SOKENDAI KEK Tsukuba/J-PARC Summer Student Program

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KEK
High Energy Accelerator Research Organization

SOKENDAI

iPNS
素粒子原子核研究所
Institute of Particle and Nuclear Studies

QUP
International Center for
Quantum-field Measurement Systems for
Studies of the Universe and Particles
WPI research center at KEK

Introduction

- From Pakistan
- Final Year Undergraduate Physics Student
- Studying at The Hong Kong Polytechnic University
- Passionate about Astronomy/Computational Astrophysics
- Working in the KEK-CMB group

An Overview of my time in Japan

- Completed Internship
- Explored Local Food Culture
- Travelled Across Regions
- Made New Friends
- Suffered from Japan’s summer

Internship Overview

- Experimental Physics
- QUP CMB Group:
    a. CMB Data Analysis
    b. Millimeter Wave Optical Characterization
    c. TES Measurement Experiment

量子場計測システム国際拠点
International Center for Quantum-field Measurement Systems for Studies of the Universe and Particles

素粒子原子核研究所
Institute of Particle and Nuclear Studies

Mr. Masaya Hasegawa

Mr. Yuji Chinone

Mr. Hayato Takakura

Mr. Hiroki Akamatsu

CMB Data Analysis

Core Project Objective:

Perform cosmological parameter estimation on a full-sky CMB temperature anisotropy map using spherical harmonic analysis and Markov Chain Monte Carlo (MCMC) sampling.

Methodology:

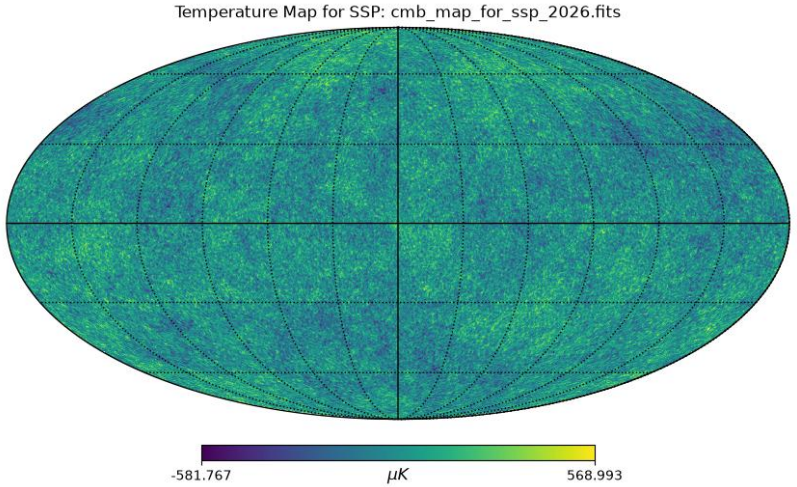
a. Map Processing & Spectrum Extraction

b. Cosmological Sensitivity Analysis

c. Quantifying Cosmic Variances

d. Likelihood Formulation

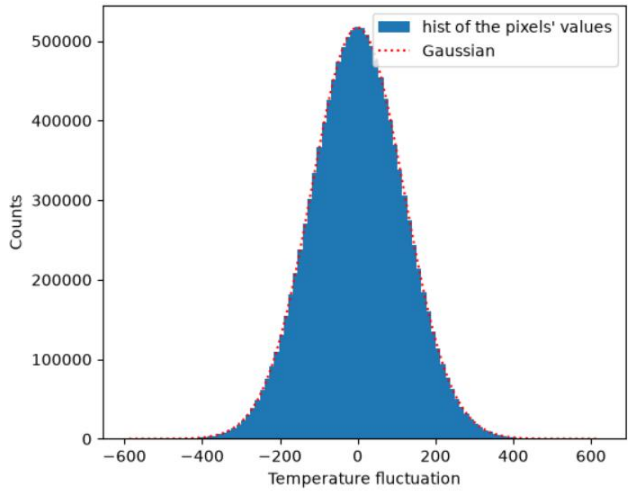
e. Parameter Inference

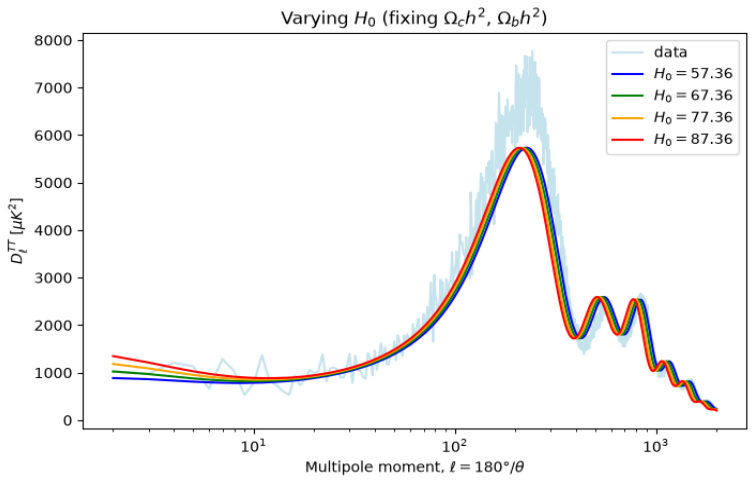


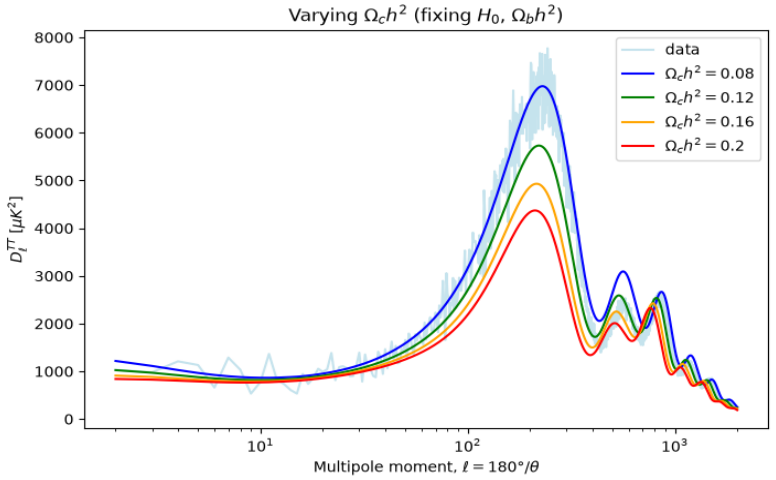
Results and Analysis

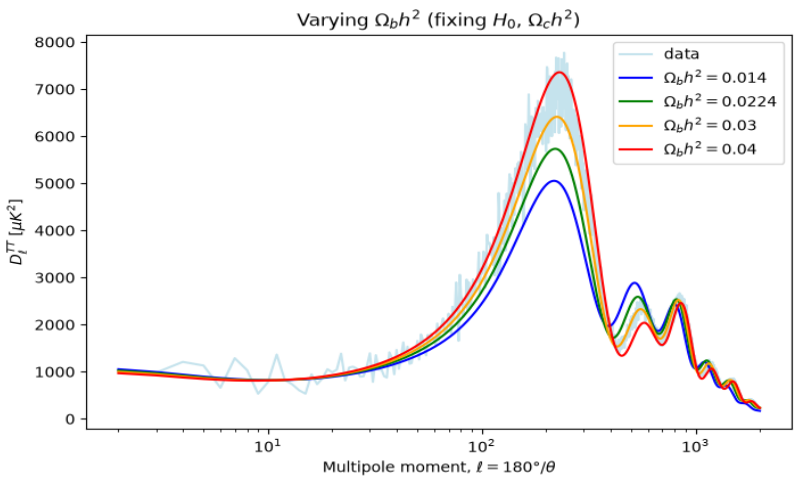
- The temperature map PDF confirmed an idealized Gaussian random field centered at $\Delta T = 0$. A 1-point histogram only measures overall variance (σ^2).

- Parameter Sensitivity Behaviors:

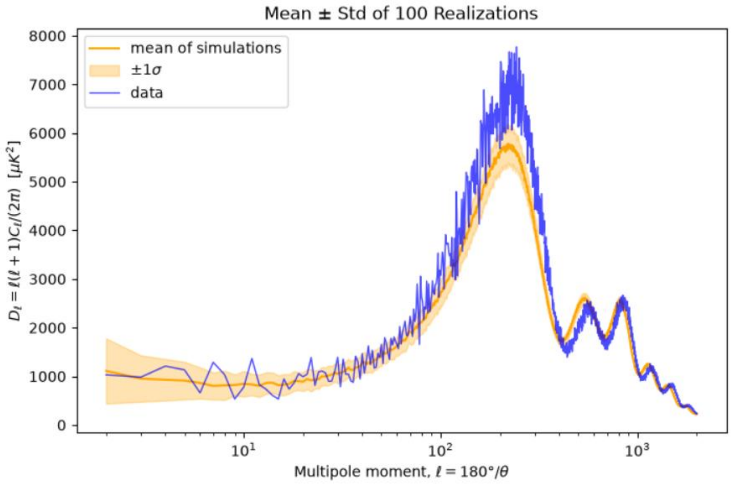




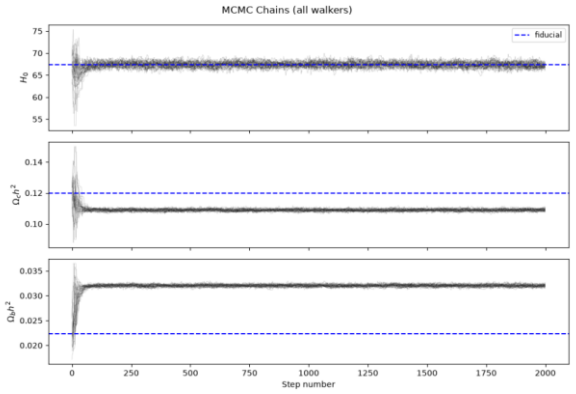


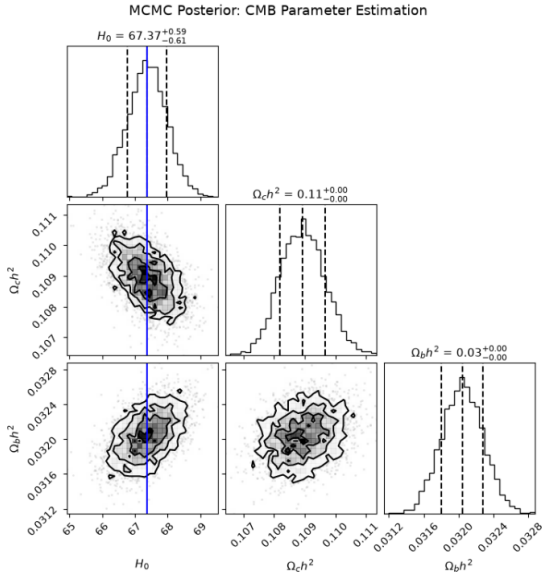


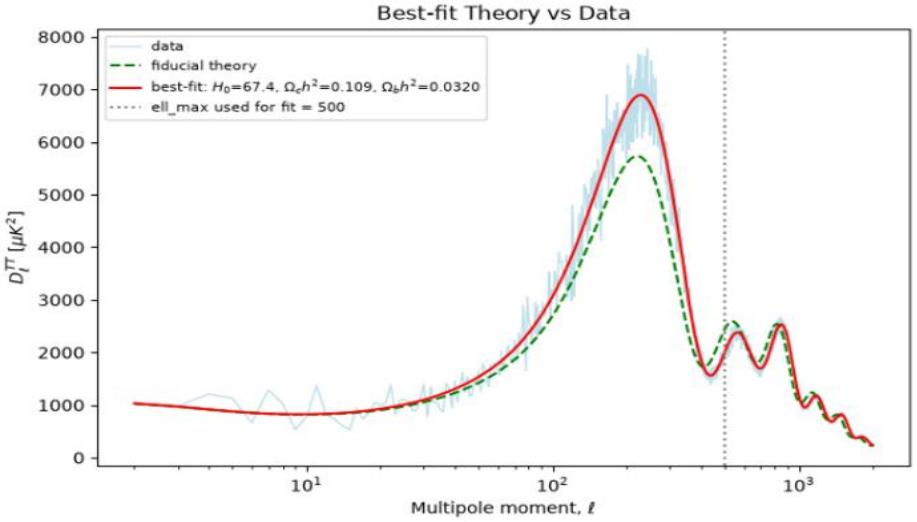
- Cosmic Variance & Multipole Scaling:



- MCMC Chain Convergence:





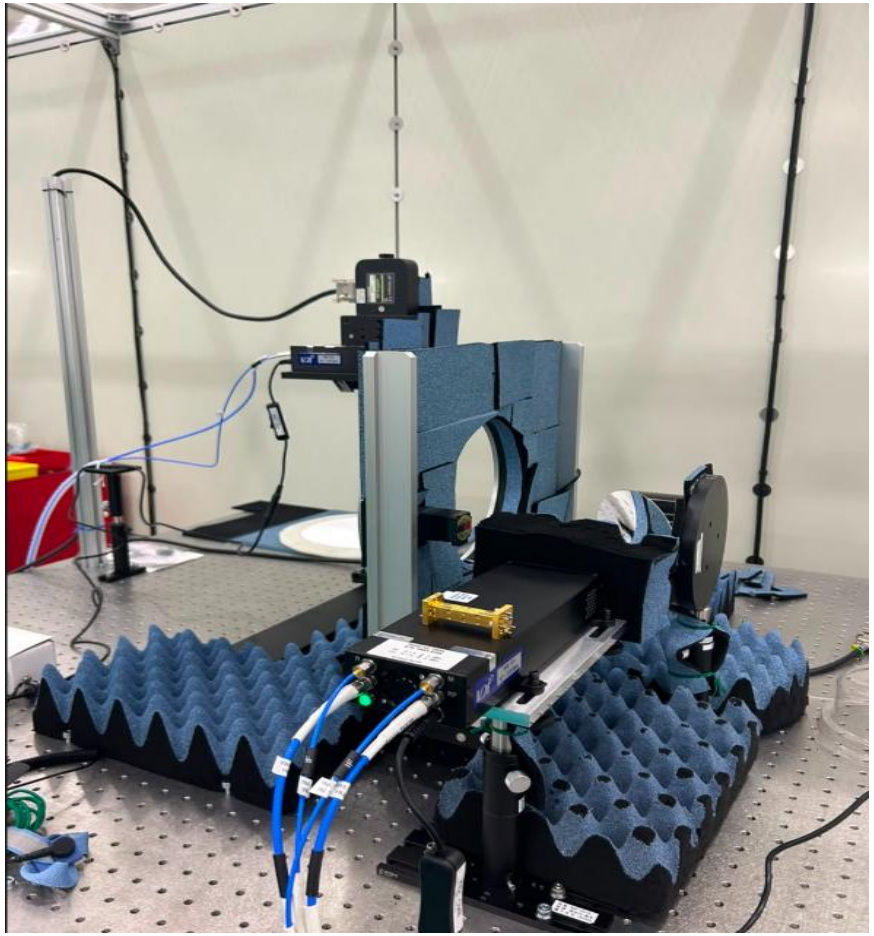


- By fitting the extracted angular power spectrum using MCMC sampling, we accurately broke parameter degeneracies and recovered the true physical cosmology of the universe, demonstrating the remarkable predictive power of the Standard Model.

Millimeter Wave Optical Characterization

Core Project Objective:

Characterizing millimetre-wave optics (lenses, windows, absorbers) to eliminate systematic errors in CMB and dark matter surveys.



Methodology:

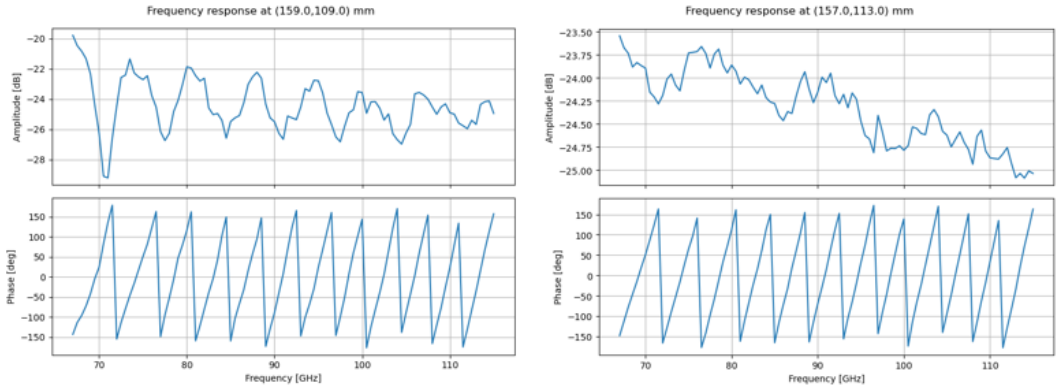
a. Planar Near-Field Scanning

b. Horn Antenna Comparison

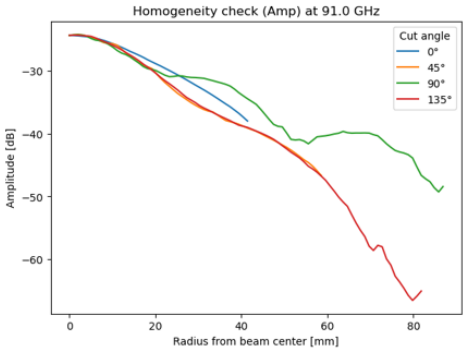
c. Systematic Component Testing

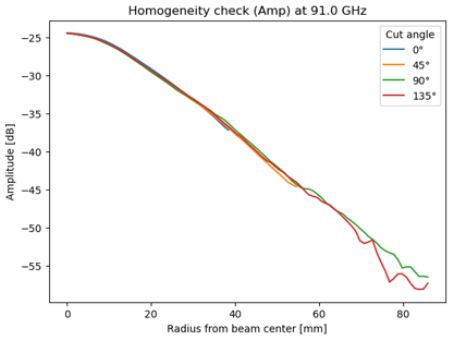
d. Fourier Holography Analysis:

- Millimeter wave absorber eliminated ~8 dB of environmental standing waves.

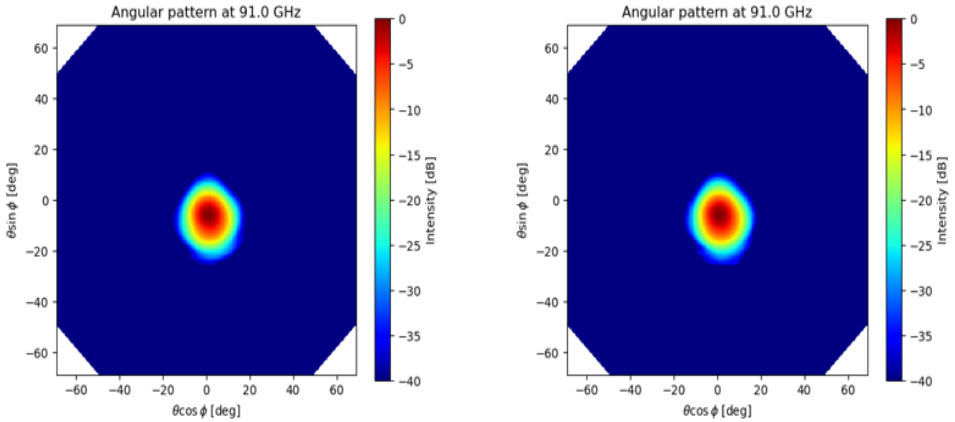


- Circular Horn achieves near-perfect rotational symmetry

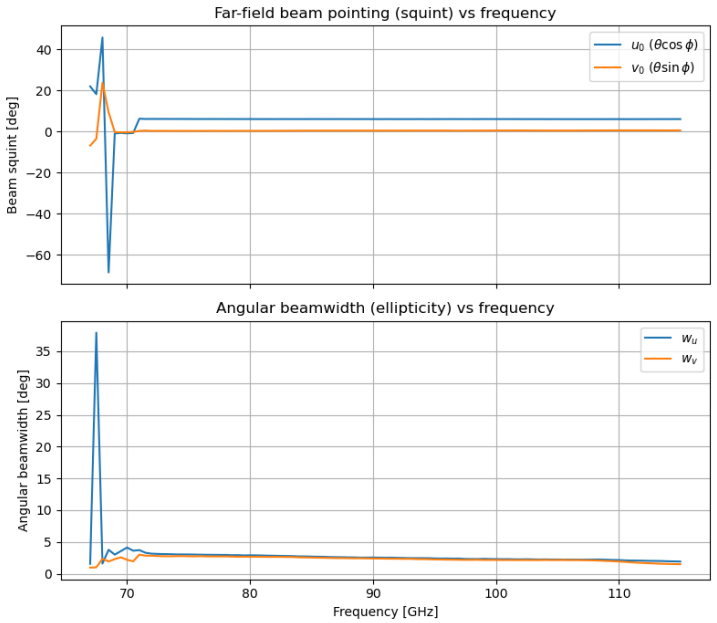


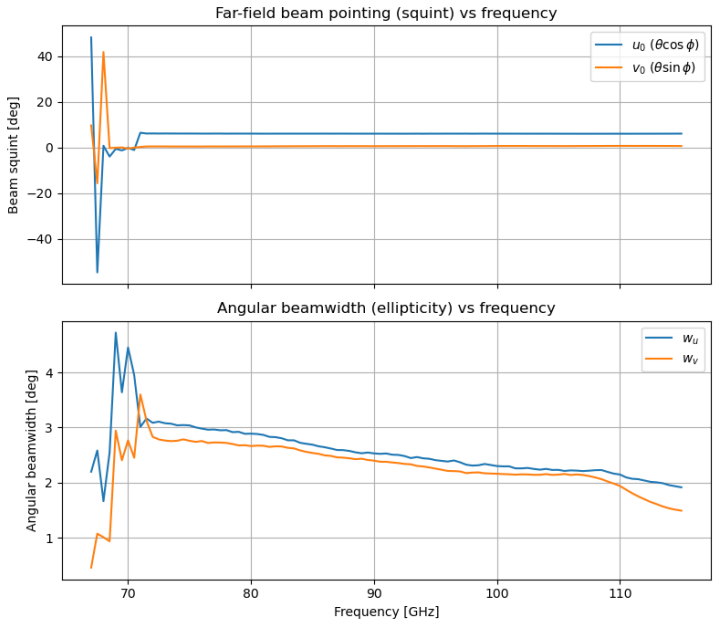


- Vacuum window does not significantly degrade the telescope's resolution

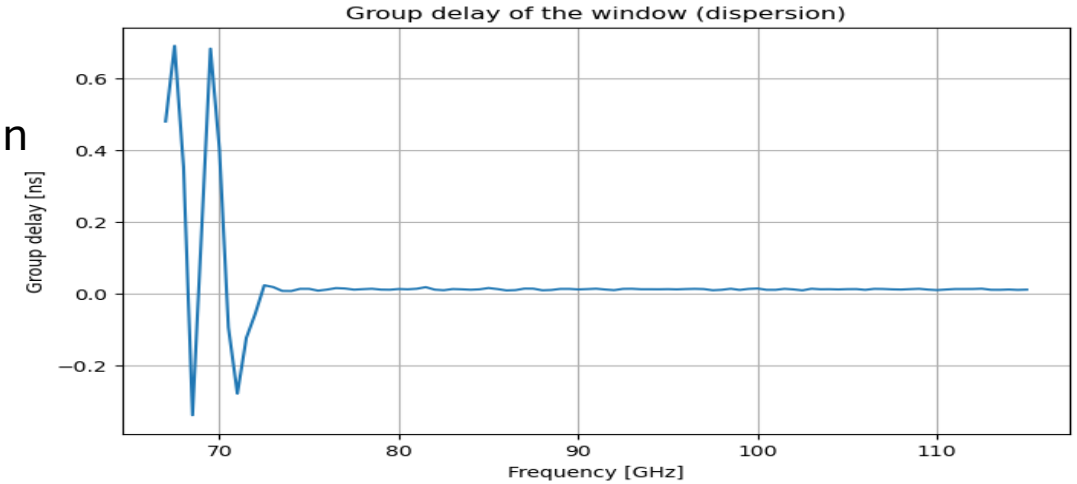


- Above the cutoff, the beam pointing becomes remarkably stable in both cases. This proves that the window does not introduce "squint" or directional shifting in the focused signal.





- The flat curve observed above 75 GHz indicates low dispersion, meaning the window delays all frequencies in the observation band equally.
- It ensures the window doesn't introduce frequency-dependent timing errors into the scientific signal



TES Measurement Experiment

Core Project Objective:

To automate the cryogenic property characterization of Superconducting Transition Edge Sensors (TES) by developing a Python-integrated measurement pipeline to determine critical performance parameters like critical current.

Methodology:

a. Python driven automation

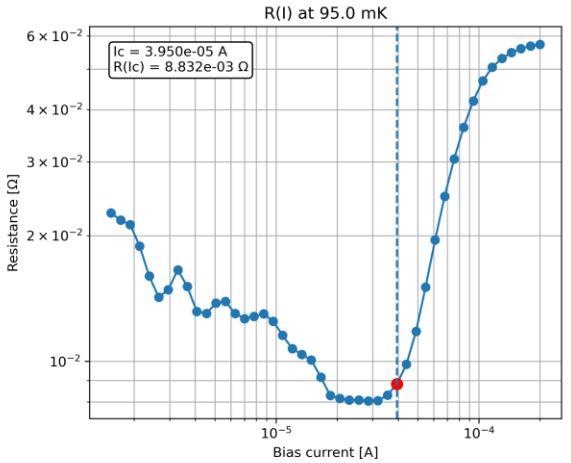
b. Parameter characterization

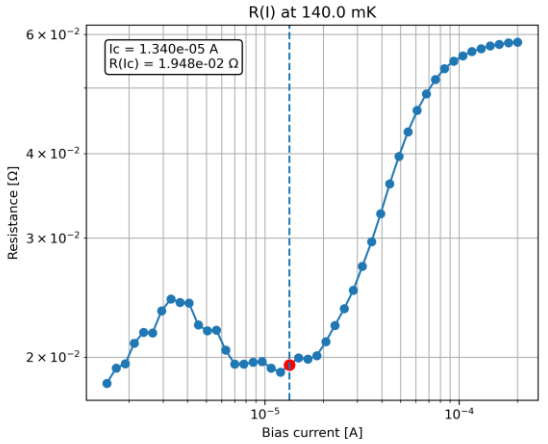
c. Noise & systematic error mitigation

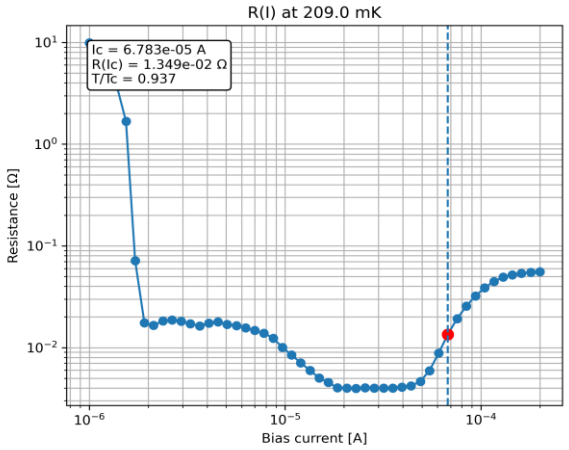
d. Critical current vs. normalized temperature analysis

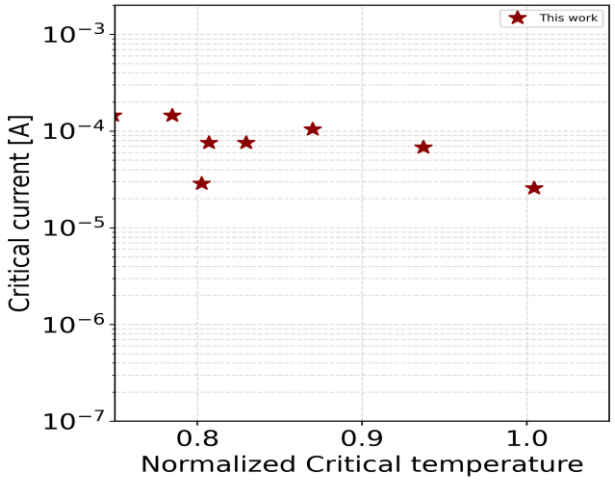
Results and Analysis

- The critical current I_c decreases as temperature increases and approaches zero near the critical temperature $T_c \approx 223$ mK.
- Below T_c, the material exhibits superconductivity with a finite I_c, which becomes larger at lower temperatures, confirming that superconductivity strengthens as thermal fluctuations decrease and weakens as the system approaches the transition temperature.









Thank you!