Michel Electron Reconstruction in DUNE

Aleena Rafique, Zelimir Djurcic

on behalf of the DUNE collaboration

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Argonne NATIONAL LABORATORY

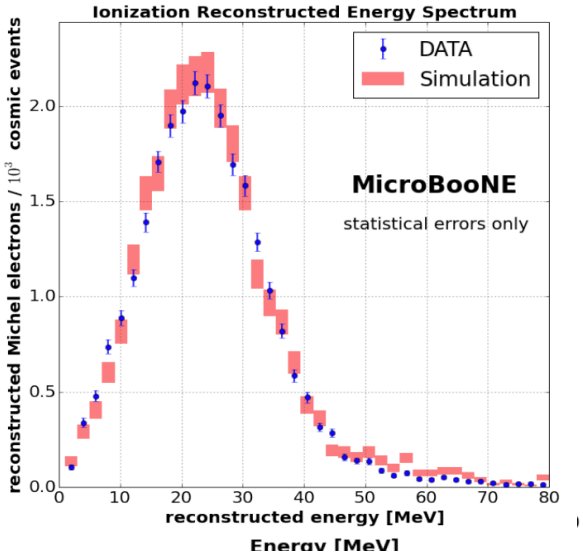
DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

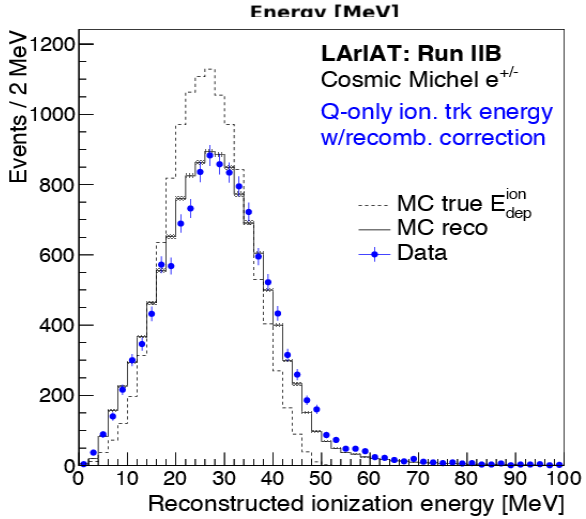
Outline

- Why study Michel electrons
- TPC Michel Reconstruction
- Energy Reconstruction and Michel Energy Spectrum
- Conclusions

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





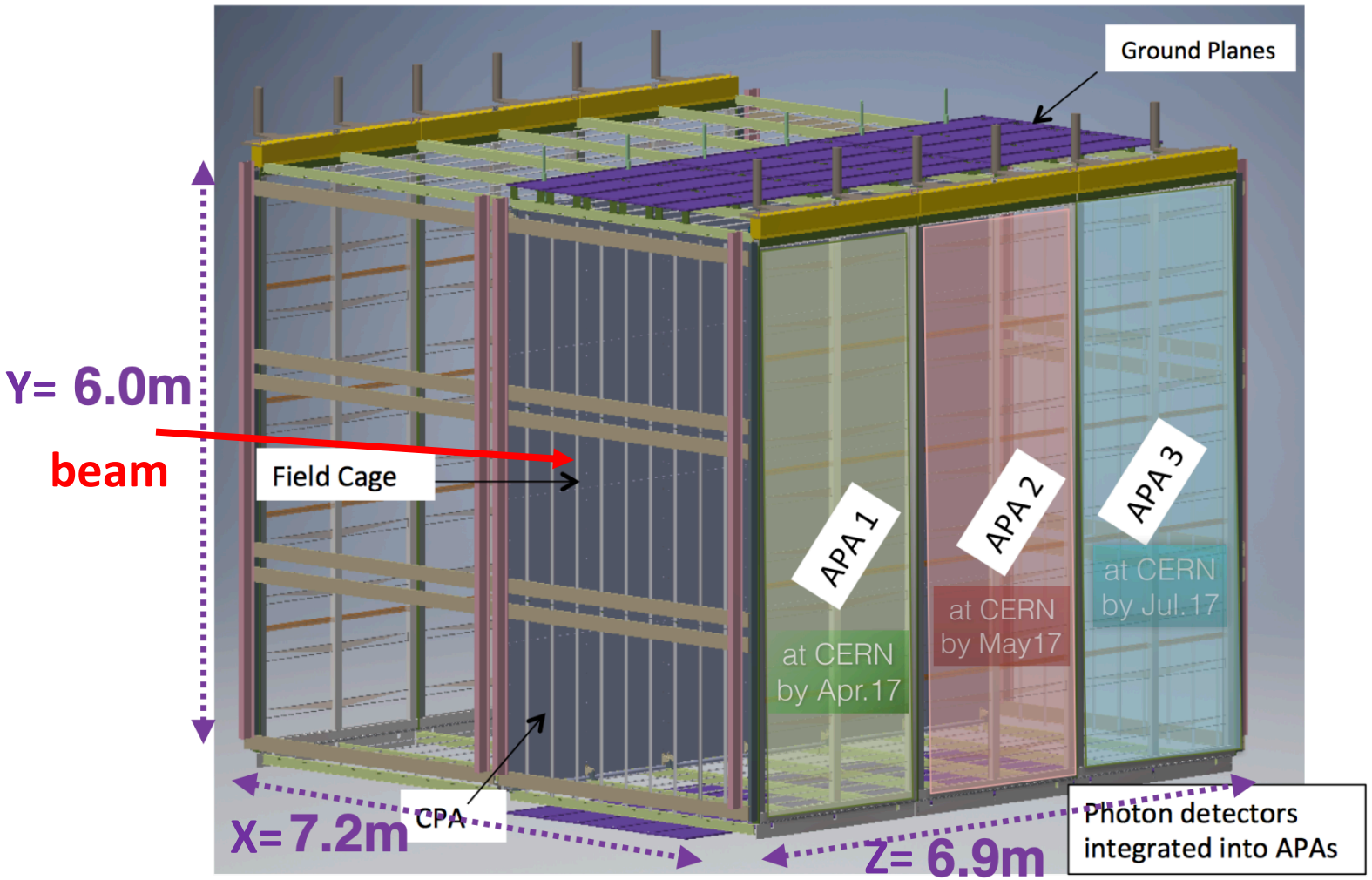
Motivations

- Show that ProtoDUNE can use the topological / calorimetric information provided by the TPC to identify a specific topology [Michel electrons].

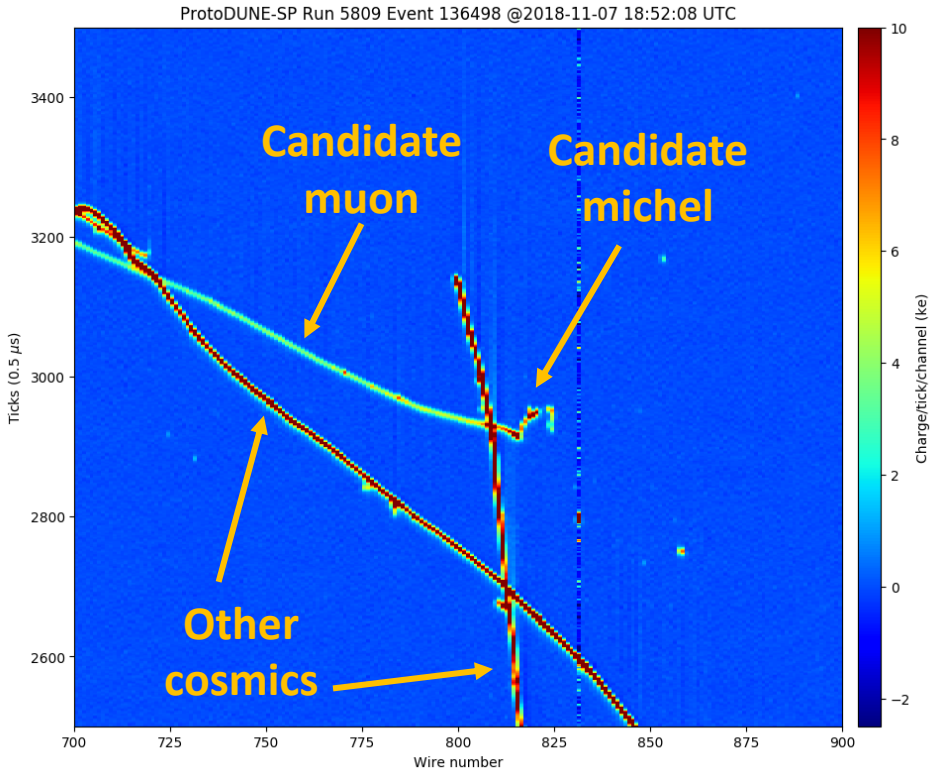
- Reconstruct the energy of Michel electrons using a simple, preliminary, energy calibration and produce a Michel electron energy spectrum.

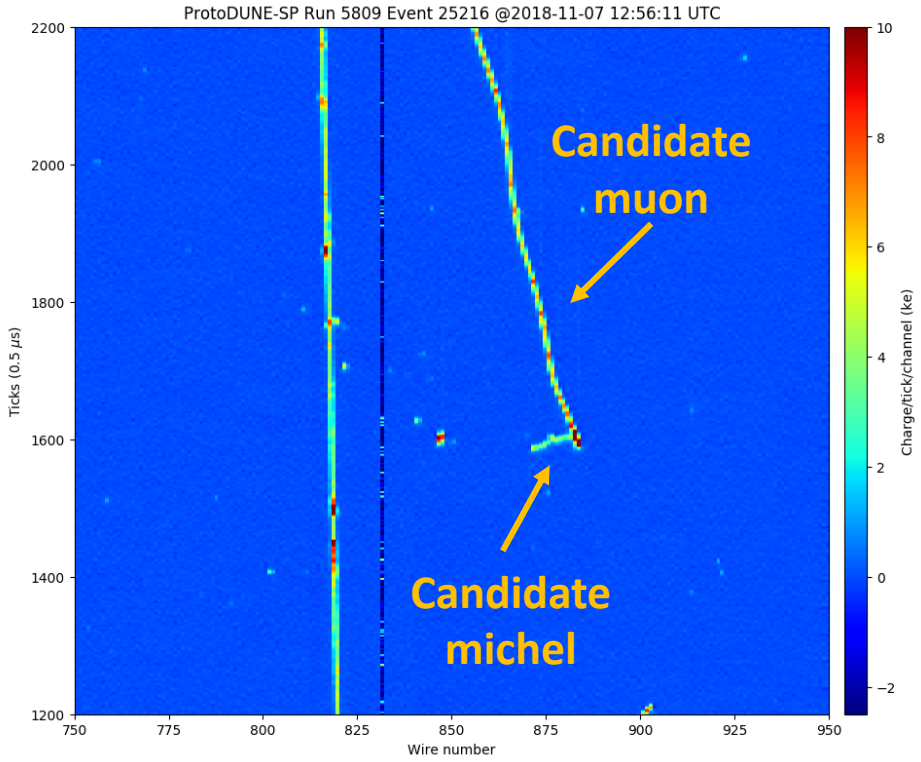
- Ideal to study detector's response to electrons in the tens of MeV energy range
  - Useful for the search of supernova events

ProtoDUNE-SP LArTPC



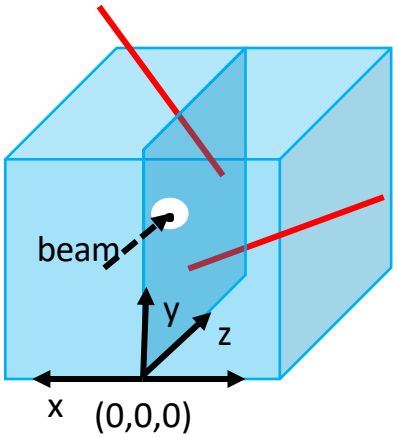
Candidate michel event displays in ProtoDUNE





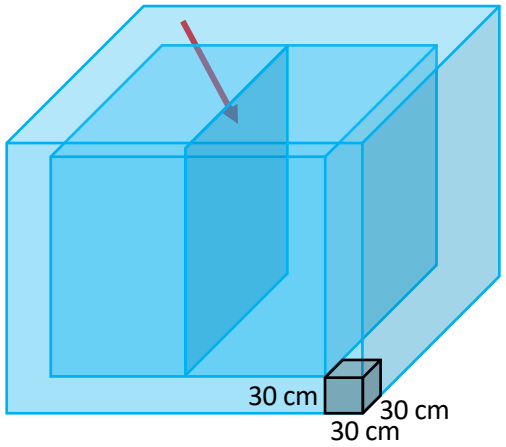
Michel event initial selection

1. T_0 tagged (cathode crossing) tracks



Michel event initial selection

1. T_0 tagged (cathode crossing) tracks



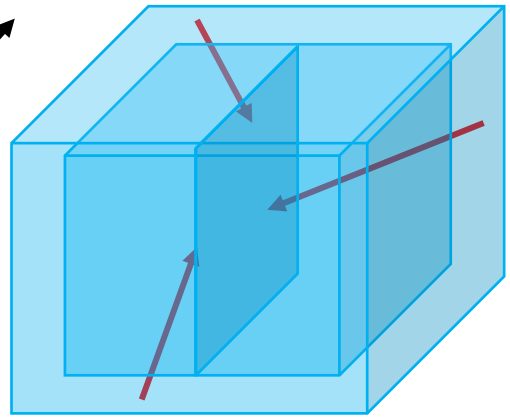
2. Tracks starting in detector edges

Michel event initial selection

1. T_0 tagged (cathode crossing) tracks

2. Tracks starting in detector edges

3. Tracks ending in FV



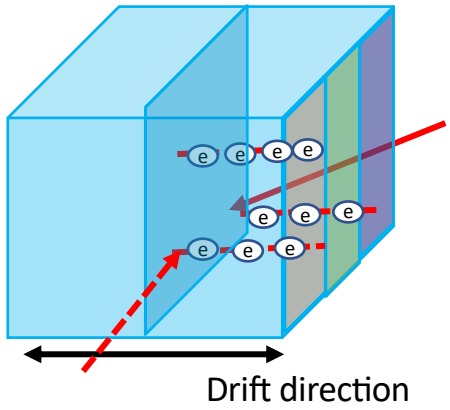
Michel event initial selection

1. T_0 tagged (cathode crossing) tracks

2. Tracks starting in detector edges

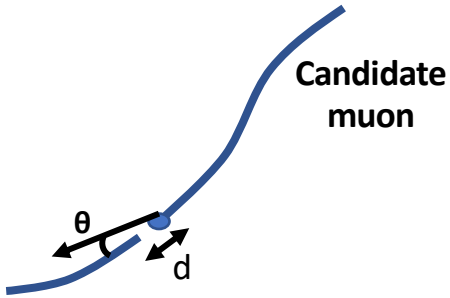
3. Tracks ending in FV

4. Tracks ending not around APA bounds



Candidate muon selection

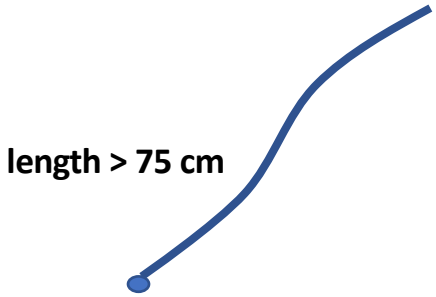
- Remove broken tracks



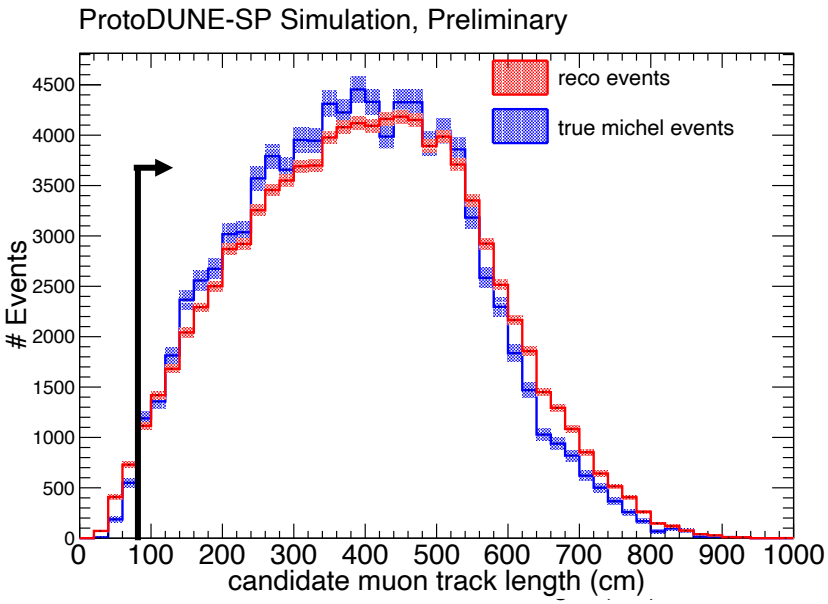
MC Sample purity = 27%

Candidate muon selection

- Remove broken tracks
- Select candidate muon tracks with > 75 cm length



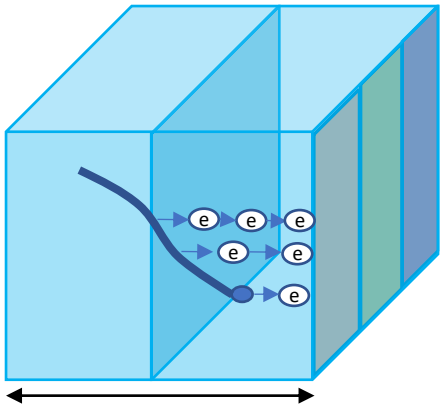
True MC normalized to reco MC

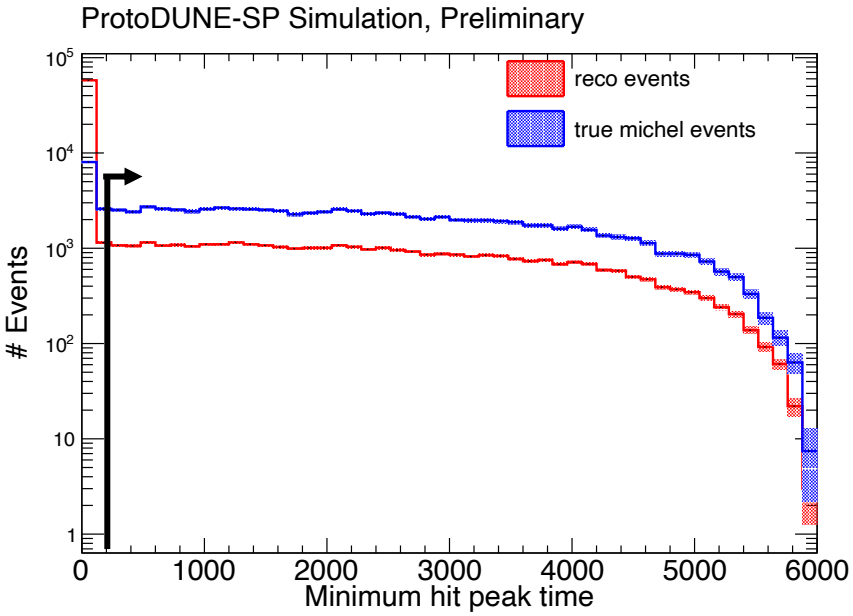


MC Sample purity = 27%

Candidate muon selection

- Remove broken tracks
- Select candidate muon tracks with > 75 cm length
- Minimum hit time > 200 ticks

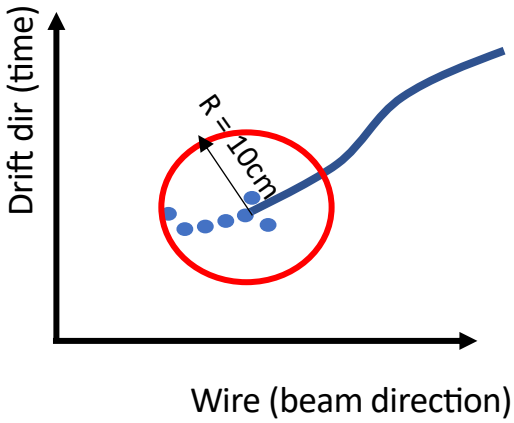


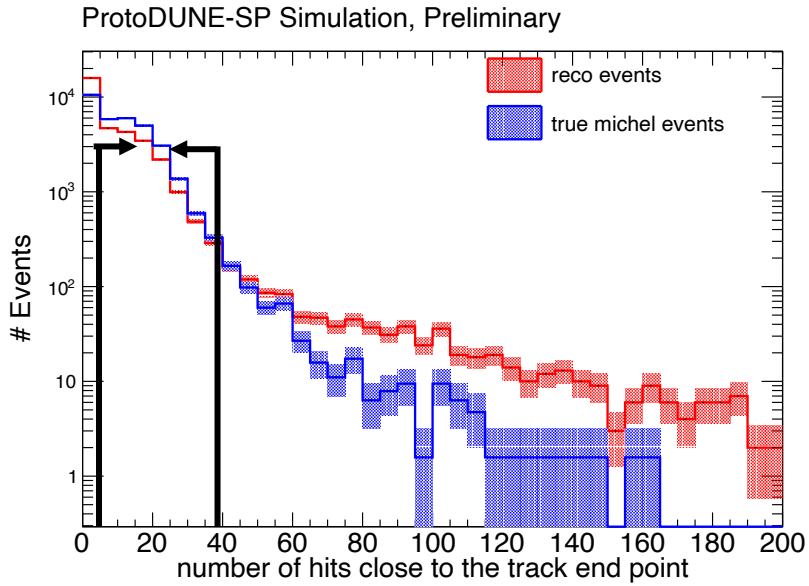


MC Sample purity = 63%

Candidate michel selection

- Remove broken tracks
- Select candidate muon tracks with > 75 cm length
- Minimum hit time > 200 ticks
- Nearby hit count > 5 & < 40

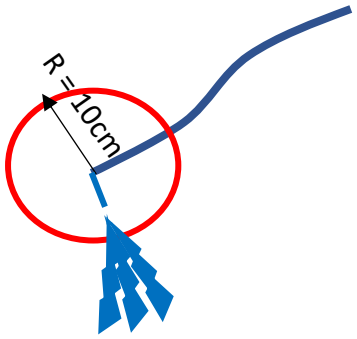


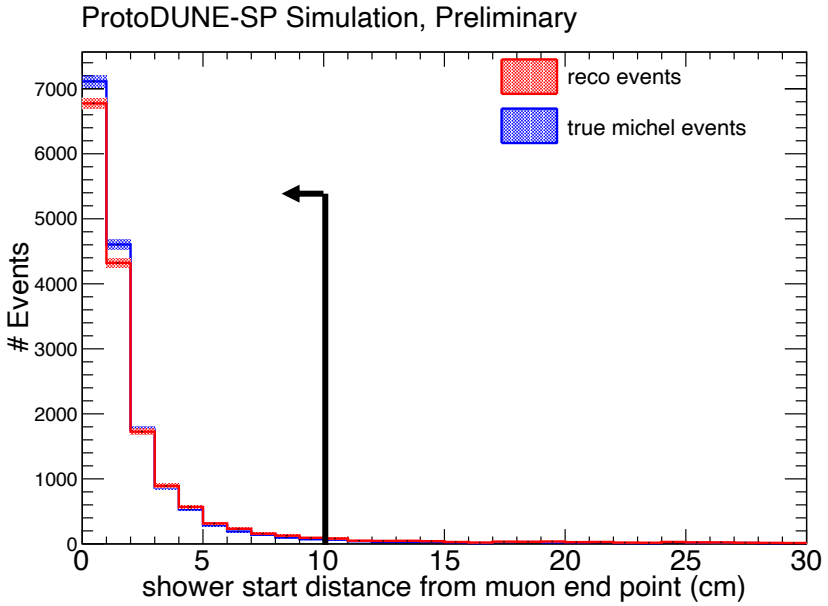


MC Sample purity = 86%

Candidate michel selection

- Remove broken tracks
- Select candidate muon tracks with > 75 cm length
- Minimum hit time > 200 ticks
- Nearby hit count > 5 & < 40
- Closest reco shower distance < 10 cm

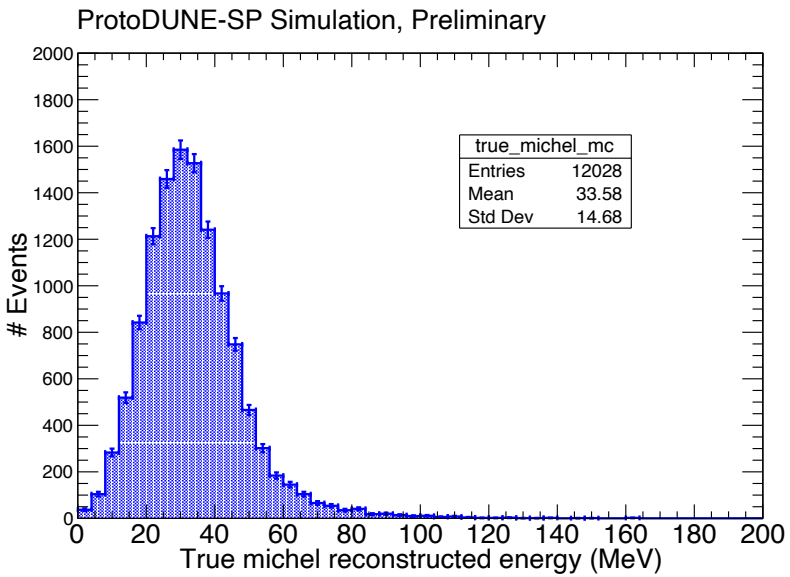




Final MC Sample purity = 89%

Michel energy reconstruction

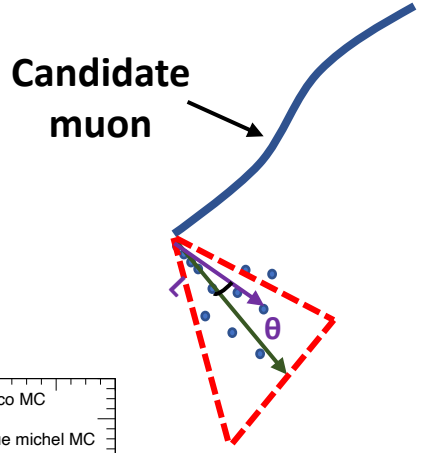
$$E = \sum_{i=coll.\,plane\ hits} \frac{Q_i * C_x * C_{yz} * Wion * Norm\_factor}{Calib\_const * Recomb\_factor}$$



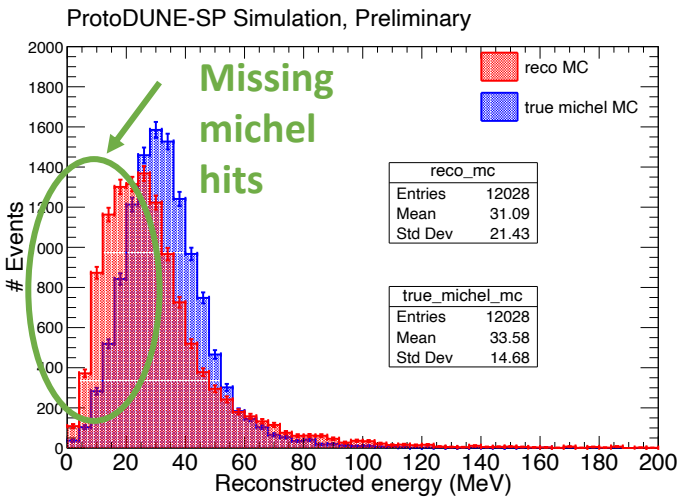
Where
Q_i = charge deposited on a hit
C_x, C_{yz} = correction factors, remove non-uniformity in dQ/dx values
Wion = 23.6e-6 MeV
Norm_factor = normalizes the dQ/dx values to the dQ/dx at anode
Calib_const = converts dQ/dx in ADC/cm into dE/dx in MeV/cm
Recomb_factor = 0.7; to incorporate the recombination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

Michel energy reconstruction

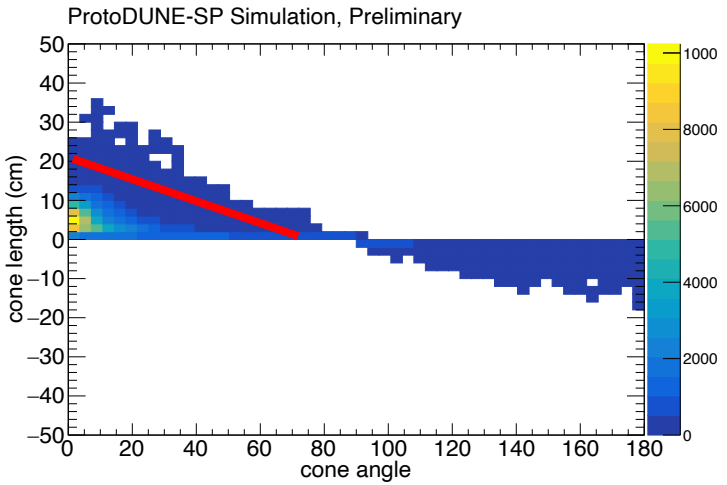
- Defined a cone at the end point of the parent muon



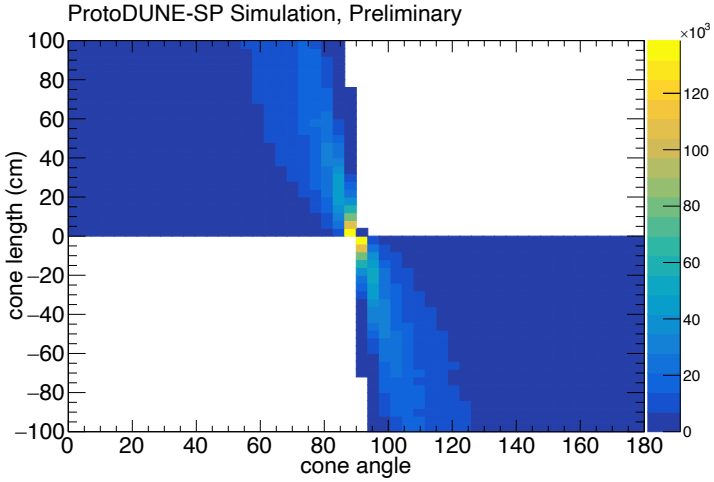
Where θ=0 corresponds to the hits along the nearby wire hits



True michel reco hits



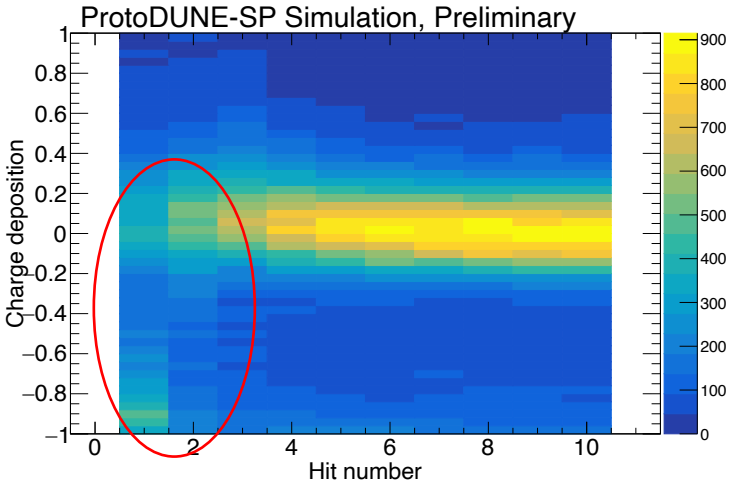
Other hits of the event



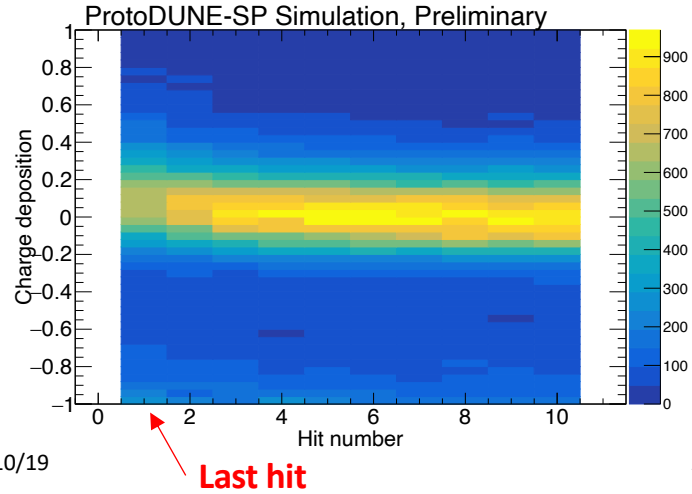
Recovering michel hits from parent muon

- 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 6% of the total missing michel hits

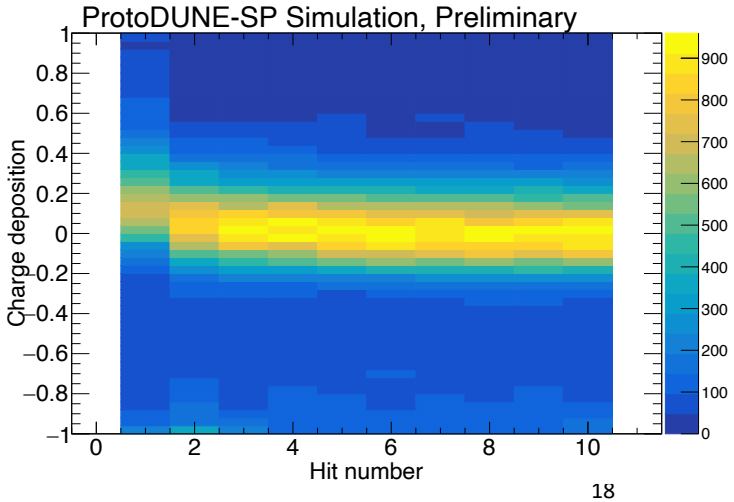
Before recovery



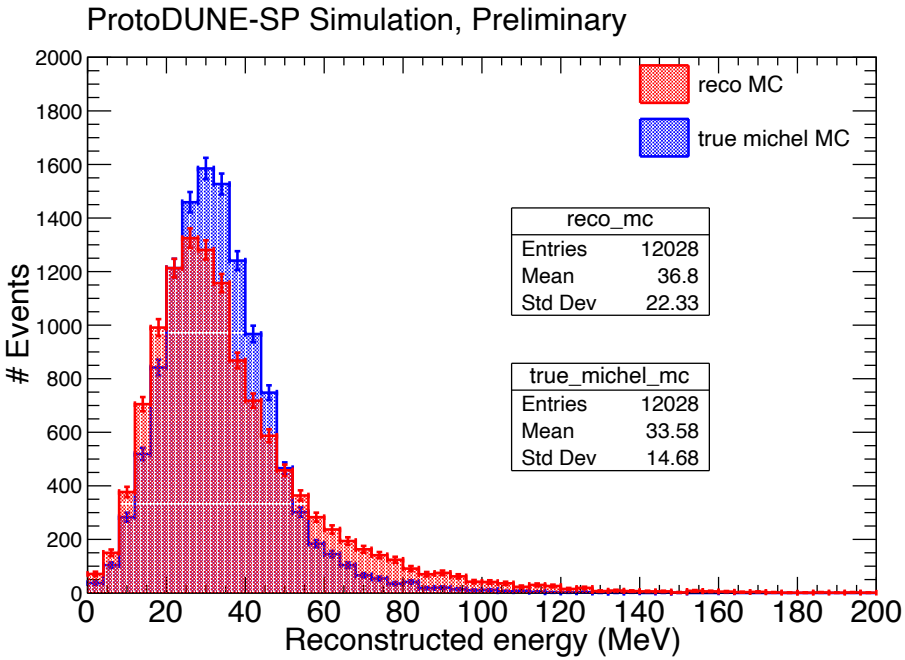
True muon

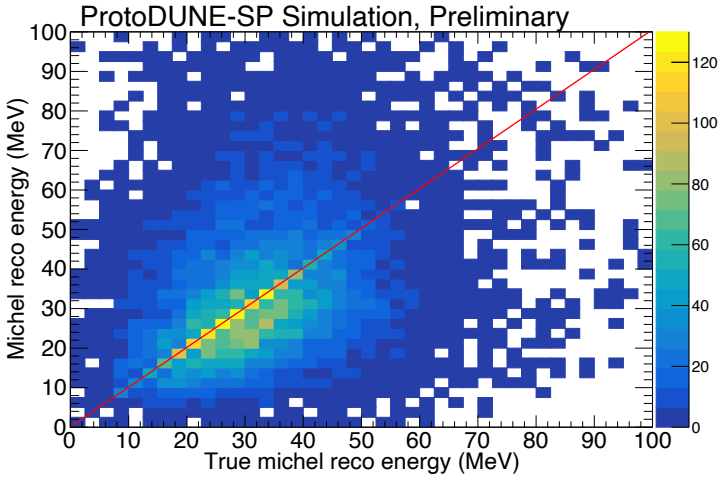


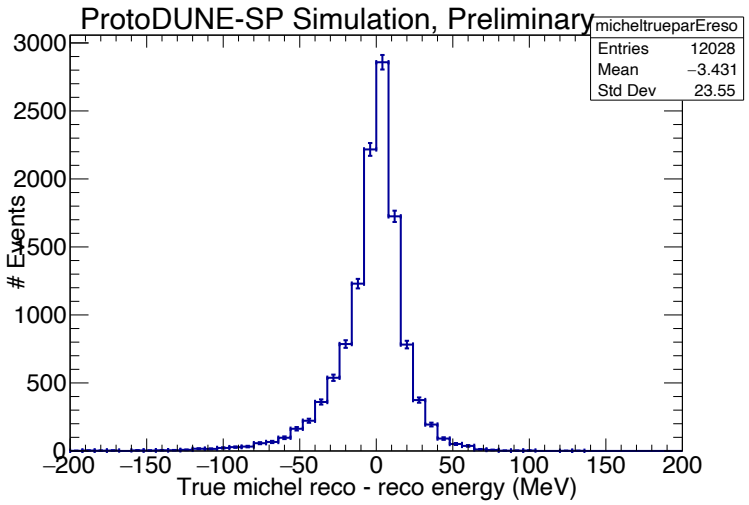
After recovery



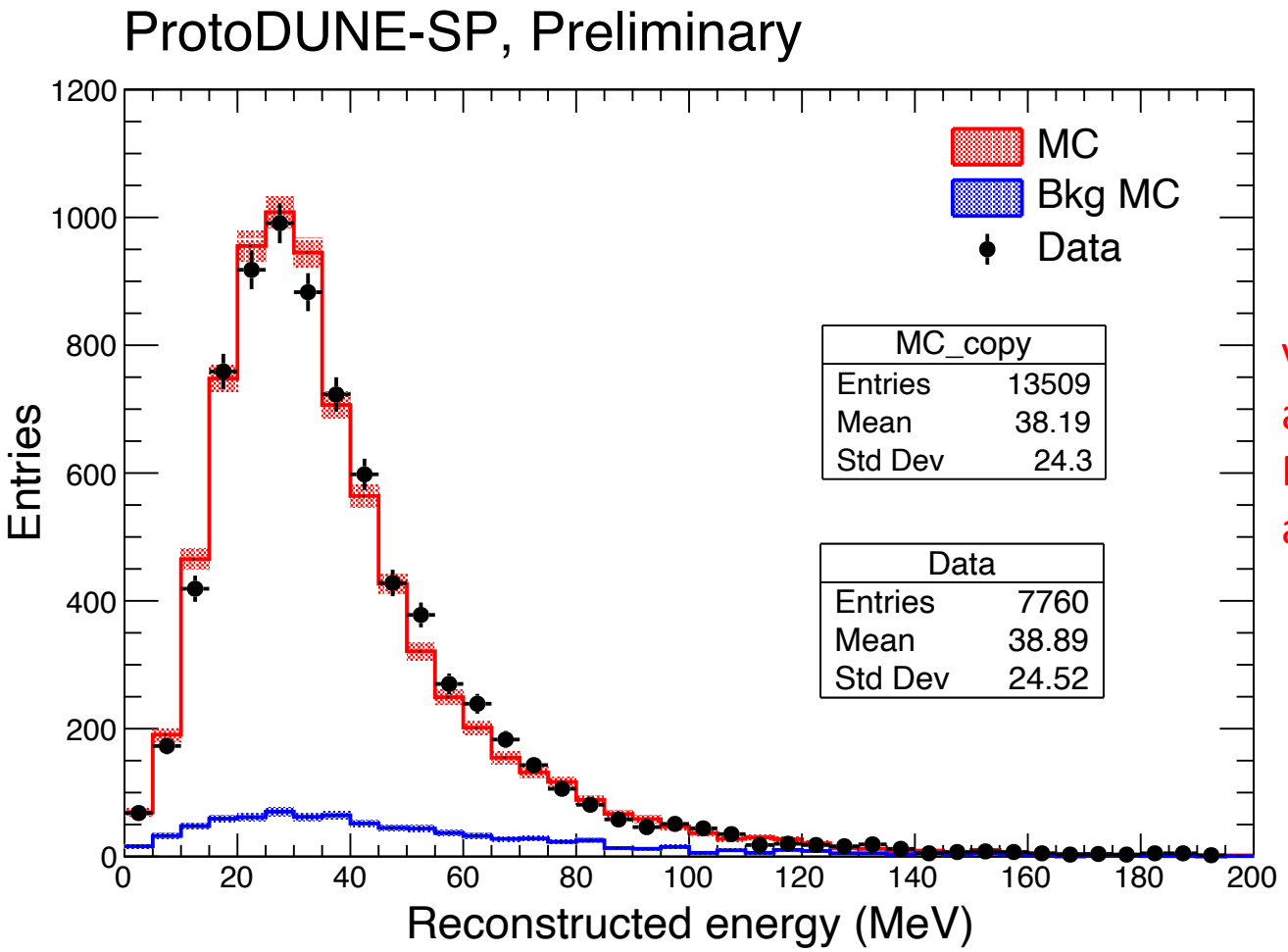
Michel energy spectrum MC







Michel energy data/MC comparison



Very good agreement in ProtoDUNE data and simulation

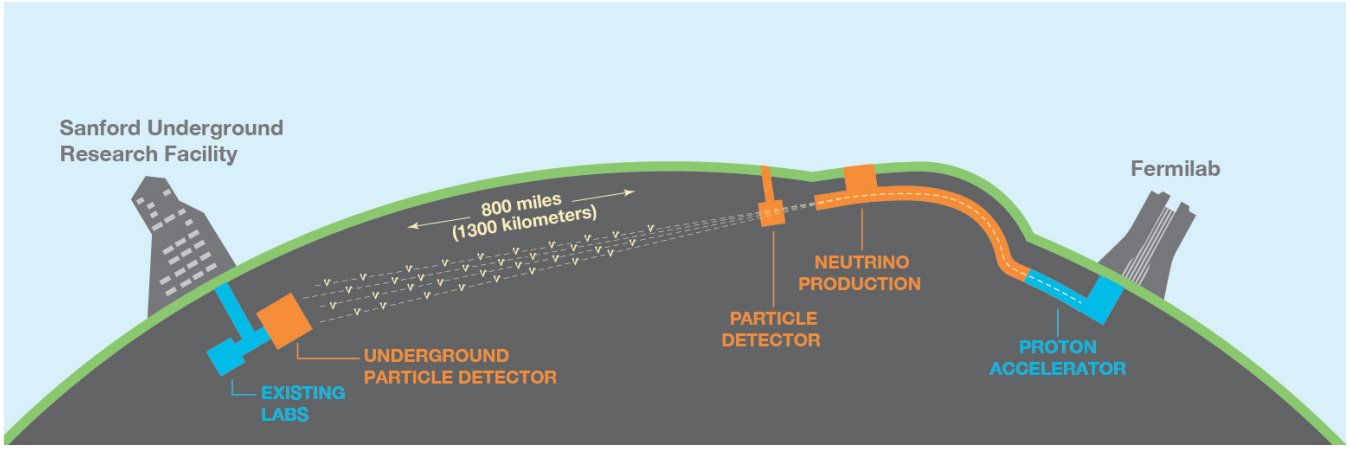
Summary

- Michel energy spectrum is obtained with a high purity michel sample
- Good agreement in simulation and ProtoDUNE data is observed for michel energy spectrum
- In the near future, will study how photon detector sees these michel events
- Note on the analysis is coming soon. Stay tuned!

Thank you for your attention

Backup slides

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**"