Detector Performance of the MicroBooNE Liquid Argon Time Projection Chamber

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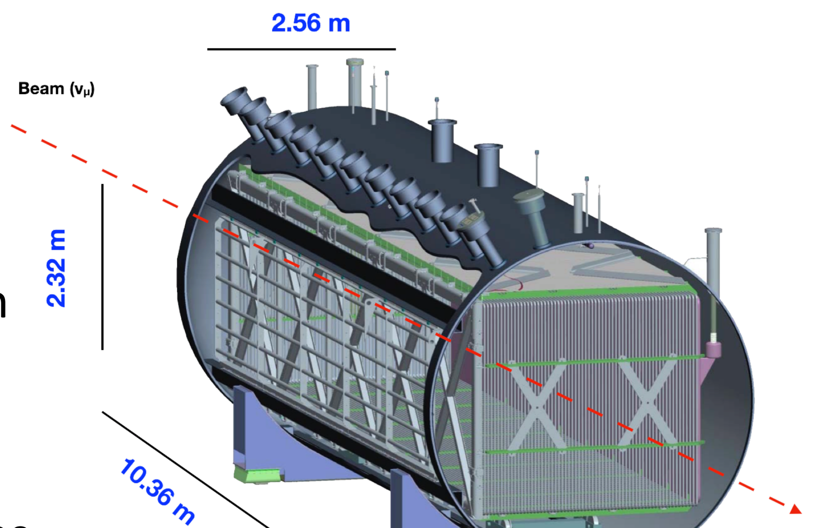
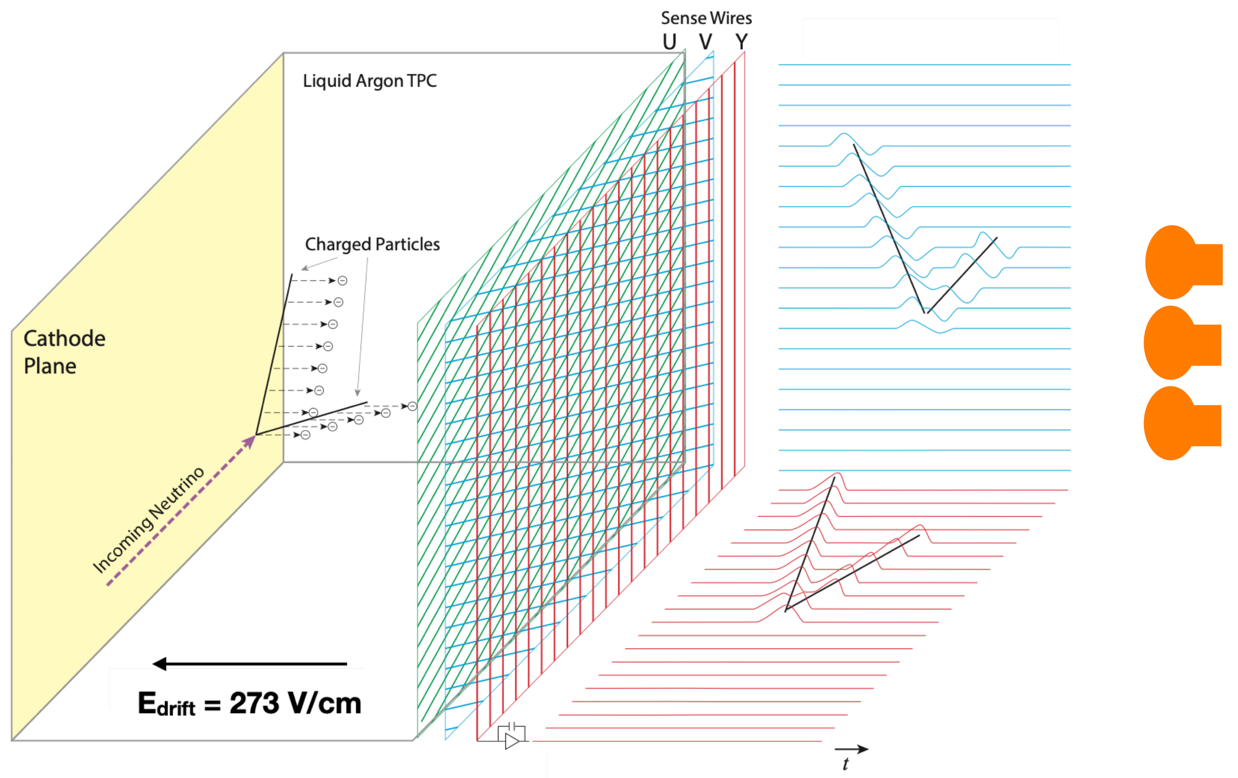
1. Introduction

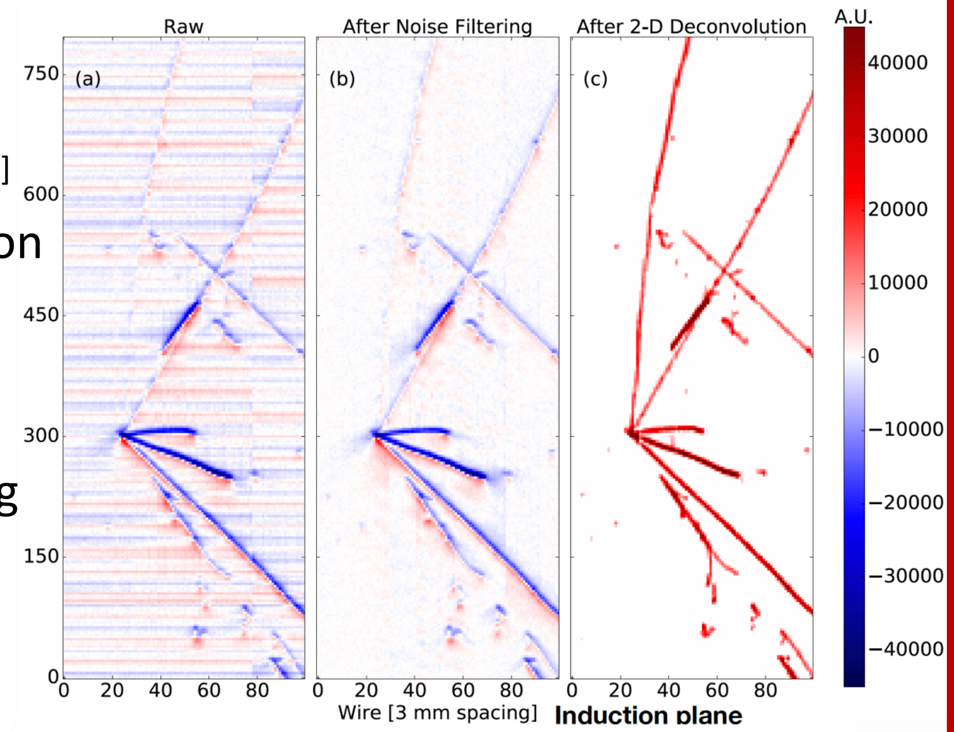


- MicroBooNE detector is a Liquid Argon Time Projection Chamber (LArTPC) with 85 tons active mass
- 3 wire planes with 8912 wires
  - 1 collection plane and 2 induction planes
  - 3 mm wire pitch and 3 mm plane separation
  - Can perform 3D reconstruction, tracking, calorimetry, etc.
- 32 8-inch Photomultipliers (PMTs)
  - Used to detect scintillation light, for trigger and event selection



2. Noise Filtering and Signal Processing

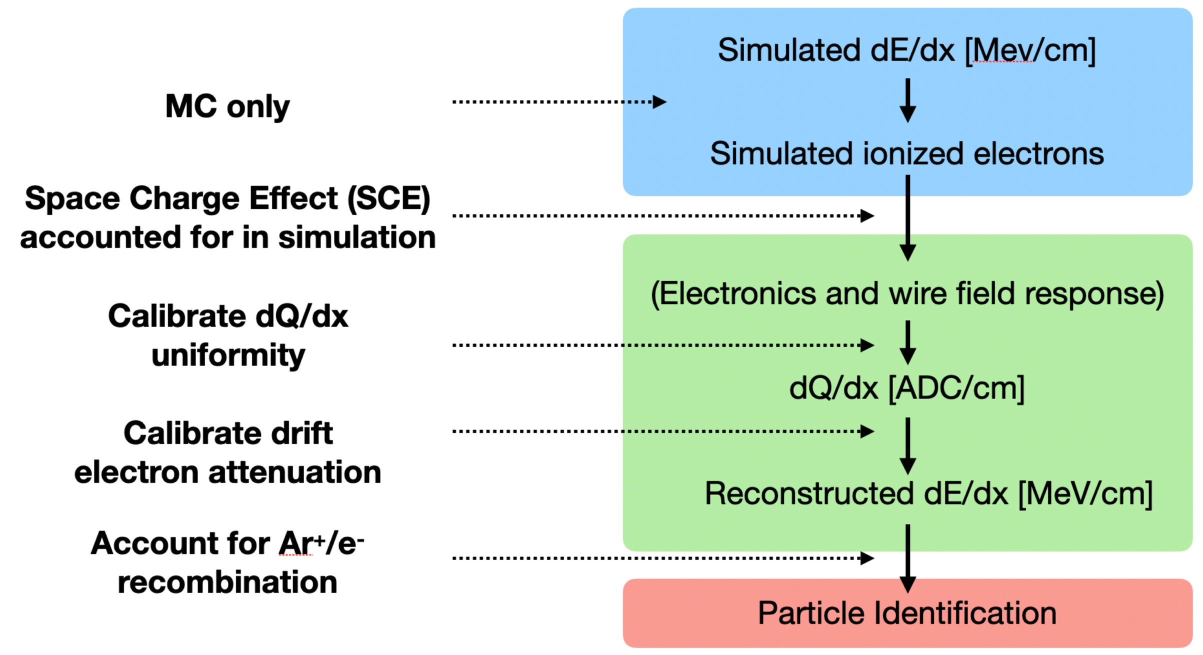
- Powerful filtering techniques can address many sources of noise[1]
- Excellent characterization of multiple wire signal response (2D deconvolution)
- Robust signal processing allows calorimetry in all three planes (enabling induction planes)[2]



References

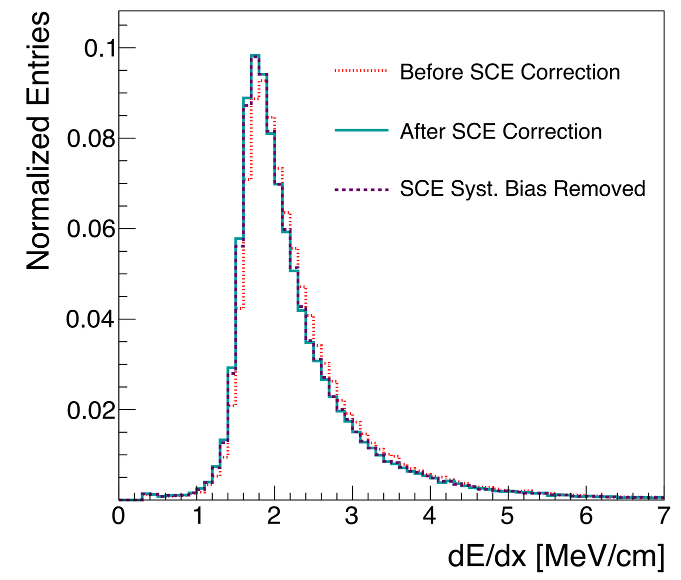
- [1] "Noise Characterization and Filtering in the MicroBooNE Liquid Argon TPC", **JINST 12, P08003 (2017)**
- [2] "Ionization of Electron Signal Processing in Single Phase LArTPC I and II", **JINST 13 P07006**, & **JINST 13 P07007 (2018)**
- [3] "A Method to Determine the Electric Field of Liquid Argon Time Projection Chambers Using a UV Laser System and its Application in MicroBooNE", **JINST 15, P07010 (2020)**
- [4] "Measurement of Space Charge Effects in the MicroBooNE LAr TPC Using Cosmic Muons", **JINST 15, P12037 (2020)**
- [5] "Calibration of the Charge and Energy Response of the MicroBooNE Liquid Argon Time Projection Chamber Using Muons and Protons", **JINST 15, P03022 (2020)**
- [6] "Measurement of the Longitudinal Diffusion of Ionization Electrons in the MicroBooNE Detector", **arXiv:2104.06551**
- [7] "Novel Approach for Evaluating Detector Systematics in the MicroBooNE LArTPC", **MICROBOONE-NOTE-1075-PUB**
- [8] "Measurement of the Electronegative Contaminants and Drift Electron Lifetime in the MicroBooNE Experiment", **MICROBOONE-NOTE-1003-PUB**

3. Detector Calibration Overview



4. Space Charge Effect Correction

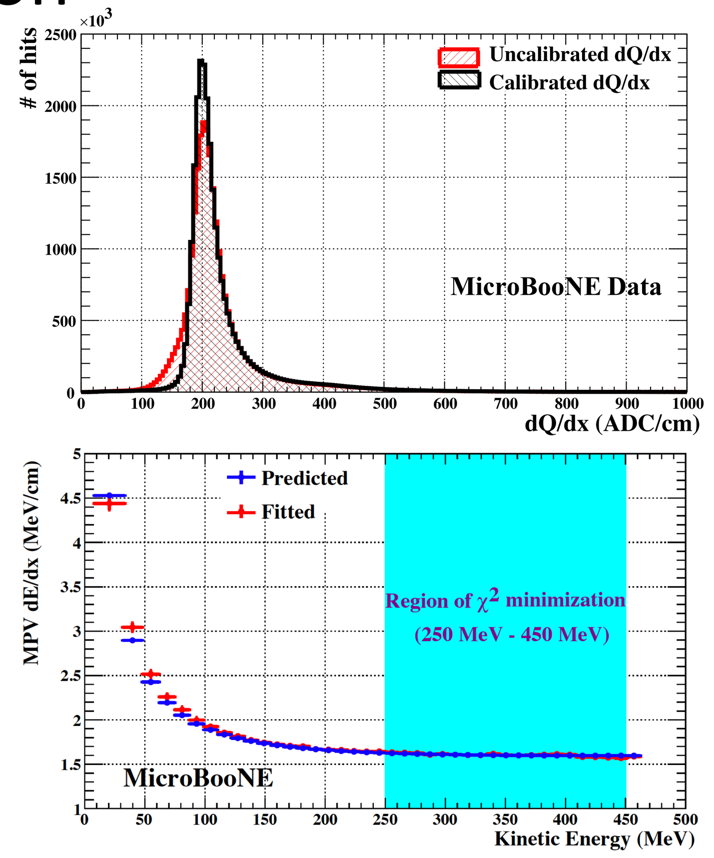
- Space charge effect (SCE) is the distortion of the drift electric field due to build-up of positive ions in the detector from cosmic rays
- SCE affects reconstructed position of signal ionization electrons and ion-electron recombination
- Dedicated studies with laser calibration system and cosmic muons to correct SCE [3,4]



5. dQ/dx, dE/dx Calibration

- Make the detector response to ionization charge uniform through out the detector
- Use anode-cathode crossing cosmic muons
- Use Modified Box model to convert dQ/dx to dE/dx [5]

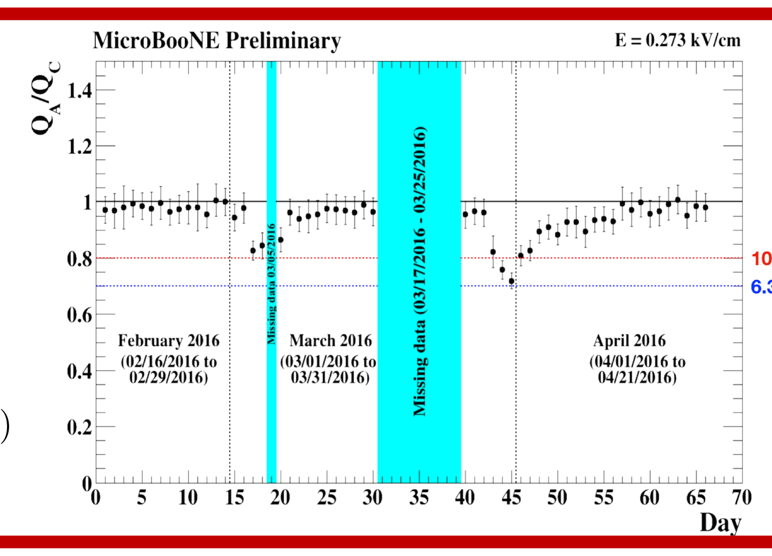
$$\left(\frac{dE}{dx}\right)_{cali} = \frac{exp\left(\left(\frac{dQ}{dx}\right)_{cali}\cdot\frac{\beta\cdot W_{ion}}{C\cdot\rho\cdot\epsilon}\right)-\alpha}{\frac{\beta}{\rho\cdot\epsilon}}$$



6. Electron Attenuation

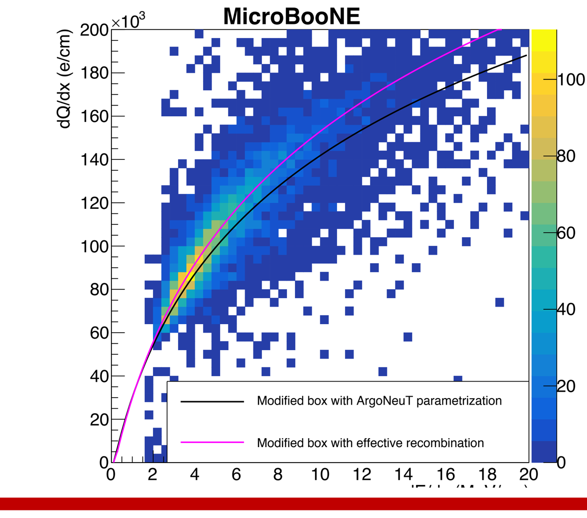
- Extract electron attenuation as a function of drift time
- Excellent LAr purity observed in MicroBooNE [8]

$$\frac{Q_A}{Q_C} = exp(-t_{drift}/\tau)$$



7. Recombination

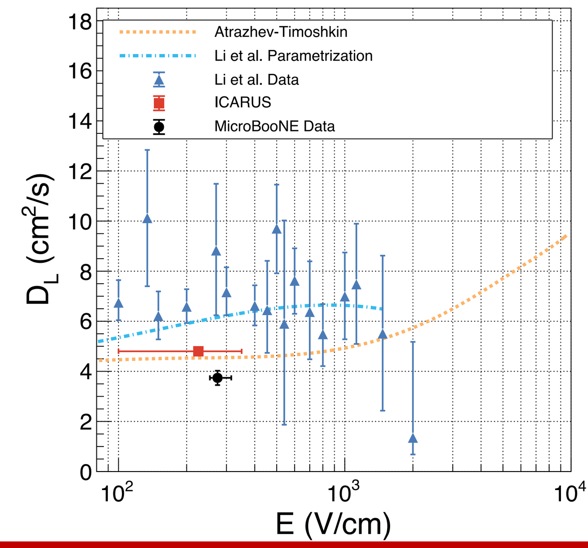
- Pure neutrino induced proton samples are used to correct for recombination effect [5]
- Modified box recombination model is used



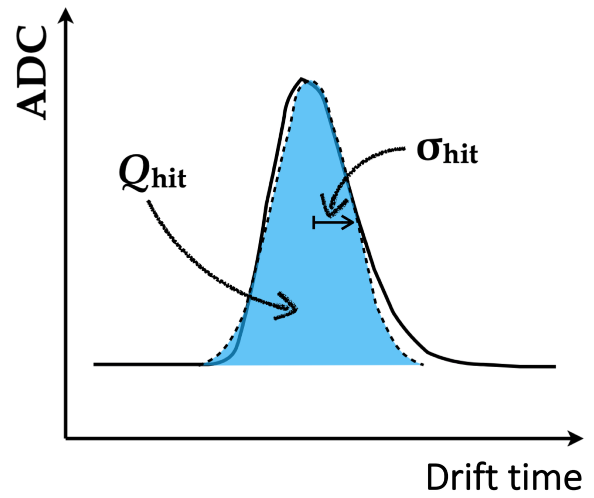
8. Longitudinal Diffusion

- First measurement in a large-scale LArTPC operating in a neutrino beam and the largest dataset ever used [6]

$$D_L = 3.74^{(+0.28)}_{(-0.29)}cm^2/s$$



9. Detector Systematics



Anode Wire Response Modification [7]

- An innovative method
- Modify charge signal waveforms on anode wires in MC to better match what is observed in data
- Cover residual and unknown detector effects

Comprehensive detector effects coverage

Category	subcategory	Effects Captured
Wire Response Modification	X (WireX)	Diffusion, Argon purity, SCE
	YZ (WireYZ)	Individual wire response and SCE residuals
	θ_{XZ} (AngleXZ)	long range induced charge effects, signal processing, deconvolution effects
	θ_{YZ} (AngleYZ)	
	dE/dx	Affects local charge deposition, e.g. recombination
Light Yield	25% down (LY)	Mis-modeling of light production
	Attentuation (LYAtt)	
	Rayleigh (LYRay)	
Other	SCE	Alternate SCE corrections
	Recombination (Recom2)	Mis-modeling of charge recombination effects

10. Summary

- The MicroBooNE detector calibrations correct most detector effects and improve the energy reconstruction and particle identification
- The detector calibration methods/strategies used at MicroBooNE can also be applied to other LArTPC based experiments
- Expect more publications on detector physics and calibration from MicroBooNE in the near future