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Search for NC-Coherent-like Single-Photon Events with MicroBooNE

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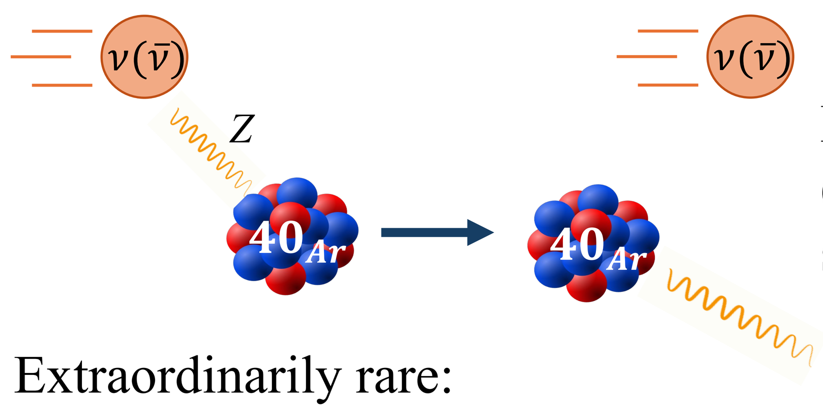
1 Introduction

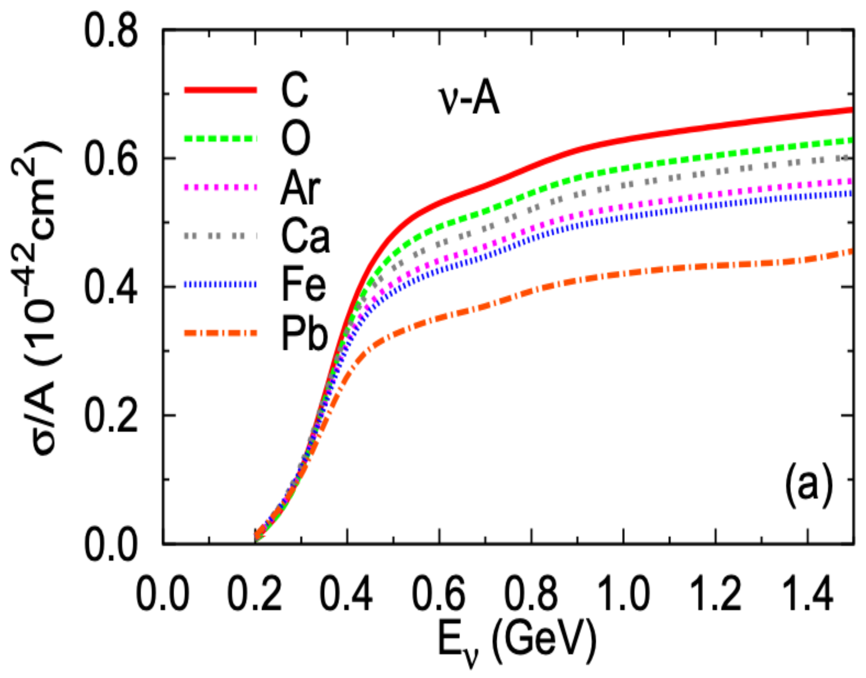
Neutral-current (NC) coherent single-photon production



Predicted by the Standard Model (SM) but never been directly searched for. Until now.

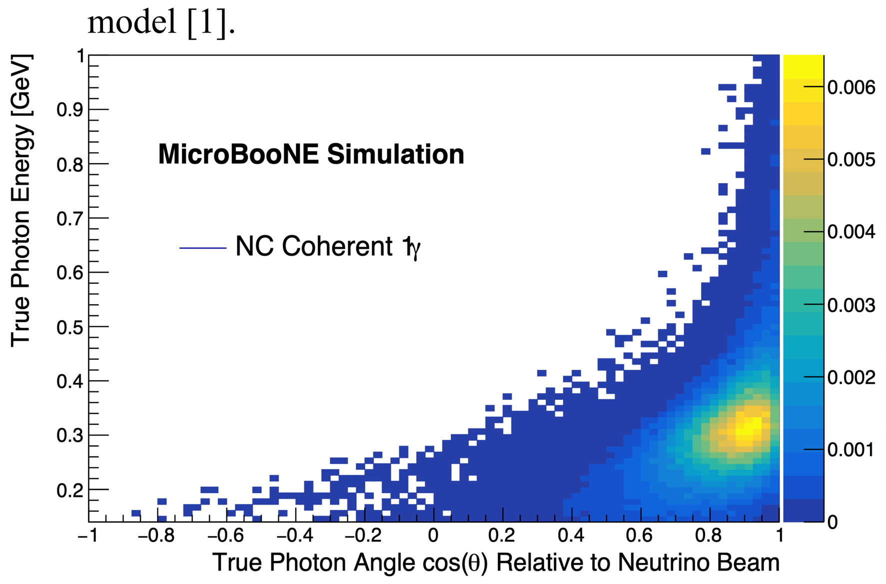
Extraordinarily rare: $\sigma/A \sim O(10^{-43}\ cm^2)$, ~16 SM events expected in the full dataset.

MicroBooNE is not sensitive to the SM rate, so rather than searching for the coherent signal itself, we searched for any anomalous enhancement above background, which could potentially point to BSM physics.



Integrated coherent NCγ cross sections for different nuclei divided by the number of nucleons [1].

Simulation based on Wang-Alvarez-Ruso-Nieves model [1].



Signal events appear as low-energy forward photons . The same signature that could explain the MiniBooNE low-energy excess [2].

2 MicroBooNE Detector & Dataset

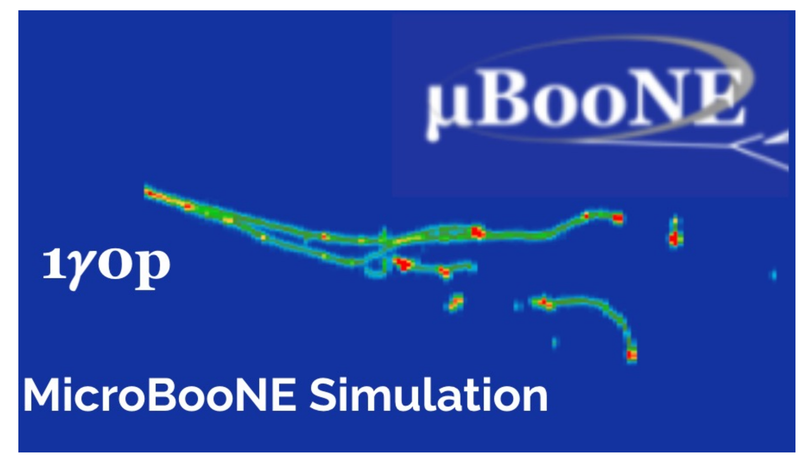
- 85 metric tons of liquid argon in its active volume
- Booster Neutrino Beam (BNB) with $< E_\nu > \approx 0.8\ GeV$
- Exposure: This analysis [3] uses dataset from Run 1-3 (6.87×10^{20} POT)
- This analysis uses Pandora reconstruction [4].

References:

1. E. Wang et al., Phys. Rev. C 89, 015503
2. A. A. Aguilar-Arevalo et al., Phys. Rev. D 103, 052002 (2021)
3. MicroBooNE Collaboration, arXiv:2502.06091v2 (2025)
4. Acciarri, R et al. *Eur. Phys. J. C* **78**, 82 (2018).
5. M. Masip et al., J. High Energy Phys. 2013, 106 (2013)
6. MicroBooNE Collaboration, Phys. Rev. D 111, 032005 (2025)

3 Event Selection

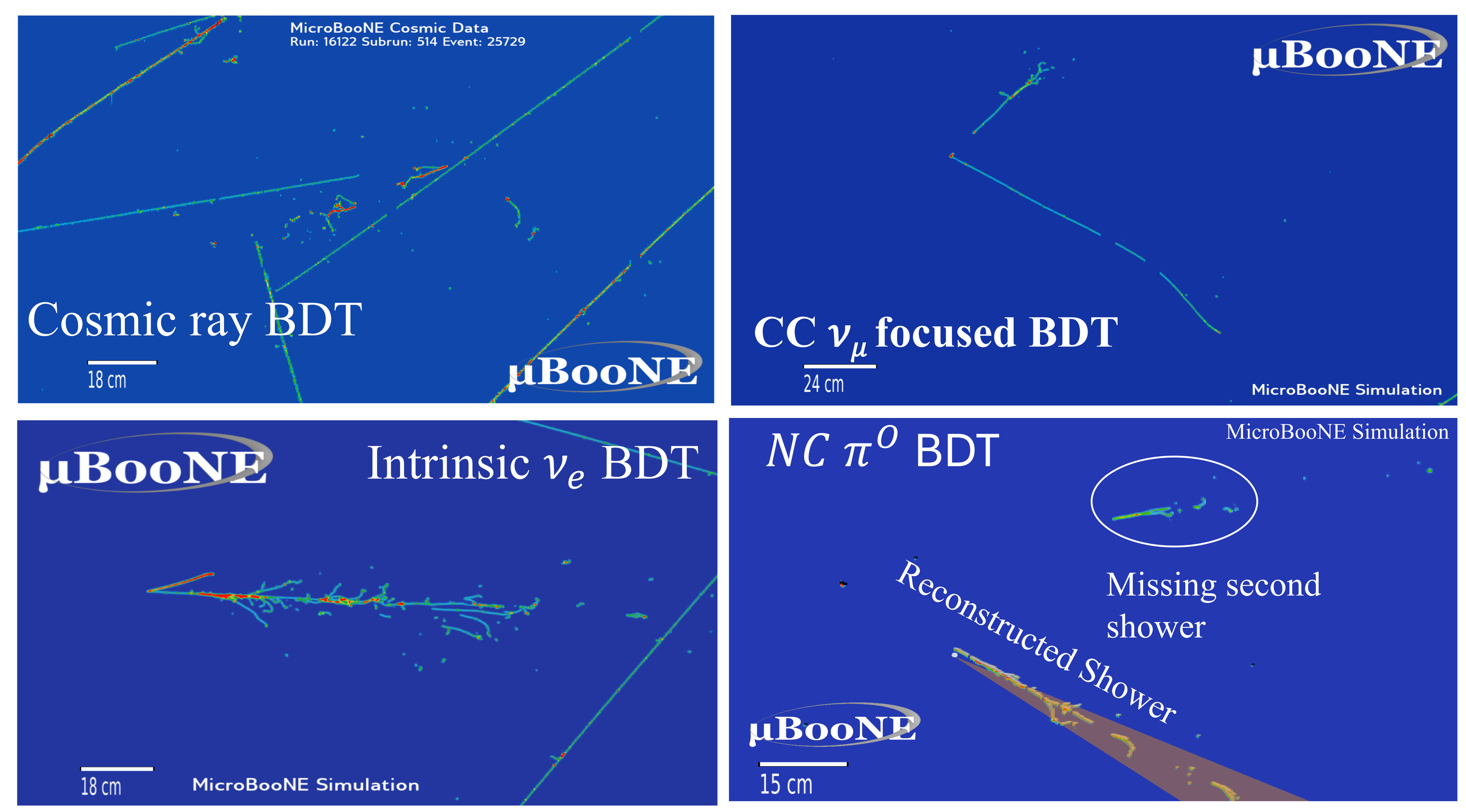
Topological requirements



Pre-selection requirements:

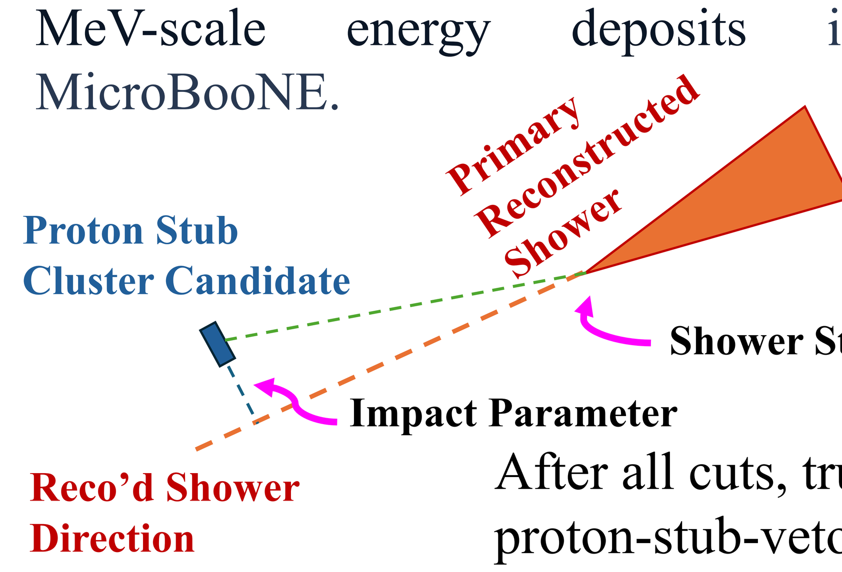
- Reconstructed shower energy > 0.05 GeV (removes Michel electron showers)
- Fiducial volume cut: distance from reconstructed shower start to space charge boundary (regions where electric-field distortions make reconstruction less reliable) > 2 cm

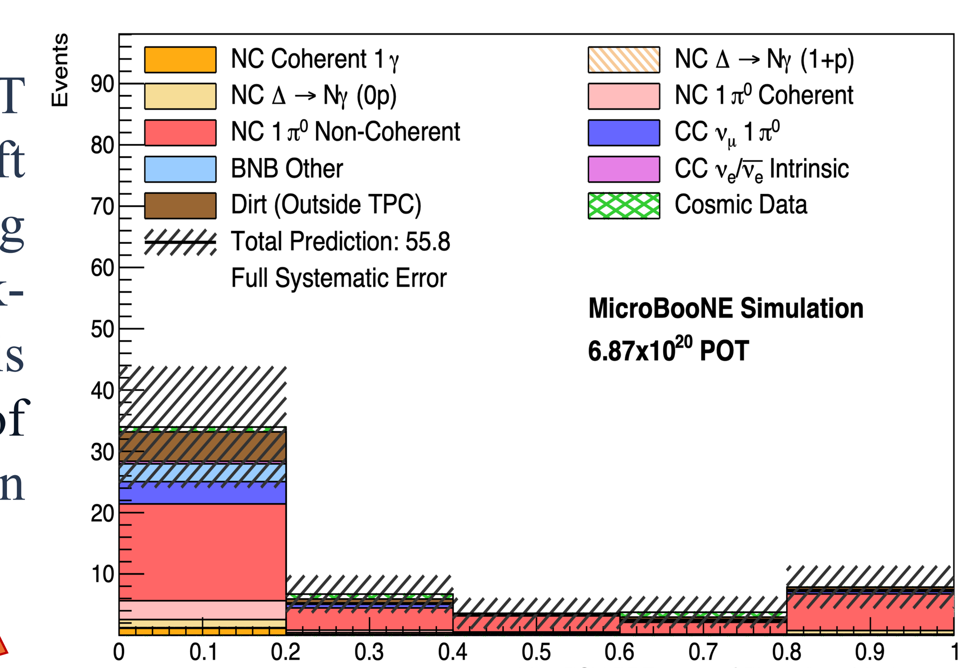
Event level boosted decision trees (BDTs)



Proton stub veto (PSV) BDT

A proton-stub veto (PSV) BDT clusters low-level TPC hits to find soft protons, below 40 MeV tracking threshold, sitting on the back-projection of the photon shower. This is the first high-level physics use of MeV-scale energy deposits in MicroBooNE.

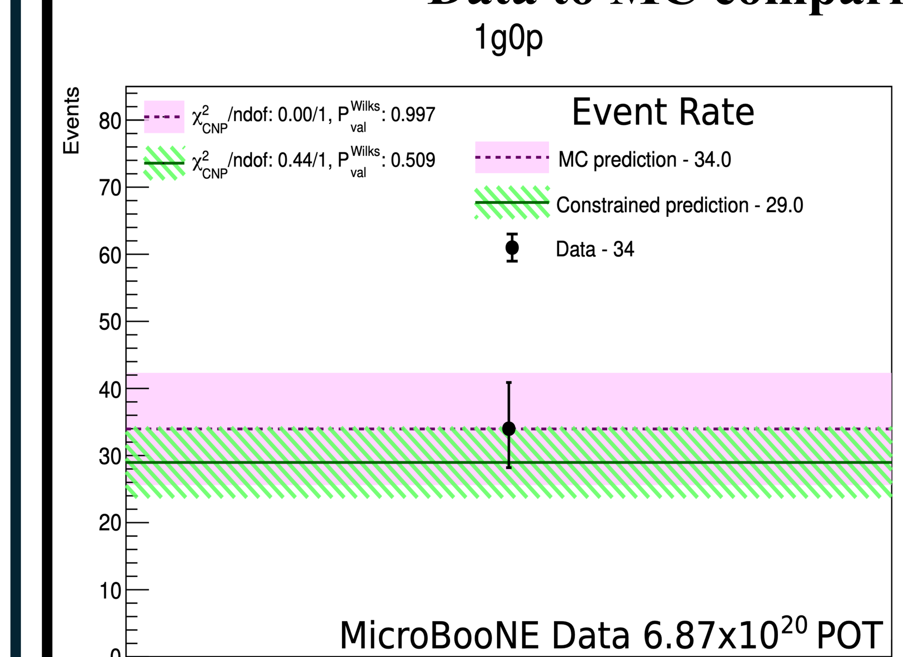




After all cuts, true coherent single-photon events cluster at low proton-stub-veto BDT scores, while backgrounds are spread more broadly [3].

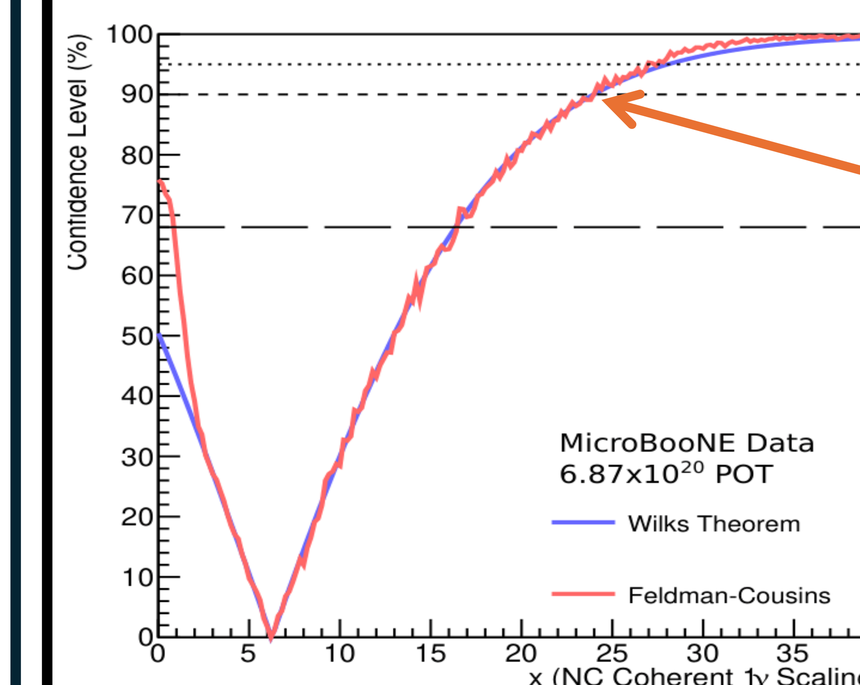
4 Results

Data to MC comparisons after final selection



MC = nominal simulation before sideband constraint.
Constrained = prediction after sideband constraint.

The observed rates are consistent with background expectation.

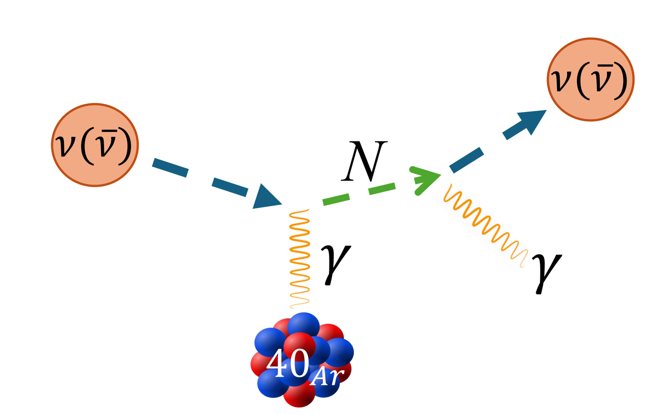


We accordingly set an upper limit on the flux-averaged NC coherent single-photon cross section of $\sigma < 1.49 \times 10^{-41}\ cm^2$ *at 90% C.L.* evaluated using the Feldman-Cousins unified frequentist method.

The world's first limit on neutrino-induced NC coherent single-photon production [3].

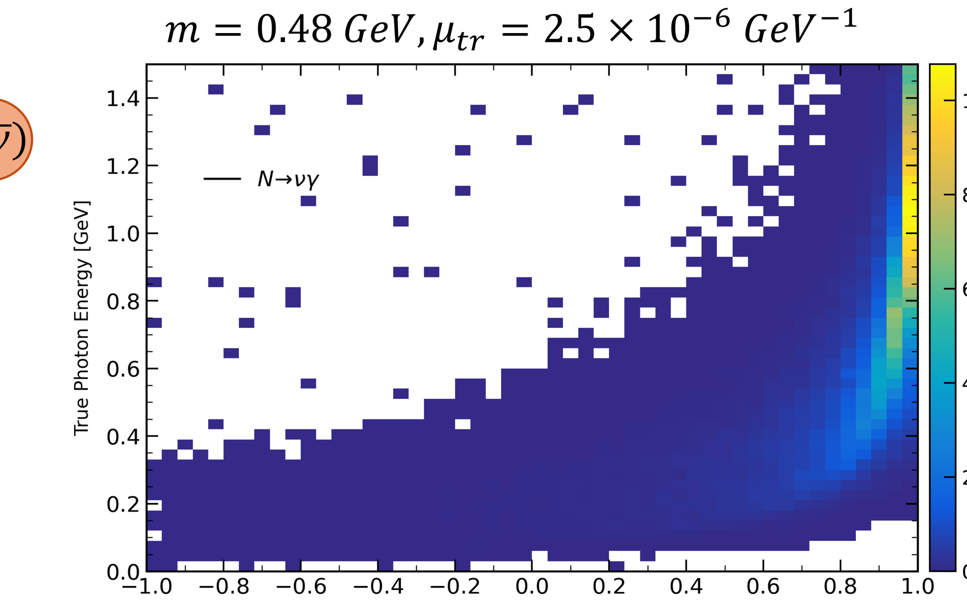
5 Future Work

The same analysis workflow can be leveraged to search for other physics signals with similar final state, e.g. heavy neutrinos with large transition magnetic moment [5].



This BSM physics predicts Primakoff upscattering and radiative decay through a transition magnetic moment.

$m = 0.48\ GeV, \mu_{tr} = 2.5 \times 10^{-6}\ GeV^{-1}$



The forward, low-energy photons are the kind of single-γ event that could mimic the MiniBooNE low-energy excess [2].

New Tools

- Blips: MeV-scale energy deposits from unreconstructed low-energy particles [6].
- Full Dataset: 1.3×10^{21} POT (Run 1-5)
- Combining Reconstruction: Pandora, Wire-Cell and Lantern.

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