Proceedings of the 30th International Cosmic Ray Conference
Rogelio Caballero, Juan Carlos D'Olivo, Gustavo Medina-Tanco,
Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia (eds.)
Universidad Nacional Autónoma de México,
Mexico City, Mexico, 2008
Vol. 5 (HE part 2), pages 897–900

30TH INTERNATIONAL COSMIC RAY CONFERENCE

Performance of the 1.5 x 10^5 front-end electronics channels of the ARGO-YBJ experiment

R. CARDARELLI[1], E. PASTORI[1] ON BEHALF OF THE ARGO-YBJ COLLABORATION.
[1] *I.N.F.N. Sez. of Rome "Tor Vergata", Viale della Ricerca Scientifica 1, 00133, Rome, Italy*

roberto.cardarelli@roma2.infn.it

Abstract: By using an 8-channel custom chip in GaAs technology, over 1.5 x 10^5 Front-end electronics channels were built, tested and installed in the resistive plate chambers (RPCs) of the ARGO-YBJ experiment. These channels were designed to obtain 1-ns time resolution over about 6000 m^2 of sensitive area. Here we present the design features, the performance and the test results of the FE electronics compared with the ARGO-YBJ detector performance at an altitude of 4300 meters a.s.l.

Introduction

The Front-End Electronics read out of the ARGO-YBJ RPCs is a full-custom GaAs circuit [1], which integrates in a single die 8 channels composed of three stages of voltage amplifier, a comparator with variable threshold and a digital ECL driver. The GaAs technology and the Front-End design outlines feature high gain-bandwidth product, which preserves the detector time resolution and results in low power consumption. The die is bonded directly on a multi-layer PCB to attain low cost for the large number of required channels. The Front-End Boards are mounted on the pick-up strip panels close to the detector inside an aluminum Faraday cage. A double zener (4.7 V) diode mounted at the input of each channel provides suitable ESD protection. For each board a complete and automatic functionality test was performed. All the measurements were recorded in a database [2]. Here we discuss the distribution of the most significant electronic parameters compared with the measured performance of the detector.

The FE electronics design features

The FE input receives voltage pulses from the pick-up strips. For each input signal (large enough to be triggered), the FE delivers a standardized logic pulse of constant amplitude and duration to the output, completely independent of all the input signal characteristics, except for the time of occurrence with a minimum jitter.

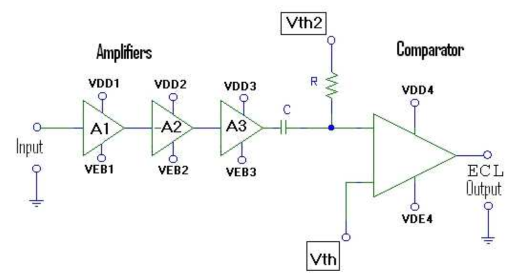

Figure 1: The GaAs die sketch.

For each board it is possible to set up the threshold voltage to achieve adequate noise protection. The input signal is amplified, added to the fixed level (V_{th2}) and compared to the variable voltage level (V_{th}) as sketched in Fig. 1.

The amplifier is composed of three noninverting-inverting-noninverting stages decoupled through integrated capacitors. The supply paths of each stage are separated and connected only on the PCB after strong filtering circuits. The final ECL buffer is AC coupled and has a single-ended output for

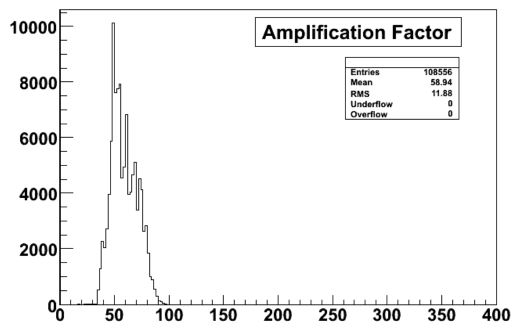

Figure 2: Amplification factor distribution.

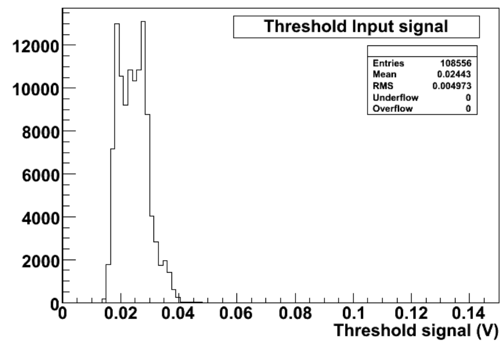

Figure 3: Input Threshold distribution.

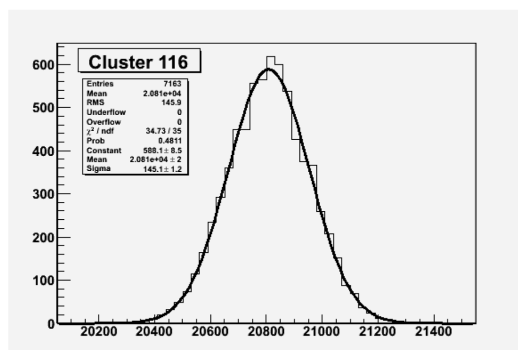

Figure 4: The single counts distribution of one cluster.

minimizing the power consumption. In addition it is capable of driving a 100-Ohm flat cable (a few meters long) connecting the front-end electronics to the local trigger logic.

The input protection against electrostatic discharge (ESD) of the FE electronic was improved by mounting two opposite-polarity Zener diodes on each input. The Zener protection has very low input capacity and does not change the performance of the electronics. Other kinds of more sophisticated and expensive protection, such as TVS diodes and multi-layer varistors, were also tested with worse results. Zener-protected FE electronic could resist at the discharge of a 250 pF capacitor (like the strip capacity) charged at 10 kV.

The FE electronics performances and their impact on the detector

The test results over 108556 tested channels (73% of ARGO detector surface) are reported. The test was performed over a long period of time (more than two years).

Systematic effects due to the set-up system have never been subtracted. Moreover the FE circuit production is composed of a large number of wafers (great dispersion in foundry parameters) from two different foundry processes.

The input signal amplification

The amplification can be calculated for each channel through the test measured parameters. The amplification distribution over 108556 tested channels is shown in Fig.2, the mean value is 59 and the RMS is about 12. The effective amplitude of the signal triggered by the FE electronics set to fixed voltage threshold V$_{th} = 1,8$ V can be extrapolated from the amplification distribution and it is shown in Fig. 3 ranging from 15 mV to 40 mV with mean value 24.4 mV and RMS about 5 mV. The expected voltage signal distribution on the pick-up strip of the detector is around 60 mV, large enough to be detected and well above the threshold distribution. Therefore the detector efficiency is not affected by the FE-threshold spread ([3]).

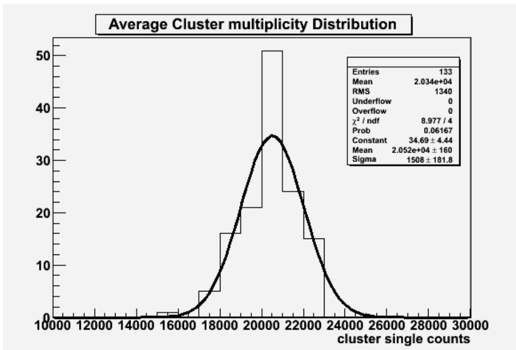

Figure 5: The average cluster single counts distribution.

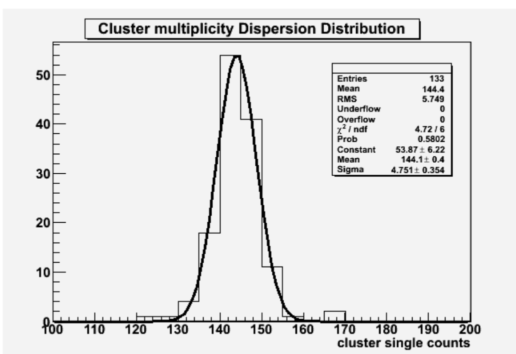

Figure 6: The dispersion cluster single counts distribution.

A good quality factor related to the detector readout performance is the cluster single-count rate. Each cluster is divided into 120 pads. For each cluster, the OR signals of all its pads are counted in a 0.5-s time window. A typical count distribution is shown in Fig. 4 for a single cluster, including dead channels (the effect of which is not subtracted) and any other factor which could affect efficiency. The mean value therefore can change from cluster to cluster. In Fig. 5 the mean-value distribution for 133 clusters is shown: the relative dispersion is 7%. The relative RMS-dispersion distribution is shown in Fig. 6: here the relative dispersion is less than 3%. This results show the good detector efficiency and the response uniformity together with good noise rejection.

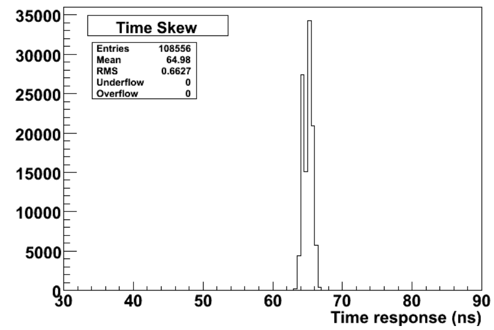

Figure 7: The time skew distribution.

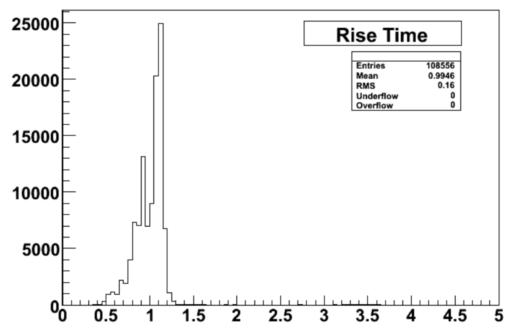

Figure 8: The rise time.

Finally, dedicated tests to measure the cross-talk between FE channels on a board have never showed any interference effect.

The FE time response

The FE time-response performance can be evaluated from Fig. 7 and Fig. 8 which show the output time-skew distribution and the output rise-time distribution. The RMS value of the time distribution is less than 1 ns. Moreover, systematic effects of the set-up test system were not subtracted.

The time resolution of the detector is crucial to reconstruct the direction of the primary particle with high angular resolution. A typical space-time distribution for a triggered event is shown in Fig. 9 [4].

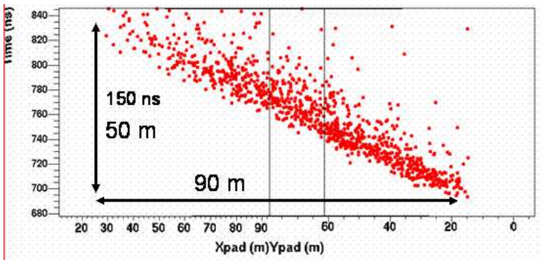

Figure 9: The time distribution vs X,Y on a shower event.

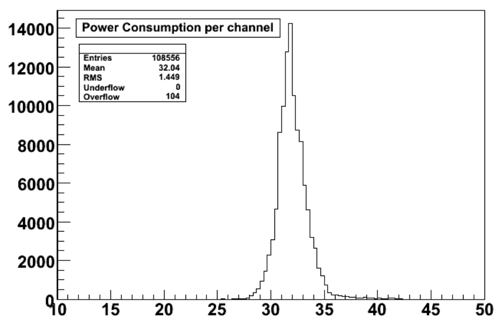

Figure 10: The Power consumption per channel.

The FE Power Consumption

The power-consumption distribution is shown in Fig. 10. The mean value with $V_{EE} = 6$ V is 32 mW per channel. The total power consumption of the ARGO-YBJ FE electronics for 147840 channels on 100 m^2 of the detector carpet is less than 5 kW.

Conclusions

The systematic tests made on the ARGO-YBJ carpet (1.5 10^5 read-out channels) show large tolerance with respect to the FE parameters (threshold and time skew) which set the performance of the detector. All the RPC chambers in the ARGO-YBJ experiment can work at full efficiency and with optimal time response by setting the same control parameters for all FE boards $V_{EE} = -6.0$ V and $V_{th} = -1.8$ V.

Acknowledgements

The authors are indebted to B. Liberti (INFN Roma Tor Vergata) for her technical support in software analysis.

References

[1] R. e. a. Cardarelli, An 8-channels GaAs IC Front-End discriminator for RPC particle detectors, in: GAAS 98 Conference, Amsterdam 1998, 1998.

[2] G. e. a. Aielli, A systematic study of the ARGO Experiment Front-End Electronics, in: International Cosmic Ray Conference, 2000, pp. 2862–2865.

[3] G. e. a. Aielli, Layout and performance of RPCs used in the Argo-YBJ experiment, Nuclear Instruments and Methods in Phys.Res. A 562 (2006) 92–96.

[4] I. f. t. A.-Y. c. De Mitri, Very high energy gamma-ray astronomy and cosmic-ray physics with ARGO-YBJ, in: ICHEP06, 2006.