Electromagnetic Energy Reconstruction in ProtoDUNE

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On behalf of the DUNE Collaboration
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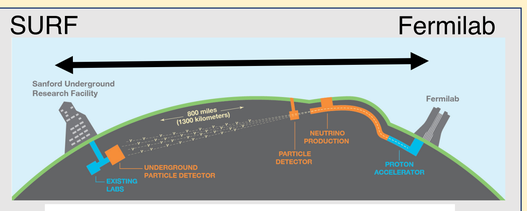
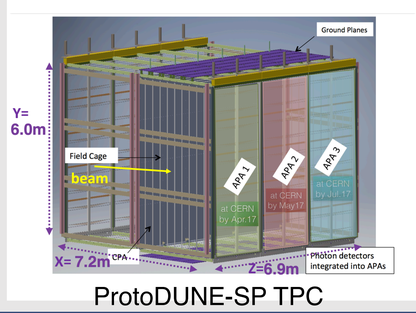
1. DUNE/ProtoDUNE Experiment

DUNE:
- 1300 km baseline
- 70 kton Liquid Argon Time Projection Chamber (LArTPC) Far Detector (FD) at SURF, South Dakota, 1.5 km underground [1]
- Multiple technologies for the Near Detector (ND) at Fermilab
- Will measure neutrino oscillation probability to determine mass ordering and CP violation phase; potential for BSM physics and supernova neutrinos

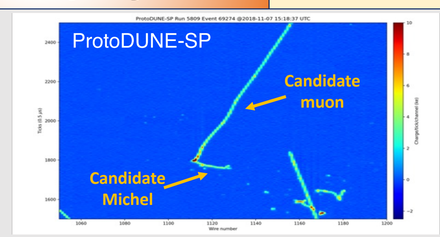
ProtoDUNE-single phase:
- ~7×6×7 m^3 in charged particle test beam at CERN
- A crucial part of the DUNE effort towards the construction of the first DUNE far detector module
- ProtoDUNE-SP I operated from September 2018 to July 2020



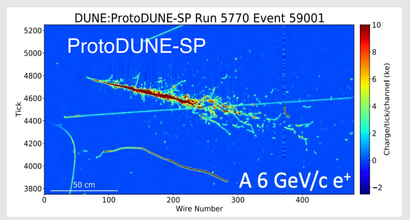


ProtoDUNE-SP TPC

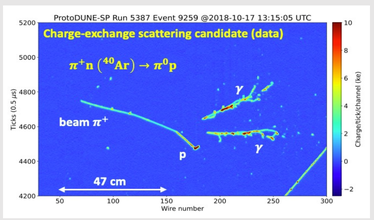
2. Event Displays



Michel electron event

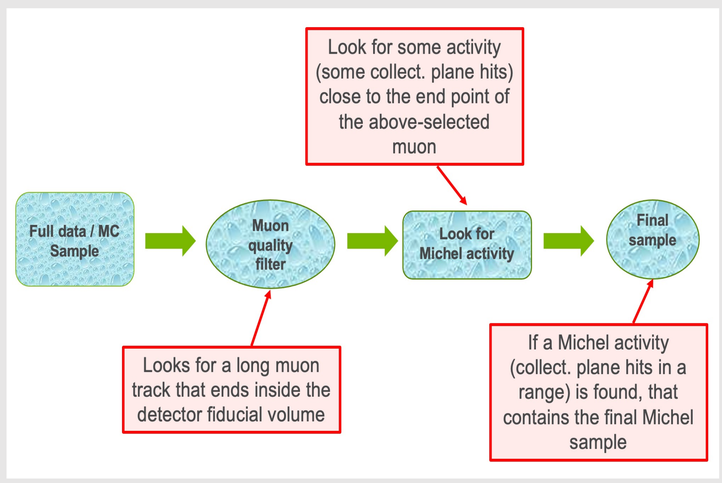


Beam electron event



Neutral pion event

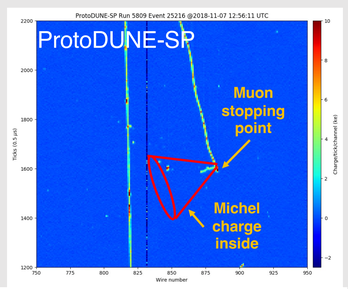
3. Michel Electron: Selection



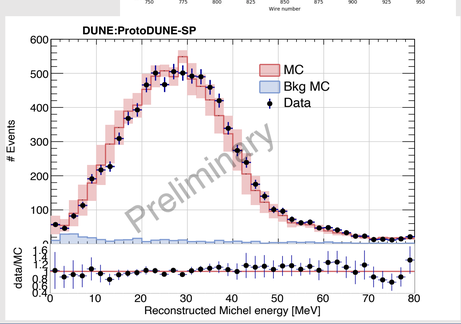
Sample purity ~ 95%

4. Reconstruction

All hits confined inside a cone at the end point of the parent muon are taken to be Michel hits.
Reconstructed Michel energy spectrum is derived using stopping muon calibration [2].



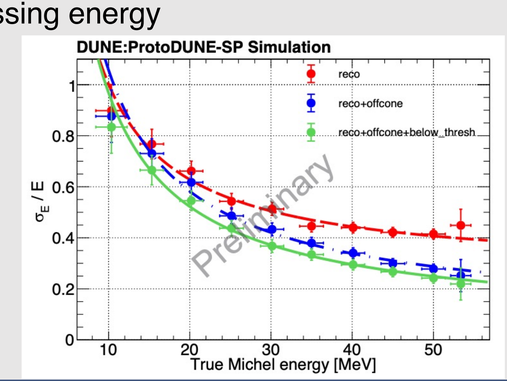
➤ Accuracy of the reconstructed Michel energy spectrum is > 98%



5. Resolution

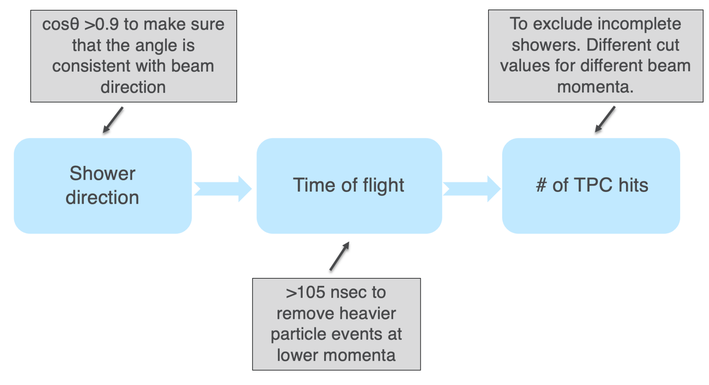
➤ Michel resolution is parametrized by: $\frac{\sigma(E)}{E} = p_0 \oplus \frac{p_1}{\sqrt{E}} \oplus \frac{p_2}{E}$

➤ The energy resolution improves after adding the reconstructed missing energy contributions (outside Michel cone and below hit reco threshold energies)
➤ The constant term captures the resolution losses due to the missing energy



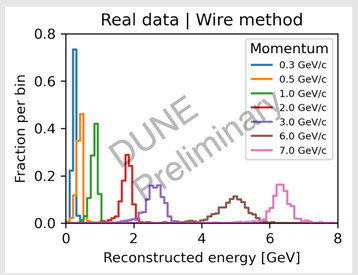
6. Beam Electron: Selection

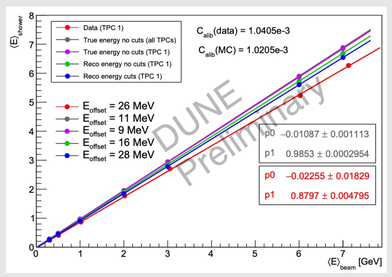
➤ Beam electron selection flow chart



7. Reconstruction

➤ Selected runs with different beam momentum values
➤ Evaluated the reconstructed electron shower energies
➤ Linear correlation between electron beam momentum and shower energy shows linear response of TPC to electron beams



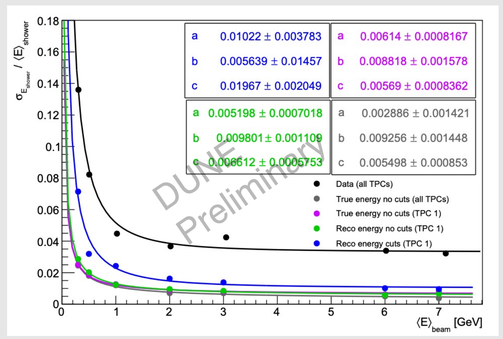


8. Resolution

➤ Beam electron resolution is parametrized by:

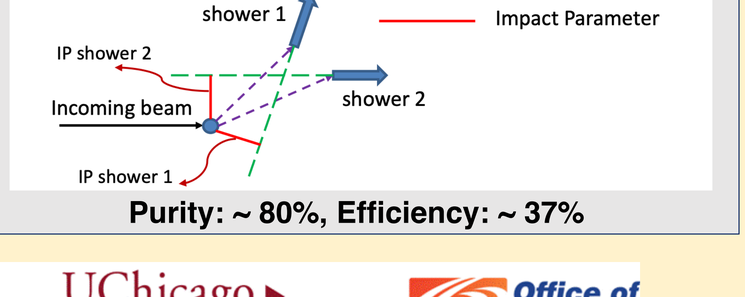
$$\sigma_E / E = \sqrt{a^2 + (b/\sqrt{E})^2 + (c/E)^2}$$

➤ True energy resolution for 1 GeV (1.2%, gray plot) comparable to values found in other simulations for liquid argon (e.g. 1.68% in [3])



9. Neutral pion: Selection

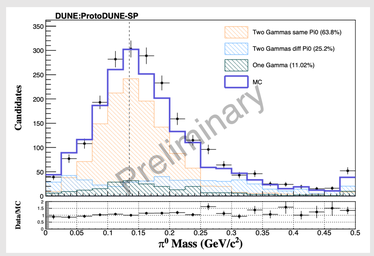
➤ 1 GeV beam sample
➤ EM CNN score > 0.5: Remove track-like daughter particles
➤ # hits (total) > 80: Remove low completeness showers
➤ 3 cm < dist. < 90 cm: Remove charged pions and muons
➤ IP < 20 cm: Remove low completeness showers



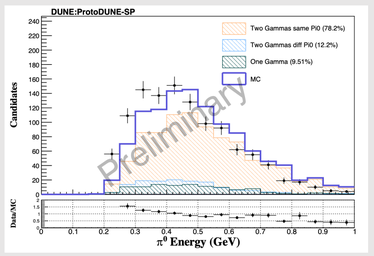
Purity: ~ 80%, Efficiency: ~ 37%

10. Reconstruction

➤ π^0 mass distribution after correcting for the negative bias (-15%) in the reconstructed shower energy

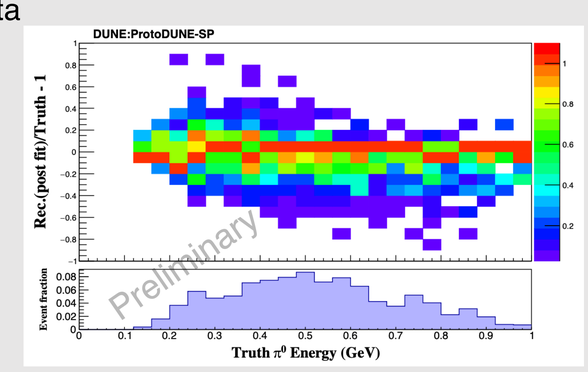


➤ The energy spectrum of reconstructed neutral pion after selections and kinematic fitting is also plotted



11. Resolution

➤ The resolution for the neutral pion energy as a function of true energy after correction and kinematic fitting is presented
➤ The analysis will be updated after including more data



[1]: JINST 15, no. 08, T08008 (2020)
[2]: JINST 15, no. 12, P12004 (2020)
[3]: Doke et al., Nucl. Instrum. Methods A 237 (1985) 475.