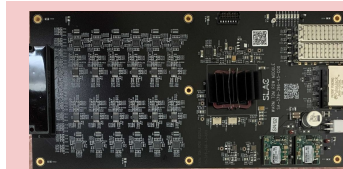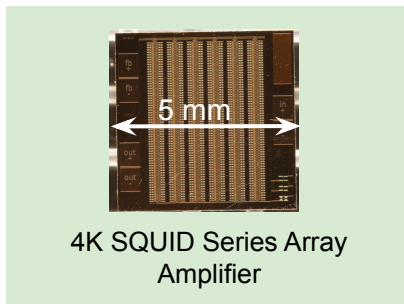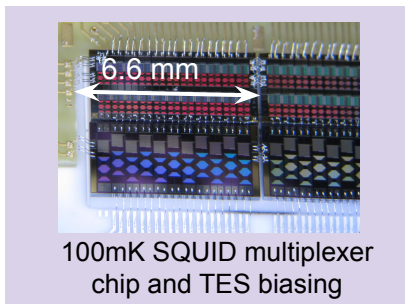# Readout Status

Zeeshan Ahmed

CMB-S4

Outline

- Overview of Readout Scope
- Technical Highlights / Progress made in the last year
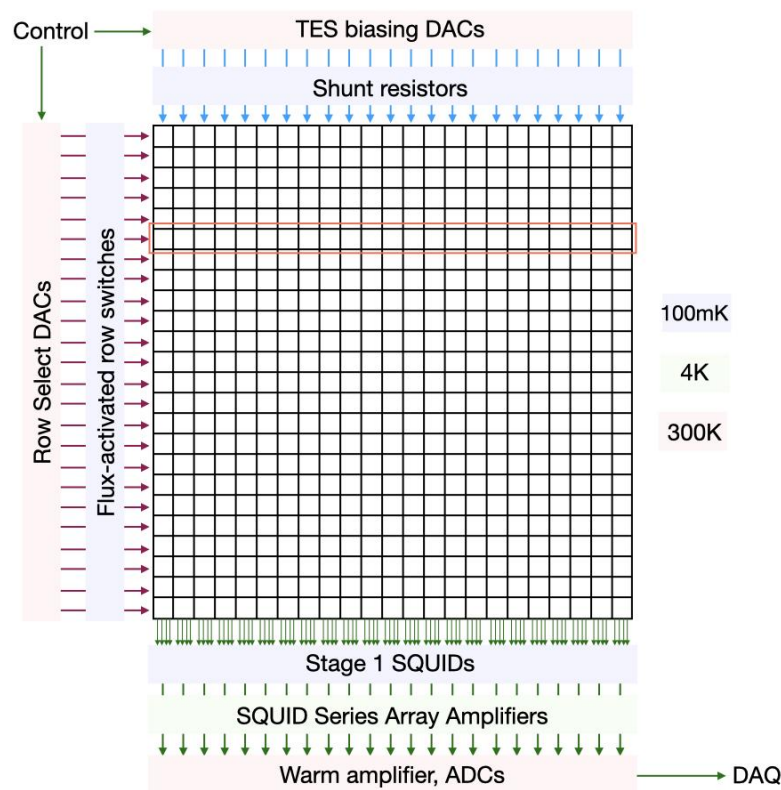- Plans through FY22

CMB-S4

System Design: Time-Division Multiplexing

- Arrange TESes of a detector wafer as a 2D logical grid
- Read one "row" at a time; switch at ~10s of kHz
- Connections to 300K scale as perimeter, not as area
- CMB-S4 will use ~80 "rows" (MUX80)

Superconducting Quantum Interference Devices (SQUIDs)
used as cryogenic amplifiers and as row multiplexer.

6.6 mm

100mK SQUID multiplexer chip and TES biasing

5 mm

4K SQUID Series Array Amplifier

Room temperature electronics are low-frequency boards with low-noise precision ADCs and DACs.

Control → TES biasing DACs

Shunt resistors

Row Select DACs

Flux-activated row switches

100mK

4K

300K

Stage 1 SQUIDs

SQUID Series Array Amplifiers

Warm amplifier, ADCs → DAQ

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System Design: Modularity Built Into Form Factor

80 rows x 4 col x 6 sides of hex =1920 channels
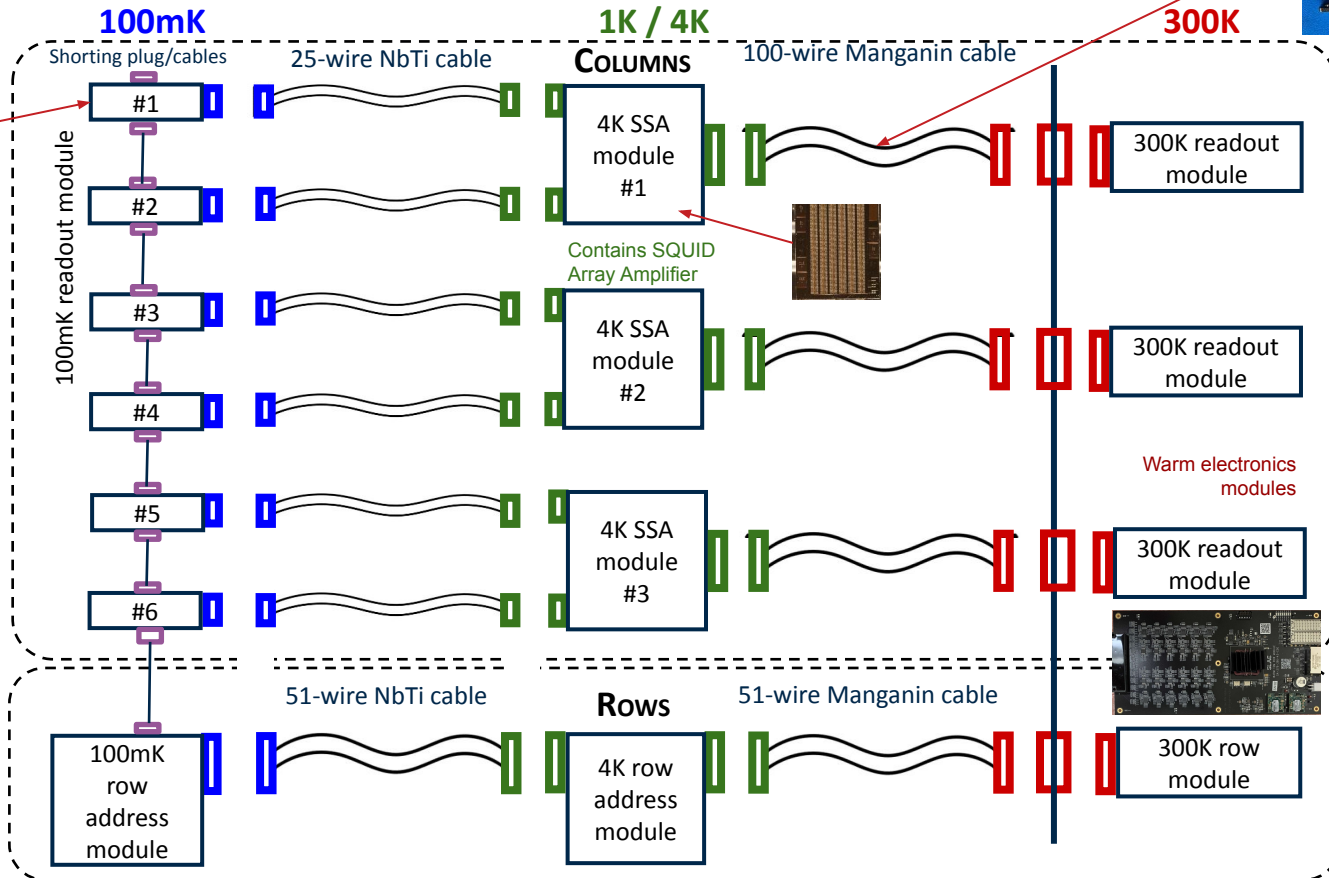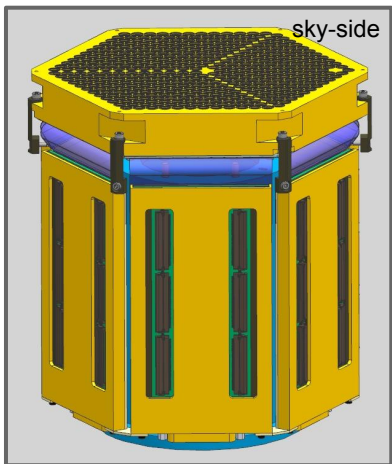
Readout Prototyping: Develop, Build And Test End-To-End Strings For Design Validation
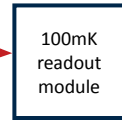
Contains SQUID multiplexer and TES bias chips

100mK

COLUMNS

1K / 4K
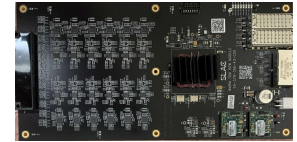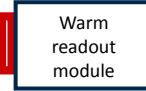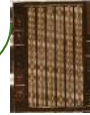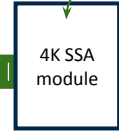
300K

Vacuum   Air

Start with MCE crates, upgrade with new warm modules.

Contains SQUID Series Array Amplifier

100mK readout module

100mK readout module

4K SSA module

Warm readout module

100mK row address module

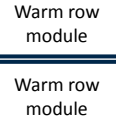Prototype test setup with 100mK readout modules mounted horizontally with detector module

ROWS

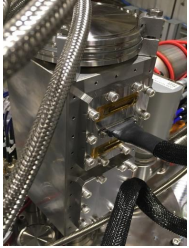100mK row address module

100-wire NbTi cable

100-wire Manganin cable

Warm row module

Warm row module

Cryogenic cabling

CMB-S4

Significant Progress In R&D: Built Out Standardized Prototype Hardware For Readout And Detector Testbeds
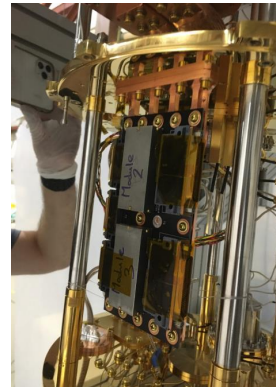

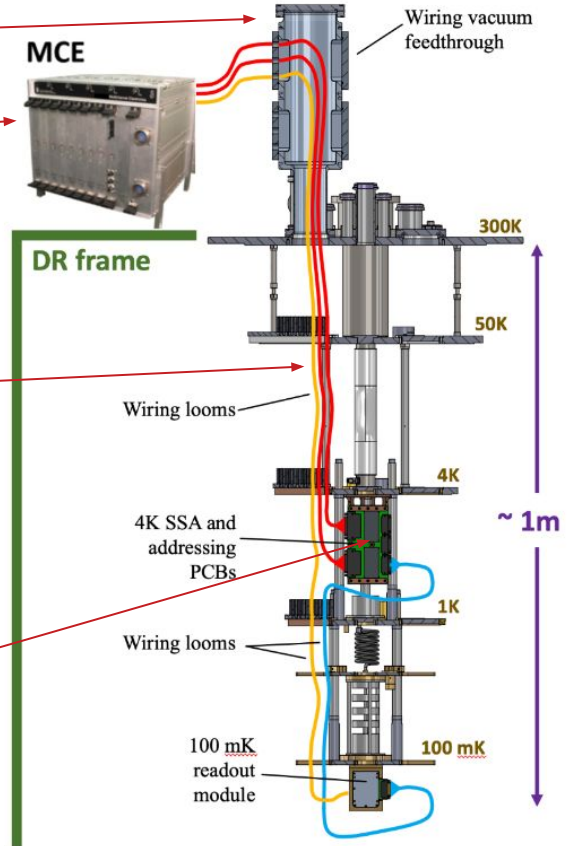300K Vacuum Feedthroughs and connectors

MCE readout electronics built by UBC used in prototyping and to start test stands

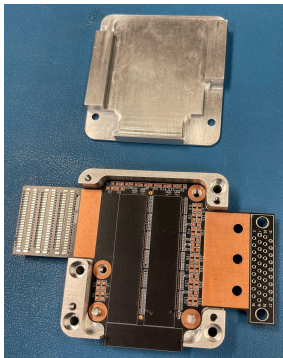300K-to-4K and 4K-to-100mK cabling and heatsinks
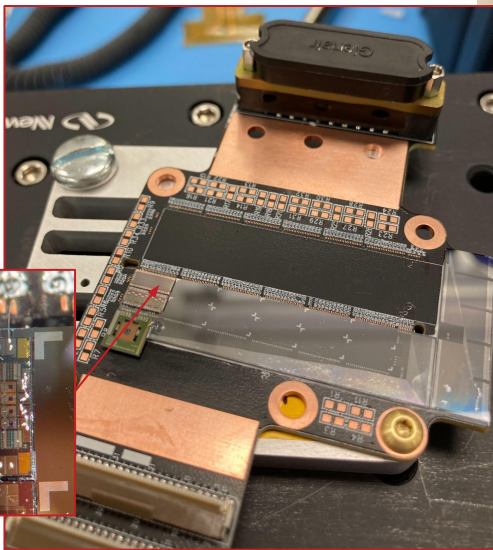
4K SSA amplifier board

MCE

Wiring vacuum feedthrough

DR frame

300K

50K

Wiring looms

4K

4K SSA and addressing PCBs

~ 1m

1K

Wiring looms

100 mK readout module

100 mK

Significant Progress In R&D: 100mK Readout Proto Module Designed and Fabricated

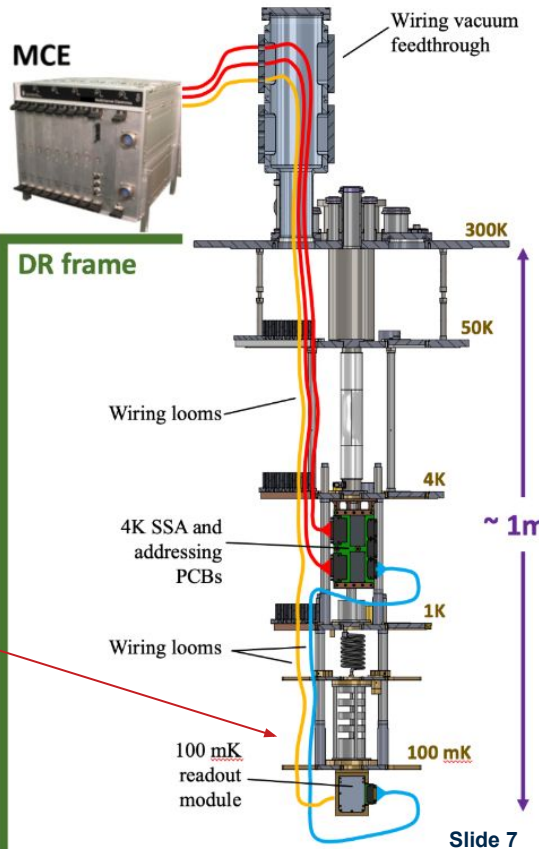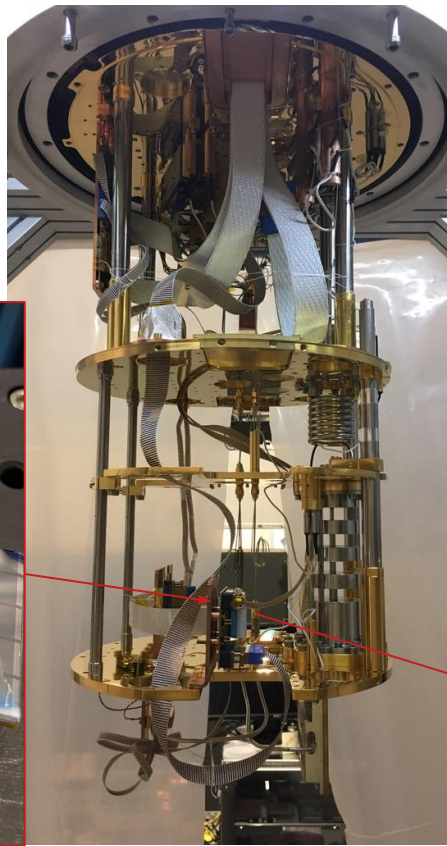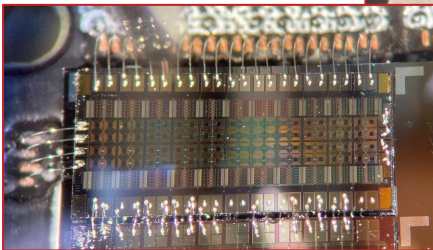100mK RO module with magnetically-shielded enclosure

100mK RO board

NIST TDM 100mK MUX chip

RO test stand at SLAC

MCE

DR frame

Wiring vacuum feedthrough

300K

50K

Wiring looms

4K

4K SSA and addressing PCBs

~ 1m

1K

Wiring looms

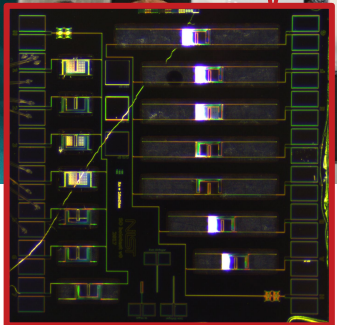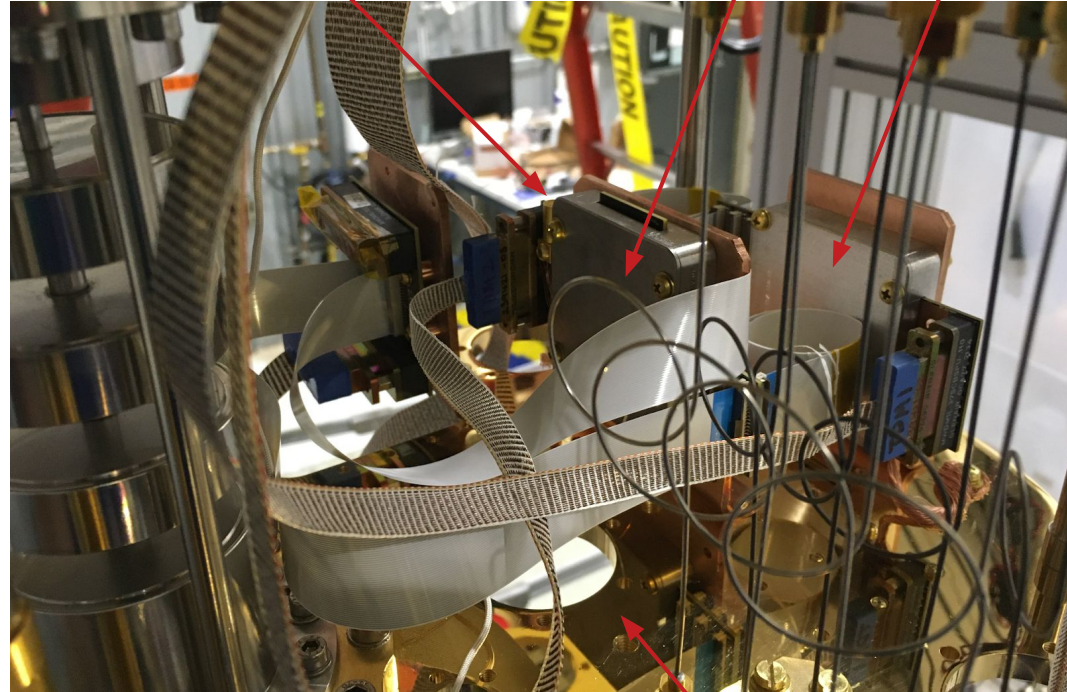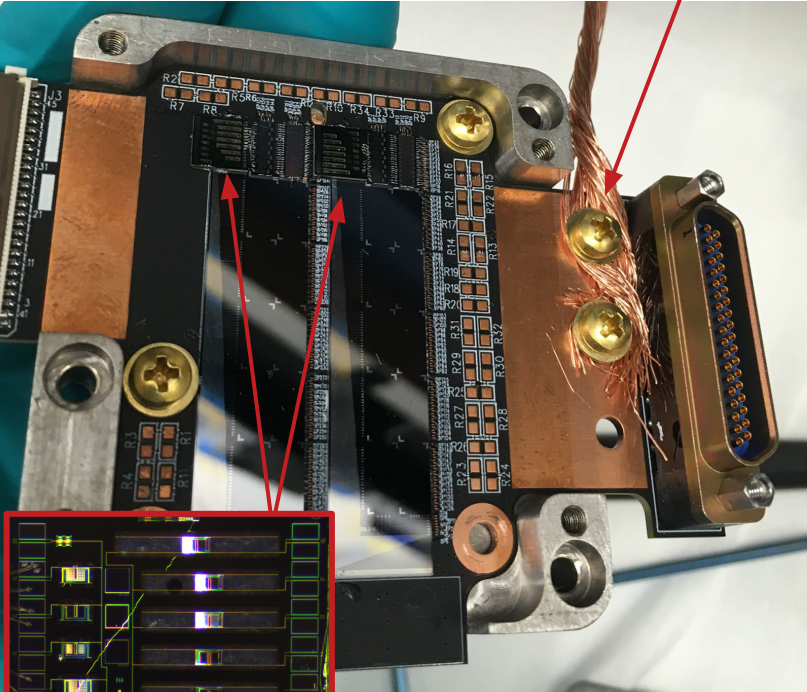100 mK readout module

100 mK

CMB-S4

Significant Progress In R&D: Full-String Tests With 100mK Readout Module

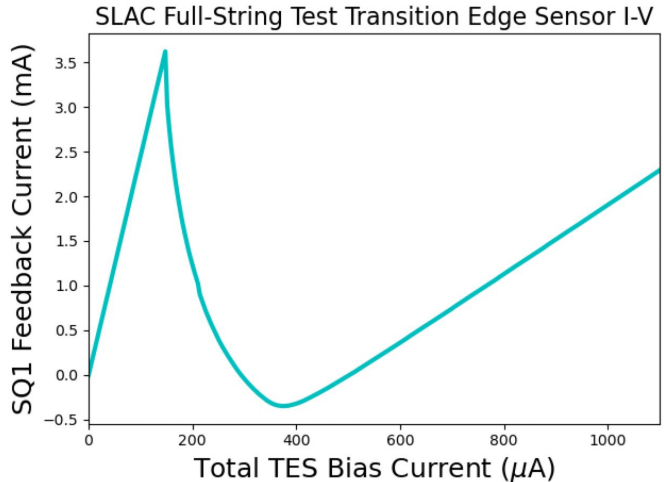OFHC copper straps on PCBs

ROX on PCB

Nb module

Al module

NIST TES bolo chips bonded directly to inputs: many 27, 90,150, 280 GHz devices

SLAC DR 100mK MXC plate

Full-String Test Results With 100mK Readout Module: SQUID Tuning And TES Biasing Into Transition

100% readout channel yield for first two 100mK readout modules after rework.

Measured SQUID performance matches NIST screening data.

2nd Stage SQUID Series Array Curve

Operating points

1st Stage SQUID Series Array Curve

Operating points

11-row MUX chip

simplified readout column schematic

↓ more rows
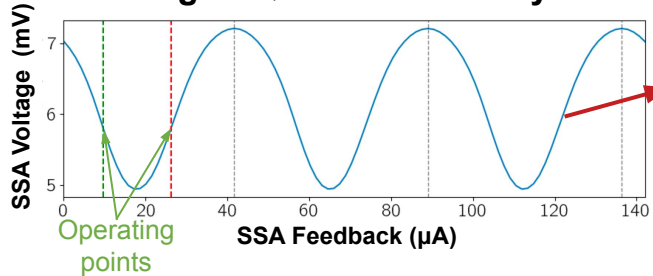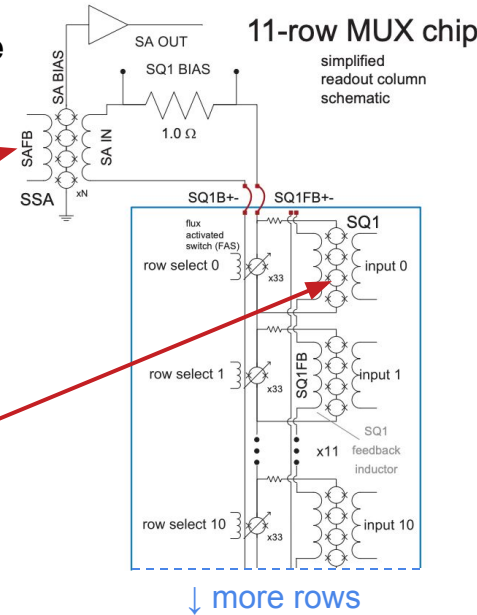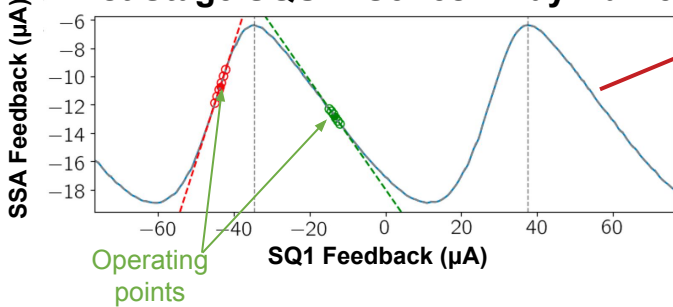
Able to recover signals injected into SQ1 inputs, take TES current vs voltage characterization data (IVs) and bias TESs into transition.

Installation and measurements by Shawn Henderson.

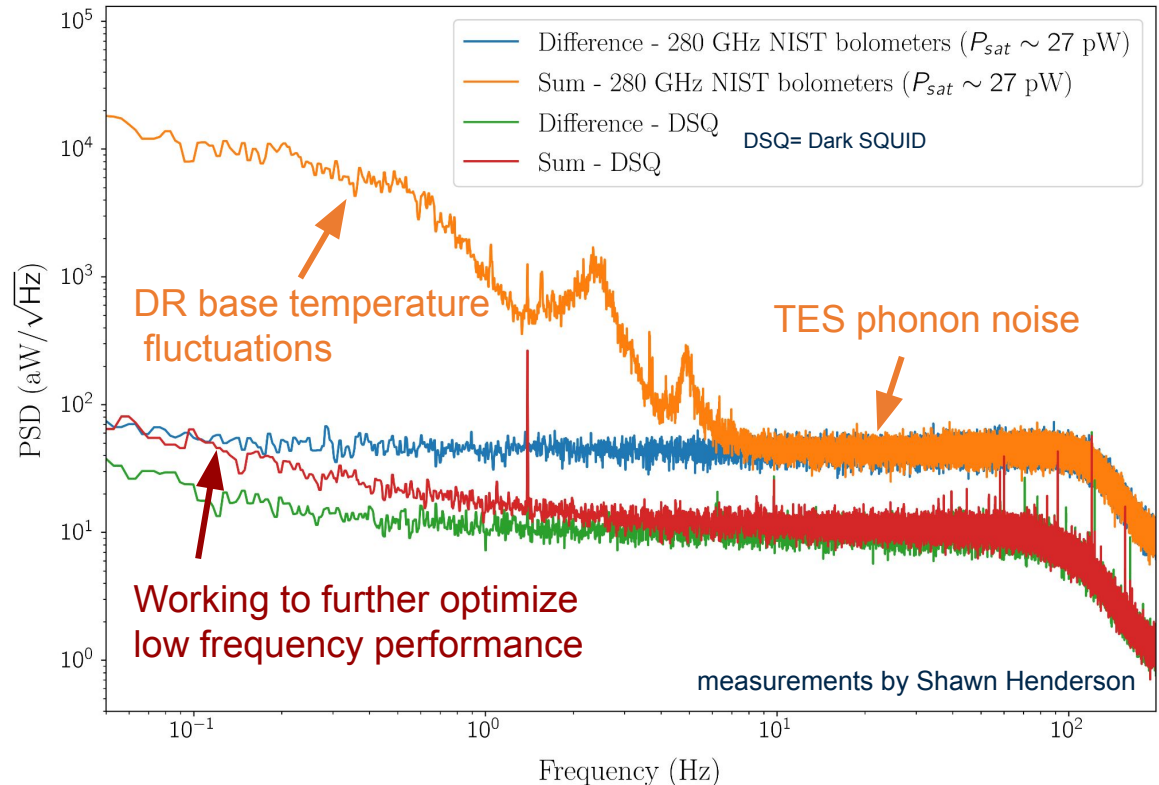# Full-String Test Results With 100mK Readout Module: Characterized TES+SQUID noise performance

- End-to-end characterization in progress with TESs connected to readout.
  - Readout performance consistent with expectations.
  - Developing end-to-end readout + TES model.

- Using test TES bolometers, able to explore performance over full range of CMB-S4 TES P_{sat} (30-280 GHz optimized devices).
  - Characterizing pairs of NIST TES test devices.

SLAC Readout String Test with NIST Bolometers

Legend:
- Difference - 280 GHz NIST bolometers ($P_{sat} \sim 27$ pW)
- Sum - 280 GHz NIST bolometers ($P_{sat} \sim 27$ pW)
- Difference - DSQ
- Sum - DSQ

DSQ= Dark SQUID

DR base temperature fluctuations

TES phonon noise

Working to further optimize low frequency performance

measurements by Shawn Henderson

PSD (aW/$\sqrt{Hz}$) vs Frequency (Hz)

Backup