# Clean Rooms validation tests, a preliminary report

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VIR-0365A-14

## 1. Requirements and acceptance tests plan

Requirements about environmental conditions and mode of operation of the new injection and detection clean rooms are described in **REF1** (VIR-0222A-13 I.Fiori, E.Genin, R.Gouaty "Model of use of the Injection and Detection Clean Area of Advanced Virgo") and their acceptance tests agreed with the project company are described in **REF2** (VIR-0223B-13 Irene Fiori, Paolo Ruggi, Massimo Bottega, "Acceptance tests for the new DET and INJ Clean Areas").

Hereafter we describe the results of tests performed by the EGO team. In some cases tests are still preliminary. Where possible, our results have been compared to results of the Project company measurements (i.e. acoustic tests). Where possible, we compare results to the set requirements and evaluate about the compliance. This document should be considered complementary to the document produced by the project company: Studio Techné, "RAPPORTO FINALE RELATIVAMENTE ALLE VERIFICHE IN CORSO D'OPERA E VERIFICHE FINALI EFFETTUATE SUI LABORATORI BANCHI E DETECTION" (hereafter cited as **REF3**).

## 2. Results

### 2.1 Acoustic isolation

INJ and DET lab substantially meet acoustic isolation requirements. The isolation performance is limited by the relatively poor transmission loss of the tower wall. It is advisable a final measurement of acoustic isolation of both INJ and DET rooms to verify performance when IB and DET towers are in-vacuum. To complete characterization of DET room it is also advisable to repeat measurement of sound reverberation time once the room is fully furnished.

***INJECTION clean room:***

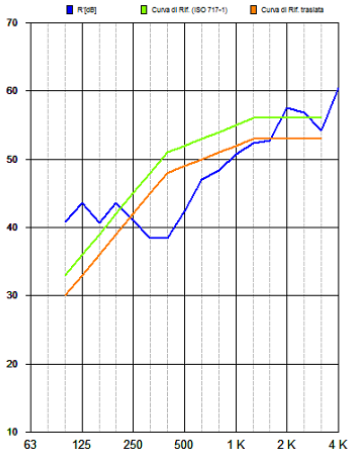
The acoustic isolation (or transmission loss) between the bench area and the central hall was measured twice by the project company following ISO 140-4 ("Calistri, October 2013" and "Calistri, February 2014" ) and once by the EGO team (Fiori and Ruggi, November 2013, eLog 31094). EGO measurement attempted to simulate a more realistic distribution of sources in the hall and managed to extend the measured frequency range below 100Hz.

Acoustic isolation looks substantially compliant with requirements. Measurements with intensimetric probe (Calistri, REF3) also evidenced that the element which determines and presently limits (at least down to 100Hz) the isolation performance of INJ clean room is the poorer transmission loss of the IB tower wall. The significantly worst isolation measured by Calistri in Feb. 2014 is likely to be attributed to the fact at that time the IB tower was partially dismounted (cover and upper virola missing).

Possible resonant modes of the INJ bench room are noted at approximately 10Hz and 20Hz (eLog 31094).

As requested by ISO 140-4, also the bench room's reverberation time versus frequency has been measured between 100Hz and 3kHz (Calistri, Feb. 2014, room being already filled with most of its final "furnitures") returning a value between 0.5s to 0.7s with very little frequency dependence.

| Frequenza f [Hz] | R' (terzo di ottava) [dB] |
|---|---|
| 50 | . |
| 63 | . |
| 80 | . |
| 100 | 40,8 |
| 125 | 43,6 |
| 160 | 40,7 |
| 200 | 43,6 |
| 250 | 41,0 |
| 315 | 38,4 |
| 400 | 38,4 |
| 500 | 42,4 |
| 630 | 47,1 |
| 800 | 48,3 |
| 1000 | 50,8 |
| 1250 | 52,4 |
| 1600 | 52,8 |
| 2000 | 57,5 |
| 2500 | 56,8 |
| 3150 | 54,2 |
| 4000 | 60,5 |
| 5000 | 63,0 |




| Frequency f, (Hz) | R' (third octave), dB |
|---|---|
| 50 | . |
| 63 | . |
| 80 | . |
| 100 | 23,1 |
| 125 | 23,4 |
| 160 | 26,4 |
| 200 | 33,9 |
| 250 | 35,5 |
| 315 | 37,1 |
| 400 | 39,3 |
| 500 | 40,3 |
| 630 | 39,3 |
| 800 | 41,2 |
| 1000 | 42,1 |
| 1250 | 44,4 |
| 1600 | 45,9 |
| 2000 | 47,9 |
| 2500 | 50,9 |
| 3150 | 50,6 |
| 4000 | 51,4 |
| 5000 | 52,3 |

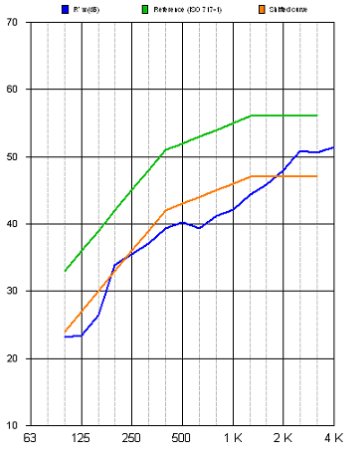



**Figure 1**. Blue curves: measured acoustic isolation (dB) as function of frequency of INJ bench area with respect to Central hall (according to ISO 140-4, and as requested in Acceptance tests document). In the measured range (above 100Hz) the requirement is 35dB of isolation. **Left:** measured in Oct. 2013, **Right**: measured in Feb 2014.

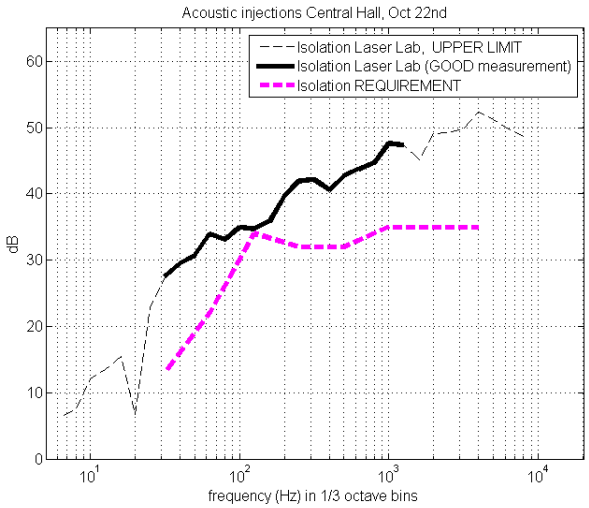



**Figure 2**. Black curve: measured acoustic isolation (dB) as function of frequency of INJ bench area with respect to Central hall (by I.Fiori and P.Ruggi, eLog 31094). Magenta curve is the required isolation (see Acceptance test doc). Respect to Figure 1 also here also frequencies below 100Hz are analyzed. It is missing a correction due to room reverberation (as foreseen by ISO 140-4) which would eventually shift the curve up by a few dB. This is essentially in agreement with measurement Calistri, October 2013.

***DETECTION clean room:***

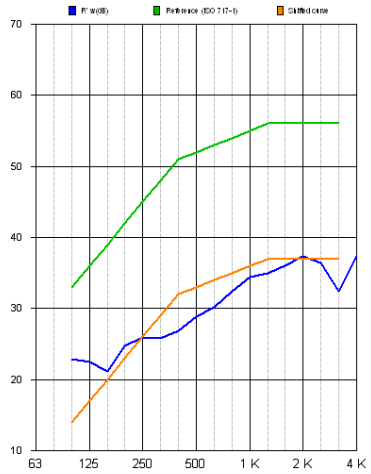
The acoustic isolation (or "sound transmission loss") between the bench area and the central hall was measured once by the project company ("Calistri, February 2014") and twice by the EGO team (Fiori and Ruggi, November 2013, eLog

31094 and I.Fiori with stage students from Roma, May 2014). EGO measurements which extended the measuring range below 100Hz. As requested in **REF 2**, the project company also measured the acoustic isolation of the separation wall between the detection laboratory and the electronics room ("Calistri, February 2014").

Substantially acoustic isolation looks compliant with requirements. The measurements below 100Hz (by EGO team, Figure 4) evidenced a reduced isolation at 65Hz associated to acoustic resonance of the room air volume or walls.

As requested by ISO 140-4, also the DET bench room's reverberation time vs frequency has been measured between 100Hz and 3kHz (Calistri, Feb. 2014, room empty) giving a value between 0.5s and 1.8Hz depending from frequency. Likley this quite large reverberation will reduce when room will be "furnished".

| Frequency f, (Hz) | R' (third octave), dB |
|---|---|
| 50 | . |
| 63 | . |
| 80 | . |
| 100 | 22,9 |
| 125 | 22,5 |
| 160 | 21,1 |
| 200 | 24,7 |
| 250 | 25,9 |
| 315 | 25,8 |
| 400 | 26,8 |
| 500 | 28,8 |
| 630 | 30,2 |
| 800 | 32,4 |
| 1000 | 34,4 |
| 1250 | 35,0 |
| 1600 | 36,0 |
| 2000 | 37,3 |
| 2500 | 36,4 |
| 3150 | 32,4 |
| 4000 | 37,3 |
| 5000 | 41,5 |




| Frequency f, (Hz) | R' (third octave), dB |
|---|---|
| 50 | . |
| 63 | . |
| 80 | . |
| 100 | 27,6 |
| 125 | 31,3 |
| 160 | 31,2 |
| 200 | 29,6 |
| 250 | 34,6 |
| 315 | 36,6 |
| 400 | 41,3 |
| 500 | 40,7 |
| 630 | 42,1 |
| 800 | 41,2 |
| 1000 | 42,2 |
| 1250 | 45,8 |
| 1600 | 46,1 |
| 2000 | 48,5 |
| 2500 | 47,9 |
| 3150 | 48,7 |
| 4000 | 49,5 |
| 5000 | 50,9 |

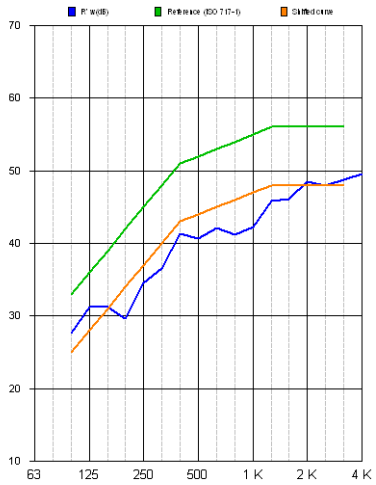



**Figure 3**. Blue curves: measured acoustic isolation (dB) as function of frequency of DET bench area (according to ISO 140-4, and as requested in Acceptance tests document). **Left:** isolation between DET lab and central hall, **Right**: isolation between Bench area and nearby electronics room.

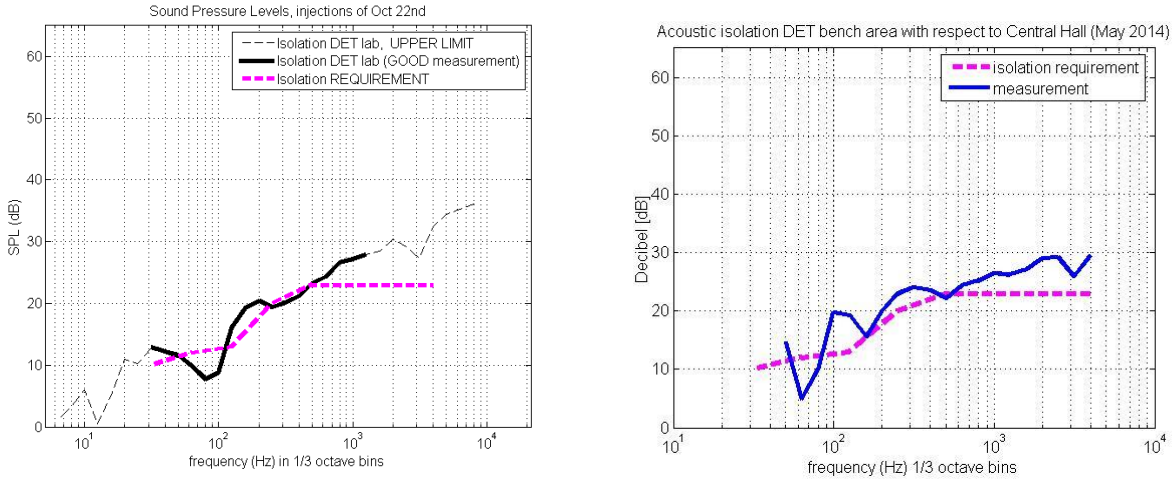



**Figure 4**. **Left:** Black curve is the measured acoustic isolation (dB) as function of frequency of the DET clean room with respect to Central hall (by I.Fiori and P.Ruggi, eLog 31094). Magenta curve is the required isolation (see Acceptance test doc). **Right:** (Fiori and Roma students, May 2014) measurement repeated once cable feed-trough holes were closed inserting the *Roxtec* elements and having improved the isolation of DET tower NW wall.

### 2.2 Sound emission of air conditioners

Sound noise produced inside the bench area by INJ air conditioner is about 10dB higher than requested, however it is also 10dB less than VSR4. The acoustic noise produced in P0 (no flux in bench area) and PR (reduced flux) modes are quite similar. This sound level is likely acceptable during AdV first phase when the noise by the Laser rack inside the bench area is the dominant source of acoustic noise above 100Hz (eLog 31172). Besides, preliminary acoustic coupling tests of EIB-SAS (VIR-0035A-14) showed SAS is not significantly affected by airco noise in P0/PR. It is needed to verify sound and air flow noise coupling to INJ system.

Sound noise produced inside DET clean rooms by its airco is slightly above requirement below 100Hz. This is presumably ok since the requirement was conservatively set, and no major acoustic sensitive device is located inside DET lab.

***INJECTION clean room:***

Acoustic noise produced by the new INJ conditioning system inside the bench area was measured by the project company (Calistri, REF3) and the EGO team (Fiori, elog 31225) simultaneously with microphones located at the EIB (our most sensitive receptor). The airco machine was operated at full nominal cycle (named "PN", about 5500m^3/h) at reduced cycle (named "PR", about 1500 m^3/h) and "P0" mode during which air grids are closed to prevent conditioned air entering the bench area while the same air flux of PR mode is kept in the surrounding atrium and minitower rooms. "PN" is the INJ airco operation set point foreseen during lab "access mode", while "P0" or "PR" are possible modes of operation of INJ airco during interferometer "Science mode". Average sound pressure level in dB was measured and compared to set requirement.

The sound level in the bench area for the PR and P0 mode look similar (**Figure 5, left**) (likely the noise generated at the room air diffusers and pipes downstream of the grids is small and the major part of the noise originates upstream of grids or directly at the airco fans). This sound noise is about 10dB (factor 3.2 in amplitude) above the requirement. However, it is also about 10dB below that produced at the EIB bench by the old airco system during VSR4 (**Figure 5**). The "PN" mode sound noise is definitely very high being 20dB (factor 10 in amplitude) larger than PR and P0.

No significant time oscillation of the noise is found. As well, we found no evidence of loud tonal noise.

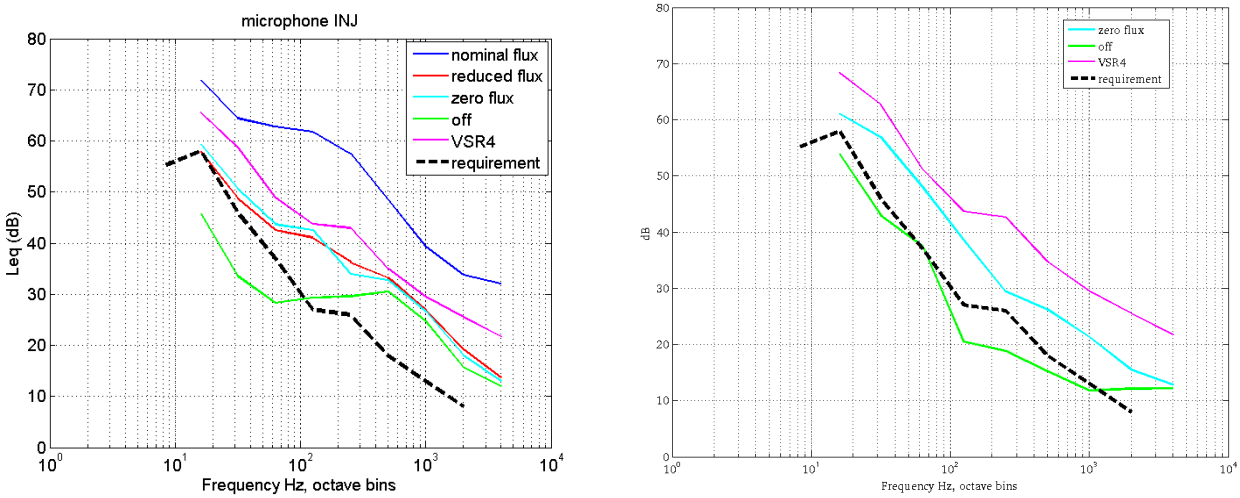



**Figure 5**. Average sound noise level spectra produced at the EIB by the new INJ clean room air conditioning system. In green the sound background noise, in magenta the noise during VSR4 used for reference, in blue, red and cyan the noise when airco is run in PN, PR and P0 air flux mode respectively. **Left:** measured in March 2014, noise from the IB tower clear air (off during science mode) was on and compromise measurements above 100Hz or so. **Right**: P0 mode was measured again in April 2014 with tower clean air off.

***DETECTION clean room:***

Acoustic noise produced by the new INJ conditioning system inside the bench area was measured by the EGO team (Fiori, elog 31225) and shown in **Figure 6** together with requirement (the requirement is set 3dB above the sound level we had at Virgo detection bench during VSR4).

We observed some oscillation of the noise intensity and production of some "whistle" sound associated to variations in the air fluxes (eLog 31225) after cures the oscillation range sensibly reduced.

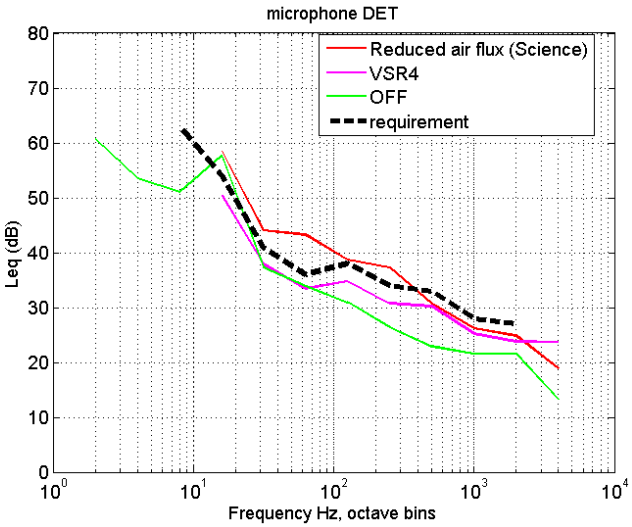



**Figure 6**. Average sound noise level spectra produced inside the new DET clean room, at approximately the location of EDB, by the new DET clean room air conditioning system. In green the sound background noise, in magenta the noise during VSR4 used for reference, in red the noise when airco is run at reduced aur flux ("PR"). Black dashed curve is the requested noise upper limit.

### 2.3 Temperature

***INJECTION clean room (only):***

Air temperature is measured both in the room (probe 2m heigh between two benches) and on the optical benches underneath the plexiglass cover. The laser and its electronics is on, and the heat power dissipated inside the bench room can be considerered representative of AdV working condition.

We monitored air temperature stability during a transition between a PN mode and P0 mode (**Figure 7**) and
A transition between PN and PR mode (**Figure 8**). Note the bench area fancoil was OFF during these tests.

We note the following (note these notes are preliminary):

- During continuous airco operation, air room temperature has no major drift (requirement is drift <2°C during one typical people access period).
- During contiuuous PR or P0 operation (i.e. no people entering the room) air room temperature fluctuates by about 1°C peak to peak (over time scale of 10minutes). This fluctuation is much reduced at benches since the plexiglass cover acts as low pass filter: typical temperature fluctuation at benches is 0.15°C peak to peak over a time scale of 1 hour or so. This is (marginally) complient with the requirement (<0.2°C pk2pk). These fluctuations are correlated to oscillations (of the order of 30%) in the total inlet and outlet air flux, associated to variations in the airco fans rotation speed (see . It should be investigated if possible to reduce it.

- A bit large and bit long lasting drift is observed when airco is switched from PN to PR or P0 modes.
  When switching from PN to P0 (**Figure 7**) the temperature transition does suffer from external temperature conditions, and in case of "hot" days if eventually fails to reach a thermal equilibrium. In case of more favorable condition (**Figure 7**, black curves) a "plateau" is reached after about 6 hours with gradient of about 0.2 °C/hour.
  When switching from PN to PR (**Figure 8**) the thermal equilibrium is indeed reached even in case of "hot" summer days, yet the thermal transient has similar characteristics, that is lasts a few hours with a T gradient of about 0.2 °C/hour.
  Further tests are needed trying for eaxmple to change (rise) the airco PN temperature set point trying to help shorten this transitions. It has to be verified the impact of this drift on laser and INJ optical systems.

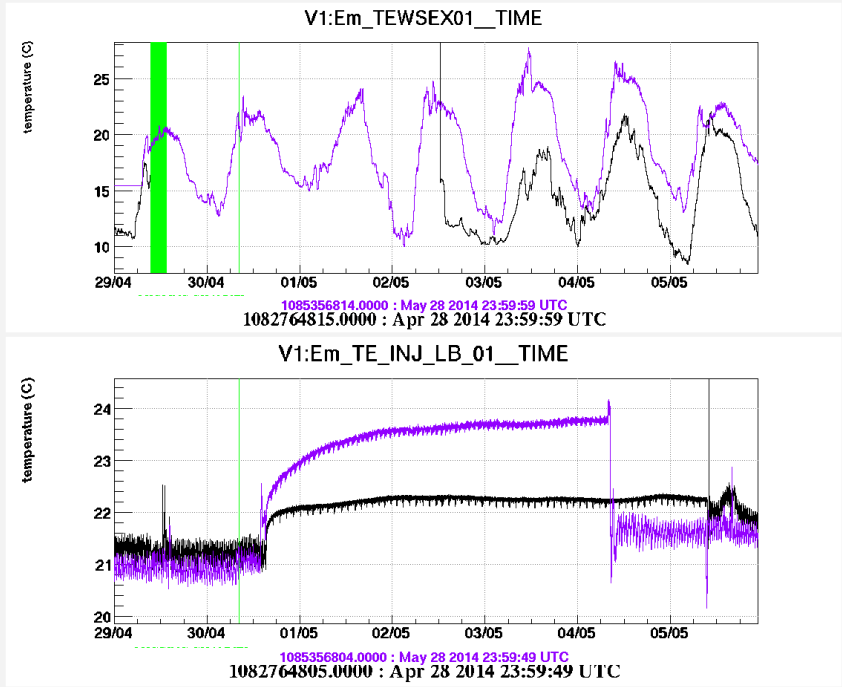



**Figure 7. Bottom**: air temperature of INJ bench room over a week. Between 30/04 and 01/05 the airco was switched from PN mode to P0 mode, the test was repeated twice (black and purple curves) corresponding to different external temperature (**Top** plot) which was higher during the purple colored test.

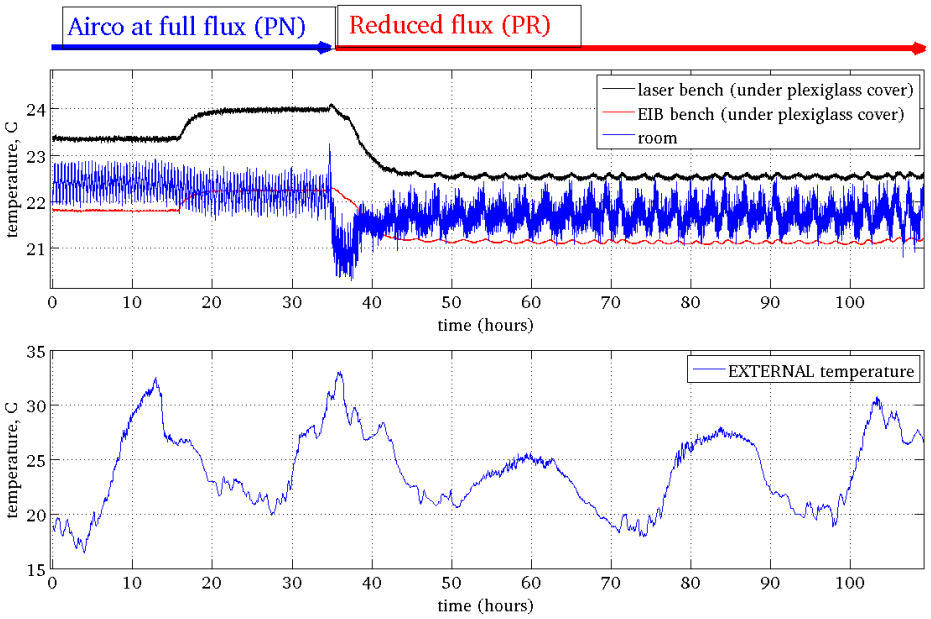



**Figure 8.** Air temperature monitors over few days. INJ airco is switched from PN mode to Reduced flux mode at 34th hour. **Top**: blue curve is bench room air temperature, black is air temperature on laser bench underneath cover, red is air temperature on EIB underneath cover. **Bottom**: external temperature (note heat peaks are above 30°C).

### 2.4 Humidity

Air relative humidity is monitored with a calibrated probe in the bench room. It always remained between 50% and 30% (requirement is RH < 70%) also during people access. Figure 9 below illustrates one week monitor of RH when airco is operated initailly in PN mode and then switched to PR.

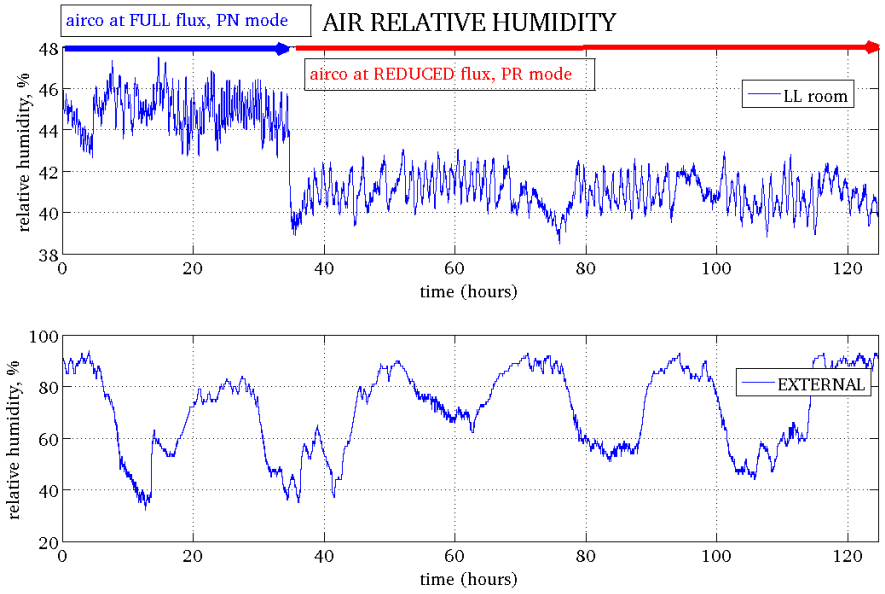



**Figure 9.** Air relative humidity monitors over few days. INJ airco is switched from PN mode to Reduced flux mode at 34th hour. **Top**: RH measured inside INJ bench room, **Bottom**: external RH.