Recombination times in aluminum co-planar waveguide KIDs

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How thin can you go: Does metal thickness affect recombination times?

INTRO

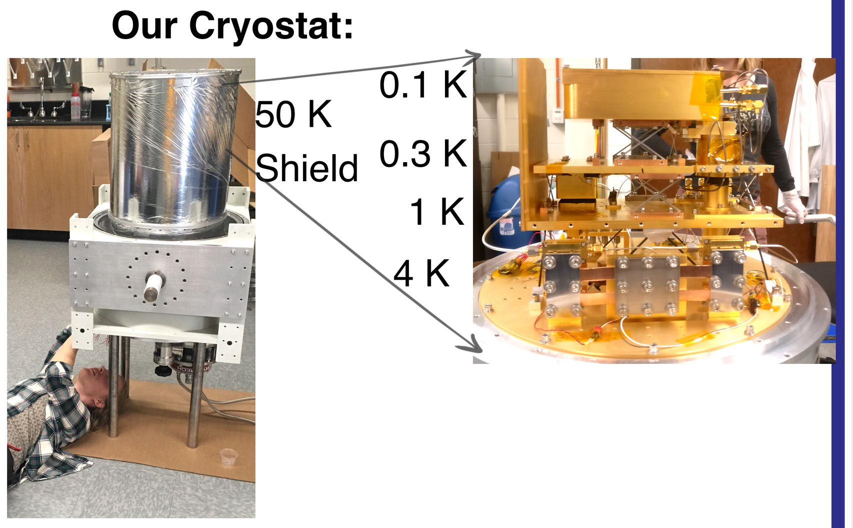
- Design study to approach low NEP's needed for Galaxy Evolution Probe [1]
- Want: long time constants *and* low volume
- Time constant τ : how long it takes quasiparticles to recombine

METHODS

- Detectors: 1/4 (grounded) and 1/2 λ (ungrounded) coplanar waveguide aluminum kinetic inductance detectors
- 20, 30, 40, 50 nm thick films
- Center conductor widths 0.6, 1.5 μm and 3 μm
- Fiber-optic carries IR LED pulses 300 K -> 100 mK
- Average 240 pulses
- Fit the following to decay[2]:

$$X(t) = \frac{A}{[1+1/x_{qp}(0)]\exp(t/\tau_{qp})-1}$$

Our Cryostat:



RESULTS

- τ similar for 30-50 nm films:

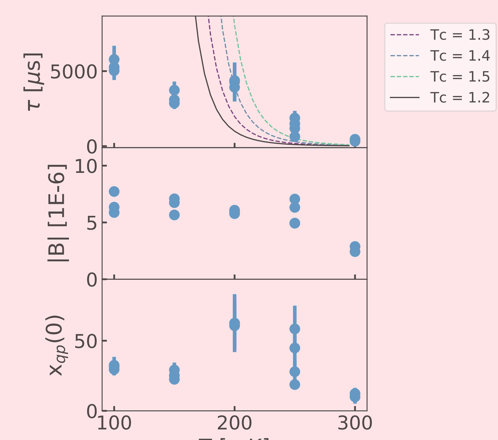
Thickness [nm]	τ [ms]
20	2.5-5
30	1-2.5
40	1-1.8
40 1/2 λ	1-2.2
50	1-1.8

- τ decreases with readout power

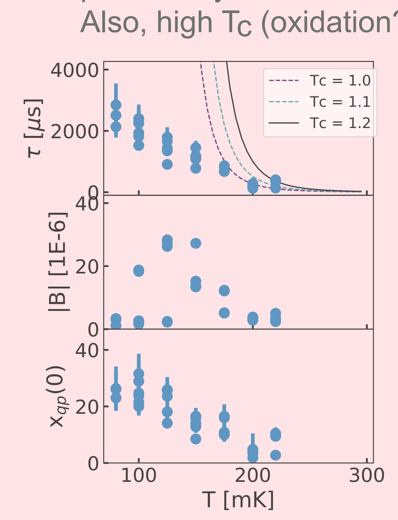
DISCUSSION

- Diffusion of quasiparticles into ground plane doesn't seem to matter
- High readout powers suppress time constants
- X(t) parameterization fits well but sensitive to noise

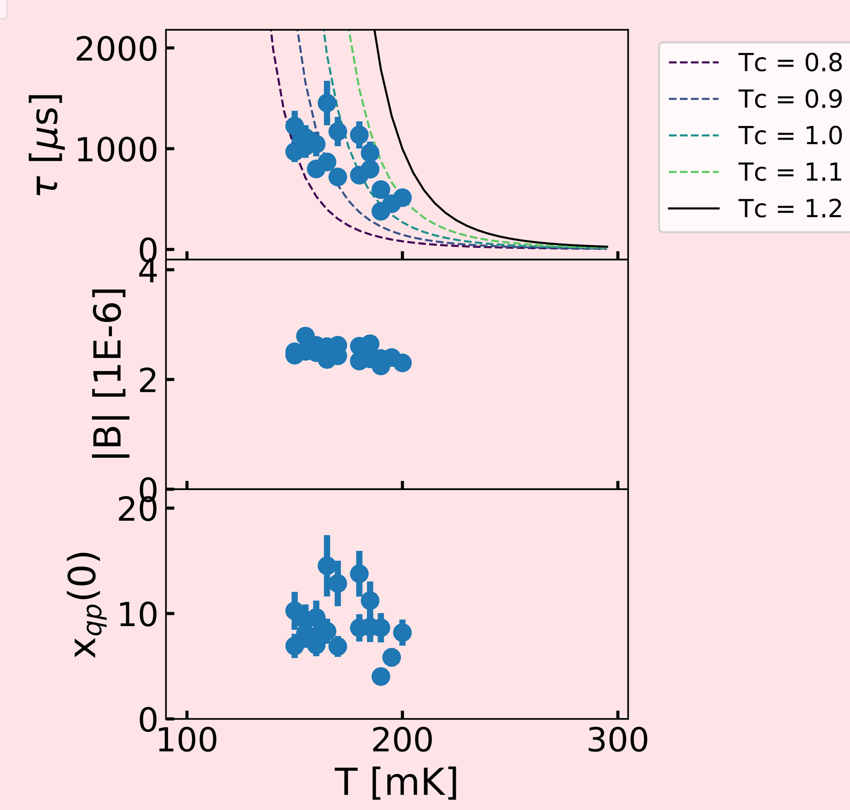
For 1/4 wavelength aluminum CPWs, 40 and 50 nm thick films have same time constant: ~1-1.8 ms.



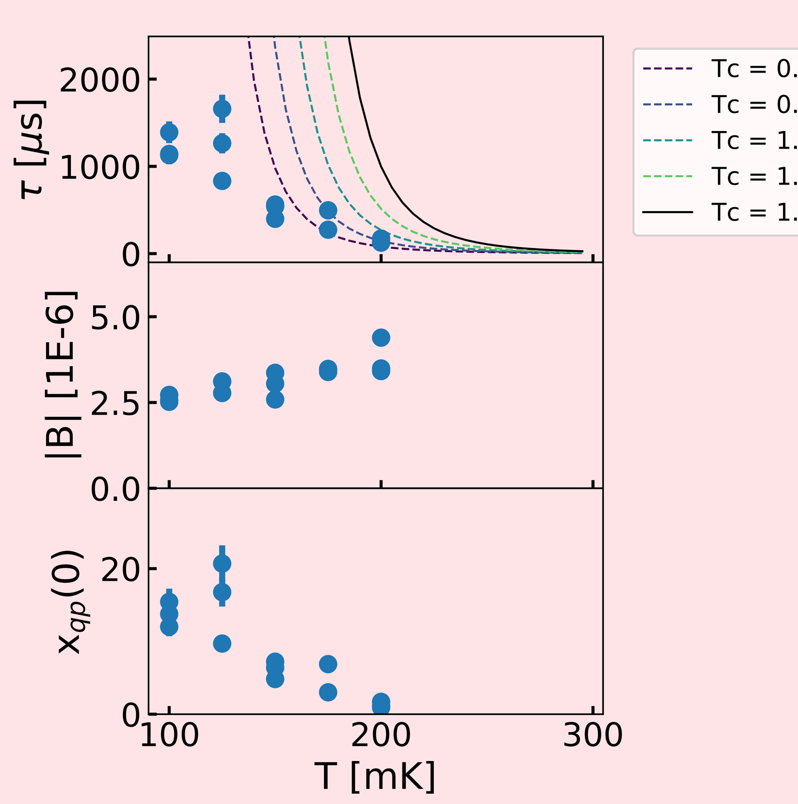
20 nm 1/4 λ:
preliminary τ ~ 2.5-5 ms.
Also, high T_C (oxidation?)



30 nm 1/4 λ:
preliminary τ 1-2.5 ms

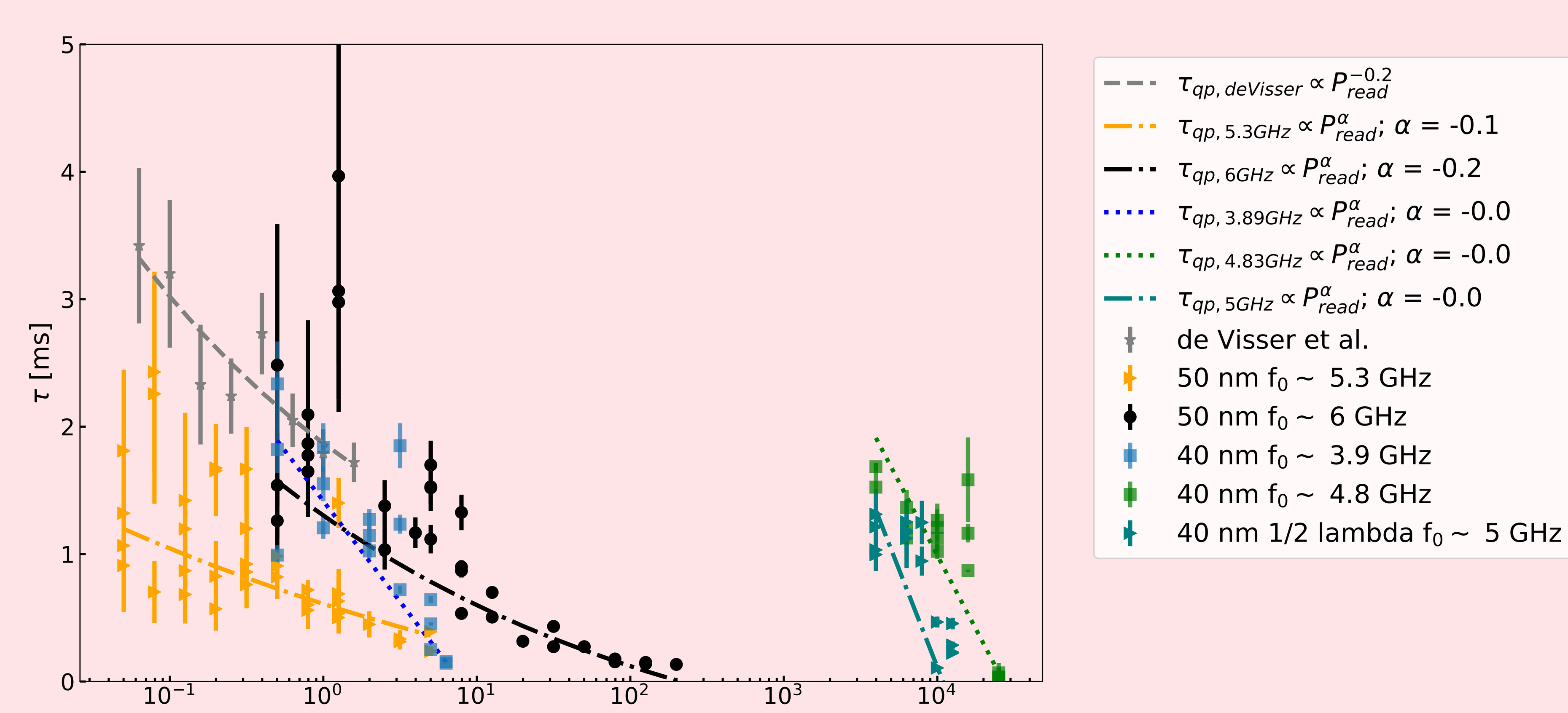


40 nm 1/4 λ
Center conductor width 1.5 μm



50 nm 1/4 λ
Center conductor width 1.5 μm
Possible under-prediction (note low T_C)

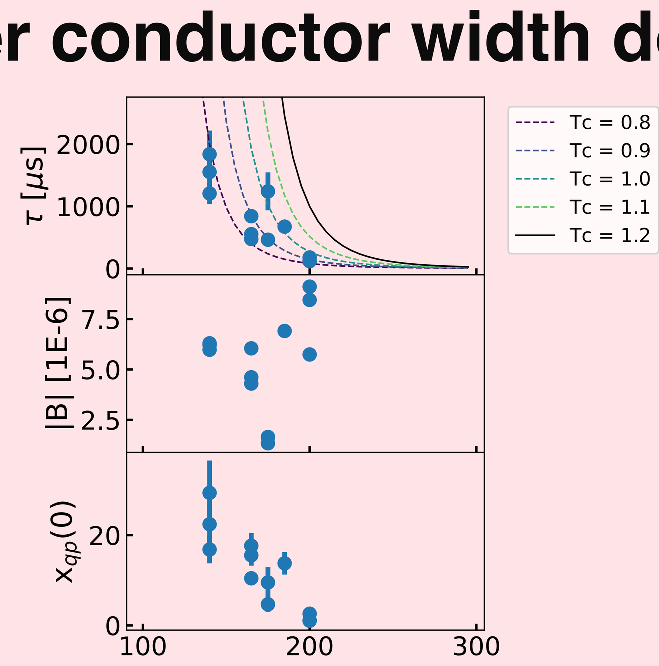
Time constants decrease with readout power



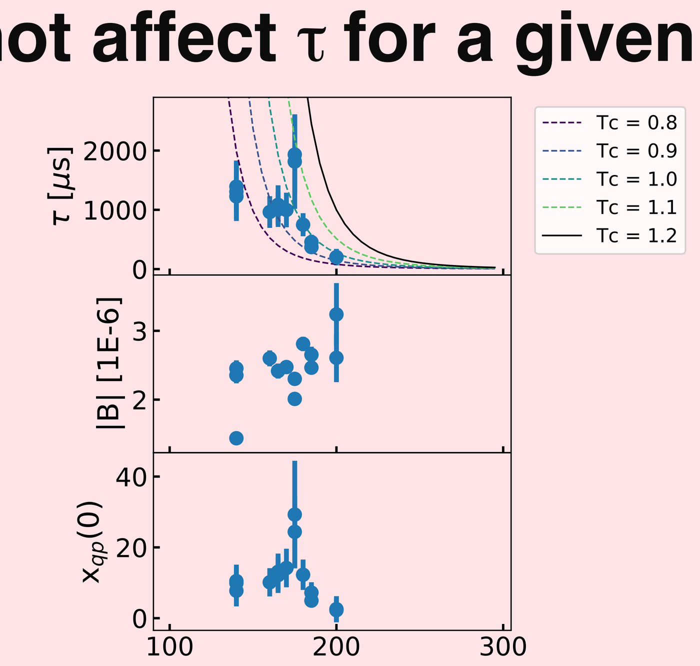
Observed behavior: flat and then a decay.
Grey data points for comparison :
de Visser, Baselmans, Bueno, Llombart, Klapwijk
Nature Communications volume 5, Article number: 3130 (2014)

Quasiparticle diffusion into ground plane does not seem to matter for grounded devices:

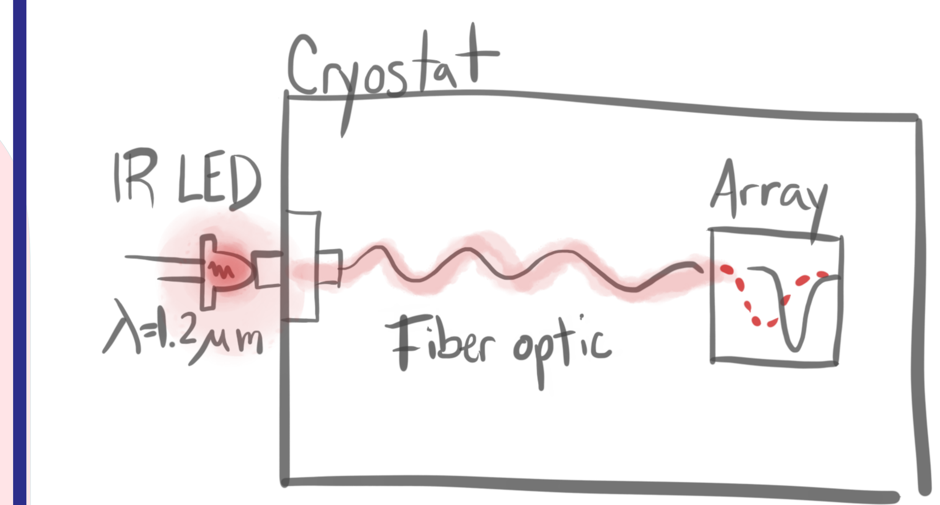
- **1/2 λ ungrounded CPWs have ~ same τ as 1/4 λ grounded CPWs**
- **Center conductor width does not affect τ for a given array**



40 nm 1/4 λ
Center conductor width 0.6 μm

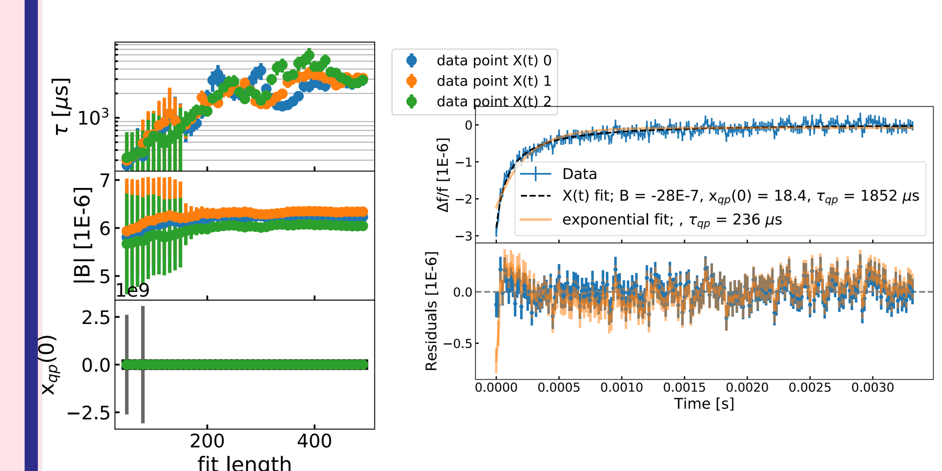


40 nm 1/2 λ
Center conductor width 1.5 μm
(compare to 1/4 λ devices above)

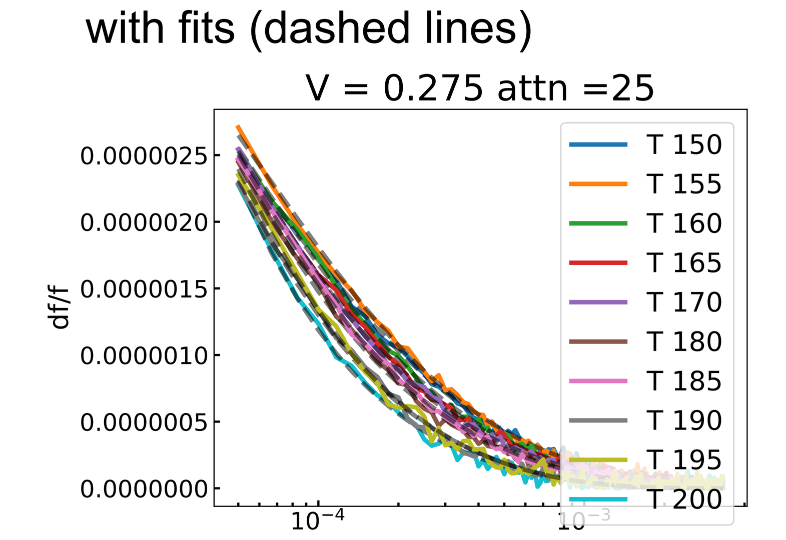


$$X(t) = \frac{A}{[1+1/x_{qp}(0)]\exp(t/\tau_{qp})-1}$$

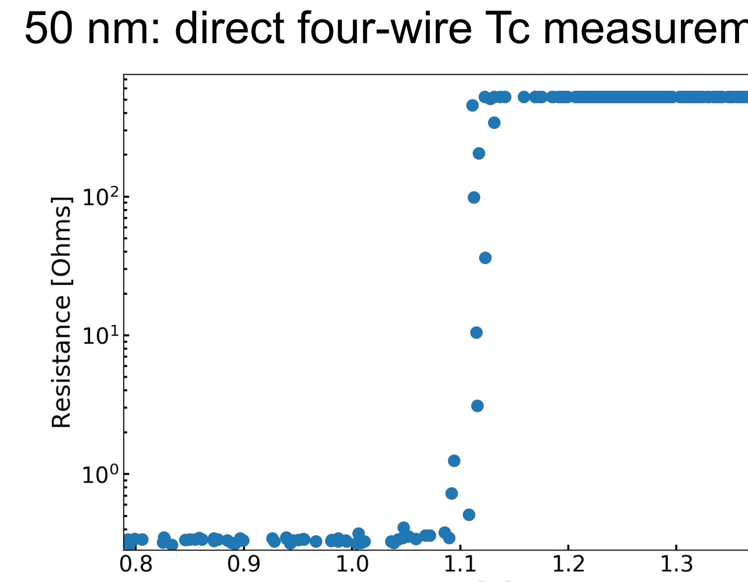
Fit parameters as a function of fit length (how much data we use) and an example fit



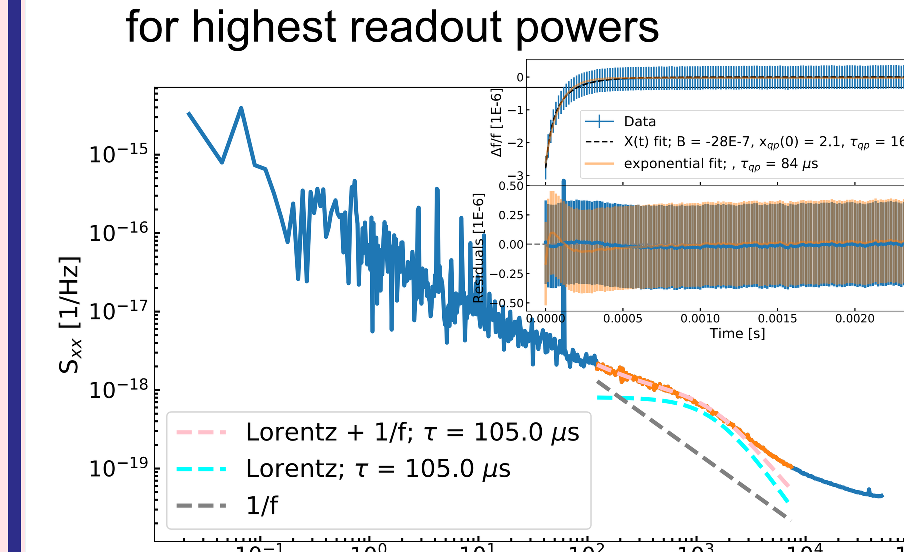
40 nm: temperature sweep of decay with fits (dashed lines)

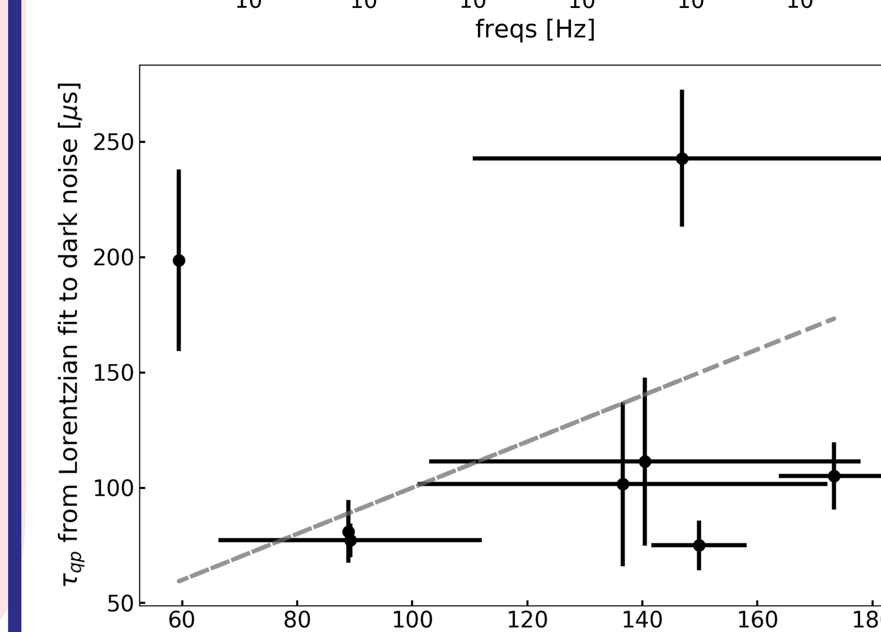


50 nm: direct four-wire Tc measurement



50 nm: corroboration with dark noise for highest readout powers





[1] Galaxy Evolution Probe Concept Study (2019), J.Glenn https://smd-prod.s3.amazonaws.com/science-red/s3fs-public/atoms/files/GEP_Study_Rpt.pdf

[2] Fyhrie et al. 2018, "Progress Towards Ultra-Sensitive KIDs for Future Far-Infrared Missions: A Focus on Recombination Times"