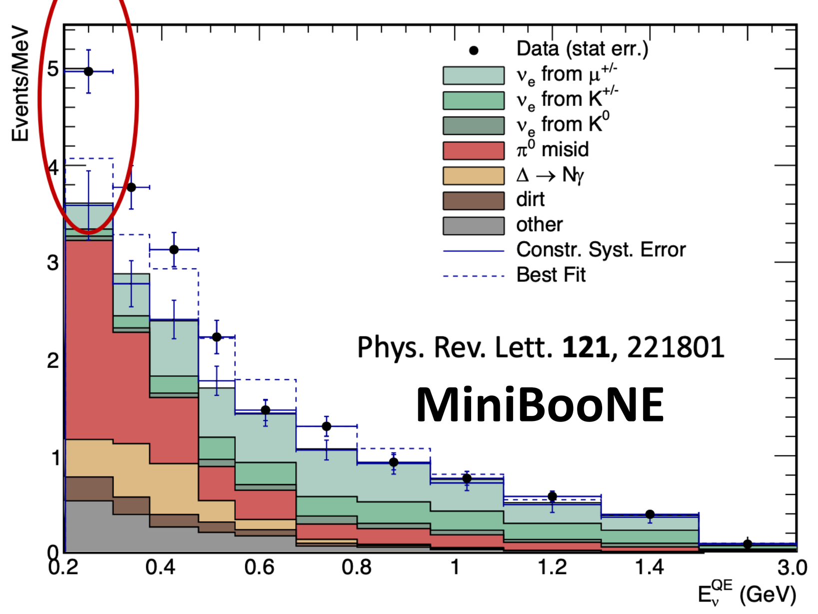
Systematic Studies in the Single Photon Low Energy Excess Search at MicroBooNE

Gray Yarbrough on behalf of the MicroBooNE Collaboration

1. Motivation

- MiniBooNE Cherenkov detector along the booster neutrino beam
- Observed low energy excess (LEE) of neutrinos.[1]
- Use data from MicroBooNE, a liquid argon time projection chamber (LArTPC), to test an explanation as neutral current (NC) Δ radiative decay
- 3x Standard Model prediction for $\Delta \rightarrow N\gamma$ would explain the excess



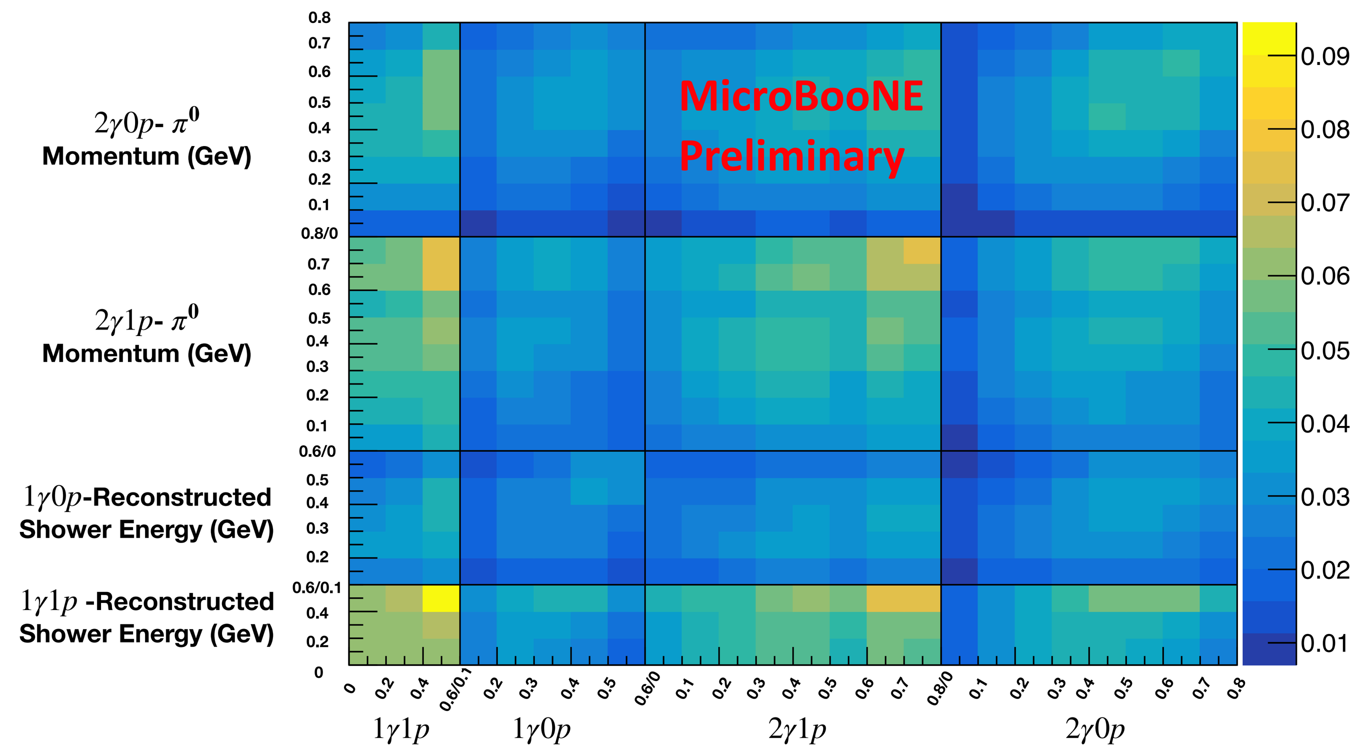
2. Eventweight Method and Samples

- The EventWeight (event reweighting) method is used to evaluate flux and cross-section systematic uncertainties.
- Limitation in that events cannot be weighted into existence, but sufficiently large samples should negate this
- This method is most optimal given limited allocated computing resources.
- We vary 56 parameters of GENIE uncertainty and 12 parameters of our source of neutrino flux: the Booster Neutrino Beam.
- The final stage samples for our $2\gamma1p$, $2\gamma0p$, $1\gamma1p$, and $1\gamma0p$ channels are examined and split into sub channels for different signals.
- GENIE is used for monte-carlo generation of events and for cross-section uncertainties. We utilize GENIE v3 with a custom MicroBooNE central value tune.[2]
- A combined GENIE variation is used including a set of approved GENIE uncertainties including quasi-elastic, meson exchange current, resonant, non-resonant, hadronization and final state interaction processes.
- Delta resonance signal uncertainties were excluded as they correspond to our final measurement.
- Individual GENIE parameters are also studied but are not included in fits or final covariance matrices.

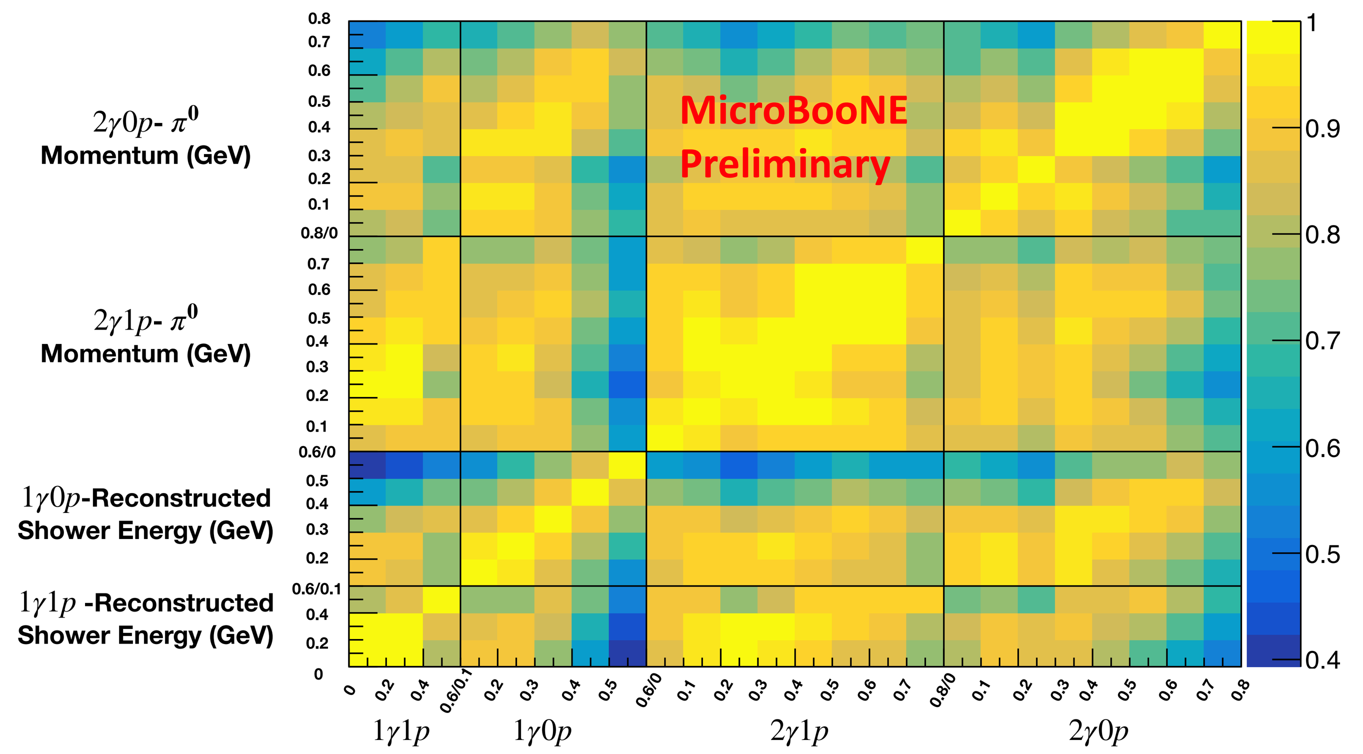
3. Fitting Module

- SBNFit (short baseline neutrino fit) is a module built for the SBN project enabling for fitting which utilizes fractional covariance matrices
- Fractional covariance matrices contain the statistical and systematic uncertainties and systematic correlations among different bins and samples
- Correlation matrices are the covariance of a bin divided by the standard deviation of the two components, and are useful for visualization

Collapsed (combined subsamples) Fractional Covariance Matrix



Collapsed (combined subchannels) Correlation Matrix



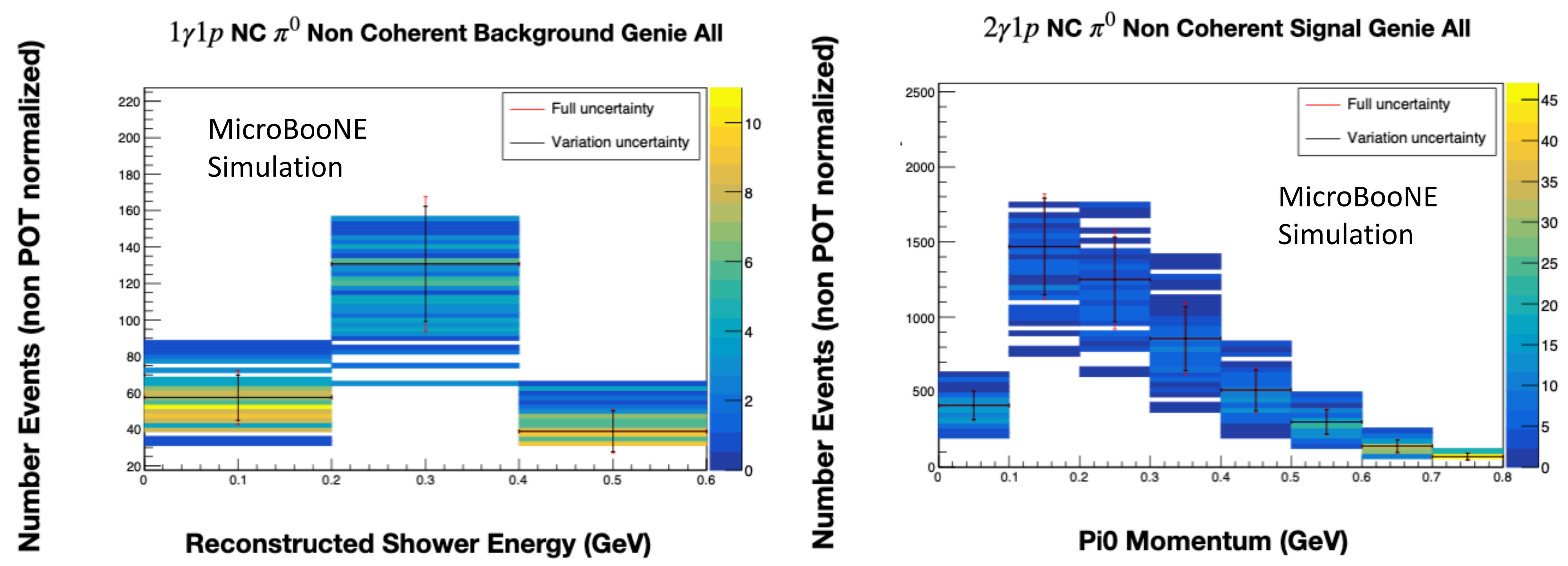
4. Constraint

- We evaluate the level of constraint on the uncertainty of the final $1\gamma1p$ signal by considering the NC (neutral current) π^0 sideband ($2\gamma1p$) measurement using the following the method.[3]
- Form a matrix of $1\gamma1p$ backgrounds and $2\gamma1p$ selection (M_{ij}).
- For the $2\gamma1p$ portion assume $\sigma_i^{\text{data}} = \sqrt{N_i^{\text{data}}}$, and $N_i^{\text{data}} = N_i^{MC}$
- Calculate a new matrix $(M_{ij}^{-1})^{new} = M_{ij}^{-1} + 1/N_i^{MC}$ and re-invert for constrained uncertainty on the $1\gamma1p$ bins.

Variation Description	Unconstrained Uncertainty $1\gamma1p$	Constrained Uncertainty $1\gamma1p$	Unconstrained Uncertainty $1\gamma0p$	Constrained Uncertainty $1\gamma0p$
All genie variables combined	22.64%	7.21%	13.82%	4.48%
Fractional cross section for N charge exchange	9.58%	6.69%	1.58%	1.10%
Axial mass for NC resonance ν production	18.94%	5.45%	10.44%	3.01%
Variation of angle of π with respect to detector z axis	7.83%	4.91%	0.98%	0.62%
Vector mass for NC resonance ν production	8.06%	4.77%	4.41%	2.61%
Fractional cross section for N charge exchange	9.32%	4.36%	4.18%	1.96%
Skin Depth-electric currents penetrate conductor	4.93%	3.41%	4.01%	2.77%
π absorption probability	5.12%	3.26%	3.33%	2.13%
Primary Hadron SW Central Spline Variation for π^+	4.51%	3.23%	3.86%	2.76%
N absorption probability.	4.91%	3.21%	4.61%	3.02%

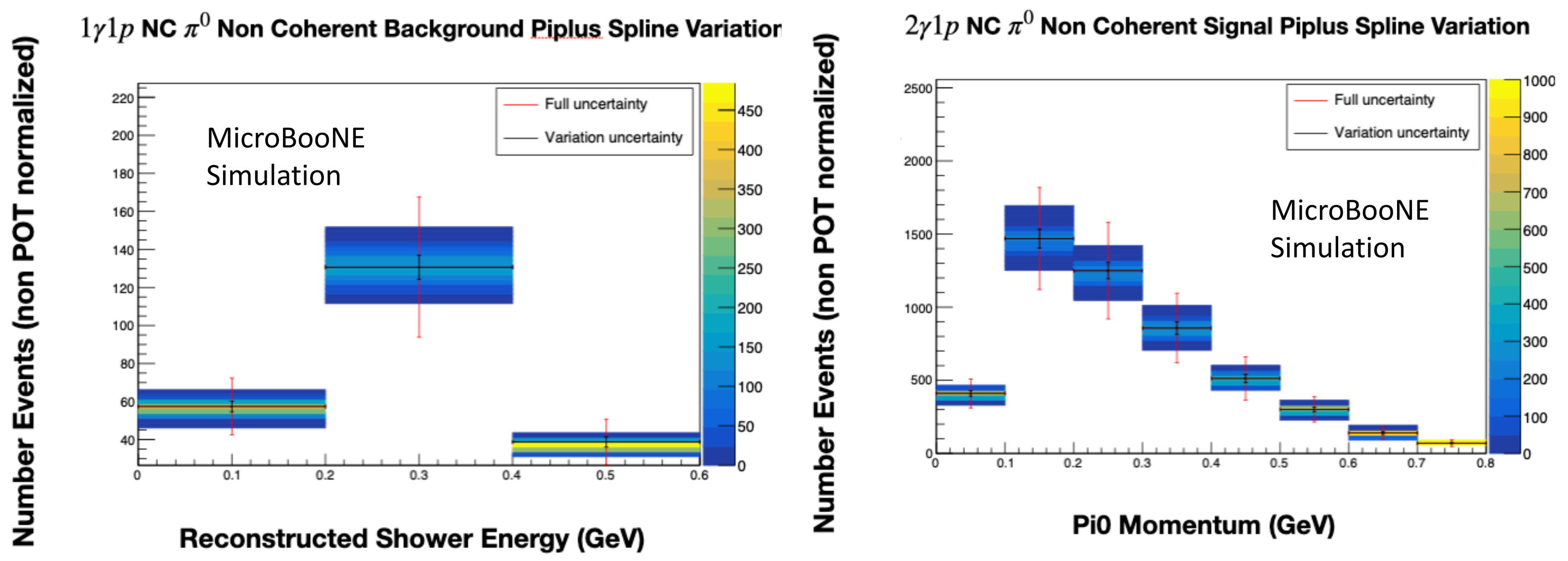
Table: Top 10 highest uncertainties after constraint in $1\gamma1p$

5. Results



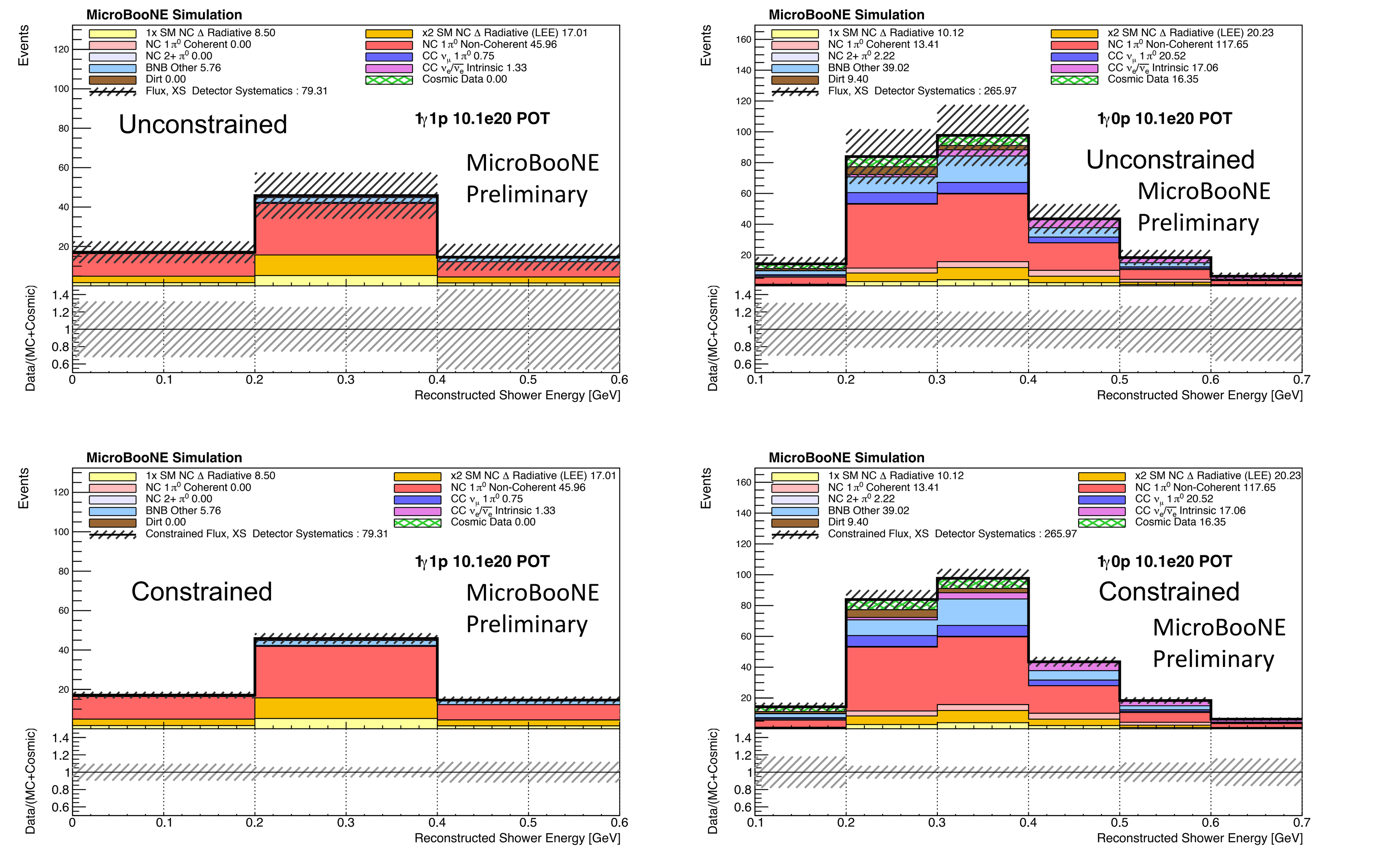
"GENIE All" (the combined GENIE variation) includes a number of highly correlated parameters for our backgrounds i.e. NC Resonance Axial Mass, so the constraint is powerful (3.11 reduction factor)

Figure: 2γ channel variation plots using the Eventweight Method for combined GENIE variations on NC π^0 non-coherent signal subchannels. (majority of all NC π^0). Y axis correlates to number of events but is not normalized to the POT of the detector. Coloration depicts the number of "multisims" that are in each bin of x and y.



Flux variations have smaller uncertainties but aren't specific to our signal so the constraint is only somewhat effective (1.40 reduction factor)

Figure: A variation plot illustrating the central Sanford Wang π^+flux uncertainty effect on the $NC\pi^0$ non-coherent signal in the final $2\gamma1p$ and $2\gamma0p$ selection. As the primary signal for neutrino production it has a comparably large uncertainty compared to other flux variations.



The per bin constraint on the $1\gamma1p$ and $1\gamma0p$ final stage samples showing a ~3 x reduction factor uncertainty for a promising evaluation of systematic reduction

- A complete flux and cross section systematic study has been performed for the single photon analysis.
- Estimated constraint is promising for uncertainties on our final measurement

References

1. Phys. Rev. Lett. 121, 221801 (2018),
2. C. Andreopoulos, "Genie physics & users manual v3 prelim." https://genie-524docdb.pp.rl.ac.uk/DocDB/0000/000002/006/man.pdf, 2019
3. M. Shaevitz, "Constraining the nue background using the observed numu events." MicroBooNE DocDB: 7635, 2017