Identification and Reconstruction of Low-energy electrons in ProtoDUNE-SP detector

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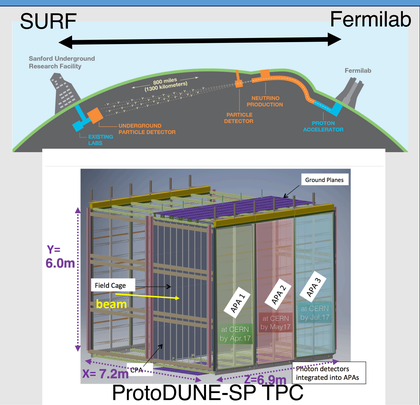
1. Motivations

➤ Key demonstration for DUNE electron selection and energy reconstruction and to demonstrate DUNE far detector capability to identify and reconstruct low-energy electron events.
➤ The analysis is important to show that ProtoDUNE can use the topological / calorimetric information provided by the TPC to identify a specific topology.

2. DUNE/ProtoDUNE Experiment

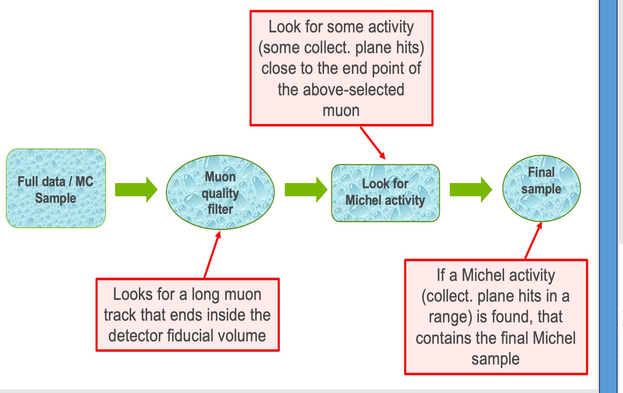
DUNE:
- 1300 km baseline
- 70 kton Liquid Argon Time Projection Chamber (LArTPC) Far Detector (FD) at SURF, South Dakota, 1.5 km underground
- Multiple technologies for the Near Detector (ND) at Fermilab
- Will measure neutrino oscillation probability to determine mass ordering and CP violation phase;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

ProtoDUNE-single phase:
- ~7×6×7 m^3 in charged 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

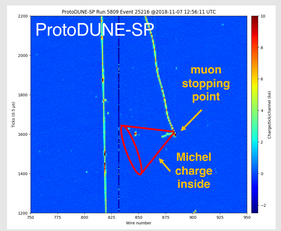
3. Event Selection

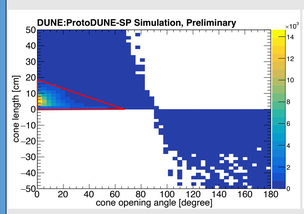


Sample purity ~ 95%

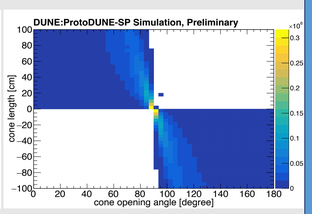
4. Michel Reconstruction

All hits confined inside a cone at the end point of the parent muon are taken to be Michel hits





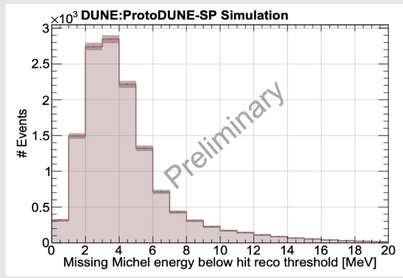
True Michel reco hits

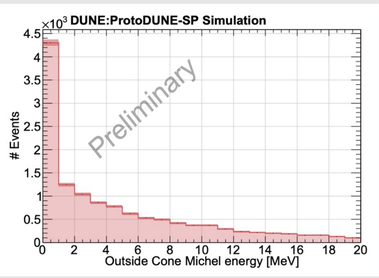


Other hits of the event

5. Missing Michel Energy

➤ ~24% of Michel true energy is missing
➤ Due to the hit reconstruction threshold, we lose 11% of the Michel energy
➤ Due to the hits outside Michel cone, we lose 13% of the Michel energy
➤ After adding both missing contributions, we retrieve all of the Michel energy

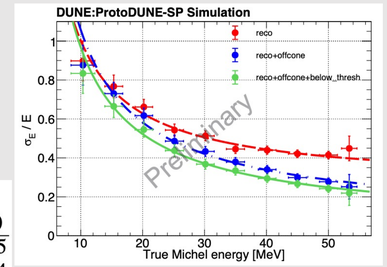




6. Michel Energy Resolution

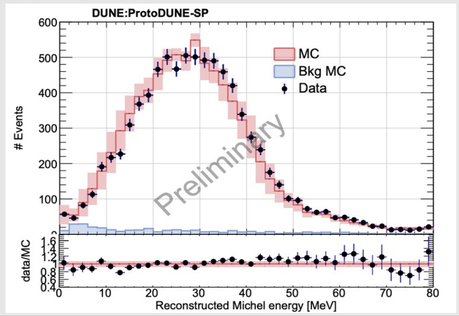
➤ Michel resolution is parametrized by: $\frac{\sigma(E)}{E} = p_0 \oplus \frac{p_1}{\sqrt{E}} \oplus \frac{p_2}{E}$
➤ The energy resolution improves after adding both missing energy contributions
➤ The constant term captures fluctuations in the missing energy After recovering the missing energy, the fluctuations become negligible.

Energy reconstruction	Energy resolution terms		
	Constant (p_0)	Stochastic (p_1)	Noise (p_2)
Cosmic muon-based nominal E-reconstruction	0.26 ± 0.12	1.91 ± 0.93	7.54 ± 3.05
Nominal with recovered missing energy (MC only)	0.00 ± 0.15	1.24 ± 0.22	8.86 ± 0.94



7. Michel Reconstructed Energy

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



8. Conclusions and Future Direction

➤ Developed Michel selection, reconstruction, and energy calibration tools important for DUNE LArTPCs.
-- Achieved 95% event purity
-- Michel electron energy accuracy is >98%
➤ Identified the major sources of the missing energy
➤ Characterized the Michel energy resolution
➤ Michel paper will soon be sent out to the collaboration for a review

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