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Online Purity Monitoring Measurements at the ICARUS T600 Detector

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Introduction

The ICARUS liquid argon time projection chamber (LArTPC) will soon be taking data on Fermilab's Booster Neutrino Beamline (BNB). In preparation for operations, we present an analysis of "online" data quality monitoring of the liquid argon purity. We evaluated the performance of the algorithm on simulated cosmic ray muon interactions in the detector. To further study the robustness of the algorithm, we also evaluated its performance under varying conditions: with different levels of noise from the TPC electronics and with different levels of space charge effect[1].

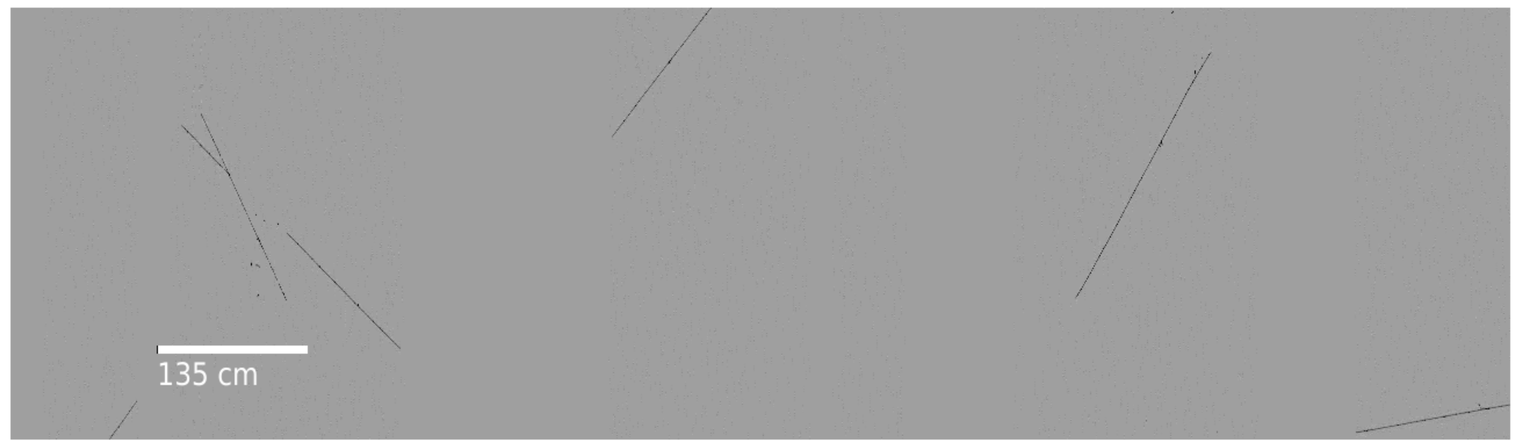

Figure 1: A cosmic MC simulation from ICARUS of the collection plane on one side of the TPC in one of the two cryostats. This image is after deconvolution.

Methodology

To monitor purity, we perform measurements of the drift electron lifetime τ_{ele} as a parameter in the following formula:

$$Q(t) = Q_0 e^{\frac{-t}{\tau_{ele}}}$$

where $Q(t)$ is the measured charge arriving at the wire planes, Q_0 is the initial free charge prior to drift in the electric field within the TPC, and t is the drift time[2]. A detailed measurement with full track reconstruction will be performed "offline" to determine calibration, but a fast "online" algorithm provides a quick first reading without full reconstruction[3].

The fast algorithm is implemented as a module in LArSoft framework, and calculates the charge attenuation on cosmic muon tracks across four TPCs[4]. The inverse of the average attenuation over many tracks is the purity measurement[5].

Results

The following plots display deviations from lifetimes of 1-10ms purity done with simulations at three noise levels of the TPC wires: 2.2 (ideal), 3.2, and 5.0 ADC RMS.

The first two plots show "space charge off", Figure 1, and "space charge on", Figure 2, results. The space charge effects are double the expected outcome from the detector to emphasize a maximum possible effect.

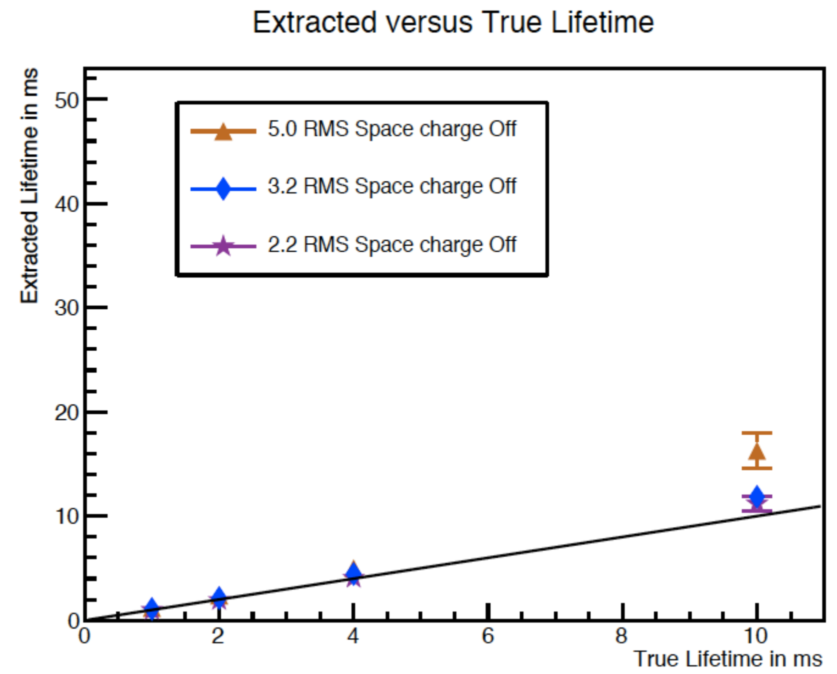

Figure 2: "Space charge Off" results for 1-10ms lifetimes.

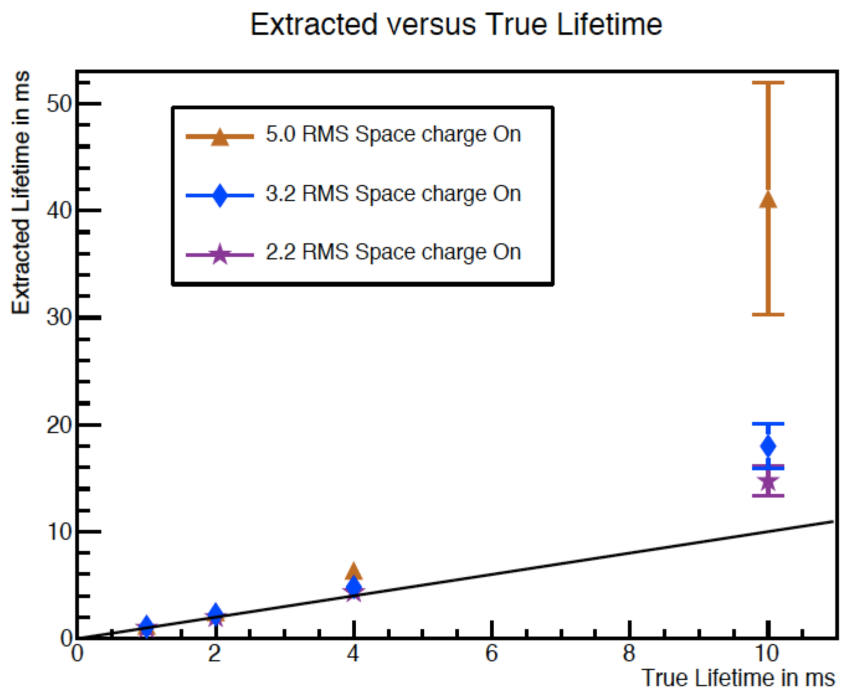

Figure 3: "Space charge On" results for 1-10ms lifetimes.

Our results indicate that at low lifetimes, space charge effects were subdominant to noise effects. However, at higher lifetimes, space charge became more dominant.

To decrease deviations and further comment on the robustness of the algorithm, we then lowered the hit threshold, which sets the minimum threshold used to determine physical hits. The quantity lowered went from 5 to 3. The next two plots show "space charge off", Figure 3, and "space charge on", Figure 4, results.

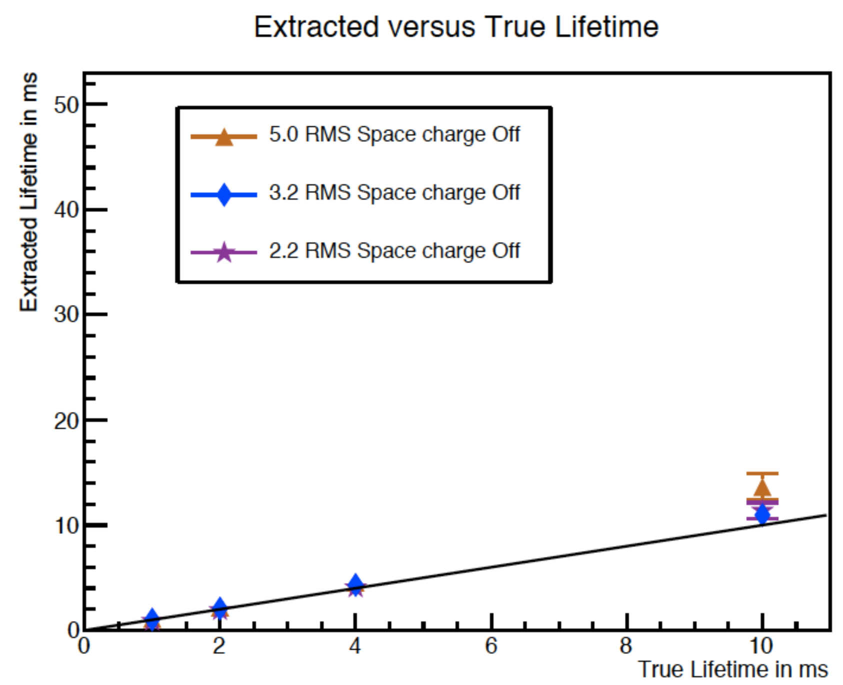

Figure 4: "Space charge Off" results for 1-10ms lifetimes with the lowered hit threshold.

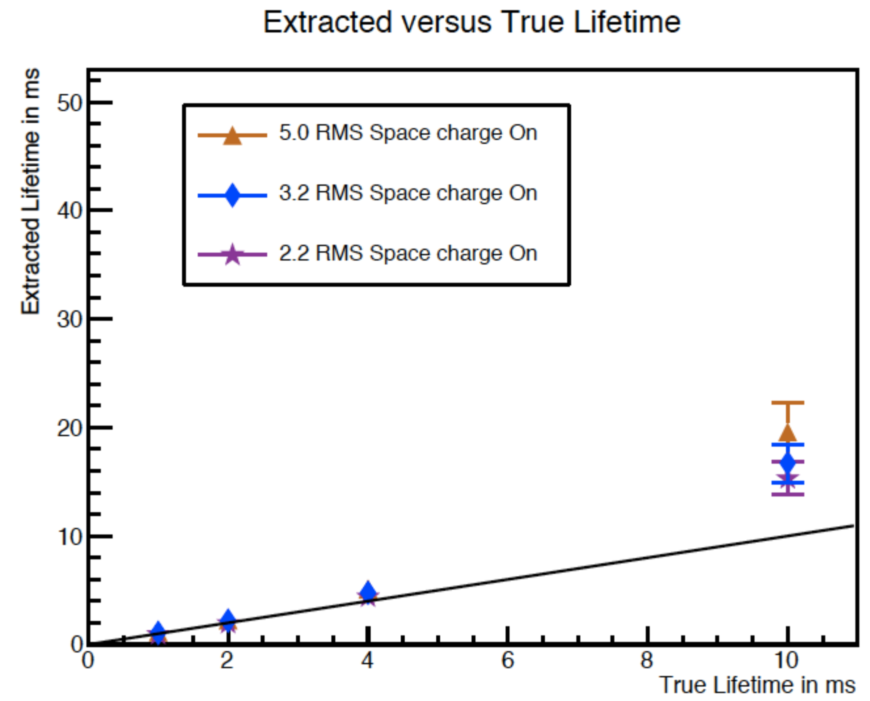

Figure 5: "Space charge On" results for 1-10ms lifetimes with the lower hit threshold.

These plots indicate that lowering the hit threshold reduces the deviations especially in "space charge on" results. This is expected, because there is an increase in statistics which leads to a better measurement despite having a small bias at high lifetimes.

Conclusions

This overview of studies was done to ascertain the performance of the "online" purity method algorithm where the online measurement can be tuned to give valuable results that are robust against noise. While space charge effects become a problem at high lifetimes, we will measure a correction factor more carefully to mitigate issues. And, the algorithm provides an effective online measurement where we want to ensure that the lifetime is above a lower limit.

Acknowledgements

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