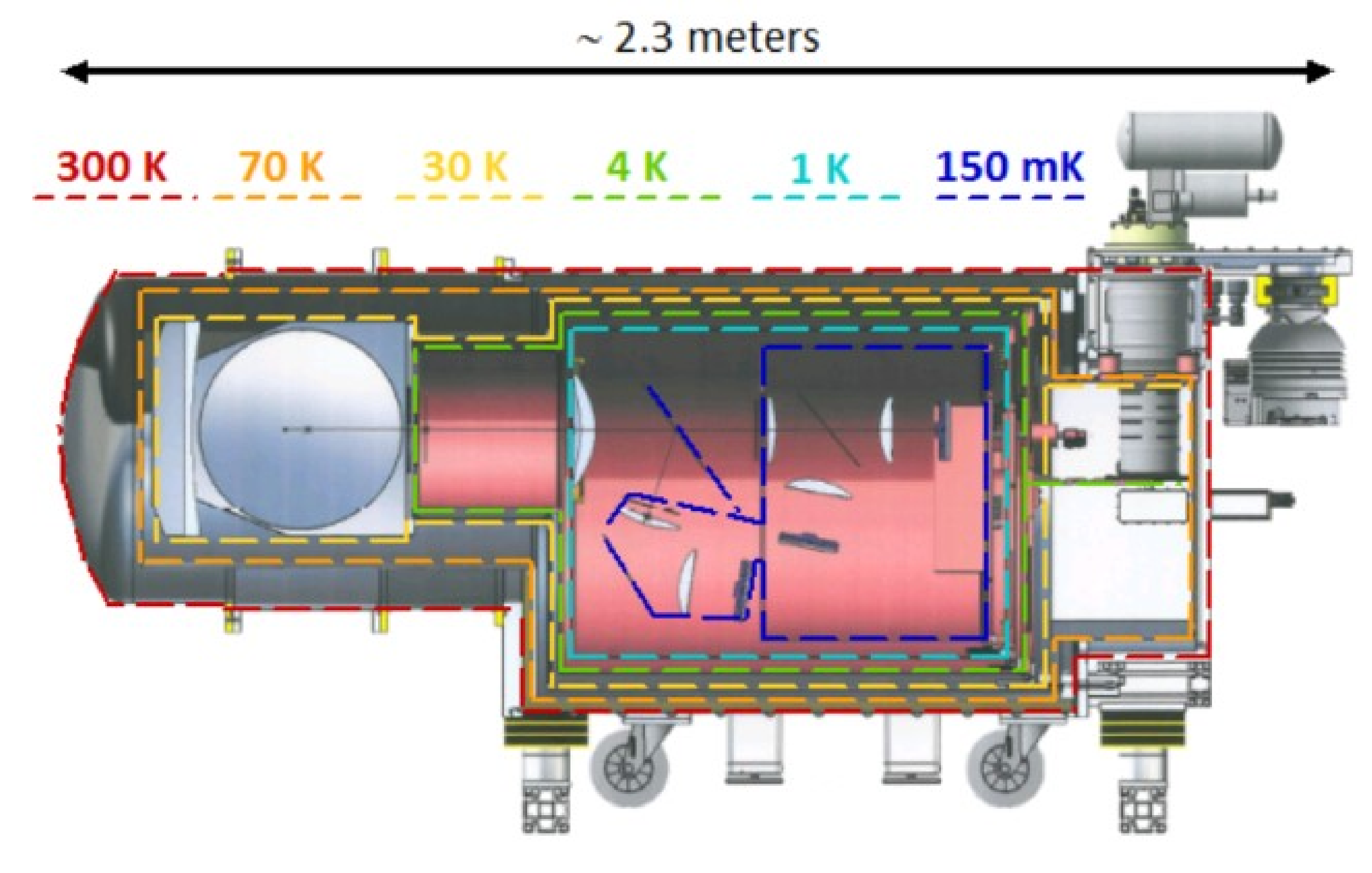
NIKA2

Description, status and possible upgrades

NIKA2 description

The NIKA2 team, Astronomy & Astrophysics 609, A115 (2018)

NIKA2 cryostat



Around 100 kg cooled to base temperature, in particular several kg of plastic and low-conductance black glue. **Remotely controlled**.

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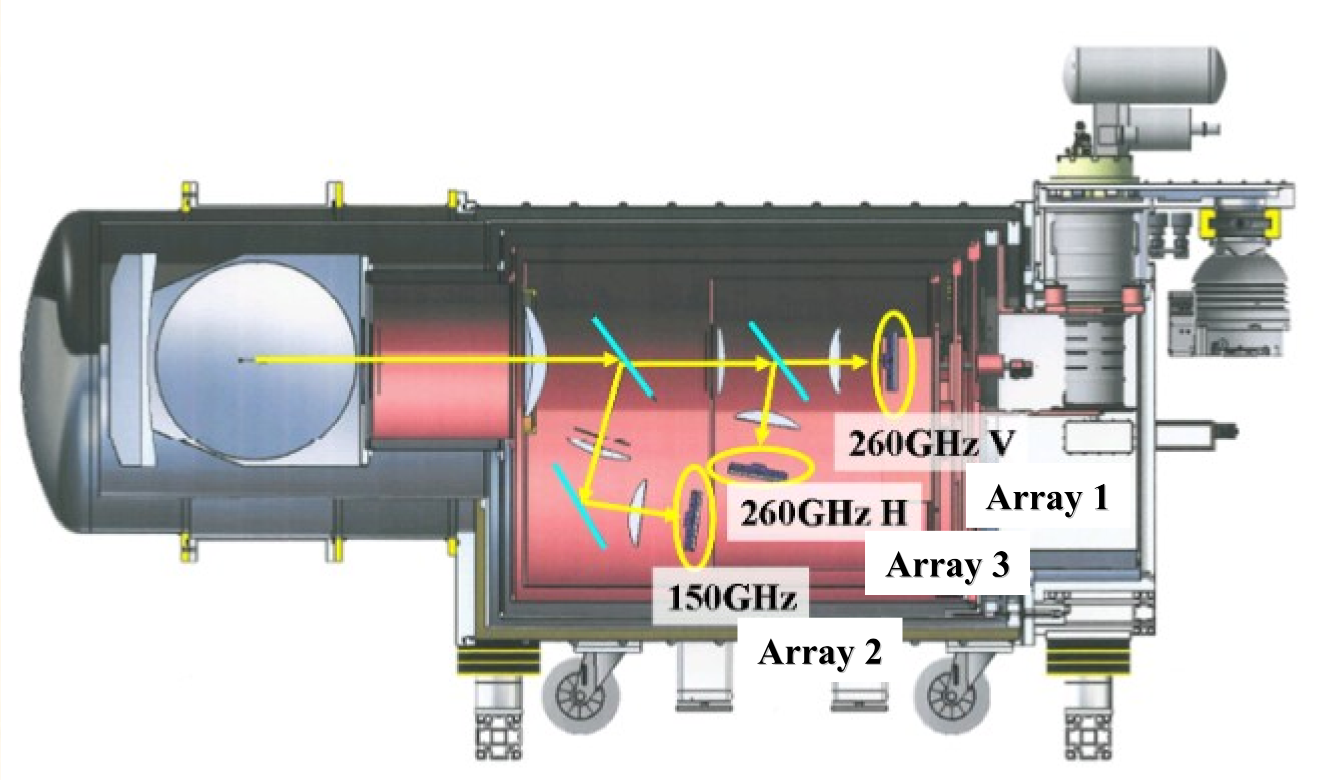
NIKA2 arrays



Array 2 → 2mm (150 GHz) – **616 pixels**

Arrays 1 and 3 → « 1mm » (260 GHz) **- 1140×2 pixels**

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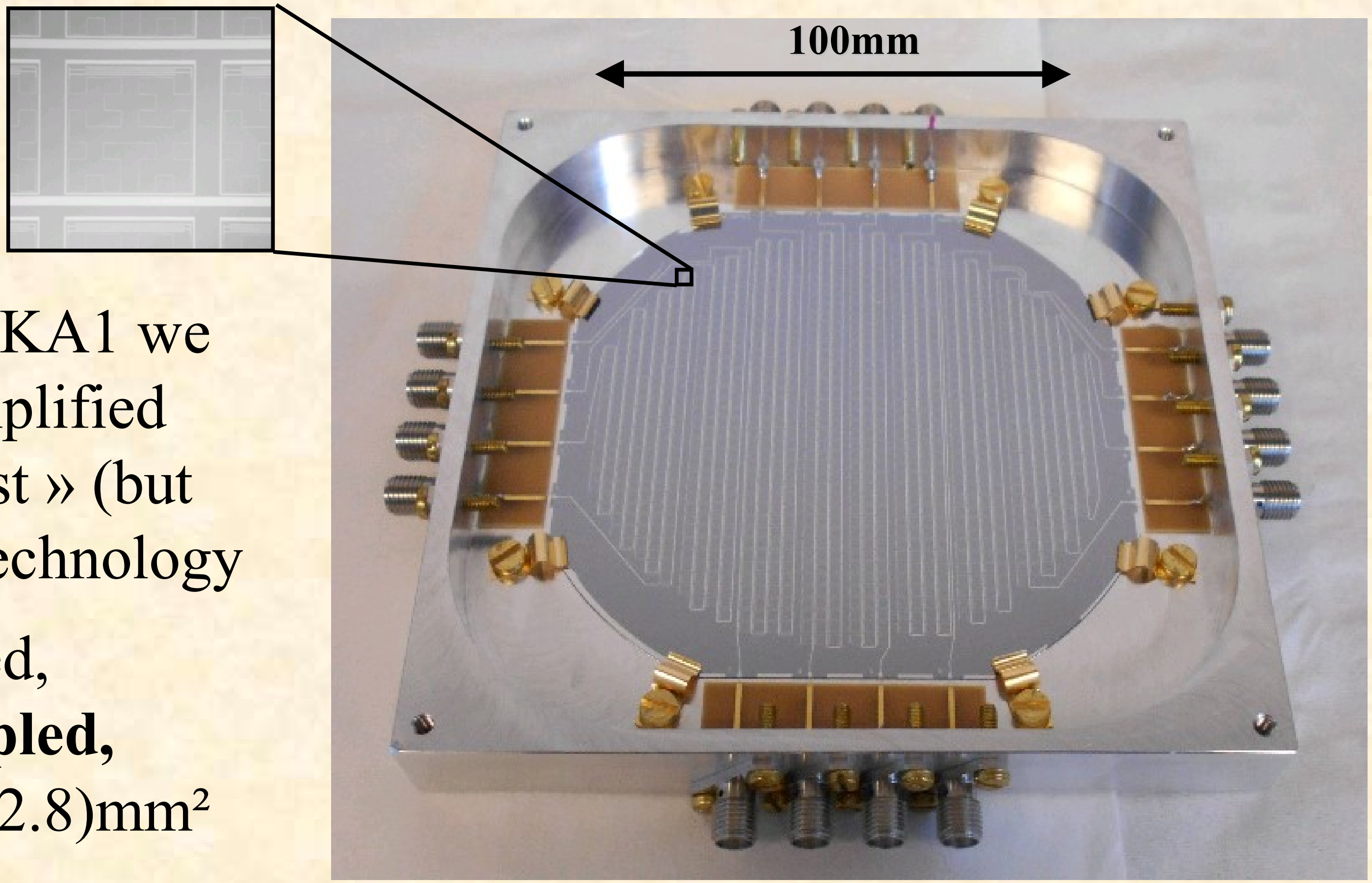
NIKA2 detectors

See J. Goupy talk



Compared to NIKA1 we have further simplified our already « fast » (but efficient) KID technology

Front-illuminated, **microstrip coupled,** pixels 2(2.8)×2(2.8)mm²

ADVANTAGES: single mode, easy packaging, robust, no penalties for sensitivity for selected applications (e.g. NIKA2)

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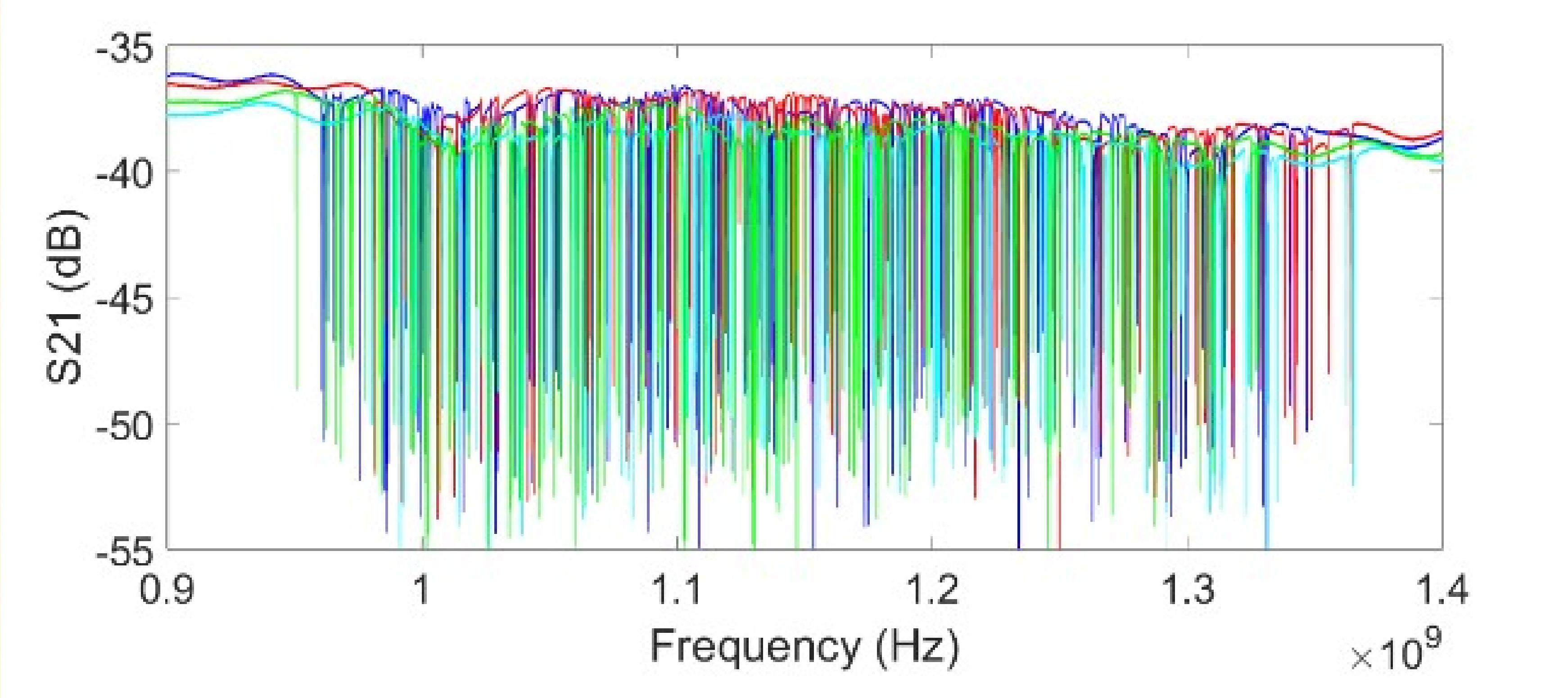
NIKA2 detectors



<u>Array 2:</u> the four readout lines over the 500 MHz band
In lab 580/616 are identified and show a beam **(94%)**

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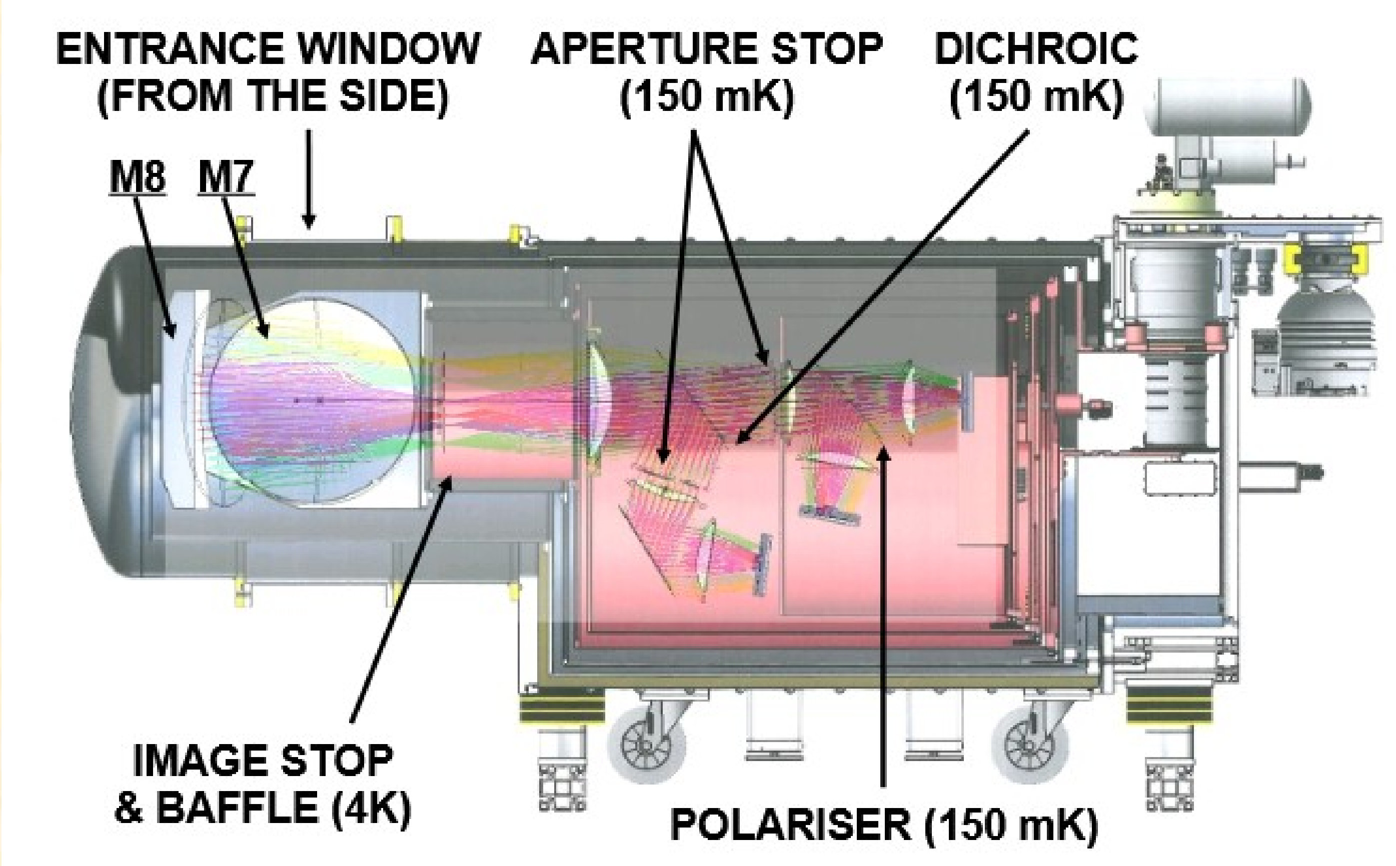
NIKA2 optics



Eight mirrors: - M1 to M4 common to other instruments

- M5 and M6 at 300K – M7 and M8

Three lenses: - one at 1K, two at base temperature

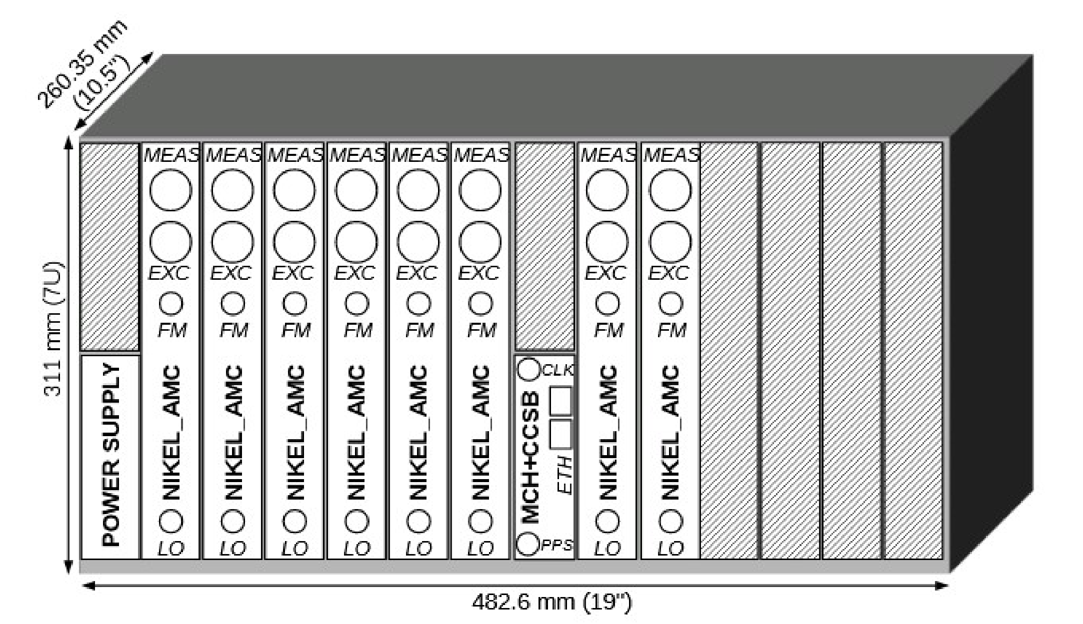
NIKA2 electronics

COLD

A number of properly selected and mounted passive components

LNA (Low Noise Amplis) from Yebes and TTI Norte

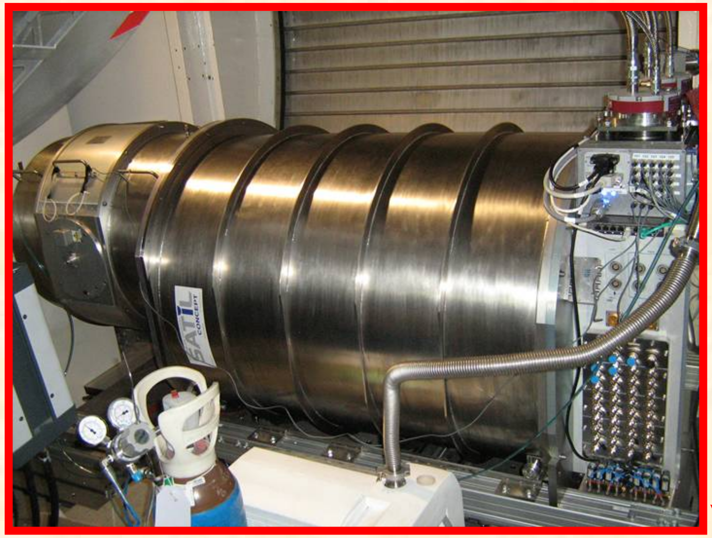
ROOM TEMPERATURE



NIKEL_AMC ad-hoc system:

- Bandwidth: 500MHz
- Up to 400 channels/board
- Maximum data rate 1KHz

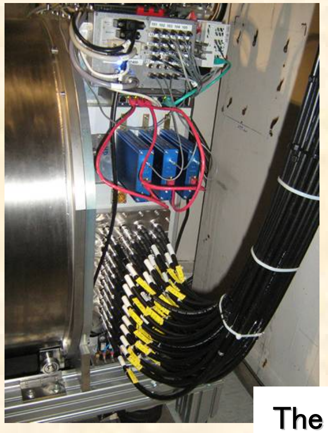
NIKA2 installation (10/2015)



The cryostat in the receivers cabin

60 meters of pipes

The dilution gas handling in the basement



The 40 COAX cables

NIKA2 figures:

- 2900 pixels over 3 arrays
- 1.2 tons; 2.5 m long; 3000 pieces
- Two Pulse Tubes
- Fully remote control
- Completely cryogen free
- Base T $\approx$ 150 mK

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NIKA2 summary

DATASHEET:

Instantaneous field-of-view: 6.5 arc-min

Bands: 125÷175 GHz and 230÷280 GHz

Angular resolution: 17.6 arc-sec and 11.1 arc-sec

Polarimetry at 260GHz (to be choosen as an option)

MAPPING SPEED:

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NIKA2 status

See for example M. Calvo, L. Perotto, N. Ponthieu, B. Ladjelate, A. Ritacco and other talks

NIKA2
Limitations
and
possible improvements

Dichroic: the story

DICHROIC 1 (rigid, 2015): 2mm beams not nice but transmission OK

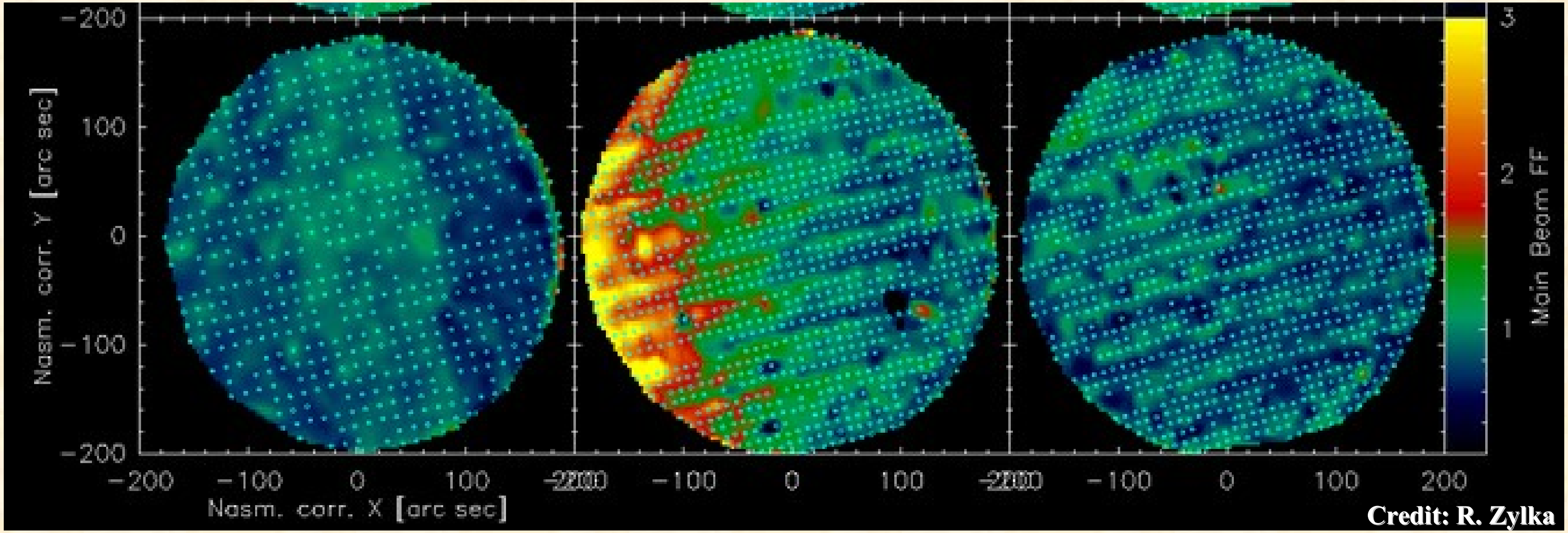
DICHROIC 2 (membranes, from 2016): 1mm transmission affected

DICHROIC 3 (rigid, 2018): 2mm beams destroyed but transmission OK

NOW <u>DICHROIC 2 back in place</u> (September 2018)

Dichroic: the problem

Array 2 **Array 1**



Credit: R. Zylka

The NIKA2 flat fields show, **<u>since the installation of dichroic 2</u>**, a striking (bad) feature in particular on Array 1. This results in practice in a penalty of sensitivity for the « 1mm band » of 20% (at least).

<u>N.B. Array 1 was by far the best « 1 mm » array</u>

Dichroic: possible solutions

THE LONG STORY:

DICHROIC 1 (rigid): 2mm beams not nice but transmission OK

DICHROIC 2 (membranes): 1mm transmission affected

DICHROIC 3: 2mm beams destroyed but transmission OK

PROBLEM:

the « membranes » dichroic cannot be optimised for transmission
AND the rigid ones bend (but ONLY when cold !!)

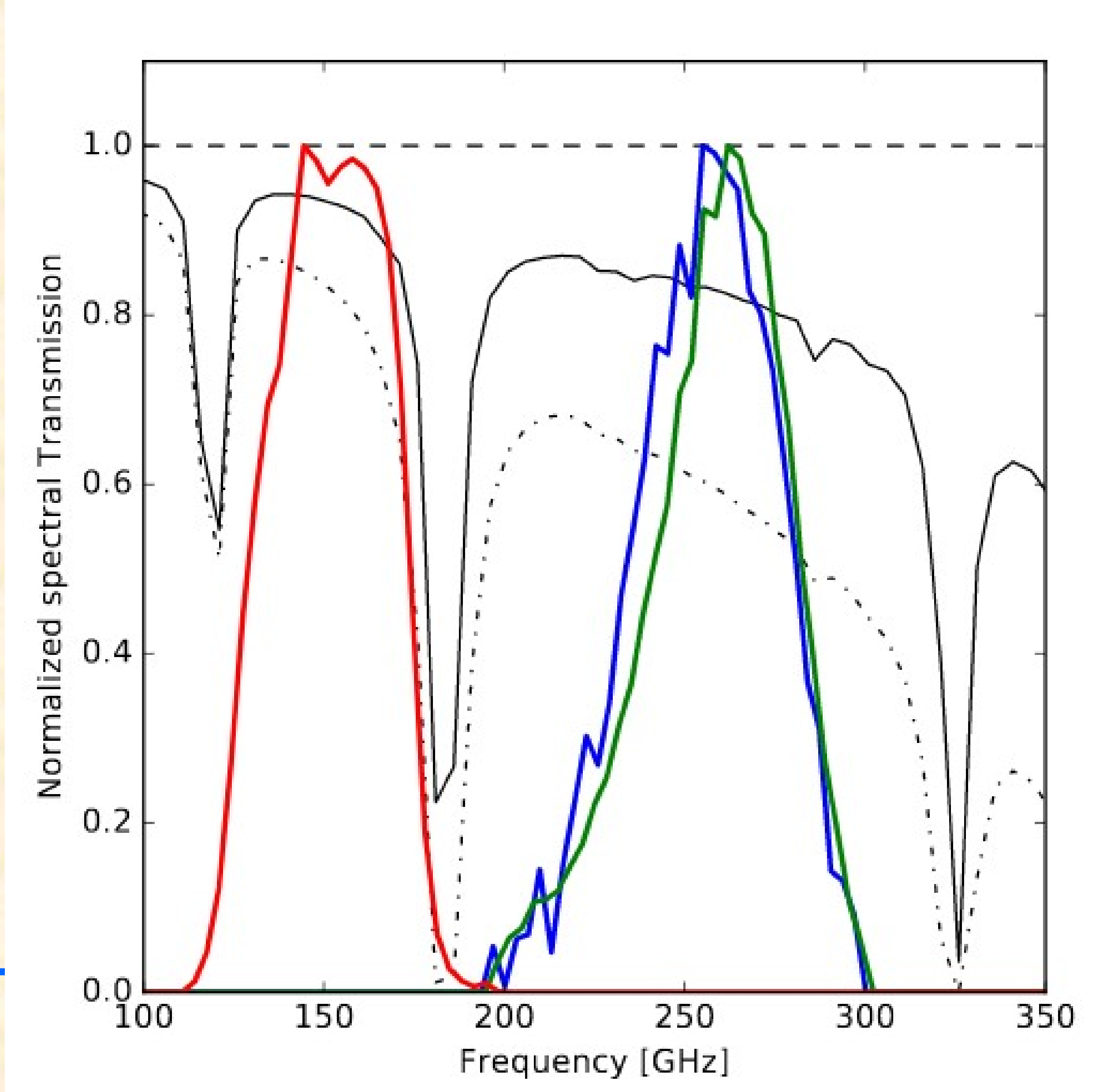
SOLUTION(S) (?):

We have demonstrated even in lab that it can bend. Strategies:
- « Try and error »: might converge but must accept work/risk
- « Proper engineering »: waiting for inputs. Risk≡0 ? YES for now

“1mm” arrays bandwidth

ADVANTAGE:
The present « 1mm » arrays were designed (after the NIKA1 experience) to be robust against high background and sky noise.

DRAWBACK:
They are not optimised for best sensitivity in best sky conditions

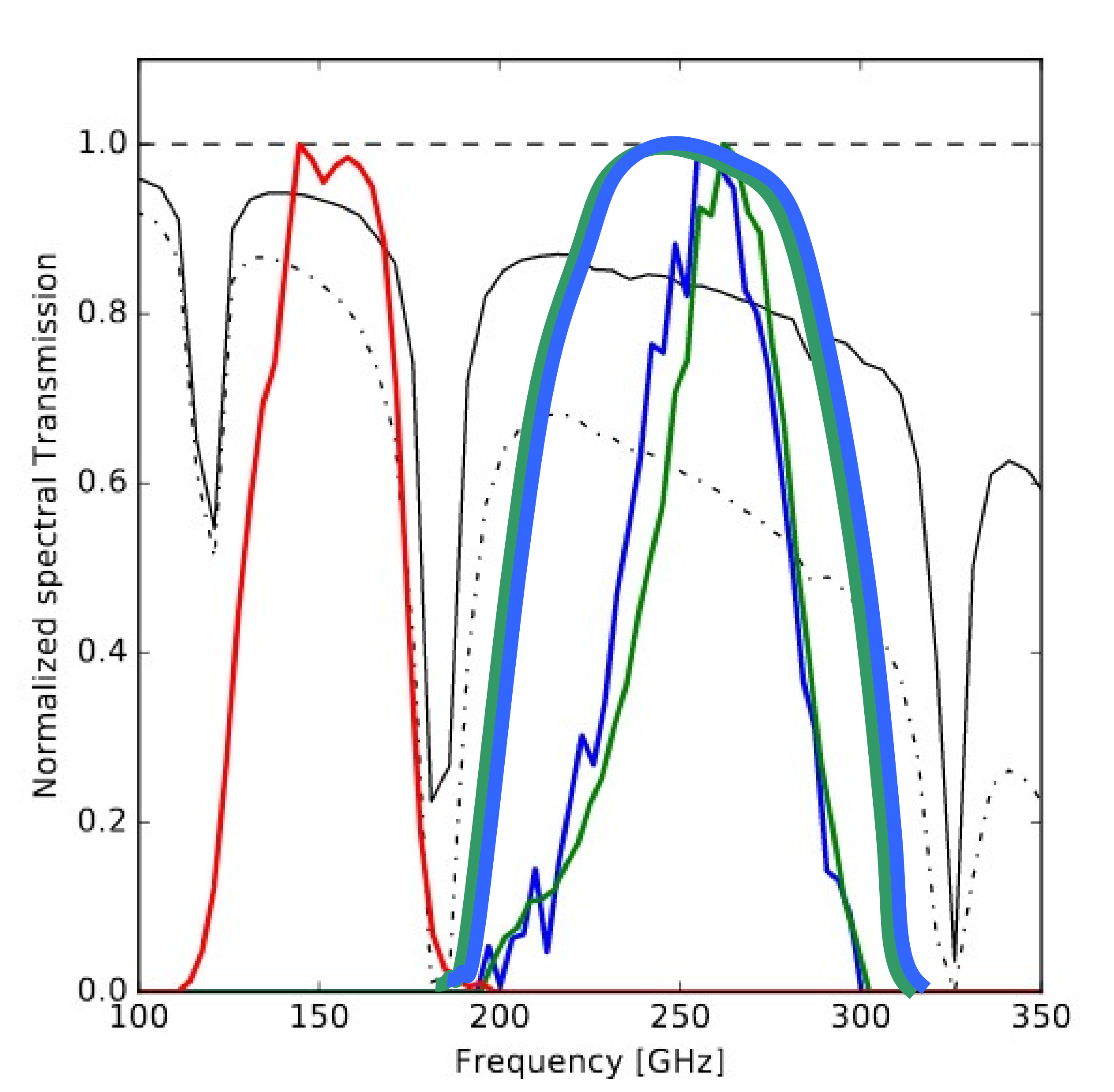


"new 1mm" arrays bandwidth

ADVANTAGE:
Optimised for best (but rare) sky conditions and high elevations

DRAWBACK:
Higher sensitivity goes with more stringent cuts on acceptable sky/elevation conditions

THREE SUCH ARRAYS AVAILABLE !



New 1GHz NIKEL electronics

For the CONCERTO project we are developing a larger band (1 GHz) warm electronics.

Once validated, it might be offered to NIKA2 (subjected to funding), allowing to:

- Eliminate (hopefully) the « sub-bands correlation » problem
- Reduce (to be debated within the collaboration) the pixels size to improve a bit the angular resolution
- Improve the cosmetics by « exploding the resonances »

Among pixels size and cosmetics, the best trade-off will have to be found.

Refractive Optics (not optimal)

<u>Known problem:</u> NIKA2 employs big/thick plastic lenses

Silicon/Sapphire lenses and ideal AR coatings would in principle allow:

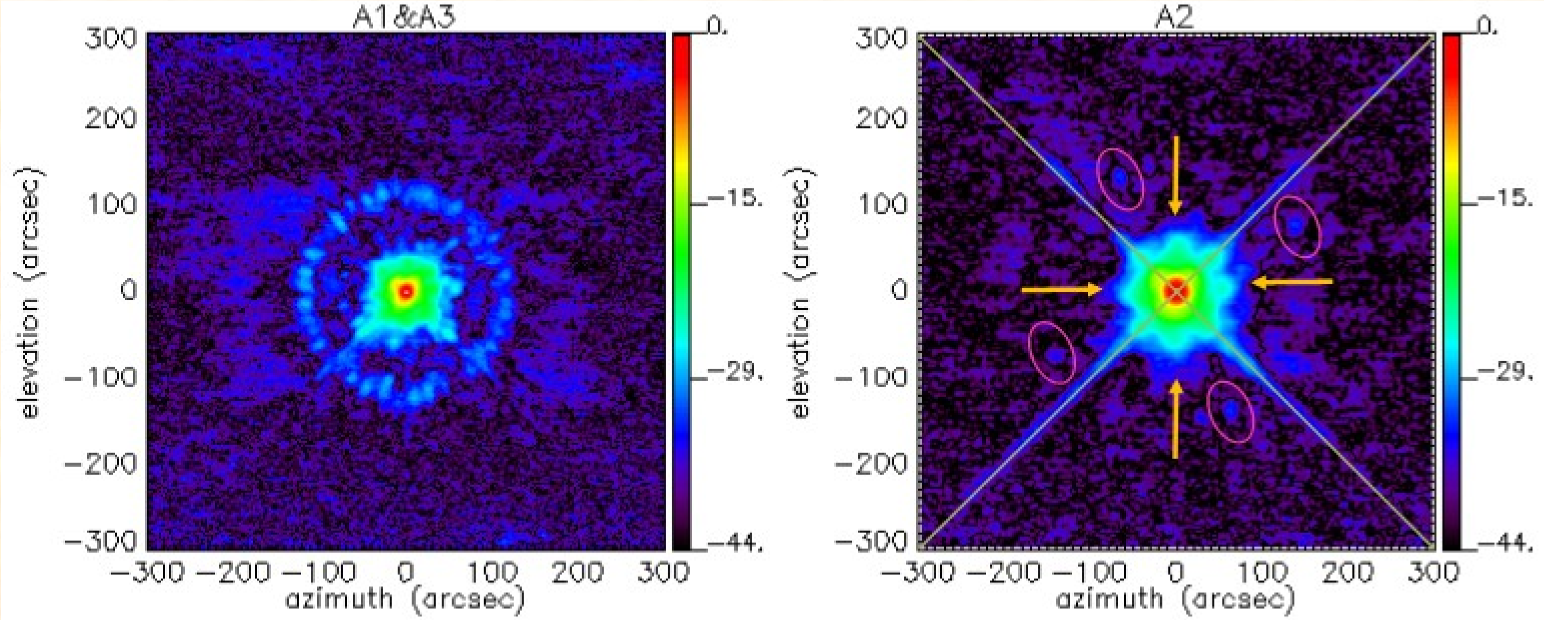
1) Significant (really) improvement of the overall optical transmission
2) Reduction of the background (for best observing conditions)

<u>BUT</u>

In practice this technology is not available, at least to our team, for such **big lenses** and to produce such an **ideal AR coating**.

<u>ALTERNATIVE:</u> we might have enough space in the NIKA2 Cryostat to design a purely reflective optics. Samuel ??

Telescope surface



« Telescope efficiency » = power in the main beam

55% at 260 GHz (reference beam 12.5' → 70% efficiency)
77% at 150 GHz (reference beam 12.5' → 85% efficiency)

→ A 20-30% sensitivity penalty for the 260 GHz band

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Cosmetics

Number of identified resonances → ~ 90% (e.g. 94% for array 2)
Number of pixels identified (with beams) in lab → ~ 90%
Number of pixels identified (with beams) at the telescope → 85-90%

Number of pixels used for maps after cosmetics cuts → ~ 70%

A fraction of the missing pixels might be saved by either:

1) Elaborating a procedure to « correct » the arrays (see S. Shu talk)
2) Further spacing the resonances (by-product of 1GHz electronics)
3) Producing/testing a number of arrays to pick up the best one

Mapping speed ≡ Sensitivity budget

150GHz → 9 mJy·s$^{0.5}$ → Great !
260GHz → 30 mJy·s$^{0.5}$ → Just acceptable, but WHY ?

How to explain the factor >3 difference ? Do we understand ?

Demonstrated penalties:

Dichroic ≈ 20%
Bandwidth ≈ 25% (mainly in best conditions)
Telescope ≈ 25%

LOGICAL ORDER OF PRIORITIES

Others more difficult to quantify (but favouring the 150 GHz):

- Background, refractive optics transmission, superconductivity …

Prudent estimation: 30·0.8·0.75·0.75 ≈ **13 mJy·s$^{0.5}$**

→ **NOTHING « BIG » TO BE UNDERSTOOD**

Ideas for a "NIKA3" ?

New bands ?

Examples:

- Splitting the « 1mm window » into two colors
- Adding a « 3mm array »
- … other ?

In any case:

- ANY CHANGE MUST BE DRIVEN BY **SCIENCE CASES**
- MUST NOT AFFECT THE **POLARIMETRY** CHANNEL
- MUST NOT AFFECT THE 6.5arc-min **FIELD-OF-VIEW**
- HAS TO TAKE INTO ACCOUNT **NEW INSTRUMENTS** THAT WILL BE OPERATED SOON (e.g. LMT, APEX…)

Low-resolution spectroscopy ?

We have developed KISS (see A. Fasano talk), and are building CONCERTO (see G. Lagache talk) for the APEX 12-meters telescope

Transforming NIKA2 into a **spectral-imager** (low spectral resolution, 3-D imager) **MUST BE POSSIBLE**, mostly by radically redesigning the cabin optics. Minor changes (or no changes) to the cryostat.

- Spectral resolution, e.g. **$R = \lambda / \Delta\lambda = 10 \div 50(100)$**
- Angular resolution → preserving the NIKA2 one

May be better to wait the CONCERTO (on APEX) first results to see if it is promising on such a big telescope.

Conclusions

1) The 150 GHz channel is traditionally the best combination of optics/detectors/electronics/telescope/observing site

2) The 260 GHz channel is less performing (but we understand why)

Hardware actions:

- Optics: dichroic (Cardiff) → **PRIORITY**
- Arrays:
  - Cosmetics (IRAM-Néel): ongoing
  - Larger band (Néel): achieved, arrays available
- Electronics (LPSC) → **FROM CONCERTO**
- Telescope (IRAM)
- Study a purely reflective optics ??? (IRAM)

Software actions:

- Have a data analysis pipeline available to the external observers

Organisation:

- Exploiting the best observing conditions for continuum observations