

# Temperature effects on RPC performance in the ARGO-YBJ experiment

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**Abstract.** The ARGO-YBJ experiment has been taking data for more than 2 years. In order to monitor continuously the performance of the Resistive Plate Chamber detectors and to study the daily temperature effects on the detector performance, a cosmic ray muon telescope was setup near the carpet detector array in the ARGO-YBJ laboratory. Basing on the measurements performed using this telescope, it is found that, at the actual operating voltage of 7.2 kV, the temperature effect on the RPC time resolution is about  $0.04 \text{ ns}/^\circ\text{C}$  and that on the particle detection efficiency is about  $0.03 \text{ \%}/^\circ\text{C}$ . Basing on these figures we conclude that the environmental effects do not affect substantially the angular resolution of the ARGO-YBJ detector.

**Keywords:** RPC, time resolution, efficiency

## I. INTRODUCTION

The ARGO-YBJ experiment, located at Yangbajing, Tibet, China, at an altitude of 4300m a.s.l is mainly designed for the observation of gamma ray sources at energies from a few hundreds GeV to some tens of TeV [Ref. 1, 2], gamma ray bursts and cosmic ray showers with energy up to the PeV. In order to detect Extensive Air Showers (EAS) with a high angular resolution, a full coverage Resistive Plate Chamber (RPC) array (see Fig.1) is implemented in the experiment. The array consists of 153 clusters of 12 RPCs each. Every RPC has 80 strips ( $6.75 \times 61.80 \text{ cm}^2$ ) to collect induced charges when particles pass through. The chambers work in streamer mode with a gas mixture of  $\text{C}_2\text{H}_2\text{F}_4/\text{Ar}/i - \text{C}_4\text{H}_{10} = 75/15/10$  and a voltage of 7.2 kV applied to the 2 mm gas gap. The signals from the strips are digitized using purposely designed front-end electronics [Ref. 3] and strips are OR-ed in groups of 8 as a single output channel (referred to as a pad) providing timing and position information for the particles. Time resolution and particle detection efficiency are the crucial quantities to be measured for the evaluation of the ARGO-YBJ detector performance. It is well known that the "knee" voltage varies with the temperature due to the change in gas density related to a change in the environmental parameters. This correlation was extensively studied also in Ref. 4, 5, 6. In order to study the temperature effects on the ARGO-YBJ detector, we built a multi-layer telescope using five RPCs near the ARGO-YBJ

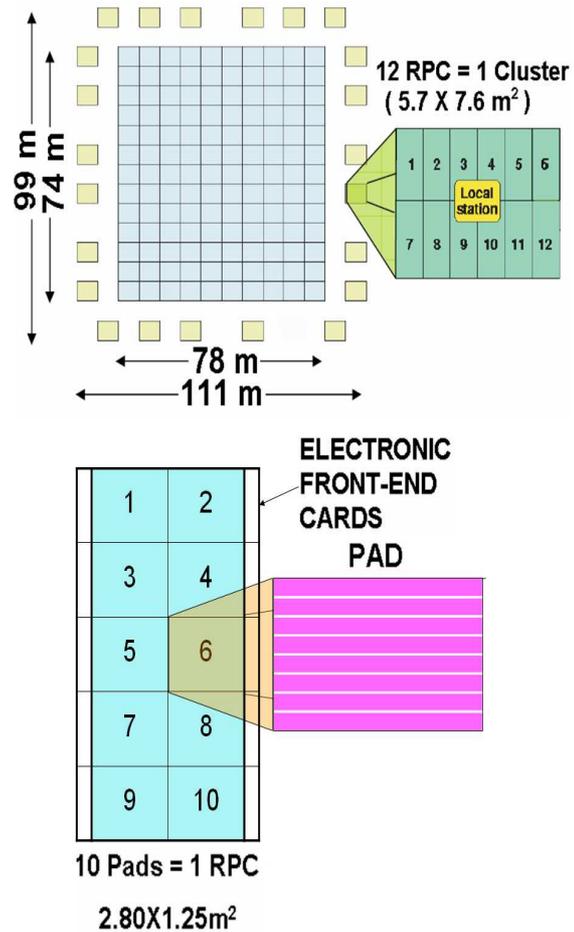


Fig. 1: Layout of the ARGO-YBJ experiment

array, which constantly monitors the efficiency and time resolution by using cosmic ray muons.

## II. APPARATUS

The telescope (see Fig. 2) is constructed by stacking five RPCs on top of each other with a layer of walking floor (8 cm thick plastic foam and a 0.05 cm thin steel sheet used as a support for the 0.5 cm thick lead plates as screening material). The RPCs used in the monitor telescope have the same structure and gas mixture as those used in the ARGO-YBJ array [Ref. 7] with a gas flow of 4 volumes/day. The event trigger for the monitor telescope is provided by the air-shower trigger

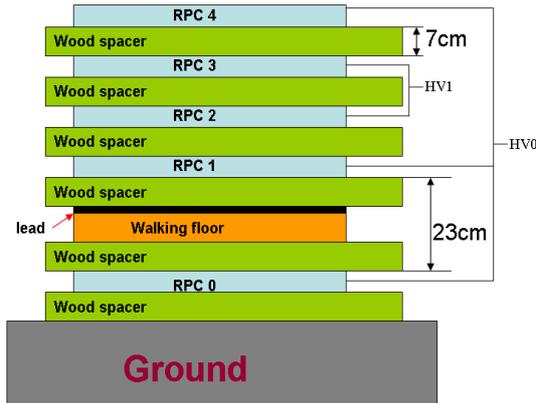


Fig. 2: Configuration of the telescope. HV0 and HV1 are independent high voltage channels

of the central ARGO-YBJ carpet, and the data from the telescope is merged into the main data acquisition (DAQ) stream as for any other cluster in the array. The detectors are numbered as in Fig. 2. The chambers RPC0, RPC1 and RPC4 are used to select vertical cosmic ray muons through a coincidence of their signals within 20 ns. RPC2 and RPC3 are supplied by a separate high voltage channel (HV1) respect to that of RPC0, RPC1 and RPC4 (HV0). The signals from RPC2 and RPC3, triggered by the coincidence signal, are used to estimate the detection efficiencies. The single-chamber time resolution is also estimated by measuring the time of flight of particles between RPC2 and RPC3, according to the procedure described later. The laboratory temperature is measured by sensors with an accuracy of  $\pm 0.25^\circ\text{C}$ , placed at different locations, and recorded using the Detector Control System (DCS) of the ARGO-YBJ experiment [Ref. 8]. The sensor closest to the telescope is used for the analysis in this paper.

### III. EXPERIMENT AND RESULTS

The events for the telescope test were selected by requiring a vertical alignment of fired pads on layers RPC0, RPC1 and RPC4 for the efficiency measurements (checking the hits on the corresponding superimposed pads of RPC2 and RPC3), and on all the five layers for the time resolution measurements. The distribution of the time of flight between RPC2 and RPC3 is used to estimate the time resolution of the ARGO-YBJ carpet. In Fig. 3 a typical experimental time of flight distribution at an applied voltage of 7.2 kV is shown. Here the bin width of 1.042 ns is the TDC clock period. The same pad of the two detectors was chosen for this measurement. It should be stressed that the distribution shown in Fig. 3 does not account only for the detector time jitter, but also for the jitters of the whole electronics chain from the front-end boards up to the TDC recording the time of each hit. The Gaussian fit to the distribution in Fig. 3 gives about 2.5 ns for its sigma. However, the corresponding  $\chi^2$ -test gives a probability as small as  $10^{-4}$  which is dominated by the non-Gaussian dis-

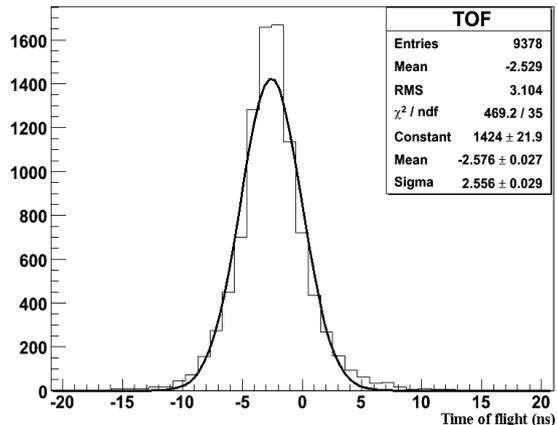


Fig. 3: Experimental distribution of the time of flight between RPC2 and RPC3 on one pad, at an applied voltage of 7.2 kV. The distribution shows a narrow peak and relatively long tails which are not well fitted by a single Gaussian distribution as displayed in the figure.

tribution tails. In order to estimate the peak width in an unbiased way we used the width of the interval containing 68 % of all events around the peak. The single-detector time resolutions reported in the following are given by the relation  $\sigma = (68\% \text{width}) / 2\sqrt{2}$ , which takes into account that the overall jitter is determined by the resolutions of both the detectors used for the time-of-flight measurements. The results reported here concern only the two chambers under test. It should be stressed however that these results show effects that are typical for the whole ARGO-YBJ detector.

#### A. Monitoring of the detector performance

The telescope described above enables a continuous monitoring of the ARGO-YBJ carpet detectors (operating at the same 7.2kV high voltage supply). Between operational day 198 and day 210 of year 2008, the temperature inside the laboratory changed between 18-19  $^\circ\text{C}$  and 25-27  $^\circ\text{C}$  with a daily period. As a consequence of the temperature effect, the efficiency and time resolution of the detector changed correspondingly. It has already been shown [Ref. 9] that the correlation between the RPC performance and the room temperature is maximum if a delay of about 78 minutes is accounted for. This delay is taken into account in all the reported results. In Fig. 4 (a), (b) and (c), respectively, the single-chamber time resolution and the particle detection efficiency of both test chambers are plotted as a function of the operational time. The monitored room temperature is also shown in Fig. 4 (d). The duration of all measurements is about one hour. The efficiency is measured by averaging over 2 chambers, while the time resolution is obtained from the time-of-flight distribution on a specific pad number of the two test chambers, as previously mentioned. Using all the data taken in that period, the particle detection efficiency for RPC2 and RPC3 (Fig. 5 (a) and (b), respectively) and the single-chamber time resolution

(Fig. 5 (c)) are found to be well correlated with the room temperature (with a 78 minutes temperature time shift applied). In order to account for the accuracy of the temperature measurements, in this correlation study the experimental data were grouped in temperature bins of  $0.5^\circ\text{C}$ . Therefore, each efficiency point corresponding to a given temperature bin is obtained as the weighted average of the efficiency measurements within this bin, and the straight line correlation fit was performed by using the weighted least squares method. Concerning the single-chamber time resolution, the value corresponding to a given temperature bin was obtained as the simple average of the time-resolution measurements within this bin, and the straight line correlation fit was performed by using the basic least squares method. The resulting expressions are:

- $\text{RPC2 efficiency}(\%) = (0.040 \pm 0.002) \times (T(^{\circ}\text{C}) - 20) + (97.84 \pm 0.01)$
- $\text{RPC3 efficiency}(\%) = (0.030 \pm 0.002) \times (T(^{\circ}\text{C}) - 20) + (97.85 \pm 0.01)$
- $R_t(\text{ns}) = (-0.045 \pm 0.002) \times (T(^{\circ}\text{C}) - 20) + (1.59 \pm 0.01)$

where  $12^{\circ}\text{C} \leq T \leq 24^{\circ}\text{C}$ .

For a typical daily temperature variation of  $6^\circ\text{C}$  in summer the time resolution changes by  $0.2\text{ ns}$  and the efficiency by  $0.2\%$ . On average, if the annual thermal excursion is considered, the overall excursions of the single-chamber time resolution and efficiency of the ARGO-YBJ detector are approximately  $0.4\text{ ns}$  and  $0.3\%$  respectively.

The effect of the temperature dependency of the time resolution on the angular resolution of the ARGO-YBJ experiment was studied with the CORSIKA software package simulating atmospheric cascades generated by primary protons, and selecting the events with  $N_{pad} \leq 500$ , as shown in Fig. 7. It can be seen that the typical daily variation of  $0.4\text{ ns}$  in time resolution (in the range between  $1$  and  $2\text{ ns}$ ) corresponds to a daily change of  $0.06^\circ$  in the angular resolution [Ref. 10]. These uncertainties are small compared with a typical angular resolution of about  $0.5^\circ$  and the particle detection efficiency of about  $98\%$  for the RPCs in the experiment.

#### B. check of the pressure effect

To check possible effects due to the atmospheric pressure changes we studied the time resolution measurements in different conditions of temperature and pressure, as shown in fig.6. In fig.6(a) the time resolution seems to show a dependence from the atmospheric pressure similar to that found for the temperature in fig.5(c). On the other side, temperature and atmospheric pressure are not independent variables. To figure out which one is the dominant factor that causes the detector performance shift, we plot the atmospheric pressure vs. time resolution (fig. 6 (b)) with fixed temperature ( $16^{\circ}\text{C} \leq T \leq 17^{\circ}\text{C}$ ) and the temperature vs. time resolution (fig. 6 (c)) with fixed atmospheric pressure ( $602\text{mb} \leq P \leq 603\text{mb}$ ).

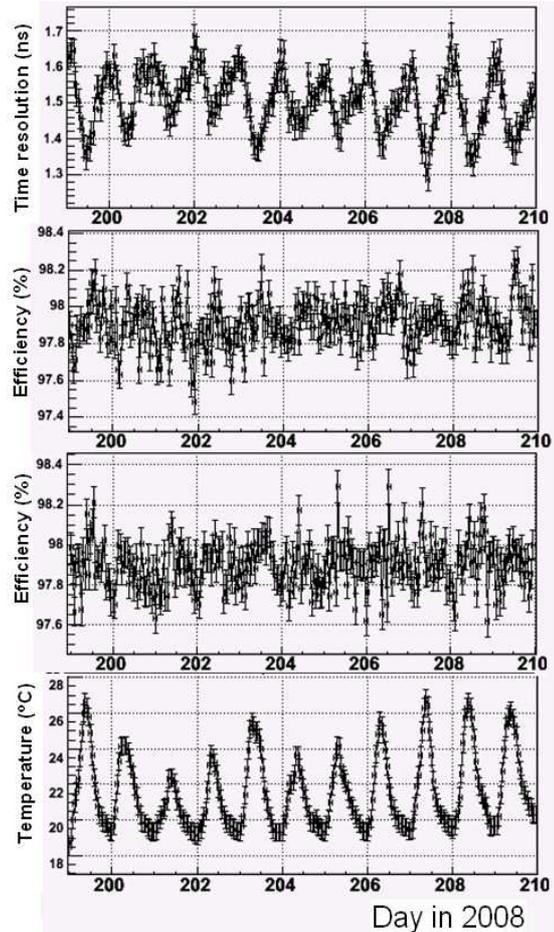


Fig. 4: Monitoring over 12 days of the room temperature inside the ARGO-YBJ hall, compared with the monitoring over the same period of the single-chamber time resolution as obtained from the time-of-flight measurement (a), the RPC2 (b) and RPC3 efficiency (c) and the room temperature (d)

In fig.6(b) (where the temperature is the same for all the measurements) any correlations between time resolution and atmospheric pressure is noticeable, while in fig.6(c) the same behaviour as in fig.5(c) is shown. We may conclude that the temperature is the dominant environment factor that affects the detector performance.

#### IV. CONCLUSIONS

At the Yangbajing laboratory,  $4300\text{m a.s.l.}$ , we monitored the variations of the RPC detection efficiency and time resolution with respect to the temperature at the preset working point of  $7.2\text{ kV}$ . RPCs show a slight improvement in efficiency and time resolution at higher temperature, as expected. We found linear correlations of those variables with the temperature. For daily temperature variations of about  $10^\circ\text{C}$  in the laboratory, the efficiency changes are only about  $0.3\%$  and those of the time resolution about  $0.4\text{ ns}$ . These variations do not affect substantially the ARGO-YBJ carpet performance.

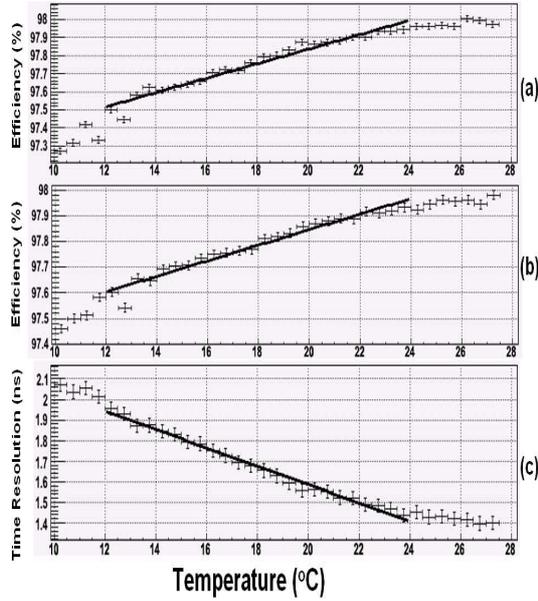


Fig. 5: Correlation plots of the RPC2 (a) and RPC3 efficiency (b) and of the single-chamber time resolution as obtained from the time-of-flight measurement (c) versus the room temperature. In these plots the data were grouped in temperature bins of  $0.5\text{ }^{\circ}\text{C}$  in order to account for the measurement accuracy.

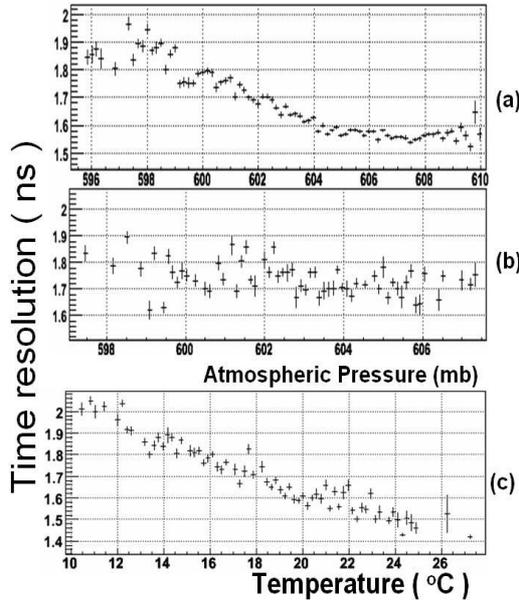


Fig. 6: Time resolution vs. atmospheric pressure (a) and time resolution vs. atmospheric pressure with fixed atmospheric temperature (b) and time resolution vs. temperature with fixed atmospheric temperature (c)

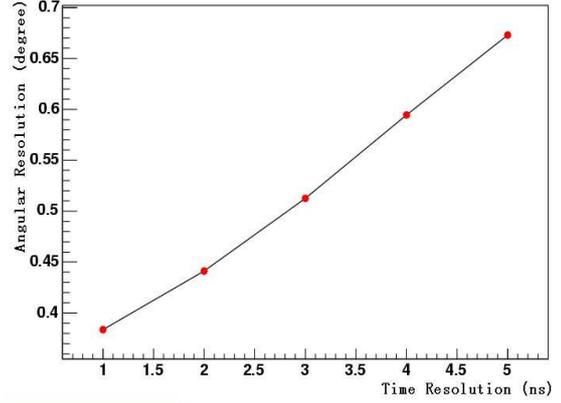


Fig. 7: Angular resolution vs. time resolution

## V. ACKNOWLEDGEMENTS

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