Band 2+3 Workshop

Robert Laing, ESO

Bands 2 and 2+3

- Band 2: 67-90 GHz
  - T < 30K (80% band), 47K (full band)
  - Original concept single sideband, 4-12 GHz IF, Low Noise Amplifier
- Band 3: 84-116 GHz
  - In operation
  - T < 37K (80% band), 60K (full band)
  - SIS, sideband-separating, 4-8 GHz IF
- Band 2+3: 67-116GHz
  - Single cartridge, replace Band 3, free 4K slot in the cryostat?
- Science cases for Band 2 and 2+3
  - Fuller et al. arXiv 1602.02414
  - Beltran et al. arXiv 1509.02702
  - NRAO Band 2 Science Workshop 2013
  - Talks by Gary Fuller and Al Wootten

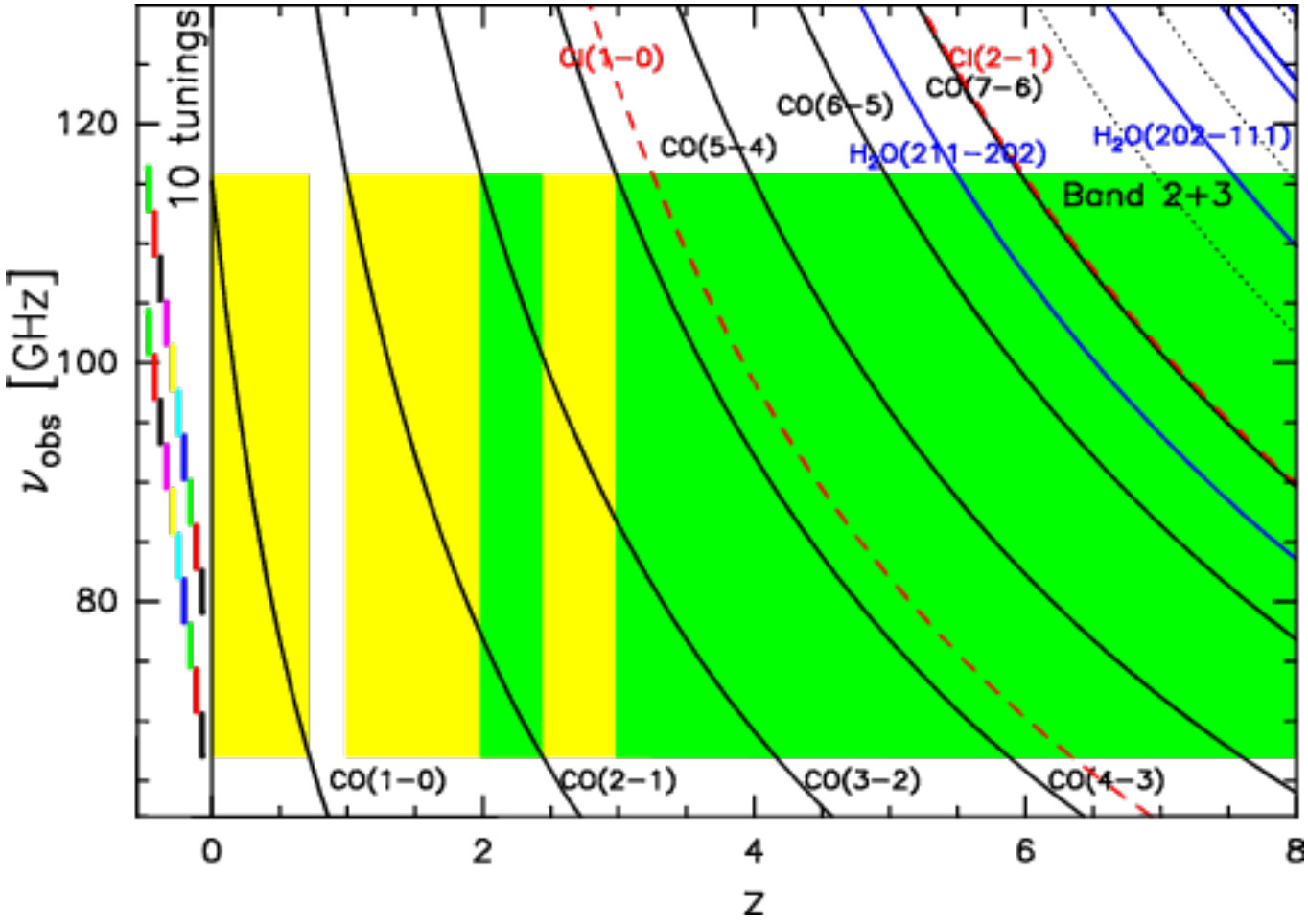
The story so far

- ESO Studies
  - Focused on feasibility of full frequency range 67-116 GHz
  - 2010 (U Man, IRAM, INAF, RAL): science case, optics and system designs, prototype feed horn and OMT
  - 2013 (U Man, INAF, STFC/RAL, U Chile, NAOJ, ESO)
    - Phase A (complete): bench test of optics (lens, feed horn, OMT)
      - Conclude that wideband system is feasible
    - Phase B (just starting): prototype ALMA cartridge
    - LNA design and test (U Manchester/Caltech)
    - LO and down-conversion (RAL)
- NRAO Project
  - Complete prototype Band 2 cartridge
  - Test results

Science

- Deuterated molecules
  - Probes of the densest, coldest gas in star-forming regions
  - Prestellar cores
  - Protostellar envelopes
  - CO “snowline” in protoplanetary disks
- High-redshift CO
  - Near-continuous redshift search coverage (preferably 2 CO lines)
  - Probe decline in molecular gas mass at $z < 2$ with low-J CO transitions
- Other science cases
  - Sunyayev-Zeldovich Effect
  - Grain physics in protoplanetary disks
  - Cold complex chemistry
  - .....

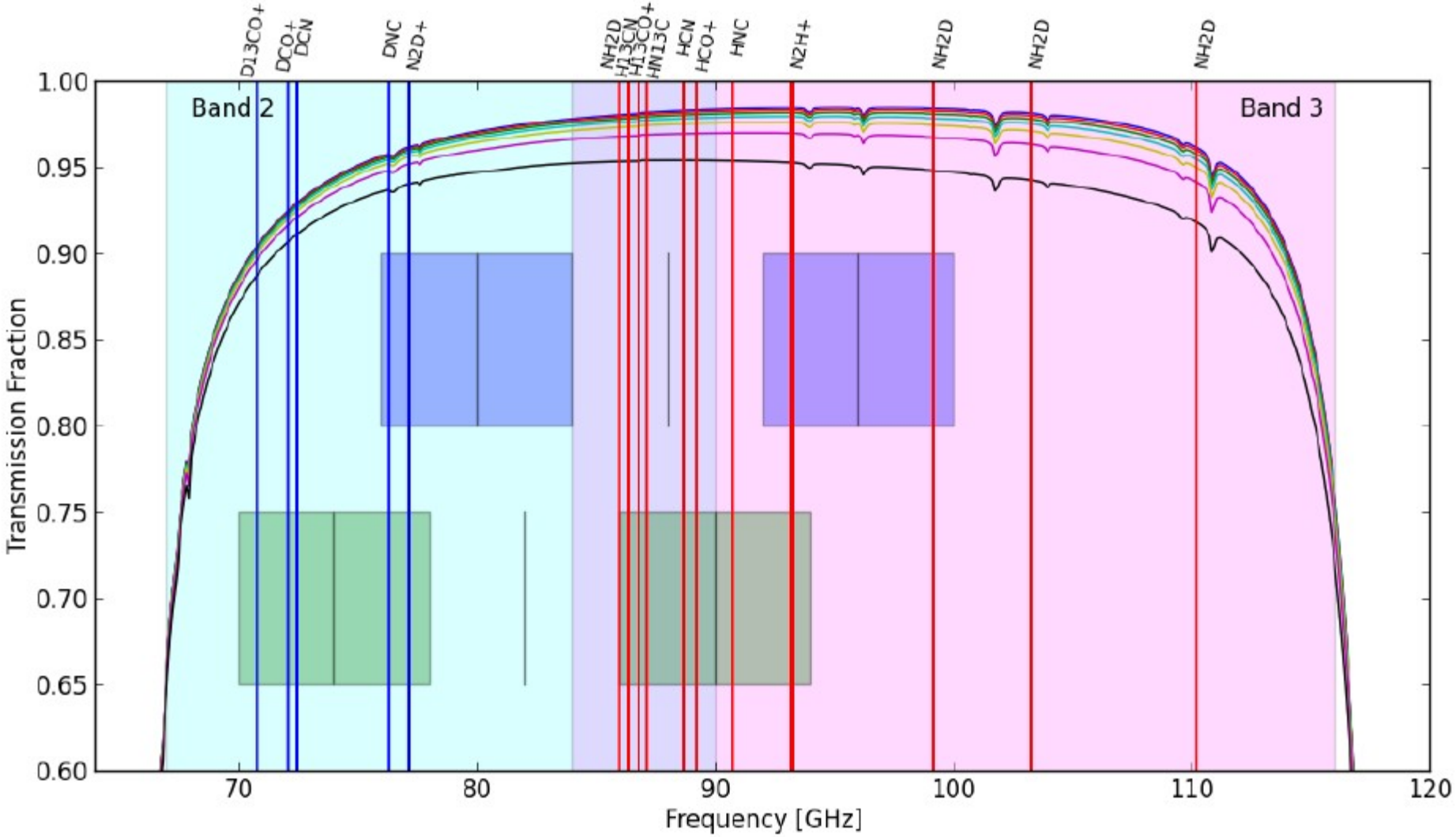
CO redshift searches in Band 2+3



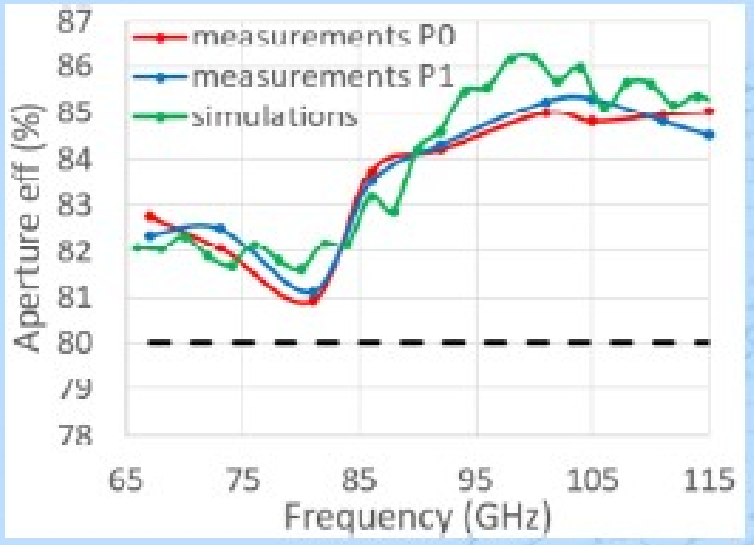
2 lines

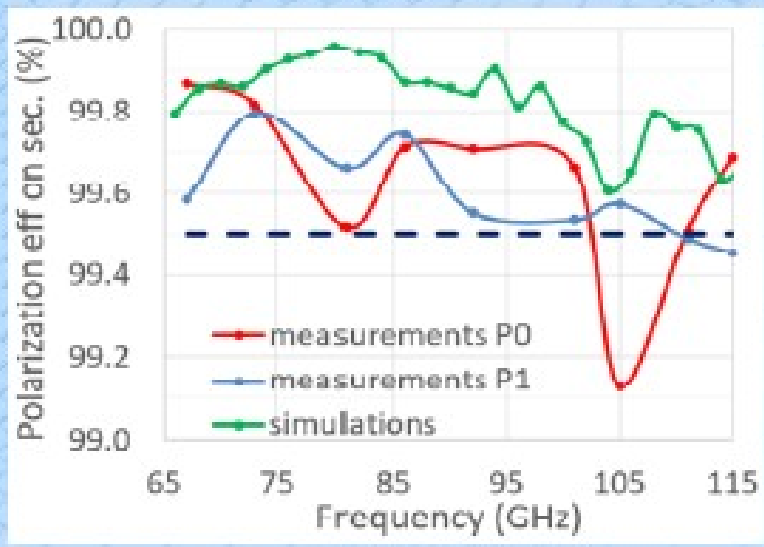
1 line

Deuterated species in Band 2+3



Band 2+3 Optics



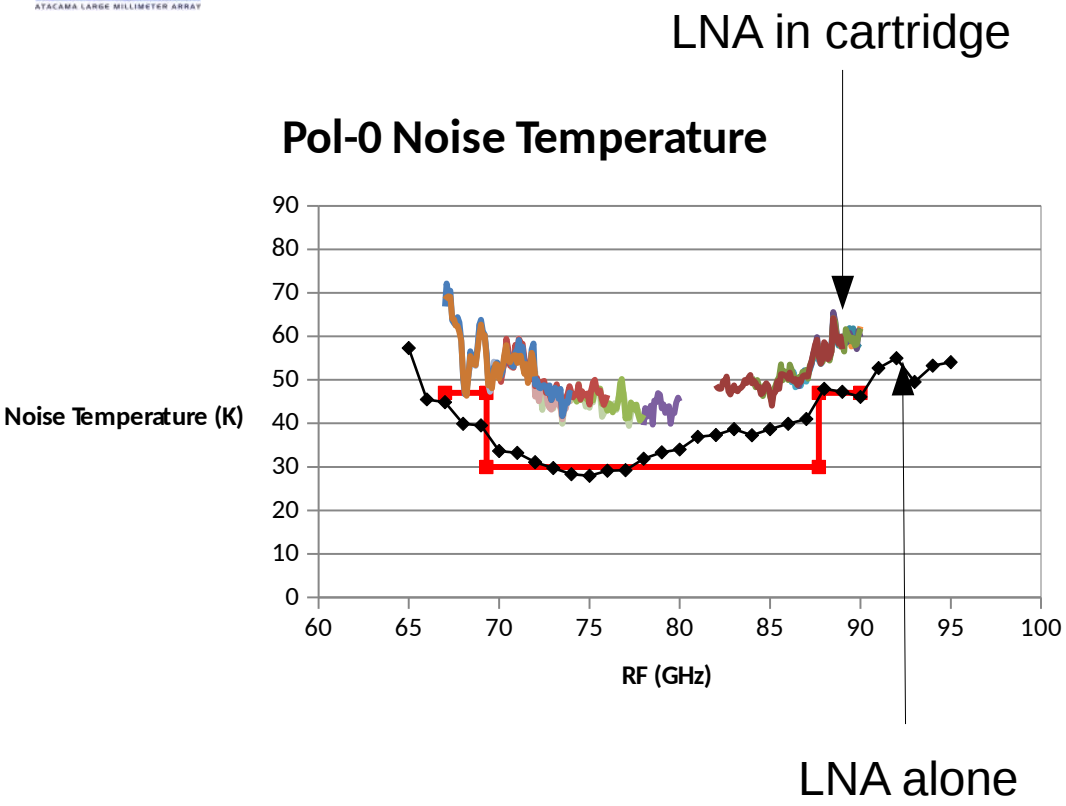


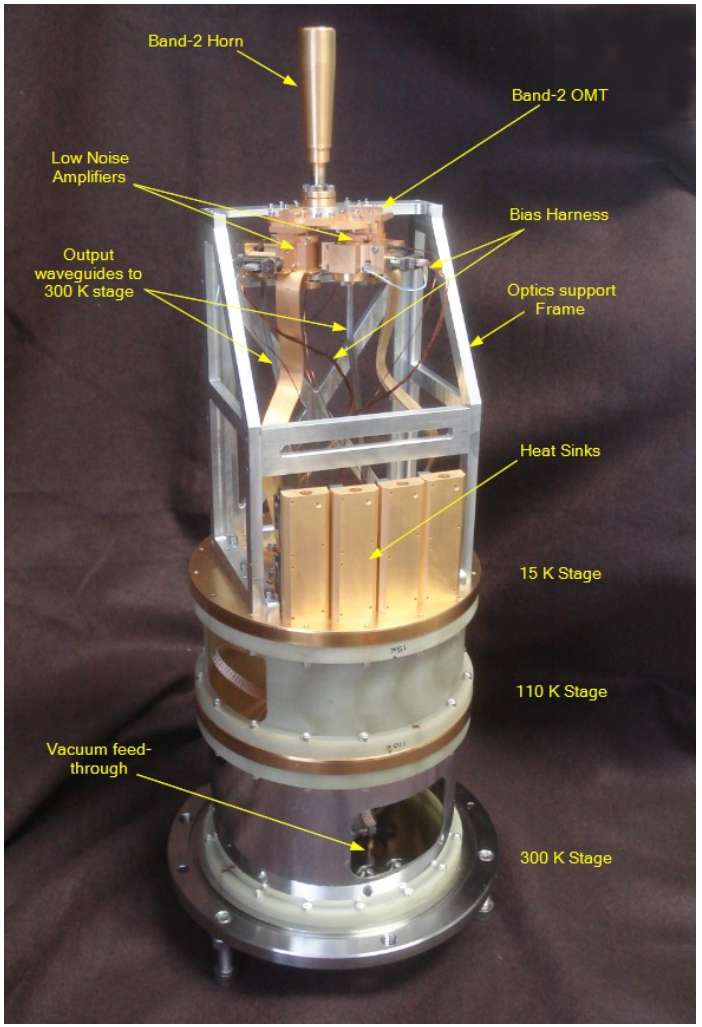
Phase A Band 2+3 optics tests at ESO
U Chile, INAF feed horns and OMTs; optics and lenses designed by NAOJ
Mostly compliant to ALMA specifications over full band 67-116 GHz
Further optimization (e.g. polarization efficiency) in Phase B

NRAO Band 2 Prototype (Saini)

- Full design (cold cartridge, LO, warm cartridge assembly)
- Chip-and-wire amplifiers → MMIC later
- Amplifier average 36.5K (67-90GHz)
- Average receiver temperature, including optics 52K
  - Not (yet) meeting original ALMA specifications (30/47K)
- Meets aperture efficiency and (mostly) polarization efficiency specifications

NRAO Band 2 Prototype





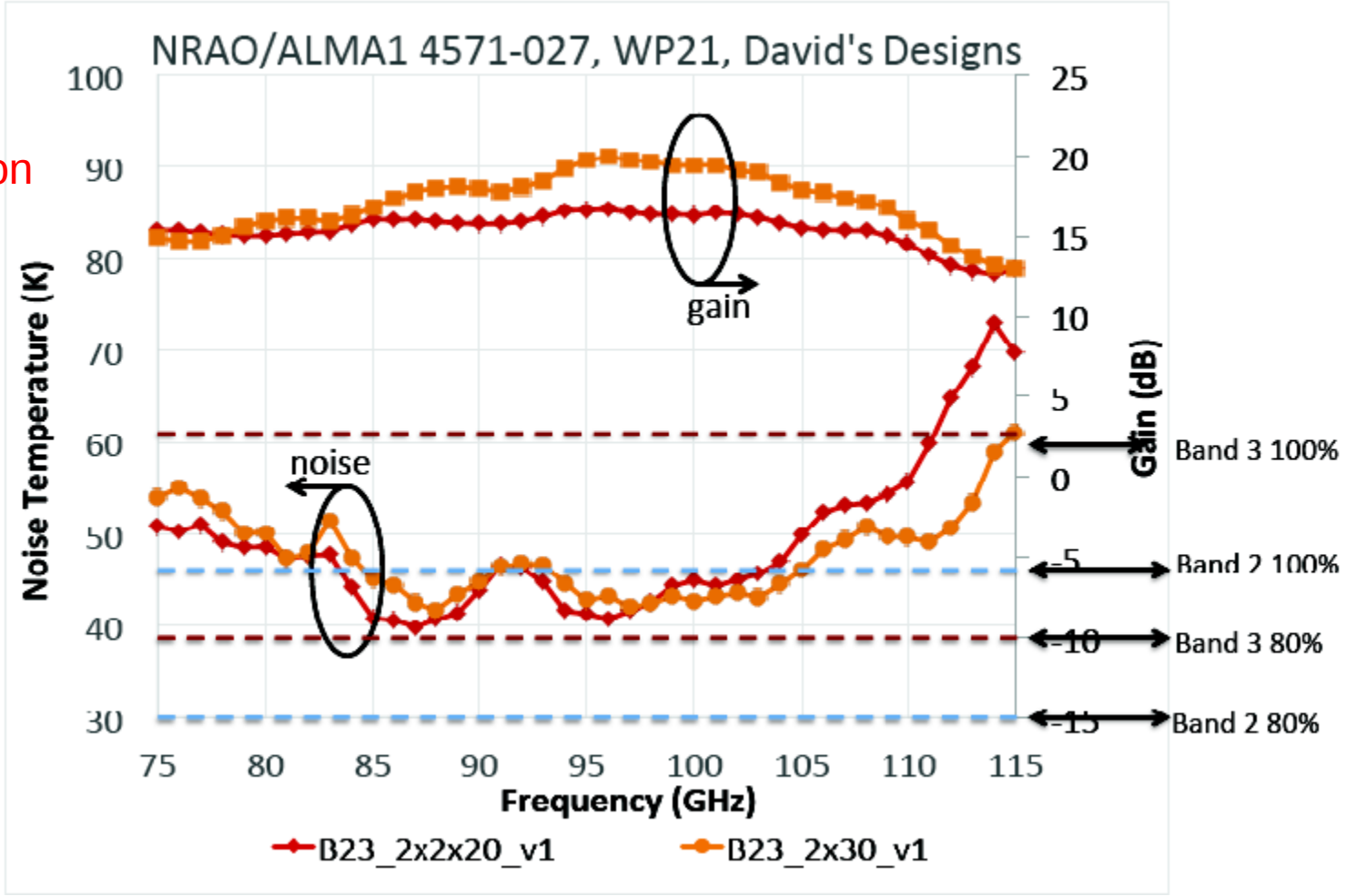
Preliminary MMIC Tests

Very preliminary
No bias optimization
~5K probe offset

U Manchester design/tests at CRAL

NGST 30nm gate length InP

Danielle George



LNA Summary

- Have probably reached the limits for MIC (chip and wire) amplifiers for Band 2
  - Average T_{sys} = 36.5K across Band 2
  - Probably unable to meet original ALMA specifications
- Promising results for Band 2 and 2+3 MMIC amplifiers from first wafer run
  - Do not meet the specification yet, but ....
  - Bias optimization June-July 2016 (U Man/CRAL)
  - NRAO tests also in progress
- Consensus: do not relax Band 2 noise specifications for now
- Noise/bandwidth trade-off (Band 2 vs 2+3)
  - Simulations suggest a few K within Band 2, but need to verify

Band 2+3 Strategy

- Band 2
  - General agreement on importance of science case
  - Prototype cartridge development by NRAO to meet original ALMA specification but with 16 GHz IF bandwidth
- Band 2+3 or Band 2 – EU/ESO view
  - We should now be designing to meet more ambitious science specifications if this is technically feasible
  - The next generation of receivers should aim to meet the requirements set by ALMA2030
  - There are science drivers for a wider band (67 – 116 GHz)
  - Eventually, could free up a 4K slot in the cryostat
  - Optics, feed horn and OMT will work over the full range
  - Even if production LNA's do not initially cover the full range, we should consider designing the optics and LO to support it with a view to future upgrades
- But:
  - Must at least maintain performance in Band 3 as well as meeting existing Band 2 specifications, both with at least 16 GHz bandwidth per polarization

Way Forward

- Optics can cover the full 67-116GHz range without loss of performance in Band 2
  - Cartridge should have wideband optics
  - Investigate high resistivity, high purity silicon to reduce noise contribution from optics
- Optimize MMIC performance to avoid compromising performance in Band 2 and to extend as far as possible into Band 3
  - Performance limits?
  - Long-term upgrade to cover full band if this is not possible immediately
- IF bandwidth
  - 16GHz per polarization
  - Assume that digital/correlator will be upgraded.

Timetable

- ~June-July 2016: bias-optimized MMIC test results available
- ~Aug 2016: revise science case with realistic performance numbers
- Oct 2016: ASAC f2f meeting
- ~Dec 2016: second wafer run
- ~Jan 2017: requirements review, followed by PDR
  - Present baseline Band 2 design and options for enhancement (wideband optics, Si lenses, LNA's)
  - Down-select
- In parallel, develop options for collaboration between ALMA partners
- March 2017: deadline for NA Development Call
- April 2017: ALMA Board