



Particle ID in liquid argon TPCs

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Introduction



We are working on particle ID in liquid argon TPCs.

Made some simulated event samples in the 35 ton detector.

Had a look at some variables that can discriminate between different particles.

Made a multivariate analysis (MVA) using those variables as input.



Introduction



Event samples are made using a particle gun that sends a single particle per event into the 35 ton detector. Particles travel in the +z direction with a Gaussian spread of that direction with $\sigma = 20^\circ$ in both x and y.

Samples are made with 10000 events for each of muons, electrons, protons and π^+ at each of 4 different values of true momentum: 0.5, 1, 2 and 3 GeV (with a Gaussian spread with $\sigma = 0.2$ GeV around those central values).

We reconstruct the events using Pandora.

For each event, we make a principal component analysis (PCA) of the hits in the reconstructed track with the largest number of hits in the event.

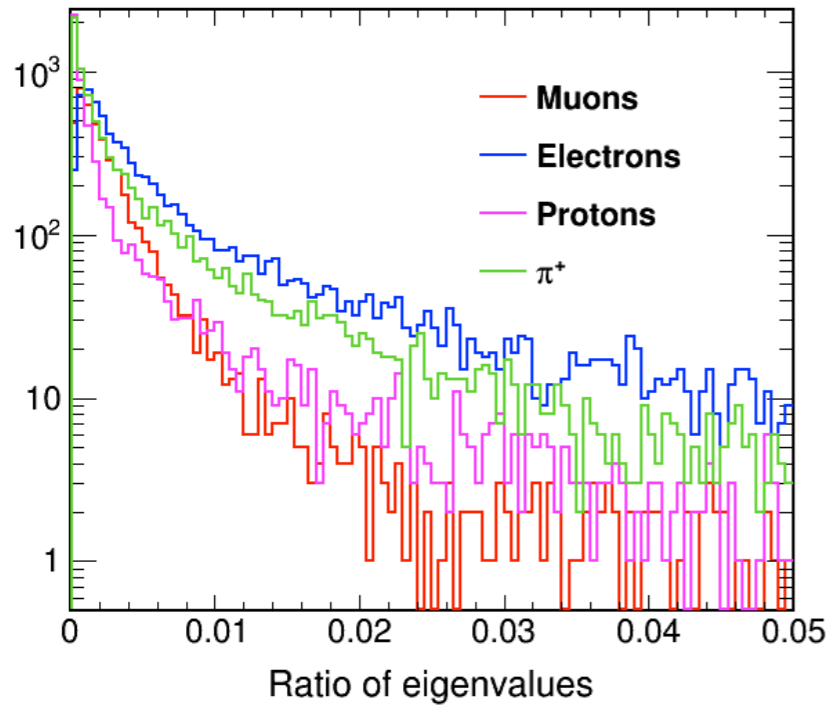
Fit a straight line in 3D to the hits in the reconstructed track with the largest number of hits in the event. This fit is made by minimising the sum of squares of residuals between the hit spacepoints and the fitted line.

The line fitted to the reconstructed hits allows us to compute the track pitch in 3D. We input this pitch to the methods in the `CalorimetryAlg` class to make a calculation of dE/dx that includes the recombination and lifetime corrections. We then calculate the average dE/dx from all the hits in the relevant part of the track. Plots in this presentation are made using dE/dx from hit area.

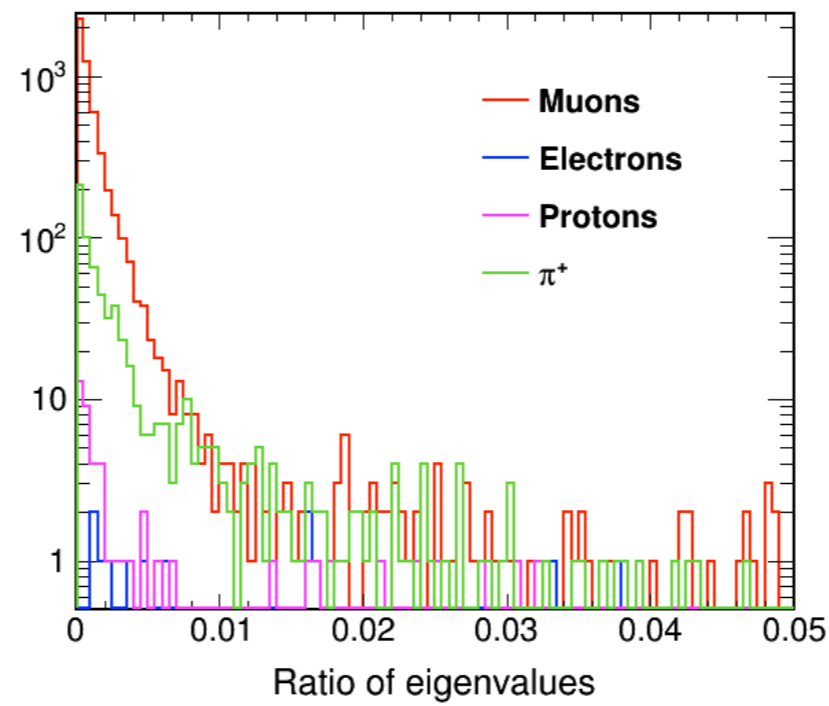
All positions, e.g. radial distance or first or last 20% of track, are computed with respect to this fitted line.

1. Remade event samples with particles starting at $z = 0$ instead of $z = -36$ cm. This is to prevent particles interacting in cryostat before reaching active volume.
2. Fixed a mistake in code that calculates average dE/dx . This was mistakenly adding both dE/dx from amplitude and dE/dx from area into the sum for dE/dx from amplitude, and neither into the sum for dE/dx from area. Hence average values of dE/dx from amplitude were too high by a factor of ~ 2 .
3. Use dE/dx from area instead of from amplitude.
4. Distinguish stopping and exiting particles using true track end positions instead of reconstructed ones.

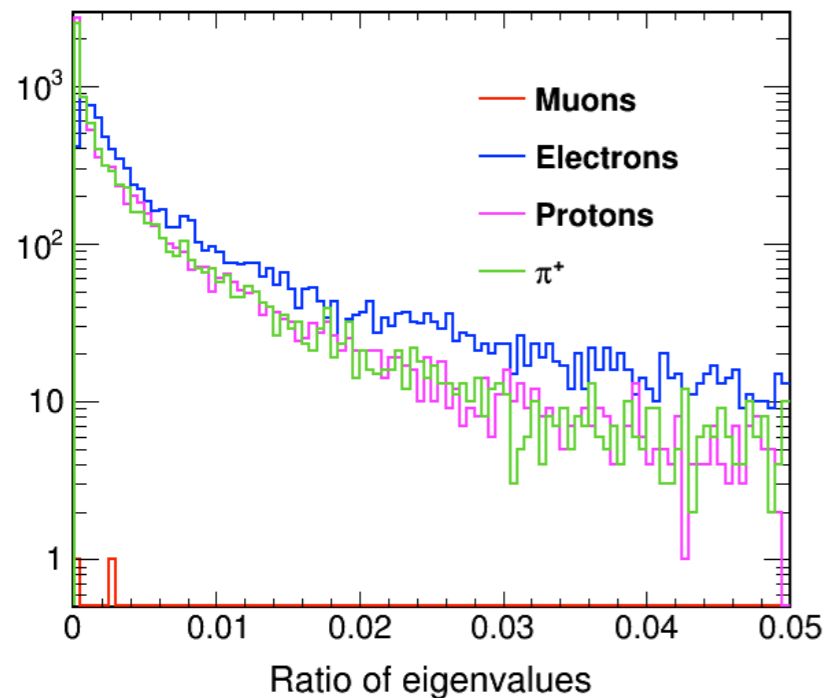
0.5 GeV sample, stopping



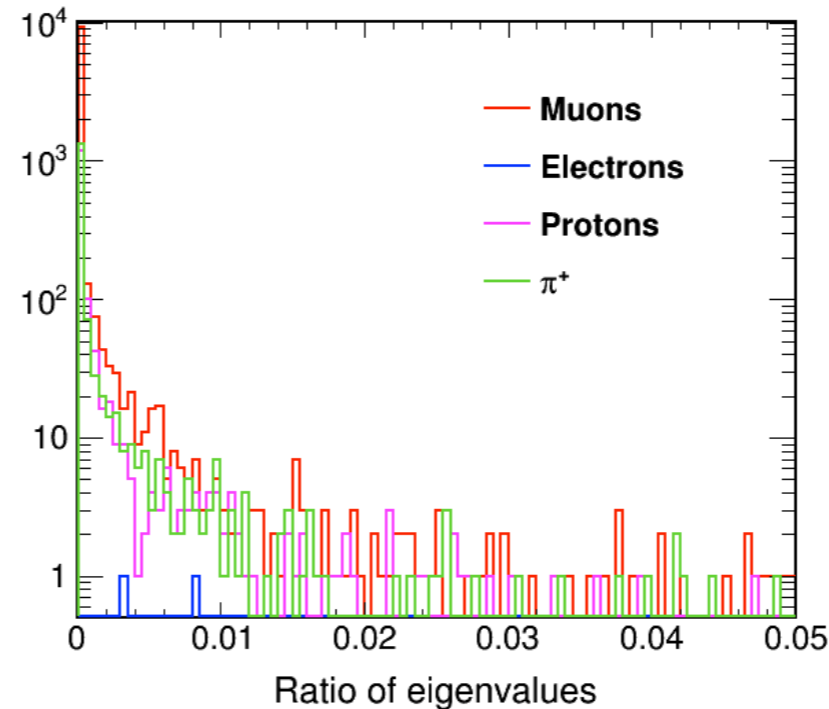
0.5 GeV sample, exiting



2 GeV sample, stopping

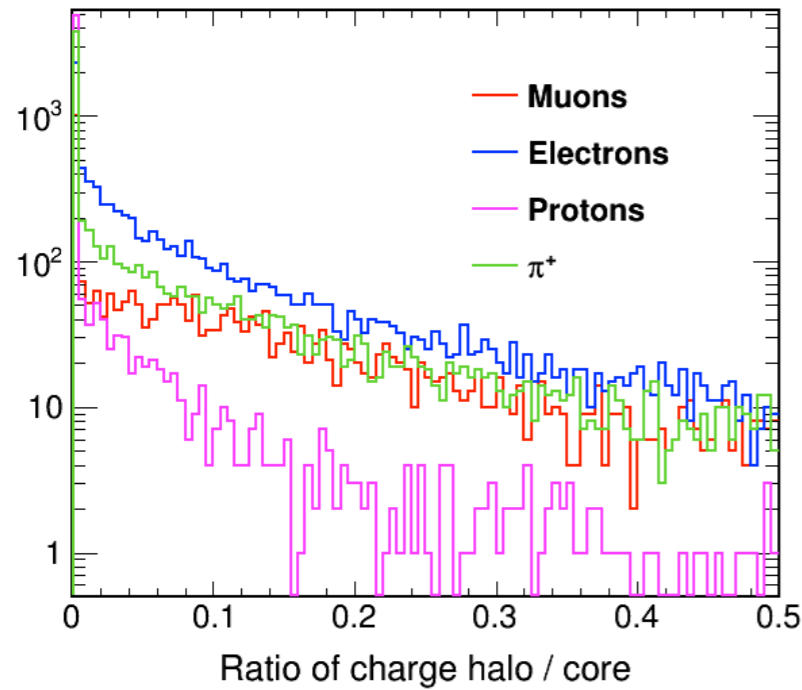


2 GeV sample, exiting

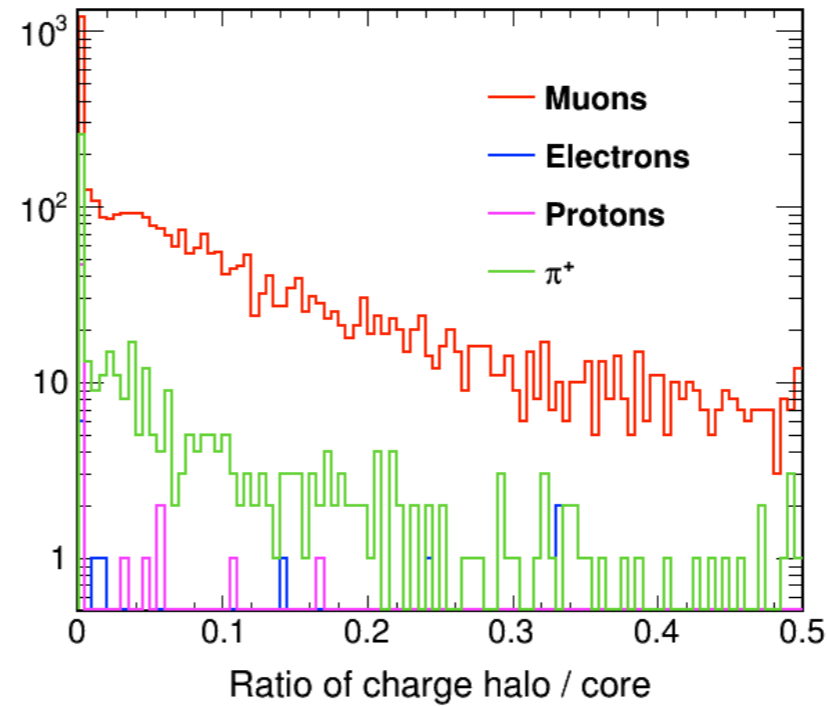


Ratio of second-largest and third-largest eigenvalues (added in quadrature) to largest eigenvalue from PCA.

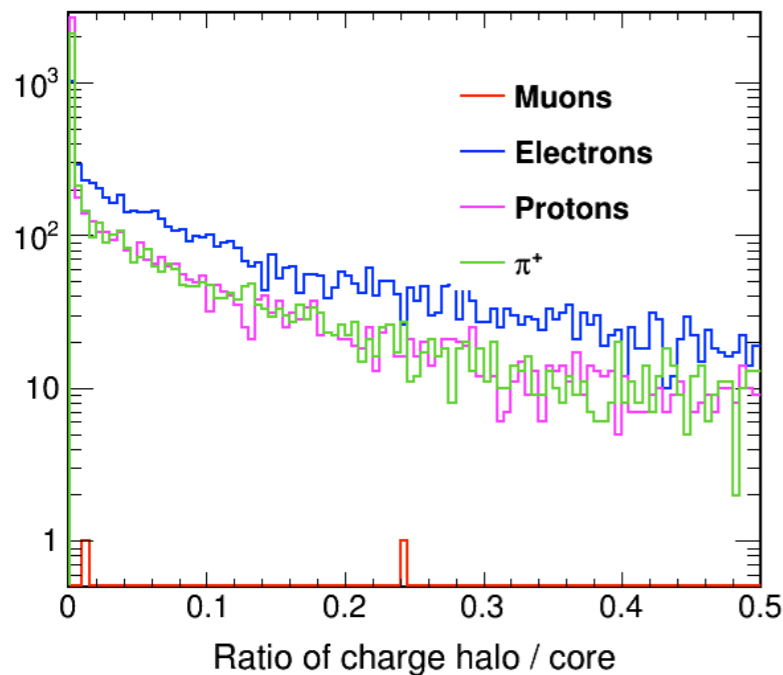
0.5 GeV sample, stopping



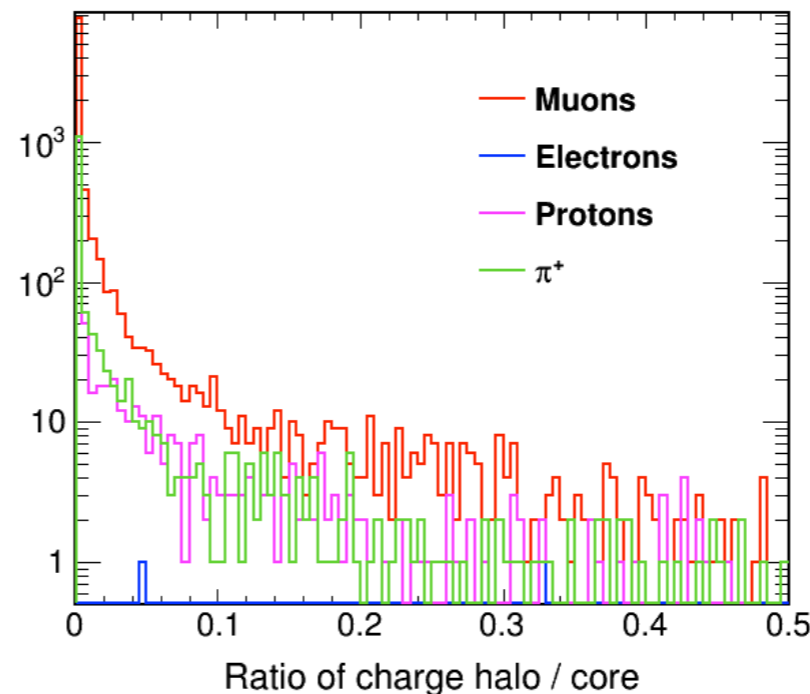
0.5 GeV sample, exiting



2 GeV sample, stopping

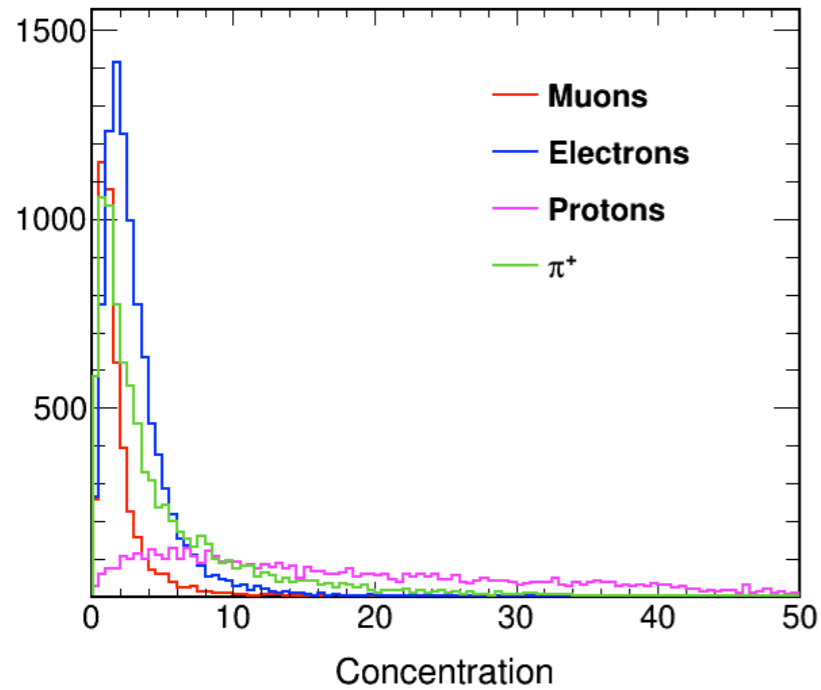


2 GeV sample, exiting

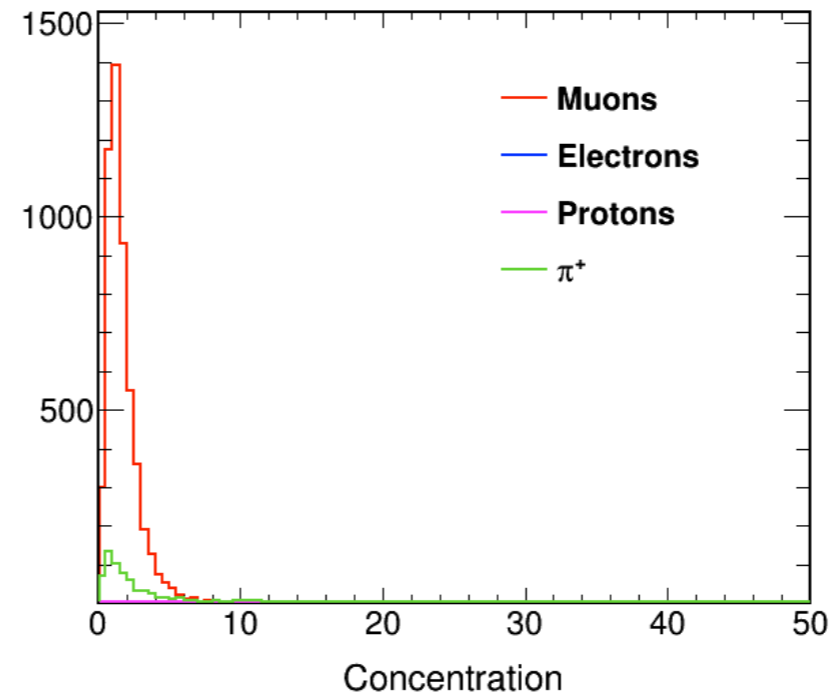


Ratio of charge deposited halo / core:
 “core” is < 0.25
 Moliere radius from line fitted to reconstructed track, “halo” is \geq than this value.

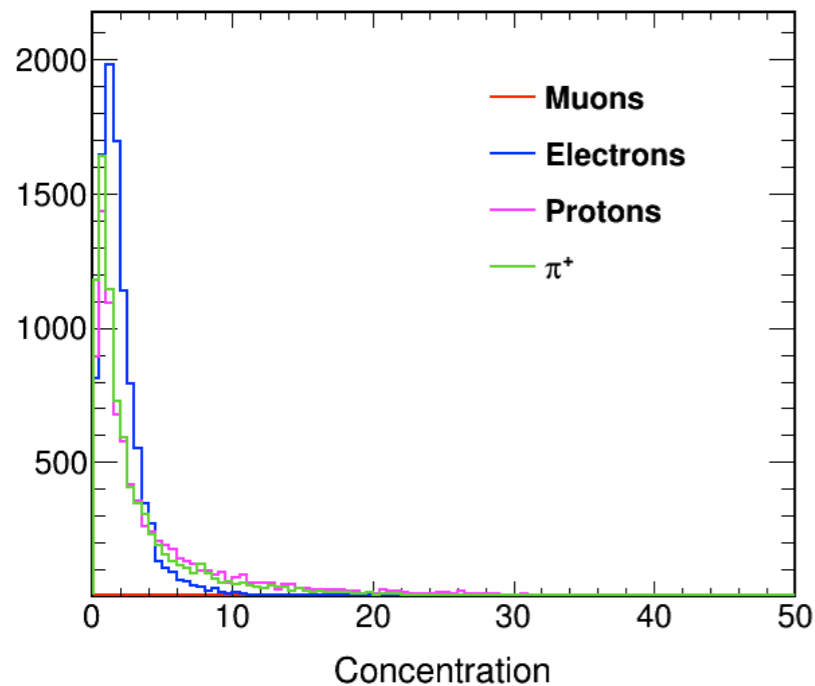
0.5 GeV sample, stopping



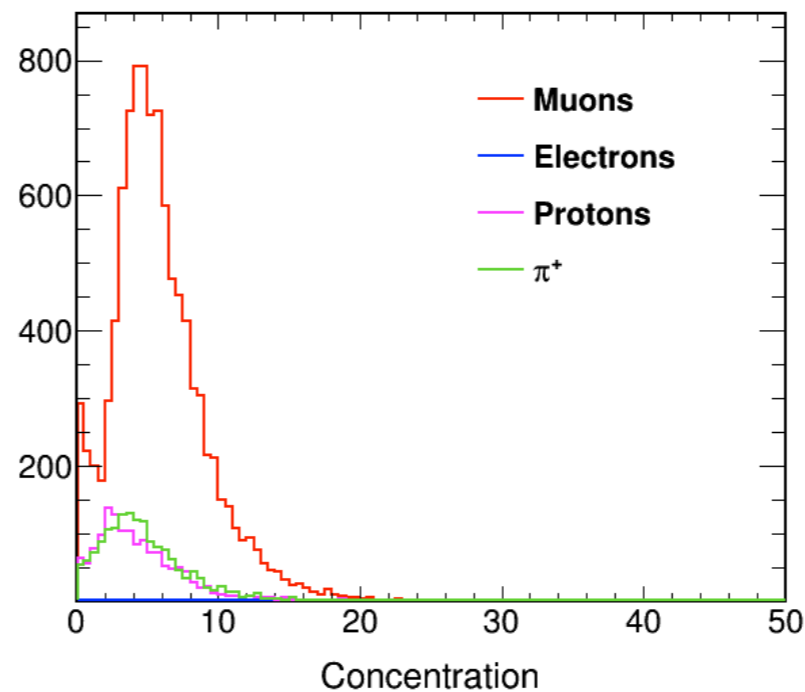
0.5 GeV sample, exiting



2 GeV sample, stopping



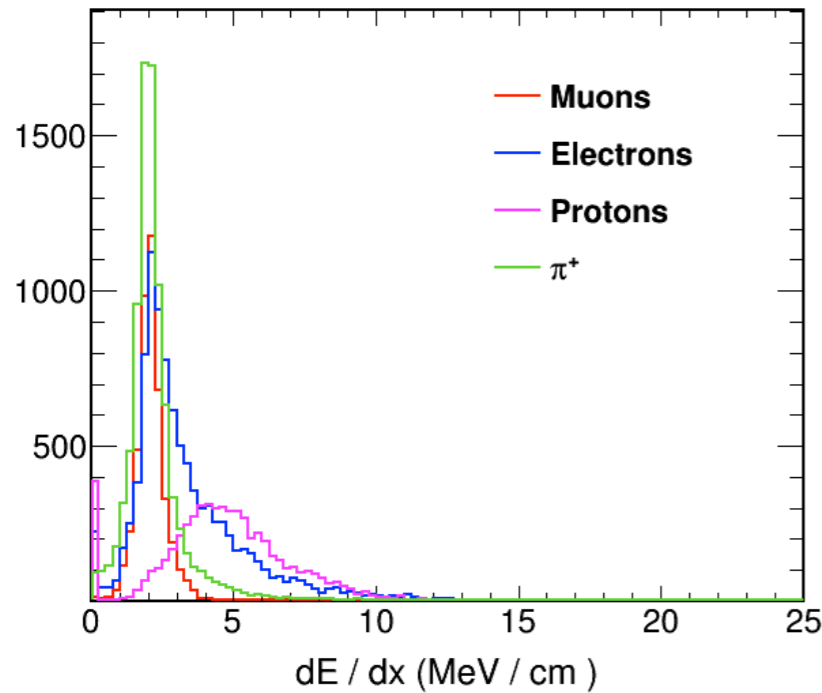
2 GeV sample, exiting



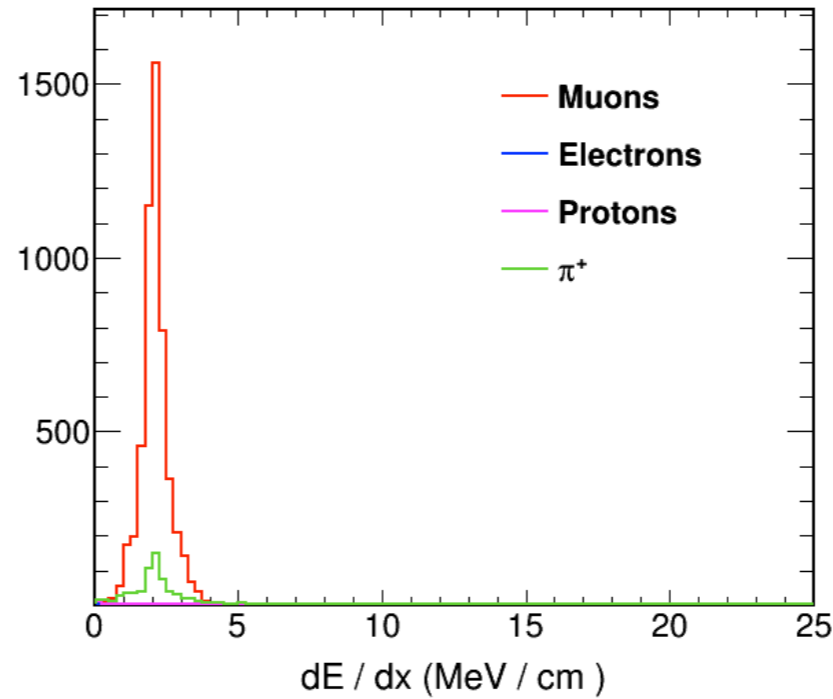
For each hit, calculate charge deposited / radial distance from line fitted to reconstructed track.

Make sum of this quantity for all hits, and divide it by total charge.

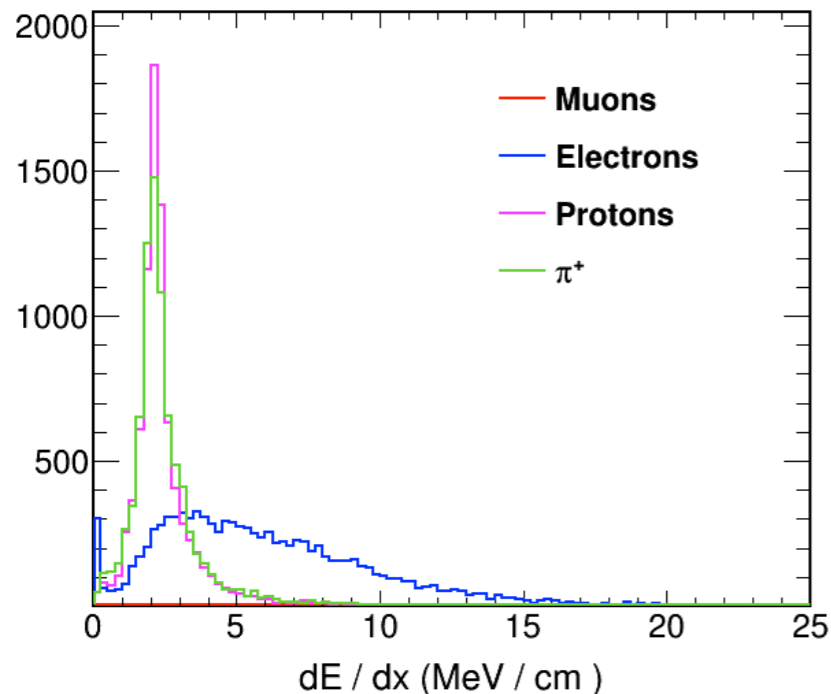
0.5 GeV sample, stopping



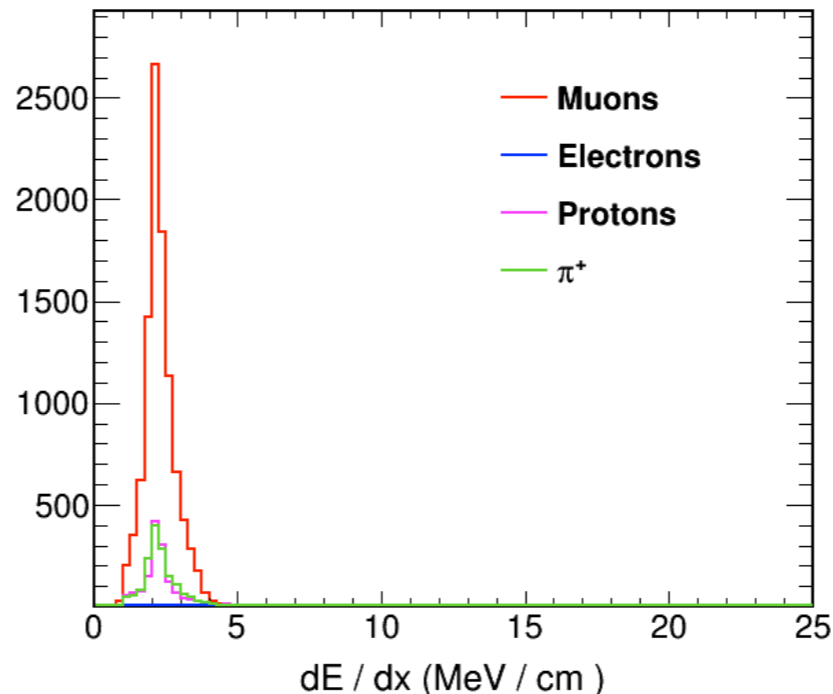
0.5 GeV sample, exiting



2 GeV sample, stopping



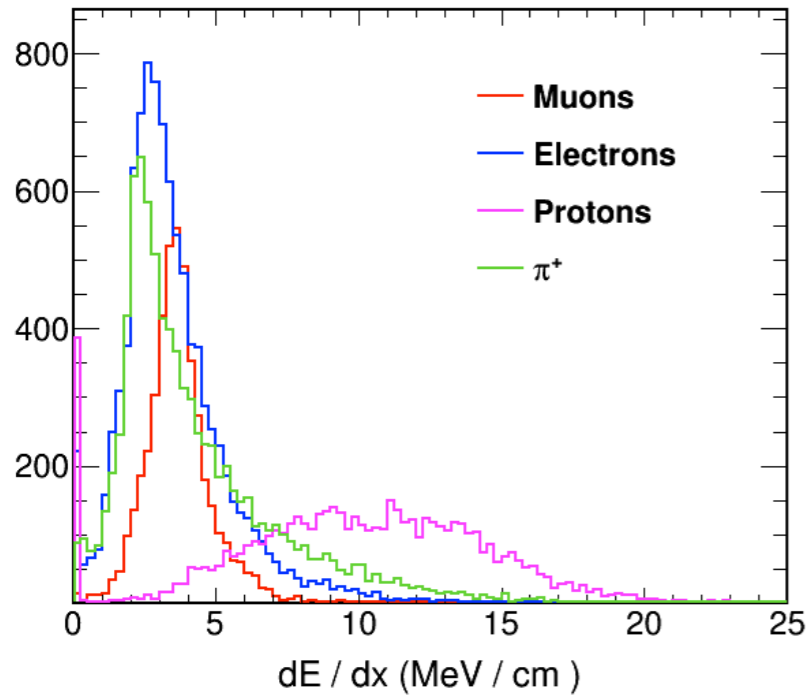
2 GeV sample, exiting



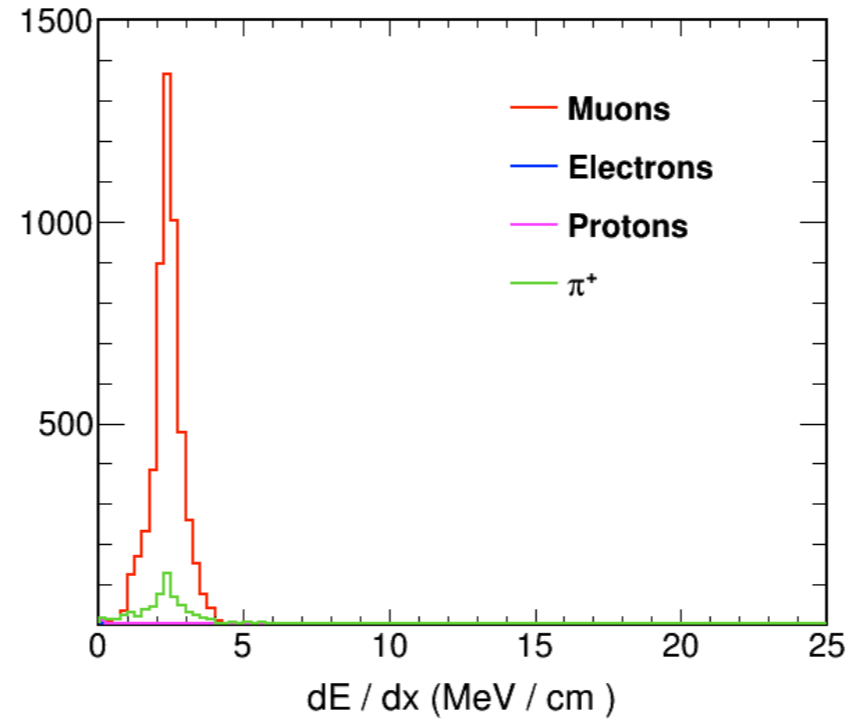
dE/dx is average value from first 20% of reconstructed track.

Spikes at 0 come from events with too few hits to make it viable to divide track into 5 sections. For these events, average dE/dx is not calculated but set to 0.

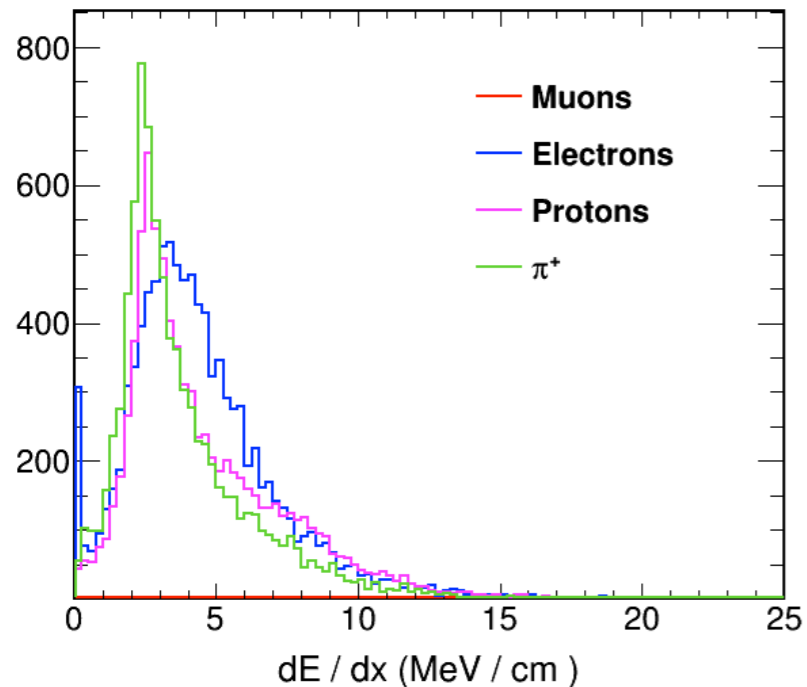
0.5 GeV sample, stopping



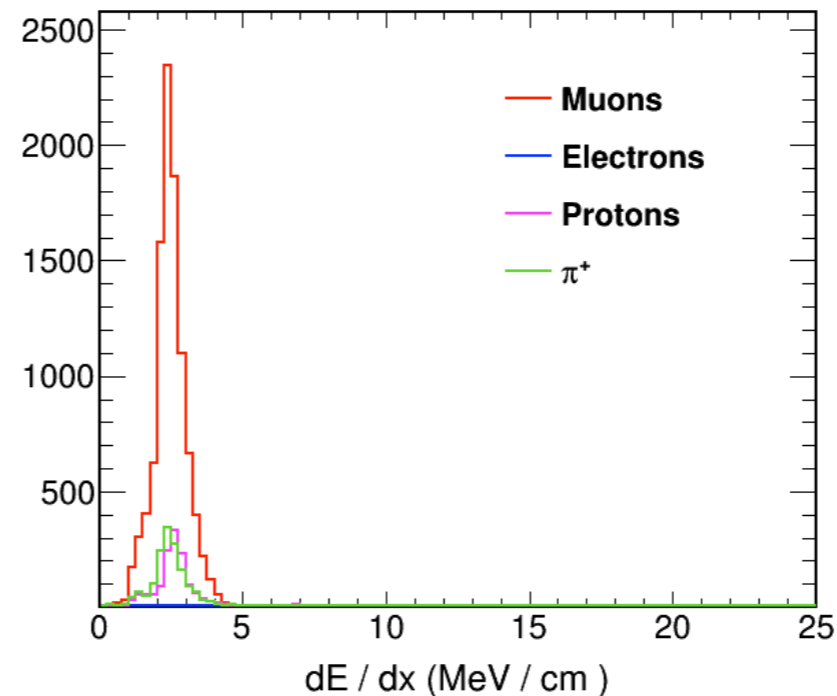
0.5 GeV sample, exiting



2 GeV sample, stopping

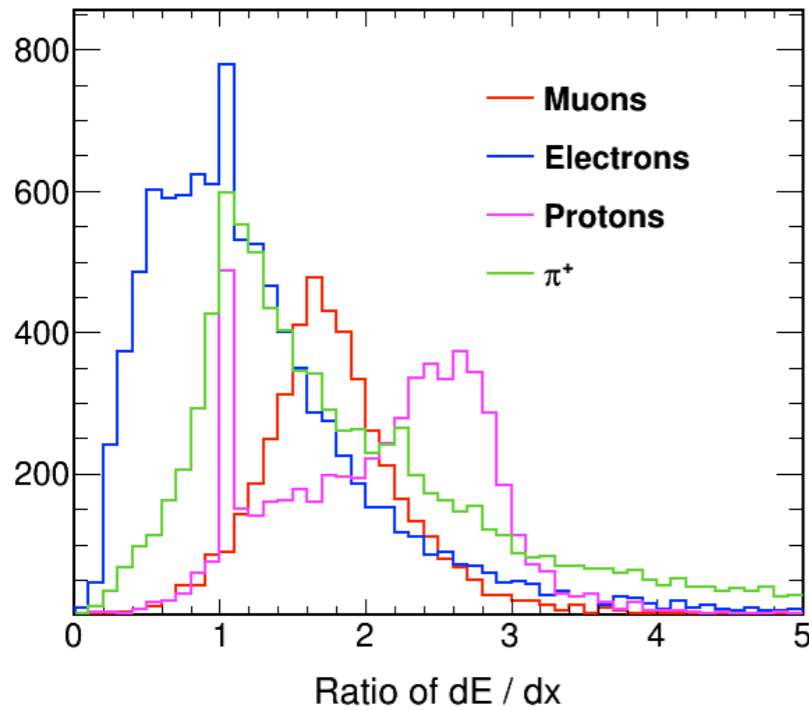


2 GeV sample, exiting

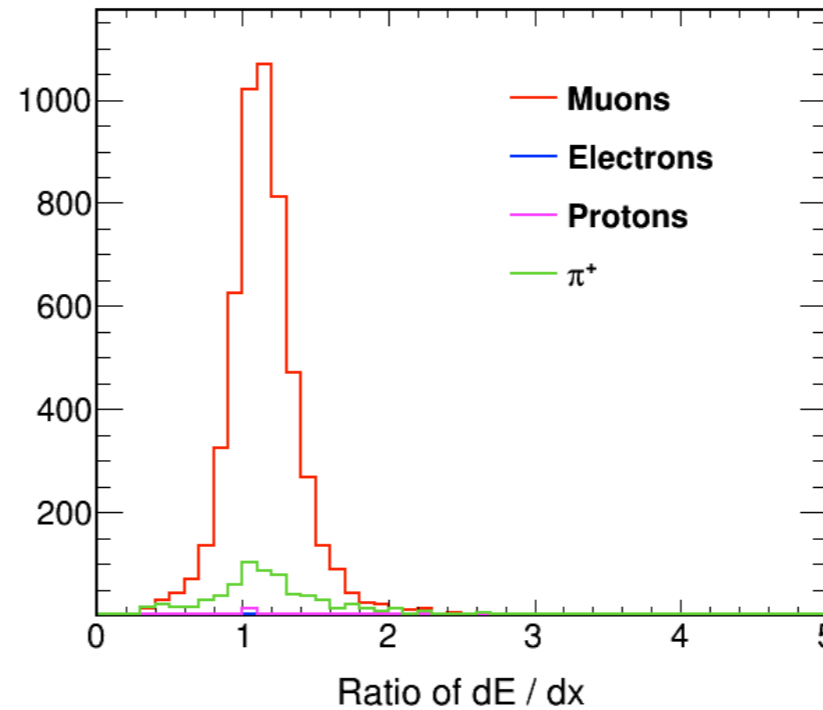


dE/dx is average value from last 20% of reconstructed track.

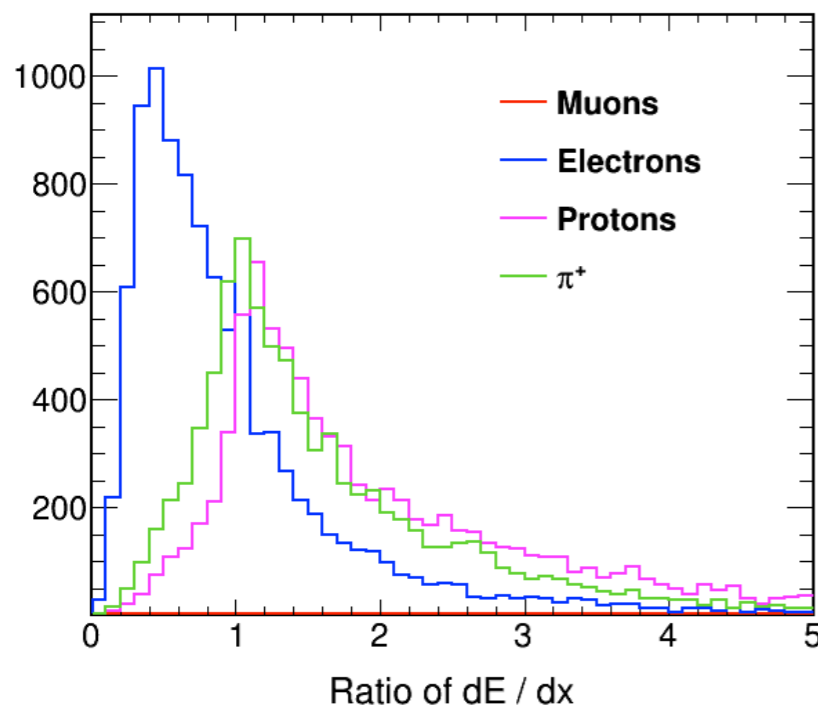
0.5 GeV sample, stopping



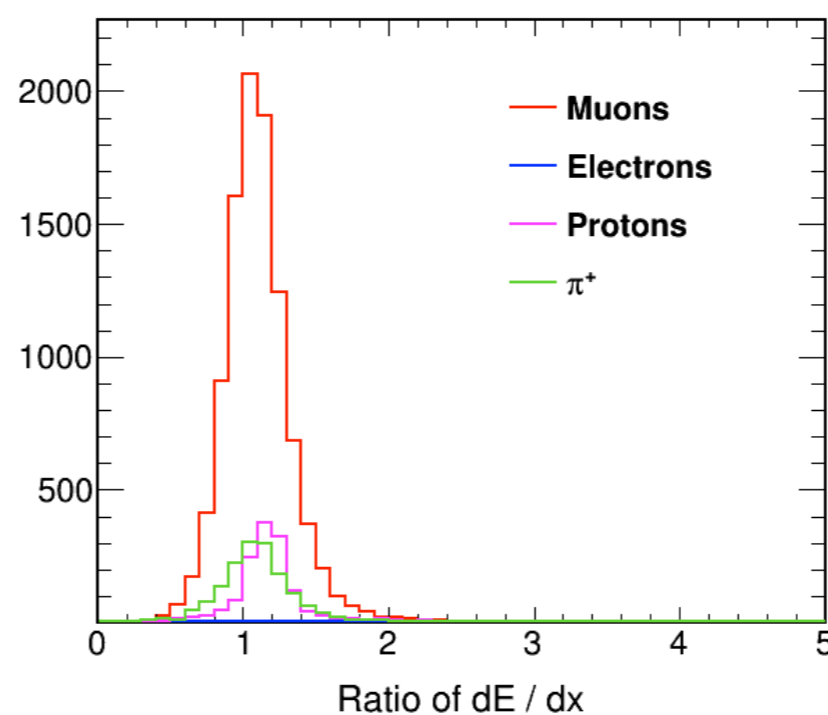
0.5 GeV sample, exiting



2 GeV sample, stopping



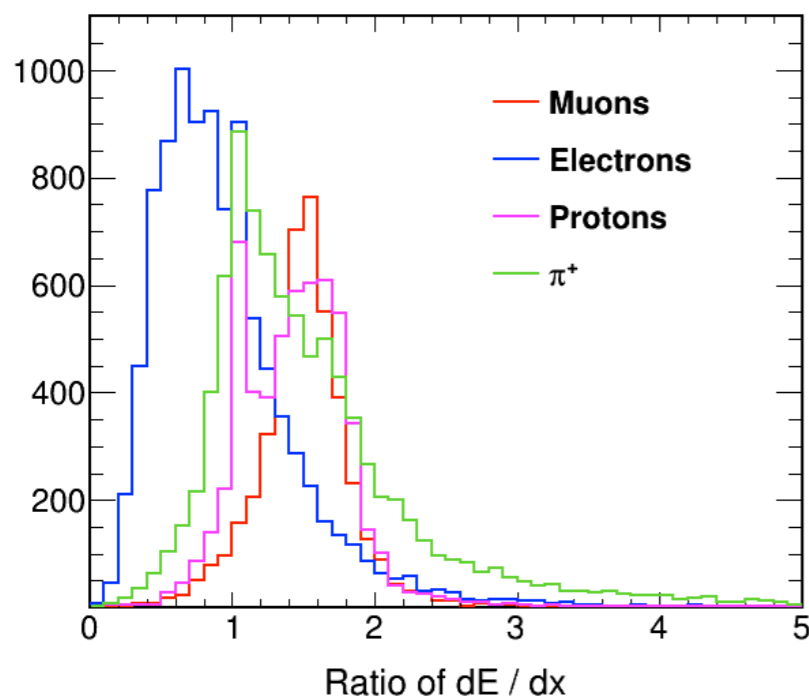
2 GeV sample, exiting



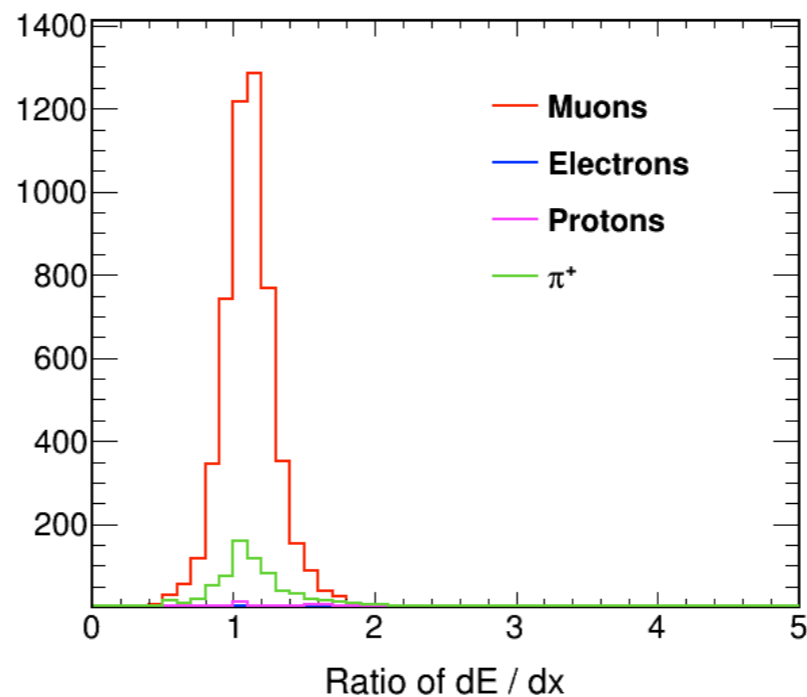
Ratio of average dE/dx in last 20% / first 20% of reconstructed track.

Spikes at 1 come from events with too few hits to make it viable to divide track into 5 sections. For these events, dE/dx ratio is not calculated but set to 1.

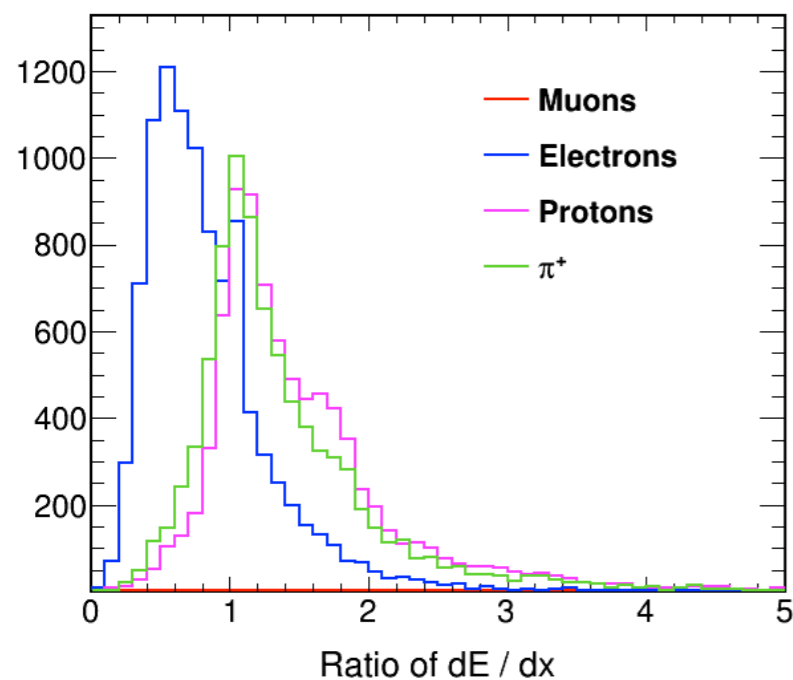
0.5 GeV sample, stopping



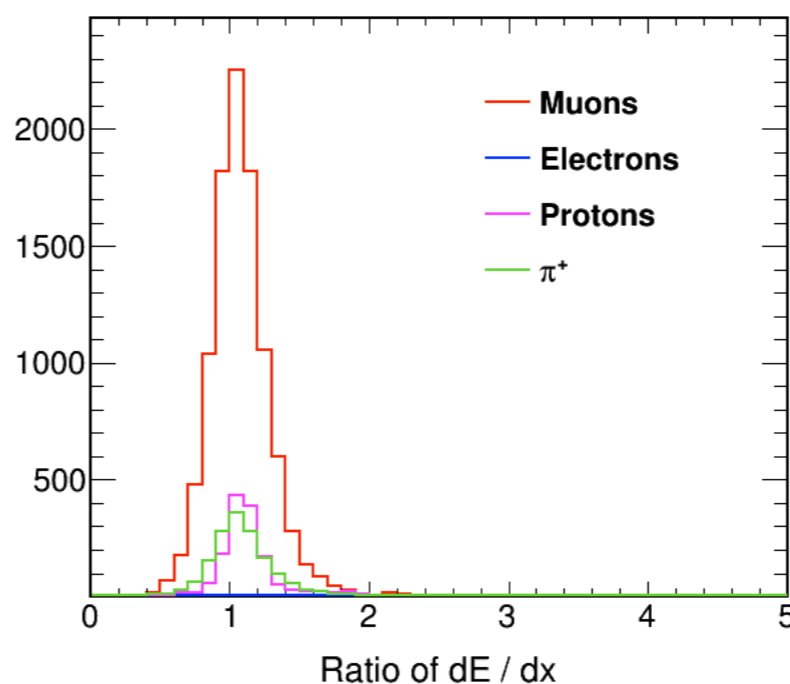
0.5 GeV sample, exiting



2 GeV sample, stopping



2 GeV sample, exiting



Ratio of
average dE/dx
in last 20% /
penultimate
20% of
reconstructed
track



Multivariate analysis



Methods used are MLP (neural net) and boosted decision tree (BDT).

Generated from same event samples as the particle ID variables.

A MVA is done separately for each value of momentum in the event samples.

Particle ID variables used are:

Ratio of eigenvalues

Ratio of charge deposited halo/core

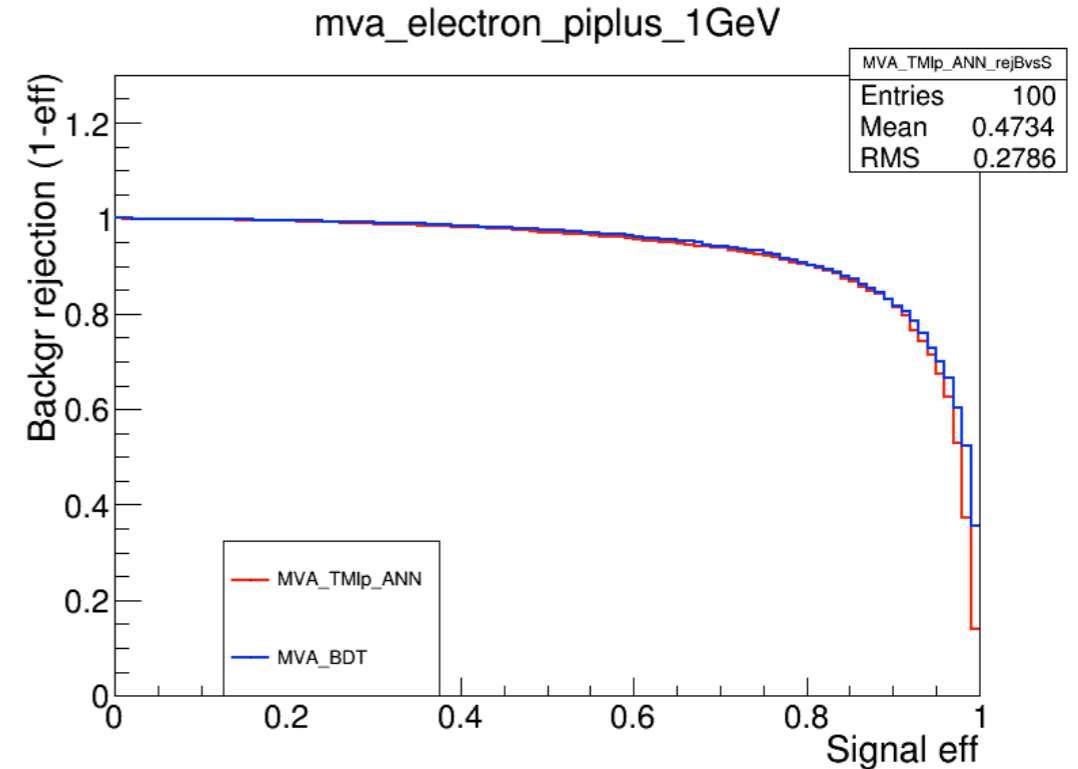
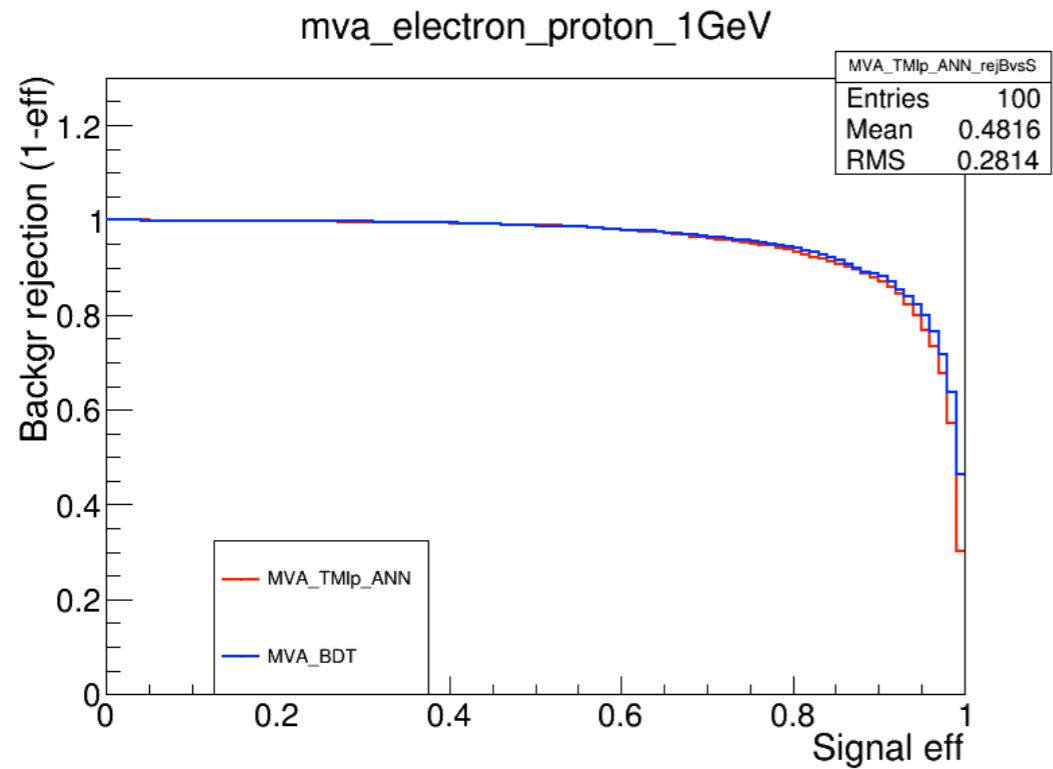
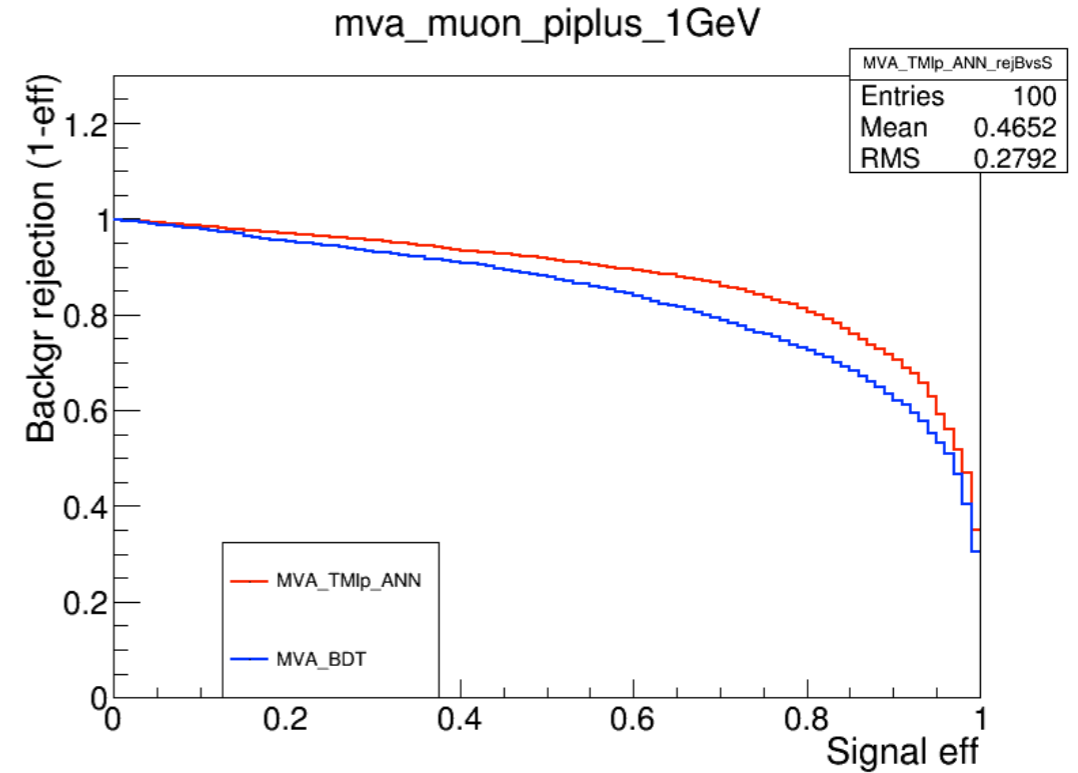
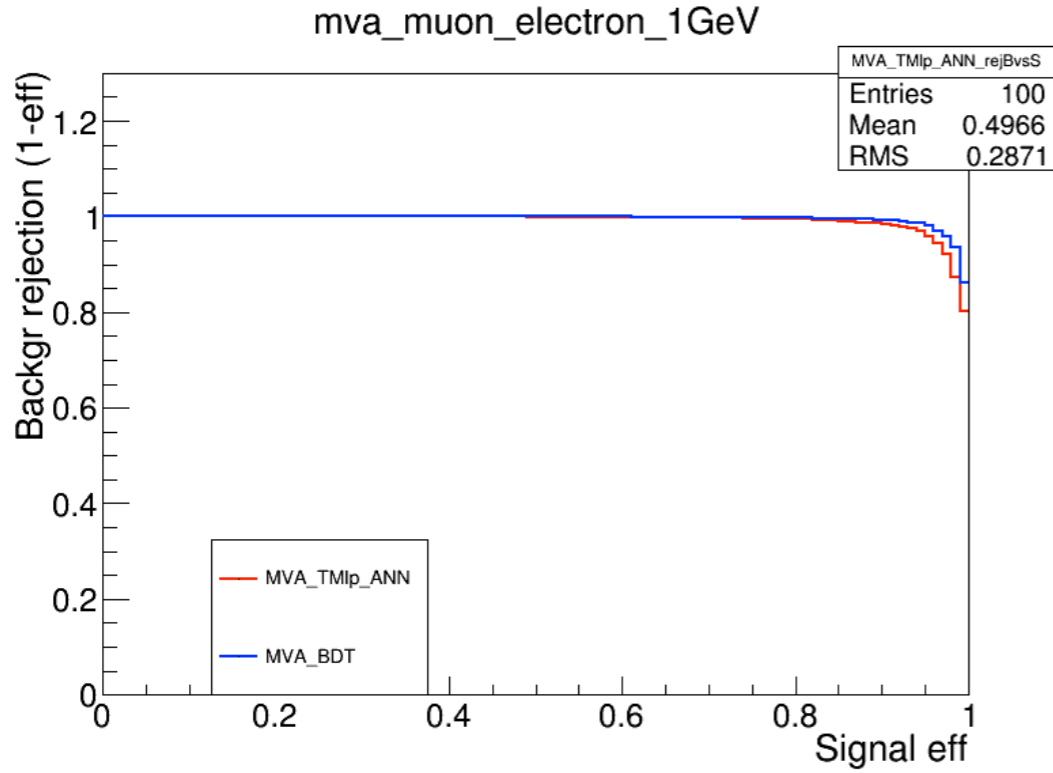
Concentration

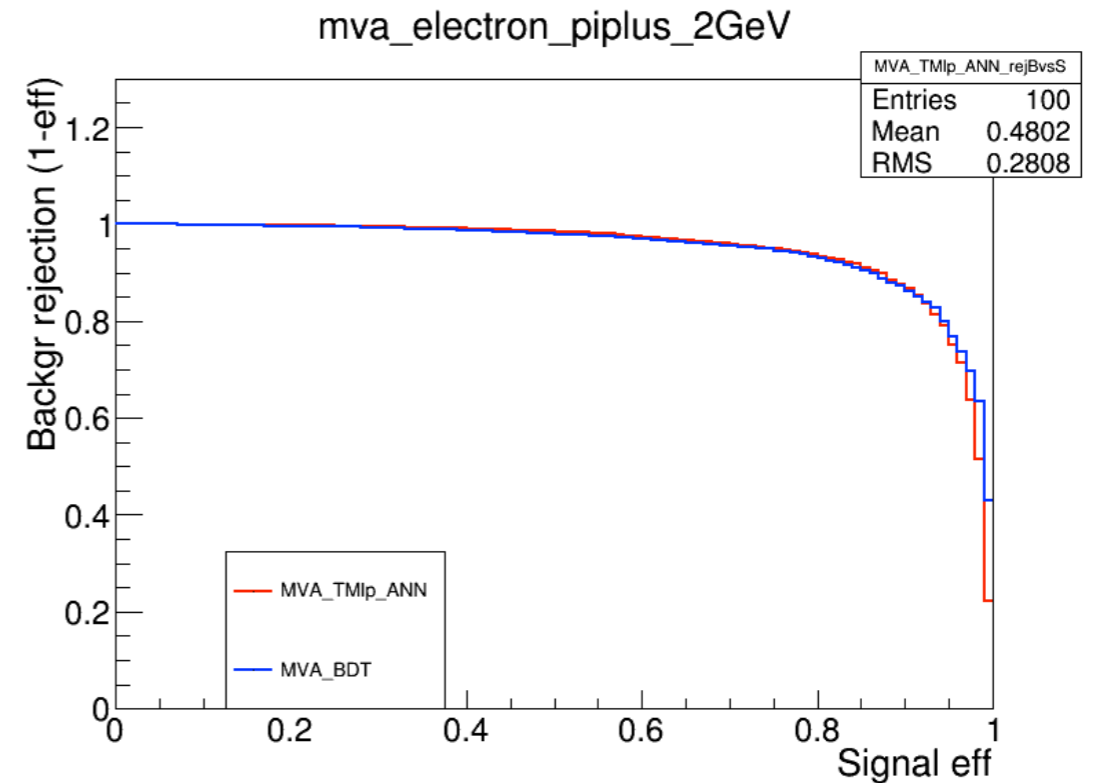
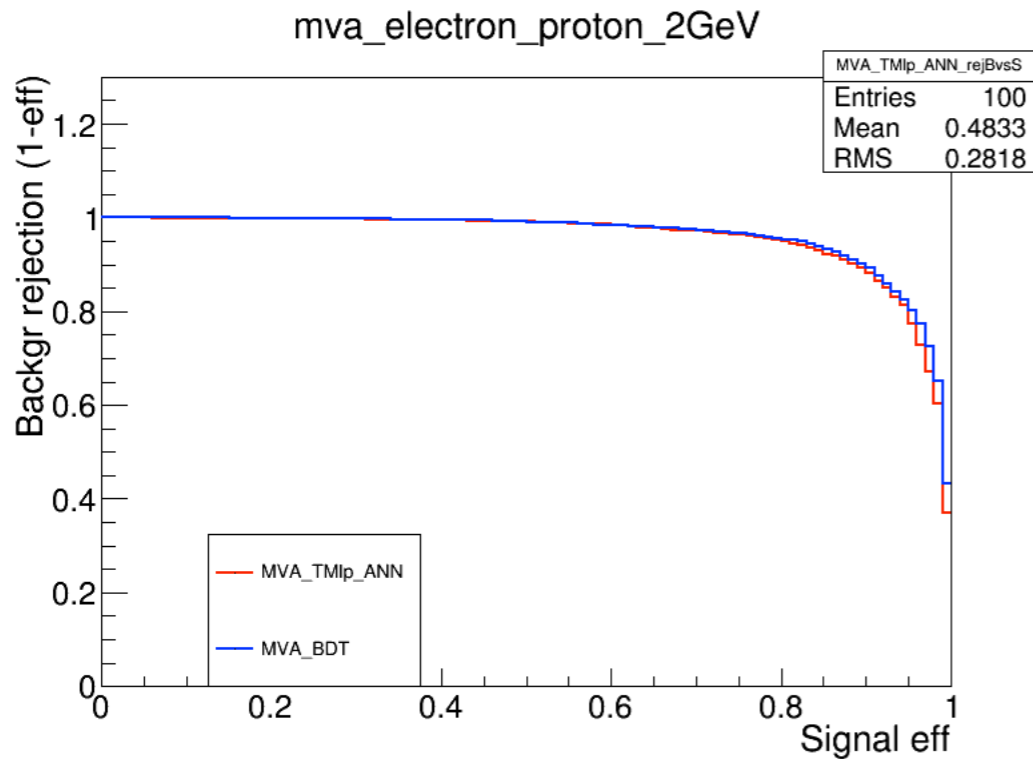
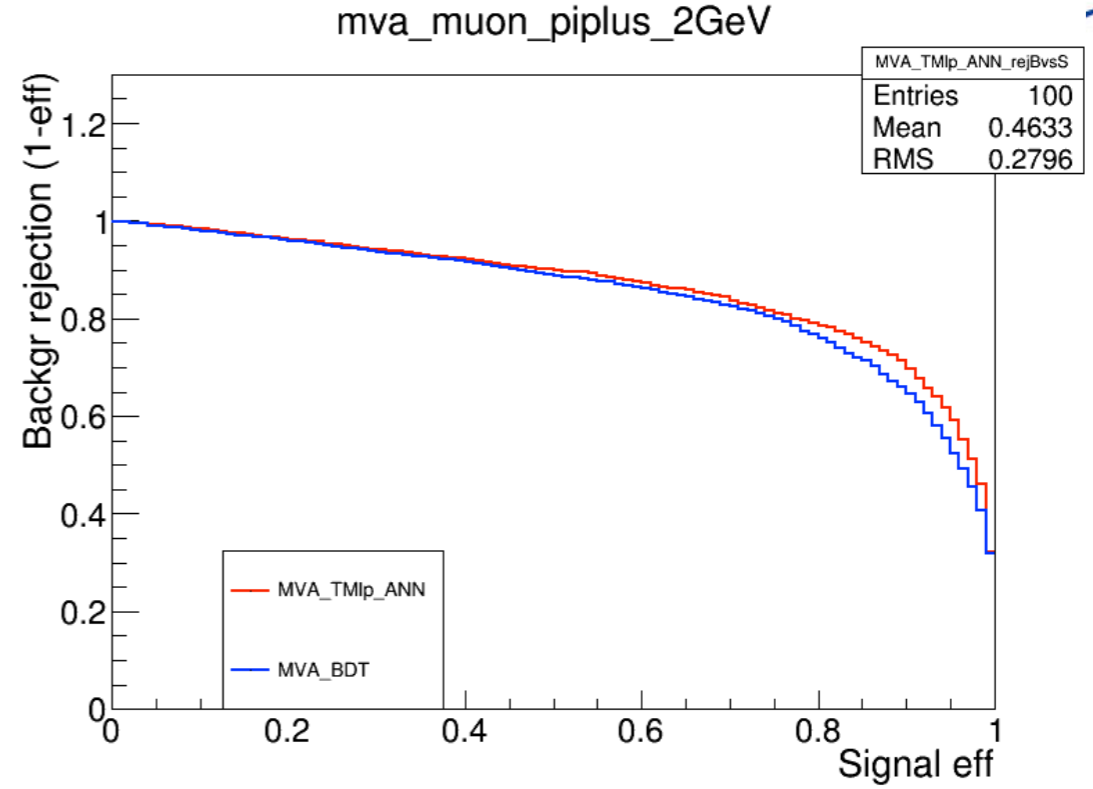
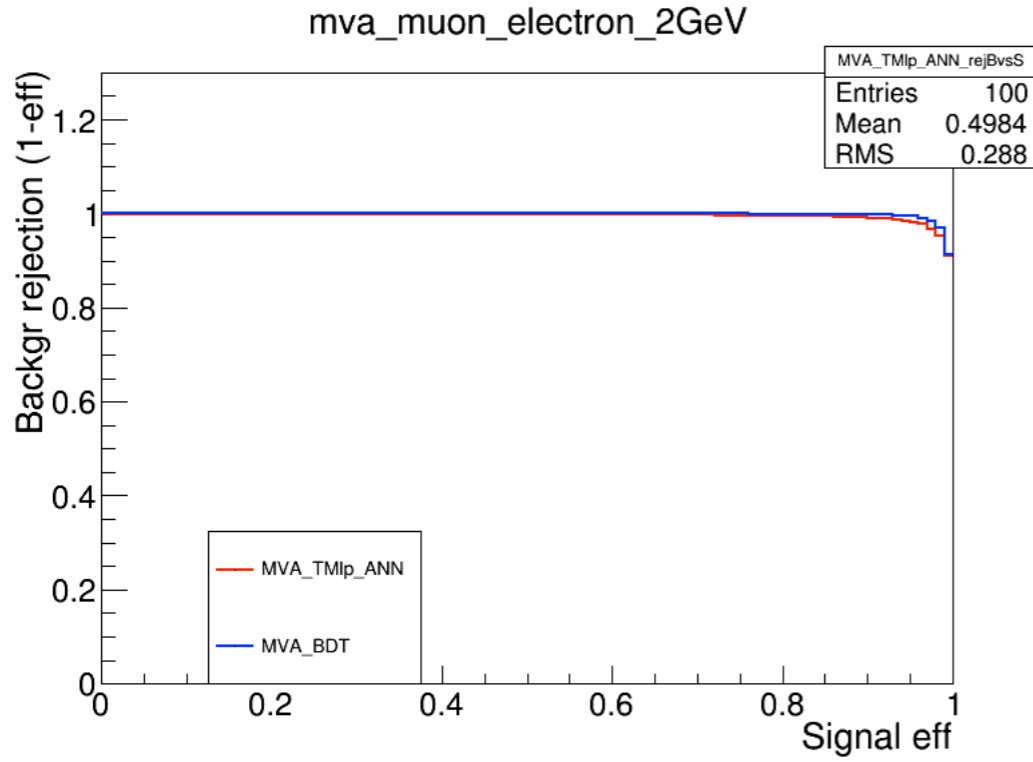
dE/dx at start of track

dE/dx at end of track

Longitudinal dE/dx ratio

End dE/dx ratio.







Conclusion



We have identified some variables that can help to distinguish muons, electrons, protons and pions in a liquid argon TPC.

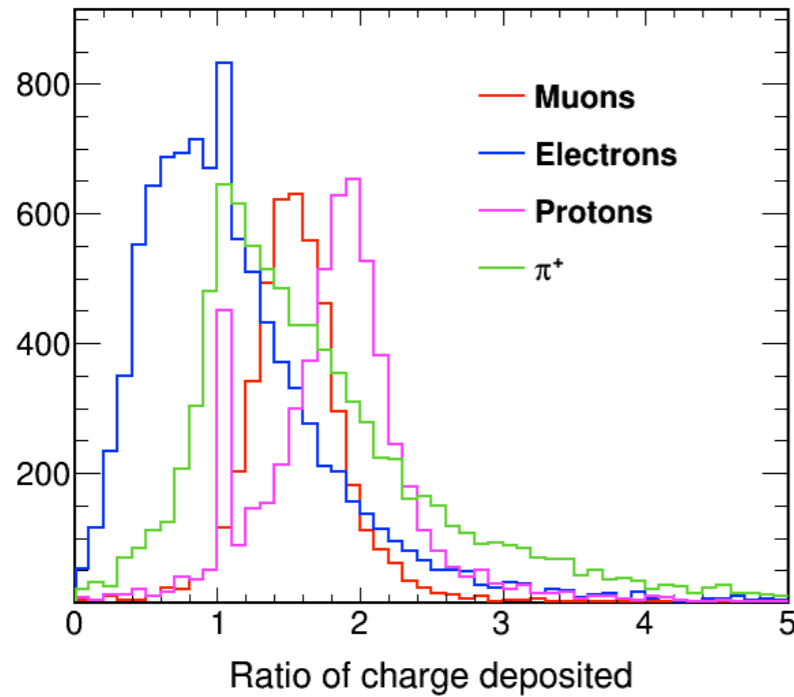
We have also made a multivariate analysis using those variables as input, and this MVA gives promising results.

We are working on adding our PID code as a module in LArSoft. This module will be an initial version, and we will continue to work on improving the performance of the PID variables and MVA.

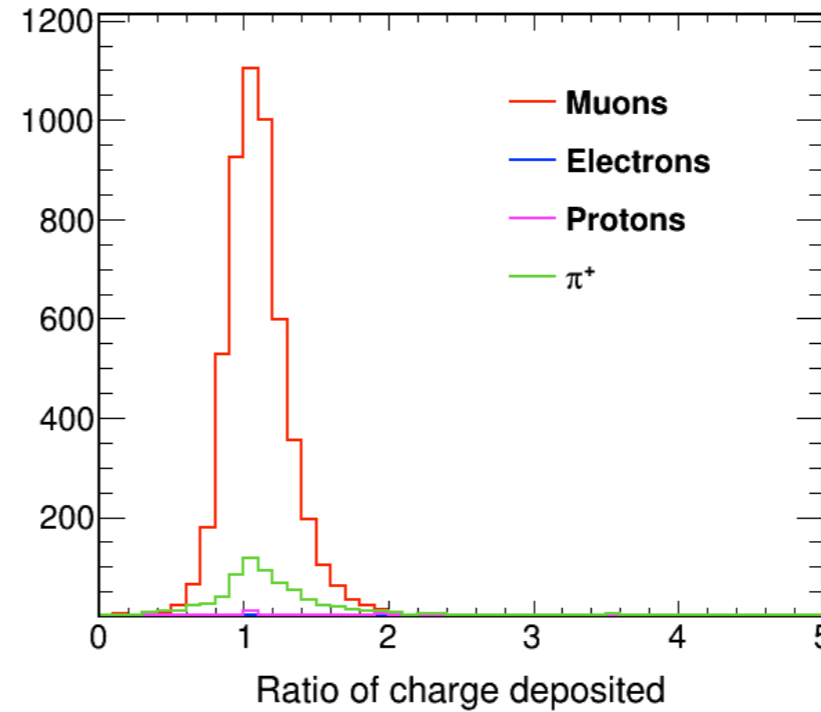


BACKUP SLIDES

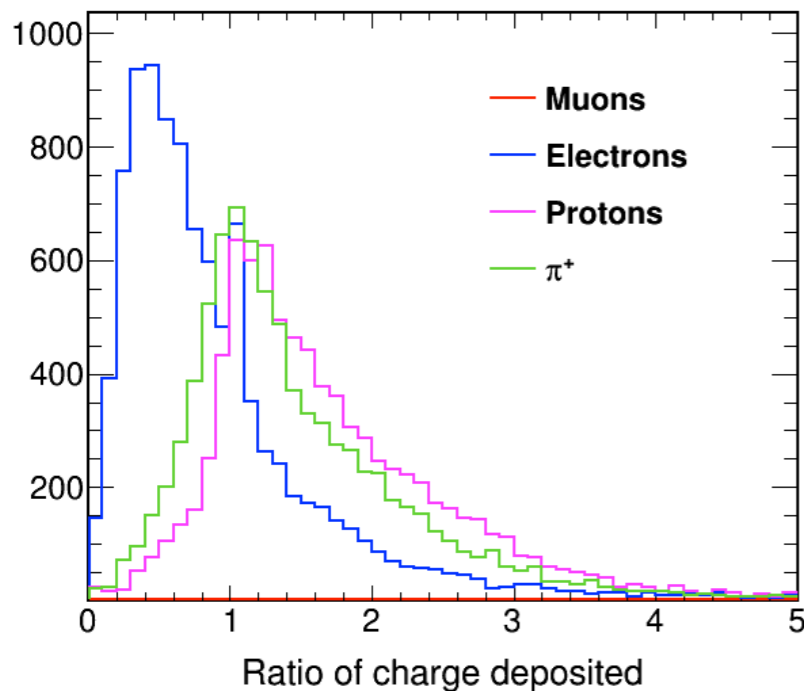
0.5 GeV sample, stopping



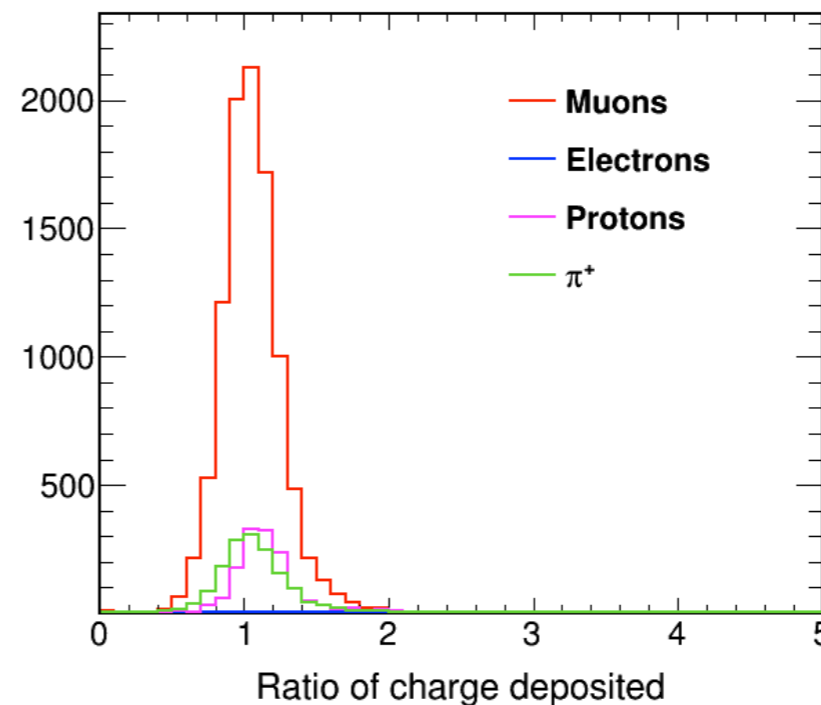
0.5 GeV sample, exiting



2 GeV sample, stopping

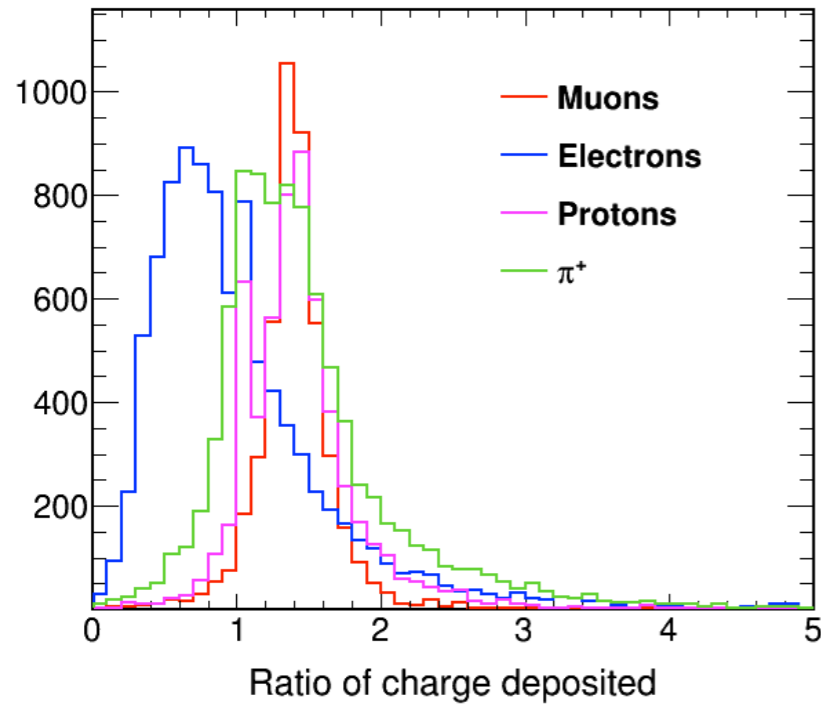


2 GeV sample, exiting

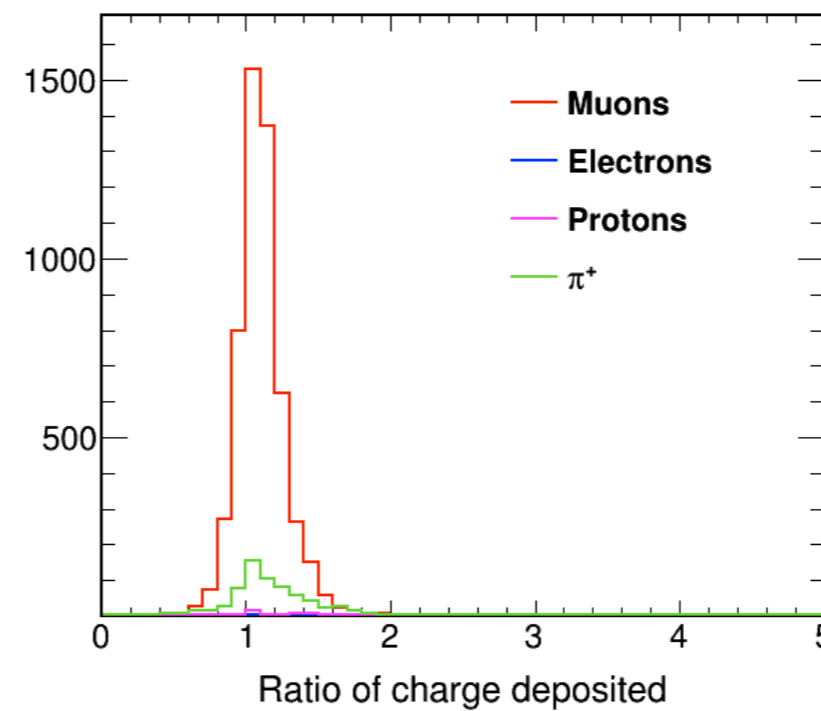


Ratio of charge deposited in last 20% / first 20% of reconstructed track

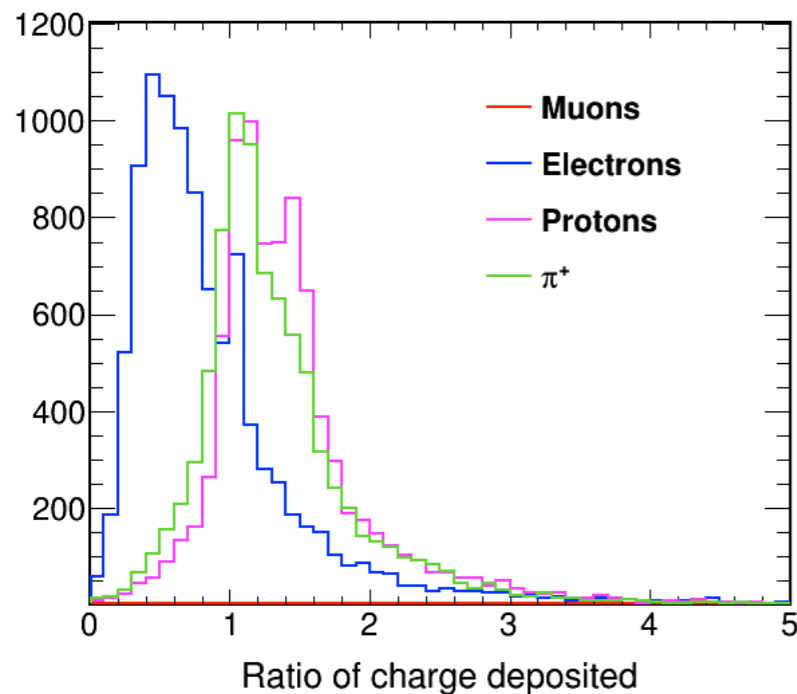
0.5 GeV sample, stopping



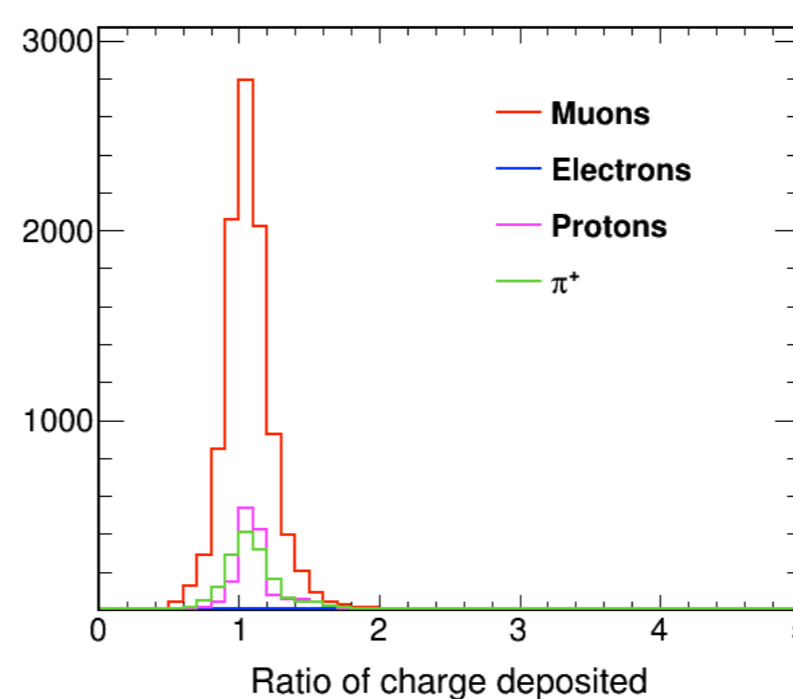
0.5 GeV sample, exiting



2 GeV sample, stopping



2 GeV sample, exiting



Ratio of charge deposited in last 20% / penultimate 20% of reconstructed track