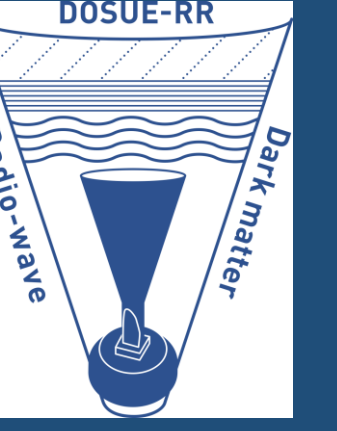


Performance Characterization of a 38-50 GHz Receiver System for Dark Photon Dark Matter Search in the DOSUE-RR Experiment

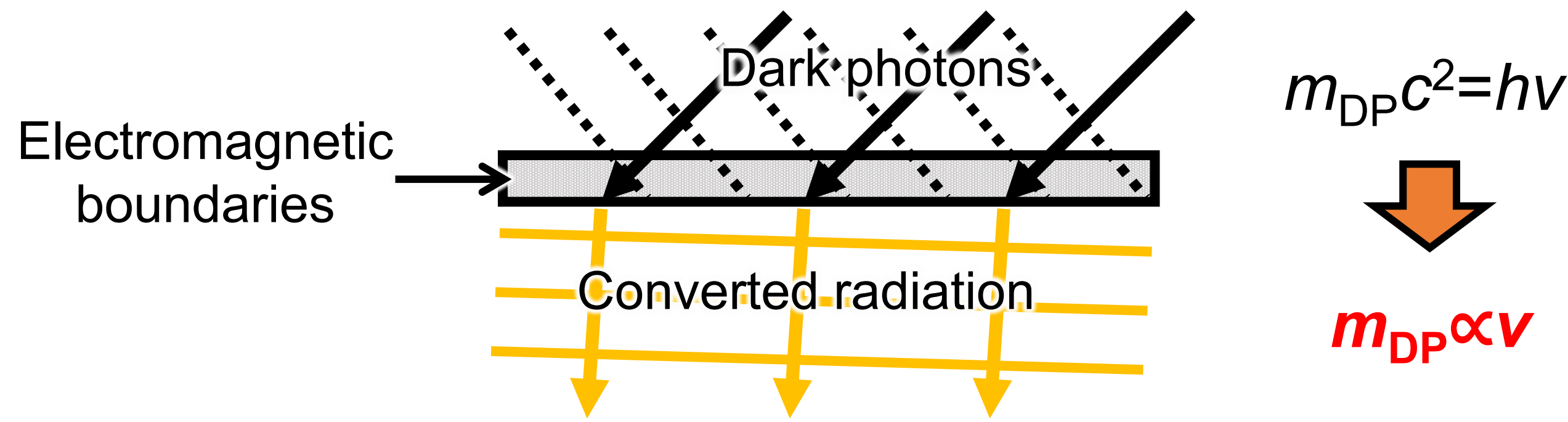


Michinori Hirose, Shunsuke Adachi^{A, E}, Shunki Endo^C, Yuki Sakurai, Junya Suzuki^B, Akihiro Takahara^A, Hiroki Takeuchi^B, Osamu Tajima^{B, E}, Takumi Tsuda, Satomi Hasegawa^D, Masaya Hasegawa^E, Keigo Hanimura^B, Shunsuke Honda^C
(Suwa University of Science, Okayama University^A, Kyoto University^B, University of Tsukuba^C, The Graduate University for Advanced Studies^D, KEK^E)



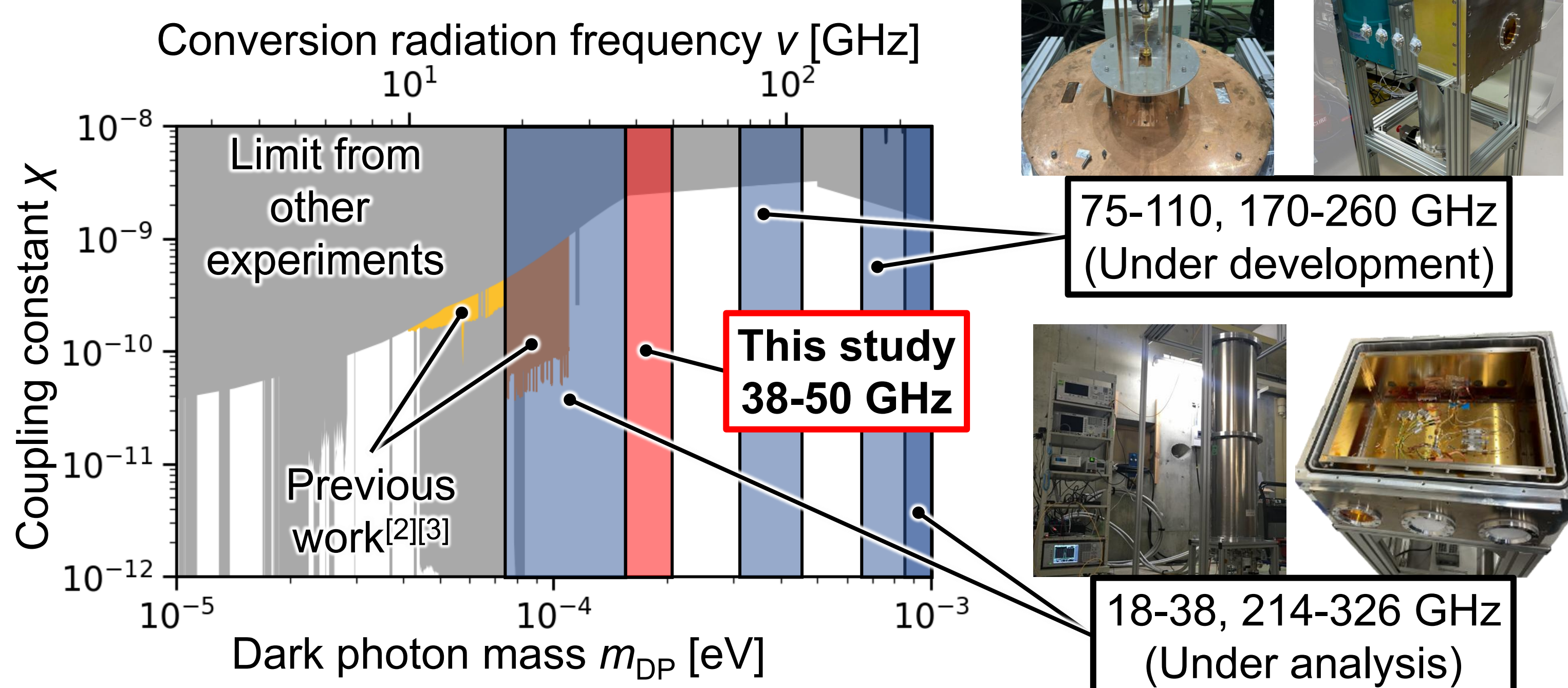
1. What are dark photons?

- They are theoretical particles and a candidates for ultra-light dark matter.^[1]
- They are predicted to convert into radiation at electromagnetic boundaries.
- The frequency of the converted radiation (ν) corresponds to the dark photon mass (m_{DP}).



2. Overview of the DOSUE-RR Experiment

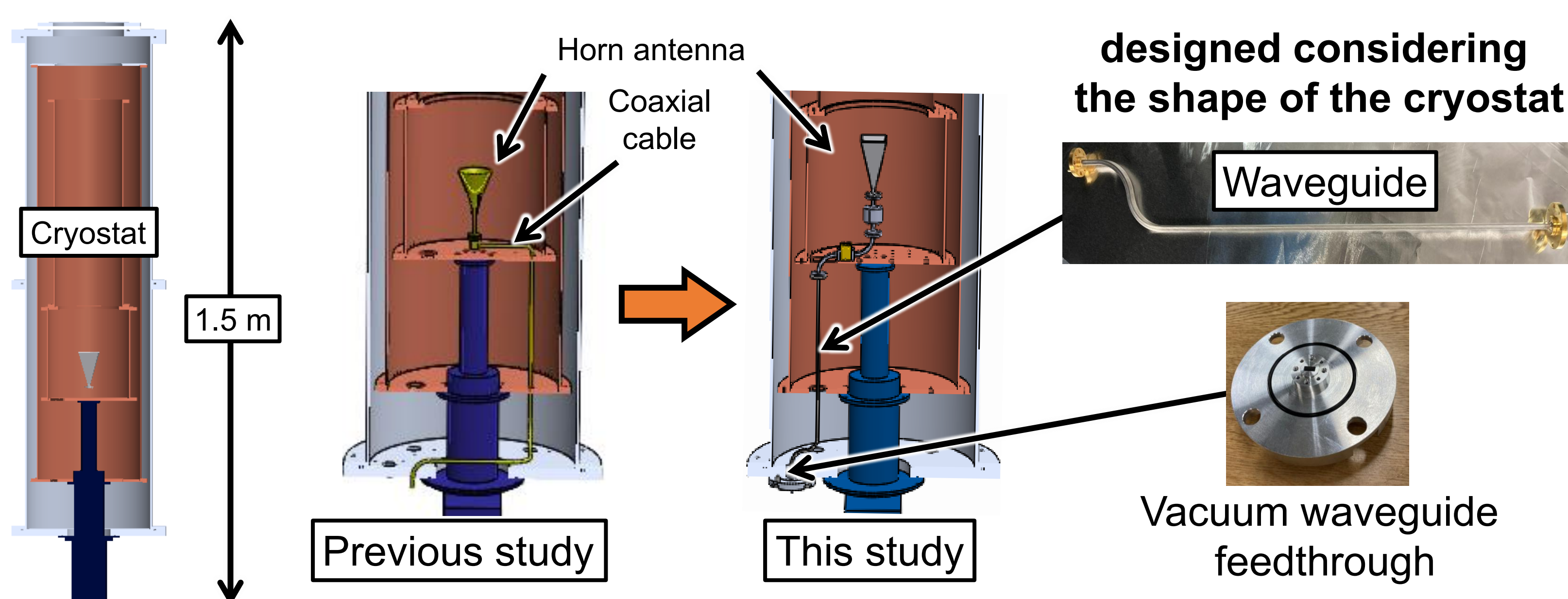
- We search for dark photons in the millimeter-wave band using radio receivers.
- We searched in the 10-26.5 GHz band but observed no significant signal.
- To expand the search range, the receiver requires redesign for each mm-wave band specification.



Development and analysis are ongoing for each frequency bands!

3. Development of a 38-50 GHz Receiver

- Based on the cryostat developed in the previous study (for the 18-26.5 GHz band), we redesigned the signal transmission system.
- To reduce transmission loss at higher frequencies, the signal lines inside the cryostat were changed from coaxial cables to waveguides.

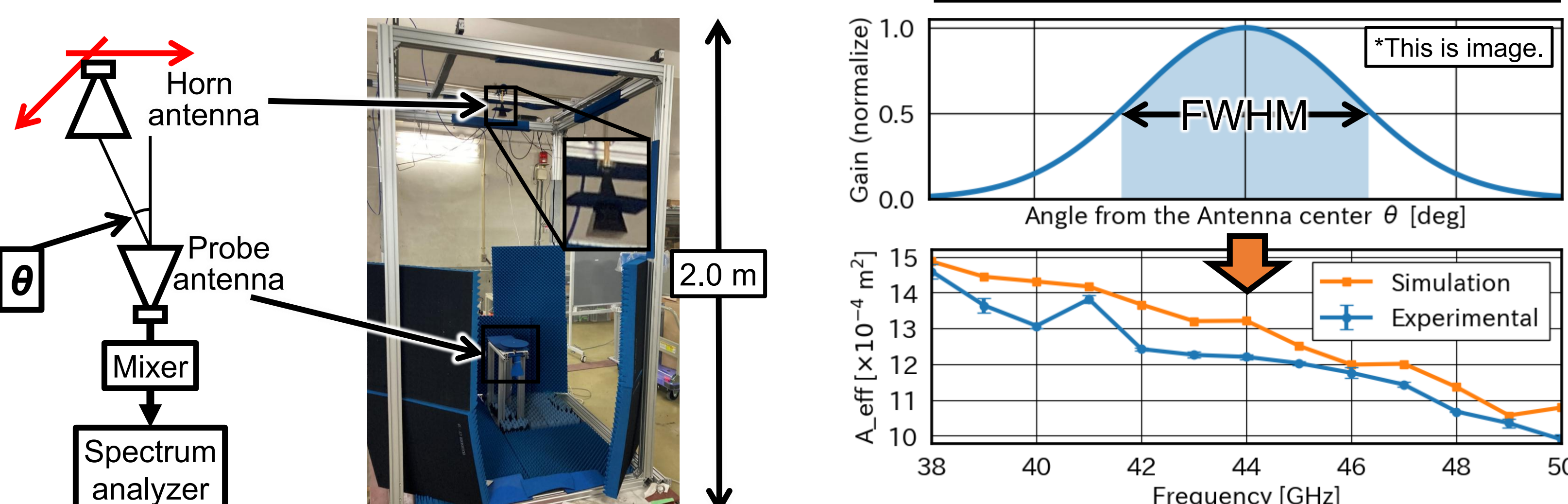


Evaluate parameters required to estimate the receiver sensitivity

- ① Effective aperture area of the antenna (A_{eff})
- ② Receiver Noise Characteristics (T_{sys})

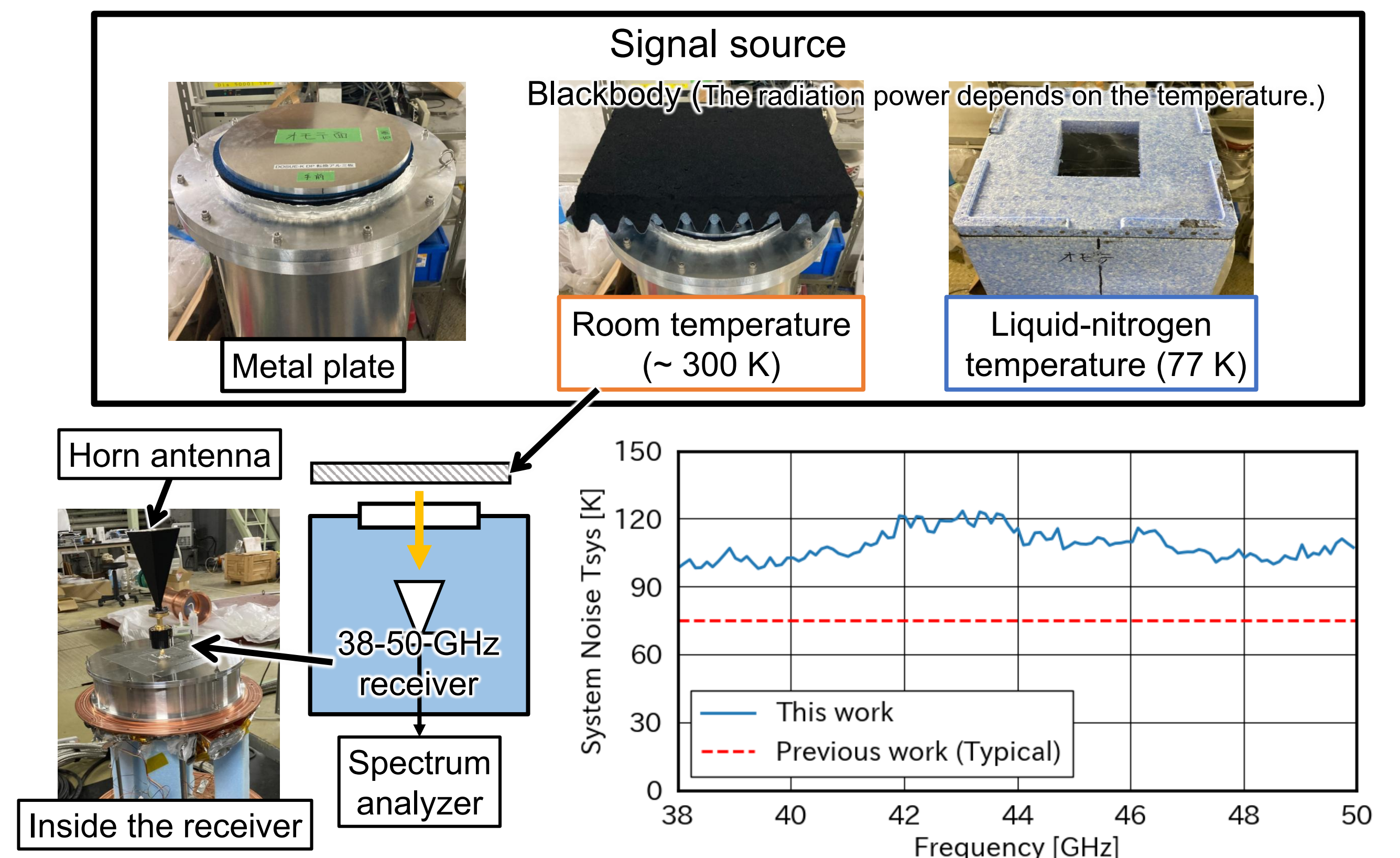
4. Effective aperture area of the antenna

- To evaluate the effective aperture area (A_{eff}), we measured the antenna beam pattern.
- The transmitting antenna was scanned in two orthogonal directions in the aperture plane.
- The measured FWHM was compared with the simulation (HFSS) results to validate the simulated beam pattern used to calculate A_{eff} .
- The measured results agreed well with the simulation results.

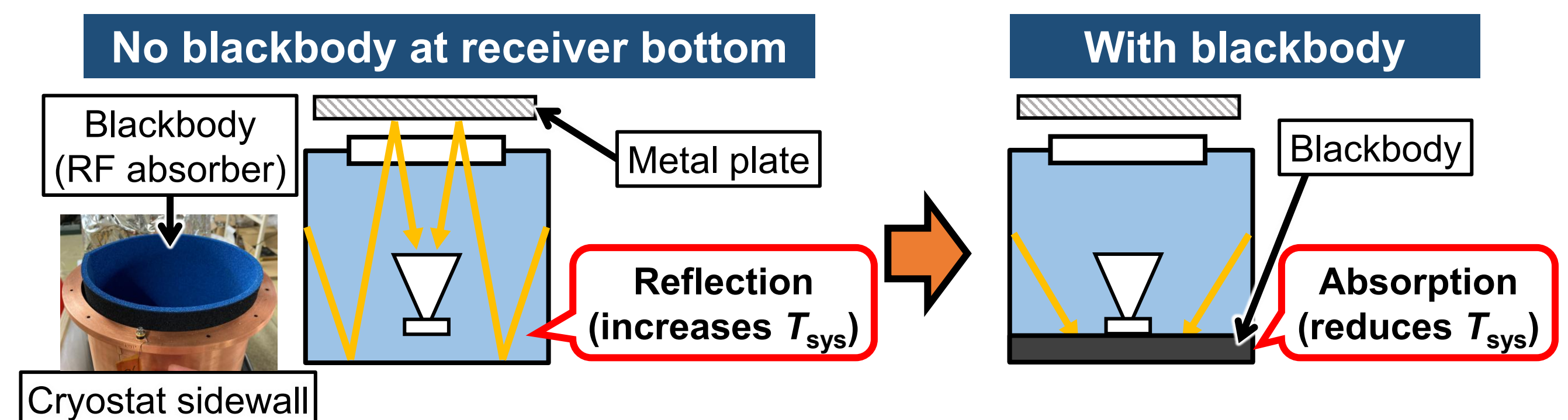


5. Receiver Noise Characteristics

- To evaluate the system noise temperature (T_{sys}), the receiver gain and radiation from a metal plate were measured.
- The receiver gain was calculated from the output difference between room temperature and liquid nitrogen cooled blackbodies.
- T_{sys} was approximately 30 K higher than in the previous work, likely due to differences in cryogenic amplifier noise characteristics.



- In the current setup, thermal radiation from the cryostat sidewall may be reflected between the metal plate and the receiver bottom before entering the antenna, increasing T_{sys} .
- We plan to install a blackbody to absorb this thermal radiation.



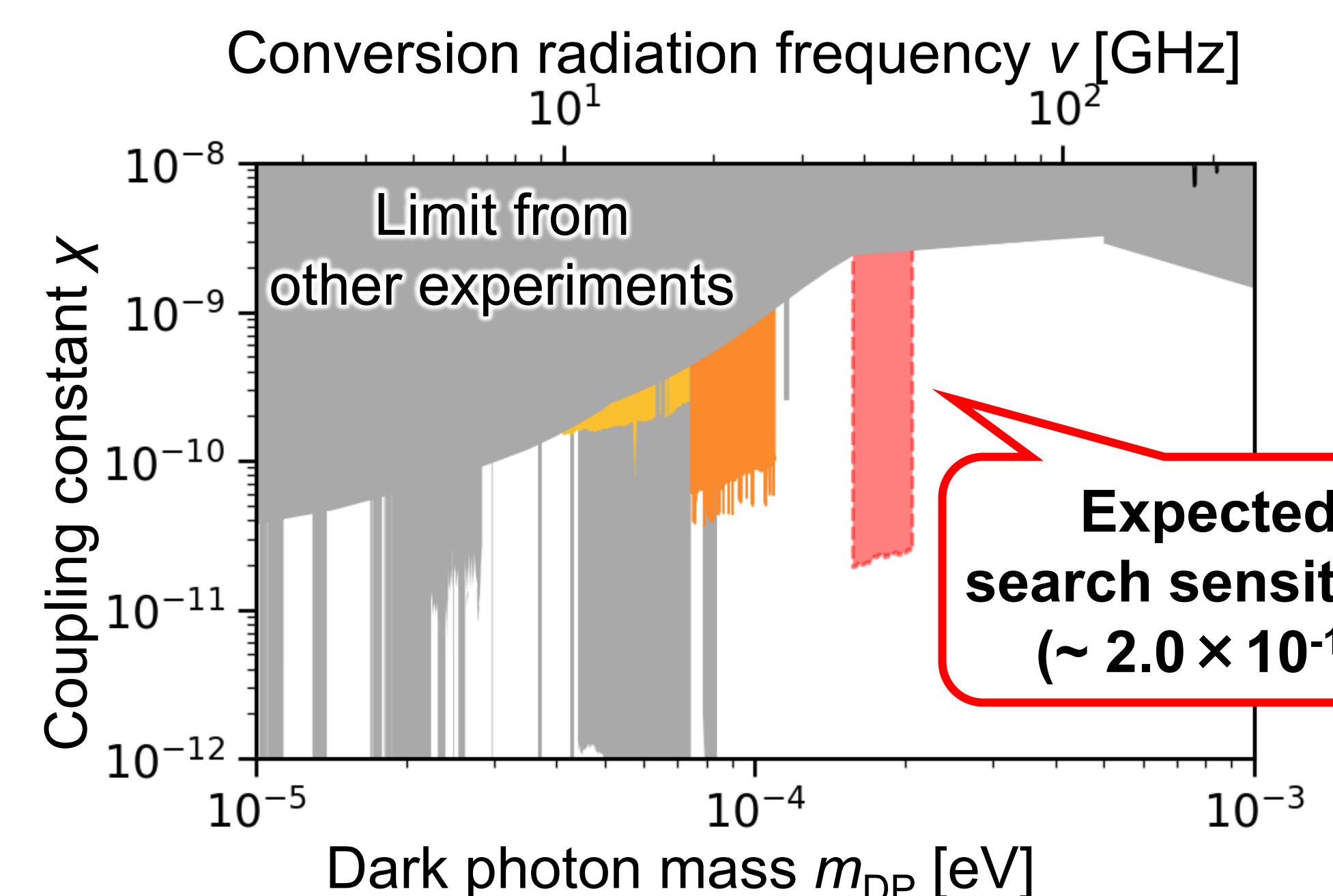
6. Estimated Sensitivity Results

- The sensitivity to the coupling constant was estimated based on the effective aperture area of the antenna (A_{eff}), the system noise temperature (T_{sys}), and relevant physical constants.
- We confirmed that when the receiver is in a cryogenic, the coupling constant can be explored down to approximately 2.0×10^{-11} .

Calculation formula and parameters

$$X = 4.5 \times 10^{-14} \left(\frac{\Delta P}{10^{-23}} \cdot \frac{0.39 \times 10^9}{\rho_{halo}} \cdot \frac{1}{A_{eff}} \right)^{\frac{1}{2}} \quad \Delta P = k_B \cdot T_{sys} \cdot \sqrt{\frac{\Delta \nu}{t}}$$

• ΔP : Minimally detectable signal power
• ρ_{halo} : Dark matter density = 3.9×10^8 eV/cm³
• $\Delta \nu$: resolution bandwidth
• t : measurement time = 1 day (86400 s)



It has an exploration sensitivity two orders of magnitude greater than the current limits of cosmic observation!

7. Future Plan

- We will evaluate the system noise temperature with a blackbody installed on the bottom of the receiver.
- After that, we will perform dark photon search measurements within FY2026 and analyze the data for significant signals.
- We aim to publish a paper summarizing the results by the end of FY2027.

[1] Dieter Horns et al., "Searching for WISPy Cold Dark Matter with a Dish Antenna", Journal of Cosmology and Astroparticle Physics, Vol.4, (2013), pp.2-9.
[2] S. Adachi et al., "Search for dark photon in the mass range 41-74 μ eV using millimeter-wave receiver and radio shielding box" Phys. Rev. D, Vol.109, (2024).
[3] S. Kotaka et al., "Search for Dark Photon Dark Matter in the Mass Range 74-110 μ eV/c²", Physical Review Letters, Vol.130, No.7, (2023), pp.7-8.