October 15, 2013

Abstract

1 Sierra Negra experimental Set Up

1.1 Detector description

1.1.1 Small detectors

Sierra Negra at 4550ma.s.l. is the first LAGO site with water Cherenkov detectors working (since early 2007). Until 2010, 3x4m^2 area Cherenkov detectors, in a 30 m triangular array were taking data at this site, filled with ultrapure water and covered with a reflective and diffuser material Tivek; each detector had an EMI 9030A photomultiplier tube, looking towards the bottom. The output of the phototube was connected to a data acquisition card used in the development of this fase phase

Data Adquisition System

Field programmable gate arrays (FPGAs) was playing an increasing role in DAQ systems in cosmic rays experiments due to their high speed and integration and their low cost and low power consumption. Modern electronics based on on-chip fast analog to digital converters (ADCs) and powerful digital signal processors (DSPs) was being ideal to be the basis of custom-made DAQ systems which are more flexible, faster and cheaper than the traditional DAQ systems based on modular electronics[**??**. We took advantage of these recent developments, in particular in the area of very high integrated circuits in the form of ADCs and FPGAs for the design of the new system which consisted of an ADC daughter board running at 200 MSPS. Each event was tagged with precise GPS time using a GPS embedded receiver with 1 PPS (one pulse per second) synchronised with the atomic clock on the GPS satellites within a corrected uncertainty of 50 ns (Motorola Oncore UT+ module). A pressure and Temperature sensor (HP03D) was adapted to the FPGA board (2FT Xilinx). A picture of the final setup in its RF box is visible in figure 1.

1.1.2 Upgrade of the SN LAGO set up

The Sierra Negra site of the LAGO experiment has four detector of 40 m^2 Three of them located at the vertex of an equilateral triangle of 30 m. Those detectors are cylindrical tanks, made with a corrugated steel plated bolted with stainless steel screws, 7.3 m of diameter and 1.15 m high. The tops and inside of each detector are covered by an EPDM (Ethylene Propylene Diene Monomer) black liner to contain and protect the radiator media. The EPDM material is elastic,

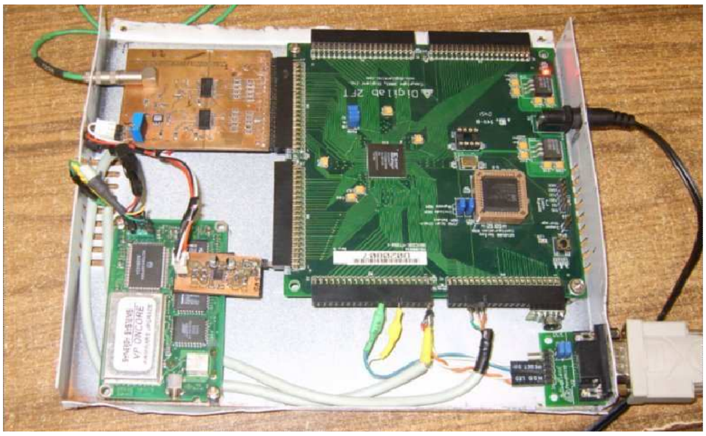

Figure 1: New electronics for LAGO. The prototype can be operated at 100 or 200 MSPS.

easy to weld and mechanically very strong, helping to have a light tight and insulated inner environment. The body and the bottom of the detector are covered with a bag of high diffusive and reflective material: white polyethylene banner. The white bag is filled with high quality purified water up to a level of 1.1 m and in the upper surface; there is a tyvek sheet floating in order to reflect the Cherenkov light produced as uniformly as possible. The special feature of this kind of Water Cherenkov Detector is its inner segmentation. To improve the light collection, we have installed reflective walls with the same material that the inner liner, The cylinder was divided at four regular sectors; one hemispherical 8 inches diameter PMT located in the centroid of each one, looking downwards, The PMT photocathode is submerged to avoid losses by any air-water interface. The entire container is covered and protected externally by a black, light-tight bag and a canvas roof. The Cherenkov light is collected by the electron phototube 9354KB of Electron Tubes Ltd., installed up towards the bottom.

At the center of the array we will set a WCD with the same area, but 4.5m height, filled with clean water and with 4 Pmt at the bottom looking upwards. This detector has the aim to reject hadrons when a extensive air shower is detected.

1.2 Data Acquisition System

The custom-made instrumentation for the DAQ system uses low power consumption, it includes: A 4-channel ADC daughter-board with two dual 10-bit ADC chip from Analog Devices, this chip was the AD9216 that is a dual, 3 V, 10-bit, 105 MSPS analog-to-digital converter. The daughter-board is connected to a second board with an FPGA, for real-time data processing (Nexys2 from Digilent Inc.); This board is a powerful digital system design platform built around a Xilinx Spartan 3E FPGA, with 16 Mb of fast SDRAM and 16 Mb of Flash ROM. The Nexys2 board is ideally suited to embedded processors like Xilinx's 32-bit RISC Microblaze. Communication and control are based on a small minicomputer Raspberry PI model B 512MB with an ARM1176JZF-S 700

Figure 2: LAGO Sierra Negra WCDs. An old array of small tanks is clearly seen between the new big stainless steel tanks. Those are covered by a black EPDM liner. B.- Internal structure of the new WCD. The structure of the PVC pipes allows us to set the banner walls to divide it into four sectors and fix the PMT and cables in a safety way. Also help us to keep the upper liner and a canvas roof.

MHz processor, this mini- computer is the main control between the host y the DAQ, and it is used for interconnection with the surface detector modules, the mother board has two ways of communication with the host, the first one uses a serial port with a typical communication rate around 115200 bits per second and the second one uses a USB port with a higher communication speed.

A pressure and temperature sensor, (HP03D from Shenzhen Hope Microelectronics Co. Ltd.) which includes a piezo-resistive pressure sensor and an ADC interface, providing 16 bit word data for pressure and temperature related voltage, is connected to the FPGA board. The algorithms developed use advanced digital signal processing techniques and particularly digital pulse processing, where the purpose of the pulse processing is to perform on-line signal processing on the digitized signals directly to minimize the data transfer size, these algorithms are implemented on the FPGA using Hardware Description Language (VHDL) and C Language for the Microblaze processor, these algorithms can be reprogrammed at any time. Each event is tagged with precise GPS time tags using an embedded GPS receiver with 1 PPS (one pulse per second) synchronized with UTC within an uncertainty of 50 ns (Motorola Oncore UT+ GPS receiver), see figure 3 and figure 4. The bitstream firmware of the DAQ system resides permanently on the Flash ROM chip located on the mother board and it gets downloaded into the FPGA upon power on. On the PC side we use Perl and Python under Linux to process, store and display the data acquired. Finally, we use ROOT programs to histogram and analyze the data.

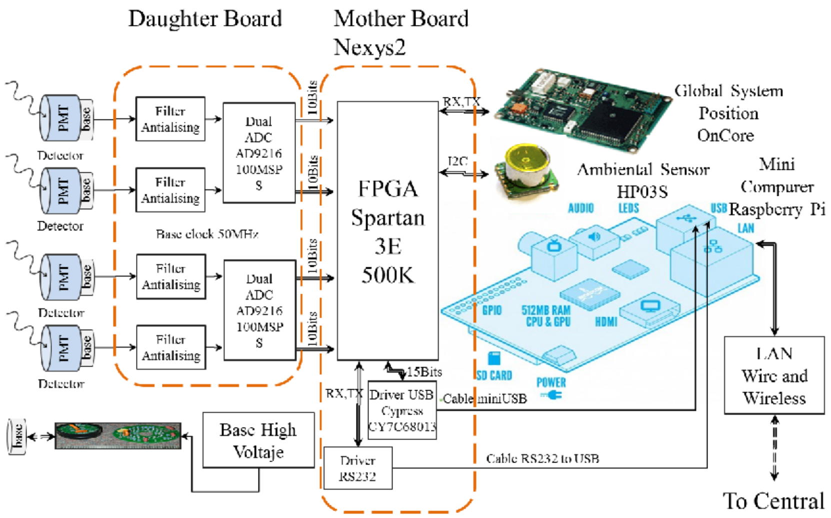

Figure 3: DAQ full blocks diagram, you can see the main parts of the DAQ.1.- Daughter Board 2.- Mother Board, and 3.- Host.

2 Operation and calibration of the WCD Detectors

Calibration mode. It consists on the data acquisition of 32 consecutive samples in 10 ns intervals (100MSPS) of the digital pulses produced by an ultraviolet LED with wavelength of 405 nm with a 15 ns wide pulse in a frequency of 10kHz located 60 cm from the PMT. The phototube polarization voltage and the LED polarization voltage are fine tuned. It provides us with a minimal response that represents a fundamental part for the calibration of a PMT.

As shown in figure 5 and figure, 6,we can plot the response to a single photo-electron using our DAQ. The curves correspond to high voltages of 1.25 kV, 1.3 kV, and 1.35 kV. The best single photo-electron response, for this PMT, is obtained at 1.3 kV and this value was set as the operation one.

Examples of traces, baseline and threshold are shown in 7

Sites Located at the Sierra Negra site (4550 m.a.s.l) in the State of Puebla, México. $18^o59^"$, $97^o18^"$ Magnetic rigidity cutoff 9 GV.

References

[1] Pierre Auger Collaboration, 2004, NIM A 523, 50-95

[2] D. Allard, C. Alvarez, H. Asorey et. al. "Operating Water Cherenkov Detectors in high altitude sites for the Large Aperture GRB Observatory", sec IV, Proceedings of the 31st ICRC, ŁODZ 2009.

[3] Conde Sanchez Rubén for the LAGO Collaboration, "The Upgrade of the LAGO Project at Sierra Negra, México", Proceedings of the 33rd ICRC, Rio de Janerio 2013.

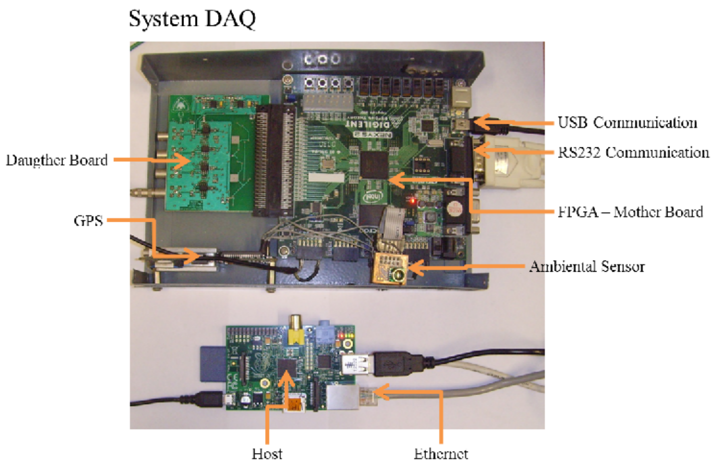

Figure 4: A view of the custom electronics used at LAGO.

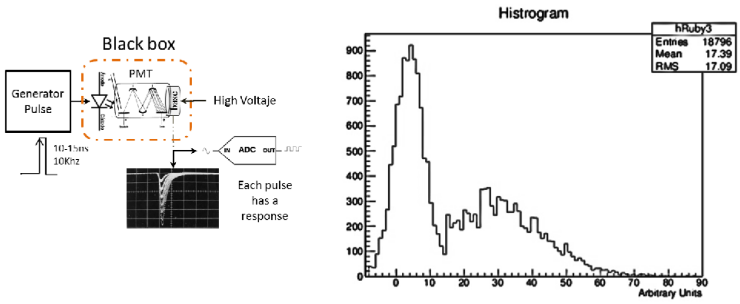

Figure 5: Mode calibration and Response to a single photo-electron, using the new DAQ.

[4] A. Sandoval for the HAWC Collaboration, "A Third Generation Water Cherenkov Observatory", Proceedings of the 33rd ICRC, Rio de Janerio 2013.

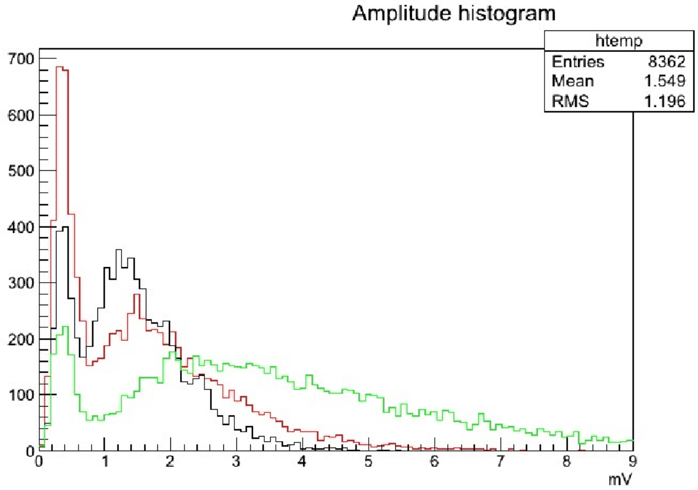

Figure 6: Plot of the response to a single photo-electron by the PMT at 1.25 kV (black), 1.3 kV (red), and 1.35 kV (green). The operation voltage was fixed at 1.3 kV.

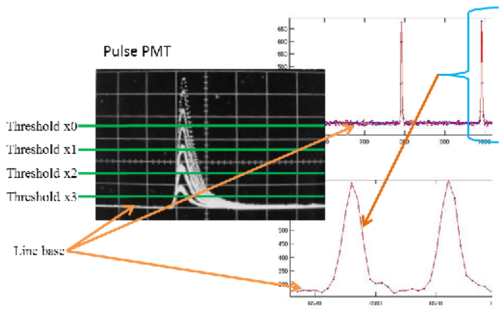

Figure 7: Example who shows the basic line, trace, rate.