PH-DT
Detector Technologies

SUMMER STUDENT PROGRAM

VALIDATION OF SINGLE WIRE PROPORTIONAL CHAMBER FOR LONG TERM OPERATION

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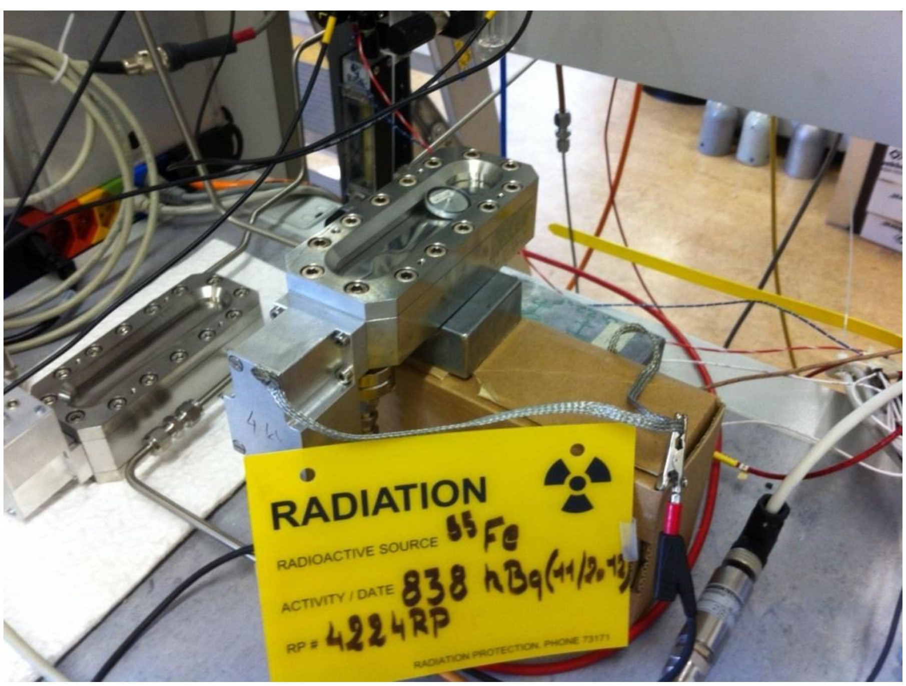

ABSTRACT

This report discusses my project, as a summer student, in PH-DT-DI department at CERN.
My study was about the operation of a single wire chamber. The final goal was the characterization of the detector performances versus time. The study aims in a future use of the single wire detector as a gas mixture monitoring tool. After a first period of operation, where a worsening of the detector performances has been observed, some components were replaces and finally a stable operation was achieved allowing to validate the complete setup.
A new single wire chamber has been built and it will soon replace the one used during the present study. A dedicated DAQ (VME, NIM, National Instrument) and data analysis (ROOT macros) system have been developed and the first results are here presented.

Contents

SINGLE WIRE GAS PROPORTIONAL CHAMBER

Proportional chambers are devices that measure the position and the energy deposited by a ionizing particle as it travels through a gaseous volume. An ionizing particle loses energy in the medium through which it travels by creation of electron-ion pairs. A very thin (≈30 μm) central sense wire is at a high positive potential and the cylindrical shell around the wire is at a ground potential. The electrons experience an electric field and therefore drift toward the wire. At a distance within a few wire radii from the center, the electrical field gets very strong, the electron kinetic energy becomes large enough that when electrons collide with gas molecules they free additional electrons which in turn accelerate and collide to create more electron-ion pairs (this process is called avalanche multiplication). It can be arranged so that a signal equivalent to the order of 10^6 electrons is produced on the wire. This produces a measurable signal after amplification. Due to their low mass the electrons move much faster than the ions, so that they are collected rapidly. However, the bulk of the electronic signal that is observed though is produced by the positive ions moving away from the central wire.

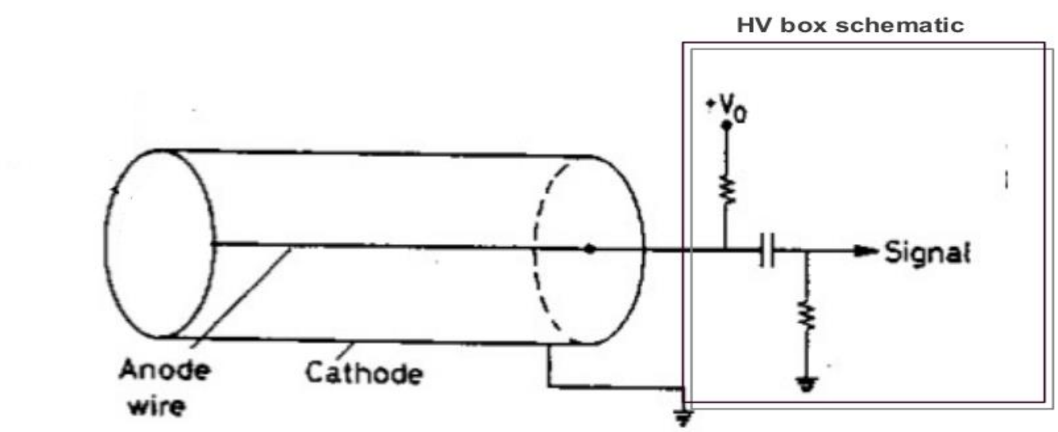

Figure 1: Schematics of a gas proportional chamber

AGING OF SINGLE WIRE CHAMBER

The aging phenomena constitute a complex and serious problem for gaseous detectors since it could affect and deteriorate the detector performance. The long term exposure to radiation can limit the detector's useful time and can cause problems like loss of gain and energy resolution, reduction of plateau, excessive currents, self-sustained current, discharge, sparking, etc. These deleterious effects can be caused by several problems like, for example, presence of layers on the cathode and anode surfaces, induced by pollutants released by detector material or by gas system or even impurities in gas itself. During the test of detector, it is needed to verify the stability of the performance (i.e. that exclude the presence of aging phenomena). In particular, in case of aging, a systematic study should be performed in order to understand the reason of the problem, which can be related to the detector itself (i.e. outgassing of dirty components) or to the gas system (i.e. polluted pipes or contaminants in the gas mixture).

HOW TO BUILD A SINGLE WIRE PROPORTIONAL COUNTER

The single wire proportional counter (SW) has been designed and built at CERN PH-DT department. The chamber's main body is made of stainless steel material, allowing a wire length of about 100mm. Two special made high voltage feedthroughs are installed at the extremities of the main body. One or two thin aluminum windows allow radiation to pass through the chamber without a negligible attenuation. All the pieces have been cleaned with special agents before the assembly of the detector in a clean room. This is necessary in order to avoid the presence of any pollutants and contaminants inside the SW chamber. The 30 μm diameter tungsten gold plated wire is inserted into the chamber by means a special tool. The part of the wire that was used, is replaced with a new clean part of wire, that is not touched from the operator. At the edges we use two pins that after crimping, can hold the wire inside the chamber. Since the wire has to be tight we firstly crimp one pin and from the other side of wire we put a weight of 17gr. In this way the wire becomes tight and we were able to cut the wire and crimp the second pin. As a final step, a special glue is positioned around the pin in order to avoid gas leaks.

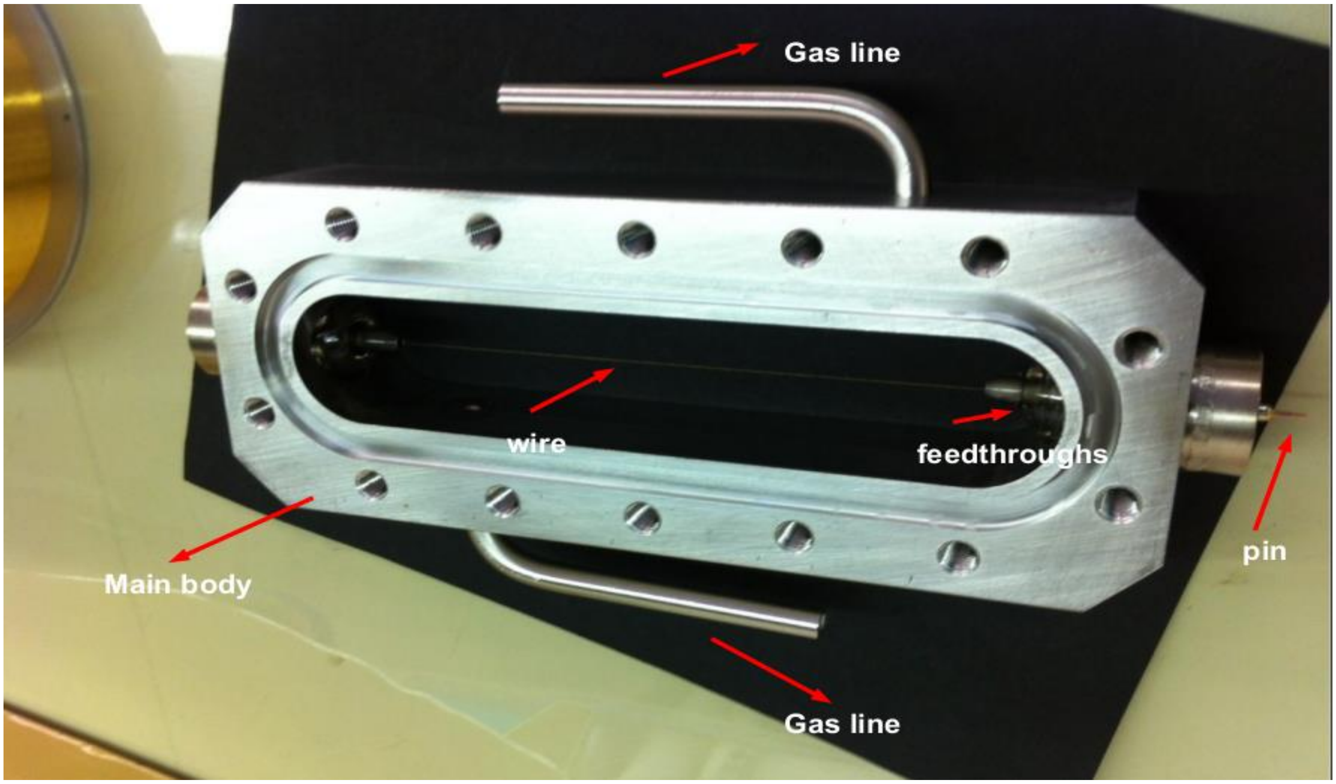

figure 2:Inside view of the single wire chamber after the insertion of the wire

The chamber is closed with the two aluminium windows. A "helicoflex" aluminium gasket guarantees the sealing of the chamber. Before use, the single wire chamber is heated up at 40º - 50º C and is flushed with the usual mixture in order to facilitate the removal of possible pollutants which hang over the cleaning procedure.

SET UP

In order to characterize the single wire detector, a dedicated setup has been prepared (figure 3). The SW is connected to a gas system where a gas mixture of Ar (45%), CO_2 (15%), and CF_4 (40%) is provided using a premixed bottle. Several sensors are connected to the gas lines in order to measure relative and absolute pressure, humidity and oxygen concentration. A HV box is connected to the single wire in order to provide a high voltage connection and to allow reading the wire signal. A ^{55}Fe source is positioned over the single wire chamber. The signal obtained is sent to the DAQ system made of several NIM and VME modules (figure 4). The DAQ acquire and record the data of each event in a computer. The recording of data is done by means of National Instrument modules and a dedicated LABVIEW software for the data acquisition has been developed. The recorded data are: current, rate, spectrum and environmental parameters (figure 5). Labview gives raw data in format of txt files. From June 1 until August 20 current and environmental parameters have been recorded every second during the operation period. Instead spectrum and rate data are acquired every 10 minutes.

During the first minute data about the rate are collected, while during the next two minutes the spectrum of the signals is acquired. Finally for seven the drawn current is recorded.

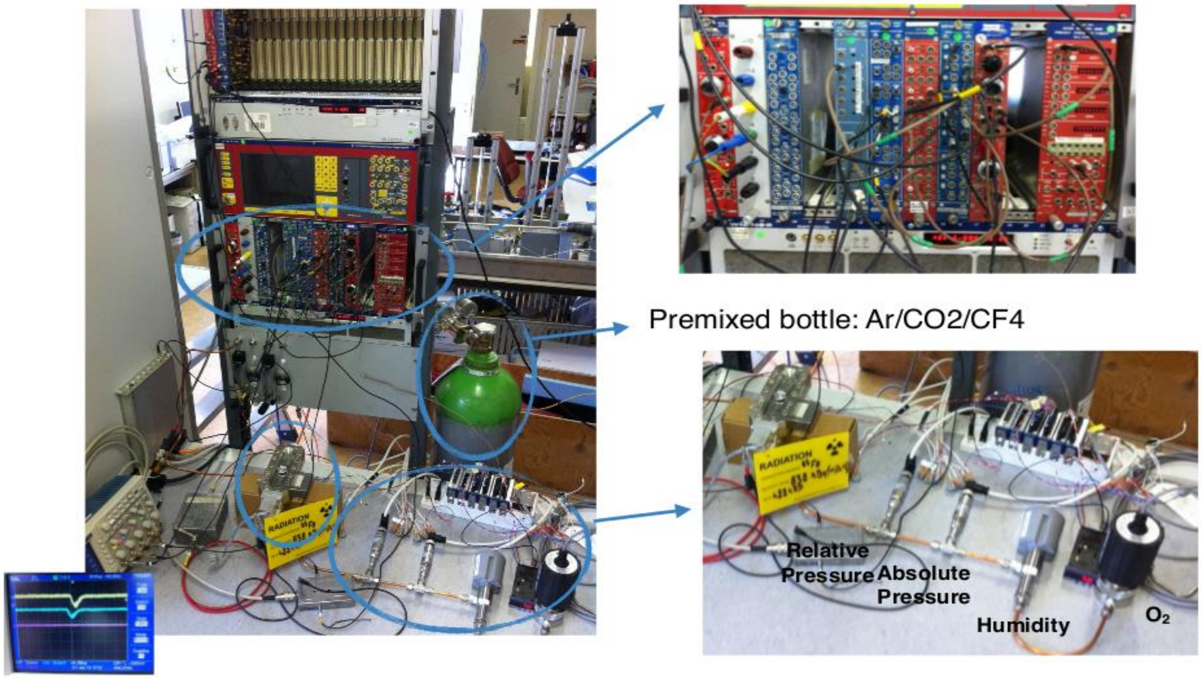

Figure 3:View of the SW experimental setup, DAQ and gas system in the laboratory

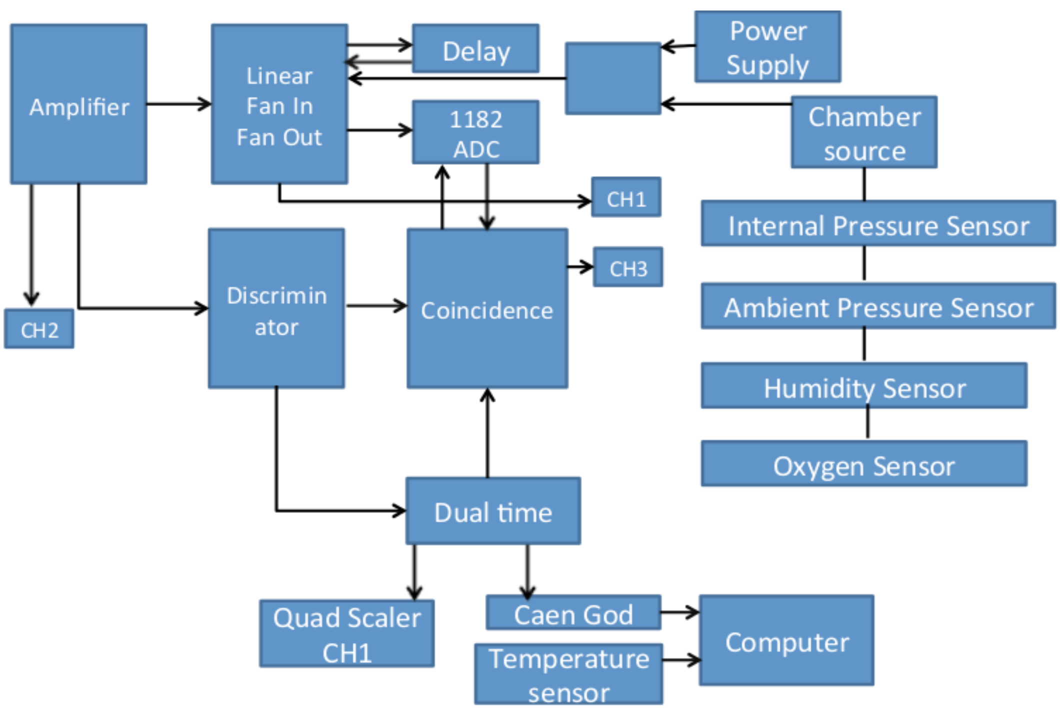

figure 4: Block diagram of the DAQ and related sensors used in the SW experimental setup

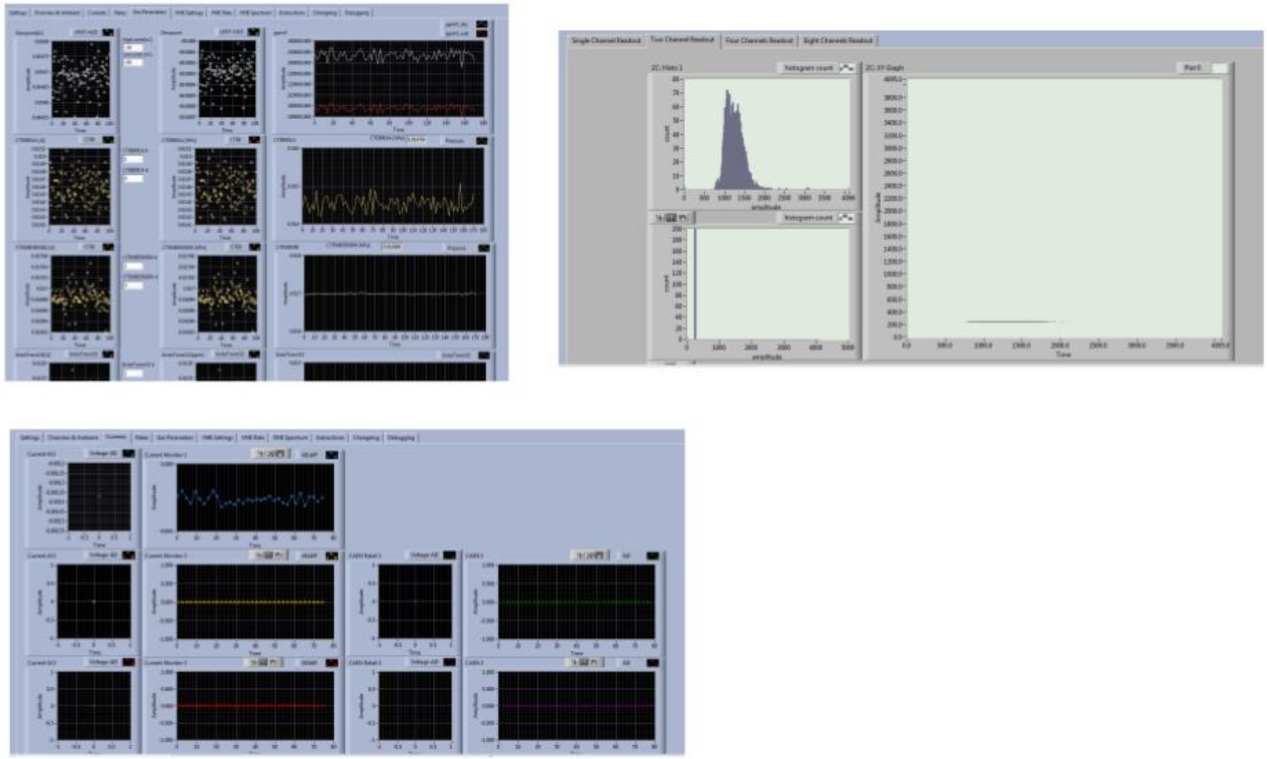

Figure 5:View of several plots observed with the Labview program and used to monitor the performance of the SW detector.

The source can be placed in five different positions allowing to scan the wire.

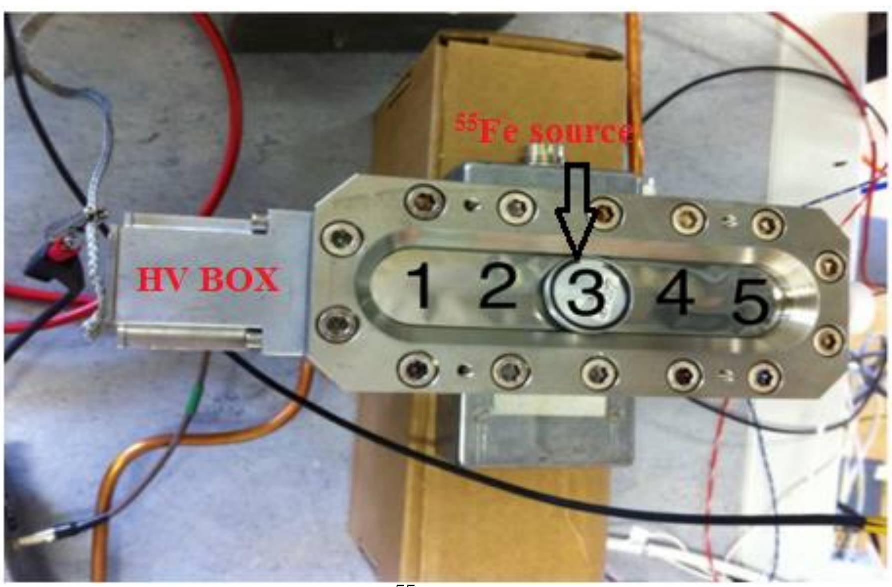

Figure 4: Possible positions of ^{55}Fe source on the SW chamber. Usually the ^{55}Fe source is placed in position 2, 3, or 4, where the electric field is uniform inside the SW.

DATA ANALYSIS

ANALYSIS OF THE SPECTRUM

In order to characterize the single wire chamber, the ^{55}Fe source was first placed in position 3. Figure 5 shows the pulse – charge spectrum of the ^{55}Fe x-rays acquired over one day. The 5.9 KeV x-ray emitted by the ^{55}Fe source produces the main peak in the distributions , while the small peak at about 800 ADC counts is the pedestrial. After several days of operation the peak shape started to change showing the presence of another peak on the low- energy side of the initial main peak (figure 6). In order to get the position of the first and second peak, a fit with two gaussian has been implemented. The peak position is an important parameter for checking the SW performance because each change can point out problem of aging in the detector. Figure 7 shows the variation of the normalized peak position over the period of operation. As it can be seen, after seven days of operation, the peak position started to move to lower value revealing a decrease in the pulse charge.

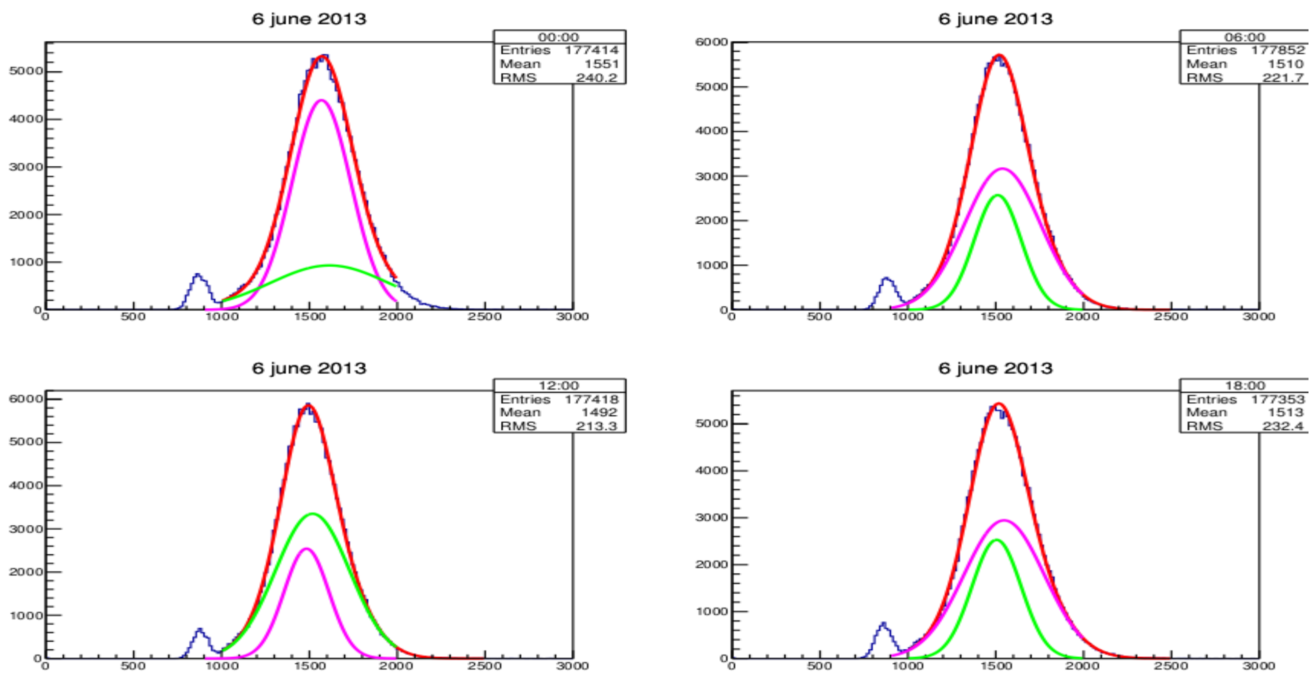

Figure 5: Double gaussian fit of ^{55}Fe source spectrum on the 6 of June (firstl day of operation). One spectrum every 6 hours is acquired. Every day 4 spectrums are obtained. The red fit is the sum of the two gaussian (green and pink).

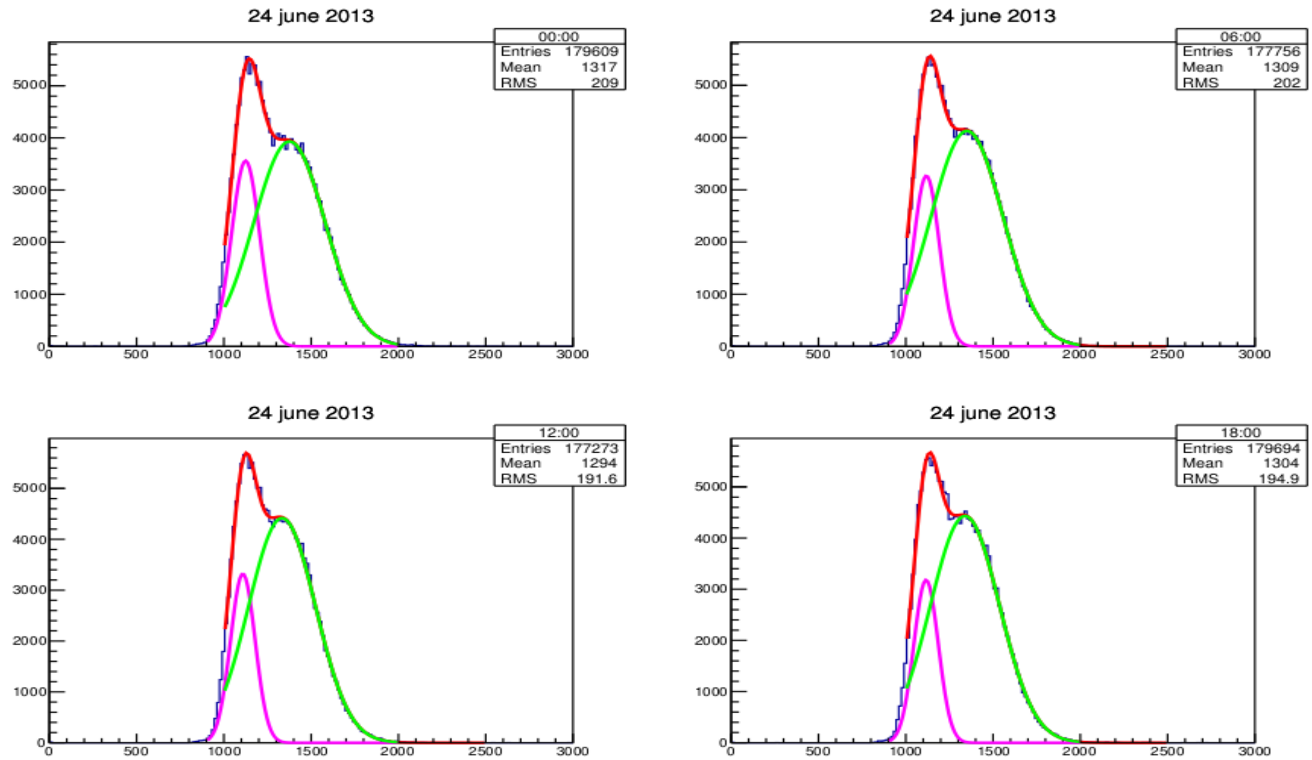

Figure 6: Double gaussian fit of ^{55}Fe source spectrum at 24 of June. After several days the spectrum consists of two peaks. A double gaussian fit has been implemented in order to get the position of the two peaks.

The aging effect, the appearance of the second peak , can be caused by a deposit on the anode wire. This contamination can produce a reduction in gas amplification, which is known to be strongly dependent on the value of the anode radius at the position where the electron avalanches reach the anode.

The two main peaks could perhaps be explained by a difference in deposit between the side of the anode facing the ^{55}Fe source and the opposite side.

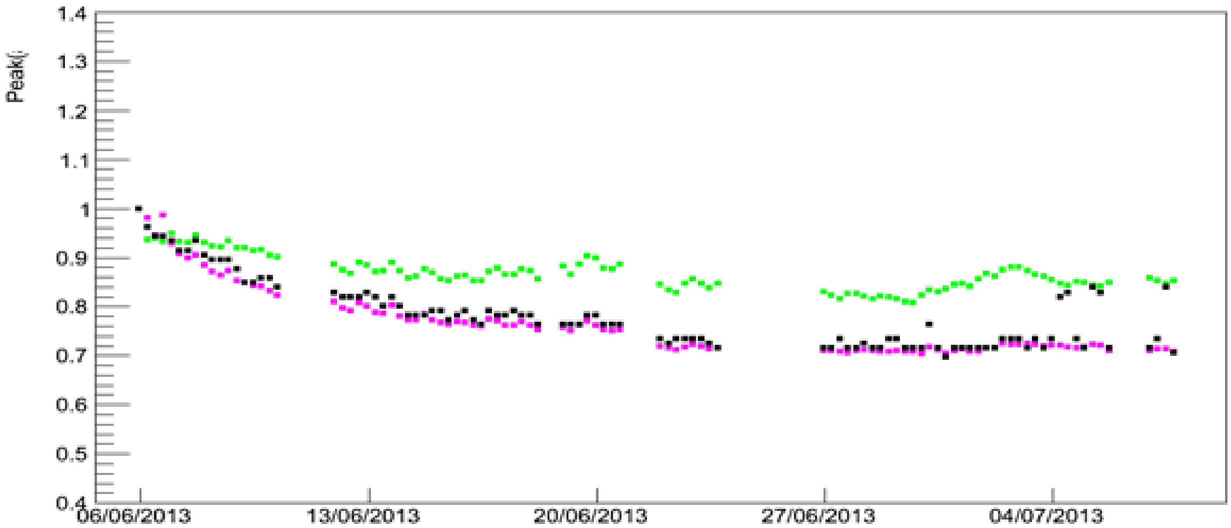

Figure 7: Peak position trend (normalized) during the data acquisition. The pink dots correspond to the position of the high peak of the spectrum on the left, which is shifted more, the green dots correspond to position of the second peak on the right, and the black dots correspond to position of the spectrums maximum. The last ones have quite the same value of the pink one.

In order to study the shift of peak position during the data acquisition, three parameters were used: two correspond to the position of two peaks used for the double Gaussian fit and one corresponds to the position of spectrum's maximum. (figure 7).

SCAN OF THE WIRE

The shape of the spectrum and the peak position were studied placing the source in different positions (1,2,3,4,5 see figure 4) along the wire. The test was performed after one month of operation of the SW with the source in position 3 in order to understand if all the wire was affected by aging.

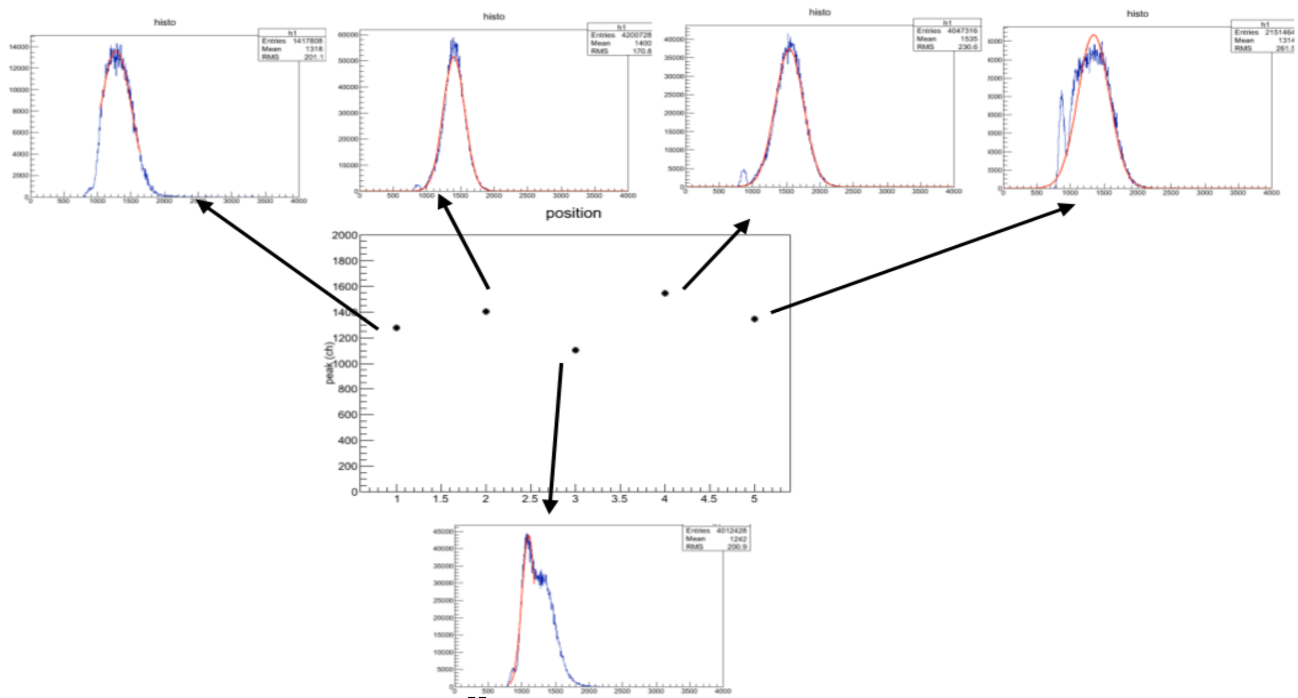

Figure 8: Charge spectra for different ^{55}Fe positions along the wire.

As we can see in figure 8, the spectrum for position 3, has not a gaussian distribution, its width is large and the peak is shifted to the left with respect to the others peaks. The spectra of position 2 and 4 have gaussian distributions and look like the spectrum in position 3 before the exposure to radiation. The spectra obtained with source in position 1 and 5 don't have a gaussian distribution because the electric field inside the chamber is not uniform at these positions. However, the maximum peak position is consistent with the one obtained placing the source in position 2 and 4. This study demonstrates that only the portion of wire irradiated has been affected by aging problem while the rest of the wire is working properly.

NEW RESULTS OBTAINED AFTER SETUP MODIFICATION

On July 10th the source was moved from position 3 to position 2 and data were acquired until the end of July. On July 31st gas system pipes (made of copper) were checked and were replaced by new ones made of stainless steel. The source was moved at position 4 until August 20th. The trend of peak position during all the operation time is showed on figure 11.

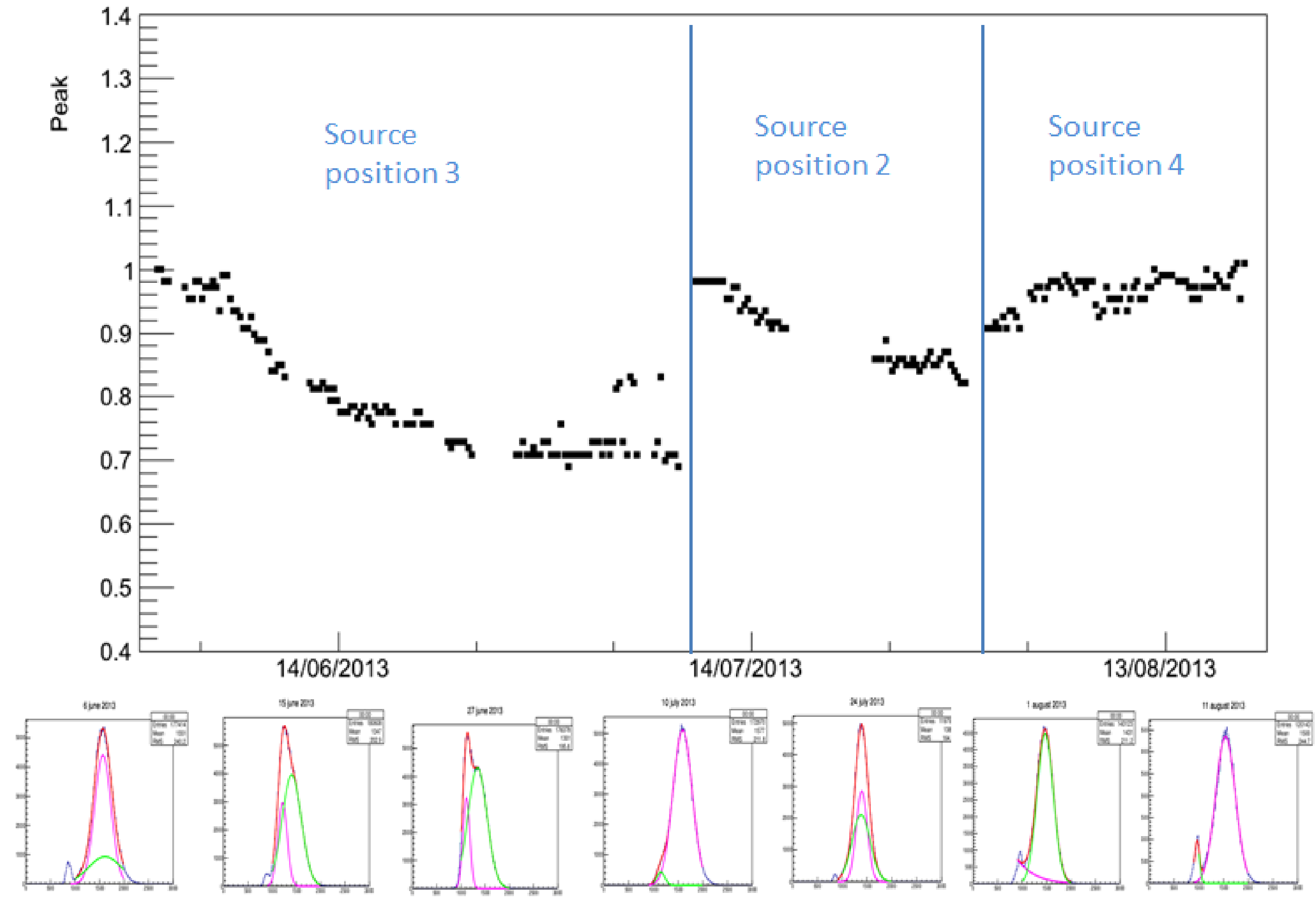

Figure 9: Peak position trend during data acquisition where the source was placed in different position along the wire. Below several spectra acquired during the test with different source positions are shown.

Figure 9 shows a decreasing trend of peak position during data acquisition, with the source placed at position 3. Until July 9th the peak position was reduced of about 30 %. Moreover, a new peak in the spectrum starts to appear. On July 10th, the source was moved to position 2 in order to verify the SW performance by irradiating a new portion of the wire. The peak returned to initial value meaning that this part of the wire was not damaged. After some days of operation, the peak position moved to lower values. The peak position with the source on position 2 and 3 has the same bad behavior after several days of operation, the wire is affected and the SW performance decreases. On the 1st August, the gas system was improved and the source was placed in position 4. After a long operation period, peak position trend is stable. This indicates that the aging problem of the detector was related to some contaminants released by the gas system. Since the peak position is stable over a long period and it doesn't show a drop like in the previous cases, we can consider our setup validated for operation.

MONITORING OF CURRENT AND ENVIROMENTAL PARAMETERS

The peak position and current drawn by the irradiated SW can change during operation, because of their dependence from changes in environmental parameters. Current and environmental parameters have been monitored along the test in order to normalize the detector performance. The current can be corrected by fluctuations induced by pressure and temperature variations, using the following formula:

$$I_C = \frac{T}{T_0}\frac{P_0}{P} I_{raw} = C I_{raw}$$

Where, $T_0 = 293\,K, P_0 = 970\,mbar$, T, I_{raw}, P are temperature, current and pressure that have been acquired in laboratory. I_C is the current that has been obtained correcting factor C after correction.

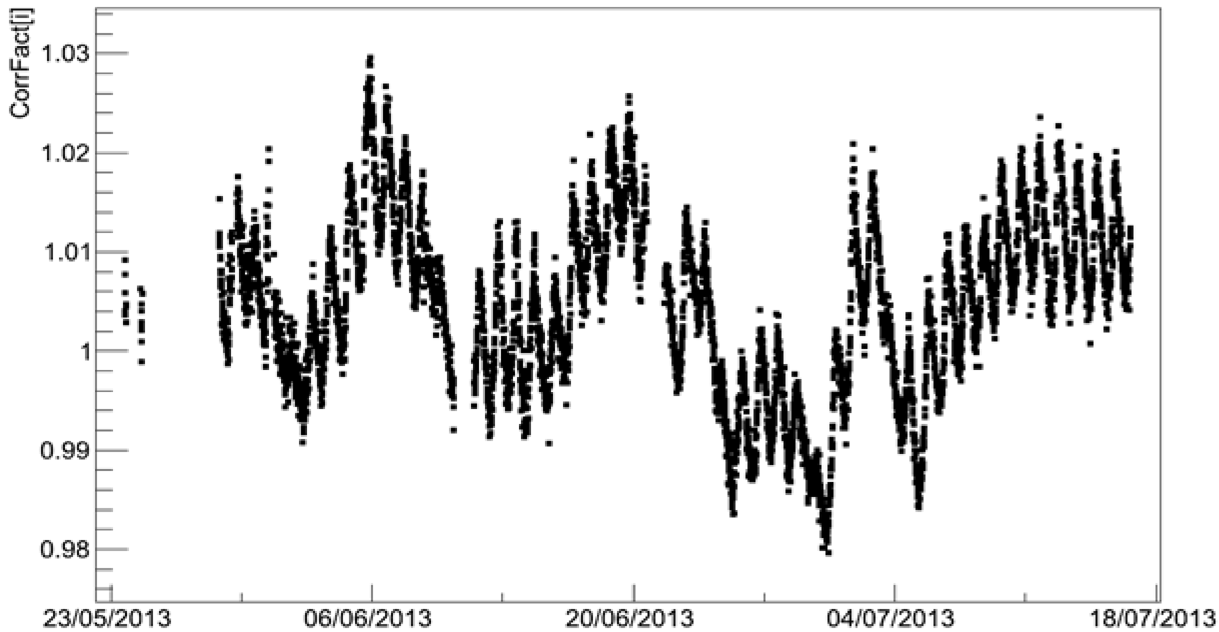

Figure 10: Trend of the correction factor over a operation period. The non-constant value indicates a change in the temperature and pressure.

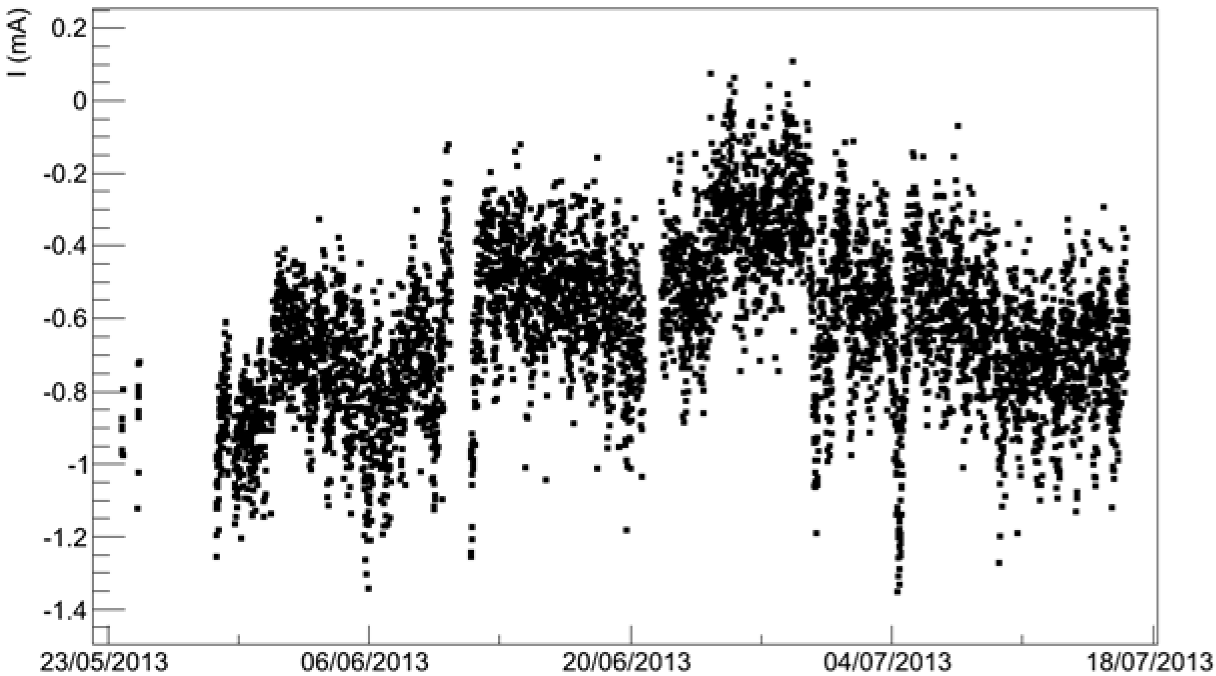

Figure 11: Trend of the corrected current drawn by the irradiated SW.

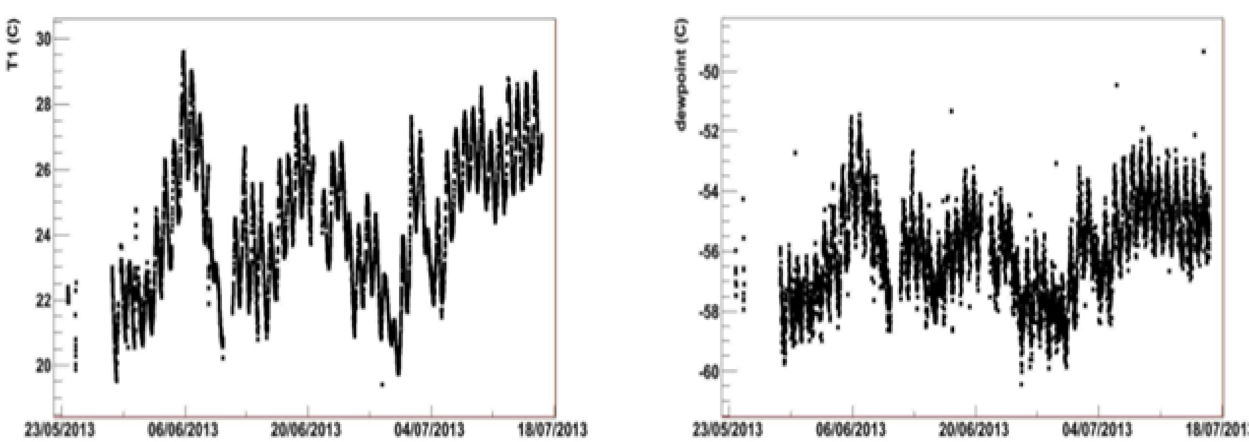

Figure 12: Example of the monitoring of environmental parameters,(temperature and dewpoin) during the data acquisition.

CONCLUSION

The aiming of this study was to validate the experimental setup and the single wire detector operation. The SW performances were monitored during the test. After a first week of operation the pulse charge started to decrease, revealing a potential aging effect. A complete study on the SW behavior in presence of aging phenomena has been performed coming to the conclusion that the aging is caused mainly by pollution which can deposit on the wire. Several components of the gas system have been cleaned and replaced in order to eliminate possible causes of pollution. After this change, the chamber was operated for a very long period (about a month) without showing aging problems.

Bibliography [1]

[1] A. C. B. a. W. G. A J F den Boggende, "Comments on the ageing effect of gas-filled proportional counters," *Journal of Scientific Instruments 1969 Series 2 Volume 2.*