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Control and monitoring of the ARGO-YBJ detector

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The ARGO-YBJ Detector Control System (DCS) is designed to control and monitor the most significant operational parameters of the experiment, related both to the detector and to the environment. Beyond monitoring the stability and the reliability of the detector operation, the DCS is also sensitive to sudden current changes in the RPCs, induced by high density air showers. The control procedures are described, and the dependence of the RPC currents on the environmental parameters is presented.

1. Introduction

The Detector Control System (DCS) of the ARGO-YBJ experiment [1] was described in [2], where its main architectural and operational features were presented. At present (June 2005), 42 clusters (about 1/3 of the central carpet) have been installed, 16 of which have been operated and monitored for more than one year. The main purpose of the DCS is to guarantee the overall reliability and robustness of the system by controlling the high-voltage power supplies and monitoring the time trends of all the significant operational and environmental parameters. The ARGO-YBJ detector is a full-coverage array of Resistive Plate Chambers (RPC) [3] operated in streamer mode. The operating voltage is chosen so that the actual single-hit time resolution is about 1 ns. Continuous monitoring of the single RPC absorption current is crucial to guarantee the stability of the efficiency of every chamber and to check that the gas flow through each RPC is regular. In addition, constant monitoring may provide important support to the data analysis, mainly concerning sudden changes in the air-shower rate if an increase lasting longer than a few seconds is observed.

2. Details of the DCS implementation

The RPC high-voltage channels are powered by CAEN SY127 mainframes, which are controlled using a PC interface (CAEN A1303 PCI board) and a dedicated program developed in the LabVIEW environment [4]. This is meant to control the applied voltage and monitor both the output voltage and the absorption current on each high-voltage channel continuously. The single RPC absorption currents, the voltage powering the RPC electronics front-end boards and the local temperature are collected by a suitably designed multiplexer board on each cluster and recorded by a VME acquisition system, which also records the barometric pressure measured by a sensor placed in the center of the experimental hall.

A three-component gas mixture is used for the RPC operation, namely $C_2H_2F_4$/Ar/i-C_4H_{10} = 75/15/10. A fourth, strongly electronegative component, SF_6, will soon be added (with an overall concentration of a few per mil) in order to reduce the average streamer charge and therefore to increase the detector robustness by reducing one of its ageing factors. The gas mixture sent to the detector is monitored continuously using mass flowmeters with adequate accuracy. Moreover, the amount of residual gas in each bottle is checked by measuring the pressure for the Argon and the weights of the bottles containing the other gas components, which are compressed liquids inside the bottles.

To check the correct behavior of the RPC detectors, it is also necessary to monitor the count rates for each RPC chamber. This feature is about to be implemented in the DCS. The count rate of each RPC is provided by the fast logical OR of 10 pads, each one corresponding to $1/10$ of the active detector area. The fast OR is provided by the local trigger station [5] and translated into differential TTL signals. The count rates are recorded by PXI FPGA boards, each one implementing over 100 count-rate channels.

3. Alarms and warnings

The DCS of the ARGO-YBJ experiment is designed to monitor the following quantities:

1. the gap currents for each RPC, the voltage powering the RPC front-end electronics and receiver boards, the local temperature on each cluster and the barometric pressure in the experimental hall: these parameters are sampled every few seconds;
2. the applied voltage and the absorption current in every high-voltage channel;
3. the gas pressure for the Argon line and the bottle weights for the liquid gas bottles.

Beyond monitoring the correct operation of the detector, the DCS must provide a prompt and reliable feedback every time some anomalous behavior is detected. The most important occurrences for alarms, warnings and feedbacks are the following:

1. High-current alarm. This is issued whenever a chamber absorption current becomes higher than a safely established upper limit, e.g. 7 μA. In order to avoid potential damages to the chambers due to high current, the DCS starts a protection procedure by switching off the corresponding high-voltage channel.
2. Working-point stabilization. Changes in the barometric pressure and in the local temperature affect the density of the gas mixture, causing the RPC working point to change. In order to keep the working point stable, the applied voltage must be constantly updated according to the relationship $V\,T\,/\,p\;=\;V_0\,T_0\,/\,p_0$, where V is the voltage to be applied at absolute temperature T and barometric pressure p if the operating voltage is V_0 at reference temperature T_0 and barometric pressure p_0. This feedback will soon be introduced.
3. Low voltage alarm. This is issued whenever the low voltage powering the RPC electronics front-end boards has wrong values.
4. Empty-bottle alarm. This is issued whenever the Ar gas pressure becomes too low or the weights of the $C_2H_2F_4$ and iC_4H_10 bottles drop below a fixed lower threshold, implying that some of the gas components are about to be exhausted.

4. Continuous monitoring of the detector

The ARGO-YBJ DCS has been monitoring the first 16 clusters of the experimental setup for over one year. The time trends of the monitored parameters are crucial to check the correct behavior of the detector.

In Fig. 1 the time trend of the total gap current for the 16 RPC clusters (monitored every 6.5 seconds for over 3.5 hours) is shown. Sudden high spikes due to the detection of dense air showers are evident.

In Fig. 2 the time trend (for 13 days in August, 2004) of the average total gap current is shown. The daily changes related to the time trends of both the barometric pressure and the temperature inside the experimental hall are clearly seen. The trends of the pressure and the inner temperature over the same time span are

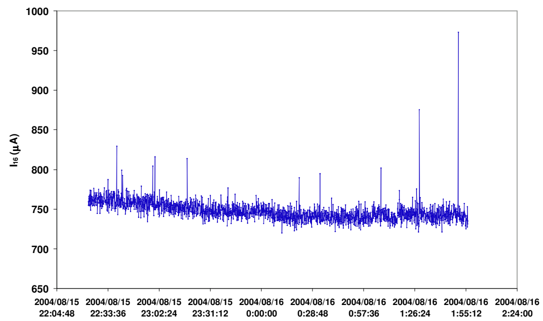

Figure 1. Time trend of the total gap current for 16 RPC clusters. The sampling time is 6.5 s. The plot refers to a 3.5-hour observation time. The spikes due to the detection of dense air showers are clearly seen.

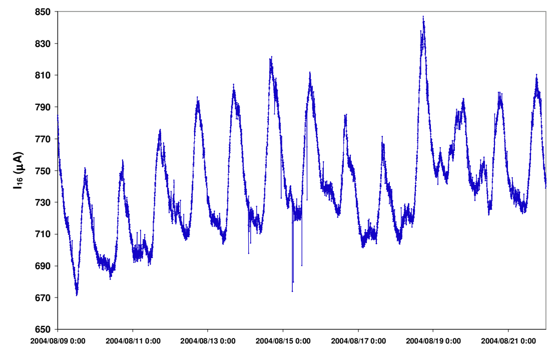

Figure 2. Time trend of the total gap current for 16 RPC clusters, averaged every 130 s, during a 13-day span in August 2004. Each point is the average of 20 measured values.

respectively shown in Fig. 3 and 4, where the typical daily trends of the two environmental parameters are seen.

These trends are crucial to correlate the RPC gap current with the local temperature at constant pressure, and with the barometric pressure at constant temperature. Examples of this type of analysis are shown in Fig. 5 and 6, where linear fits to the experimental points are also added. In the chosen conditions, the estimated differential changes of the gap current are about 3% / °C and -2% / mbar respectively.

5. Conclusions

The DCS of the ARGO-YBJ experiment provides continuous monitoring and control of all the relevant parameters which affect the detector operation. Its support to the data analysis will be increased very soon with the addition of the single RPC count-rate monitoring system.

References

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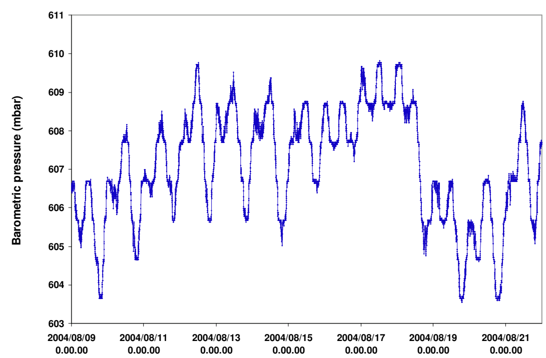

Figure 3. Time trend of the barometric pressure, averaged every 130 s, during a 13-day span in August 2004. Each point is the average of 20 measured values.

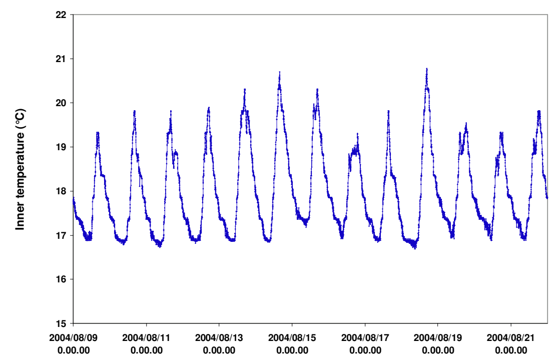

Figure 4. Time trend of the temperature inside the ARGO-YBJ experimental hall, averaged every 130 s, during a 13-day span in August 2004. Each point is the average of 20 measured values.

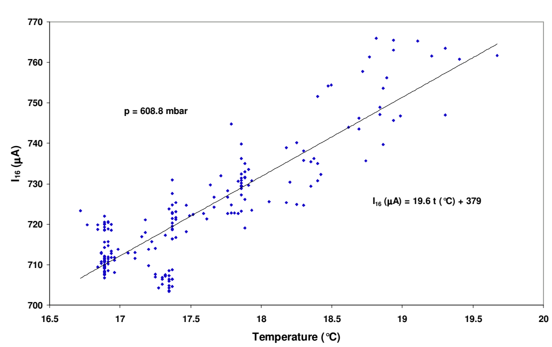

Figure 5. Correlation plot of the total current on 16 clusters versus the experimental hall inner temperature, both averaged every 130 s, at constant barometric pressure (608.8 mbar).

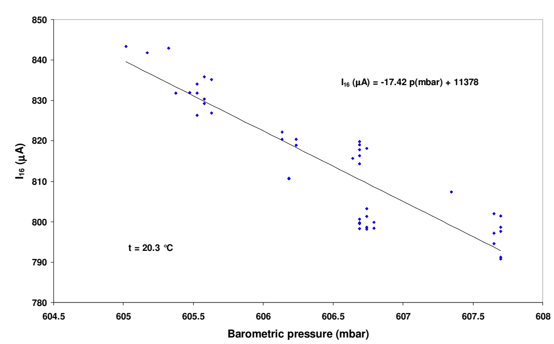

Figure 6. Correlation plot of the total current on 16 clusters versus the barometric pressure, both averaged every 130 s, at constant inner temperature (20.3 °C).