Instrument Model

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CMB-S4

Overview of current instrument model

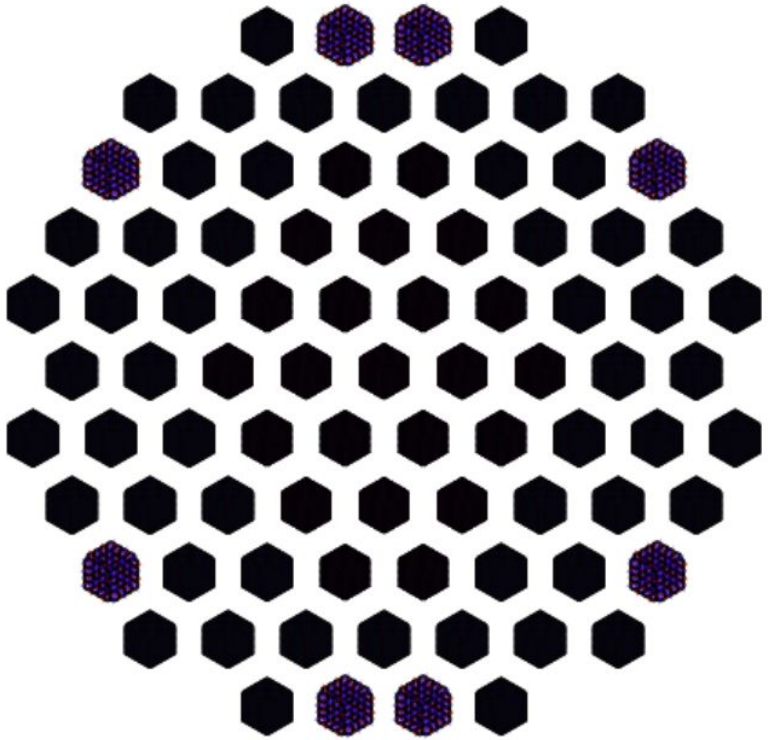
- Instrument definition is codified into a set of dictionaries output to a human-readable file (toml)
  - bands→ bandpasses + noise parameters for each band
  - wafers→ detector layout on wafer
  - tubes→ wafer layout in tube, optical platescale
  - telescopes→ tube layout in telescope, beam information
  - cards→ dummy readout information
  - crates→ dummy readout information
  - detectors→ pixel, band, wafer, beam, polarization, readout, and full position information
- All inputs variables and their definitions are described here
- Current description is simplistic→ Can build in additional complexity as design matures, especially for systematic studies

Two types of modifications

1. Modify the instrument model directly → This is good for global values, changing wafer layouts, changing optics tube frequency mappings, etc.
2. Modify values in the output toml file→ This is good for values that you want to vary detector by detector

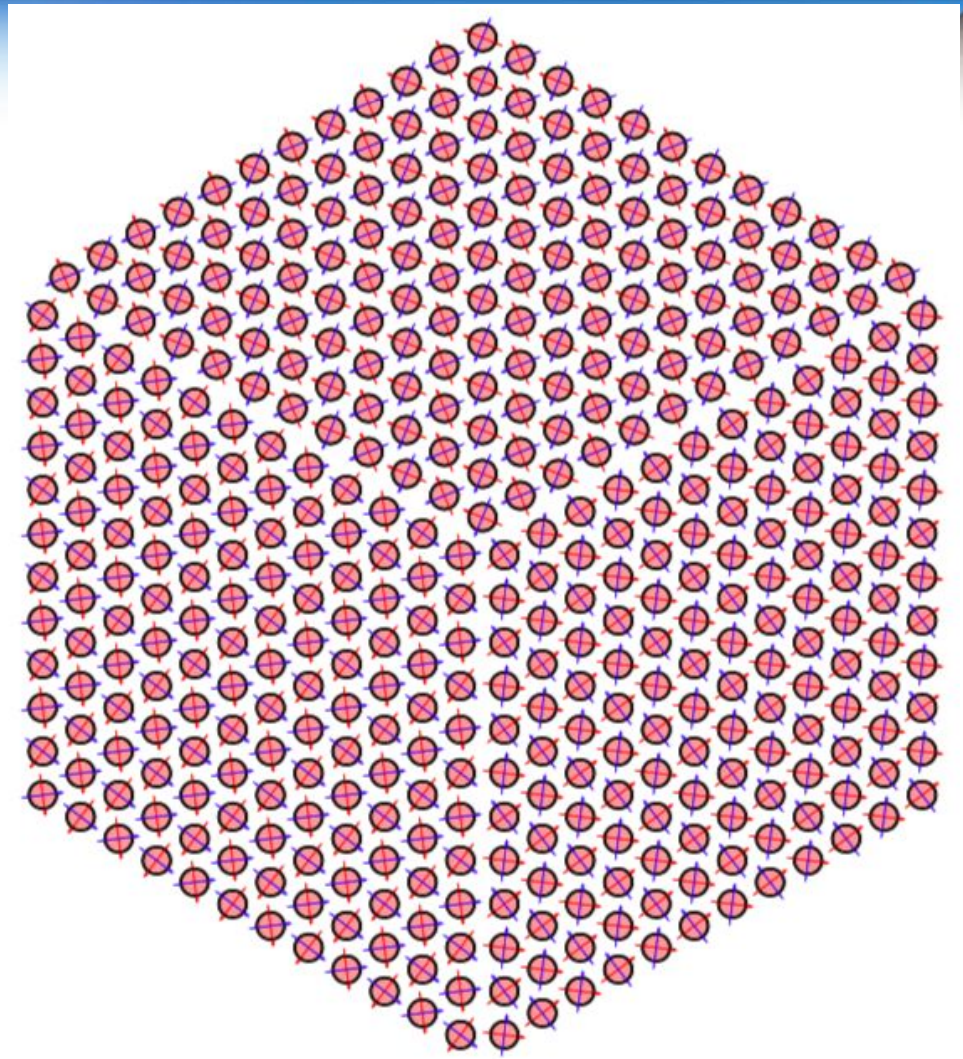
Optics

- Single Gaussian FWHM for each band → could be modified for each individual detector
- Focal plane projected onto sky with a simple scale factor → could be modified for each individual detector
- LAT optics tube frequency mapping balanced between optical quality and uniform coverage with scan strategy→ may need updating as we learn more/update the scan strategies
- Boresight rotation information captured in main simulation code, not instrument code



Wafer Layouts

- Rhombus and hex-packed layout options, with pixel sizes and numerology
- Wafer-to-wafer spacing
- Clocking of wafers is all the same, but can be adjusted once defined
- All these can be updated as our knowledge of the design matures



Readout Model

- Readout model is a dummy model (better suited for uMUX right now)→ Not actually used in simulations at this point
- Would need if we wanted to do studies like crosstalk
- General structure could be updated in instrument definition code
- Mapping to detectors could be done in instrument definition code or with mapping files

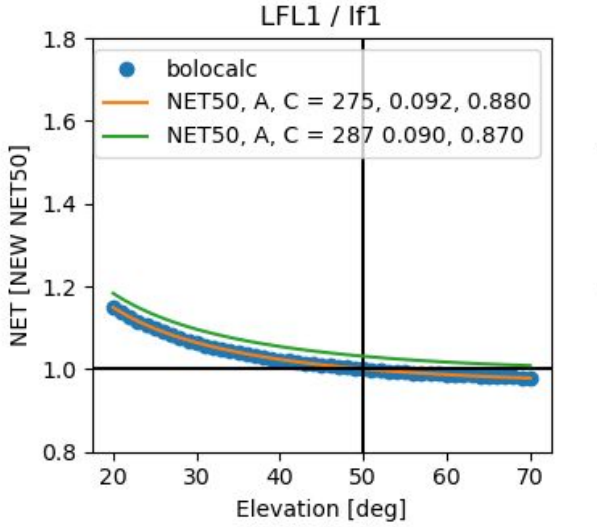
Bandpasses

- Currently top-hat bandpasses with lower+higher band edges and center frequency
  - Set by flat-band bandpasses used to calculate white noise
- Could adapt to take a bandpass from a file
  - Would want to make sure that the noise calculator does this as well
  - Simulated bandpass files from Sonnet/Microwave Office could be used
  - Could also add effects from optics (e.g. stop efficiency variation with frequency)
  - Could also add in systematic variations

White Noise

- Base NET from upgraded BoloCalc at elevation of 50˚
  - CHLAT Psat optimized for 35˚ elevation, others to 50˚ elevation
- Elevation dependence fit parameters (based of BoloCalc output) normalized to 50˚ elevation
- Could integrate BoloCalc directly into model in future, but BoloCalc interface too complex right now

$$\mathrm{NET} = \frac{A}{\sin\theta_{el}} + C$$



Instrument Noise

- Add an instrumental 1/f noise component (does not include atmosphere)

$$\mathrm{PSD} \propto \frac{f^{\alpha} + f_{knee}^{\alpha}}{f^{\alpha} + f_{min}^{\alpha}}$$

- α = 1, f_{knee} = 50 mHz, f_{min} = 0.01 mHz
- Can be adjusted for each individual band

Discussion

- Are there any critical pieces that are missing?
- How can we tighten the loop between instrumentation changes and implementation in the instrument model?
- Should think about what modifications to the instrument model we need to accommodate high priority systematics