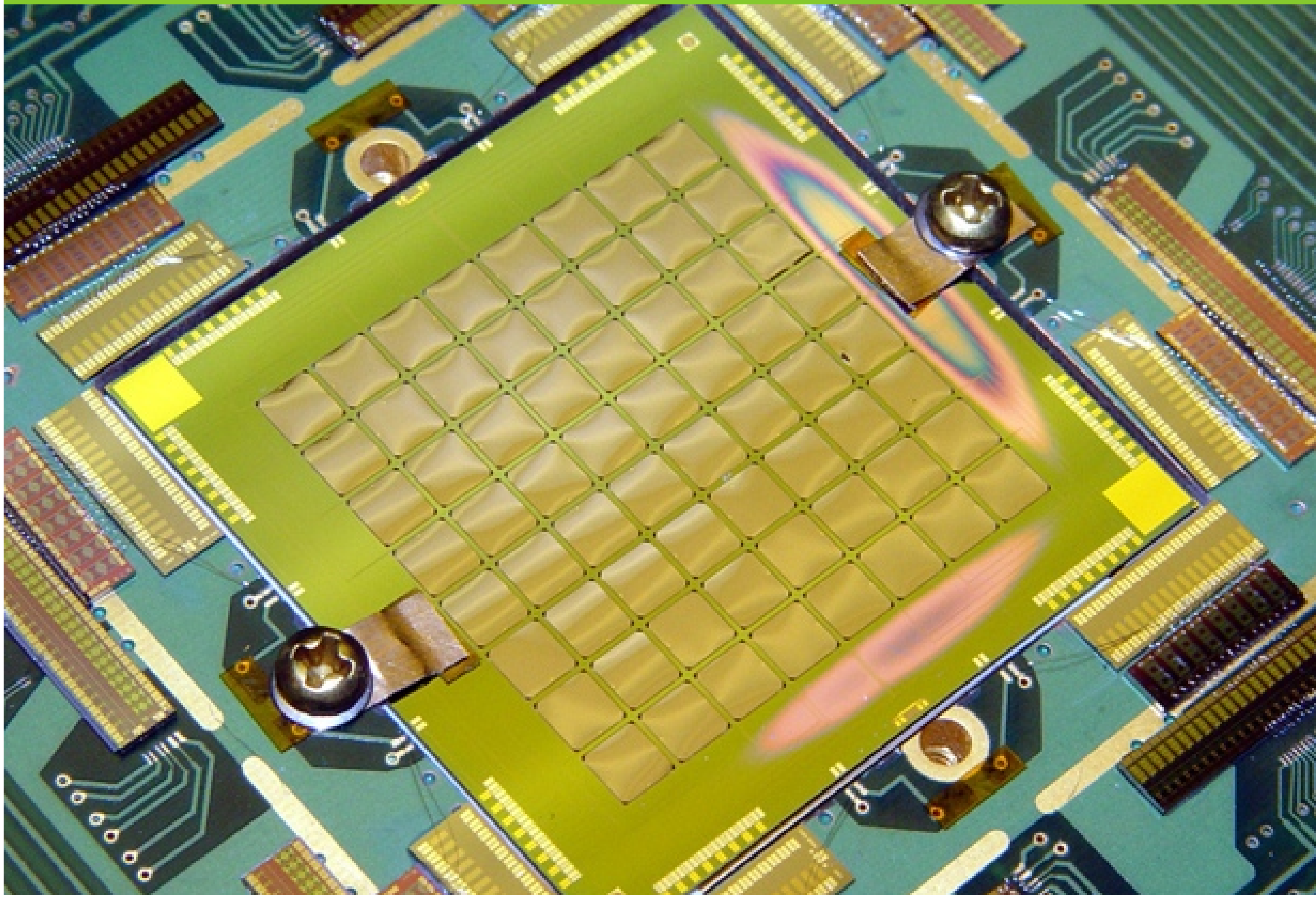
Characterizing the PAR Detectors

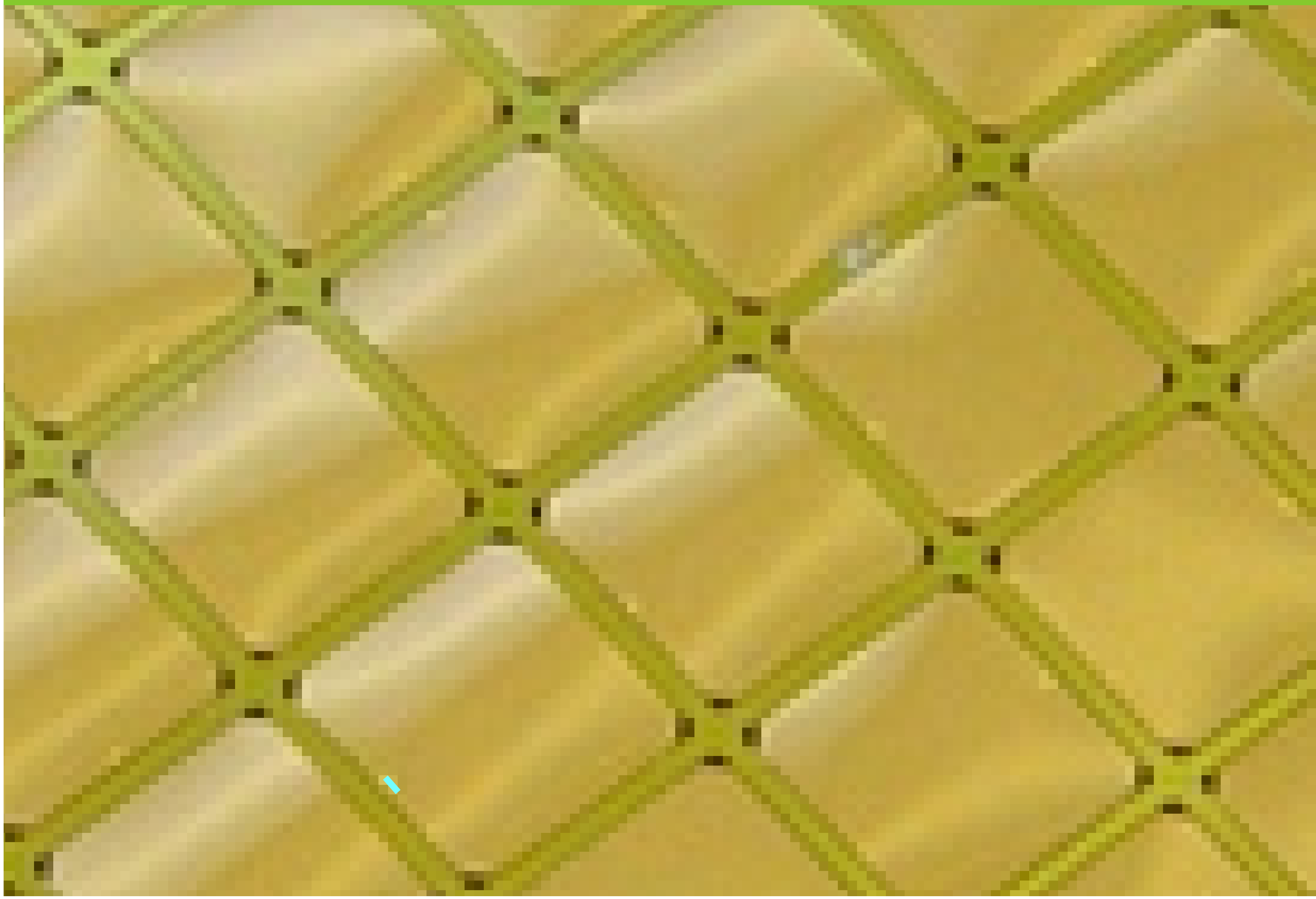
Enectali Figueroa-Feliciano, Miriam Huntley,
Youngsoo Park

All data from Simon, Phillip, et al. at UPenn

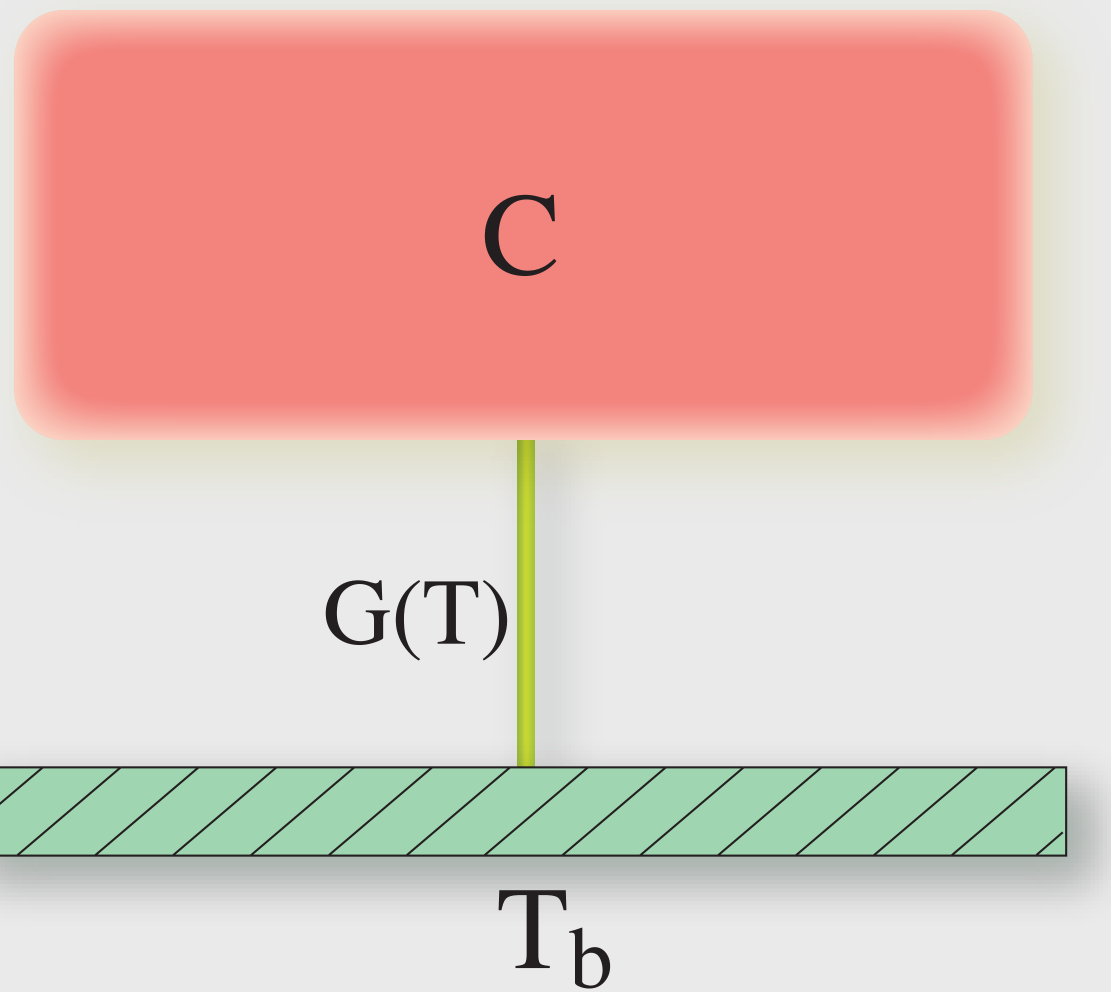
The UPenn Array



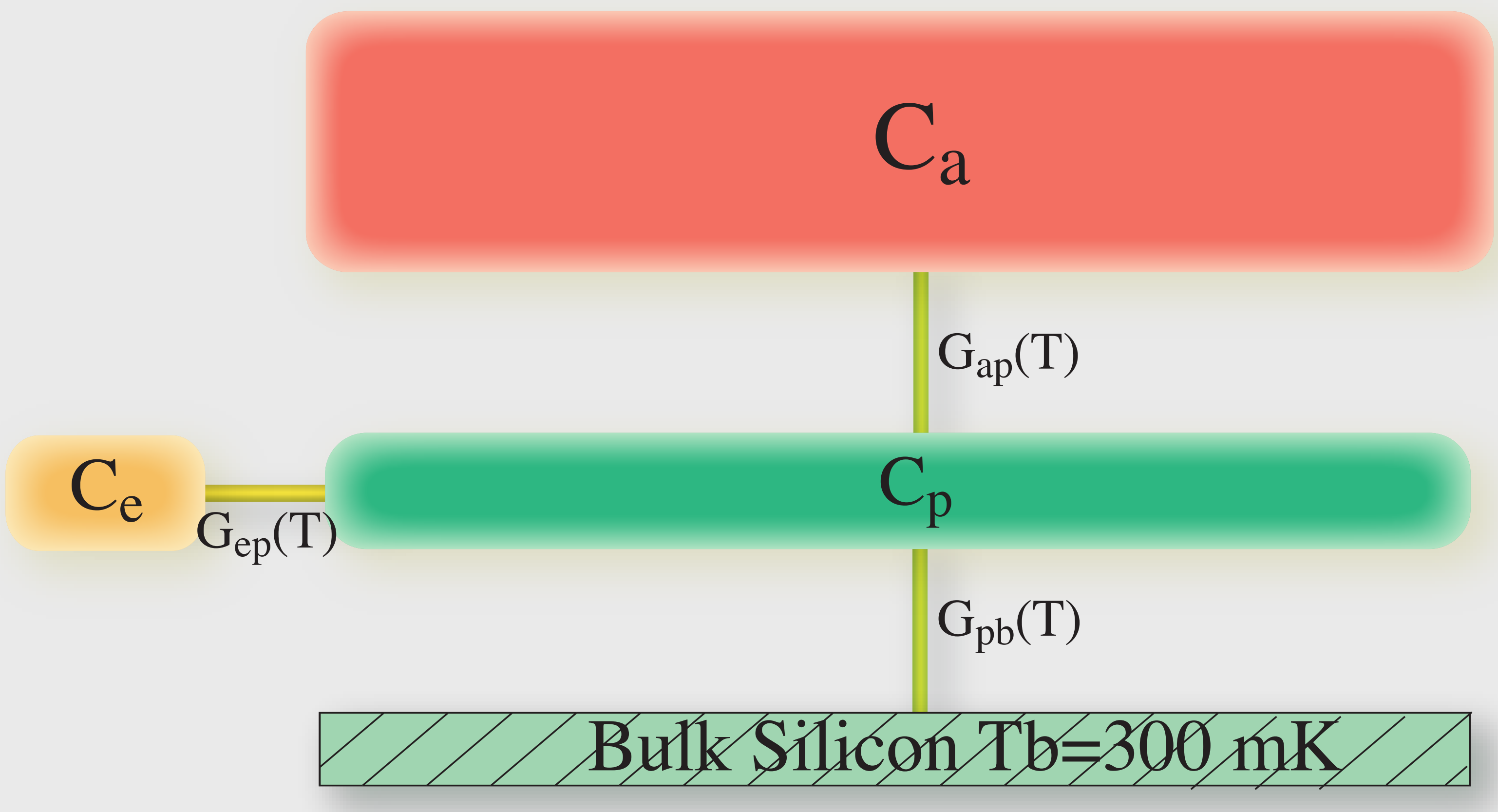
The TESs are Small!



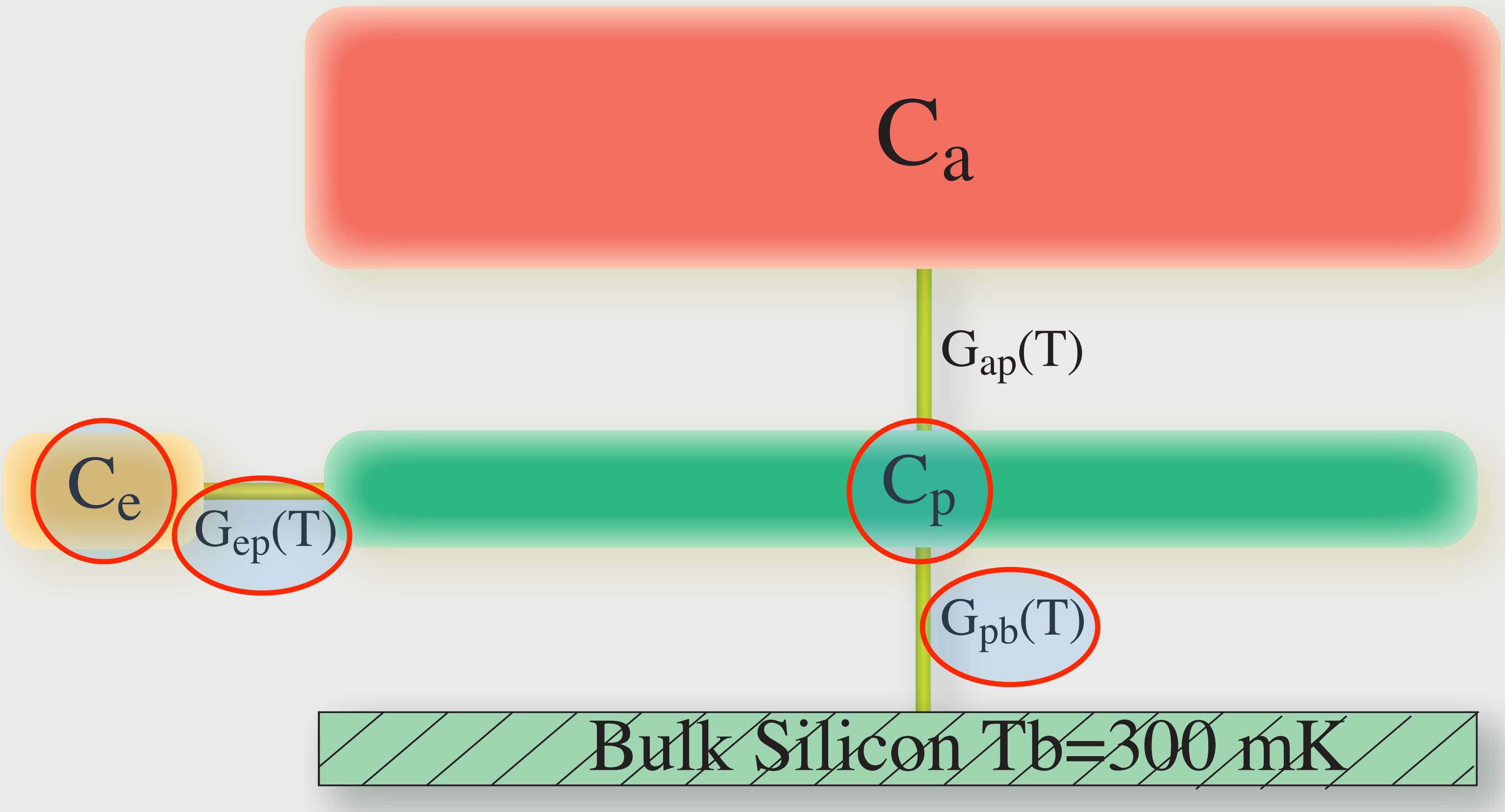
The Ideal Model



A Better Model



Estimating Parameters



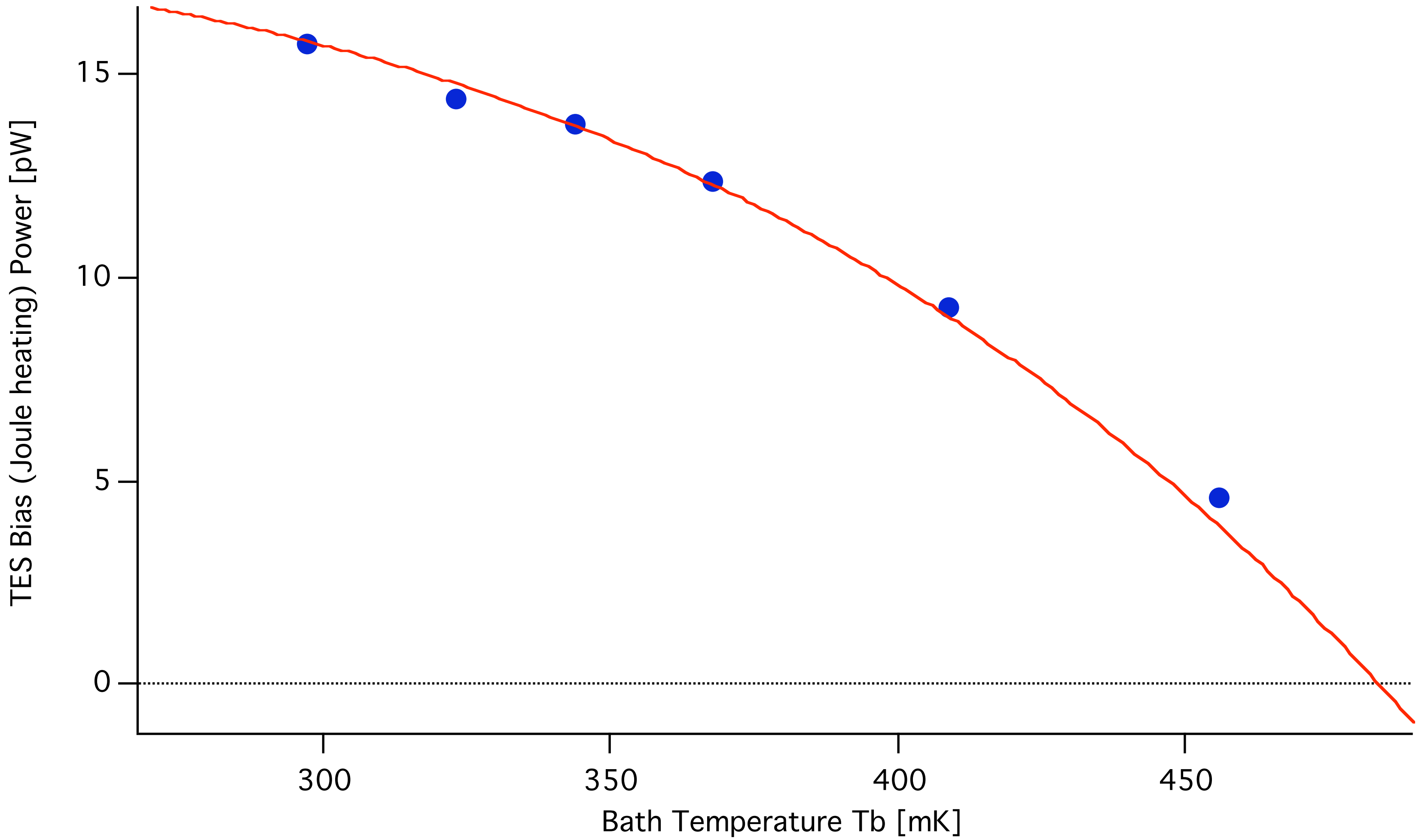
Estimating Parameters

- The TES and phonon heat capacities are calculated from published values of heat capacities for Mo, Au, and Silicon.
- $C_e = 160$ fJ/K, $C_p = 650$ fJ/K
- The electron-phonon thermal conductance is also estimated from the literature, but there is about a factor of 10 uncertainty in the actual number
- $G_{ep} = 5\text{-}50$ nW/K @ 480 mK

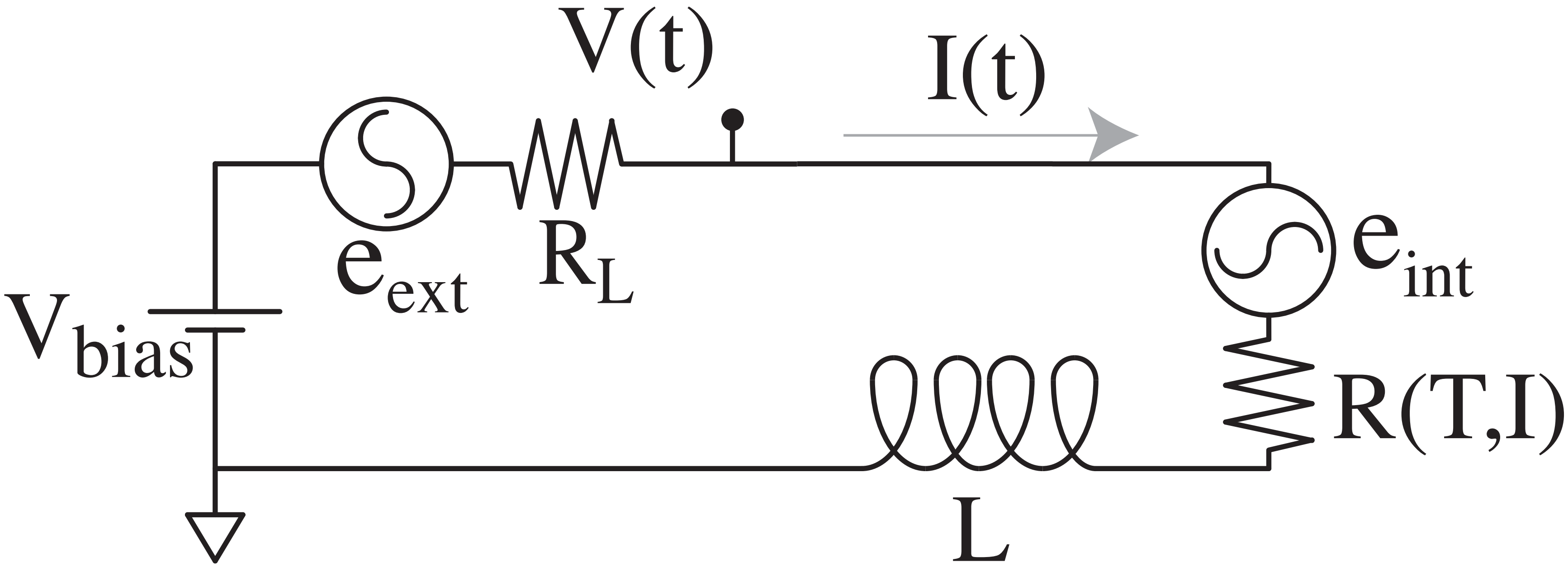
Estimating Parameters

- The thermal conductance to the silicon substrate, G_{pb}, is calculated from fitting the bias power vs bath temperature curve
- G_{pb} = 140 pW/K @ 480 mK

Power vs Bath Temperature

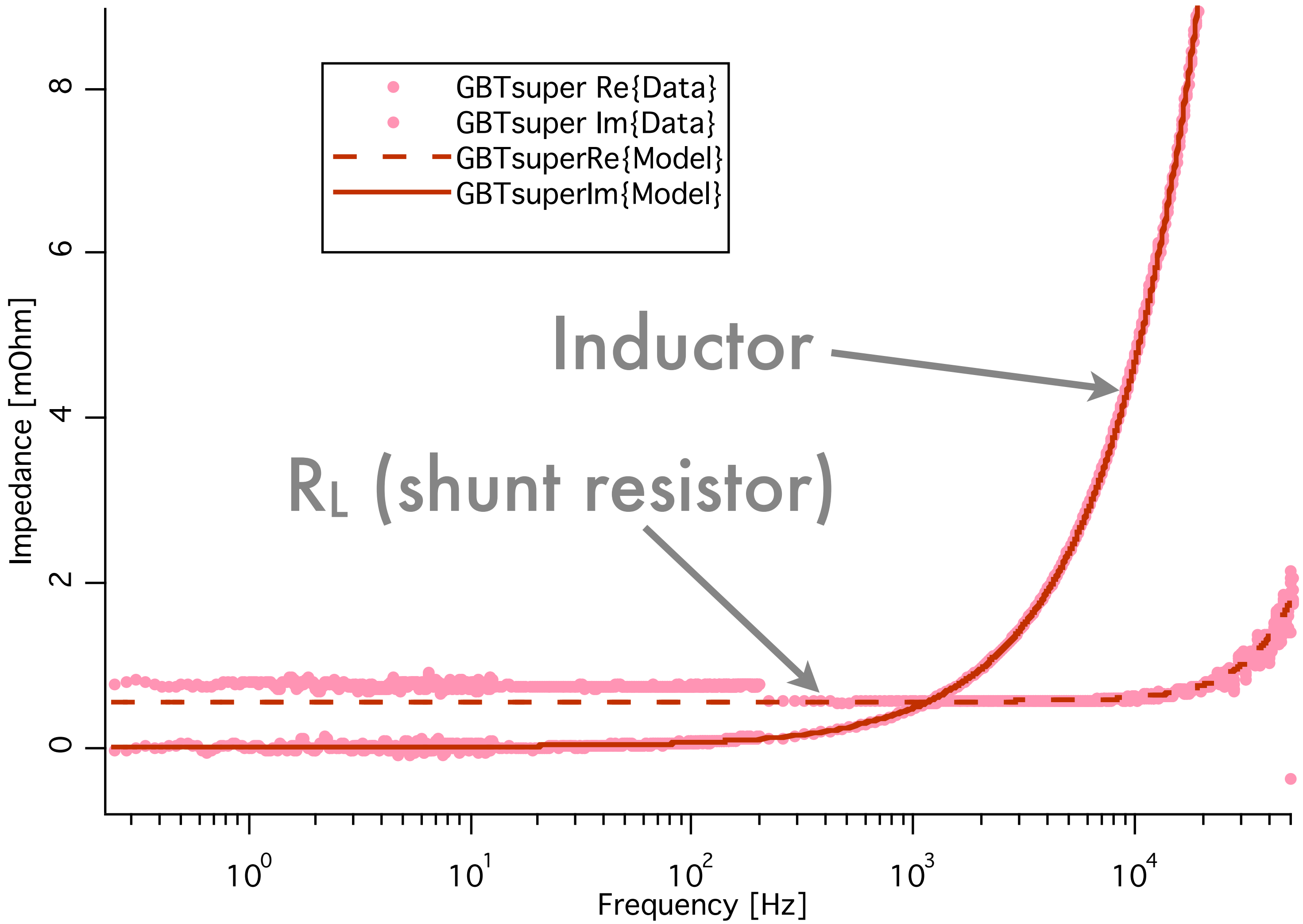


Circuit Parameters

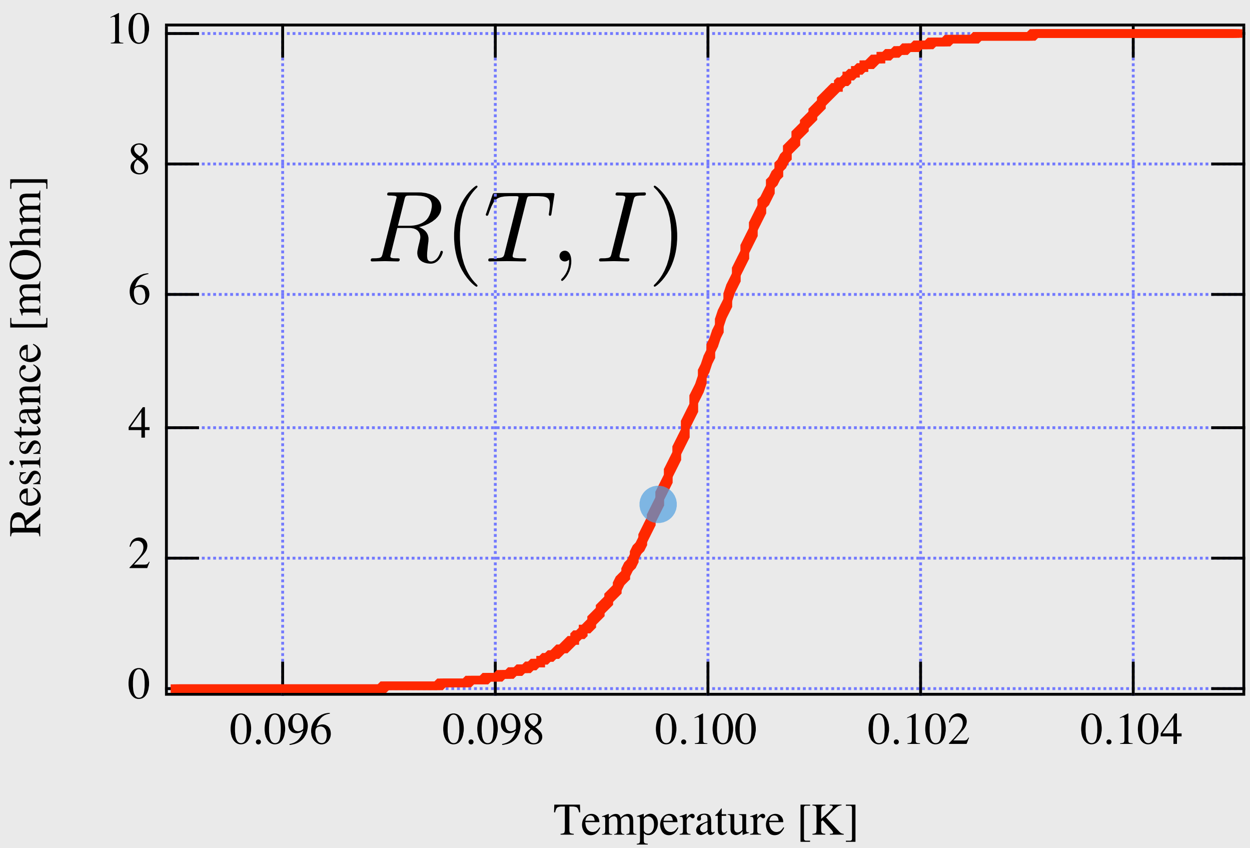


- $R_L = 0.55$ mOhm
- $R_n = 7.3$ mOhm
- $L = 74$ nH

Fitting to R_{TES} =0 Data



TES Parameters

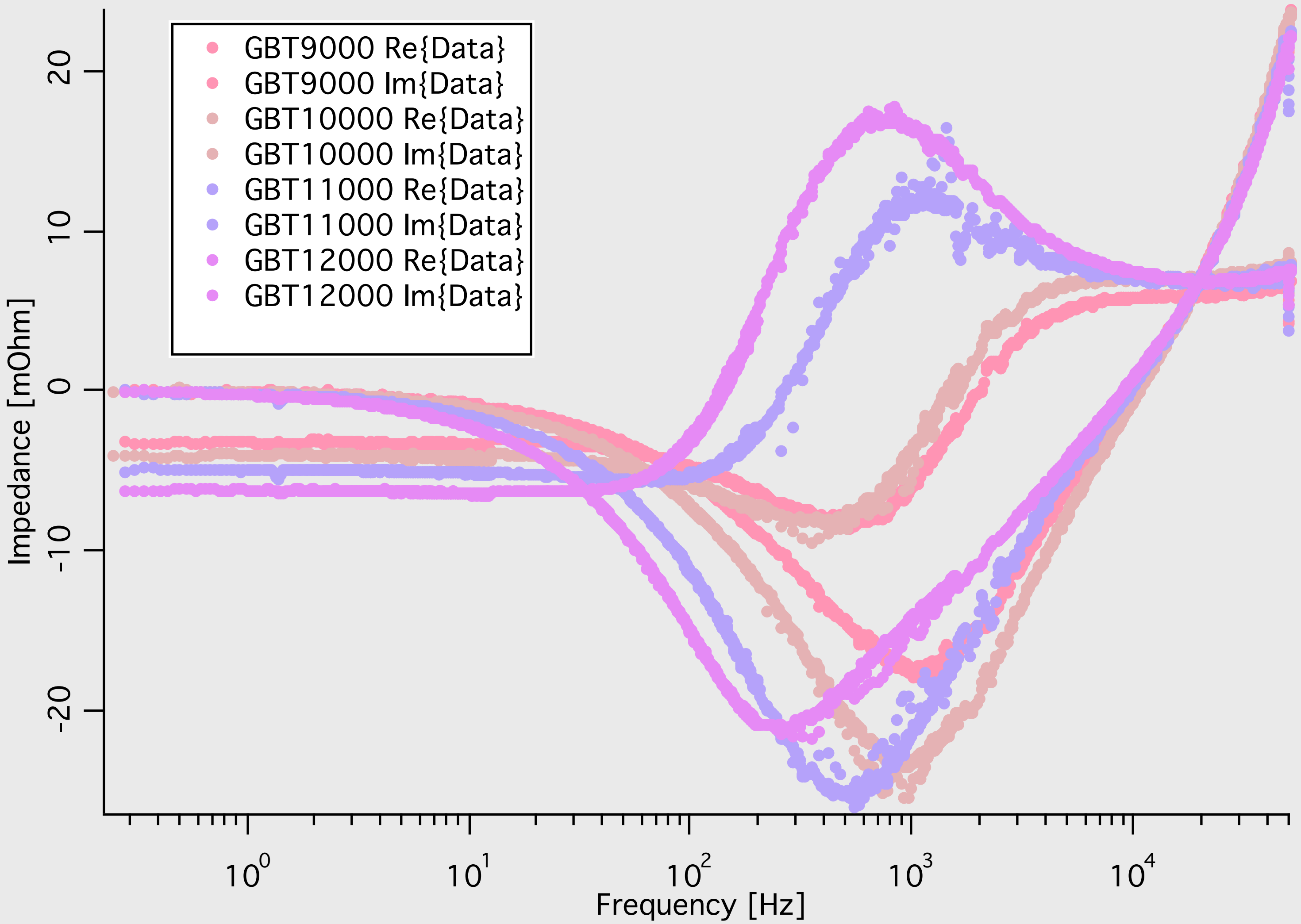


$$\alpha = \frac{T}{R}\frac{\partial R(T,I)}{\partial T}\bigg|_{I=\text{const}} \qquad \beta_i = \frac{I}{R}\frac{\partial R(T,I)}{\partial I}\bigg|_{T=\text{const}}$$

Results before fitting

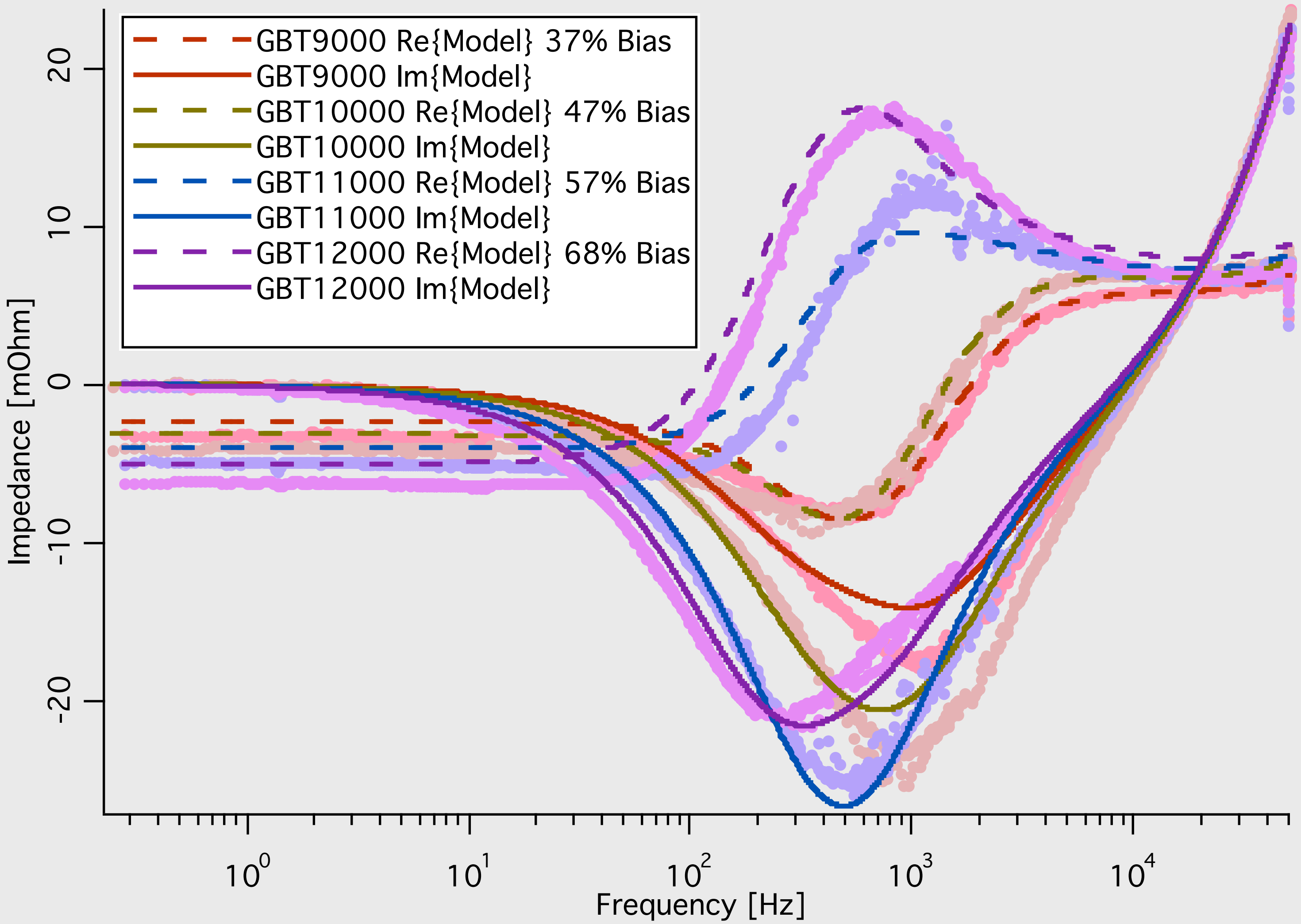
Parameters	Values	Unknown
C_e (TES)	160 fJ/K	C_a (Bi) (est: 1.6-2.2 pJ/K)
C_p (Si)	650 fJ/K	
G_{ep}	5 nW/K	G_{ap}
G_{pb}	140 pW/K	alpha
T_c	484 mK	beta
T_b	298 mK	
R_n	8.28 mOhm	
R_L(shunt)	.055 mOhm	
L (inductor)	74 nH	

The Data



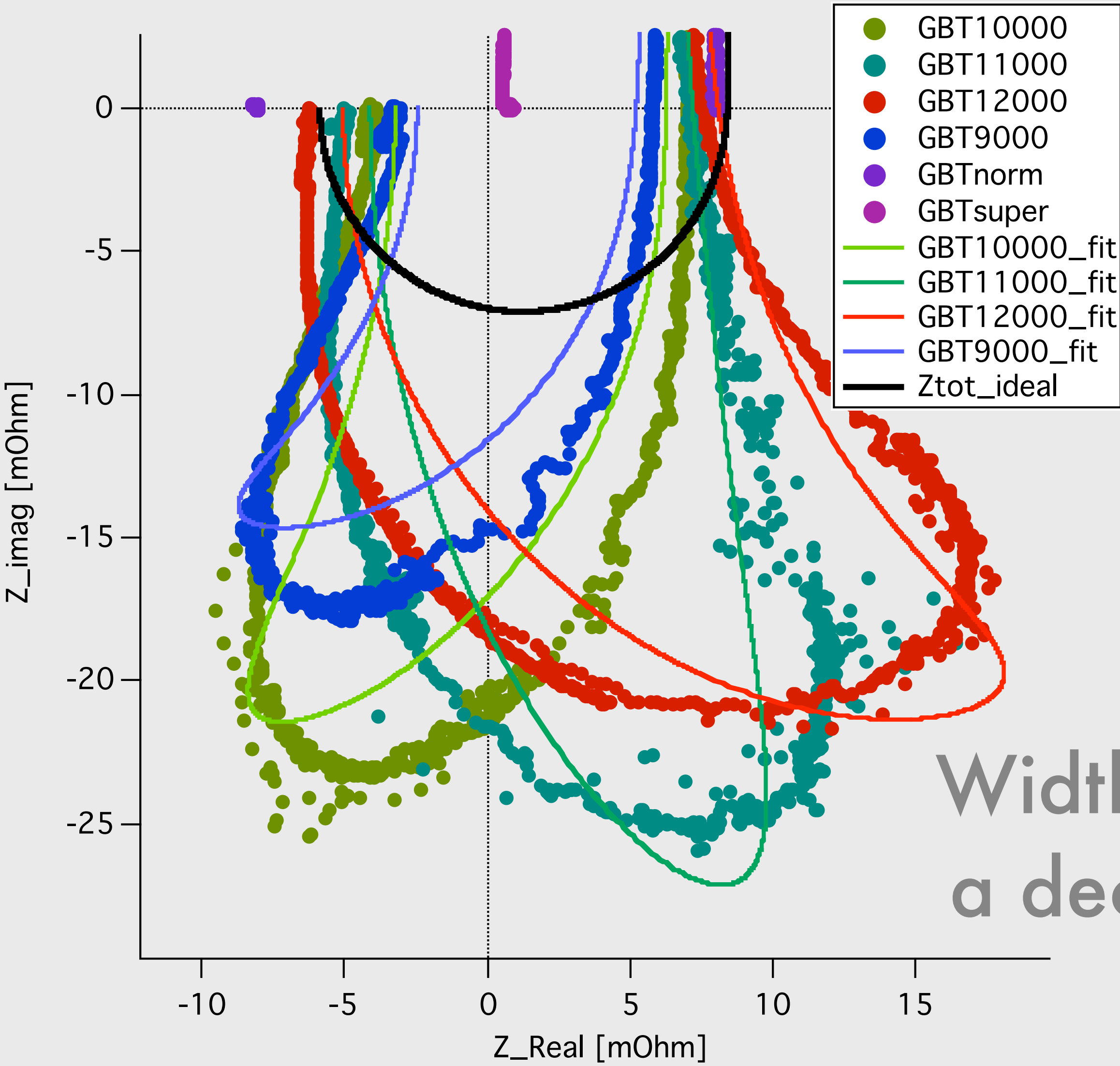
GBT9000 Re{Data}
GBT9000 Im{Data}
GBT10000 Re{Data}
GBT10000 Im{Data}
GBT11000 Re{Data}
GBT11000 Im{Data}
GBT12000 Re{Data}
GBT12000 Im{Data}
Impedance [mOhm]
20
10
0
-10
-20
10^0
10^1
10^2
10^3
10^4
Frequency [Hz]

The Fits



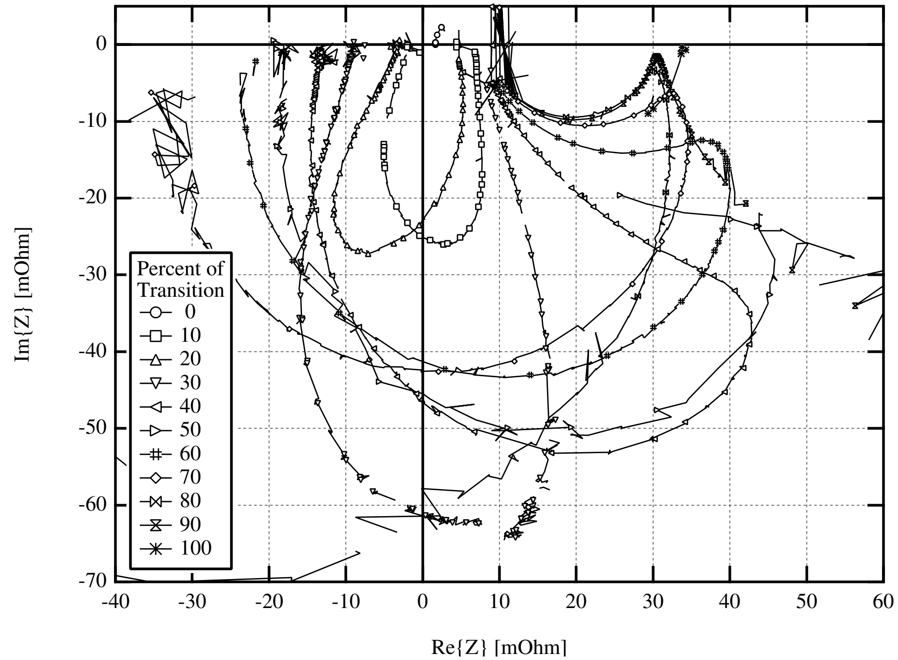
GBT9000 Re{Model} 37% Bias
GBT9000 Im{Model}
GBT10000 Re{Model} 47% Bias
GBT10000 Im{Model}
GBT11000 Re{Model} 57% Bias
GBT11000 Im{Model}
GBT12000 Re{Model} 68% Bias
GBT12000 Im{Model}
Impedance [mOhm]
20
10
0
-10
-20
10^0
10^1
10^2
10^3
10^4
Frequency [Hz]

Imaginary vs Real

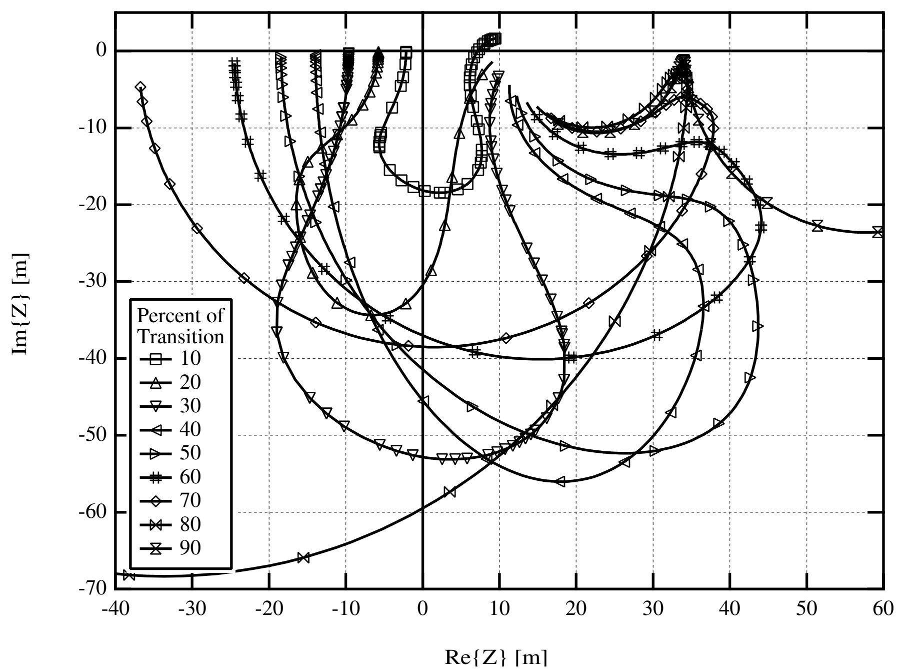


Width of data suggests a decoupled absorber

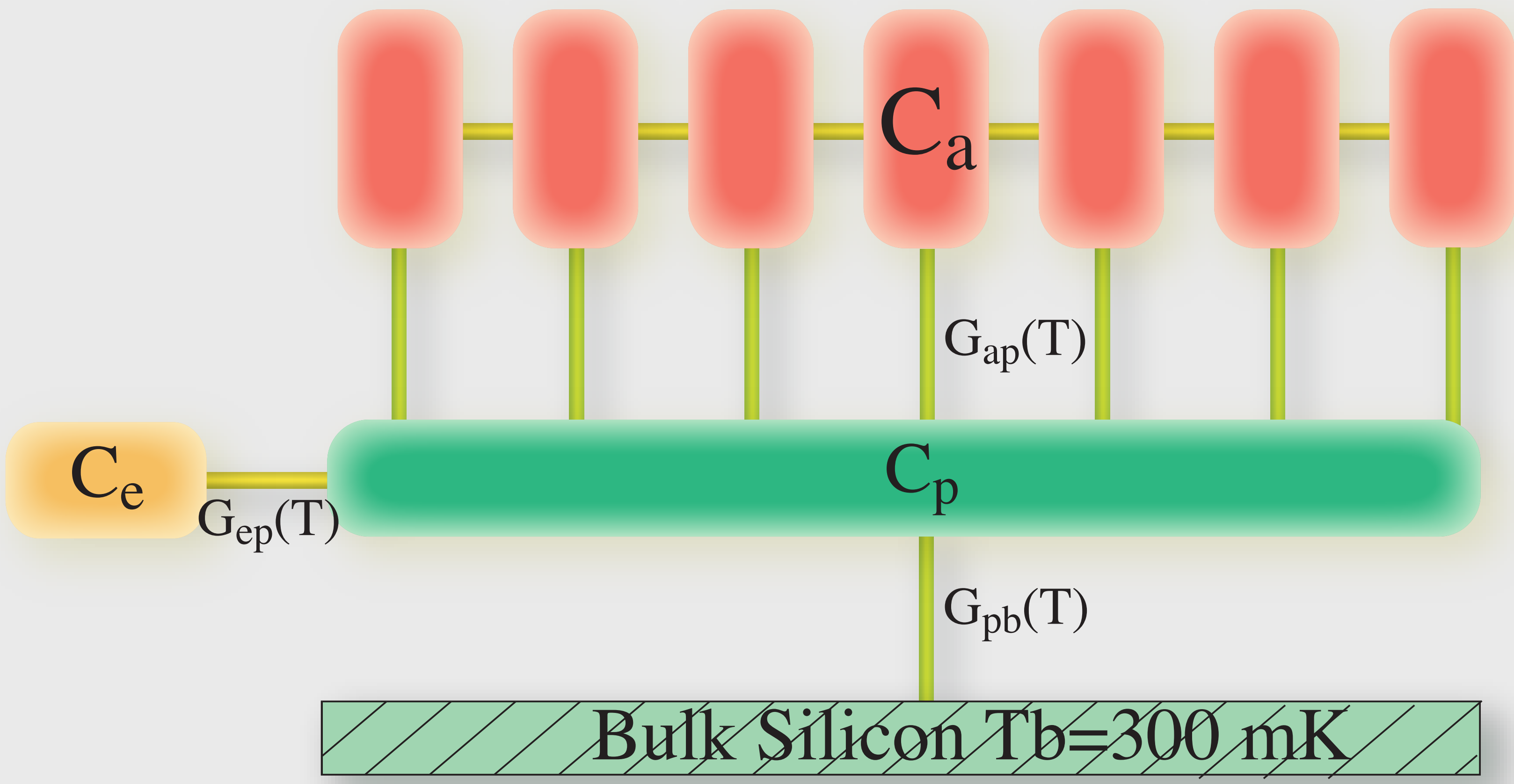
X-ray position-sensitive TES impedance data Distributed Absorbers!



(a) Impedance data for segmented Bi/Cu mushroom-absorber PoST



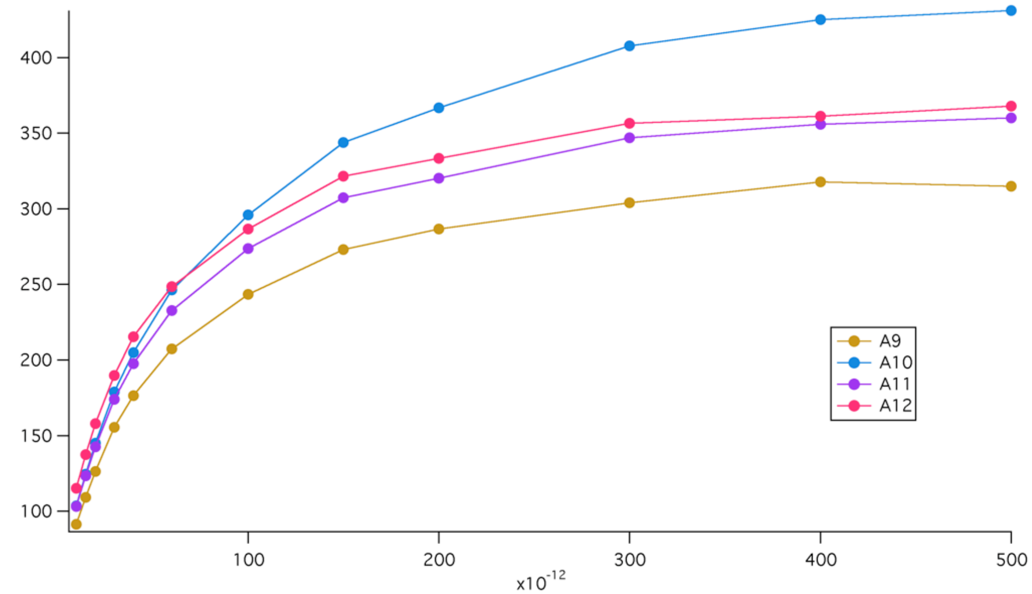
Distributed Model

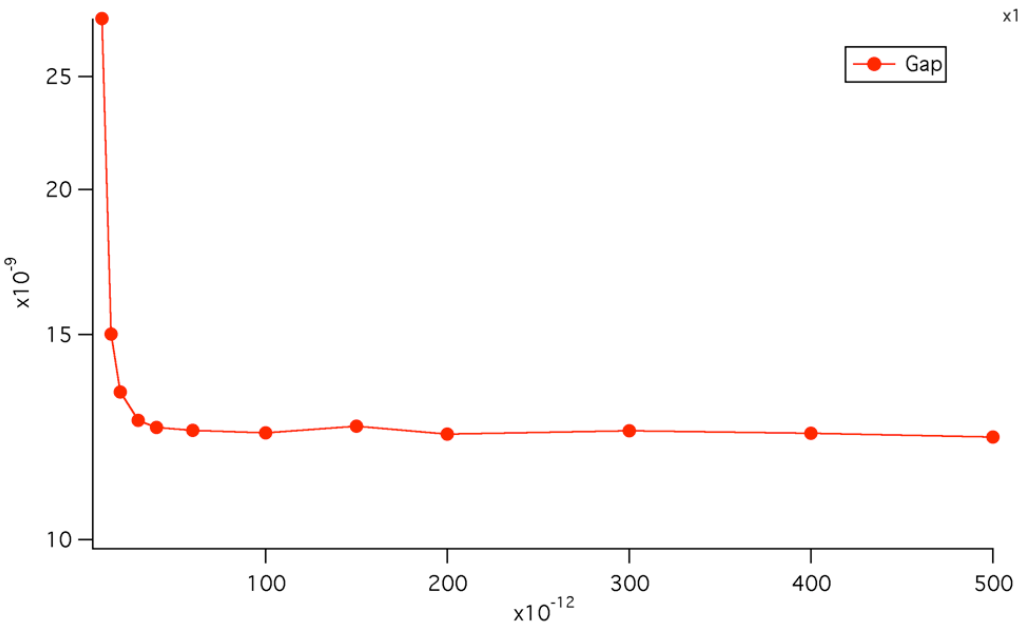


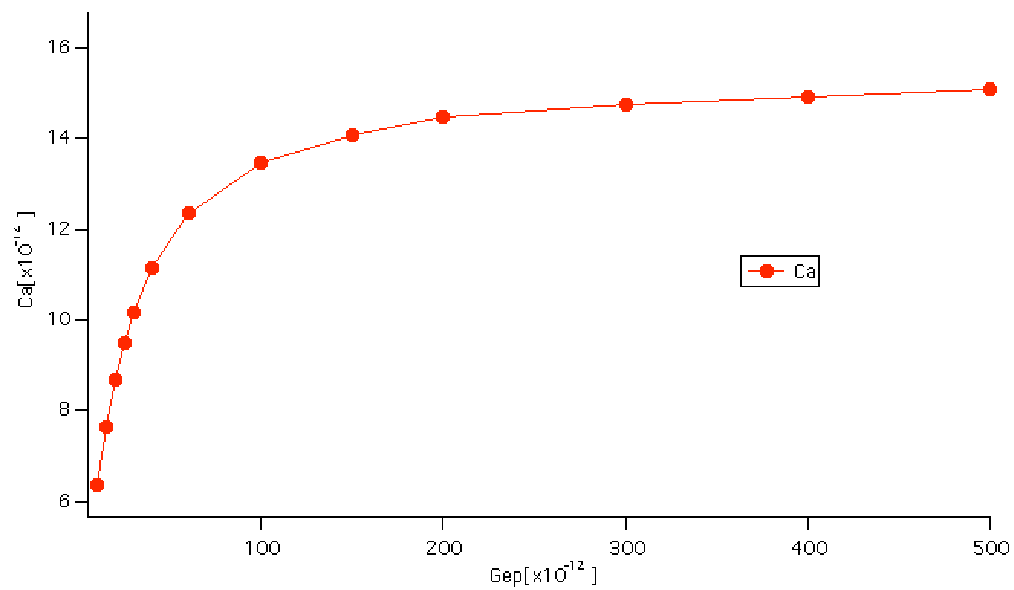
Modeling Results

Calc. Pars	Values	Fitted Pars	Values
C_e (TES)	160 fJ/K	C_a (Bi)	4 pJ/K
C_p (Si)	650 fJ/K	G_{ap}	8.7 nW/K
G_{ep}	5 nW/K	alpha	170
G_{pb}	140 pW/K	beta	0.9
T_c	484 mK		
T_b	298 mK	*Values at operating point*	
R_n	8.28 s mOhm		
R_L(shunt)	.055 mOhm		
L (inductor)	74 nH		

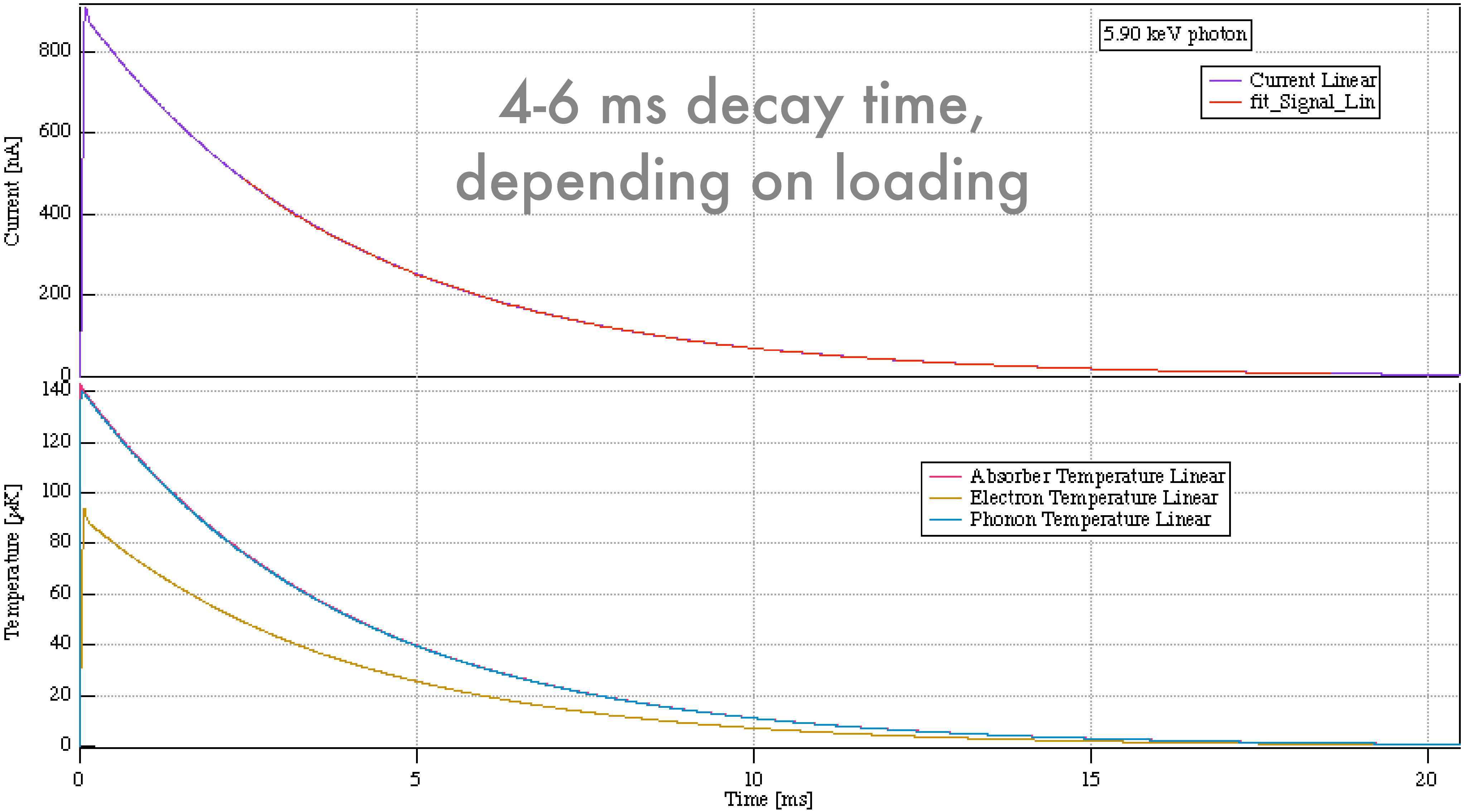
Variation as func. of G_{ep}



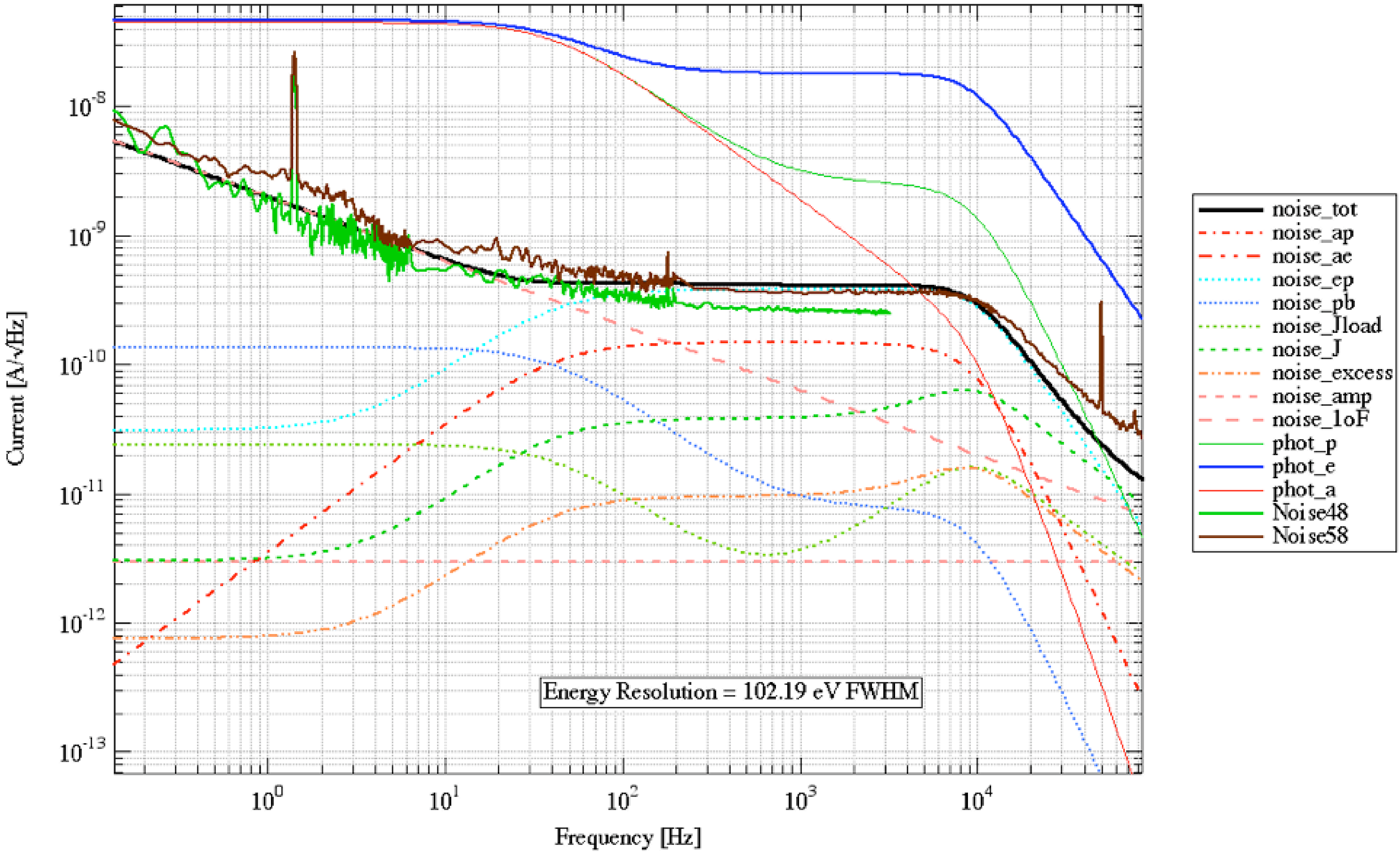




Time Constants

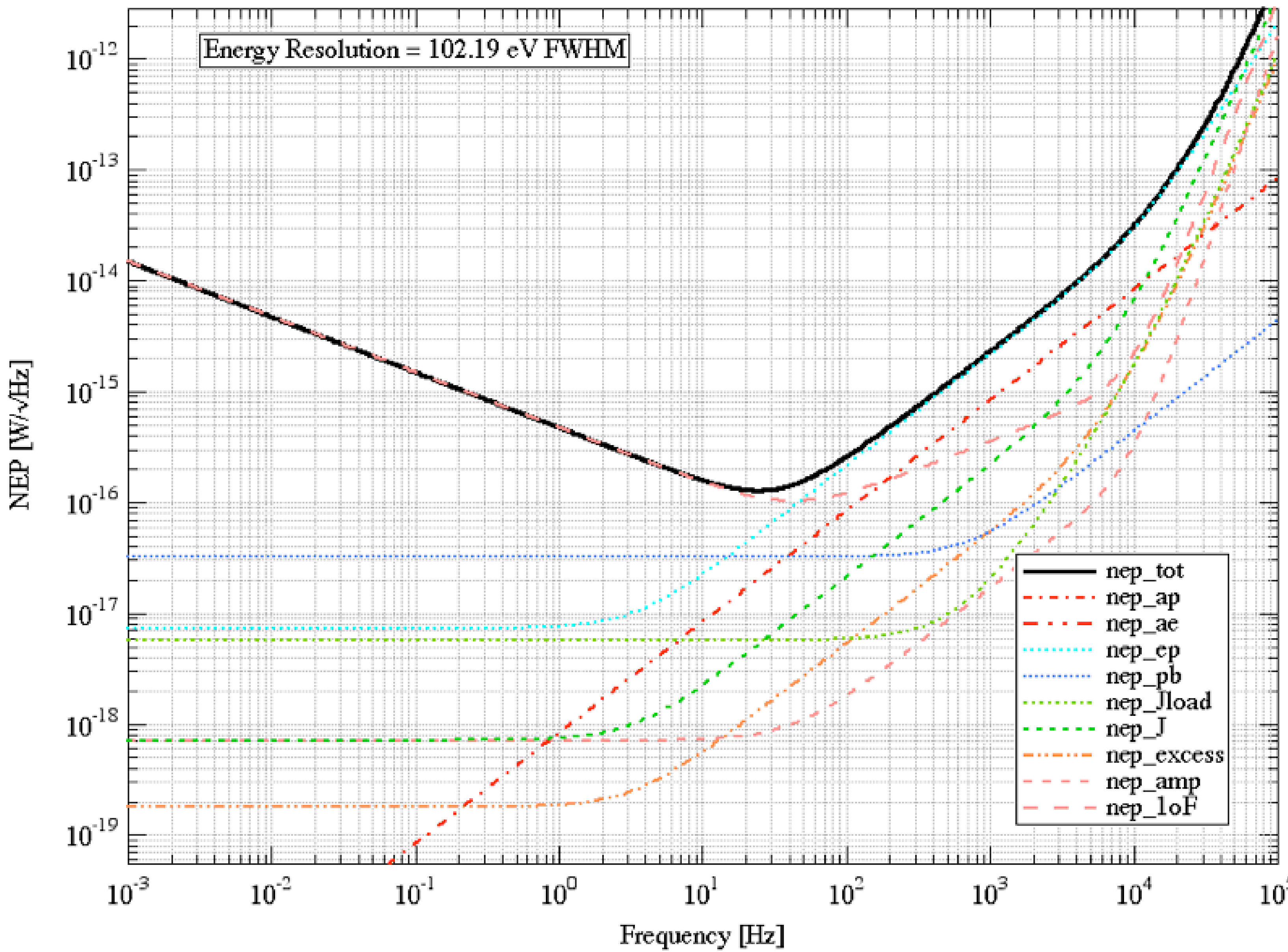


Noise



Current [A/√Hz]
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Frequency [Hz]
Energy Resolution = 102.19 eV FWHM
noise_tot
noise_ap
noise_ae
noise_ep
noise_pb
noise_Jload
noise_J
noise_excess
noise_amp
noise_1oF
phot_p
phot_e
phot_a
Noise48
Noise58

NEP



Energy Resolution = 102.19 eV FWHM
NEP [W/√Hz]
Frequency [Hz]
nep_tot
nep_ap
nep_ae
nep_ep
nep_pb
nep_Jload
nep_J
nep_excess
nep_amp
nep_1oF