HardHaQ 2025 – UdeS Superconducting Challenge

RUNNER-UP PROJECT | TEAM X-QUBITS

ALESSANDRO • SHARVESH • SASHA • LIMO

→

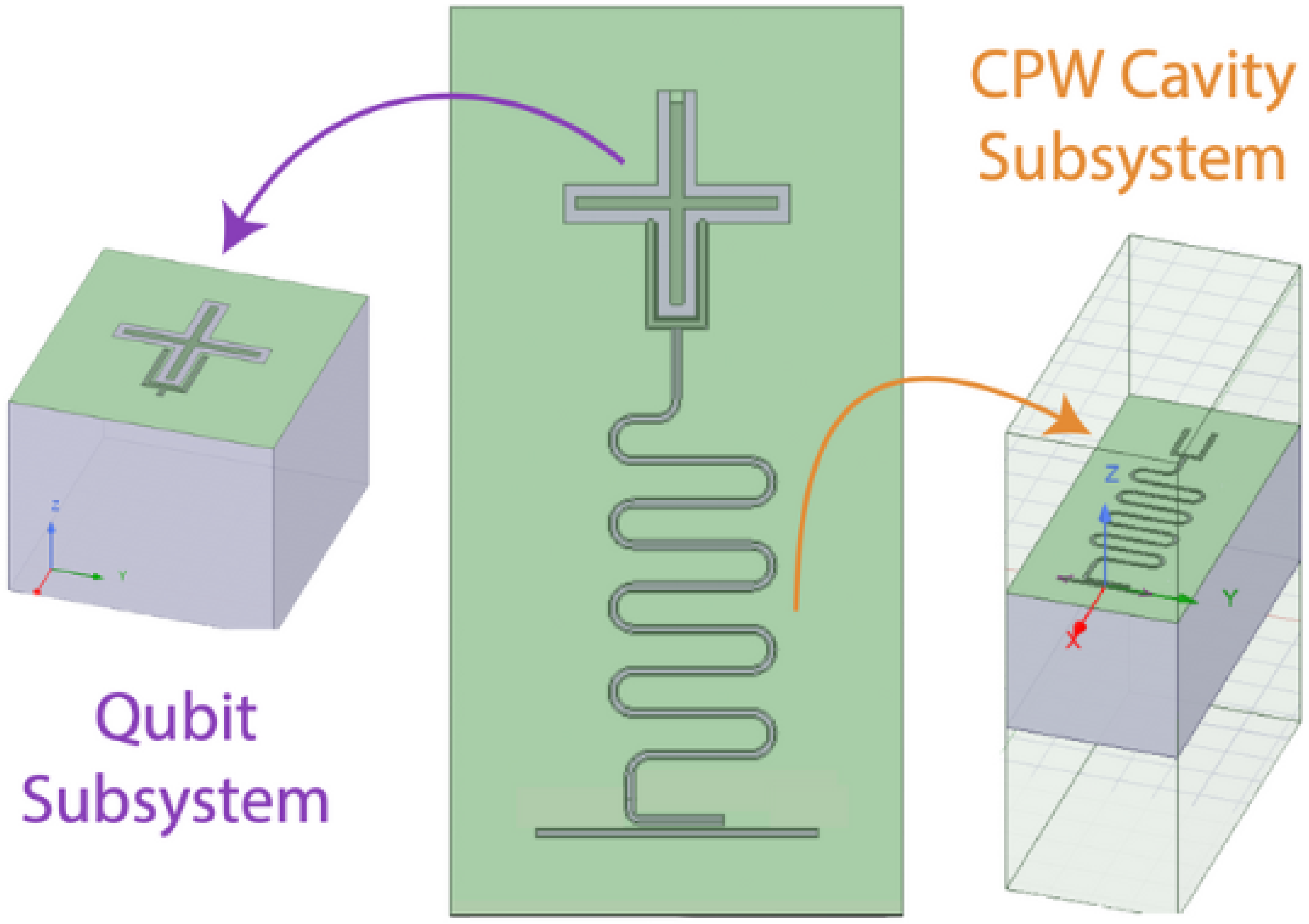
Project Summary

Design Goal

ENGINEER A 1-QUBIT SUPERCONDUCTING PROCESSOR ON HIGH-RESISTIVITY SILICON.

System Components

- 50 Ω Coplanar Waveguide (CPW) feedline
- λ/4 readout resonator
- Transmon qubit
- Qubit-resonator coupling



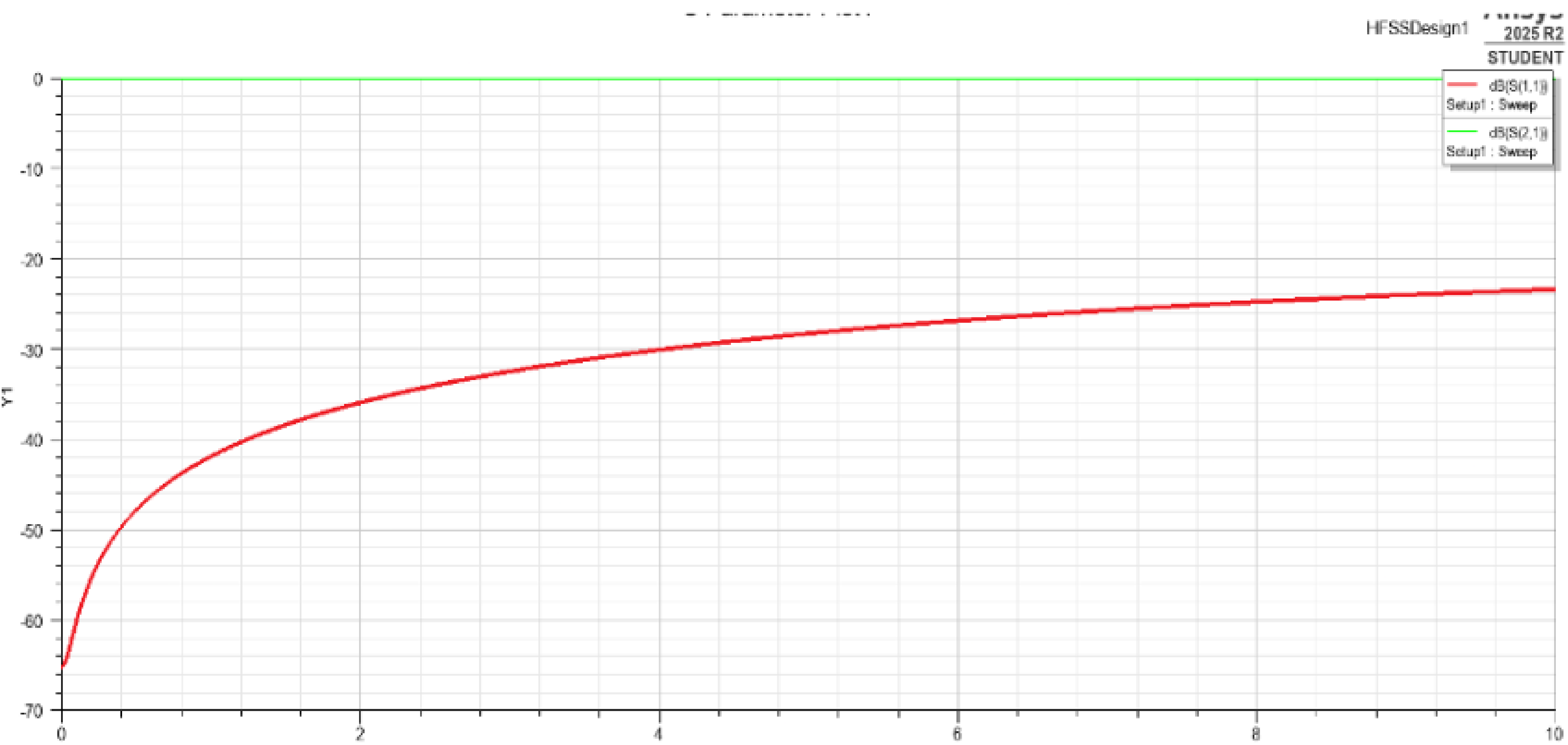
(LEVENSON-FALK & SHANTO, 2024)

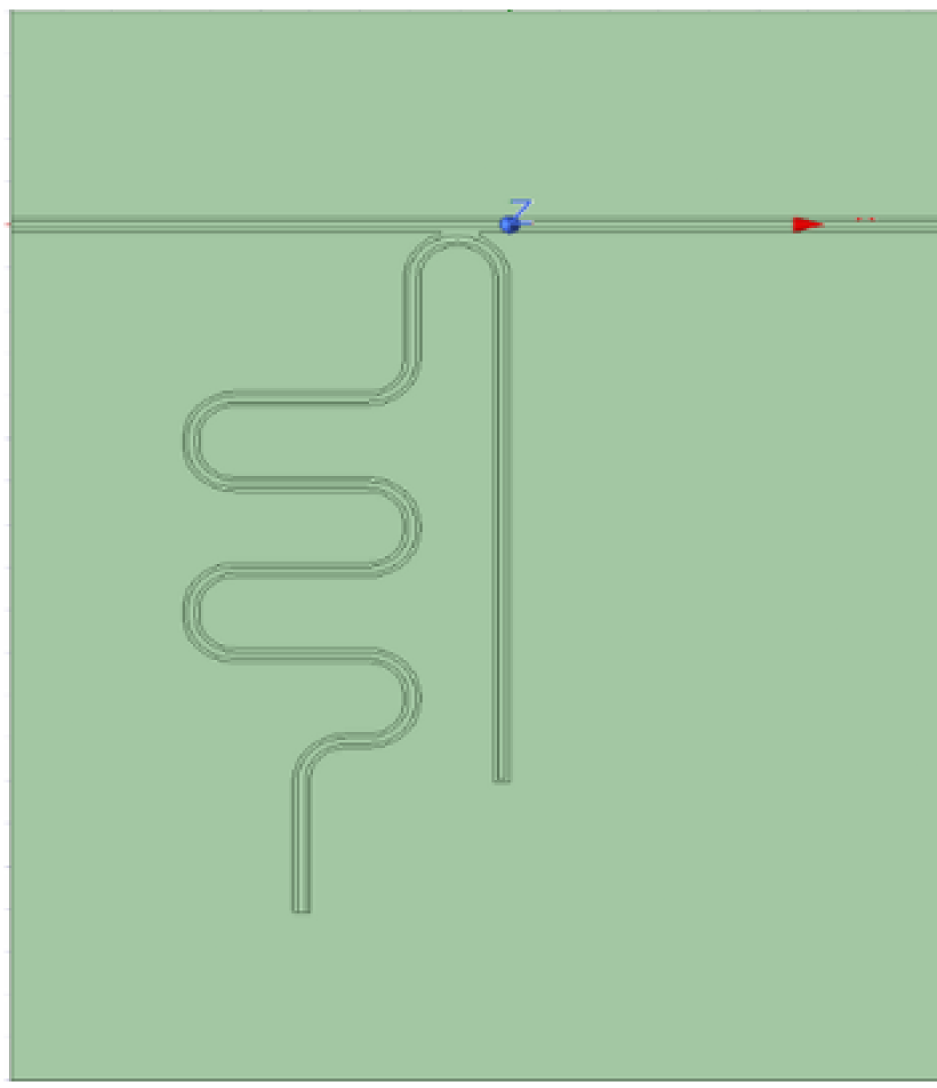
→

Transmission Line (CPW)

50 Ω Transmission Line

- Conductor width: 15 µm
- Gap width: 9 µm
- Substrate: high-resistivity silicon
- Verified through S_{11}/S_{21} for low reflection and strong power delivery

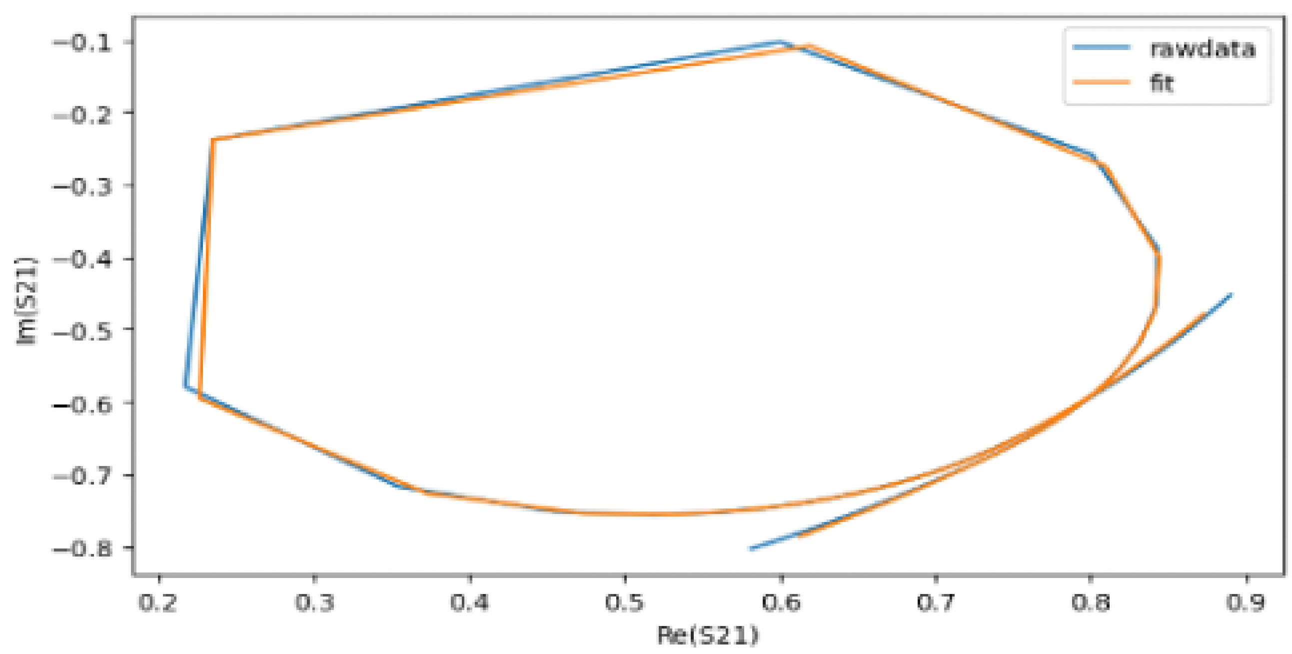


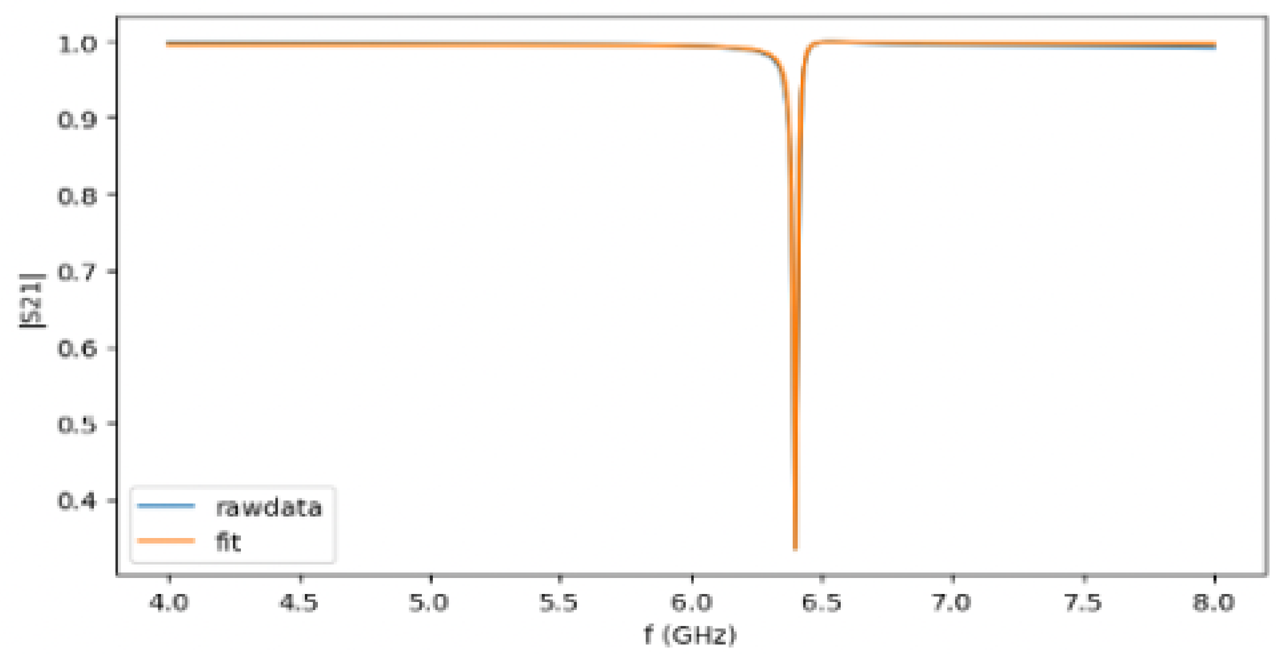


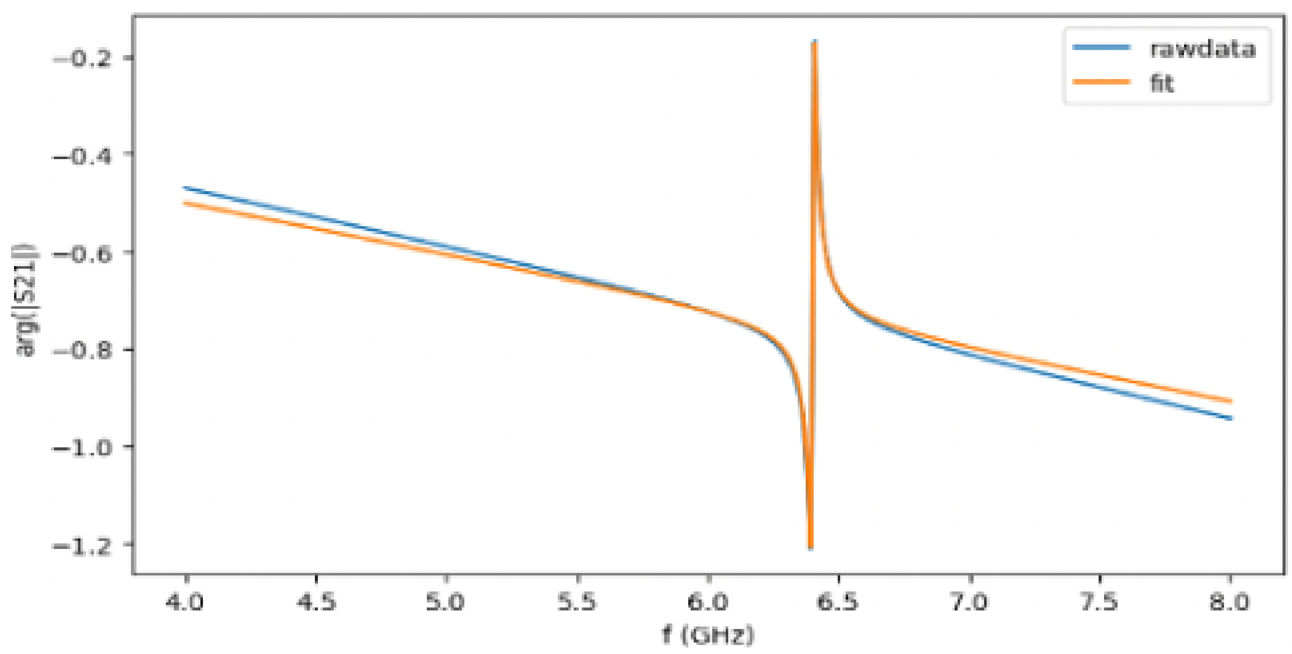
Readout Resonator

λ/4 Notch Resonator

- Resonant Frequency: 6.4 GHz
- External Q: 424
- Internal Q: 846
- Total Q: 282
- Photon decay rate: ~15.1 MHz







Qubit–Resonator Coupling

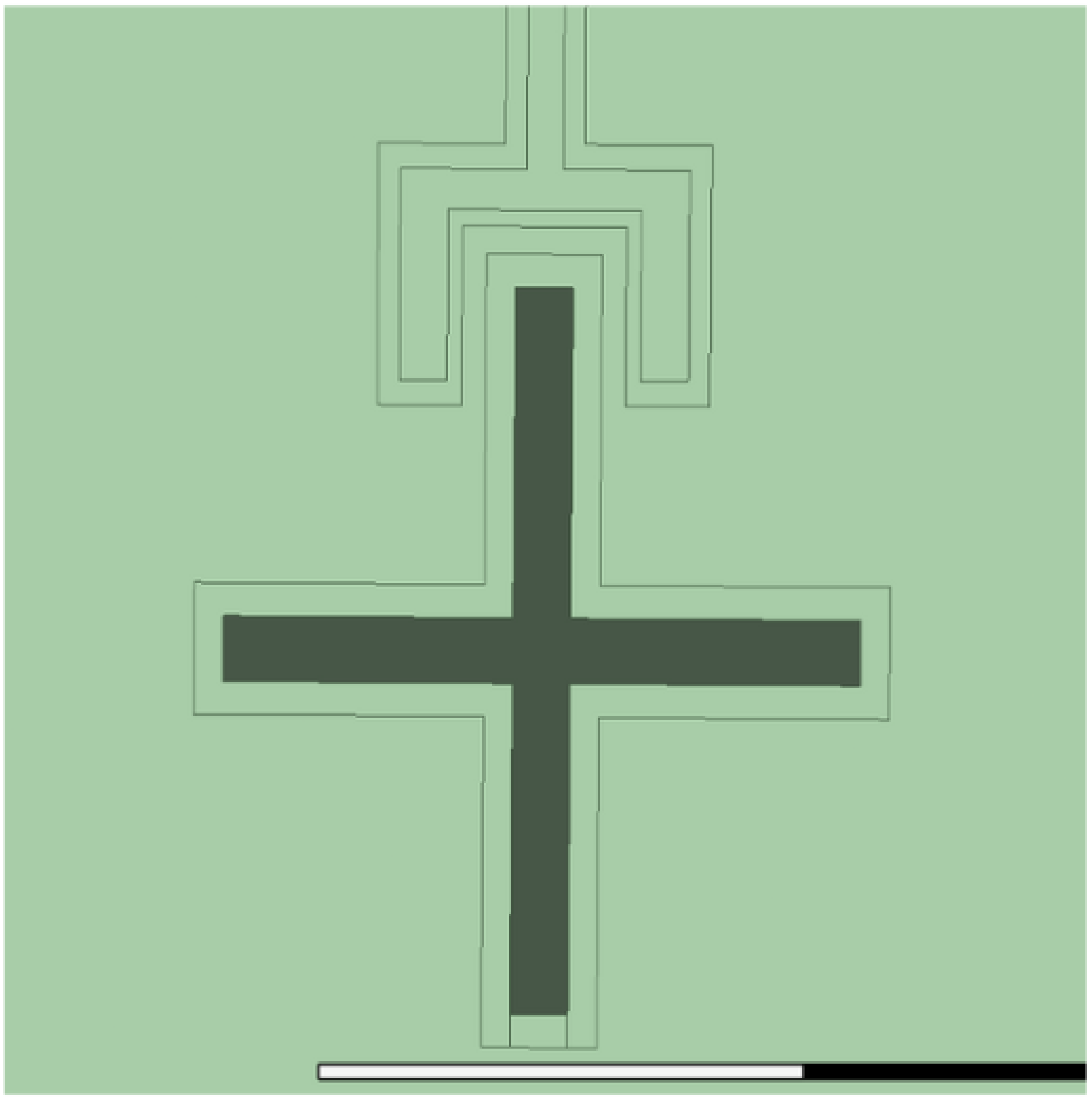
Capacitive Claw Coupling

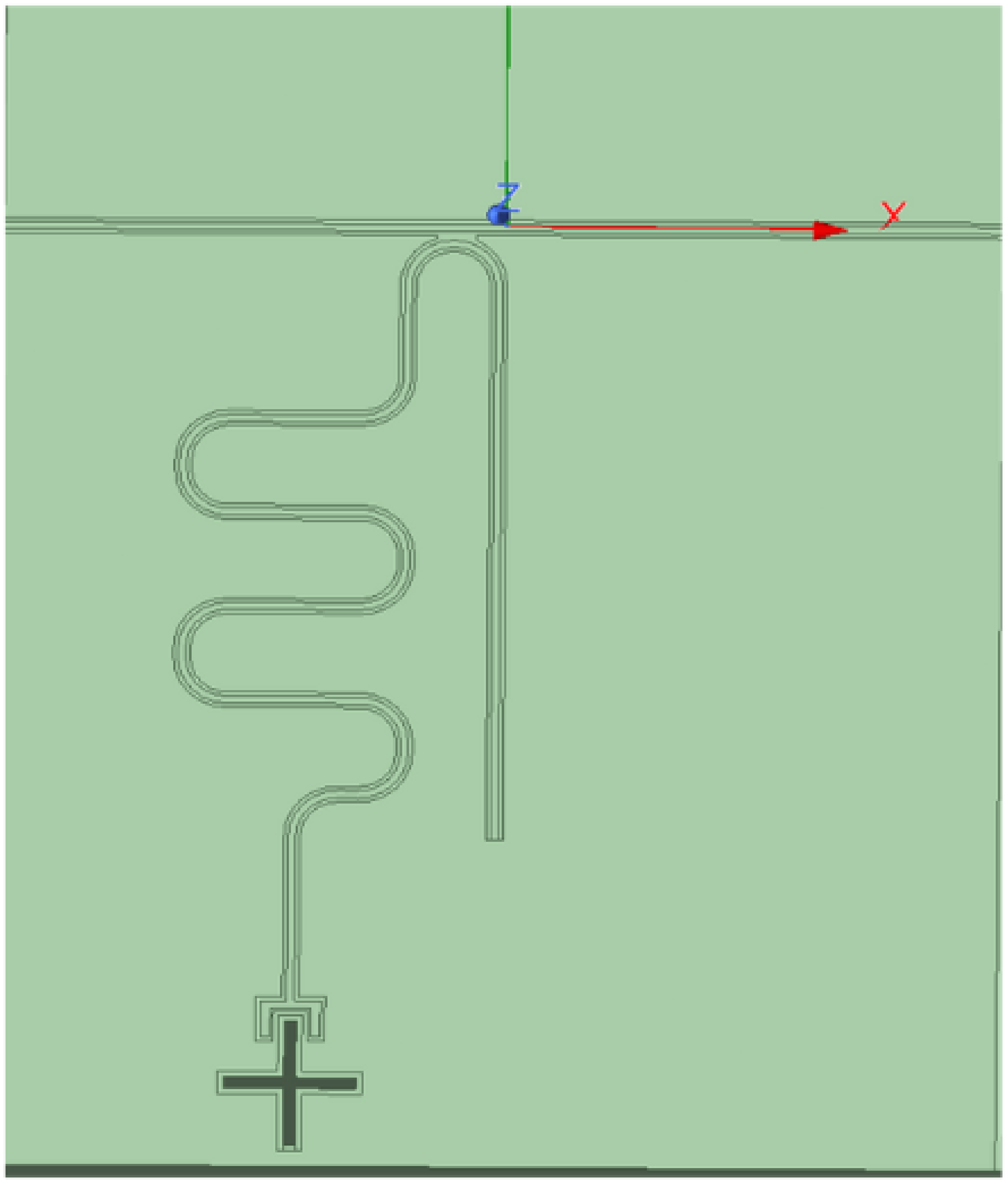
- Coupling capacitance: 2.1 fF
- Coupling strength: g = 33.2 MHz
- Detuning: 1.28 GHz
- Regime: Deep dispersive ($g \ll \Delta$)

$$g = \frac{1}{2}\frac{C_{qr}}{\sqrt{C_q C_r}}\sqrt{\omega_q \omega_r}$$

- C_{qr} = coupling capacitance
- C_q, C_r = qubit + resonator capacitances
- $\omega_q,\ \omega_r$ = angular frequencies

From: "Introduction to Circuit QED," arXiv:2005.12667 (2020)





Going Further: Materials Study

Substrate Comparison

Silicon: scalable, industry-standard, slightly higher loss

Sapphire: ultra-low-loss, high coherence, but difficult to fabricate at scale

Superconductor Comparison:

Tantalum (Ta): 0.3–1 ms coherence, low-noise oxide

Titanium Nitride (TiN): ~300 µs coherence, robust, scalable

Next Steps

- Add a Purcell filter
- Integrate a flux line for tunability
- Expand to a 2-qubit architecture
- Explore alternative substrates and metal stacks

Special Thanks To

NORTH AMERICAN QUANTUM CONSORTIUM
EST. NA QC 2025

IONQ

ENGINEERING | McMaster University

CMC MICROSYSTEMS

UdS Université de Sherbrooke

Ansys