Search for a Single-Photon Anomalous Excess in MicroBooNE

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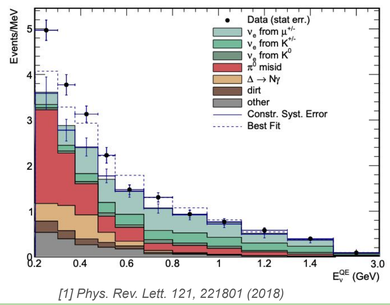
representing the MicroBooNE collaboration

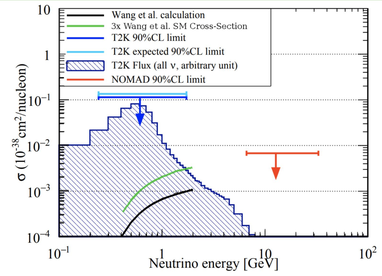
1. The "Low Energy Excess (LEE)"



- An **excess in low energy region** in electron-like events is observed by MiniBooNE [1]
- MiniBooNE is a **Cherenkov detector** situated downstream the Fermilab Booster Neutrino Beam (BNB).
- One of the possible interpretations is the excess is due to extra **mis-identified photons**

[1] Phys. Rev. Lett. 121, 221801 (2018)

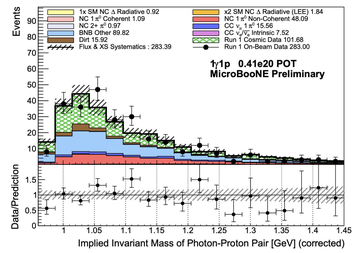
2. NC Δ Radiative Interpretation



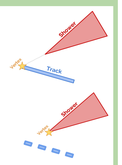
- Explicitly assume excess photon is from neutral current (NC) Δ radiative decay ($\Delta \rightarrow \gamma$ + N)
- **~3x of the Standard Model (SM) predicted** NC Δ radiative decay events would be needed to explain the MiniBooNE LEE [2][3]
- T2K's 90% CL limit on NC single photon (NC1γ) cross section is **O(100) the SM prediction** [4]

[4] J. Phys. G: Nucl. Part. Phys. 46 (2019) 08LT01

3. Single Photon Analysis [5]



- MicroBooNE's search targets two topologies
  - one (1) shower and one (1) track - 1γ1p
  - one (1) shower and zero (0) track - 1γ0p

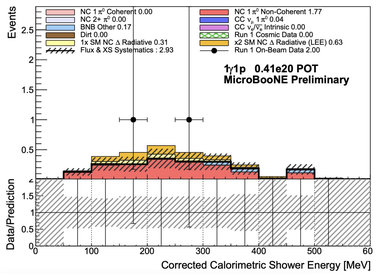


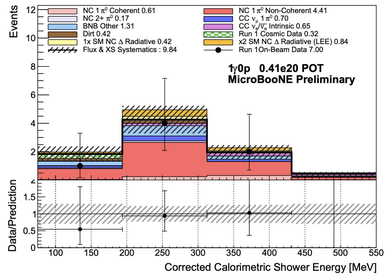
Analysis overview

- Topological cut
- Pre-selection cut to get rid of obvious background and events with poorly reconstructed objects
- A few boosted decision trees (BDTs) targeting different types of backgrounds

[5] MICROBOONE-NOTE-1087-PUB

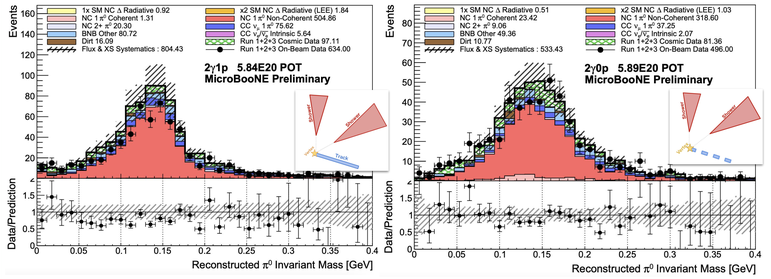
4. Final Distributions





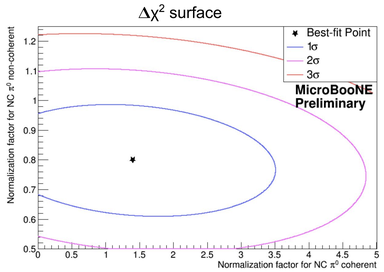
- **Overall good agreement** between data and MC central value (CV) for both selections
- Due to blind analysis policy, the final distributions here are from only 5% of the full MicroBooNE Run1-5 data set, but ~15x more statistics are expected once Run1-3 data is unblinded
- Note that **NC π^0 is the dominant background** in both selections

5. NC π^0 Measurement



- High-statistics measurement, high purity of NC π^0 (~60%) in both selections
- With flux and cross section uncertainty, **data and MC CV agree reasonably well**
- **~20% and ~7% data deficit** observed in 2γ1p and 2γ0p respectively

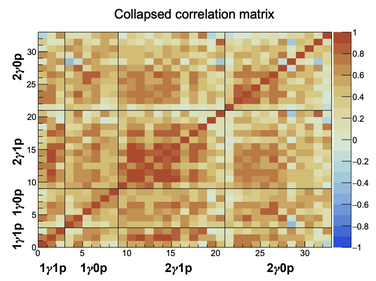
6. In-situ NC π^0 Correction?



- Fit to 2γ1p and 2γ0p cos(θ_{π^0}) distribution simultaneously
- Extract normalization factors for NC π^0 coherent and non-coherent events (N_{coh}, $N_{non\text{-}coh}$)
- Best fit is found at (N_{coh} = 1.4, $N_{non\text{-}coh}$ = 0.8)

- While MC CV (N_{coh} = 1, $N_{non\text{-}coh}$ = 1) sits outside the 1σ region of the data-derived uncertainty, **data is consistent with MC CV given large GENIE uncertainty**
- Instead of correcting GENIE prediction of NC π^0, simultaneous fit of both 1γ and 2γ selections is performed to constrain background in 1γ selection

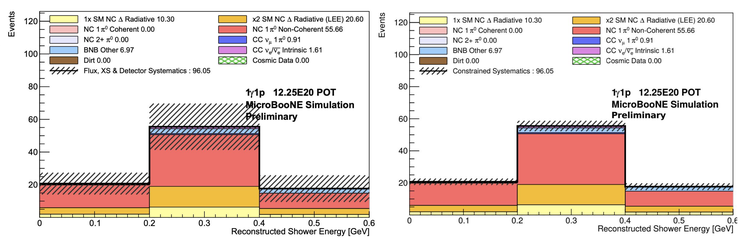
7. Simultaneous Final Fit



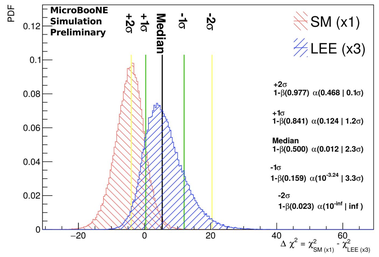
A simultaneous fit to 1γ and 2γ final selections side-by-side to **extract the scaling of branching ratio (BR) of NC Δ radiative decay (x_Δ)** is performed, which makes use of the strong correlations between 1γ and 2γ selections to

- Indirectly constrain the selected 1γ rate predictions
- Effectively reduce the systematic uncertainty in 1γ selection

- Reduction of full systematic uncertainty on the 1γ MC prediction for MicroBooNE Run1-5 statistics



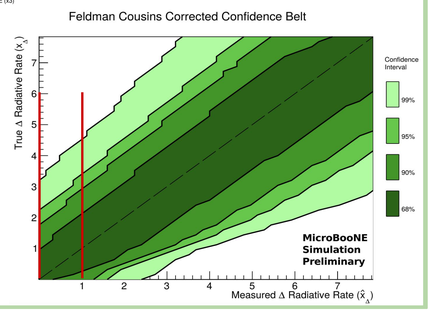
8. Projected Sensitivity



The median significance of rejecting the SM hypothesis (x_Δ = 1) in favor of LEE hypothesis (x_Δ = 3), assuming LEE is true is 2.3σ (for full MicroBooNE Run1-5 statistics)

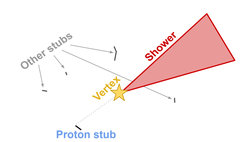
With full MicroBooNE Run1-5 data set

- If no NC Δ radiative events are observed, the LEE hypothesis could be ruled out at >95% confidence level (C.L.)
- If SM NC Δ radiative prediction is observed, the LEE hypothesis could be ruled out at >90% C.L.



9. Summary & Outlook

- ❖ Yield the world's most sensitive measurement of neutrino-induced NC Δ radiative decay with neutrino beam energy below 1 GeV
- ❖ Show high potential of this analysis in probing the hypothesis of NC Δ radiative photon excess for MiniBooNE LEE interpretation
- ❖ Developed with 5% of the full MicroBooNE data, the 1γ part of the analysis will soon be allowed access to **MicroBooNE Run1-3 data (x15 more statistics**)
- ❖ Yield the world's highest-statistics NC π^0 measurement
  - ➢ Data deficit in 2γ1p has motivated a cross section extraction for the NC π^0 events
- ❖ Watch out for our new result soon!



- Same framework is planned to be used for coherent single photon search
- Of events satisfying 1γ0p topology, non-negligible amount have proton tracks in truth that are not reconstructed due to low energy
- Current efforts focusing on vetoing events with low-energy, unreconstructed proton stubs

References

[1] *Phys. Rev. Lett. 121, 221801 (2018)*
[2] *MICROBOONE-NOTE-1043-PUB*
[3] *Phys. Rev. D 103, 052002 (2021)*
[4] *J. Phys. G: Nucl. Part. Phys. 46 (2019) 08LT01*
[5] *MICROBOONE-NOTE-1087-PUB*

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