Bandpass Calibration with the **F**requency-selectable **L**aser **S**ource (FLS)

Shreya Sutariya
On behalf of the Simons Observatory Collaboration

Bandpass Calibration with the FLS

Motivation

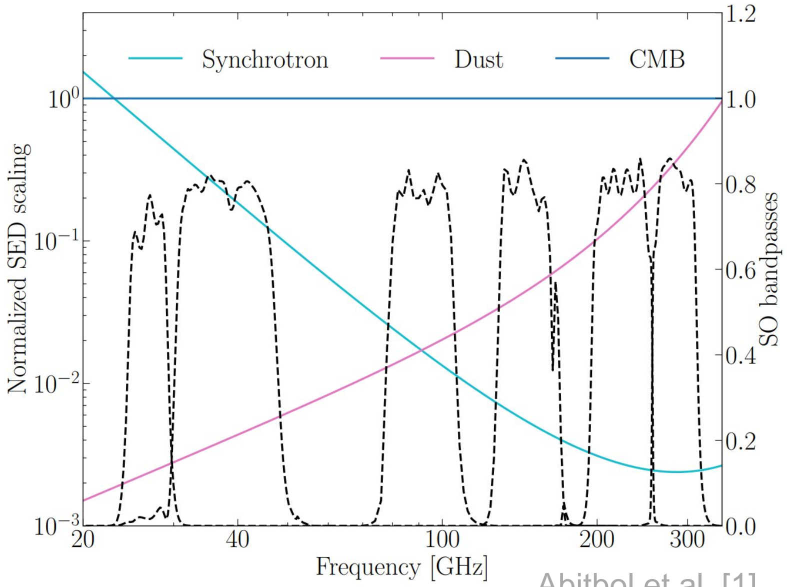
Frequency-selectable Laser Source (FLS) Instrument Design

FLS Characterization

Measurement Procedure and Results

Bandpass Calibration and Component Separation

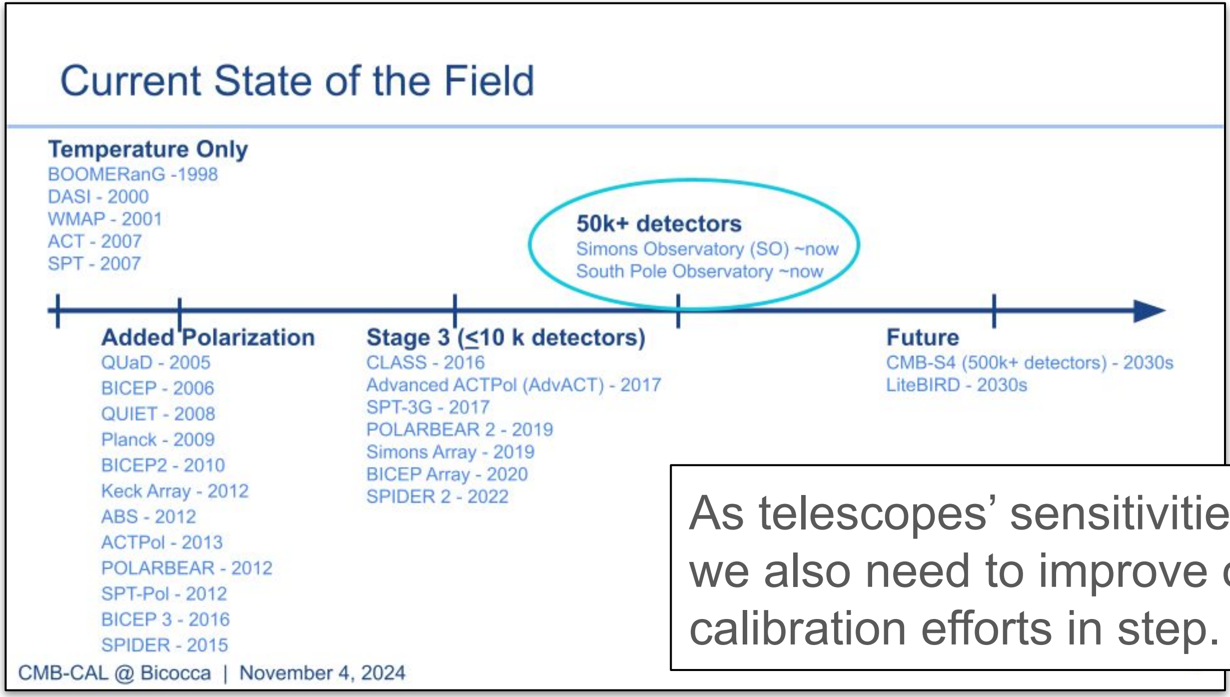
- Astrophysical components like synchrotron and dust also emit in the CMB frequencies.
- Each component has its own frequency dependence, its Spectral Energy Distribution.
- Component separation requires knowledge of the detectors' bandpasses to successfully isolate the different signals.



Abitbol et al. [1]

1. Maximilian H. Abitbol et al., "The Simons Observatory: gain, bandpass and polarization-angle calibration requirements for B-mode searches," JCAP05 (2021) 032

Bandpass Calibration for next-generation CMB experiments



As telescopes' sensitivities increase, we also need to improve our calibration efforts in step.

Credit: S. Simon

Bandpass Calibration for next-gen CMB experiments

- Currently, Fourier Transform Spectrometers (FTSes) achieve a few percent-level accuracy of the bandpasses [T. Alford et al., in prep]
- Science drivers like inflation and cluster science for current and future experiments put more stringent requirements on bandpasses.

Outline

Motivation

Frequency-selectable Laser Source (FLS) Instrument Design

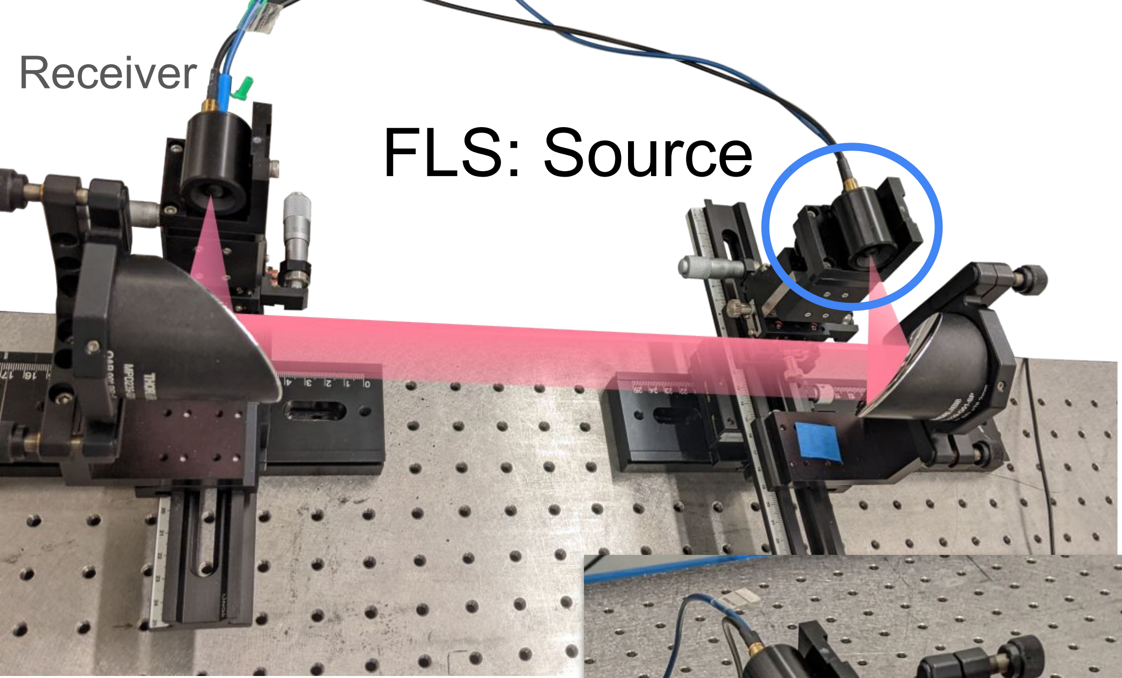
FLS Characterization

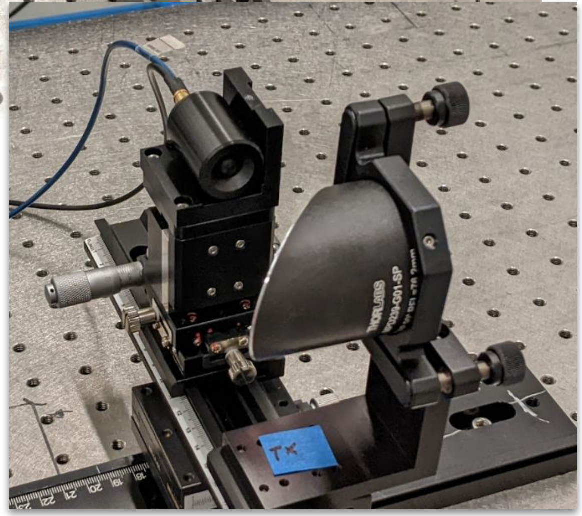
Measurement Procedure and Results

- The FLS is a calibration instrument to measure bandpasses and out-of-band leakage.
- FLS and FTS measurements show agreement, with the FLS being able to measure edges more sensitively.

1. **Source**
2. Attenuators
3. Coupling Optics

FLS: Source





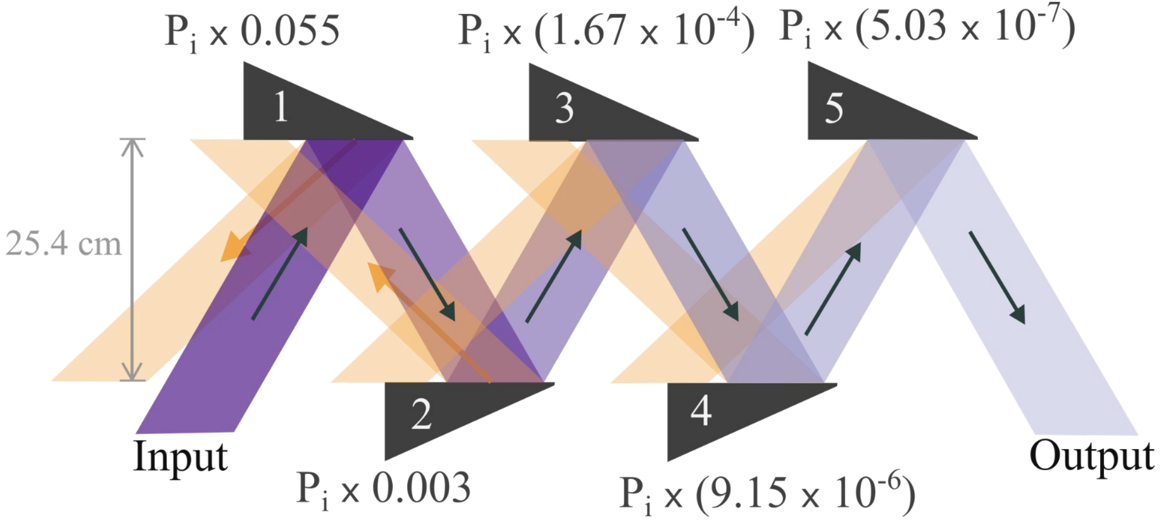
Commercially available GHz/THz laser that emits from 20 - 1200 GHz with fine resolution.

- The laser system consists of photomixer source and receiver.
- Emits ~65 uW at 100 GHz.

Prism Attenuators + Power Variability

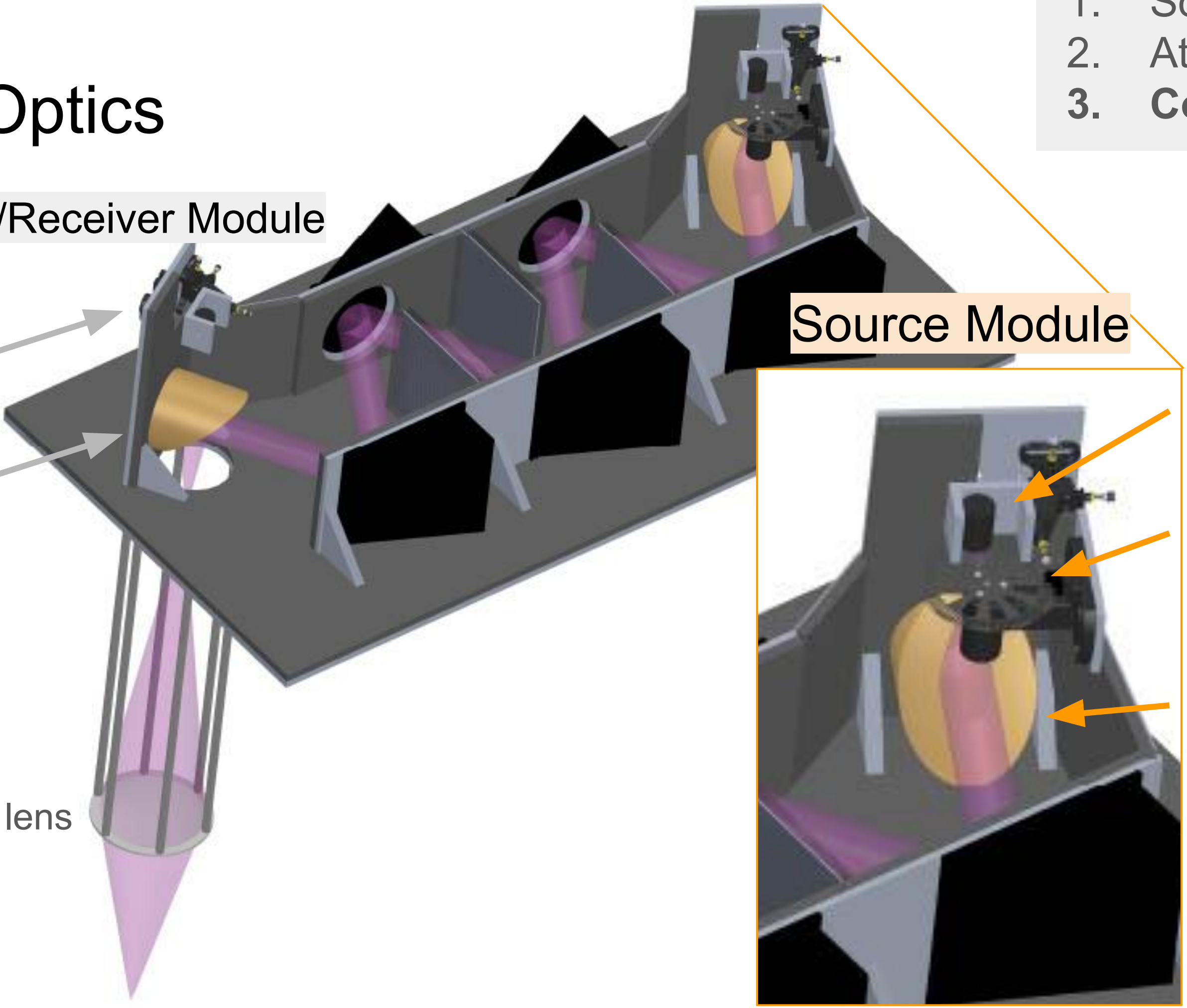
- Incident light loses ~94% of its power after one reflection
- Using up to five prisms can significantly attenuate the laser power.

Each prism is replaceable by a reflective plate, allowing for power tunability.



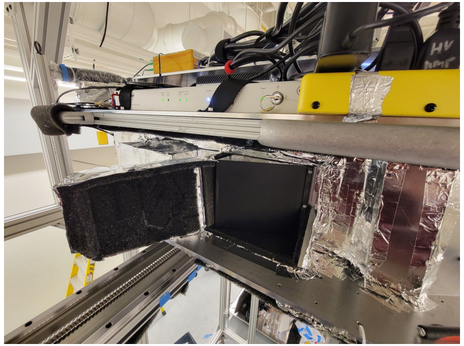
1. Source
2. Attenuators
3. **Coupling Optics**

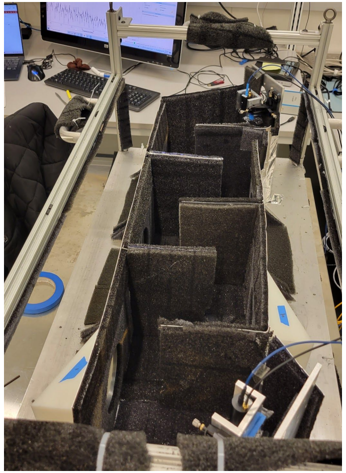
Coupling Optics

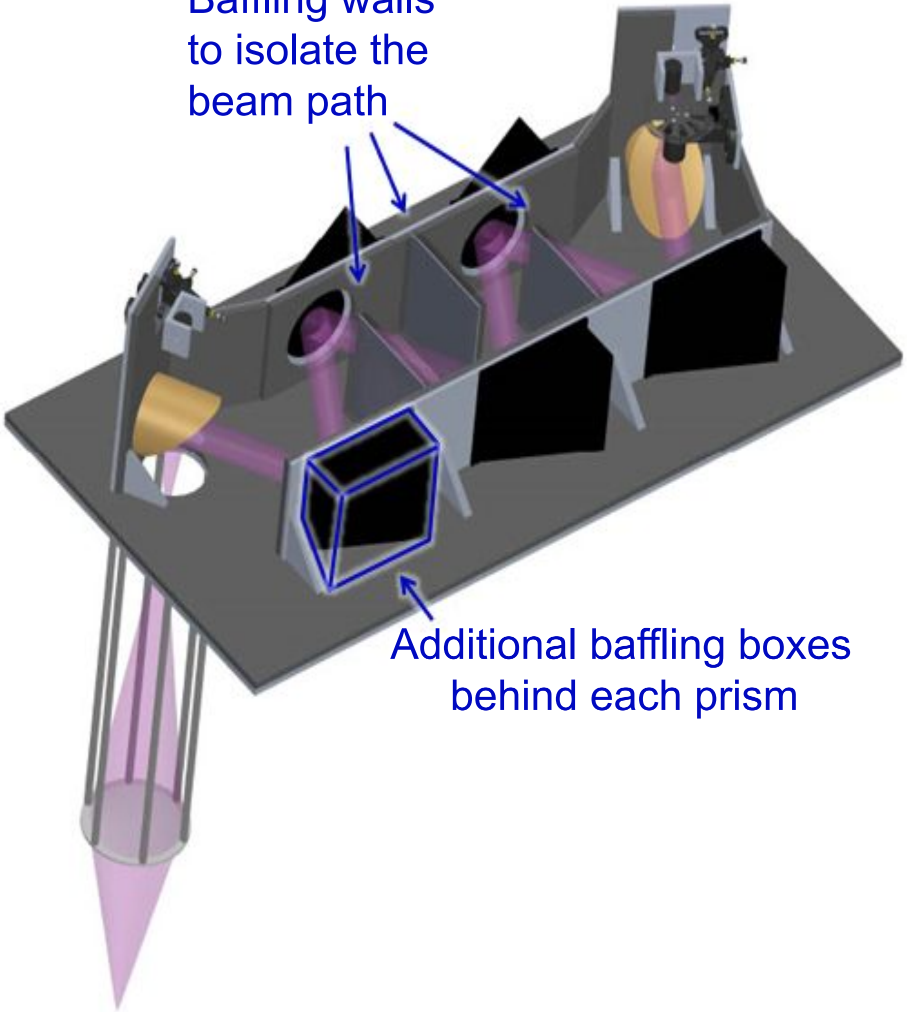


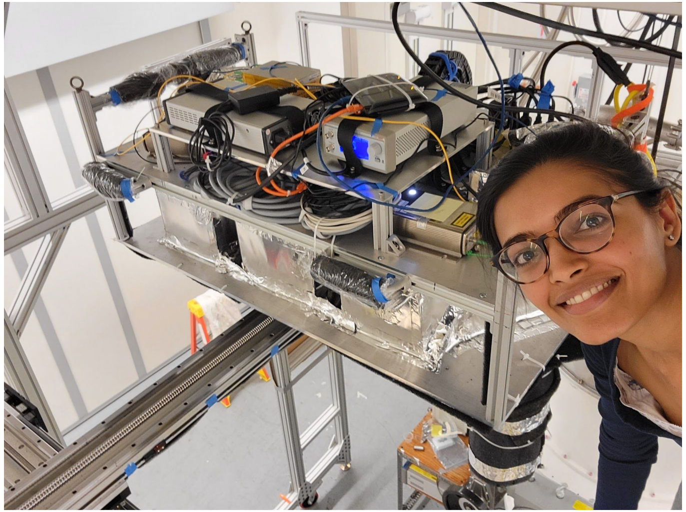
Absorptive Baffling

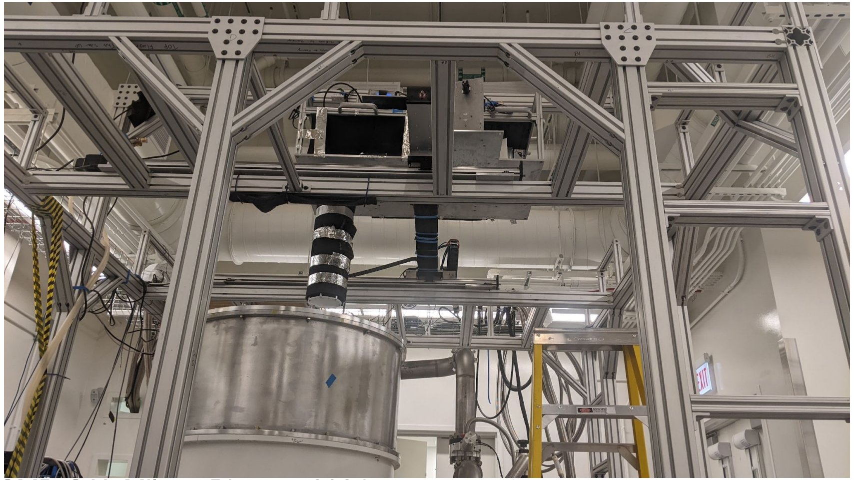
As a result of attenuating away so much power, the system becomes more vulnerable to unwanted scattering and other systematics.

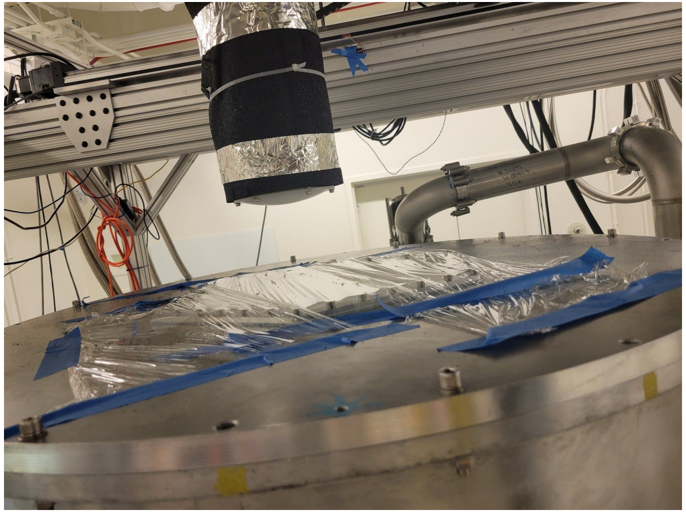









EXIT



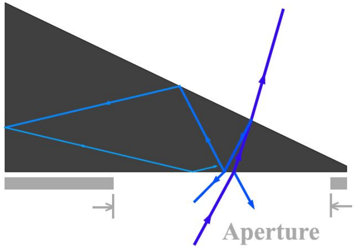
Outline

Motivation

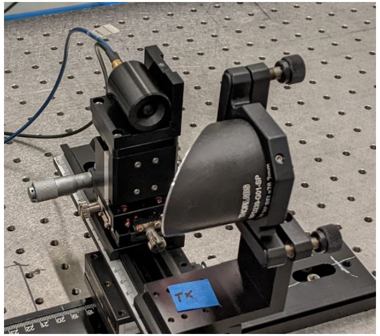
Frequency-selectable Laser Source (FLS) Instrument Design

FLS Characterization

Measurement Procedure and Results

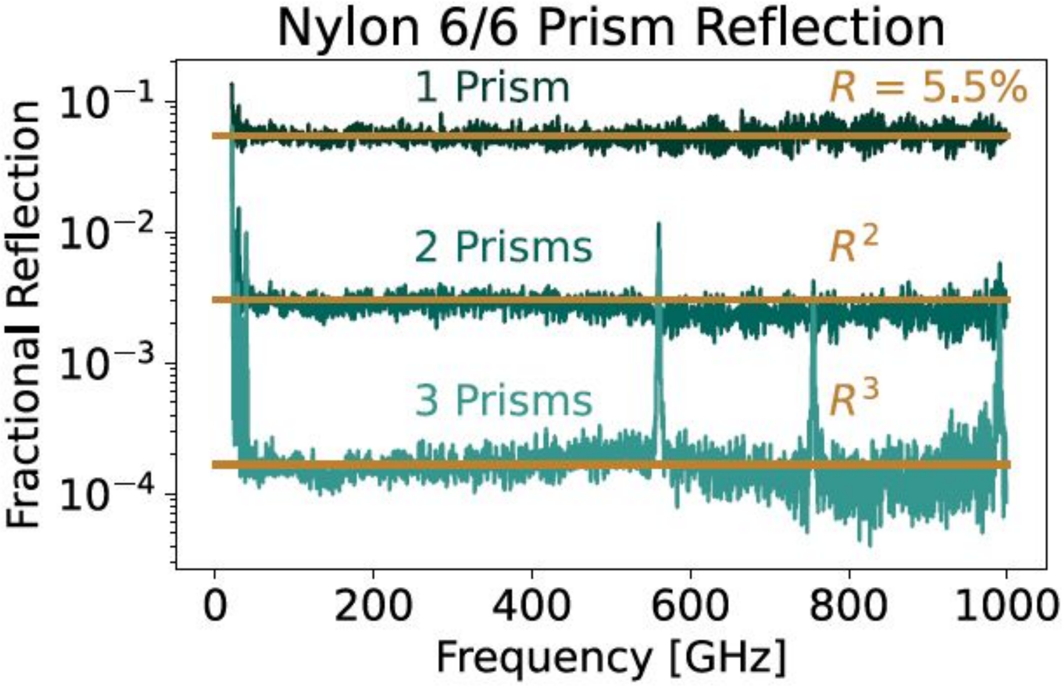


Prism Reflectance as a function of frequency



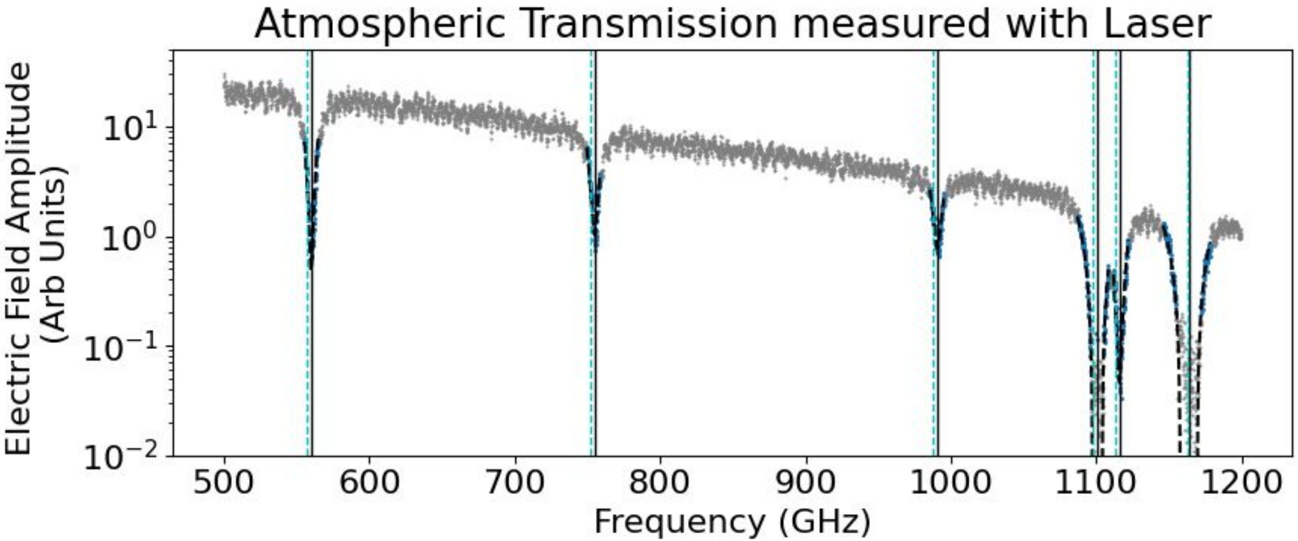
Source Frequency and Power Characterization

Prism Reflectance



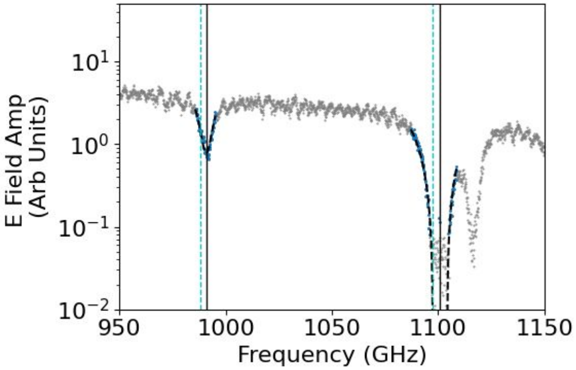
The prisms provide a neutral attenuation across a wide frequency range.

Frequency Calibration

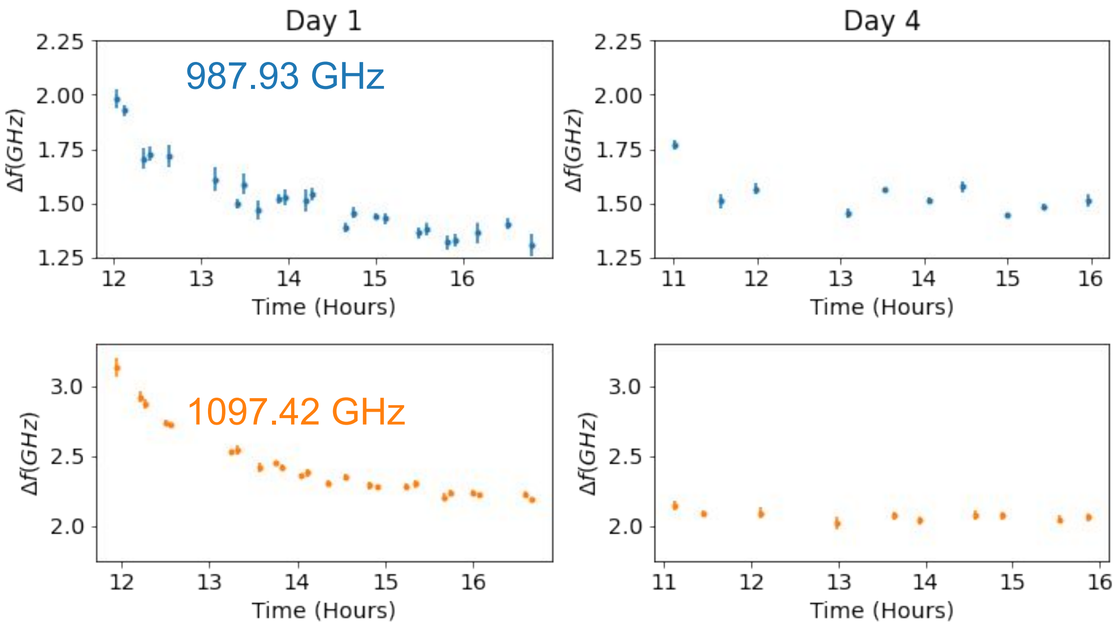


We can measure the frequency accuracy by measuring the water vapor absorption lines and comparing them to known values.

Frequency Settling Time

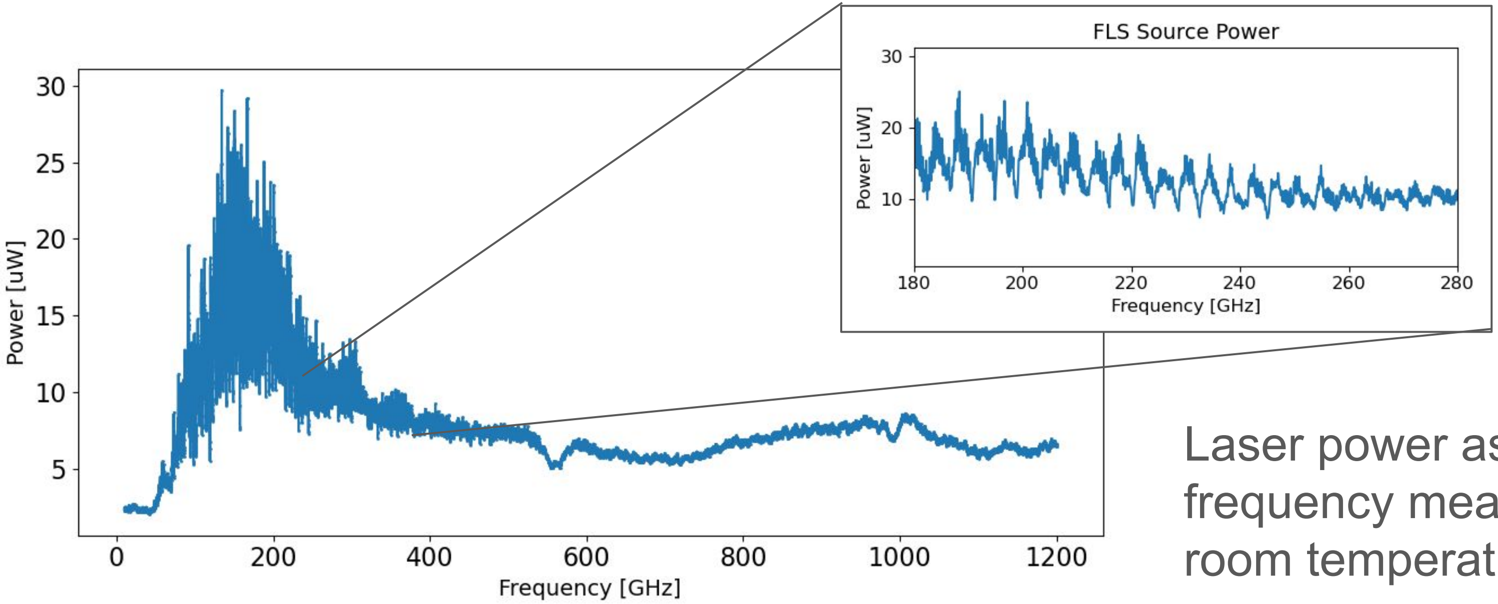


Frequencies settle after ~36 hours and retain a constant offset that can be corrected.



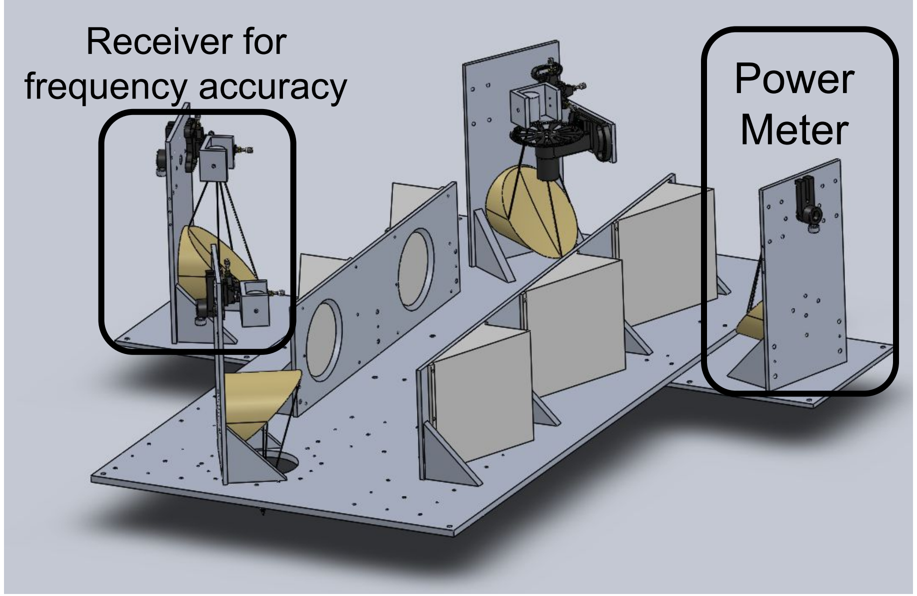
Credit: Lauren Saunders

Power Calibration Measurement



Laser power as a function of frequency measured with a room temperature bolometer.

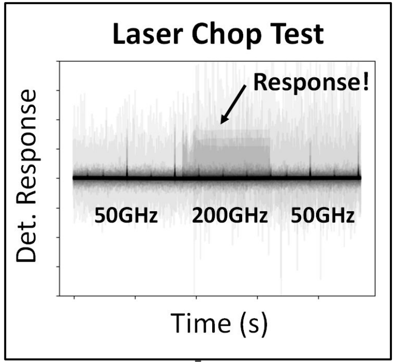
Design for in-situ calibration modules

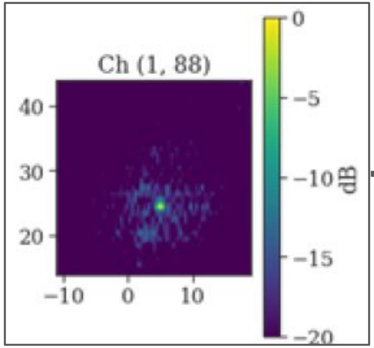


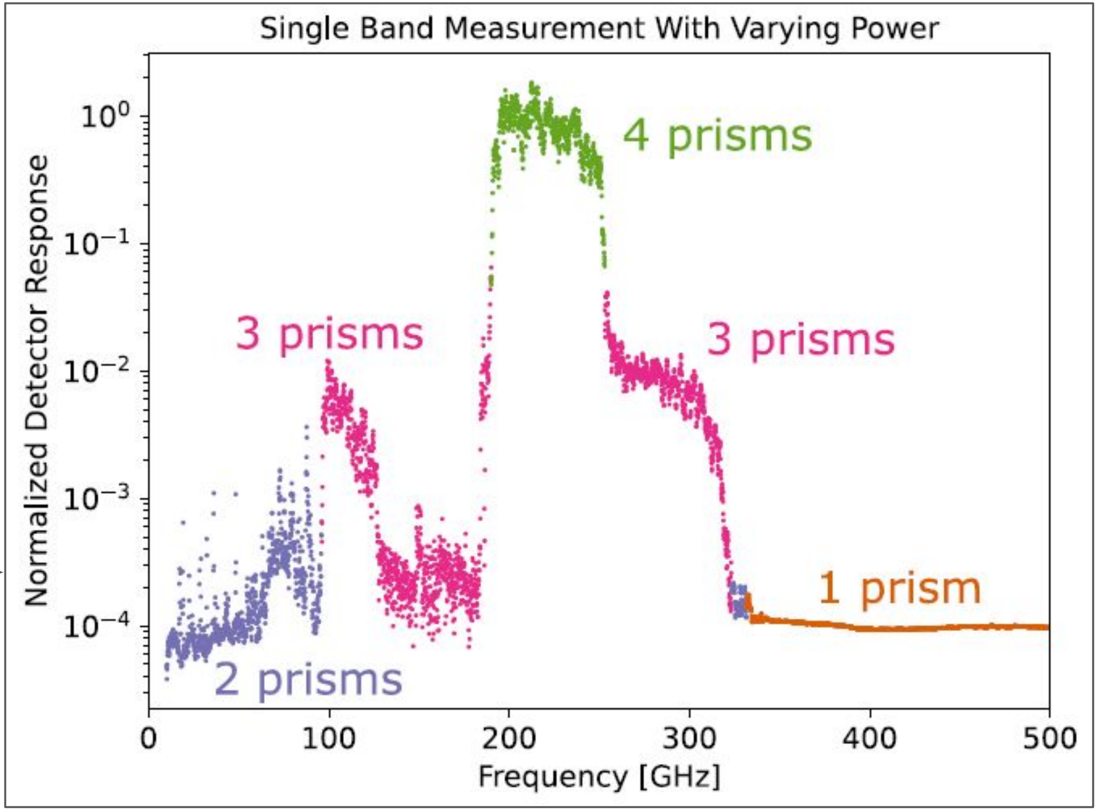
In-situ modules incorporated into next version of FLS! Upgrades in progress by L. Saunders and S. Simon

Outline

Beam Maps and Bandpass Measurements

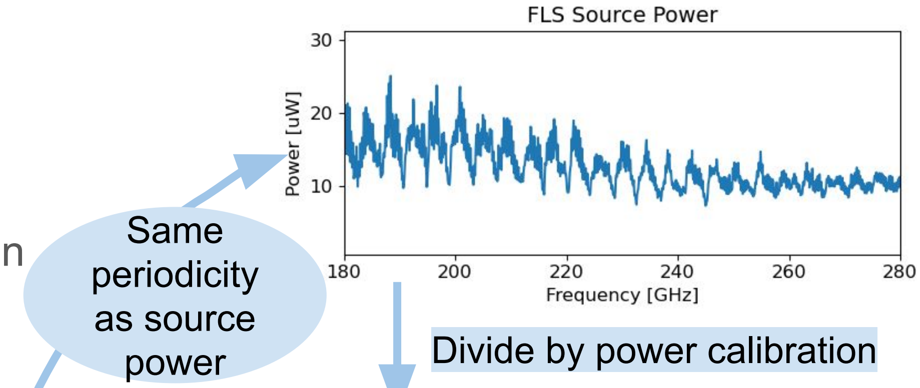


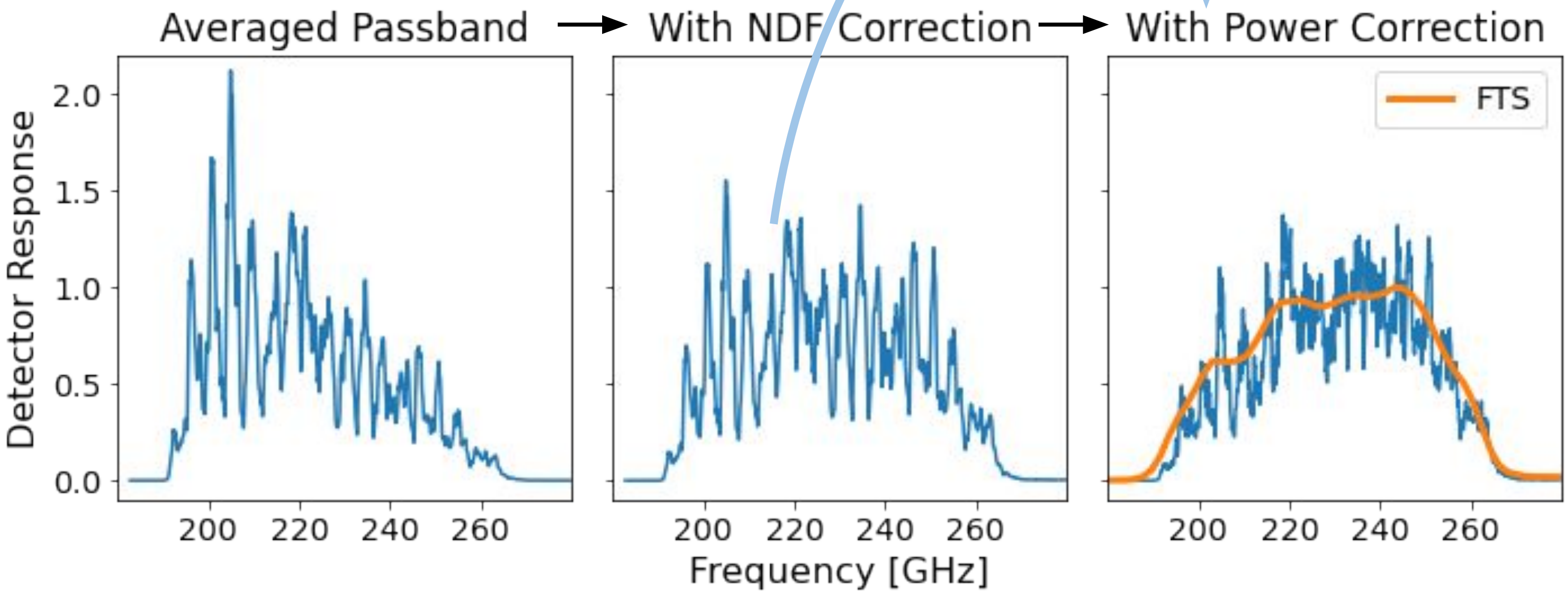




Post-measurement Corrections

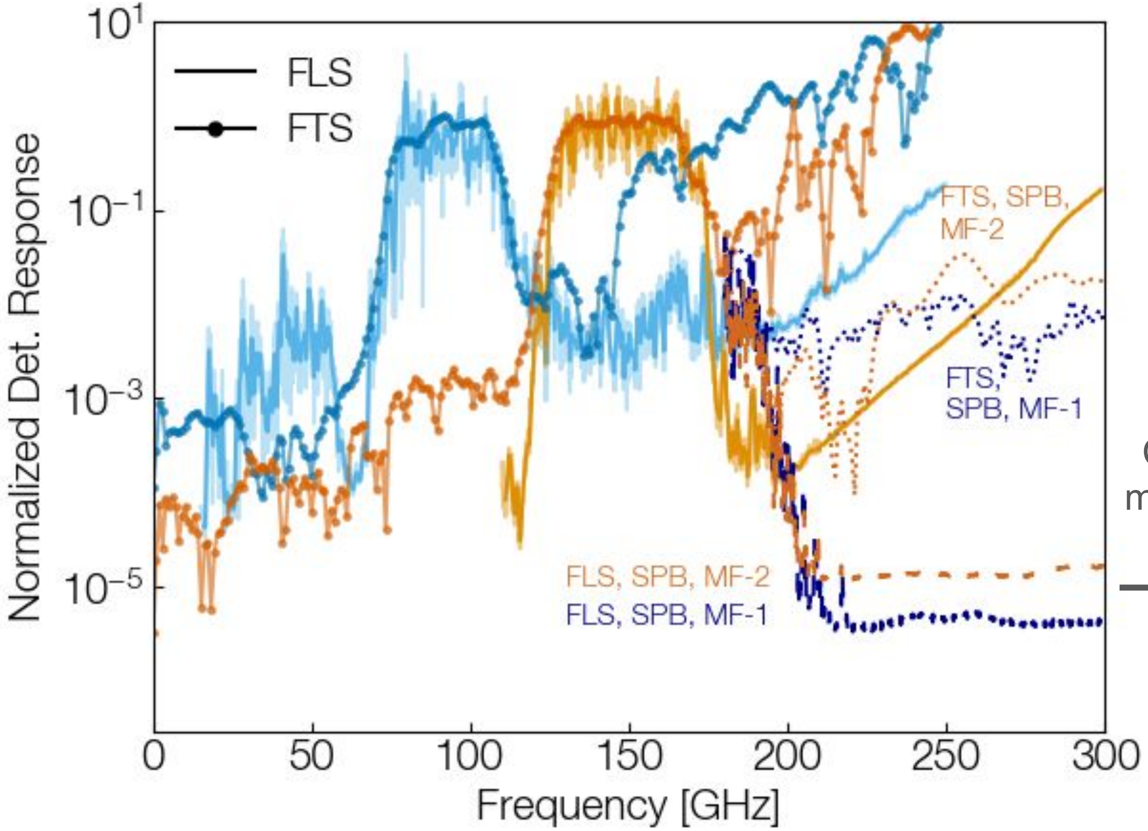
- non-Neutral Density Filter (NDF) correction
- Power correction





Mid-Frequency LAT Tester Passbands - 90/150 GHz

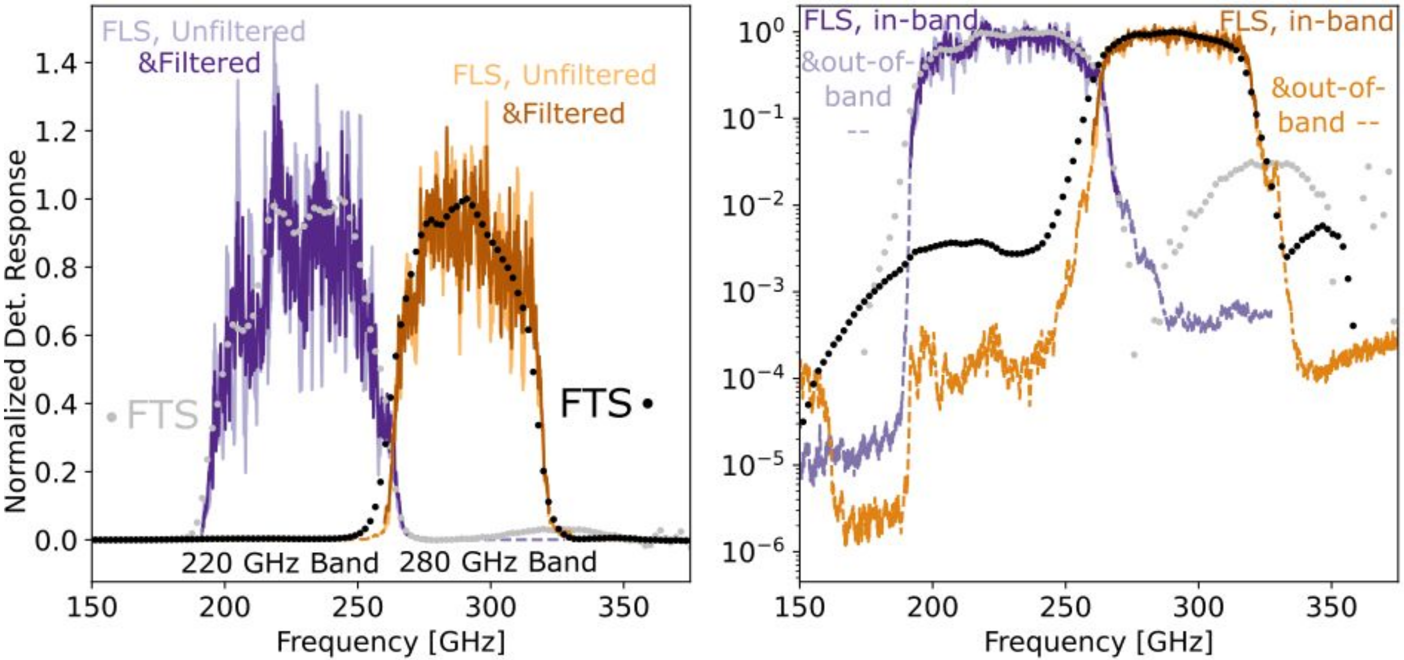
- FLS and FTS show agreement.
- FLS is more sensitive to band edges and out of band leakage.
- FTS bands are averaged over detector array; FLS bands are individual detectors.



Capable of measuring to 1 THz

Ultra-High Frequency LAT Tester Passbands - 220/280GHz

- FLS and FTS in agreement wrt band shapes.
- FLS bands smoothed over handful of detectors → less noisy band.
- FTS bands are detector array averages.



Summary

- Driving down uncertainties on bandpass measurements is an important and challenging goal.
- The FLS and FTS passbands show agreement and are complementary techniques since they have different systematics.
- Being able to vary the FLS' attenuation allows us to more robustly measure out-of-band and band edge features.
- The FLS offers a promising avenue for bandpass calibration for future experiments.

Thank You!