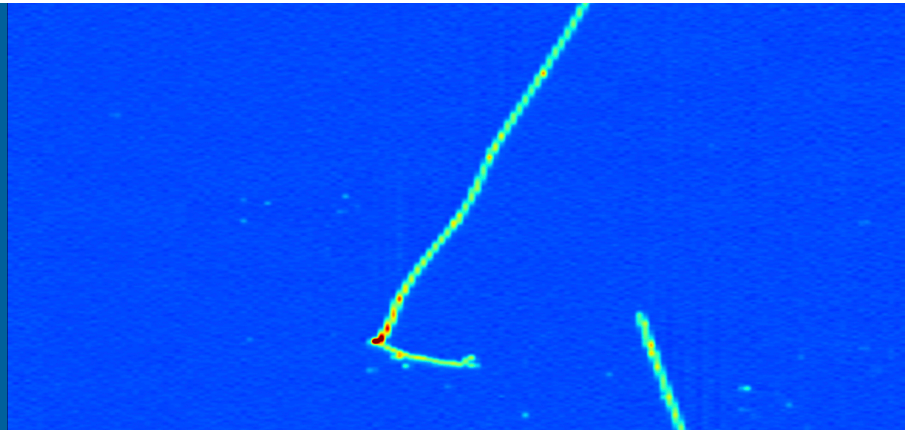
IDENTIFICATION AND RECONSTRUCTION OF MICHEL ELECTRONS IN PROTODUNE-SP



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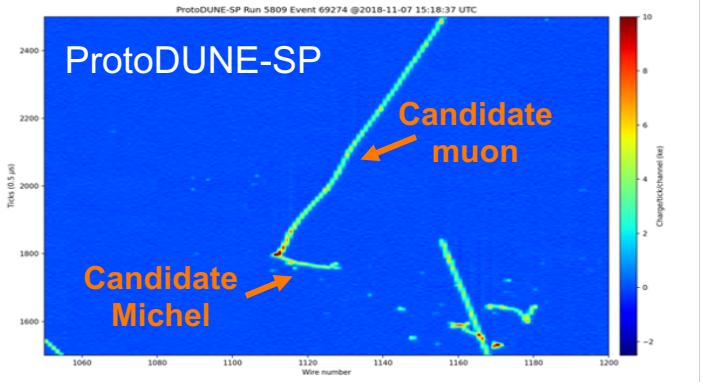
MICHEL ELECTRONS

- 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:
  - Select and reconstruct Michel electrons in ProtoDUNE
  - Obtain the Michel energy spectrum in data and MC
  - Derive the relation between true and reconstructed Michel energy spectrum

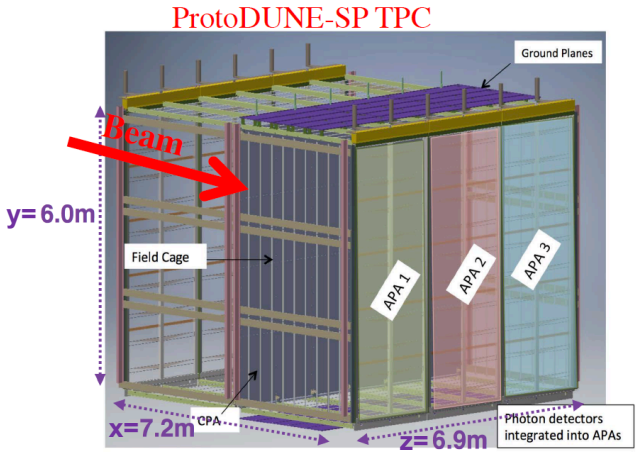


MOTIVATIONS

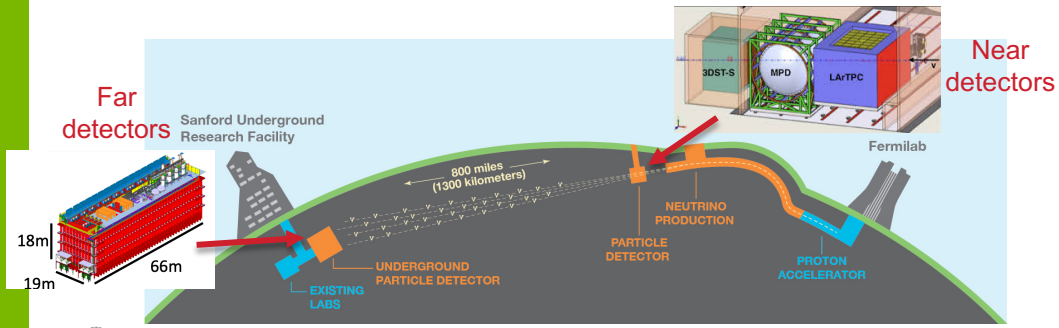
- DUNE goal is to measure CP-violation via ν_e appearance ($\nu_\mu \rightarrow \nu_e$)
  - To measure ν_e appearance we need to select electron showers in LAr TPC, and reconstruct their energy
- Show that ProtoDUNE can use the topological / calorimetric information provided by the TPC to identify a specific topology [Michel electrons]
- Reconstruct the energy of Michel electrons using energy calibration and produce Michel electron energy spectrum
- Ideal to study detector's response to electrons in the tens of MeV energy range
  - Useful for the search of low energy events e.g supernova

DEEP UNDERGROUND NEUTRINO EXPERIMENT

- Major US project to measure CP-violation
- Consists of two detectors
  - Near detector (ND) at Fermilab
  - Far detector (FD) at South Dakota
- Prototypes (called ProtoDUNE) of FD are created to check the technological and operational challenges

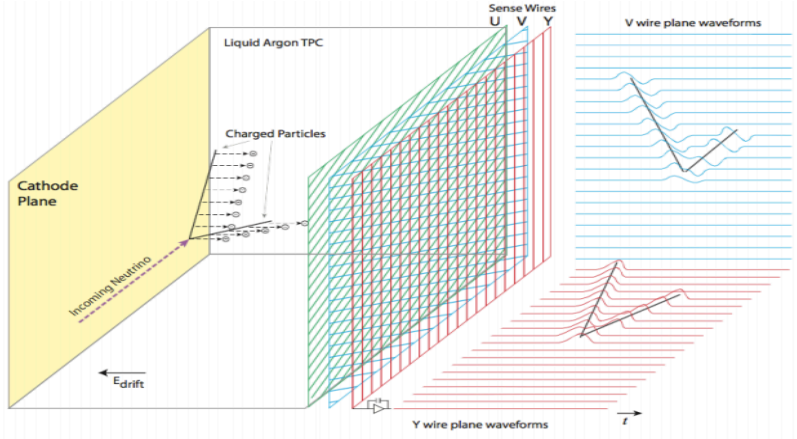


- Prototype for the first DUNE Far detector modules
- 1-kt “ProtoDUNE-SP” in charged test beam at CERN
- Test of component installation, commissioning, and performance for DUNE

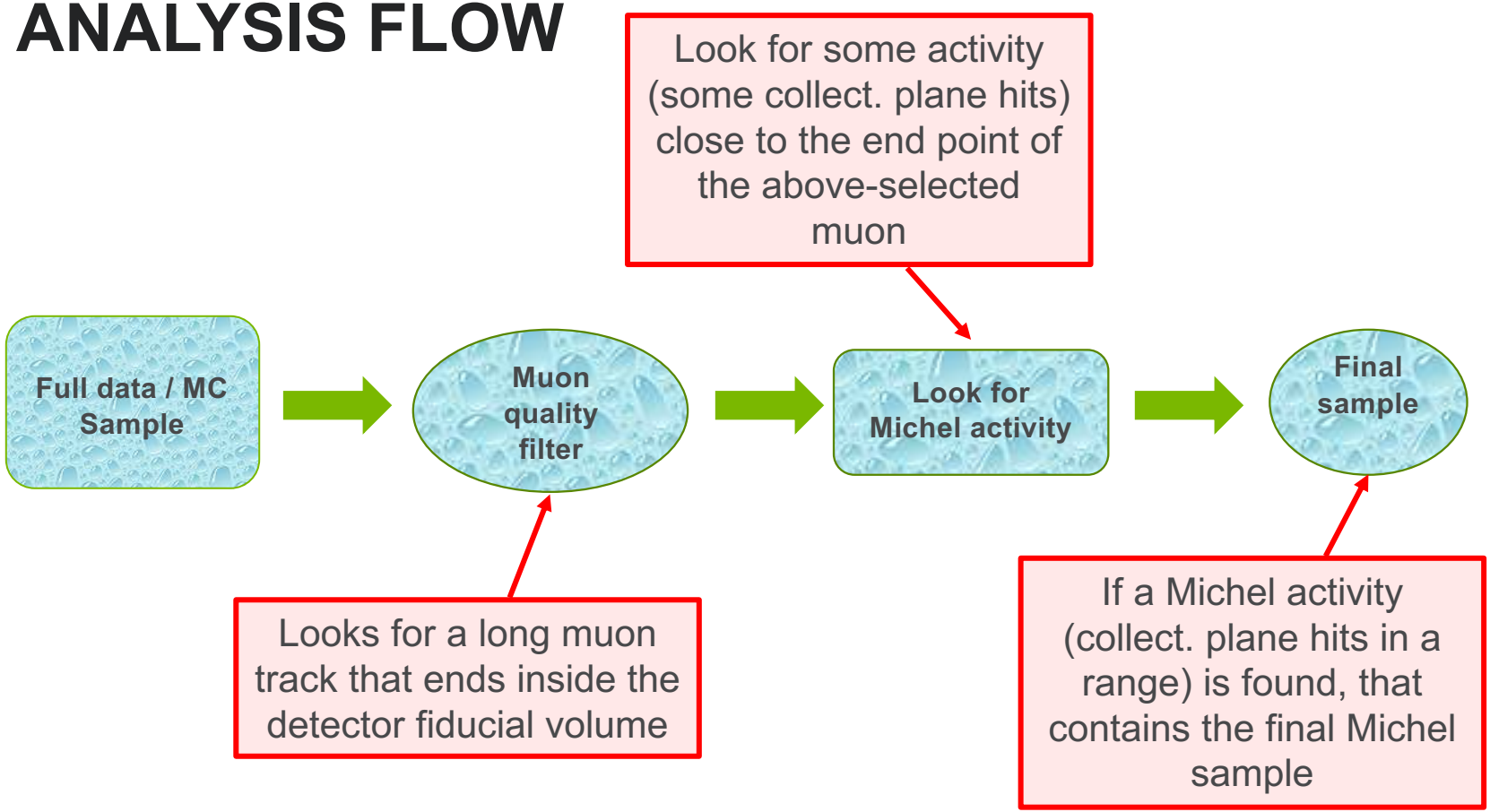


PRINCIPLE OF LARTPC

- 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 is called "**Time projection chamber**"

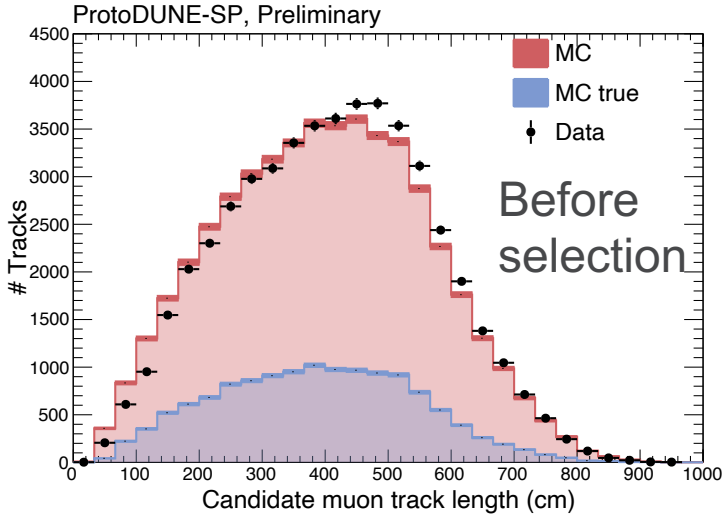


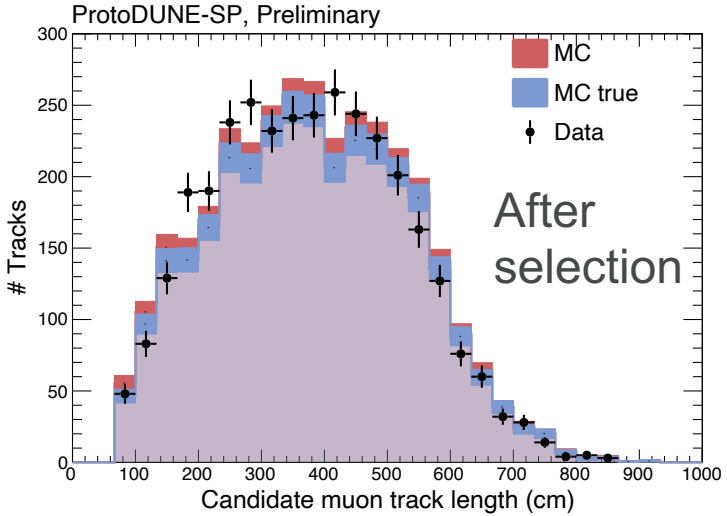
ANALYSIS FLOW



KINEMATIC PLOTS BEFORE AND AFTER SELECTION

Candidate muon track length





Michel event selection purity ~ 96%

CHARGE TO ENERGY CALIBRATION

- Performed energy calibrations to extract Michel electron energy spectrum

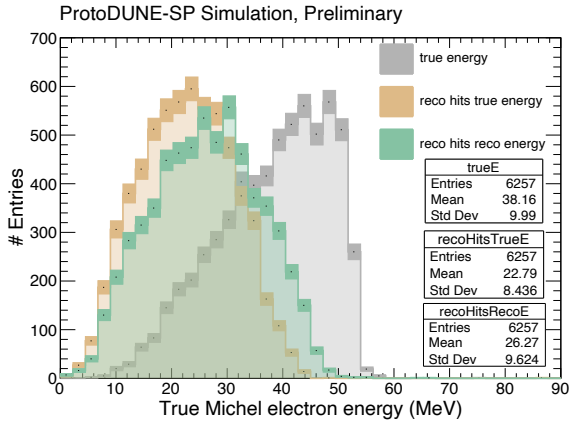
$$E = \sum_{i=1}^{n} \frac{Q_{corr,i} W_{ion}}{C_{calib}} \qquad \text{where} \qquad Q_{corr,i} = \frac{Q_{reco,i} N F_x F_{yz}}{R}$$

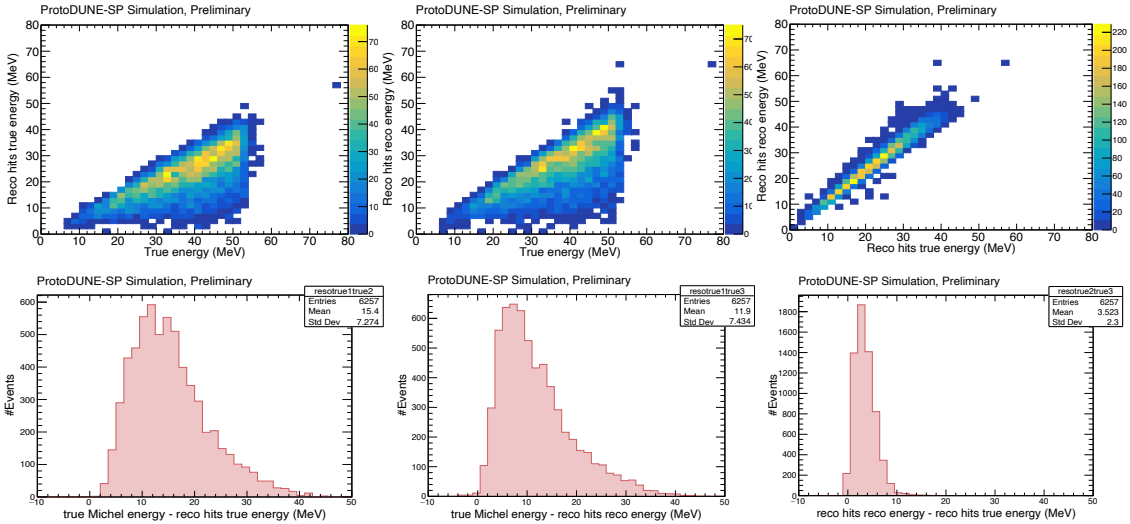
- $Q_{reco,i}$ is the reconstructed measured charge deposited on a hit
- W_{ion} is the work function for ionizing an argon atom
- C_{calib} represents the calibration constant that converts ADC to MeV
- N normalizes the dQ/dx values to the dQ/dx at the anode plane
- F_x is the space charge correction
- F_{yz} is the dead wires correction factors
- R is recombination factor that accounts for recombination effects in the detector

TRUE MICHEL ENERGY

Calculated in three different ways

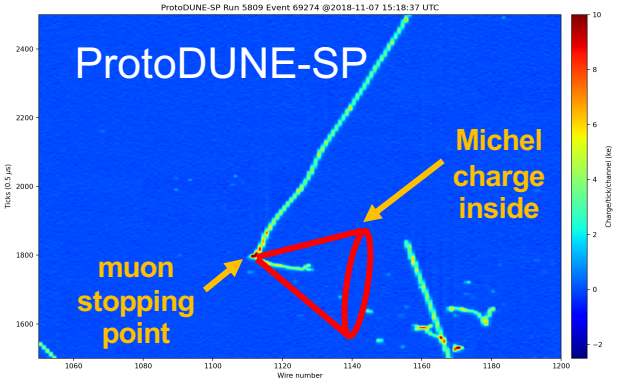
- True Michel true Energy: by extracting energy directly from GEANT for the true Michel
- True Michel reco hits true energy: by summing up the true energy of true Michel deposited on all reconstructed hits
- True Michel reco hits reco energy: by summing up the reconstructed energy of true Michel deposited on all reconstructed hits



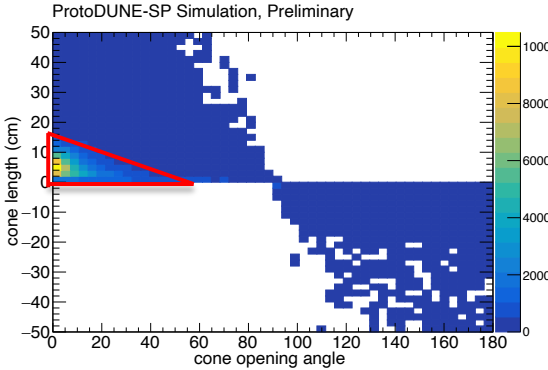


MICHEL ENERGY RECONSTRUCTION

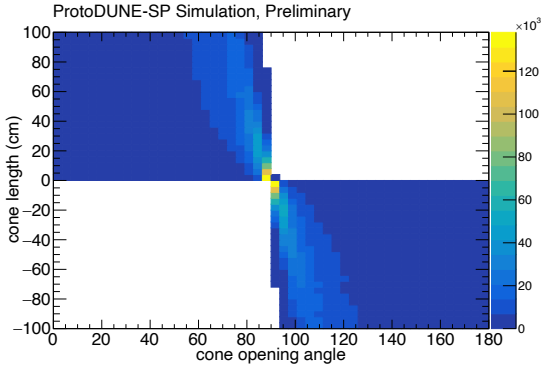
- Defined a cone at the end point of the parent muon
- All hits inside the cone are taken to be as candidate Michel hits



True Michel reco hits

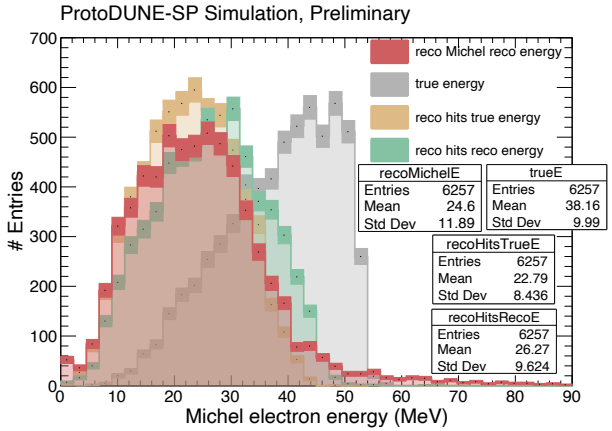


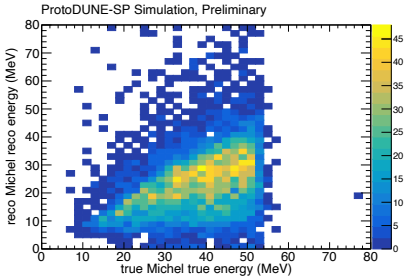
Other hits of the event

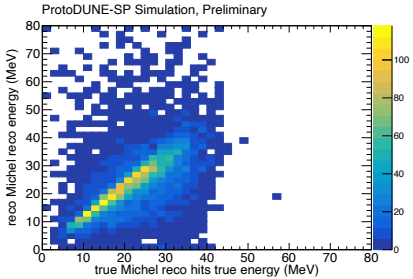


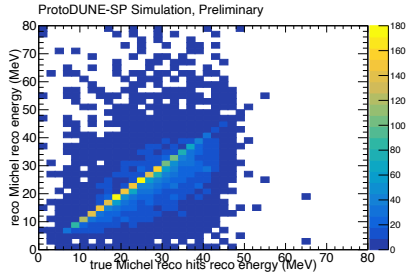
MICHEL RECONSTRUCTED AND TRUE ENERGY

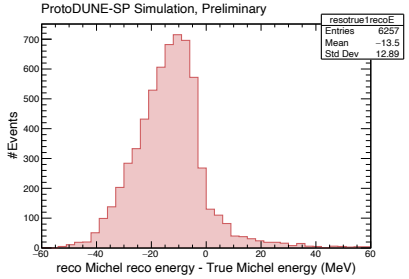
- Reco Michel reco energy: by summing up the reconstructed energy of a reconstructed Michel
- Presented the 2D plots of reco versus true energies
- Presented energy resolution plots

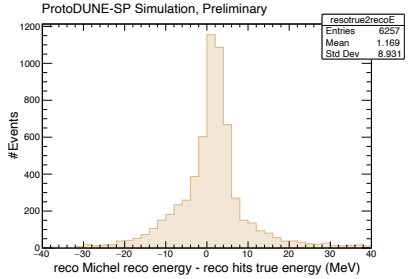


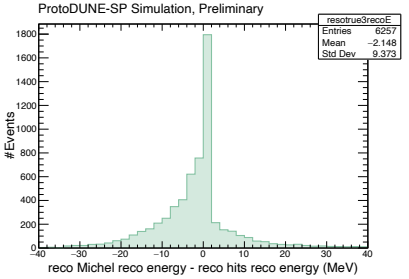






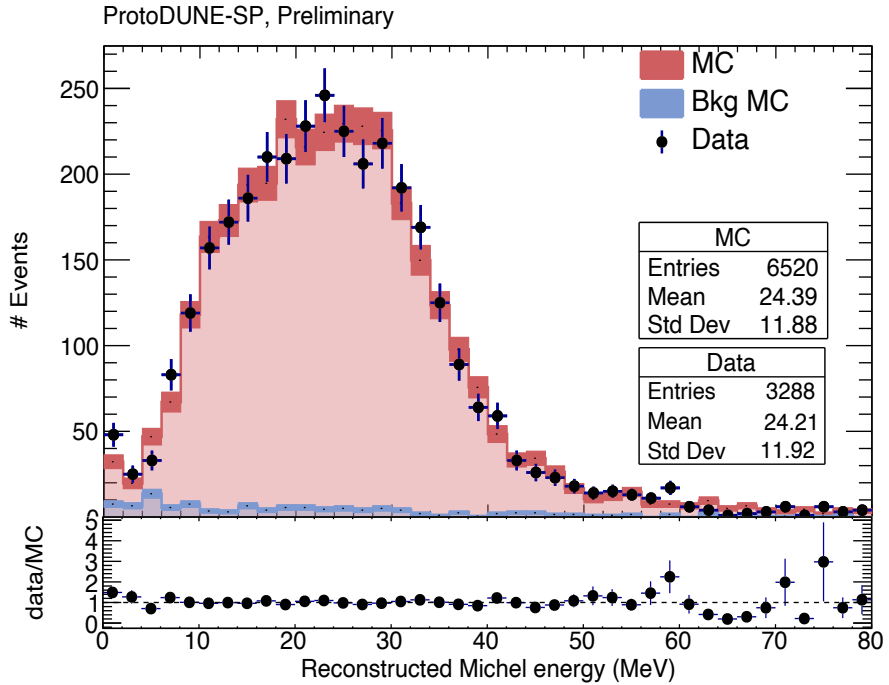






MICHEL ENERGY DATA AND MC COMPARISON

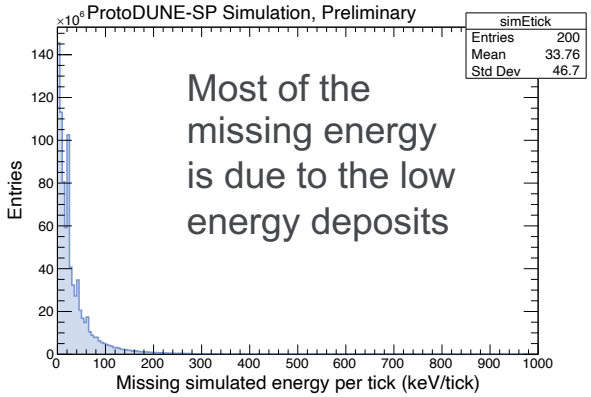
- Simulation agrees very well with the data
- Michel electron energy accuracy
  - >98%

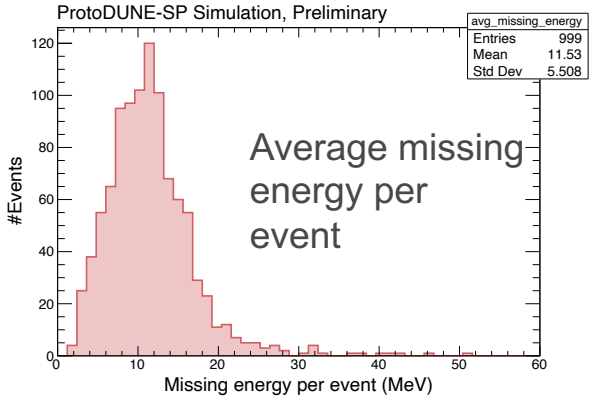


MISSING ENERGY DUE TO HIT RECONSTRUCTION THRESHOLD

hit reconstruction threshold ~ 100 keV/tick

- Using Michel-only MC
- Almost all missing energy is due to the hit reconstruction threshold.

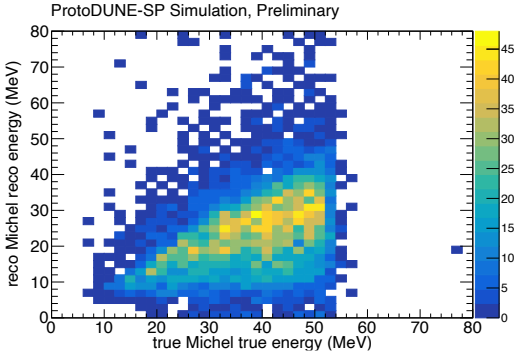


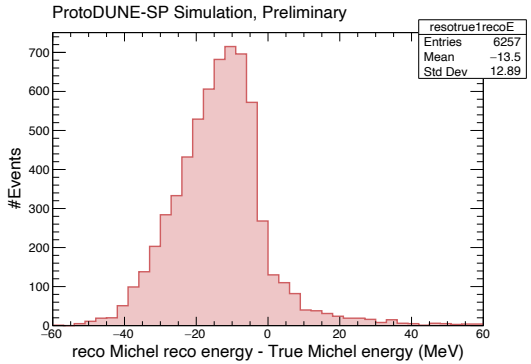


UPDATED RECONSTRUCTED MICHEL ENERGY

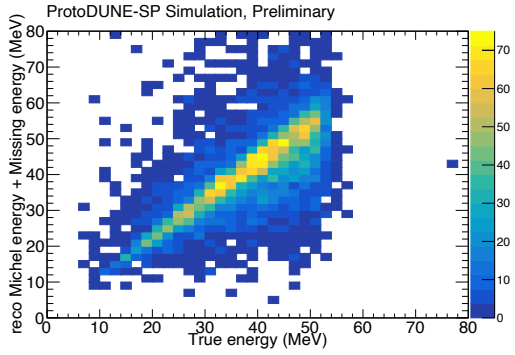
- Compared energy resolution plots before and after the addition of the missing energy per event
- Energy resolution:
  - Before: δ(E)/E = 26% at 50 MeV
  - After: δ(E)/E = 18% at 50 MeV

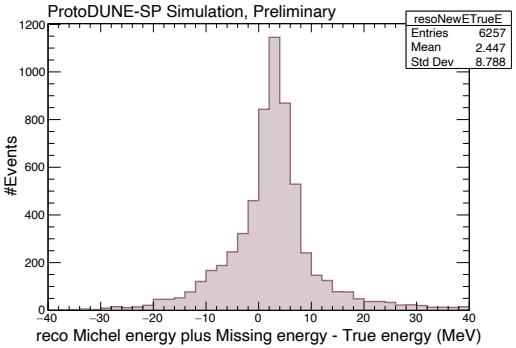
Before





After





SUMMARY

- Developed selection, reconstruction, and energy calibration tools for ProtoDUNE-SP
  - Achieved 95% event purity
  - Michel electron energy accuracy is >98%
- Understood the source of missing energy in the spectrum
  - Hit reconstruction threshold
- Paper in progress
  - Stay tuned!

BACKUP SLIDES