MicroBooNE Background and Resolution Studies for Single Photon Analysis

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Outline

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Single Photon Background

These studies were done for the BDT single photon analysis.

The first sensitivity studies done before Neutrino 2018 were full of NCPi0 background.

This plot shows how reducing background will improve sensitivity. Therefore, it is beneficial to study how misidentified Pi0 events are misidentified so we can work toward reducing them.
Single Photon Background

The majority (85%) of background is NCPi0.
Major Causes of NCPi0 Background

Keng Lin and I handscanned a little over 100 NCPi0 events and determined the major reasons why the second shower was missed.

(https://docs.google.com/spreadsheets/d/1N3ApEN5OFjxffWobK8OK7tJvCbkvhPbfkGIBXCOy8HY/edit?usp=sharing)
“Too Weak”

Collection

Induction 0

Induction 1
“Perfect Storm”

Collection
Induction 0
Induction 1
Second shower overlaps
Second shower in dead wire region
Second shower overlaps a cosmic
Another way to reduce background:

In NC Delta Resonant events followed by Delta radiative decay, the invariant mass of the proton and photon system is equal to the invariant mass of a Delta baryon. However, for background events, the invariant mass can be a distribution of masses. So another way to tell if an event is a true single photon event is to reconstruct its invariant mass.

\[
M^2_{\Delta} = m^2_p + 2(E_p + E_\gamma) - (P_p \times P_\gamma \cos \theta_{p\gamma})
\]

We needed to make sure that the track energy, shower energy, and angular resolutions were sufficient.
Shower Energy Resolution

I studied reconstructed shower energy of the single photon signal sample after selection.

Reconstructed energy is in general lower than the true energy due to missing parts of the shower during reconstruction.
Corrected Shower Energy

The magenta points represent the most probable value in each of the 50MeV segments.

The parameters were extracted from the fit line

$$E_{\gamma}^{Corr} = (1.37 \pm 0.225)E_{\gamma}^{Reco} - (0.018 \pm 0.143)[GeV]$$
PSTAR Database provides range traveled in Ar for various proton kinetic energies. I used projected range to reconstruct proton kinetic energies.
The majority of angles between track and shower of selected vertices is reconstructed quite well.

Using the angle, shower energy, and track energy, we can calculated the reconstructed and true invariant mass of the proton/photon system.
The invariant mass squared of the proton/photon system should be equal to the mass squared of a Delta baryon (1.517GeV^2).
Invariant Mass, after correction

After correcting the shower energy, the reconstructed invariant mass peaks closer to the true invariant mass peak.

**True** (Mean: 1.50189GeV²; Sigma: .128665)

**Reco** (Mean: 1.47160GeV²; Sigma: .179544)
Conclusions

From handscanning NCPi0 background events, we determined that around 40% are caused by showers that are visible but not reconstructed by Pandora. Many of such events can recovered using other reconstruction algorithms such as SSNet, which will reduce NCPi0 background.

By studying energy resolution, we were able to apply a correction that improved the reconstructed Delta invariant mass, which also helps reduce background.

True (Mean: 1.50189$\text{GeV}^2$; Sigma: .128665)
Reco before (Mean: 1.28743$\text{GeV}^2$; Sigma: .129489)
Reco after (Mean: 1.47160$\text{GeV}^2$; Sigma: .179544)
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