LSPE: the Large Scale Polarization Explorer

Aniello Mennella for the LSPE collaboration

University of Milan, Dept. of Physics

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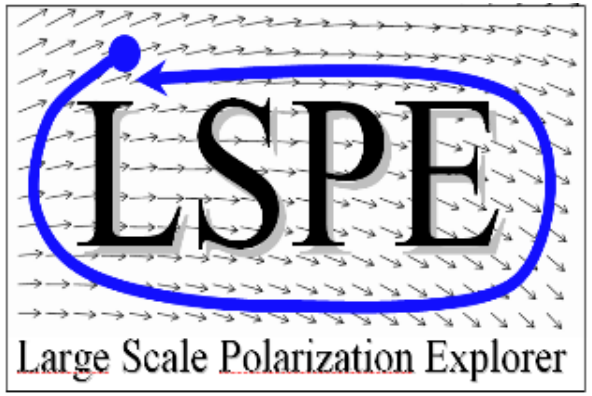
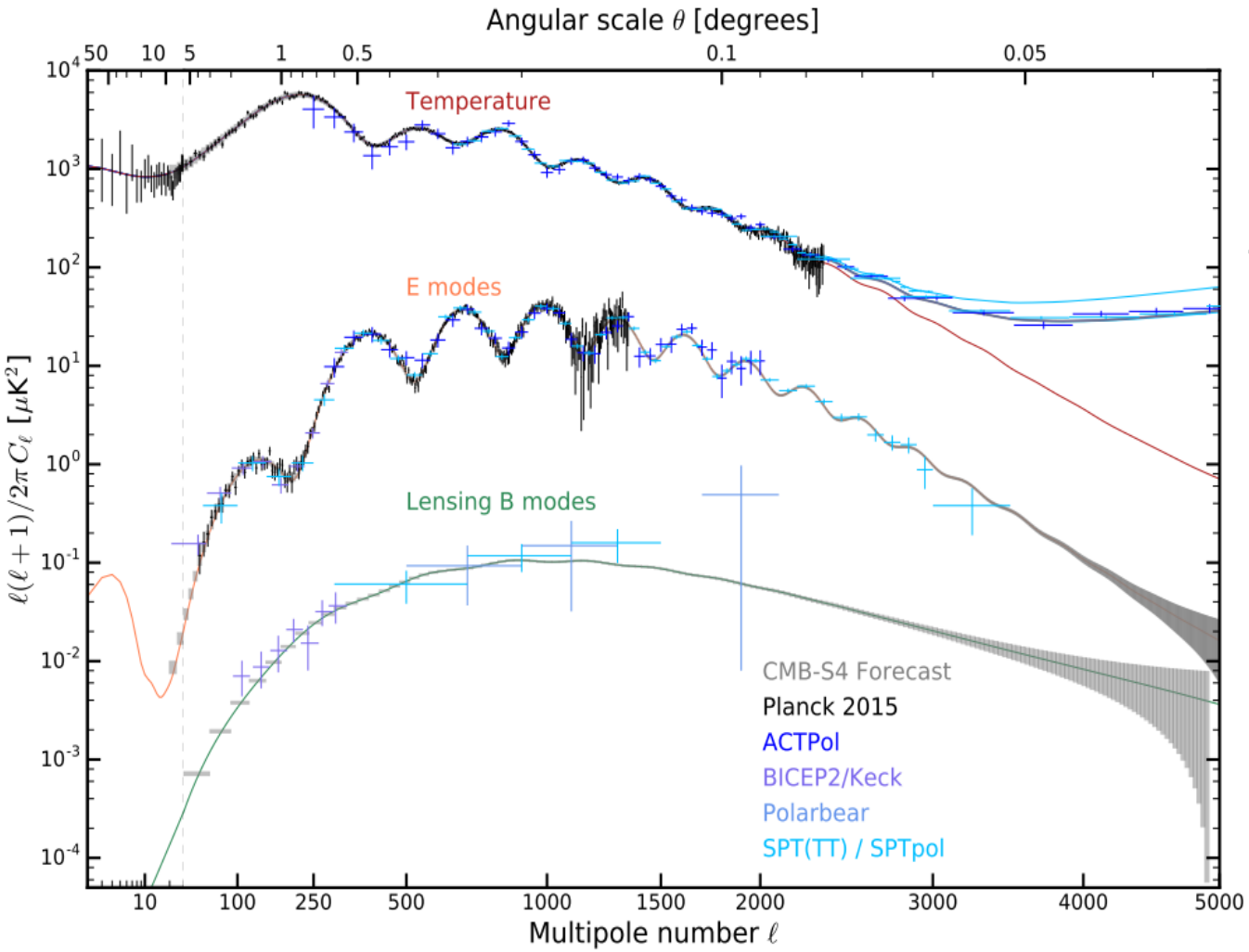
Collaboration and funding agencies



Measurements state of the art

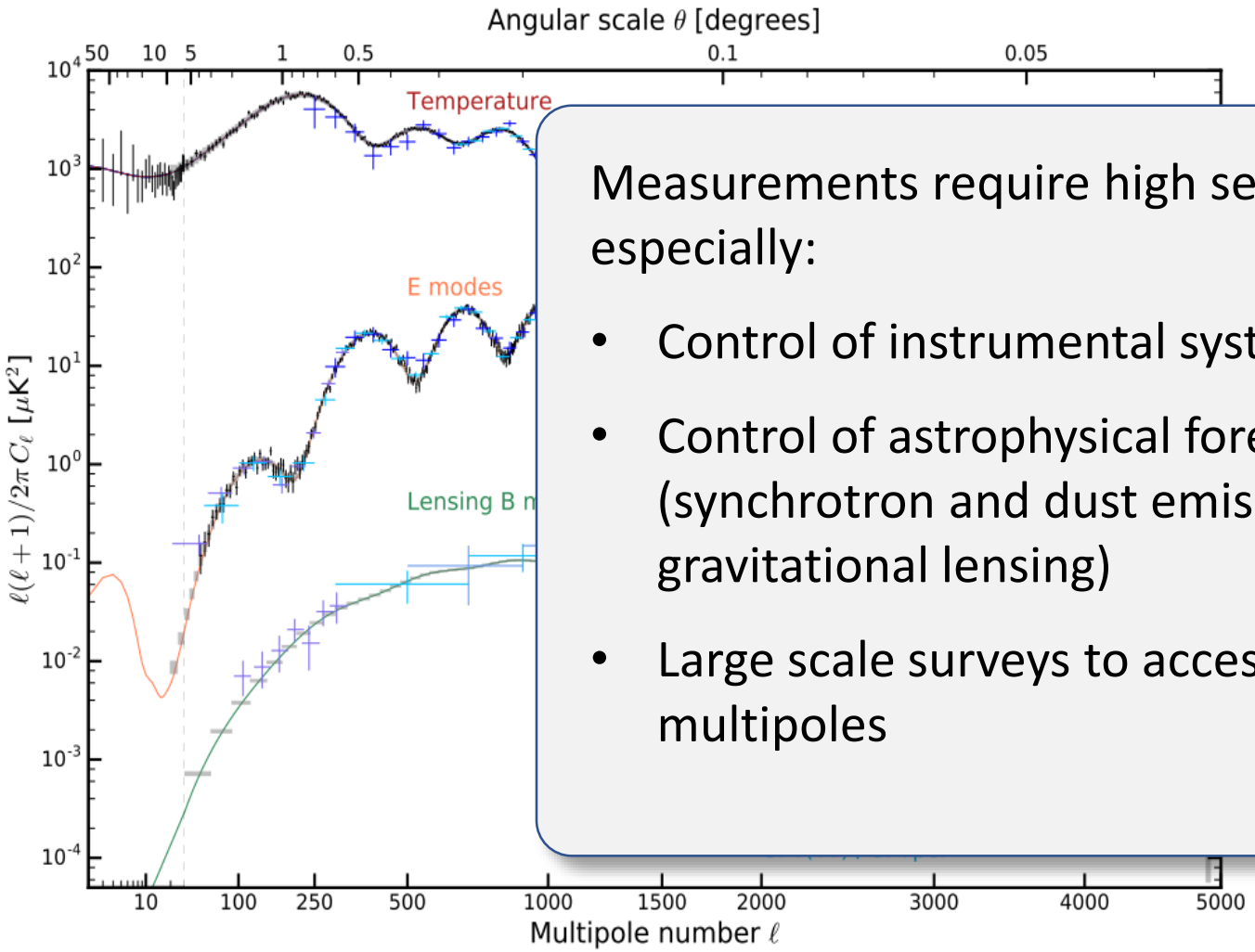


Total intensity: measured with *ultimate* precision

E-modes: measured *very* precisely

B-modes: current measurements have detected only those caused by gravitational lensing

Measurements state of the art



Measurements require high sensitivity but, especially:

- Control of instrumental systematic effects
- Control of astrophysical foregrounds (synchrotron and dust emissions, gravitational lensing)
- Large scale surveys to access signal at low multipoles

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Worldwide competition

Project	Country	Location	Status	Frequencies (GHz)	ℓ range value	Ref.	$\sigma(r)$ goal no fg.	with fg.
QUBIC	France	Argentina	2018	150,220	30-200		0.006	0.01
Bicep3/Keck	U.S.A.	Antartica	Running	95, 150, 220[1]	50-250	[22]	$2.5\ 10^{-3}$	0.013
CLASS	U.S.A.	Atacama	> 2017	38, 93, 148, 217	2-100	[29]	$1.4\ 10^{-3}$	0.003
SPT3G	U.S.A.	Antartica	2017	95, 148, 223	50-3000	[23]	$1.7\ 10^{-3}$	0.005
AdvACT	U.S.A.	Atacama	Starting	90, 150, 230	60-3000	[24]	$1.3\ 10^{-3}$	0.004
Simons Array	U.S.A.	Atacama	≥ 2017	90, 150, 220	30-3000	[25]	$1.6\ 10^{-3}$	0.005
LSPE	Italy	Arctic flight + Tenerife	2018	43, 90, 140, 220, 245	3-150	[30]		0.007
EBEX10K	U.S.A.	Antartica	≥ 2017	150, 220, 280, 350	20-2000	[28]	$2.7\ 10^{-3}$	0.007
SPIDER	U.S.A.	Antartica	Running	90, 150	20-500	[26]	$3.1\ 10^{-3}$	0.012
PIPER	U.S.A.	Multiple	2017?	200, 270, 350, 600	2-300	[27]	$3.8\ 10^{-3}$	0.008

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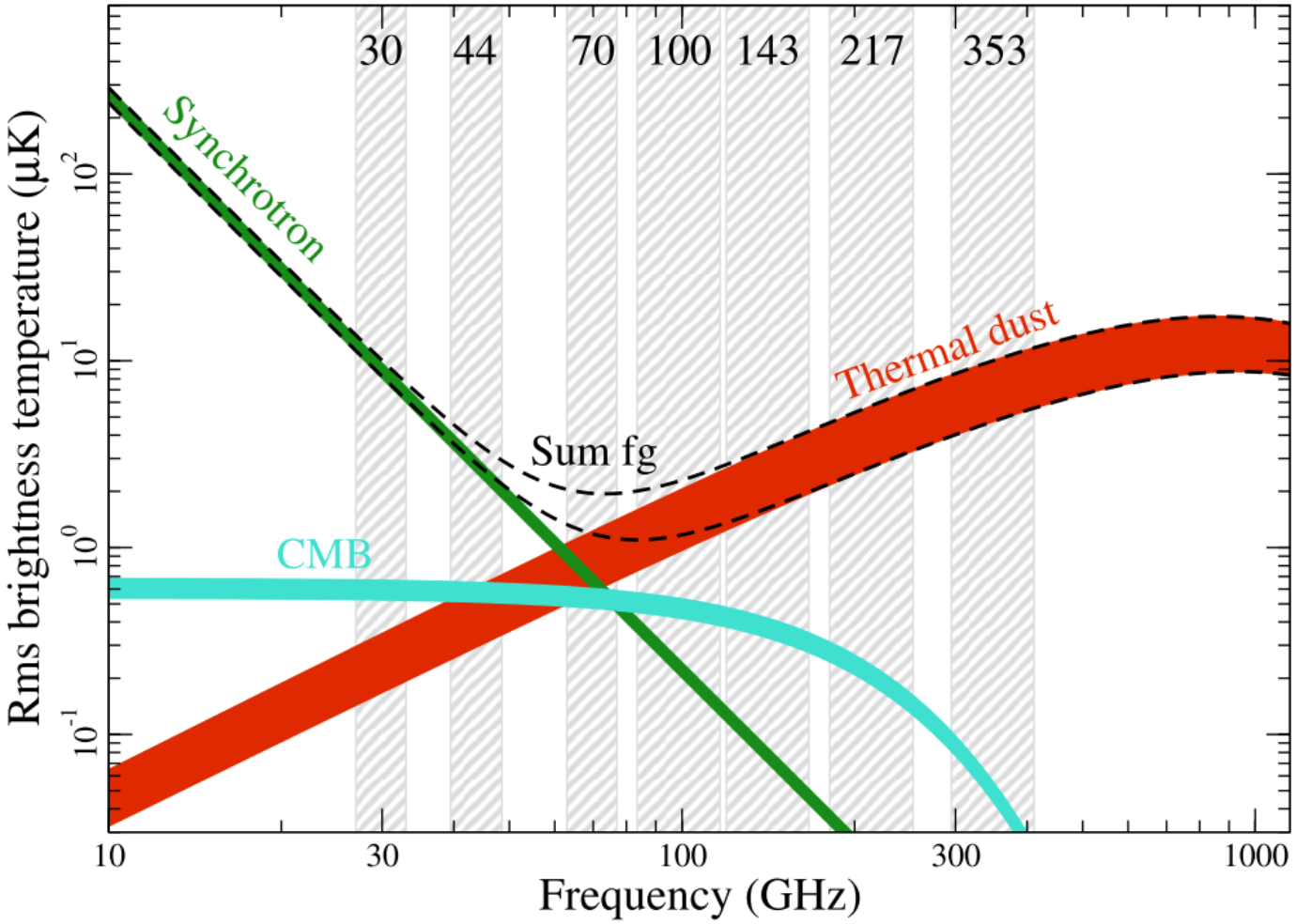
+ Simons observatory, 2016 – 2021

+ CMB S4, 2020 – 2024

Foreground control



Planck collaboration et al, 2015, A&A, 594, A10

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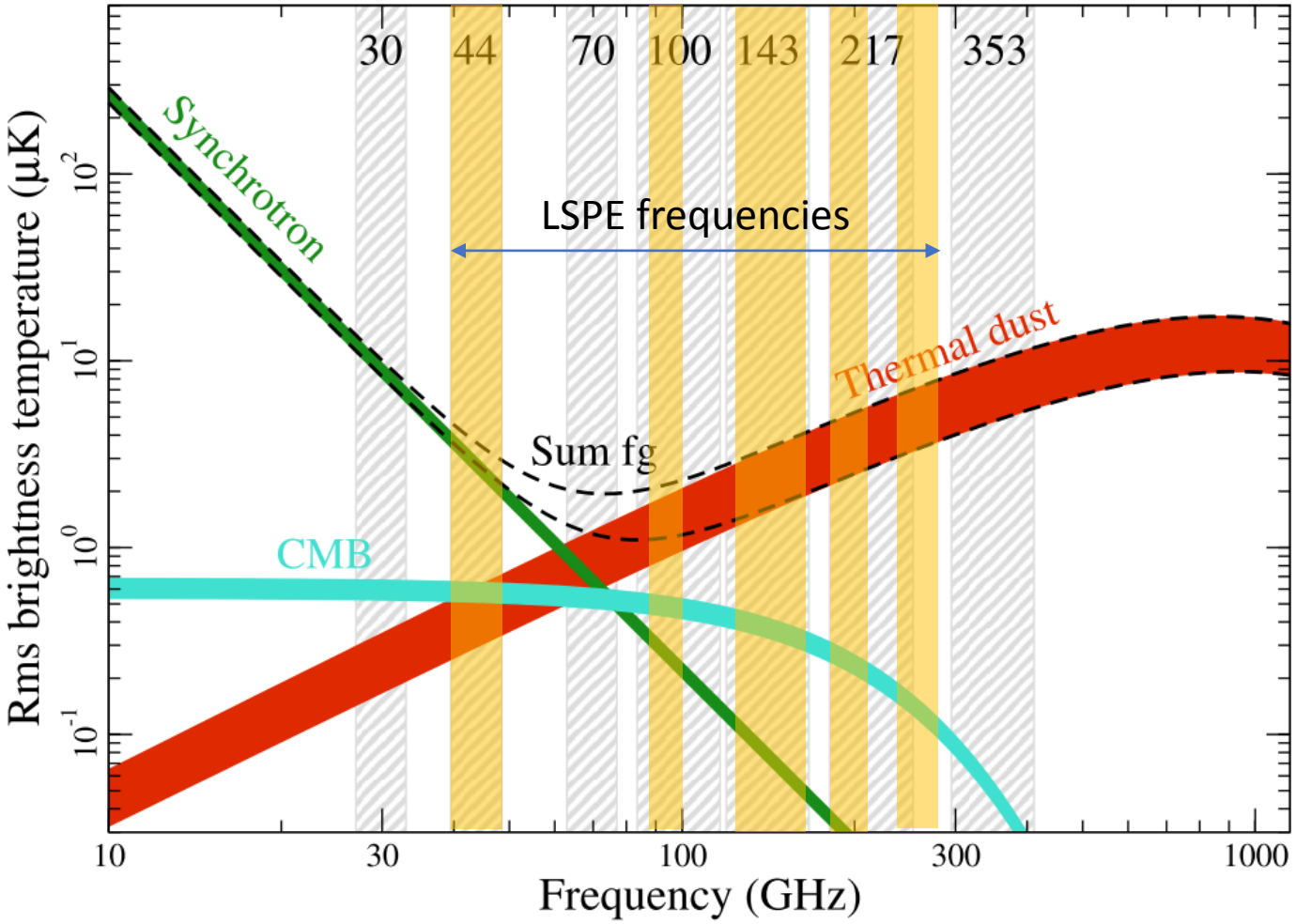


Planck collaboration et al, 2015, A&A, 594, A10

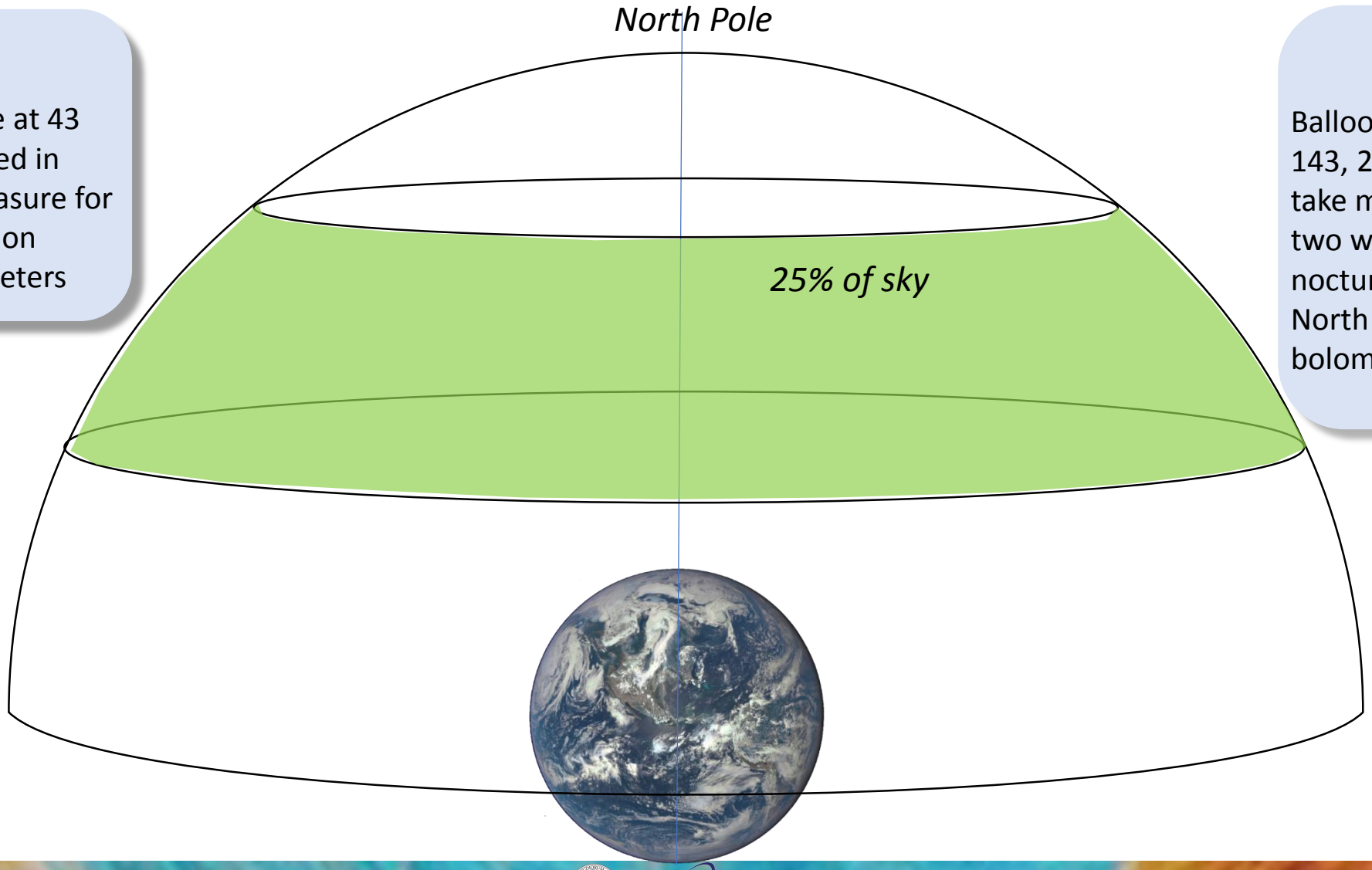
LSPE frequencies

- LSPE exploits the combination of different technologies to cover a wide frequency range
- It will measure microwave emissions from synchrotron and thermal dust

Scanning and operations

STRIP

Ground telescope at 43 and 95 GHz located in Tenerife. Will measure for two years. Based on coherent polarimeters



SWIPE

Balloon borne telescope at 143, 220 and 240 GHz. Will take measurements for two weeks during a LDB nocturnal flight around the North Pole. Based on TES bolometers

Scanning and operations

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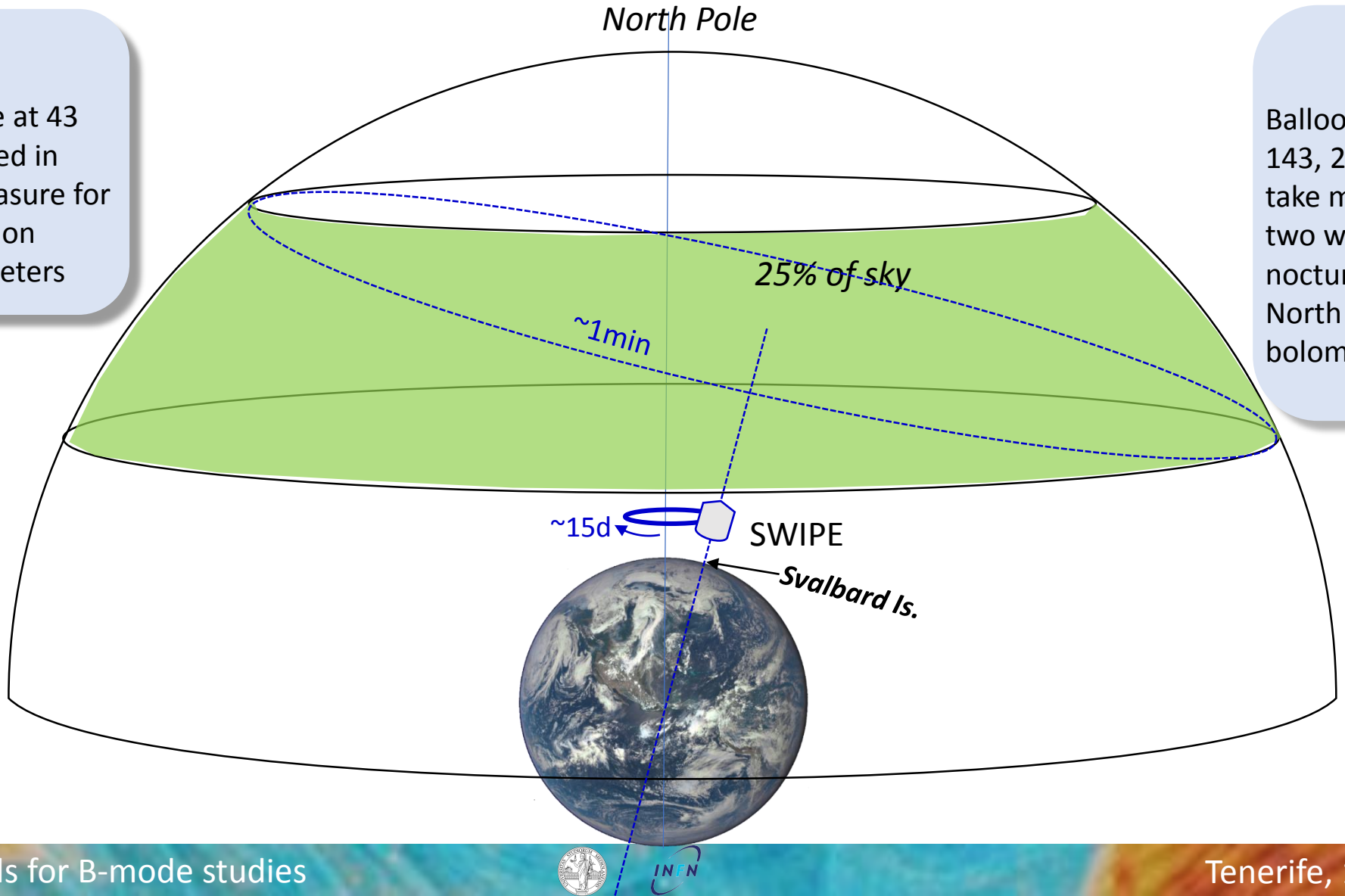

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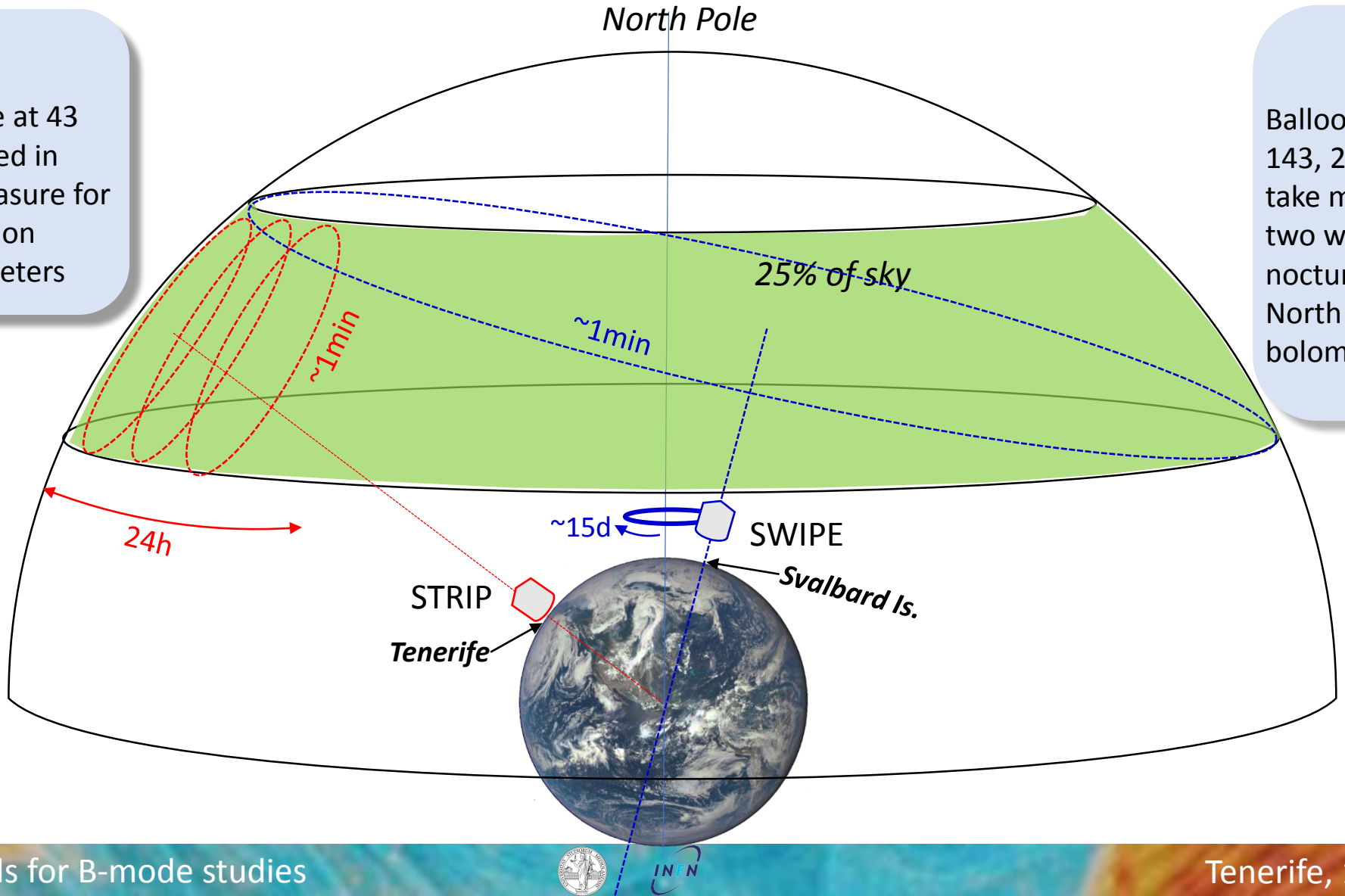

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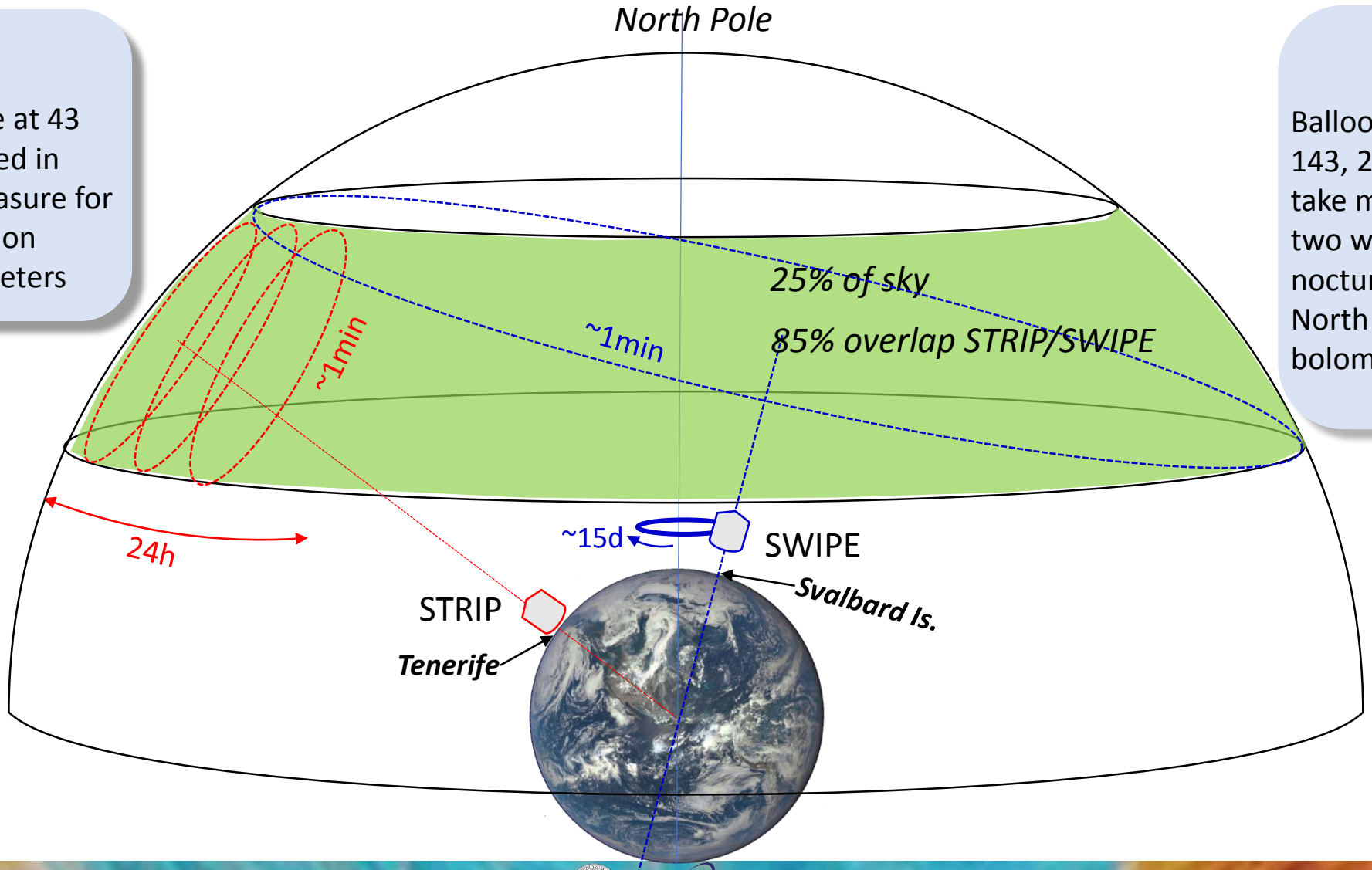

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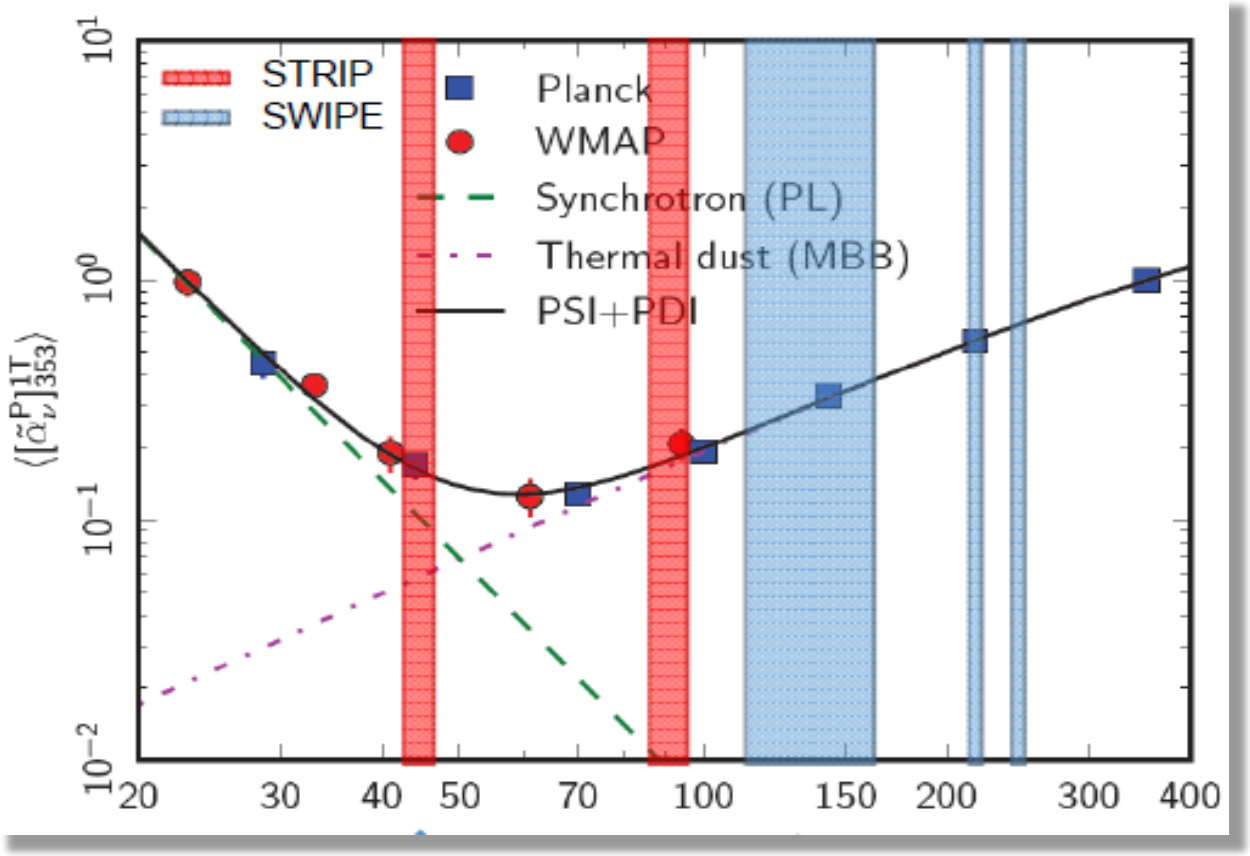
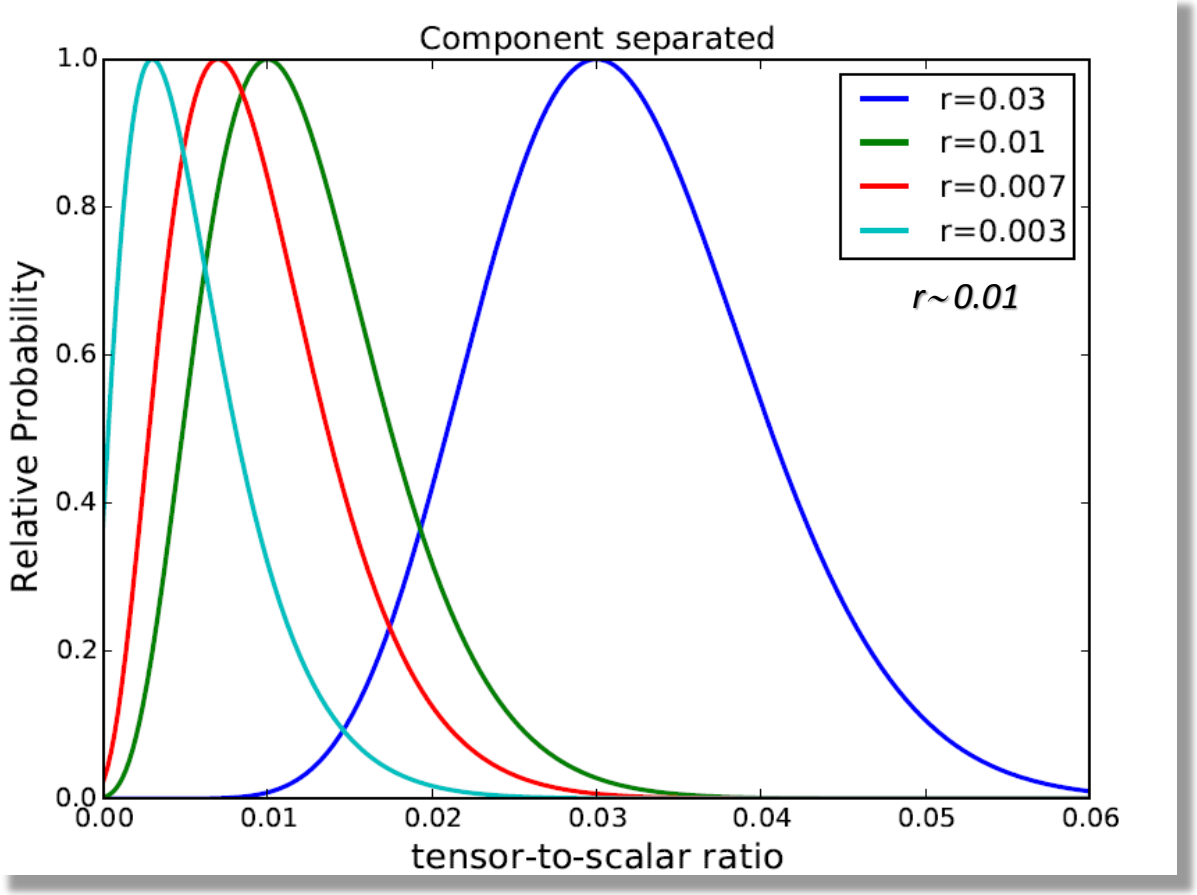
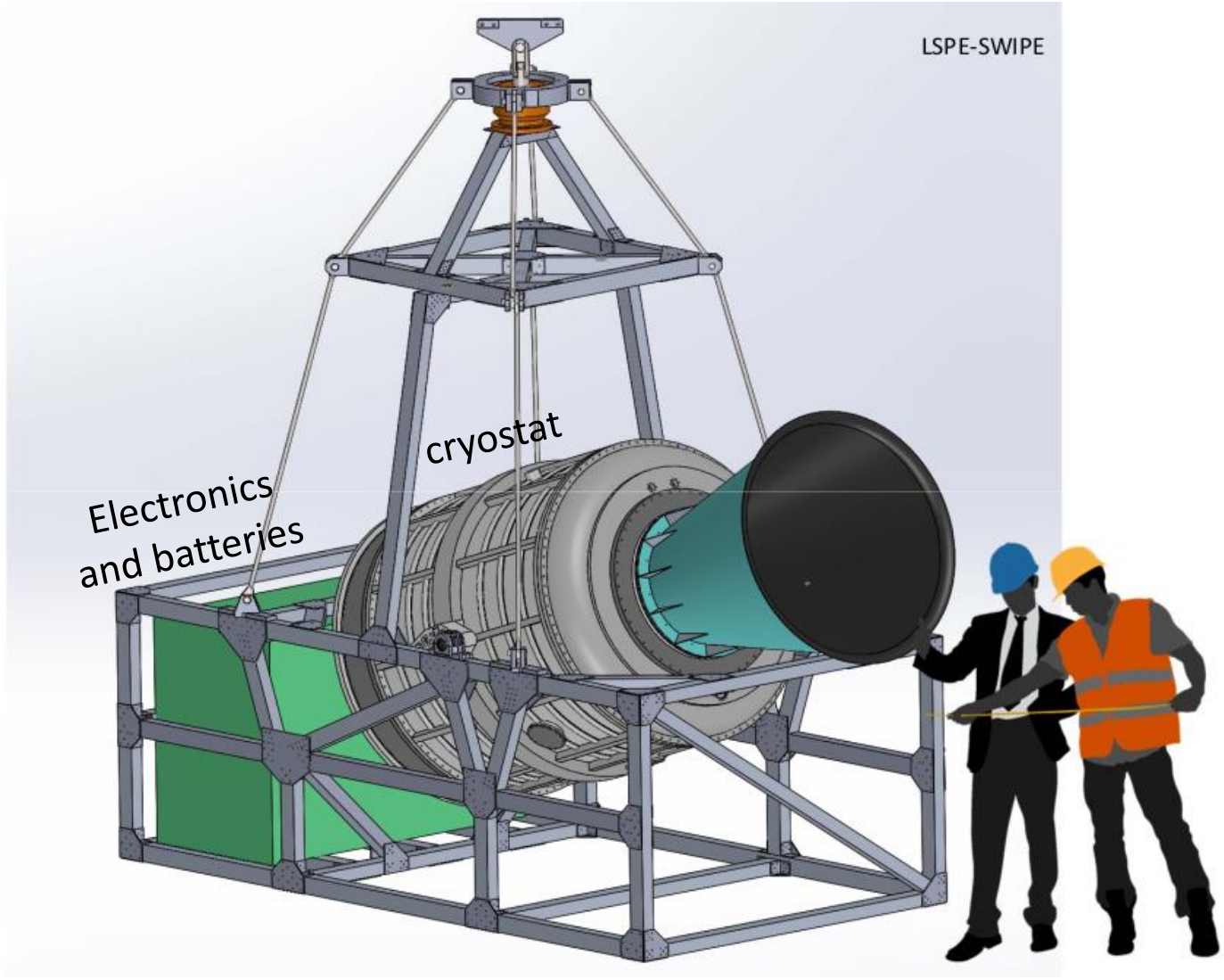
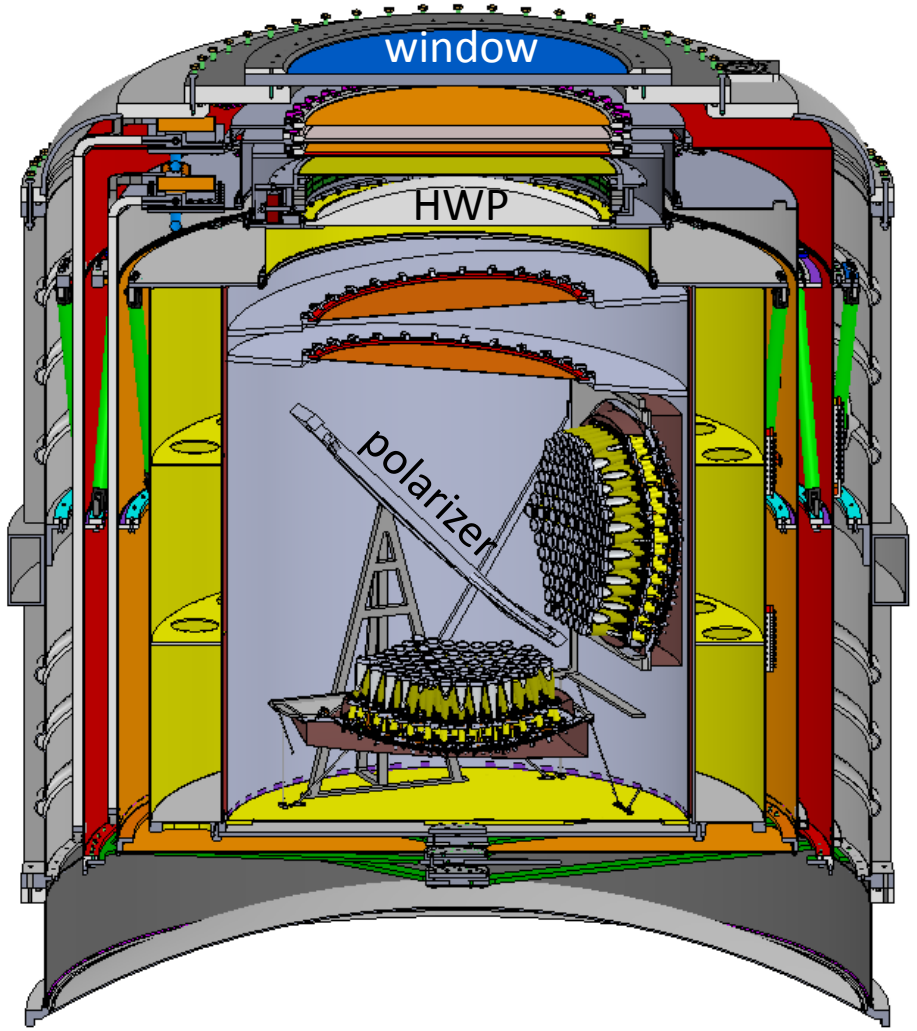
LSPE scientific objectives



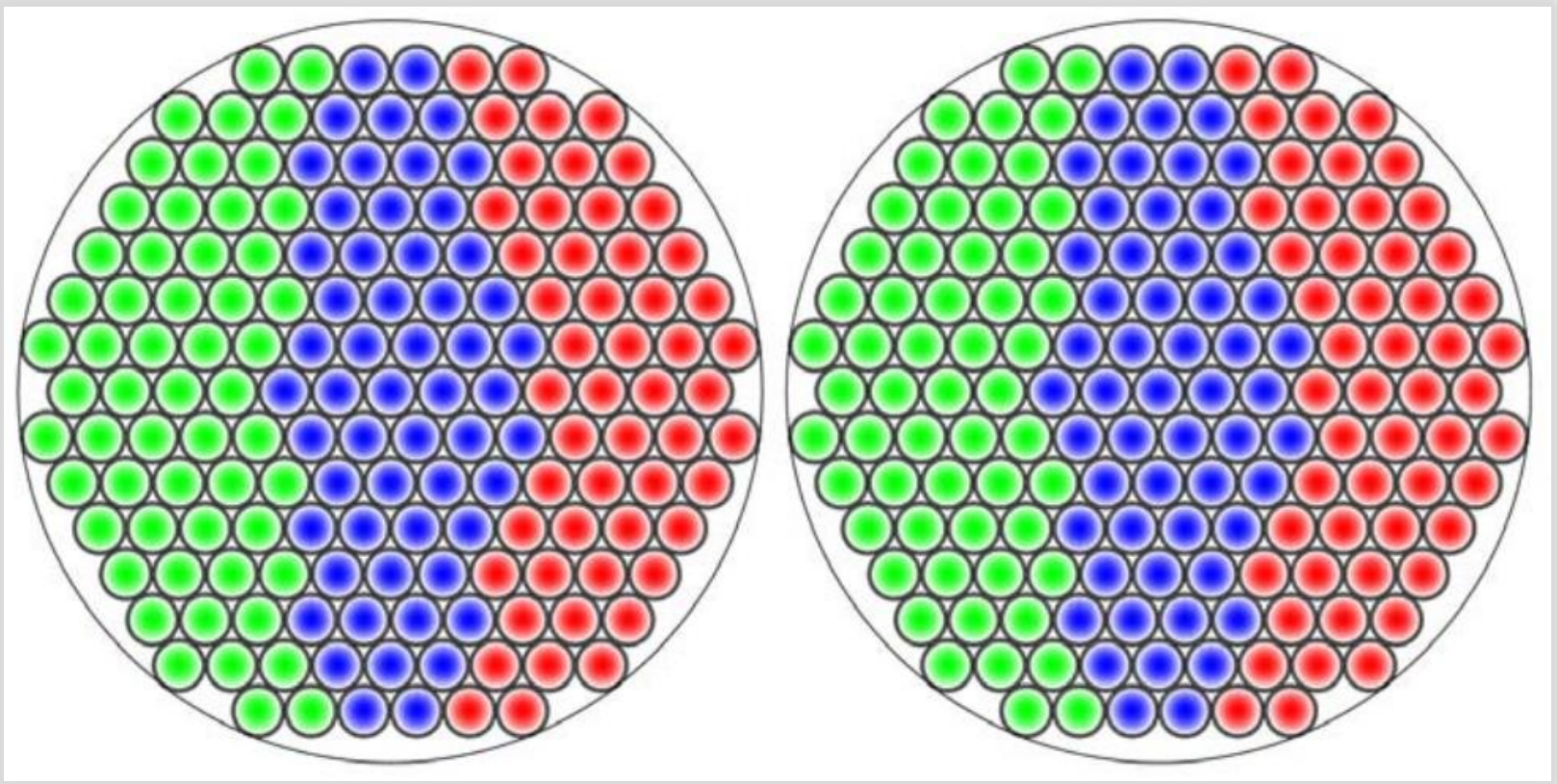


LSPE – The SWIPE instrument





LSPE – The SWIPE focal planes

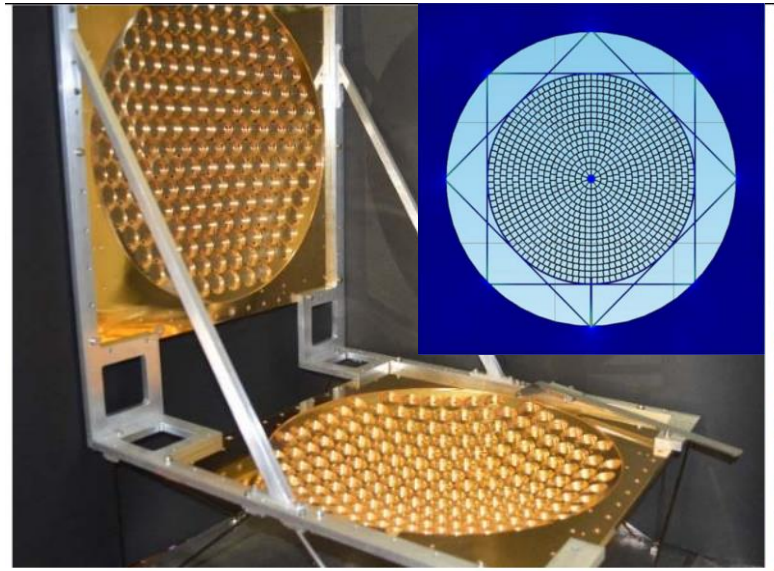


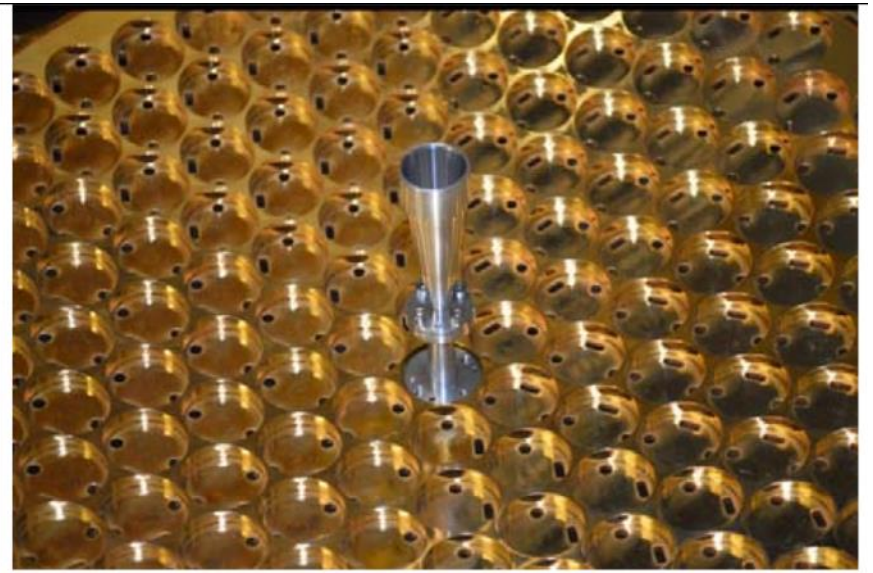
The SWIPE focal plane

- 110 detectors at 140 GHz
- 112 detectors at 220 GHz
- 112 detectors at 240 GHz

LSPE – The SWIPE focal planes

With 10-20 modes per frequency channel this configuration allows a final sensitivity ranging from 10 μK-arcmin at 140 GHz to 80 μK-arcmin at 240 GHz

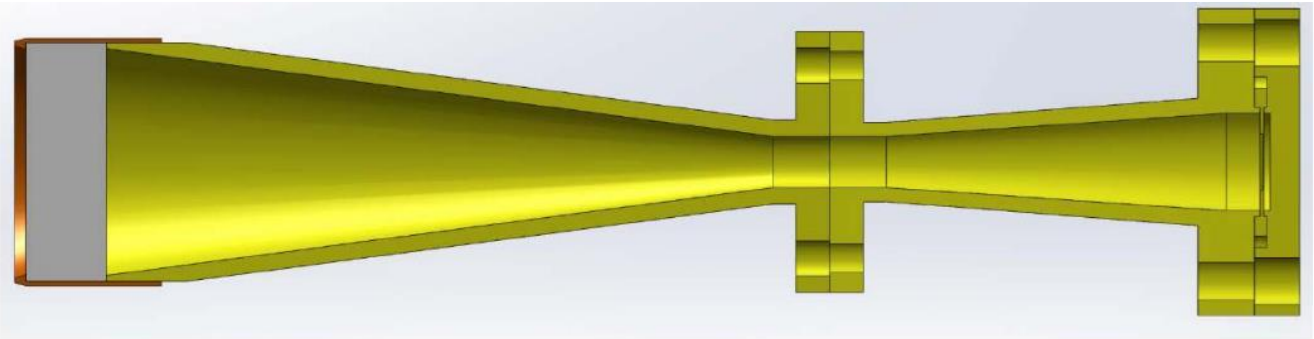


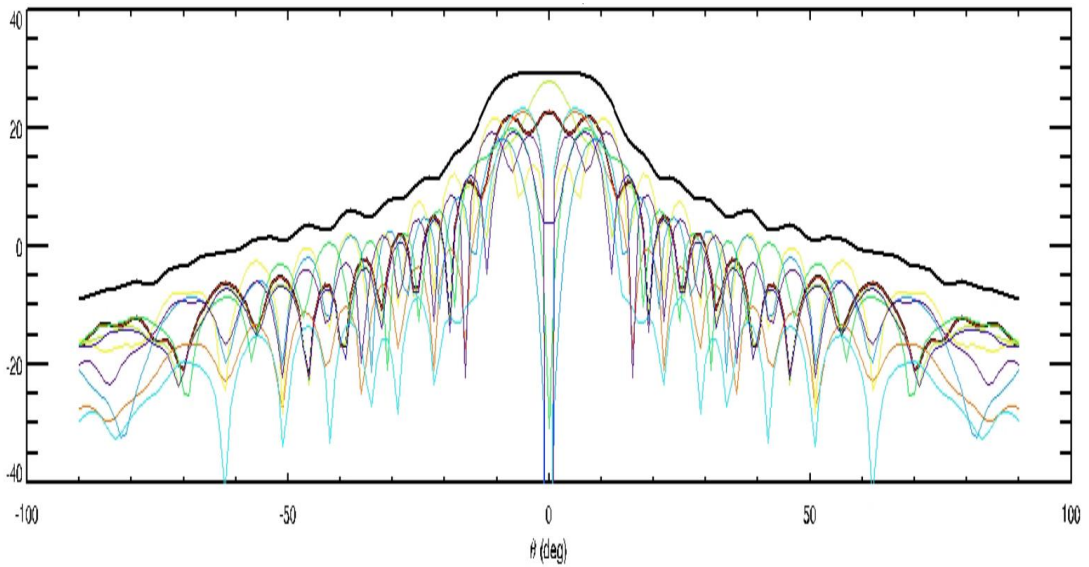


The SWIPE focal plane

- 110 detectors at 140 GHz
- 112 detectors at 220 GHz
- 112 detectors at 240 GHz
- TES bolometers coupled to multi-moded feedhorns

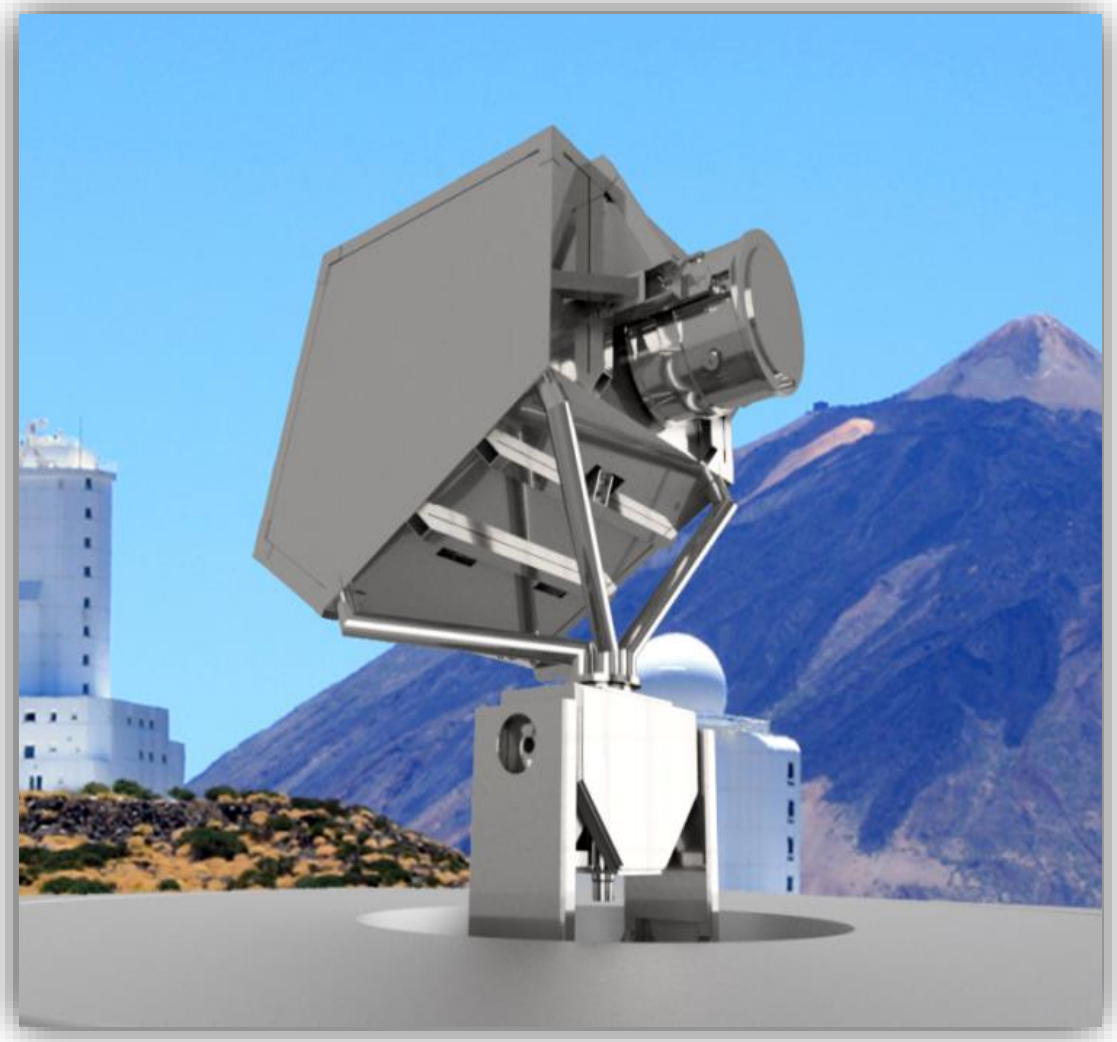
LSPE – The SWIPE feed horns





Channel	ν_{min}(GHz)	$N_{modes}(\nu_{min})$	ν_{max}(GHz)	$N_{modes}(\nu_{max})$	ν_{eff}(GHz)	$N_{modes}(\nu_{eff})$
140	119	10	161	17	140	12
220	214	28	226	31	220	30
240	234	32	246	35	240	34

LSPE – The STRIP instrument



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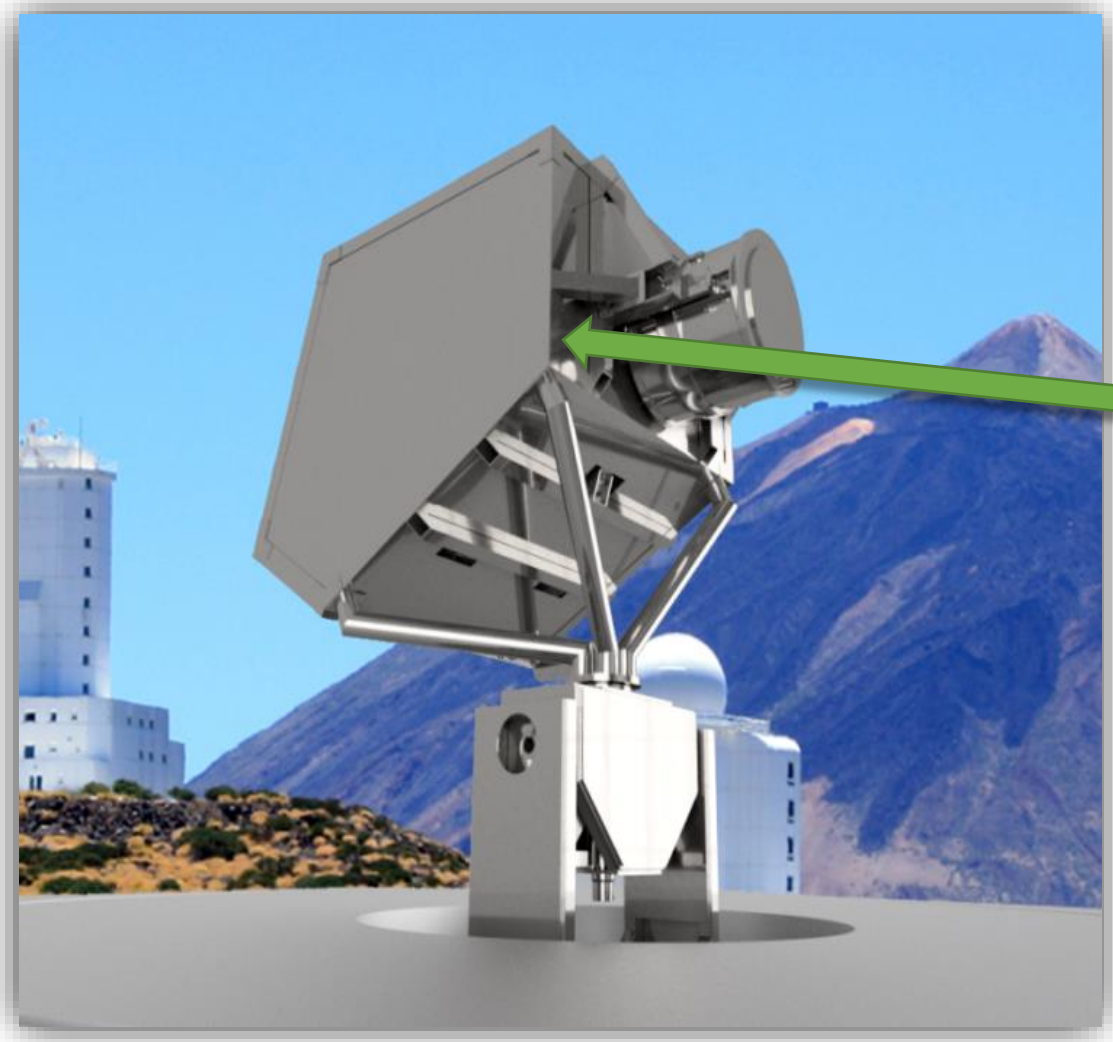

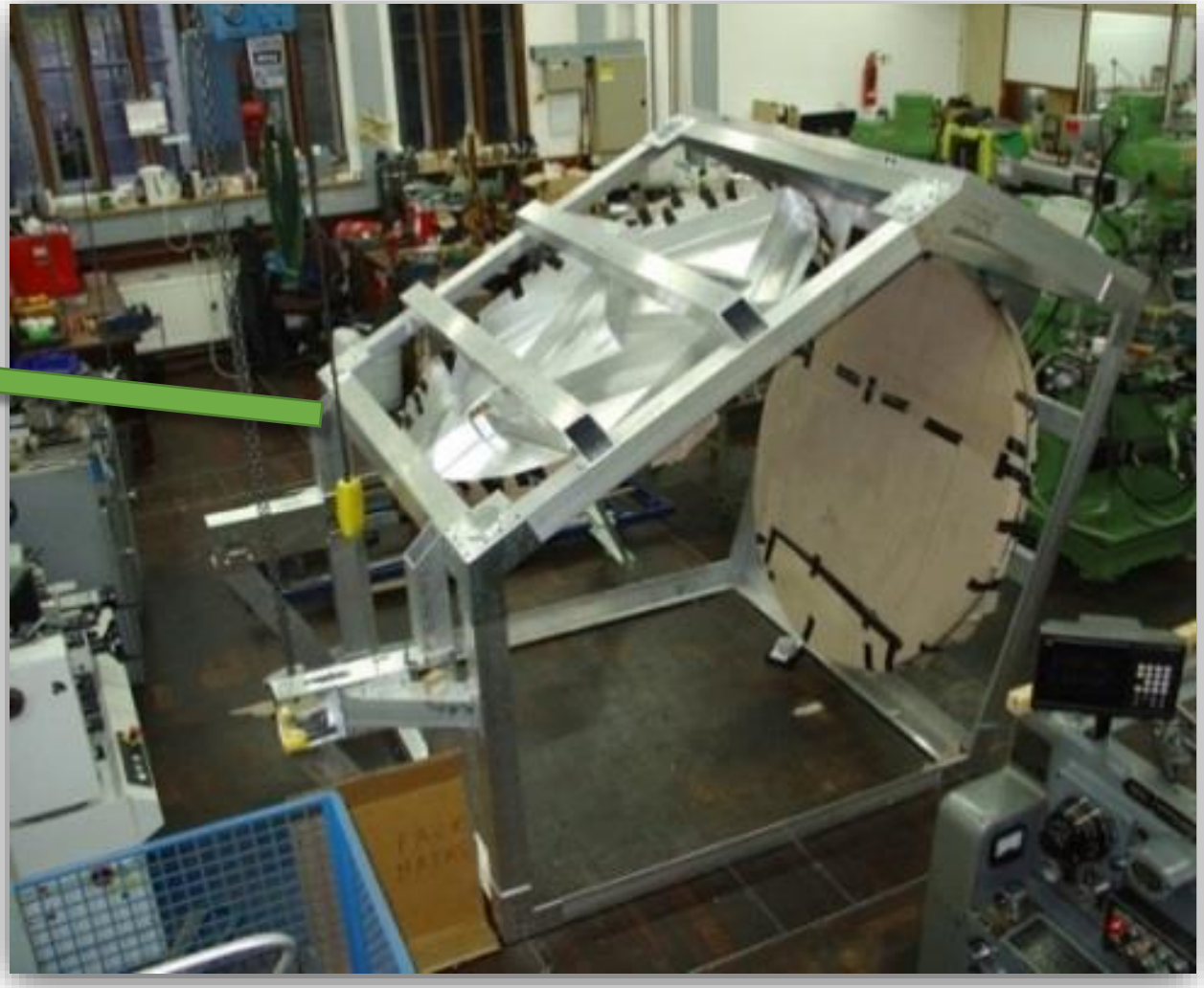

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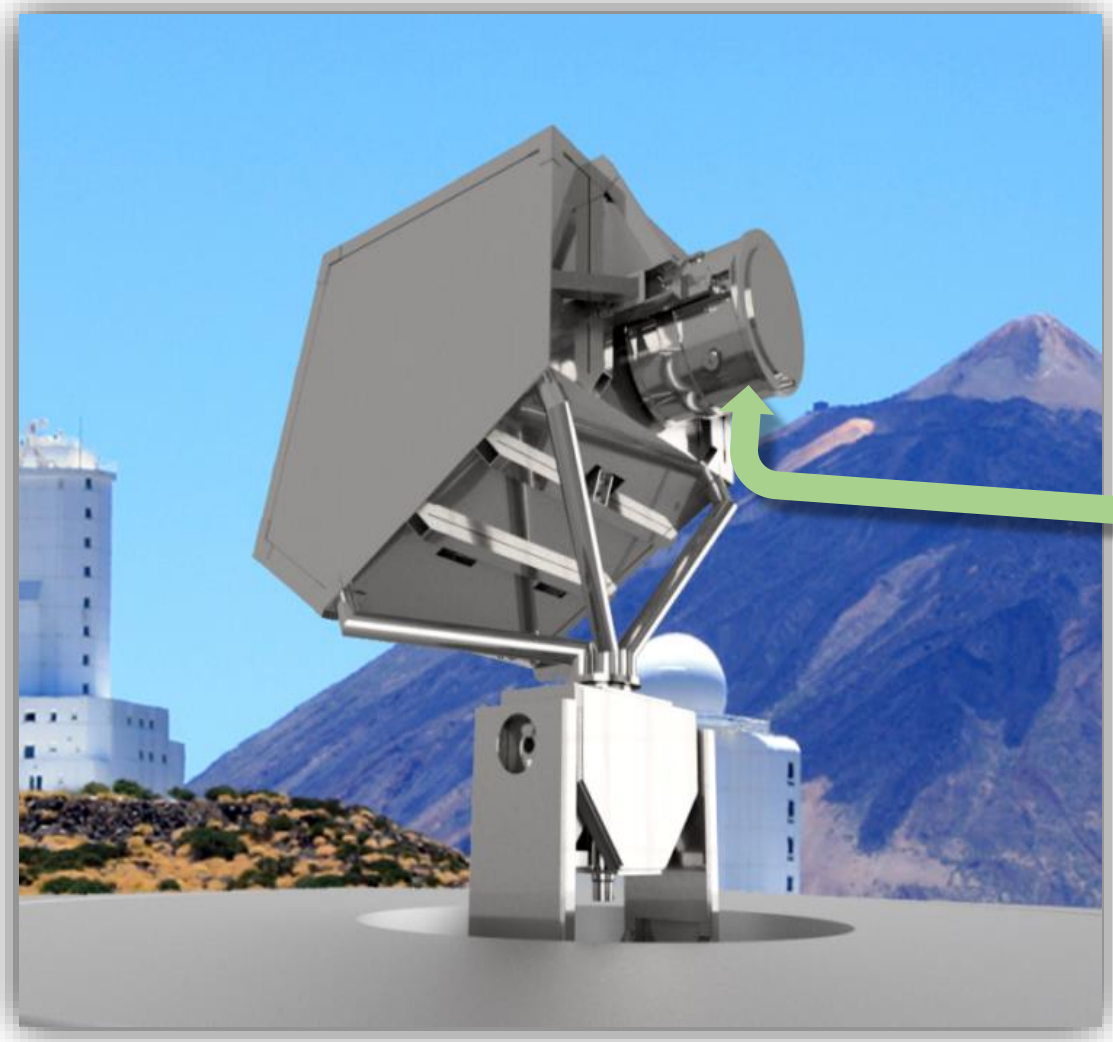
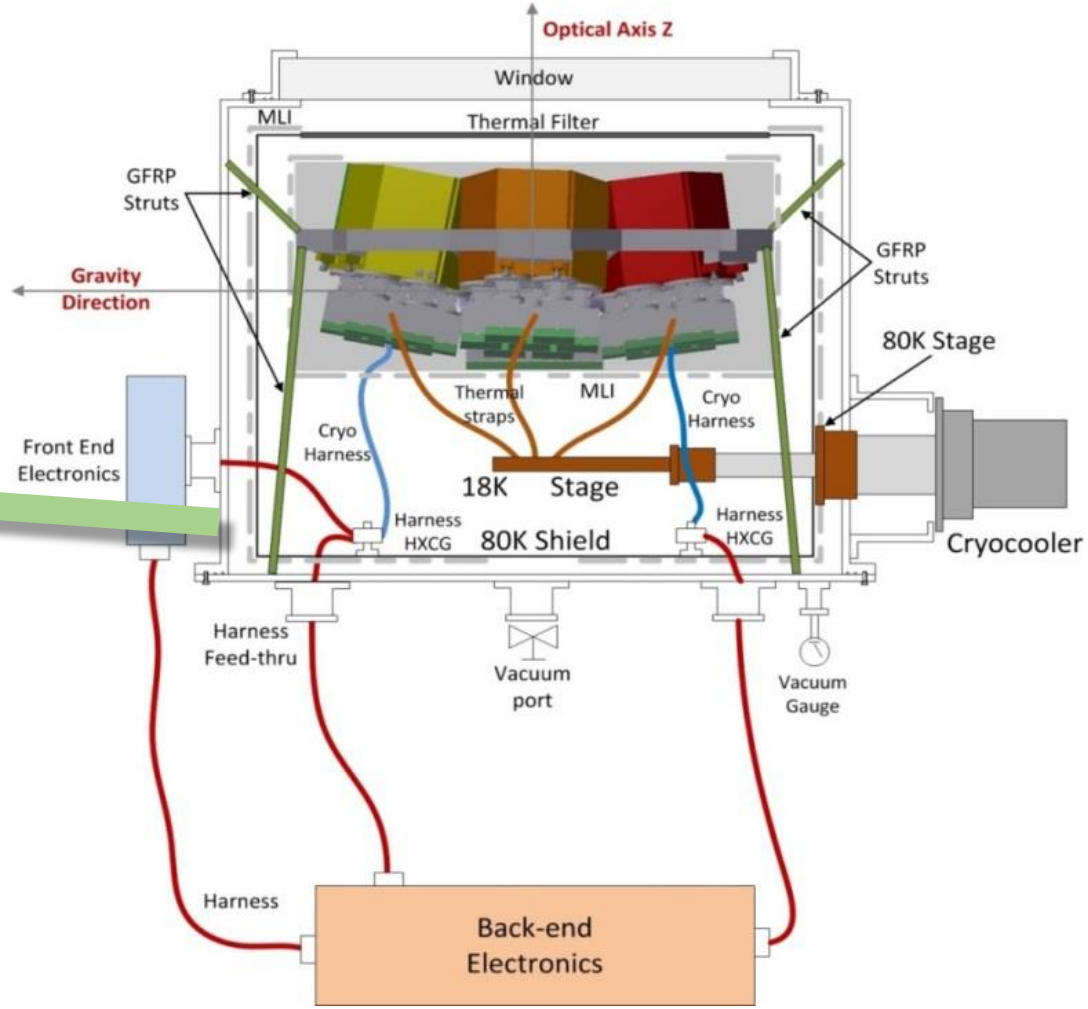
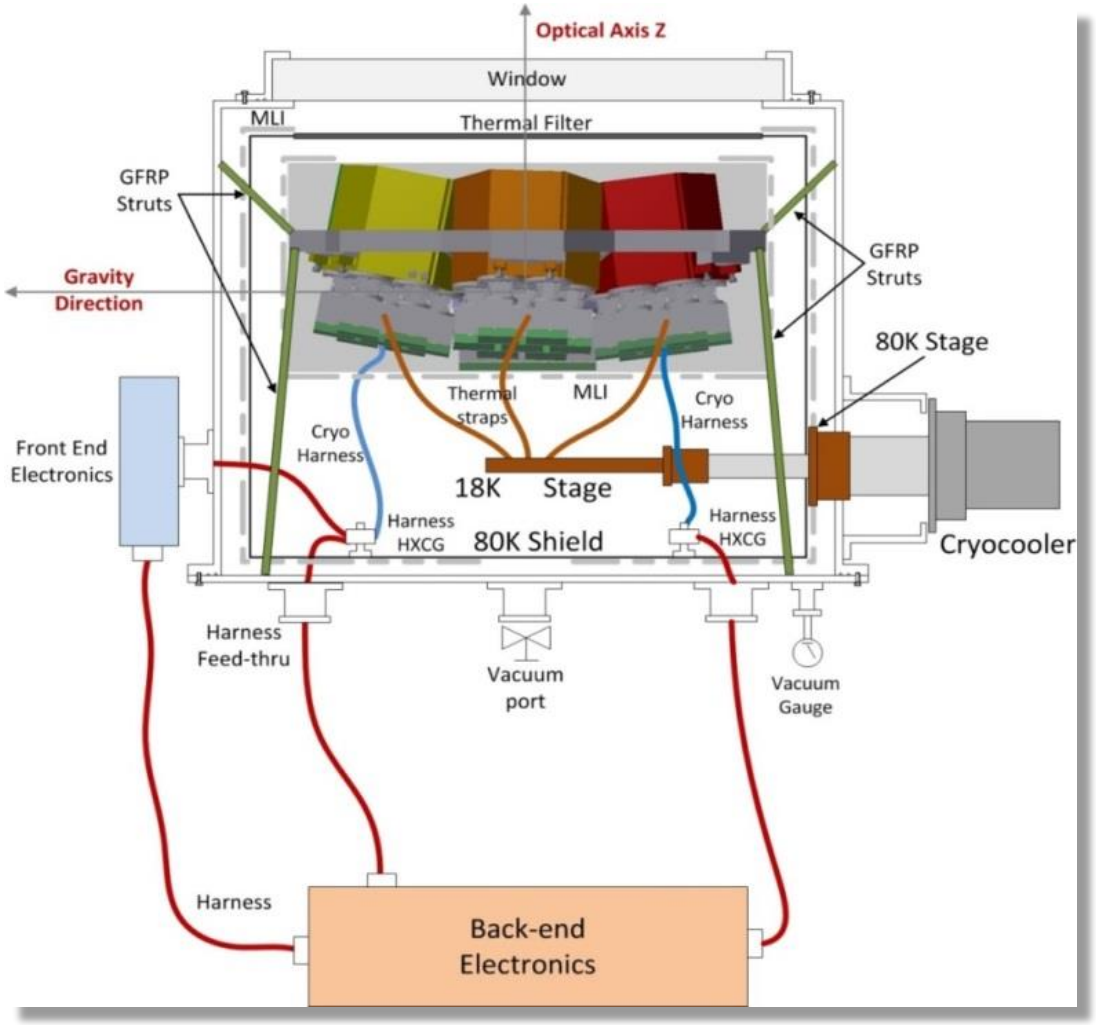




LSPE – STRIP overview



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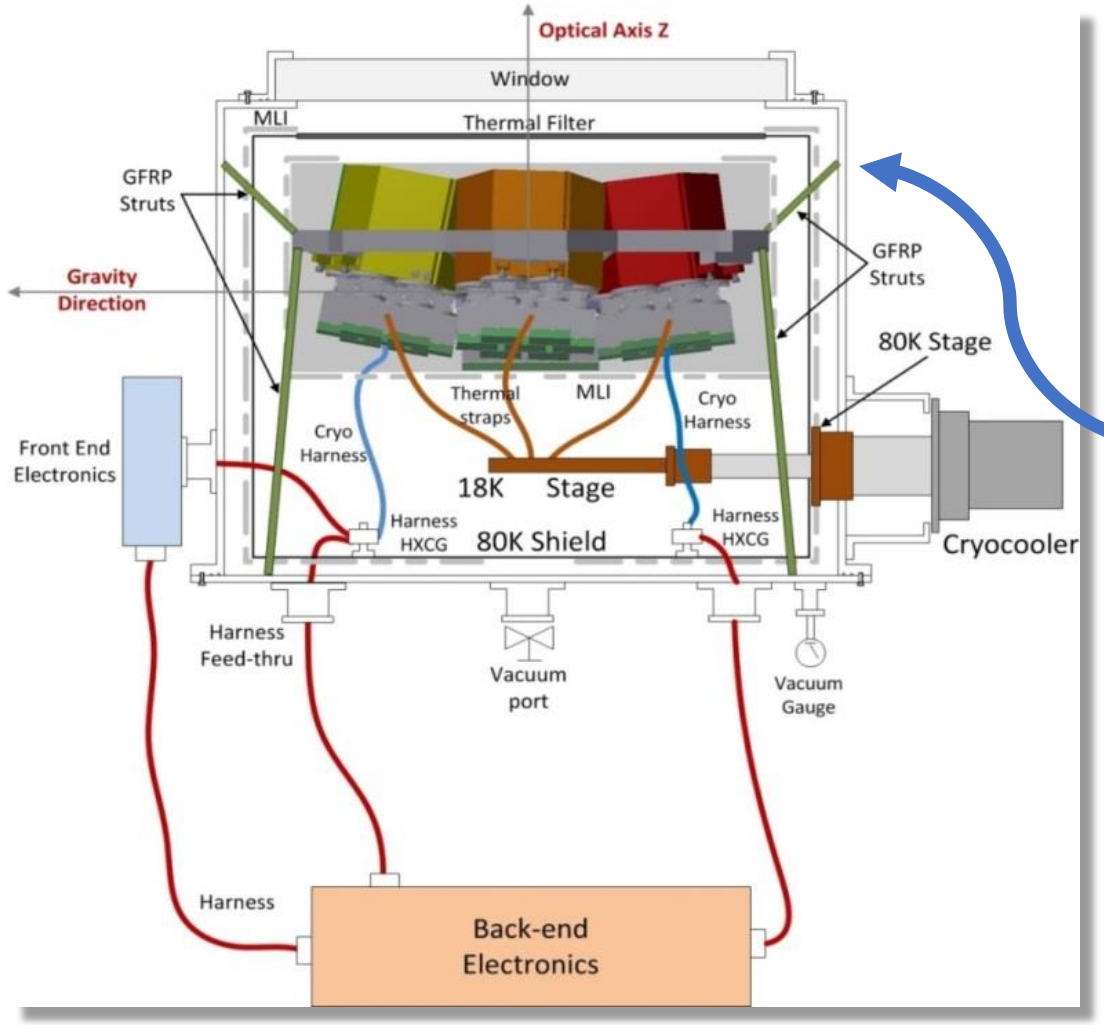

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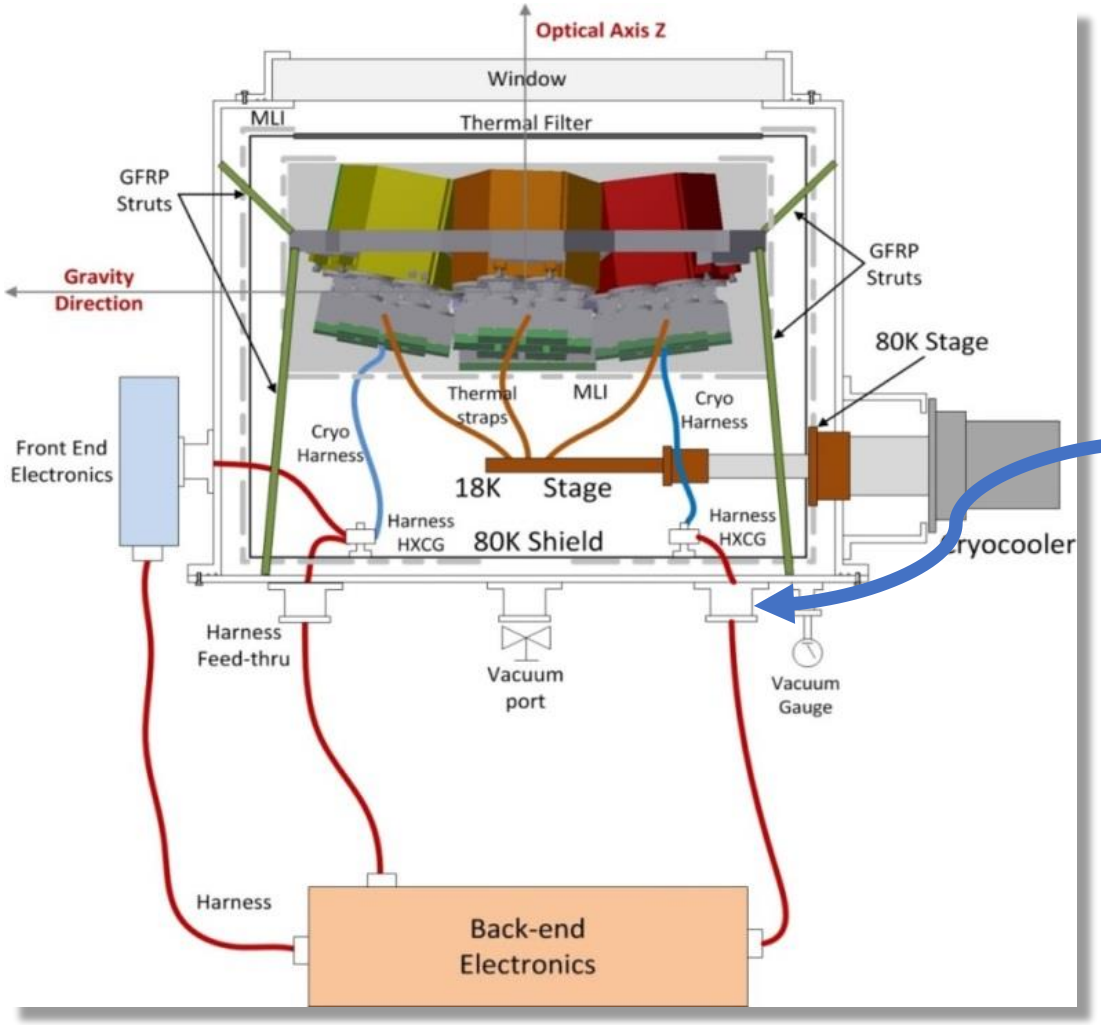

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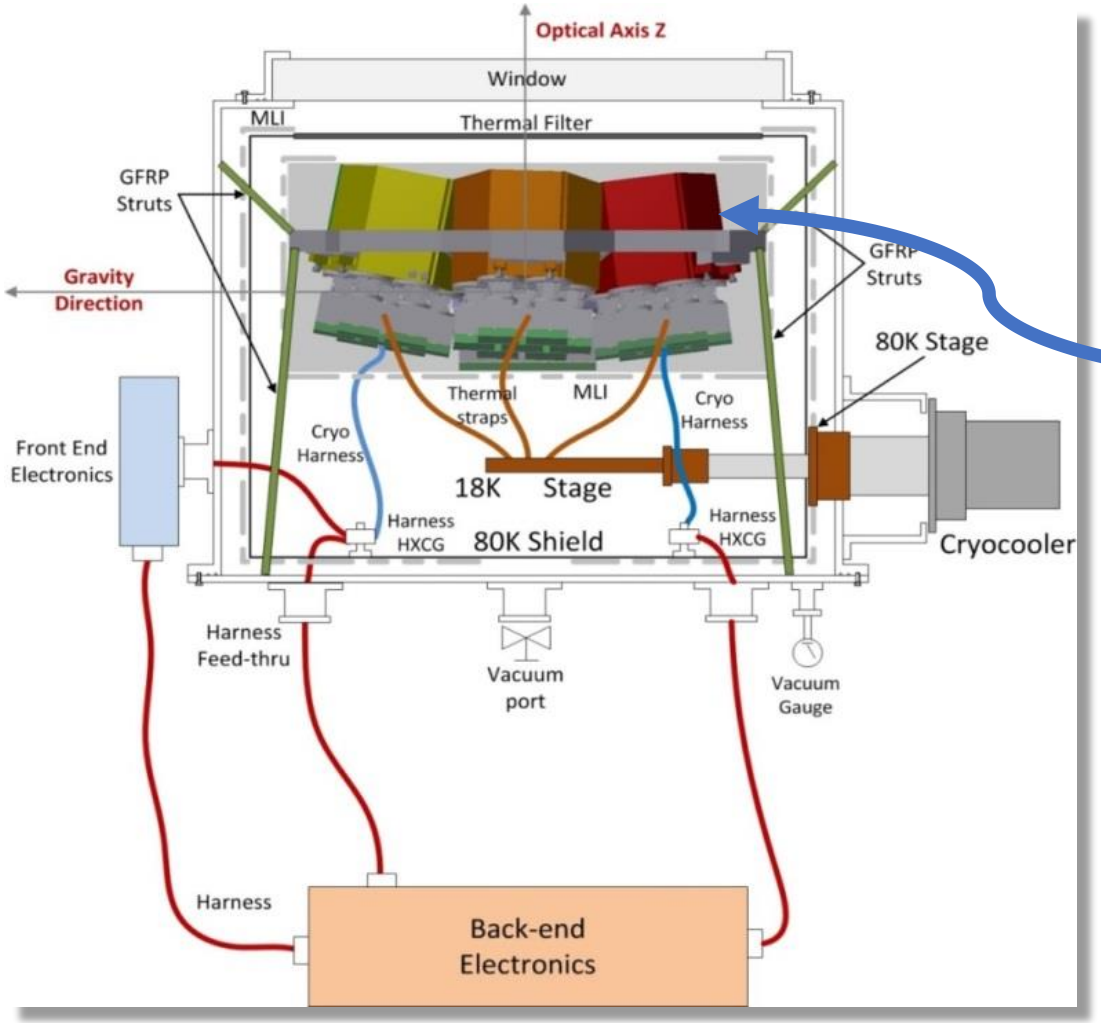
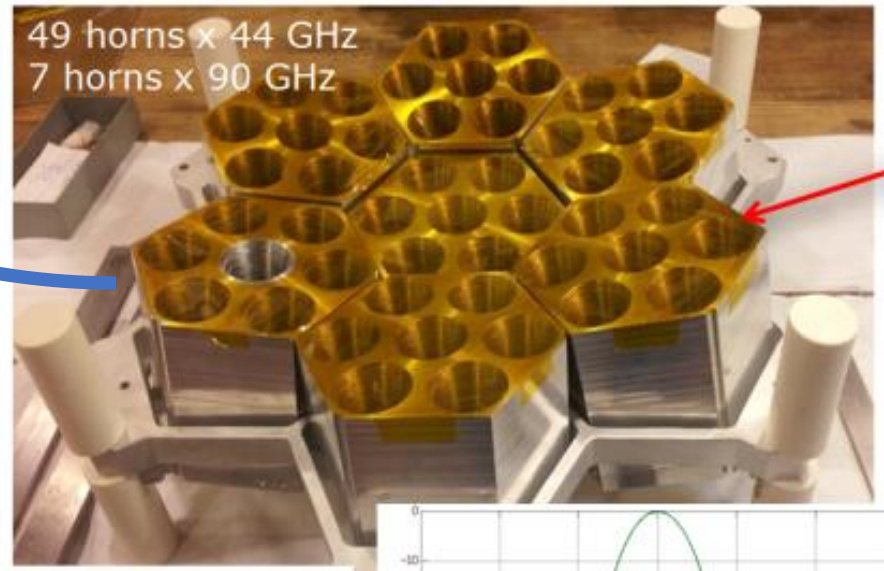
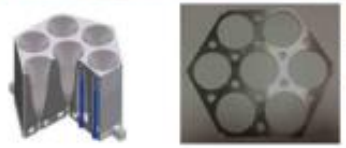
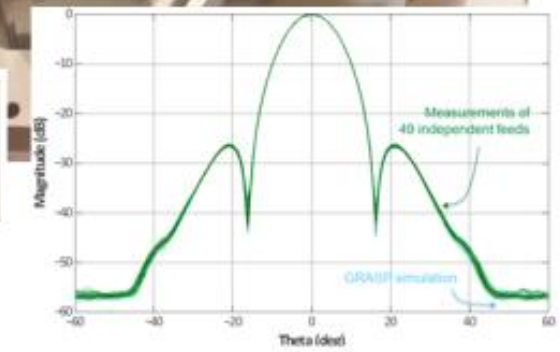
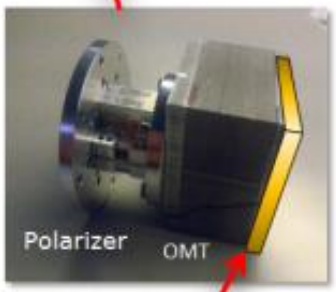


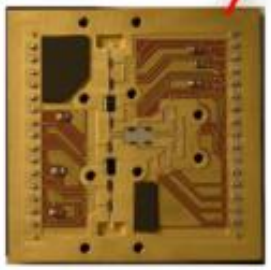




State-of-the-art platelet technique

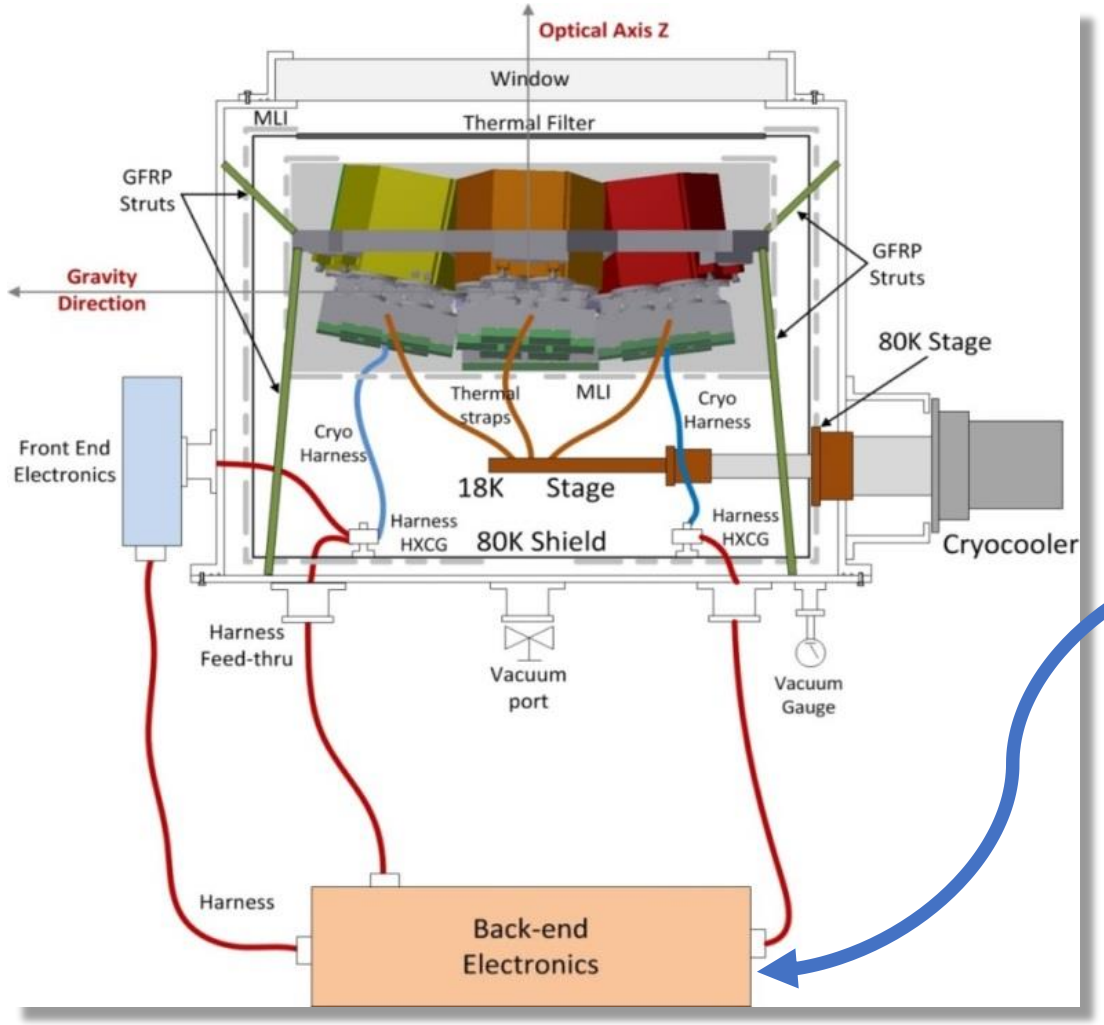


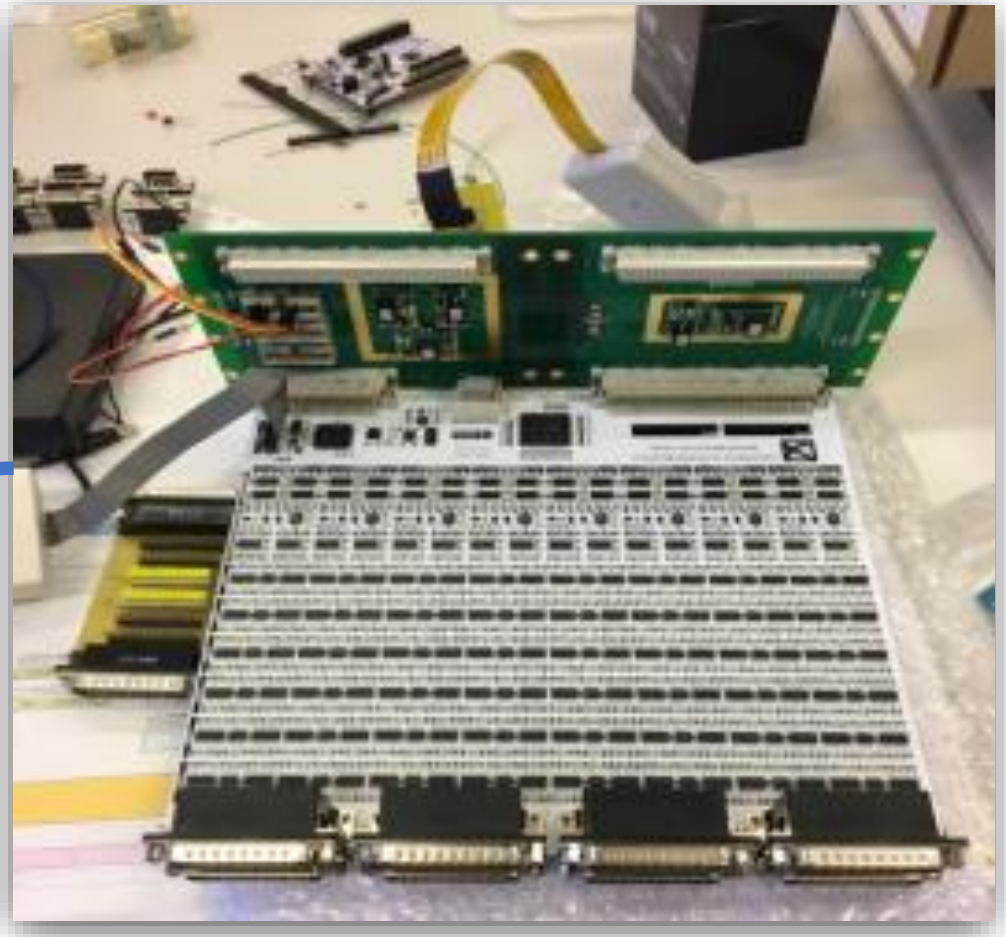




Polarimeter

LSPE – STRIP overview





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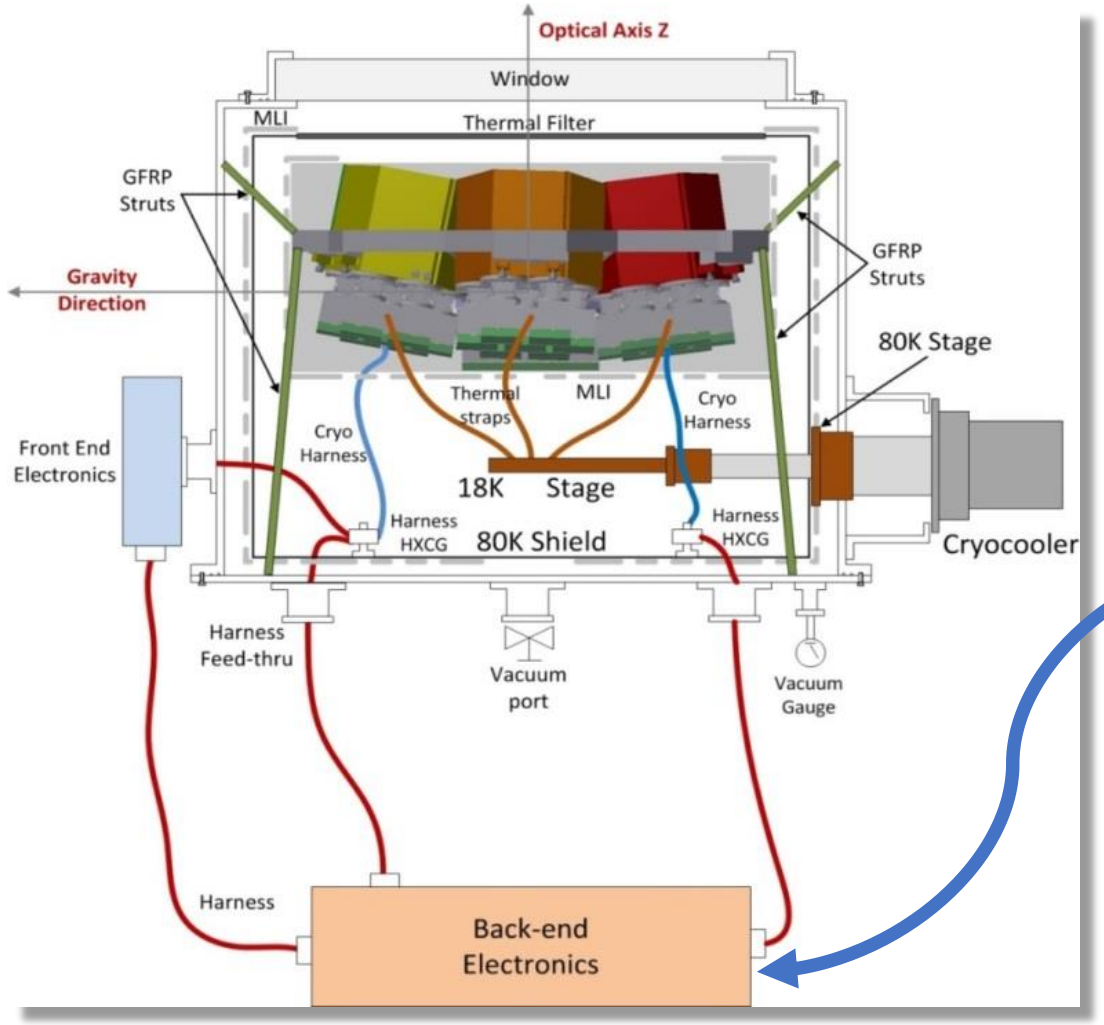
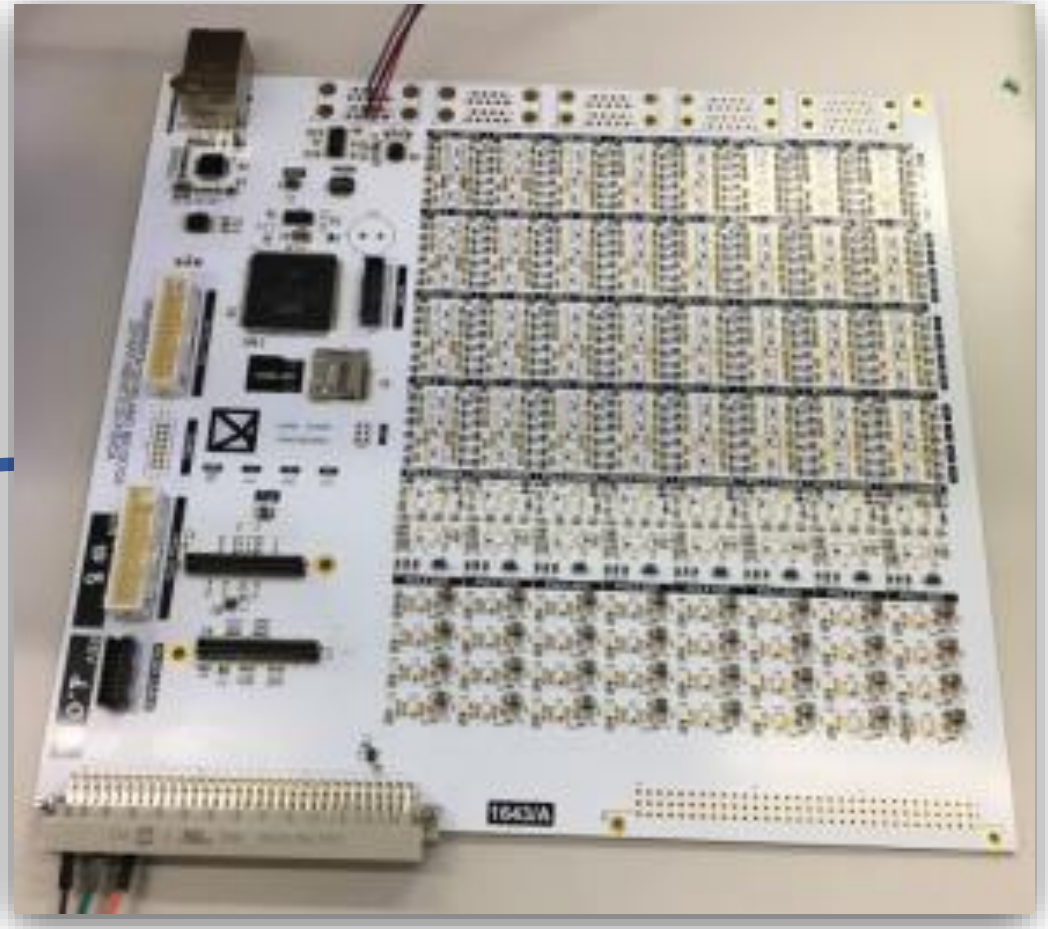
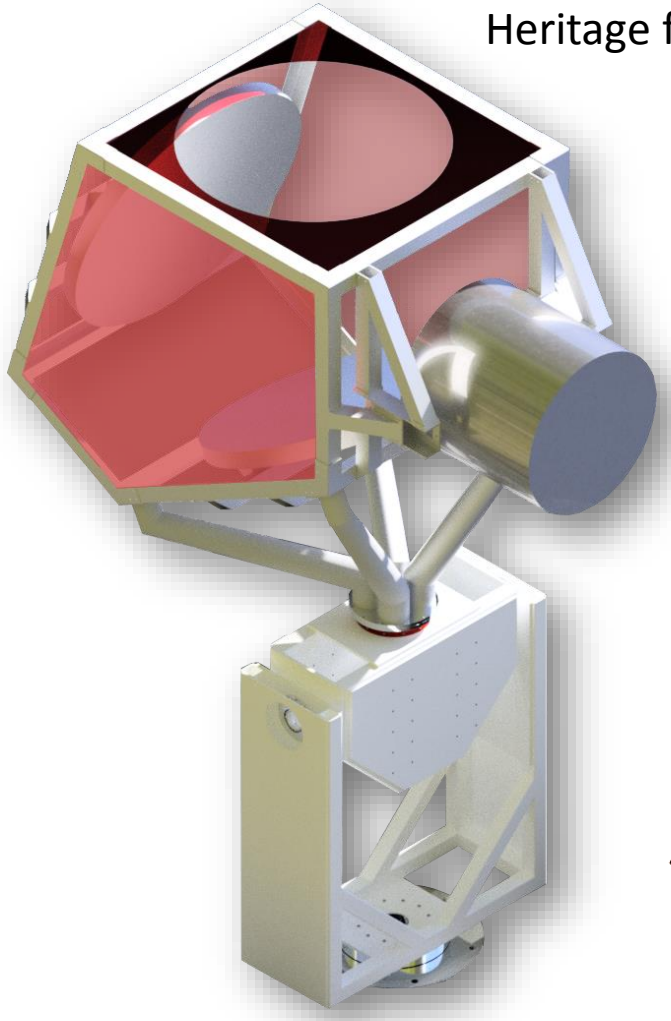
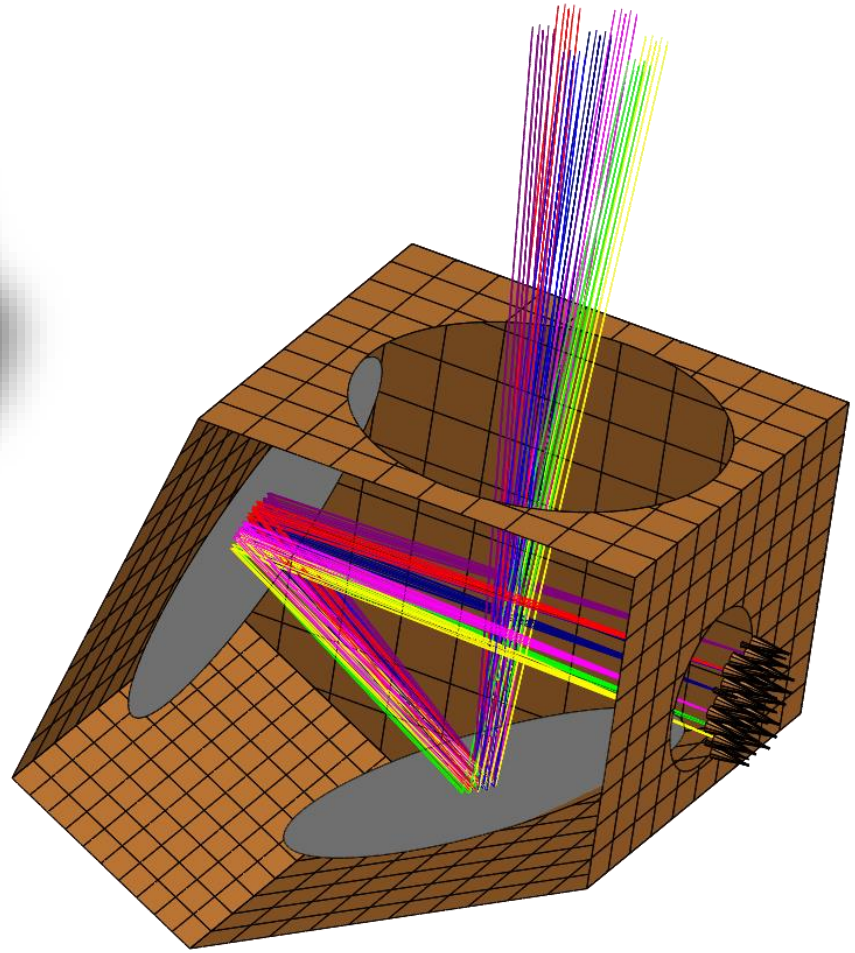




STRIP mount and optics

Heritage from CLOVER (Oxford team)





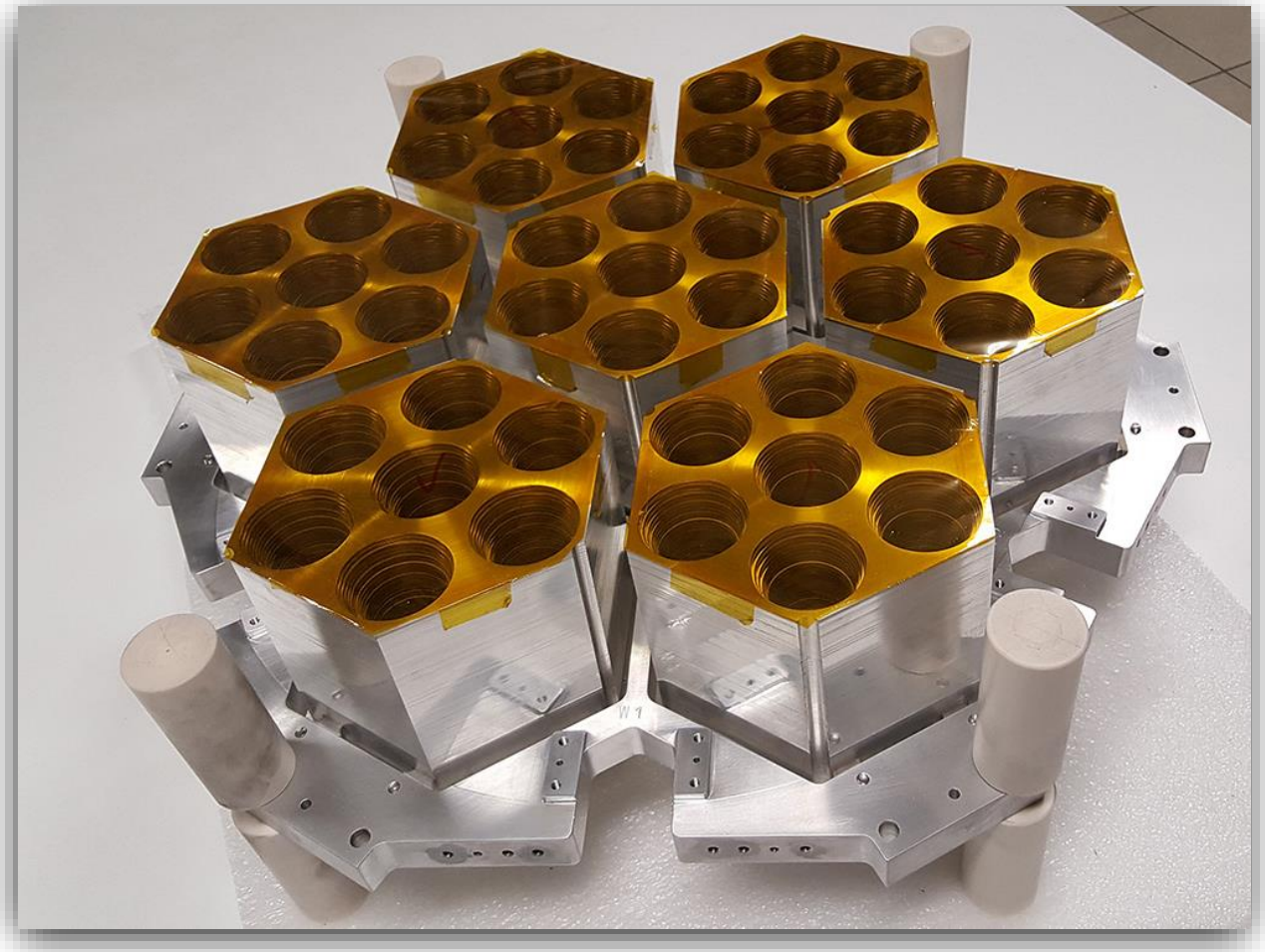
3-AXES TELESCOPE MOUNT

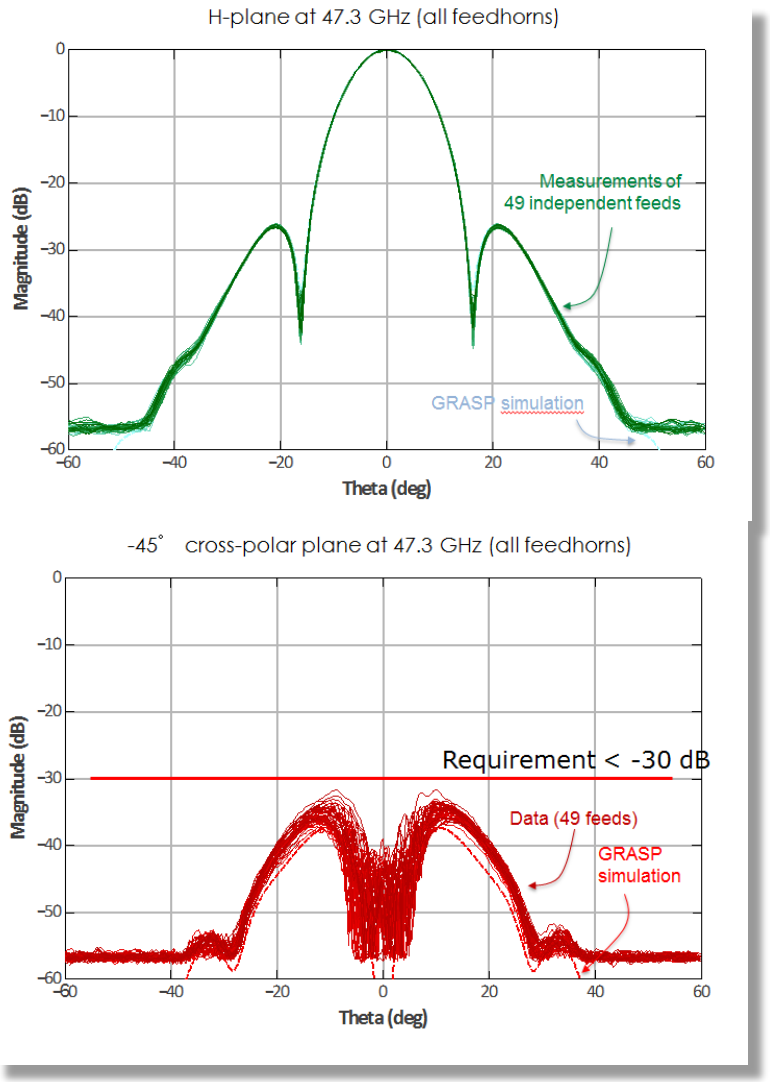
- Fully rotating **azimuth axis** at 1 r.p.m.
- **Elevation axis** fixed at 20°
- **Boresight axis** (fixed)

OPTICS

- **Crossed-Dragone configuration** with 1.5 m aperture
- F/# = 1.8
- Comoving baffle

STRIP optics performance





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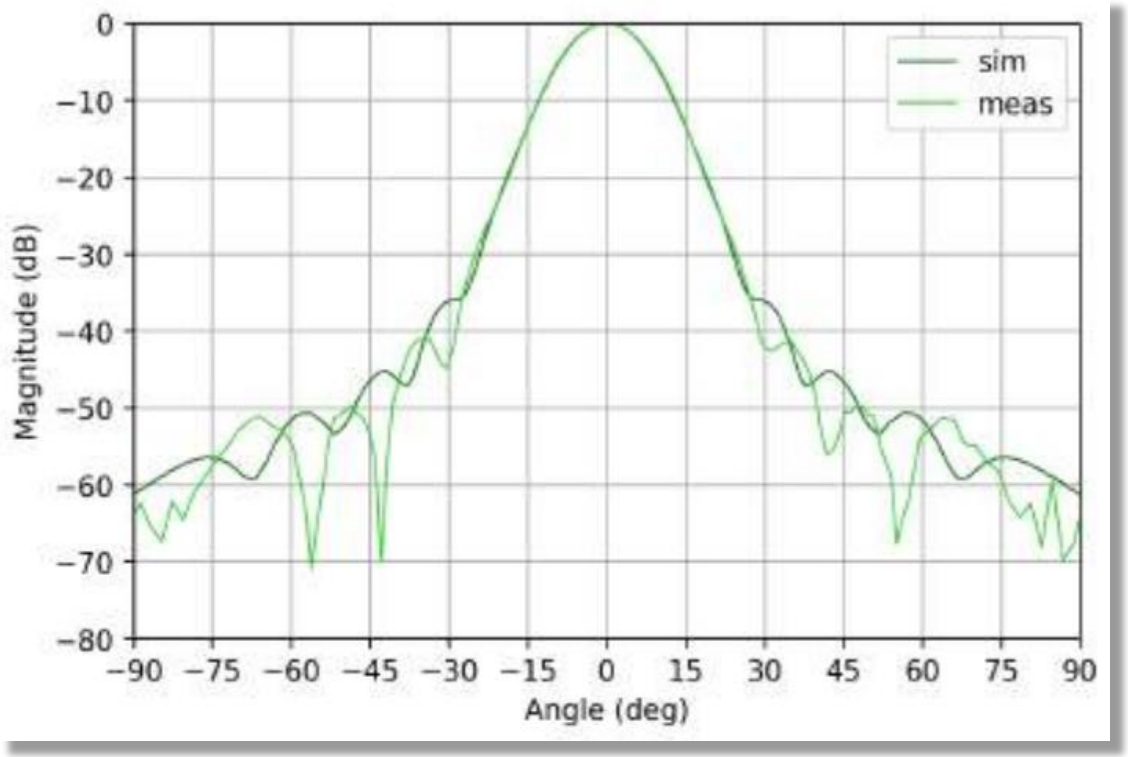
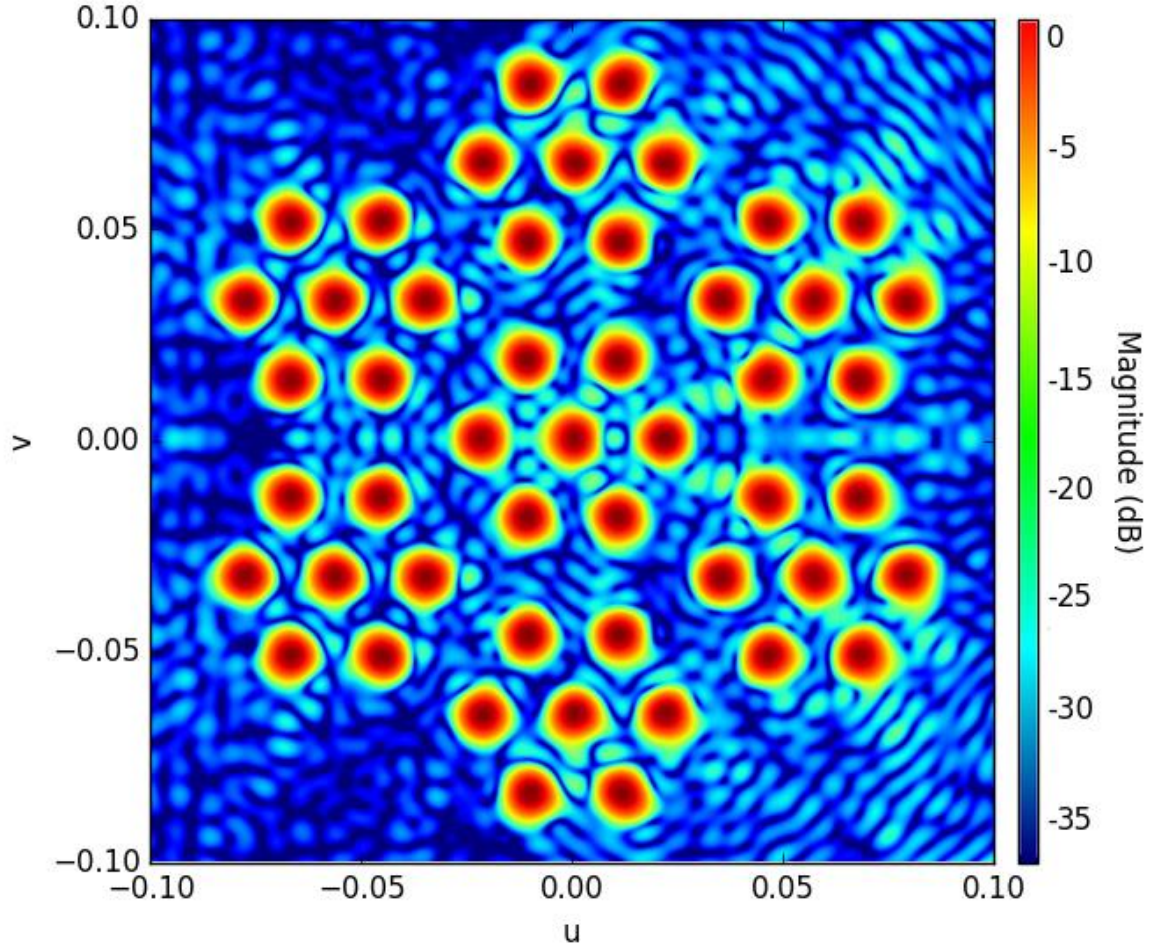


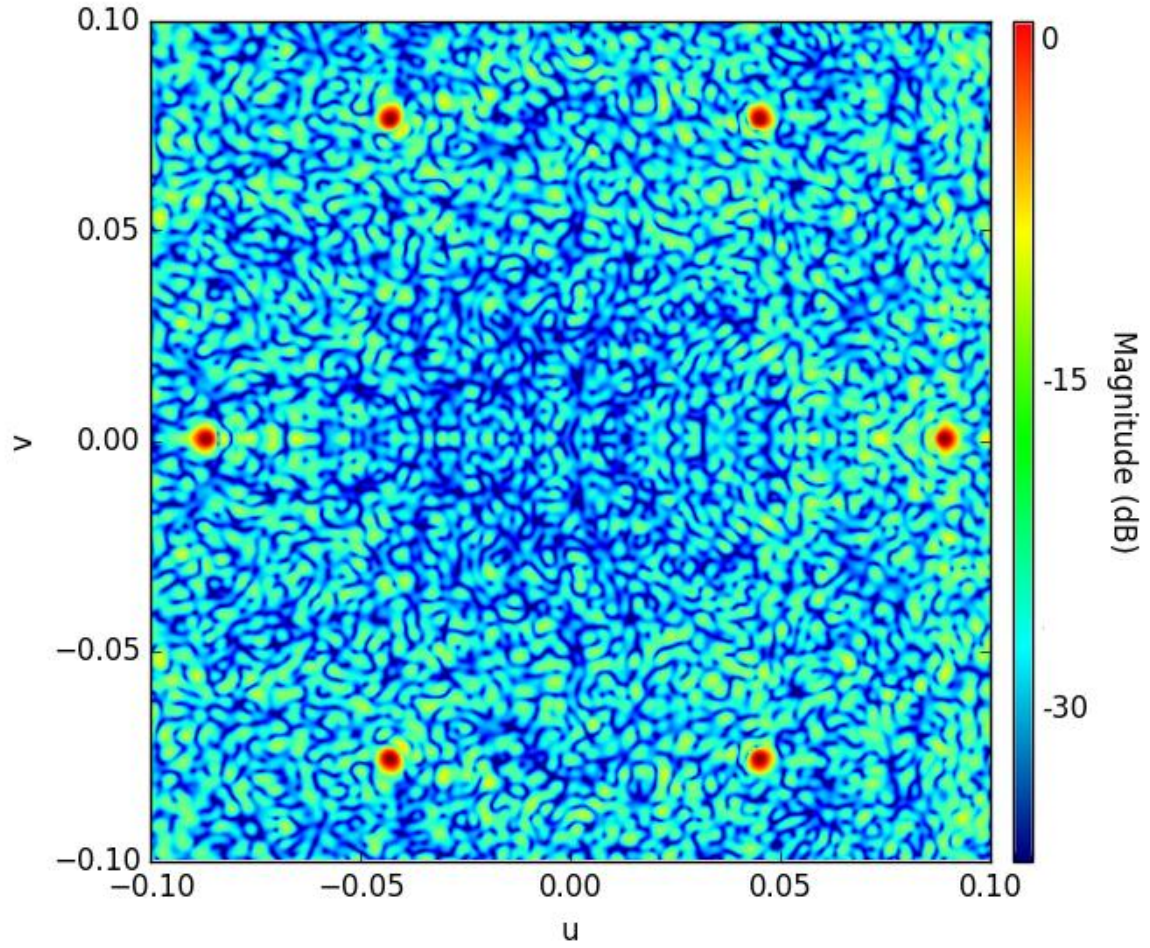
STRIP optics performance



Q-BAND

- FWHM ≈ 21 arcmin
- Ellipticity 1.003 – 1.033
- Directivity ≈ 54.7 dBi
- Cross-polarization < -40 dB

STRIP optics performance



Q-BAND

- FWHM ≈ 21 arcmin
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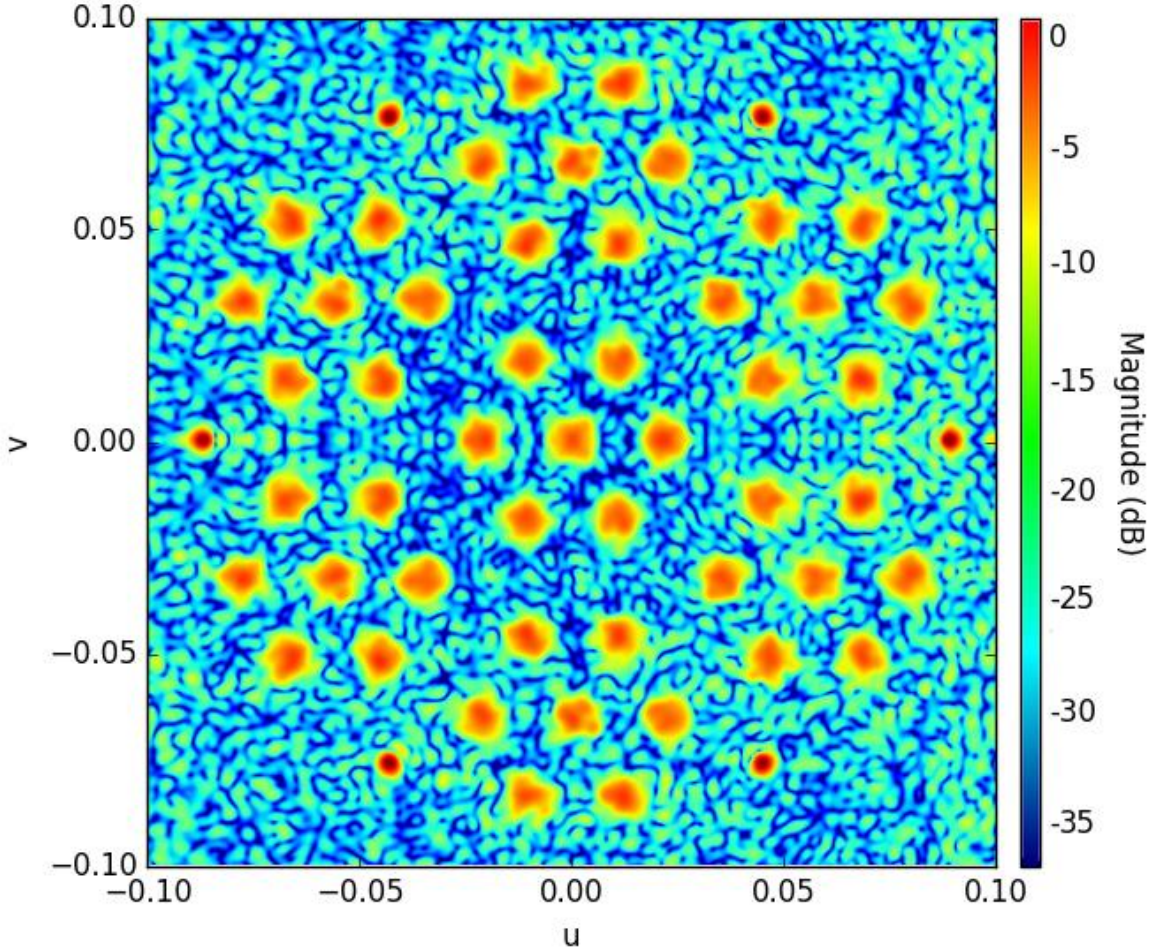
W-BAND

- FWHM ≈ 9.5 arcmin
- Ellipticity 1.006 – 1.041
- Directivity ≈ 61.4 dBi
- Cross-polarization < -40 dB

STRIP optics performance



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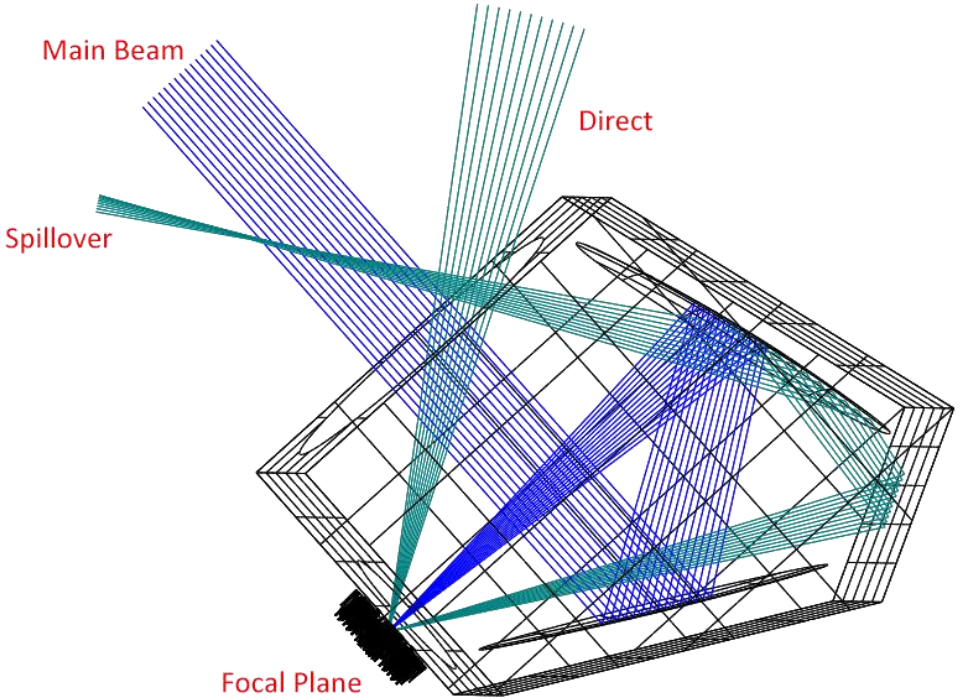
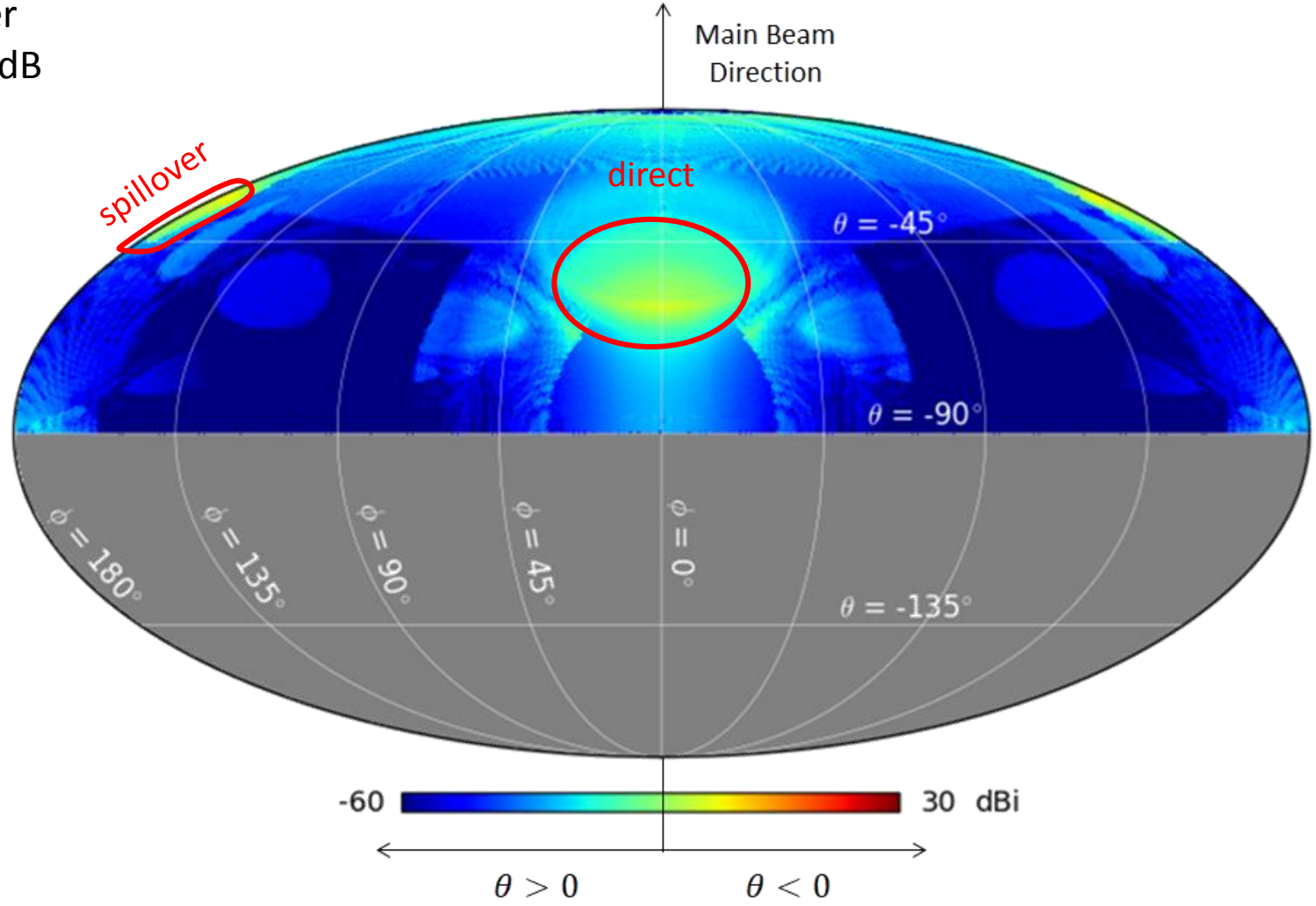
W-BAND

- FWHM ≈ 9.5 arcmin
- Ellipticity 1.006 – 1.041
- Directivity ≈ 61.4 dBi
- Cross-polarization < -40 dB

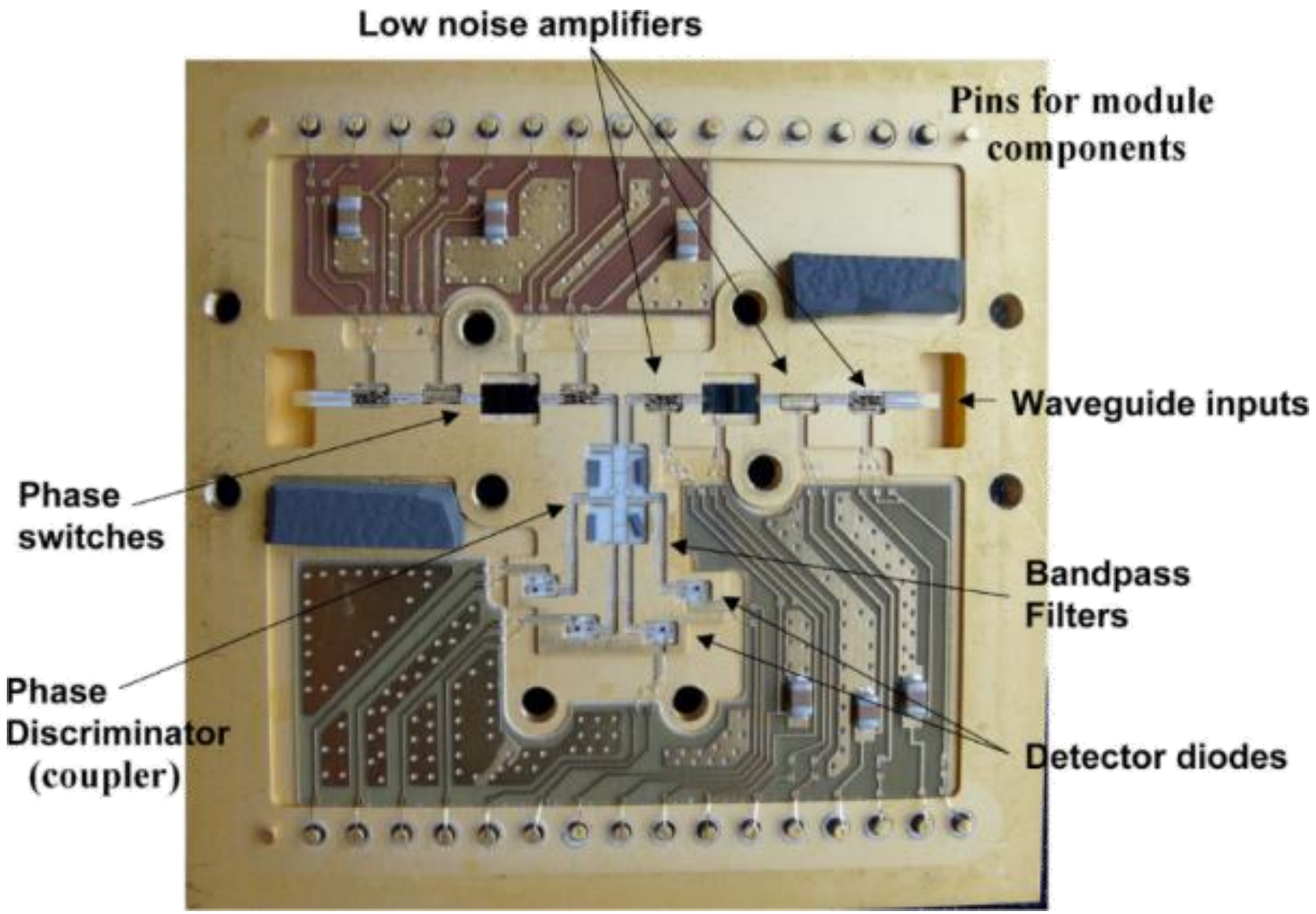
STRIP optics performance

Main sidelobes contributions from spillover and direct straylight at the level of -55 - -60 dB





STRIP receivers



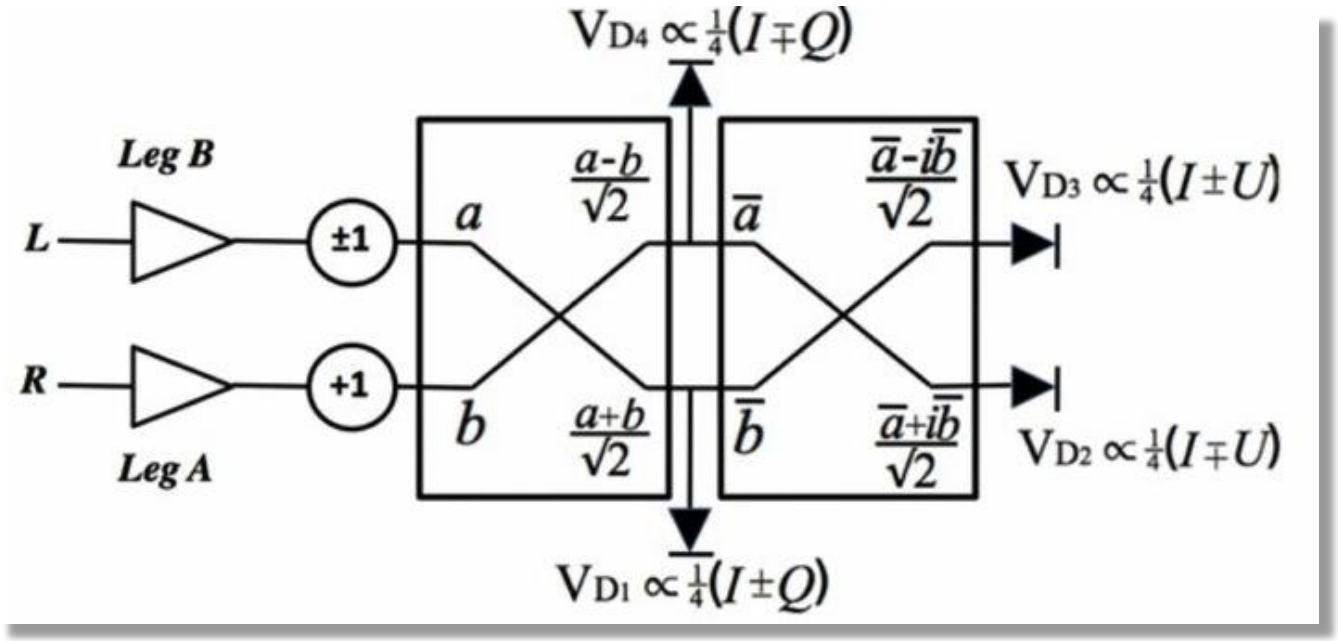
Heritage from QUIET

Receivers based on QUIET design

- 49 receivers at 43 GHz: 19 QUIET receivers + 30 custom-built on the same design.
- 6 QUIET receivers at 95 GHz

Courtesy of the QUIET collaboration

STRIP receivers

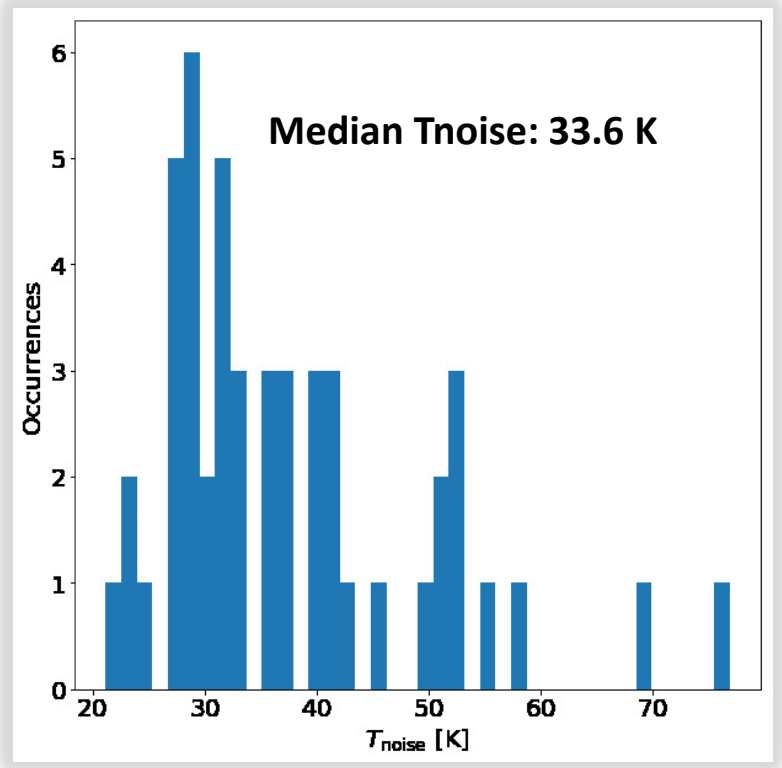


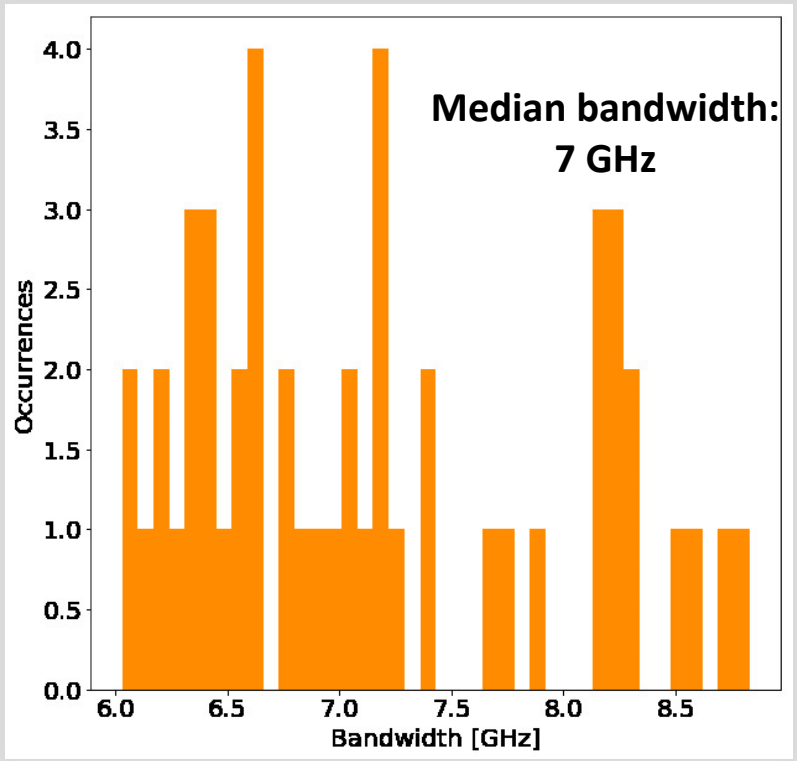
QUIET polarimeters architecture

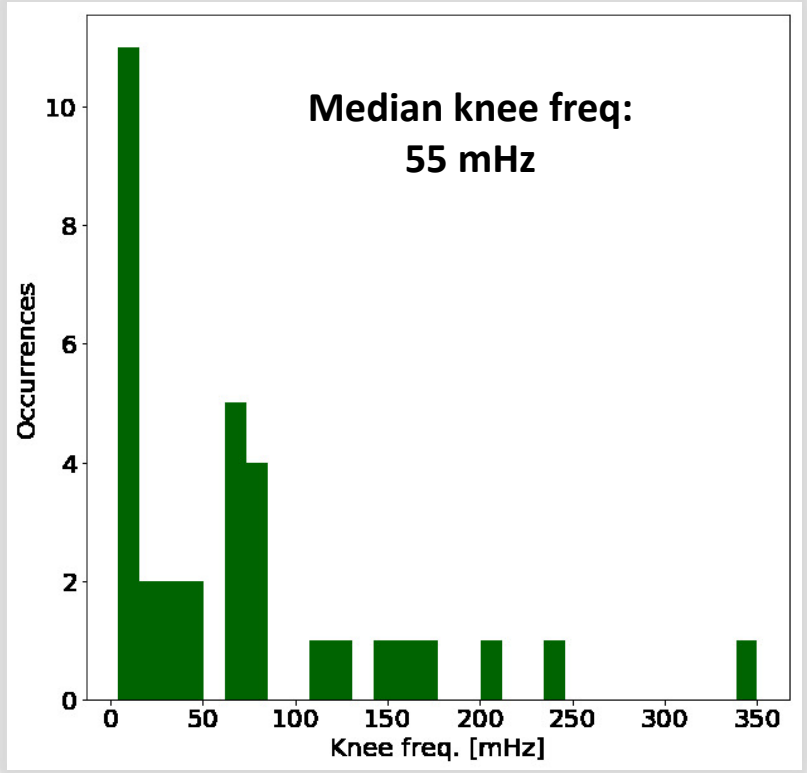
- Allows to measure directly Q and U from each feed-horn
- Insensitive to total intensity
- Exceptional stability and insensitivity to systematic effects

STRIP Q-band polarimeters measured performance

Preliminary – Before tuning optimization (to be performed at system level)

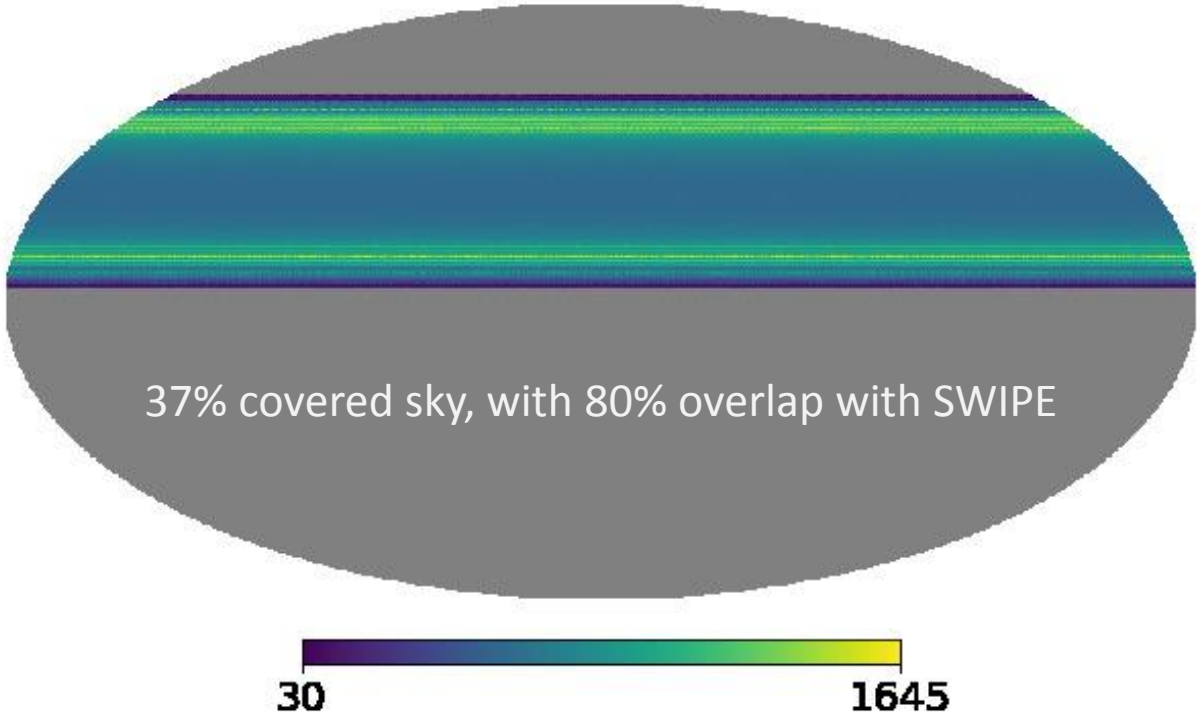






Observed sky and expected sensitivity

STRIP Q-band surveyed sky and hit count for one day observations



Expected final sensitivity (two years, 35% duty cycle)

- ΔQ/U ~ 1.7 μK.degree
- Estimated ~ 17 K noise temperature from atmosphere and optics (telescope, window, filters)

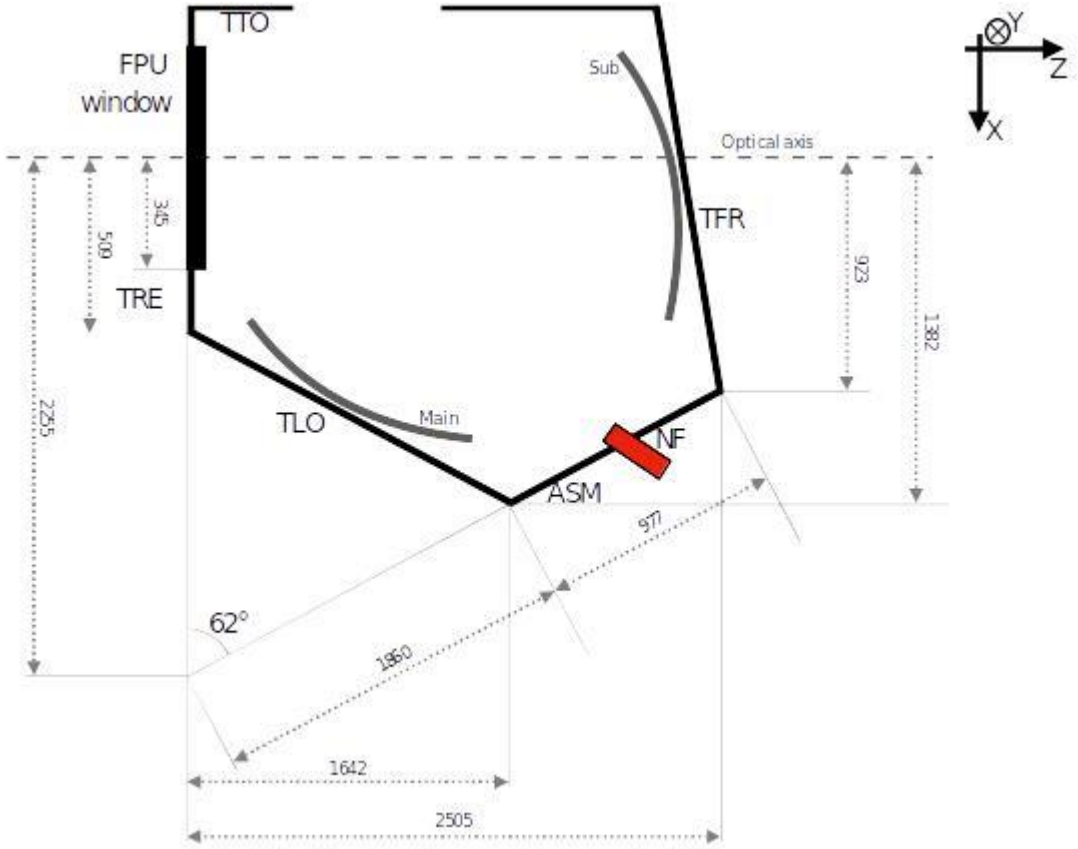
Conclusions and perspectives

- The LSPE approaches the quest for CMB B-modes by measuring a large portion of the Northern sky over a wide frequency range, allowing us to assess the synchrotron and dust contributions.
- The signal at high frequencies will be measured from the stratosphere to eliminate the effect of the atmosphere
- The 40 GHz measurements will be carried out from Tenerife, a precious opportunity to join efforts with the QUIJOTE team in the characterization of low frequency foregrounds
- STRIP be deployed at the end of 2019 and will start observing during 2020. SWIPE launch will be during the winter 2019-2020

Backup slides

- Near and far-field calibrators
- Polarizers and OMTs
- Feedhorn antenna test setup
- Polarimeters cryogenic test setup
- System level test setup

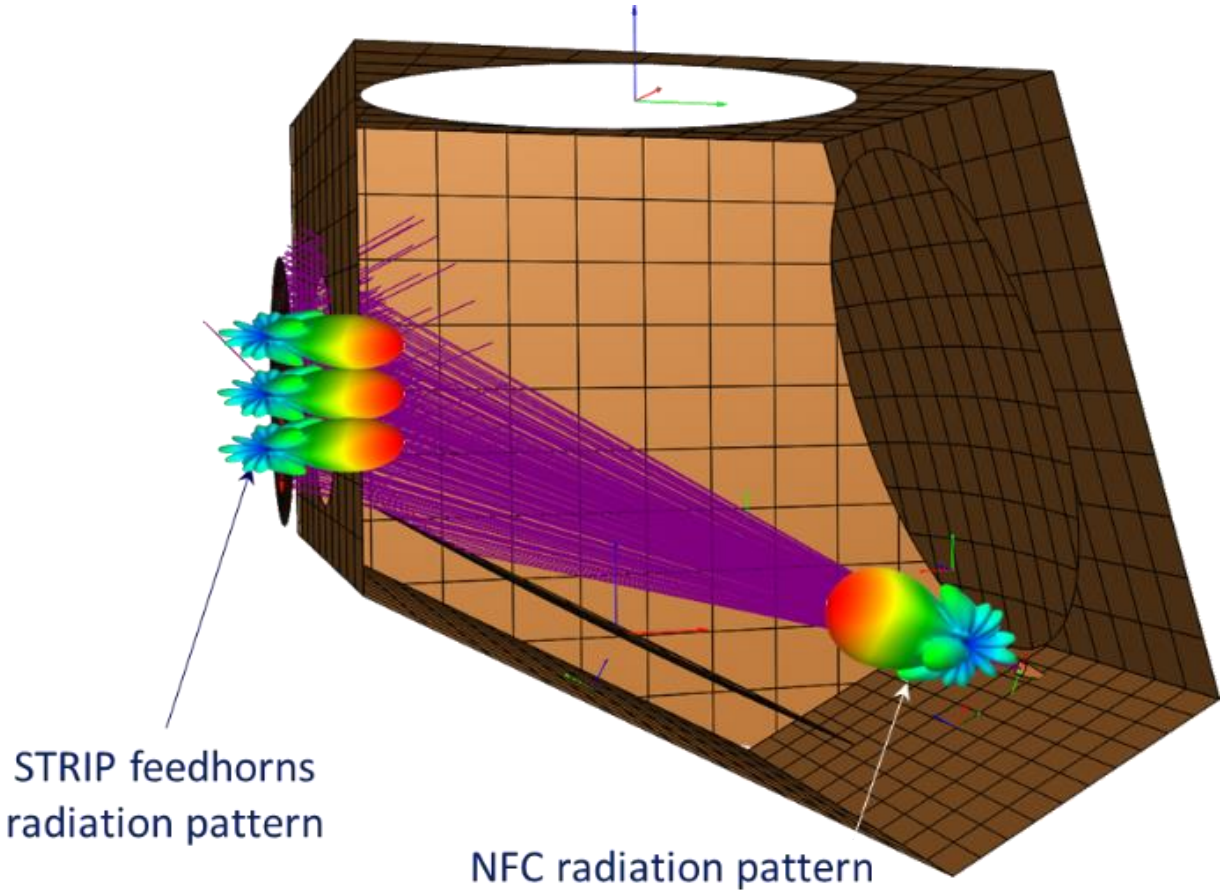
STRIP receiver calibration system



Relative calibration

- Near field calibration system illuminates the focal plane with periodic stable signal
- Noise generator / Gunn diode installed into optical assembly

STRIP receiver calibration system



Relative calibration

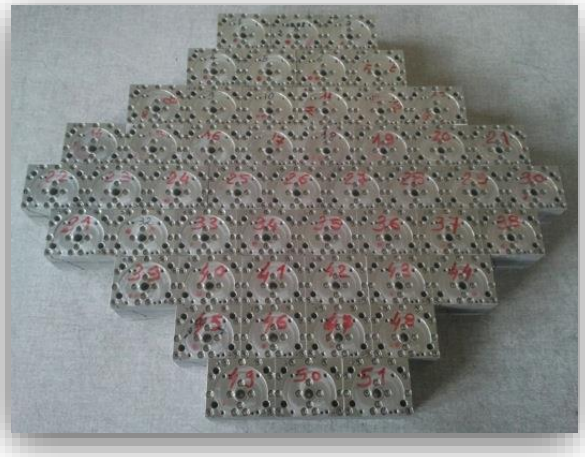
- Near field calibration system illuminates the focal plane with periodic stable signal
- Noise generator / Gunn diode installed into optical assembly

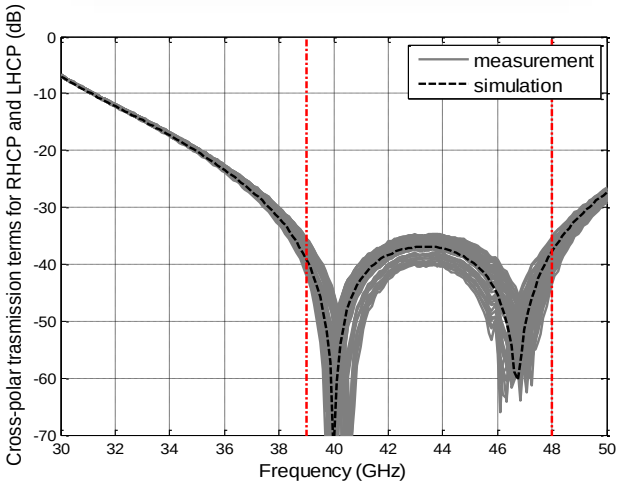
STRIP far field calibration system

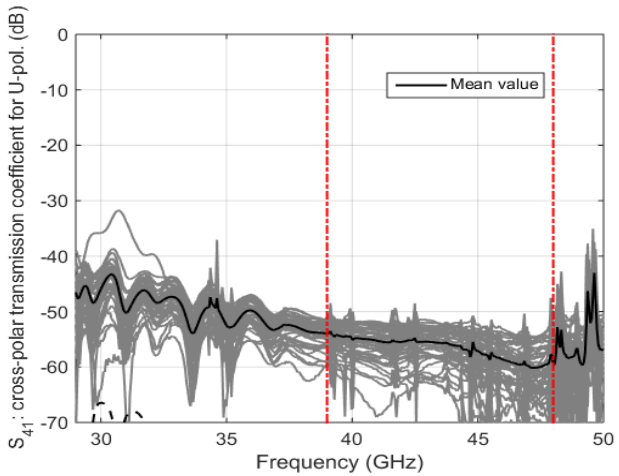
Far field calibration system

- Signal generators in Q and W-bands carried on drone
- Will be used to calibrate main beams and sidelobes during on-site calibration phase

STRIP polarizers and OMTs



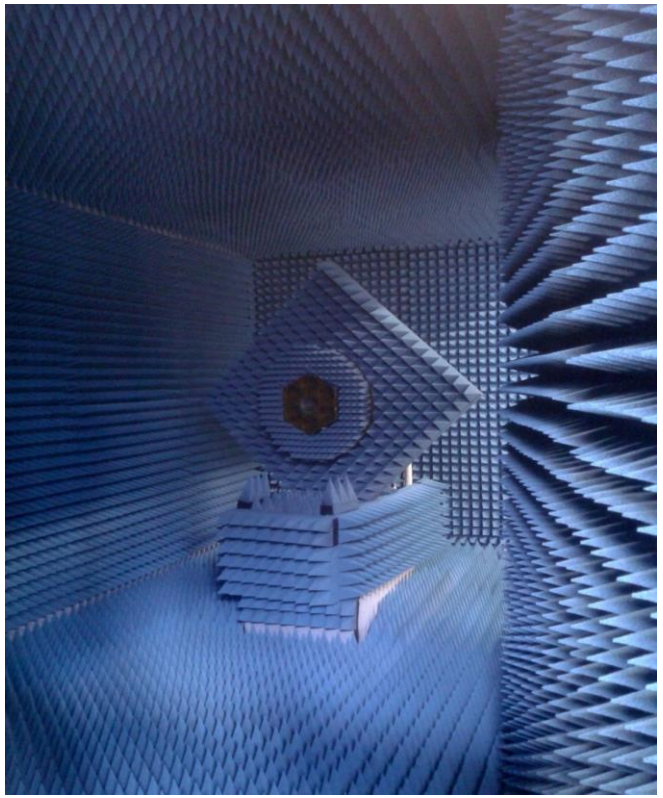


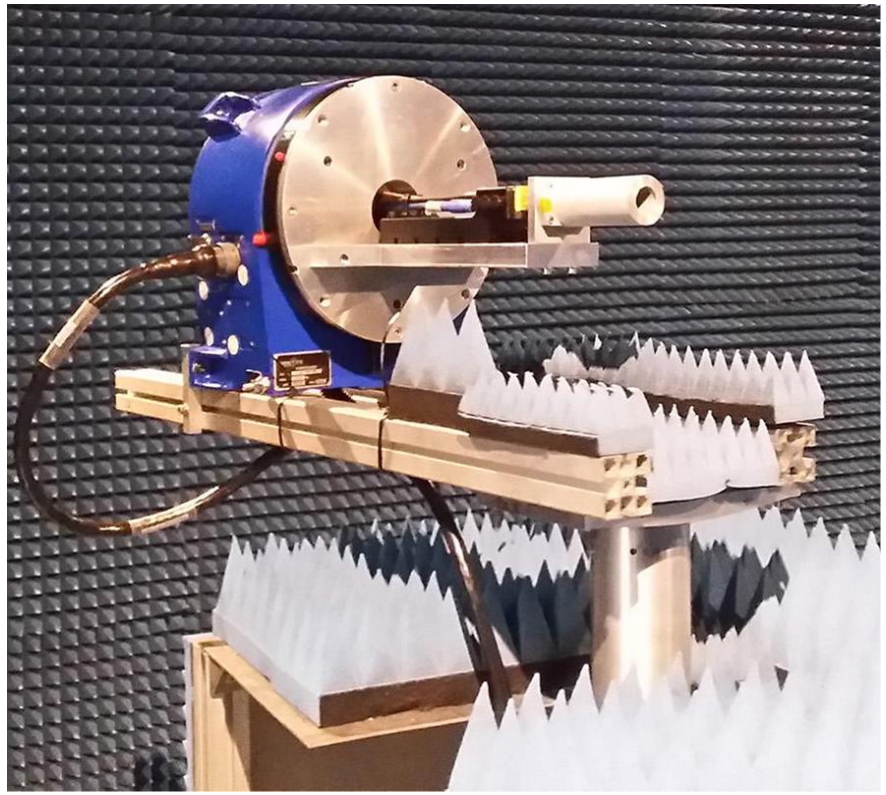


Polarizer and OMT assemblies (CNR-IEIIT, Turin)

- Circular polarization input to polarimeters produced with a polarizer-OMT assembly
- Exceptional performance in terms of low level of cross polarization

STRIP antenna testing

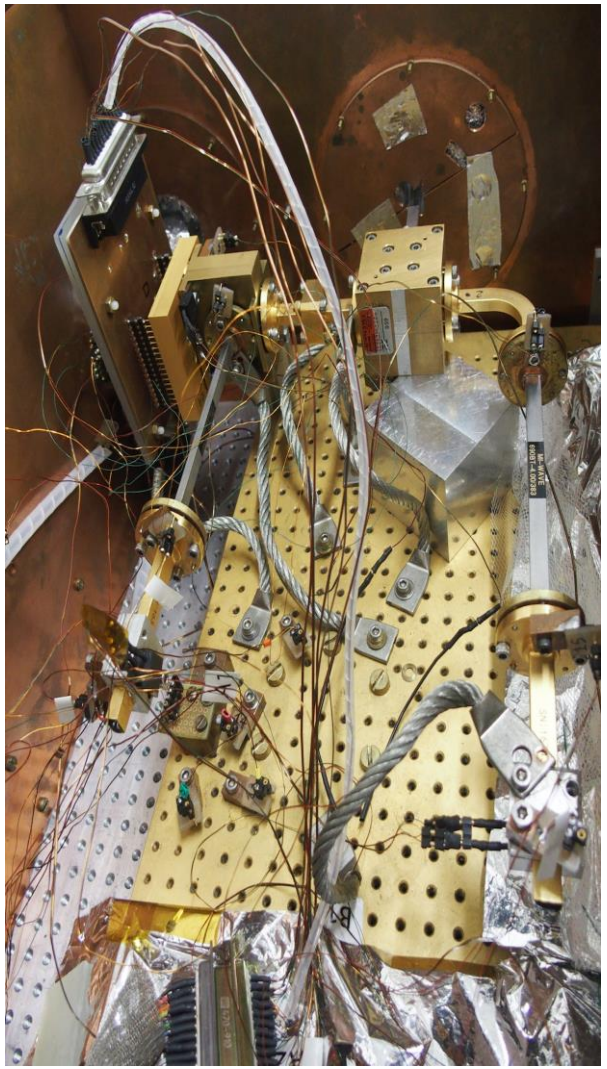


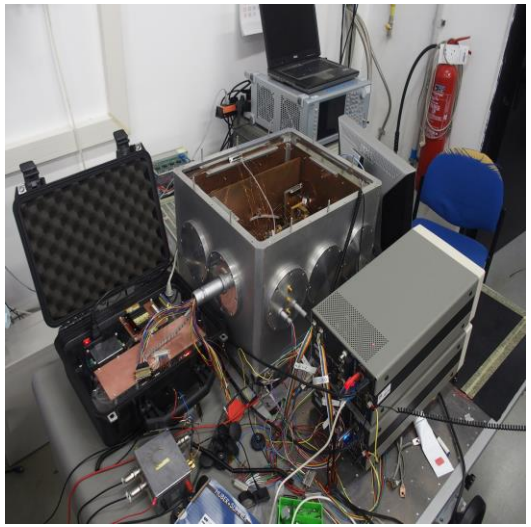


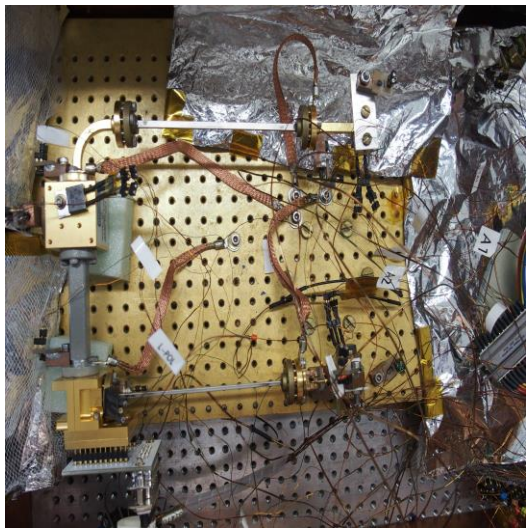
Antenna test setup at Uni. Milan

- Feed horns tested in anechoic chambers with VNA up to 110 GHz
- Extremely low level systematic effects allowed us to test sidelobes down to -50 dB

STRIP polarimeters cryogenic testing



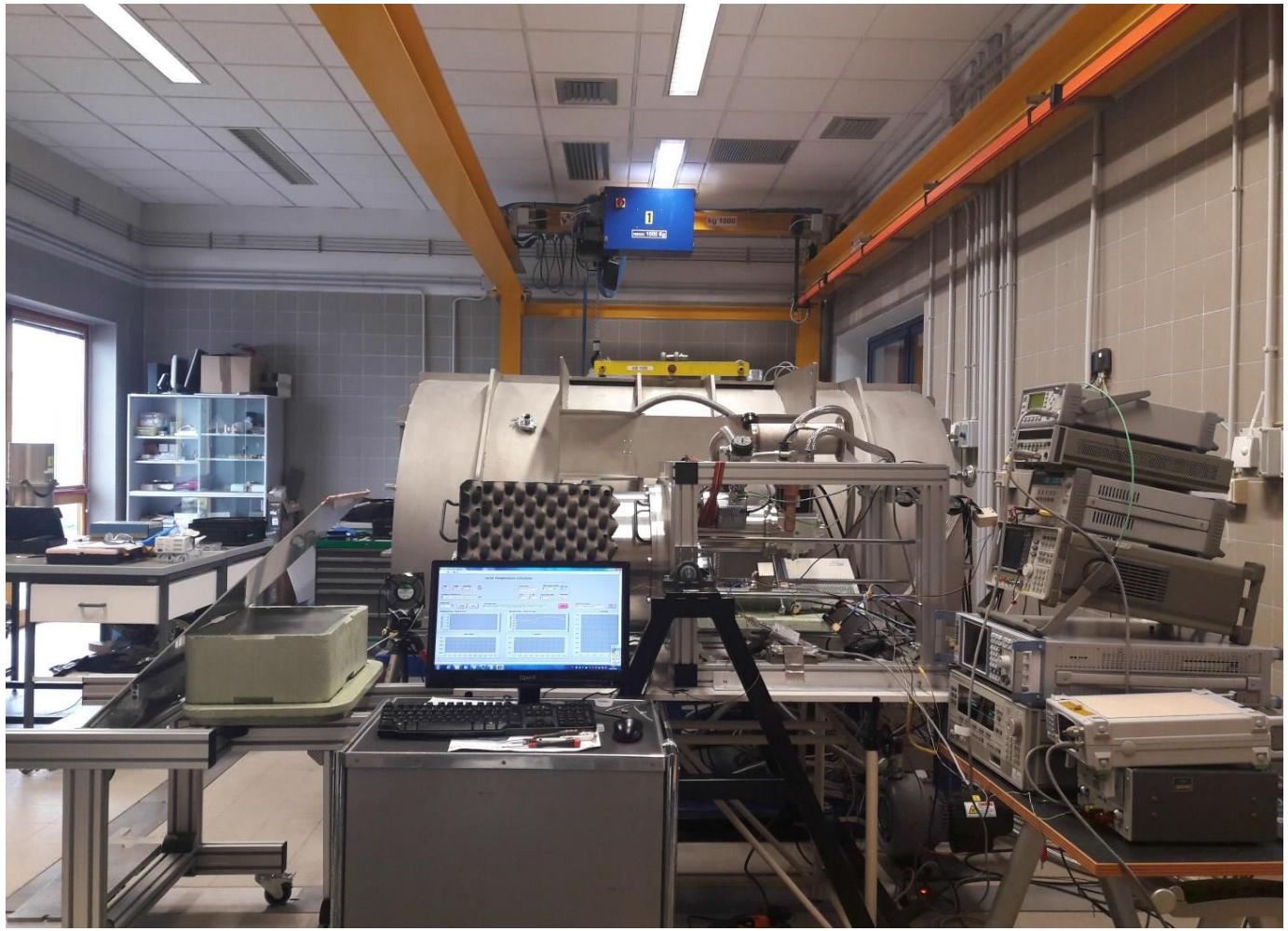




Test setup at Uni. Milan Bicocca

- Polarimeters tested for functionality, Tnoise, bandwidth and stability
- Signal injected in polarimeters via a magic T to mix a thermal load with a swept source CW signal

STRIP system level testing



Test setup at INAF Bologna

- Crane Bridge
- Areas for assembly
- Shelfs for storage
- He gas / LN2
- RF Instruments
- Thermal control & monitoring
- Clean Room Cl 100.000
- Storage room