Refining Reconstruction for the Single Photon Search

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Pandora: Pattern Recognition Program

Groups hits into categories:
1. Cosmic Slice
2. Neutrino Slice

- Tracks
- Showers
- Unassociated hits

Colored = Neutrino Slice
Gray = Not Neutrino Slice

Cosmic Slice
Shower
Unassociated
Track

6 cm
Reconstructed Objects

Tracks
- Protons
- Muons
- Cosmic rays

Showers
- Electrons
- Positrons
- Photons

Unassociated
- Noise
- Trouble reconstructing
- Anything
Short Baseline Anomaly and Low Energy Excess

- Anomaly first observed by LSND
- Anomaly supported by MiniBoone
- $> 3\sigma$ Low Energy Excess observed by MiniBoone
- Two interpretations of LEE
  - Electron
  - Photon

\[ \bar{\nu}_e + n \rightarrow e^+ + n \]
NC Delta Radiative Decay Interpretation

- A photon interpretation of LEE
- Mis-prediction of delta radiative decay events
- 3 times prediction could account for LEE

\[
\Delta \rightarrow \gamma + n
\]
Defining Signal

- Two NC Delta Radiative topologies:
  - 1 photon, 1 proton = 1 shower, 1 track
  - 1 photon, 0 proton = 1 shower, 0 tracks
- Gap between shower and track vertex means shower could be photon which then pair produced
Selecting Signal

After Pandora reconstruction of objects:

1. Topological selection
   a. Events with only 1 track and 1 shower
   b. Or events with 0 tracks and only 1 shower

2. Pre-selection cuts (precuts)
   a. E.g. distance of event to edge of detector
   b. E.g. reconstructed energy of the shower
   c. E.g. length of proton track
   d. Isolation of proton?

3. Cosmic Boosted Decision Tree

4. Booster Neutrino Beam Boosted Decision Tree
Quantifying Proton Isolation

Examining hits on a plane by plane basis, NOT by looking at 3D reconstructed objects

- **Number of shower hits within r cm of track**
- **Number of unassociated hits within r cm of track**
Cut Performance on Number Hits within r cm

Efficiency = \frac{\text{number of events which pass cut}}{\text{total number of events}}

Cut on Number of Shower Hits:
- Sensitive to approximate conversion distance on a plane

Cut on Number of Unassociated Hits:
- Sensitive to noise around track possibly indicating poor object reconstruction

Efficiency of Cut on Shower Hits within 2 cm

Efficiency of Cut on Unassociated Hits within 2 cm
Cut Performance by Particles

Examining events on a particle data group basis
- Greatest drop in efficiency for non-photon showers
- Least drop in efficiency for proton tracks and photon showers (NC delta rad signal)
Cut Performance on True Isolated Protons

Correlation between conversion distance and number of shower hits within cm of the track
- Appears that even with true signal events which convert further from that track, still lose ~10% of signal
Example of Possible Cut

MC Simulation of a NC Delta Radiative Decay event

Potential Cut:
- If cut placed on <6 shower hits within 2 cm on all three planes
- If cut placed on <10 unassociated hits within 2 cm on all three planes

This event passed!

Signal = 83.4%
Background = 70.9%

Signal = 62.5%
Background = 50.3%
Example of Possible Cut

MC Simulation of a NC Delta Radiative Decay event
Potential Cut:
- If cut placed on <6 shower hits within 2 cm on all three planes
- If cut placed on <10 unassociated hits within 2 cm on all three planes
This event failed.

<table>
<thead>
<tr>
<th>Plane 0 signal event fails</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plane 1 signal event fails</td>
</tr>
<tr>
<td>Plane 2 signal event fails</td>
</tr>
</tbody>
</table>

Signal = 83.4%
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Example of Possible Cut

MC Simulation of a NC Delta Radiative Decay event
Potential Cut:
- If cut placed on <6 shower hits within 2 cm on all three planes
- If cut placed on <10 unassociated hits within 2 cm on all three planes

This event failed due to bad Pandora reconstruction.
Conclusions

- Selecting events from Pandora reconstructed 2D neutrino slices
  - Demanding isolation on 3/3 planes cuts ~50% of signal
  - Right = preliminary results after precut stage with isolation cut restriction on 1 plane
  - Dead wires near tracks can make proton appear isolated
    - In the future, will want to take into consideration dead wires
- Other Applications
  - Could be adapted to find low energy protons, which Pandora failed to reconstruct as tracks
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Questions?
Backups
Cut Performance on Number Hits within r cm

Efficiency = \frac{\text{number of events which pass cut}}{\text{total number of events}}

Cut on Number of Shower Hits:
- Sensitive to approximate conversion distance on a plane

Clear decrease in efficiency at 6 hits within 2cm
- MicroBooNE wires separated by 0.3 cm.
- 6 wires can fit within 2cm

![Graph showing efficiency of cut on shower hits within 2 cm]