



Overview of ALMA Band 2

Neil Phillips





Outline

- Very brief history of the wideband Band 2 development
- Tuning opportunities of wideband+2SB Band 2
- Receiver architecture
 - Some detail on the Warm Cartridge Assembly (not covered by other talks)
- Brief commissioning status
- Cycle-13 offering and plans for future cycles



Very brief history of the wideband Band 2

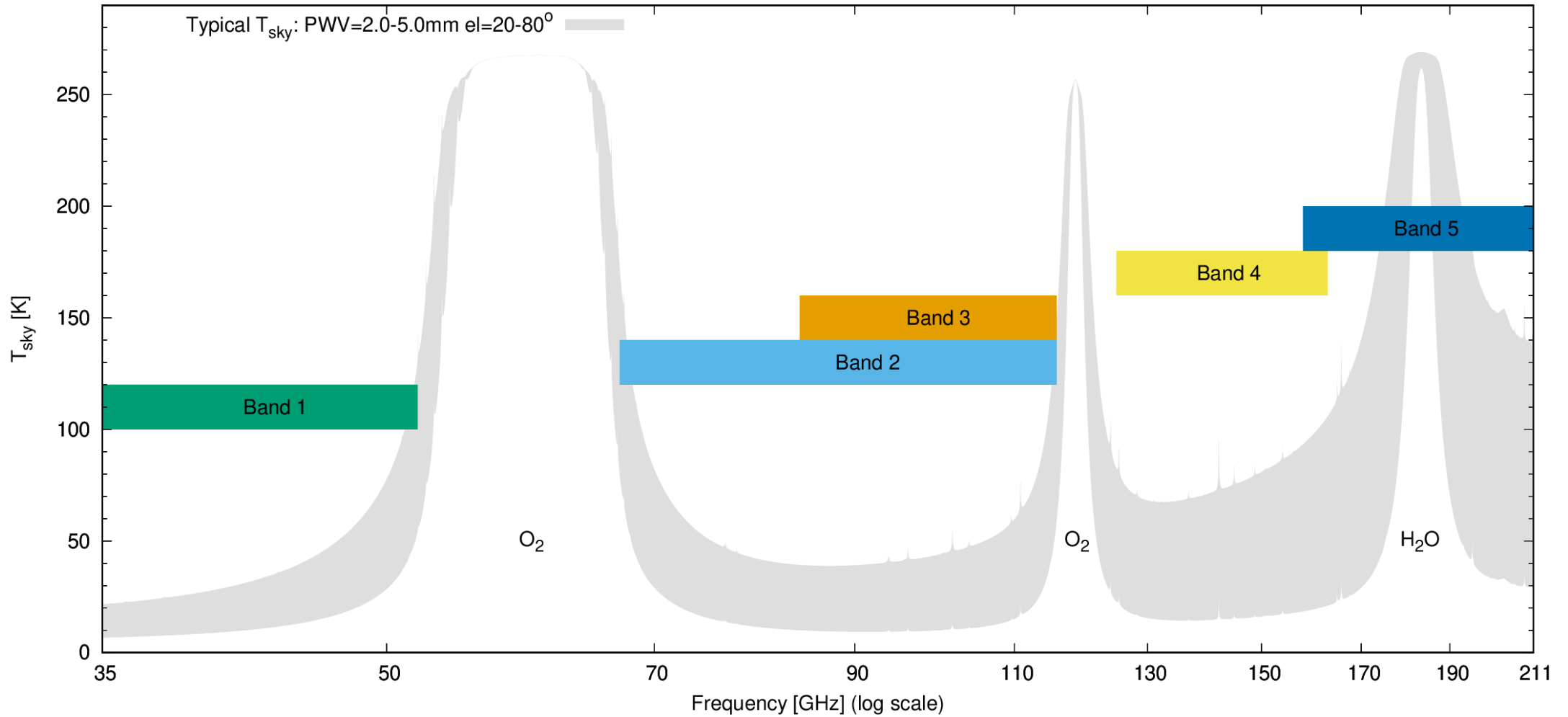
- In development since 2012, first light 2023, completing production and first PI offering in 2026
 - At least 14 years with many groups and people involved!
 - More details in following talk by F. Villa
- Science cases for wideband Band 2 developed previously:
 - Beltrán et al. 2015 “*Italian Science Case for ALMA Band 2+3*” (arXiv:1509.02702)
 - Fuller et al. 2016 “*The Science Case for ALMA Band 2 and Band 2+3*” (arXiv:1602.02414v3)
 - Mroczkowski et al. 2019 “*Wide Bandwidth Considerations for ALMA Band 2*” (arXiv:1905.09064)
 - Looking forward to seeing the latest cases in this workshop!
- Cryogenic RF LNA development was key => low noise without limited bandwidth
 - Optimising other components for wide RF and IF was also challenging
- Developed from the last construction band into the first WSU band



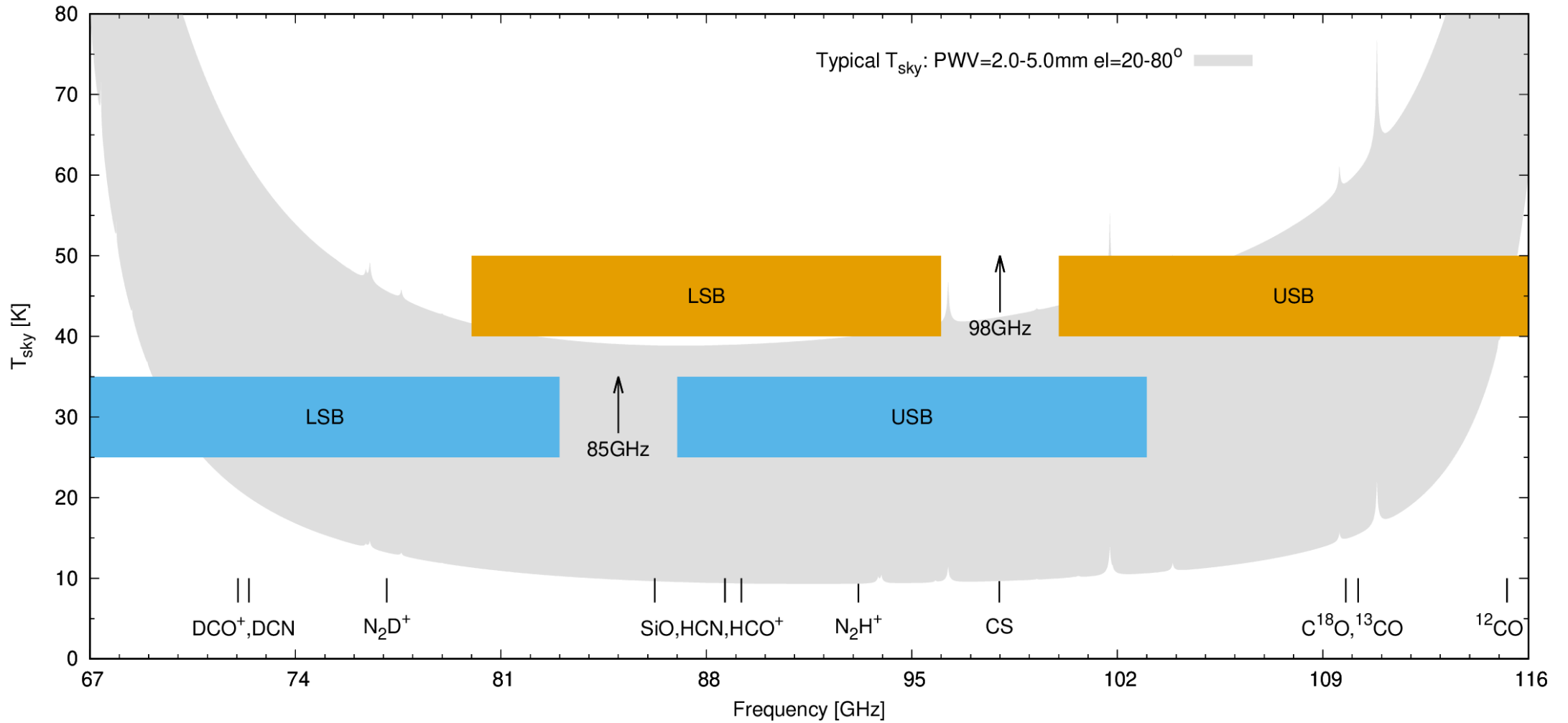
Very brief history of the wideband Band 2

- Originally envisaged Band 2 specifications from ALMA construction times:
 - RF 67–90 GHz (LO 79–94 GHz)
 - Single Sideband (SSB): LSB
 - IF 4–12 GHz (8GHz total BW)
 - $T_{RX} < 30K$ over 80% of 67–90 GHz
- Implemented Band 2:
 - RF 67–116 GHz (LO 79–104 GHz)
 - Sideband separating (2SB)
 - IF 2–18 GHz (32 GHz total BW – meets WSU goal)
 - $T_{RX} < 30K$ over 80% of 67–90 GHz (unchanged)
 - Full RF range accessible with legacy back-end (IF 4–12 GHz)

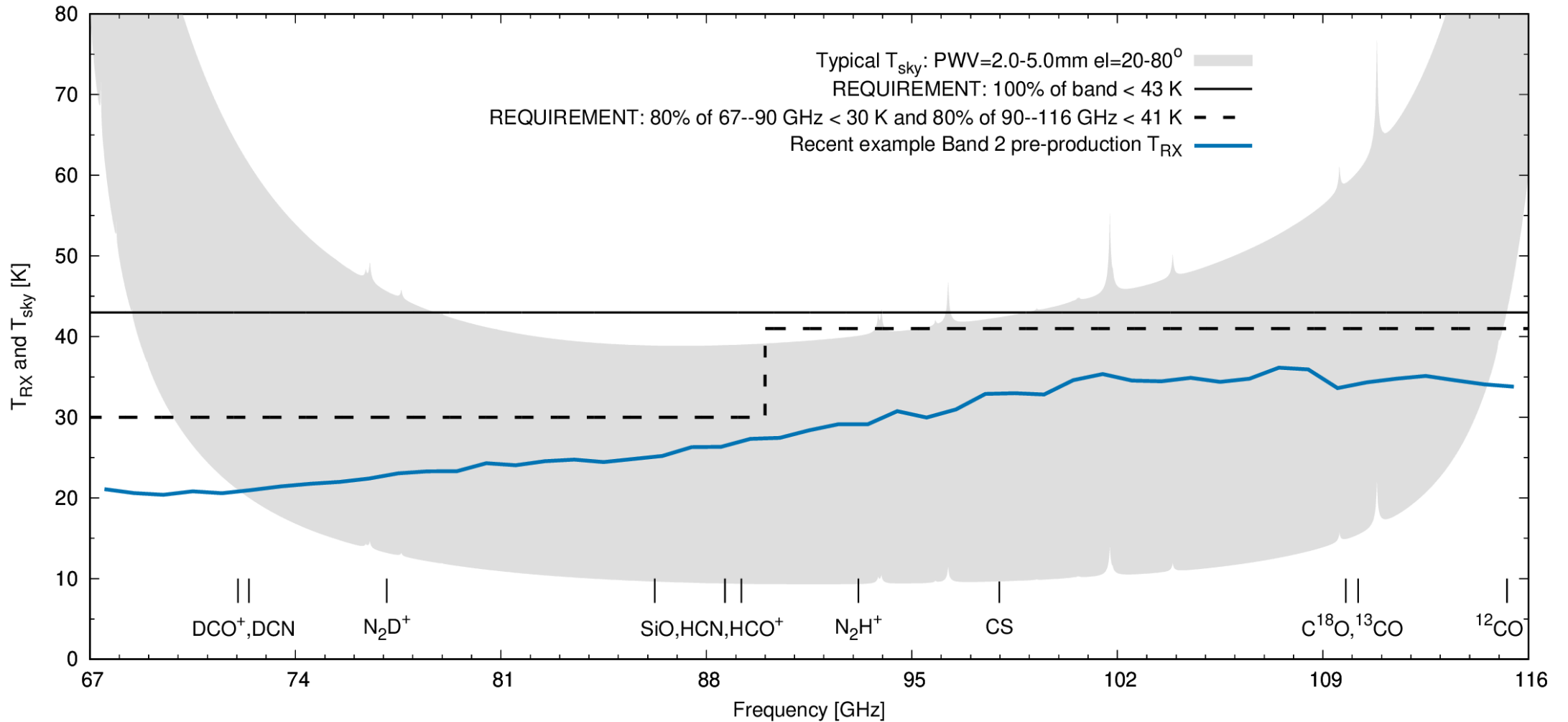
Band 2 RF band in context



Band 2 IF bands example in WSU



Band 2 receiver noise

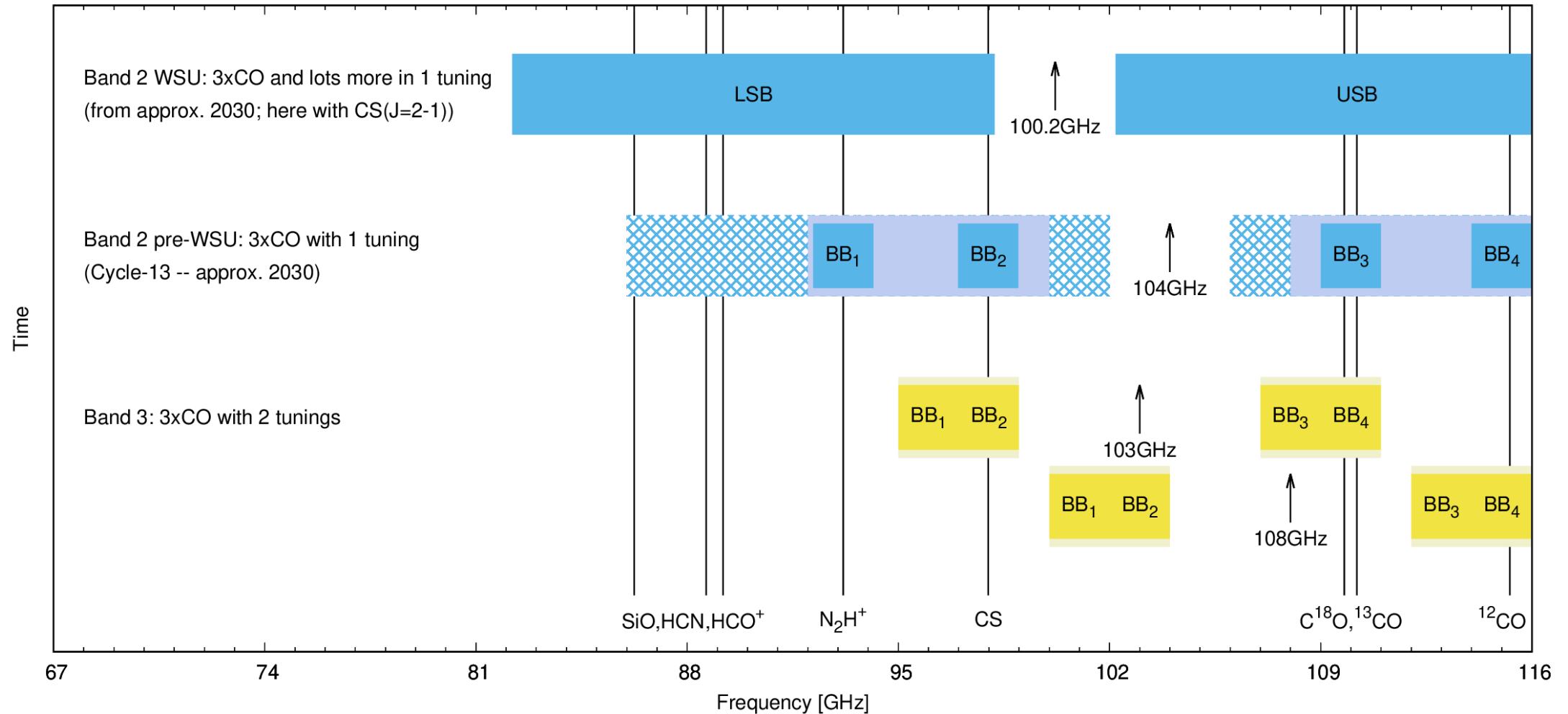




Wideband Band 2 advantages

- Tuning flexibility in general
 - e.g. more line combinations possible within a single tuning
 - No arbitrary boundary between bands in the 3mm window
 - Remember: you can put 2 BBs in each sideband or all 4 BBs in one sideband
- Instantaneous fractional bandwidth grasp
 - e.g. for SED characterisation (often multiple continuum emission mechanisms)
 - Will increase further with WSU (24GHz now, 36 GHz then)
- Spectral scan efficiency
 - Any range within 3mm window

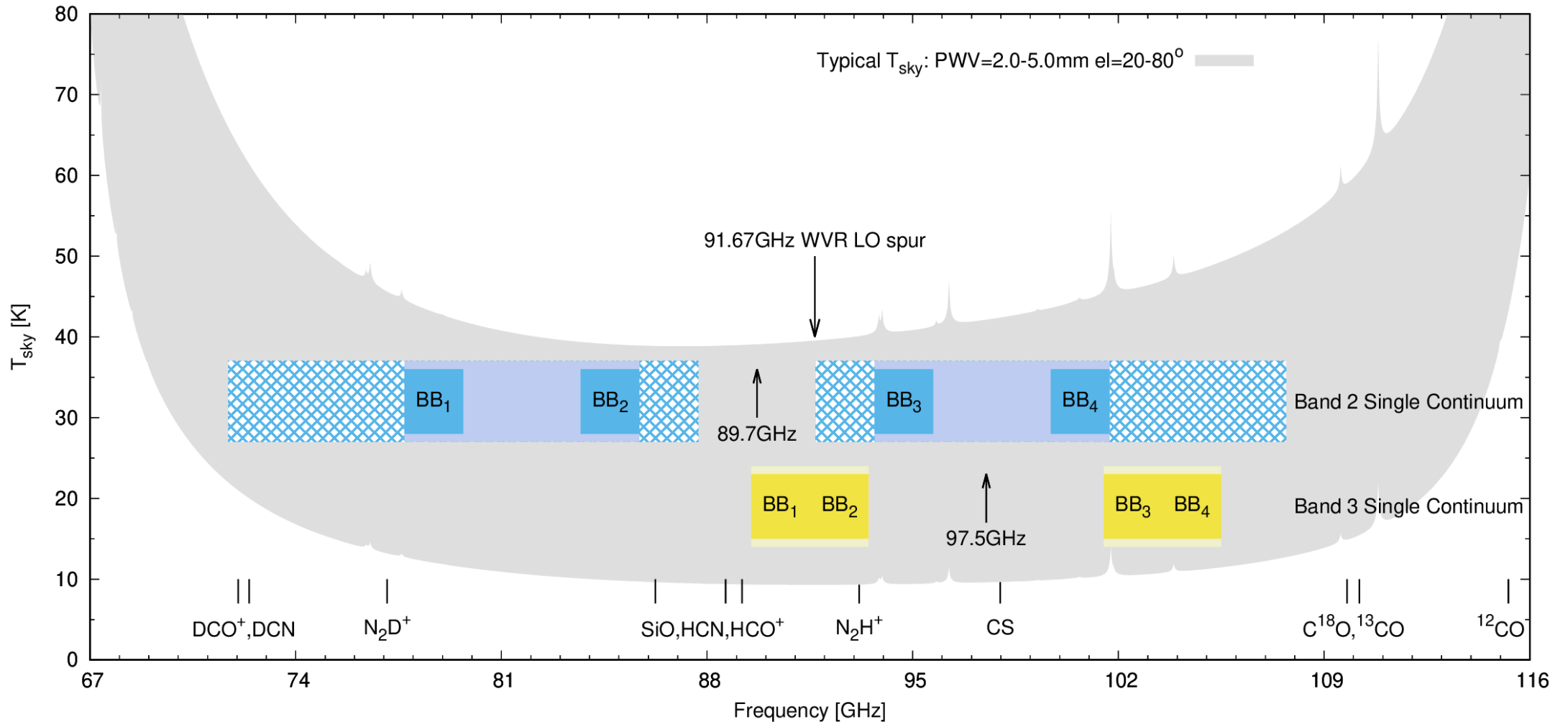
Tuning flexibility: current system and wide LO



Continuum: fractional BW and SED sampling



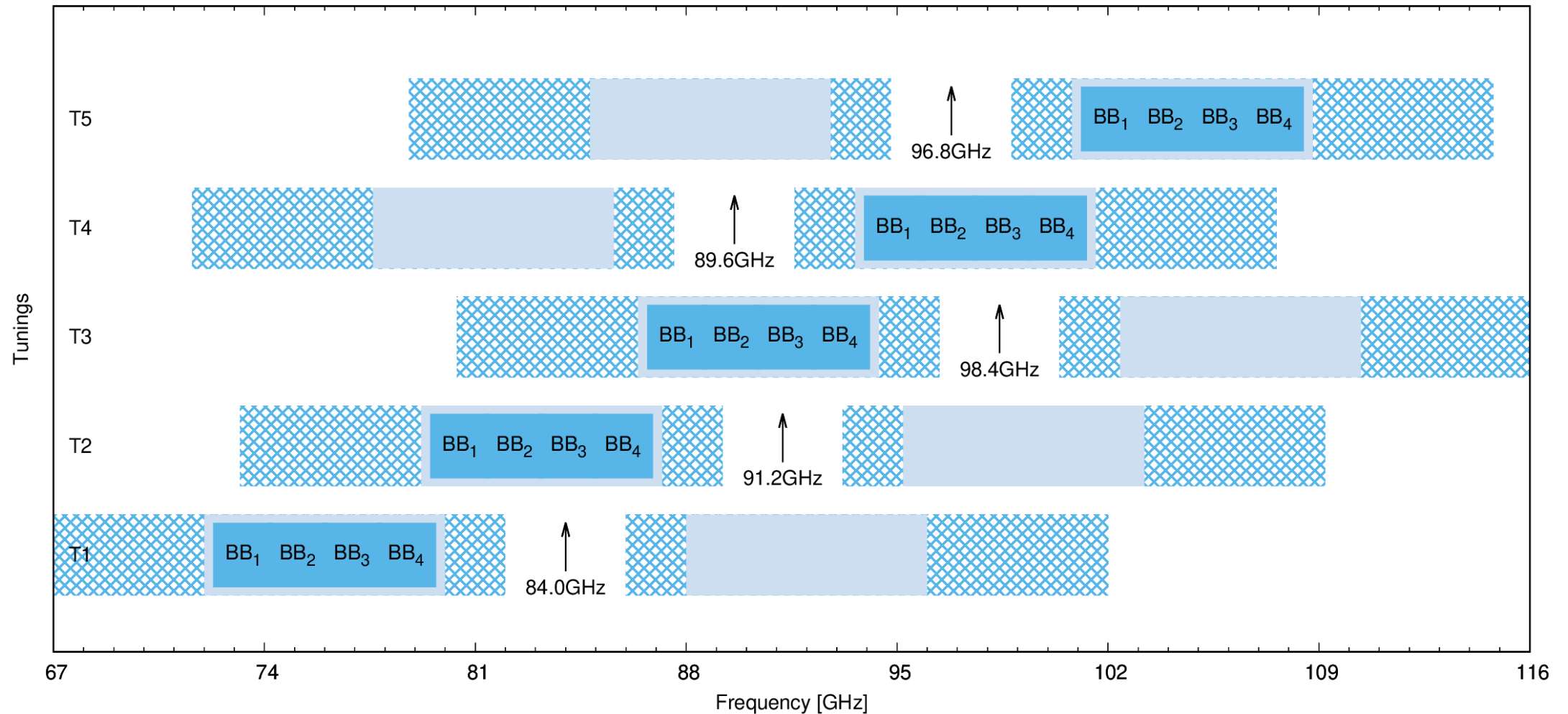
Fractional BW span: approx. 40% with WSU, 25% with legacy system, 17% with Band 3



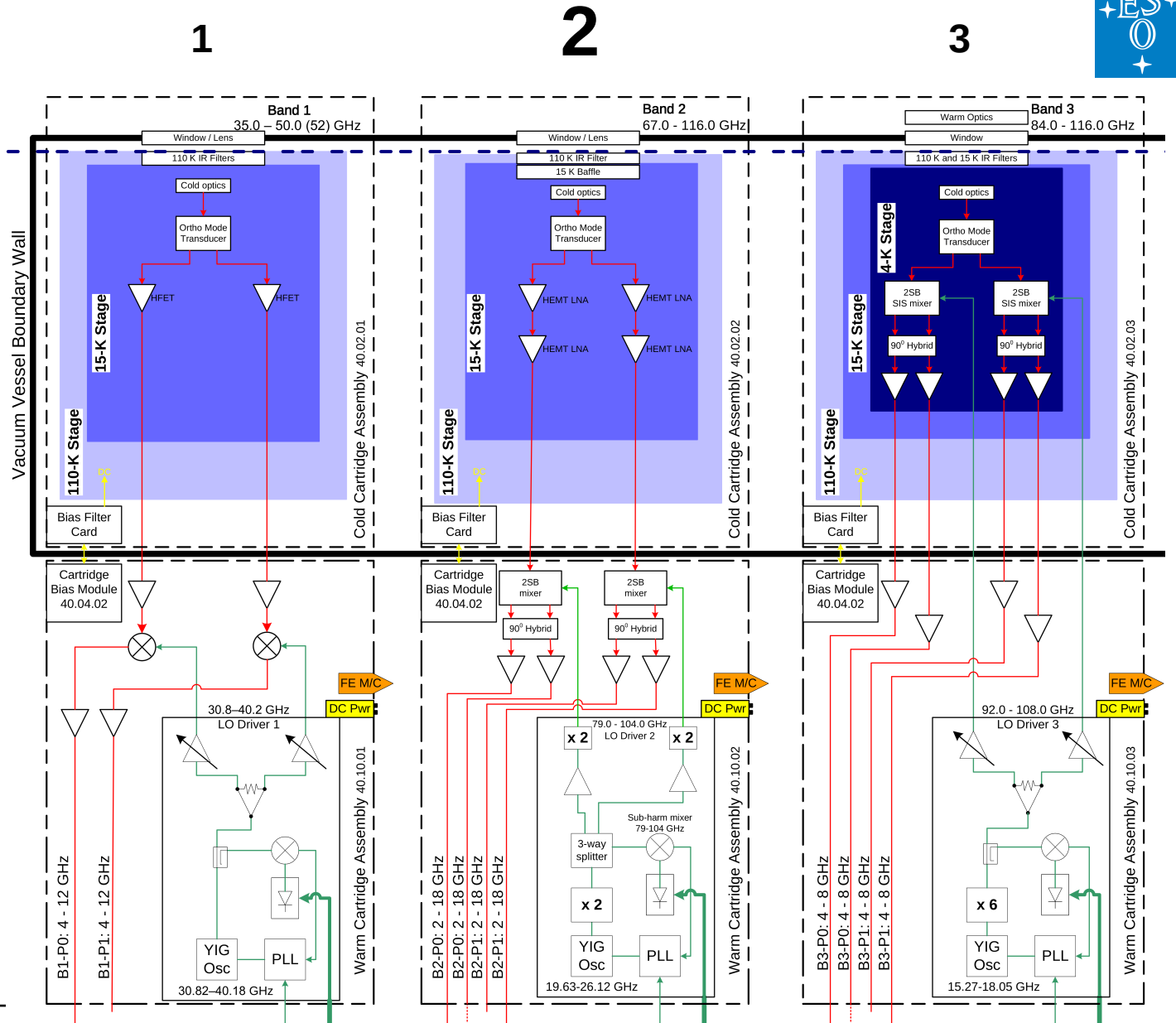
Efficient spectral scans with 1.875GHz SpWs



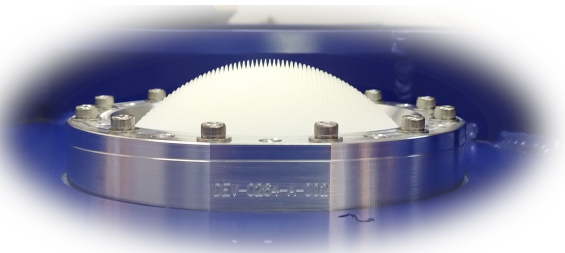
Placing all 4 BBs in one sideband allows spectral scans with uniform coverage



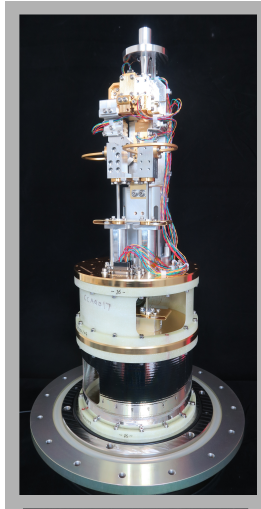
Receiver architecture



Receiver architecture



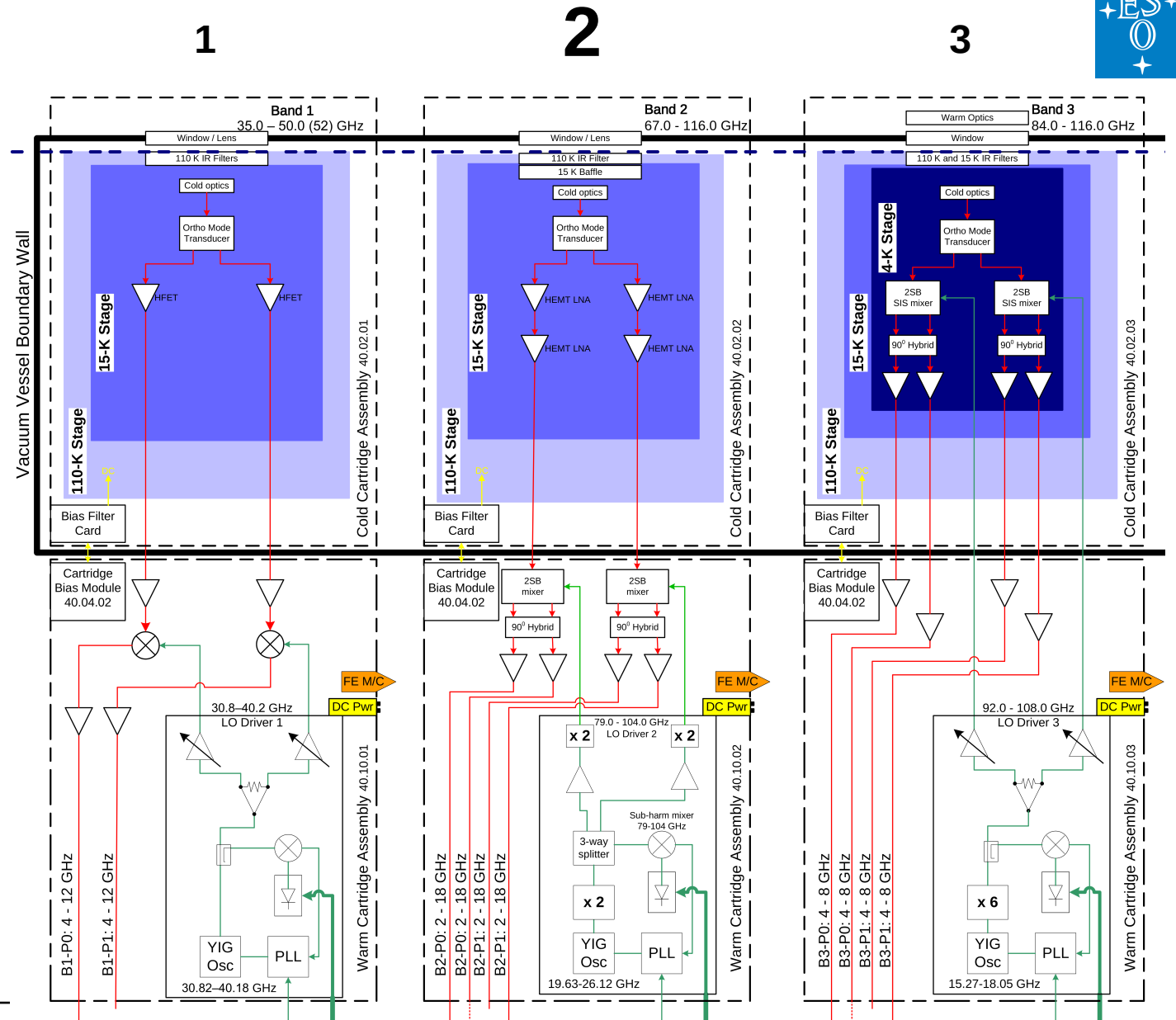
lens



Cold Cartridge Assembly



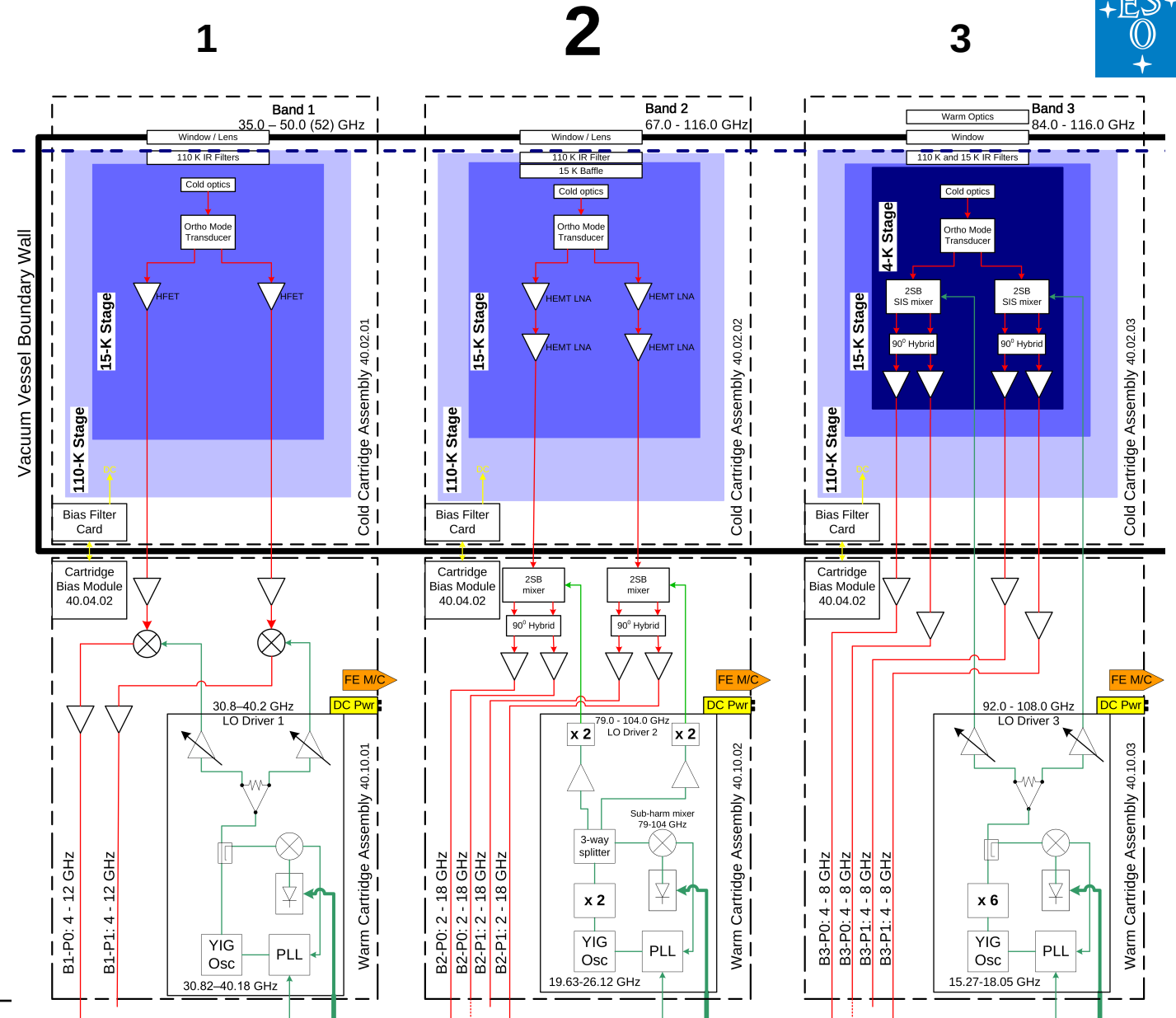
Warm Cartridge Assembly



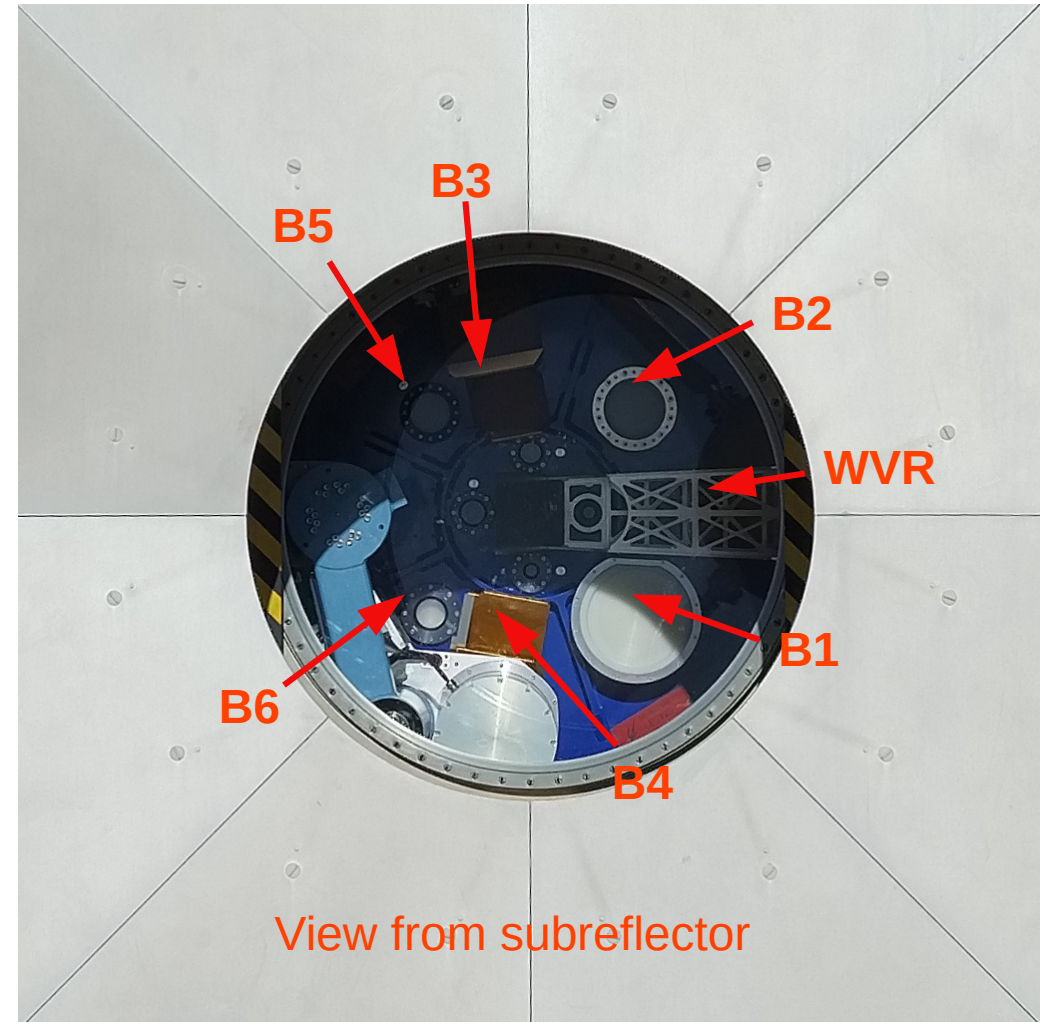
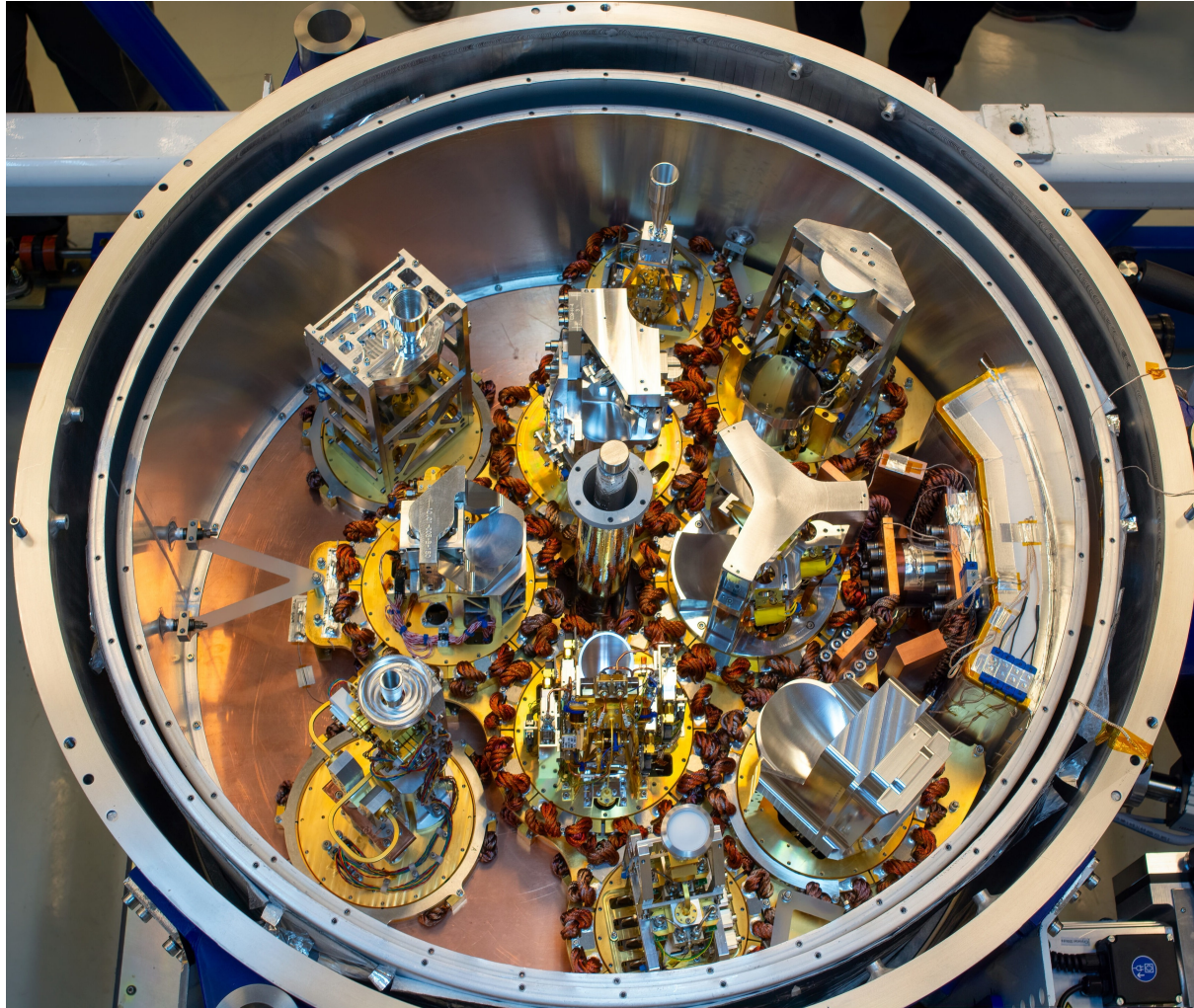
Receiver architecture

- Lens / vacuum window (UHMWPE)
- Cold Cartridge Assembly:
 - 15 and 110K stages (no 4K interface to B1,2 slots)
 - Low noise amplifiers (LNAs)
- Warm Cartridge Assembly:
 - LO generation
 - Sideband separating downconverter

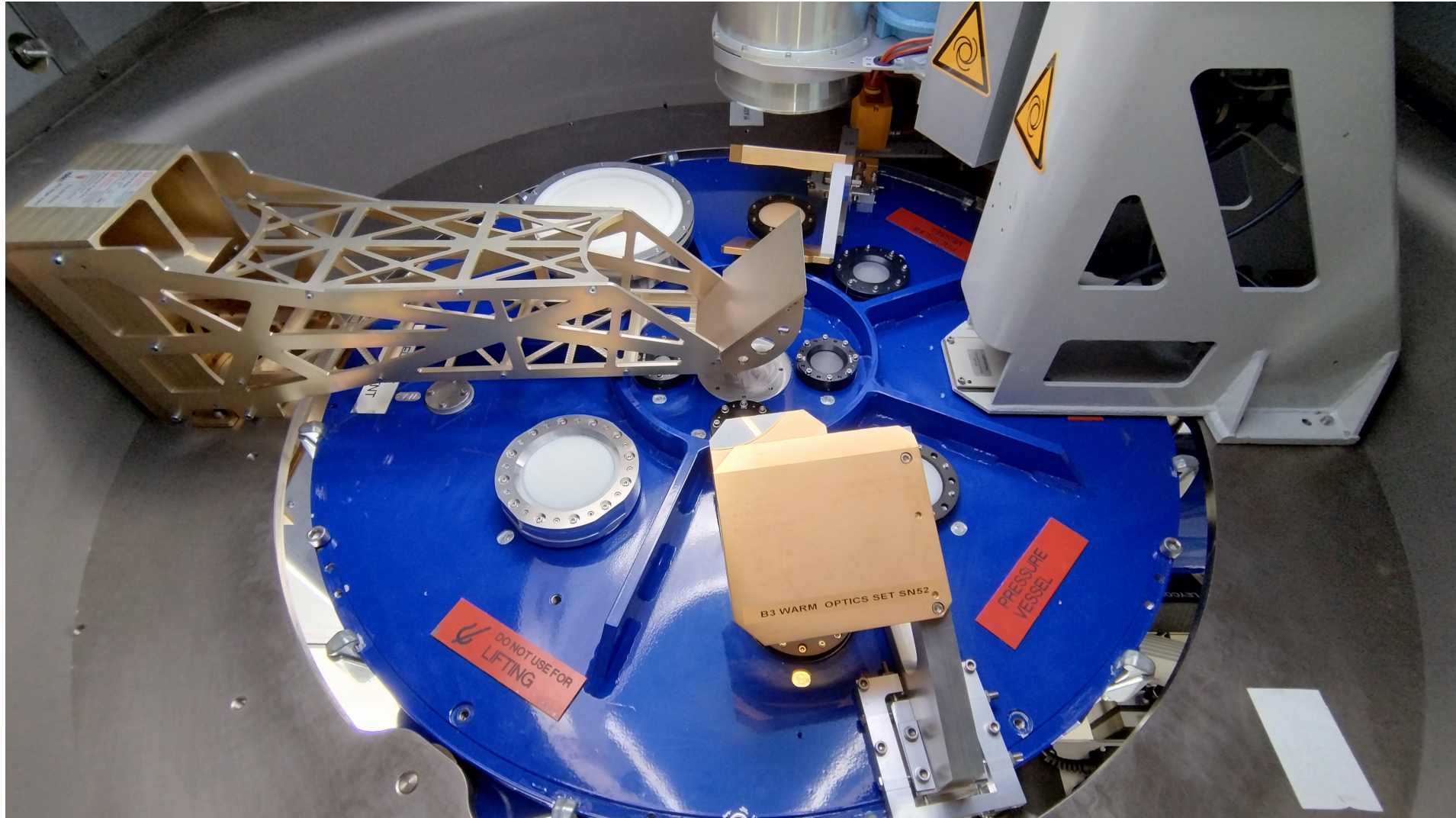
Cut-out of ALMA system block diagram (rev. T) showing Bands 1, 2 and 3



CCA in ALMA cryostat and FE in antenna



FE with Band 2 in antenna



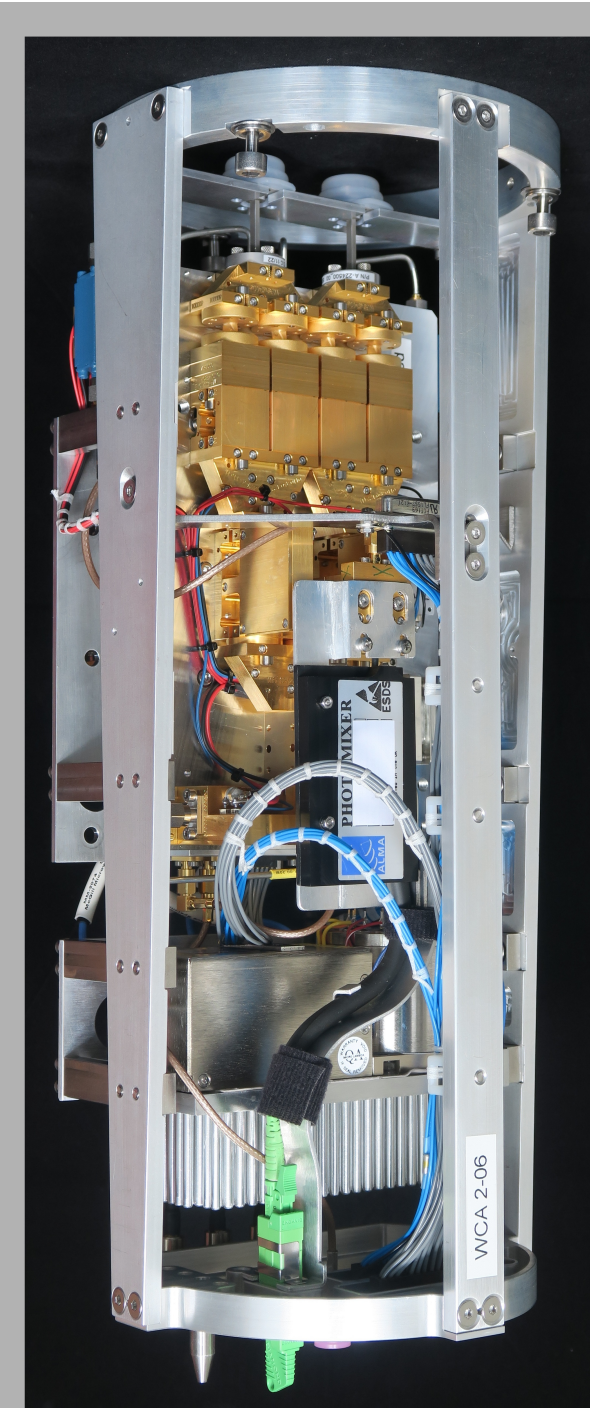
Cold Cartridge Assembly (CCA)

- Mostly thermalised to 15K (no 4K stage)
- $>\sim 40\text{dB}$ (10^4) RF gain
- Delivered by consortium: NOVA + GARD + INAF; includes:
 - Horn+OMT provided by NAOJ
 - 1st stage LNA from MPI/IAF; 2nd stage LNA from LNF
 - Isolator from RPG
 - Waveguide components for RF signal transport
 - Reflective baffle as part of 15K filter alternative
 - Bias module provided by ESO
- **See following talks by F. Villa and A. Camisasca**



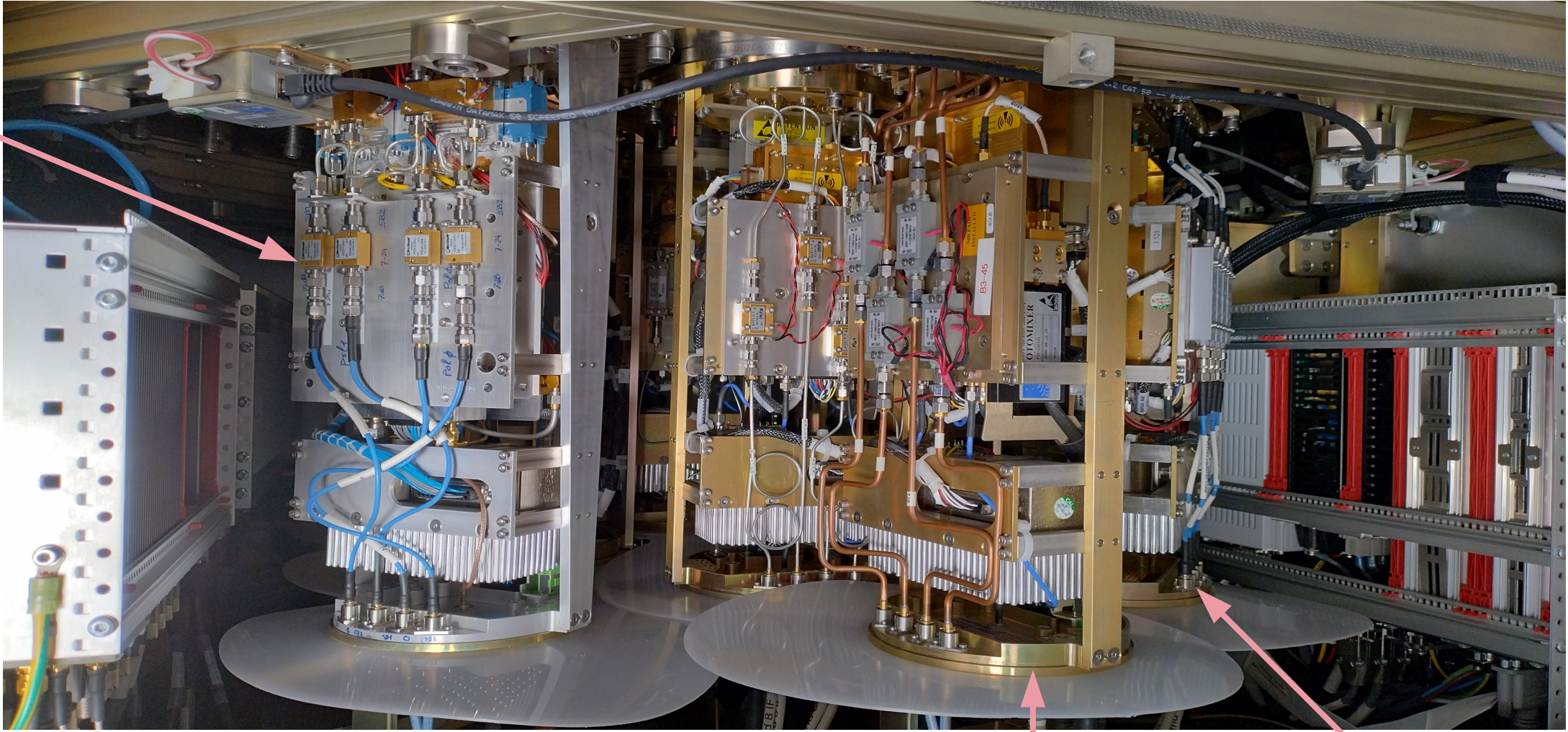
Warm Cartridge Assembly (WCA)

- Responsible for a lot of the receiver functionality
- Delivered by NOVA; includes (among other things):
 - 2SB Down-Converter Unit inc. LO chain (DCU; subcontracted to RPG)
 - YIG-tuned oscillator
 - PLL+M&C (NOVA/SRON, adapted standard ALMA design)
 - Photomixer (RAL, provided through ESO)
 - Per-channel selected IF gain slope equalisers and attenuators
- IF cables for USB outputs provided by ESO



Pre-production WCA in an FE assembly

B2



B3

B5

WCA Down-Converter Unit from RPG/R&S

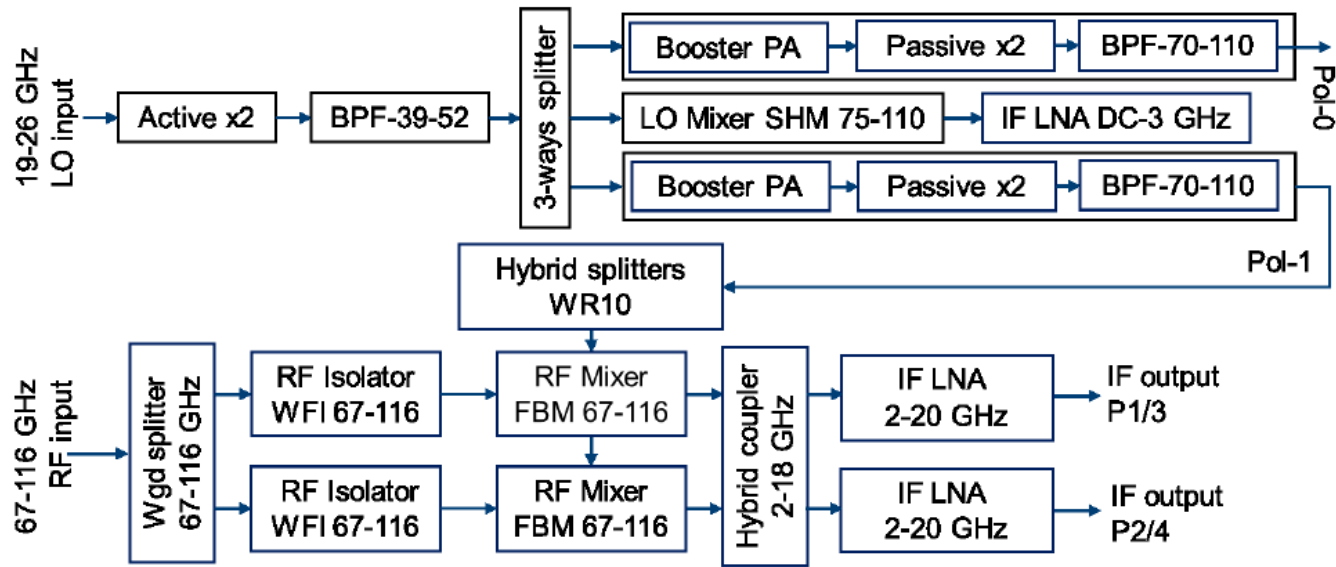
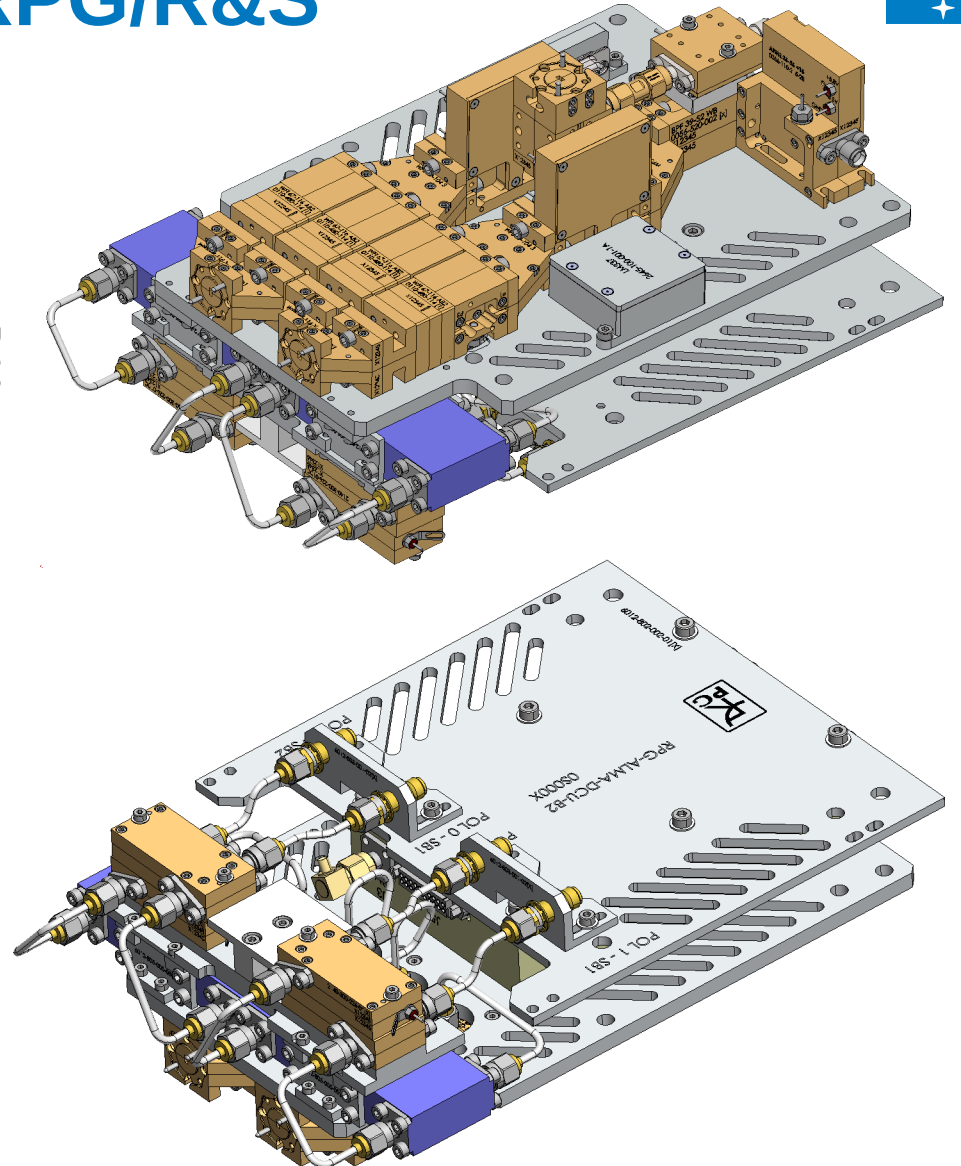
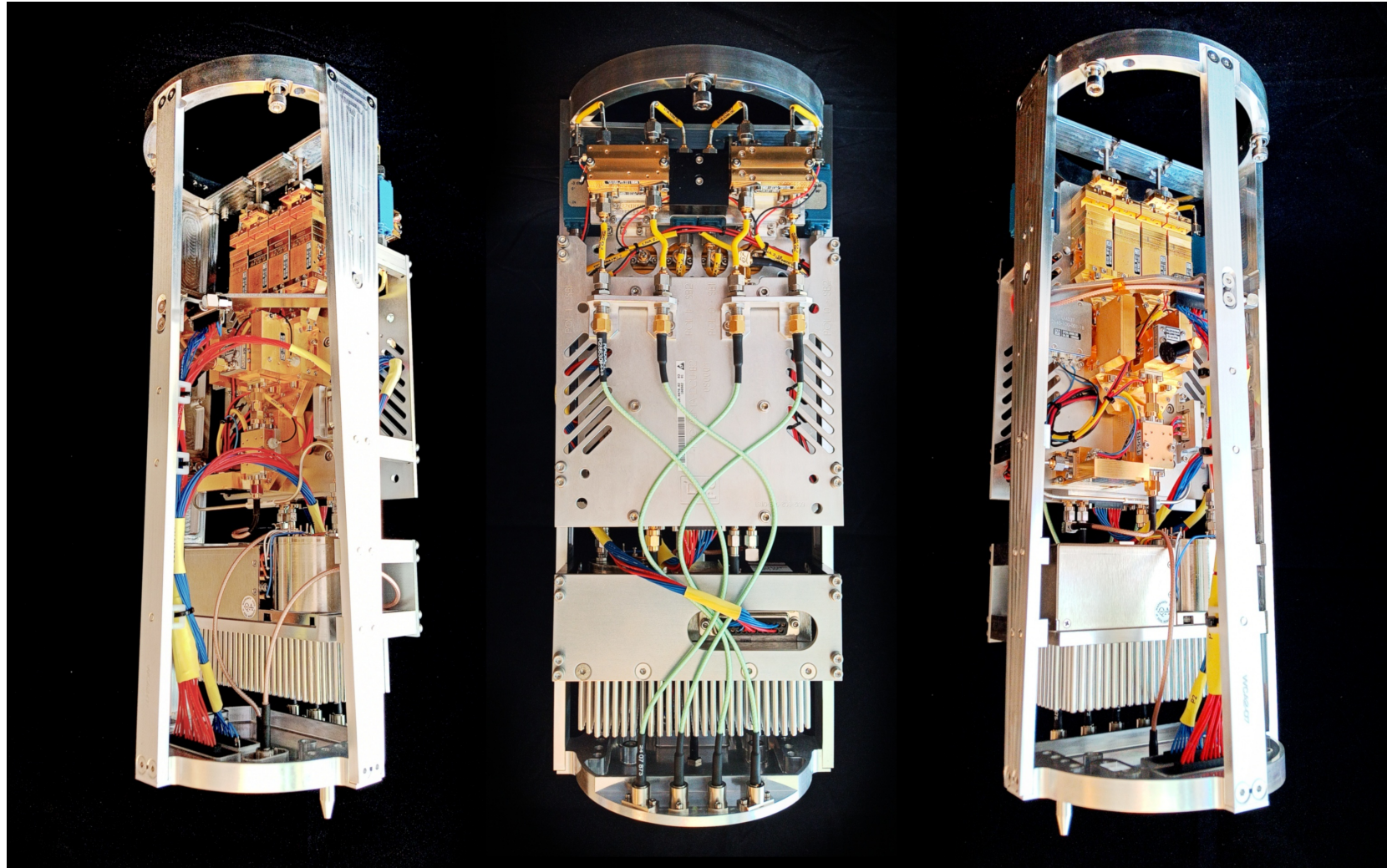


Figure 2 Schematic diagram of the 2SB down-converter architecture selected from pre-production.



Production WCA



Commissioning summary / open issues

- Integration and commissioning in 12m antennas (2023–2026) has generally gone smoothly
- A highlight: polarisation D-terms are impressively small and there are no narrow features
- One software issue has complicated automated pipeline calibration: the source catalogue was not returning fluxes between 52–84 GHz
 - Now partially addressed (B1 algorithm up to 84 GHz, B3+ algorithm above)
 - This was partly why SV data release has taken a while
- First 7m antenna received Band 2 recently => 7m commissioning to start soon
- TP currently blocked by unstable standing wave between receiver and Cassegrain hole membrane
 - Also blocks Band 1 TP – they are both close to perpendicular to the membrane
- 12m wide-field polarisation and VLBI/Pulsar not commissioned yet but no blocker
- Solar needs technical investigation (e.g. develop bias detuning) that may take some years



Cycle-13 offered capabilities

- 12m array only
 - Currently on track for >43 12m antennas at the start of Cycle-13
 - 31 in 12m antennas today, several in FEs in the lab at OSF ready to go up
- All interferometric modes with 12m array except:
 - Solar
 - VLBI/Pulsar (phased array)
 - Wide-field polarisation
- Quoted limits (e.g. mosaic pointings) and uncertainties for other low frequency bands apply

Band 2 vs. 3 selection applied for Cycle-13

- If the SpW/BB frequencies can be achieved in Band 3 => use Band 3
- If not, but they can be achieved with Band 2 => use Band 2
 - This can apply even with all SpWs above 84 GHz due to the wider IF range of Band 2
- If Band 2 is selected but the mode or required arrays are not allowed (7m/TP) => validation error
- Spectral scan within an SG:
 - Band 2 if start freq < 84 GHz, B3 if start freq > 84 GHz
- Calculated sensitivity will be the same for either band for Cycle-13
 - Band 3 TRX assumption of 40K copied for Band 2
 - Aim to improve the model in future: add frequency dependence and add measured forward efficiency of each band (too much work for Cycle-13)



Expectations / hopes for future cycles

- Cycle-14 aiming to offer:
 - 12m wide-field polarisation
 - 7m
 - Phasing (VLBI/Pulsar)
- Further future cycles / more uncertain:
 - TP (if not by Cycle-14)
 - Solar



Summary

Many years of development by many groups has led to series production of very capable receivers covering the full 3mm window

Band 2 offers much improved tuning flexibility and instantaneous fractional BW span in the 3mm window even before the WSU

12m array offered for Cycle-13 with most modes

Remaining modes, 7m and TP being worked on for following cycles

Band 2 is also the first WSU wideband receiver (32GHz BW)!