QuarkNet Report 2019
University of Tennessee, Knoxville

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The summer work at UTK focused on developing the MicroBooNE-based neutrino masterclass mainly developing three main exercises:

1. Determining the momentum of particles using the track length of stopped muons and protons in MicroBooNE
2. Analyze cosmic ray muon data from MicroBooNE to extract the electron drift-lifetime measurement
3. Analyze cosmic ray muon data from MicroBooNE to extract the drift velocity of ionization electron signals

As part of developing the MicroBooNE masterclass, a development workshop was held at UTK in July 2019 by the UTK QuarkNet center mentors with the QuarkNet staff Ken Cecire and Shane Wood, Spencer Pesaro from Fermilab, and Nathaniel Tagg who is also a MicroBooNE collaborator. Both teachers participated in the workshop.

The analysis of the MicroBooNE data and event selection is done through the web interface program called "ARGO" that provides event displays of the MicroBooNE data (https://argo-microboone.fnal.gov/masterclass). This tool is developed by Nathaniel Tagg. Both teachers used ARGO as they developed and tested various measurements with MicroBooNE. In addition to the above measurements, the event display tools are also equipped to allow performing various other simple measurements such as angular distribution of cosmic ray particles.

Electron drift-lifetime measurement:
MicroBooNE is a liquid argon based neutrino detector. In MicroBooNE neutrinos or cosmic rays enter the detector and interact with liquid argon producing charged particles which then ionize the argon atoms. As a result, ionization electrons (signals) are formed which drift towards the anode under the influence of an electric field. As the electrons are drifted, if there are impurities in argon (e.g. water, Oxygen), they get captured by the impurities resulting in signal loss. Hence it is very important to keep liquid argon very pure in MicroBooNE. Cosmic muon tracks were used to extract the signal attenuation, electron drift-lifetime, and O_2 equivalent argon contamination. This is a track-by-track analysis. Using ARGO, measurements of charge loss over time were taken on approximately 100 tracks in two different batches of liquid argon. The first lot of events were generated from "high" purity liquid argon. The second lot of events were generated from a "lower" purity batch of liquid argon. The data collection was analyzed in a spreadsheet. The statistical and graphical analysis of both samples is presented in the images below:

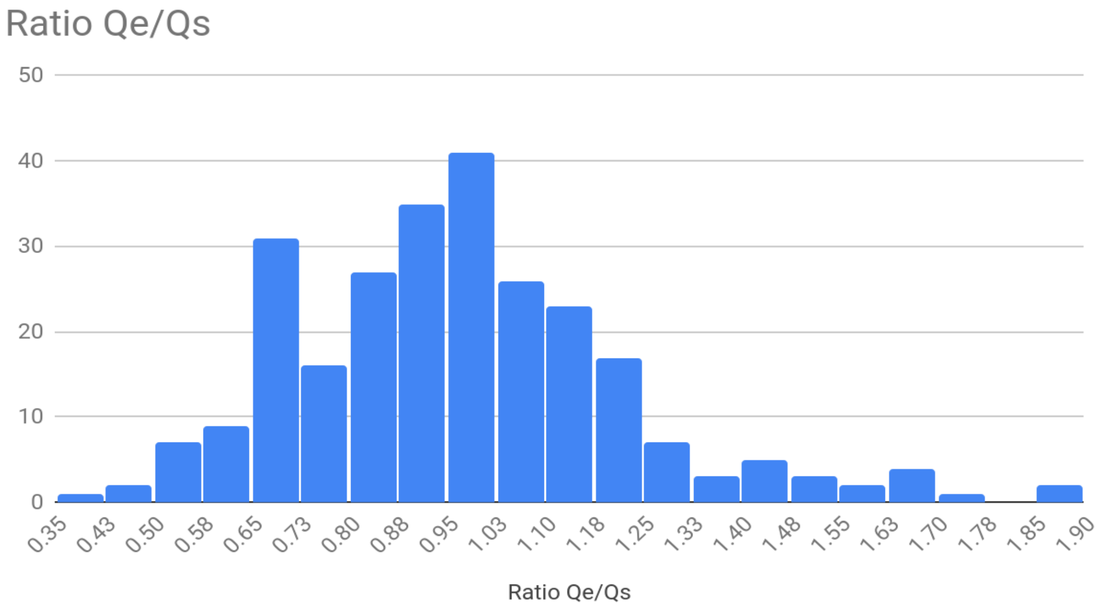


Figure 1: High purity liquid argon sample. Ratio of final charge over initial charge is plotted for about 100 tracks. If $Q_e/Q_s = 1$, then no signal attenuation. The peak value from the histogram lies very close to 1 which means the signal loss is very minimal and thus the liquid argon purity is very high.

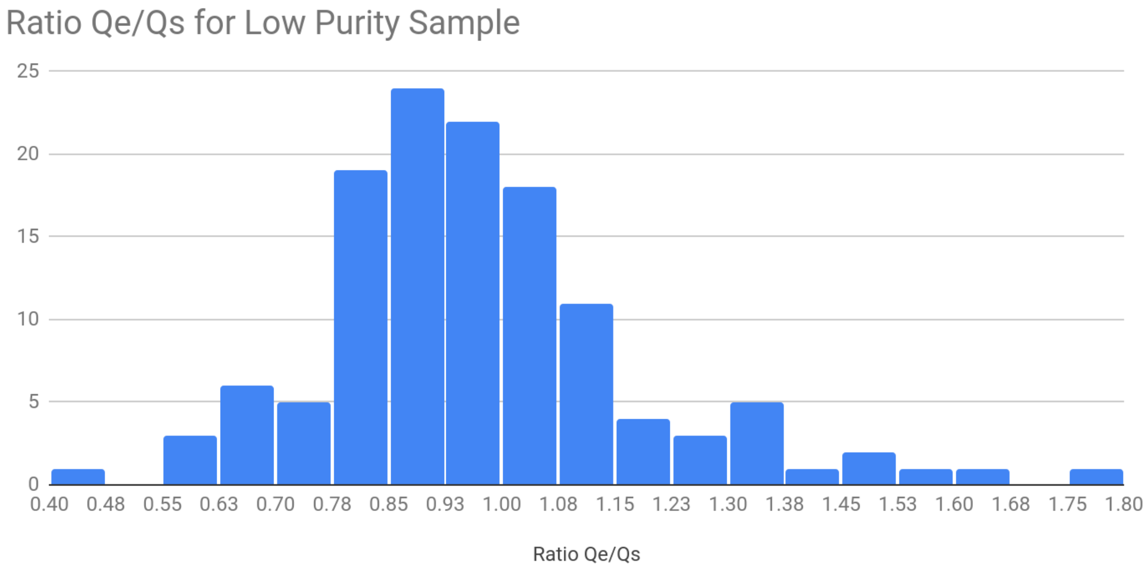


Figure 2: Low purity liquid argon sample. Ratio of final charge over initial charge is plotted for about 100 tracks. The peak value from the histogram lies around 0.93. This value is still very high and the liquid argon purity is very good.

Drift Velocity measurement:
In MicroBooNE, knowing drift velocity of the ionization electrons is very important in order to get 3D reconstruction of events. The "x" coordinate of the signal electrons is obtained by multiplying the drift time measurement with drift velocity. Drift velocity depends on applied electric field and liquid argon temperature. While both of these quantities are expected to be uniform across the detector, several other factors impact their uniformity. Hence it is important to precisely measure the drift velocity. Teachers analyzed approximately 35 crossing tracks (tracks that cross both anode and cathode) using another tool in the Masterclass version of ARGO. After identifying a crossing track in a cosmic ray muon event, teachers tabulated the drift times at each end of the track. And, since the crossing distance of the track is 256 cm (equal to the width of the detector), the velocity calculation is given by, Delta x/Delta t. Those results were tabulated and charted. The results are included below.

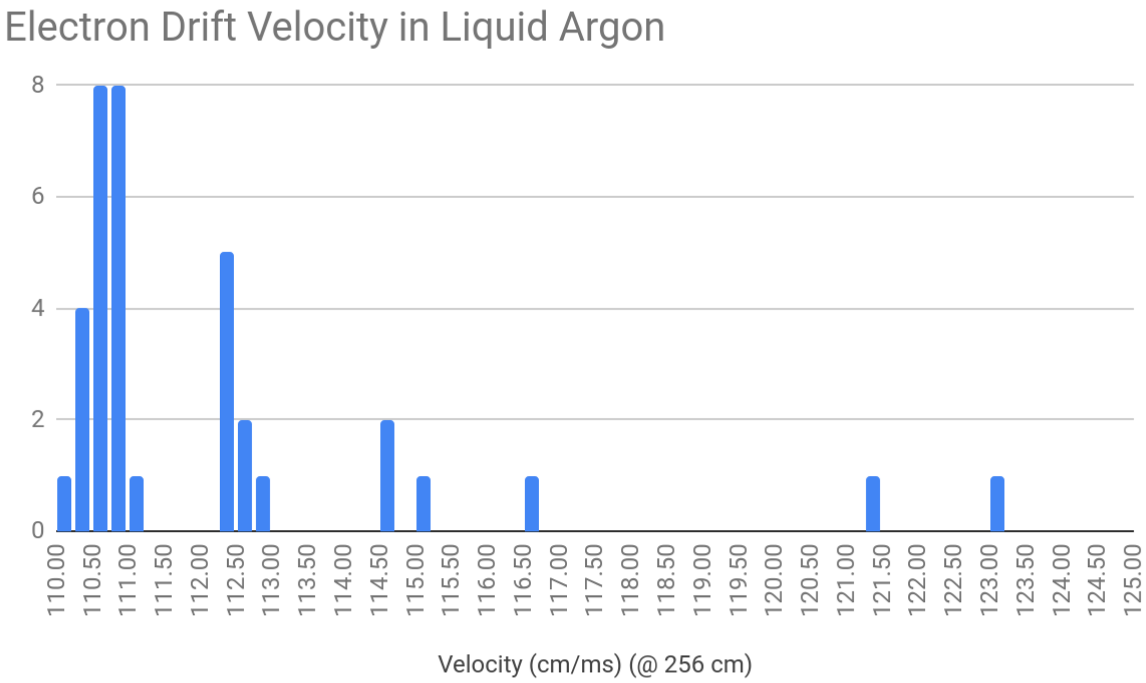
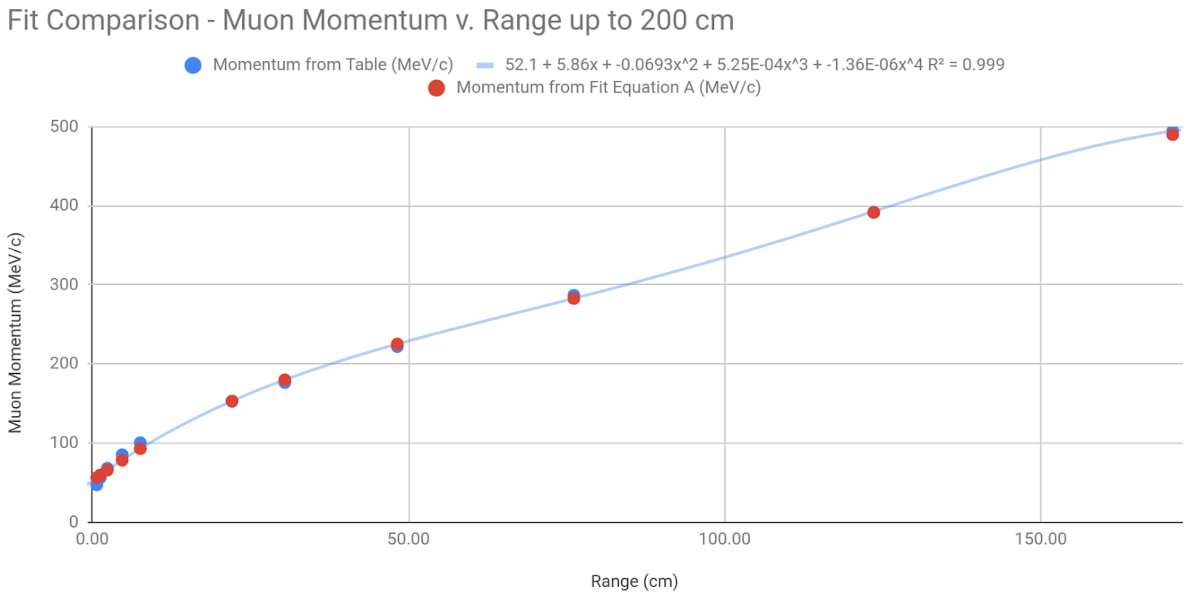


Figure 3: Drift velocity histogram using MicroBooNE cosmic muon data. At 273 V/cm which is the MicroBooNE electric field, the expected drift velocity is 111.4 cm/ms. The peak value from the histogram matches to the expected value.

Extracting Momentum of stopping particles:

Teachers analyzed published data on the relationship of kinetic energy and momentum of stopping tracks of both muons (Muon Data) and protons (Proton Data) in Liquid Argon. The graph shown below is a fit to the published data available in order to extract a functional form to the data. Using simulation datasets, this technique of momentum calculation for a given muon or proton track was verified.


Fit Comparison - Muon Momentum v. Range up to 200 cm
● Momentum from Table (MeV/c)
52.1 + 5.86x + -0.0693x^2 + 5.25E-04x^3 + -1.36E-06x^4 R² = 0.999
● Momentum from Fit Equation A (MeV/c)
Muon Momentum (MeV/c)
500
400
300
200
100
0
0.00
50.00
100.00
150.00
Range (cm)