A Digital Optical Module Simulation for IceCube

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The IceCube experiment [1, 2] will provide a cubic kilometer of instrumented ice volume at the South Pole for the detection and study of high energy astrophysical neutrinos. This instrumentation will be accomplished by deployment of 80 kilometer-length strings, each containing 60 digital optical modules (DOMs). Each DOM contains a photomultiplier tube (PMT) that detects the Cherenkov light generated in the ice by muons and electrons produced by neutrino interactions. Also included are main board electronics that process and capture the signal. Physics studies require realistic simulation; to this end a simulation of the DOM main board has been developed.

The section of the DOM main board simulated is shown in the block diagram of Fig. 1. The main board

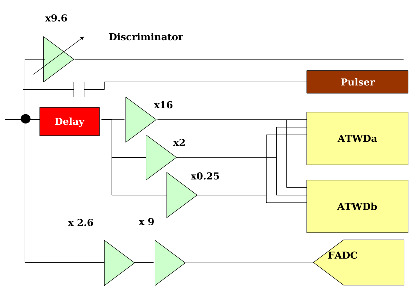

FIG. 1: Section of the DOM main board simulated.

electronics apply a threshold trigger to the PMT analog signals and digitize the ones above threshold. Fast waveform sampling and capture (128 samples at 300 MHz) is provided by two analog transient waveform digitizers (ATWDs). Longer duration signals (up to 6.4 μs) are sampled at 40 MHz by a fast analog-to-digital converter (FADC). Each ATWD consists of three channels of differing gain providing a dynamic range over signals produced by 1 to $\sim$ 500 single photoelectrons (SPEs). All of this functionality is present in the simulation.

The simulation also includes the delay line before the ATWDs, "ping-ponging" between the two ATWDs to minimize deadtime, local coincidence bits that account for nearest-neighor (or more) DOM coincidences in an adjustable time window, and the pedestal. The pedestal for the ATWD and FADC is simulated utilizing the calibration values that characterize the actual pedestal for deployed DOMs. A further feature that is accounted for in the simulation is an effect that comes from the AC coupling of the PMT transformer. While the transformer is not technically part of the DOM main board, this effect manifests as a undershoot in the pedestal of the waveforms and is therefore handled in the simulation. Inversion of a digital filter developed as a correction for this effect allows for simulation of the undershoot. An example can be seen in Fig. 2.

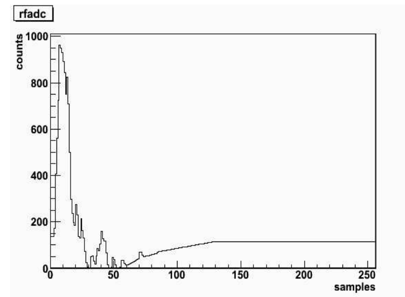

FIG. 2: Simulated pedestal undershoot in the FADC. After the initial large signal the indershoot is visible; it recovers between 100-150 counts.

A comparison of the peak and width of real and simulated single photoelectron waveforms (as seen in the first ATWD channel) indicates that the simulation models the real waveforms quite well. The results of the comparison can be seen in Fig. 3.

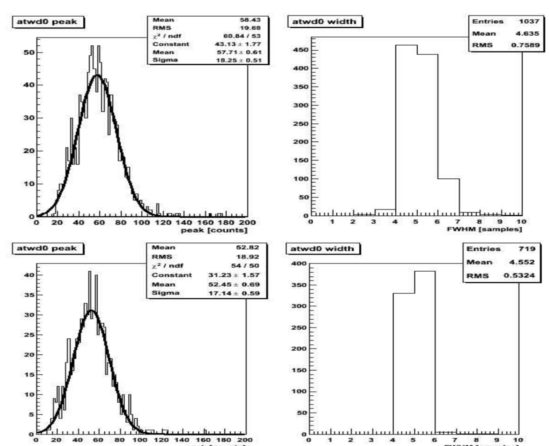

FIG. 3: Peak (left) and width (right) distributions of SPE waveforms for data (upper plots) and simulation (lower plots).

[1] `http://icecube.wisc.edu`
[2] A. Achterberg *et al.* [IceCube Collaboration], arXiv:astro-ph/0604450.