Development of an FPGA-based Readout for Particle Tracking

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Introduction

Particle tracking is an important objective in many of the low or high energy nuclear physics experiments as well as in various other imaging applications, like muon tomography, medical imaging, etc. The tracking can be accomplished with a series of position-sensitive detectors which facilitate the reconstruction of the particle tracks from the position information obtained from each of them. The collection of position data requires a multi-parameter data acquisition (DAQ) system which can acquire the information from all the detectors triggered by a single event. This paper reports a developmental work done for building such a DAQ using Field Programmable Gate Array (FPGA) for tracking cosmic muons. FPGA is an integrated circuit that can be customized for a specific application. It contains millions of logic blocks that can be wired in different configurations according to the logical requirements of the application.

The final objective of this work is to develop a muon tomography setup for imaging unknown test objects using cosmic muons as the source. In this connection, an experimental setup comprising of several plastic scintillators has been operated for tracking the muons and testing the FPGA-based DAQ. The measurements done for 2-fold, 3-fold and 4-fold coincidence with the FPGA-DAQ have been compared to that obtained with the standard nuclear electronics for studying its performance also.

Experimental Setup

A few scintillators of various cross-sections have been used for the experimental setup. The analog signals of the detectors have been fed to the discriminator and then converted to TTL logic pulse through a module. The TTL pulse (width ~ 75 ns) are passed to the FPGA. NI Labview software is used to make coincidence logic and counter.

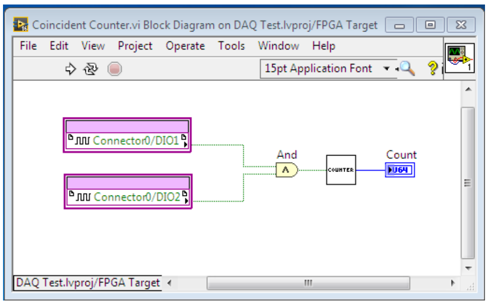

Fig 1. Labview block diagram of a simple 2-fold coincidence counter.

In our experiment, we test 2-fold, 3-fold and 4-fold coincidence with the FPGA-DAQ. we can add any amount of time delay using FPGA with same muon signal, which is very useful to find chance coincidence and delayed signal. Also, we can store event information with time stamp, from this information we can calculate the time gap between two consecutive events.

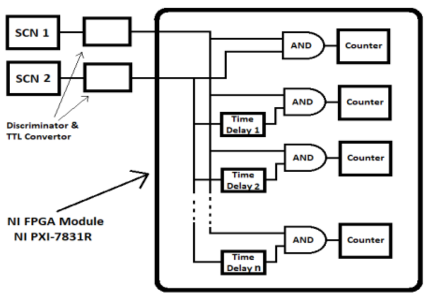

Fig 2. Schematic diagram to find delayed coincidence.

Experimental Results

Using FPGA we have measured the 2-fold, 3-fold and 4-fold coincidence count muon signal and also verified with the counts of NIM modules. To avoid chance coincidence, we also measured the time-shifted coincidence between two signals. There is a limitation of the number of inputs and time delay in the NIM module, but in FPGA we can add many input channel and any time delay.

While measuring the delayed coincidence with different time delay, we observed an anomalous behavior near 500 ns delayed signal. There is a second pulse nearly 500 ns after the muon signal.

When we measure the time gap between two scintillator signal using FPGA we get a peak near 500 ns.

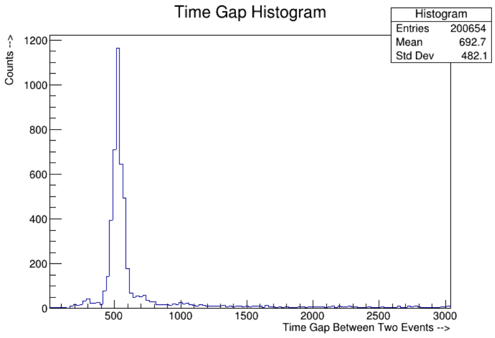

Fig 3. The time gap between two consecutive signals graph.

Conclusions

From the measurements, it can be noted that the FPGA-DAQ has been designed appropriately to collect the data for particle tracking. Since its coincidence and counting algorithm working well, So FPGA is a good replacement of NIM module. There is a flexibility to add more input channel in FPGA based DAQ system, which is useful for our muon tomography setup.

Along with FPGA can give the time information about the event, which helps us to find exact muon event.

In our above experiment we can see the there is a second pulse nearly 500 ns after the main pulse. Probably this is an ion feedback signal of PMT which comes after 400 to 500 ns after the main signal. Without using FPGA we cannot able to distinguish these pulses. This is the one advantage of using FPGA-DAQ.

Acknowledgments

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