Characterization of the ACORDE scintillator counters using a PCI electronic card

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We present an automatic system for performing the characterization of plastic scintillator counters to be used by ACORDE (ALICE Cosmic Ray detector). This detector consists of a 120 scintillator counter array placed on the three top faces of the ALICE magnet. In order to characterize each of those detectors, an automatic system has been implemented, consisting of three main elements: a custom-made PCI electronics card, a standard high voltage power supply, and an automatic control program, running in a PC computer. The control system has been developed within the LabVIEW framework. The whole characterization system reaches the plateau, detector efficiency and the attenuation length of a scintillator counter in about 20 minutes.

Keywords: Scintillator counters; automatic system; PCI DAQ card.

Presentamos un sistema automático para caracterizar los centelladores que se usarán en ACORDE (Detector de Rayos cósmicos de ALICE). Este detector consta de un arreglo de 120 centelladores ubicados en las tres caras superiores del magneto de ALICE. Para poder caracterizar cada uno de los centelladores, un sistema automático ha sido desarrollado y consiste en una tarjeta PCI desarrollada específicamente para este propósito, una fuente de alto voltaje y una computadora. Un software de control ha sido desarrollado en plataforma LabVIEW. Este sistema obtiene el plateau, la eficiencia y la longitud de atenuación de un centellador en aproximadamente 20 minutos.

Descriptores: Contadores de centelleo; sistema automático; tarjeta de adquisición de datos PCI.

PACS: 96.50.S-; 29.40.Mc; 29.90.+r

1. Introduction

ALICE (A Large Ion Collider Experiment at CERN) is a general-purpose heavy-ion detector designed to study the physics of strongly interacting matter and the quark-gluon plasma in nucleus-nucleus collisions at the LHC [1]. The ALICE Cosmic Ray Detector (ACORDE) will provide the cosmic ray trigger (CRT), a level-zero trigger signal generated when atmospheric muons impinge upon the ACORDE scintillator array. This signal will be useful for the calibration, alignment and performance of several ALICE tracking detectors, mainly the TPC, TOF, TRD and HMPID. The cosmic ray trigger signal will be capable to deliver a signal before and during the operation of the LHC beam. The typical rate for single atmospheric muons crossing the ALICE Cavern will be less than 5Hz/m^2 [2]. ACORDE, together with some other ALICE tracking detectors, will provide precise information on cosmic rays with primary energies around 10^{15-17}eV [2]. The energy threshold of cosmic muons reaching the ALICE hall is approximately 17 GeV, while the upper energy limit for reconstructed muons will be less than 2 TeV, depending on the magnetic field intensity (up to 0.5T) [3].

ACORDE consists of an array of 60 counter modules placed on the top three faces of the ALICE magnet. The current layout of the cosmic ray trigger is shown in Fig. 1, covering the three upper faces, arranged perpendicular to the LHC beam.

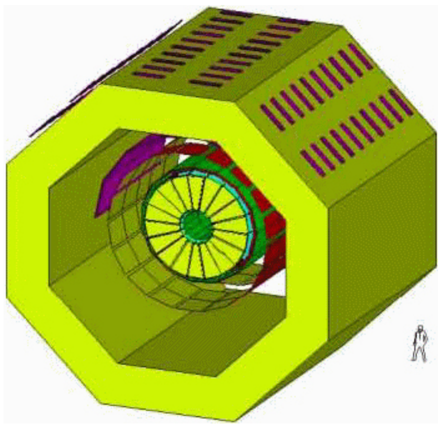

FIGURE 1. ACORDE scintillator array on top of the ALICE magnet.

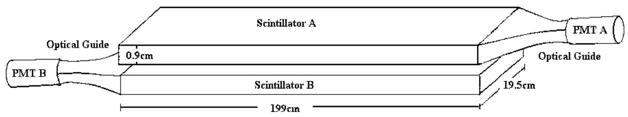

FIGURE 2. Dimensions of an ACORDE module, with two scintilator paddles, light guide, and PM tubes.

Each module consists of two scintillator counters with a 1.99 × 0.195 m^2 effective area, arranged in a doublet configuration. A doublet consists of two superimposed scintillator counters with their PMT located on the ending part of each plastic paddle, facing back to back (see Fig. 2).

In this paper we present a characterization method for analyzing the performance of the ACORDE modules. With this method, we automatically find the plateau region of the ACORDE PMTs, an estimation of the ACORDE detection efficiency, and the attenuation length of a scintillator counter in about 20 minutes. In what follows, we describe the automatic system implemented by this method. Then we present a performance test, the results and finally, some concluding remarks.

2. Automatic system

The automatic system is composed of:

i) a PC computer to control the entire characterization process,

ii) a PCI bus electronic card (called from now on a PCI-DAQ card) with a 10 LEMO connector input channel, specifically designed and developed to do this task,

iii) a 10 PMT analog signal [4], and

iv) a CAEN SY2527 high voltage power supply mainframe with a 12-channel HV card [5].

The software was developed within the LabVIEW framework. A block diagram of the general system is shown in Fig. 3.

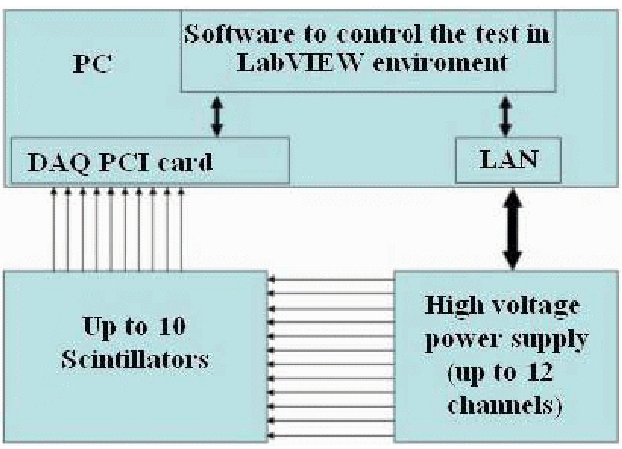

FIGURE 3. Block diagram of the general system to improve the characterization.

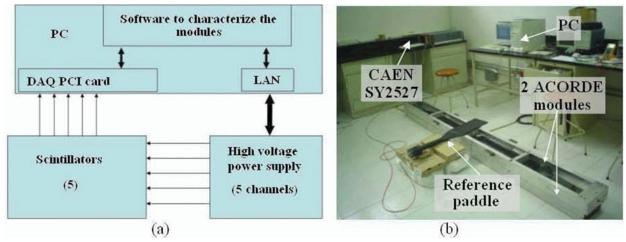

FIGURE 4. Experimental Setup. (a) Block diagram and (b) Photo, we can see 2 ACORDE modules, the reference paddle, the High voltage power supply CAEN SY2527 and the PC.

It is possible to control the CAEN SY2527 system remotely through a Local Area Network (LAN) connection. To set up the communication between this HV power supply and the PC, we use the default network node identification addressees, which means 192.168.0.2 and 192.168.0.1 IP addresses for the HV power supply and a PC, respectively [5]. We use standard communication software (CAENHVOPC-Server_2.7) between the power supply and the PC LAN port. A LabVIEW virtual device is created to operate this task.

Having installed the electronic card in a PCI slot and established the communication with the HV power supply, we were able to start the ACORDE module characterization procedure. The LabVIEW program operates independently to the high voltage of each of the 12 channels in the CAEN SY2527 system, while the PCI-DAQ card discriminates, counts, and executes several logic operations on the PMT input signals using an ALTERA FPGA chip.

We were able to find the plateau and detector efficiency of two ACORDE modules (four scintillator counters) at the same time (see Fig. 4b). The upper module contain scintillators A and B, while the module underneath contains scintillators C and D. Because of the long ACORDE scintillator, we used another scintillator counter (plastic E) with a small effective area (20cm × 20cm) to measure the module detector efficiency as a function of the longitudinal length. We measure the cosmic ray rate registered by scintillator counters A, B, C, D, in coincidence with scintillator E; at the same time we recorded the event rate for the OR and AND logic combinations from the two scintillator counters in an ACORDE module. The time window for coincidence between scintillator counters was 100ns. The experimental setup is shown in Fig. 4.

The automatic system receives 5 signals coming from scintillators A, B, C, D, and E. We use five channels of the CAEN SY2527 power supply to power the PMTs on each scintillator. The LabVIEW software controls the data acquisition, the duration of the characterization test, and the high voltage of each PMT.

2.1. PCI DAQ card

For the plateau and detector efficiency tests, we use 5 inputs of the PCI-DAQ card. Each signal coming from these inputs is applied to an individual discriminator and then the output of each discriminator is applied to a mono-stable circuit to produce a 40ns pulse; this pulse is sent to a counter chip. To set the voltage threshold through the computer, we included a 8-bit Digital to Analog Converter (DAC); the voltage threshold can be set between -150mV and 0V. The PCI-DAQ card has 6 counter chips with a maximum of 15000 counts and 4 counters with a maximum of 1000 counts. To read out the counter output, we implemented a state machine system to send counter data (one by one) to the computer. A block diagram of the PCI DAQ card is shown in Fig. 5.

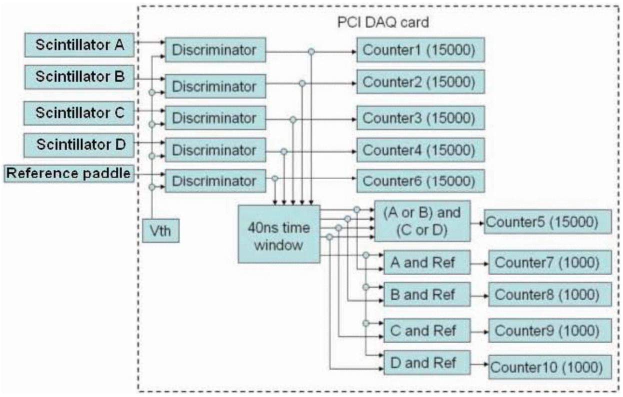

FIGURE 5. Block diagram of the PCI DAQ configuration.

FIGURE 6. Photo of the PCI DAQ card.

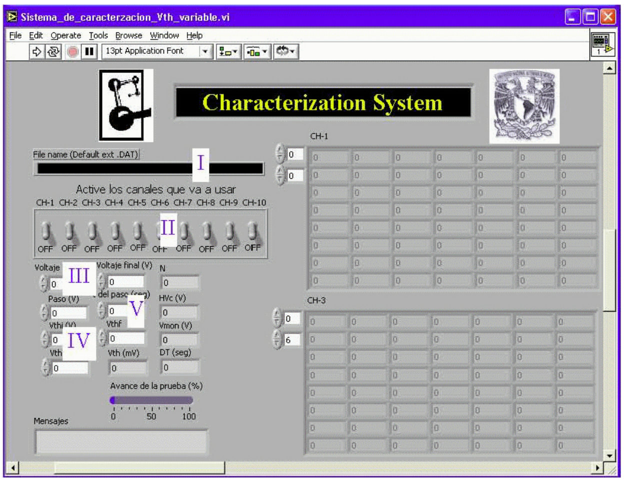

FIGURE 7. LabVIEW user interface.

To perform logical operations between PMT signals, we use an ALTERA EPC7256AETC144-5 FPGA. This FPGA is reprogrammable, so we can change the firmware, depending on the test requirements, or use it for other applications. The MAXIM MAX9203ESA discriminator that we use has a rise and fall time of 2ns, +/- 5mV hysteresis. The BURR-BROWN DAC7613 chip is a 12-bit DAC; but in the card we use only 8 bits so as to have a voltage resolution of 1 mV. With this device, we can set the voltage threshold between -150mV and 0V, with an accuracy of +/- 1 mV. A photo of this card is shown as Fig. 6.

2.2. Software to automate the characterization of the modules

A LabVIEW program was developed to configure and control the PCI-DAQ card and HV power supply through a LAN connection. The user interface is shown as Fig. 7.

This program offers the possibility of preparing each characterization run and changing the value of several input parameters. For each run, we are able to name the data file which stores the cosmic ray rate registered by an ACORDE scintillator module (see label I in Fig. 7). We can switch on or off any of the ten input channels from the PCI-DAQ card (Label II). It is possible to set the time period of the run; usually we chose 30-60 sec to accumulate enough cosmic ray data. Finally, to obtain a plateau curve, we measure the count rate at fixed PMT high-voltage value, in a wide high-voltage range. In our case, we cover a 1300-1600 voltage window, with a 50V step for each run. Also, because we are looking for the optimal voltage threshold of the PMT pulse signal, we run the test for different voltage threshold values. Here, we start from -30mV up to -10mV, with increasing of 5mV. Using this LabVIEW program, we set the time period, voltage threshold, high voltage, and the increasing step for those voltages to automatically obtain a data file with the result of the run. Then we plot the plateau curves reading this data file.

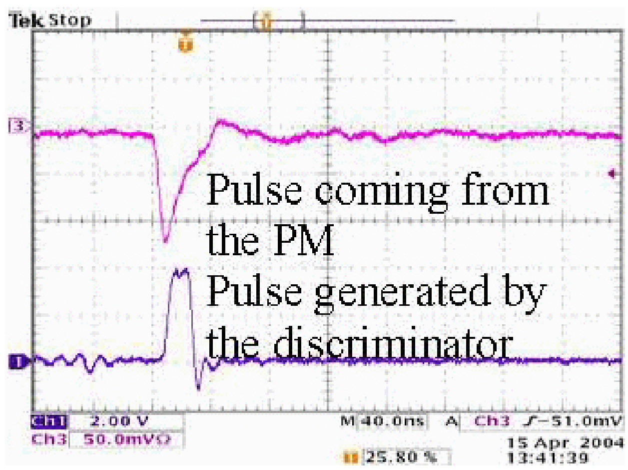

FIGURE 8. Discriminator test result.

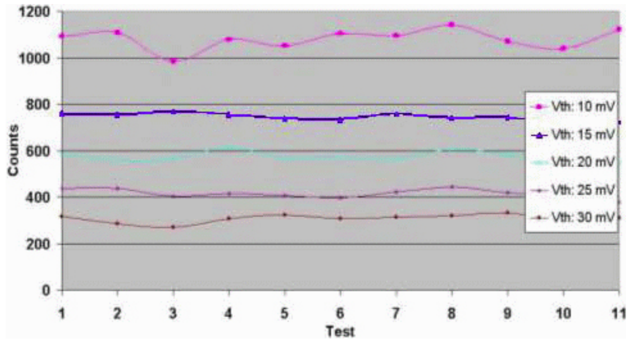

FIGURE 9. Counts of plastic E during each change of HV of the PMs contained in scintillators A, B, C and D.

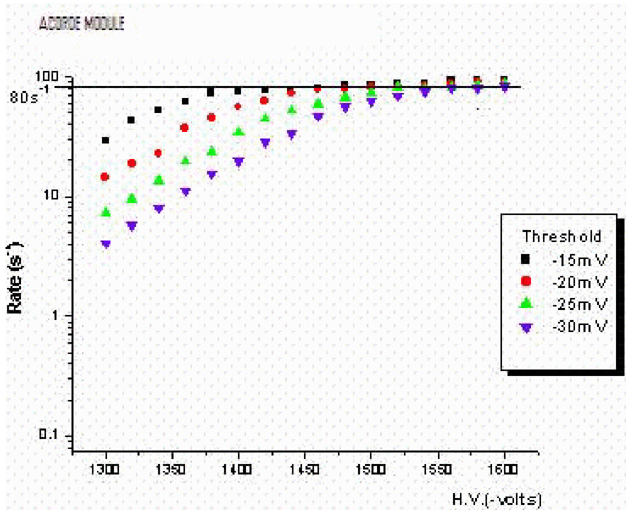

FIGURE 10. Rate vs. HV for different voltage threshold values.

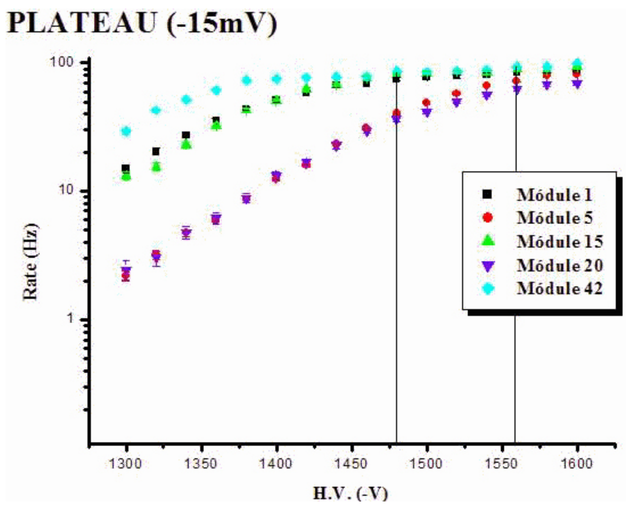

FIGURE 11. Plateau curves for a set of ACORDE module, at fixed threshold of -15mV. As we can see in this figure, some modules reach the plateau at 1550V (modules 5, 20) while other modules get their optimal voltage at lower voltage (1450V, for modules 1, 15, 42).

3. Performance test

To verify the performance of the MAXIM MAX9203ESA discriminator contained in the DAQ card, we applied a pulse coming from one of the ACORDE module PMT and we displayed the output signal generated by this discriminator (see Fig. 8) comparing it with the normal PMT pulse.

The test result shows a pulse with a 4V amplitude with a rise and fall time of 2ns, which is good enough for our application.

We can see from Fig. 9 that the count rate presents a small variation, proving the stability of the automatic system during the tests.

4. Test results

As we discussed in previous sections, we were able to characterize ACORDE modules using this automatic system. Here we present some results of this application.

4.1. Optimal operational voltage

Figure 10 shows the rate of one ACORDE module as a function of the PMT high voltage, for different PMT pulse height threshold voltages. The rate corresponds to the AND coincidence of the signals from PMT A and PMT B for a given threshold voltage. It is clearly seen that the optimal operational signal (plateau region) is reached at around 1500V for all thresholds. Because the sensitivity of the scintillator counter increases for lower threshold voltages, the rate is higher when we operate the module at low thresholds; however, we have to work at threshold values above the environment signal noise, which will be higher than 10mV at the ALICE hall place. To avoid this problem, we decided to fix a pulse height threshold of -15mV for all ACORDE modules. Figure 11 shows the plateau curves for a set of five modules. Here we can see that modules 1, 15 and 42 reach the plateau at 1450V, while modules 5 and 20 reach it at a higher voltage (around 1550 V).

4.2. Detector efficiency

In order to measure the efficiency of the modules, we took data at five positions along the ACORDE module. We triggered on vertical muons by using a scintillation hodoscope consisting of two plastic scintillation paddles, one placed above the module and the other below; the vertical separation between these paddles was 30 cm. In order to harden the muon spectrum and to get rid of low energy muons, we used a 1-inch steel slab just above the lower paddle. The trigger was given by the coincidence between the PMT signals from the two scintillation paddles within a time window of 40 ns.

The trigger signal was obtained at a rate of around 0.17 Hz by using the same electronics described above for the plateau measurement. As mentioned above, the overlap between the two scintillators is 188 cm. The first position

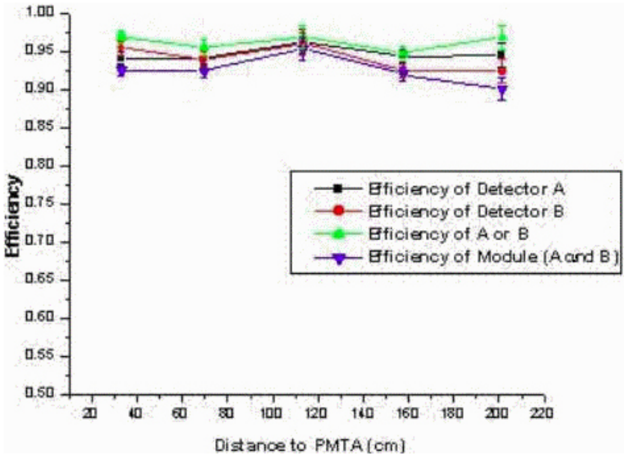

FIGURE 12. Detector efficiency along one ACORDE module, for several combinations between two scintillators, in a module.

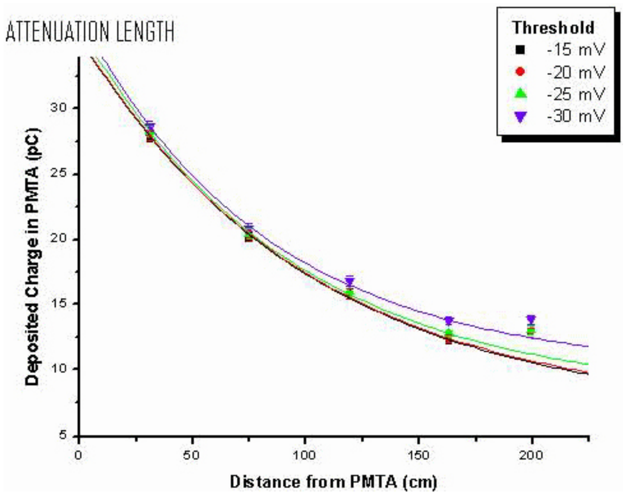

FIGURE 13. Attenuation length of an ACORDE scintillator. Here we plot the charge deposited in PMT A as a function of the distance from this PMT.

where we positioned our scintillation hodoscope was 15 cm away from the start of the overlap at the end closest to PMT A, the second position was 20 cm away from the first position, and so on.

The area of the upper paddle was 20cm $\times$ 20cm. The area of the lower paddle of the scintillation hodoscope we used was smaller than the area of the upper one, to guarantee that a straight line crossing the two paddles would necessarily cross the active area of the ACORDE module under test. The trigger signal was used to read the traces of PMT A and PMT B of the module under test into a PC through the PCI-DAQ card.

Figure 12 shows the detection efficiency of one ACORDE module as a function of the distance from PMT A. Each point represents the ratio between the PMT A (or B) rate and the number of the trigger rate for a certain period of acquisition time. The efficiency curves for individual scintillator counters A and B are shown, as well as the detection efficiency for the logic combinations A AND B and A OR B. For us, the detector efficiency of one ACORDE module comes from the coincidence PMT A AND PMT B (curve line in Fig. 12). As we can see, the detector efficiency is higher than 90%, along the ACORDE module.

4.3. Attenuation length

In order to gain, further understanding of quality in the scintillator we are using, we made a measurement of the attenuation length of light along the plastics of the ACORDE modules we analyzed. Using a digital oscilloscope (Tektronix TDS 220), we were able to measure the amplitude and charge distributions of PMT A and B for five test positions separated by 50 cm for each module. Extracting the most probable value (MPV) of the charge distribution for each position, we plot this value as a function of the distance from PMT A or B. Assuming an exponential attenuation of light along the plastics, and setting a pulse threshold of -15mV for PMT A and PMT B, we get attenuation lengths of 84.7 cm and 89.8 cm for scintillator A and B of an ACORDE module, respectively. We obtained longer attenuation lengths, up to 120cm, for higher (-30mV) threshold voltages (see Fig. 13).

5. Conclusion

Using a custom-made PCI electronics card and a CAEN HV power supply, we were able to run an automatic system to characterize the ACORDE-ALICE scintillator counter modules. This system is capable of discriminating analog PMT signals, converting them to digital information, measuring cosmic ray rates and performing logical operations between several PMT signals. We found the optimal PMT voltage operation, and measured the detector efficiency and attenuation length of several scintillator counters. Our results are in agreement with the reported measurements using standard devices (NIM modules and DAQ acquisition cards). The characterization procedure described in this paper was useful for making a systematic test performance of the ACORDE-ALICE scintillator counter array.

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1. F. Carminati *et al.*, *Journal of Physics G: Nuclear and Particle Physics* (2004) 30.
2. O. Adriani *et al.*, *NIMA* **488** (2002) 209.
3. A. Fernandez *et al.*, *Proceedings of the 29th International Cosmic Ray Conference*, 2005, Pune, India, Universal Academic Press, pp. 1203-1206.
4. R.I. Dzhelyadin *et al.*, DELPHI Internal Note 86-108, TRACK 42, (1986), CERN.
5. CAEN, Universal multichannel power supply system, hardware installation guide, page. 37 November 30^{th}, ©2000.