NIKA2 consortium

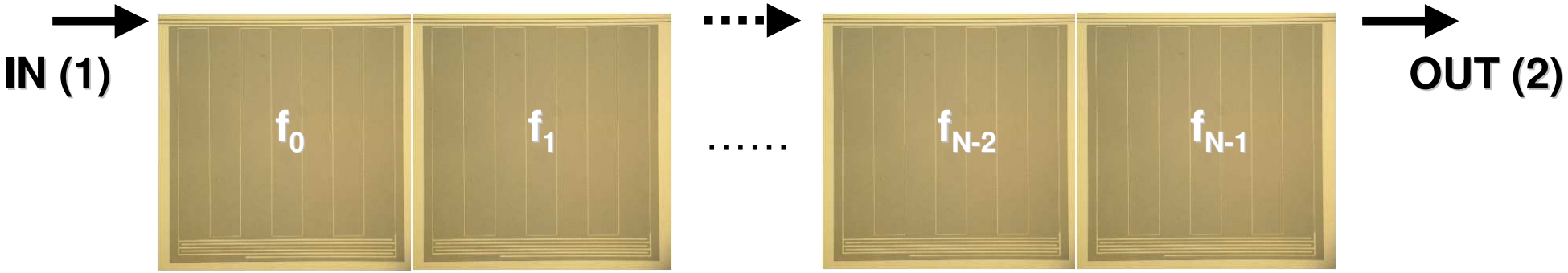
Original idea, cryostat, detectors, RF electronics, FPGA electronics, cold amplifiers, optics, software, interfacing, integration, science, management etc.

Filters, half-wave plate, amplifiers for laboratory test-bench, science

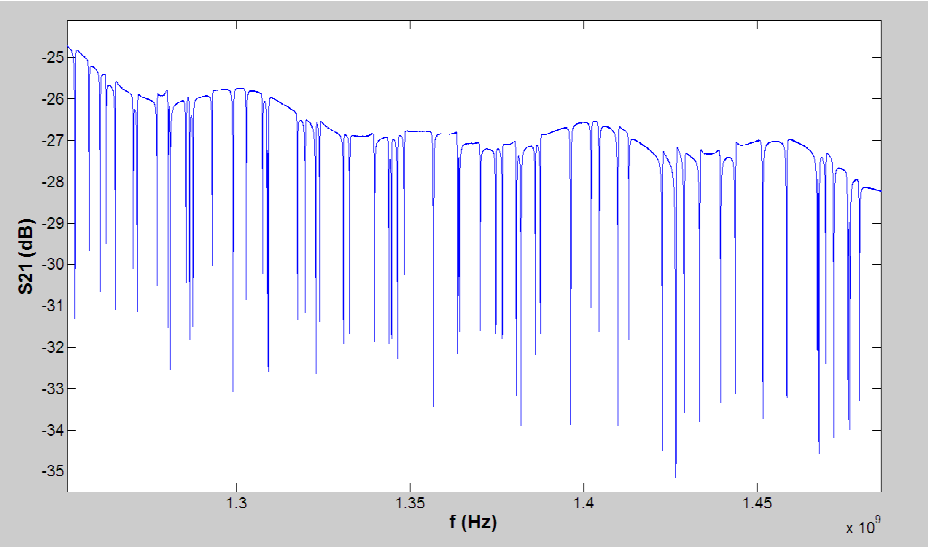
HARDWARE

Science exploitation
(large programs 1300 hours)

Kinetic Inductance Detectors



High-Q (10^4-10^7) superconducting (R ≈ 0) LC resonator :



GHz range !!

$$f_{res} \propto \frac{1}{\sqrt{L \cdot C}}$$

→ Natural f-domain multiplexing
→ High MUX factor (e.g. N > 1,000)

Main limitations:
ADC band/bits, LNA dynamics

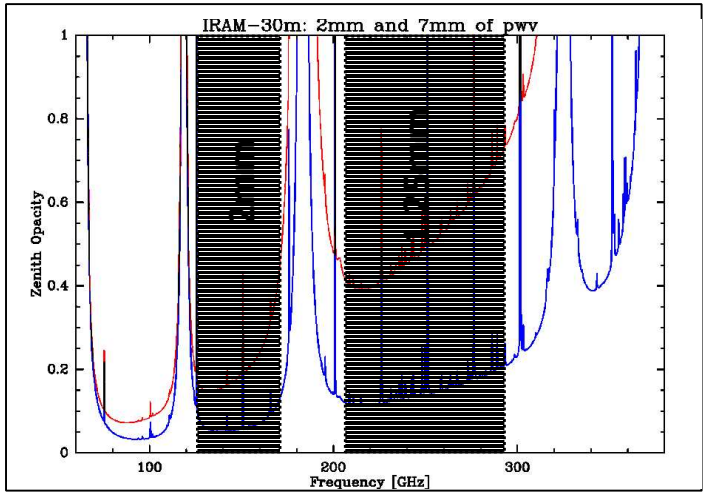
The IRAM 30m telescope

NIKA: New IRAM KID Array

NIKA was, and NIKA2 is the new continuum instrument of the 30m telescope

Sierra Nevada (Spain) @2900m a.s.l.

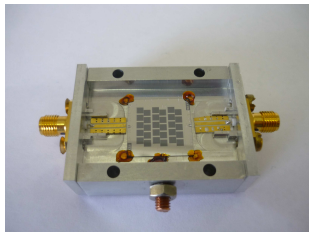
- 30 m aperture
  - 16 arcsec @ 2mm
  - 11 arcsec @ 1.15mm
- Correct Field Of View up to 6.5 arcmin
- Simultaneous dual-band



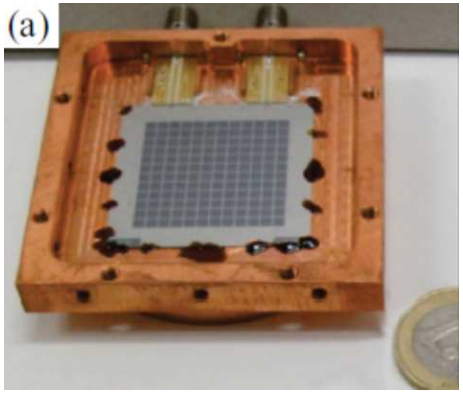
The 30-meters represents a unique tool for mm-wave astronomy!

The LEKID arrays evolution

2009: NIKA0 (30 pix)

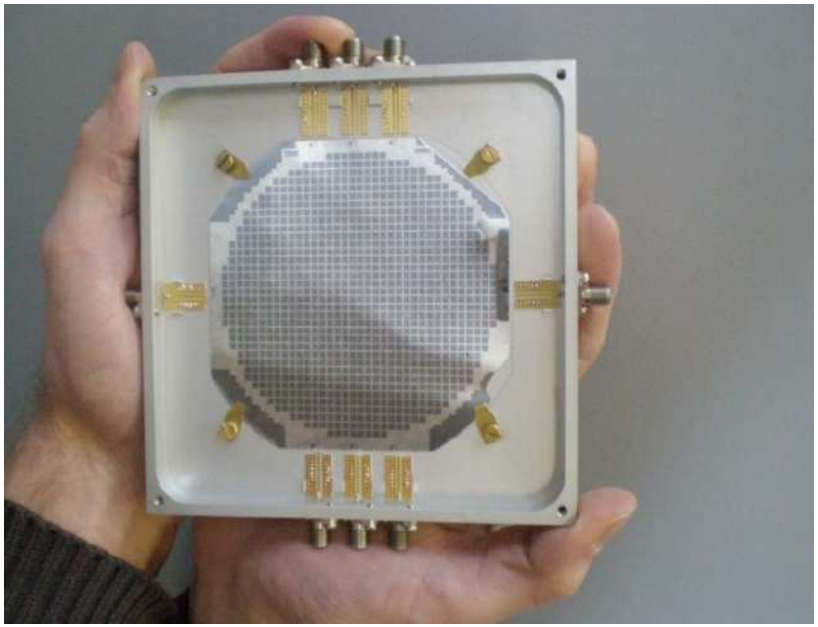


2010-2013: NIKA1 (300 pix)



READY TO SCALE TO 10^4 PIXELS – IF A PROJECT REQUIRES

2014-2016: NIKA2 (3000 pix)



2009:

- 30 pixels, detectors noise limited

First imaging LEKID ever

> 2014:

- kpixels, photon-noise limited
- large area (full 4 inches)
- Readout line 2.5 m long !!

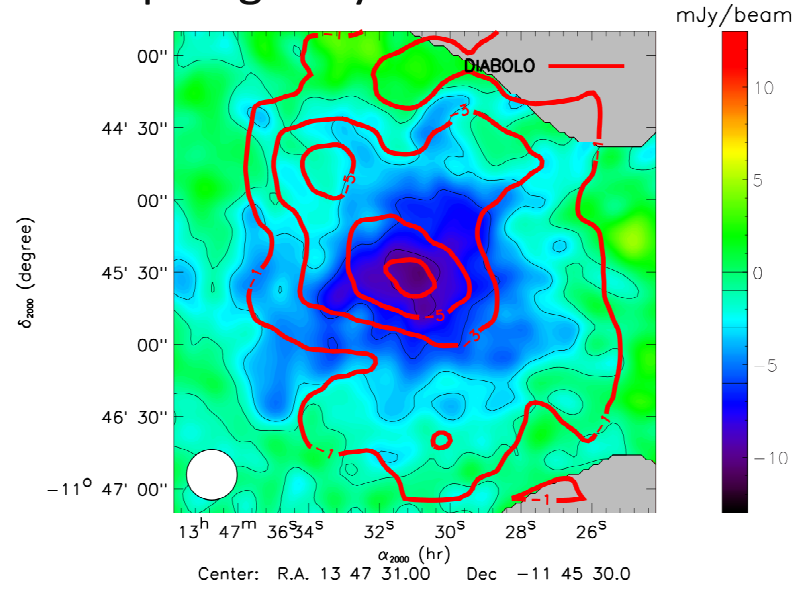
The NIKA camera (< 2015) “first times“

A good number of “first times”:

- First full-mux KID camera on the sky (2009), i.e. the reason to make KID
- First demonstration of imaging capabilities of LEKID (2009)
- First demonstration of the on-sky sensitivity, e.g. wrt GISMO → KID = TES
- First KID camera opened to the large astronomical community

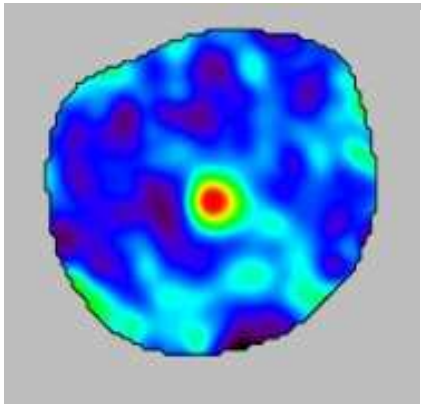
→ a number of Science results

tSZ map of galaxy cluster RX J1347.5-1145

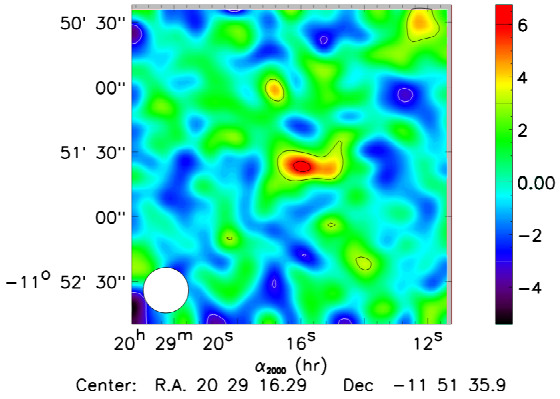


R. Adam et al., ***A&A***, 569 (2014) A66

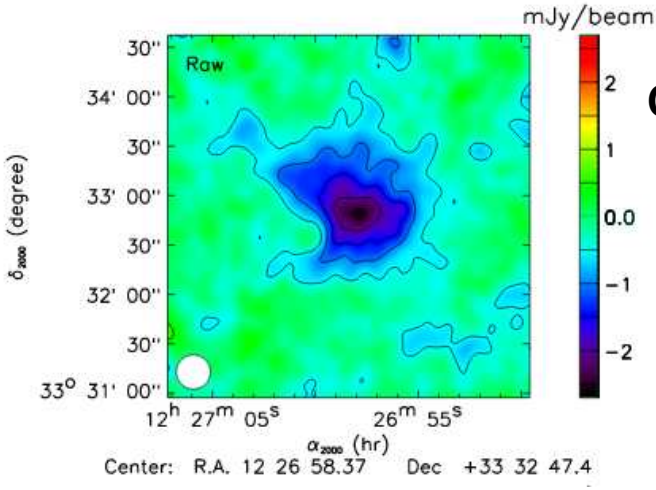
Some selected NIKA images



Pluto at 150GHz

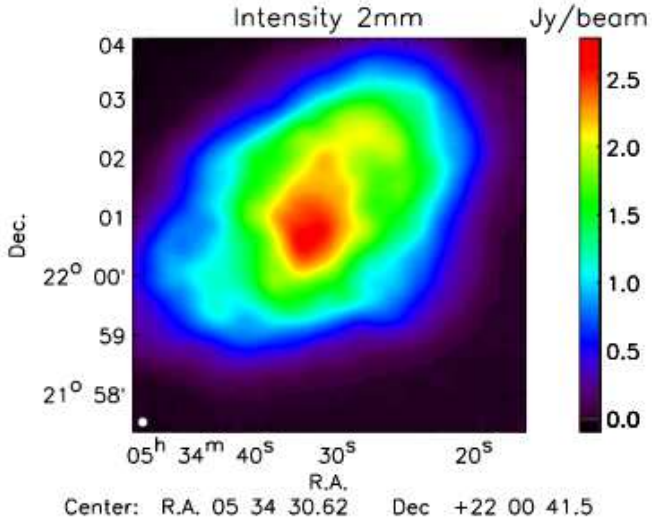


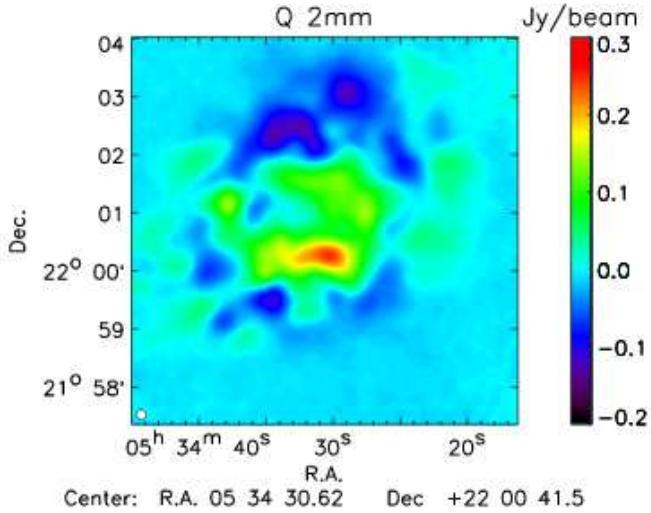
GRB121123A

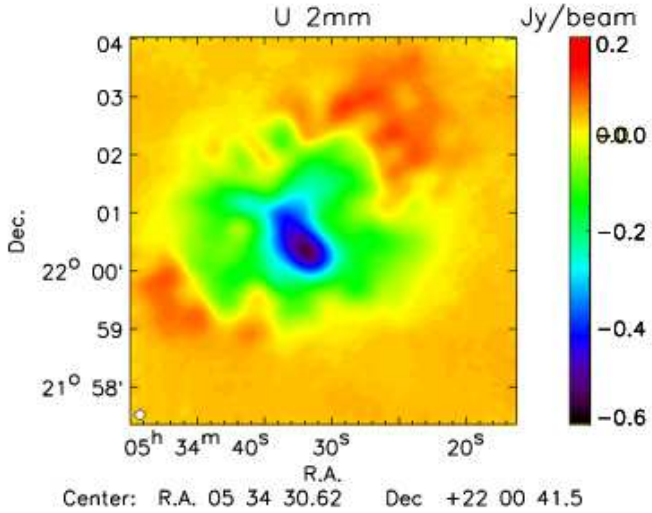


CL J1226.9+3332
(z = 0.89)

Adam et al., A&A 576, A12 (2015)







The Crab nebula – Intensity and polarisation (A. Ritacco et al., arXiv:1508.00747)

The first map of kSZ

R. Adam, I. Bartalucci, G.W. Pratt et al.: kSZ mapping toward MACS J0717.5+3745

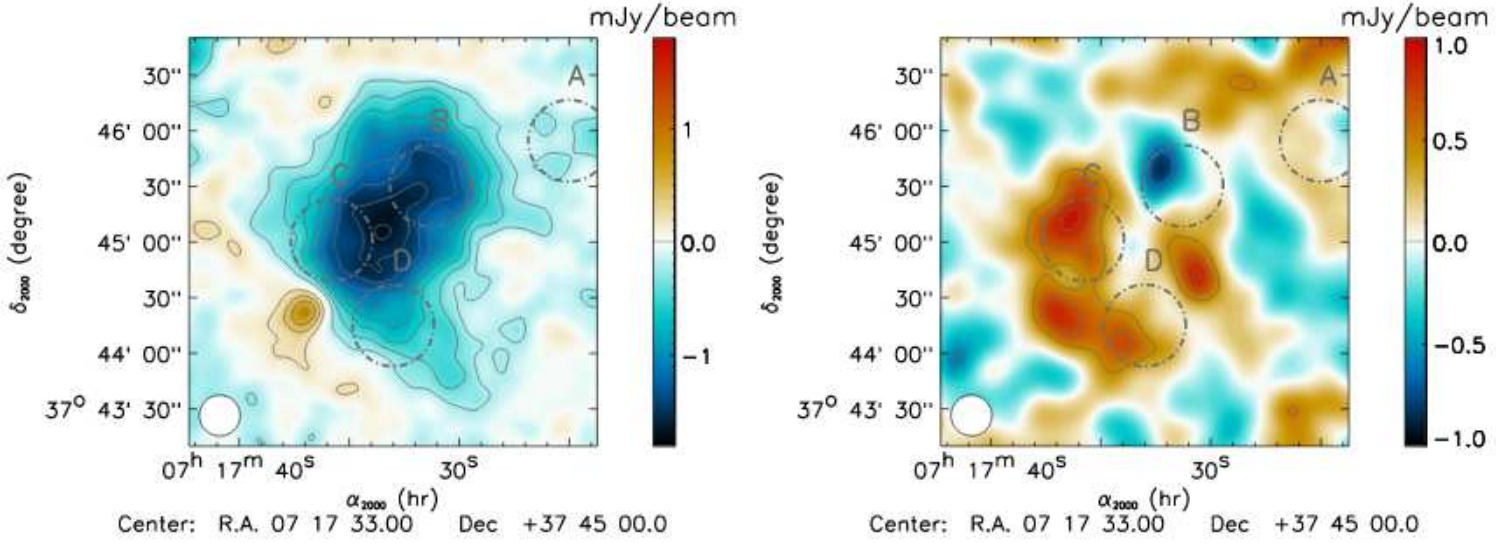


Figure 1. NIKA maps of MACS J0717.5+3745 at 150 GHz (left) and 260 GHz (right). The gray contours show the significance in units of standard deviation. They are multiples of 2σ at 150 GHz and 1σ at 260 GHz, starting at $\pm 2\sigma$. Both maps have been smoothed to have the same effective resolution of 22 arcsec FWHM, as represented by the white circle on the bottom left corner of the maps. The regions defined in Table 2

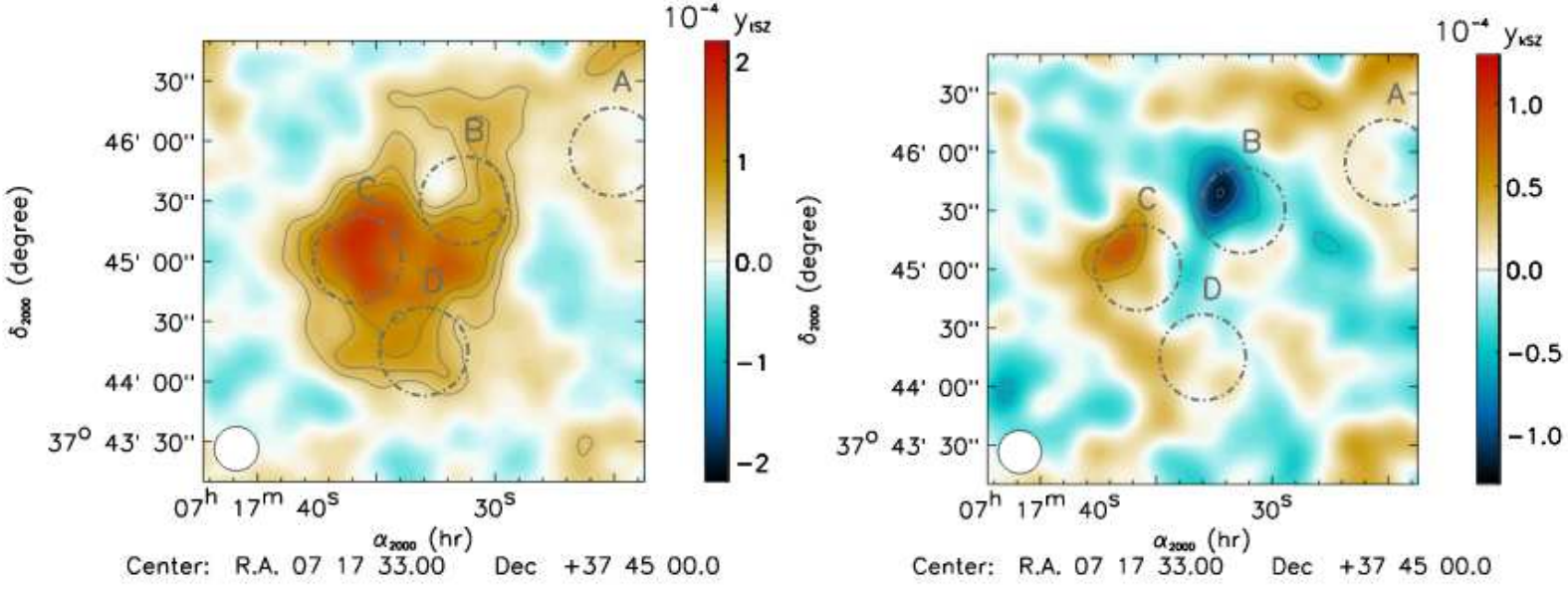
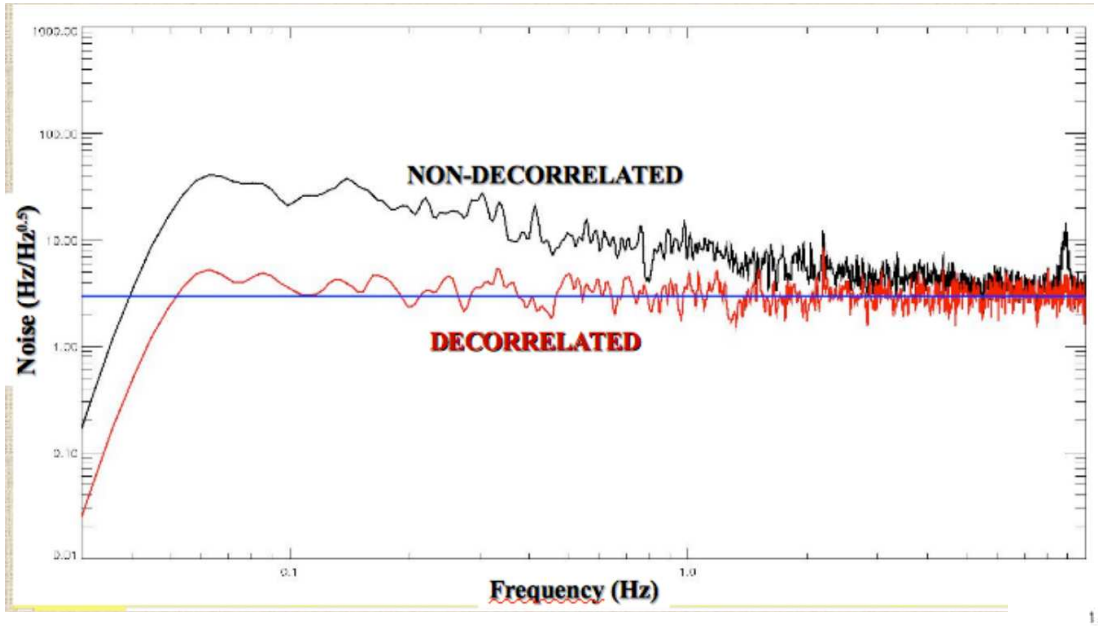


Figure 5. Map of the thermal SZ effect, y_{tSZ} (left), and the kinetic SZ effect, y_{kSZ} (right). Gray contours are multiples of 1σ, starting at $\pm 2\sigma$. The map effective resolution, 22 arcsec, is shown as a white circle on the bottom left corner. Subcluster regions are also represented in gray.

Keys results: decorrelation and photometry

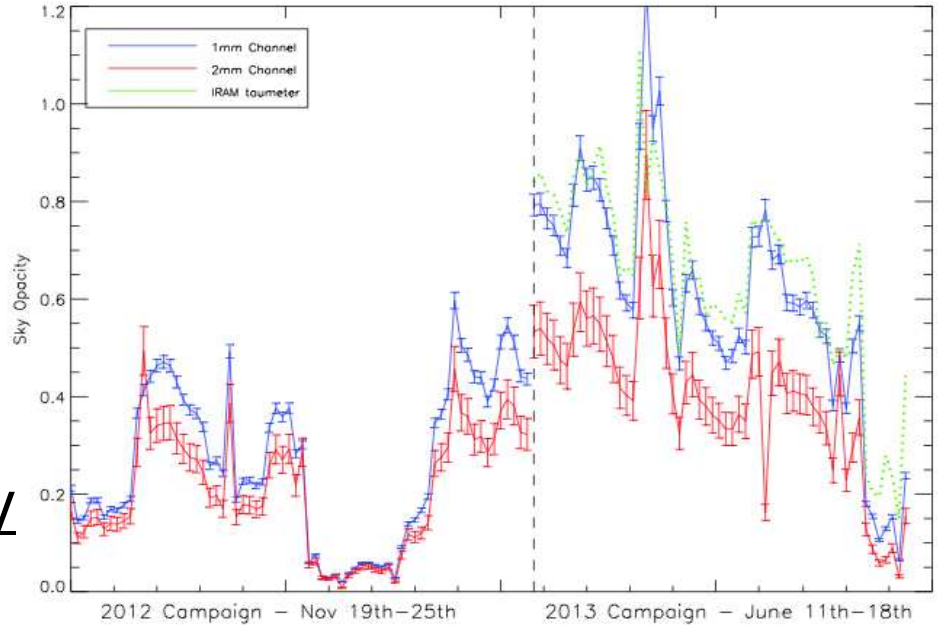


The raw 1/f noise
is mostly correlated

Each pixel is at the same time a very sensitive probe and a real-time taumeter:

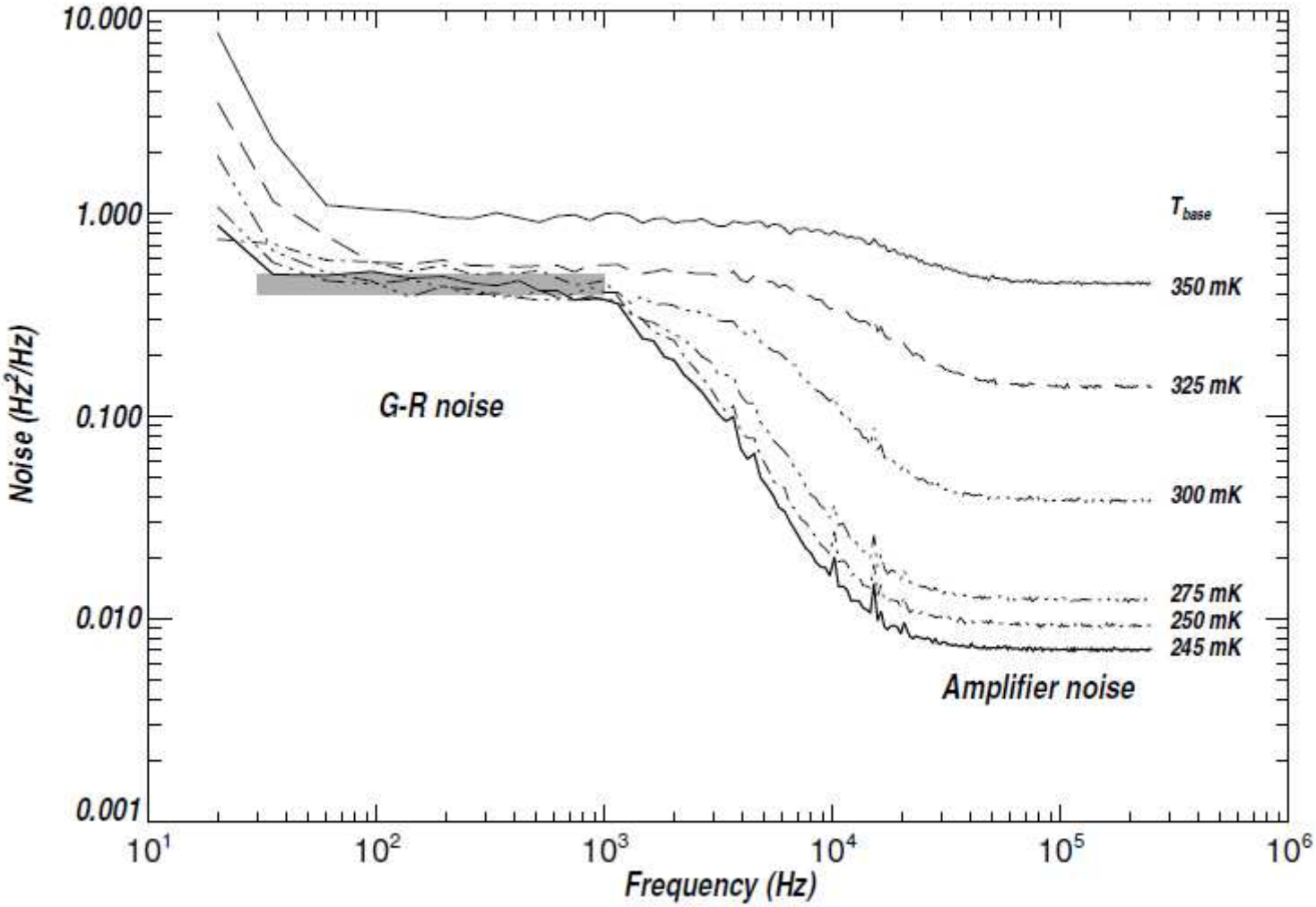
$$f_{resonance} \propto Power \propto T^{RJ}_{atm}$$

Sensitivity + Dynamics + Photometry



Fundamental noise in NIKA detectors

Mauskopf et al., LTD15 Proceedings



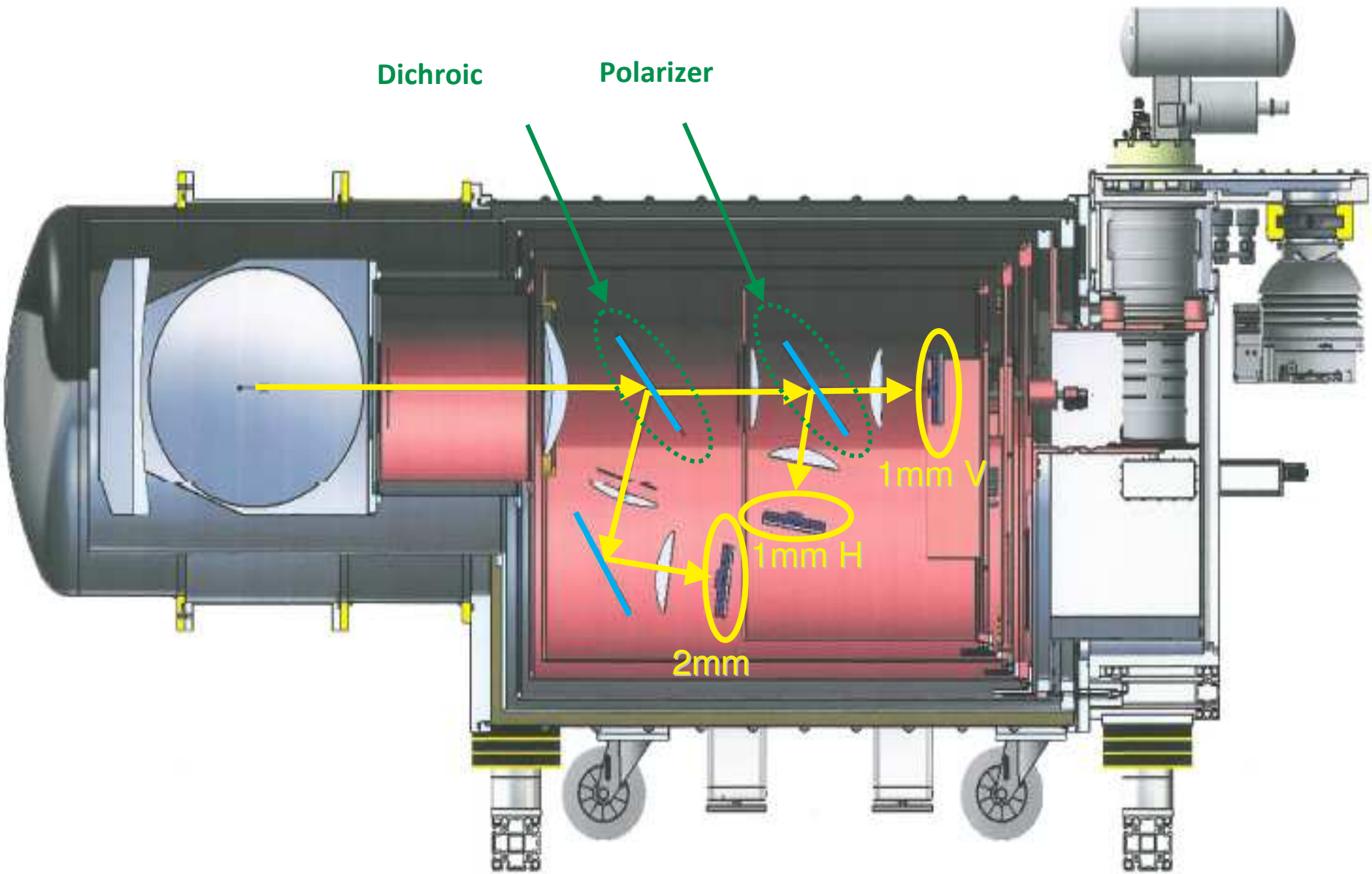
From NIKA to NIKA2

NIKA2 designed to get the most out of the IRAM 30m telescope:

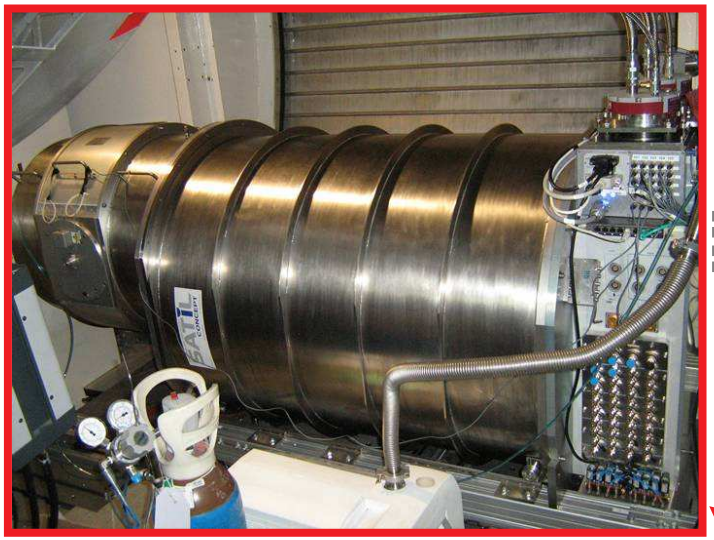
- Correct FOV: 2 arcmin → ***6.5 arcmin***
- Total pixel count: ≈ 300 → ***≈3000***
- Arrays count: 2 (2mm + 1.25mm) → ***3 (2mm + 2 x 1.25mm)***

A major impact on all components at all levels! (NIKA *and* telescope)

The cryostat



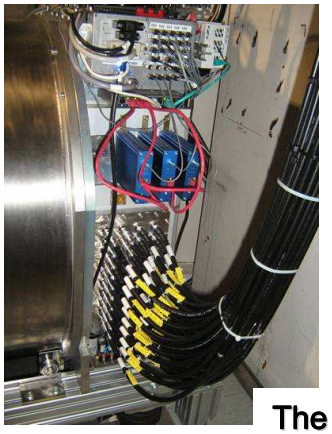
NIKA2 at the 30-meters



The cryostat in the receivers cabin

60 meters of pipes

The dilution gas handling in the basement

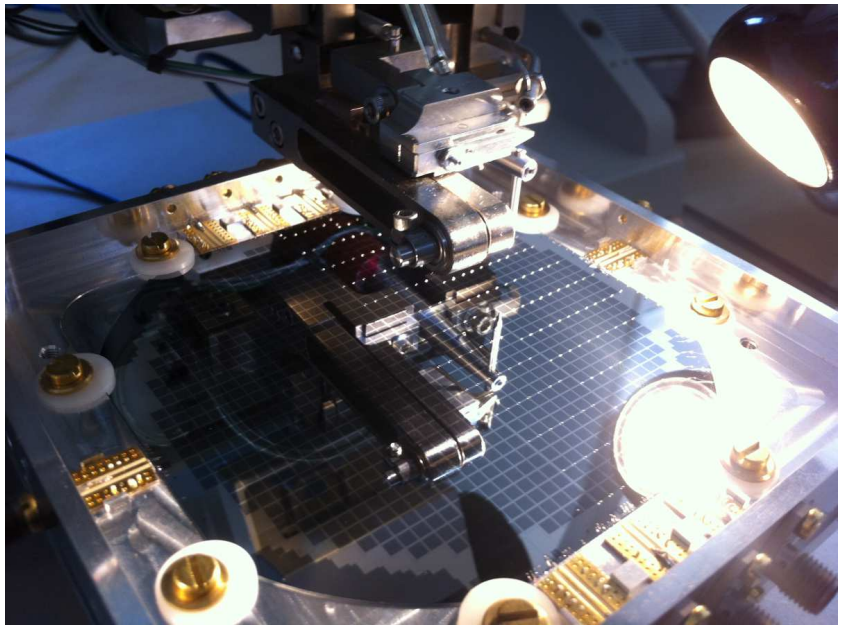


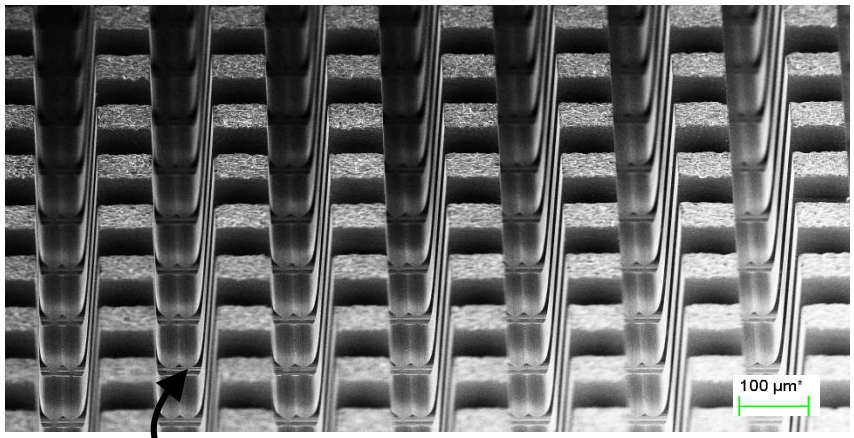
The 40 COAX cables

NIKA2 figures:

- 3300 pixels over 3 arrays
- 1.2 tons; 2.5 m long; 3000 pieces
- Two Pulse Tubes
- Fully remote control
- Completely cryogen free
- Base T ≈ 100 mK
- Standard operating T = 160 mK

NIKA2 arrays





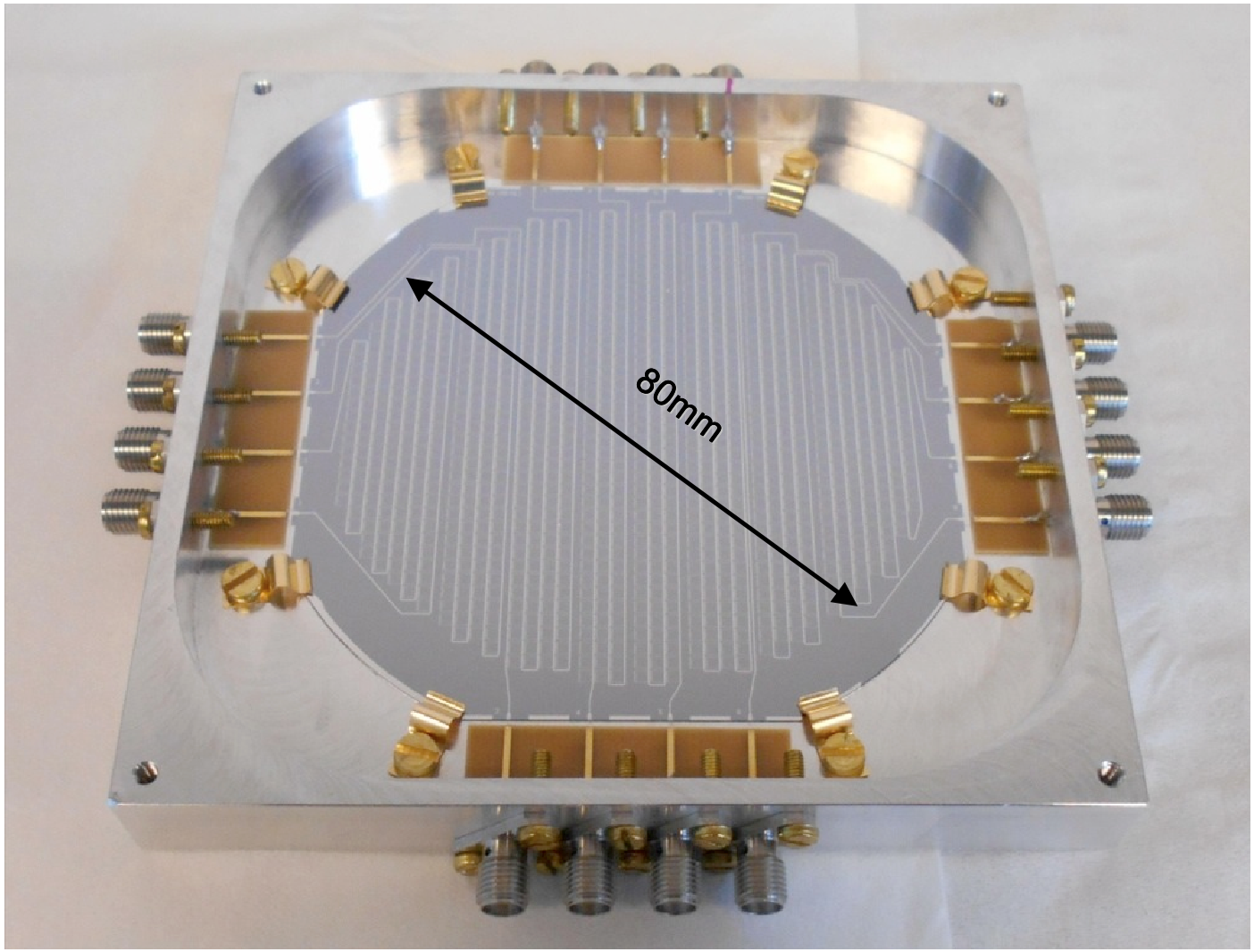
Dicing for AR layer

- Pixels similar to NIKA1 (Hilbert LEKID)
- Films: thin Al (18÷25 nm)
- Different arrays tested:

Small pixels (0.7Fλ)	↔	Large pixels (1Fλ)
No AR layer	↔	AR layer (dicing, etching)
CPW feedline	↔	MS feedline

- **2mm**: 3 very good arrays
- **1.25mm**: 3 good arrays (cosmetics..)

NIKA2 microstrip array (260 GHz)



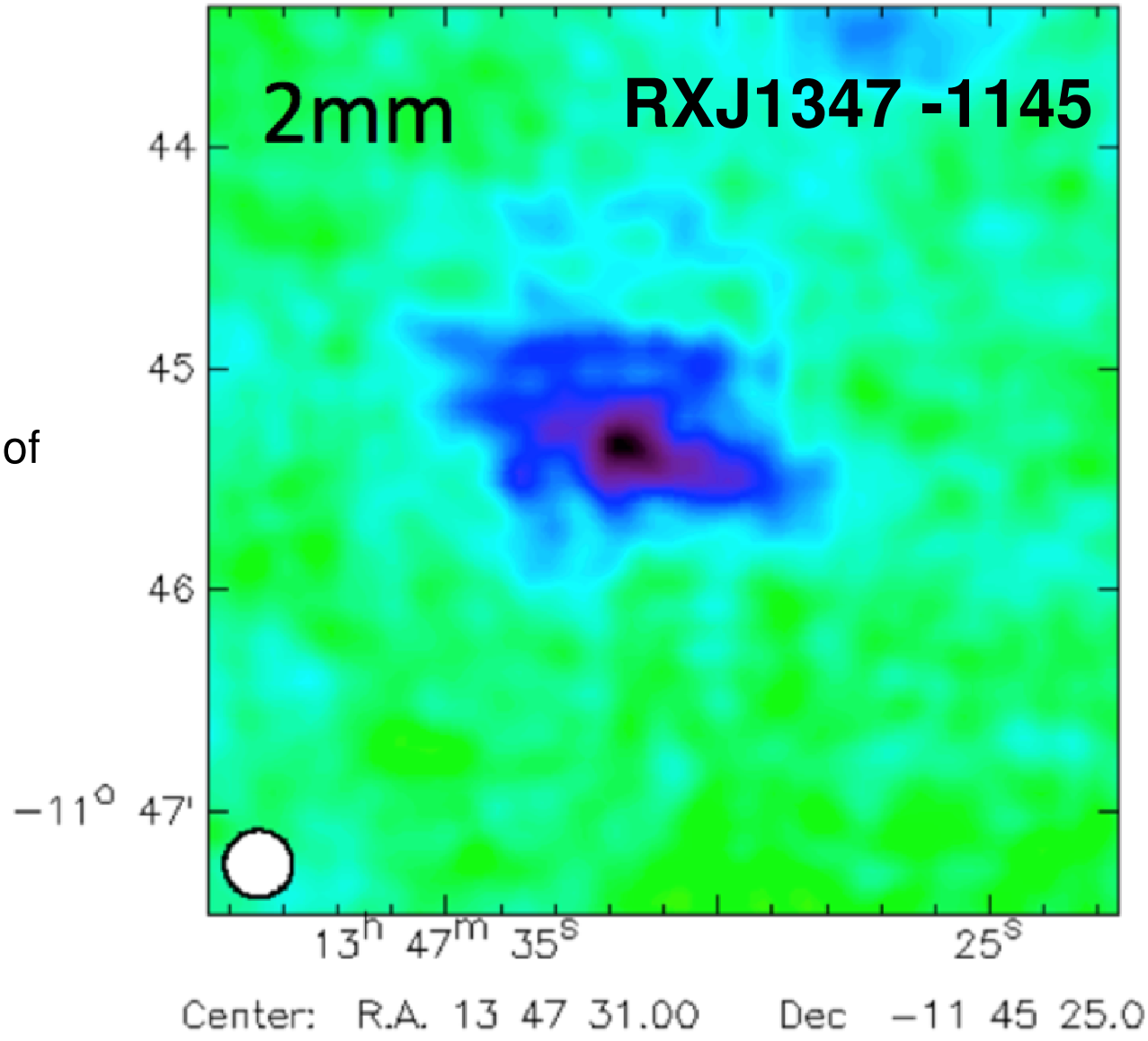
NIKA2 timeline

09/2012	Project funding and kick-off. First drawings
04/2013	CDR at Néel Institute
08/2013	Launched cryostat fabrication
02-06/2014	NIKA2 assembly ('empty' cryostat)
01-02/2015	Integration of optics and electronics
02-06/2015	Detectors optical characterization and validation of full system
End 2015	Planned installation at IRAM
Fall 2015	Actual installation at IRAM!

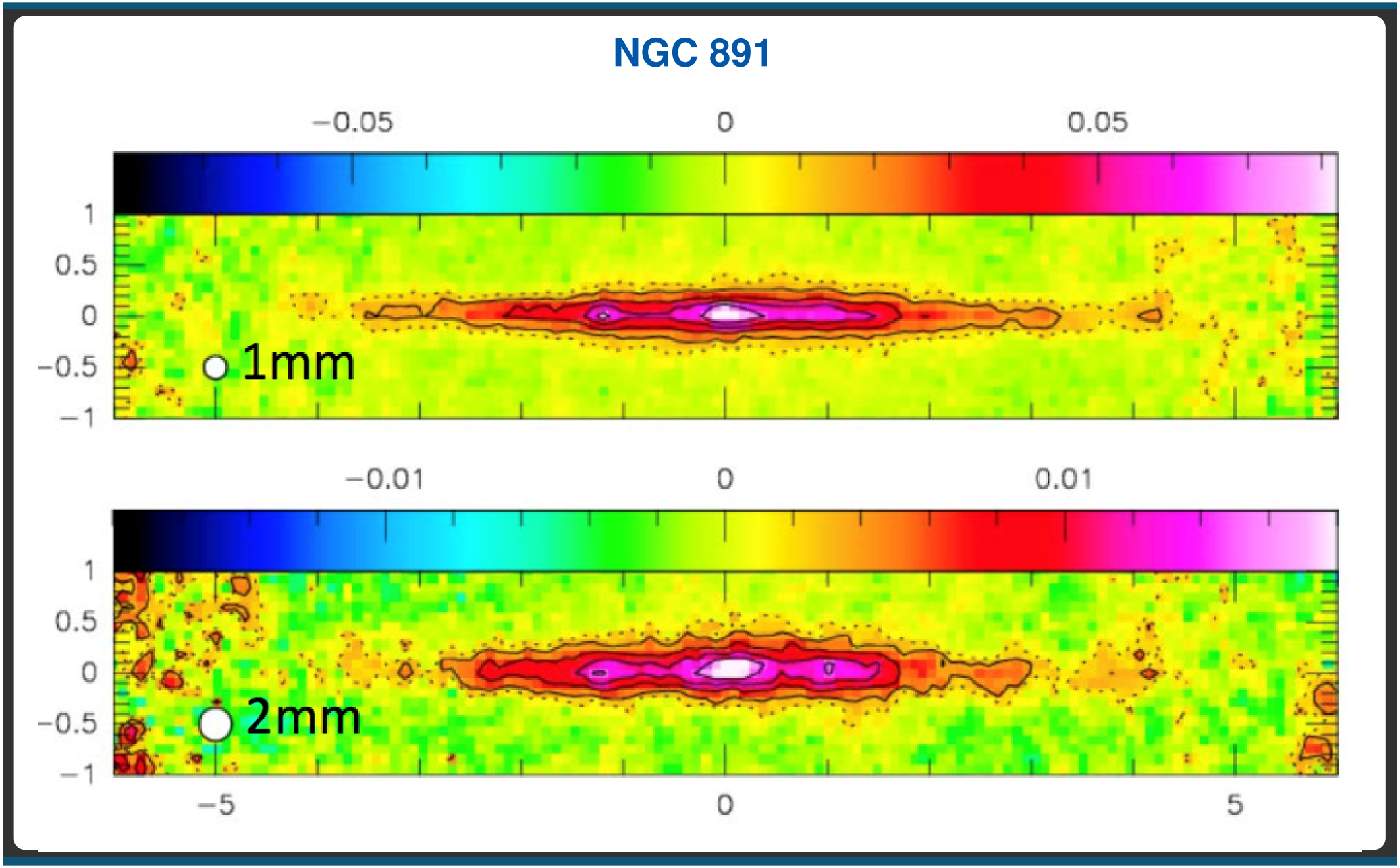
Instrument concept → *instrument installation* = ***3 years***

Some fun during commissioning

- Already observed by NIKA
- Technical time observation of January 2016
- Integration time ≈ 1 hour



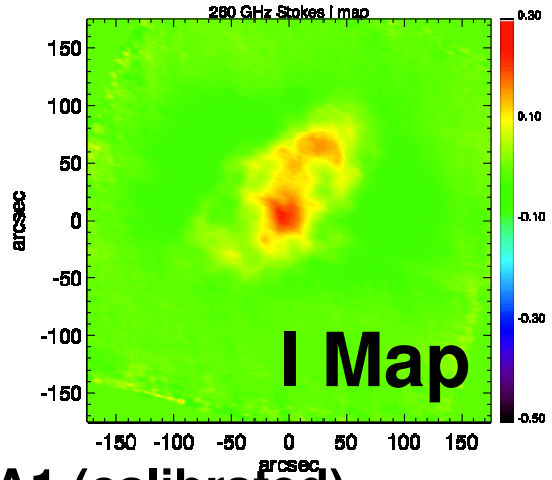
More fun during commissioning

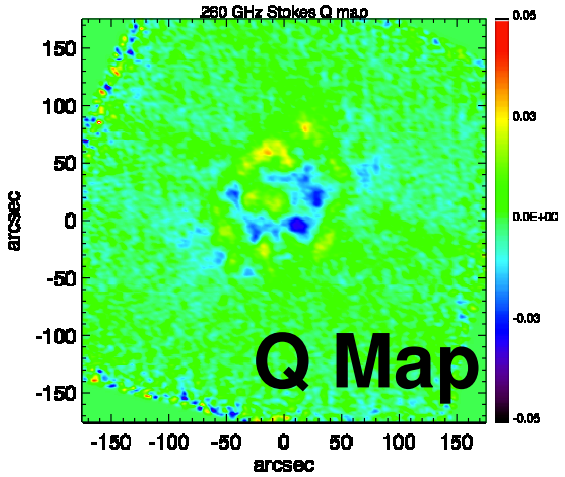


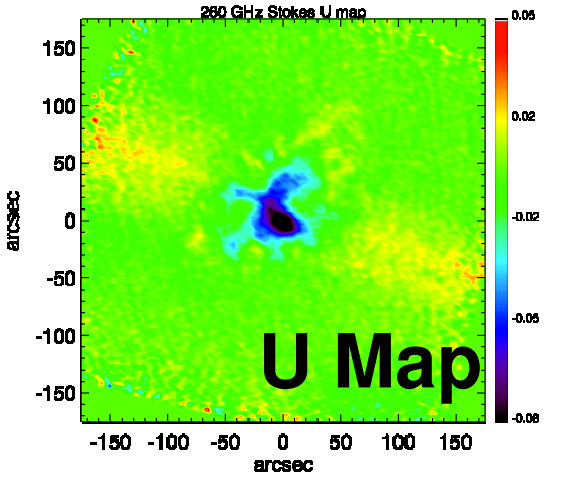
Polarized fun

First Polarisation Light on Crab Nebula

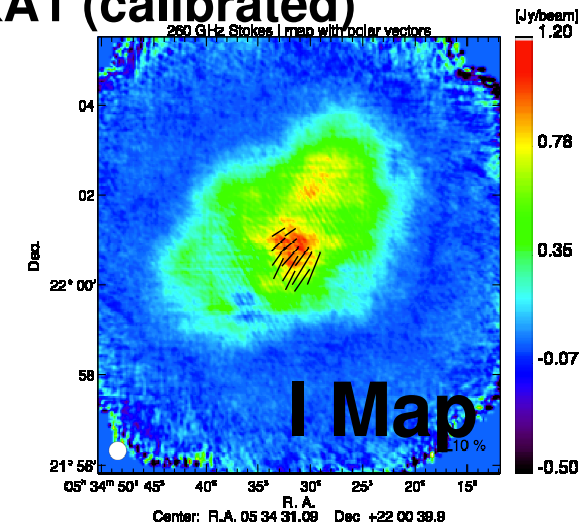
NIKA2 (not calibrated)

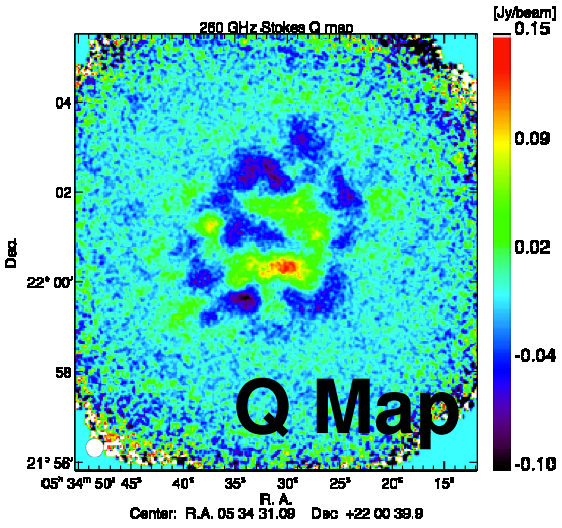


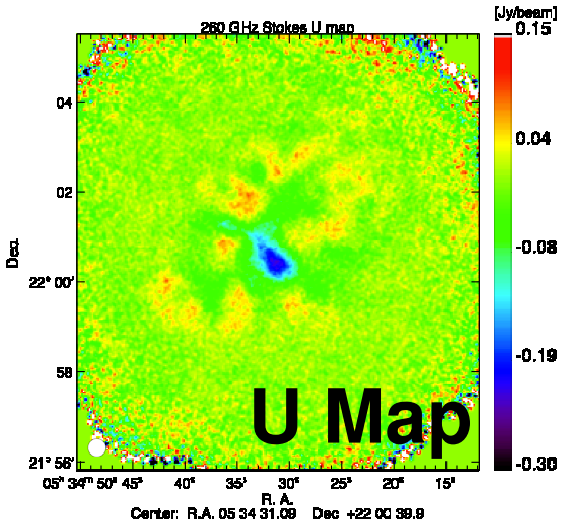




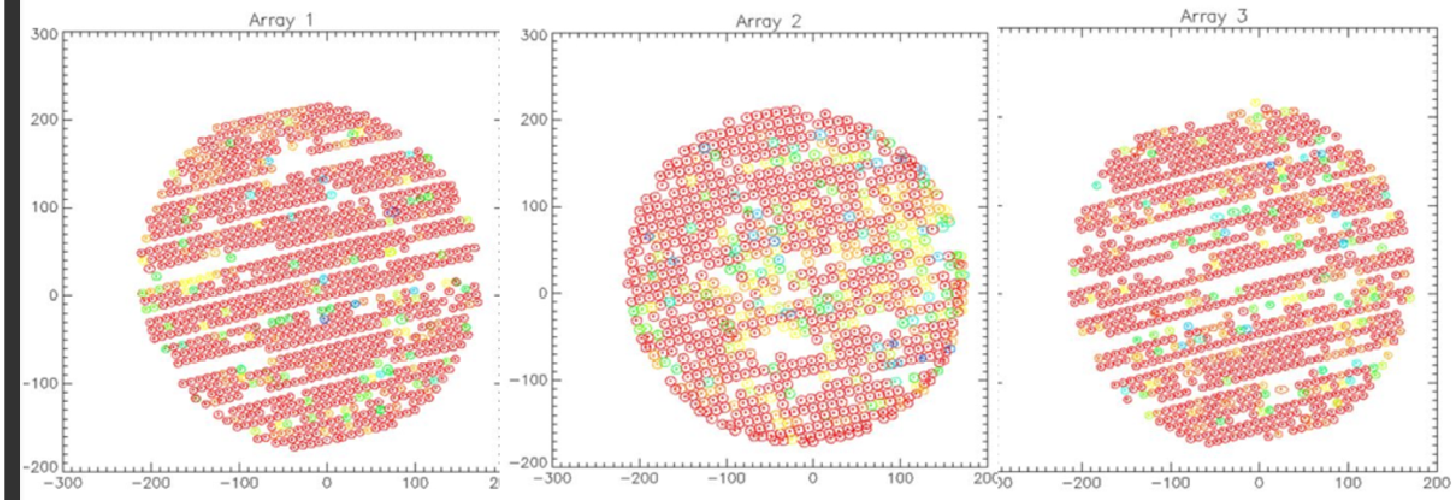
NIKA1 (calibrated)







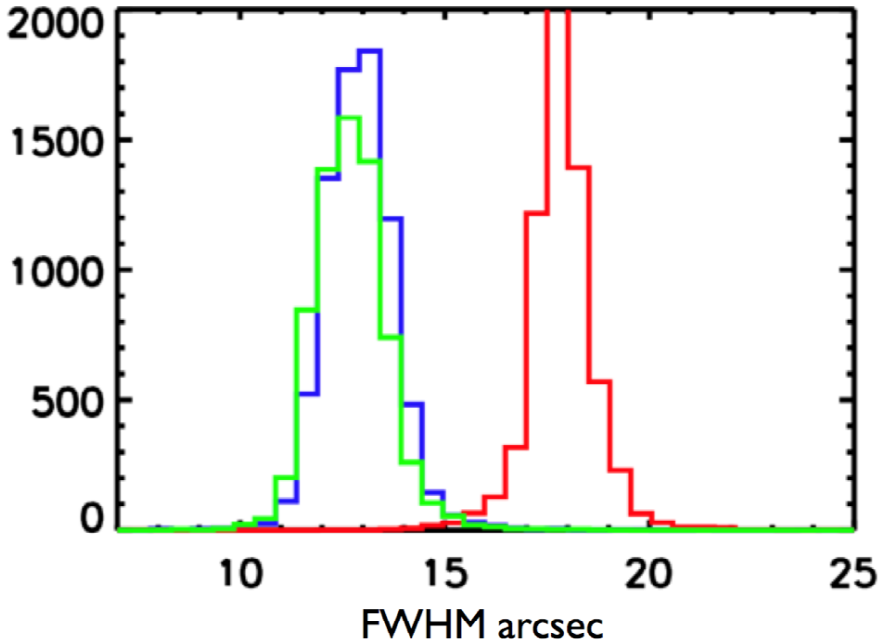
Less amusing: the real commissioning

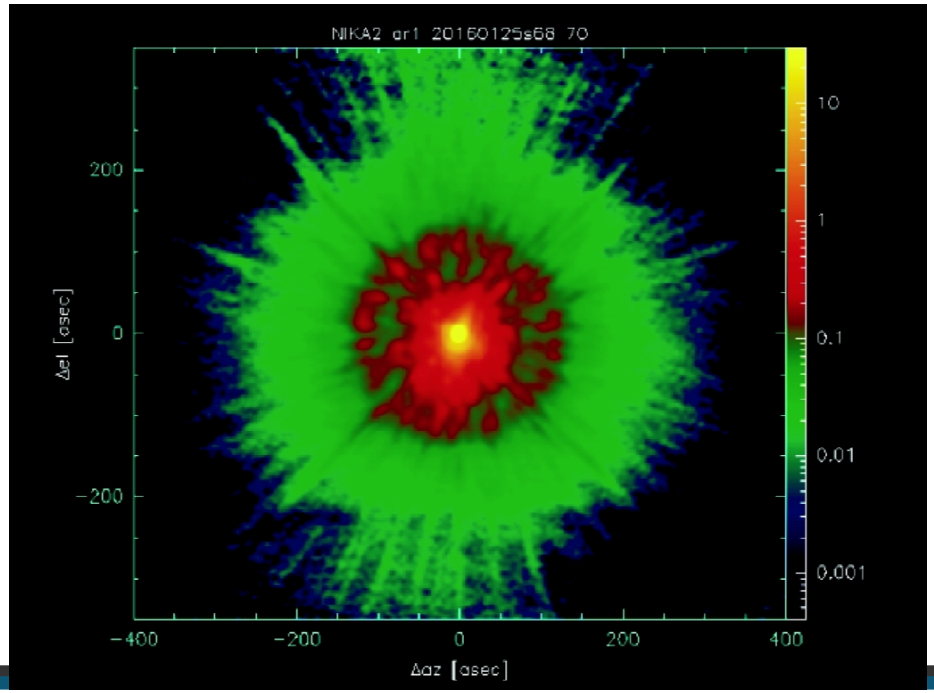


A lot of hard work for the data analysis group

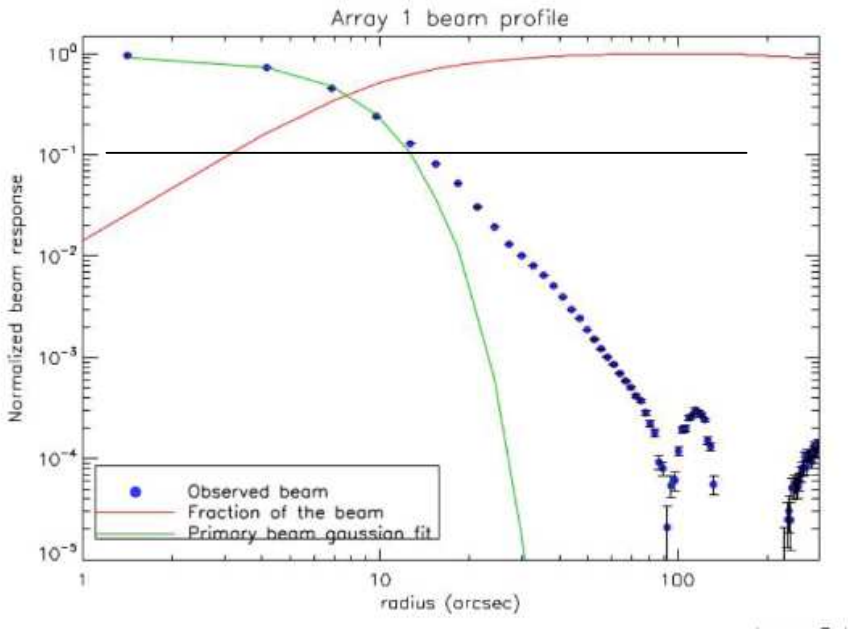
ONGOING

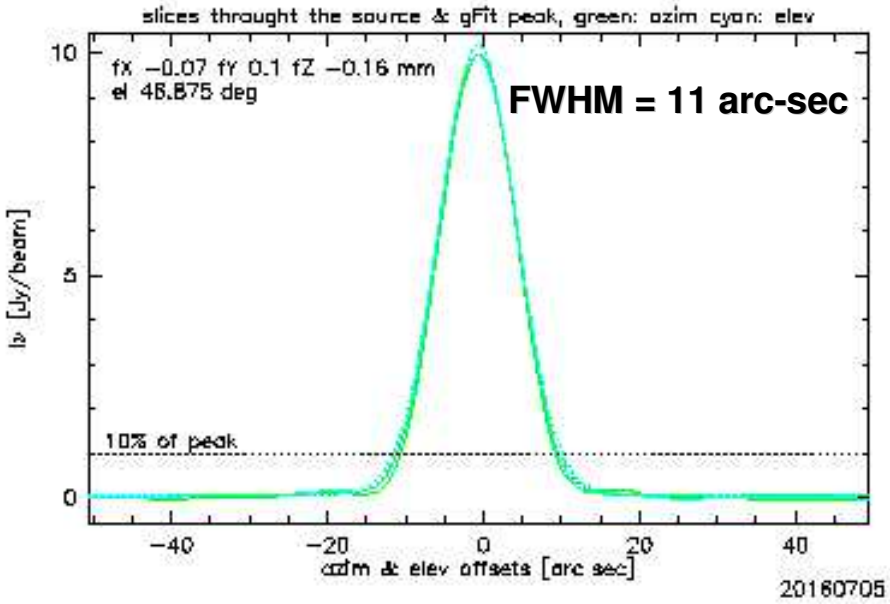
Highest-contrast map ever made at the 30-meters





First open observations: coming winter





Despite many things remain to be characterised and understood …

Very preliminary NEFD!

260 GHz: 15-30 mJys$^{1/2}$

150 GHz: 10-20 mJys$^{1/2}$

FIRST NIKA2 call !!

The 30-meter Telescope

Proposals for three instruments will be considered for the coming semester (1 December 2016 to 31 May 2017):

1. the EMIR receiver offering four bands at 3, 2, 1.3, and 0.9 mm wavelengths in both polarisations, and
2. the 9 pixel dual–polarization heterodyne receiver array, HERA, operating at 1.3 mm wavelength.
3. In addition, a limited amount of time will be available with the NIKA2 camera.

NIKA2 experience for e.g. CORE+

- NIKA, and now NIKA2, are the first/only instruments employing KID and **operating at CMB frequencies**

- The on-sky sensitivity has reached the state-of-the-art (e.g. TES) in the **band 120-300 GHz**. A number of other advantages, e.g. photometry

- The NEP is scaling down according to the background down to Planck bolometers levels (A. Catalano et al., A&A 2015)

- We have demonstrated in the lab that the **band 60-120 GHz** can be addressed using multi-layers (e.g. Ti-Al, Ai-Al-Au, Al-Ag etc.)

- The quantum efficiency, for $\Delta\nu/\nu \approx 30\%$, can really approach 100%

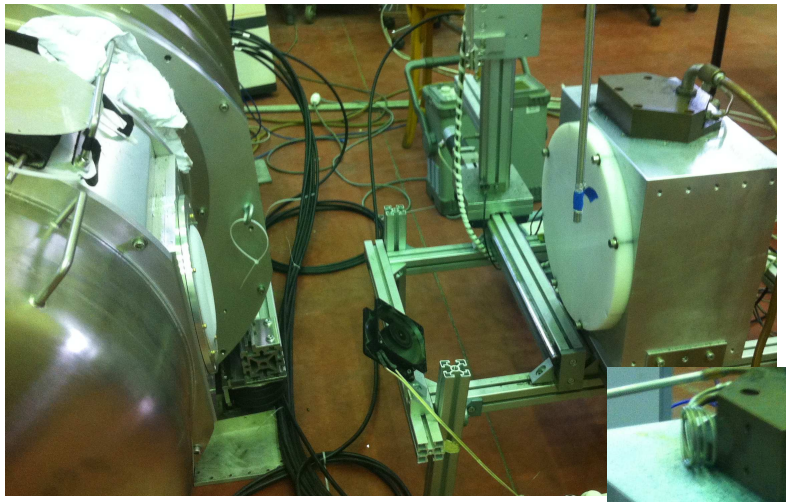
→ **Further optimised NIKA-like detectors might already cover 90% (tbc) of the proposed CORE+ focal plane (60-300 G**

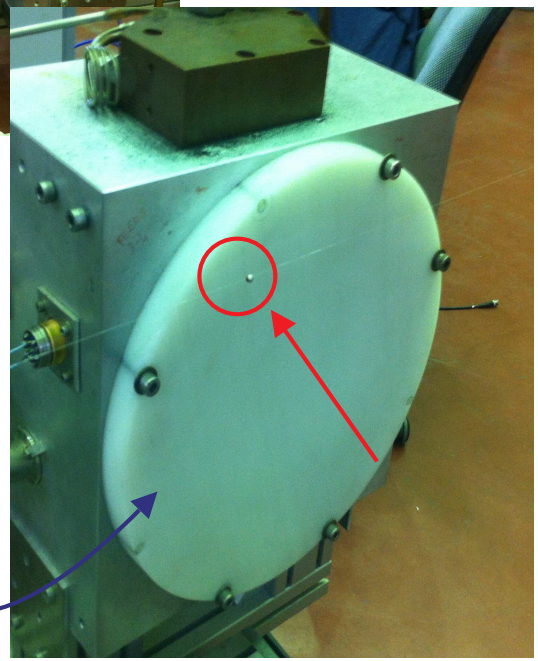
→ The bands 300-600 GHz can also be covered by LEKID (e.g. demonstrated during the planB R&D in 2015-2016)

THE END

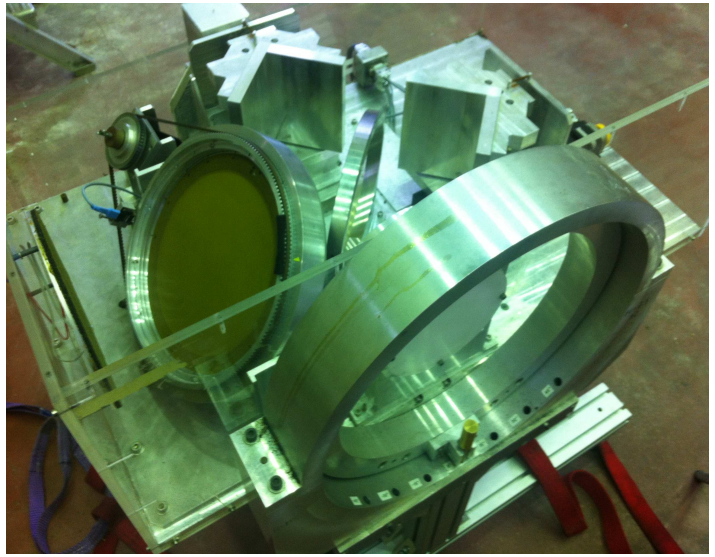
Lab characterization testbench

- Sky simulator
  - beam maps/responsivity



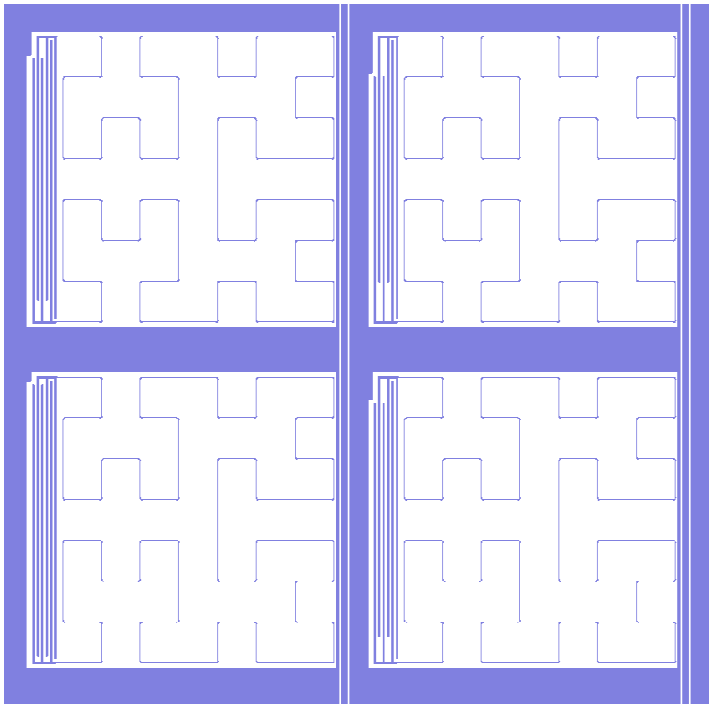


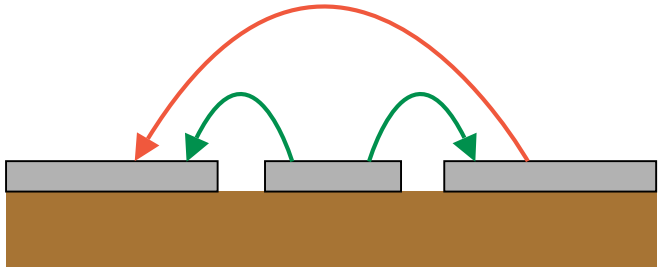
- Martin-Pupplet interferometer
  - absorption spectra



Feedline choice

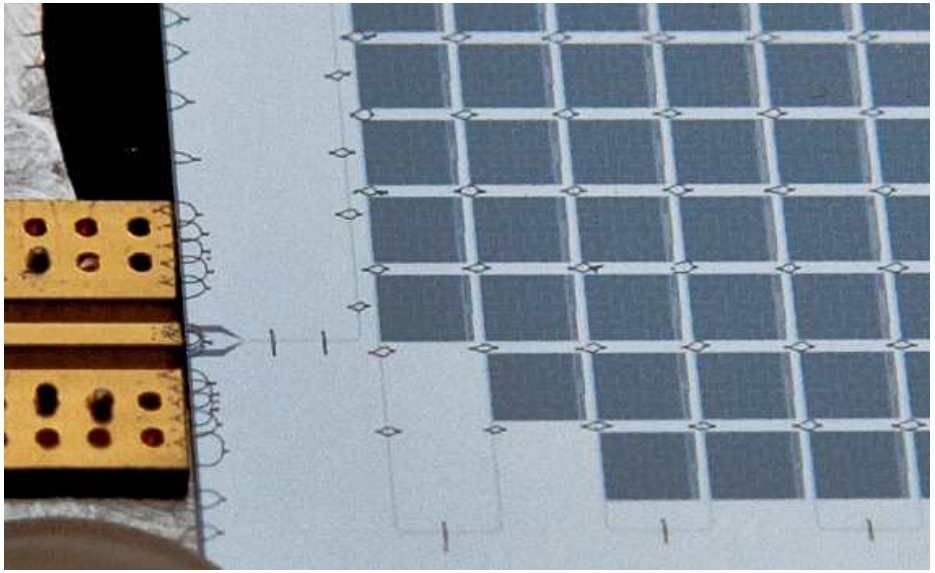
- CPW:





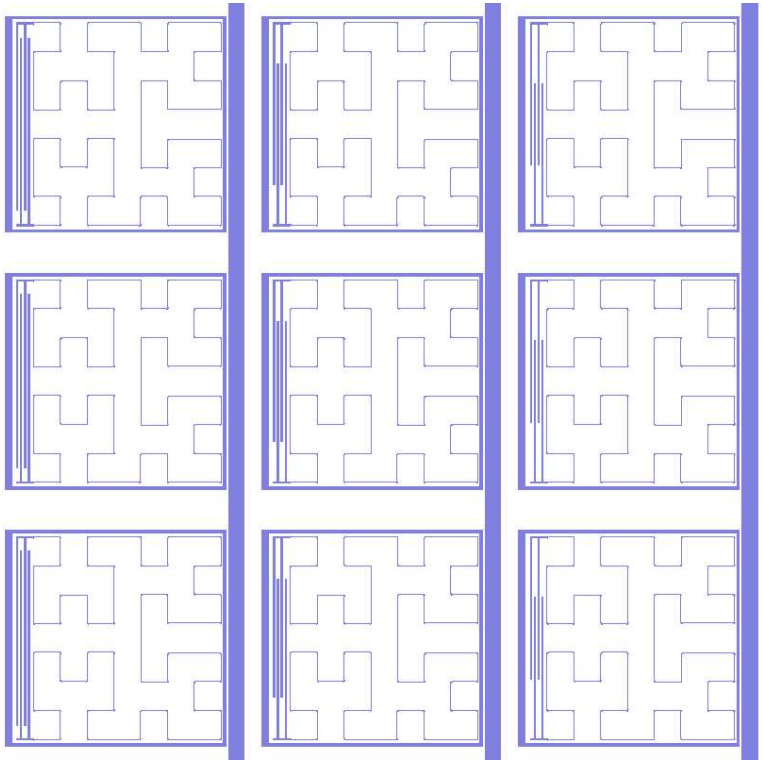
CPW mode

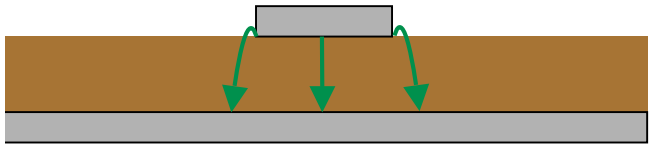
Slotline mode



Feedline choice

- Microstrip :

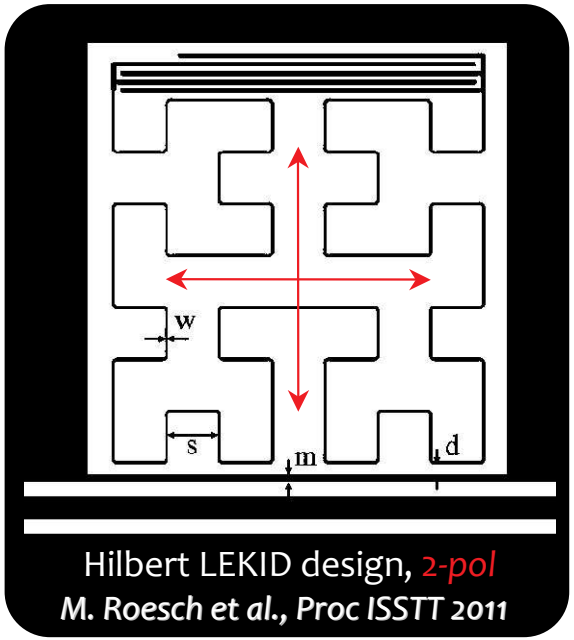




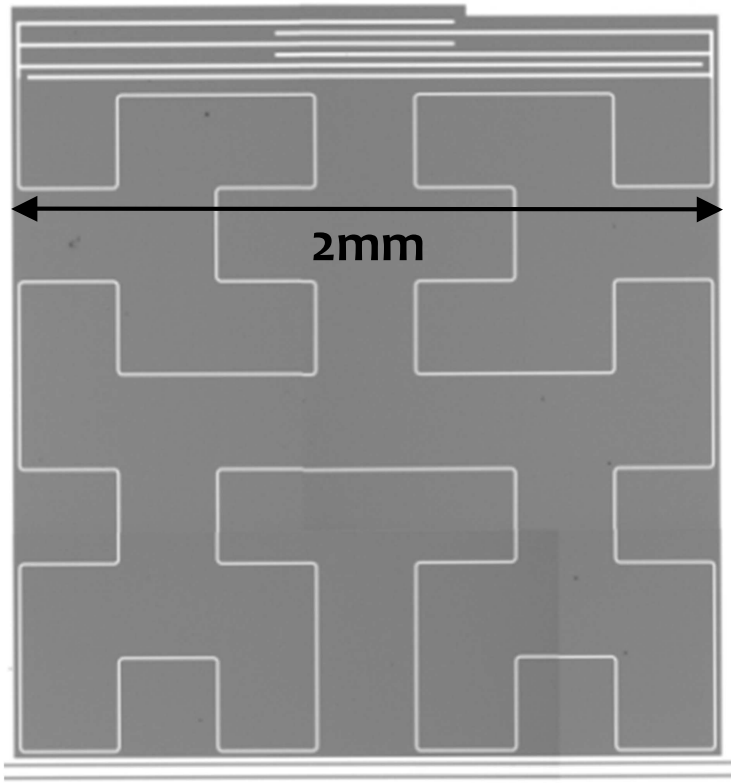
Only MS mode!

- Improved Q_c uniformity!
  (and morale of people in charge of wire bondings too!)

Hilbert geometry for LEKID

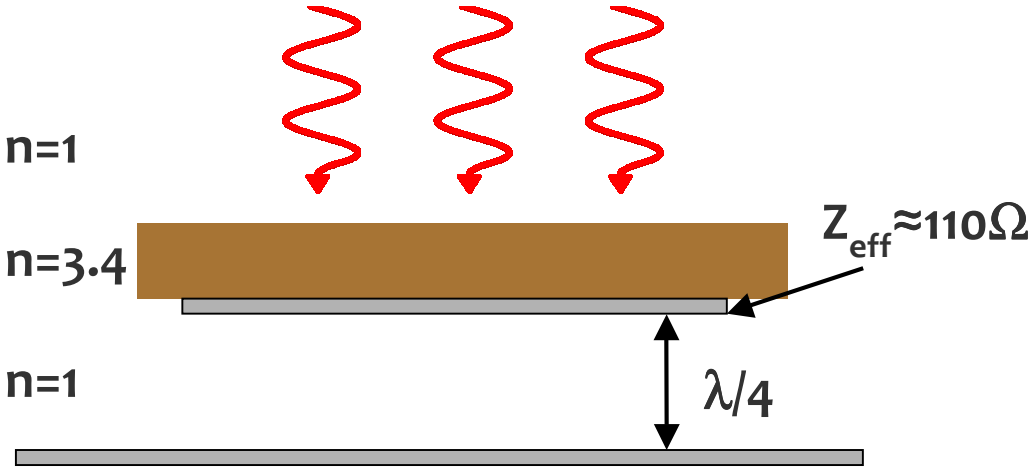


Hilbert LEKID design, 2-pol
M. Roesch et al., Proc ISSTT 2011

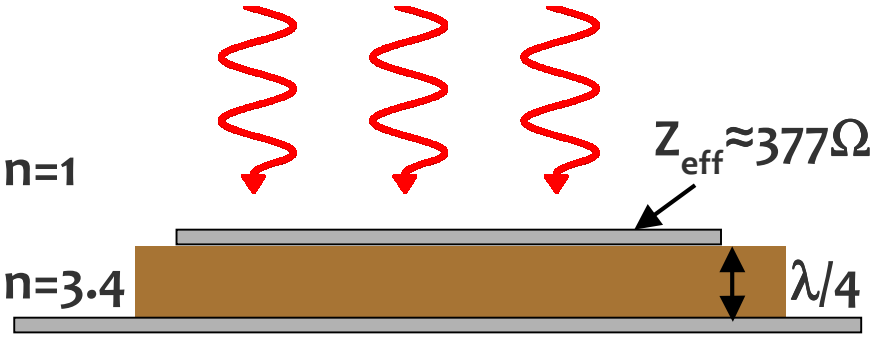


Coupling to radiation

- CPW : back-illumination + λ/4 backshort



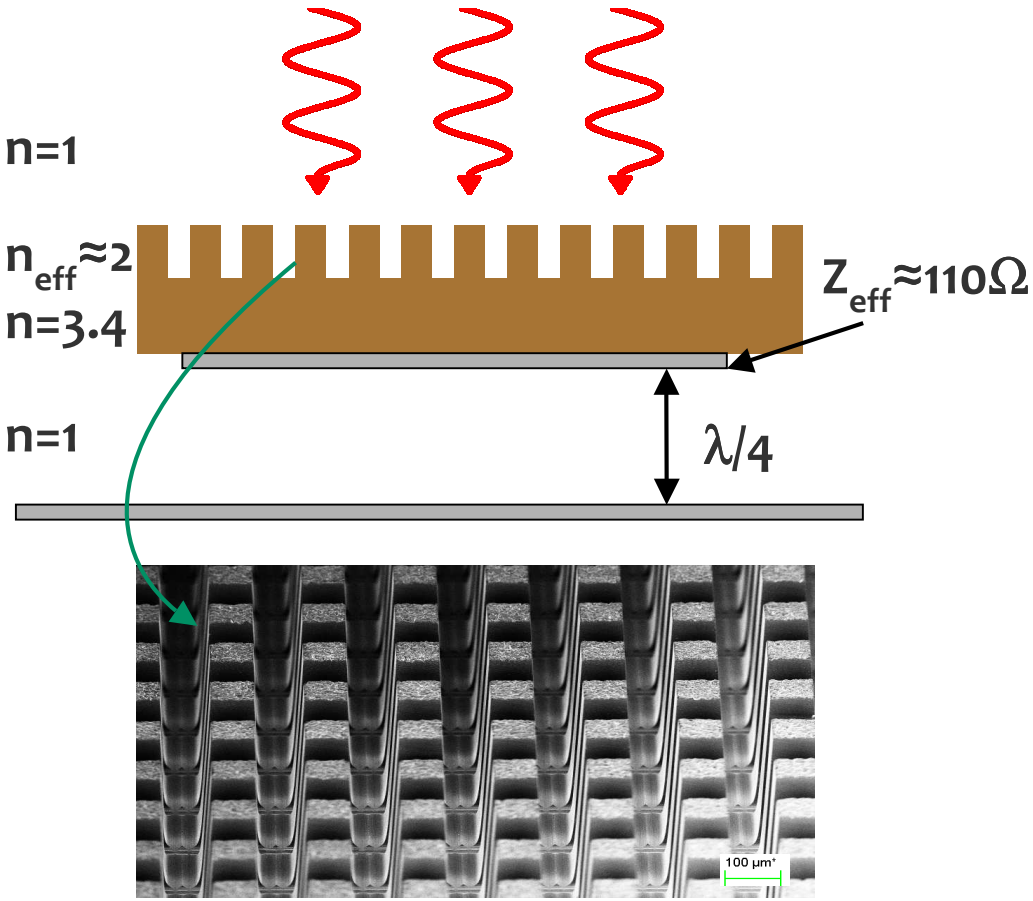
- Microstrip : front illumination



Coupling to radiation

- CPW : back-illumination + λ/4 backshort

AR coating: integrated



- Microstrip : front illumination

AR coating: external