DM Radio:

A Quantum-*Accelerated* Axion Search

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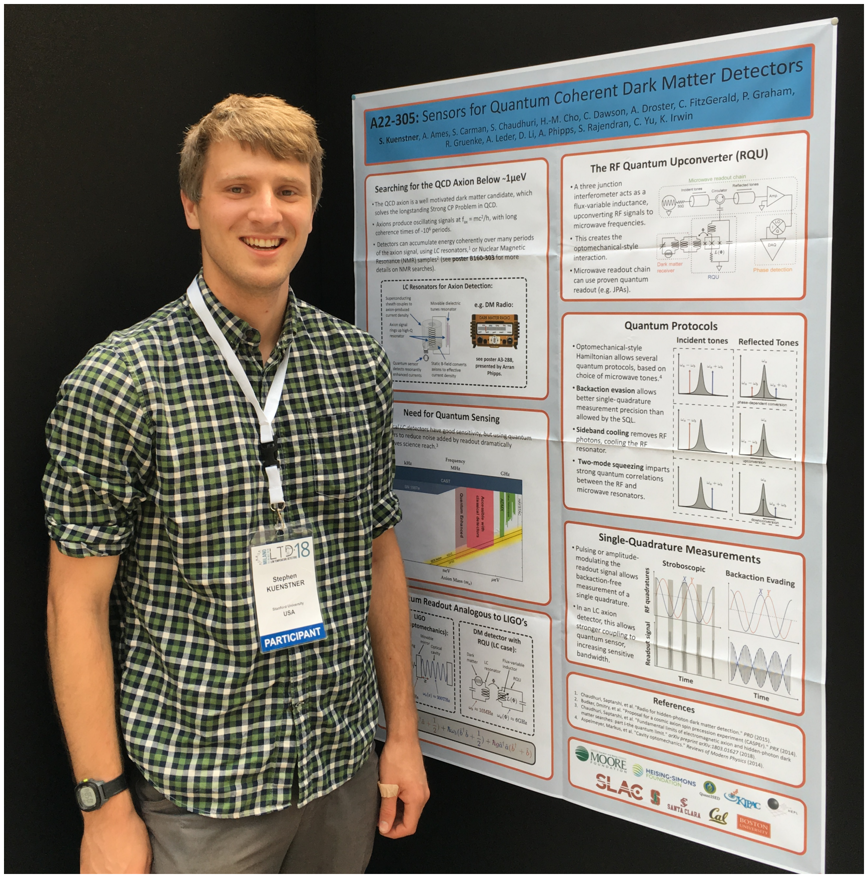
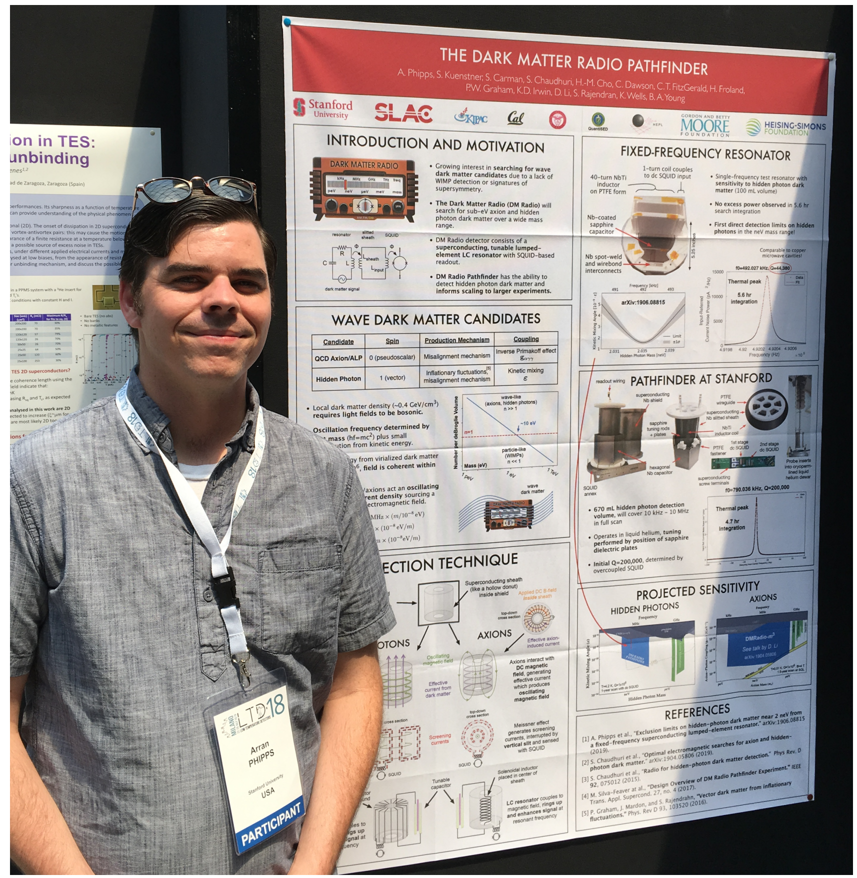
For more details please visit our posters!

RF Quantum Upconverters
See Stephen's Poster #22-305



DM Radio Pathfinder
See Arran's Poster #3-288



DM Radio tunes into dark matter waves

- DM Radio is optimized to search for wave-like dark matter:
  Axions and Hidden Photons

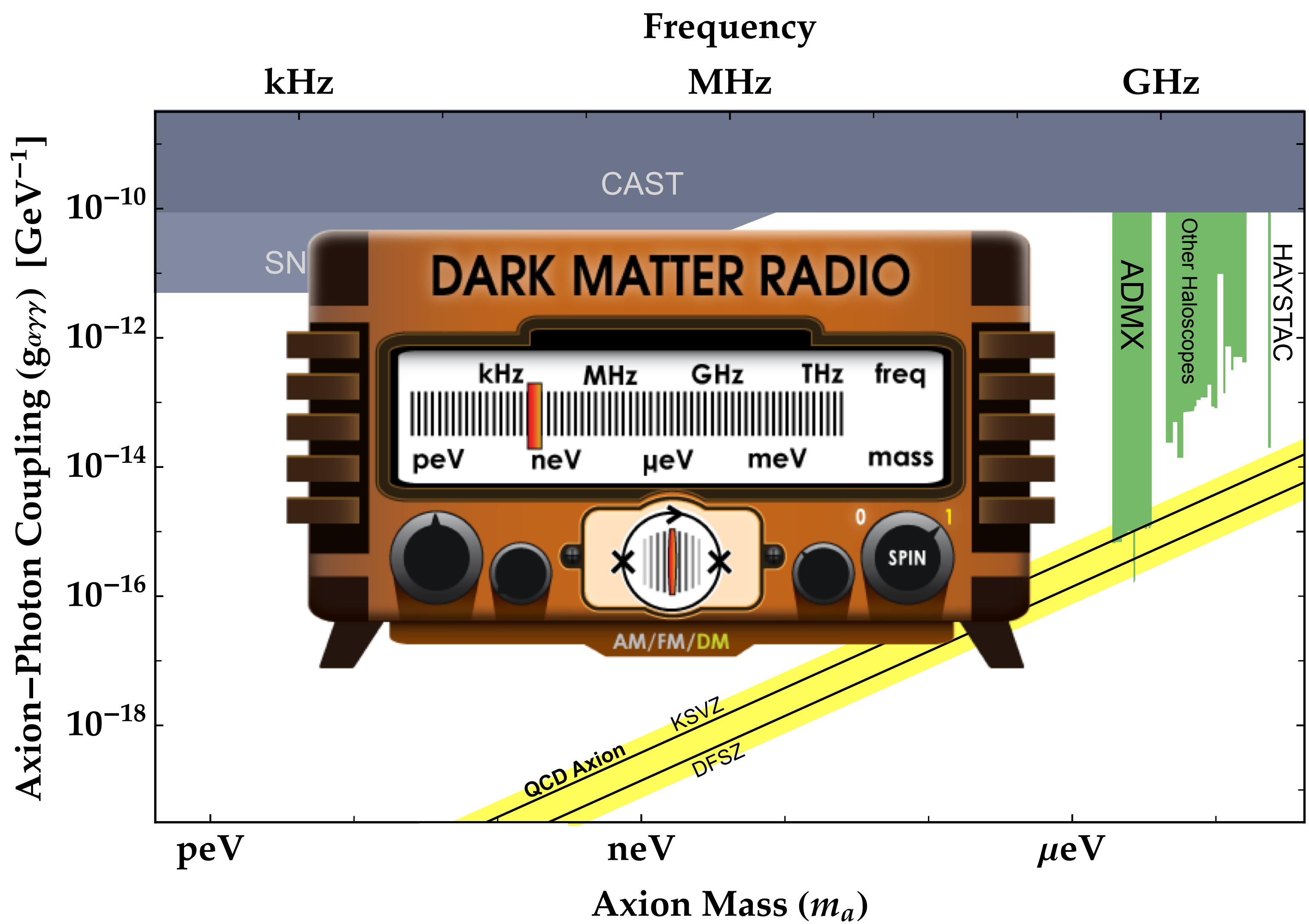
- Below 1 eV wavelengths are very long and the number density is big

$$\lambda_{\text{coherence}} \approx 100\,\text{km} \times (10^{-8}\text{eV}/m)$$

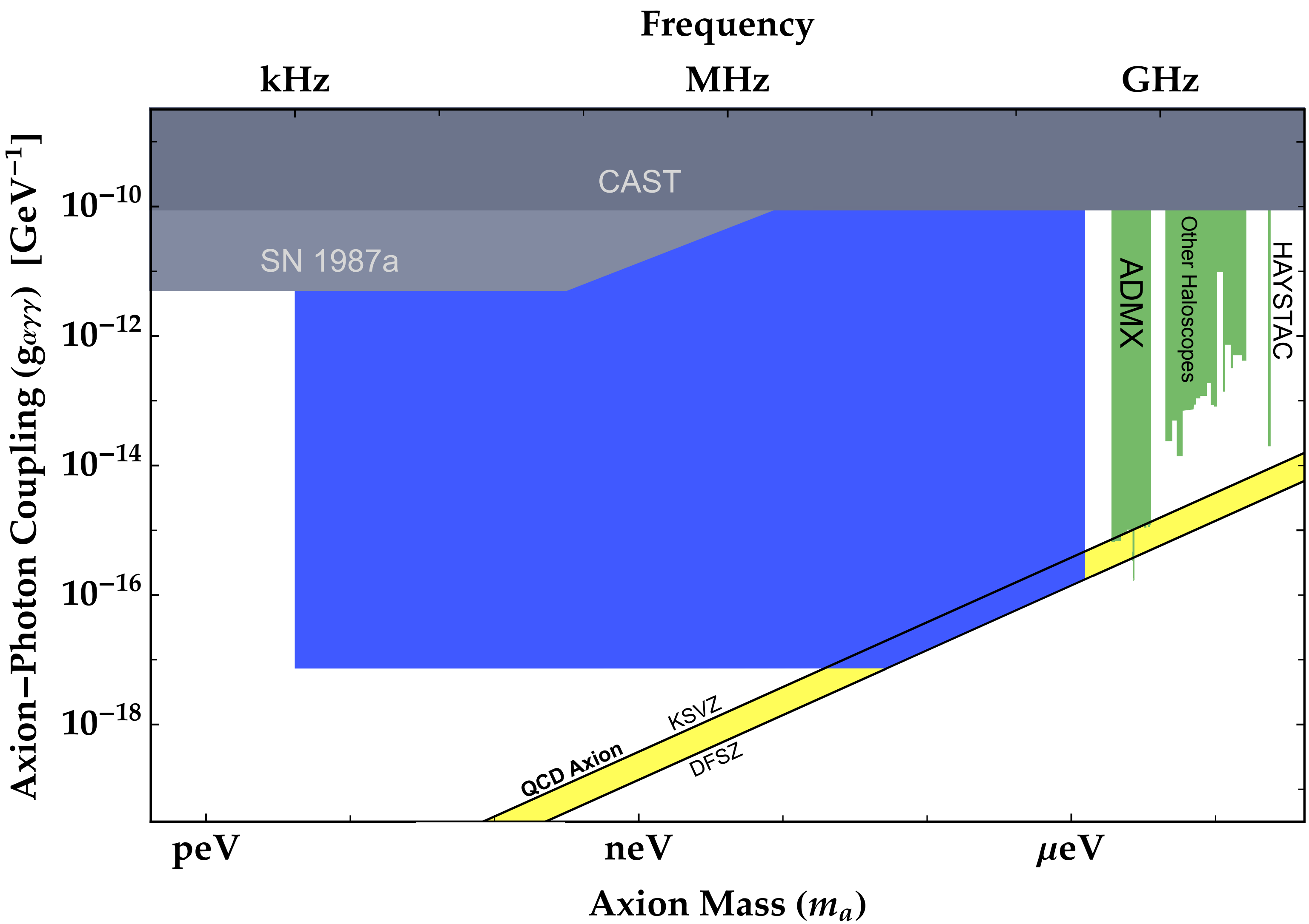
- Lumped-Element resonators give us an advantage of an extremely wide tuning range from 1 kHz to 300MHz!

- Quantum Sensors will allow us to probe a swath of the QCD Axion band

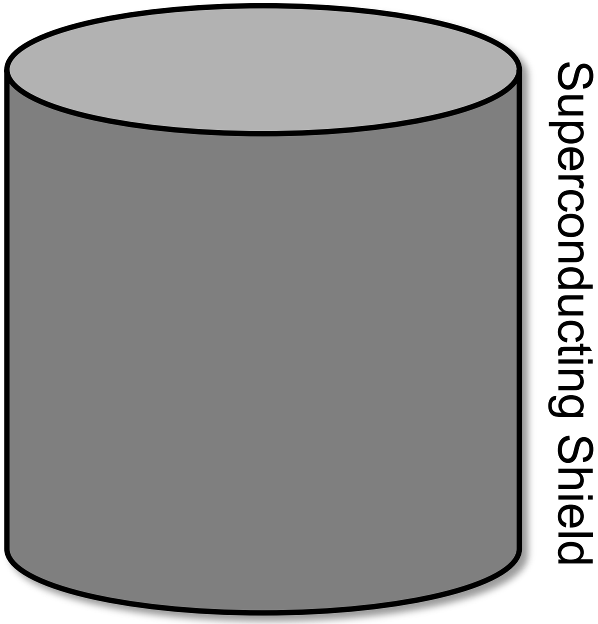
Lumped-element approach can tune a huge range



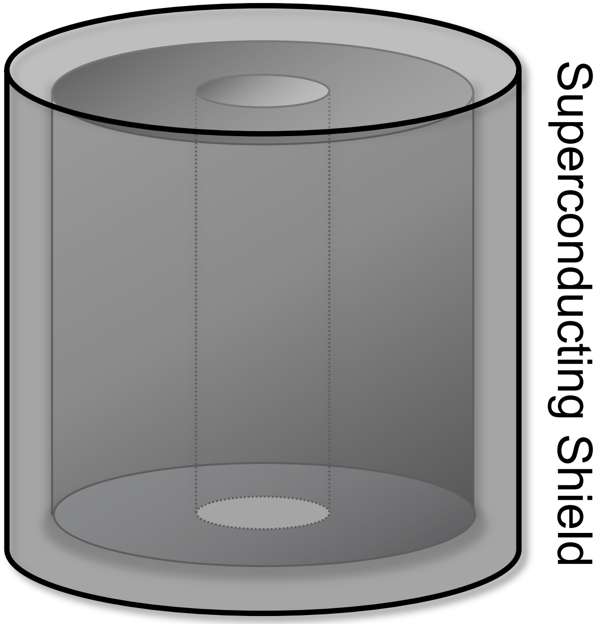
DM Radio will detect or rule-out axions in big area



Building up the DM Radio for axion detection

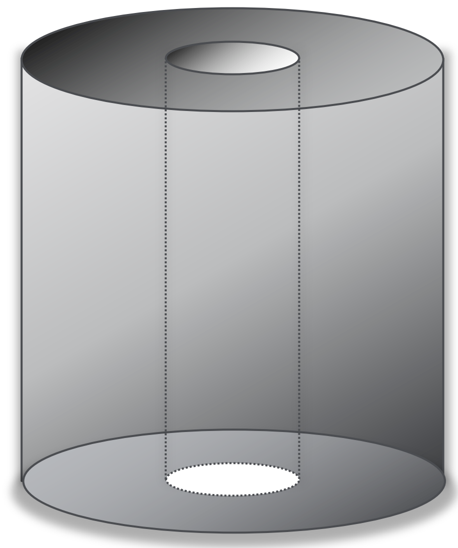


Building up the DM Radio for axion detection

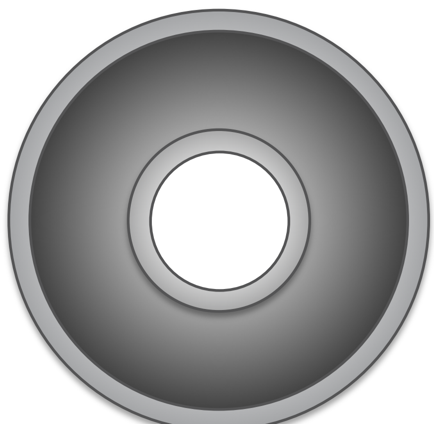


Building up the DM Radio for axion detection

Side View

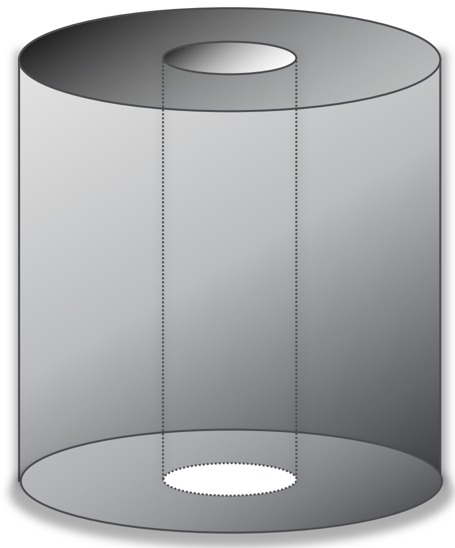


Top Cutaway



Building up the DM Radio for axion detection

Side View



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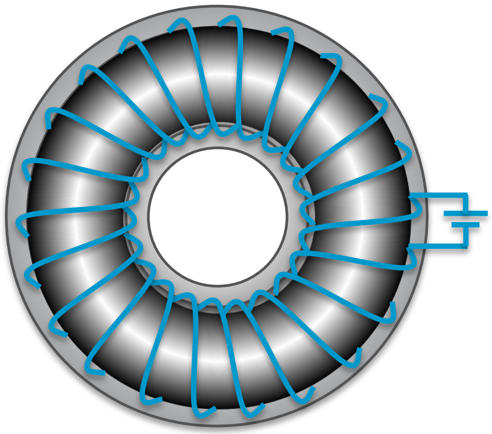
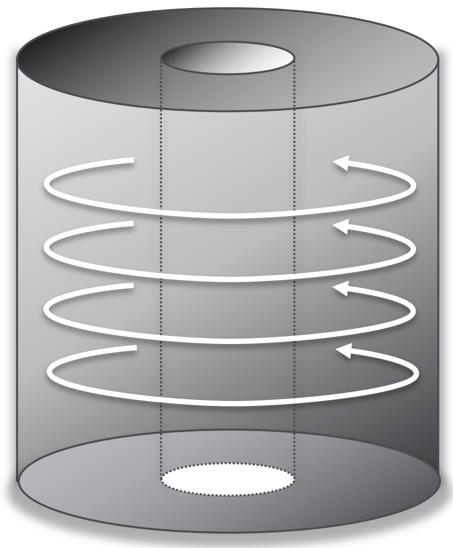


Add a toroidal magnet inside for conversion of axions to photon fields

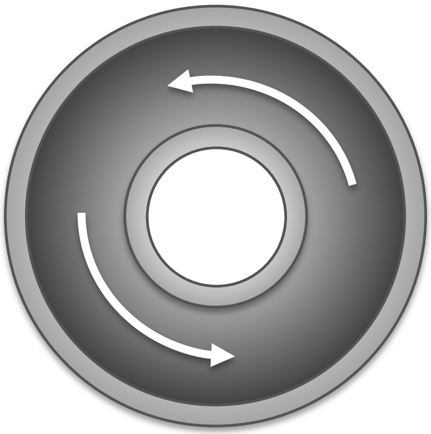
Building up the DM Radio for axion detection

Side View



B_0 toroid inside

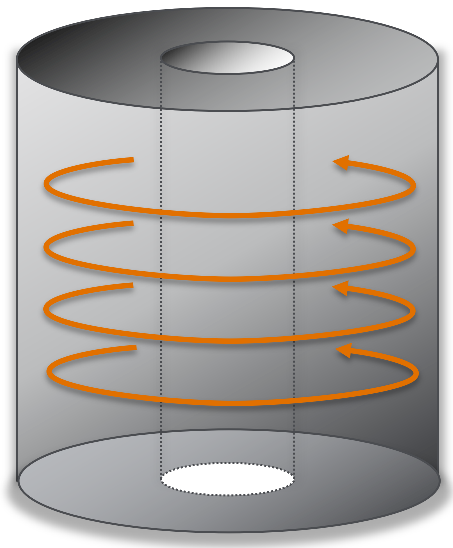
Top Cutaway



B_0
dc circulating field

Building up the DM Radio for axion detection

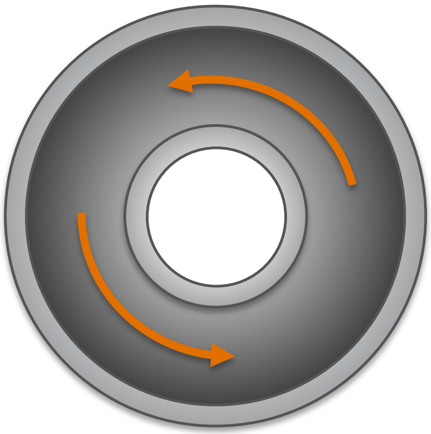
Side View



A coupled axion will create an oscillating current parallel to B_0

$$\vec{J}_a(t)$$

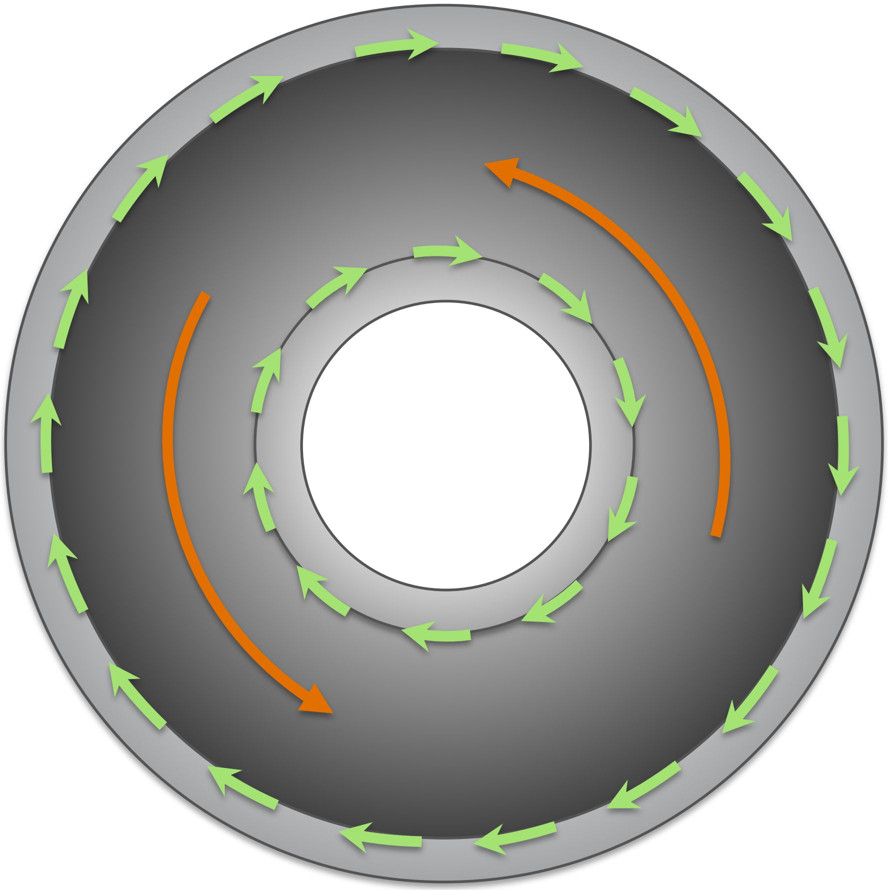
Top Cutaway



Building up the DM Radio for axion detection

SLAC

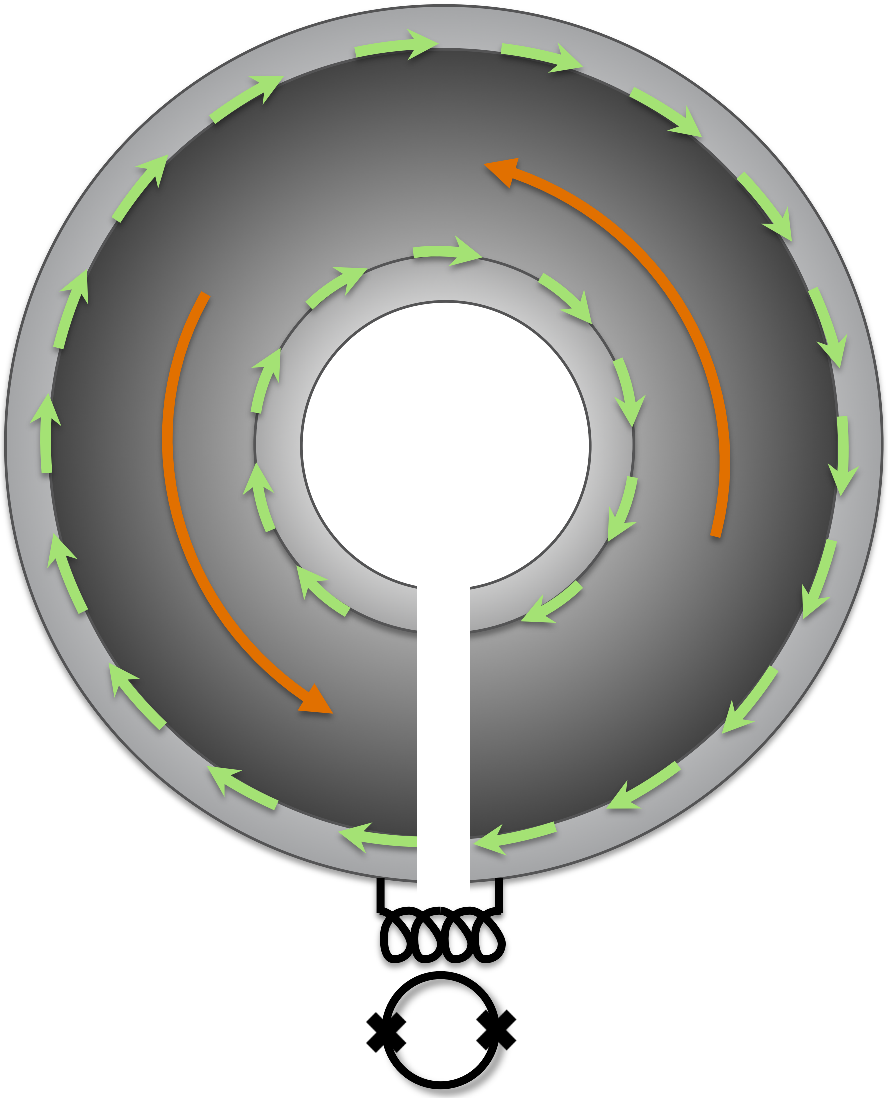
Top Cutaway

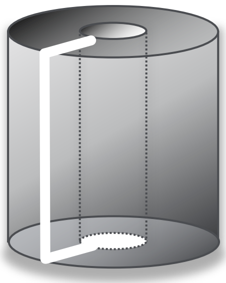


$$\vec{J}_a(t)$$

Building up the DM Radio for axion detection

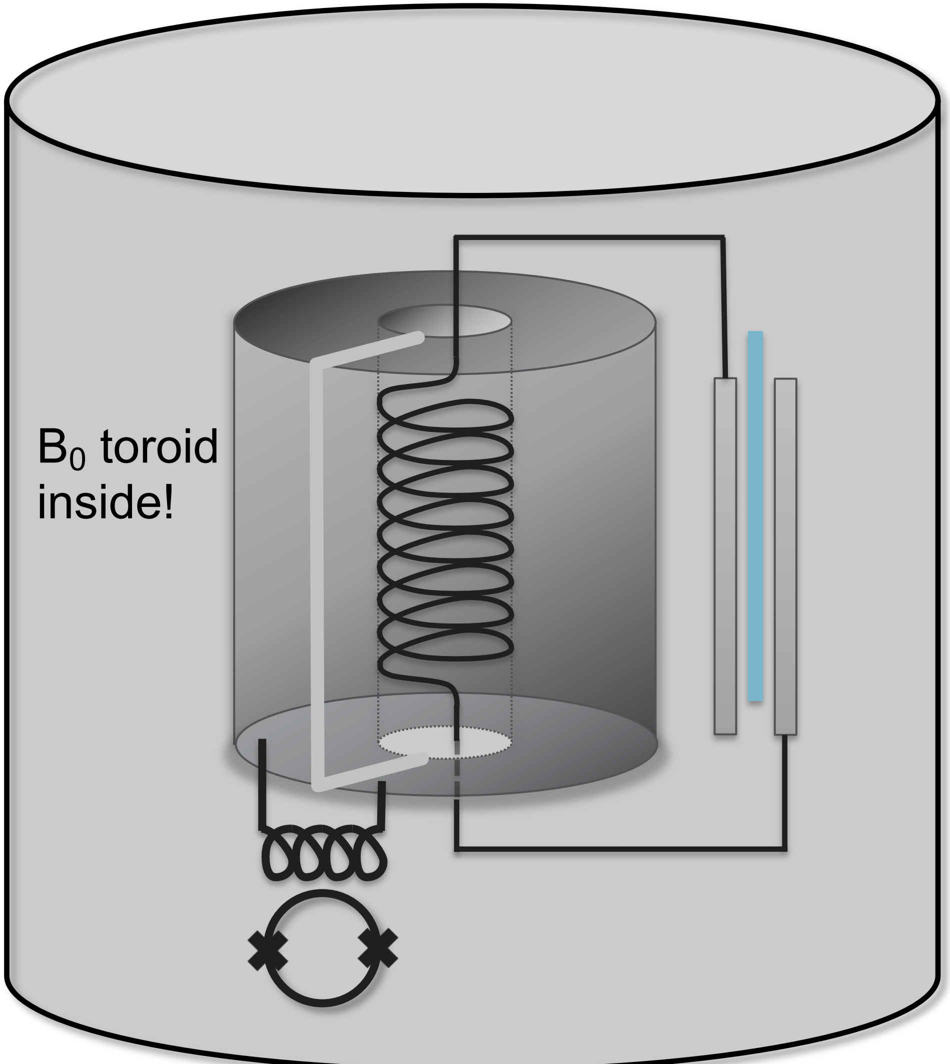
Top Cutaway

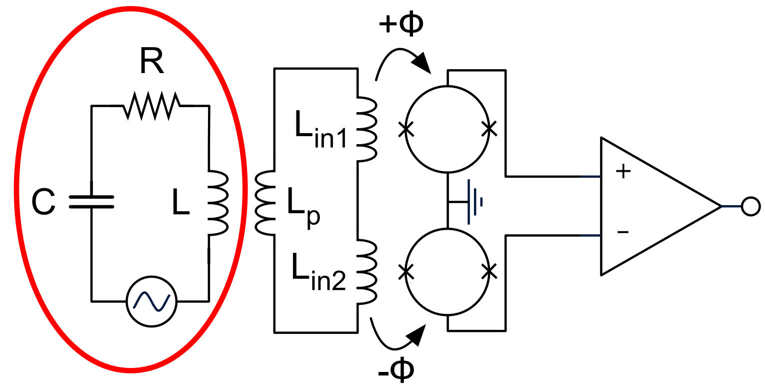




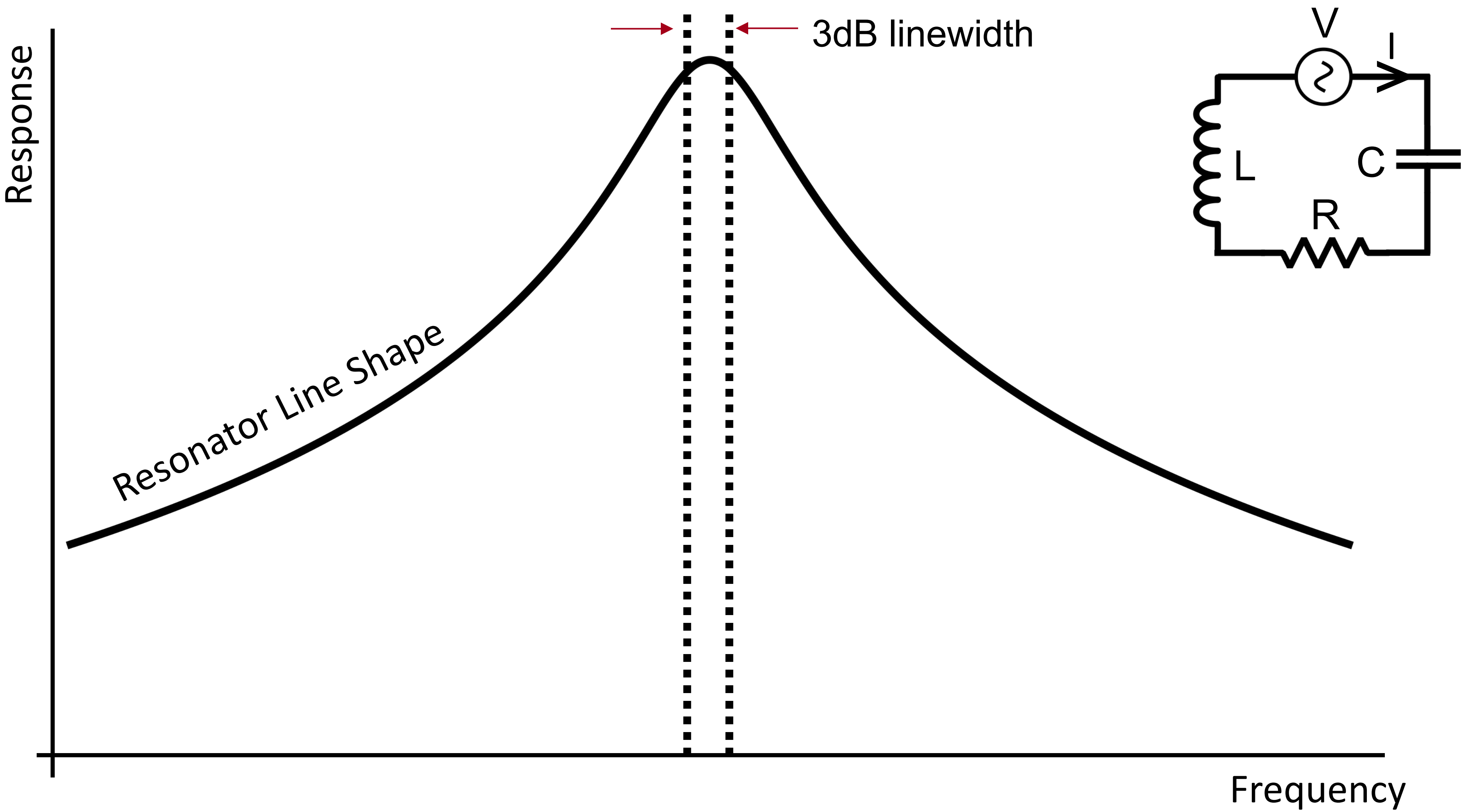
Side View

DM Radio is a lumped-element dark matter detector

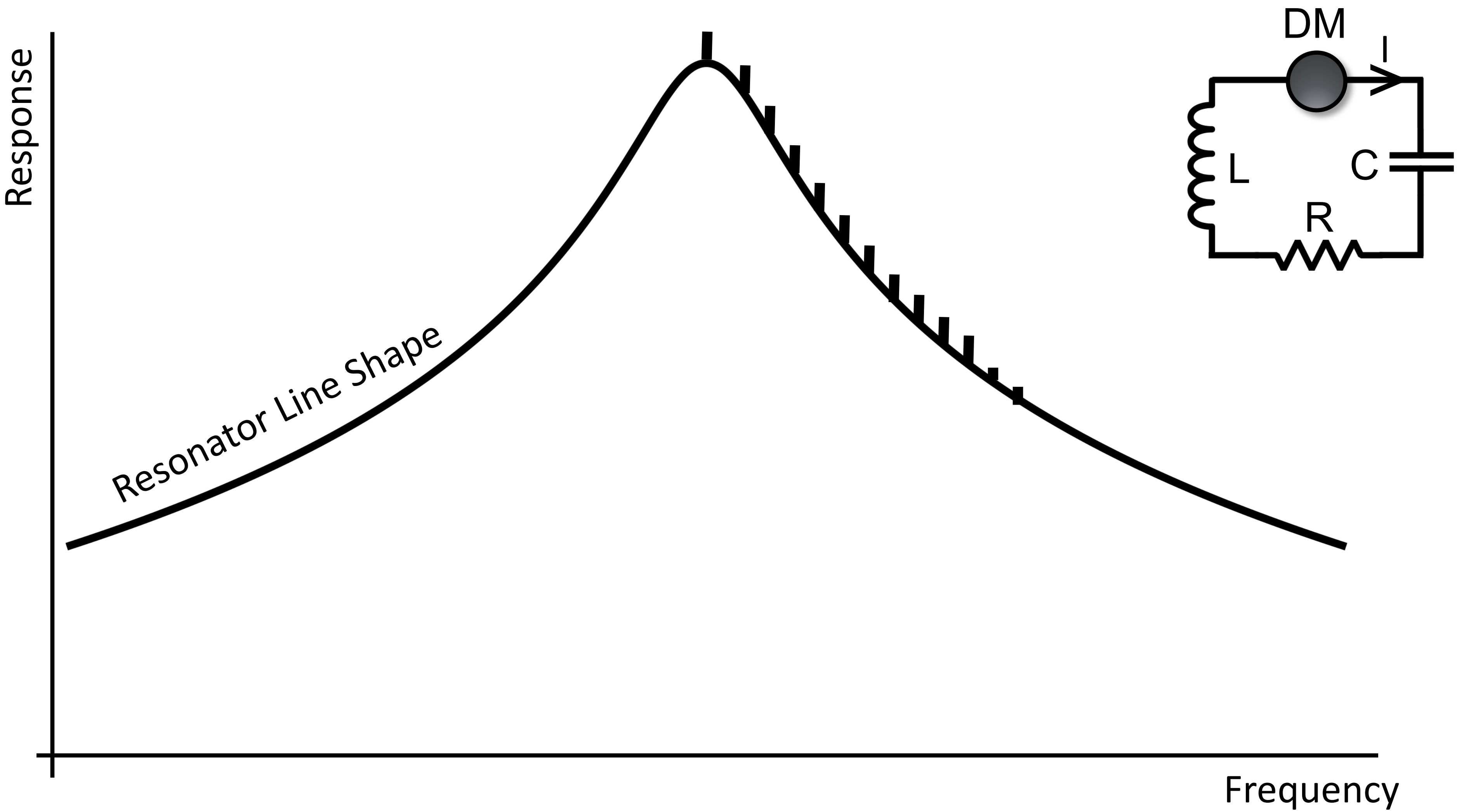




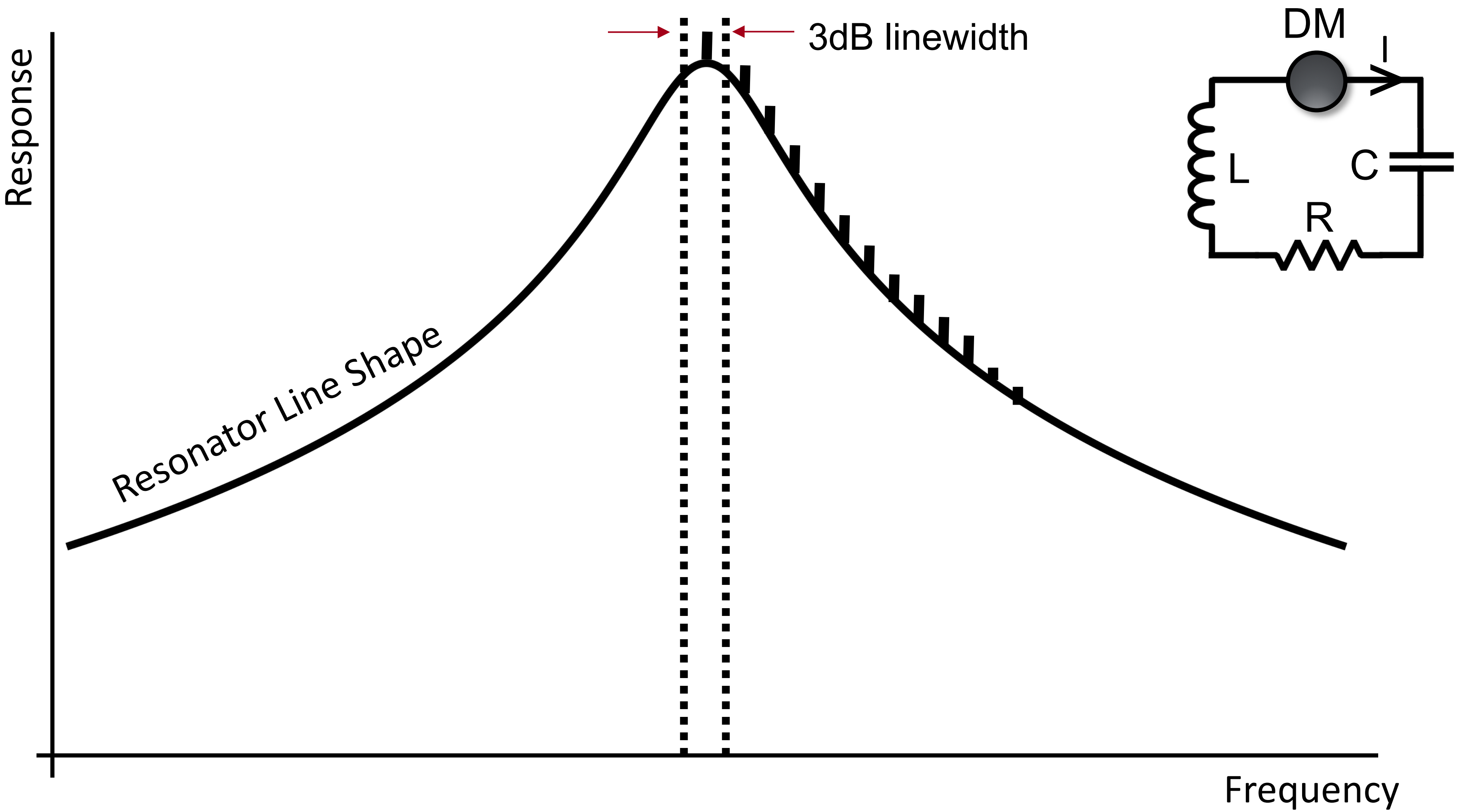
Resonators are typically characterized by linewidth



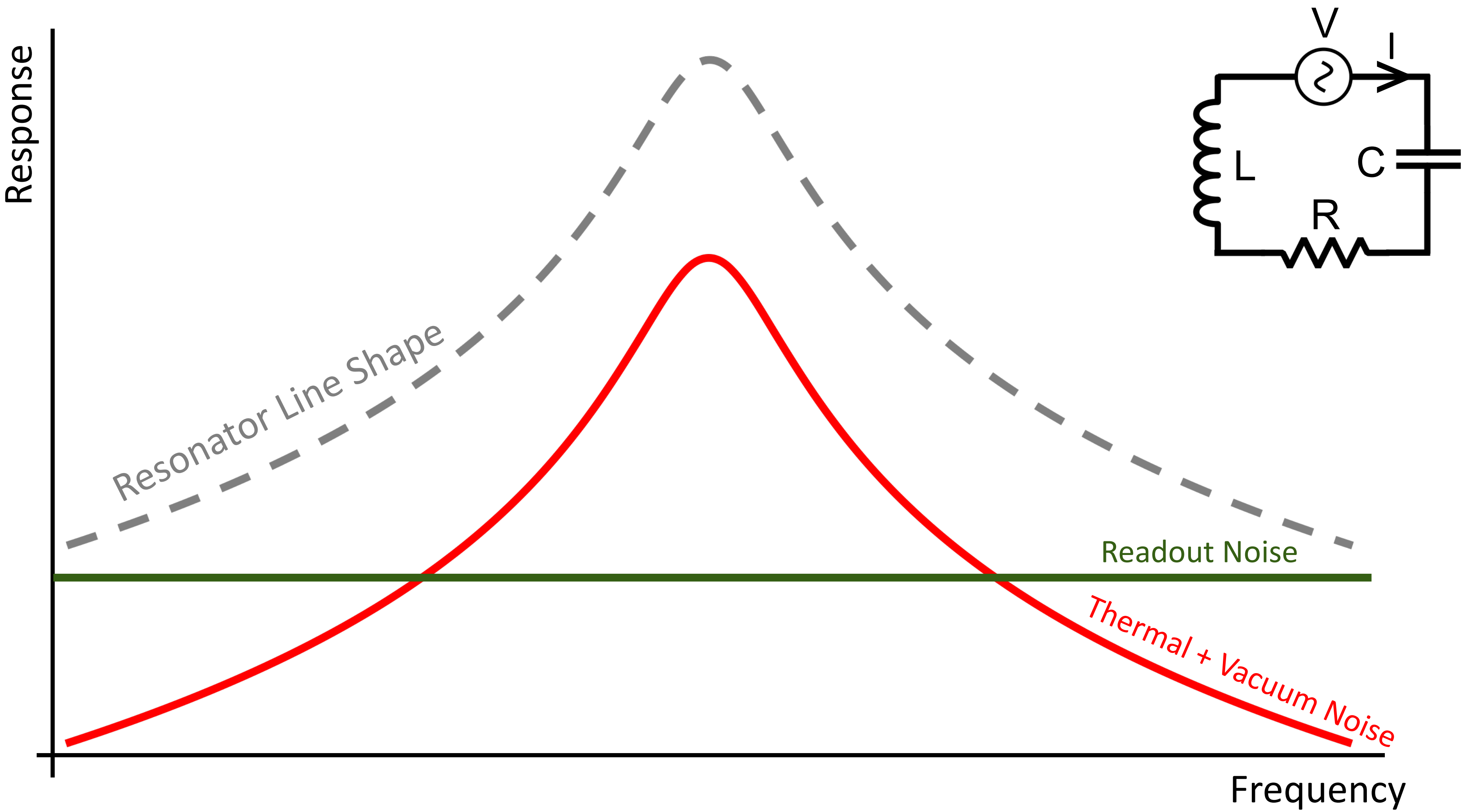
But the Signal exists far out from the linewidth



Signal/Noise has not degraded far outside the linewidth



Resonators have different noise contributions



Search faster with larger sensitivity bandwidth

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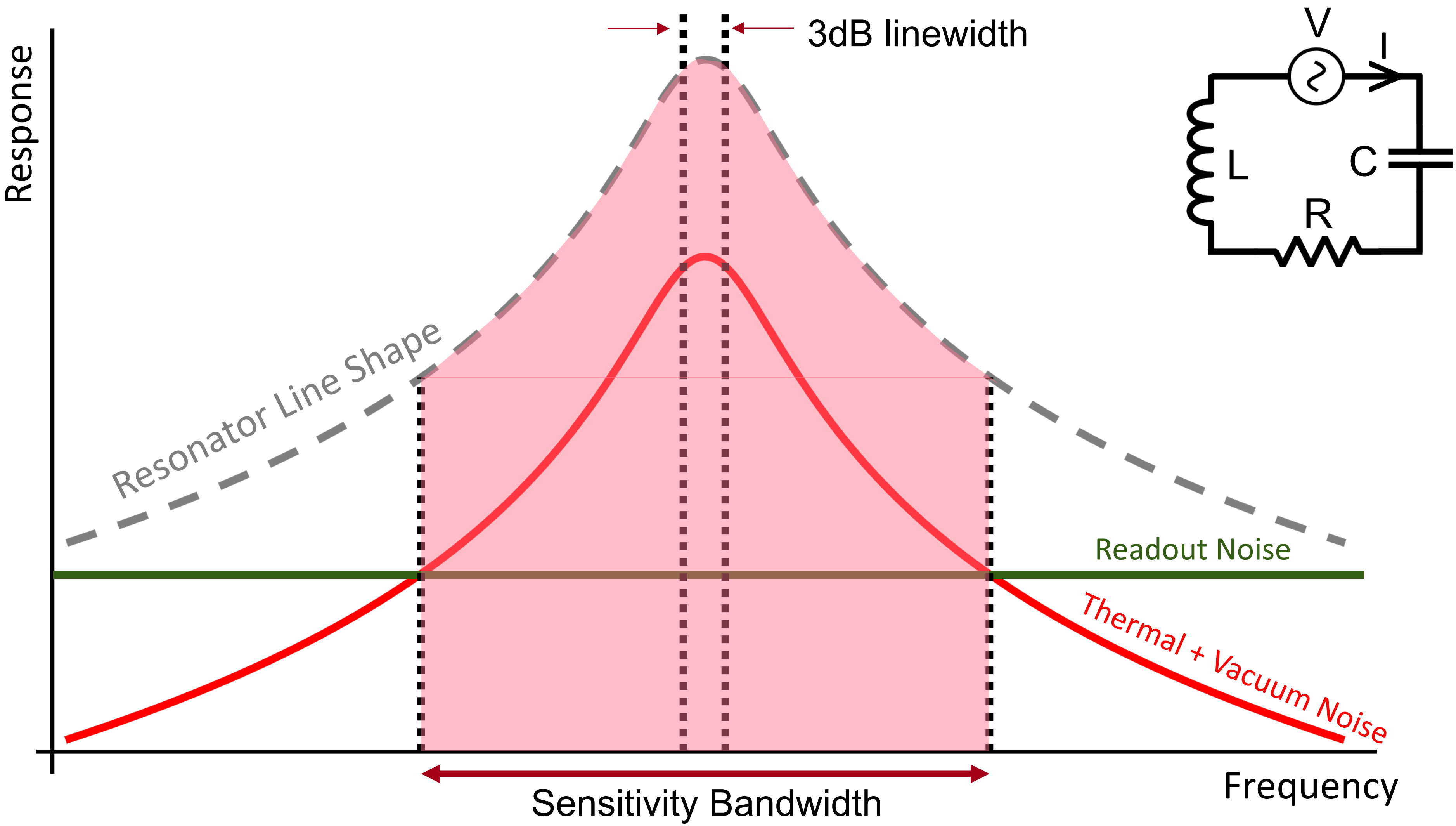
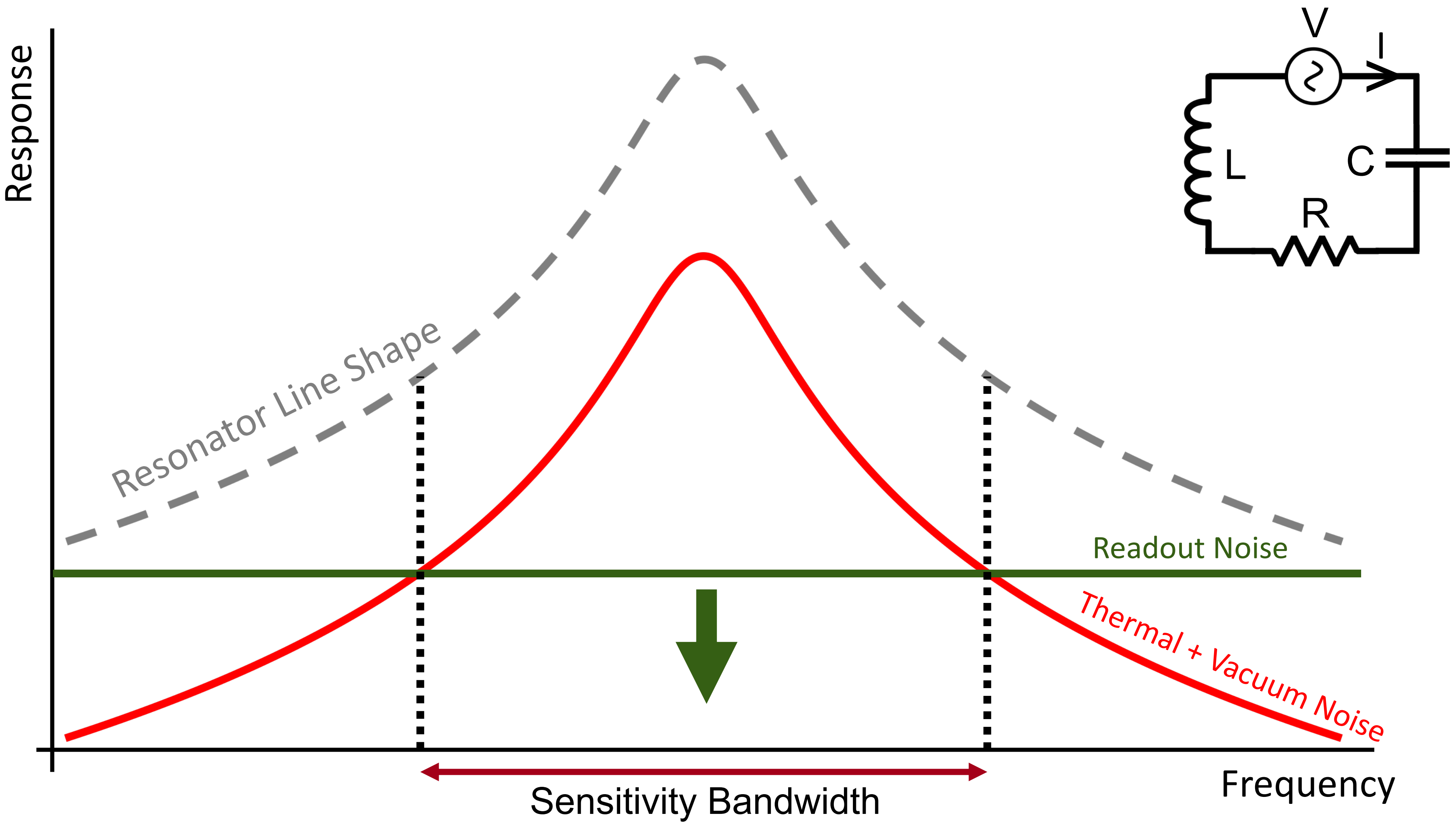
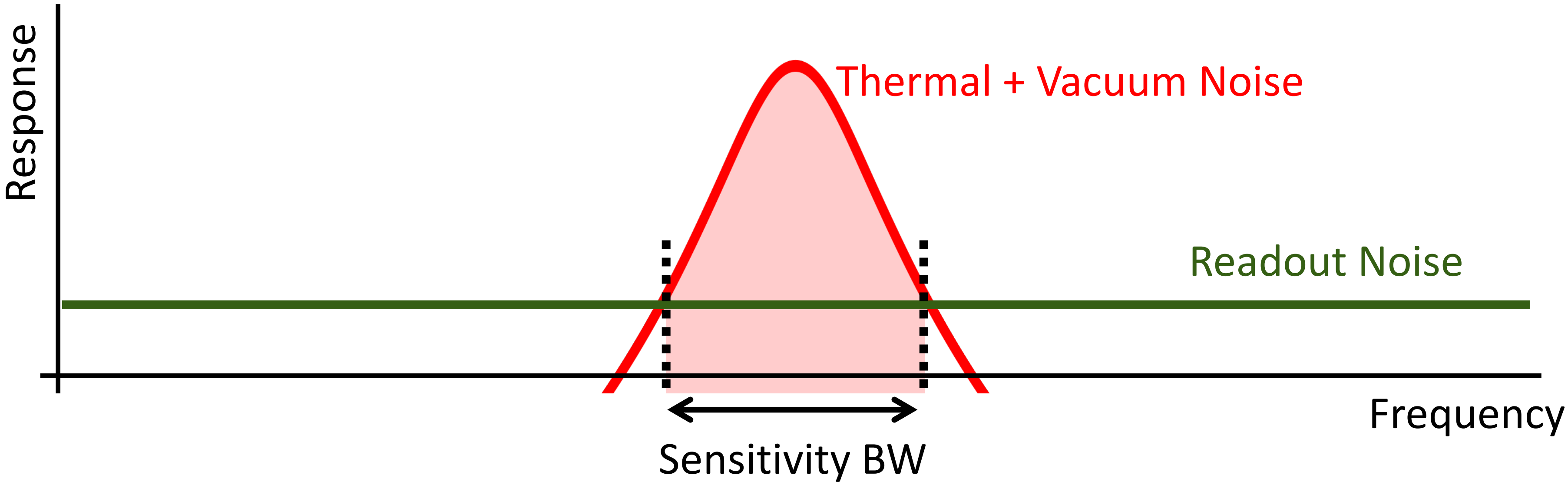


Lower readout noise to improve sensitivity bandwidth

SLAC



The readout noise is just the tip of the iceberg



Increase coupling to lower imprecision noise

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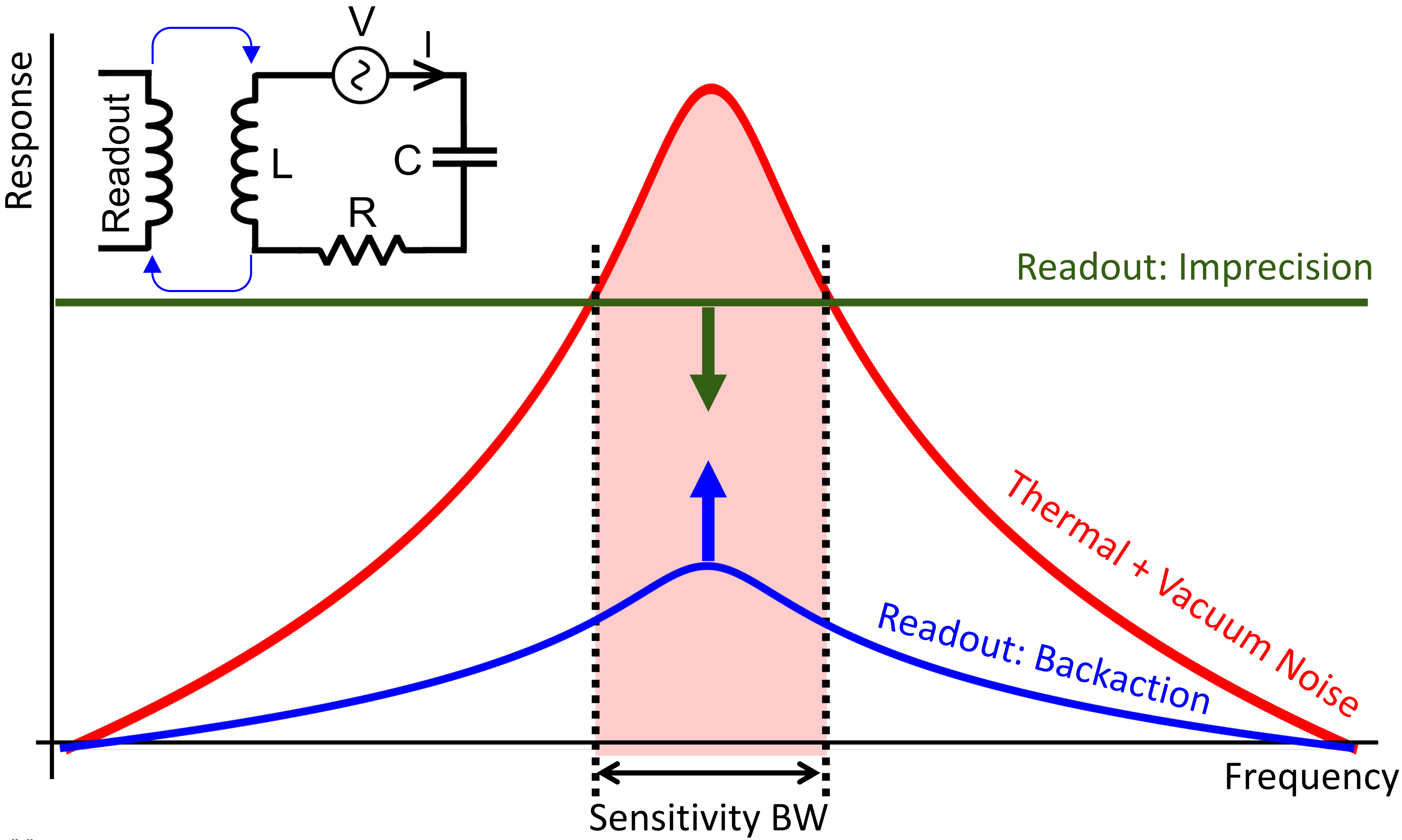
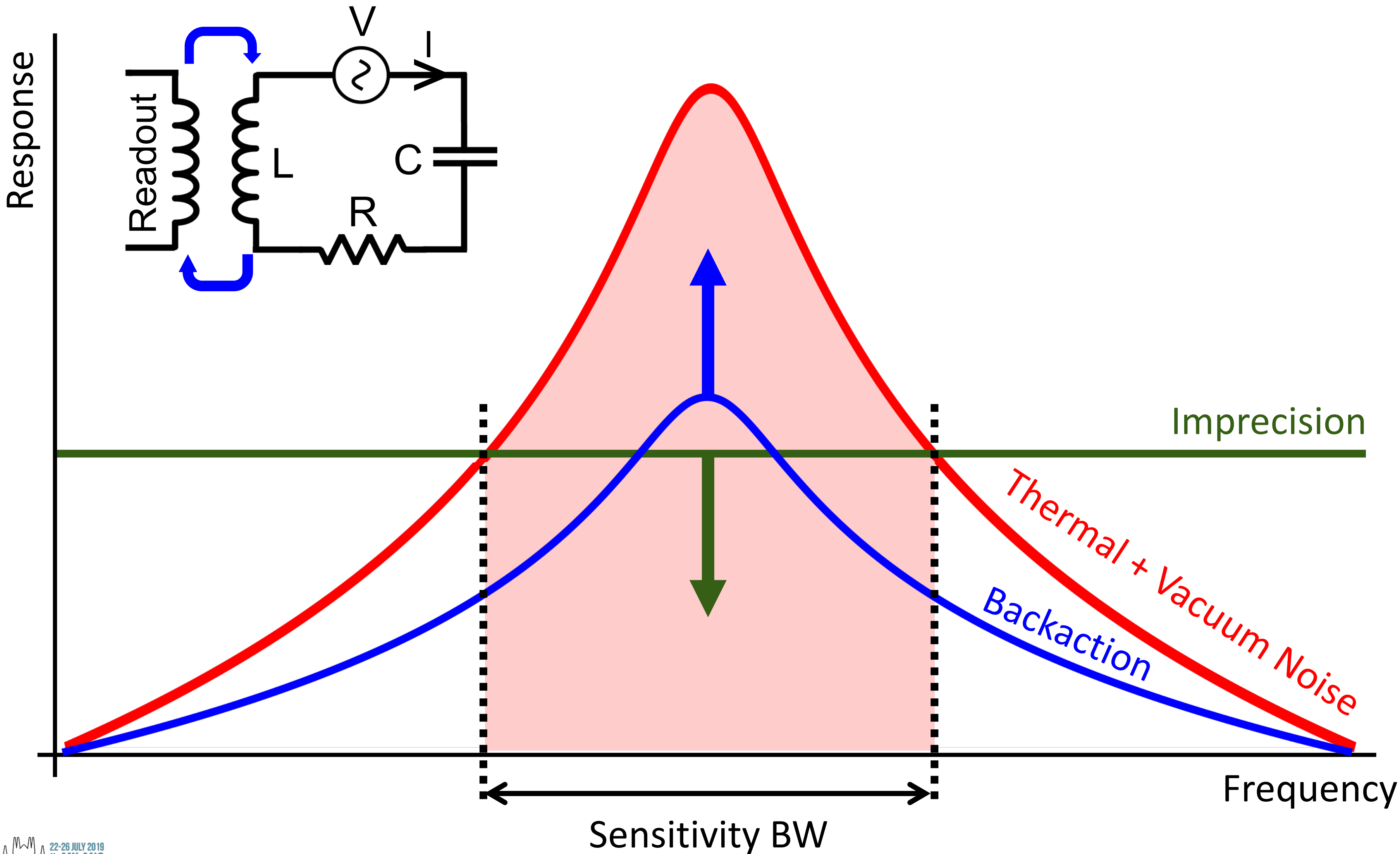


Backaction is exchanged for imprecision noise



Maximize backaction to maximize sensitivity bandwidth

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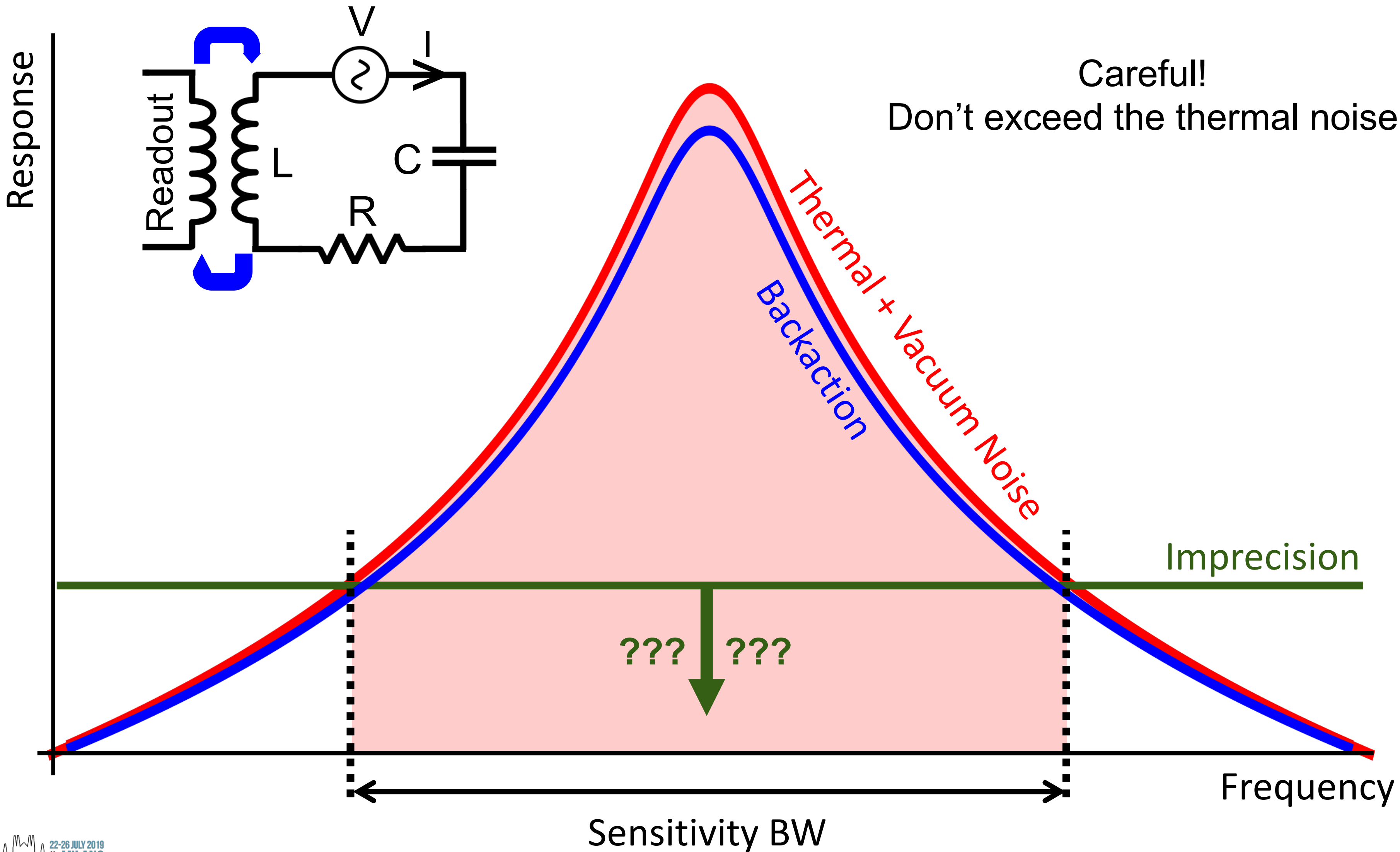

Borrow Backaction Evasion protocol from LIGO

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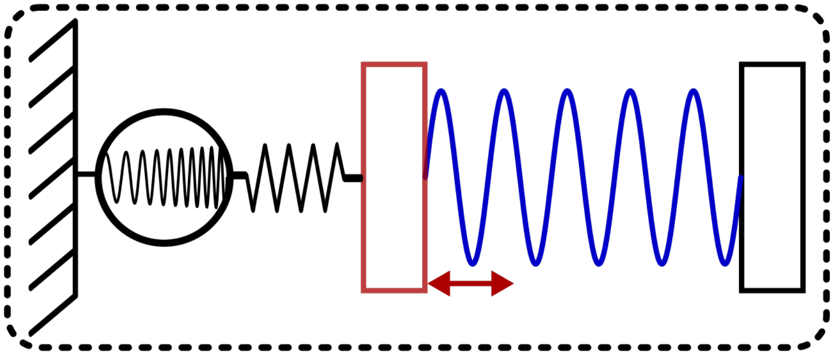
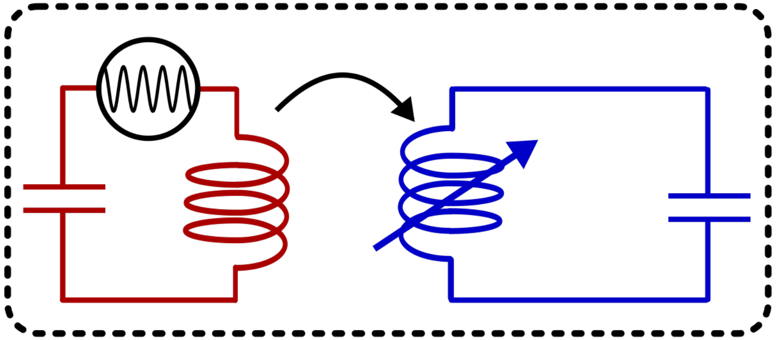
LIGO: Mechanical oscillator coupled to optical cavity. Use optical drive to tune coupling.

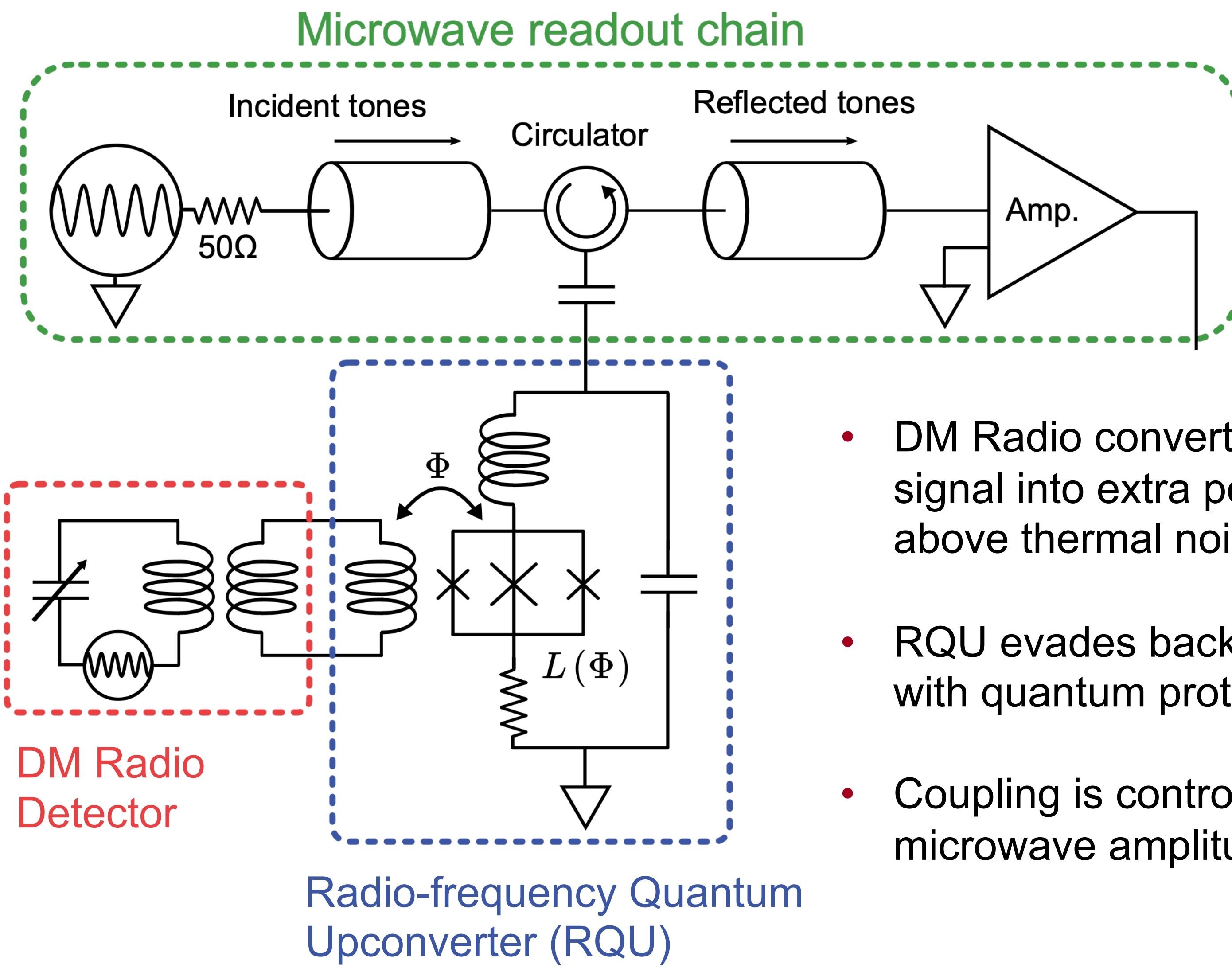
DM Radio: Low frequency resonator coupled to high frequency resonator. Use microwave drive to tune coupling.





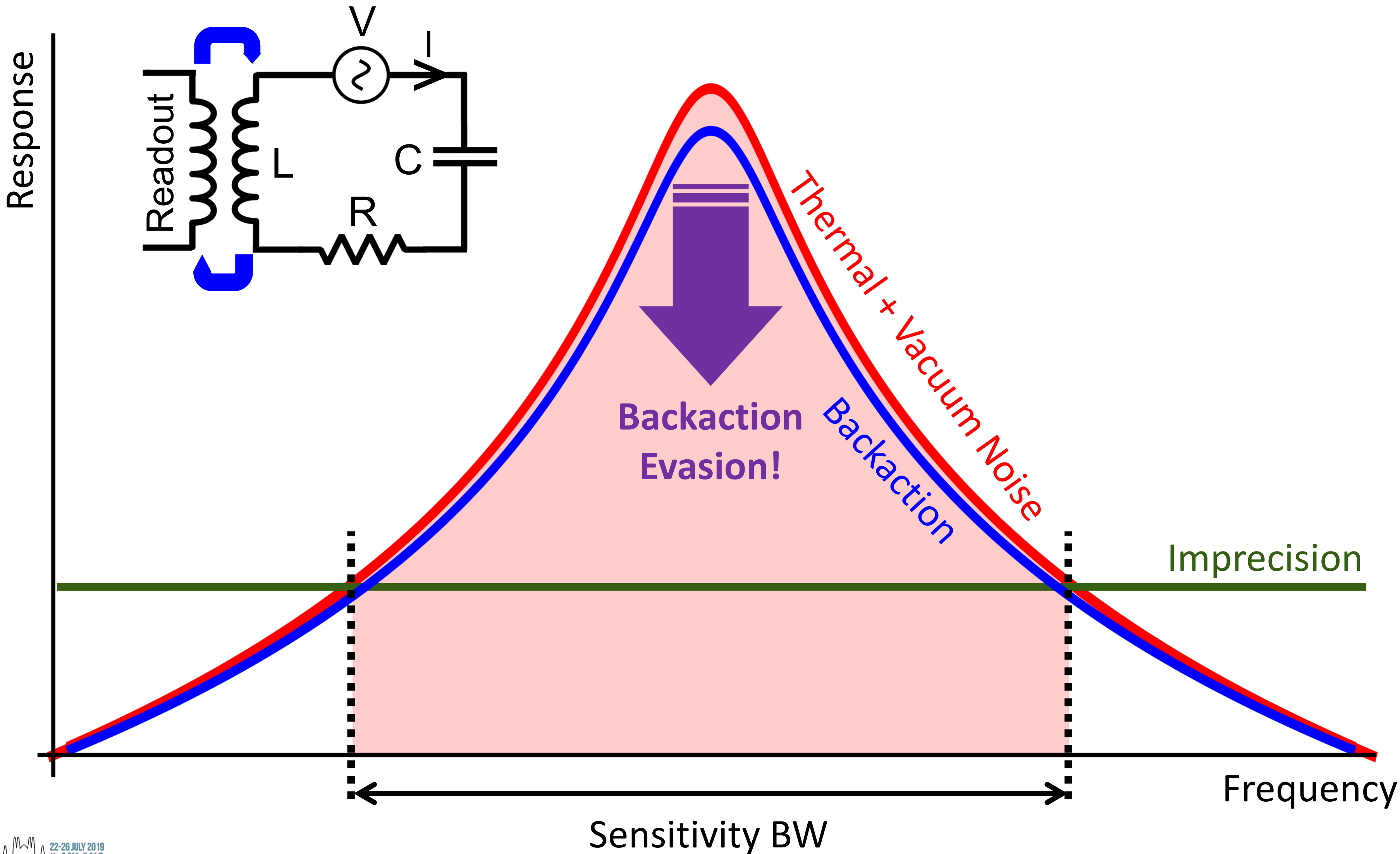
$$\hat{H} = \hbar\omega_a(\hat{a}^\dagger \hat{a} + \frac{1}{2}) + \hbar\omega_b(\hat{b}^\dagger \hat{b} + \frac{1}{2}) + \hbar g \hat{a}^\dagger \hat{a}(\hat{b}^\dagger + \hat{b})$$

Driving with a sideband modulated signal for BAE



- DM Radio converts axion signal into extra power above thermal noise
- RQU evades backaction with quantum protocol
- Coupling is controlled by microwave amplitude

RQU can evade backaction making more room



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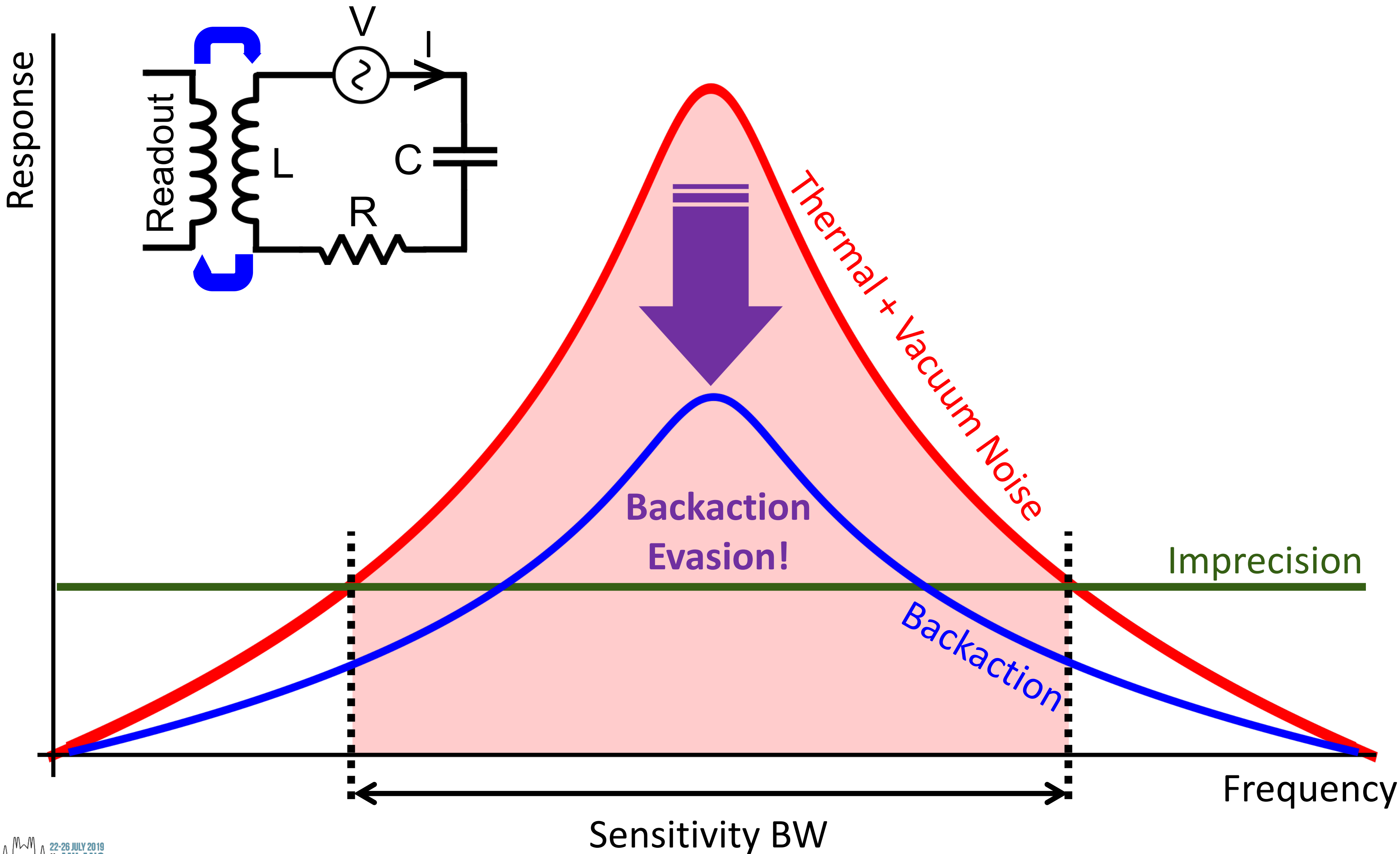

Increase coupling again for even more sensitivity!

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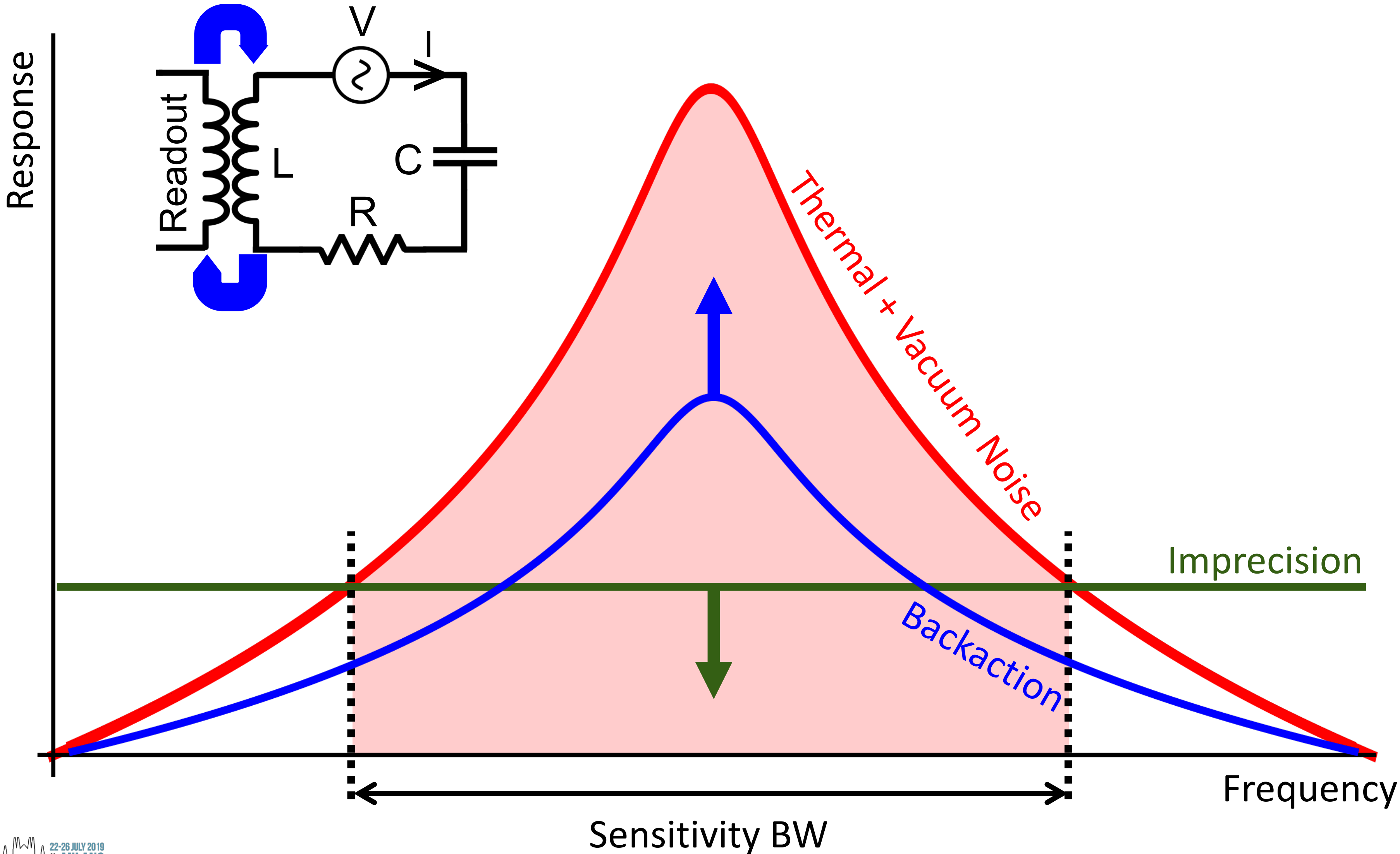
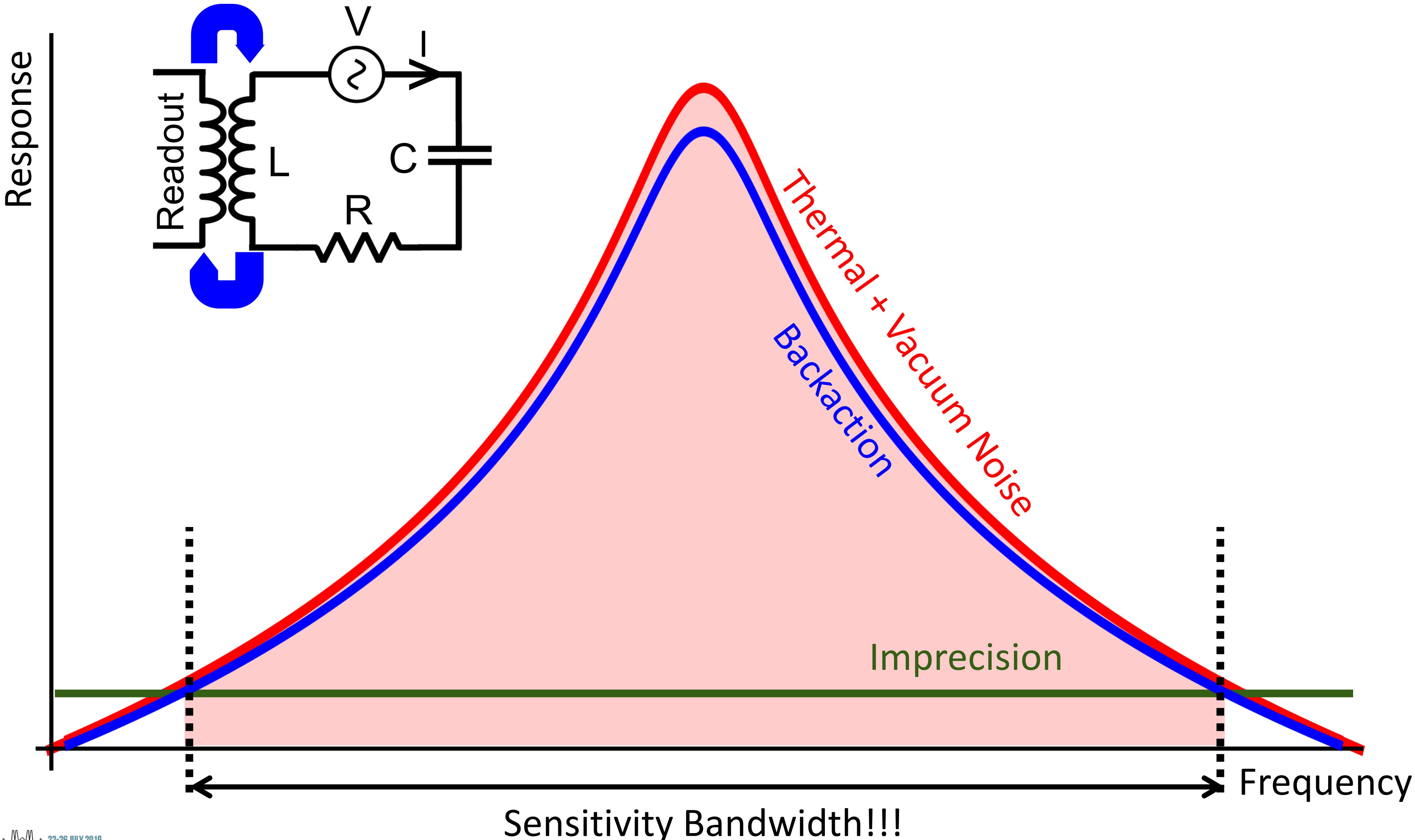


Combine strong coupling and BAE for max sensitivity!



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