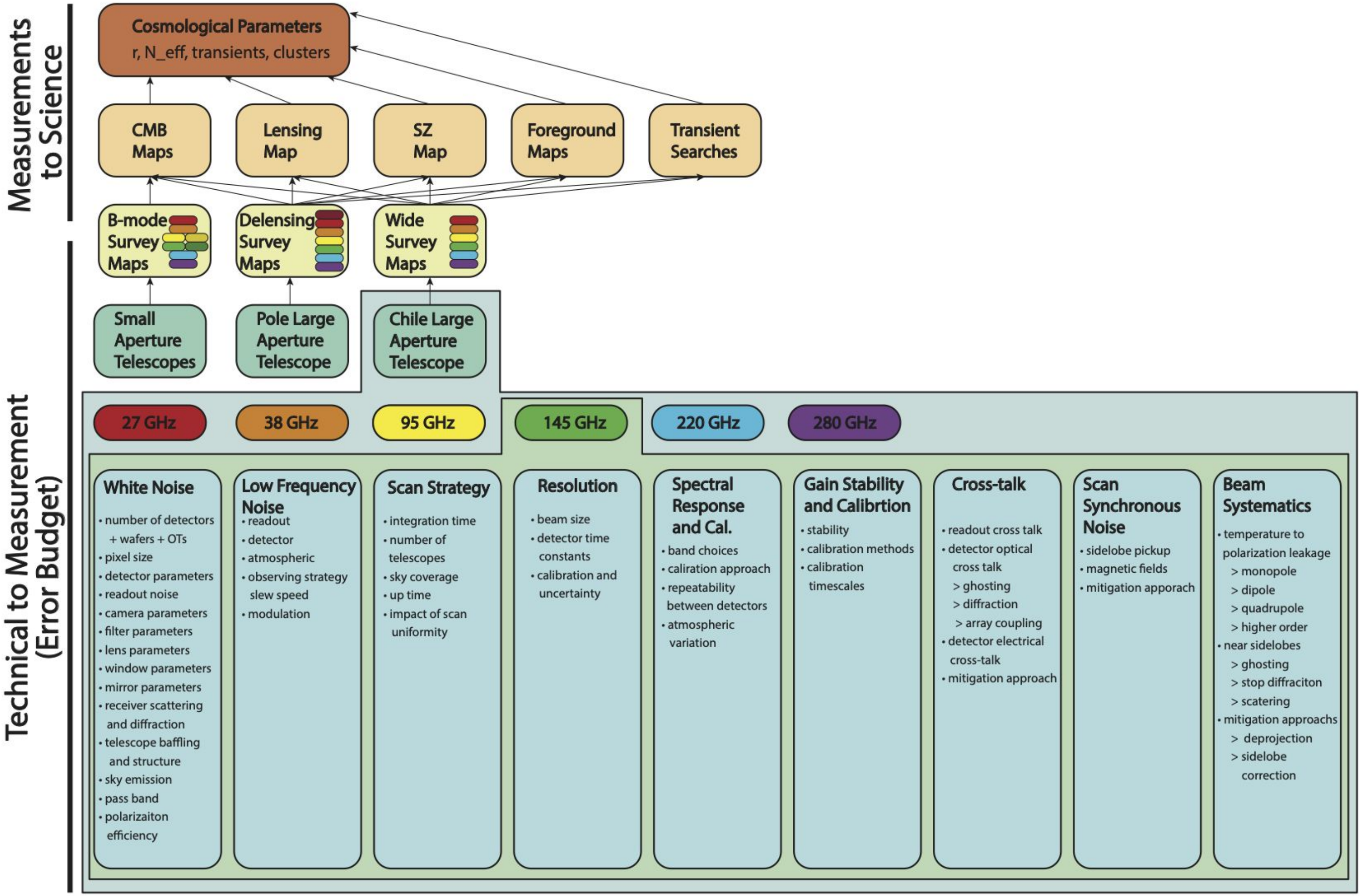
LAT Systematics

CMB-S4

Systematics Error Budget

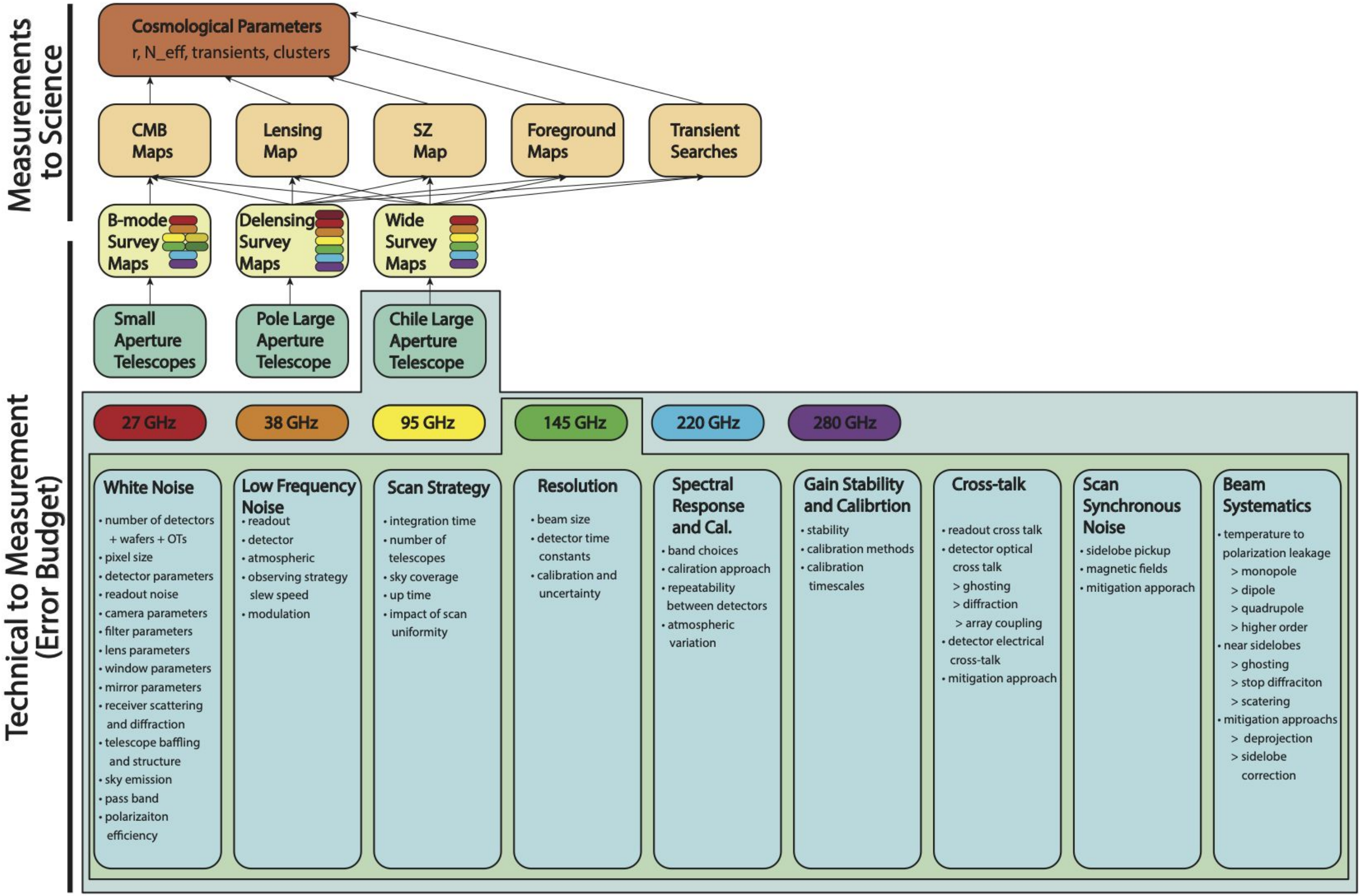
- For systems engineering we need a systematic effect error budget
- Tools are under development for this purpose (map based and time domain)
- Consideration of systematic effects is rooted in experience from past experiments
- Here we discuss the most concerning systematics, plans to meet these challenges, and the work to develop this budget



Largest Concerns for LATs

- **Common to SPLAT and CHLAT**
  - Beam calibration
  - Band-pass calibration
  - Scan synchronous pickup

- **Differences between SPLAT and CHLAT**
  - SPLAT requires improved systematics for large angular scales



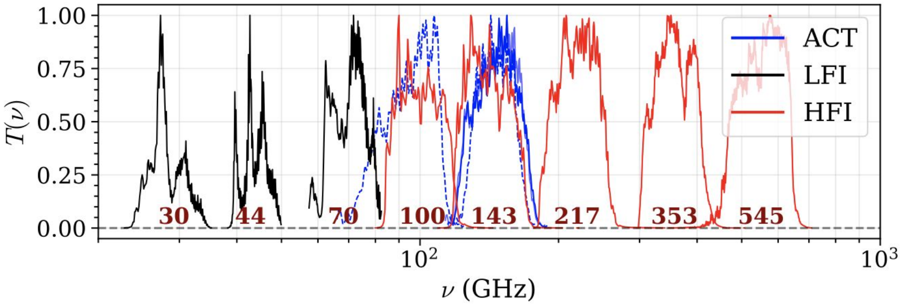
Concern: LAT band pass calibration

- SZ measurements require separating CMB+kSZ, dust, synchron, from the tSZ signals
- Quoting from: Madhavacheril et al:

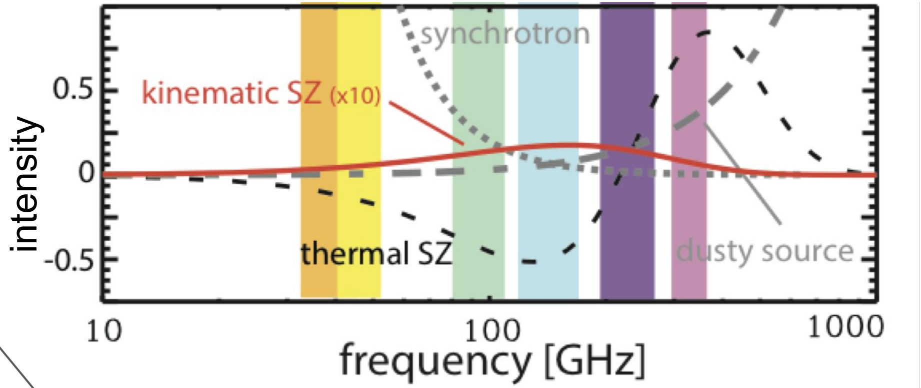
Looking ahead to Advanced ACTPol and Simons Observatory [38], reductions in these systematic uncertainties will be necessary in order to avoid biasing measurements; e.g., for a Simons Observatory tSZ cross-correlation with LSST galaxies, absolute calibration of the bandpasses approaching 0.1% precision will be necessary (see, e.g., [70] for similar considerations). However, the bandpass calibration requirements are less stringent for CMB power spectrum measurements (e.g., as used to constrain $N_{\rm eff}$ and other cosmological parameters), because calibration errors are absorbed in free parameters associated with the SEDs of astrophysical foregrounds (the tSZ contribution being a notable exception, as its SED has no free parameters). The situation is also helped by the fact that the TE power spectrum drives the constraining power on parameters [38], for which the only foregrounds are Galactic dust and synchrotron, whose free SED parameters can absorb bandpass uncertainties (at the cost of biasing the physical interpretation of those foreground parameters).

https://arxiv.org/pdf/1911.05717.pdf, see Appendix A

Representative band-pass calibration



Signals requiring separation



Motivates ongoing work to understand FTS systematics and to develop alternative calibration methods, also PWV monitoring

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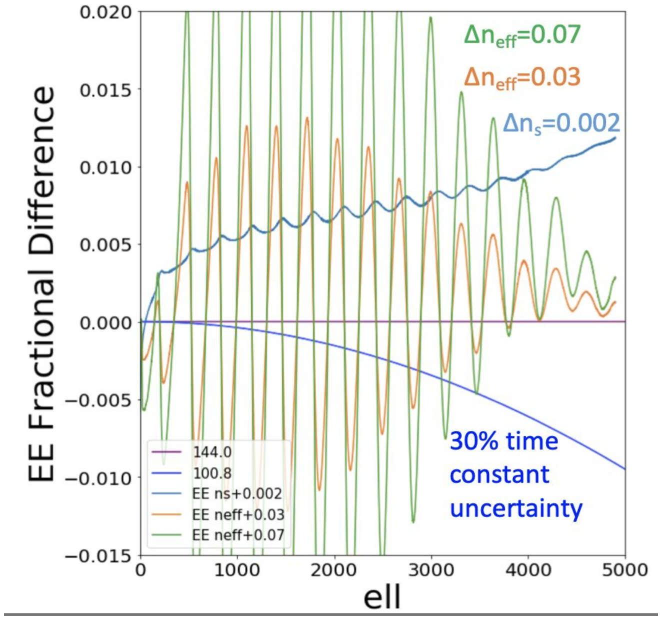
Concern: Time-Constant Calibration

- Time constant calibration requirements and a calibration plan are key
- Time constants, their stability, and their calibration lead to detector level requirements
- These are already incorporated into the plan, but should be tracked carefully

Time constant calibration errors: S. Simon

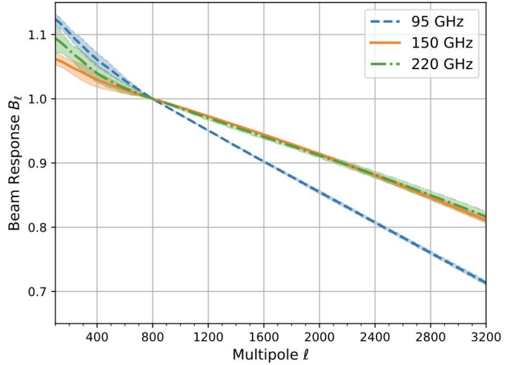


- spectrum level modeling provides a useful upper limit
- Use component separation + parameter extraction to determine bias on cosmology
- need to balance the requirement on this parameter against other systematics (eg, beams)

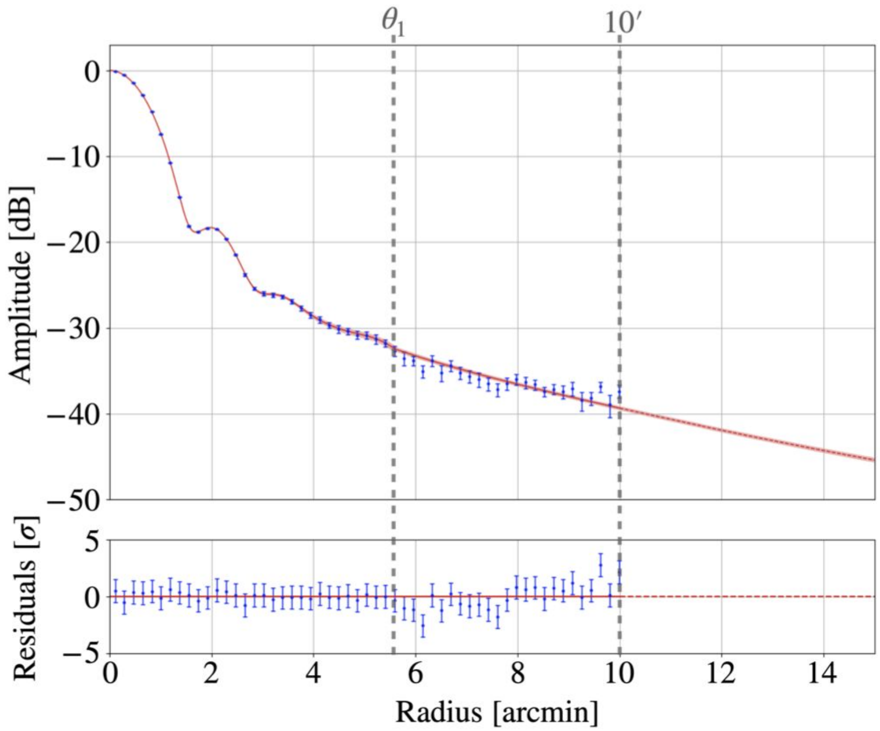
Concern: Beam Calibration

- Beam calibration is critical to understanding high ell CMB signals
- SPT and ACT demonstrate that < 1% calibration accuracy above ell ~ 1000 is possible.
- Determine calibration requirements

Beam calibration: SPT3G: D. Dutcher et al

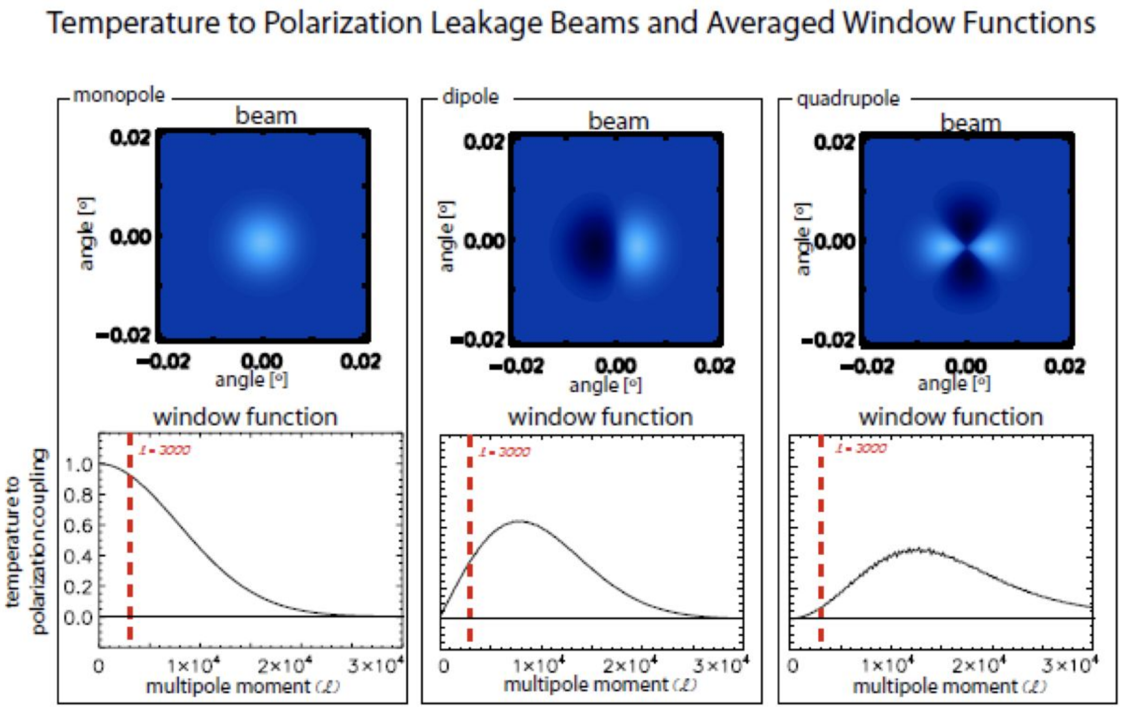


Beam calibration: ACTPol: Lungu et al



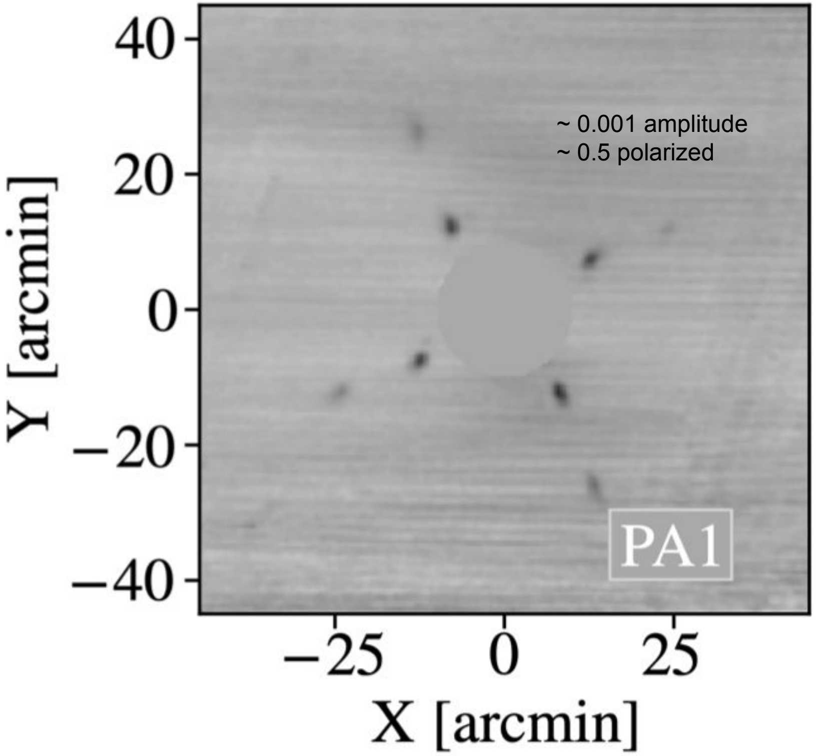
Main Beam Polarization Leakage

- Large telescopes push the impact of main beam polarization to extremely high ell
- Lungu et al. measures T→B leakage ~0.05% for ell< 3000 for the best characterized ACTPol array, excluding monopole



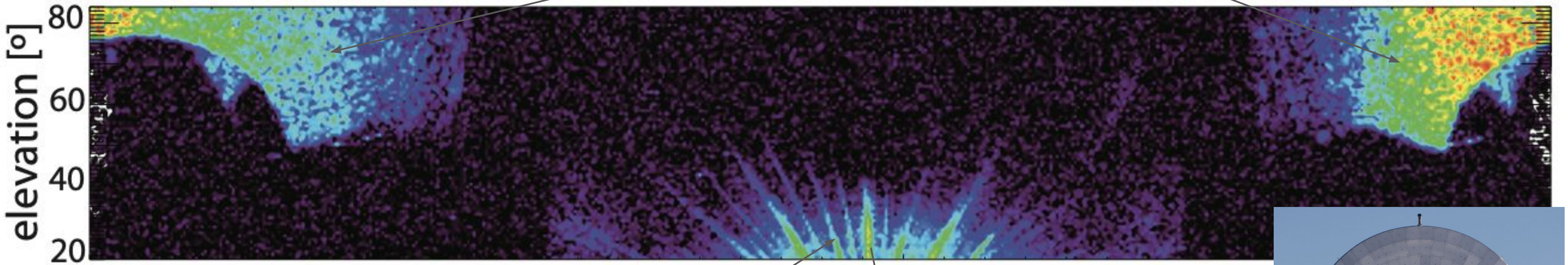
Concern: Near Sidelobes

- ACTPol saw near sidelobes which are believed to arise for diffractive effects in our metal mesh filter
  - Lungu et al
- SPT-3G doesn't see this type of effect
- SO appears to be free from this effect from lab testing
- Illustrates the type of pathology that must be carefully treated in the design and verification stage of the project



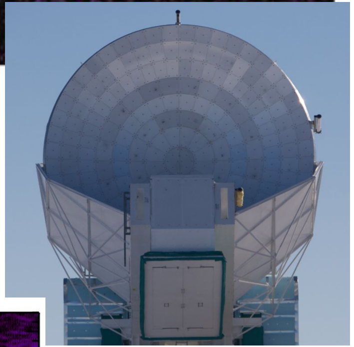
Concern: Sidelobes / Scan Synchronous Pickup

Scattering from the receiver, hits the ground

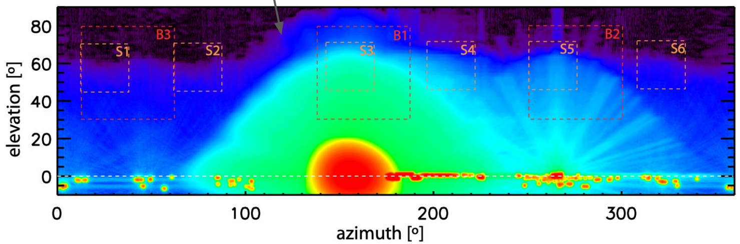


Panel gap diffraction, hits the ground

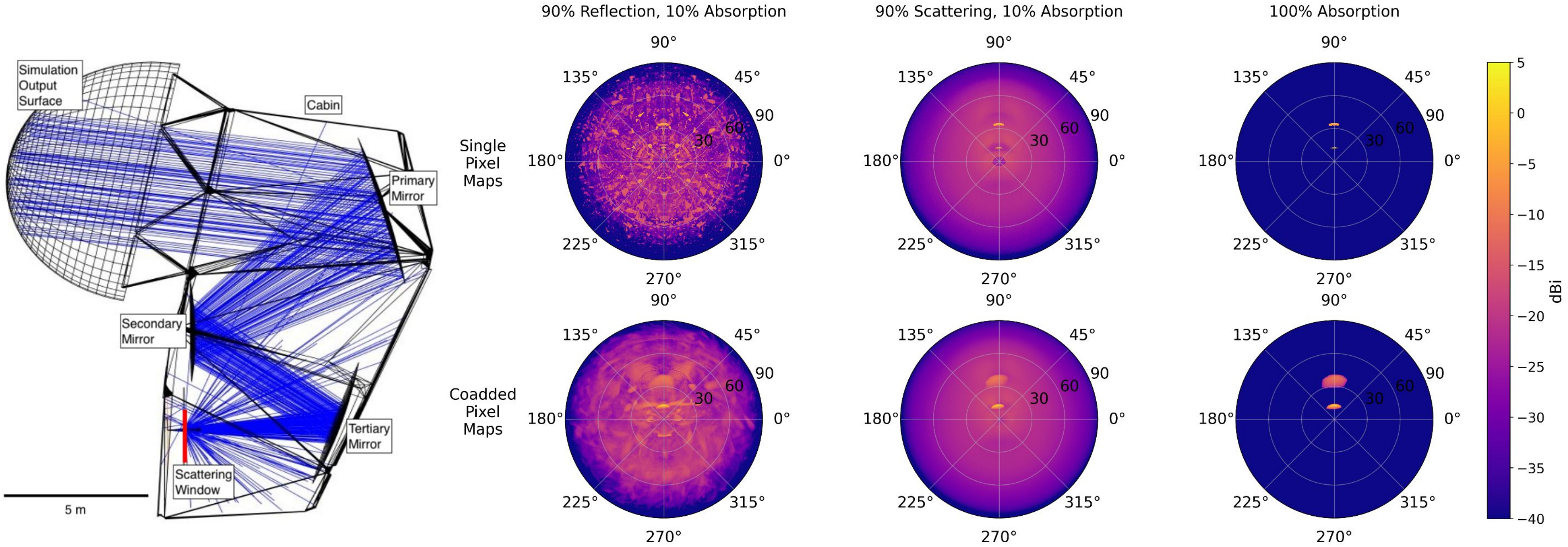
Convolved with ground to estimate scan synchronous signals



Measurements of the SPT-SZ far sidelobes



Simulating TMA Sidelobes

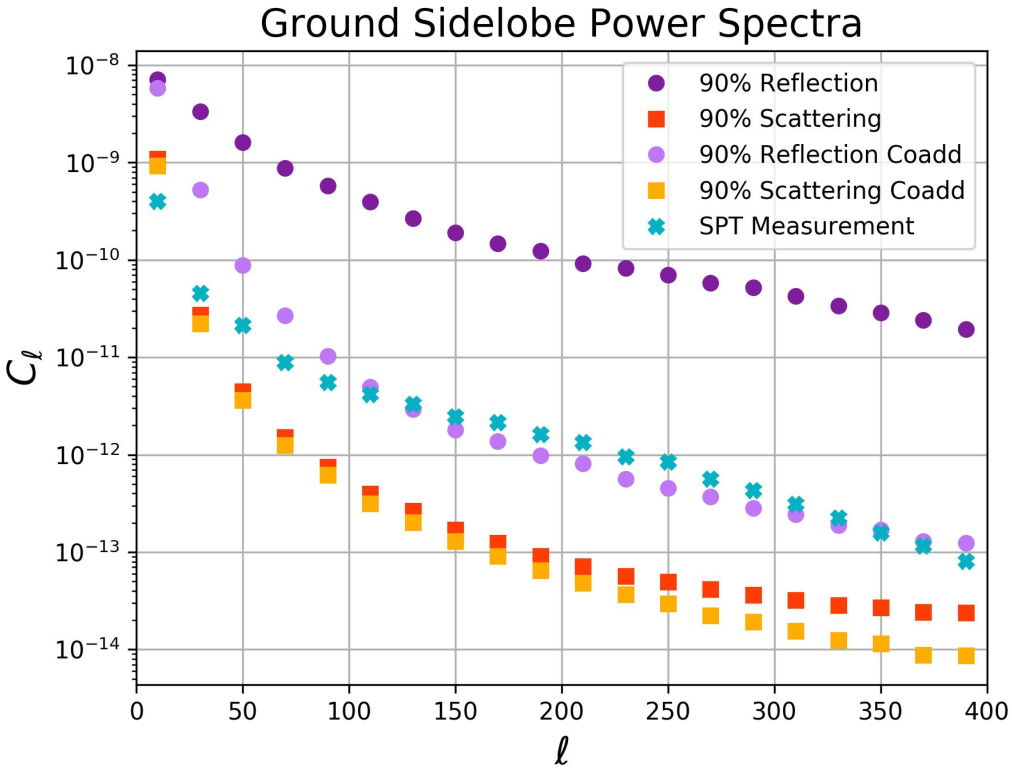


Use ray tracing sims to map sidelobes with different cabin wall treatments

Reflective walls → Sharp features, Scattering walls → Blurry sidelobes

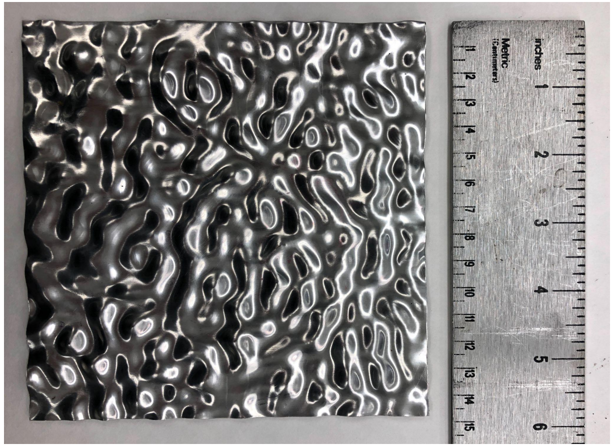
CWRU+WUSTL

Comparing Baffle Performance



Only scattering baffles have lower ground pickup than current instruments

Random Noise Surface ~ 5 mm rms



CWRU+WUSTL

Polarization Angle Calibration

- Optical simulations of polarization angles combined with point source measurements provide a good estimate.
- E-B calibration is sufficient to confirm this prediction
- Cross-correlation with SAT data should transfer the SAT calibration as it improves.

Qualitative status appraisal

CHLAT

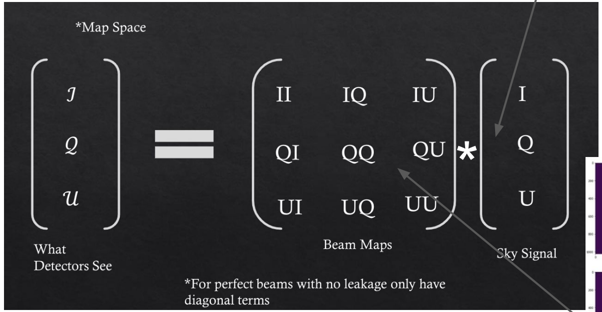
- Biggest concern: pass band calibration (also applies to SPLAT)
  - Risk: could degrade the SZ results
  - Remedy: improve calibration before the termination of observations
- Other systematics appear contained
  - Beam characterization with planets will provide a sufficient calibration
  - control near and far side lobes is likely to be sufficient with the design
    - Buddies will be eliminated
    - Panel gap sidelobes are OK given the measurement requirements

SPLAT

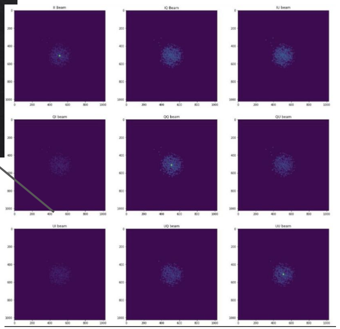
- Systematics for lensing appear well controlled
  - Beam, pointing, band-pass calibration, sidelobe pickup
- Systematics for the 20 GHz low-ell B-mode
  - Boresight rotation + no panel gaps make it extremely likely that the systematics will be well controlled
- Extending to low-ell B-modes and r
  - Beam, near, and far sidelobes are likely to be well controlled with the TMA design
  - Low frequency noise (atmospheric) appears adequate (see 3G)
  - Cross-correlation with SAT data is a low risk path for extraction of this information

Towards a systematics error budget: developing the map multitool

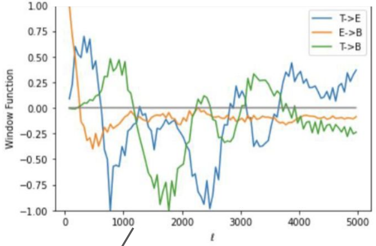
convolution



Toy model of crostalk as mixing beams



Leakage spectra



Bias on cosmological parameters

Alec Hryciuk's work

tau (ms)	Uncertainty	ombh2	omch2	tau	thetastar	As (e-9)	ns	Neff	chi2
5	0	0.022	0.12	0.07	0.010409	2.2	0.96	3.046	0
5	0.01	0.022	0.119988	0.070011	0.010409	2.20001	0.959988	3.046676	0.027815
5	0.05	0.021998	0.119845	0.071023	0.010409	2.203557	0.960288	3.049932	1.292447
5	0.1	0.021997	1.20E-01	0.070764	0.010409	2.202426	0.960247	3.053862	3.004147
5	0.2	0.021992	1.20E-01	0.070991	0.010409	2.203037	0.959923	3.057211	10.390673
5	0.3	0.021992	1.20E-01	0.069982	0.010409	2.198872	0.959979	3.065411	18.809009

Compliments time domain efforts

Conclusion

- Systematics represent a set of contained problems
- The largest issues are tractable
- Getting to low ell with the TMA is promising
- Development of an integrated systematics error budget is underway