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Low Energy Excess and New Physics Searches with MicroBooNE

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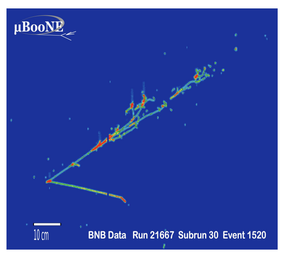
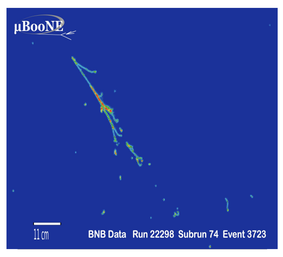
On behalf of the MicroBooNE Collaboration

First Full Dataset Search for a ν_e Low Energy Excess

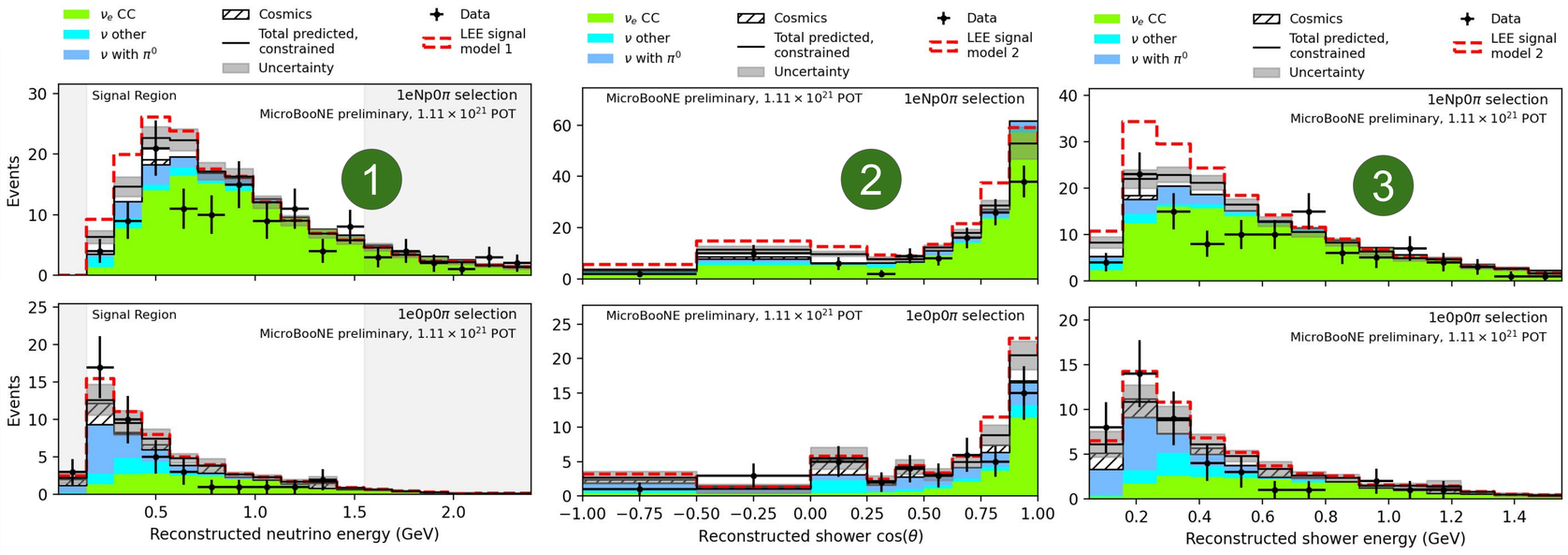
For the first time, the full set of 1.11x10^{21} POT is used to search for the low-energy excess (LEE) observed in MiniBooNE. This search tests whether the excess is due to an increase in the number of electron neutrinos. Two models are tested: one that models the excess as a function of the neutrino energy and one that preserves the distribution of the shower kinematics in MiniBooNE. Results using the first 6.86x10^{20} POT of this dataset were published in [1].



Final state with protons

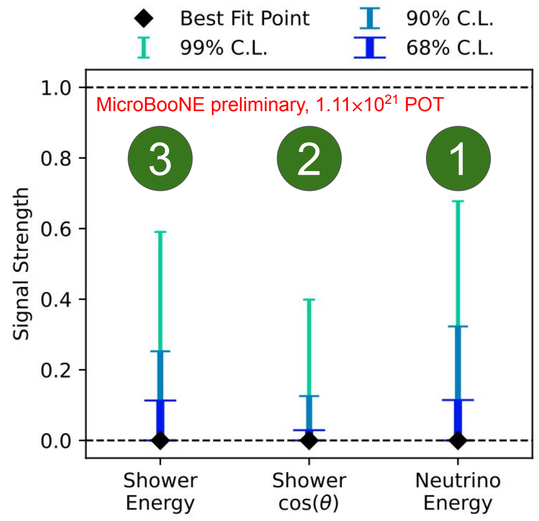


Final state without protons

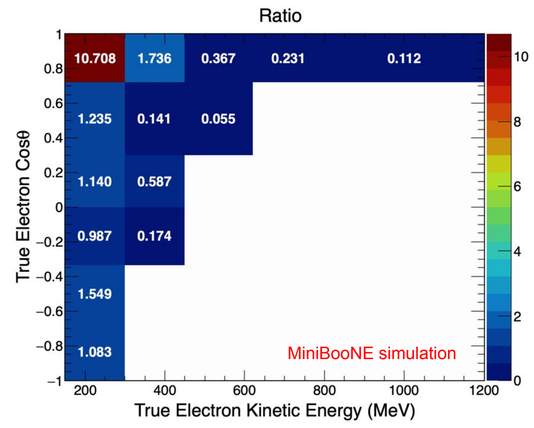


Signal selections binned in reconstructed neutrino energy. The MiniBooNE LEE signal is unfolded from the CCQE electron neutrino energy.

Signal selections binned in reconstructed shower energy and cos(θ). The MiniBooNE LEE signal is unfolded from the shower energy and angle distributions.



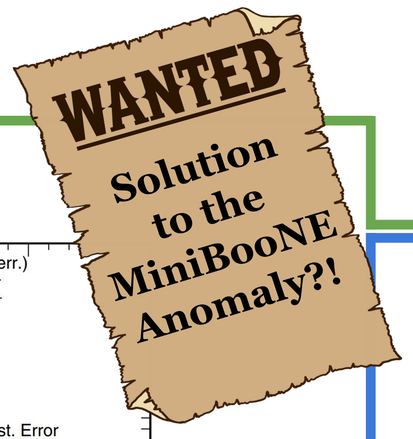
Signal strength = 1 corresponds to LEE expectation.



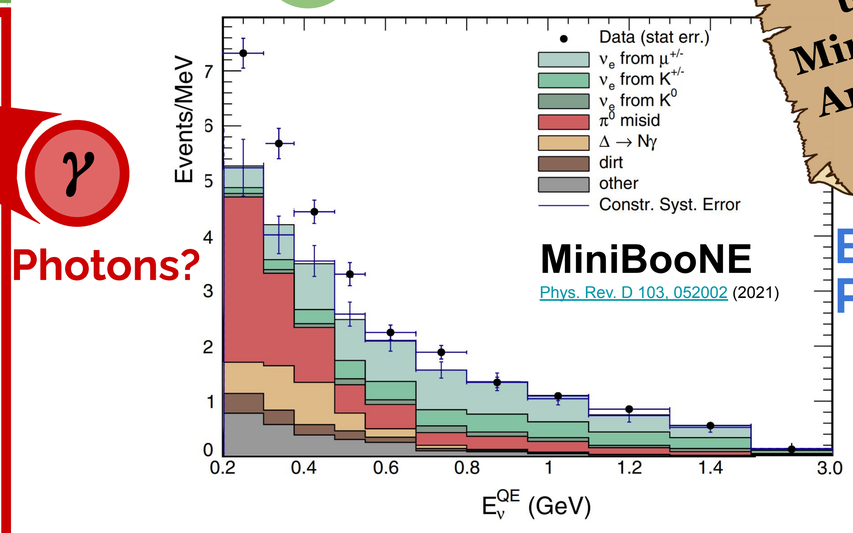
The LEE ratio model unfolded from MiniBooNE shower 2D kinematic variables.

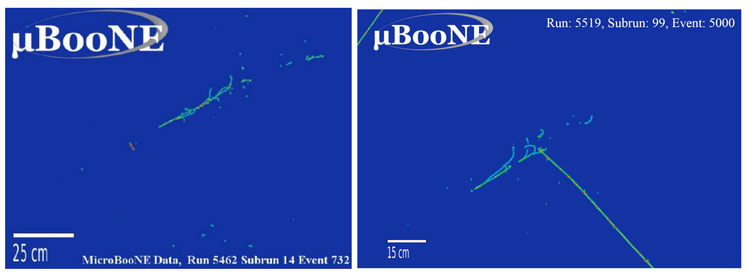
MicroBooNE Public Note 1127

All public notes are available at: https://microboone.fnal.gov/public-notes/

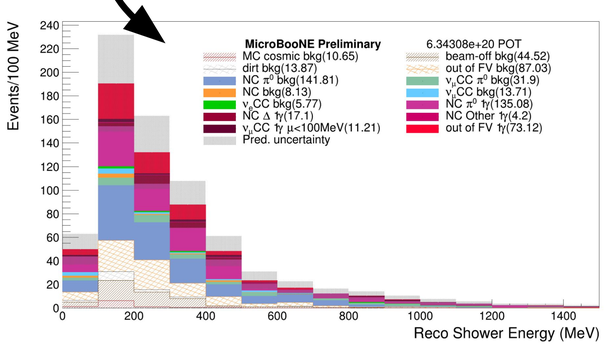


Single Photon Searches





To search the whole photon phase-space for signs of an excess, an **inclusive single photon** analysis has been developed. The analysis targets any final state consistent with what would be observed as a single photon in MiniBooNE, rather than testing a particular model. A selection using Wire-Cell reconstruction[2] tools and targeted BDTs achieves an efficiency of 7.0% and a purity of 40.2%.



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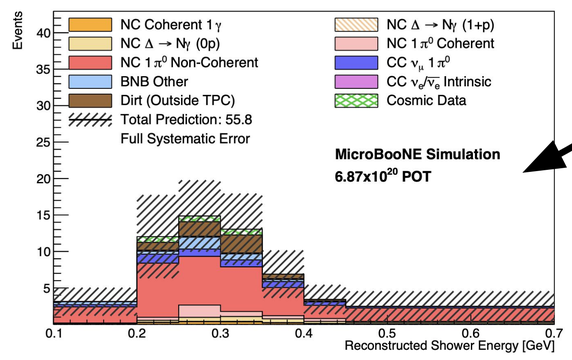
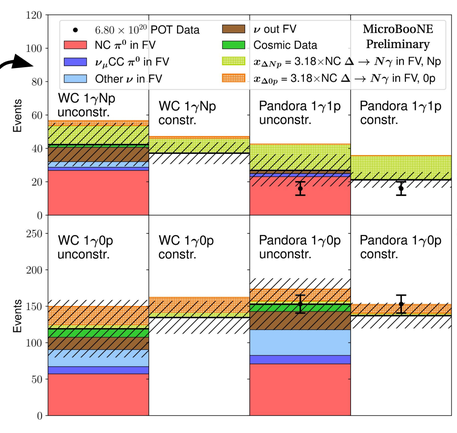
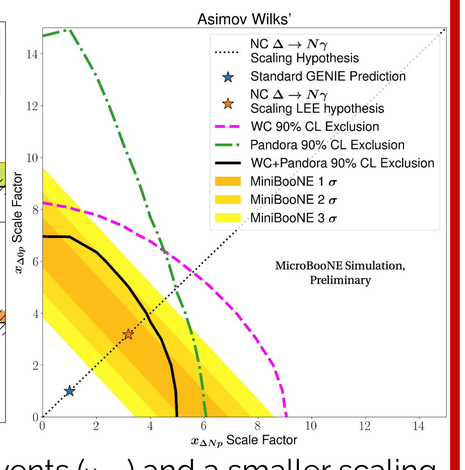


Coherent single photon production is a very rare process, and no search has ever been performed. Signal events appear as low energy photons in the forward direction. We use new tools to help reject low energy hadronic activity.

MicroBooNE Public Note 1131

Previous results showed no excess of **NC Δ→Nγ** events with protons. This expanded analysis will have more sensitivity to NC Δ→Nγ events with no protons, compared to [4].

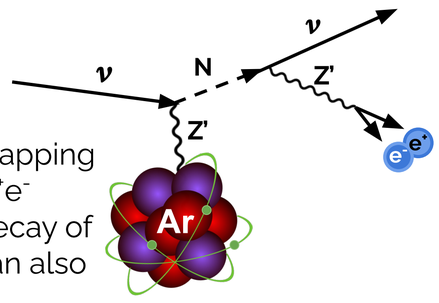




MicroBooNE Public Note 1126

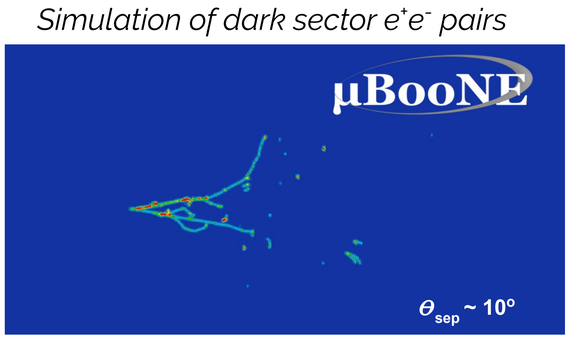
The LEE could consist of a larger scaling factor for 0p events ($x_{\Delta 0p}$) and a smaller scaling factor for Np events ($x_{\Delta Np}$). These possibilities can be represented as a 2D phase space, and we expect to exclude a larger region than in our previous result.

Dark-Sector e^+e^- Solutions



Sufficiently overlapping or asymmetric e^+e^- pairs from the decay of BSM particles can also mimic potential MiniBooNE signals.

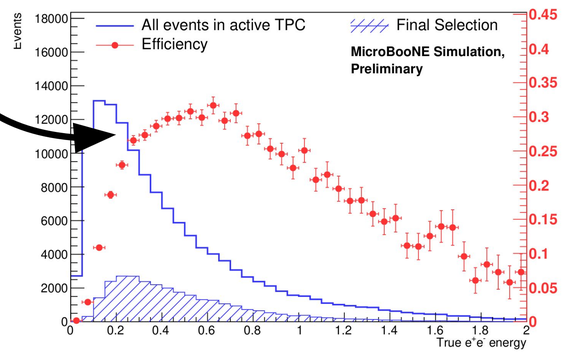
Simulation of dark sector e^+e^- pairs



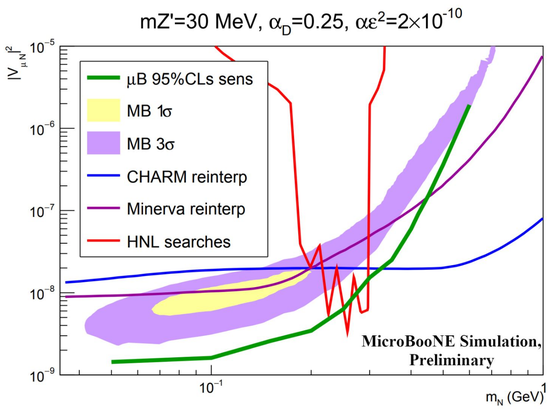
In one class of such models neutrinos act as a portal to the **dark sector**. Active neutrinos upscatter via a dark photon (Z') off an Argon nucleus to produce an unstable heavy sterile neutrino (N). This heavy sterile neutrino then decays back to a visible e^+e^- pair which can be detected.

MicroBooNE Public Note 1124

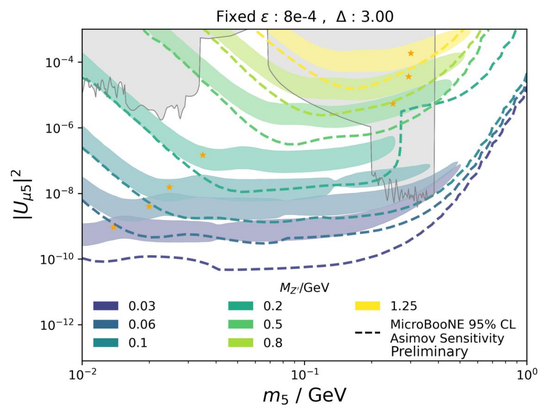
Targeted boosted decision trees can select these dark sector e^+e^- events at high efficiencies of 30 to 40%, depending on model parameter space.



MicroBooNE has two ongoing dark sector e^+e^- searches using both the Wire-Cell[2] and Pandora[3] reconstruction frameworks.



95% CLs sensitivity to a **targeted** 3+1 light Z' model, with $m_{Z'}$ = 30 MeV. Model and MiniBooNE allowed region taken from E. Bertuzzo et al[5].



95% CL Sensitivity to a **broad class** of heavy and light Z' model, highlighting seven masses of Z' ranging from 30 MeV to 1.25 GeV. Model and MiniBooNE allowed regions taken from [6] and using the DarkNews BSM generator[7].

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References

[1] MicroBooNE, Phys. Rev. D 105, 112004 (2022)
[2] MicroBooNE. JINST, vol. 17, no. 01, p. P01037, 2022
[3] R. Acciarri et al. EPJC, vol. 78, no. 1, p. 82, (2018)
[4] MicroBooNE, Phys. Rev. Lett. 128, 111801 (2022)
[5] E. Bertuzzo et al, Phys. Rev. Lett. 121, 241801 (2018)
[6] A. Abdullahi et al, arXiv:2308.02543 [hep-ph]
[7] A. Abdullahi et al, Comp. Phys 297, p. 109075, 2024