Detector calibration using through going and stopping muons in the MicroBooNE LArTPC

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MicroBooNE LArTPC

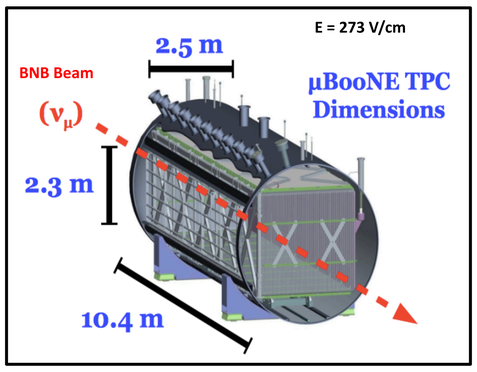

Fig 1: MicroBooNE LArTPC.

- Major physics goals include resolving MiniBooNE low energy excess and studying neutrino-argon interactions at ~1 GeV energy regime.
- Capable of exceptional calorimetric and track reconstruction to study neutrino-argon interactions.
- TPC consists of three wire planes to collect information for ionization signals (two induction planes and one collection plane).

LArTPC calibration

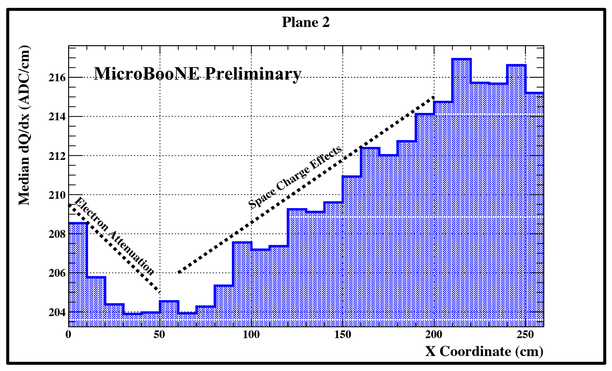

Fig 2: Non-uniformities in dQ/dx in the drift direction (Data).

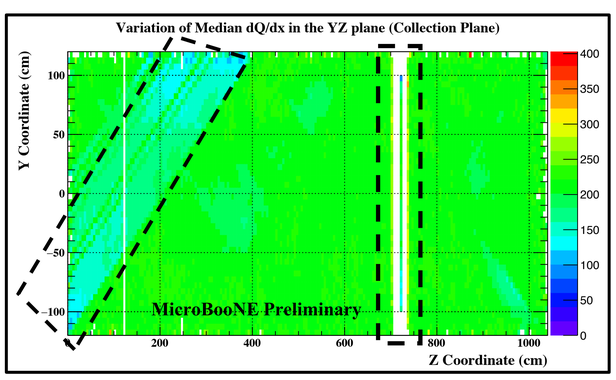

Fig 3: Non-uniformities in dQ/dx in the YZ plane (Data).

- Effects such as,
  - Distortions in detector response due to misconfigured or cross-connected TPC channels [1].
  - Space Charge E-field and spatial distortions [2, 4].
  - Electron Attenuation [4].
  - Diffusion and drifting electrons.
  - Ion Recombination [5].

  can smear the dQ/dx spectrum.
- To determine the energy deposited by charge particles inside TPC, above effects should be corrected.

Analysis Method

Step 1 : dQ/dx Calibration

- Trace back the dQ/dx before drift and after recombination.
- Use **Anode-Cathode crossing muons**.
- YZ plane is segmented into 5 cm by 5 cm cells and correction factor is defined (Eq.1).
- Drift direction is segmented into 10 cm long bins and for each bin a correction factor is defined (Eq.1).
- To remove non-uniformities of dQ/dx in time, a time correction factor is defined on a daily basis (Eq.2).
- Corrected dQ/dx values are calculated using Eq. 3.

Step 2 : dE/dx Calibration

- Determine the constant of proportionality (Calibration constant) which translates the corrected dQ/dx in **ADC /cm** to **number of electrons/cm** after recombination.
- Use contained **stopping muons** from neutrino interaction (See Figure 6).
- dQ/dx values are translated into dE/dx assuming the Modified Box model [5] for recombination (Eq. 4).
- **Calibration constant C** is tuned until the best agreement between the prediction and the fitted distributions of the Most Probable dE/dx profiles for stopping muons, is attained.

$$\textbf{Eq. 1}\ C(y,z)\ \text{or}\ C(x) = \frac{(dQ/dx)_{Global}}{(dQ/dx)_{Local}}$$

$$\textbf{Eq. 2}\ C(t) = \frac{(dQ/dx)_{Reference}}{(dQ/dx)_{Global}}$$

$$\textbf{Eq. 3}\ (dQ/dx)_{Calibrated} = C(y,z) * C(x) * C(t) * (dQ/dx)_{Reconstructed}$$

$$\textbf{Eq. 4}\ (dE/dx)_{Calibrated} = \frac{\mathrm{Exp}\left\{\frac{(dQ/dx)_{Calibrated} * \beta' * W_{ion}}{C * \rho * \varepsilon}\right\} - \alpha}{\beta'/(\rho * \varepsilon)}$$

C : Calibration Constant W_{ion} : 23.6 x 10^{-6} MeV/electron

ε : 0.273 kV/cm ρ : 1.38 g/cm^3

β': 0.212(kV/cm)(g/cm^2)/MeV α : 0.93

Refer **MicroBooNE-NOTE-1048-PUB (2018)**

Results (dQ/dx calibration)

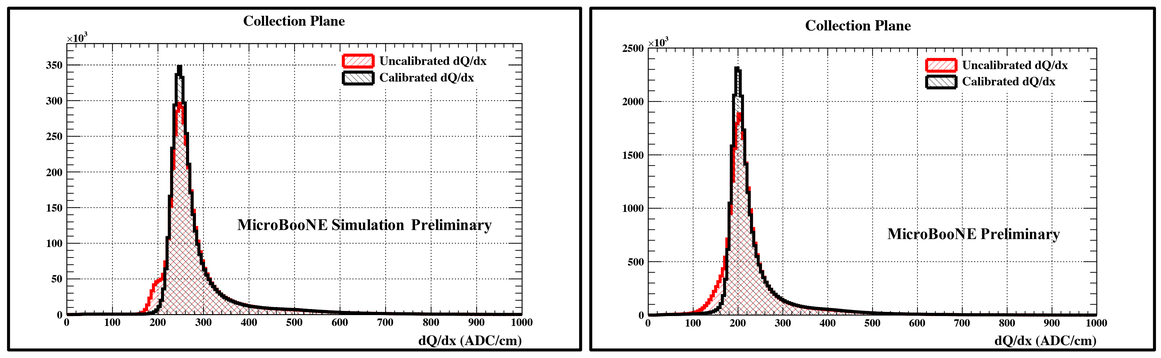

Fig 4: Comparison between calibrated and uncalibrated dQ/dx spectra in the collection plane. (Left) Monte-Carlo. (Right) Data.

Results (dE/dx calibration)

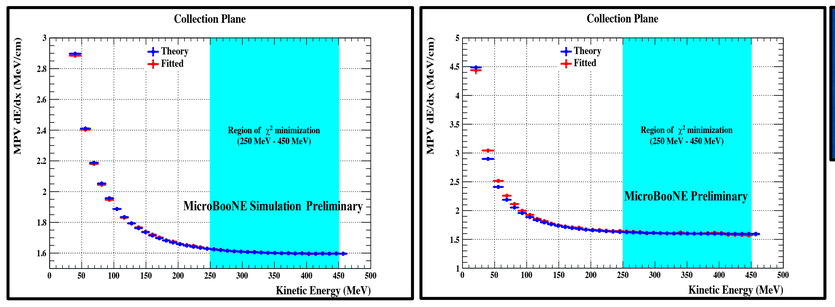

Fig 5: Comparison between Most Probable dE/dx distributions between prediction and the fitted in the collection plane. (Left) Monte-Carlo. (Right) Data.

Fig 6: Stopping muon in data.

- Uncertainties in the field and electronic responses between data and Monte-Carlo result in a different calibration constant in data compared to the input calibration constant of 5×10^{-3} in Monte-Carlo.

	Calibration constant in the collection plane
Monte - Carlo	$(5.076 \pm 0.001) \times 10^{-3}$
Data	$(4.113 \pm 0.011) \times 10^{-3}$

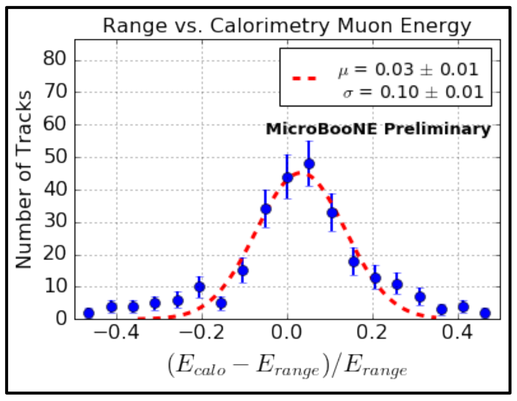

Fig 7: Fractional difference between range vs. calorimetric kinetic energies.

- Calibration produces results which is consistent within **3%** with energy reconstructed by range for a sample of stopping muons.

Angular dependence study

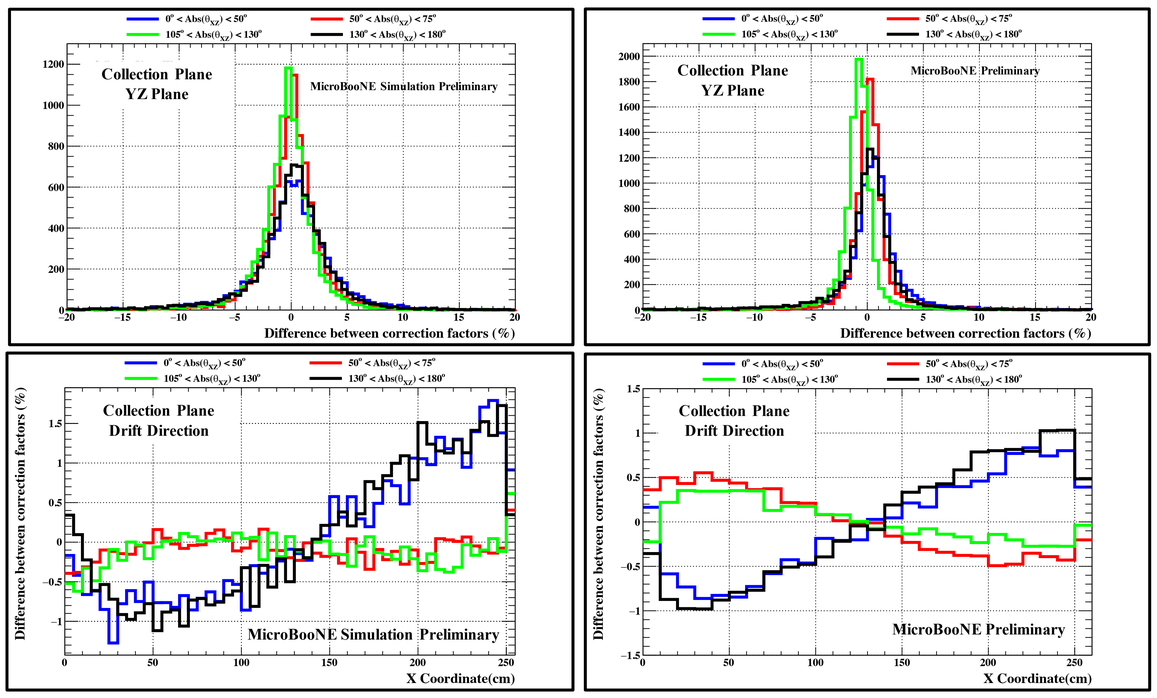

Fig 8: Fractional difference between correction factors. (First raw) YZ plane correction factors. (Second raw) Drift direction correction factors. (First Column) Monte-Carlo. (Second Column) Data.

- Want to see the effect of tracks at high angles on the calibration scheme.
- Assign **1%** systematic on YZ correction factors and **1.5%** systematic in drift direction correction factors.

Conclusions

- This calibration procedure improves the resolution of the reconstructed dQ/dx spectrum.
- Range based kinetic energy and calorimetric kinetic energy agrees to within **3%**.

References:
[1] The MicroBooNE Collaboration, JINST 12, P08003 (2017).
[2] MicroBooNE-NOTE-1018-PUB (2016).
[3] The MicroBooNE Collaboration, arXive:1802.08709.
[4] MicroBooNE-NOTE-1026-PUB (2017).
[5] The ArgoNeuT Collaboration, JINST 8, P08005 (2013) .