Optical testing

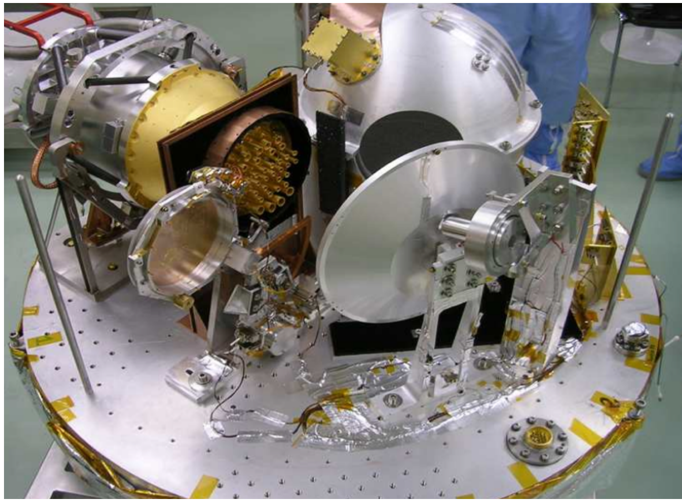
Bruno Maffei

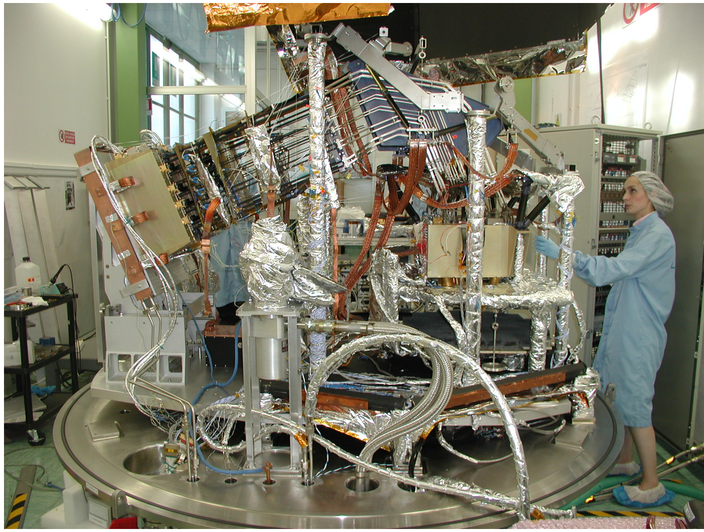
Parameters needed from optical test

- Transmission / Gain
  - Possibly of each component
  - For sure for all integrated pixels
  - Sensitivity
  - Spectral response
- Main Beams
  - Full map for all pixels
  - Variation with frequency within band
  - X-pol main beam maps
- Far sidelobes
  - Ideally over 4π steradian
  - Check for contamination

Optical tests performed on Planck (and more generally on CMB experiments)

- Transmission at component and/or instrument level
  - HFI
    - Use of Fourier Transform Spectrometer on some horns, all filters, all integrated pixels and on full instrument.
    - Use of calibration source on overall instrument to measure sensitivity across integrated spectral bands.
  - LFI
    - Use of Vector Network Analyser on components and integrated detection chains
    - Tests with loads of variable temperature





Planck Telescope: verification

- Mechanical alignment
- Photogrammetry
- Specific RF component added on FPU for ground tests
  - Extra horn + diode at 320 GHz (RTH)

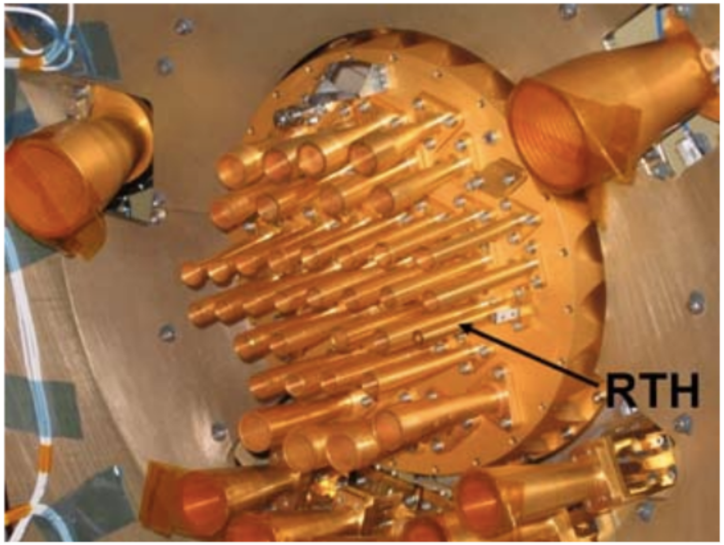
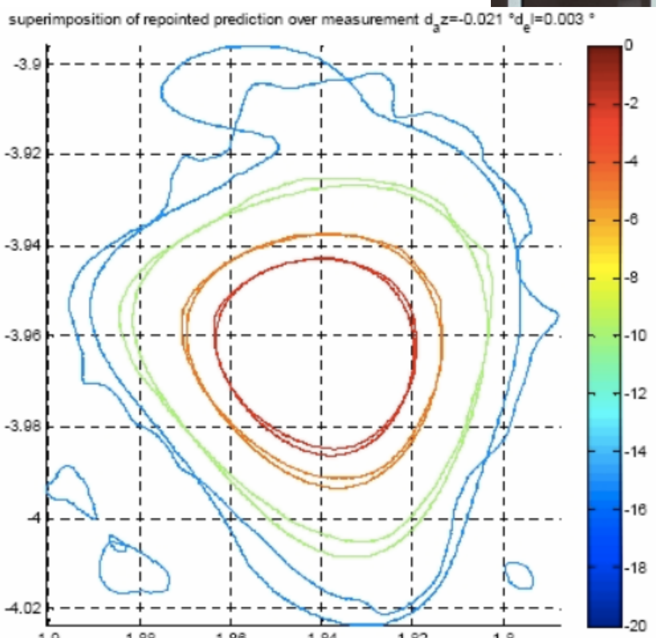
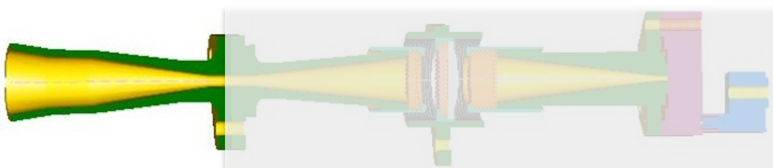


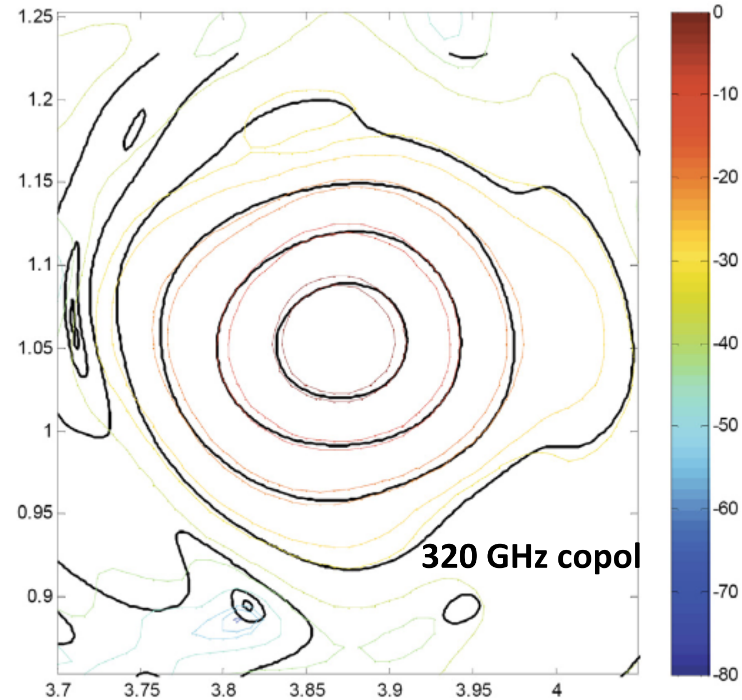
Fig.3. The 320 GHz Reference Test Horn in Planck's Focal Plane



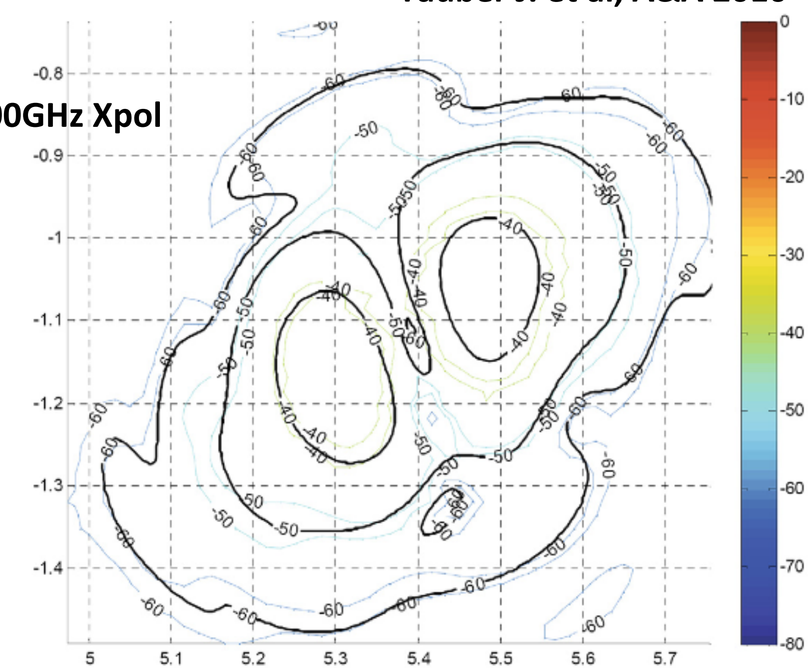
Beam characterisation for Planck

- Measurement of all horns (beam cuts)
- Telescope beams **not** measured for all pixels (ground) RFQM / RFFM
  - One "pixel" for each band up to 320 GHz





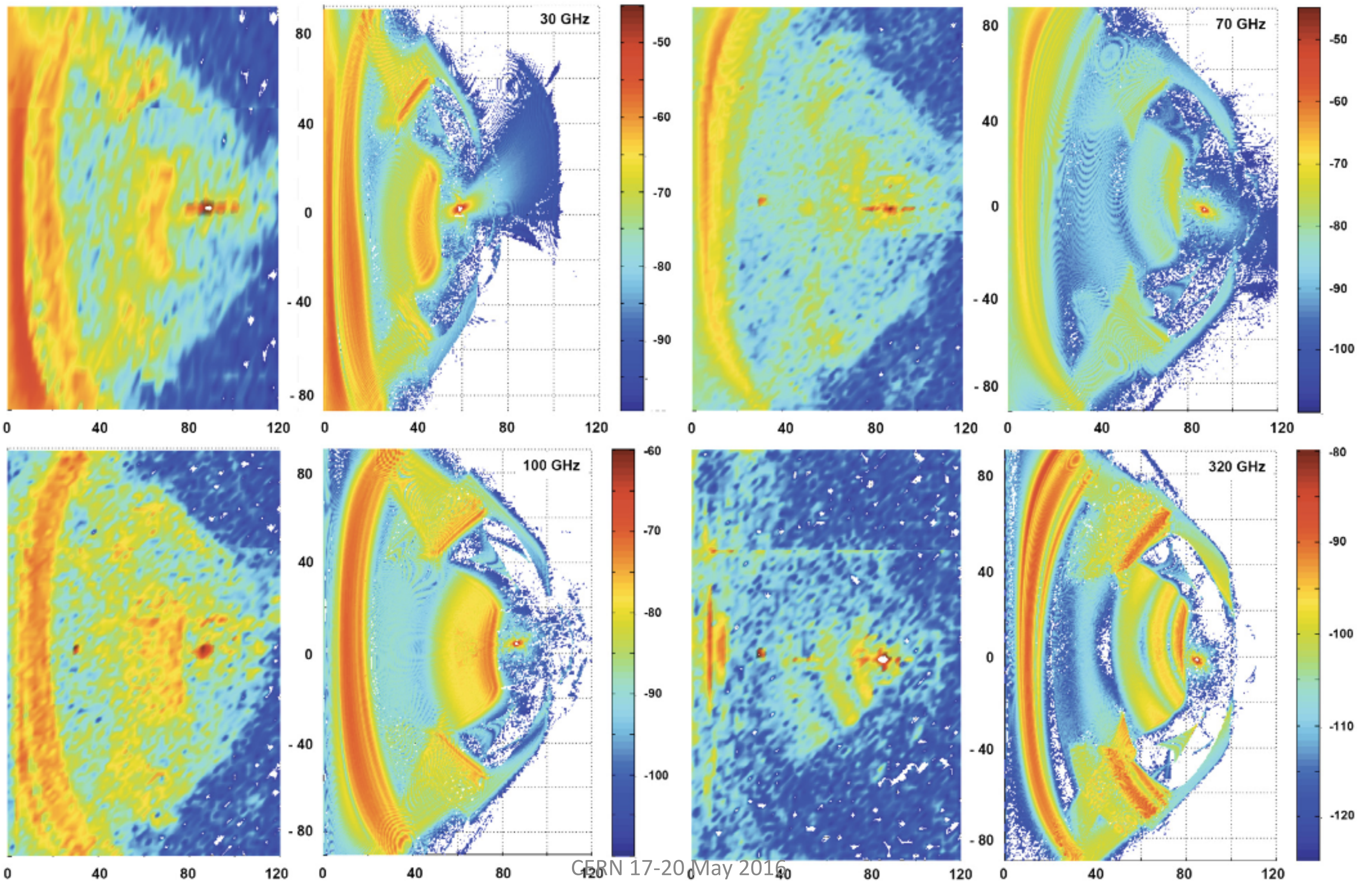
Tauber J. et al, A&A 2010



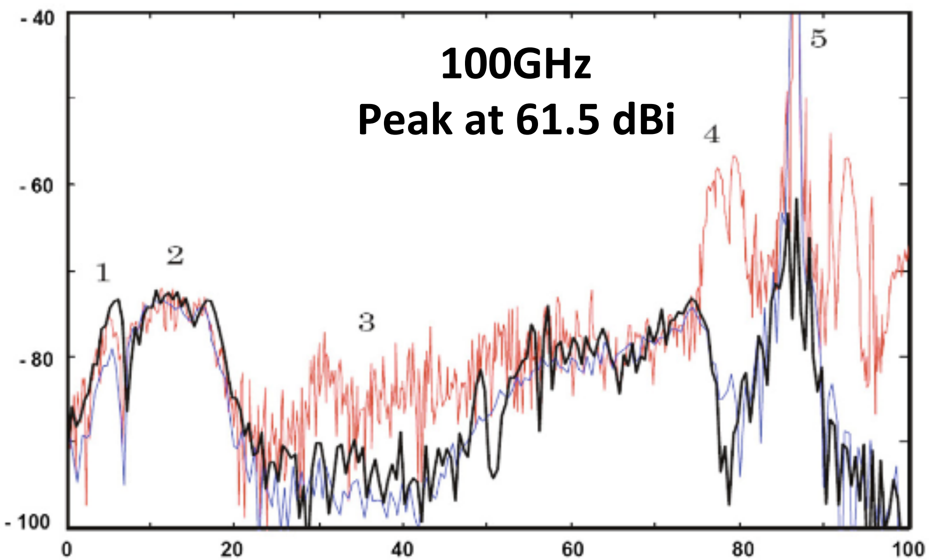
Far sidelobes characterisation for Planck (RFQM)

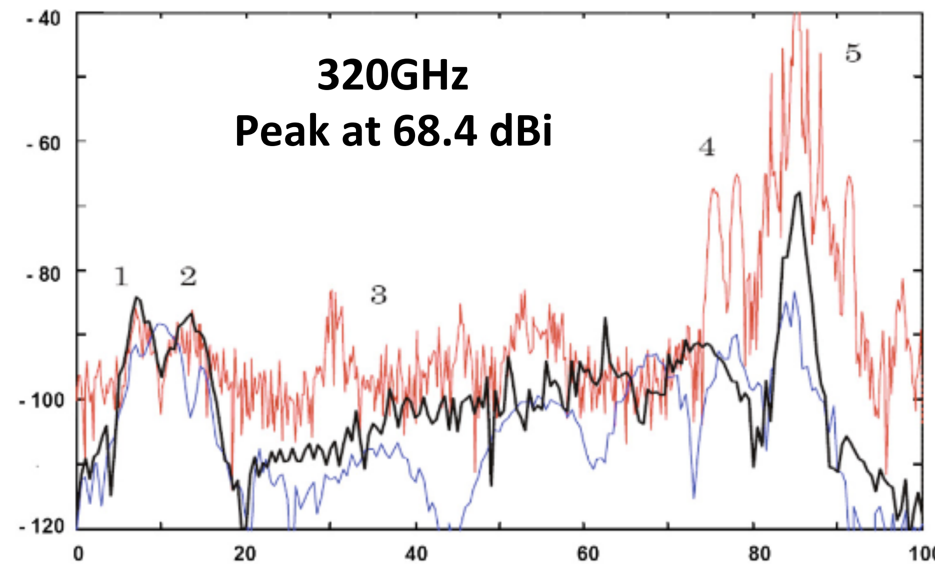
Comparison between simulations and measurements

Measured **Simulated**



Far sidelobes characterisation for Planck (RFQM)





Comparison between simulations and measurements

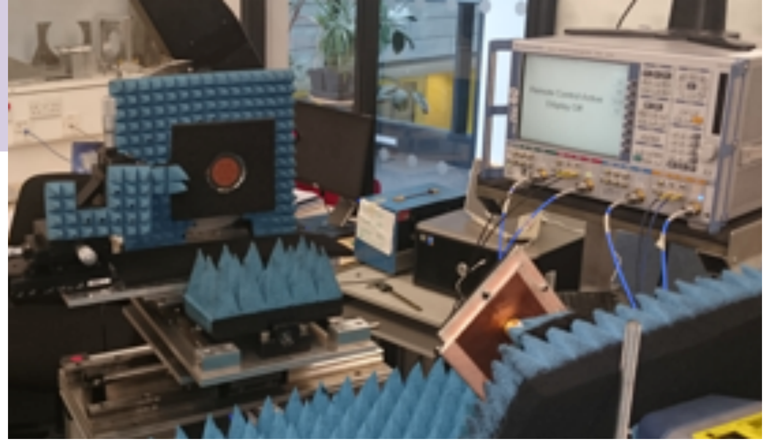
From Planck to COrE

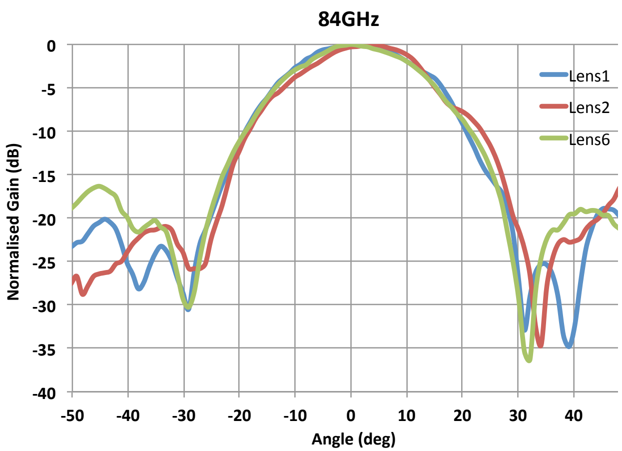
- Similarities
  - Telescope
  - Can re-use the same technology
  - Can re-use verification / alignment procedures
- Differences
  - Many more pixels (10s to 1000s)
  - More spectral bands (9 to 15?)
  - Calibration needs more accuracy
    - due to increase sensitivity (x30) → need to have a better understanding of the instrument / reduce systematics
  - Different technology
    - Use of planar / lens technology with possibility of cold stop and potentially higher straylight

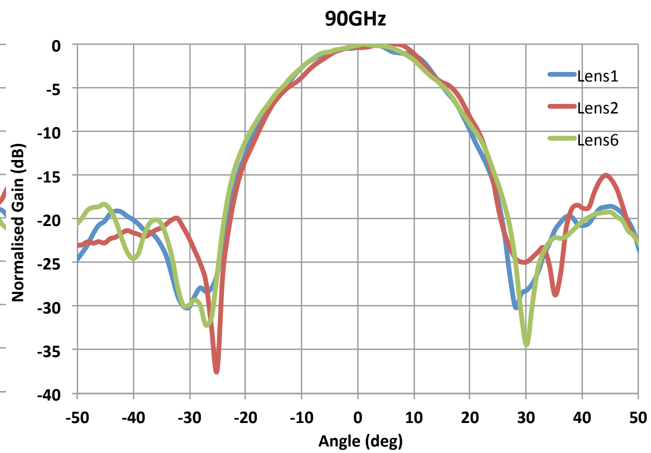
Higher measurement accuracy needed

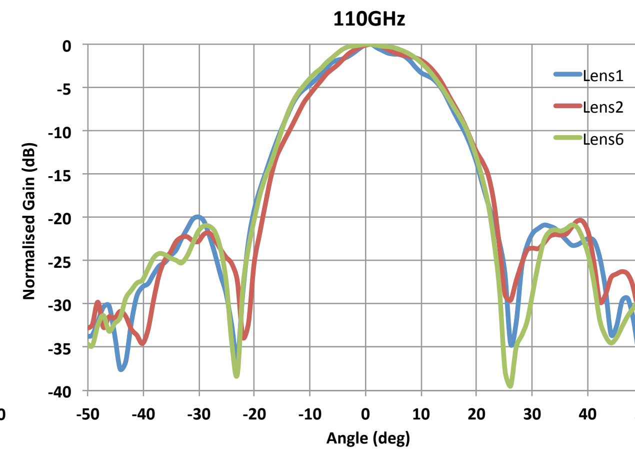
- Will need to use more accurate equipment
  - FTS and broadband (as for HFI) not enough
  - Probably need to move to VNA-like system where **amplitude** and **phase** are measured with very large dynamic range
- Will need to be performed on separate components and integrated systems
- 1000s of detectors → which testing strategy?
  - Test on samples for components?
  - Then rely on integrated tests on overall instrument?
- But at the end of the day will need to include the definitive detector (bolometer or KID)
  - Back to previous measurement system?
  - How could we improve the accuracy?

Example on waveguide coupled flat lens









	Lens 2	
	90GHz	110GHz
Max Value	-39.8dB	-36.2dB
FWHM (deg)	21.4	18.4

	Lens 1	
	90GHz	110GHz
Max Value	-40.0dB	-35.9dB
FWHM (deg)	23.6	17.0

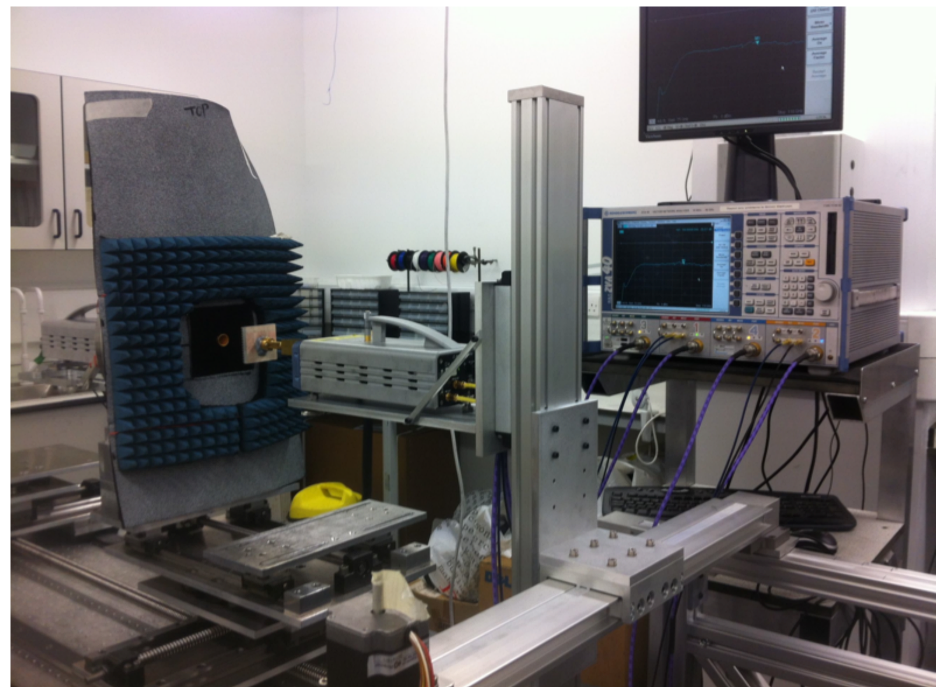
	Lens 6	
	90GHz	110GHz
Max Value	-39.6dB	-35.9dB
FWHM (deg)	23.0	19.9

NUI MAYNOOTH Ollscoil na hÉireann Má Nuad · MANCHESTER 1824 The University of Manchester · CHALMERS · SAPIENZA Università di Roma · université PARIS DIDEROT · CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD · esa European Space Agency

Far Field / Near Field

Far field horn beam pattern with bolometer

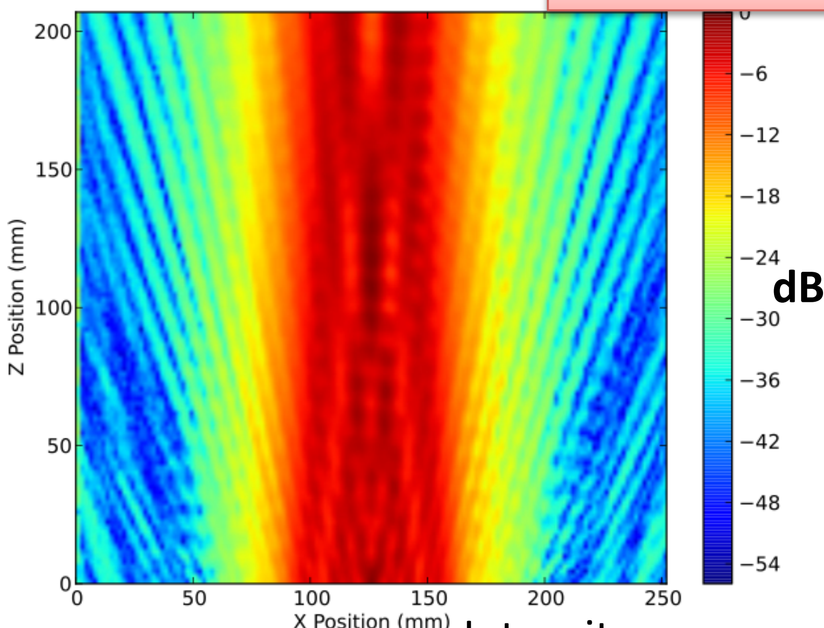
3D EM near-field measurement with VNA

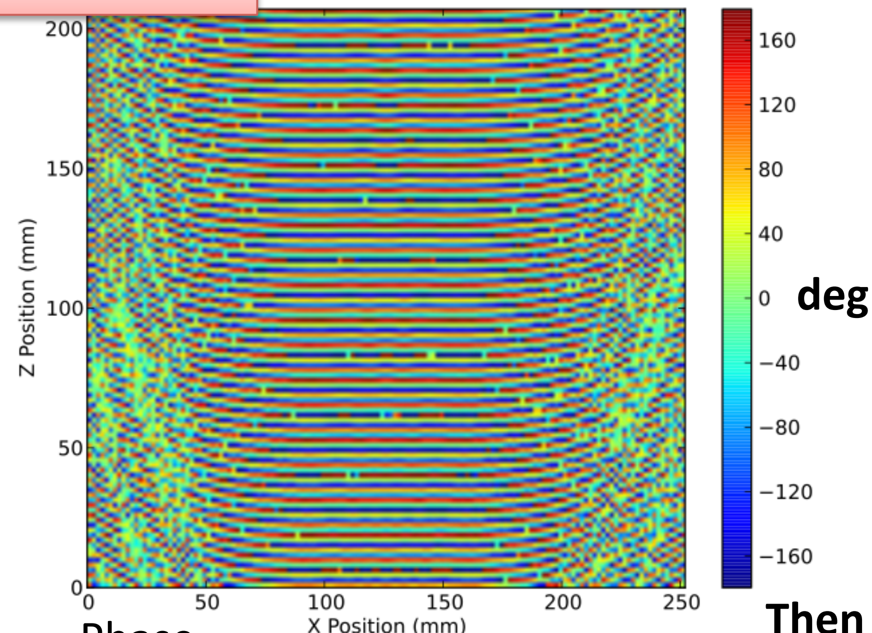


Reconstruction of far-field

Example 2: 3D near field measurement of a polyethylene lens @100GHz

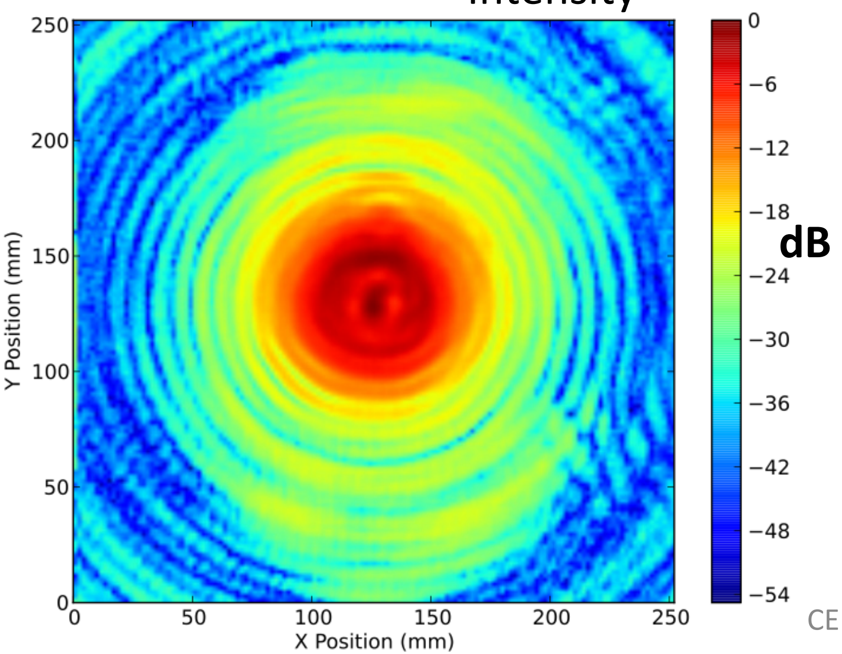
P. Schemmel et al, ESA antenna 2013

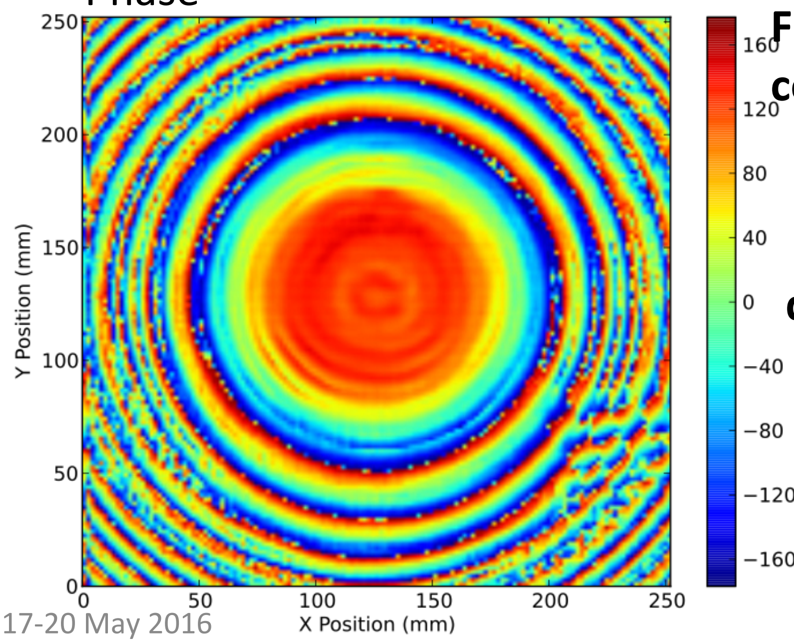




Intensity

Phase



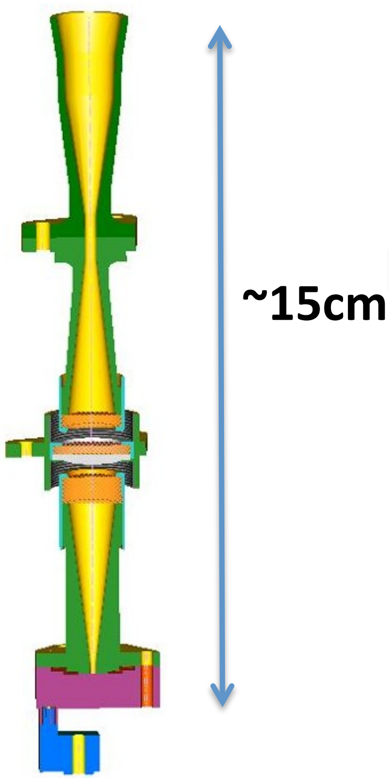


Then Far Field re-construction

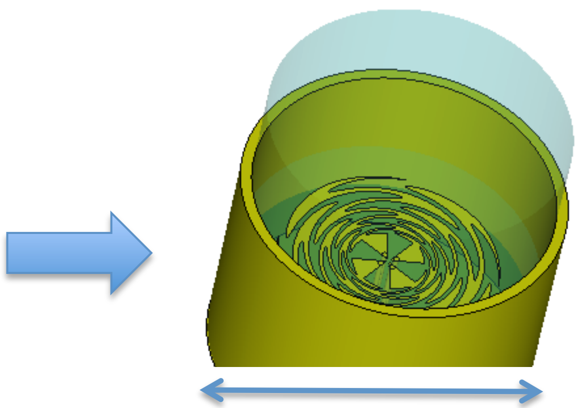
FPU Technology

- 1000s of pixels → Is it realistic to use horns?
- If European technology used
  - Use of planar / lens technology with possibility of cold stop and potentially higher straylight

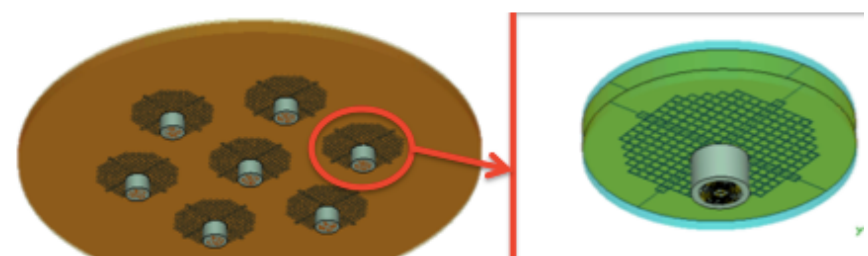
NUI MAYNOOTH Ollscoil na hÉireann Má Nuad | MANCHESTER 1824 The University of Manchester | CHALMERS | SAPIENZA Università di Roma | université PARIS DIDEROT | CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD | esa European Space Agency



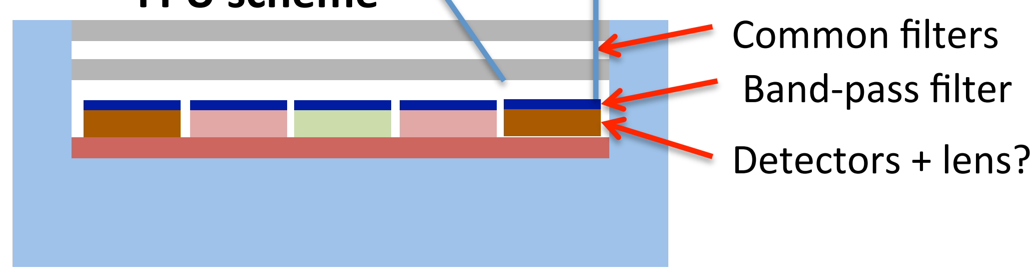
HFI bolometric detector



Array



FPU scheme

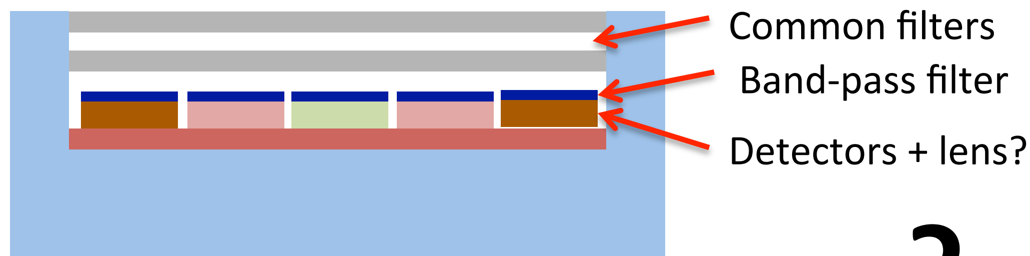


How to get an accurate representative measurement?

Equivalent of RFQM beam measurement

Cold stop ?

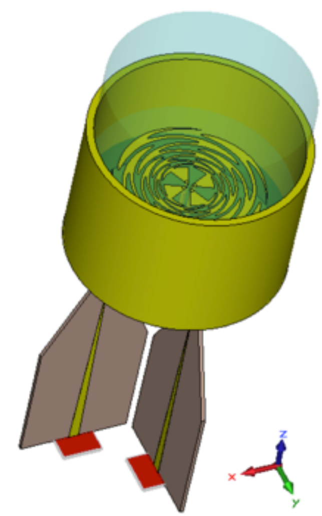
Baffles



?

- Telescope with a cold instrument in CTR?
  - Unlikely feasible by industry (Thales, Airbus space) or at a huge cost
  - Warm instrument → need to replace detector
  - Could we think of a test at Liege facility?

Design of cavity-backed sinuous antenna with baluns.



Conclusion

- Optical tests and more generally calibration will have to be thought well in advance
- Need to re-use what has been used for Planck as much as we can
- Do we need to include a test plan in the proposal?