Thoughts on Calorimetry Calibration and Various Miniature Studies

Richie Diurba (Minn.)

diurb001@umn.edu

Motivation

- There are various inputs to the calibration ranging from the purity monitor to recombination modelling.
- I wanted to be a bit more thorough in presenting and documenting what we have and what we need.

Questions that arise:

1. Do these inputs make an impact on the output calibration of the calorimetry?
2. If they do, do these changes match expectation?

These studies may not be necessary nor complete for the analyses or in general, but instead attempt to answer any possible questions that may arise.

I will only discuss dQ/dx(X,Y,Z) calibration in these slides.

Work could not be possible without Ajib and Mitch's development of dQ/dx calibration macros. Big thanks goes out to them.

Complicating factors: or why should we be extremely verbose?

Examples:

- Space charge effect:
  - Adding capability to go forward and backward in SCE maps under a common tool (See Jake's talk tomorrow).
  - The input SCE map may create different effects than what is observed with the current map. Unlikely, but still possible.
- Recombination measurements:
  - Recombination assumptions are made for the calibration (Modified Box vs. Birks).
  - These need to be documented and discussed when fitting dQ/dx calibrated data to a recombination model.

Various Inputs to the Calibration and their Impact

Input	dQ/dx(YZ)	dQ/dx(X)	Gain constant Calibration
Track angle (impacts bin statistics)	X	X	
Purity monitor		X	
SCE Efield corr.		X	X
SCE track pitch corr.	X		
Recombination model		X	X

Table of variables that impact calibration as marked with an "X." These are variables that are fed into the calibration to scale the dQ/dx.

The track angle and purity monitor inputs have been tested and their studies have been reproduced in the backup.

The ability of the cathode-crossing tracks to measure the drift electron lifetime has also been investigated (click here)

SCE Track Pitch Corrections

Can the SCE track pitch correction impact calibration?

Methodology:

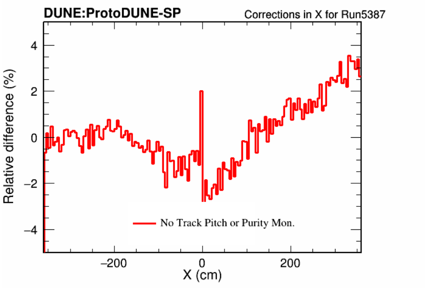
- Run two different calibrations and compare:
  1. Default
  2. No track pitch or purity monitor correction (This is due to how the reco handles these sequentially).

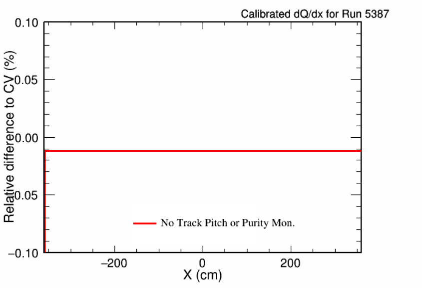
Francesca has already looked into this issue for beam particles. See slides: (click here).

Trk Pitch Corr.

We want to see if the norm. and corrections match expectation relative to the nominal calibration.

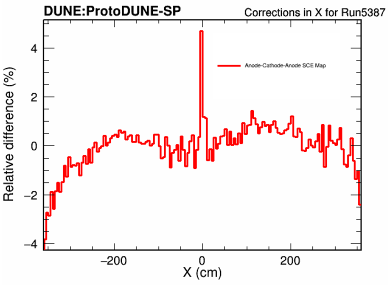
Need to investigate secluded samples closer to z=0 and with altered coverage in the detector.

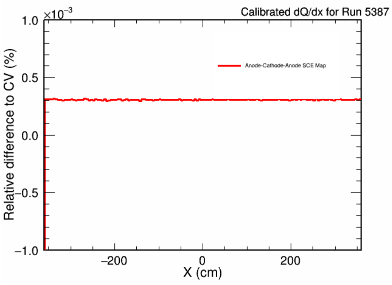




Alternative Map

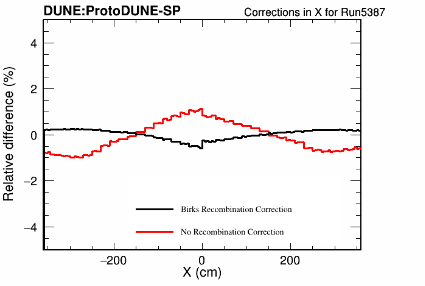
Use Ajib's map for the recombination correction.

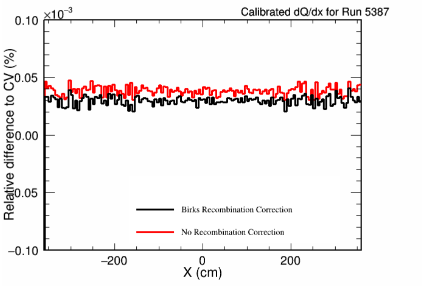




Recombination Modelling

Compare the dQ/dx output calibration using the Birks' calibration and with no recombination correction.





Will git push the macros soon with Birks' model.

Conclusion

- Laid out various inputs to the calibration and if they break the calibration.
- For the dQ/dx calibration, there does not appear yet to be something to cause too much worry.
- Want to investigate further with the gain calibration added to these various inputs where relevant.

Back-up Slides

Calibration of dQ/dx

Five steps done on a run-by-run basis:

- Correct the SCE of dQ/dx using interpolated map and apply the purity monitoring measurement based on dQ/dx as a function of position in the drift distance direction.
- Measure the fluctuations of dQ/dx as a function of YZ for both drift volumes using selected cathode-crossing cosmics.
- Measure the fluctuations of dQ/dx as a function of X using selected cathode-crossing cosmics.
- Calculate a normalized value of a median X value measured over a series of runs to be used in the next step (N_Q).
- Measure the gain conversion (C_{cal}) from ADC counts to ionized electrons by comparing a theoretical dE/dx to a dE/dx from the calibrated dQ/dx.

$$\mathrm{dQ/dx_{full\,calib.}} = \frac{\mathrm{dQ/dx_{sce.corr} C_x C_{yz} N_Q exp(t_{drift}/\tau)}}{\mathrm{C_{cal}}}$$

Calibration of dE/dx

- Select cathode-crossers with residual range 120-200 cm.
- Use the corrected dQ/dx and measure the dE/dx with a given gain constant to find the one with the best fit to the theoretical dE/dx for muons at high residual range using χ^2 over approx. 40 slices of the residual range.

More information can be found from the ProtoDUNE-SP Performance paper or from an ICHEP contribution. They can be found here and here, respectively.

Purity Monitor-Related Studies

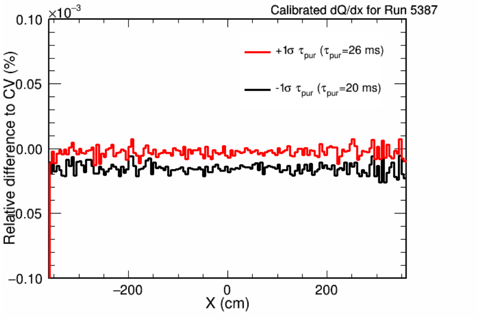
Does the current smearing calibration as a function of drift distance actually correct for any purity monitor uncertainties?

- Alter the purity monitor calibration by $\pm 1\sigma$.
- Rerun the dQ/dx correction as a function of drift distance.
- Compare post-calibrated values with the $\pm 1\sigma$ shifts to the calibrated values with the central-value purity monitor correction.

Calibrated dQ/dx(X) with Different Purity Monitor Corrections

Normalization factor using various purity monitor corrections:

- $+1\sigma$: 59.88 ADC*tick/cm
- CV: 59.98 ADC*tick/cm
- -1σ: 60.46 ADC*tick/cm



Difference in Calibrated dQ/dx with different initial purity monitor calibrations for Run 5387 ($\tau_{pur,CV}$=25 ms)

MicroBooNE's Method of Associating Uncertainties

ProtoDUNE-SP uses the calibration scheme from MicroBooNE; therefore, it is informative to find how they ascertain uncertainties.

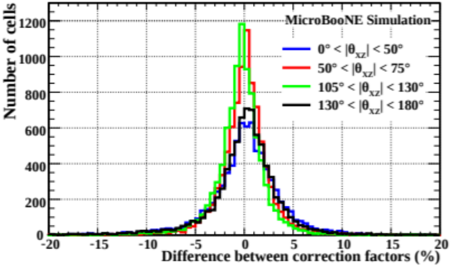
- Divide the sample of cathode or anode crossers amongst four different angles.
- Use the subsample for the YZ correction.
- Do the same thing for the X correction.

The uncertainties are then ascertained by comparing the corrections in the subsample to that of the broader sample.

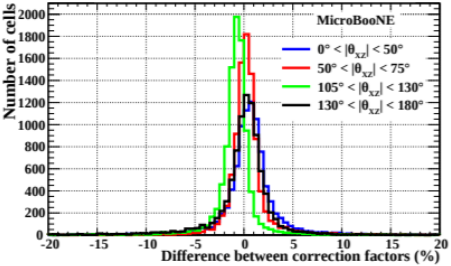
This has an effect of both evaluating the statistics fluctuations and the track angle dependence on the hit charge measured.

MicroBooNE MCC8 Calibration Uncertainties

Based on the paper, the MicroBooNE calibration omits a preliminary SCE and lifetime calibration.



(a) Collection plane, MC

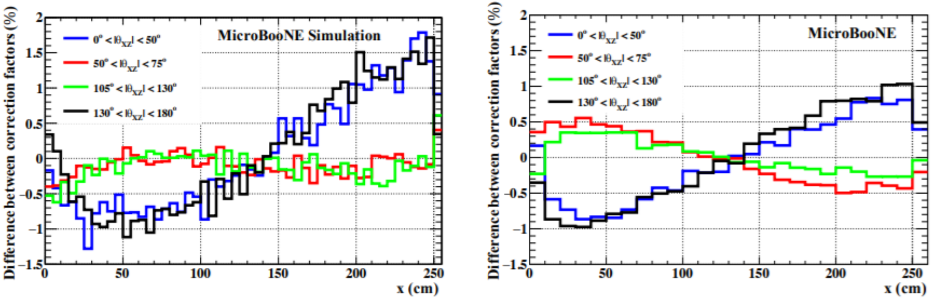


(b) Collection plane, data

Corrections in YZ measured in MicroBooNE for MCC8. Taken from MicroBooNE calibration paper.

Applied a 2% uncertainty based on peak differences between subsamples and sample.

MicroBooNE MCC8 Calibration Uncertainties



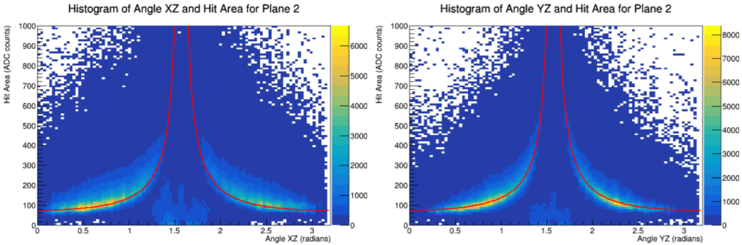
(a) Collection plane, MC (b) Collection plane, data

Corrections in X measured in MicroBooNE for MCC8. Taken from MicroBooNE calibration paper.

Applied a 1.5% uncertainty based on spread in data.

Angle-Folding

Update was made to fold the angles to 0-90 degrees:



MicroBooNE Monte Carlo crossing cosmic track hits binned by angle in XZ and YZ. Notice the symmetry, which led me to bin angles into one quadrant. This is empirically quantified by $Q = a/|cos(\theta)|$. Ajib cuts all XZ angles above 65 degrees and YZ angles above 70 degrees.

This idea was proposed for MicroBooNE by Andy Furmanski and was implemented for this MicroBooNE Monte Carlo wire modification project documented at the moment by this tech note.

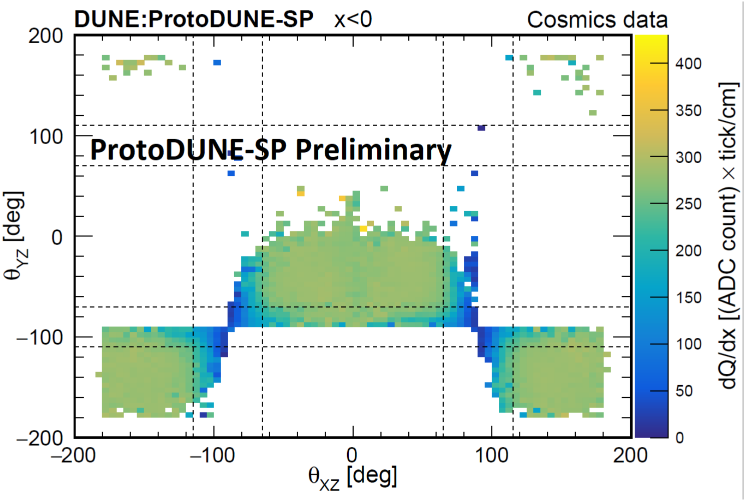
Binning of dQ/dx and dE/dx Uncertainty Methodology

With an increase in statistics, I have created three different types of angle binning that we can decide upon:

- Two bins of 30 degrees in θ_{XZ}.
- Minimize impact of θ_{YZ} by cutting by 40 degrees. Instead, bin a low bin with enough statistics (θ_{XZ} <40 degrees) and an "overflow bin."
- Three equal bins of θ_{XZ} (20 deg, 40 deg, 60 deg). All bins have more than 10k tracks. (See backup)

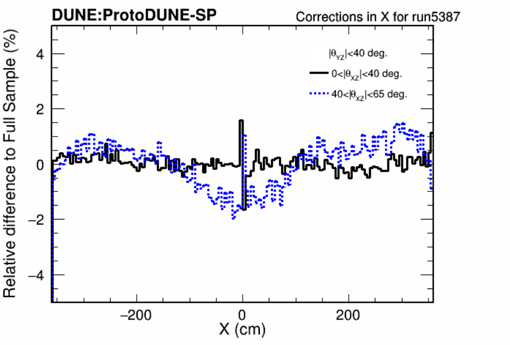
I prefer the second option as it is what I produced last month and reflects the fact that $\theta_{YZ,beam}$ is appox. 20 degrees. I found the cut of 40 degrees in θ_{YZ} is the lowest angle whereby there are enough statistics in a subsample.

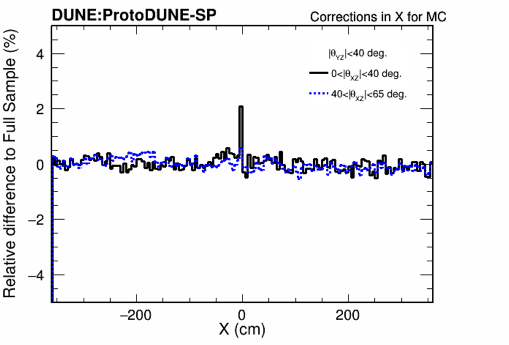
Distribution of cathode-crossing Tracks



Run 5770 track distribution by angle for beam right.

Comparisons with a cut on θ_{YZ}



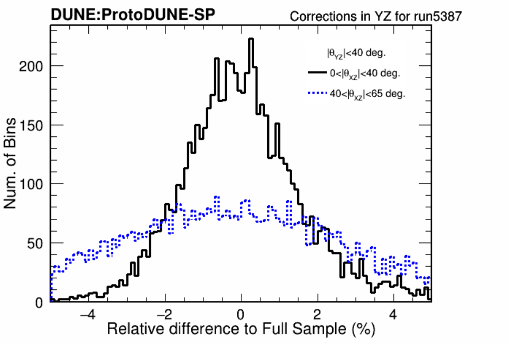


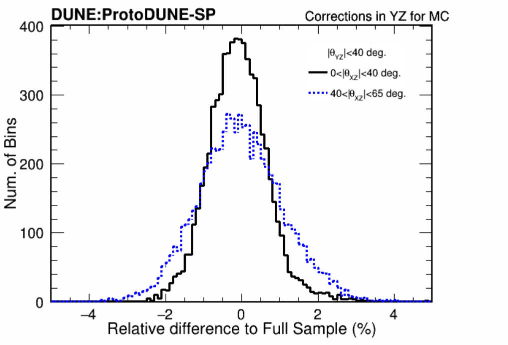
Comparisons with a cut on θ_{YZ}

For data:

- θ_{XZ} <40 degrees: approx. 13.9k tracks
- θ_{XZ} >40 degrees: 3,271 tracks

Fluctuations likely due to these different statistics.





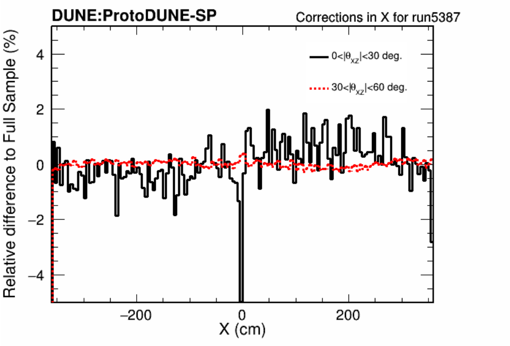
Overall Uncertainties

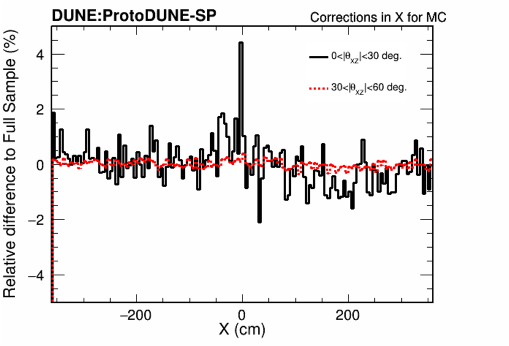
The dE/dx calibration relies on the factor (N_Q/C_{cal}). For the subsample below, this quantity matched between the two subsamples below (0.949) and the broader sample (0.949). Therefore, I am now omitting it from consideration.

Run	σ_{YZ}	σ_X	Calculated $\sigma_{dE/dx_{MIP}}$
Run 5387 w/ 40 deg. cuts	1.5%	0.3%	1.68%
MC w/ 40 deg. cuts	1.0%	0.3%	1.5%

Percent uncertainties on various calibration steps using the 40 degree cuts.

MicroBooNE Binning with Reduced MC Statistics





Statistics reduced in MC to better reflect the statistics for Run 5387. We could run over more data if we pick this binning option to correct for the spike at x=-30 cm in MC.

MicroBooNE Binning with Reduced MC Statistics