Low-energy electron data analysis for DUNE

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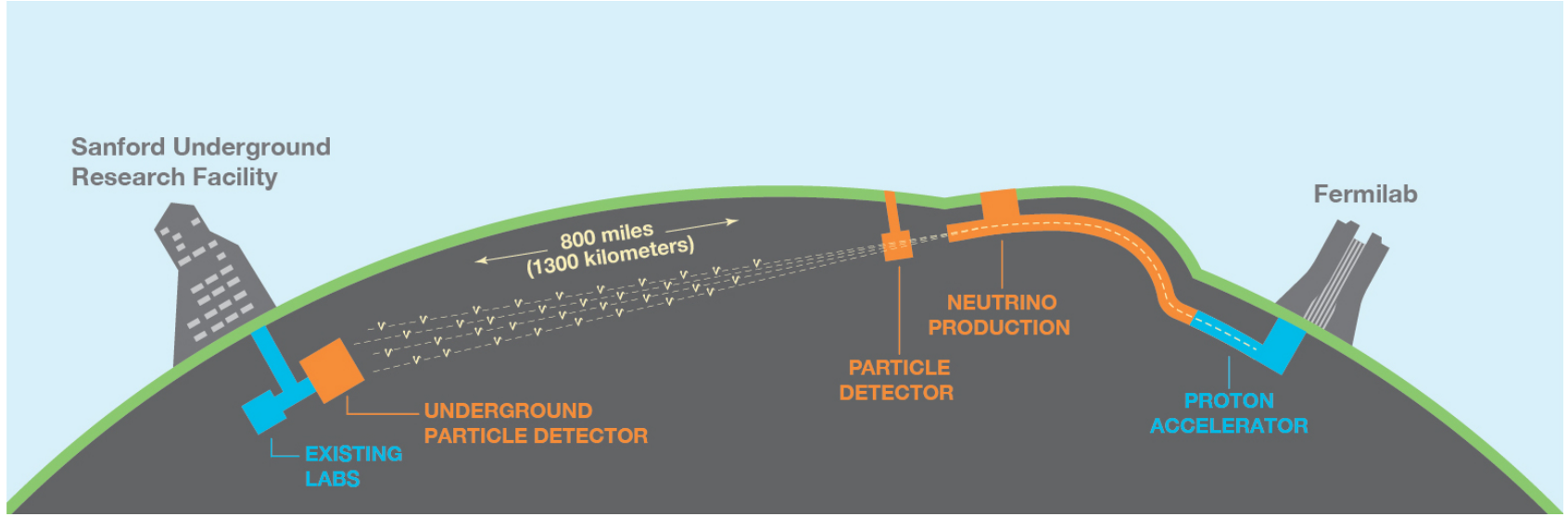
Argonne NATIONAL LABORATORY

DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

Deep Underground Neutrino Experiment (DUNE)



DUNE will be a world-class neutrino observatory

- 1300 km baseline
- Consists of a large LArTPC far (40 kTon) and near detectors
- A broad and rich physics program: Neutrino oscillations, CP violation searches in the neutrino sector, neutrino mass hierarchy, supernova neutrinos, baryon number violation searches
- The world's most intense neutrino beam from Fermilab
- A deep underground site, massive liquid argon detectors and a precision near detector

ProtoDUNE Single Phase

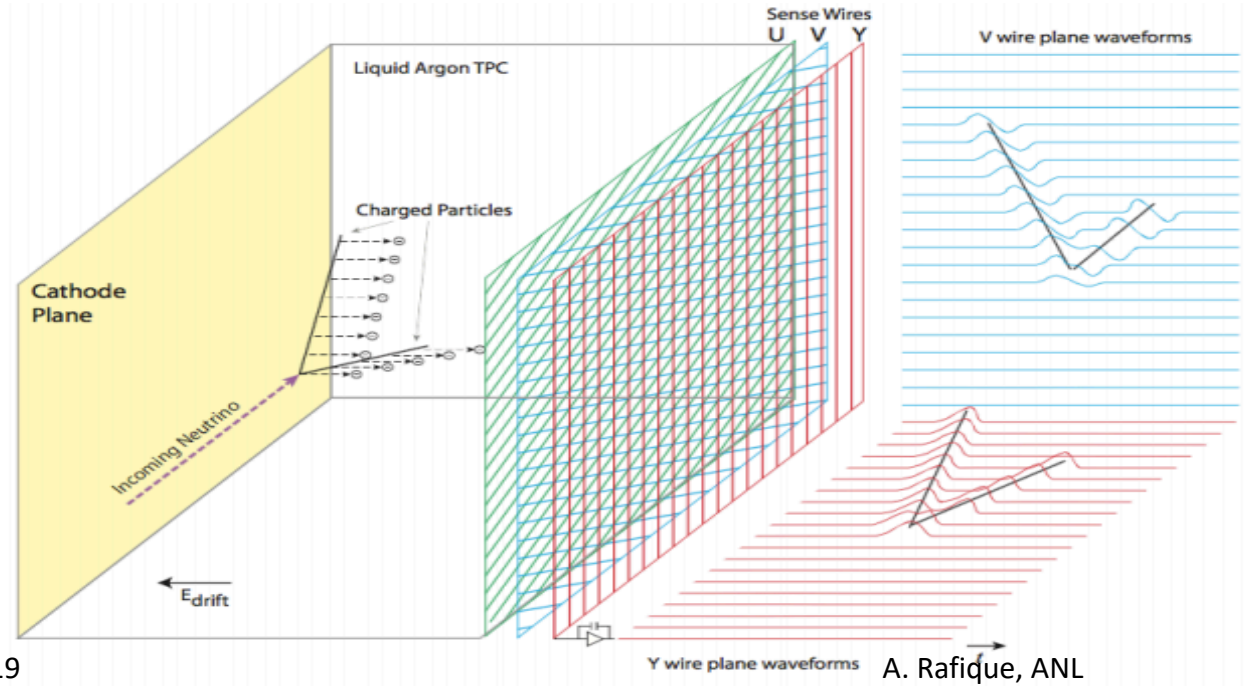
- ~7×6×7 m^3 (770 tons of LAr) in charged test beam at CERN
- ProtoDUNE-SP operating since September 2018
- Accumulating test-beam data to understand/calibrate response of detector to different particle species
- A crucial part of the DUNE effort towards the construction of the first DUNE
- Prototyping production and installation procedures for DUNE Far Detector Design
- Validating design from perspective of basic detector performance
- Demonstrating long term operational stability of the detector

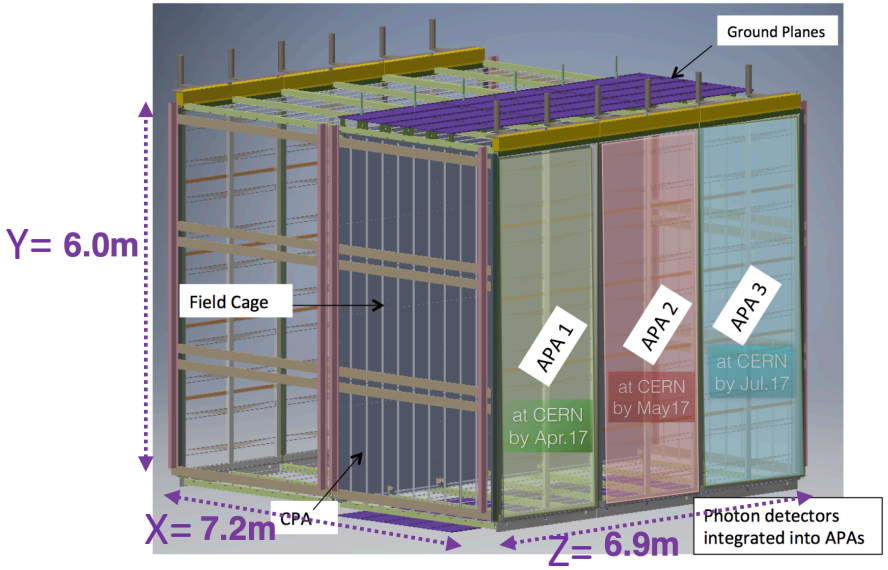
ProtoDUNE-SP at CERN neutrino platform

Principle of LArTPC

LArTPCs make 3D reconstruction possible.

- Wire planes give 2D position information
- The third dimension is obtained by combining timing information (t_0) with drift velocity (v_d) → hence, a "**Time projection chamber**"

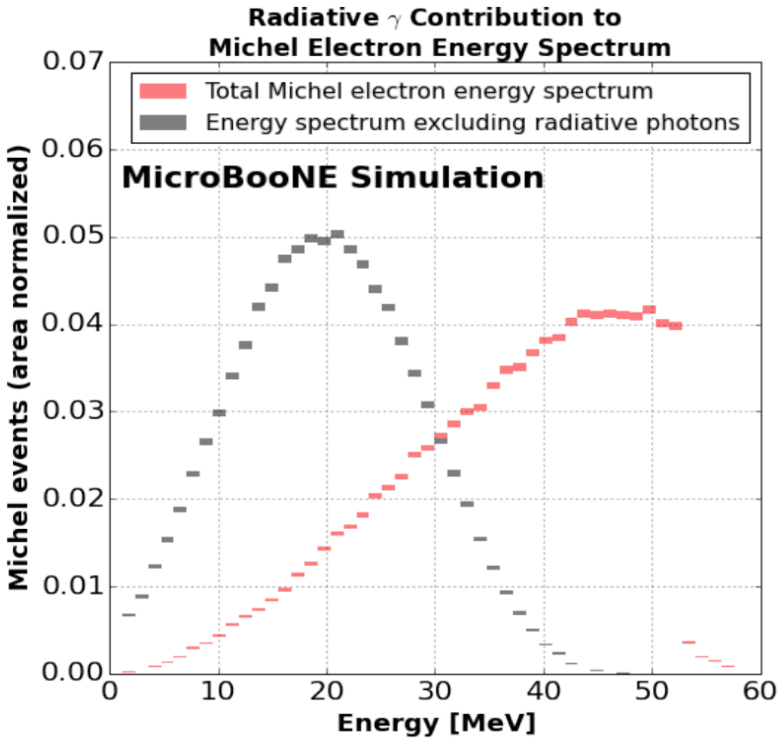




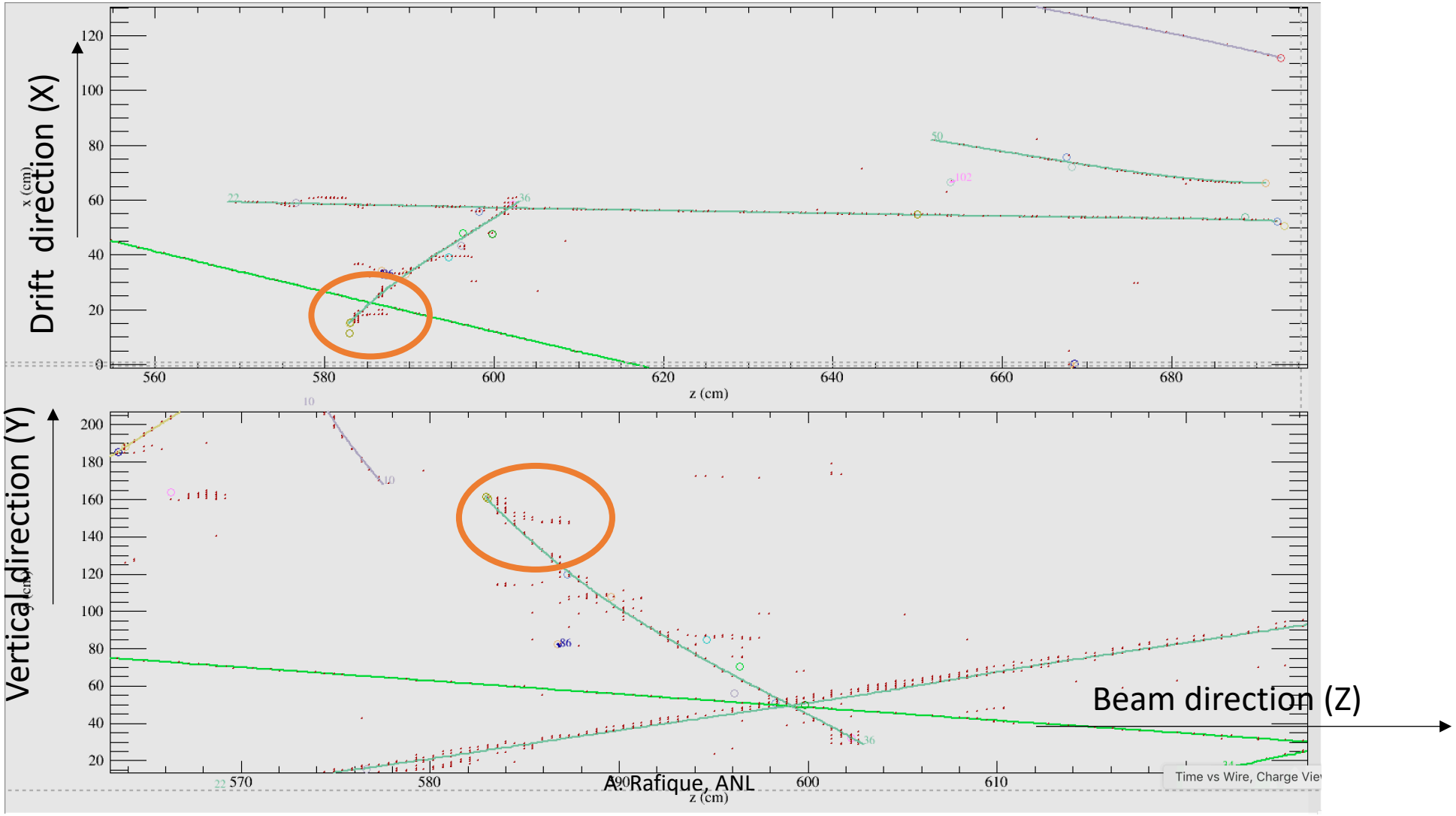
ProtoDUNE TPC

Michel electrons

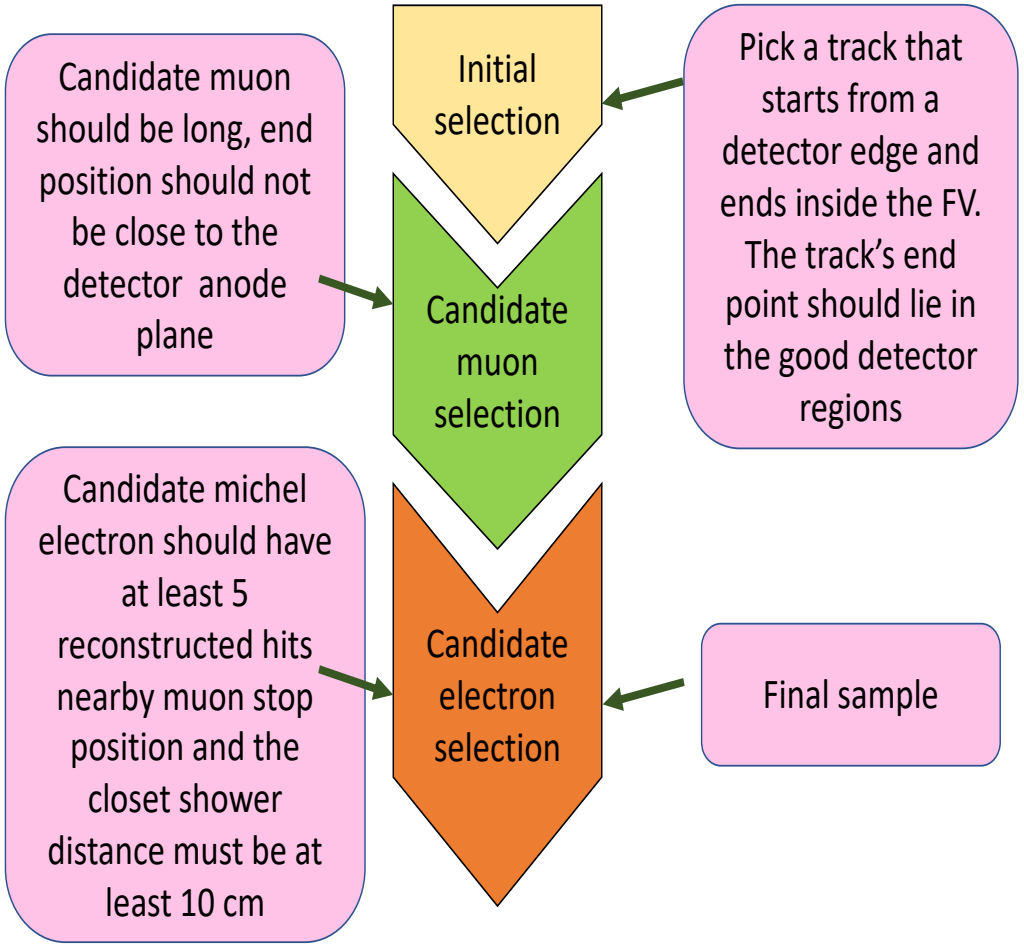
- Michel electrons are electrons from the decay of muons (0-50 MeV)
- Common channels (in ProtoDUNE):
  - $\mu^{+} \rightarrow e^{+} \bar{\nu}_{\mu} \nu_{e}$ (80%)
  - $\mu^{-} \rightarrow e^{-} \nu_{\mu} \bar{\nu}_{e} n\gamma$ (20%)
- Analysis makes use of low energy shower reconstruction– useful for many DUNE analyses
- Analysis goals:
  - Obtain michel electron energy spectrum
  - Correlate these events with the photon detector data



Michel event display in ProtoDUNE



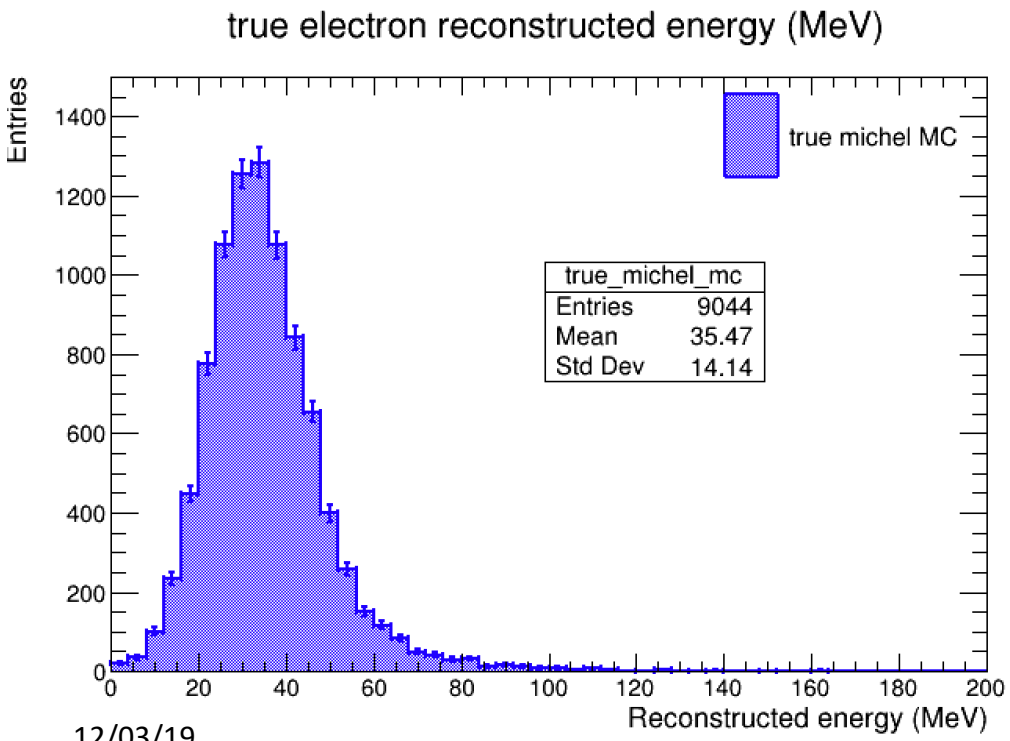
Michel event selection



Sample purity ~90%

Energy spectrum from true michel reconstructed hits

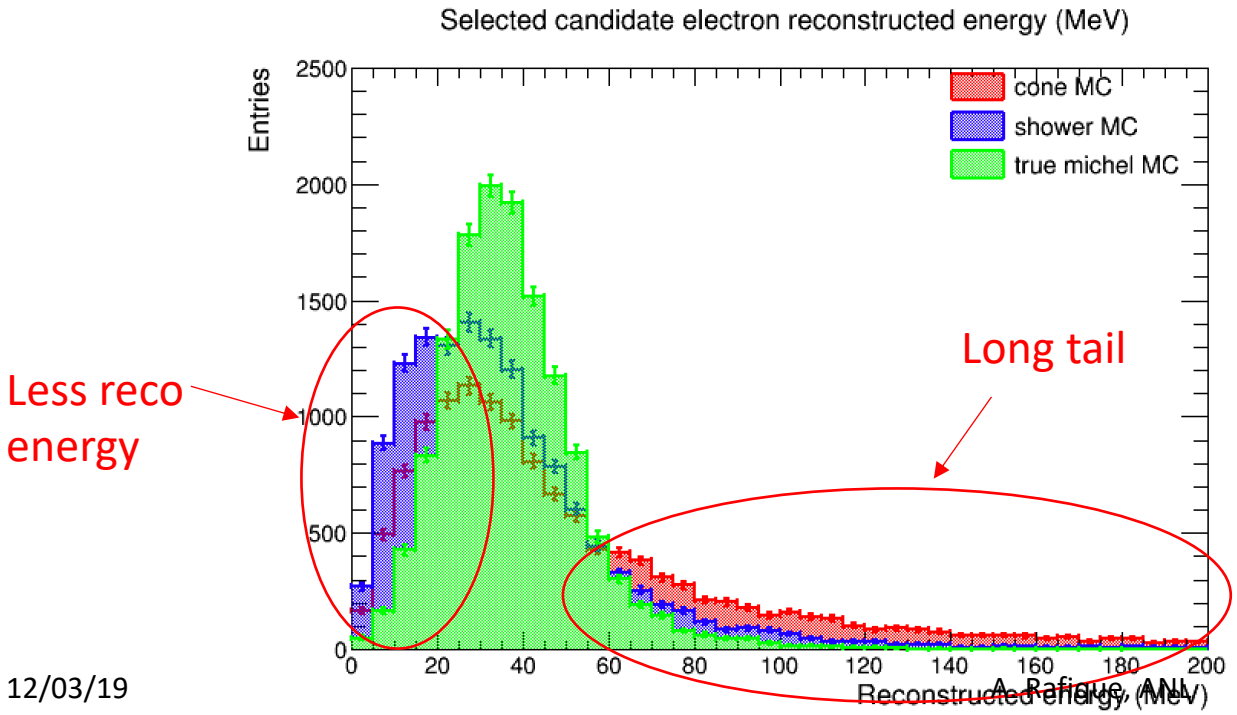
- $E = \sum_{i=coll.\,plane\ hits} \frac{Q_i * Cx * Cyz * Wion * Norm\_factor}{Calib\_const * Recomb\_factor}$

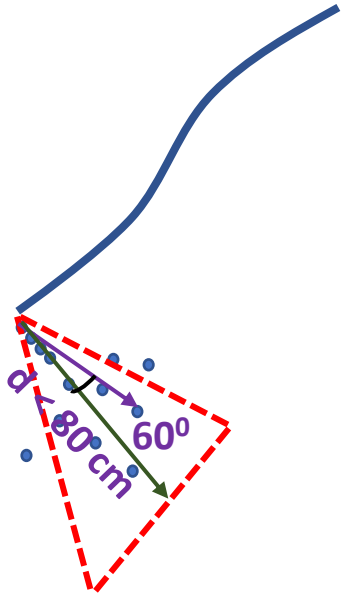


Where
Q_i = charge deposited on a hit
C_x, C_{yz} = correction factors, remove non-uniformity in dQdx values due to nonresponsive wires
Wion = 23.6e-6; from ArgoNeuT experiment
Norm_factor = normalizes the dQ/dx values to the dQ/dx at anode
Calib_const = converts dQ/dx in ADC/cm into dE/dx in MeV/cm
Recomb_factor = 0.7; to incorporate the recombination effects

Michel energy reconstruction

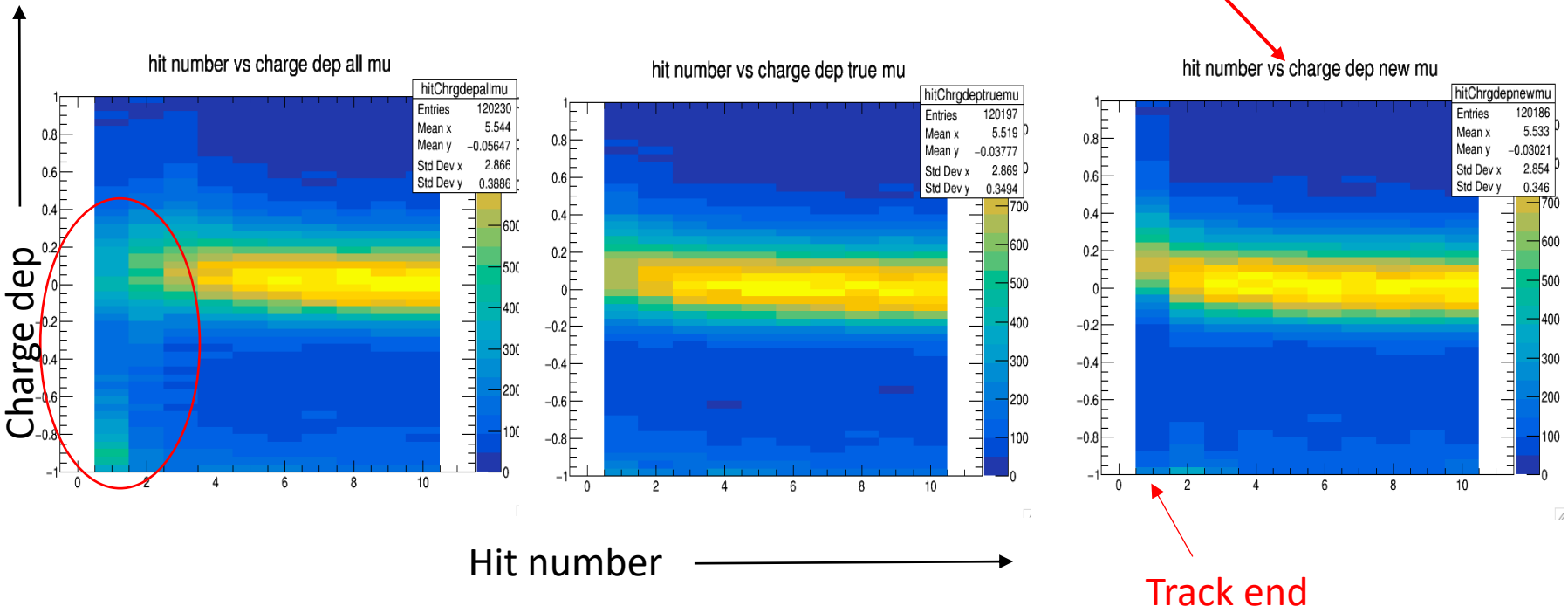
- Performed in two ways:
  - Nearest reconstructed shower energy from the corresponding reco hits
  - Construction of a cone with an opening angle and a length

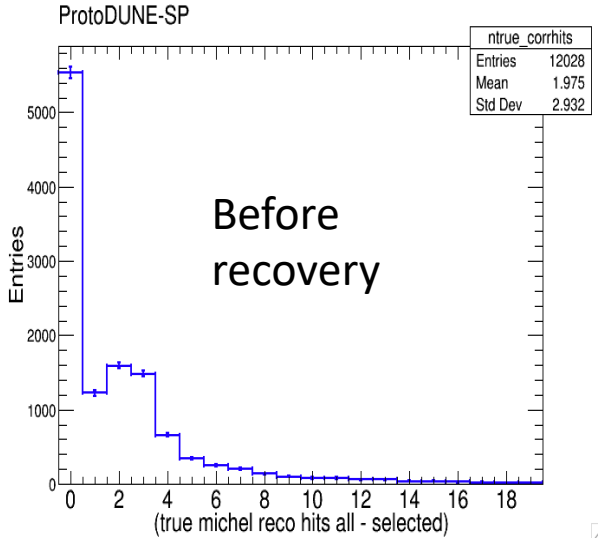


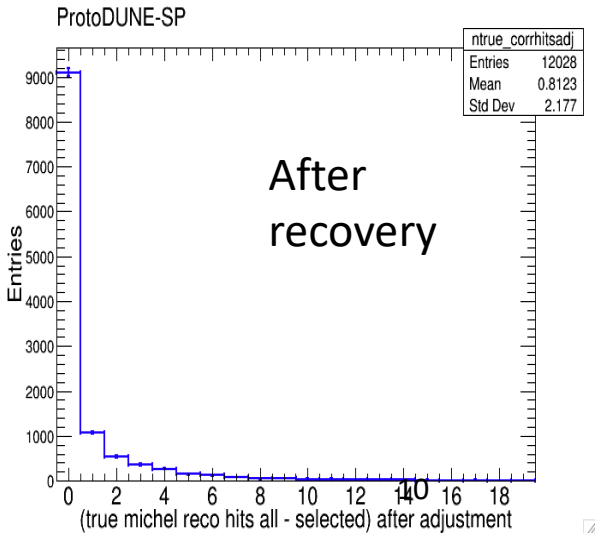


Recovering some michel hits from parent muon

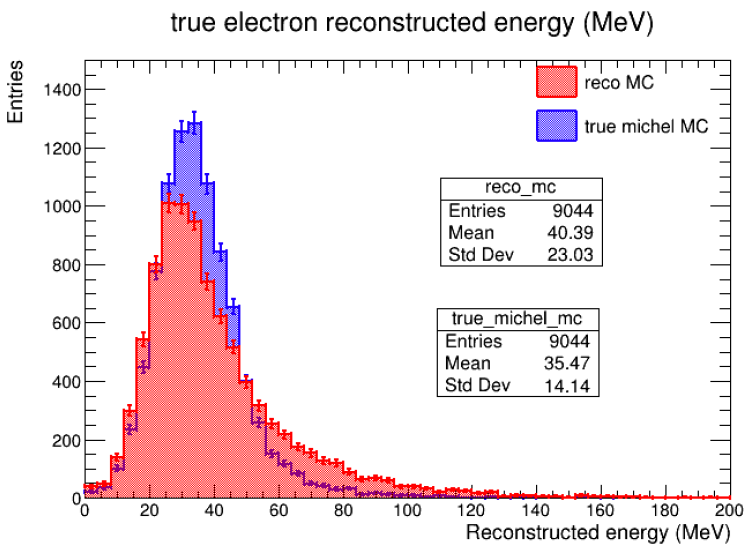
- Look at the charge deposition at the last 10 hits of reco muons
- Charge dep = $(Q_i - Q_{i-1})/Q_{i-1}$
- After removing hits beyond the maximum truncated charge value
  - Recovered 8% of the missing michel hits

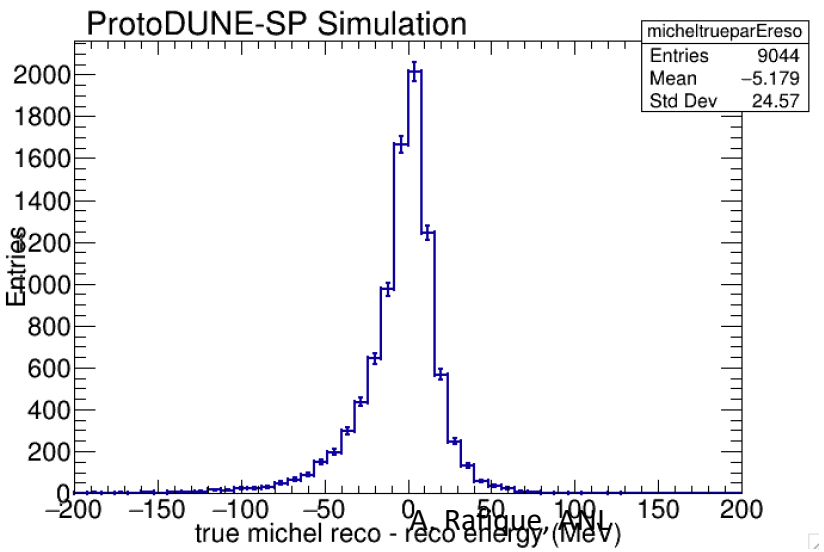


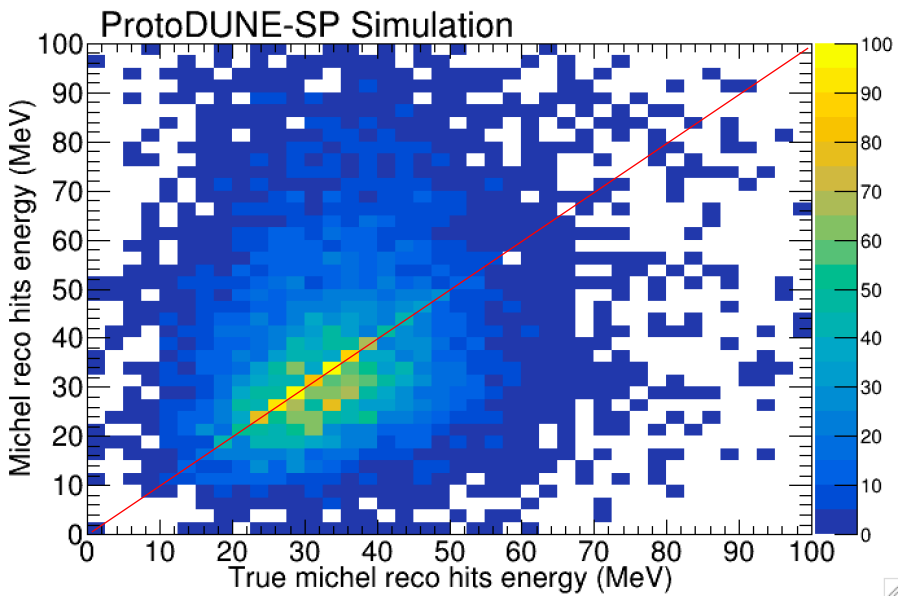




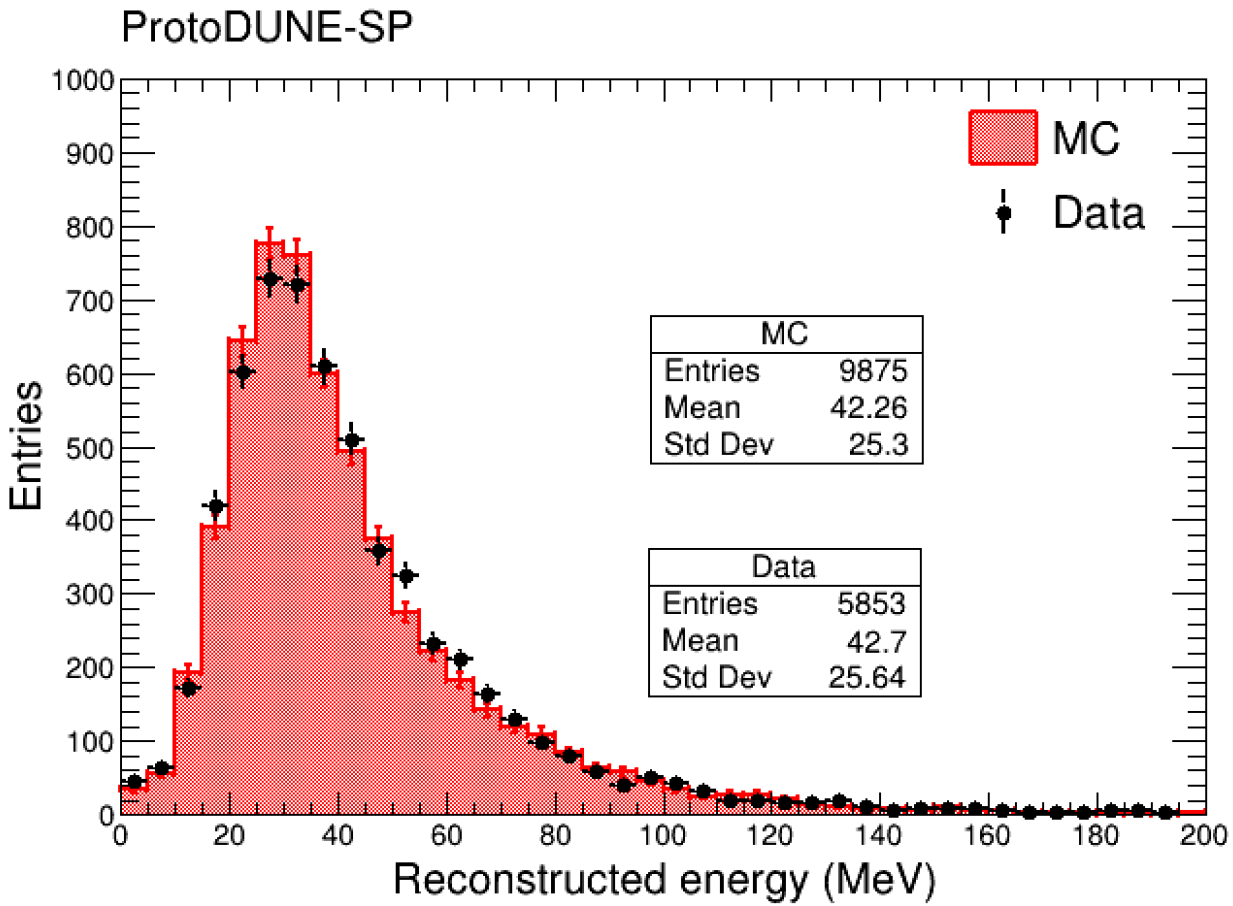
Michel energy spectrum in MC







Michel energy data and MC comparison



A very good agreement in ProtoDUNE data and simulation

Summary

- Obtained a pure sample of michel events in ProtoDUNE
- Were able to recover most of the michel hits
- Good data and MC agreement for the michel energy spectrum
- In the future, this study will include the observation and search for michel electrons in photon detector system of the ProtoDUNE experiment
- This study will present a ground to machine learning reconstruction techniques in ProtoDUNE