Ratio of frequency-to-dissipation response in MKID resonators

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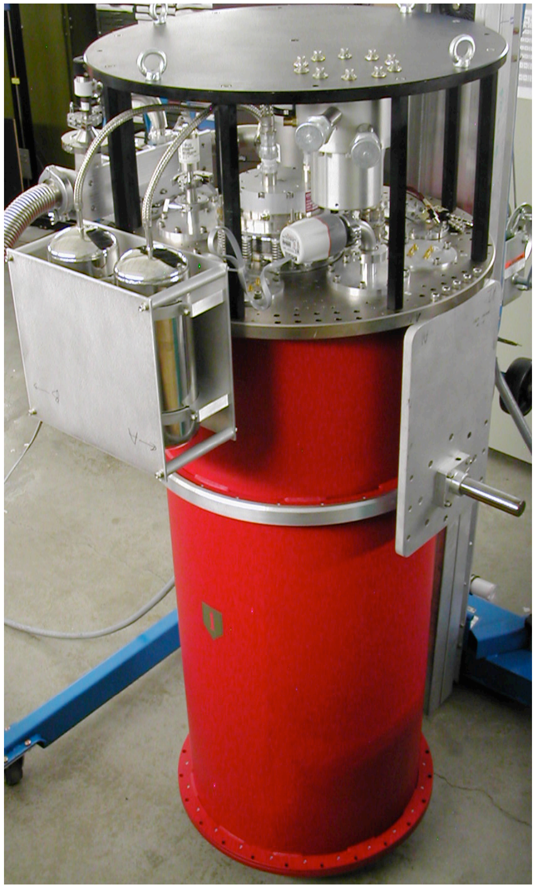
and the MUSIC collaboration



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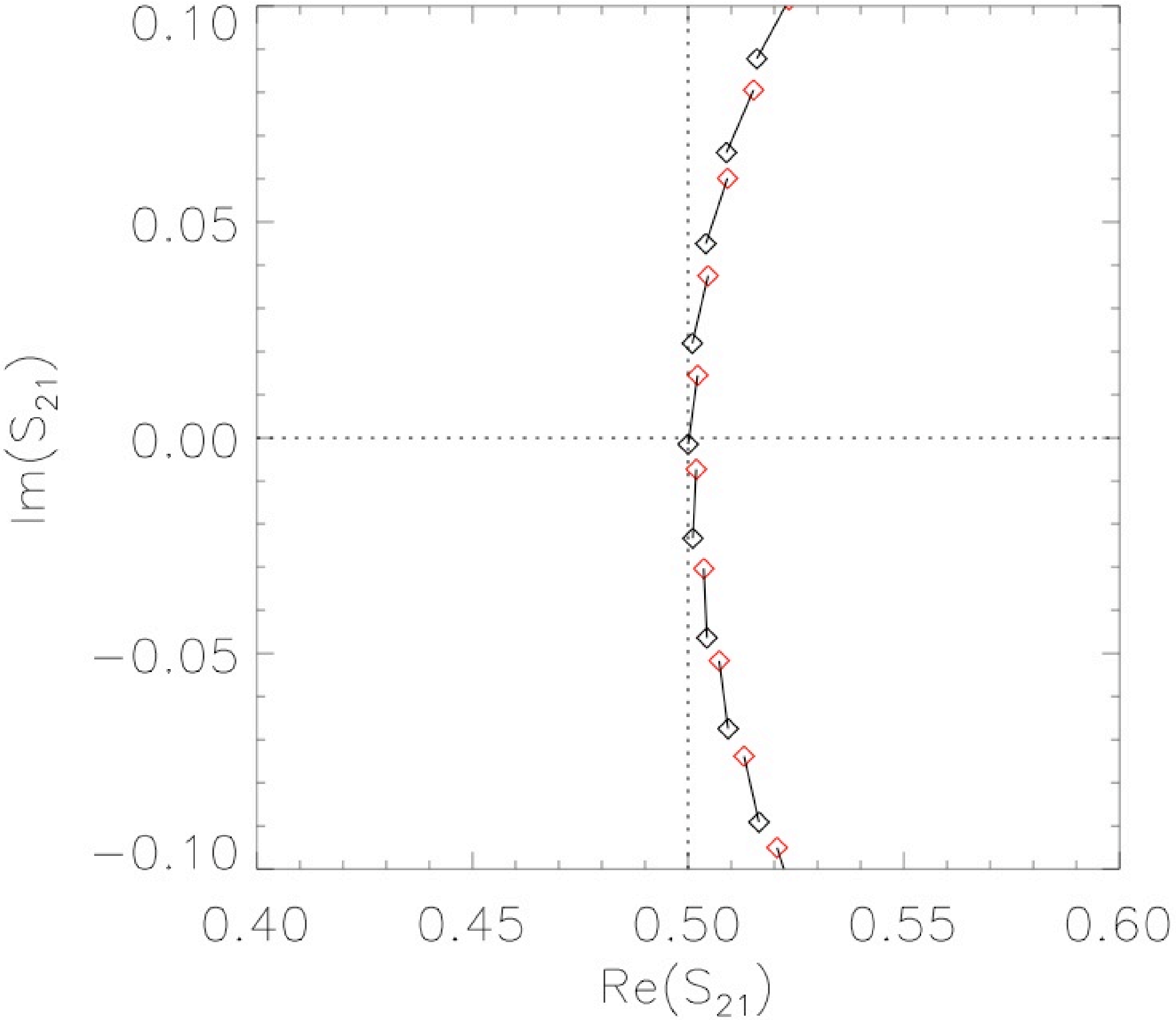
Overview

- Introduction
- Part I: using the frequency-to-dissipation ratio as a diagnostic tool
- Part II: how the ratio changes at high readout powers ($P_{read}>>P_{opt}$); how this affects sensitivity

Quasiparticle response in an MKID - both frequency and dissipation

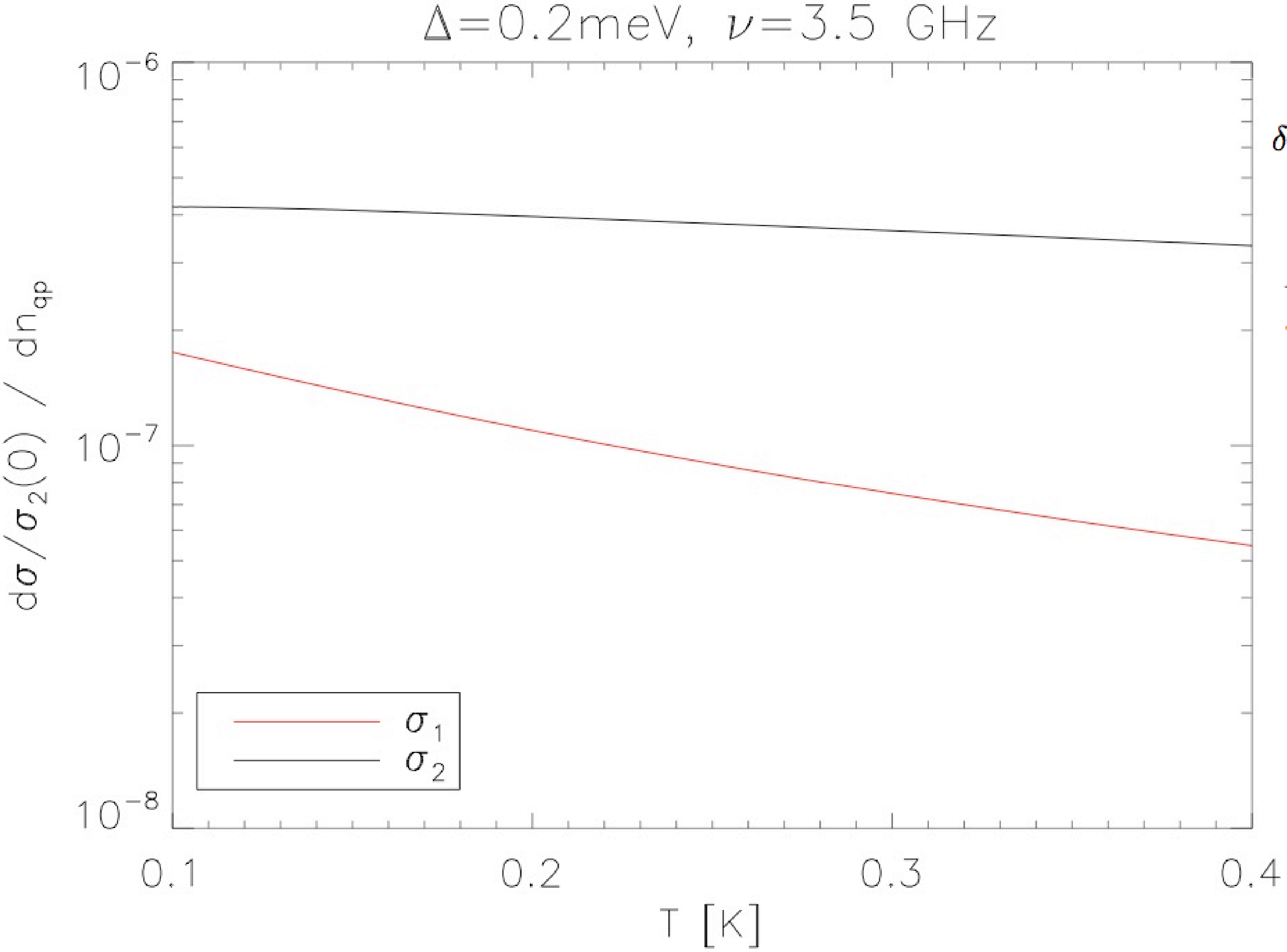


Response to 2.8 kHz shift;

Here, frequency response =

4.5 x dissipation

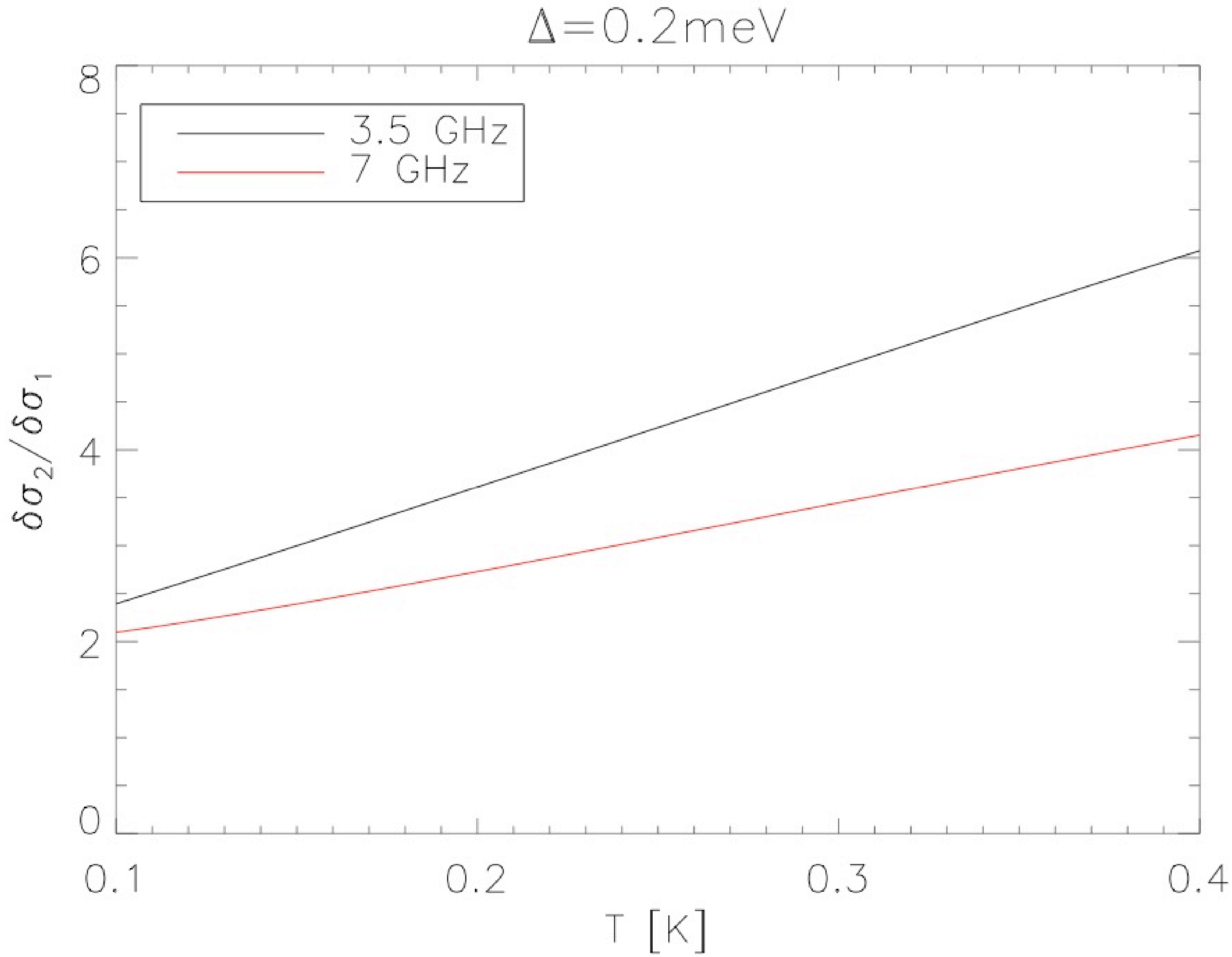
Responsivity in σ_1 and σ_2 decline with temperature



$$\delta\left(\frac{1}{Q_i}\right) = \alpha\frac{\delta\sigma_1}{\sigma_2(0)}$$

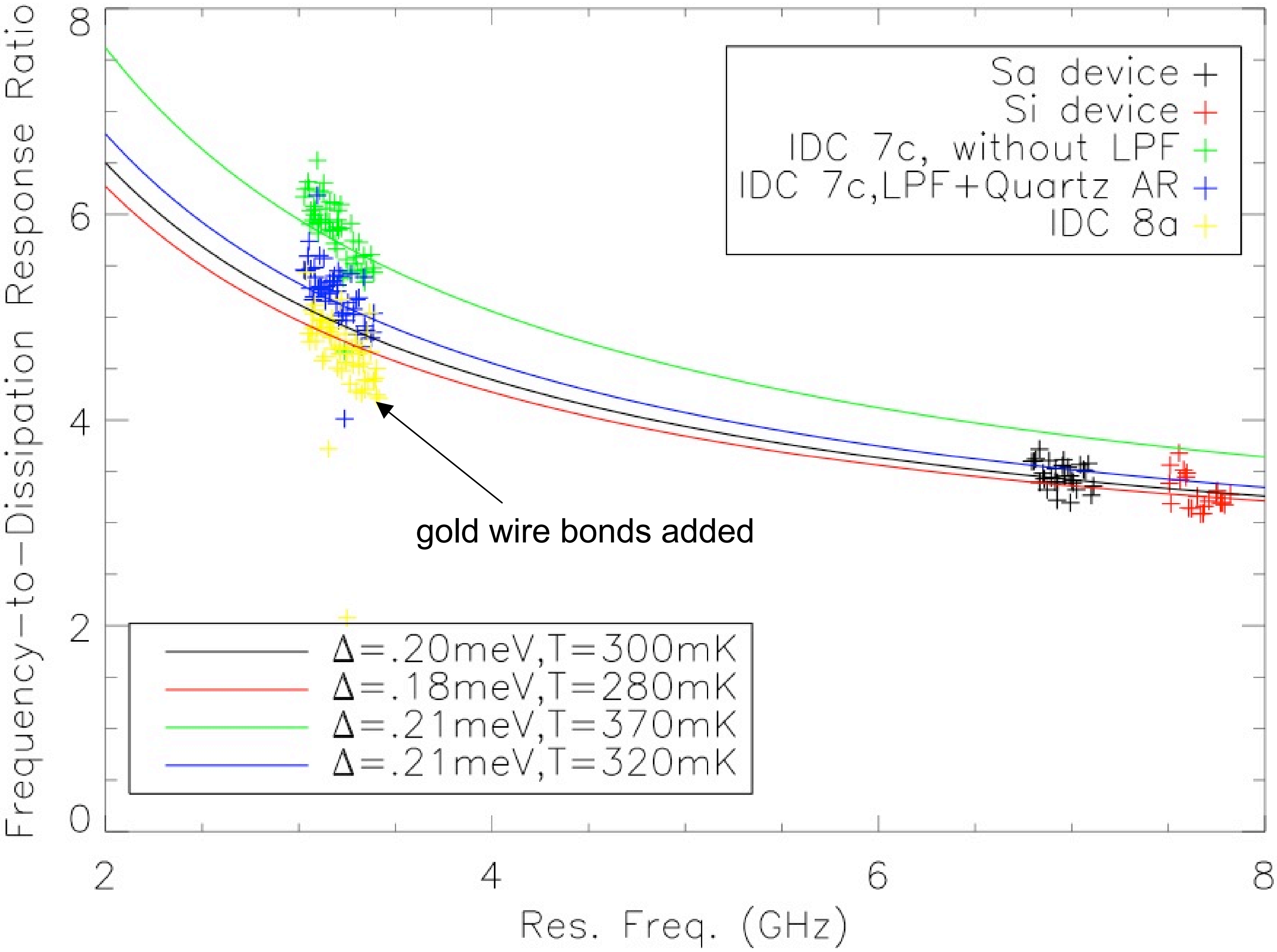
$$\frac{\delta f_0}{f_0(0)} = \frac{\alpha}{2}\frac{\delta\sigma_2}{\sigma_2(0)}$$

Ratio is heavily temperature dependent

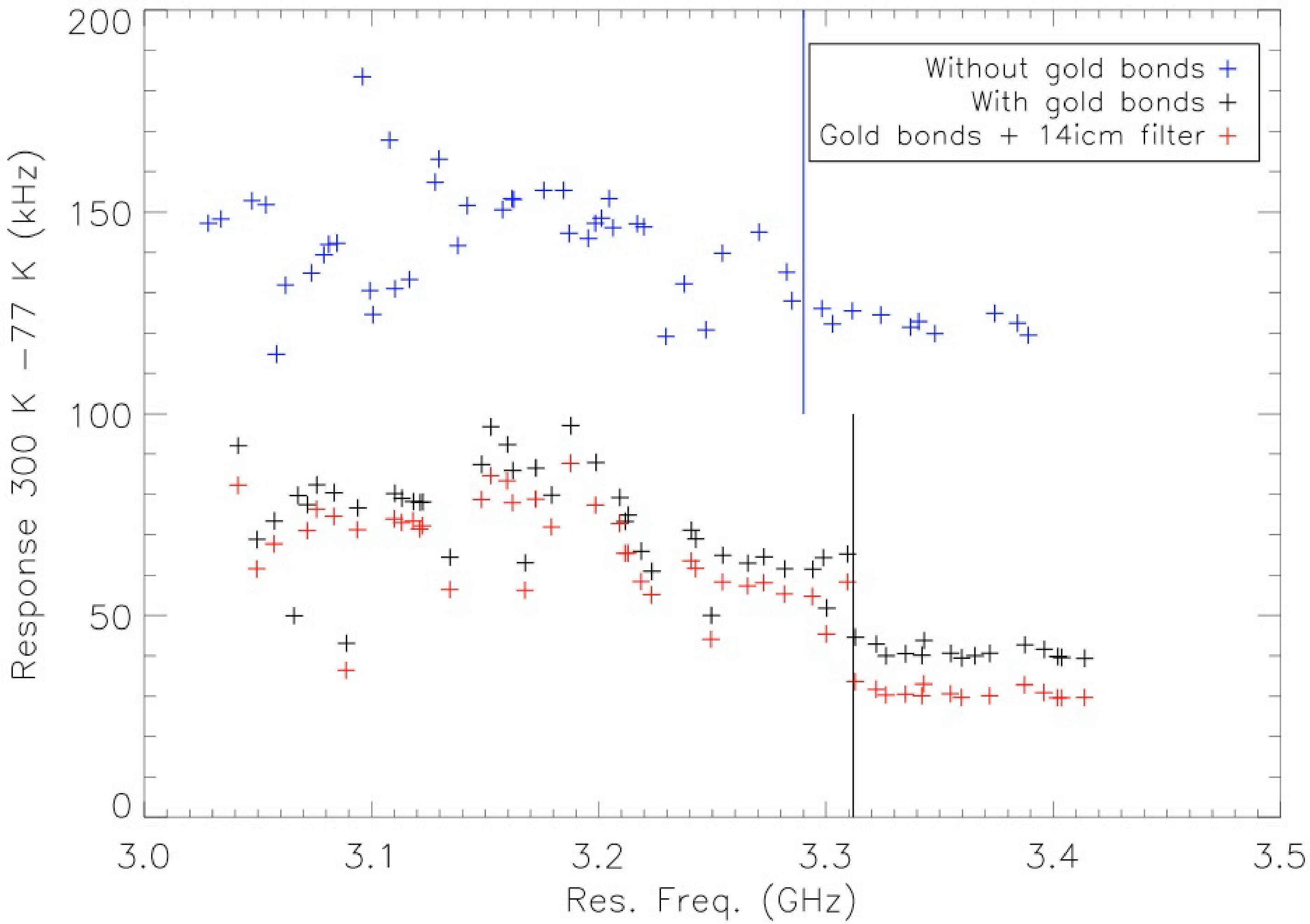


We can use this as a diagnostic tool

Can diagnose substrate heating under load

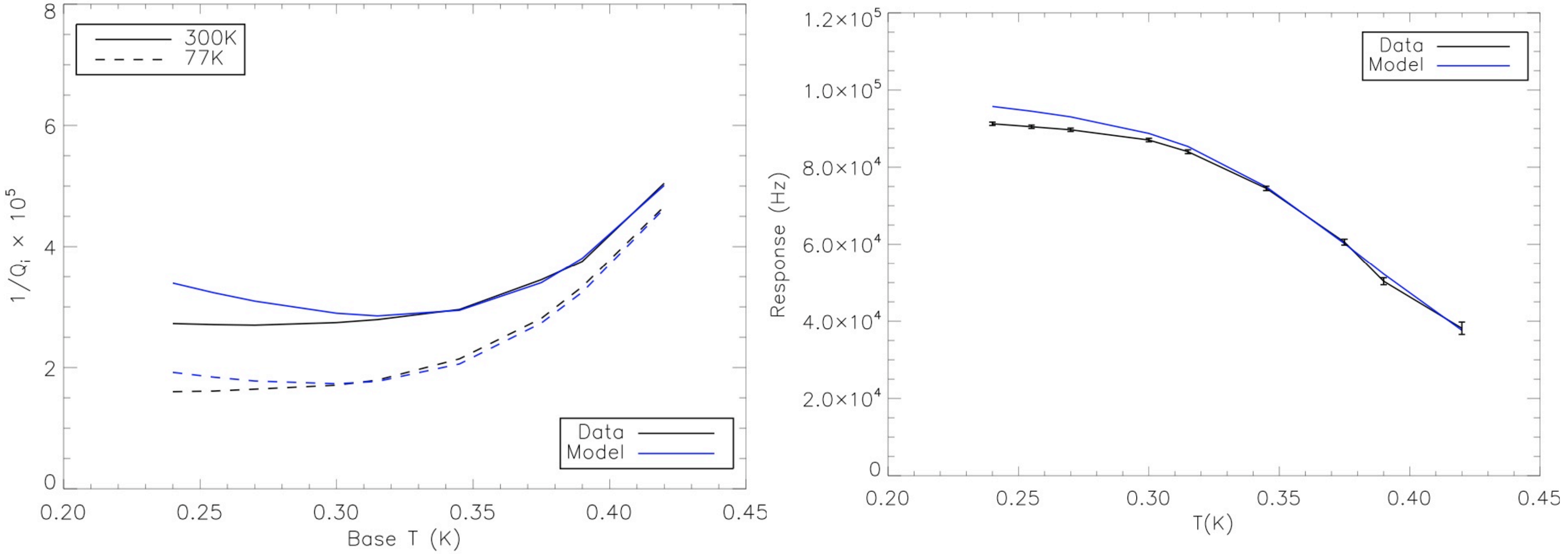


“Dark” detectors greatly decrease in response to hot/cold loads



Antenna-coupled (Light) | Dark

Are quasiparticle temps already elevated relative to substrate under optical load?



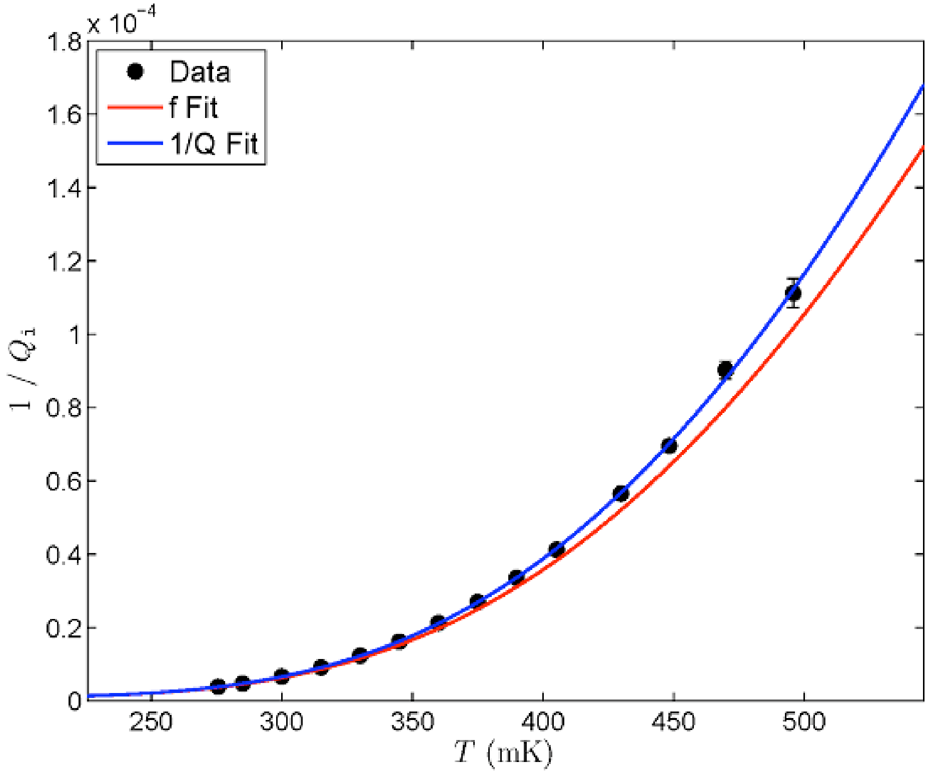
Resonator $1/Q_i$ under 77K/300K optical load

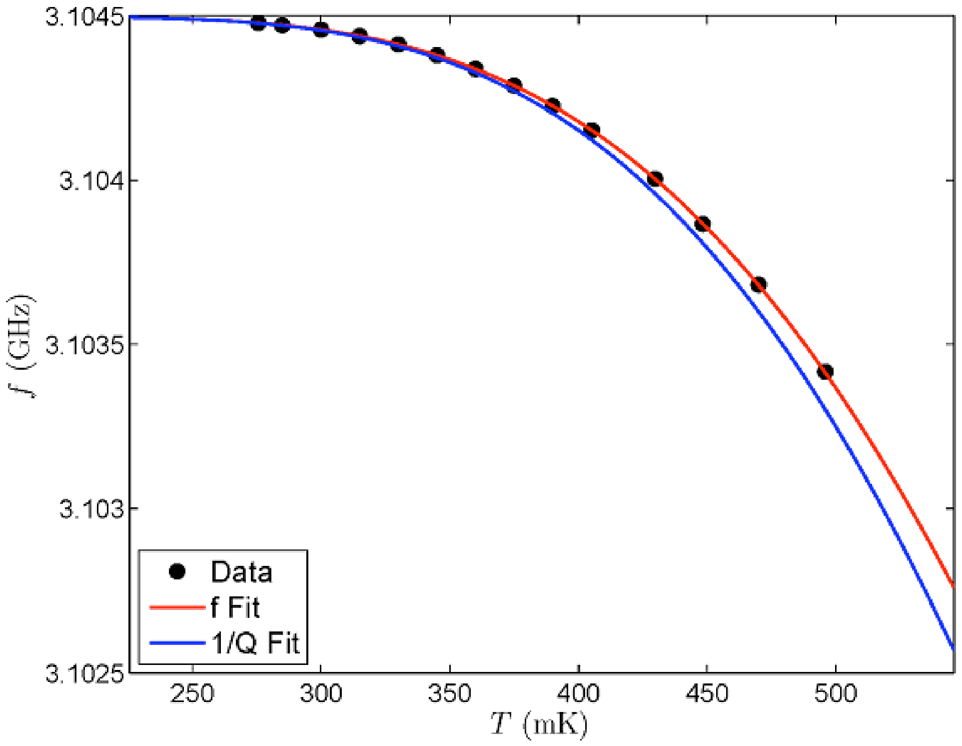
$|f_{300} - f_{77}|$

290 GHz antenna-coupled resonator

Clear departure from Mattis-Bardeen (blue) at low temperature; hurts dissipation response most

A quandary - temperature sweep fits to δ(1/Q) and δf give different α





Figures courtesy of Seth Siegel

Part 2: High readout power

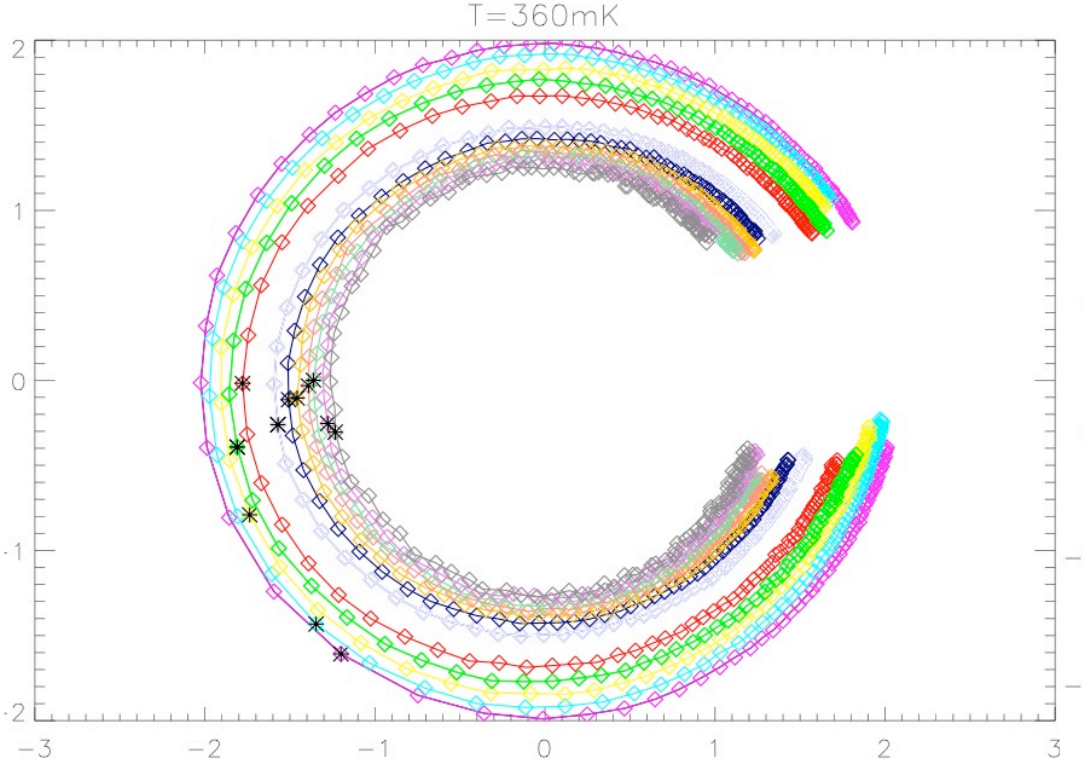
Two effects

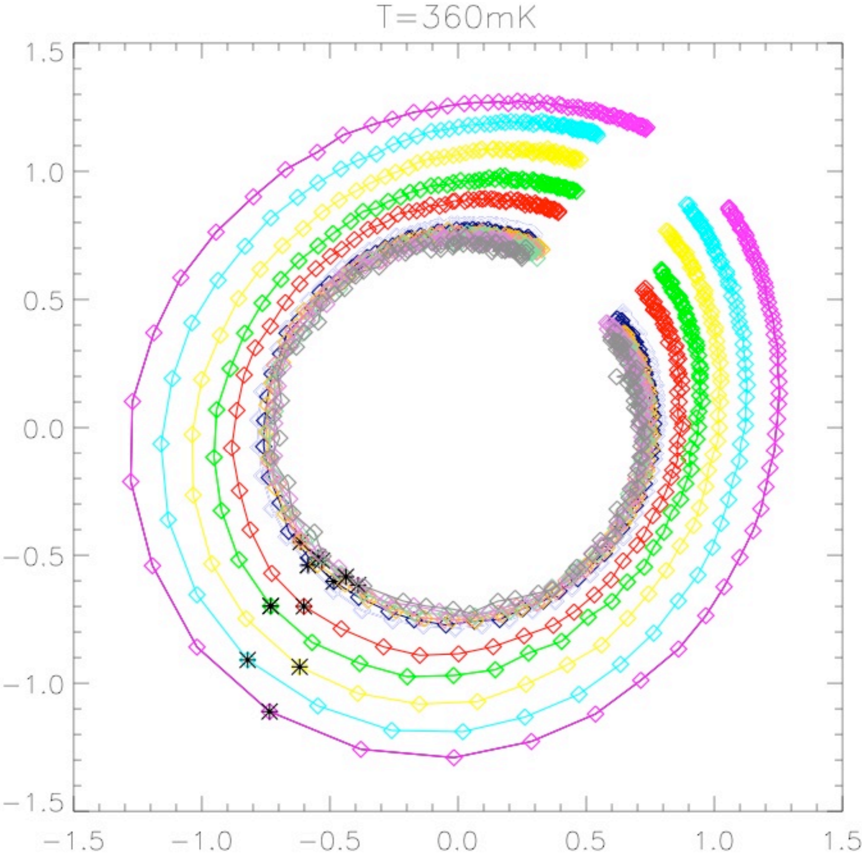
- Heating of quasiparticles gives lower frequency response and much lower dissipation response

- Distortion of resonances makes frequency and dissipation responses non-orthogonal; direction perpendicular to resonance loop

High power with steady-state qp population

P_{read} from -101 dBm to -73 dBm

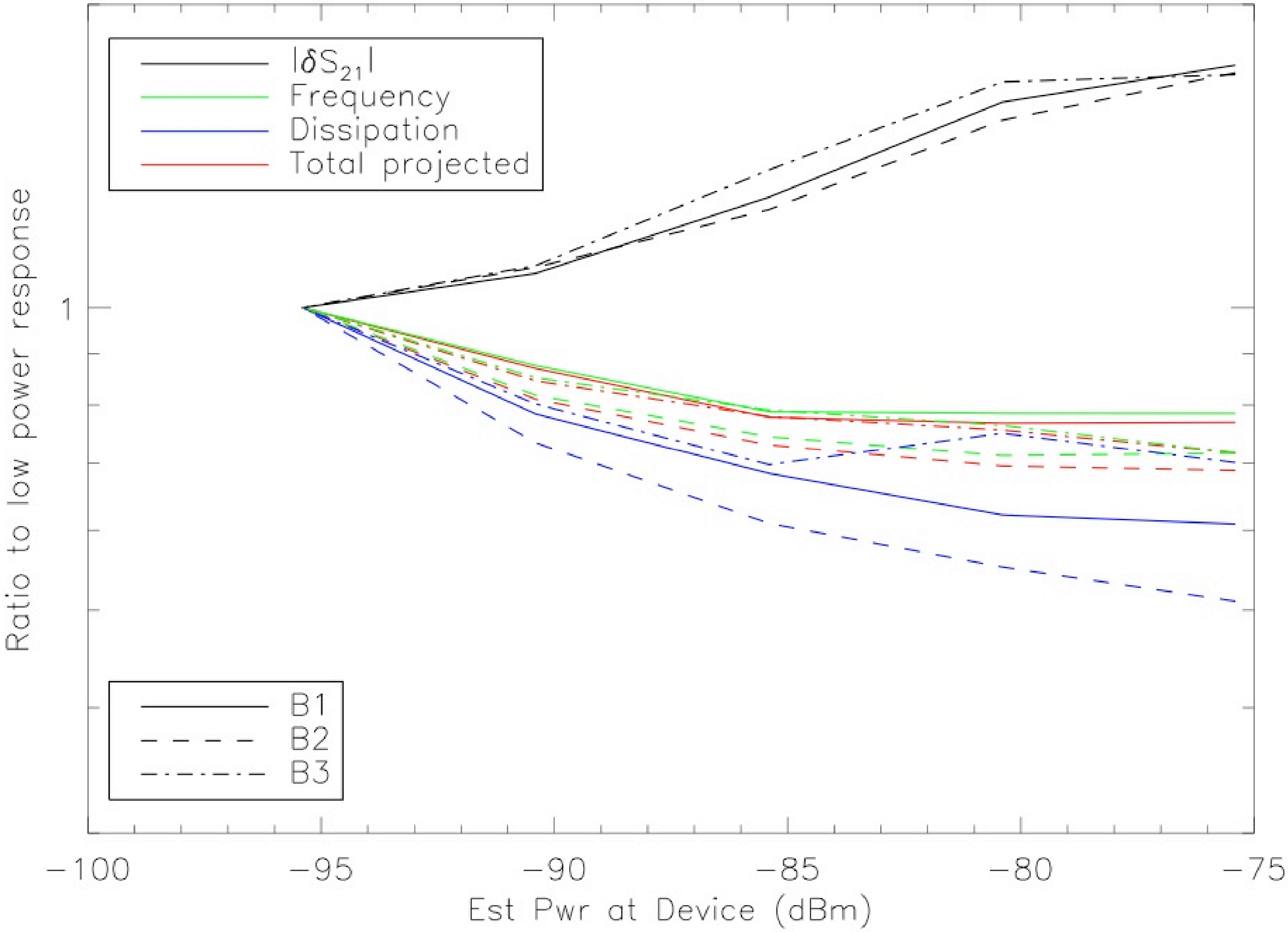




Higher power gives bigger resonance loops: less $\delta(1/Q)$ per quasiparticle

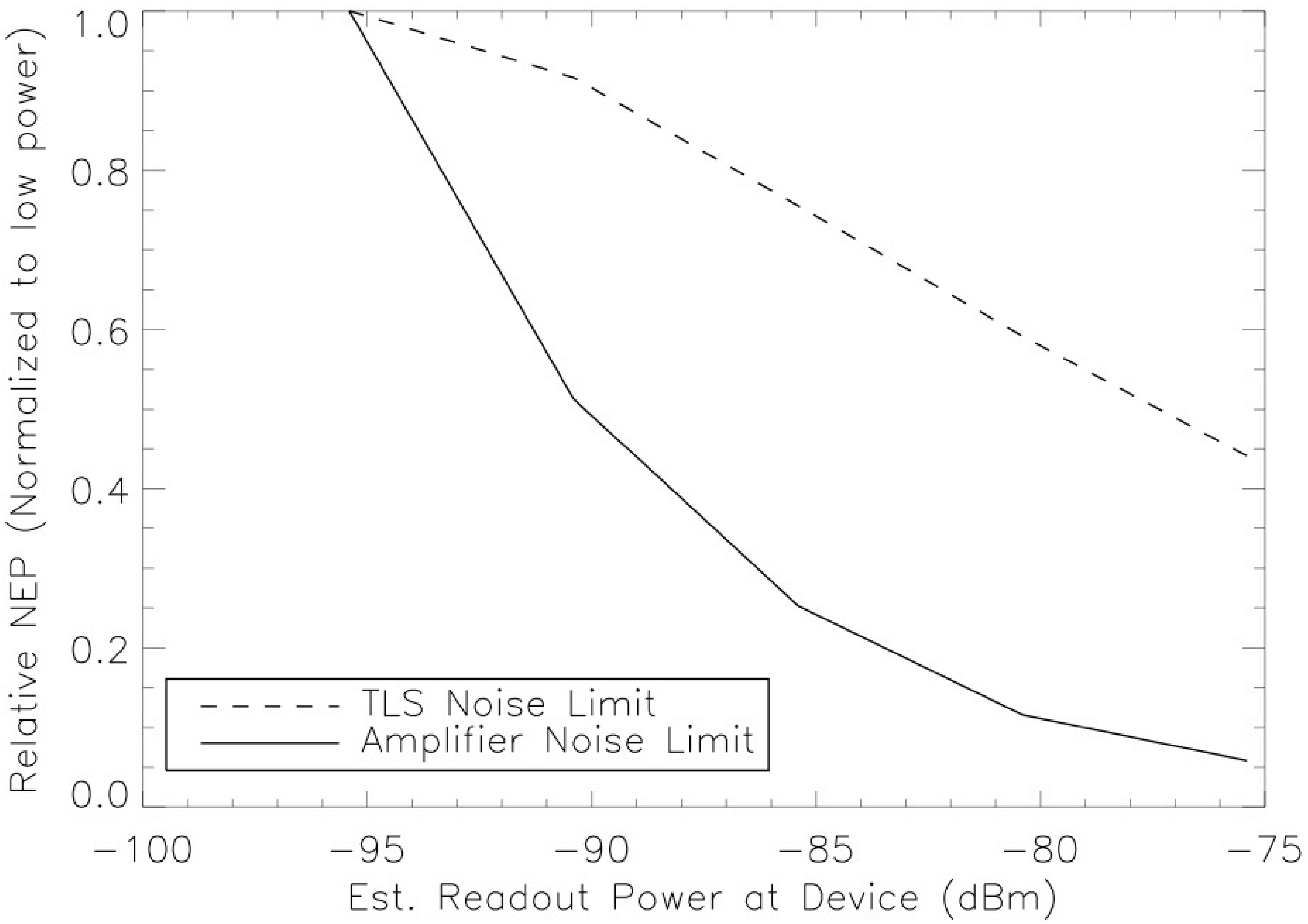
High power: do MKIDs win?

$$\delta S_{21} = \frac{Q^2}{Q_c}\left(\delta\frac{1}{Q_i} + 2i\frac{\delta f_0}{f_0}\right)$$



Band 1 = 230 GHz, Band 2 = 290 GHz, Band 3= 350 GHz

High power: MKIDs vs. types of noise



Not plotted above: multiplicative 1/f noise, needs more thought

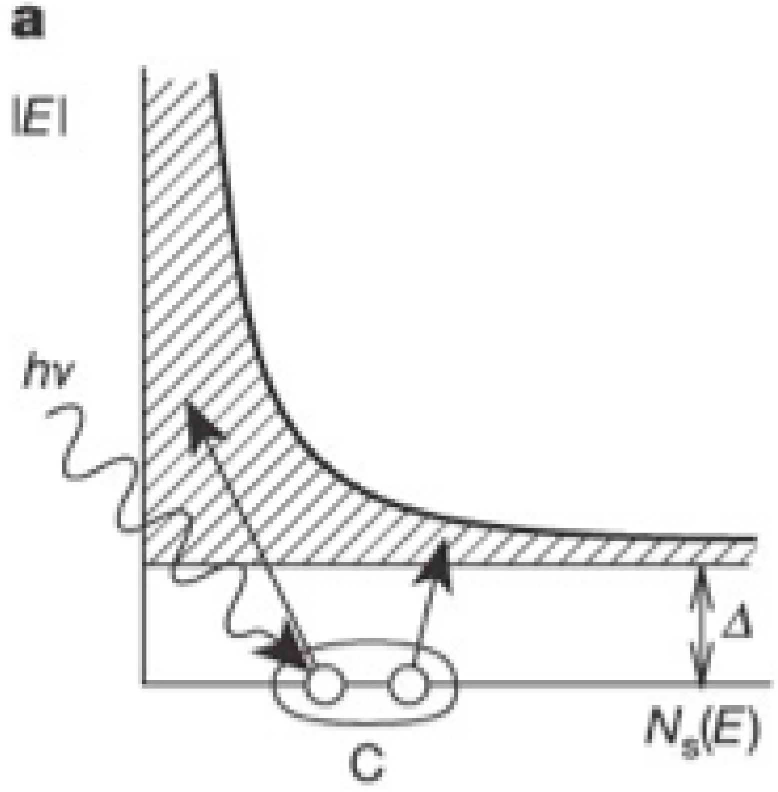
Conclusions

- Frequency-to-dissipation ratio can be a useful diagnostic tool for understanding quasiparticle energy distribution

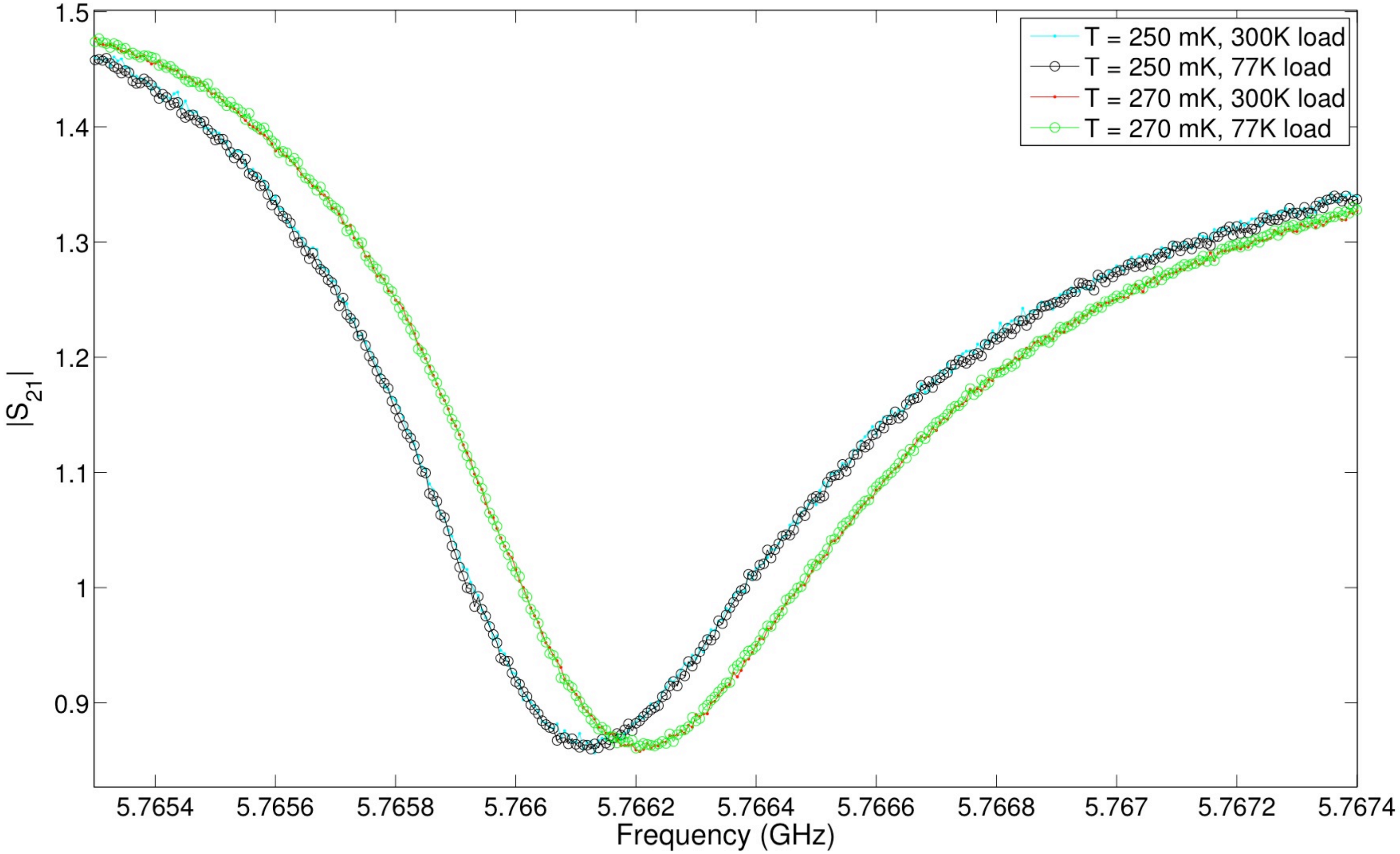
- Some anomalies are not entirely explained - is there a difference between thermal and submm-created quasiparticles, or just a model problem?

- High readout power can change this ratio in multiple ways; may be beneficial (higher Q under load) or not (reduced responsivity)

Fermi thermal distribution

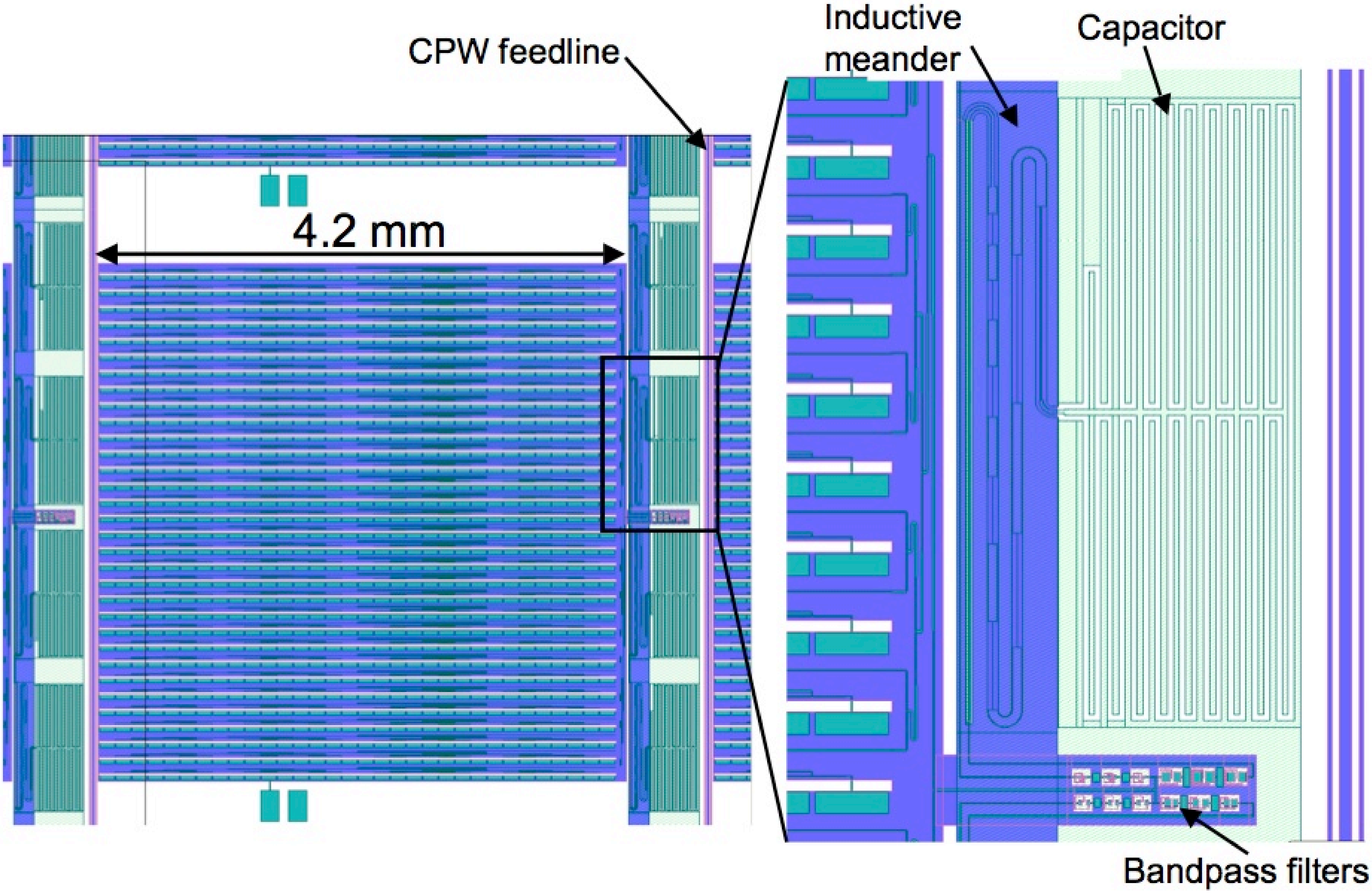


How do we know substrate still isn't heating up?



Nb resonance with parallel plate capacitor - temperature sensitive TLSs

MUSIC pixel


CPW feedline
4.2 mm
Inductive meander
Capacitor
Bandpass filters