



# IRAM 30m Front-ends

Present and future



## Current instrument configuration at 30m



There are two heterodyne receivers and one continuum camera installed at the 30m, in the RX cabin (Nasmyth focus – cabin remains static).

### EMIR

Multicolor RX

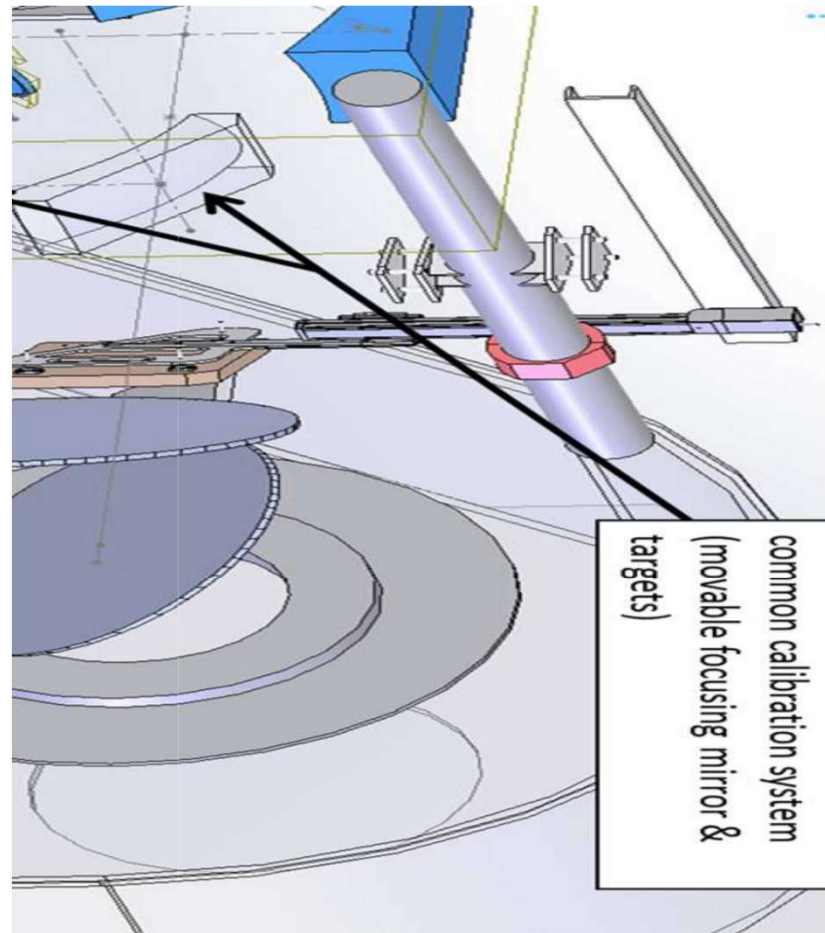
HERA

Multipixel RX

### NIKA2

Continuum camera

Cabin optics is mostly flat mirrors, with M3 corotating with Elevation of the telescope.



Common 30  
-1  
-2  
-1  
?



# EMIR: the Eight Mixer Receiver

Four color single pixel dual pol 2SB RX.

EMIR band	Alias	Sky Frequency GHz	Trx K	mixer type	Pol	IF width GHz	Image Rej. dB	Combinations			Trx K	LO type	Remarks
								E0/2	E1/3	E0/1			
E0 / E090	Band 1	<b>73-117</b>	50	2SB	H/V	8	>10	X		X	65	GUNN + PLL	
		LSB: 73-97 (102)											
		USB: 89-117											
E1 / E150	Band 2	<b>125-184</b>	50	2SB	H/V	8	>10		X	X	65	GUNN + PLL	
		LSB: 125-168											
		USB: 141-184											
E2 E230	Band 3	<b>202-274</b>	80	2SB	H/V	8	>10	X			95	GUNN + PLL	
		LSB: 202 (LO) - 263.5 (LI)											
		USB: 217 (UI) - 274 (UO)											
E3 / E330	Band 4	<b>277-350 (375)</b>	80	2SB	H/V	8	>10		X		95	YIG + PLL	ALMA Band 7 mixer
		LSB: 277-335											
		USB: 293-350 (375)											

Full details: <https://publicwiki.iram.es/EmirforAstronomers>

- EMIR is an IRAM workhorse.
- In continuous service since 2011\* (with upgrades)
- There are plans for upgrades on EMIR key electronics, control computer and optics.

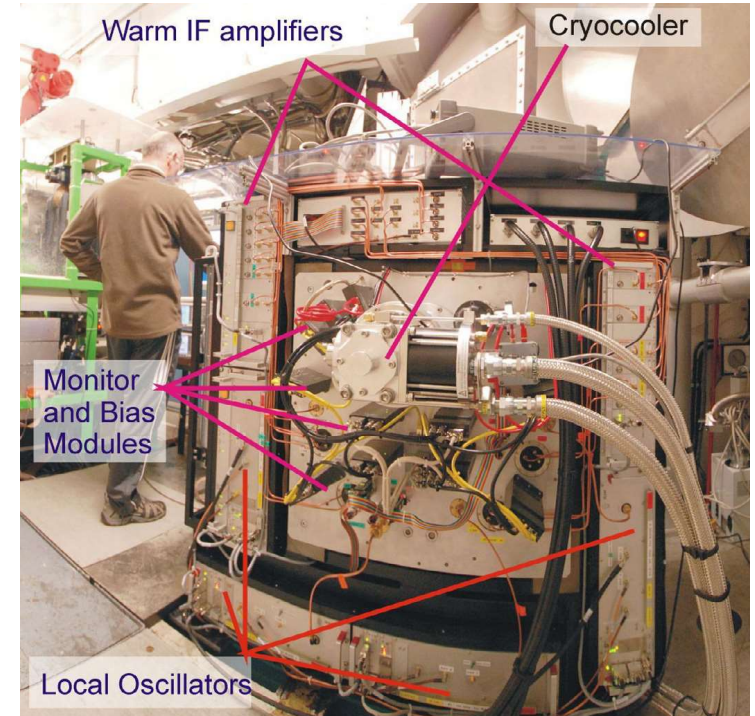
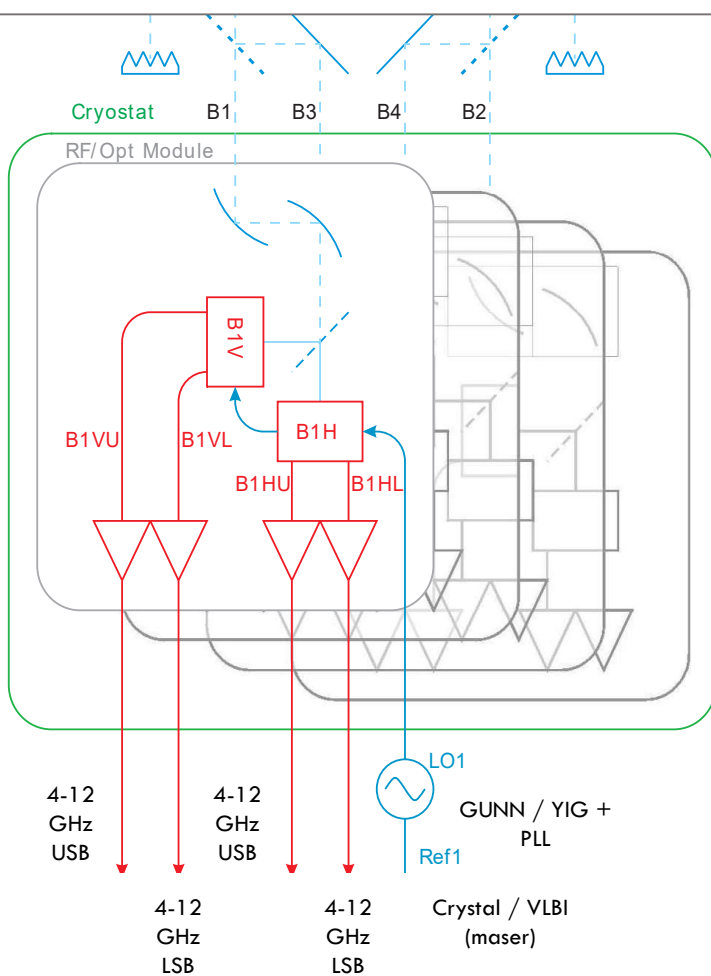


# EMIR: the Eight Mixer Receiver

Four color single pixel dual pol 2SB RX.

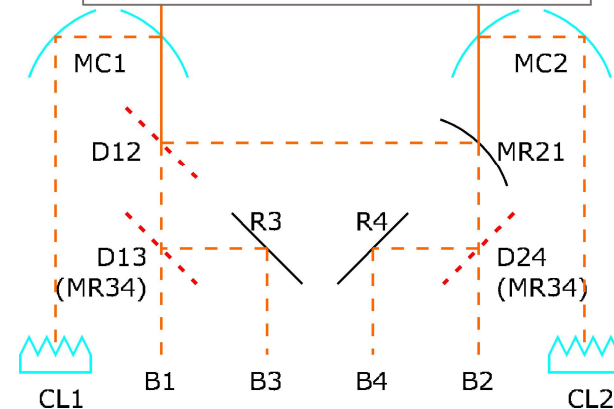
Sky(A)                      Sky(B)

Of the total 16 x (4-12 GHz) IF (or 32 x 4GHz BW IF) only 8 x 4 GHz BW are carried out down to backends (cables ~ 100m)



Sky(A)                      Sky(B)

Two optical "paths"

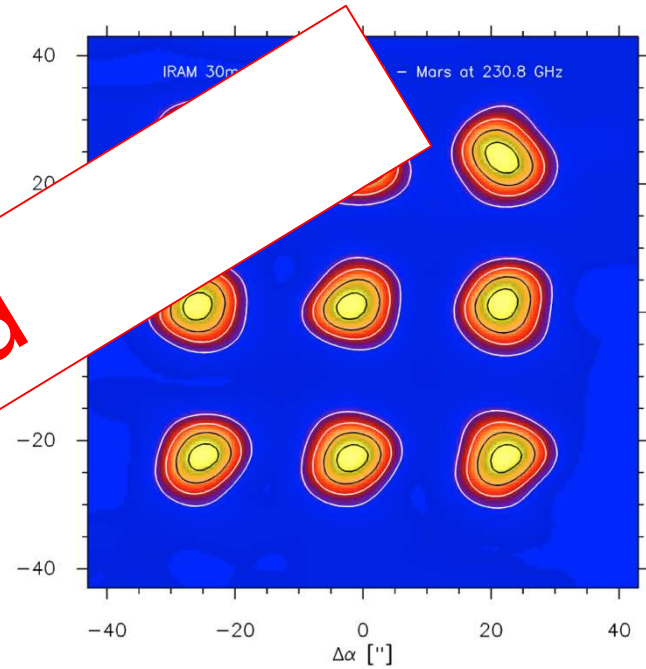
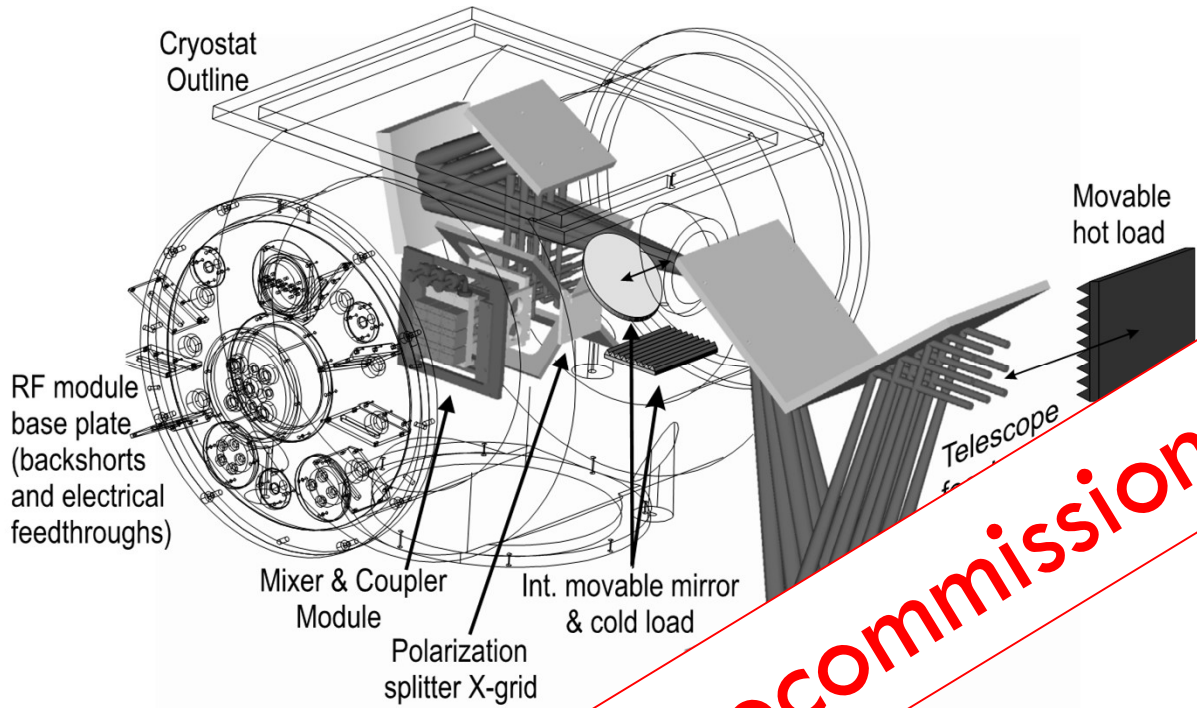


Optical combinations  
(table previous page)

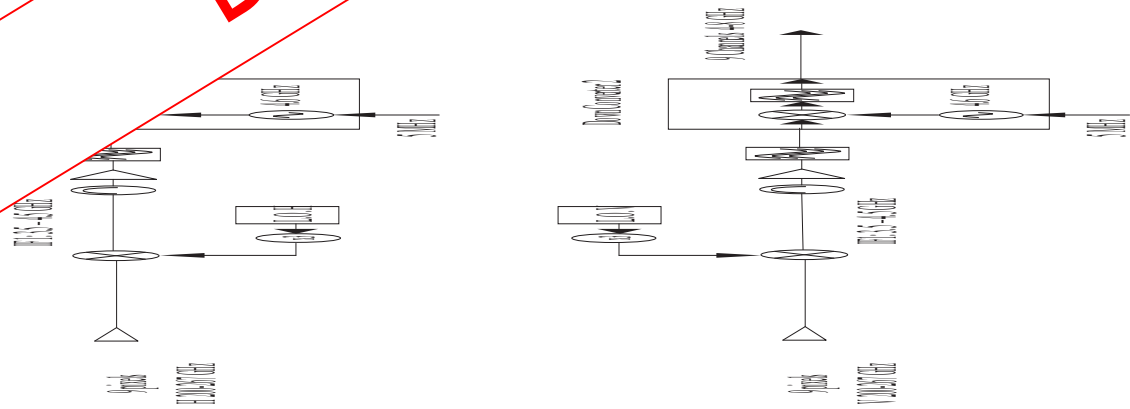


# HERA: Heterodyne Receiver Array

9-pixel dual pol heterodyne RX at 230 GHz

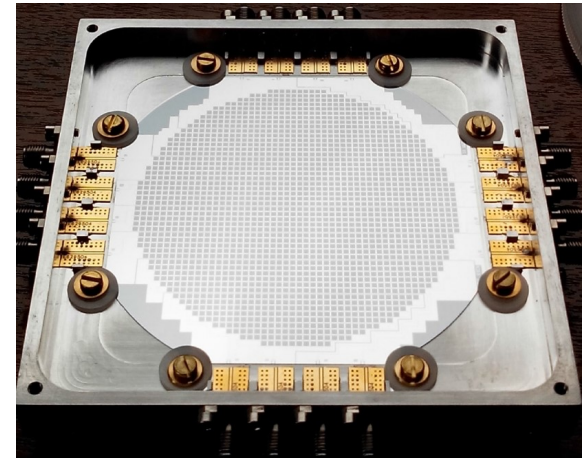
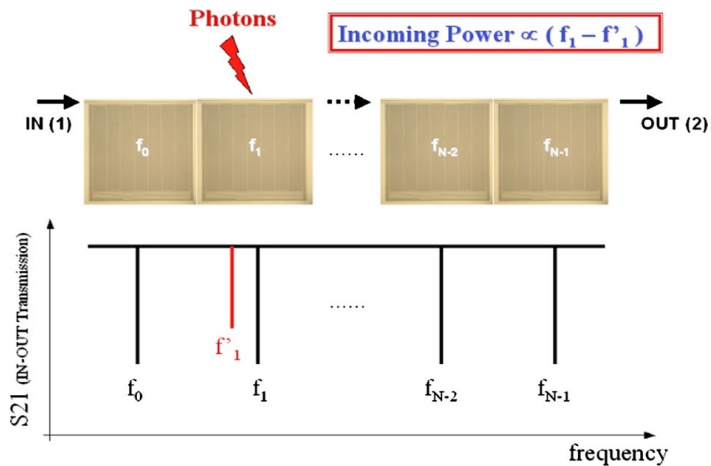


**Decommissioned**

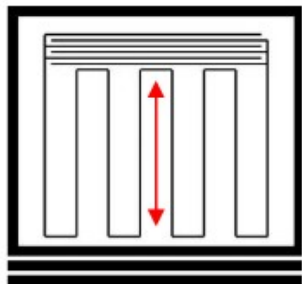


# NIKA2: New IRAM KID Arrays 2

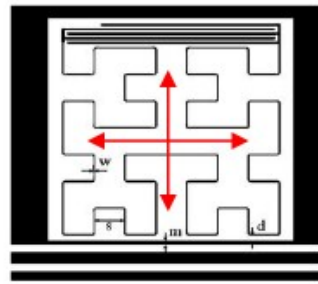
Multicolor Kinetic Inductance Detector based camera



1020 pixel array of NIKA2



Standard LEKID



Hilbert LEKID

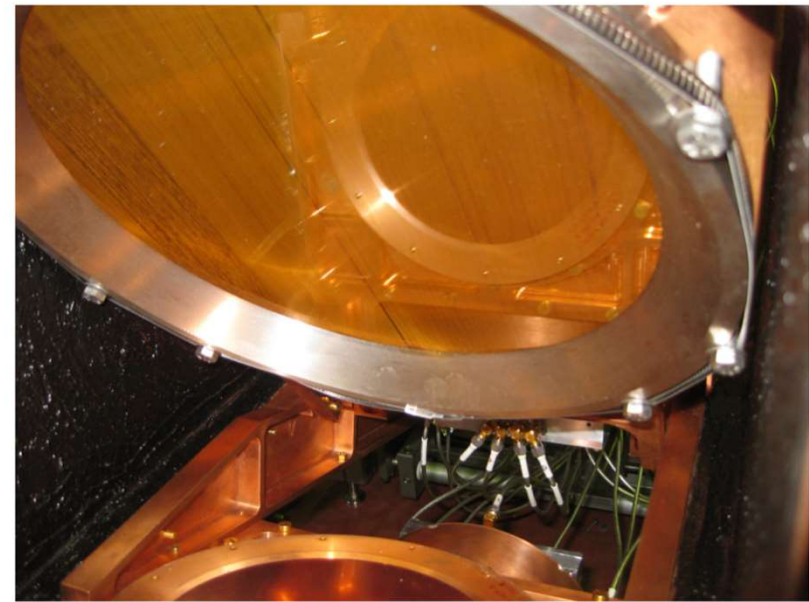
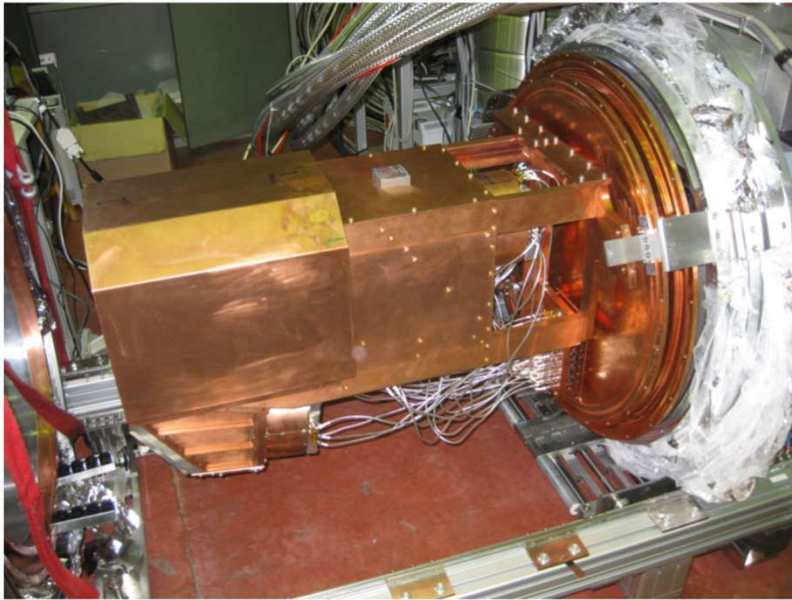
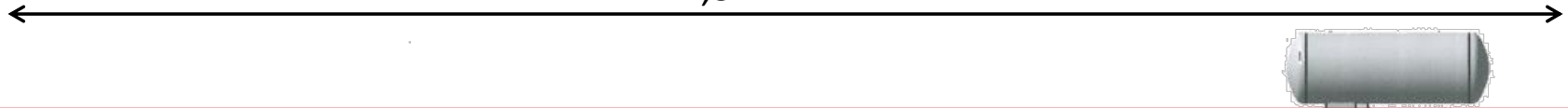
- KID: Resonant (R)LC networks
- NIKA2 is another workhorse, in operations since 2017
- Many upgrades have been implemented since → a good example of constant improvement of a system (next one for Feb-March 2024)



# NIKA2: New IRAM KID Arrays 2

Multicolor Kinetic Inductance Detector based camera

~ 2,3 m



Wire grid polarizer for 1.15 mm band at 150mK

GHz  
Pol /  
px

2 PT + He3/He4 dilution cooler

260 GHz / H-Pol /  
1140px

## What comes next?



The MRT (30m telescope) is a real pioneer of the radioastronomy

We have been discussing for a long time about making a major upgrade in the instrumentation.

In fact our telescope is being upgraded (more on M. Castillo and S. Sanchez presentations)

We envision long term plans for the whole observatory, on a coordinated effort:

IRAM30-30, IRAM30-40? (still to be discussed)





## Future Multibeam: a very brief summary

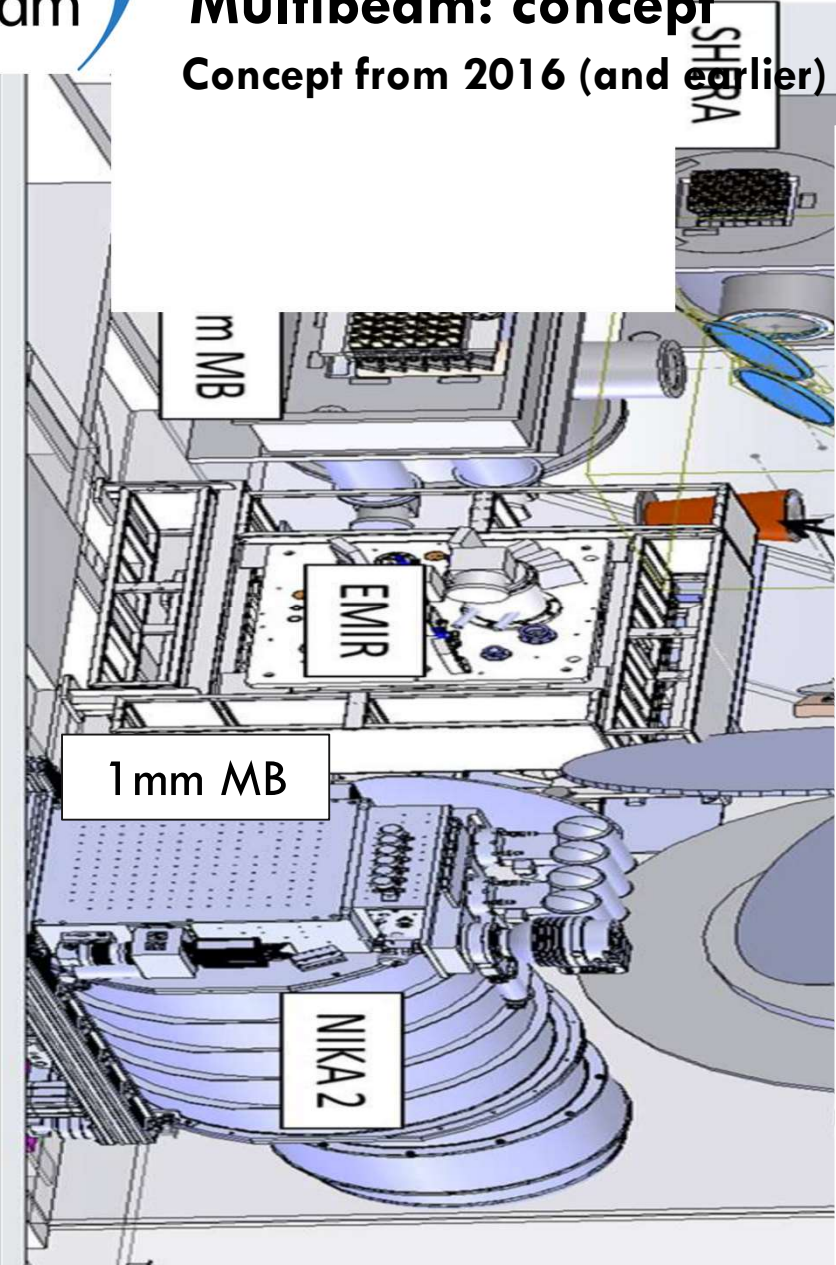
**High stability dual color dual pol 2SB extended IF coaligned multibeam with pixel derotation and high spectroscopic resolution...**

- Long standing ambition / project ( $> 12$  years)
- In the meantime, key required technology is being explored and developed, and "proofs of concepts" have been built.
- Resources have been focused on NOEMA instrumentation  $\rightarrow$  direct synergy



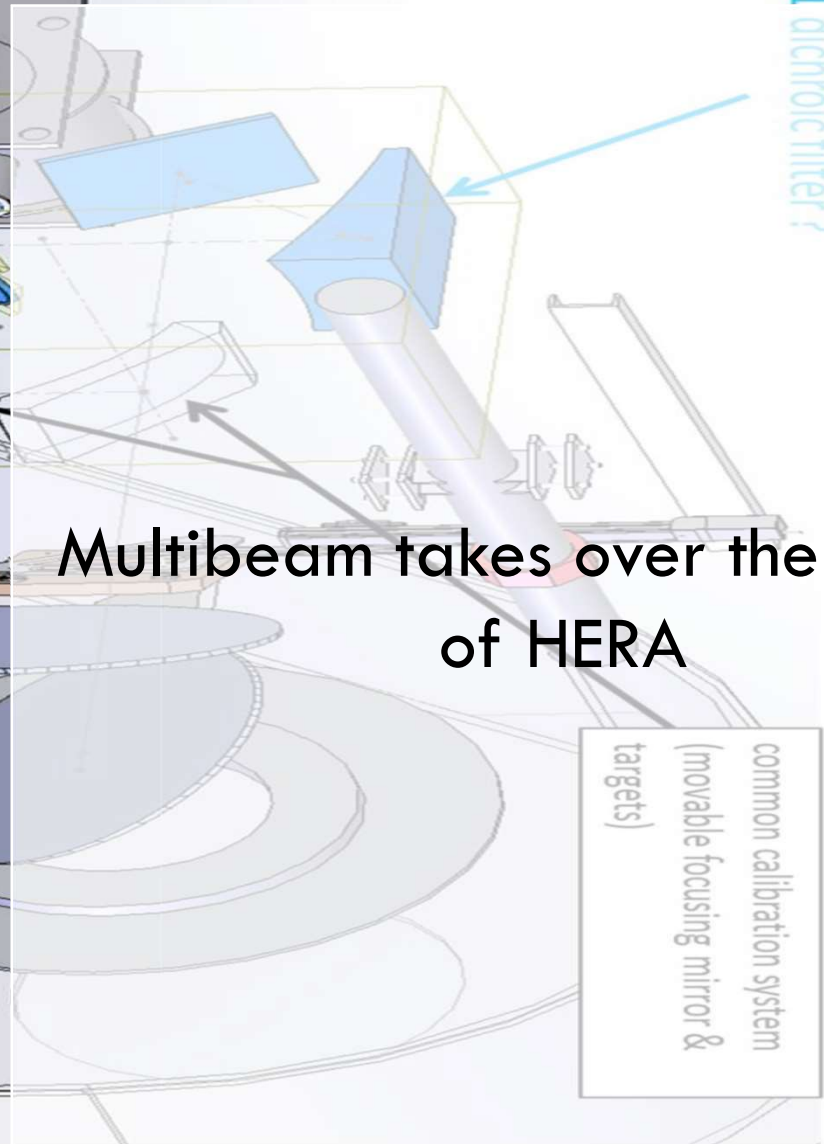
# Multibeam: concept

Concept from 2016 (and earlier)



Common 300K optics:

- 1 focusing mirror
- 2 flat mirrors
- 1 dichroic filter?



Multibeam takes over the position of HERA

common calibration system  
(movable focusing mirror & targets)



## Multibeam: Design key concepts to account for

### Modular

- 2 cryostats with common warm optics. Central pixels coaligned : LFA & HFA.
- Common Hot / Cold loads (cold load @77K with Stirling cooler)
- Modular Bias and control electronics
- Modular mounting of mixers / HEMTs (blocks)
- (Warm) Optics as an assembly group with references.
- IF modules and backends (FFTs) in the telescope (even in the cabin)

### De-rotation of pixels

- K-mirror close to Focal Plane and limited travel < 180 Deg phys.
- Compact / Removable / horizontal mounting
- **SW de-rotation?**

### Easily maintainable

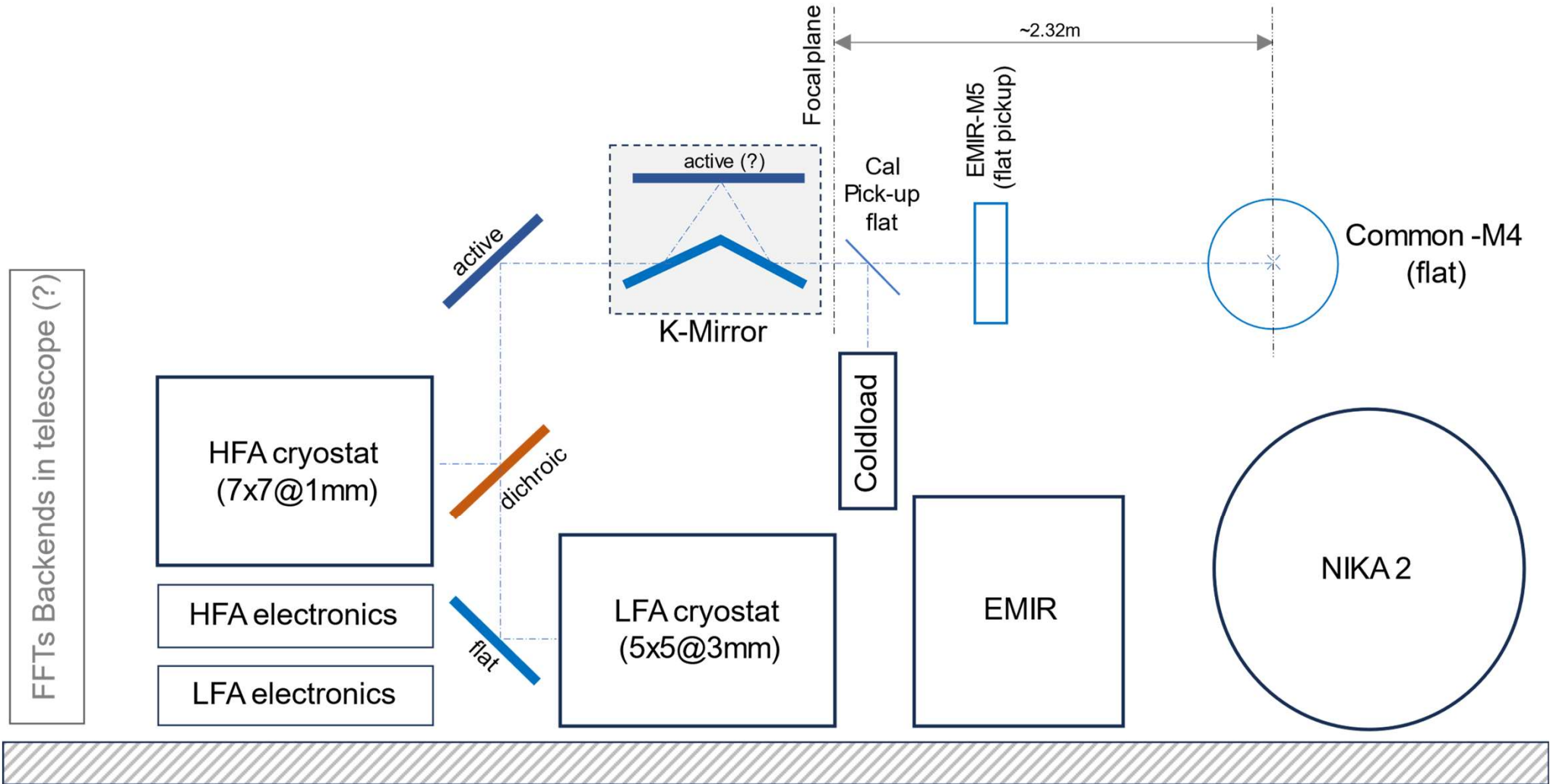
- Cryostats bolted to the floor on rails → optics and alignment
- Coldheads mounted vertically → removable with the crane
- Electronics mounted in subracks → replacement and upgrades

### Flexible

- Being modular, means easier upgrades of electronics and control computer



# Multibeam: updated concept



**Based on the 2016 concept, a de-rotator can be included**



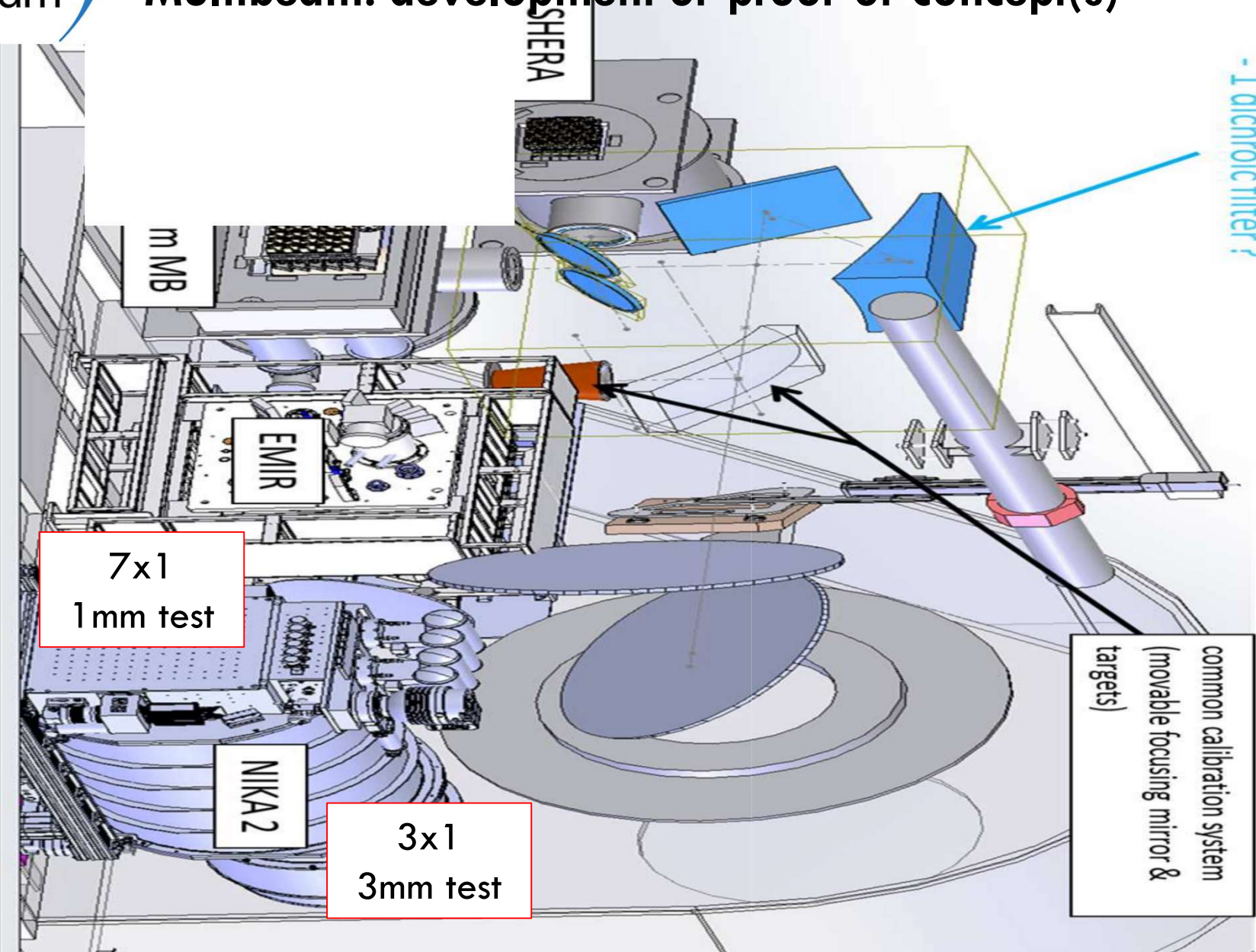
## Multibeam: some design challenges

- Dual Pol + 2SB + Extended IF (>4-12)
- Development of HEMTs (?) and SIS (demonstrators experience)
- Development of OMTs
- LO power and distribution
  - Solid state chains with enough power + distribution modules
- Base synthesizers with YIG filters
- Heat dissipation (cryogenics)
  - Cryostat, cooling machine
  - windows / filters
- IF signals and sub-bands
- Type and amount of Backends to cover all sub-bands (FFTs?)
- Different operational modes : **LFA, HFA, LFA + HFA, LFAc + HFAC**
- FE control system
- Cabling and routing ( $\rightarrow 32\text{GHz} / \text{pixel}$  or  $8 \times 4\text{GHz BW} / \text{Pixel}$  )
  
- Coordination of different teams: IRAM-ES, IRAM-FR, Partners, External
- Short time scale  $\rightarrow$  **target 3 years.**

# Multibeam: development of proof of concept(s)

Common 300K optics:

- 1 focusing mirror
- 2 flat mirrors
- 1 dichroic filter?



common calibration system  
(movable focusing mirror &  
targets)

7x1  
1mm test

3x1  
3mm test

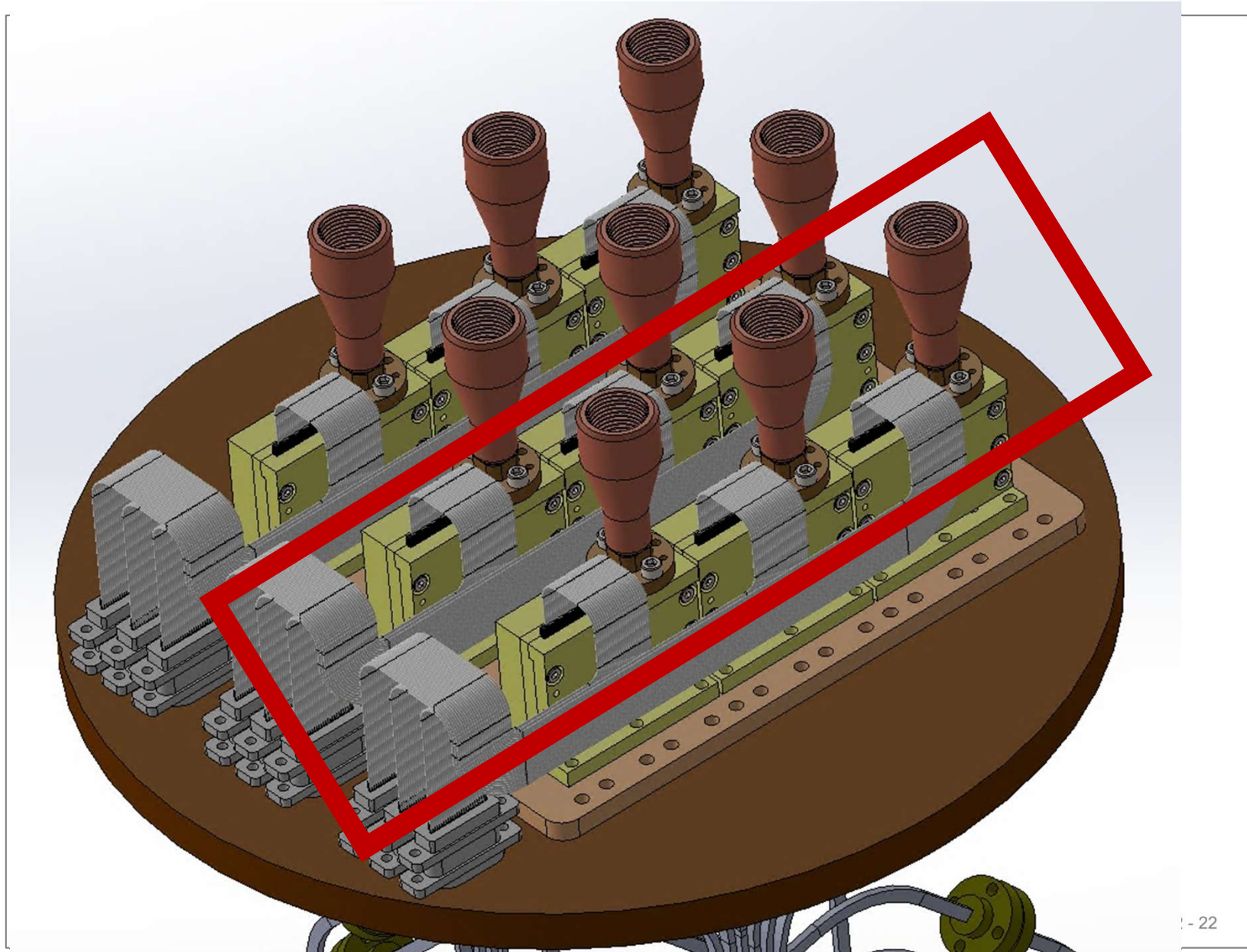
NIKA2

EMIR

m MB

SHERA

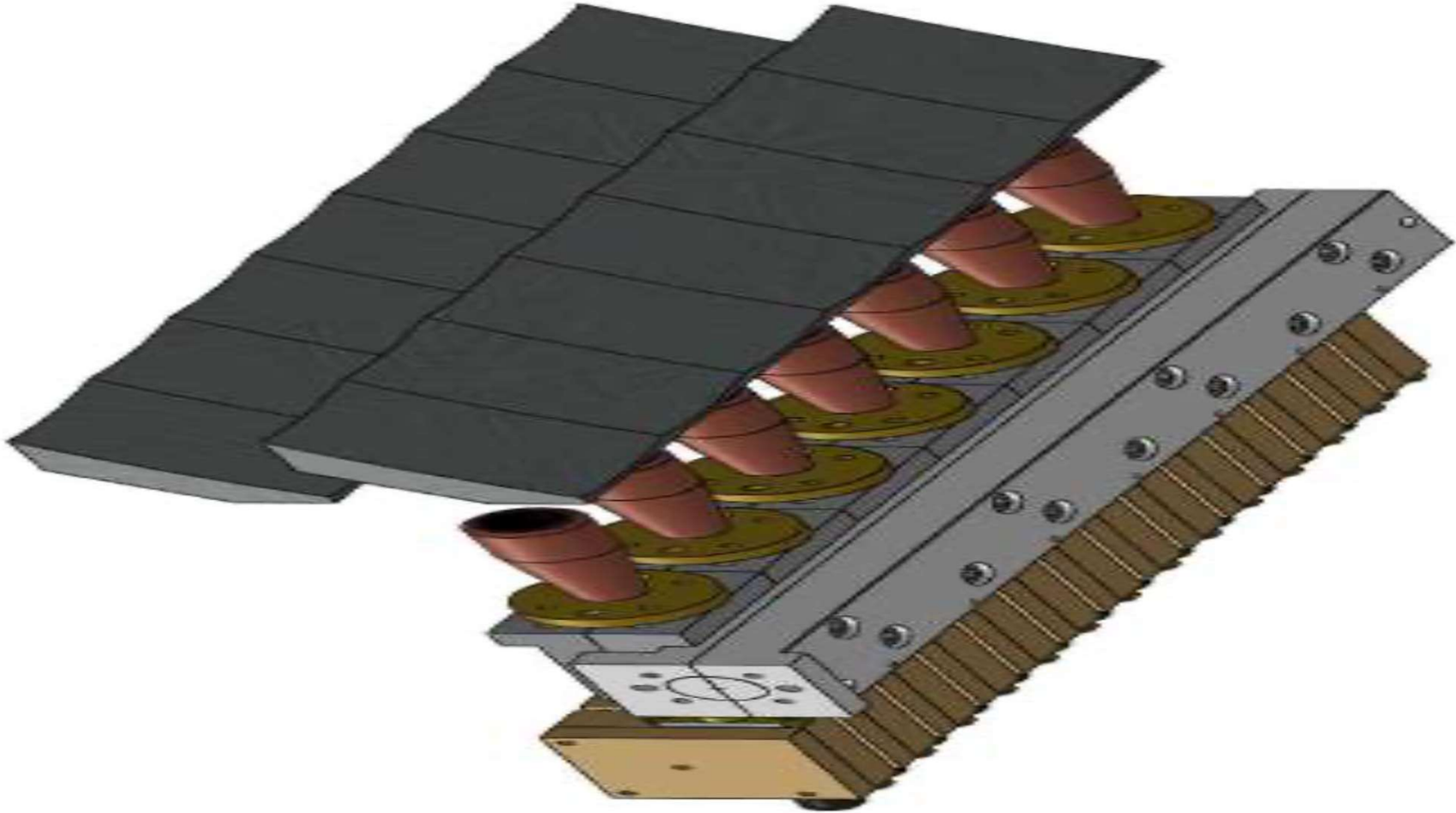
# Functional Proofs of concepts (part of Aethra WP5.1)



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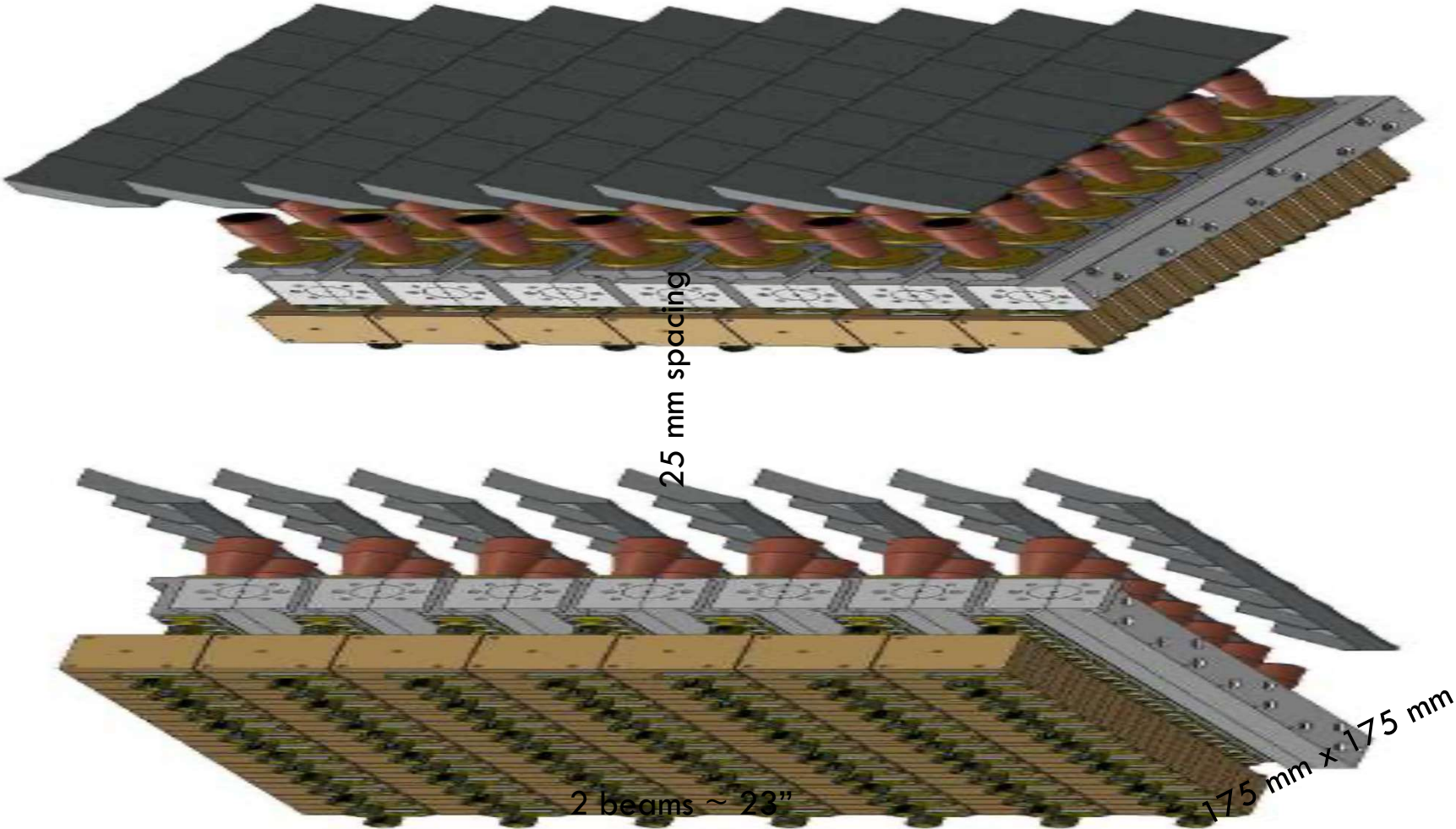
## Radionet projects







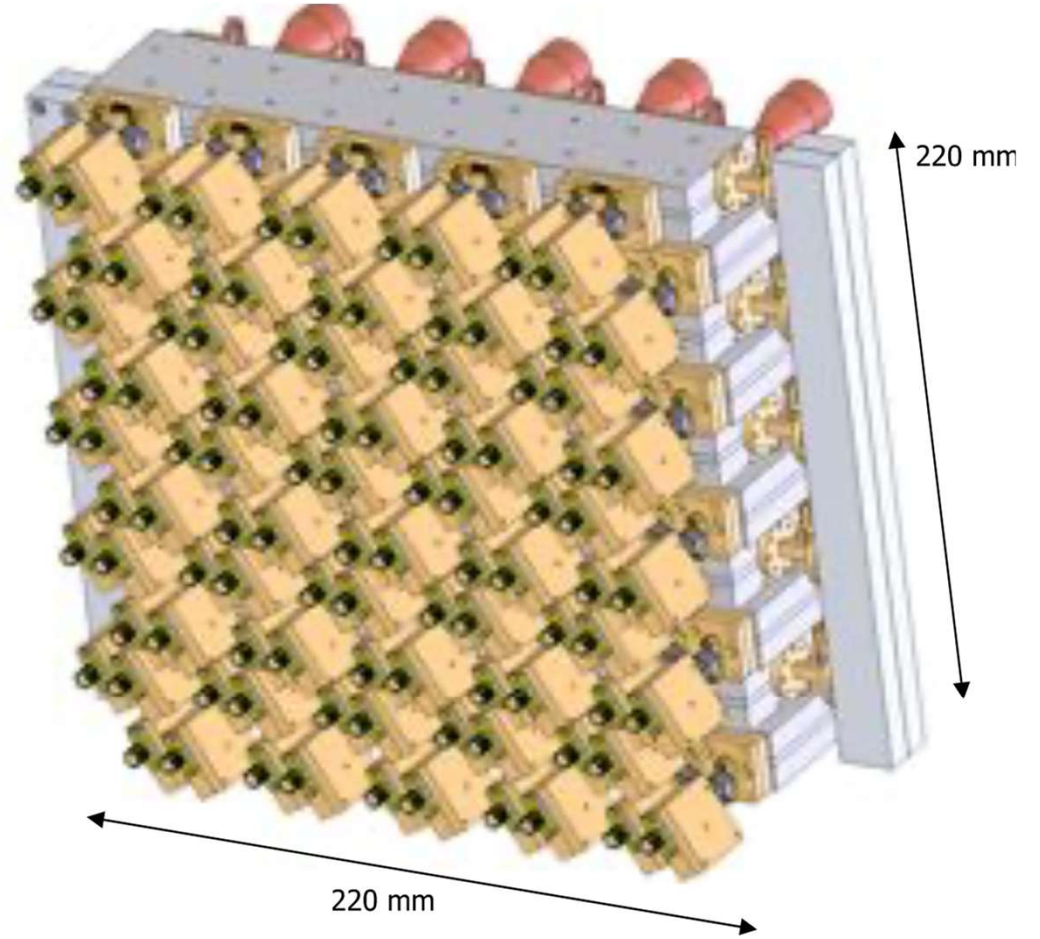
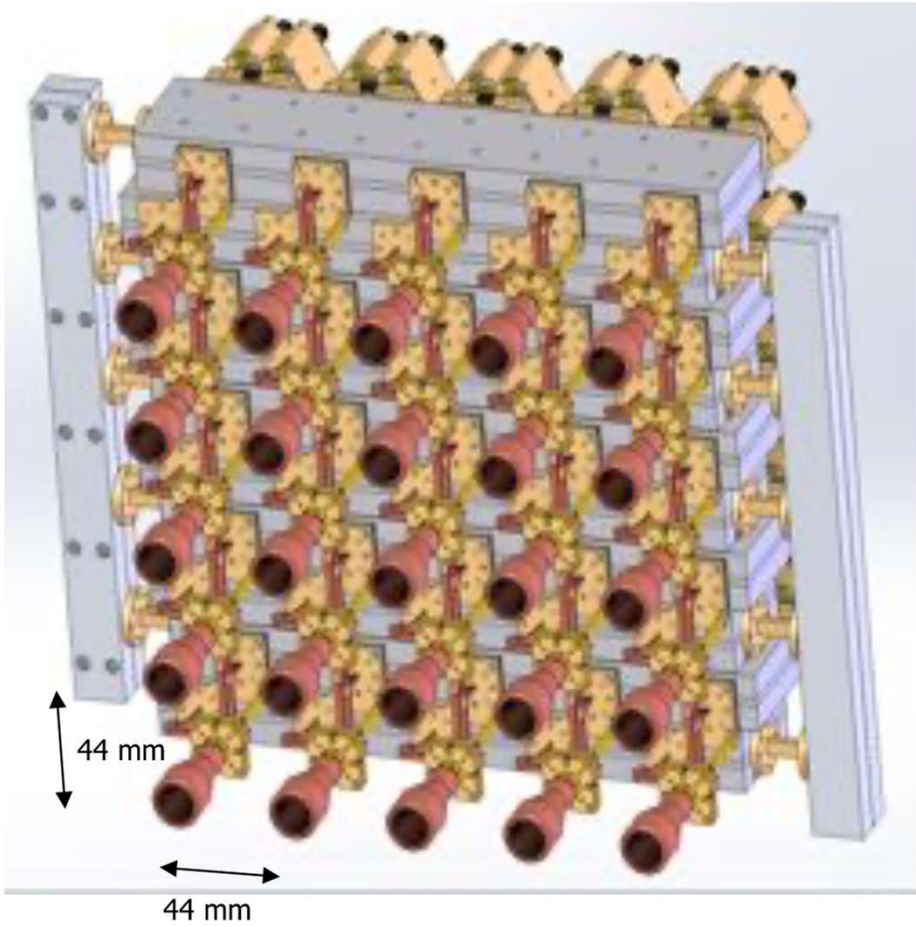
# Multibeam: HFA based on concept 7x1 SIS demonstrator



Optics design by Anne-Laure Fontana – Mixer design by Doris Maier



# Multibeam: LFA based on concept 3x1 HEMT demonstrator



Beam separation on the sky:  $\sim 2\text{FWHM} \rightarrow 48''$

Optics design by Anne-Laure Fontana – Mixer design by Doris Maier



# Multibeam: HFA + LFA based on demonstrators

Specs: goals and baseline

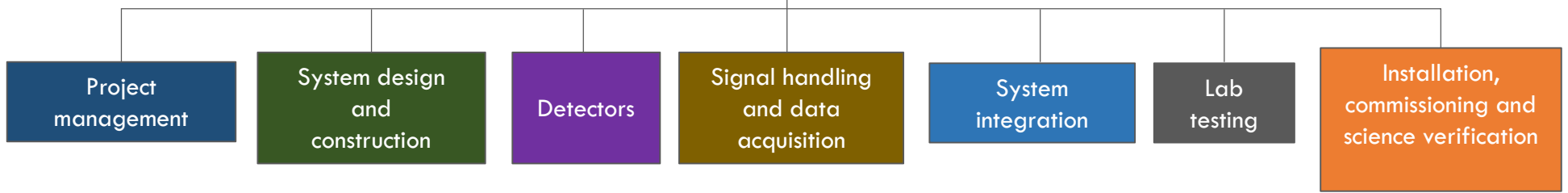
Feature	HFA 1mm			LFA 3mm		
	Goal	Baseline		Goal	Baseline	
<b>Frequency range</b>	<b>196 -- 280</b>	200 -- 276	GHz	<b>67 -- 117</b>	72 -- 116.5	GHz
LO range	<b>208 -- 268</b>	212 -- 264	GHz	<b>79 -- 105</b>	84 -- 104.5	GHz
IF range	<b>4 -- 12</b>	4 -- 12	GHz	<b>4 -- 12</b>	4 -- 12	GHz
<b>Mixer topology</b>	<b>2SB Dual Pol</b>			<b>2SB Dual Pol</b>		
<b>TRX for 80% of the RF band</b>		≤ 83		50		K (SSB)
TRX at any frequency		≤ 138		≤ 70		K (SSB)
Spread in Trec between pixels (%)	≤ 10			≤ 15	≤ 30	%
Sideband ratio	< -20			< -20	< -10	dB
Spectroscopic stability with 1 MHz BW (Allan time)	≥ 20		s	≥ 120	≥ 100	s
Total power stability with 1 MHz BW (Allan time)			s	≥ 20	≥ 10	s
Total power stability for 4-12 GHz IF			up tp 100s	<b>4x10<sup>-7</sup> A.V. up tp 100s</b>		
			up tp 300s	<b>3x10<sup>-6</sup> A.V. up tp 300s</b>		
Backend resolution		≥ 64	KHz	≥ 32	≥ 64	KHz
Array layout	<b>7 x 7</b>			<b>5 x 5</b>		
Pixel separation (physical)		25	mm		44	mm
On-sky separation (@ lowest f)		> 2	HPBW		> 2	HPBW
HPBW beam size (high)	<b>9 -- 12</b>	9 -- 12	"	<b>21 --- 34</b>	21 --- 34	"
Edge taper	<b>14</b>	14	dB	<b>14</b>	14	dB
Alingment accuracy between sub-arrays	≤ 0.5	≤ 1	"	≤ 0.5	≤ 1	"
Co-alingment between sub-arrays / pixels (on sky)	≤ 1	≤ 2	"	≤ 1	≤ 2	"
Co-alingment between sub-arrays for central pix (on sky)	≤ 0.5	≤ 1	"	≤ 0.5	≤ 1	"
Main beam efficiencies	≥ 0.60	≥ 0.53		≥ 0.80	≥ 0.75	
Aperture efficiency	≥ 0.50	≥ 0.41		≥ 0.65	≥ 0.60	
Forward efficiency	≥ 0.95	≥ 0.88		≥ 0.98	≥ 0.95	

**A good approximation of final specs; to be defined soon → Workshop!**



# Multibeam: Work breakdown structure

Proposed workpackages for project development (work breakdown structure)



Multibeam : Work breakdown structure v 1.1

Project Management				System design and construction										Detectors				Signal handling and data acquisition				System integration						Lab Testing						Installation, commissioning, acceptance and science verification																	
Task ID	Task Name	Start	End	Task ID	Task Name	Start	End	Task ID	Task Name	Start	End	Task ID	Task Name	Start	End	Task ID	Task Name	Start	End	Task ID	Task Name	Start	End	Task ID	Task Name	Start	End	Task ID	Task Name	Start	End	Task ID	Task Name	Start	End	Task ID	Task Name	Start	End												
MP-001	Project Management	2023-01-01	2023-12-31	SC-001	System Design	2023-02-01	2023-06-30	SC-002	Construction	2023-07-01	2023-11-30	SC-003	Optics	2023-02-01	2023-03-31	SC-004	Layout	2023-04-01	2023-05-31	SC-005	Mechanical Design	2023-06-01	2023-07-31	SC-006	Electrical Design	2023-08-01	2023-09-30	SC-007	Software Development	2023-09-01	2023-10-31	SC-008	Integration	2023-11-01	2023-11-30	SC-009	Commissioning	2023-12-01	2023-12-31	SC-010	Acceptance	2023-12-01	2023-12-31	SC-011	Verification	2023-12-01	2023-12-31	SC-012	Science	2023-12-01	2023-12-31
MP-001	Project Management	2023-01-01	2023-12-31	SC-001	System Design	2023-02-01	2023-06-30	SC-002	Construction	2023-07-01	2023-11-30	SC-003	Optics	2023-02-01	2023-03-31	SC-004	Layout	2023-04-01	2023-05-31	SC-005	Mechanical Design	2023-06-01	2023-07-31	SC-006	Electrical Design	2023-08-01	2023-09-30	SC-007	Software Development	2023-09-01	2023-10-31	SC-008	Integration	2023-11-01	2023-11-30	SC-009	Commissioning	2023-12-01	2023-12-31	SC-010	Acceptance	2023-12-01	2023-12-31	SC-011	Verification	2023-12-01	2023-12-31	SC-012	Science	2023-12-01	2023-12-31





# Multibeam: WBS : WP-2000

System design and construction WP-2000						
Optics WP-2100	Cryostat WP-2200	Cooling WP-2300	Control computer and FE interface WP-2400	BIAS Electronics / hot electronics WP-2500	Wiring / Harnessing WP-2600	Simulaitons and models WP-2700
Warm optics & K-Mirror WP-2110	Cryostat(s) design WP-2210	Heat budget WP-2310	FE control SW / GUI WP-2410	Bias electronics WP-2510	Wiring WP-2610	Mechanical models WP-2710
OMTs WP-2120	Vacuum & sensors WP-2220	Coldhead(s) and compressor WP-2320	Tunning strategies and operations modes WP-2420	Warm amplifiers / attenuators WP-2520	Filter and feedthroughs WP-2620	Optical simulations WP-2720
Cold Optics WP-2130	Mechanical interfacing WP-2230	Compressor chiller requirements WP-2330	Debugging and diagnostics tools WP-2430		RF cables / connector WP-2630	F.E. Analysis & mechanical deformations WP-2730
Windows and filters WP-2140			Computer interfaces WP-2430			
Dichroics / Wiregrids WP-2150						
Cal Unit WP-2160						



# Multibeam: WBS : WP-3000 & WP-4000

Detectors WP-3000				Signal handling and Data acquisition WP-4000		
HFA 1mm SIS WP-3100	LFA 3mm HEMTs WP-3200	Local Oscillators WP-3300	LNAs, Equalizers, waveguides WP-3400	IF Processor WP-4100	Spectrometers WP-4200	Acquisition and forming WP-4300
SIS mixers WP-3110	HEMTs WP-3210	LO technology and reference WP-3310	LNAs WP-3410	IF Sub-band separation WP-4110	Attenuators / amplifiers WP-4210	Data pipeline WP-4310
Magnets WP-3120	Mixers WP-3220	LO distribution WP-3320	Equalizers WP-3420	IF signal switches WP-4120	Digitiser & optic fiber WP-4220	Fits writer WP-4320
Horns (individual / blocks) WP-3130	Horns (individual / blocks) WP-3230	LO pumping, attenuation and control WP-3330	Waveguides and isolators WP-3430		FFT cards WP-4230	
					Control computer WP-4240	



# Multibeam: WBS : WP-5000

System integration WP-5000					
Cryostat / cooler integration WP-5100	LO integration WP-5200	Optics WP-5300	Detectors / mixers WP-5400	Wiring and interfacing WP-5500	Cold / warm electronics WP-5600
Mechanical integration WP-5110	Synthesizer and chains WP-5210	Horns / OMTs WP-5310	HFA SIS / LNA WP-5410	Temperature and vacuum sensors WP-5510	Temperature and vacuum sensors WP-5610
Thermal connections WP-5120	LO distribution WP-5220	Cold optics WP-5320	LFA HEMT / MIXER WP-5420	Feedthroughs WP-5520	Preamplifiers and bias electronics WP-5620
Filters and windows WP-5130	Attenuators / control WP-5230	Warm optics WP-5330		RF (IF) Lines WP-5530	Warm amplifiers WP-5630
		K-Mirror and Control WP-5340		Mixers / amplifiers WP-5540	
		Select optics and control WP-5350			





# Multibeam: WBS : WP-6000

Lab Testing WP-6000						
Cryostat / cooler testing WP-6100	Local Oscillators WP-6200	HFA pixels Characterization WP-6300	LFA Pixels Characterization WP-6400	Optics characterization WP-6500	HFA / LFA characterization WP-6600	Full system characterization WP-6700
Vacuum testing WP-6110	LO Spectral purity WP-6210	Individual pixel characterization WP-6310	Individual pixel characterization WP-6410	Gain and losses WP-6510	Beam maps WP-6610	Beam maps WP-6710
Thermal load testing WP-6120	LO pumping and attenuation control WP-4410	Array characterization WP-6320	Array characterization WP-6420	Filters response WP-6520	TRx and Allan variance WP-6620	TRx and Allan variance WP-6720
					Sideband rejection WP-6630	Sideband rejection WP-6730
					Crosstalk WP-6640	Crosstalk WP-6740

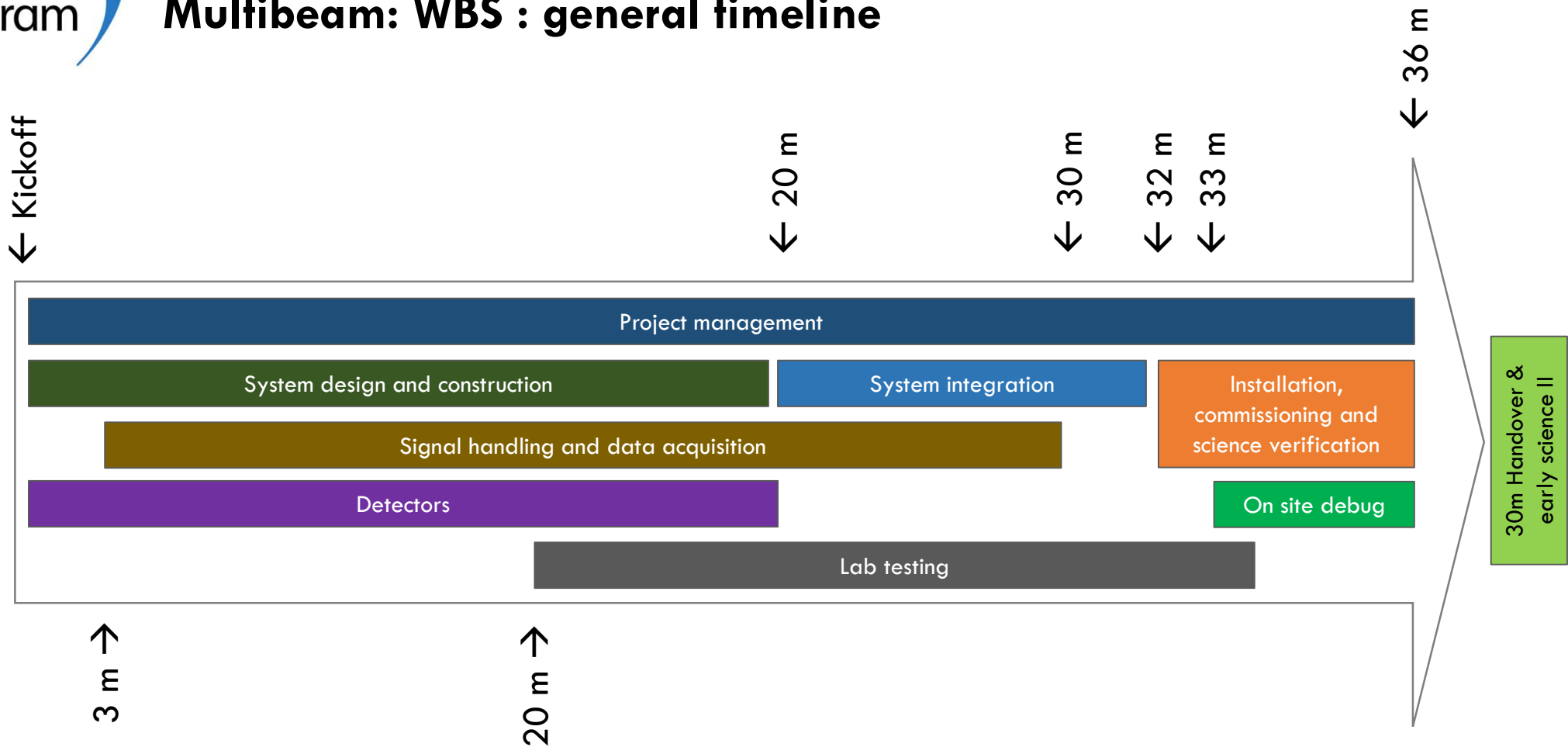


# Multibeam: WBS : WP-7000

Installation, commissioning, acceptance and science verification WP-7000					
Technical commissioning WP-7100	Alignment and Optics characterization WP-7200	LFA Characterization WP-7300	HFA characterization WP-7400	Full system characterization WP-7500	Science commissioning WP-7600
Pre-commissioning and acceptance WP-7110	Optics alignment WP-7210	On-Sky beam maps WP-7310	On-Sky beam maps WP-7410	Pointing model WP-7510	Science commissioning plan execution WP-7610
Installation & Technical commissioning (plan execution) WP-7120	Alignment reproducibility WP-7220	Pixel alignment WP-7320	Pixel alignment WP-7420	Beam maps and efficiencies WP-7520	General performance WP-7620
Technical commissioning report WP-7130		Coalignment with HFA Central Pixel WP-7330	Coalignment with LFA Central Pixel WP-7430	Full system allan variance WP-7530	mapping capabilities WP-7630
Technical paper(s) WP-7140				Sideband separation WP-7540	Spectral capabilities WP-7640
				Tuning optimization WP-7550	Science commissioning report WP-7650
					First light and early science papers WP-7670



# Multibeam: WBS : general timeline



- This short time scale (target 3 years) requires close coordination and collaboration between all parties: IRAM-ES, IRAM-FR, Partners and External (vendors and others).
- Workshop being prepared for late 2023 → Kickoff to happen after that.



**Multibeam: one last thing; A proper name for RX system.**



**Advanced Large Heterodyne Array for Millimeter Band Radio Astronomy**