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 first look at some variables that can discriminate between different particles.

Made an initial 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 5 different values of true momentum: 0.5, 1, 2, 3 and 4 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.

Introduction

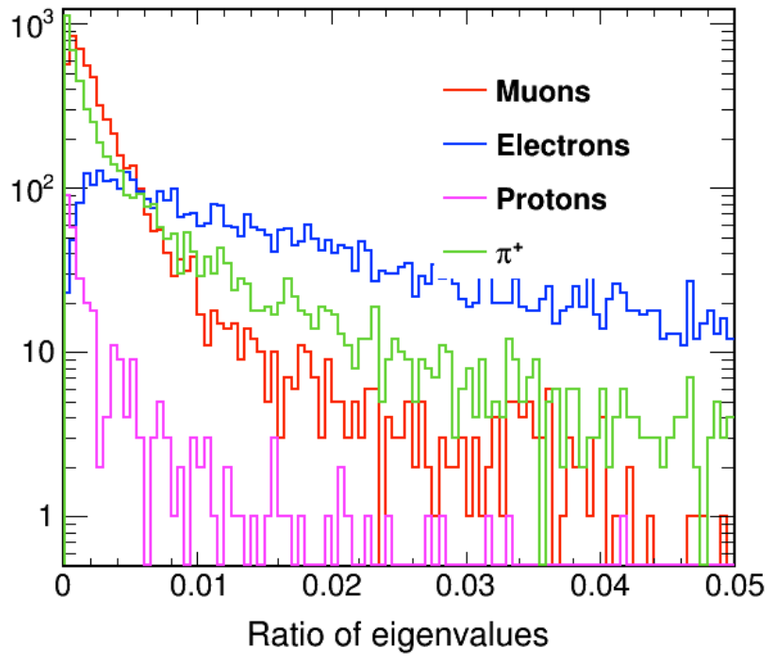
Fit a straight line in 3D to the hits in the reconstructed track with the largest number of hits in the event. This fit is made by minimising the sum of squares of residuals between the hit spacepoints and the fitted line.

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 (previously we used only the hits from the collection plane). Plots in this presentation are made using dE/dx from hit amplitude.

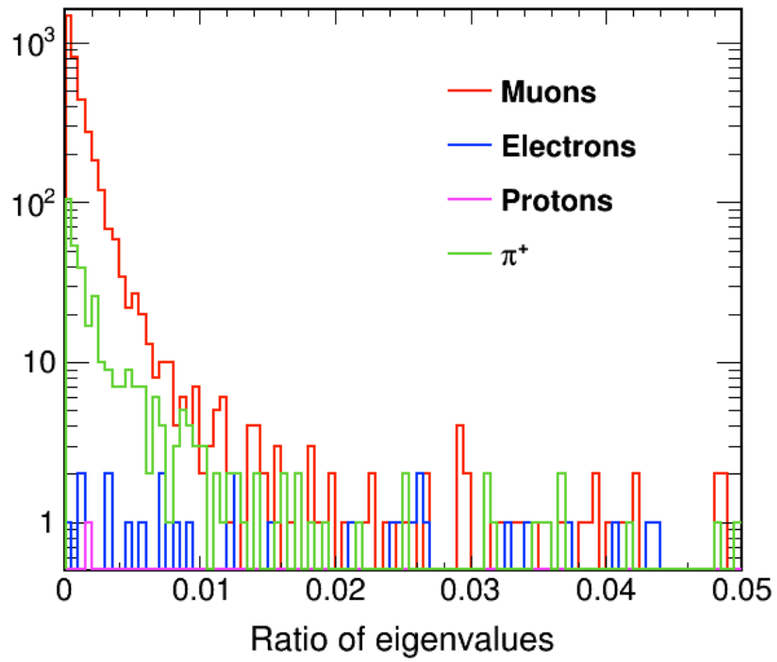
All positions, e.g. radial distance or first or last 20% of track, are computed with respect to this fitted line (previously they were computed with respect to the principal axis from the PCA).

Ratio of eigenvalues

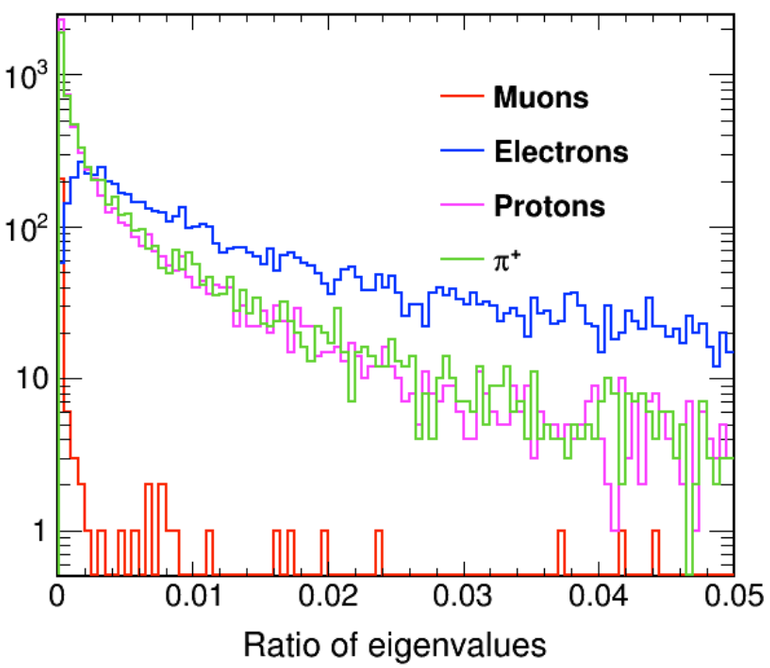
0.5 GeV sample, stopping



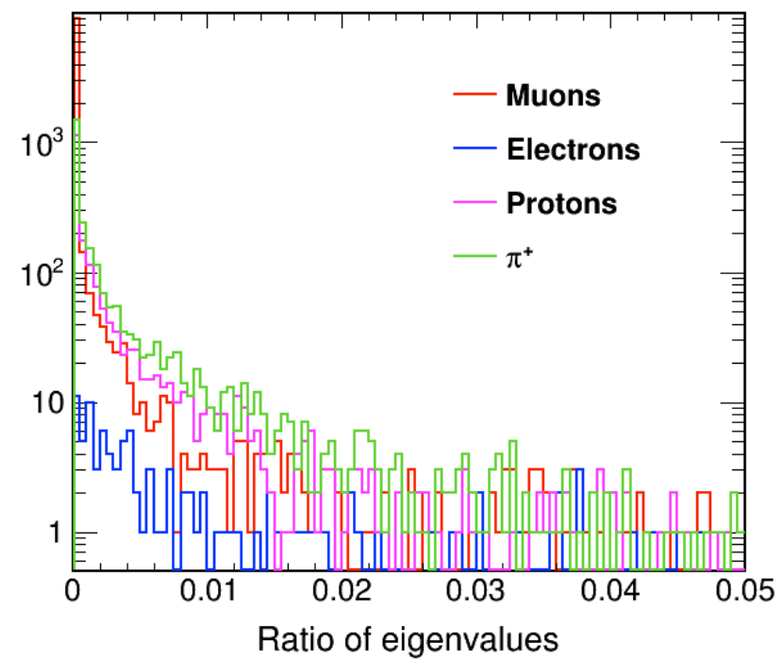
0.5 GeV sample, exiting



2 GeV sample, stopping



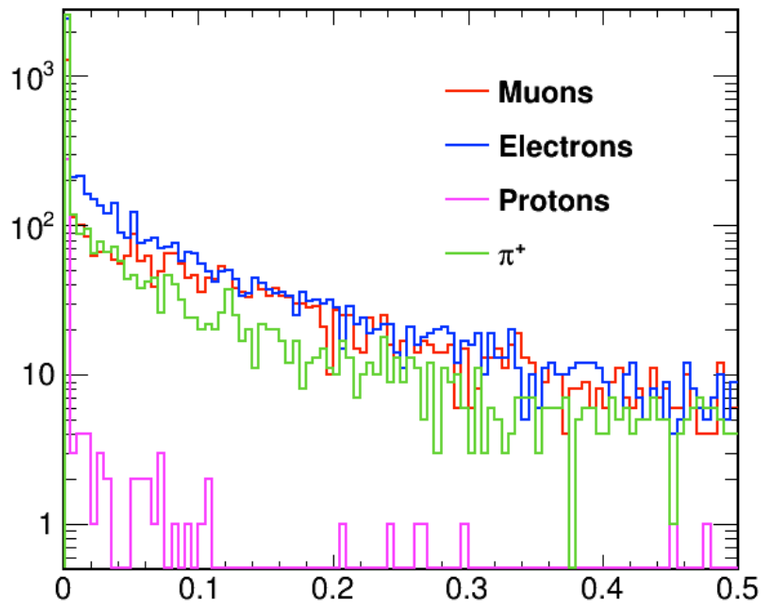
2 GeV sample, exiting



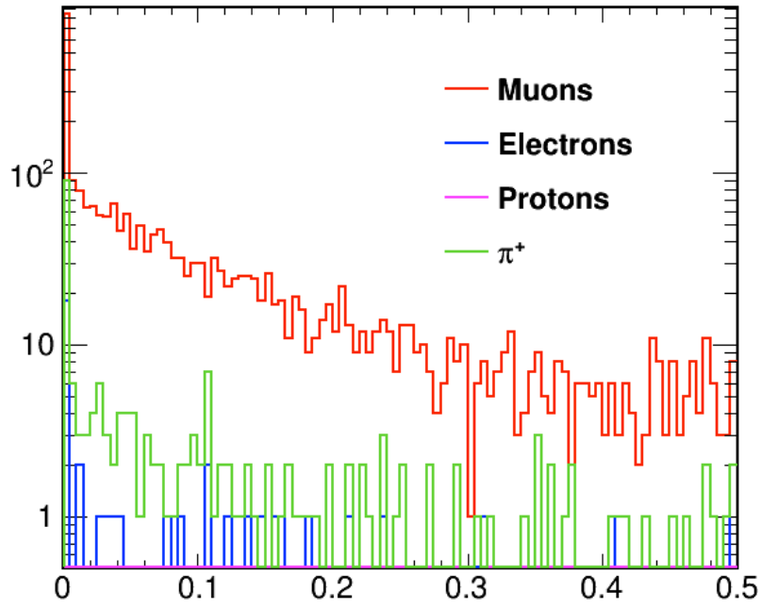
Ratio of second-largest and third-largest eigenvalues (added in quadrature) to largest eigenvalue from PCA.

Ratio of charge halo / core

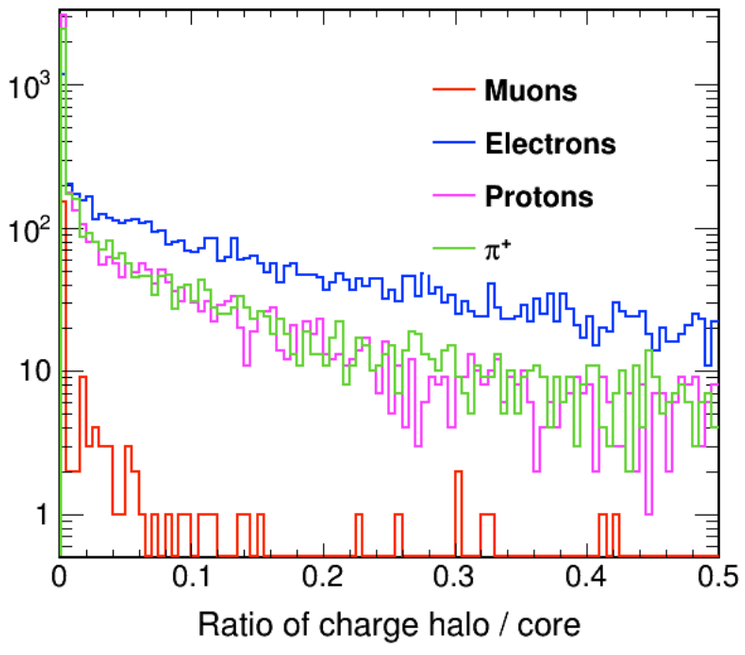
0.5 GeV sample, stopping



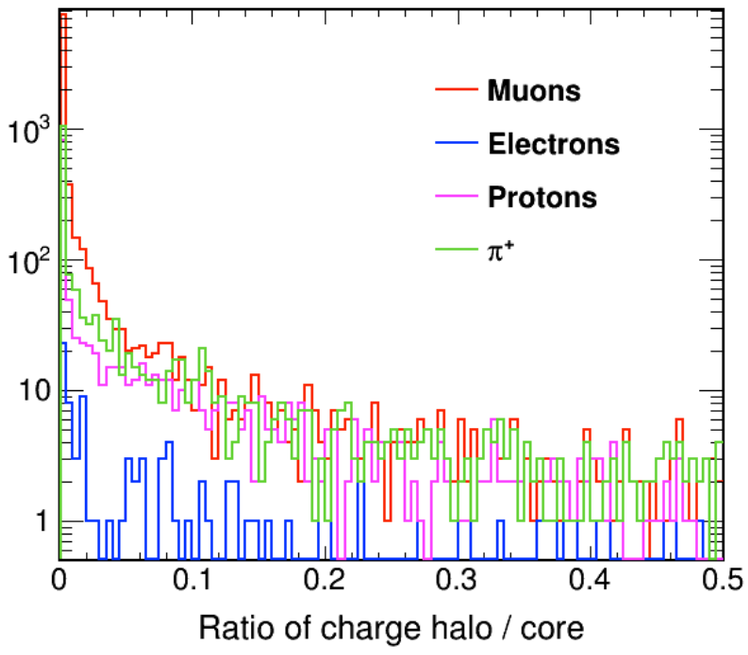
0.5 GeV sample, exiting



2 GeV sample, stopping



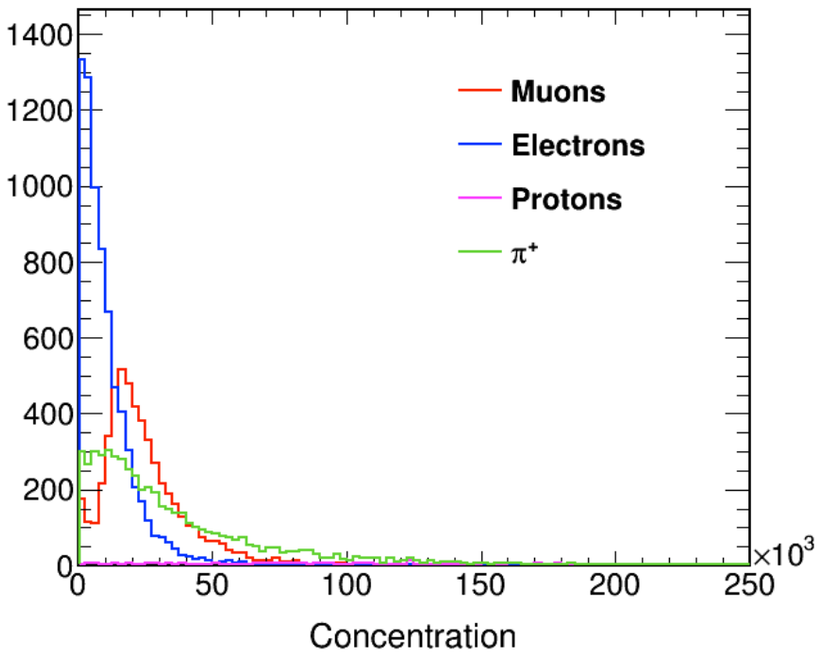
2 GeV sample, exiting



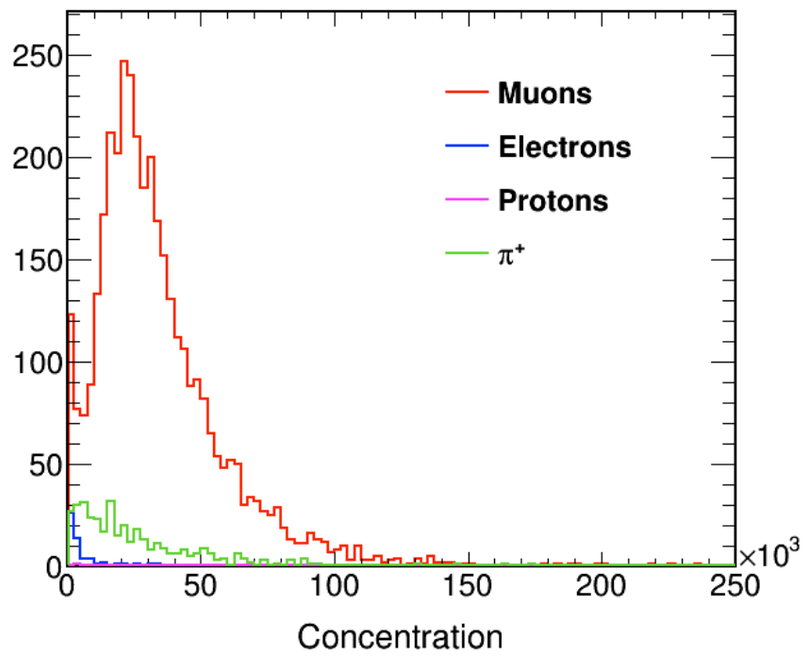
Ratio of charge deposited halo / core:
"core" is < 0.2 Moliere radius from line fitted to reconstructed track, "halo" is >= than this value.

Concentration

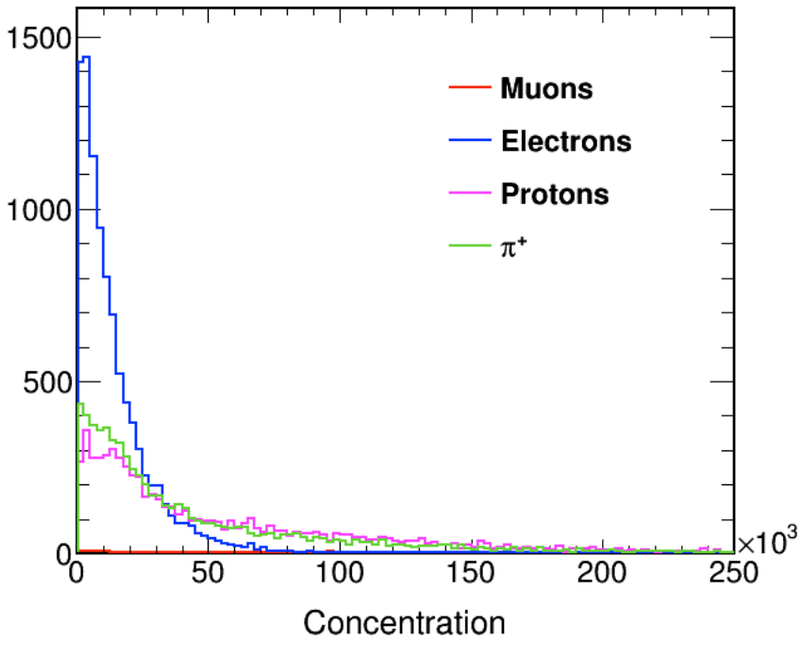
0.5 GeV sample, stopping



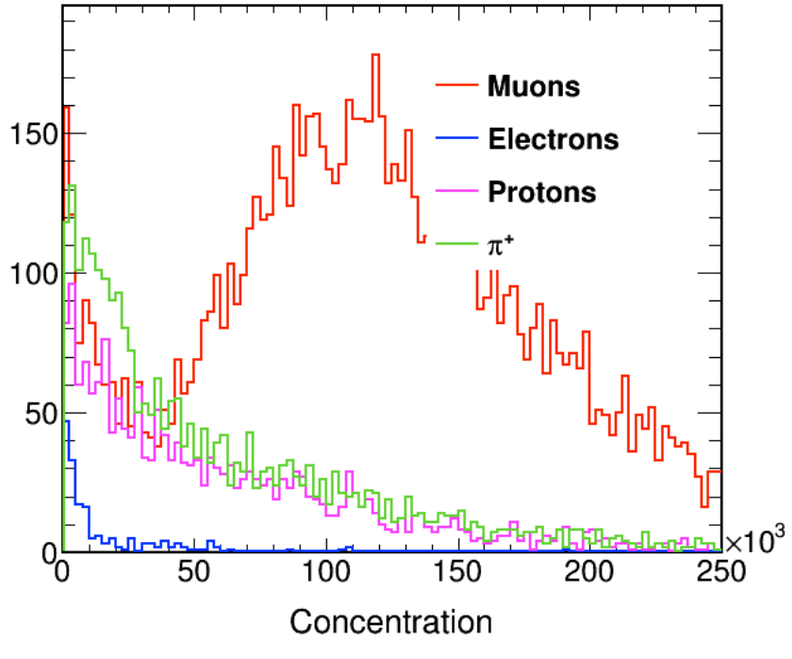
0.5 GeV sample, exiting



2 GeV sample, stopping



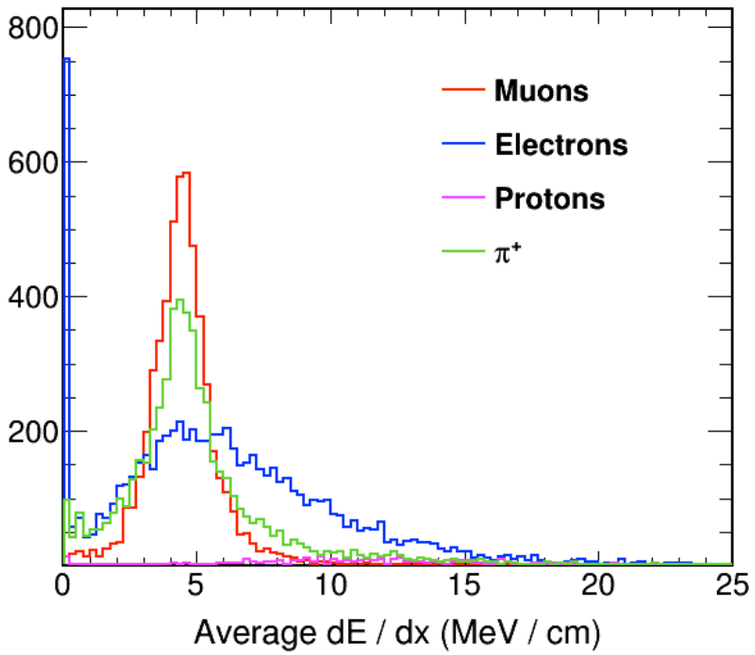
2 GeV sample, exiting



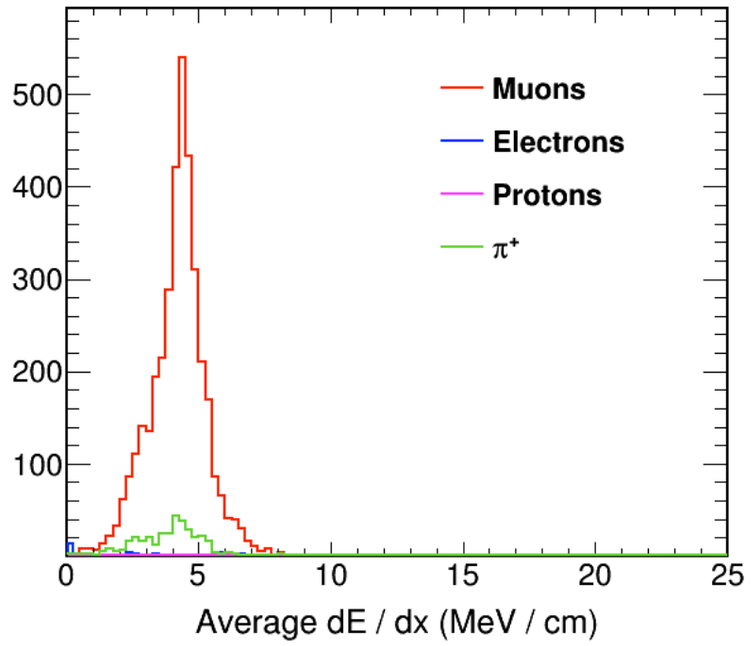
Sum of (charge deposited / radial distance from line fitted to reconstructed track)

Average dE/dx (first 20%)

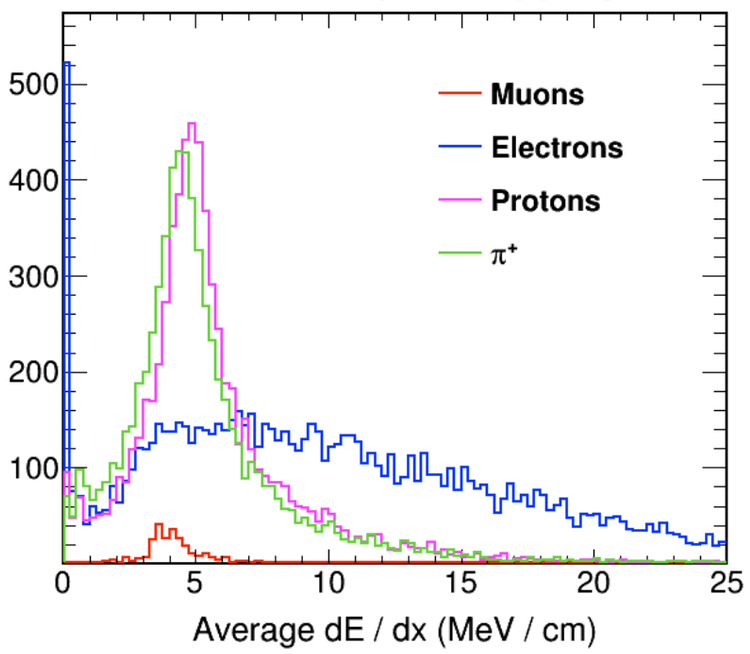
0.5 GeV sample, stopping



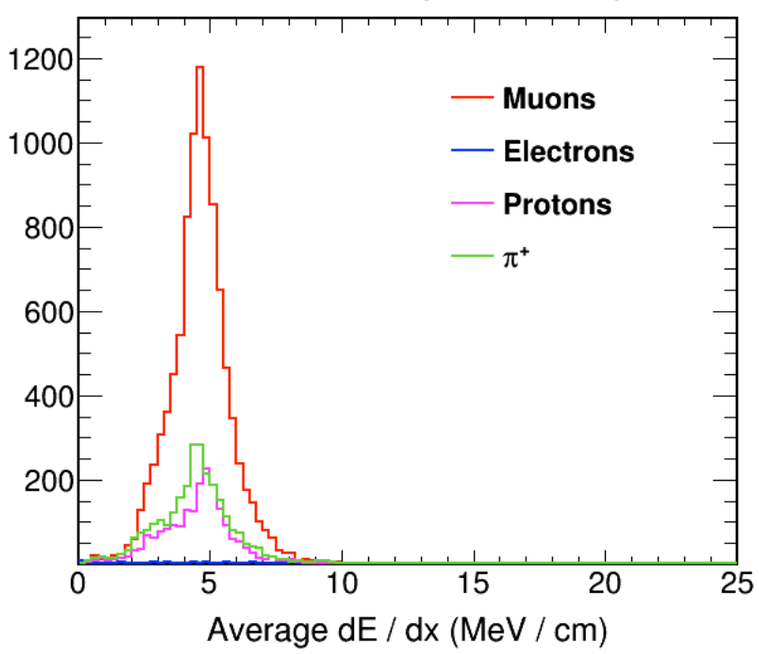
0.5 GeV sample, exiting



2 GeV sample, stopping



2 GeV sample, exiting

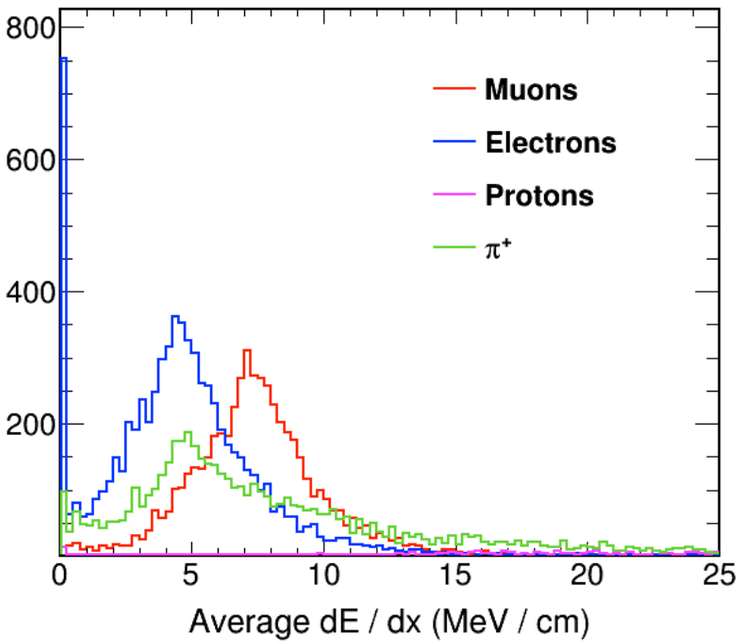


dE/dx is average value from first 20% of reconstructed track.

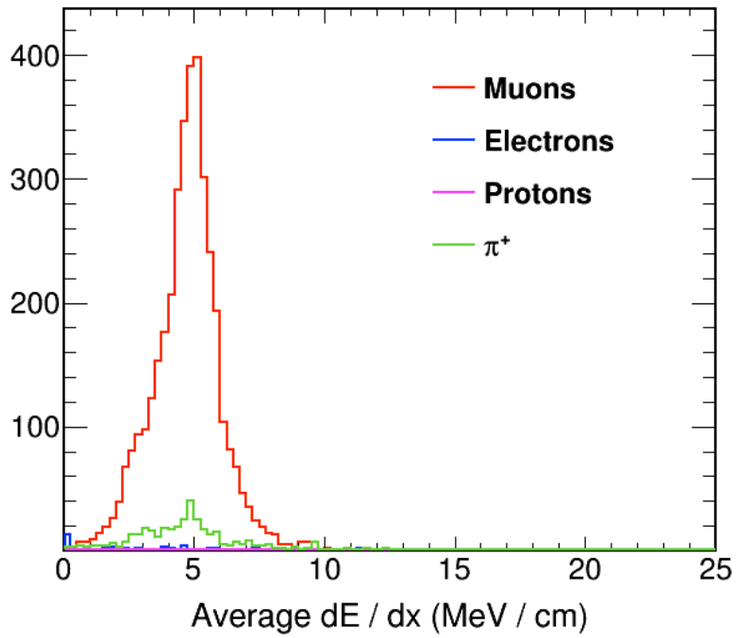
Spikes at 0 come from events with too few hits to make it viable to divide track into 5 sections. For these events, average dE/dx is not calculated but set to 0.

Average dE/dx (last 20%)

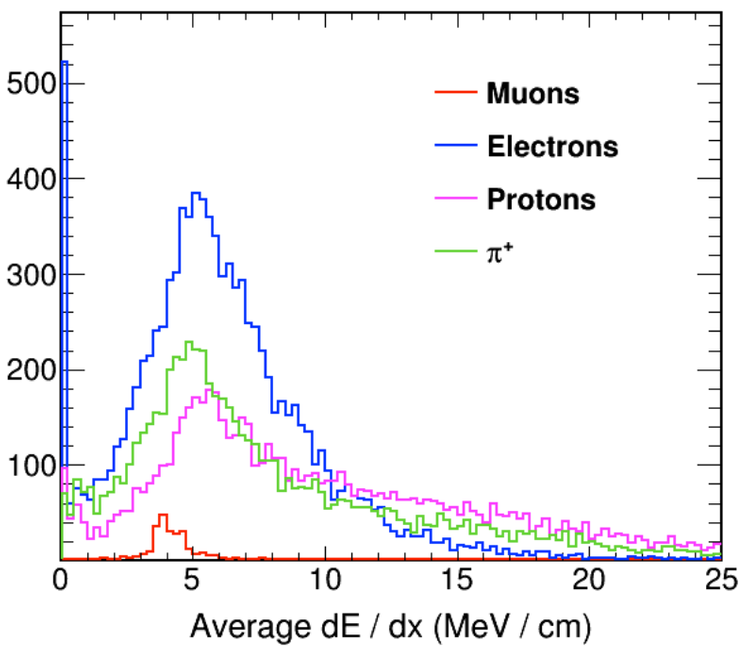
0.5 GeV sample, stopping



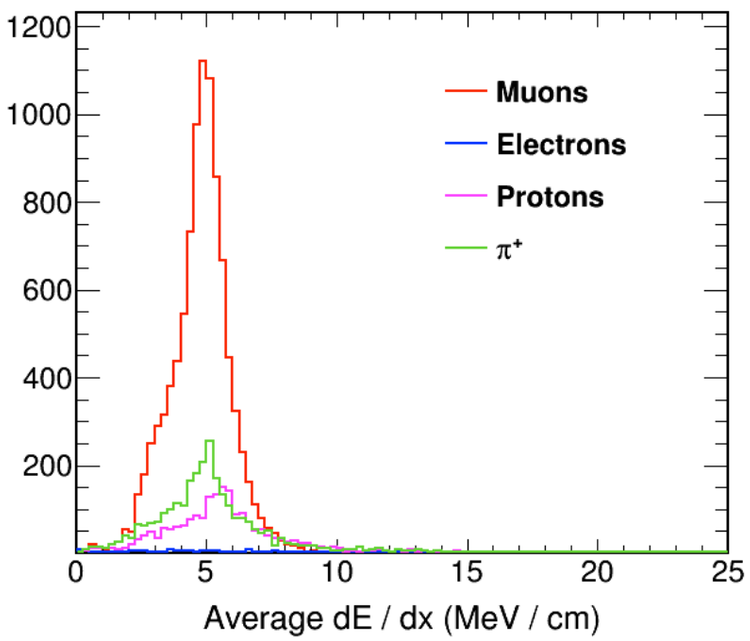
0.5 GeV sample, exiting



2 GeV sample, stopping



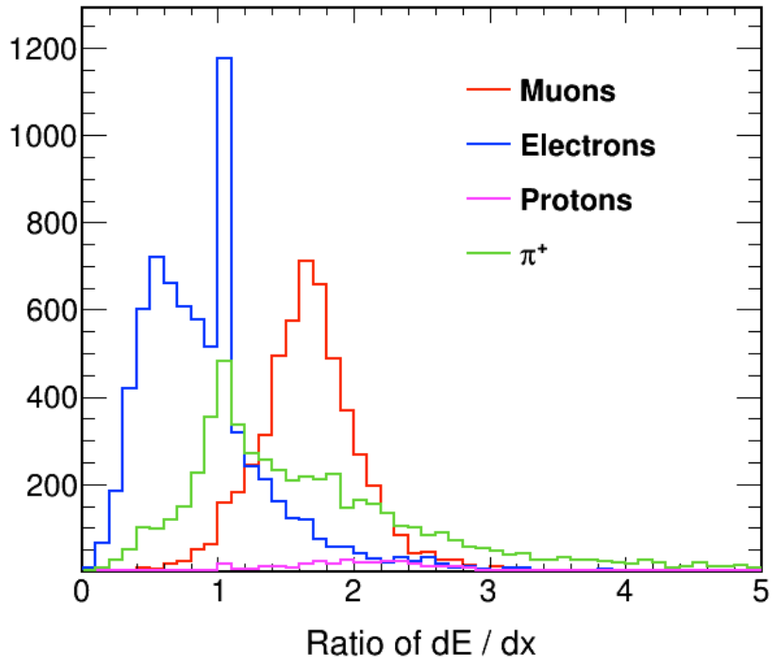
2 GeV sample, exiting



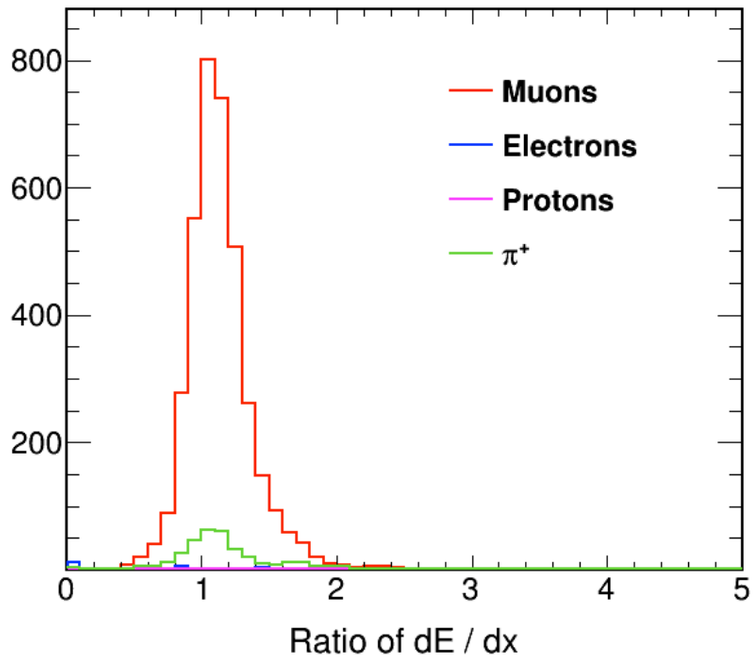
dE/dx is average value from last 20% of reconstructed track.

Longitudinal dE/dx ratio

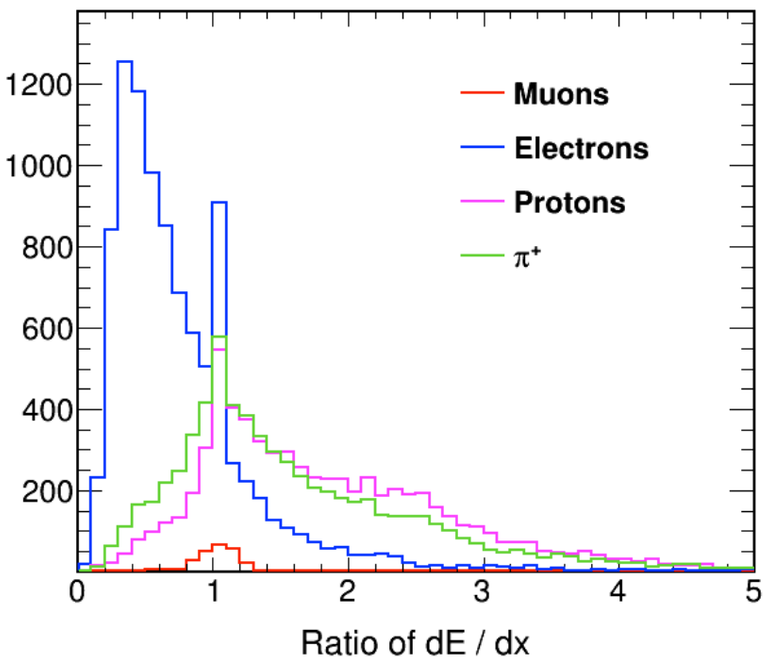
0.5 GeV sample, stopping



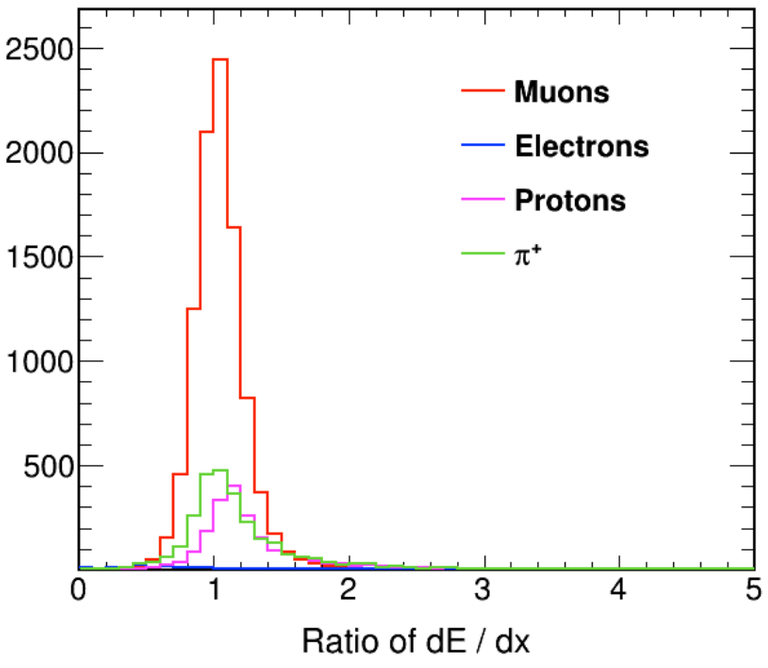
0.5 GeV sample, exiting



2 GeV sample, stopping



2 GeV sample, exiting

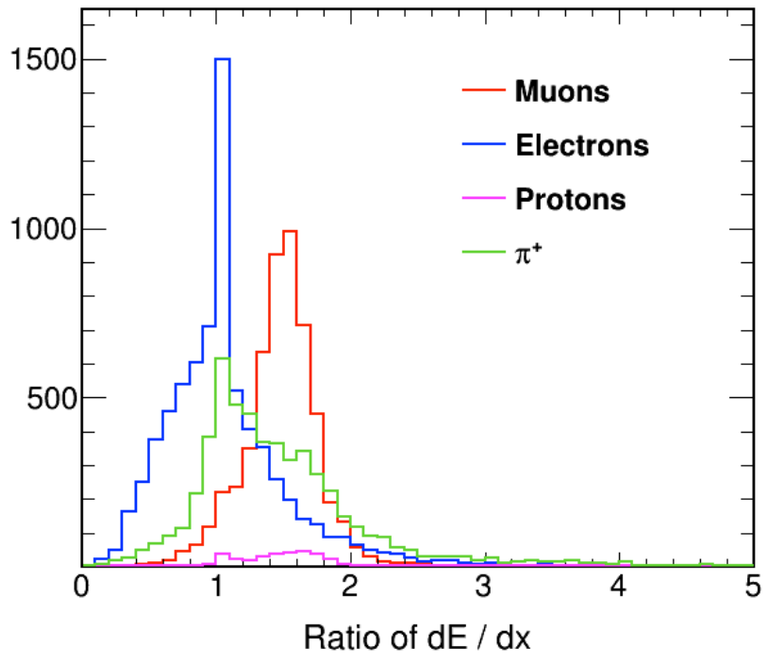


Ratio of average dE/dx in last 20% / first 20% of reconstructed track.

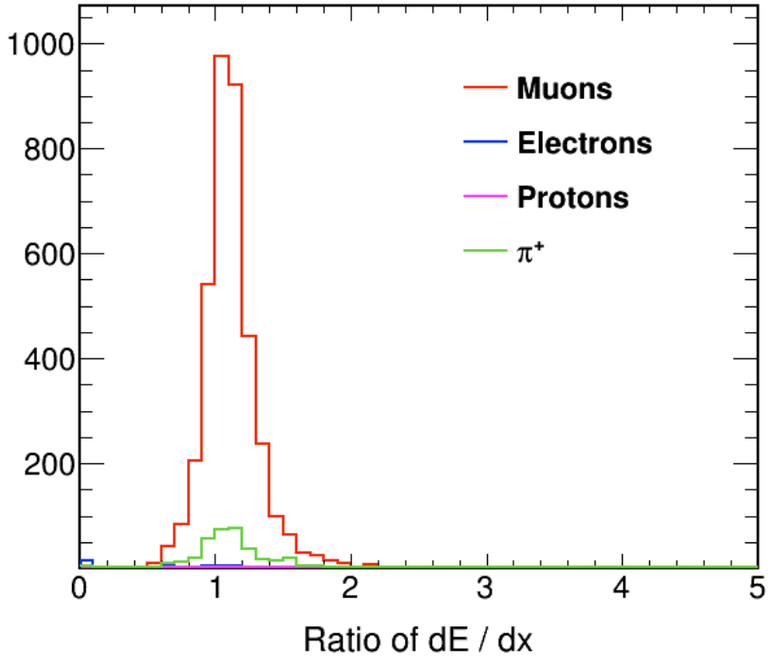
Spikes at 1 come from events with too few hits to make it viable to divide track into 5 sections. For these events, dE/dx ratio is not calculated but set to 1.

End dE/dx ratio

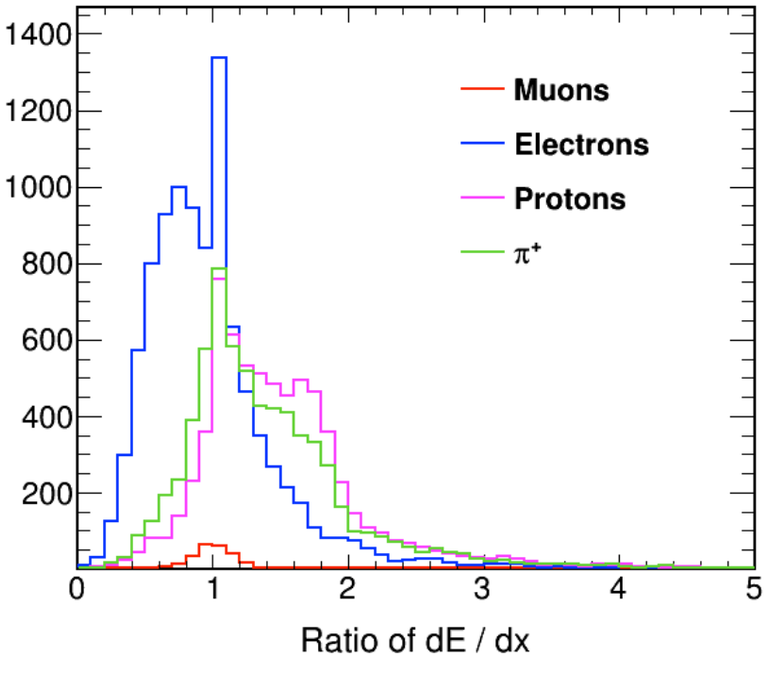
0.5 GeV sample, stopping



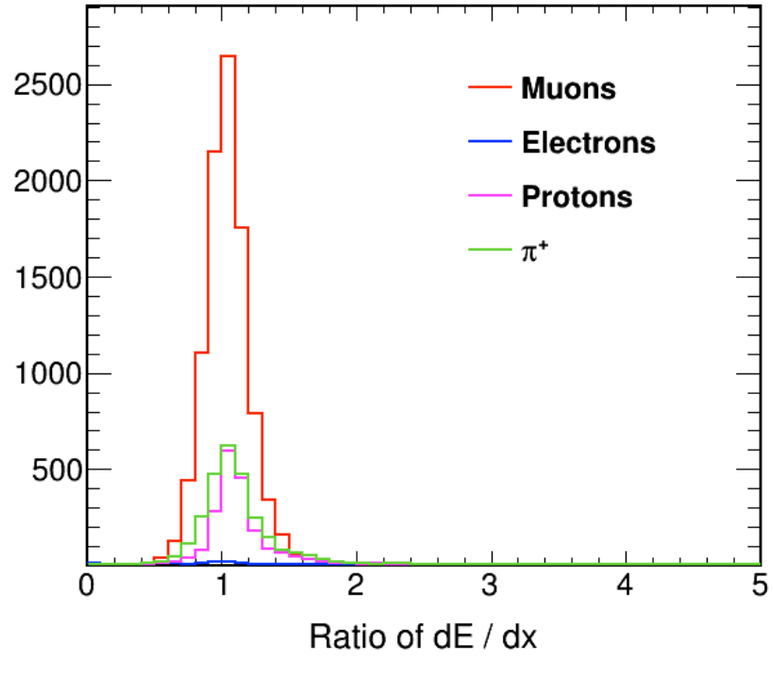
0.5 GeV sample, exiting



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).

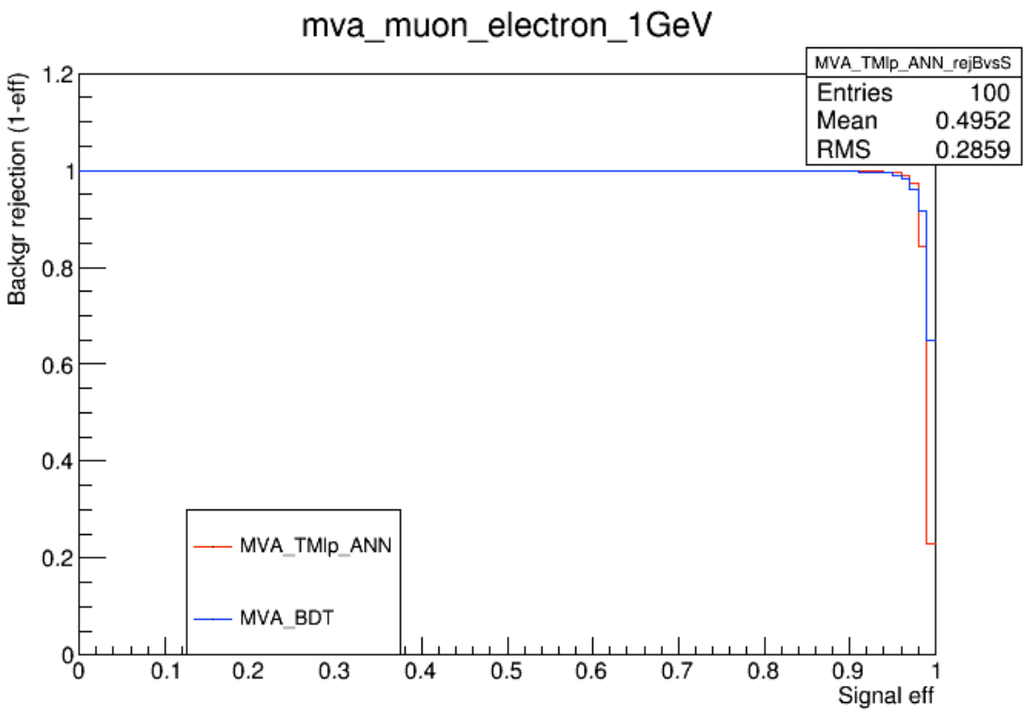
Generated from same event samples as the particle ID variables.

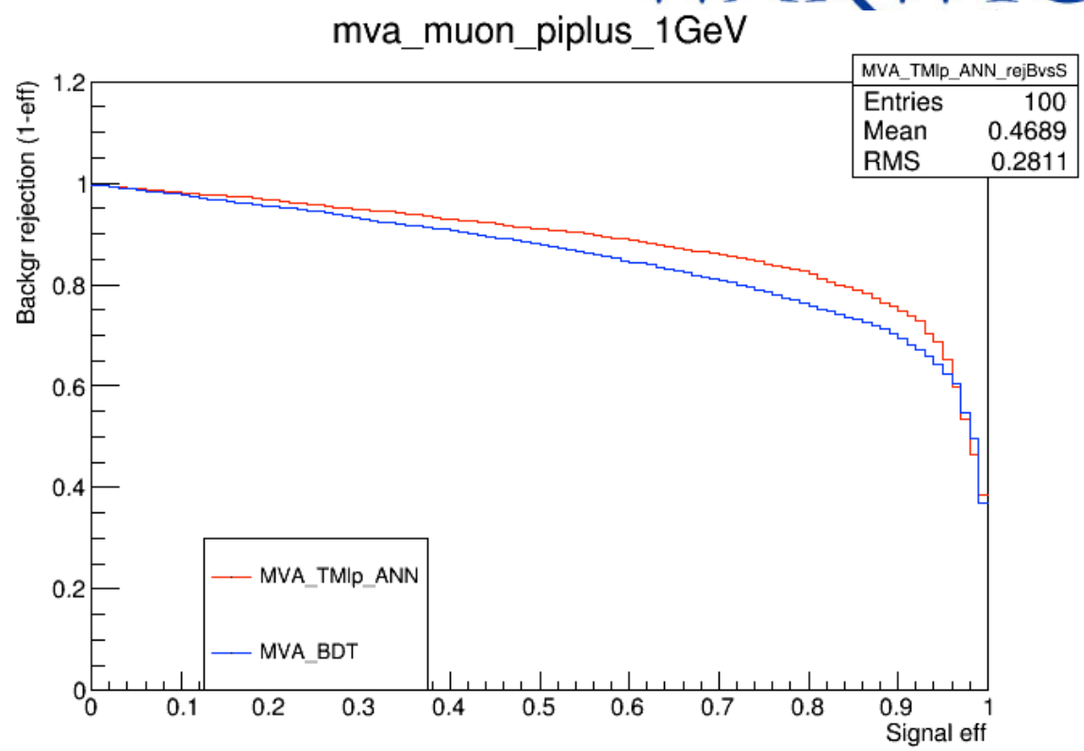
A MVA is done separately for each value of momentum in the event samples.

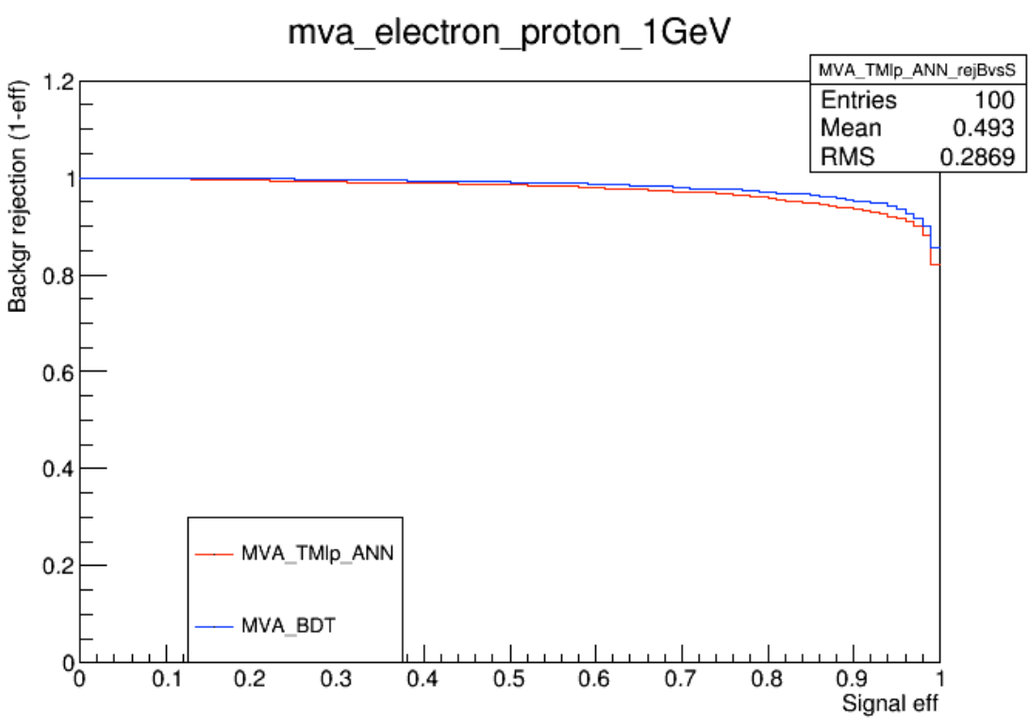
Particle ID variables used are:

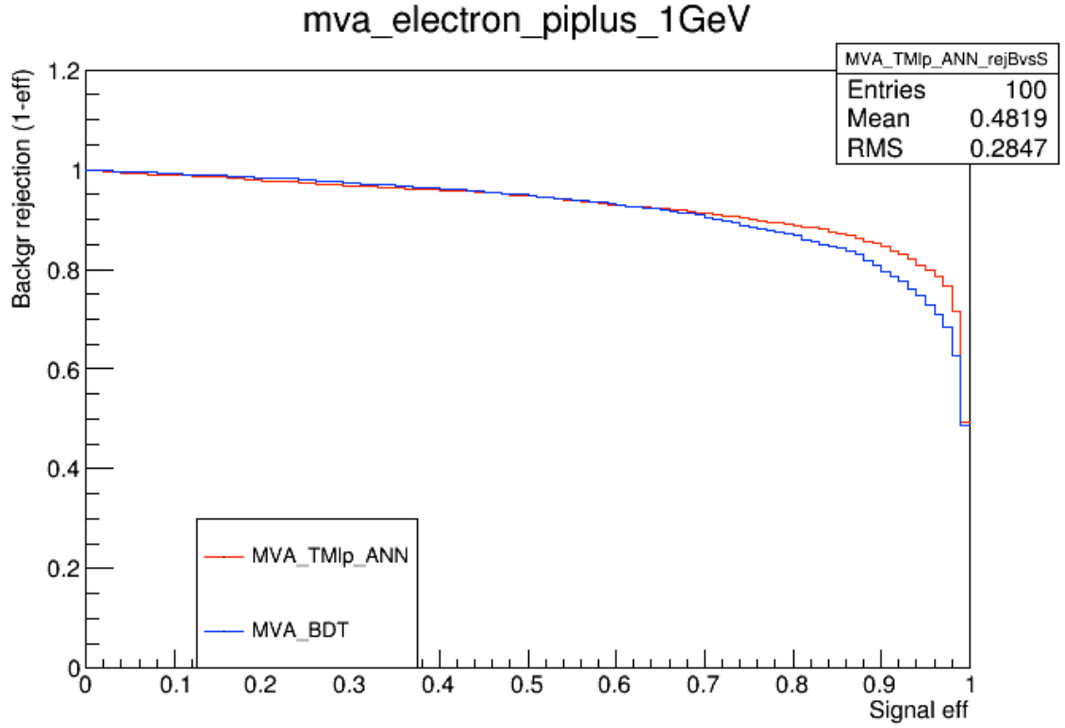
Ratio of eigenvalues
Ratio of charge deposited halo/core
dE/dx at start of track
dE/dx at end of track
Longitudinal charge ratio
End charge ratio.

MVA results (1 GeV)

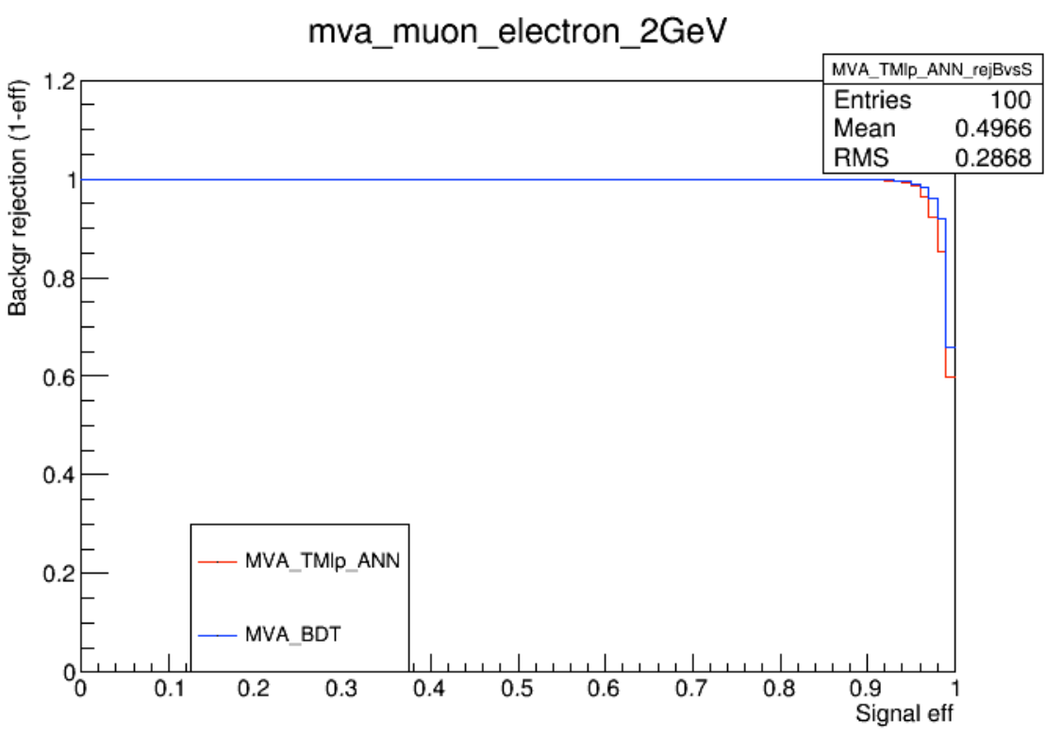


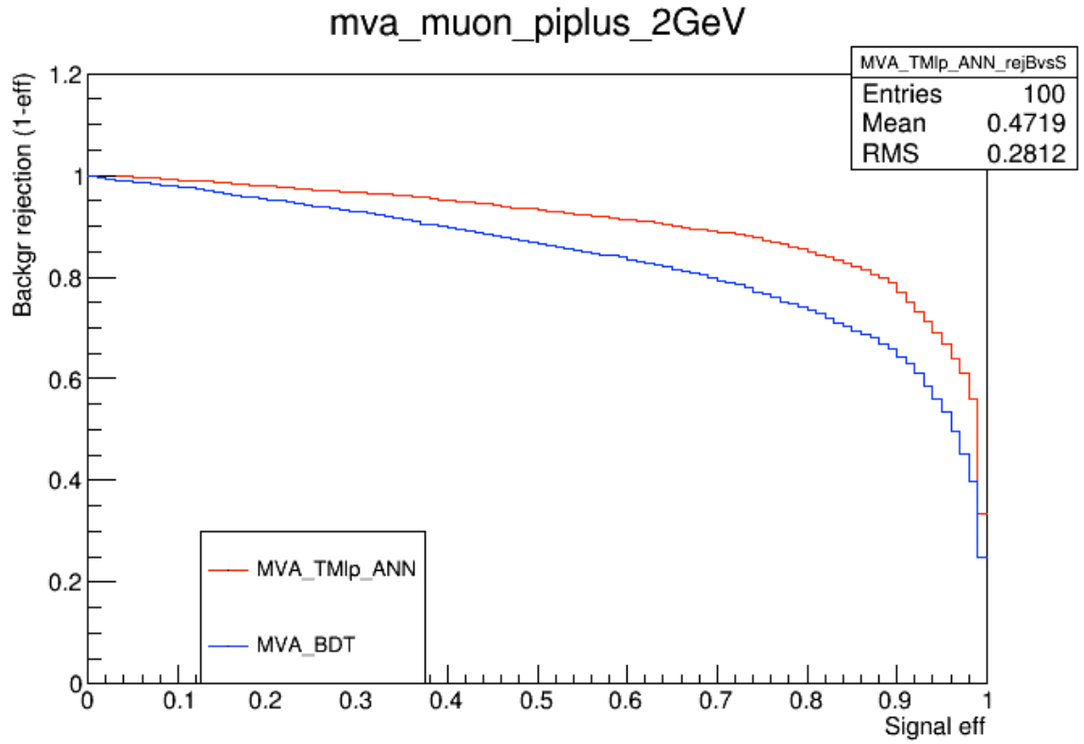


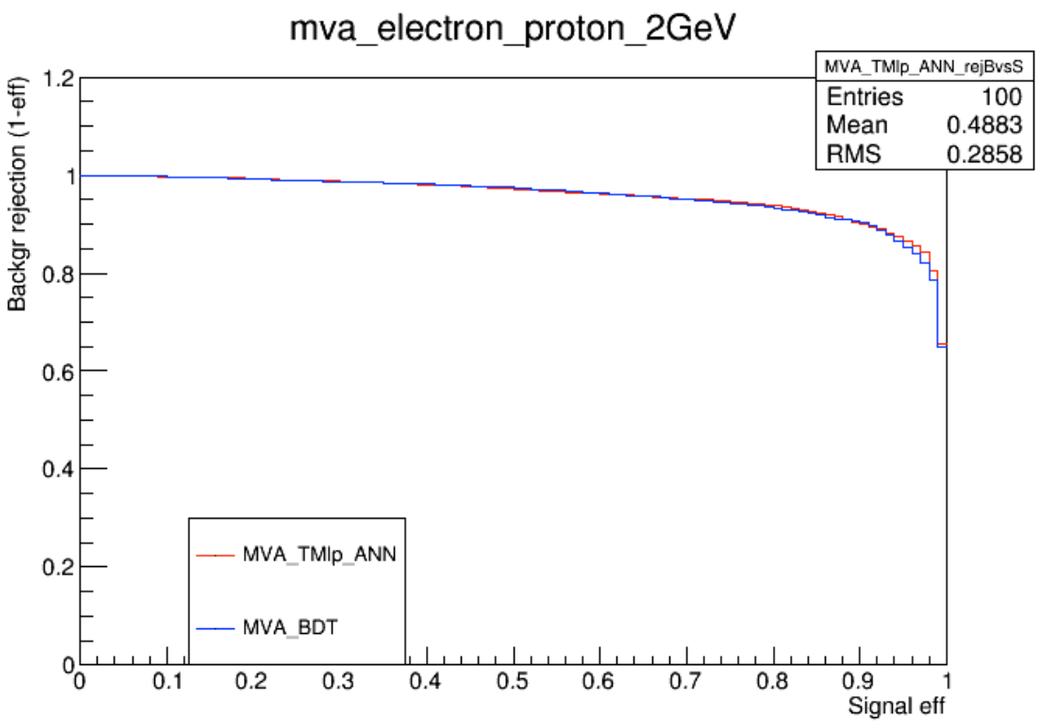


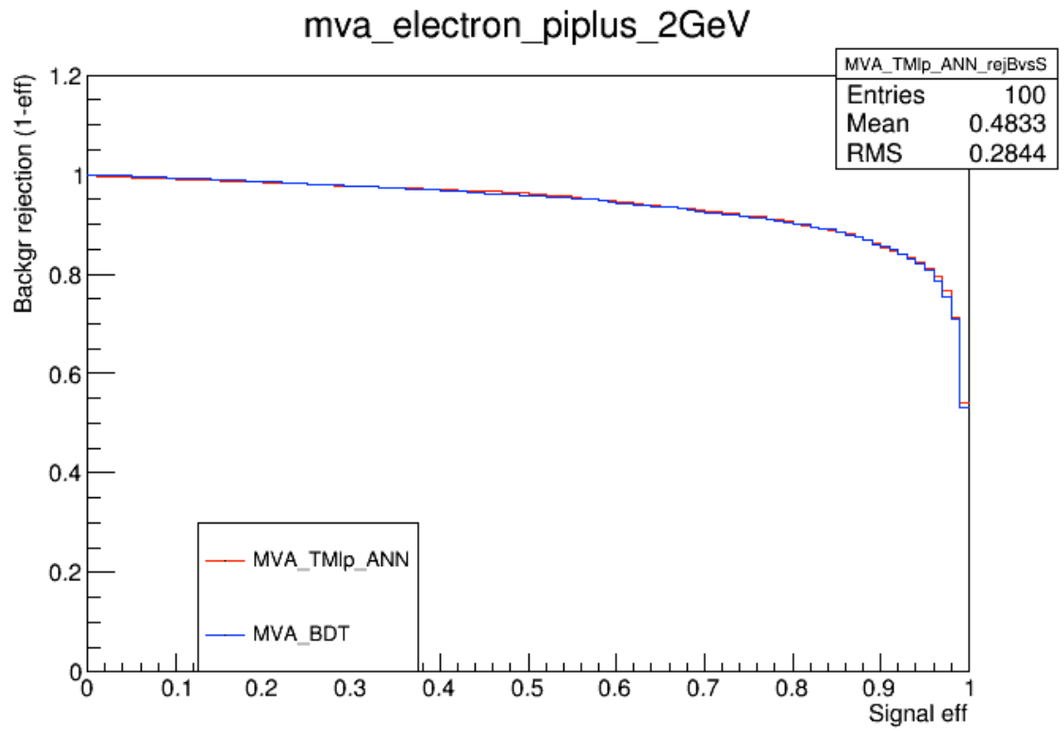


MVA results (2 GeV)









Conclusion

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

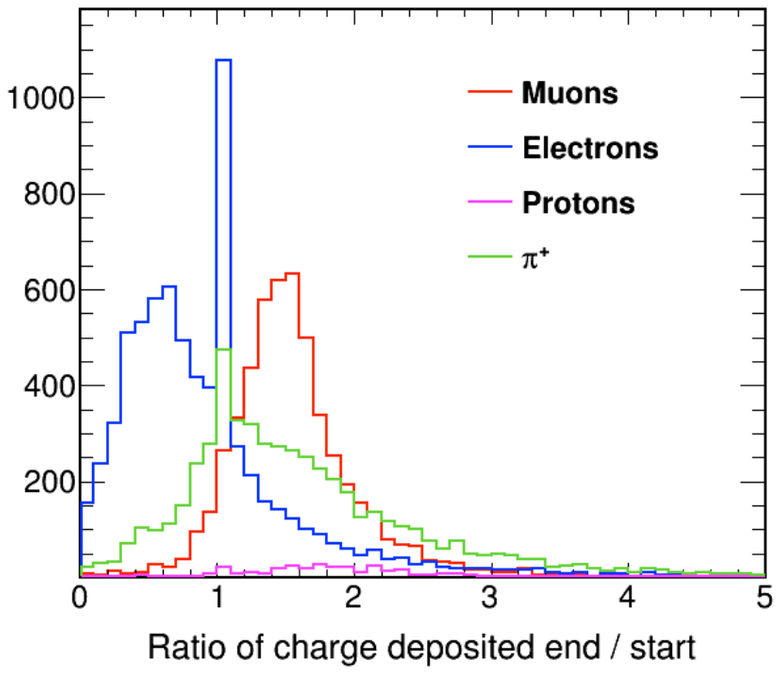
We have also made an initial version of a multivariate analysis using those variables as input, and this MVA gives promising results.

Our eventual aim is to develop a particle ID for the 10 kton detector. However we cannot currently reconstruct events in that detector since the particle stitching in Pandora is not yet available. We intend to move to using event samples in the 10 kton detector as soon as possible.

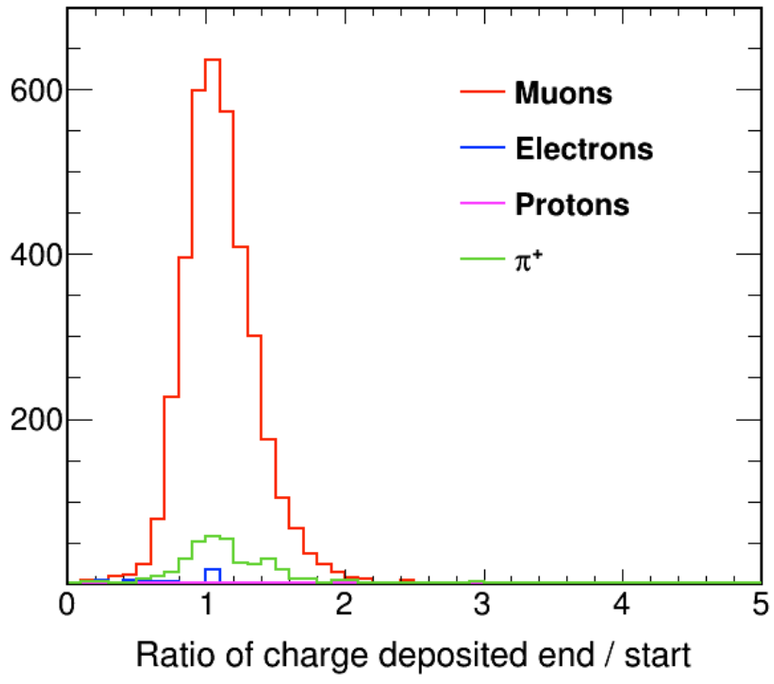
BACKUP SLIDES

Longitudinal charge ratio

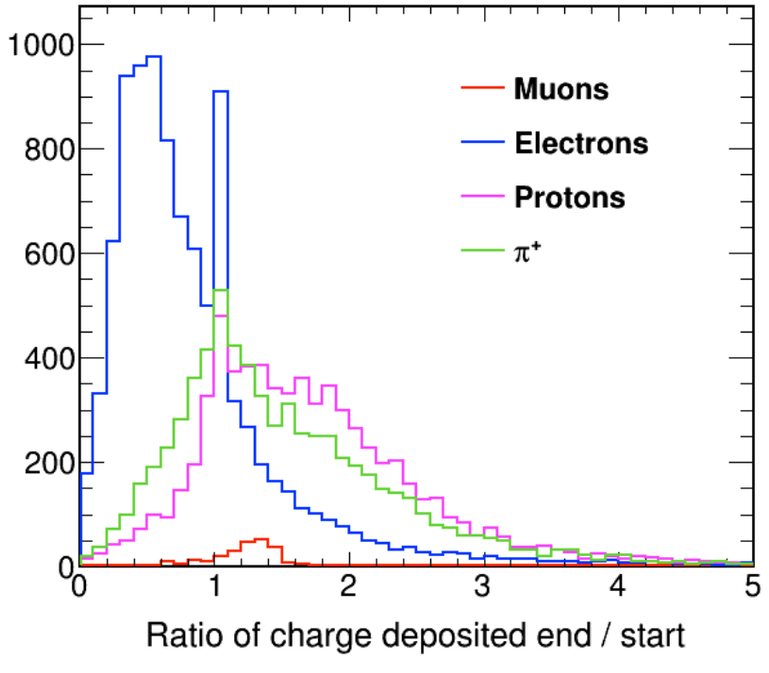
0.5 GeV sample, stopping



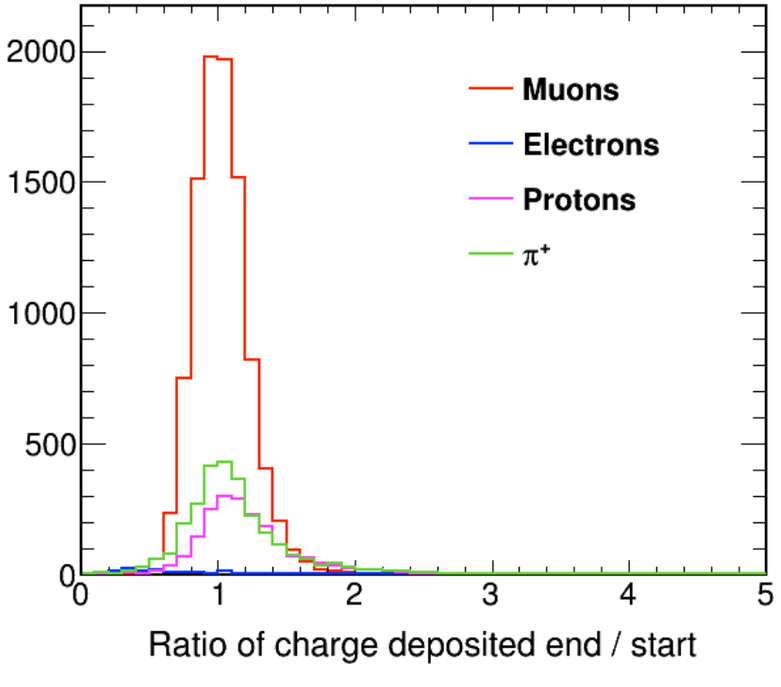
0.5 GeV sample, exiting



2 GeV sample, stopping



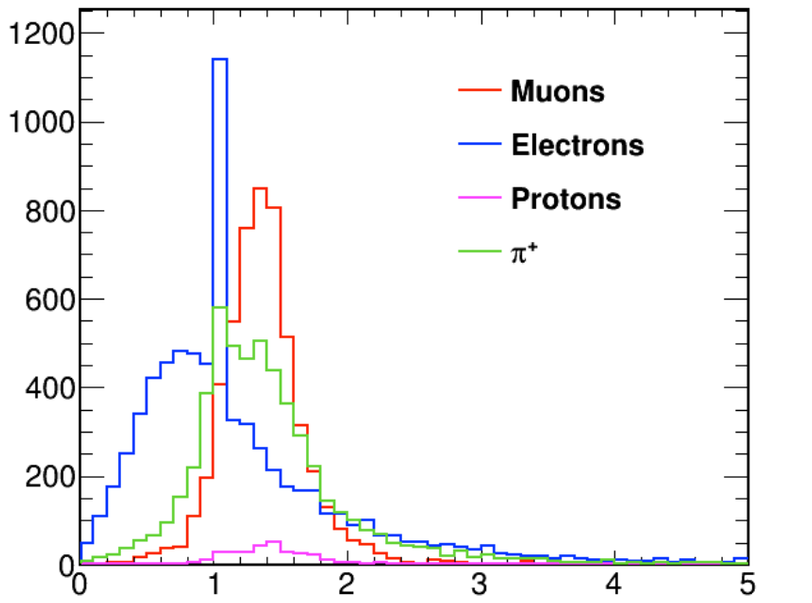
2 GeV sample, exiting



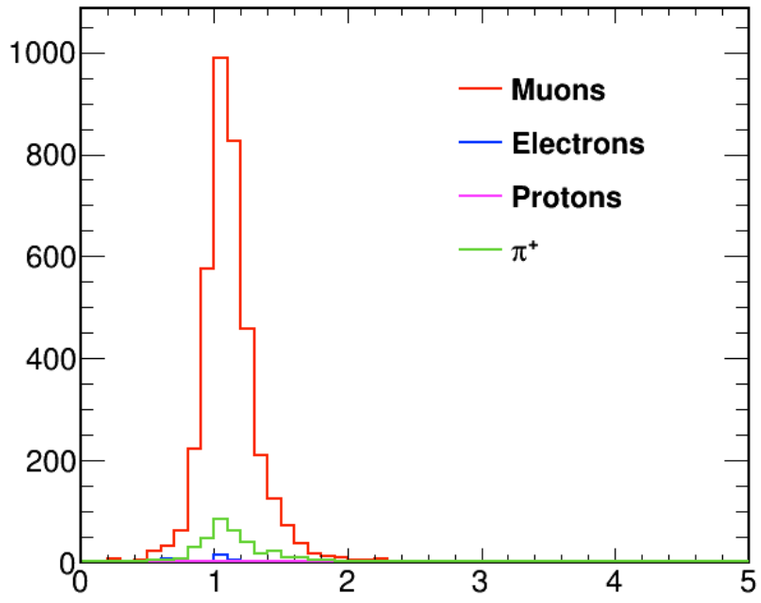
Ratio of charge deposited in last 20% / first 20% of reconstructed track

End charge ratio

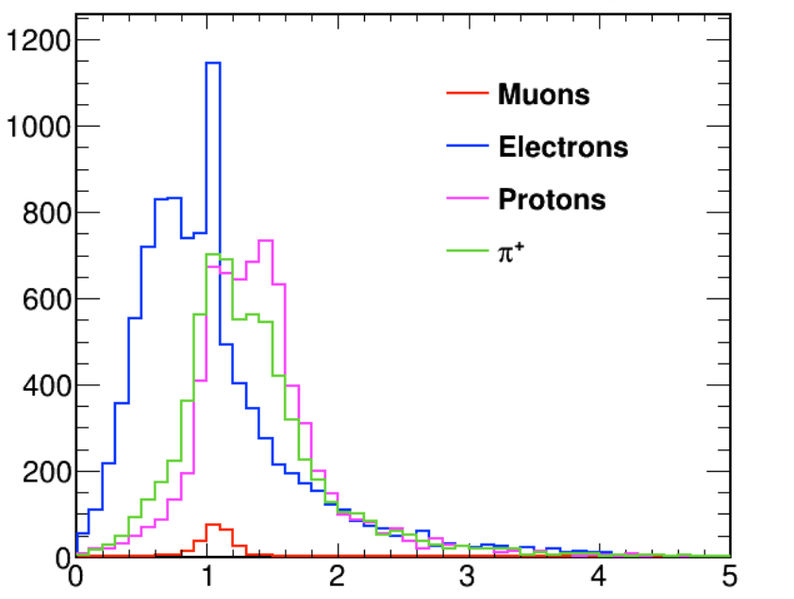
0.5 GeV sample, stopping



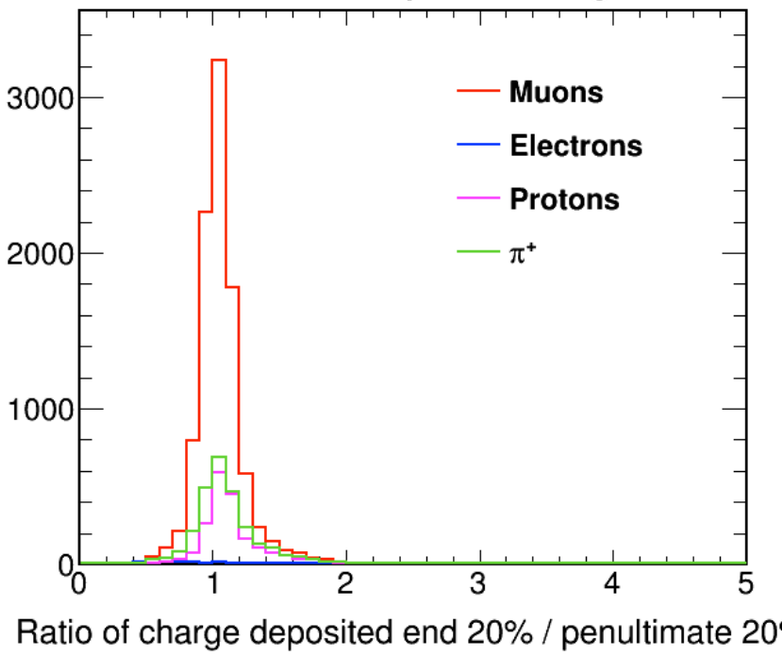
0.5 GeV sample, exiting



2 GeV sample, stopping



2 GeV sample, exiting



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