PROCEEDINGS OF SCIENCE

Performance of the LAGO Water Cherenkov detector in Chiapas, Mexico

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The Latin American Giant Observatory (LAGO) is an observatory extended along Latin America, with the capability to detect the galactic cosmic rays background and to develop studies for space weather and atmospheric radiation at ground level. It consists of a network of several Water Cherenkov Detectors (WCD) located at institutions in different countries along the American Continent (from Mexico down to the Antarctic region). One of the main goals of LAGO is to encourage and support the development of experimental basic research in Latin America, mainly with low cost equipment. The astroparticle physics group of Facultad de Ciencias en Física y Matemáticas (FCFM) at Universidad Autónoma de Chiapas (UNACH), as part of the LAGO project, is in the installation final phase of a WCD at the FCFM campus and it is planning to set up another one at the top of Tacaná volcano. In this paper, we describe the scientific purpose of the experiment, details of the detector characteristics, numerical simulations carried out to estimate its sensitivity and an electronic novelty used for the data acquisition system.

36th International Cosmic Ray Conference -ICRC2019-
July 24th - August 1st, 2019
Madison, WI, U.S.A.

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PoS(ICRC2019)358

1. Introduction

Nowadays astroparticle physics is one of the major fields of science due to its great contributions to the understanding of the universe, mainly those that are related to the most energetic phenomena in the cosmos. Astroparticle physics includes, beside neutrinos, gamma rays and cosmic rays. Cosmic radiation has been studied for over one hundred years since their discovery, in 1912, by Victor Hess. Water Cherenkov Detectors (WCD) have been one of the most used instruments for the study of cosmic radiation. This kind of detectors is designed to observe extensive air showers caused by the interaction of high energy cosmic rays with the Earth's atmosphere. The Latin American Giant Observatory (LAGO) is an international network of WCD, which are located in different places throughout Latin America at different altitudes, covering a wide range of geomagnetic cutoff rigidities for cosmic rays (see Figure 1).

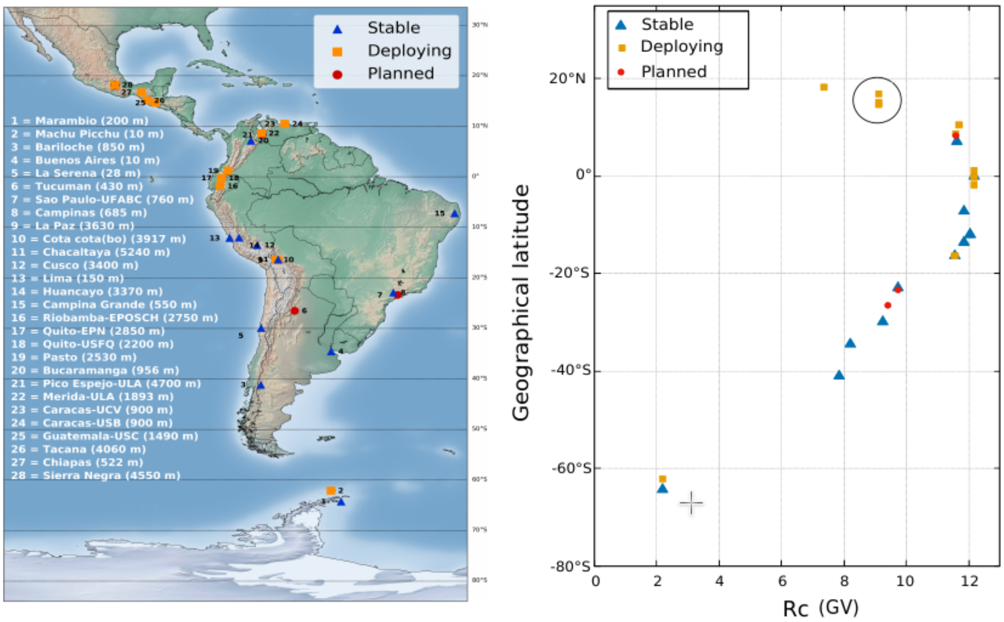

Figure 1: Current status of the LAGO project in each of the participant countries (left) and geomagnetic rigidity cutoff (R_c) for the different LAGO sites as a function of its latitude (right), the squares in the black circle correspond to the rigidity cutoff in Chiapas ~ 9 GV [1].

The main scientific goals of LAGO are related to space weather, atmospheric radiation at ground level, galactic cosmic rays modulation, as well as to transient phenomena, like gamma ray bursts (GRB). It operates in an energy range that goes from 0.5 GeV to tens of TeV. As part of the LAGO project, the astroparticle physics group of Facultad de Ciencias en Física y Matemáticas (FCFM) of UNACH are making substantial efforts to install two new WCD in two sites: FCFM campus in Tuxtla Gutiérrez and the top of Tacaná volcano, both in the state of Chiapas, Mexico.

2. Computation of fluence at the detector's sites

To characterize the new WCD, a complete and detailed simulation is needed to get a precise estimation of the secondary flux at the detectors' positions. The simulation must take into account several important factors such as magnetic rigidity of the galactic cosmic rays (GCR), the interaction of GCRs with the atmosphere, the variations in atmospheric depth, and the response of the detector to the secondary particles. CORSIKA (COsmic Ray SImulations for KAscade) is a software that allows to perform detailed simulations of extensive air showers initiated by high energy cosmic rays [2].

Using the latest version of CORSIKA (7.6900) and the set of tools developed by the LAGO Collaboration to analyse the showers, we simulate one hour of flux at the sites: FCFM campus, at ~ 522 m a.s.l, and the top of Tacaná volcano, at ~ 4060 m a.s.l. For the simulations we need to set the geographical coordinates and the horizontal (B_x) and vertical (B_z) components of the geomagnetic field. These parameters are shown in Table 1. B_x and B_z were calculated with IGRF-12 model by using the NOAA–NCEI Magnetic Field Calculators. For the arrivals of the primary cosmic rays we consider a zenith angle in the range $0 < \theta < 90$ and an azimuthal angle in the range $-180 < \phi < 180$. The hadronic interaction models used at high and low energies were QGSJETII-4 and GHEISHA, respectively (see the CORSIKA manual for more details [2]). The distribution of primaries at the top of the atmosphere was calculated according to [3], taking into account the measured spectra for nuclei with atomic number within the range $1 \leq Z \leq 28$ [4]. In Figure 2, we show the fluence at the detector level for the FCFM campus and in Figure 3 for the top of the Tacaná volcano site. The results are as expected, according to the calculations for other sites of LAGO [5].

Site	Geographical Coordinates	B_x (μT)	B_z (μT)
FCFM campus	16°45′11″ N, 93°06′56″ W	27.521	27.211
Tacaná volcano	15°07′48″ N, 92°06′45″ W	27.631	25.598

Table 1: Geographical coordinates and horizontal and vertical components of the geomagnetic field, for the sites where the detectors will be deployed.

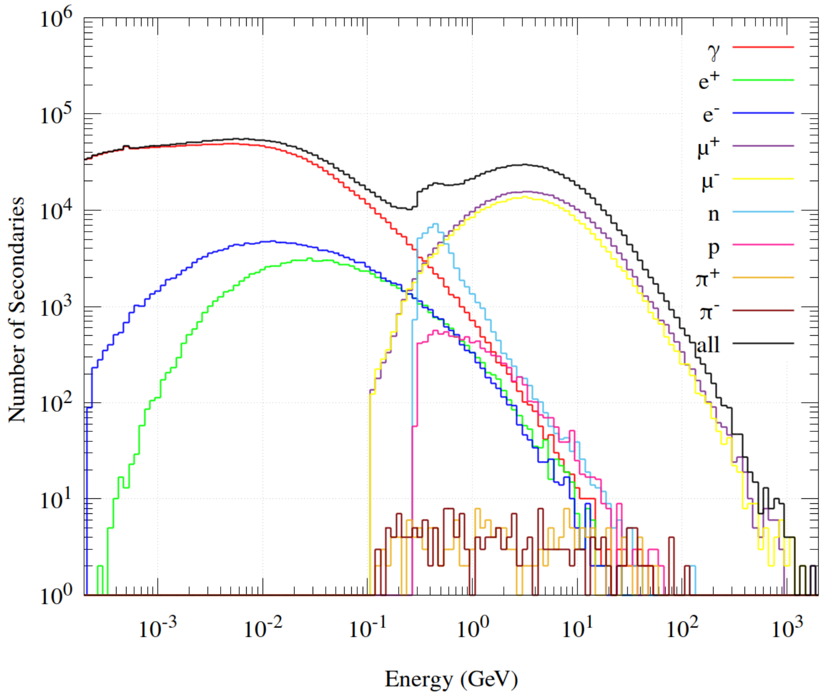

Figure 2: Flux of secondaries at FCFM campus at an altitude of 522 m a.s.l.

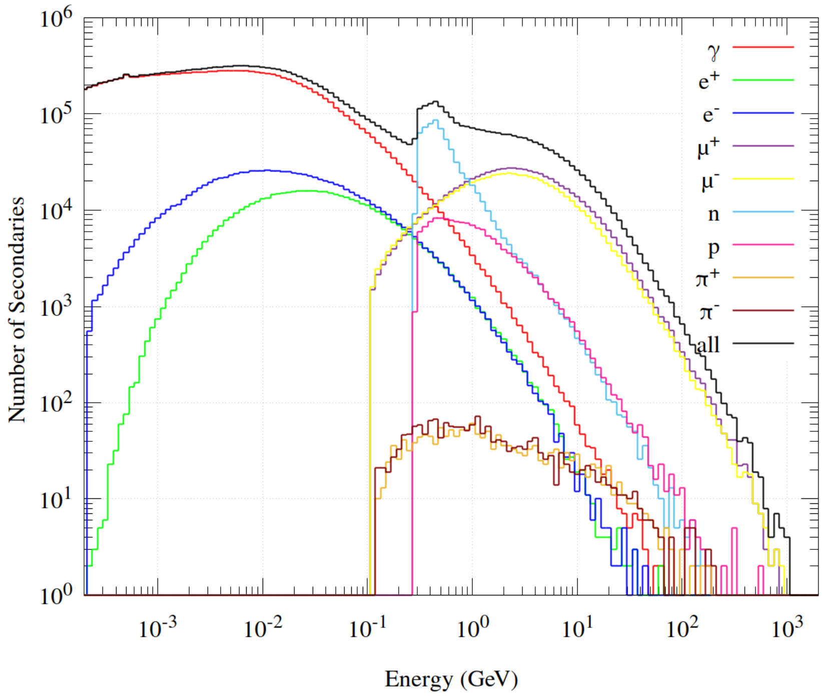

Figure 3: Flux of secondaries at Tacaná volcano at an altitude of 4060 m a.s.l.

3. Advances in the performance of the WC detector LAGO-Chiapas

3.1 Electronics

With respect to the electronics of the WC detector at FCFM campus, a high voltage divider circuit for polarizing the PMT has been implemented. The data aquisition system (DAQ) is achieved through a digitizer (VME1720 of CAEN) and the high voltage-polarizing card (VME1633), and to allow the PC communication with the digitizer and the high voltage card, we use a bridge car (VME1718) [6]. The DAQ includes a C-program that uses an Application Programming Interface (API), provided by the manufacturer; this program was modified according to our needs. The events are stored in an output file. Values of temperature and pressure are incoporated to this file using a BMP280 sensor. In addition, a GPS Ublox Neo 6M provides the timing labels for the events. The divider circuit was protected by a PVC-pipe case and isolated by a silicon substance. An accesory was made in order to uphold the PMT in the top of the tank. The tank is covered inside by a reflective paper and outside by a plastic material to isolate it from light.

3.2 The signal processing

The output file is adequately formatted so that it can be processed by the software ANNA (see http://www.iafe.uba.ar/wikilago/index.php?title=ANNA for more detailes), a set of tools developed by the LAGO Collaboration for data analisys. ANNA performs several analysis over the data, as charge and peak histograms, solar analysis, etc. ANNA had to be tailored to process our data. The main reason for this was the length of each event. It processes events of 12 bins (an aquisition window of around 300 ns, for a FPGA operating at 40 MHz). In our case 75 bins are acquired for each event (the digitizer operates at 250 MHz). Other changes were the position of the Offline trigger and the baseline given by the digitizer (2136 mV) different from the 0V used by ANNA; among others changes. Characterization of linearity, gain, single photomultiplier, etc. are being done as the last step in the process of installation of one detector in the FCFM campus, UNACH.

4. Conclusions

The installation of the WCD at FCFM campus is almost complete and in a near future it will be in operation to join the LAGO network. The remaining short term work regarding the simulations is to perform a Geant4 simulation of the detector to know its response to secondary particles arriving at the sites. Studies on dark current for the PMT are also ongoing.

5. Acknowledgements

The LAGO Collaboration is very thankful to all the participating institutions and to the Pierre Auger Collaboration for their continuous support. Furthermore, we also want to thank the high performance computing center LARCAD–UNACH (http://larcad.mx/), were the simulations presented in this work were carried out.

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