The $\nu e/\nu \mu$ Ratio in the NuMI Beam

Alex Moor, on behalf on the MicroBooNE Collaboration

6/4/22

UNIVERSITY OF CAMBRIDGE

MicroBooNE

Part of the Short Baseline Neutrino Program

Liquid Argon Time Projection Chamber

https://microboone.fnal.gov/detector/

On the BNB with Off-Axis NuMI Componant

Built to further investigate previous interesting results

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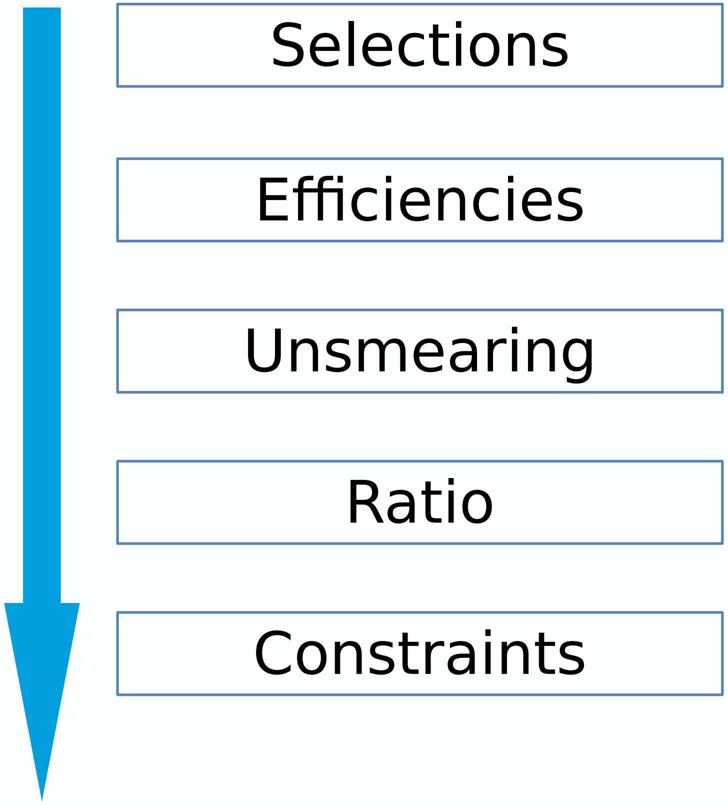
Motivation

- The **differences between νe and νμ** cross sections on argon are **key in neutrino oscillation analyses**
- The ratio of these is **poorly known experimentally,** especially in the low energy region
- A combination of MicroBooNE’s strong **ability for low energy work** and the relatively **high νe content** of the NuMI flux makes this a good place to study such a ratio

Foundations of this Study

- First goal is to **examine the νe/νμ ratio** in bins of energy, with potential to characterise the ratios of other kinematic variables
- An **exclusive and equivalent selection** for νes and νμs will be defined and examined
- Considering each energy bin, examine the **bin efficiency** and background, then use an **unsmearing matrix** to move from reco to true space
- This ratio can then be used to **constrain the corresponding ratio in the BNB**



Ratio Equation

$$\nu_e = N_{\nu_e} \text{ CC with at least 1 proton} > 40 \text{ MeV}$$
$$\nu_\mu = N_{\nu_\mu} \text{ CC with at least 1 proton} > 40 \text{ MeV}$$

$$R^j_{\frac{\nu_e}{\nu_\mu}} = \frac{\epsilon^j_\mu U^{ij}_{\nu_e}\left(N^{SelData}_{\nu_{ei}} - B^{SelMC}_{\nu_{ei}}\right)}{\epsilon^j_e U^{ij}_{\nu_\mu}\left(N^{SelData}_{\nu_{\mu i}} - B^{SelMC}_{\nu_{\mu i}}\right)}$$

- j represents the **true bins**; i the **reconstructed bins**
- E are the **efficiencies** in each bin
- U are the **unsmearing matricies**
- N is the **number of data events** selected
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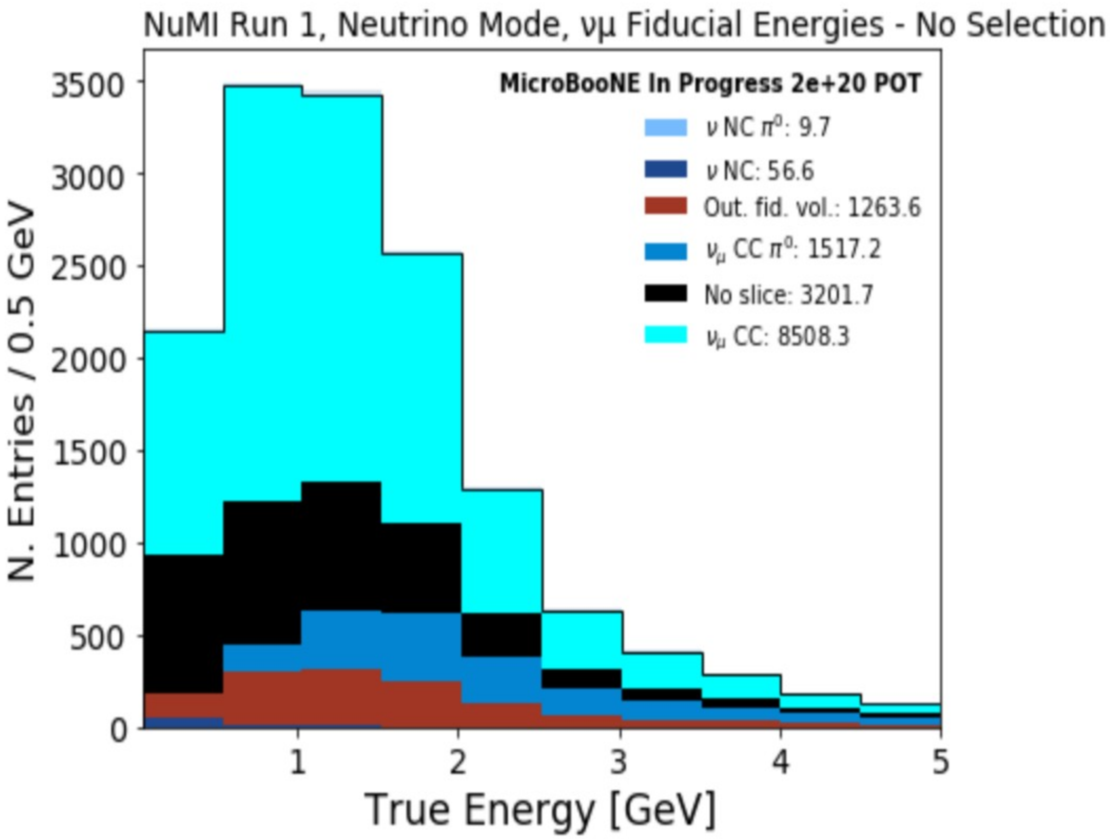
νμ: Selection Plan



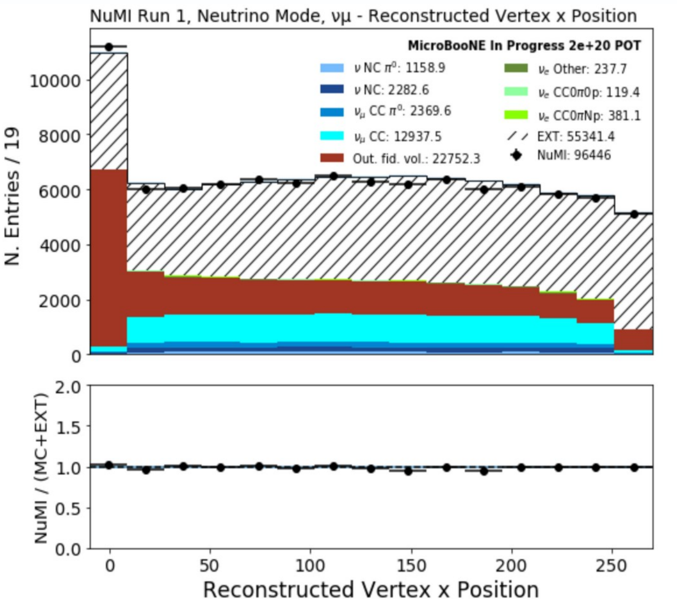
As a first pass of the analysis, we use a very simple **νμ exclusive selection**.

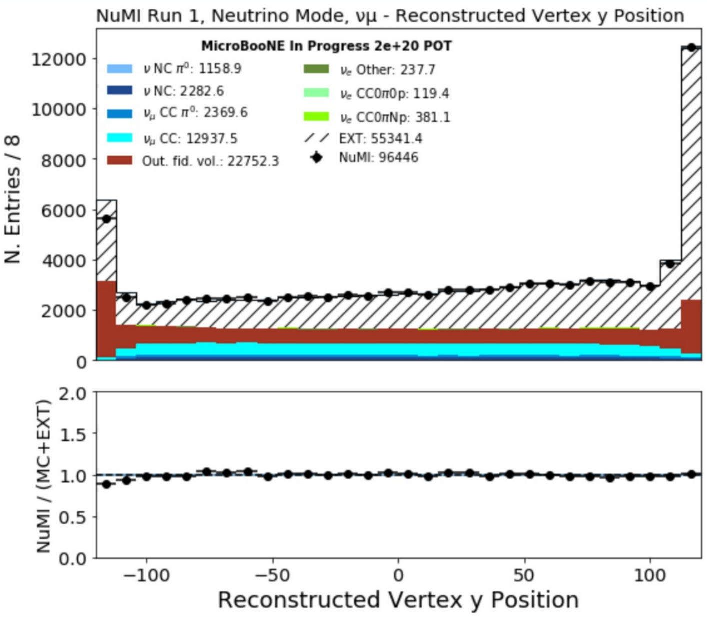
We require that:

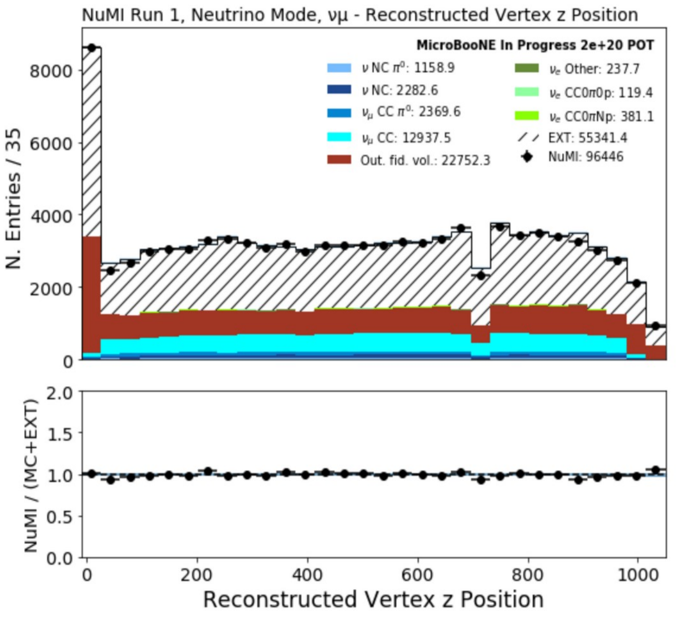
--> a pandora neutrino **slice is present**
--> the event produces **enough light in the detector** to be consistent with a neutrino
--> the reconstructed neutrino vertex is **within the fiducial volume**
--> **at least one muon** is present
--> **at least one proton** is present

Data Validation at Early Selection Stage

- Consider the position of the reconstructed neutrino vertex
- Add cut to take off parts that are not wanted

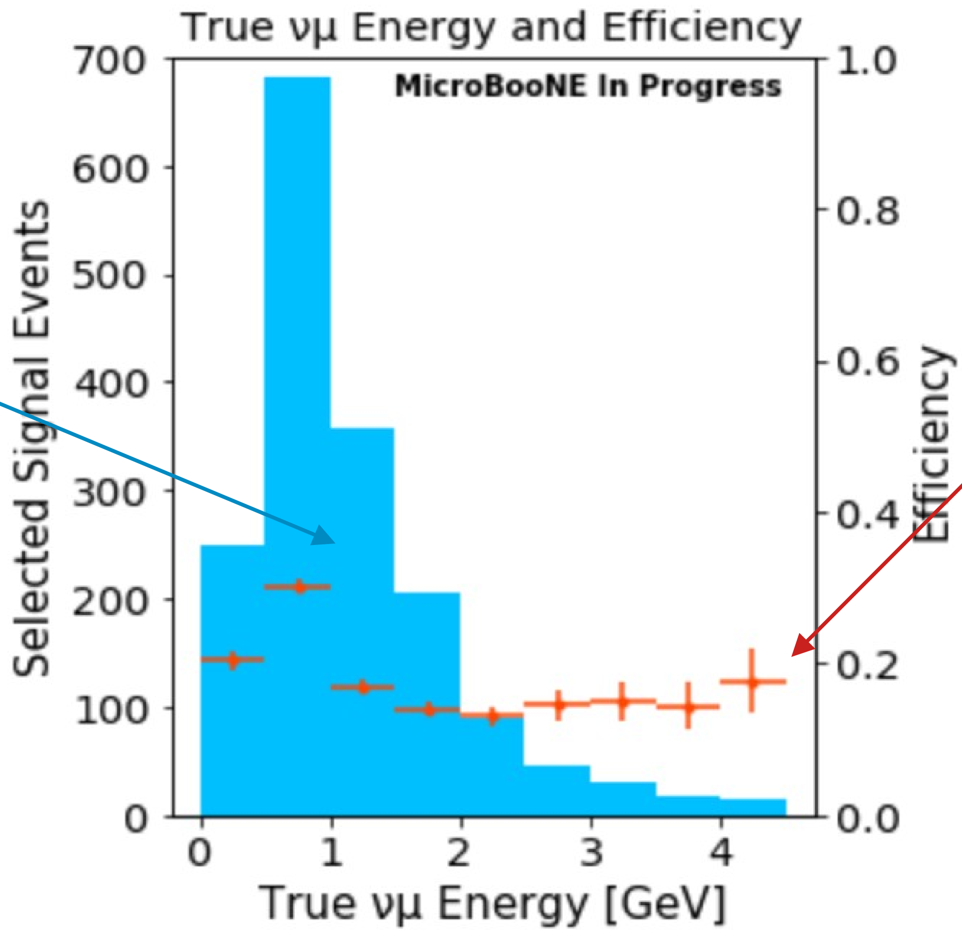






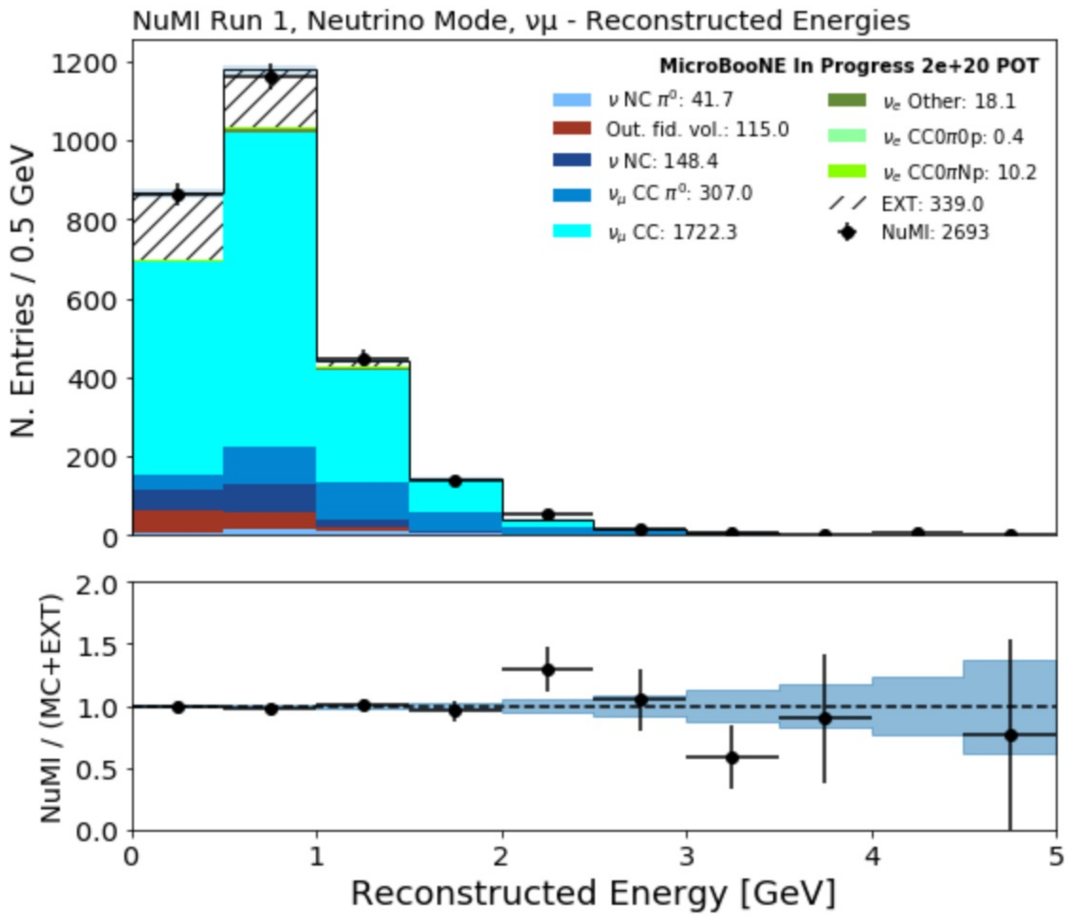
νμ: Bin Efficiencies

Selected events binned directly by their true energies



# of selected events (binned by true energy) over generated events

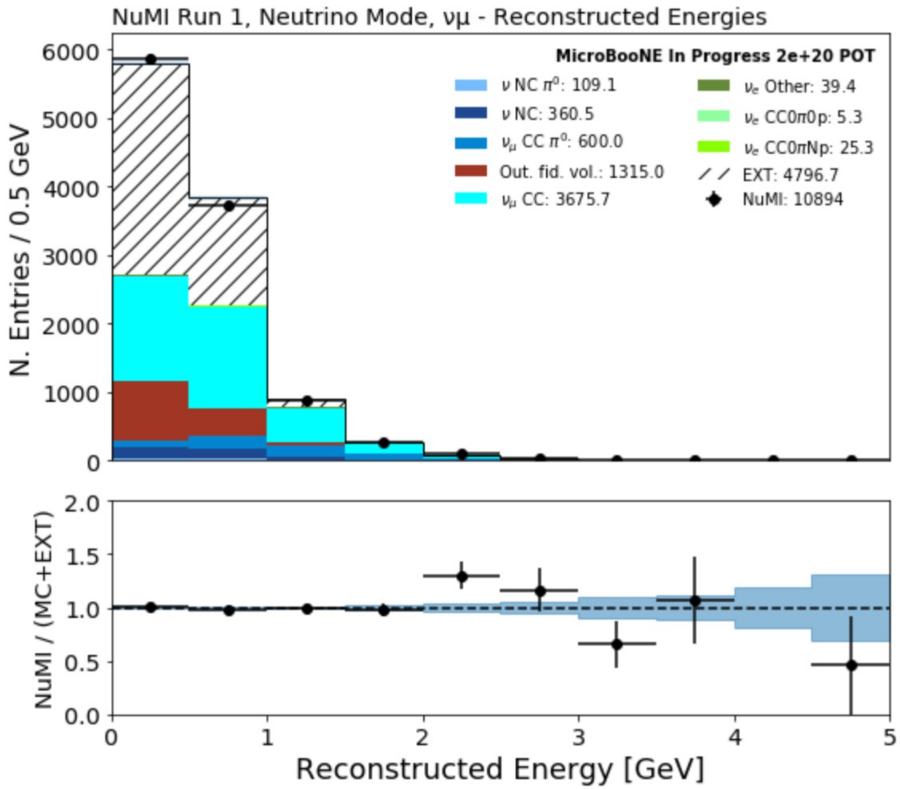
Reconstructed ν Energy



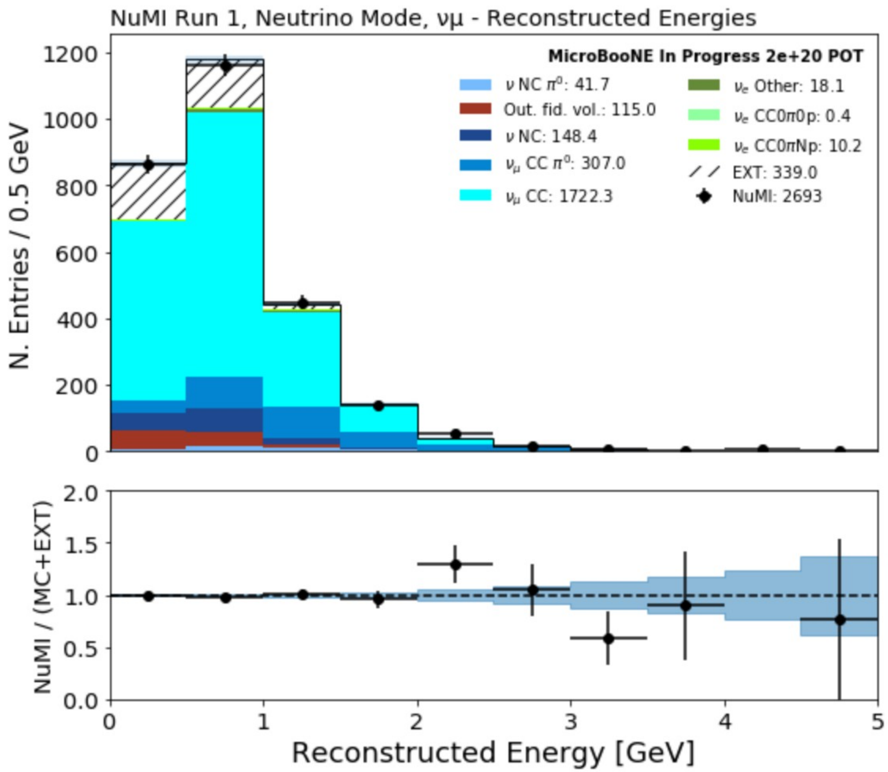
This is after the five selection steps given on slide 16

We now have everything we need for the ratio from νμ!

Why an exclusive selection?

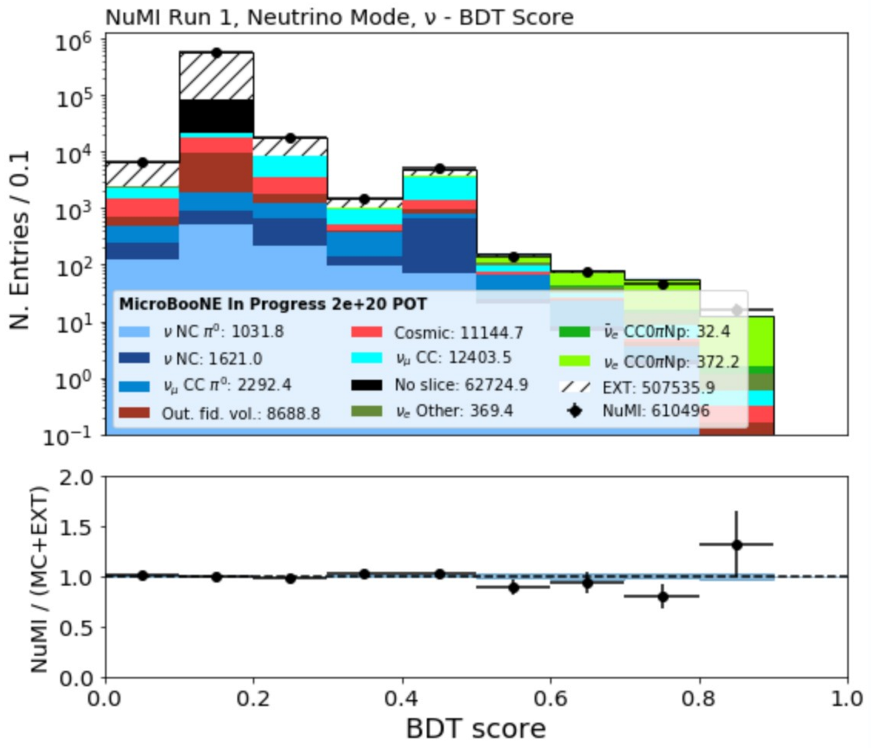


PRE PROTON SELECTION

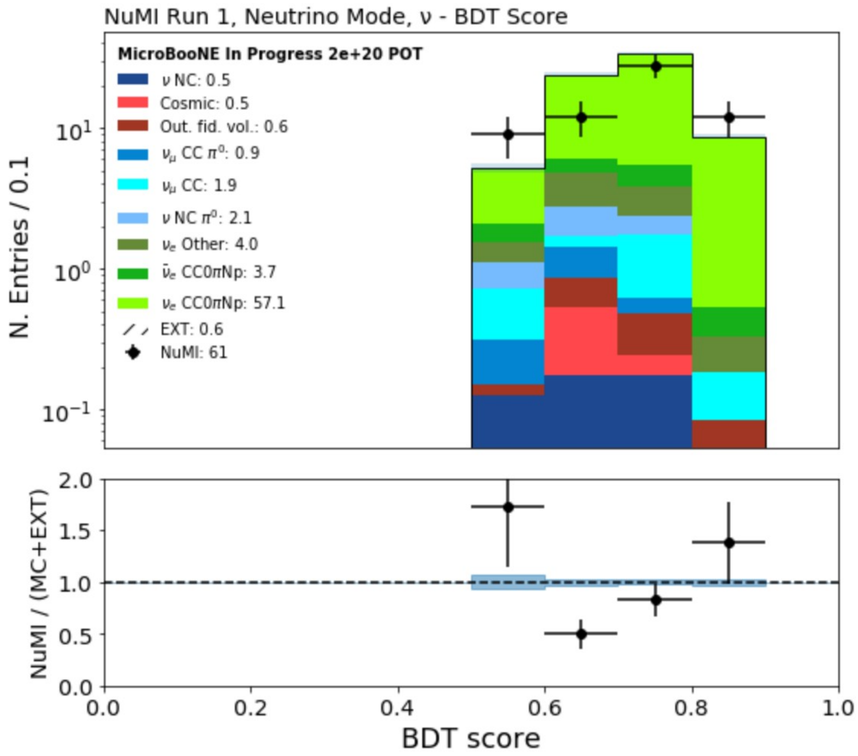


POST PROTON SELECTION

νe: BDT Cuts



No Cut



Loose Cuts + BDT > 0.575

BDT and cuts from Katrina Miller, U. Of Chicago

νe: Bin Efficiencies

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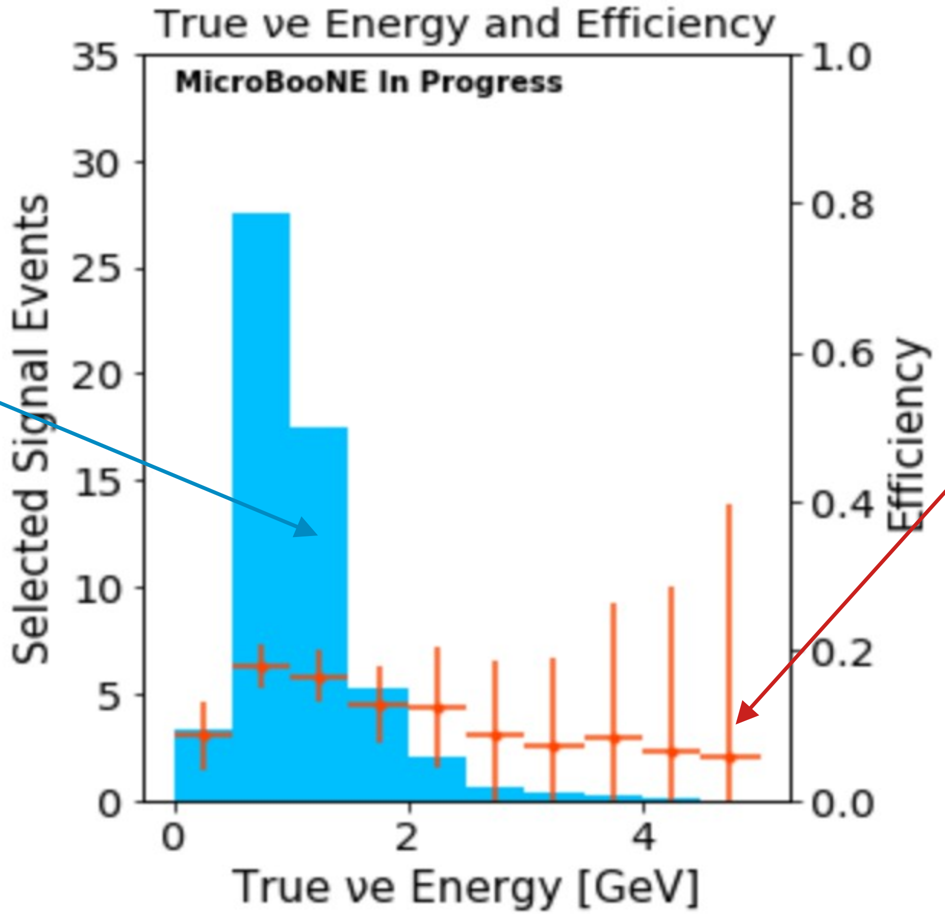

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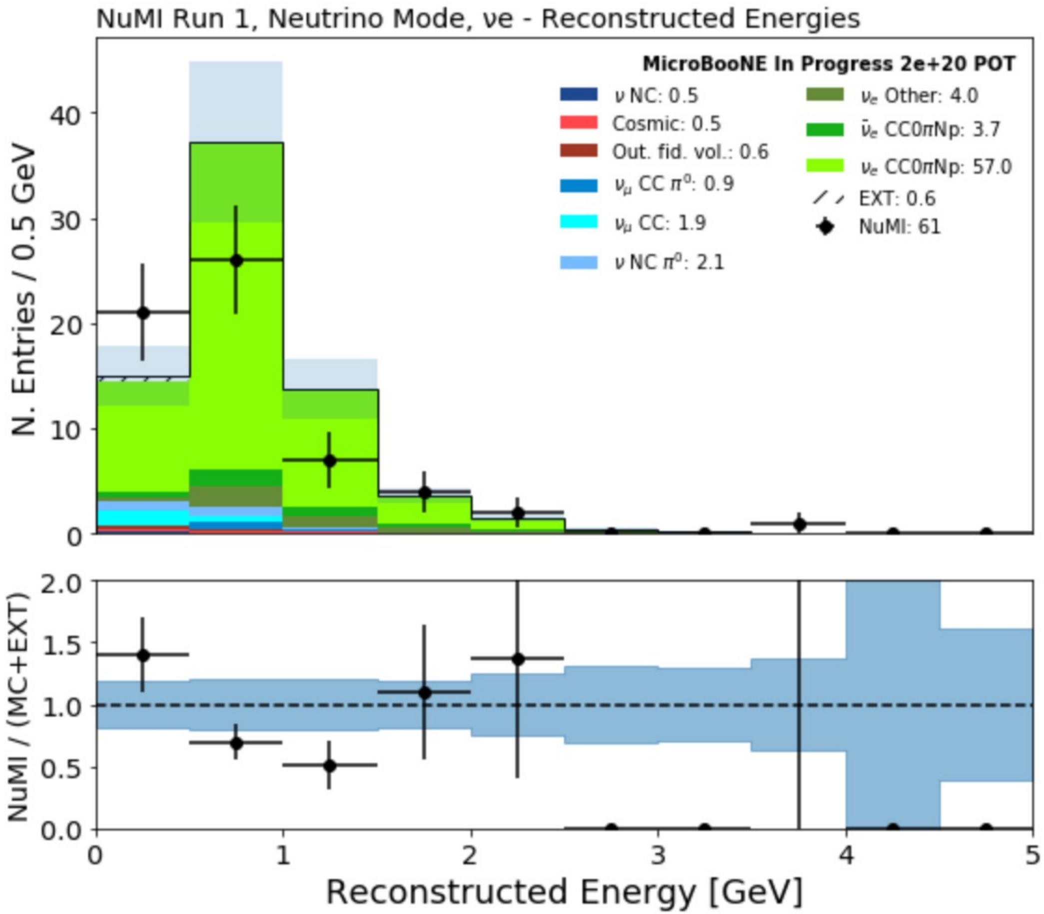
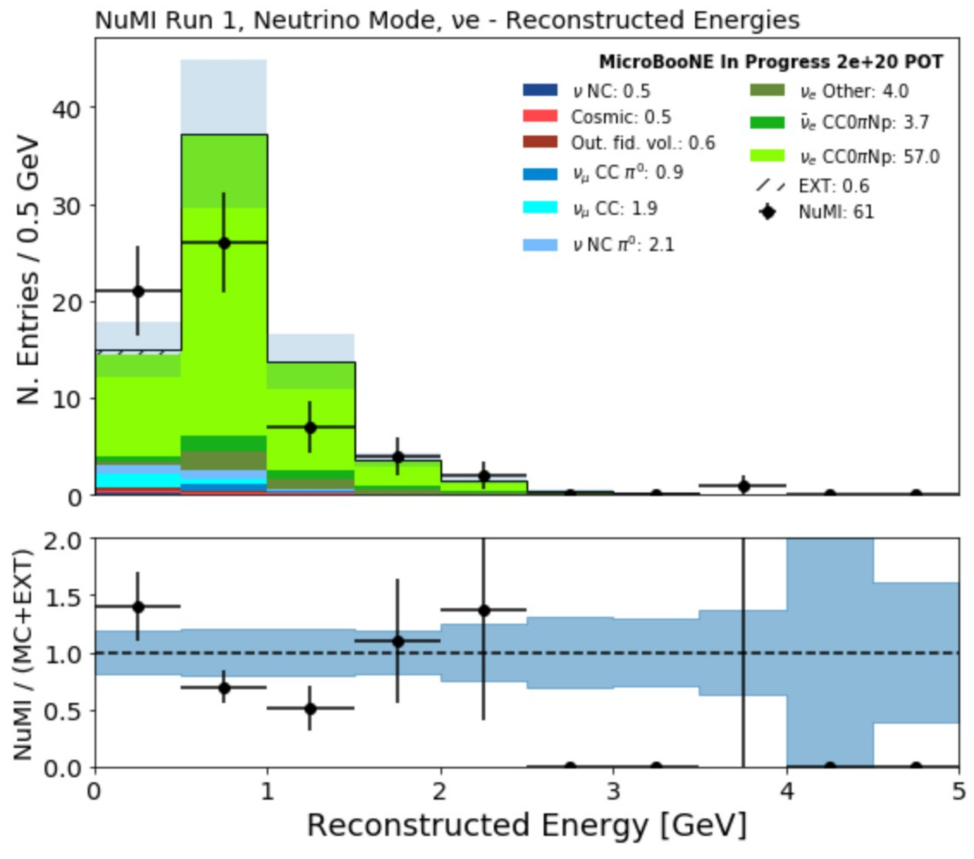
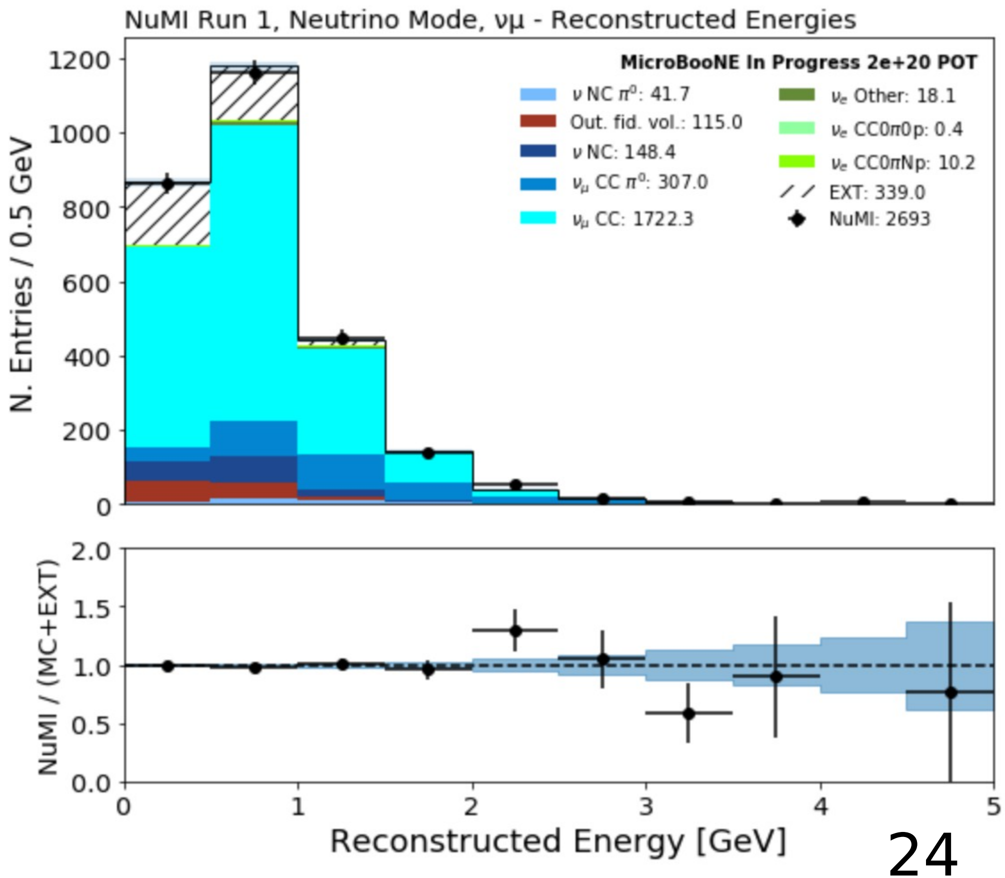
Reconstructed ν Energy



So we now have everything we need from the νe selection!

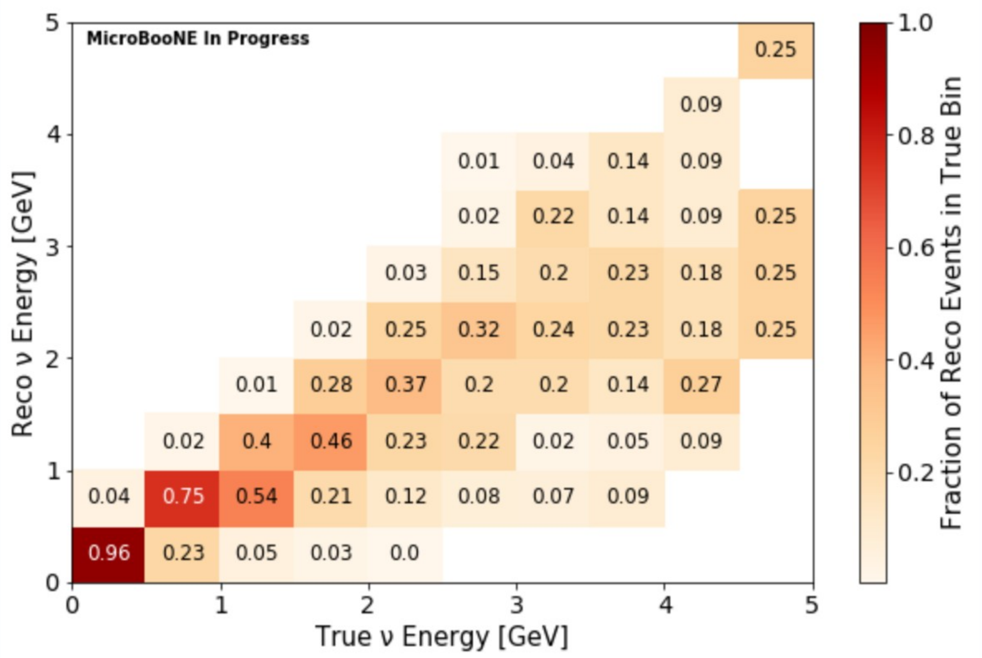
νe/νμ Comparison



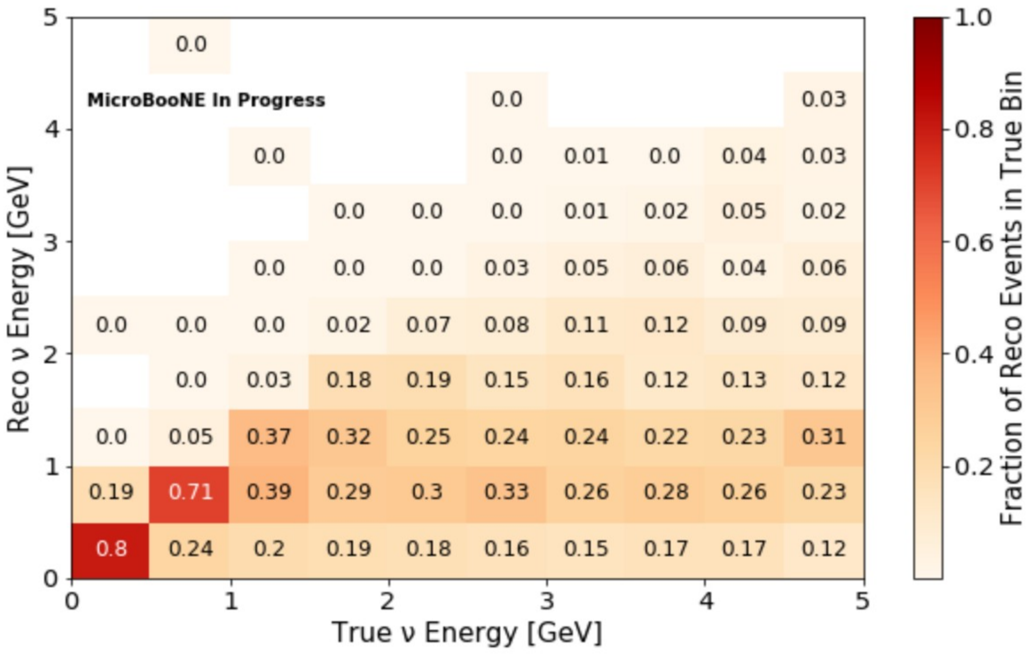


Unsmearing Matricies

- These allow us to move from reco to truth space

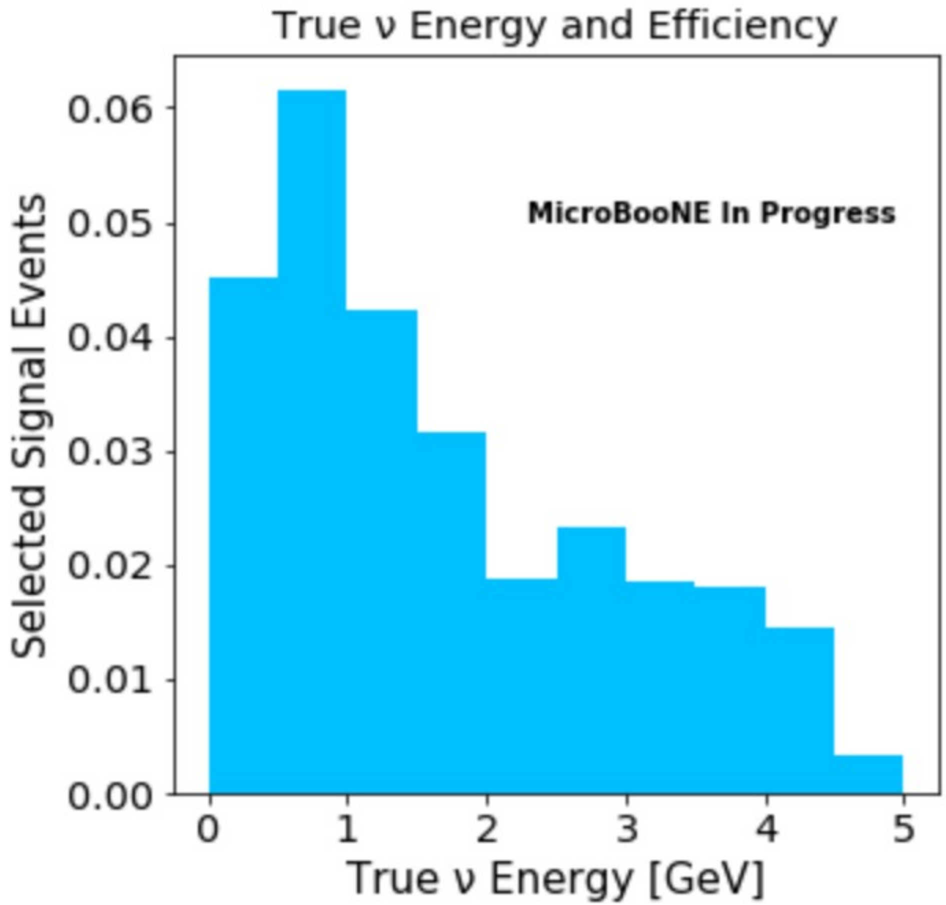


νe



νμ

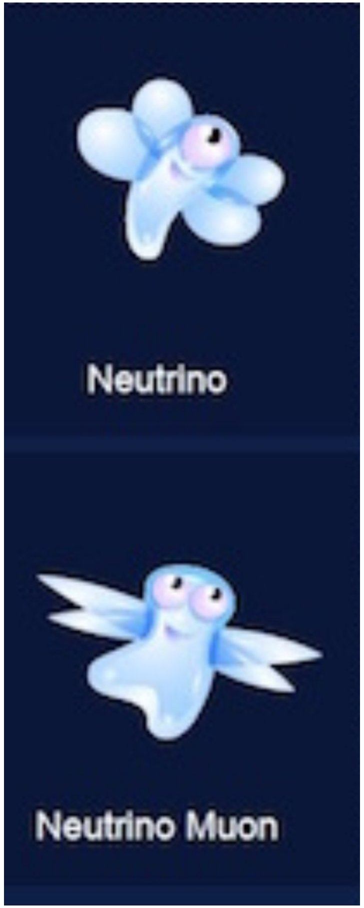
Resulting Ratio



- **Ratio** when all the νe/νμ bin rations are plotted in bins of true energy
- **Overlaps** from each selection have been considered – it is **0 or negligible** in all cases
- **Uncertainties** currently being considered

Conclusions

- Both a **νe** and a **νμ selection** have been defined
- **Unsmearing matricies** and **selection efficiences** were used to move the selection from reco to truth space and **form the νe/νμ ratio**
- **Uncertainties** on the νe/νμ ratio are **being considered**
- This ratio will then be used to **constrain the corresponding ratio in the BNB**



https://faculty.wcas.northwestern.edu/enectali-figueroa-feliciano/research/neutrinos.html