(Not …!) Clover

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Background History

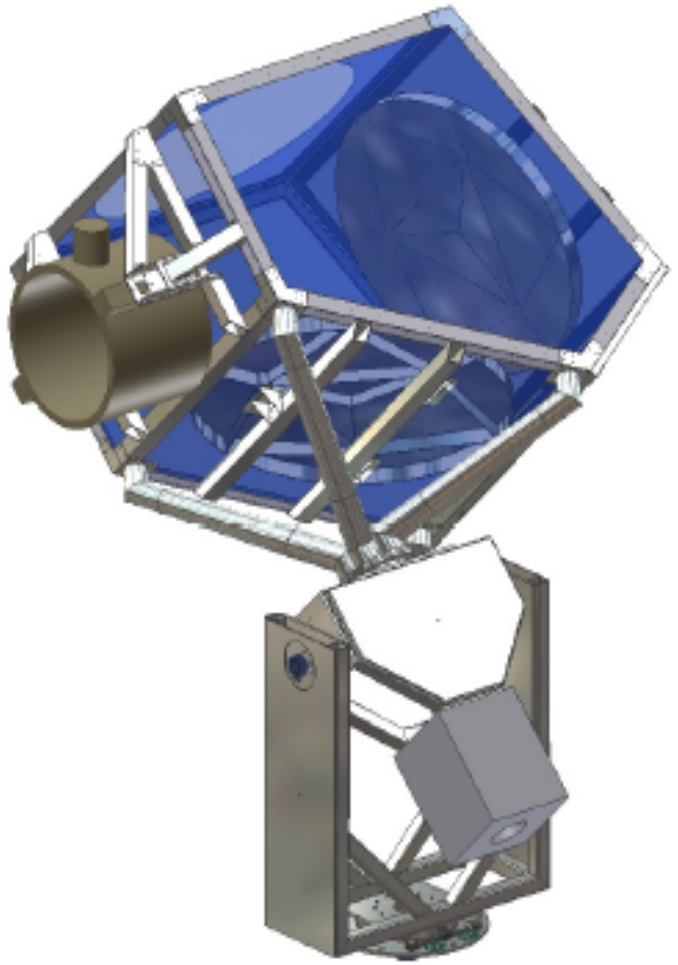
- In 2004 UK PPARC committed to fund a state-of-the-art B-mode experiment "CLOVER" involving Cardiff and Cambridge Universities
- Project expanded to include Oxford and Manchester in the UK, plus technical collaboration with UBC/NIST for SQUID readouts & MCE & U. de Chile as site is in Chile
- In 2009 project ready to begin preparations on-site for delivery early 2010 , but had committed all original funding….

Science Goals

- Clover is an experiment to measure polarization properties of the CMB
- Primary aim is to measure or obtain world-leading upper limits on B-mode polarization signal
- B-modes are a signature of primordial gravitational waves and a diagnostic of the energy scale of inflation
- Figure of merit is the primordial scalar-to-tensor ratio r. Clover is aiming for r ~0.03

Experimental Characteristics

Central Frequencies [GHz]	97, 150, 225
Number of single polarisation detectors	192, 192, 192
Beam FHWM [arcmin]	7.5, 5.5, 5.5
Sky area [deg²]	1000
l-range	20 to 1000
NET [μK.s$^{0.5}$]	164, 254, 664
Observing time [years]	2
Integration time [years]	0.8
T sensitivity per 8′ pixel [μK]	0.8
Q,U sensitivity per 8′ pixel [μK]	1.1
Minimum *r*	0.03

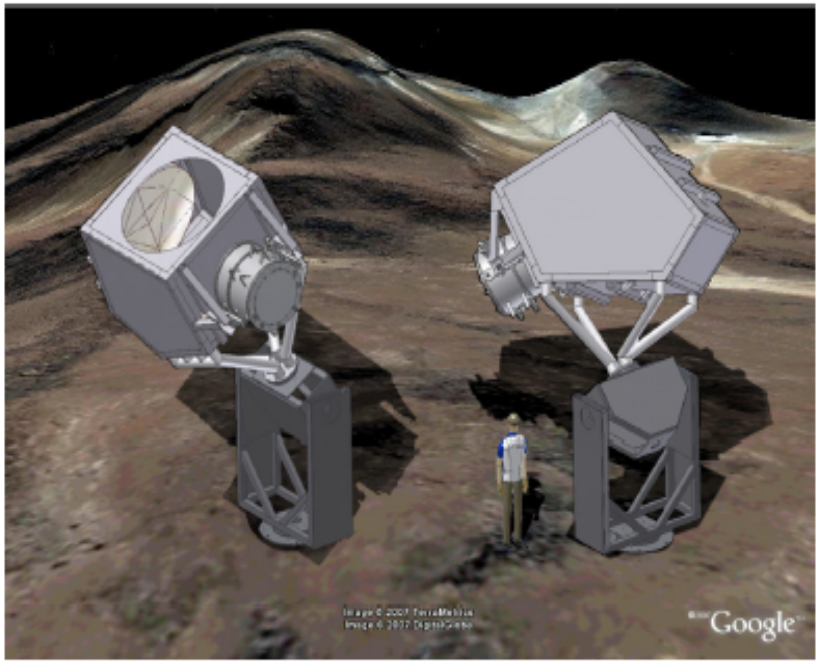


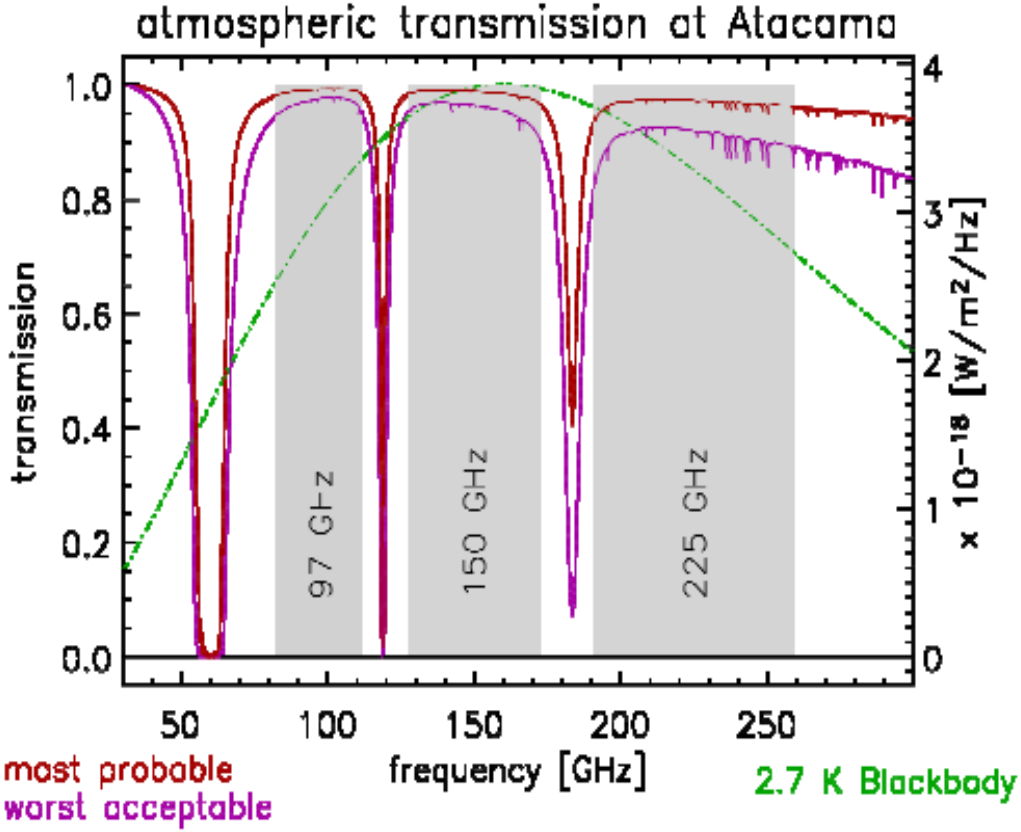
Instrument Requirements

Instrument Characteristic	Requirement
Pointing error	< 0.6 beam FWHM
Polarisation beam alignment	< 0.003 beam FHWM
Average Beam ellipticity	< 0.85
Differential Eccentricity	< 0.012
Residual Q↔U rotation (cross-polarisation)	< 0.24° (<1.4%)
Cross-polarisation	< -47 dB
Residual T→Q,U mixing (instrumental polarisation)	< 0.02%
Modulation Efficiency	> 90%
Absolute Calibration	< 5%

Frequency Coverage

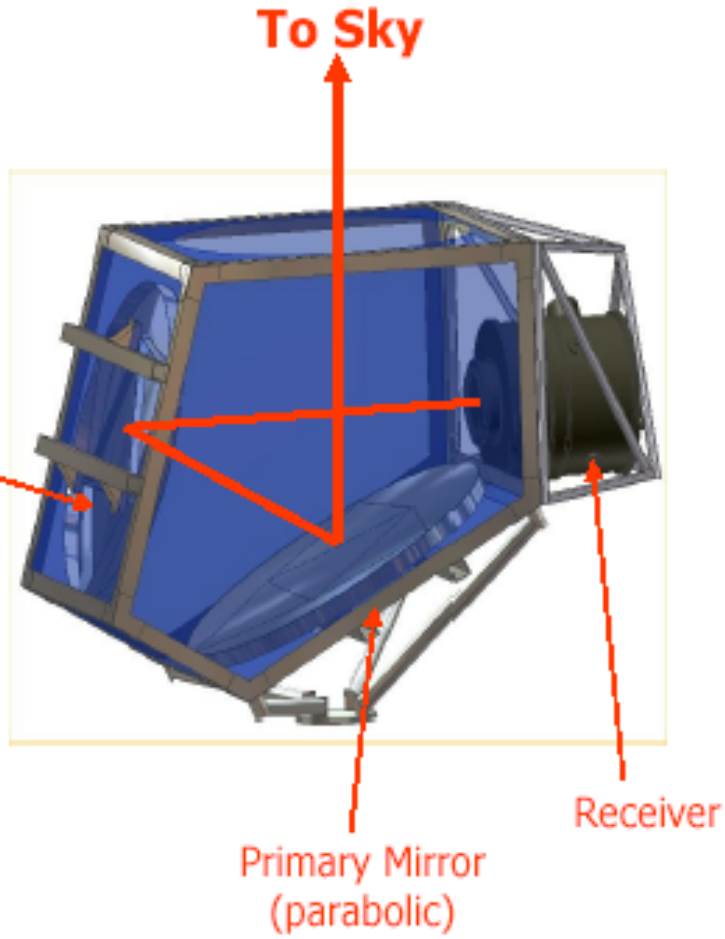
- Two telescopes
  - 97 GHz
  - 150 & 225 GHz





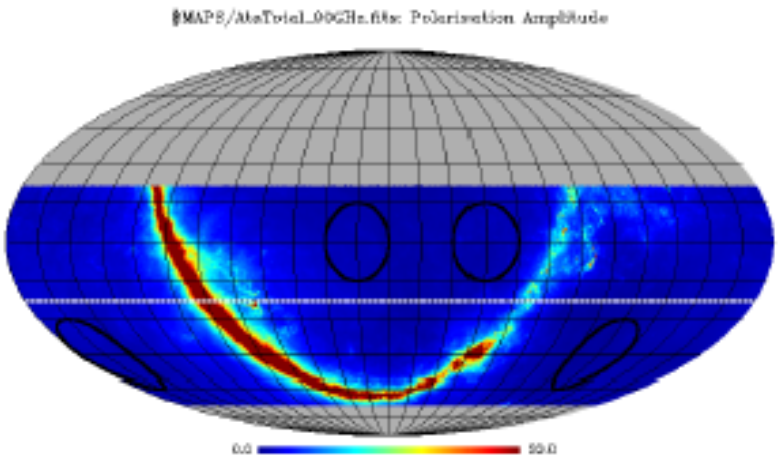
Optical Layout

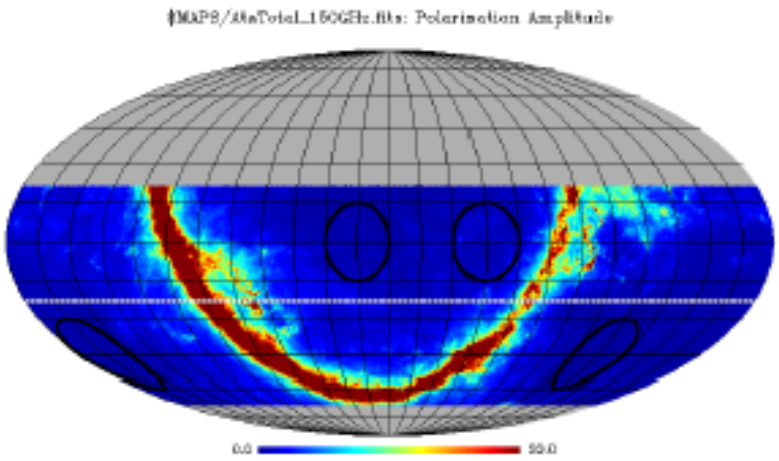
- Compact Range Antenna
  - Large, flat focal plane
  - Very low cross-polarisation

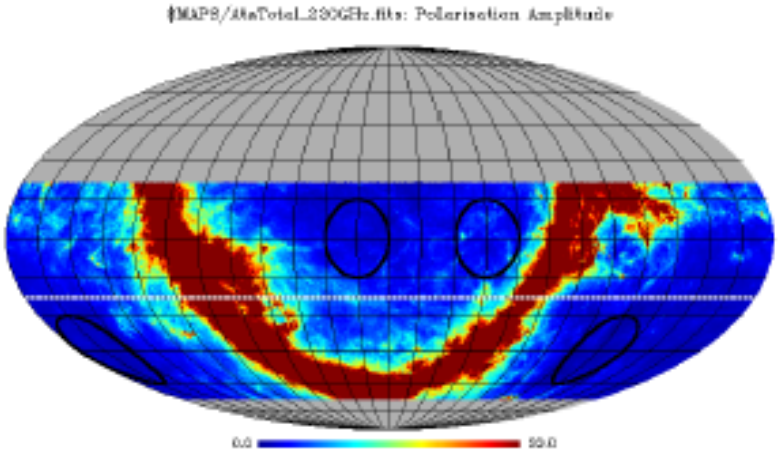


	97 GHz	150 GHz	225 GHz
Primary Diameter	1.8 m	1.5 m	
Beam FWHM	7.5 arcmin	5.5 arcmin	
Strehl Ratio	> 0.96	> 0.96	> 0.96
Spillover	< 1.4%	< 2.1 %	< 0.1%
Eccentricity	< 0.23	< 0.27	< 0.19
Cross-pol	< -38 dB	< -41 dB	< -42 dB

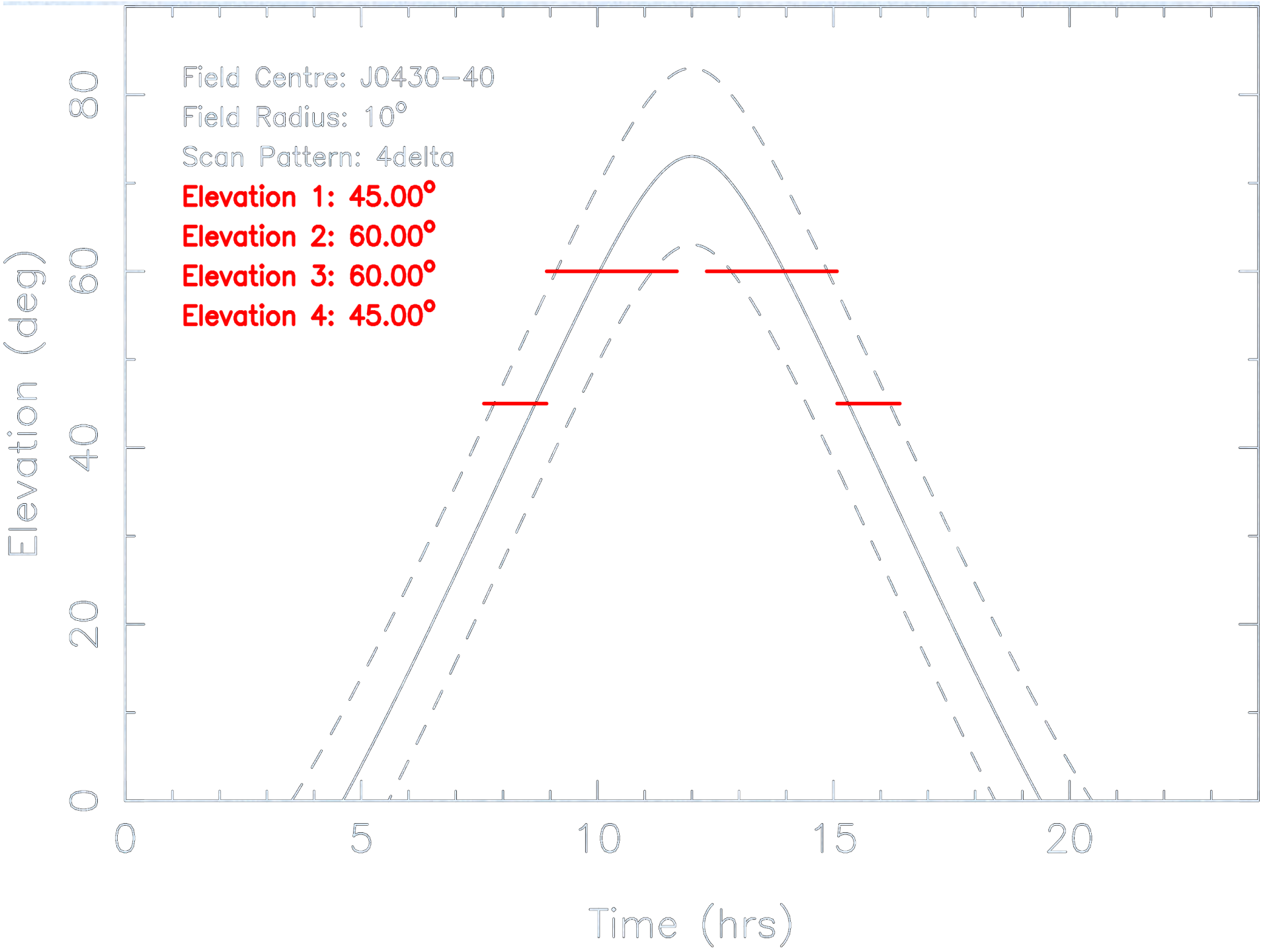
Observing Fields



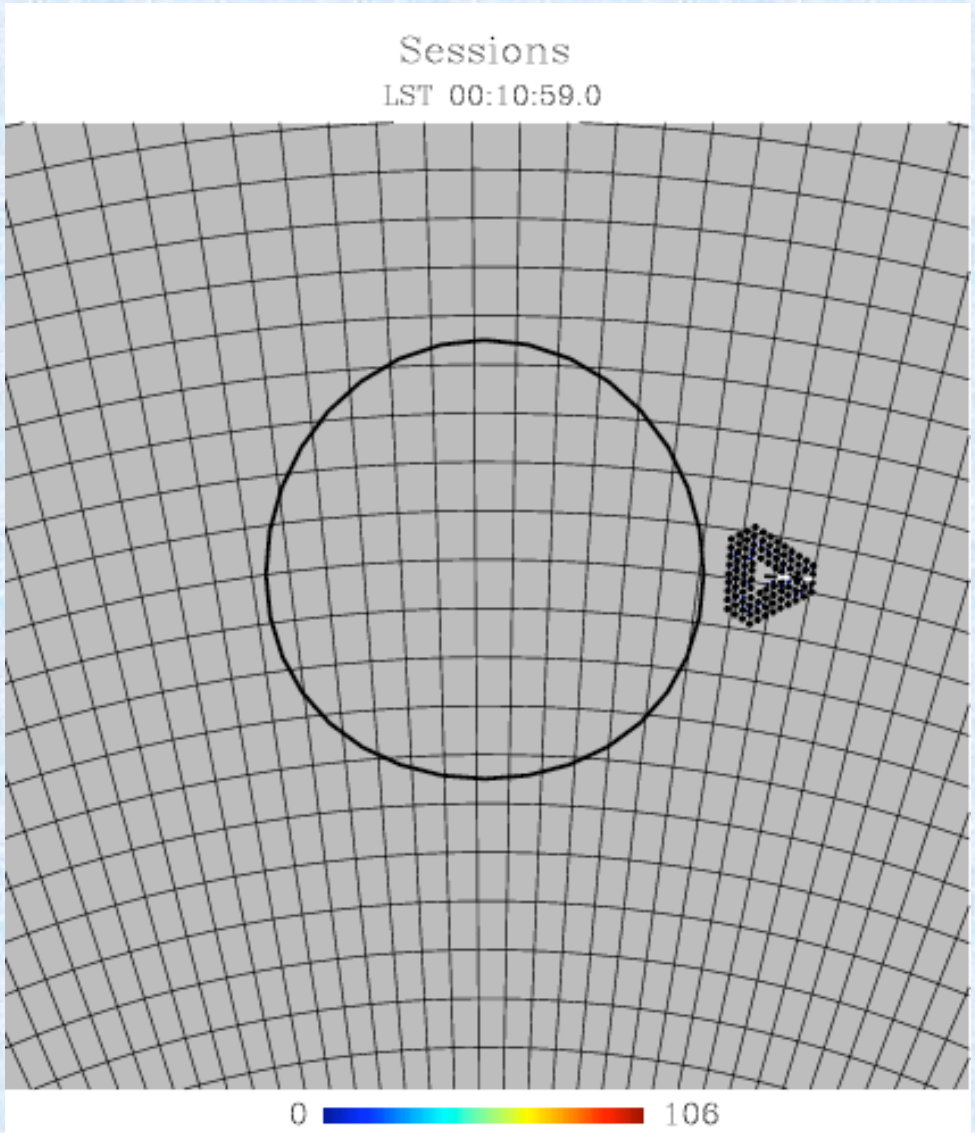




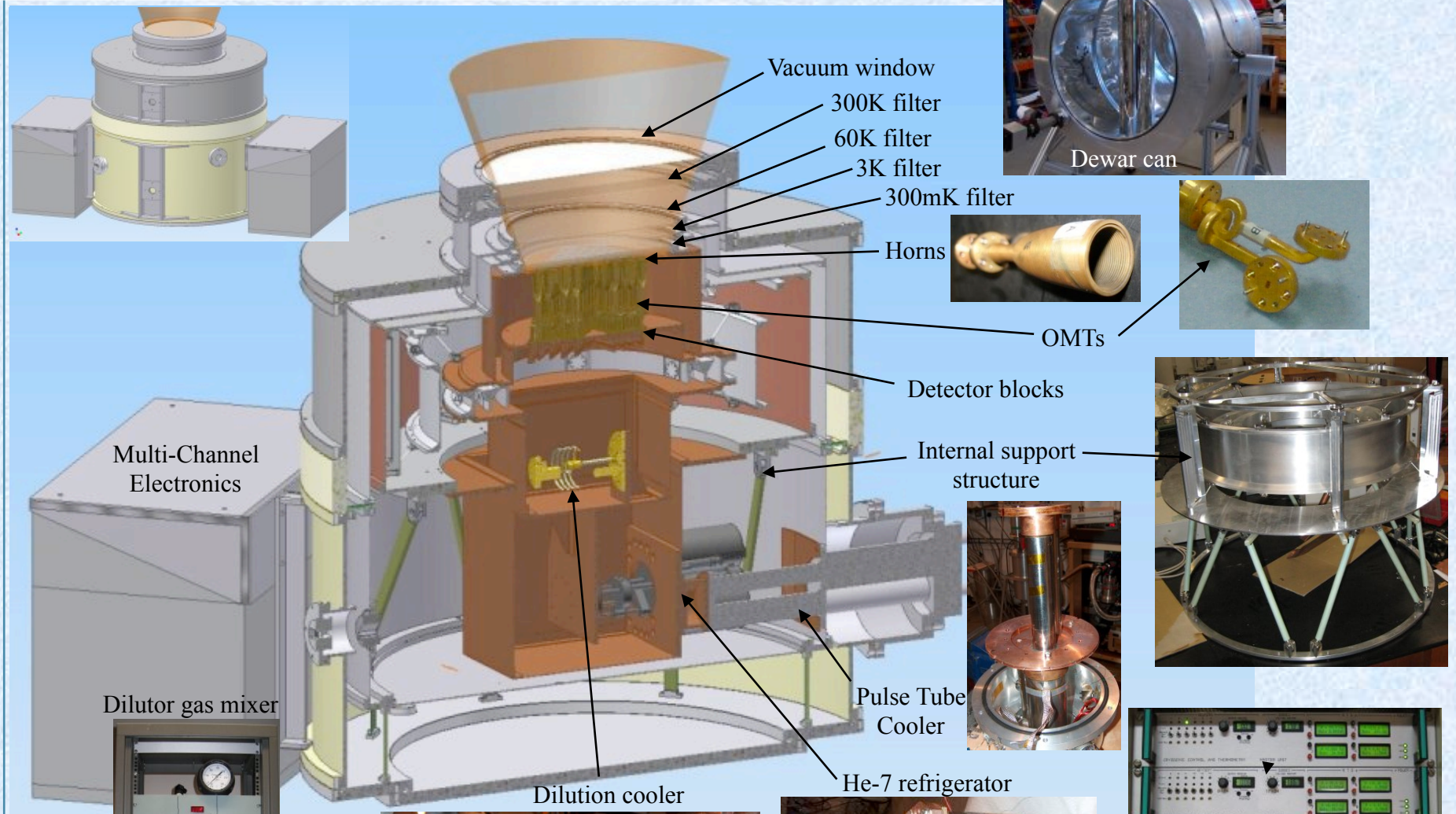
Field center (HHMM-DD)	rms polarized temperature (μK)		Time above elevation 45 degrees
	90 GHz	220 GHz	
0430-45	1.0	2.7	6.5h
0900-00	1.7	7.3	5.2h
1300-00	2.0	4.7	5.2h
2300-45	2.0	2.6	6.5h

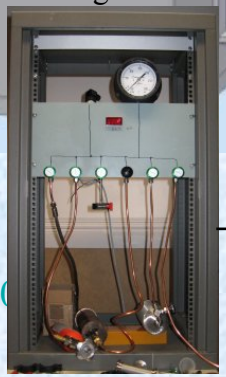

Field Centre: J0430-40
Field Radius: 10°
Scan Pattern: 4delta
Elevation 1: 45.00°
Elevation 2: 60.00°
Elevation 3: 60.00°
Elevation 4: 45.00°
Elevation (deg)
0
20
40
60
80
0
5
10
15
20
Time (hrs)

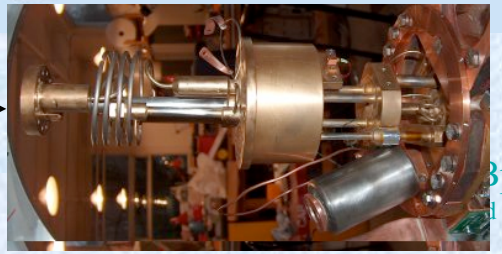
One day observing on one Field

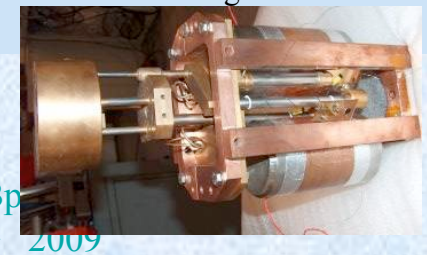


97 GHz Receiver cut-away and photos





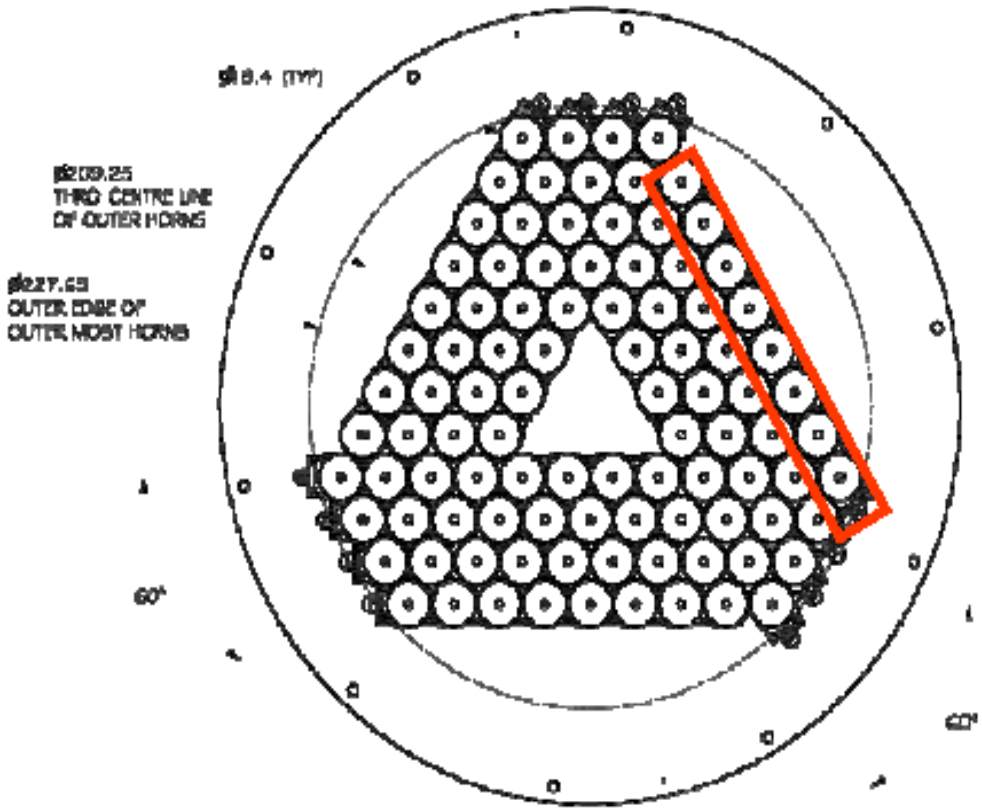


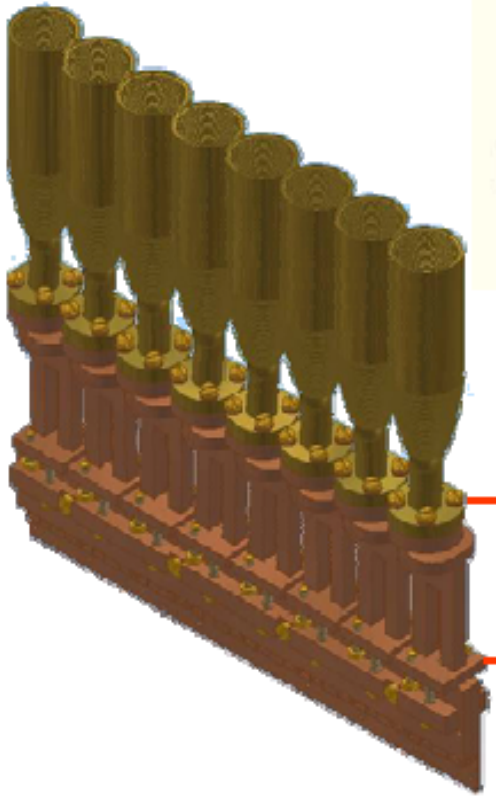


Dewar controller and thermometry

Focal Plane

- 97 GHz
  - 8x1 blocks of detector pairs
  - 96 pixels (192 detectors)
  - 230 mm diameter



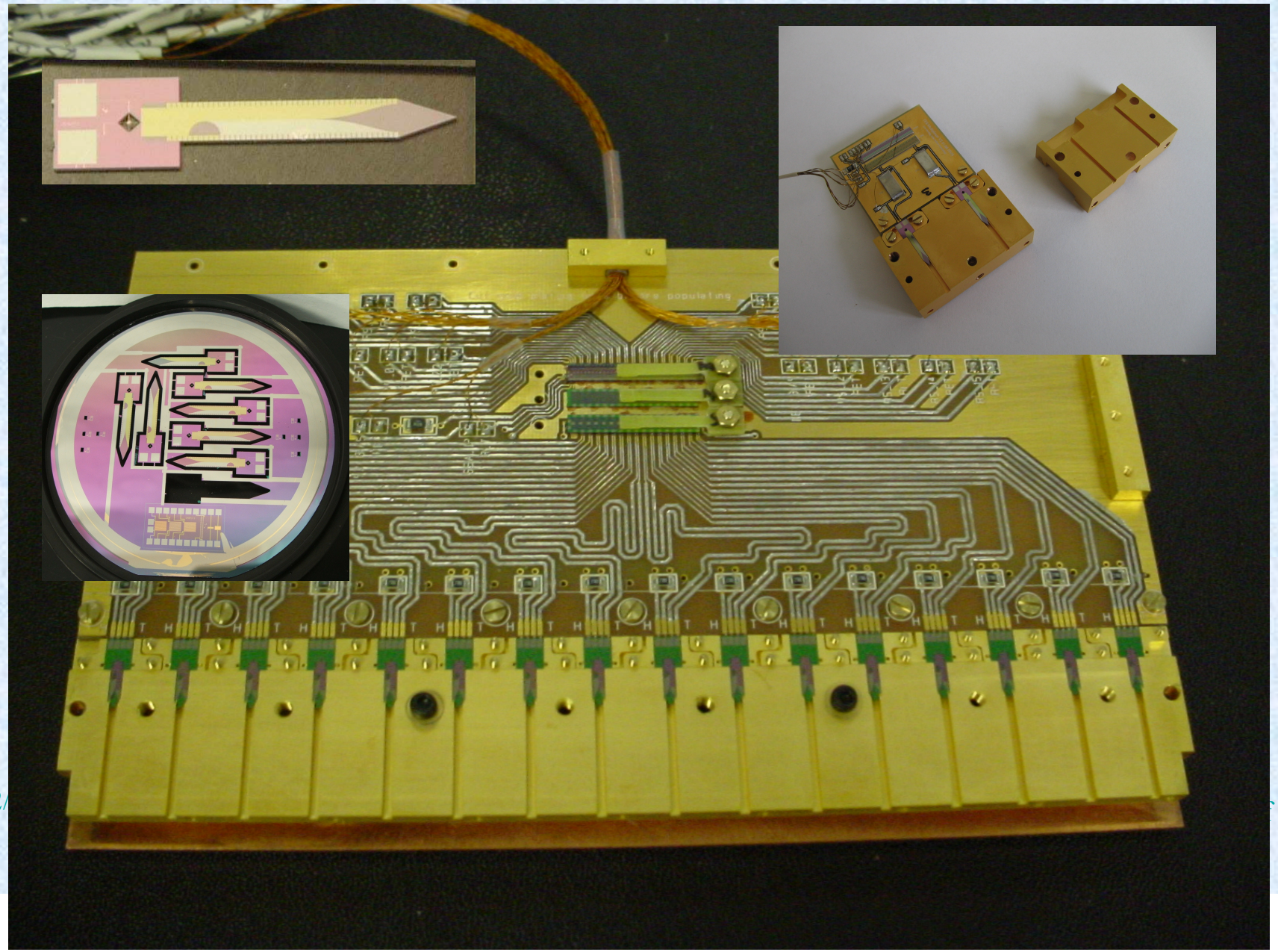


Corrugated Profiled Horn

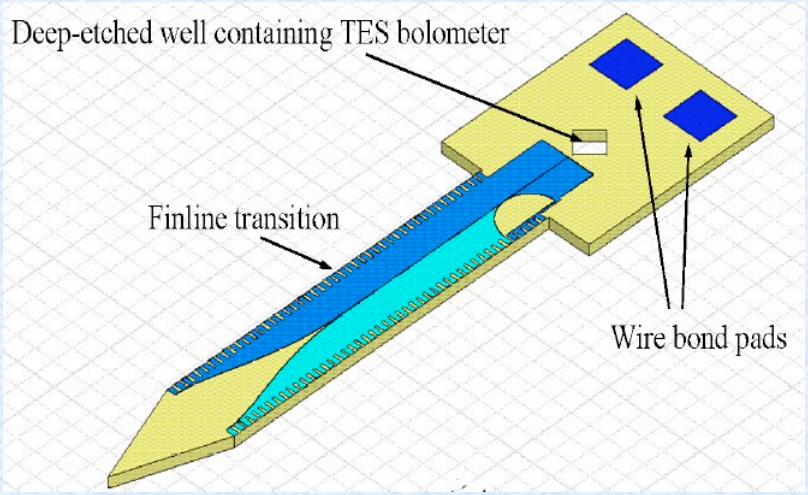
Waveguide OMT

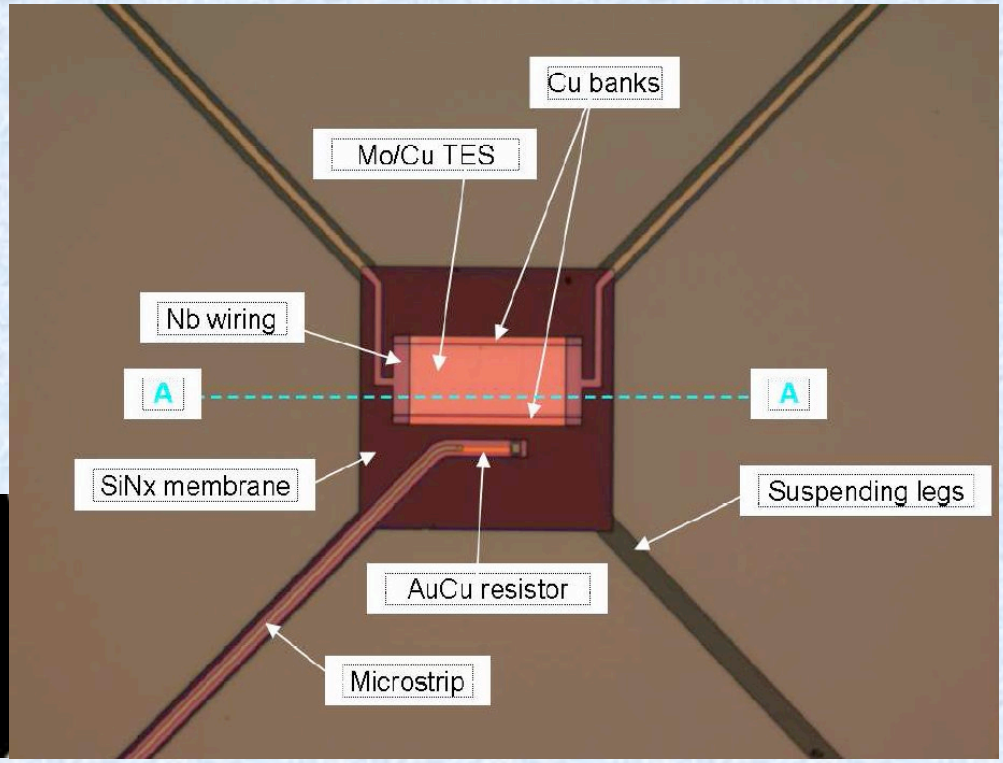
Finline Detector Blocks

Clover 97 GHz detector: wired up block of 16: 128 now manufactured



TES bolometers





• The detectors used in the 97GHz CLOVER are Transition Edge Sensors (TES) and these work at the edge the onset of superconduction as thus have a very large and fast change in resistance with temperature.

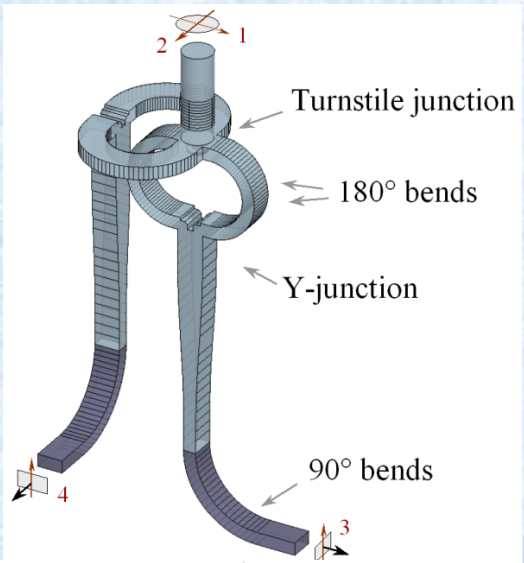
•They receive the RF power from the OMT rectangular waveguides via a superconducting fin-line probe. They are designed using a Mo/Cu bilayer on suspended SiNx membrane legs which is heated by a AuCu resistor in which the RF power from the fin-line is dumped.

97 GHz Horns

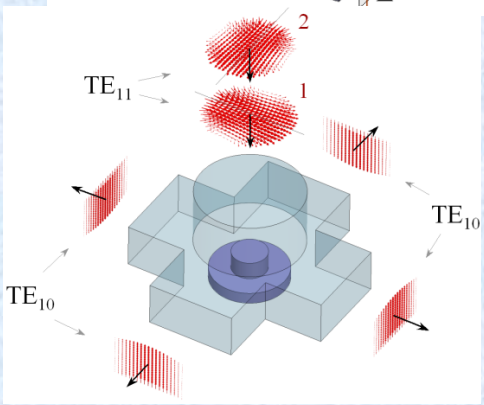
All 96 horns have been delivered

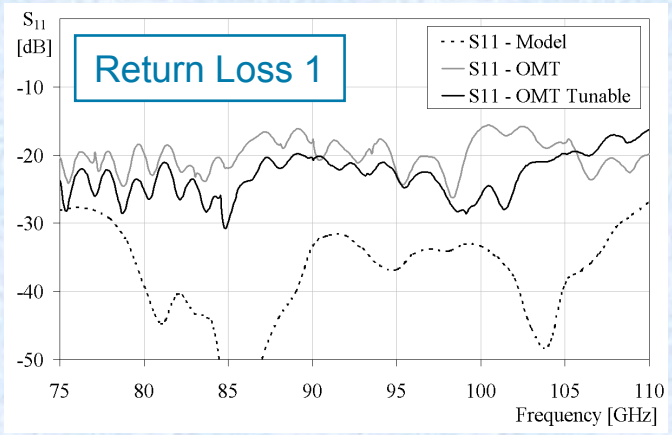
97 GHz Orthomode Transducer v.3: Design and Tests

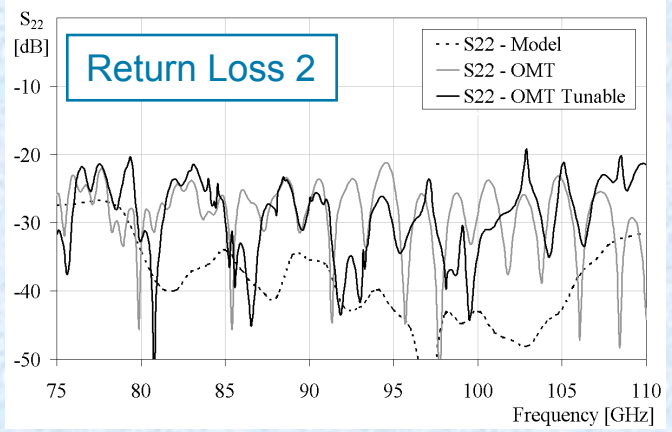
Pisano et al. - IEEE Micr.Wir.Comp.Lett. (4/2007)

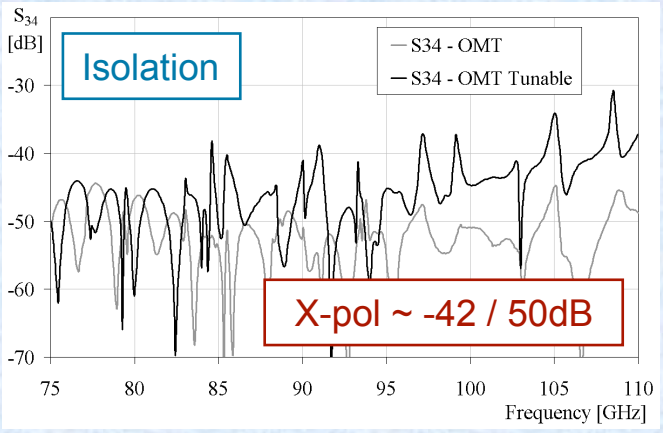


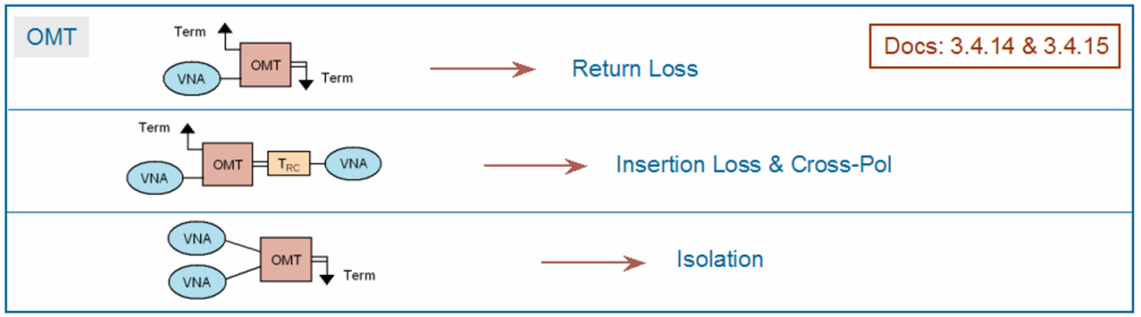
OMT v.2





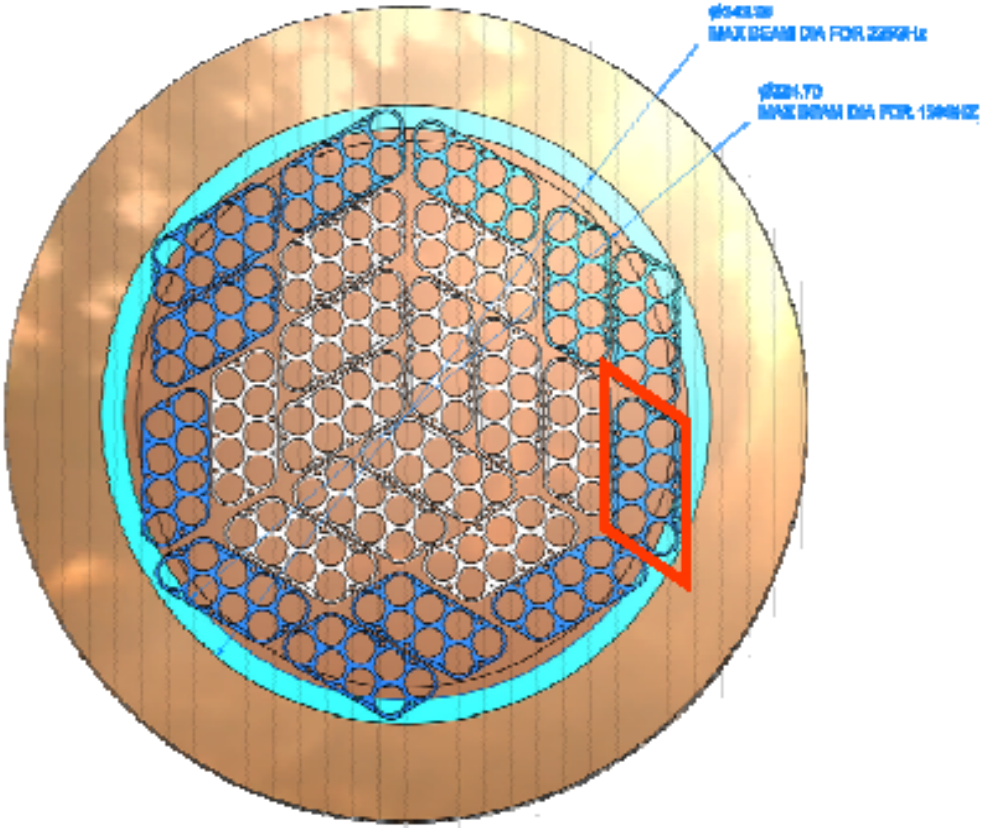


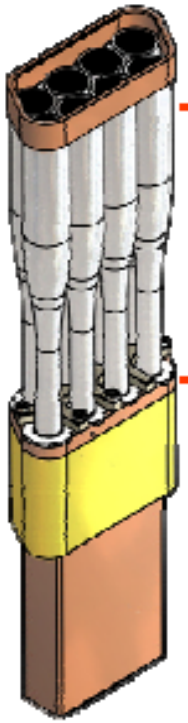




Focal Plane

- 150/225 GHz
  - 4x2 blocks of detector pairs
  - 96 pixels (192 detectors) per frequency
  - 220/230 mm diameter





Filter Stack

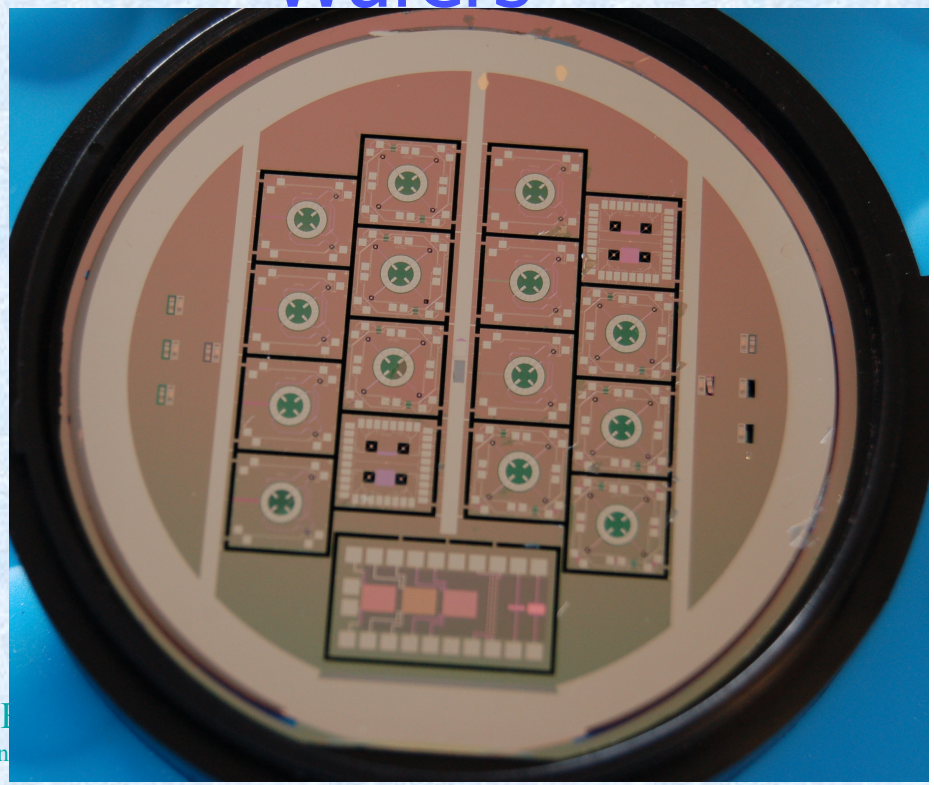
Corrugated Profiled Horn

Radial-probe OMT and Detectors

150/220 GHz detectors

Four-probe Detector Mount

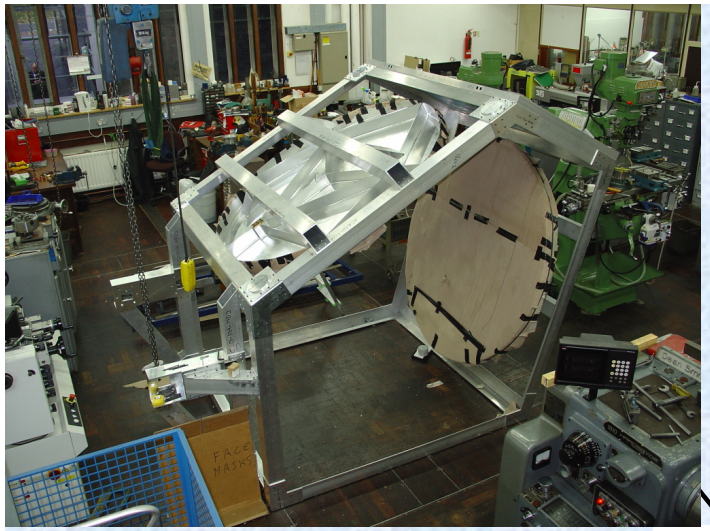
- Mass production Wafers

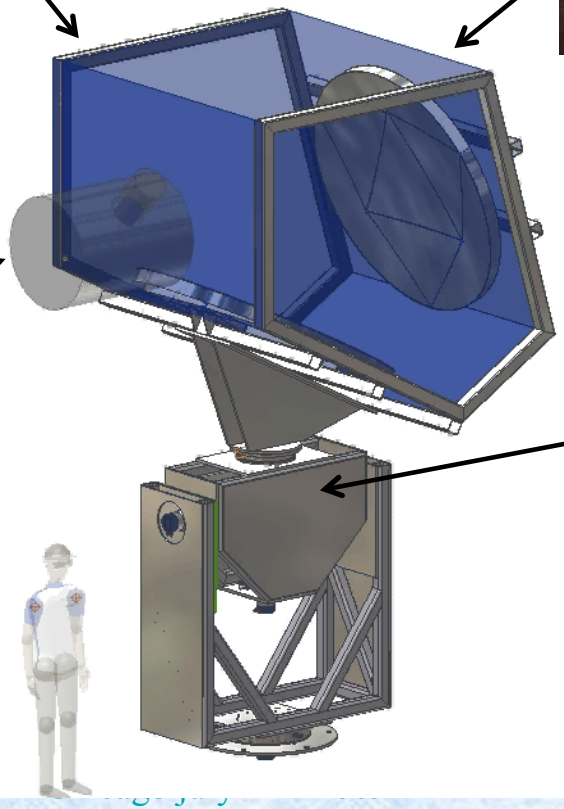


Some technical highlights

- First demonstration of TES detectors with finlines and microstrip coupling.
- Novel 'turnstile' OMTs for 97 GHz (& mass-produced)
- Demonstrated mm-wave radial probe OMTs (for 150/220 GHz) & first time with TES detectors
- Novel antenna mount design, allows comparatively large antenna with small central bearing
- 100 mK Dilution fridge operating at +/- 45 deg tilt
- Demonstrated large waveplates at mm wavelengths with required performance, both cryogenic (150/220 GHz) and room temperature (97 GHz), also large filters

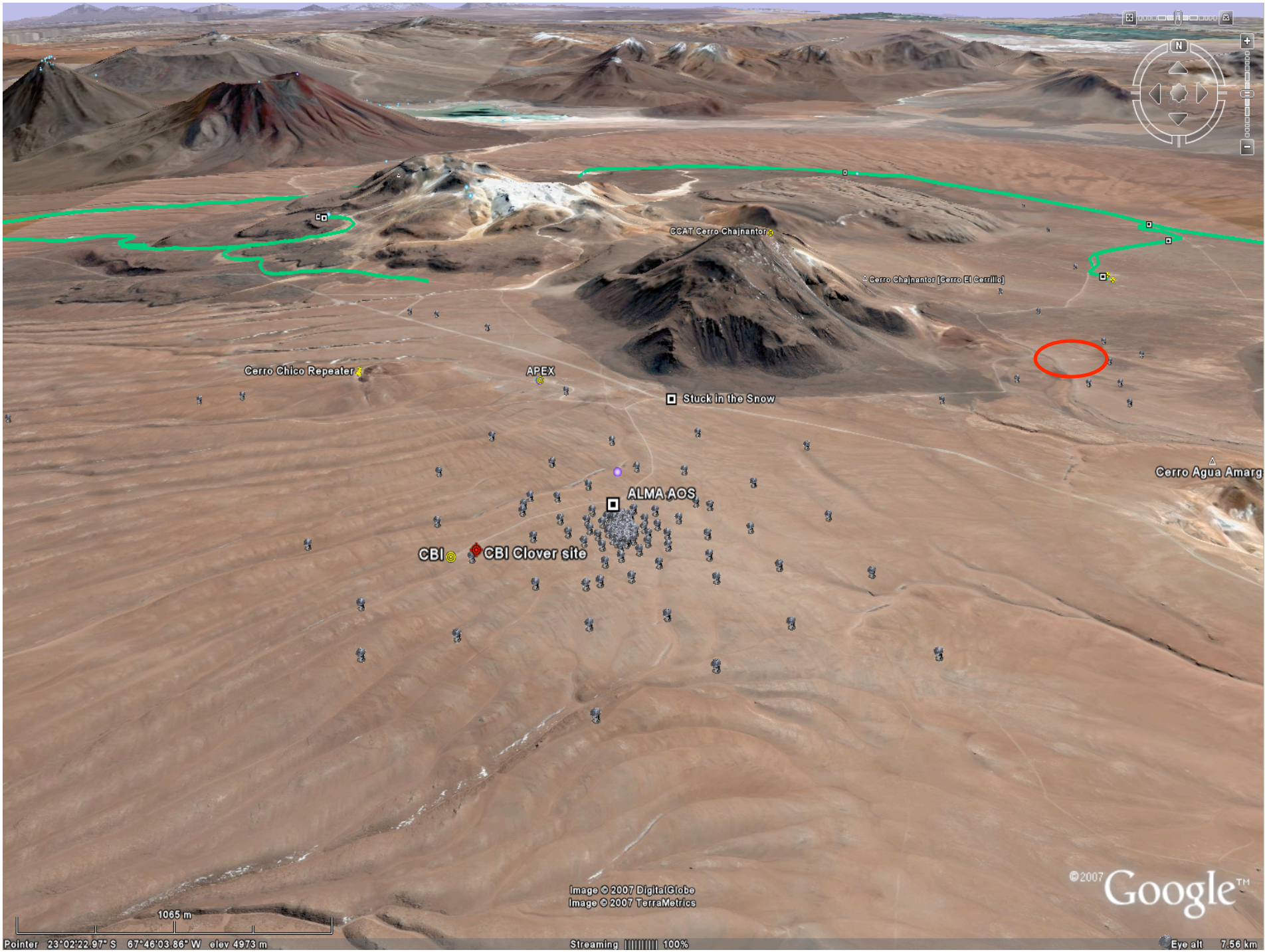
Hardware almost complete
AIV underway

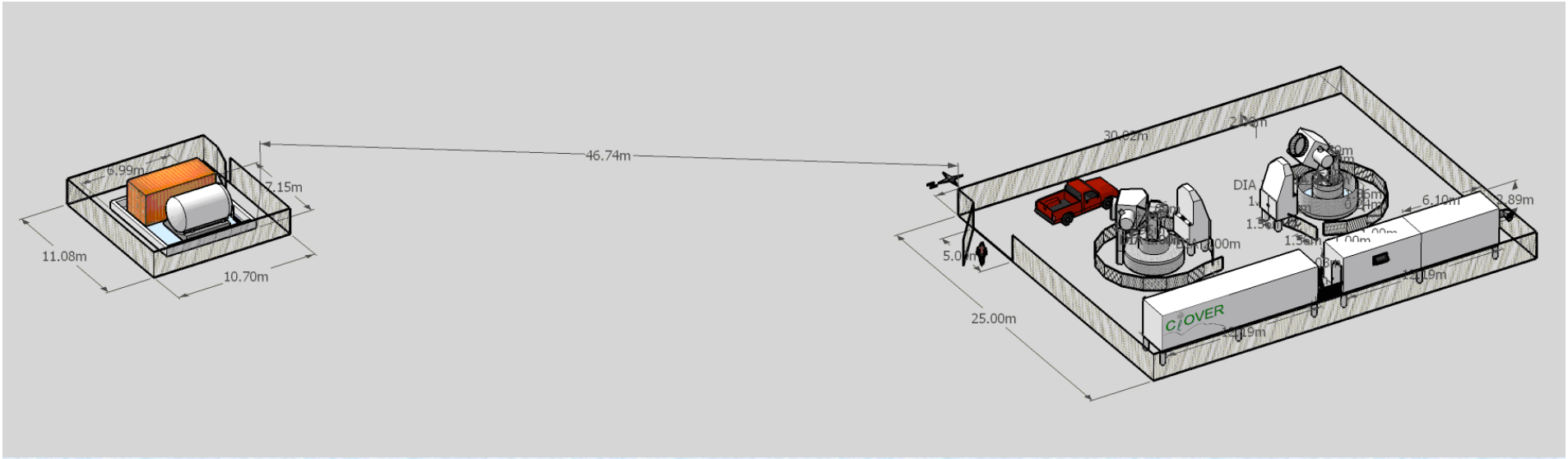


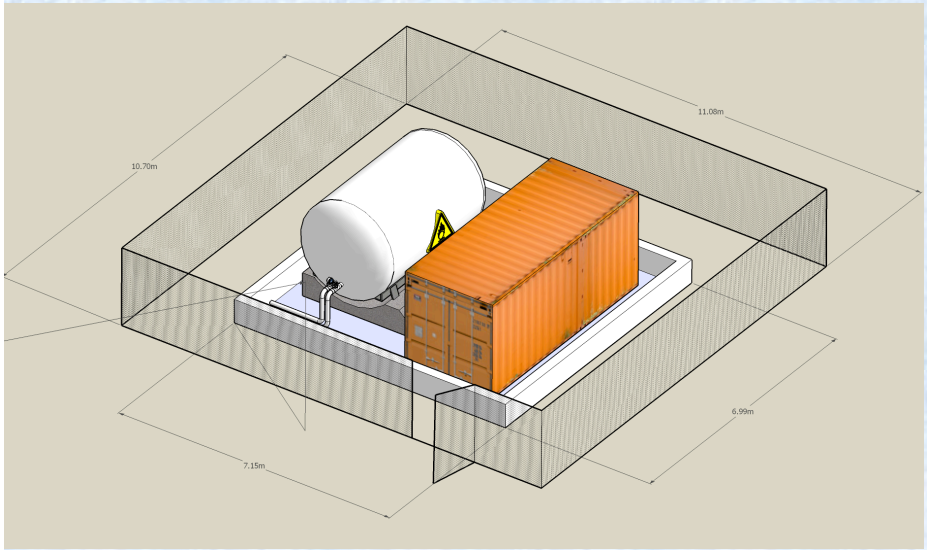


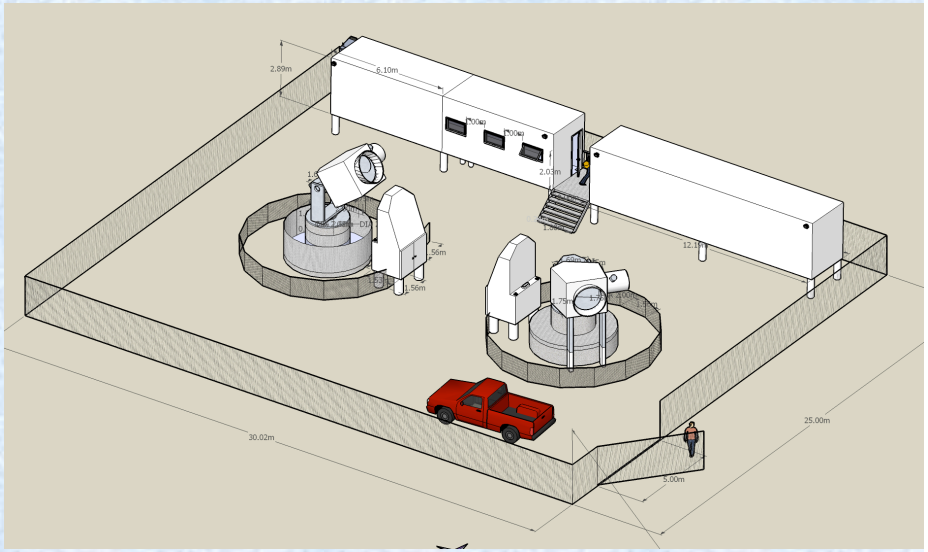
Detailed Plans for site, logistics and operations also made

- Originally proposed to ALMA board to be allowed to operate on Pampa La Bola (before recent security issues arose)
- Close to Apex or QUIET alternate possibilities
- Robotic operation, only maintenance on-site
- SPdA base in Don Estaban facility (CBI/ QUIET, ASTE, ACT)
- Planned to start site preparation about now…
- Delivery of first instrument early 2010
- All of this subject to funding by STFC….


CCAT Cerro Chajnantor
Cerro Chajnantor [Cerro El Cerrillo]
Cerro Chico Repeater
APEX
Stuck in the Snow
Cerro Agua Amarg
ALMA AOS
CBI
CBI Clover site
Image © 2007 DigitalGlobe
Image © 2007 TerraMetrics
©2007 Google™
1065 m
Pointer 23°02'22.97" S 67°46'03.86" W elev 4973 m
Streaming 100%
Eye alt 7.56 km


6.99m
7.15m
11.08m
10.70m
46.74m
30.02m
DIA
6.10m
2.89m
5.00m
25.00m
COVER


11.08m
10.70m
6.99m
7.15m


2.89m
6.10m
30.02m
25.00m
5.00m

Now the Bad News....

- UK is hit VERY badly by global financial crisis – possibly worst of G8 countries
- Astronomy funding was already under very severe pressure before this crisis (25% cut in grant funding)
- Clover request to STFC for £2.5M additional funding to complete deployment and commissioning has been denied, Clover is officially cancelled....
- [Catch-22: Originally being an almost entirely UK project was regarded as a good thing, but makes it much easier to cancel without causing international incident..!!]
- BUT....STFC has indicated it is willing to consider a reduced cost proposal with additional partners...

What do We Need ?

- $1-2M in cash would be VERY helpful !!
- Sharing of site facilities, inc power, data transfer etc would be beneficial
- Also sharing of operations costs
- Integrating Clover hardware into another existing project is also a possibility…
- Preliminary discussions are being held but nothing definite yet
- We are still open to offers !!