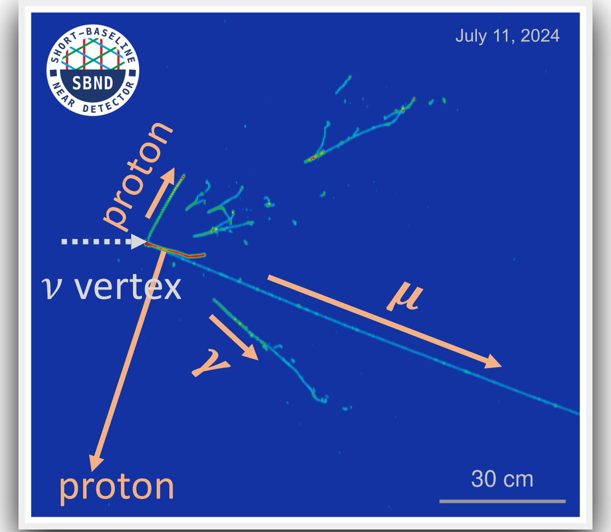
Near Detector Event Selection for SBN Oscillation analysis



Shweta Yadav,
on behalf of the SBND collaboration

NuFact 2024

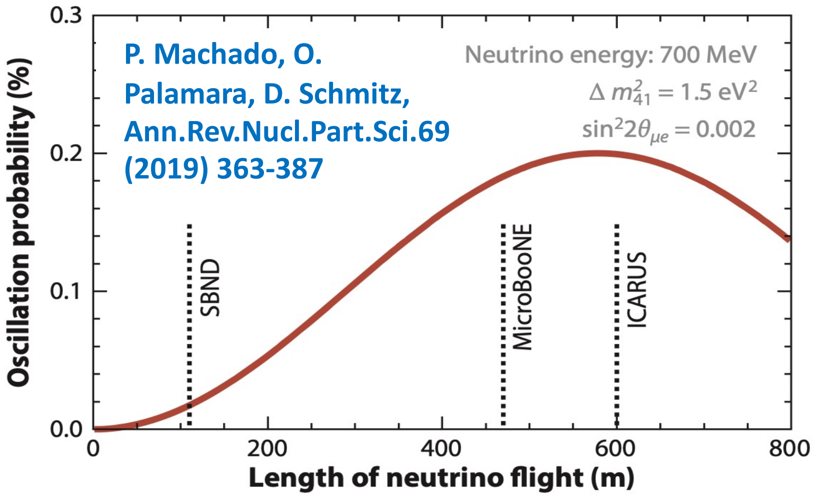
The 25th International Workshop on Neutrinos for Accelerators
Argonne National Laboratory
September 16-21, 2024

Goal of SBN Program

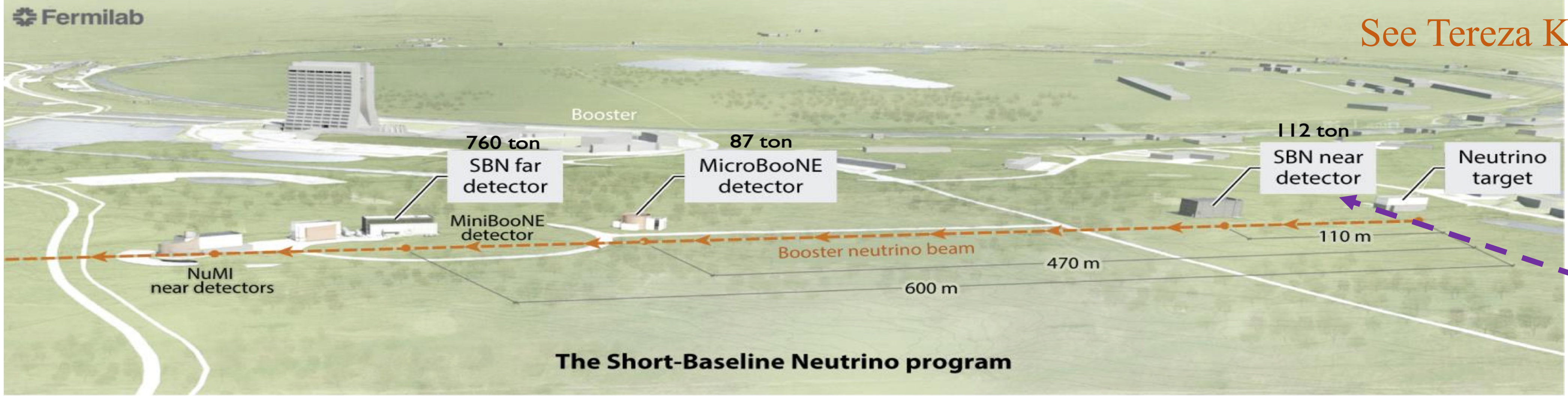
It is essential to resolve the current observed anomalies, which are hinting towards the existence of "sterile" neutrinos

- SBN aims to measure both appearance and disappearance with excellent neutrino identification and effective background rejection

- SBND data will constrain predictions and uncertainties for the FD (ICARUS)



See Tereza Kroupova's talk



Role of SBND is to constrain uncertainties

ND constraint strategy

To fully exploit ND statistics, we use all inclusive events splitted into fully exclusive topologies to enhance different neutrino interaction modes.

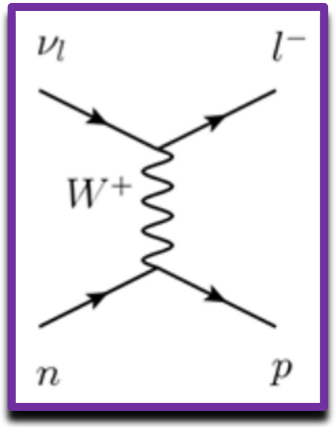
This way reduces model dependency in the FD prediction –

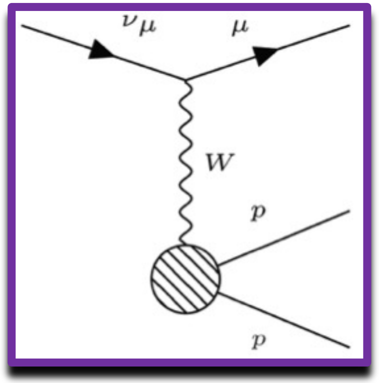
- Detail on the next slide

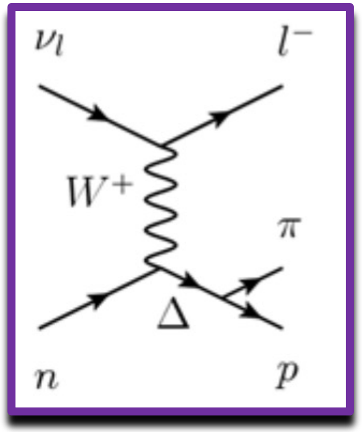
ND event selection for oscillation :

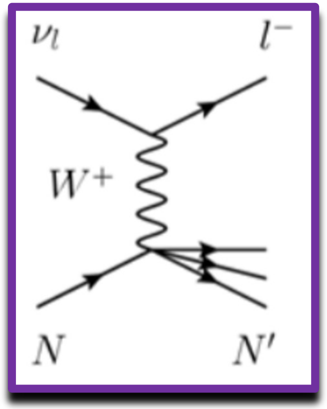
- **ν_μCC 0p 0π**
- **ν_μCC 1p 0π**
- **ν_μCC Np 0π (N>1)**
- **ν_μCC 1$\pi^\pm$ (any number of nucleons)**
- **ν_μCC Others**

ν_μCC inclusive









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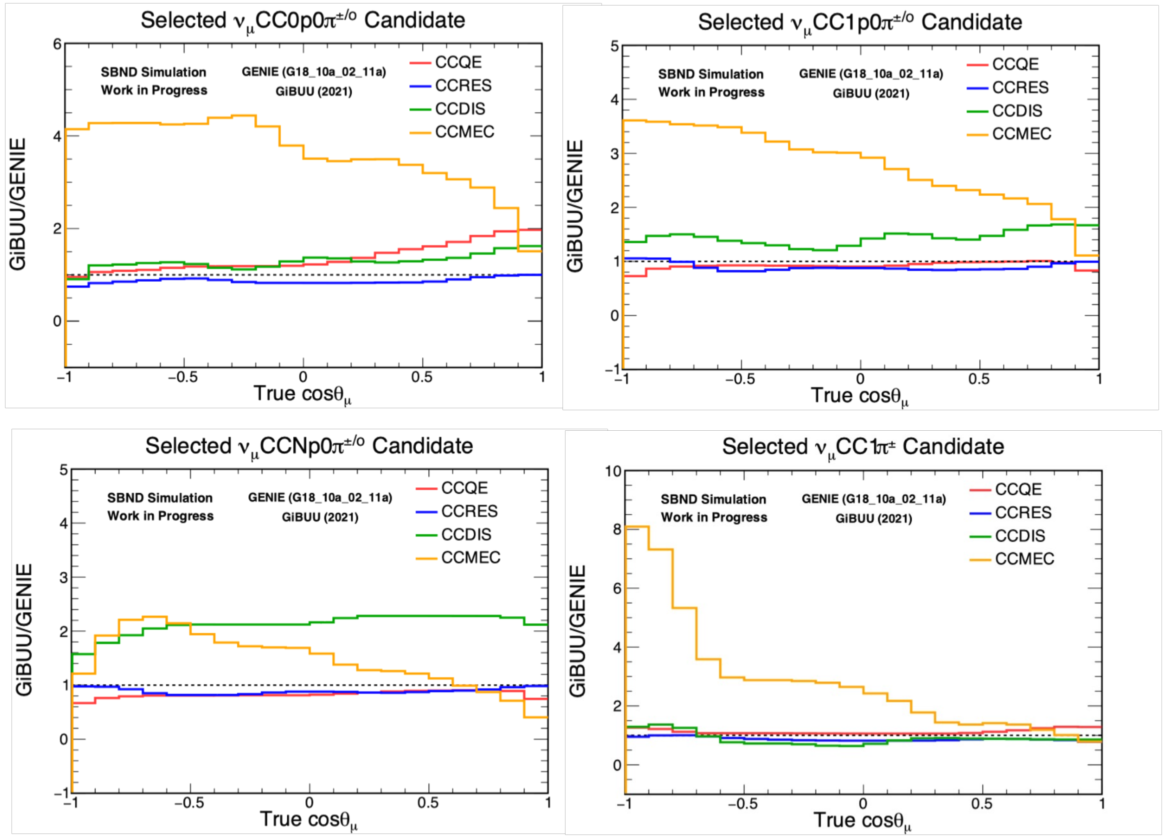
ν_μCC inclusive

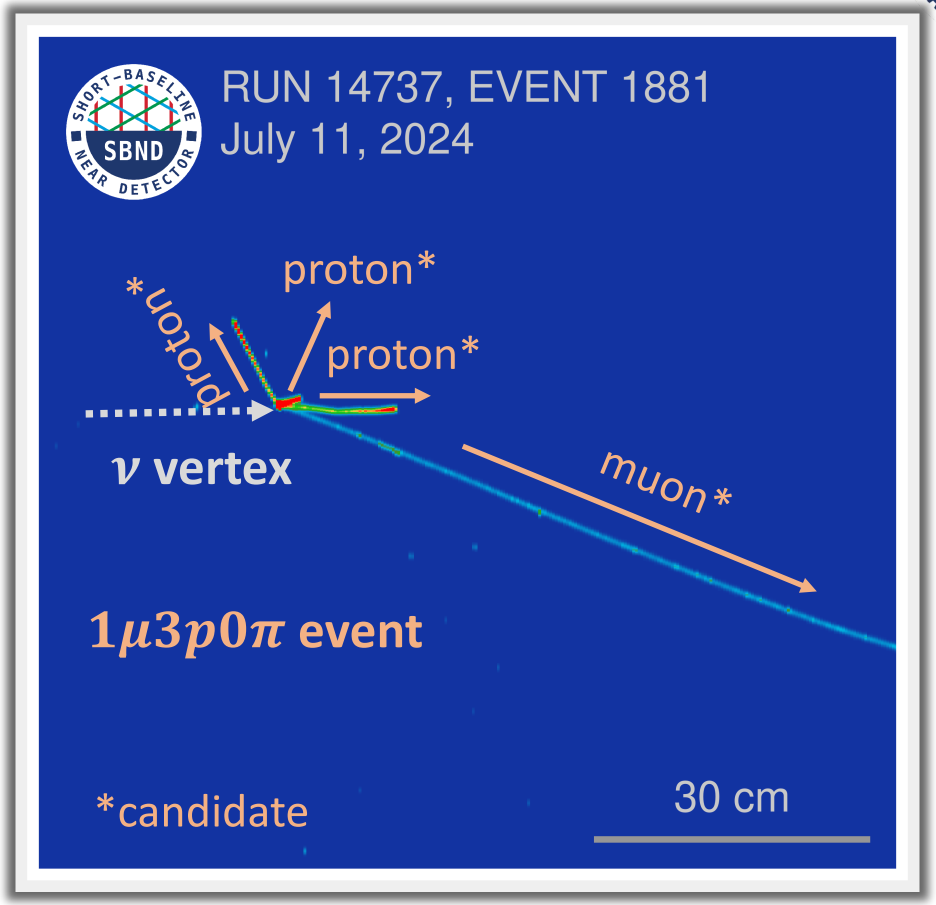


Showing differences between generators in a very simple variable cosθ_μ at truth level

Event selection for ND constraint

Particle Identification :

- Signal definition : Protons and Pions with $E_{kE,p} > 22$ MeV and $E_{kE,\pi} > 10$ MeV
- Reconstructed tracks using Pandora with $L > 5$cm and starting within 4 cm from vertex
- Particles are identified based on reconstructed dE/dx



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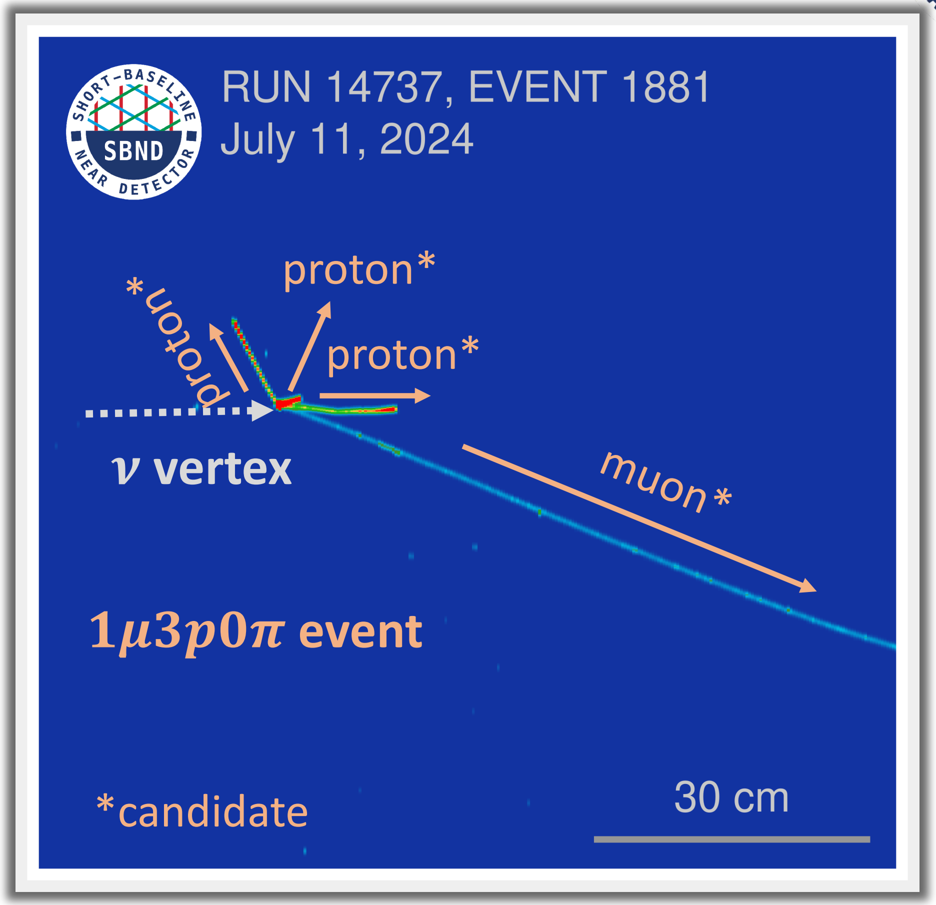
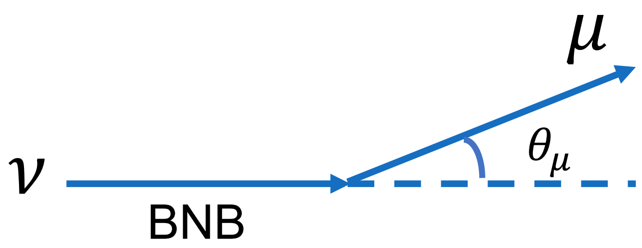
Obtained purities :

- >85% for muons
- >95% for protons
- >60% for pions

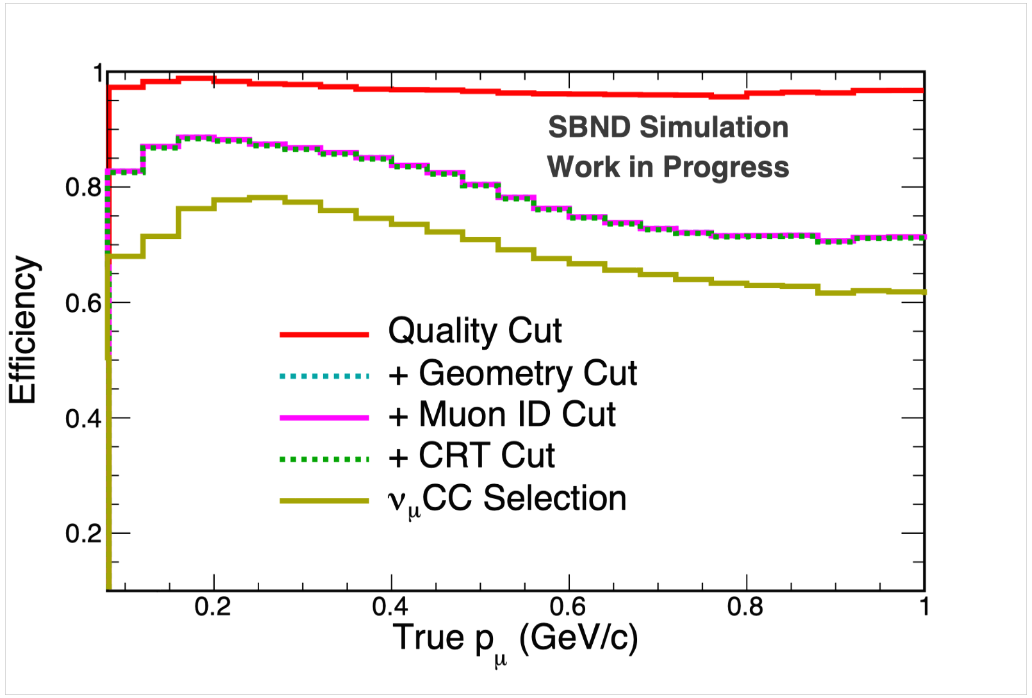


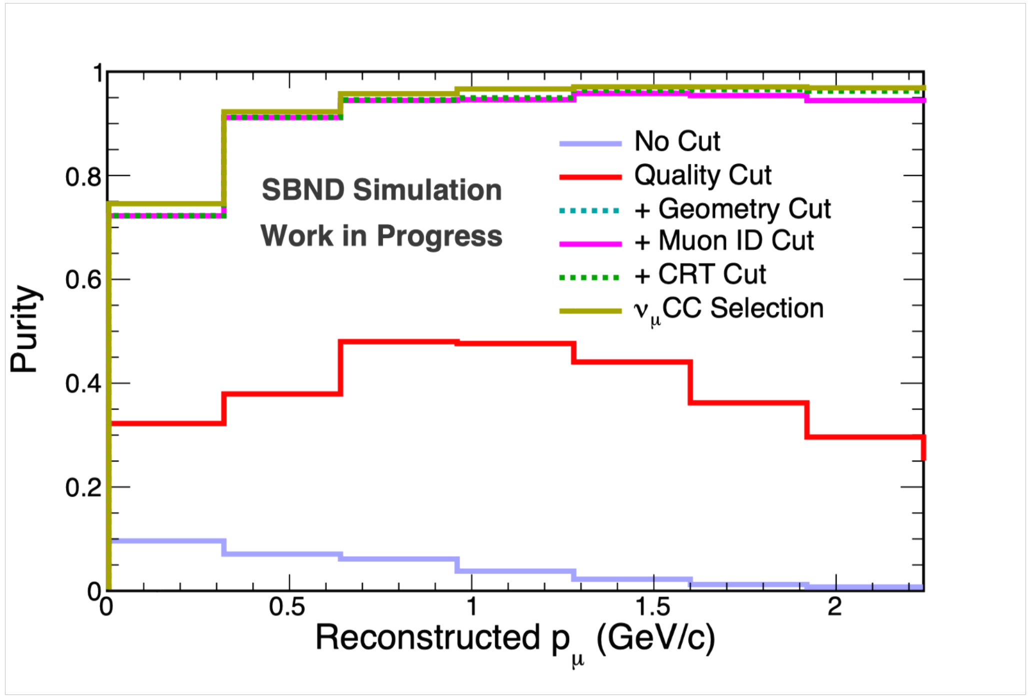
ν_μCC Selection

- Highly pure ν_μCC candidates are obtained
  - contained and exiting muon tracks and contained secondaries (protons and pions) are selected
  - Reconstructed momenta uses momentum by range information for contained and MCS* for exiting tracks



* Multiple Coulomb Scattering





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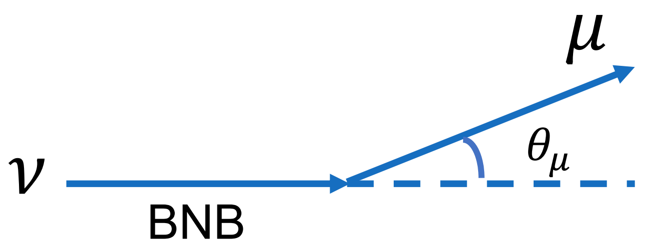

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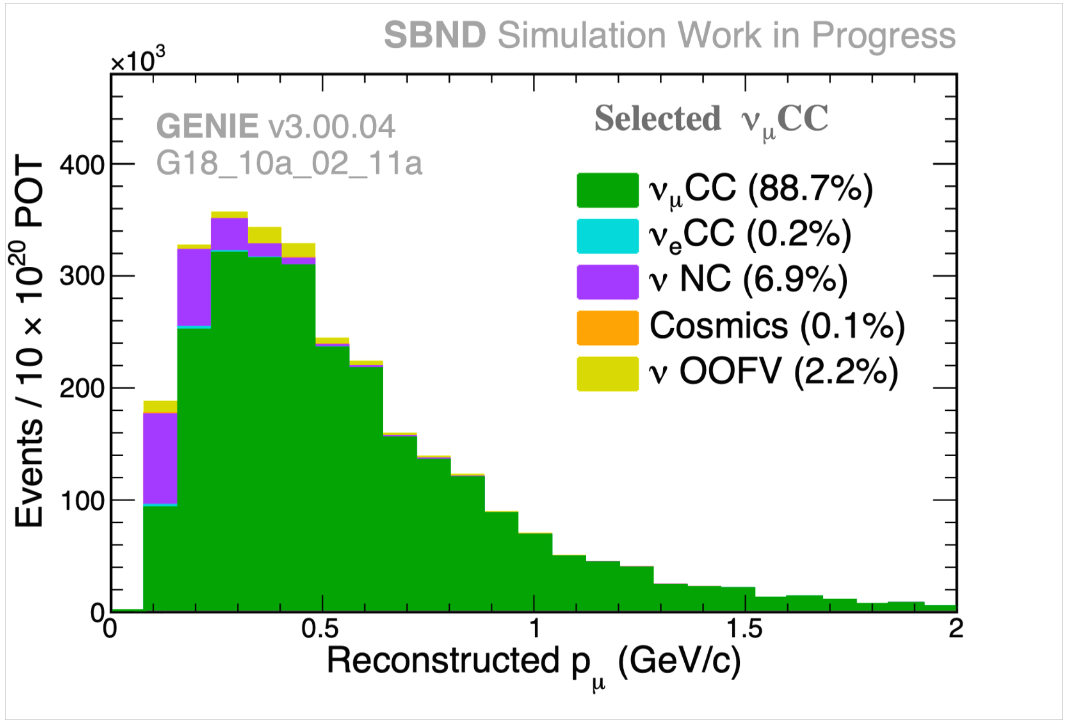
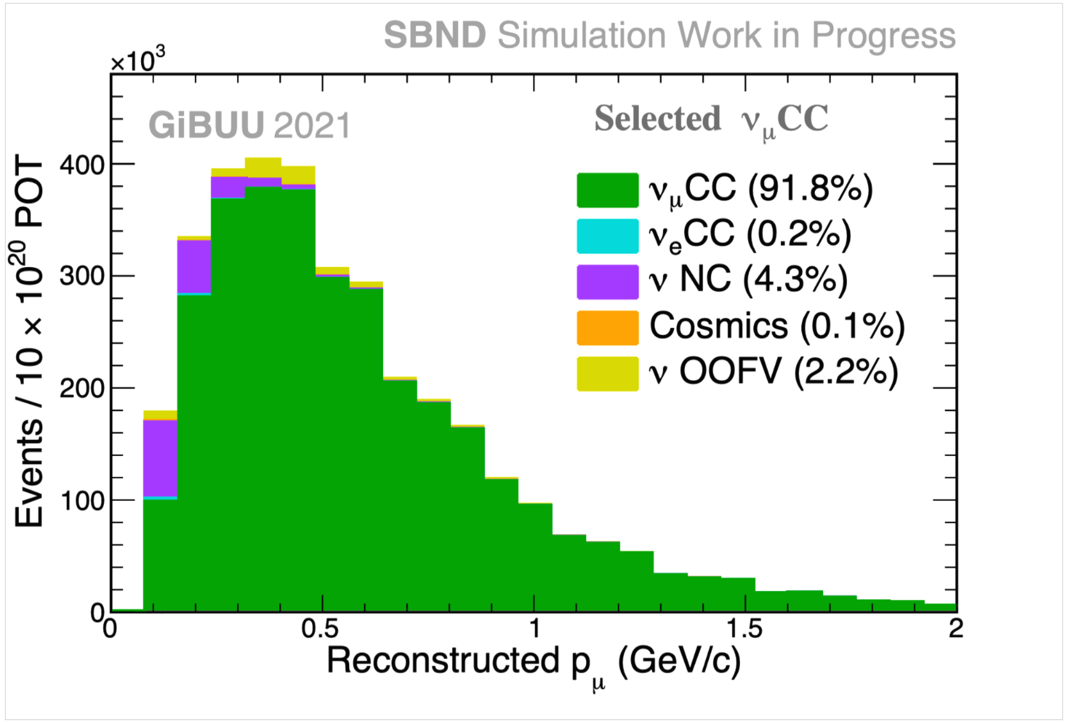
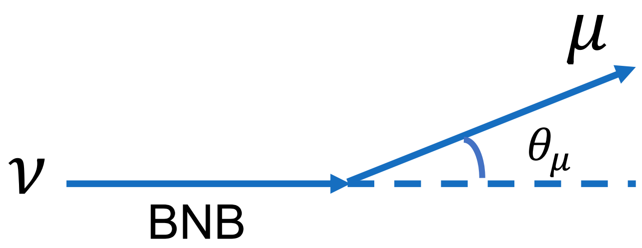




ν_μCC Selection

- Highly pure ν_μCC candidates are obtained
  - Reconstructed momenta use momentum by range for contained and MCS* for exiting tracks
  - Migration between NC and CC



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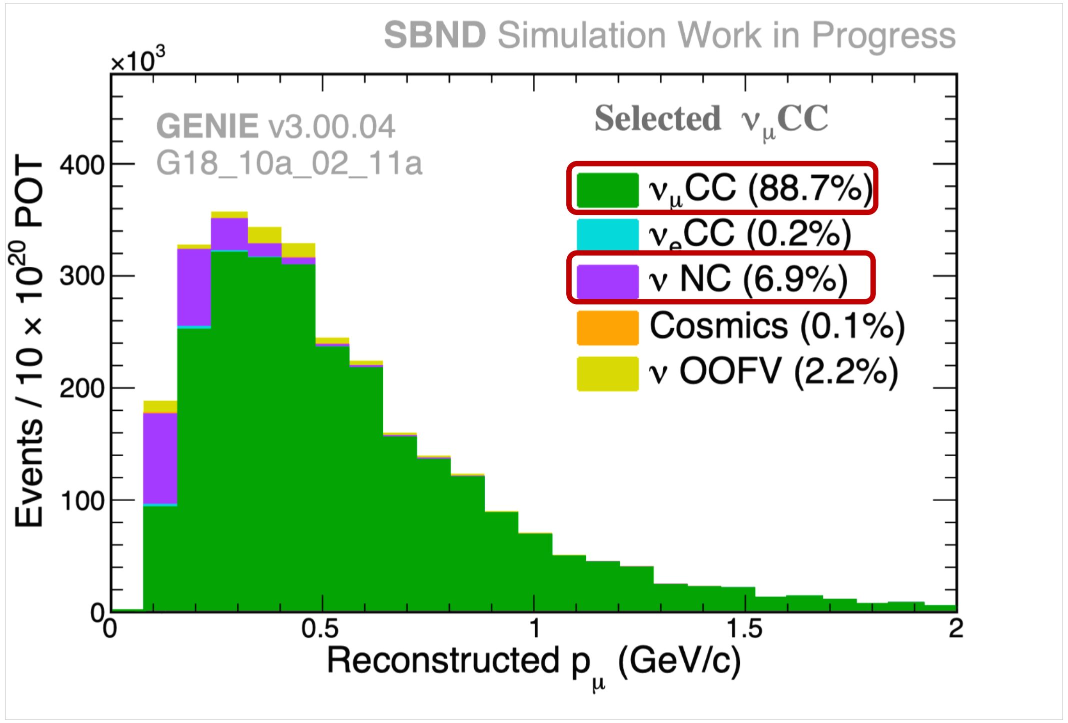
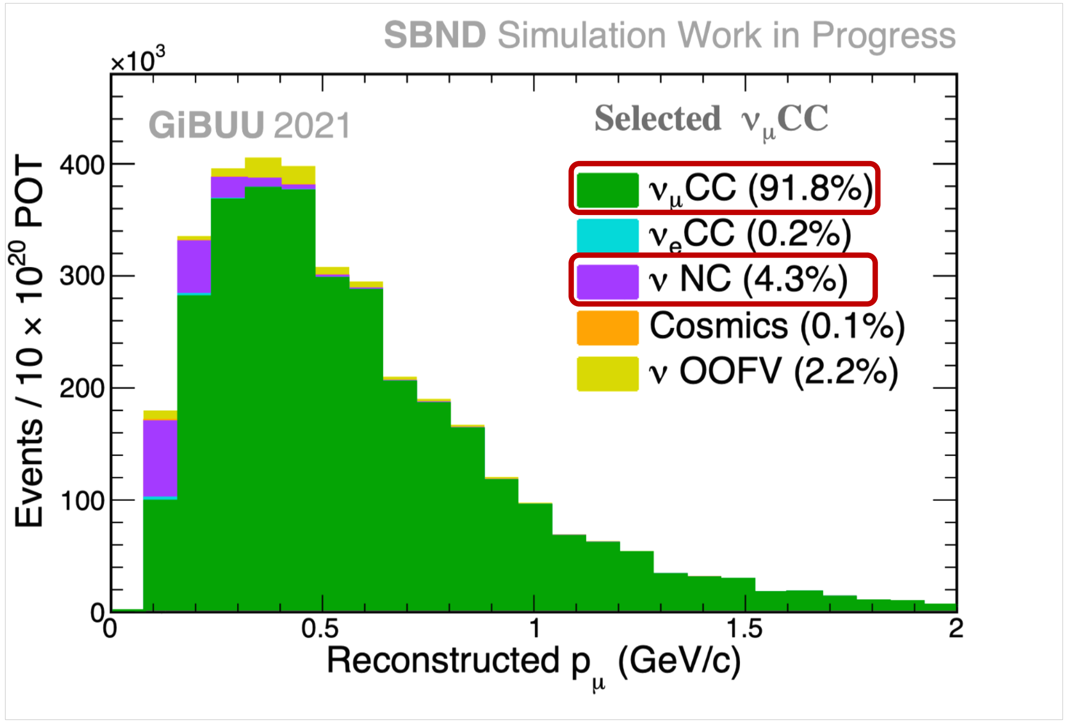
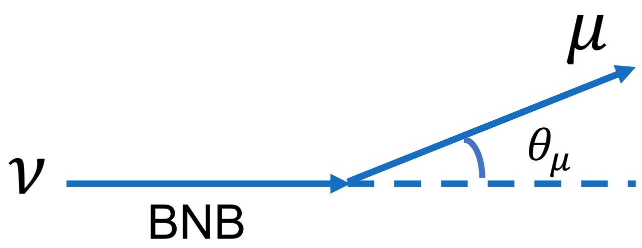
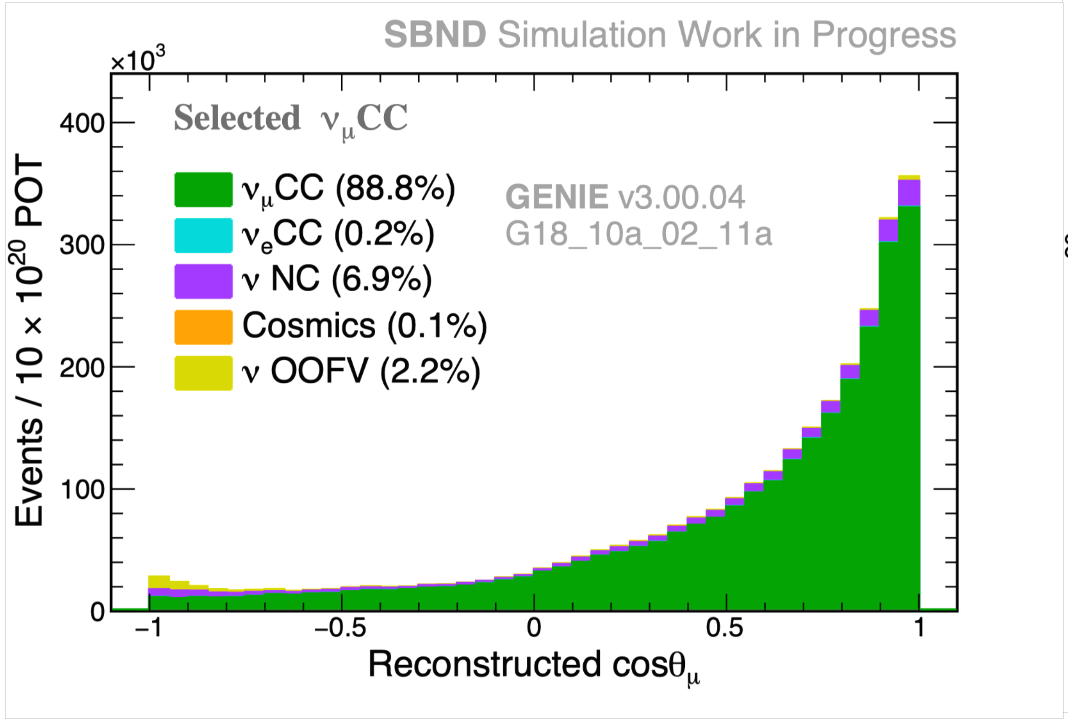


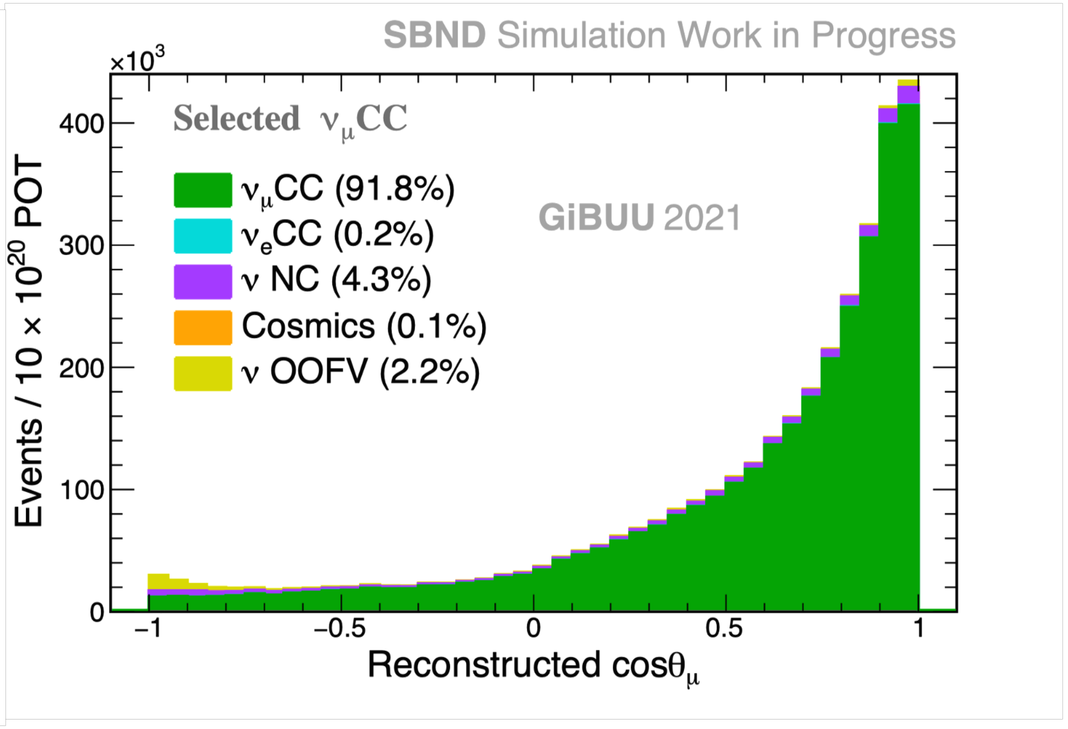


ν_μCC Selection

- Highly pure ν_μCC candidates are obtained
  - contained and exiting muon tracks and contained secondaries (protons and pions) are selected
  - Reconstructed cosθ_μ is shown here

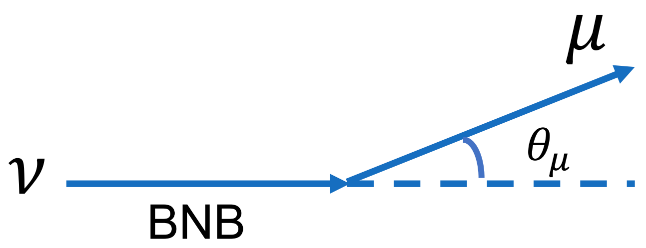


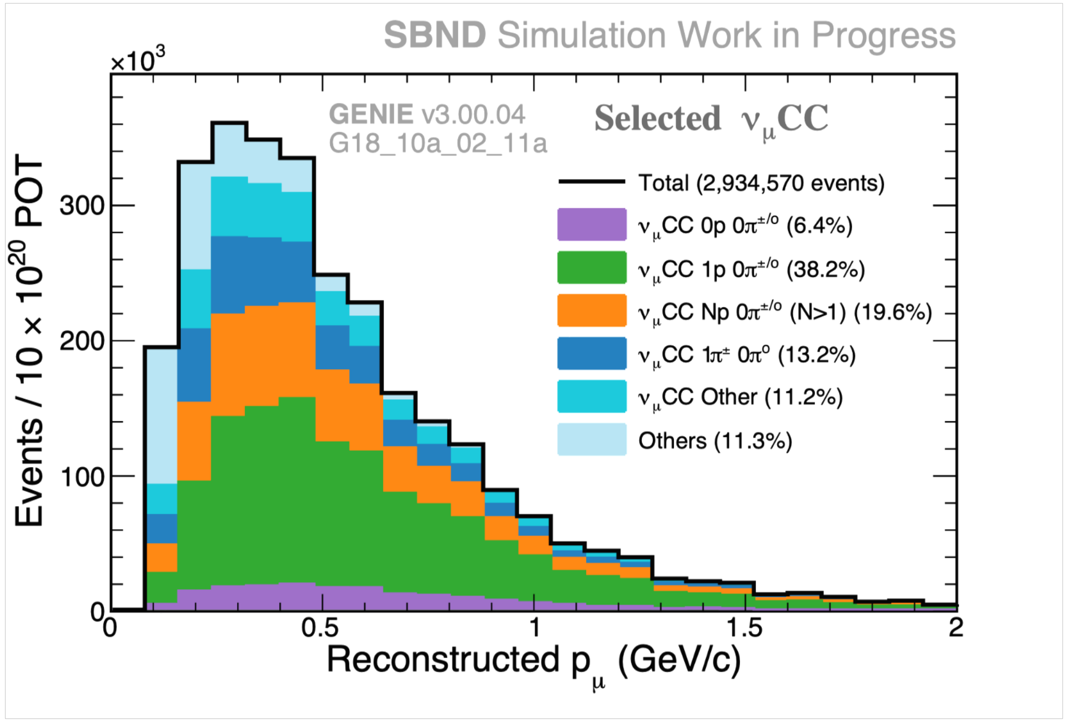


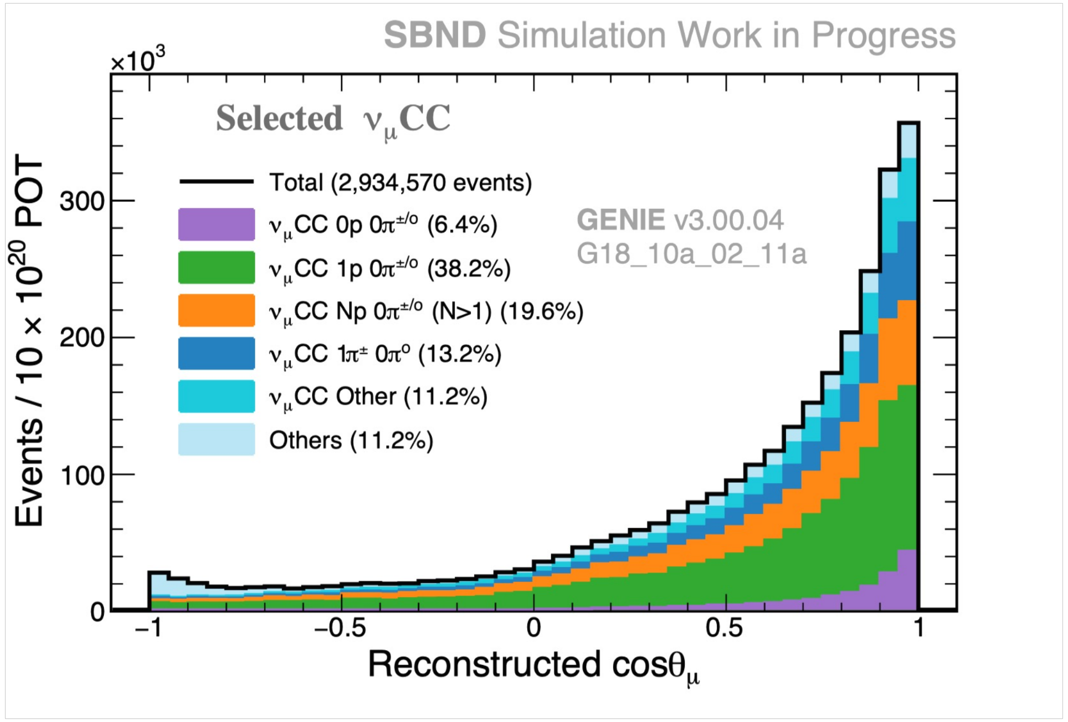


ν_μCC Selection

- Kinematics of the selected ν_μCC per topology
- Projected number of events to be collected with 10e20 POT

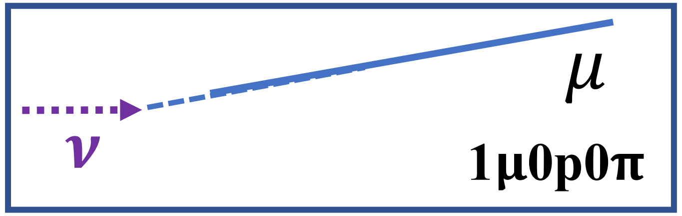


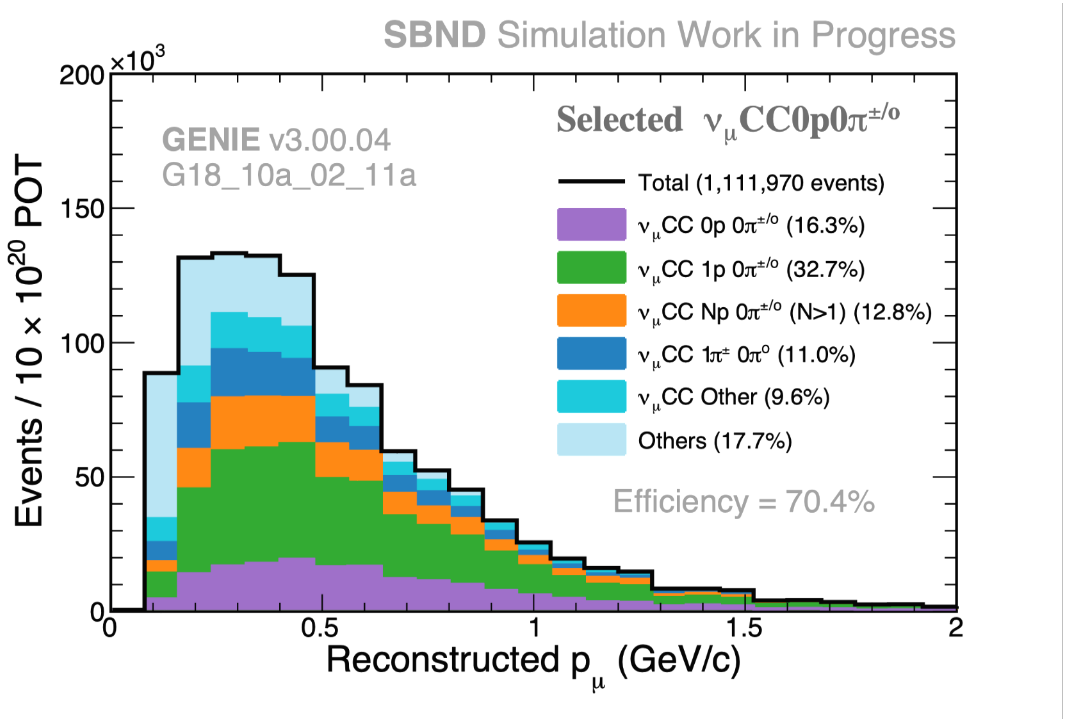


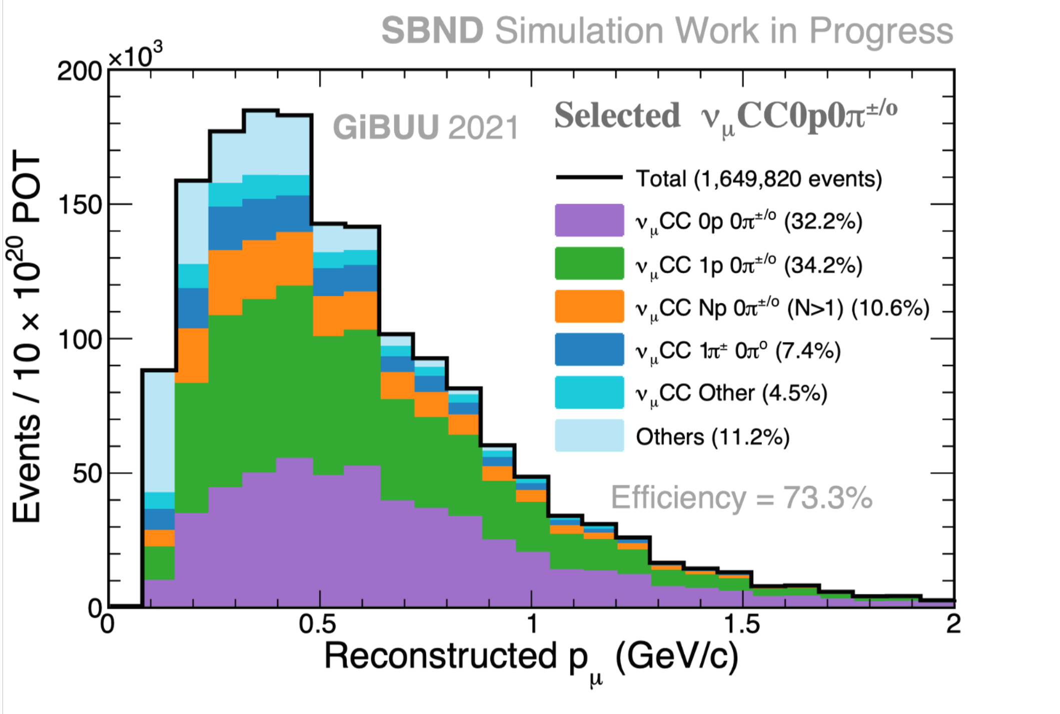


ν_μCC 0p0π Selection

- This topology is dominated by CCQE in GENIE (50.4%) and GiBUU (56.0%)



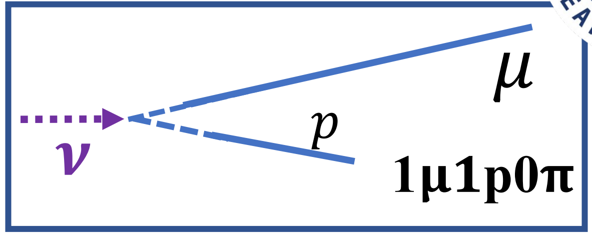


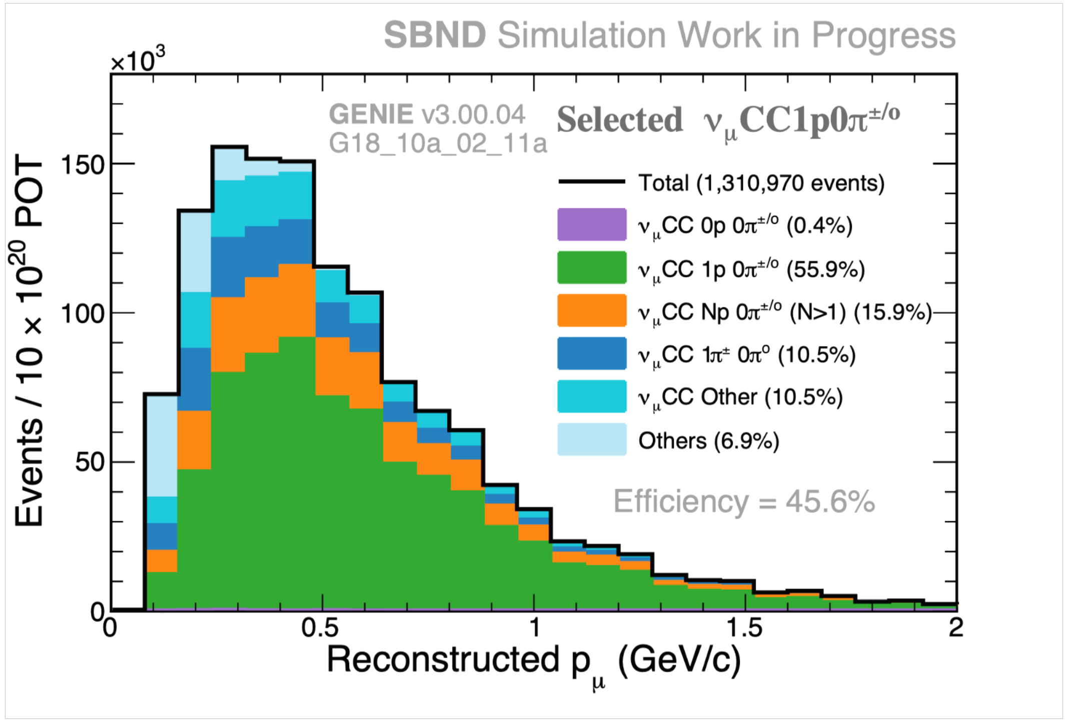


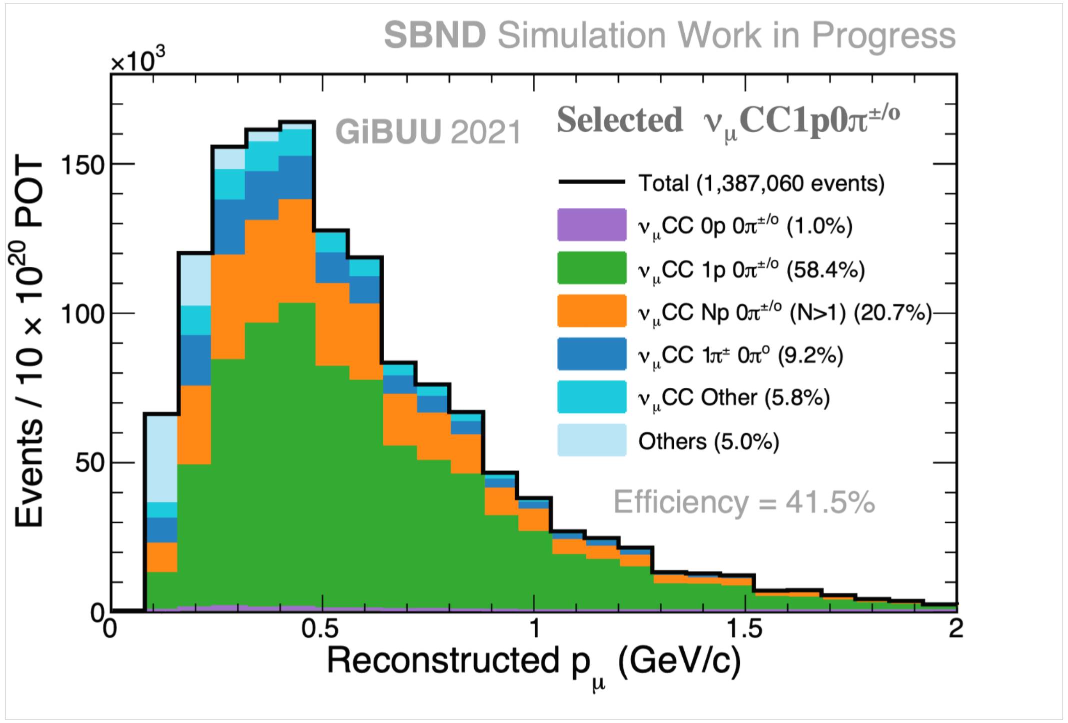
- This topology is crucial to understand low energy neutrinos from BNB

ν_μCC 1p0π Selection

- Channel is dominated with :
  - CCQE (56.2%), CCRES (23.3%) and CC 2p2h (10.2%) in GENIE
  - CCQE (50.0%), CCRES (20.9%) and CC 2p2h (18.8%) in GiBUU



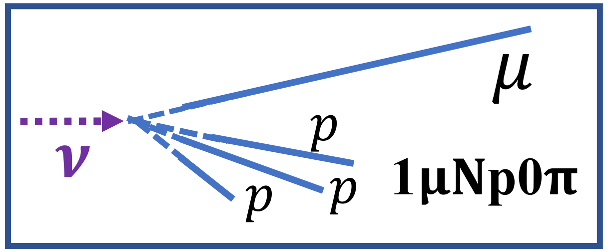


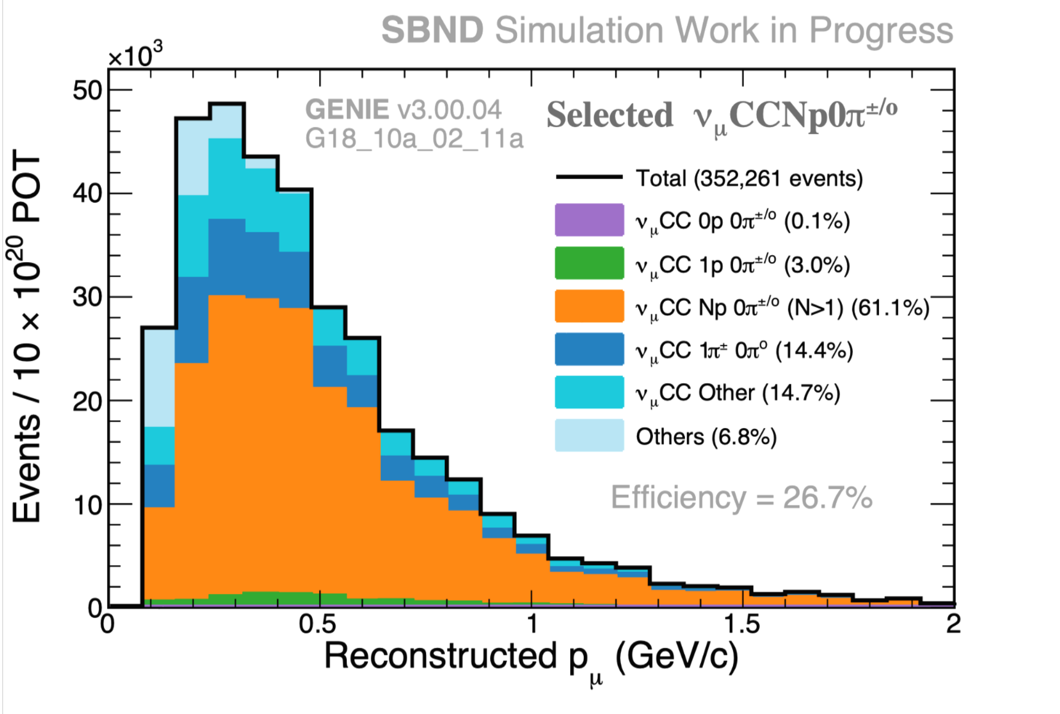


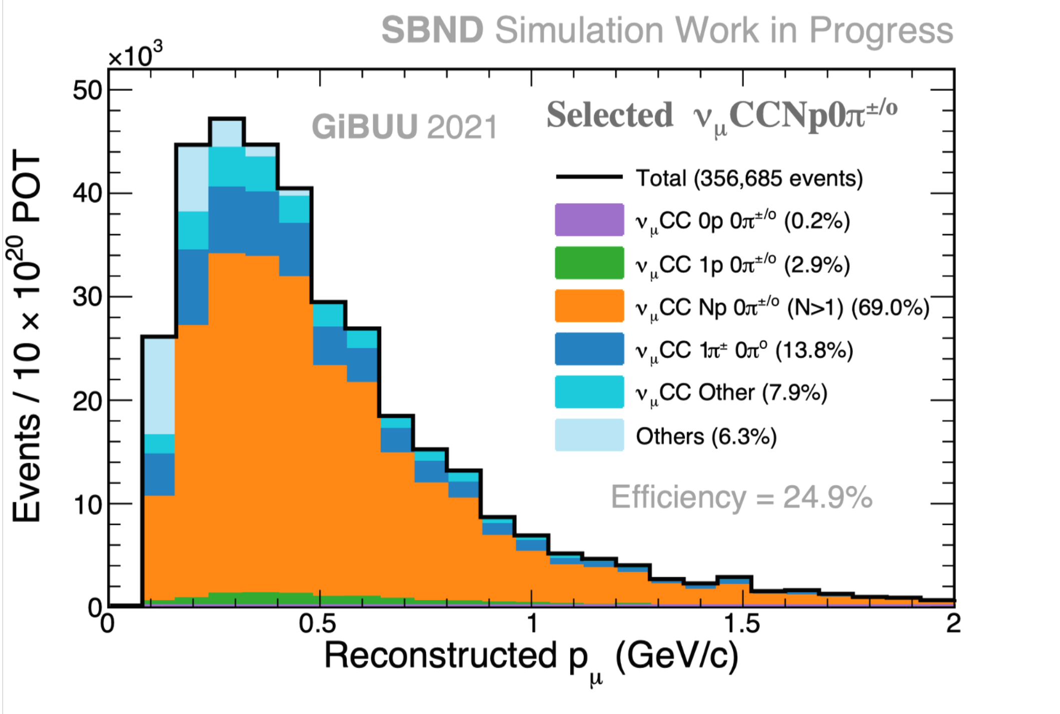
- This will help better constrain QE and 2p2h

ν_μCC Np0π Selection

- Channel is dominated with :
  - CCRES (47.1%) and CC 2p2h (21.1%) in GENIE
  - CCRES (43.2%) and CC 2p2h (20.1%) in GiBUU







- This will help better constrain 2p2h and pion absorption

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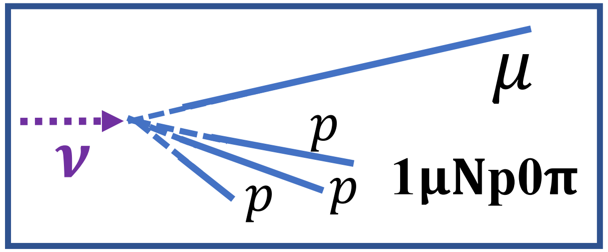
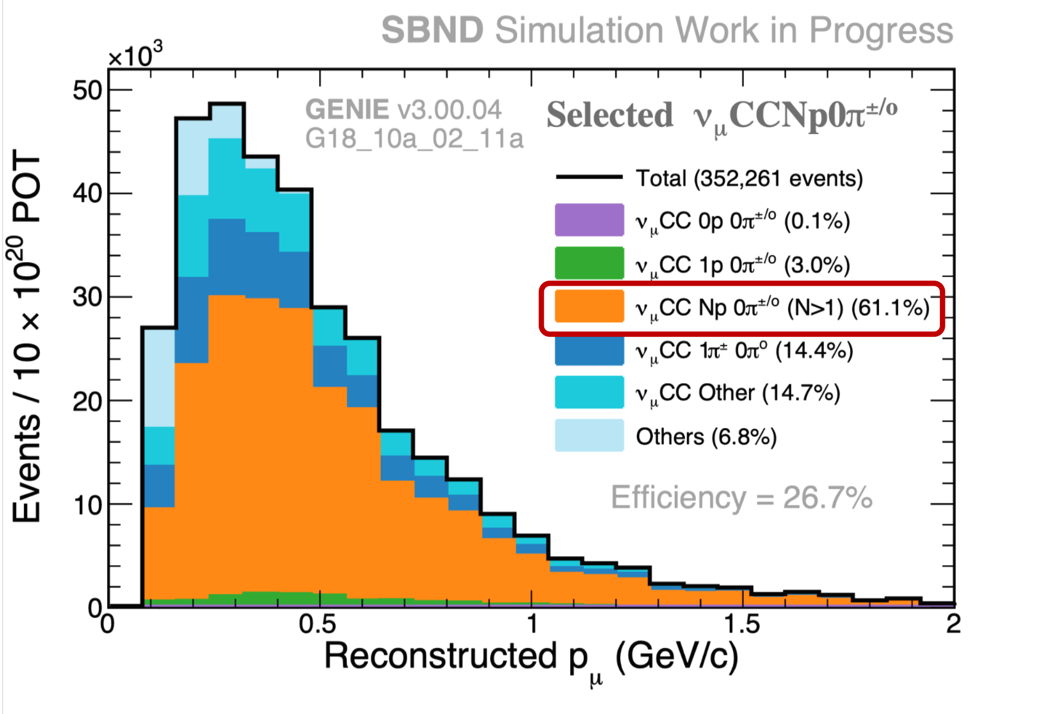
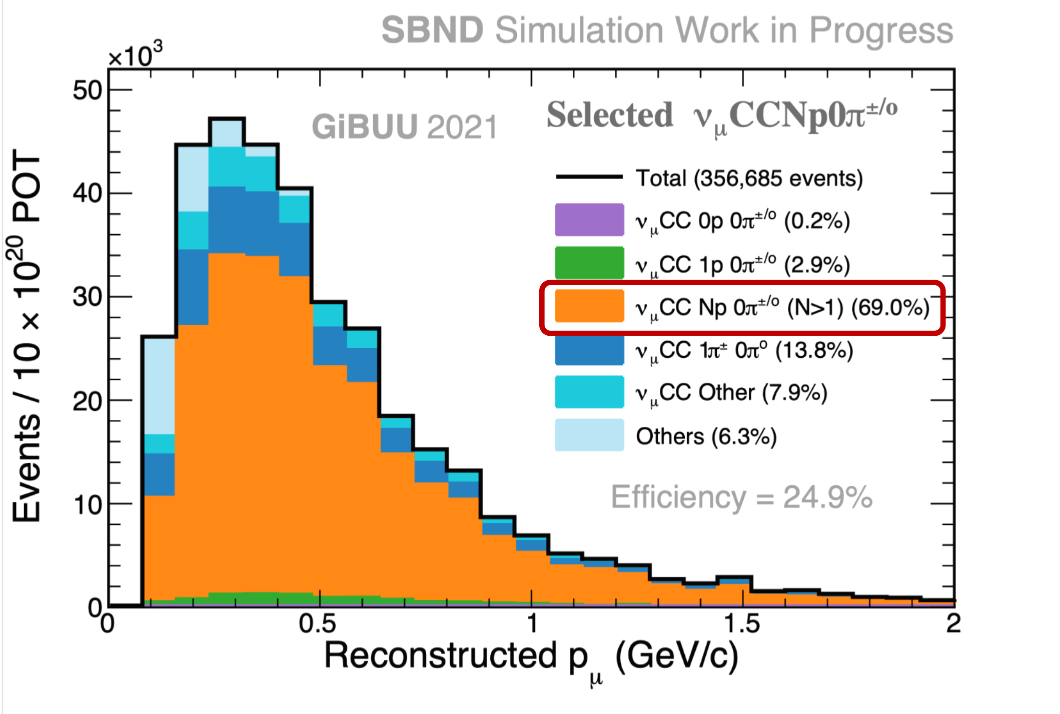


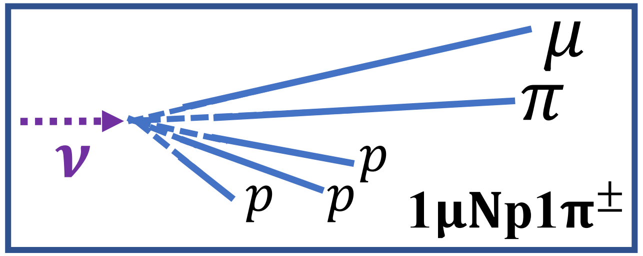


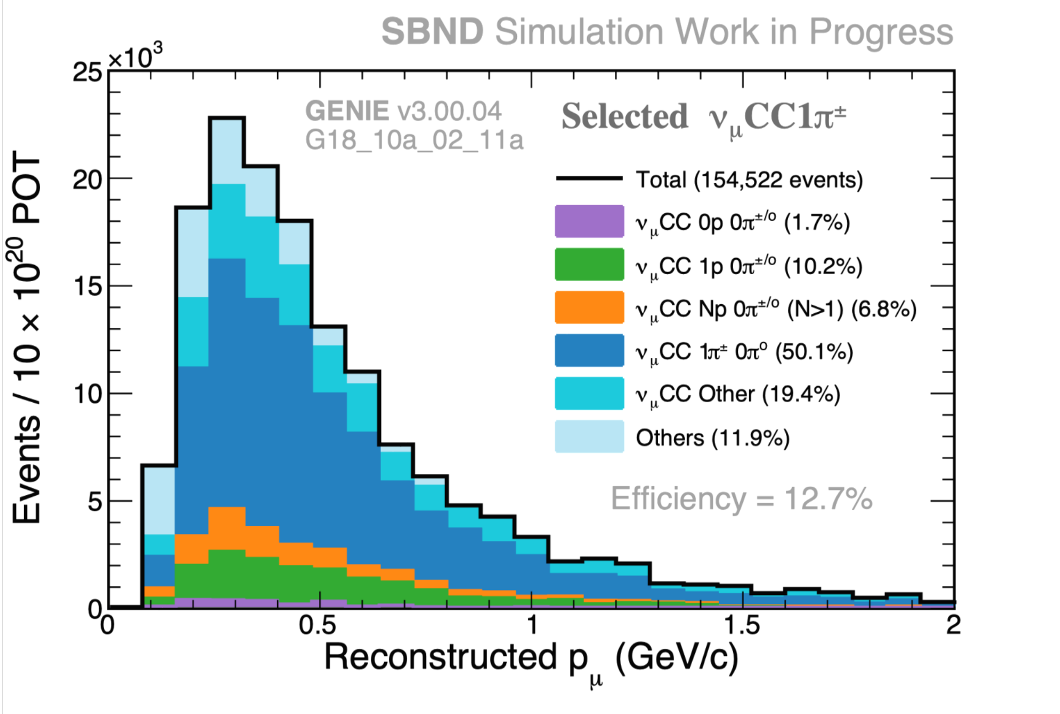


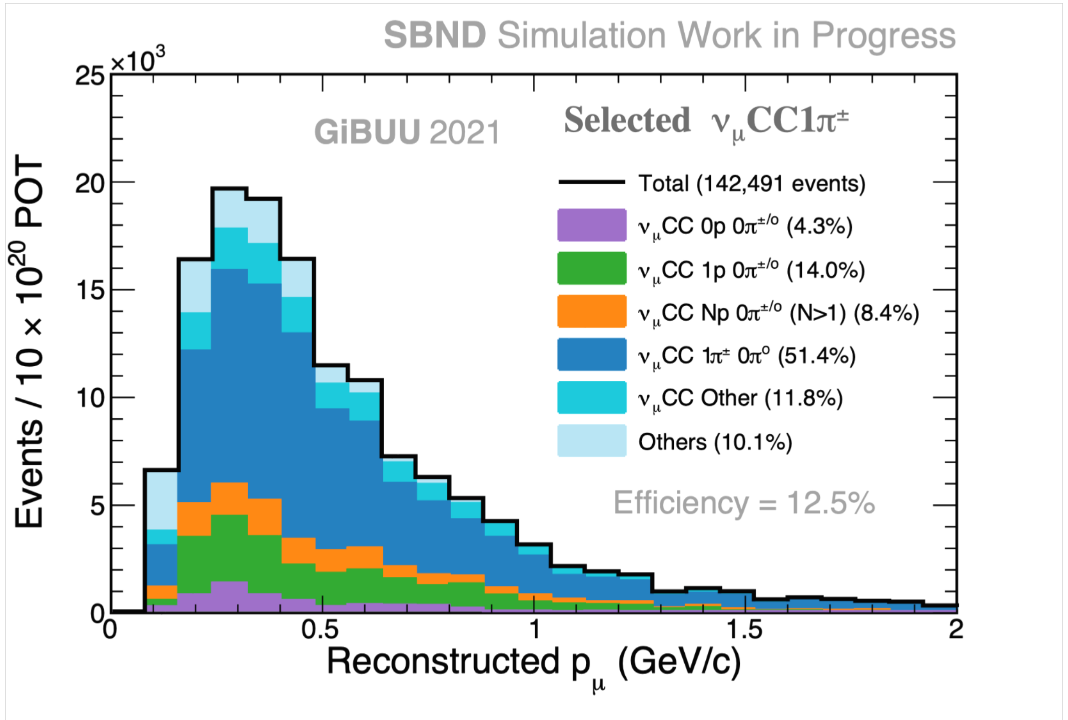
- This will help better constrain 2p2h and pion absorption

ν_μCC $1\pi^\pm$ Selection

- Channel is dominated with :
  - CCRES (55.7%) and CCDIS (16.7%) in GENIE
  - CCRES (53.8%) and CCDIS (16.2%) in GiBUU



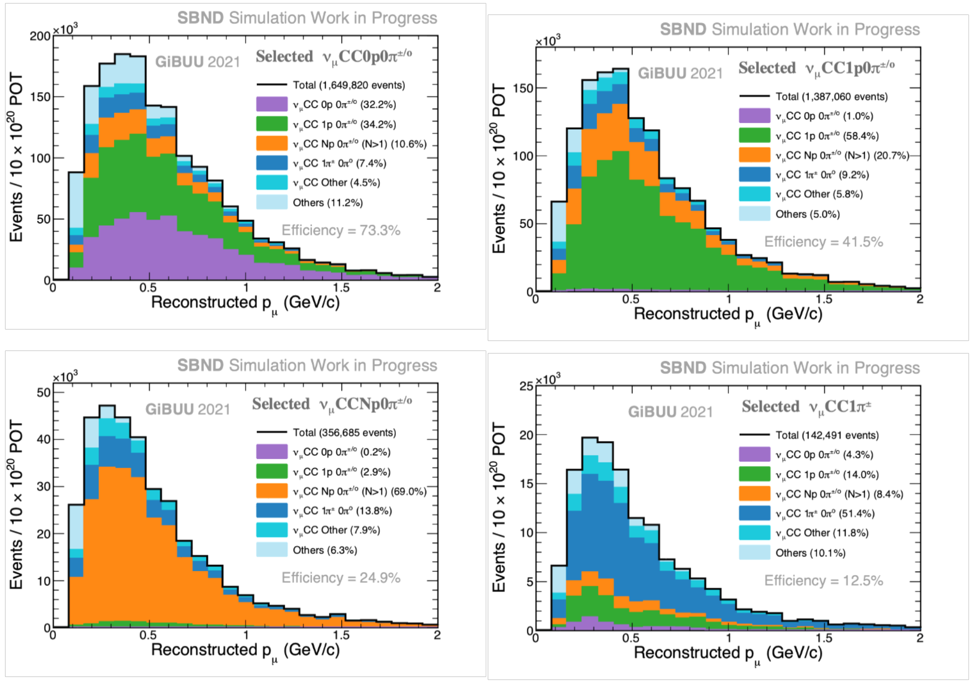




- This will help better constrain RES and DIS, very important to understand pion production modelling, which is the main background for ν_eCC searches at the FD

Summary

- Studies with exclusive (combination of which is also inclusive) topologies is shown
- SBND captured its first neutrino interactions in data during July this year – Really exciting time for our collaboration



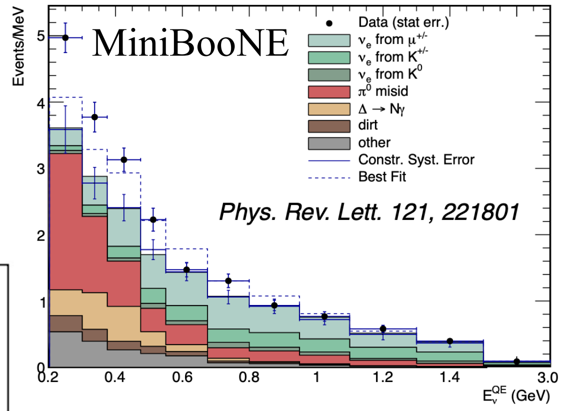
Thank You all !

Backup

The enigma of sterile neutrinos

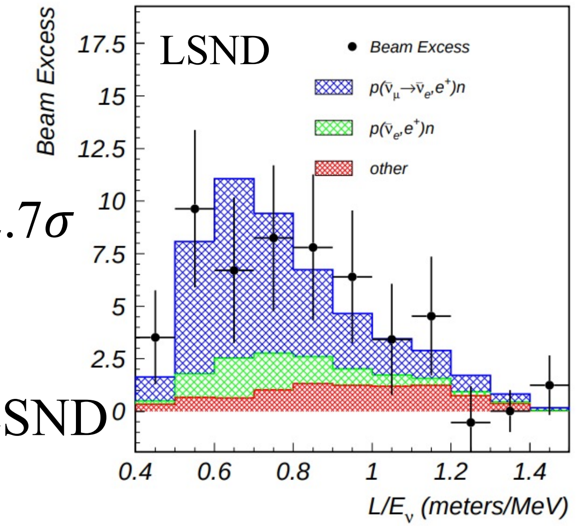
Over the past few decades, observations of experimental anomalies have been hinting towards the existence of "sterile" neutrinos with $\Delta m^2_{new} \sim O(eV^2)$

PhysRevLett.121.221801



- Gallium-based experiments:
  - Deficit in the rate of observed/predicted rate (R = 0.84 $\pm$ 0.05) of ^{71}Ge production is shown by SAGE and GALLEX
  - Confirmed by BEST with 4σ

arxiv/hep-ex/0104049



- Reactor experiments:
  - Observed/predicted rate, R_{avg} = 0.938 $\pm$ 0.023 at 2.7σ

- Accelerator experiments:
  - Excess of $\bar{\nu}_e$ is observed in $\bar{\nu}_e p \rightarrow e^+ n$ at 3.8σ in LSND
  - MiniBooNE reported excess in ν_e and $\bar{\nu}_e$ at 4.7σ

Recent results from the combined analysis of Neutrino-4 with GALLEX, SAGE and BEST provides a best fit of $\mathbf{\Delta m^2_{14} = (7.3 \pm 1.17)\ eV^2}$ and $\mathbf{\sin^2 2\theta_{14} = 0.36 \pm 0.12}$ arxiv:2005.05301