MiniBooNE Low-Energy Excess

- Observed excess of neutrino events below 600 MeV
- Cherenkov detector; difficulty distinguishing photons and electrons
- **Photon-like** and electron-like hypotheses
- MicroBooNE is searching for $\Delta \rightarrow N\gamma$ to investigate photon-like
Neutral Current (NC) $\pi^0$

- NC $\pi^0$'s comprise ~80% of backgrounds for the NC $\Delta$ radiative decay search
  - See Kathryn Sutton’s talk
- NC $\pi^0$ events in which only one photon is reconstructed look nearly identical to radiative decays
- Plan: use single-photon framework to select NC $\pi^0$ events for data-driven rate constraint
Analysis Flow

Input Pandora [1] reconstructed tracks and showers

Select for signal topology

Pre-selection cuts

Cosmic background rejection with cosmic-trained Boosted Decision Tree (BDT)

BNB* background rejection with BNB-trained BDT

Signal Topologies

2γ1p


*Booster Neutrino Beam
BDT Training Variables

- BDT takes MC signal/background distributions as input
- On-beam events generally harder to reject than cosmics
BDT Cuts

- Topological selection dominated by cosmics
- Cosmic BDT removes ~99% of cosmic events
  - Also ~90% of BNB backgrounds
- BNB BDT removes ~20% of remaining BNB
- Minimal impact on signal
MC Backgrounds

- Largest background is **charged current (CC) \( \pi^0 \)**
- All CC events comprise ~70% of background
  - Largely caused by mis-ID’ed muons/pions
- Some background events caused by Pandora mis-reconstruction
- Currently working to implement PID algorithms

<table>
<thead>
<tr>
<th>Background</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC ( \pi^0 )</td>
<td>43.5</td>
</tr>
<tr>
<td>Other CC events</td>
<td>26.1</td>
</tr>
<tr>
<td>Cosmic coincidence</td>
<td>17.5</td>
</tr>
<tr>
<td>NC BNB Background</td>
<td>8.7</td>
</tr>
<tr>
<td>Other</td>
<td>4.2</td>
</tr>
</tbody>
</table>
Data/MC: BDT Response

- Cut on BDT response to reject backgrounds
- Cut value chosen to maximize efficiency times purity
Data/MC: Invariant Diphoton Mass

- Good data/MC agreement after applying BDT cuts
- Expect ~60% pure final selection
- Note: shower energies losses in reconstruction
  - ~20% effect
Corrected Diphoton Mass

- Apply energy correction factor to each shower
- Shifts mass peak closer to expectation

![Graph showing the effect of applying the correction](image)

KS: 0.630236  \( \chi^2_{\text{ndof}} : 1.990 \)

KS: 0.888233  \( \chi^2_{\text{ndof}} : 9.9778 \)
Run 5512
Subrun 50
Event 2538

March 19th, 2016
Run 5512
Subrun 50
Event 2538

March 19th, 2016

Proton Track

Photon Showers

18 cm
Run 5564
Subrun 142
Event 7127

March 23rd, 2016
Summary

• First demonstration of NC $\pi^0$ selection in MicroBooNE
• Demonstrated the effectiveness of BDTs in cutting cosmic and beam-related backgrounds
• Predicted final selection includes several hundred good NC $\pi^0$ events with low background contamination
• Will provide a good systematic uncertainty constraint for the single-photon analysis
• Reconstructed diphoton mass data/MC comparison gives confidence in our selection
• Future work will involve reducing the CC background
• Stay tuned for more MicroBooNE NC $\pi^0$
Backup
Boosted Decision Trees

- Inputs are MC samples and discriminating variables
  - MC samples broadly fall into “signal” and “background” samples
  - BDT trains itself to distinguish between the two
## List of BDT Training Variables

<table>
<thead>
<tr>
<th>Cosmic BDT</th>
<th>Beam BDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track dE/dx</td>
<td>Track dE/dx</td>
</tr>
<tr>
<td>Shower energies</td>
<td>Shower energies</td>
</tr>
<tr>
<td>Shower conversion distances</td>
<td>Shower conversion distances</td>
</tr>
<tr>
<td>Track length</td>
<td>Track length</td>
</tr>
<tr>
<td>Track vertical angle</td>
<td>Track vertical angle</td>
</tr>
<tr>
<td>Ratio of track start/end dEdx</td>
<td>Opening angle between showers</td>
</tr>
<tr>
<td>Shower vertical angle</td>
<td>Shower angle w.r.t beam direction</td>
</tr>
</tbody>
</table>
List of Pre-Selection Cuts

- One reconstructed flash and 20 PE in beamgate
- Fiducial volume cut: reconstructed vertex within 10 cm of any TPC wall
- Sensible calorimetry
- Track length < 500 cm
- Shower energies > 10 MeV