Two-Parameter Analysis of the Temporal Behaviour of Resistive Detectors

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The biggest constraint in the RPCs operation is the drop of their efficiency with the counting rate, consequence of charge gain decrease. This effect is normally attributed to the voltage drop on the dielectrics, although not supported by quantitative measurement. In this work we present the first results of a two-parameter analysis of the charge pulse height time variation from a cylindrical resistive detector, operating in proportional regime, under high irradiation rates. The dynamic behaviour of this detector was investigated through the determination of the time decay constants related to its stationary condition, where the charge gain becomes constant. To perform this study, a data acquisition system, which allows the users to observe in real-time the temporal variation of the energy spectrum, was specially designed. The fitting of the peak centroid position as a function of time, obtained for rates range from 220Hz up to 1230Hz, showed it can be described by a sum of two exponentials plus a constant term, what is in accordance to the dielectric delayed polarization processes.

1 Introduction

Detectors with highly resistive electrodes, namely the Resistive Plate Chambers (RPCs), have been studied extensively in recent years envisaging their use as a muon trigger in the Large Hadron Collider at CERN. However, the biggest constraint in the RPCs operation is the drop of their efficiency with the counting rate, consequence of charge gain decrease [1, 2, 3, 4, 5]. The origin of this problem has been investigated assuming a stationary regime, where the charge gain becomes constant. Since some authors attributes this effect to the polarization phenomena of the dielectrics, we decided to investigate the charge gain variation of a cylindrical resistive detector during the occurrence of these processes (dynamic behaviour), which are particularly important because a small area around the discharge spot remains inactive during a given period of time, thus limiting the rate capability of the detector.

In order to improve the results that some of us previously obtained about the dynamic behaviour of resistive detectors[6, 7, 8], mainly from what concerns the charge pulse amplitude reduction with the increase of current across the gas gap, it was developed a data acquisition system[9], which allows the users to observe in real-time the temporal variation of the energy spectrum and exports the data as text or binary file to be used with an external analysis package. In this work, we present the first successfully results on the two-parameter fitting of the peak centroid position, using specific analysis functions trying to describe the transient response of resistive detectors.

2 Experimental Setup

The relaxation mechanisms of resistive detectors was investigated using a glass cylindrical proporcional counter, described in previous papers[6, 7, 8], operating with Ar + 10% CH_4 gas mixture at atmospheric pressure and irradiated with different counting rates by 22 keV X-rays from a ^{109}Cd source. The charge gains of this detector were measured using a conventional charge amplifier electronic system and a NIM ADC (Nuclear Data - ND582), whose digital output is retrieved with an IO board, as can be seen in Fig. 1. The computer program gets the data from the device driver and then builds and displays a two-dimensional matrix (energy $\times$ time histogram) representing the data. Fig. 2 shows a edited display window of the program. In the upper part of it appears the data matrix and in the lower one the one-dimensional histograms corresponding to two different time intervals of it.

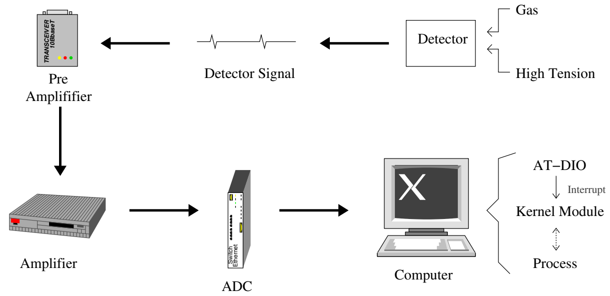

Figure 1. Layout of the experimental system.

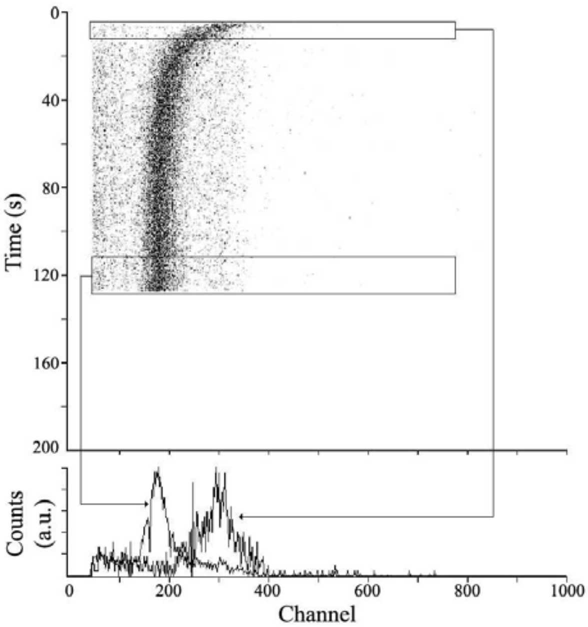

Figure 2. Display window showing a real time data acquisition run.

3 Data Analysis

Taking into account that the peak behaves as a Gaussian, according to the Eq. 1, its position as a function of time can be described by a sum of two exponentials plus a constant term, due to the complexitiy of the glass delayed polarization processes[7, 8, 10]:

$$F(x,t) = \frac{A}{\sqrt{2\pi s^2}} e^{-\frac{1}{2}\left(\frac{x-x_c}{s}\right)^2} + C \tag{1}$$

where

$$x_c = x_c(t) = x_0 + a_1 e^{-b_1 t} + a_2 e^{-b_2 t} \tag{2}$$

is the centroid of the gaussian peak. The standard deviation was modeled by a sum of a exponential plus a constant term, as:

$$s = s(t) = s_0 + s_1 e^{-s_2 t} \tag{3}$$

where a_1, b_1, a_2, b_2, s_0, s_1 and s_2 are parameters; C is a constant related to a possible flat background and A corresponds to counts.

4 Results

Figures 3 and 4 present the charge pulse height as a function of time for 270Hz and 1230Hz counting rates, respectively.

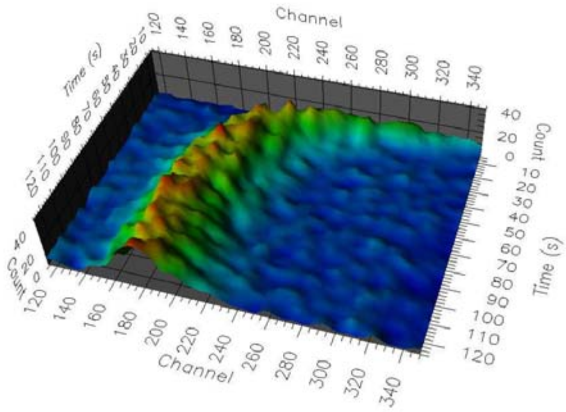

Figure 3. Experimental results in two-dimension plot for counting rate of 270 Hz.

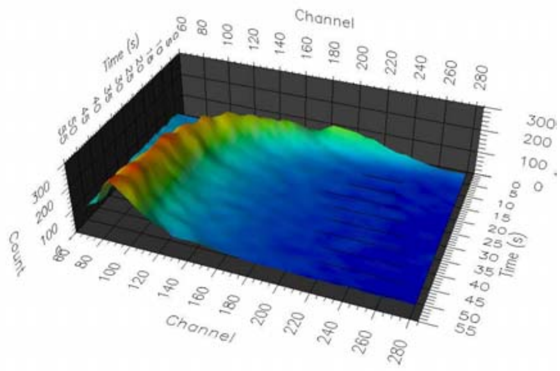

Figure 4. Experimental results in two-dimension plot for counting rate of 1 230 Hz.

The fitted function and the corresponding residues are shown in Figures 5 and 6. The residues being defined by

$$R(x,t) = \frac{F(x,t) - y(x,t)}{s(x,t)} \tag{4}$$

where $y(x,t)$ is the counts in “channel” (x,t).

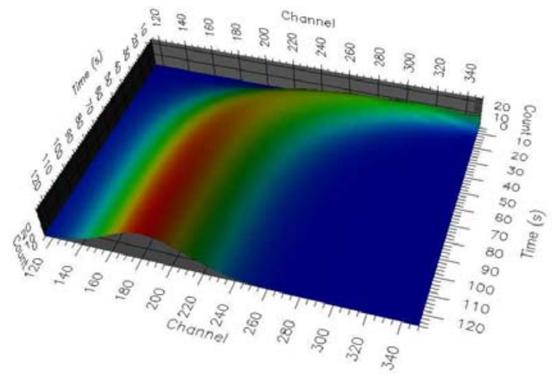

Figure 5. Fitted function in two-dimension plot for the counting rate of 270Hz.

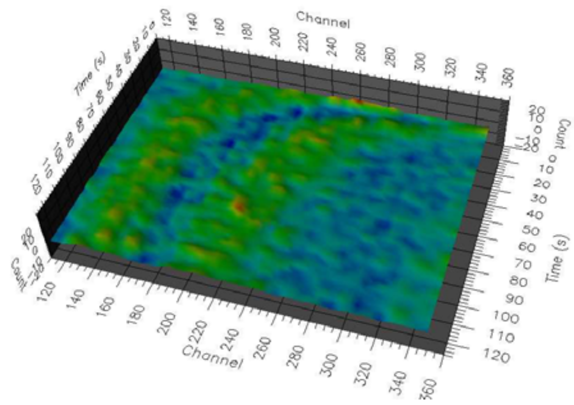

Figure 6. Residues for the fitted function in two-dimension plot for the counting rate of 270Hz.

TABLE 1. Parameters obtained by least squares fit of data to the function of Eq. 1.

Parameter	219 Hz	270 Hz	400 Hz	1230 Hz
$x_0 \cdot 10$	21.9(5)	18.30(5)	14.900(20)	8.44(3)
$a_1 \cdot 10$	37(19)	42(6)	34(3)	23.5(3)
a_2	98(9)	108(7)	92(3)	91.0(20)
b_1	0.21(6)	0.31(3)	0.370(20)	0.577(11)
$b_2 \cdot 10^{-1}$	0.21(5)	0.51(3)	0.515(16)	0.910(20)
s_0	21.3(6)	20.20(20)	21.31(12)	20.18(15)
$s_1 \cdot 10$	9(8)	8(3)	22(4)	3.69(10)
s_2	0.16(7)	0.26(4)	0.52(4)	0.137(5)
$A \cdot 10^2$	4.2(4)	12.0(12)	31(3)	120(12)
C	3	2	2	2
χ^2	1.7	0.57	0.88	5.6

The resulting fitting parameters (adjusted by least squares minimum method) obtained for rates range from 219 Hz up to 1 230 Hz are summarized in Table 1 (assuming A = constant). The time decay constants, t_1 and t_2, extracted from these data are plotted in Figs. 7 and 8 as a function of counting rate. The analysis of these curves evidences the decrease of time constants with the increasing rates, what is in accordance with previous results[8].

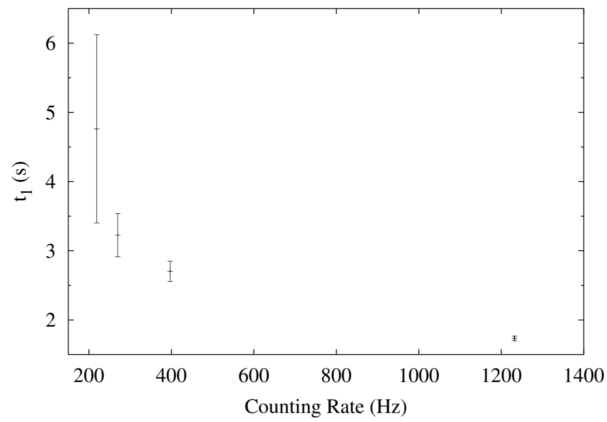

Figure 7. Time decay constant for $t_1 = 1/b_1$.

5 Conclusion

Even though these results are preliminary, they have been shown that is possible to apply the fitting procedure described in this work to study the transient behaviour of resistive detectors. It is important to stress that in our method the running time for the fitting is lower than that spent in conventional one (as detailed in refs. [6, 7, 8]), since it treats all the data simultaneously, giving all parameters needed.

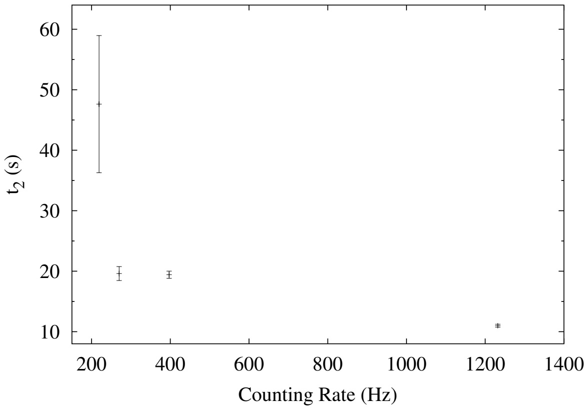

Figure 8. Time decay constant for $t_2 = 1/b_2$.

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