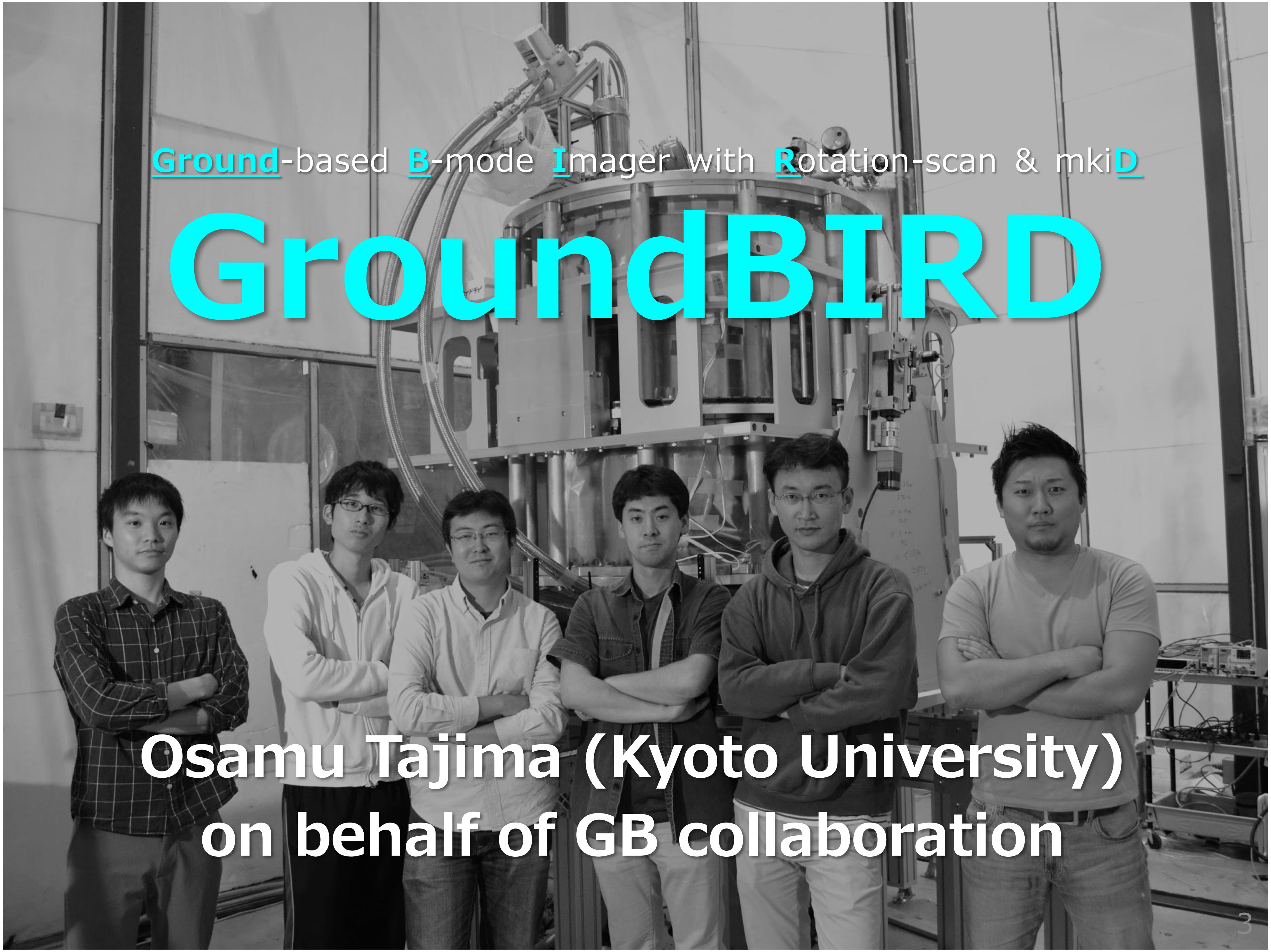


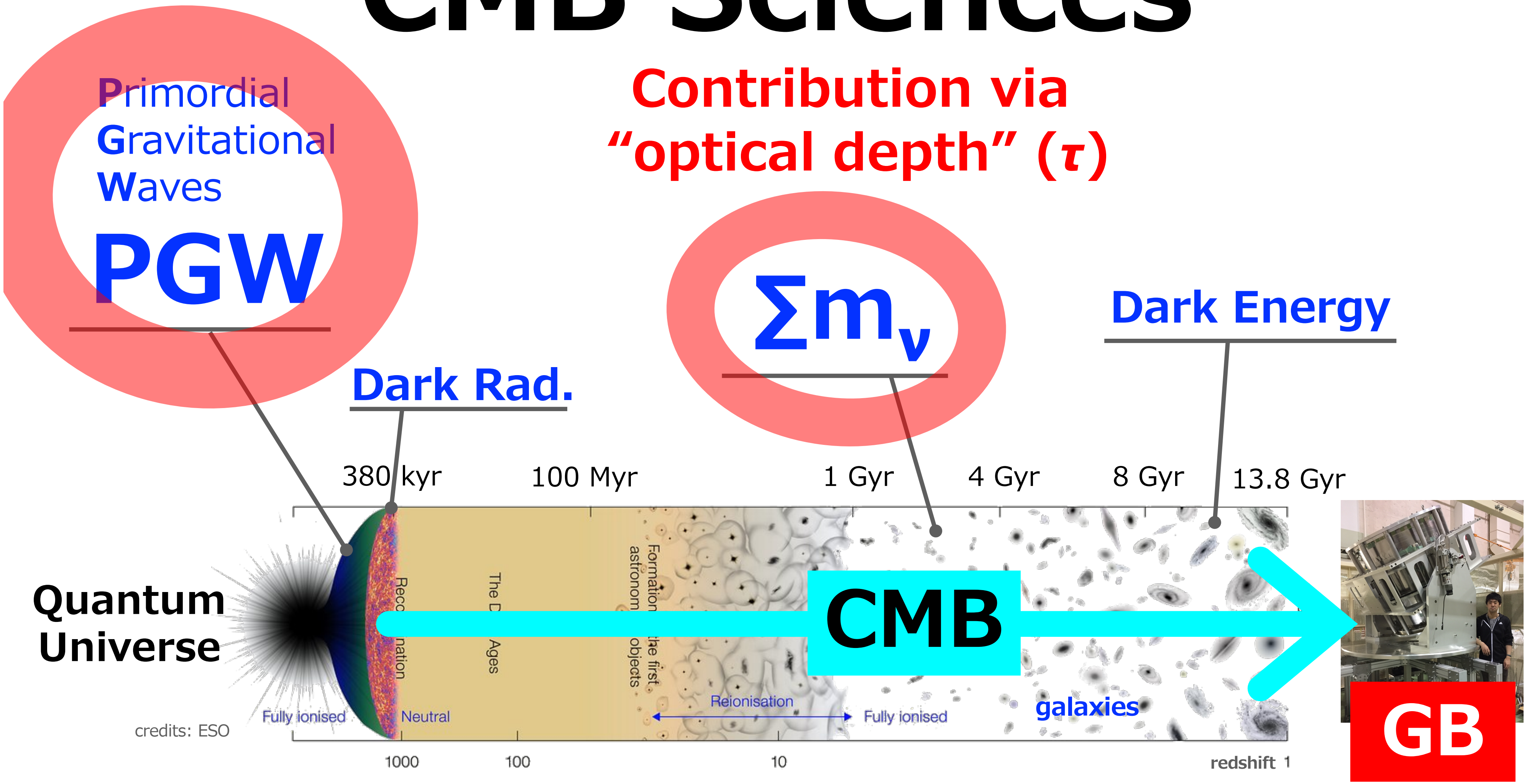
Ground-based B-mode Imager with Rotation-scan & mkiD

GroundBIRD

Osamu Tajima (Kyoto University)
on behalf of GB collaboration

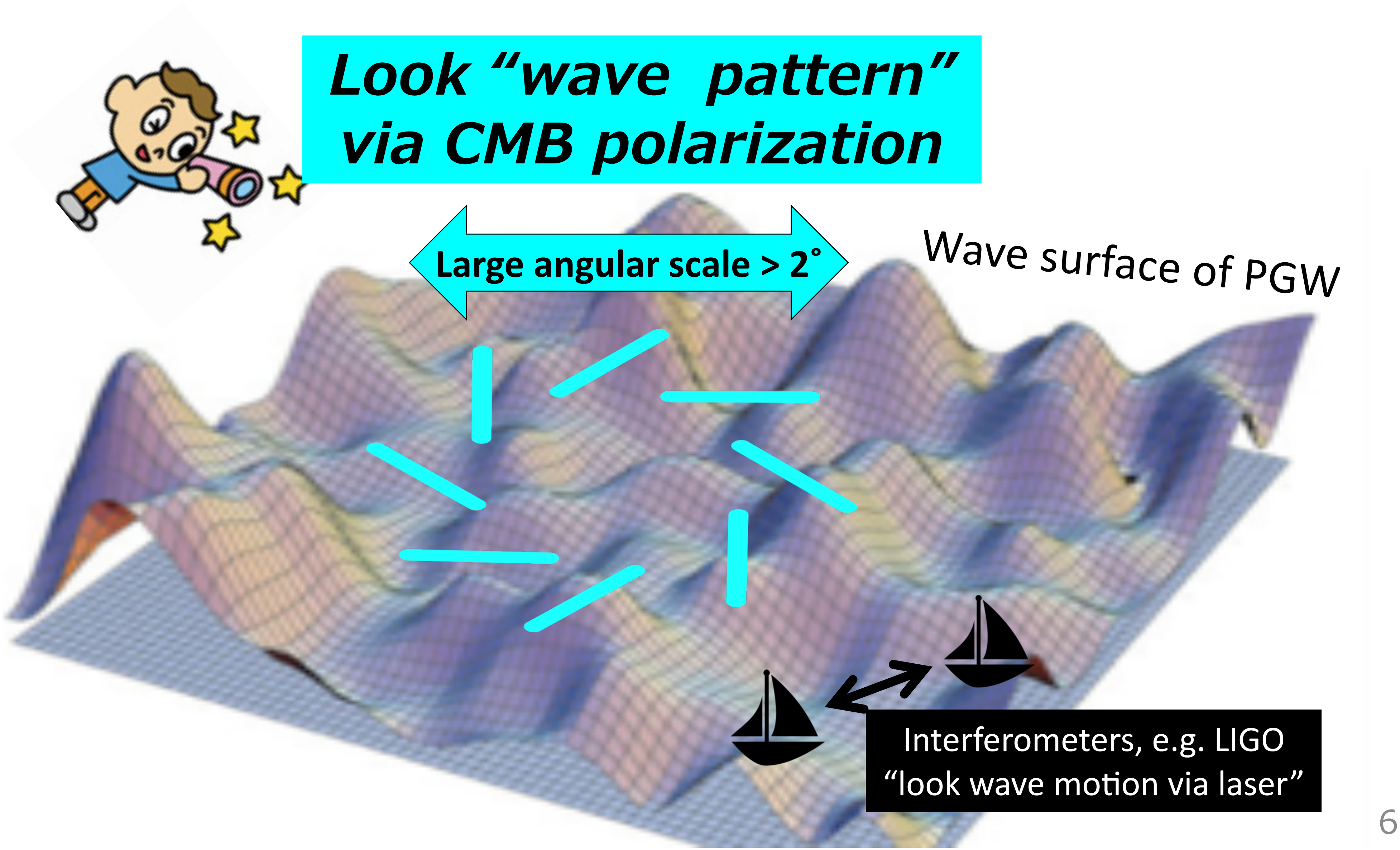

Led by young!
S. Honda
(Kyoto)
H. Kutsuma
(Tohoku)
J. Komine
(Kyoto)
S. Oguri
(RIKEN)
J. Suzuki
(Kyoto)
T. Nagasaki
(RIKEN)

CMB Sciences

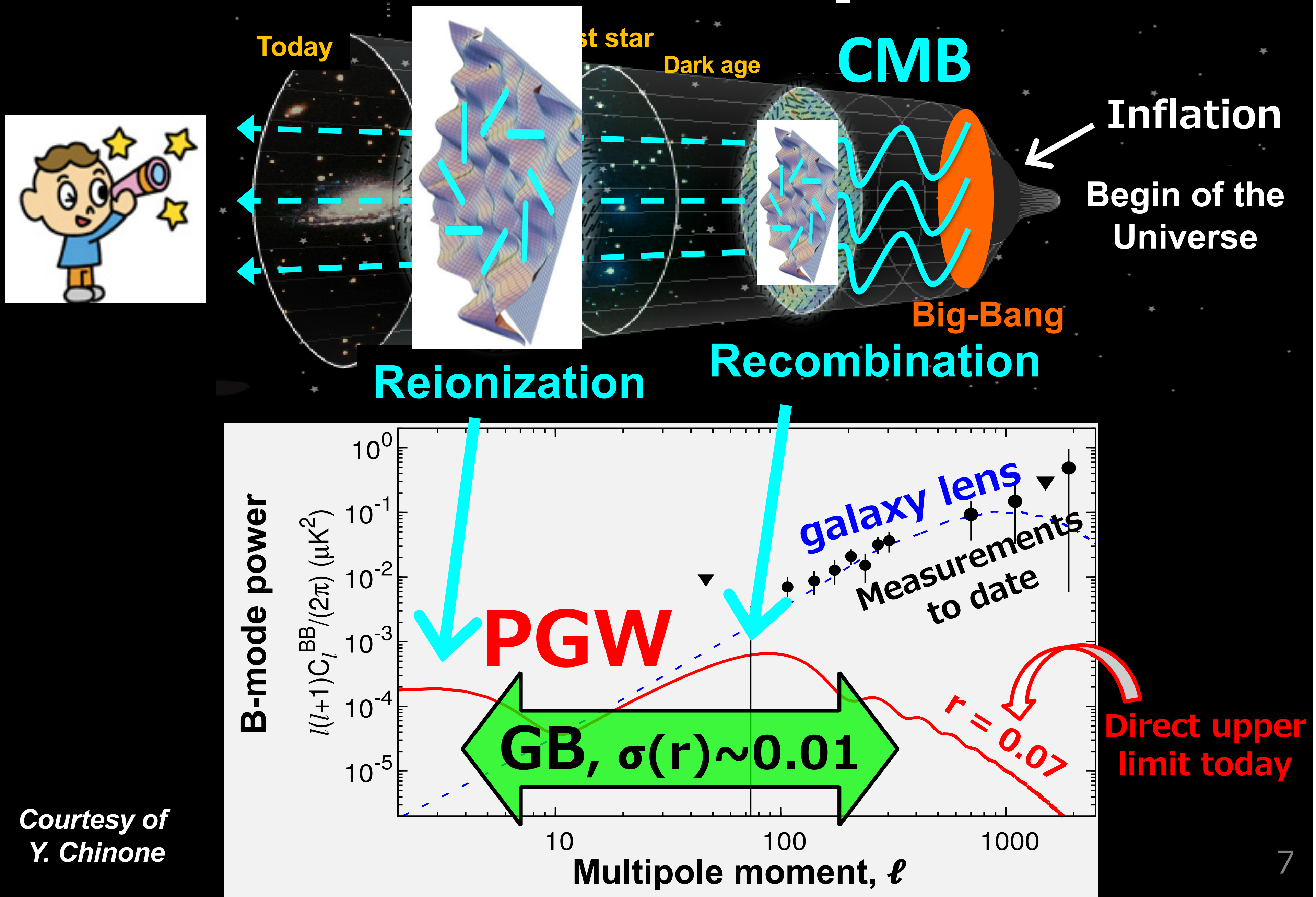


GB aims CMB polarization patterns in large angular scale, O(1˚~10˚)

PGW detection by B-mode



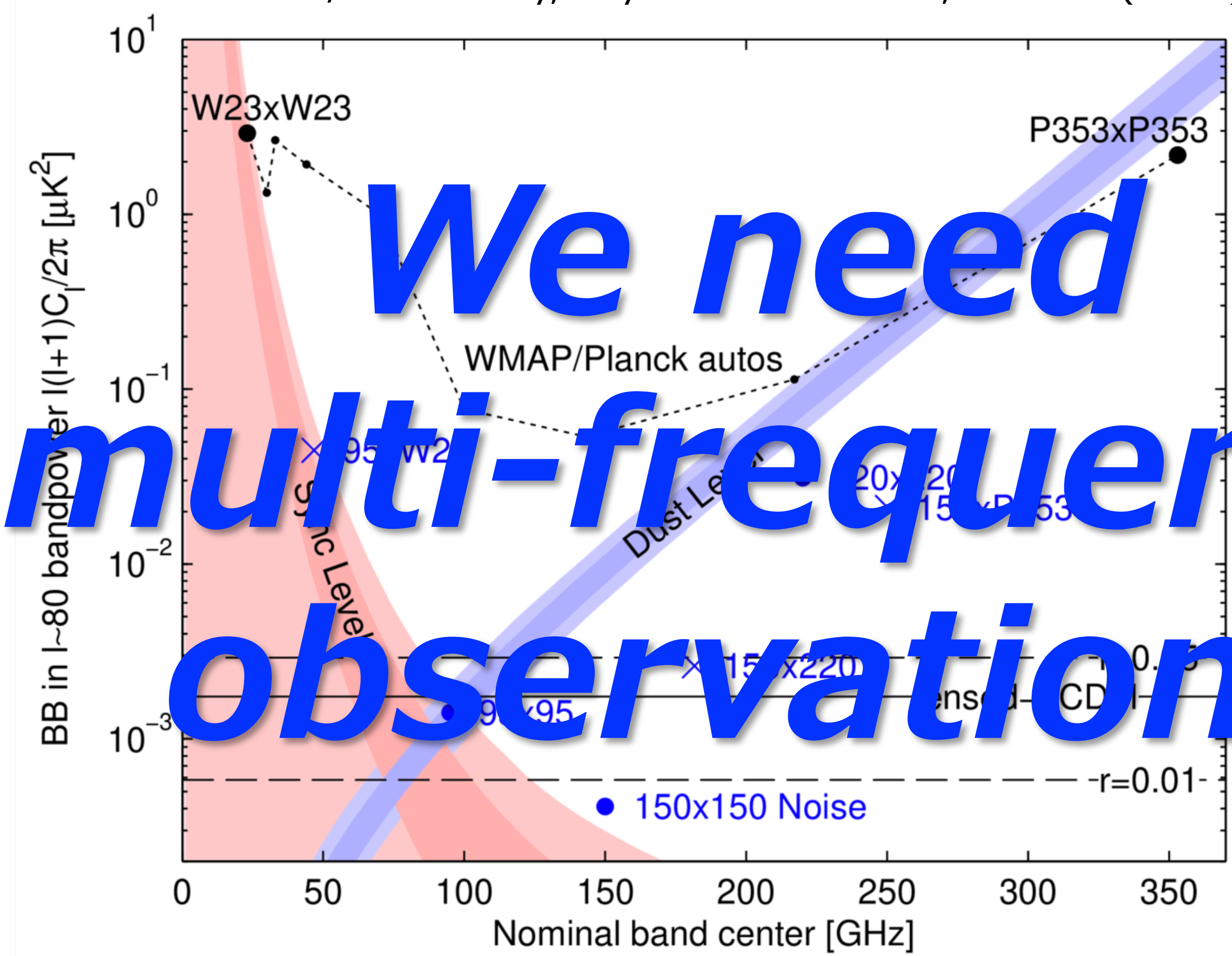
"Look" B-mode pattern



Courtesy of Y. Chinone

Foregrounds limit "r"

BICEP2 / Keck Array, Phys. Rev. Lett. 121, 221301 (2018)



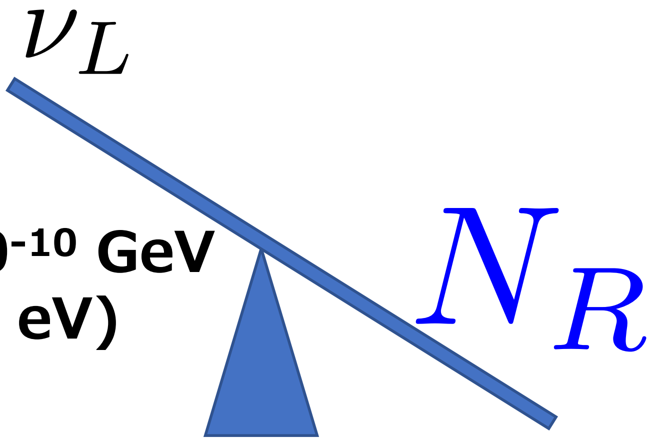
We need multi-frequency observation!

r < 0.07 (95% C.L.)

m_ν why important ?

An example: "See-saw" mechanism

N_R ("right-handed" $\boldsymbol{\nu}$) whose mass is M_{GUT}
can make super-light neutrino mass



$m_\nu \simeq 10^{-10}$ GeV
(0.1 eV)

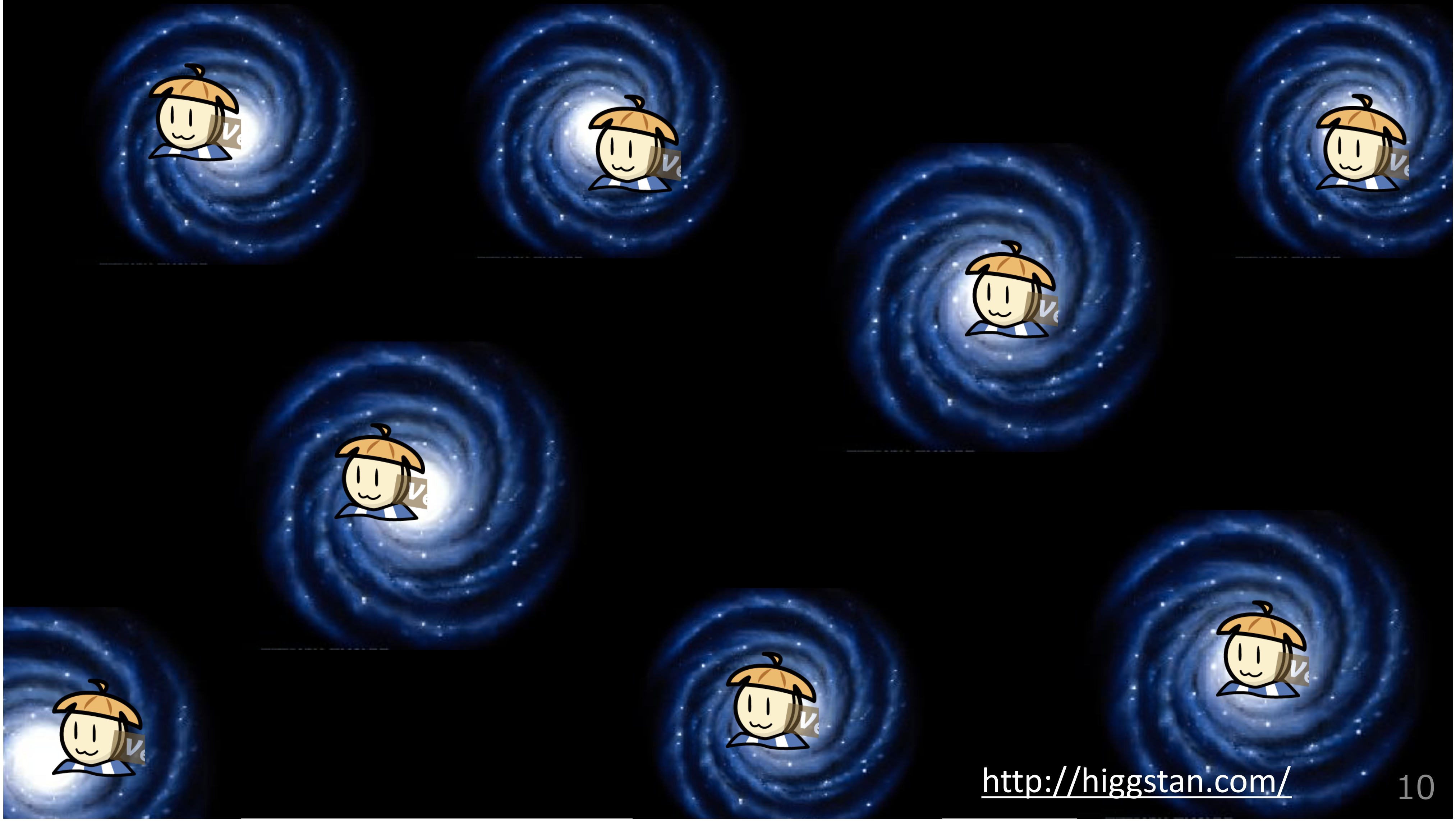
$M_{GUT} \simeq 10^{16}$ GeV

Neutrino mass term

$$(\bar{\nu}_L, \bar{N}_R)\begin{pmatrix} \frac{g_\nu^2 \langle\phi\rangle^2}{M_{\mathrm{GUT}}} & 0 \\ 0 & M_{\mathrm{GUT}} \end{pmatrix}\begin{pmatrix} \nu_L \\ N_R \end{pmatrix}$$

Tool to probe GUT-scale physics

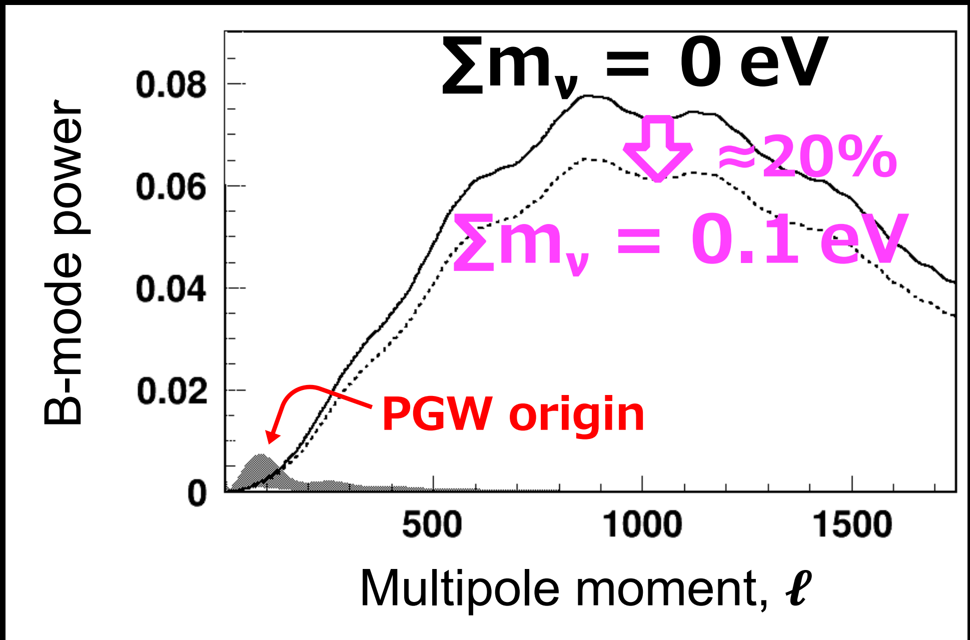
CνB is unique massive particle NOT localized in galaxy haloes

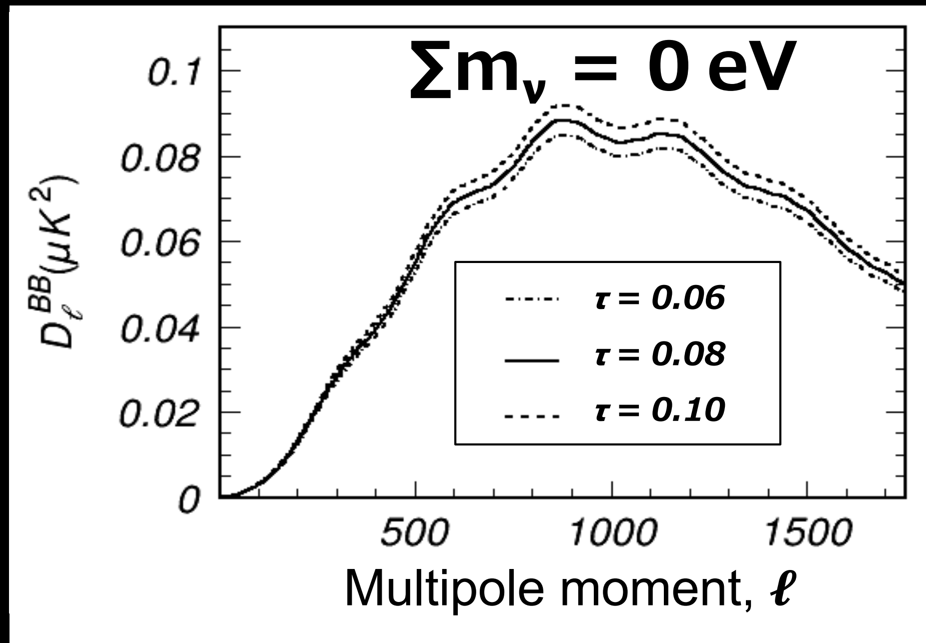


http://higgstan.com/

Σm_ν makes thinner lens

Correlation with τ should be unfolded

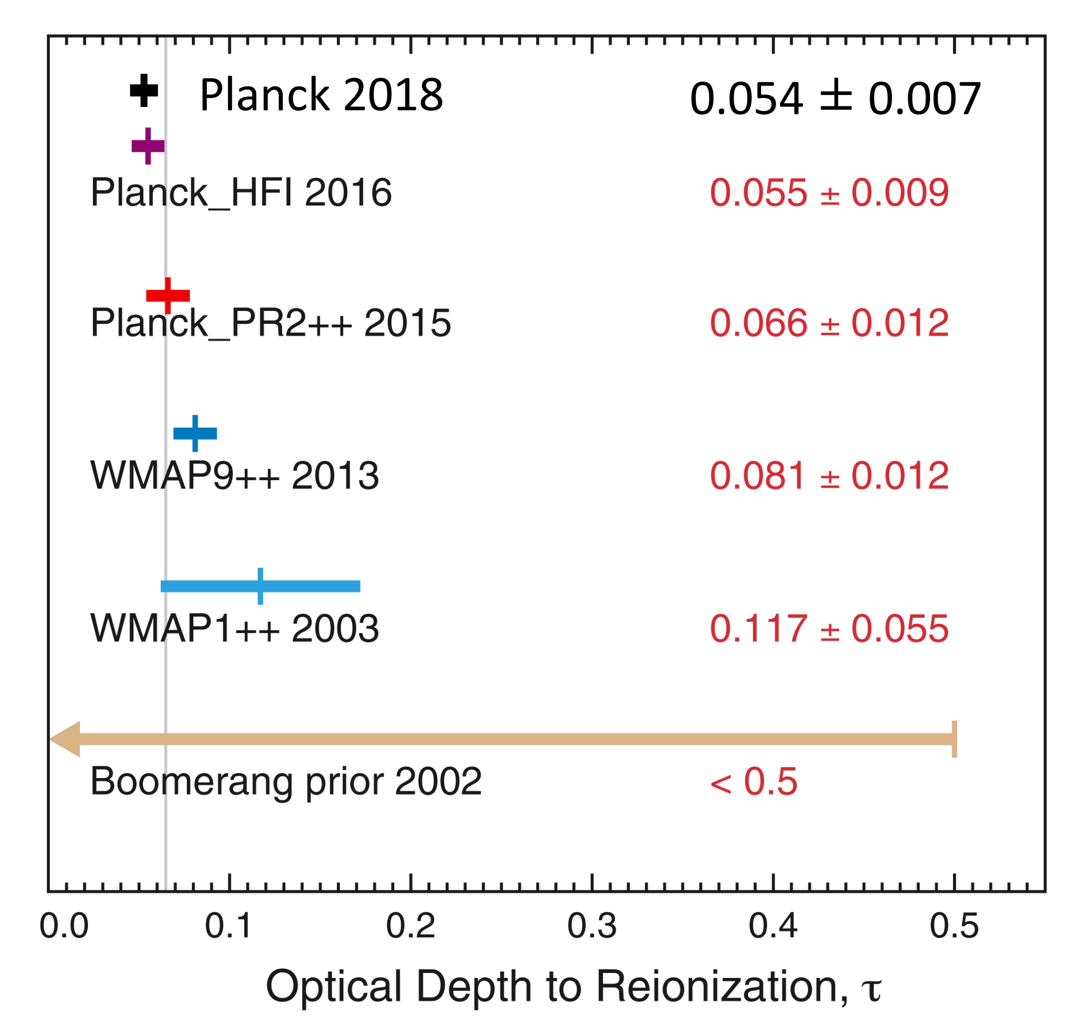




Planck 2018: τ = 0.054 ± 0.007

Δ(Σm_ν) ~ 0.02 eV

History of τ

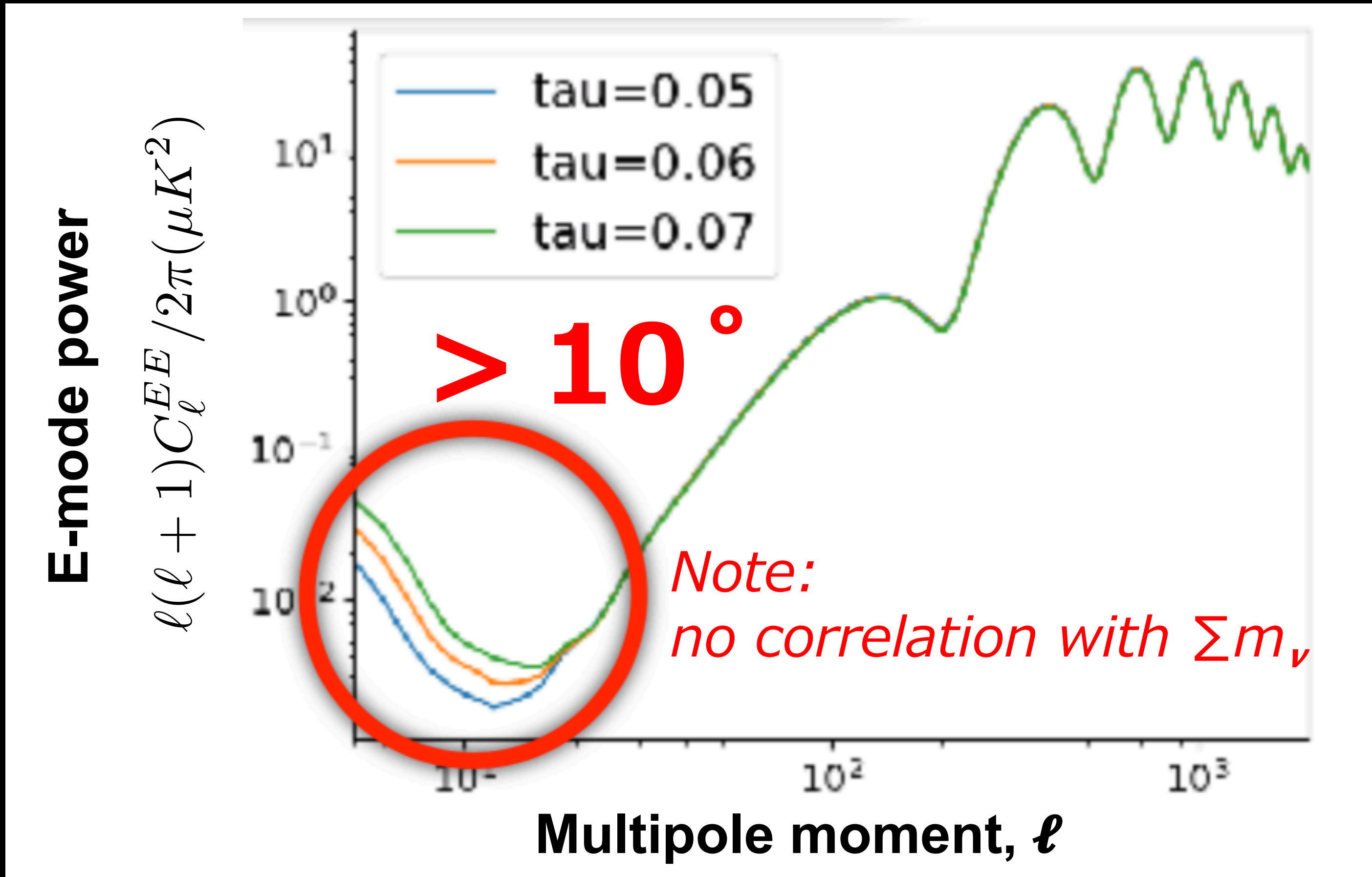


collage plot of LAMBDA web

Why don't you measure it ?

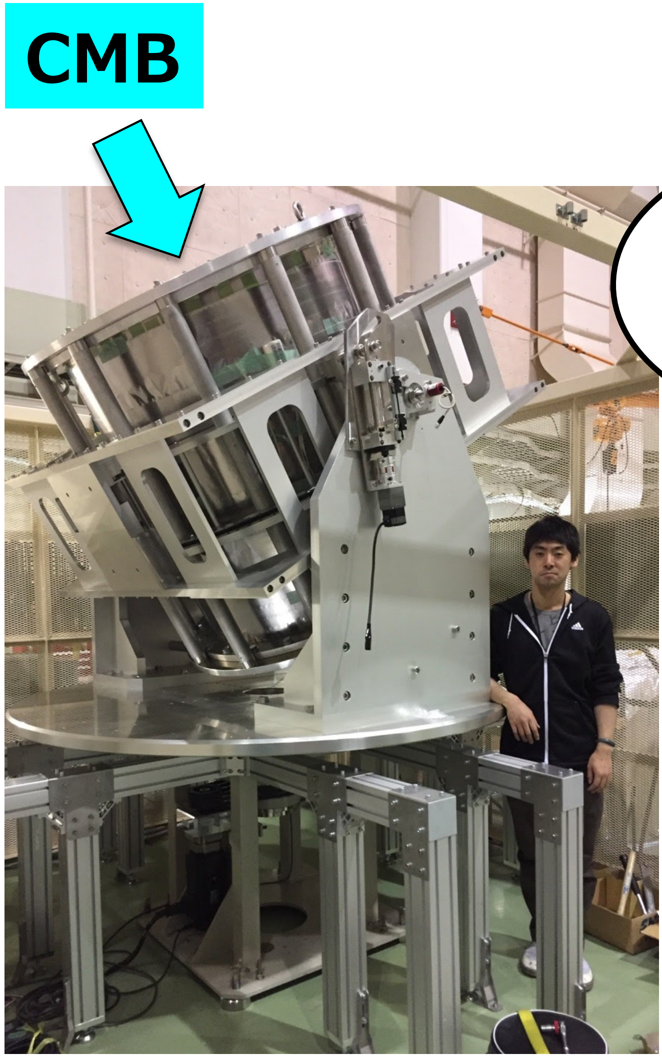
Another σ(τ) ~ 0.01 should be useful input

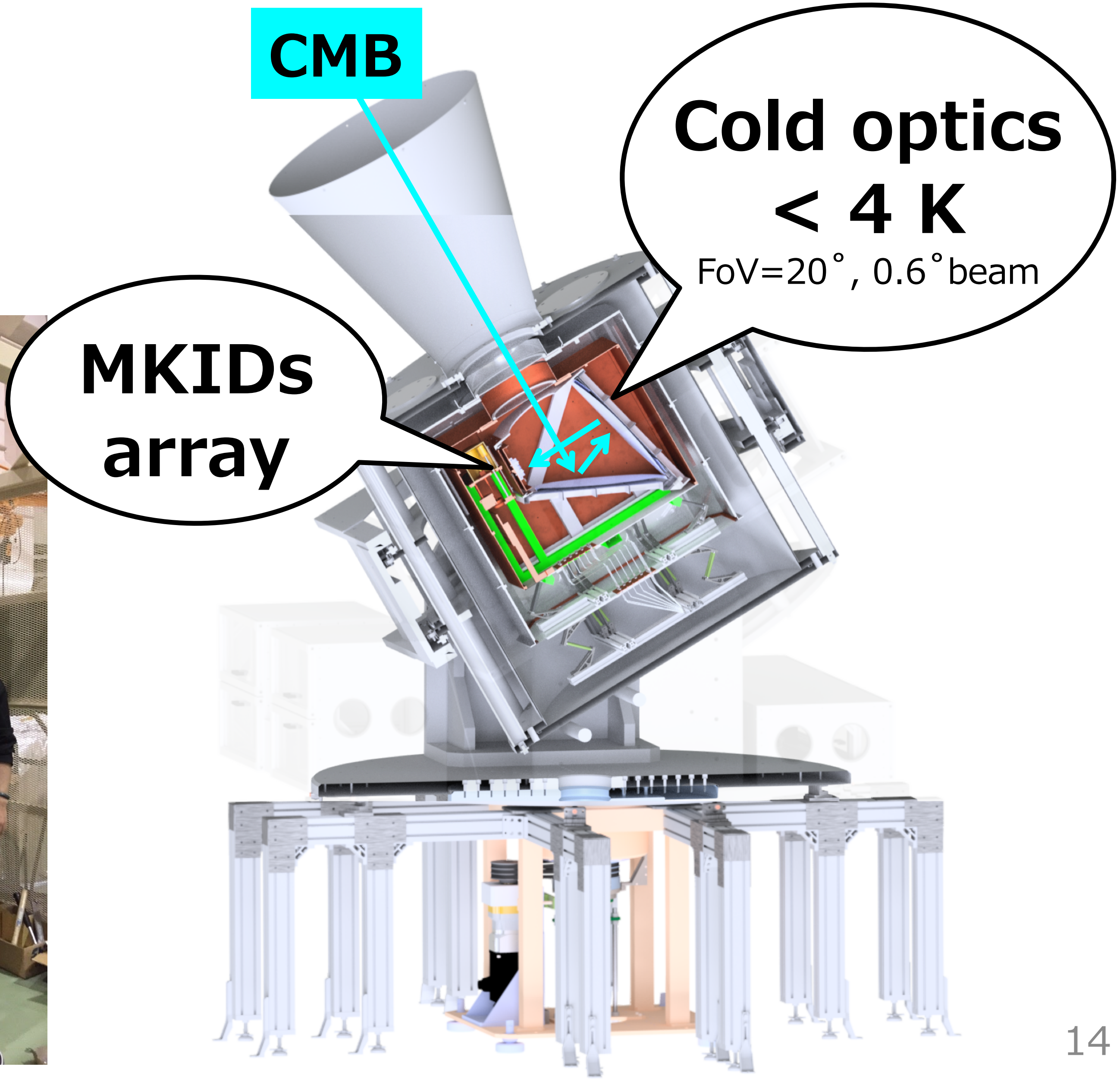
τ from E-mode



GB target $\sigma(\tau)$~0.01

GB aims large angular scale





High-speed Rotation-scan

HsRs mitigates effects of atmospheric fluctuation

J. Low Temp. Phys. 176, 691 (2014), and Proc. SPIE 8452, 84521M (2012).

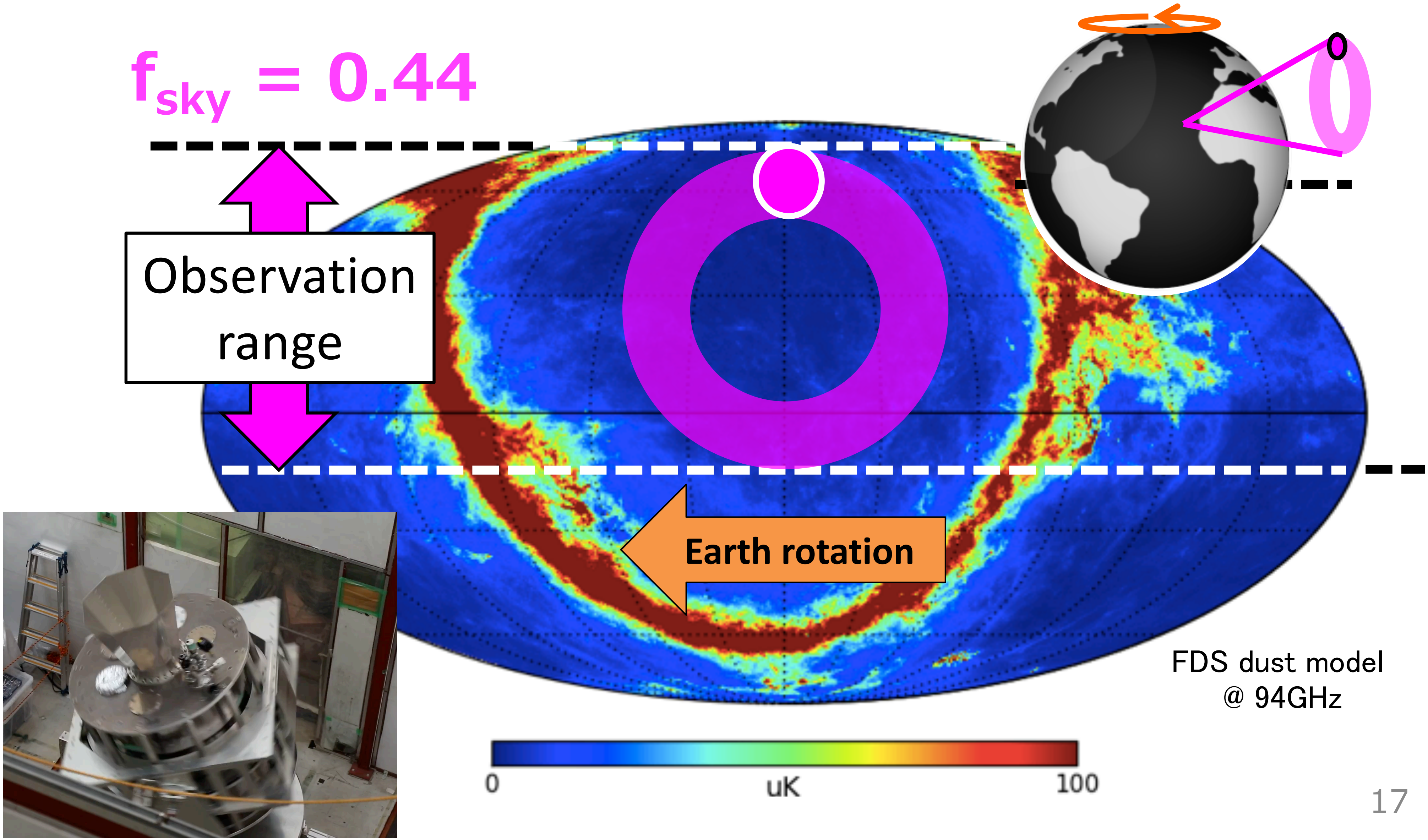
Now deploying GB in the Canaries

Teide Observatory, 2,400 m alt.

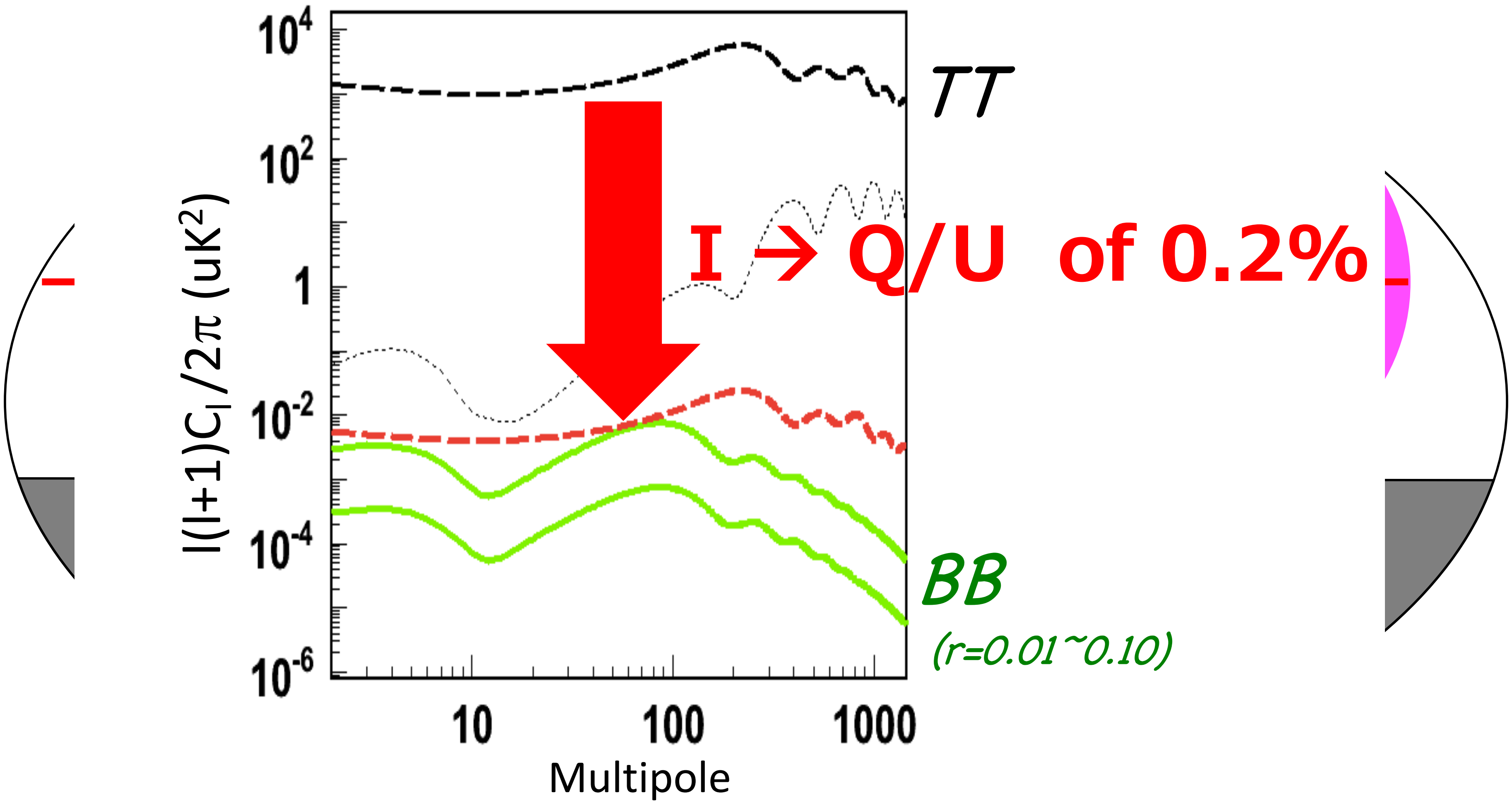
Dry area above clouds

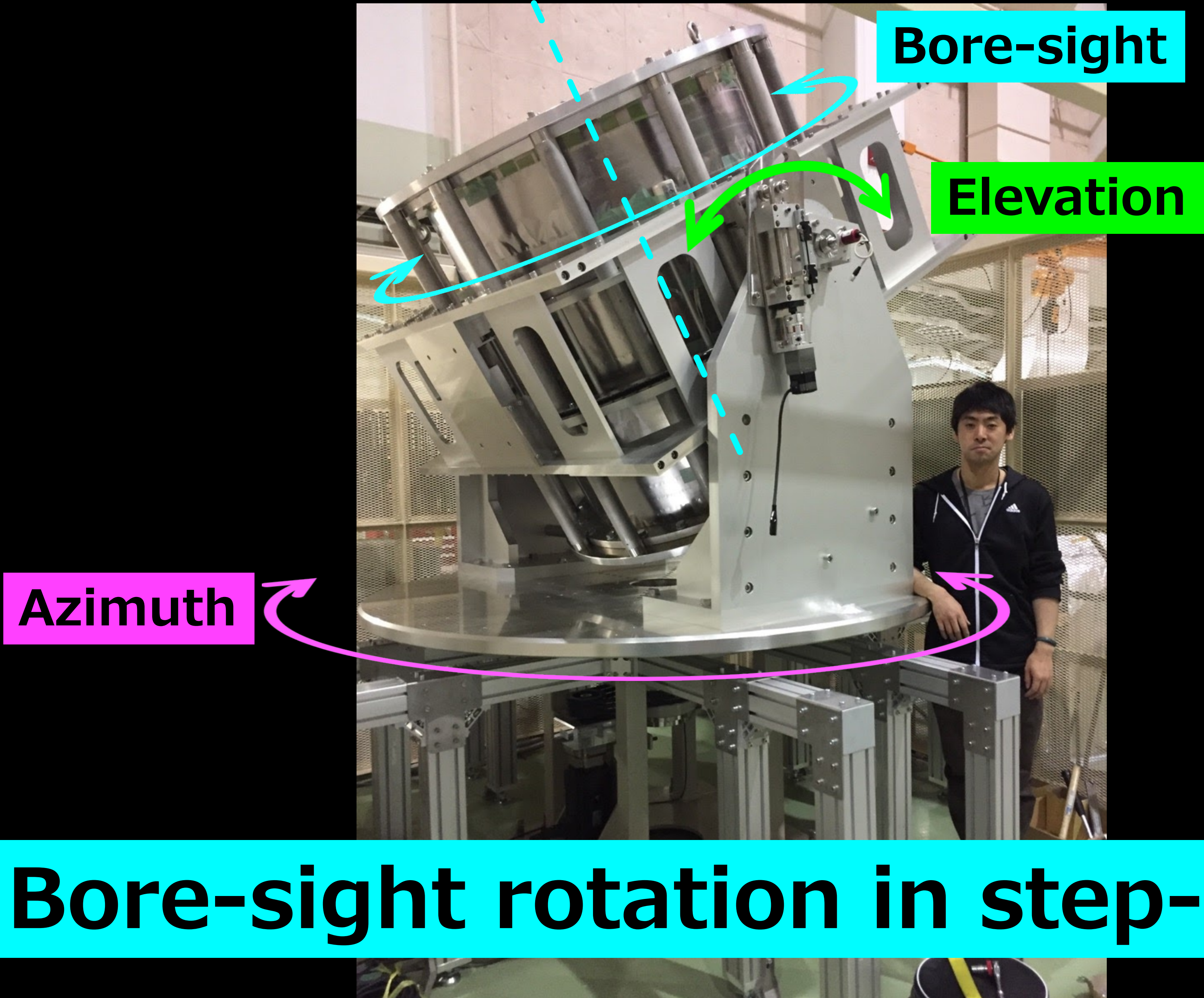
+28.3˚, -16.5˚

High-speed Rotation-scan provides large-sky coverage



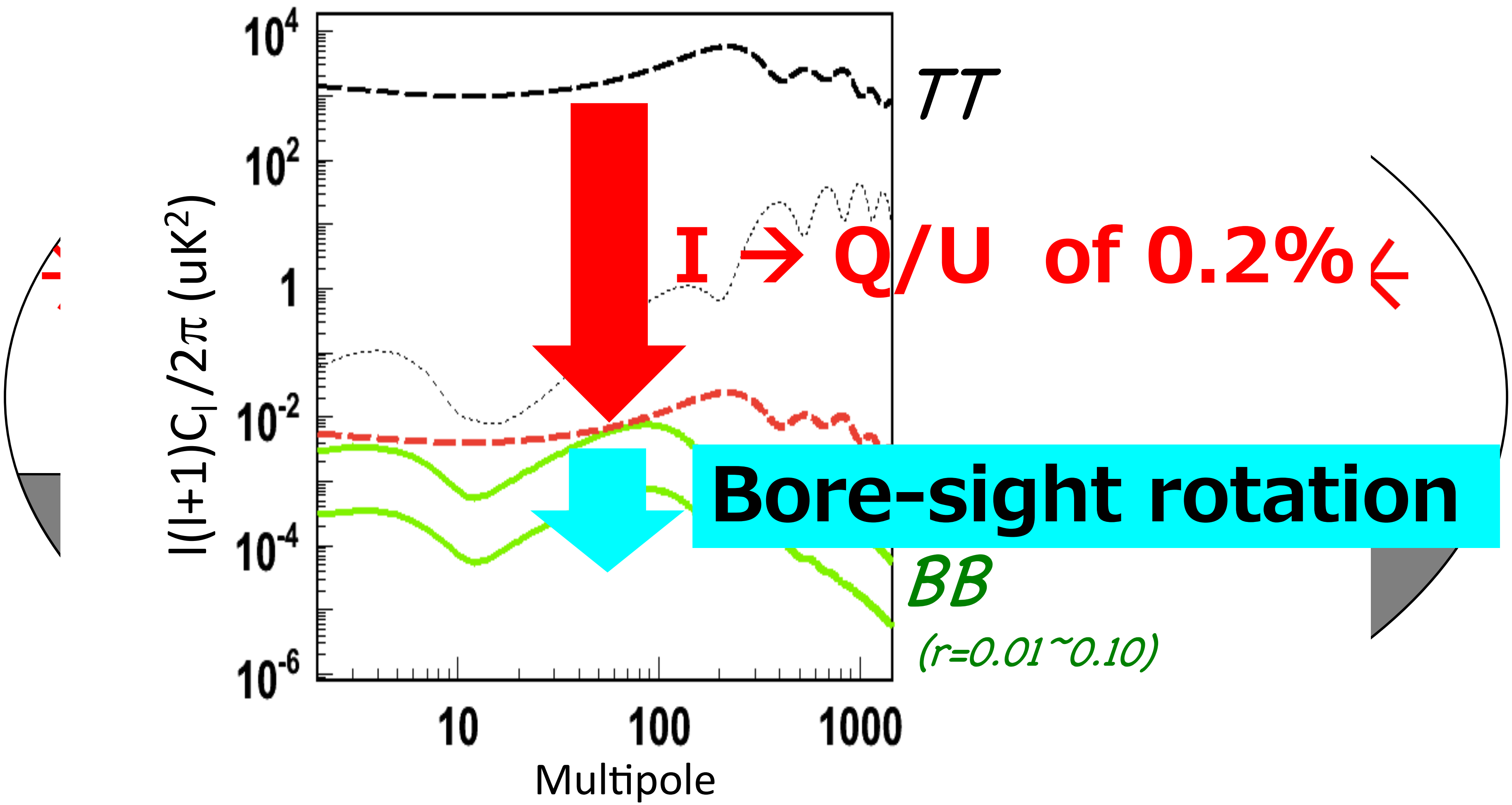
Suppose there is fake-polarization of O(0.1%) due to imperfection of instruments



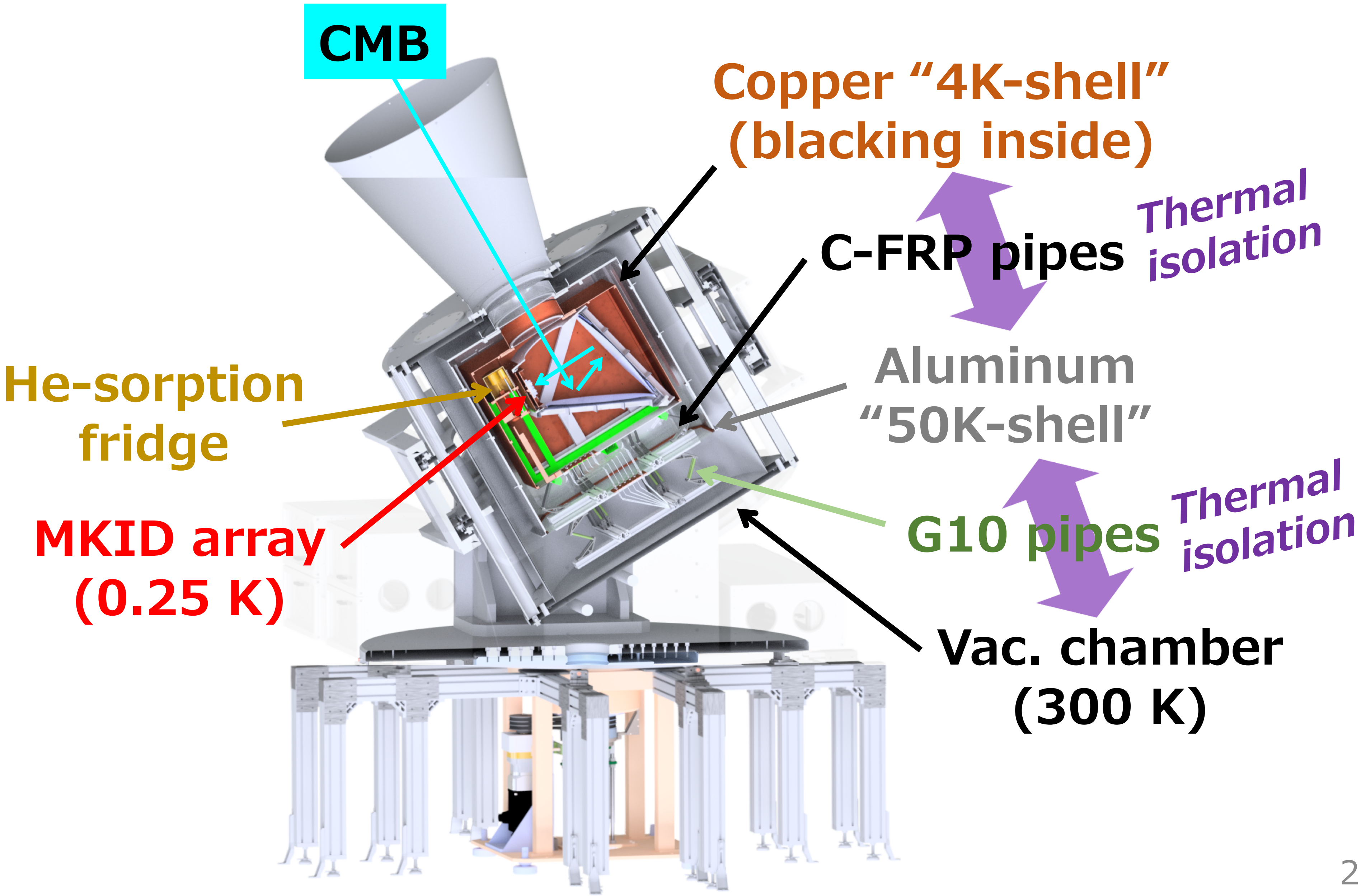


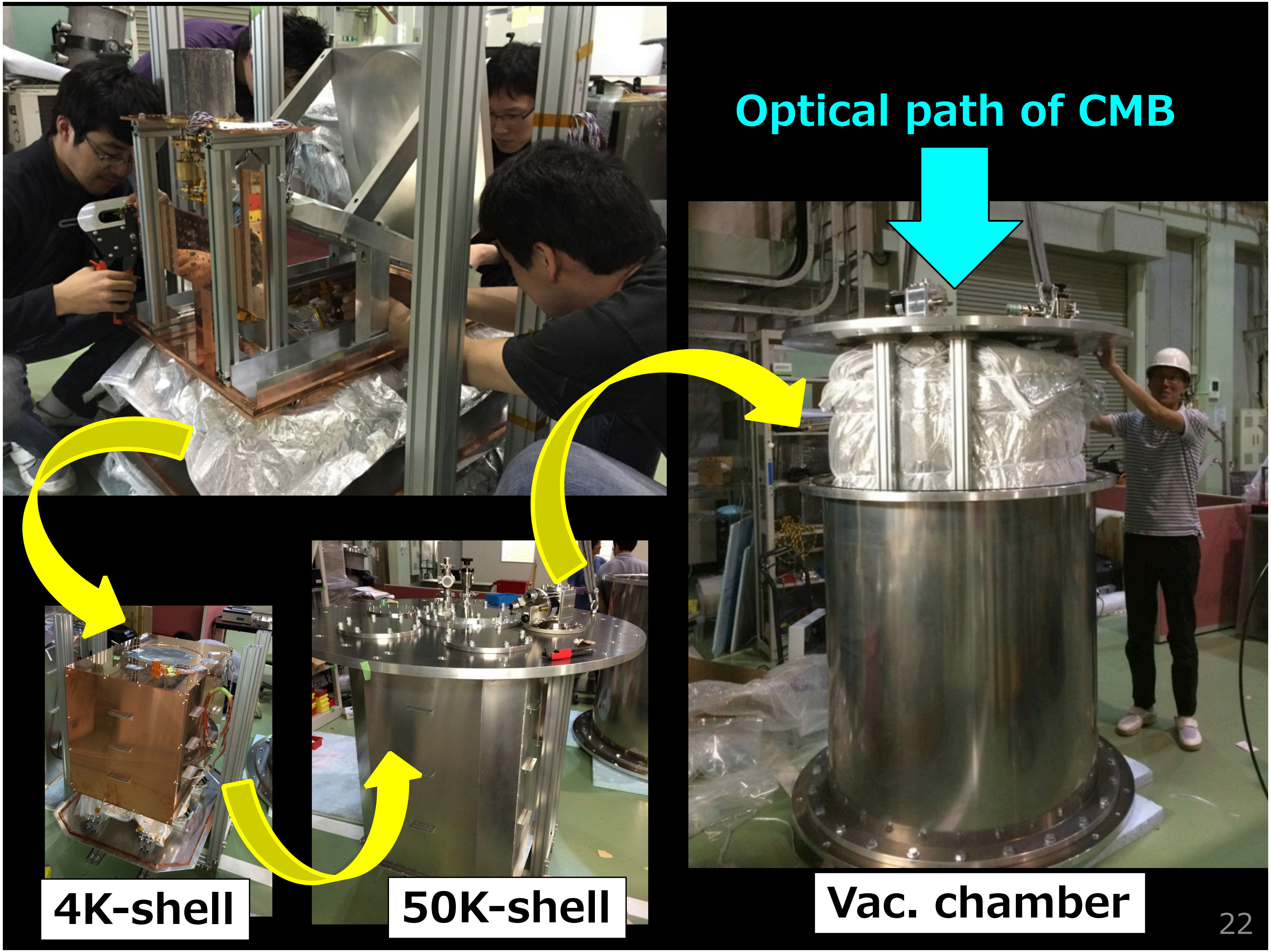
Bore-sight rotation in step-wise

Impact of bore-sight rotation



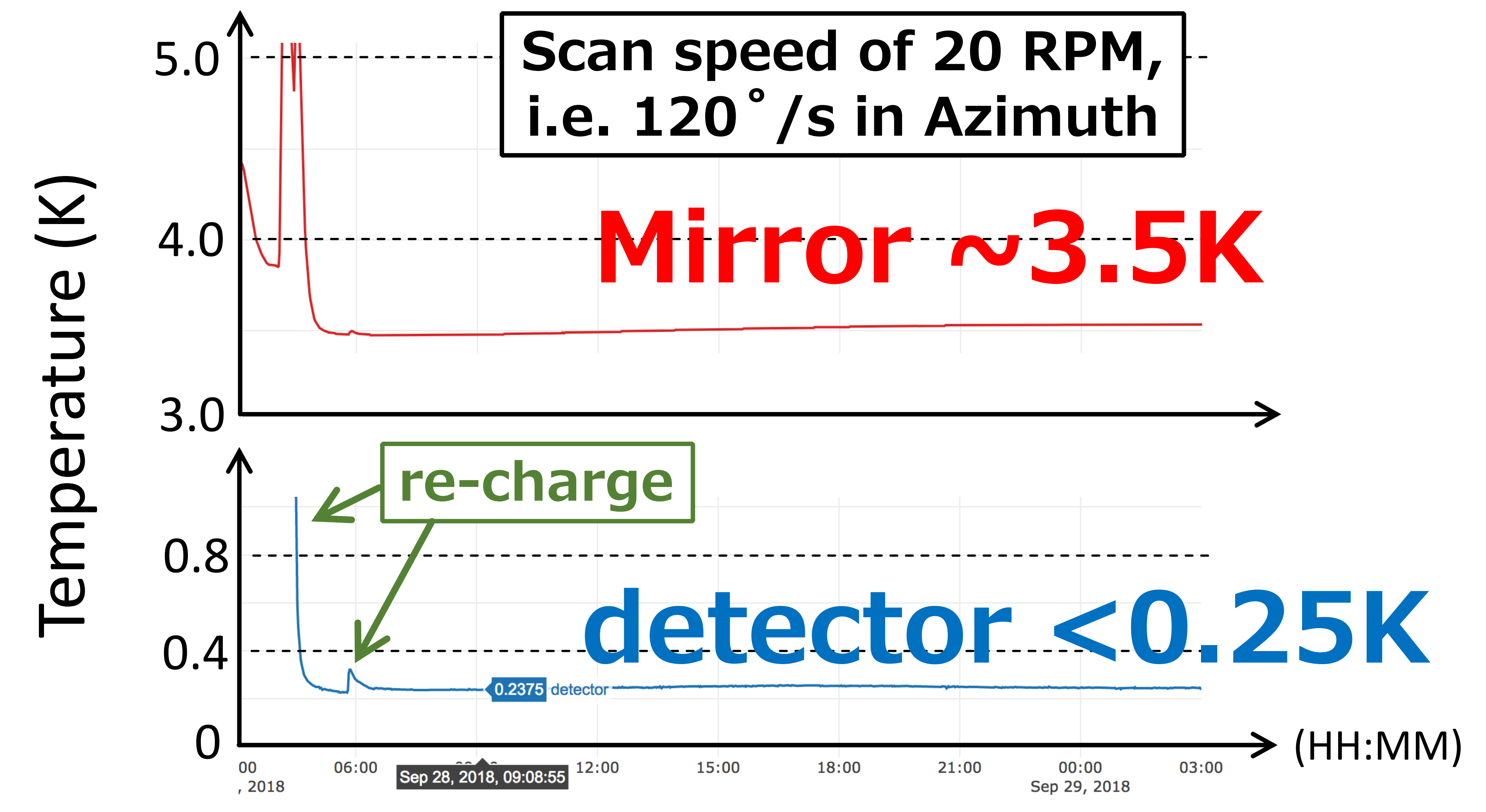
Cryogenic optics minimize thermal noise




Optical path of CMB
4K-shell
50K-shell
Vac. chamber

24H *T* trends with HsRs

optical loading of T_{room}

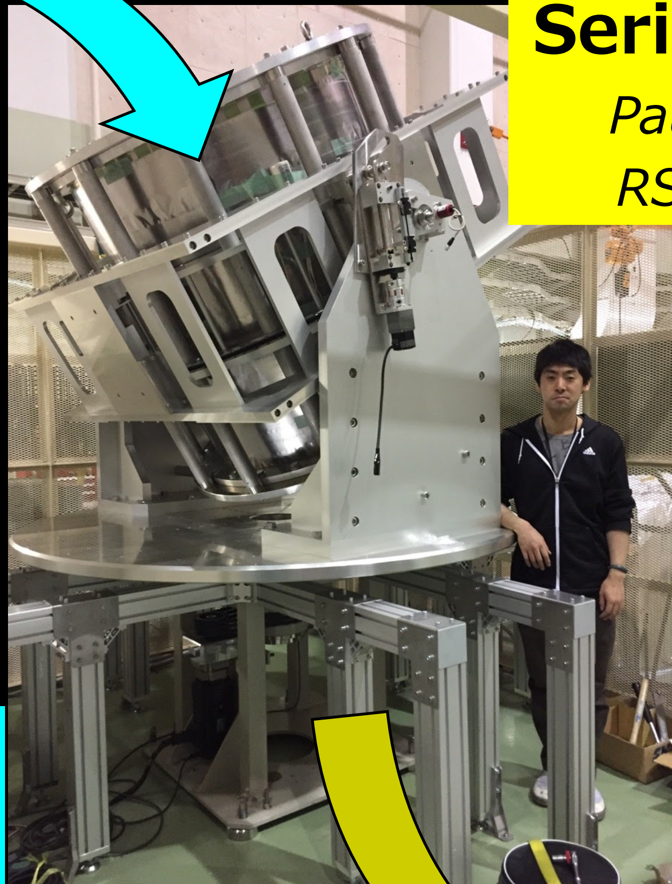


"Cool" technologies for GB

RT-MLI for IR-blocking

Patent: JP6029079

RSI, 84, 114502 (2013).



Series of rotary joints

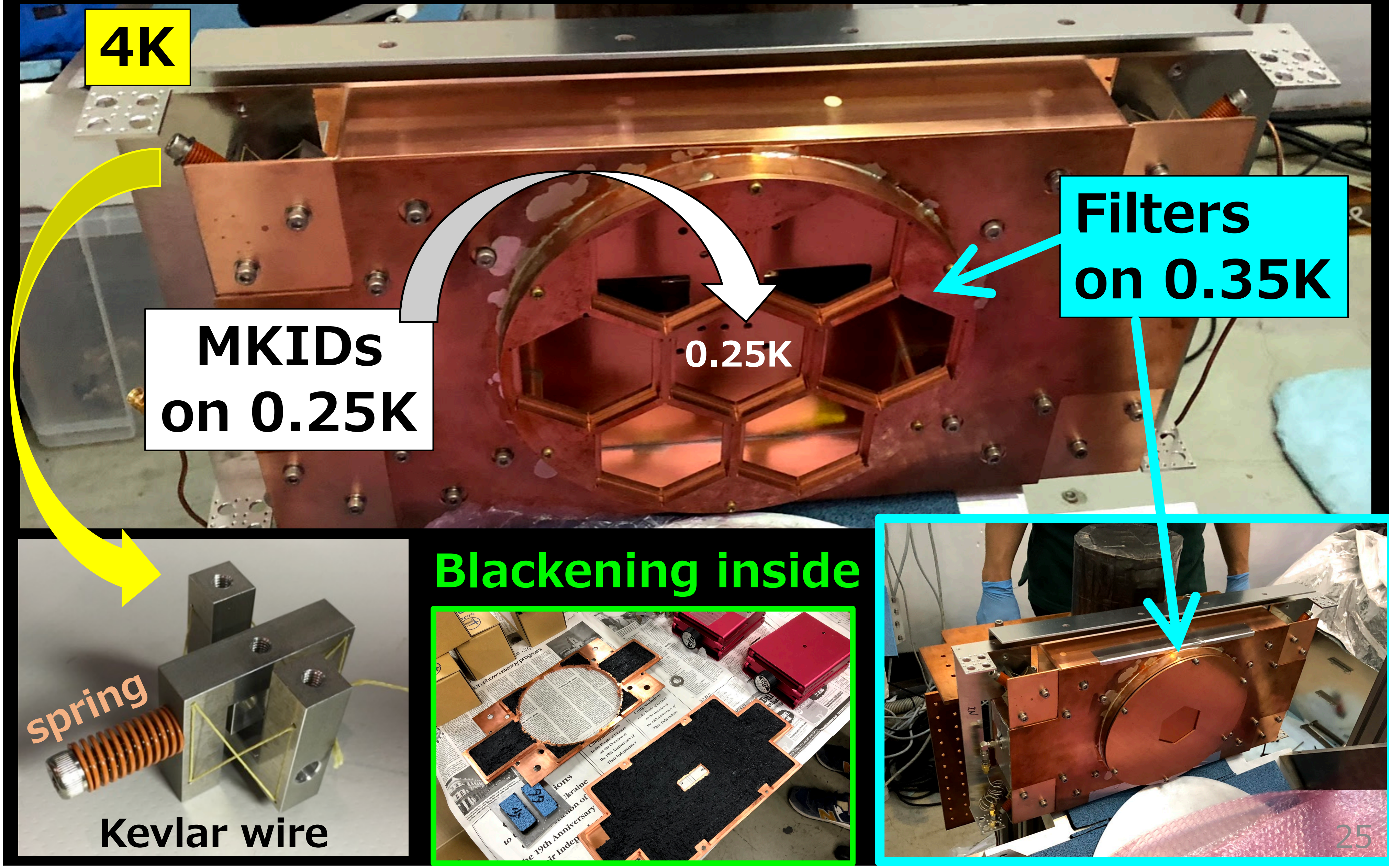
Patent: US 9,316,418-B2

RSI, 84, 055116 (2013).

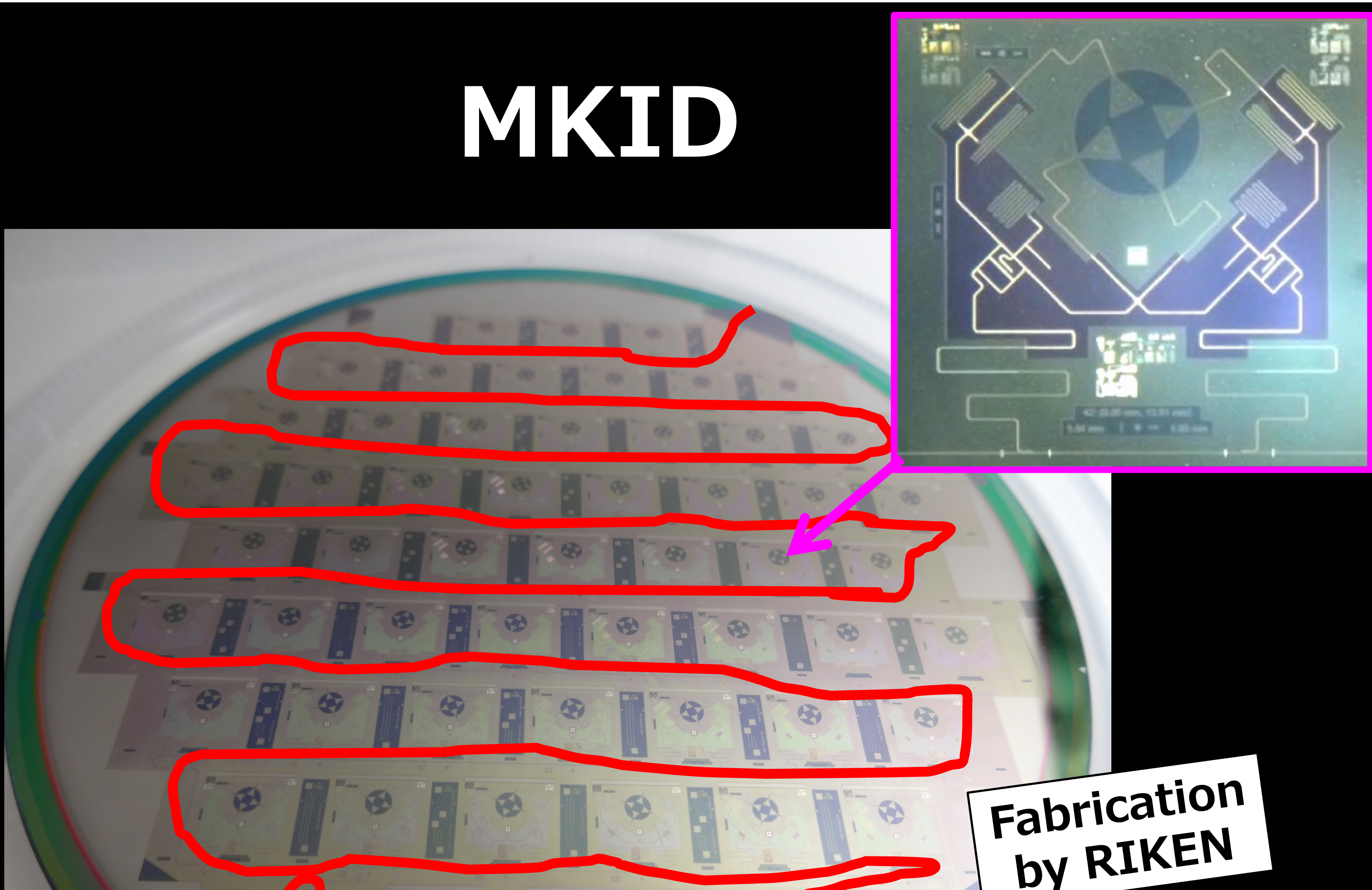
He-gas lines for PTC

Electric lines

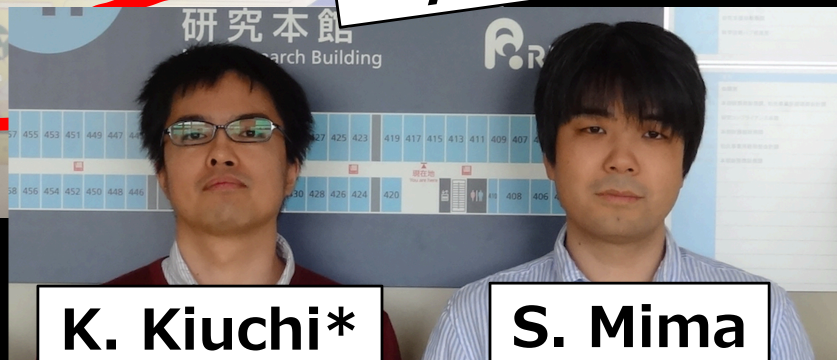
Focal plane mechanical structure



MKID



Fabrication by RIKEN



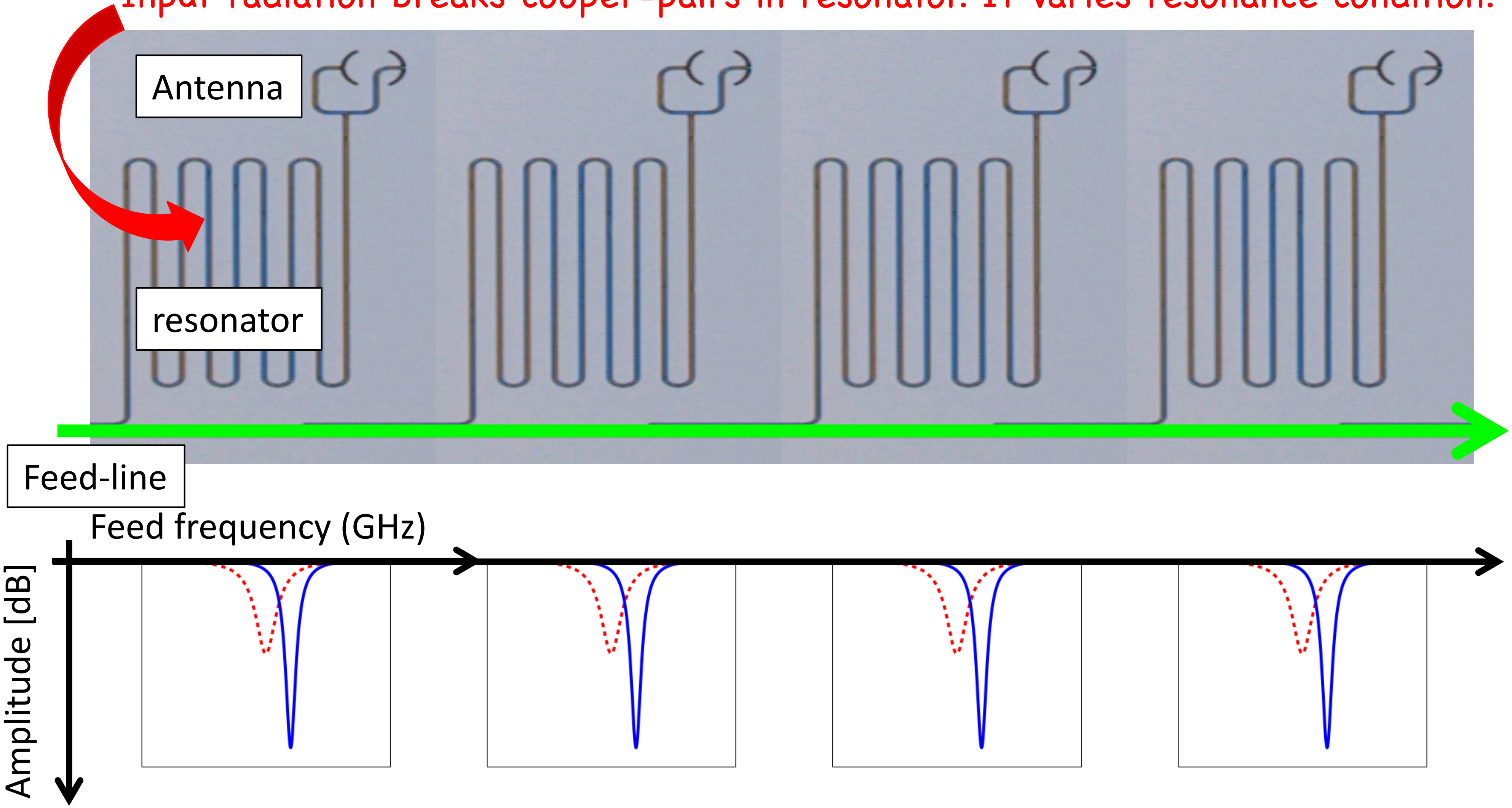
K. Kiuchi*

S. Mima

*Now in UTokyo

Benefit of MKID
"resonator = detector"

Input radiation breaks cooper-pairs in resonator. It varies resonance condition.



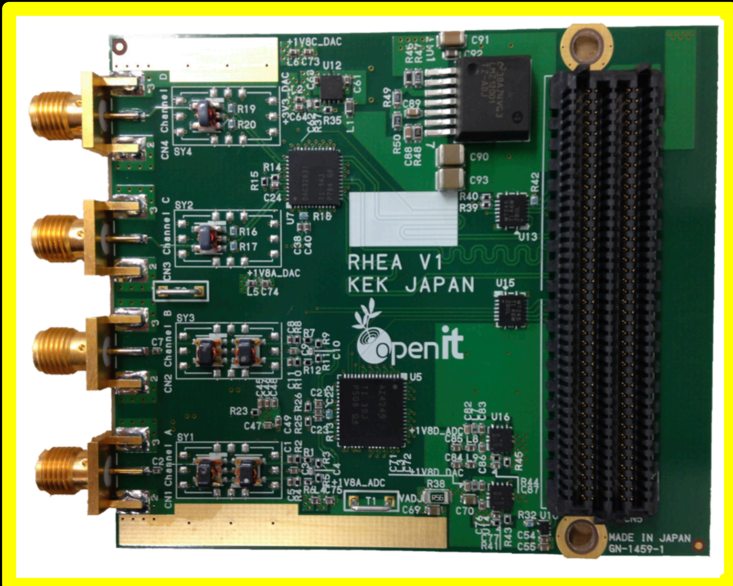
Natural frequency domain MUX

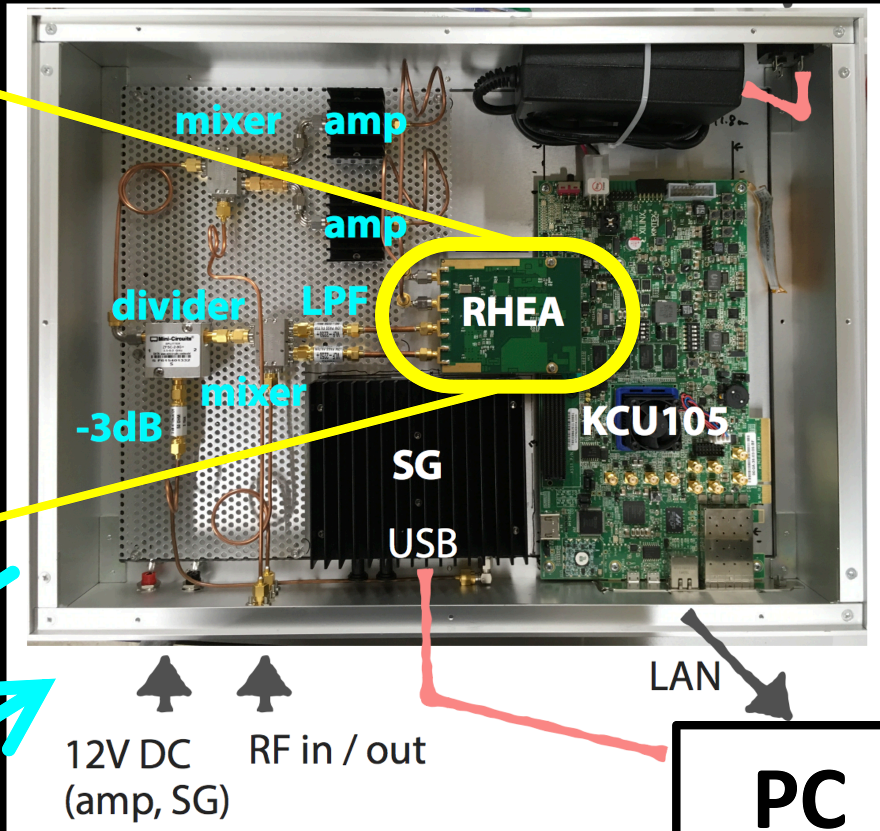
MKID readout electronics

DA/AD board "RHEA" :

- 120-MUX in 250 MHz band width
- 1 kSpS high-speed sampling w/o deadtime

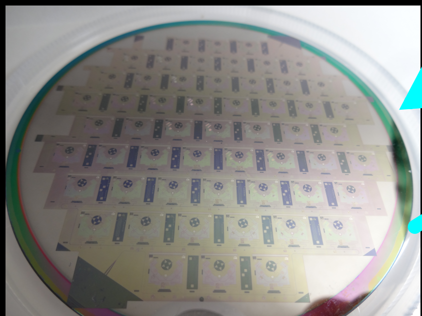
H. Ishitsuka et al, J. Low Temp. Phys., 184, Issue 1 (2016)



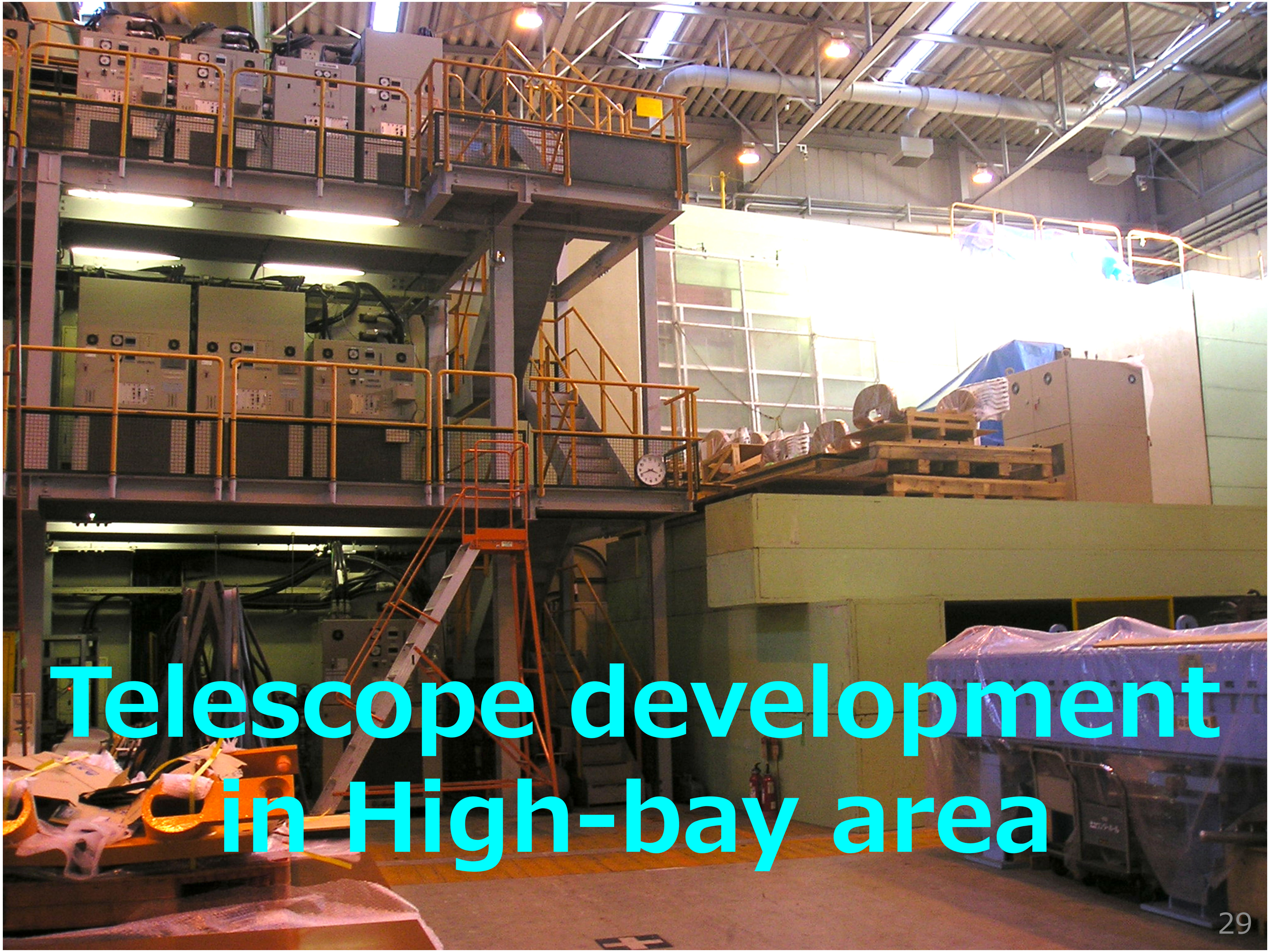


PC

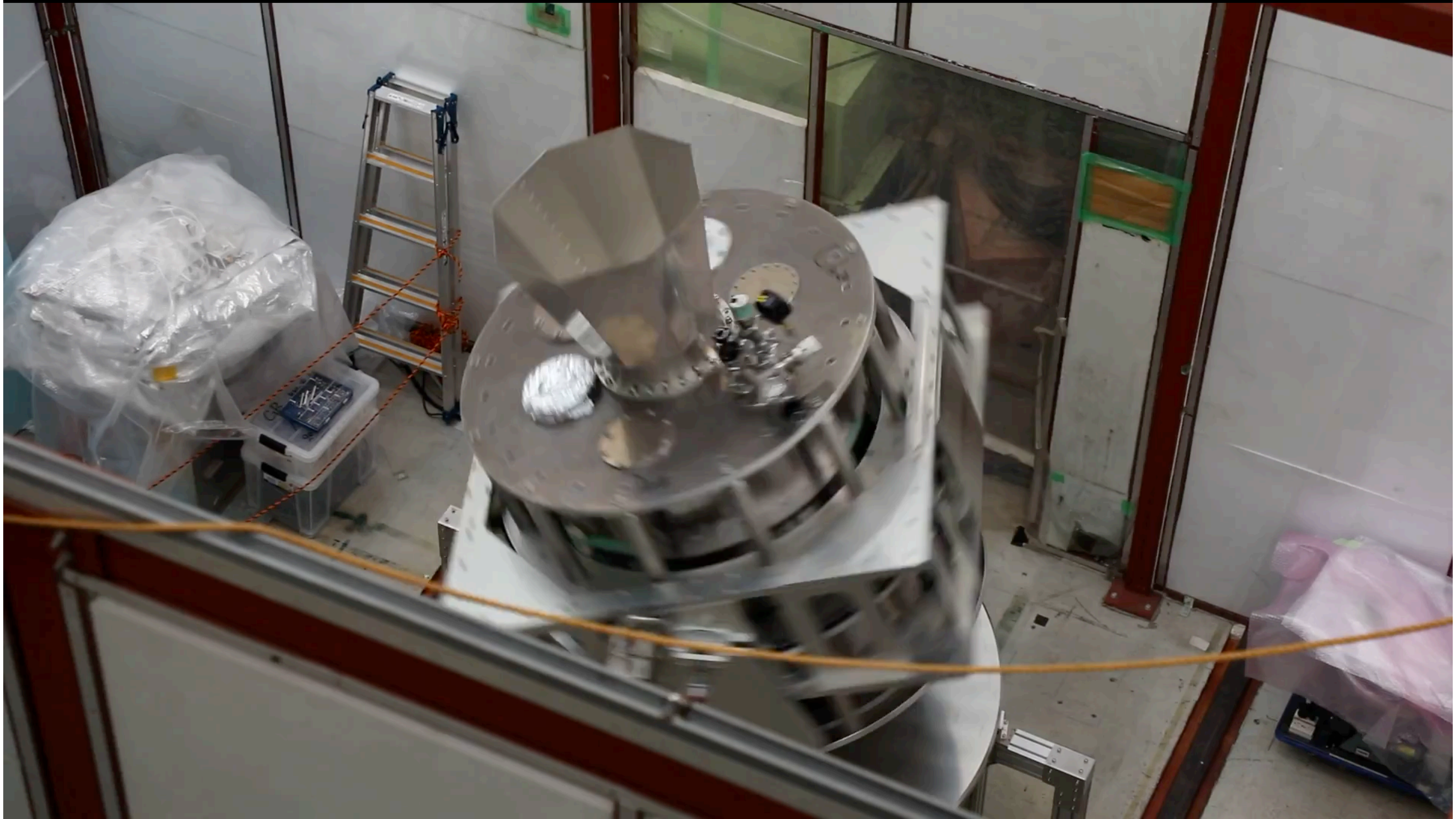
MKIDs
in cryostat



Telescope development in High-bay area



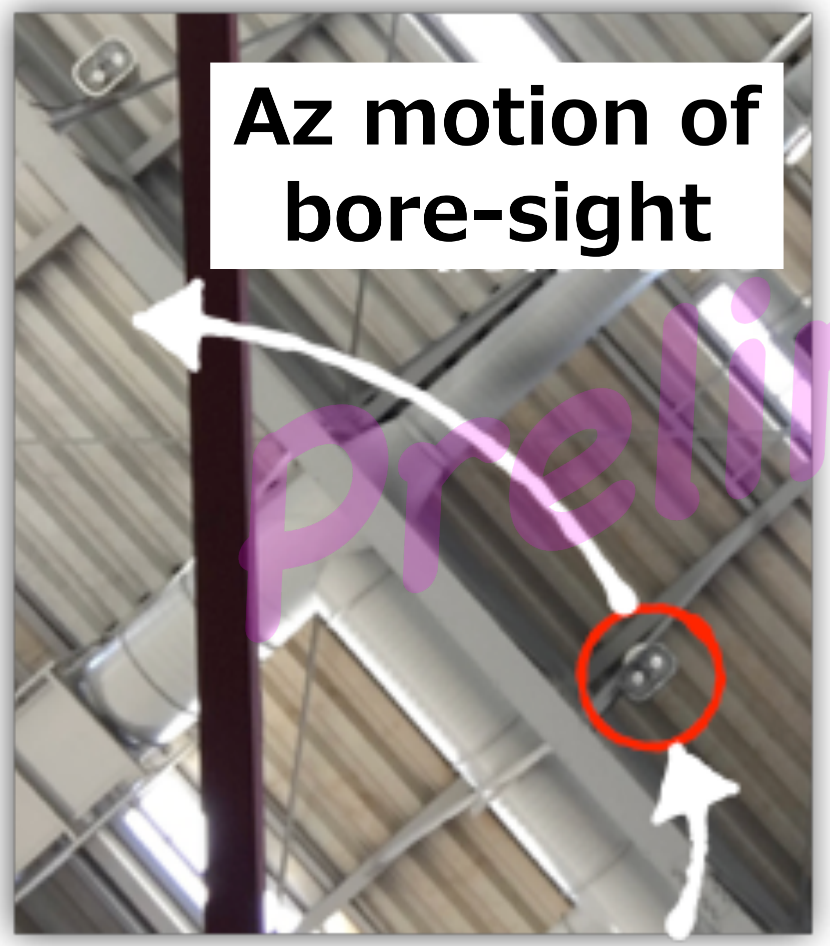
Rotation-scan in High-bay



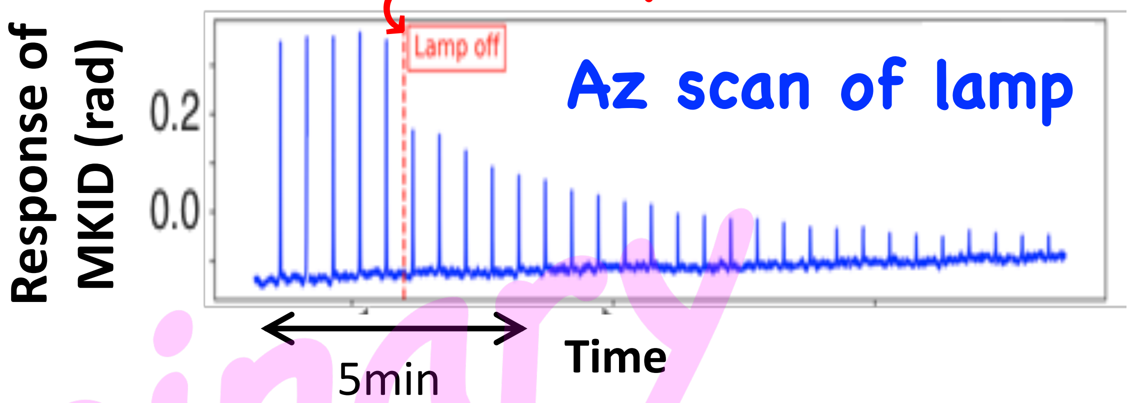
Demonstration of scan

"First light" in High-bay

Benefit of MKID:
No saturation in T_{room} loads

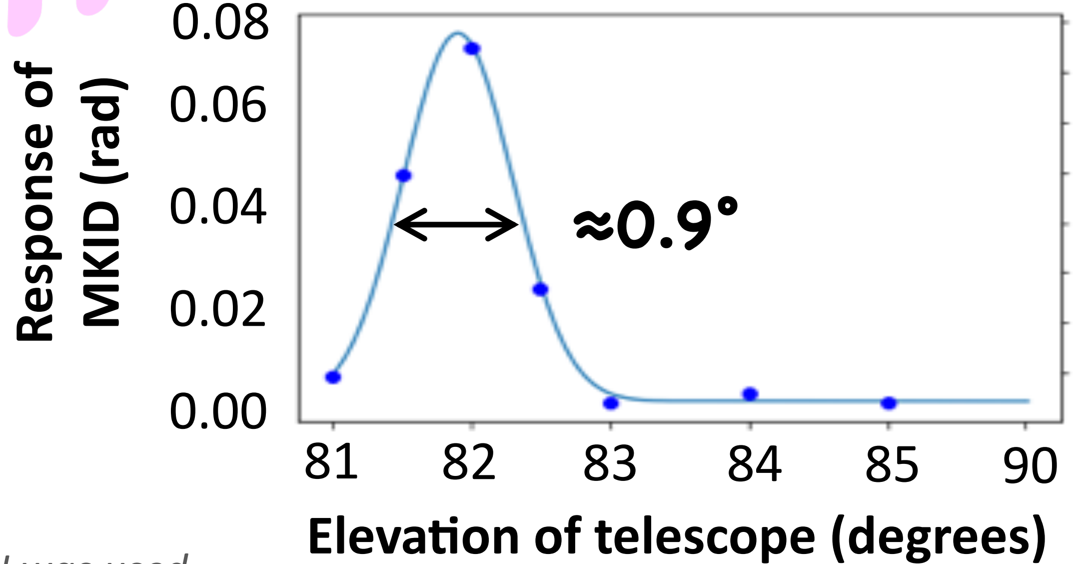


Turn off the lamp



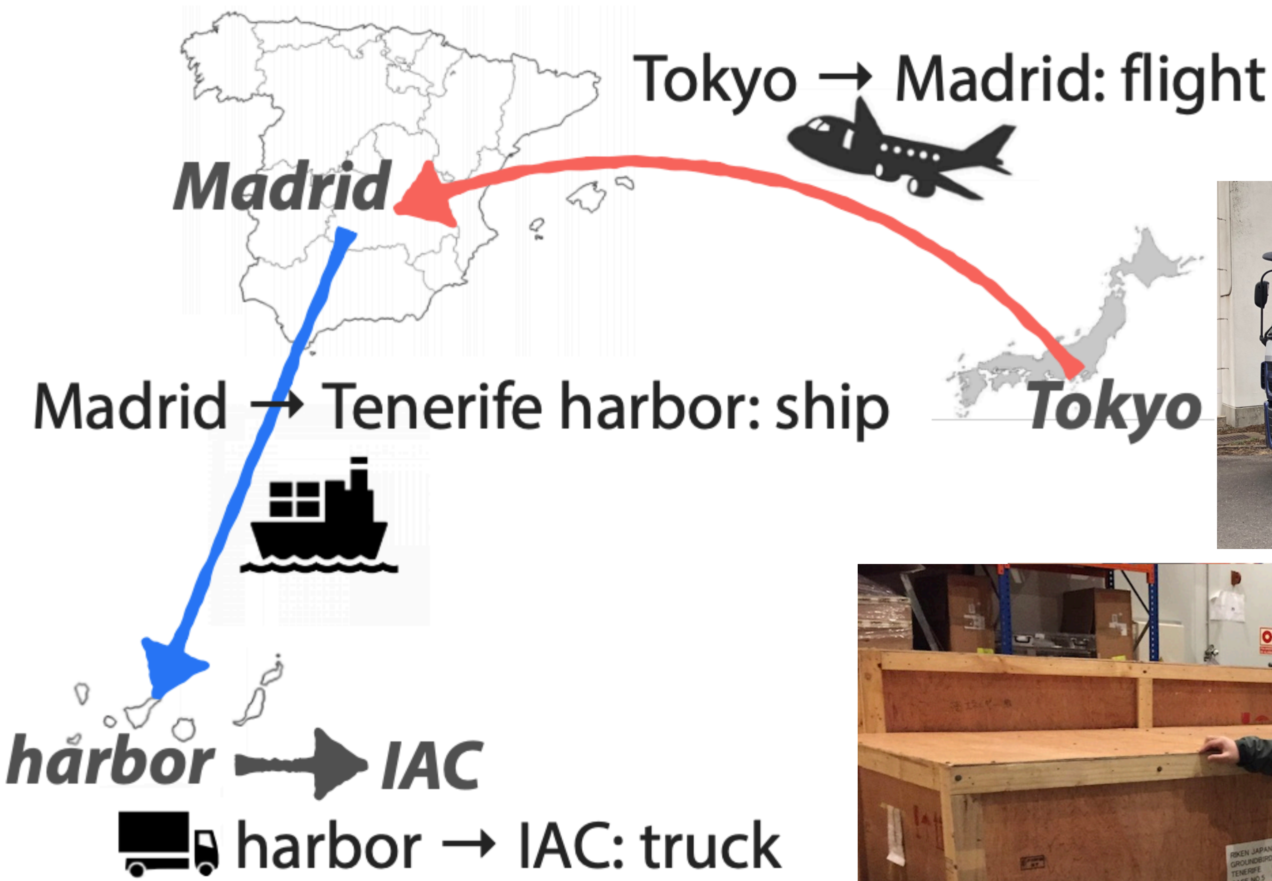
Preliminary

Size of lamp ⊗ beam



Acknowledgement: MKID borrowed from SRON was used.

Japan → The Canaries



Departure
Feb. 13, 2019

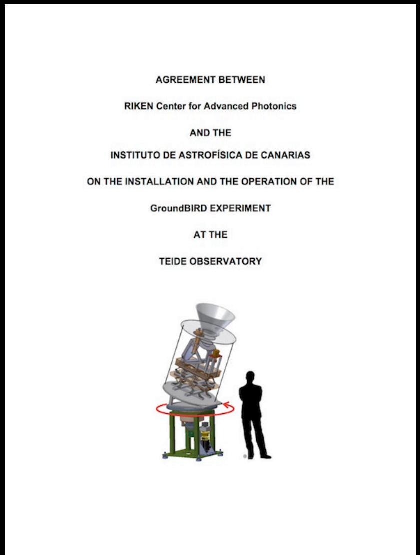
Arrival
Mar. 8, 2019

Taketo Nagasaki
(RIKEN)

Prep. observation site

MOU RIKEN btw IAC (May, 2015)

Agreements (Aug. 2016)



AGREEMENT BETWEEN

RIKEN Center for Advanced Photonics

AND THE

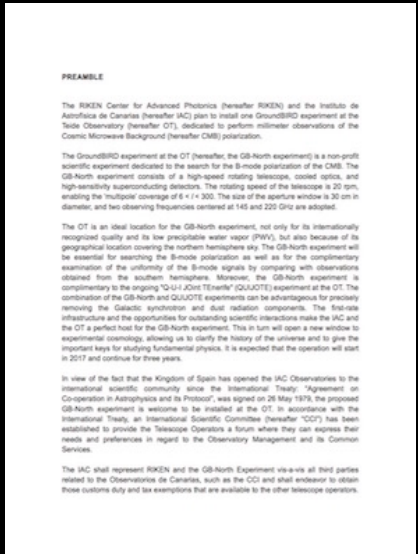
INSTITUTO DE ASTROFÍSICA DE CANARIAS

ON THE INSTALLATION AND THE OPERATION OF THE

GroundBIRD EXPERIMENT

AT THE

TEIDE OBSERVATORY



PREAMBLE

The RIKEN Center for Advanced Photonics (hereafter RIKEN) and the Instituto de Astrofisica de Canarias (hereafter IAC) plan to install one GroundBIRD experiment at the Teide Observatory (hereafter OT), dedicated to perform millimeter observations of the Cosmic Microwave Background (hereafter CMB) polarization.

The GroundBIRD experiment at the OT (hereafter, the GB-North experiment) is a non-profit scientific experiment dedicated to the search for the B-mode polarization of the CMB. The GB-North experiment consists of a high-speed rotating telescope, cooled optics, and high-sensitivity superconducting detectors. The rotating speed of the telescope is 20 rpm, enabling the 'multipole' coverage of 6 < l < 300. The size of the aperture window is 30 cm in diameter, and two observing frequencies centered at 145 and 220 GHz are adopted.

The OT is an ideal location for the GB-North experiment, not only for its internationally recognized quality and its low precipitable water vapor (PWV), but also because of its geographical location covering the northern hemisphere sky. The GB-North experiment will be essential for searching the B-mode polarization as well as for the complimentary examination of the uniformity of the B-mode signals by comparing with observations obtained from the southern hemisphere. Moreover, the GB-North experiment is complimentary to the ongoing "Q-U-I JOint TEnerife" (QUIJOTE) experiment at the OT. The combination of the GB-North and QUIJOTE experiments can be advantageous for precisely removing the Galactic synchrotron and dust radiation components. The first-rate infrastructure and the opportunities for outstanding scientific interactions make the IAC and the OT a perfect host for the GB-North experiment. This in turn will open a new window to experimental cosmology, allowing us to clarify the history of the universe and to give the important keys for studying fundamental physics. It is expected that the operation will start in 2017 and continue for three years.

In view of the fact that the Kingdom of Spain has opened the IAC Observatories to the international scientific community since the International Treaty: "Agreement on Co-operation in Astrophysics and its Protocol", was signed on 26 May 1979, the proposed GB-North experiment is welcome to be installed at the OT. In accordance with the International Treaty, an International Scientific Committee (hereafter "CCI") has been established to provide the Telescope Operators a forum where they can express their needs and preferences in regard to the Observatory Management and its Common Services.

The IAC shall represent RIKEN and the GB-North Experiment vis-a-vis all third parties related to the Observatorios de Canarias, such as the CCI and shall endeavor to obtain those customs duty and tax exemptions that are available to the other telescope operators.

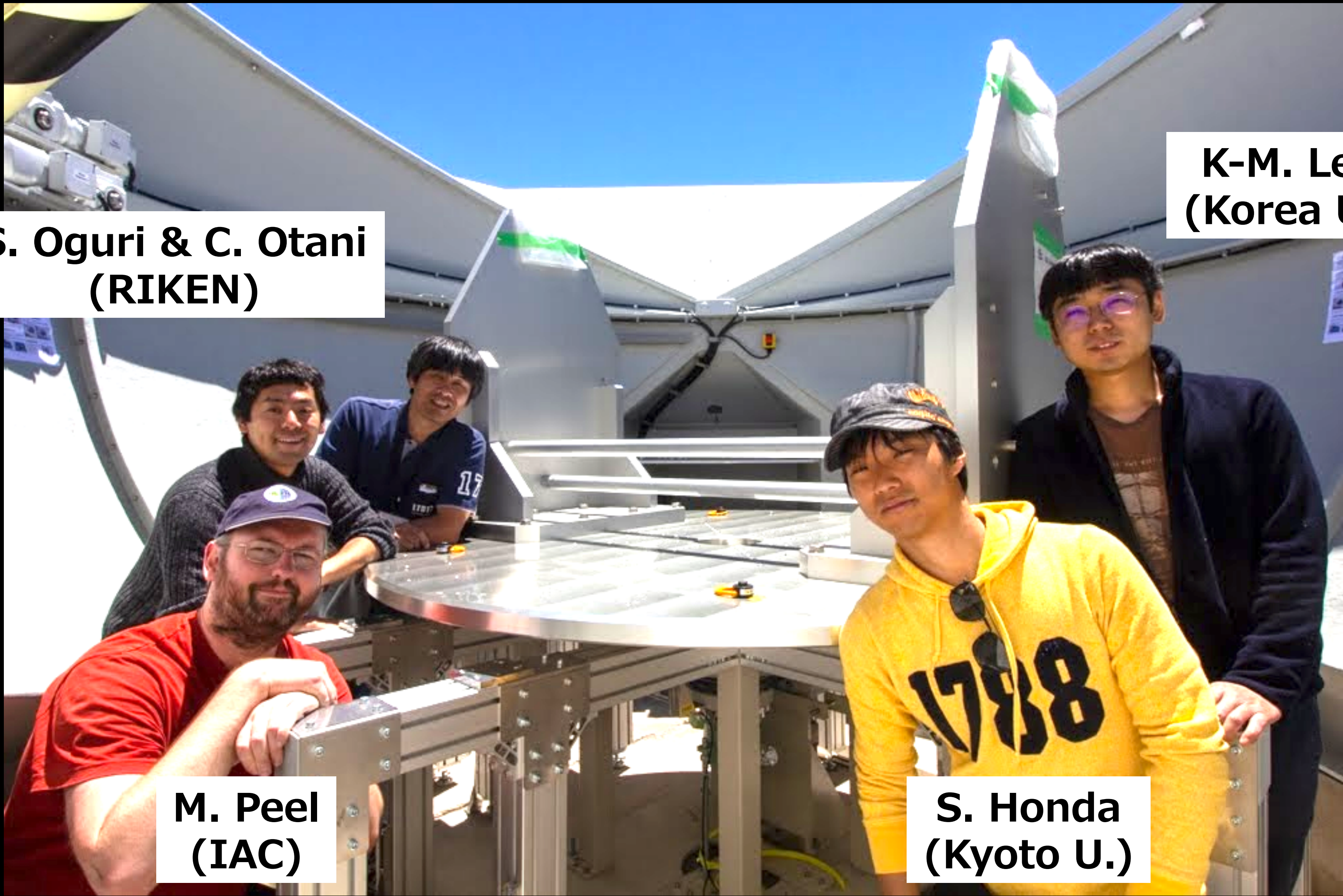
Ground shielded area for GB

- ✓ electrical power
- ✓ G-bits internet

Dome for weather proofing
end of Oct. 2018

Construction of telescope mount in June

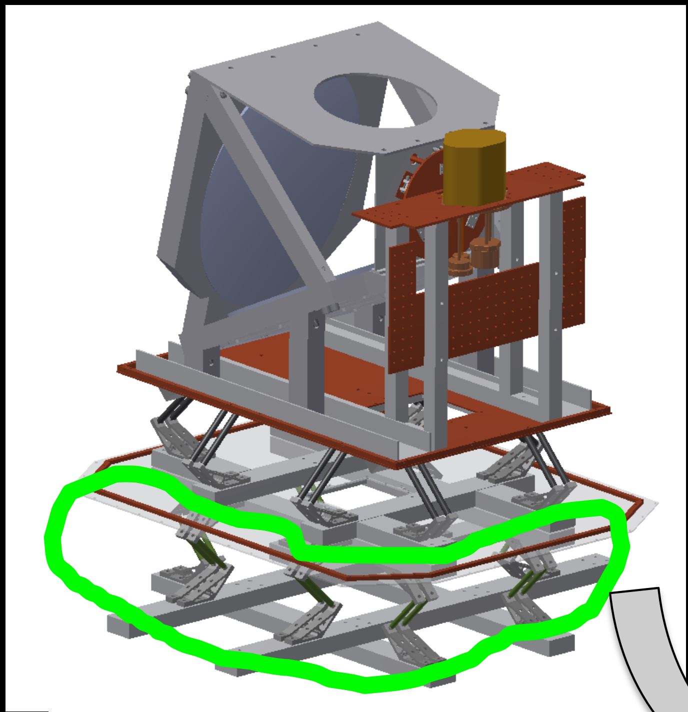
Complete construction of the mount in June 11 !

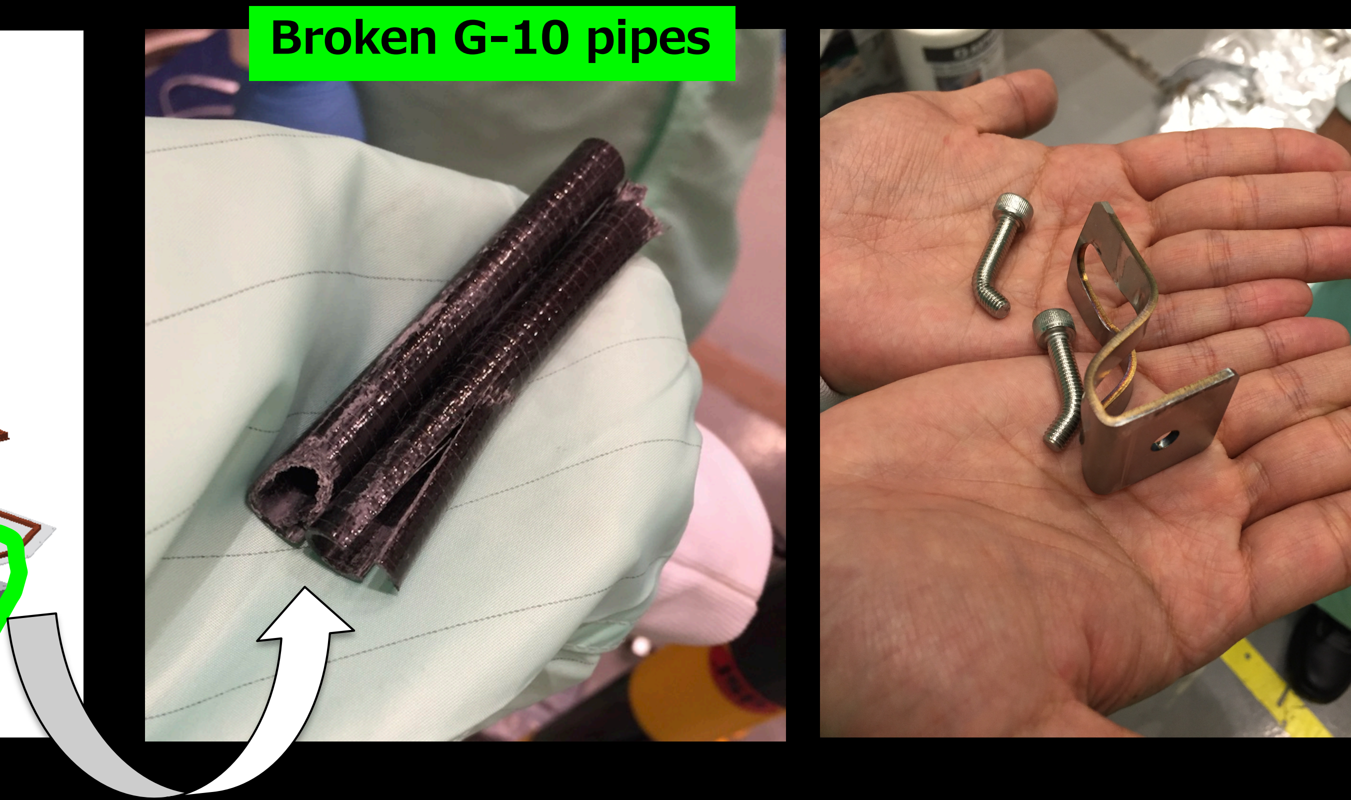


Final checking of receiver in IAC (lab at 500m alt.)

The receiver will be deployed after checking of performances

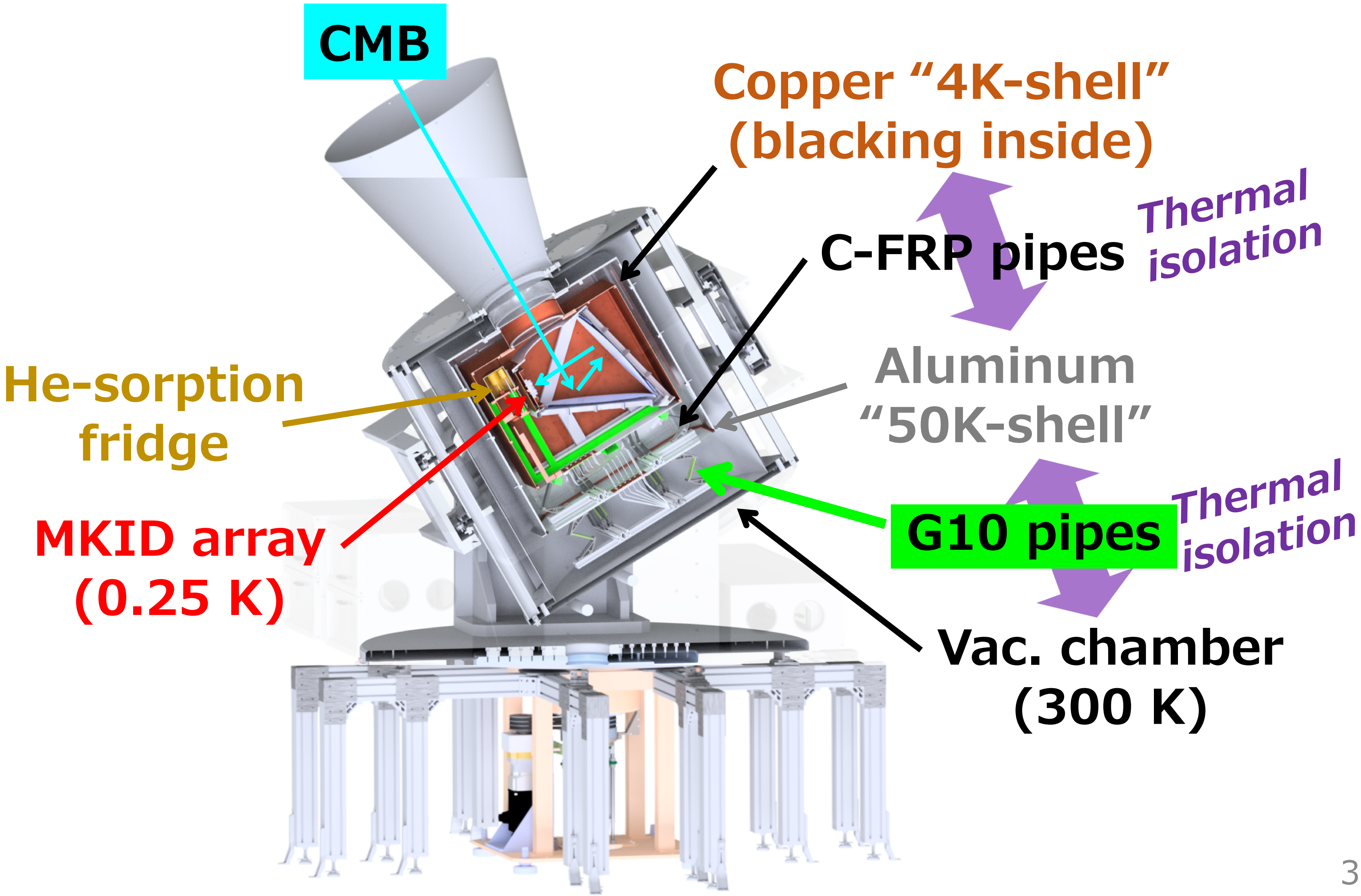
Trouble during shipping ☹
It was repaired on site



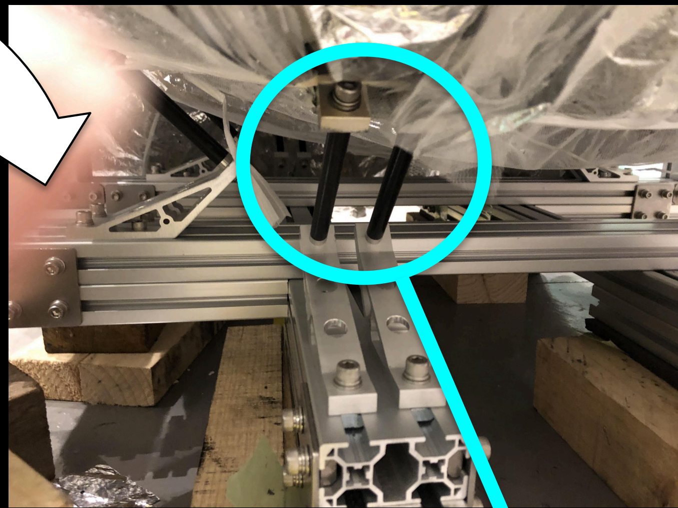


Support structure for 50K-shell (all G10 pipes, and a few screws) were broken

Cryogenic optics

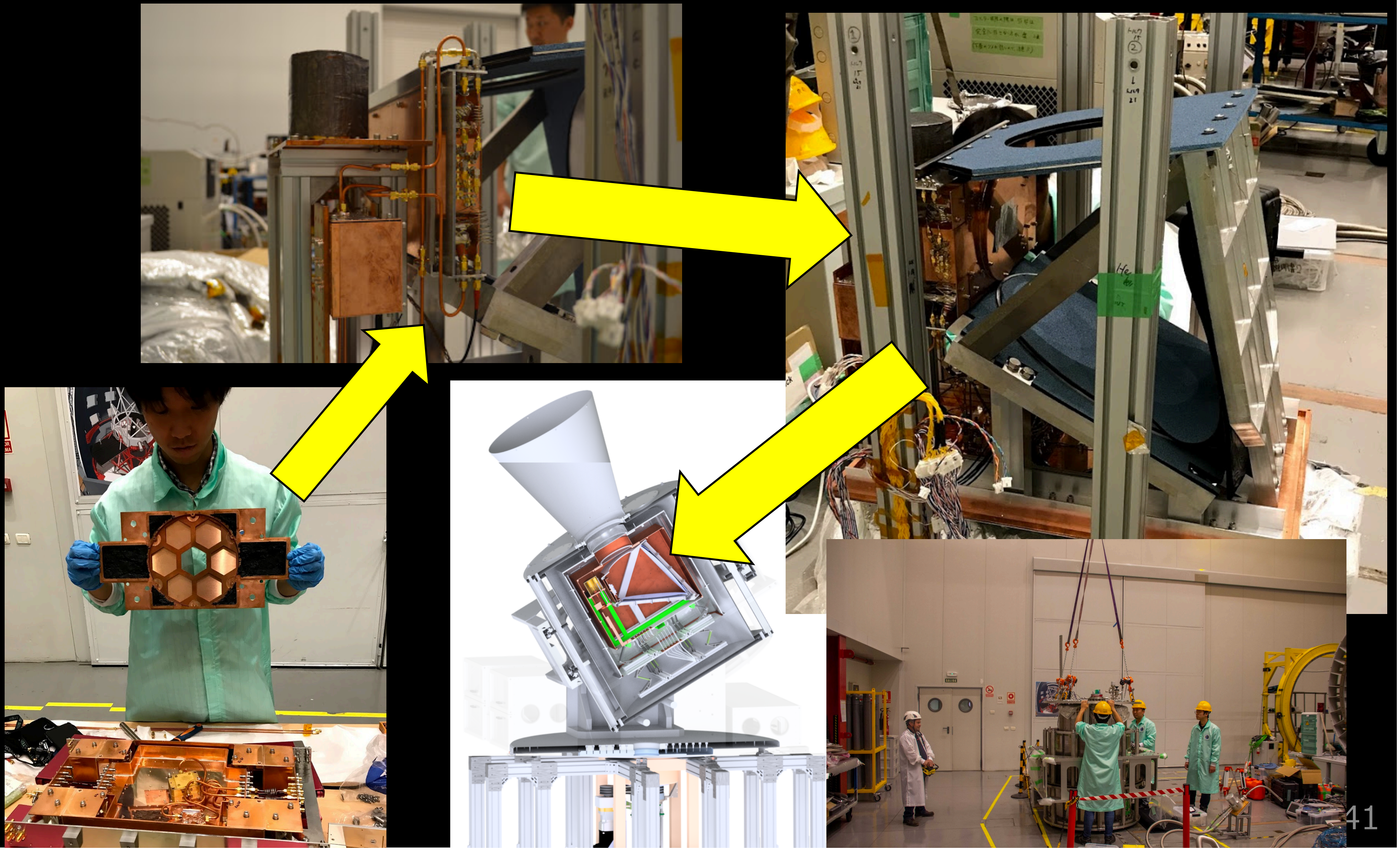


Broken parts were replaced

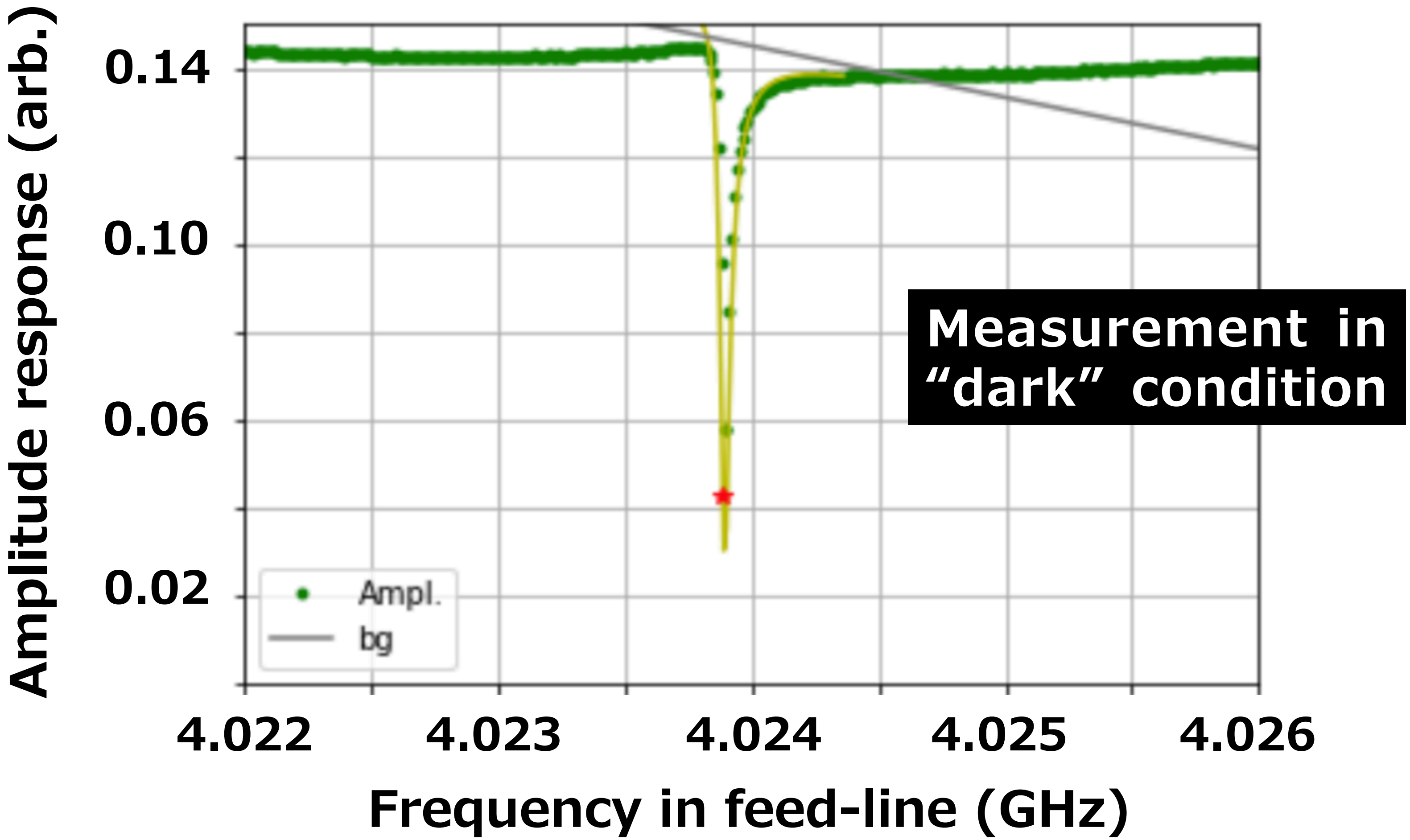


On-site cooldown test

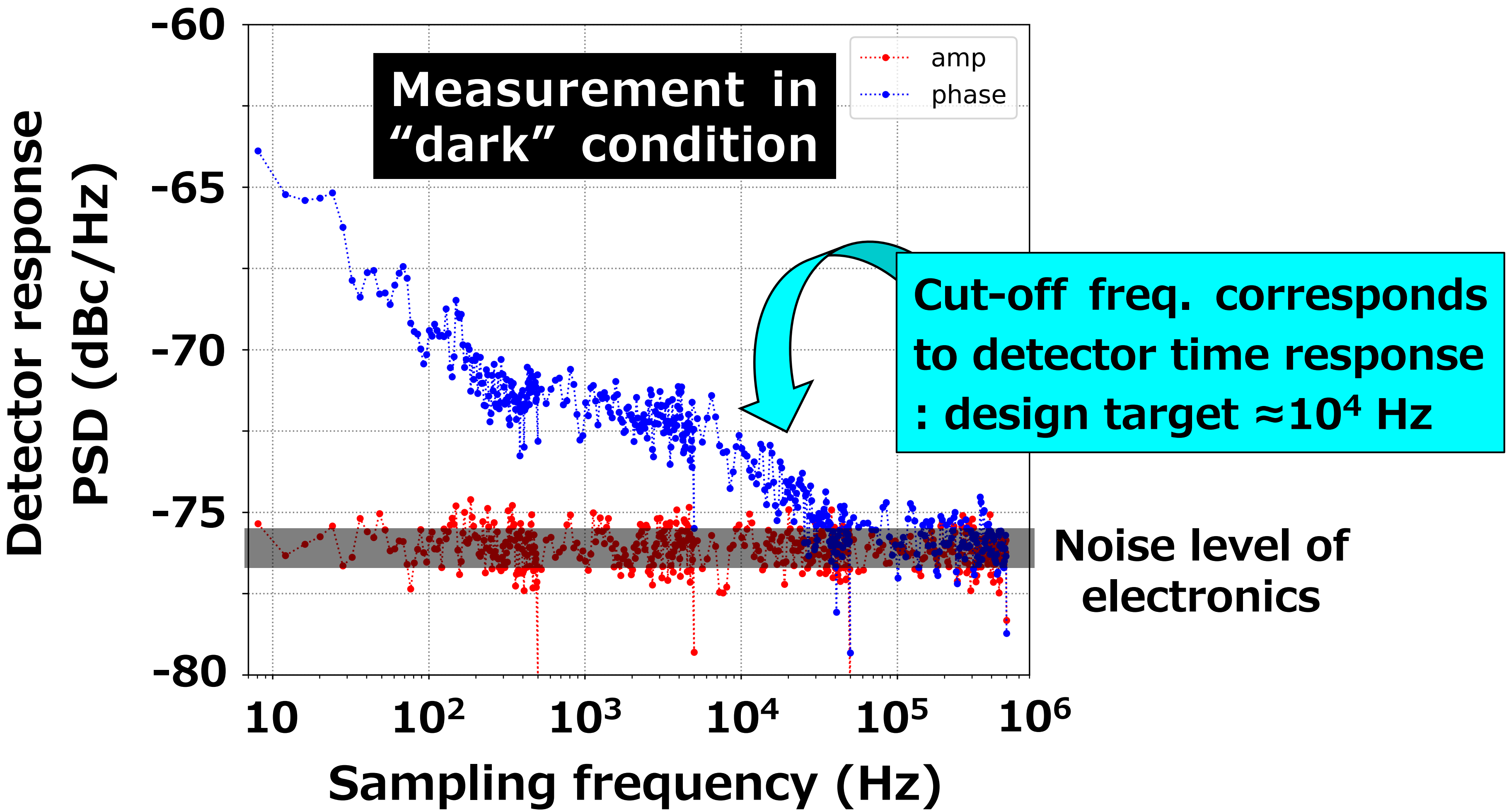
Success to achieve 0.23 K!



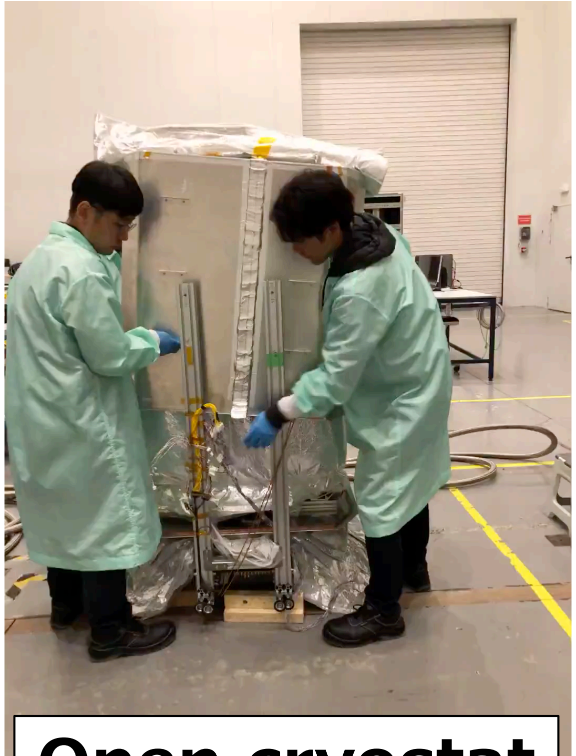
The first MKID's signal in the Canaries!



The first MKID's signal in the Canaries!

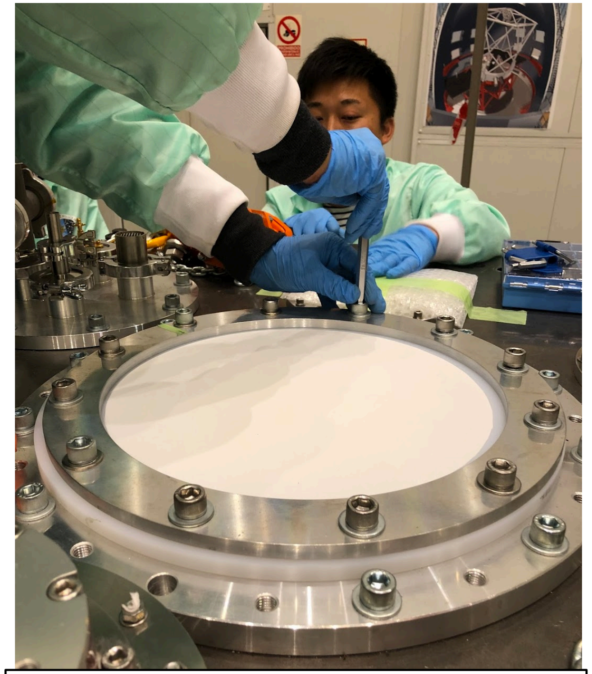


After “under illumination” check, receiver will be mounted at the site



Open cryostat

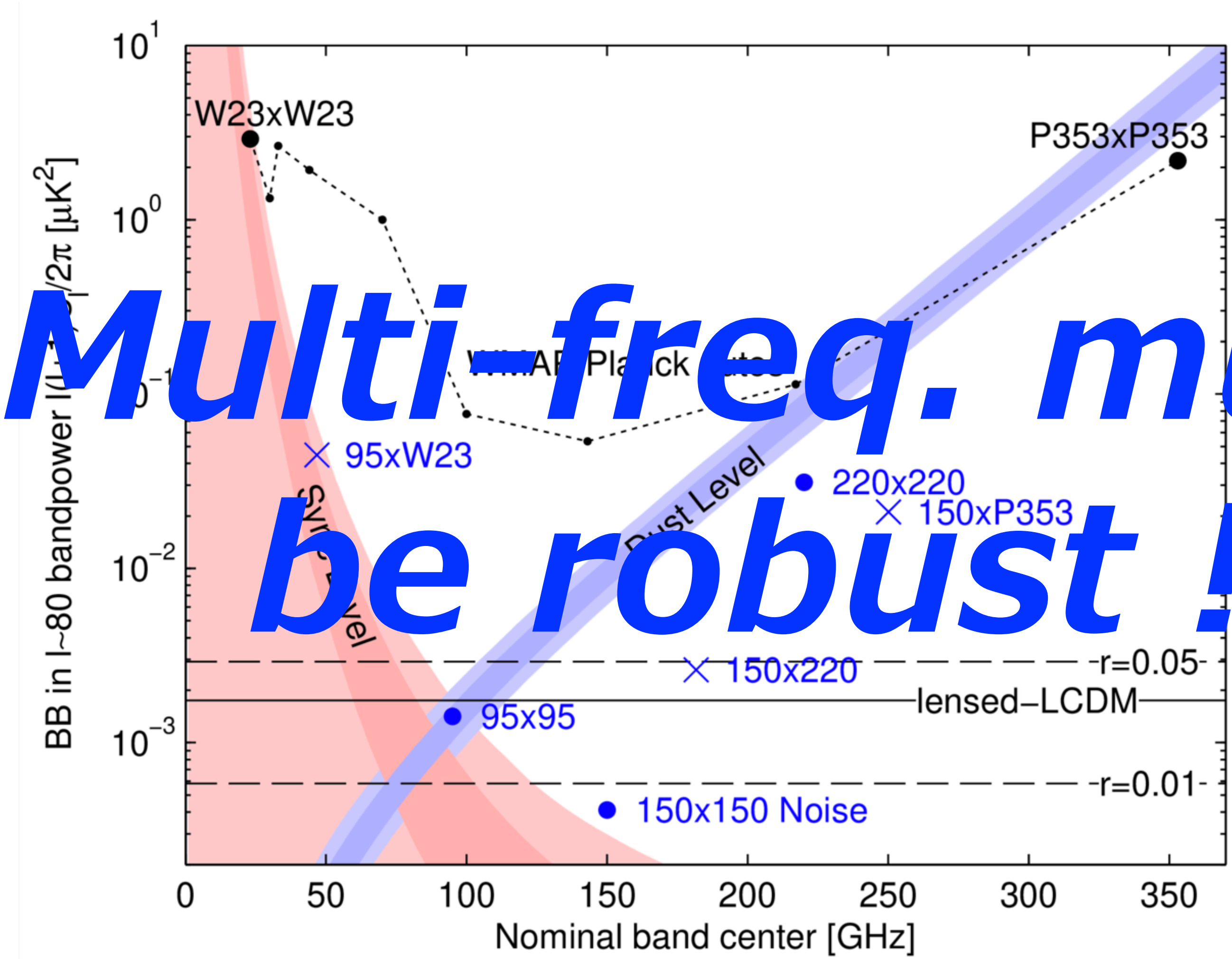
Peeling off light-cut tapes



Installation of optical window

“First light” soon! (in Sep.?)

Foregrounds limit “r”

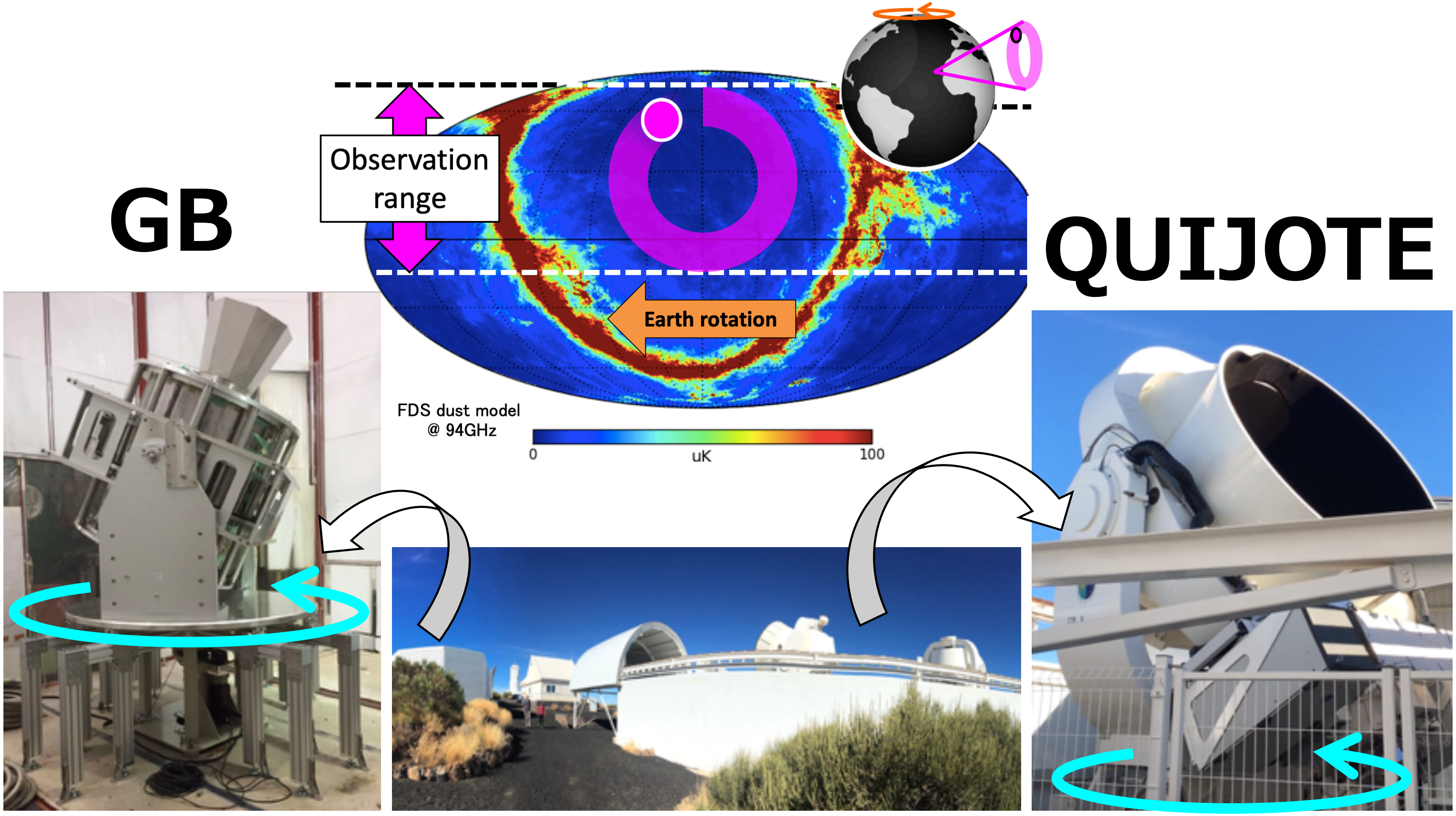


Multi-freq. must be robust !

BICEP2 / Keck Array, Phys. Rev. Lett. 121, 221301 (2018)

Option under discussed

Foregrounds vs QUIJOTE×GB

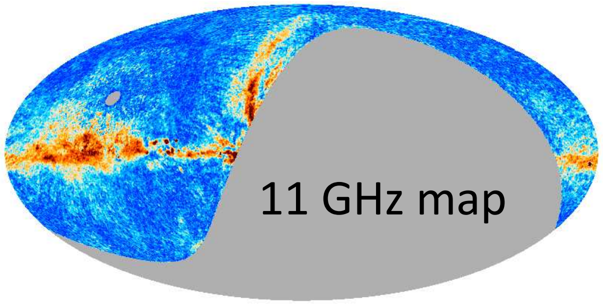


Similar scan strategy at the same location

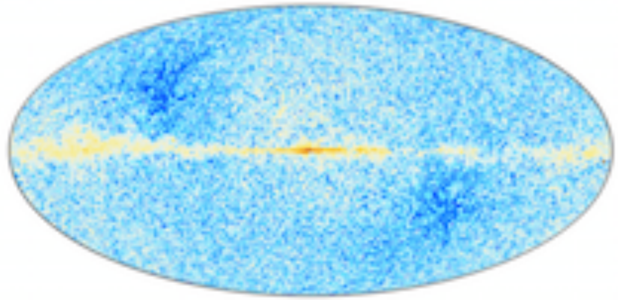
Option under discussed

Foregrounds vs QUIJOTE×GB

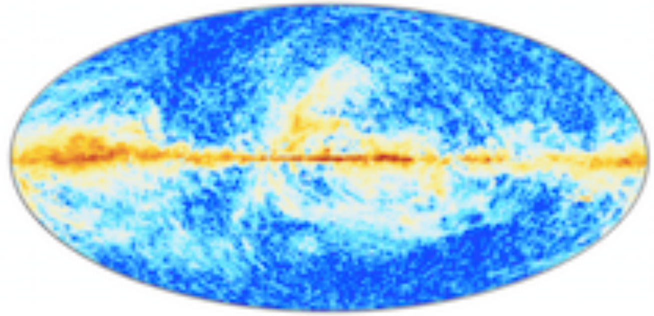
QUIJOTE | **QUIJOTE × GB** | **GB**



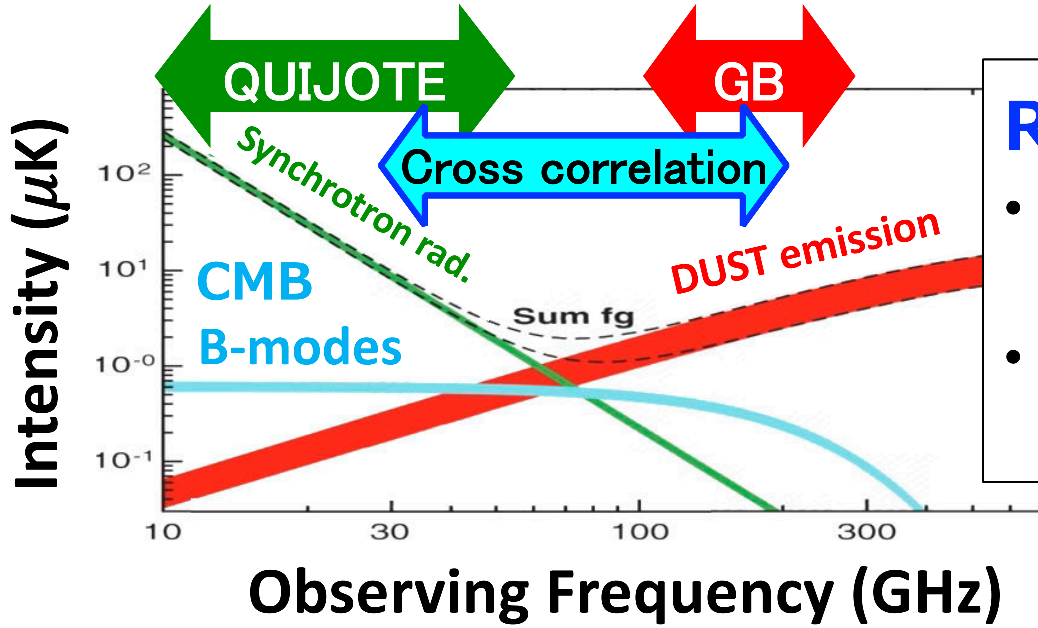
11,13,17,19, 30, 40 GHz
(Courtesy of the QUIJOTE collaboration)



Cross–correlated bands



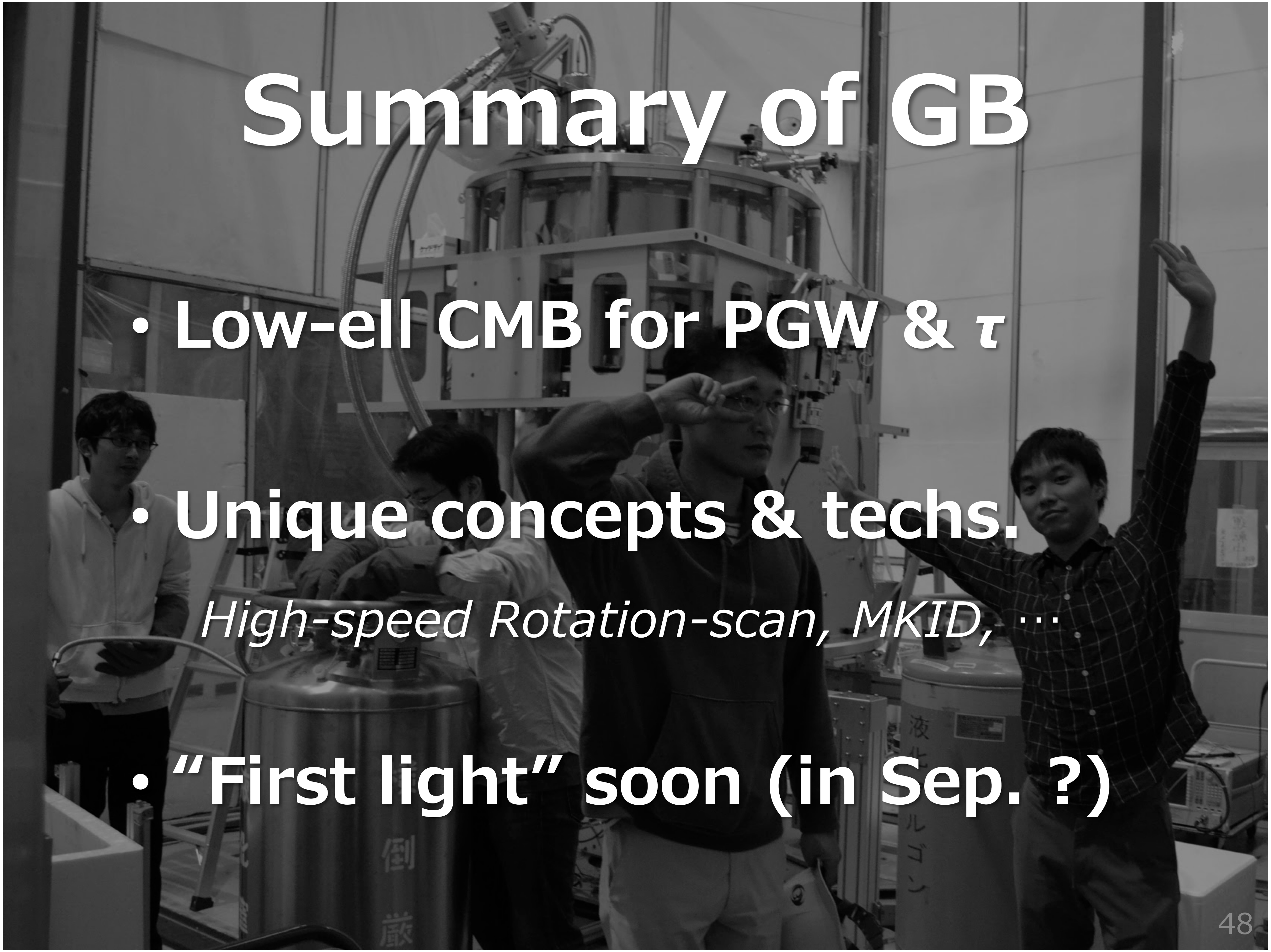
145, 220 GHz
(Fig. Planck 143 GHz)



Robust strategy to F.G.

- **The world's largest number of frequency bands: 8 bands**
- **"Effective" new freq. bands by cross-correlation**

Simulation study underway (led by K. Lee, Korea U.)



Summary of GB

- **Low-ell CMB for PGW & *τ***
- **Unique concepts & techs.**
  High-speed Rotation-scan, MKID, …
- **"First light" soon (in Sep. ?)**