Characterizing Feedhorns for CMB-S4

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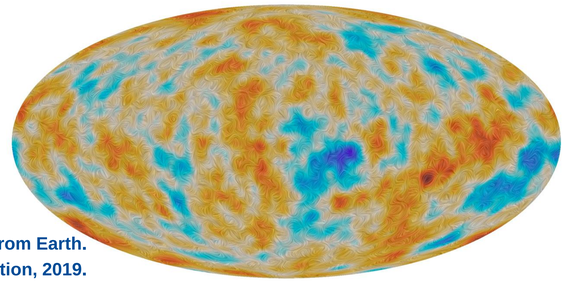
Introduction

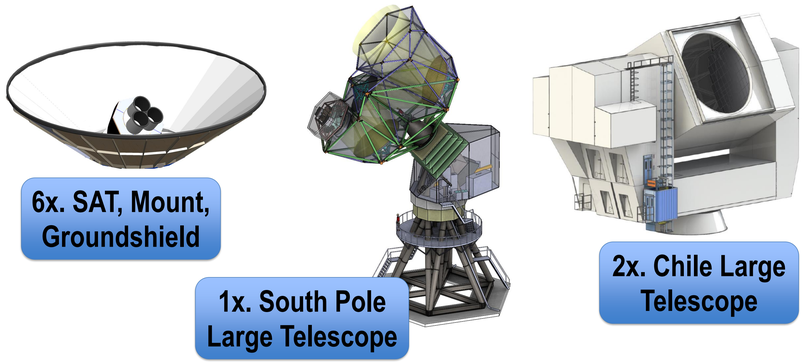
The CMB is the earliest light in the universe, holding a wealth of information like the energy scale of inflation.

Inflationary theory is a period of rapid expansion in the early universe and has yet to be measured. Such a measurement would give evidence for inflation and help us differentiate between different theoretical models.



CMB Map of the sky from Earth. Plank Collaboration, 2019.

CMB-S4 is a collaborative experiment utilizing small and large aperture telescopes to measure CMB radiation. As the sensitivity of individual detectors has been maximized, the next step in increasing sensitivity is to increase the number of detectors. But with better sensitivity, comes increased susceptibility to systematic effects.



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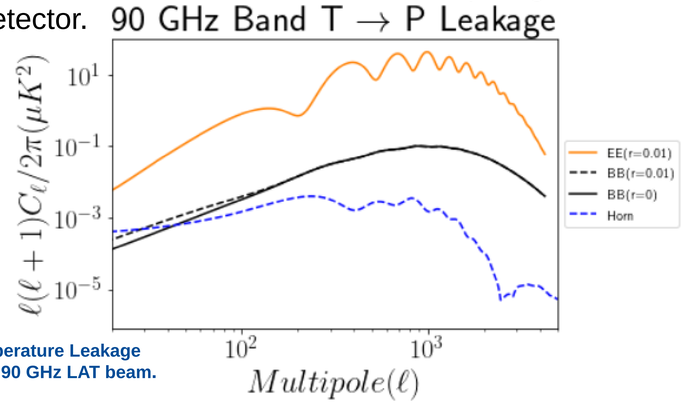
Beam Mapping Facility

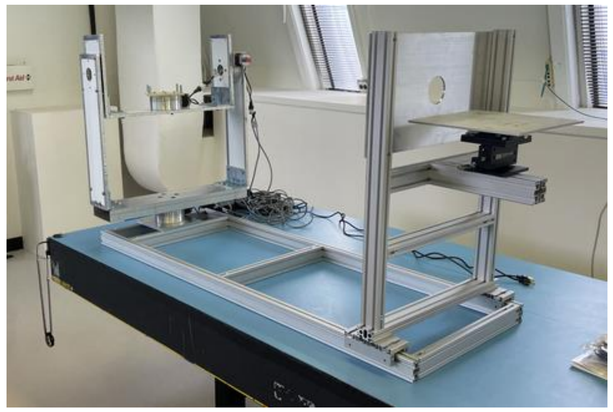
A key optical element in the telescopes is the feedhorns which define the detector beams and couple light onto the detector.



Temperature Leakage for a 90 GHz LAT beam.

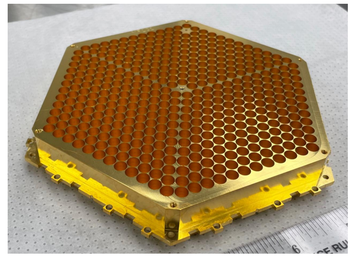
We can model the effect of beam systematics on the power spectrum. I developed a python notebook that made existing beam systematics code more streamlined and easily accessible for public use.

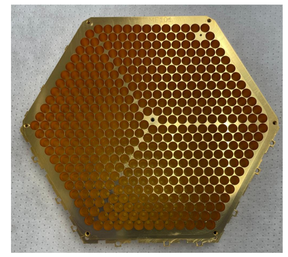
To meet the production needs of CMB-S4, feedhorns are now fabricated from aluminum. We must ensure that the beams measured from these horns match simulated performance. I developed motion control software for our beam mapper to perform these scans.



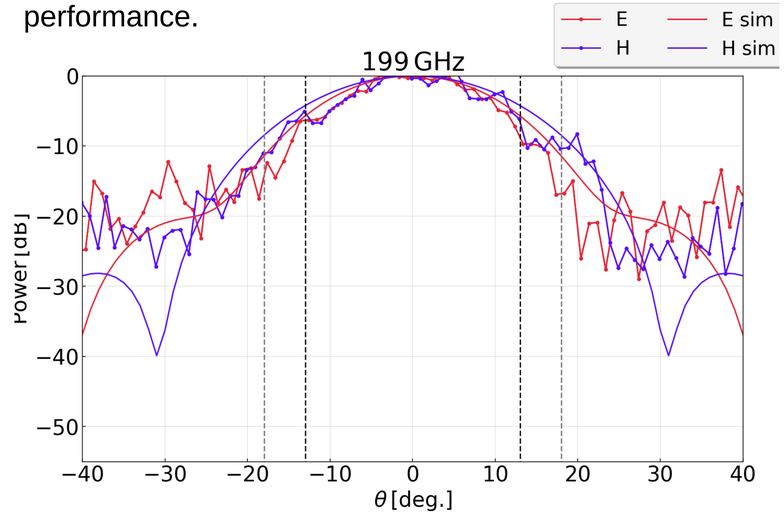
Commissioned beam mapping apparatus (still in progress).

Beam Measurements





As the Fermilab beam mapper is still in development, we utilized its sister system at University of Chicago to measure feedhorn beams. The figure below shows our measurement of the beam with its simulated performance.



E- H-plane plot of simulation vs data at 199GHz

Conclusion

I developed motion control, systematics simulation, and analysis code that will be used to design and test the first CMB-S4 feedhorn arrays at Fermilab. We find that measurements from the metal feedhorns are consistent with their simulations. This fabrication technique will help enable the production of over 500 feedhorn arrays for CMB-S4, which will reach critical thresholds on measuring inflation.