

Gas Leakage and HV Test procedure for the INFN Muon MWPCs

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1. Abstract

The Muon MWPCs produced by INFN laboratories are subject to gas leakage and HV tests before installation on the LHCb experiment. The test procedure and the software tools developed are described in this paper.

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4. Overview

All the MWPCs produced by INFN laboratories¹ are subject to complete gas leakage and HV tests before being installed on the apparatus [1] and [2]. Three different tests have been setup to check the quality of chambers. Starting ideas are taken from system in use in the production sites [1]

1. Gas Leakage Measurement;
2. High voltage conditioning and measurement of the residual dark current at 2800 V;

All tests can be performed with chambers on the trolley used for transportation (Figure 1). No chamber movement is needed. This reduces the manpower requested and the time needed. 18 chambers are present in each trolley subdivided in three groups of 6 chambers: group A, group B and group C.

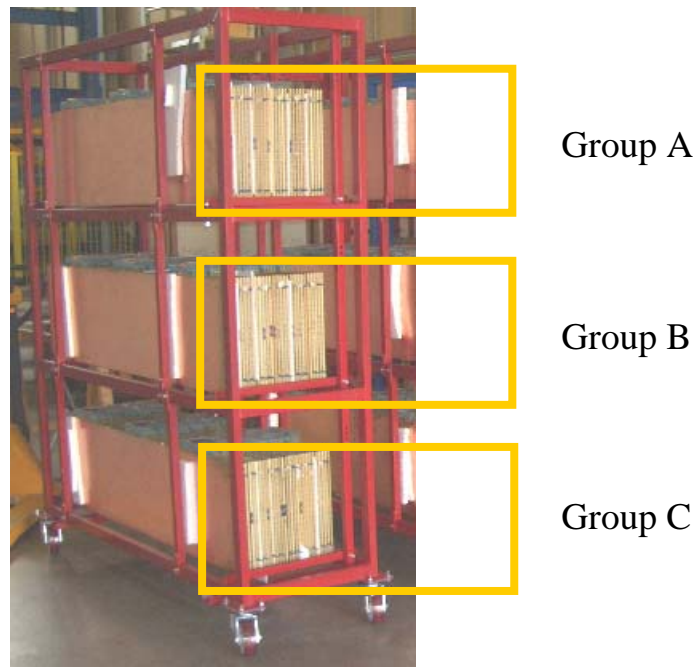


Figure 1: Chambers on trolley

4.1 The test procedure and timing

The main goal of the test is to “produce” 5 chambers completely tested a day. In order to do that, the sequence of the operations could be the following:

¹ Cagliari, Ferrara, Firenze, Frascati, Roma1 and Roma2

(The really first day of tests)

- i. The gas leakage of two groups (A and B) of chambers has to be measured. About 20 minutes are needed to test two chambers in parallel. The chambers of a group can be tested in one hour.
- ii. As soon as all the chambers of a group have been measured, the group can be flushed with the nominal gas mixture with a flow rate of about 3 NI/h. The chambers in a group are piped in series while the groups are gas supplied in parallel.

1st Day

- iii. After more than 20 hours of gas flushing the chambers of a group (e.g. A) can be connected to the high voltage cables and the conditioning can start.

2nd Day

- iv. After 24 hours all the 6 chambers of a group should have achieved 2800 V and should be ready for the test of the front end electronics by means of cosmic rays.
- v. The chambers are then disconnected from gas, high and low voltage and are ready to go to the pit for installation.
- vi. The following group (e.g. B) of chamber has to be connected to the high voltage supply and starts the conditioning procedure.
- vii. The gas leakage of the chambers of group C can be tested and thus the chambers should be flushed with the nominal gas mixture.

3rd Day

- i. Restart operation on group C as on 1st Day for group A.

General remarks on PC setup

The PC used for the test is PCHVLHCB156. The user should login in the local domain (PCHVLHCB156). No other simultaneous login is allowed. All programs needed for the test have a link to the folder MWPCTest on the desktop. In general all the LabView vi's are in the folder C:\Labview\VIs.

All data of the measurements will be recorded on the PC in the folder C:\Documents and Settings\tester\MWPCData. For each chamber a folder will be created named MXRYC00Z containing three data files: HVConditioning.dat, GasLeakage.dat and CosmicRate.dat.

5. The gas leakage measurement

The gas leakage of a chamber is measured by monitoring the decrease in time of an over pressure applied. In our setup two chambers can be tested a time. The two tests are completely independent and can proceed in parallel way. The measurement of the difference between the pressure inside the chamber and the atmospheric one is performed by two digital differential pressure meters GMSD-25MR which have the precision of 0.01 mbar in a range of -19.99÷25.00 mbar. In order to correct for variation of temperature and external pressure the use of a “reference” chamber is useful.

5.1 Chamber setup and piping

The chamber to be tested has to be connected to one of the two gas lines used for this test and closed on the corresponding sensor as shown in fig 1. Two lines labeled as “LEAK TEST 1” and LEAK TEST 2” have to be used for the measurement. Each line is made by two pipes: one connected to the gas line through a suitable valve on the gas panel and one connected to the corresponding sensor.

Another chamber on the trolley can be used as “reference”. It should be connected, as illustrated below, from one side to the pipe labeled as “Ref” and from the other on closed.

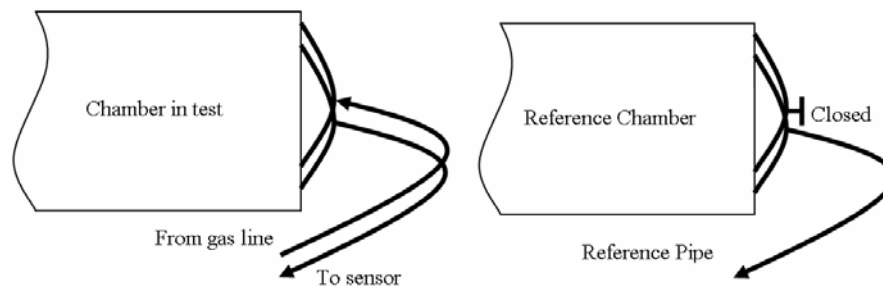


Figure 2: Sketch of gas leakage test piping

5.2 The data acquisition program

The data acquisition program is based on a server-client system. A program, called “GMH_server.vi”, reads and decodes every 500 ms data from the two differential pressure sensors and publishes them. This program (Figure 3) is automatically loaded and launched by LabView. If the values of the indicators “ch1” and “ch2” (Figure 3) are constant and different from the ones indicated on the GMH sensors it is possible that “GMH_server.vi” is not running. In this case it is possible to open its front panel, in the folder MWPCTest on the PC desktop, and start it. It is very important NOT TO STOP OR CLOSE IT by using the cross in the right-high corner of the window if it is running. The window can be closed only when the program has been stopped with the STOP button.

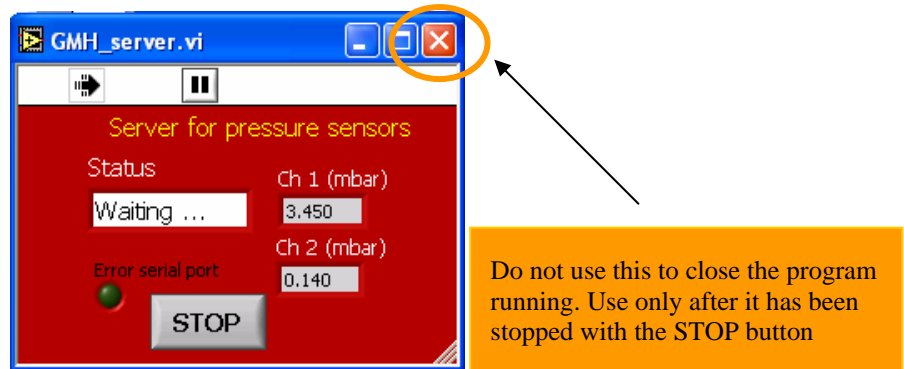


Figure 3: Pressure sensor readout program

Once the chamber is piped the program for the data acquisition and analysis should be called: LeakTest_ch1.vi (or LeakTest_ch2.vi). In Figure 4 the control panel of program for acquiring data from channel 1 is shown. We can follow the measurement procedure step by step:

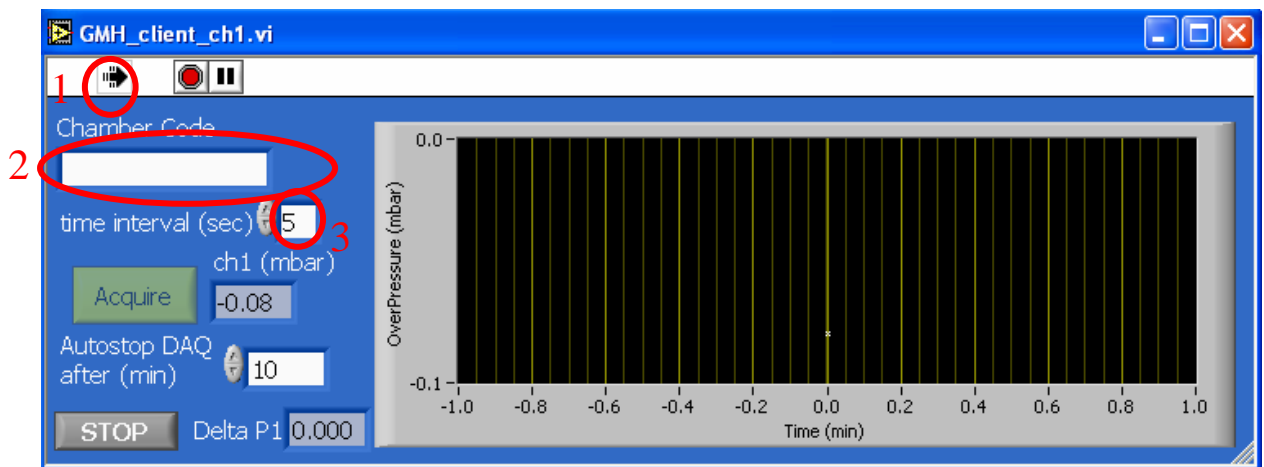


Figure 4: Panel of the program for the gas leakage measurement

1. Once the program is open it is made run by clicking on the white arrow in the left-top corner. The current value of the overpressure inside the chamber is shown in the indicator “ch1 (mbar)” and on the corresponding plot.
2. An important step is to set the chamber code in the control that will be used by the program to save the data of the measurements. Until the “chamber code” field is not correctly filled, the “Acquire” button will be disabled. The code can be manually inserted or more easily read my means of a laser bar code reader
3. With the control “time interval (sec)” is possible to choice the time interval between to acquisitions. The default value is 5 s.
4. Open the valve on the gas line in order to start to inflate the chamber. In this phase the time interval value should be kept lower than of 10 s in order to have a fast feedback of the overpressure increase;
5. When the overpressure reaches the value of 5 mbar the valve must be closed. The plot shows the pressure increase within the chamber (see Figure 6).

- The acquisition of data used to evaluate the gas leakage of the chamber is started by clicking the button “Acquire” (Figure 5) which later will be disabled as in Figure 6.

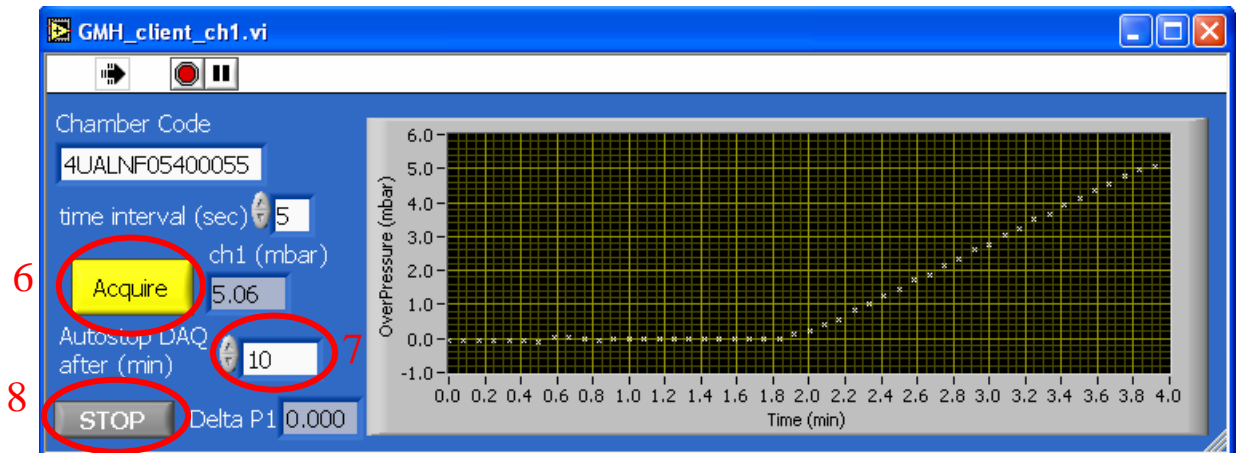


Figure 5: How to start the data acquisition after chamber has been inflated

- The acquisition of data on the pressure decrease will last the time set (in minutes) in the control “Autostop DAQ after (min)” (Figure 5);
- At any moment the acquisition can be stopped by means of the STOP button;

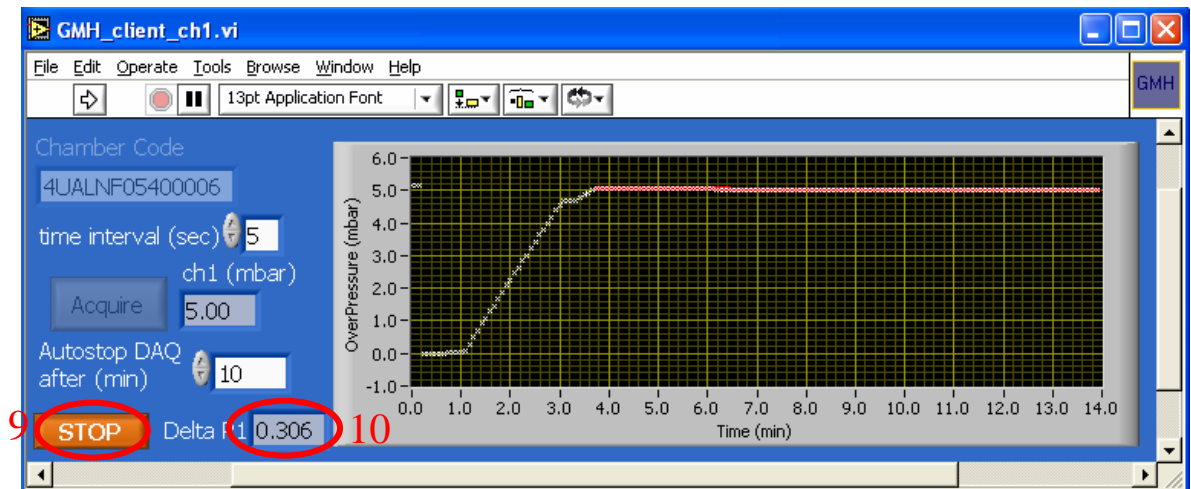


Figure 6: Stop of measurement and fit result

- The measurement is completed when the “Stop” button becomes orange.
- In both cases (6 and 7) the program will perform an exponential fit on the data acquired. The curve calculated from the fit is shown in red on the plot (Figure 6) and the value of the extrapolated value of the pressure decrease for 1 hour is shown in indicator “Delta P1”. In order to be accepted a chamber should have a leakage rate lower the 2 mbar/h.

6. Chamber high voltage conditioning

Once the gas leakage of a chamber has been measured, a high voltage conditioning is performed. At least 3 volumes of the nominal gas mixture must have flushed before starting with the high voltage conditioning. As much as 44 chamber gaps (i.e. 8 four-gap chambers at positive voltage and 3 chambers at negative voltage) a time can be conditioned in a completely parallel way. The 4 gaps of a chamber to be conditioned must be connected to the 4 HV cables of one of the 11 groups. The HV supply IP address is 137.138.254.19.

6.1 The HV conditioning program

The HV conditioning of a chamber is a completely automated procedure performed by the LabView programs called “HVGroup1.vi”, ..., “HVGroup8.vi” for positive voltage and “HVInv1.vi”, ..., “HVInv3.vi” for negative voltage. Each of them follows the same procedure:

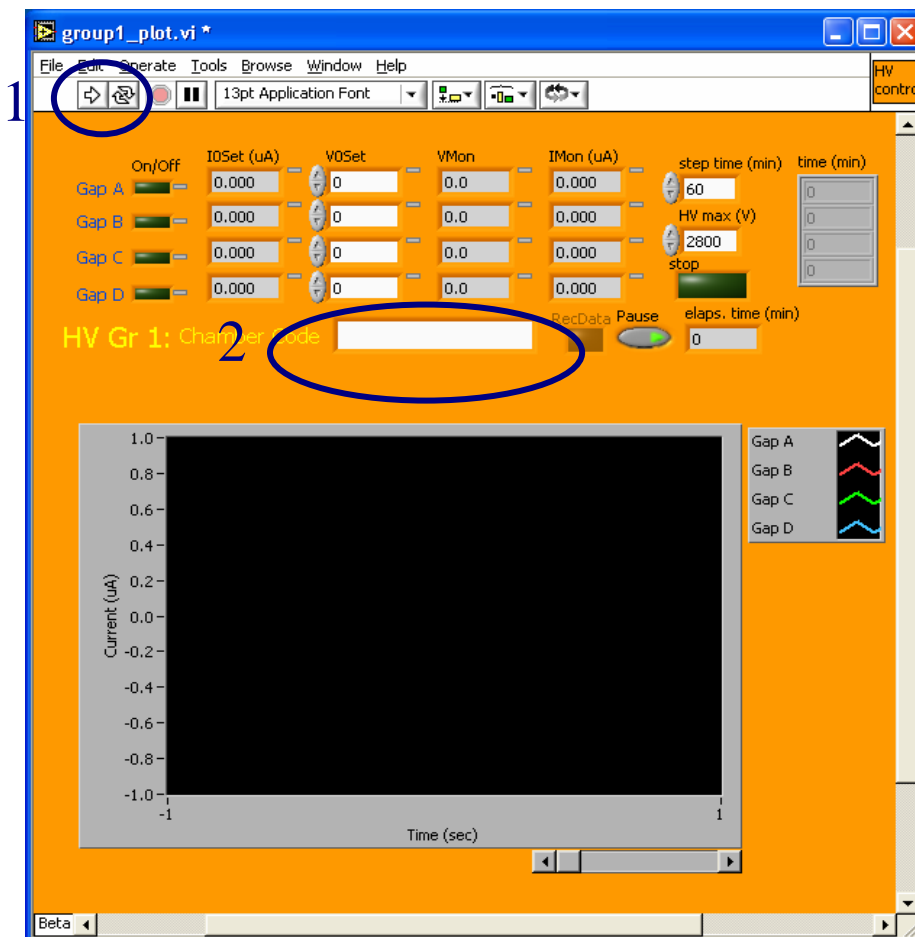


Figure 7: Panel of the program for the high voltage conditioning

1. The program is run by clicking on the white arrow (Figure 6).
2. When running the programs it's automatically updated to the HV situation present on the chamber connected to its group of cables. User must set the proper chamber code in the control in order to make the program save data in the correct file. Until that field is not correctly filled it is no possible to start the record of the data of the conditioning procedure

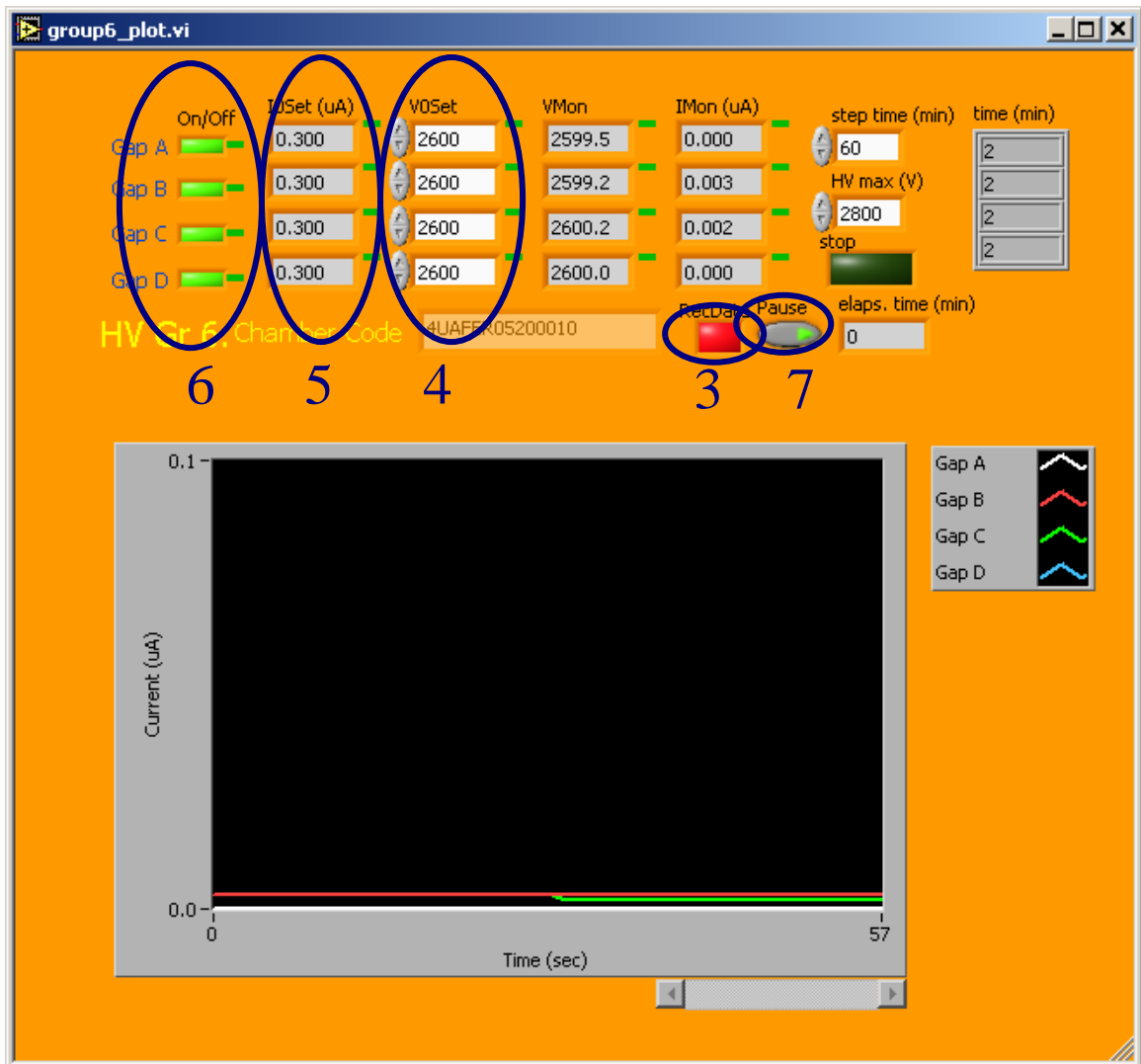


Figure 8: Panel of the program for the high voltage conditioning running

3. If the chamber type and number are inserted the button “RecData” is enabled and it is possible to start data recording. The data filename is “HVCondition.dat”; if this file it is already present in the directory of that chamber, it will be moved to “HVCondition_n.dat” where n is the first number not already used.
4. The initial voltage of the gaps to be conditioned must be set to 2000 V. The “V0Set” controls can be used at any time to tune the value of the voltage set for each single gap (Figure 8).

5. The maximum current of the gaps to be conditioned is automatically set to 0.3 μA for positive voltage and 3 μA for negative one.
6. It is now possible to turn On the high voltage in the chamber. The “On/Off” controls can be used at any time to switch On or Off the high voltage in each single gap (Figure 8).
7. When the program is launched, the conditioning procedure is in “pause”. This means that the voltage of the chamber is kept stable to the value set in 4. By switching the pause button the conditioning procedure is started. At any time it is possible to push the pause button and “freeze” the conditioning (Figure 8).

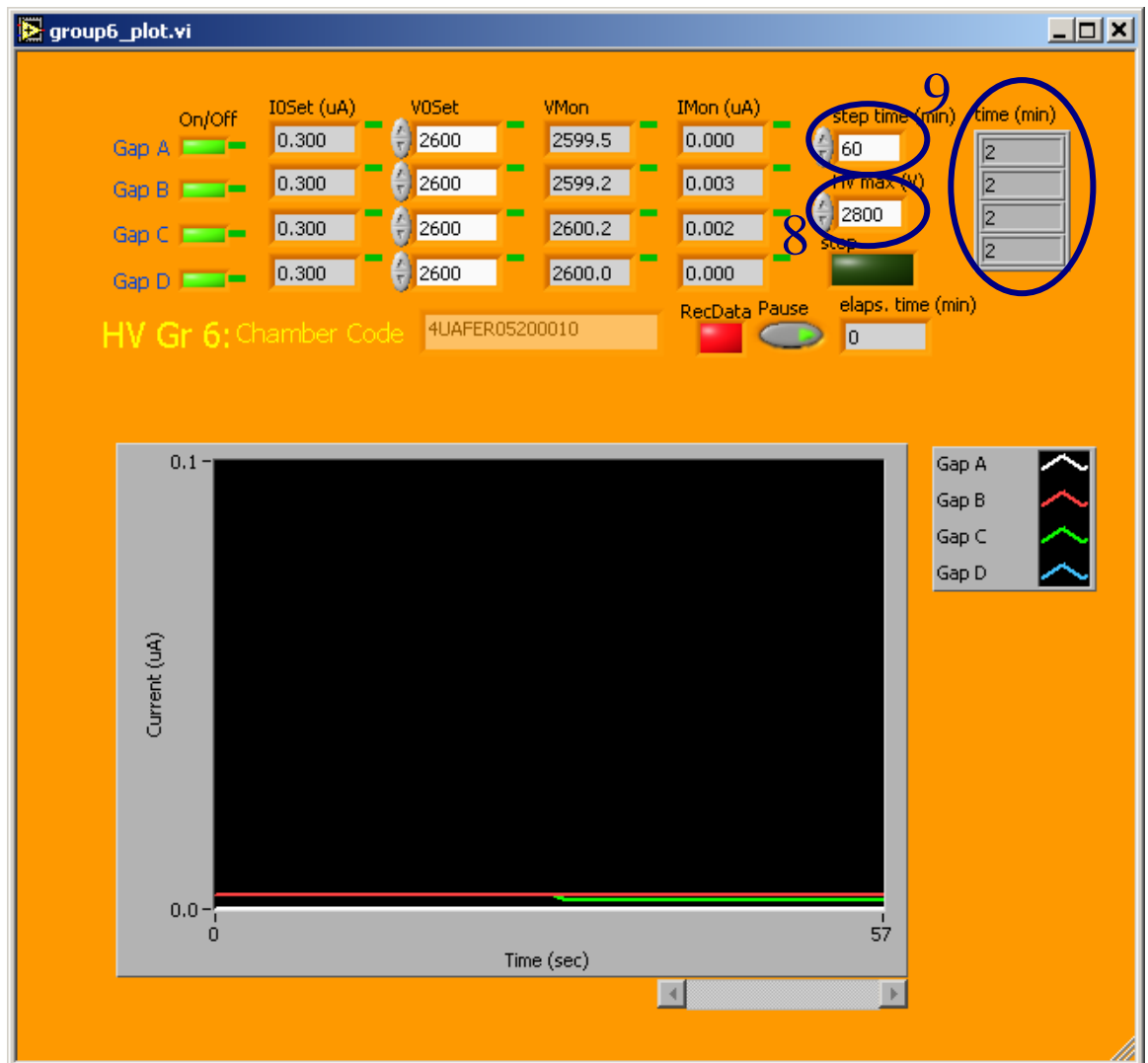


Figure 9: How to change time step and maximum high voltage

8. When the conditioning starts the voltage of each gap is increased up to the voltage set in the “HV max (V)” control in steps of 100 V at the beginning and 4 steps of 50V for the last 200V.

9. For each gap, between one step and the following, the programs waits for the current drawn by the gap becomes lower than 20 nA and then a chronometer is started. When the chronometer arrives to time value set in the “step time (min)” control, the voltage is increased. The current value of the chronometer is shown in the “Time (min)” indicator (Figure 9).
10. If the current drawn becomes higher than 20 nA, the chronometer is reset and starts again when the current decreases below the above limit.

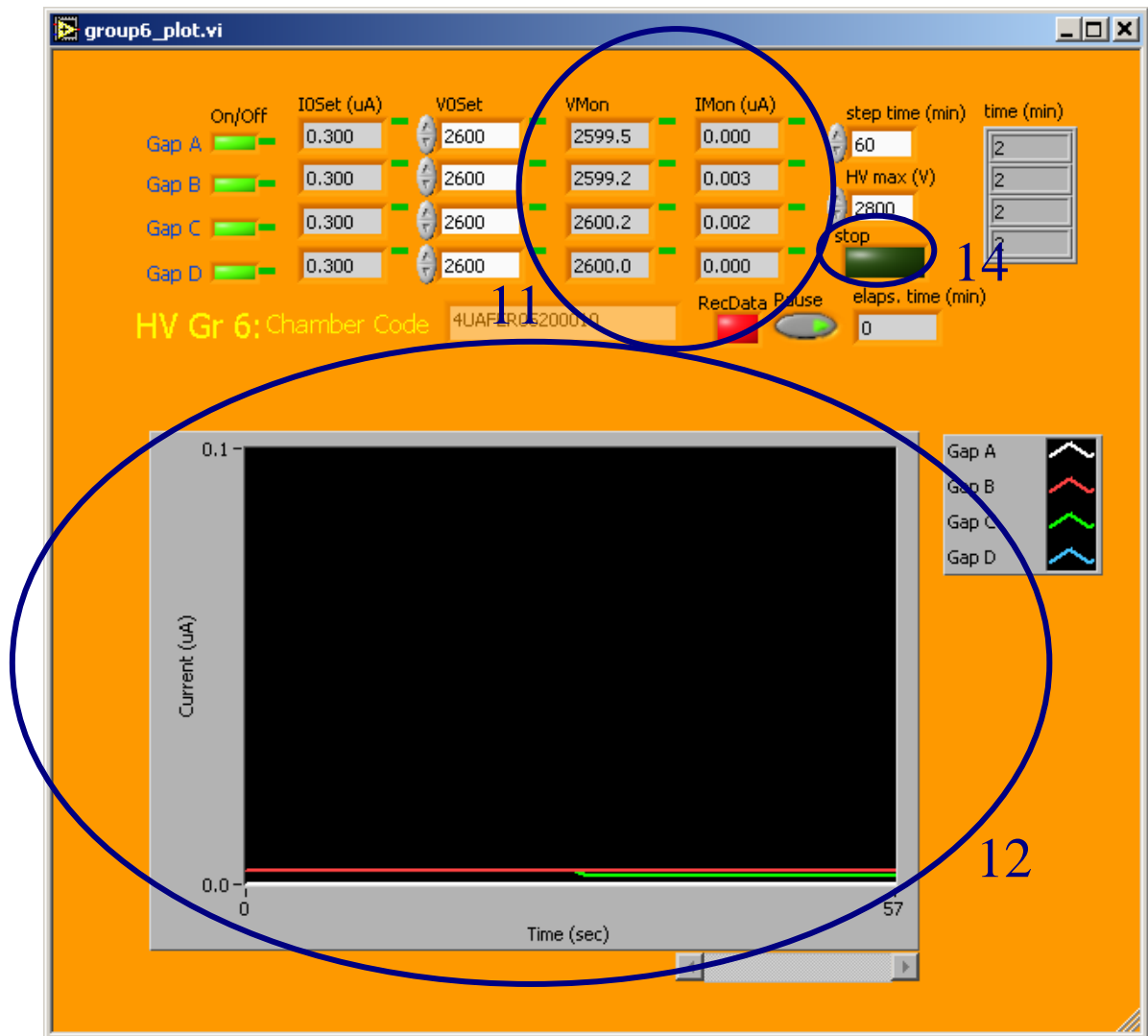


Figure 10: How to read the voltage and current drawn by the gaps

11. The on-line values of the voltage and of the current drawn by each gap can be read in the “VMon” and “IMon” indicators (Figure 10).
12. In the plot it is possible to follow the behavior of the currents drawn by the four gap as a function on time.

13. If the status of one channel becomes over-current, its tension is automatically decreased of 100V to avoid a channel trip. If 100V are not enough, the voltage continues to be decreased until the over-current go off.
14. The program can be stopped at any time by the control "Stop" which DOES NOT TURN OFF HV. It only stops the conditioning procedure and makes also impossible to see what is happening to the chamber. Thus, this button should be used only to exit the program when the chamber is switched Off (Figure 10).

7. Data Files

The summary of the results of the tests has to be written by hand in a suitable excel file named "TestSummary.xls" that can be found in the folder MWPCData on PC desktop. Moreover, as cited above all the data of the high voltage conditioning, gas leakage test and front-end electronics check will be automatically recorded in a folder having the chamber name (MXRYC00Z) in the folder MWPCData on the PC desktop. The contents of those files if briefly explained in the following.

7.1 TestSummary.xls

The results of the each test performed on the chambers have to be written by the user in a suitable Excel file. The structure of the file is shown in Figure 11.

1	ChamberName	GasLeakage	I(nA) at 2.7kV				I(nA) at 2.8kV				I(nA) at 2.9kV				Notes
2		(mb/h)	gap	gap	gap	gap	gap	gap	gap	gap	gap	gap	gap	gap	
3			A	B	C	D	A	B	C	D	A	B	C	D	
4	4UAFER05200004	0.5	0	4	6	4									was leaking from gas pipes, replaced by blue pipes
5	4UAFER05200010	0.7	2	8	6	4									was leaking from gas pipes, replaced by blue pipes
6	4UAFER05200011	1	0	0	0	0									
7	4UAFER05200013	0.2	2	4	6	4									
8	4UAFER05200014	0.7	0	0	4	2									
9	4UAFER05200025	1	0	0	4	2									
10	4UAFIRO5400007	0.3	2	0	0	0									
11	4UAFIRO5400008	0.5	0	2	2	2									
12	4UAFIRO5400011	0.2	0	6	4	4									Needed inverse polarity
13	4UAFIRO5400013	0.4	0	4	6	2									
14	4UAFIRO5400014	0.4	0	4	8	4	2	4	10	10					
15	4UAFIRO5400015	0.5	0	0	2	2	2	2	6	4					
16	4UAFIRO5400024	0.2	0	10	4	4									
17	4UAFIRO5400027	0	2	0	0	0	0	6	6	6	8	14	8	12	
18							8	8	10	18					
19	4UAFIRO5400028	0.1	2	6	6	4									
20	4UAFIRO5400029	99.9													
21	4UAFIRO5400034	0.4	0	0	0	0									was leaking from gas pipes, replaced by blue pipes
22	4UAFIRO5400036	0.1	2	6	10	6									
23	4UAFIRO5400041	0.3	999	2	4	4									Trip at 1570 V. Bubble?
24	4UAFIRO5400044	0.3	0	4	4	4									
25	4UAFIRO5400046	0.8	0	0	4	4									
26	4UAFIRO5400047	0.3	0	4	4	4	6	2	2	2					
27	4UAFIRO5400049	99.9													
28	4UAFIRO5400050	6.9													
29	4UAFIRO5400054	0.2	0	2	4	2									
30	4UAFIRO5400055	5.1													
31	4UAFIRO5400056	0.2	0	0	4	2	8	8	14	8					

Figure 11: The excel file containing the results of the tests

- A. The first column the code of the chamber. Also in this case it can be easily read by means of the laser bar code reader or manually inserted.

- B. The value shown, after the end of the measurement and data fit, in the indicator “DeltaP” in the Gas Leakage Test panel (Figure 6) has to be copied in the second column. If it is impossible to keep an overpressure inside the chamber and to measure the value of the leakage a 9999 should be put. If the value in the cell is higher than 2 the cell becomes automatically red.
- C. The value of the current drawn by the gap A at the end of the conditioning (2700 V) expressed in nA should be copied here. In case gap does not reach 2700 V the value 999 must be written and the cell background becomes automatically red.
- D. The value of the current drawn by the gap B at the end of the conditioning (2700 V) expressed in μ A should be copied here. In case gap does not reach 2700 V the value 999 must be written and the cell background becomes automatically red.
- E. The value of the current drawn by the gap C at the end of the conditioning (2700 V) should be copied here. In case gap does not reach 2700 V the value 999 must be written and the cell background becomes automatically red.
- F. The value of the current drawn by the gap D at the end of the conditioning (2700 V) should be copied here. . In case gap does not reach 2700 V the value 999 must be written and the cell background becomes automatically red.
- G. Columns from G to N must be used to report the final currents drawn by the chamber gaps for high voltage conditioning reaching 2800 V or 2900 V.
- O. Notes must be written in this column.

7.2 GasLeakage.dat

This file contains the information of the overpressure behaviour inside the chamber.

File	Edit	Format
0.833	5.020	
1.000	5.000	
1.167	5.000	
1.333	4.990	
1.500	4.980	
1.667	4.970	
1.833	4.960	
2.000	4.950	
2.167	4.940	
2.334	4.930	
2.500	4.920	

1 2

1. The first column contains data on the elapsed time in minutes.
2. The second column contains data on the overpressure in mbar inside the chamber with respect to the “reference” chamber.

7.3 HVConditioning.dat

This file contains the record of the currents drawn and the voltage applied to the gaps of the chamber during the whole conditioning procedure.

File	Edit	Format	View	Help					
0.000	2651.750	0.000	2651.750	0.000	2651.250	0.000	2651.500	0.000	
1.000	2651.750	0.000	2651.750	0.000	2651.250	0.000	2651.500	0.000	
2.000	2651.750	0.000	2651.750	0.000	2651.250	0.000	2651.250	0.000	
3.000	2651.750	0.000	2651.750	0.000	2651.250	0.000	2651.250	0.000	
4.000	2651.750	0.000	2651.750	0.000	2651.250	0.000	2651.250	0.000	
5.000	2651.750	0.000	2651.750	0.000	2651.250	0.000	2651.250	0.000	
6.000	2651.750	0.000	2651.750	0.000	2651.250	0.000	2651.250	0.000	
7.000	2651.750	0.000	2651.750	0.000	2651.250	0.000	2651.250	0.000	
8.000	2651.750	0.000	2651.750	0.000	2651.250	0.000	2651.250	0.000	
9.000	2651.750	0.000	2651.750	0.000	2651.250	0.000	2651.250	0.000	

1 2 3

1. In the first column the elapsed time in minutes is recorded;
2. In the second column the voltage, in Volt, applied to the first gap is recorded;
3. In the third column the current, in μA , drawn by the first gap is recorded;
4. In the other column the voltage and the currents pf the other gaps are shown.

8. Appendix 1: Performance of the Gas Leakage Test

To study the performance of the gas leakage test station we took several data in different days, with five chambers. Three chambers M5R4 (one classified like leaking other like no leaking and a reference) and two M5R3 (a chamber classified in the limit of leaking or not and our reference). The system used is exactly the same for standard measurements and explained in Section 5. For each measurement, before starting the data acquisition we open just a few seconds the system between the sensor and the reference to avoid difference between the pressure inside and outside the reference. We started our sequence of measurements with the two chambers M5R4. The chambers selected for this test are number 64 from LNF (classified as leaking with a leakage of 4.591 mbar/h) and number 58 from LNF (classified as no leaking with a leakage of 0.177 mbar/h). For these two chambers we used as reference the chamber number 65 from LNF (classified as no leaking with a delta of 0.535 mbar/h). The results are shown in Figure 12. In these plots we have the data separate by the day of acquisition (red, green and blue lines) and we fit over the sum of all days (black line). The results of the Gaussian fit are shown on the top right of each figure.

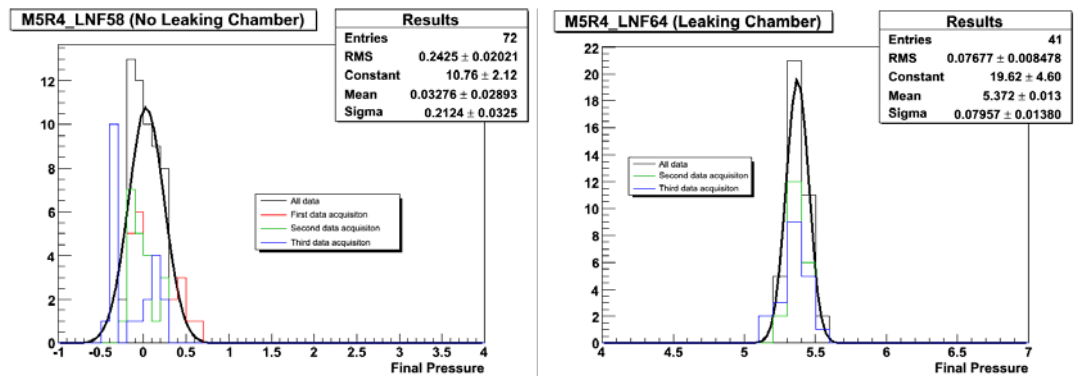


Figure 12: Histograms of the results of the leakage test for a "No leaking" (left) and a "High leaking" (right) chambers

As expected the accuracy obtained for a high leaking chamber is higher (rms of 0.08 mbar/h) than the one for a low leaking chamber (rms 0.2 mbar/h). In both cases a very good reproducibility was found. To study if the result depends of the dimension of the chamber, and how a chamber in the limit of our classification is influenced by external conditions, we selected two M5R3 chambers. The chambers tested are number 27 from LNF (with a leakage of 1.514 mbar/h) and as reference the chamber number 45 from LNF (with a leakage of 0.259). The results of this chamber are shown in Figure 13 . Also in this case the data are separate by the day of acquisition (red, green, blue and yellow lines) and we fit over the sum of all days (black line). The results of the fit are on the top right of the figure.

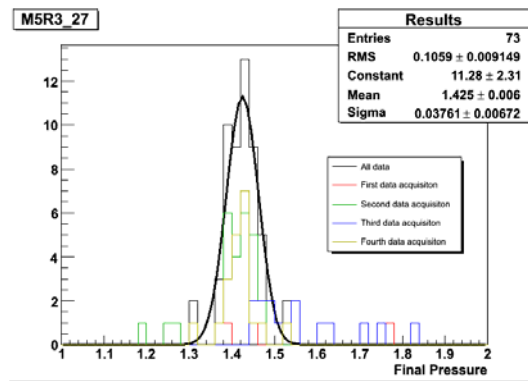


Figure 13: histogram of the results of the gas leakage test for a chamber in the limit of our classification

An important observation about this set of data is that after the second day of data acquisition this chamber passes by the electronic test and to do it all tubes of the leakage test had to be disconnected from the chamber. What we could see is that even with our interference in the test station, the result continues to have a good agreement with the others first two days.

9. References

- [1] LHCb Collaboration, "LHCb Muon System Technical Design Report" CERN/LHCC 2001-010.
- [2] LHCb Collaboration, "Addendum to the LHCb Muon System Technical Design Report" CERN/LHCC 2003-002.
- [3] M. Anelli et al. "Quality tests of the LHCb muon chambers at the LNF production site" Published in IEEE Trans.Nucl.Sci.53:330-335, 2006.
- [4] D. Pinci and A. Sarti. "Production and test of the LHCb Muon Chambers", presented at the "Hadron Collider Physics Symposium (HCP05), Les Diablerets, Switzerland.