Constraining the NC π^0 Background for MicroBooNE's Single Photon Search

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On behalf of the MicroBooNE Collaboration

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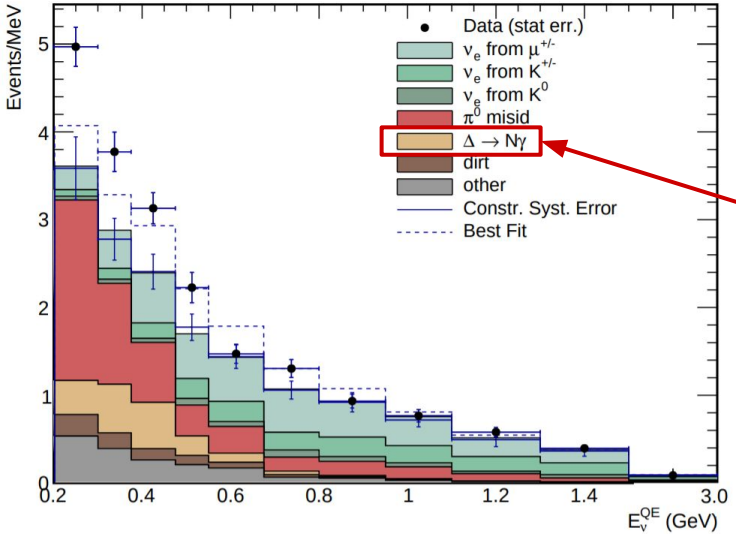
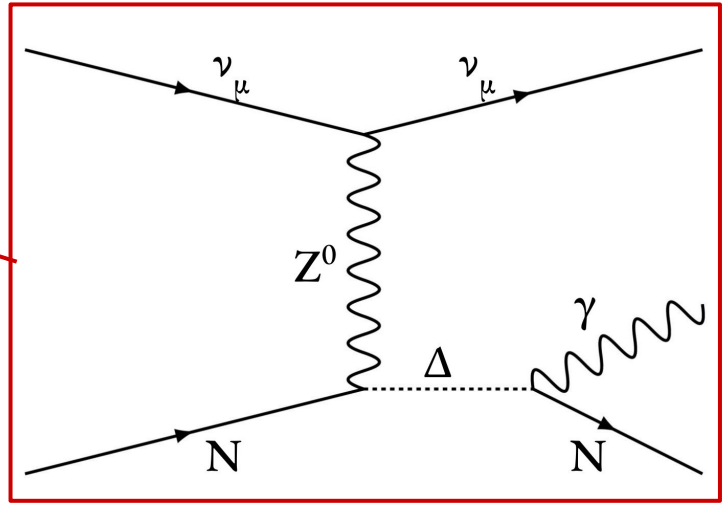
MiniBooNE Low-Energy Excess

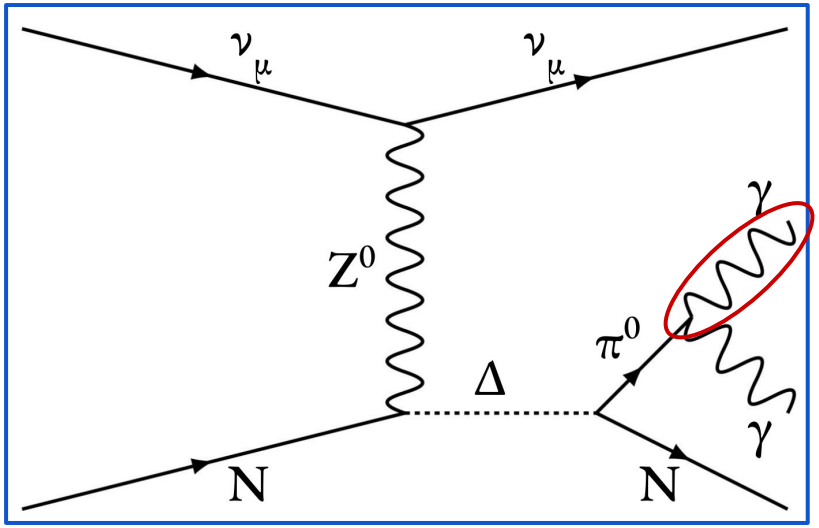
- Observed excess of neutrino events below 600 MeV
- Cherenkov detector; difficulty distinguishing photons and electrons
- **Photon-like** and electron-like hypotheses
- MicroBooNE is searching for **Δ → Nγ** to investigate photon-like





Neutral Current (NC) π^0

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



Analysis Flow

Input Pandora [1] reconstructed tracks and showers

↓

Select for signal topology

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Pre-selection cuts

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

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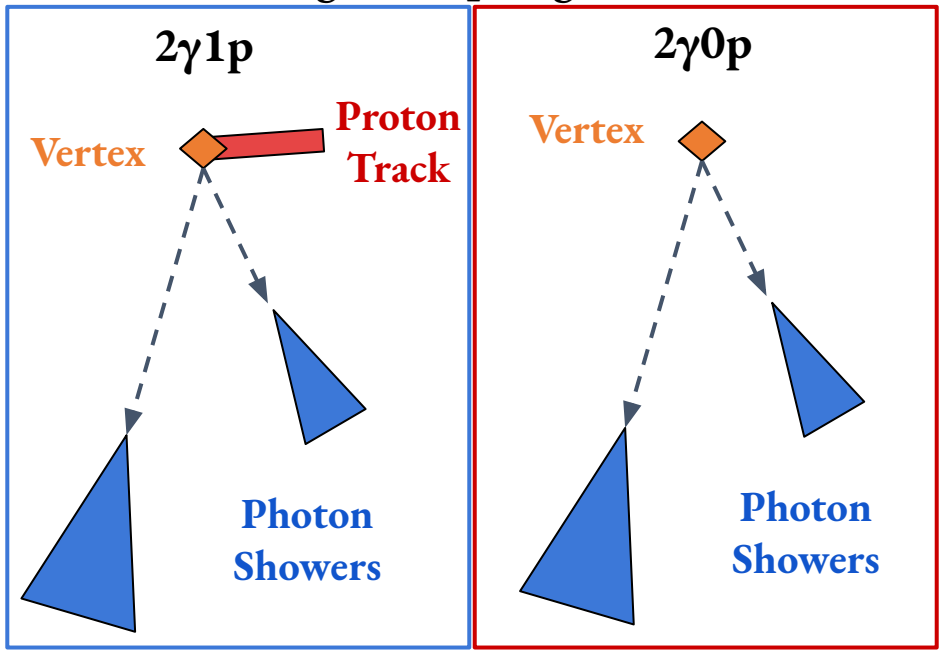
BNB* background rejection with BNB-trained BDT

Signal Topologies

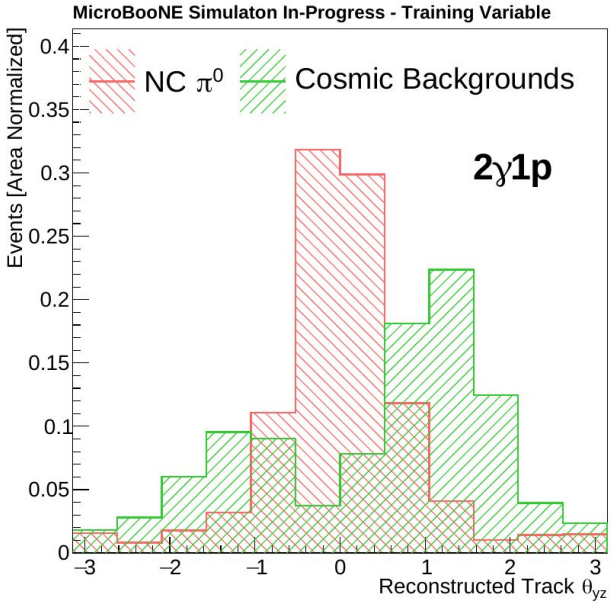


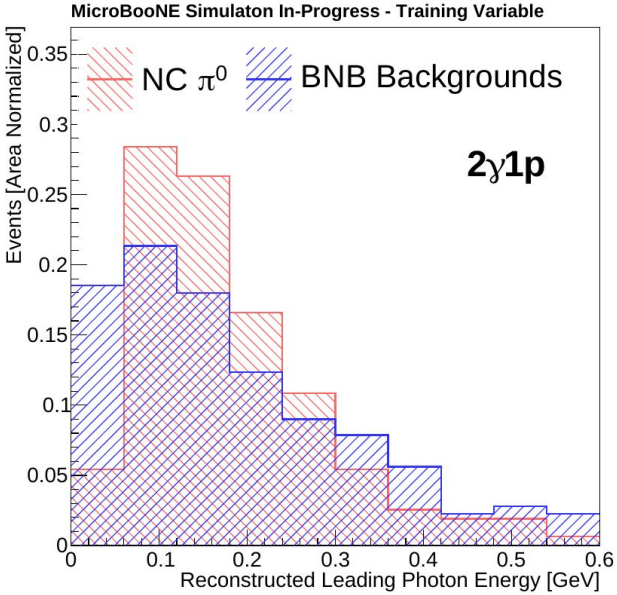
[1] Eur. Phys. J., C75(9):439, 2015.

*Booster Neutrino Beam

BDT Training Variables

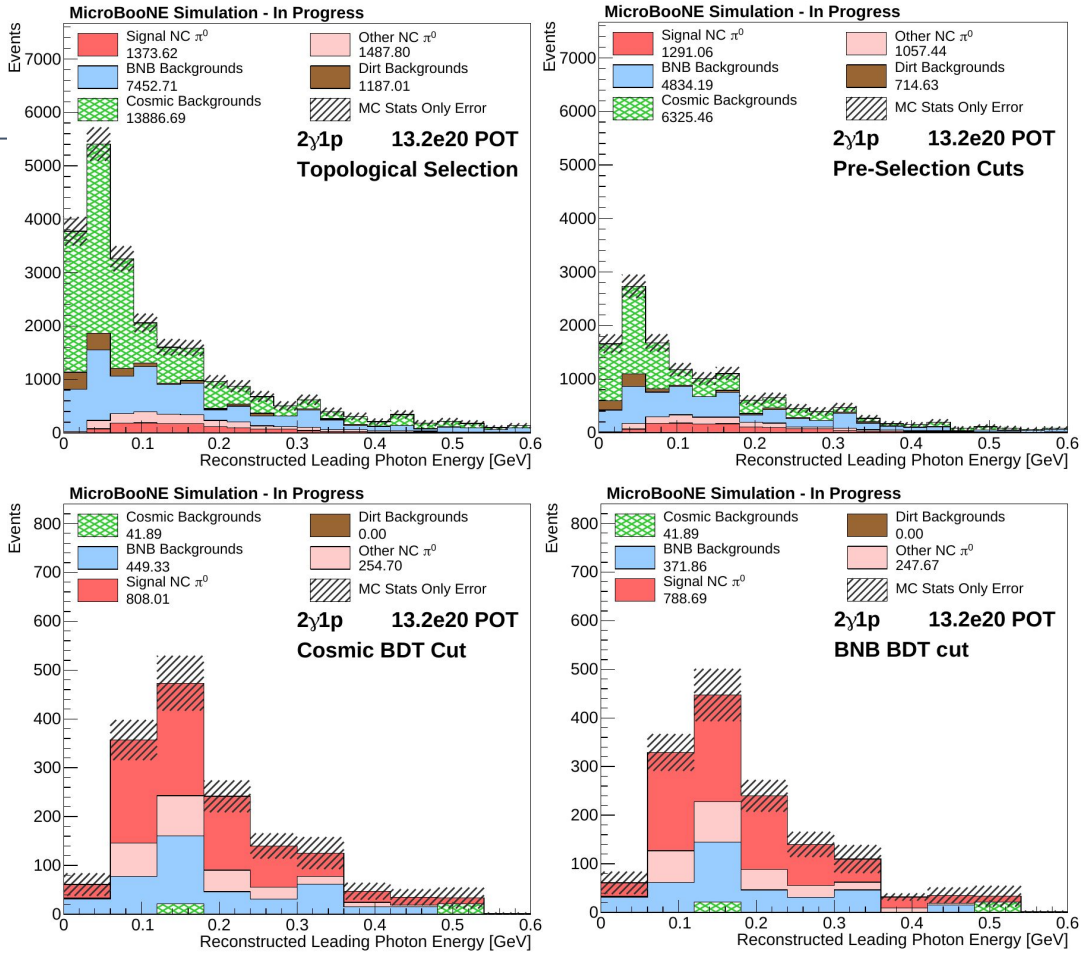
- BDT takes **MC signal/background distributions** as input
- On-beam events generally harder to reject than cosmics





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



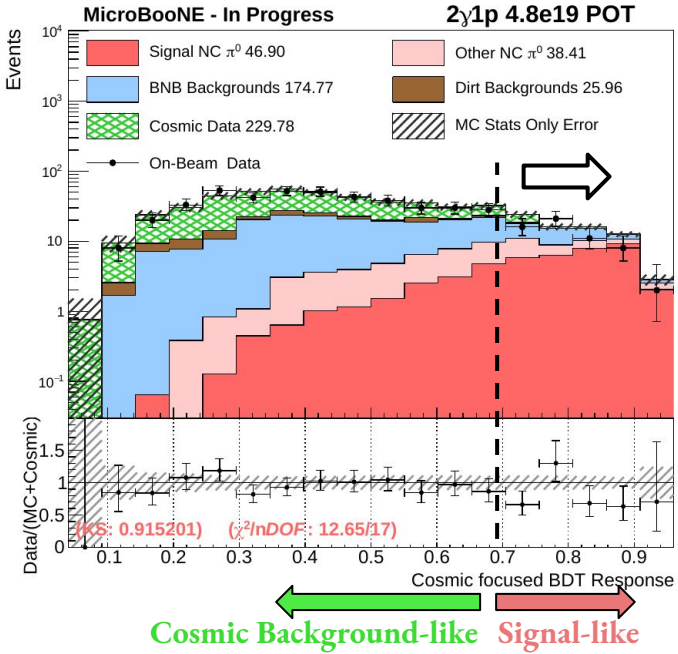
MC Backgrounds

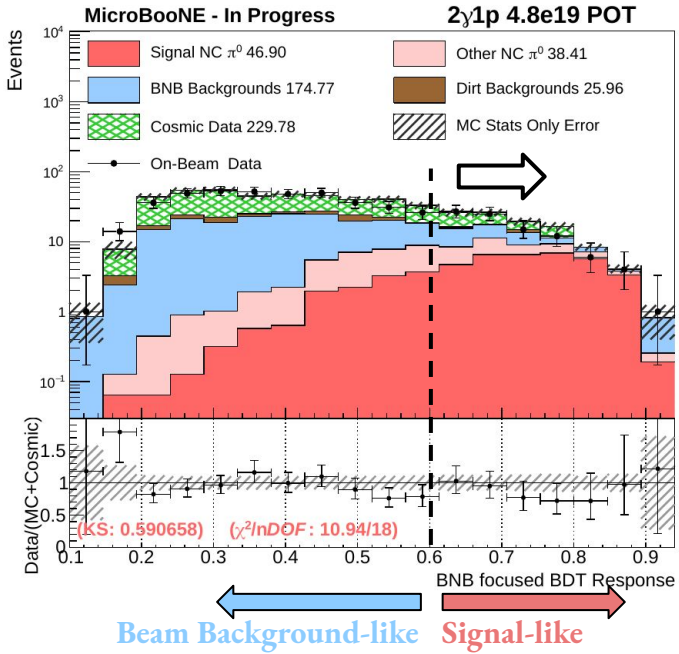
- Largest background is **charged current (CC) π^0**
- All CC events comprise ~70% of background
  - Largely caused by mis-ID'ed muons/pions
- Some background events caused by Pandora mis-reconstruction
- Currently working to implement PID algorithms

Background	Percentage
CC π^0	43.5
Other CC events	26.1
Cosmic coincidence	17.5
NC BNB Background	8.7
Other	4.2

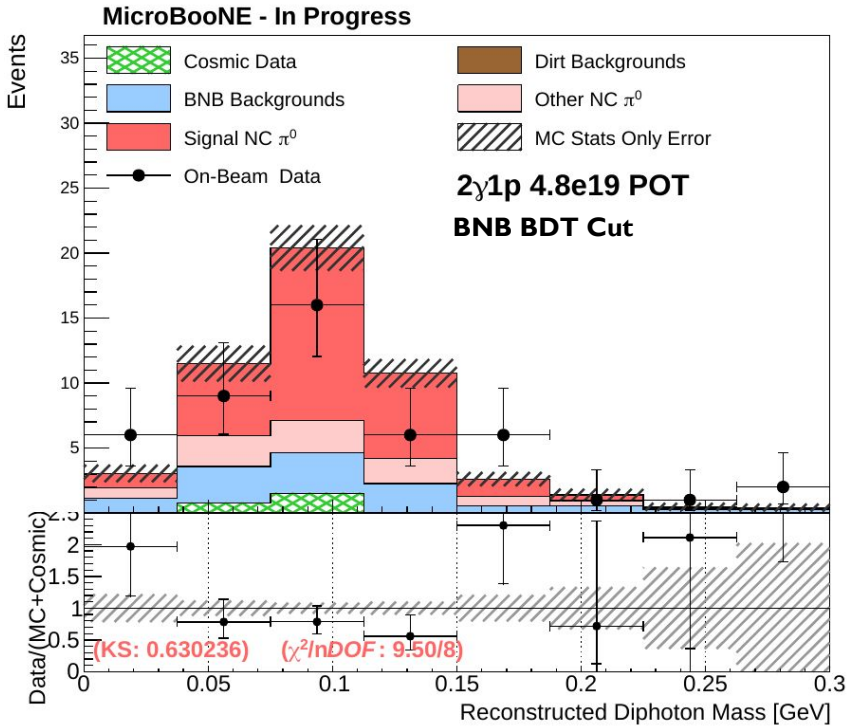
Data/MC: BDT Response

- Cut on BDT response to reject backgrounds
- Cut value chosen to maximize efficiency times purity





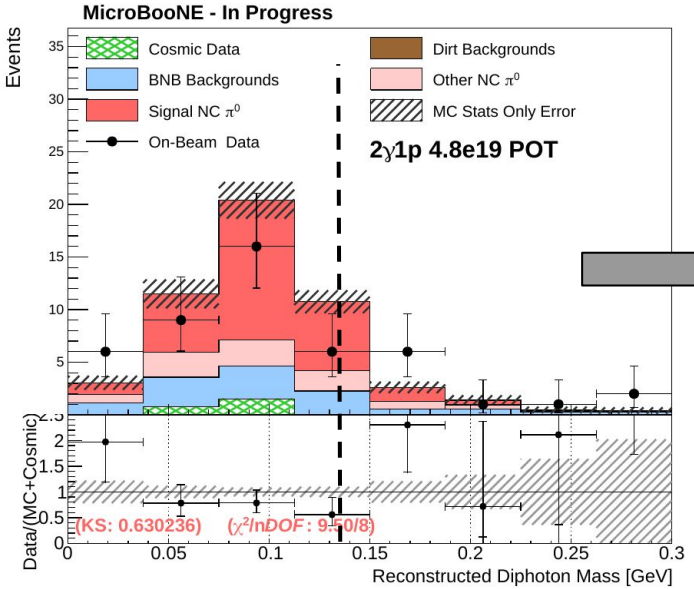
Data/MC: Invariant Diphoton Mass

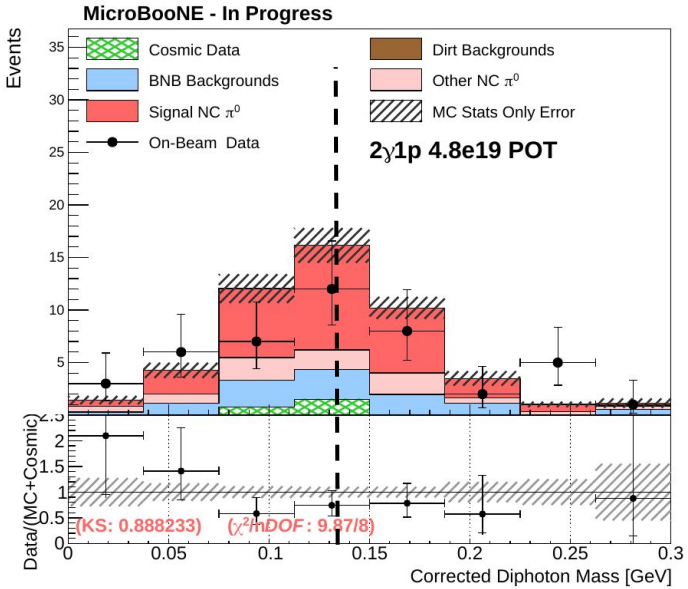


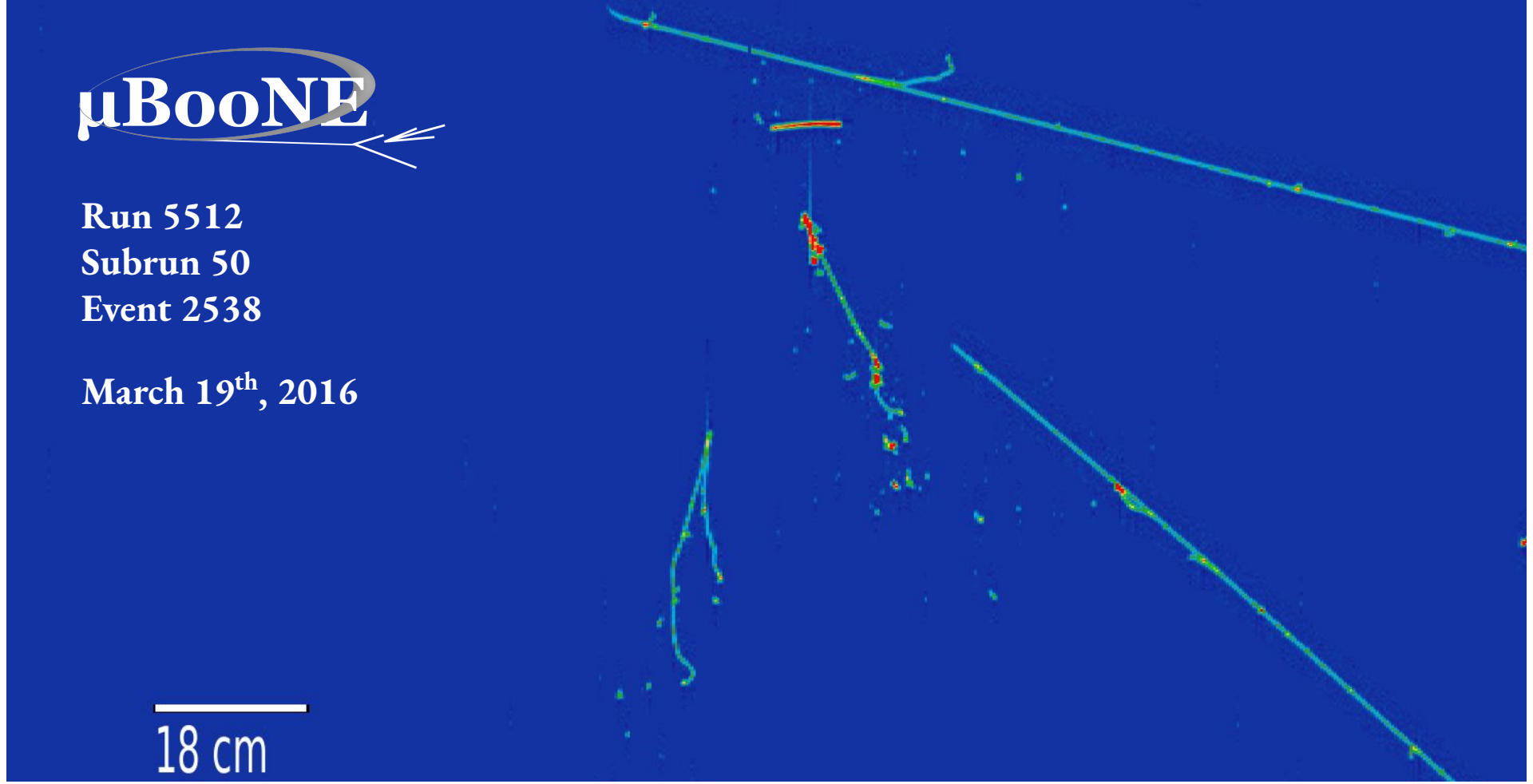
- Good data/MC agreement after applying BDT cuts
- Expect ~60% pure final selection
- Note: shower energies losses in reconstruction
  - ~20% effect

Corrected Diphoton Mass

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



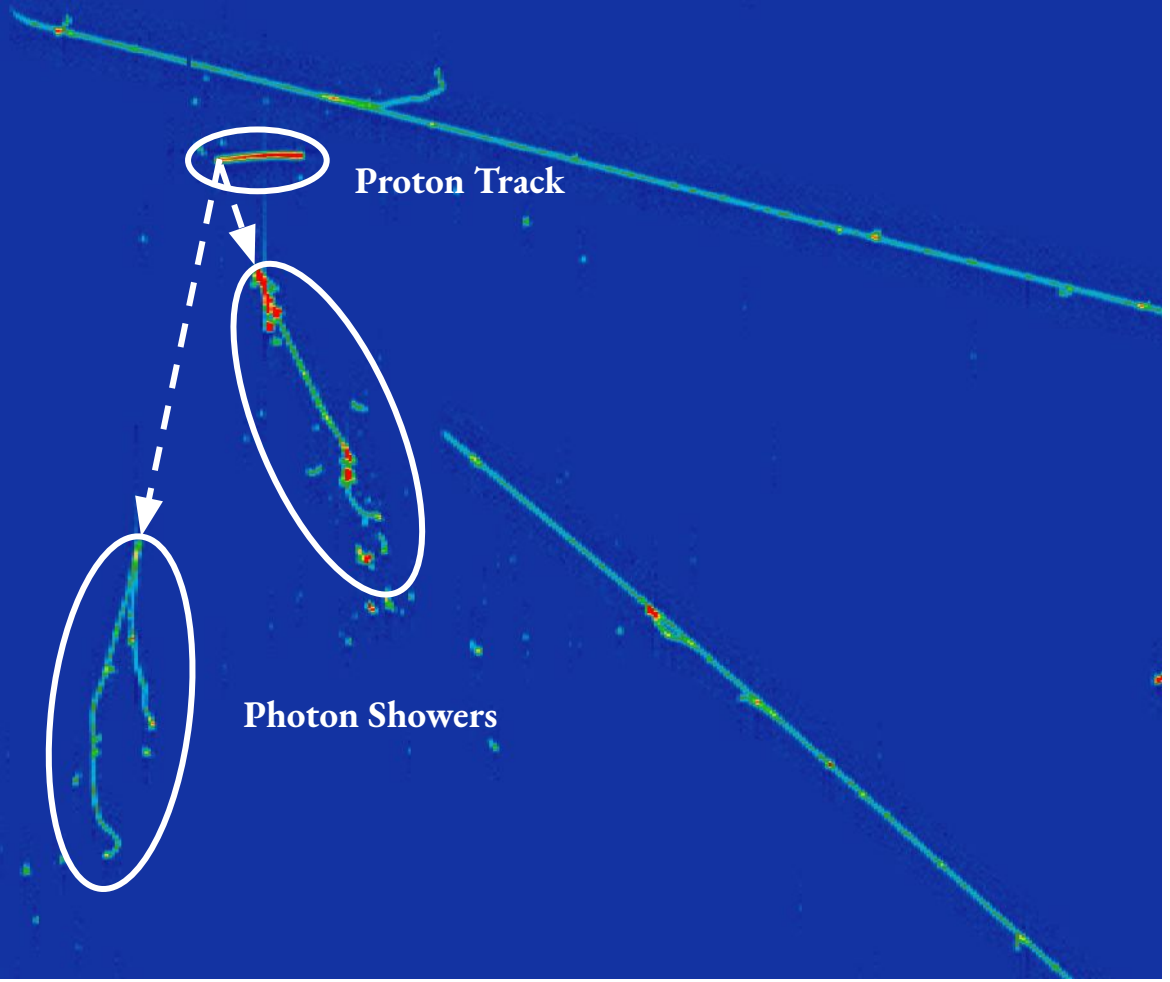


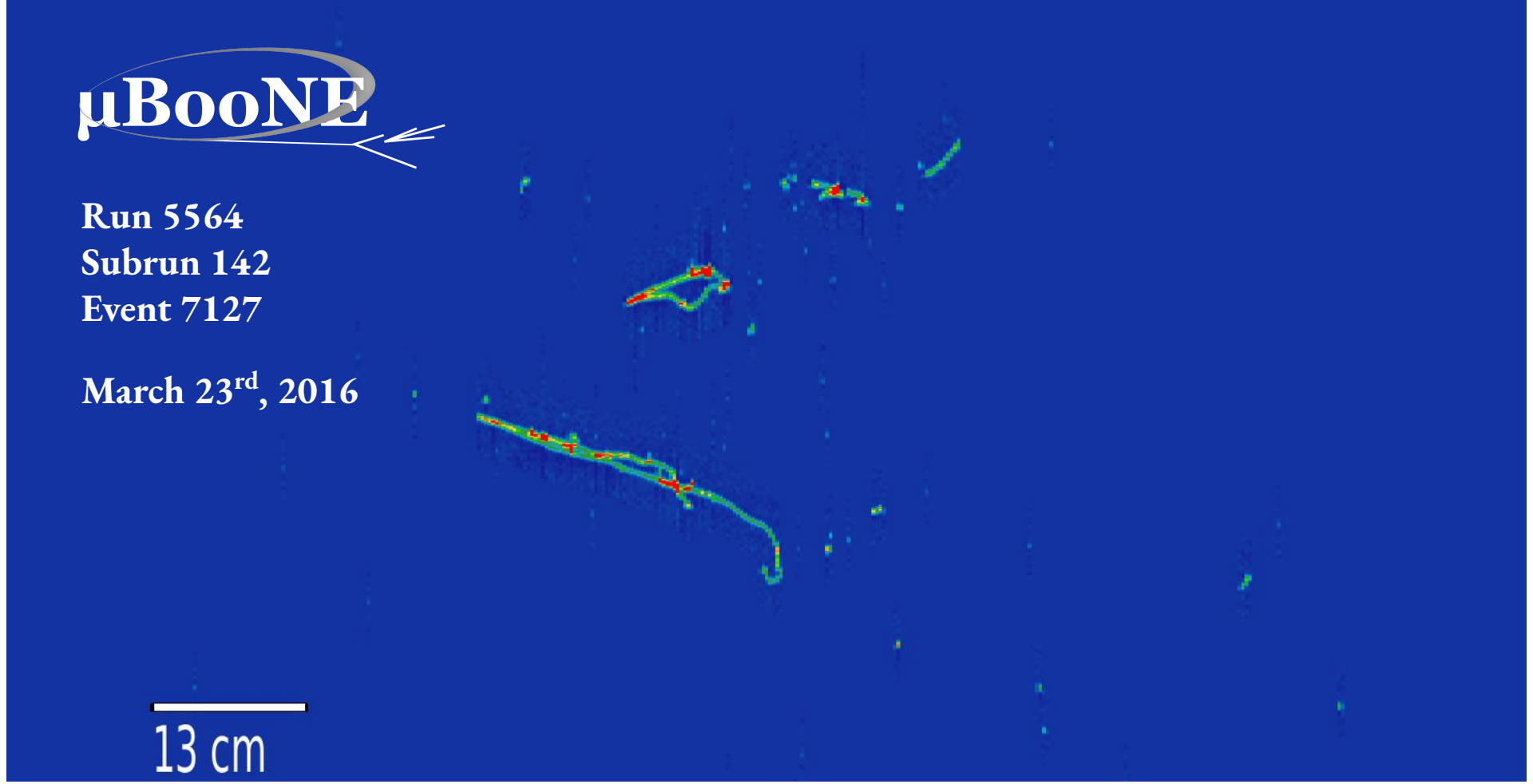

μBooNE
Run 5512
Subrun 50
Event 2538
March 19th, 2016
18 cm

µBooNE

Run 5512
Subrun 50
Event 2538

March 19th, 2016




μBooNE
Run 5564
Subrun 142
Event 7127
March 23rd, 2016
13 cm

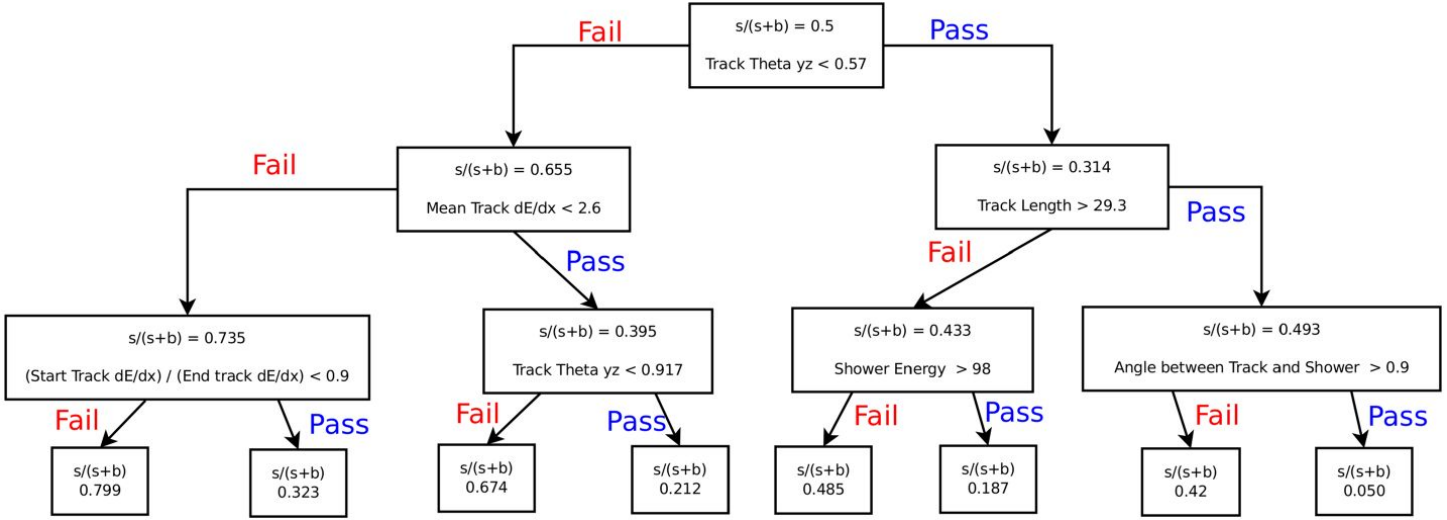
Summary

- First demonstration of NC π^0 selection in MicroBooNE
- Demonstrated the effectiveness of BDTs in cutting cosmic and beam-related backgrounds
- Predicted final selection includes several hundred good NC π^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 π^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

Cosmic BDT	Beam BDT
Track dE/dx	Track dE/dx
Shower energies	Shower energies
Shower conversion distances	Shower conversion distances
Track length	Track length
Track vertical angle	Track vertical angle
Ratio of track start/end dEdx	Opening angle between showers
Shower vertical angle	Shower angle w.r.t beam direction

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