Instituto Geográfico Nacional
Organismo Autónomo Centro Nacional de Información Geográfica

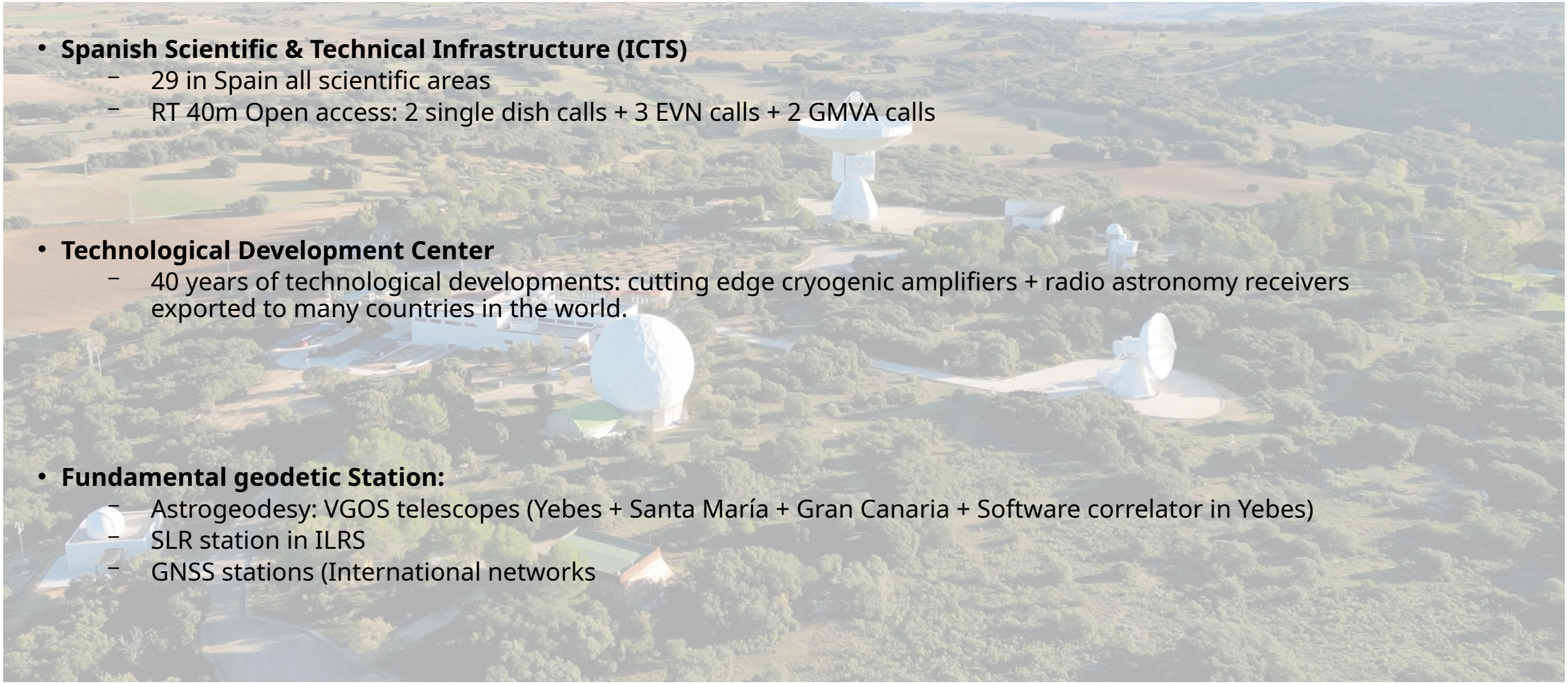
The Yebes 40m RT multifrequency system

28 October 2025

Pablo de Vicente on behalf of:
Cristina García-Miró, Javier González
& the Yebes engineering team

GOBIERNO DE ESPAÑA
MINISTERIO DE TRANSPORTES Y MOVILIDAD SOSTENIBLE
INSTITUTO GEOGRÁFICO NACIONAL
YEBES

Yebes Observatory: main facts

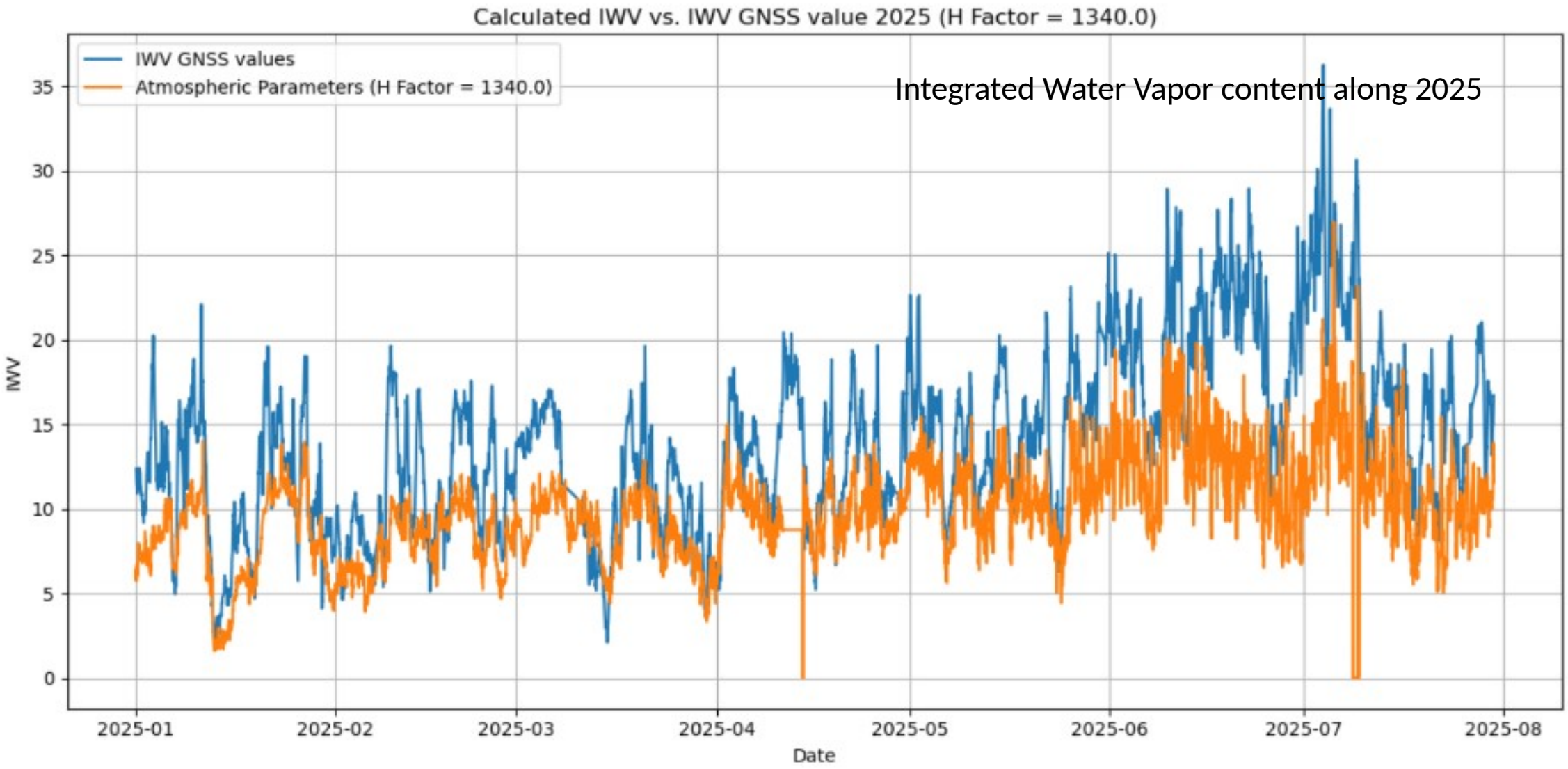


- **Spanish Scientific & Technical Infrastructure (ICTS)**
  - 29 in Spain all scientific areas
  - RT 40m Open access: 2 single dish calls + 3 EVN calls + 2 GMVA calls

- **Technological Development Center**
  - 40 years of technological developments: cutting edge cryogenic amplifiers + radio astronomy receivers exported to many countries in the world.

- **Fundamental geodetic Station:**
  - Astrogeodesy: VGOS telescopes (Yebes + Santa María + Gran Canaria + Software correlator in Yebes)
  - SLR station in ILRS
  - GNSS stations (International networks

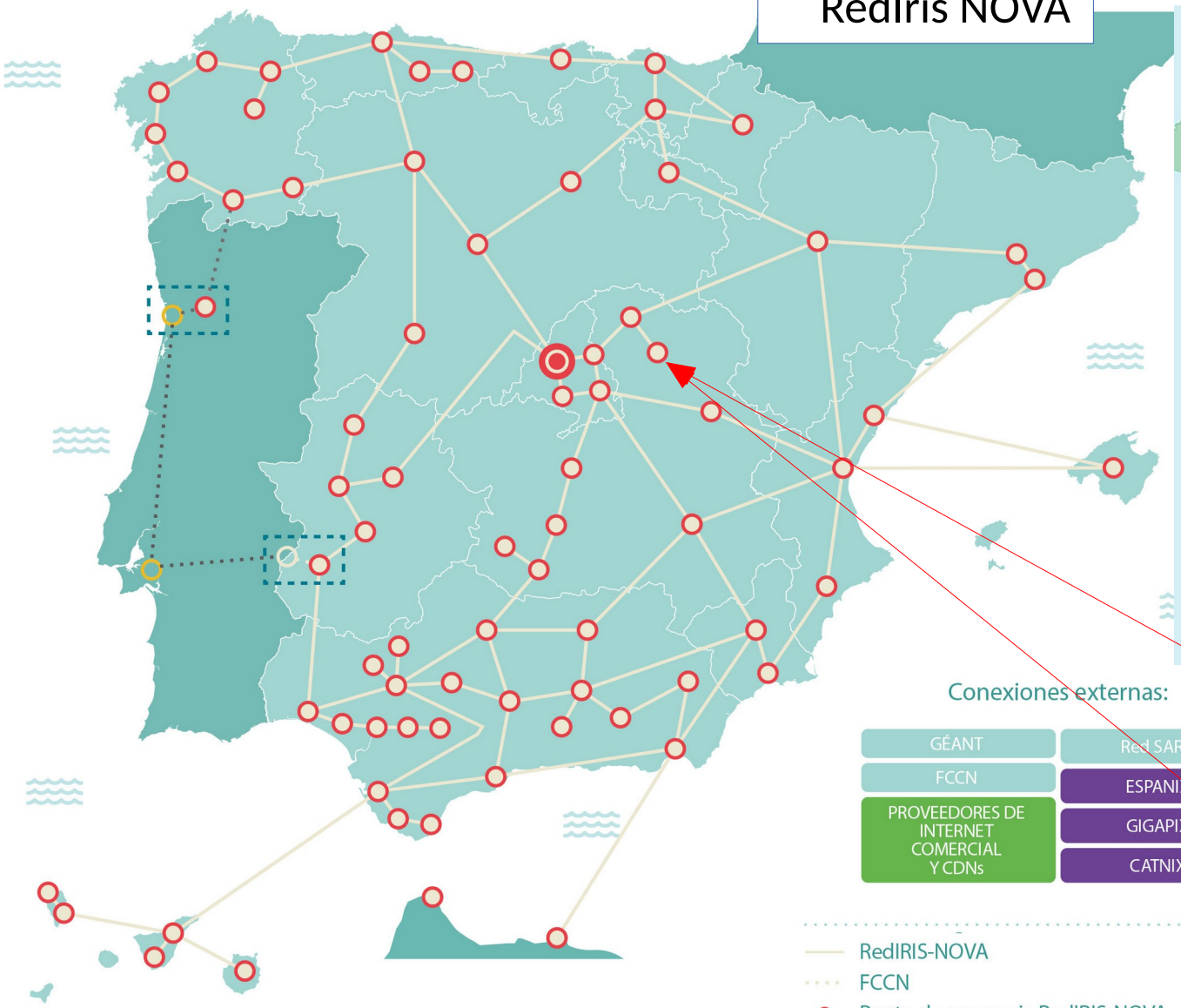
Atmospheric conditions

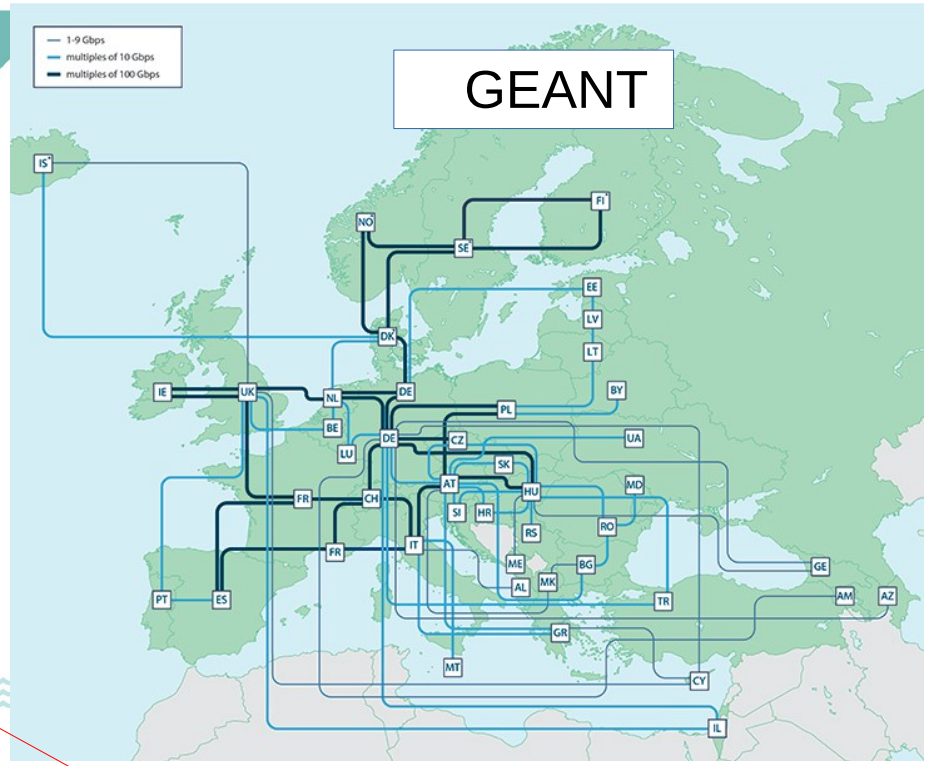


Integrated Water Vapor content along 2025

Internet connectivity

RedIris NOVA





Conexiones externas:

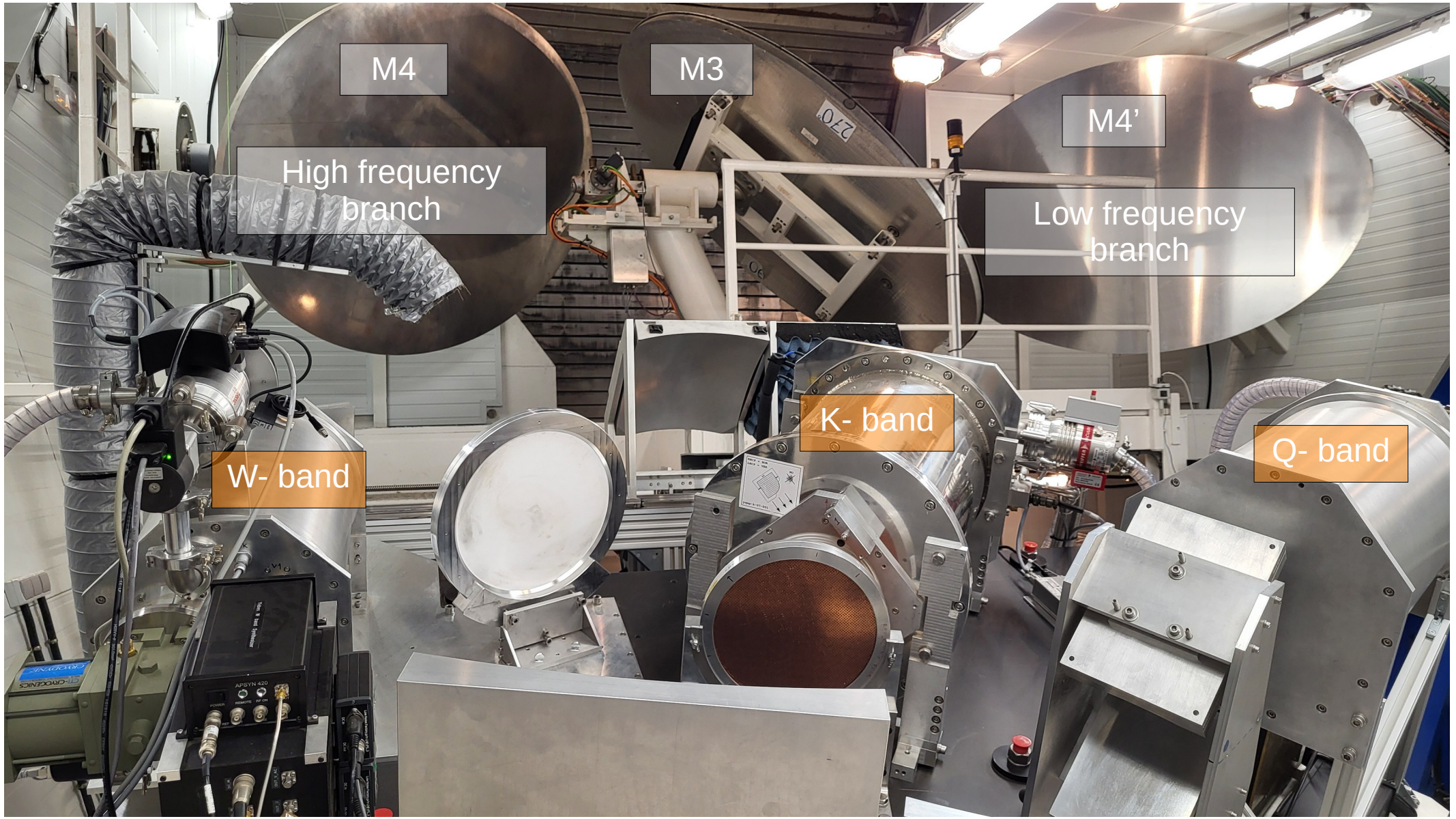
GÉANT	Red SARA
FCCN	ESPANIX
PROVEEDORES DE INTERNET COMERCIAL Y CDNs	GIGAPIX
	CATNIX

RedIRIS-NOVA
FCCN
Punto de presencia RedIRIS-NOVA
Punto de presencia FCCN
Punto de presencia RedIRIS-NOVA y GÉANT

2010 - 2022: **10 Gb/s**

2023 - : **100 Gb/s**

The 40m RT receiver cabin

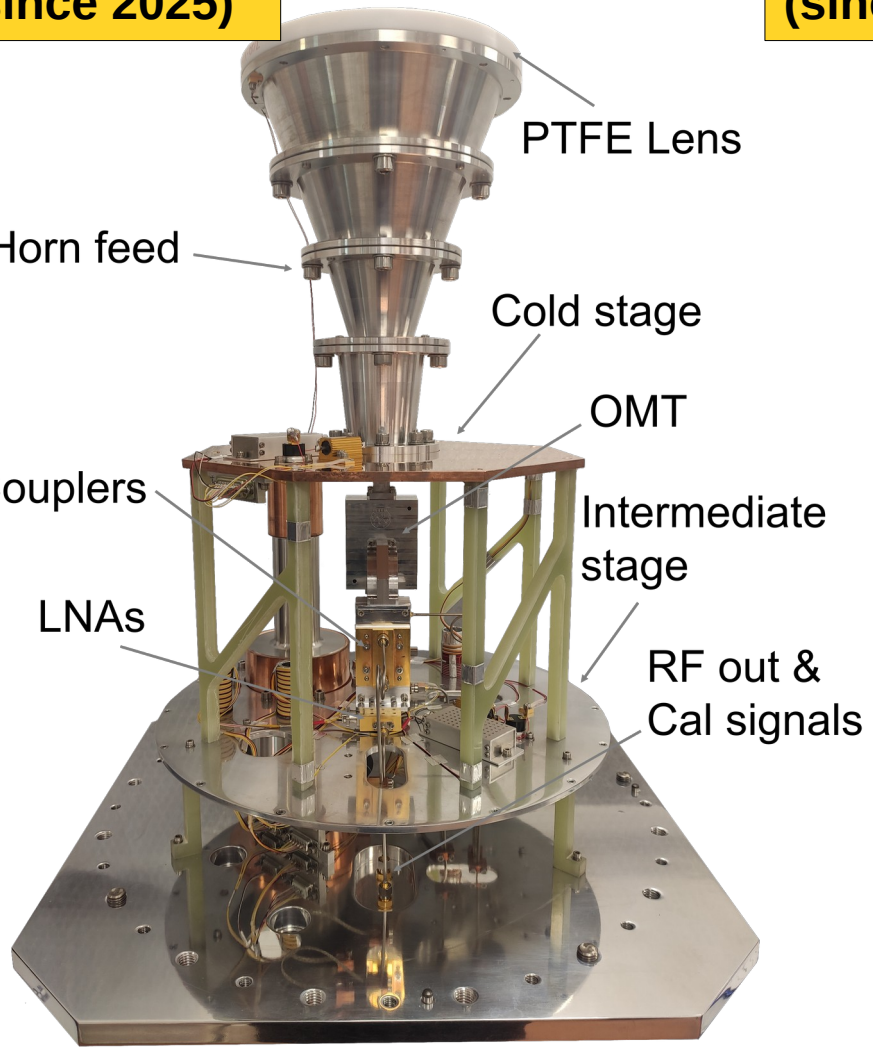


The 40m radio telescope receivers

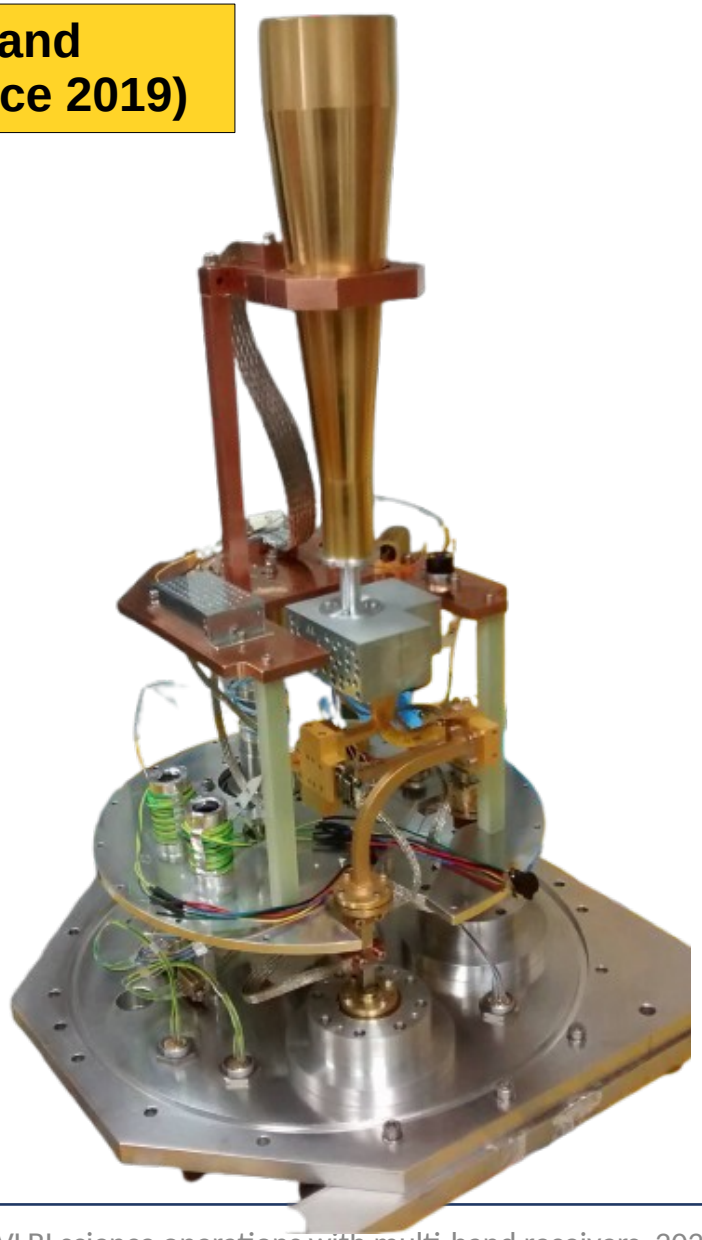
Receiver	Freq. Range (GHz)	b/w	Pol	Trec (K)	Resol (SD)	SEFD (Jy)	DPFU (K/Jy)	Call mode	phasecal
S legacy	2.2 - 2.4	170 MHz	R/L	50		1400	0.32	ND 80Hz	every MHz
CX band	4.5 - 9	500 MHz/ 4 GHz	R/L	12		165	0.28	ND 80Hz	every MHz
X legacy	8.1 - 8.6	500 MHz	R/L	10		200	0.22	ND 80Hz	every MHz
K band	18 - 32.3	14 GHz	H/V	15	16 KHz	430	0.26	ND + LOAD	yes
Q band	31.3 - 50.6	18 GHz	H/V	30	38 KHz	480	0.23	HOT/COLD	no
W band	72 - 90	18 GHz	H/V	50	38 KHz	600	0.11	HOT/COLD	no

The 40m radio telescope receivers

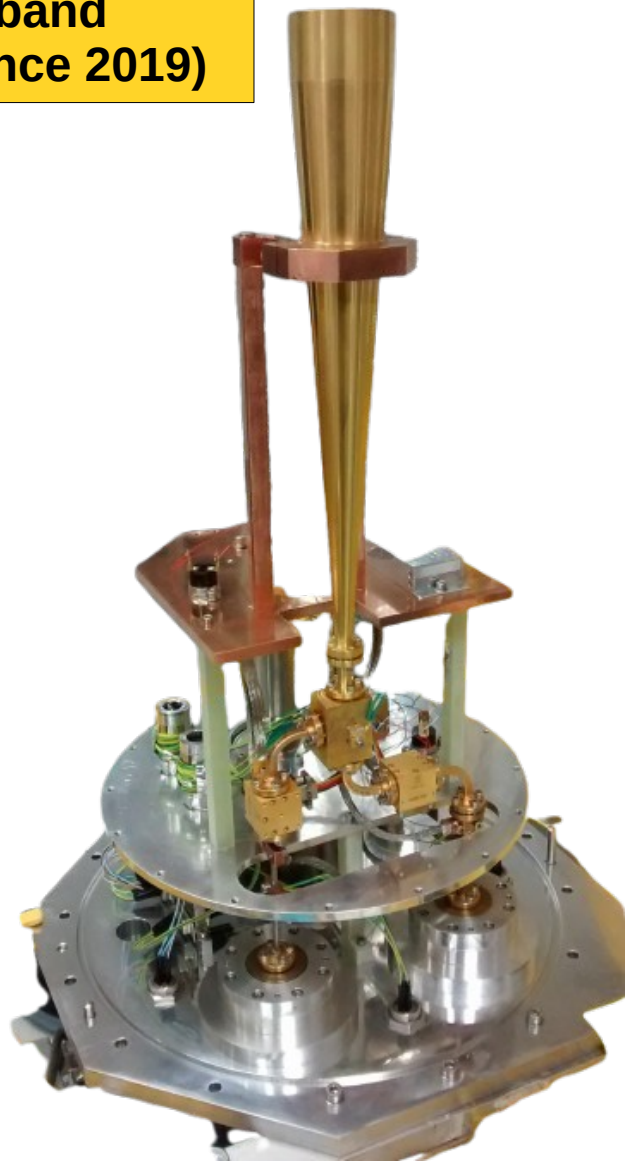
K-band (since 2025)



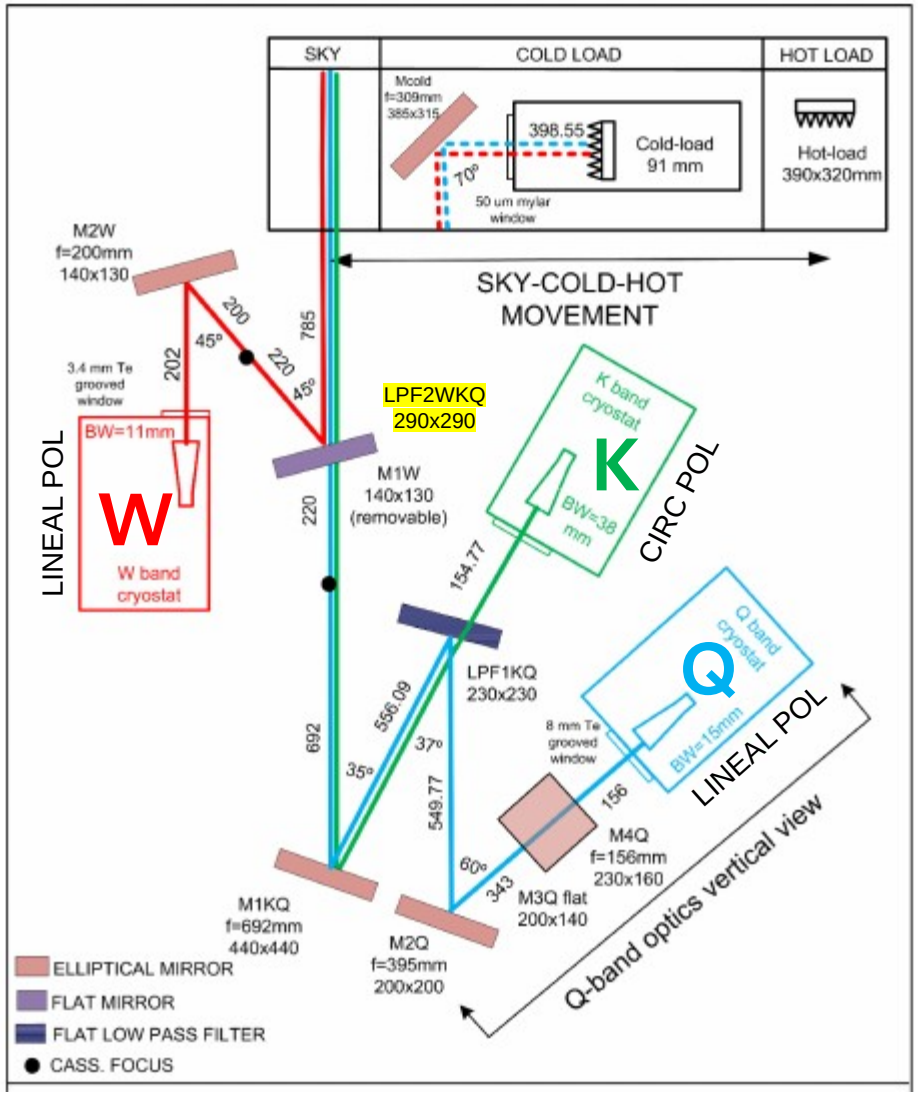
Q-band (since 2019)



W-band (since 2019)



The 40m RT multi frequency system: optics



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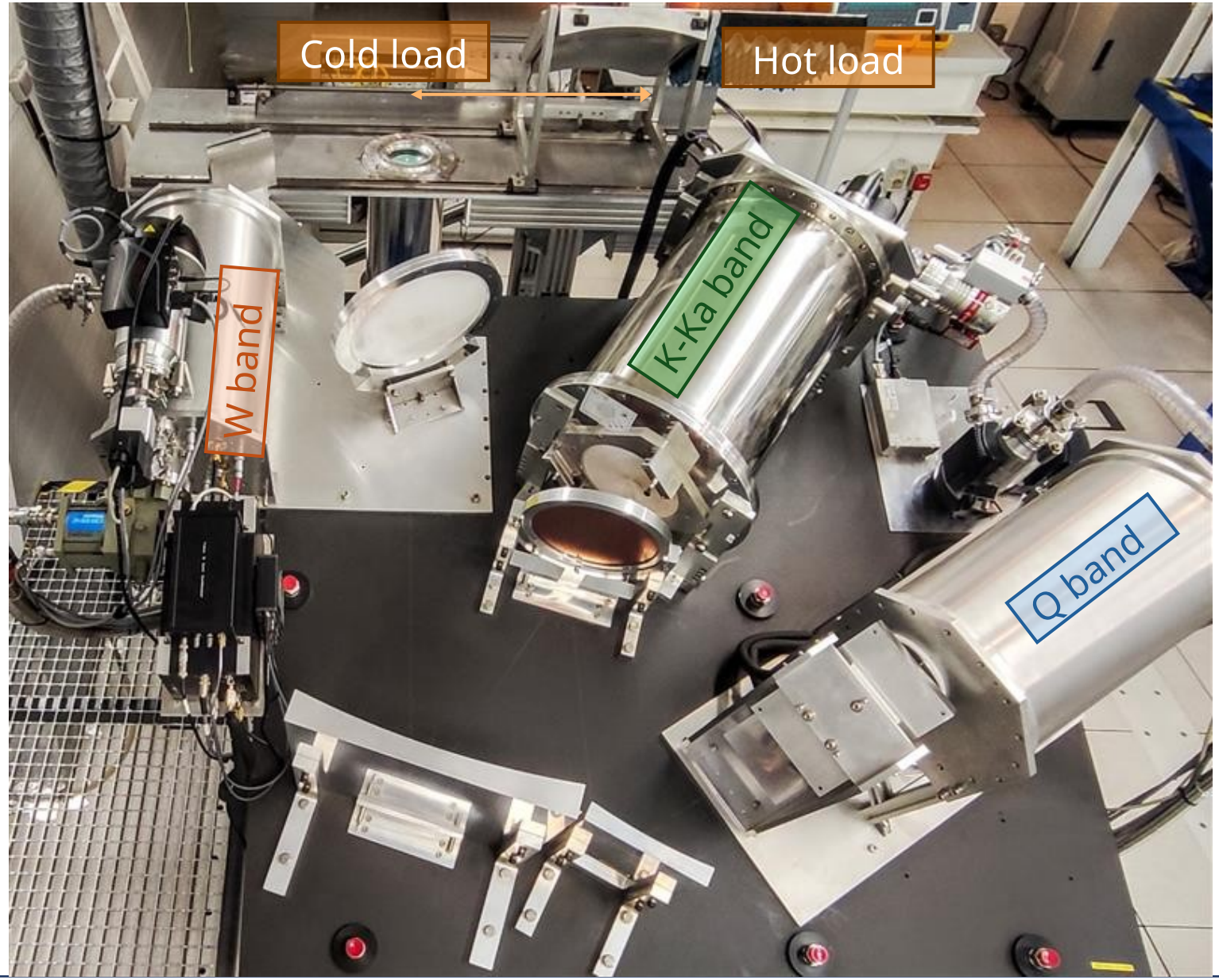

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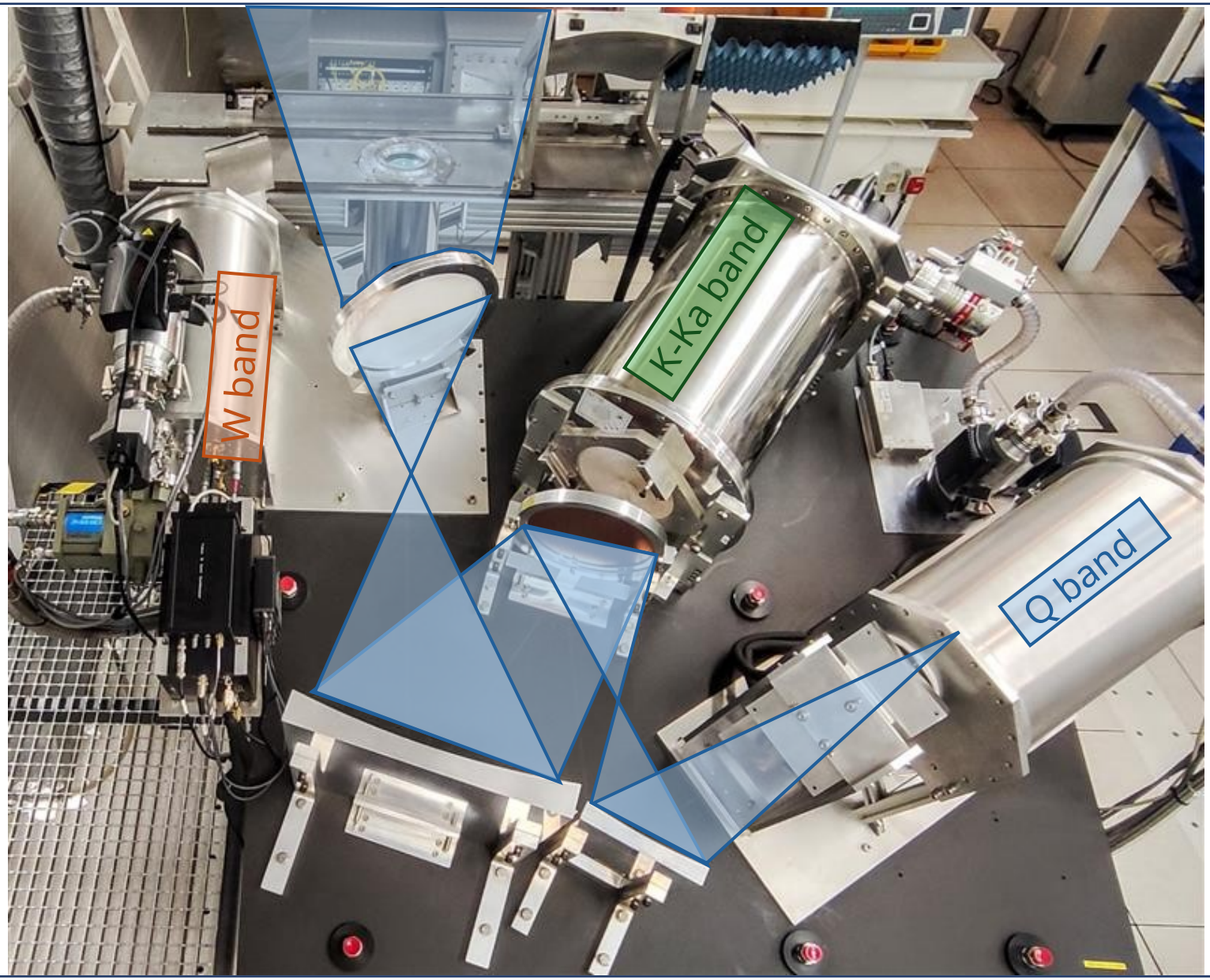

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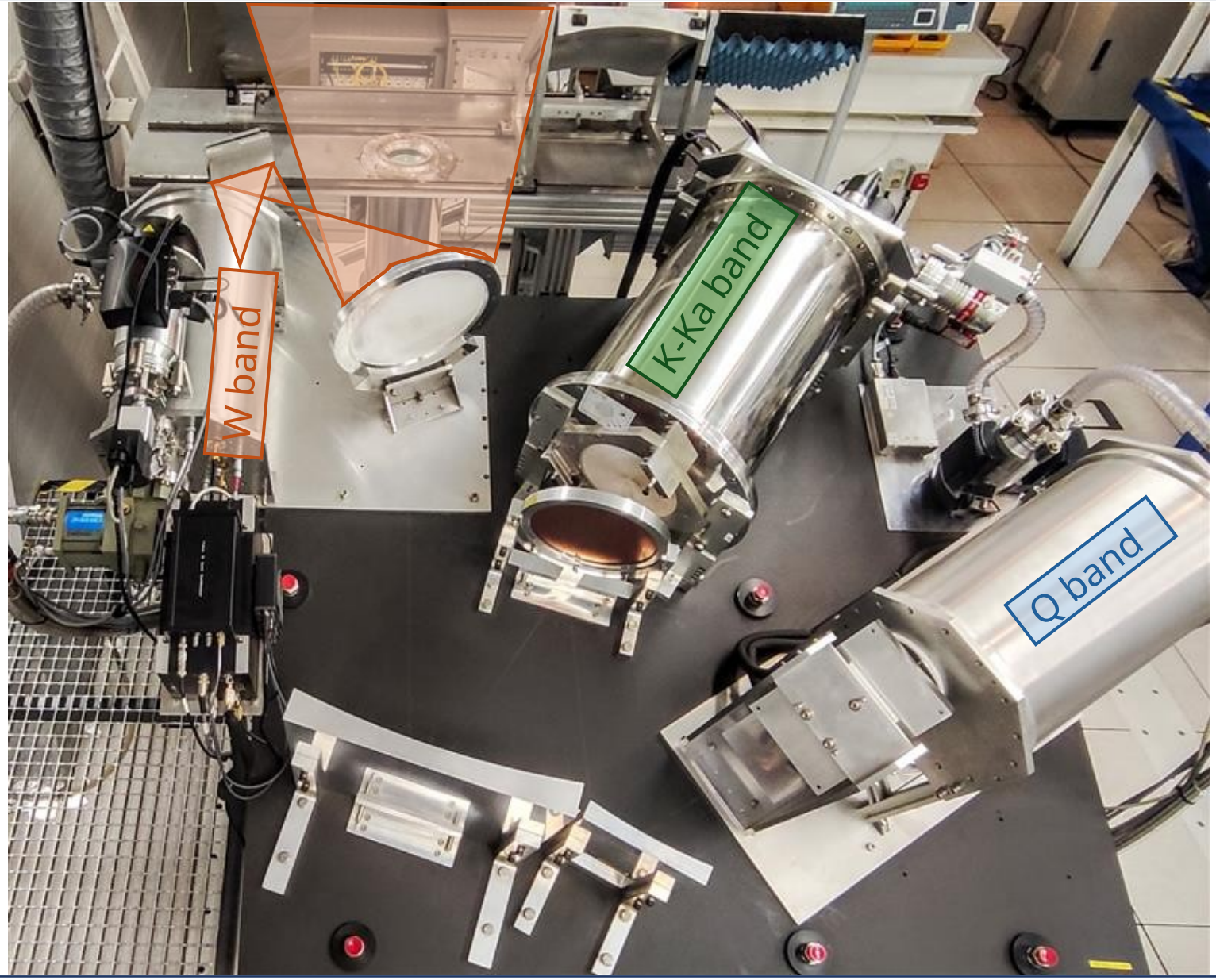
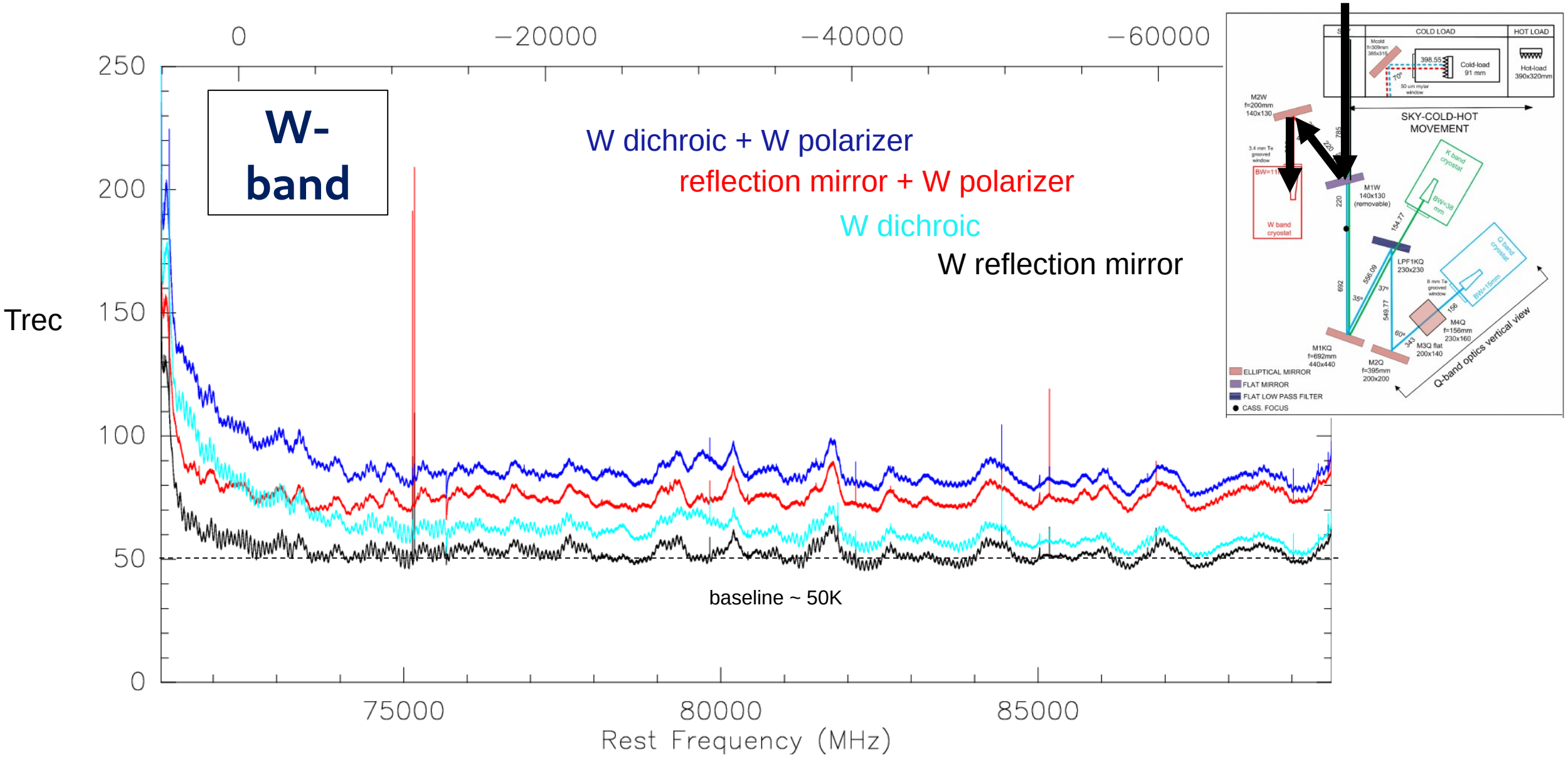


The 40m RT multi frequency system: Trec



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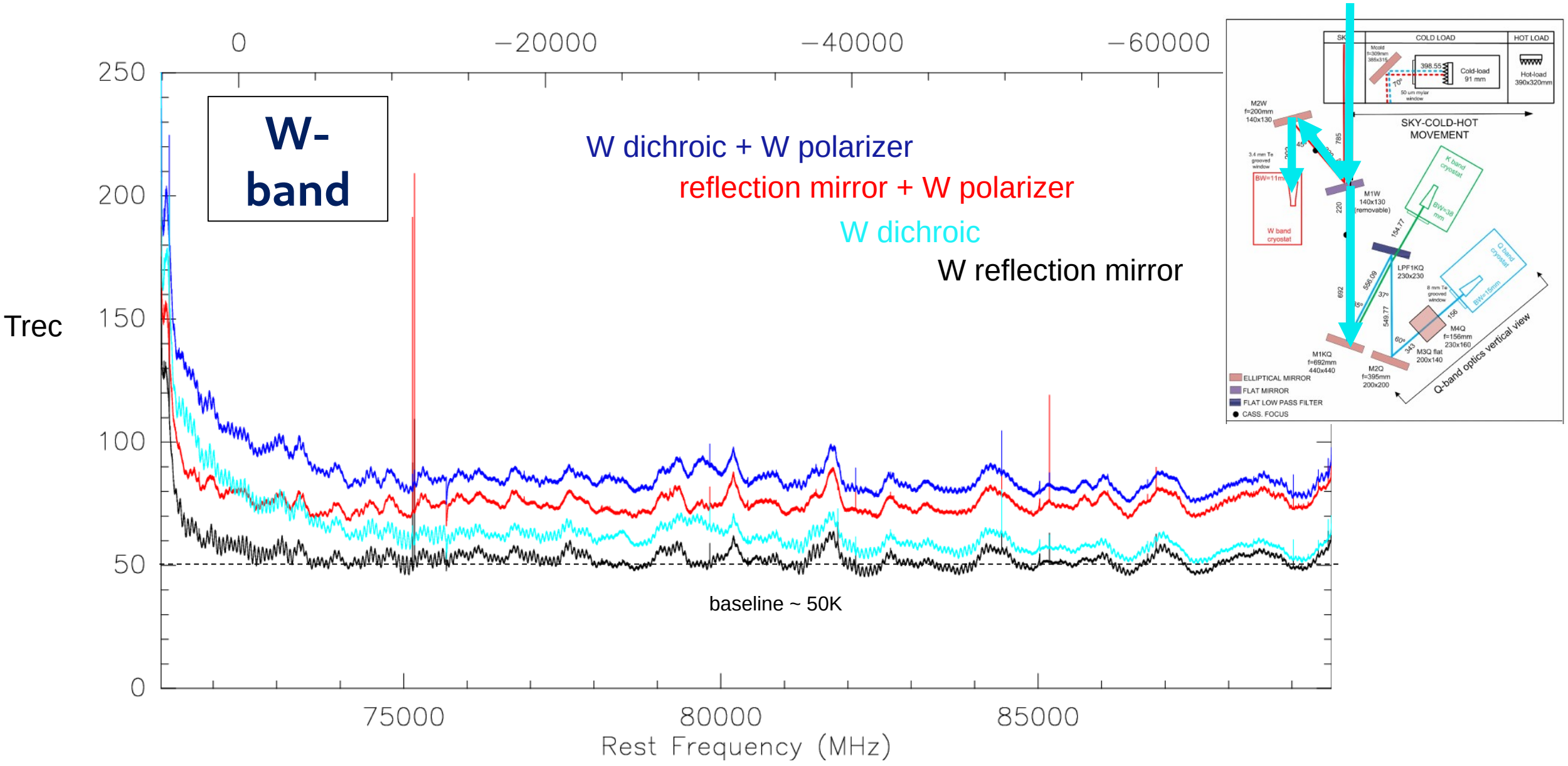

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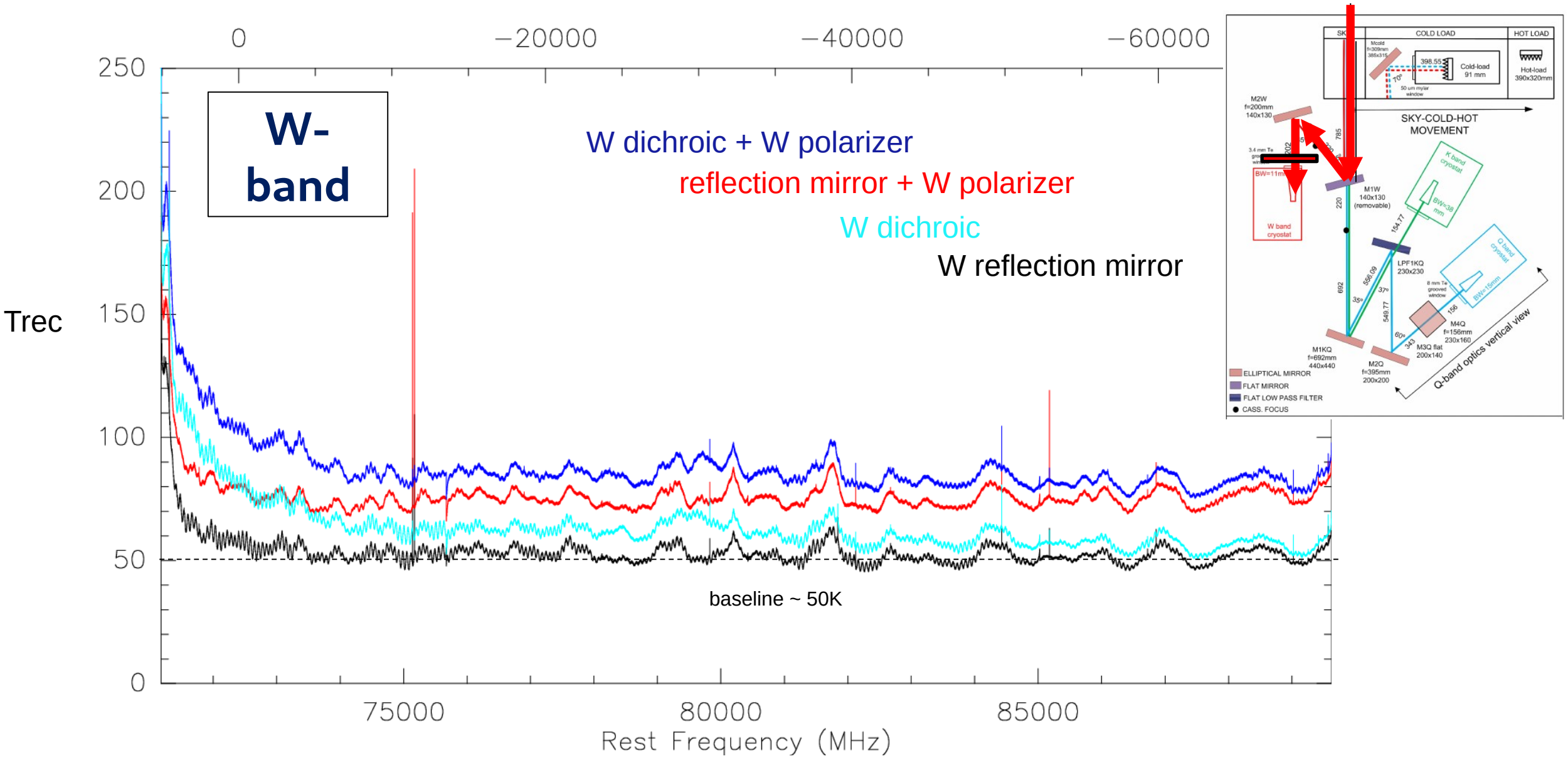

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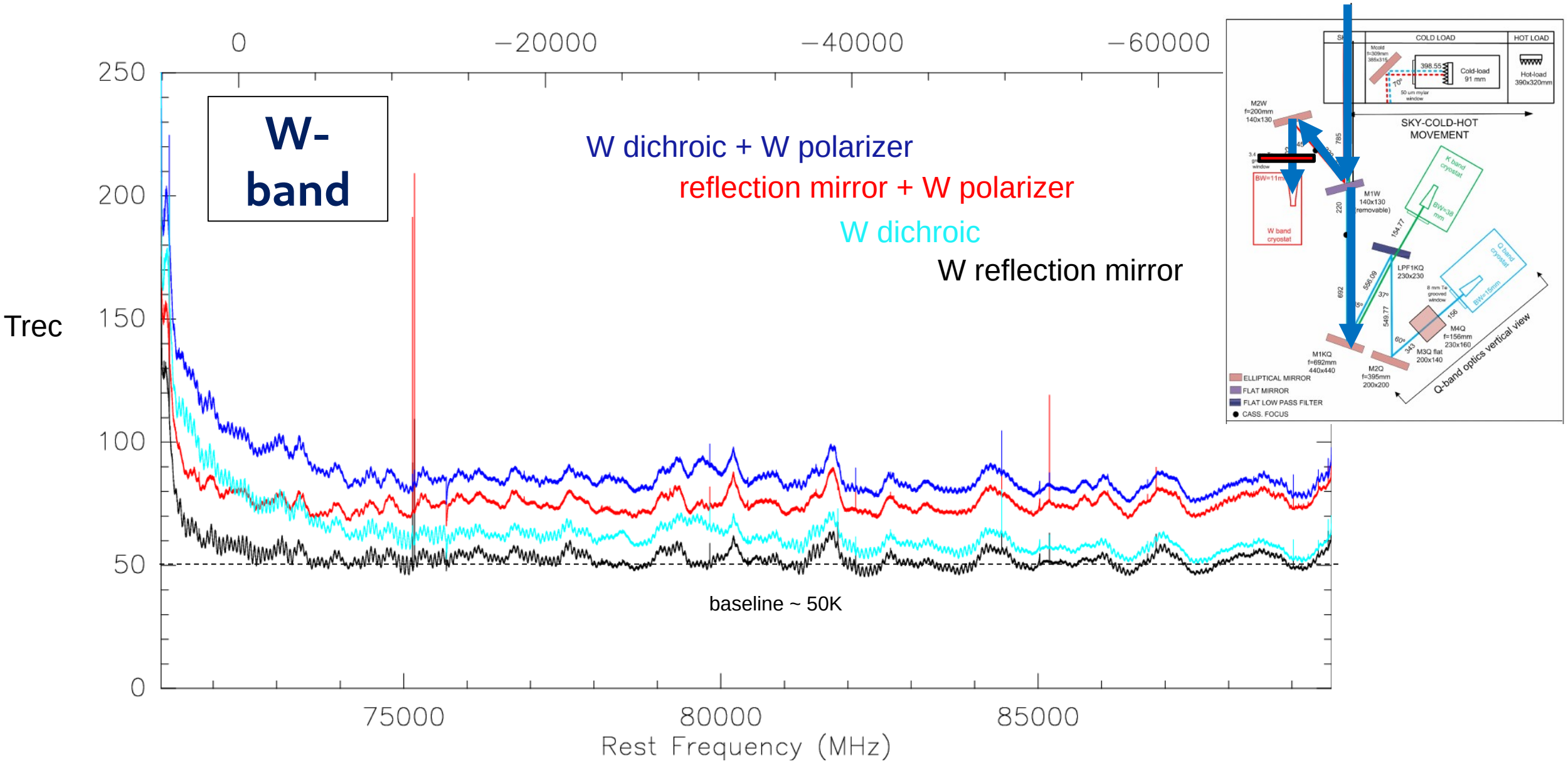

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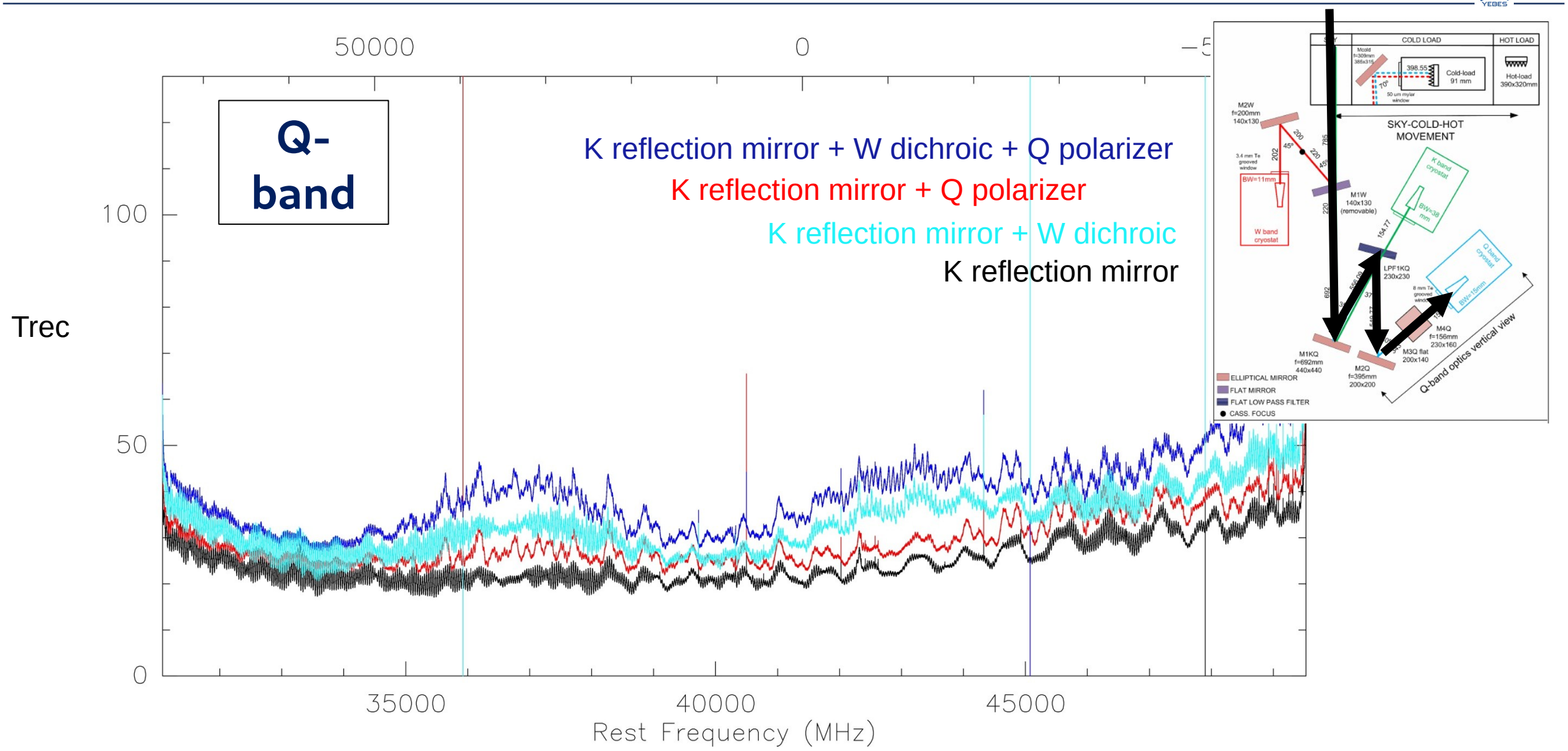

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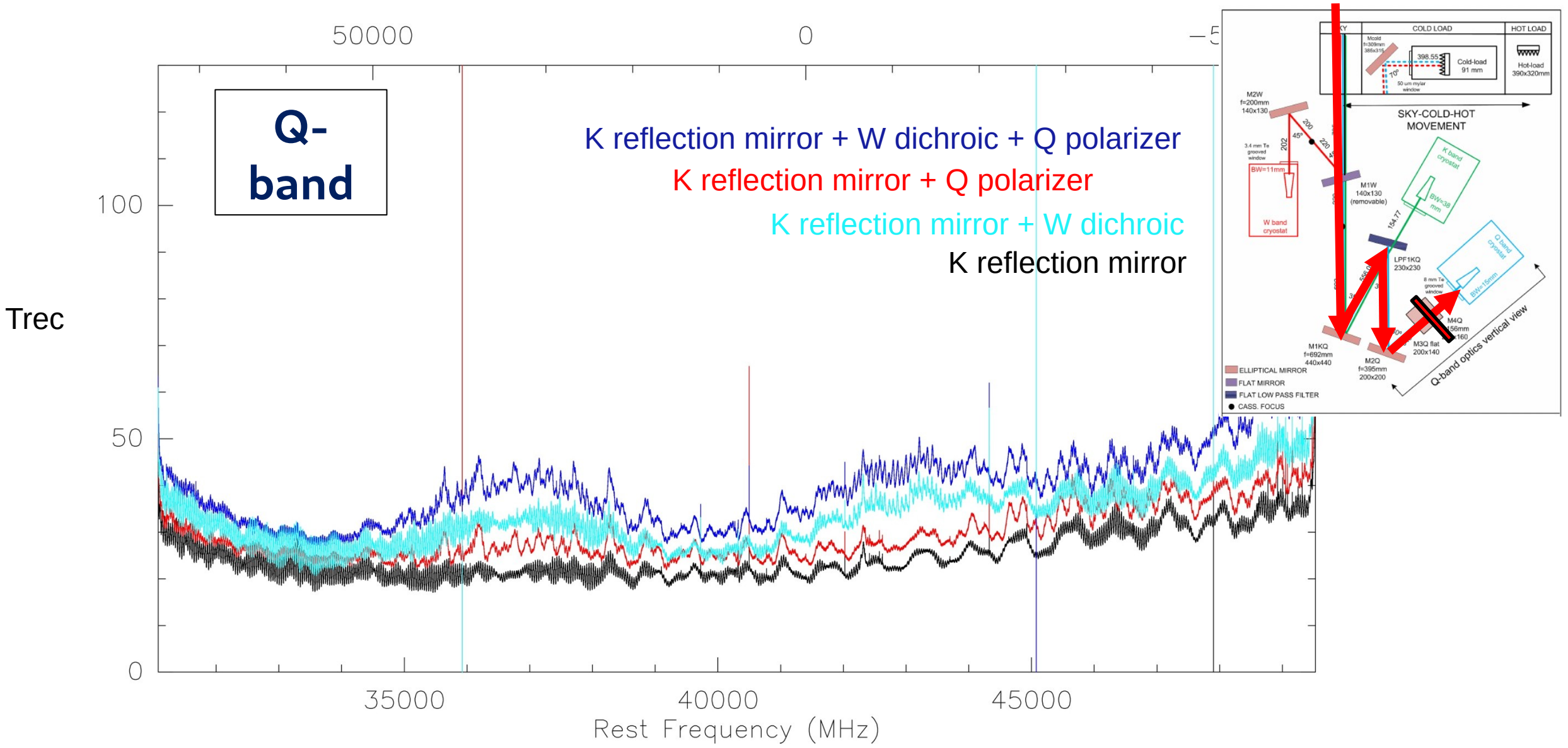

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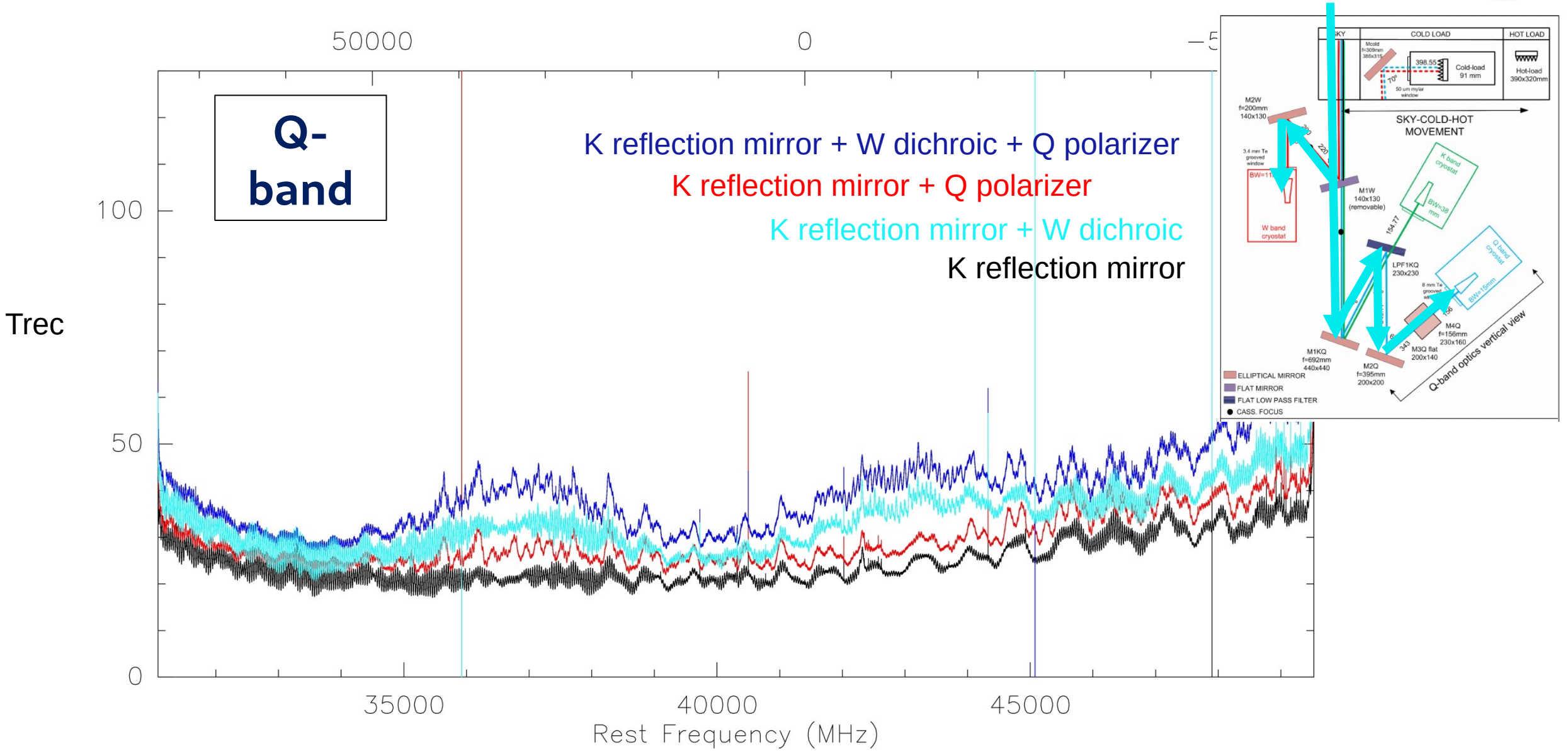

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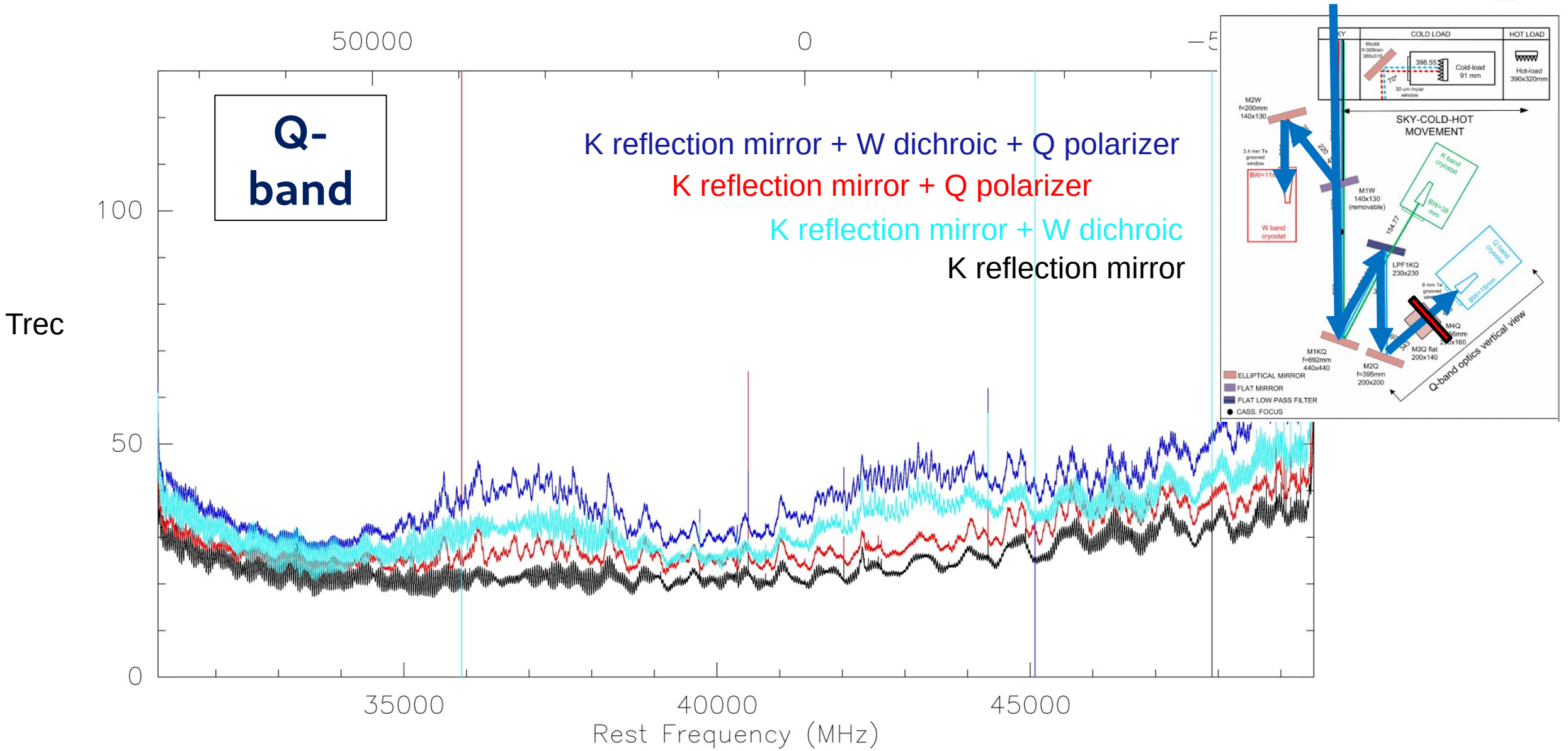

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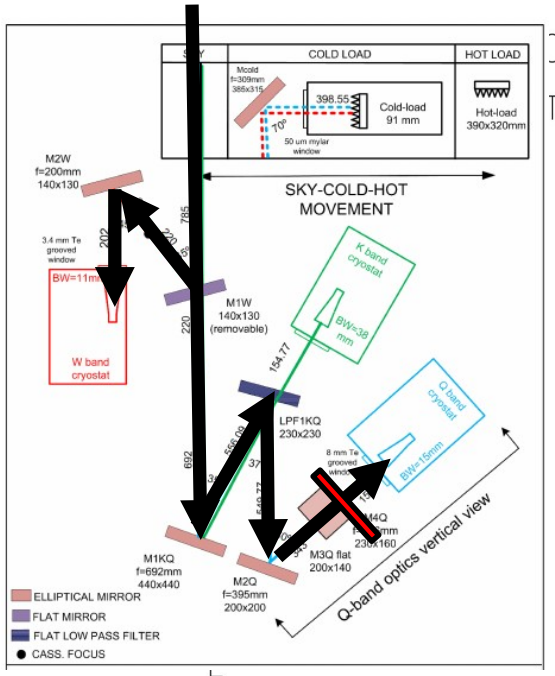
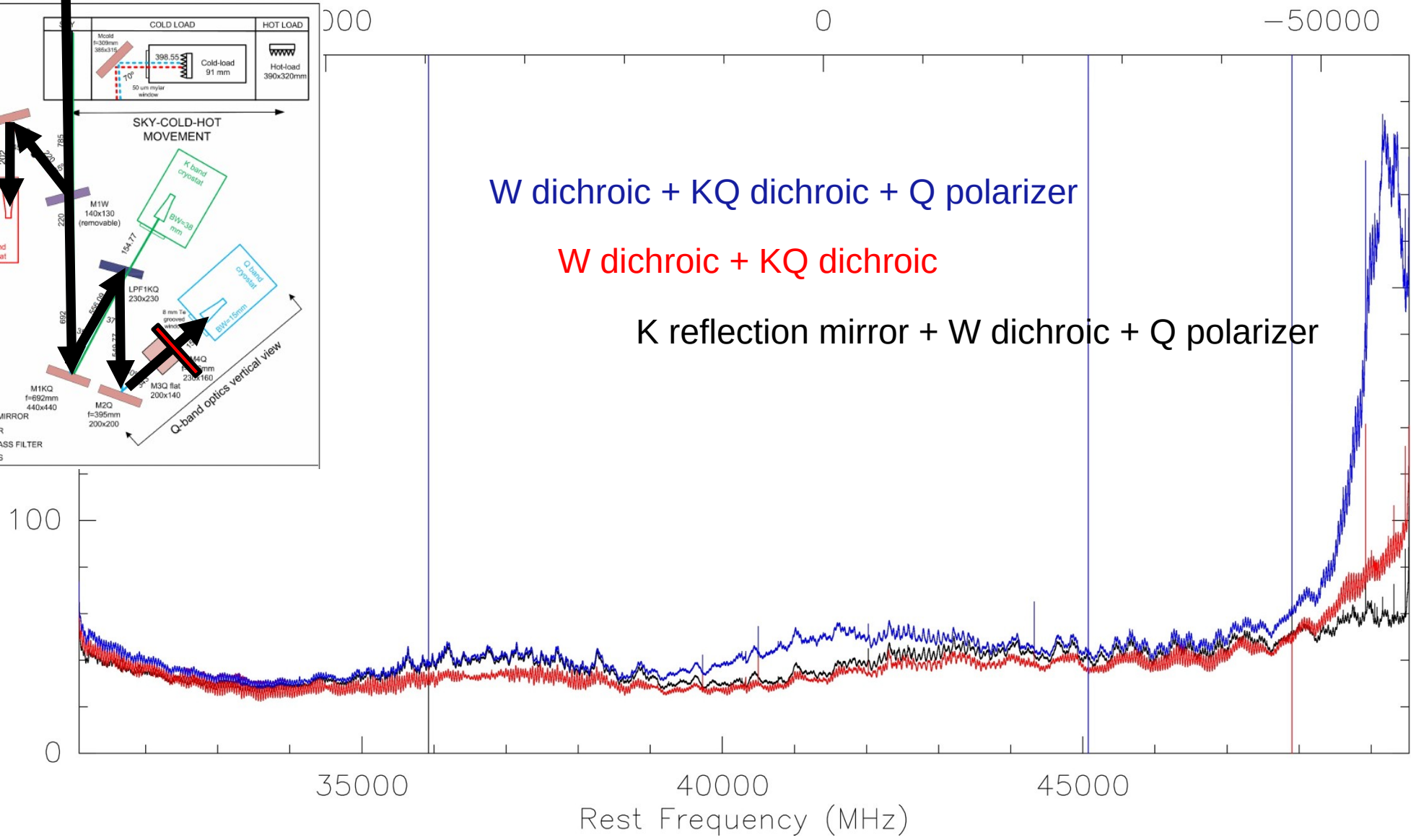
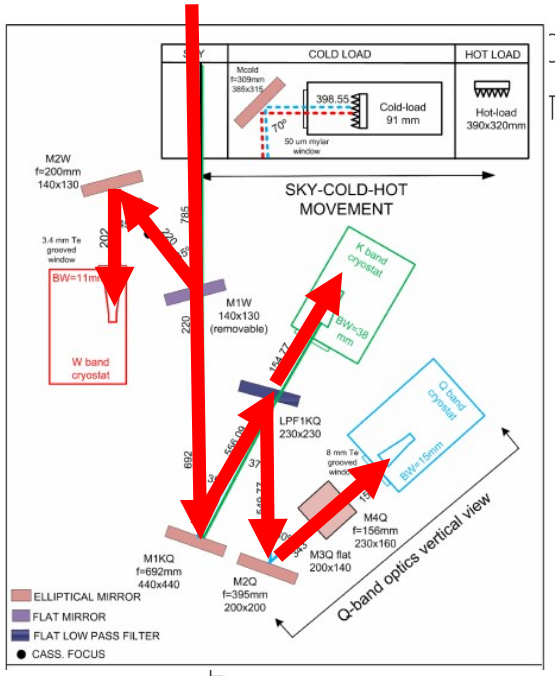
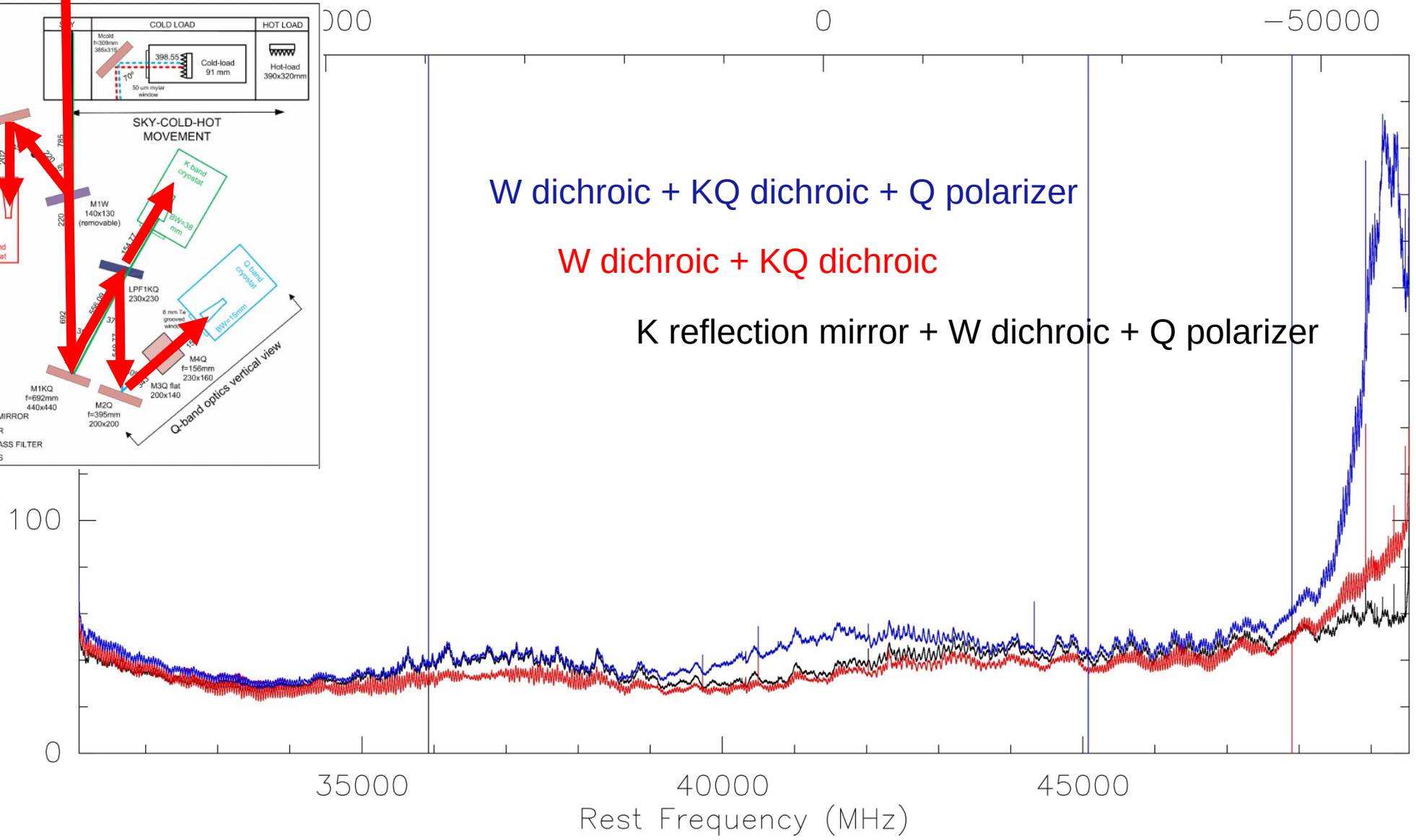




Q-band

The 40m RT multi frequency system: Trec





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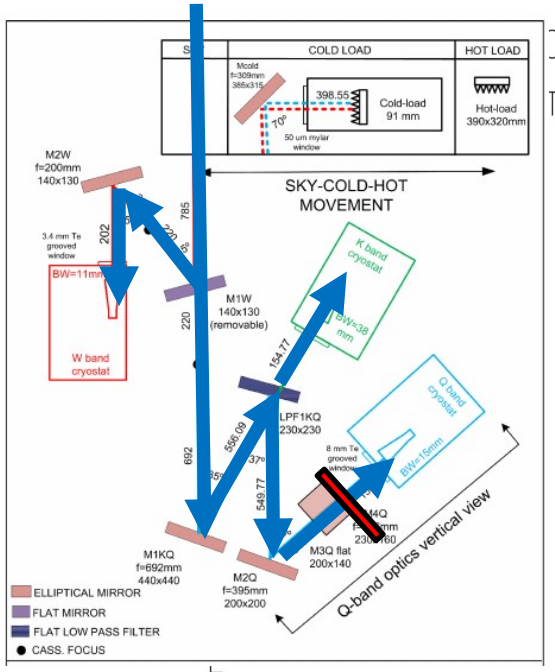

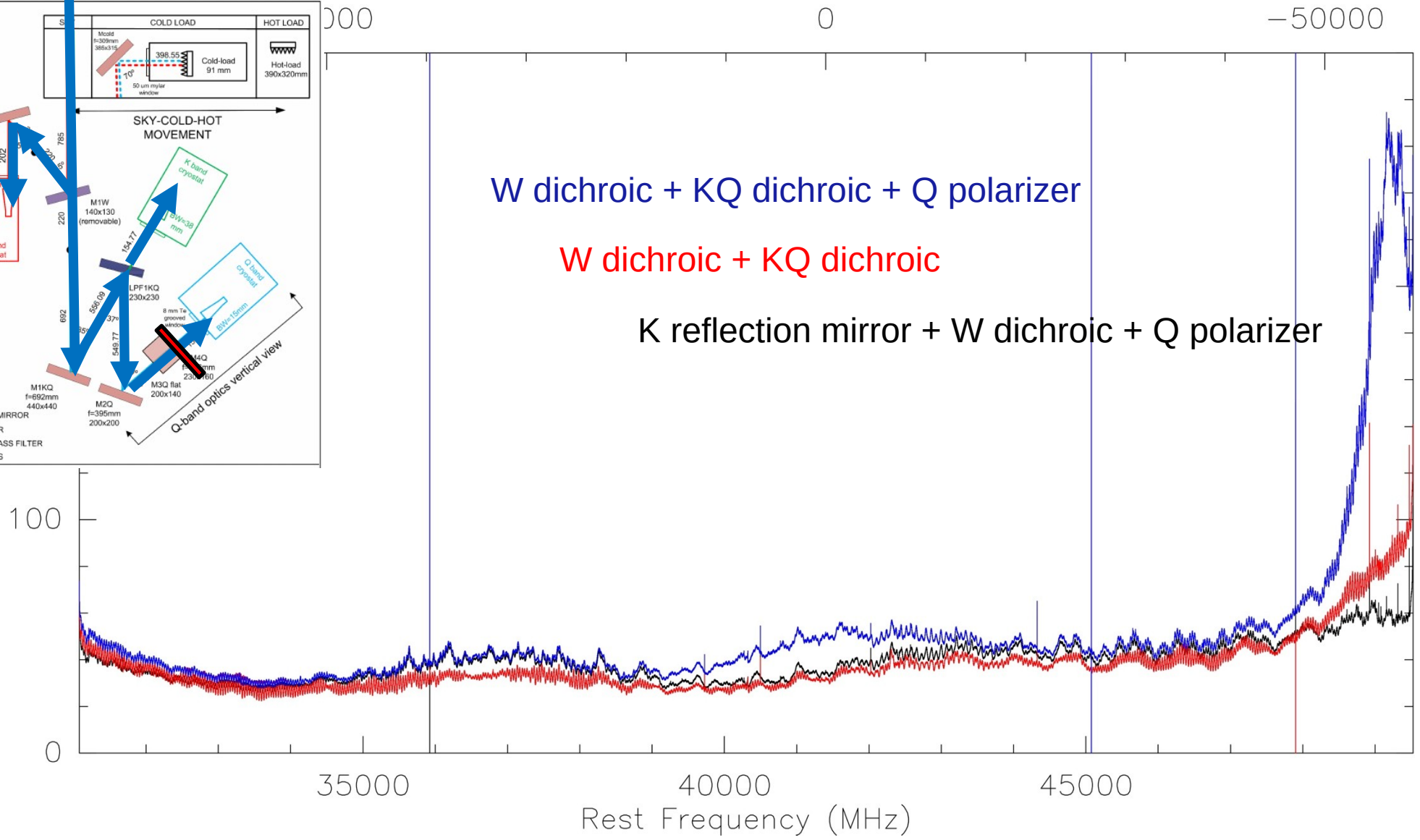

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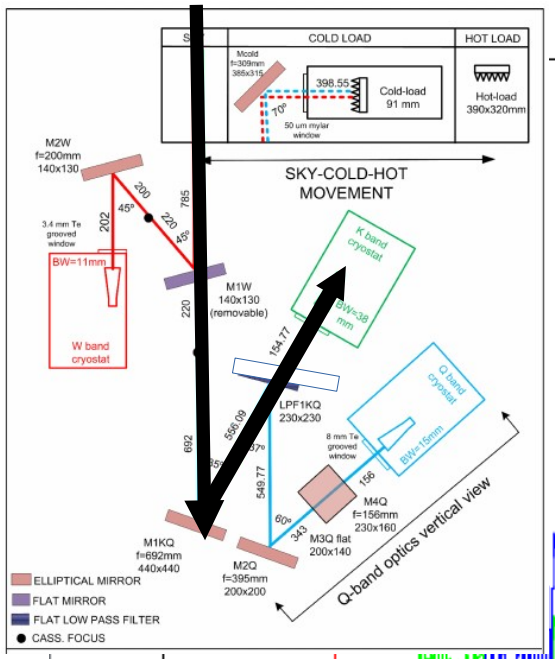


WQ dichroic + KQ dichroic

WQ dichroic

KQ dichroic

No mirror

K-band

50

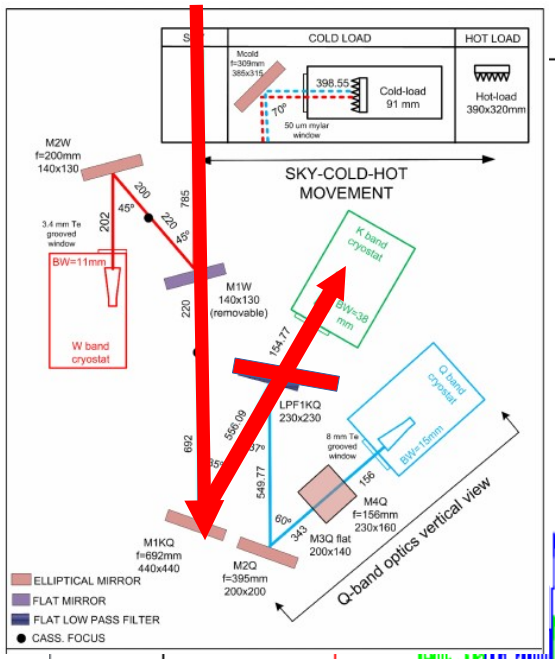
0

20000

25000

30000

The 40m RT multi frequency system: Trec



WQ dichroic + KQ dichroic

WQ dichroic

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No mirror

K-band

50

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20000

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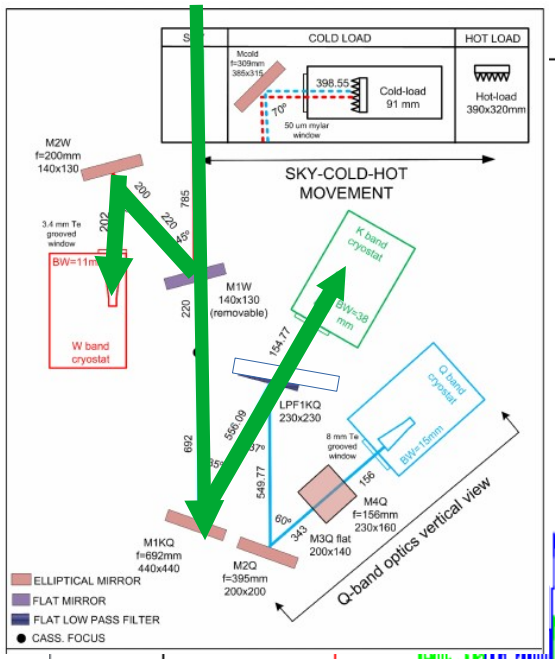

WQ dichroic + KQ dichroic

WQ dichroic

KQ dichroic

No mirror

K-band

50

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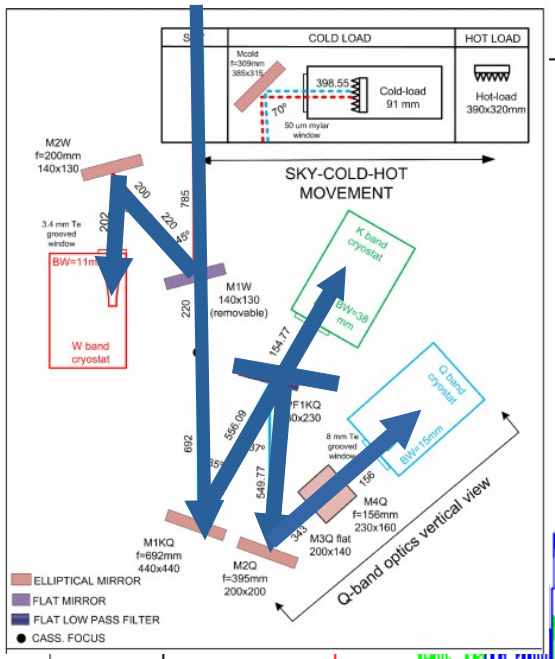


WQ dichroic + KQ dichroic

WQ dichroic

KQ dichroic

No mirror

K-band

50

0

20000

25000

30000

Some quick conclusions on the optics

- The mirrors are **removable** allowing very low Tsys for single bands
- WQ dichroic increases Trec by
  - 50 % Q-band Trec (20 → 30 K)
  - 30% W-band (50k → 70 K)
- WQ **dichroic** (Low Pass filter) increases K-band Trec by **100% (20 k→ 40K)**
- Polarizers should be avoided if the correlation can handle it (PolConvert) or the DBBC4 handles it
- Polarizer + KQ dichroic causes nasty resonances at 49 GHz

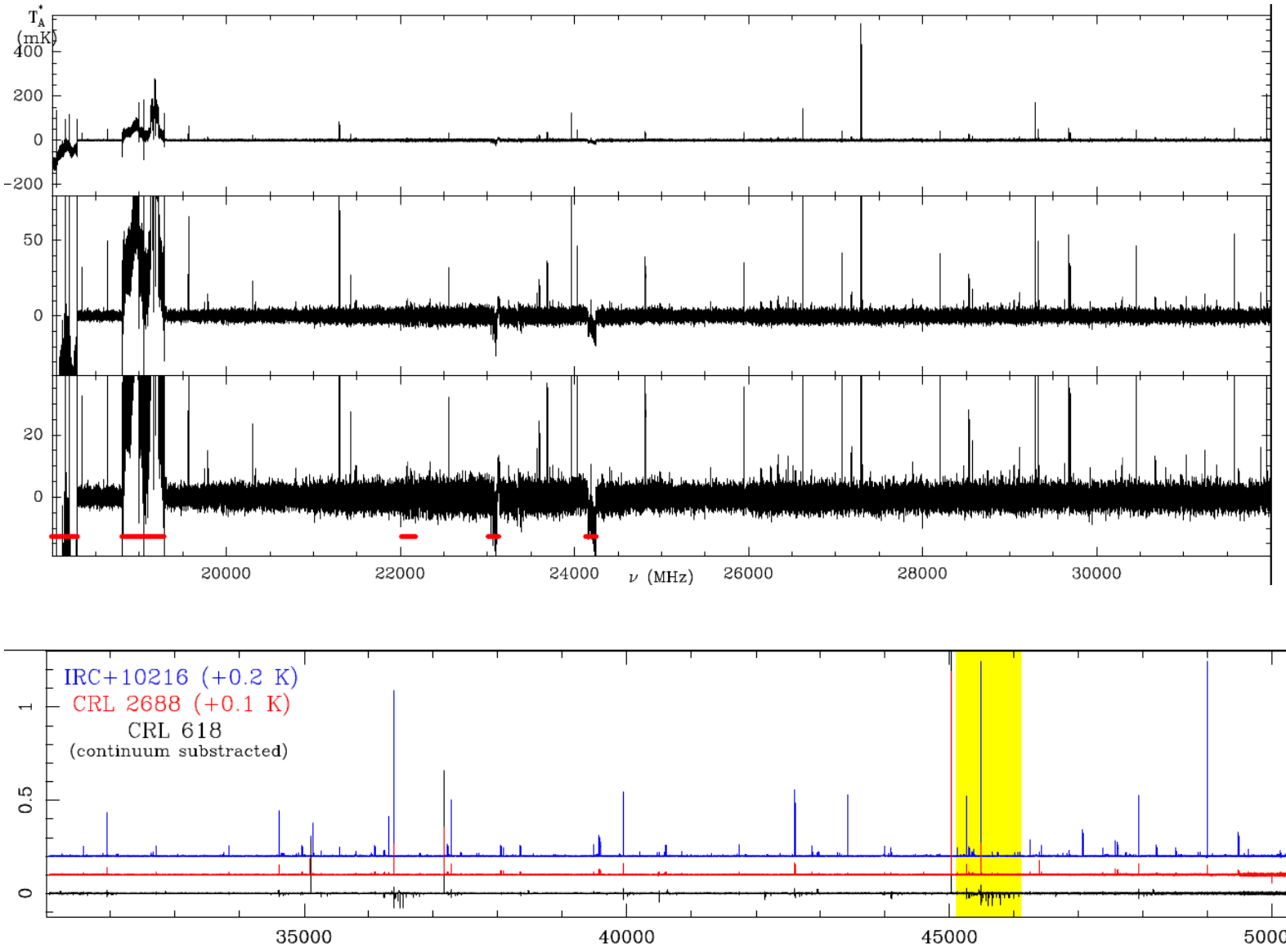
The 40m radio telescope backends room

The 40m radio telescope backends: FFTs

- **18 - 32 GHz receiver**
  1 GHz band width FFTs
  Frequency resolution: 19 KHz
  Installed in 2024 and commissioned in 2024 & 2025
  Lopez-Pérez et al. (2025) Submitted to A&A

- **32 - 50 GHz receiver**
  - 2.5 GHz band width FFTs
  - Frequency resolution: 38 KHz
  - Installed and commissioned in 2019
  - Tercero et al. (2020): A&A

The 40m radio telescope backends: FFTs



The 40m radio telescope backends: VLBI

K-band

Q-band

W-band

512 MHz

10 Gbps
Ethernet switch

up to 4 Gbps

up to 8 Gbps

<60 Gbps

Flexbuff <32 Gbps

K-band

Q-band

W-band

2.5 GHz

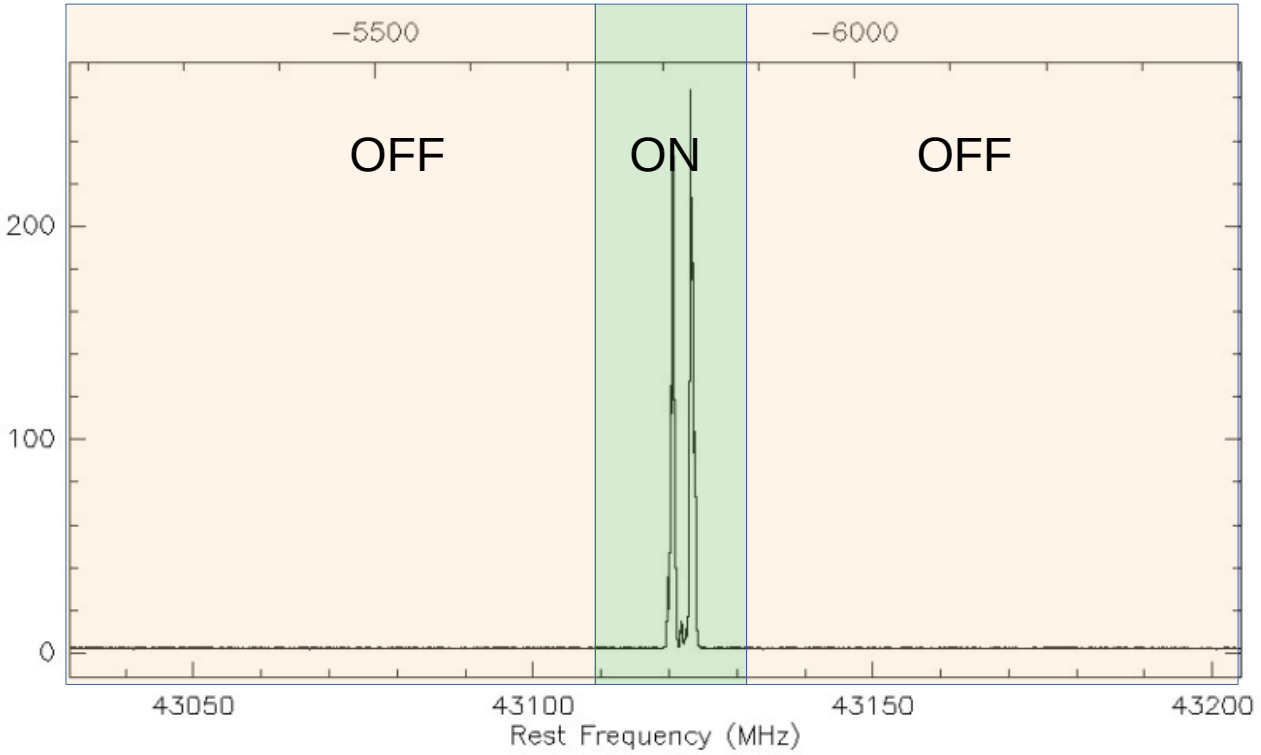
Calibration procedure in VLBI observations:

- **W- & Q- band receivers**
  - Hot & cold loads: 30 seconds execution time (versus 10 seconds)
  - Postob / Preob
  - rxg_file: constant Tcal
  - Sky opacity estimations from ATM

- **K- band receivers**
  - Noise diode, but **new one** still uses hot/cold load
  - Postob / Preob or Continuous cal (for noise diode)

Pointing

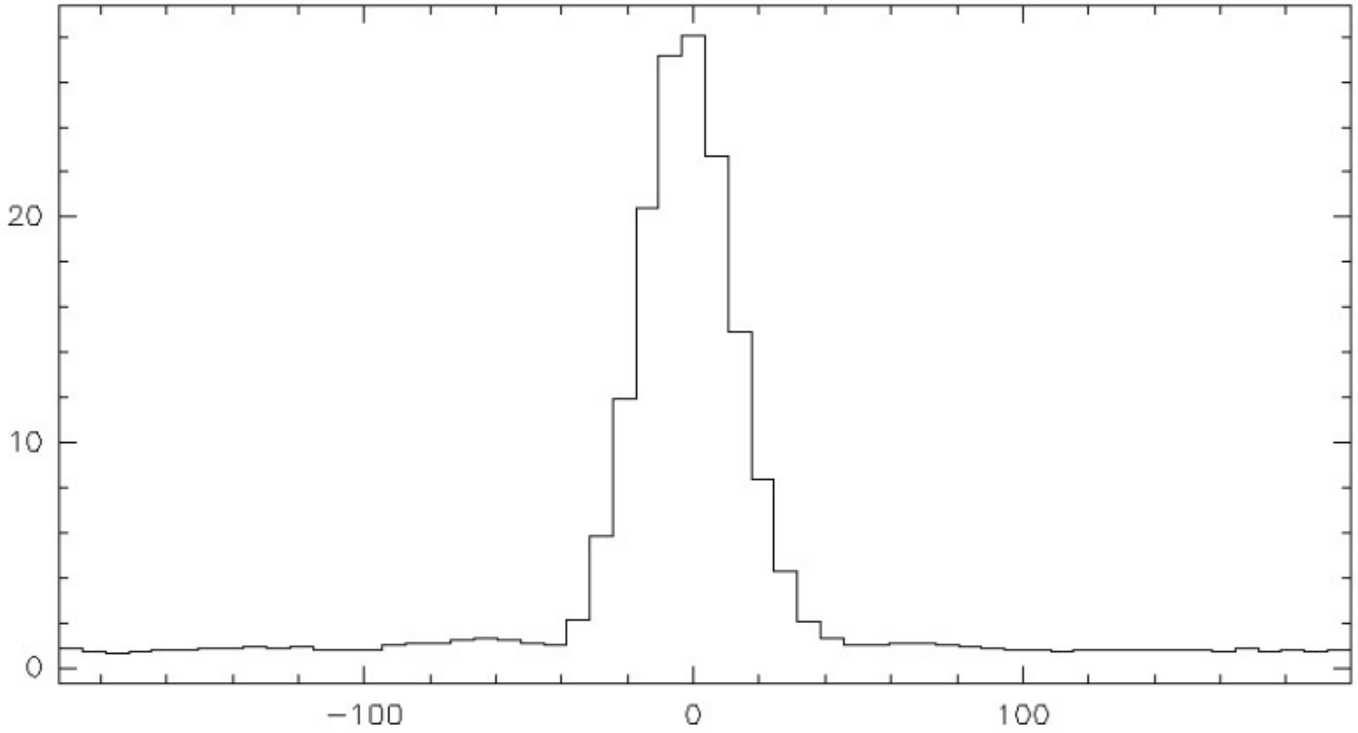
- Relative pointing error W-, Q- and K- band < 5 arcsecs
- Single pointing model for the 3 receivers
- Pseudo continuum: SiO masers at 43 GHz or 86 GHz



- Good strategy at high frequency with atmospheric variability
- Requires a spectral backend

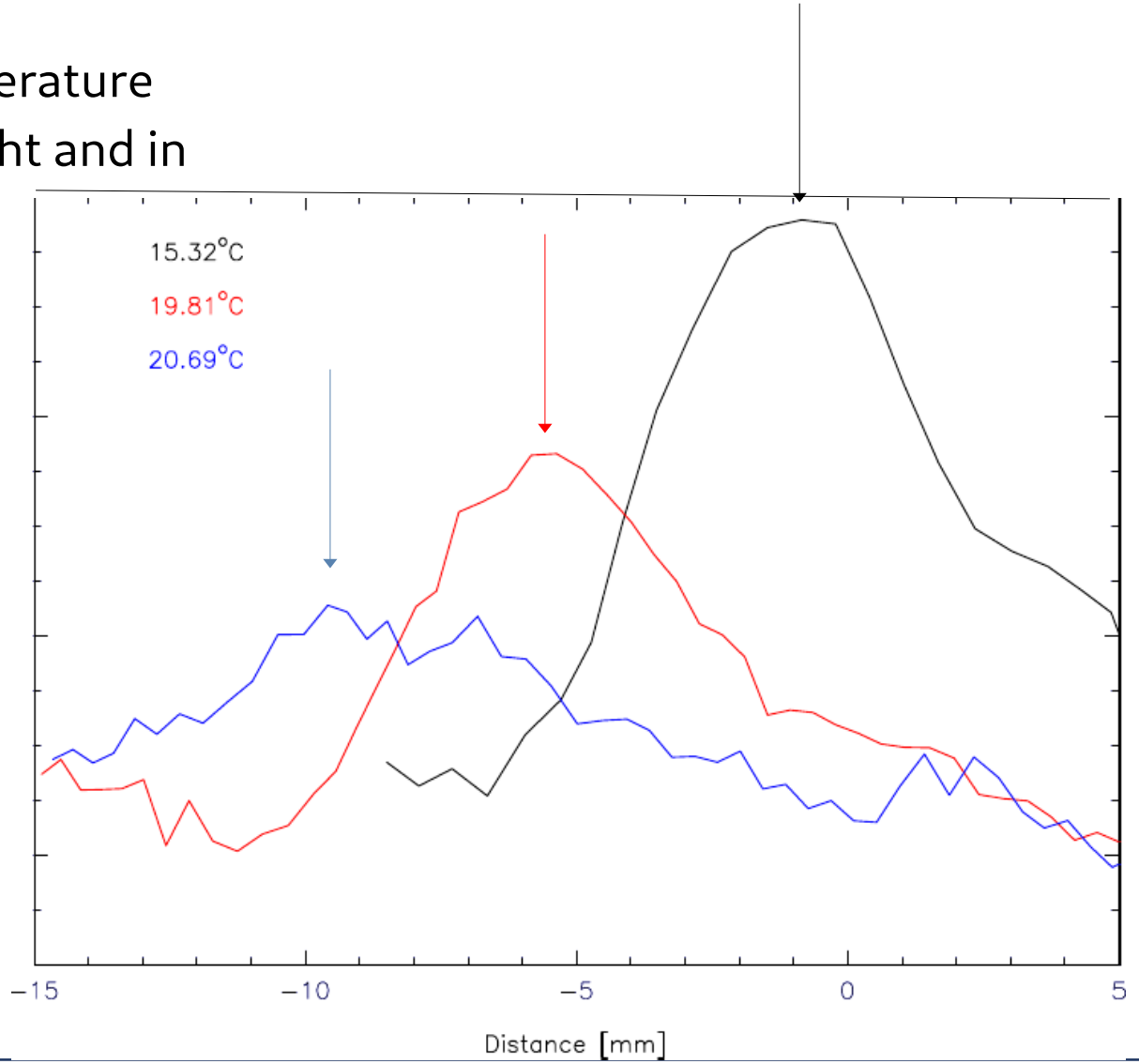
Pointing

- Relative pointing error W-, Q- and K- band < 5 arcsecs
- Single pointing model for the 3 receivers
- Pseudo continuum: SiO masers at 43 GHz or 86 GHz



Focus

- Large variability with temperature
- W- band is advisable at night and in winter (day + night)



Observations since 2018

Observations with KVN [and VERA]

2018 Legacy Q-band / Legacy K- band + DBBC2

2021 Wide Q-band / Legacy K-band + DBBC2

2022- 2023: Few experiments, no fringes. [Missunderstandin in the channel assignements]

2024 October – 2025: Wide Q-band / Wide K-band + DBBC2

2025 June: Wide W-band / Wide Q-band / Wide K-band + DBBC2 + [DBBC3 in parallel]
Subreflector spindle breakdown → No focus

2026 January: Hopefully resume VLBI tri-band observations.

Take away messages

- Minimum of 6 A/D boards: 3 bands x 2 polarizations
- Test, thorougly the backend (**DBBC3**).
- Different modes in KVN and european antennas: check the channel assignments to make it compatible with non-DBBC3/non-DBBC2 backends and use the Zoom mode in DifX: .
- Pointing and focus isssues at high frequencies impact efficiencies.
- Amplitude calibration with loads takes time in the scans.
- Linear polarization → Circular polarization requires phase cal if using PolConvert

Pablo de Vicente
Observatorio de Yebes
Cerro de la Palera S/N, Yebes
19141 Guadalajara, Spain

Tel: +34 949 290 311
Email: p.devicente@oan.es