

# QualityBREAD Updates

BREAD Collaboration Meeting 2026

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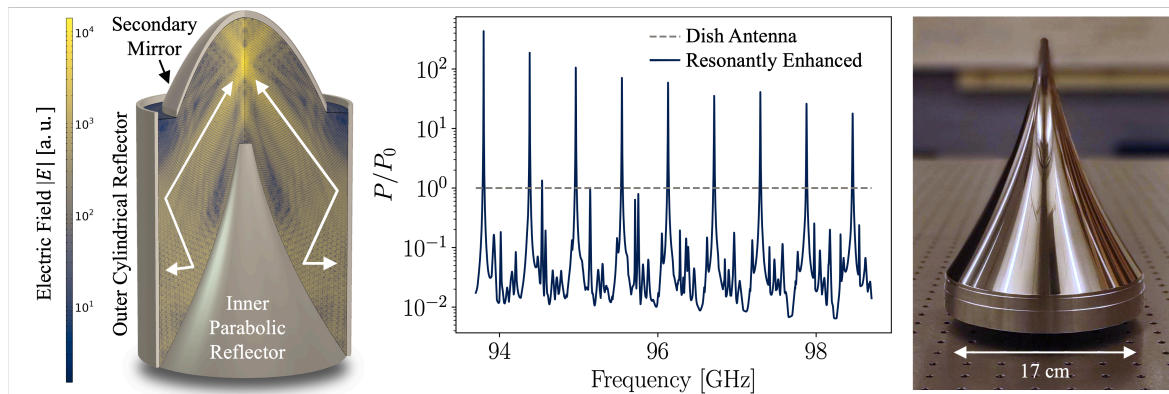
Gabe Hoshino

University of Chicago



# Concept

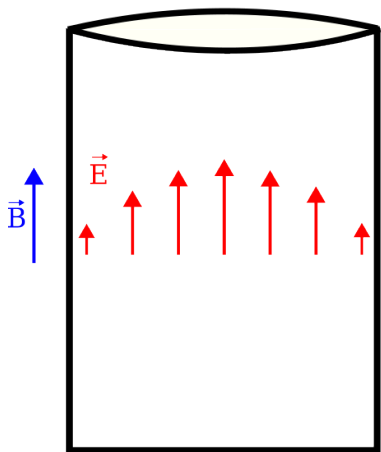
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- Fabry-Perot resonances
- Smaller reflector which fits in the cryostat at Harvard
- Enhances signal by about  $\sim 1-2$  orders of magnitude
- Secondary mirror separation can be adjusted to tune

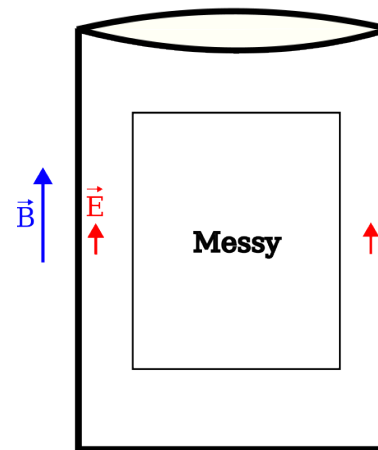


## Standard Cavity



- Form factor can be defined for the fundamental mode of a cavity

## BREAD "Cavity"



- Complicated geometry and higher order mode  $\rightarrow$  we only understand conversion at the surface

## Quality Factor

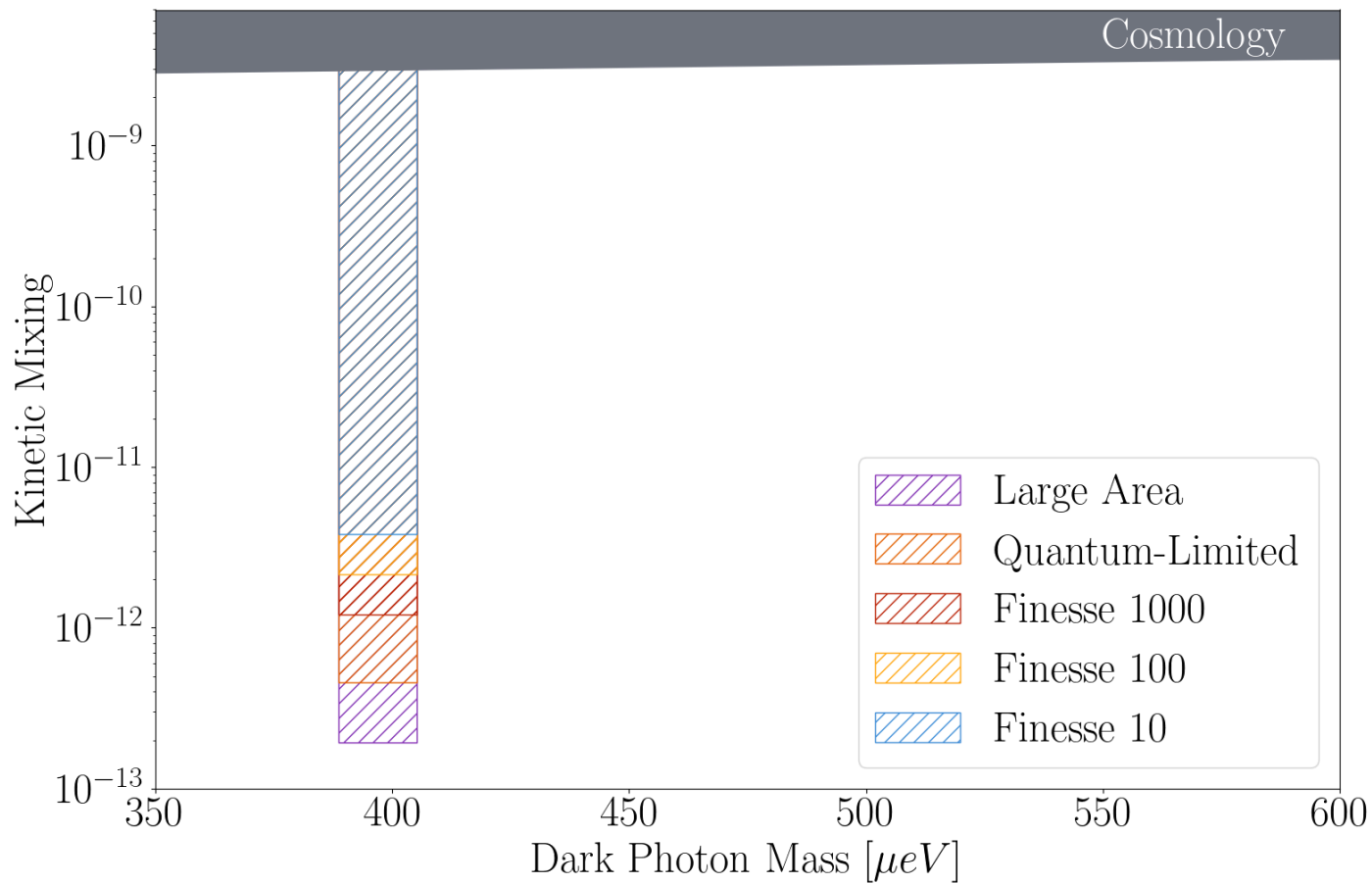
- $Q = \frac{f_r}{\Delta f}$
- Energy storage vs dissipation within one cycle of the **mode**
- Enhancement of coupling to the cavity mode

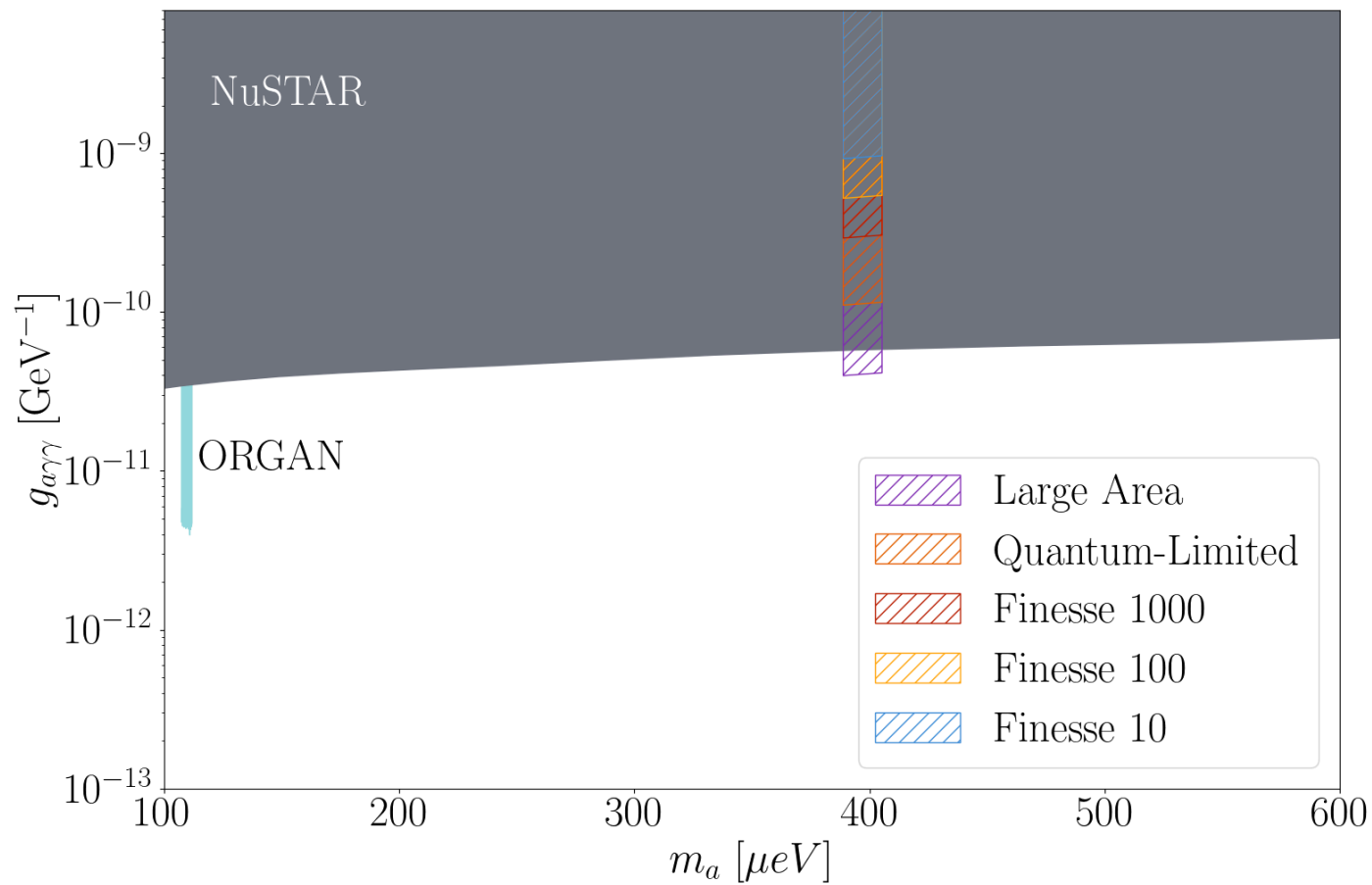
$$P_{\text{sig}} \propto QV$$

## Finesse

- $\varepsilon_f = Q \frac{\text{FSR}}{f_r} = \frac{\text{FSR}}{\Delta f}$
- Energy storage vs dissipation within one **photon round-trip**
- Enhancement of the coupling to approximately “free” photons

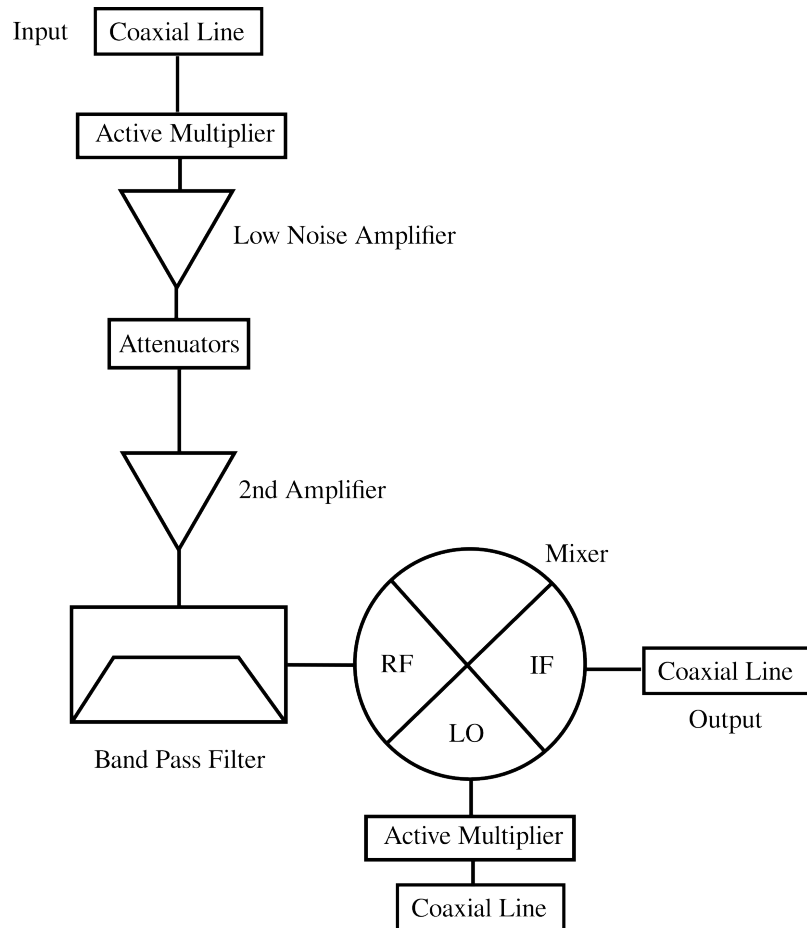
$$P_{\text{sig}} \propto \varepsilon_f A$$





# Receiver Chain

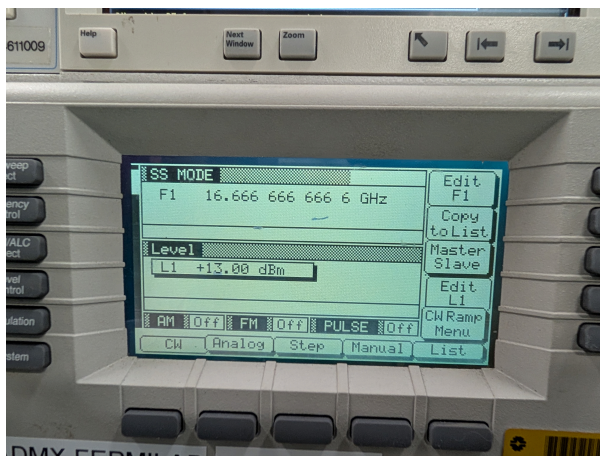
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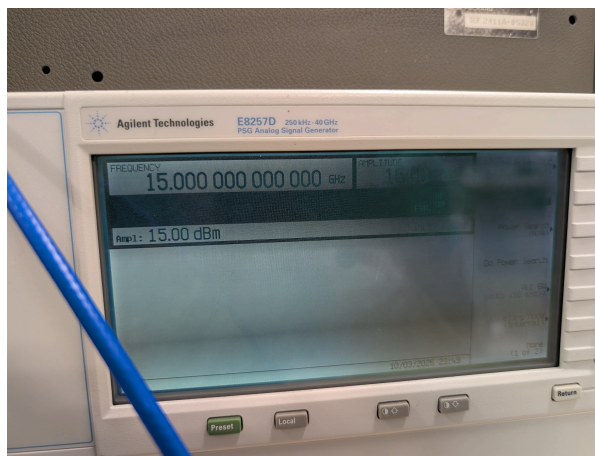
- A low noise receiver chain is being developed and tested at FNAL using off-the-shelf parts
- A W-band mixer is used with an LO produced by a 6x frequency multiplier and a lower frequency signal generator

- Receiver chain works as expected at room temperature.
- A 16.66 GHz signal was multiplied with a frequency multiplier and input into the receiver
- An LO of 15 GHz was used and the signal was read-out with a frequency of 10 GHz as expected

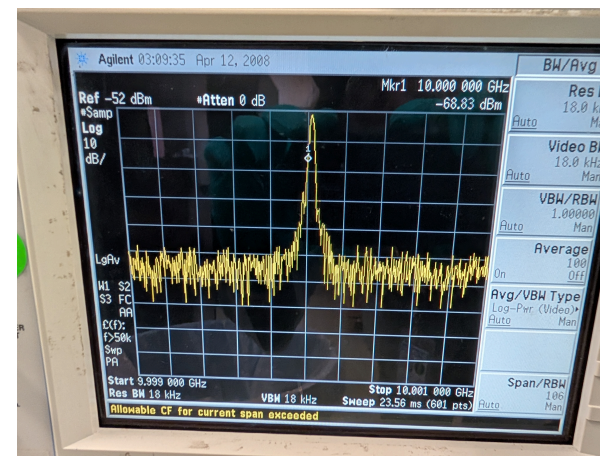
## Test Signal:



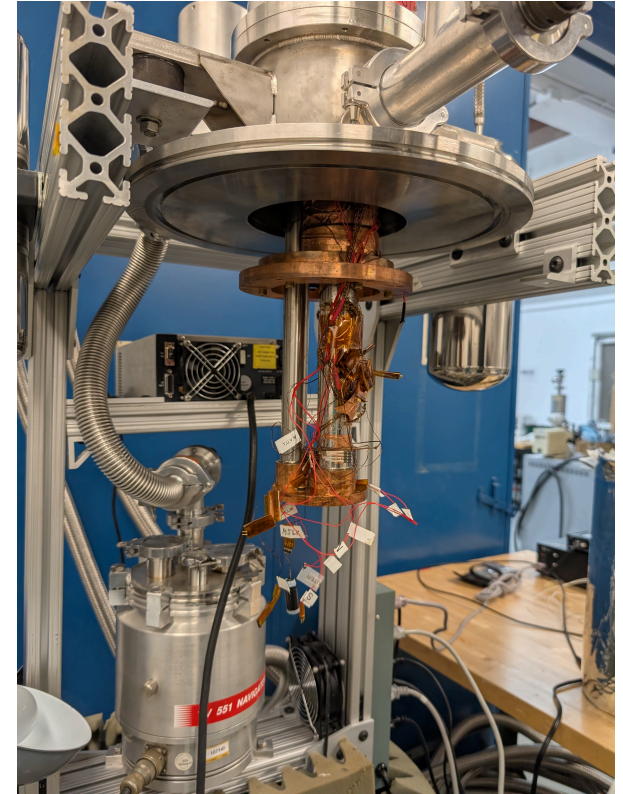
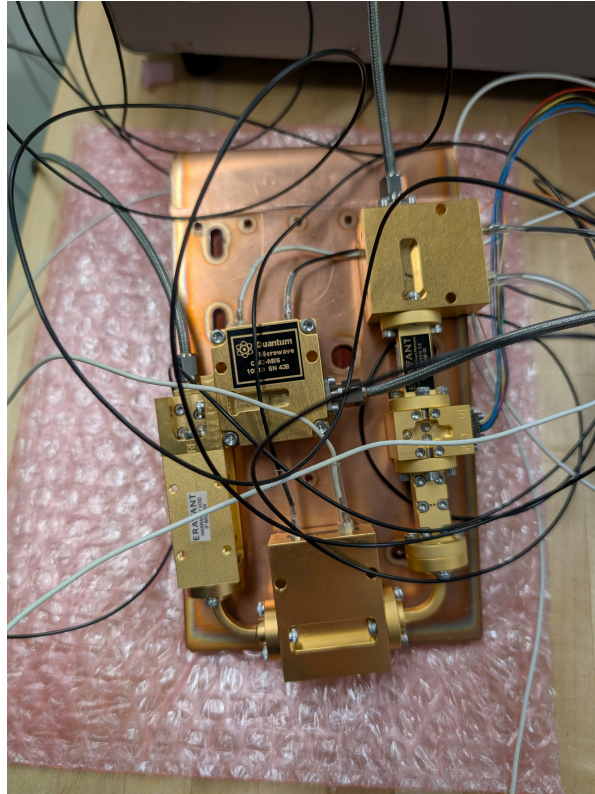
## LO



## Spectrum Analyzer



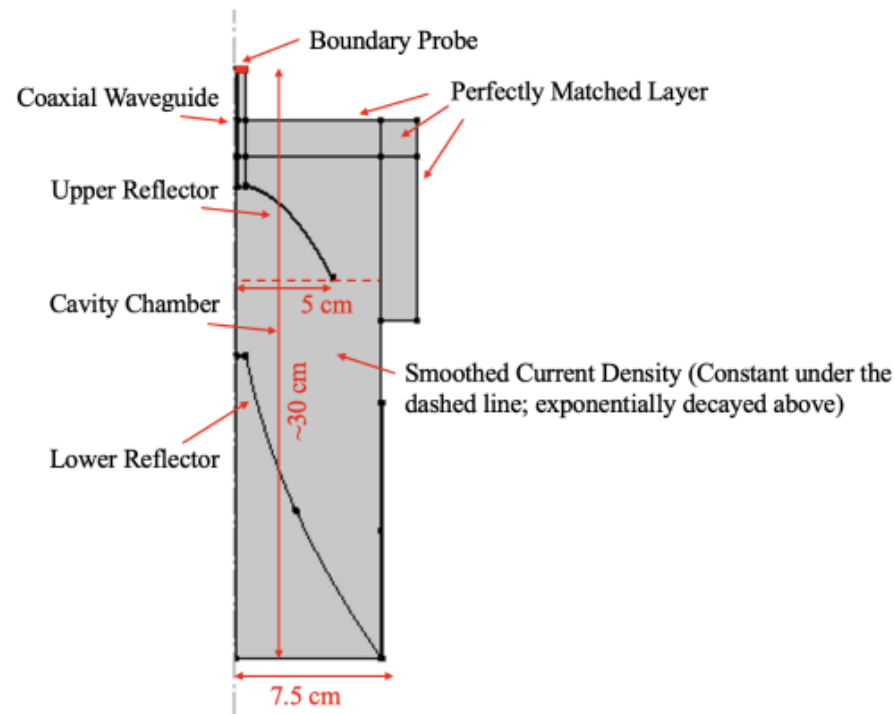
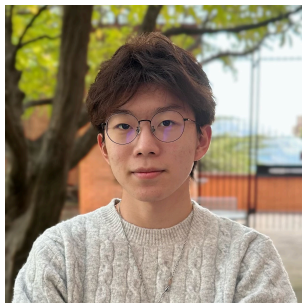
- The receiver chain has been cooled to 4K but that was too cold for everything but the LNA.
- Receiver will need to be reconfigured to have only the LNA at 4K using stainless steel waveguides.

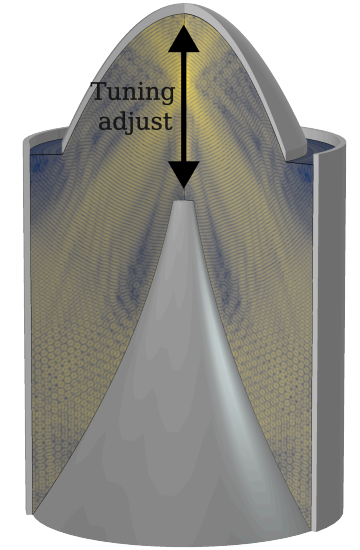
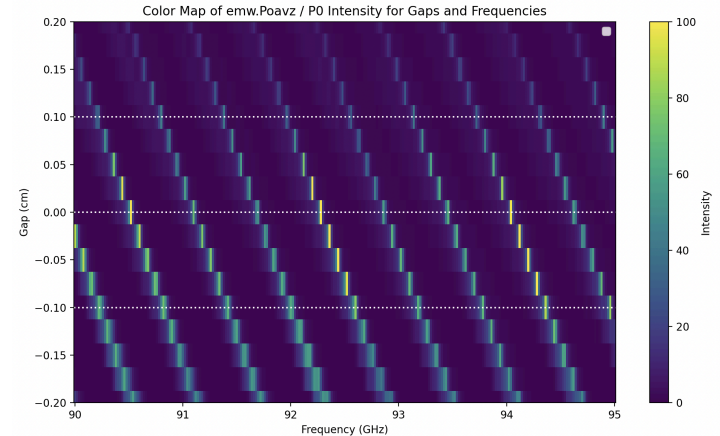
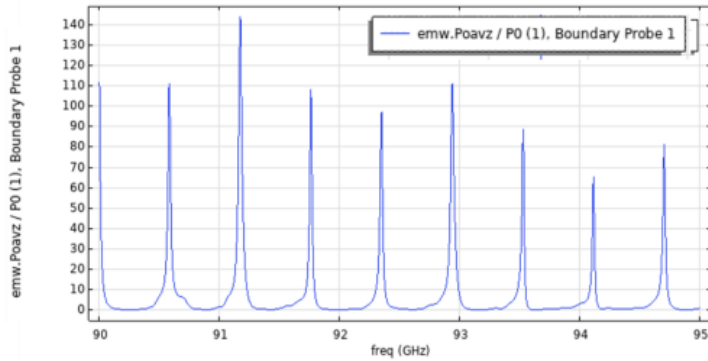


# Simulation Results

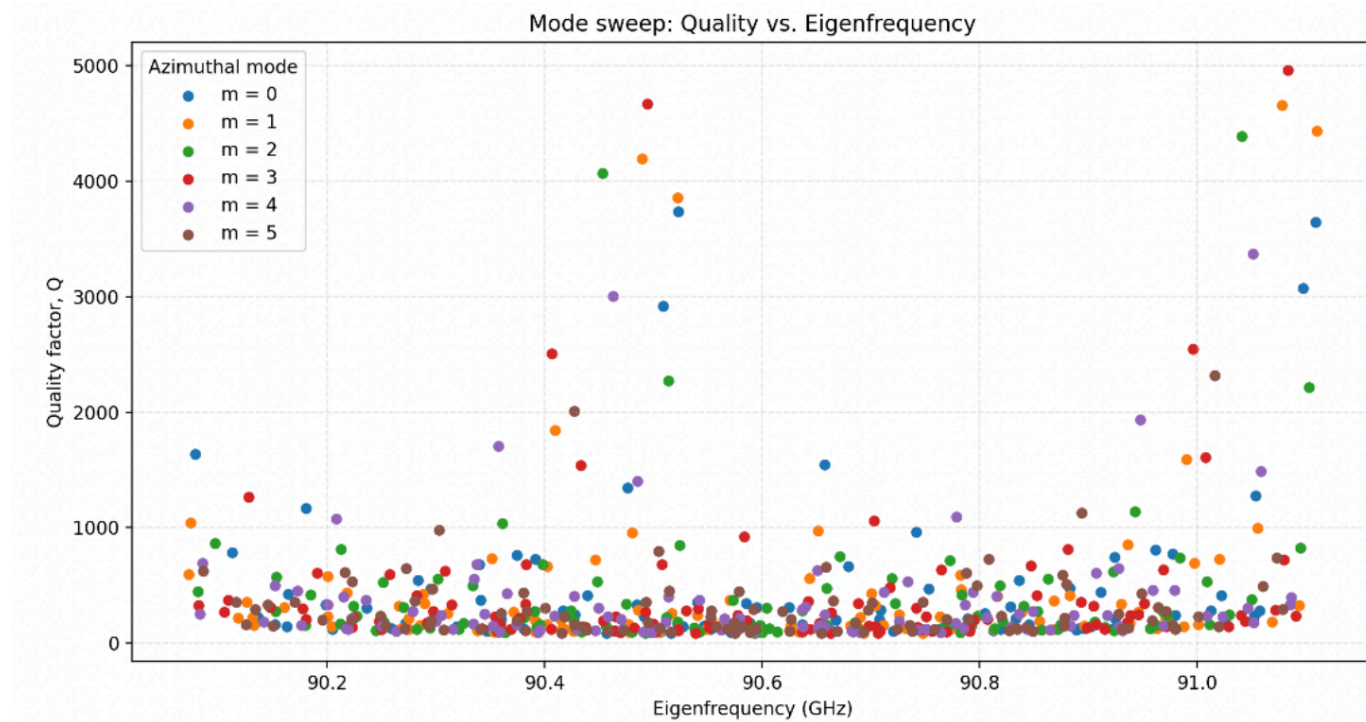
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- Initial optimization done by UChicago undergraduates Mira Littmann and Xiaoyu Chen using the COMSOL RF and optimization modules.
- A simple secondary parabolic reflector was optimized to yield a finesse of  $\sim 10$ – $100$  at around 90 GHz





- Simulations show that the resonances are tunable by moving the secondary mirror with respect to the primary BREAD reflector
- Tuning can span the entire free spectral range between two peaks

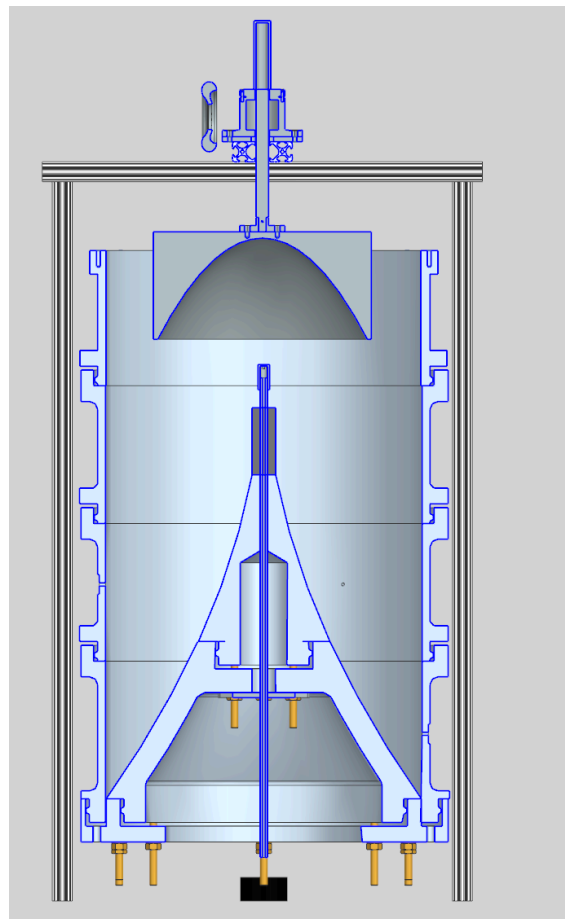


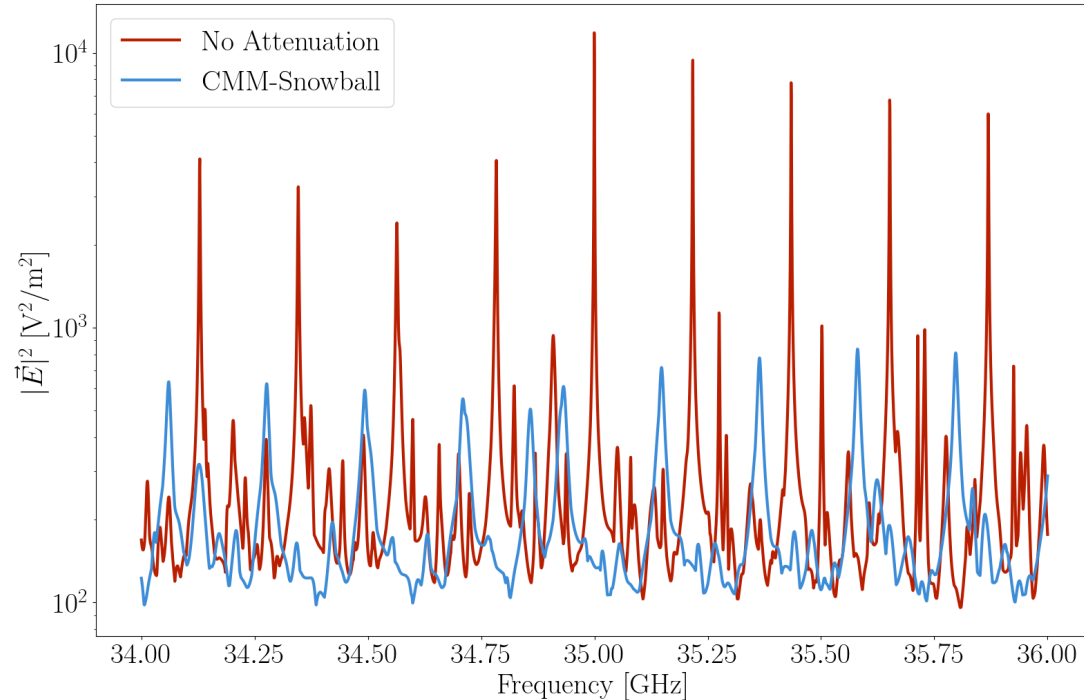
- Eigenfrequency simulations show modes which break azimuthal symmetry that have high quality factor. May make tuning challenging

# Low Frequency Prototype

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- We are building a prototype operating at around 35–40 GHz
- It will reuse the reflector used for GigaBREAD
- This will provide a cost-effective way to characterize modes which break azimuthal symmetry
- It will allow us to adjust the coupling in ways that would break azimuthal symmetry





- The GigaBREAD reflector was not designed to operate as high as 35–40 GHz.
- Simulating the effects of surface loss and using geometric deviations from the CMM data, we see that the resonances attenuated by an order of magnitude.

Thanks Everyone!

# Backup

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- Our sensitivity across a given frequency range is related to our signal power and integration time:

$$g_{a\gamma\gamma} \propto \frac{1}{\sqrt{P_{\text{sig}}}} \frac{1}{(\Delta t)^{\frac{1}{4}}}$$

- The finesse scales the signal power by resonantly enhancing axion-photon conversion at the walls of the reflector  $P_{\text{sig}} \rightarrow \varepsilon_f P_{\text{sig}}$ .

- Adding an enhancement from the finesse  $\varepsilon_f$  also increases our tuning steps since our sensitivity is only on peaks.

$$\varepsilon_f = \frac{\text{FSR}}{\text{FWHM}} = \frac{\text{Distance Between Peaks}}{\text{Width of Peaks}}$$

- So the total effect is:  $P_{\text{sig}} \rightarrow \varepsilon_f P_{\text{sig}}$ ,  $\Delta t \rightarrow \frac{1}{\varepsilon_f} \Delta t$ :

$$g_{a\gamma\gamma} \propto \left( \frac{1}{\varepsilon_f} \right)^{\frac{1}{4}}$$