Novel Active Noise Cancellation Algorithms for CUORE

Invisibles 2021

Kenneth Vetter

UC Berkeley Department of Physics

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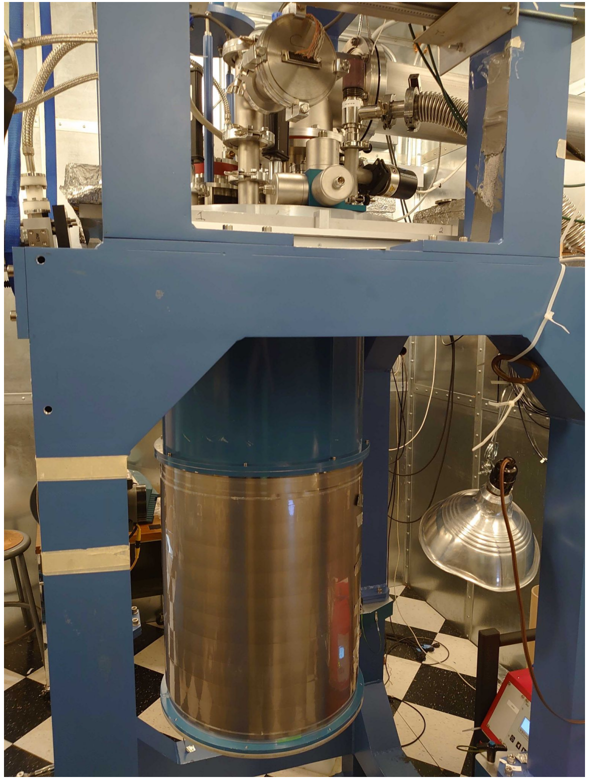
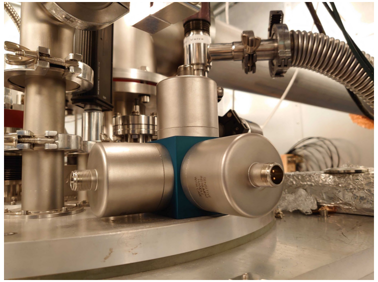
The Experimental Setup

Our refrigerator cools detectors (NTD calorimeters & TES-based light detectors) to ~ 12 mK.

We have connected accelerometers (top right) and a Helmholtz coil antenna (bottom right) to measure vibrational and electrical noise respectively.

Our goal is to remove vibrational and electrical noise from our detectors using these "auxiliary" devices.





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Approaching the Problem

Method 1: "Linear" Noise Cancellation (LNC)

- Assume a linear transfer function from auxiliary devices to bolometers
- Done in Fourier space rather than Laplace space (IIR filter, not FIR filter)
- Algorithmically similar to building an Average Noise Power Spectrum

Method 2: Adaptive Noise Cancellation (ANC)

- First implemented by S. Zimmerman for GRETA (NIMA, 2013)
- Assumes a finite impulse response from auxiliary devices to bolometers
- Employs a gradient descent algorithm to find the transfer function adaptively

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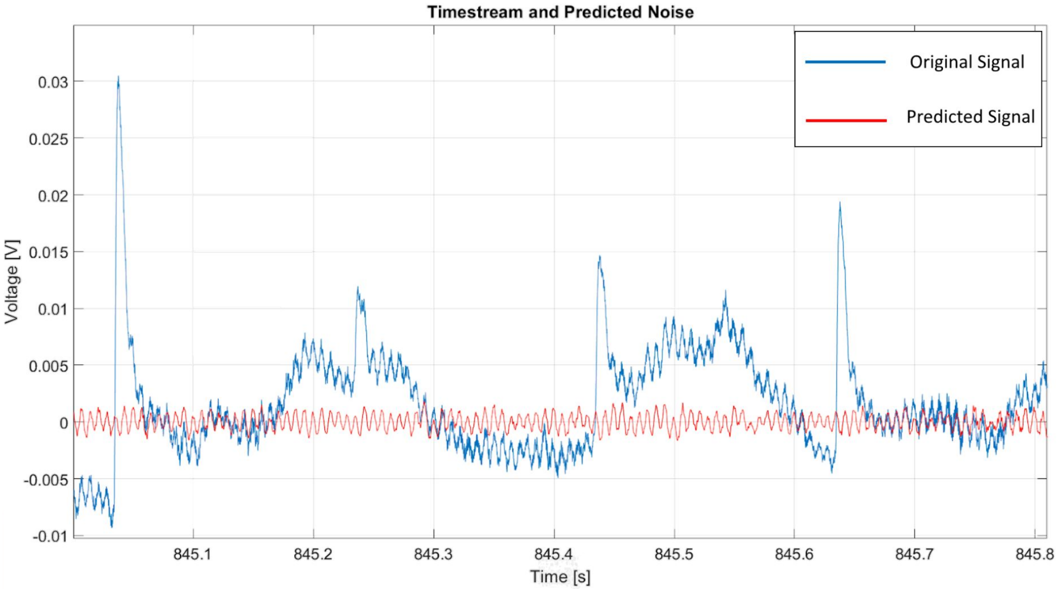
The Nature of Noise Prediction

In both LNC and ANC, we try to find the transfer function from auxiliary devices to bolometers.

Convolving the time-domain version of this filter with the auxiliary device timestream gives the predicted signal.

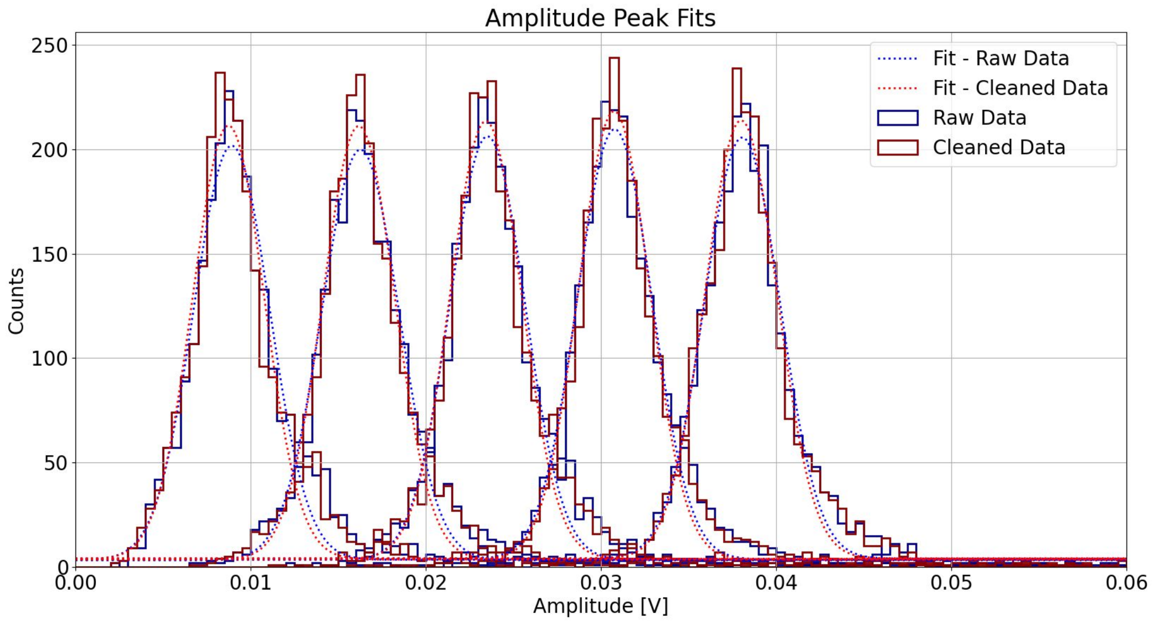
Subtracting the predicted signal from the original effectively reduces the noise.



Original NTD calorimeter signal (blue) and predicted signal from LNC algorithm (red)

Improvement in Energy Resolution using LNC

	Raw		Cleaned	
E	μ [mV]	σ^* [mV]	μ [mV]	σ^* [mV]
1	8.92	2.17	8.74	2.04
2	16.27	2.20	16.18	2.05
3	23.52	2.14	23.43	2.04
4	30.78	2.13	30.75	2.03
5	38.07	2.16	38.00	2.06



Note: Each peak contains ~ 2500 events
*uncertainties on σ are roughly 0.05 mV

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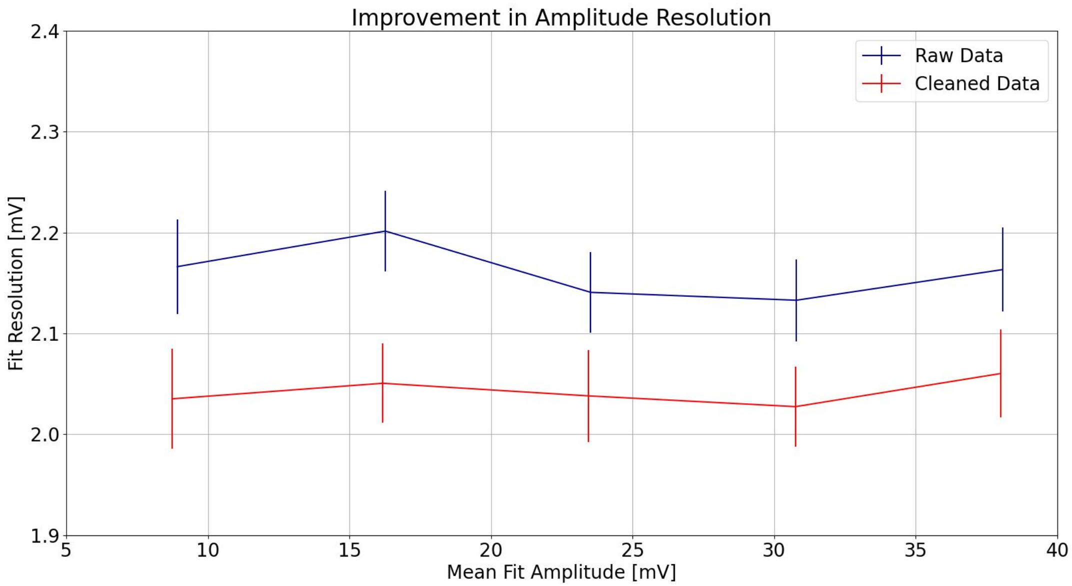
Comparing Fit Resolutions

E	$\Delta\mu/\mu_{raw}$	$\Delta\sigma/\sigma_{raw}$
1	-2.1%	-6.0%
2	-0.6%	-6.9%
3	-0.4%	-4.8%
4	-0.1%	-4.9%
5	-0.2%	-4.8%

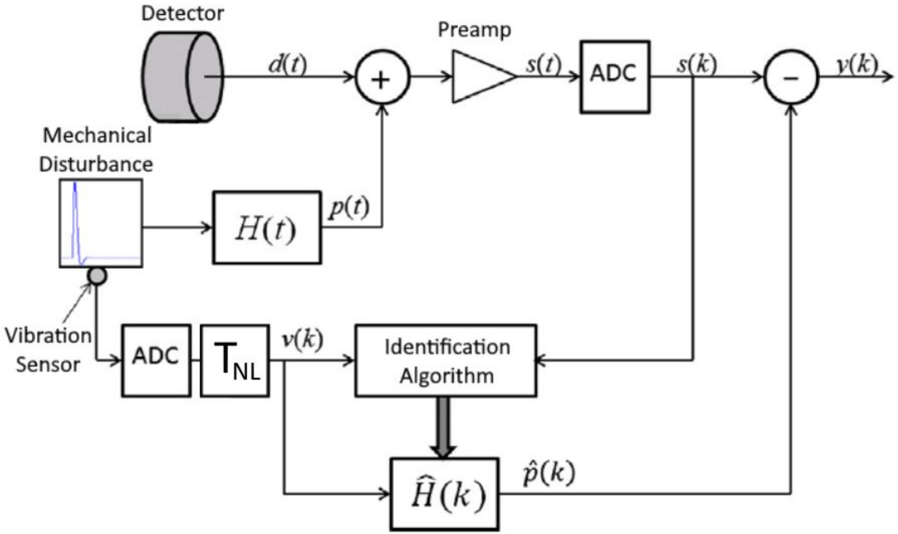


Adaptive Noise Cancelling

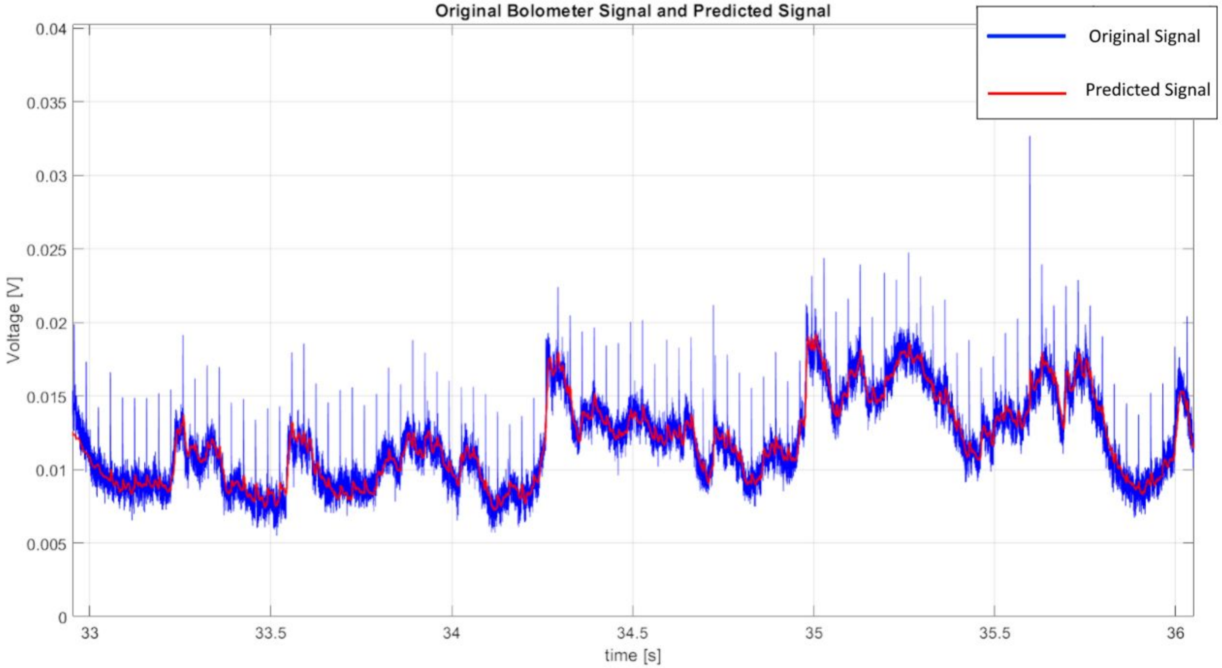
Thanks to Sergio Zimmerman, whose algorithm provides a starting point for this development and whose guidance has been extremely useful throughout these studies.

Adaptive noise cancelling algorithms have been in use for years (consider noise cancelling headphones)

Here, we try to minimize the noise by identifying the *finite impulse response* of the bolometer from accelerometer data.



Results of Algorithm (Berkeley TES LED Data)



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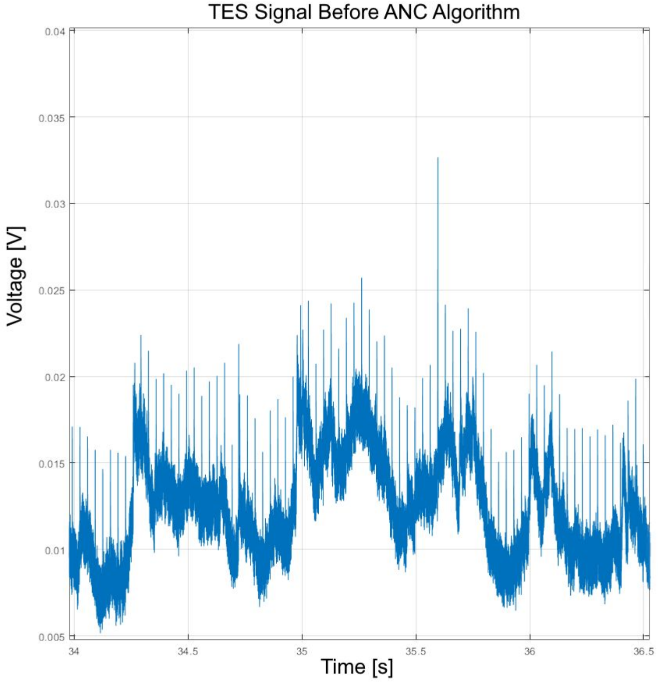

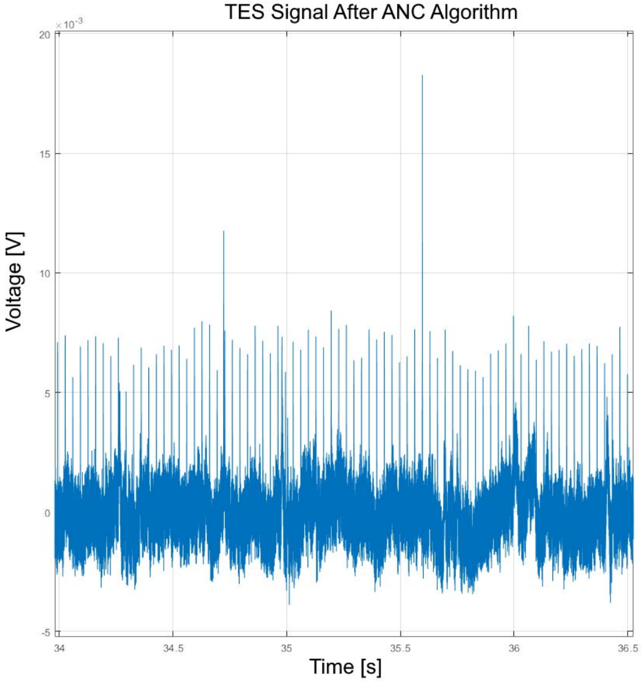

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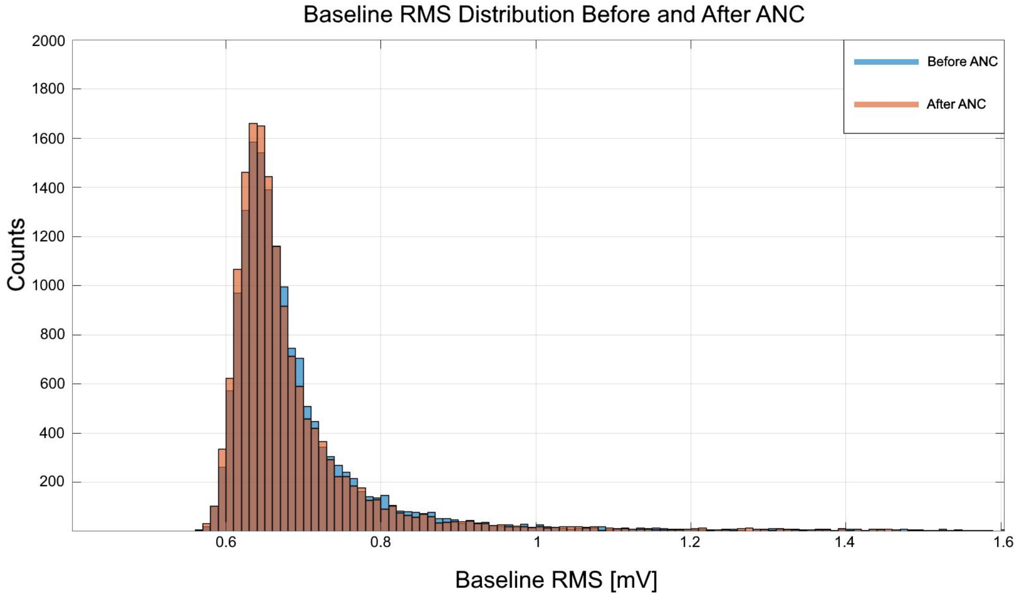
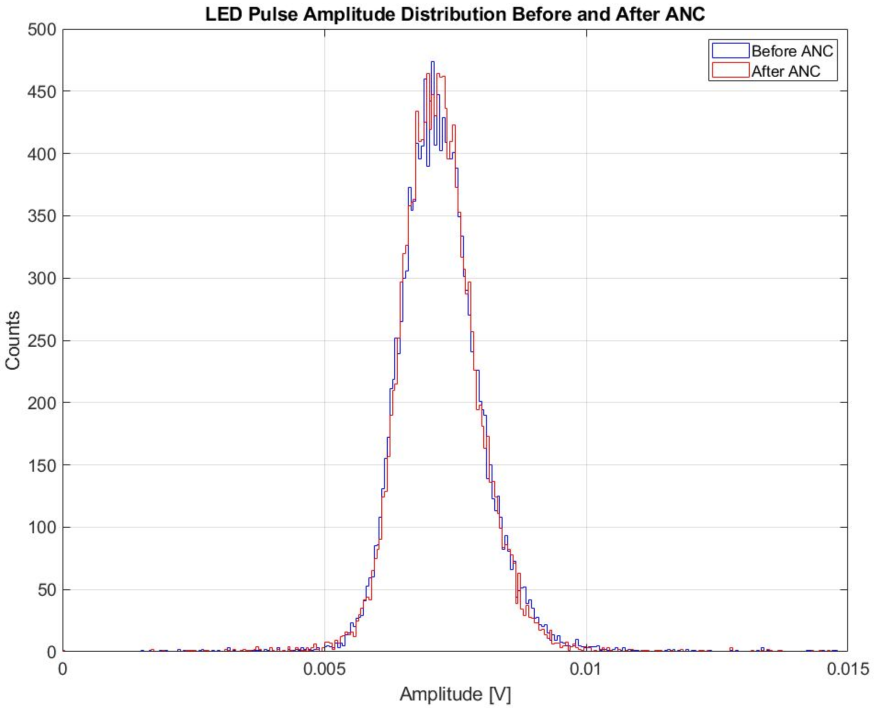
Some Preliminary Findings





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Thank You!