Planar detection architecture for CMB polarisation observations

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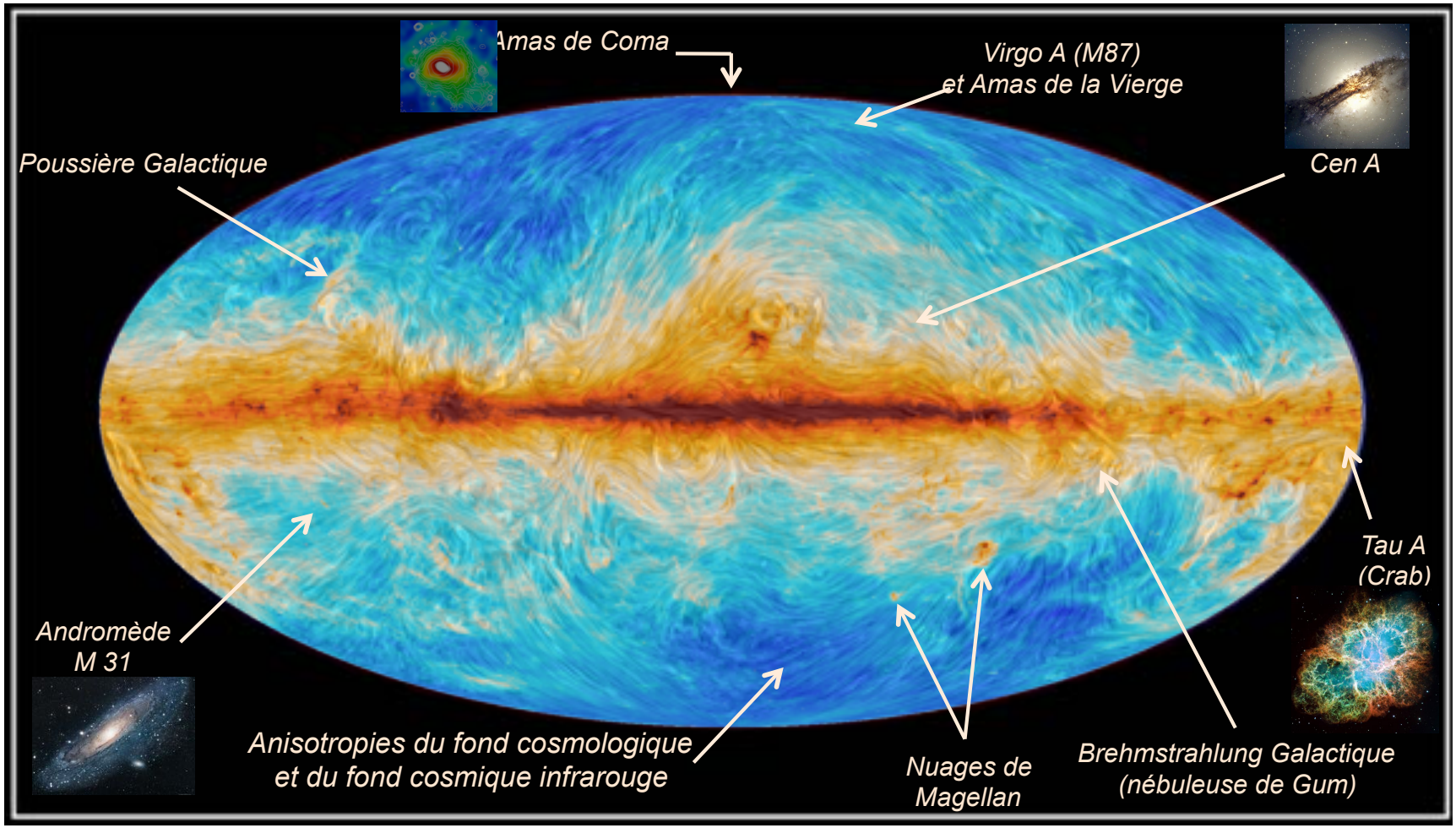
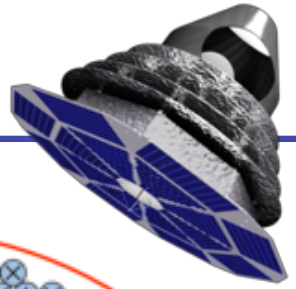
CSNSM - C2N - Observatoire de Paris - Néel Institut – APC

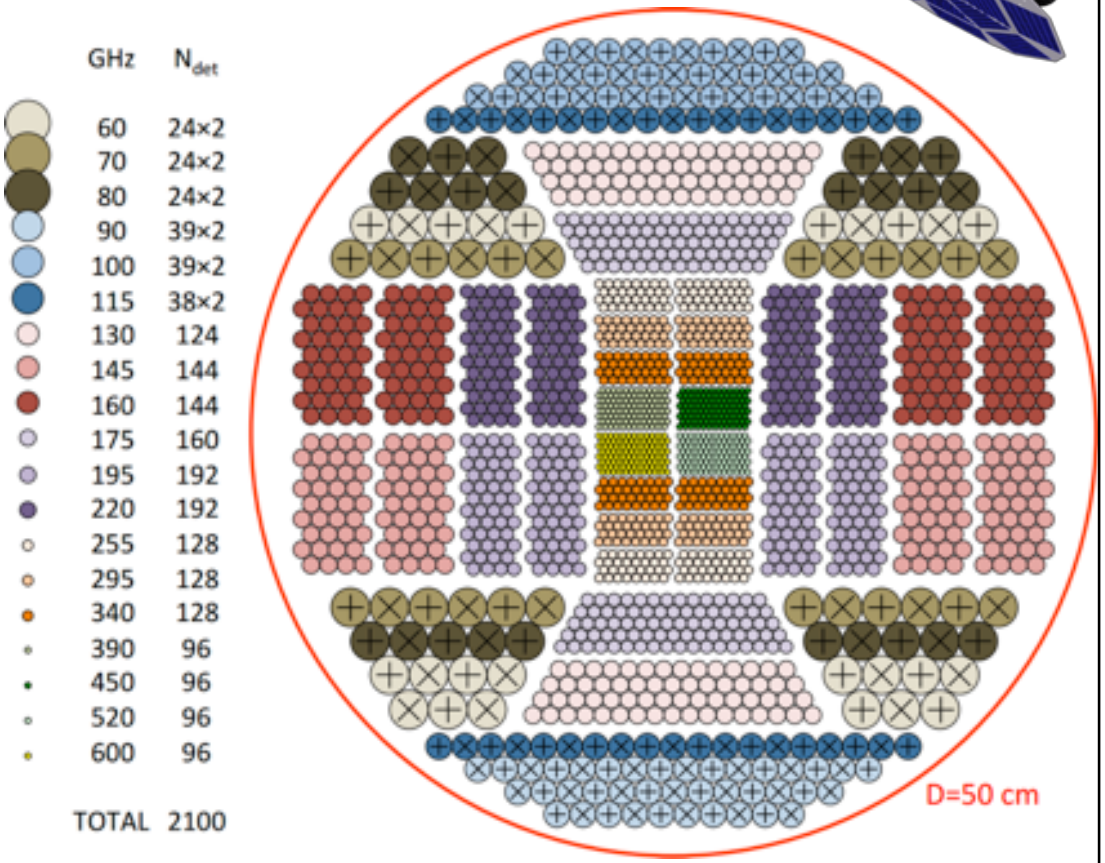
The mm/sub-mm sky



CORE: a CMB polarisation space mission



- **Large number of detector required**
  - **Direct detectors @ T<0.3K: bolometers, KIDs**
- **Problem: large focal plane area**
- **Solution: multichroic architecture**
  - One antenna feeding several detectors
  - Lower focal plane area!
- ESA ITT *Next Generation Sub-millimetre Wave Focal Plane Array Coupling Concepts*
  - with Maynooth (leader), Manchester, Cardiff, Roma and Chalmers

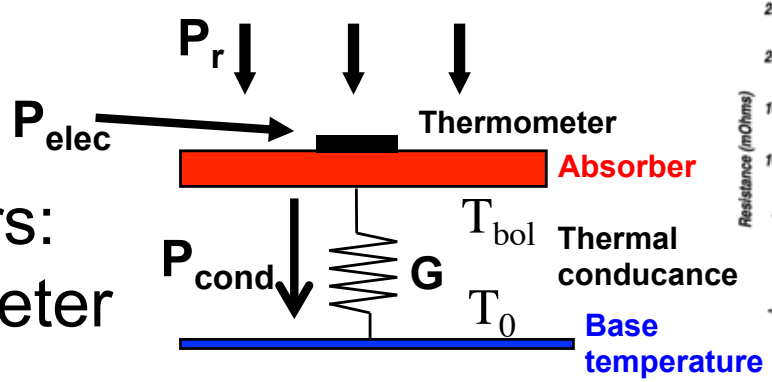


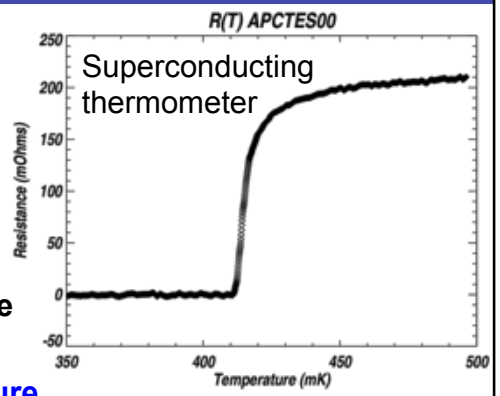
CORE focal plane

Outline

1. CMB detectors:
   - Transition Edge Sensors (TESs)
   - Kinetic Inductance Detectors (KIDs)
2. Development of multichroic detection architecture with Lumped Element KID

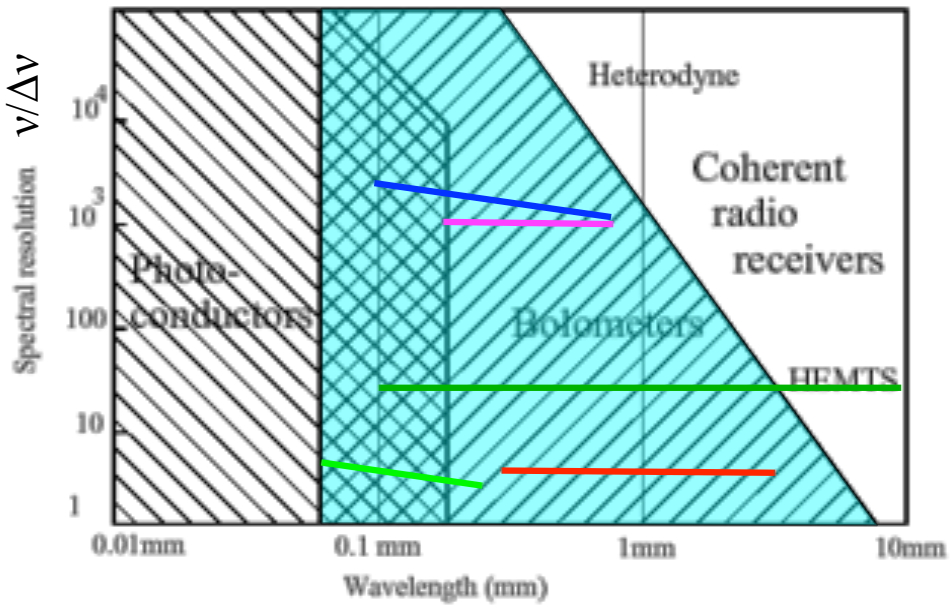
1. CMB detectors: Transition Edge Sensors (TESs)





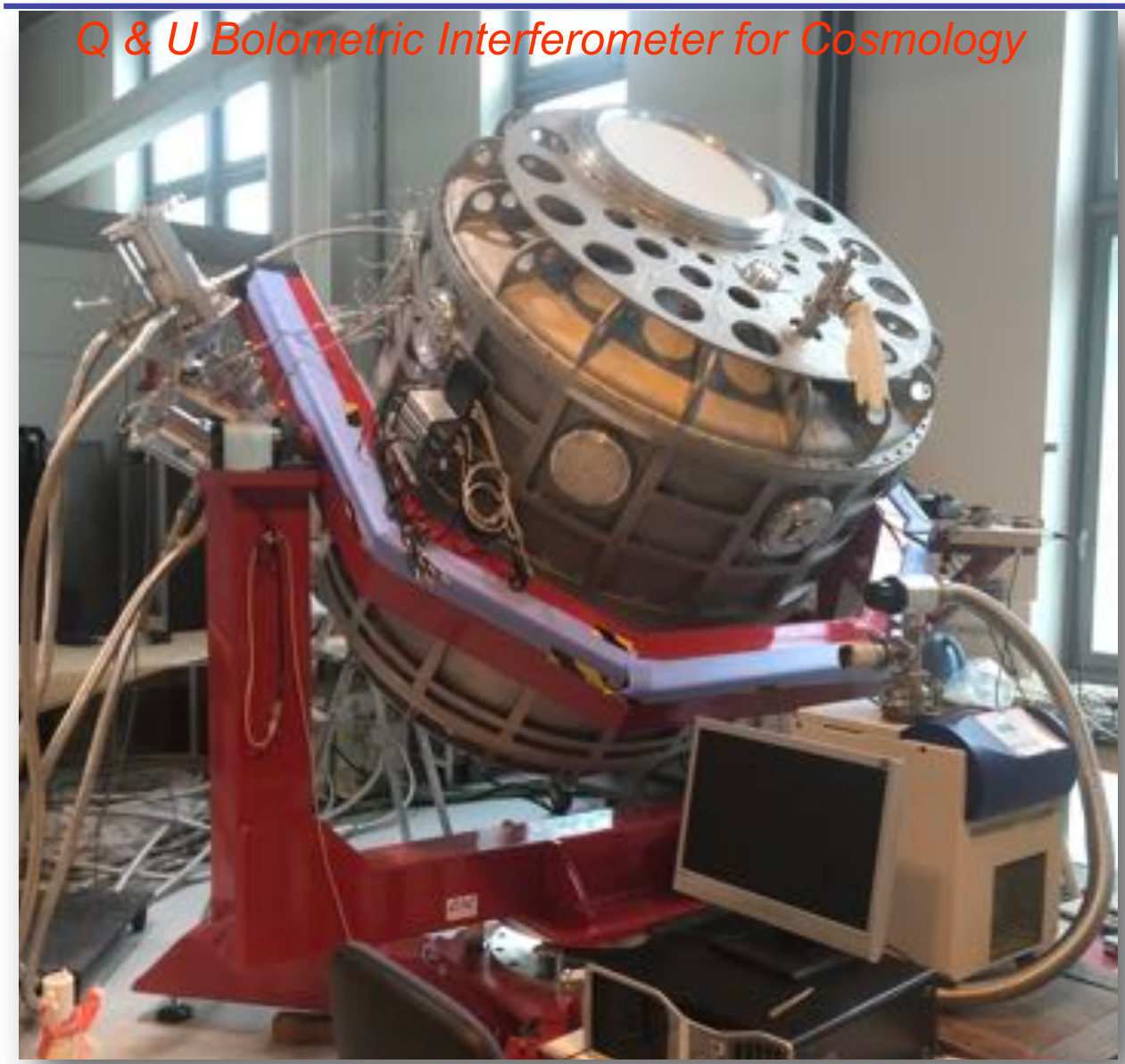
- Transition Edge Sensors: superconducting bolometer

- Bolometer: the best detectors for <u>large bandwidth</u> detection in the wavelength range 100µm → 3mm
  - Cooled to low T < 300mK
  - Planck: sensitivity limited by CMB photon noise



From top to bottom: SAFIRE Herschel-SPIRE COBE-FIRAS Herschel-PACS Planck-HFI

The QUBIC instrument

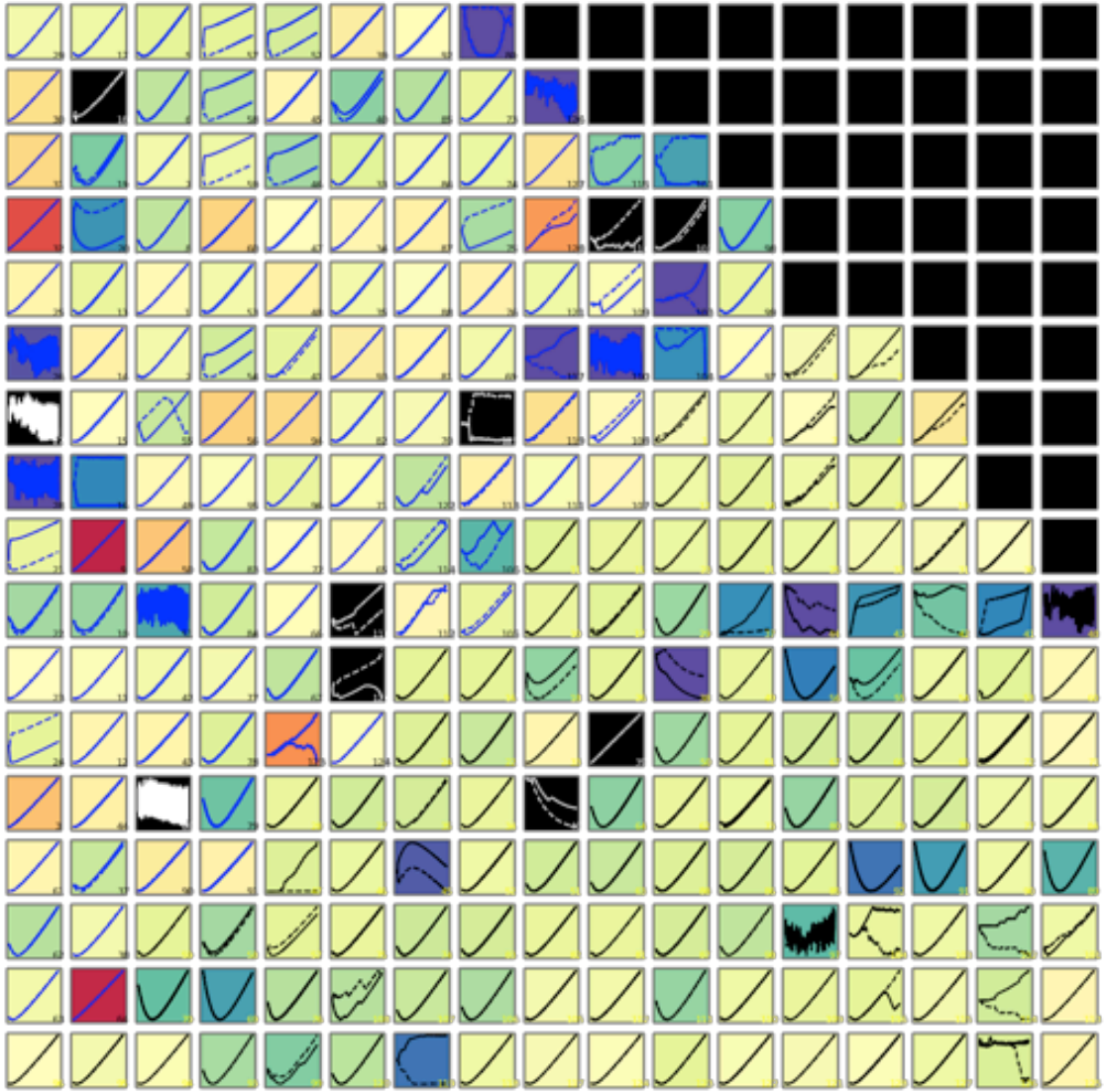


The only ground-based European CMB polarisation experiment

1.547m high
1.42m diameter
About 800kg

QUBIC TES array

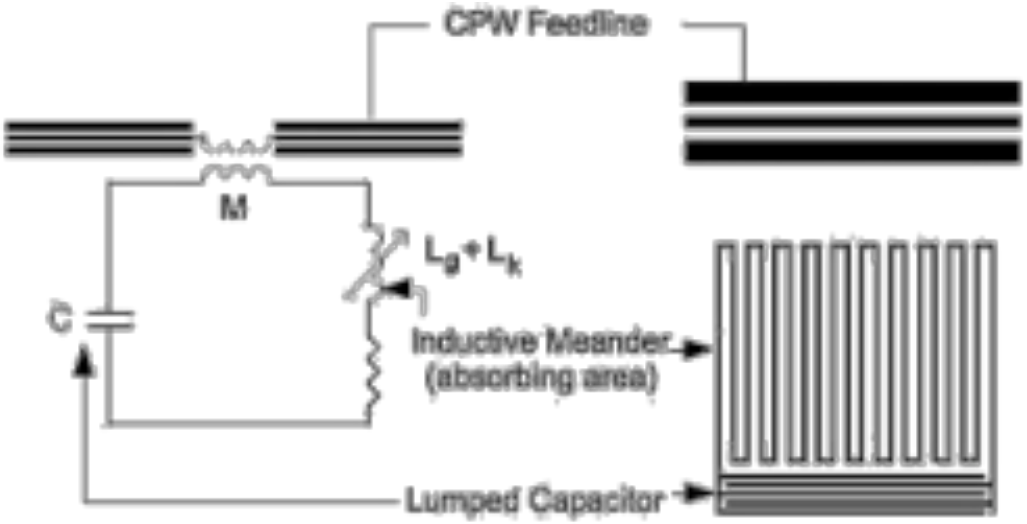
QUBIC TESs: I-V measurements



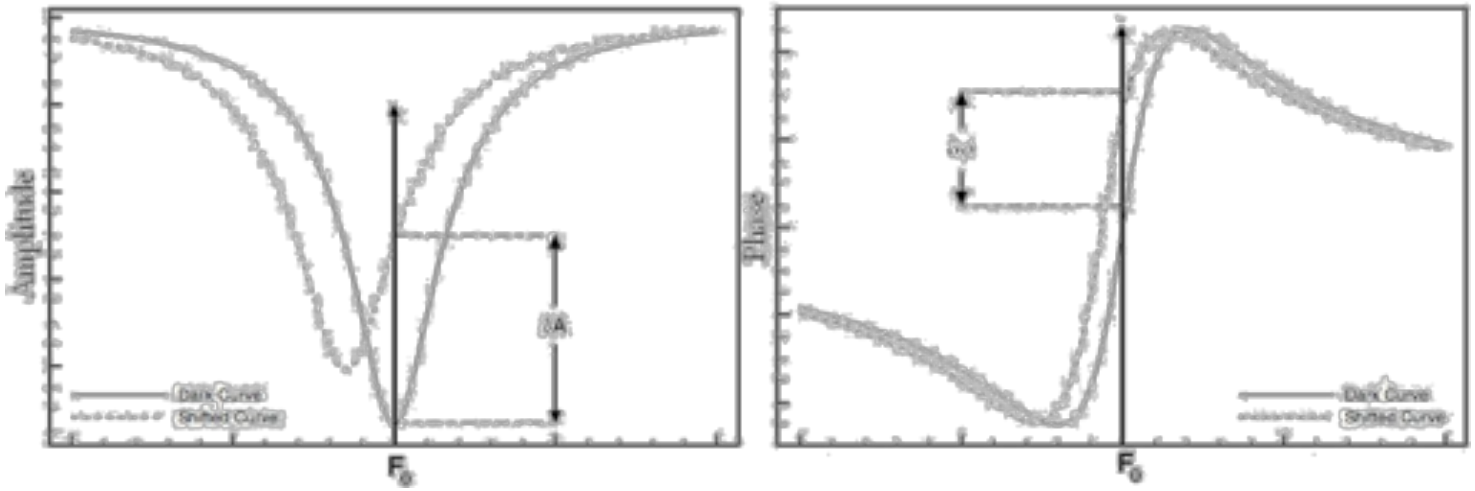
- I-V at 360mK
  - Good homogeneity
- TDM MUX factor = 128
  - ASIC SiGe @ 50K + SQUIDs @ 1K
- Yield: ~84% (array ref P87)
- **State of the art**

CMB detectors: Kinetic Inductance Detectors (KIDs)

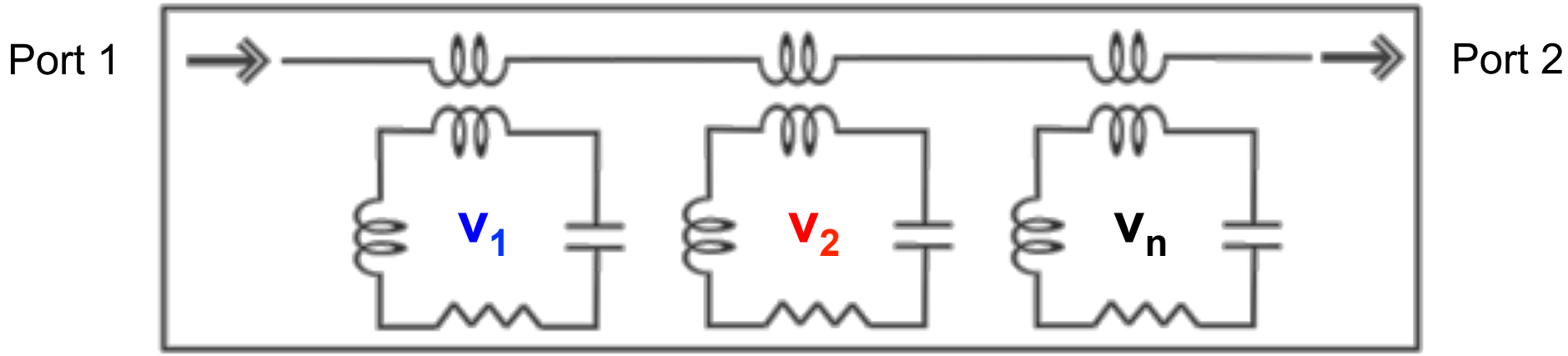
- Kinetic inductance variation of a superconducting absorber in a resonant circuit
  - Recent development: P. Day et al., Nature 2003
  - Very fast developments
  - $T<T_c/10$ so $T<0.12K$ for Al

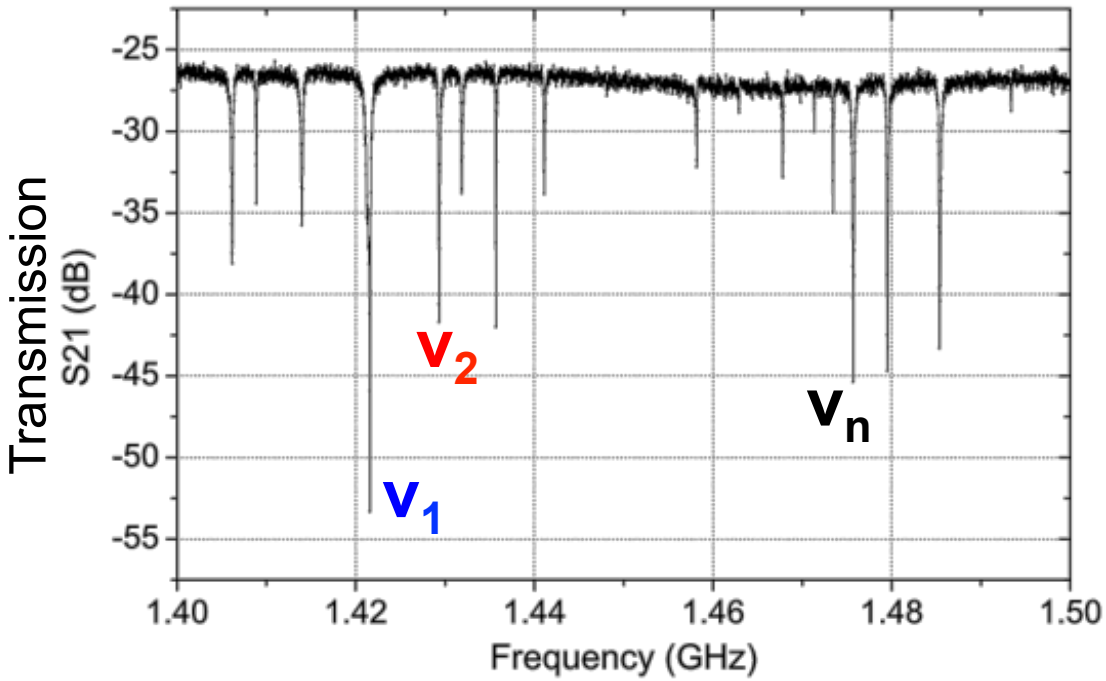


LEKID



KIDs multiplexing





- Naturally frequency multiplexed
  - limited by quality factor and readout electronic
  - Single line for 100s of detectors

See Ph. Camus presentation

CMB detectors trade-offs

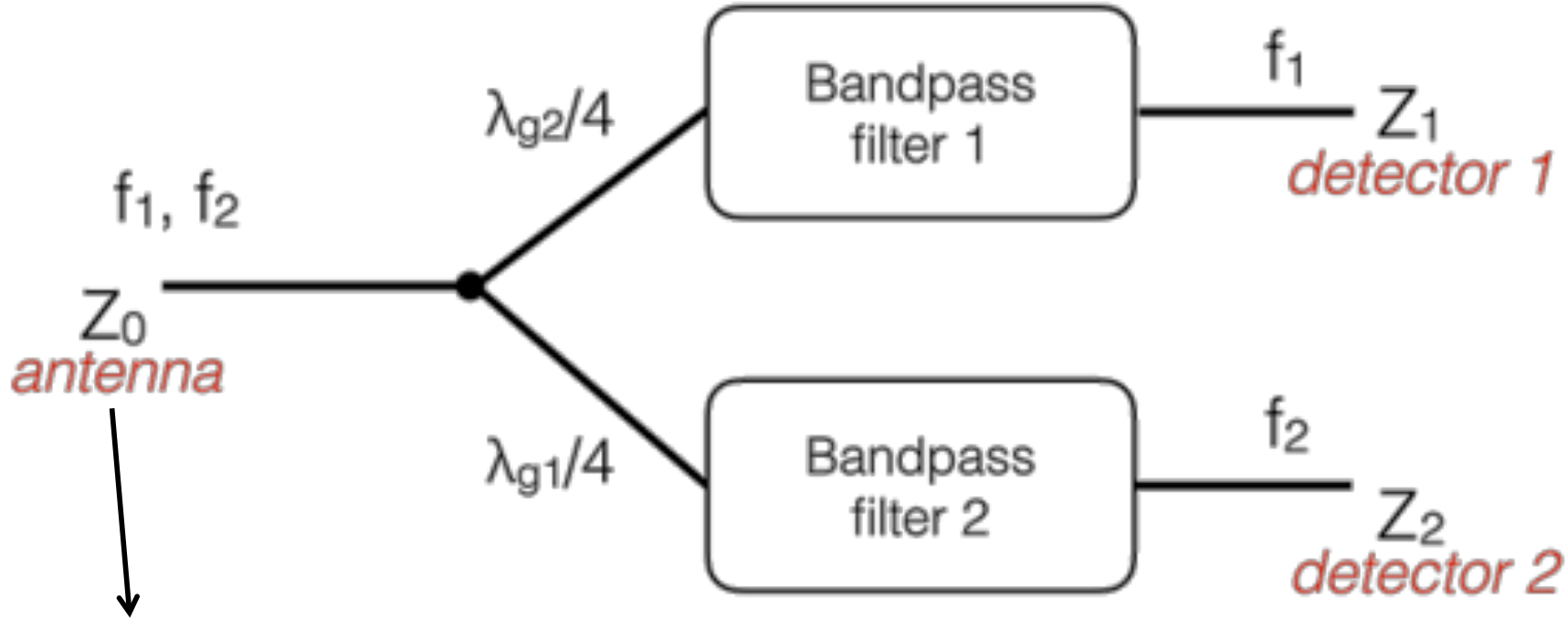
Color code: Meet specs Limitation Critical

	TESs	KIDs
Sensitivity		R&D
Frequency range		Limited by energy gap
Time constant	ms range	Fraction of ms
Multiplexing	Complex at cold T	Natural
Fabrication complexity	10's process steps	Few steps
Sensitivity to Cosmic Rays	Balistic phonons	R&D
Power consumption	Low freq. electronics	Engineering
Pol sensitivity	Antenna coupled	R&D
Sensitivity to δT	Bath temperature	
Sensitivity to B	Readout (SQUIDs)	Intrinsic sensitivity
TRL	TESs: 5-6	3-4

2. Dual color antenna-coupled LEKID development

- Goal:
  - Antenna coupling to LEKID
  - Separate two sub-bands centered at 140 GHz and 160 GHz with ~ 10% bandwidth
  - Reduce the impact of Two Level System noise (no dielectric on the KIDs)
  - Keep the fabrication as simple as possible (few levels, via-less)
- Difficulty: high frequency power to be dissipated in the inductance
- Alessandro Traini (CNES PhD)

Dual-Color Antenna-Coupled LEKID architecture

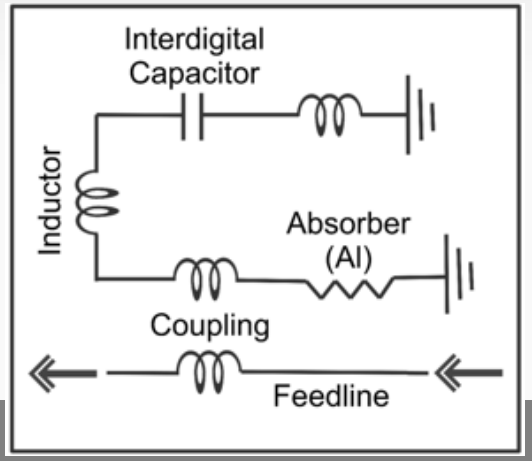


Slot Antenna:

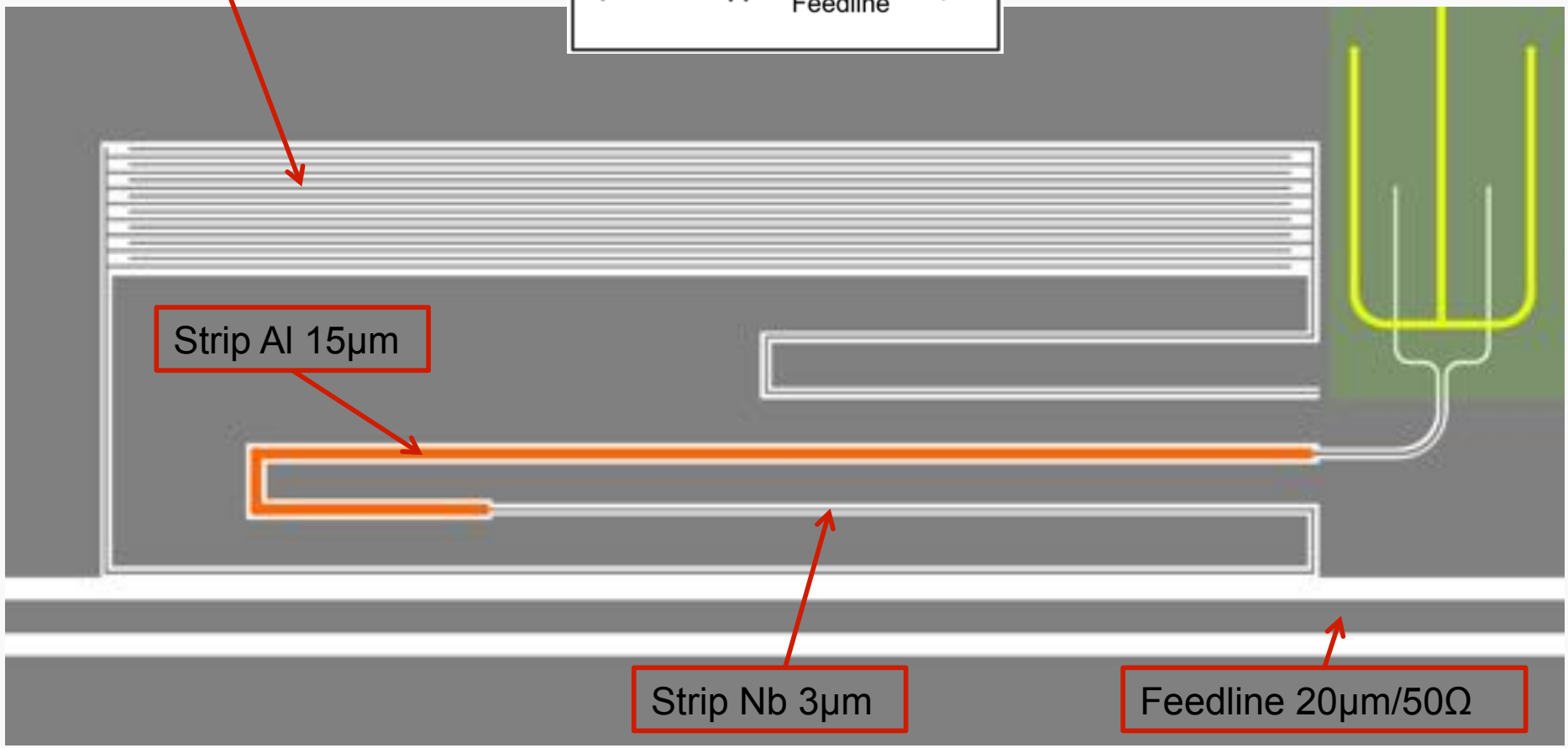
- Microstrip excited
- Basic element for more complex antennas

Detector Design: CPW LEKID

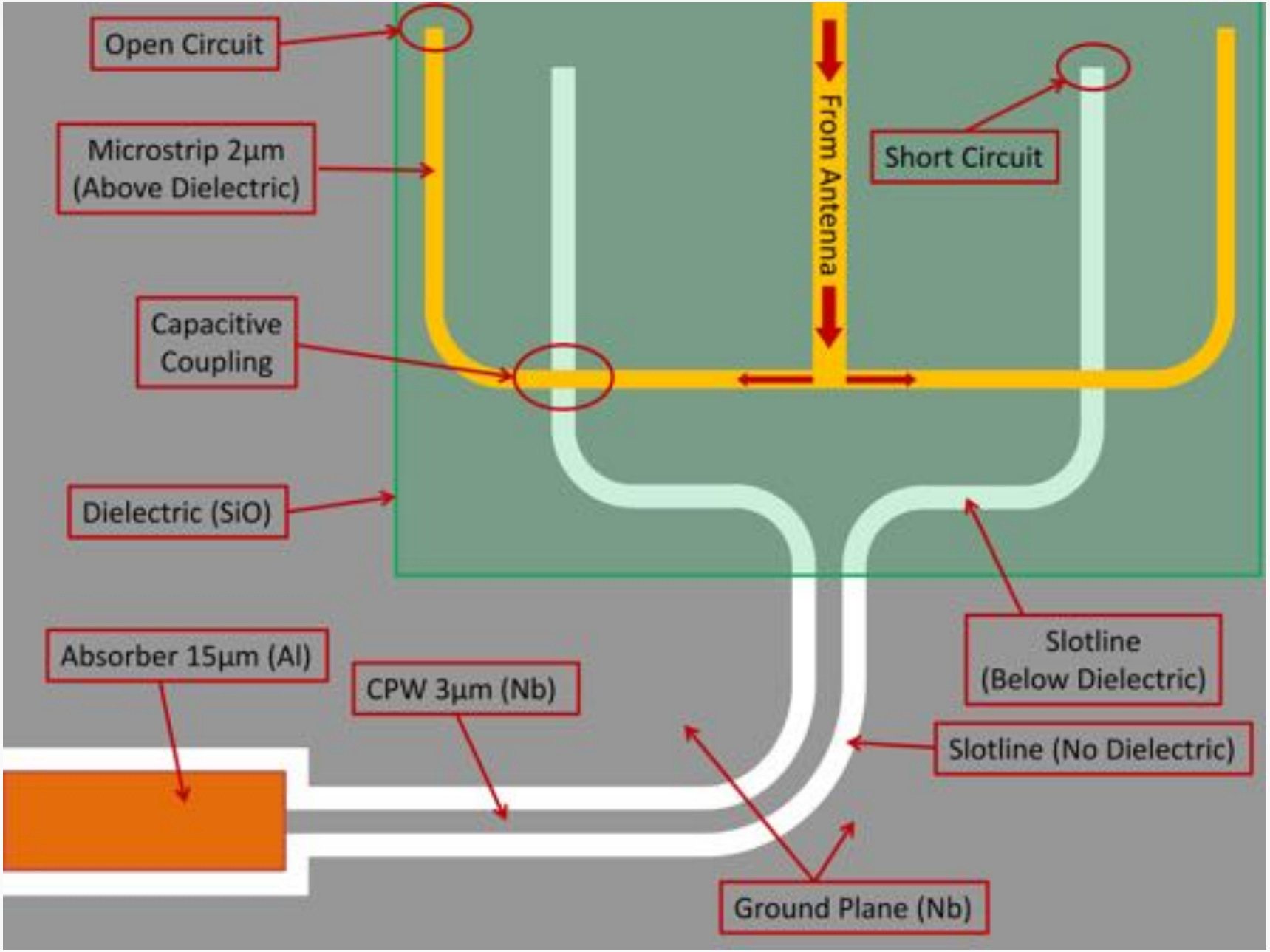
[Alessandro Traini PhD]



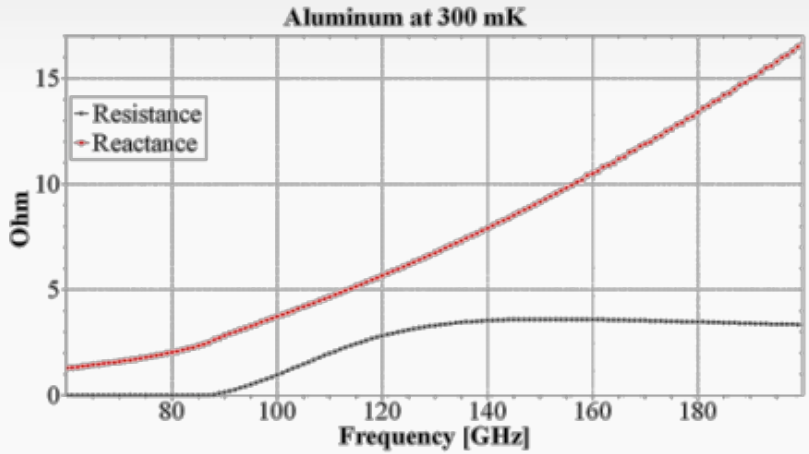
Diplexer: 120 nm Nb
Dielectric: 500 nm SiO
Slot - LEKID: 120 µm Nb
20 nm Al
Substrate: 300 µm Si



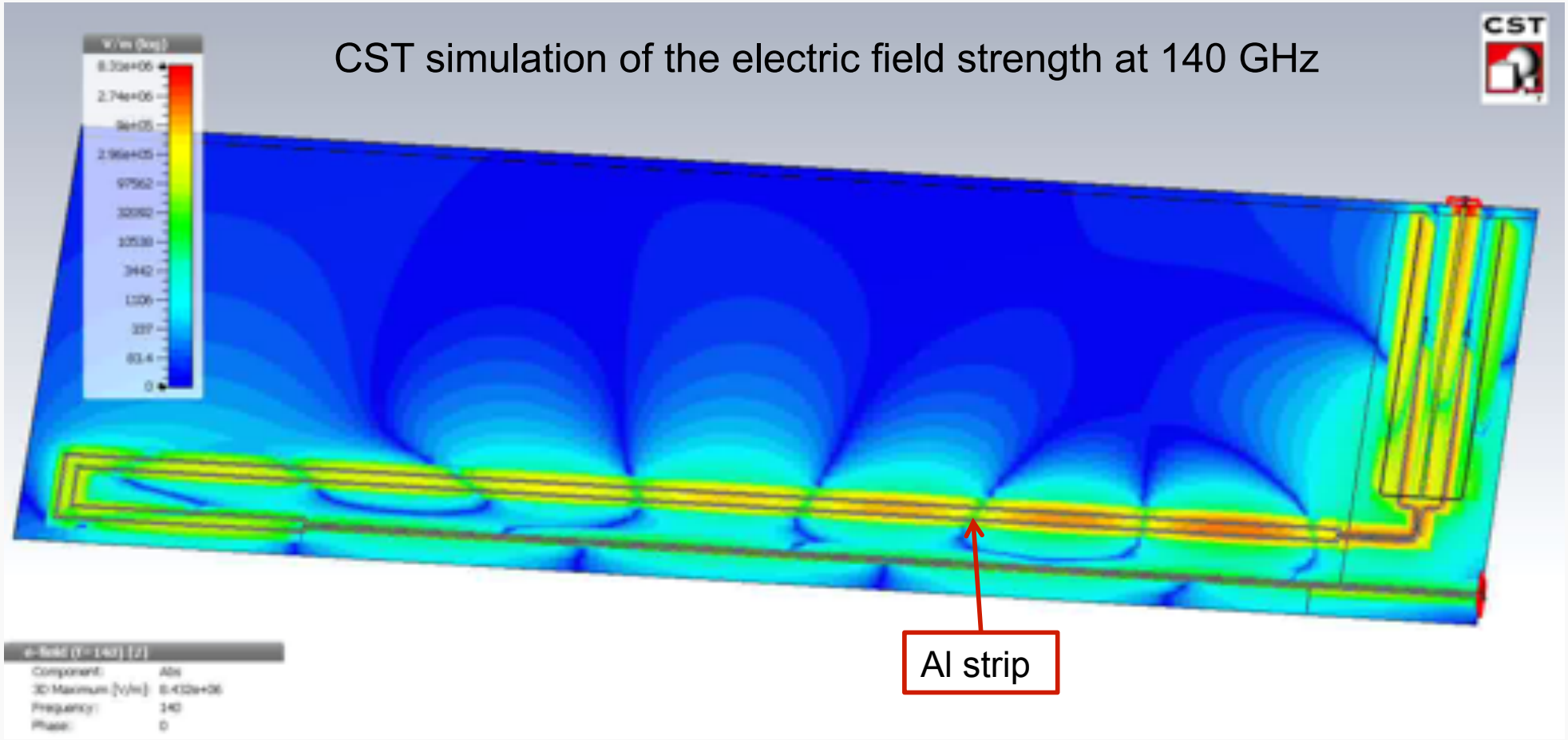
Detector Coupling



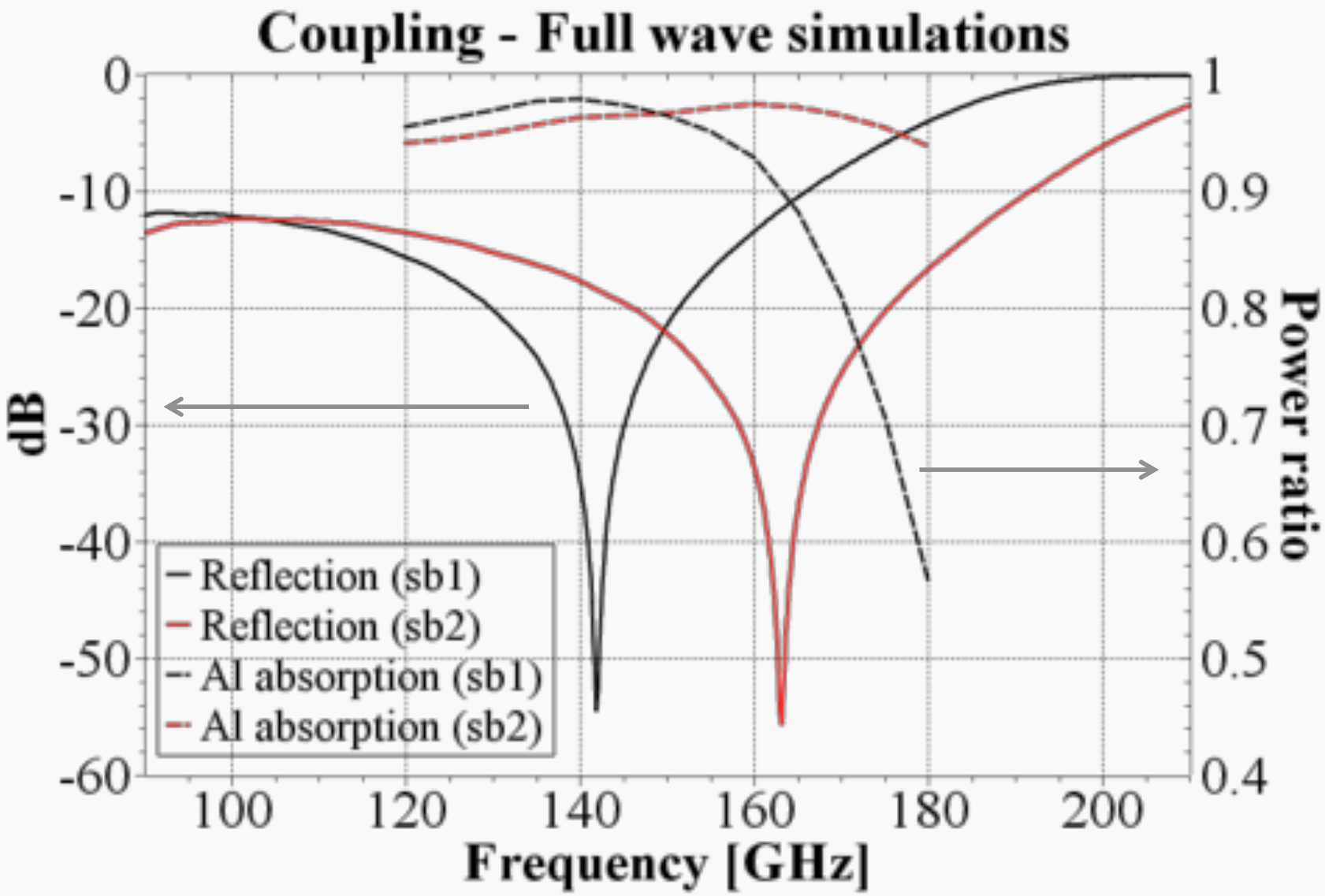
Detector Coupling



Al at 300mK data from
Mattis-Bardeen integrals

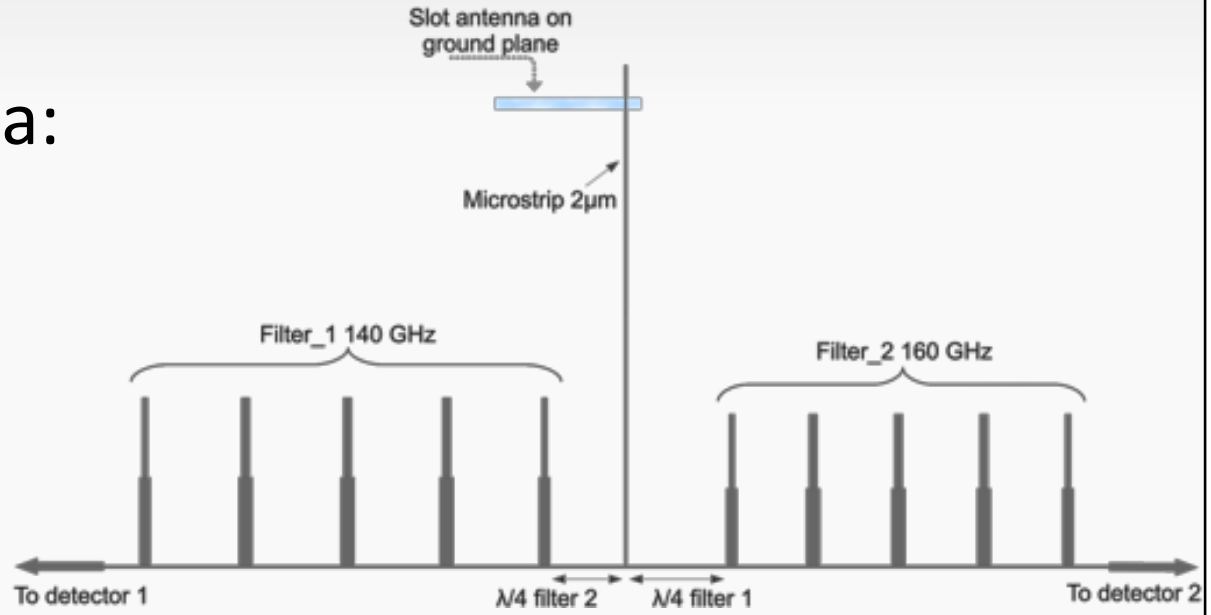


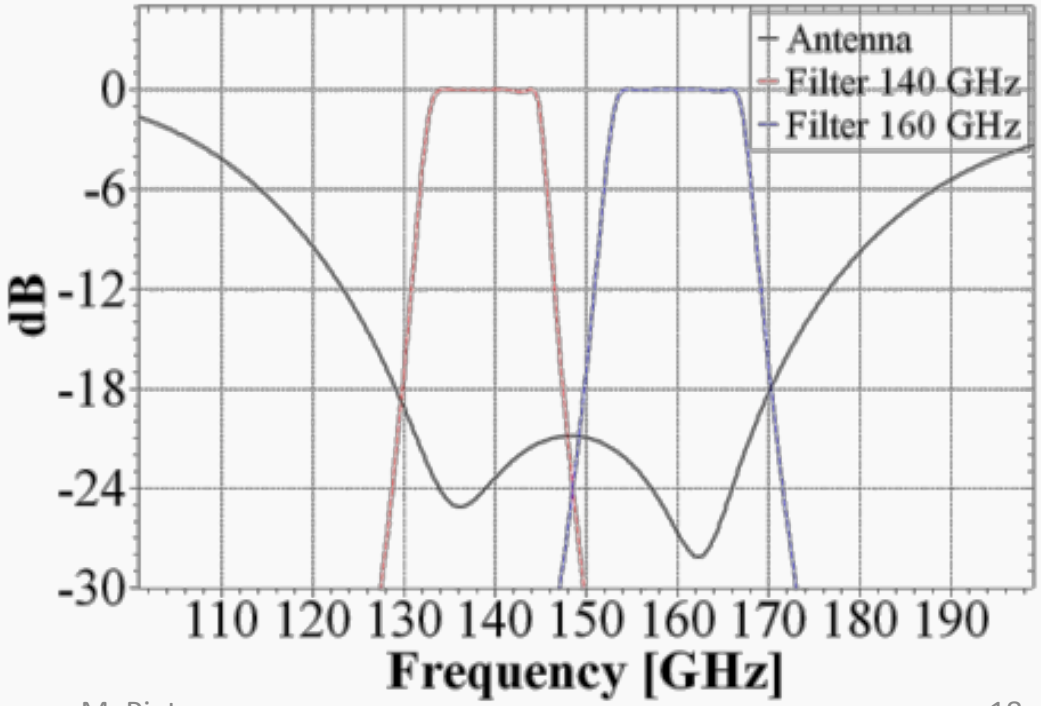
Detector Coupling



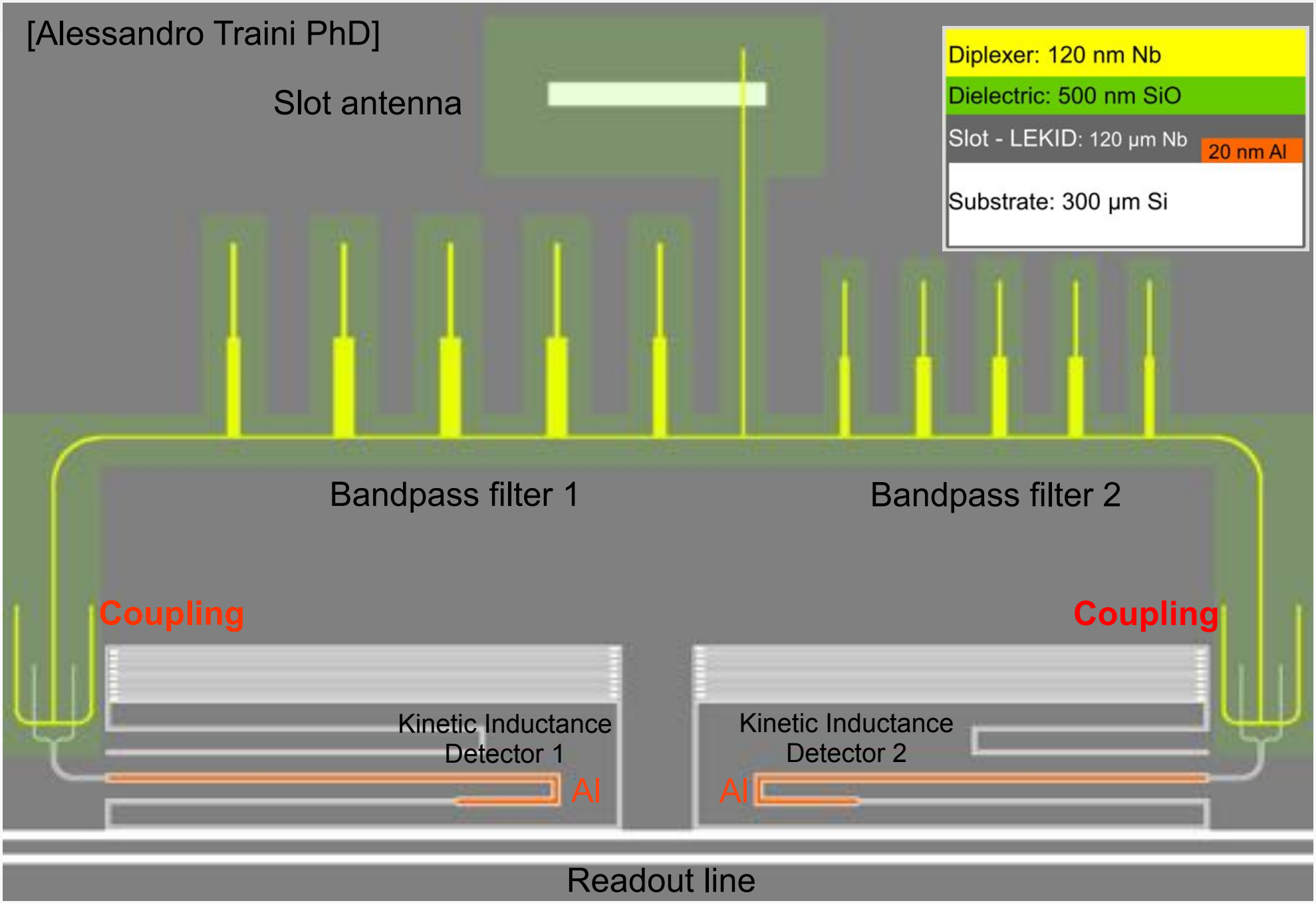
Slot Antenna Antenna + Diplexer

- Wide band slot antenna:
  - [N. Behdad et al. 2005]
  - Fictitious short circuit concept
- Diplexer:
  - N=5 Chebyshev open-stub Bandpass Filter
  - No capacitive coupling
  - Does not require a VIA
  - 10% bandwidth
  - Filter bands overlap below 20 dB

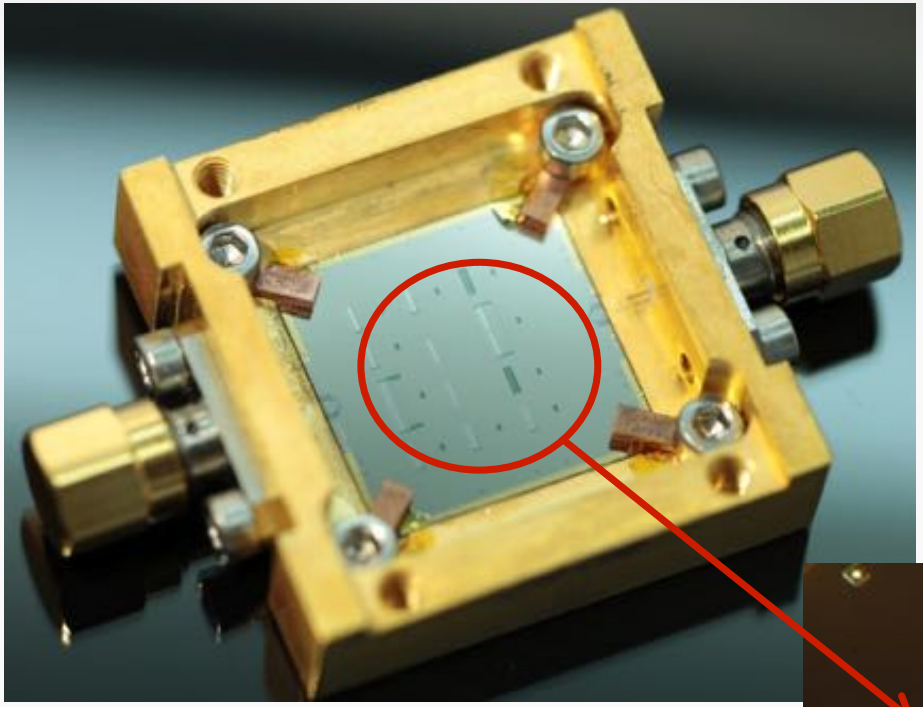




Dual-band pixel



Chip Set Layout

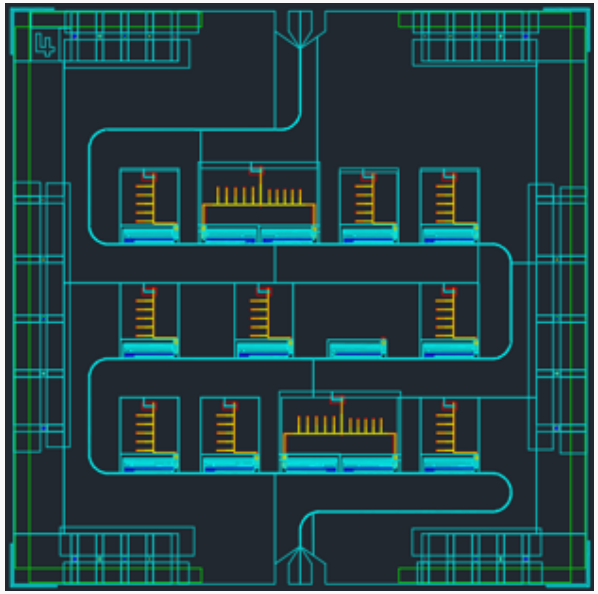


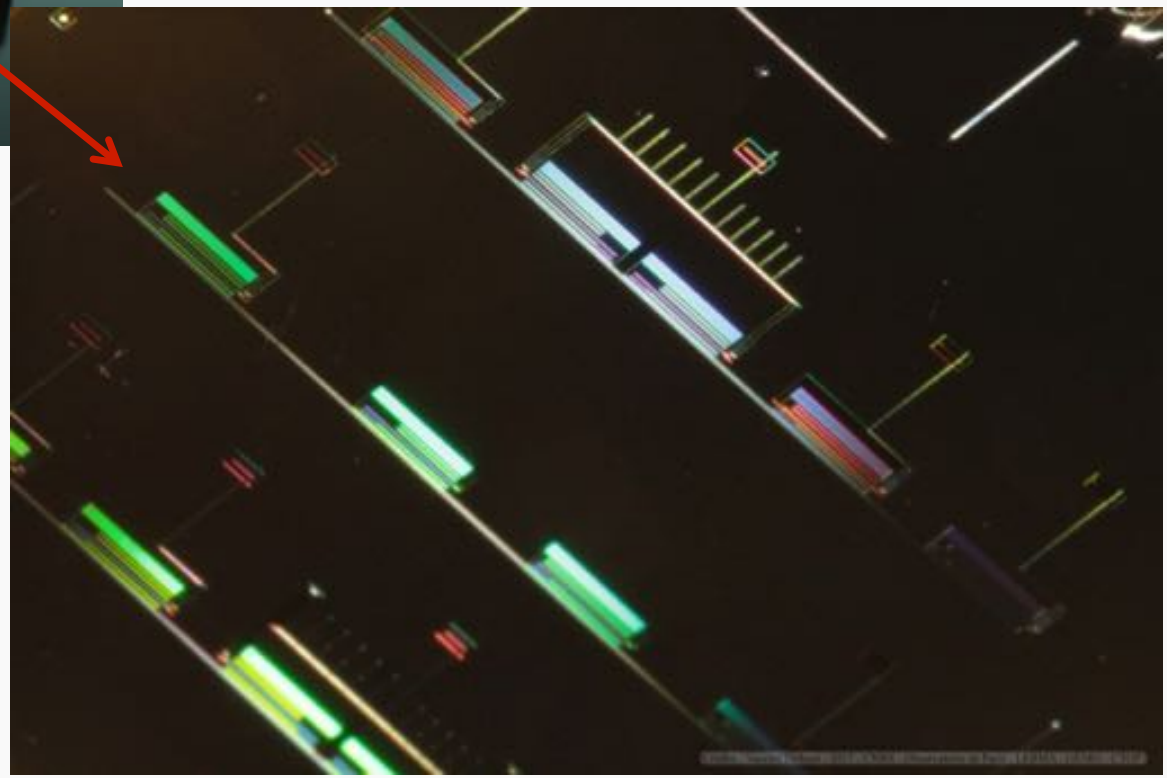
Five chips out of a 3 inch silicon wafer

Each chip contains:

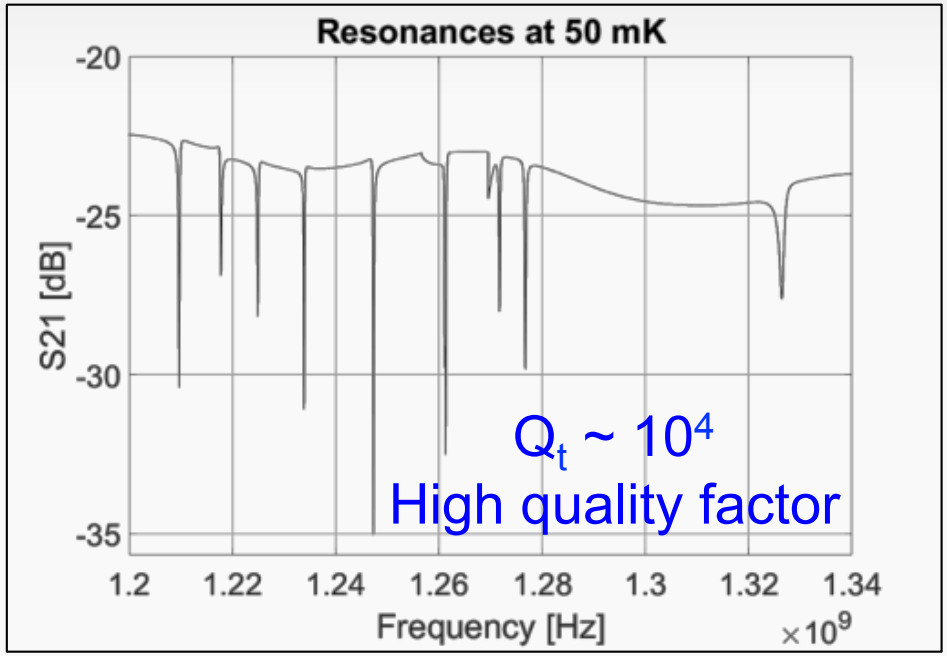
- Two dual-band pixels
- One/Two uncoupled detectors
- Up to nine mono-frequency antenna-coupled LEKID

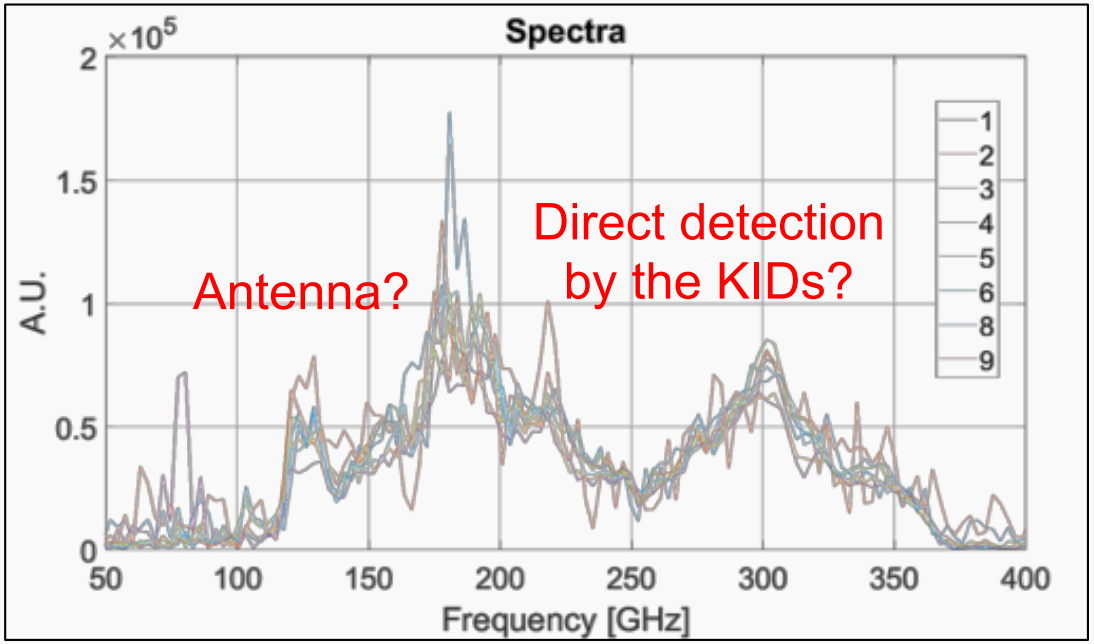
Tests at APC and IN

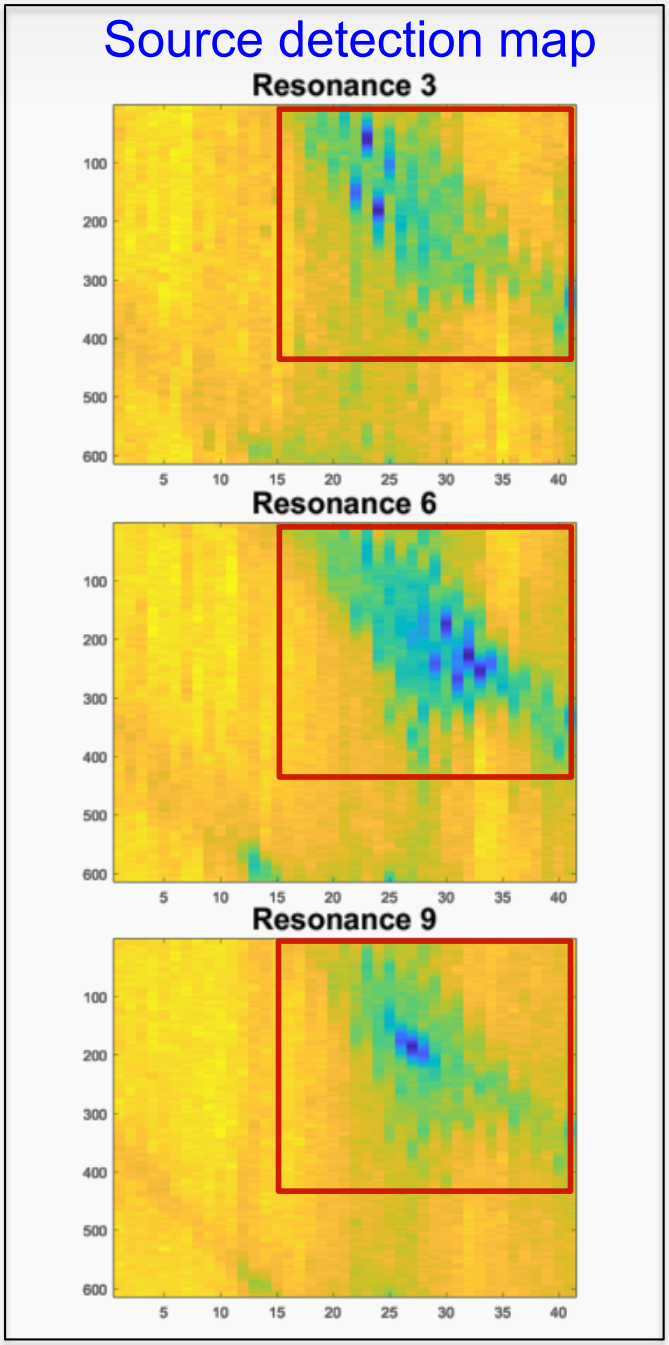




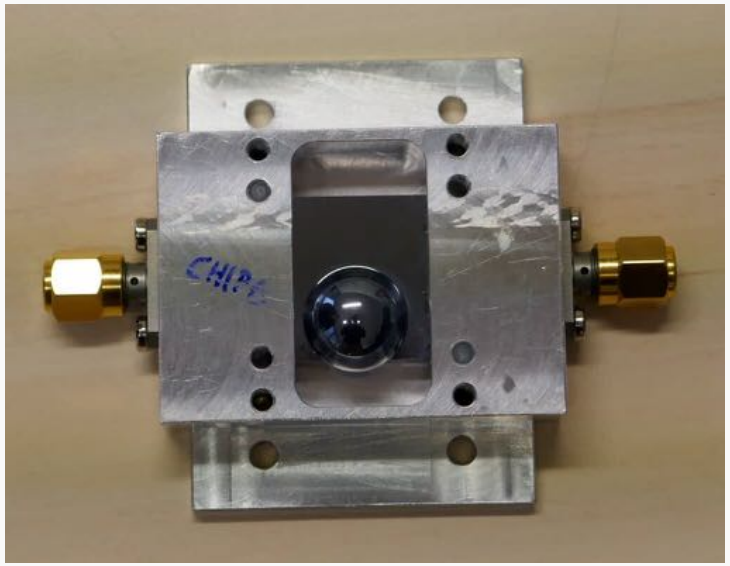
Measurements at Institut NEEL – Second Run – chip 6

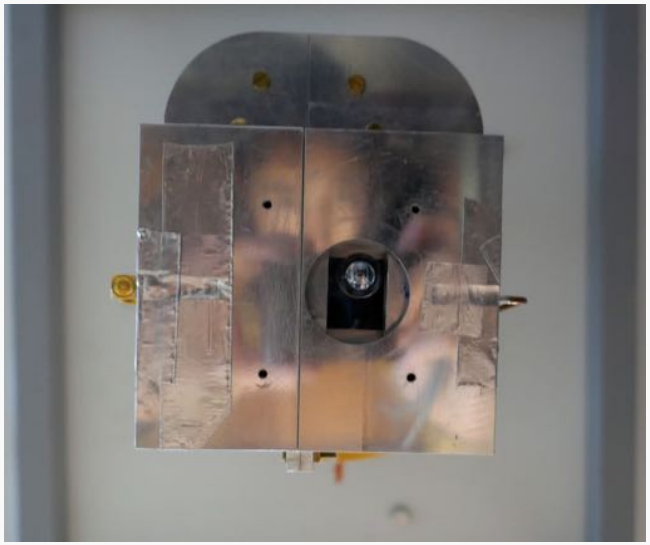




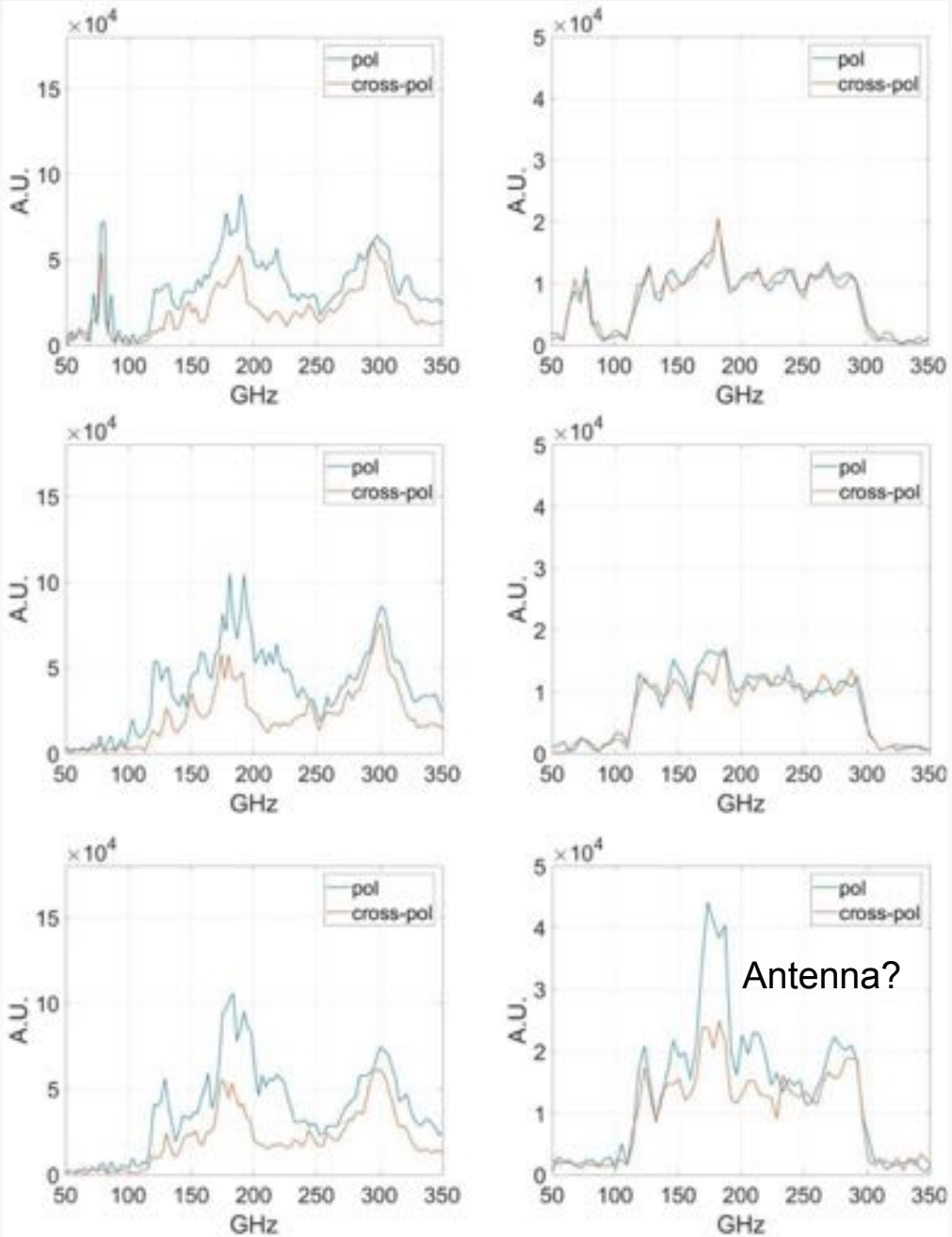


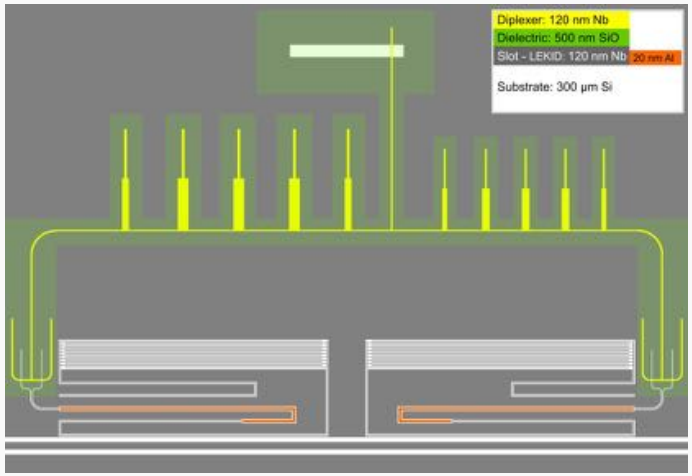
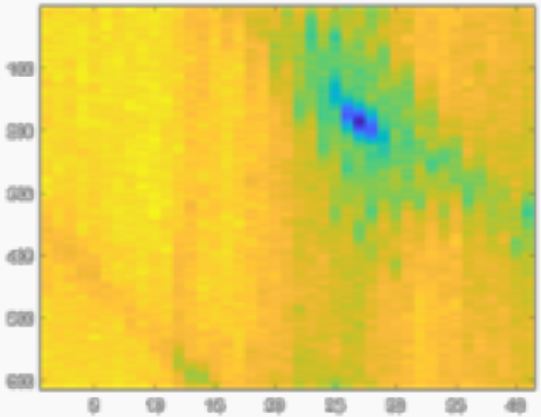
Slot Directivity Improvement: Silicon Lens (from LERMA)





NO lens **With lens**



Conclusions

- Multichroic architecture: R&D *CMB planar detection architecture*
  - Reduction of focal plane area
  - Applied to LEKIDs
    - New promising technology
    - Current design: unclear detection mechanism, low coupling efficiency
  - New samples being produced
    - PhD Alessandro Traini