SWIPE multi-mode pixel assembly
-
Beam pattern measurement

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on behalf of SWIPE detector team

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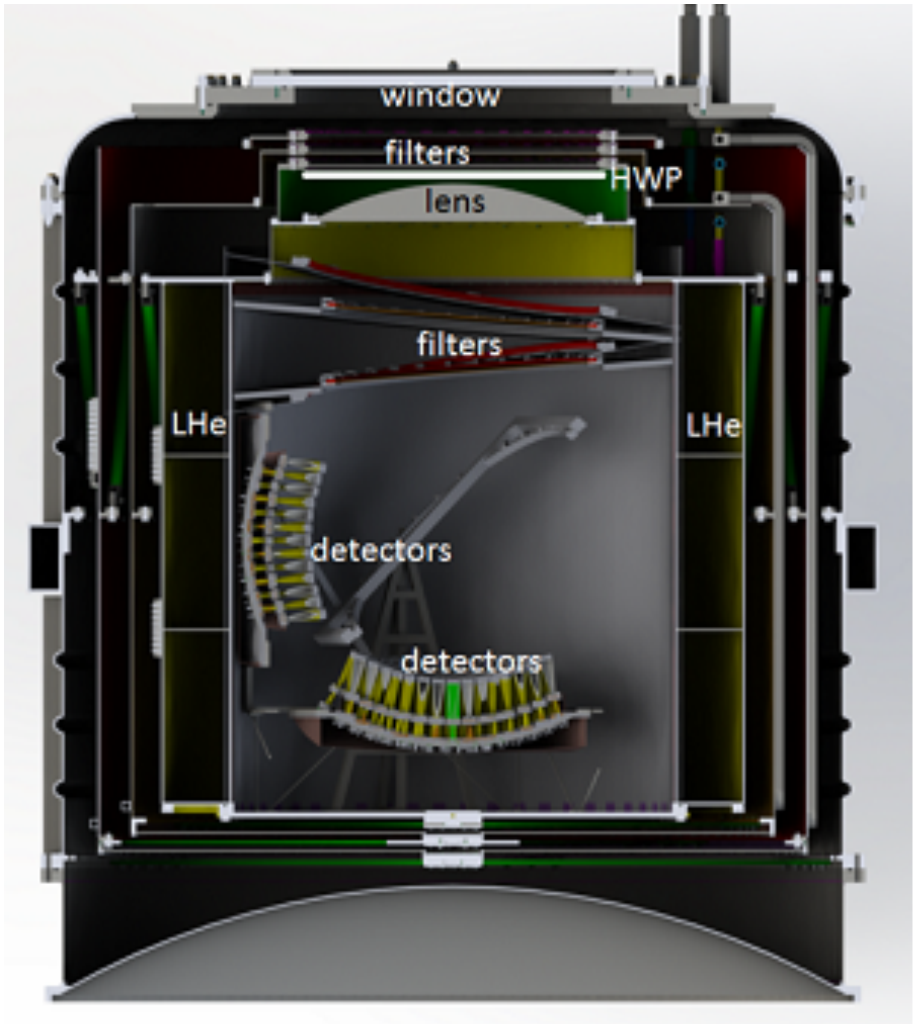
23/07/2019, LTD18 - Milano

LSPE - SWIPE



POSTER 165 - L. Lamagna

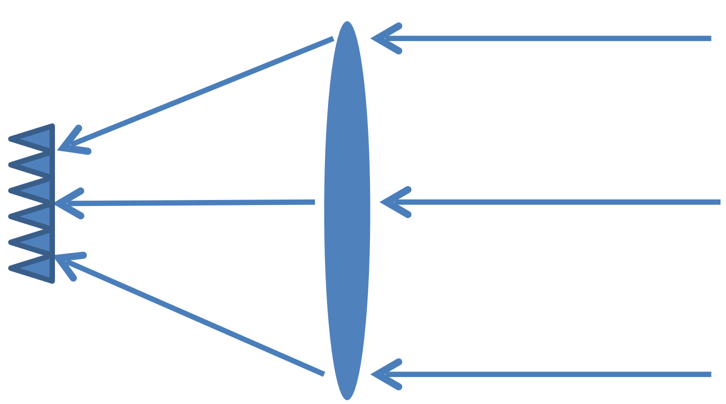
The Large Scale Polarization Explorer

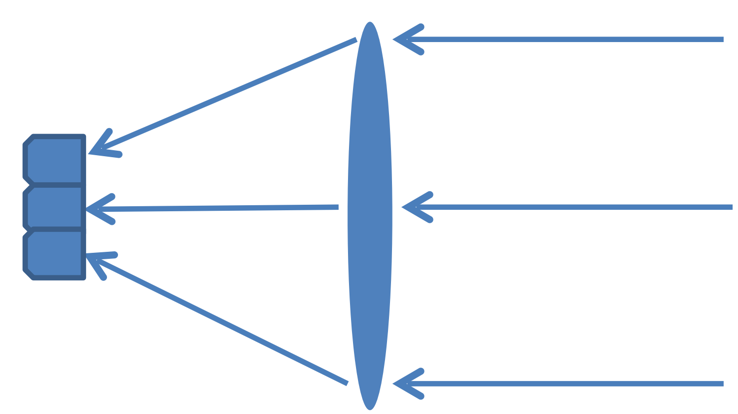
- Stratospheric balloon which will be launched from the Longyearbyen airport in Svalbard Islands
- Goal r = 0.01
- Stokes Polarimeter with 500 mm aperture refractive telescope
- Cryogenic HWP polarization modulator
- 2 large focal planes, filled with multimode bolometers at 140, 220, 240 GHz cooled by a ^{3}He refrigerator at 0.3K

Single-mode vs multi-mode design

- Diffraction- and photon-noise limited operation over quite a broad band demonstrated
- Solid modeling techniques
- Reliable methods for assessing real-life performance.
- Instrument design is complicated but huge experience accumulated by community over the last few years.
- Large numbers of detectors needed to break photon noise limit

- Reduce the number of individual sensitive elements each hitting the photon noise limit more easily
- Sensitivity per individual device scales like $N_{modes}^{1/2}$
- Comparatively larger detector units and coarser angular resolution.
- Viable and cost-effective when sensitivity is a stronger requirement than diffraction-limited operation (e.g. Planck 545 and 857 GHz)
- CMB spectral distortion and large scale B-mode searches can fully take advantage of mm design (PIXIE, LSPE)





Testing the pixel angular response is essential

The SWIPE pixel assembly

- 326 detectors divided in the 3 frequency bands: **140 GHz**, 220 GHz, 240 GHz
- ~8800 modes collected

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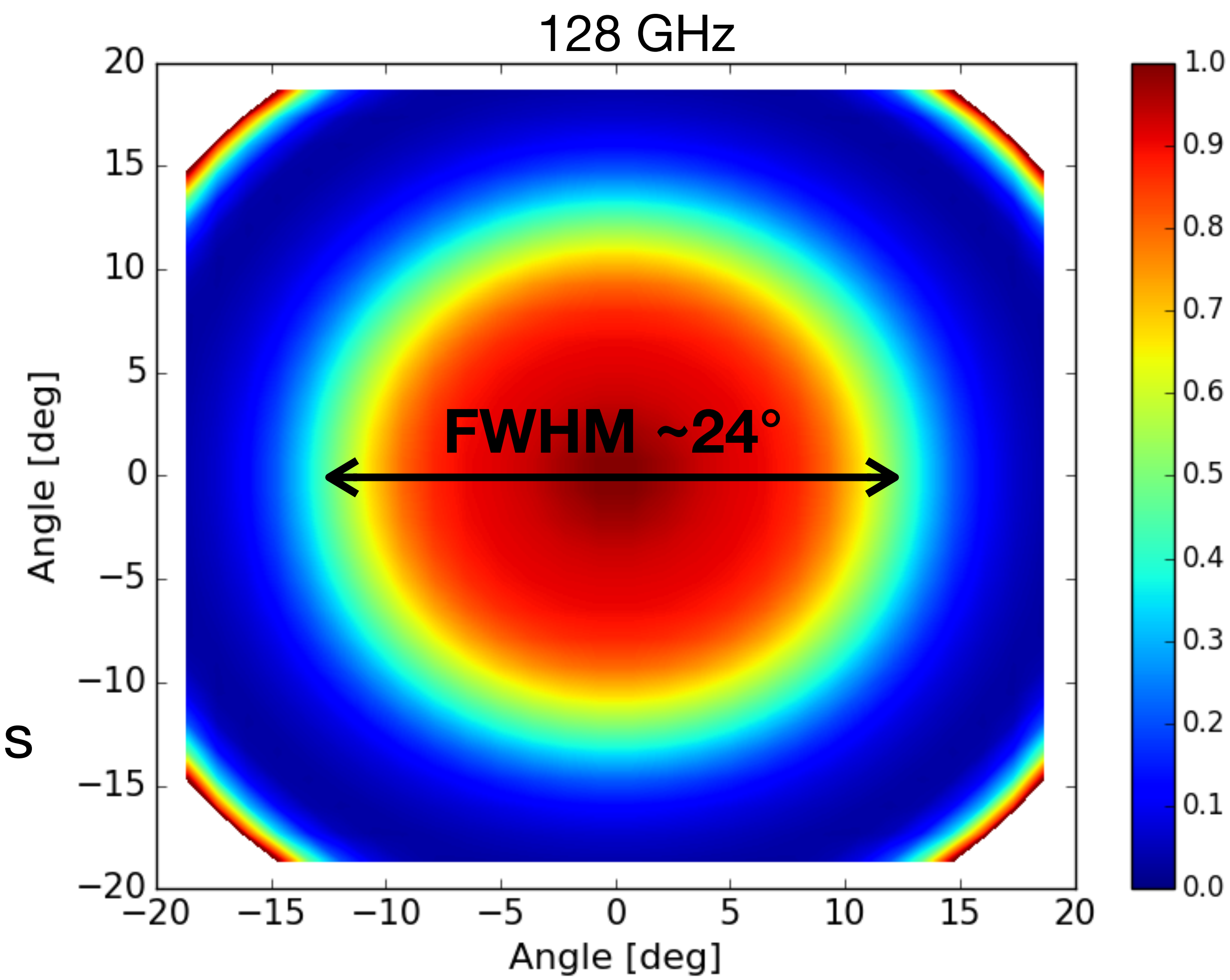
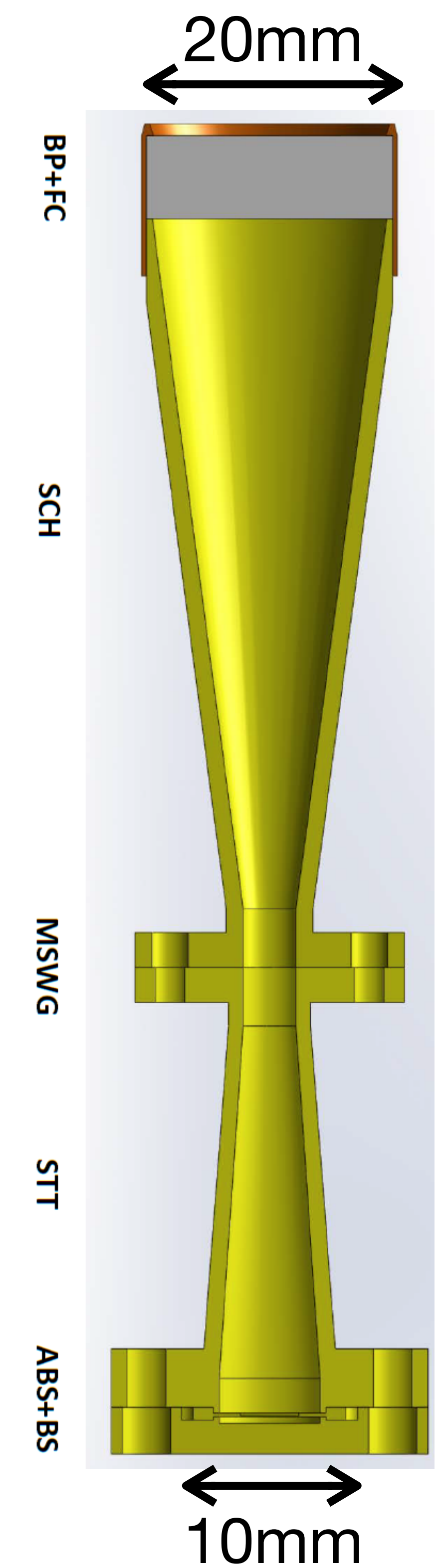
Same sensitivity of ~9k pixels





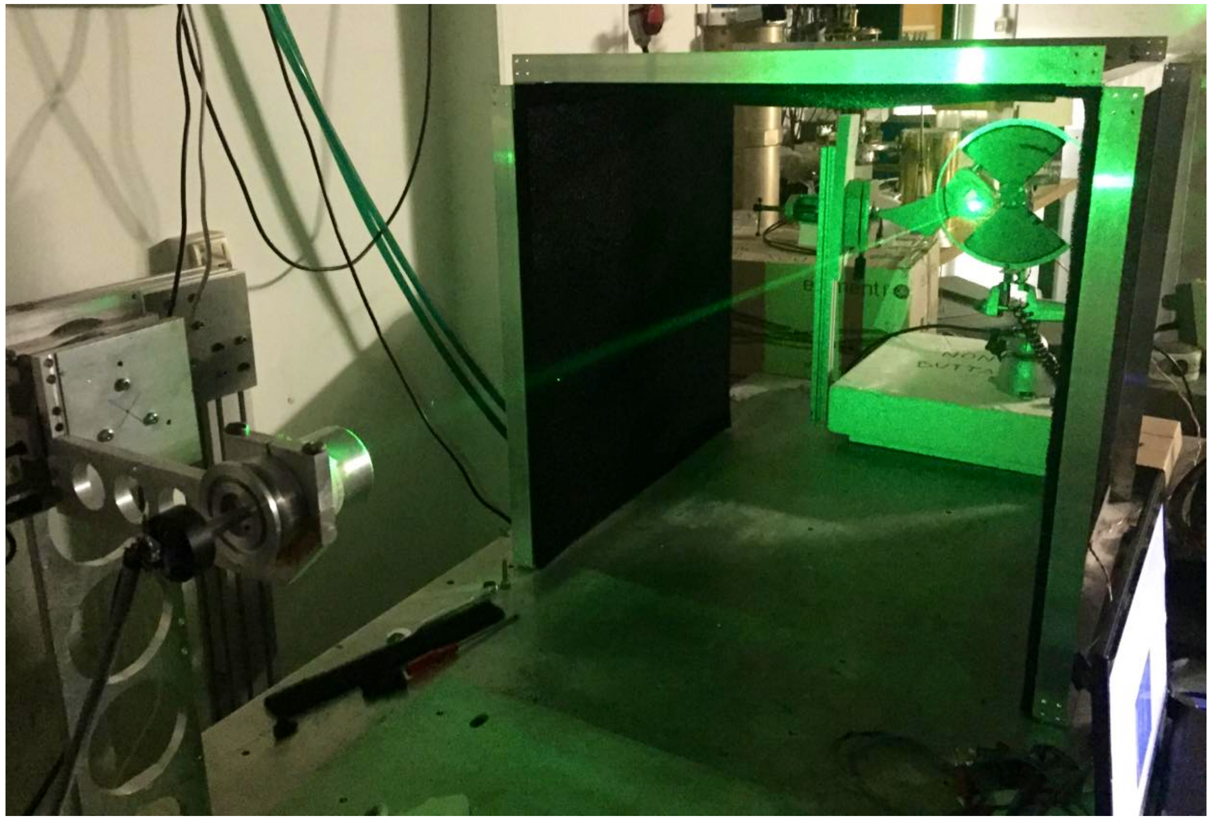
Nominal freq (GHz)	Bandwidth	Min freq (GHz)	Max freq (GHz)
140	30%	119	161
220	5%	214.5	225.5
240	5%	234	246

Table 1 – main features of the SWIPE bandpasses (source: C. Tucker, Cardiff Univ.)

Channel	ν_{min}(GHz)	$N_{modes}(\nu_{min})$	ν_{max}(GHz)	$N_{modes}(\nu_{max})$	ν_{eff}(GHz)	$N_{modes}(\nu_{eff})$
140	119	10	161	17	140	12
220	214	28	226	31	220	30
240	234	32	246	35	240	34

Table 2 – number of coupled modes N_{modes} at the center and at the edges of each SWIPE band. The total optical throughput at frequency ν is $N_{modes}c^2/\nu^2$.

Room temperature measurements

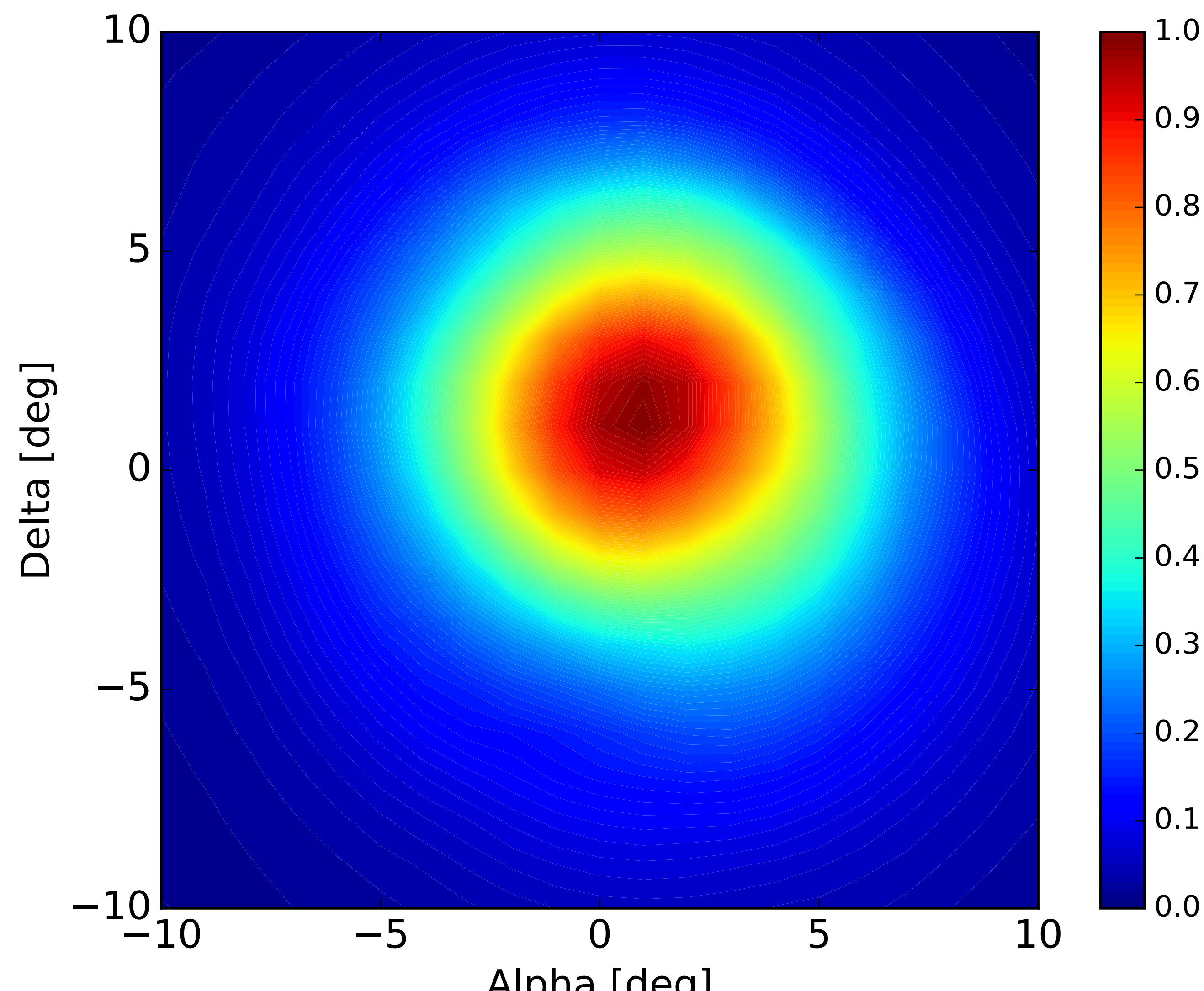


Bolometer replaced with a white paper diffuser and a custom holder. SWIPE horn coupled with a visible light photodiode.

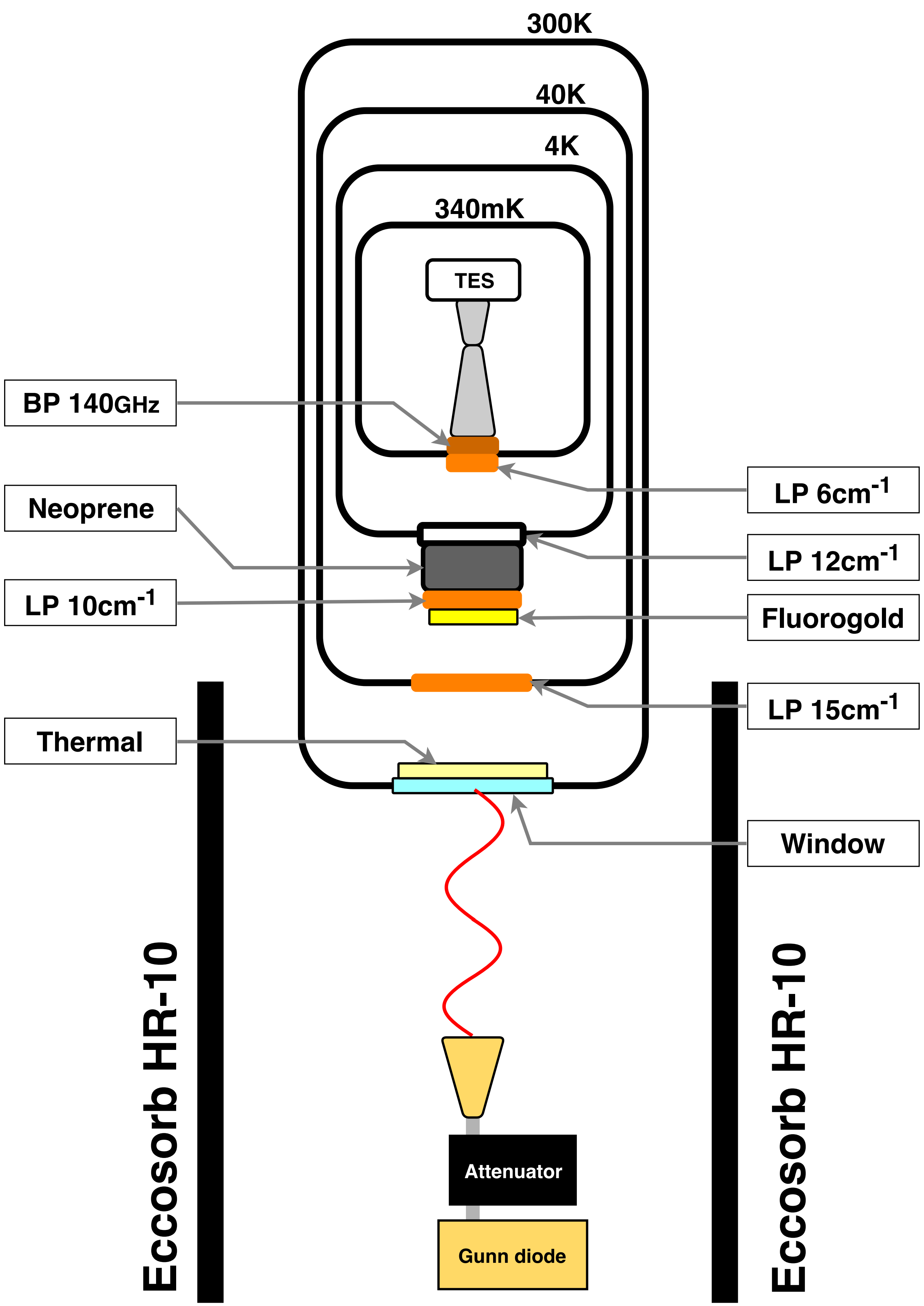
Expected circular beam

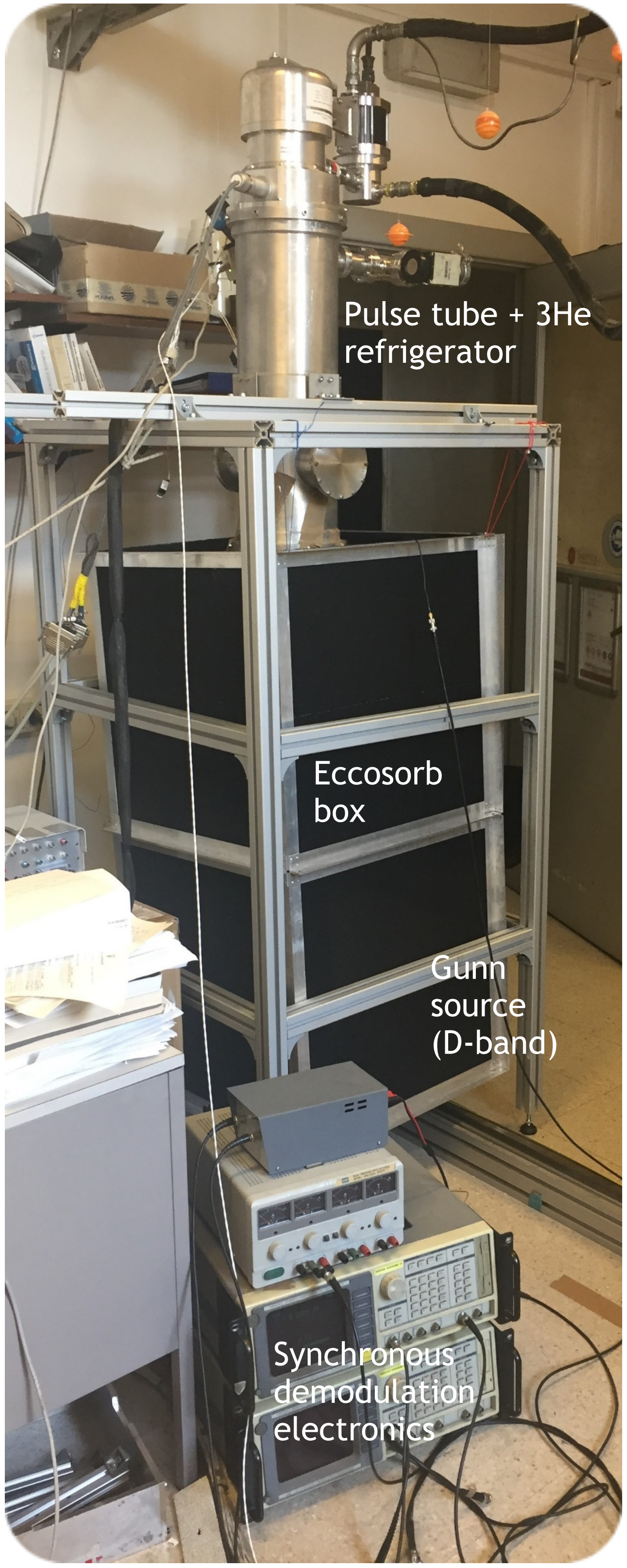
⇩

Symmetric pattern

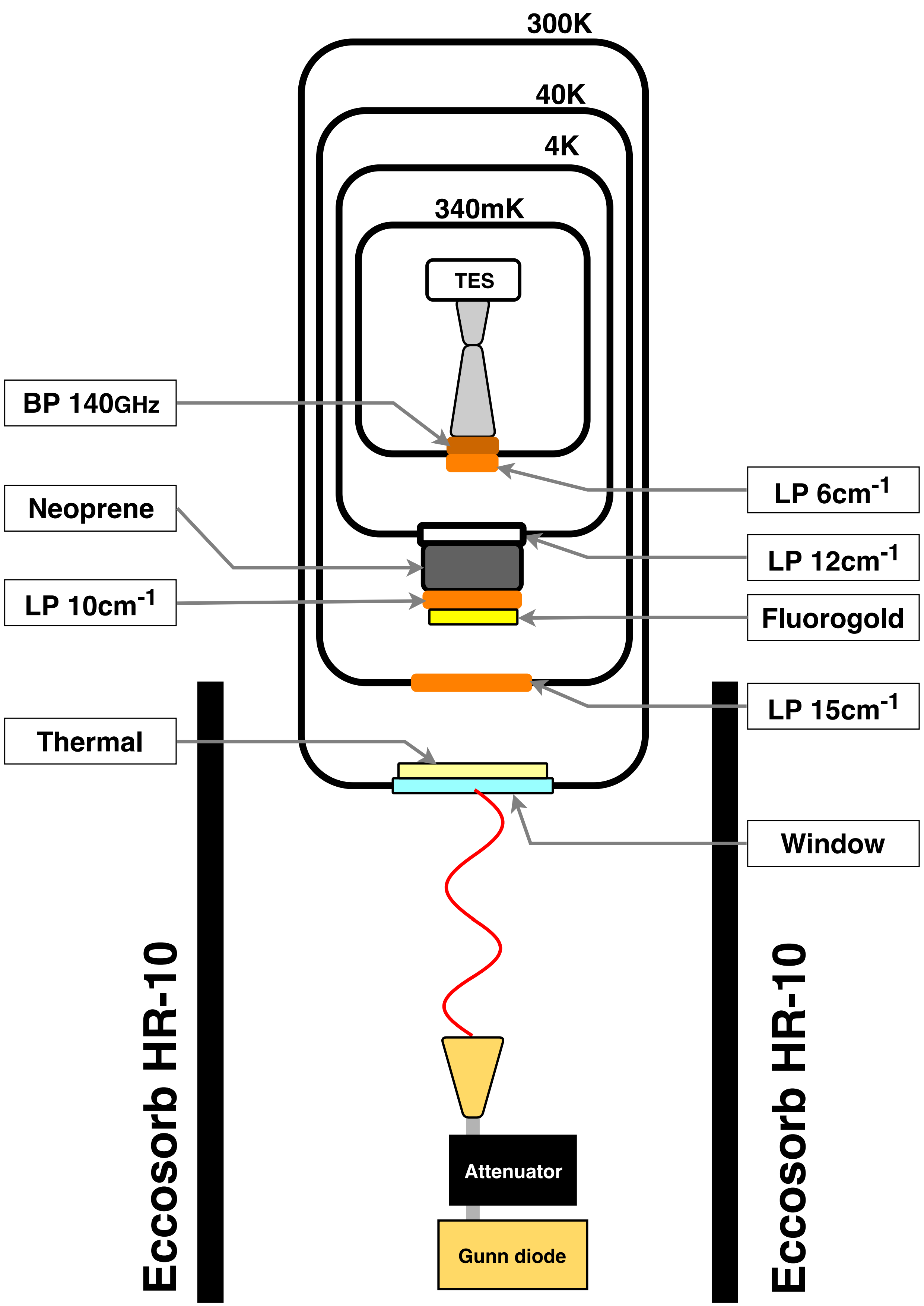


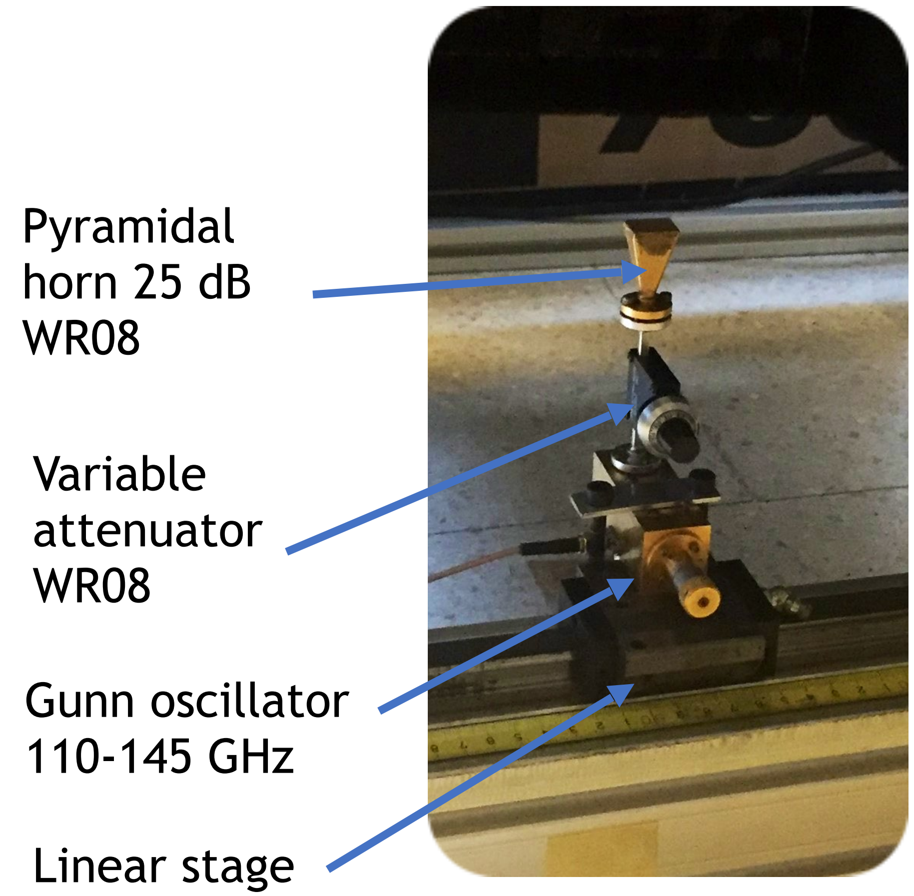
Testbed

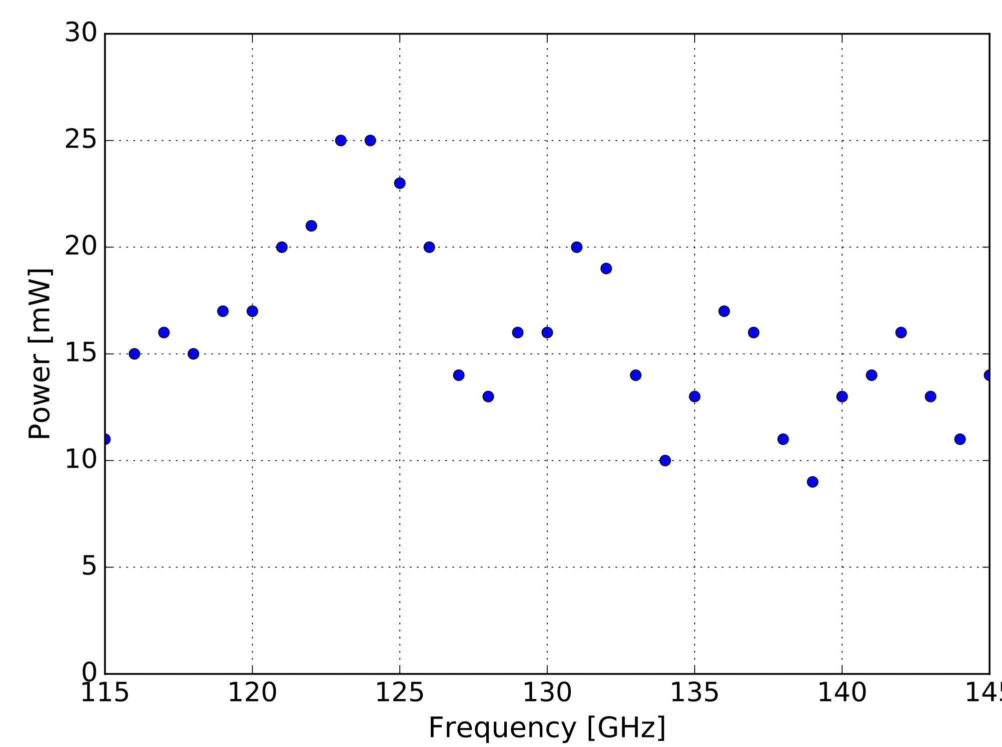

300K
40K
4K
340mK
TES
BP 140GHz
Neoprene
LP 10cm-1
Thermal
LP 6cm-1
LP 12cm-1
Fluorogold
LP 15cm-1
Window
Eccosorb HR-10
Eccosorb HR-10
Attenuator
Gunn diode


Pulse tube + 3He
refrigerator
Eccosorb
box
Gunn
source
(D-band)
Synchronous
demodulation
electronics

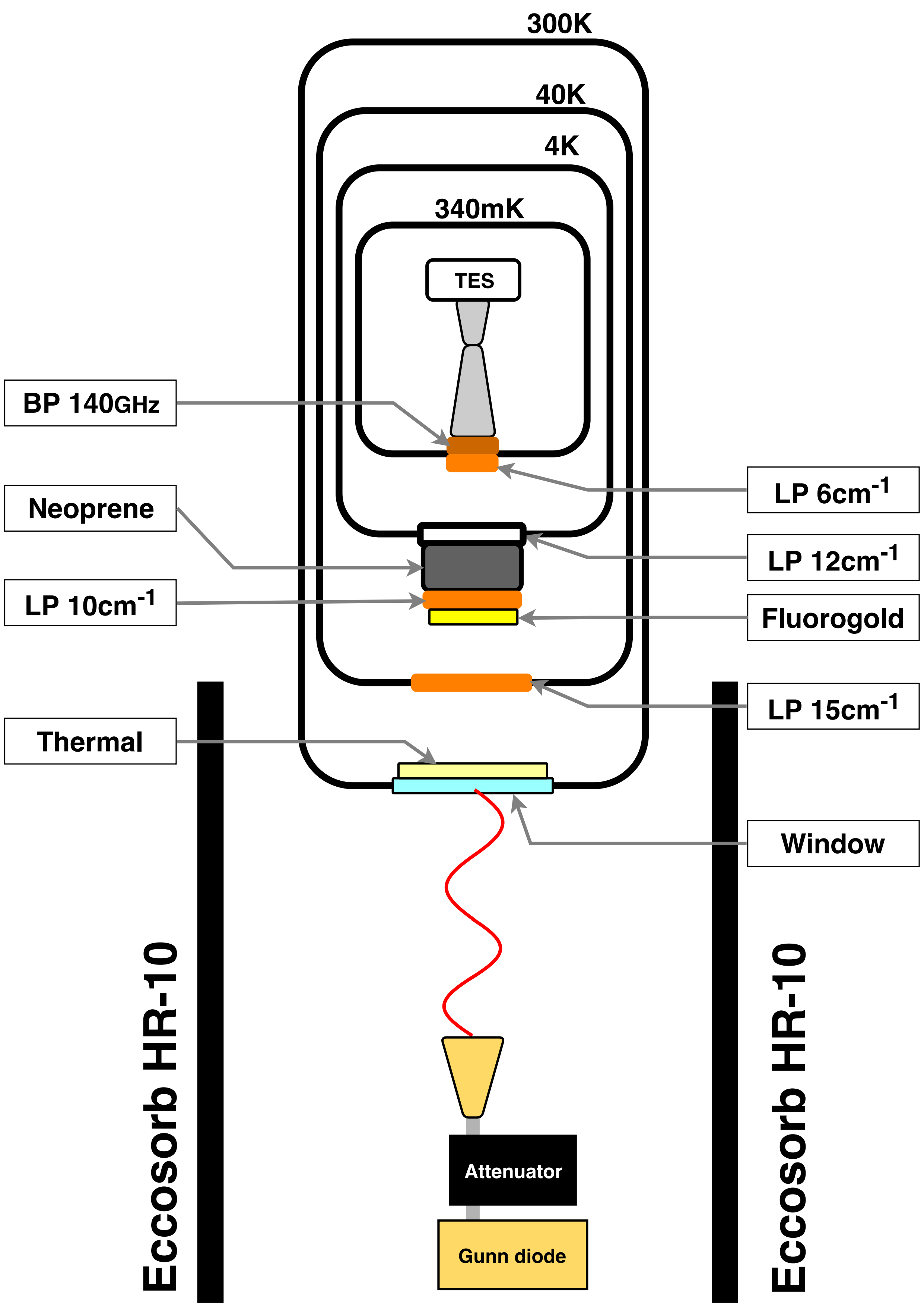
Testbed

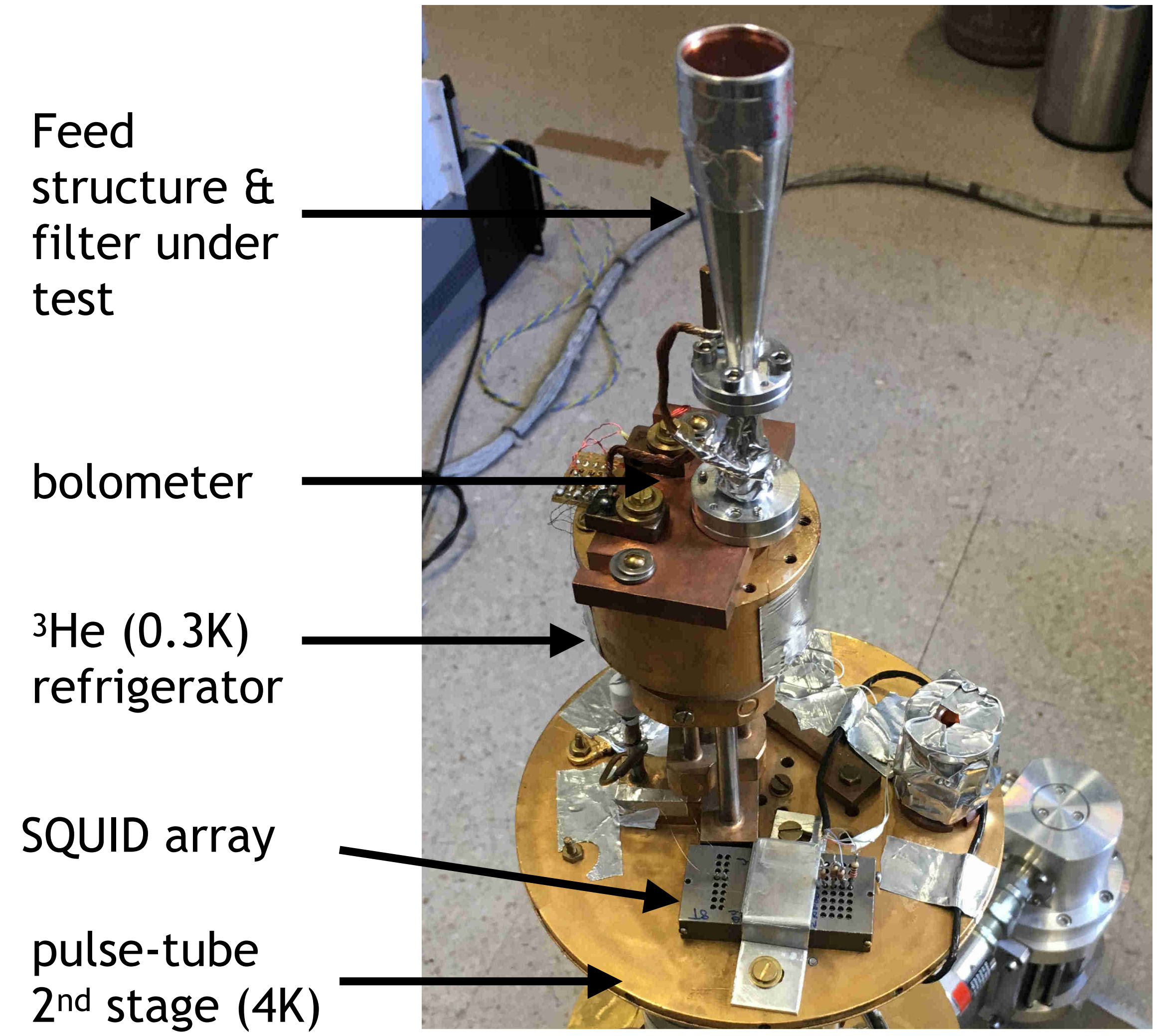

300K
40K
4K
340mK
TES
BP 140GHz
Neoprene
LP 10cm-1
Thermal
LP 6cm-1
LP 12cm-1
Fluorogold
LP 15cm-1
Window
Attenuator
Gunn diode
Eccosorb HR-10
Eccosorb HR-10

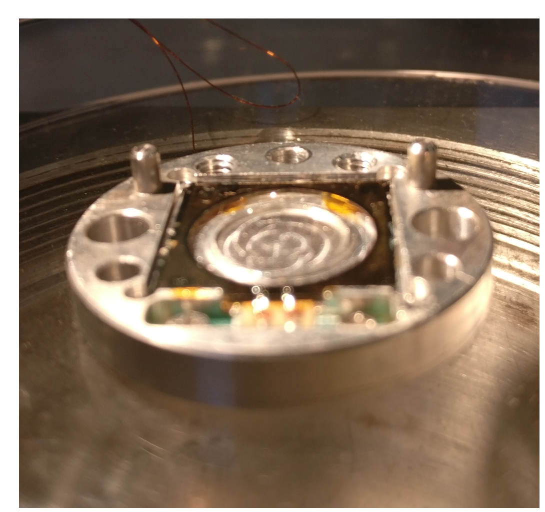

Pyramidal horn 25 dB WR08
Variable attenuator WR08
Gunn oscillator 110-145 GHz
Linear stage

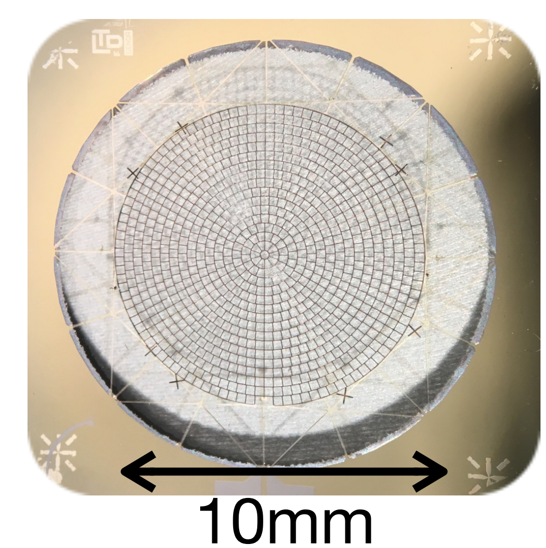

Power [mW]
Frequency [GHz]
0
5
10
15
20
25
30
115
120
125
130
135
140
145

Testbed









POSTER 400 - B. Siri

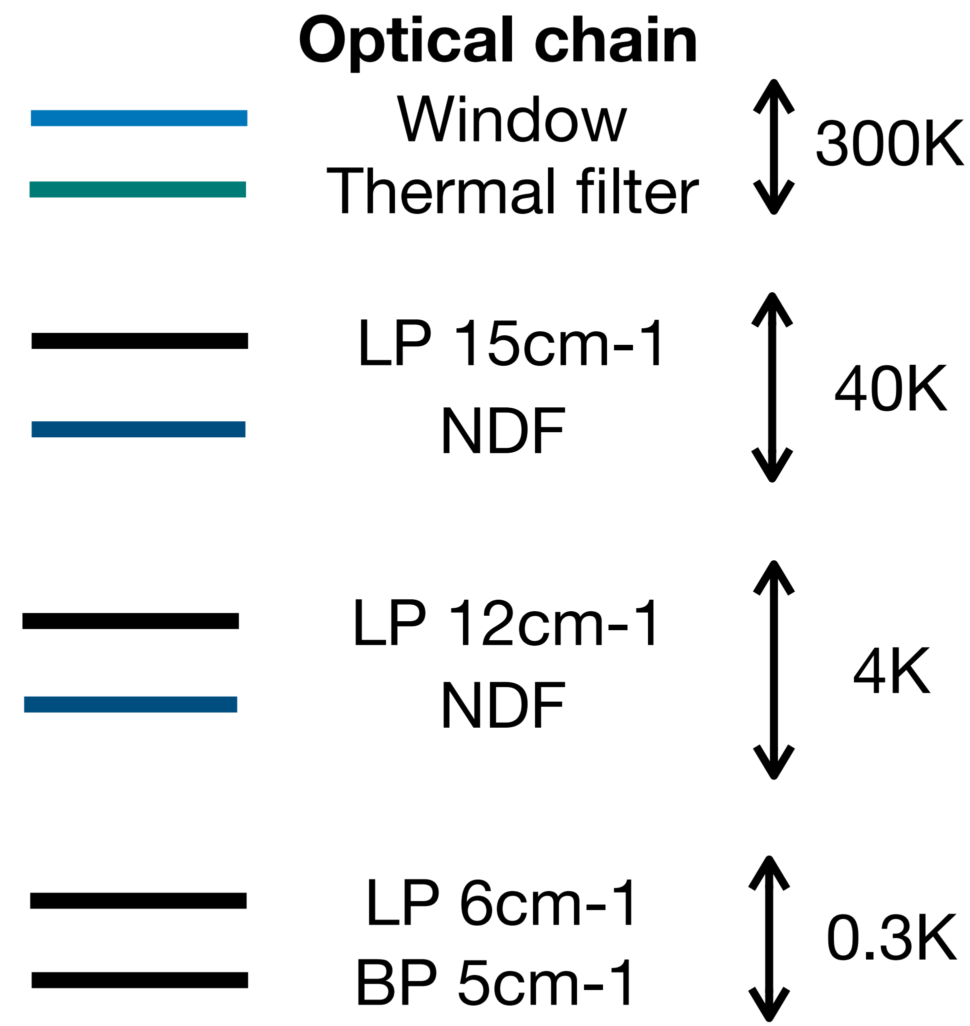
Bismuth-Gold absorber for large area TES spiderweb bolometers

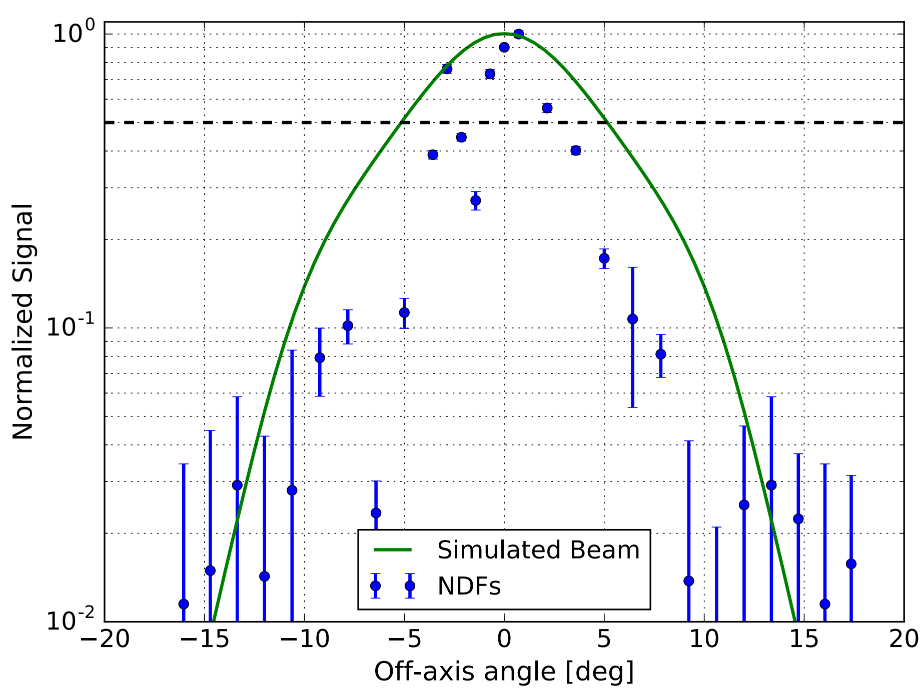
NDFs configuration

	Temperature [K]	Trasmissivity	Emissivity	Load [pW]
BP 4.7cm-1	0,3	0,9	0,01	<0,1
LP 6cm-1	0,3	0,9	0,01	<0,1
NDF	7,5	0,003	<0,01	~1,2
LP 12cm-1	7,5	0,9	0,01	<0,1
NDF	40	0,01	<0,01	<0,1
LP 15cm-1	40	0,95	0,01	<0,1
Thermal	300	0,99	<0,01	<0,1
Window	300	0,7	0,008	<0,1

Stratospheric background ~ 10pW

Total detector background ~ 2pW





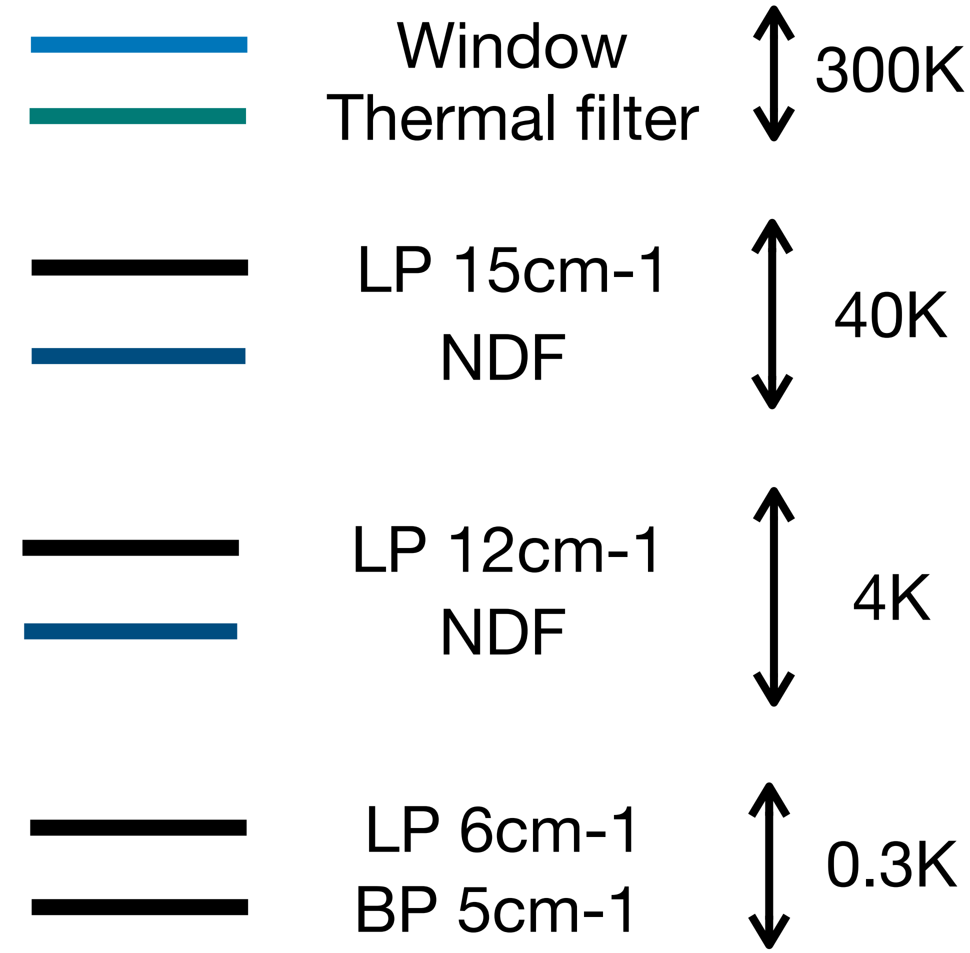
NDFs configuration

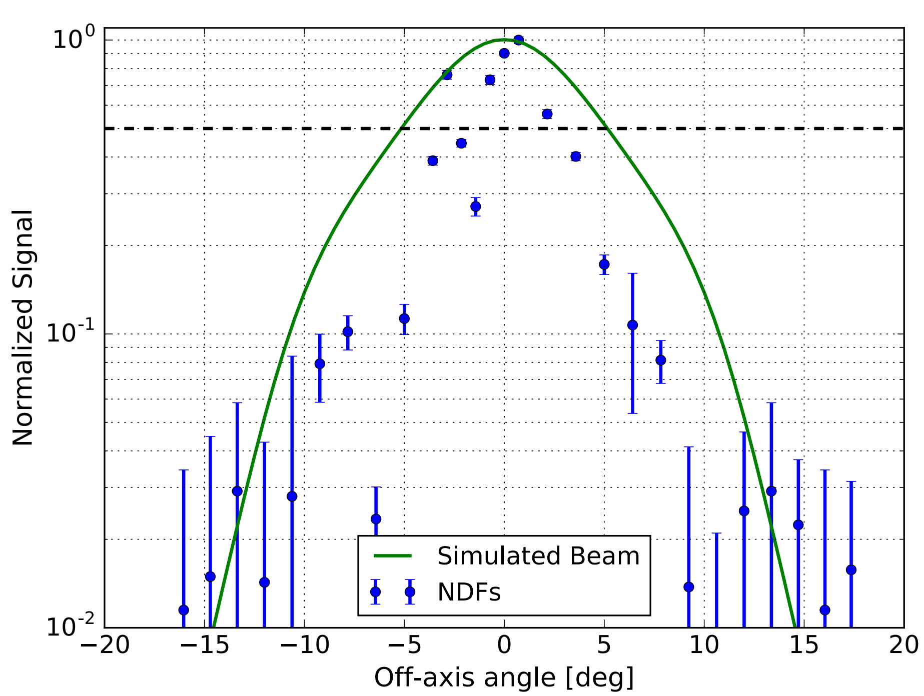
	Temperature [K]	Trasmissivity	Emissivity	Load [pW]
BP 4.7cm-1	0,3	0,9	0,01	<0,1
LP 6cm-1	0,3	0,9	0,01	<0,1
NDF	7,5	0,003	<0,01	~1,2
LP 12cm-1	7,5	0,9	0,01	<0,1
NDF	40	0,01	<0,01	<0,1
LP 15cm-1	40	0,95	0,01	<0,1
Thermal	300	0,99	<0,01	<0,1
Window	300	0,7	0,008	<0,1

Stratospheric background ~ 10pW

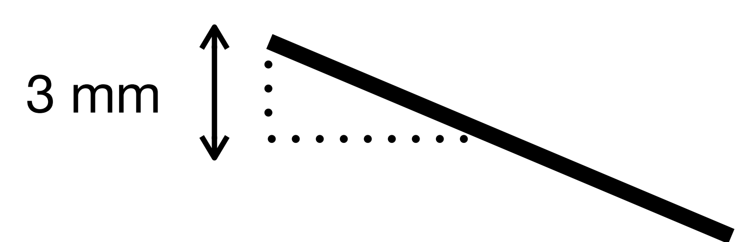
Total detector background ~ 2pW

Optical chain





140 GHz —> ~ 2 mm



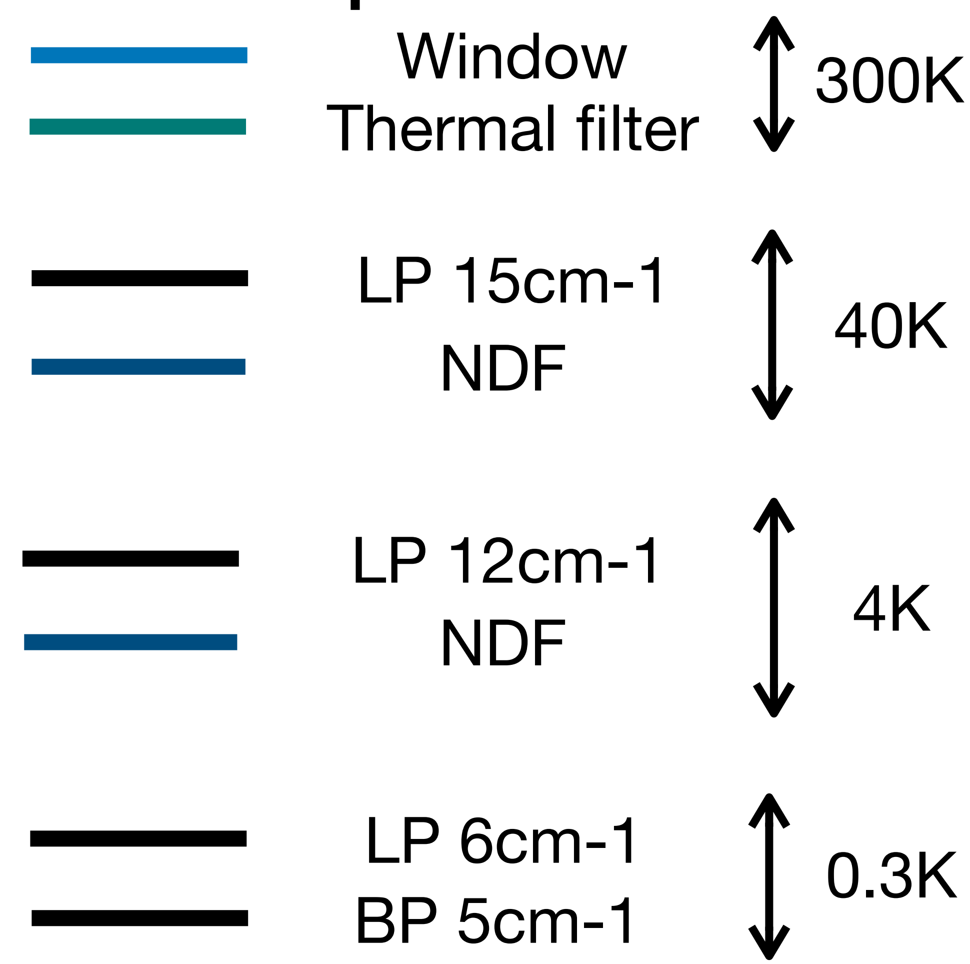
NDFs configuration

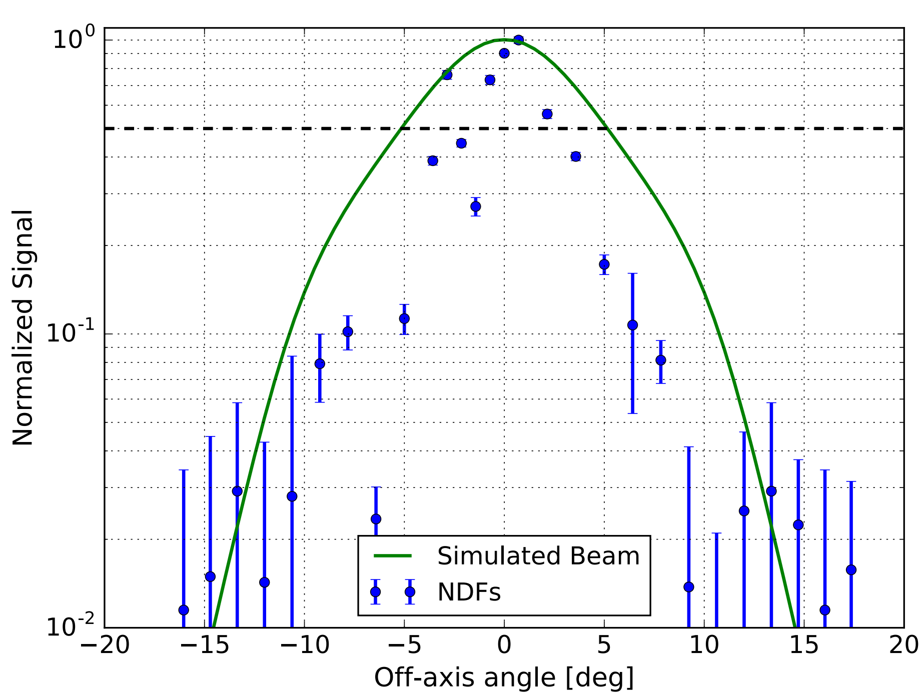
	Temperature [K]	Trasmissivity	Emissivity	Load [pW]
BP 4.7cm-1	0,3	0,9	0,01	<0,1
LP 6cm-1	0,3	0,9	0,01	<0,1
NDF	7,5	0,003	<0,01	~1,2
LP 12cm-1	7,5	0,9	0,01	<0,1
NDF	40	0,01	<0,01	<0,1
LP 15cm-1	40	0,95	0,01	<0,1
Thermal	300	0,99	<0,01	<0,1
Window	300	0,7	0,008	<0,1

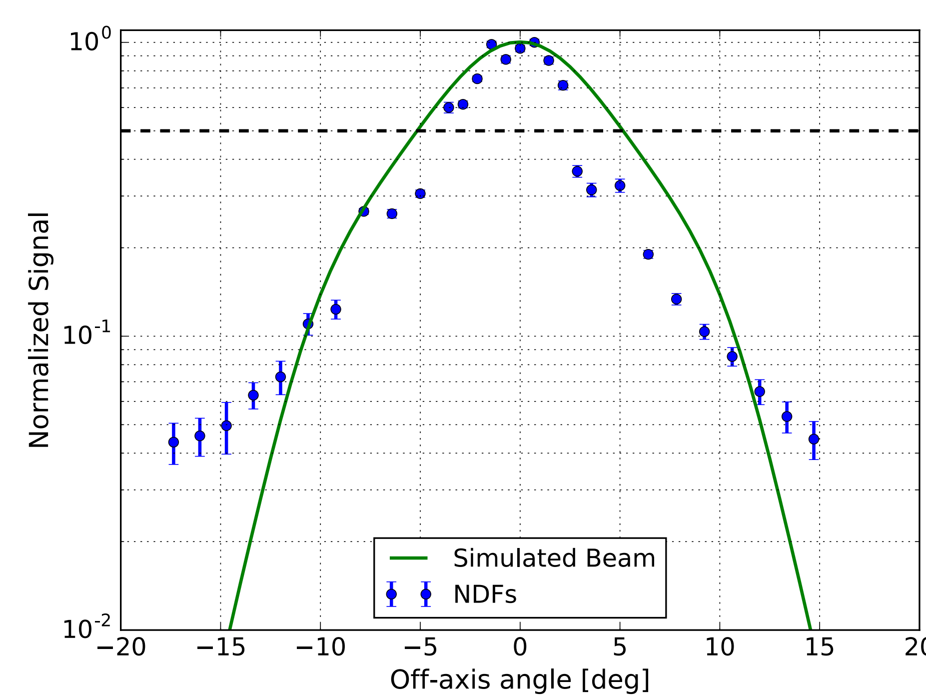
Stratospheric background ~ 10pW

Total detector background ~ 2pW

Optical chain







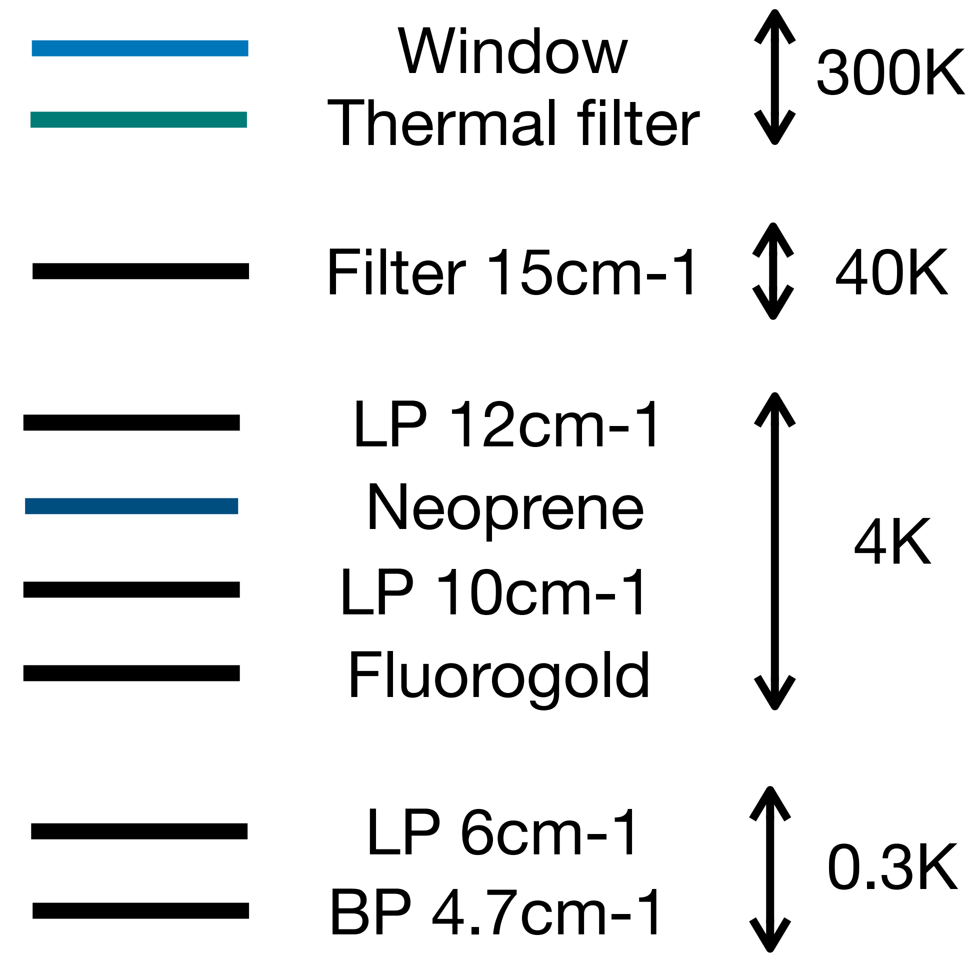
Neoprene configuration

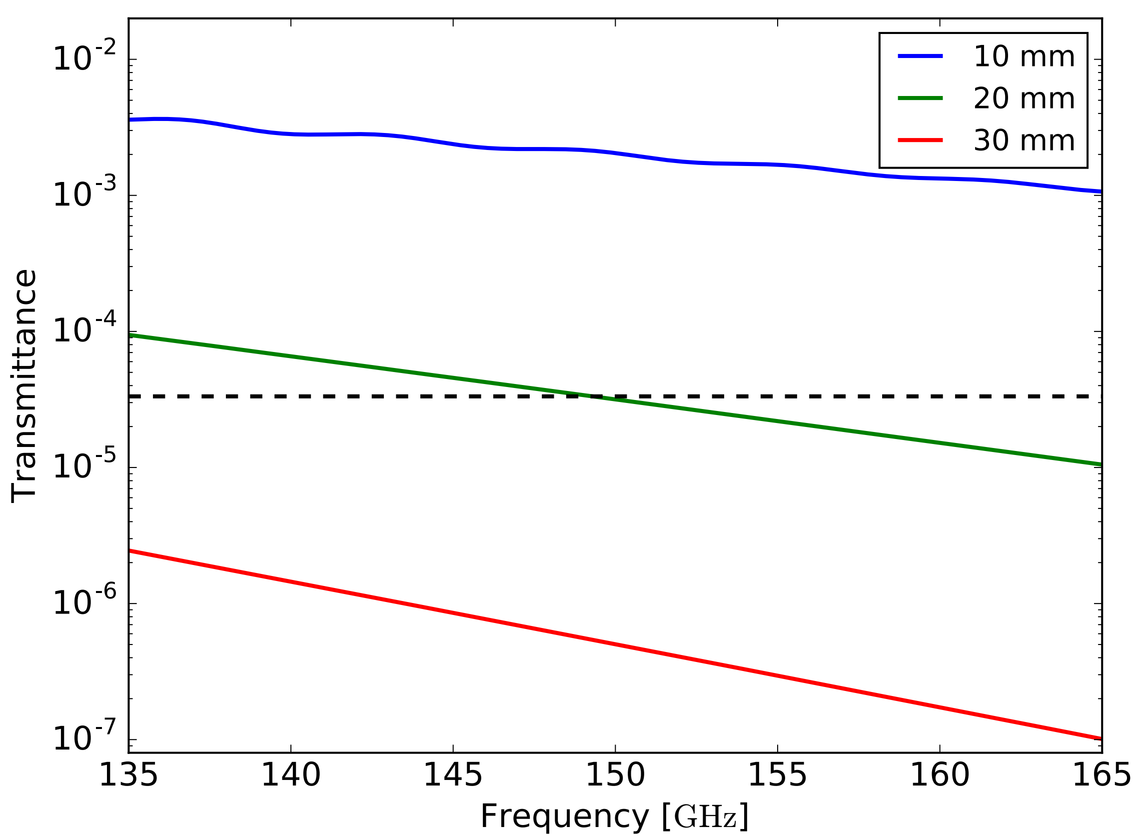
	Temperature [K]	Trasmissivity	Emissivity	Load [pW]
BP 4.7cm-1	0,3	0,9	0,01	<0,1
LP 6cm-1	0,3	0,9	0,01	<0,1
LP 12cm-1	7,5	0,9	0,01	1,2
Neoprene	7,5	$\sim 10^{-6}$	0,13	14
Fluorogold	7,5	0,85	0,02	<0,1
LP 10cm-1	7,5	0,95	0,01	<0,1
LP 15cm-1	40	0,95	0,01	<0,1
Thermal	300	0,99	<0,01	<0,1
Window	300	0,7	0,008	<0,1

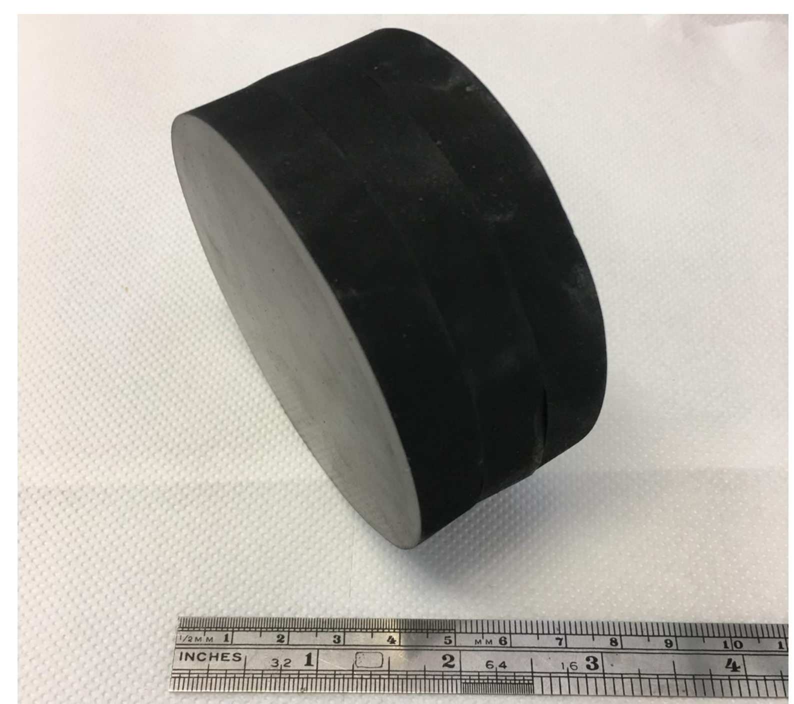
Stratospheric background ~ 10pW

Total detector background ~ 16pW

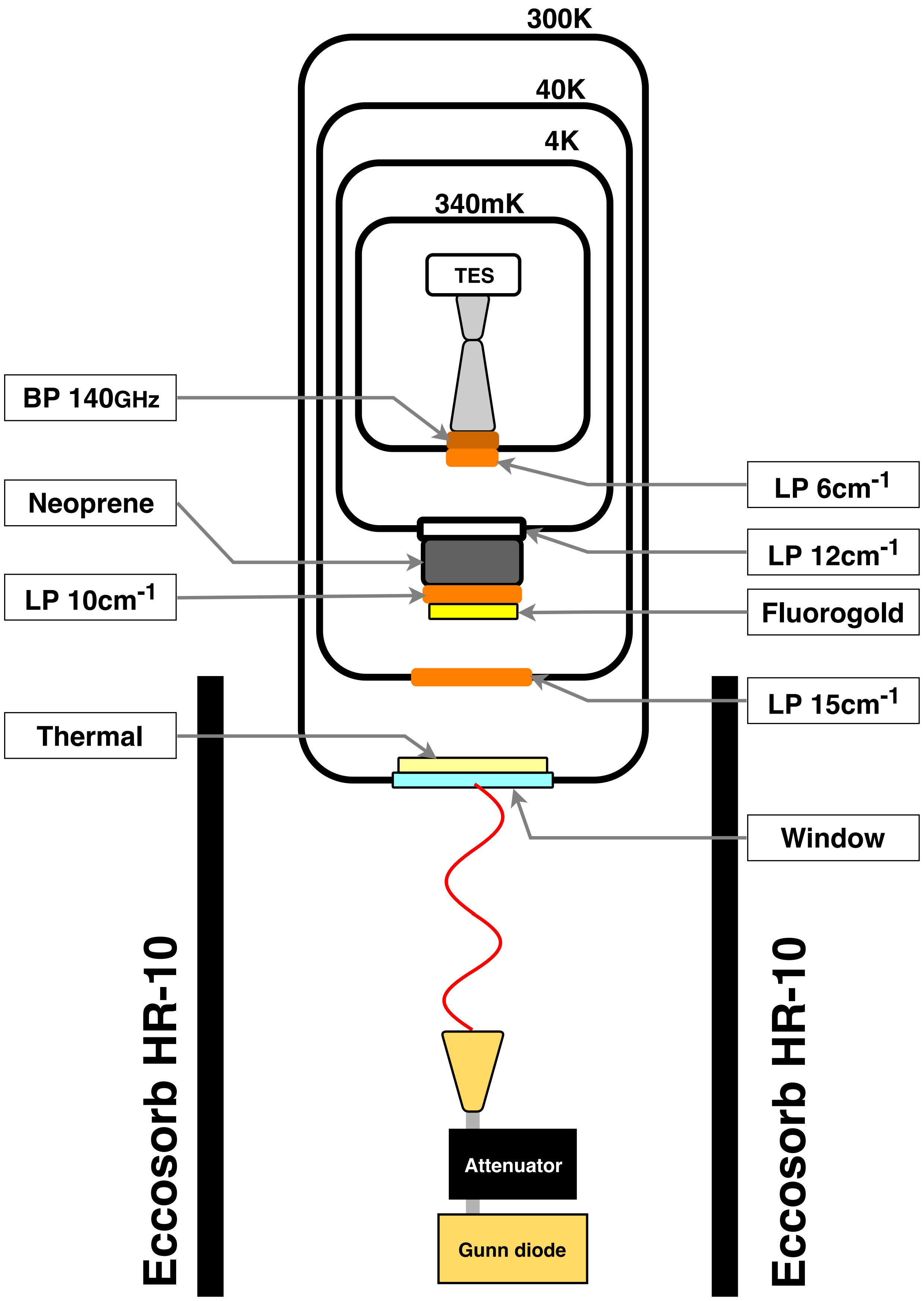
Optical chain



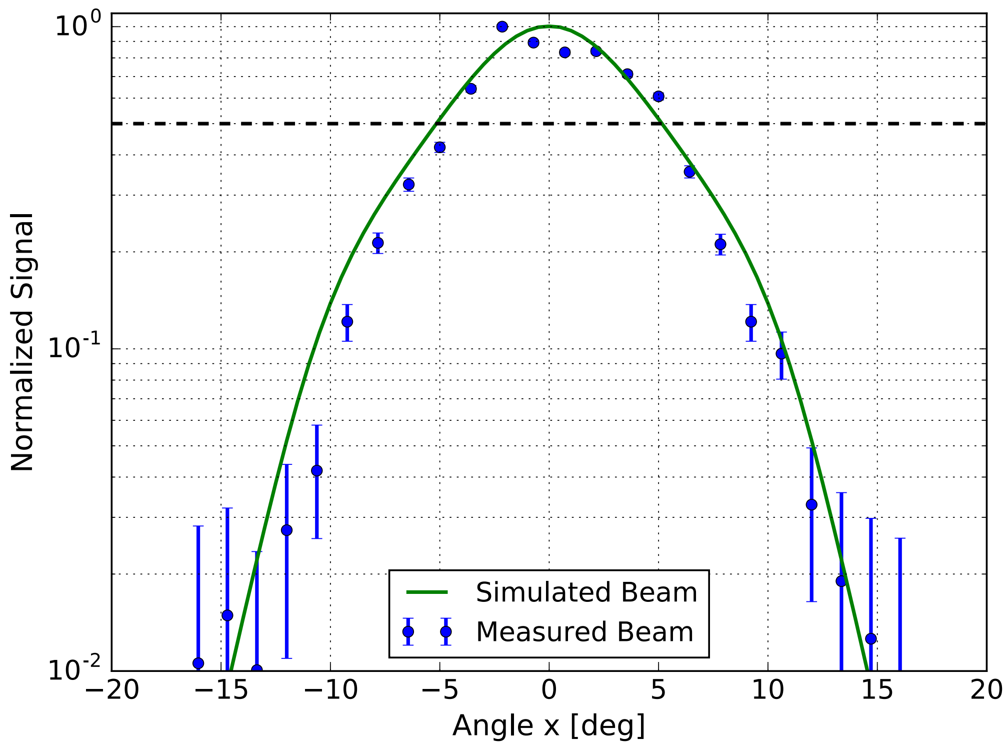




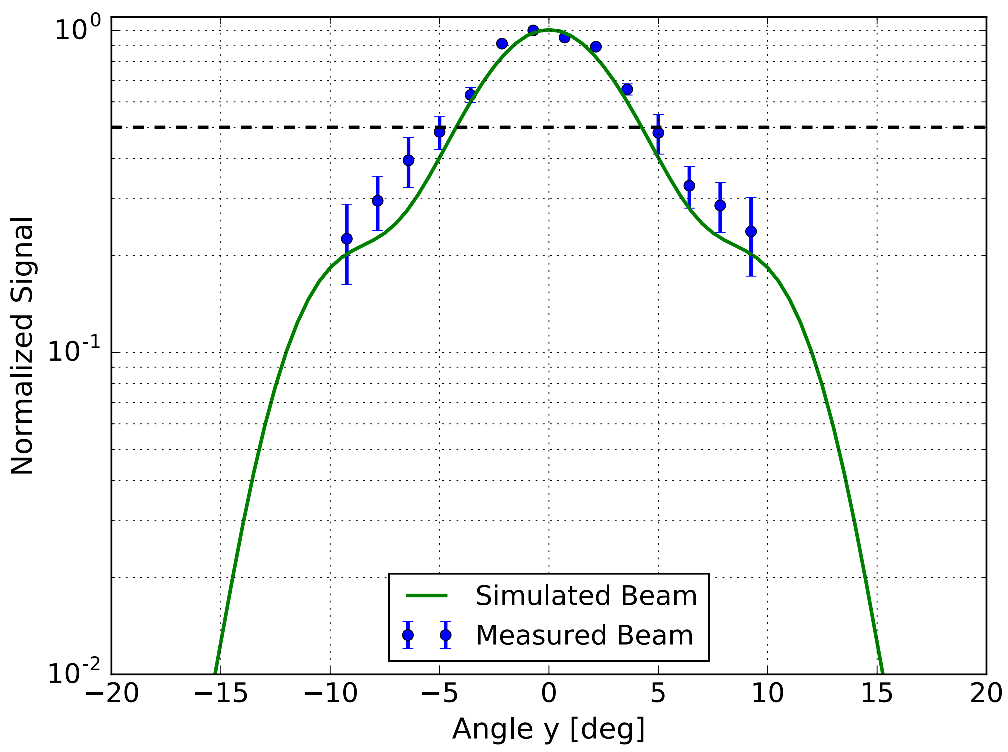
Neoprene configuration



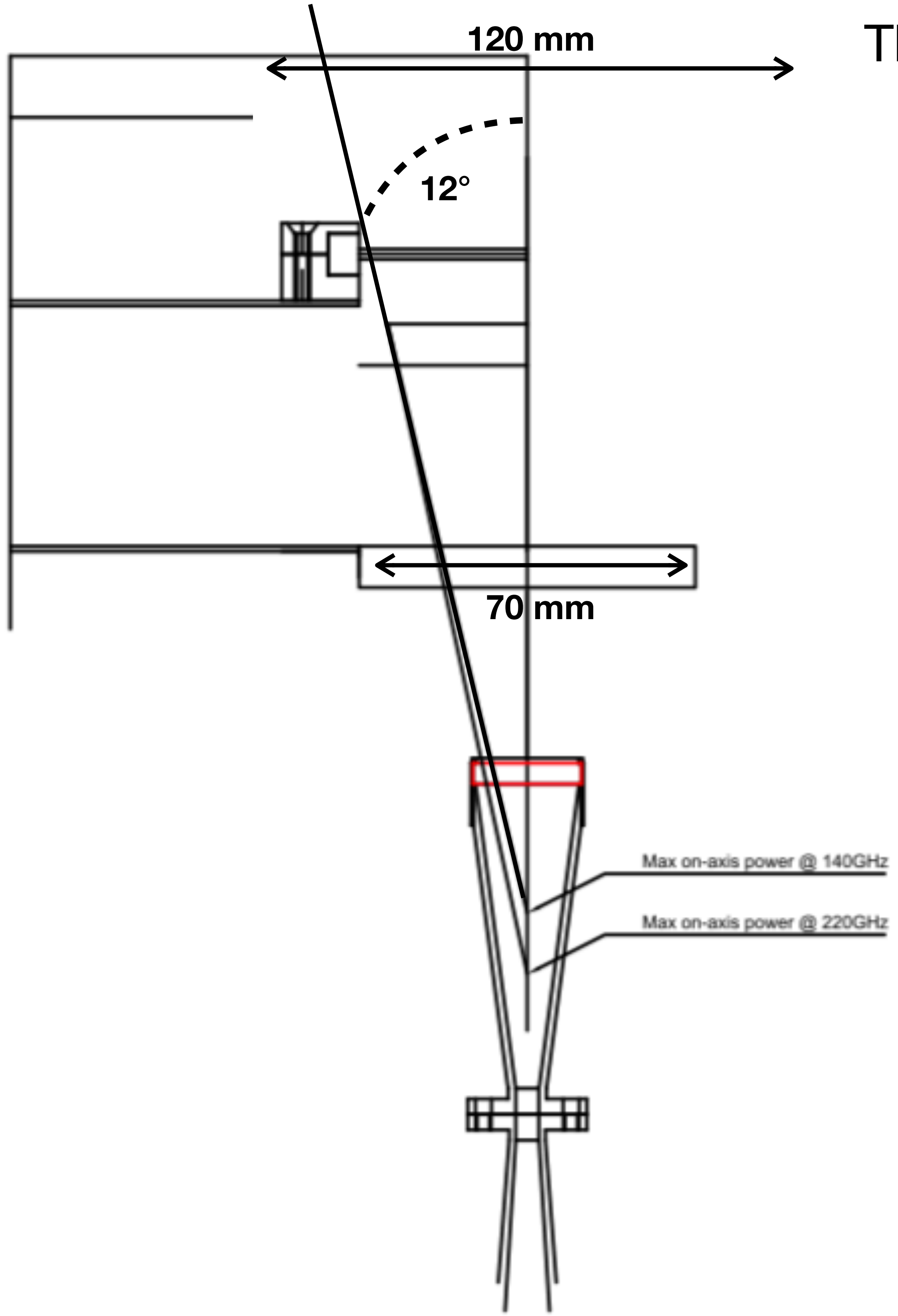
Cross-polar



Co-polar



Beam measurements



The criticality of this system is represented by its free optical throughput.

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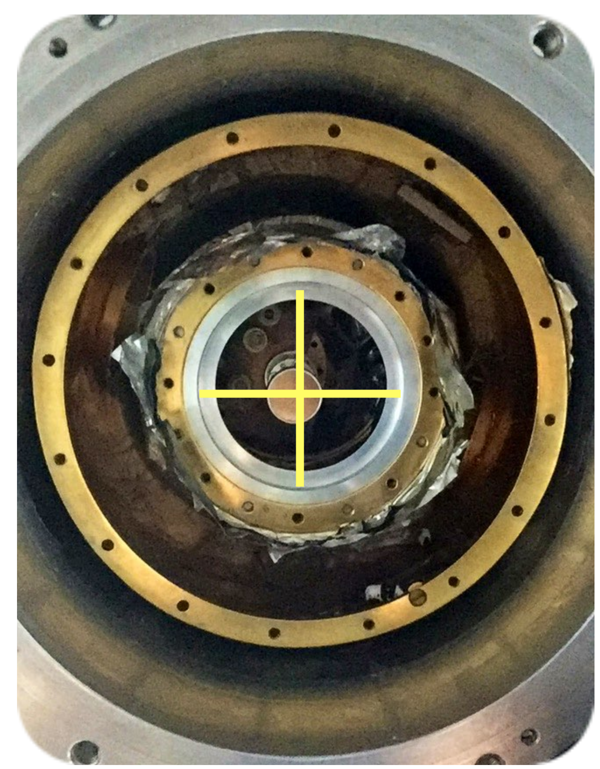
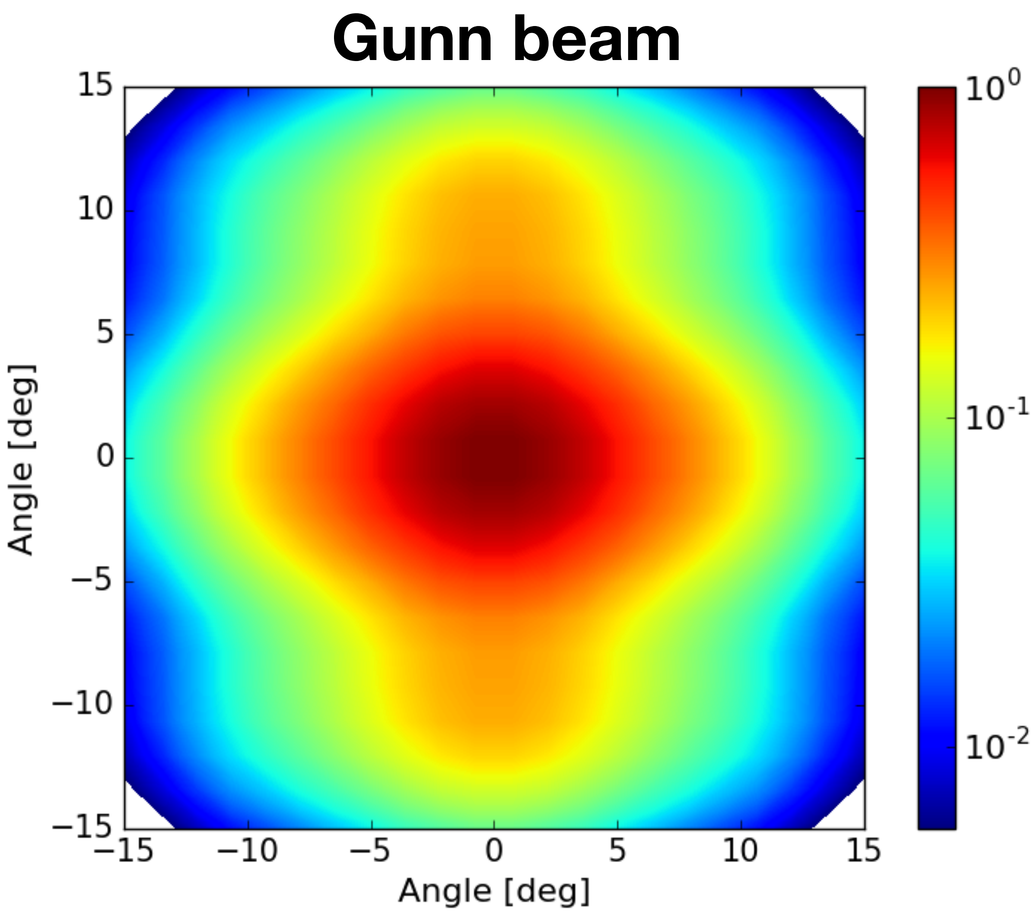
- Beam truncation
- Different power distribution

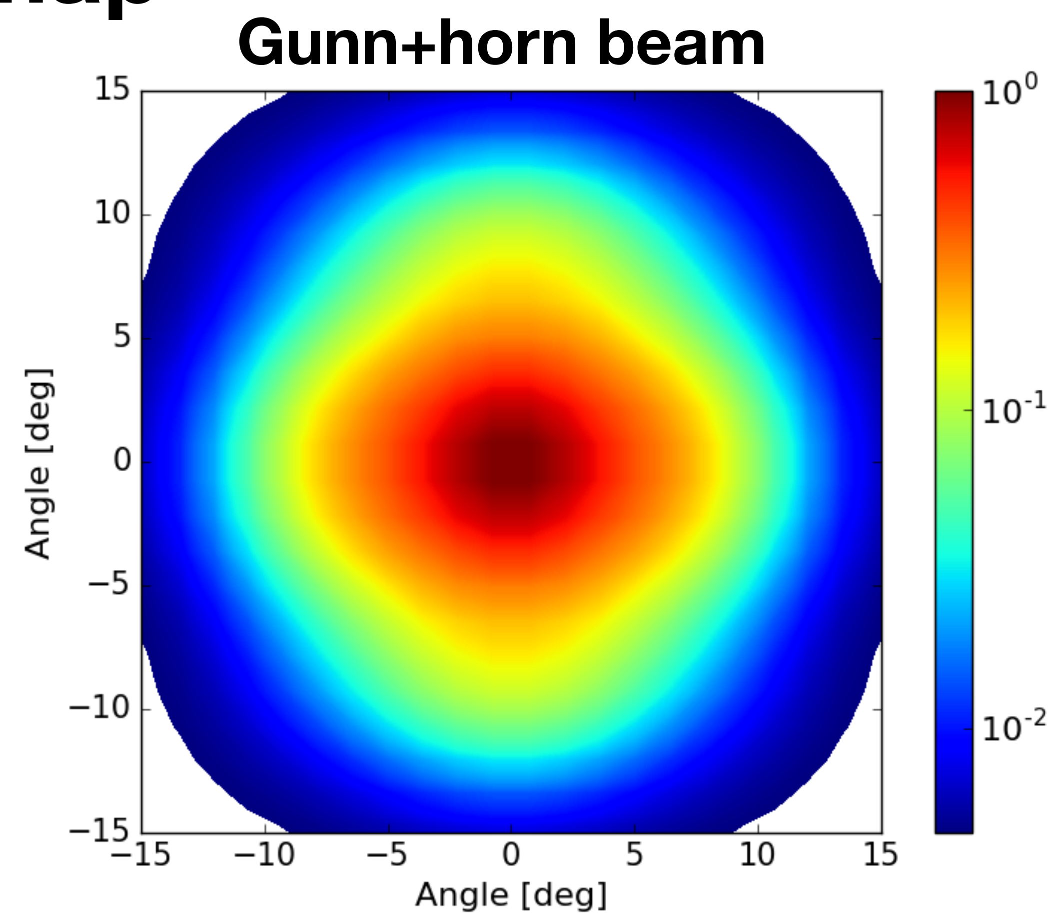
Main beam ——> Yes
Side lobes ——> Impossible!



Asymmetry in vignetting

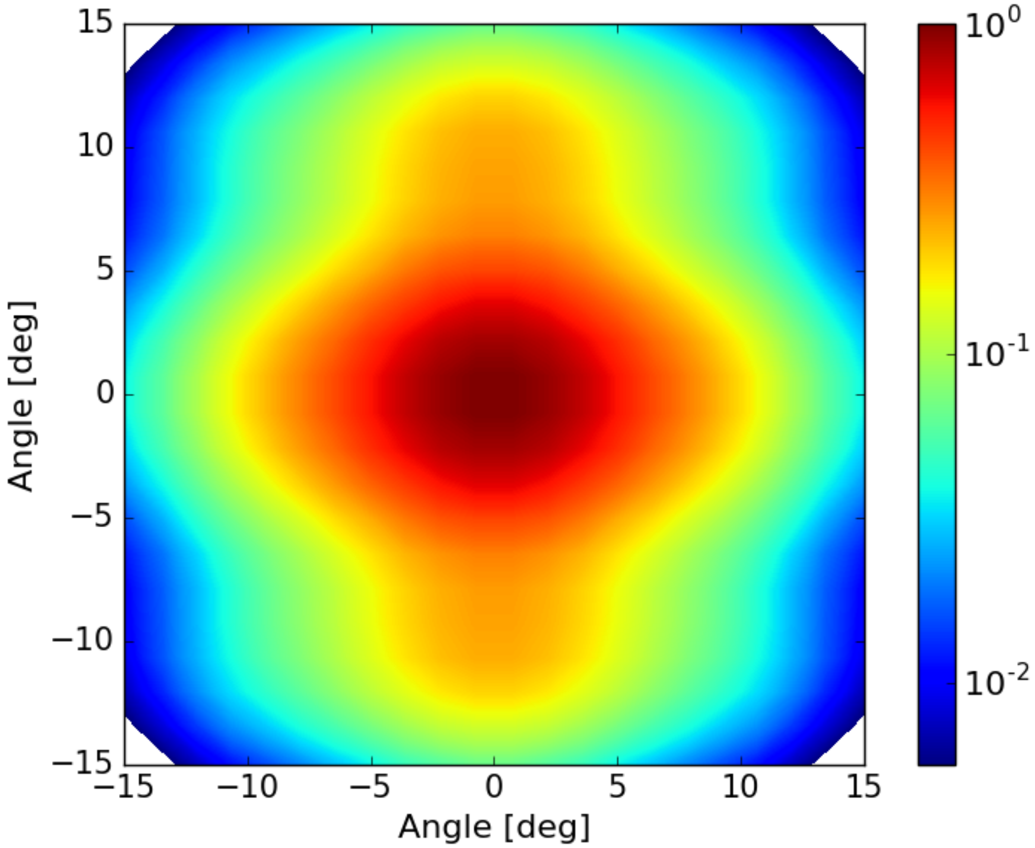
2D beam map


Gunn beam
15
10
5
0
−5
−10
−15
Angle [deg]
−15
−10
−5
0
5
10
15
Angle [deg]
10^0
10^-1
10^-2

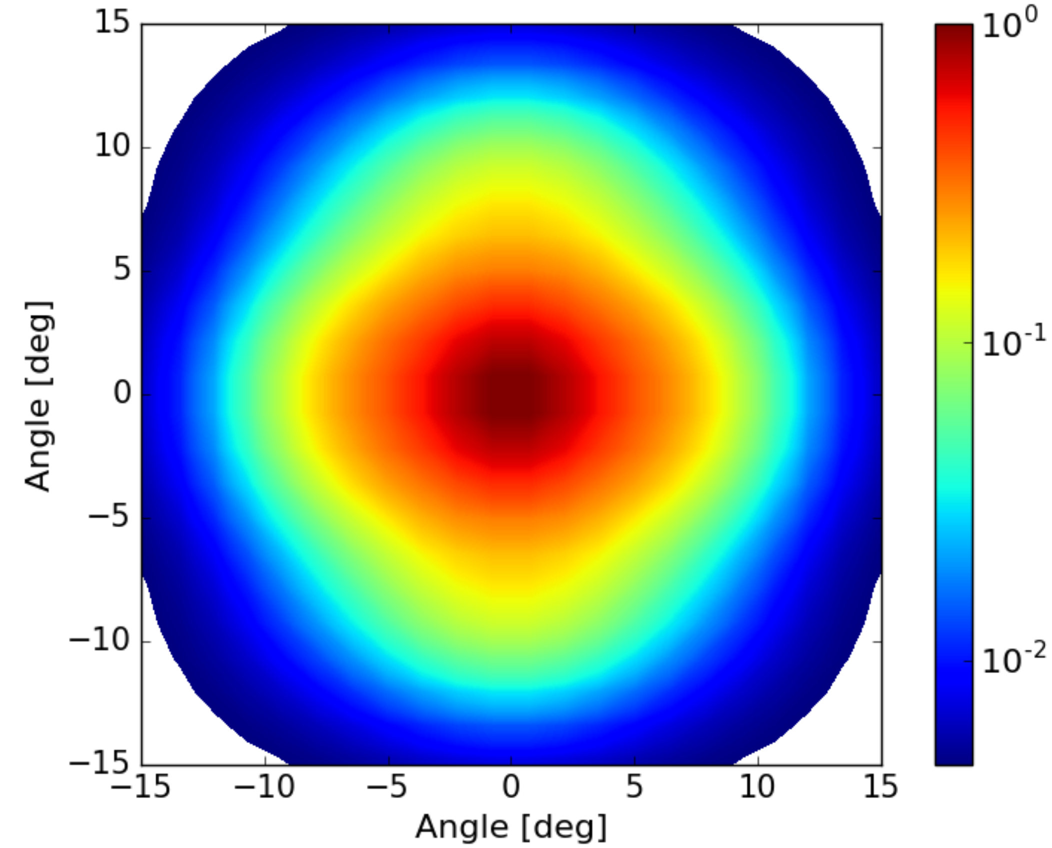

Gunn+horn beam
15
10
5
0
−5
−10
−15
Angle [deg]
−15
−10
−5
0
5
10
15
Angle [deg]
10^0
10^-1
10^-2

2D beam map

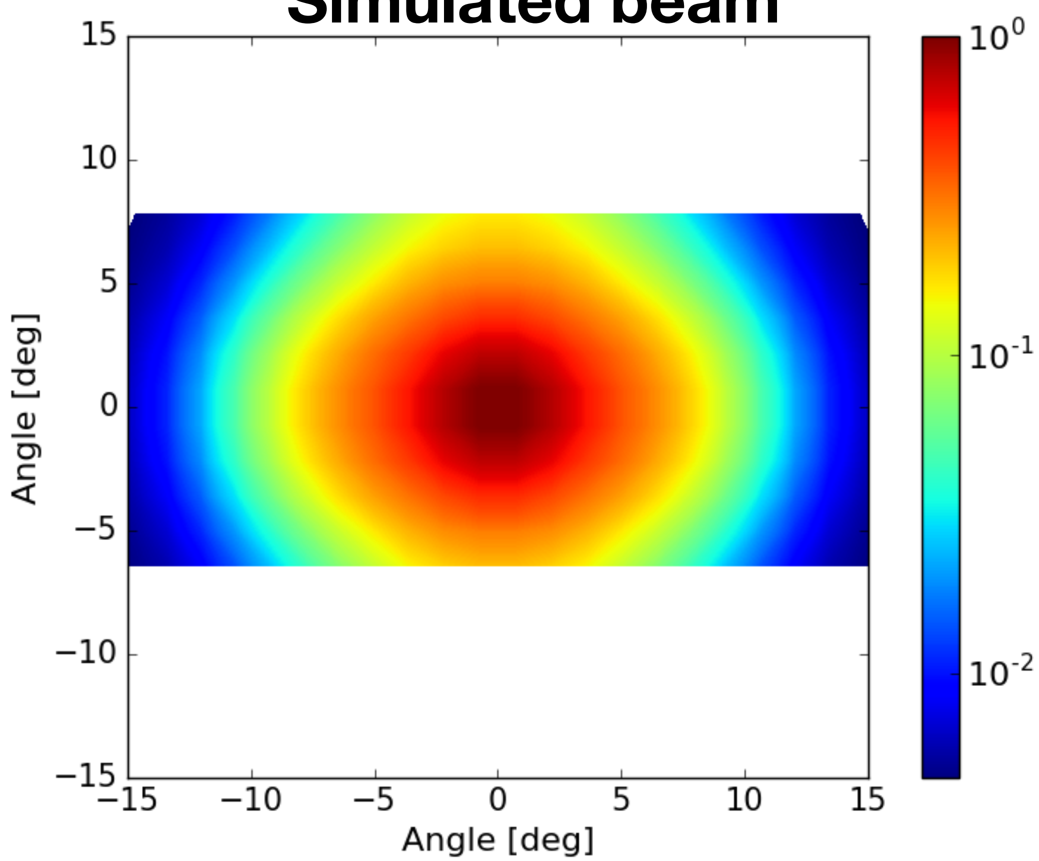
Gunn beam



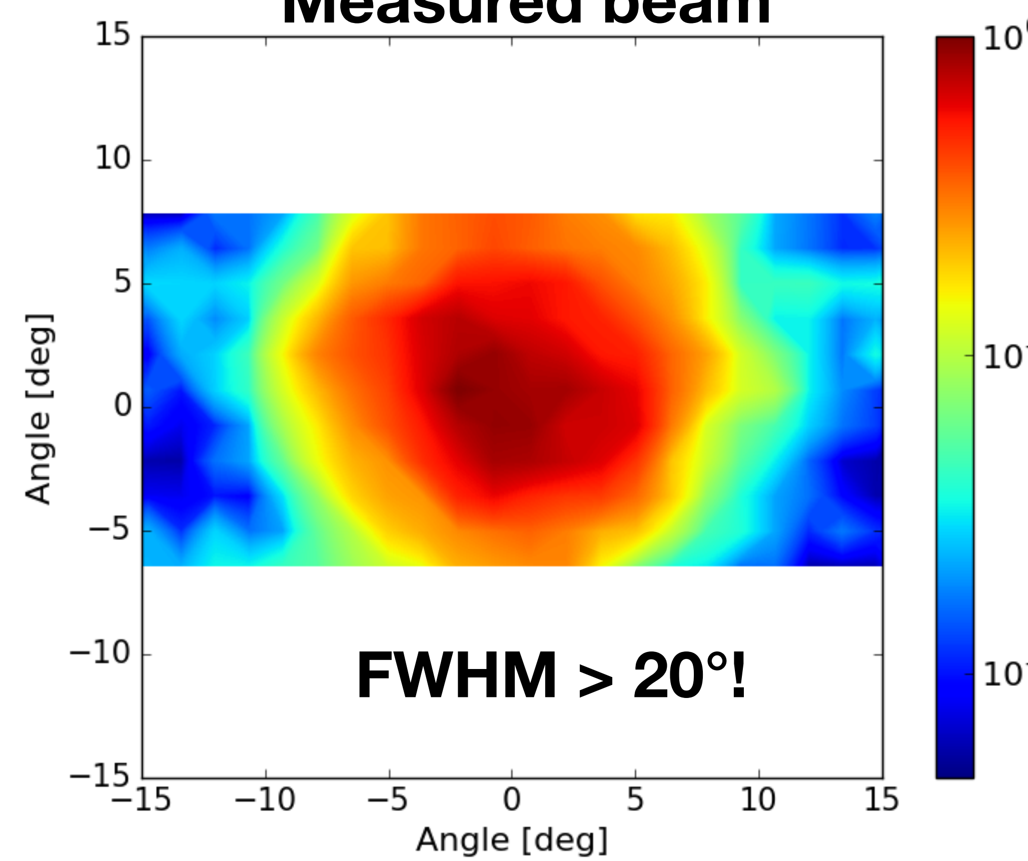
Gunn+horn beam



Simulated beam



Measured beam



Conclusions

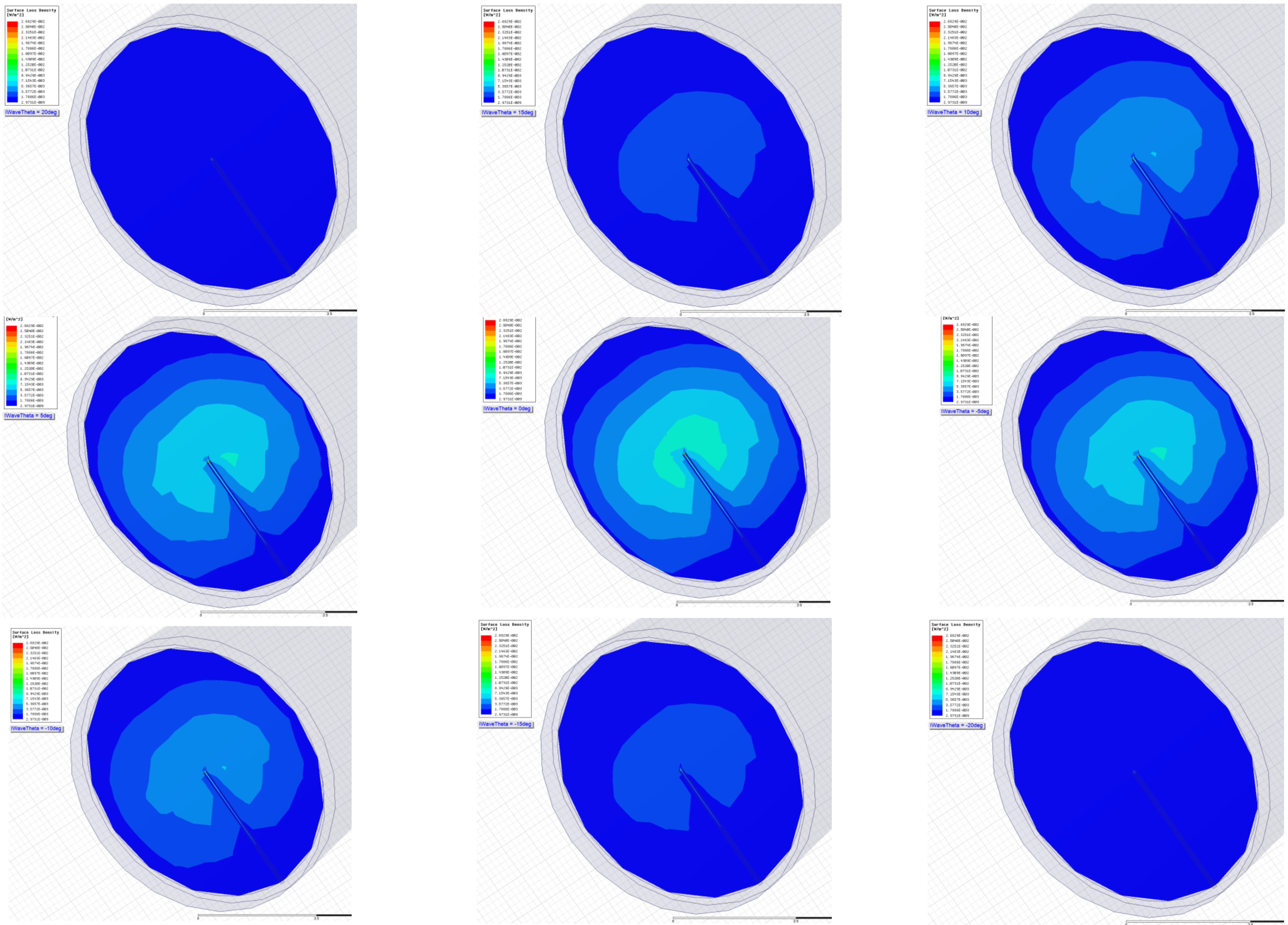
- The feedhorn assembly has reproduced the expected circular symmetry at room temperature.
- The facilities developed produces repeatable results in controlled conditions.
- Many systematic effects have been understood and controlled.
- Good beam shape measured in a cryogenic environment. Vignetting from the filters.
- Measurements will be repeated in the SWIPE cryostat which has a very large optical window ad filters set

Feedback from simulations

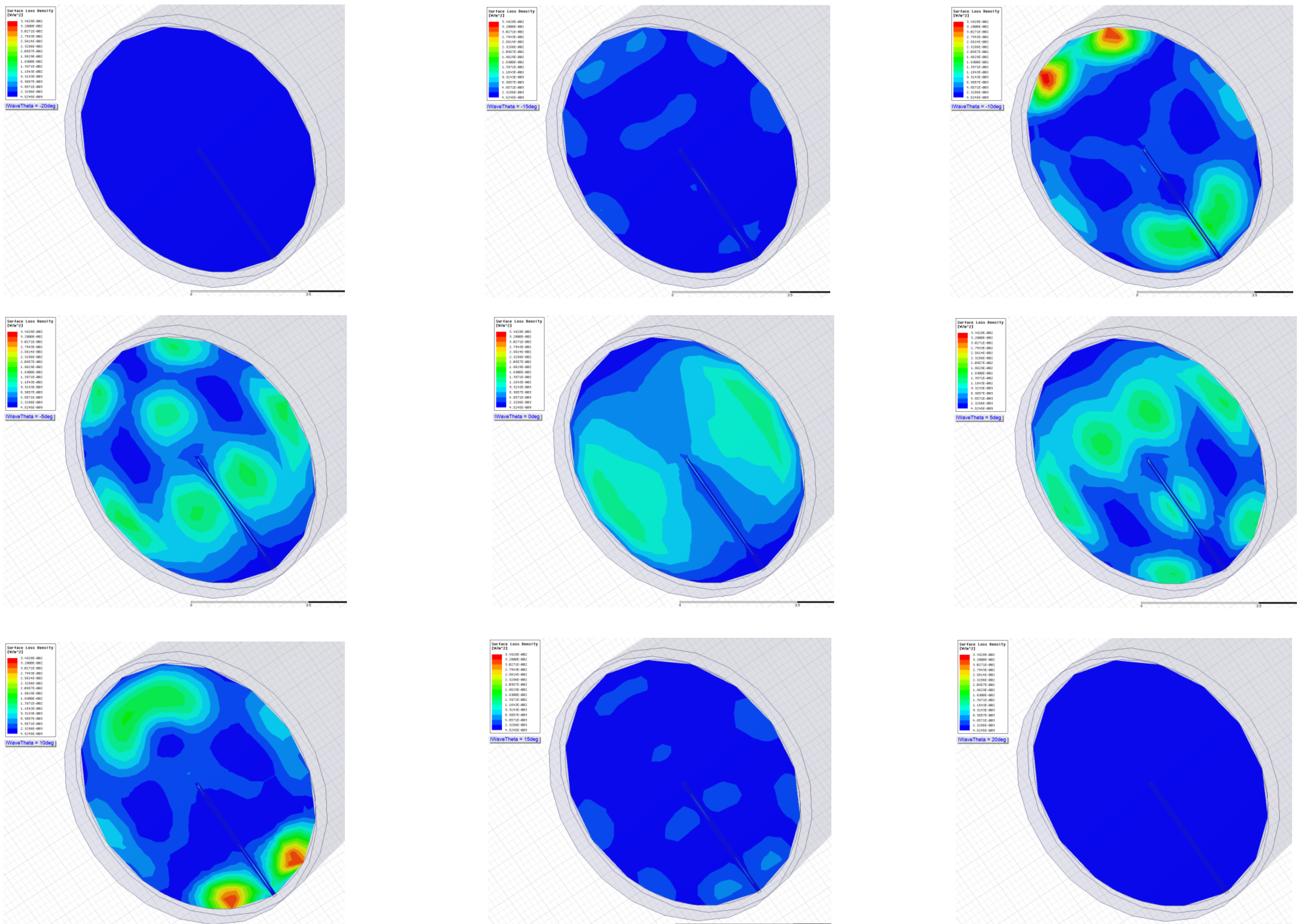
New simulation setup featuring:

- Direct illumination of horn aperture from far field (i.e. linear polarized, incident plane wave excitation with sweeps over θ and ϕ) – old setup was reverse path from the waveguide and made large use of symmetry assumptions to speed-up calculations.
- Full field propagation through horn, waveguide, flare, cavity, to evaluate flux distribution over the absorber with proper phase delays between the modes (determined by incidence angle at the aperture)
- Absorber still modeled as a planar, position-dependent impedance with conductive tracks from thermistor to readout
- Possibility to evaluate power leakage from the border
- Needs significant additional processing power, impliying a few tradeoffs in numerical accuracy and parameter resolution

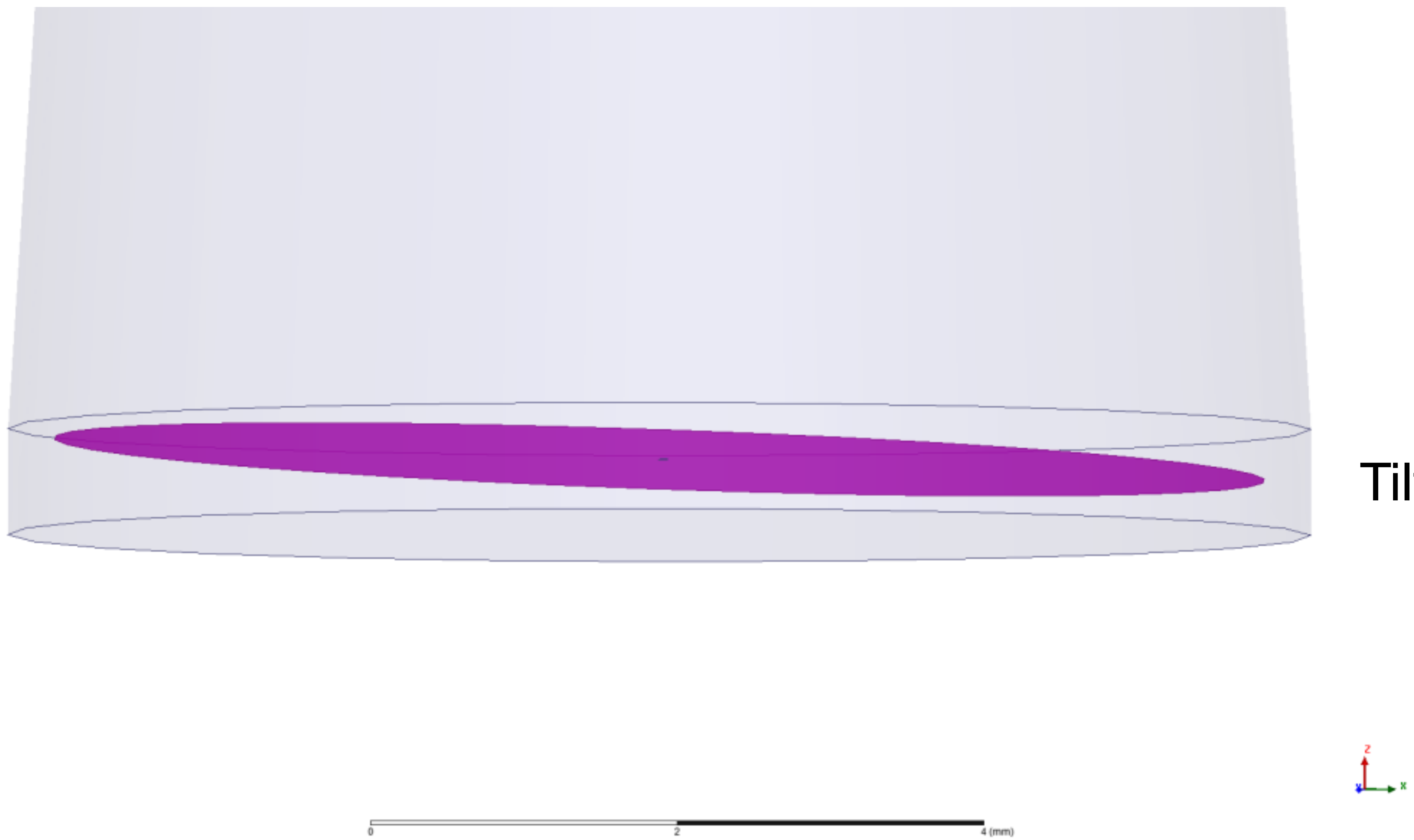
Absorber illumination vs incidence angle – single mode



Absorber illumination vs incidence angle – multi-mode



Test #1 – Absorber position



Tilt = 2deg

- Seems unlikely given the positioning method employed by manufacturer
- Needs macroscopic tilt/deformation to generate even the smallest observable feature in the beam.
- Basically ruled out as the dominant form of non-ideality.