TITLE: **LSPE-STRIP cryogenic system acceptance tests**

DOC. TYPE: **Test report**

PROJECT REF.: **LSPE-STRIP-RP-016** **PAGE: I of IV, 19**

ISSUE/REV.: **1/00** **DATE: November 21st, 2018**

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CHANGE RECORD

Issue	Date	Sheet	Description of Change	Release
1.0	November 2018	All	First issue of the document	1.0

APPLICABLE DOCUMENTS

AD-1	LSPE-STRIP Scientific Requirements	LSPE-STRIP-SP-001 v. 4.2	Apr 2017

REFERENCE DOCUMENTS

RD-1	Fornitura di un criostato per lo strumento STRIP dell’esperimento LSPE	Capitolato Tecnico	2016

Table of Contents

1 Introduction

The LSPE-STRIP cryostat is aimed at hosting the instrument polarimeters observing the microwave sky at about 40 GHz (Q band 49 detector channels) and 90 GHz (W band 6 detector channels). The key devices driving the performance of the instrument are the Low Noise Amplifiers (LNAs), mounted on the focal plane in a compact package option, whose optimal operating temperature is around 20K and typical dissipation is at the level of few tens of mW.

The main performance required to the cryostat are then:

- to allow the the absolute temperature of the STRIP cold focal plane (polarimeters + feed-OMT system) to be 20 K ± 2 K (derived from STRIP-INS-7 in AD1)
- to lift the power dissipated by the active devices of the STRIP polarimeters, estimated to be 3.360 W ± 0.800 W (derived from STRIP-INS-8 in AD1)
- to have a refrigerating capacity allowing the absorption of any other power input on the 20 K stage, estimated as not exceeding 11.440 W ±1.000 W (derived from STRIP-INS-8 in AD1)

The cryostat vessel was delivered to INAF –OAS on June 2018.

Scope of this document is

(i) to describe the configuration of the cryostat acceptance dry run aimed at verifying its basic performance

(ii) to show the results of the cryostat dry run.

2 LSPE-STRIP Cryostat Overview

The LSPE-STRIP cryostat design is detailed in RD-1.
The overall scheme is shown in Figure 1.

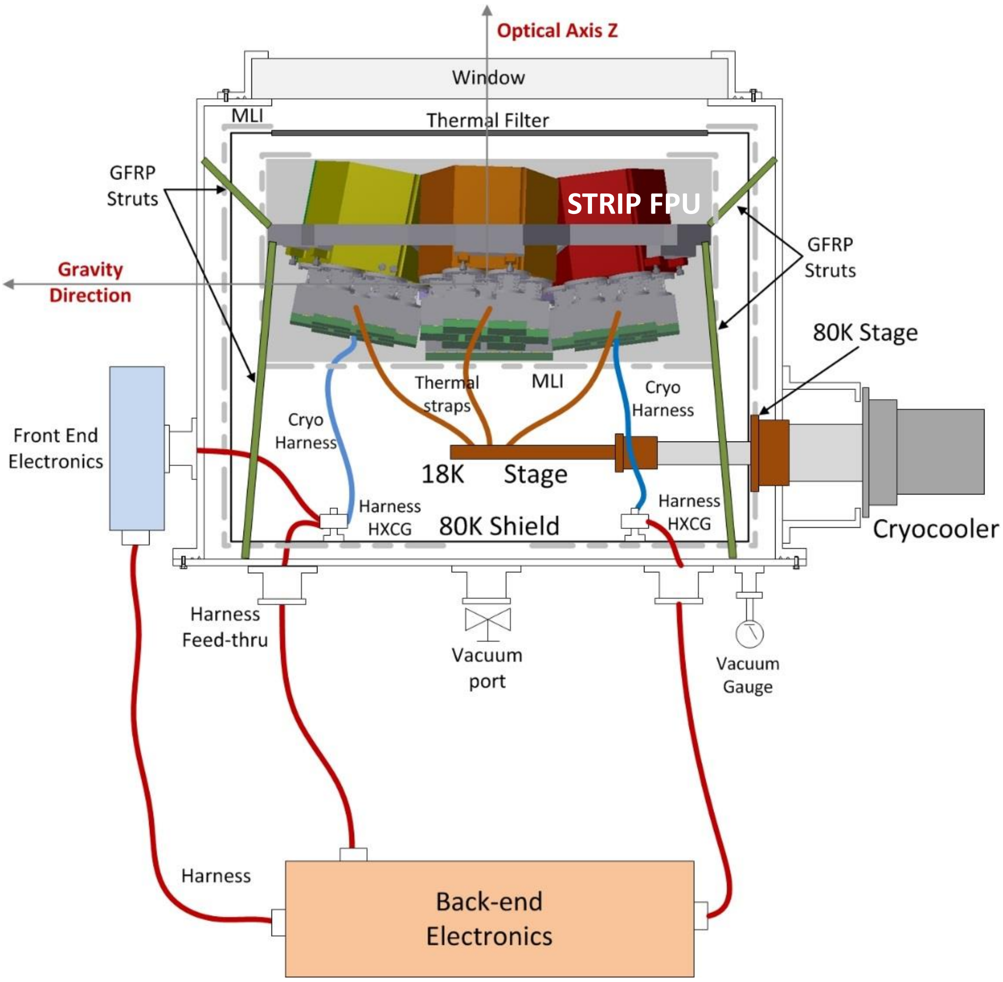

Figure 1 The cryostat assembly scheme.

The outer vacuum vessel has a cylindrical envelope allocation of about 880mm diameter and 830mm height (Figure 2). The radiation enters the polarimeter feed horns passing through a UHMW- PE vacuum window on the top of the cryostat (Figure 4) and a set of PTFE infrared thermal filters, sized according to the receiver modules, located on the top of an intermediate shield cooled at about 80 K (Figure 3). A two-stage cryocooler cold head (Figure 2, model Leybold RGD 1245) enters the cryostat in the bottom part of the side surface and its first stage linked to the intermediate shield side surface, while the second stage is clinked through high conductance copper straps to the focal plane parts allowing the cooldown to less than 20K

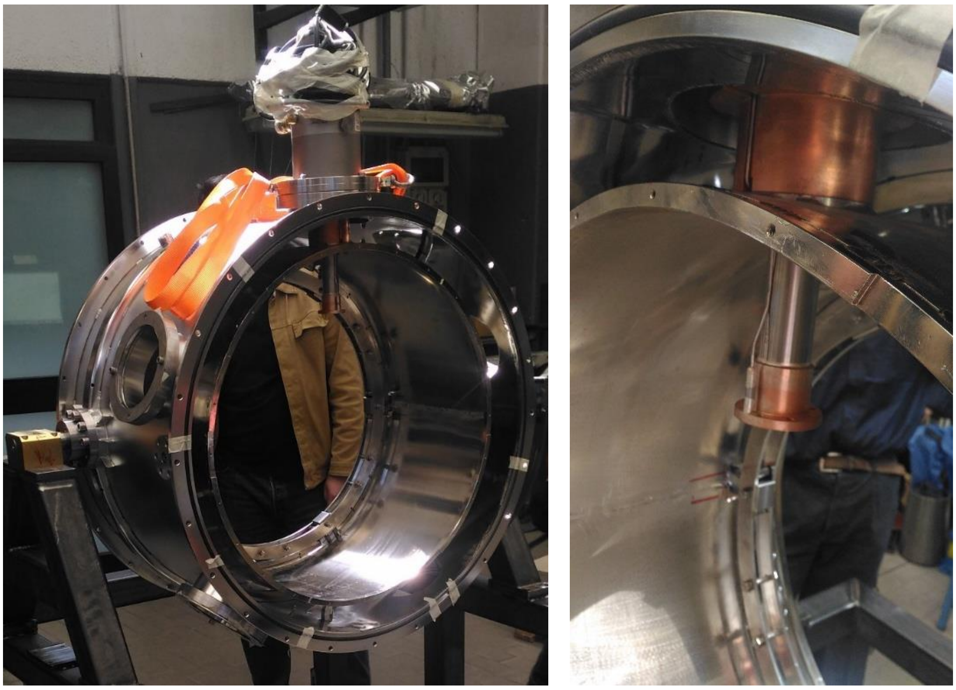

Figure 2 Left panel: a global view of the side surface of the cryostat outer wall and 80 K shield. Right panel: a detailed view of the cooler cold head interfaces.

A set of four apertures on the side surface provides allocation for the electrical connection of the internal harness to the outer electronics, while on the bottom part, four smaller apertures allow the connection of the vacuum bench and pressure sensors together with spare flanges for electrical passthrough connectors (Figure 4).

Figure 3 The top part of the 80K shield with the apertures dedicated to host the thermal filters.

Figure 4 Top panel: the top cover of the cryostat with the window aperture. Bottom panel: The bottom cover of the cryostat with the apertures for the vacuum bench connection flanges and spare connector flanges.

3 Acceptance Test Setup

The cryostat has been delivered to INAF-OAS Bologna by the manufacturer on June 2018. All the vacuum flange apertures were closed by blank flanges except one valved aperture for the vacuum connections. The window aperture was closed by an aluminum disc sealing the top cover. No filters were integrated in the intermediate shield, so the 80 K shield cover was covered with a MLI blanket (Figure 7).

The equipment provided by INAF-OAS to run acceptance test consisted of:

- a scroll pump by Agilent Technologies, model TriScroll PTS300;
- a turbo pump by Edwards Vacuum, model EXT75XD with related Turbo Instrument Controller;
- a Pirani pressure sensor Edwards APGX
- a set of four temperature sensors whose type and location are detailed in Table 3-1
- a LakeShore temperature monitor model 218
- a LakeShore temperature controller model 331, supplying power to a Minco ribbon heater, located on the 20K cold head in order to evaluate the heat lift

Sensor ID	Type	Fixation	Location
TS-I1	Cernox CX-1050-CU	Screwed	20 K Cold head
TS-I2	Cernox CX-1050-CU	Al Tape	80 K shield base
TS-I3	Cernox CX-1050-SD	Kapton Tape	80 K shield side
TS-I4	Cernox CX-1050-CU	Screwed	80 K shield cover

Table 3-1 Temperature sensors location during acceptance test

After a preliminary set of vacuum and leak detection tests, an optimal connection scheme for the vacuum bench has been selected, with the primary scroll pump on one side valved directly on the cryostat for preliminary vacuum and on the other way pumped as backing pump on the turbo for the final pumping phase (Figure 5).

Figure 5 Vacuum bench setup and connections

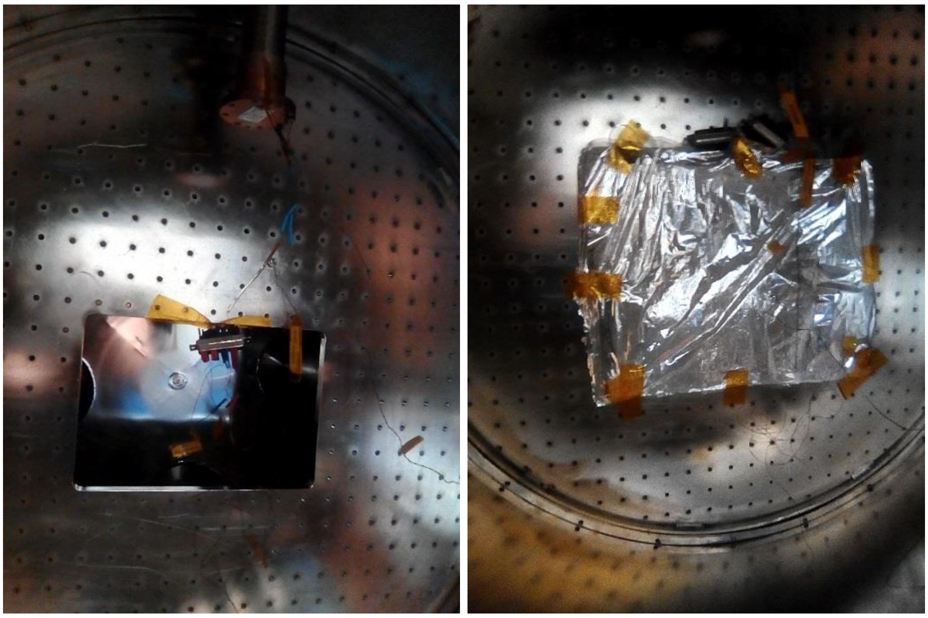

Figure 6 Left panel: the 80K bottom flange aperture for the cryoharness routing; also the heater and sensor on the cooler cold head are visible. Right: the aperture was closed with a radiative blanket

Figure 7 The filter apertures on the top of the 80K cover (left) have been closed by thermal MLI blankets in order to shield radiative loads on the colder part of the cryostat.

4 Test Data

On August 23rd, at 11:50 the cryostat was closed and sealed and pumping was started. The scroll pump was left active all over the night so that the morning after the pressure had dropped down to about $7.5 \cdot 10^{-3}$ mBar. On August 24th the turbo pump has been activated and the pressure dropped down to less than 10^{-4} mBar in less than 30 minutes (Figure 8). The system was left evacuating by turbo pump for the following week end.
On August 28th at 11:33, the cryocooler was switched on. The second stage cold head reached the temperature of about 21 K in 25 minutes, while the steady state low temperature of the cryostat was reached after about three days (Figure 9), mainly due to the high copper intermediate shield thermal inertia.

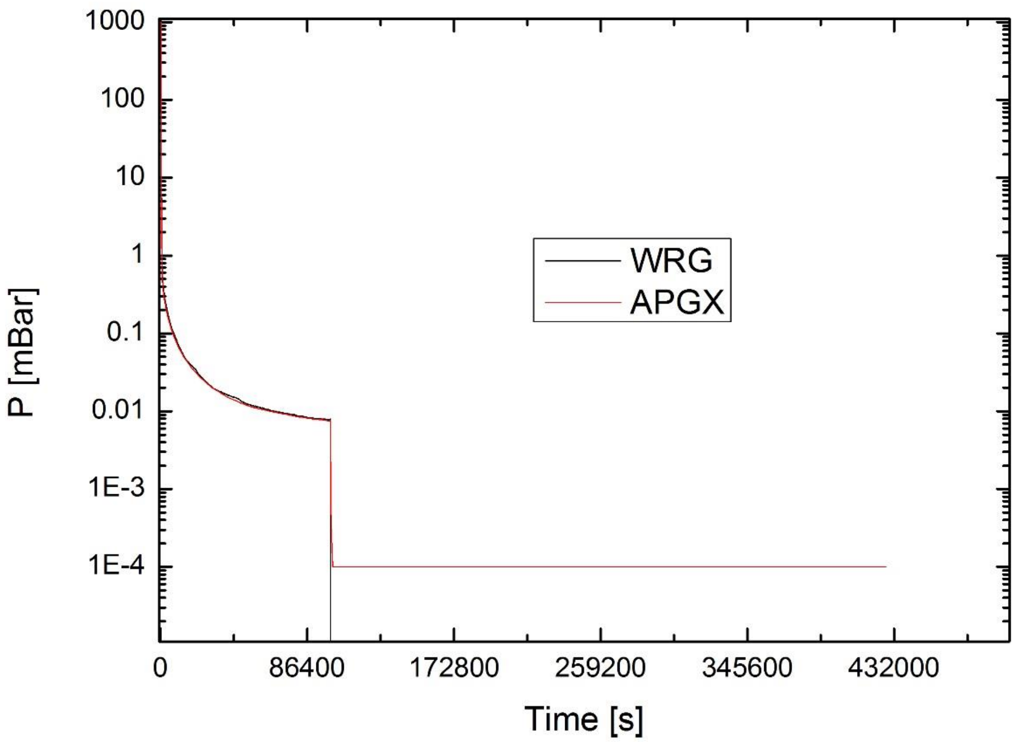

Figure 8 The pressure profile of the cryostat during the acceptance test run. The Pirani reference sensor (APGX) is not sensitive to pressure lower than 10^{-4} mBar. The start of the turbo pumping is evident as a steep drop of the pressure during the second day of test.

When the intermediate shield reached its low temperature steady state the 20 K cold head cooled down to its minimum temperature of about 11.3 K, coherently with its nominal performance in the case of negligible load. The steady state data together with relevant statistics are shown in Figure 10.

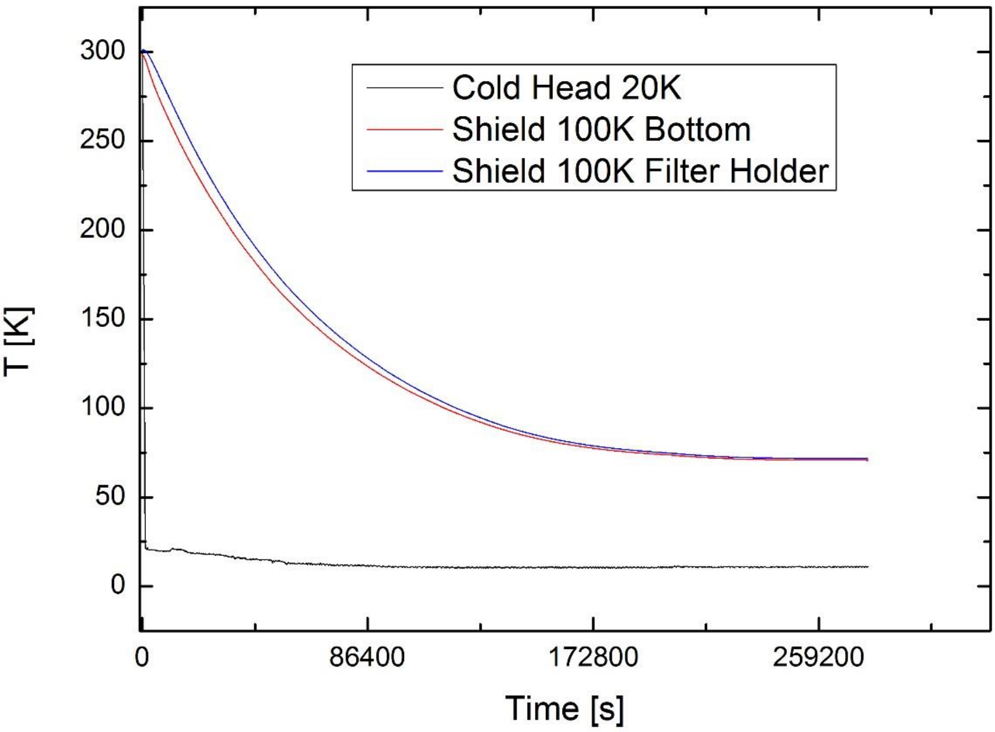

Figure 9 The cooldown temperature curve of the cryostat

The final step of the acceptance test has been the verification of the heat lift required to the cooler cold head to keep the STRIP focal plane to its nominal operating temperature.
Two different power load were applied to the cooler cold head:

- 4 W, corresponding to the highest level of estimated total active load coming from polarimeters;
- 18 W, corresponding to the highest level of estimated total load on this stage with margin

The corresponding temperature curves are shown in Figure 11.
Unfortunately, the highest power load phase lasted only about three minutes, due to a wire short with the metal shield as evidenced after the cryostat opening following the test.
The 4W power caused a first step in temperature with a stabilization to about 12.6 K, while as shown in Figure 12, the trend of the 18W power step is compatible with a stabilization at about 18 K, confirming that the cooling capacity of the Strip cryogenic system is compliant to the required performance.

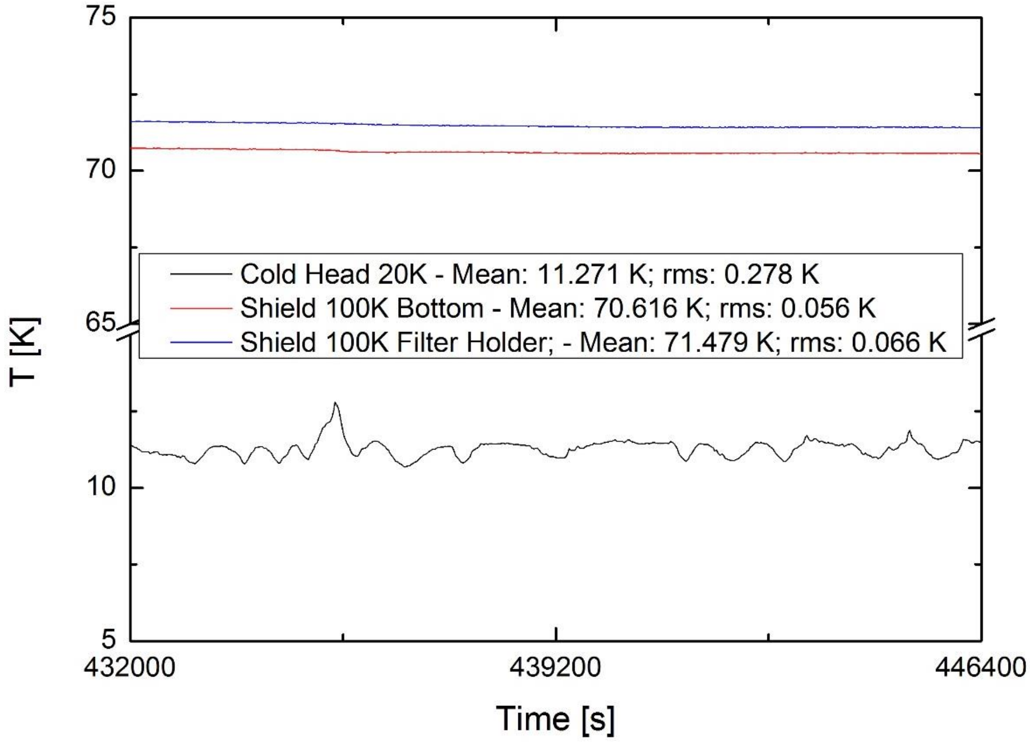

Figure 10 The low temperature steady state curves of the acceptance test run

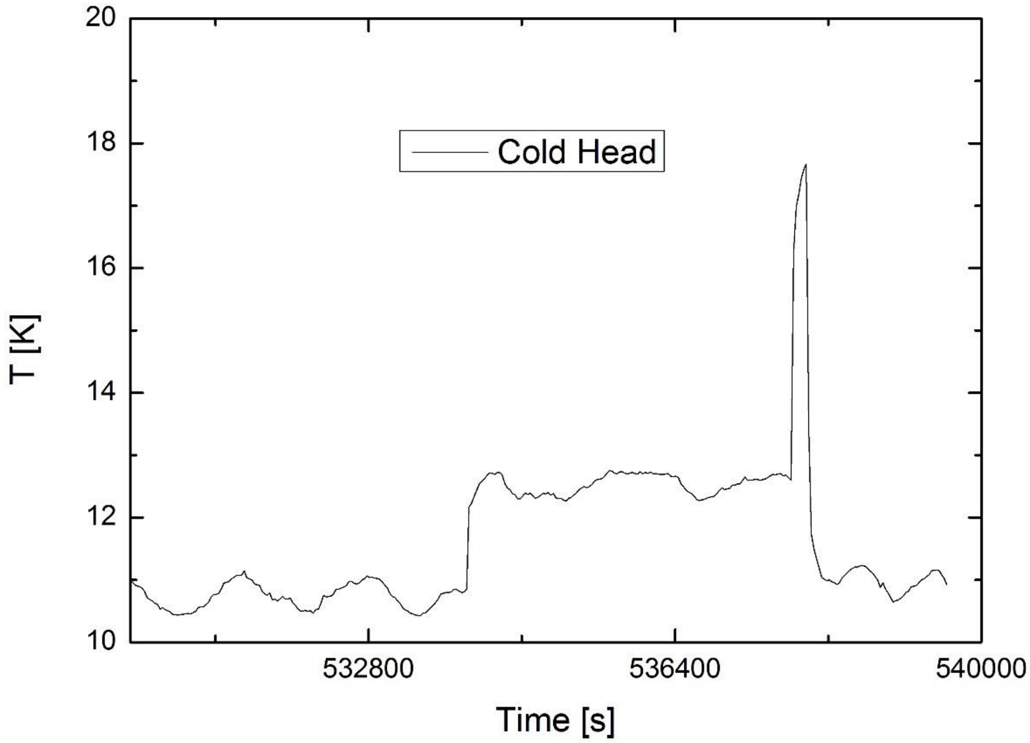

Figure 11 The 20K cold head temperature curve during the heat load test phase.

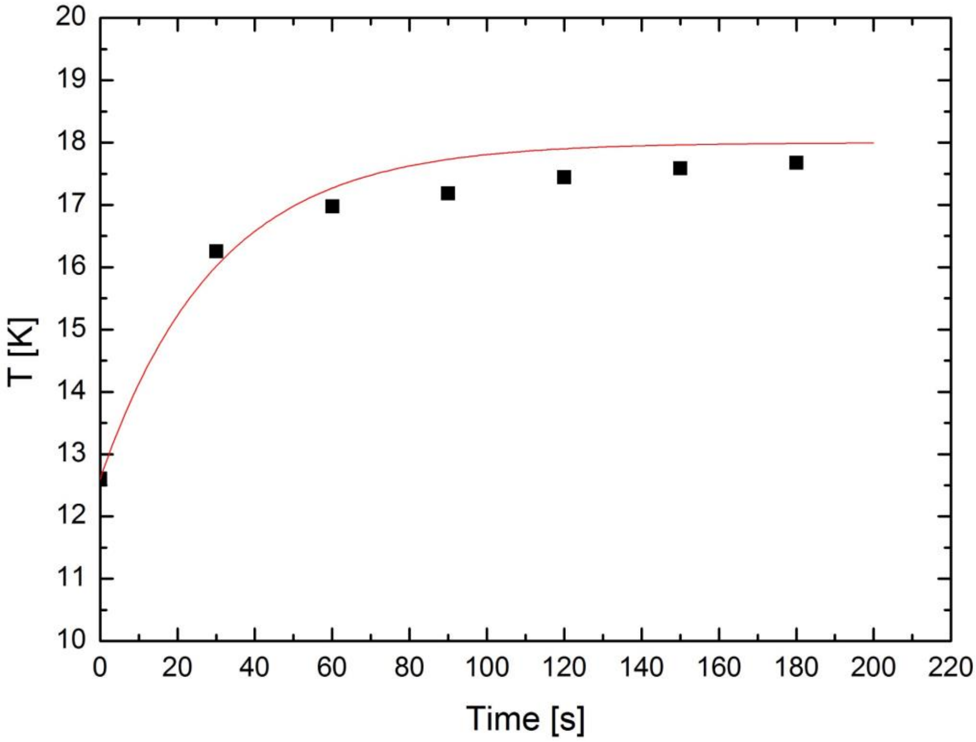

Figure 12 Detailed view of the second power value applied (scatter points) together with the curve fit for an asymptotic stabilization at 18 K (red line)

At the end of the cooling power test the cooler was switched off on September, 3rd at 17:25. The system was left warming up with no active heating device support. In such configuration, as shown in **Figure 13**, the cryostat sensors were reaching a temperature higher than 280K after about 80 hours.

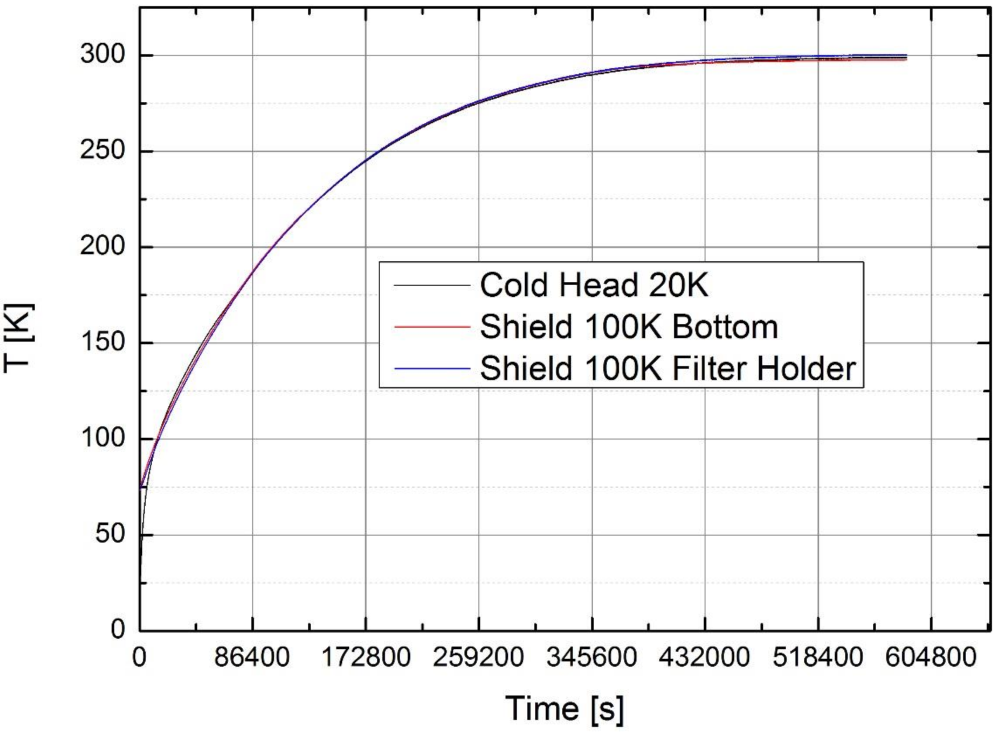

Figure 13 The cryostat warmup temperature curve

5 Conclusion

The cryostat built to host the LSPE-STRIP instrument was delivered to INAF OAS on June 2018. An acceptance test campaign run in August and September 2018 verified that the basic performance of the system were compliant to the requirement specification.