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Online and Offline Monitoring of the ICARUS Detector

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Overview

In preparation for the launch of the ICARUS -T600 far detector in the Short Baseline Neutrino program, (SBN), it is important to monitor the performance of the detector and quality of the data in real-time. Particularly important to monitor are noise levels of the TPC readout electronics, and the purity of the liquid argon in the TPC, as these can affect the overall sensitivity of the detector to detecting and reconstructing neutrino interactions.

Figure 1: Photo of two TPC chambers inside the ICARUS detector.

Introduction

SBN plans to study experimental neutrino anomalies at the forefront of neutrino physics such as the existence of sterile neutrinos, which could be found in non-standard oscillations of $\nu_\mu \rightarrow \nu_e$ in muon to electron neutrino appearance measurements [1].

The detector is comprised of a cryostat split into two-half modules and filled with 760 tons of ultra-pure liquid argon (LAr). A high voltage is then applied creating an electric field of $E_D = 500 \frac{V}{cm}$. [2].

When a neutrino interacts with the LAr, charged particles can be produced, which then ionize the LAr as they travel through the detector. Electrons from these ionization tracks drift up to ~1 m in the electric field and are detected by three wire planes of the time projection chambers (TPCs). As these planes have wires at different angles, and the drift time is known, a 3D reconstruction of the event can be made [3].

In order to identify and reconstruct these ionization tracks, it is important to have low noise in the readout of the detector, as large noise can produce fake signals, and that the purity of the LAr is kept high, as impurities can collect drifting electrons and reduce the signal strength. To make sure the detector is taking good data, the noise and purity of the TPC must be monitoring "online", as data is collected. Further calibration corrections can then be applied in later data processing ("offline").

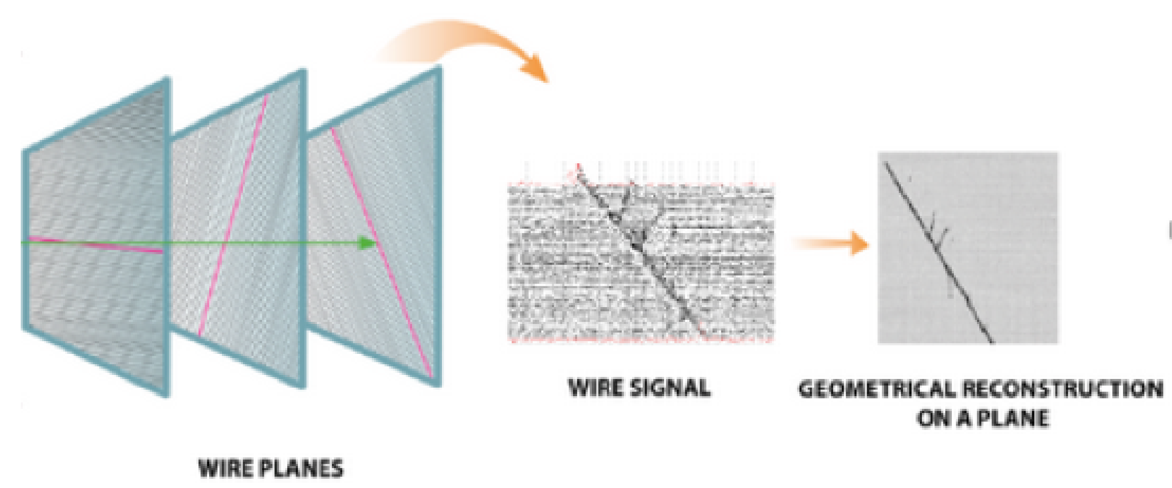

Figure 2: This shows how a neutrino event is reconstructed from the signals recorded on the TPC wire planes from an incoming neutrino.

Method

Monitoring Algorithms

Using the common physics software package *LArSoft* [4], a module called TPCWaveformAndFfft was made to create waveforms per each TPC channel. From these, both the waveform pedestals and RMS (overall level of noise) are calculated.

Also within this module, another function creates a fast Fourier transformation (FFT) of the frequency representation of the waveform ADC (analog to digital) values. It can be used to show more clearly the strength of the signals from the detector and can be used to identify electrical noise issues.

Finally, a separate purity module called ICARUSPurityDQM has been optimized to track the purity values across the entire detector. It calculates the signal attenuation over the drift volume from cosmic-ray muon tracks, from which we can extract the purity, usually expressed as the electron lifetime.

Online Monitor

In order to monitor the stability of the detector in real time, the noise and purity values must be viewed by shifters. A series of websites was created to house all of this information and this is the online monitor (OM). Data are stored in a fast in-memory database (Redis) by the analysis software, and can be accessed through these webpages. [5].

Results

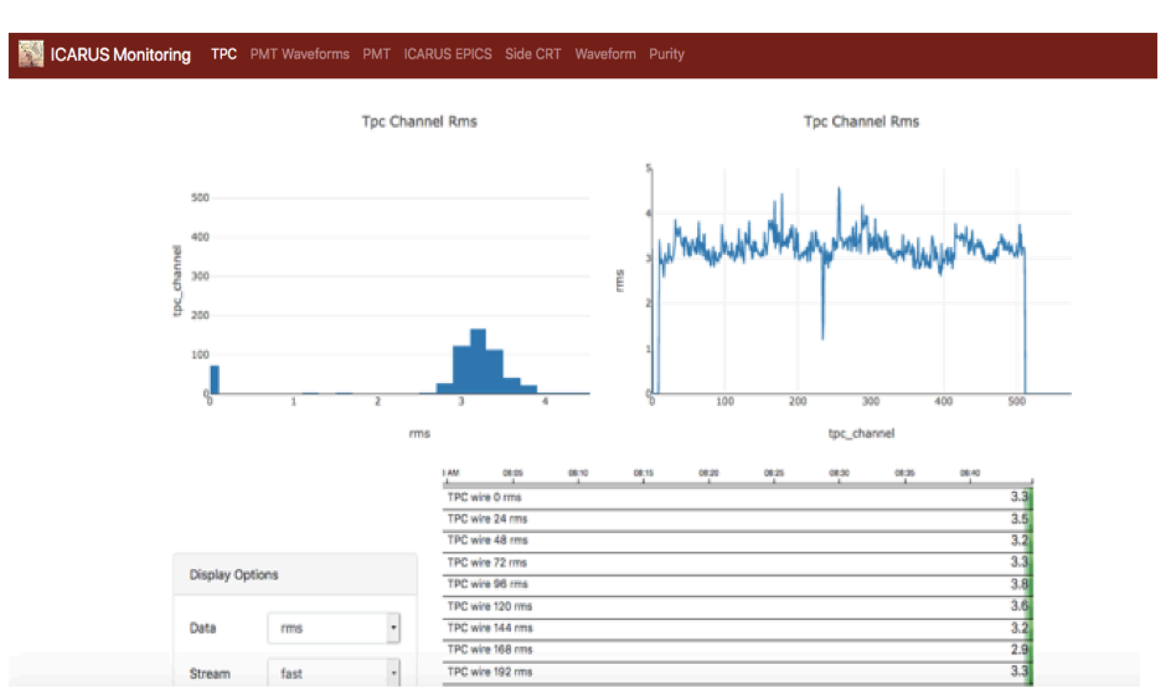

Figure 3: Above is a sample webpage displaying metric of the RMS in a recent run of archived live data. The green metrics show that data is being processed, which is when the above plots are active.

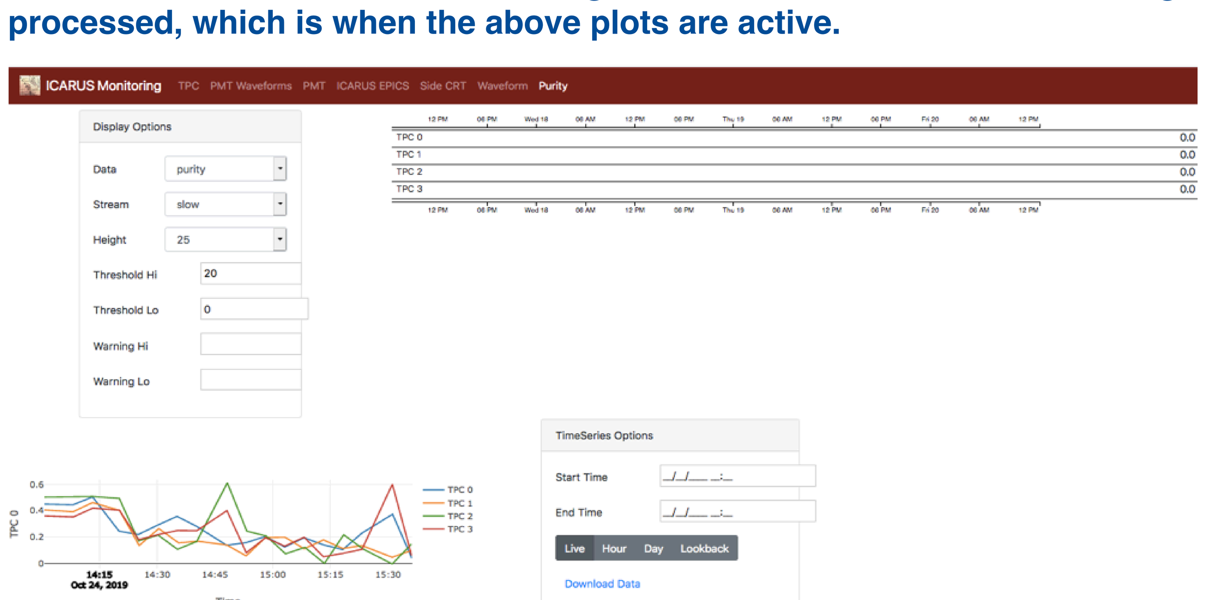

Figure 4: Above is a sample webpage displaying the purity values for each of the four TPCs during a simulation in October, 2019.

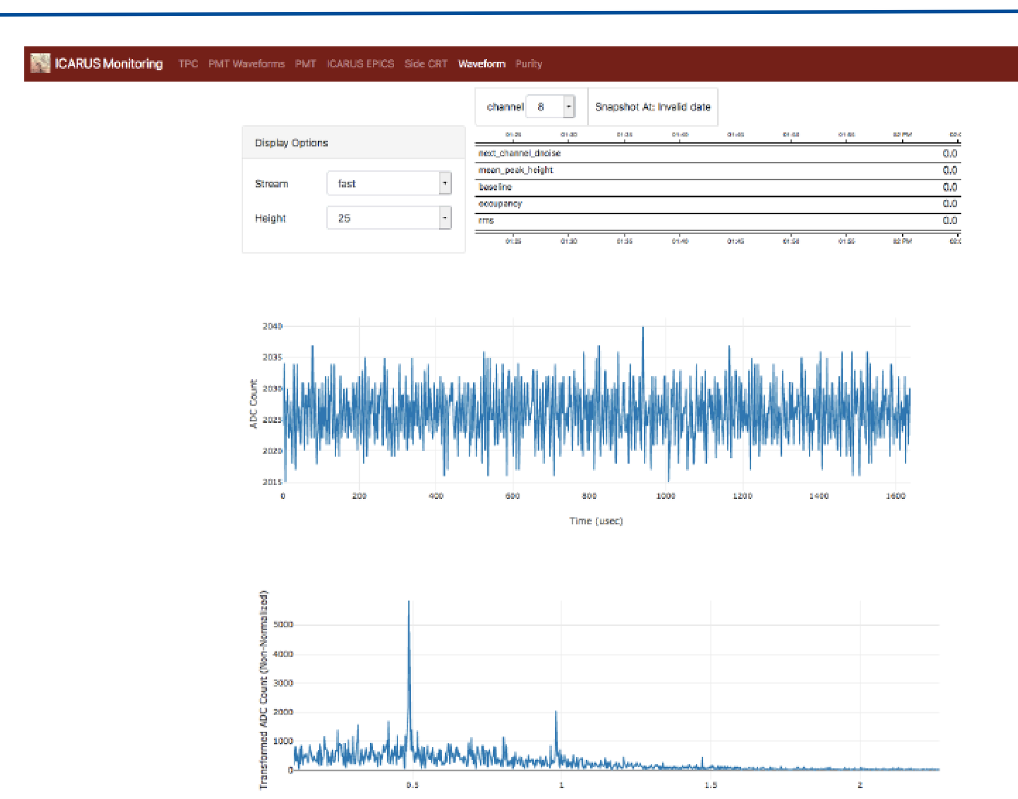

Figure 5: Above is a sample webpage displaying the waveform and FFT for wire number 8.

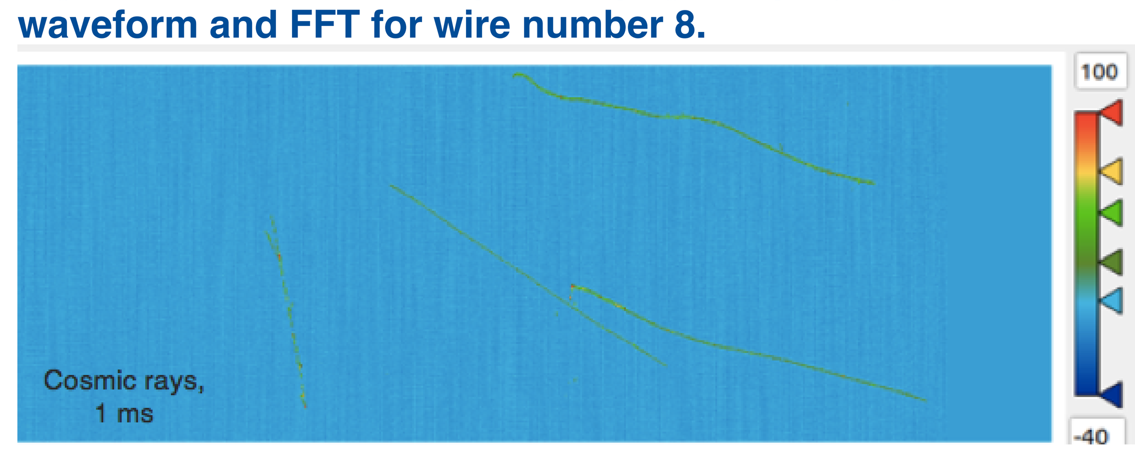

Figure 6: Above shows cosmic rays on one plane from a simulated event, assuming a very low purity of 1 ms as a test.

Discussion and Conclusions

In preparation for the full launch of the ICARUS in spring 2020, there are now operational metrics for both TPC and purity monitoring available on the OM as seen in figures 3, 4, and 5. This work plays an important role during the commissioning process, since it will be used to monitor the detector in real time.

Looking ahead, some optimization of the online purity measurement is still ongoing. Also, the impact of other detector effects on the purity measurement are currently being simulated and studied. Comparisons of the extracted lifetime from simulations with known lifetime are being carried out and will be used to calibrate the online purity measurement.

Finally, a detailed comparison on the offline and online purity measurements will also be carried out once the detector is running. This will be used to better understand the operations of ICARUS, to ensure collection of good data and provide input for calibration of the TPC.

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SBN Program

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