TITLE: Thermal test of4K Reference Load FM targets

DOC. TYPE: REPORT

REF. NUMBER : PL-LFI-TES-RP-019 **PAGE:** I of IV, 23, A1-10

ISSUE/REV.: 1.0 **DATE:** Sept 2005

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CHANGE RECORD

Issue	Date	Sheet	Description of Change	Release
1.0	23/05/2005	All	First issue of the document	

TABLE OF CONTENTS

1 SCOPE

1.1 Purpose

Purpose of this document is to report results of thermal verification and cycles for the FM 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, reported in Section 6, refer to cooldown and warmup curves during thermal balance tests.
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, 1.3)
[AD 14] *4K Reference Load Thermal Test Procedures* (PL-LFI-TES-PR-003, 2.0)
[AD 15] *4K Reference Load Design Report* (PL-LFI-TES-RP-001)

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	2	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

An Al6061 mechanical structure, used for the vibration tests, supports the reference load mounted upon it; its mechanical interface is representative of the HFI flight interface and it is set in front of a cylinder at a higher temperature (Fig. 1). This setup simulates the flight environment, where targets are mounted on the HFI 4K shield in front, and at a comparable distance, of the quasi cylindrical LFI main frame at about 20 K.

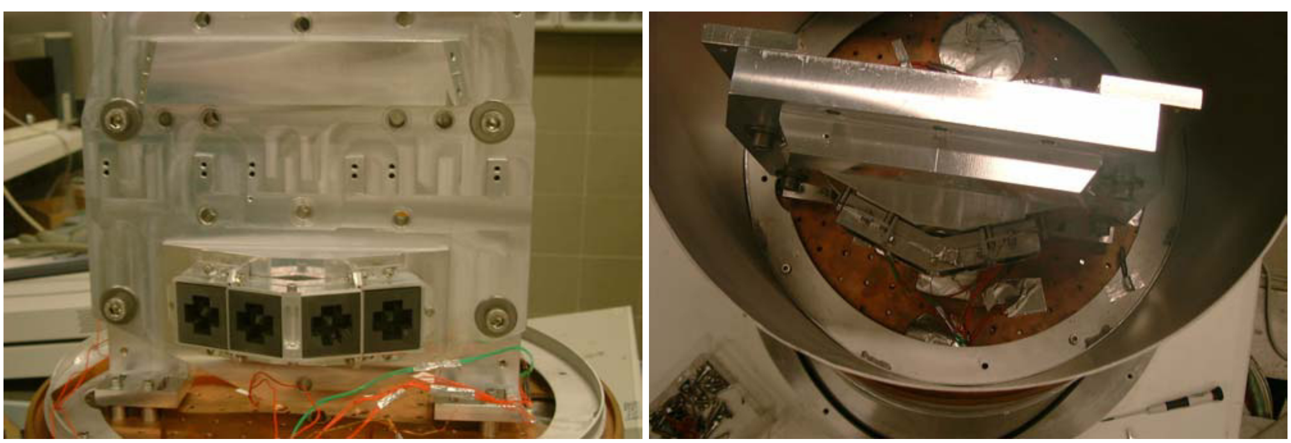

Fig. 1 The 30 GHz Reference Load mounted on a dedicated structure, whose interfaces are representative of the HFI 4 K shield ones (left), surrounded by a radiative shield, representative of the LFI main frame environment (right, top view).

Both the Al structures 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 dissipated on the cold stage of the cooler. The thermal regulation is obtained by means of Minco film heaters fixed to the shields (Fig. 2).

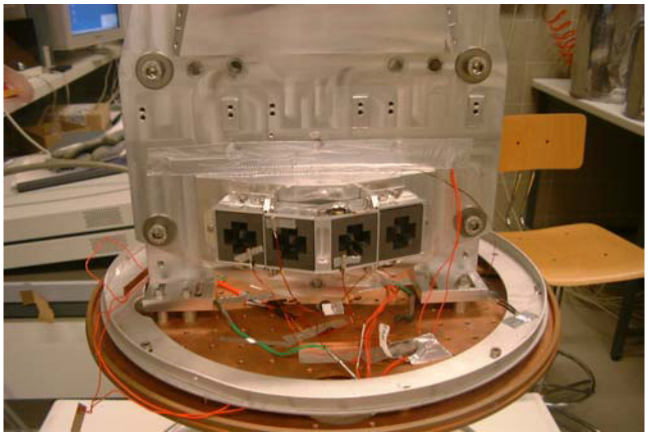
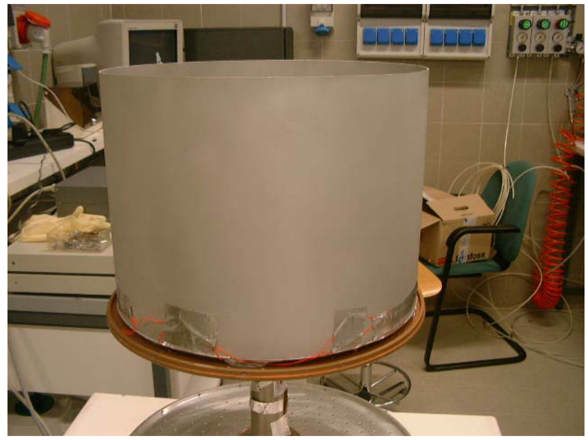

Fig. 2 Heater strips are attached to the Aluminum internal (left figure, on the 30GHz assembly) and external (right figure) structure by means of Al tape.

A first run was performed in order to check the temperature uniformity in different regions of the 20 K shield during QM tests. Two sensors were mounted on the shield and we found that temperature difference in steady state was less than 40 mK. Following this verification, only one sensor was mounted on the shield for monitoring its temperature.

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	Calibration
A	DT670 SD	27 mK	0.4 mK	LakeShore Calibration
B	CX1050 CU	10 mK	0.1 mK	Cal in 4K CF: Run-ID 04-012
G0	CX1050 AA	10 mK	0.1 mK	Cal in 4K CF: Run-ID 04-012
G1	GR200A AA	30 mK	0.3 mK	Cal in 4K CF: Run-ID 04-012
G2	GR200A AA	30 mK	0.3 mK	Cal in 4K CF: Run-ID 04-012
G3	GR200A CU	30 mK	0.3 mK	Cal in 4K CF: Run-ID 04-012

Table 2: Temperature sensor properties

4 30 GHz thermal balance test

4.1 Sample and sensors' mounting

The 30 GHz assembly is mounted on the dedicated Aluminum fixture, in six fixation points as will be in flight conditions on the HFI 4K shield. The screw torque is fixed to the specification value of

1.1 N·m. Six stainless steel thermal washers and six stainless steel M3 screws are used for mounting.
Sensor locations for this test is reported in Table 3 and shown in Fig. 3 while envirnmental conditions are reported in Table 4. The target surface covered with Al tape can be considered negligible in the evaluation of radiative heat load. The sensors' fixation is checked before and after the test in order to be sure that thermal contact between sensors and fixation surface is sufficient.

Sensor ID	Type	Location
A	DT670 SD	20K shield
B	CX1050 CU	Al envelope of assembly
G0	CX1050 AA	Left lateral target face (PLTES048A)
G1	GR200 AA	Left central target face (PLTES048B)
G2	GR200 AA	Right central target face (PLTES049B)
G3	GR200 CU	4K shield interface

Table 3 Sensor locations for 30 GHz thermal balance test

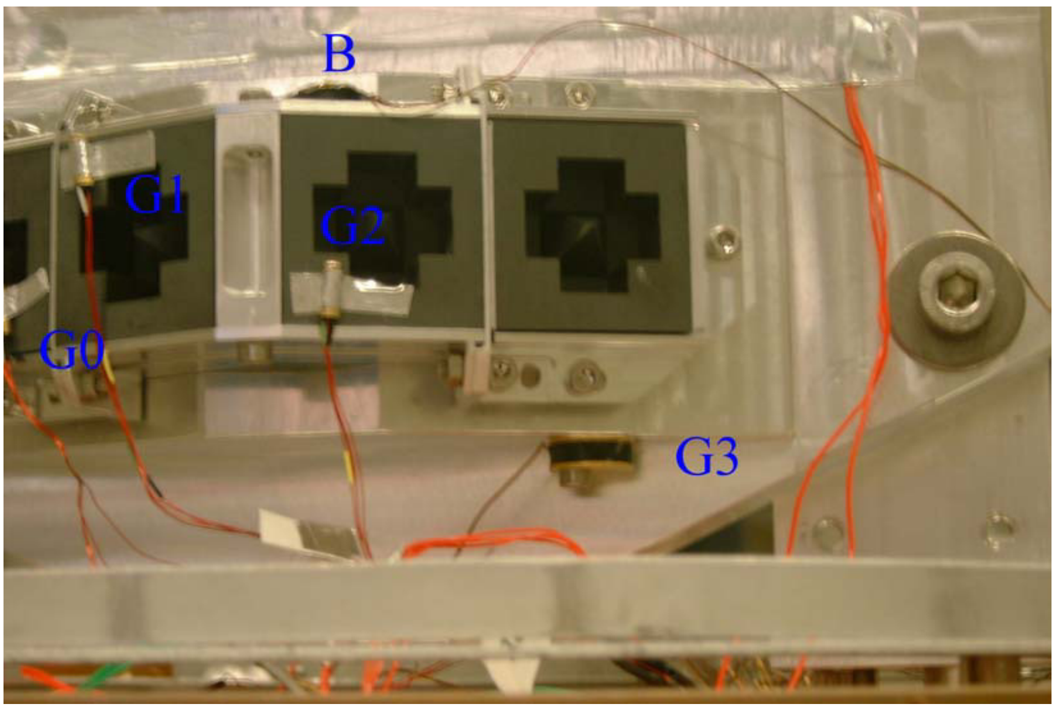

Fig. 3 Sensors mounting for 30GHz tests.

Parameter	Nominal value	Measured value
Relative Humidity [RH %]	20-60	50.6
Temperature [°C]	22 ± 4	24.5

Table 4 Laboratory environmental conditions during the test

4.2 Steady state test

After the system thermalization below 4 K, the outer shield is stabilized at a temperature of 19.390 ± 0.010 K. The 4K stage is then warmed up in order to reach a stable temperature of 4.624 ± 0.001 K (the G3 sensor is visible in Fig. 3) and other temperatures are measured (Fig. 4). The G1 sensor is systematically lower in temperature with respect to what expected, but always compliant with its accuracy of 30 mK.

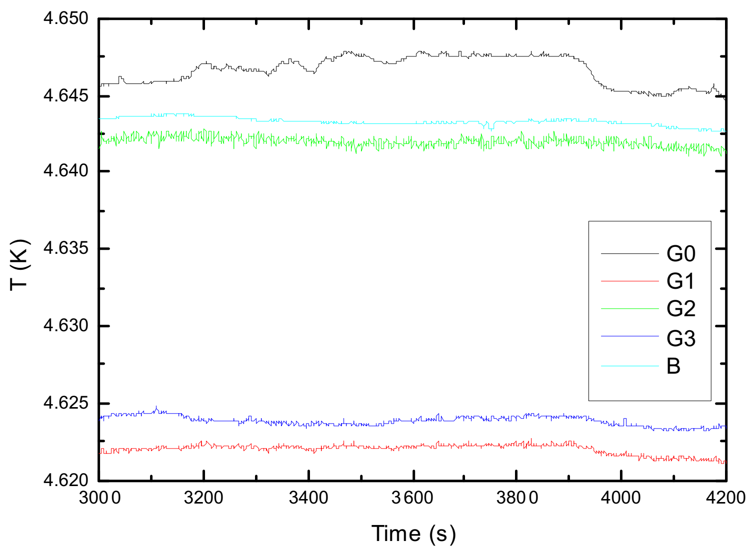

Fig. 4 Steady state temperatures measured. The G1 sensor has a lower temperature than expected but its accuracy of 30 mK explains this anomalous value.

T (G3)	4.62 ± 0.03 K
T (B)	4.64 ± 0.01 K
Total heat load	80 ± 170 μW

Table 5 Summary of the results for the steady state test

Due to the monitoring of the Al envelope (sensor B), it is sufficient evaluate the heat transferred through the thermal washers (total heat conductance about 4mW/K), so that thermal conductances of the stainless steel interfaces 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 5. Even though temperature curves have an rms of about 1 mK, given by the good sensors' sensitivity, temperature differences are comparable to sensors' accuracies so that errors are relevant. This feature is common to all steady state tests.

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 (20% of 60mW) to 4K stage, a sinusoidal power (amplitude 18% 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 6 and Table 7.

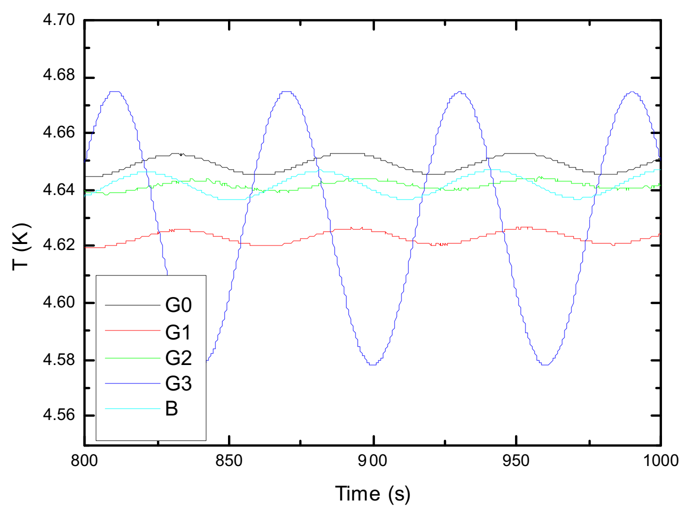

Fig. 5 Transient test of fluctuation of 60 sec period data

[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:

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

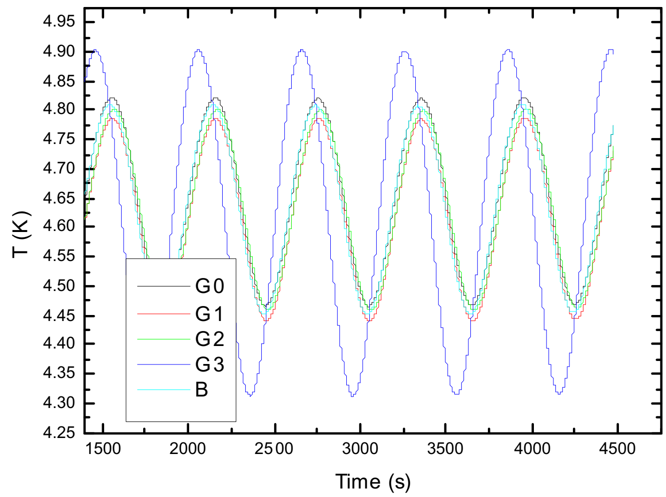

Fig. 6 Transient test of fluctuation of 600 sec period data

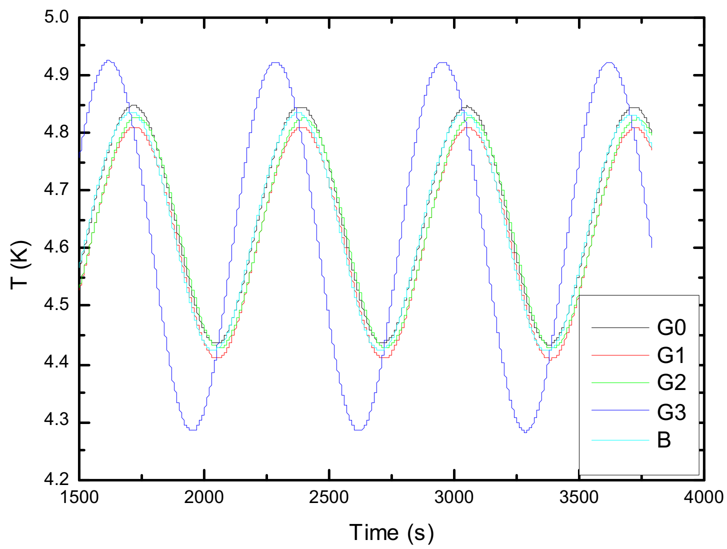

Fig. 7 Transient test of fluctuation of 667 sec period data

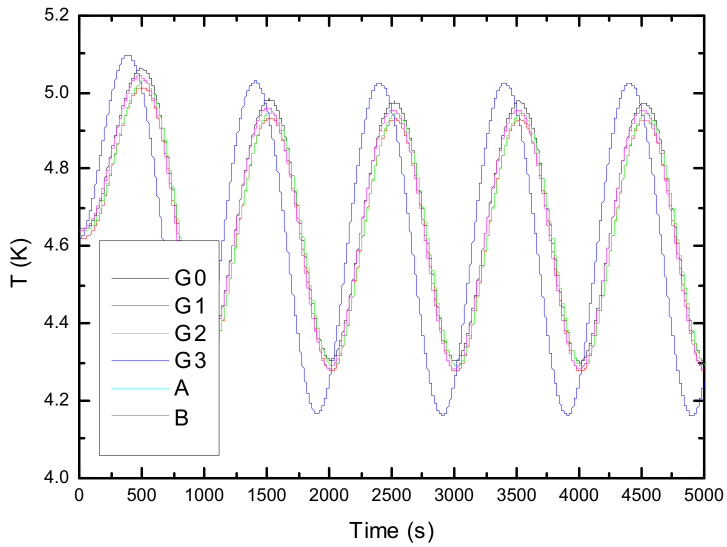

Fig. 8 Transient test of fluctuation of 1000 sec period data

Period (s)	Left side face A	Left mid face A	Right mid face A	Interface A
60	3.83 ± 0.09	2.95 ± 0.07	2.0 ± 0.1 **	48.2 ± 0.1
600	176.7 ± 0.1	170.9 ± 0.1	169.8 ± 0.1	293.8 ± 0.1
667	204.6 ± 0.2	198.6 ± 0.2	197.7 ± 0.2	319.3 ± 0.2
1000	335.7 ± 0.3	327.2 ± 0.3	327.4 ± 0.3	430.5 ± 0.3

Table 6 Amplitude (A) of fluctuations measured by all sensors, values are in mK. **Very noisy measurement.

Period (s)	D_f of left lateral target	D_f of left central target	D_f of right central target
60	$(7.95 \pm 0.20)\cdot 10^{-2}$	$(6.12 \pm 0.16)\cdot 10^{-2}$	$(4.15 \pm 0.22)\cdot 10^{-2}$
600	0.6014 ± 0.0006	0.5817 ± 0.0005	0.5779 ± 0.0005
667	0.641 ± 0.001	0.622 ± 0.001	0.619 ± 0.001
1000	0.780 ± 0.001	0.760 ± 0.001	0.761 ± 0.001

Table 7 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 three 44 GHz assemblies are mounted on the dedicated Aluminum fixture. Two stainless steel thermal washers and two stainless steel M3 screws are used for mounting each assembly. Screw torque is fixed at the specification value of 1.1 N·m.

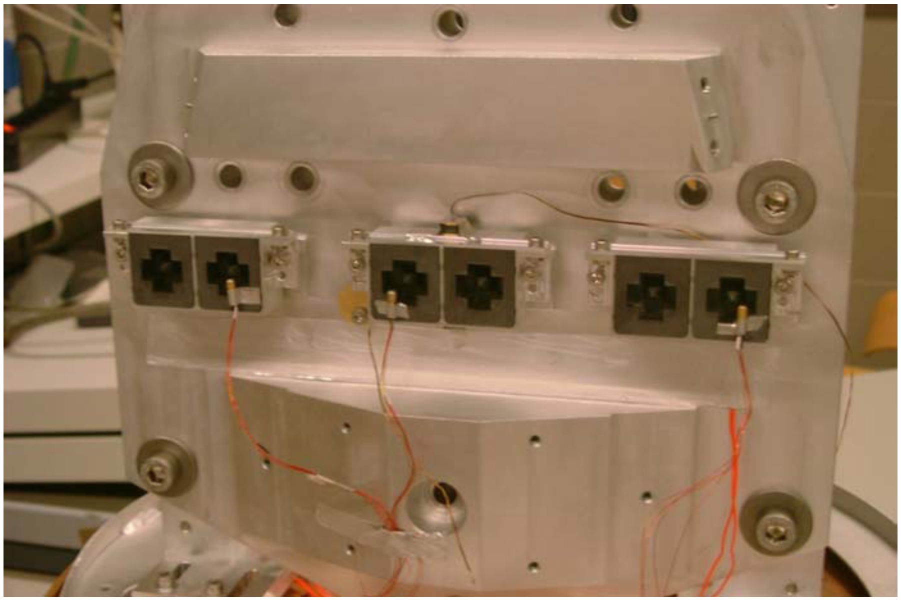

Fig. 9 The samples are mounted on the fixture by means of two stainless steel screws and washers. Temperature sensors are visible.

Sensors are fixed by means of Aluminum tape on the face and envelope of the targets, while the sensor used to monitor the fixture temperature, close to the 4K RL fixation point, is screwed. Sensors are visible in Fig. 9, while their identification and location are described in Table 9. Also in this case the surface covered by the Al tape is negligible for the test results. Table 8 reports laboratory environmental data.

Parameter	Nominal value	Measured value
Relative Humidity [RH %]	20-60	55.7
Temperature [°C]	22 ± 4	23.8

Table 8 Laboratory environmental conditions during the test

5.2 Steady state test

Sensor ID	Type	Location
A	DT670 SD	20K shield
B	CX1050 CU	Al envelope of central target (PLTES046C)
G0	CX1050 AA	Right side of right target (PLTES045B)
G1	GR200 AA	Right side of left target (PLTES047B)
G2	GR200 AA	Left side of central target (PLTES046A)
G3	GR200 CU	Interface with 4K stage

Table 9 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 19.690 ± 0.010 K. The 4K stage is then warmed up in order to reach a stable temperature of 4.571 ± 0.001 K (the G3 sensor is visible in Fig. 9, side of the central target) and other temperatures are measured (Fig. 10).
Low heat load is evident, so that temperature differences are measured within the sensor accuracies.

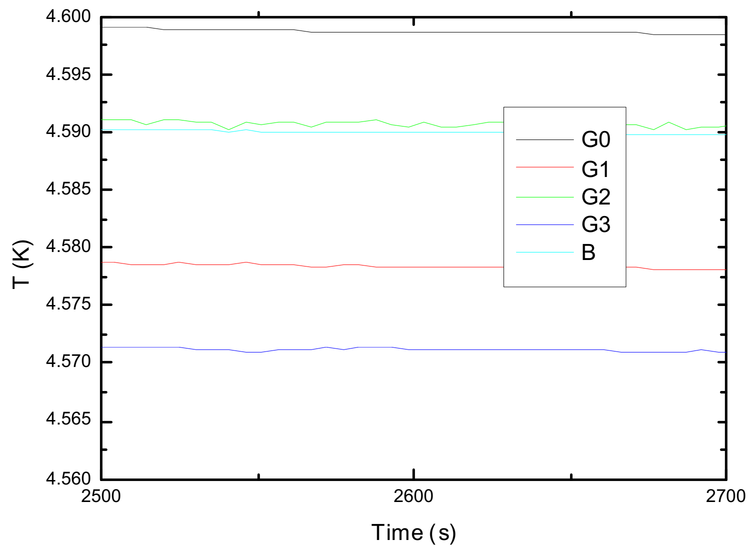

Fig. 10 Steady state temperatures measured.

T (B)	4.59 ± 0.01 K
T (G3)	4.57 ± 0.03 K
Total heat load	30 ± 70 μW

Table 10 Summary of the results for the steady state test

Thermal conductance between Aluminum envelope and fixture is given by thermal washers and it is about 1.66 mW/K. It is 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 10.
Even though temperature curves have an rms of about 2 mK, given by the good sensors' sensitivity, temperature differences are comparable to sensors' accuracies so that 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 11 and Table 12.

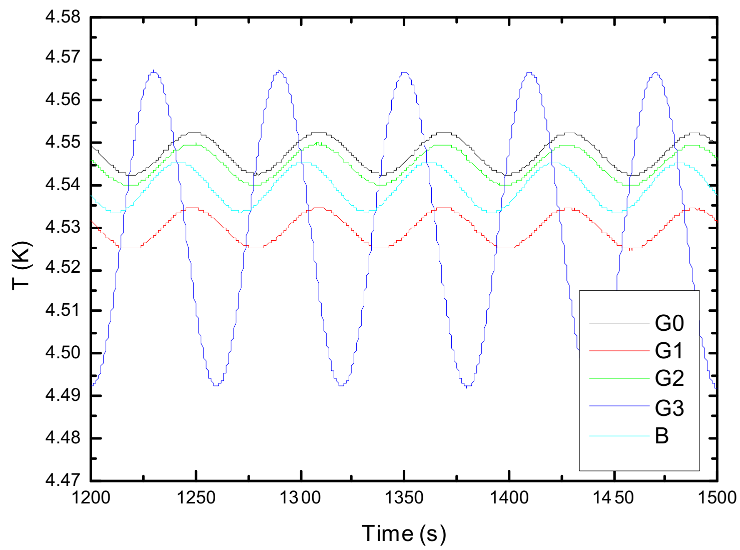

Fig. 11 Transient test of fluctuation of 60 sec period data

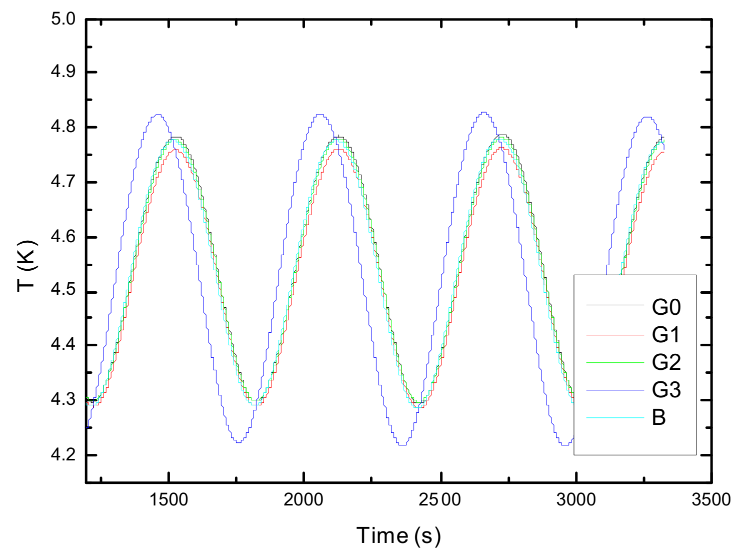

Fig. 12 Transient test of fluctuation of 600 sec period data

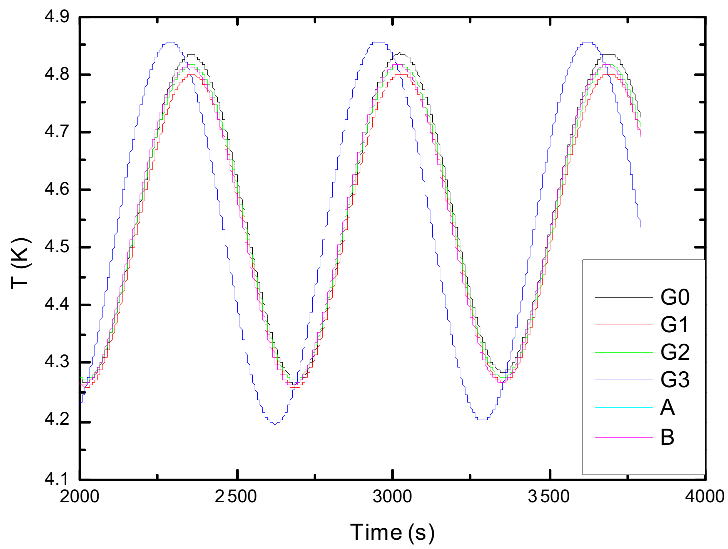

Fig. 13 Transient test of fluctuation of 667 sec period data

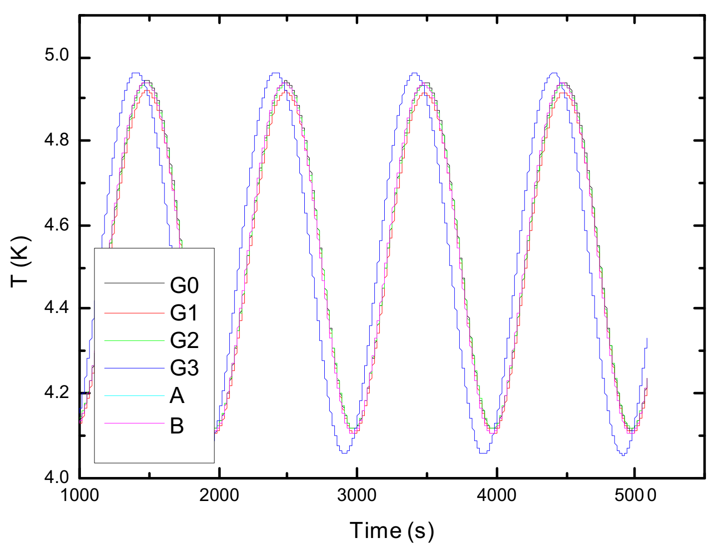

Fig. 14 Transient test of fluctuation of 1000 sec period data

Period (s)	G0 Ampl	G1 Ampl	G2 Ampl	Interface A
60	4.96 ± 0.01	4.84 ± 0.01	4.84 ± 0.01	37.40 ± 0.02
600	244.4 ± 0.2	236.8 ± 0.2	240.9 ± 0.2	301.8 ± 0.2
667	278.2 ± 0.5	267.8 ± 0.4	271.1 ± 0.2	328.5 ± 0.3
1000	412.4 ± 0.3	404.0 ± 0.3	407.7 ± 0.3	452.6 ± 0.3

Table 11 Amplitude (A) of fluctuations measured by all sensors, values are in mK.

Period (s)	D_f of right target face	D_f of left central target	D_f of right central target
60	0.1326 ± 0.0003	0.1294 ± 0.0003	0.1294 ± 0.0003
600	0.810 ± 0.001	0.785 ± 0.001	0.798 ± 0.001
667	0.847 ± 0.002	0.815 ± 0.002	0.825 ± 0.001
1000	0.911 ± 0.001	0.893 ± 0.001	0.901 ± 0.001

Table 12 Damping factors evaluated for 44 GHz reference load

6 Thermal cycles for 30 GHz and 44 GHz targets

In the following sections thermal cycles are reported.
In the FM test campaign only one cycle is foreseen, so that the cooldown and warmup associated to the thermal balance tests are sufficient.

6.1 30 GHz FM thermal cycle

Sensors location is the same of Table 3.
Cooldown procedures, reported in [AD 14], started at 18:18 of July, 6th.
Cooldown and warmup data are reported in Fig. 15 and Fig. 16.

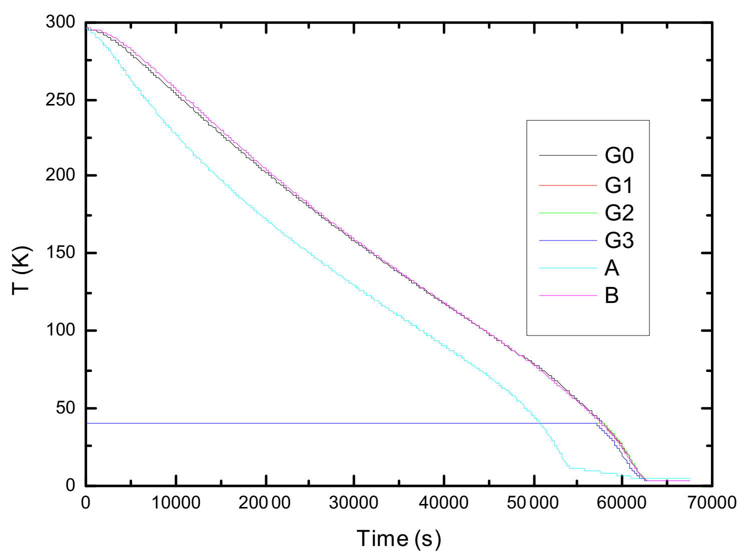

Fig. 15 Cooldown data for the 30 GHz FM targets

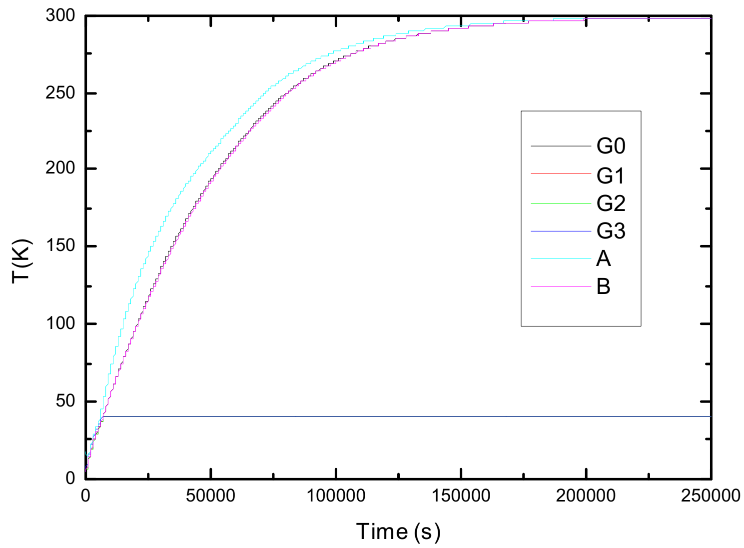

Fig. 16 Warmup data for the 30 GHz FM targets

6.2 44 GHz FM thermal cycle

Sensors location is the same of Table 9.
Cooldown procedures, reported in [AD 14], started at 17:48 of July, 11th.
Cooldown and warmup data are reported in Fig. 17 and Fig. 18.

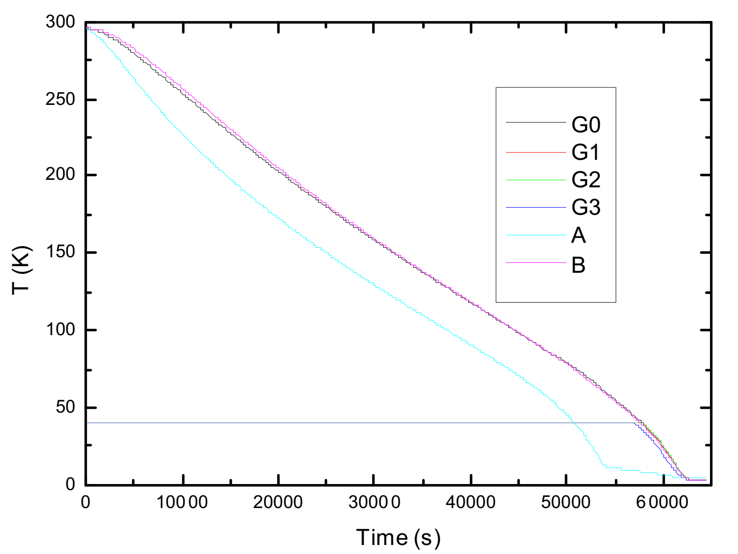

Fig. 17 Cooldown data for the 44 GHz FM targets

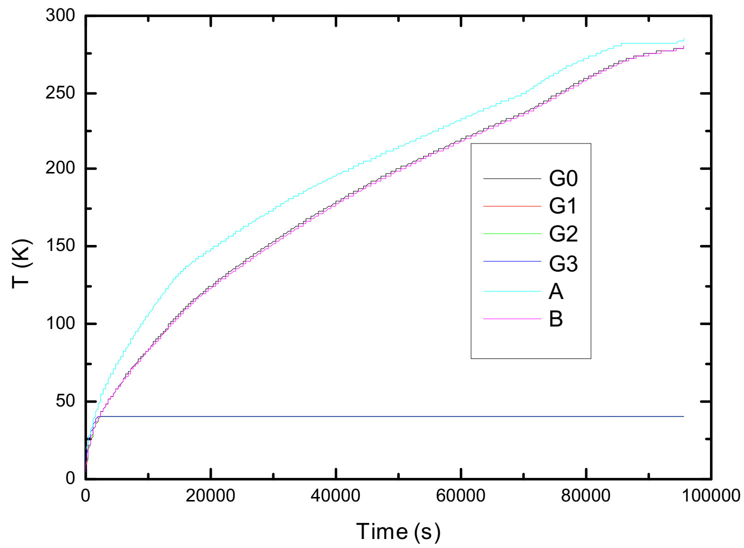

Fig. 18 Warmup data for the 44 GHz FM targets

7 70 GHz thermal balance test and thermal cycles

According to [AD 14], the 70 GHz RL ring is mounted on the dedicated Aluminum fixture (Fig. 19), 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 13 while environmental conditions are reported in Table 14.
In this test the surface covered by Al tape of the G2 sensor is not negligible. In the steady state test result a 10% error has to be taken into account in the heat load. This is well within the evaluated error.

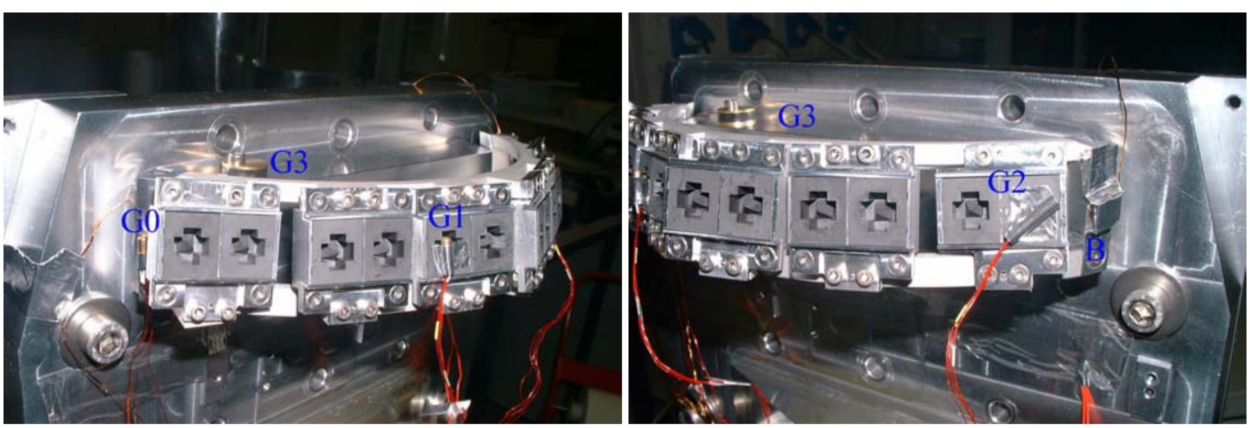

Fig. 19 Left and right part of the 70 GHz RL ring with sensors mounted for FM thermal tests.

Sensor ID	Type	Location
A	DT670 SD	20 K shield support
B	CX1050 CU	Aluminum ring structure on the right fixation point
G0	CX1050 AA	Aluminum ring structure on the left fixation point
G1	GR200 AA	Left central target face (PLTES042A)
G2	GR200 AA	Right lateral target face (PLTES039B)
G3	GR200 CU	4 K fixture close to ring interface

Table 13 Sensor locations for the 70 GHz RL thermal tests (see Fig. 19).

Parameter	Nominal value	Measured value
Relative Humidity [RH %]	20-60	56.0
Temperature [°C]	22 ± 4	23.2

Table 14 Laboratory environmental conditions during the test

7.1 Steady state test

After the system thermalization below 4 K, the outer shield is stabilized at a temperature of 19.72 ± 0.01 K. and the 4K stage warmed up in order to reach a stable temperature of 4.522 ± 0.002 K. Data are shown in Fig. 20.
The presence of the sensors B and G0 on the two interface of the ring let us to evaluate total heat load summing the two contributions on both sides (conductance is 3.68 mW/K for each side).

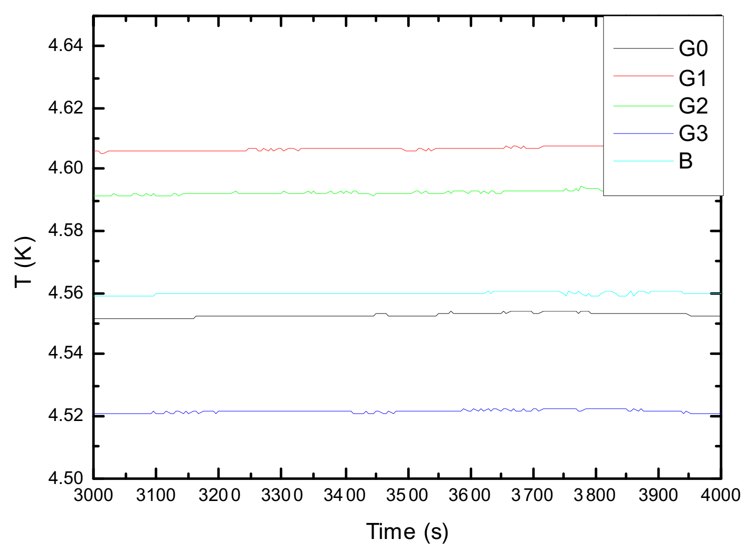

Fig. 20 Steady state data

Heat load from 70 GHz channel is larger than other frequencies and this is not expected, due to smaller surfaces involved in the radiative heat exchange. A deeper view in the data underlined a parasitic heat load in the system. Actually even in the case that external shield is at temperature lower than 5 K, when the foreseen heat load is of order tens of nW, temperature differences are not negligible, as shown in Fig. 21.
Results are summarized in Table 15.

T (G3)	4.52 ± 0.03 K
T (G0)	4.55 ± 0.01 K
T (B)	4.56 ± 0.01 K
Heat Load from FM 70 GHz ring (left side)	110 ± 150 μW
Heat Load from FM 70 GHz ring (right side)	140 ± 150 μW
Total heat load from 70 GHz ring	250 ± 300 μW

Table 15 Summary of steady state results for 70 GHz

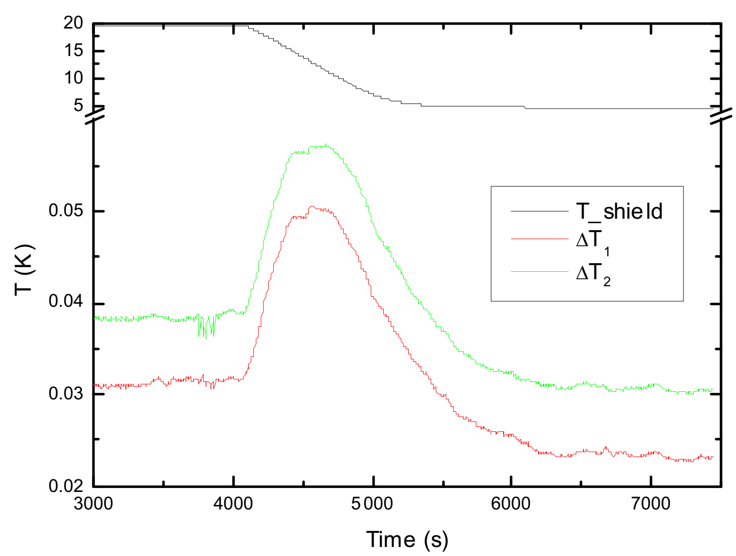

Fig. 21 In the top part of the plot absolute temperature of external shield is shown, while under the y axis break temperature differences between alumuminum ring and 4K stage are reported (see also text).

In this figure, data plotted refer to external shield temperature (on top scale), while in the bottom part (before y axis break) the corresponding differences ΔT_1=T(G0)-T(G3) and ΔT_2=T(B)-T(G3) are shown. As evident in the right part of the plot, a comparable heat load holds also in the case of a cold temperature of the external shield.
In the Table 16, temperature differences are described and heat loads are evaluated.

T ext shield (sensor A)	20 K	5 K
ΔT_1	0.03 ± 0.04 K	0.02 ± 0.04 K
ΔT_2	0.04 ± 0.04 K	0.03 ± 0.04 K
Heat Load from FM 70 GHz ring (left side)	110 ± 150 μW	85 ± 150 μW
Heat Load from FM 70 GHz ring (right side)	140 ± 150 μW	110 ± 150 μW
Total heat load from 70 GHz ring	60 ± 300 μW	

Table 16 Extended steady state analysis. Net heat load is evaluated as the difference between the heat load measured and described in Table 15, when T(A)=19.7 K, and the parasitic heat load, measured with T(A)=4.7K

7.2 Transient state test

After thermalizing the system, applying a stable heat load offset (16% of 60mW) to 4K stage, a sinusoidal power (amplitude 15% of 60mW) was added, at the required frequencies. Procedures reported in [AD 14] are applicable. Then the same data analysis used for the other frequency channels is performed.
In next plots measurements for each fluctuation frequency are shown, while tables summarize the data analysis results.

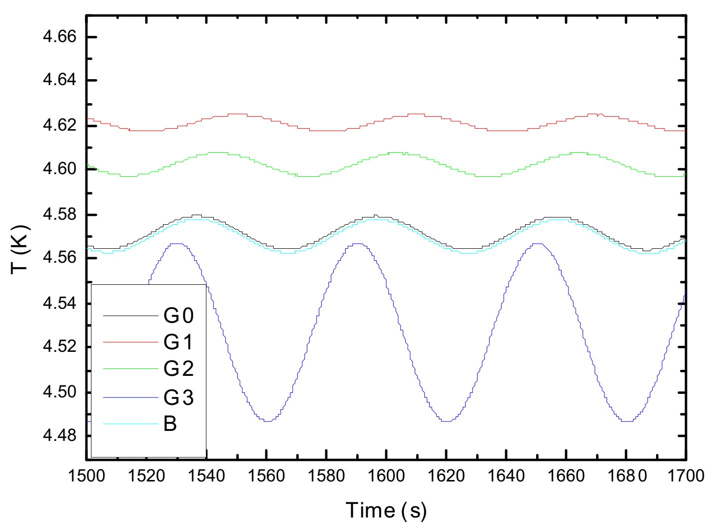

Fig. 22 Stable data used in the fit for transient test of fluctuation of 60 sec period.

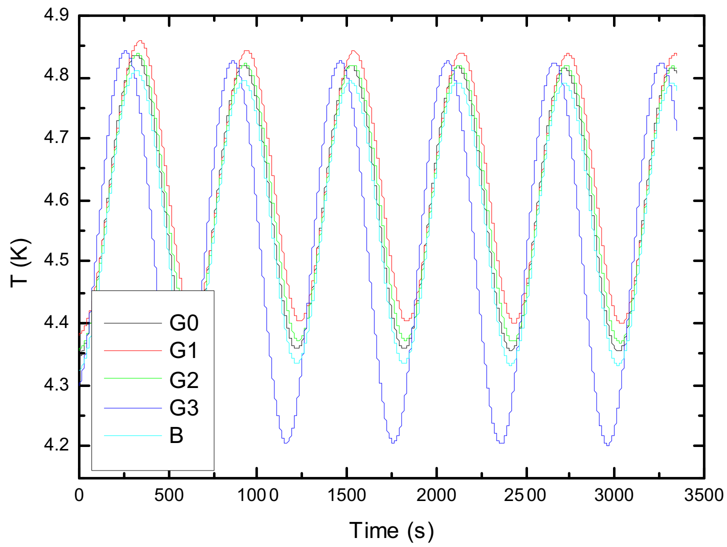

Fig. 23 Transient test of fluctuation of 600 sec period. Stable data over 1200s were used in the fit.

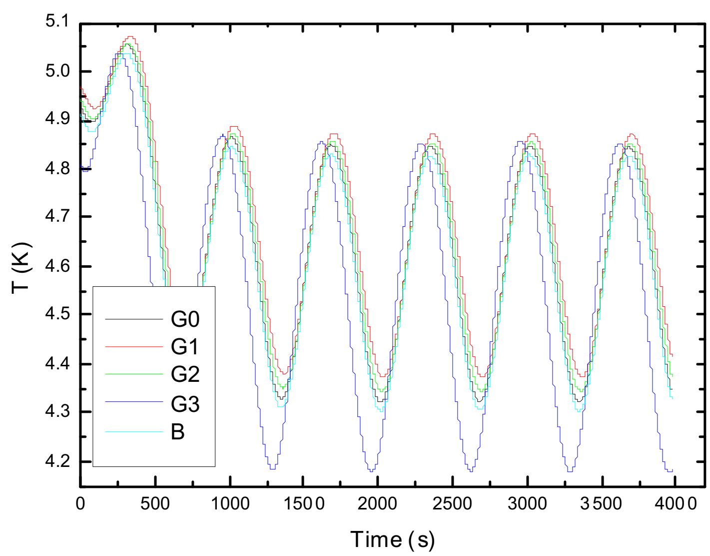

Fig. 24 Transient test of fluctuation of 667 sec period. Stable data over 1500s were used in the fit.

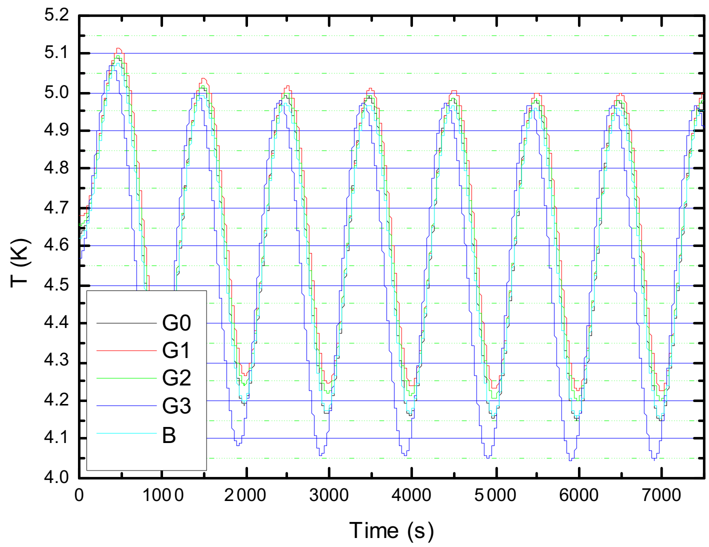

Fig. 25 Transient test of fluctuation of 1000 sec period. Stable data over 5000s were used in the fit.

Period (s)	A of central target face	A of lateral target face	A of interface
60	3.78 ± 0.01	5.24 ± 0.01	40.15 ± 0.01
600	218.7 ± 0.2	223.6 ± 0.2	309.9 ± 0.2
667	248.6 ± 0.2	253.7 ± 0.2	337.5 ± 0.2
1000	385.6 ± 0.3	388.6 ± 0.3	457.3 ± 0.4

Table 17 Amplitude of fluctuations measured by all sensors, values are in mK

Period (s)	D_f of central target face	D_f of lateral target face
60	0.0941 ± 0.0003	0.1305 ± 0.0003
600	0.706 ± 0.001	0.722 ± 0.001
667	0.737 ± 0.002	0.752 ± 0.002
1000	0.843 ± 0.001	0.849 ± 0.001

Table 18 Damping factors evaluated for 70 GHz reference load

7.3 Thermal cycles

The test started on July, 20th, 2005 at 18:22. As for other frequency channels, only one cycle is performed, consisting in the cooldown and warmup of thermal balance tests. Sensor location is the same reported in Table 13.

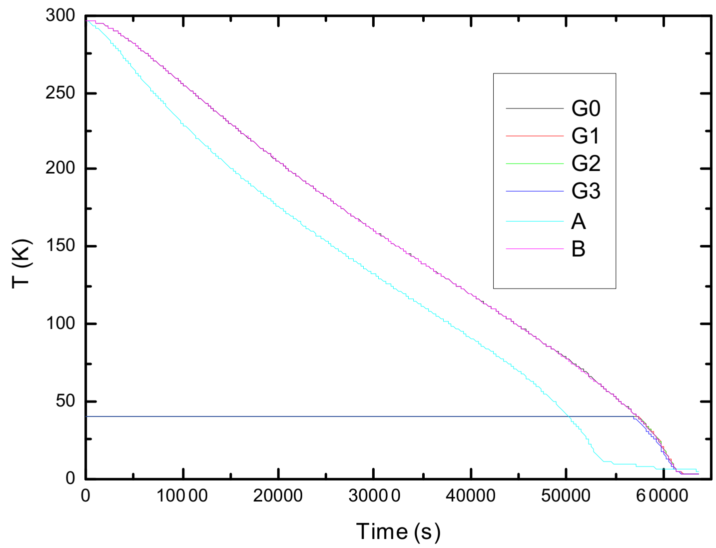

Fig. 26 Cooldown for the 70 GHz tests

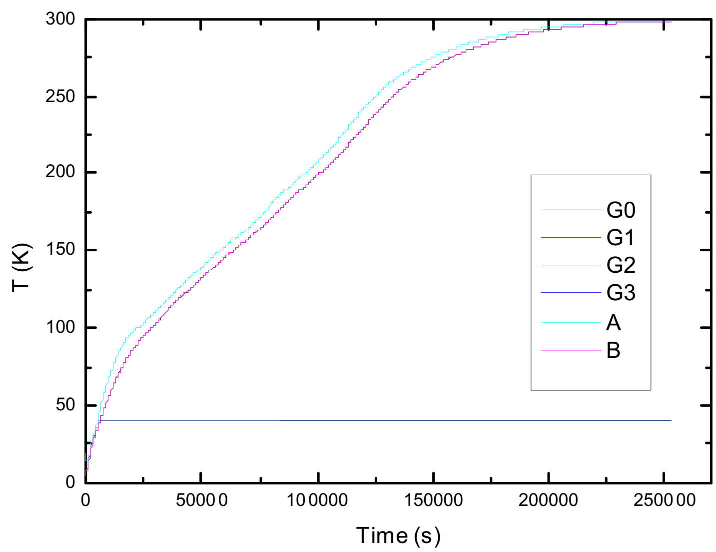

Fig. 27 Warmup for the 70 GHz tests

8 Conclusions

In the Table 19 a summary of the results of the thermal test campaign and the conformity with requirements are given.
As far as the steady state regards the sensors' accuracy, it has a great impact on the estimate of heat load but also considering this great error the value is compliant with requirement.
In the transient case sensors' sensitivity allows a very precise measurements, but a 5% error is added, taking into account the systematic error deriving from different sensors contact pressures. This correction explains small differences between damping factors of targets which would have the same values of oscillation, due to their simmetric location in the system, in the case of 30 and 44 GHz loads.

VCN	Parameter under test	ν	Requirement	Test result	NCR
025	Total heat load	All	1 mW	360 ± 540	C
024	Damping factors 60 s period	30 GHz	< 0.1	$(8.0 \pm 0.4)\cdot 10^{-2}$	C
		44 GHz		0.133 ± 0.007	NC-X
		70 GHz		0.131 ± 0.007	PC
023	Damping factors 600 s period	30 GHz	< 0.9	0.60 ± 0.03	C
		44 GHz		0.81 ± 0.04	C
		70 GHz		0.72 ± 0.04	C
023	Damping factors 667 s period	30 GHz	< 0.9	0.64 ± 0.03	C
		44 GHz		0.85 ± 0.04	C
		70 GHz		0.75 ± 0.04	C
023	Damping factors 1000 s period	30 GHz	< 0.9	0.78 ± 0.04	C
		44 GHz		0.91 ± 0.05	PC
		70 GHz		0.85 ± 0.04	C

Table 19 Summary of the test results. Legend for last column: C conformal, NC non-conformal, PC partially conformal (it depends on the position of target)

The analysis of the QM non conformity evidenced that data were sufficiently good to ensure scientific performance. For the FM, data are better than that, so that non conformities have decreased and we are confident we are within scientific performance (a technical note will follow).
During the tests no damage in the SUTs was observed.

A APPENDIX 1: TEST CONTROL SHEETS

<table>
<tr><td colspan="2">Test title: Thermal Balance steady state for 30 GHz FM</td><td>Date:
Start 06/07/2005
End 11/07/2005</td></tr>
<tr><td>Test N°: PLTES-RL30-TB-SS-04</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: 30 GHz FM Reference Targets ID PLTES048 - PLTES049</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 FM 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 steady state for 44 GHz FM RL</td><td>Date:
Start 11/07/2005
End 14/07/2005</td></tr>
<tr><td>Test N°: PLTES-RL44-TB-SS-05</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: 44 GHz FM Reference Targets ID PLTES045 - PLTES046 - PLTES047</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 FM 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:

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</table>

<table>
<tr><td colspan="2">Test title: Thermal Balance steady state for 70 GHz FM RL</td><td>Date:
Start 20/07/2005
End 25/07/2005</td></tr>
<tr><td>Test N°: PLTES-RL70-TB-SS-06</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 FM ring structure and targets Reference Targets ID PLTES038 - PLTES039 – PLTES040 - PLTES041 - PLTES042 - PLTES043 - PLTES044</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 FM 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>

Test title: Thermal Balance transient state for 30 GHz FM RL	**Date:** Start 06/07/2005 End 11/07/2005
Test N°: PLTES-RL30-TB-TS-04	**Conductor:** Luca Terenzi
Requirements: [AD 12]/VCN-022, VCN-023, VCN-024	
DUT name: 30 GHz FM Reference Targets ID PLTES048 - PLTES049	
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 target surface 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:	
Conductor Signature: ________________________	

<table>
<tr><td colspan="2">Test title: Thermal Balance transient state for 44 GHz FM RL</td><td>Date:
Start 11/07/2005
End 14/07/2005</td></tr>
<tr><td>Test N°: PLTES-RL44-TB-TS-05</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: 44 GHz FM Reference Targets ID PLTES045 - PLTES046 - PLTES047</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 FM 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 target surface 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:</td></tr>
<tr><td colspan="3">Conductor Signature:

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</table>

Test title: Thermal Balance transient state at 70 GHz		**Date:** Start 20/07/2005 End 25/07/2005
Test N°: PLTES-RL70-TB-TS-03	**Conductor:** Luca Terenzi	
Requirements: [AD 12]/VCN-022, VCN-023, VCN-024		
DUT name: 70 GHz FM ring structure and targets Reference Targets ID PLTES038 - PLTES039 – PLTES040 - PLTES041 - PLTES042 - PLTES043 - PLTES044		
Objective: To verify that the reference target fluctuation damping at different frequencies is compliant with specifications:		
Test methodology: The FM 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 target surface 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:		
Conductor Signature: ________________________		

Test title: Thermal cycles at 30 GHz		**Date:** Start 06/07/2005 End 11/07/2005
Test N°: PLTES-RL30-TC-01	**Conductor:** Luca Terenzi	
Requirements: No relevant change in DUT after visual inspection.		
DUT name: 30 GHz FM Reference Targets ID PLTES048 - PLTES049		
Objective: To verify that the reference target mechanical properties are unchanged after one thermal cycle, which is cycles performed during other tests.		
Test methodology: The FM Reference targets and mounting structure are once cooled down and warmed up in the cryo facility.		
Notes:.		
Conductor Signature: ________________________		

Test title: Thermal cycles at 44 GHz		**Date:** Start 11/07/2005 End 14/07/2005
Test N°: PLTES-RL44-TC-05	**Conductor:** Luca Terenzi	
Requirements: No relevant change in DUT after visual inspection.		
DUT name: 44 GHz FM Reference Targets ID PLTES045 - PLTES046 - PLTES047		
Objective: To verify that the reference target mechanical properties are unchanged after one thermal cycle, which is cycles performed during other tests.		
Test methodology: The FM Reference targets and mounting structure are once cooled down and warmed up in the cryo facility.		
Notes:		
Conductor Signature: __________________________		

Test title: Thermal cycles at 70 GHz		**Date:** Start 20/07/2005 End 25/07/2005
Test N°: PLTES-RL70-TC-03	**Conductor:** Luca Terenzi	
Requirements: No relevant change in DUT after visual inspection.		
DUT name: 70 GHz FM ring structure and targets Reference Targets ID PLTES038 - PLTES039 – PLTES040 - PLTES041 - PLTES042 - PLTES043 - PLTES044		
Objective: To verify that the reference target mechanical properties are unchanged after one thermal cycle, which is cycles performed during other tests.		
Test methodology: The FM Reference targets and mounting structure are once cooled down and warmed up in the cryo facility.		
Notes:		
Conductor Signature: ________________________		