Reconstruction of Electrons from Muon Decay in MicroBooNE

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Final Presentation
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The MicroBooNE Experiment
Looking For Low Energy Excess

- **MiniBooNE:**
  - Looked at $\nu_\mu \rightarrow \nu_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$
  - Observed an excess of $\nu_e$ and $\bar{\nu}_e$ (more $e^+/e^-$) and at a lower energy than expected
  - Couldn’t distinguish $\gamma \rightarrow e^- + e^+$ and $e^-$
  - Sterile neutrinos? CP violation? Misidentified $e^-$?

- **MicroBooNE** proposed to probe lower energy ranges
LArTPC

- Liquid Argon Time Projection Chamber
- 170 tons liquid argon cryostat
- 3 Wire Planes
- 32 PMTs
Wire Planes

Deconvolution required for U and V planes because of induced signal
Michel Electrons
Michel Decay

Michel Energy Spectrum

Sharp Drop at 52 MeV
Why Michels in MicroBooNE?

**Motivation**

- Michel spectrum is benchmark for low energy scale calibration
  - Study low energy shower characteristics
  - PMT correlation(!)
- Demonstrates our understanding of the detector
- High statistics cosmic data during commissioning is a great source of stopping muons

![MC truth Michel Spectrum](image_url)

- Entries 2710
- Mean 34.68
- RMS 10.96
Michels

Goals

• With 2D reconstruction information:
  • tag stopping muons
  • cluster the Michel shower

• Simple algorithm development:
  • Use only collection plane
  • No matching across planes, possibly no deconvolution needed

• Apply lifetime correction to charge spectrum to get MeV scale
Clustering Michel Shower

**Input**

- Sample of isotropic cosmic muons
  - `prod_muminus_0.1-2.0GeV_isotropic_uboone`
- 100K sample muons $\rightarrow$ filter events with Michels ($\sim$5%)
Cluster Michel and Muon
0. Take fuzzycluster selected gaushits

Reco Y Plane

Cluster 1

Cluster 2

e-
1. Order cluster points based on nearest neighbor with minimum distance cutoff. This defines a single 2D trajectory from the cluster.
Step 2: Merge Clusters

2. Merge clusters which have “near” start or end points
Find Michel Start
Charge Deposition Along the Path

- Scan charge vs. distance along the ordered hits in cluster

- Apply truncated mean to smooth out, trimming hits above the local mean
Differential Charge Deposition Along the Path

- Apply “Lanczos differentiator” to calculate $dQ/ ds$ with suppressed noise

Sharp peak @ last muon hit
Reconstruction

- Use *largest* peak in truncated mean and *largest* dip in dQ/ds to identify region of interest in true Q
- Use to find Michel start point based on local peak in charge
All Events...

- **Reco Z [cm] vs. True Z [cm]**
  - Entries: 2710
  - Mean: 
  - RMS: 2.799

- **Reco X [cm] vs. True X [cm]**
  - Entries: 2710
  - Mean: 0.2047
  - RMS: 3.686

- **Count/0.80 [cm]** plots for Reco - True Z and Reco - True X:
  - Mean for Reco - True Z: 
  - Mean for Reco - True X: 
  - RMS for Reco - True Z: 2.799
  - RMS for Reco - True X: 3.686
Identify Michel and Muon
We know the boundary point....

• Determine which segment is the Michel
• Use local linear fit chi-square and Reco track/charge info
Michel Charge Spectrum
Add up hit charge in circle ignore only hits before Michel start point (muon hits)
Simple E Reco...

Our Q Reconstruction

![Histogram of Michel Q [ADC]](image)

- Entries: 2710
- Mean: 3925
- RMS: 2702

![Histogram of True Shower N e^-](image)

- Entries: 2710
- Mean: 8.584e+05
- RMS: 3.429e+05
Lifetime Correction Drift Electrons

\[ Q^\text{corr} = Q^\text{raw} e^{t/\tau} \]

\[ \tau = 3 \text{ ms} \]

\[ v = 160 \text{ cm/ms} \]

\[ t_{\text{drift}} = X/v \]

Before

After

Reco

Entries 2710
Mean 4937
RMS 3046
Reconstructed E

1 MeV $\sim 0.008219$ ADC

Our Energy Spectrum

Reco Q * Lifetime Correction * 0.008219

Charge vs. Energy for Truth Single Electrons

\[ \chi^2 / \text{ndf} = 3.49 \times 10^7 / 5890 \]

\[ p0 = 0.008219 \pm 1.952 \times 10^{-5} \]
Identifying Michel Signal
Background/Signal Mis-ID

Signal Selection:
• ~60,000 Muon-only Background
• ~5000 Michel + Muon Signal
Applying Cuts

Number of hits in Michel cluster
mis-ID boundary

Highest chi-square value
at least one bend in track (rejects straight muons)

Chi-square value at boundary point
chosen boundary occurs at kink

Mean chi-square value
mostly straight track

Optimize signal/background
Results with Cuts

Signal Purity ~ 81%

Purity = selected true signal / total selected

Signal Efficiency 183/4828 ~ 4%

Efficiency = selected true signal / total true signal

Mis-ID Efficiency 42/61692 ~ 0.07%

Efficiency = selected background / total background
Summary

- **Progress:**
  - We have defined an algorithm that uses 2D Reco information to:
    - cluster a muon and Michel track
    - find the Michel start
    - cluster the Michel hits
    - Michel charge spectrum
  - With cuts on chi-square parameters we can filter signal from background

- **Next Steps:**
  - Further tune algorithm on cosmic data file
  - Apply to real cosmic data!
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