Study of cosmic ray effects on the LiteBIRD satellite

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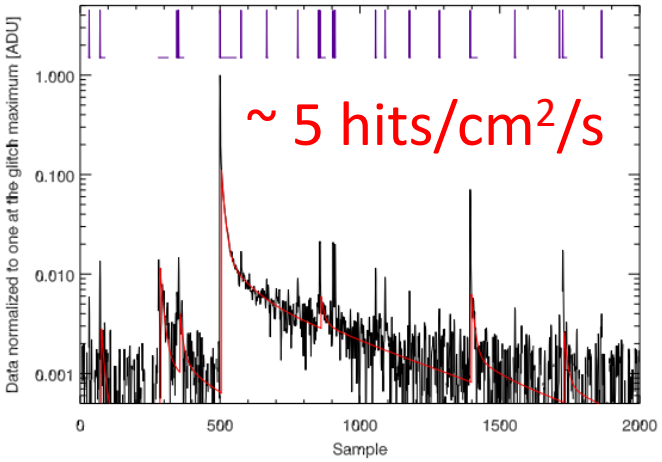
KEK

A challenge in space (Sun-Earth Lagrangian point 2)

Space environments require good cosmic-ray hit mitigation that is not necessary on ground

Experience from Planck

- They lost some amount of data because of cosmic-ray hits on their detectors
  - Glitch signals in the timestream of detector read-out
- Planck group estimated that the glitch is created from ballistic phonons and thermal diffusion from the deposited energy by a cosmic-ray



Glitch event and fitted templates at Planck

In LiteBIRD

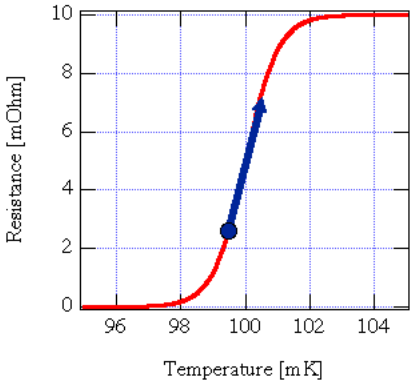
- Hit rate for a detector substrate is ~ 800 Hz
- Time constant of a detector is 1~10 ms

⇒ ~30% contamination

arXiv:1101.2048v2 [astro-ph.CO]

How cosmic-rays create glitches?

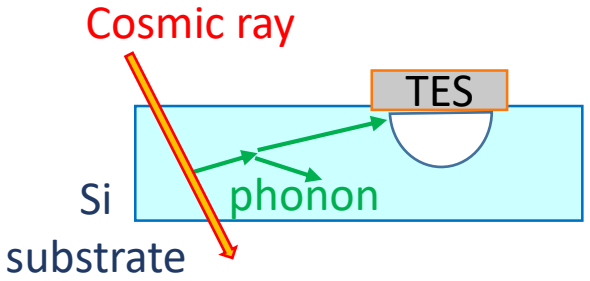
TES bolometers are used in the LiteBIRD satellite



http://web.mit.edu/figueroagroup/ucal/ucal_tes/

- TES(Transition Edge Sensor)
- Sensitive detector that utilises a transition edge
- TES works in ~100 mK environment
- A TES bolometer is on a silicon substrate

- Cosmic-ray deposits energy in the silicon substrate
- From the energy phonons are created
- Some phonons are propagated to the TES bolometer
- The TES bolometer detects phonons and glitches are made

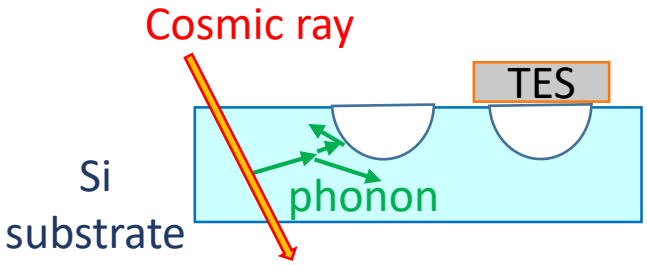


Ideas to reduce cosmic-ray effects

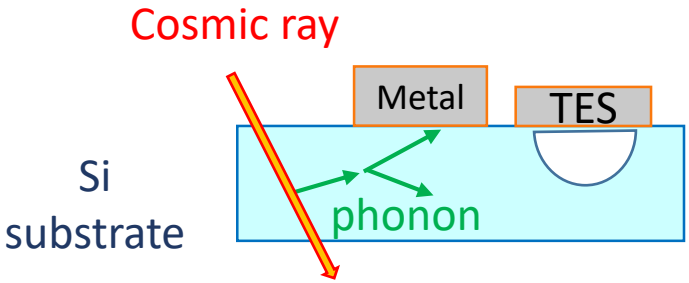
To reduce the cosmic-ray effects, phonons should be reduced
I checked two ideas to reduce the phonon propagation

- Block paths of phonons by cutting out silicon substrate
- Absorb the phonons by adding metal on the silicon substrate

- Cut out in a Si substrate

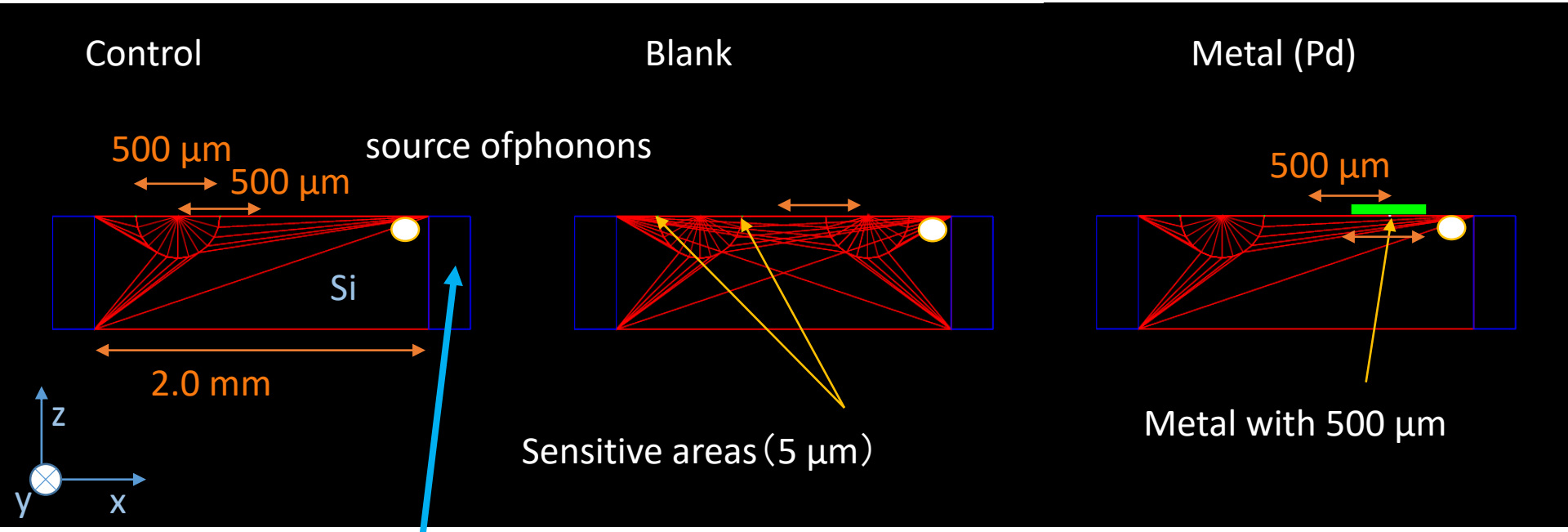


- Absorb by adding a metal



Check the ideas with a Monte-Carlo simulation

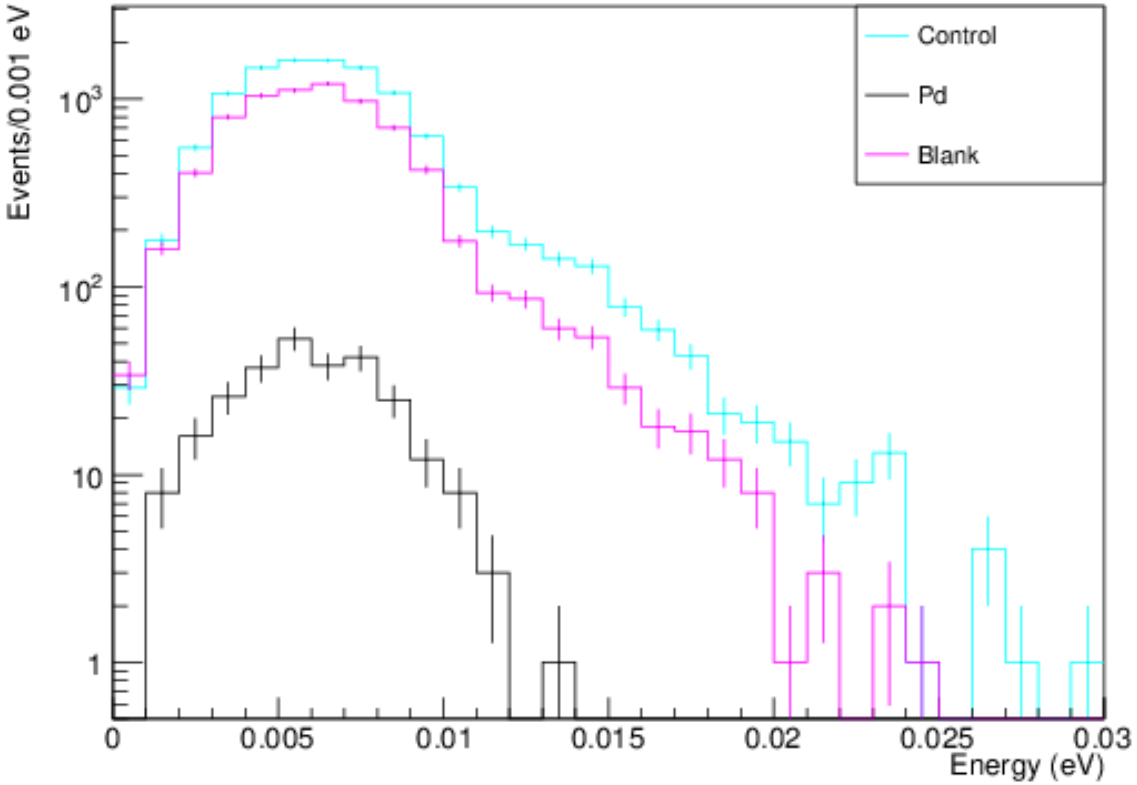
- Using phonon simulator (G4CMP), phonon propagation is simulated with a Monte-Carlo method



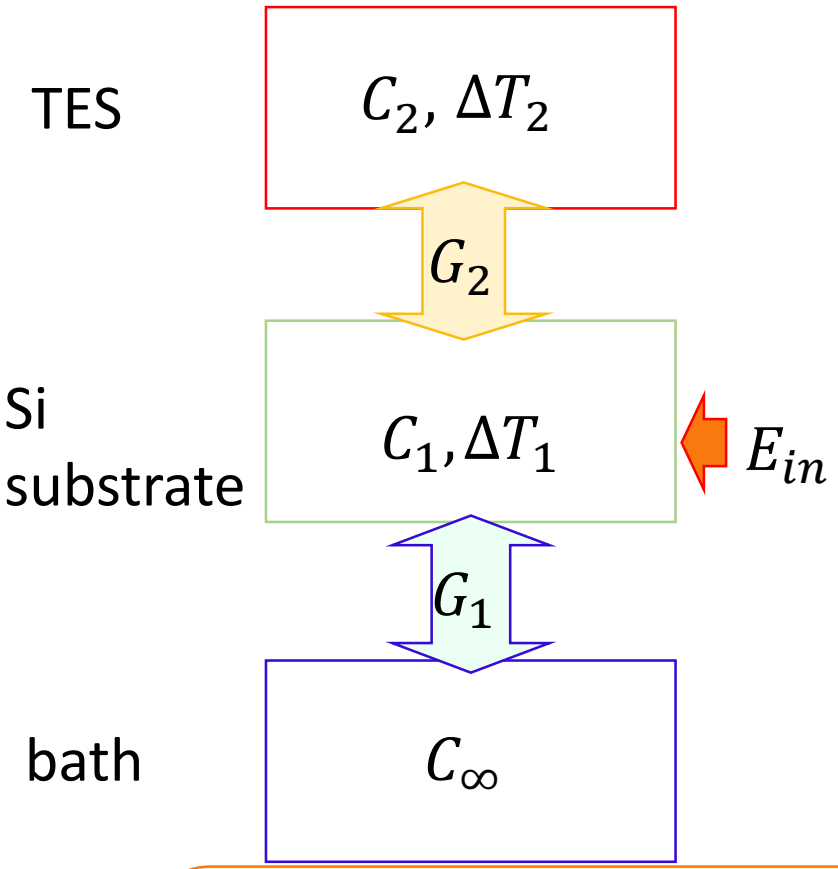
100% absorption in x-direction
100% reflection in y-direction

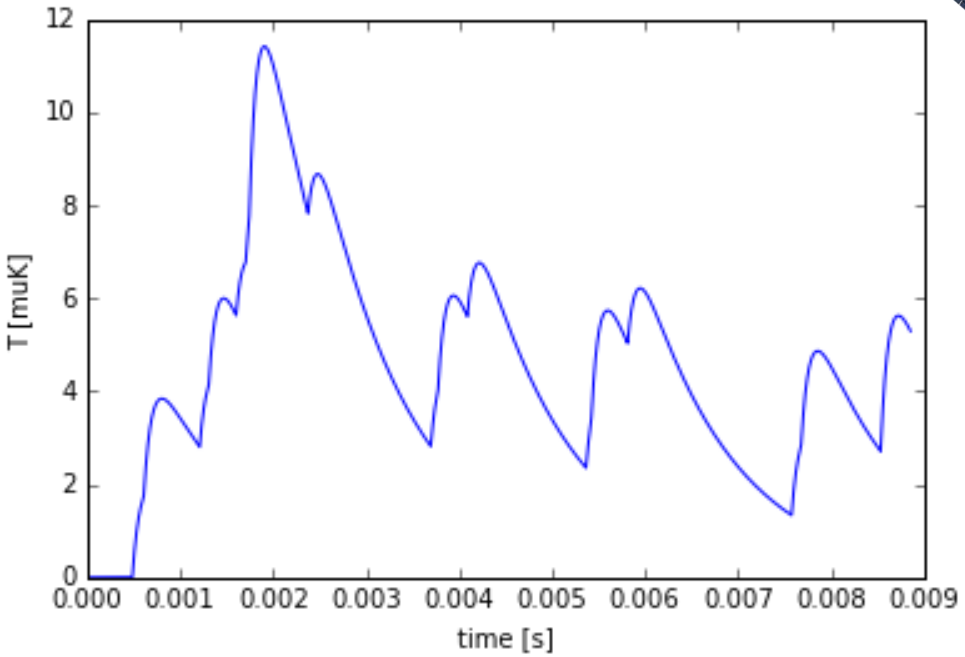
Results of the simulation

- Blank and Pd (metal) can mitigate the number of phonos
  - Adding a metal on the substrate is more effective



Effects of thermal diffusion





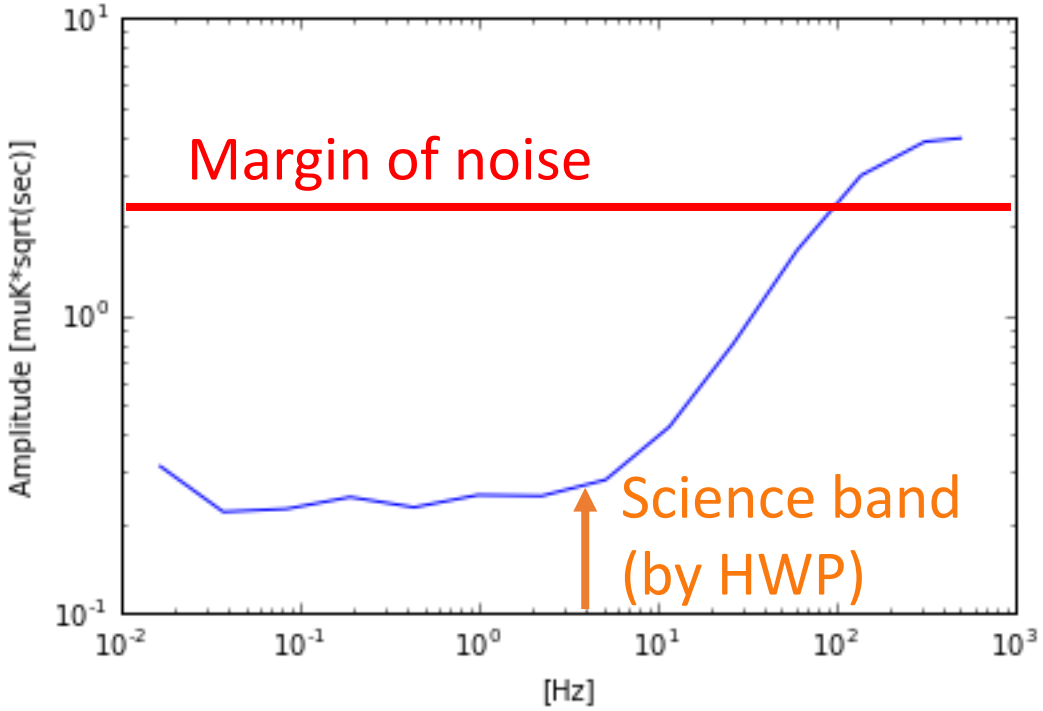
Time ordered data of ΔT2

- I modeled the system with a bath, a Si substrate, and TES
- Ein is from L2 flux
- Rate and temperature fluctuation are shown as plotted
- Rate is high and the scale of temperature fluctuation is of order ~μK

Noise Equivalent Temperature (NET) spectrum

$$NET_{CMB} = \frac{NEP}{\sqrt{2}\left(\frac{dP}{dT_{CMB}}\right)}$$

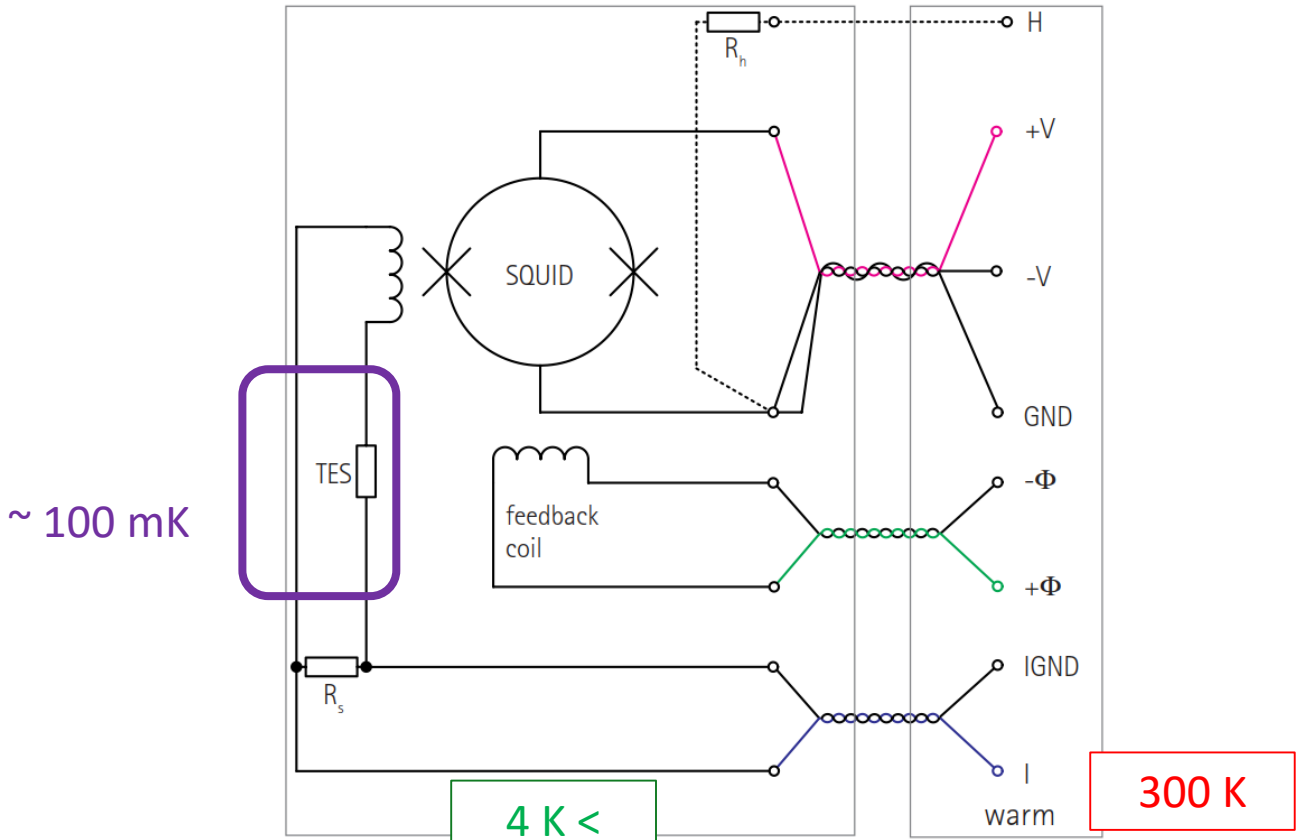
$$\frac{dP}{dT_{CMB}} = \int_{34\ GHz}^{46\ GHz} d\nu \left[\frac{\eta}{k_B}\left(\frac{h\nu}{T_{CMB}\left(e^{\frac{h\nu}{k_B T_{CMB}}} - 1\right)}\right)^2 e^{\frac{h\nu}{k_B T_{CMB}}}\right] = 1.05e-13$$



- NET is order of 10^-1
- Low enough compared to the prepared noise margin

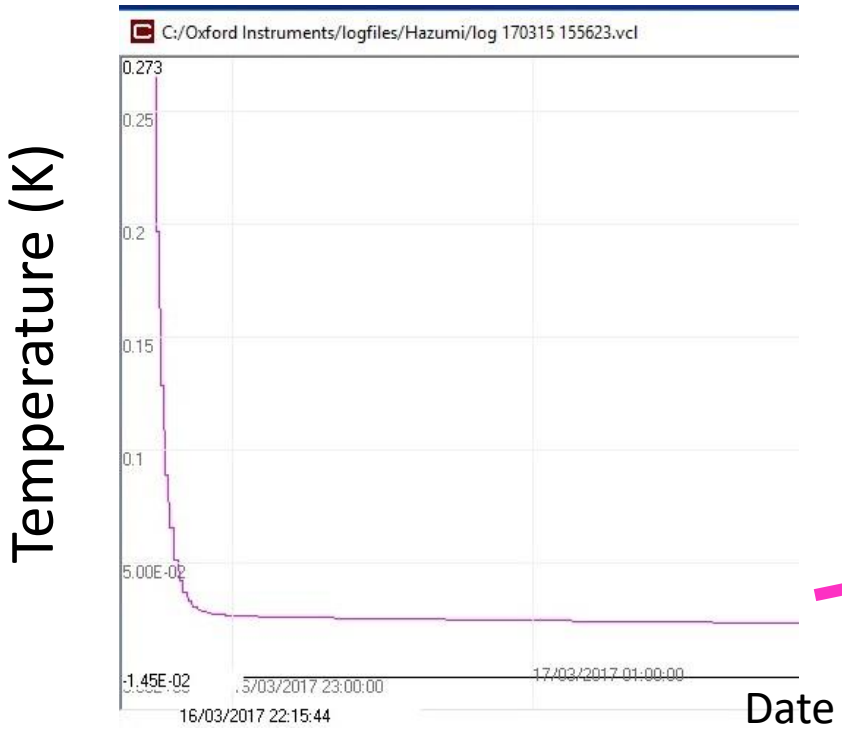
For the radiation test of the TES bolometers

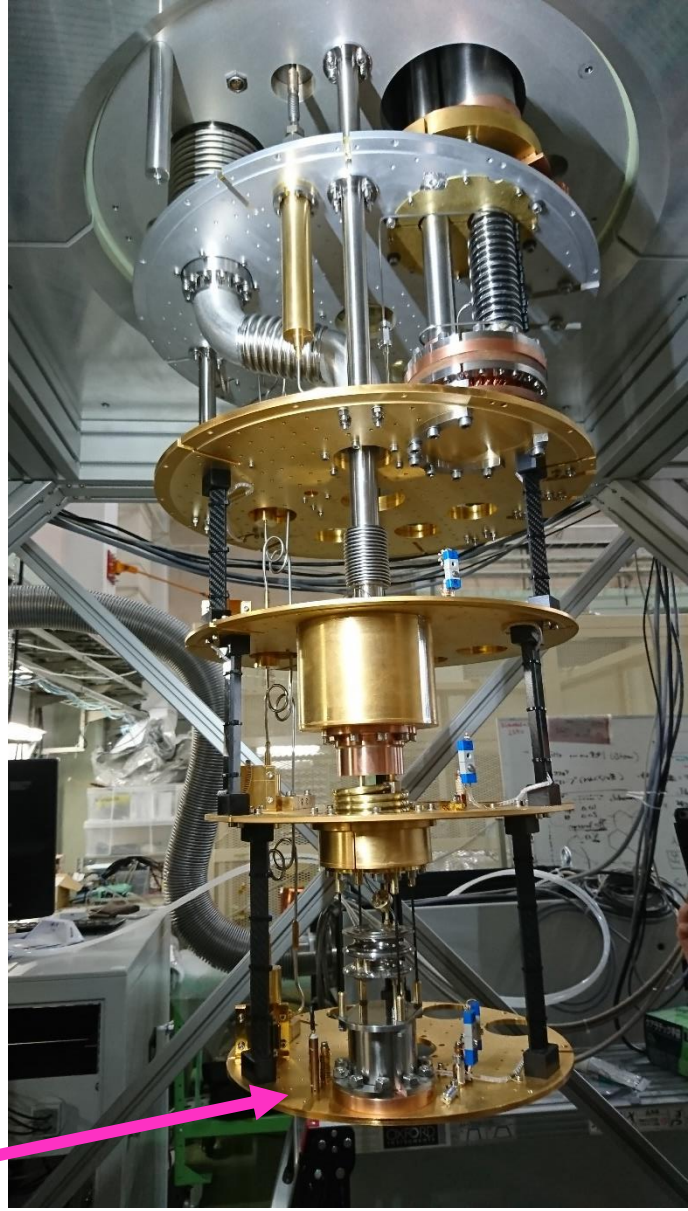
- Irradiate TES bolometer using radiation source to demonstrate that the ideas can really mitigate the cosmic-ray effects
- For that TES read-out system is needed in KEK
  - TES signal is amplified by SQUIDs
- Low temperature environment and read-out systems are needed



Low temperature environment

- Installed dilution refrigerator at KEK
- Achieved 17 mK
- Next step is
  - to read-out a SQUID
  - to read- out a TES bolometer





Wiring

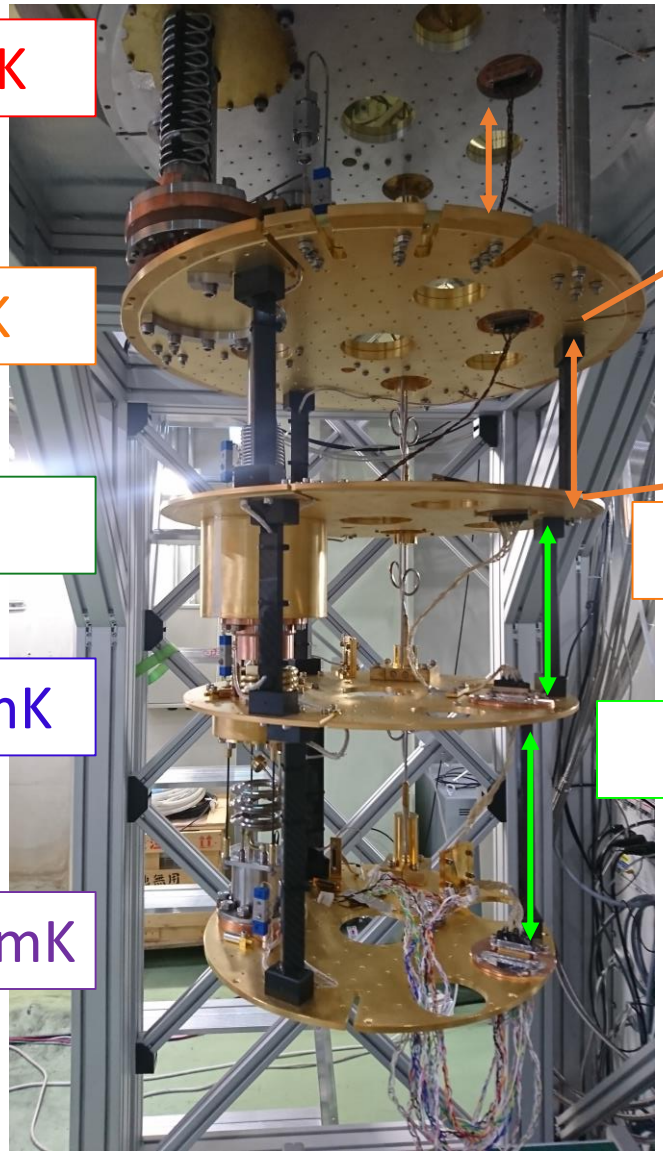
300 K

70 K

4 K

100 mK

< 100 mK



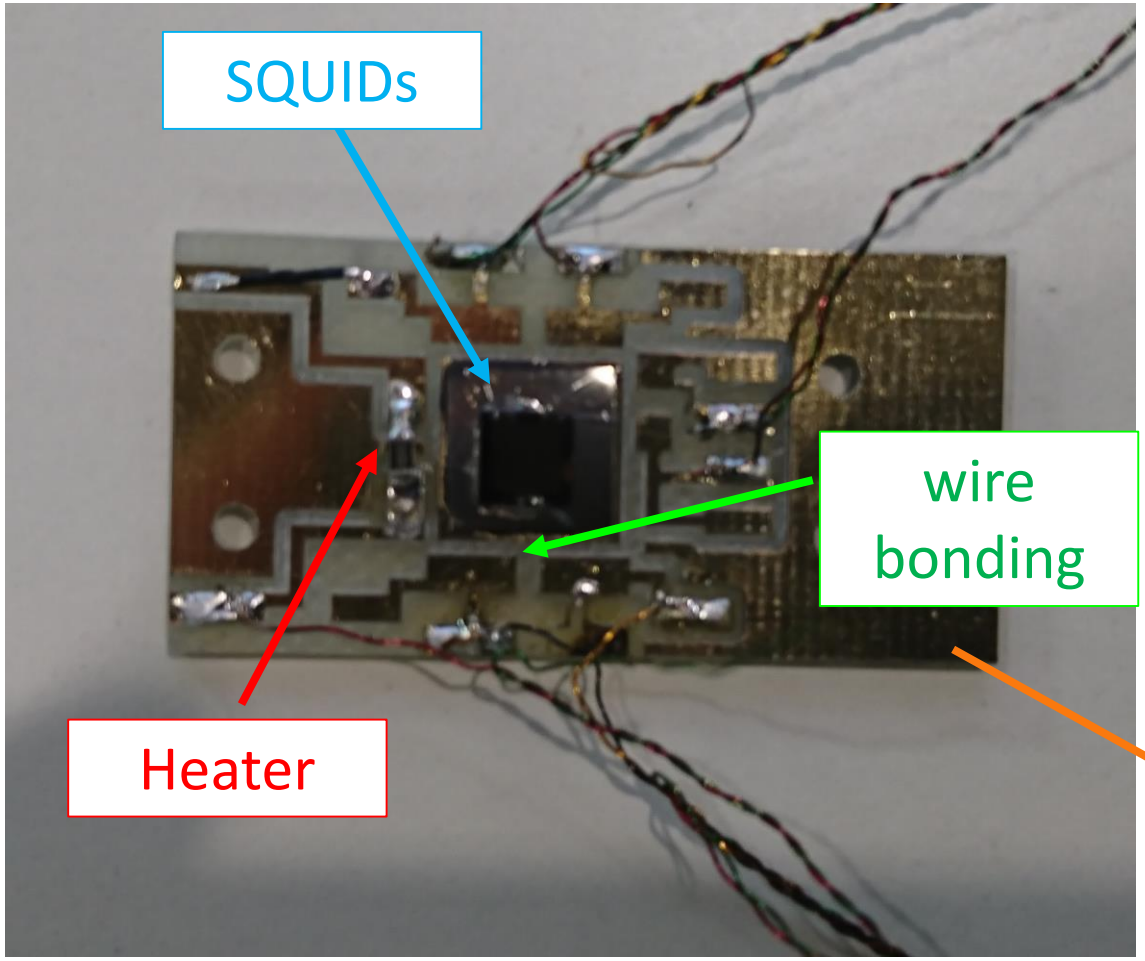
µD-sub wire harness

Phosphor bronze wire

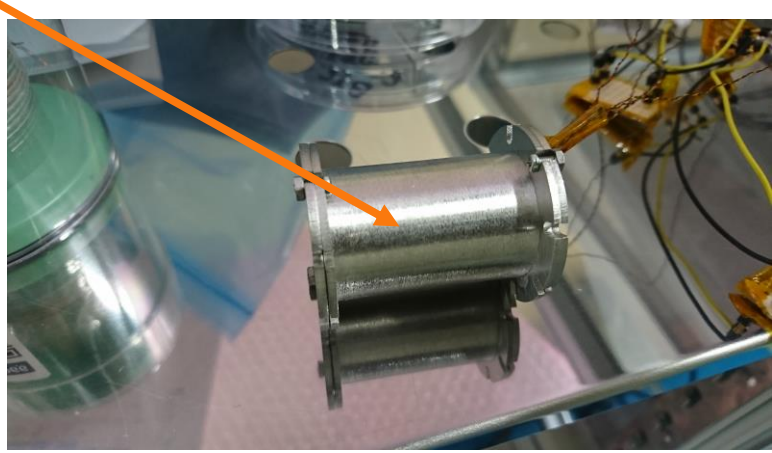
Nb-Ti wire

- From 300 K to < 100 mK, wires are already prepared

State of preparations for SQUIDs read-out



- SQUID:NIST SA4
- Heater is put on
- Wire-bonding is done at KEK
- SQUIDs substrate is put in a magnetic shield (Cryoperm)



- Read-out test will be done in next month

Summary

- Cosmic-ray effects are concerned in the LiteBIRD mission
- Deposited energy by a cosmic-ray creates heat, and the heat is propagated by
  - Ballistic phonons
  - Thermal diffusion
- I checked the mitigation ideas with simulation software
  - Adding metal is effective
- For the demonstration of mitigation ideas, preparation for the test systems are underway
  - SQUID read-out system is prepared
  - TES read-out should be prepared