Smart Fast-Digitizer system for astro-particle detectors

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We developed a Fast-Digitizer based zero-suppression algorithm which supports single channel self-triggering, TDC and ADC functionalities, and detector triggering capabilities. We implemented and successfully tested the system in the DarkSide experiment for the search of dark matter. The system can be used as it is for any next generation dark matter or neutrino experiments which use photo-detectors and is scalable up to tens of thousands of channels.

Introduction

Various experiments in astroparticle physics require the acquisition of high-speed signals coming from a large number of photo-multipliers tubes (PMT).
Usually, the signal of interest of a single PMT is limited to relatively short pulses (10-20 ns) generated by specific events. The detector requires continuos acquisition, but only the data (sampled data and time of the pulse) associated with these pulses is of scientific interest.

We implemented a novel system for data reduction and software group trigger to satisfy these needs. The system is based on National Instruments PXIe-5162 waveform digitizers (4 channels, 1.25 GSample/s/ch).

We tested the performance of the system by acquiring the veto detectors of DarkSide-50, composed by 110 liquid scintillator channels and 80 water Cherenkov channels.

Pulse Identification, Zero-Suppression

Each channel of the waveform digitizer is able to identify pulses and perform zero-suppression. When a pulse is identified, a 64 bit time-stamp, that encodes the time of a pulse, is generated.
Timestamps can be read independently from the waveform data of the pulses. This feature allows TDC functionalities and detector triggering capabilities.

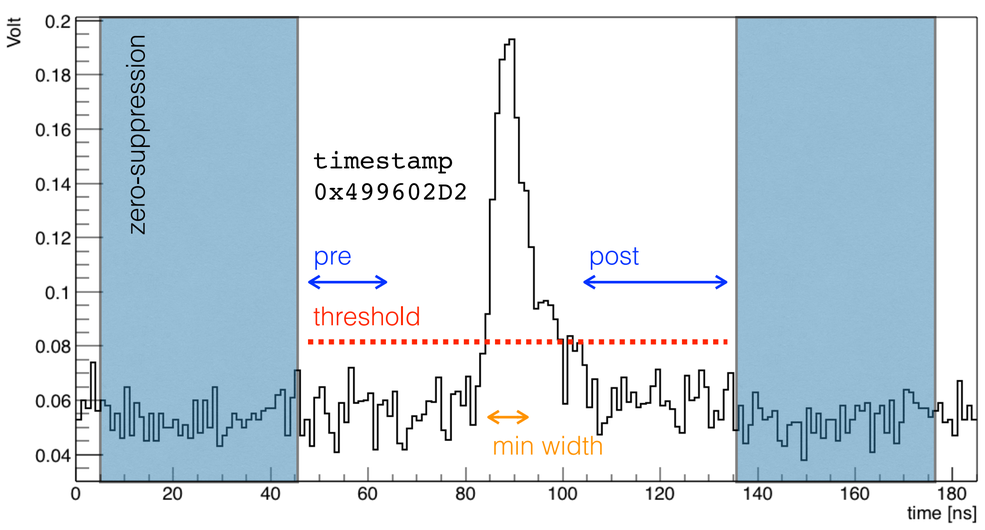

Fig. 1 - Zero-Suppression algorithm

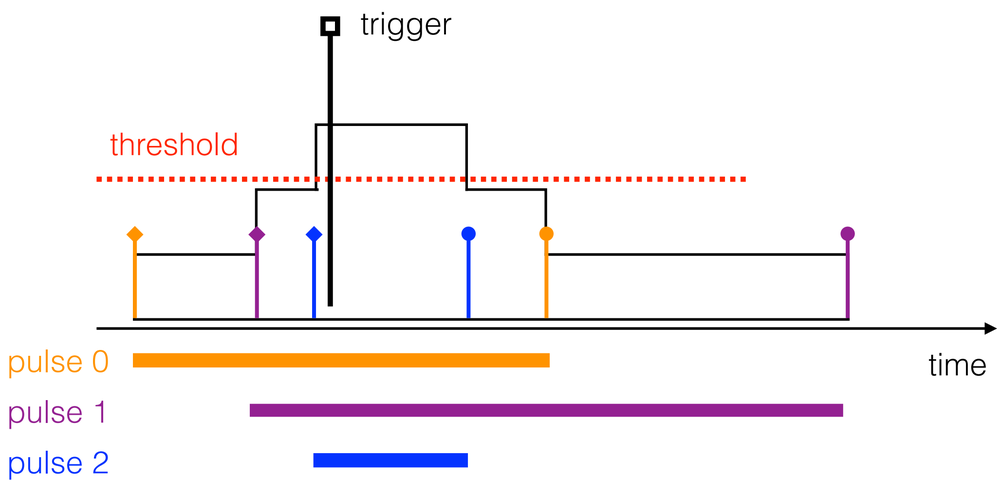

Fig. 2 - Illustration of TDC and triggering functionalities

DAQ Architecture, Software Trigger

The trigger of the system is entirely generated by software, that reads the time-stamps and evaluates a group trigger condition.
The waveform data of the relevant pulses are only read on demand by the DAQ when the software group trigger is issued.

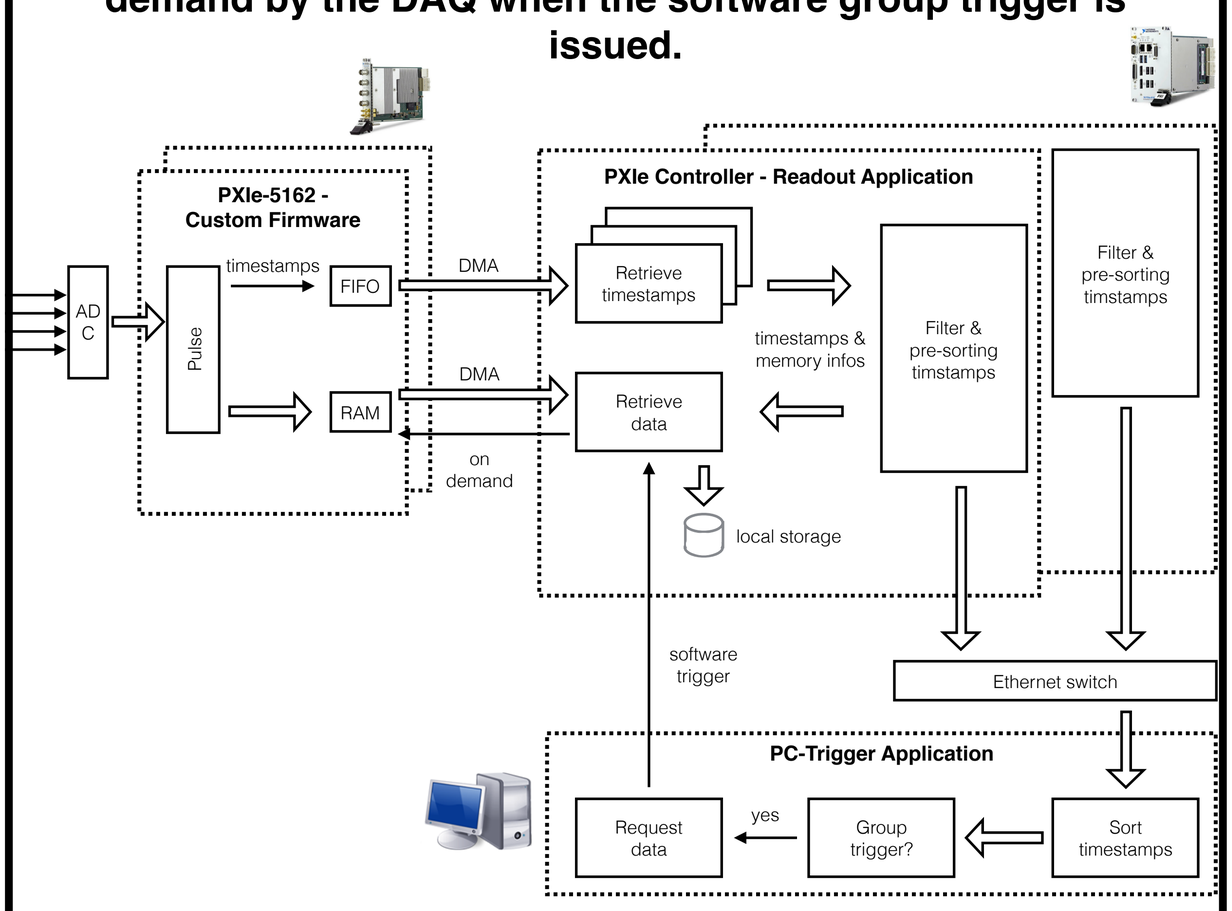

Fig. 3 - Block diagram of the data flow of the system

Test, Performances, Outlook

We successfully tested the system in the veto detectors of the DarkSide-50 experiment. Negligible latency is induced by sorting and transmitting timestamps, and generating and transmitting the software trigger.

The maximum pulse rate in a single channel that the system can stand is about 80 kHz. With a data acquisition gate of 100μs, the system can sustain a trigger rate up to 1kHz.

We simulated the activity of a larger number of channel to study the scalability of the system. We showed that the system, as it is, is scalable to one thousand of channels. With a distribution of the computing, which is natural if a detector can be segmented by its geometry or its materials, the system can be scalable up to many thousands of channels.

This DAQ system can be used by next generation dark matter or neutrino experiments which use photo-detectors like PMTs or SiPMs.