# Latest Update from DUNE ND-LAr $2 \times 2$ Prototype

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# Current Status

- The $2 \times 2$ Prototype is in action: Recorded its first data in from July 8th to July 12th (4 a.m.) NuMI beam in RHC mode (4.5 days).
  - For high-level validation, a ~2-hour period of measured data, from midnight to 2am on July 9, is available.
- We also have 3.5-days simulated data (with 1E19 POT).
- ➤ We developed a preliminary *selection criteria* and used this to analyze comparisons between sandbox $2 \times 2$ real data and the produced simulated data.
- ➤ The selection was performed by ML-reco reconstruction implemented at CAFs level on Reconstructed Data and Reconstructed MC Simulation.

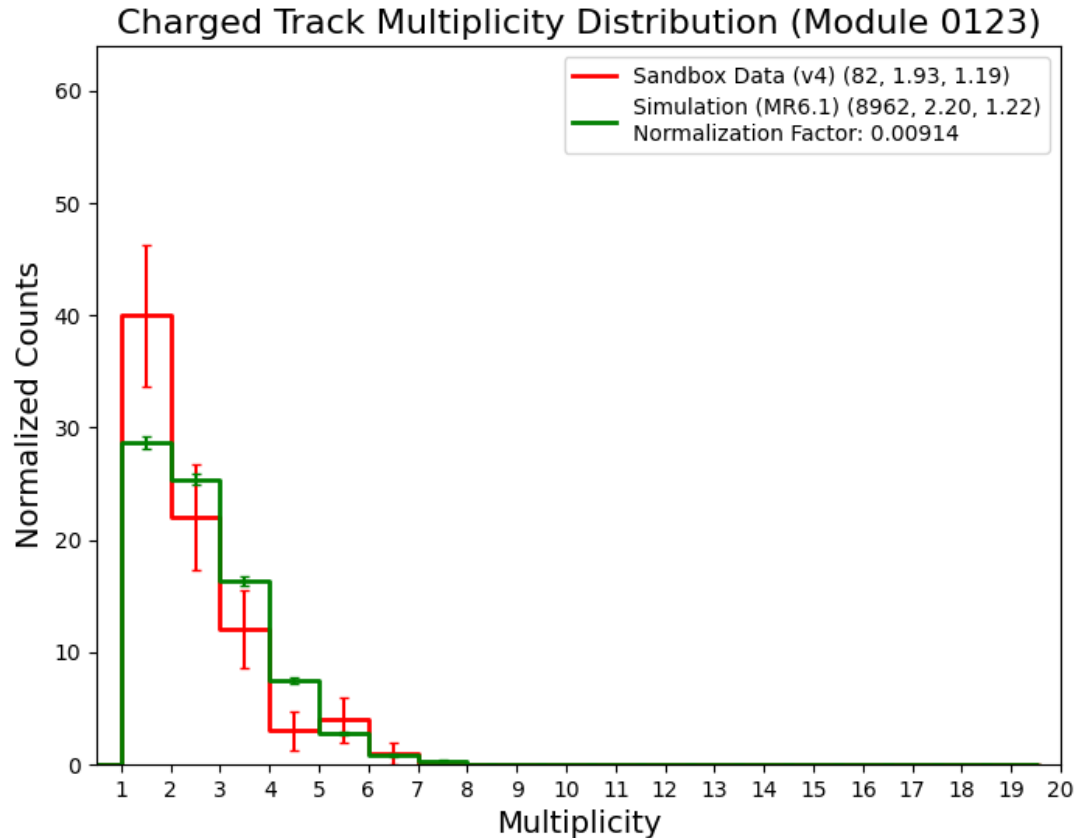| FV Bounds are (in cm) |
|---|
| $X (-63.931, +63.931)$ |
| $Y (-62.076, +62.076)$ |
| $Z (-64.538, +64.538)$ |

## Signal Selection

- All interactions have at least one outgoing muon candidate and are within LArFV.
- For each module, distance from outer walls is set to 5 cm in all directions (except cathodes).
- Muon 2x2 - MINERvA pairing is further applied on muons from these interactions.
- Minimum track length is set to be greater than $> 2$ cm.
- Multiplicity plots are shown with the full event selection.
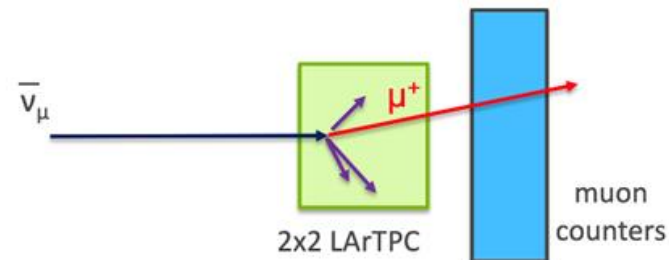
# Charged Track Multiplicity Distribution (Module-by-Module Basis)

➢ Multiplicity distribution for charged tracks (muons, protons, charged pions, charged kaons), with the full event selection, is shown.

➢ Number of interactions in MC simulation is normalized to the number of interactions in data.

➢ Same normalization factor is applied in the rest of the talk when MC and data are compared.



Charged Track Multiplicity Distribution (Module 0123)

Sandbox Data (v4) (82, 1.93, 1.19)
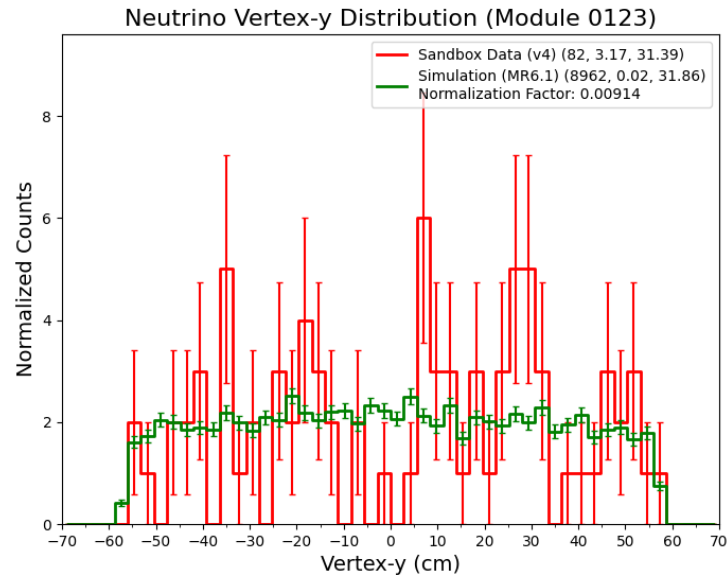Simulation (MR6.1) (8962, 2.20, 1.22)
Normalization Factor: 0.00914
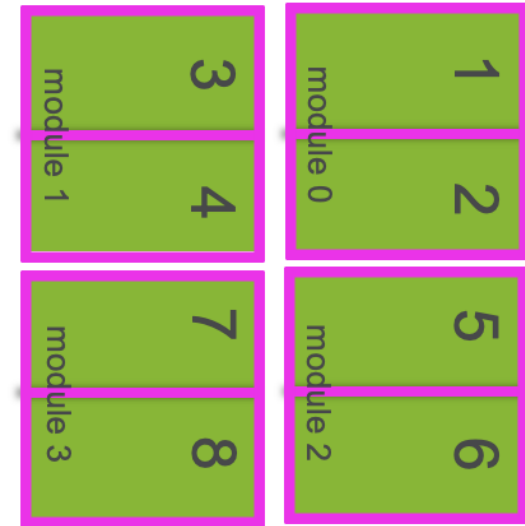
# Neutrino Interaction Vertices

➢ 1D histograms of neutrino interaction vertices from data and MC simulation are shown, from full event selection.

➢ MC simulation is normalized according to data and normalization factor is calculated from total number of interactions.
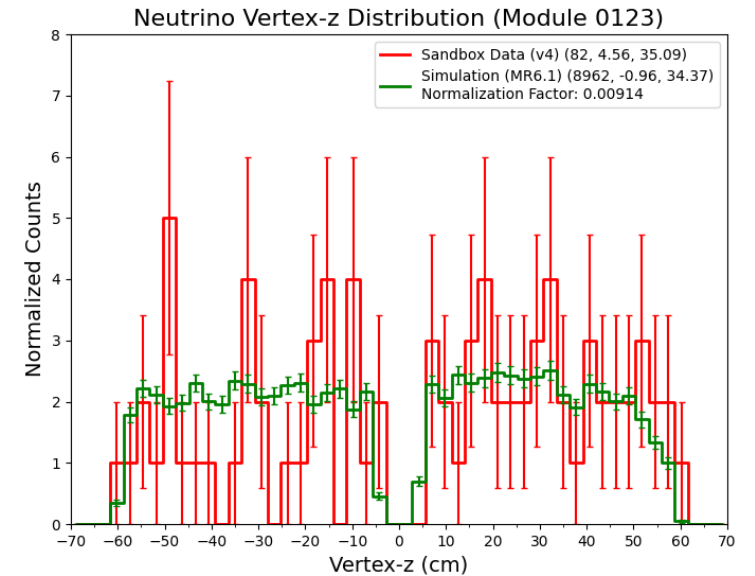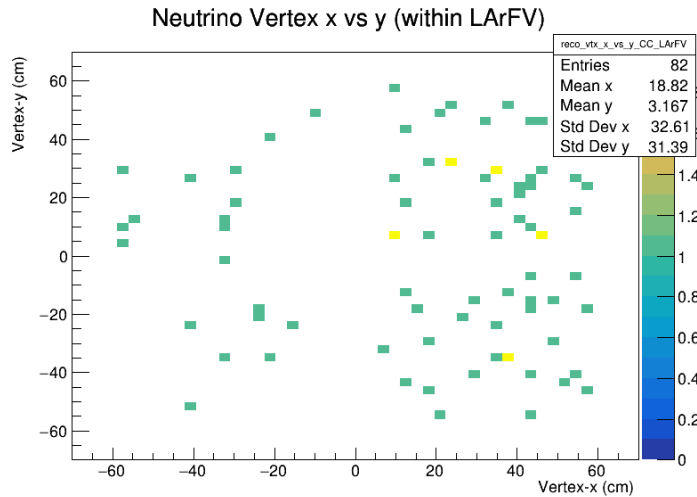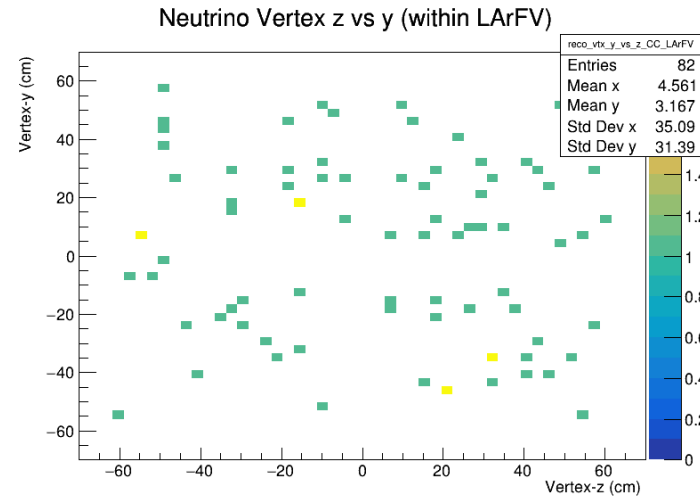
➢ Vertex-x
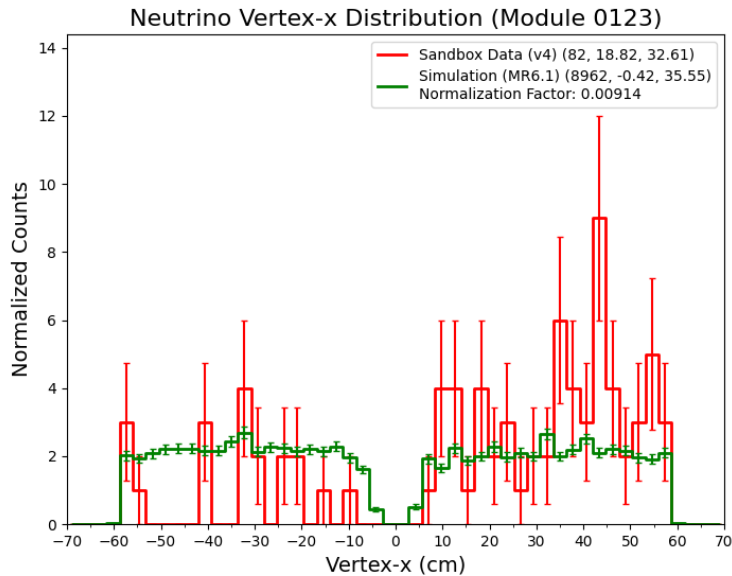
➢ Vertex-y

➢ Vertex-z

# Neutrino Interaction Vertices

➤ Neutrino interaction vertices, for reconstructed data and reconstructed MC simulation, are shown within LArFV.
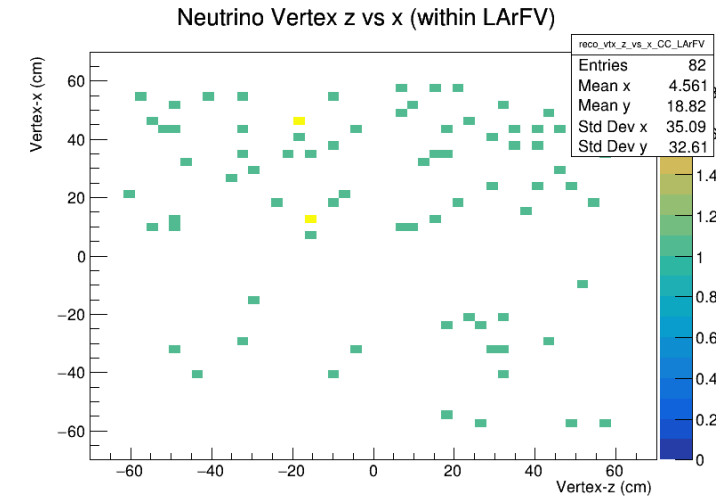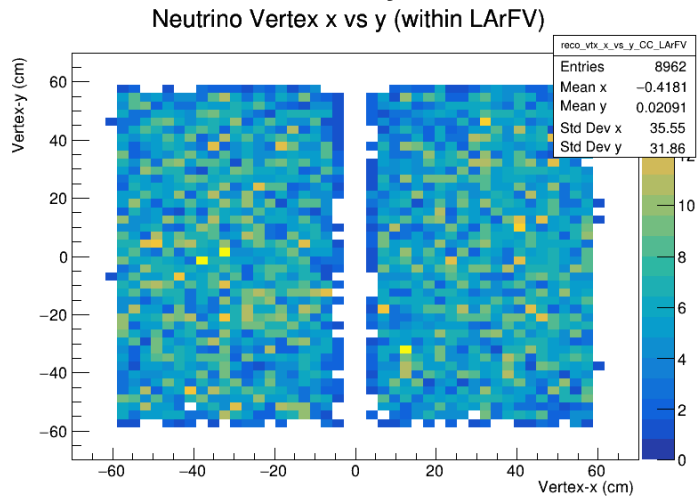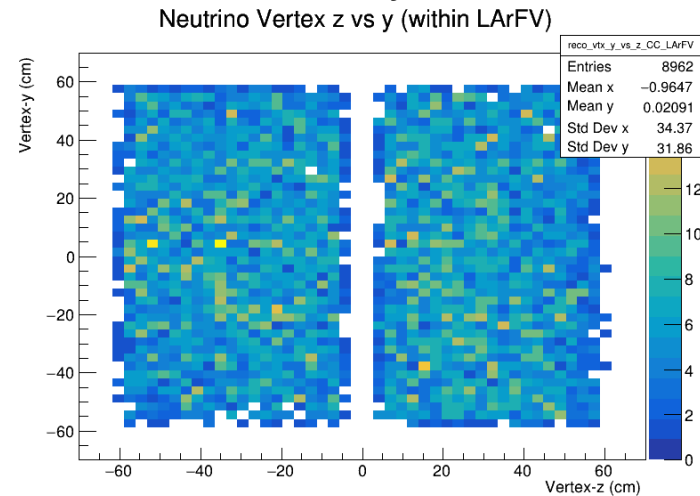
➤ Data-Reco ($x$ vs. $y$)

➤ Data-Reco ($z$ vs. $y$)
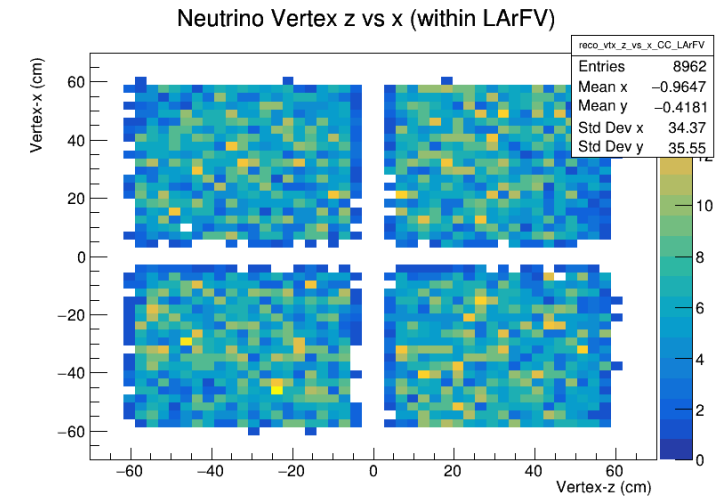
➤ Data-Reco ($z$ vs. $x$)



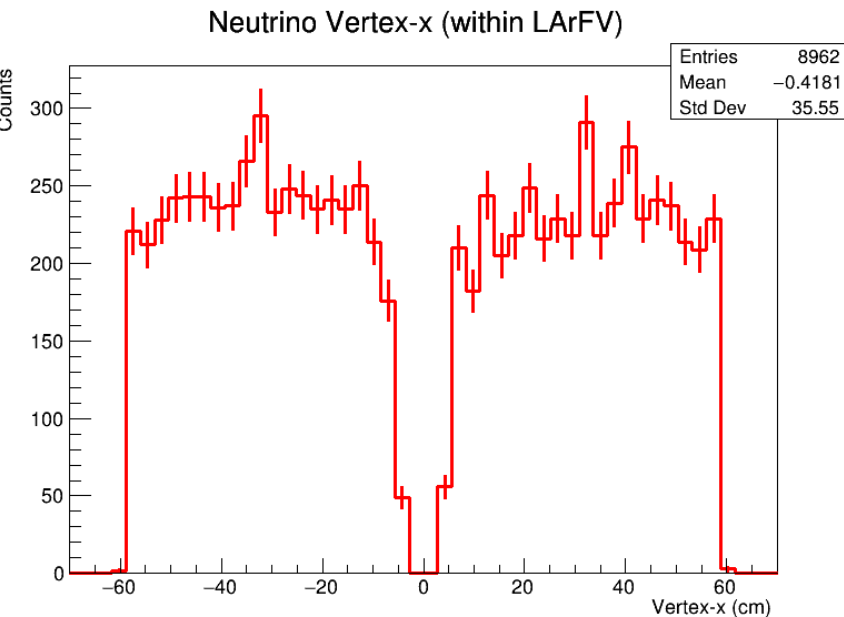➤ Sim-Reco ($x$ vs. $y$)

➤ Sim-Reco ($z$ vs. $y$)
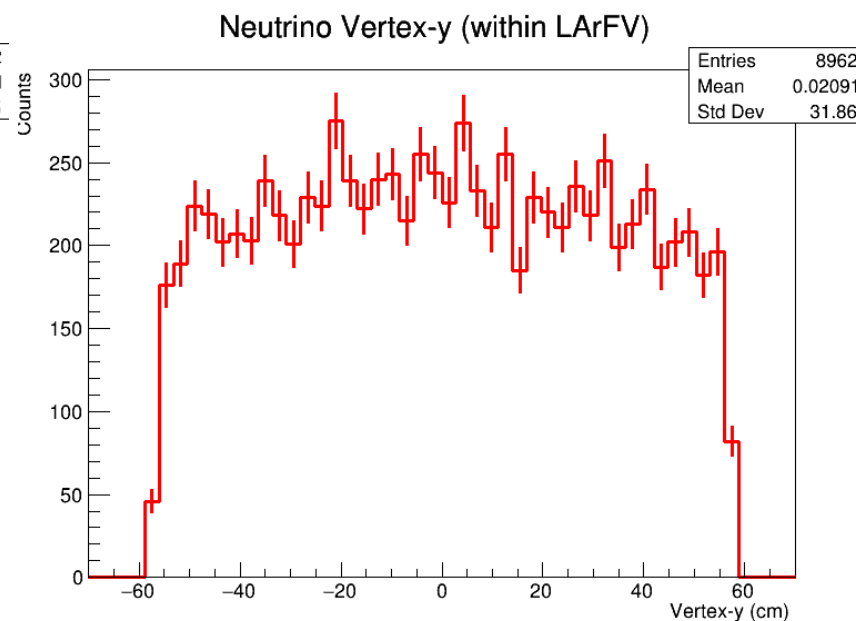
➤ Sim-Reco ($z$ vs. $x$)

# Neutrino Interaction Vertices

➤ 1D histograms of neutrino interaction vertices from MC simulation are shown, from full event selection.

➤ We can see spikes around cathodes ($x = \pm 35 \text{ cm}$).

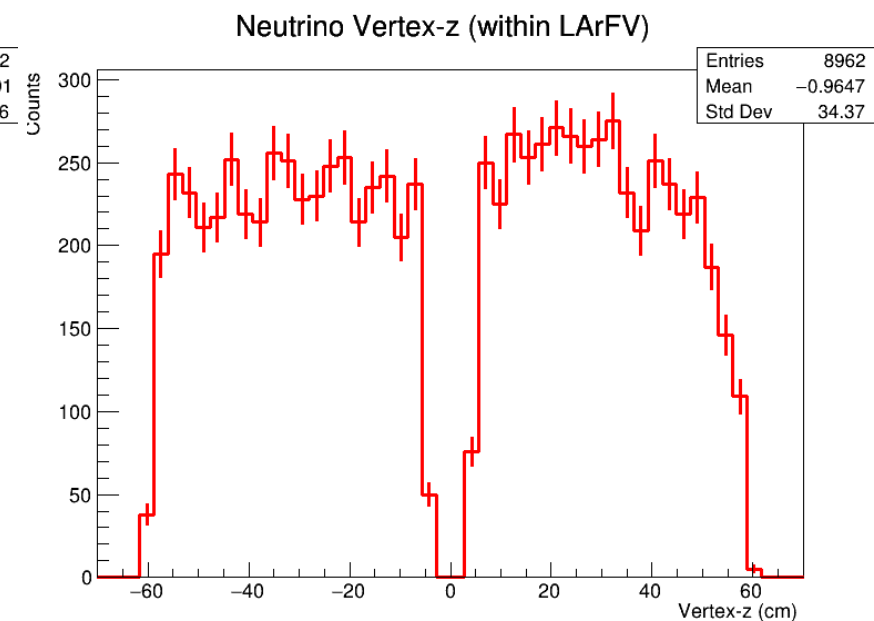➤ This is the zoomed-in neutrino vertices shown on the previous slide.
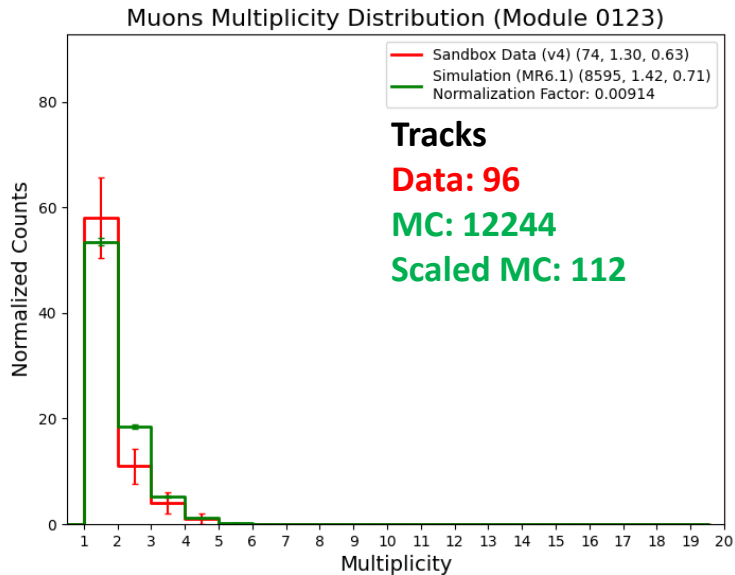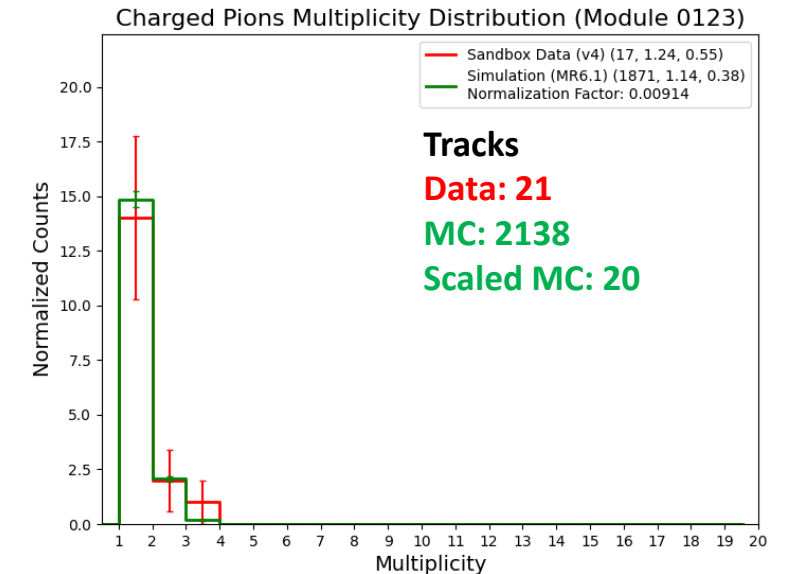
➤ Vertex-x

➤ Vertex-y

➤ Vertex-z

# Individual Charged Track Multiplicity Distribution (All Modules)

➢ Multiplicity distribution for muons, charged pions, protons, and kaons with the full event selection, is shown.

➢ Normalization is applied based on the total charged track multiplicity.

➢ There are multiple muon candidates can be seen in the muon distribution.
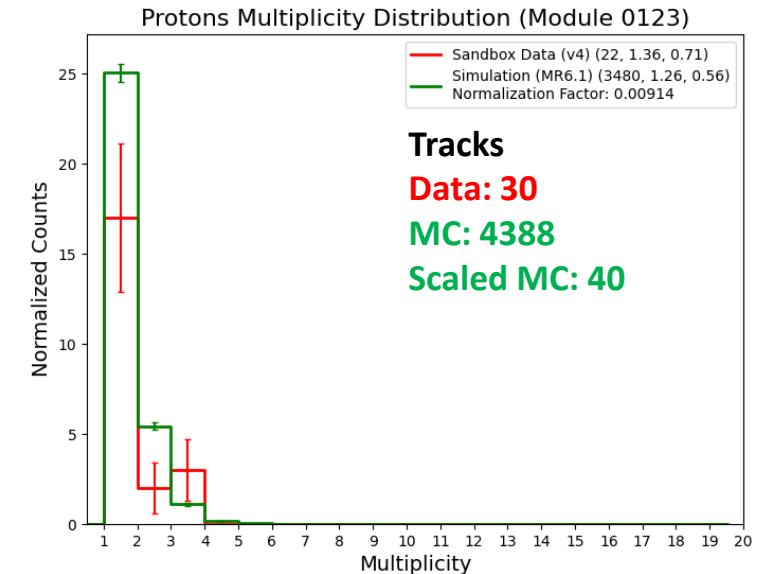
➢ Muons

➢ Charged Pions

# Individual Charged Track Multiplicity Distribution (All Modules) [contd.]

➢ Multiplicity distribution for muons, charged pions, protons, and kaons with the full event selection, is shown.

➢ Normalization is applied based on the total charged track multiplicity.

➢ Charged Kaons
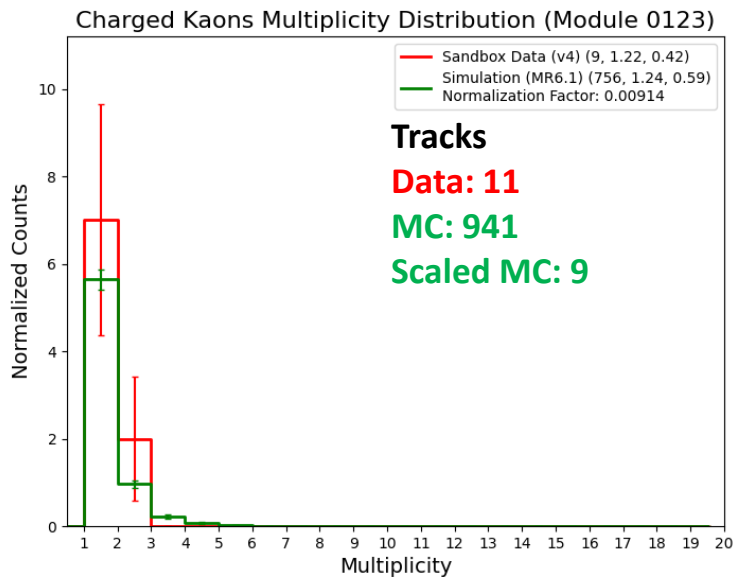
➢ Protons

# Study of Some Features around Cathodes

➢ We notices some potentially interesting features (spikes) at cathode locations, in the MC simulation.

➢ We try to examine these features.
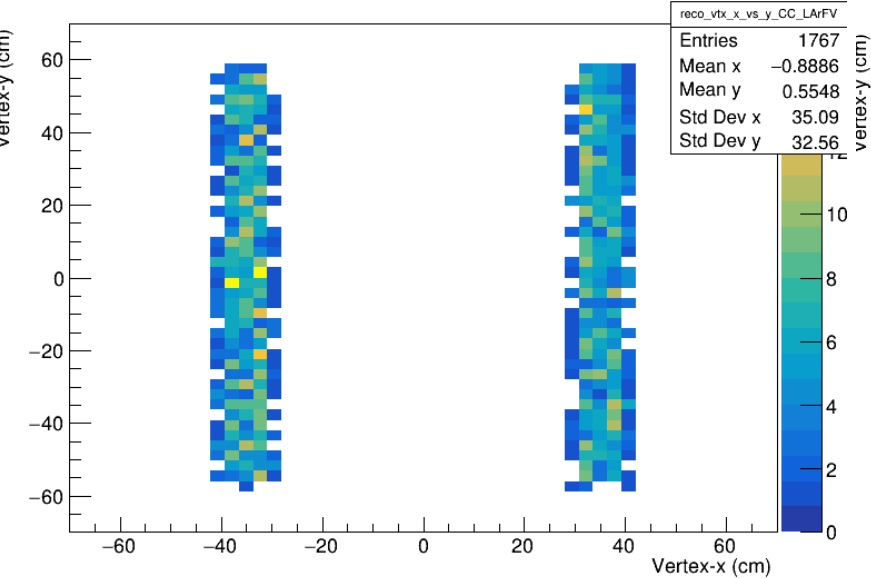
# Neutrino Interaction Vertices around Cathodes

➢ Neutrino interaction vertices, for reconstructed MC simulation, are shown around 5 cm region of both cathodes.

➢ Breakdown of interactions:
  - Negative Cathode ($-30 < x < -40$ cm): 907
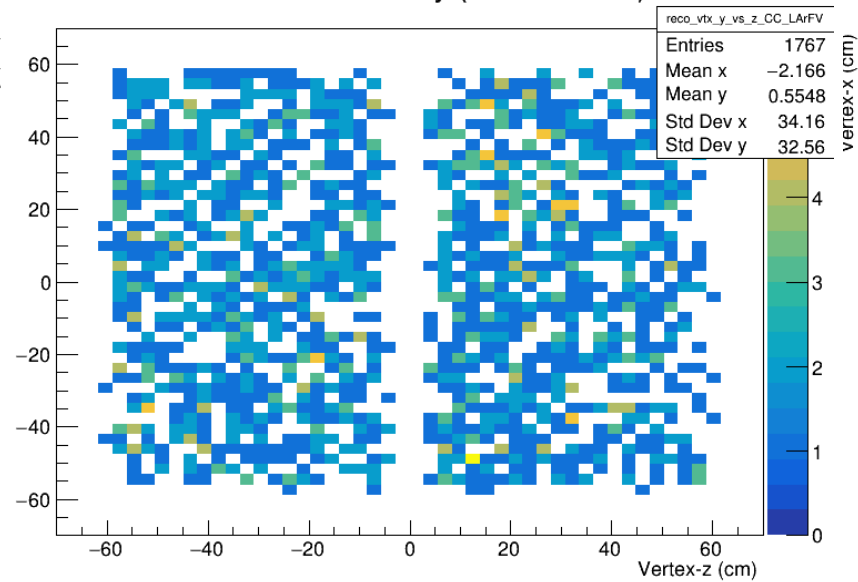  - Positive Cathode ($+30 < x < +40$ cm): 860

➢ Sim-Reco ($x$ vs. $y$)          ➢ Sim-Reco ($z$ vs. $y$)          ➢ Sim-Reco ($z$ vs. $x$)
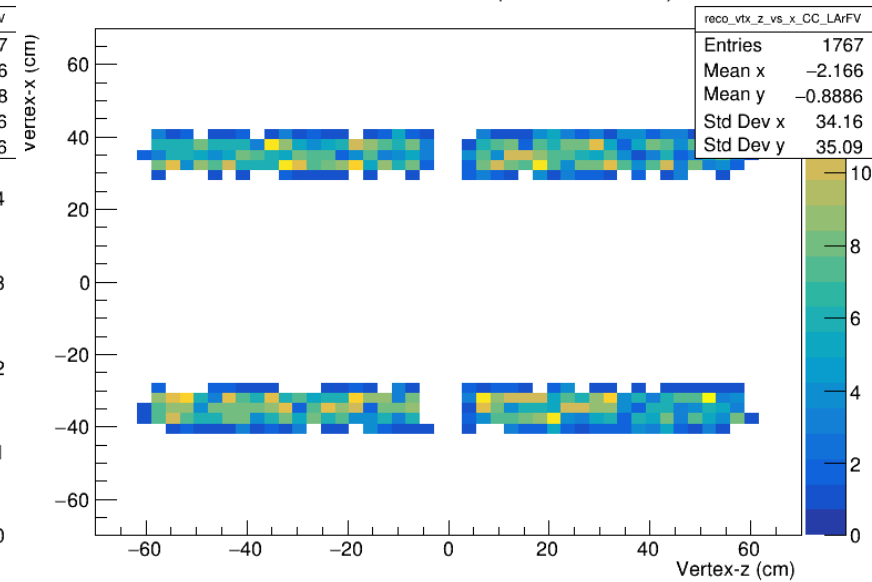
# Muon Multiplicity Distribution around Cathodes

➢ Multiplicity distribution for muons, with the full event selection, is shown around each cathode.

➢ There are approximately equal number of multiple muon candidates around both cathodes.

➢ We will repeat this study near anode walls between modules.

- We further plan to look at the track length and angular distributions of each muon to better understand this multiple muon candidacy.

➢ Negative Cathode
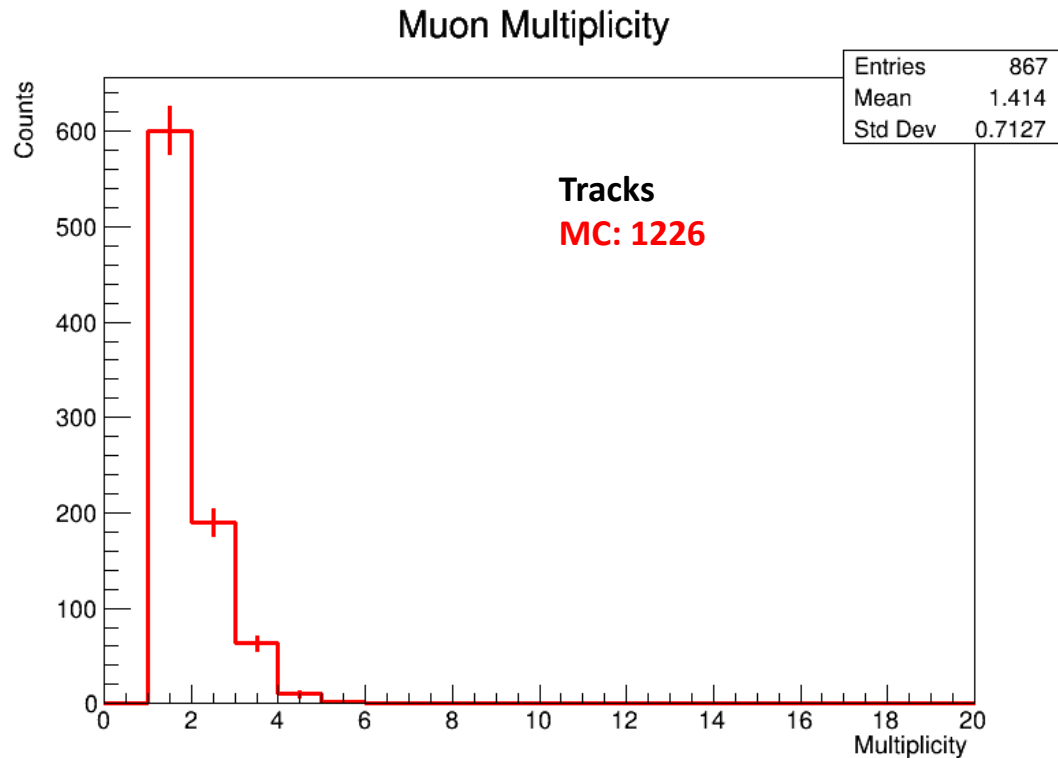
➢ Positive Cathode
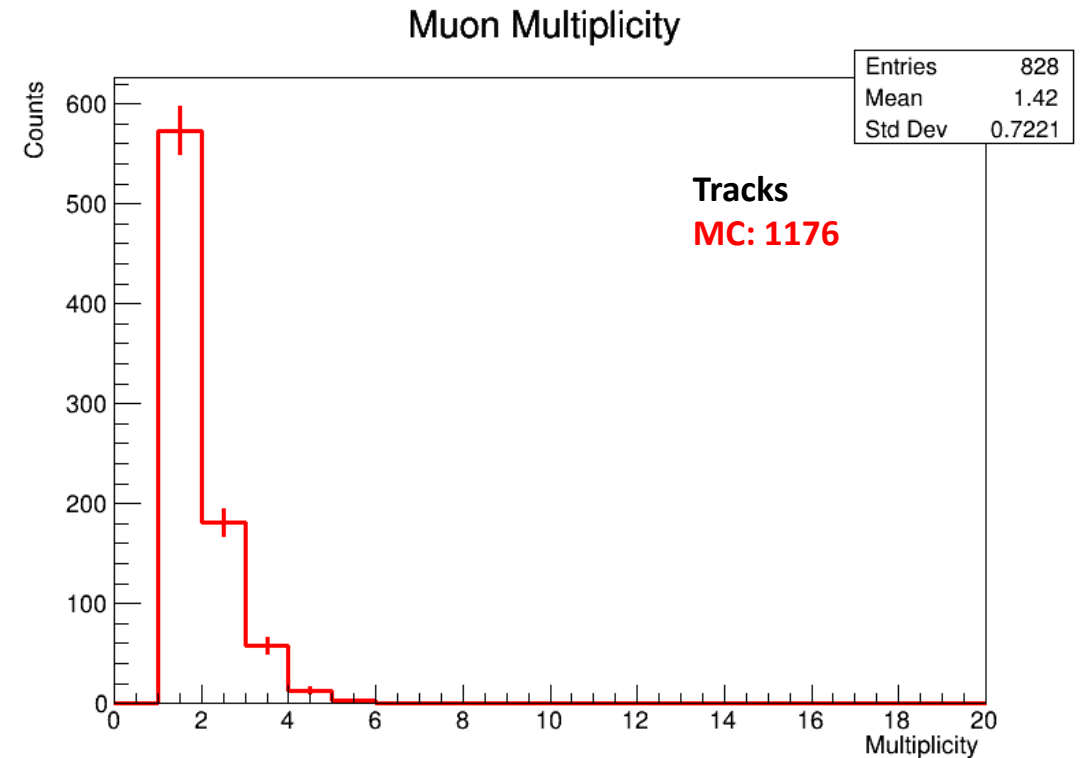
# Summary

➢ Studied the $2 \times 2$ multiplicity events with the latest measured data and reconstructed simulation (MiniRun6.1) with the existing event selection.

➢ Stats are low but presented reconstructed distributions provide a guidance on what to expect from next run of $2 \times 2$ measured data.

➢ Some interesting features are observed at cathode location, and we started to look at them.

➢ Our plans are to:

- Relax existing cuts and optimize the selection.
- hand scan these events in the SPINE Flow files and traceback to their truth counterparts.

# Backup Slides