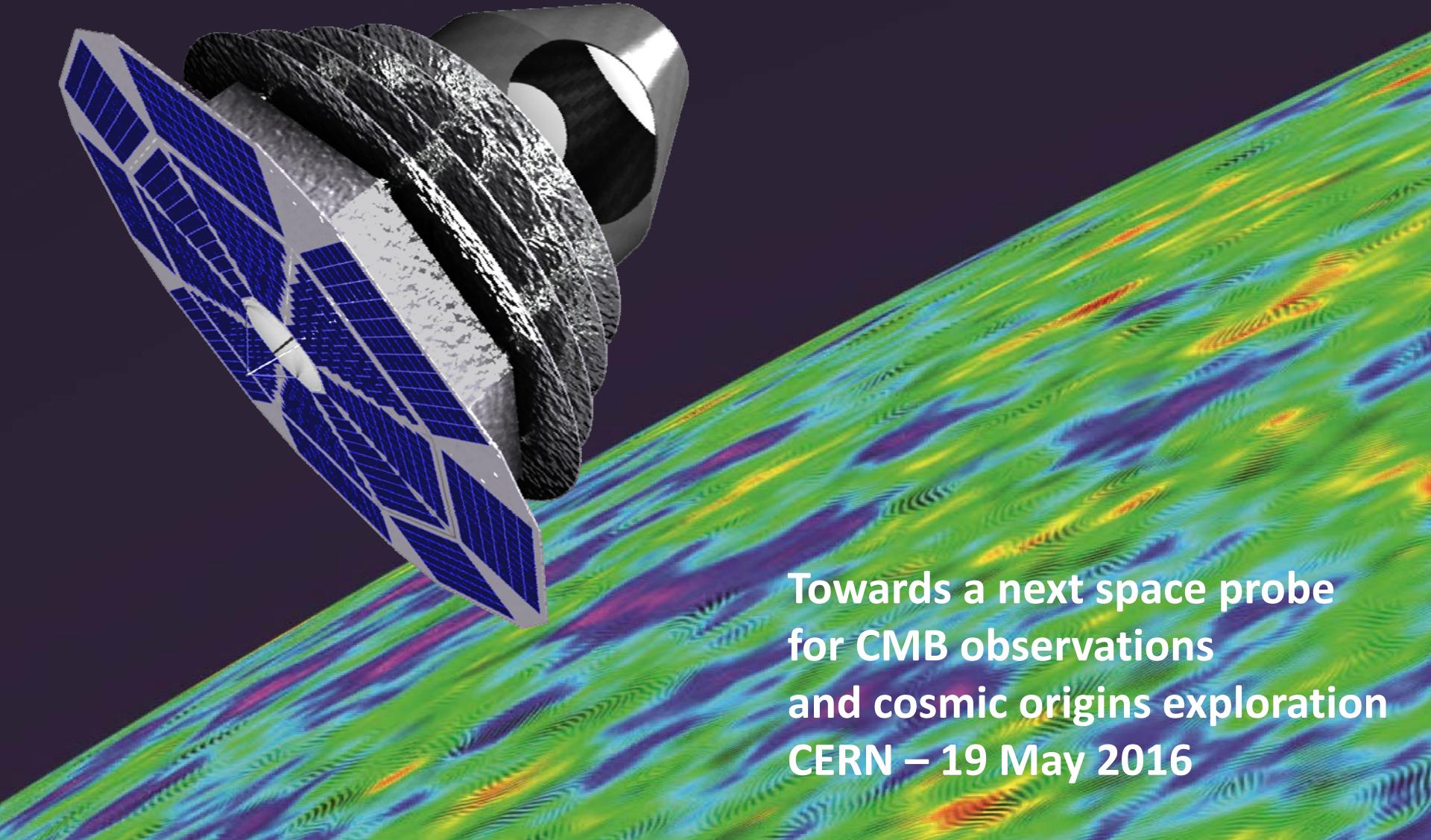


Target sensitivity, focal plane tradeoffs and requirements

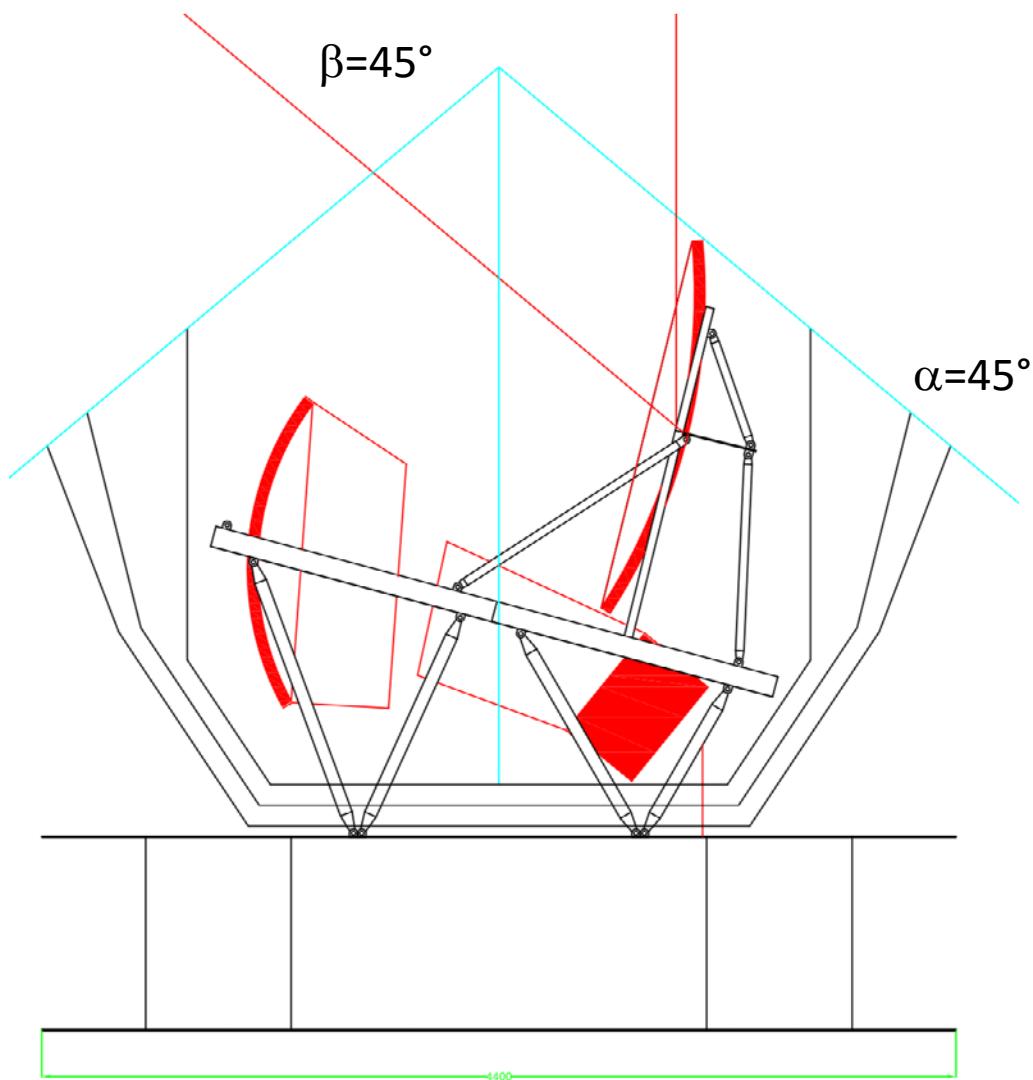
M. Piat – Laboratoire Astroparticule et Cosmologie (APC) - Paris

P. de Bernardis – Sapienza University of Rome and INFN - Italy



Towards a next space probe
for CMB observations
and cosmic origins exploration
CERN – 19 May 2016

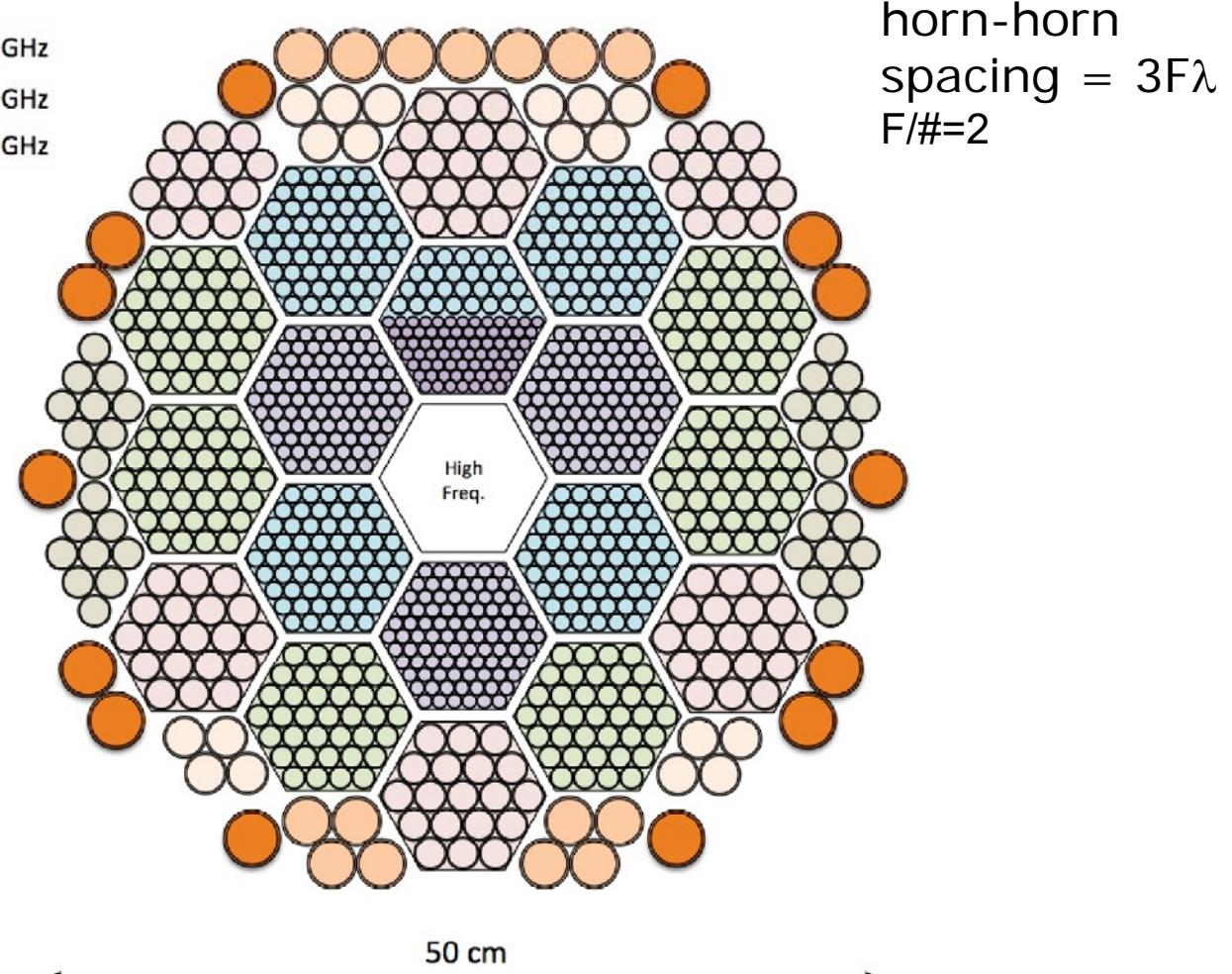
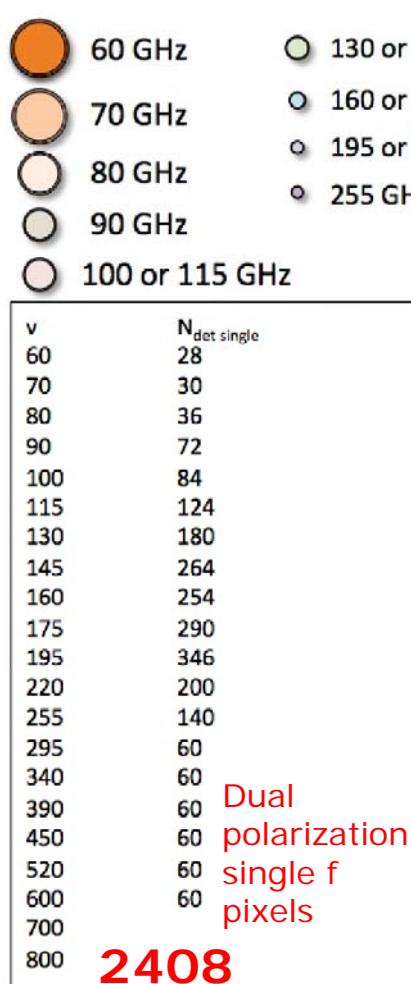
1.5m Gregorian telescope @ 100K



Focal Plane

- COrE will reach the required sensitivity to CMB polarization using a large focal plane, hosting a number of detectors (several thousands) covering a wide frequency range (60-600 GHz) in many bands (15-20 for components separation).
- The baseline for the focal plane area is a 50 cm diameter disk (possibly not flat).
- M4 proposal:

Mission/instrument implementation: focal plane

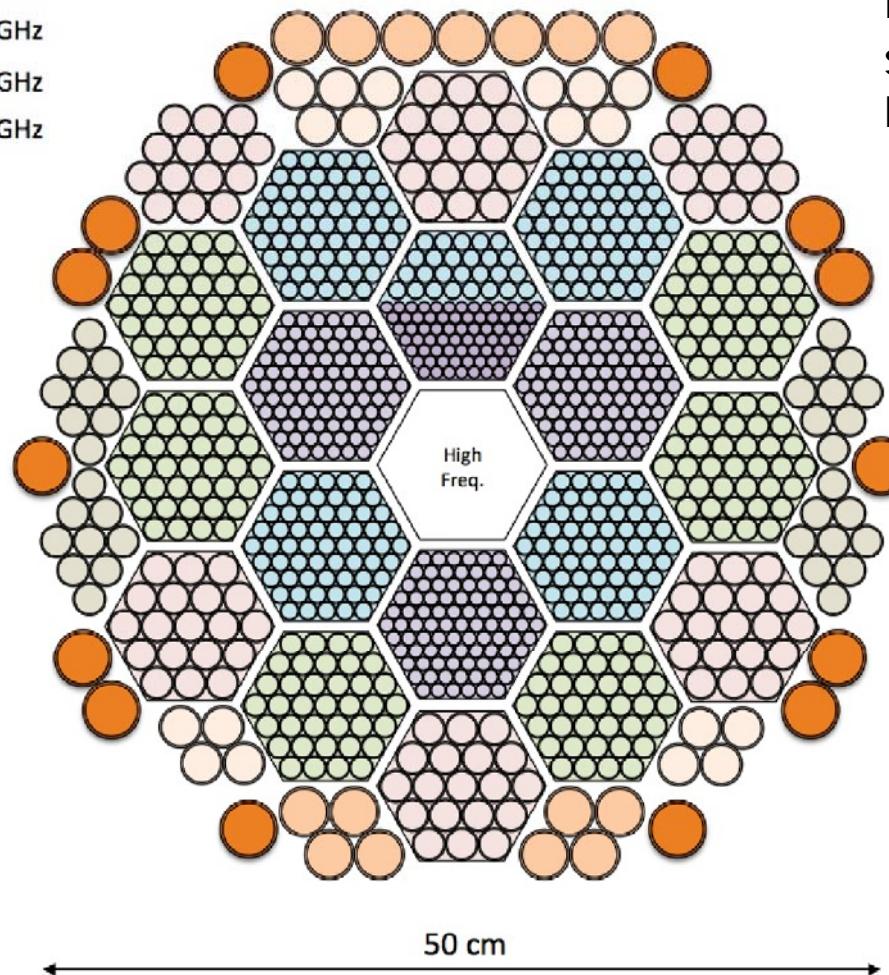


Mission/instrument implementation: focal plane



v	$N_{\text{det dual}}$
60	28
70	30
80	64
90	102
100	120
115	196
130	264
145	388
160	434
175	554
195	600
220	490
255	486
295	260
340	200
390	120
450	120
520	120
600	120
700	60
800	60

4816
Dual polarization dichroic pixels

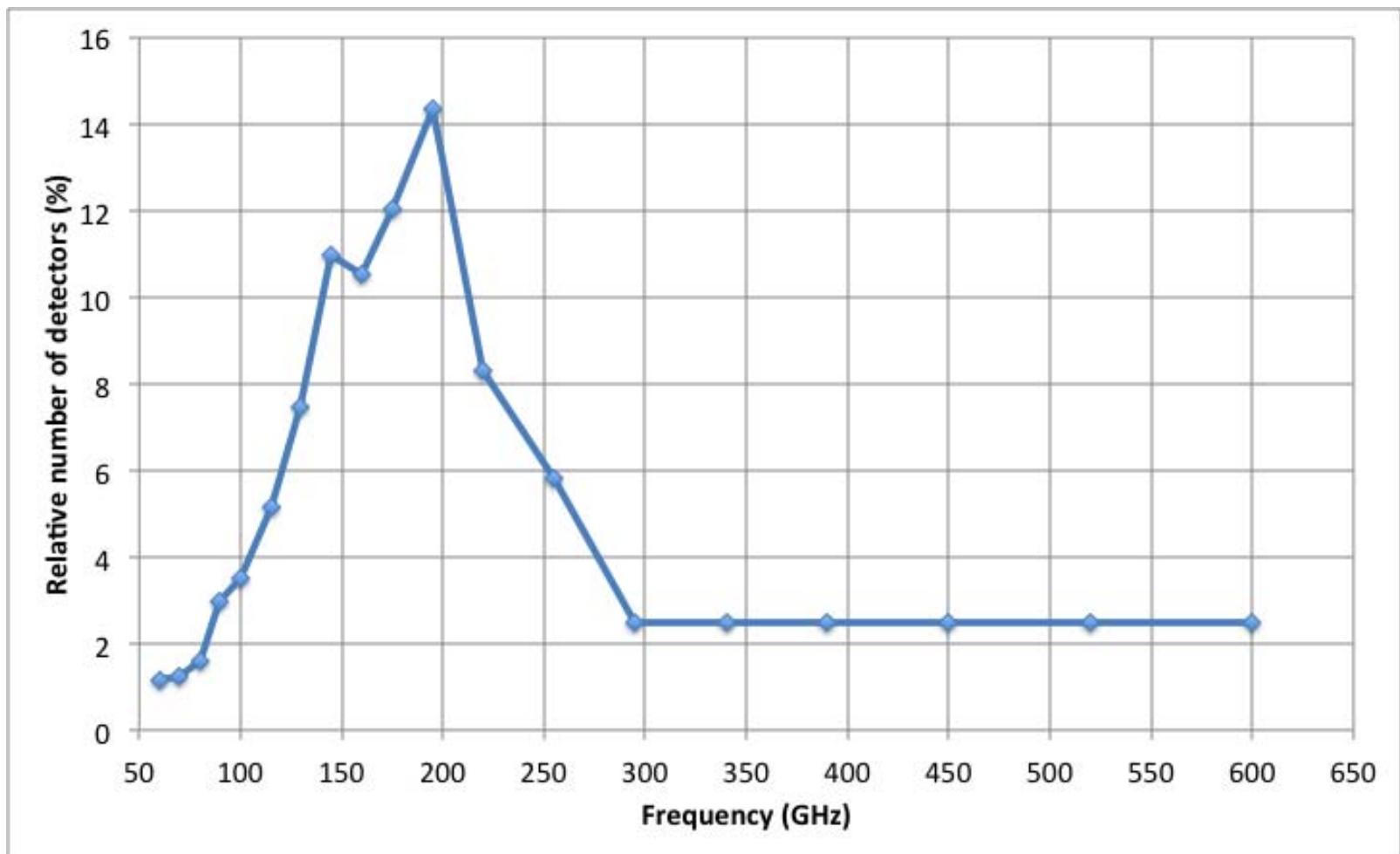


horn-horn
spacing = $3F\lambda$
 $F/\# = 2$

Assumptions for the M5 baseline

- Mission duration: 3 years
- Rotation speed: 1rpm
- Boresight angle: 45°
- Telescope diameter: 1.20m
- Telescope emissivity: 1% (0.5% per mirror)
- Telescope temperature: 100K
- Edge taper: -23dB
 - 0.5% of spillover; but see below.
- Power background: telescope + enclosure + CMB + CIB (from Jacques Delabrouille)

Frequency channel repartition

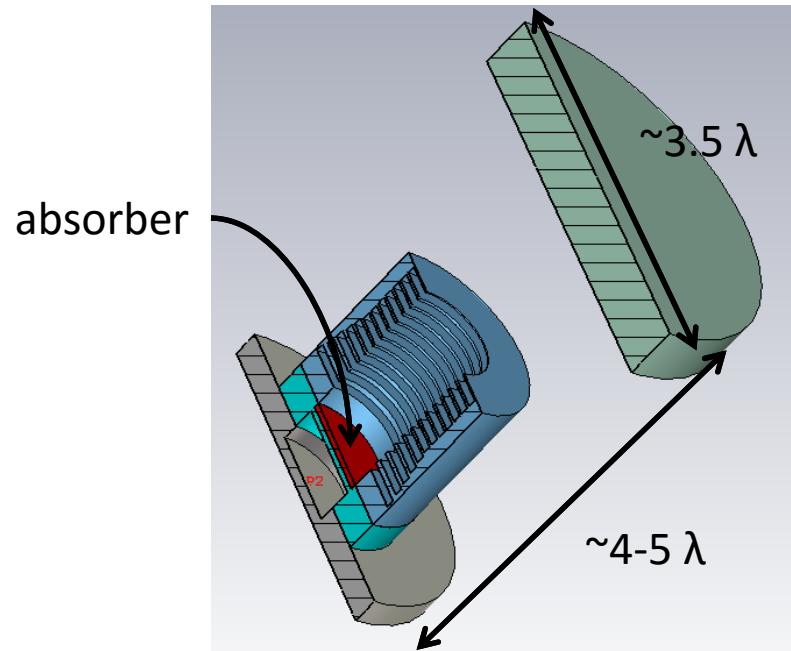


Horns coupled detectors (as in M4)

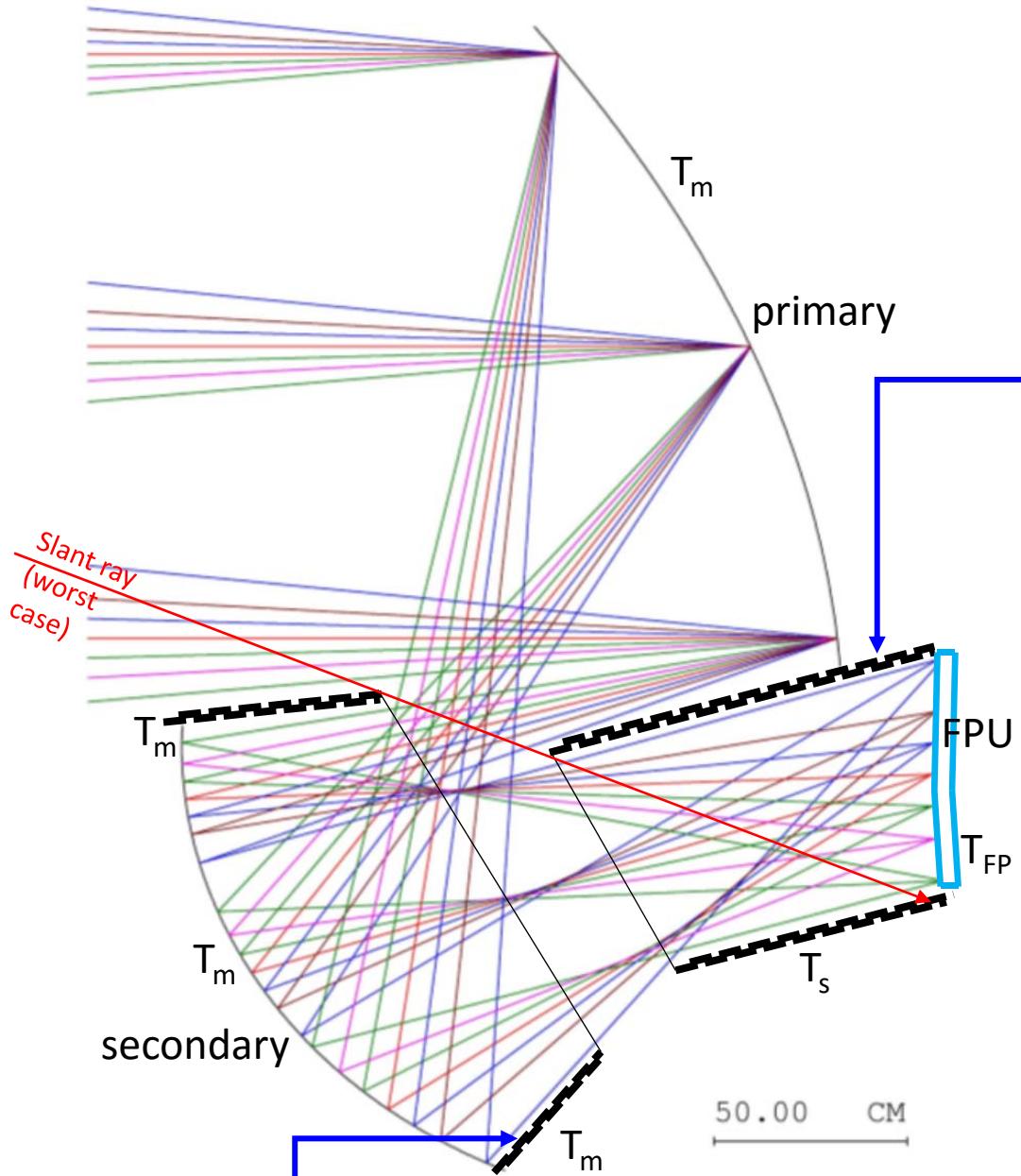
- -23dB edge taper with f#=2 telescope:
 - ~ 6.4λ diameter single moded horns
 - Assuming 100K enclosure
- With 50cm diameter focal plane: single/dual polarisation detectors
 - **1100/2200 detectors**
 - **Polarised sensitivity: 4.5/3.2 μ K.arcmin**
- However, the weight of the focal plane with horns is estimated around 30 kg.

Lens coupled detectors (new)

- Solution proposed by Giampaolo Pisano and Andrea Tartari:
 - Mesh lens + absorbing element (TES or LEKID)
- Estimated edge taper: -6dB
 - Requires extra control of sidelobes
- With 50cm diameter focal plane and single polarisation detectors, assuming 0.8 filling factor:
 - **3200 detectors**
- Assuming 1K enclosure :



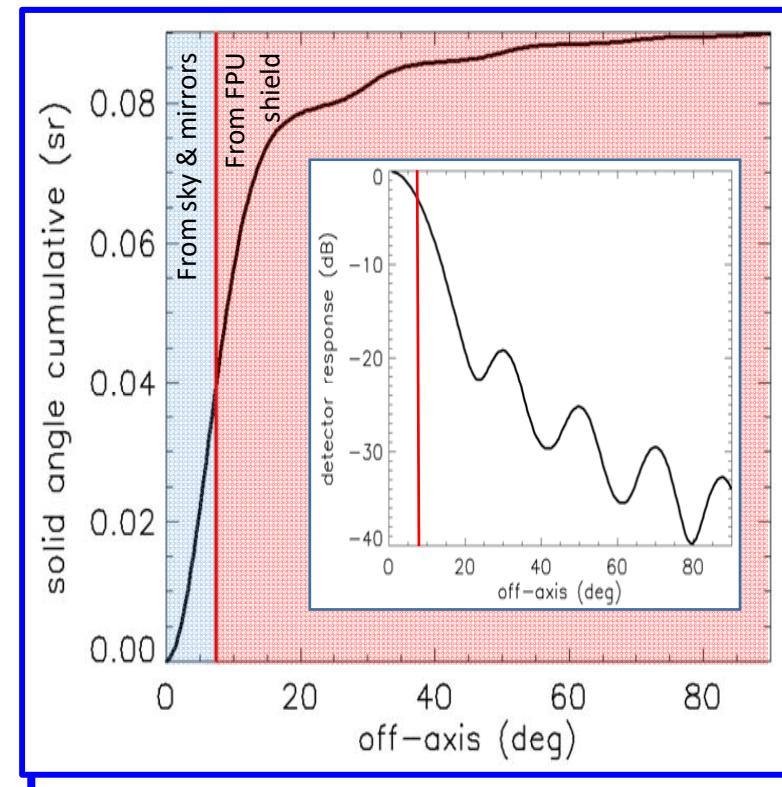
Gregorian telescope – simpler to baffle



Secondary baffle : Probably shiny, to reduce BKG.

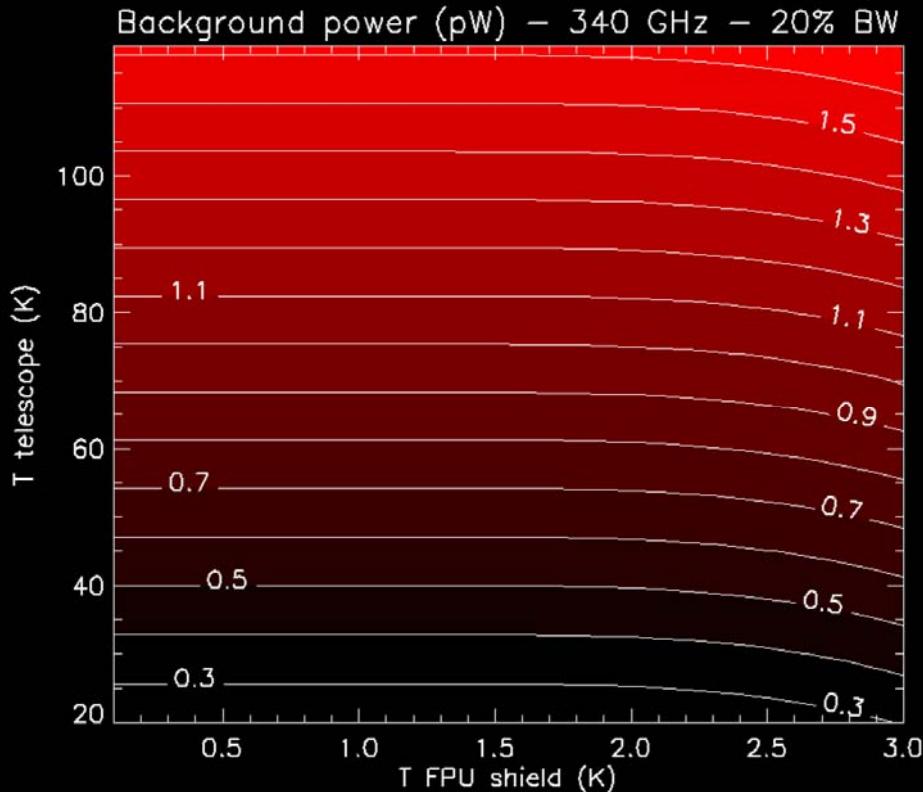
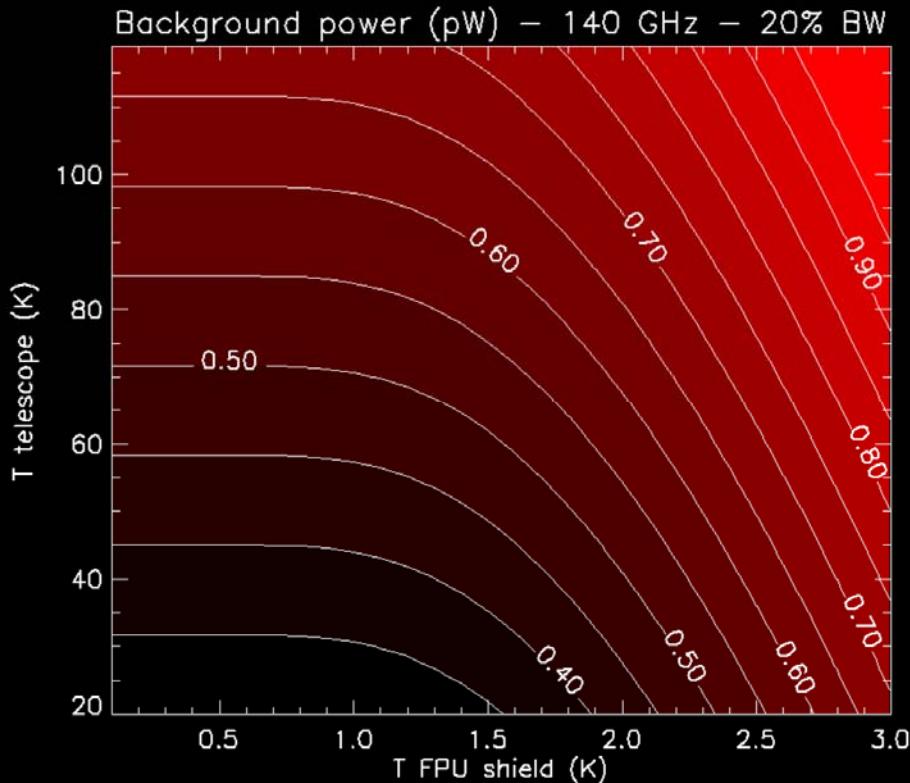
Cold & black FPU baffle :

- Reduces straylight (combined with secondary baffle)
- Reduces the radiative background on the detectors:
 - No need for horns
 - T mirrors doesn't need to be extremely low



- 0.04 sr from sky (140 GHz)
- 0.05 sr from cold FPU baffle

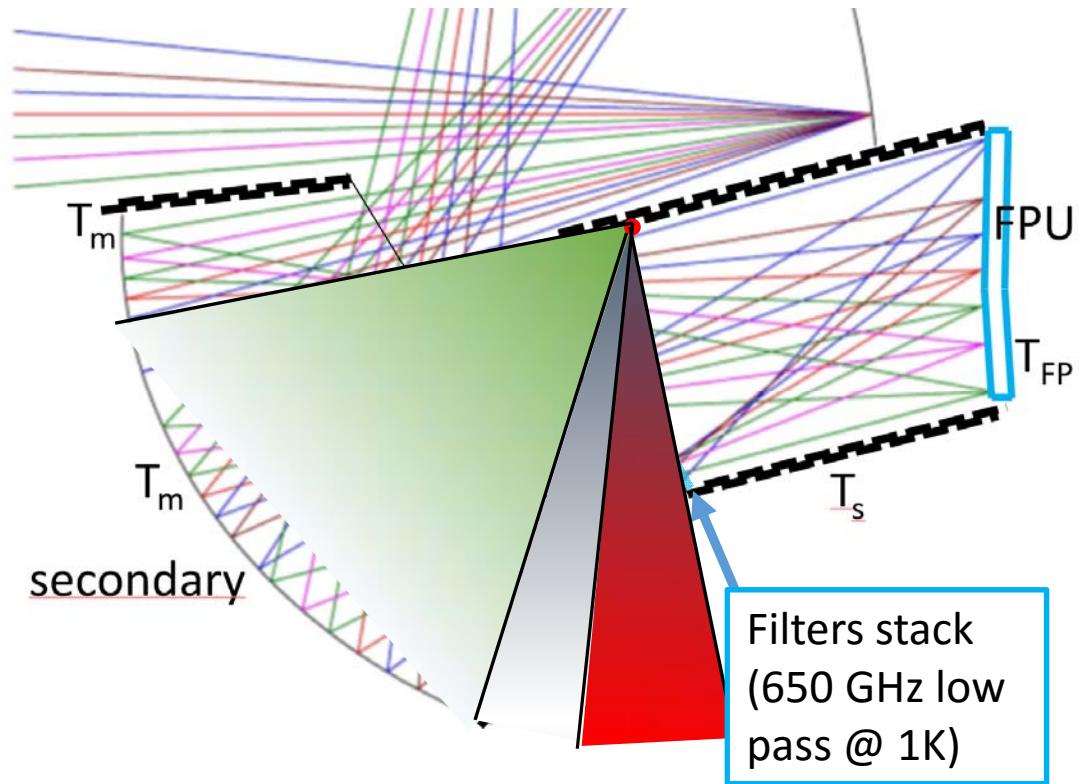
Background on detectors from CMB, telescope, and FPU baffle



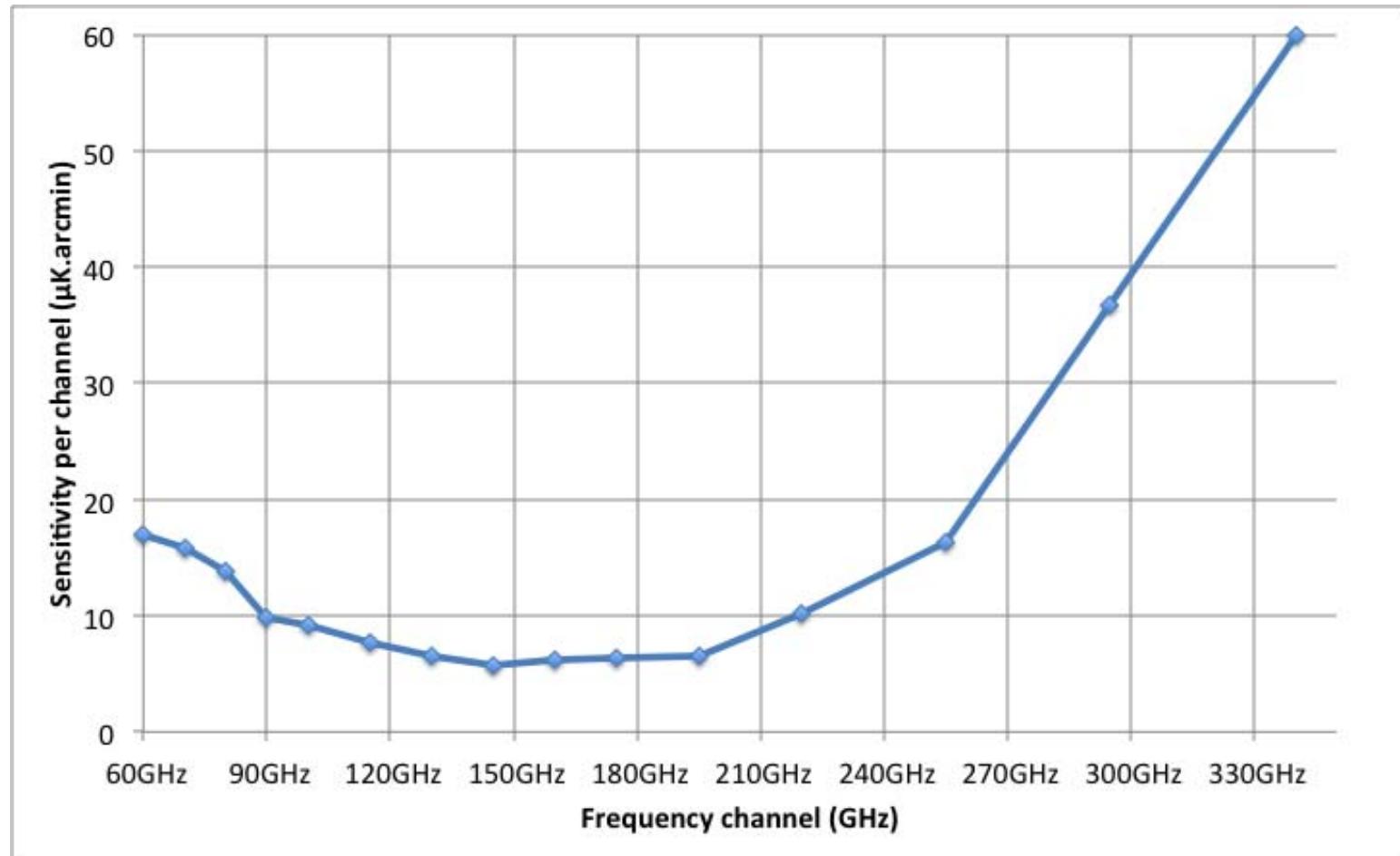
- Single-mode, single polarization detectors
- bkg from secondary baffle assumed negligible (ε optimization required)
- Bkg from telescope slowly rising with telescope temperature
- 1K for the FPU baffle looks very reasonable

Required cooling power for 1K FPU baffle

- Each area element of the cold shield views different radiators under different solid angles.
- The view factors should be computed, and then the total power collected.
- For sure we need a stack of cold low-pass filters at the optical entrance of the 1K cavity, connected to the concentric shields surrounding the 1K shield, with the last one, connected to 1K, being a 650 GHz low pass.
- *Rough estimate:* if the solid angle is filled 50% with 100K and 50% with 3K, the total power load (with filters stack !) on the 1K stage is **2mW**. To be considered in the cryo budget.
- Minimization of radiating components in the telescope environment is a must.

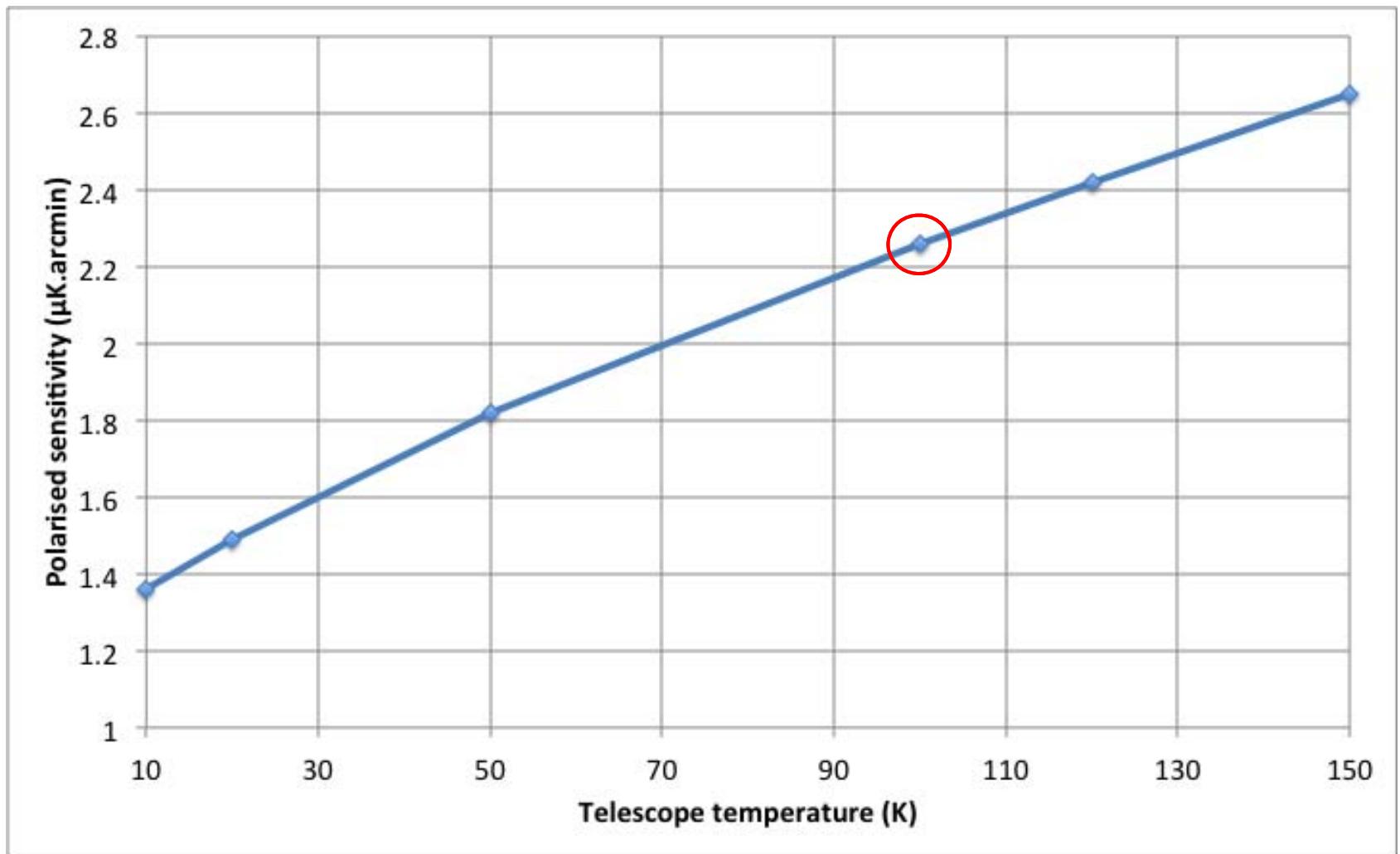


Sensitivity per frequency channel (lens case)



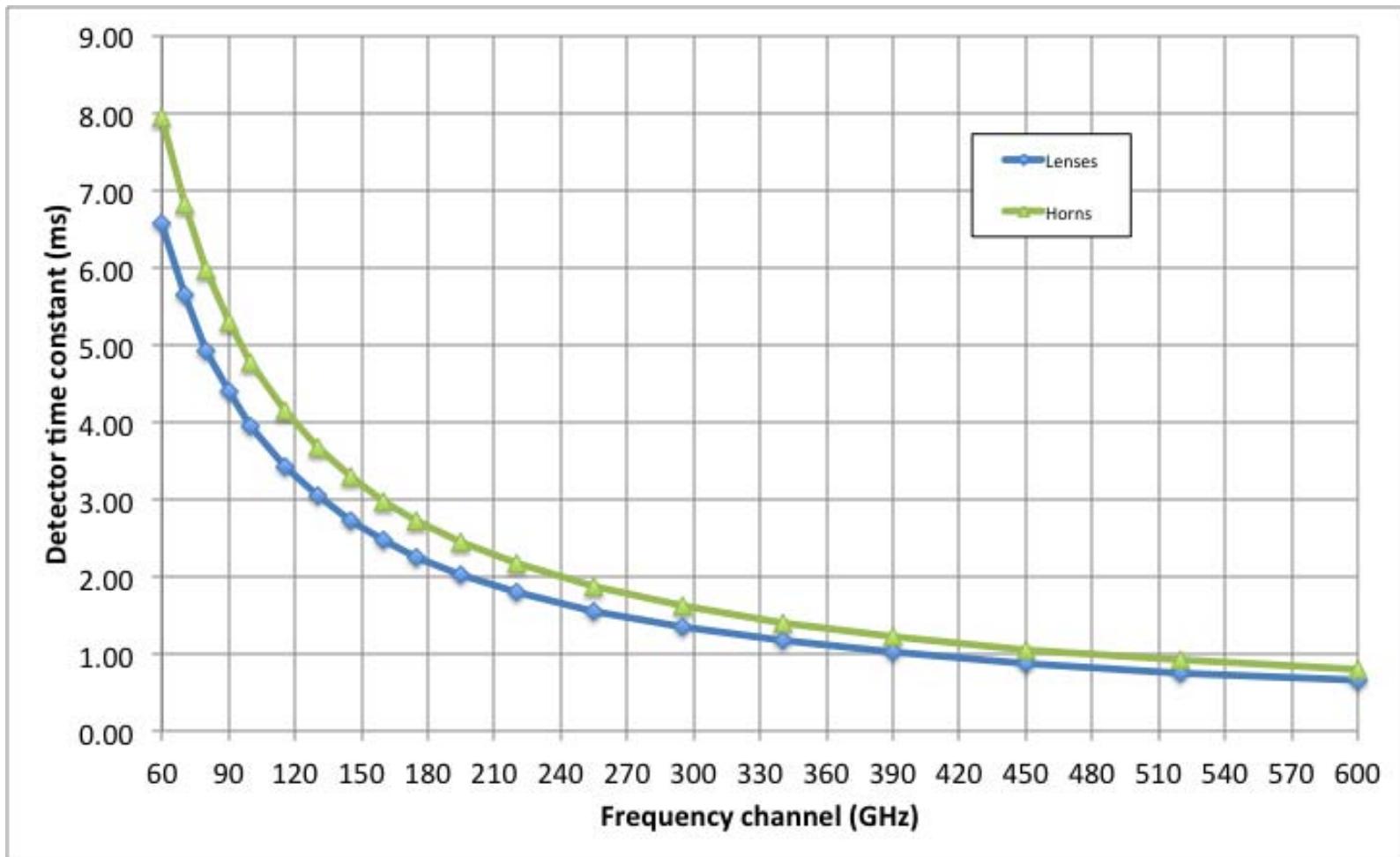
Polarised survey sensitivity: $2.3\mu\text{K.arcmin}$

Effect of telescope temperature

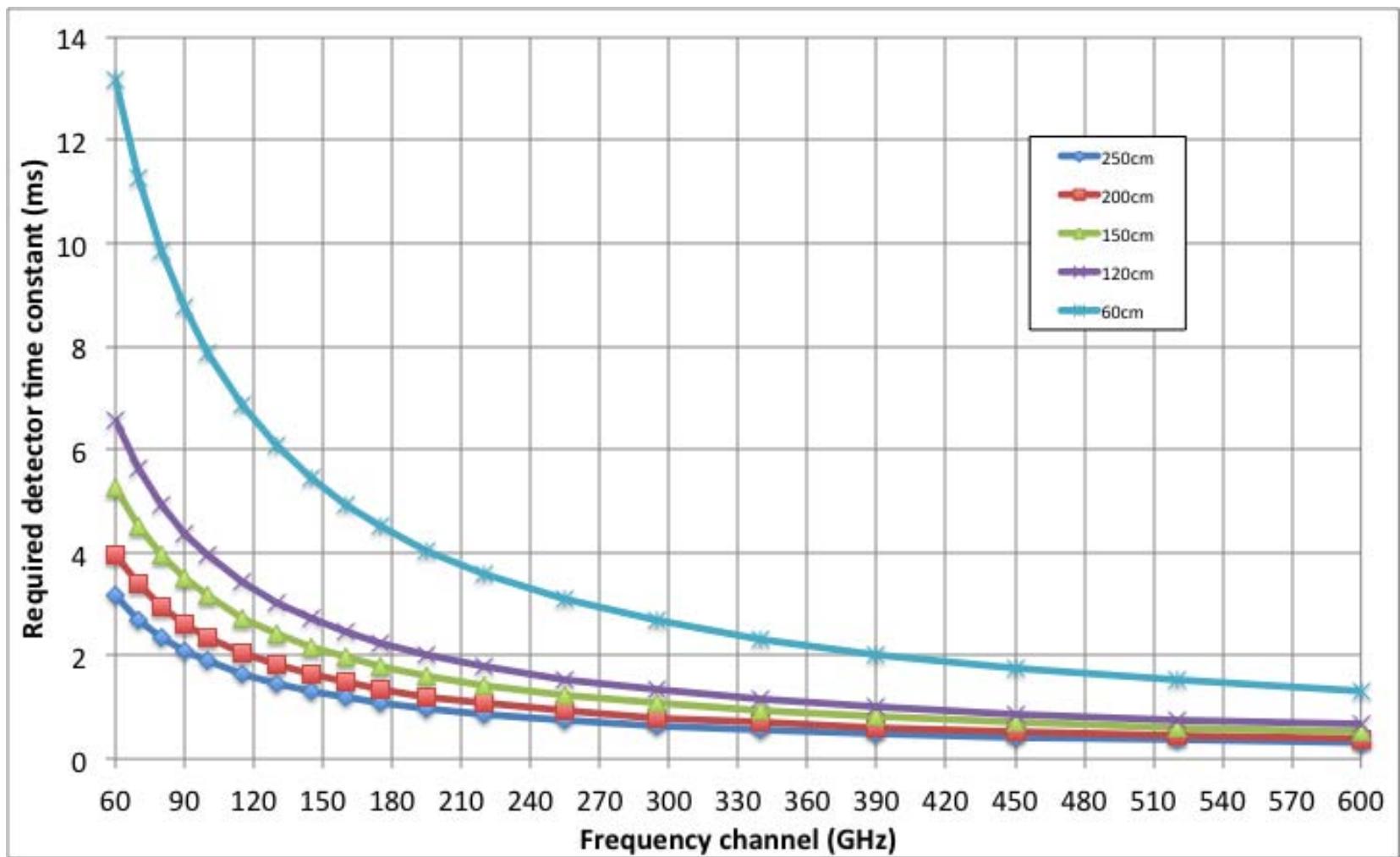


Required detector time constant

- 3π time constants per beam FWHM, 120 cm tel.



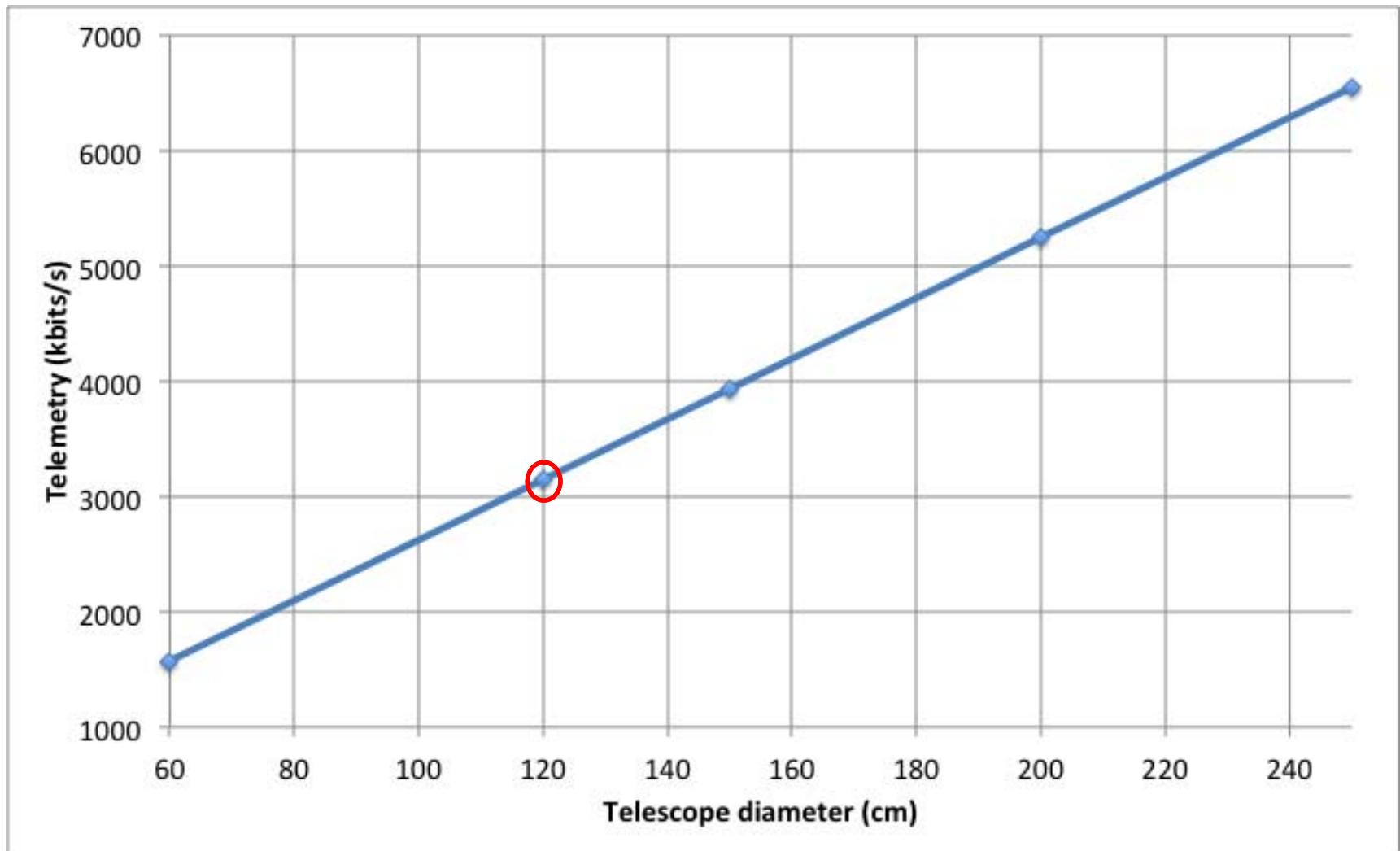
Detector time constant versus telescope diameter (lens solution)



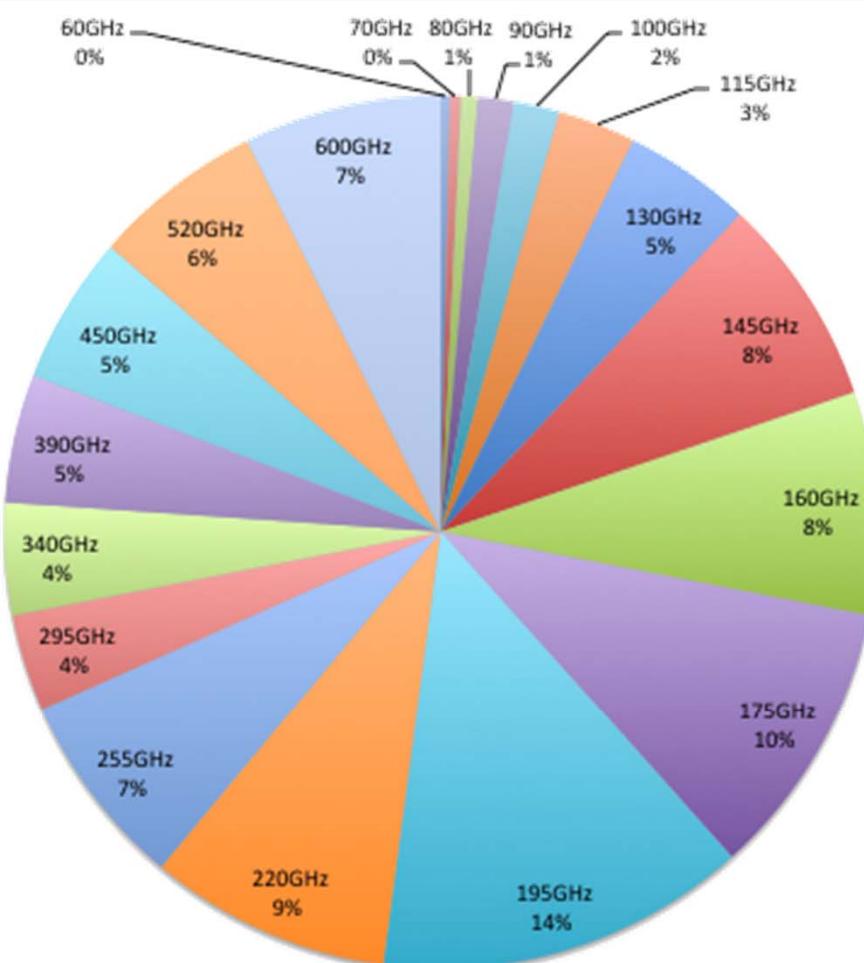
Telemetry

- Assumptions:
 - 4 samples per beam FWHM
 - 16 bits per sample, compression factor: 4
 - 50cm diameter focal plane
 - 1.2m telescope
- Single/dual pol, horns coupled detectors:
885/1767kbits/s i.e. 9.56/19.1 GB/day
- Single pol, lens coupled detectors:
3140kbits/s i.e. **33.9 GB/day (1.2m)**
- **42.1 GB/day (1.5m)**

Telemetry versus telescope diameter (lens solution)



Telemetry per channel



Conclusions

- Baseline instrument defined
- 1.2/1.5m Gregorian telescope, passively cooled @100K
- Focal plane baseline:
 - 50 cm diameter
 - Split in tiles (one or more per band, see M4) following the best focal surface
 - 3200 single polarization, single frequency pixels
 - planar lens coupling
 - black shield @1K surrounding the focal plane to control straylight
- Survey sensitivity (in polarization) $2.3 \mu K \text{ arcmin}$
- Time constant required in the ms range
- TM required 33-42 GB/day
- Issues requiring further investigation :
 - Control of edge taper / optical cross-talk
 - Heat load on the 1K stage