Form 8

Research Result Report
ICRR Inter-University Research Program 2022

Research Subject: Development of new trigger electronics for the ALPACA experiment

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Summary of Research Result: Observation of ultra-high energy gamma-rays will bring evidence about the origin of cosmic rays in our Galaxy, one of the important unresolved questions in physics. Nevertheless, instruments used for this purpose require great sensitivity. The ALPACA experiment is a new project between Bolivia, Japan and Mexico; with the goal of installing a hybrid surface array with underground muon detector in the Bolivian Andes. To reach the required sensitivity above 1 PeV we require the development of new trigger electronics using state-of-the-art technology that enable us to scale the system for a larger number of channels and guarantee stable operation.On the fiscal year 2022 we developed a prototype of the trigger electronics with 32 input channels. This research included the design and development of a novel pulse generator, capable of reproducing the timing characteristics of the air shower experiment.
The development of the two systems was done using five FPGA development boards, which were bought using the budget from the Inter-university research program. For the design of the pulse generator system, we used a custom-made Monte Carlo simulation of the ALPAQUITA surface array to extract the timing information of the experiment. After this, the design of both systems consisted in describing special purpose pulse processors inside the FPGA and evaluated its performance by hardware simulation and with real experiment.The results of the evaluation of three channels from the pulse generator are shown in figure one. For this experiment we configurated the system to produce pulses with a random distribution in time, each which follows a Gaussian shape. The pulse delay of each pulse is measured with a Time digital converter, from the beginning of the time window (a timestamp generated by the circuit to mark the start of each event) and the

rising edge of each generated. The orange line on each distribution represents the input parameters to the circuit, meanwhile the blue histogram represents the measured values. From this we conclude that the pulse generator can reproduce the input distribution with good accuracy.

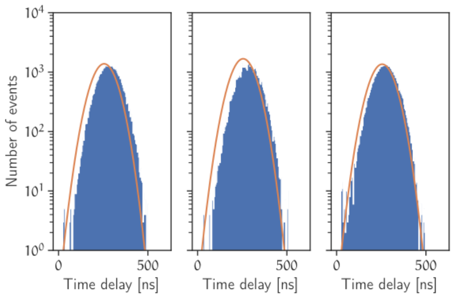

Figure 1. Pulse delay distributions produced by the generator.

Figures two and three show the evaluation of the trigger electronics and pulse generator, and the results of the test, respectively. To be able to perform this test we included in our design a network interface (an ethernet protocol, which requires a raspberry Pi and ethernet modules) to acquire data for long periods of time. The blue histogram on figure three shows the number of trigger events per period of 20 sec, produced by the trigger electronics when the pulse generator is producing 32 randomly distributed pulses. The orange line represents the ideal case when the trigger electronics response to all events generated by the generator. The blue histogram is the real data obtained during 8 hours of operation. From these results we can conclude that the operation of the prototype is satisfactory, and the next step will be to extend our design to a larger number of channels. The results of this research will be published in an original paper in the near future.

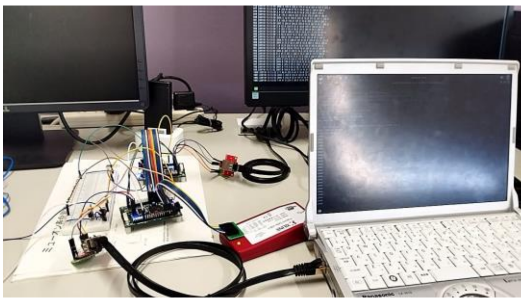

Figure 2, Picture of the trigger electronics prototype being tested in the laboratory.

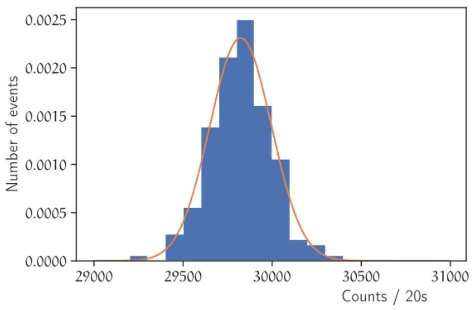

Figure 3. Histogram of the number of trigger events produced by the system.