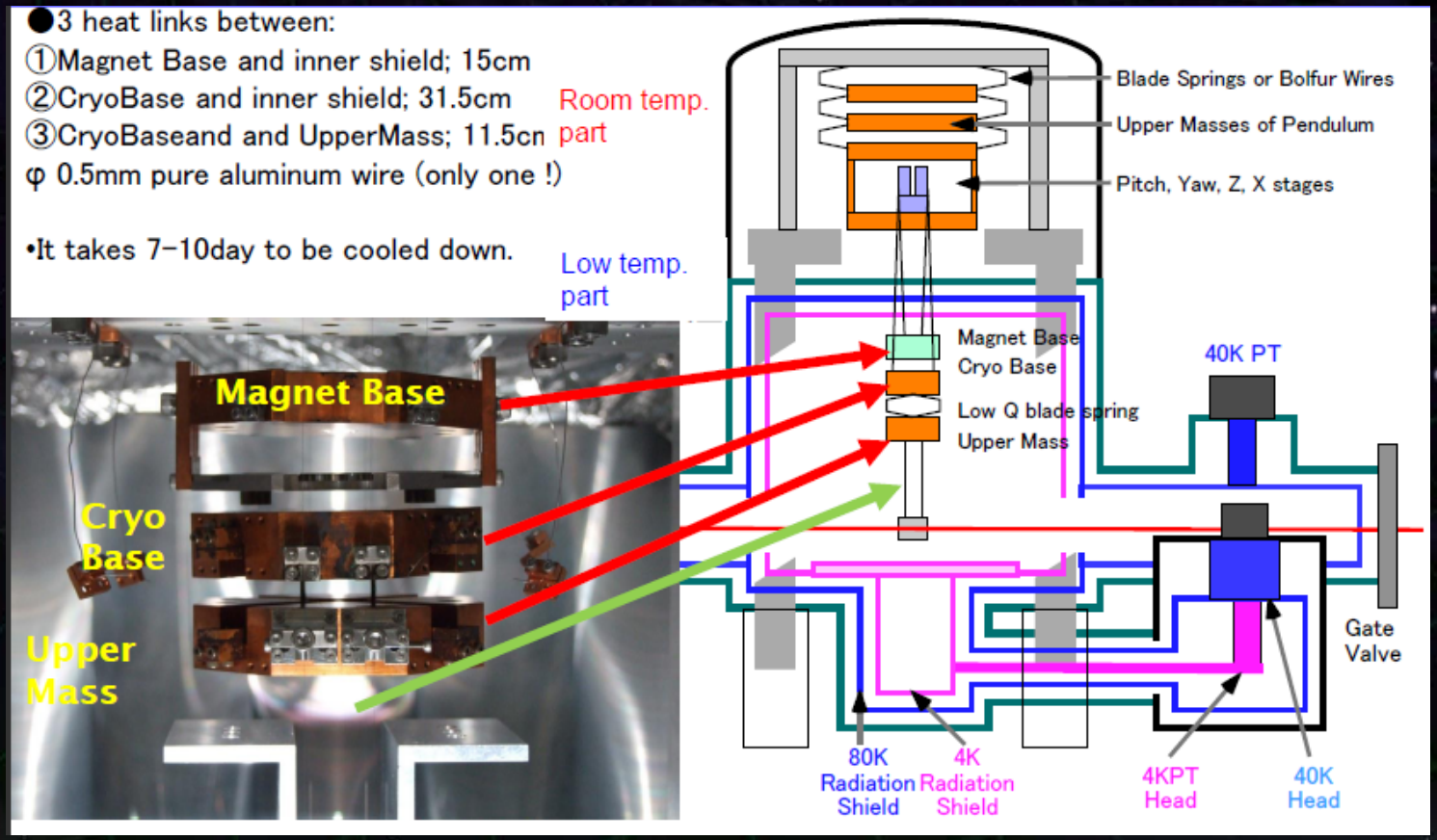
CLIO Configuration

Two input test masses were cooled down



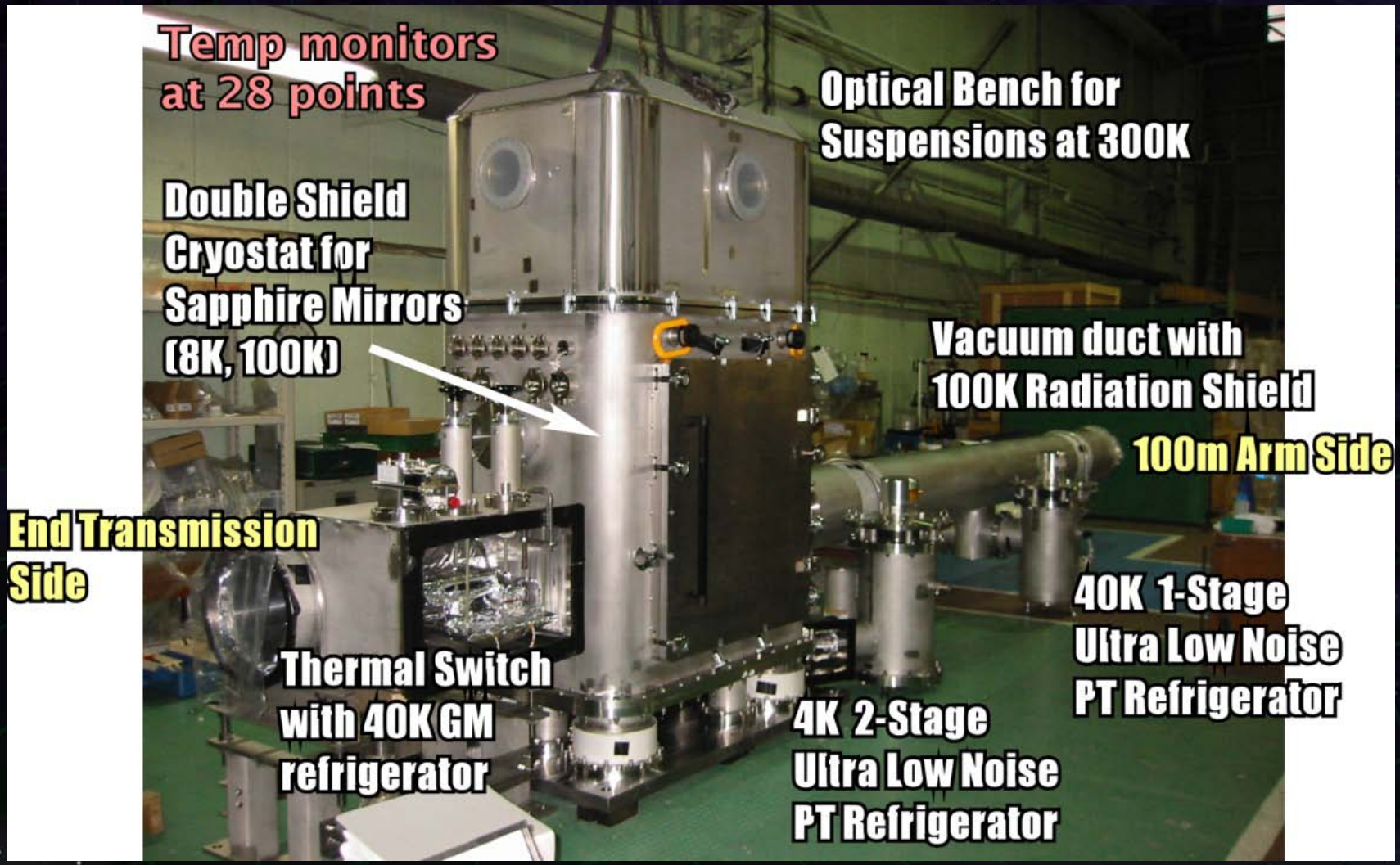
Cryogenic Test-Mass

Test mass: Sapphire 2 kg, ϕ100 x t60 mm
Suspension: 3 stages at room-temp, 3 stages in cryostat
Heat links for conductive cooling
Low-vibration pulse-tube cryo-cooler



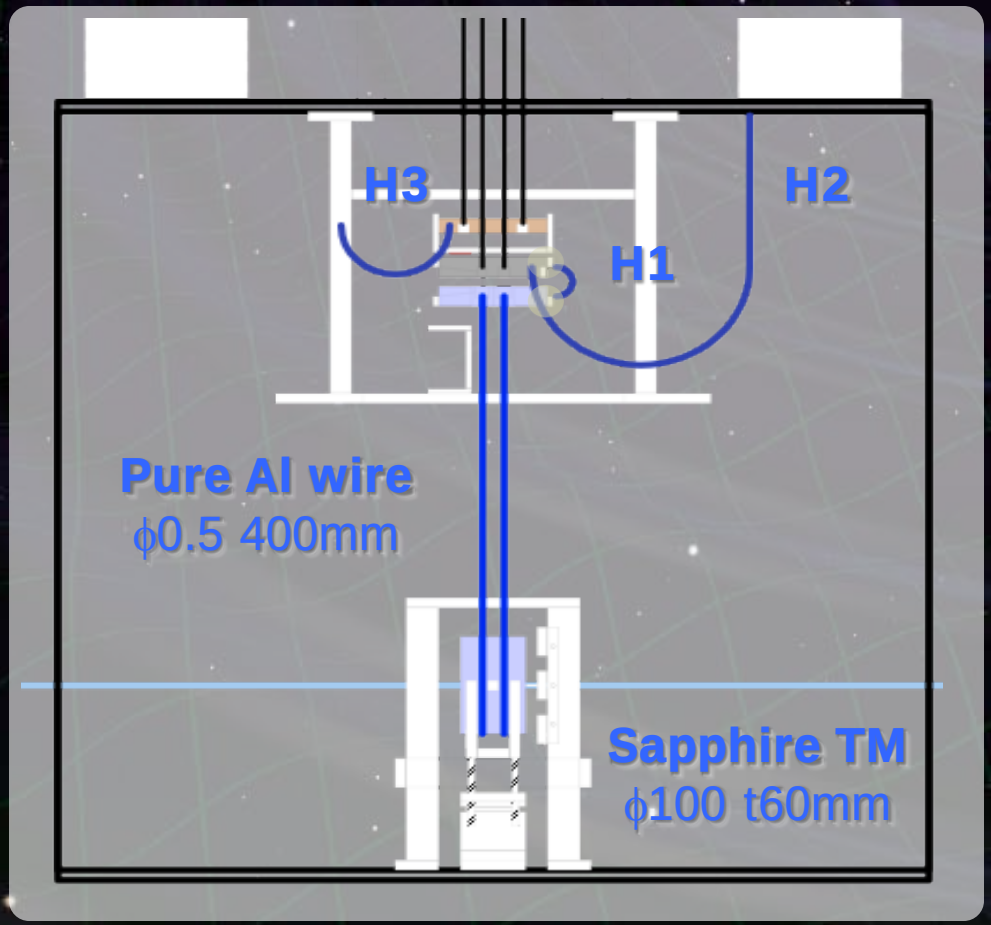
CLIO Cryogenic system

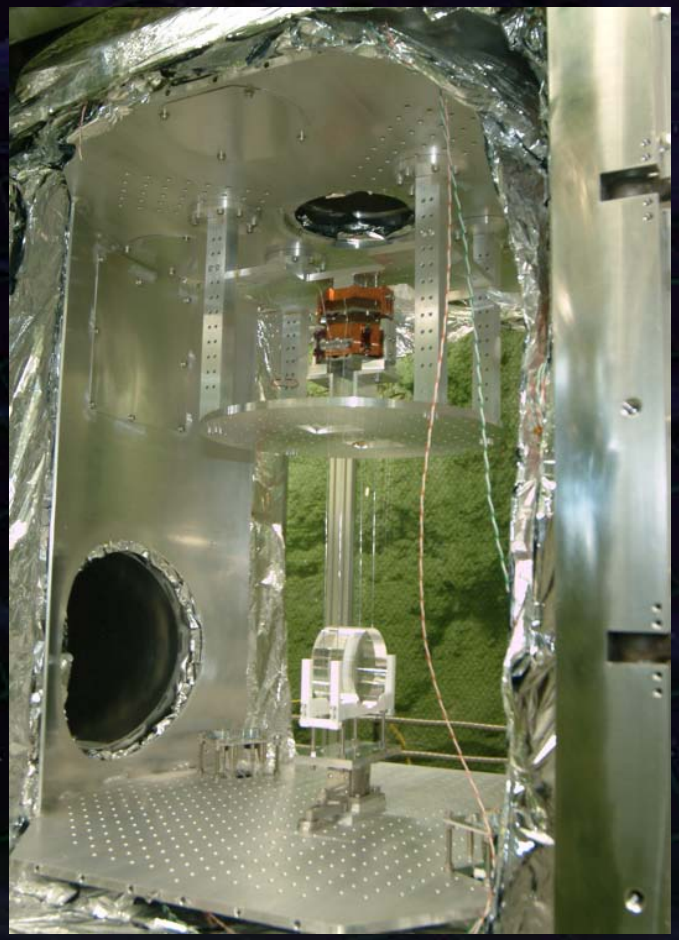
Cryostat, cryo-cooler and radiation shield



CLIO Cryogenic Suspension

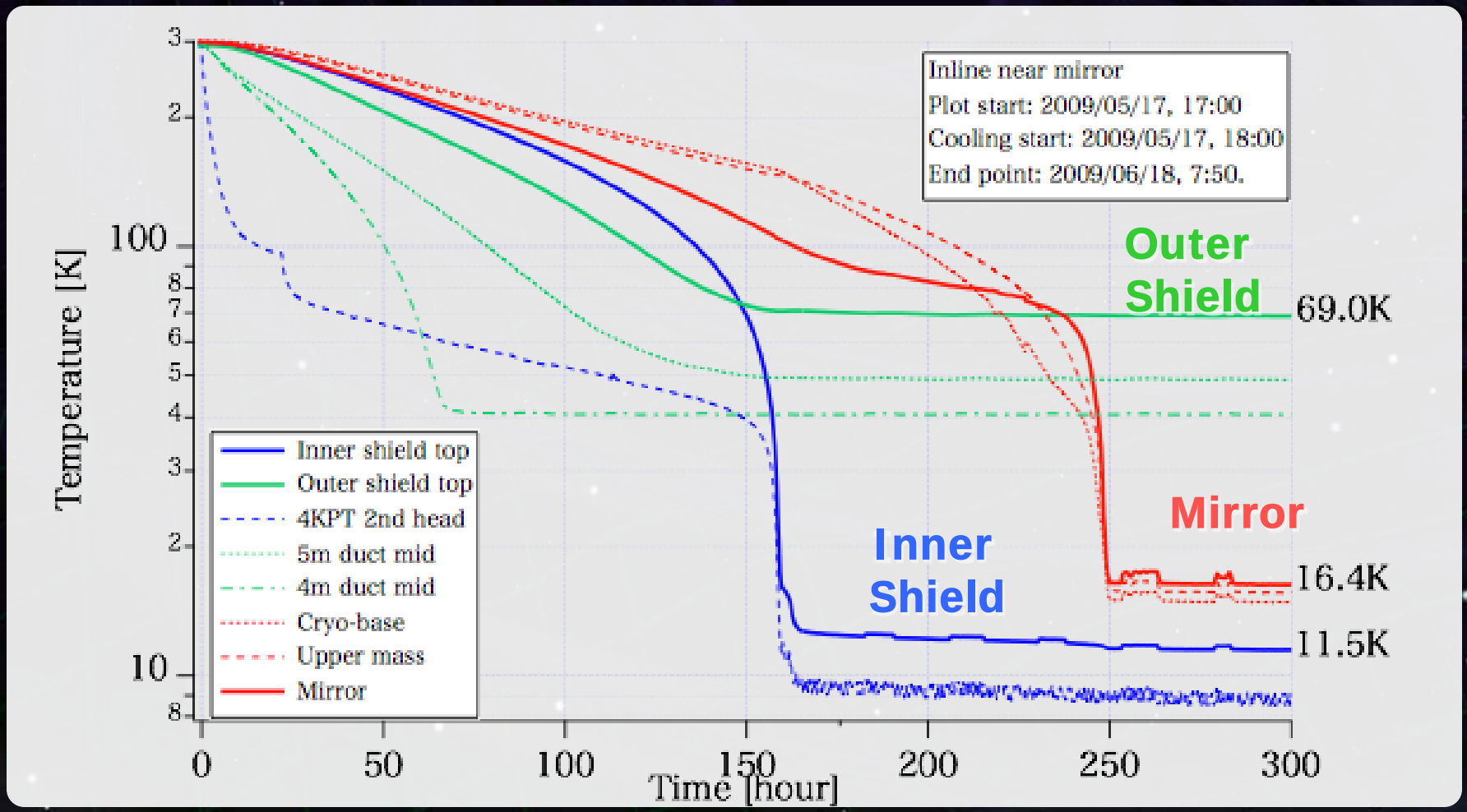
Triple pendulum in cryostat
Sapphire test mass: 2 kg, ϕ100 x t60 mm





CLIO Test-Mass Cooling

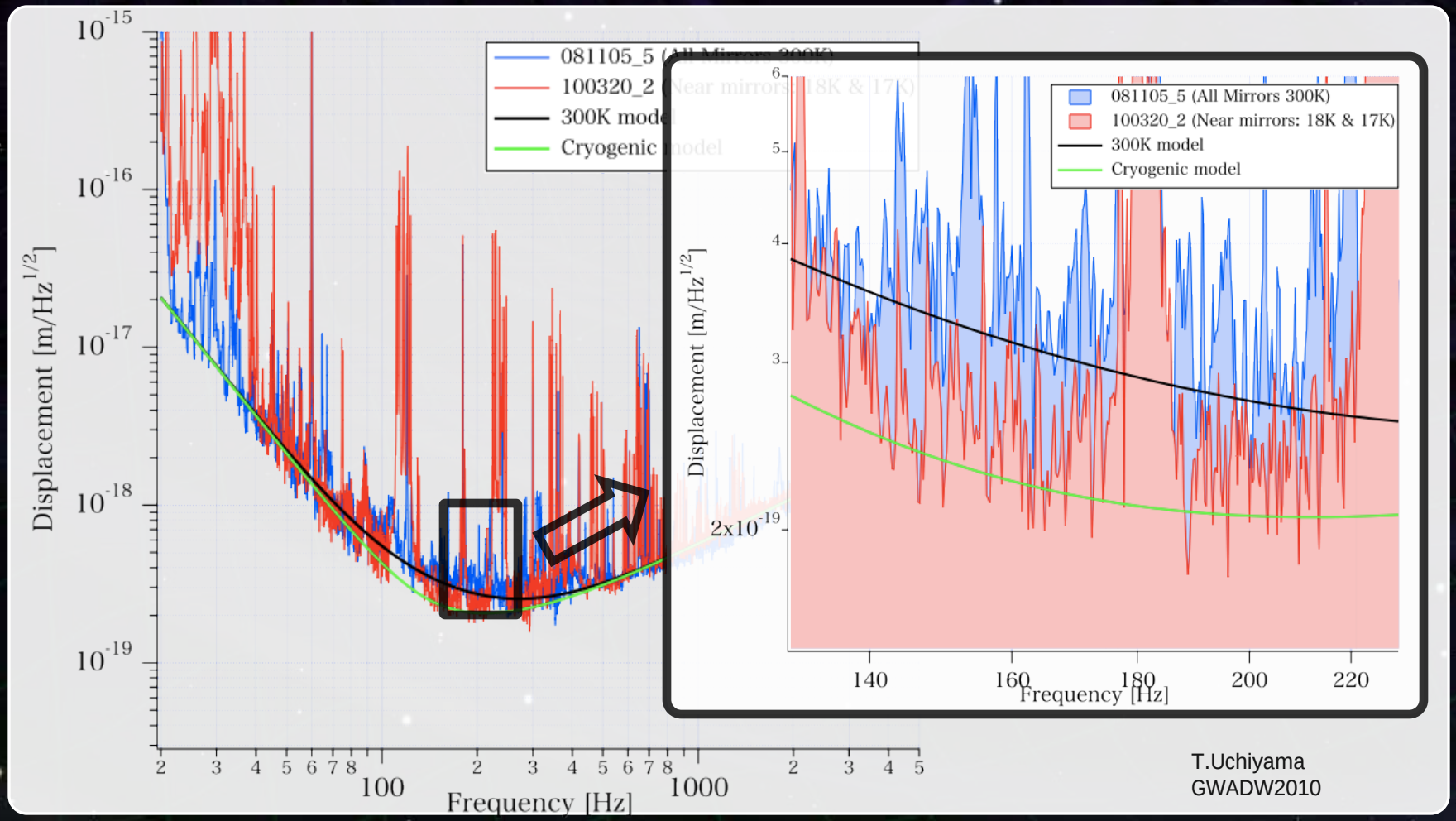
Cooling time: 250 hours for the test-mass mirror.
→ Cooled down to 16.4K



CLIO sensitivity

Sensitivity improvement with cryogenic operation

→ Seems to be Sapphire mirror thermo-elastic noise

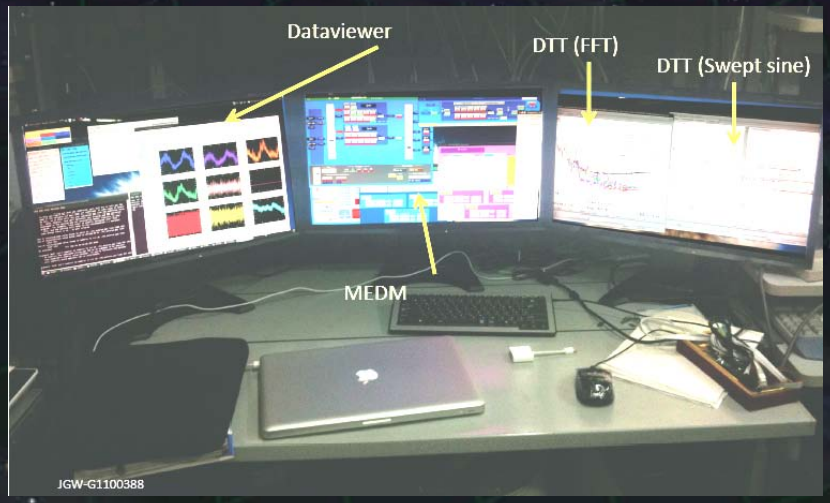


CLIO digital system

LCGT will employ
LIGO's digital system

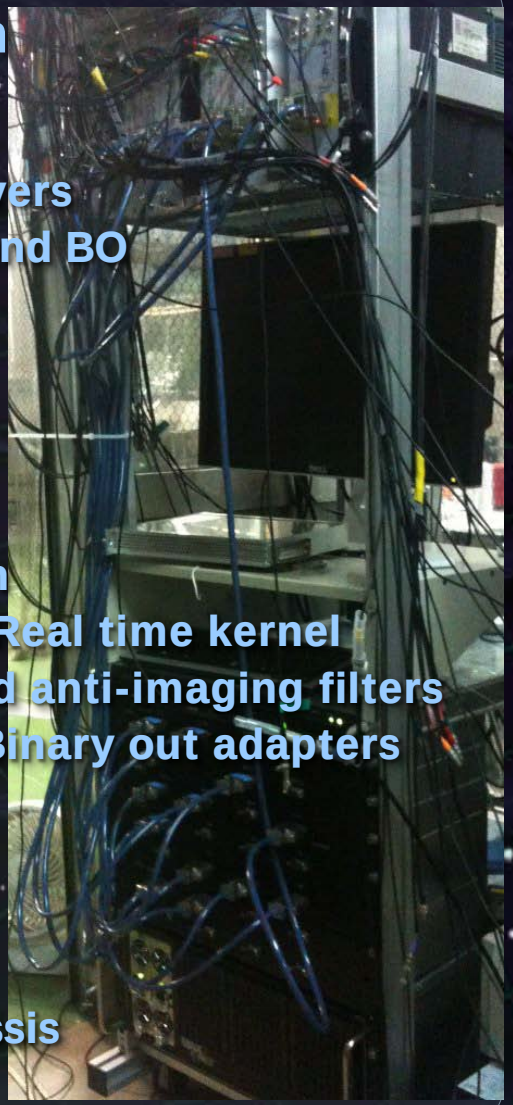
Full-scale test of the control system at CLIO, based on MOU with LIGO laboratory

Client System



Main System

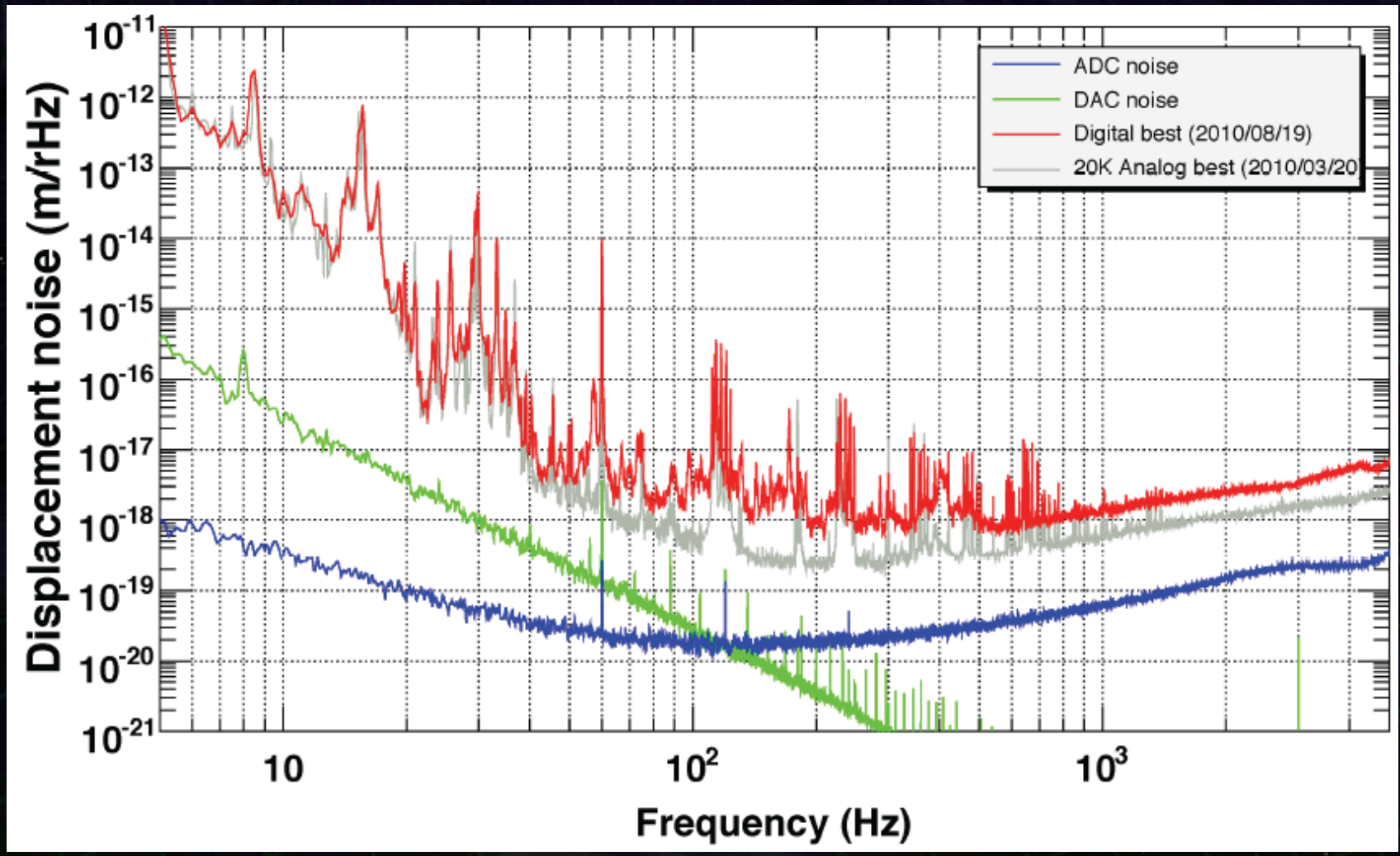
Differential drivers
for ADC, DAC, and BO



Real time PC
4core x 2 Xeon
CentOS 5.2 + Real time kernel
Anti-aliasing and anti-imaging filters
ADC, DAC, and Binary out adapters

ADC/DAC In
Expansion Chassis

CLIO sensitivity with digital control



- 測定時はターボポンプon, 中周波はアラインメントに大きく依存
- 高周波はショットノイズではない、phase shifterのトラブル?

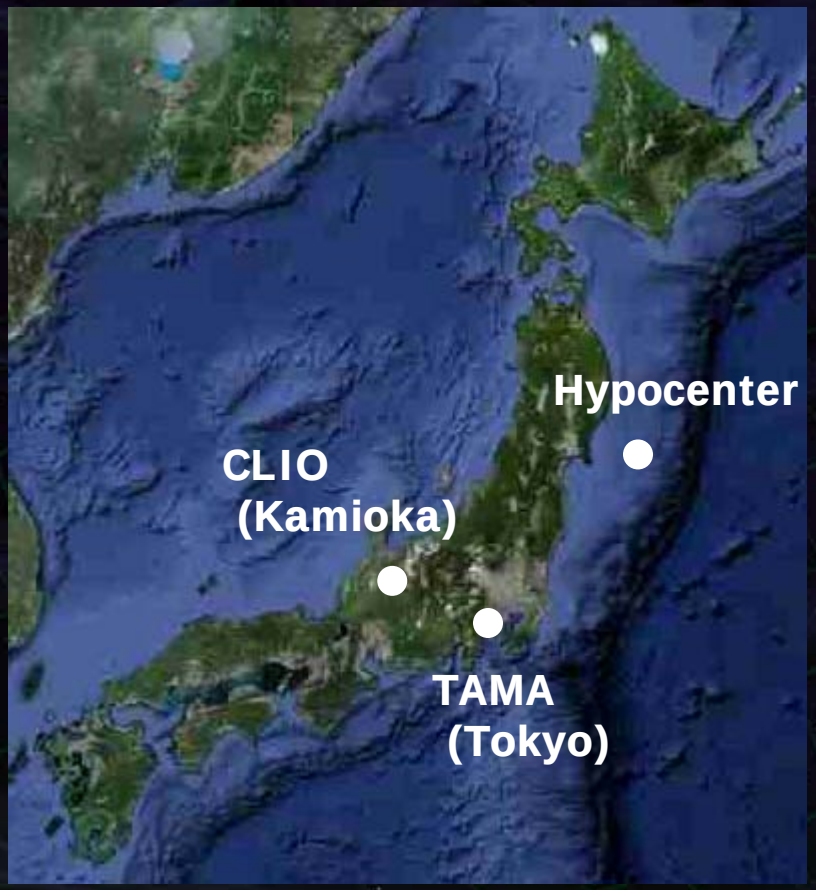
Earthquake on March 11th and Geophysics

※ Most of the materials were prepared by
A. Araya, and R. Takahashi

•CLIO (Kamioka, Gifu ~500km away from hypocenter)

- Two people (Miyakawa, Saito) were working at CLIO site.
  → did not noticed the shake.
- MC couldn't be kept locked more than a few seconds. This condition continues >1 hour.

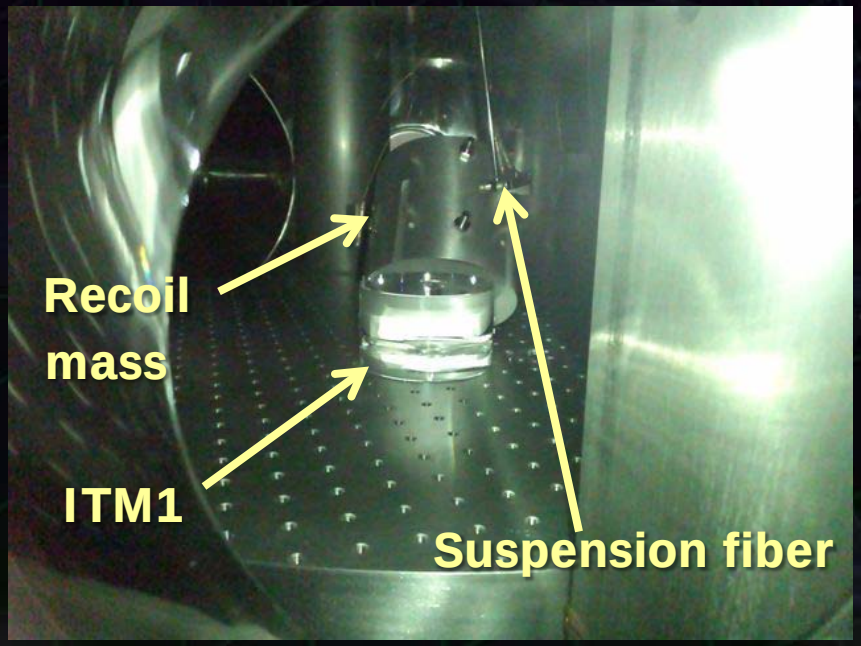
- No serious damages:
  mirror, suspension,
  cryostat system, vacuum system.
- Small misalignment in suspended optics.

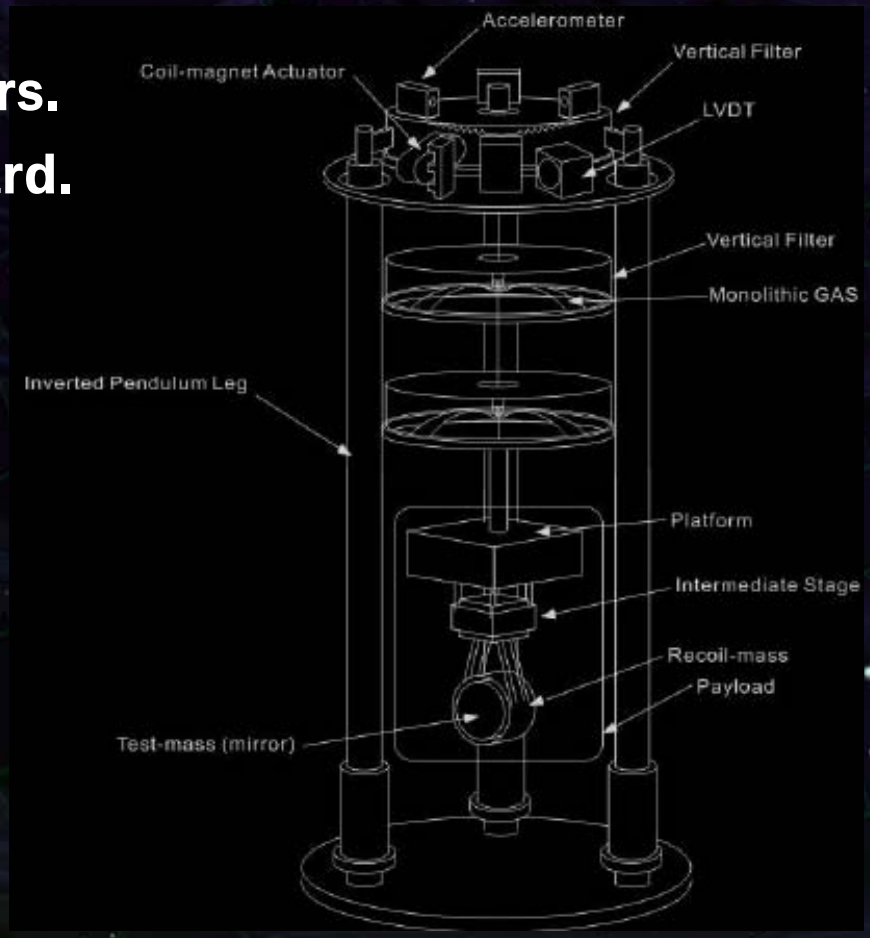


- **TAMA** (NAOJ, Tokyo ~400km away from hypocenter)

  Serious damages in suspensions and mirrors.

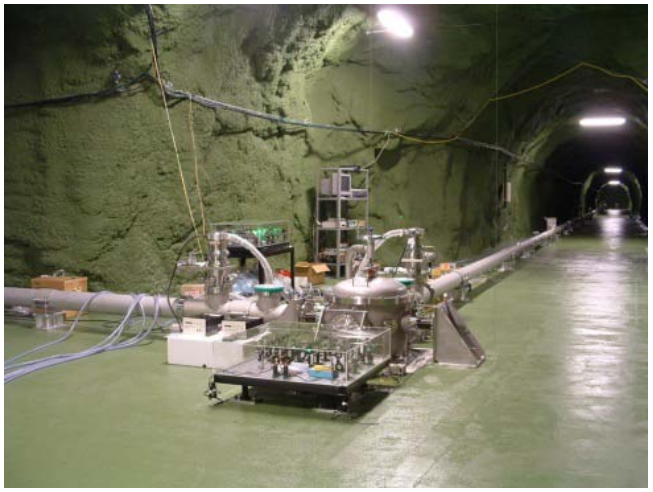
  Three TMs fell onto breadboard.

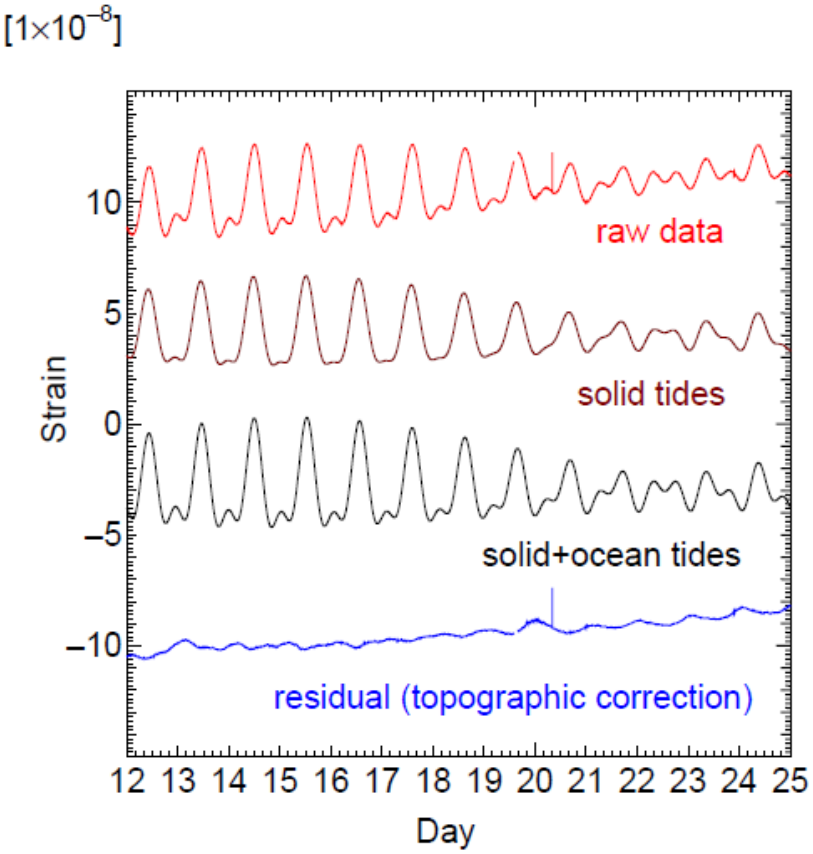




Kamioka 100-m laser interferometer (in operation)

1. 1000-m underground
2. Frequency stabilized 532nm laser
   ... resolution ~10^{-13} in strain.





Observation of earth tides (100m IFO)

Determination of

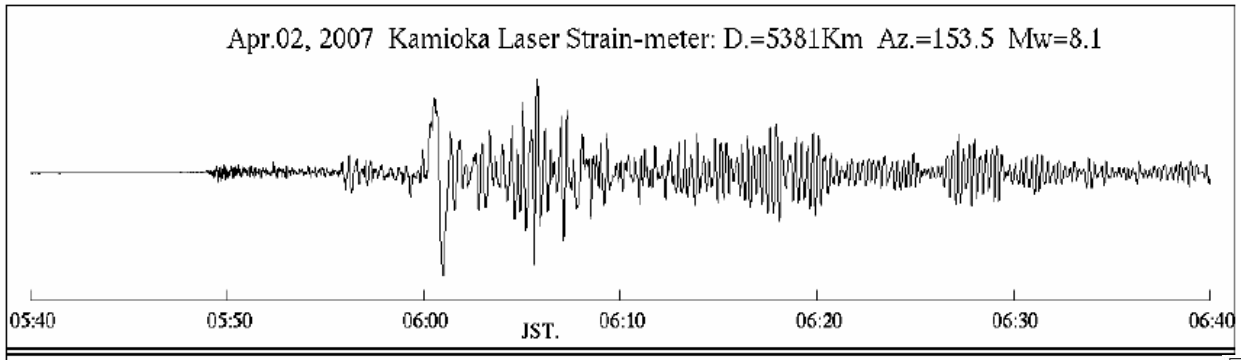
1. Tidal model
   (solid structure
   and ocean load)

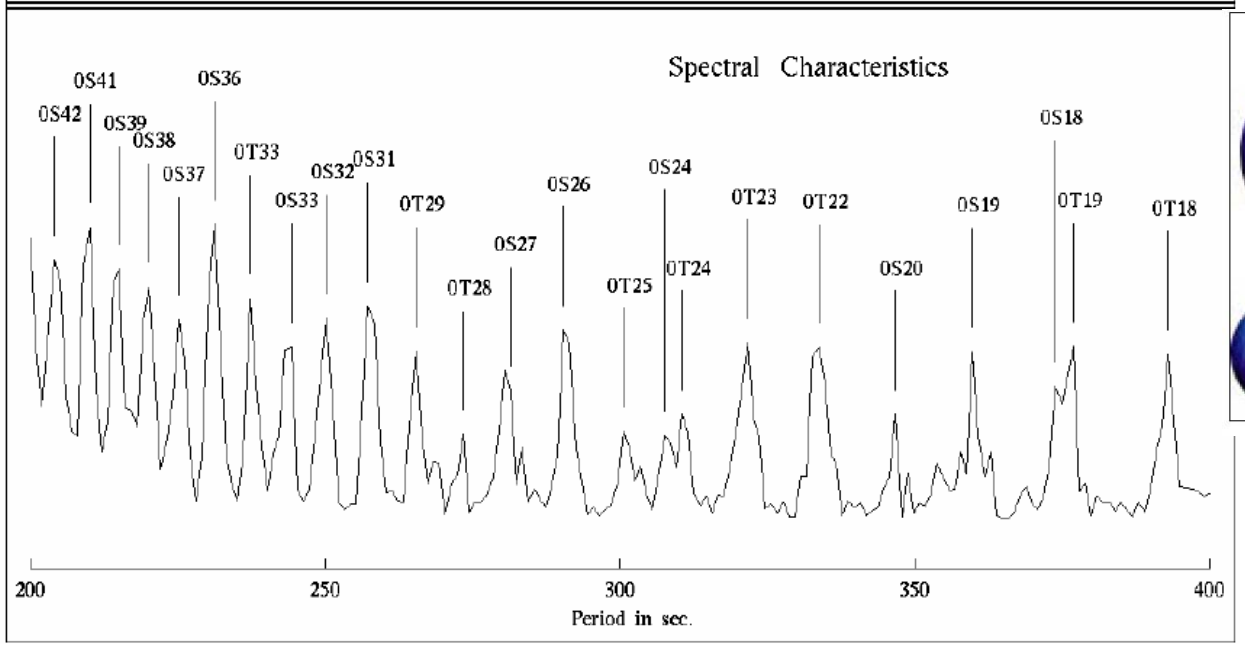
2. Earth interior structure

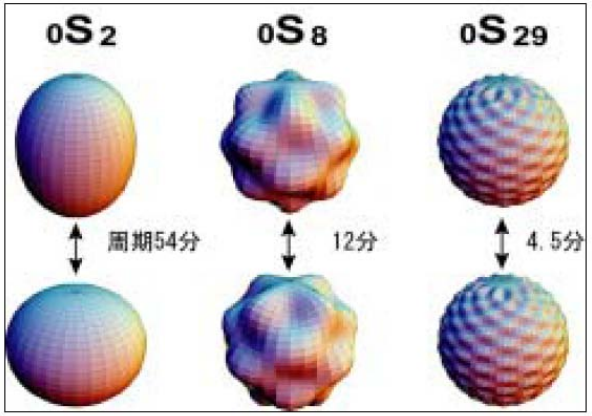
3. Topographic effects

Earth's free oscillations of off Solomon earthquake (Apr.2, 2007, M8.1)

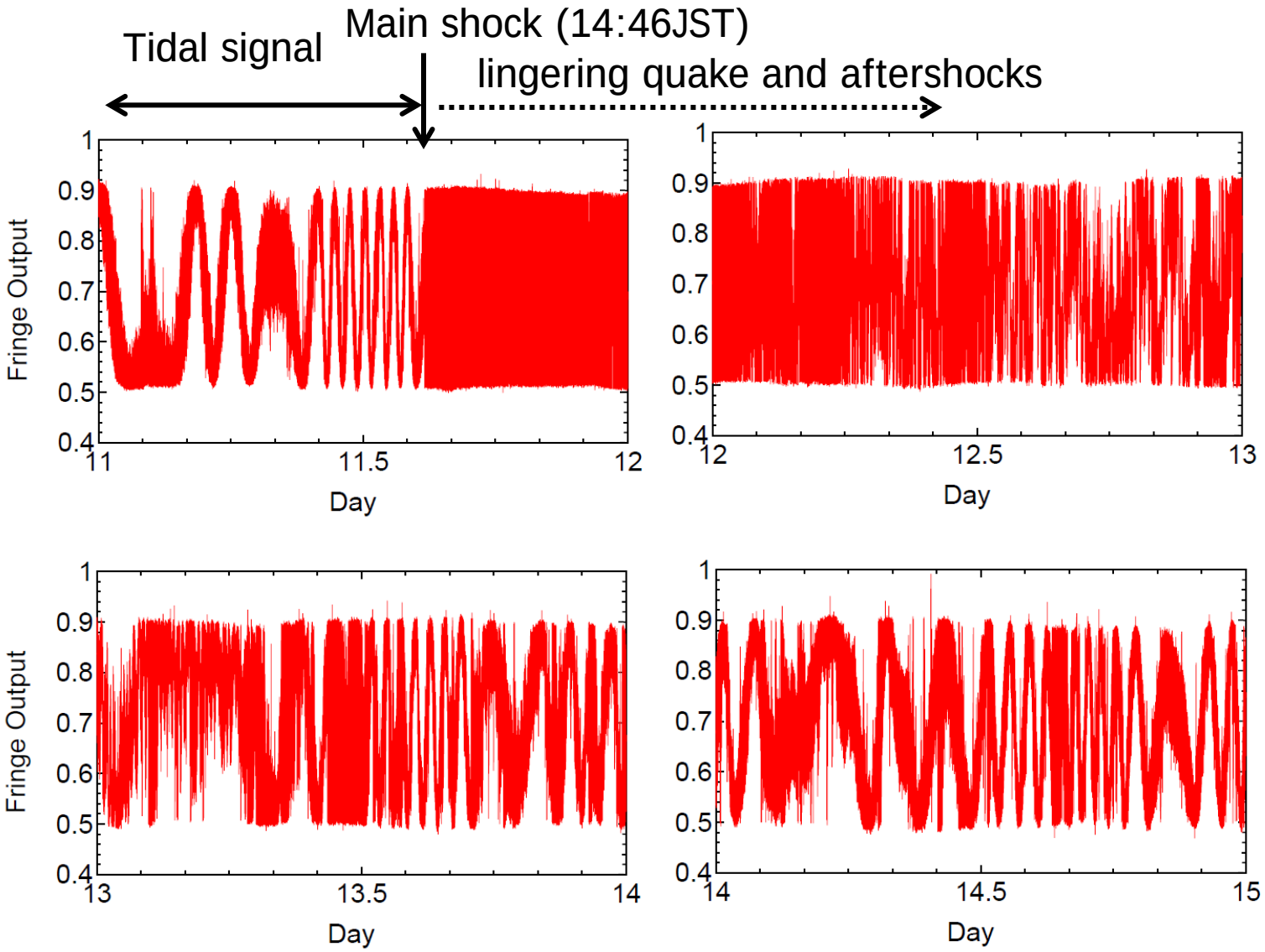
Determination of deep interior structure of the earth







Fringe output of the Kamioka laser strainmeter on Mar.11, 2011



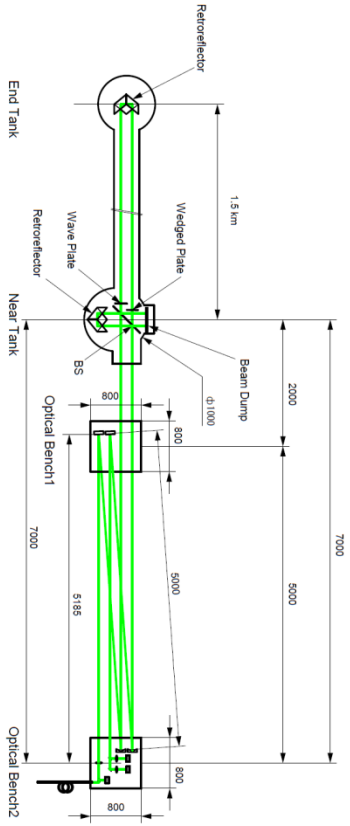
So rapid fringe change ... now trying to retrieve strain from the fringe signal.

Plan

Two baseline-monitor interferometers (1.5km) along LCGT

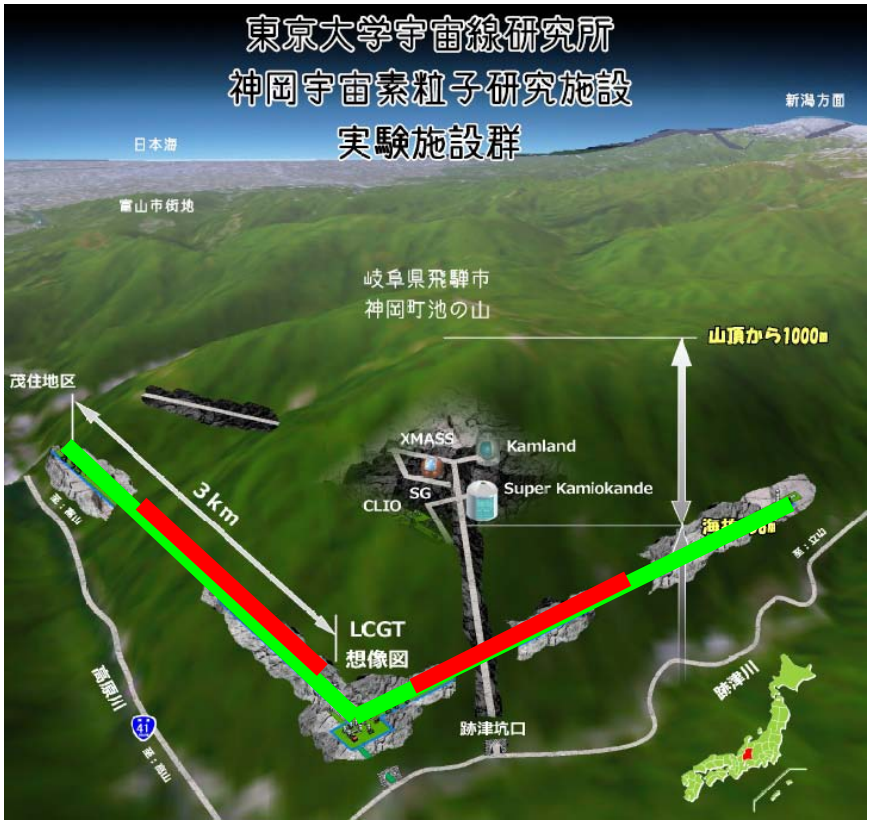
Targets

1. Baseline monitor for LCGT (Tides, microseisms, and earthquakes)
2. Fault-creep monitor for the Atotsu fault deformation...in the middle of Niigata-Kobe Tectonic Zone
3. Deep interior of Earth (Monitoring Earth's free oscillations)



Gneiss and Amphibolite ···metamorphic hard rock

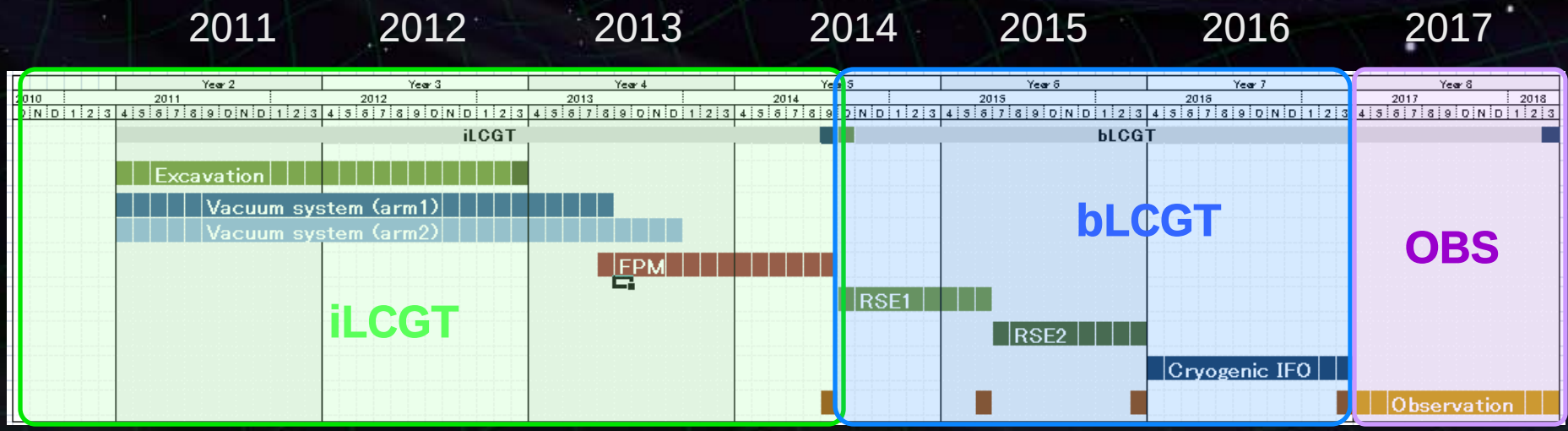
Geophysics Interferometers along LCGT



Schedule and Status

Master Schedule

- 3 Major stages
  - iLCGT (- 2014.9) Stable operation on large-scale IFO
    - → 3km FPM interferometer at room temperature, with simplified vibration isolation system
    - ~1 month (TBD) engineering run
  - bLCGT (2014.10 – 2017.3) Observation run with final configuration
    - → RSE, upgraded VIS, cryogenic operation
  - OBS (2017.4 -) Long-term observation and detector tuning



Design Reviews

- **Internal review (Dec. 2010 – Feb. 2011)**
  - Review design, schedule, etc. of each subsystem by the subsystem leaders, Ando, and Kawamura
  - We had 15 internal reviews in three months
- **External review (2/28 - 3/4, summary report 3/12)**
  - Review design, schedule, etc. of each subsystem by external experts in the GW field
  - The most important review for the technical aspects of LCGT

Special thanks to Reviewers: M.Zucker (chair), S.Ballmer, A.Bertolini, R.Flaminio, A.Freise, W.Johnson D.Ottaway, B.Willke

- **Program advisory board (June 21,22 at ICRR)**
  - Review management, progress, design, etc. of LCGT by senior (management) people in the GW and neighboring fields

Reviewers: S.Whitcomb (Chair), M.Iye , D.McClelland , B.Mours, T.Nakamura, B.Schutz, G.Sanders, A.Yamamoto

Summary

Summary

LCGT : Project started

- Costs have been partially funded
- Form global network with 2nd generation detectors

⇨ Aim to detect GW, and to open new astronomy

- LCGT will demonstrate 3rd generation detector techniques: cryogenics and underground

Design and R&D

- Detailed design underway : internal and external reviews
- TAMA and CLIO experiences

  TAMA : GW observatory, TAMA-SAS

  CLIO : Cryogenic interferometer, underground site
- Prototype developments : SAS, Digital system, Cryostat

By the way...

LCGT will have a new Nickname soon...

- Invite candidates from the public
  → over 600 applications (already closed)
- Naming committee with 6 peoples
  Chair: Y. Ogawa (Novelist)
- Will be selected and announced in June.

End