

# TRACK MULTIPLICITY ANALYSIS UPDATE

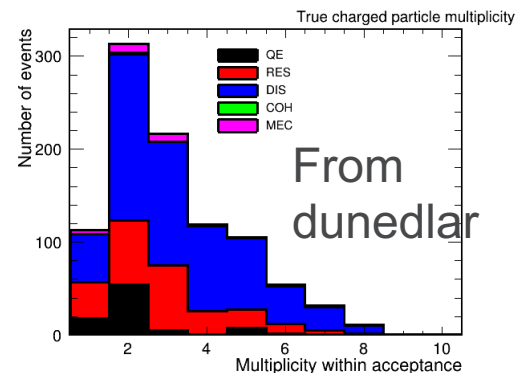
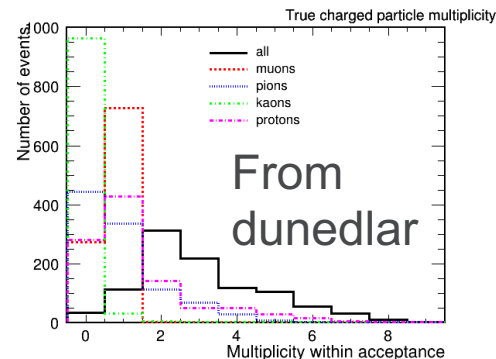
ALEENA FOR THE TRACK MULTIPLICITY GROUP  
2x2 first analysis meeting

# OVERVIEW

- We have performed truth-based analysis of track multiplicity within analysis acceptance using the official flow files
- We have been working on validating the preliminary reconstruction file from Pandora team
- We are also performing the neutrino energy estimation analysis

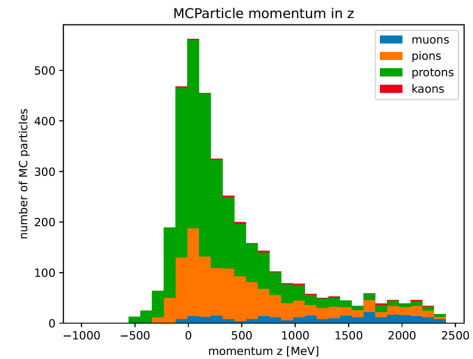
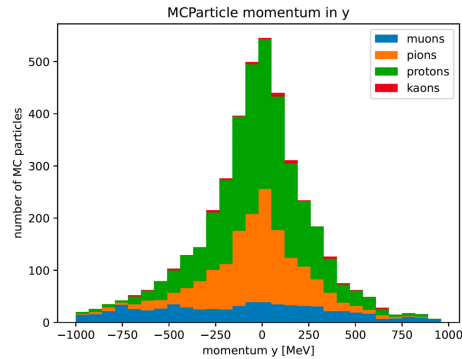
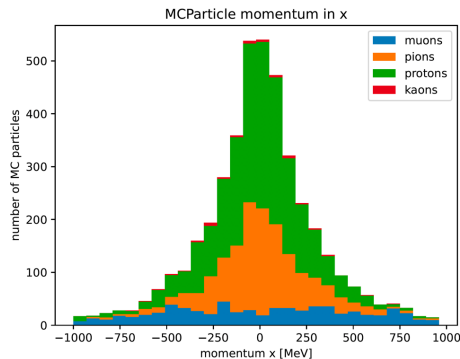
# MULTIPLICITY WITHIN ACCEPTANCE

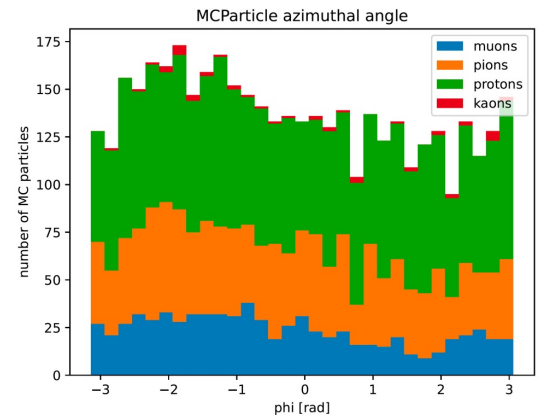
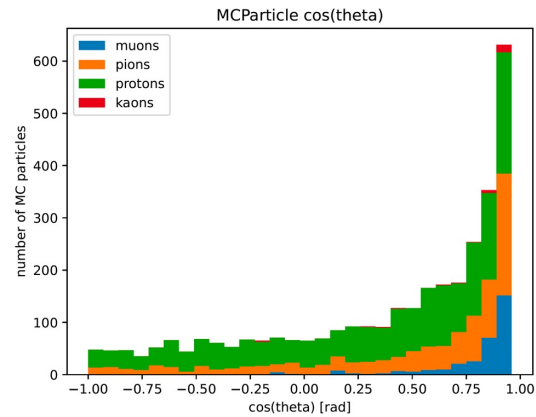
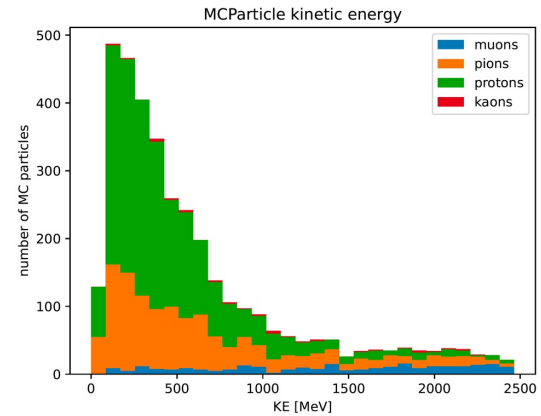
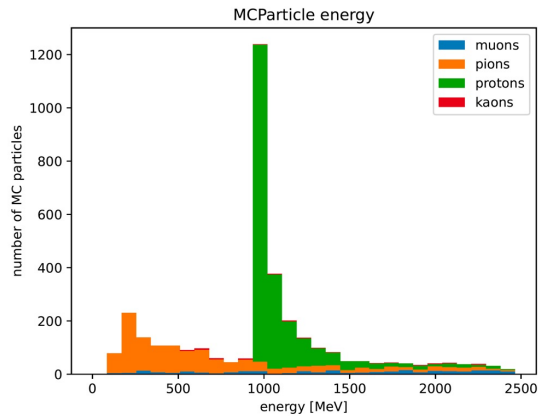
- We present kinematics and multiplicity plots within analysis acceptance using official 2x2 flow files.
  - Previously, we presented multiplicity within acceptance using “dunendlar” package.
- Input files:
  - MicroRun 3.1: 1E18 POT FHC, GENIE 3.4
  - Location:
    - /pnfs/dune/tape\_backed/users/mkramer/prod/MicroRun3.1/MicroRun3.1\_1E18\_FHC.flow
  - Looking at the following datasets
    - “**mc\_truth/interactions**” one entry per neutrino interaction
    - “**mc\_truth/stack**” one entry per mc particle (only available in the latest production sample)



# INITIAL SELECTION

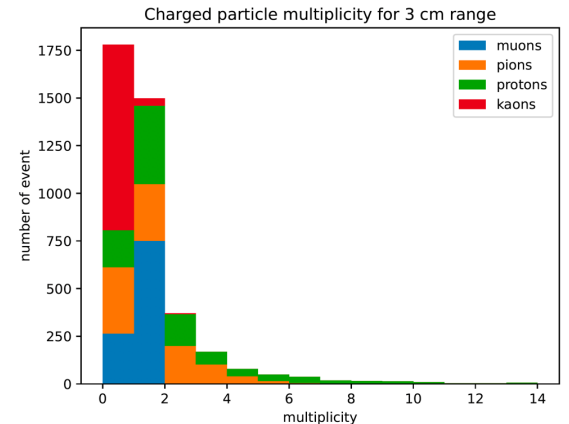
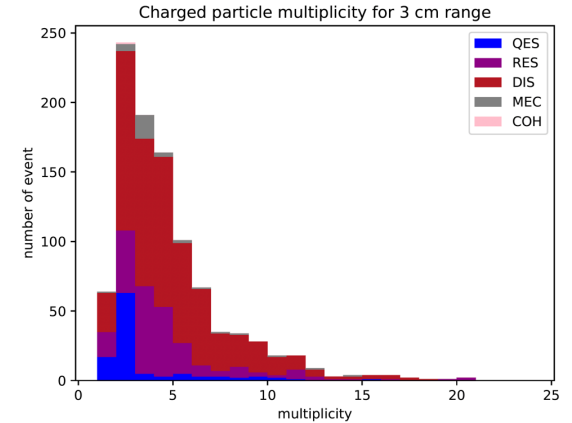
- Loop over neutrino vertices and make sure that the vertex is within fiducial volume of  $2 \times 2$
- For the same interactions, loop over MC particles and only select  $\mu^\pm, \pi^\pm, K^\pm, p$
- The energy, momentum and angular plots are presented in the following slides
  - We show quantities as per particle type





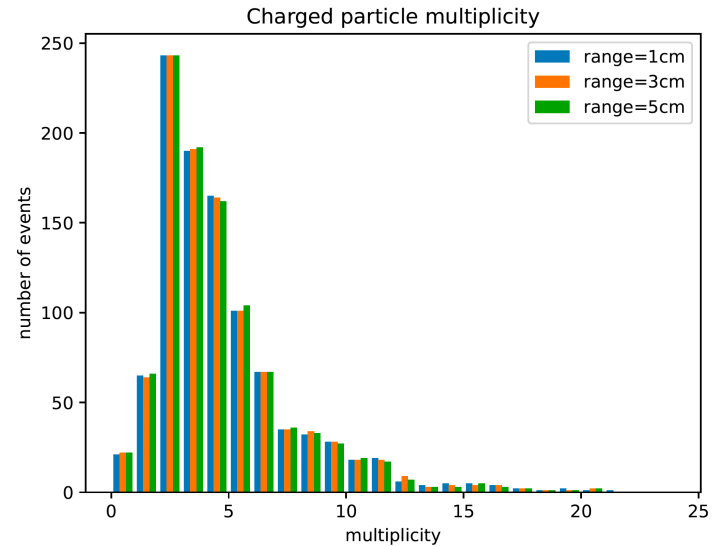
# ACCEPTANCE FOR MULTIPLICITY DISTRIBUTIONS

- For the analysis acceptance, there should be a well-defined particle-type-dependent KE threshold applied to particles that are included in the multiplicity distribution.
  - For details, see:  
[https://indico.fnal.gov/event/59212/contributions/263828/attachments/165722/220257/CPM\\_04062023.pdf](https://indico.fnal.gov/event/59212/contributions/263828/attachments/165722/220257/CPM_04062023.pdf)
- We compare the minimum range for different particles and convert range  $\rightarrow$  KE for different particles



# ACCEPTANCE FOR MULTIPLICITY DISTRIBUTIONS (CONT.)

- Comparison for different ranges is shown here
- For details, see: <https://docs.dunescience.org/cgi-bin/sso/ShowDocument?docid=28706>
- In the near-term future, we plan to redo this analysis for RHC mode sample, once available

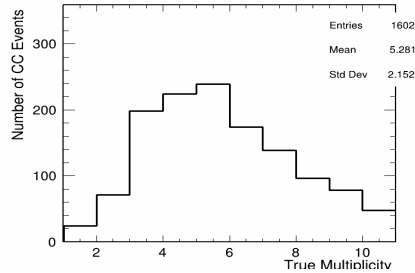


# TRUE MULTIPLICITY STUDIES

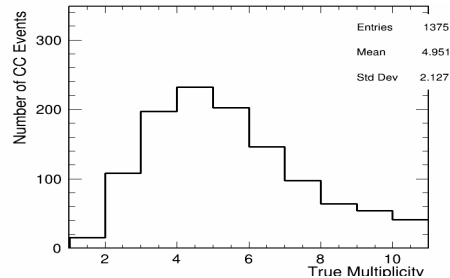
Bilal, Zelimir, Aleena  
et al.

- Characterized expected true multiplicity in terms of numbers i.e., number of events per neutrino interaction type and its multiplicity, for FHC and RHC.
- Contains muon, kaons, pions, neutral pions, protons and neutrons

-FHC Mode (MCP KE > 50 MeV cut)



-RHC Mode (MCP KE > 50 MeV cut)

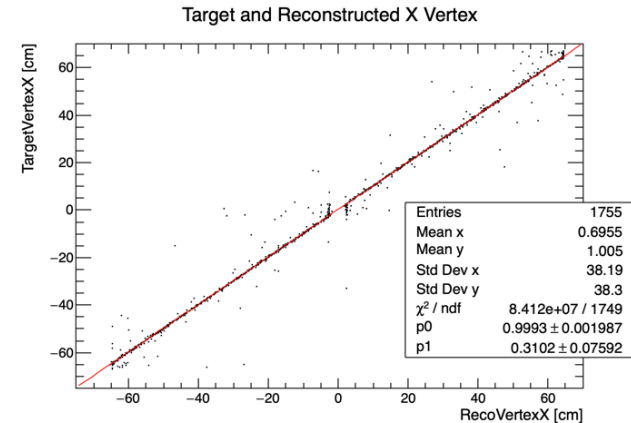
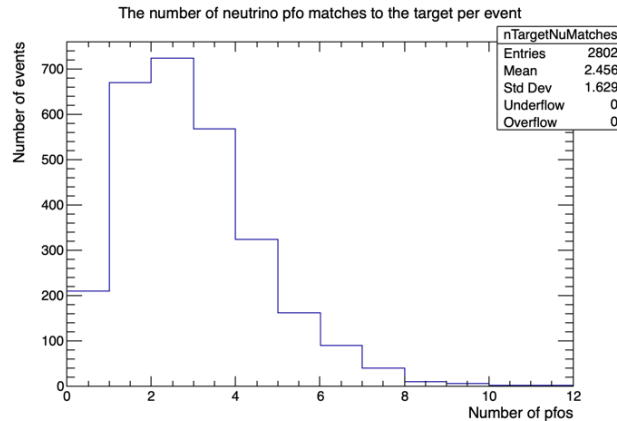


| Neutrino Mode                  | CC Events | Average Multiplicity | Expected FS Particles |
|--------------------------------|-----------|----------------------|-----------------------|
| FHC Mode (no cut)              | 2233      | 5.2                  | ~11,000               |
| FHC Mode (MCP KE > 50 MeV cut) | 1602      | 5.2                  | ~8,300                |
| RHC Mode (no cut)              | 2115      | 4.9                  | ~10,000               |
| RHC Mode (MCP KE > 50 MeV cut) | 1375      | 4.9                  | ~6,700                |



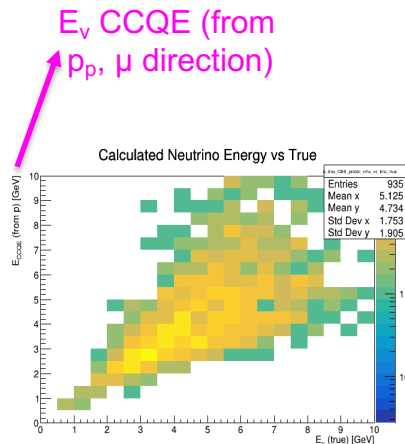
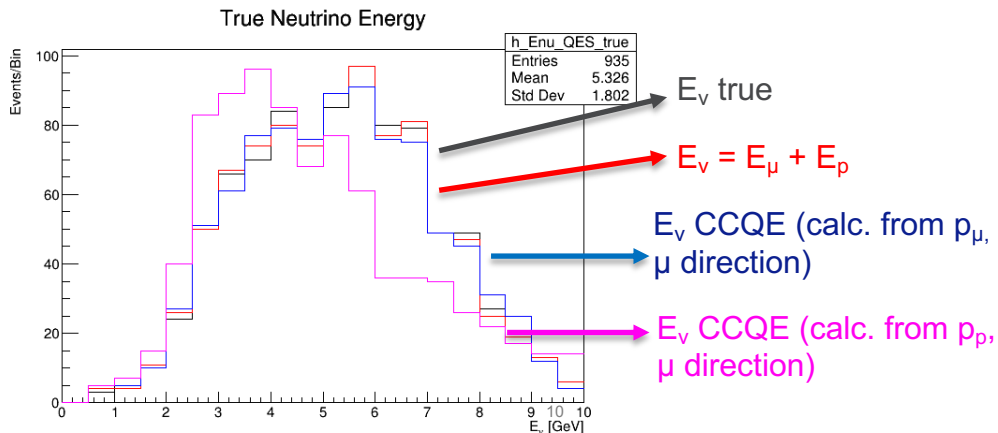
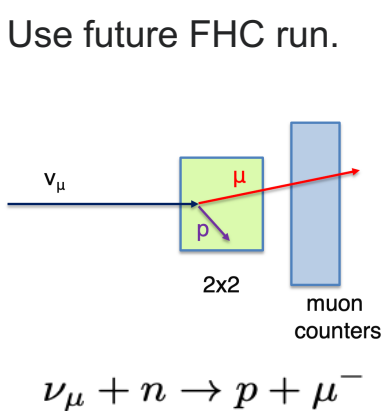
# RECO VALIDATION STUDIES

- A preliminary reco validation file has been provided (Thanks Pandora team and Richie!)
  - **Location:** /pnfs/dune/persistent/users/rdiurba/Validation\_both\_RHC\_withSkips\_RHC\_0-3011.root
  - For detailed plots, please see: <https://docs.dunescience.org/cgi-bin/sso/ShowDocument?docid=28706>
  - Future plan is to look into the official reco validation samples and the CAF files.

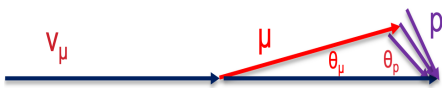


# NEUTRINO ENERGY ESTIMATION STUDIES

- Inspiration from our multiplicity studies.
- Started working on the possibility to estimate neutrino energy with 2x2 LArTPC alone.
- Use future FHC run.



- Energy estimated with muon  $E_{CCQE}$  (from  $\mu$ ) is correlated with true  $E_{\nu}$ ; however, we do not contain muon momentum/energy with 2x2 LArTPC.
- Assuming we reconstruct proton momentum ( $p_p$ ), proton angle ( $\cos\theta_p$ ), muon angle ( $\cos\theta_{\mu}$ ):



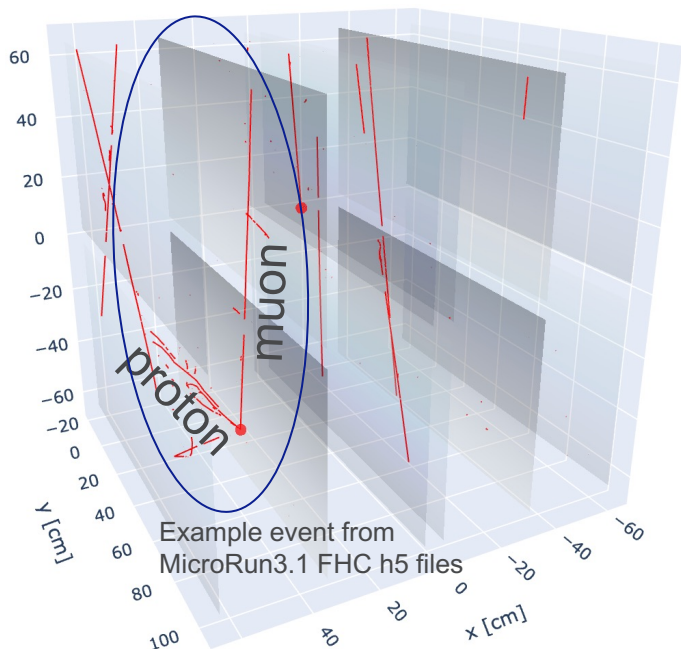
$$p_{\mu}(calc) = \frac{p_p \sin \theta_p}{\sin \theta_{\mu}}$$

$$E_{\nu} = \frac{-2E_{\mu}(calc)m_n - m_p^2 + m_{\mu}^2 + m_n^2}{2(E_{\mu}(calc) - m_n - p_{\mu}(calc) \cos \theta_{\mu})}$$

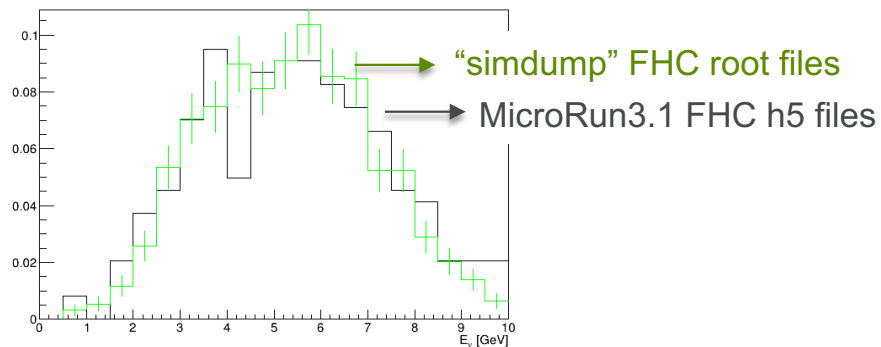
$E_{\nu}$  CCQE (from  $p_p, \mu$  direction)

# NEUTRINO ENERGY ESTIMATION STUDIES (CONT.)

- Used/validated 256 MicroRun3.1 FHC h5 files (thanks to Matt Kramer!)

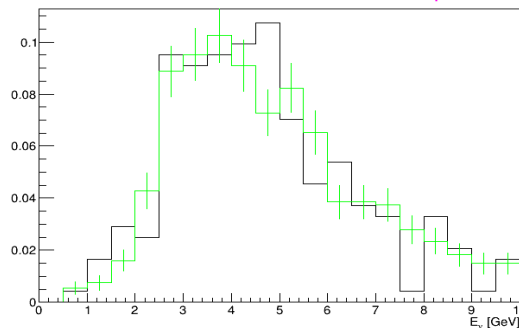


True Neutrino Energy



$E_\nu$  CCQE (from  $p_p, \mu$  direction)

Calculated Neutrino Energy



- Writing first technote on these preliminary studies.

# SUMMARY

- Our group is performing studies on various sub-topics
  - Truth-based analysis studies
  - Reconstruction validation studies
  - Neutrino energy estimation
- Will perform reconstructed event selection once obtain CAF files
- Performing generator level studies using nusystematics
  - An update will be provided in an upcoming meeting

# THANK YOU!



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