Low Energy Single-Photon Search in MicroBooNE

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On behalf of the MicroBooNE Collaboration

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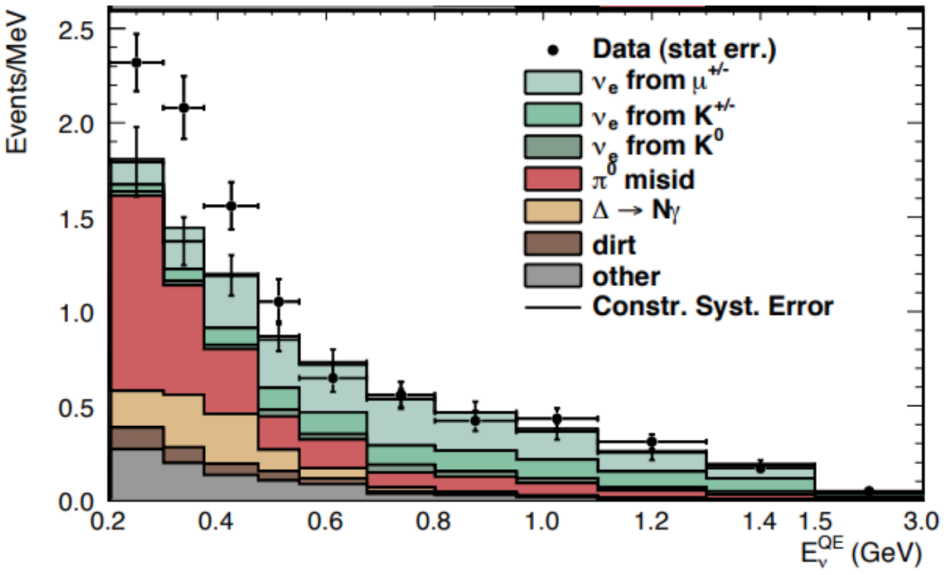
MiniBooNE Low Energy Excess (LEE)

- MiniBooNE is a Cherenkov detector on the Booster Neutrino Beam-line (BNB).
- Observed an excess of electromagnetic shower events at low energy.
- MinBooNE could not discriminate between electrons and photons but its successor MicroBooNE can.
- Electron-like LEE could be evidence for sterile neutrinos.



Phys.Rev.Lett.102:101802,2009

- Photon-like LEE could be evidence for a photon background process not predicted by current neutrino generators.

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NC Δ Radiative Decay

- Produces a single shower giving it the same signature as the LEE events.
- **Primary goal is to test the single-photon LEE hypothesis.**
- **Never measured in neutrino scattering.**
- Rare in MicroBooNE, ~100 events produced per 6.6e20POT (3 years of running).
- MiniBooNE LEE rate ~3x the size of the predicted NC Δ radiative rate.

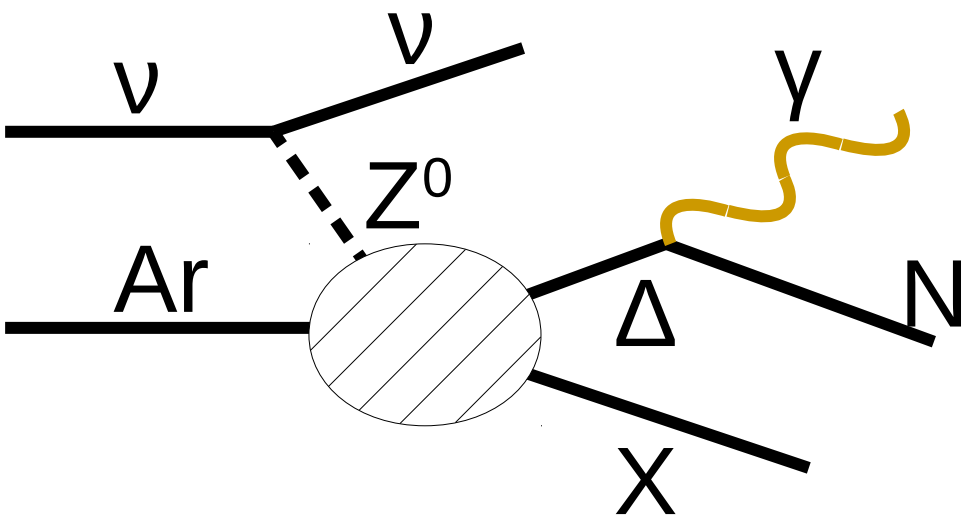
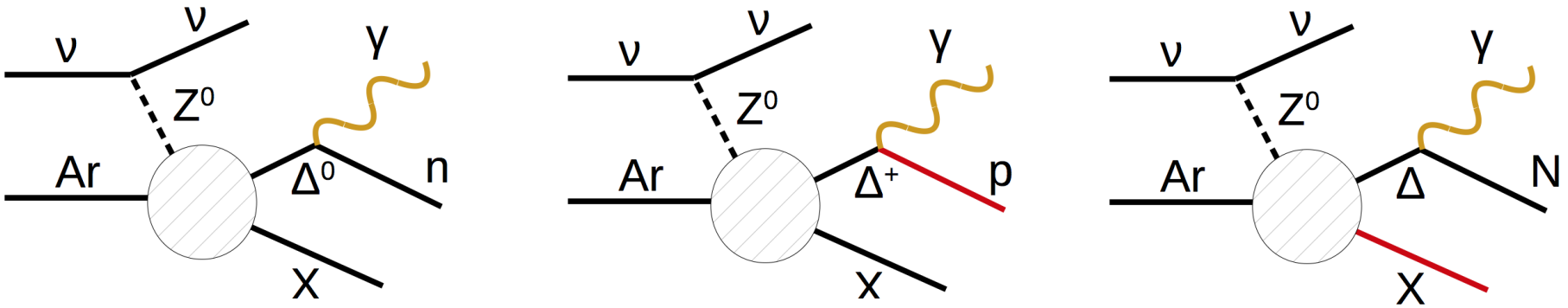
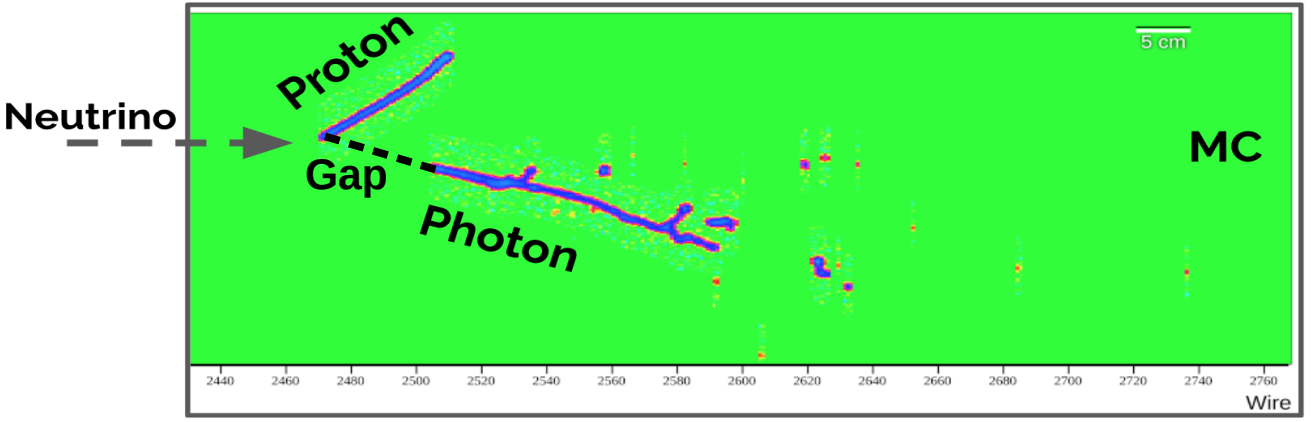


Diagram of NC Δ radiative decay.

Event Topologies





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Analysis Flow

Input: reconstructed tracks and showers (produced by The Pandora Software Development Kit for Pattern Recognition, arXiv:1506.05348).

1. Vertex Reconstruction

- Outputs reconstructed vertices with a single associated shower.

2. Pre-selection

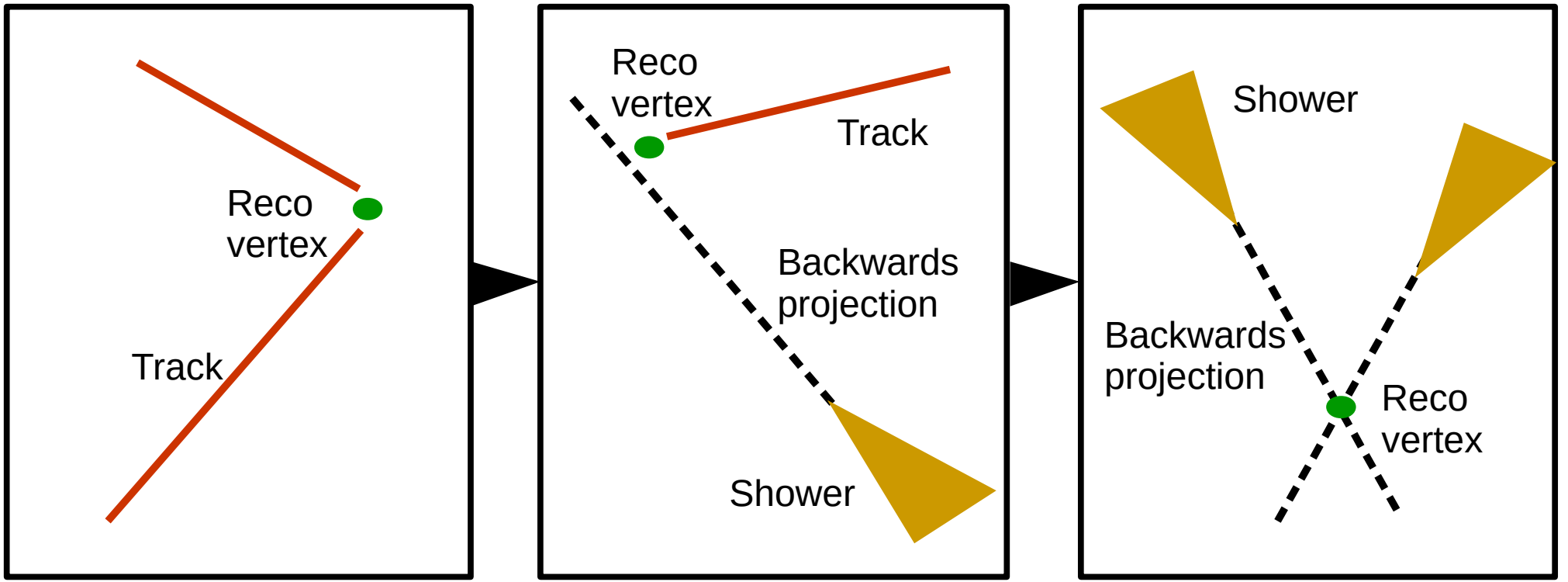
- Apply cuts to reduce cosmic background and to constrain some variables to be in regions of interest for the signal.

3. Boosted Decision Tree (BDT)

a. BDT for Cosmic background.

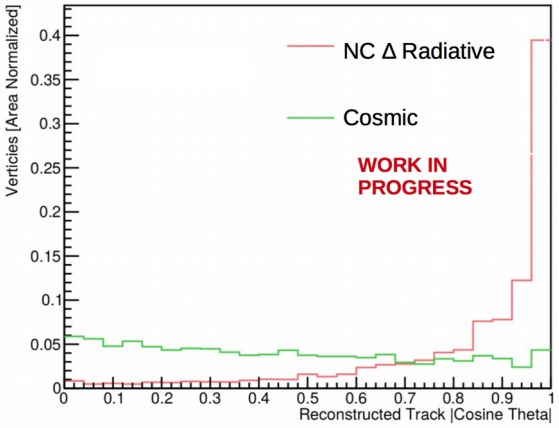
b. BDT for BNB background.

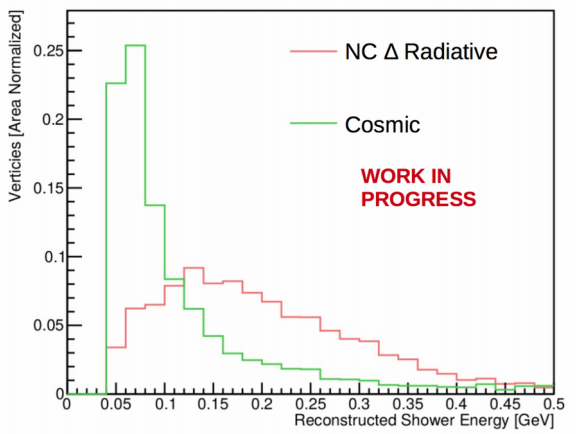
Vertex Reconstruction



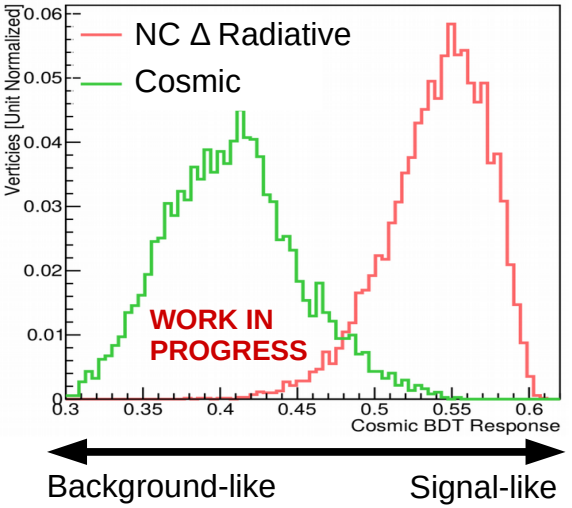
Associates reconstructed tracks and showers with each other and creates candidate vertices from these associations.

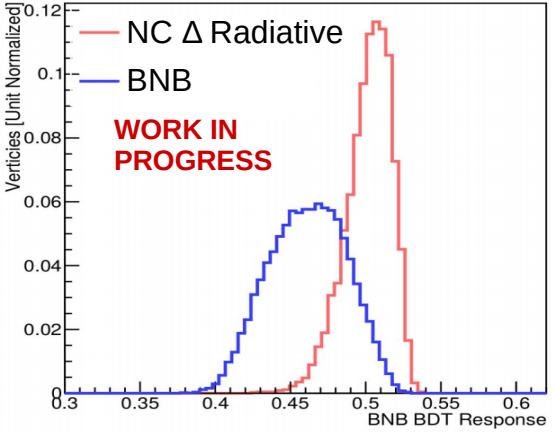
Boosted Decision Tree





- Hand the BDT a set of variables from the signal and background vertices.
- Trained BDT will place a series of 1-d cuts on these variables to produce a response variable which quantifies how signal or background-like a vertex is.
- Two pronged approach to Background Rejection:
  - BDT trained for cosmic backgrounds
  - BDT trained for BNB backgrounds





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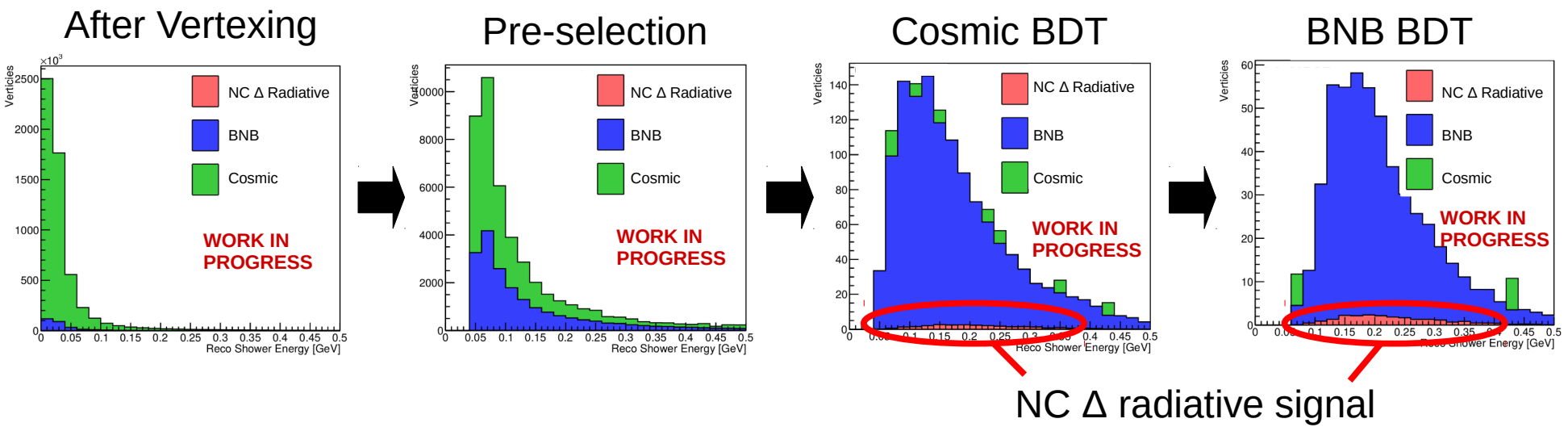
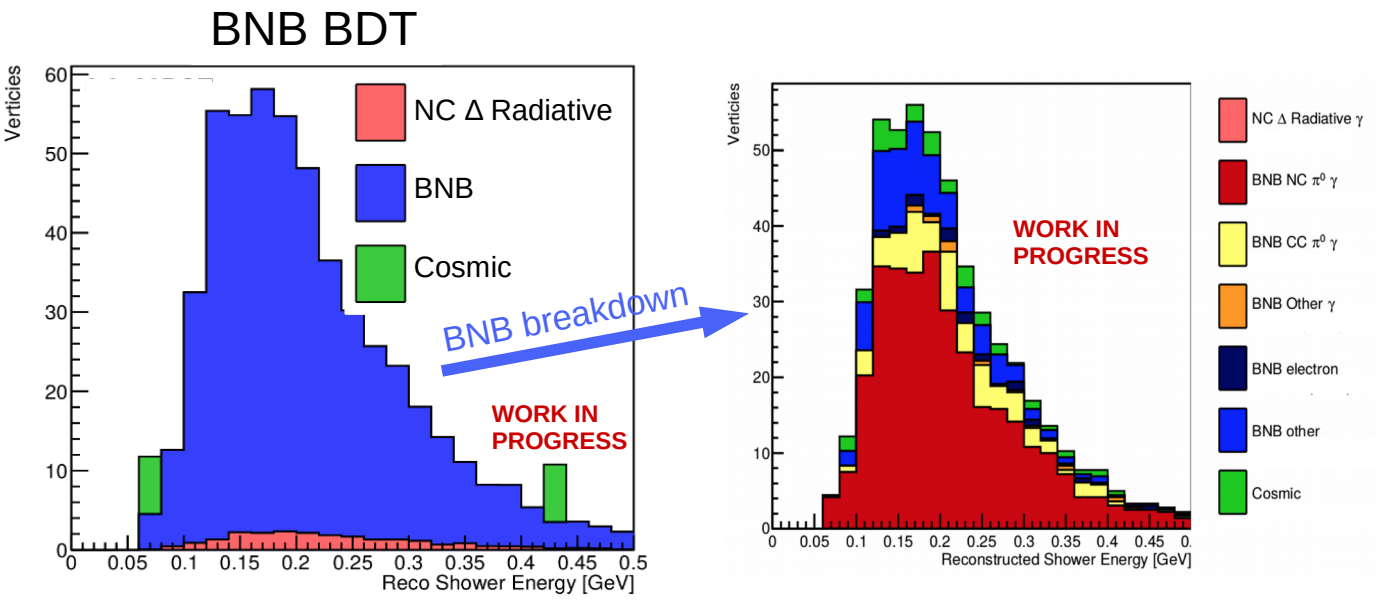
Selection (Work in Progress)



NC Δ radiative signal has been scaled up by a factor ~3 to match the LEE in MiniBooNE.

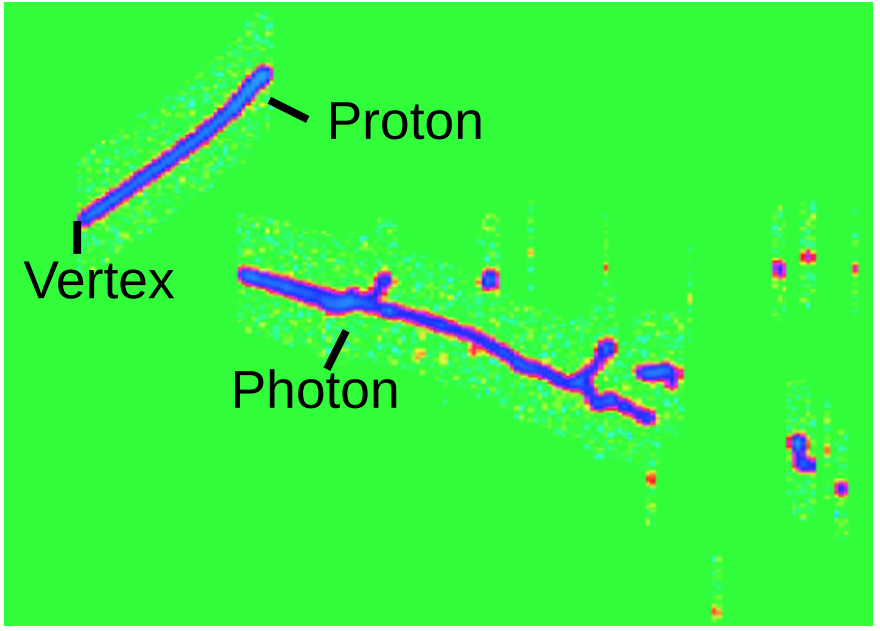
Background (Work in Progress)

- Largest background contribution post-selection is from π^0 -> 2γ decay accounting for ~76 % of all background.

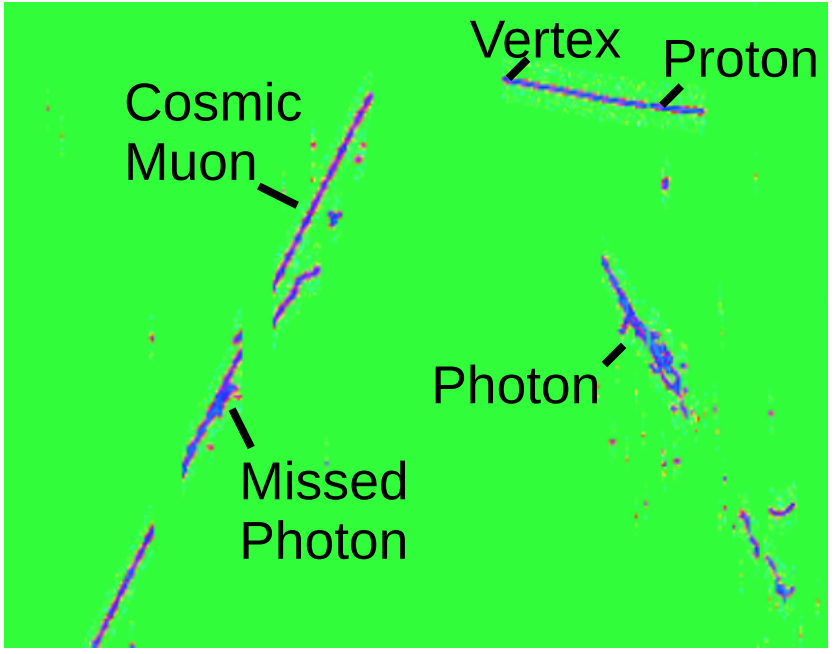


- π^0 decay is almost indistinguishable from signal if one of the two photons is not observed.

NC Δ Radiative Signal



π^0->2γ Background



Summary

- This is the first attempt at measuring low energy NC Δ radiative events from neutrino scattering.
- Challenging analysis due to low signal event rate and high background rate.
- Significant cosmogenic background rejection has been achieved, while maintaining good signal efficiency.
- Future work:
  - Optimization of all stages of analysis.
  - Further background mitigation strategies for dominant π^0 background.

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Backup

Pre-selection

Implemented for two main purposes:

- To reduce cosmic vertices to a sufficient level such that what remains can be used to train the cosmic rejection BDT efficiently.
- To constrain some variables to be in regions of interest for the signal.

Cut values:

1. Reconstructed Neutrino Vertex < 10cm from closest TPC wall
2. Total photo-electrons inside the beam gate > 50
3. Reconstructed Shower Energy > 50 MeV
4. Length of longest associated track < 150cm
5. Distance between shower start and reconstructed vertex > 2cm

Cosmic and BNB BDT Variables

All vertices:

- Shower Reconstructed energy
- Shower Theta
- Shower Phi
- Shower dE/dx
- Vertex position
- Vertex distance to closest TPC boundary
- Total PE sum of in time flashes
- Distance between shower and closest in-time flash.

Additional variables for vertices with > 0 tracks:

- Shower start - vertex distance
- Number of tracks
- Longest track length
- Longest track Theta
- Longest track Phi
- Longest track dE/dx proton PID
- Angle between track and shower