CMB-CAL @ BICOCCA

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FOCUS
Focal Plane Array for Universe Sensing

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CENTRE NATIONAL D'ÉTUDES SPATIALES

POLARIZATION DETECTION WITH KIDS FOR THE NEXT GENERATION OF CMB TELESCOPES

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Milan - November 6, 2024

WHY DO WE NEED A PRECISE ABSOLUTE POLARIZATION ANGLE CALIBRATION?

Calibration challenge

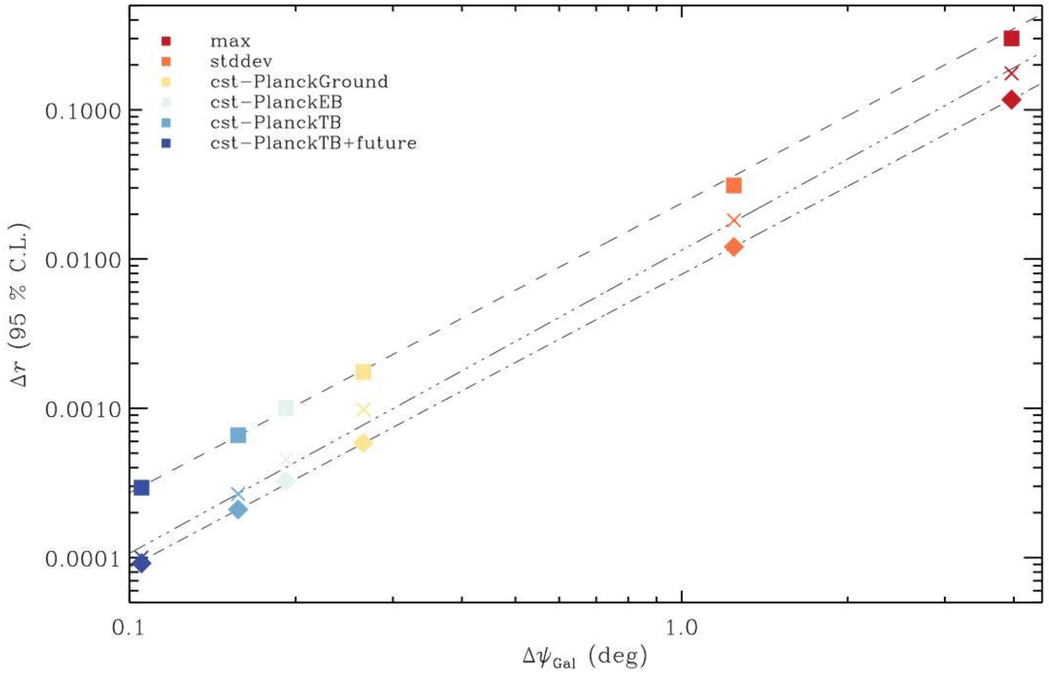
sub-degree accuracy for cosmological parameter constraints ($r = 0.01$ demands error $< 0.1°$)

GOAL

demonstrate that LEKIDs are a competitive technology applicable to CMB instruments

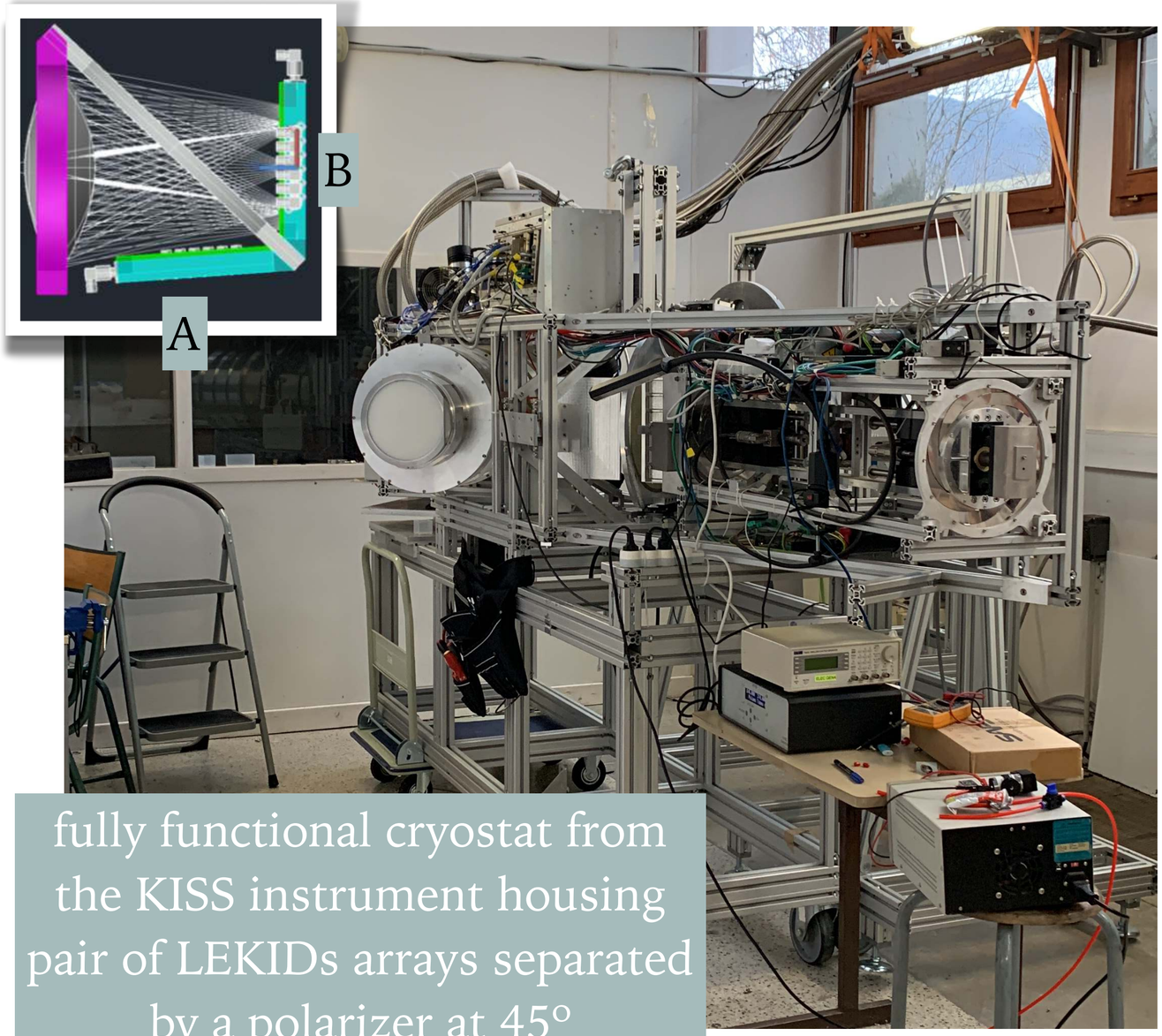
APPLICATION

French KIDs-based SAT for SO

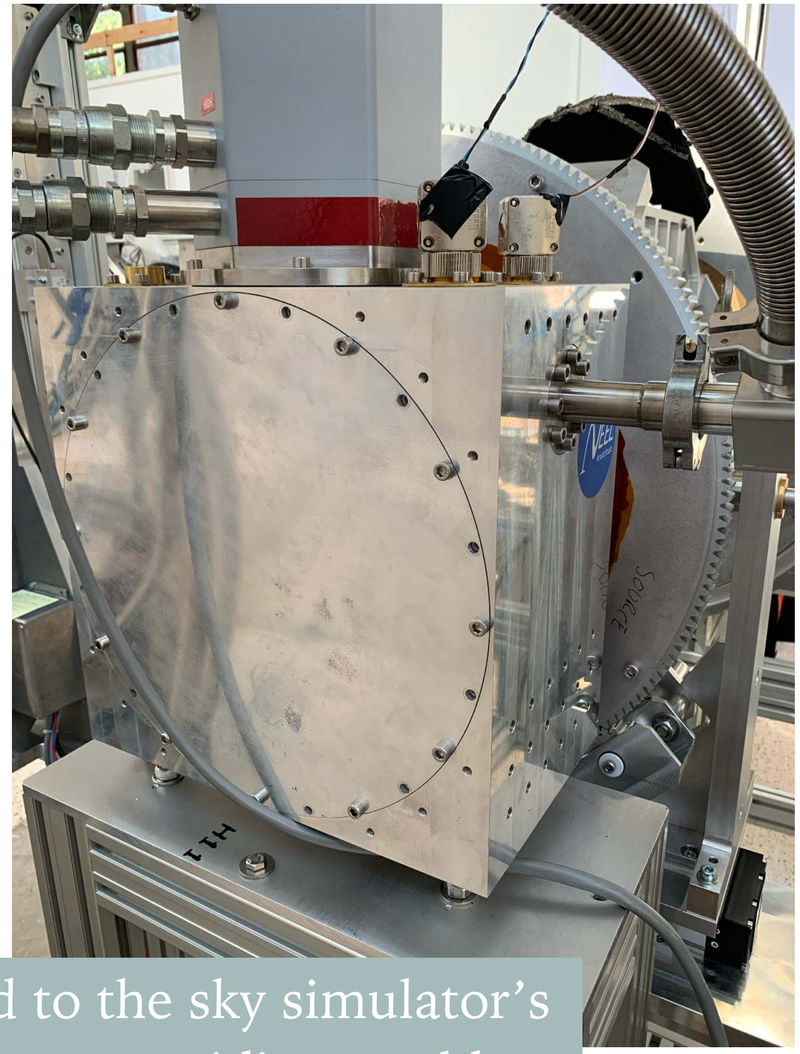


Aumont et al, 2020

A FULLY-EQUIPPED FACILITY TO SIMULATE REAL OBSERVING CONDITIONS

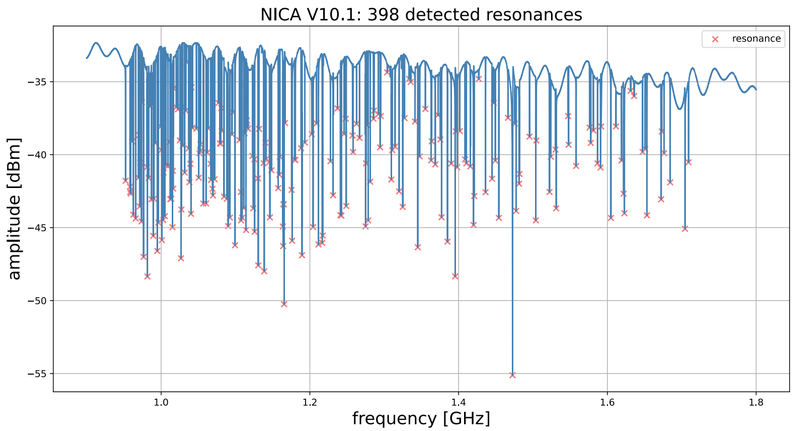


fully functional cryostat from the KISS instrument housing pair of LEKIDs arrays separated by a polarizer at 45°

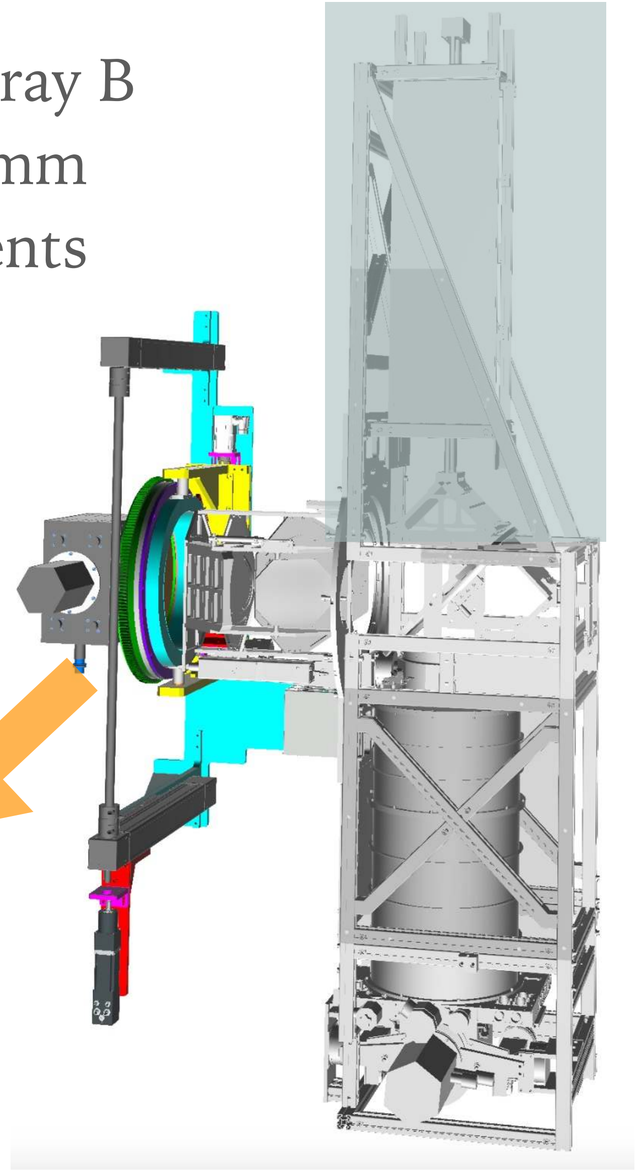


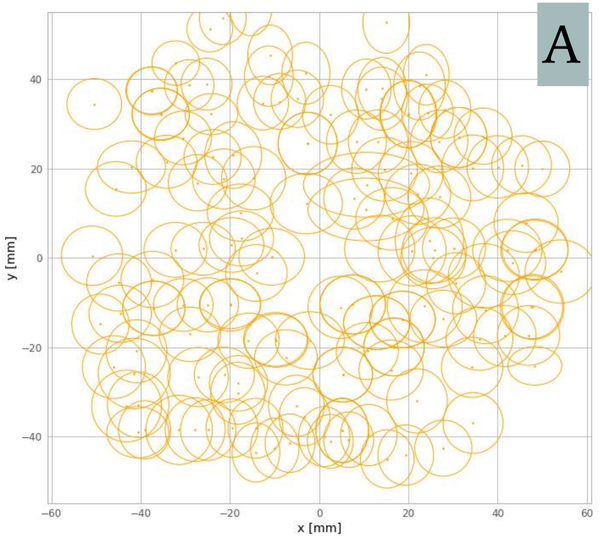
coupled to the sky simulator's cryostat providing a cold background as the atmosphere

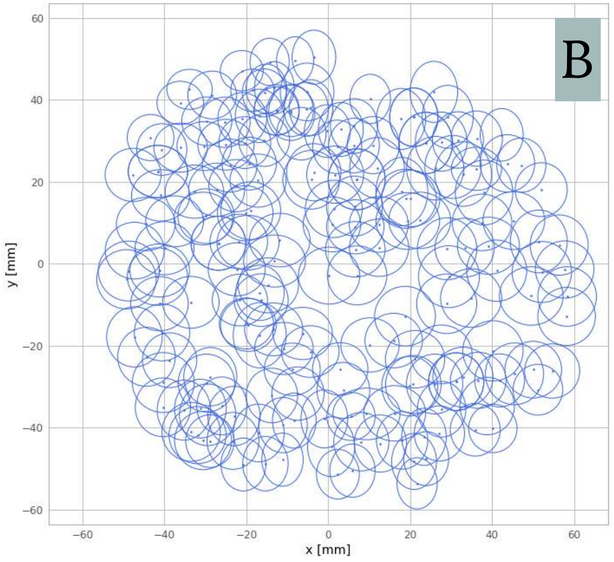
PHOTOMETRY : POINT-LIKE UN-POLARIZED SOURCE FOR FOCAL PLANE GEOMETRY



feedline of array B used for 2 mm measurements

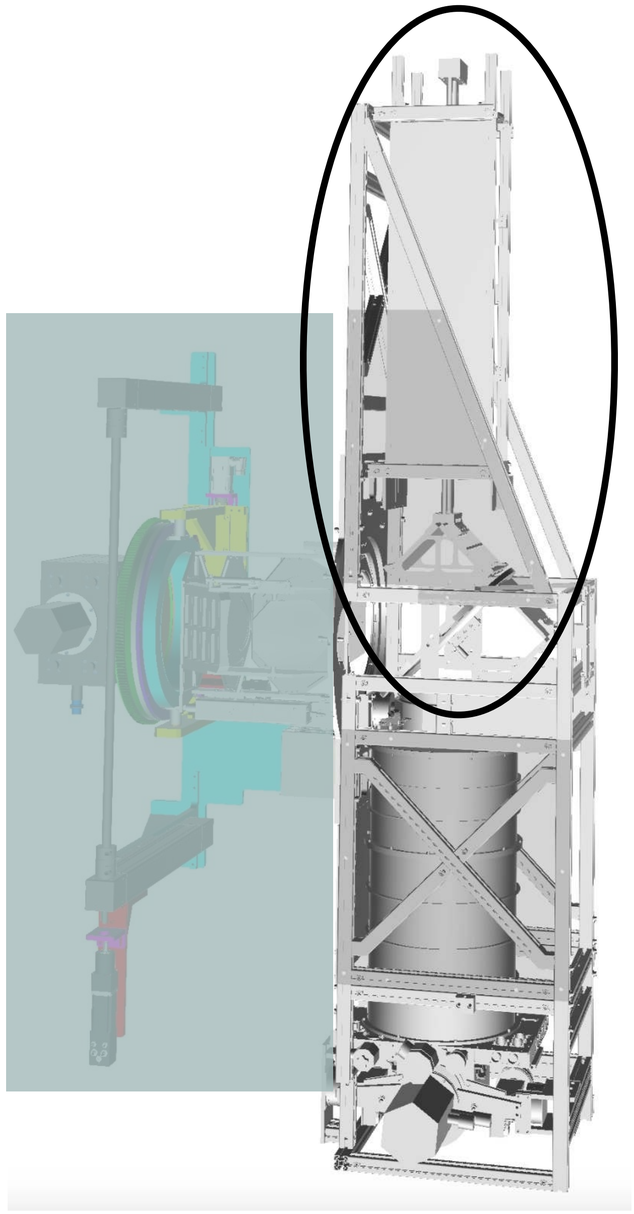






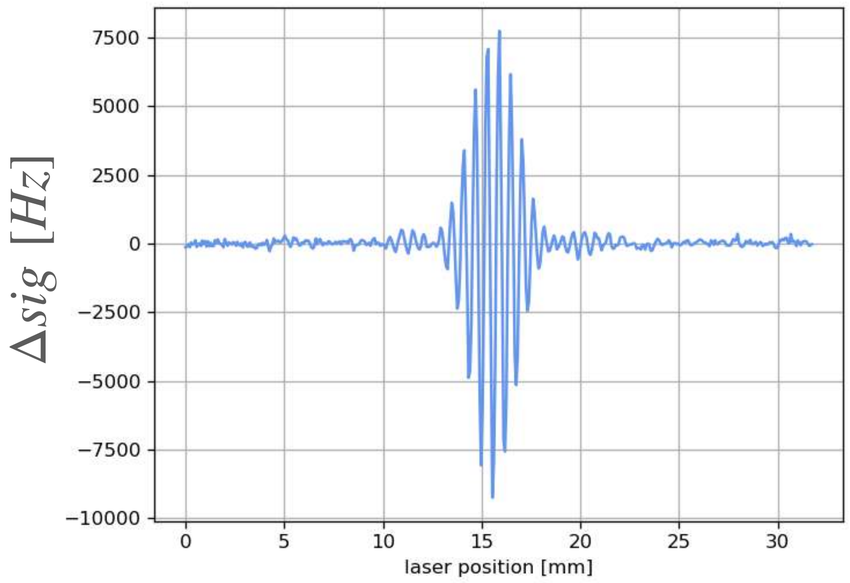
scan the point-like un-polarized source to obtain focal plane geometry (position and beam)

SPECTROSCOPY : INTERFEROGRAMS AND BANDWIDTH

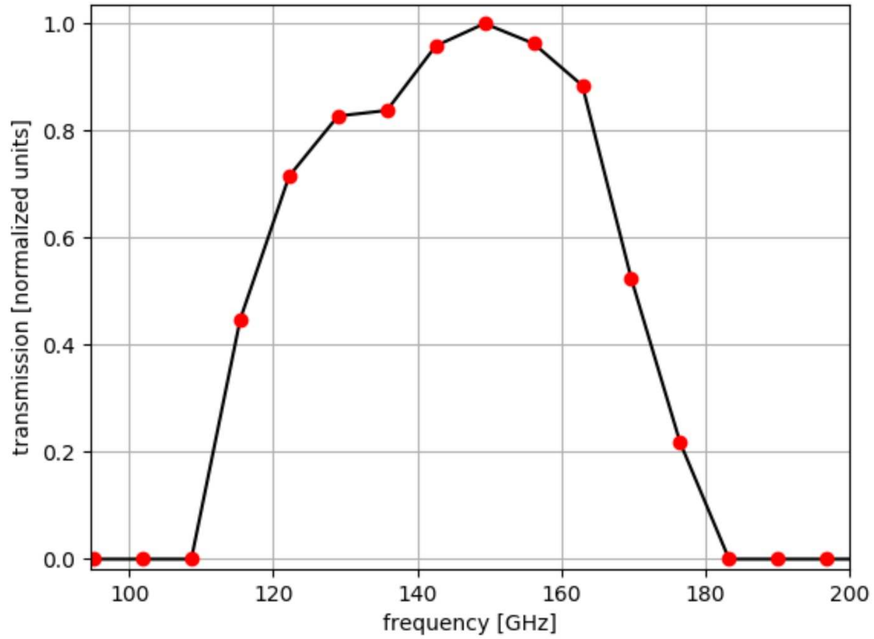


Martin-Puplett interferometer for spectroscopy

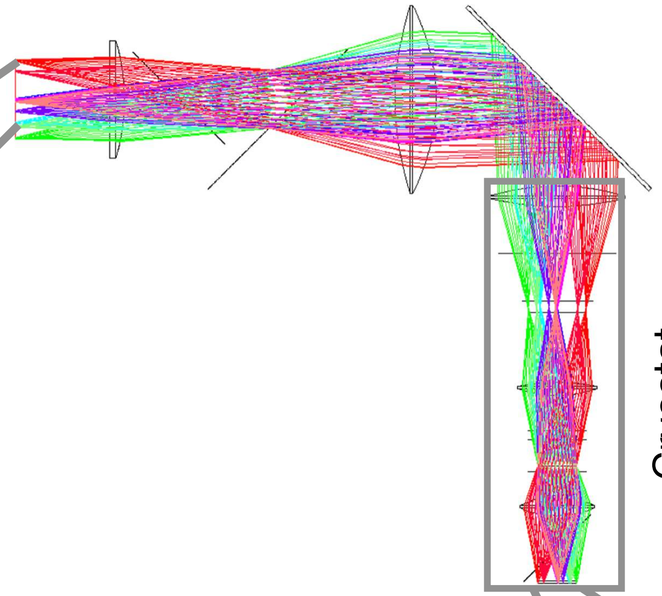
interferogram



110 - 180 GHz or ~2 mm



LEKIDS FOR CMB POLARIZATION : IN-LAB PROOF OF CONCEPT



compare source's polarization with detected

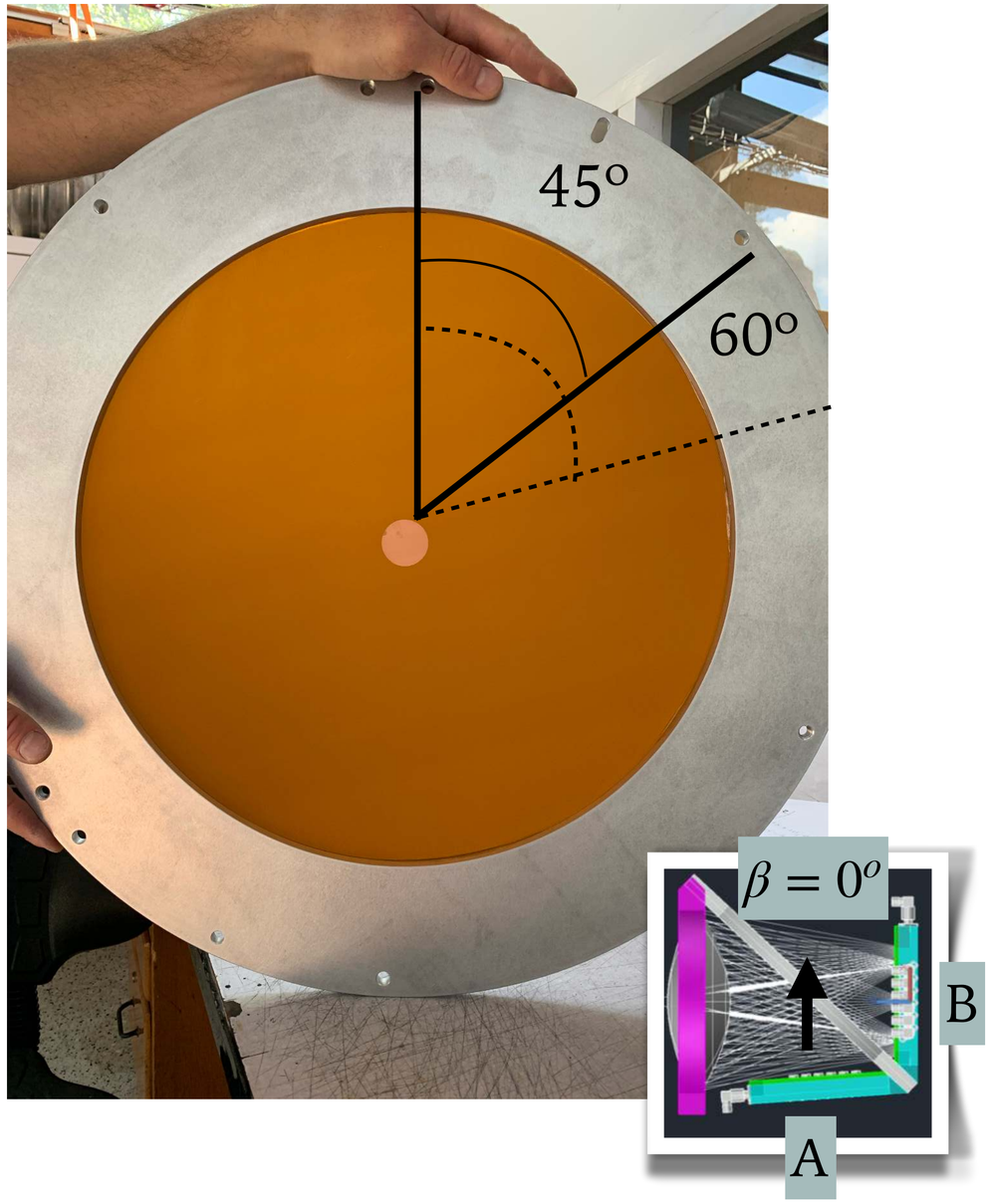
→

the difference gives the **systematic effects contribution**

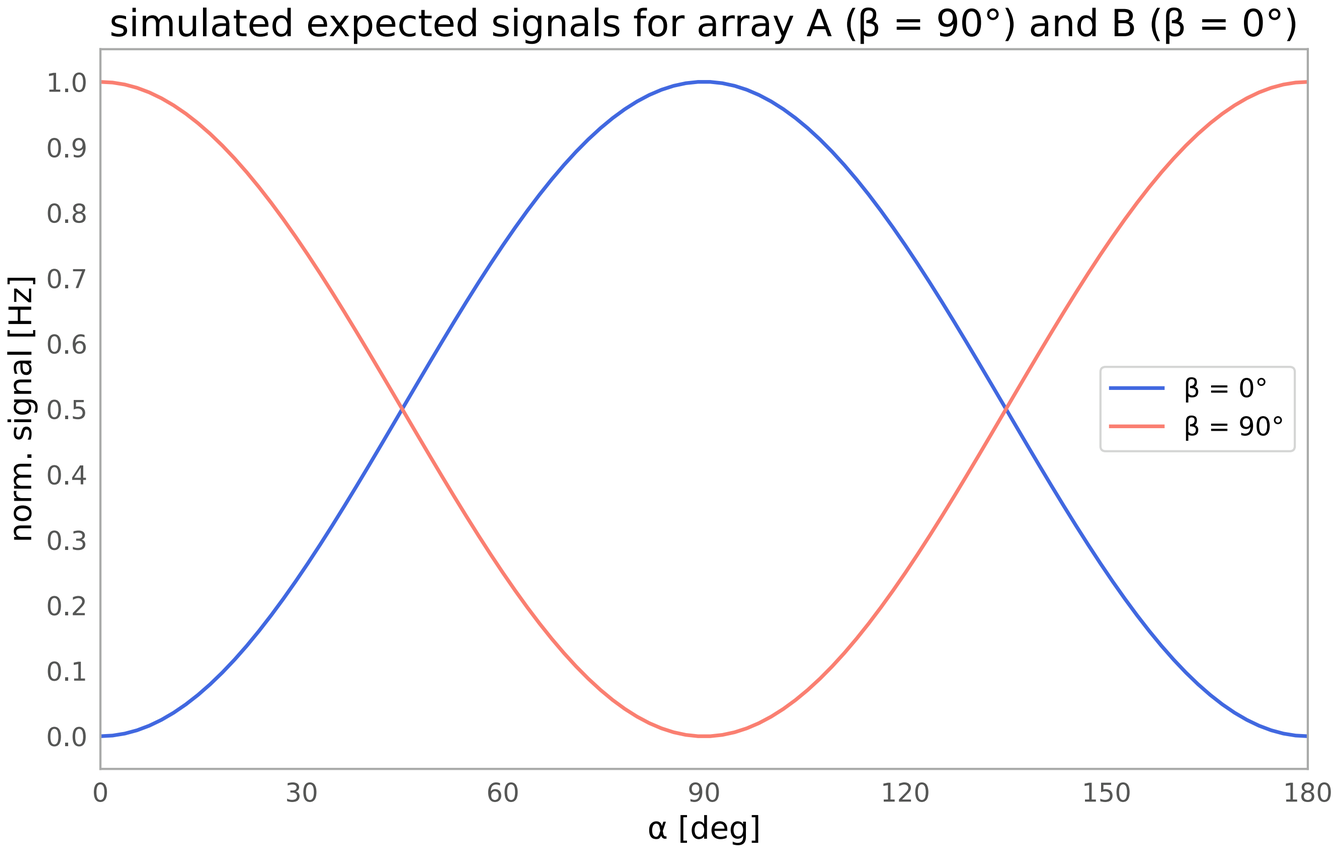
PolarKID R&D Project:

Can we use LEKIDs in a filled array configuration to measure polarization?

MEASUREMENT STRATEGY AND MODEL

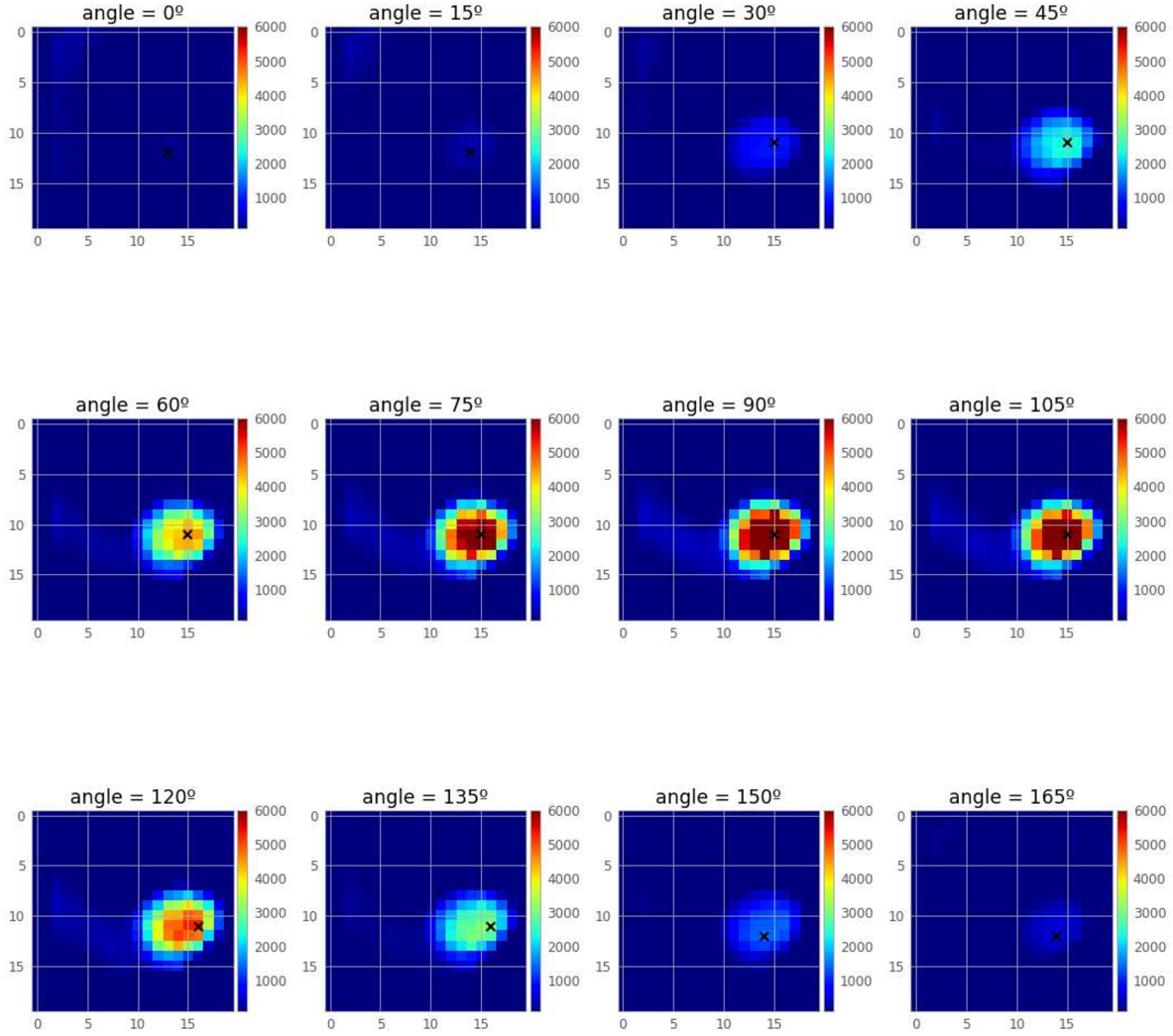


scan the linear polarizer at various angles to reconstruct the fully polarized signal incident on the two orthogonal arrays

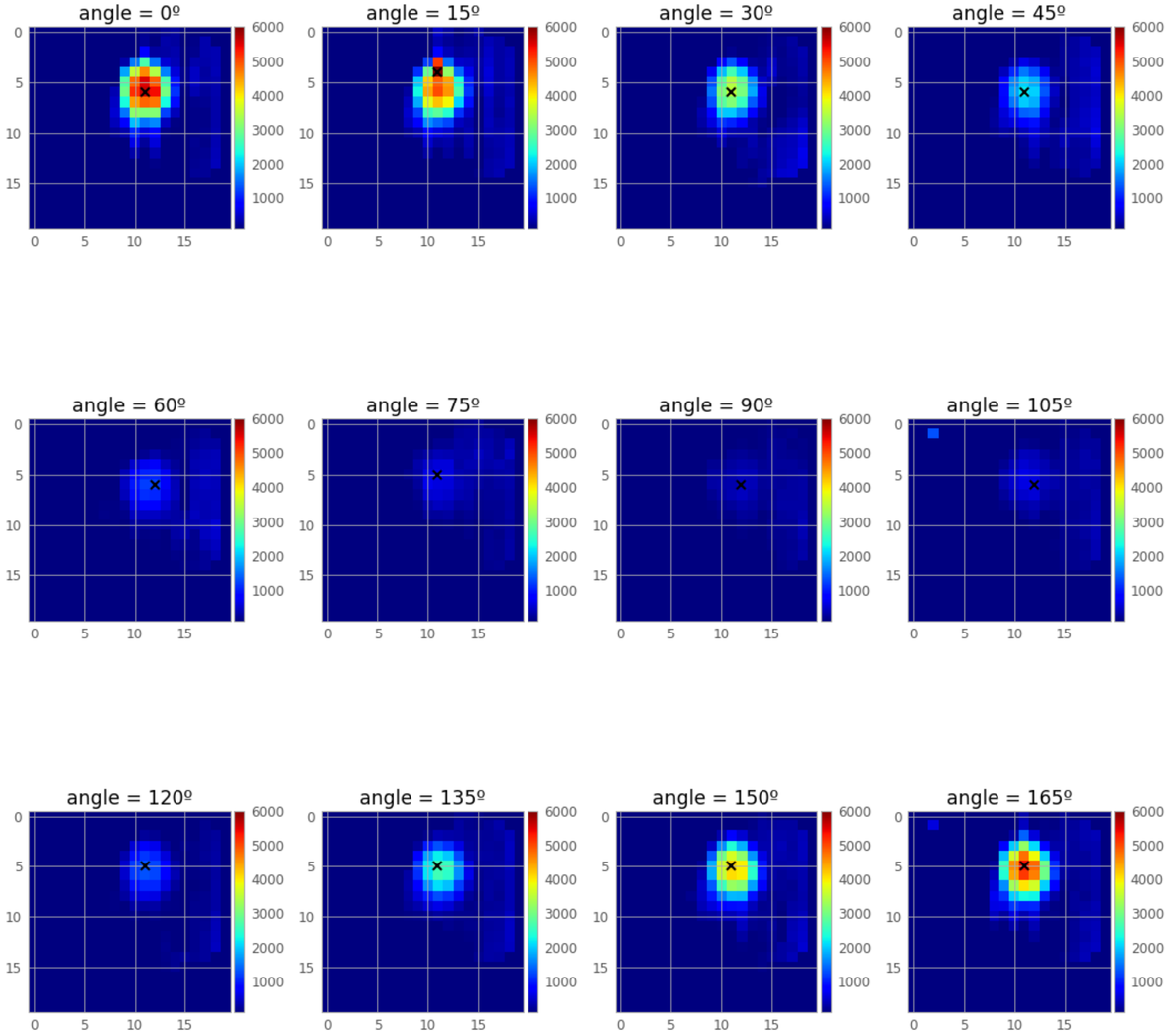


PRELIMINARY RESULTS: COMPLEMENTARY MAPS ON THE TWO ARRAYS

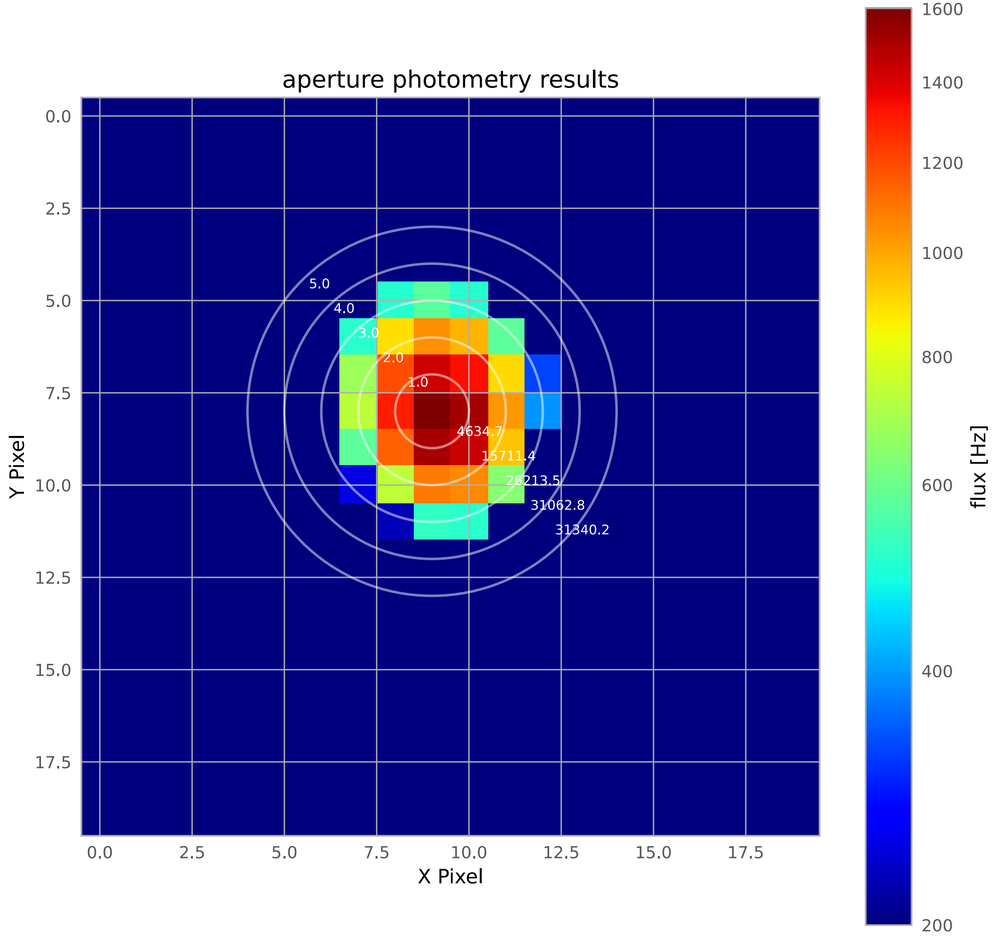
array B : transmission



array A : reflection

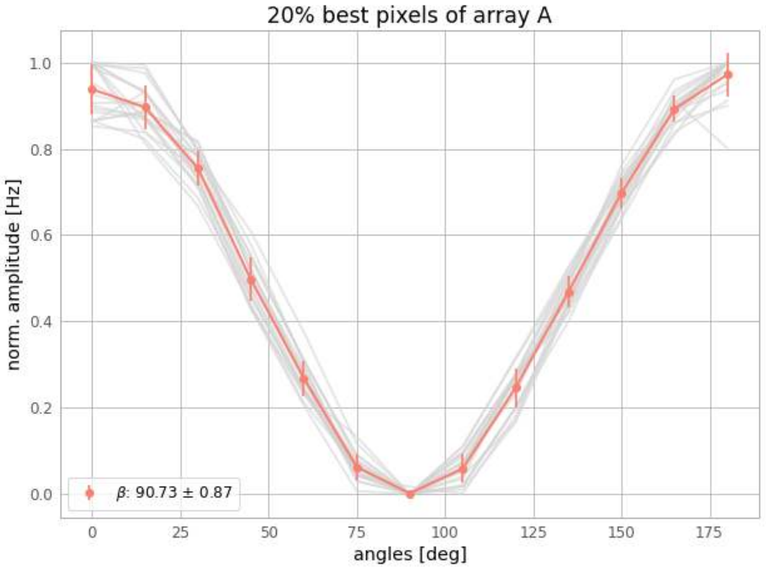


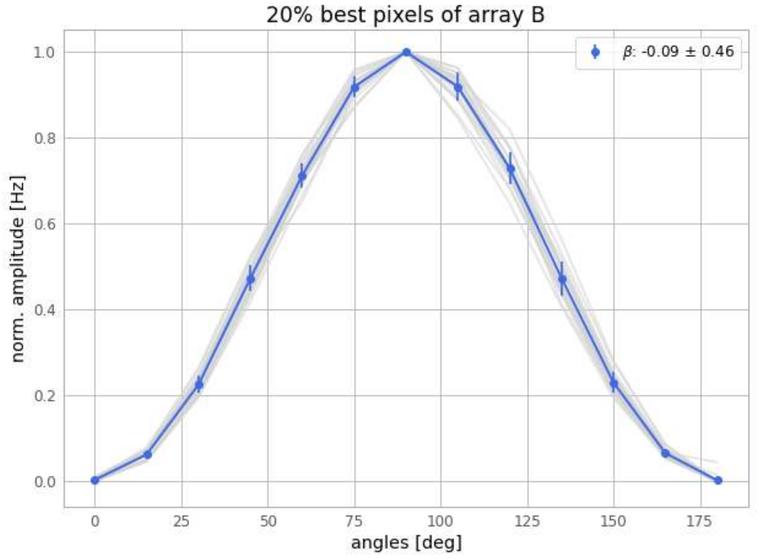
PRELIMINARY RESULTS: BEST PIXELS ANALYSIS



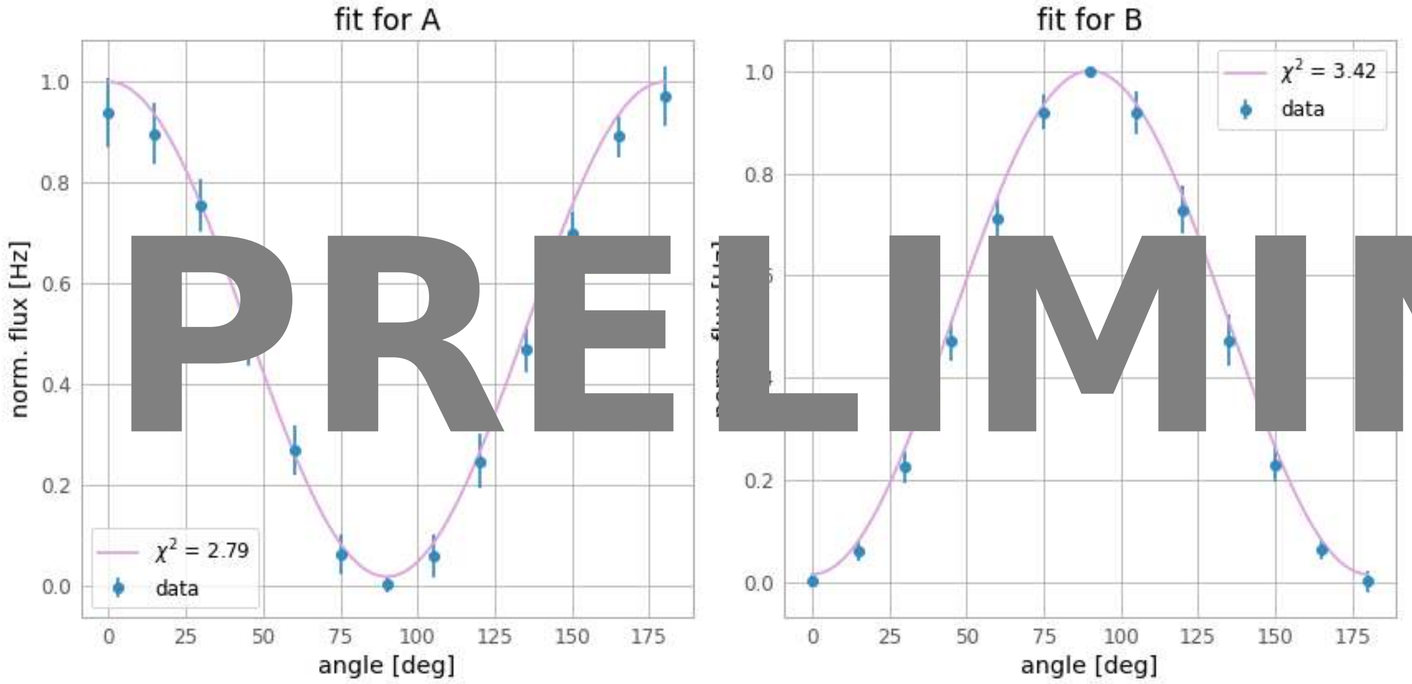
aperture photometry

- intensity per angle per pixel
- average over 20% best pixels
- fit curves to model

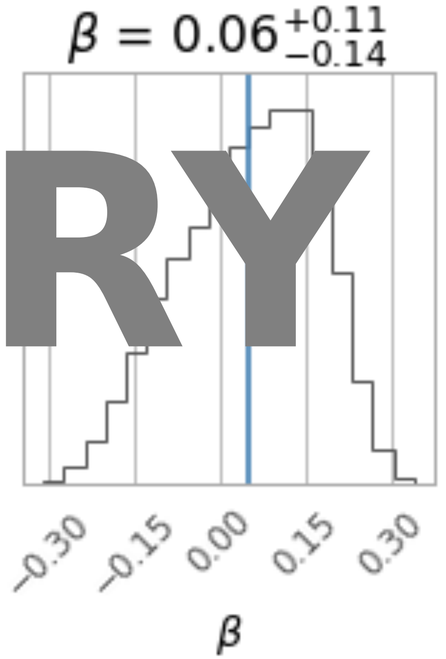




PRELIMINARY RESULTS: FIT OF POLARIZATION ANGLE



Savorgnano et al, in prep



Model function derived through Stokes and Mueller formalism:

$$S = 1 + sin2\beta cos2\alpha + cos2\beta sin2\alpha$$

fitted parameter:

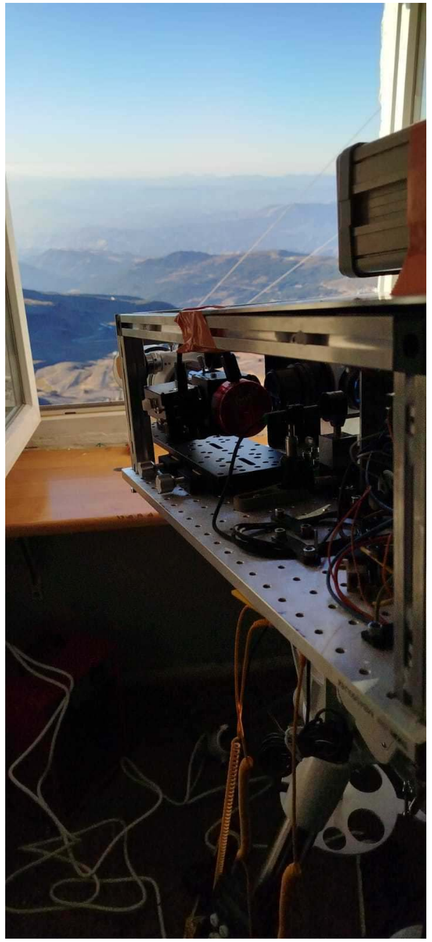
$$\beta = 0.06^{o} \pm 0.11^{o}$$

no systematics

in agreement with requirements

OUR PLATFORM ACCESSIBLE FOR OTHER EXPERIMENTS : COSMOCAL
PROOF OF CONCEPT AND SUBSEQUENT STEPS OF THE PROJECT

in-lab proof of concept → IRAM 30m → on a satellite in geo-stationary orbit



A. Ritacco's talk

COSMOCAL MEASUREMENT STRATEGY : IN-LAB & @IRAM 30M

- **FIRST STEP :** ensure signal detection through KIDs arrays
- **SECOND STEP :** align the source's main beam to the cryostat/antenna
- **THIRD STEP :** rotate the COSMOCal polarizer and capturing fixed track scans
- … compare results between KIDs arrays, diffraction pattern and photogrammetry

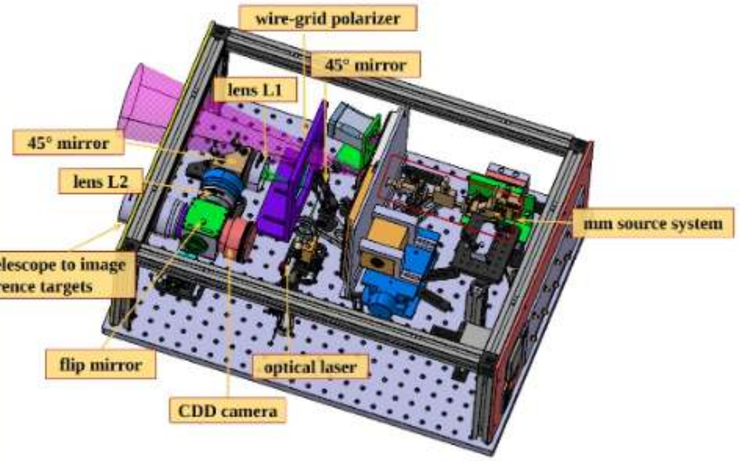
check L. Bizzarri's poster !

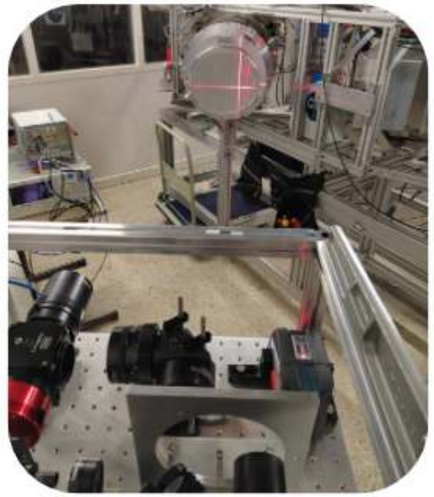
COSMOCAL : IN-LAB PROOF OF CONCEPT – LPSC, FEBRUARY '24

Freq. 260 GHz

Built in Paris:
LPENS,
Observatoire de Paris.

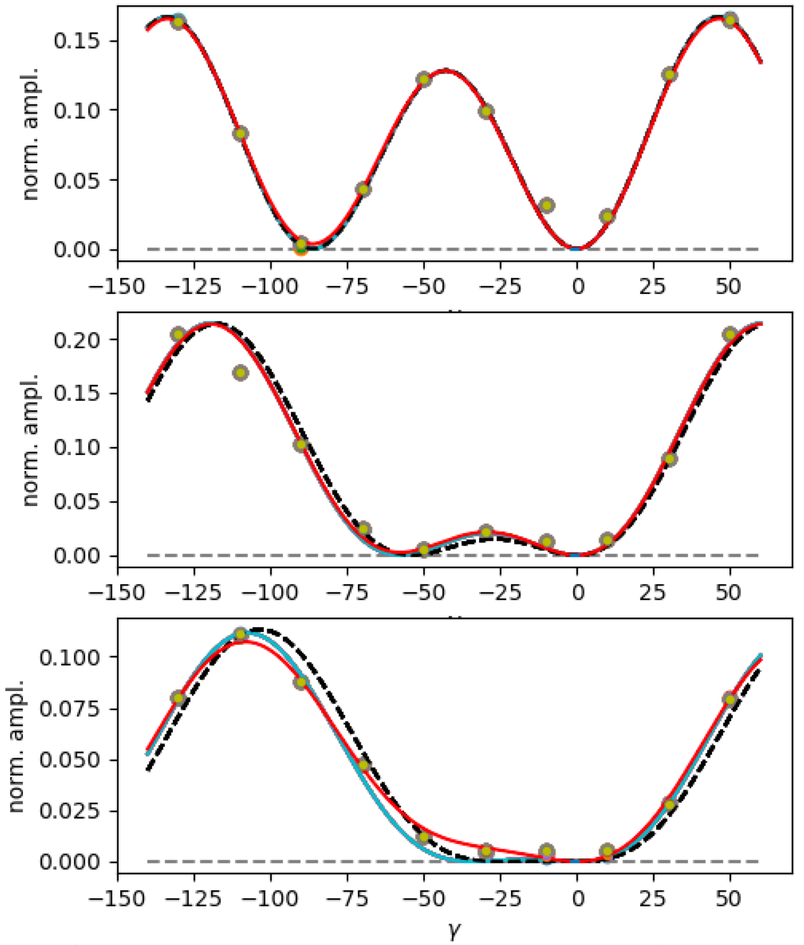
Tested in Paris & Grenoble:
LPENS, IAS,
LERMA, LPSC.





Laboratory measurements

Goal: 0.1 deg.
Results: 0.06 deg.

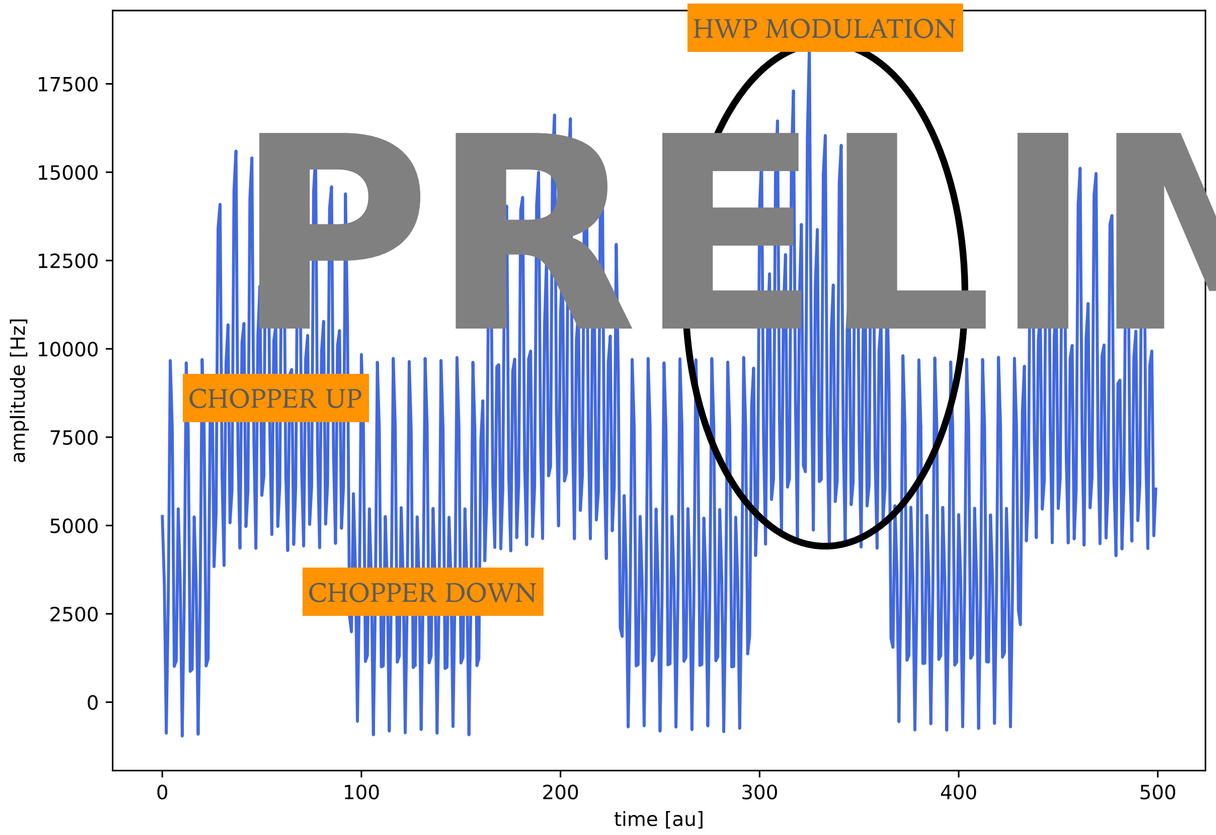


ψ_{box}	ψ_{det}	A	B	ϕ
(4.357 ± 0.069)°	(4.3 ± 0.7)°	0.146 ± 0.002	0.0116 ± 0.0001	(77 ± 5)°
(36.539 ± 0.077)°	(35.6 ± 0.9)°	0.069 ± 0.003	0.023 ± 0.005	(78 ± 6)°
(64.724 ± 0.066)°	(63.8 ± 0.8)°	0.027 ± 0.003	0.012 ± 0.004	(76 ± 5)°

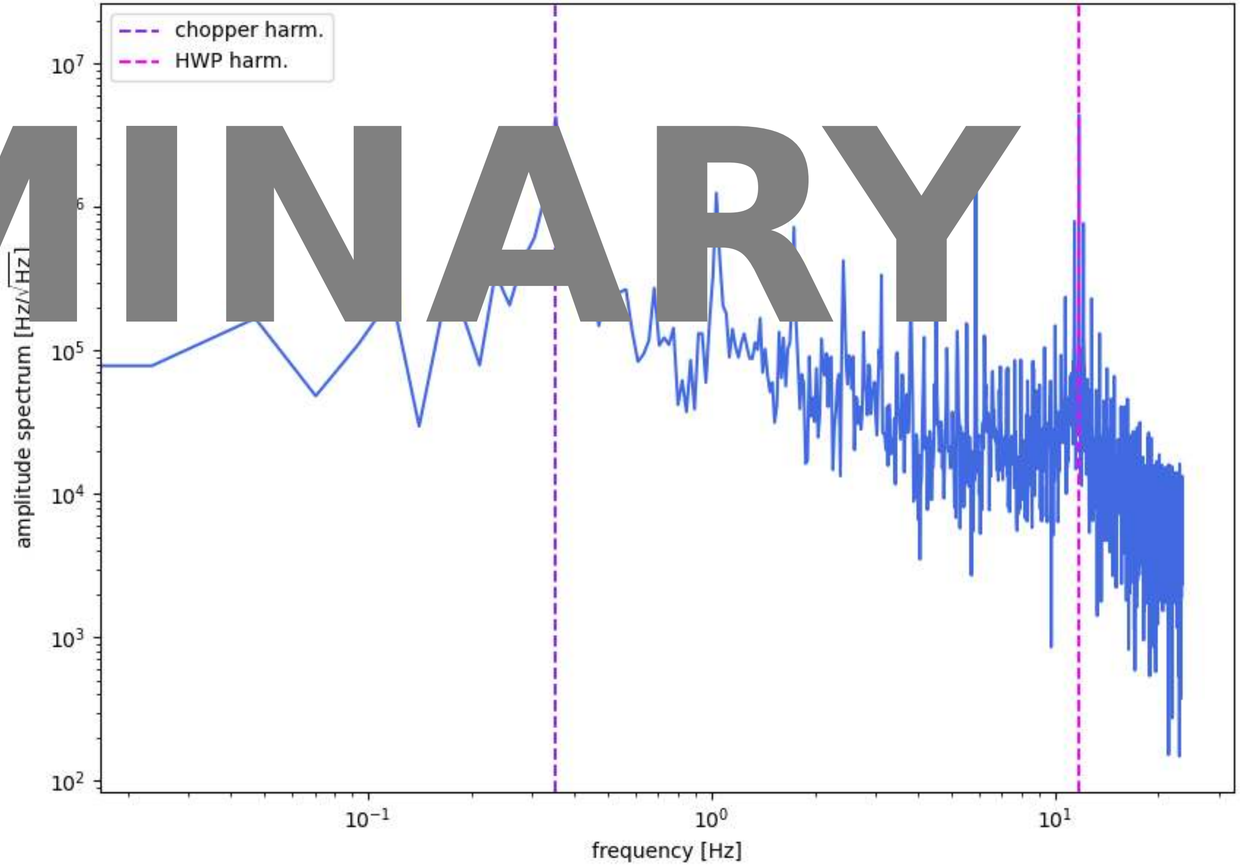
Ritacco, Bizzarri, **Savorgnano** et al, PASP, 2024

1. FIRST DETECTION BY NIKA2- RAW SIGNAL AND ITS CHARACTERISTICS

typical timeline for a sample pixel

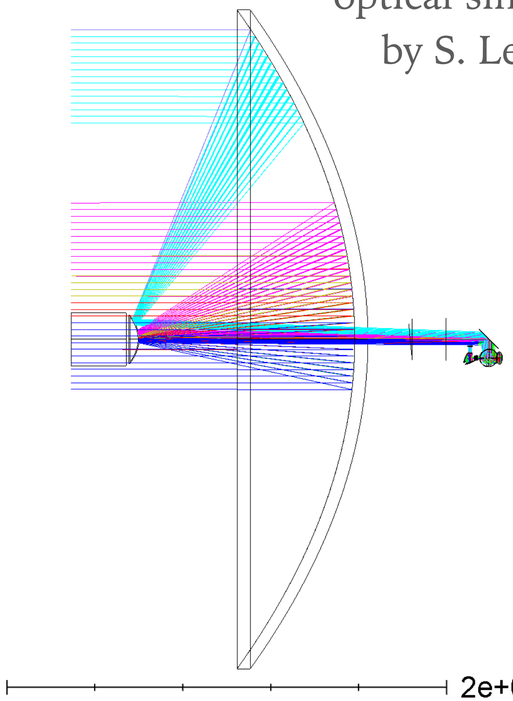


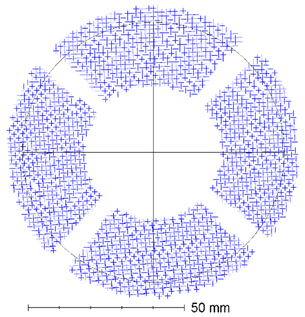
amplitude spectrum showing chopper and HWP harmonics

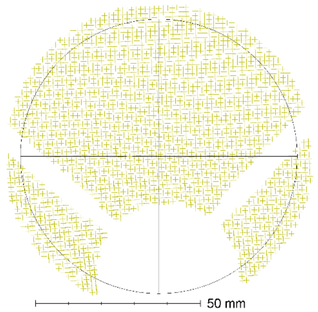


2. FINDING THE OPTIMAL ALIGNEMENT

optical simulations
by S. Leclercq





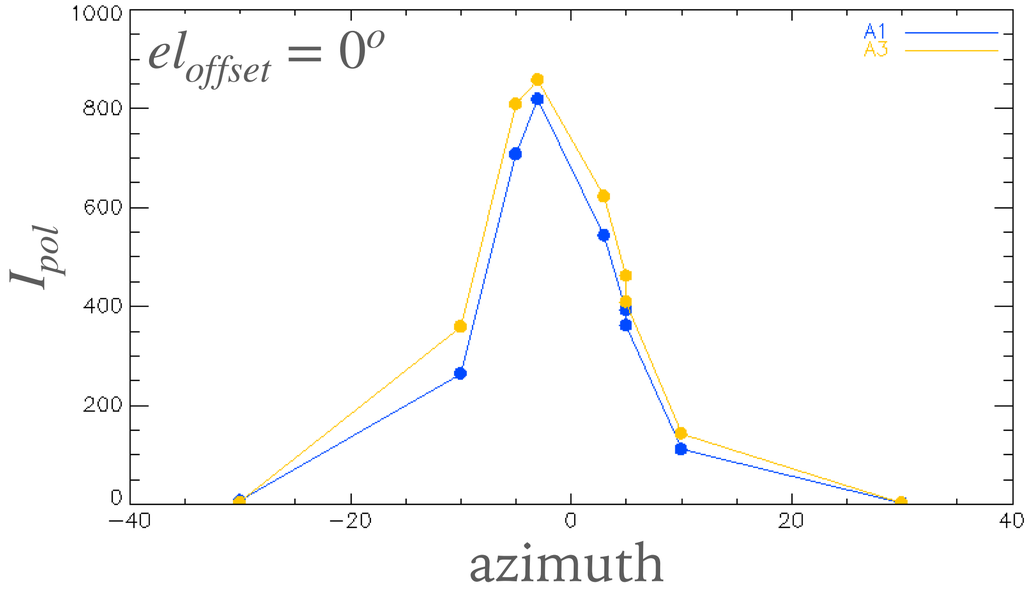


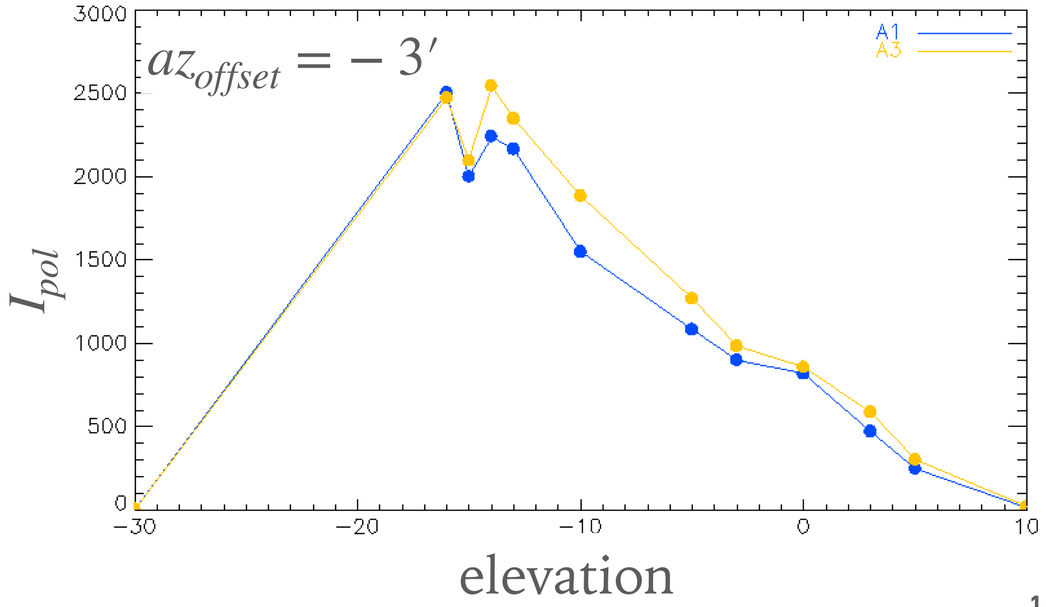
3’ tilt of the source gives 2 m tilt on the primary

careful with alignment!

source’s coordinates:
[116.18º, 10.24º]

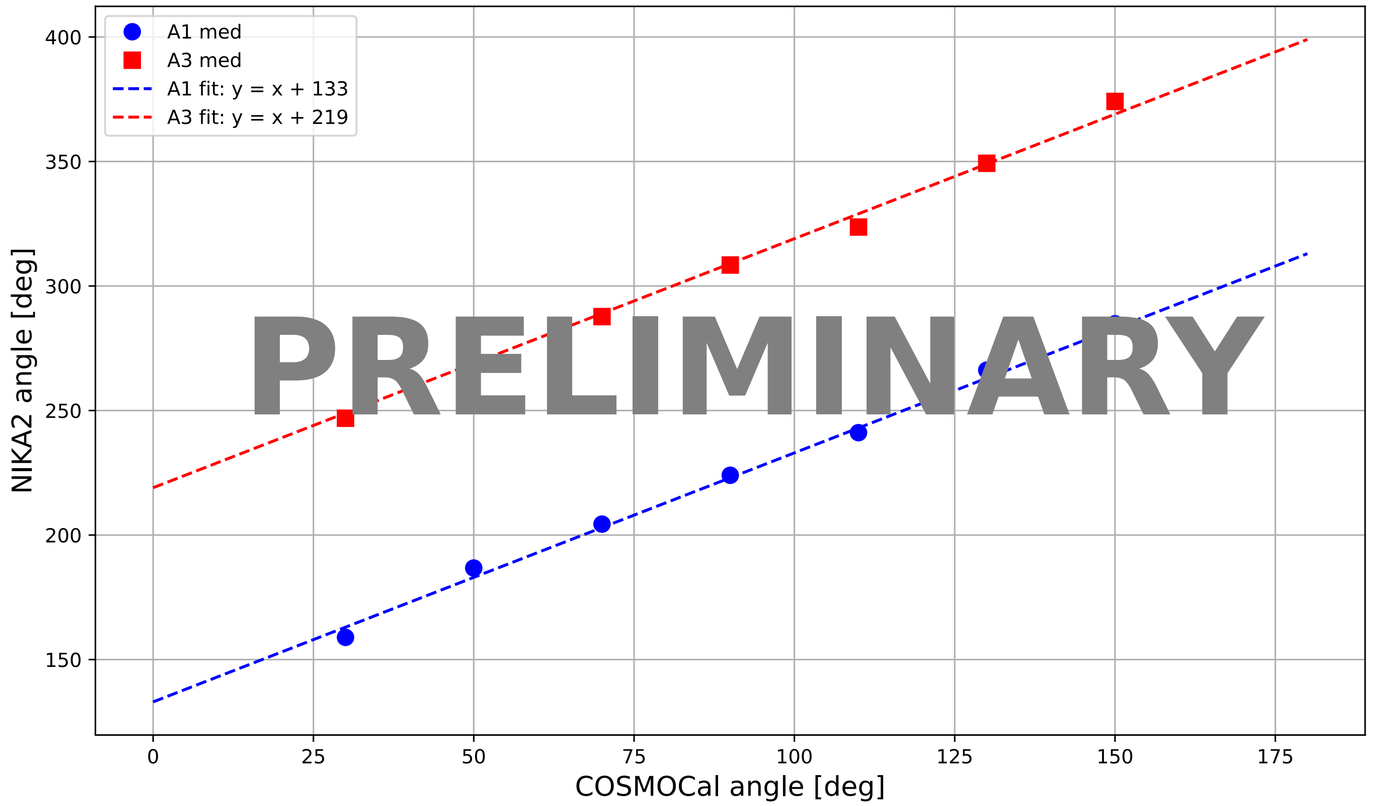
best-alignement offsets:
[-3’, -16’]





3. POLARIZATION MAPS : DETERMINE POLARIZATION ANGLE WITH <0.1° UNCERTAINTY

- **GOAL :** find correspondence between NIKA2 and COSMOCal detected polarization angles
- **STRATEGY** : turning COSMOCal's polarizer and acquiring fix track scans
- **RESULT** : perfect correlation
- **PERSPECTIVE** : further analysis is ongoing



TAKE-HOME MESSAGES

- At LPSC, we dispose of a **fully-equipped facility** that simulates real observing conditions and represents an excellent tool to test KIDs technology
- The POLARKID project results proved that LEKIDs used in a filled array configuration can assure **precisions suitable for cosmological polarization experiments**
- By confirming these **results at 1 mm** too, we would be ready to employ this technology for future experiments such as the KIDs-based French SAT
- The **first COSMOCal campaign** at IRAM 30m showed promising results and further analysis is ongoing

THANK YOU !