

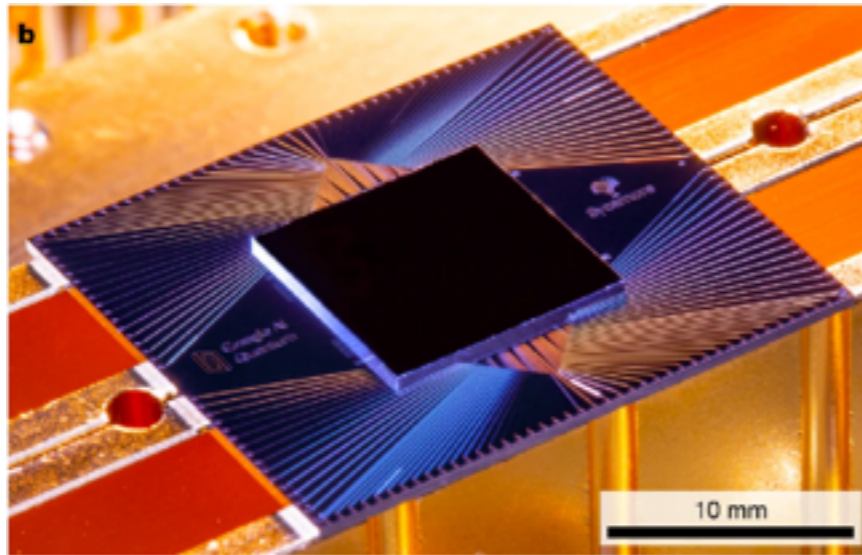
A decorative graphic featuring a horizontal line at the top with a pencil icon on the right. Below the line, several paper clips are arranged vertically, some overlapping. The main title is centered over this graphic.

New platforms for quantum computing

Nathalie de Leon
Department of Electrical and Computer Engineering
Princeton University

Next Steps in Quantum Computing workshop
May 18, 2023

Improving the lifetime of superconducting qubits

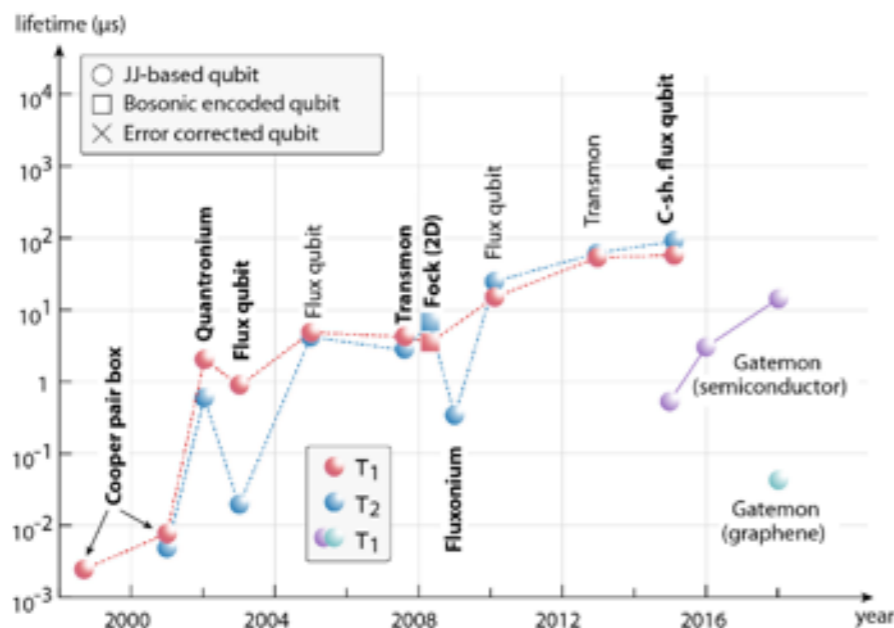


Arute et al *Nature* 2019

large scale (NISQ) processors

quantum chemistry, quantum simulation, time crystals

Schoelkopf's Law

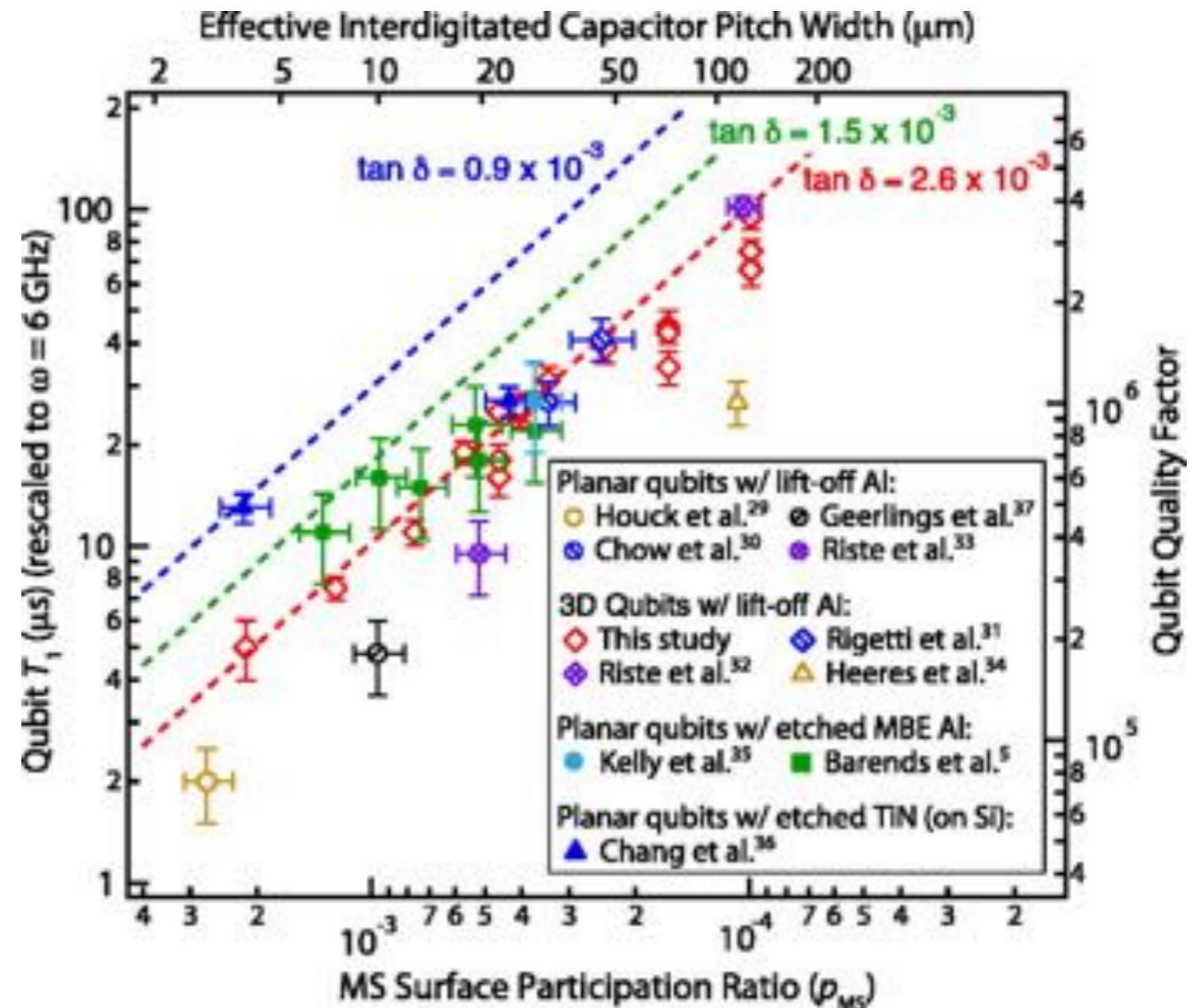


Last record for planar device set in 2012

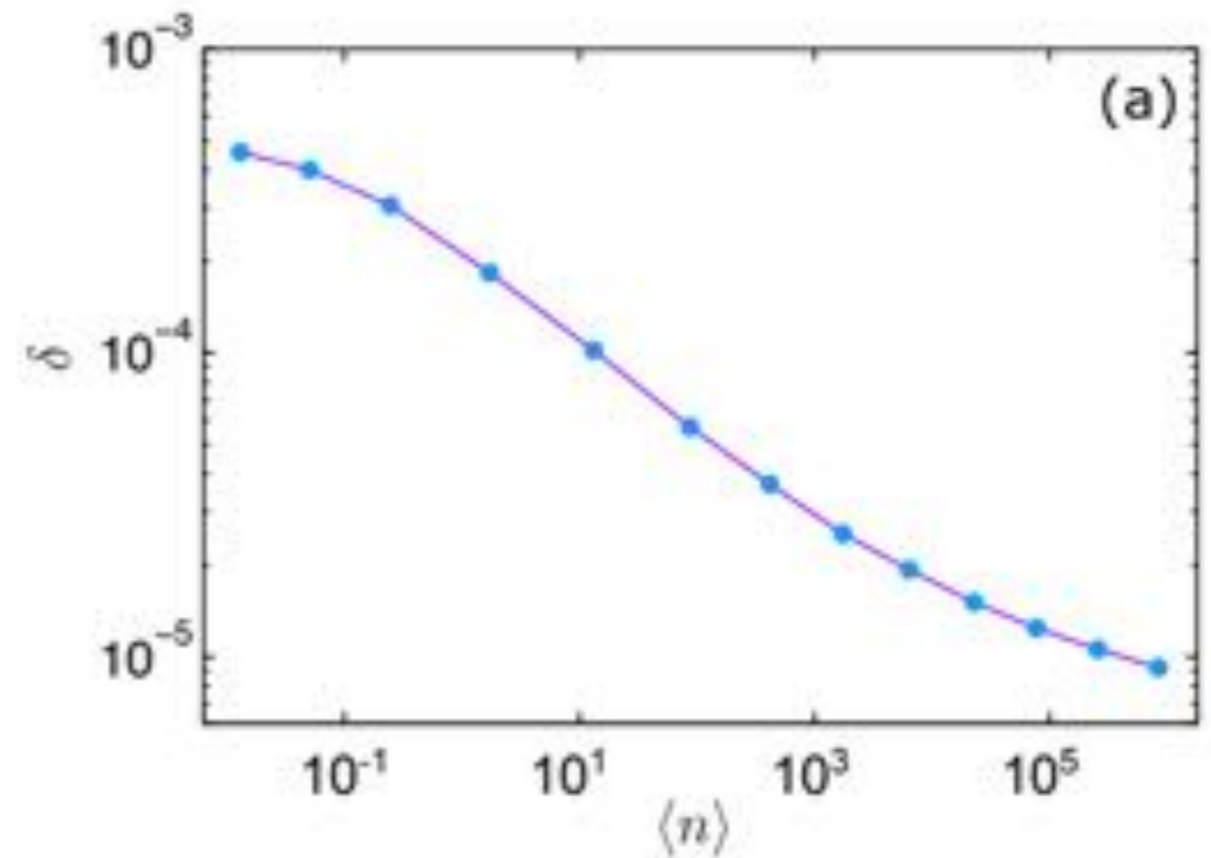
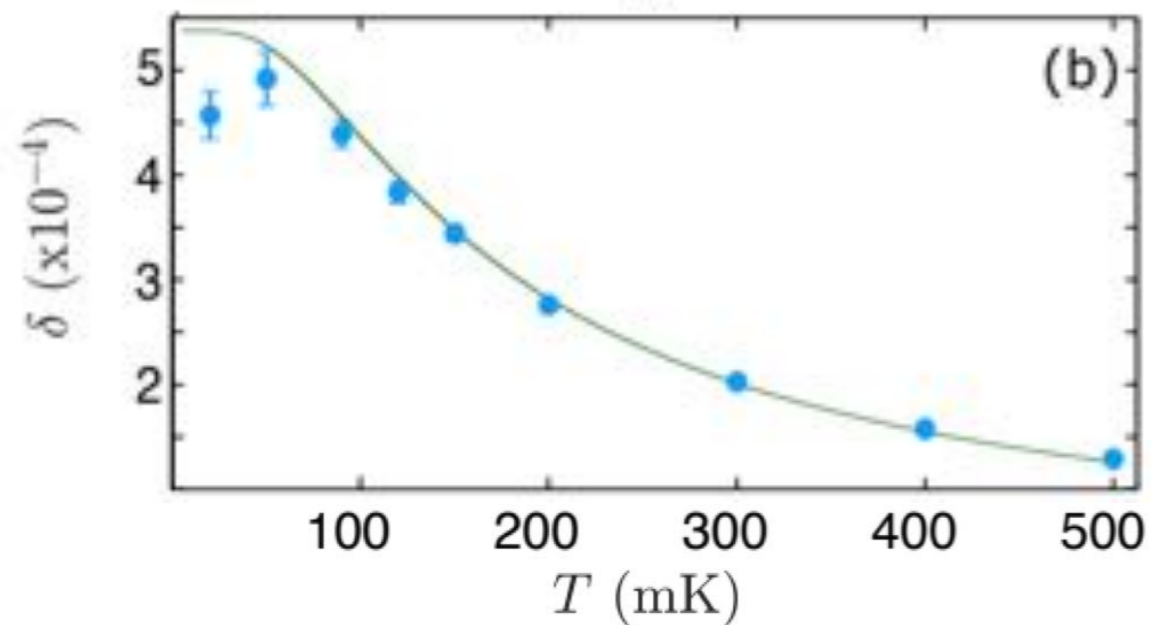
limited by dielectric loss

Losses related to surfaces

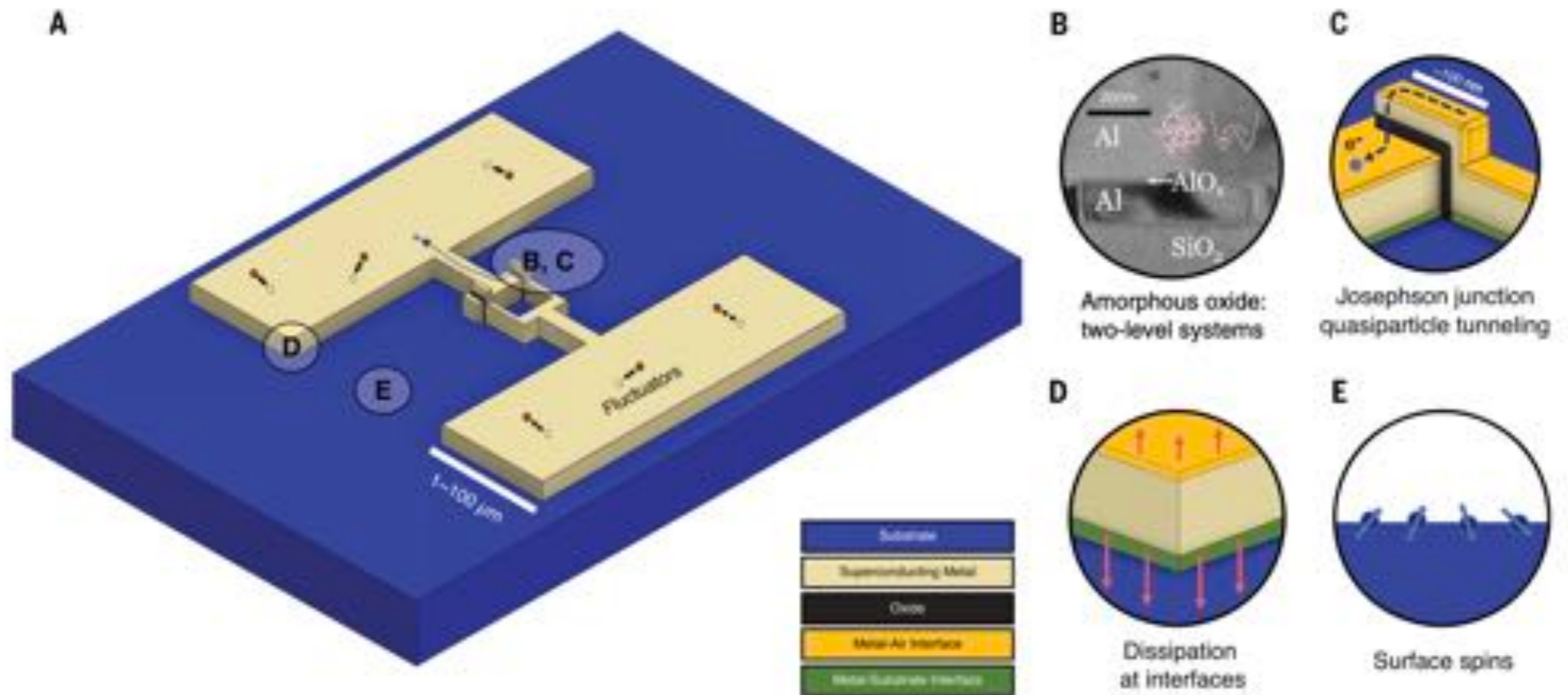
bulk loss set by sapphire
should allow for $Q \sim 10^9$



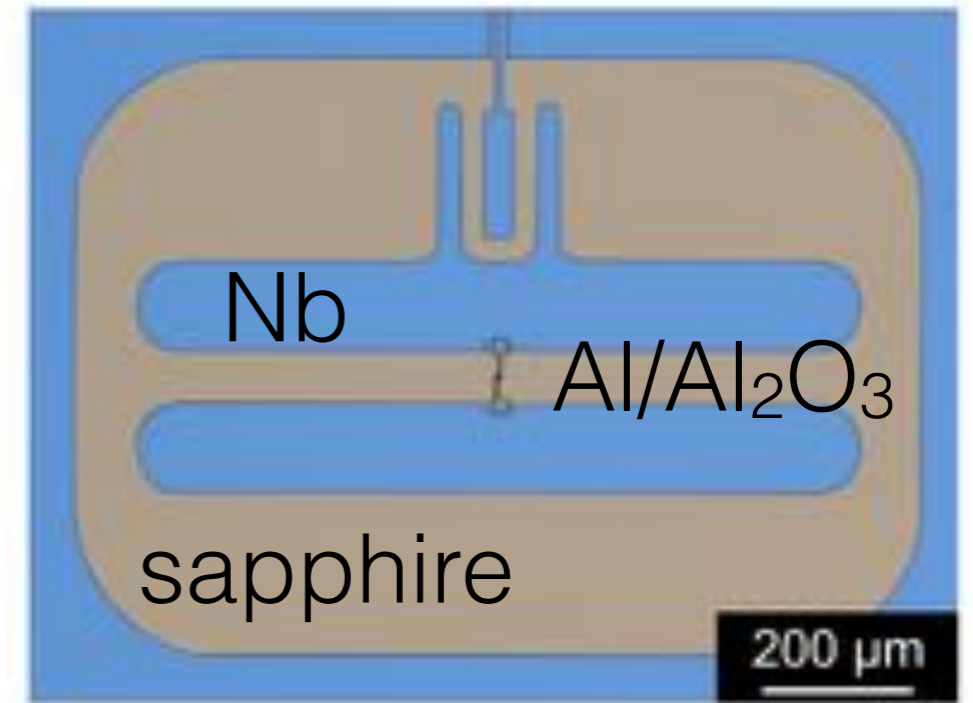
Losses get worse at low temperature, low power



Candidates for loss, noise

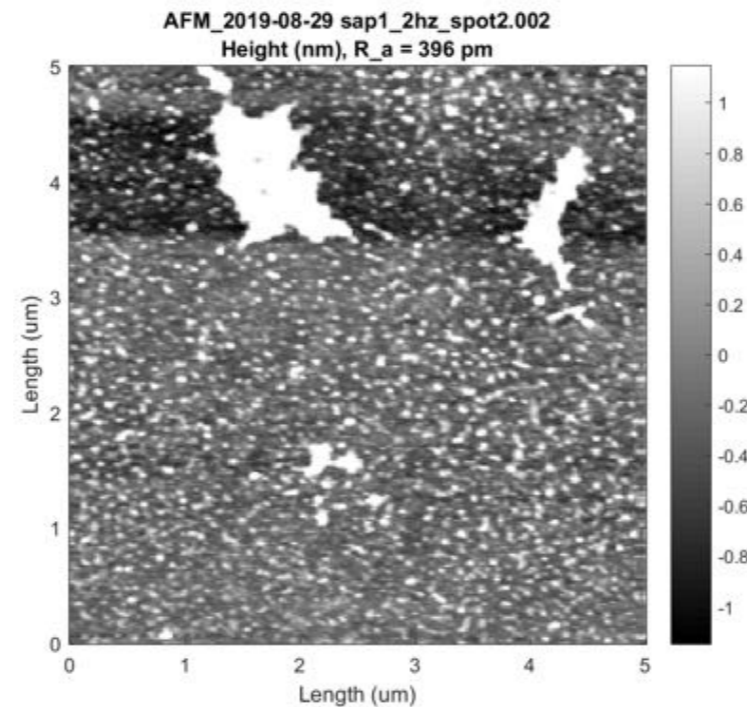


New material platforms for superconducting qubits

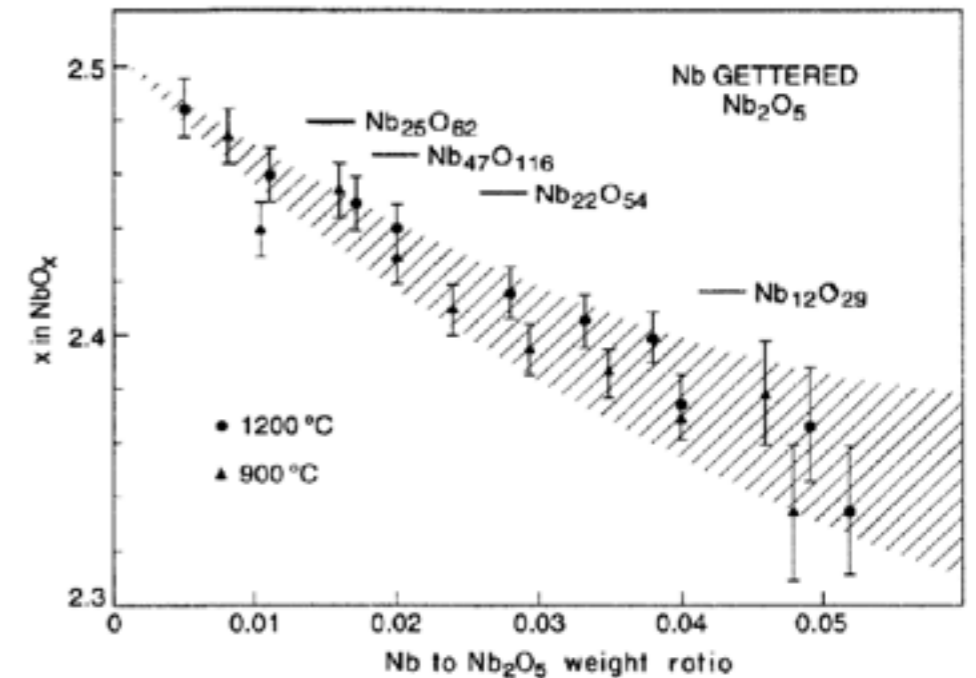


Substrate contaminants

Two hypotheses for dielectric loss



Nb oxides are complicated -> resistive loss



Cava et al, PRB 1991

collaboration with Andrew Houck, Bob Cava

Replace Nb with Ta: T_1 exceeding 0.3 ms

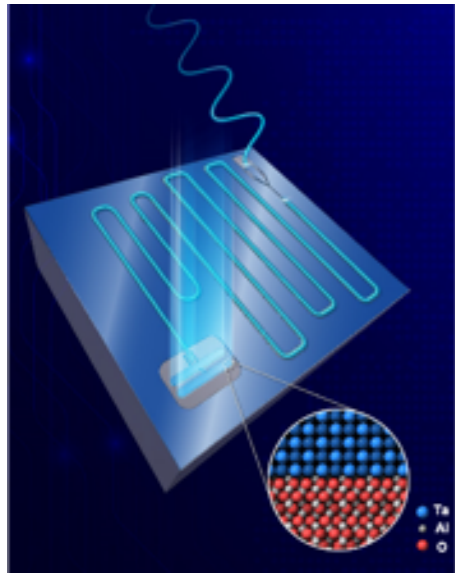
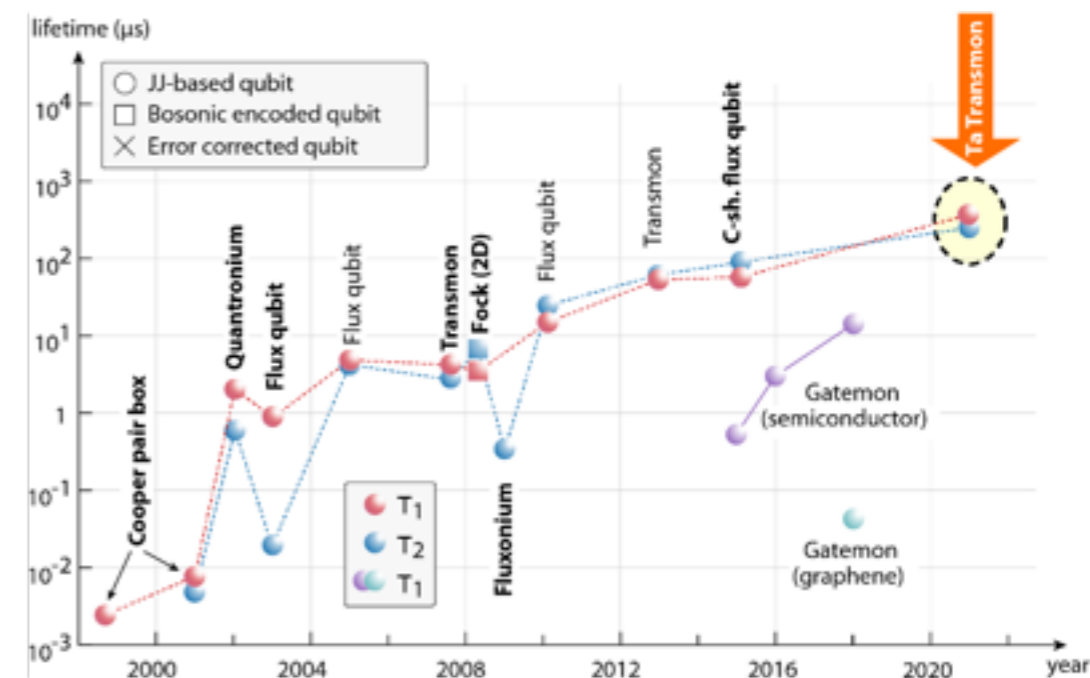
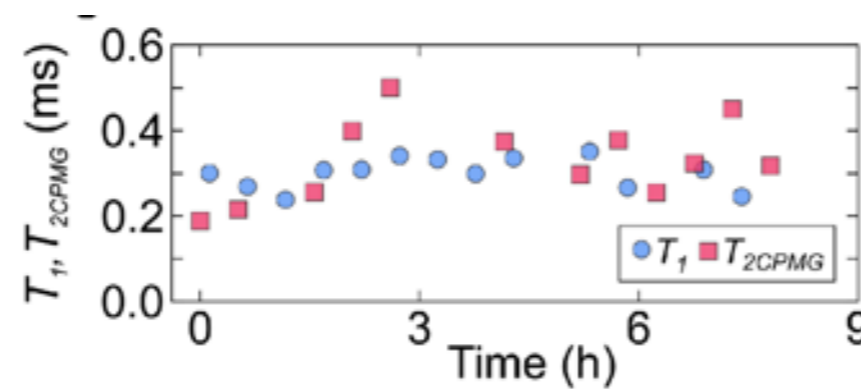
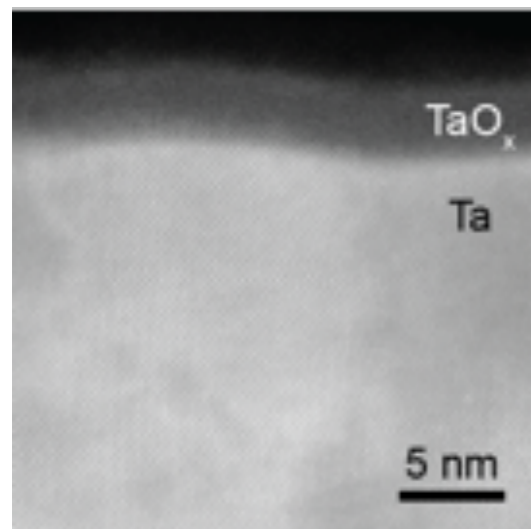
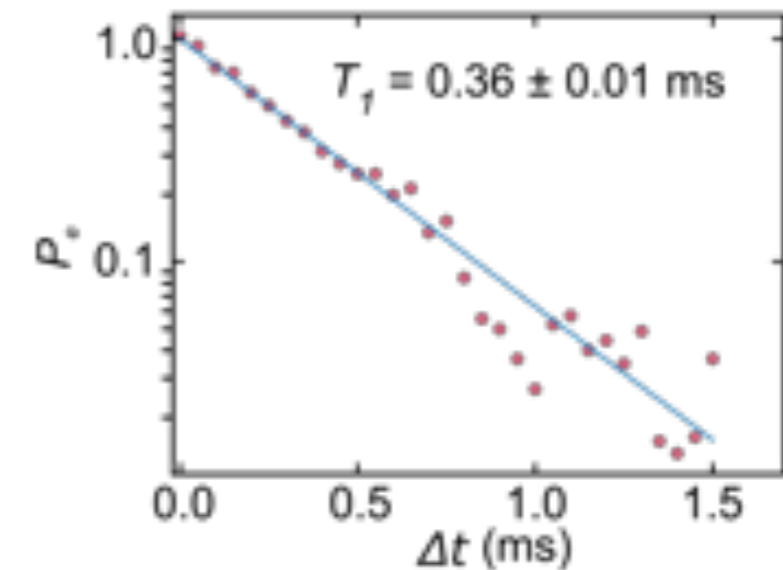
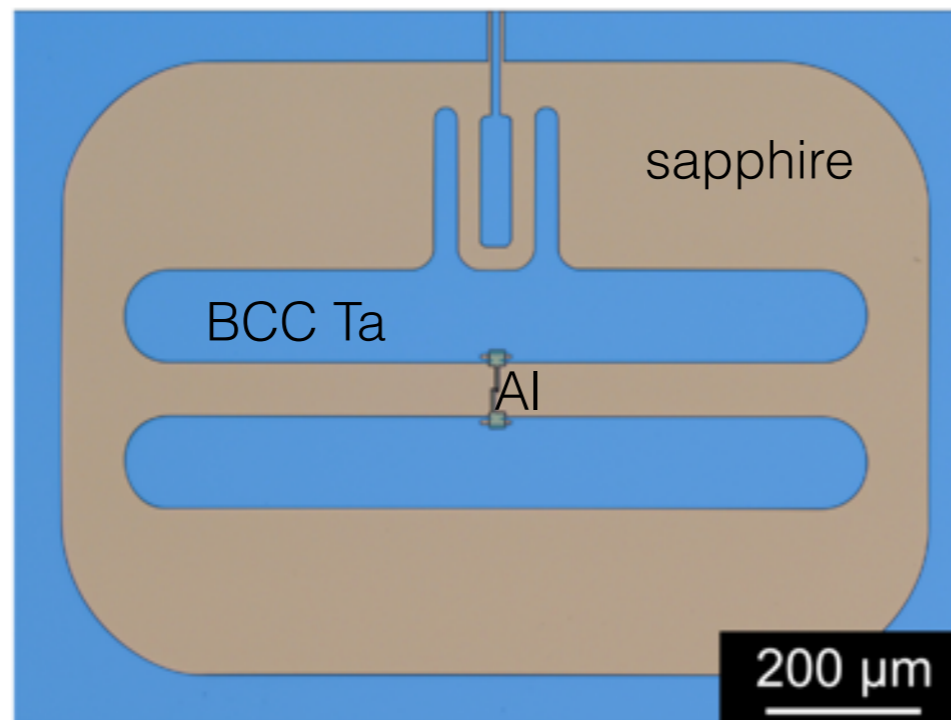
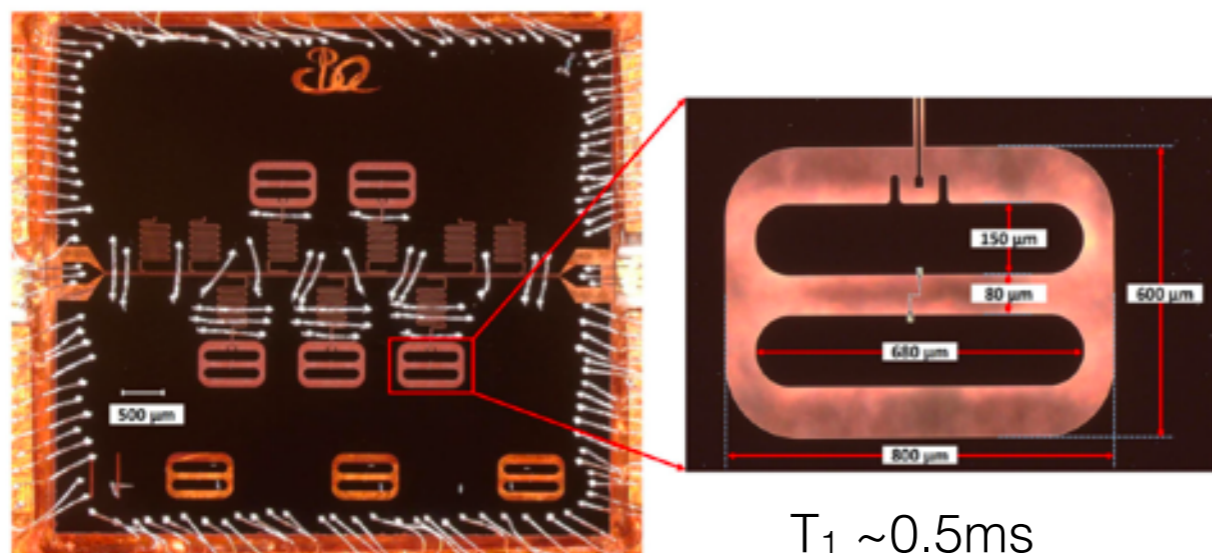


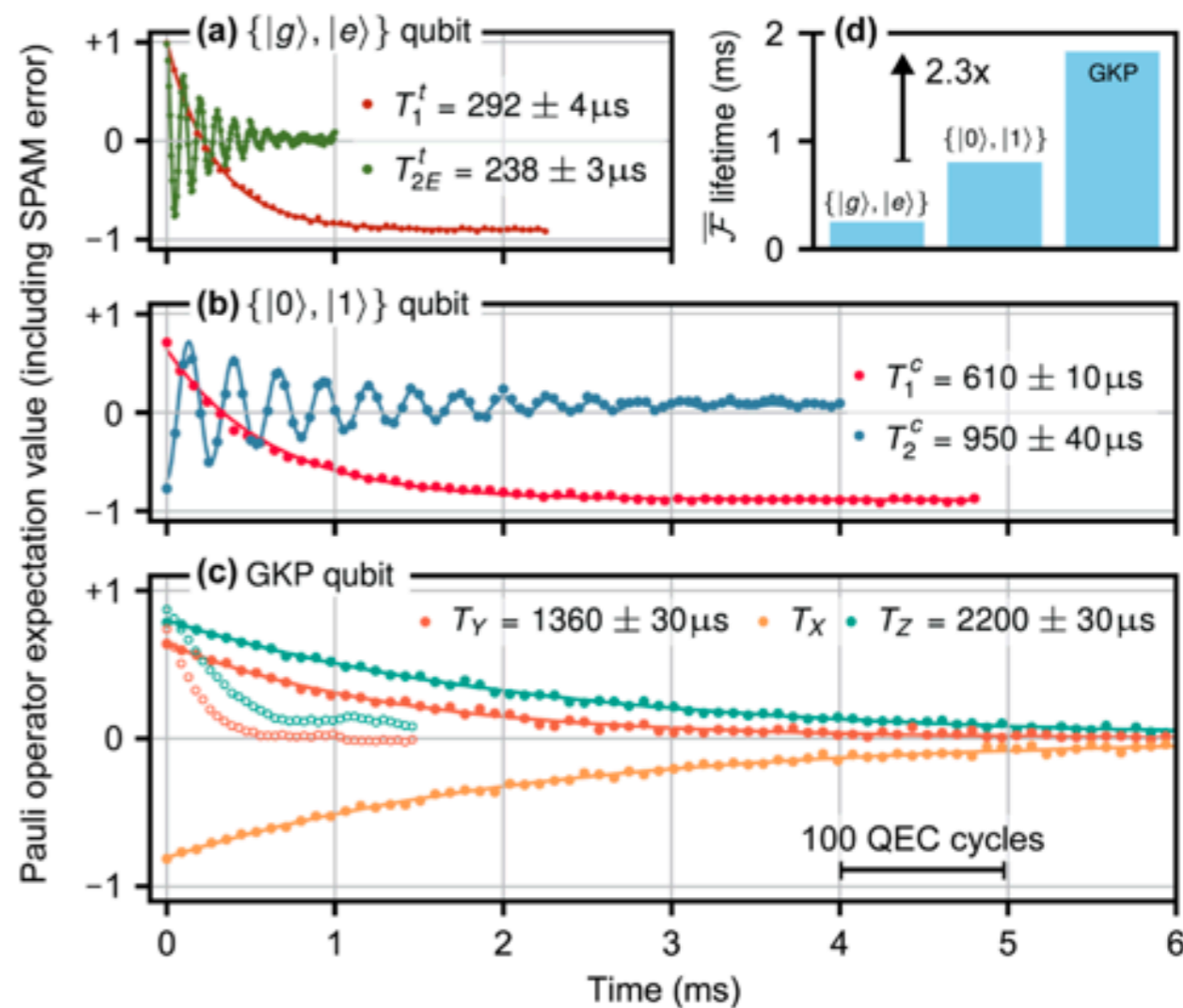
image courtesy Mingzhao Liu (BNL)



Reproduced in many labs

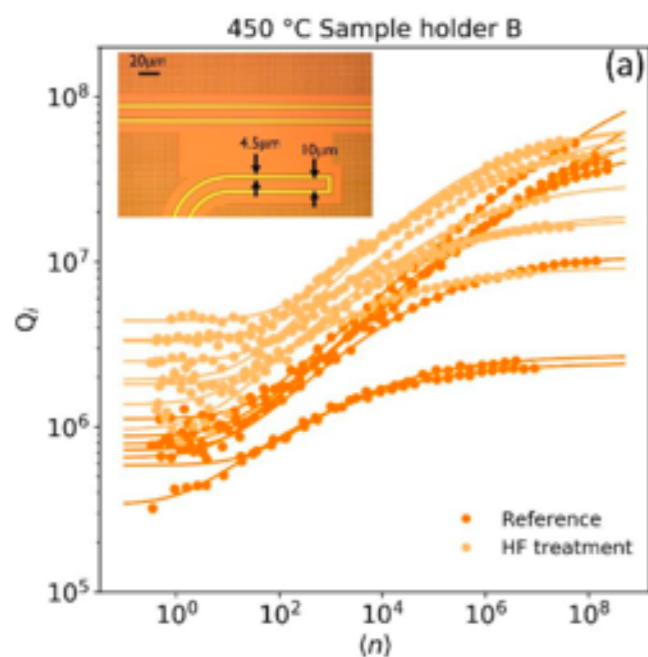


Wang, et al, npj Quantum Information 2022



integrated with cavity for real-time, break even QEC with GKP code

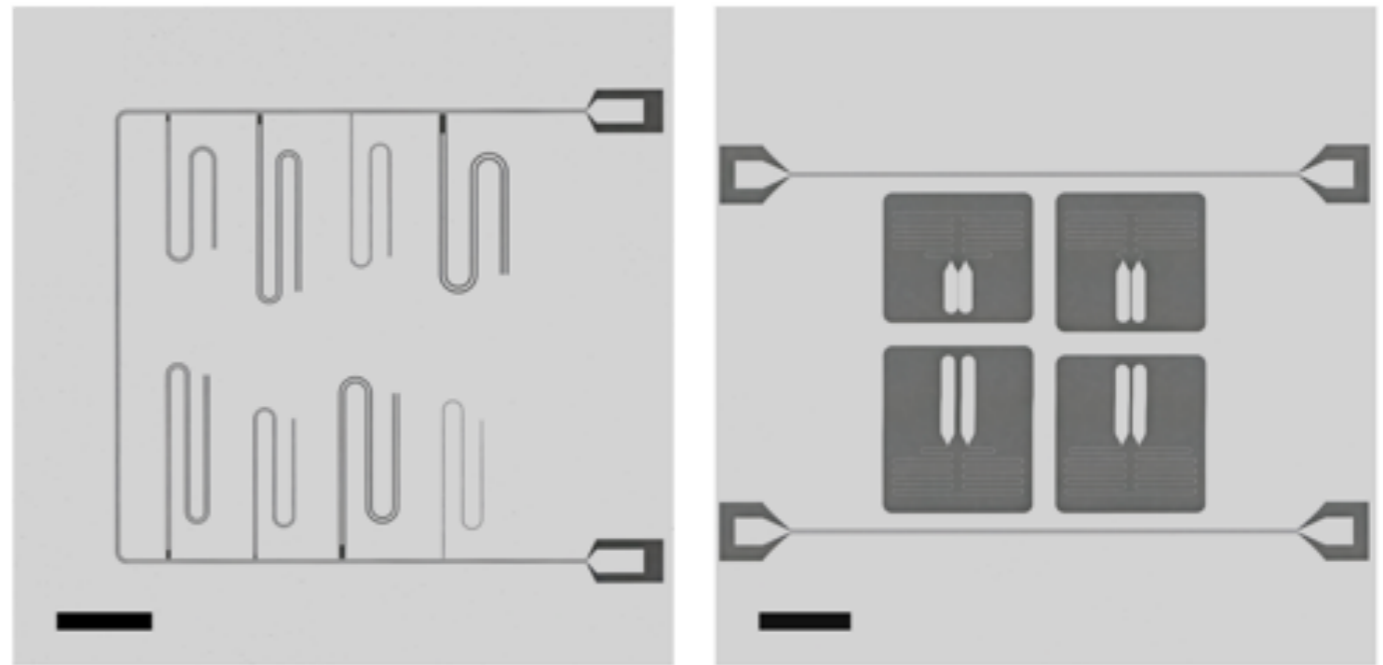
Sivak, et al, Nature 2023



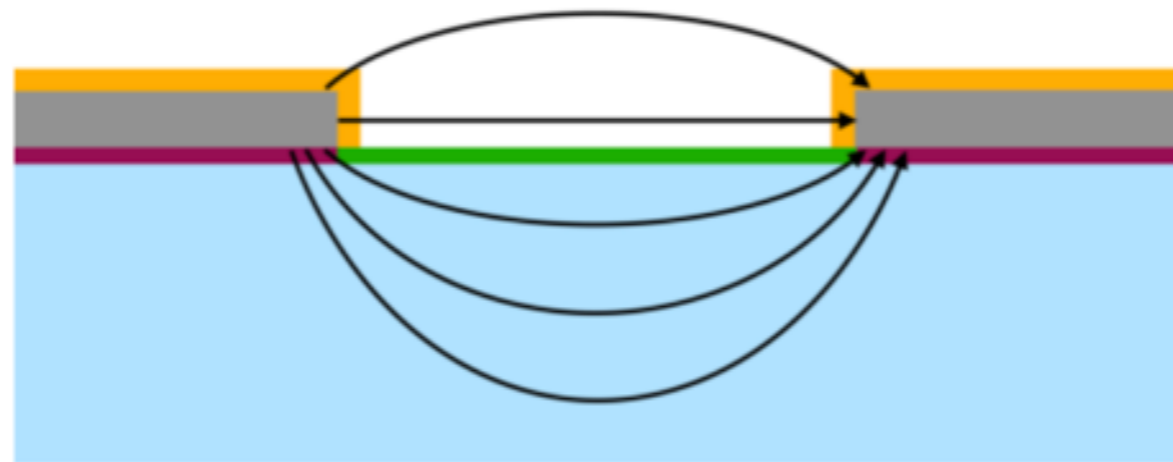
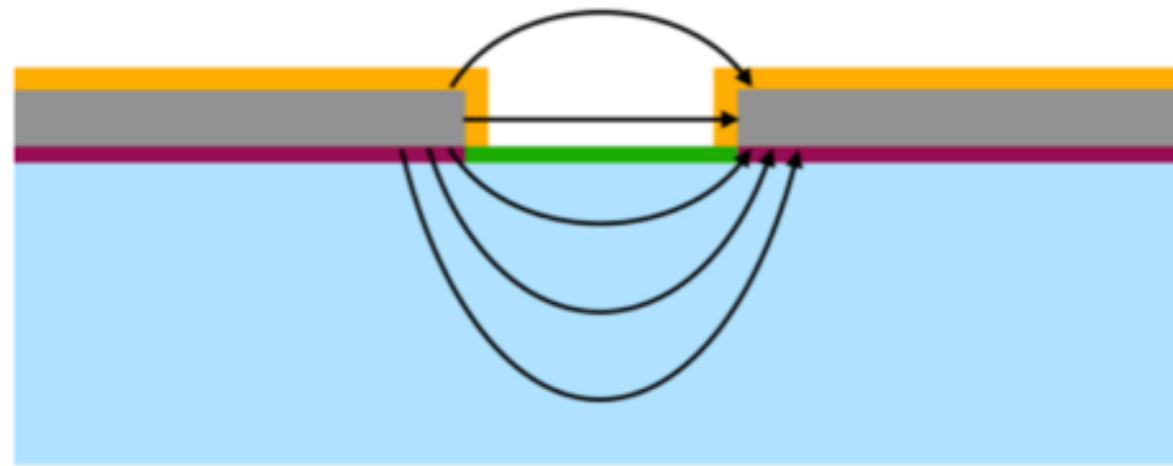
Lozano, et al, arXiv:2211.16437

Systematic studies of Ta resonators

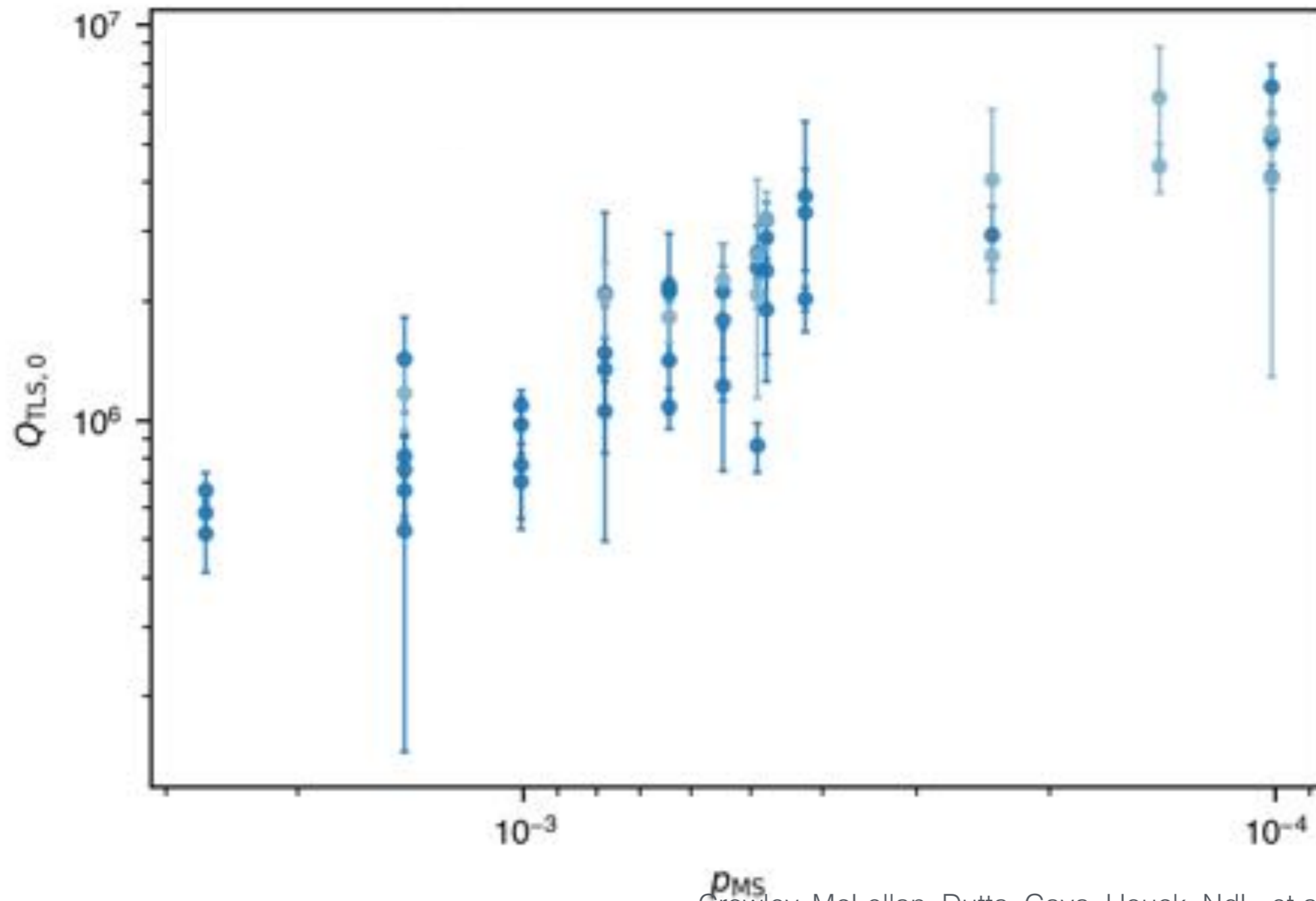
- eliminate variation in junction fab
- robust to processing
- larger temperature / power range
- much faster measurements!



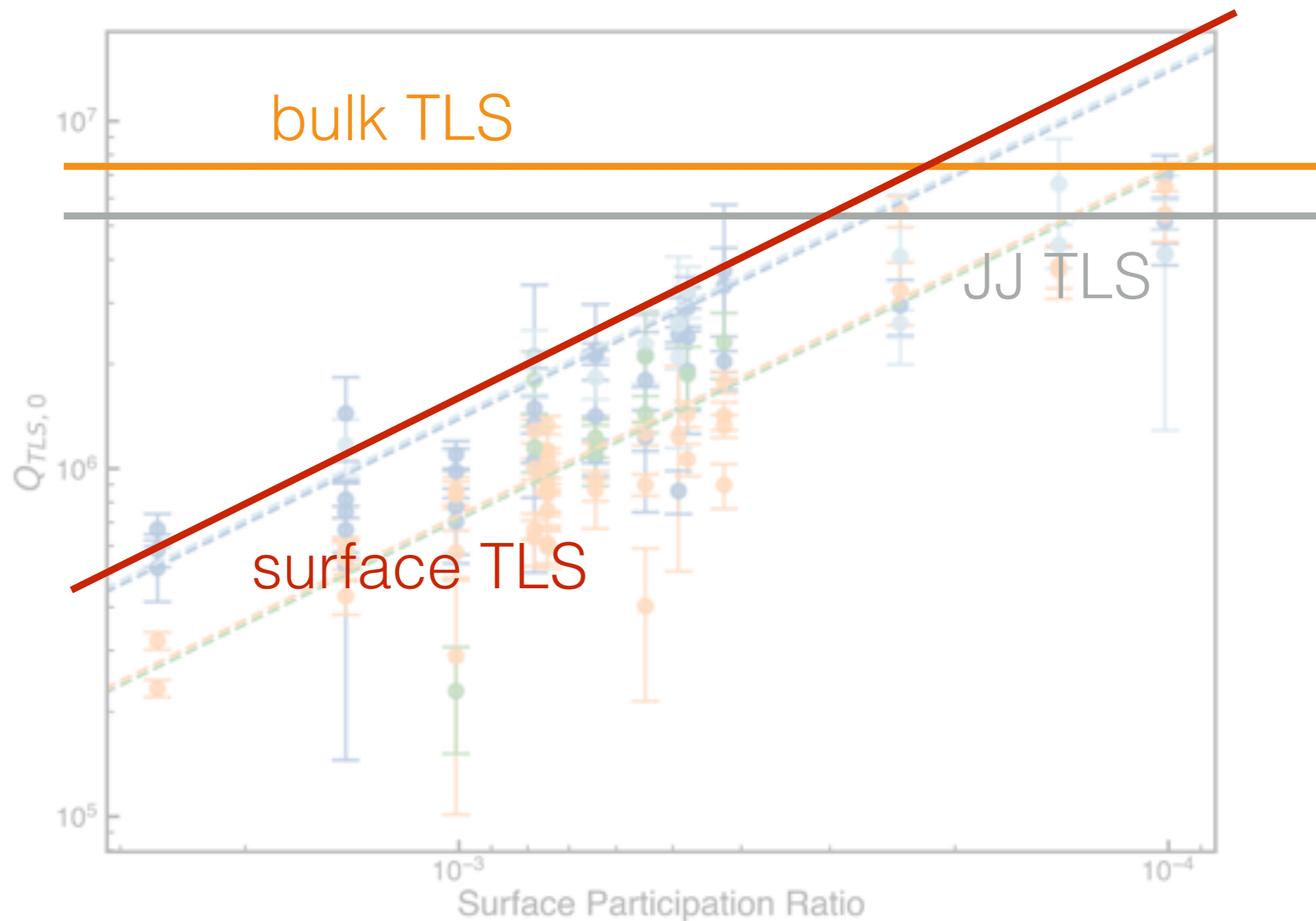
Surface participation dependence



Surface participation dependence



Losses in state of the art devices



New qubits and new material systems: grand challenges

- identifying and addressing microscopic sources of loss, noise models: problems affect (almost) all platforms
- systematic search for new materials: parametrization is important!
- material issues affect size/scalability, couplers, other components, architecture

Acknowledgements



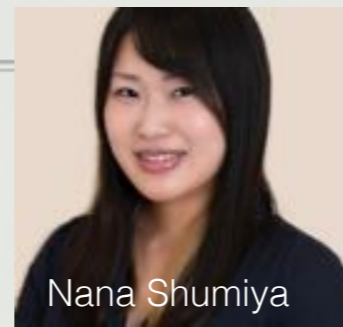
Russell McLellan



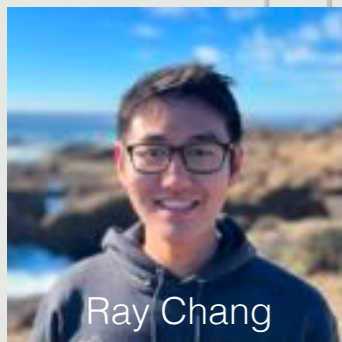
Aveek Dutta



Lila Rodgers



Nana Shumiya



Ray Chang



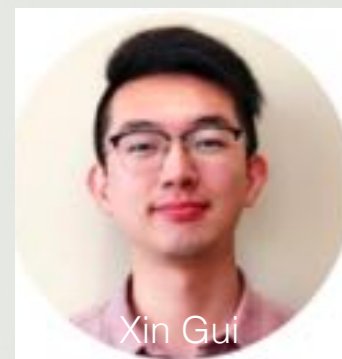
Kevin Crowley



Alex Place



Matthew Bland



Xin Gui



Hoang Le



Youn Gang



Trisha Madhavan



Bob Cava



Andrew Houck

Andrew Walter, Andi Barbour, Ignace Jarrige, Conan Weiland, Ira Waluyo, Steve Hulbert (BNL NSLSII), Yichen Jia, Chenyu Zhou, **Mingzhao Liu** (BNL CFN)



NSF RAISE TAQS
DOE NQIS: C2QA

