# Stabilization of the operating point of the ARGO-YBJ Resistive Plate Chambers

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**Abstract:** The ARGO-YBJ detector is located at Yang Ba Jing (P.R. China), at 4300 m a.s.l. and atmospheric depth of 606 g/cm$^2$. The Resistive Plate Chambers (RPCs) of the ARGO-YBJ detector are operated with a three-component gas mixture ($C_2H_2F_4$/Ar/i$C_4H_{10}$=75/15/10) in streamer mode at a constant applied voltage of 7200 V, at room temperature and atmospheric pressure. However, at constant applied voltage the gas gain is a function of the gas density, depending specifically on the temperature and the atmospheric pressure. By using a test stack of RPCs placed nearby the main ARGO carpet, the effective voltage in the RPC gas gap is controlled by exploiting the monitoring of the environmental parameters provided by the ARGO detector control system. The goal of this study is to develop a reliable procedure for the stabilization of the gas gain in the RPCs of the ARGO detector.

**Keywords:** Gaseous detector, Resistive Plate Chamber, environmental parameters

## 1 Introduction

The ARGO-YBJ experiment [1] has been running almost uninterruptedly with its complete layout since October 2007. The stable behaviour of the detector, a full-coverage array of Resistive Plate Chambers (RPCs) covering a surface of 74 $\times$ 78 m$^2$ surrounded by a guard ring, allowed this. Nevertheless, the work to optimize the stability of the experimental setup is still going on. The monitoring information provided by the Detector Control System (DCS) is crucial in this respect. The recorded daily and seasonal changes of temperature and barometric pressure affect the density of the gas mixture inside the detector and consequently its behaviour, in particular the time resolution and, to a lesser degree, the efficiency [2]. The aim of this study is to plan a straightforward procedure in order to equalize and possibly stabilize the detector response.

## 2 Operating voltage of the ARGO-YBJ RPCs

As reported in previous works, the gas gain in RPCs depends on the environmental conditions, namely on the local temperature and barometric pressure [3]. If $V_{app}$ is the fixed applied voltage when the measured absolute temperature is $T$ and the measured barometric pressure is $p_0$, then the effective voltage, if the reference absolute temperature and barometric pressure are chosen to be $T_0$ and $p_0$ respectively, is

$$V_{eff} = V_{app} \frac{T}{T_0} \frac{p_0}{p} \tag{1}$$

This means, for instance, that a temperature increase or a pressure decrease at fixed applied voltage are equivalent to an increase of the applied voltage at constant temperature and pressure.

The strategy for correcting this effect follows immediately. Standard operating conditions for the ARGO-YBJ RPCs correspond to applied voltage $V_0$ at absolute temperature $T_0$ and barometric pressure $p_0$. Accounting for the fact that the effect of temperature changes affects the ARGO-YBJ RPCs with a delay of about one hour [4], the applied voltage at a generic time $t$ can be set according to the following rule:

$$V_{app}(t) = V_0 \frac{T_0}{p_0} \frac{p(t)}{T(t-1h)} \tag{2}$$

This algorithm is meant to stabilize the gas gain inside the RPCs, so that the detector can always work at constant operating conditions. However, it must always be kept in mind that this procedure only concerns the gas gain in the RPCs, and does not account for possible further effects connected to temperature changes in the whole acquisition chain.

## 3 Testing and monitoring facility at the ARGO-YBJ site

A small-size cosmic-ray telescope was installed close to the South side of the ARGO-YBJ carpet as a monitoring and testing facility for the RPCs. It has been already used to study the dependence of the detector efficiency and time resolution on the monitored temperature [2]. For the present study the cosmic-ray telescope has been slightly modified, and its basic layout is shown in Fig. 1.

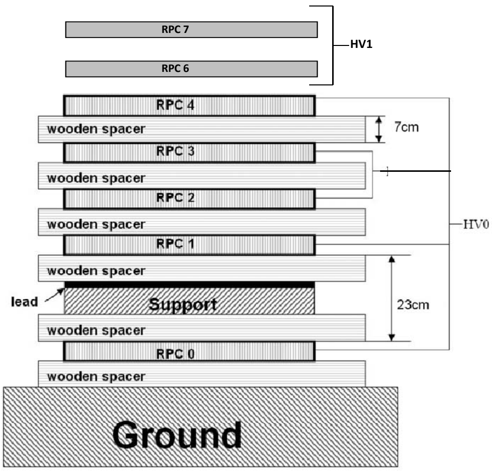


Figure 1: Layout of the cosmic-ray telescope located by the ARGO-YBJ RPC carpet.

This telescope is connected to the general ARGO-YBJ acquisition system, so its data are recorded according to the standard trigger condition on the ARGO-YBJ carpet. Therefore, the analysis on the telescope must be performed with an off-line procedure. Cosmic-ray tracks are tagged by a coincidence of chambers 0, 1 and 4. These three chambers, together with chambers 2 and 3, are powered at 7200 V which is the standard voltage applied to the RPCs in the ARGO-YBJ carpet. The telescope has been running since 2008, using chambers 2 and 3 as the test chambers. The effect of the varying environmental conditions could be studied in detail.

Figure 2 shows the time evolution between January and July 2010 of the time resolution as obtained from the measurement of the time of flight between chambers 2 and 3(upper plot) and the average efficiency of chambers 2 and 3 (lower plot).

If we consider the time evolution of the effective voltage in the same time interval, as shown in Figure 3, a clear correlation with the trends shown in Figure 2 is evident: an increase of the effective voltage always leads to slightly greater efficiency and lower time jitter for the RPC response.

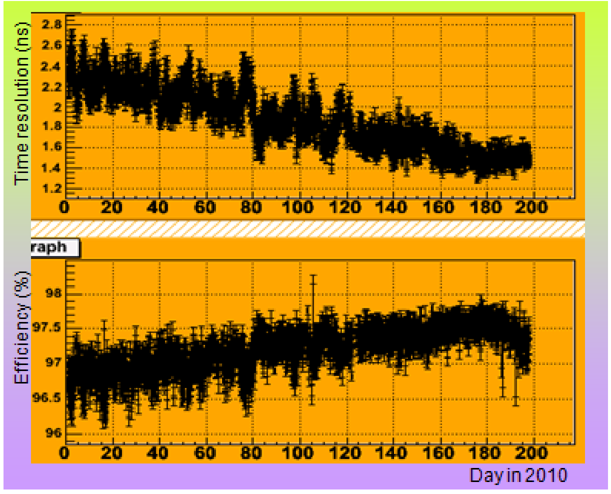


Figure 2: Time evolution (January-July, 2010) for the average efficiency of chambers 2, 3 and the time resolution as derived from the time of flight between chambers 2 and 3.

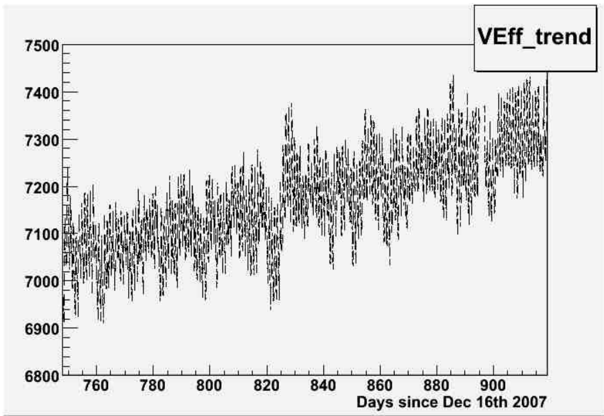


Figure 3: Time evolution (January-July, 2010) for the effective voltage acting on the test RPCs of the cosmic-ray telescope. The reference temperature and barometric pressure have been set to $T_0 = 288.65$ K and $p_0 = 600$ mbar respectively.

With respect to the previous telescope layout, chambers 6 and 7 have been added to the stack for this test. These two chambers are powered according to the algorithm described previously in Eq. 2. This way, a continuous comparison can be made between a “standard” behaviour in which the applied voltage is left unchanged and a “corrected” behaviour in which the applied voltage is suitably regulated to compensate the gas-gain changes. It is necessary to point out that the trigger configuration of the telescope, as described previously, is not optimized for the geometrical acceptance of the two added chambers. Therefore every efficiency measurement performed on chambers 6 and 7 will actually give a value of the efficiency times the geometrical acceptance. However, this is not a crucial issue in this test. The reference values for the absolute temperature and the barometric pressure are chosen to be close to the yearly average values provided by the monitoring system (DCS), namely $T_0 = 288.15$ K and $p_0 = 600$ mbar.

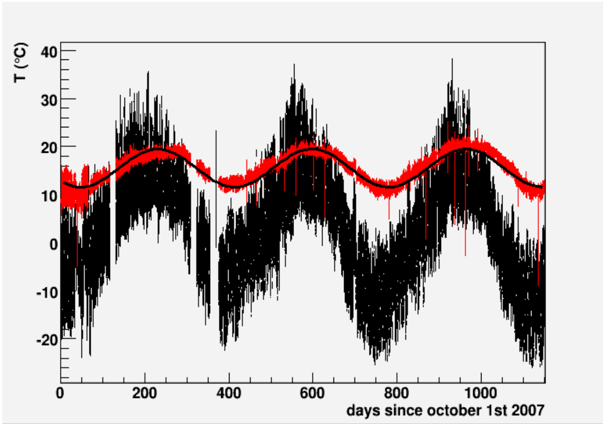


Figure 4: Time trend of the temperature monitored at the ARGO-YBJ experimental site, both outside (black) and inside (red), since the start in October, 2007. The yearly average value of the inner temperature is 15.5 °C
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Figure 4 shows the time evolution of the temperature at the ARGO-YBJ experimental site. In particular, the temperature inside the experimental hall shows a 1-year period with average value equal to 15.5 °C.

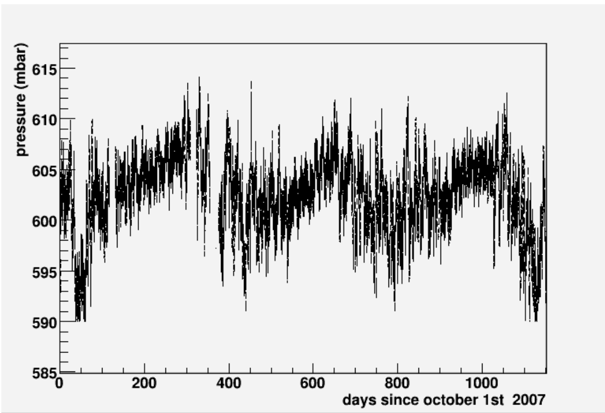


Figure 5: Time trend of the barometric pressure monitored at the ARGO-YBJ experimental site since the start in October, 2007. The yearly average value is about 600 mbar.

Figure 5 shows the time evolution of the barometric pressure at the ARGO-YBJ experimental site. It shows a 1-year period with average value about 600 mbar.

The DCS, which includes all the monitoring and control procedures of the ARGO-YBJ experiment, must act at regular time intervals so that the voltage change to be applied each time is not greater than a few Volts. In this test, the time interval was chosen to be 15 minutes.

The complete high-voltage control algorithm also includes safety checks: for instance, the "new" voltage to be applied is used only if it is close enough to the previous applied voltage, to avoid critical mistakes induced by possible failures in the read-out of the environmental sensors. In addition, limits on the current absorbed by the power supply are set, so that the detectors are protected against any possible dangerous increase of current.

## 4 Implementation of the high-voltage control on the test facility

The voltage-control procedure on the chambers 6, 7 in the cosmic-ray telescope started on January 12th, 2011. The behaviour of these two chambers immediately before and immediately after this was compared.

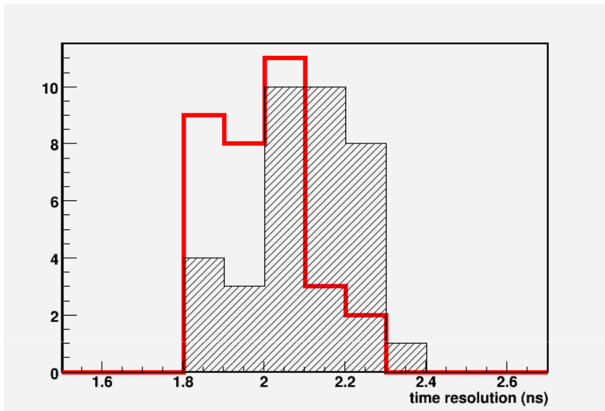


Figure 6: Distribution of the RPC time resolution as derived from the measurement of the time of flight between chambers 6 and 7. The black distribution refers to January 9-12, 2011, with a r.m.s. of 133 ps. The red distribution refers to January 12-15, 2011, with a r.m.s. of 98 ps.

Figure 6 shows the distributions of the time resolution obtained from the measurement of the time of flight between chambers 6 and 7, for the period January 9-12, 2011 (shaded) and for the period January 12-15, 2011. The voltage-control procedure led to a significant decrease in the r.m.s. of the distribution, which went from 133 ps to 98 ps.

Figure 7 shows the distributions of the average efficiency times the geometrical acceptance for chambers 6 and 7, for the period January 9-12, 2011 (upper, black) and for the period January 12-15, 2011 (lower, red). The voltage-control procedure led to a significant narrowing of the distribution: the r.m.s. went from 1.1 % to 0.5 %.

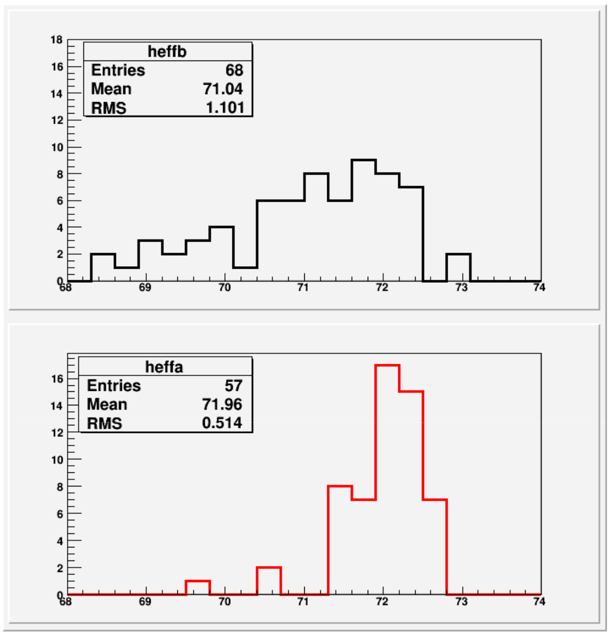


Figure 7: Distribution of the RPC efficiency times acceptance (in %) for chambers 6 and 7. The black distribution refers to January 9-12, 2011, with a r.m.s. of 1.1 %. The red distribution refers to January 12-15, 2011, with a r.m.s. of 0.5 %.

## 5 Conclusions

This test leads to the following conclusions:

- Before starting the voltage-control procedure, the efficiency times the geometrical acceptance of the chambers 6 and 7 varied between 67 % and 73 % with a r.m.s. greater than 1 %. The time resolution obtained from the measurement of the time of flight between the RPCs 6 and 7 varied between 1.8 ns and 2.5 ns with a r.m.s. of 133 ps.

- After applying the voltage-control procedure, the efficiency times the geometrical acceptance of the chambers 6 and 7 varies between 70 % and 72.5 % with a r.m.s. about 0.5 %. The time resolution obtained from the measurement of the time of flight between the RPCs 6-7 varies between 1.8 ns and 2.2 ns with a r.m.s. of 98 ps .

It must always be kept in mind that the measured time resolution of Resistive Plate Chambers is related to the following main effects:

- intrinsic time resolution of each RPC;

- time spread due to the angular distribution of the tracks with respect to the vertical direction (although this is somehow limited by requiring that the track crosses only corresponding vertical pads);

- time spread due to the different propagation times of the signals in strips on different layers due to non-vertical tracks;

- Time spread due to the jitter introduced by the whole acquisition chain.

The voltage regulation under study acts only on the RPC intrinsic time resolution. However, the effect of the voltage-control procedure is therefore visible in spite of the reduced spread of the operating parameters (efficiency times geometrical acceptance, and time resolution). The applied correction leaves a residual spread on the time resolution. This can be explained because this parameter is connected not only to the intrinsic time resolution of the detector, as explained previously.

The positive result of this study is promising towards the final goal of extending the voltage-control procedure to the whole ARGO-YBJ detector.

## 6 Acknowledgements

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