Detector calibration for 1 GeV/c data

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Hadron Analysis Meeting

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Introduction

- Currently there are many on-going hadron-argon cross section measurements
  - Inclusive pion-argon cross section
  - Inclusive proton-argon cross section
  - Pion absorption/charge exchange
  - TKI
  - Neutron cross section
  - Kaon cross section
  - etc.
- Most of the analyses currently use a single 1 GeV/c data run 5387
  - It is ok to use a single run to develop analysis .
  - The final results should use all 1 GeV/c data for good statistics.
- **We need to calibrate all 1 GeV/c data.**

Detector calibration

- We calibrate the detector response to track particles in two steps
  - Equalization of detector response (dQ/dx calibration)
    - Electronic gain calibration, space charge calibration and lifetime calibration were applied during reconstruction/production.
    - Additional YZ and X calibration constants are derived using crossing muons.
  - Absolute energy scale (ADC -> number of electrons) is determined using stopping muons (dE/dx calibration).
- The procedure is documented in the performance paper and wiki page.
- The dQ/dx calibration constants can be uploaded to the calibration database.

YZ, X, and Normalization Corrections

- Divide the *yz* plane into 5x5 cm² bins and divide the *x* coordinate into 5 cm bins
- Correction factors calculated using global *dQ/dx* (median value across *x* coordinate or *yz* plane) and local *dQ/dx* (median value in bin)
- Normalization using median *dQ/dx* at anode and global *dQ/dx*

YZ correction factor:

$$C(y,z) = \frac{(dQ/dx)_{\mathrm{YZ}}^{\mathrm{global}}}{(dQ/dx)_{\mathrm{YZ}}^{\mathrm{local}}}$$

X correction factor:

$$C(x) = \frac{(dQ/dx)_{\mathrm{x}}^{\mathrm{global}}}{(dQ/dx)_{\mathrm{x}}^{\mathrm{local}}}$$

Normalization factor:

$$N_Q = \frac{(dQ/dx)^{\mathrm{anode}}}{(dQ/dx)^{\mathrm{global}}}$$

$$(dQ/dx)_{\mathrm{calibrated}} = N_Q C(y,z) C(x) (dQ/dx)_{\mathrm{reconstructed}}$$

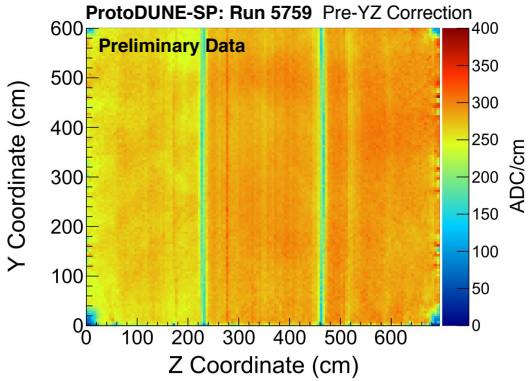

Fig 4: *dQ/dx* distribution in plane 2 for x < 0 before *yz* correction.

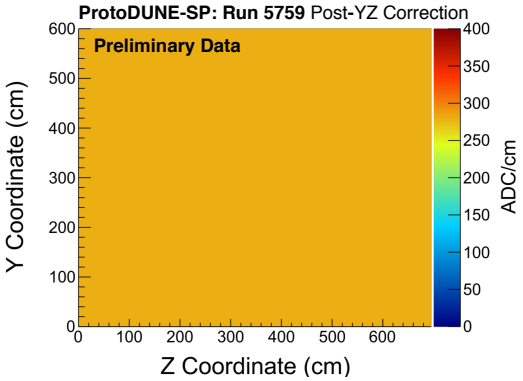

Fig 5: *dQ/dx* distribution in plane 2 for x < 0 after *yz* correction.

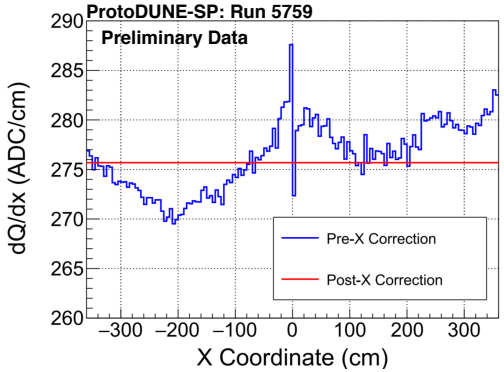

Fig 6: *dQ/dx* vs *x* coordinate after *yz* corrections for plane 2 comparing before and after *x* correction.

Graham Chambers-Wall's poster

Absolute Energy Calibration

Modified Box Model:

$$\left(\frac{dE}{dx}\right)_{\text{calibrated}} = \left(\exp\left[\frac{\left(\frac{dQ}{dx}\right)_{\text{calibrated}}}{C_{\text{cal}}}\frac{\beta' W_{\text{ion}}}{\rho\mathcal{E}}\right] - \alpha\right)\left(\frac{\rho\mathcal{E}}{\beta'}\right)$$

C_{cal} = Constant used to convert ADC values to number of electrons,
W_{ion} = 23.6 x 10^{-6} MeV/electron (work function of argon),
$\mathcal{E}$ = ProtoDUNE-SP E field based on the space charge maps,
ρ = 1.39 g/cm^3 (liquid argon density at a pressure of 105 kPa)
β' = 0.212 (kV/cm)(g/cm^2)/MeV, and
α = 0.93.

The calibrated *dQ/dx* values of stopping muons are used in the Modified Box Model [2] to fit the *dE/dx* values.

Calibration Constants (10^{-3} ADC/electron)			
Plane	Run 5759	Run 5770	Run 5841
0	5.353±0.0065	5.325±0.0063	5.411±0.0062
1	5.328±0.0062	5.261±0.0057	5.403±0.0061
2	4.891±0.0063	4.828±0.0054	4.855±0.0071

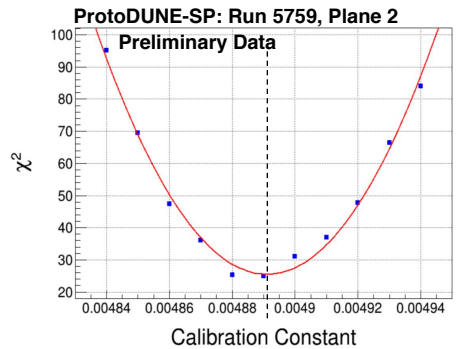

Fig 8: χ^2 vs calibration constant.

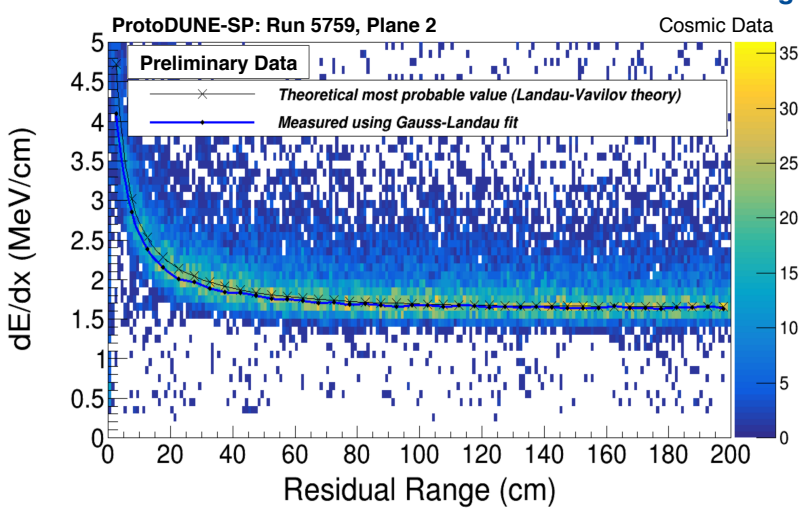

Fig 9: *dE/dx* vs residual range of stopping muons.

Graham Chambers-Wall's poster

Current production status

- Prod4 of 1 GeV/c data and MC is complete, see wiki page.
- Starting from this production, the production team saves the "michelremoving" TTree, which can be used to derive calibration constants.

Momentum (GeV/c)	Definition Name	SAM Query Links
0.5	PDSPProd4_MC_0.5GeV_reco1_sce_datadriven_v1	describe, summary, files
0.5	PDSPProd4_MC_0.5GeV_pandora_sce_datadriven_v1	describe, summary, files
0.5	PDSPProd4_MC_0.5GeV_michelremoving_sce_datadriven_merged_v1	describe, summary, files
1	PDSPProd4_MC_1GeV_reco1_sce_datadriven_v1	describe, summary, files
1	PDSPProd4_MC_1GeV_pandora_sce_datadriven_v1	describe, summary, files
1	PDSPProd4_MC_1GeV_michelremoving_sce_datadriven_merged_v1	describe, summary, files
6	PDSPProd4_MC_6GeV_reco1_sce_datadriven_v1_00	describe, summary, files
6	PDSPProd4_MC_6GeV_pandora_sce_datadriven_v1_00	describe, summary, files
6	PDSPProd4_MC_6GeV_michelremoving_sce_datadriven_merged_v1	describe, summary, files

- Prod4a of 1 GeV/c MC is on-going
  - Simulate the effect of electron diverters (Ref: Tom's talk)
  - Save additional true trajectory points (Ref: Jake's talk)
  - This is the likely to sample for the first cross section results/publications.

Current calibration status

- Ajib provided the calibration constants for the Prod4 1 GeV/c MC and run 5387.
- Mitch Mote (LSU) has started working on detector calibration
  - He finished dQ/dx and dE/dx calibration for Prod4 1 GeV/c MC.
  - He has started to work on calibrating data.
  - He is also working on an automated version of the codes that can be used much more easily and with less change of parameters inside the C files themselves.
- Reddy Pratap Gandrajula also worked on the data calibration in 2020
  - See his talk at the collaboration meeting.

Plan for detector calibration

- Once Prod4a of 1 GeV/c MC is done, we need to calibrate it.
- We should organize the efforts to calibrate 1 GeV/c data.
  - We need to create a good run list first
    - Good beam run list
    - We need to identify all 1 GeV/c data at the nominal running conditions (HV = 180 kV)
  - We would like people to volunteer to calibrate data runs
    - Mitch/Ajib can give a tutorial
  - We also need one person to upload calibration constants to database.
  - Once the detector calibration is finished, we will request the production team to reprocess data to have calibrated dE/dx information.
- We can use the slack channel #pdsp-calibration to coordinate the efforts.

Comments for the group

- It would be good to give regular updates at the DRA meeting.
  - E.g. new thin slice methods, latest cross section results.
  - Could be a summary talk by the convener and/or individual talks by analyzers.
- It would be good to get regular updates on each analysis.
  - What is the current status?
  - What is the timeline of the analysis?
  - Are you waiting for new samples or having trouble in your analysis?
  - When will the paper come out? ☺