POLARIZATION MEASUREMENT AND CALIBRATION WITH KIDS FOR THE NEXT GENERATION OF CMB INSTRUMENTS

A. Catalano

Sofia Savorgnano

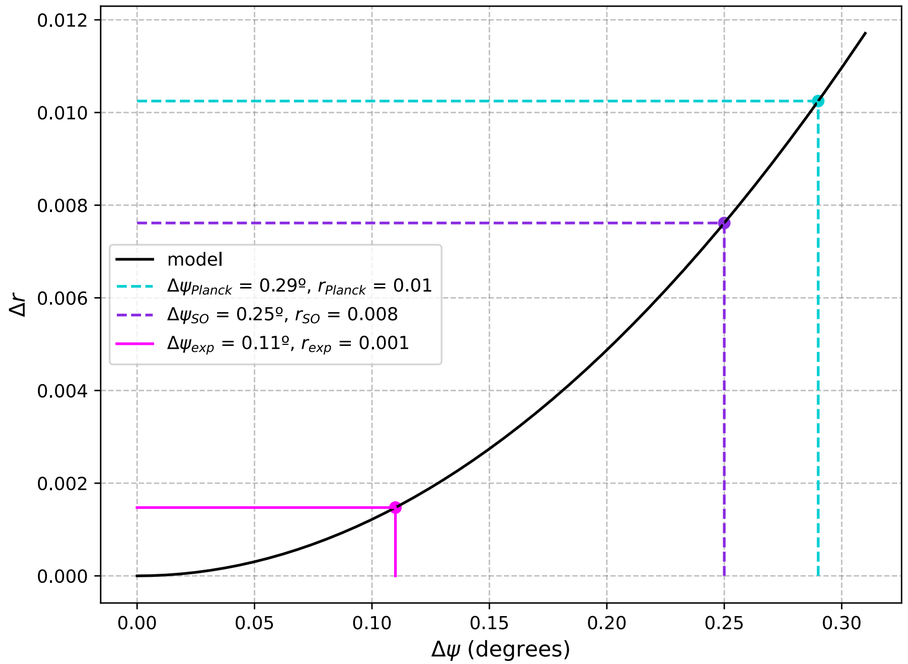
A. Monfardini

CMB France #6, IHP Paris - December 19, 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 < 0.1º)



Savorgnano et al, in prep

GOAL

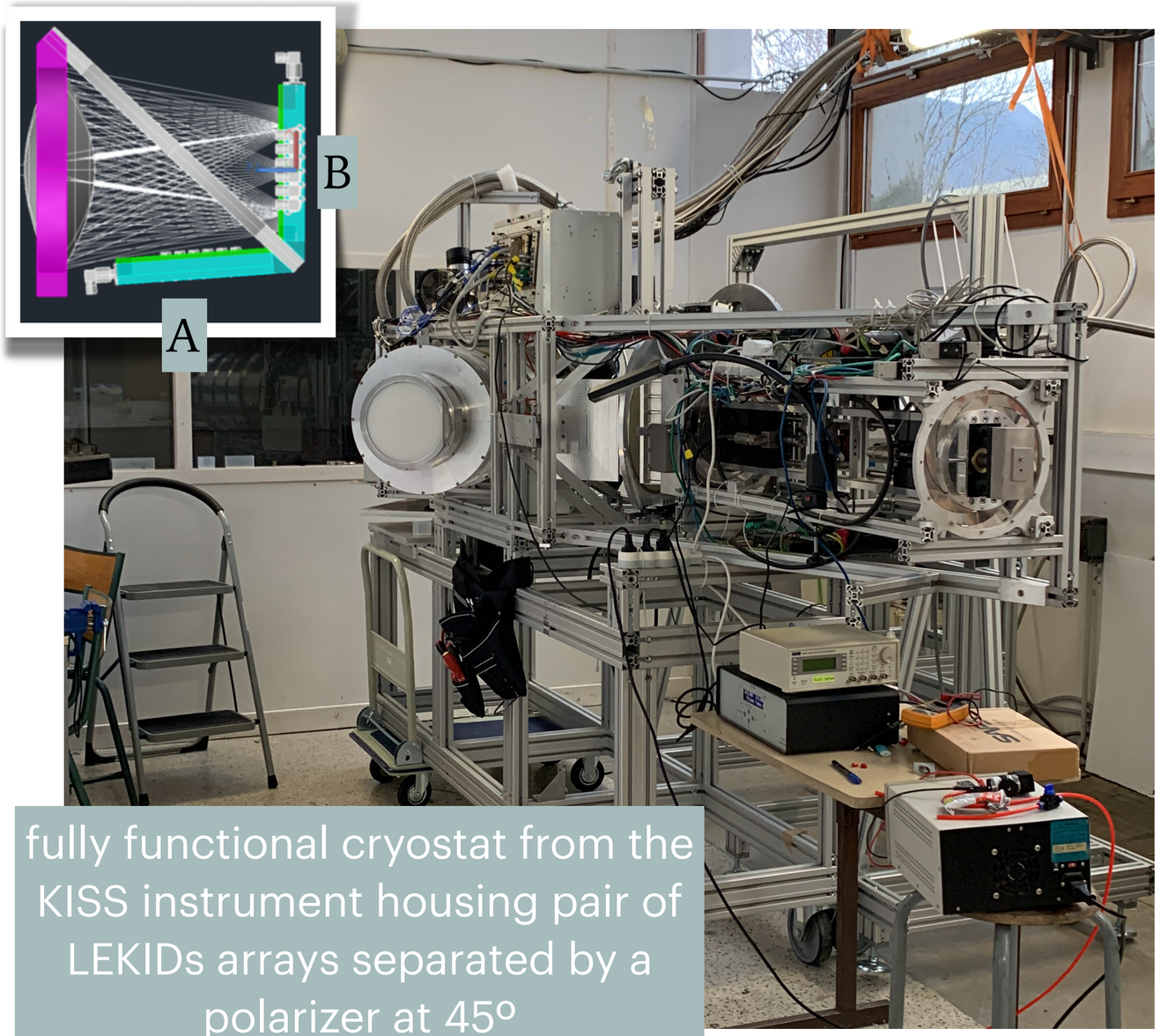
demonstrate that LEKIDs are a competitive technology applicable to CMB instruments

APPLICATION

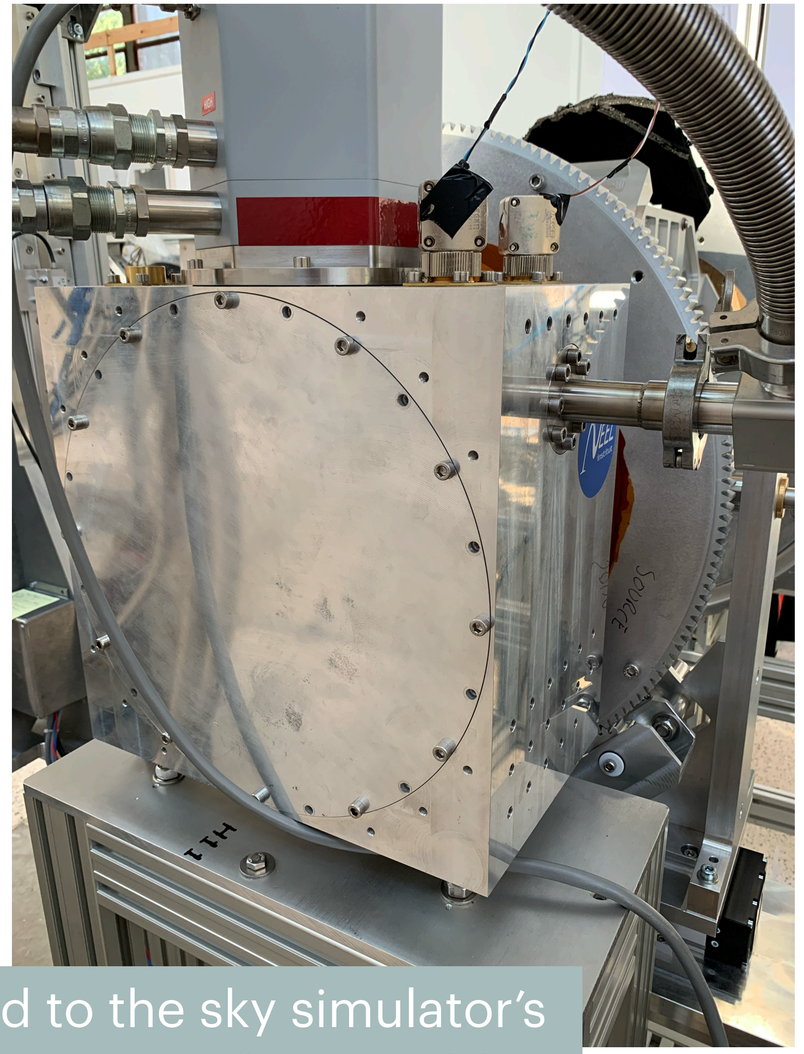
French KIDs-based SAT for SO (KAIROS project)

A. Catalano's talk

A FULLY-EQUIPPED FACILITY TO SIMULATE REAL OBSERVING CONDITIONS

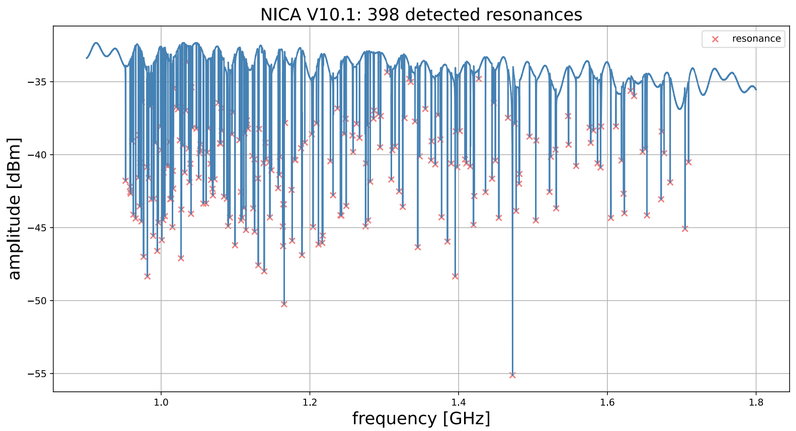


fully functional cryostat from the KISS instrument housing pair of LEKIDs arrays separated by a polarizer at 45º

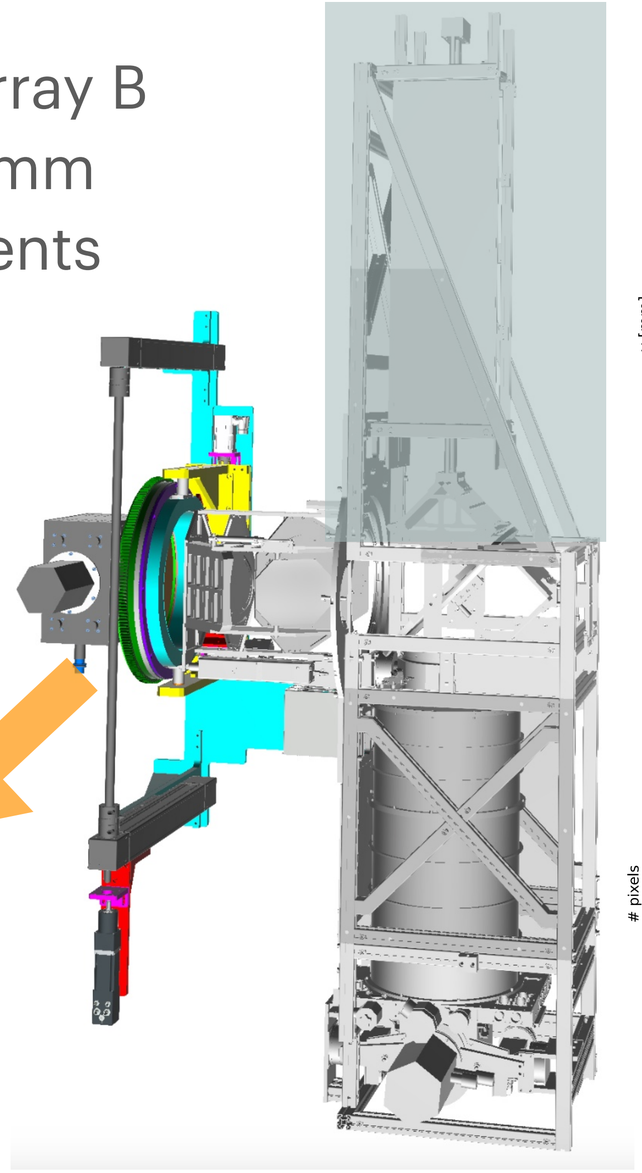


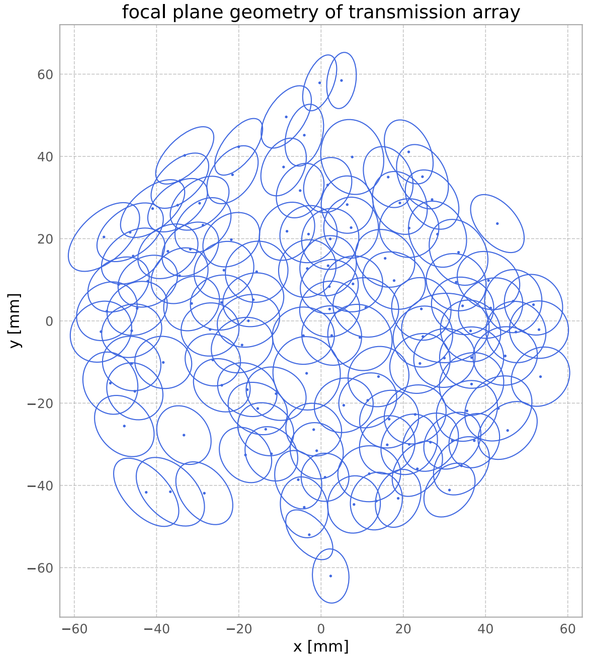
coupled to the sky simulator's cryostat providing a cold background as the atmosphere

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

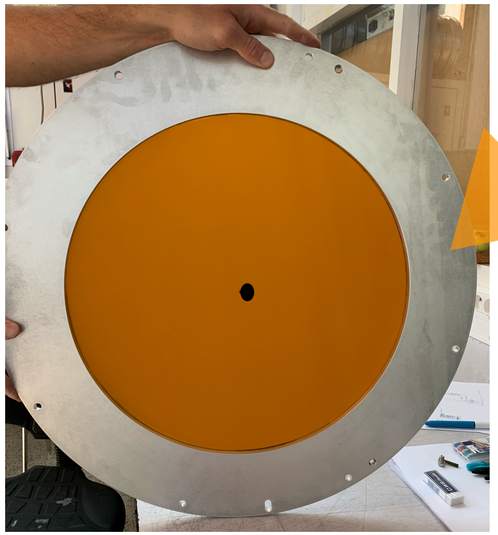


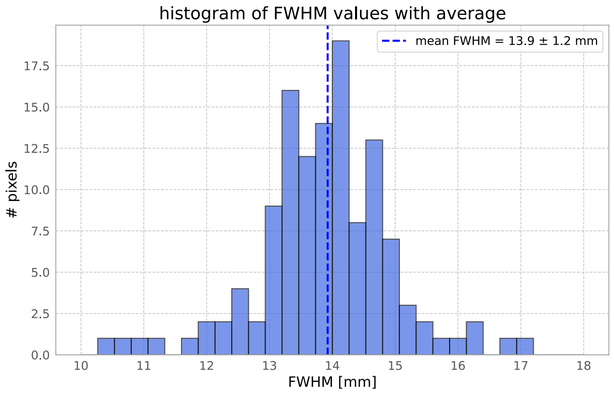
feedline of array B used for 2 mm measurements



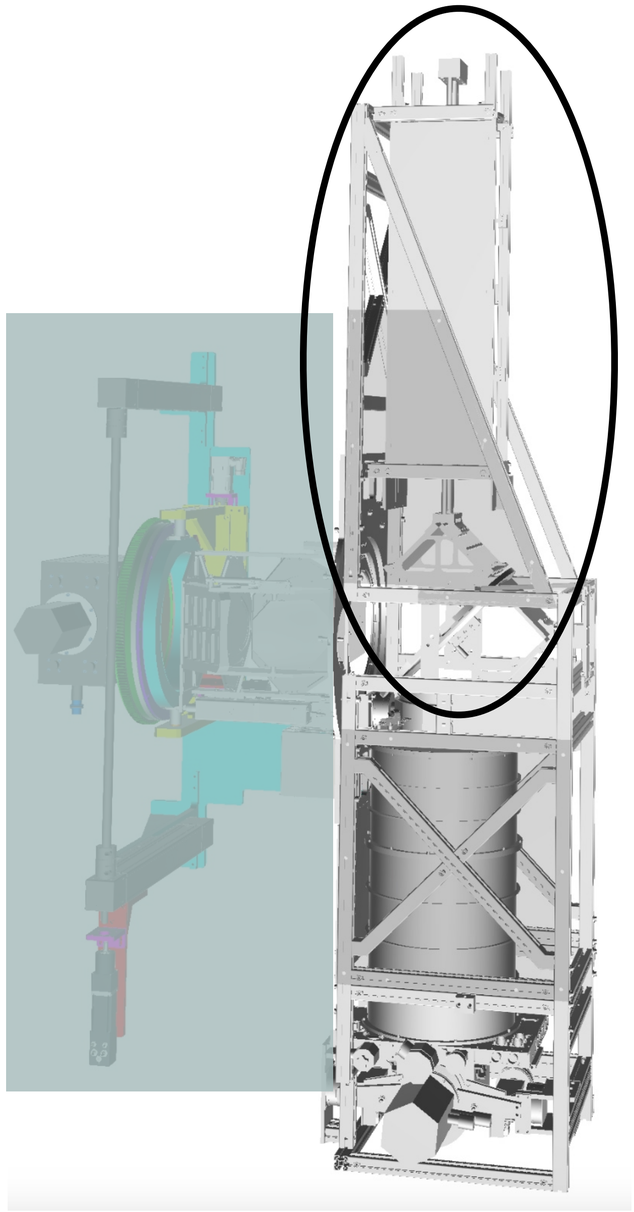


scan the point-like un-polarized source to obtain focal plane geometry (position and beam)



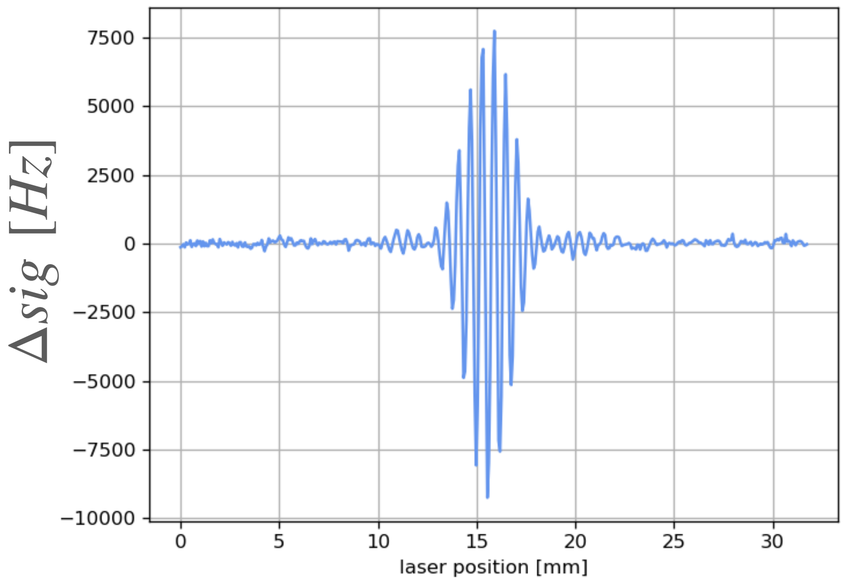


SPECTROSCOPY : INTERFEROGRAMS AND BANDWIDTH

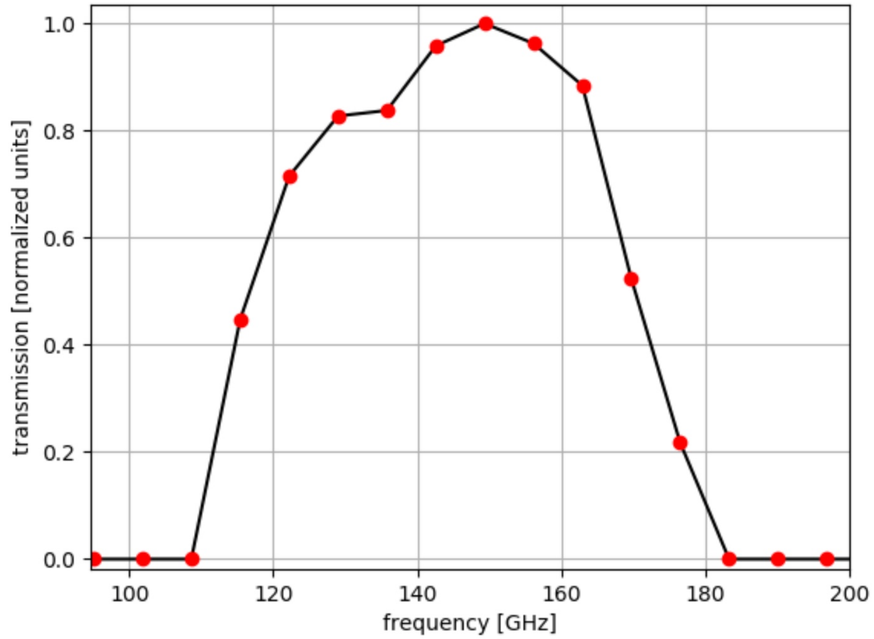


Martin-Puplett interferometer for spectroscopy

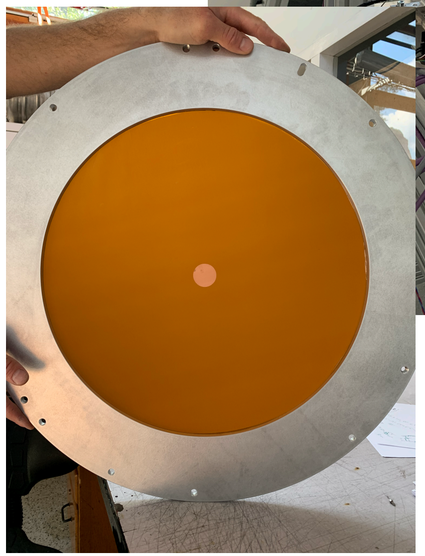
interferogram

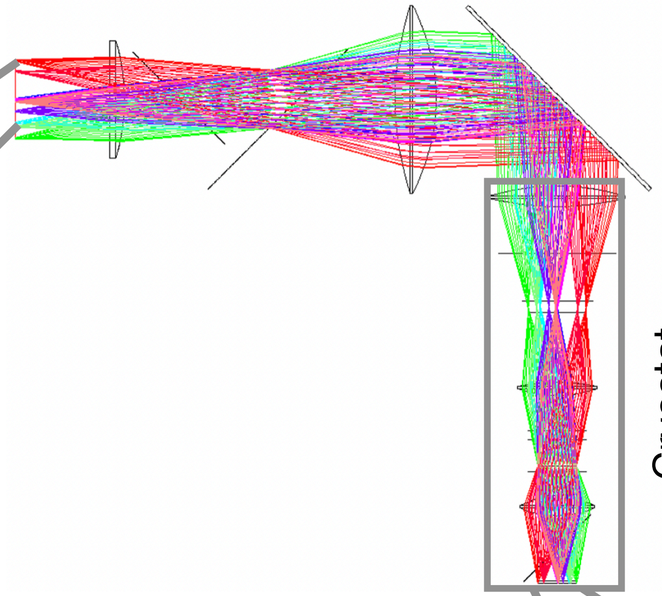


110 - 180 GHz or ~2 mm



LEKIDS FOR CMB POLARIZATION : IN-LAB PROOF OF CONCEPT





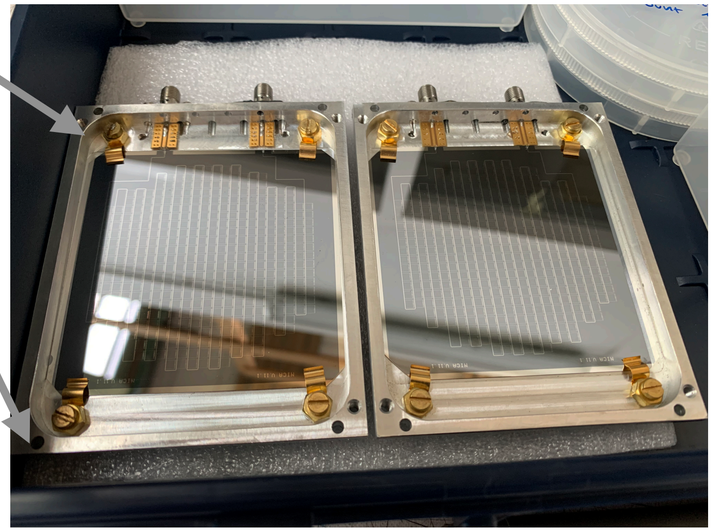
compare source's polarization with detected

→

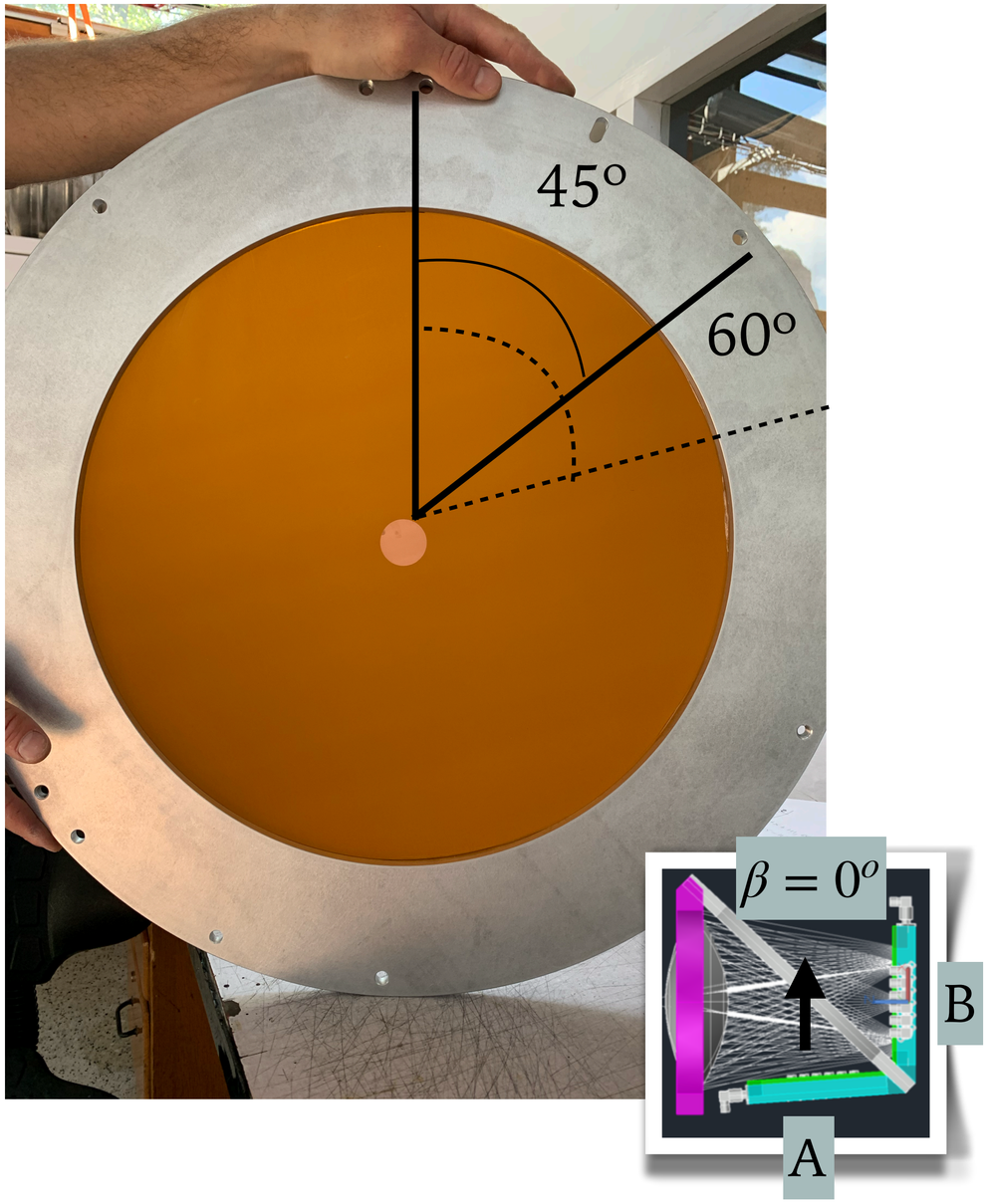
the difference gives the **systematic effects contribution**

PolarKID R&D Project:

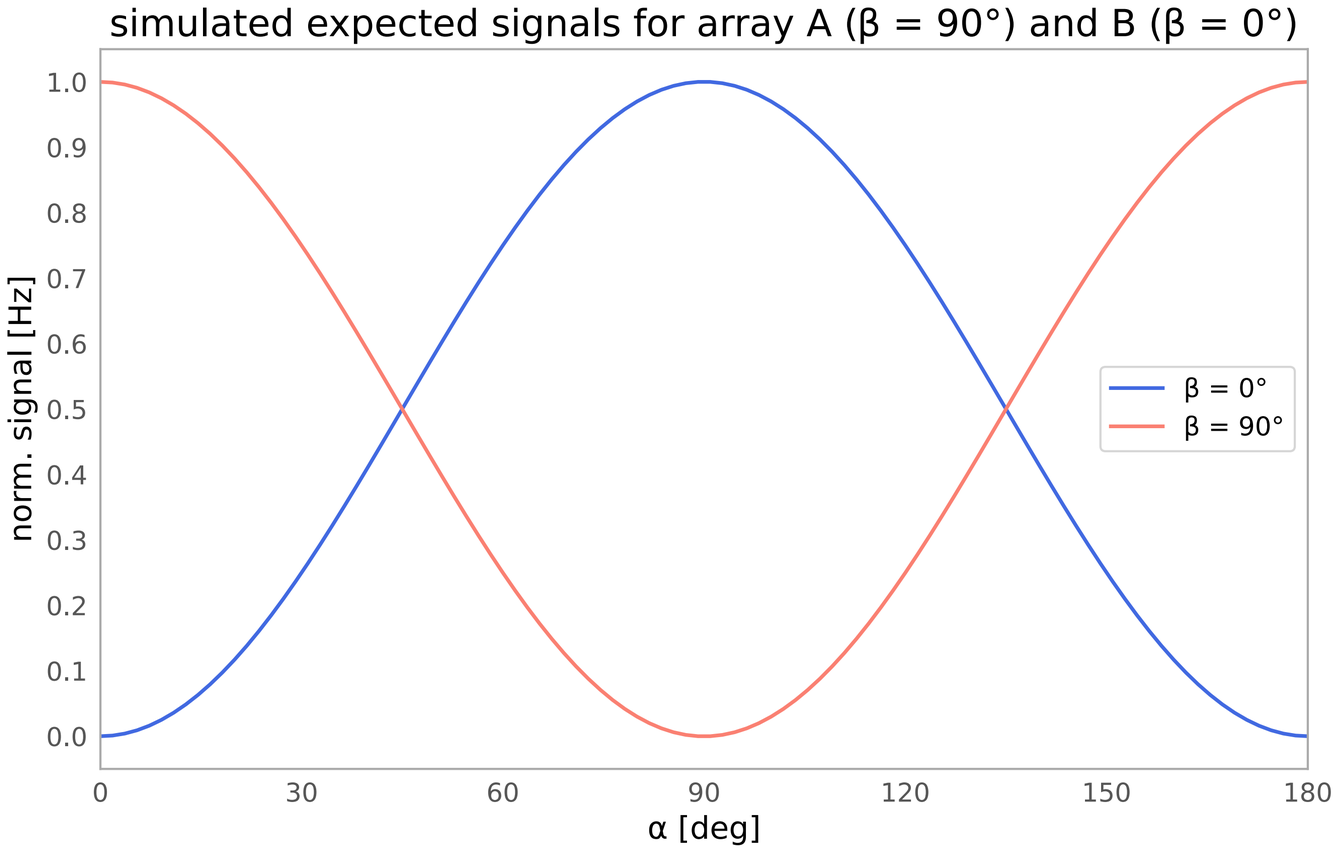
Can we use LEKIDs in a filled array configuration to measure polarization?



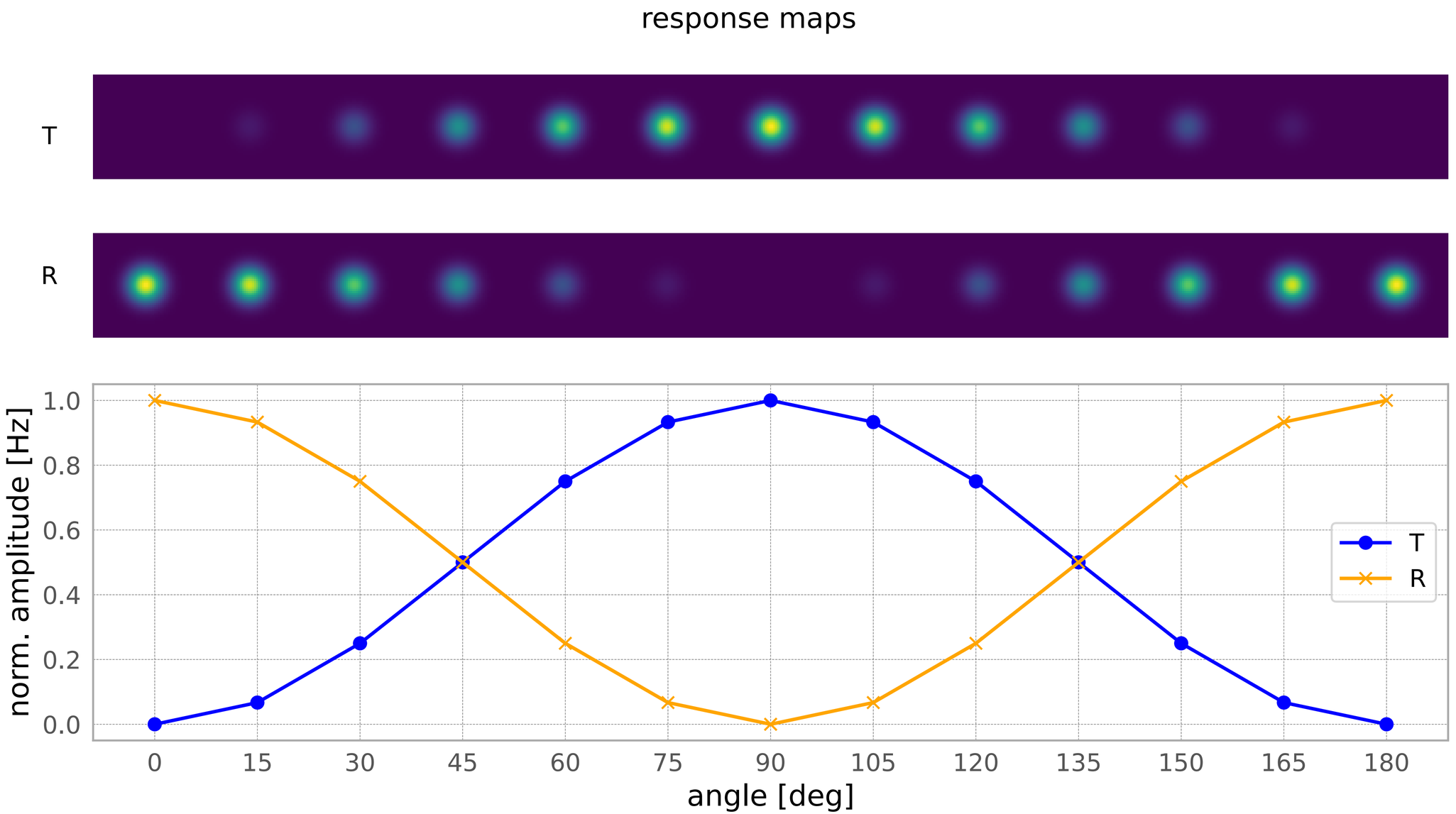
MEASUREMENT STRATEGY AND MODEL



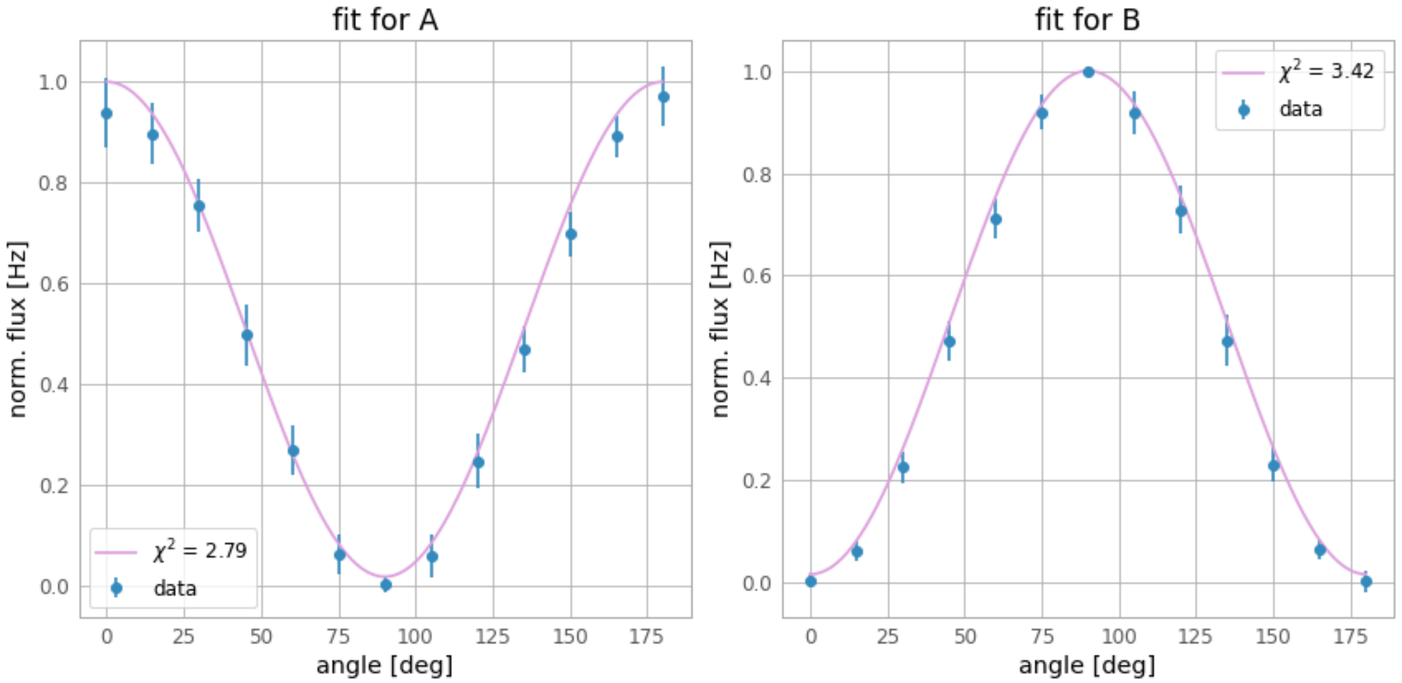
scan the linear polarizer at multiple angles to reconstruct the fully polarized signal incident on the two orthogonal arrays



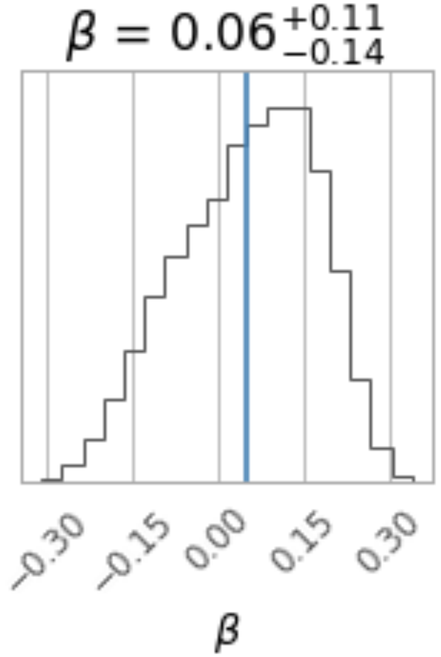
PRELIMINARY RESULTS: COMPLEMENTARY MAPS ON THE TWO ARRAYS



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:

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

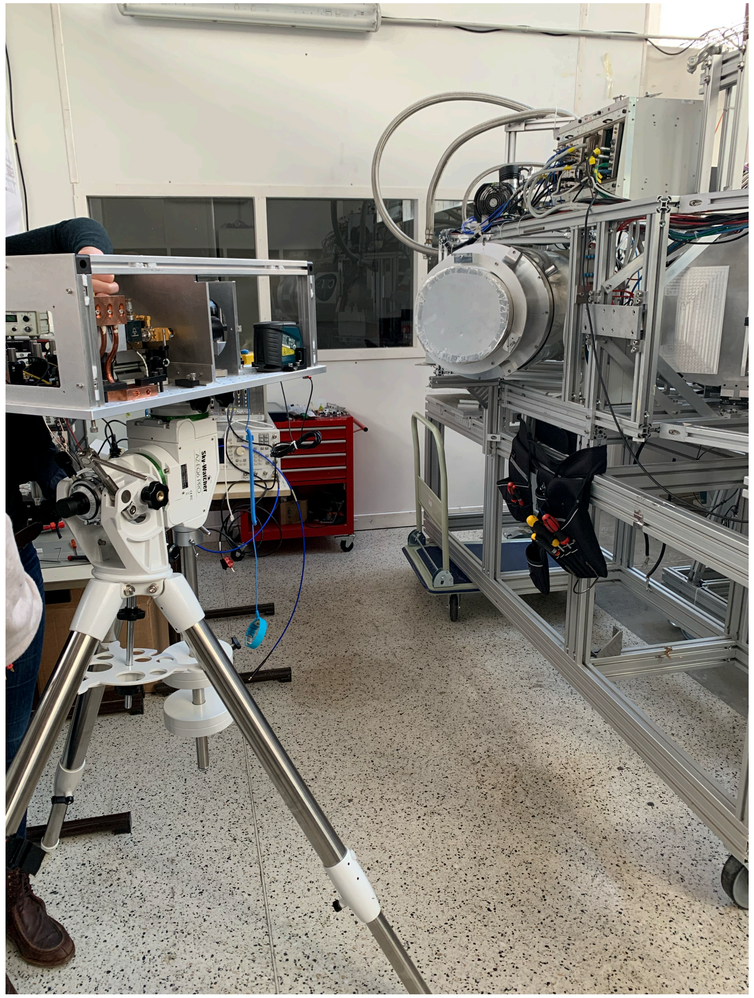
good control of systematics

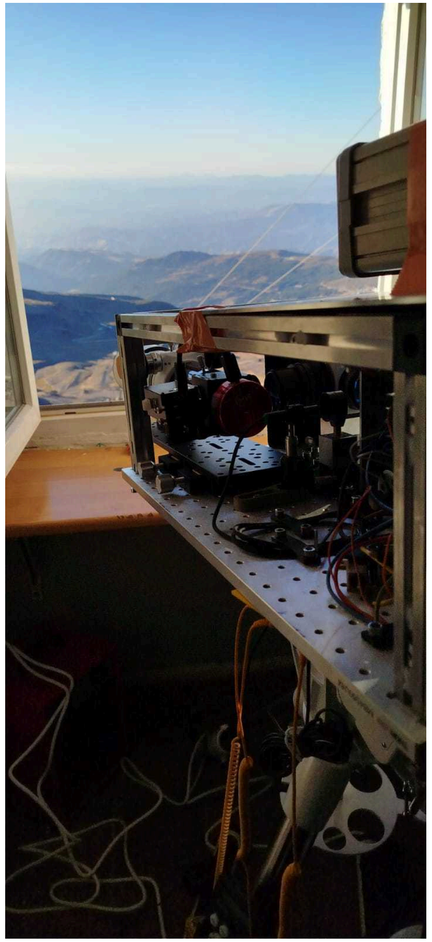
in agreement with requirements

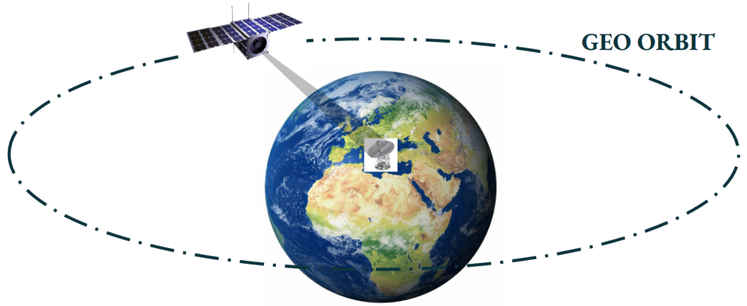
FROM LEKIDS CHARACTERIZATION …
… TO THEIR APPLICATION IN CALIBRATION SYSTEMS

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







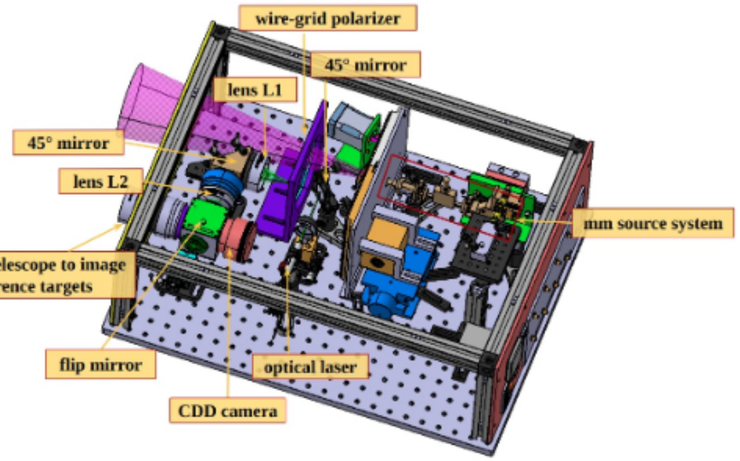
A. Ritacco’s talk

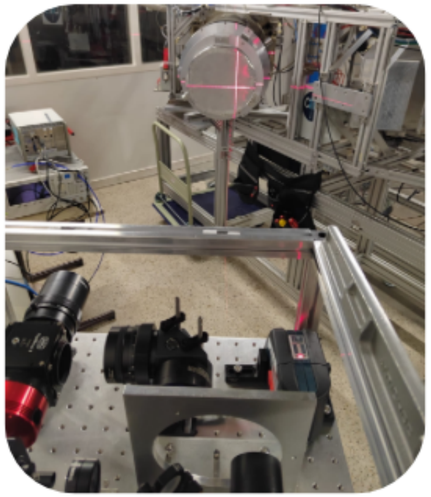
COSMOCAL : IN-LAB PROOF OF CONCEPT - LPSC, FEBRUARY ‘24

Freq. 260 GHz

Built in Paris:
LPENS,
Observatoire de Paris.

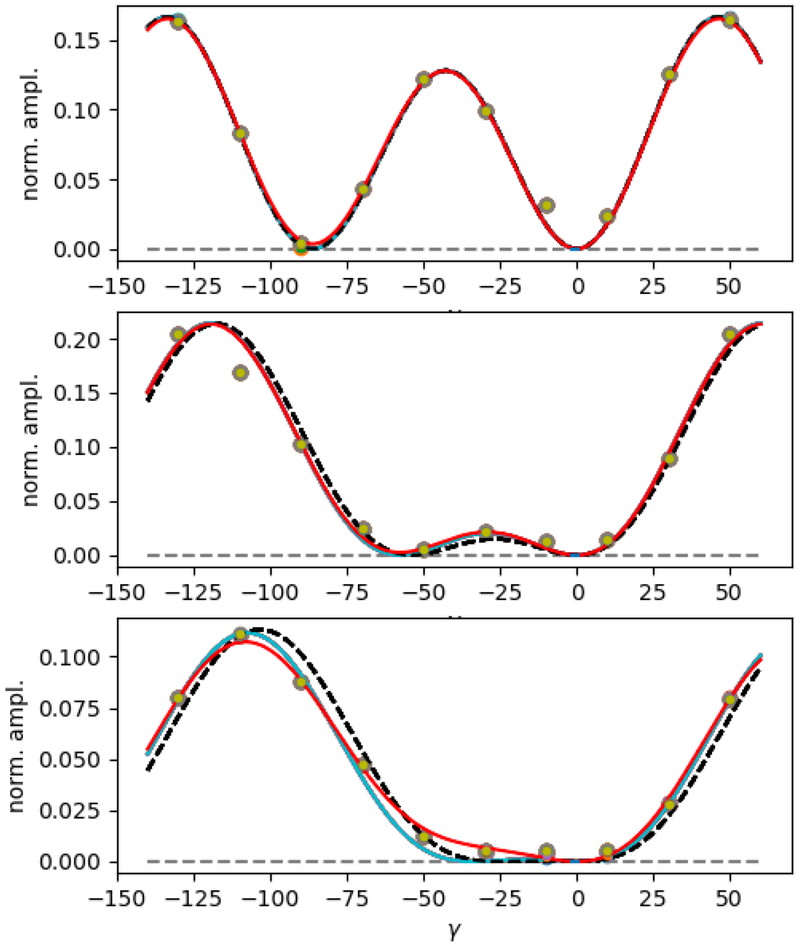
Tested in Paris & Grenoble:
LPENS, IAS,
LERMA, LPSC.





Laboratory measurements

Goal: 0.1 deg.
Results: 0.06 deg.

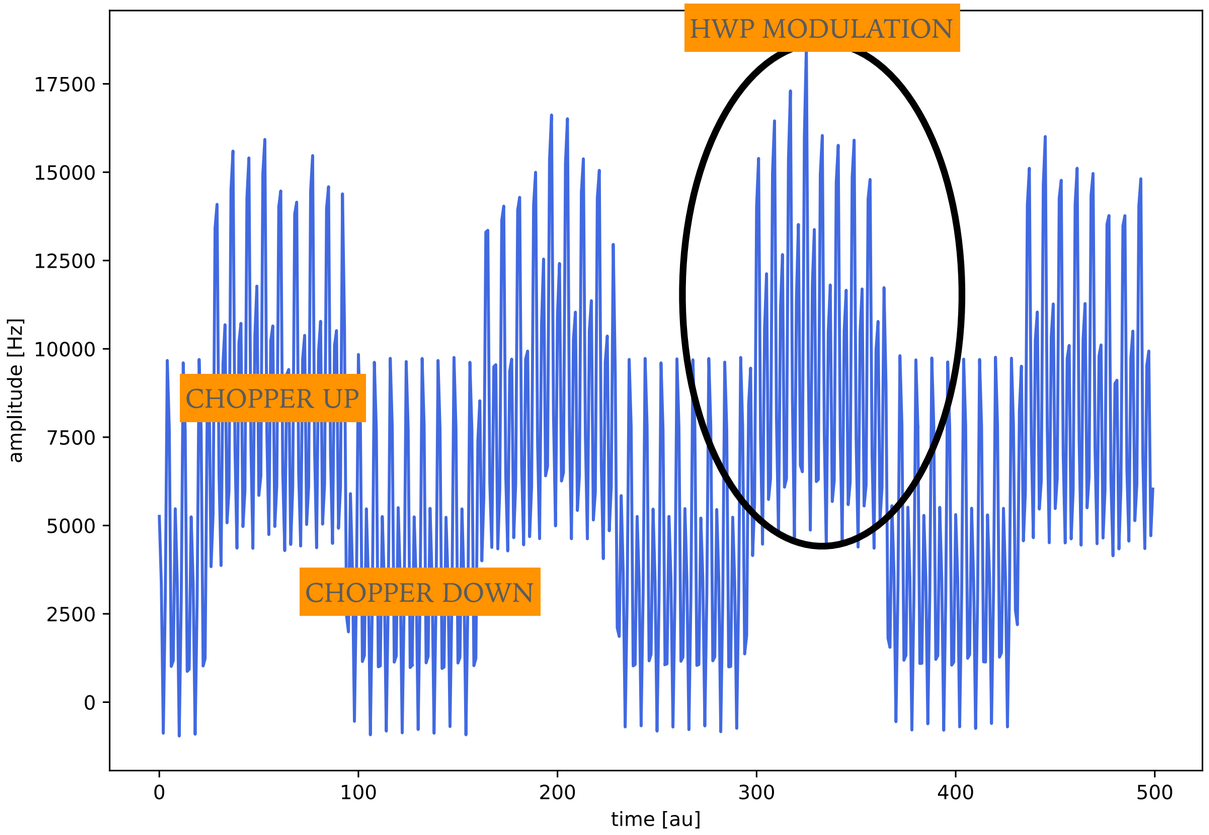


ψ_{box}	ψ_{det}	A	B	ϕ
(4.357 ± 0.069)°	(4.3 ± 0.7)°	0.146 ± 0.002	0.0116 ± 0.0001	(77 ± 5)°
(36.539 ± 0.077)°	(35.6 ± 0.9)°	0.069 ± 0.003	0.023 ± 0.005	(78 ± 6)°
(64.724 ± 0.066)°	(63.8 ± 0.8)°	0.027 ± 0.003	0.012 ± 0.004	(76 ± 5)°

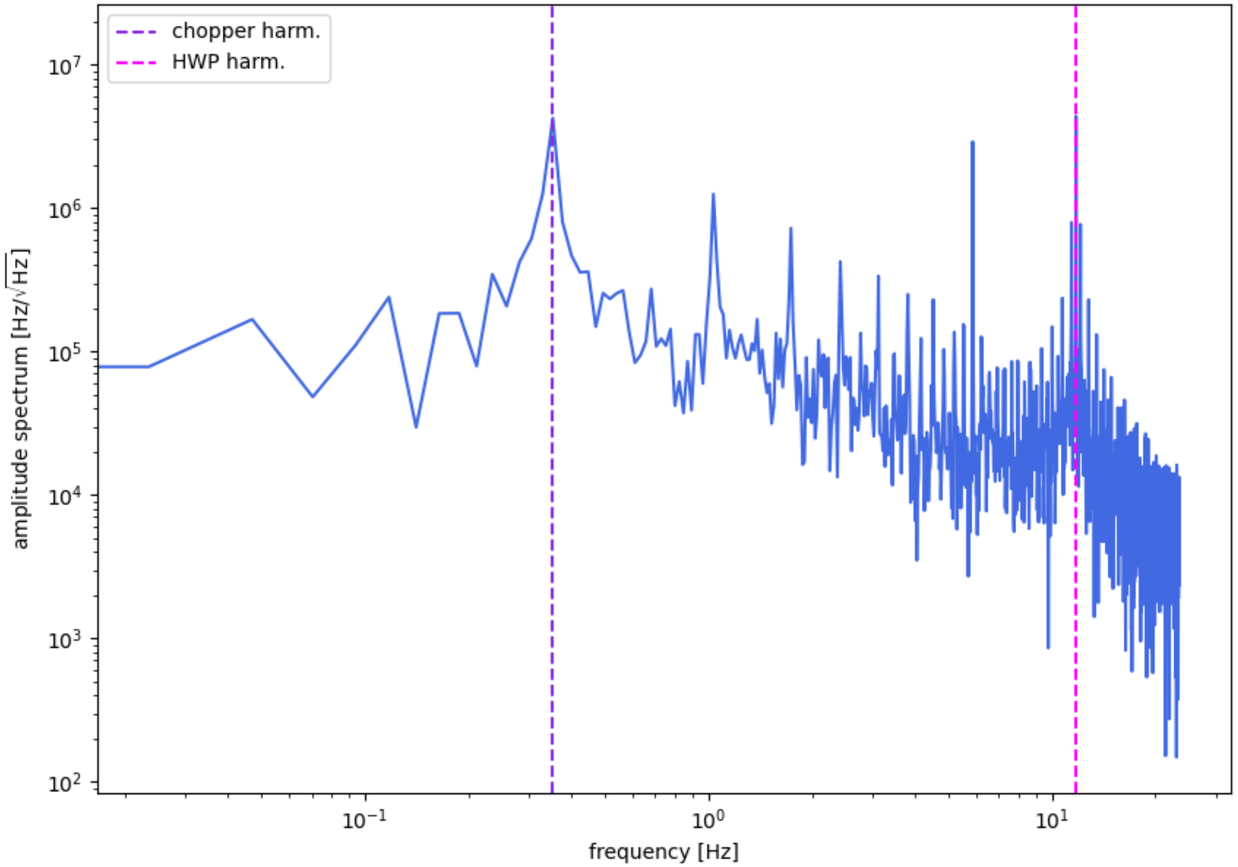
Ritacco, Bizzarri, **Savorgnano** et al, *PASP* 136 115001

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

typical timeline for a sample pixel

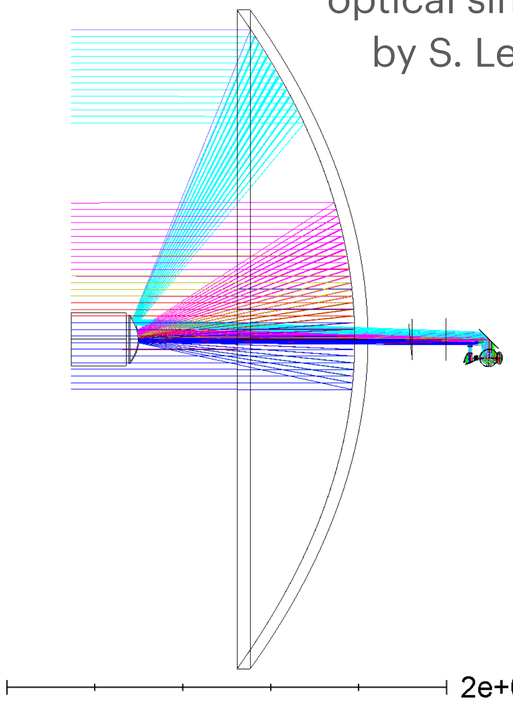


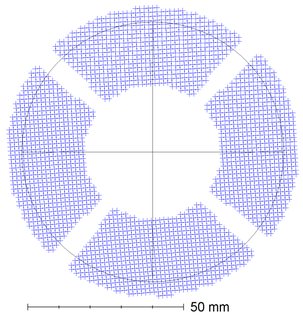
amplitude spectrum showing chopper and HWP harmonics

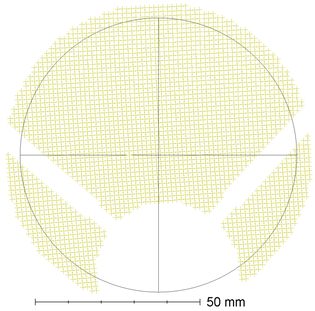


2. FINDING THE OPTIMAL ALIGNEMENT

optical simulations
by S. Leclercq





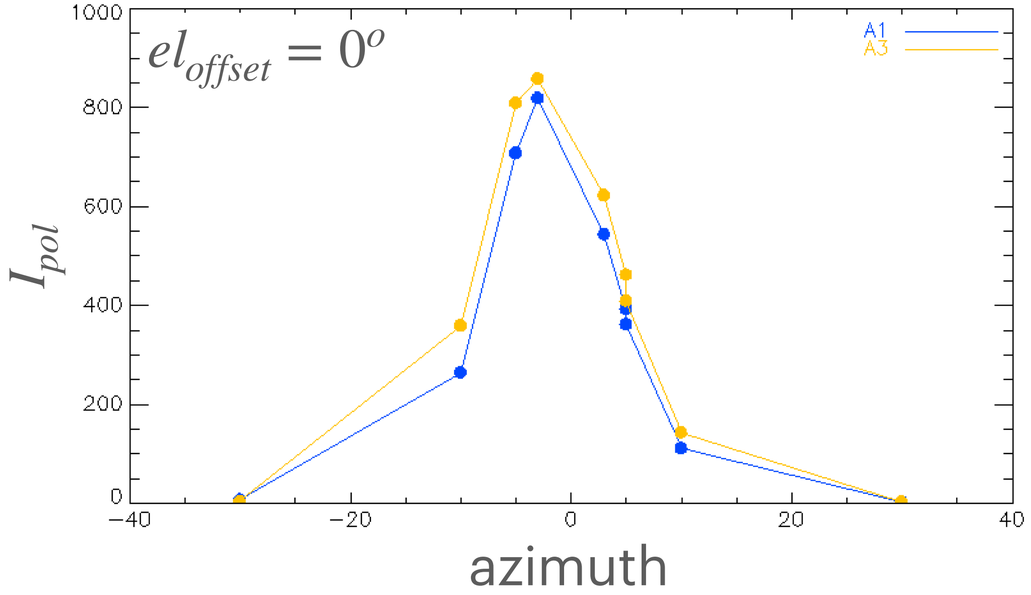


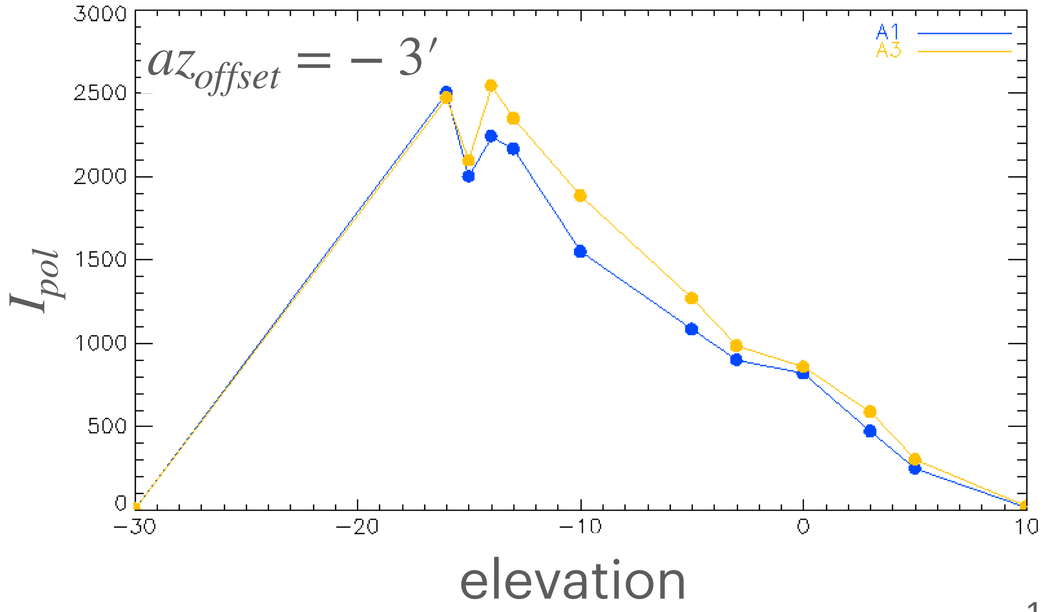
3′ tilt of the source gives 2 m tilt on the primary

careful with alignment!

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

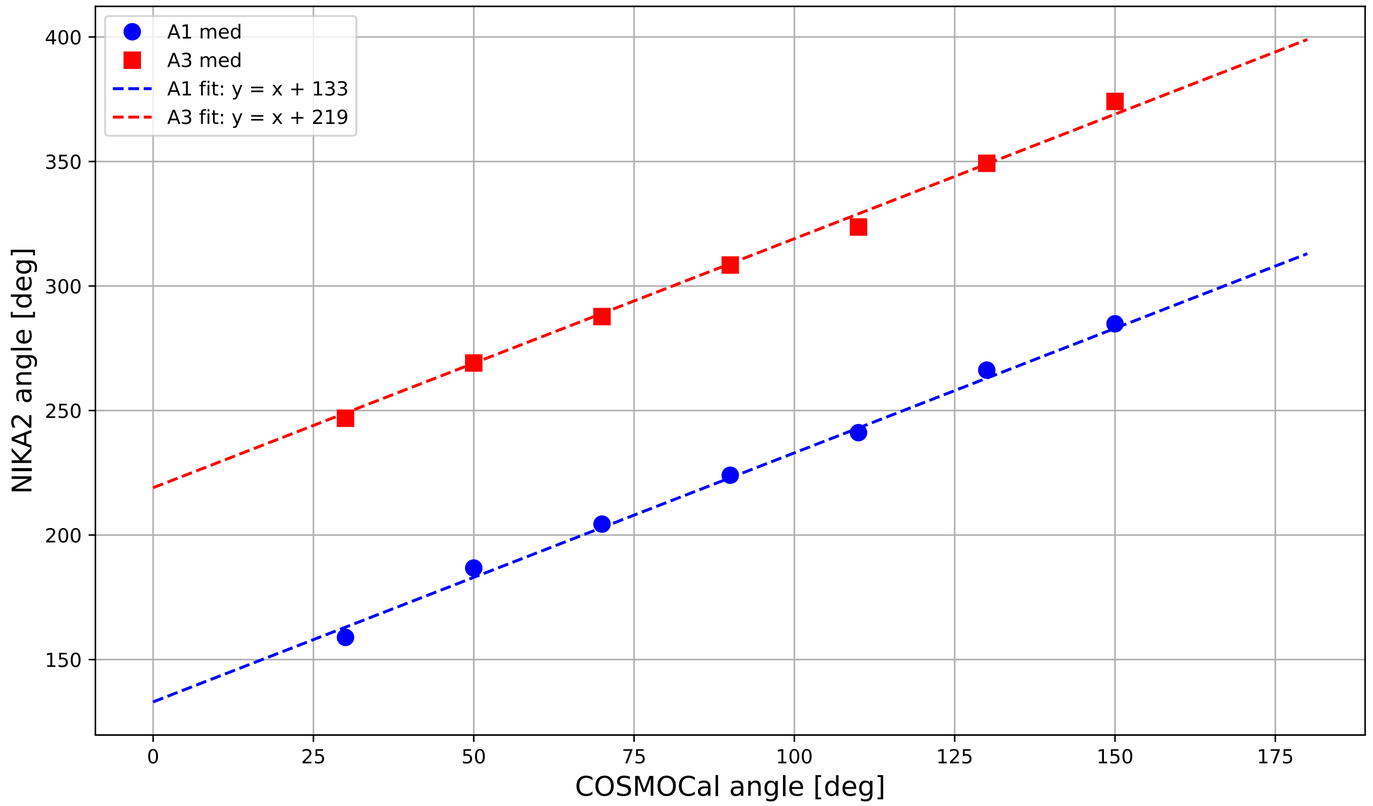
best-alignement offsets: [-3′, -16′]





3. POLARIZATION MAPS : DETERMINE POLARIZATION ANGLE WITH <0.1º 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



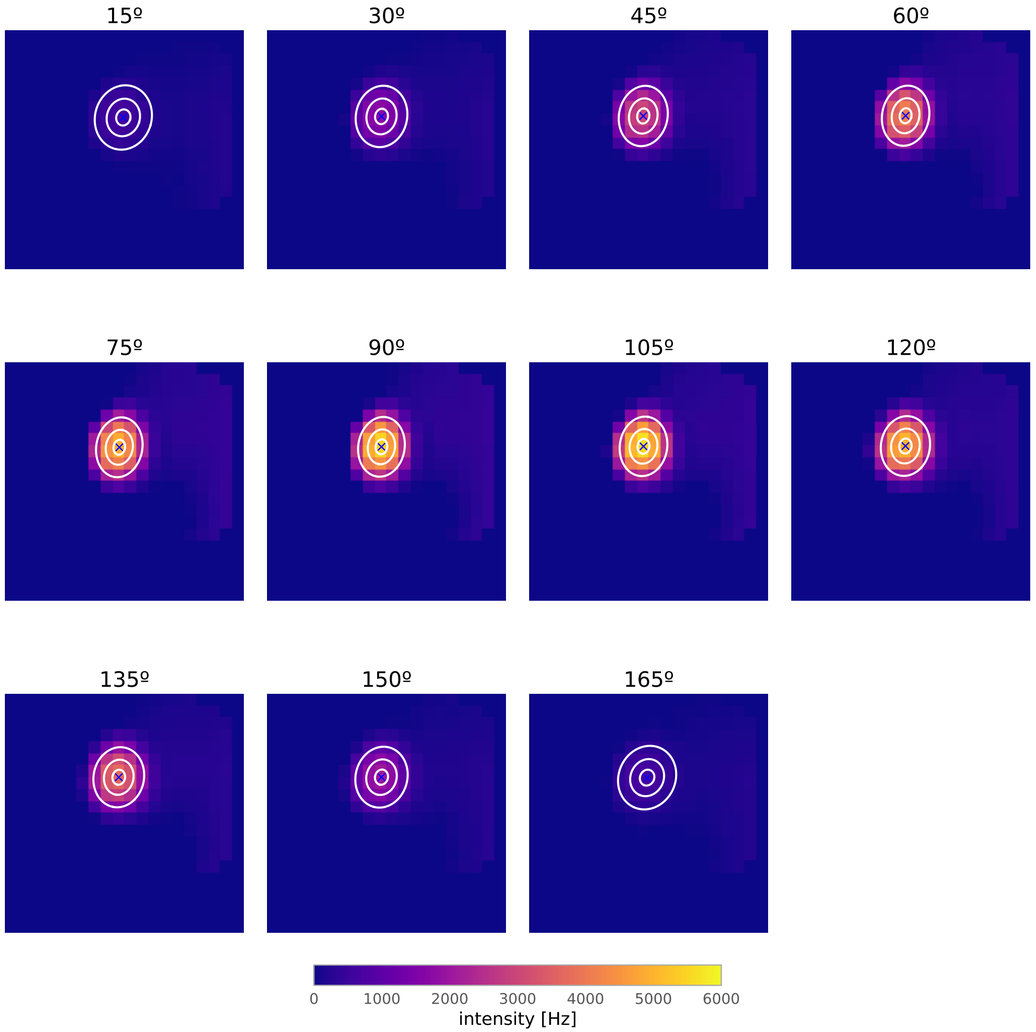
TAKE-HOME MESSAGES

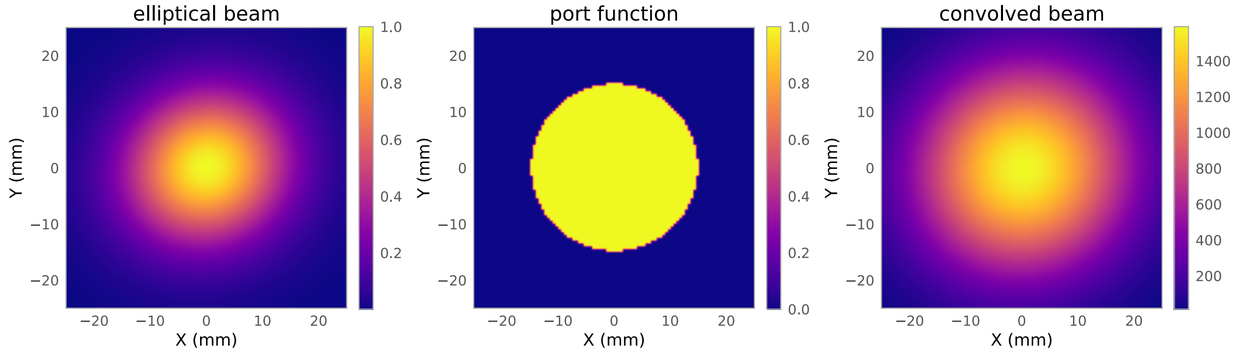
- At LPSC, we dispose of a **fully-equipped facility** that simulates real observing conditions and represents an excellent tool to test KIDs technology
- POLARKID results proved that LEKIDs used in a filled array configuration can assure **precisions suitable for cosmological polarization experiments (KAIROS project)**
- **Perspectives**: estimating beam distortions and measurements at 1 mm
- The **COSMOCal proof of concept and first campaign** at IRAM 30m showed promising results and further analysis is ongoing

thank you !

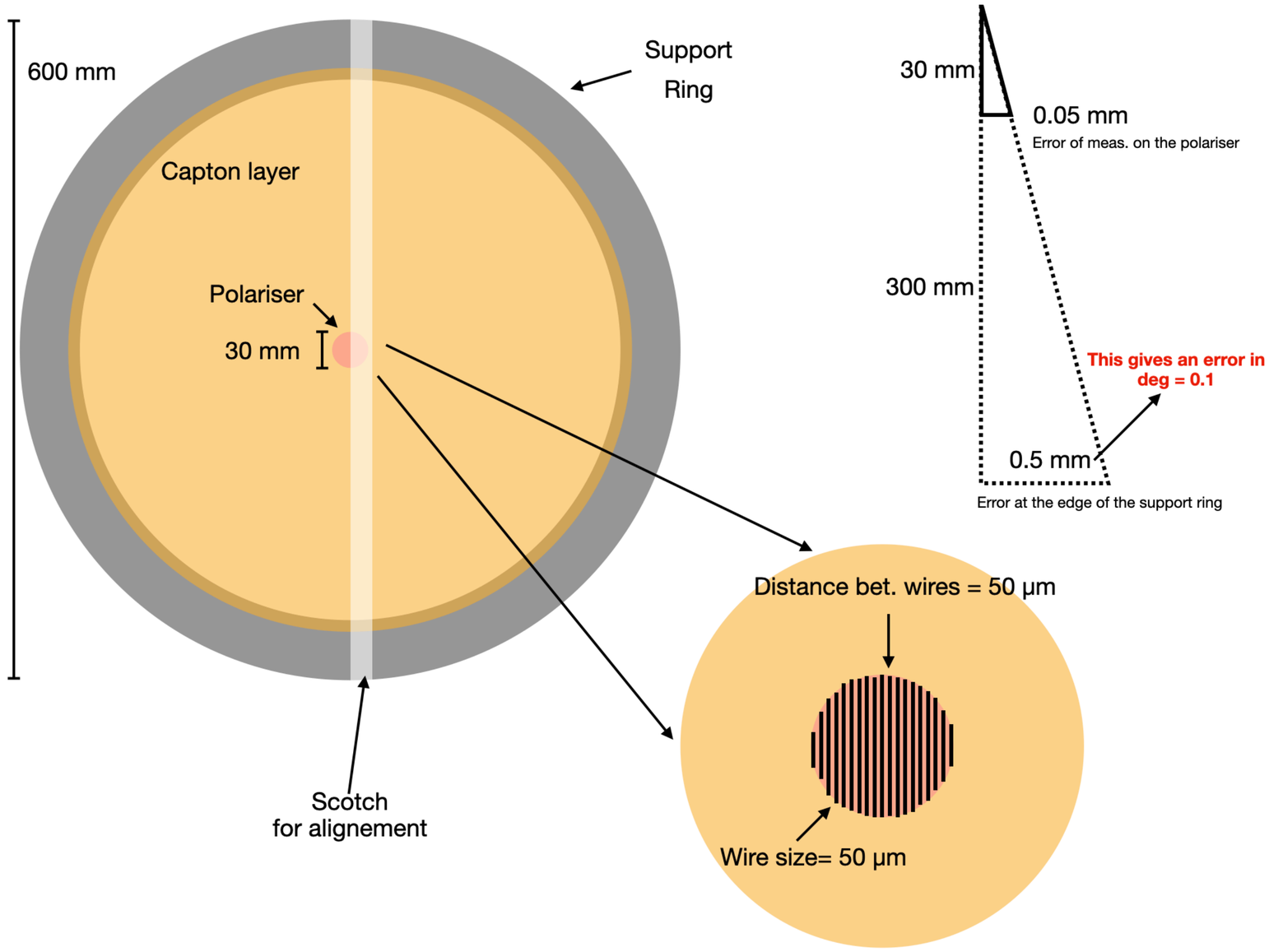
sofia.savorgnano@lpsc.in2p3.fr

BEAM DISTORTION ANALYSIS

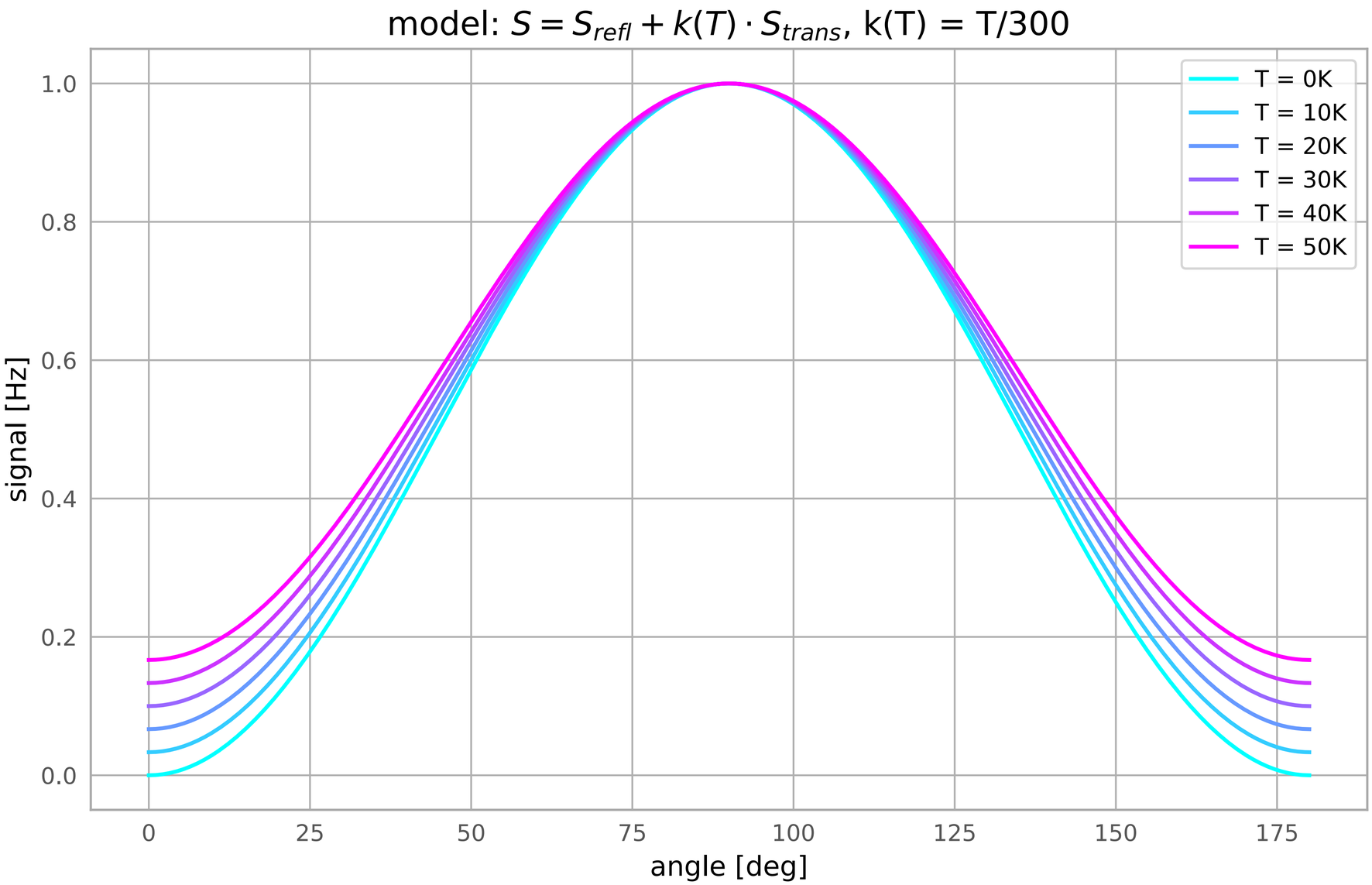




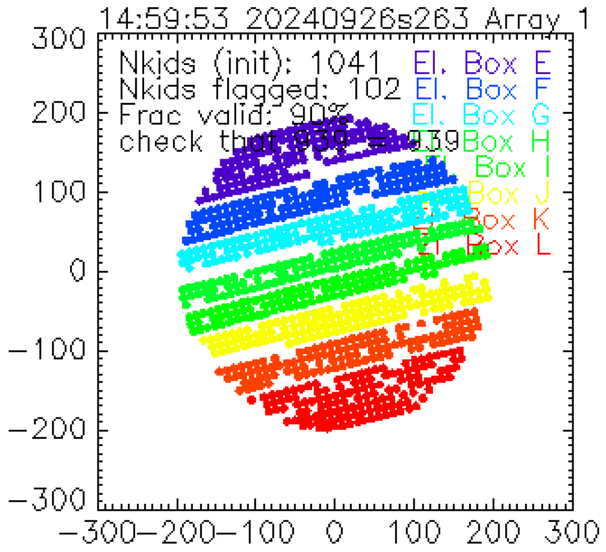
PRE-CALIBRATION OF THE SOURCE POLARIZER

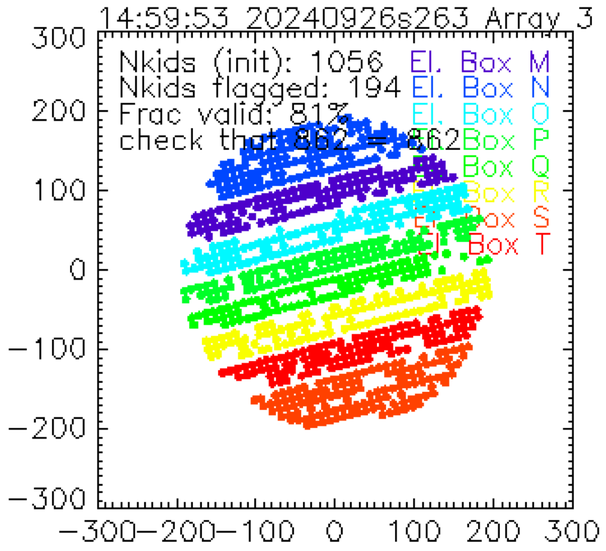


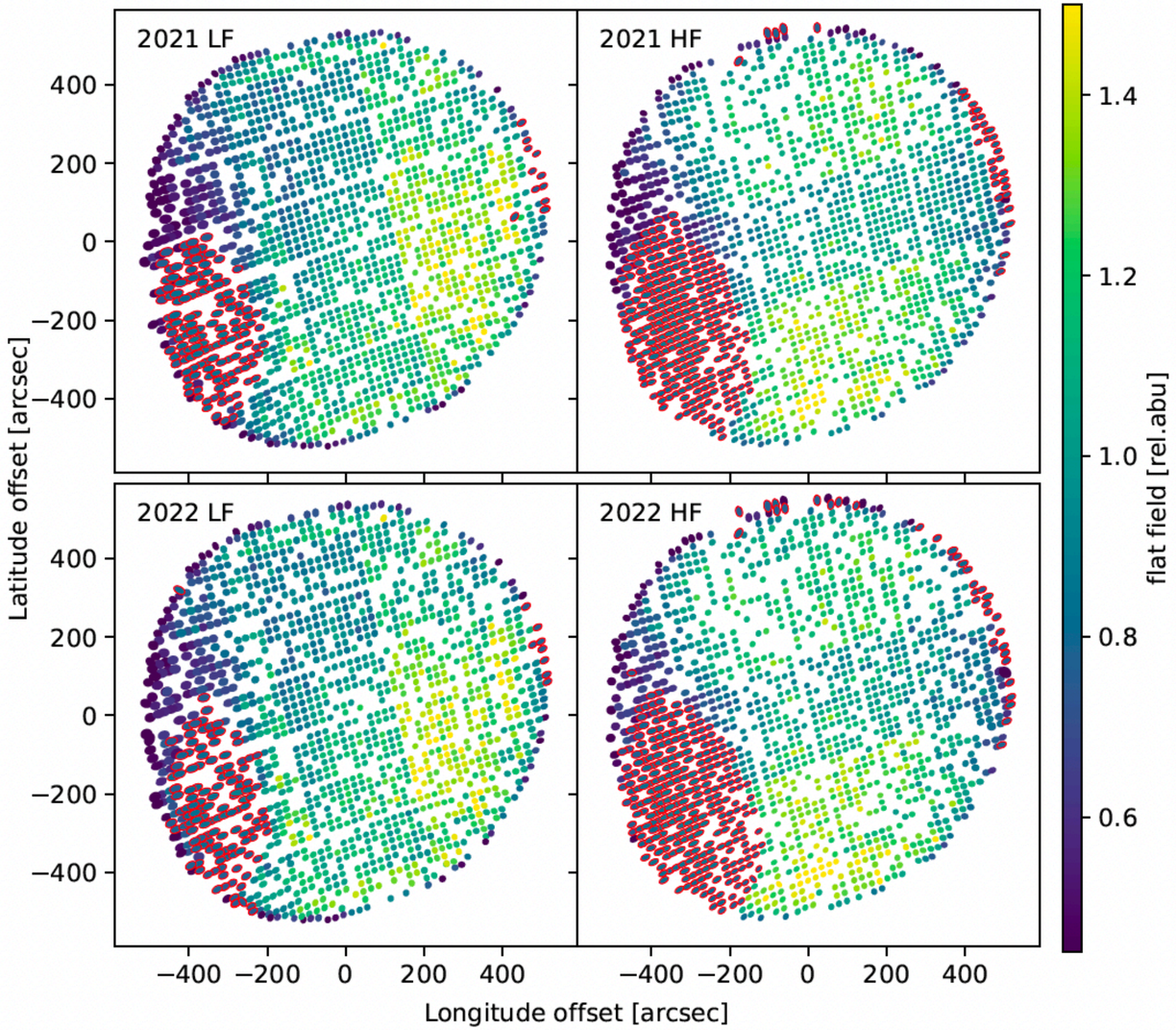
DOUBLE COMPONENT MODEL : REFLECTION DOMINATES OVER TRANSMISSION



FOCAL PLANE GEOMETRIES OF NIKA2 AND CONCERTO

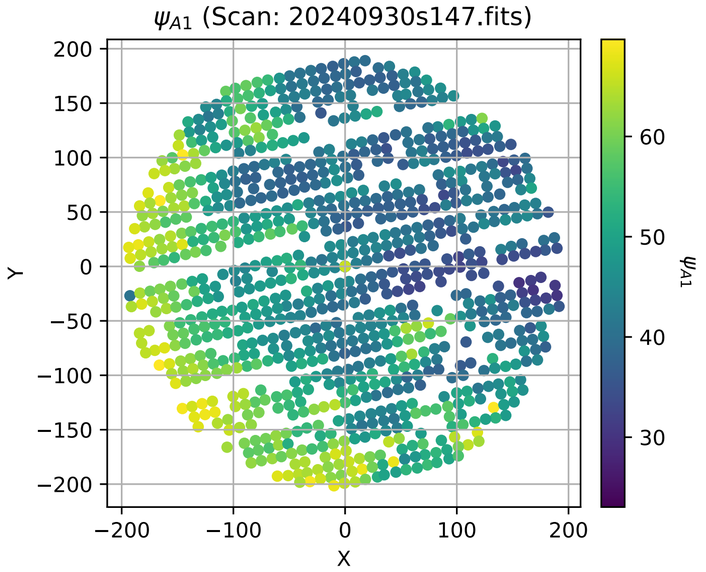


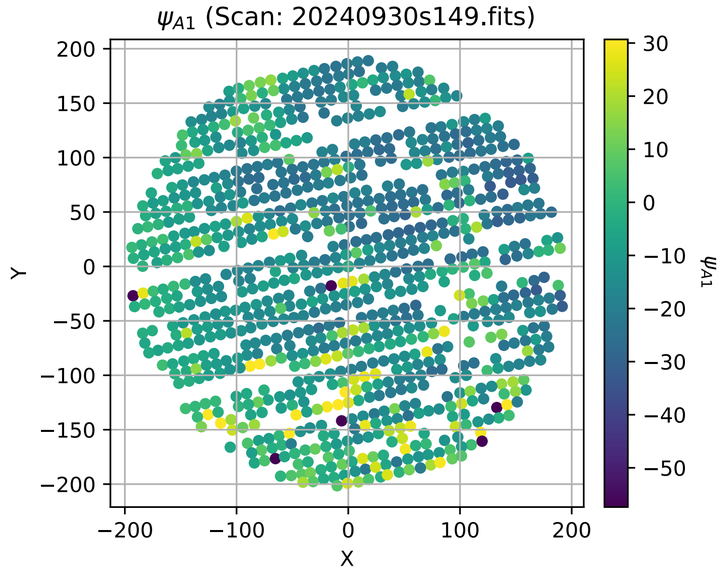


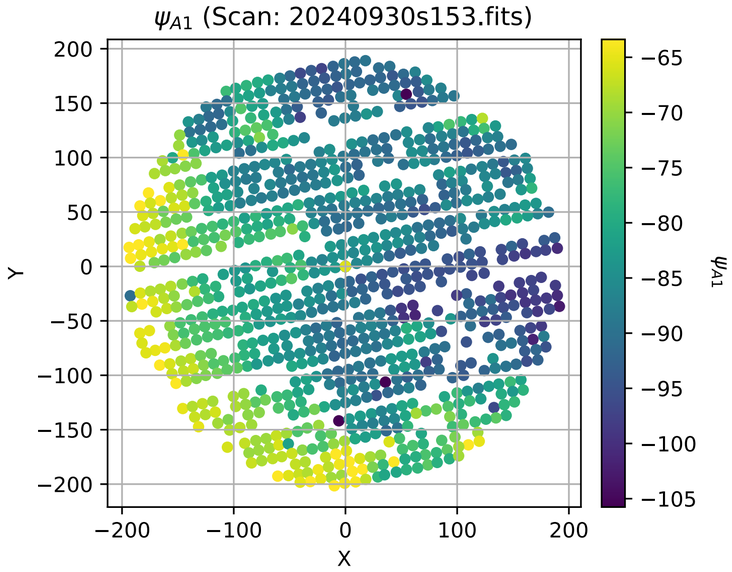


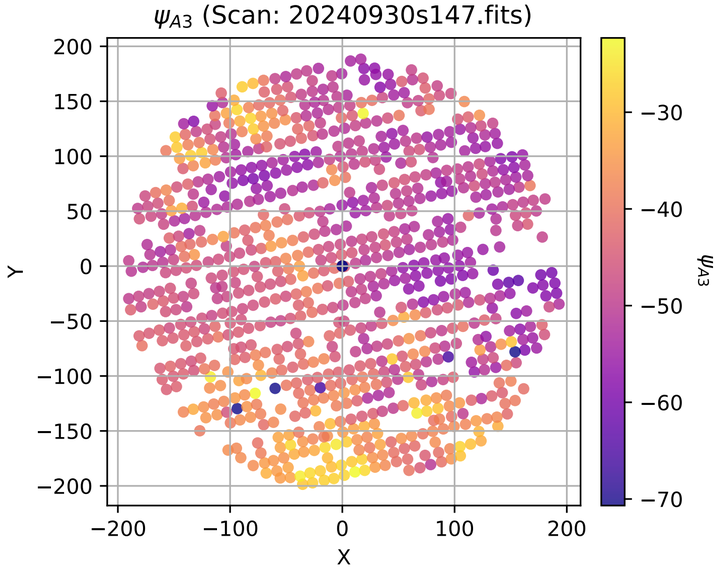
Hu W. et al, 2024

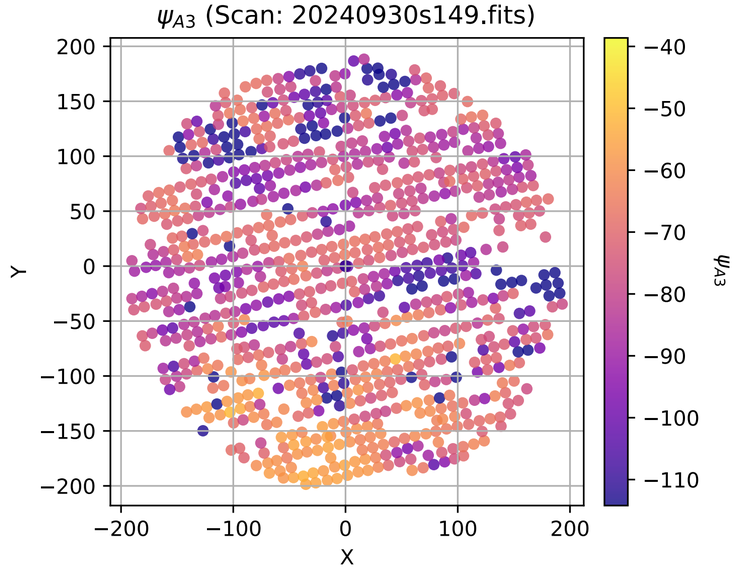
POLARIZATION ANGLE DISTRIBUTION OVER A1&A3

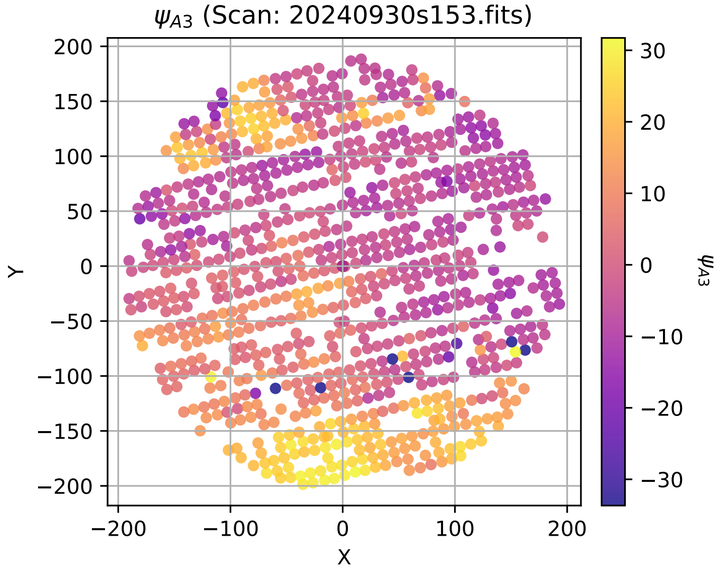




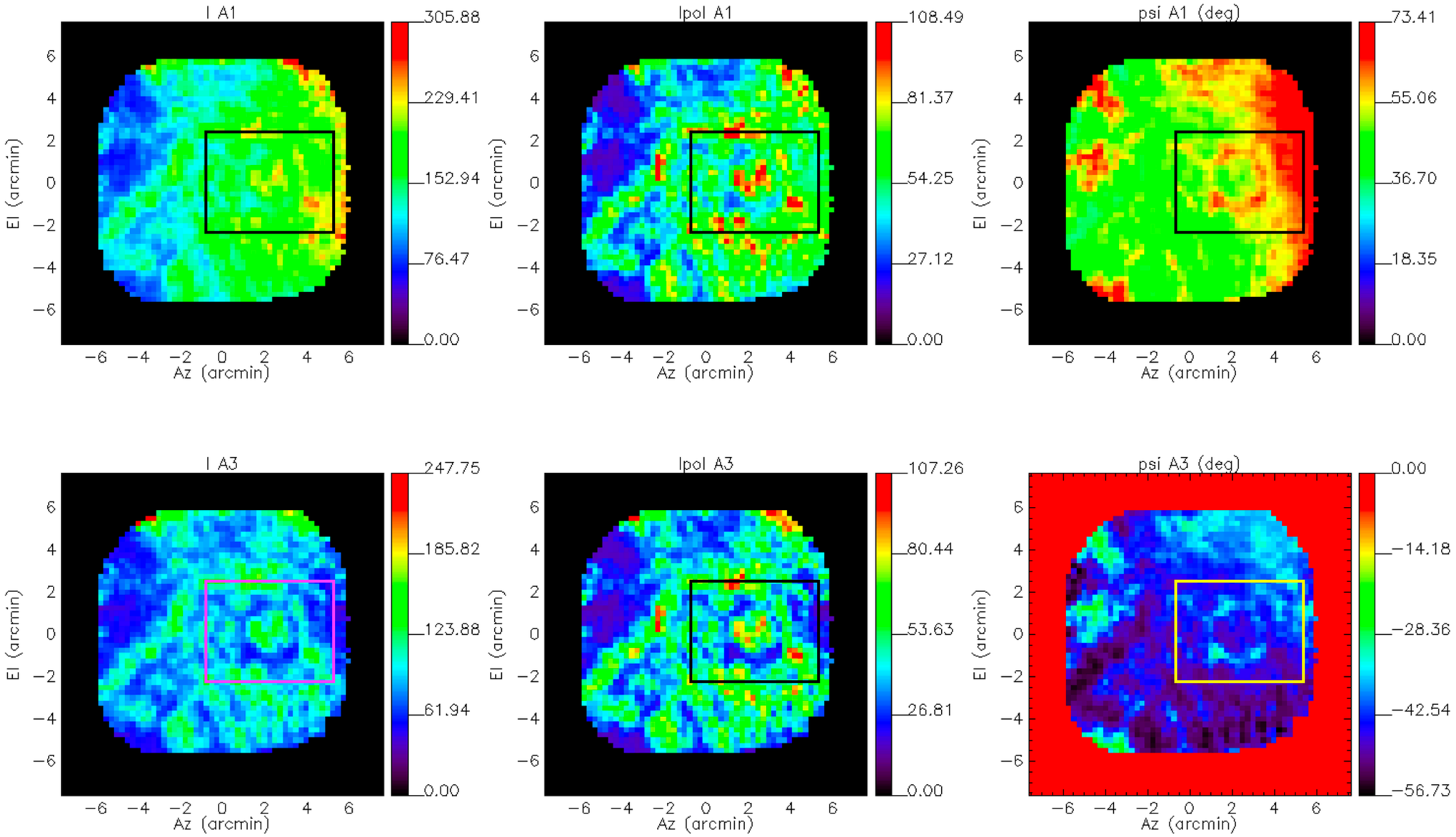








5' X 5' MAPS CENTERED IN BEST-ALIGNEMENT POSITION



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

- **STEP 1 :** ensure signal detection through KIDs arrays
- **STEP 2 :** align the source’s main beam to the cryostat/antenna
- **STEP 3 :** rotate the COSMOCal polarizer and capturing fixed track scans
- **STEP 4** : compare results between KIDs arrays, diffraction pattern and photogrammetry