MILLIMETRIC SARDINIA RADIO TELESCOPE RECEIVER BASED ON ARRAY OF LUMPED ELEMENTS KIDS

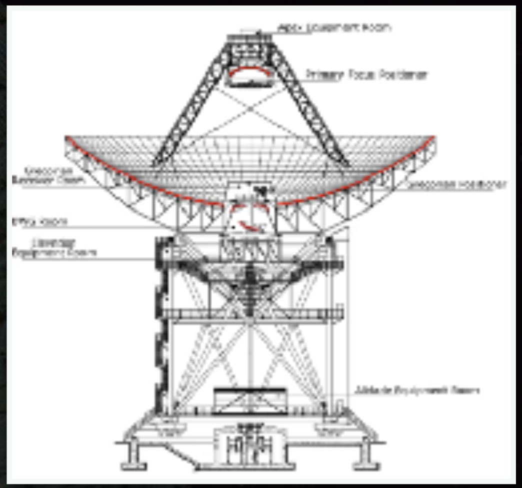
GIUSEPPE D'ALESSANDRO, E.BARBARAVA, E.S.BATTISTELLI, P.DE BERNARDIS, F. CACCIOTTI, E.CARRETTI, F.COLUMBRO, A.COPPOLECCHIA, A.CRUCIANI, M.DE PETRIS, F.GOVONI, G.ISOPI, L.LAMAGNA, P.MARONGIU, S.MASI, L.MELE, E.MOLINARI, M.MURGIA, A.NAVARRINI, A.ORLATI, A.PAIELLA, G.PETTINARI, F.PIACENTINI, T.PISANU, S.POPPI, G.PRESTA, F.RADICONI

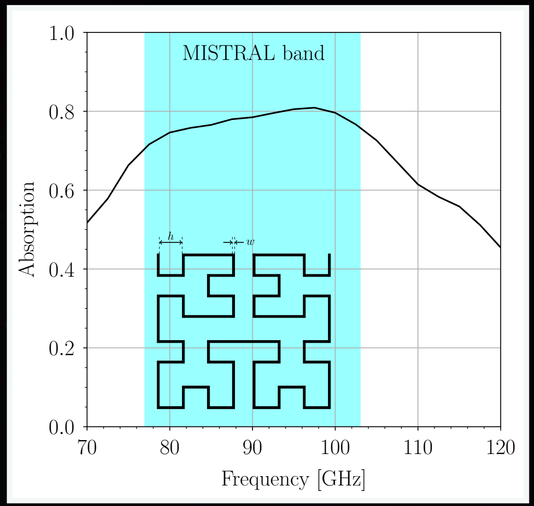
2nd mm Universe @Nika2 28June-2July 2021 Sapienza University in Rome

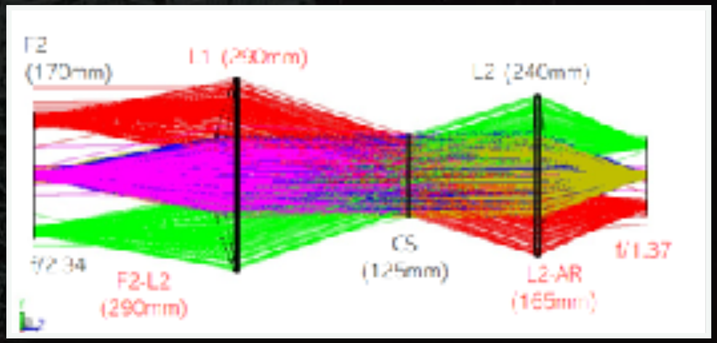
Photo credits: Sergio Poppi / INAF Cagliari

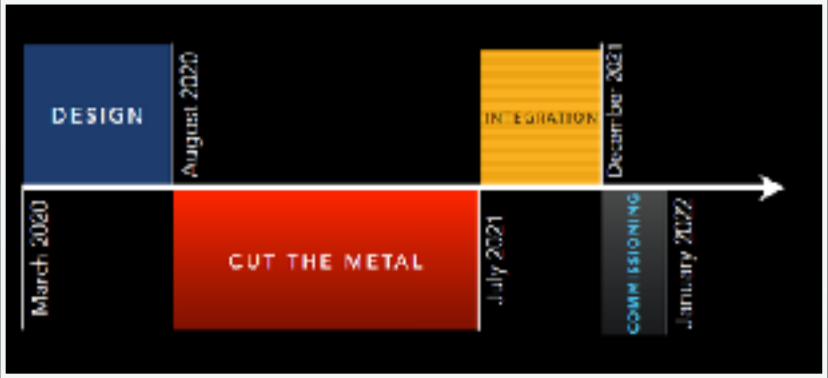
OVERVIEW:

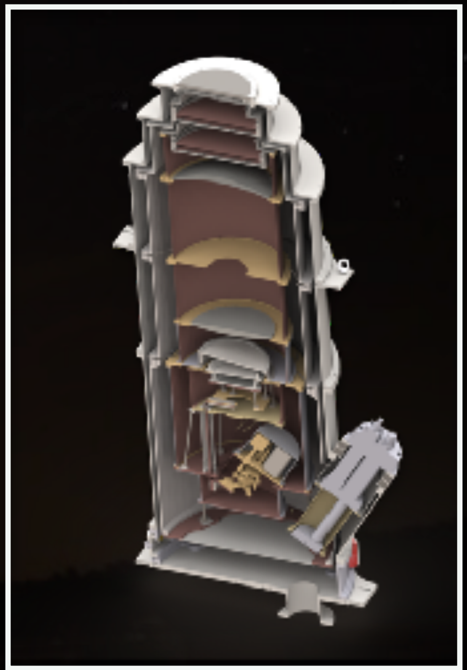
- Sardinia Radio Telescope
- MISTRAL instrument
  - cryostat
  - optic
  - detectors array
- schedule
- science case
- conclusion











SARDINIA RADIO TELESCOPE

Sardinia radio telescope, SRT Lat. 39.4930N - Long. 9.2451E, is a multipurpose instrument operated in either single dish or Very Long Baseline Interferometer mode.

Manufacturing started in 2003 and completed in August 2012. The technical commissioning phase to validate scientific performances was managed by National Institute for Astrophysics and concluded in 2014.

The Early Science Program observations started in 2016, and regular proposal in 2018.

Navarrini et al. https://openaccess.inaf.it/handle/20.500.12386/28787

SARDINIA RADIO TELESCOPE

Placed at 600m above sea level in Sardinia near Cagliari.

50 years of radiosonde profiles taken at Cagliari airport (30Km far, at sea level) and scaled for SRT site shows PWV<11mm (50th percentile) and opacity <0.2 (50th percentile) at 100GHz. [Nasir et al. Exp Astron 29:207-225(2011)]

Estimation of sky opacity, based on recorded atmospheric data, forecasts [http://hdl.handle.net/20.500.12386/28787]

<0.15 (50th percentile) **at 93GHz** during the winter nights. The PWV in the same conditions is mainly 8mm.

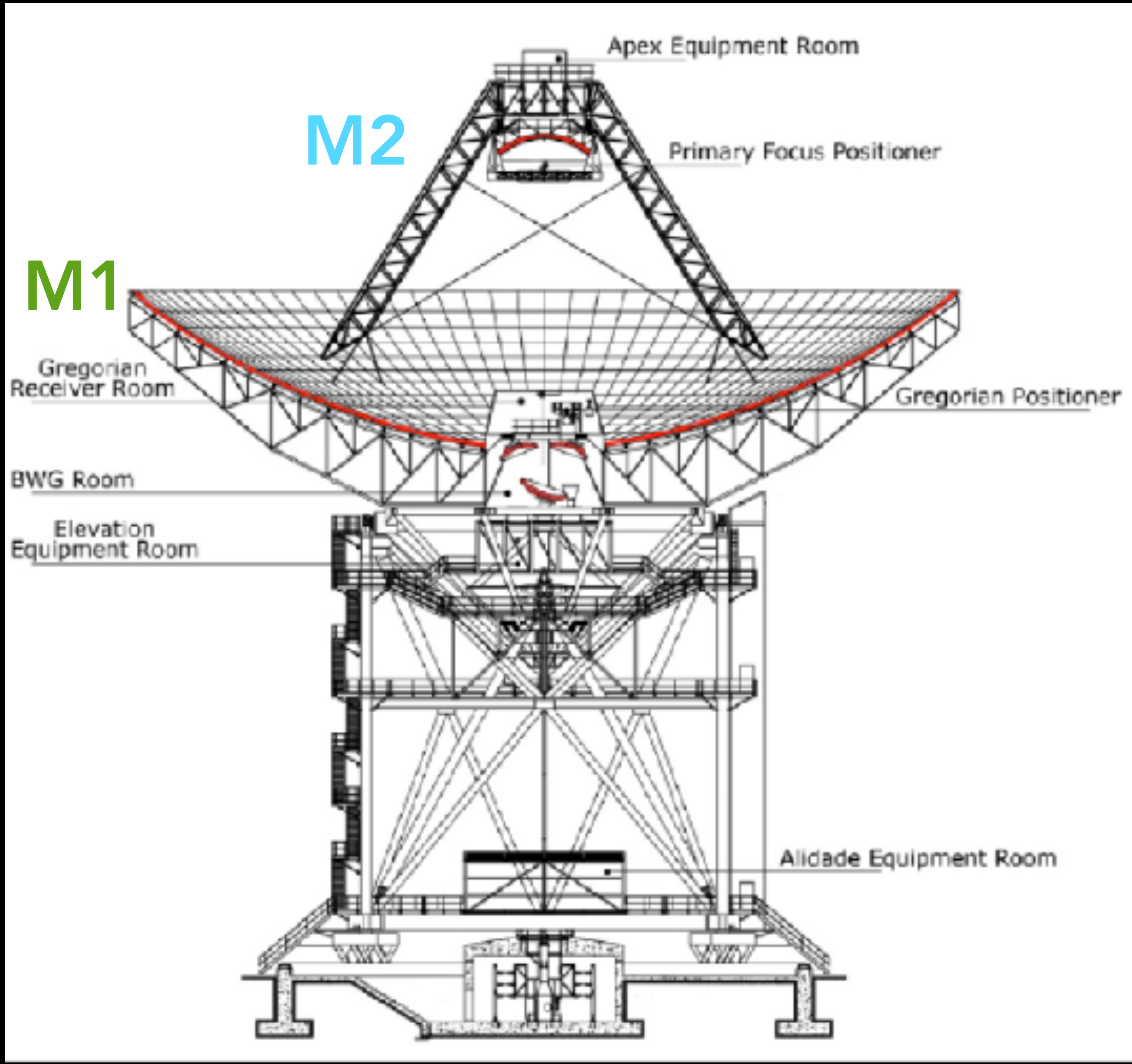
Green Bank Telescope tau<0.125 (50th percentile) @86GHz, and PWV<9mm (50th percentile) [https://www.gb.nrao.edu/mustang/wx.shtml]

SARDINIA RADIO TELESCOPE

The antenna (**M1**) is fully steerable, 64m in diameter. Composed of 1008 aluminum elements controlled by electromechanical actuators.

M1 and M2 are shaped to minimize spillover and the standing waves between the feed and the subreflector.

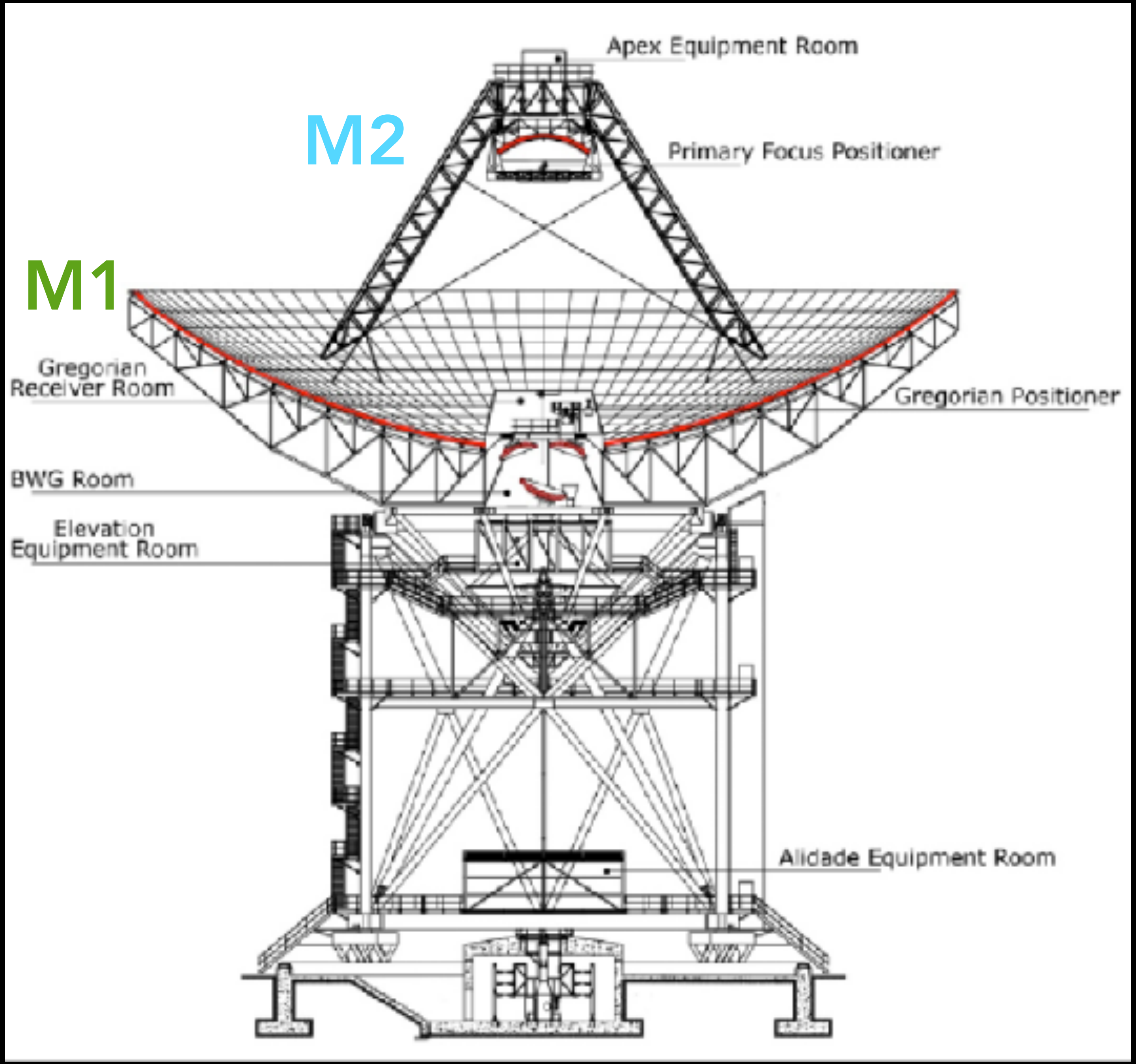
Olmi et al. Mem. S.A.It. Suppl. Vol. 10, 19



Bolli at al. Journal of Astronomical Instrumentation, Vol. 4, Nos. 3 & 4 (2015)

SARDINIA RADIO TELESCOPE

An f/0.33 primary focus occurs near the **M2** sub-reflector. 7.9m in diameter is composed of 49 aluminum elements. Its position can be changed for focus adjustment.



Bolli at al. Journal of Astronomical Instrumentation, Vol. 4, Nos. 3 & 4 (2015)

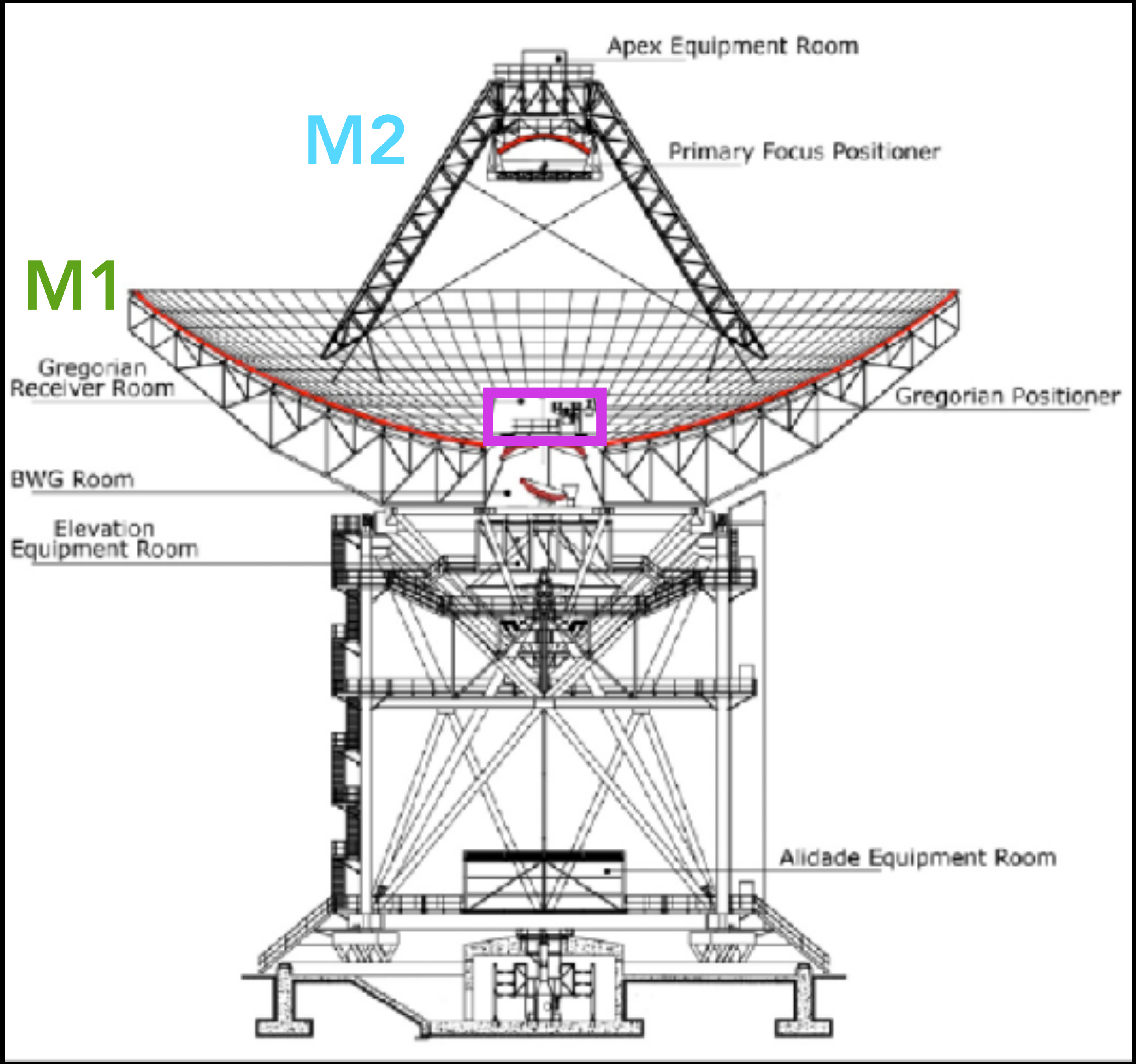
M1 and M2 are shaped to minimize spillover and the standing waves between the feed and the subreflector.

Olmi et al. Mem. S.A.It. Suppl. Vol. 10, 19

SARDINIA RADIO TELESCOPE

The gregorian focus, f/2.34 occurs around 20 meters below M2 in the **Gregorian room**.

MISTRAL will be placed in this room by using the gregorian focus of SRT.



Bolli at al. Journal of Astronomical Instrumentation, Vol. 4, Nos. 3 & 4 (2015)

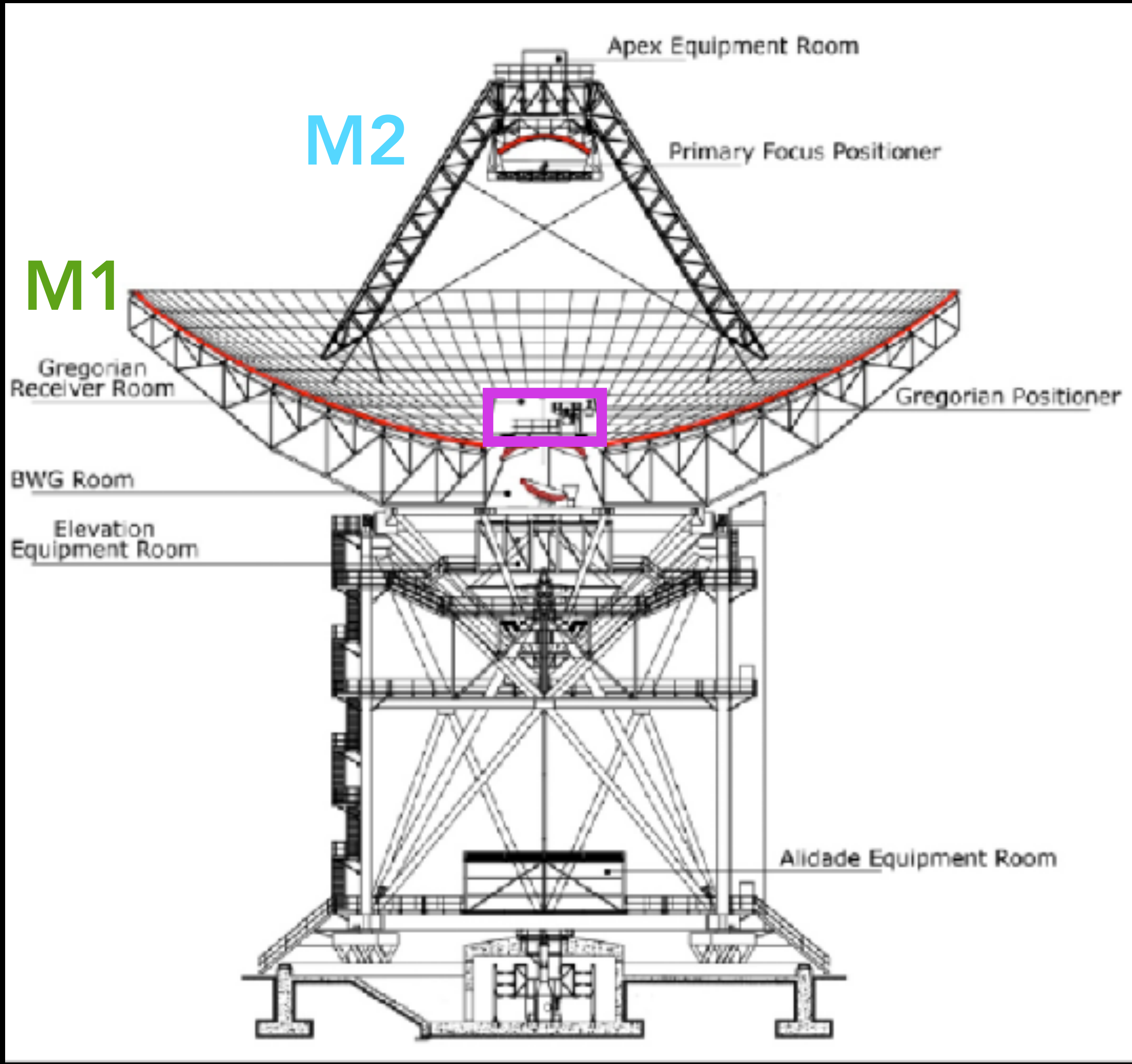
SARDINIA RADIO TELESCOPE

Data resume:

M1 primary mirror	64m	SHAPED
M2 sub reflector	7.9m	
Primary focus	f/0.33	
Gregorian focus	f/2.34	

Pointing accuracy	2-13 arcsec
Range in elevation	5-90deg
Range in Azimuth	180+/-270deg

ALLOCATED SPACE FOR MISTRAL EXPERIMENT IN GREGORIAN ROOM: 700MM X 700MM X 2400MM



Bolli at al. Journal of Astronomical Instrumentation, Vol. 4, Nos. 3 & 4 (2015)

MISTRAL

Bolli at al. Journal of Astronomical Instrumentation, Vol. 4, Nos. 3 & 4 (2015)

Table 3. Microwave receivers installed and under construction for the SRT.

Receiver	Freq range [GHz]	Focal position	Pixels × polarizations	Expected antenna gain [K/Jy]	Expected system temperature at zenith [K]	Status
L- and P- band coaxial feed	0.305–0.410	F1	1 × 2	0.47–0.59	50–80	Commissioned
	1.3–1.8		1 × 2	0.50–0.60	17–23	
C-band mono-feed	5.7–7.7	F3	1 × 2	0.64–0.70	24–28	Commissioned
K-band multi-feed	18–26	F2	7 × 2	0.60–0.66	40–70	Commissioned
S-band multi-feed	2.3–4.3	F1	5 × 2	0.76	54	Under construction
C-band (low) mono-feed	4.2–5.6	F4	1 × 2	0.62–0.70	30–35	Under construction
X- and Ka-band coaxial feed	8.2–8.6	F1	1 × 1	0.64	120	Under testing
	31.8–32.3		1 × 1	0.57	190	
Q-band multi-feed	33–50	F2	19 × 2	0.45–0.56	45–120	Under construction
W-band mono-feed	84–116	F2	1 × 1	0.34[a]	115	Under refurbishment

- Q BAND
- *W BAND(16 BEAMS POLARIZATION SENSITIVE)*
- W BAND (408 BEAMS)
- *K/Q/W BANDS(1 BEAM POLARIZATION*

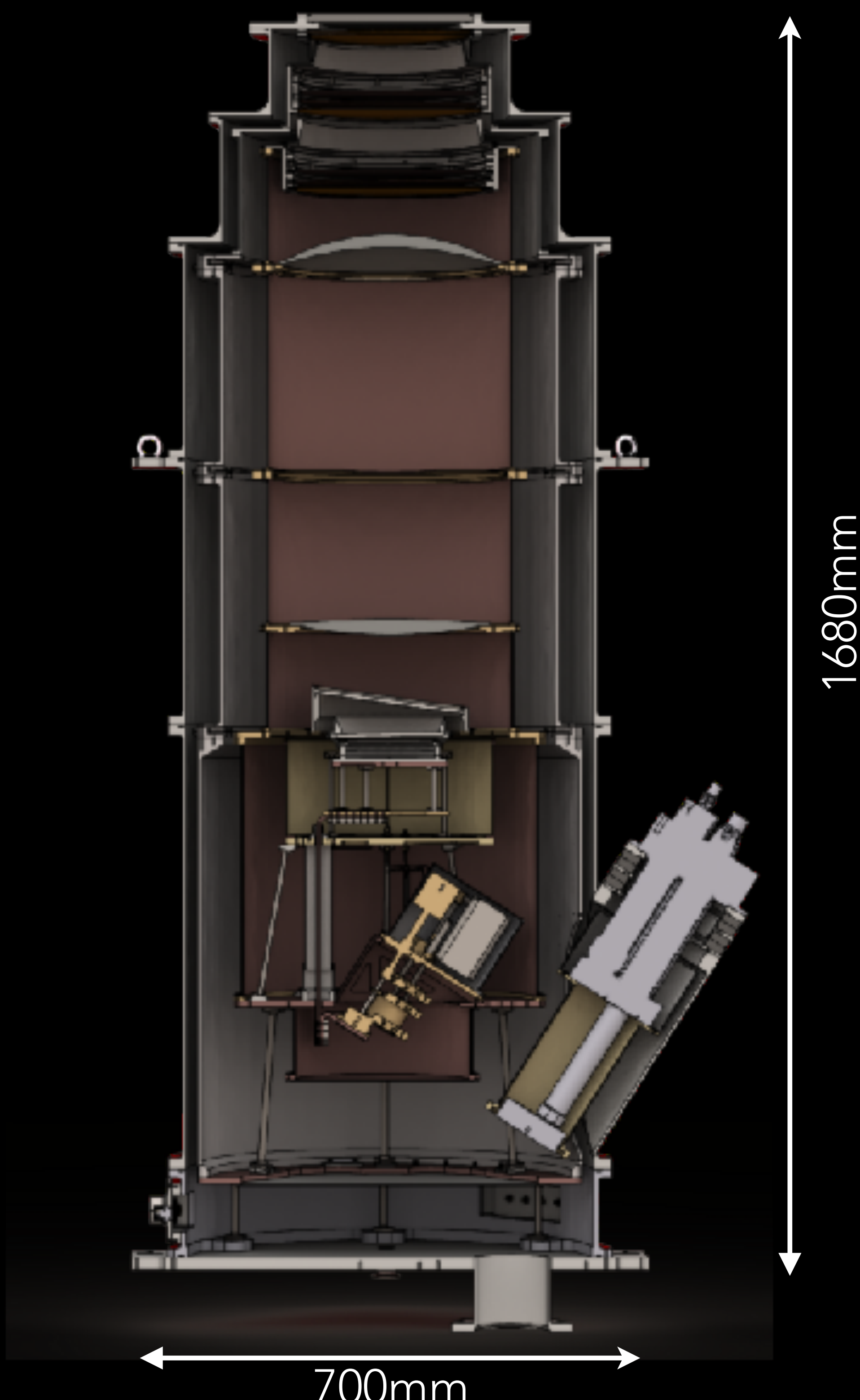
2019

2020

Note: the S band will have 7 feeds.

MISTRAL: CRYOSTAT

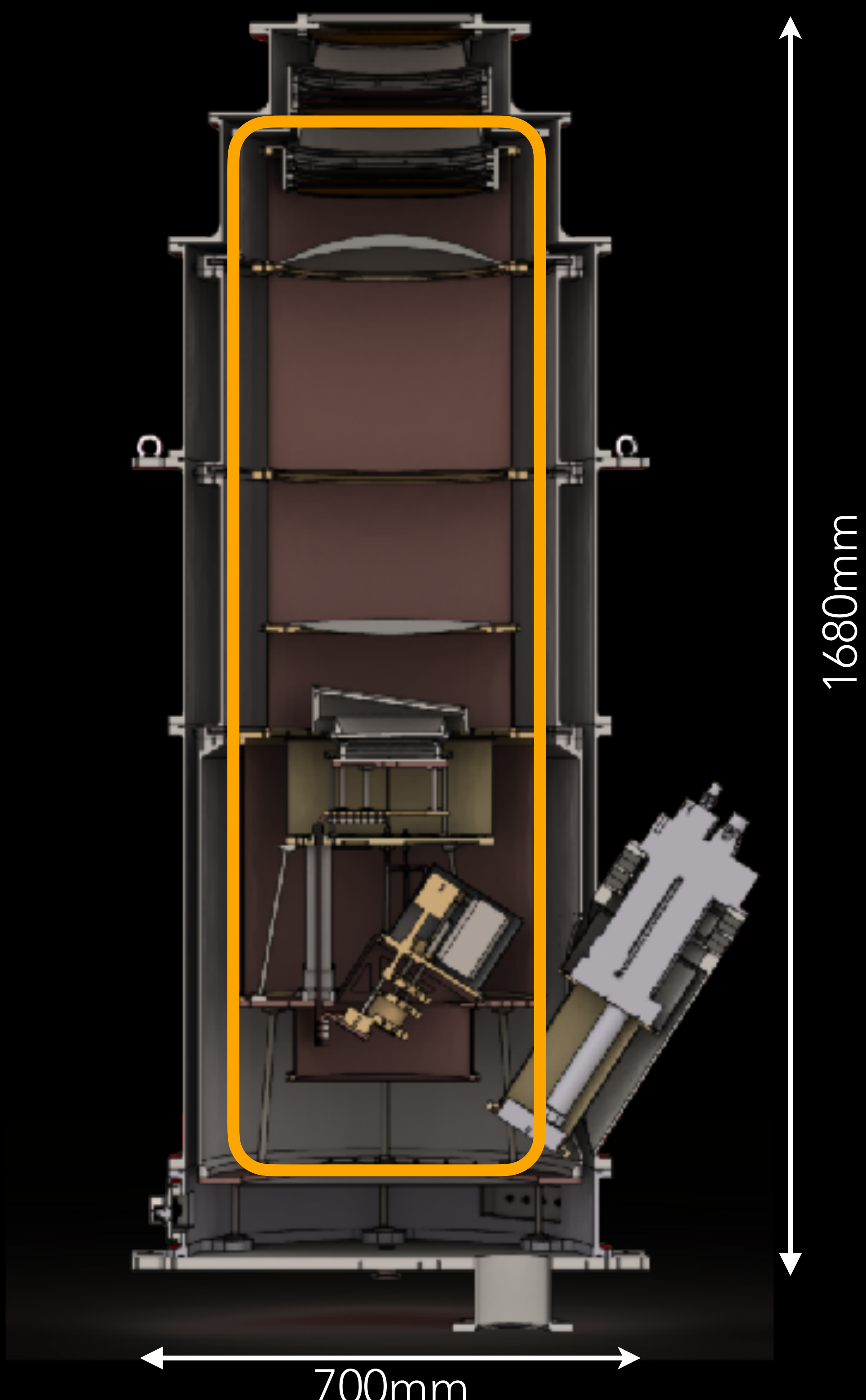
~250Kg, ~1m3



The cryostat has been provided by QMC. It is composed of two radiation shields at **40K** and **4K** cooled down by a pulse tube. Another shield, cooled at **1K** by He4 fridge, surrounding the focal plane assembly. The detectors reach **250mK** thanks to He6 fridge.

MISTRAL: CRYOSTAT

~250Kg, ~1m3



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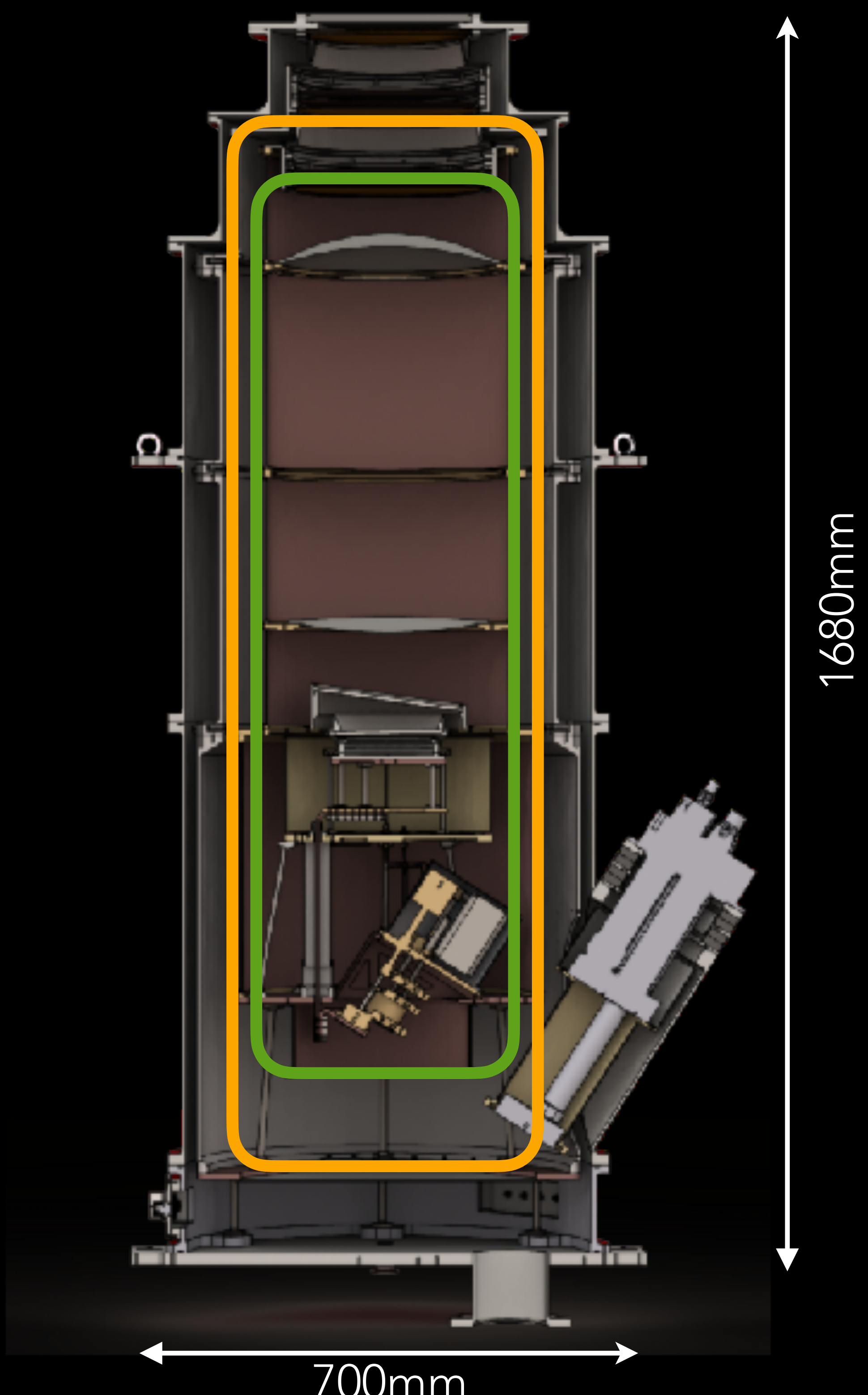
MISTRAL: CRYOSTAT

QMC INSTRUMENTS

~250Kg, ~1m3



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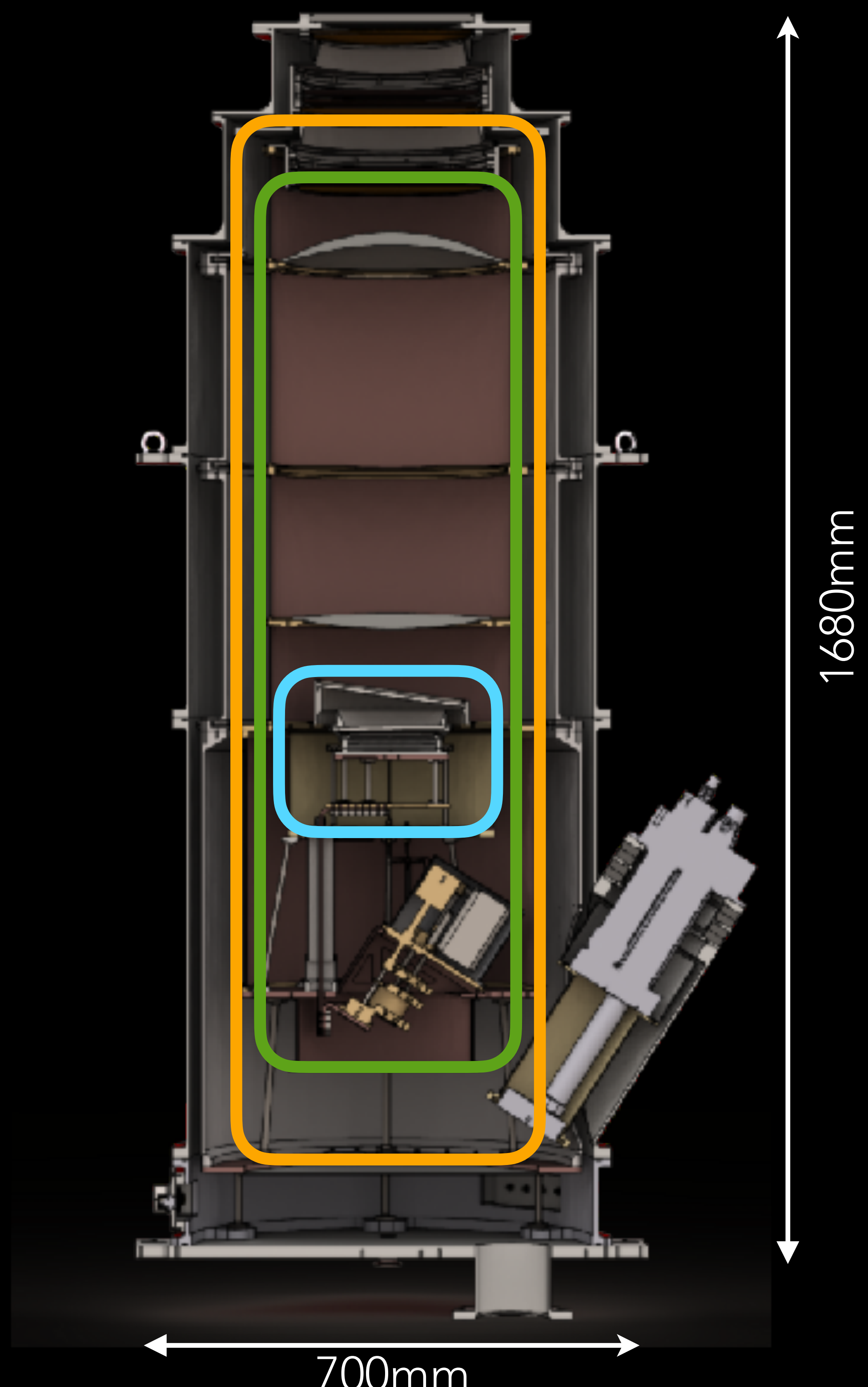
MISTRAL: CRYOSTAT

~250Kg, ~1m3



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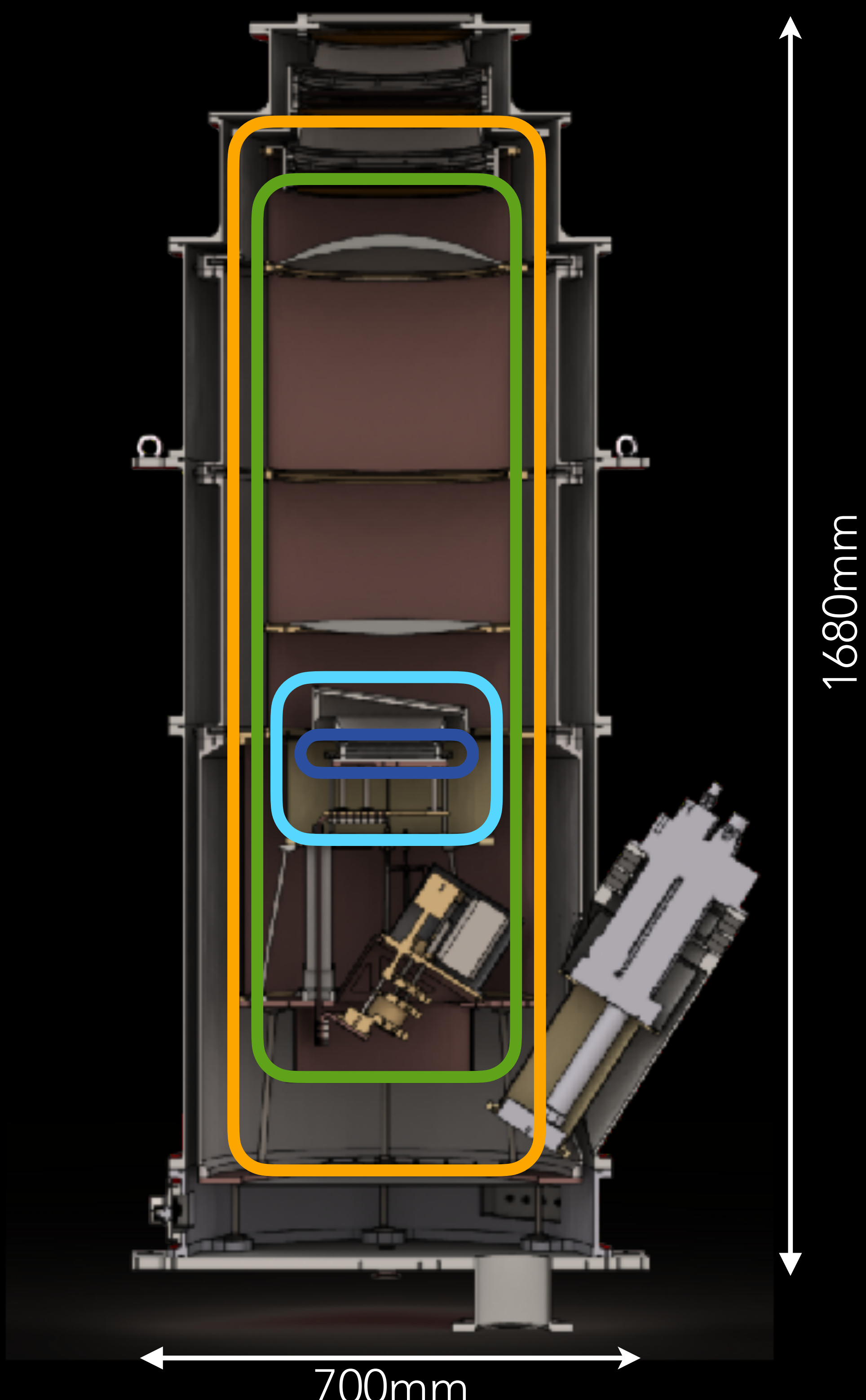
~250Kg, ~1m3



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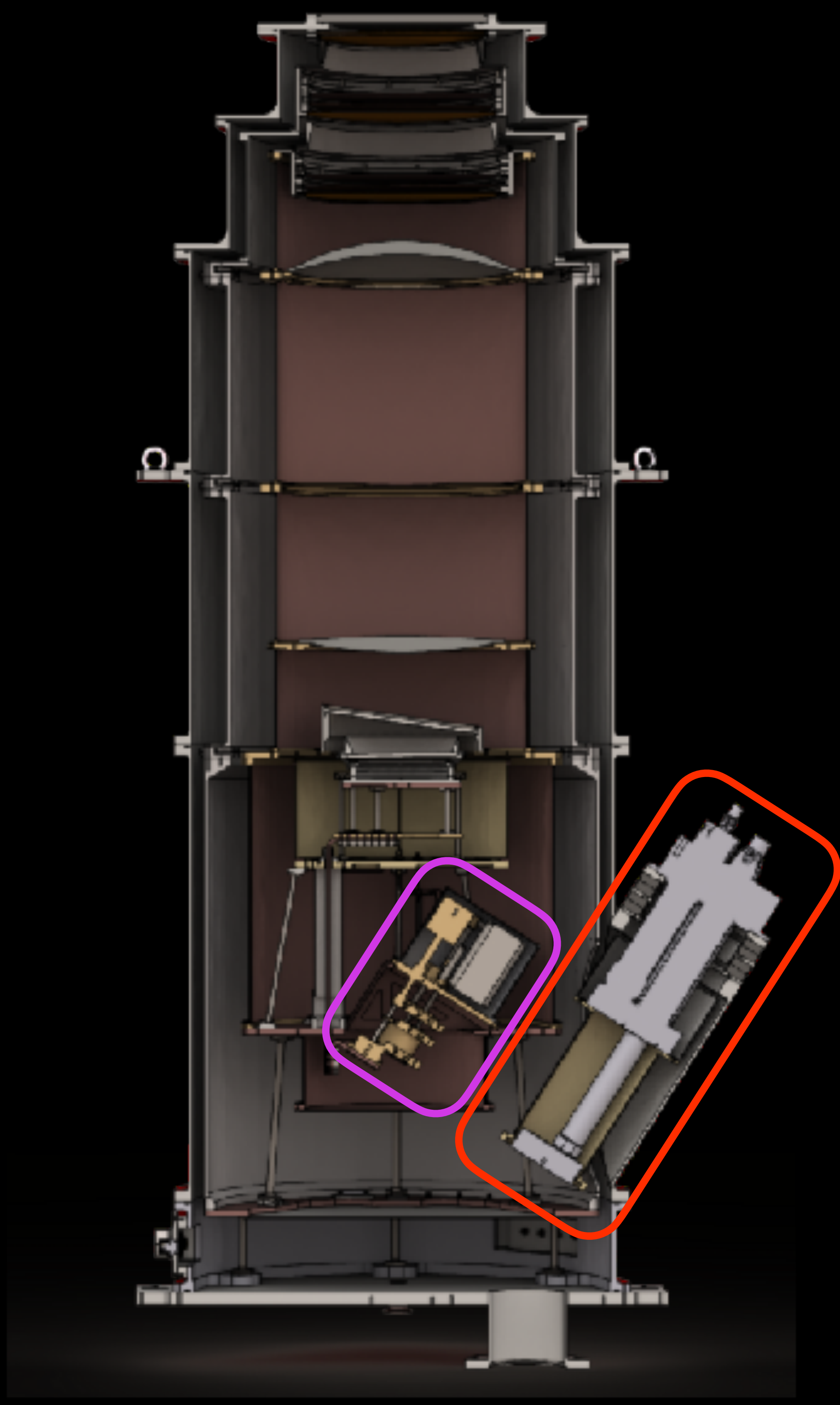
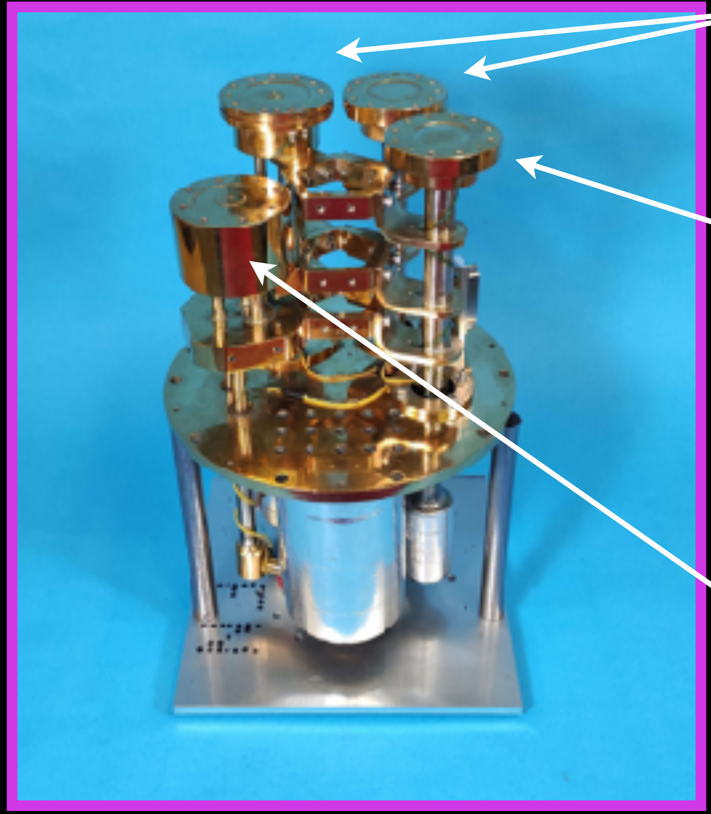
MISTRAL: CRYOSTAT



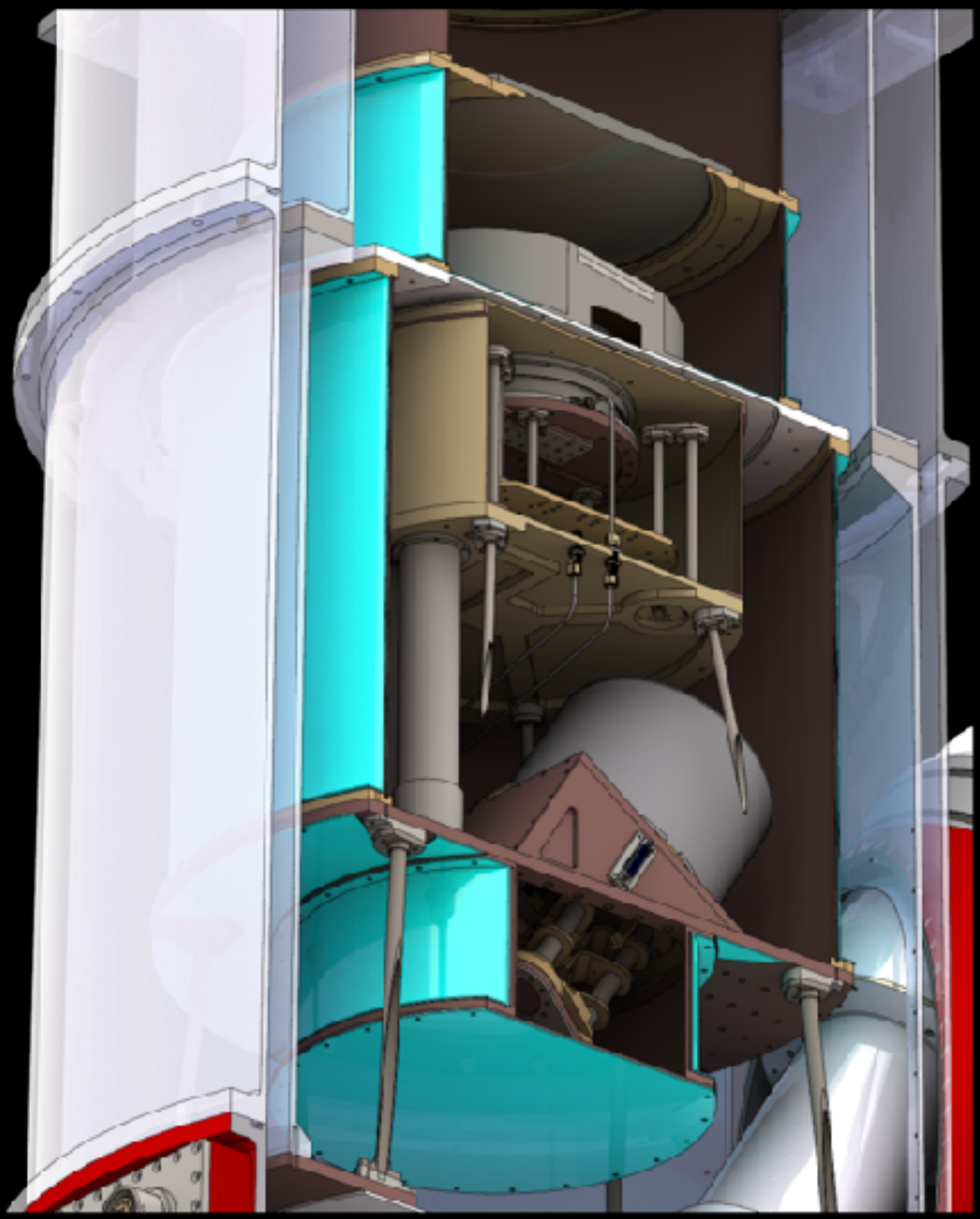
Sumitomo RP-182B2S-F100H

1.5W @ 4.2K and 36W @ 48K
- remote valve
- air cooled
- 100m He lines [Coppolecchia et al. @LTD-19th]

Chase Twin GL10 fridge



MISTRAL: MAGNETIC SHIELD

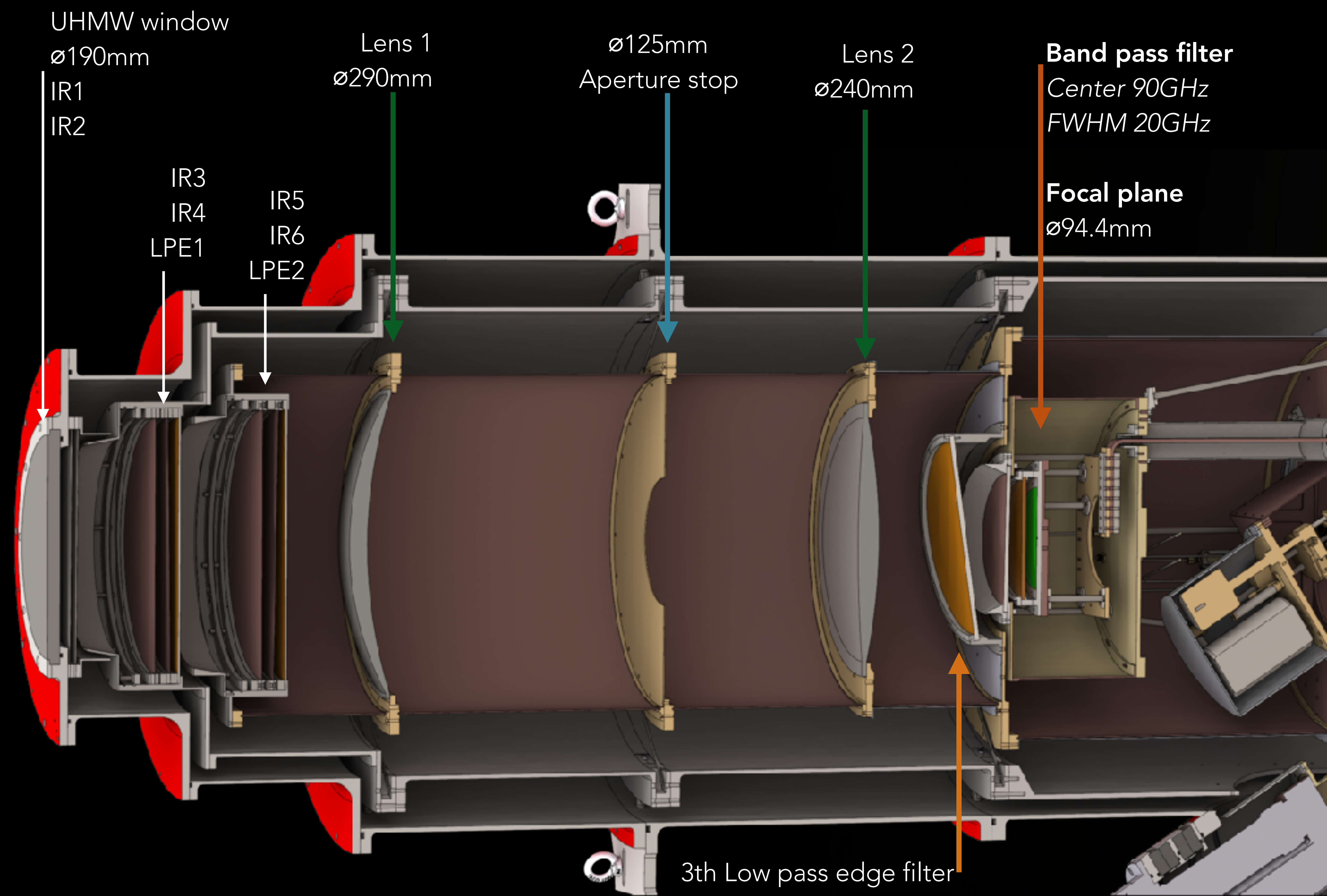


The experiment will change elevation several times during the observations. A magnetic **shield** surrounds the detectors, fridges, and relevant read-out parts to mitigate the earth's magnetic field effects.

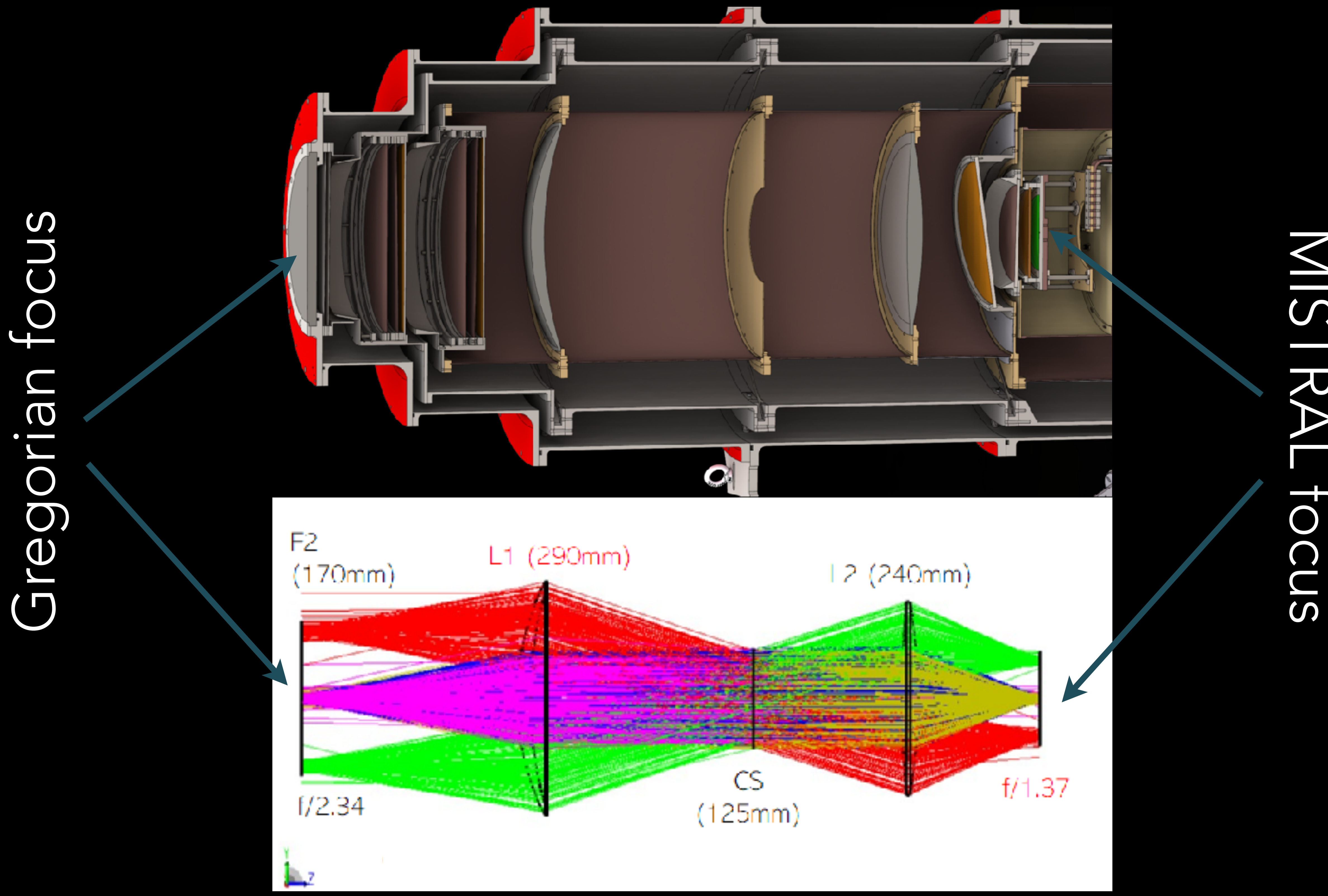
The shield (1mm thick) is made of *Cryoperm 10* with
$\mu_r > 70000$

Credits: Fabio Columbro

MISTRAL: OPTICS CHAIN



MISTRAL: OPTICS DESIGN

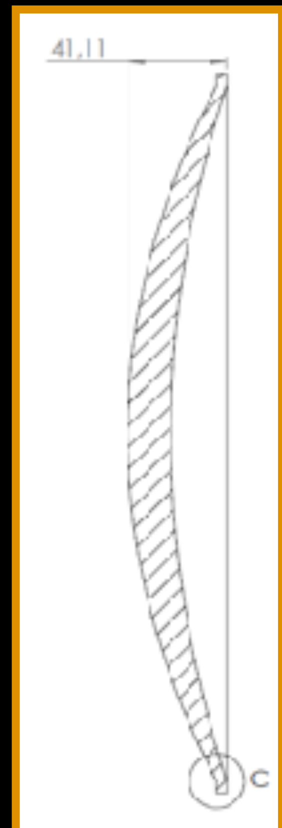


re-imaging optical system

Credits: Marco De Petris

MISTRAL: OPTICS DESIGN

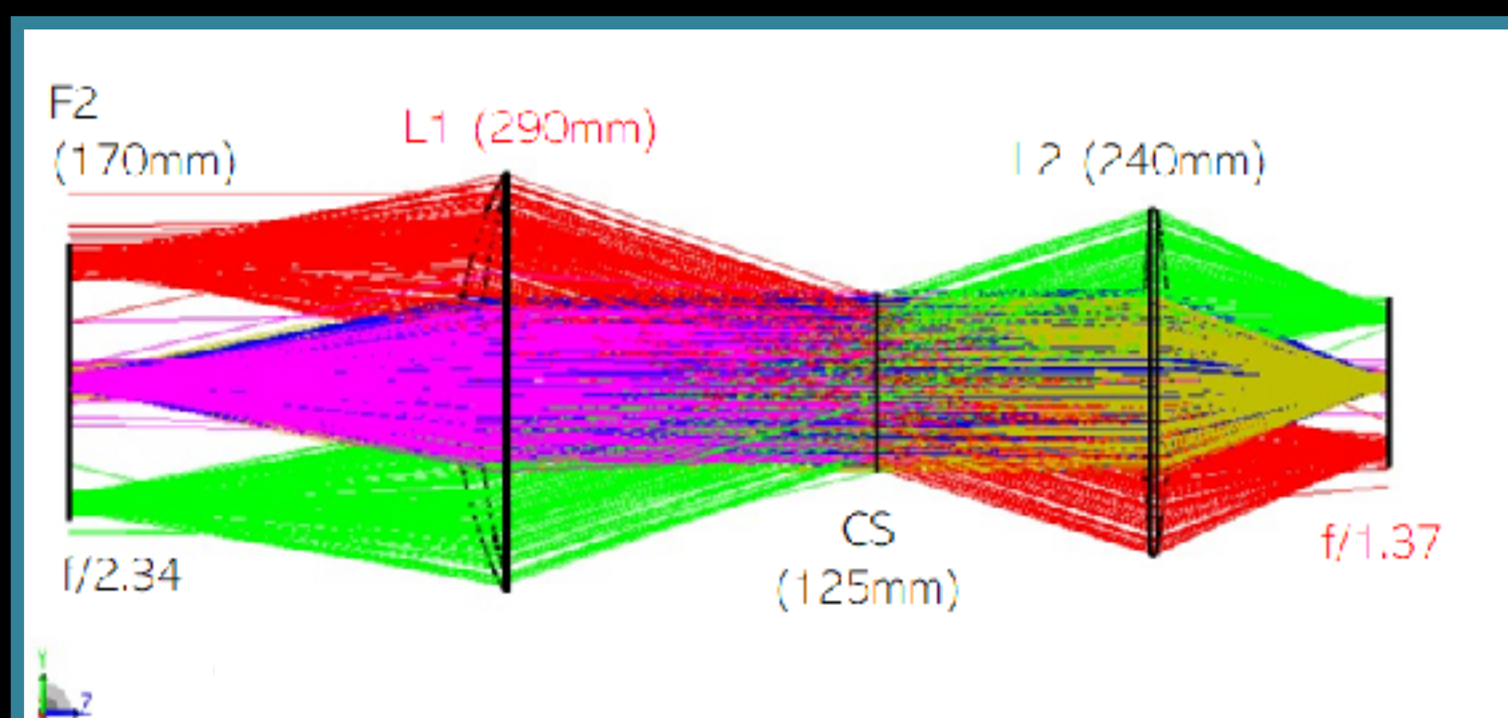
R1=293MM
K1=-0.4
R2=450MM
K2=-1.4
N=3.4 @4K



COLD STOP:
125MM CIRCULAR APERTURE COATED WITH ABSORBER MATERIAL (I.E. ECCOSORB AN72)

R1=1304MM
K1=1.6
R2=-556MM
K2=2.8
N=3.4 @4K

Anti reflection coating will cover each lenses surfaces

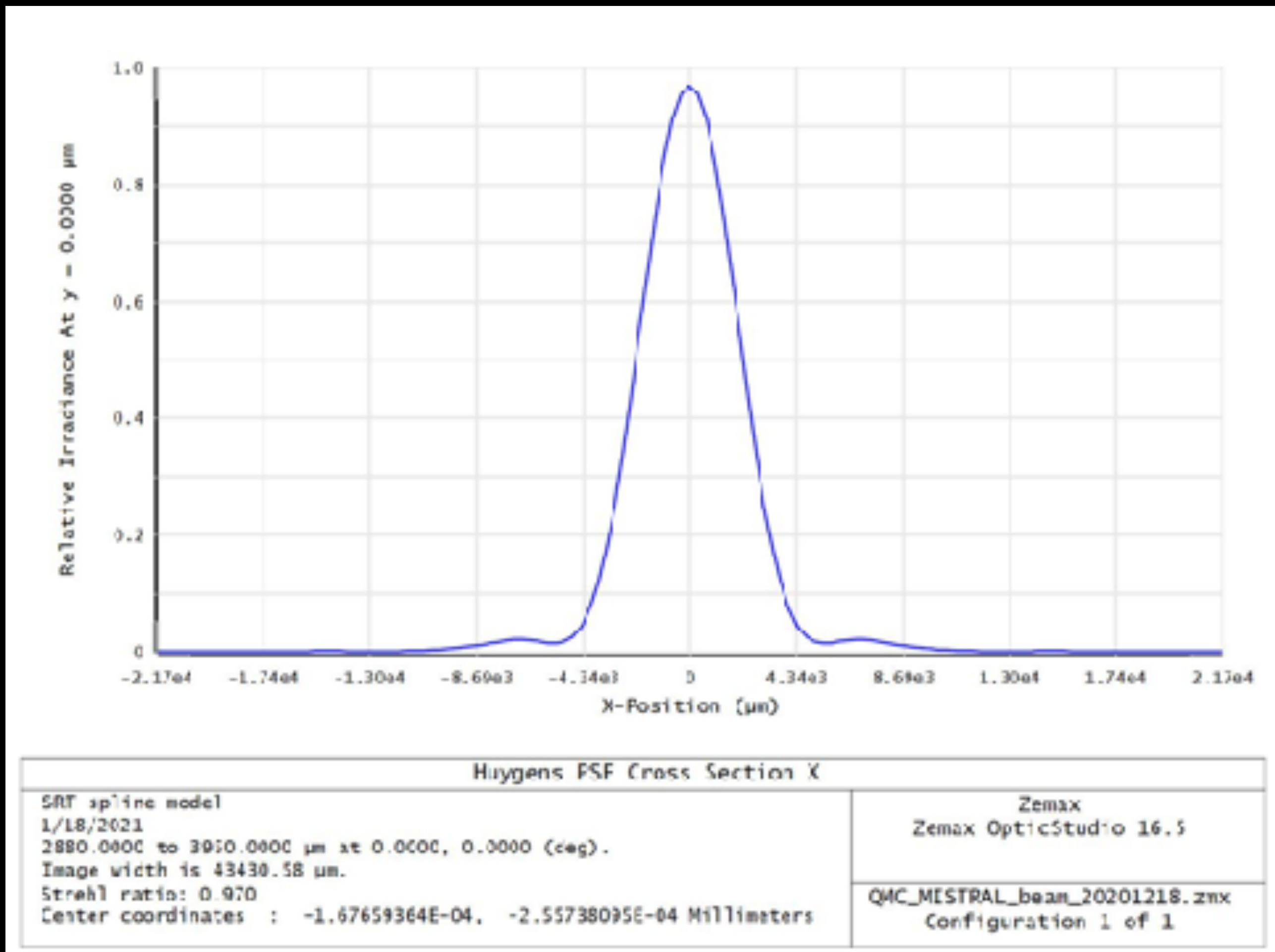


FOV=4′->
94.4MM
FOCAL SCALE RATIO =
2.54′′/MM

Credits: Marco De Petris

MISTRAL: OPTICS DESIGN

MISTRAL FOCUS

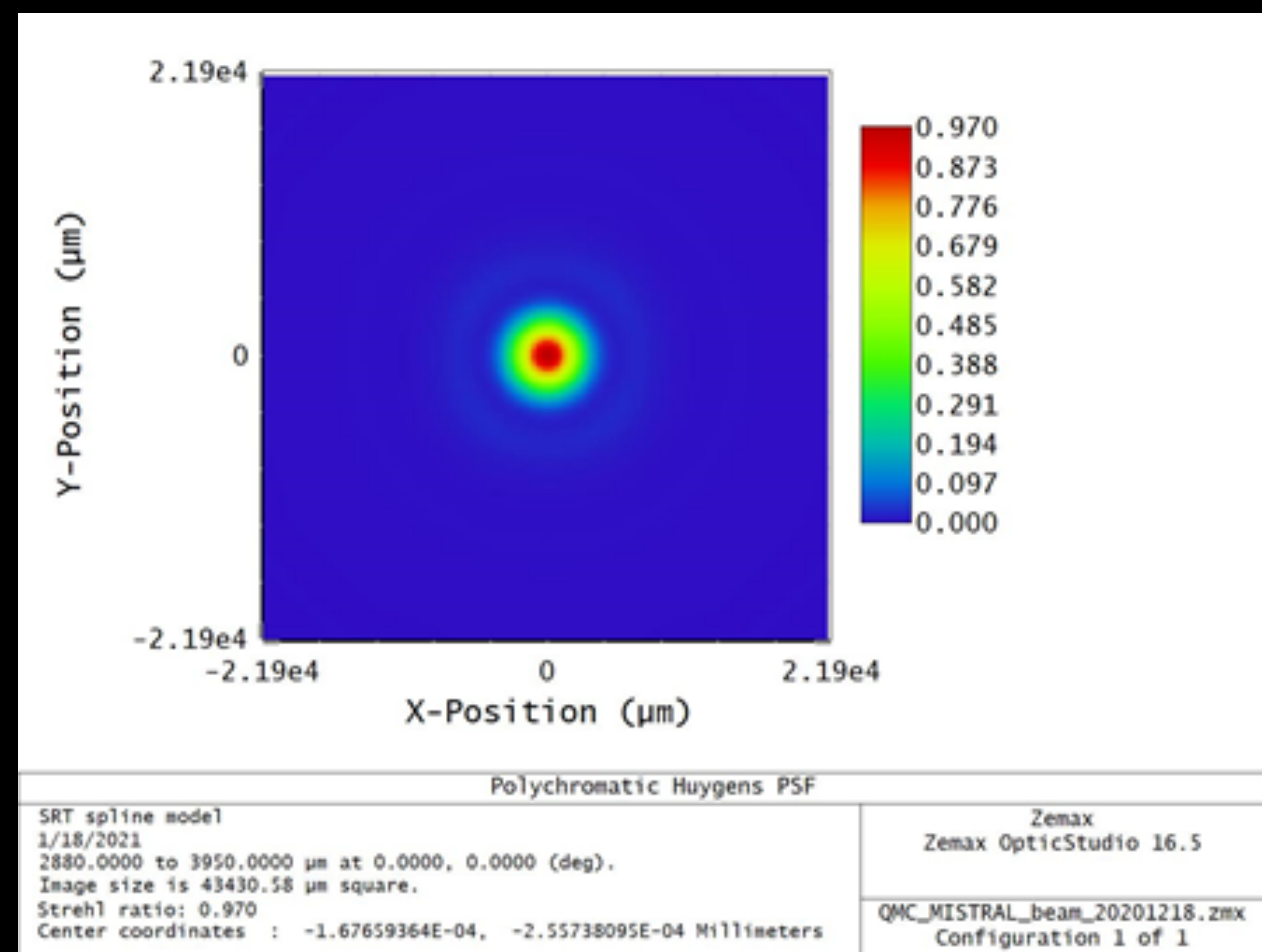


H-PSF avg in band

Field 0.0 arcmin

Strehl Ratio = 0.97

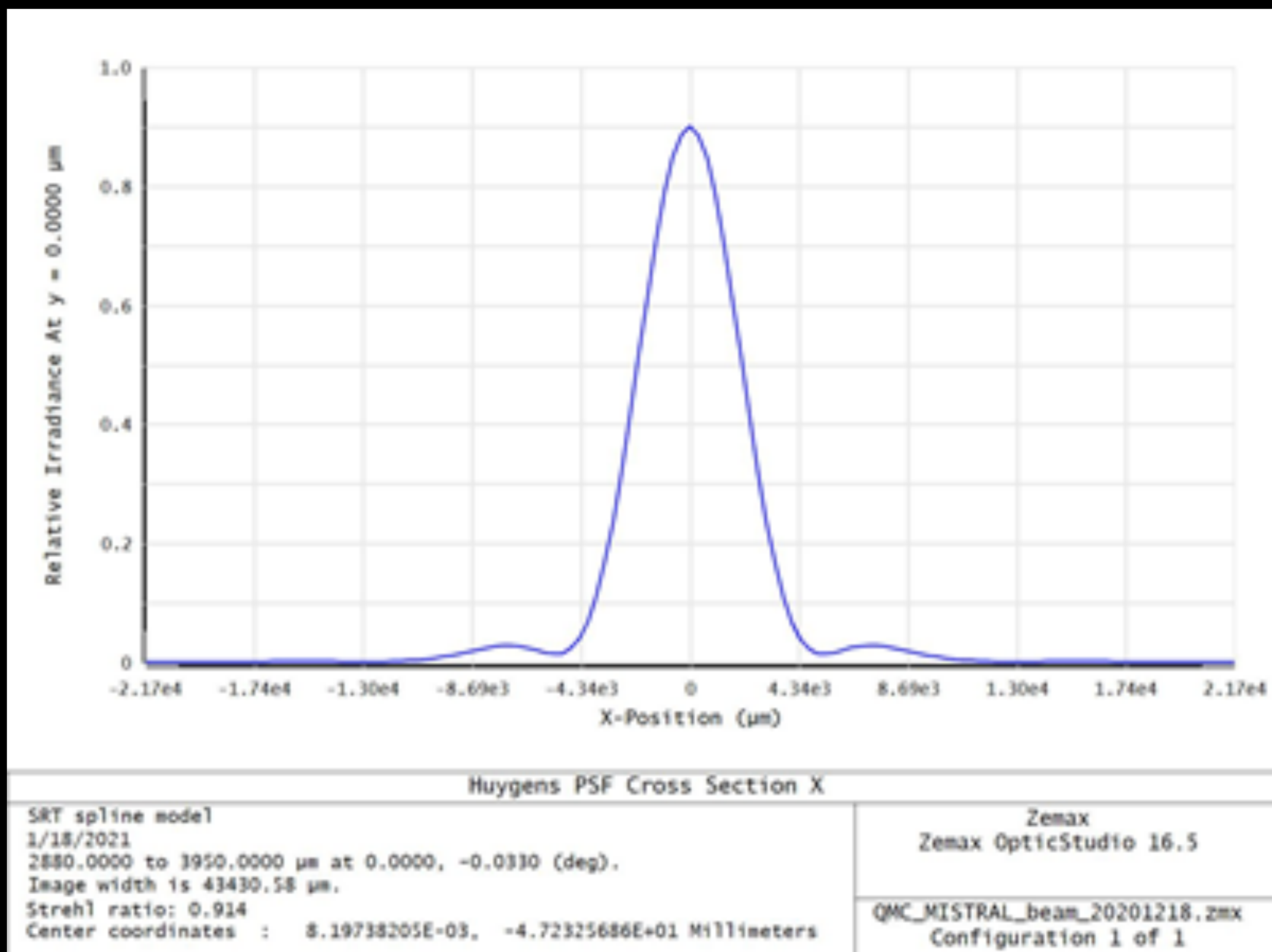
FWHM = 4.8mm = 12.2arcsec



Credits: Marco De Petris

MISTRAL: OPTICS DESIGN

MISTRAL FOCUS

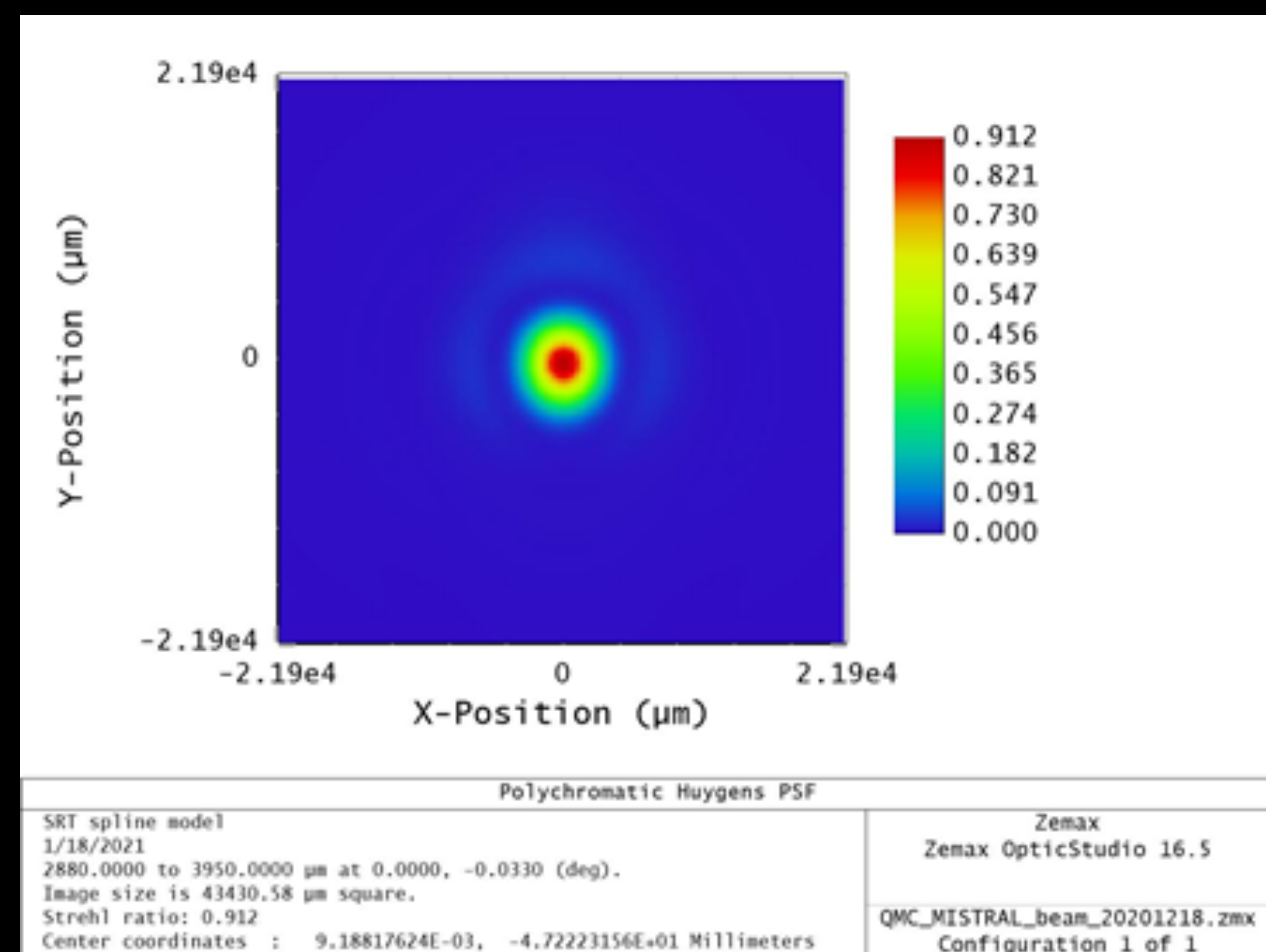


H-PSF avg in band

Field 2.0 arcmin

Strehl Ratio = 0.91

FWHM = 5mm = 12.7arcsec

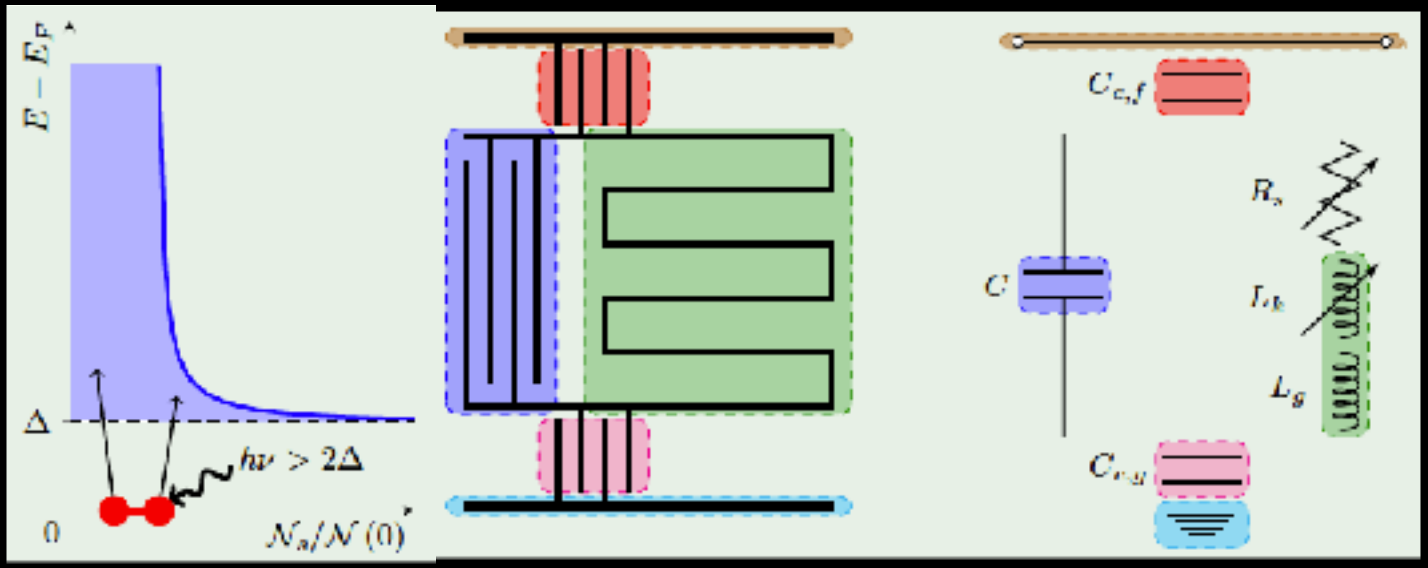


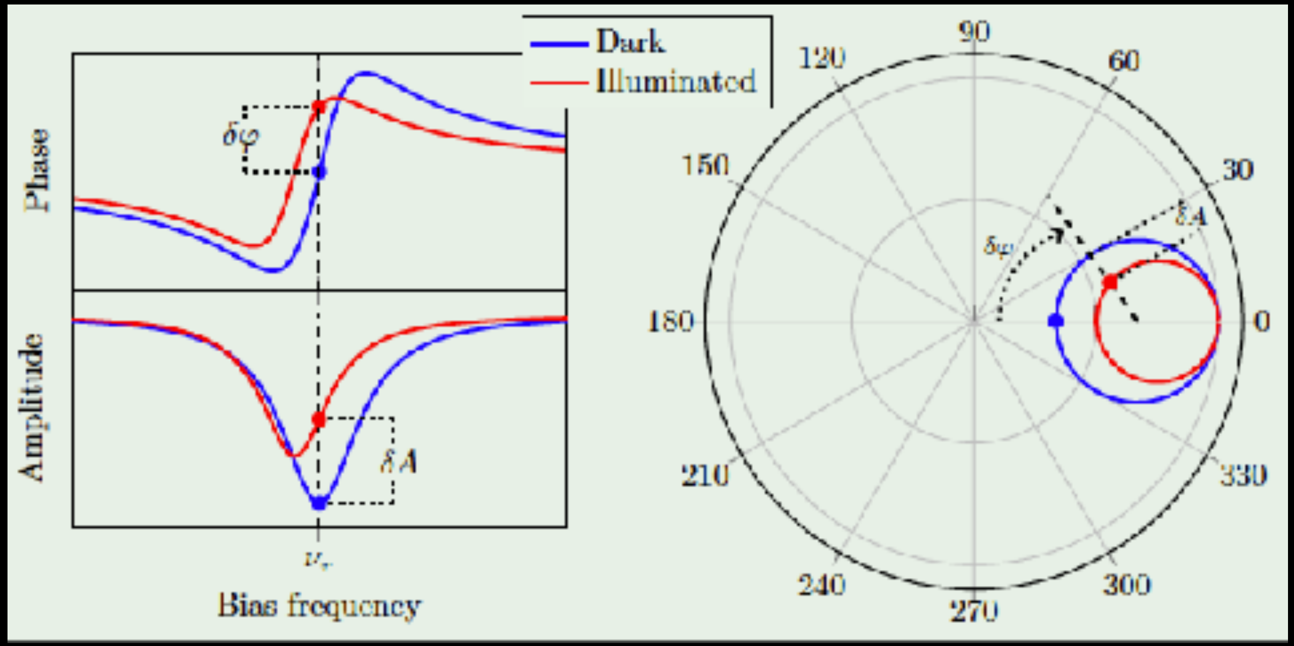
Credits: Marco De Petris

MISTRAL: DETECTORS

LEKID & WORKING PRINCIPLE

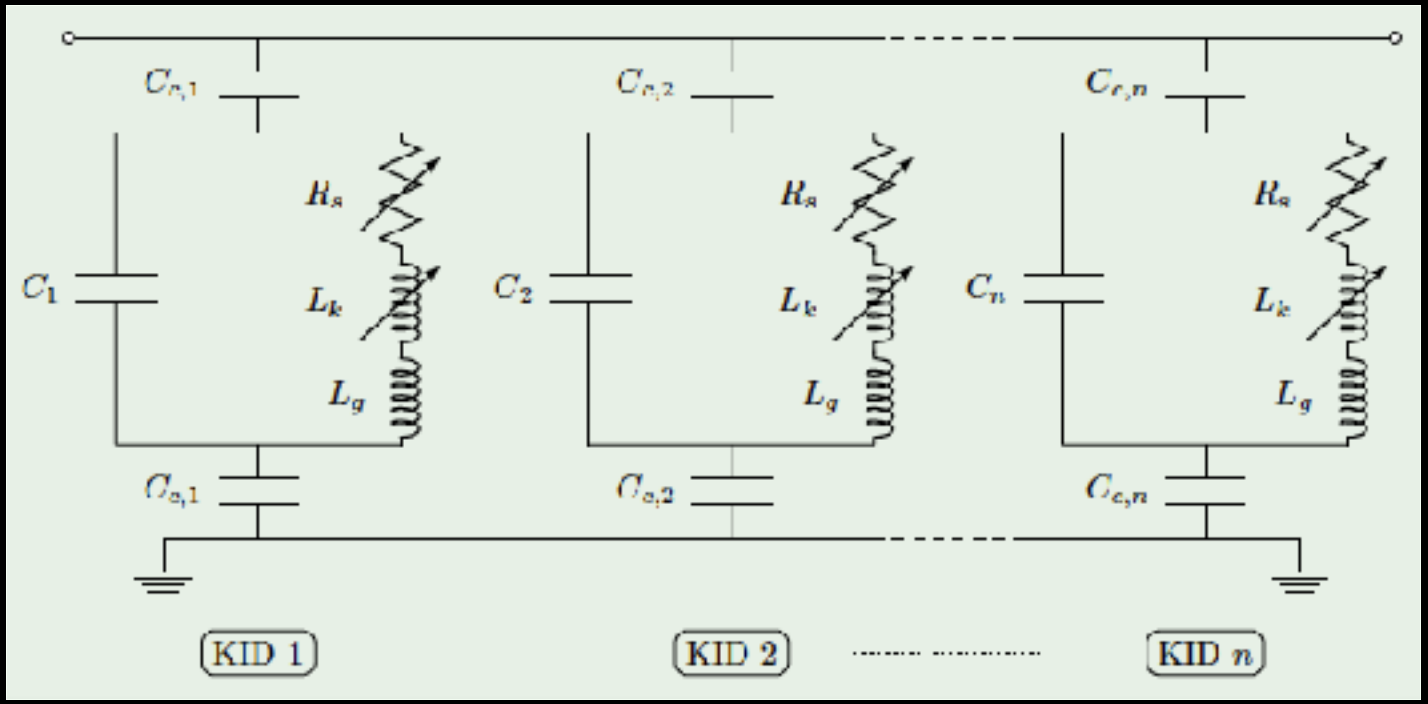
- Low temperature, fast, superconductive detectors;
- Cooper pair binding energy: $2\Delta = 3.52 k_B T_c$;
- Radiation with $h\nu > 2\Delta$ can break Cooper pairs, producing a change in the population densities, and thus in the kinetic inductance, L_k.
- High-Q LC resonators.





- In the resonator, the change in L_k, produces a change in the resonant frequency ν_r, and in the quality factor Q,
- They can be sensed by measuring the change in the amplitude and phase of the bias signal, transmitted past the resonator through the feedline.

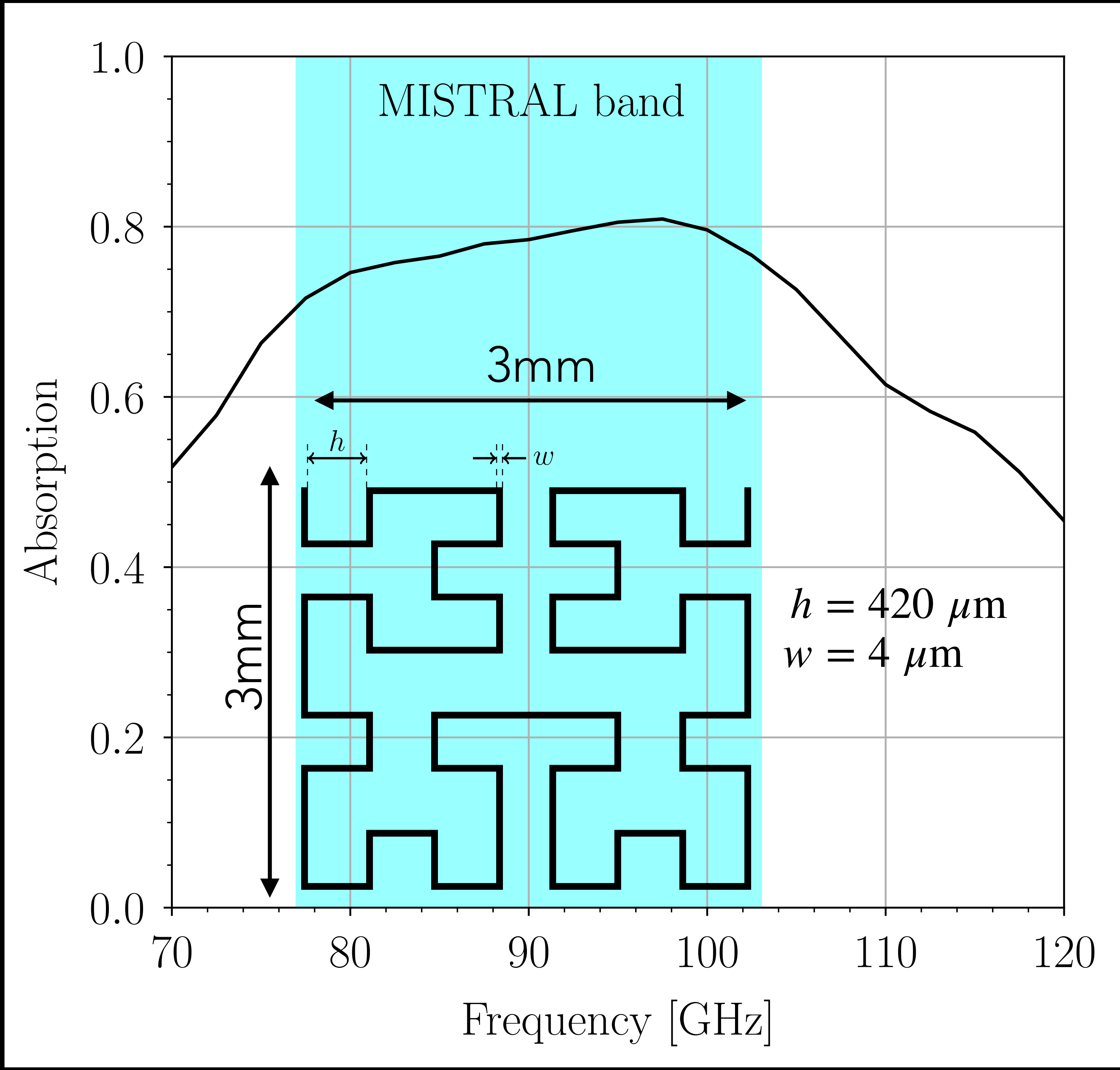
- High values of Q allow to multiplex thousands of KIDs, with different ν_r, all coupled to the same feedline.



Credits: Alessandro Paiella

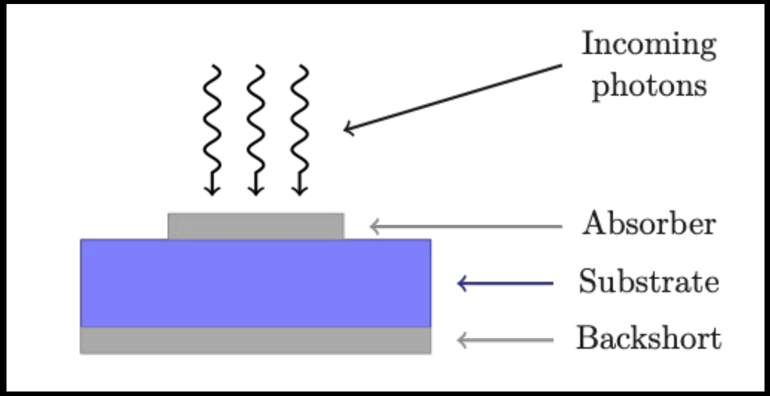
MISTRAL: DETECTORS

HFSS ABSORBER DESIGN RESULTS



Optimisation Results:

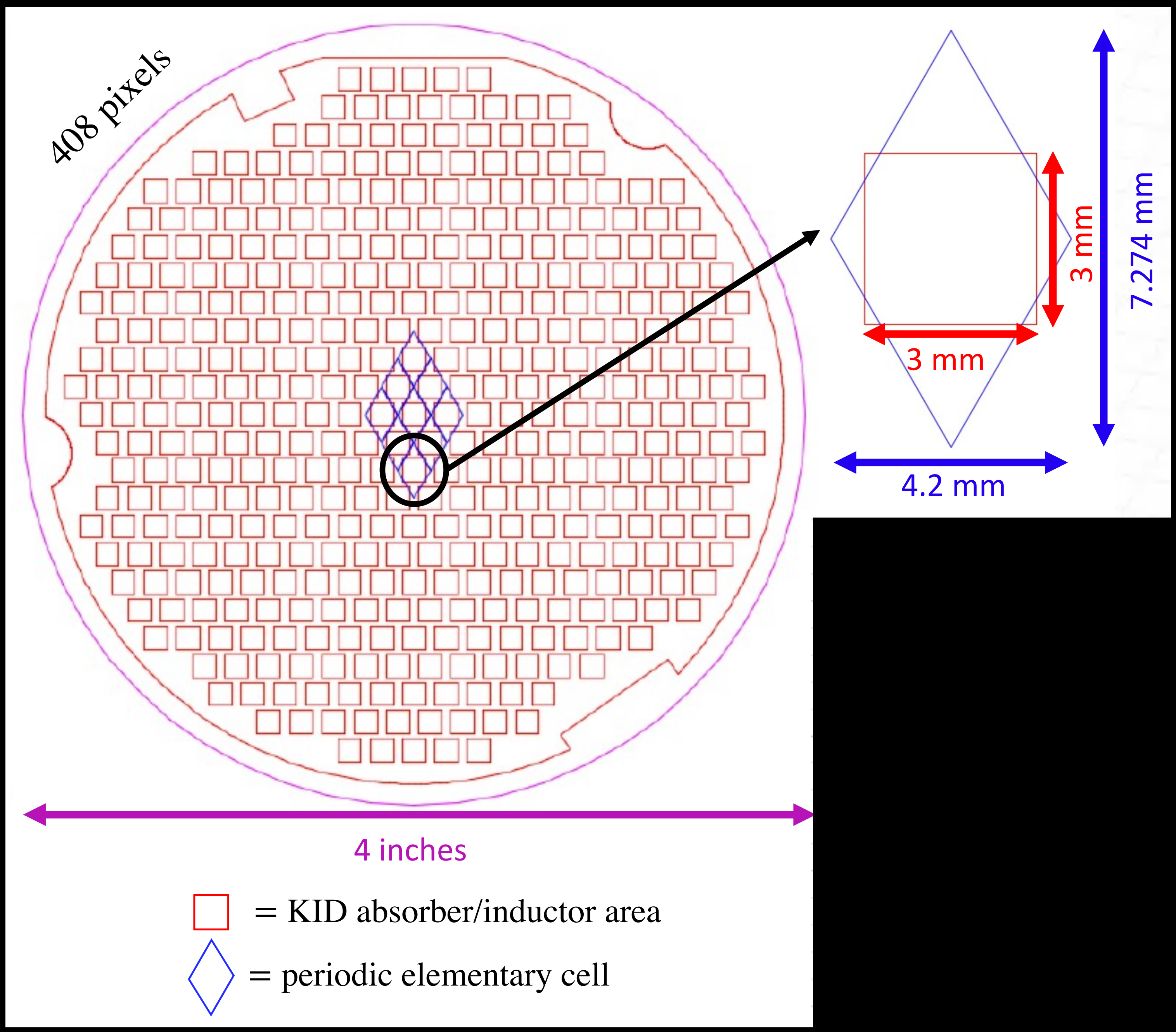
- superconductor in Ti-Al bilayer $10 + 30$ nm thick $(T_c = 945\ \text{mK})$; [Catalano et al. A&A 580 A15 2015]
- Silicon substrate $235\ \mu m$;
- Front-illuminated 3rd order Hilbert crude absorber with backshort



Credits: Alessandro Paiella

MISTRAL: DETECTORS

PIXEL ARRANGEMENT

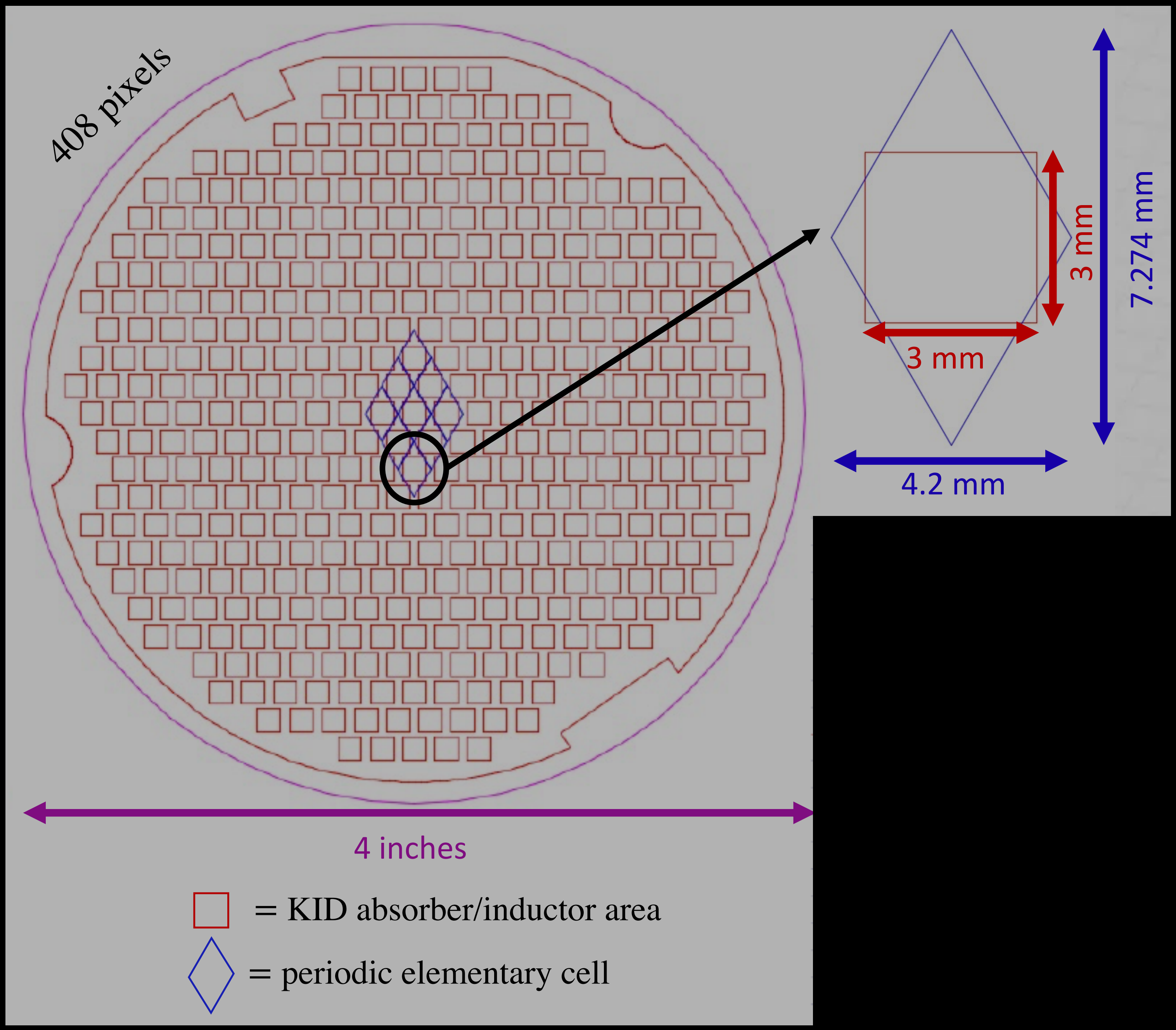


3mm X 3mm absorbers arranged on a equilateral triangle, with a side 4.2mm.

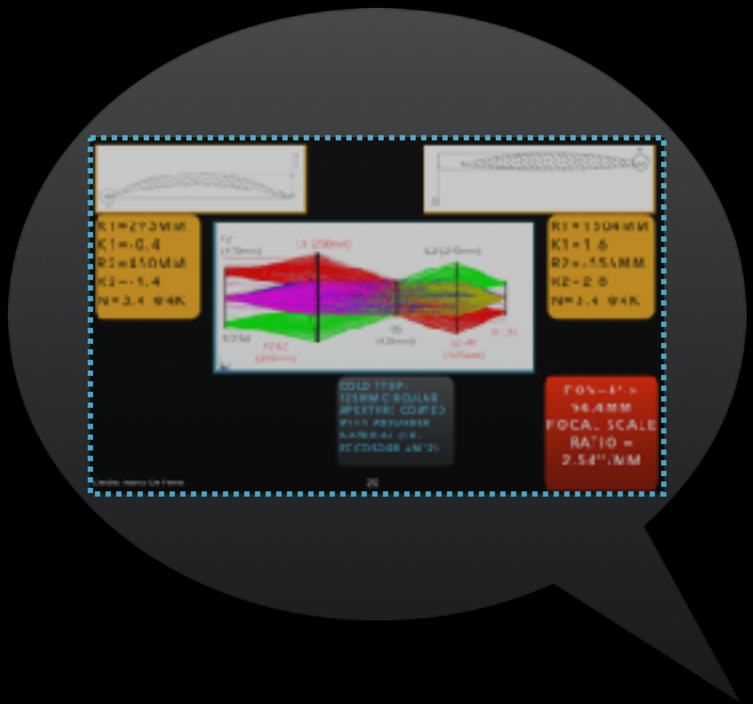
Credits: Alessandro Paiella

MISTRAL: DETECTORS

PIXEL ARRANGEMENT



3mm X 3mm absorbers arranged on a equilateral triangle, with a side 4.2mm.



FOV=4'->
94.4MM
FOCAL SCALE
RATIO = 2.54''/MM

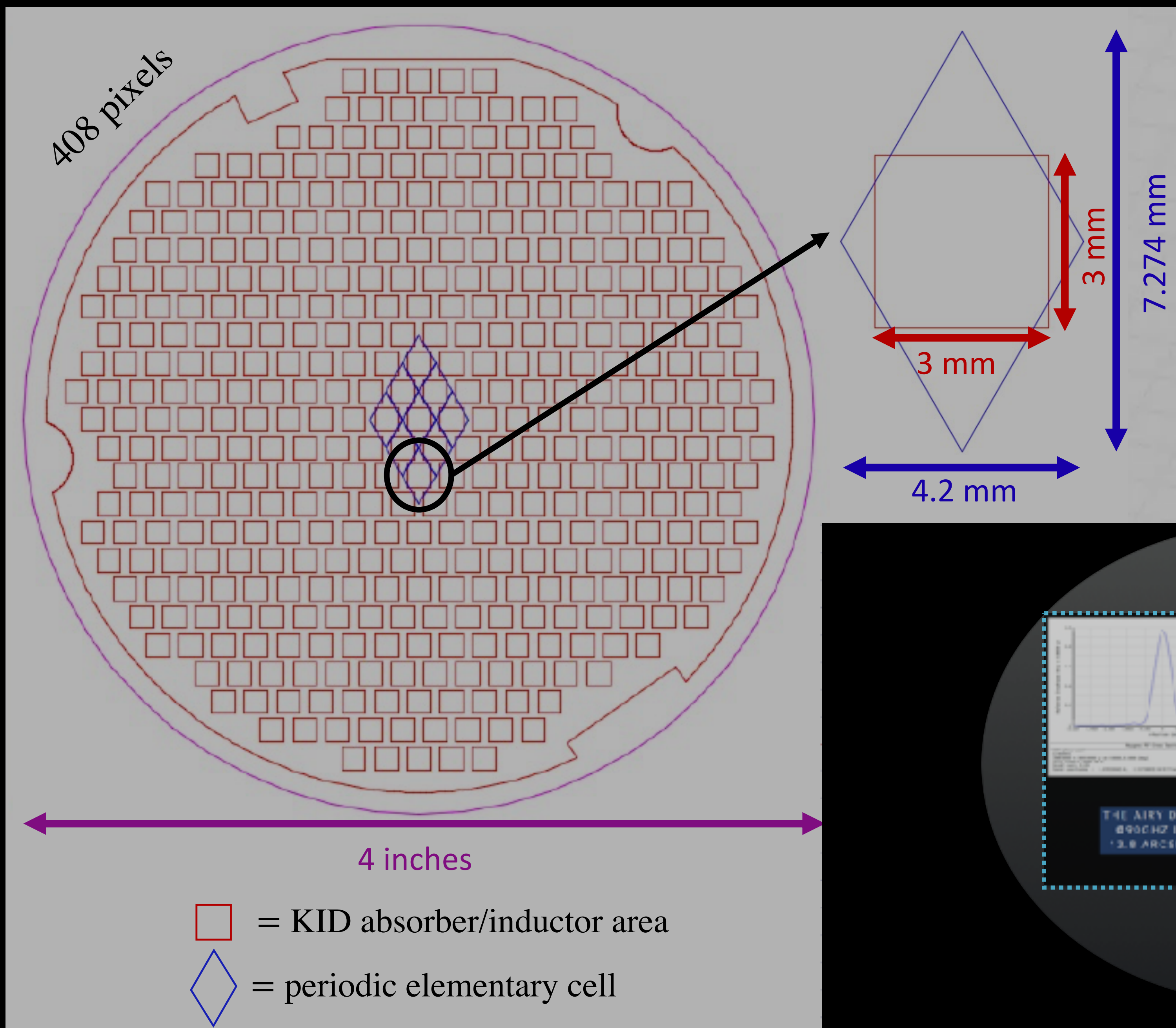
....

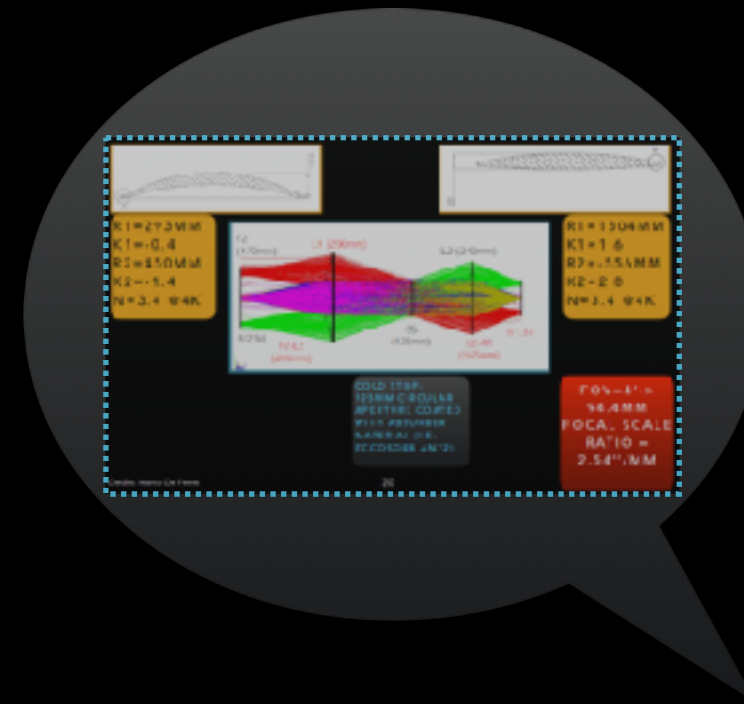
PIXEL
SEPARATION=10.6''

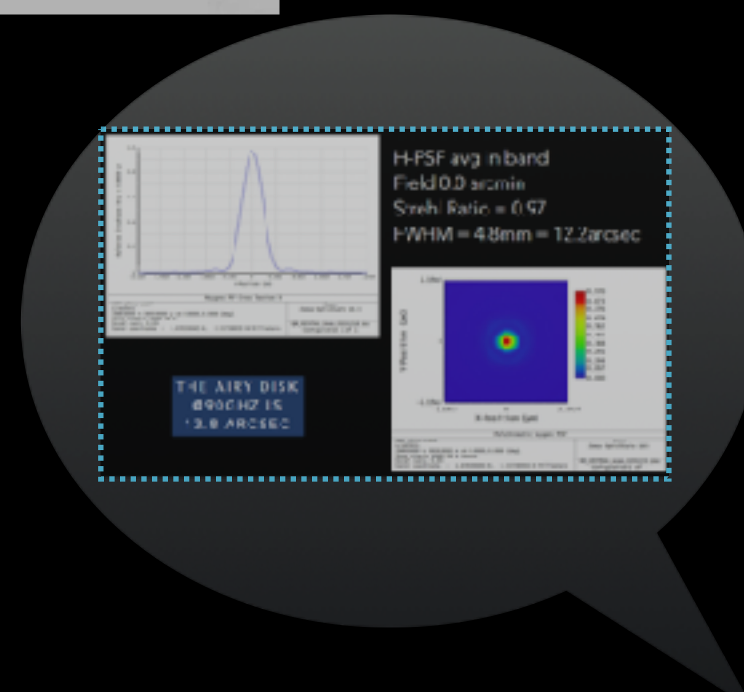
Credits: Alessandro Paiella

MISTRAL: DETECTORS

PIXEL ARRANGEMENT







FOV=4'-> 94.4MM
FOCAL SCALE RATIO = 2.54''/MM

....

PIXEL SEPARATION=10.6''

....

FWHM=12.2''

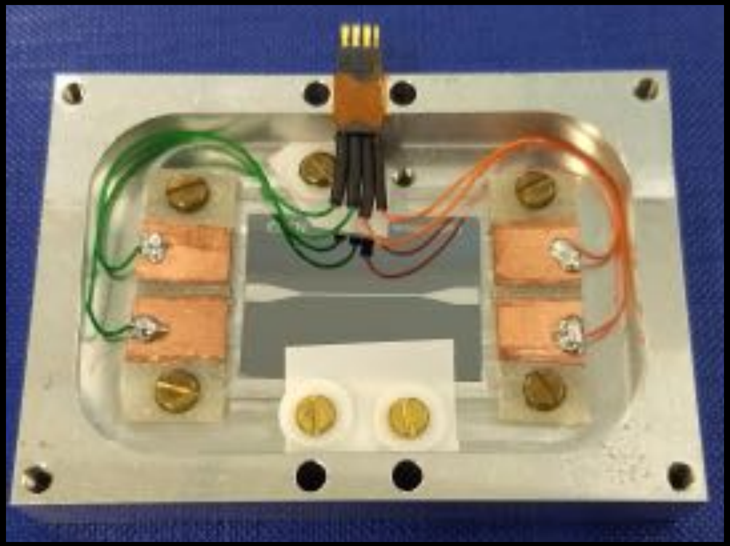
3mm X 3mm absorbers arranged on a equilateral triangle, with a side 4.2mm.

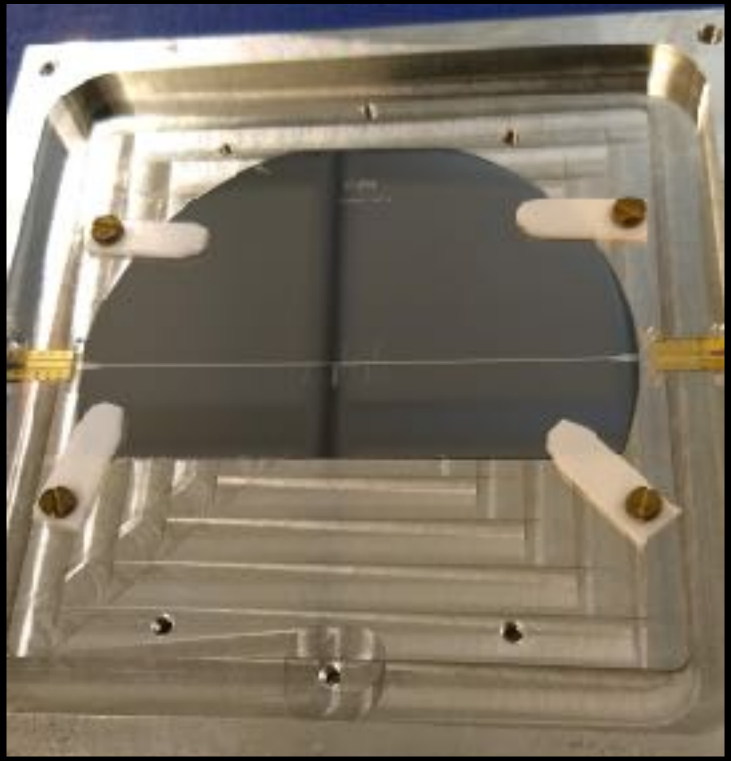
Credits: Alessandro Paiella

MISTRAL: DETECTORS

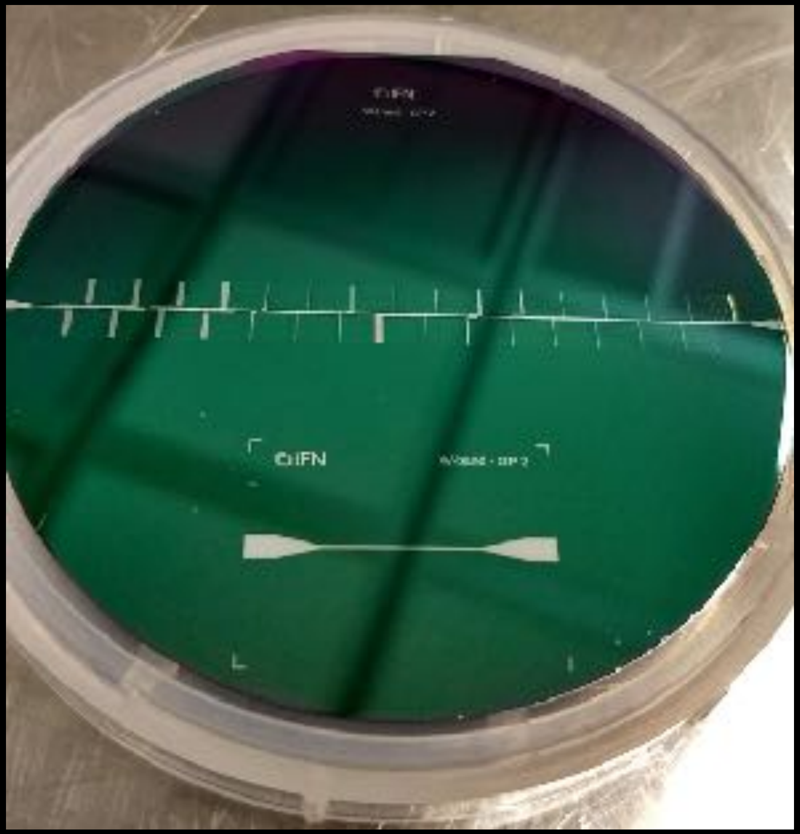
CNR IFN Istituto di Fotonica e Nanotecnologie

Wband_GP1: 3'', 5 pixel + feedline





Wband_GP2: 3'', 31 pixel + feedline



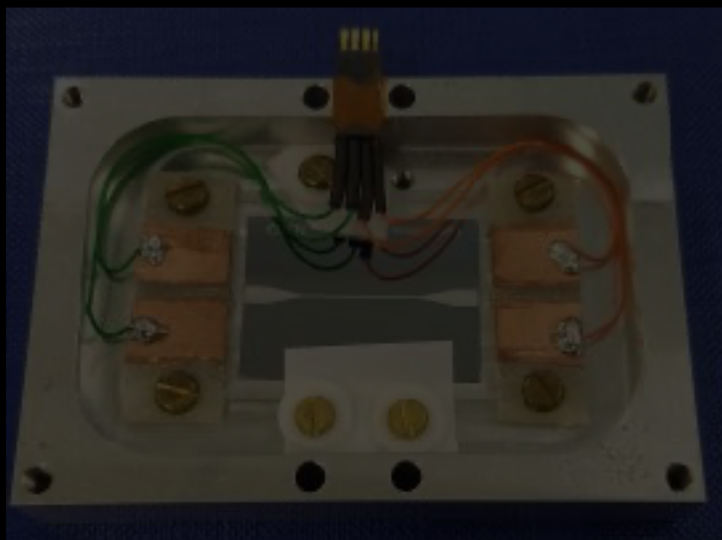
MISTRAL_GP1: 4'', 31 pixel + feedline

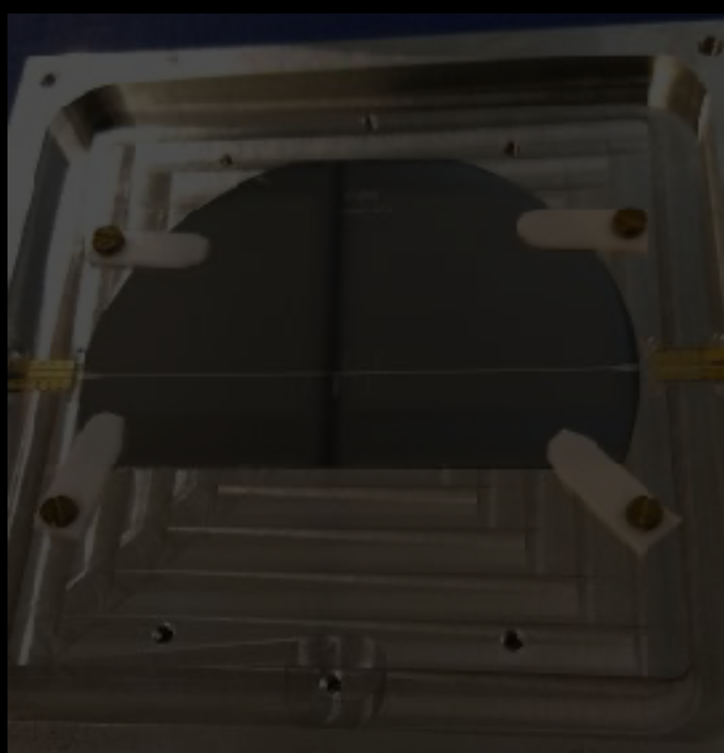
Prototype storyline

Credits: Alessandro Paiella, Giorgio Pettinari

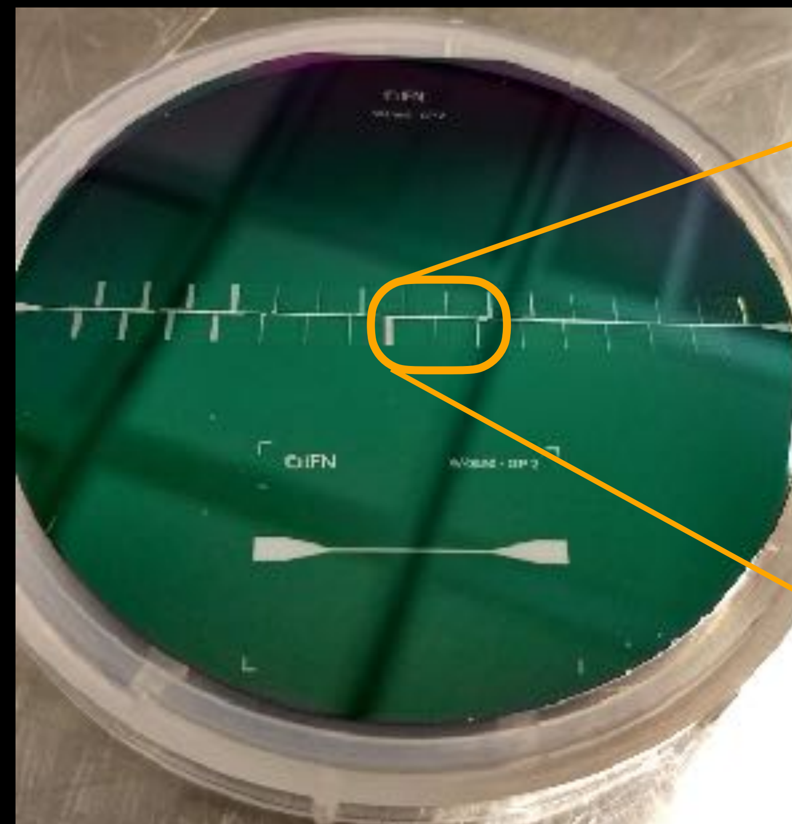
MISTRAL: DETECTORS

Wband_GP1: 3'', 5 pixel + feedline

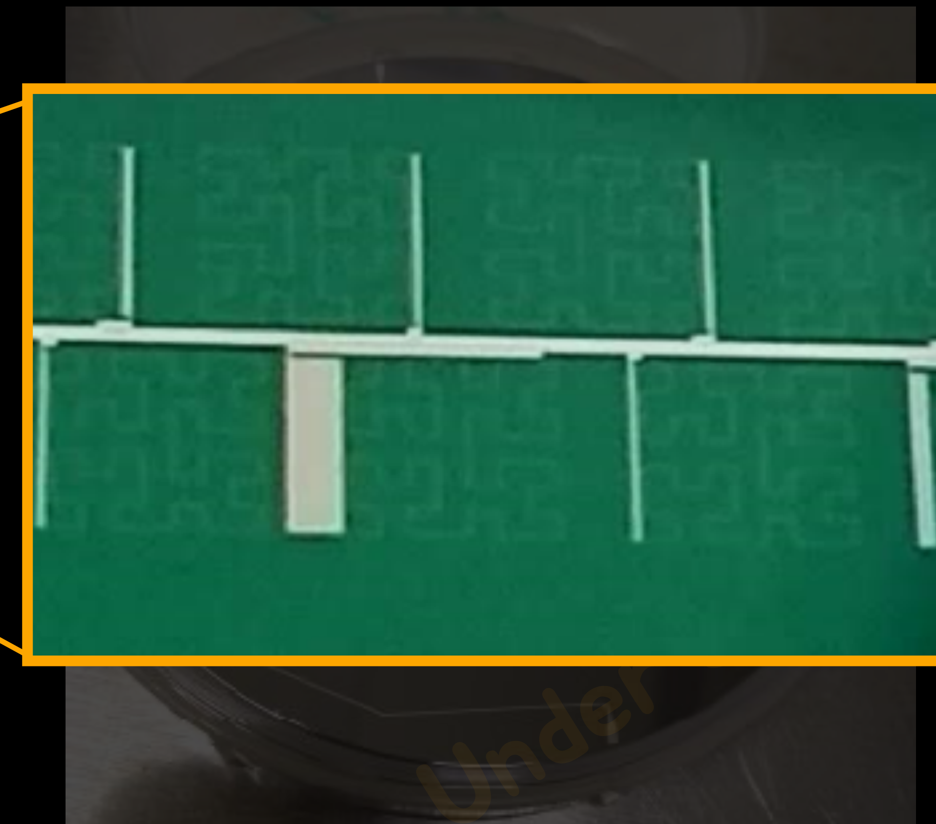




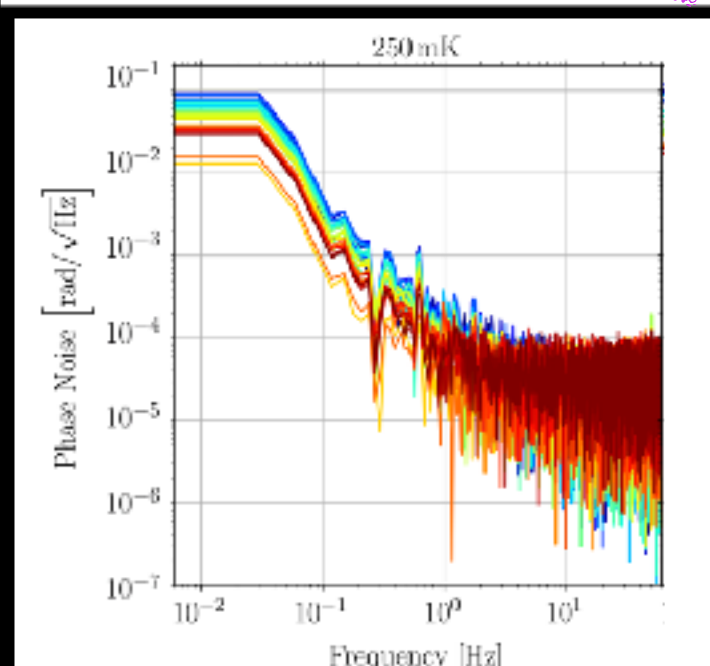
Wband_GP2: 3'', 31 pixel + feedline



MISTRAL_GP1: 4'', 31 pixel + feedline



		Operation Temperature		
		150 mK	250 mK	300 mK
NEP_{dark}	Avg.	41.5	280	520
$[aW/\sqrt{Hz}]$	Best	17.0	110	180
	Worst	73.0	500	[illegible]060



One order magnitude less of site background

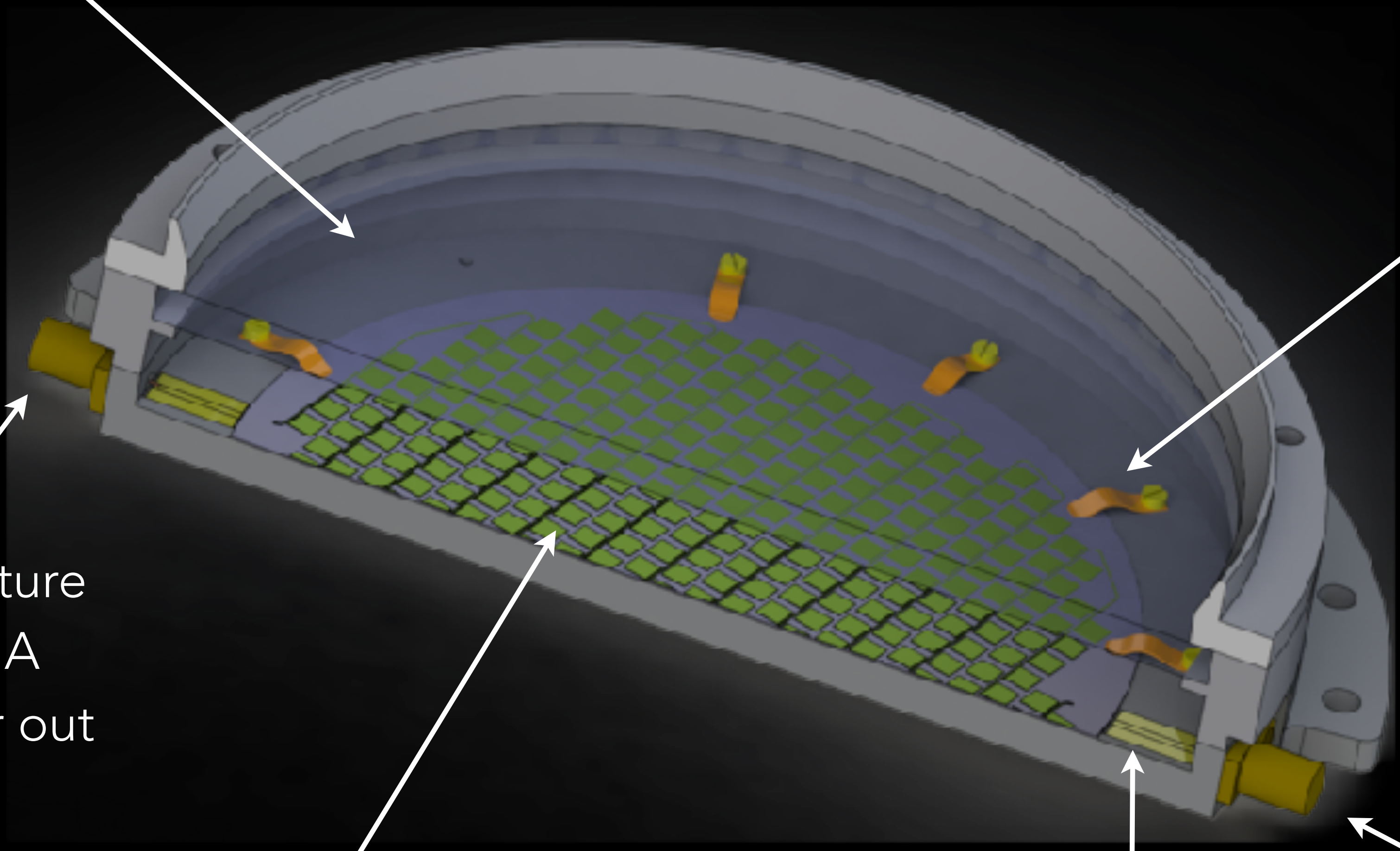
(considering unstable atmosphere)

- electrical tests
- electrical responsivity measurement
- Noise Equivalent Power as a temperature function
- Sensitivity to the magnetic field

Credits: Alessandro Paiella, Giorgio Pettinari

MISTRAL: DETECTORS

HOLDER DETAILS

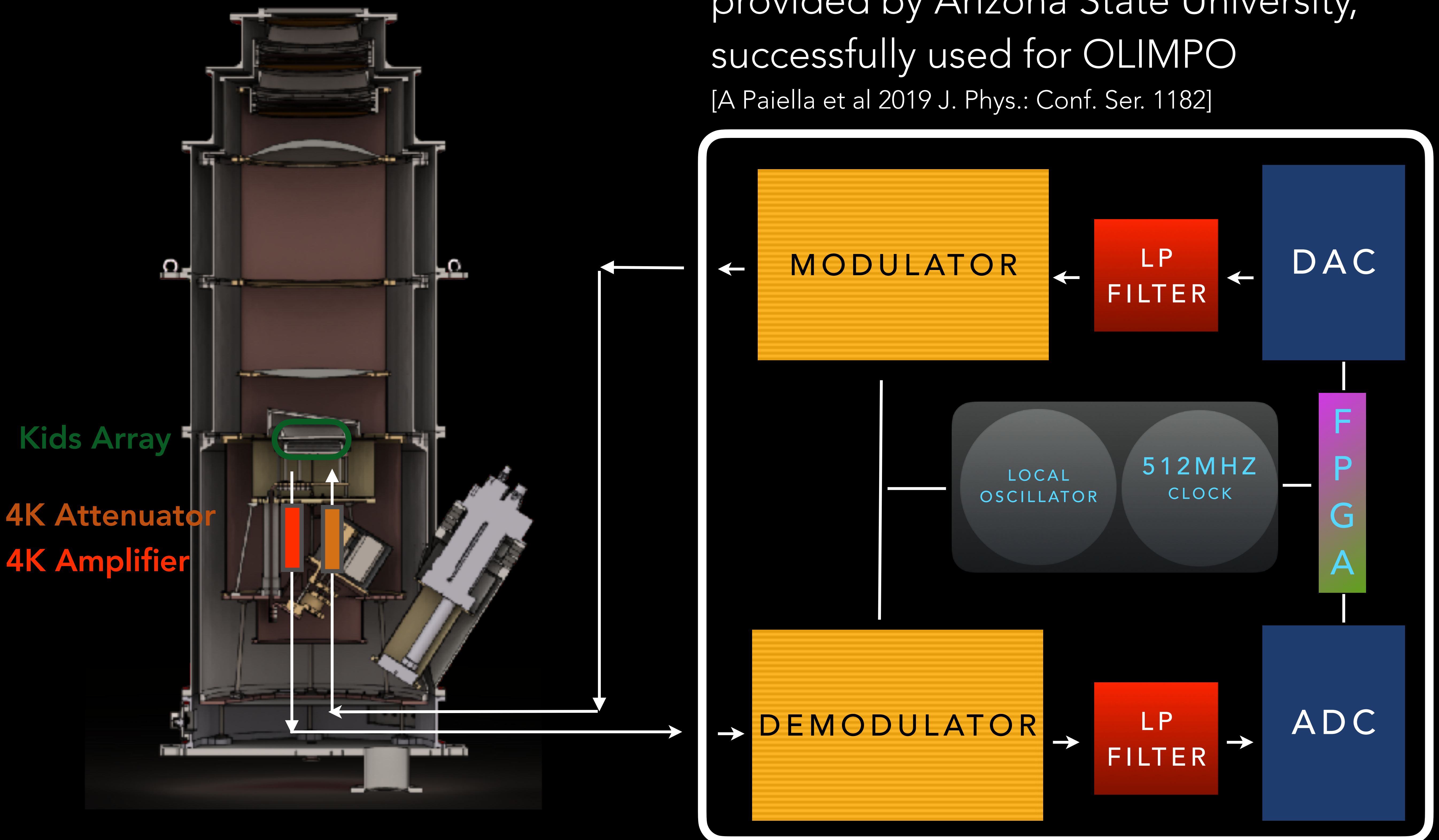


Credits: Alessandro Coppolecchia

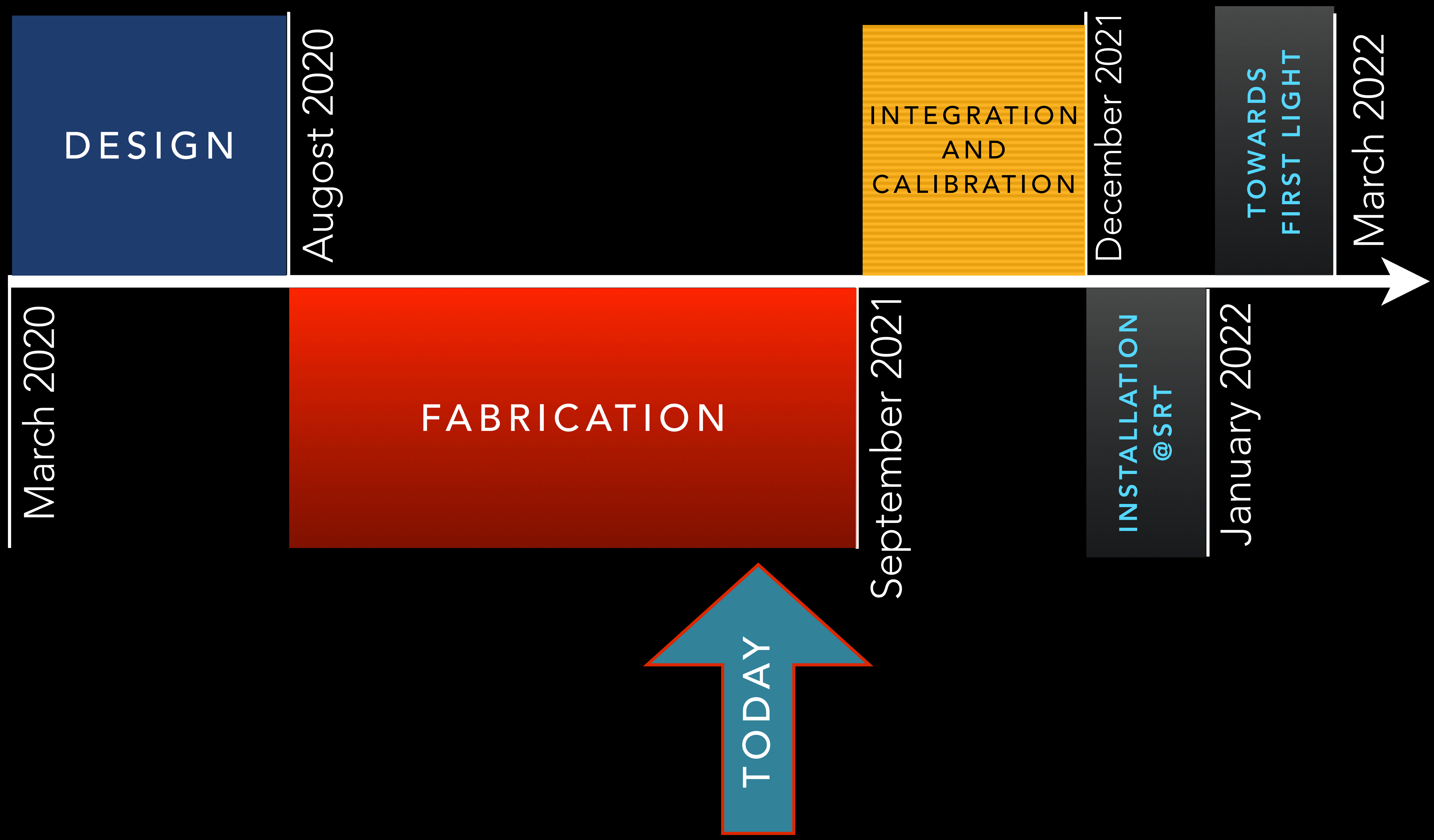
MISTRAL: READ OUT

Roach2: FPGA system based, provided by Arizona State University, successfully used for OLIMPO

[A Paiella et al 2019 J. Phys.: Conf. Ser. 1182]



SCHEDULE


DESIGN
Augost 2020
INTEGRATION
AND
CALIBRATION
December 2021
TOWARDS
FIRST LIGHT
March 2022
March 2020
FABRICATION
September 2021
INSTALLATION
@SRT
January 2022
TODAY

W-BAND HIGH ANGULAR RESOLUTION (SOON AT SRT)

Galaxies

Spectral energy distribution

AGN and radio galaxies

Spiral galaxies continuum observation

Mm-wave detection of circumstellar discs

Medium

Dense core in giant molecular clouds

Synchrotron

Non thermal jet/hot spot

S-Z effect

ICM Thermodynamics, mass profile
Shocks, cold fronts
Filament, Cosmic web
Point sources

More and more, by correlating with other experiment

W-BAND HIGH ANGULAR RESOLUTION (SOON AT SRT)

Observing with the Italian radio telescopes

Welcome to the Italian radio telescopes users' page

Here you can access all of the resources needed to achieve successful single-dish and extra-EVN interferometric observations

Contact us

Regular call is closed. Next deadline will be in October 2021.

Proposals for ToOs and DDT can be submitted anytime.

The offered instrumentation is listed here.

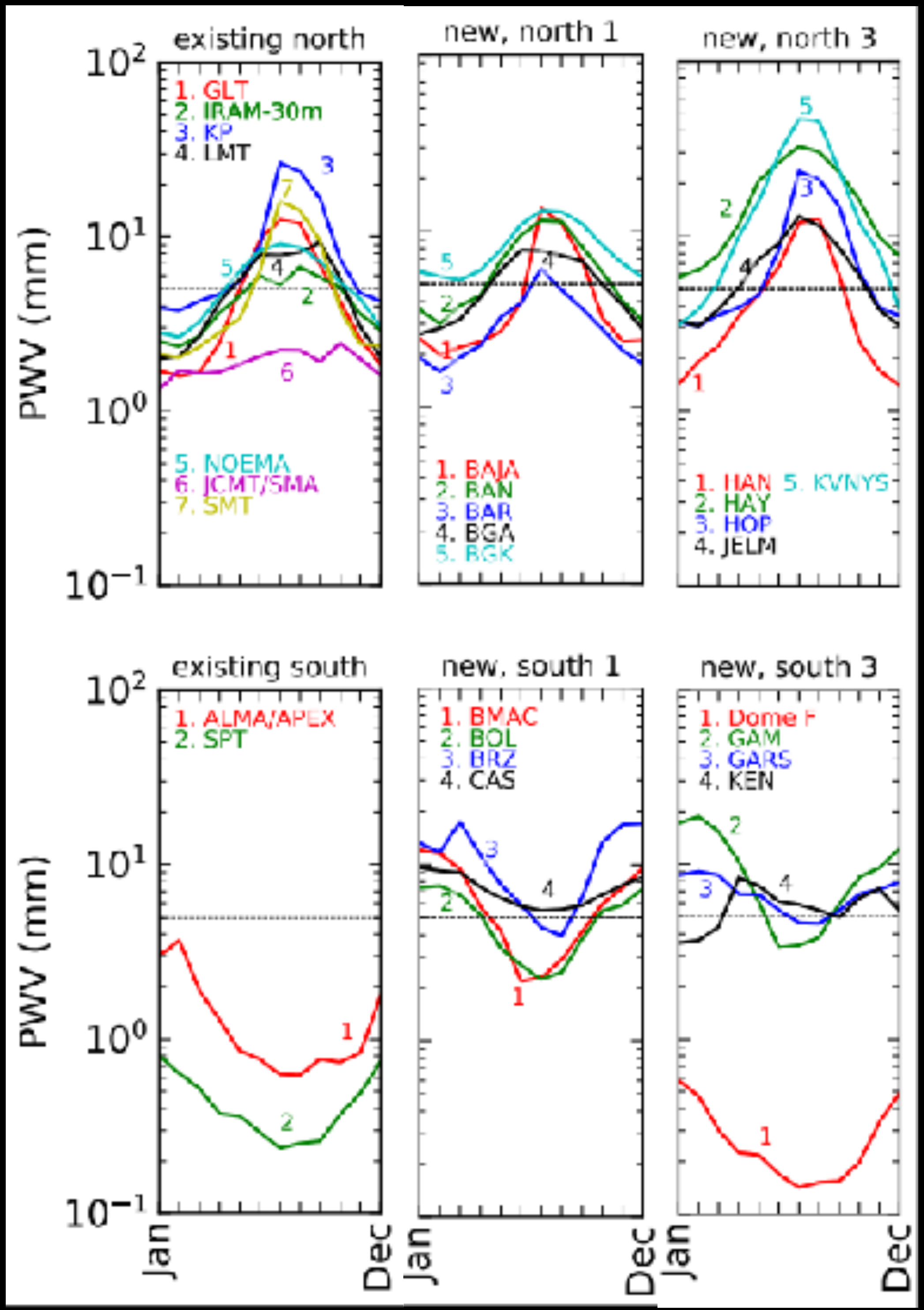
CONCLUSION:

- The Sardinia Radio Telescope (SRT) is a multipurpose observatory designed to measure a wide range of radio wavelengths: from 300MHz to 116GHz
- At SRT, the sky opacity in winter is <0.15 (50th percentile) at 93GHz
- MISTRAL will be coupled with SRT with a re-imaging optical system. The minimum spatial resolution (FWHM) is 12.2arcsec
- The 408 LEKIDs array has been optimised for best 90GHz absorption and for the background at SRT.
- MISTRAL scientific commissioning will start on January 2022

backup slides

SARDINIA RADIO TELESCOPE

Evaluation of New Submillimeter VLBI Sites for the Event Horizon Telescope



[Raymond 2021, ApJ 253:5 2021]

Estimation of sky opacity, based on recorded atmospheric data, forecasts

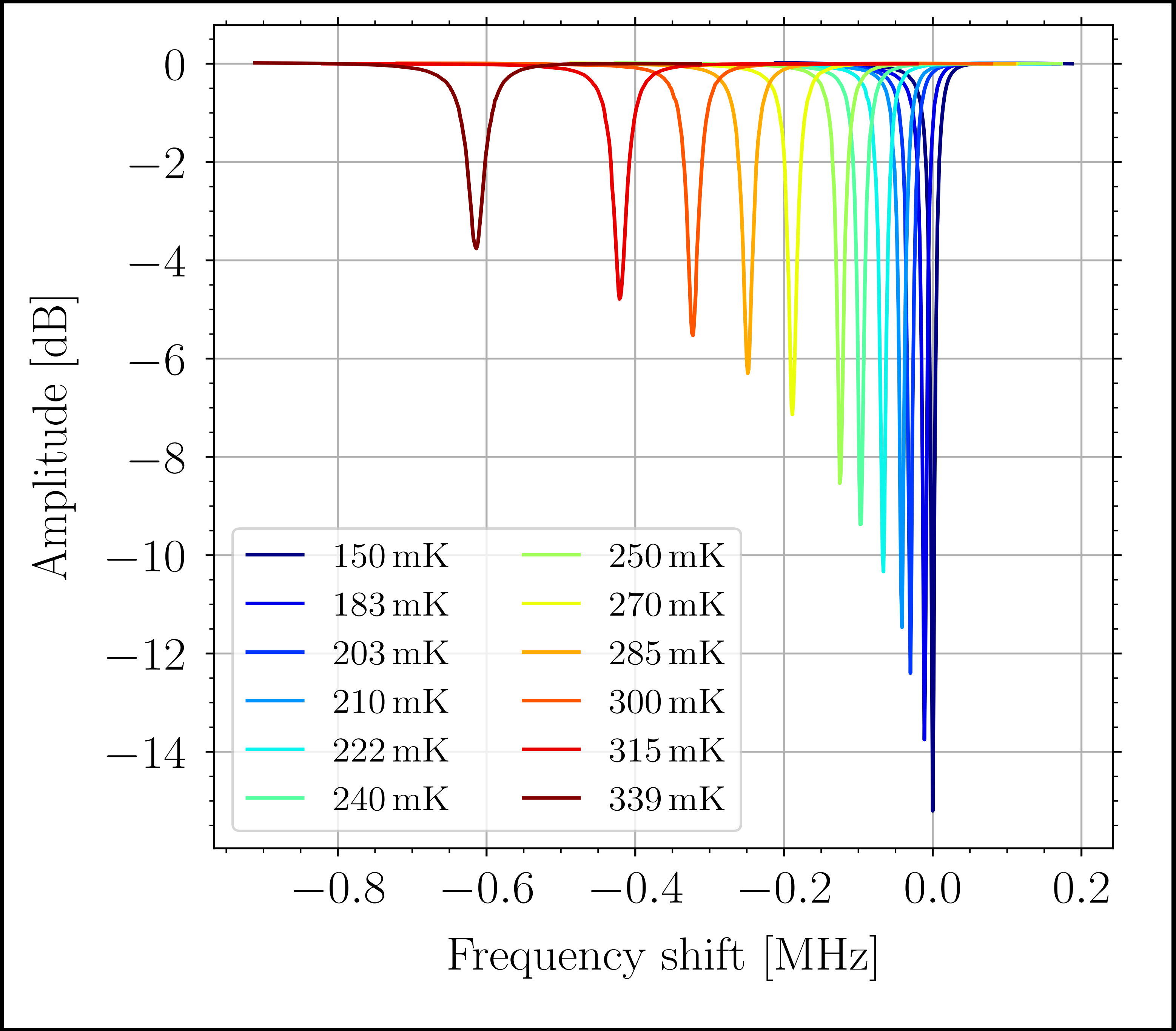
[http://hdl.handle.net/20.500.12386/28787]

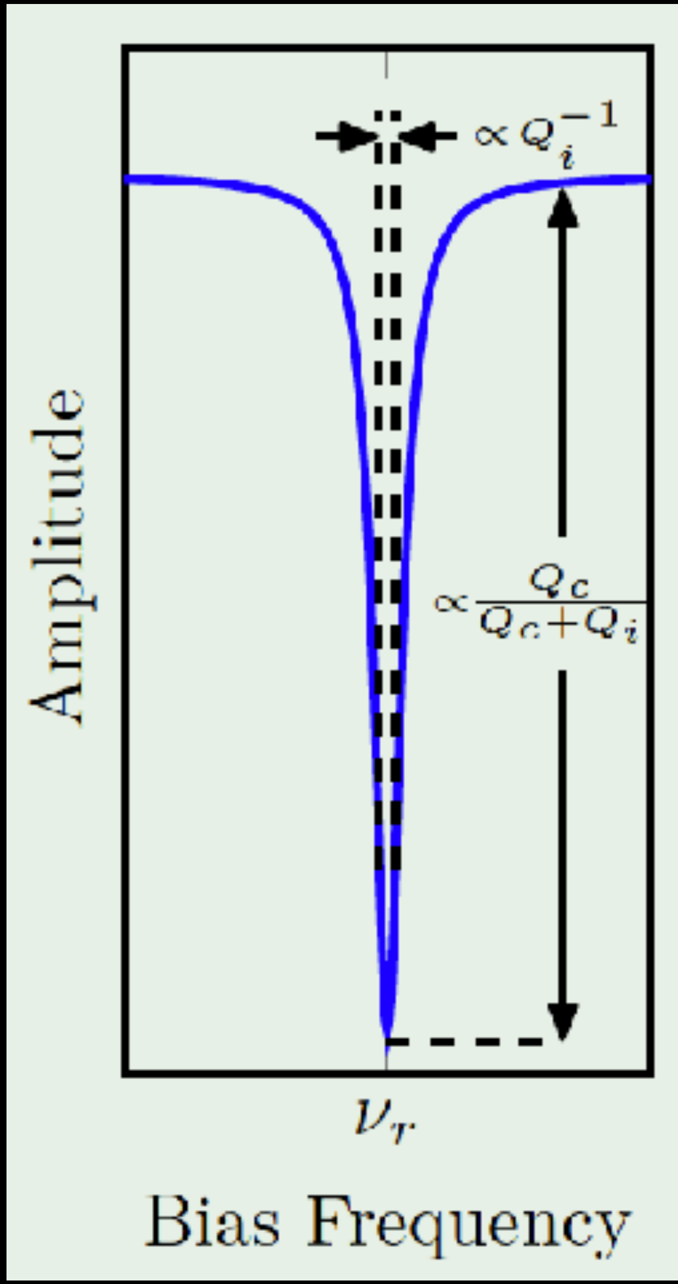
<0.15 (50th percentile) **at 93GHz** during the winter nights. The PWV in the same conditions is mainly 8mm.

Green Bank Telescope tau<0.125 (50th percentile) @86GHz, and PWV<9mm (50th percentile) [https://www.gb.nrao.edu/mustang/wx.shtml]

MISTRAL: DETECTORS

KID DESIGN & ELECTRICAL PARAMETERS



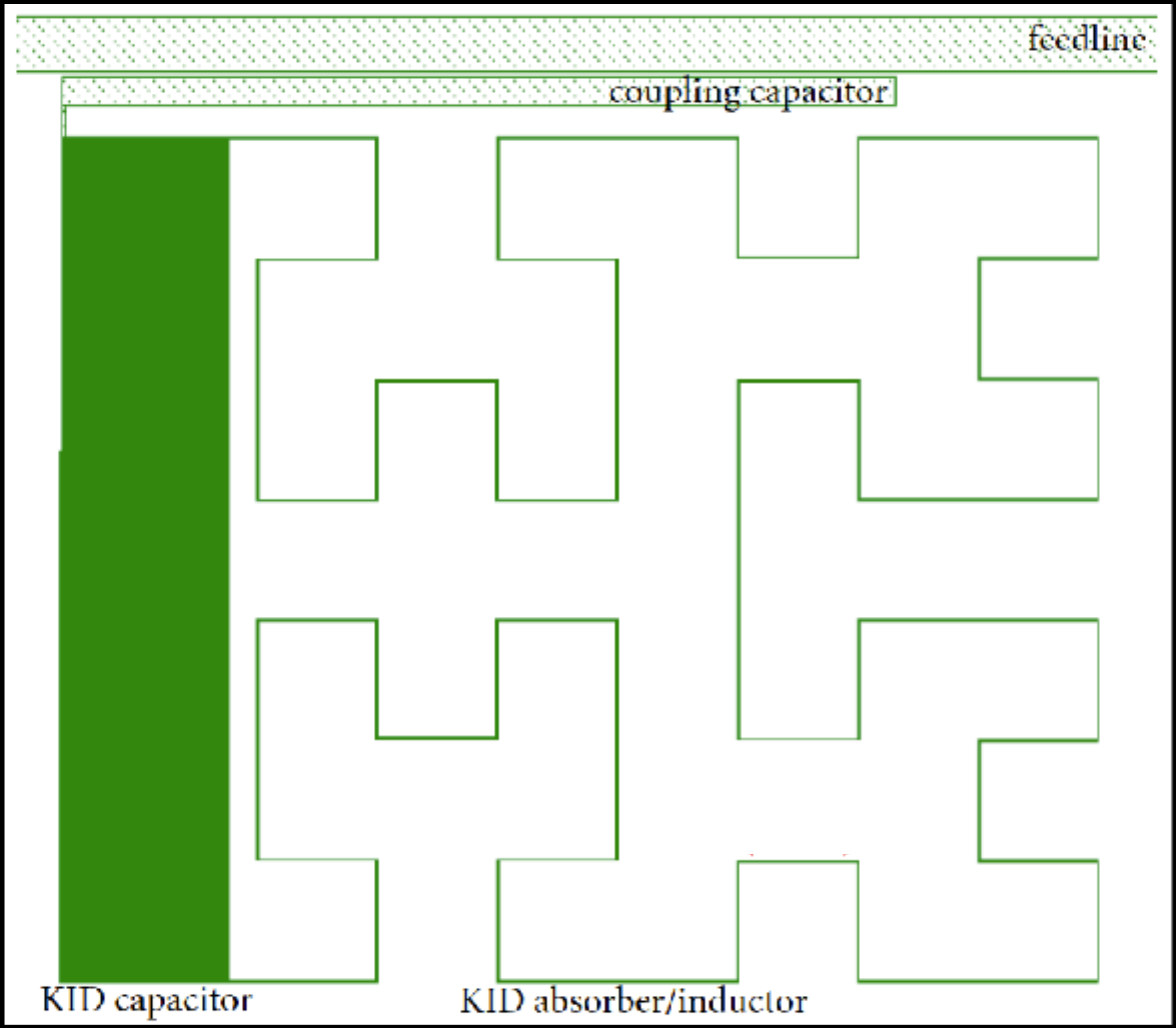


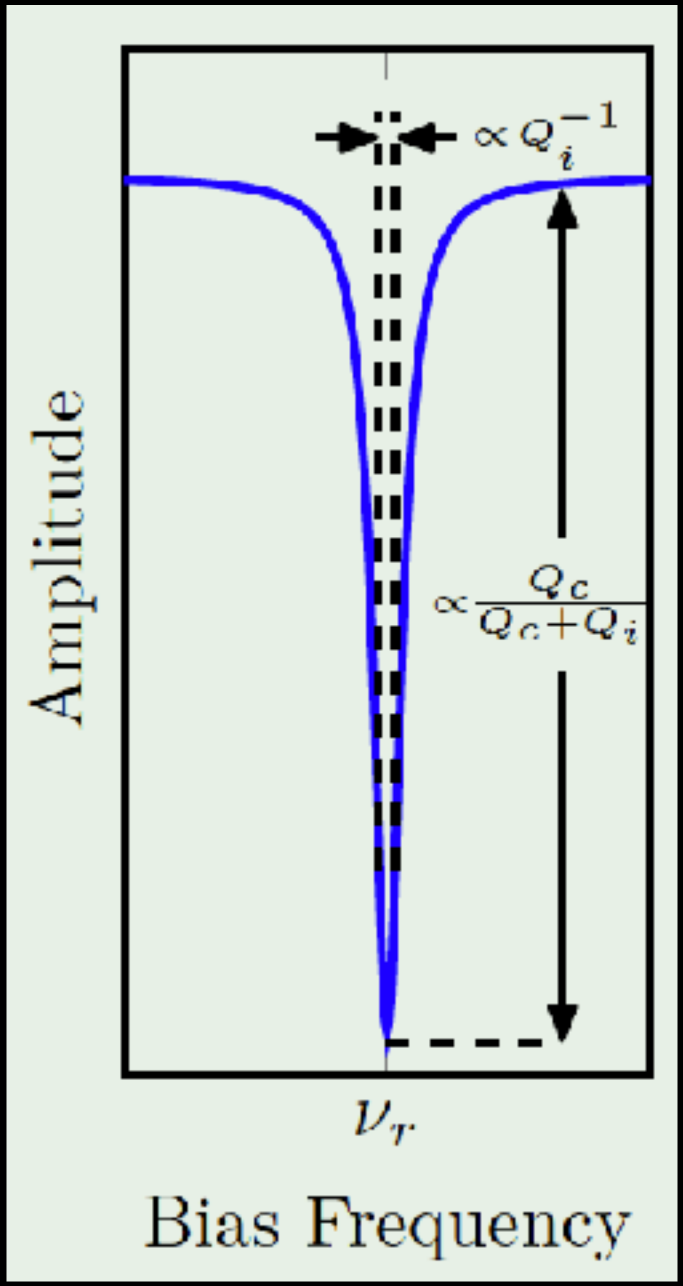
- Multiplexing factor $\propto Q_i > 50000$
- Dynamics $\propto \dfrac{Q_c}{Q_c + Q_i}$ $(Q_c \sim 20000)$
- Responsivity $\propto Q \sim 15000$

Credits: Alessandro Paiella

MISTRAL: DETECTORS

KID DESIGN & ELECTRICAL PARAMETERS





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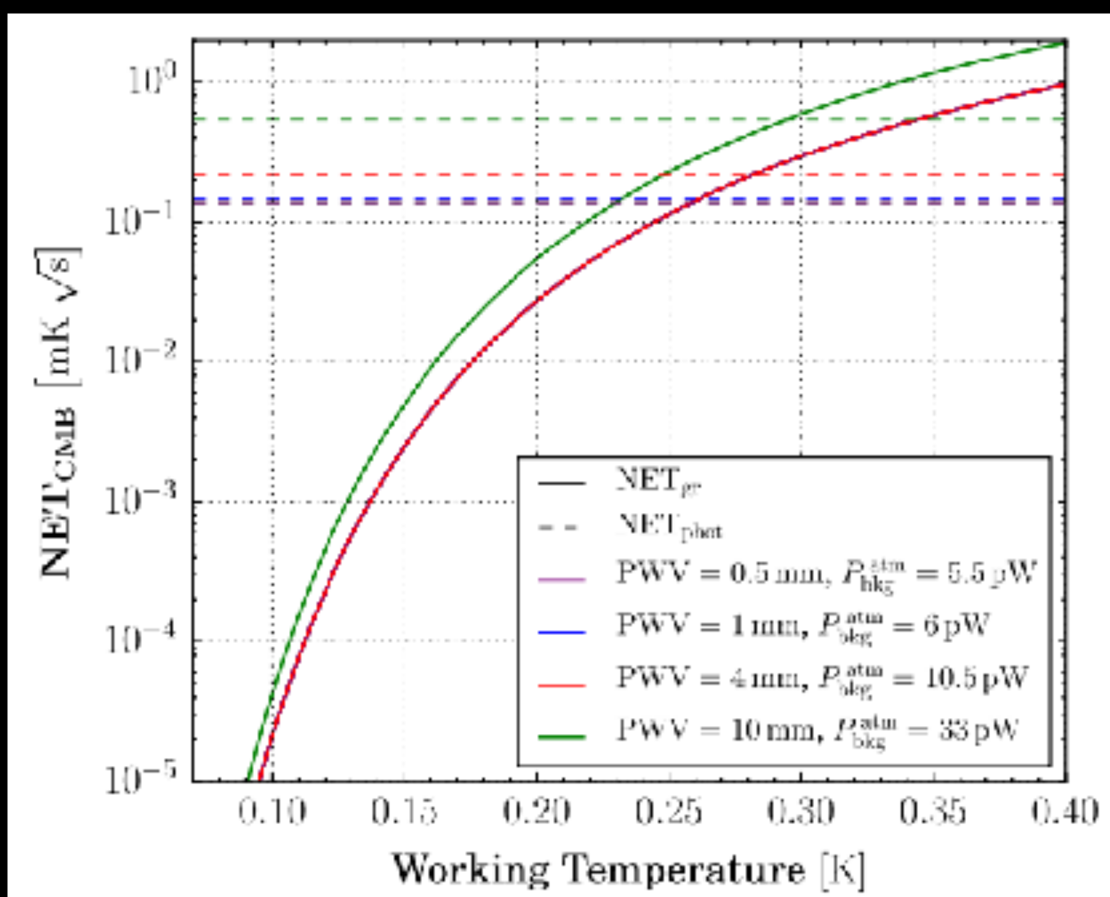
Credits: Alessandro Paiella

MISTRAL: DETECTORS

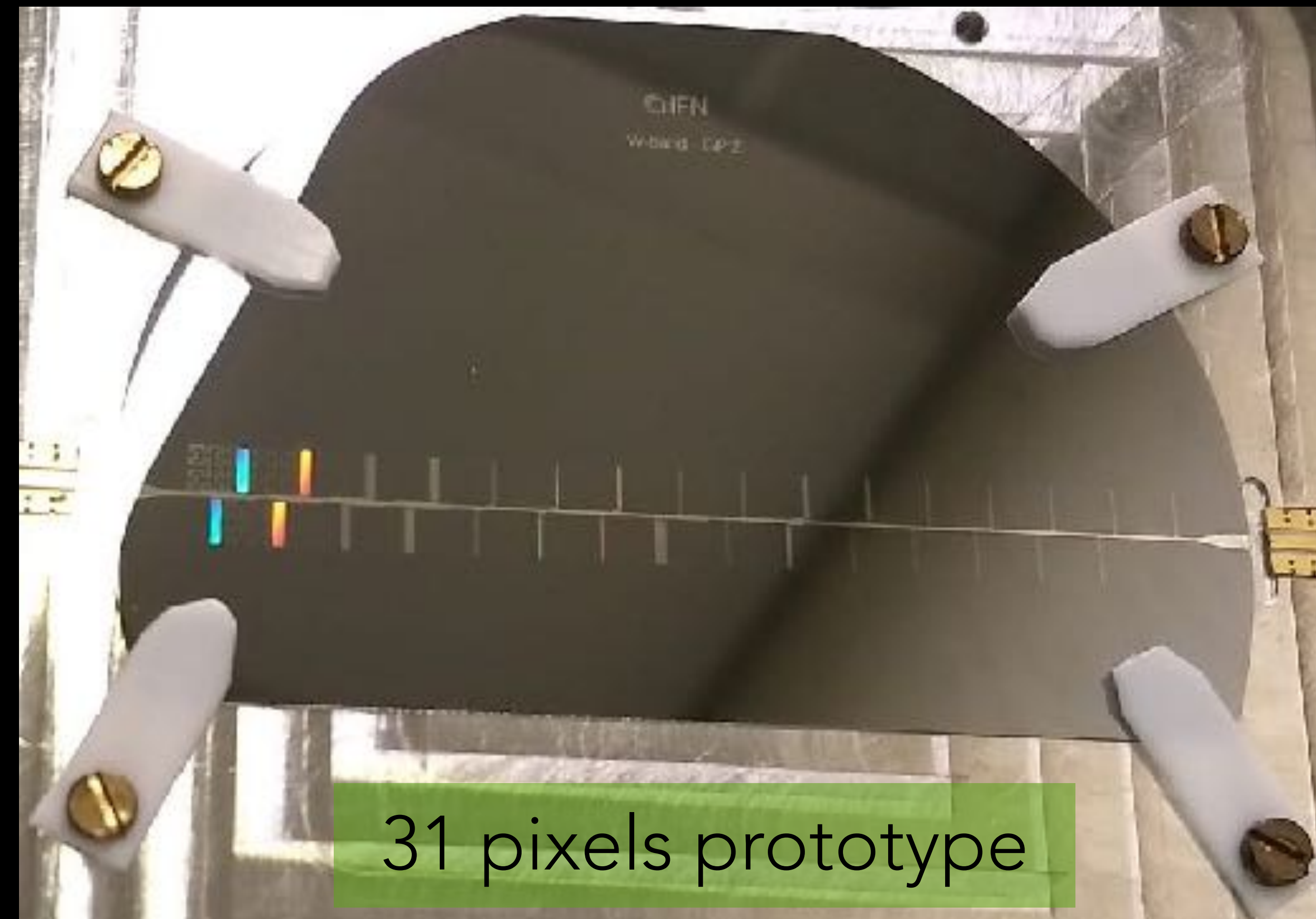
PRELIMINARY TESTS

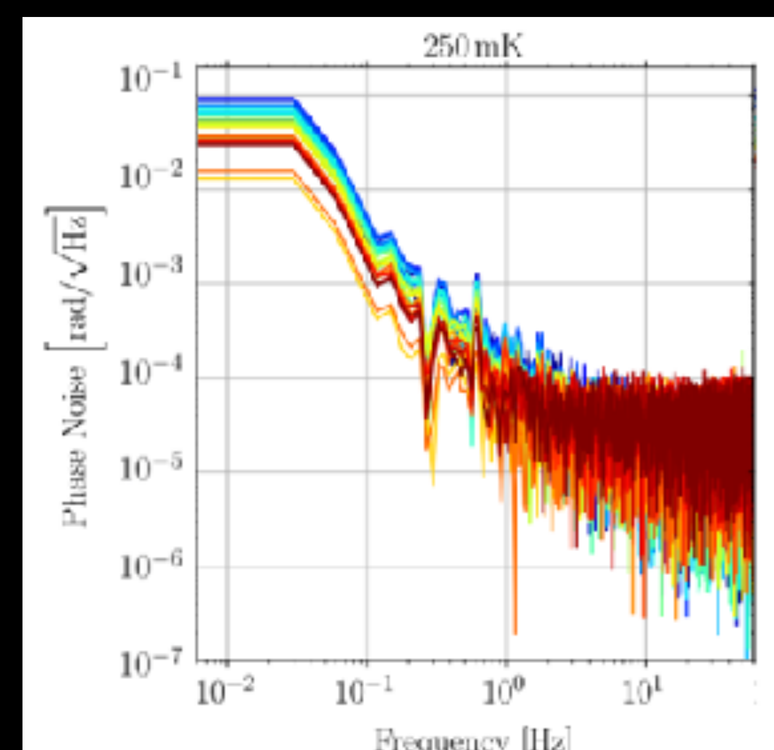
		Operation Temperature		
		150 mK	250 mK	300 mK
$\mathrm{NEP_{dark}}$ $[\mathrm{aW}/\sqrt{\mathrm{Hz}}]$	Avg.	41.5	280	520
	Best	17.0	110	180
	Worst	73.0	500	1060

$$\mathrm{NEP_{ph,bkg}} = 5000\ \mathrm{aW}/\sqrt{\mathrm{Hz}}$$



Coppolecchia et al. Journal of Low Temperature Physics (2020) 199:130–137





Credits: Alessandro Paiella

MISTRAL: DETECTORS

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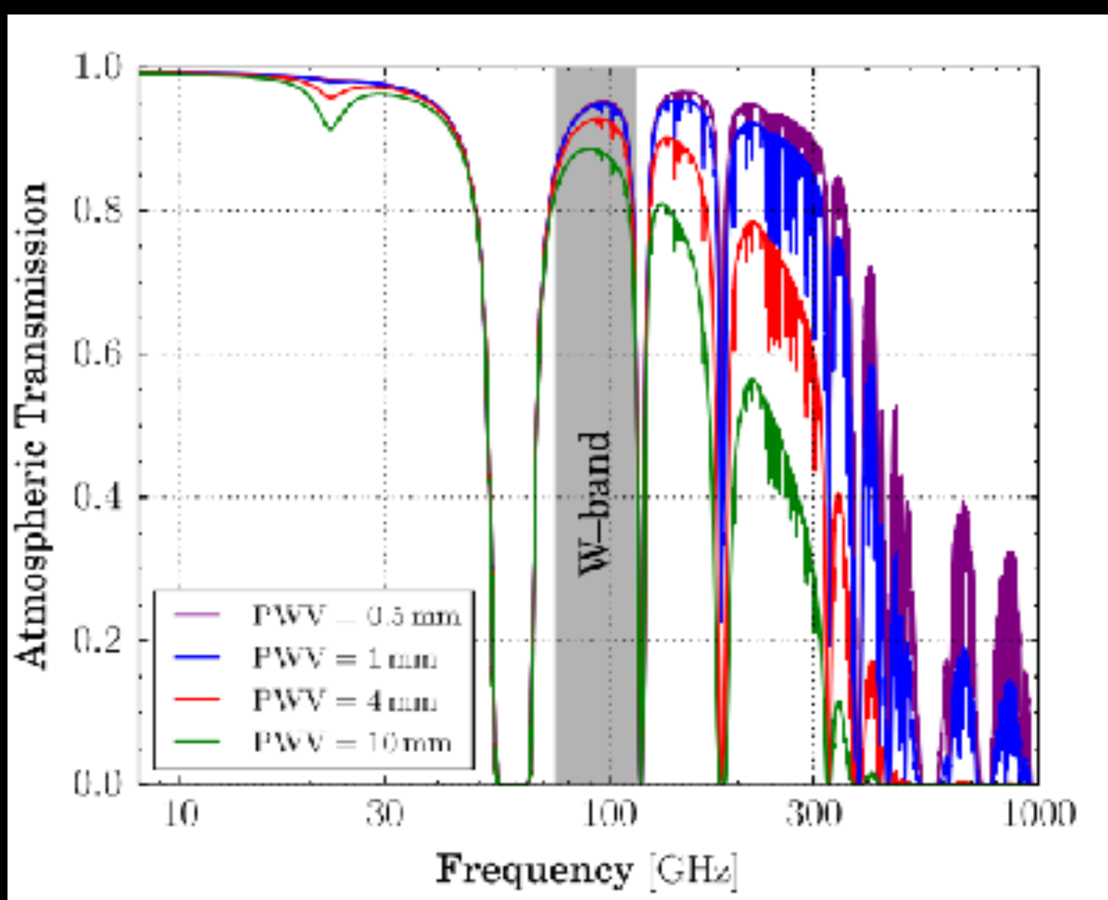
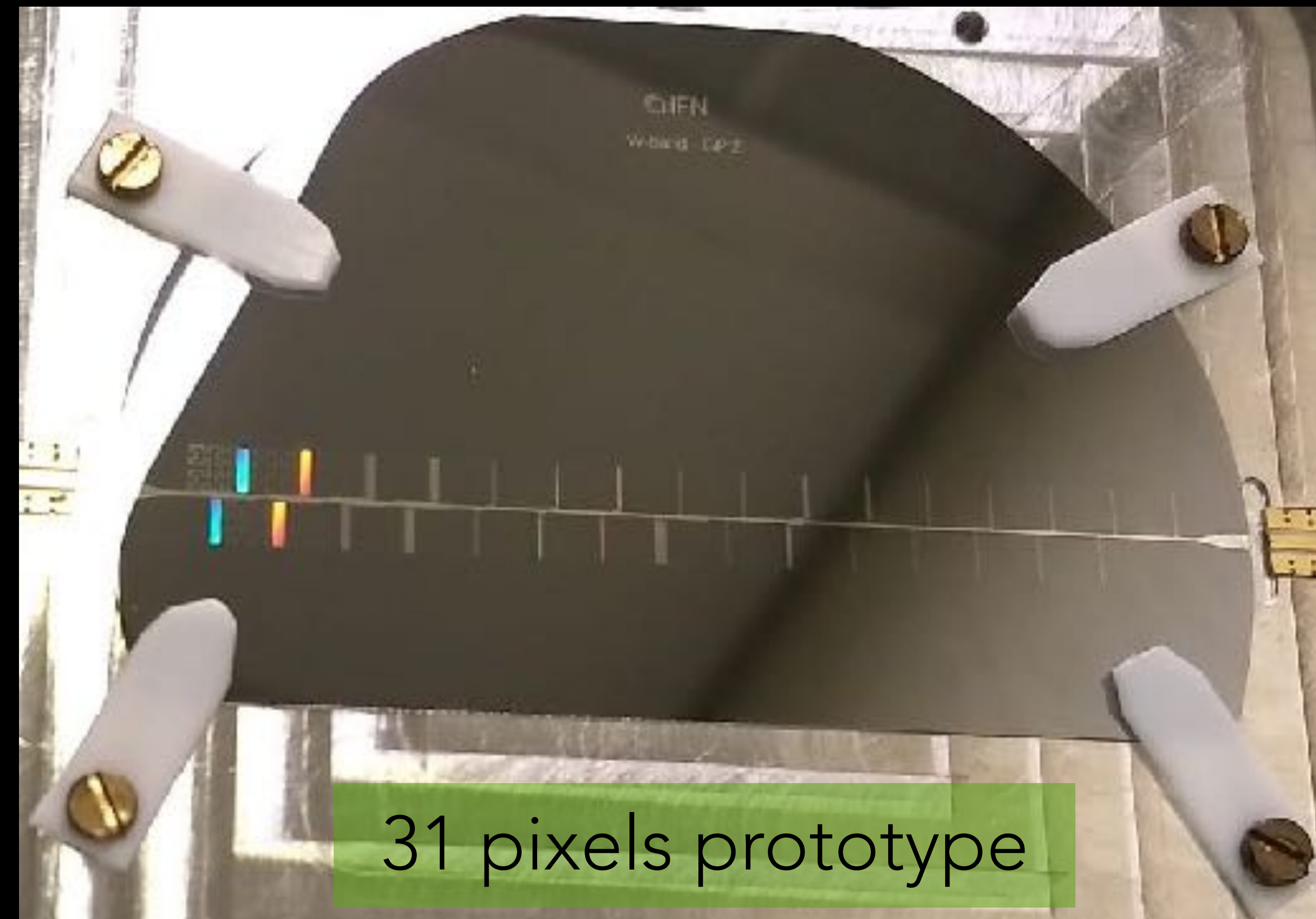
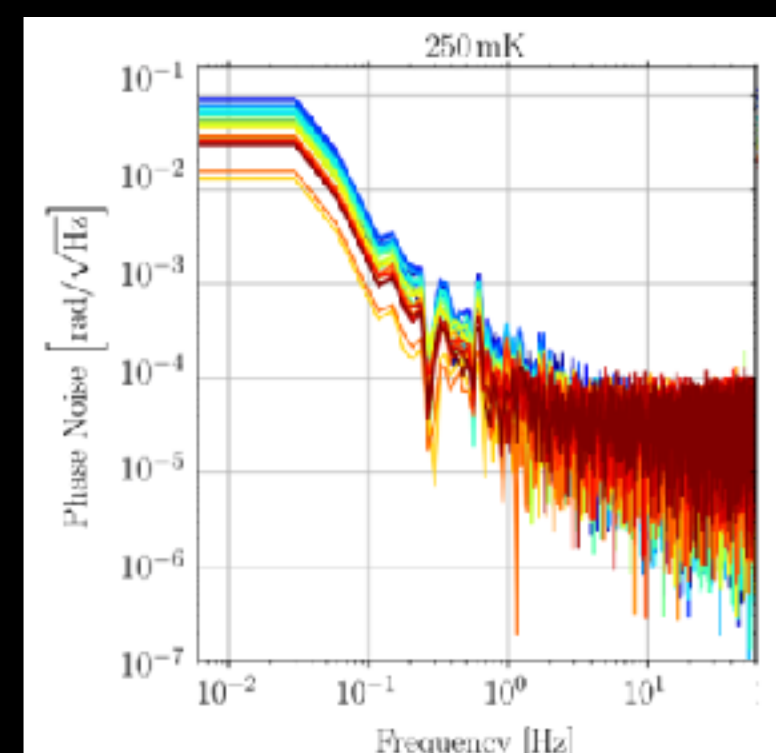


Coppolecchia et al. Journal of Low Temperature Physics (2020) 199:130–137

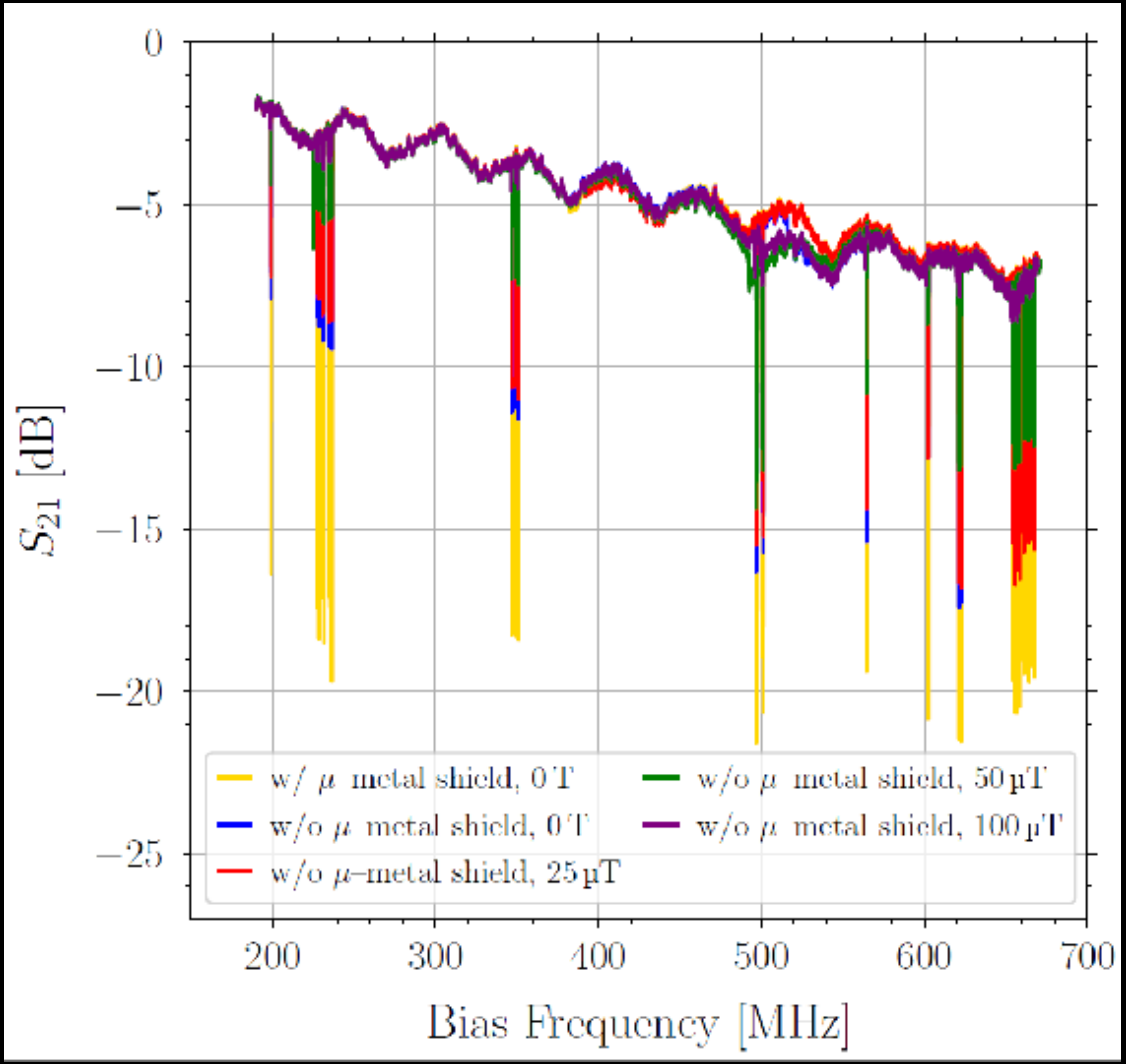




Credits: Alessandro Paiella

MISTRAL: DETECTORS

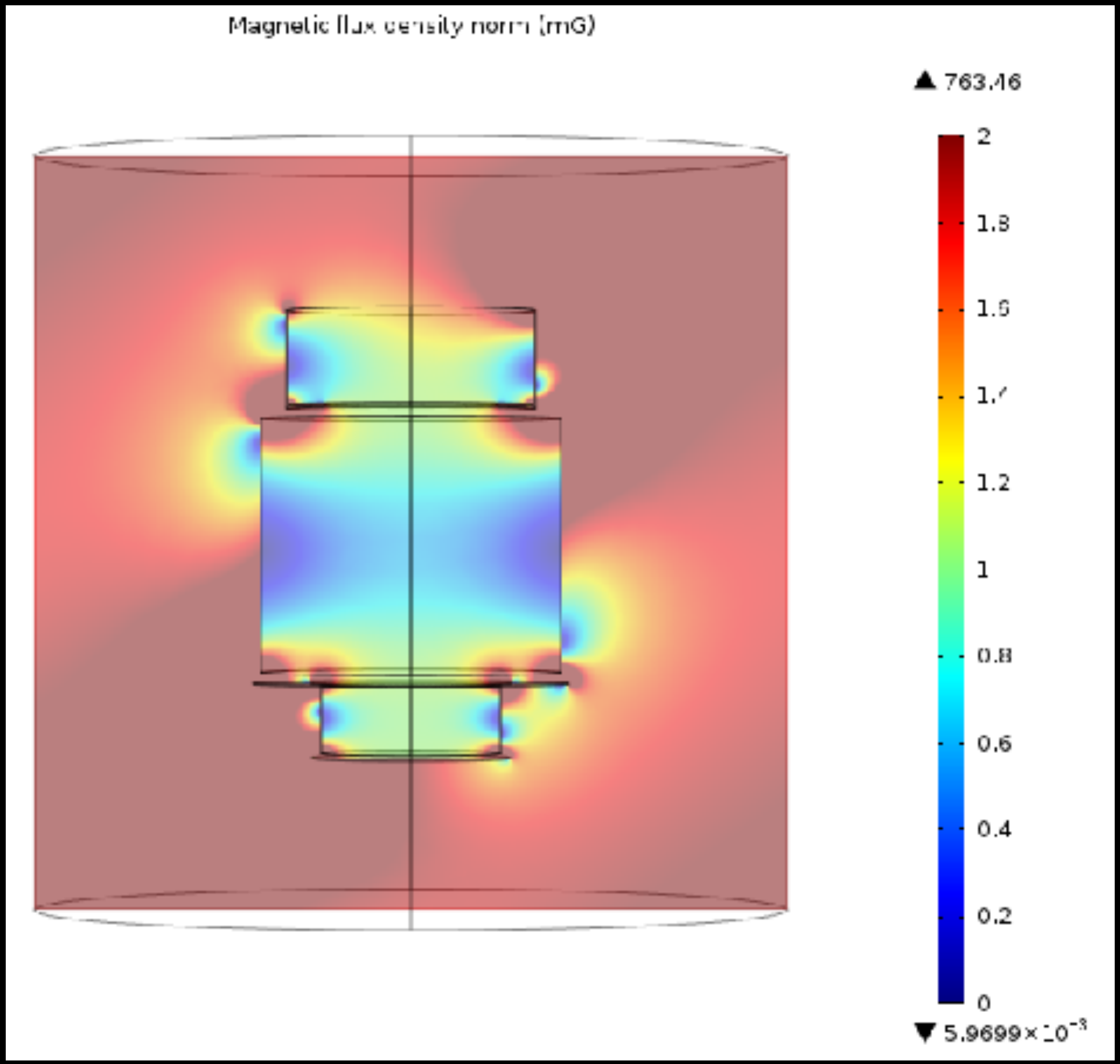
KID MAGNETIC FIELD SENSITIVITY



Credits: Alessandro Paiella

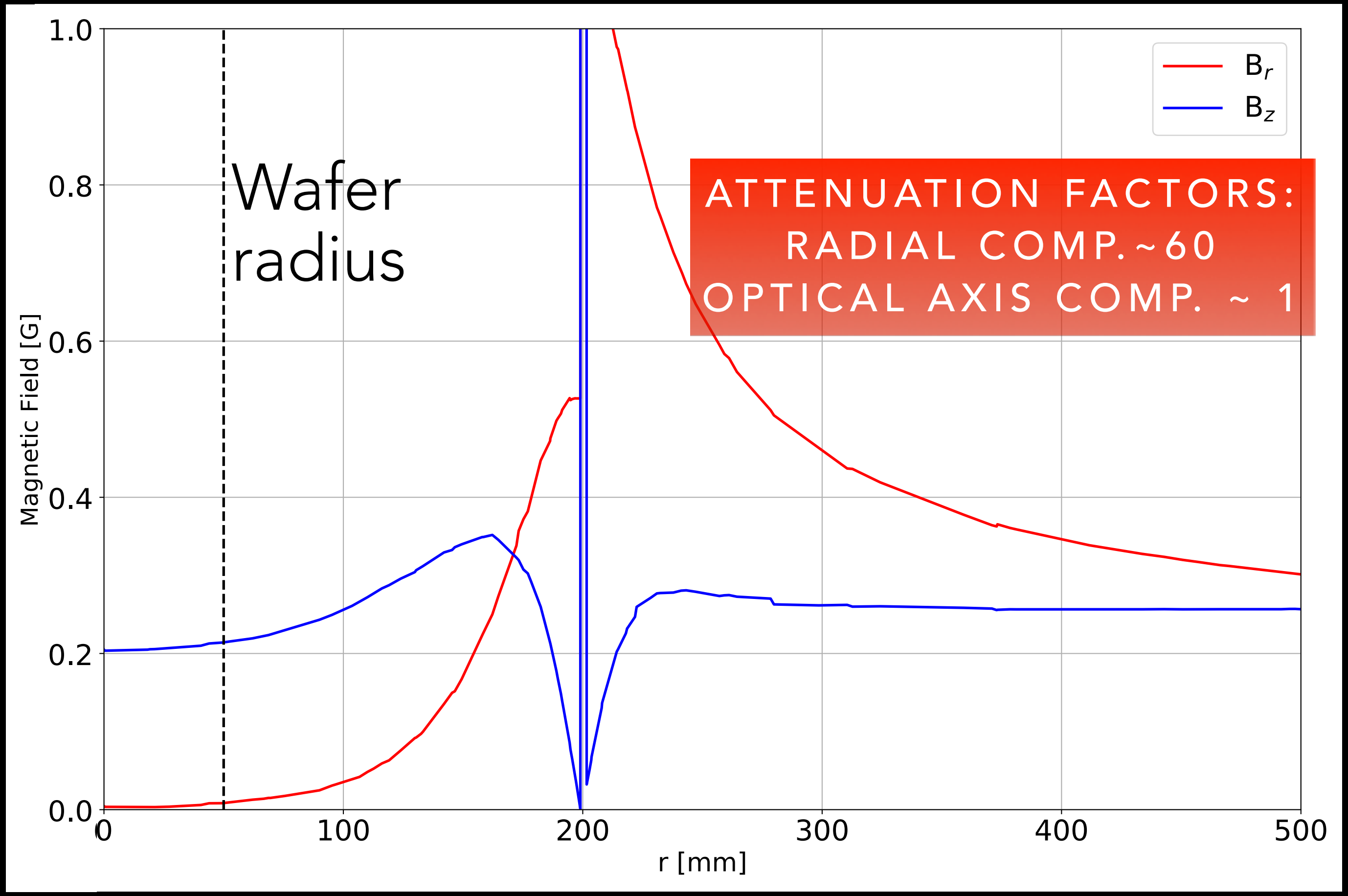
MISTRAL: MAGNETIC SHIELD

The simulations were performed with the strongest component of the geomagnetic field aligned with the cryostat optical axis.



Assumptions:

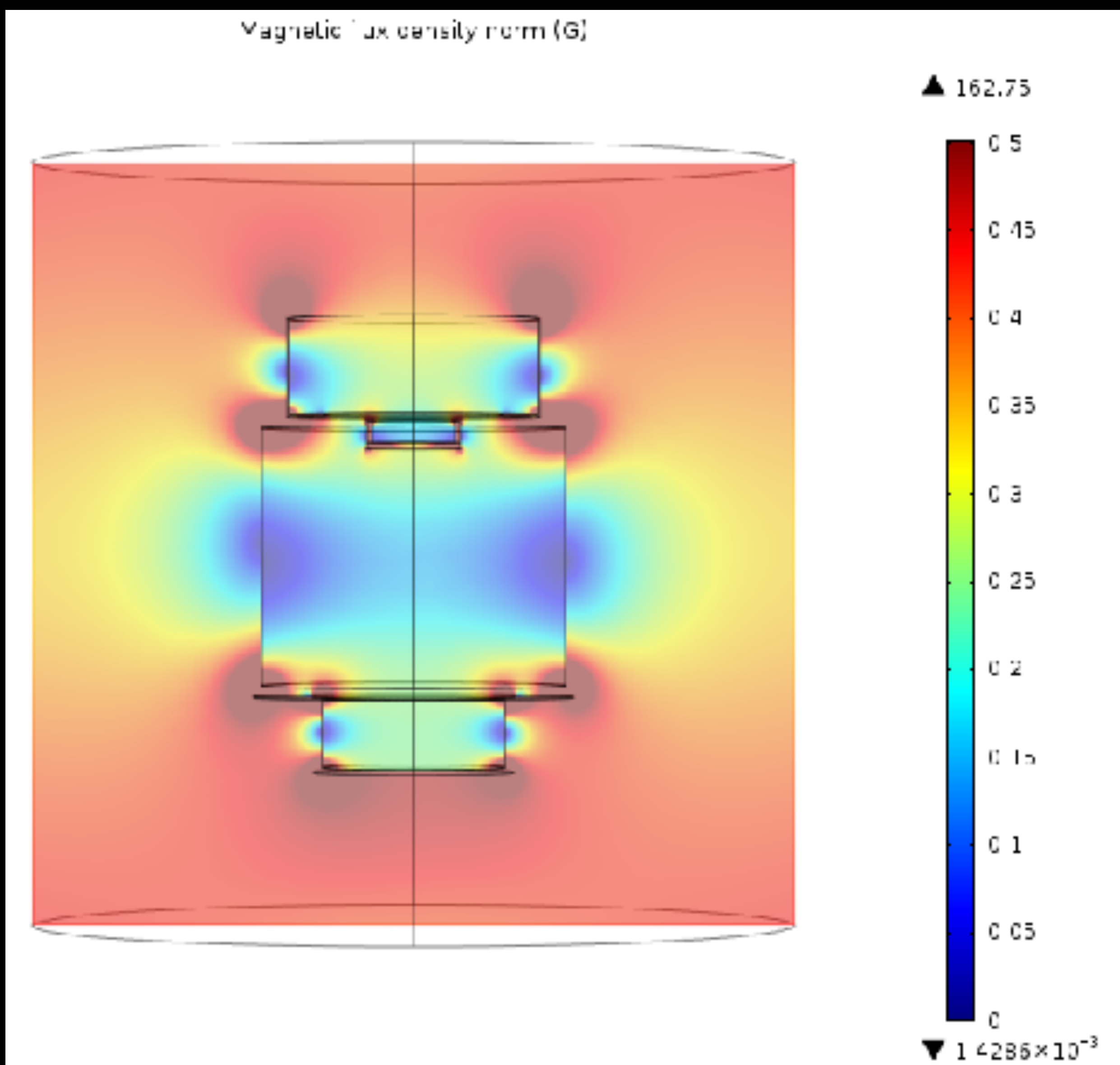
- $\mu_r = 70000$
- **no aluminum holder around the detector**
- no magnetic tape around the gaps



Credits: Fabio Columbro

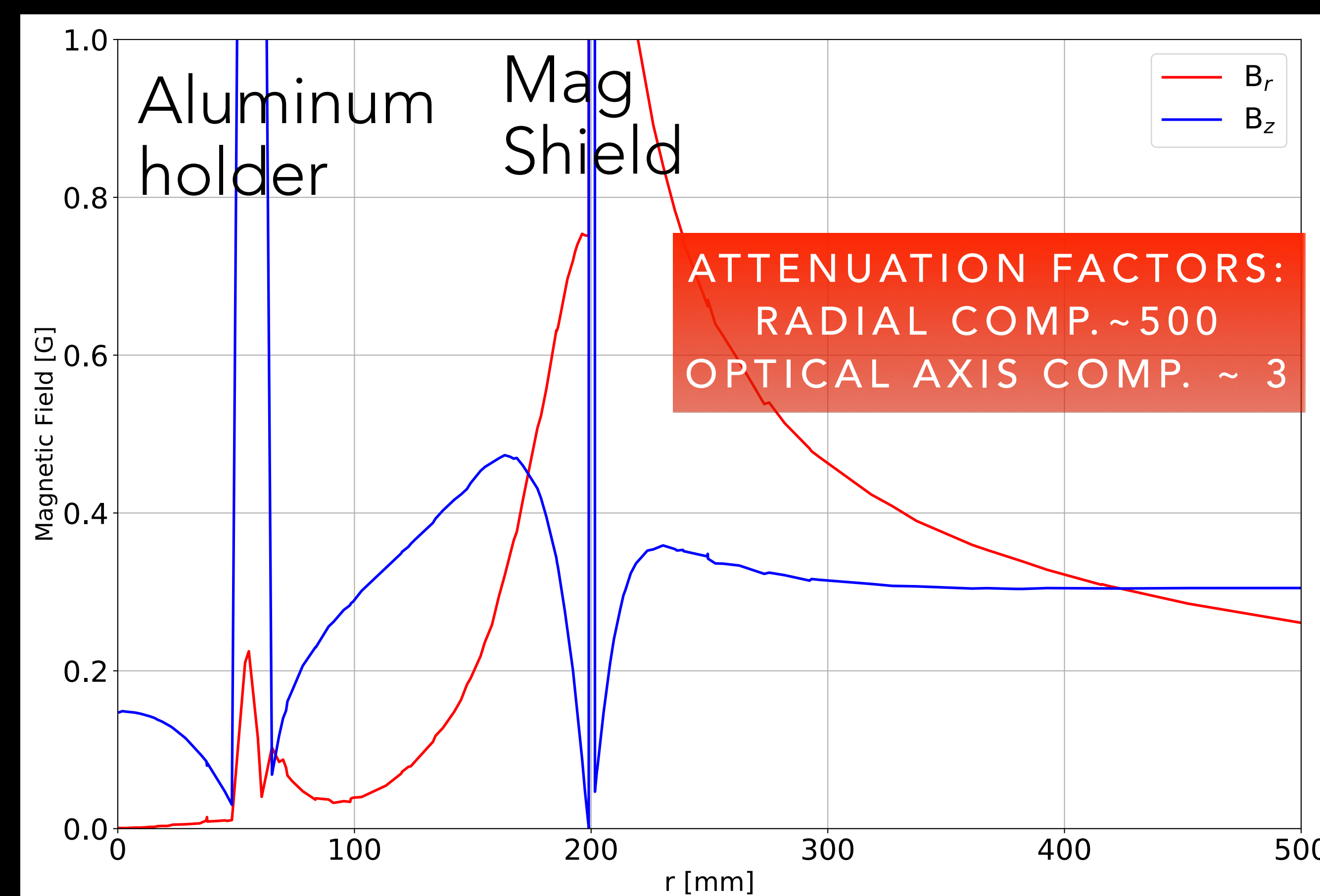
MISTRAL: MAGNETIC SHIELD

The simulations were performed with the strongest component of the geomagnetic field aligned with the cryostat optical axis.



Assumptions:

- $\mu_r = 70000$
- no magnetic tape around the gaps



Credits: Fabio Columbro