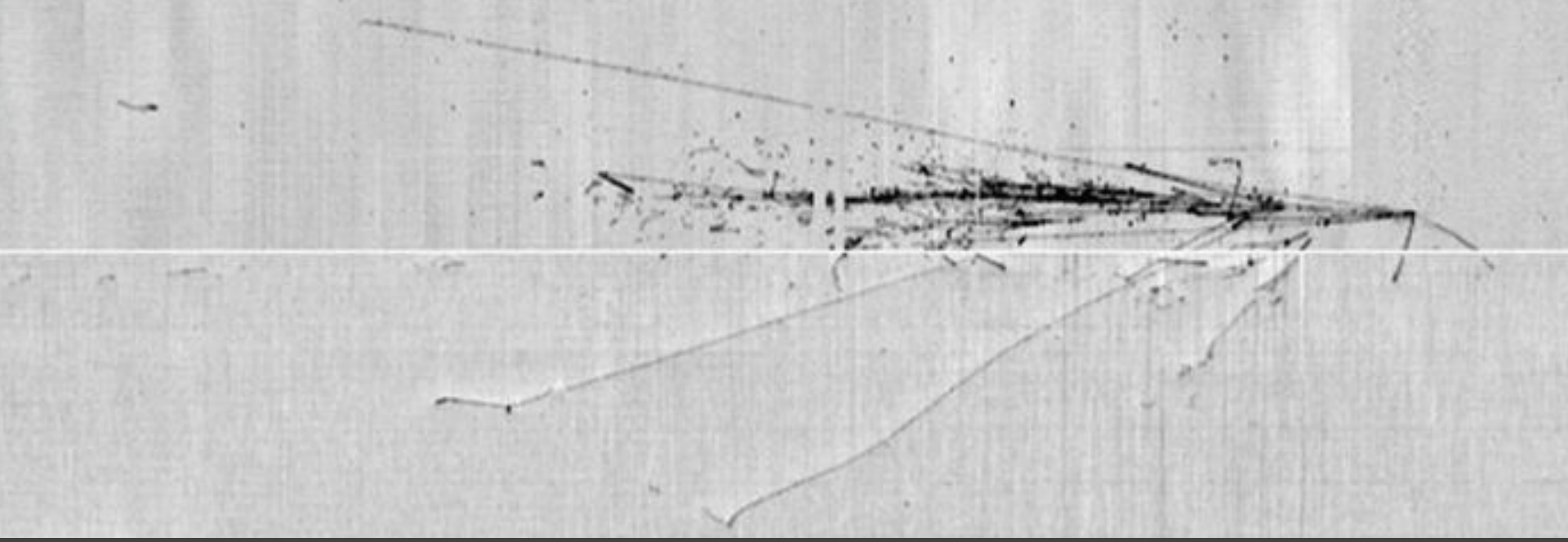


Toward Commissioning: Machine Learning Based Michel Electron Reconstruction

***Laura Domine**, François Drielsma, Kazuhiro Terao, Tracy Usher*
SLAC National Accelerator Lab.
ICARUS Collaboration Meeting @ FNAL
September 12th 2019

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Michel Electron Reconstruction for High-level Detector Commissioning Analysis

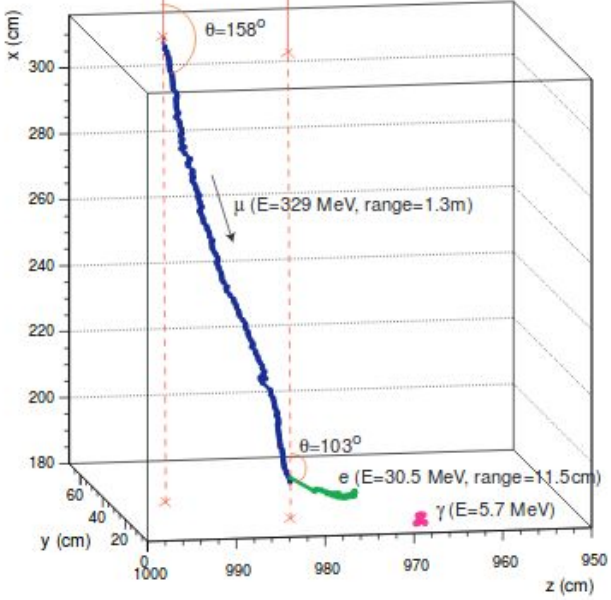
SLAC

Michel electron = useful benchmark and calibration sample.

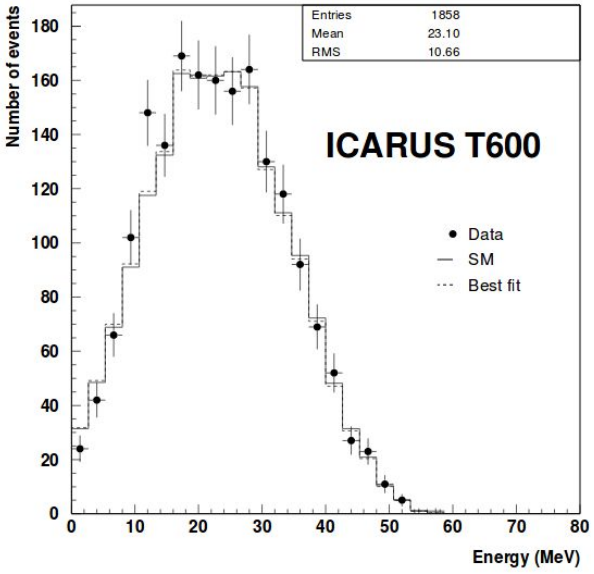
Ingredients for Michel TPC reconstruction

- Noise filtering + signal processing for high quality imaging
- Reconstruction: identification + clustering of Michel electron pixels
- Calibration: primarily lifetime and recombination effect (for MIP)

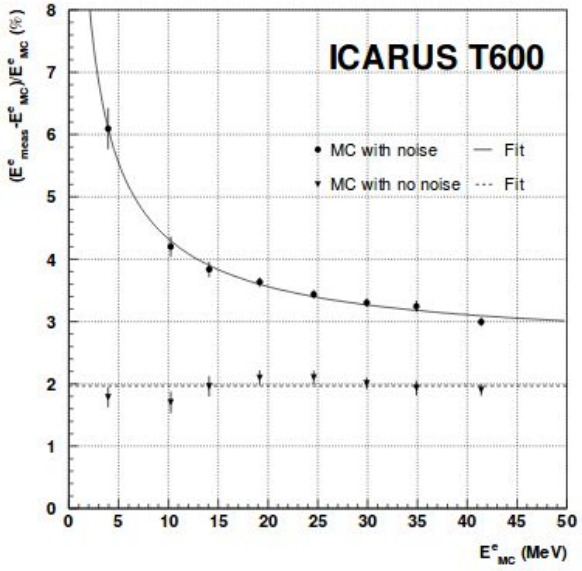
Reconstruction



Calibrated Energy



Detector Response Study



ICARUS Collaboration. "Measurement of the μ decay spectrum with the ICARUS liquid Argon TPC." The European Physical Journal C-Particles and Fields 33, no. 2 (2004): 233-241.

Michel Electron Reconstruction for High-level Detector Commissioning Analysis

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Michel electron = useful

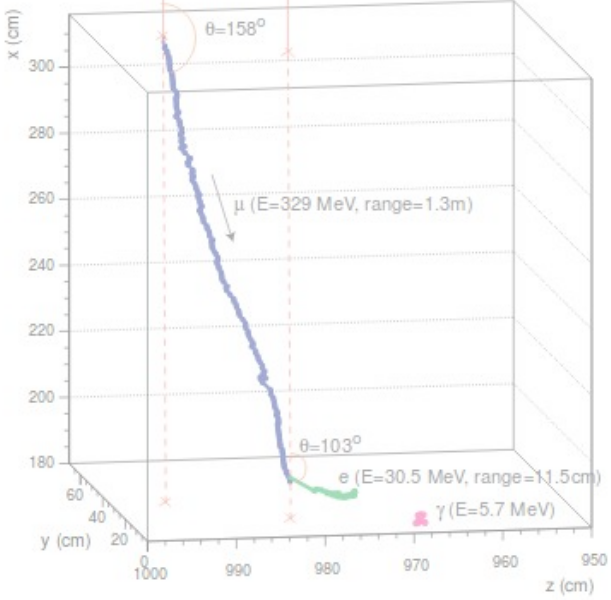
- Ingredients for TPC recon

Planned participation during commissioning, members' experience from MicroBooNE

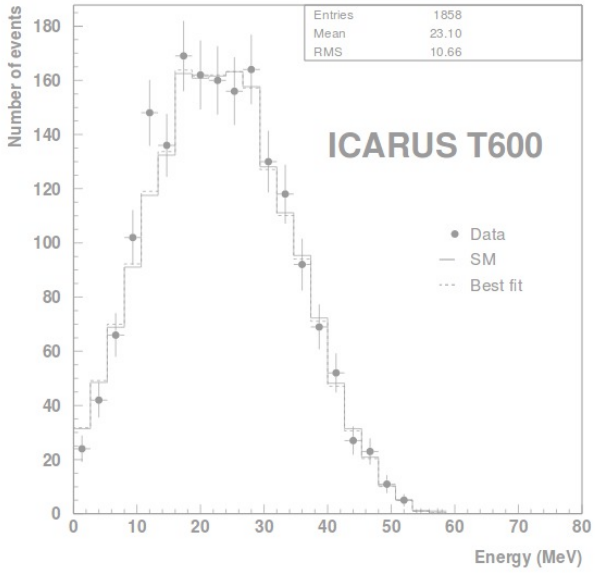
- Noise filtering + signal processing for high quality imaging
- Reconstruction: identification + clustering of Michel electron pixels
- Calibration: primarily

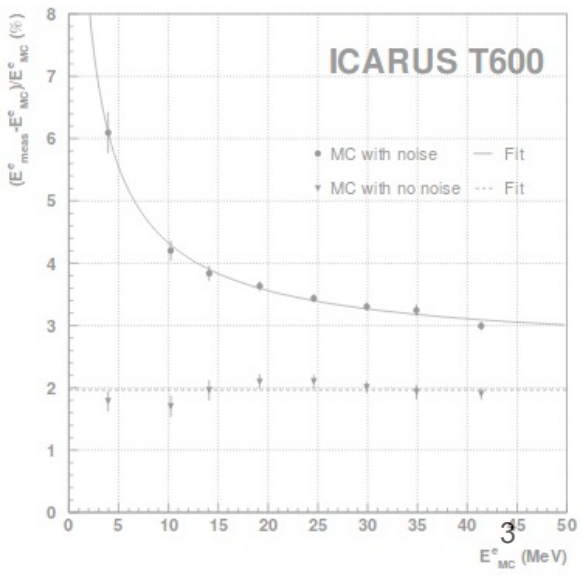
Benchmark target + data vs. simulation study sample for some machine learning algorithms

Reconstruction



Study





Michel Electron Reconstruction for High-level Detector Commissioning Analysis

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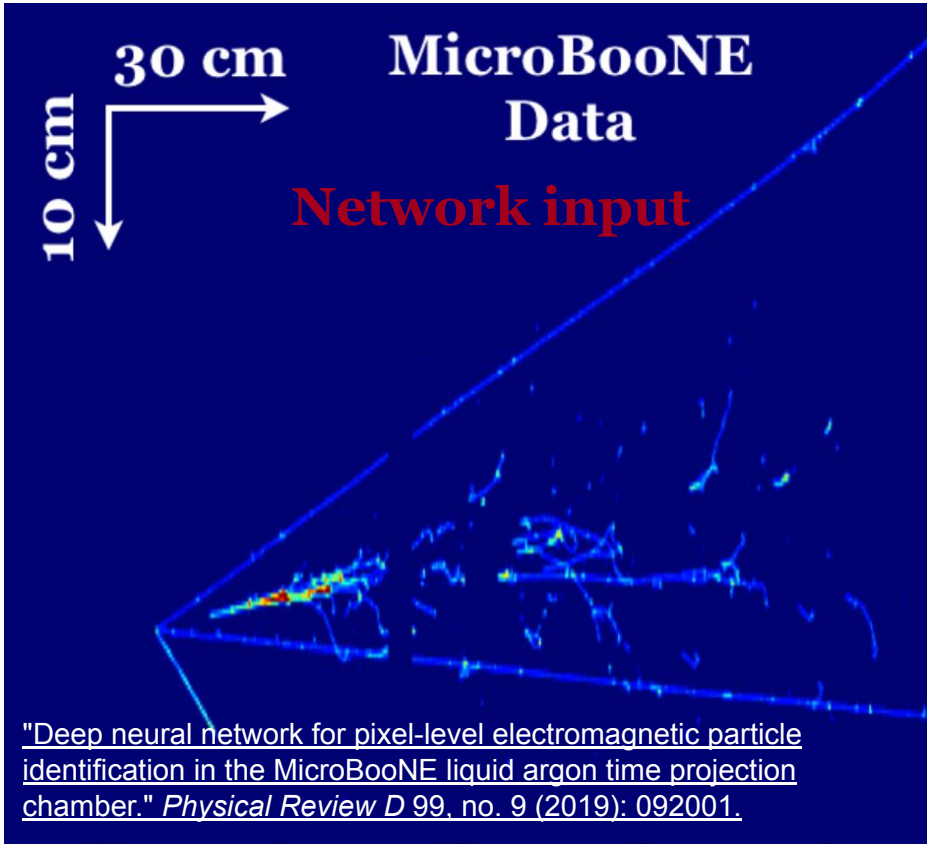
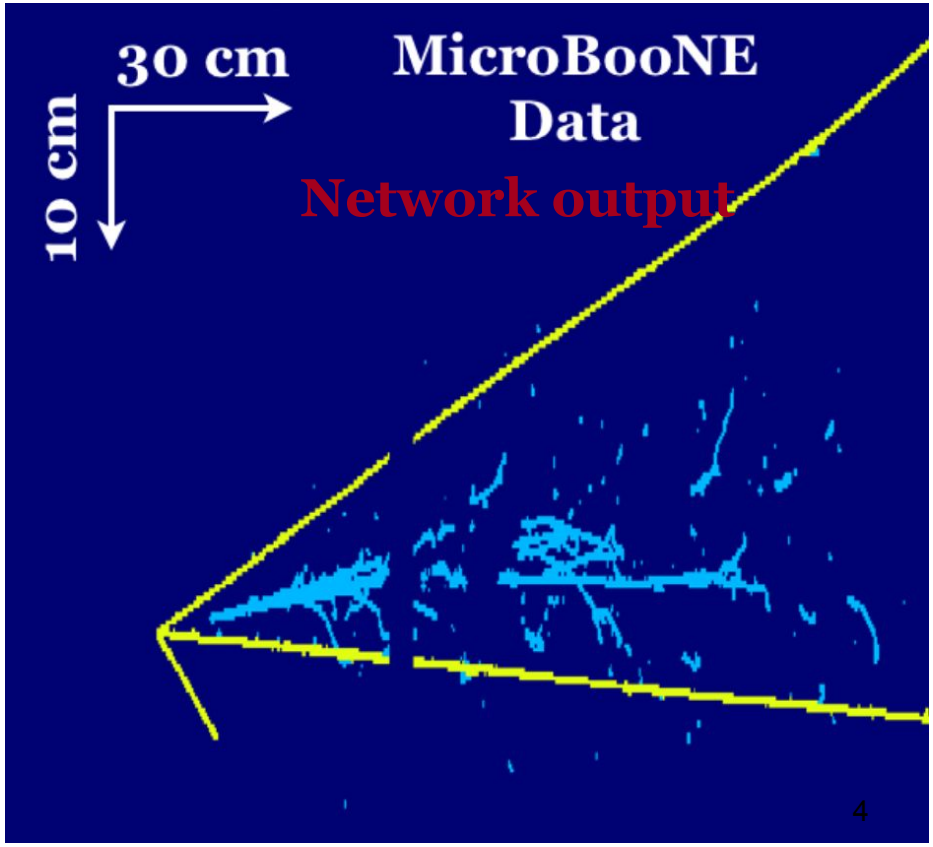
Machine learning algorithm for **pixel-level type identification**

- applied for MicroBooNE, ProtoDUNE, DUNE-ND
- **Would like to apply for ICARUS physics analysis**





"Deep neural network for pixel-level electromagnetic particle identification in the MicroBooNE liquid argon time projection chamber." *Physical Review D* 99, no. 9 (2019): 092001.

Michel Electron Reconstruction for High-level Detector Commissioning Analysis

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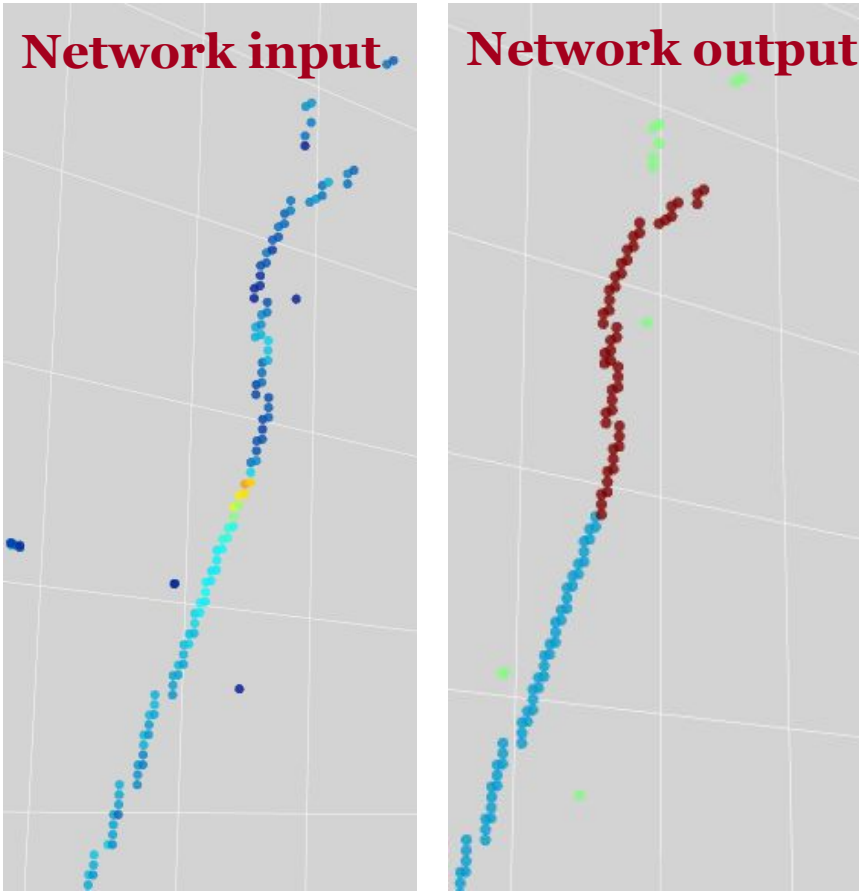
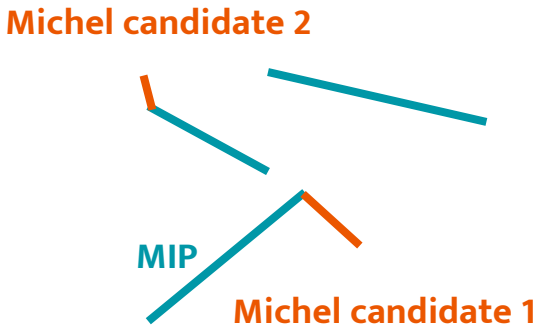
Machine learning algorithm for **pixel-level type identification** … can distinguish **Michel electron/MIP trajectory** using pattern recognitions at the pixel level.



Accuracy (fraction of pixels correctly predicted in each class):

- MIP = 99%
- Electromagnetic shower = 99%
- Michel = 95%

Find Michel electron cluster attached to the edge of a MIP cluster



Michel Electron Reconstruction for High-level Detector Commissioning Analysis

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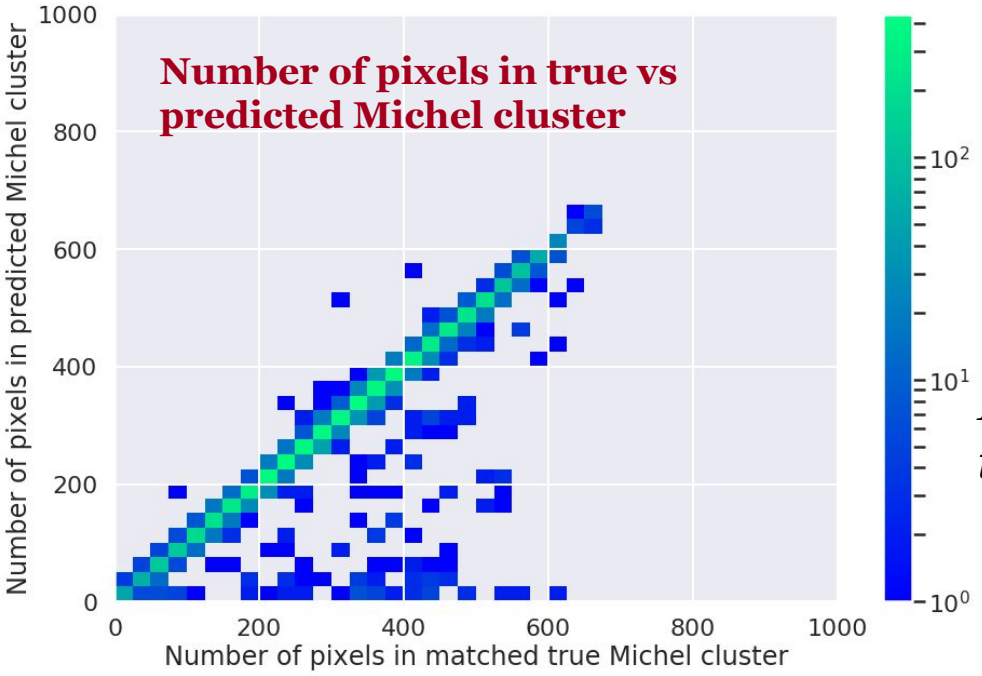

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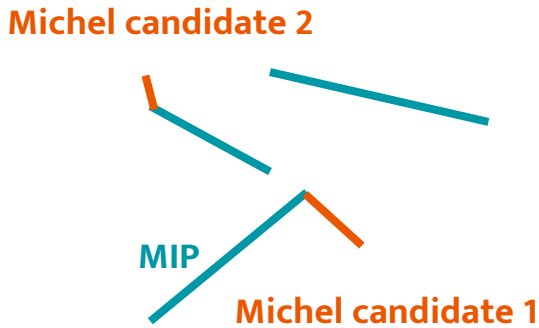

Michel Electron Reconstruction for High-level Detector Commissioning Analysis

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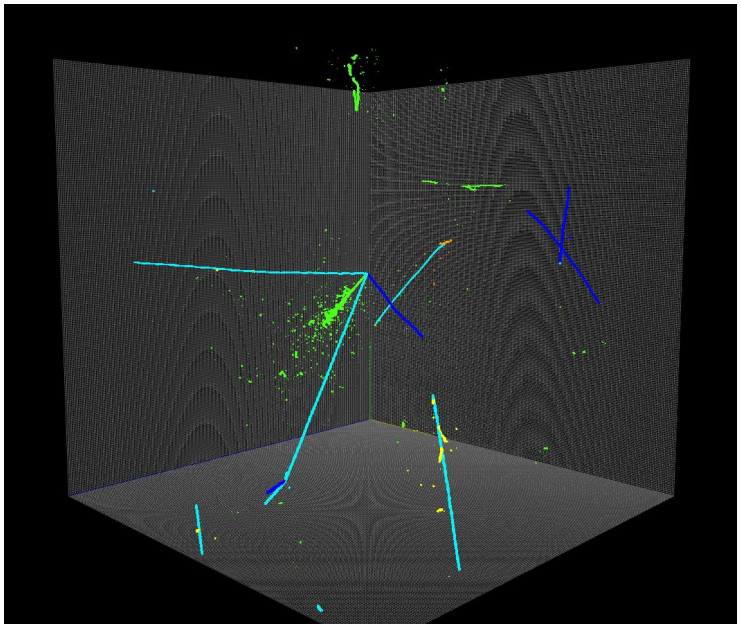
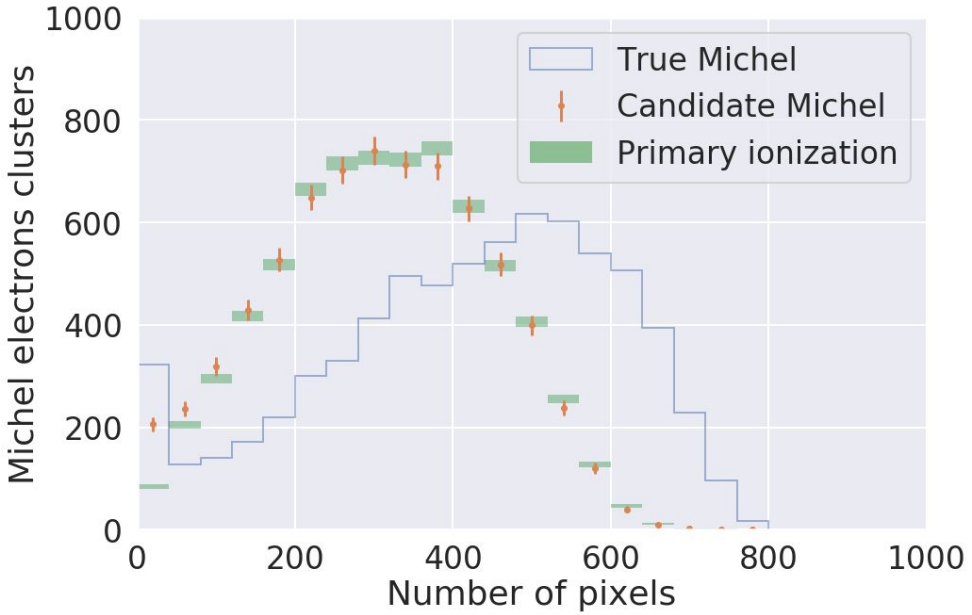
Benchmark study on 3D simulation for pixel LArTPC

- Michel identification efficiency > 98%
- Michel identification purity > 93%

… compared to 2-3% and 80-90% from the MicroBooNE experiment!

Computation estimate of for all ICARUS wire planes: 2.5s





Michel Electron Reconstruction for High-level Detector Commissioning Analysis

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Next steps (*SBN workshop next week*)

- Clustering of photon energy (radiation from Michel electron)
- Data vs. simulation discrepancy mitigation
- MIP dE/dX value for “Charge to MeV” calibration
- TPC-PMT (“flash”) matching for lifetime correction

Michel Electron Reconstruction for High-level Detector Commissioning Analysis

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Next steps (*SBN workshop next week*)

- Clustering of photon energy (radiation from Michel electron)
  - … useful for electron neutrino energy reconstruction
- Data vs. simulation discrepancy mitigation
  - … needed for machine learning algorithms on real data
- MIP dE/dX value for "Charge to MeV" calibration
  - … needed for EM shower energy scale
- TPC-PMT ("flash") matching for lifetime correction
  - … useful for cosmic rejection of neutrino selection

… while this is for commissioning analysis, all aspects are to be used for electron neutrino identification and reconstruction.

Michel Electron Reconstruction for High-level Detector Commissioning Analysis

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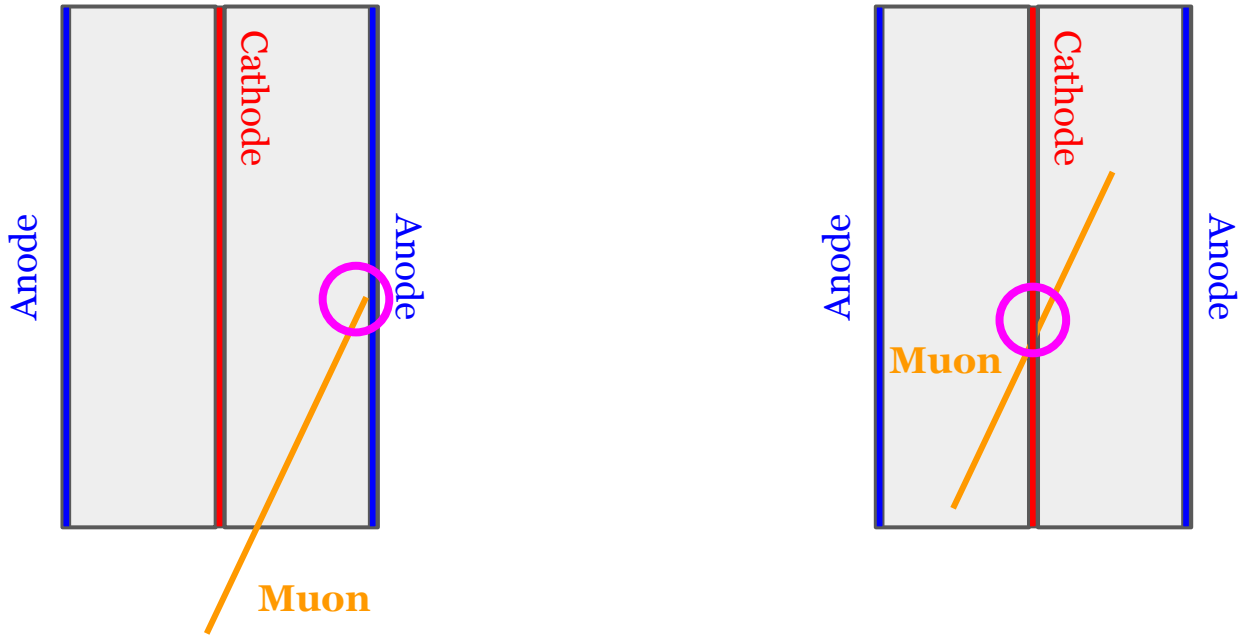
TPC-PMT ("flash") matching development

- Software is available, needs to be tuned for ICARUS data
- Crucial sample: "tagged cosmic rays" with known t_o
  - Can both calibrate & benchmark PMT-TPC matching
  - Also a crucial sample for other calibration work



Michel Electron Reconstruction for High-level Detector Commissioning Analysis

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Summary

- Software development @SBN workshop that will allow Michel electron reconstruction during ICARUS detector commissioning
- Short term:
  - useful benchmark for machine learning algorithms
  - calibration sample for ICARUS
- Longer term:
  - Develop useful tools for electron neutrino reconstruction and identification

Backup

Michel Electron Reconstruction for High-level Detector Commissioning Analysis

SLAC

TPC-PMT ("flash") matching development

- Software is available, need to be tuned for ICARUS data
- Crucial sample: "tagged cosmic rays" with known t_0
  - Can both calibrate & benchmark PMT-TPC matching
  - Also a crucial sample for other calibration work

One extra step: Michel electron analysis using PMTs

If possible, can be used for **PMT gain non-linearity study**

- Our approach has a potential for high efficiency Michel ID
- High statistics Michel sample + energy estimate from TPC
  - Expect hundreds to thousands photons (for max PMT) for ~30 MeV Michel electron
  - Enough to study non-linearity (observed photoelectrons vs. estimate from TPC MeV)