TITLE: Thermal test of 4K Reference Load QM targets

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CHANGE RECORD

Issue	Date	Sheet	Description of Change	Release
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TABLE OF CONTENTS

1 SCOPE

1.1 Purpose

Purpose of this document is to report results of thermal verification and cycles for the QM targets of the 4 K Reference Load. Compliance of results with the requirements, reported in [AD 12], will be analyzed.

1.2 Document Overview

After introducing the experimental configuration in Section 3, the 30 GHz and 44 GHz thermal balance test are described in Sections 4 and 5.
Thermal cycles data for 30 and 44 GHz channels are shown in Section 6.
The whole set of QM 70 GHz thermal test are described in Section 7.
Finally, in Section 8, test results are summarized and compared with requirements specification and then conclusions are drawn.

1.3 TERMS and ACRONYMS

CF:	Cryo Facility
SUT:	Sample under test
4KRL	4 K Reference Load
QM	Qualification model

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable documents

[AD 1] *FIRST/Planck Instrument Interface Document*, Part A (SCI-PT-IIDA-04624, 3/0)
[AD 2] *FIRST/Planck Instrument Interface Document,* Part B (SCI-PT-IIDB/LFI-04142, 2/0)
[AD 3] *LFI Interface Control Document* (PL-LFI-PST-ID-010, 2.0)
[AD 4] *LFI/HFI Interface Document* (PL-LFI-PST-ID-001, 1.0)
[AD 5] *LFI Specification* (PL-LFI-PST-SP-001, 3.0)
[AD 6] *Planck LFI Instrument Design and Development Plan* (PL-LFI-PST-PL-002, 2.0)
[AD 7] *Planck LFI Product Assurance Plan* (PL-LFI-PST-PL-003, 3.0)
[AD 8] *Planck LFI Assembly Integration* & Verification Plan (PL-LFI-PST-Pl-004, 3.0)
[AD 9] *FIRST/Planck Operations Interface Requirements Document* (SCI-PT-RS-07360, 2/1)
[AD 10] *LFI Configuration and Data Management CADM Plan* (PL-LFI-PST-PL-001, 3.0)
[AD 11] *LFI Instrument Deliverable Documentation List* (DDL) (PL-LFI-PST-LI-007, 1.0)
[AD 12] *4K Reference Load Requirement Specification* (PL-LFI-TES-SP-001, 3.1)
[AD 13] *4K Reference Load Test Plan* (PL-LFI-TES-PL-001)
[AD 14] *4K Reference Load Thermal Test Procedures* (PL-LFI-TES-PR-003)

2.2 Reference documents

[RD 1] *Planck LFI Mechanical Design* (PL-LFI-LAB-RP-001, 3.0)
[RD 2] *HFI Temperature stability requirements* (SR-PH211-990141-IAS, Issue 01)
[RD 3] *LFI signal oscillations induced by Sorption Cooler temperature variation* (PL-LFI-PST-TN-010, Issue 1.0)
[RD 4] *HFI thermometers and heaters specifications* (SP-PHAC0-100044-IAS, Issue 0/0,12.2.00)
[RD 5] The 4KRL Cryo Facility (PL-LFI-TES-TN-010, 1.0)
[RD 6] *Preliminary evaluation of the impact of temperature fluctuations in the HFI 4K stage on LFI* (PL-LFI-PST-TN-048, 1.0)
[RD 7] LFI 4K Reference Load thermal model (PL-LFI-PST-TN-049, 1.0)
[RD 8] Lakeshore DT670 data sheet
[RD 9] *The 4KRL cryo facility*, PL-LFI-TES-TN-010
[RD 10] *LakeShore Model 340 Temperature controller user's manual,* Rev. 1.8

3 Test setup

Test is performed in the IASF-Bo 4K cryo facility, fully described in[RD 5]. Parts are manufactured by Officine Pasquali and assembled at IASF/BO.
Instrumentation used is shown in Table 1

EQUIPMENT LABEL (e.g. name)	QUANTITY	MANUFACTURER
Temperature Controller Model 340	1	LakeShore CryoTronics
Vacuum dry pump Model XDS5	1	BOC Edwards
Temperature sensors (see 3.1)	6	LakeShore CryoTronics
Film heaters	5	Minco
Pressure monitor	1	

Table 1 Instrumentation used in the tests

According to procedures ([AD 14]), two different setup are used. For the thermal balance test, a mechanical structure, representative of the radiative environment, is used and the reference load is mounted upon a dedicated aluminum shield in front of a cylinder at a higher temperature (Fig. 1). For thermal cycles the SUTs can also be mounted on a copper support, fixed at the facility cold flange.

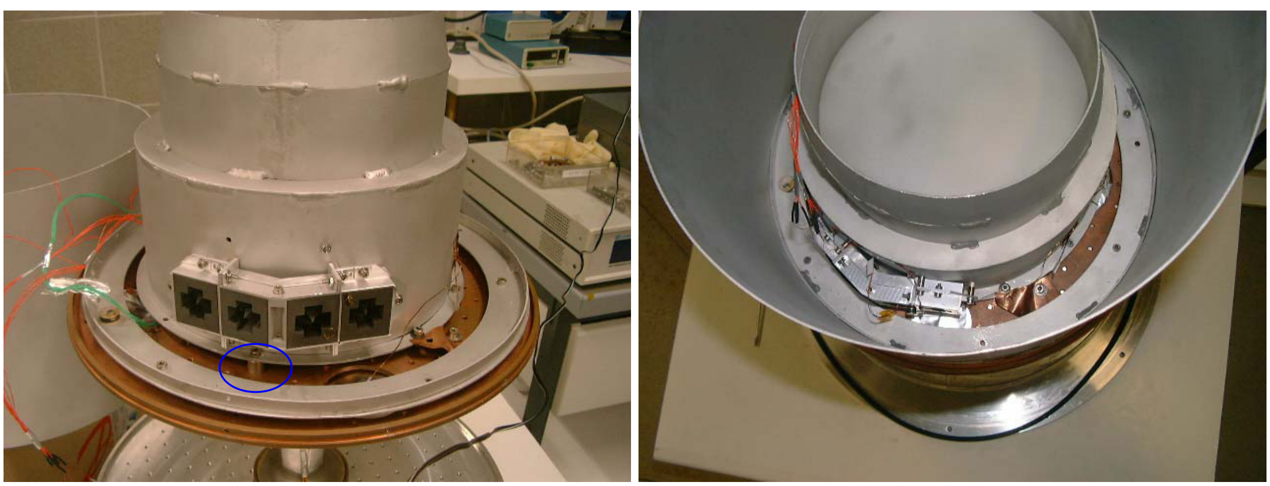

Fig. 1 The 30 GHz Reference Load mounted on a dedicated shield, representative of the HFI 4 K shield (left), surrounded by a radiative shield, representative of the LFI main frame environment. One of the thermal washers is shown in the blue circle.

Both the radiative shields are connected to the cold flange via stainless steel thermal washers, whose dimensions are studied in order to obtain the wanted stable temperatures with minimal heat load upon the cold stage of the cooler. The thermal regulation is obtained by means of Minco film heaters fixed to the shields (Fig. 2).

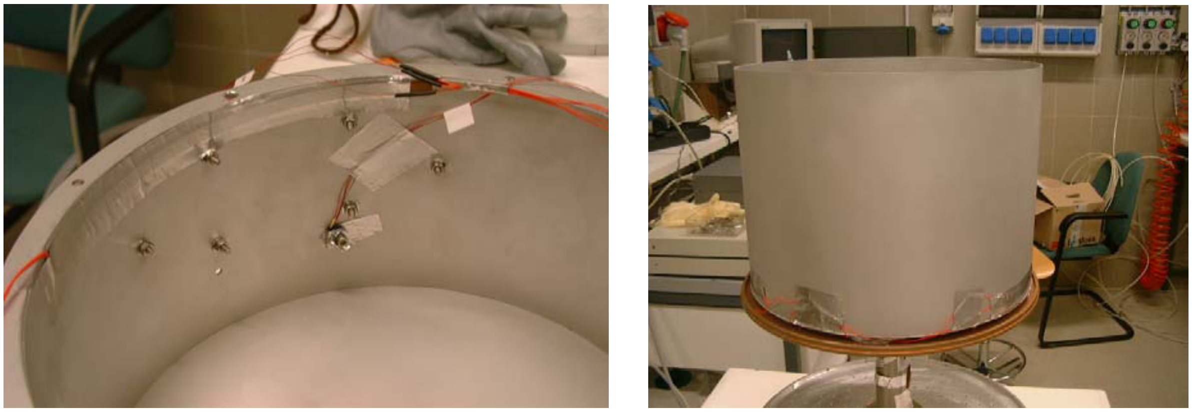

Fig. 2 Heater strips are attached to the Aluminum internal (left figure) and external (right figure) shield by means of Al tape.

A first run was performed in order to monitor relevant regions of the 20 K shield. Two sensors (SA and SB in Fig. 3) were mounted on the shield, SB is mounted on the shield support while SA is located at the level of targets. Their thermalization was monitored and we found that temperature difference in steady state was less than 40 mK (Fig. 4). Following this calibration, only the sensor on the support was mounted for monitoring the shield temperature.

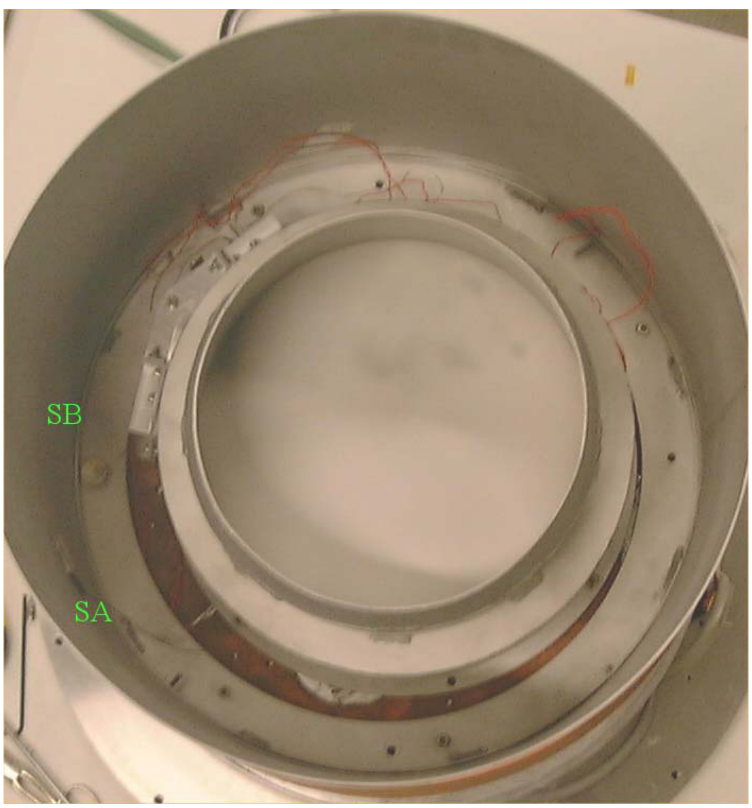

Fig. 3 Sensor position in the calibration of the external shield

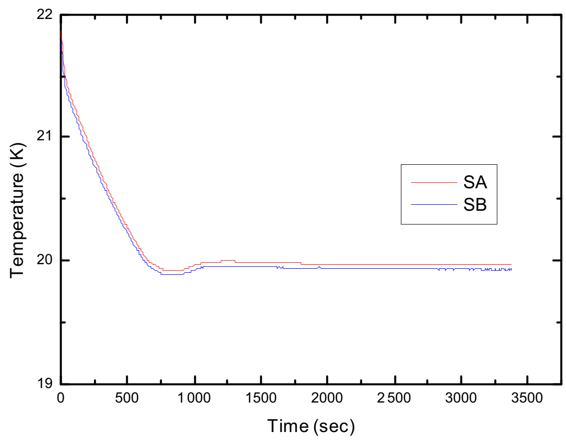

Fig. 4 Temperature calibration of the different regions of 20 K stage

3.1 Temperature sensor characteristics

All the temperature sensors used are LakeShore calibrated sensors. A calibrated silicon diode DT670, two calibrated Cernox CX1050 and three calibrated Germanium GR200A sensors are used. Their accuracies and sensitivities, at 4 K, with a LakeShore temperature controller 340 readout ([RD 10]) are reported in Table 2.

Sensor ID	Type	Accuracy at 4 K	Sensitivity at 4 K
A	DT670 SD	27 mK	0.4 mK
B	CX1050 CU	10 mK	0.1 mK
G0	CX1050 AA	10 mK	0.1 mK
G1	GR200A AA	30 mK	0.3 mK
G2	GR200A AA	30 mK	0.3 mK
G3	GR200A CU	30 mK	0.3 mK

Table 2: Temperature sensor properties

4 30 GHz thermal balance test

4.1 Sample and sensors' mounting

According to [AD 14], the 30 GHz assembly is mounted on the dedicated Aluminum shield, in six fixation points as will be in flight conditions on the HFI 4K shield. Six stainless steel thermal washers and six stainless steel M3 screws are used for mounting. In the two lateral fixation points, two copper adaptors are used in order to allow the correct mounting (Fig. 5).
Sensor locations for this test is reported in Table 3.

Sensor ID	Type	Location
A	DT670 SD	Al support of 44 GHz
B	CX1050 CU	Face of one central target
G0	CX1050 AA	Interface between 30 GHz assembly and 4K shield
G1	GR200 AA	Pyramid in one central target
G2	GR200 AA	Face of one lateral target
G3	GR200 CU	20 K shield

Table 3 Sensor locations for 30 GHz thermal balance test

Fig. 5 The sample is mounted on the shield by means of six stainless steel screws and washers (blue line). The lateral fixation is fitted to the cylindrical wall by means of copper adaptors (yellow line).

4.2 *Steady state test*

After the system thermalization below 4 K, the outer shield is stabilized at a temperature of 20.260 ± 0.010 K (Fig. 6). The 4K stage is then warmed up in order to reach a stable temperature of 4.447 ± 0.001 K (the G0 sensor is visible in Fig. 2) and other temperatures are measured (Fig. 7).

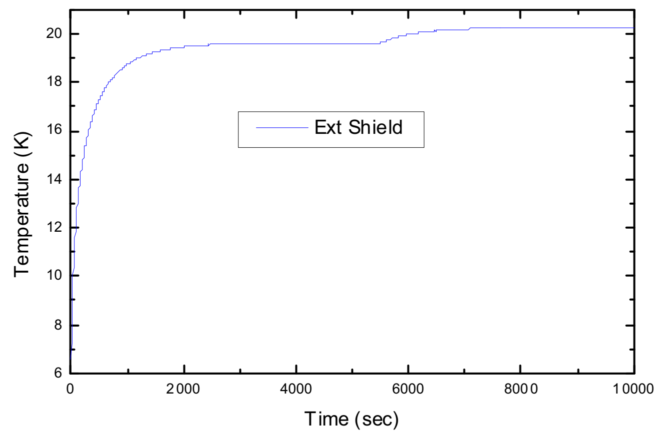

Fig. 6 Thermalization of the 20 K stage for the steady state test

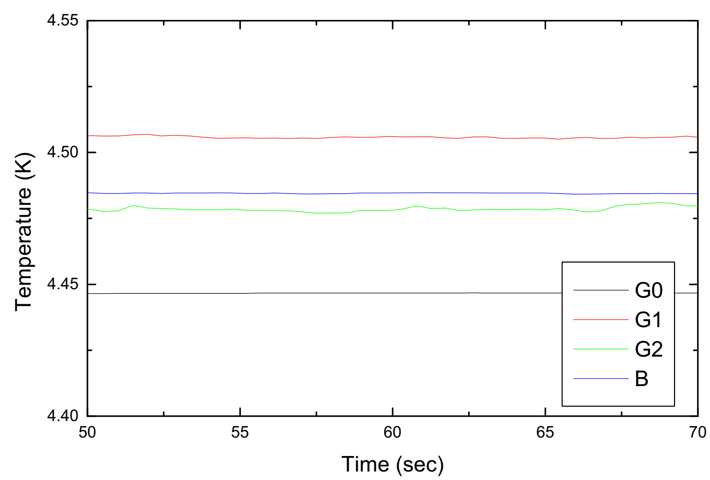

Fig. 7 Steady state temperatures measured.

T (G0)	4.447 ± 0.010 K
T (G2)	4.479 ± 0.030 K
T (B)	4.485 ± 0.010 K

T (G1)	4.506 ± 0.030 K
Heat Load from pyramid	4.8 ± 2.5 μW
Heat Load from the face of central target	58 ± 30 μW
Heat Load from the face of lateral target	70 ± 70 μW
Total heat load	270 ± 200 μW

Table 4 Summary of the results for the steady state test

Thermal conductances from the updated thermal model are used to evaluate the heat load on the HFI shield, according to:

$W = K \cdot \Delta T$

where W is the power transferred, K is the conductance between the two regions and ΔT is the temperature difference. Results are summarized in Table 4. Since the temperature differences are comparable to sensors' accuracies, errors are relevant.

4.3 Transient test

A number of transient tests were performed, in order to check and verify temperature fluctuations damping performances of the 4K RL. Requirements are set on damping factors for fluctuation periods of 60, 600, 667 and 1000 s. Procedures reported in [AD 14] are applicable.
After thermalizing the system applying a stable heat load offset (12% of 60mW) to 4K stage, a sinusoidal power (amplitude 8% of 60mW) was added, at the required frequencies. Each curve is then fitted to the typical sinusoidal function:

$$T(t) = T_0 + A \cdot \sin(2\pi\, \nu\, t + \phi)$$

and ratios (damping factors[1]) of amplitudes measured at the different regions to the amplitude measured at the interface between 4K shield and Reference Load washer are evaluated.
In next plots measurements for each fluctuation frequency are shown, while results are summarized in Table 5 and Table 6.

[1] In [AD 12], for each frequency ν, we have defined a thermo mechanical transfer function $D_f(\nu)$, representing the damping factor of fluctuations through the 4KRL structure, according to:

$$\Delta T_{RT}(\nu) = D_f(\nu) \cdot \Delta T_{HFI}(\nu)$$

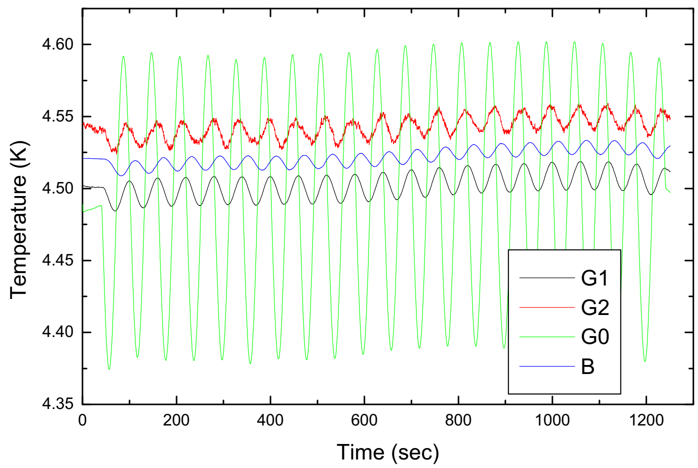

Fig. 8 Transient test of fluctuation of 60 sec period data

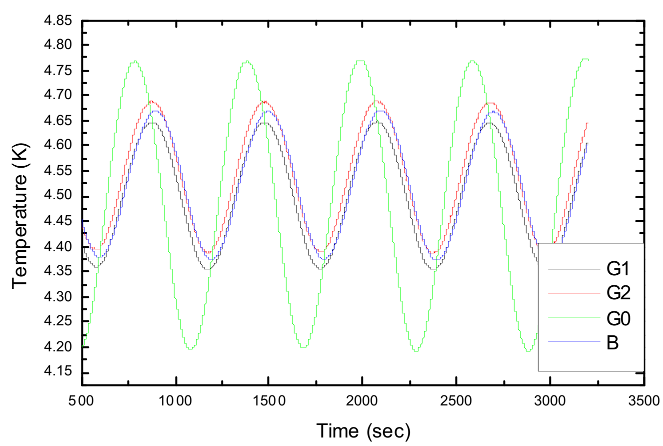

Fig. 9 Transient test of fluctuation of 600 sec period data

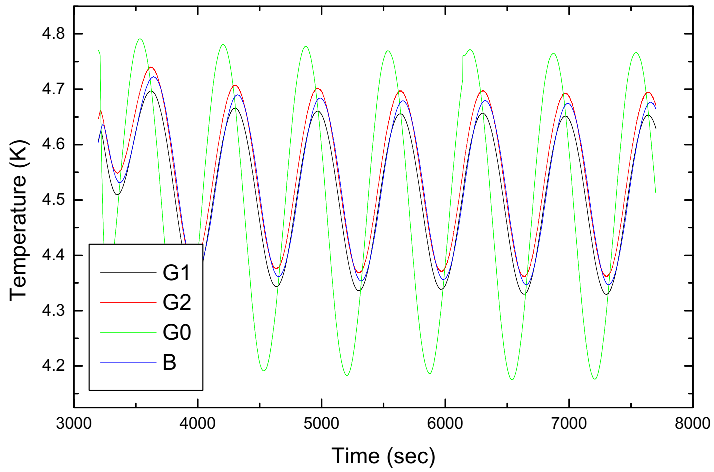

Fig. 10 Transient test of fluctuation of 667 sec period data

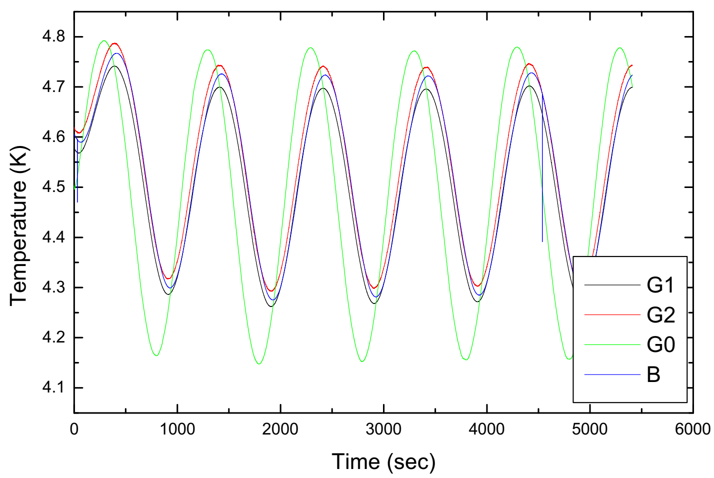

Fig. 11 Transient test of fluctuation of 1000 sec period data

Period (s)	A of lateral target face	A of central target face	A of pyramid	A of interface
60	7.67 ± 0.46	4.76 ± 0.12	9.85 ± 0.07	108.49 ± 2.36
600	149.06 ± 0.08	147.03 ± 0.08	146.11 ± 0.08	287.98 ± 0.08
667	164.94 ± 0.19	162.79 ± 0.16	161.16 ± 0.17	294.62 ± 0.28
1000	220.92 ± 0.10	220.50 ± 0.11	215.16 ± 0.10	311.25 ± 0.10

Table 5 Amplitude of fluctuations measured by all sensors, values are in mK

Period (s)	D_f of lateral target face	D_f of central target face	D_f of lateral target pyramid
60	$(7.07 \pm 0.58)\cdot 10^{-2}$	$(4.39 \pm 0.21)\cdot 10^{-2}$	$(9.08 \pm 0.26)\cdot 10^{-2}$

600	0.5176 ± 0.0004	0.5106 ± 0.0004	0.5075 ± 0.0004
667	0.560 ± 0.001	0.553 ± 0.001	0.547 ± 0.001
1000	0.7098 ± 0.0006	0.7084 ± 0.0006	0.6913 ± 0.0005

Table 6 Damping factors evaluated for 30 GHz reference load

5 44 GHz thermal balance test

5.1 Sample and sensors' mounting

According to [AD 14], the 44 GHz assembly is mounted on the dedicated Aluminum shield, in two fixation points as will be in flight conditions on the HFI 4K shield. Two stainless steel thermal washers and two stainless steel M3 screws are used for mounting. In the fixation points, two copper adaptors are used in order to allow the correct mounting (Fig. 12).

Fig. 12 The sample is mounted on the shield by means of two stainless steel screws and washers fitted to the cylindrical wall by means of copper adaptors (blue circle).

5.2 Steady state test

Sensor ID	Type	Location

A	DT670 SD	Cold flange
B	CX1050 CU	Face of one target
G0	CX1050 AA	Interface between 44 GHz assembly and 4K shield
G1	GR200 AA	Pyramid in one target
G3	GR200 CU	20 K shield

Table 7 Sensor locations for 44 GHz thermal balance steady state test

After the system thermalization below 4 K, the outer shield is stabilized at a temperature of 19.915 ± 0.010 K (Fig. 6). The 4K stage is then warmed up in order to reach a stable temperature of 4.870 ± 0.001 K (the G0 sensor is visible in Fig. 2) and other temperatures are measured (Fig. 7).
Low heat load is evident, so that temperature differences are measured within the sensor accuracies.

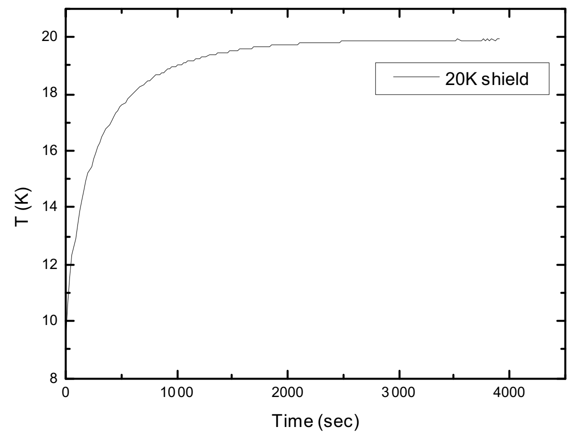

Fig. 13 Thermalization of the 20 K stage for the steady state test

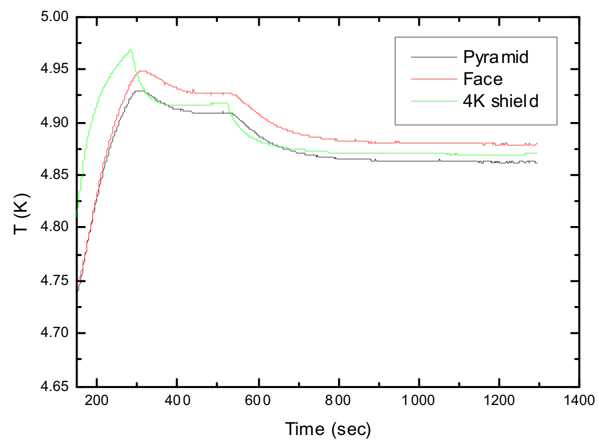

Fig. 14 Steady state temperatures measured.

T (G0)	4.870 ± 0.010 K
T (B)	4.879 ± 0.010 K
T (G1)	4.863 ± 0.030 K
Heat Load from pyramid	-0.4 ± 2.0 μW
Heat Load from the face of one target	19 ± 40 μW
Total heat load	110 ± 250 μW

Table 8 Summary of the results for the steady state test

Thermal conductances from the updated thermal model are used to evaluate the heat load on the HFI shield, according to:

$W = K \cdot \Delta T$

where W is the power transferred, K is the conductance between the two regions and ΔT is the temperature difference. Results are summarized in Table 8. Since the temperature differences are comparable to sensors' accuracies, errors are relevant.

5.3 Transient test

A number of transient tests were performed, in order to check and verify temperature fluctuations damping performances of the 4K RL. Requirements are set on damping factors for fluctuation periods of 60, 600, 667 and 1000 s. Procedures reported in [AD 14] are applicable.

After thermalizing the system applying a stable heat load offset (30% of 60mW) to 4K stage, a sinusoidal power (amplitude 30% of 60mW) was added, at the required frequencies. Then the same data analysis used for the 30 GHz is performed.

In next plots measurements for each fluctuation frequency are shown, while results are summarized in Table 9.

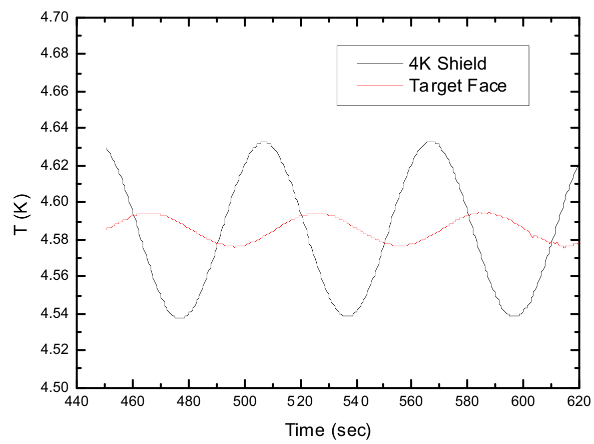

Fig. 15 Transient test of fluctuation of 60 sec period data

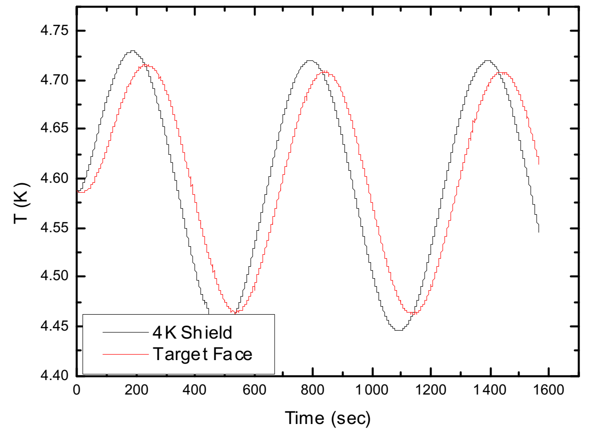

Fig. 16 Transient test of fluctuation of 600 sec period data

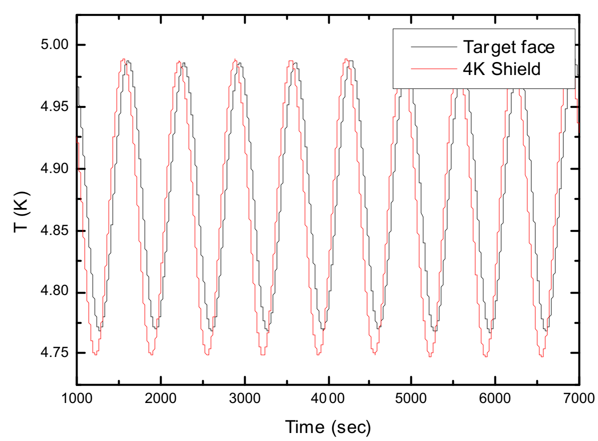

Fig. 17 Transient test of fluctuation of 667 sec period data

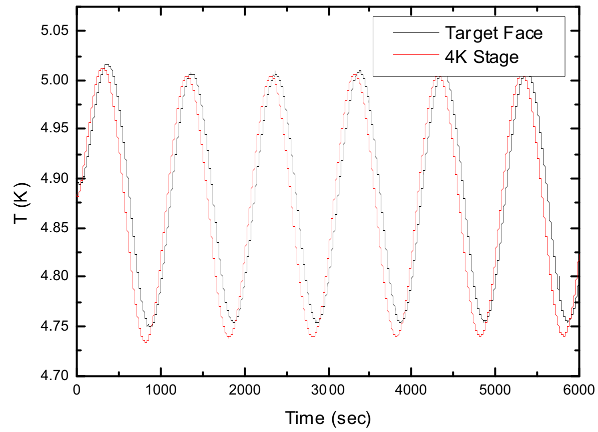

Fig. 18 Transient test of fluctuation of 1000 sec period data

Period (s)	A of target face	A of interface	D_f of target face
60	8.88 ± 0.04	47.29 ± 0.07	0.188 ± 0.01
600	120.29 ± 0.06	137.15 ± 0.12	0.877 ± 0.001
667	108.90 ± 0.06	119.99 ± 0.05	0.9076 ± 0.0009
1000	126.65 ± 0.05	132.63 ± 0.05	0.9549 ± 0.0007

Table 9 Results of the transient state test

6 Thermal cycles for 30 GHz and 44 GHz targets

In the following sections thermal cycles are reported.
Test procedures reported in [AD 14], Section 9, are applicable.
At the end of each series of cycles a visual inspection is made.

6.1 Cycle 1-3

The test started on November, 11th, 2004 at 20:00.
The 30 GHz assembly is mounted on the 4K stage, while 44 GHz is mounted on the cooler cold flange.
The sensors setup is reported in Table 10; it reports sensors mounted on the 30 GHz, while the sensor mounted on the 44 GHz sample was damaged during first cooldown.

Sensor ID	Type	Location

A	DT670 SD	External target face
B	CX1050 CU	External shield
G0	CX1050 AA	External target pyramid
G2	GR200A AA	Internal shield

Table 10 Sensor location during cycles 1-3

Cool down and warm up curves of the cycles are shown in the figures below.
No damage was reported in the visual inspection.

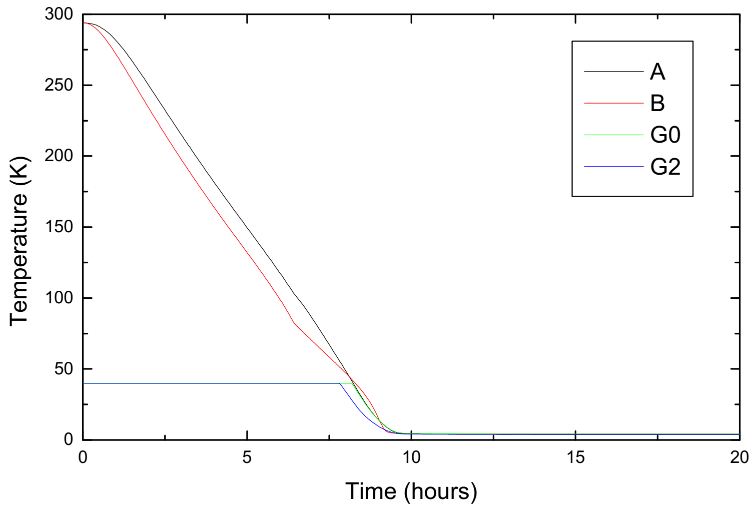

Fig. 19 Cool down data for the first cycle

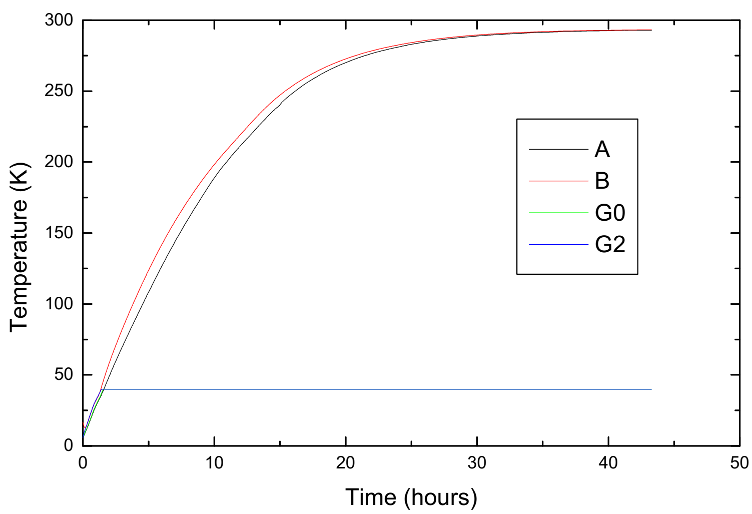

Fig. 20 Warm up data for the first cycle.

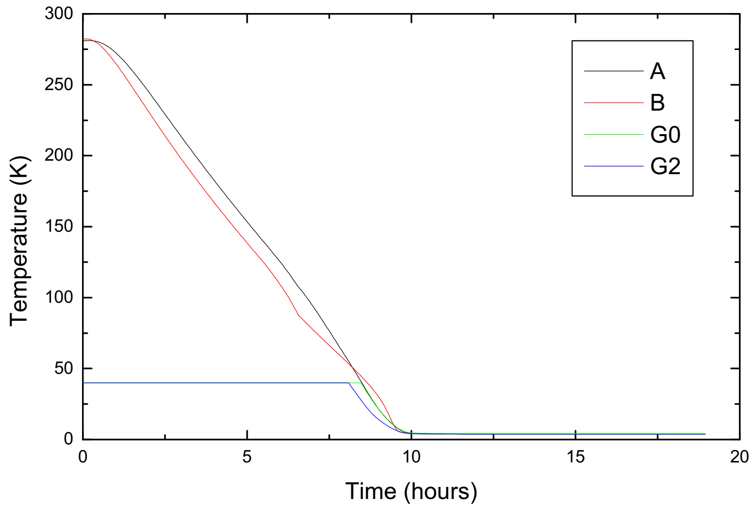

Fig. 21 Cool down data for the second cycle

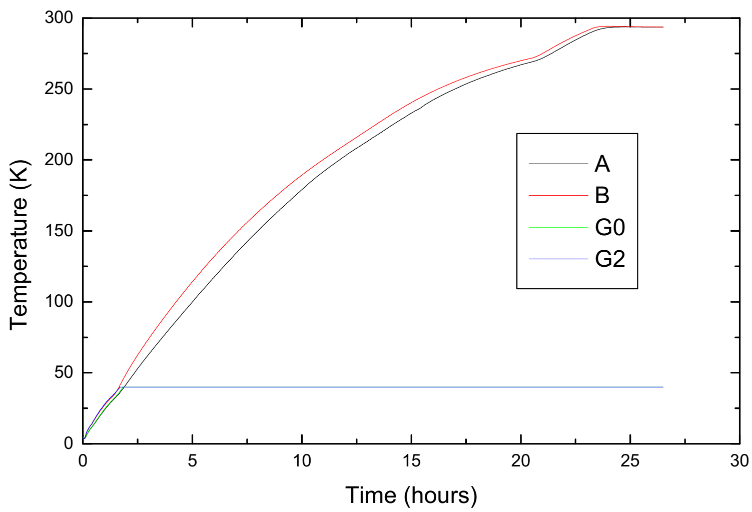

Fig. 22 Warm up data for the second cycle.

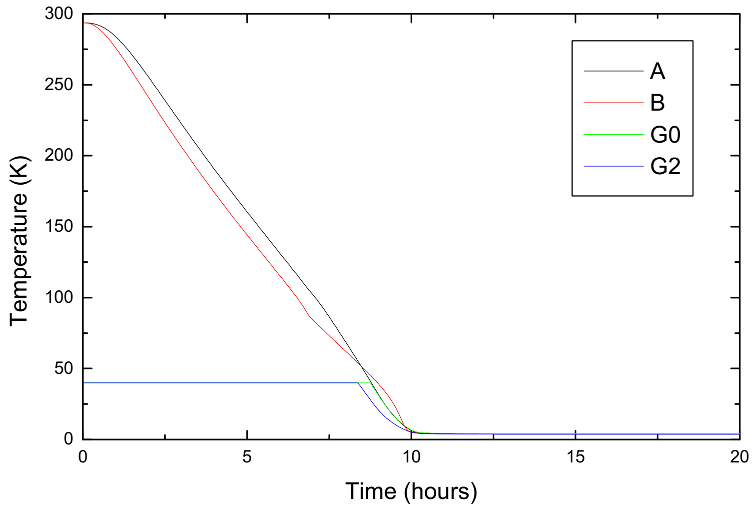

Fig. 23 Cool down data for the third cycle

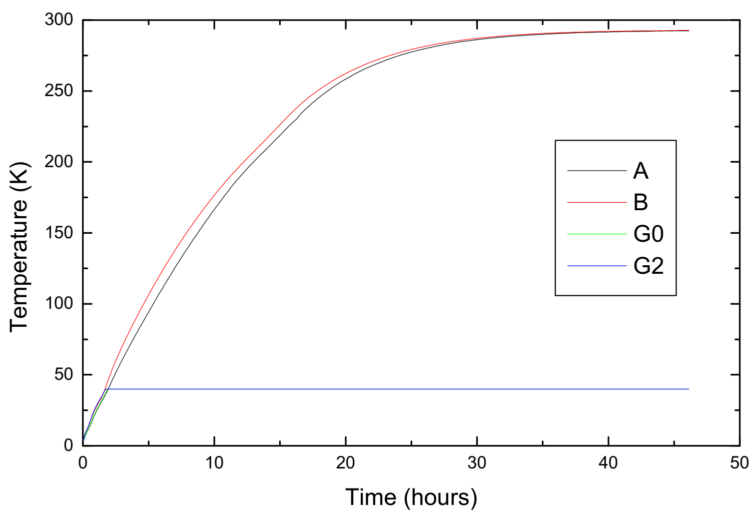

Fig. 24 Warm up data for the third cycle

6.2 *Cycles 4-5*

The test started on December, 8th, 2004 at 17:50. Following test procedures reported in [AD 14]-Section 9, cycles 4 and 5 were performed.
The 30 GHz assembly is mounted on the 4K stage, while 44 GHz is mounted on the cooler cold flange.
The sensors setup is reported in Table 11

Sensor ID	Type	Location

A	DT670 SD	44 GHz envelope
B	CX1050 CU	30 GHz Internal target face
G0	CX1050 AA	4K shield
G1	GR200A AA	30 GHz pyramid
G3	GR200A AA	20 K shield

Table 11 Sensor locations during cycles 4-5

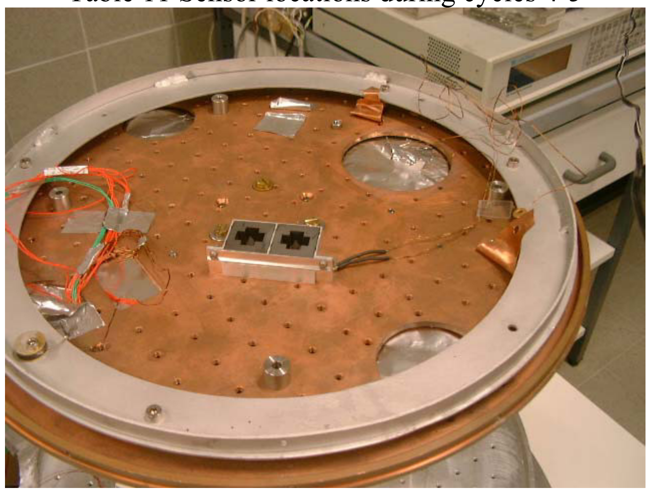

Fig. 25 44 GHz during cycles 4 and 5, sensor is visible in the right corner of the Al envelope.

Cycle temperature data are shown in next figure.

No damage was reported in the visual inspection.

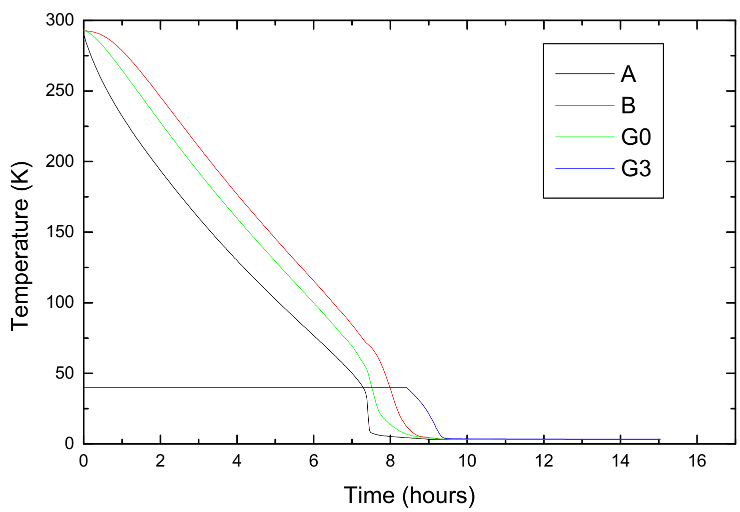

Fig. 26 Cool down data for the fourth cycle

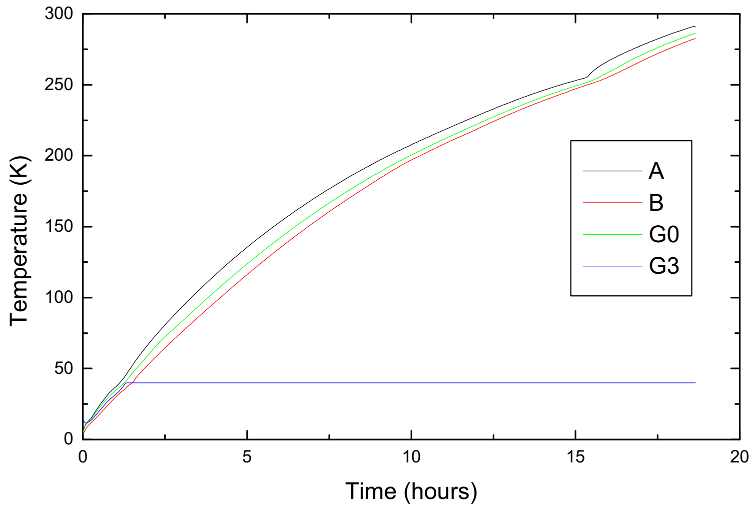

Fig. 27 Warm up data for the fourth cycle

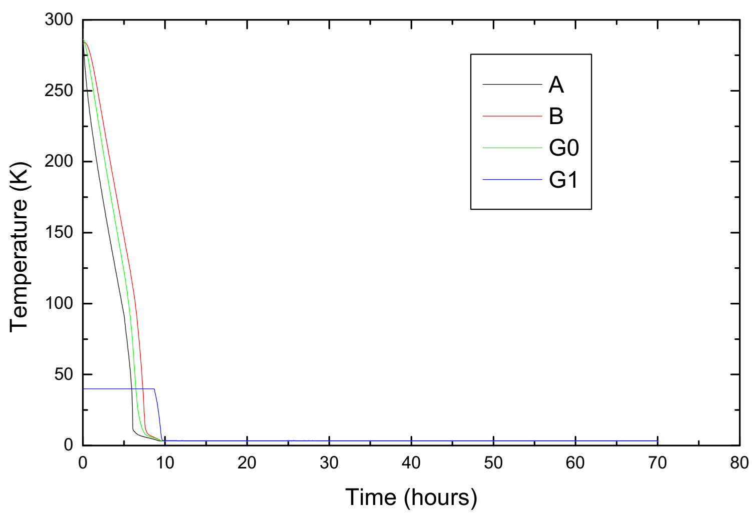

Fig. 28 Cool down data for the fifth cycle

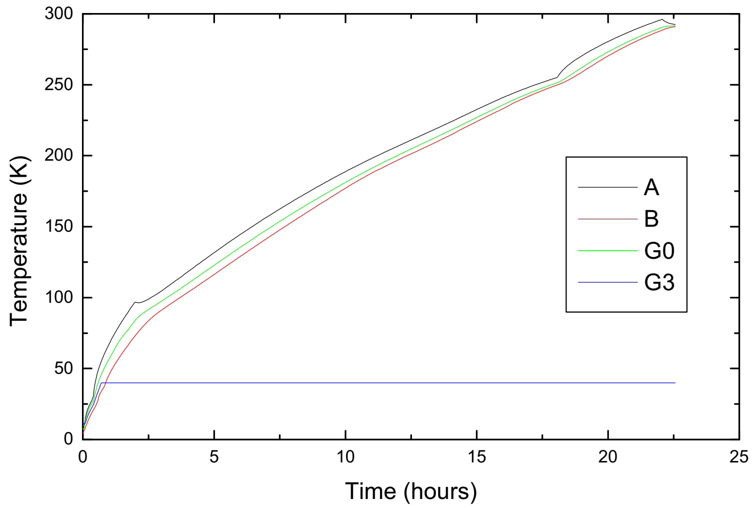

Fig. 29 Warm up data for the fifth cycle

6.3 Cycles 6-7

The test started on December, 16th, 2004 at 16:36. Following test procedures reported in [AD 14]-Section 9, cycles 6 and 7 were performed.
Both the 30 GHz and 44 GHz SUT are mounted on the cooler cold flange; temperature sensors are fixed on the aluminum envelopes. No damage was reported in the visual inspection.

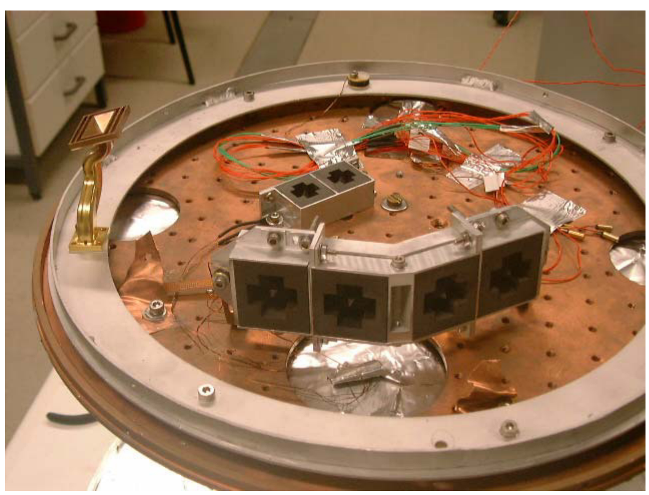

Fig. 30 Cryo facility setup for the cycles 6-7. Both the 30 GHz and 44 GHz targets are mounted on the cooler copper flange. The 30 GHz assembly is linked to the flange by means of two copper supports.

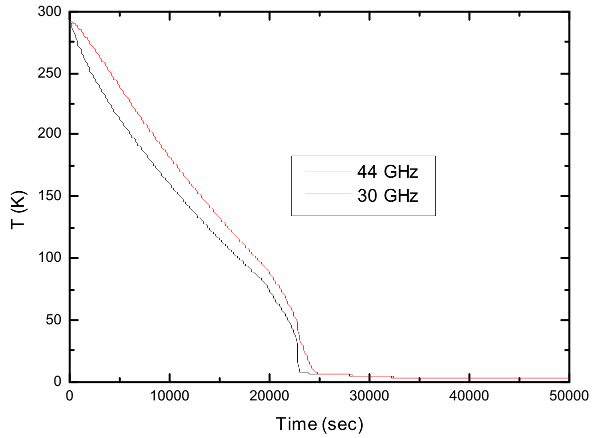

Fig. 31 Cooldown data for the 6th cycle

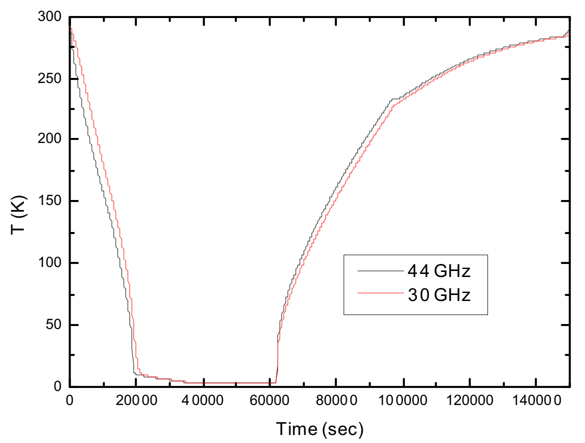

Fig. 32 Cooldown and warmup data for the 7th cycle

6.4 44 GHz cycle 8

The test started on January, 10th, 2005 at 16:12. Only the 44 GHz couple of targets are mounted on the cryofacility cold flange. No damage was reported in the visual inspection.

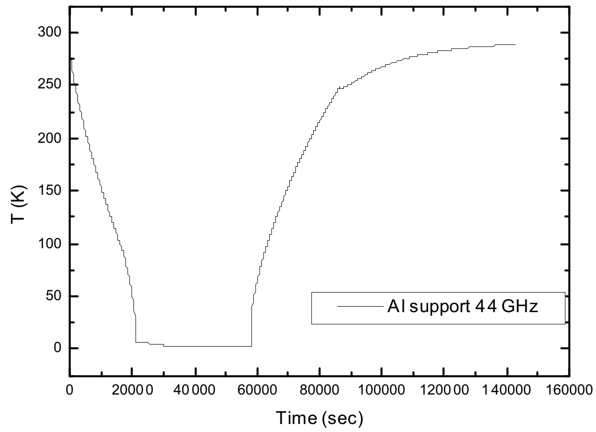

Fig. 33 Cooldown and warmup data of the 8th cycle for the 44 GHz QM reference load

6.5 30 GHz cycle 8 and 44 GHz cycle 9

The test started on January, 13th, 2005 at 18:05. Both the 30 and 44 GHz samples are mounted on the 4 K shield used as HFI dummy. Sensors are mounted on the target plane faces. No damage was reported in the visual inspection.

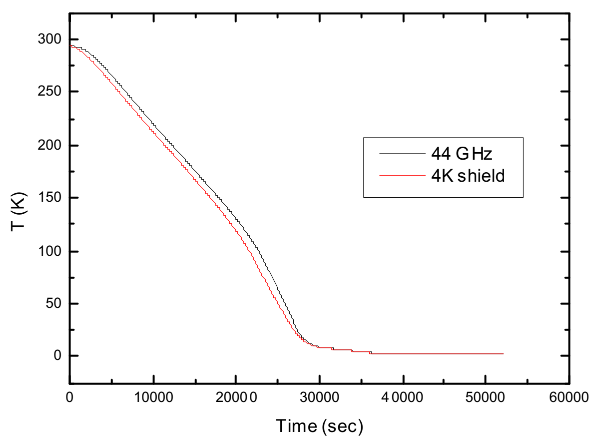

Fig. 34 Cooldown data for the cycle 8 (9) of the 30 (44) GHz QM reference load

6.6 30 GHz cycle 9-14 and 44 GHz cycle 10-15

The test started on January, 18th, 2005 at 18:09. Both the 30 and 44 GHz samples are mounted on the 4 K shield used as HFI dummy. Sensors are mounted on the target plane faces. During the last cycle a problem occurred in the acquisition card (see Fig. 40), so that tests were interrupted. Before starting the new series of tests, after the acquisition substitution, the facility was opened to adjust a sensor fixing and closed immediately. No accurate visual inspection was performed. Two pictures were taken, but resolution is not sufficient to perform any analysis (see Fig. 41 and Fig. 42)

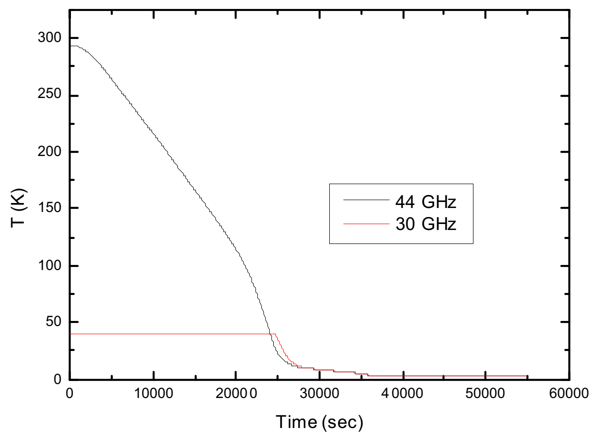

Fig. 35 Cooldown data for the cycle 9 (10) of the 30 (44) GHz QM reference load

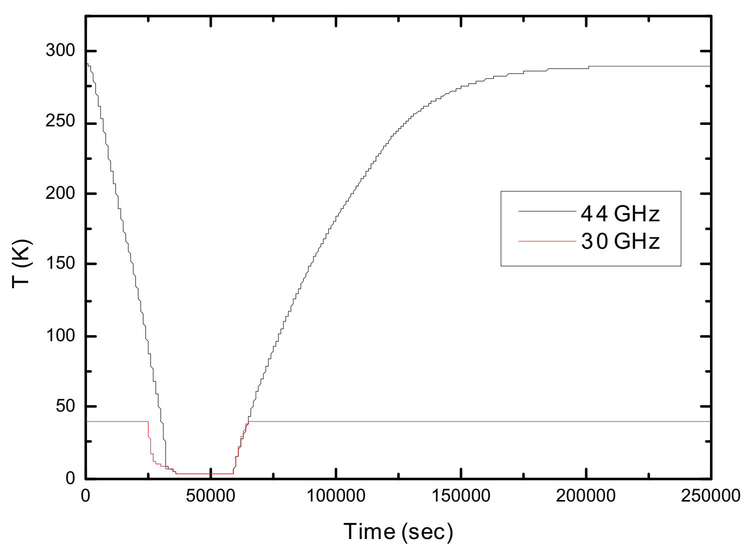

Fig. 36 Cooldown and warmup data for the cycle 10 (11) of the 30 (44) GHz QM reference load

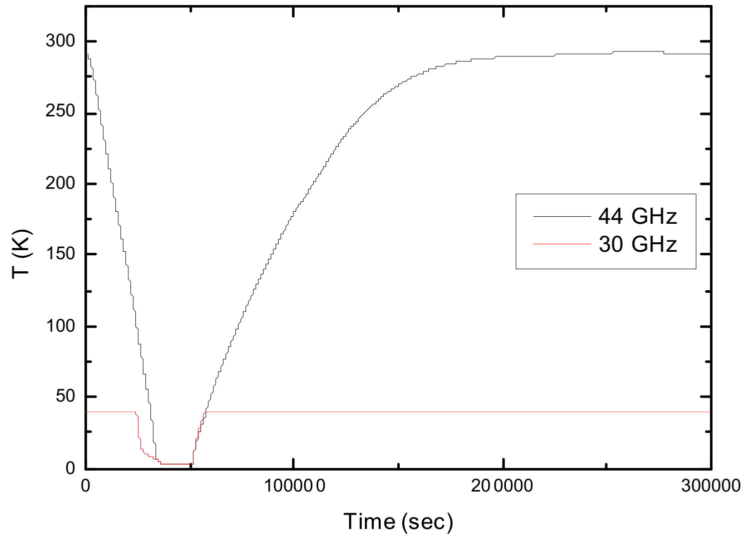

Fig. 37 Cooldown and warmup data for the cycle 11 (12) of the 30 (44) GHz QM reference load

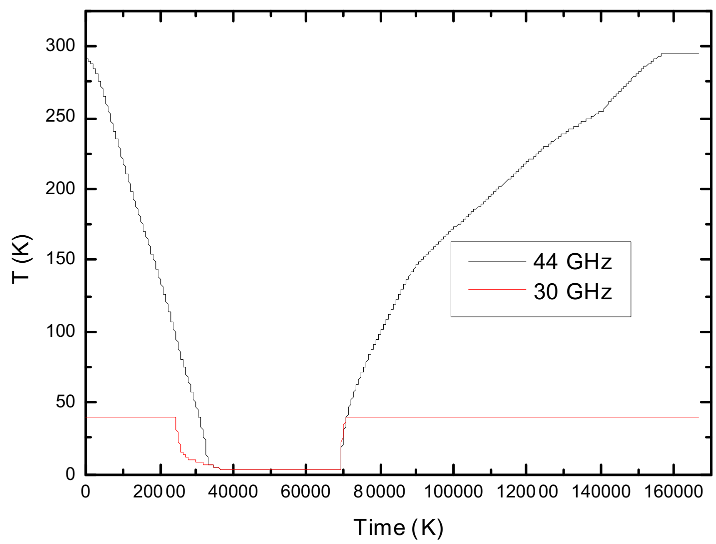

Fig. 38 Cooldown and warmup data for the cycle 12 (13) of the 30 (44) GHz QM reference load

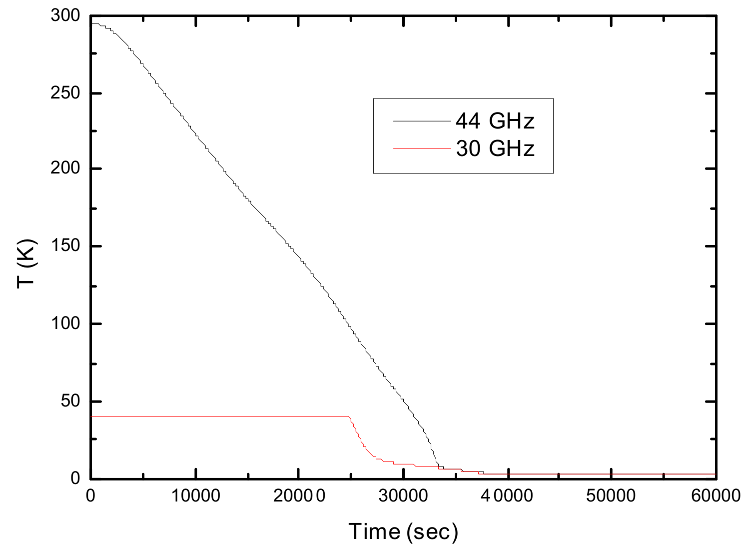

Fig. 39 Cooldown data for the cycle 13 (14) of the 30 (44) GHz QM reference load

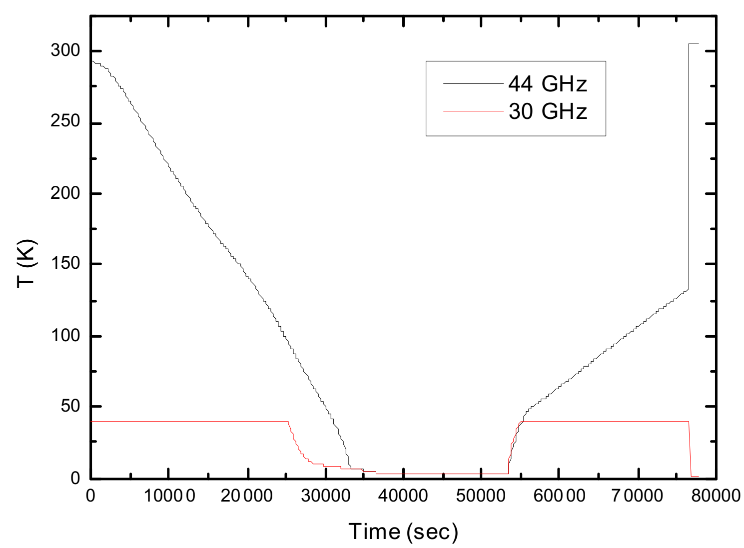

Fig. 40 Cooldown and warmup data for the cycle 14 (15) of the 30 (44) GHz QM reference load. It is evident the sudden temperature gap in the right side of the graph due to the damage occurred in the acquisition.

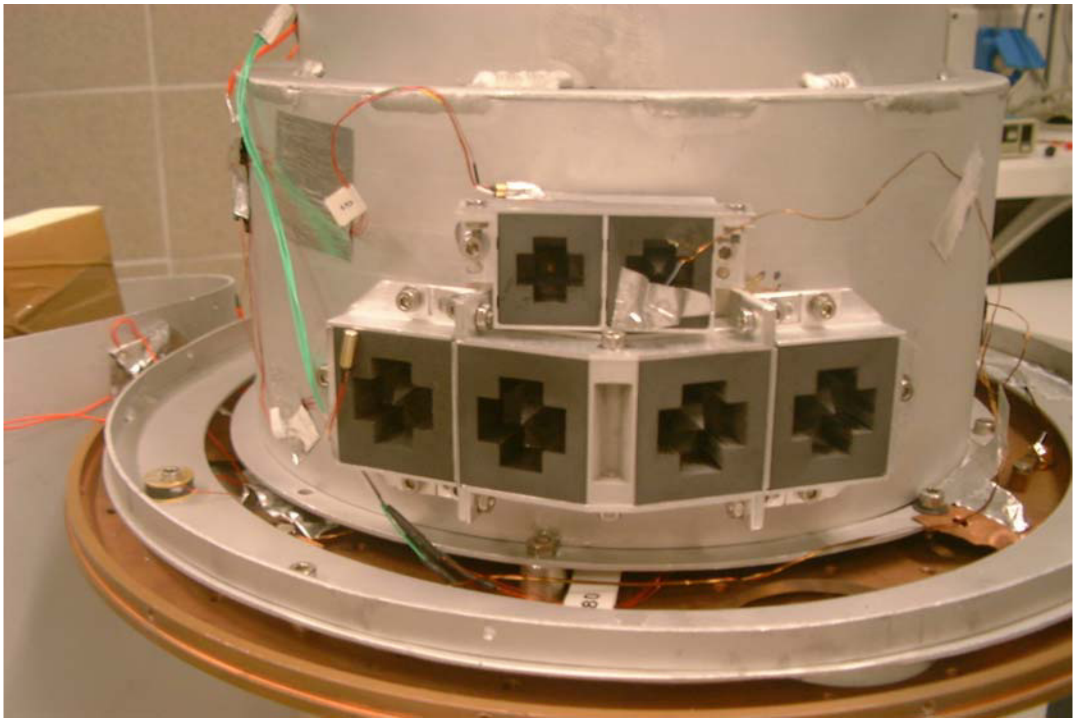

Fig. 41 Photo taken at the end of cycle 15. Sensor on the 44 GHz target was losing its adherence so an aluminum tape was used to fix it

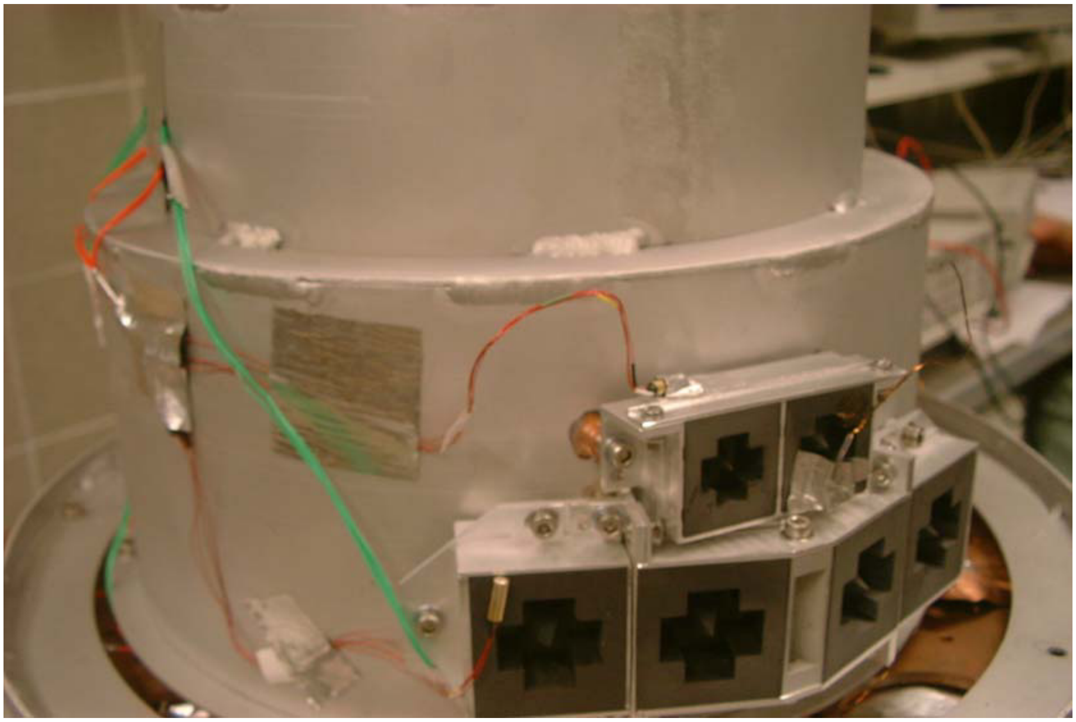

Fig. 42 Photo taken at the end of cycle 15.

6.7 30 GHz cycle 15-16 and 44 GHz 16-17

The test started on February, 23th, 2005 at 17:08. Both the 30 and 44 GHz samples are mounted on the 4 K shield used as HFI dummy. Sensors are mounted on the target plane faces. Visual inspection after the de-mounting of the samples from the facility the visual inspection evidenced many cracks on a 30 GHz target. A more detailed inspection by means of a microscope showed a crack also on the 44 GHz target where the sensor was attached in cycles 10-15 (see Fig. 45 and Fig. 46).

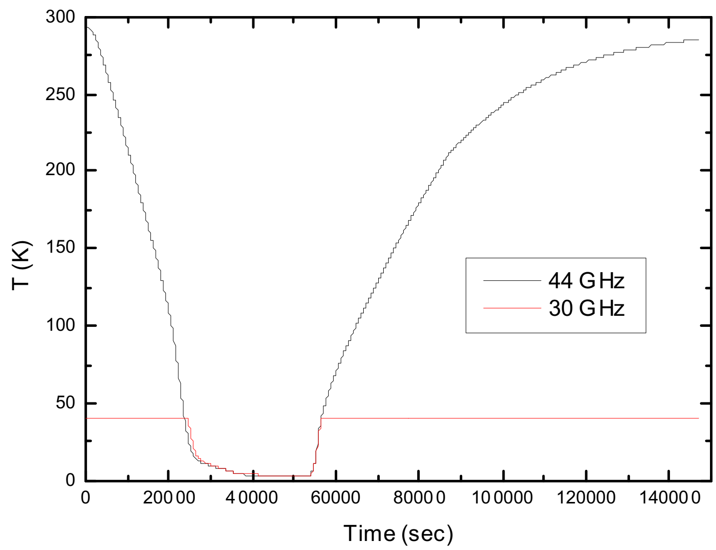

Fig. 43 Cooldown and warmup data for the cycle 15 (16) of the 30 (44) GHz QM reference load

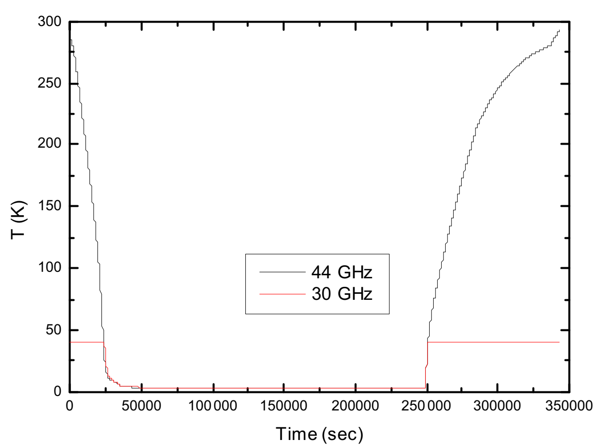

Fig. 44 Cooldown and warmup data for the cycle 16 (17) of the 30 (44) GHz QM reference load

Fig. 45 Cracks on the lateral 30 GHz target (left) and detailed microscope view (right)

Fig. 46 Microscope image of the 44 GHz crack

7 70 GHz thermal balance test and thermal cycles

According to [AD 14], the 70 GHz RL ring is mounted on the dedicated Aluminum shield (Fig. 47), in four fixation points as will be in flight conditions on the HFI 4K shield. Four stainless steel thermal washers and four stainless steel M3 screws are used for mounting.
Sensor locations for this test is reported in (Table 12).

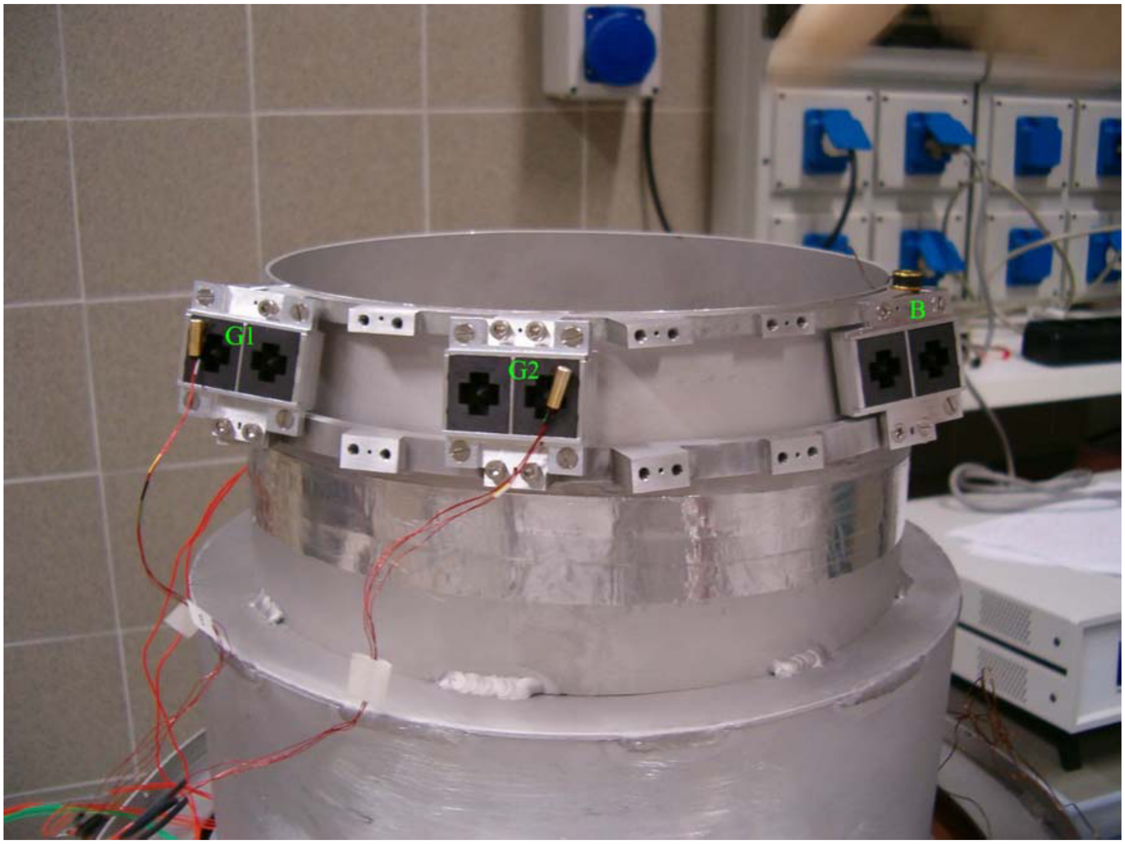

Fig. 47 Experimental setup for 70 GHz RL QM thermal tests. Sensor locations are shown.

Sensor ID	Type	Location
A	DT670 SD	Cold flange
B	CX1050 CU	Aluminum ring structure (Fig. 47)
G0	CX1050 AA	Interface between 70 GHz mounting and 4K shield (Fig. 48)
G1	GR200 AA	Lateral target face (Fig. 47)
G2	GR200 AA	Central target face (Fig. 47)
G3	GR200 CU	20 K shield

Table 12 Sensor locations for the 70 GHz RL thermal tests

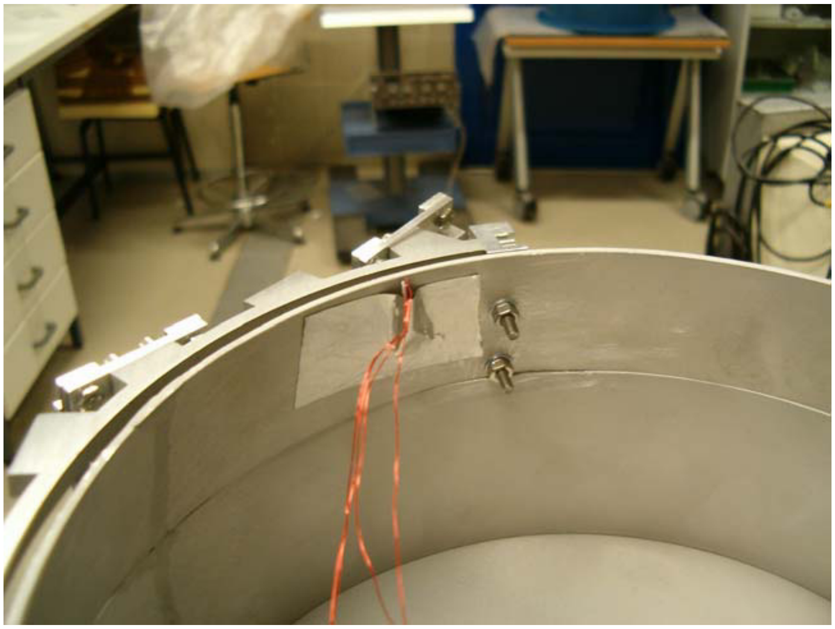

Fig. 48 Sensor G0 location for monitoring interface temperature on one of fixation point.

7.1 Steady state test

After the system thermalization below 4 K, the outer shield is stabilized at a temperature of 19.985 ± 0.010 K (Fig. 6). The 4K stage is then warmed up in order to reach a stable temperature of 4.615 ± 0.002 K.

The presence of the sensor B on the aluminum support near the interface with the 4 K shield allows to avoid some uncertainties on the thermal conductances through the targets and the shield, so that we can evaluate the heat load simply measuring the temperature differences between the B and the G0 sensors (see Fig. 48) and considering the thermal resistance due to the washers at the interface. Measurements during the temperature rise of the 4 K shield were not so stable (Fig. 49), but differences can be evaluated and show a better stability (Fig. 50). Low heat load is evident, so that temperature differences, between G0 and B sensors, are measured within the sensor accuracies.

T (B) – T (G0)	- 0.5 ± 20 mK
Heat Load from QM 70 GHz ring	- 3.6 ± 152 µW
Total Heat Load foreseen from FM 70 GHz ring	- 10 ± 200 µW

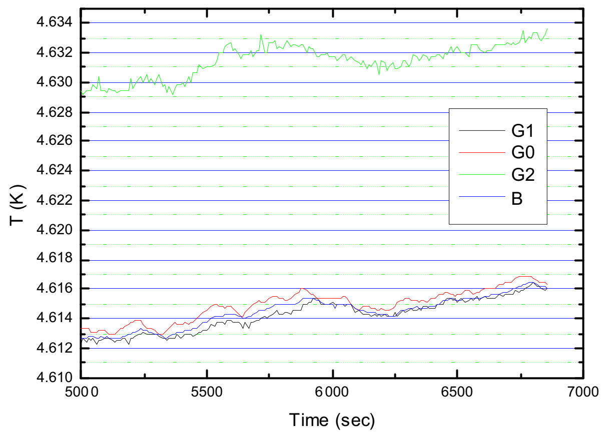

Fig. 49 Steady state analysis was not so stable

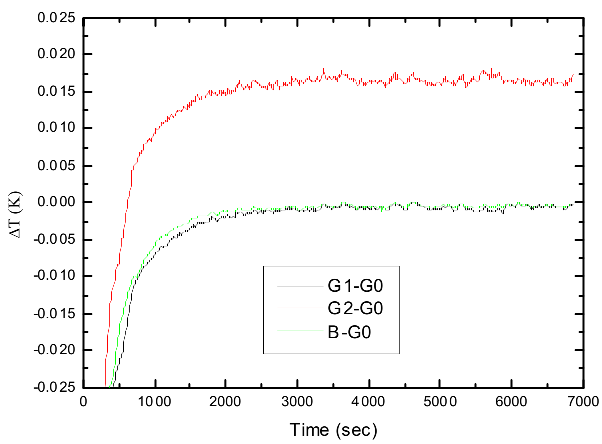

Fig. 50 Temperature differences during the steady state test show an rms fluctuation lower than sensitivity.

7.2 Transient state test

After thermalizing the system applying a stable heat load offset (10% of 60mW) to 4K stage, a sinusoidal power (amplitude 10% of 60mW) was added, at the required frequencies. Procedures reported in [AD 14] are applicable. Then the same data analysis used for the other frequncy channels is performed.
In next plots measurements for each fluctuation frequency are shown, while tables summarize the data analysis results.

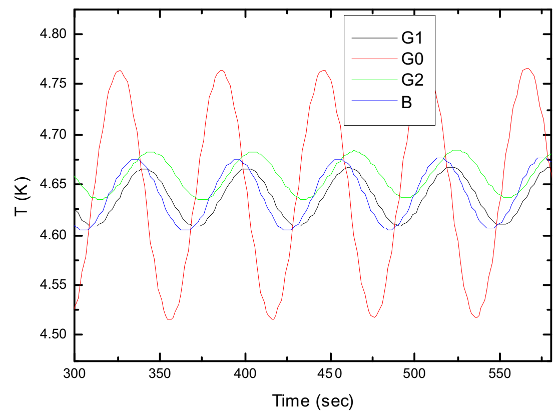

Fig. 51 Transient test of fluctuation of 60 sec period data

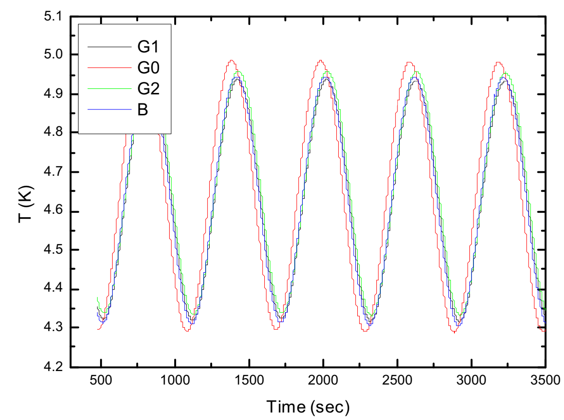

Fig. 52 Transient test of fluctuation of 600 sec period data

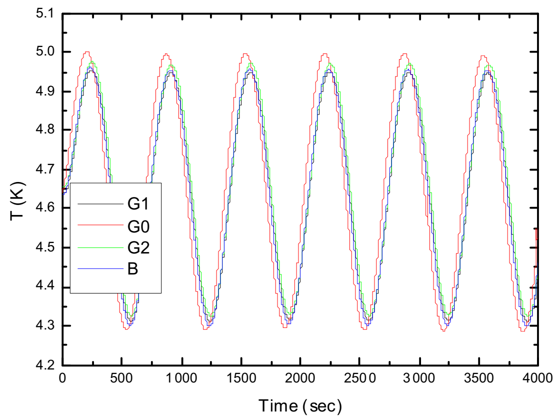

Fig. 53 Transient test of fluctuation of 667 sec period data

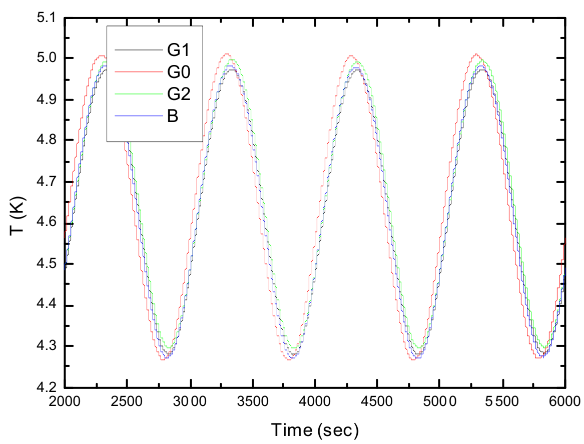

Fig. 54 Transient test of fluctuation of 1000 sec period data

Period (s)	A of lateral target face	A of central target face	A of interface
60	29.0 ± 0.1	23.9 ± 0.1	121 ± 1
600	308.5 ± 0.2	312.1 ± 0.2	346.8 ± 0.2
667	316.7 ± 0.5	319.7 ± 0.5	352.8 ± 0.3
1000	346.5 ± 0.2	349.5 ± 0.2	370.6 ± 0.2

Table 13 Amplitude of fluctuations measured by all sensors, values are in mK

Period (s)	D_f of lateral target face	D_f of central target face
60	0.240 ± 0.003	0.198 ± 0.002

600	0.890 ± 0.001	0.900 ± 0.001
667	0.898 ± 0.002	0.906 ± 0.002
1000	0.935 ± 0.001	0.943 ± 0.001

Table 14 Damping factors evaluated for 70 GHz reference load

7.3 Thermal cycles

The test started on March, 2nd, 2005 at 20:08. Due to strict schedule reason only one cycle is performed.

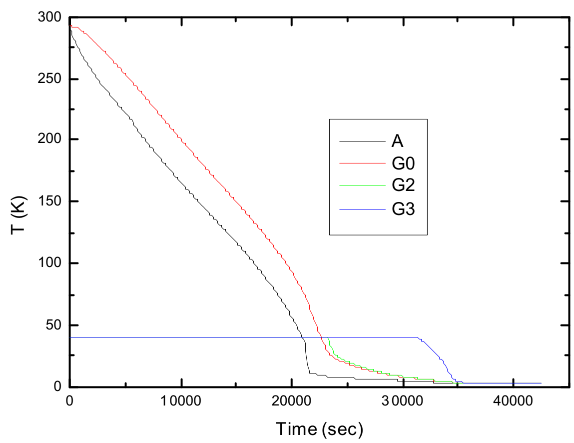

Fig. 55 Cooldown for the 70 GHz tests

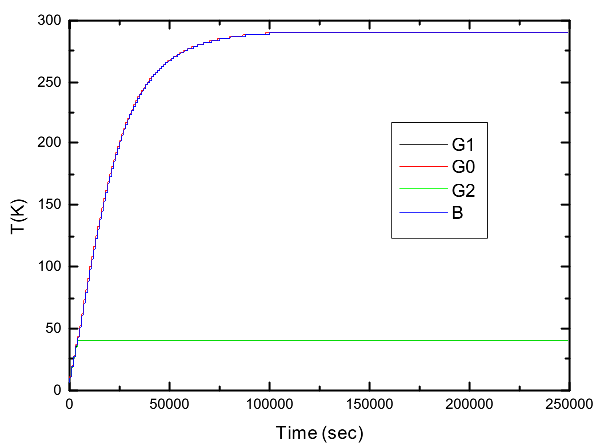

Fig. 56 Cooldown for the 70 GHz tests

8 Conclusions

In the Table 15 a summary of the results of the thermal test campaign and the conformity with requirements are given.

VCN	**Parameter under test**	FREQUENCY	REQUIREMENT	**Test result**	**NCR**
025	Total heat load	All	1 mW	360 ± 650	C
022	Damping factors 1 s period	30 GHz	< 0.001	--	NC-026
		44 GHz		--	NC-026
		70 GHz		--	NC-026
024	Damping factors 60 s period	30 GHz	< 0.1	0.091 ± 0.003	C
		44 GHz		0.19 ± 0.01	NC-027
		70 GHz		0.240 ± 0.003	NC-027
023	Damping factors 600 s period	30 GHz	< 0.9	0.5075 ± 0.0004	C
		44 GHz		0.877 ± 0.001	C
		70 GHz		0.900 ± 0.001	C
023	Damping factors 667 s period	30 GHz	< 0.9	0.560 ± 0.001	C
		44 GHz		0.9076 ± 0.0009	NC-028
		70 GHz		0.906 ± 0.002	PC
023	Damping factors 1000 s period	30 GHz	< 0.9	0.7098 ± 0.0006	C
		44 GHz		0.9549 ± 0.0007	NC-028
		70 GHz		0.943 ± 0.001	NC-028

Table 15 Summary of the test results. Legend for last column: C conformal, NC non-conformal, PC partially conformal (it depends on the position of target)

A more detailed analysis of the impact of these data on the scientific measurements, in view of new data available about HFI 4K stage stabilty, could relax requirement in such a way that non conformities would not affect instrument performances.

A APPENDIX 1: TEST CONTROL SHEETS

Test title: Thermal Balance steady state at 30 GHz		**Date:** Start 08/12/2004 End 14/12/2004
Test N°: PLTES-RL30-TB-SS-01	**Conductor:** Luca Terenzi	
Requirements: see [AD 12]/VCN-025		
DUT name: 30 GHz QM Reference Targets ID PLTES021 - PLTES022		
Objective: To verify that the reference target outer parts temperatures and heat load on HFI shield at steady state are compliant with specifications		
Test methodology: The QM Reference targets and mounting structure are cooled down in the cryo facility in presence of a conductive and radiative heat transfer representative of in flight conditions. Temperatures are measured after the system has thermalized and heat load is evaluated as indicated in [AD 13]		
Notes:		
Conductor Signature: ________________________		

Test title: Thermal Balance steady state at 44 GHz	**Date:** Start 13/01/2005 End 18/01/2005
Test N°: PLTES-RL44-TB-SS-02	**Conductor:** Luca Terenzi
Requirements: see [AD 12]/VCN-025	**Requirements**: see [AD 12]/VCN-025
DUT name: 44 GHz QM Reference Targets ID PLTES018	**DUT name:** 44 GHz QM Reference Targets ID PLTES018
Objective: To verify that the reference target outer parts temperatures and heat load on HFI shield at steady state are compliant with specifications	**Objective:** To verify that the reference target outer parts temperatures and heat load on HFI shield at steady state are compliant with specifications
Test methodology: The QM Reference targets and mounting structure are cooled down in the cryo facility in presence of a conductive and radiative heat transfer representative of in flight conditions. Temperatures are measured after the system has thermalized and heat load is evaluated as indicated in [AD 13]	**Test methodology:** The QM Reference targets and mounting structure are cooled down in the cryo facility in presence of a conductive and radiative heat transfer representative of in flight conditions. Temperatures are measured after the system has thermalized and heat load is evaluated as indicated in [AD 13]
Notes:	**Notes**:
Conductor Signature: _______________________	**Conductor Signature:** _______________________

<table>
<tr><td colspan="2">Test title: Thermal Balance steady state at 70 GHz</td><td>Date:
Start 02/03/2005
End 07/03/2005</td></tr>
<tr><td>Test N°: PLTES-RL70-TB-SS-03</td><td colspan="2">Conductor: Luca Terenzi</td></tr>
<tr><td colspan="3">Requirements: see [AD 12]/VCN-025</td></tr>
<tr><td colspan="3">DUT name: 70 GHz QM Reference Targets ID PLTES012 - PLTES017</td></tr>
<tr><td colspan="3">Objective: To verify that the reference target outer parts temperatures and heat load on HFI shield at steady state are compliant with specifications</td></tr>
<tr><td colspan="3">Test methodology: The QM Reference targets and mounting structure are cooled down in the cryo facility in presence of a conductive and radiative heat transfer representative of in flight conditions. Temperatures are measured after the system has thermalized and heat load is evaluated as indicated in [AD 13]</td></tr>
<tr><td colspan="3">Notes:</td></tr>
<tr><td colspan="3">Conductor Signature:

______________________</td></tr>
</table>

<table>
<tr><td colspan="2">Test title: Thermal Balance transient state at 30 GHz</td><td>Date:
Start 08/12/2004
End 14/12/2004</td></tr>
<tr><td>Test N°: PLTES-RL30-TB-TS-01</td><td colspan="2">Conductor: Luca Terenzi</td></tr>
<tr><td colspan="3">Requirements: [AD 12]/VCN-022, VCN-023, VCN-024</td></tr>
<tr><td colspan="3">DUT name: 30 GHz QM Reference Targets ID PLTES021 - PLTES022</td></tr>
<tr><td colspan="3">Objective: To verify that the reference target fluctuation damping at different frequencies is compliant with specifications:</td></tr>
<tr><td colspan="3">Test methodology: The QM Reference targets and mounting structure are cooled down in the cryo facility in presence of a conductive and radiative heat transfer representative of in flight conditions. An oscillating temperature boundary is provided at the interface with the 4 K stage and pyramid tip temperatures are measured in order to evaluate the fluctuation transfer function as indicated in [AD 13]. The test is repeated for different oscillation frequencies.</td></tr>
<tr><td colspan="3">Notes: Test at 1 Hz was not performed</td></tr>
<tr><td colspan="3">Conductor Signature:

________________________</td></tr>
</table>

Test title: Thermal Balance transient state at 44 GHz		**Date:** Start 13/01/2005 End 18/01/2005
Test N°: PLTES-RL44-TB-TS-02	**Conductor:** Luca Terenzi	
Requirements: [AD 12]/VCN-022, VCN-023, VCN-024		
DUT name: 44 GHz QM Reference Targets ID PLTES018		
Objective: To verify that the reference target fluctuation damping at different frequencies is compliant with specifications:		
Test methodology: The QM Reference targets and mounting structure are cooled down in the cryo facility in presence of a conductive and radiative heat transfer representative of in flight conditions. An oscillating temperature boundary is provided at the interface with the 4 K stage and pyramid tip temperatures are measured in order to evaluate the fluctuation transfer function as indicated in [AD 13]. The test is repeated for different oscillation frequencies.		
Notes: Test at 1 Hz was not performed		
Conductor Signature: ________________________		

Test title: Thermal Balance transient state at 70 GHz		**Date:** Start 02/03/2005 End 07/03/2005
Test N°: PLTES-RL70-TB-TS-03	**Conductor:** Luca Terenzi	
Requirements: [AD 12]/VCN-022, VCN-023, VCN-024		
DUT name: 70 GHz QM Reference Targets ID PLTES012 - PLTES017		
Objective: To verify that the reference target fluctuation damping at different frequencies is compliant with specifications:		
Test methodology: The QM Reference targets and mounting structure are cooled down in the cryo facility in presence of a conductive and radiative heat transfer representative of in flight conditions. An oscillating temperature boundary is provided at the interface with the 4 K stage and pyramid tip temperatures are measured in order to evaluate the fluctuation transfer function as indicated in [AD 13]. The test is repeated for different oscillation frequencies.		
Notes: Test at 1 Hz was not performed		
Conductor Signature: ________________________		

Test title: Thermal cycles at 30 GHz	**Date:** Start 11/11/2004 End 02/03/2005
Test N°: PLTES-RL30-TC-01	**Conductor:** Luca Terenzi
Requirements: No relevant change in DUT after visual inspection.	
DUT name: 30 GHz QM Reference Targets ID PLTES021 - PLTES022	
Objective: To verify that the reference target mechanical properties are unchanged after at least 15 thermal cycles, including cycles performed during other tests.	
Test methodology: The QM Reference targets and mounting structure are continously cooled down and warmed up in the cryo facility for 15 times.	
Notes: 16 cycles performed. One of the four targets under test heavily damaged.	
Conductor Signature: ________________________	

Test title: Thermal cycles at 44 GHz		**Date:** Start 11/11/2004 End 02/03/2005
Test N°: PLTES-RL44-TC-02	**Conductor:** Luca Terenzi	
Requirements: No relevant change in DUT after visual inspection.		
DUT name: 44 GHz QM Reference Targets ID PLTES018		
Objective: To verify that the reference target mechanical properties are unchanged after at least 15 thermal cycles, including cycles performed during other tests.		
Test methodology: The QM Reference targets and mounting structure are continously cooled down and warmed up in the cryo facility for 15 times.		
Notes: 17 cycles performed. One of the two targets under test shows a little crack.		
Conductor Signature: ________________________		

Test title: Thermal cycles at 70 GHz		**Date:** Start 02/03/2004 End 07/03/2005
Test N°: PLTES-RL70-TC-03	**Conductor:** Luca Terenzi	
Requirements: No relevant change in DUT after visual inspection.		
DUT name: 70 GHz QM Reference Targets ID PLTES012 - PLTES017 and flight spare PLTES014		
Objective: To verify that the reference target mechanical properties are unchanged after at least 15 thermal cycles, including cycles performed during other tests.		
Test methodology: The QM Reference targets and mounting structure are continously cooled down and warmed up in the cryo facility for 15 times.		
Notes: 16 cycles performed. One of the four targets under test heavily damaged.		
Conductor Signature: _______________________		