NIKA and NIKA2

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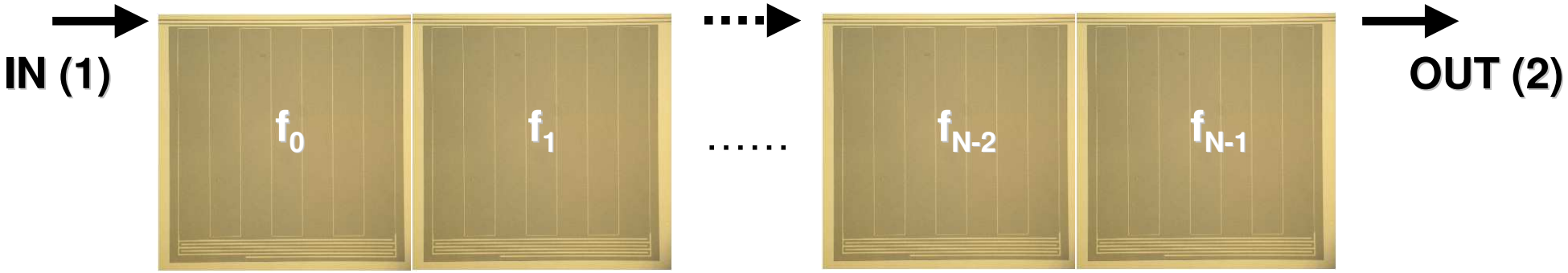
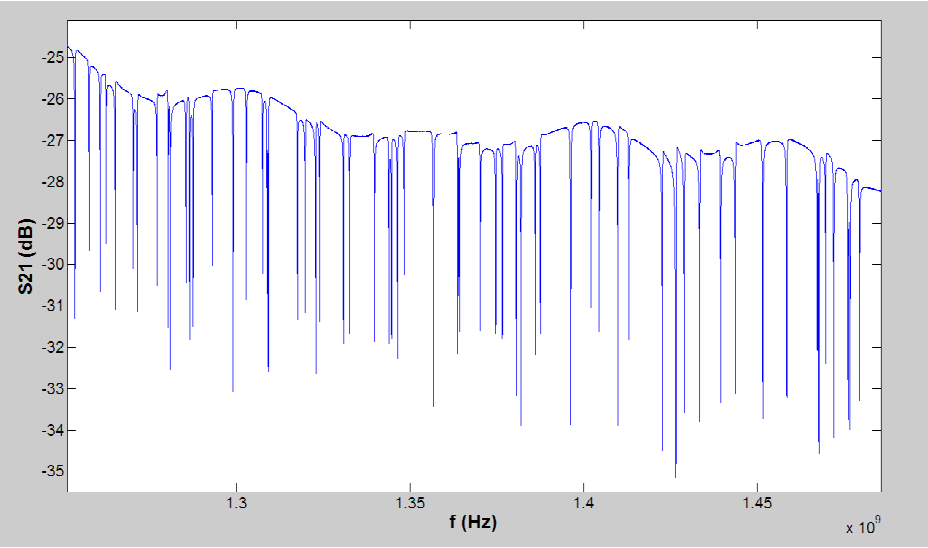
Kinetic Inductance Detectors



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



GHz range !!

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

Proposed by Caltech (2002) but first MUX instrument in 2009 (NIKA)

→ **Natural f-domain multiplexing**

→ **High MUX factor (e.g. N > 1,000)**

today limited only by the warm electronics ADC bandwidth

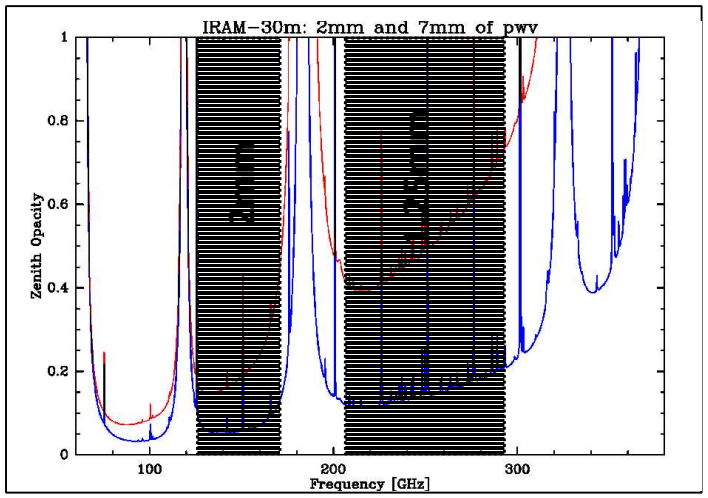
The IRAM 30m telescope

NIKA: New IRAM KID Array

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

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

- 30 m aperture
  - 16 arcsec @ 2mm
  - 12 arcsec @ 1.25mm
- Correct Field Of View up to 6.5 arcmin
- Multi-bands measurements



One of the best telescopes for mm-wave astronomy!

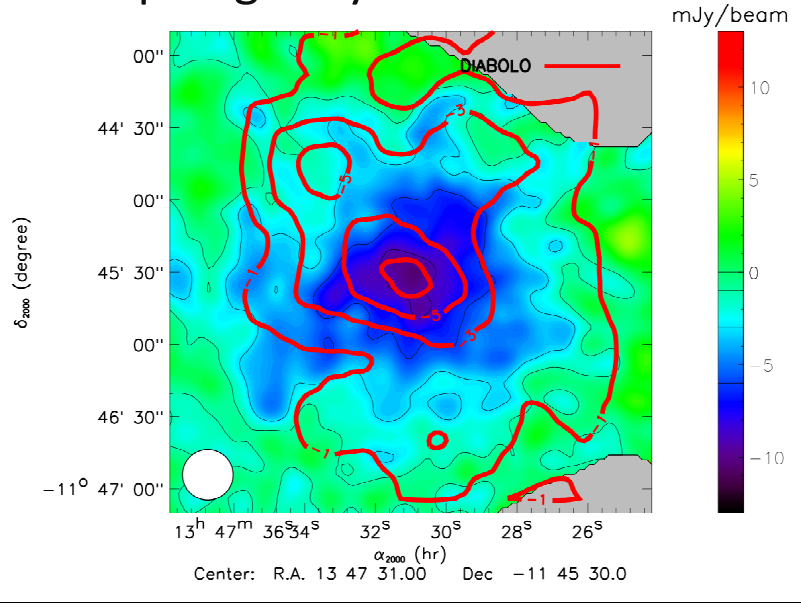
The NIKA camera

NIKA: a smaller (2 arcmin FOV) pathfinder camera (2010-2014)

- First camera to achieve multiplexed on-sky observations (> 300 pixels) ✓
- Many 'technical' runs and **a lot** of experience gained, e.g. photometry ✓
- First polarization measurements done ✓
- Three 'open pool' runs for the science community (again, a 'first time'!) ✓
- Scientific-grade data acquired ✓

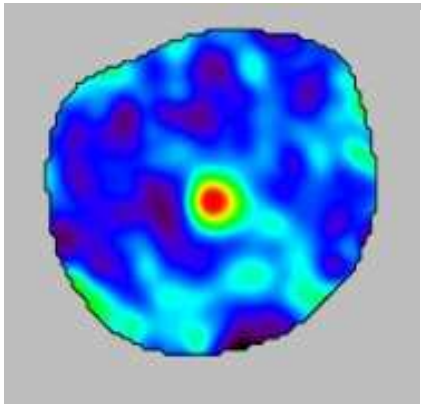
NIKA1 @ IRAM

tSZ map of galaxy cluster RX J1347.5-1145

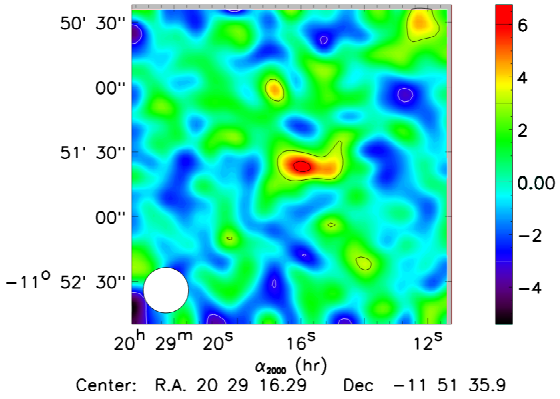


R. Adam et al., ***A&A***, 569 (2014) A66

Some selected NIKA images



Pluto at 150GHz



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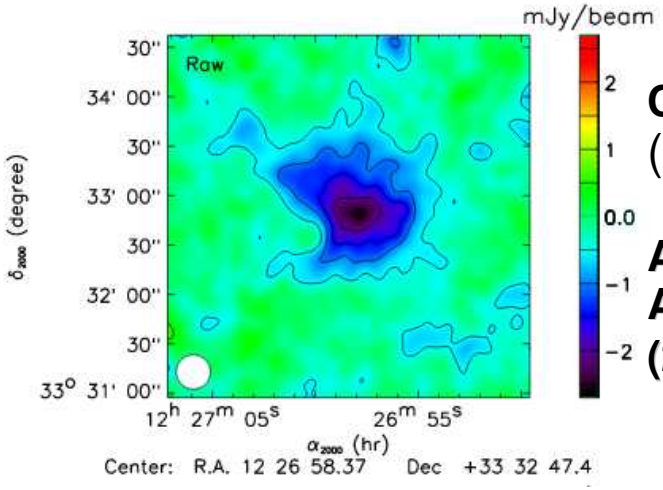
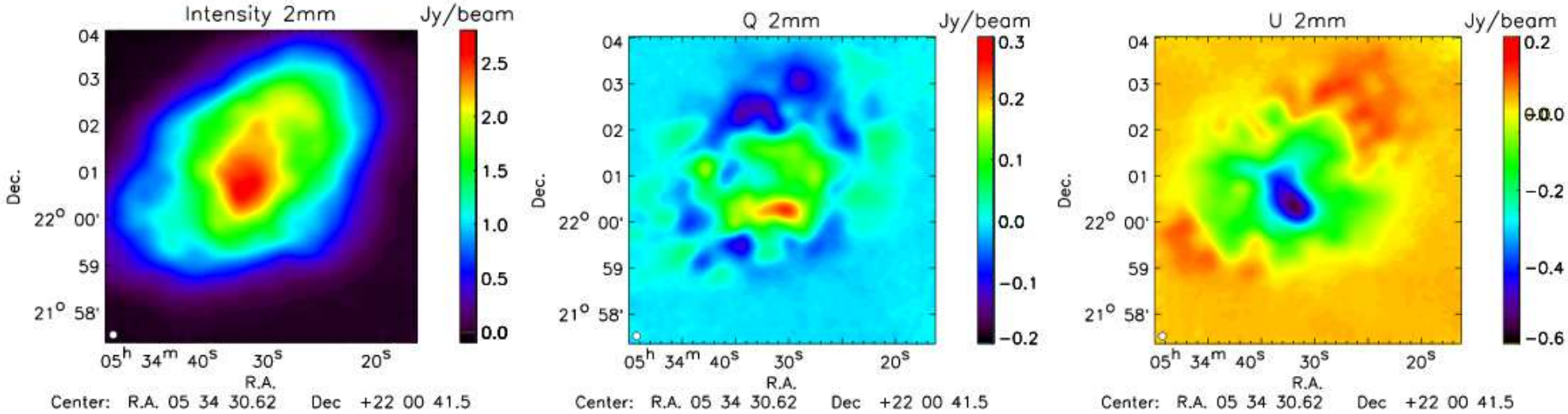


CL J1226.9+3332
(z = 0.89)

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



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

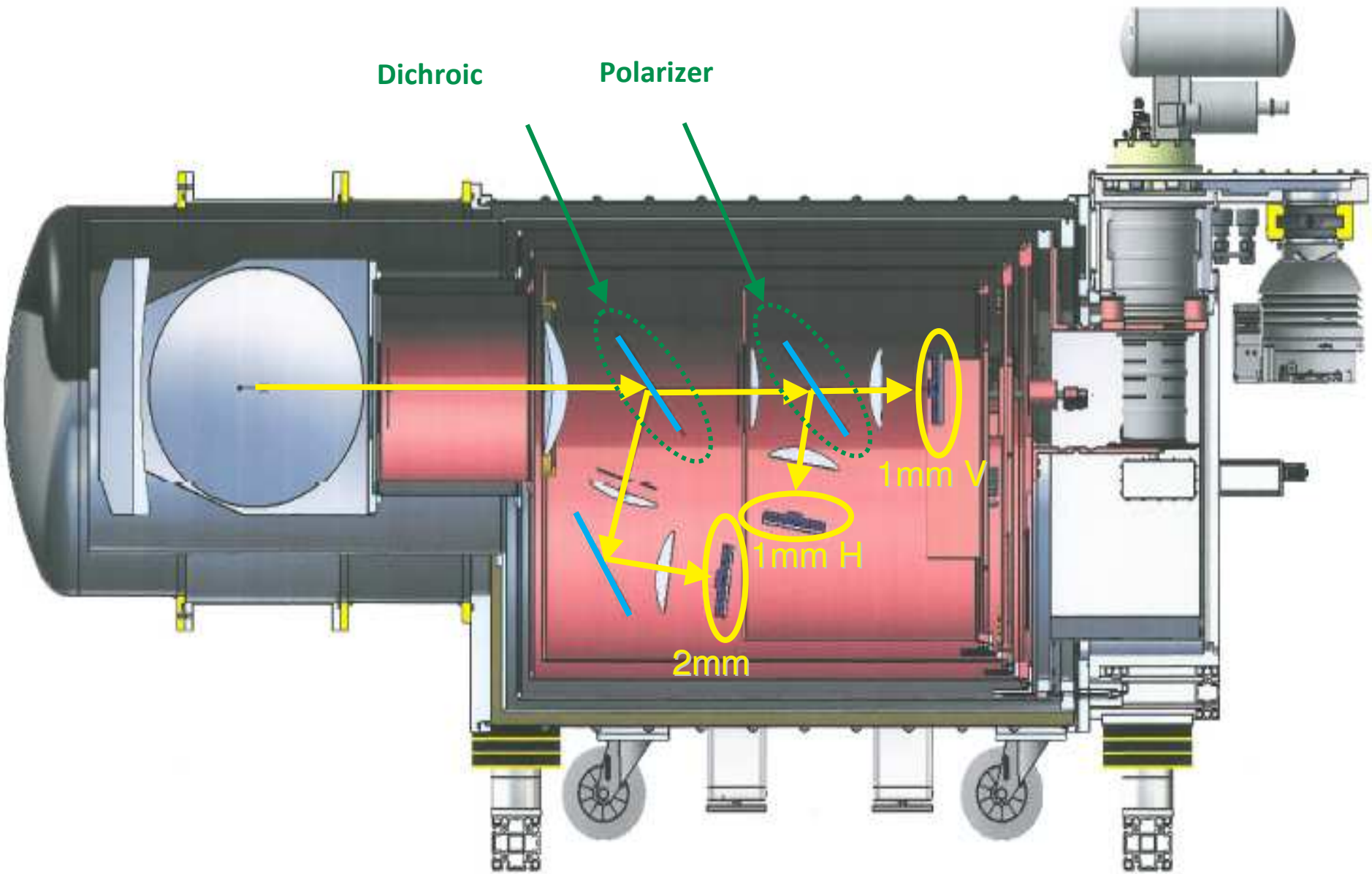
From NIKA to NIKA2

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

- Correct FOV: 2 arcmin → ***6.5 arcmin***
- Total pixel count: ≈ 300 → ***≈5000***
- 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



The cryostat

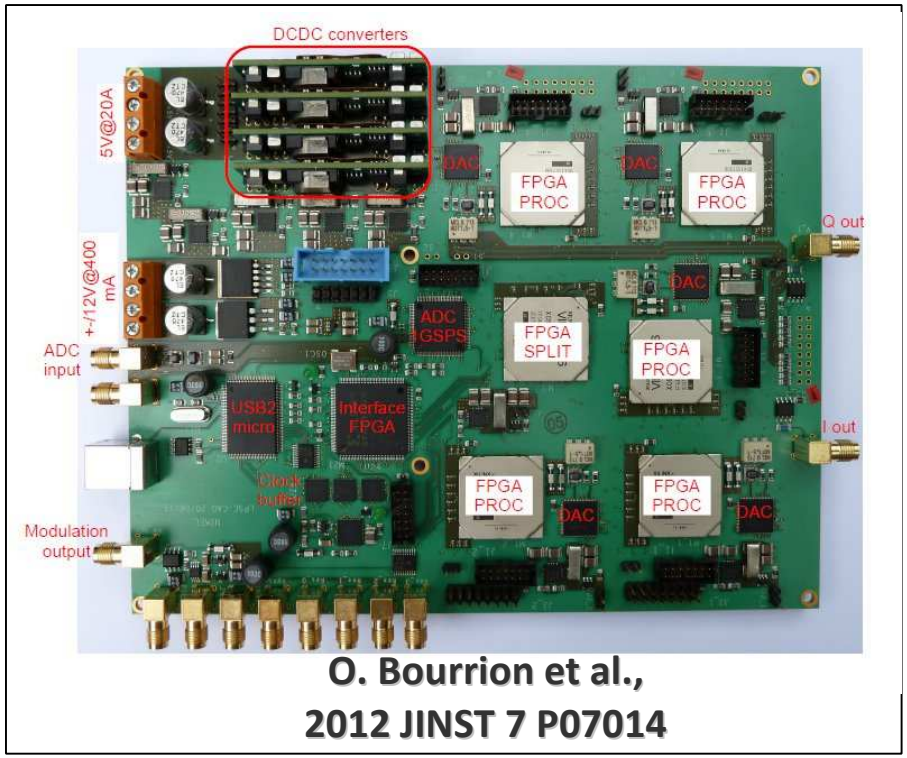
It's *massive* :

- 1.1 ton
- 2.3 m length
- 2 Pulse Tubes (2 x 1.35 W)
- ≈ 3000 pieces
- ≈ user friendly !

Operational, equipped with optics, detectors, cold electronics

- > 20 cooldowns
- Full remote operation + cryogen free
- Base T ≈ 100mK; NIKA2 detectors optimised for 150mK operation

Electronics



O. Bourrion et al.,
2012 JINST 7 P07014

Based on *NIKELv1* boards

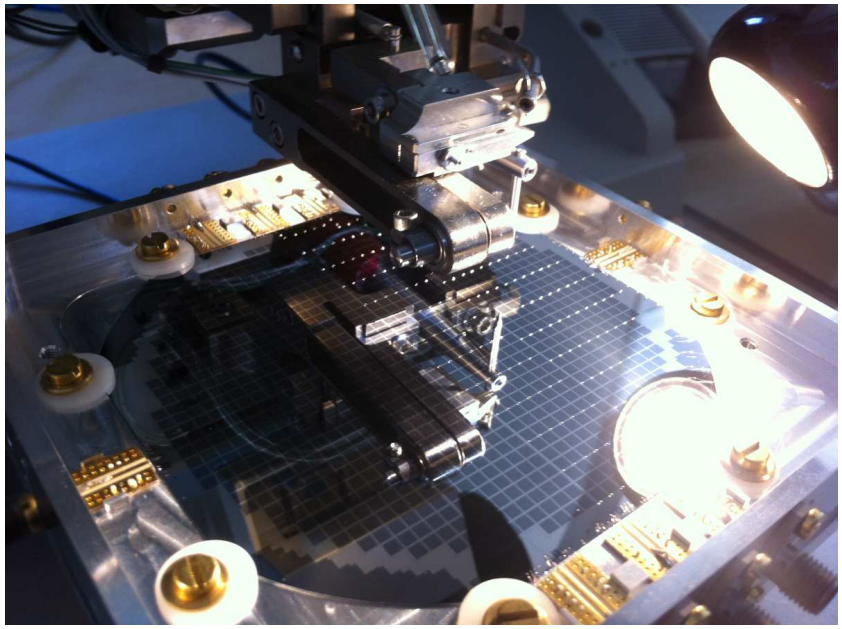
- 1 board = up to 400 tones over 500MHz
- Safe approach (+ limits due to Q_i) :

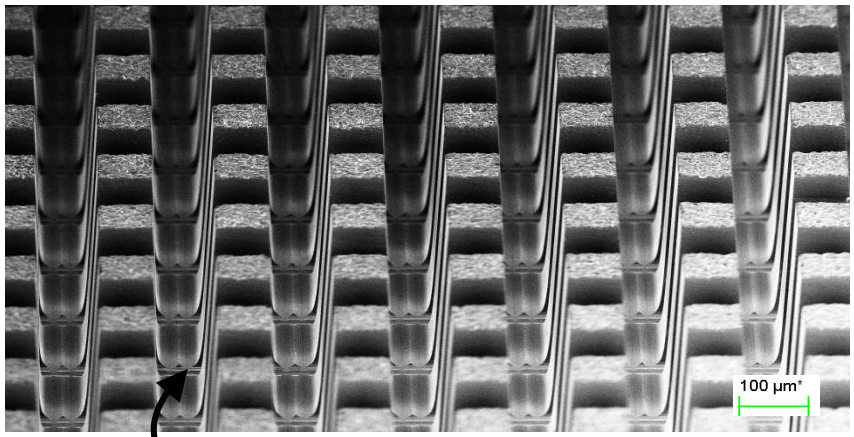
250 tones per board

- 2mm: 600 ÷ 1000 pixel ⟼ 4 feedlines
- 1.25mm: 1200 ÷ 2000 pixel ⟼ 8 feedlines

20 complete RF lines (coax in/out + LNA) in place

NIKA2 arrays





Dicing for AR layer

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

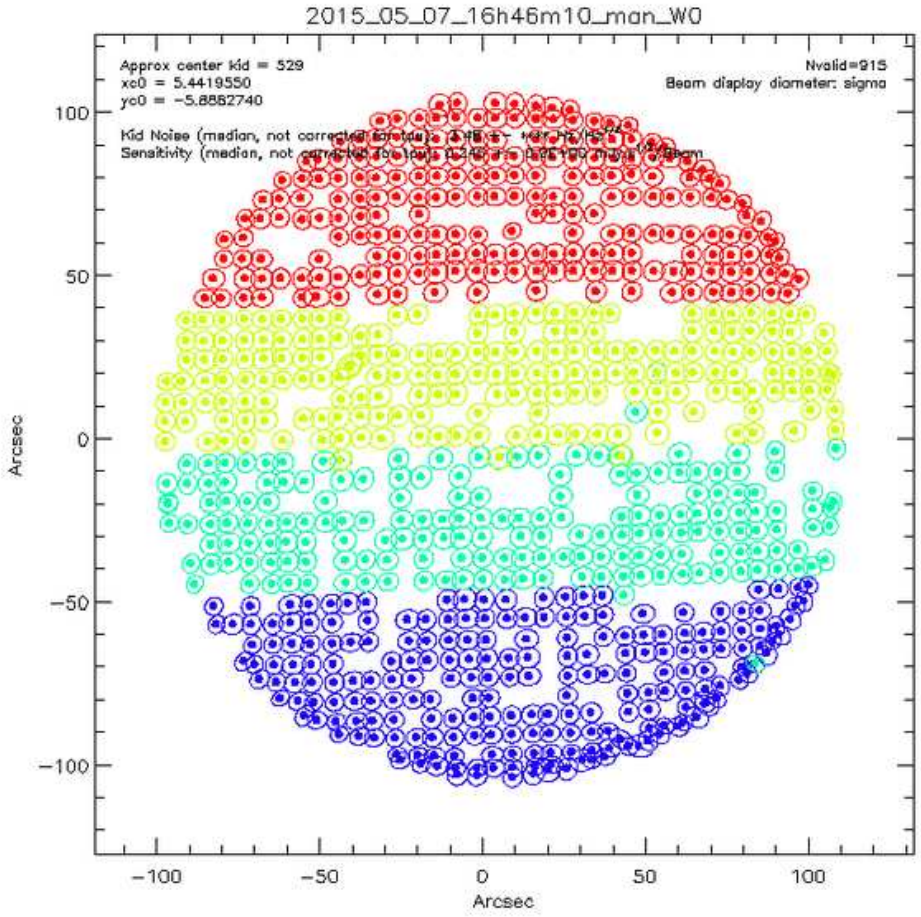
Small pixels (0.7Fλ)	↔	Large pixels (1Fλ)
No AR layer	↔	AR layer (dicing, etching)
CPW feedline	↔	MS feedline

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

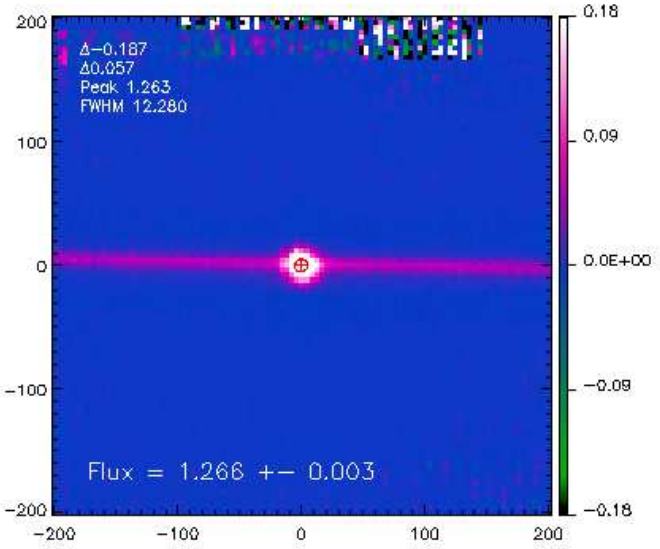
2mm arrays performances

- NIKA2 '**AR11**' array:

  1020 pixels, CPW feedline, with bondings, AR layer by dicing



90% good pixels!

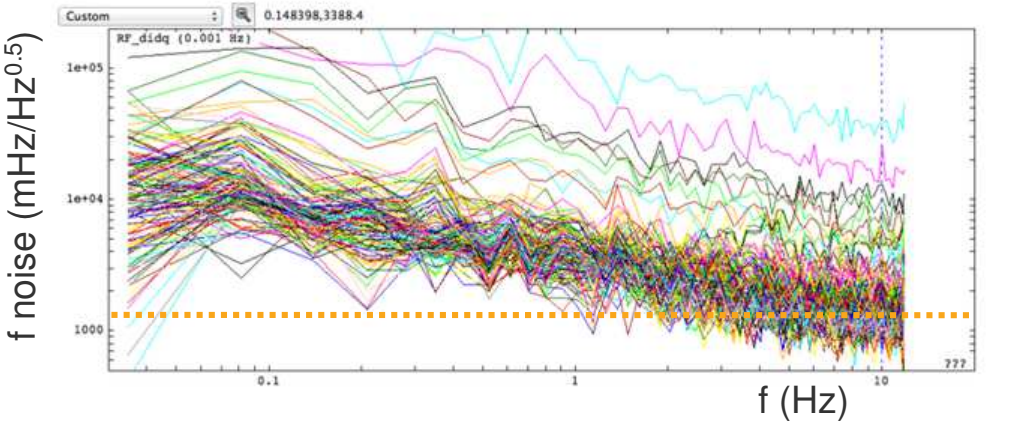


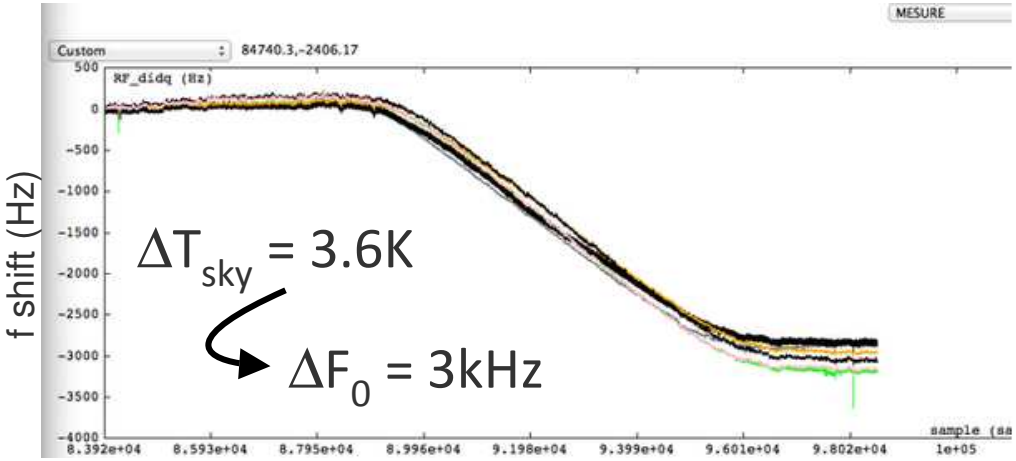
Reconstructed image of planet (and wire..)

2mm arrays performances

- NIKA2 '**AR11**' array:

  1020 pixels, CPW feedline, with bondings, AR layer by dicing





Noise level: 1÷2 Hz/Hz$^{0.5}$ @ 10Hz

Responsivity: 0.8 kHz/K

NET ≈ 1÷2 mK/Hz$^{0.5}$ per pixel

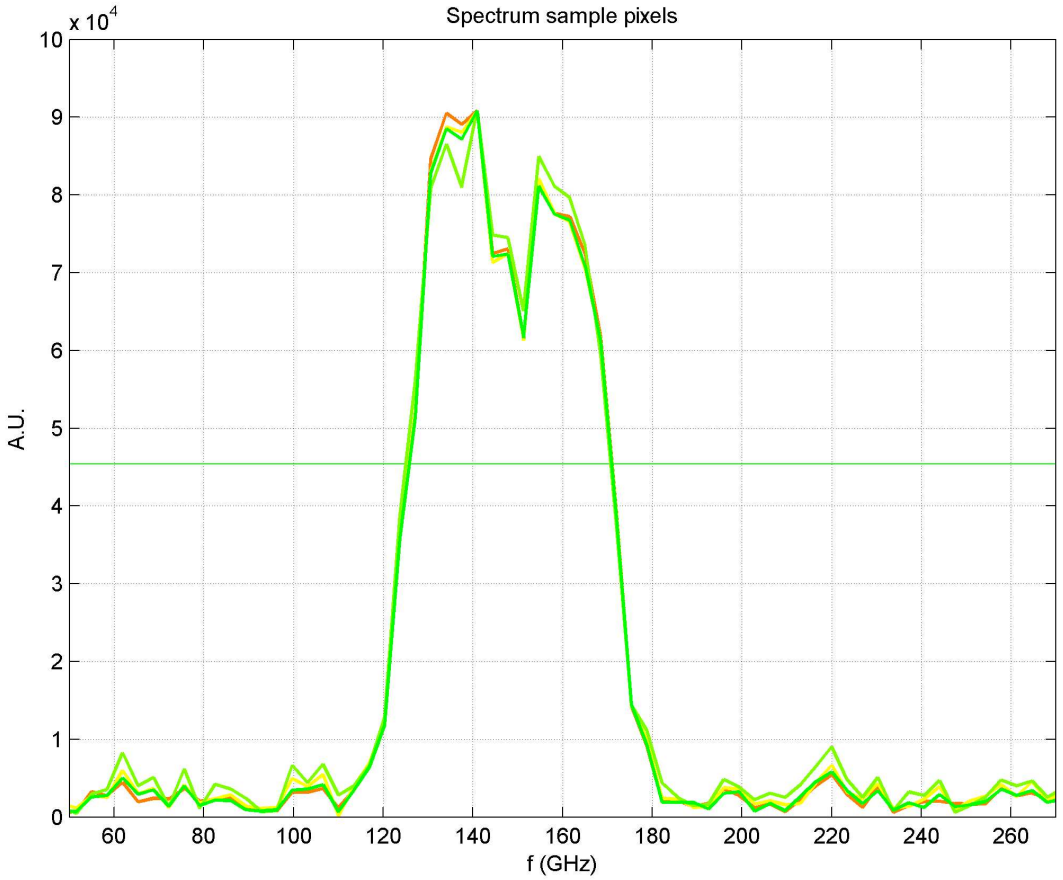
Comparable to NIKA1!

A. Catalano et al.,
***A&A*, 569 (2014) A9**

2mm arrays performances

- NIKA2 '**AR11**' array:

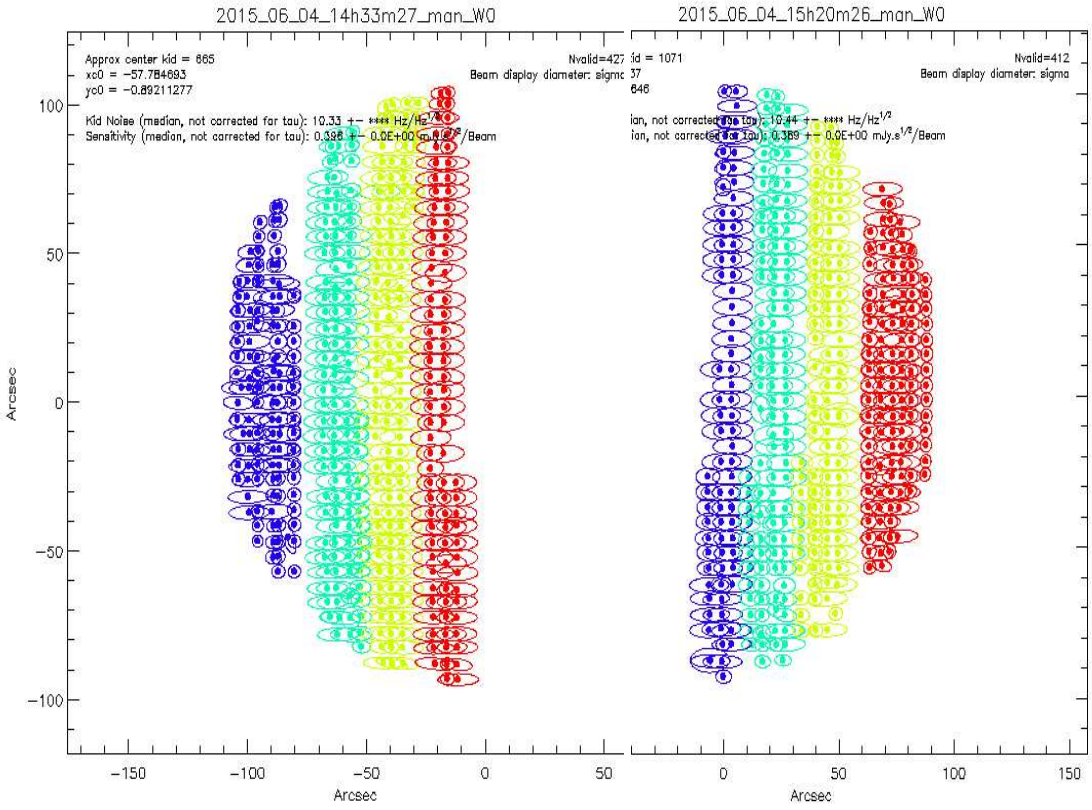
  1020 pixels, CPW feedline, with bondings, AR layer by dicing



- AR layer gives ≈ flat spectrum
- Large band as desired (FWHM 125-175Gz)

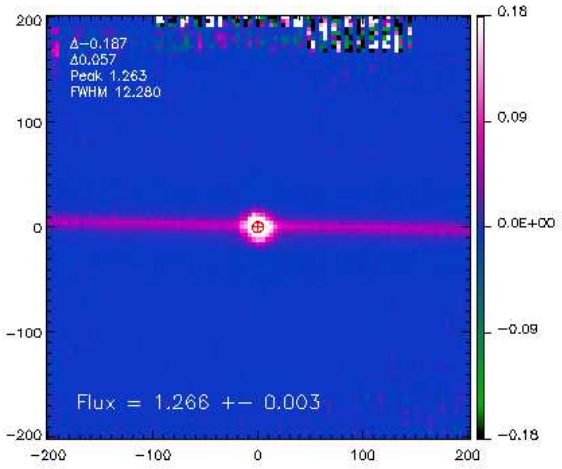
Microstrip feedline arrays

- Alternative : use MS feedline to get rid of spurious modes!
- First tested on 1.25mm arrays, being tested on 2mm as well
- Results are encouraging...



>80% good pixels

Lobes elongated because of wire signal



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***

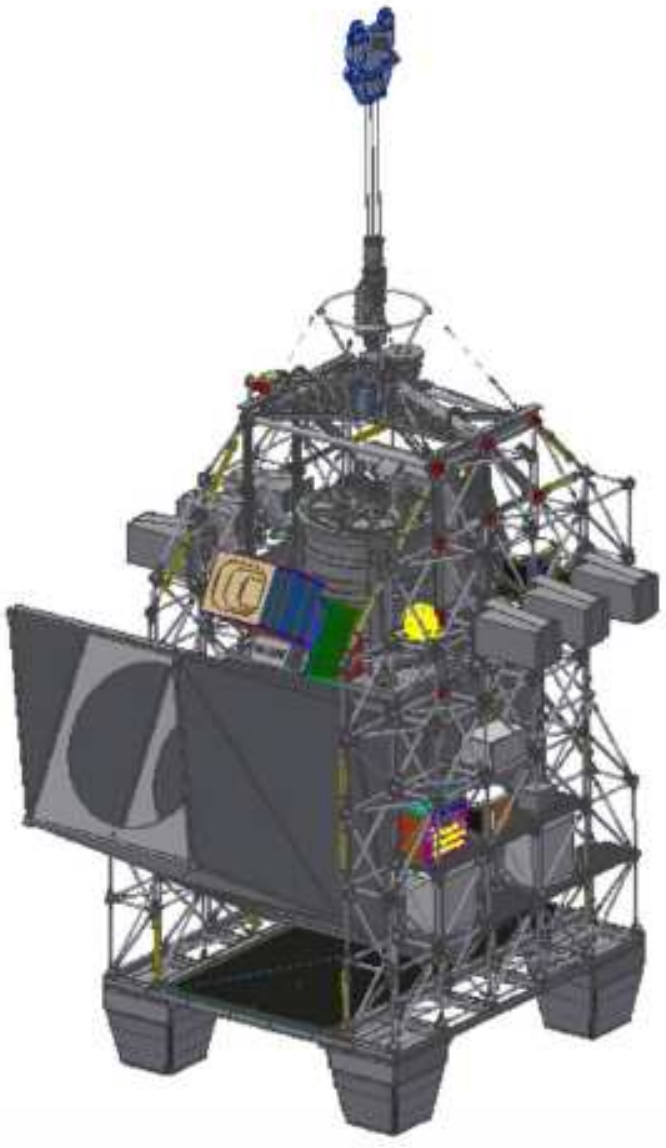
planB

The collaboration involves so far the four Grenoble labs (Néel, LPSC, IPAG, IRAM), IRAP (Toulouse), IAS (Orsay), Cardiff (UK) plus others not participating, at least So far, to the hardware discussions.

Still open …

Status: just an idea, made calculations, identified hard points, started building a testing bench for the detectors, submitted an (approved) proposal to CNES for funding the detectors R&D.

PlanB

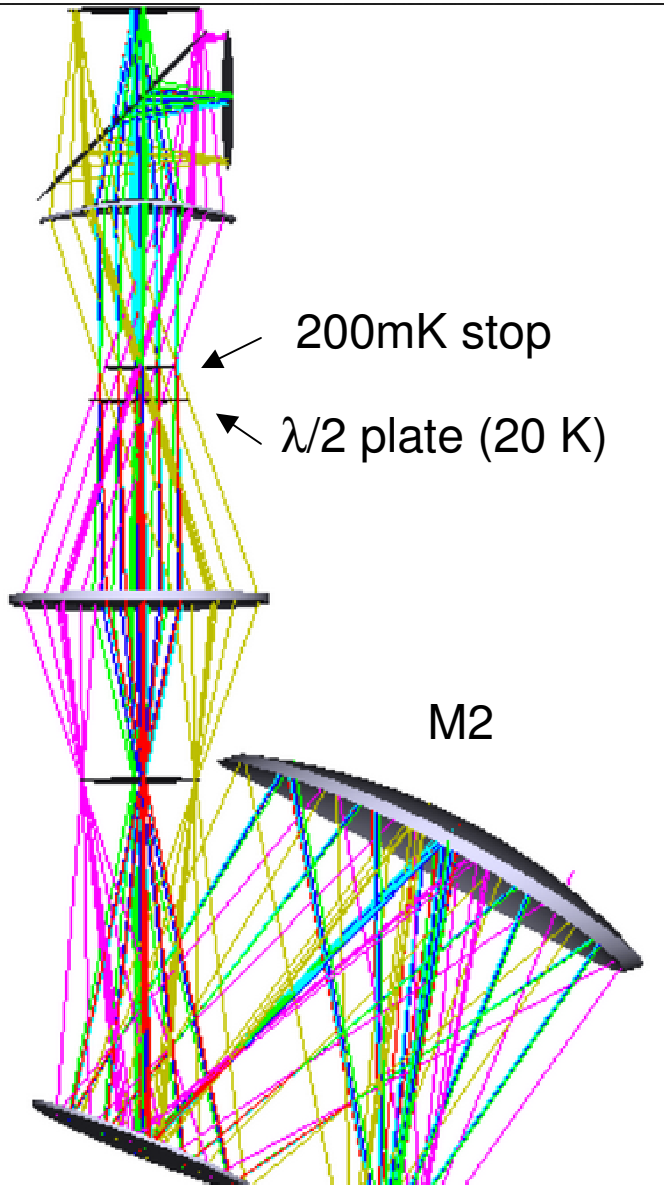


The overall architecture (e.g. gondola, power supply) will be strongly derived from the existing PILOT balloon working at 1.2 THz (240μm). Even the M1 and M2 mirrors might be recycled if needed.

A "simple" list of items:

- Use **LEKID** operating at **400-700 GHz**, **paving the full focal plane**
- developing a new closed-cycle dilution cryostat **including space-compatible parts**
- optimise the PILOT optics (e.g. **increase the overall transmission**, maximise FoV)
- use a fast rotating cold (20K) λ/2 plate

PlanB optics (first draft)



- We have started designing the optics

Pretty straightforward assuming AR Silicon lenses (e.g. collaboration with the University of Michigan or developed in Europe TBD). Focal planes will be **2 x 1000 pixels LEKID** with AR coating realised in-house.

-We have designed and we are realising a laboratory test-bench for detectors testing.

Cryostat design and construction is scheduled for 2016. The R&D on the sub-mm KID will continue in parallel in the dedicated existing cryostat.

Summary

- We have demonstrated (NIKA and NIKA) to well survive the international competition in the bands 100-300GHz

- We have demonstrated in laboratory sensitivities approaching the goals for a future CMB satellite at least in the band 80-300 GHz (Catalano et al., A&A 580, A15, 2015, arXiv:1504.00281)

- The NIKA/NIKA2 detectors behave very well even under lower background conditions. Optimum forcedly exists, to be found.

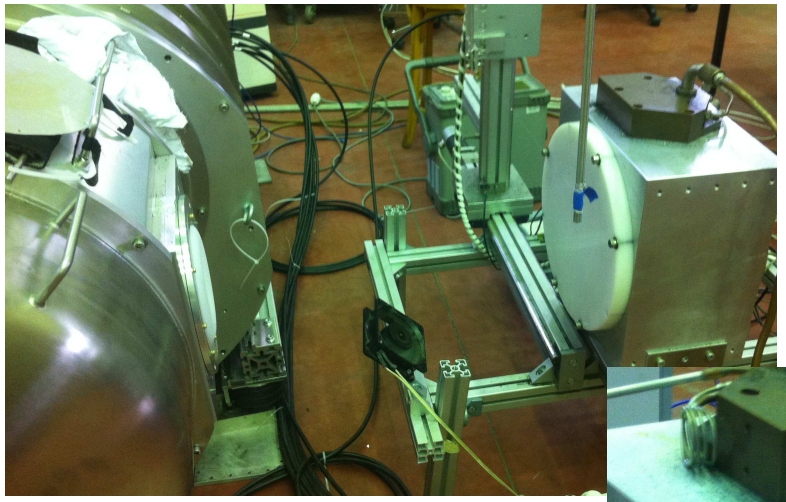
- We have started a new balloon program, planB, that will allow extending our design, production and testing capabilities up to at least 600GHz

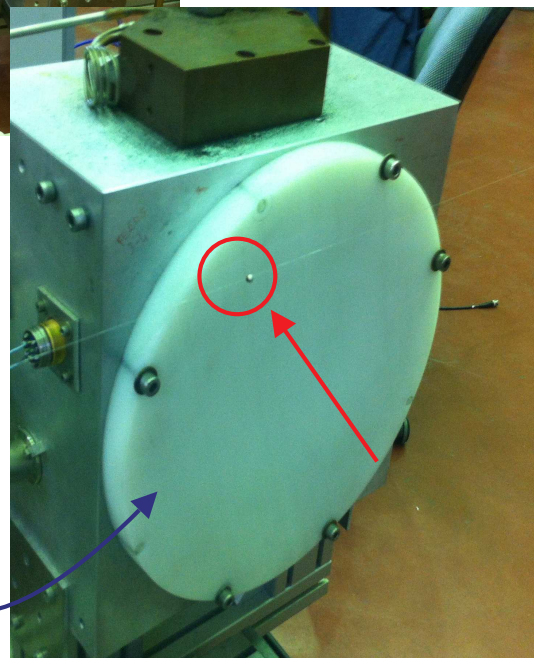
- We have found (e.g. under our responsibility and in the framework of the SPACEKIDS collaboration), recipes to strongly attenuate the CR effect that is now under control

THE END

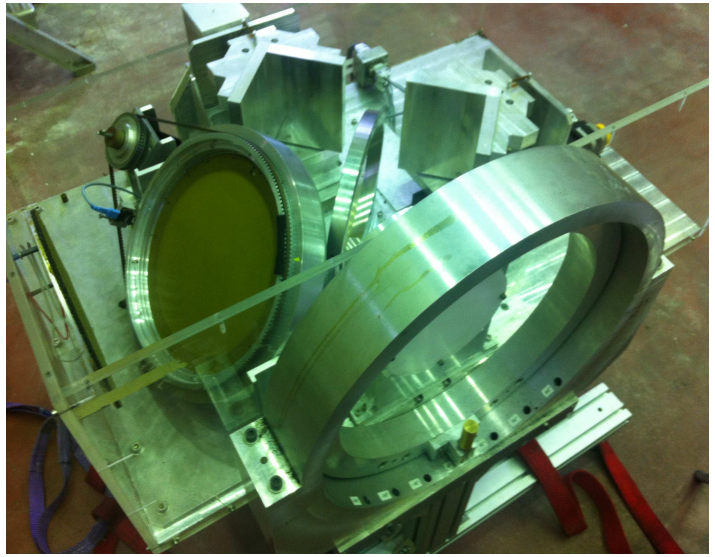
Lab characterization testbench

- Sky simulator
  - beam maps/responsivity



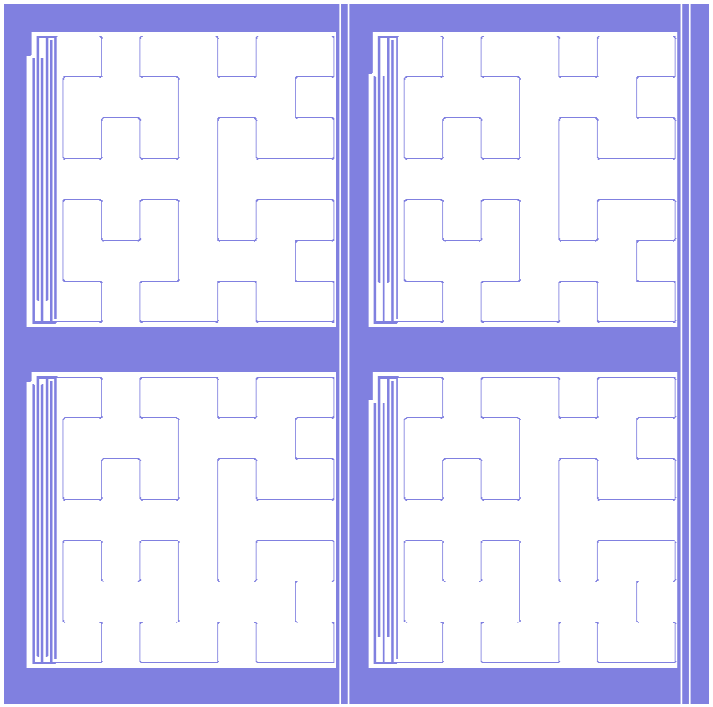


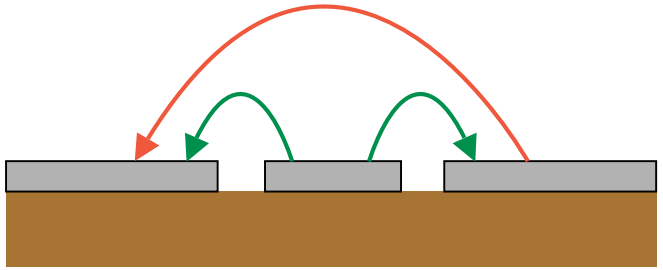
- Martin-Pupplet interferometer
  - absorption spectra



Feedline choice

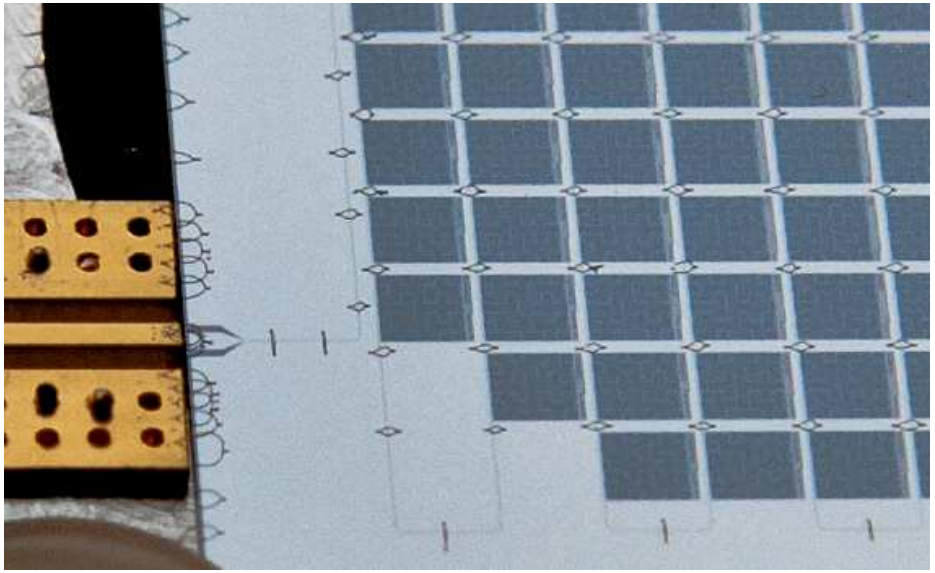
- CPW:





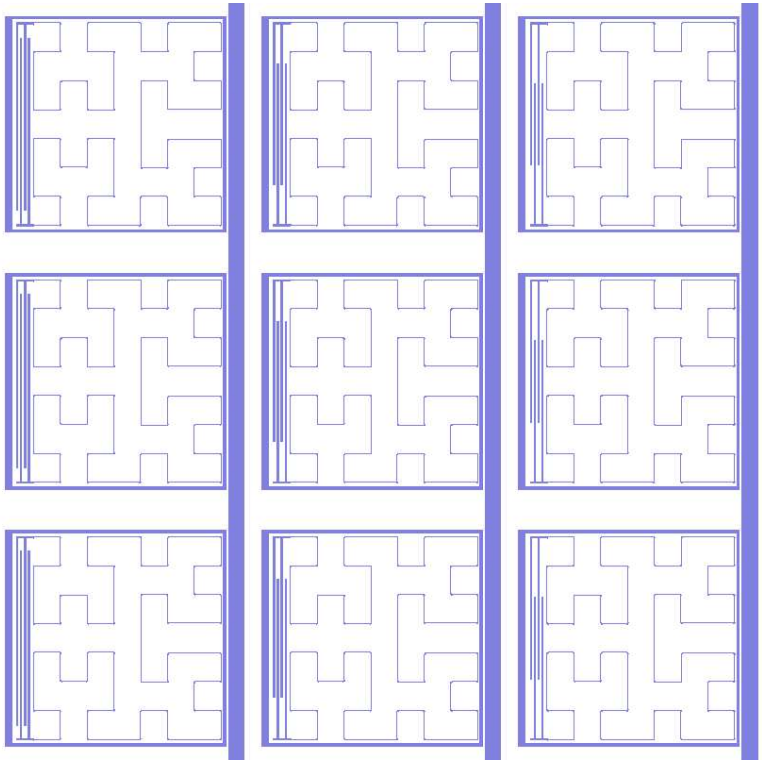
CPW mode

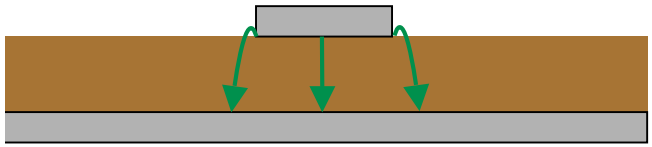
Slotline mode



Feedline choice

- Microstrip :

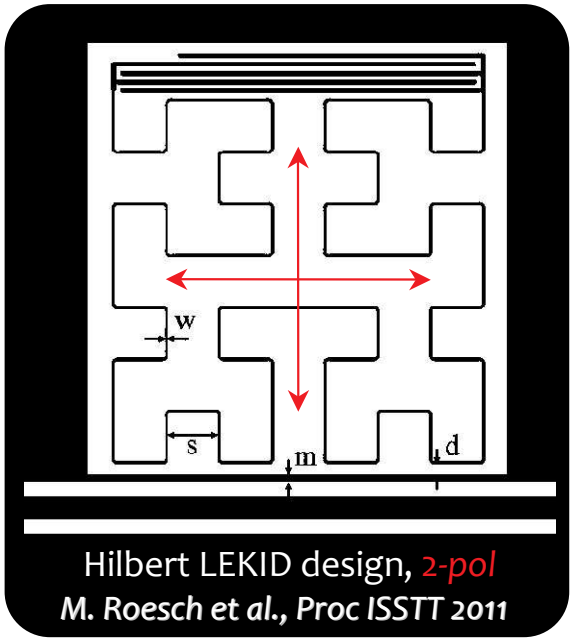




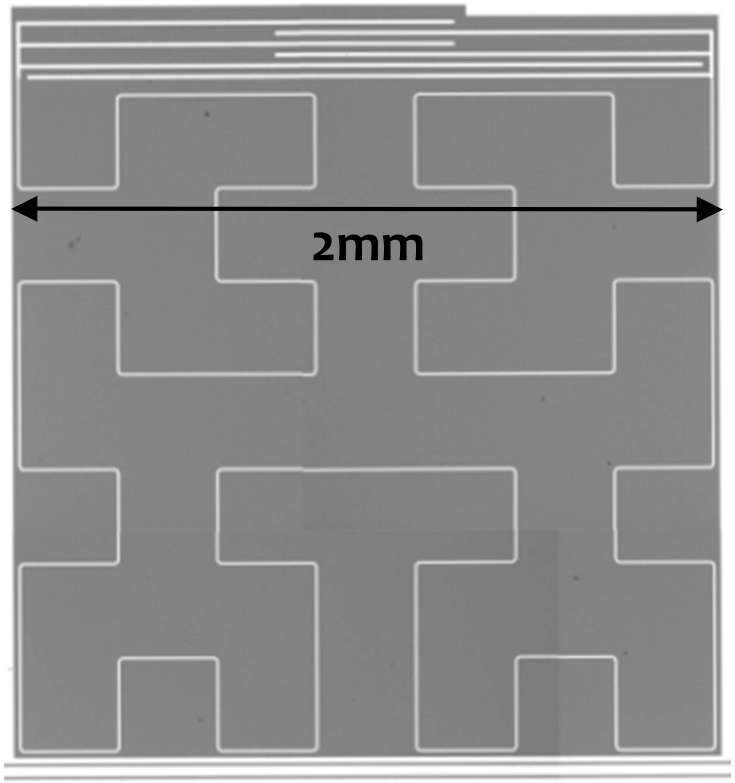
Only MS mode!

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

Hilbert geometry for LEKID

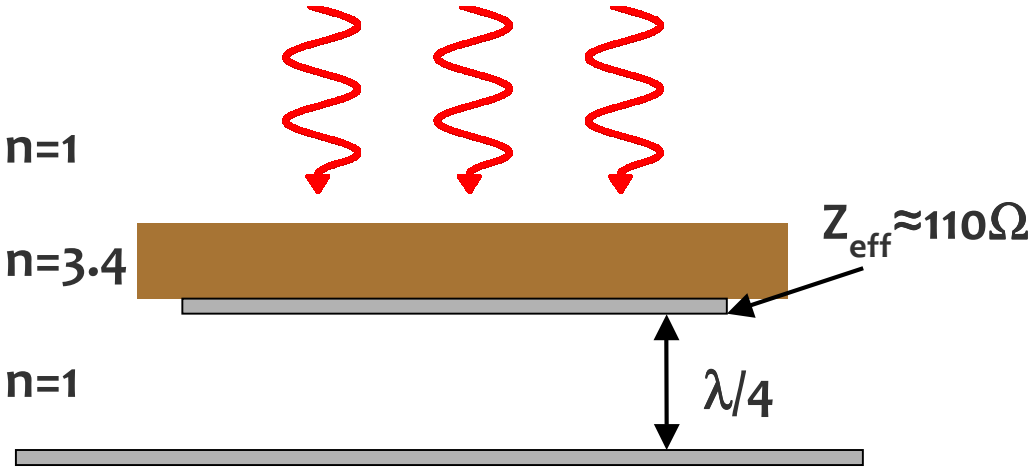


Hilbert LEKID design, 2-pol
M. Roesch et al., Proc ISSTT 2011

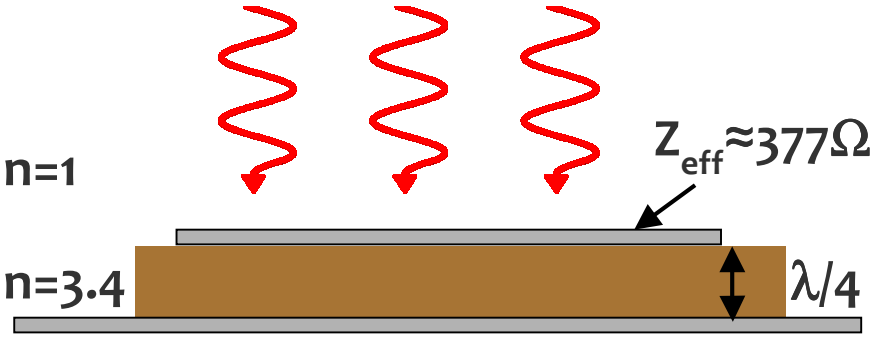


Coupling to radiation

- CPW : back-illumination + λ/4 backshort



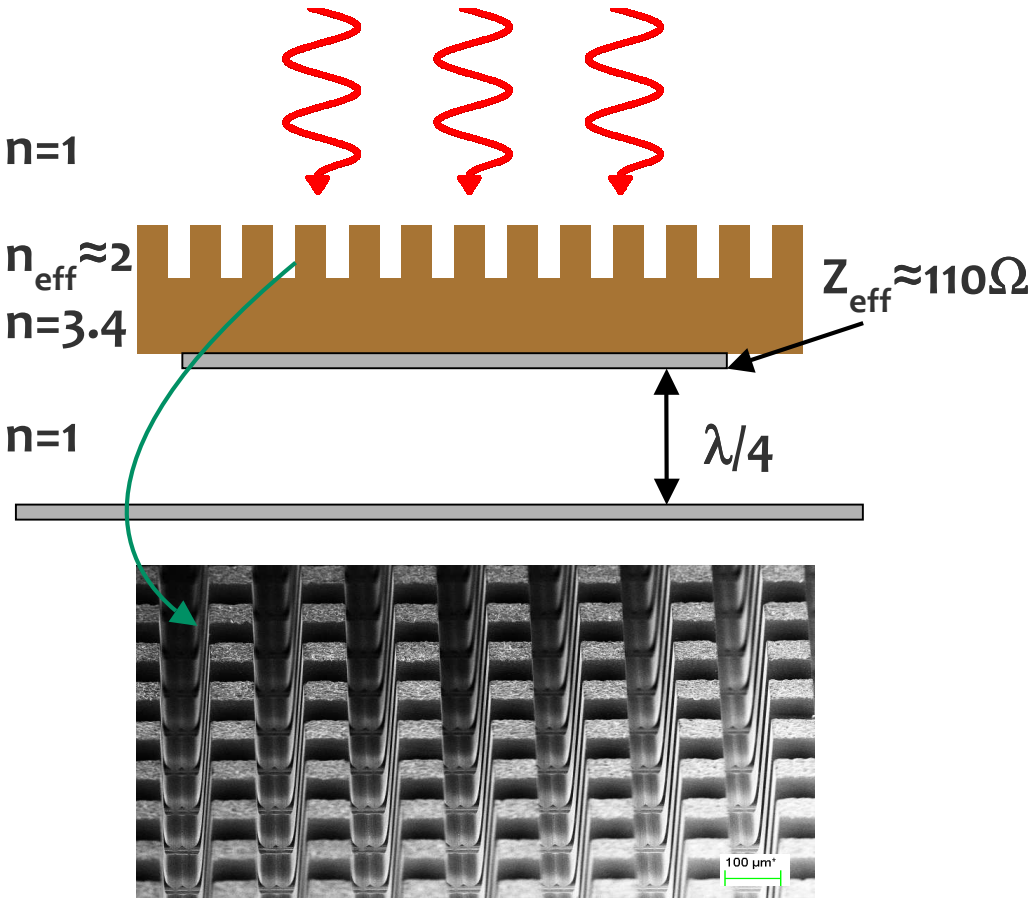
- Microstrip : front illumination



Coupling to radiation

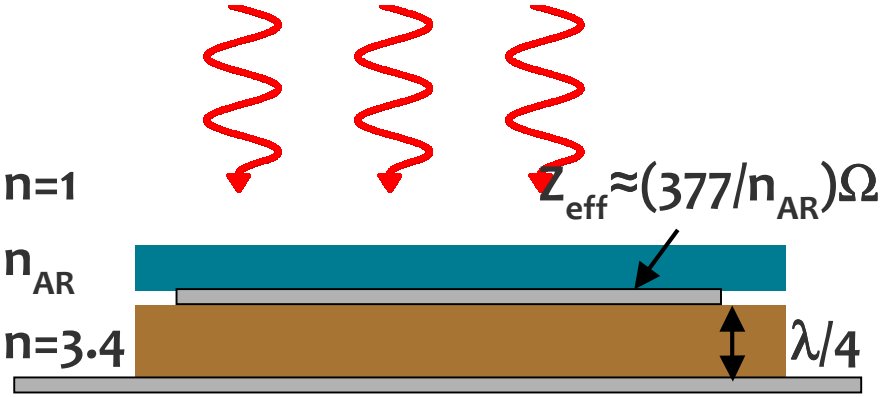
- CPW : back-illumination + λ/4 backshort

AR coating: integrated



- Microstrip : front illumination

AR coating: external



Decorrelation