Comments on the Analysis of dE/dx vs. Wire Tension in A. Lister, DUNE-doc-20861-v1

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DUNE APA Technical Board Meeting

November 6, 2023

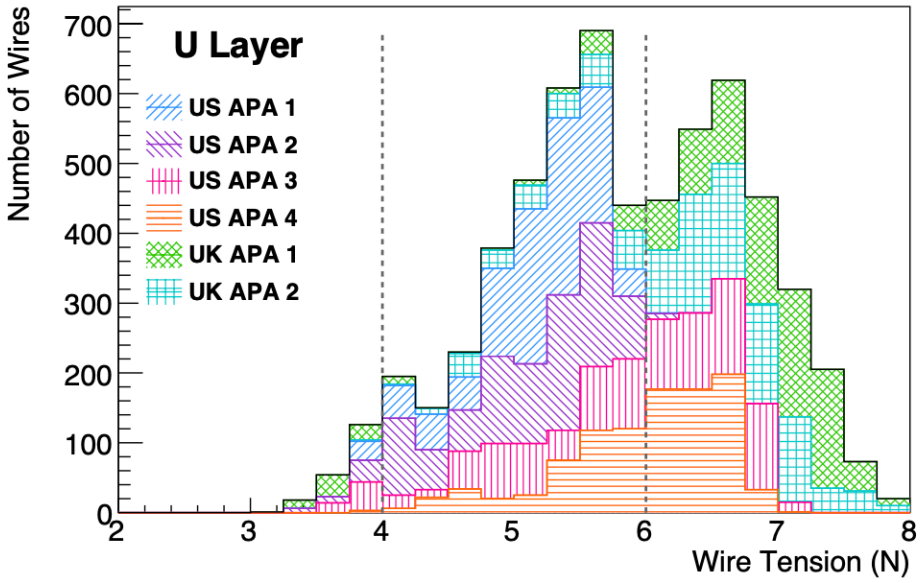
Adam Lister's Analysis

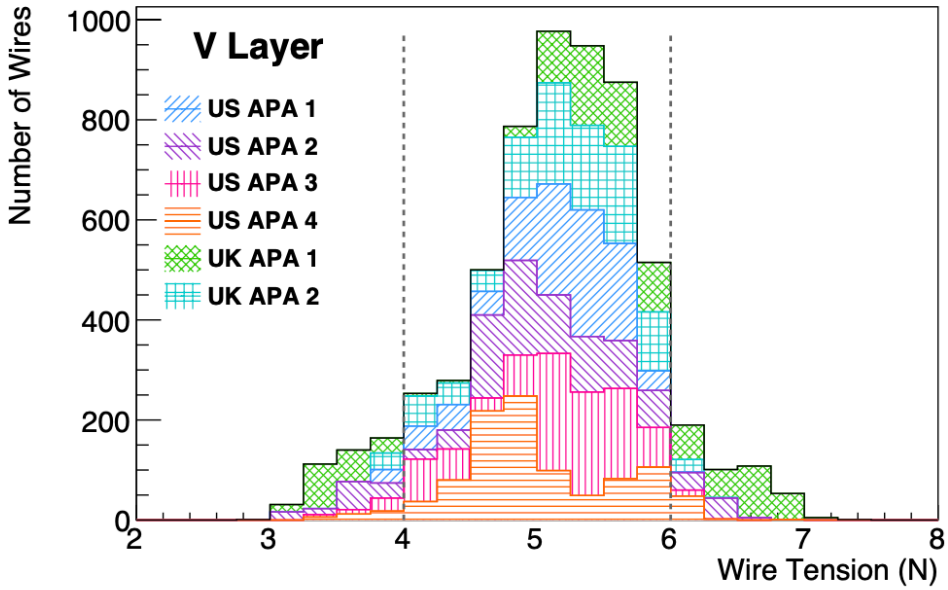
- I remember seeing the analysis presented in the DRA meeting, but I do not remember much discussion on it.

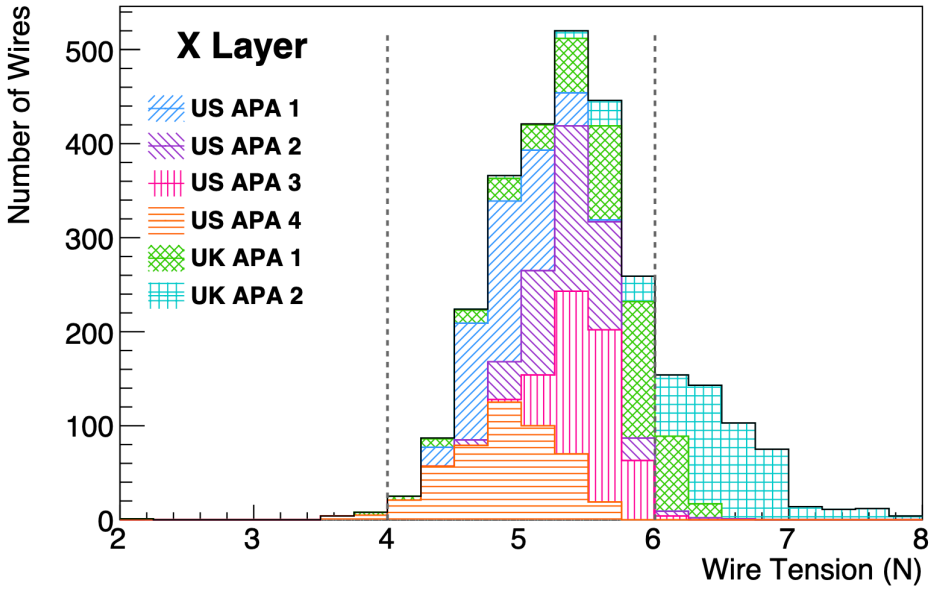
  https://indico.fnal.gov/event/45860/

- Usually, we ask a few questions at the meeting, but review for publications is much more thorough.
- ARC reviews can be lengthy and very detailed. This did not go through that kind of review.
- Data of course are data, but I do have some reservations about the interpretation.

PDSP Wire Segment Tension Distributions







Spreadsheets with measurements in DUNE-doc-20861-v1

DUNE-doc-20861-v1

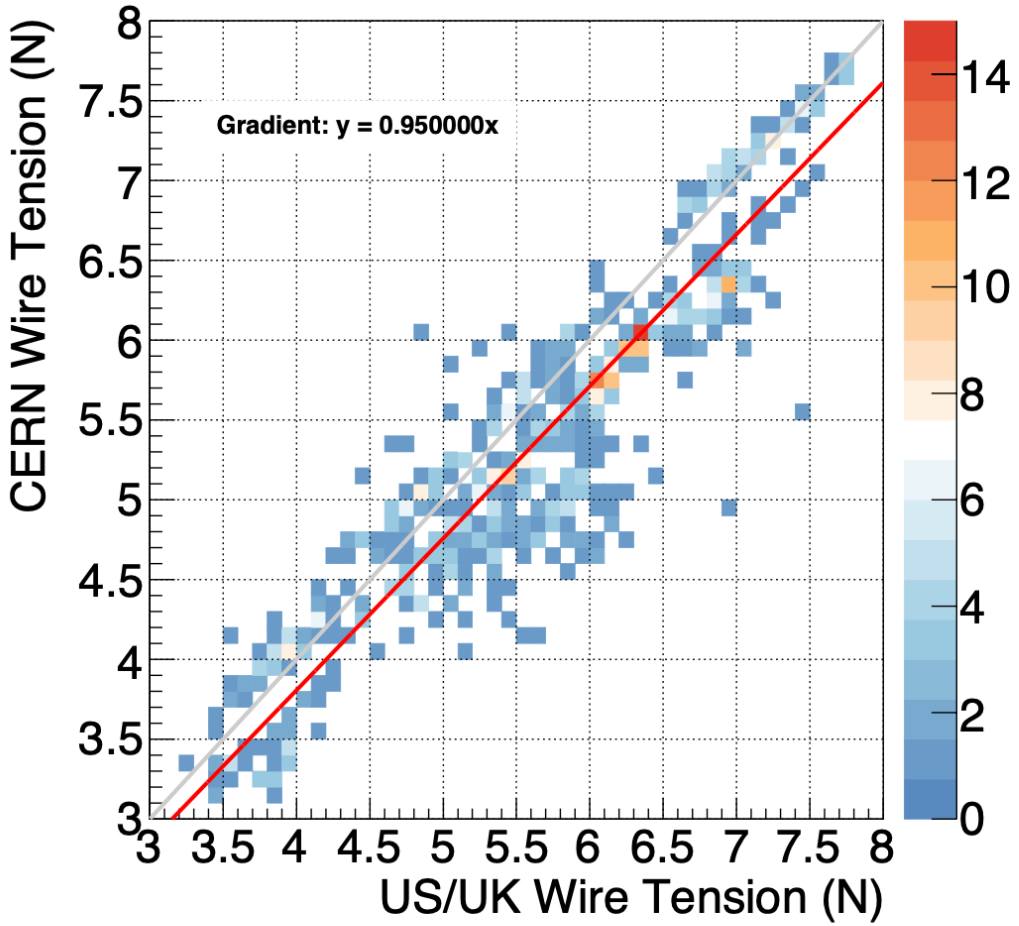
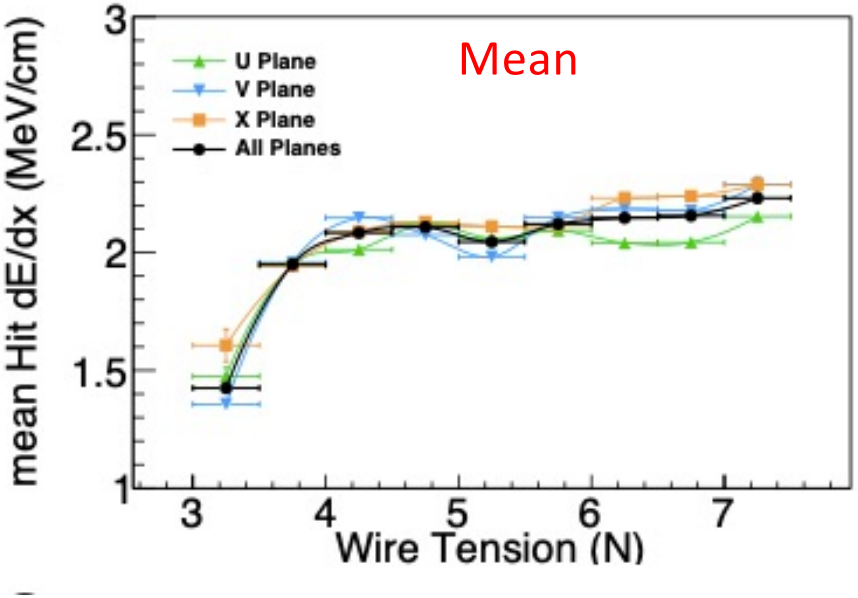
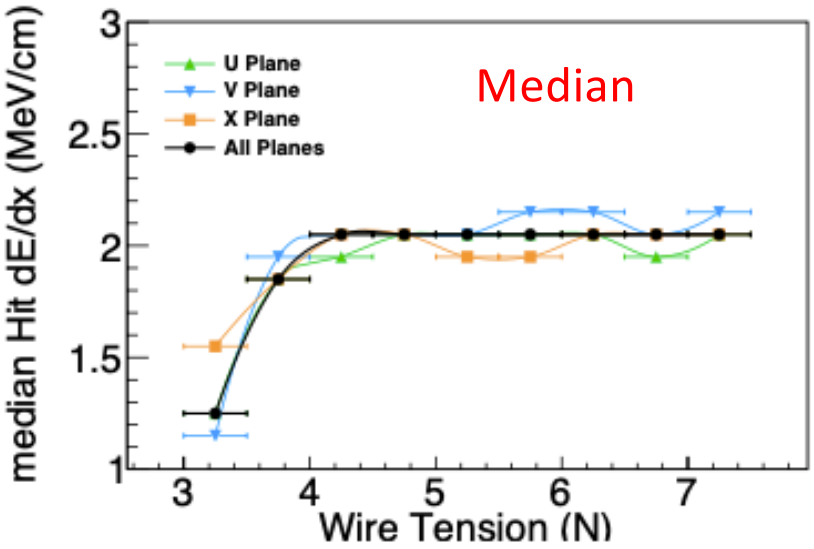


Figure 5: Wire tension as measured at production sites (US/UK Wire Tensions) versus those measured at CERN before installation in ProtoDUNE. The grey line represents the scenario where the wires do not change tension between the two measurements, while the red line is a fit to the data points, showing that on average the tension decreases by approximately 5%.

Aggregate Result Plots

No error bars drawn on median





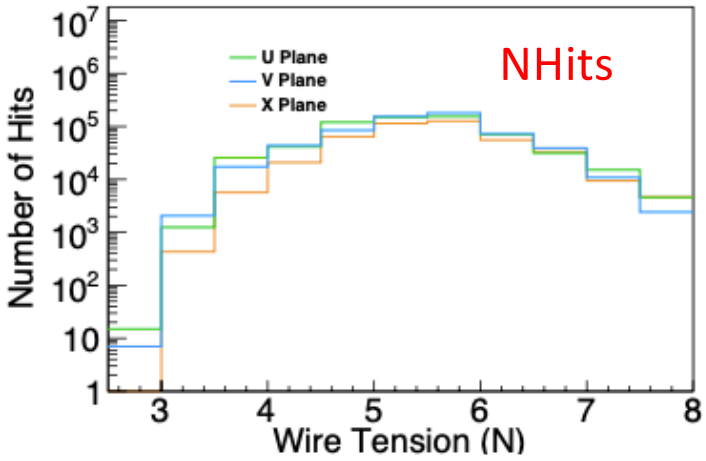


Fig. 16

Tension Maps

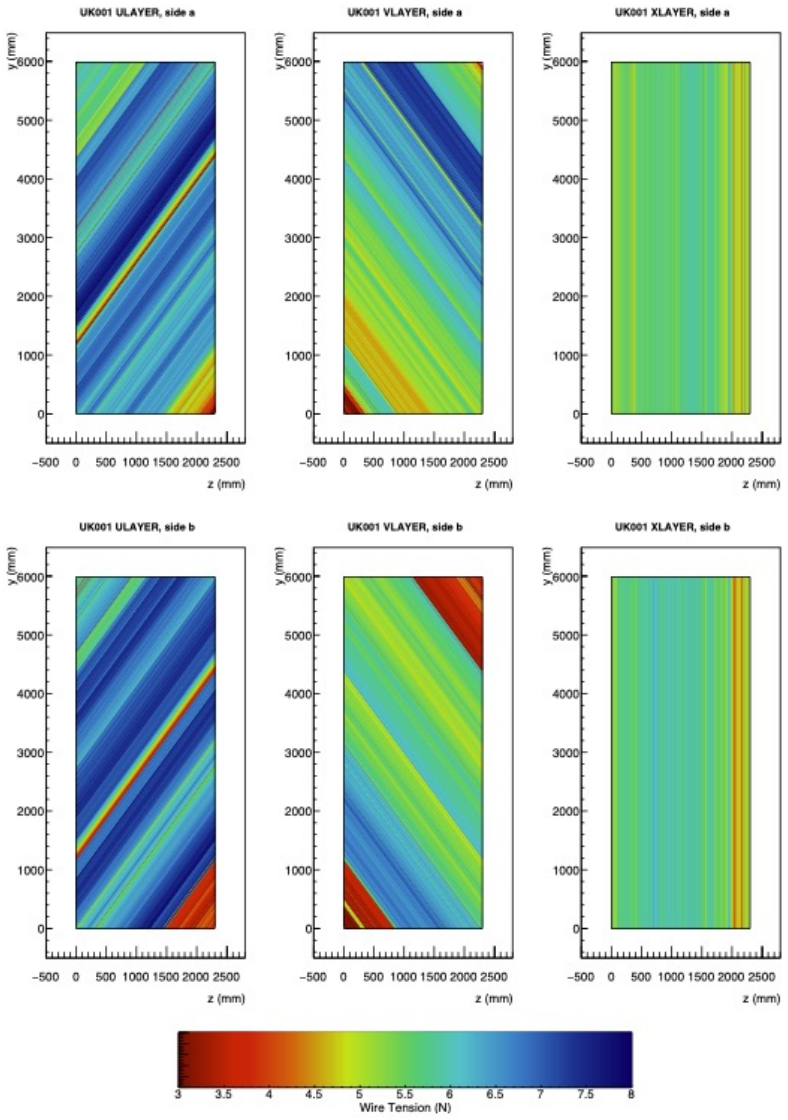


Figure 17: Wire tensions from APAUK001. Each wire is represented by a line coloured according to its tension. The top row shows side a, the bottom ror shows side b.

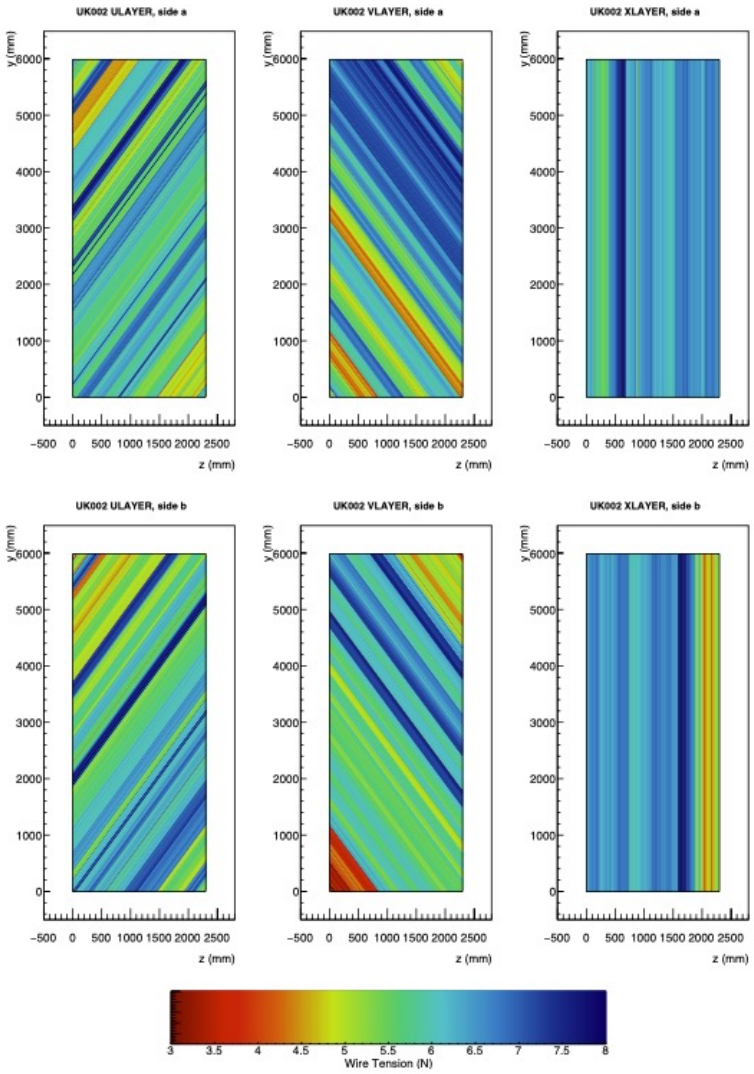


Figure 18: Wire tensions from APAUK002. Each wire is represented by a line coloured according to its tension. The top row shows side a, the bottom ror shows side b.

Tension Maps

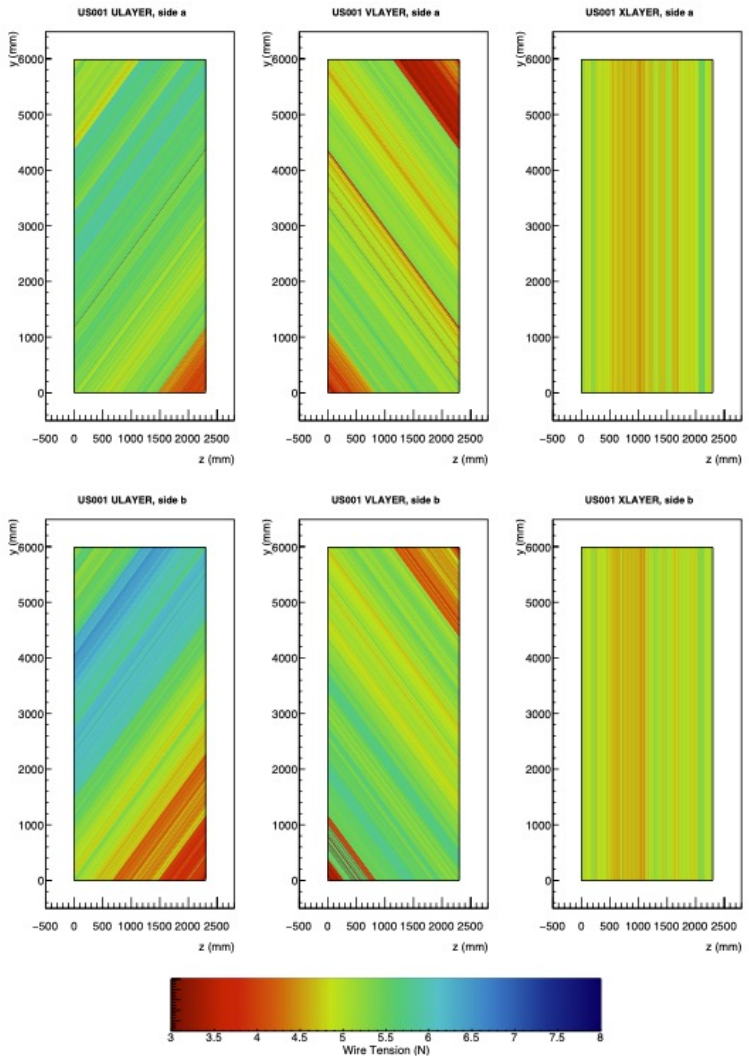


Figure 19: Wire tensions from APAUS001. Each wire is represented by a line coloured according t tension. The top row shows side a, the bottom ror shows side b.

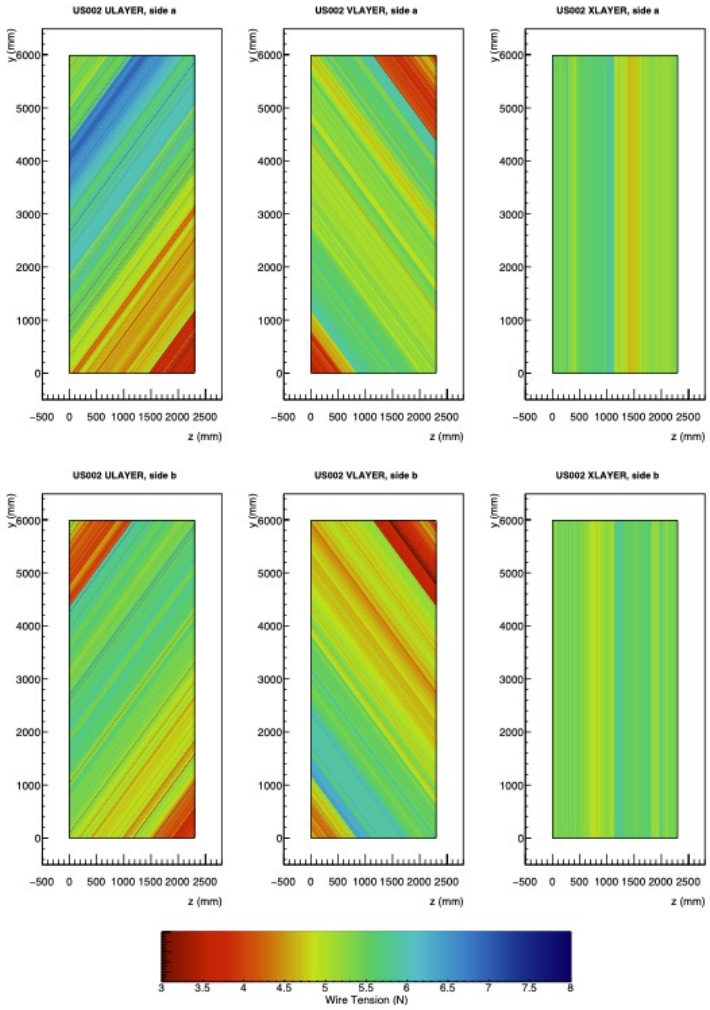


Figure 20: Wire tensions from APAUS002. Each wire is represented by a line coloured according to its tension. The top row shows side a, the bottom ror shows side b.

Tension Maps

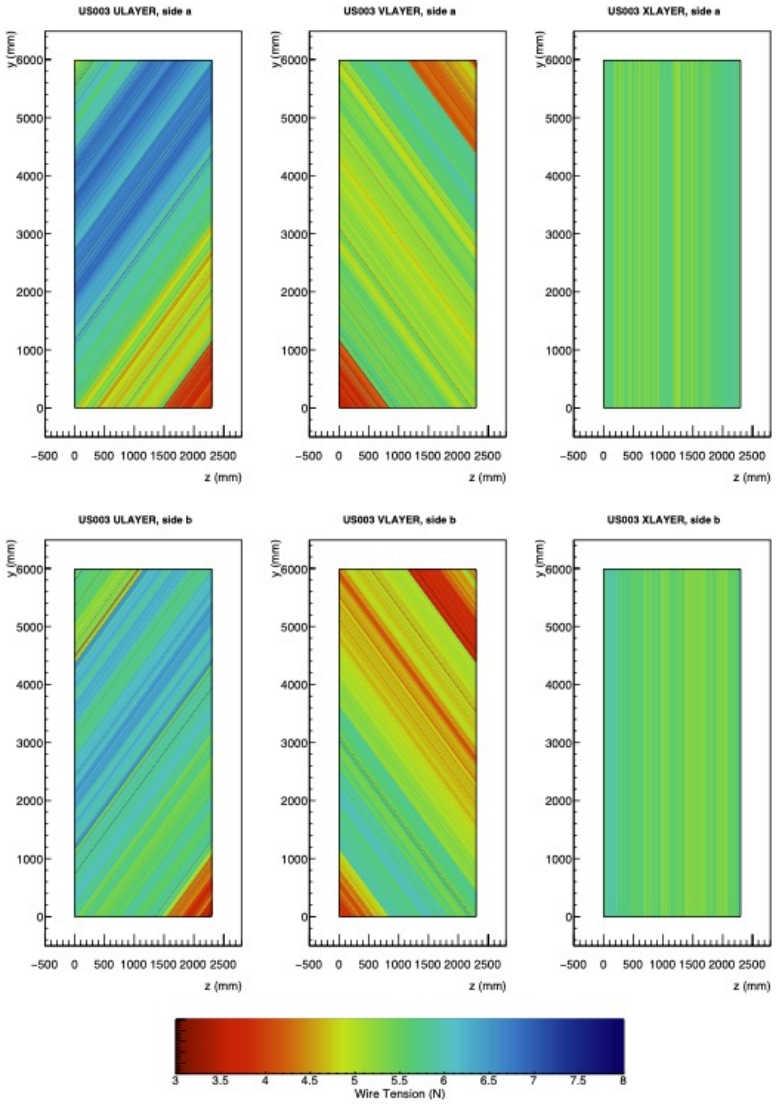


Figure 21: Wire tensions from APAUS003. Each wire is represented by a line coloured according to its tension. The top row shows side a, the bottom ror shows side b.

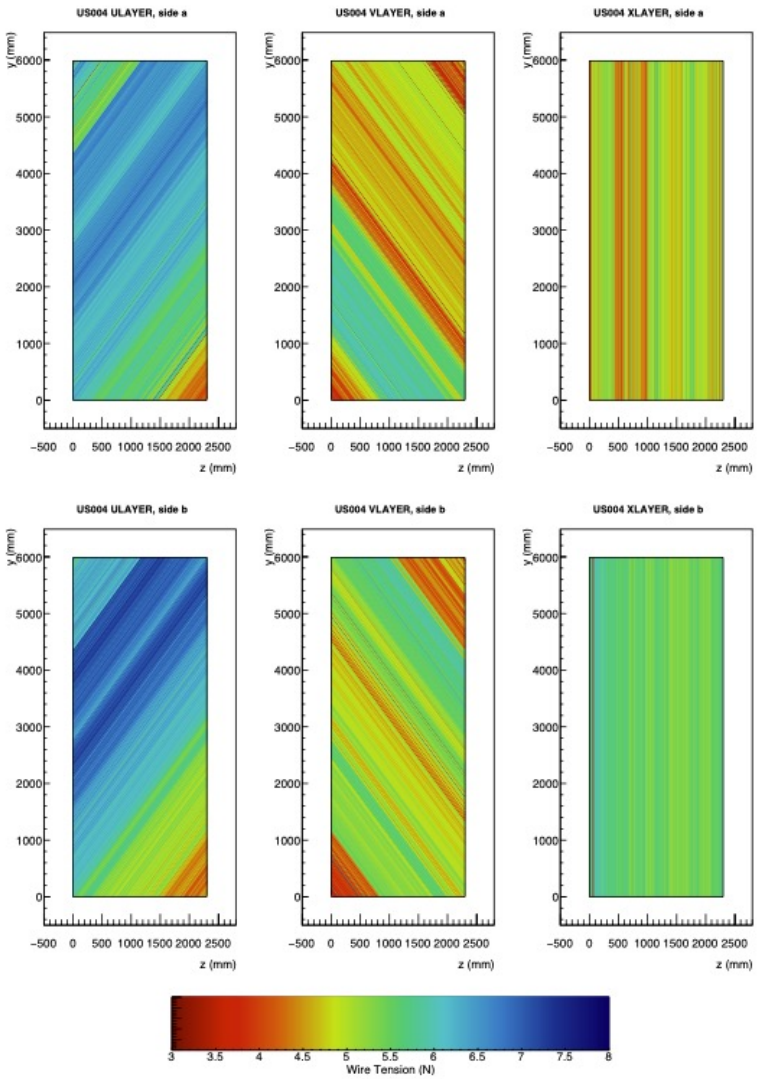


Figure 22: Wire tensions from APAUS004. Each wire is represented by a line coloured according to its tension. The top row shows side a, the bottom ror shows side b.

Results per APA

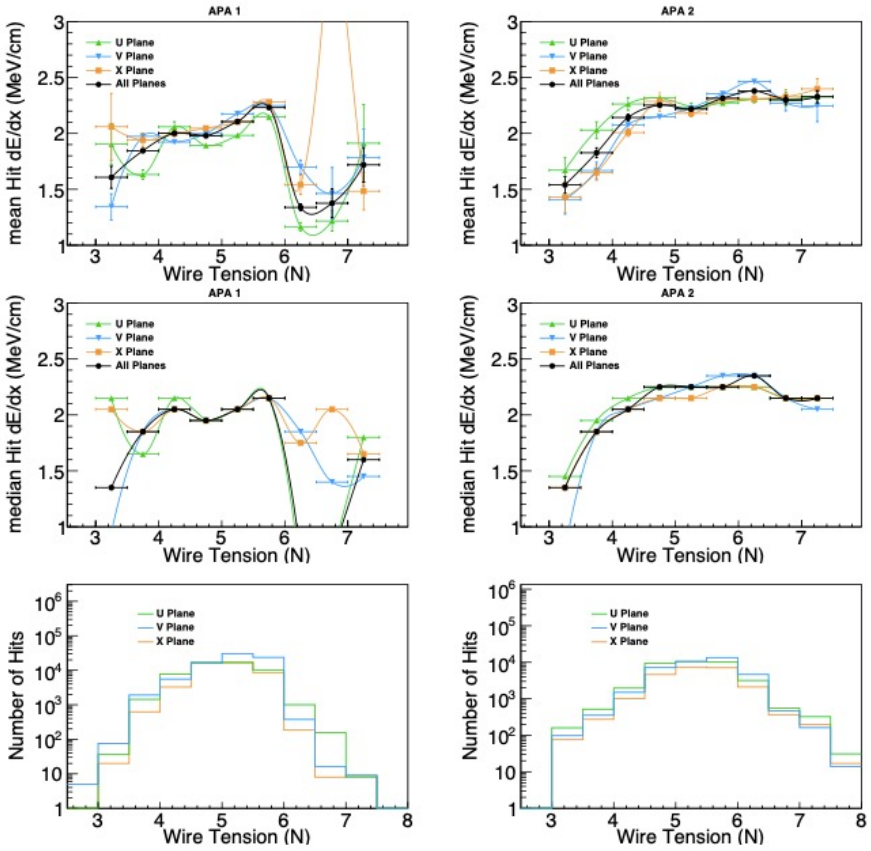


Figure 23: Mean (top) and median (middle) dE/dx values as a function of wire tension for APAs 1 (US001, left) and 2 (US002, right). In addition, the number of hits used in each tension bin is shown (bottom).

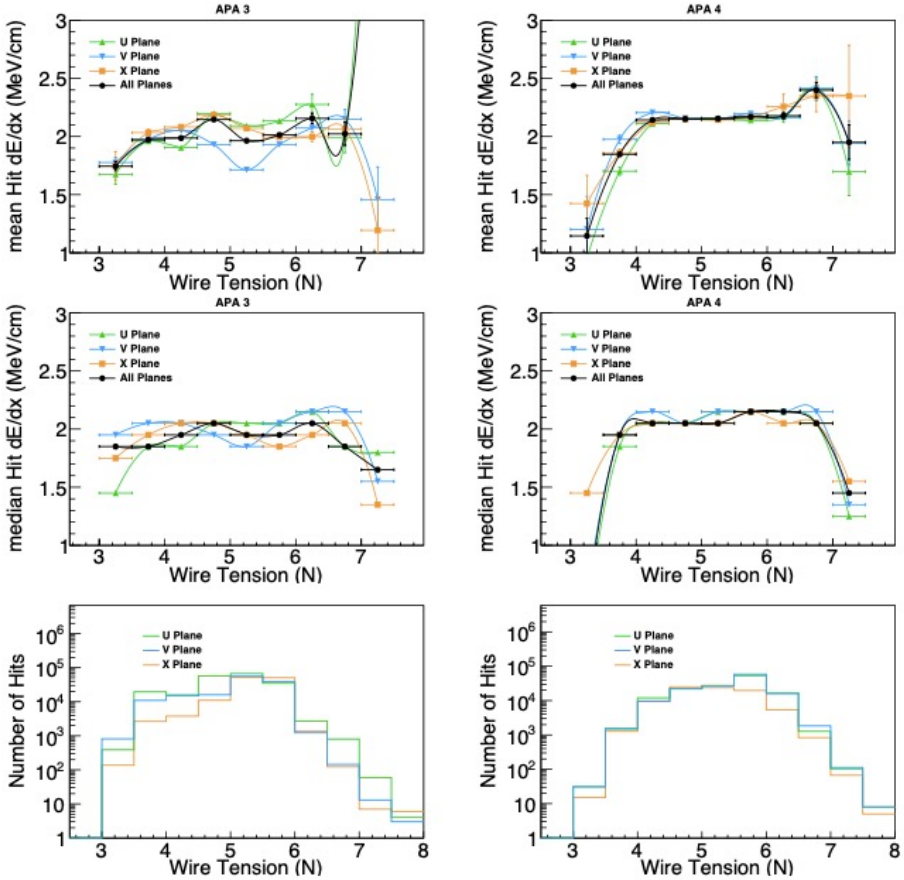


Figure 24: Mean (top) and median (middle) dE/dx values as a function of wire tension for APAs 3 (UK001, left) and 4 (US003, right). In addition, the number of hits used in each tension bin is shown (bottom).

Figure 24: Mean (top) and median (middle) dE/dx values as a function of wire tension for APAs 3 (UK001, left) and 4 (US003, right). In addition, the number of hits used in each tension bin is shown (bottom).

If you take the error bars seriously, there might be problems at high tensions too, on some APAs. Or even some intermediate tensions.

Results Per APA

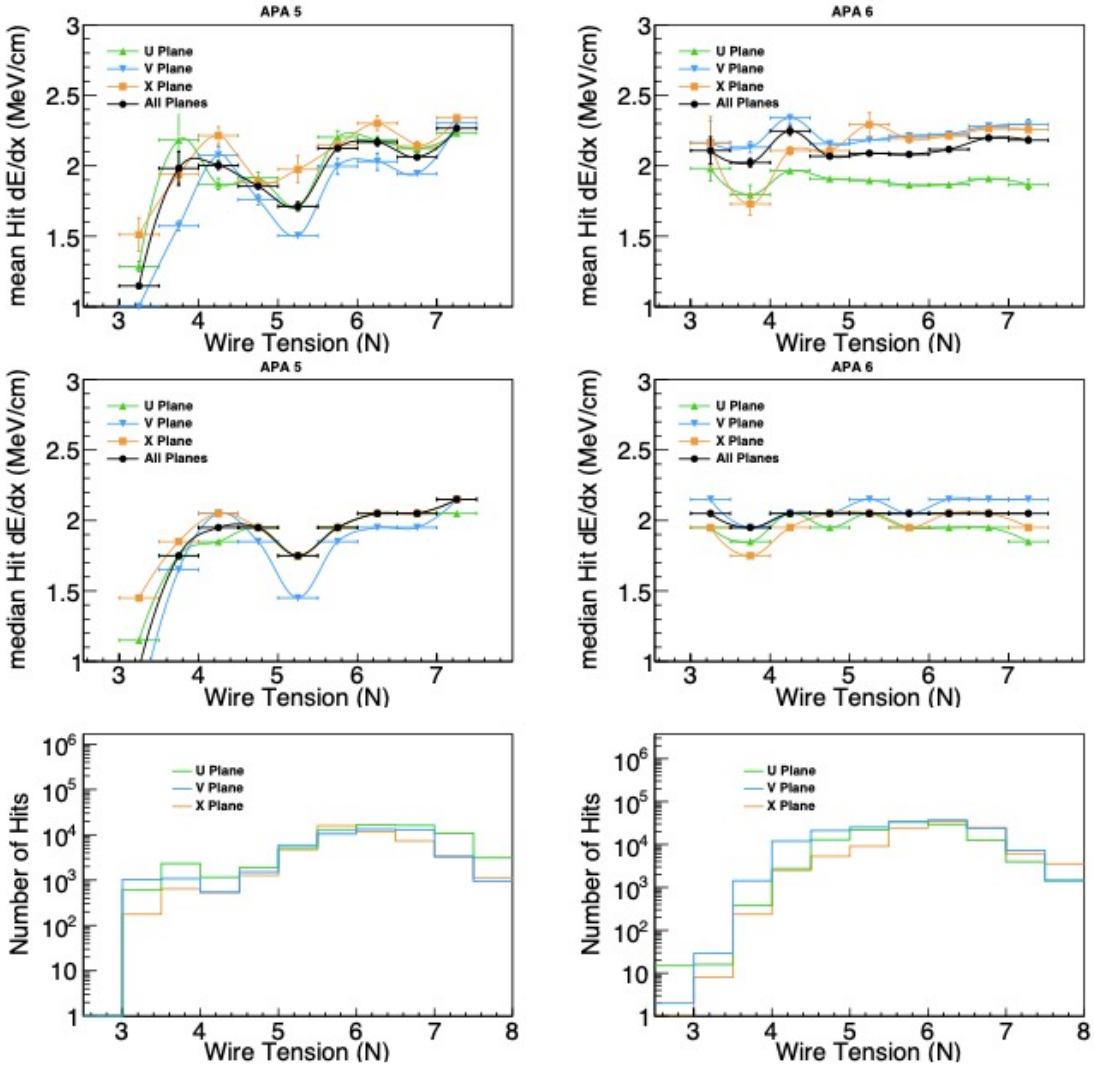
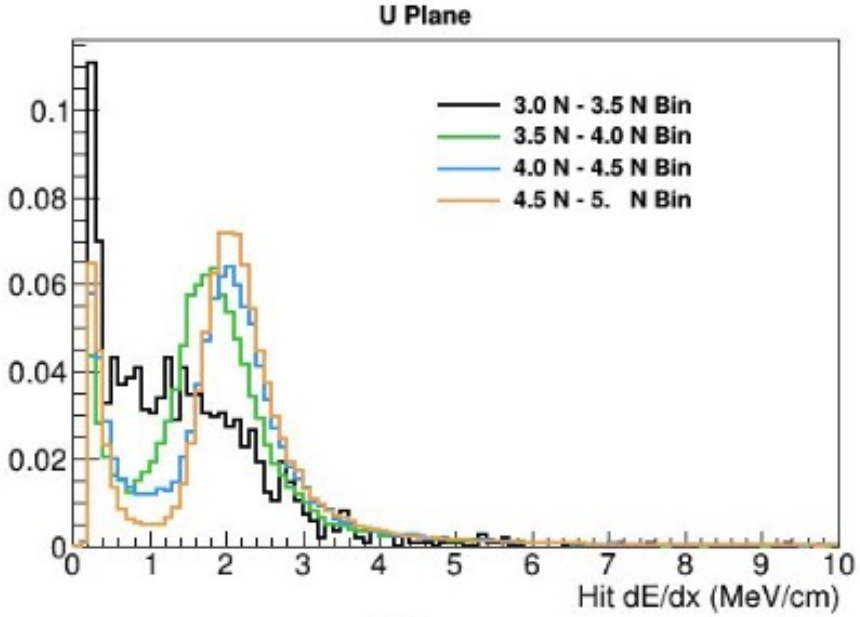
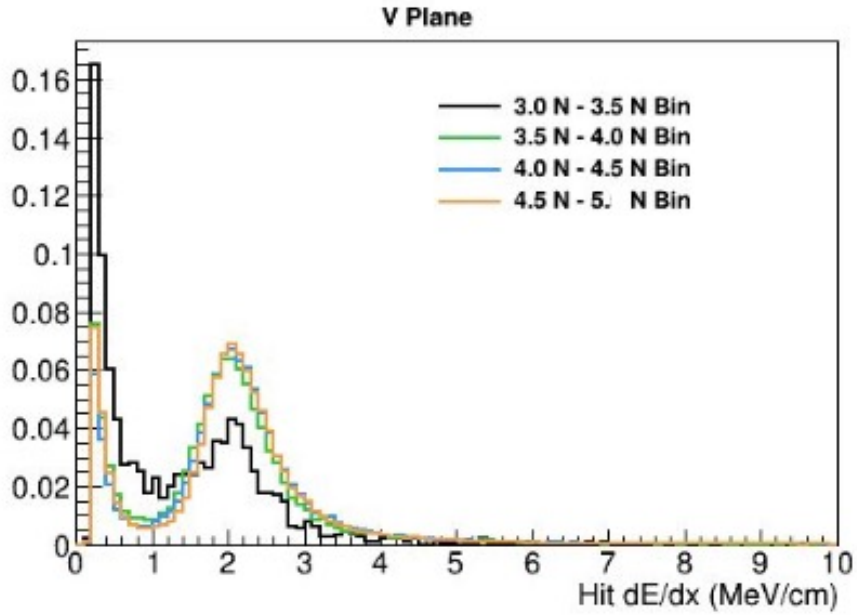
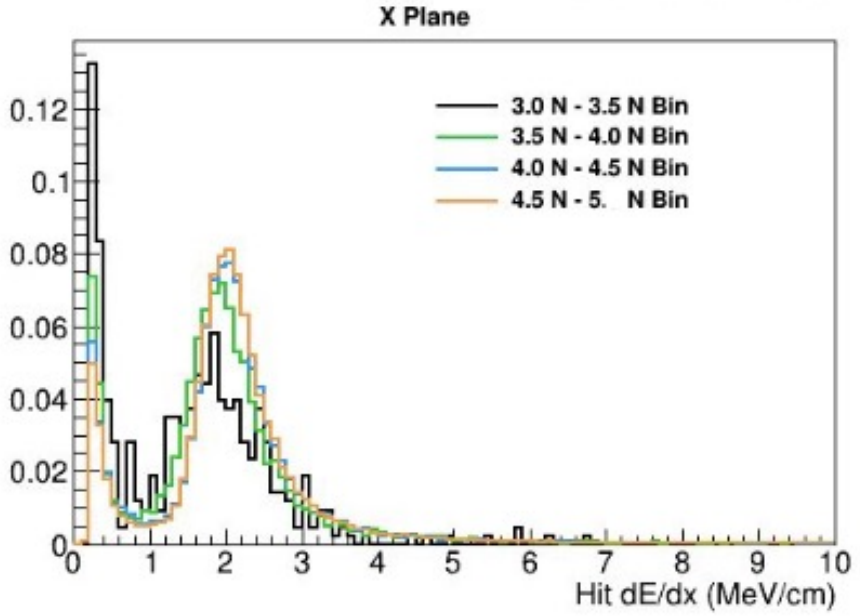


Figure 25: Mean (top) and median (middle) dE/dx values as a function of wire tension for APAs 5 (UK002, left) and 6 (US004, right). In addition, the number of hits used in each tension bin is shown (bottom).

So What's Happening Here?







As the tension is reduced

➔ there are small shifts in the dE/dx peak

➔ there is a large increase in the number of *very low* dE/dx values, and this is likely what drives most of the effect

The first I think could be calibrated out, the second is more difficult to deal with

Summary

From Adam Lister, Oct 28 2020 DRA meeting

Having low wire tensions reduces the measured dE/dx values

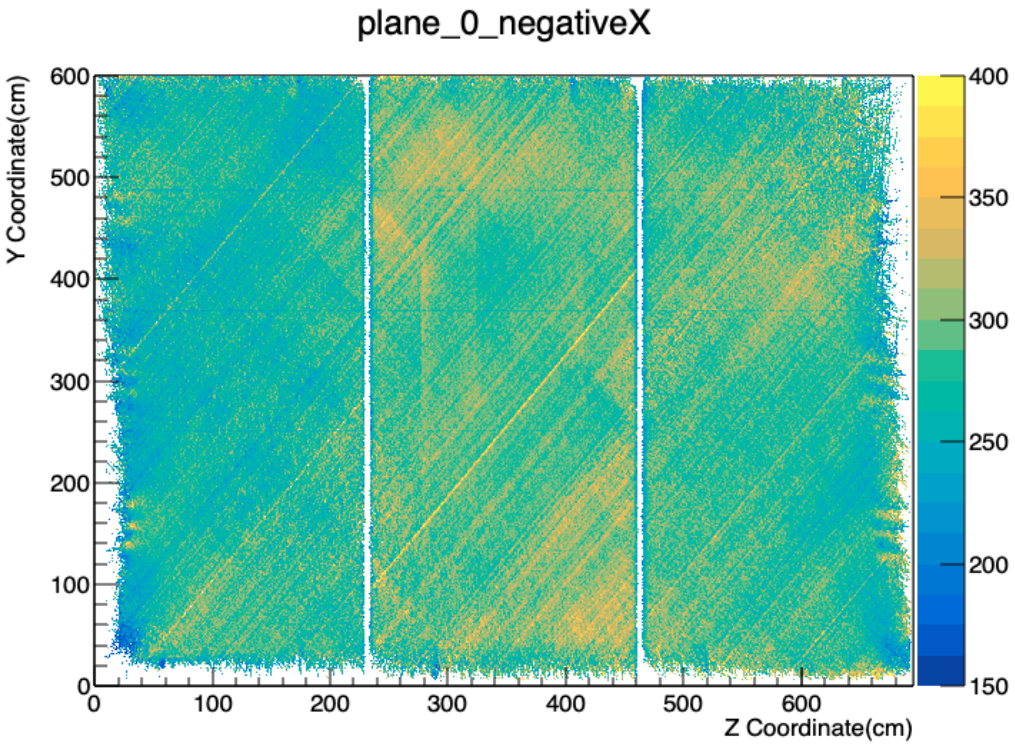
➔ After calibration, X plane wires in the 3-3.5 N bin have a reduction of > 20%!
➔ Results on the U and V planes are consistent with the X plane, though no YZ calibration has applied on those planes

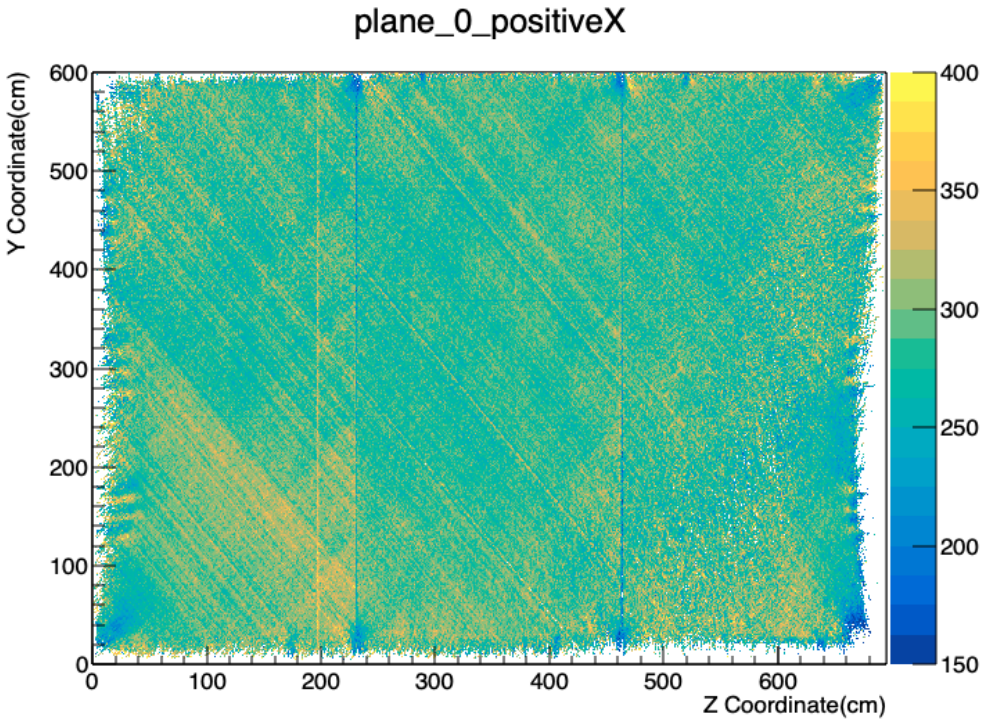
This seems to be caused by two effects:

➔ There is a shift in the 2.1 MeV/cm peak dE/dx value to lower values
➔ There is a significant increase in the low dE/dx peak

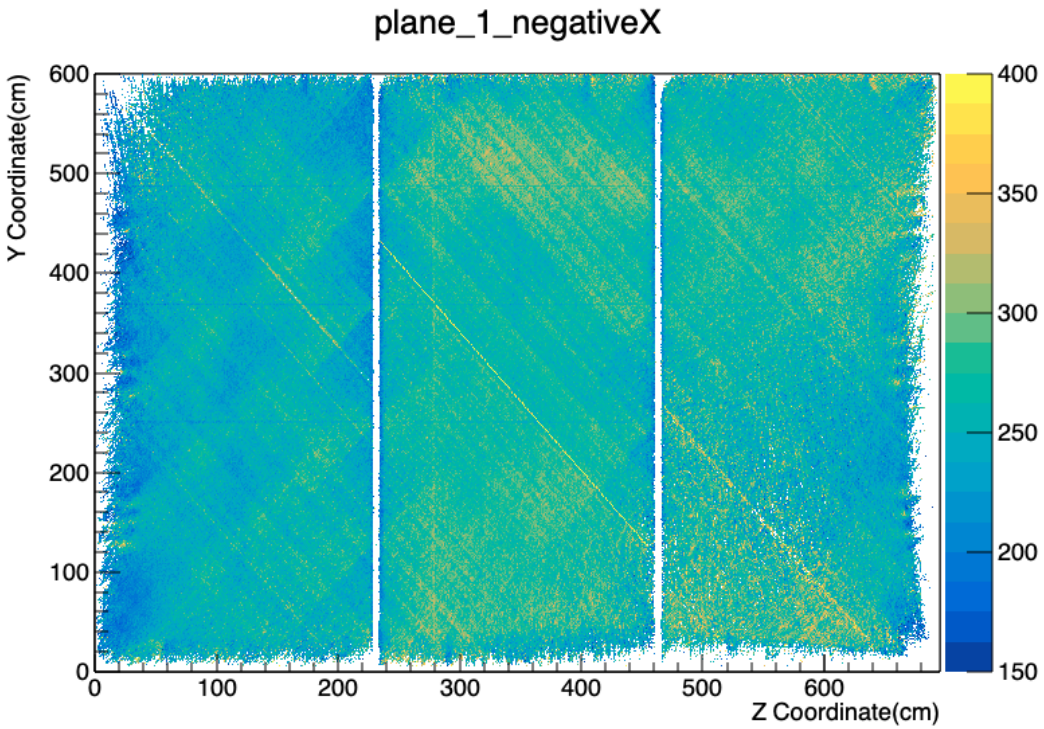
There's discussion in the APA group ongoing to determine the nominal tension we should aim for and the tolerance on that value.

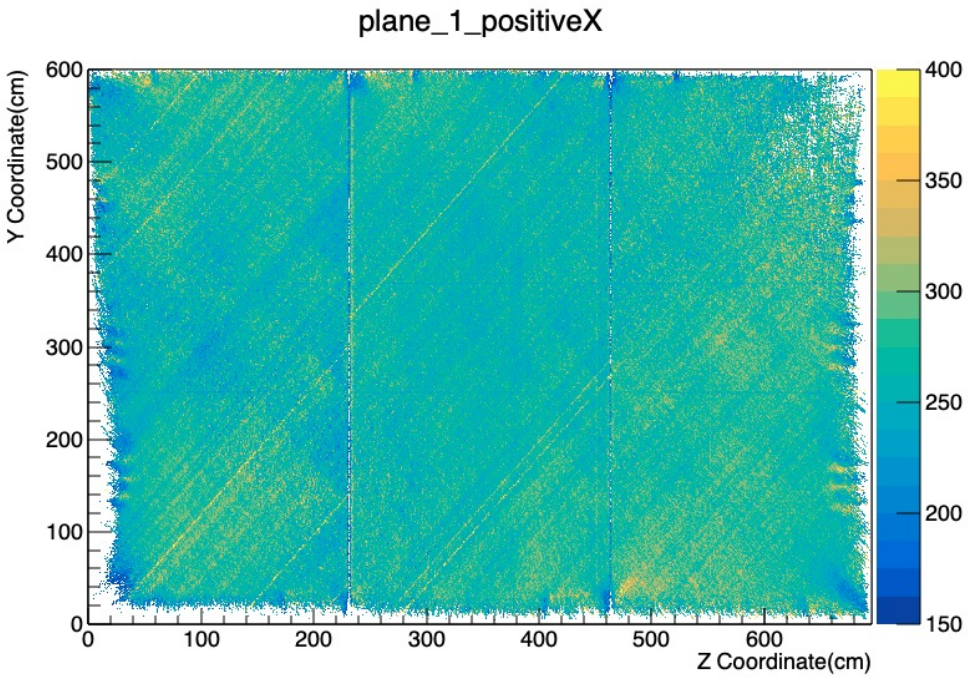
Ajib's Uncalibrated dQ/dx distribs



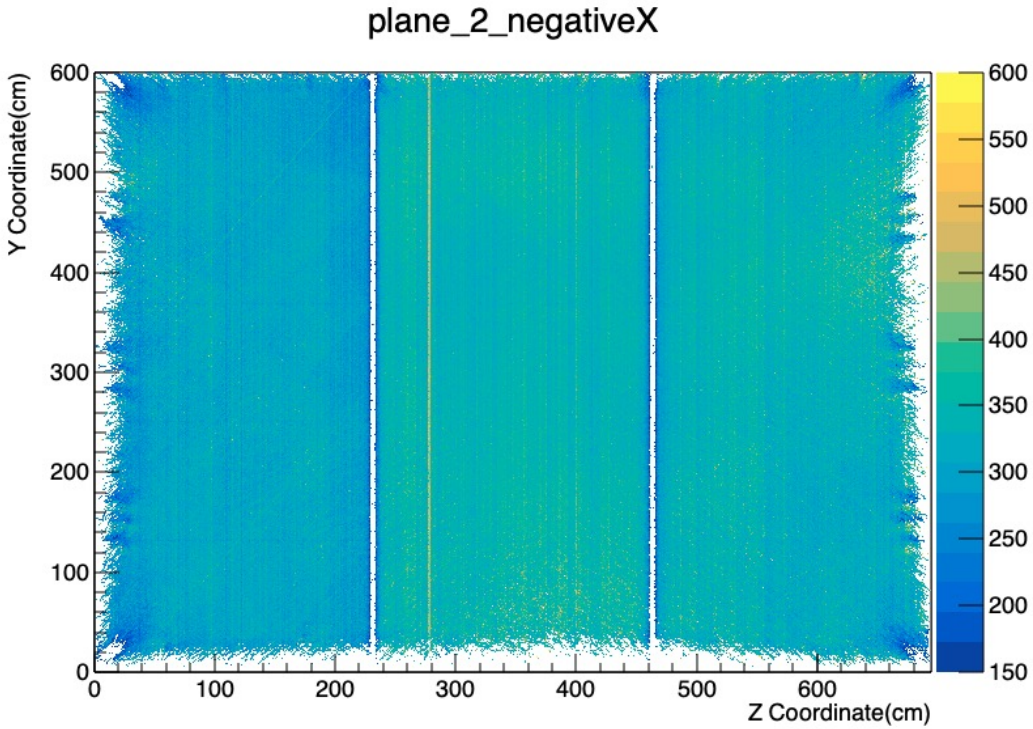


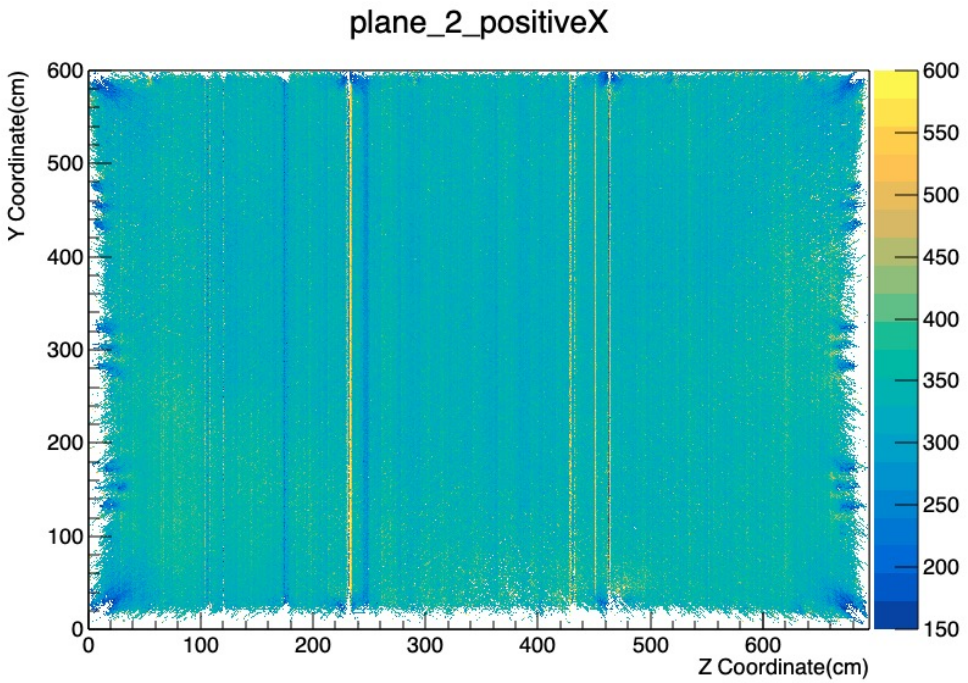
Ajib's Uncalibrated dQ/dx Plots





Ajib's Uncalibrated dQ/dx Plots





Potential Map from the LBNE CDR

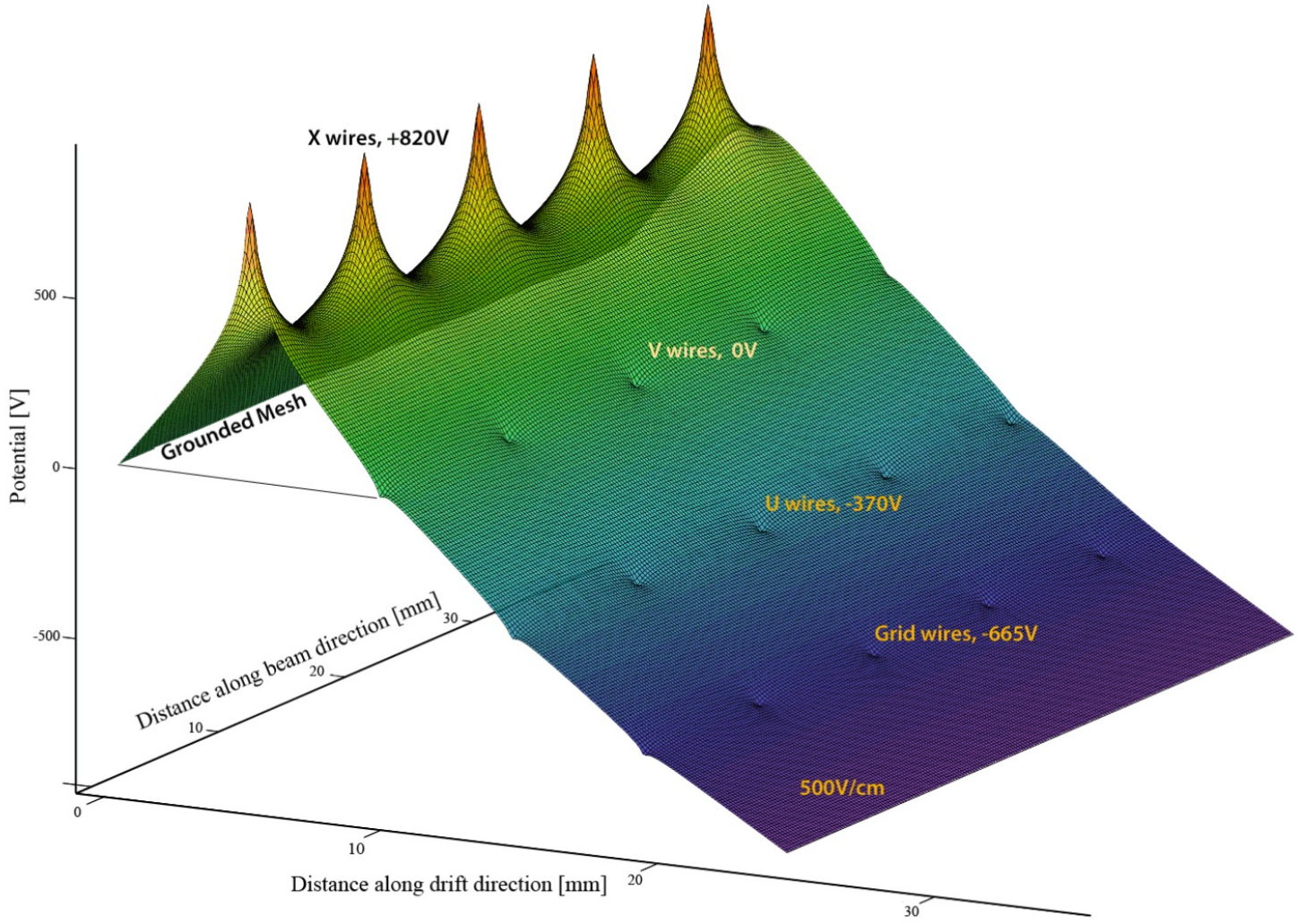


Figure 3–3: A surface plot of the electric potential distribution near the wire planes. The voltages on the wire planes are biased to provide complete electron transparency through the first three planes, and complete collection on the fourth plane.

Horizontal electrostatic forces on all wire planes are very small, and get smaller if the wires sag to relieve stress.

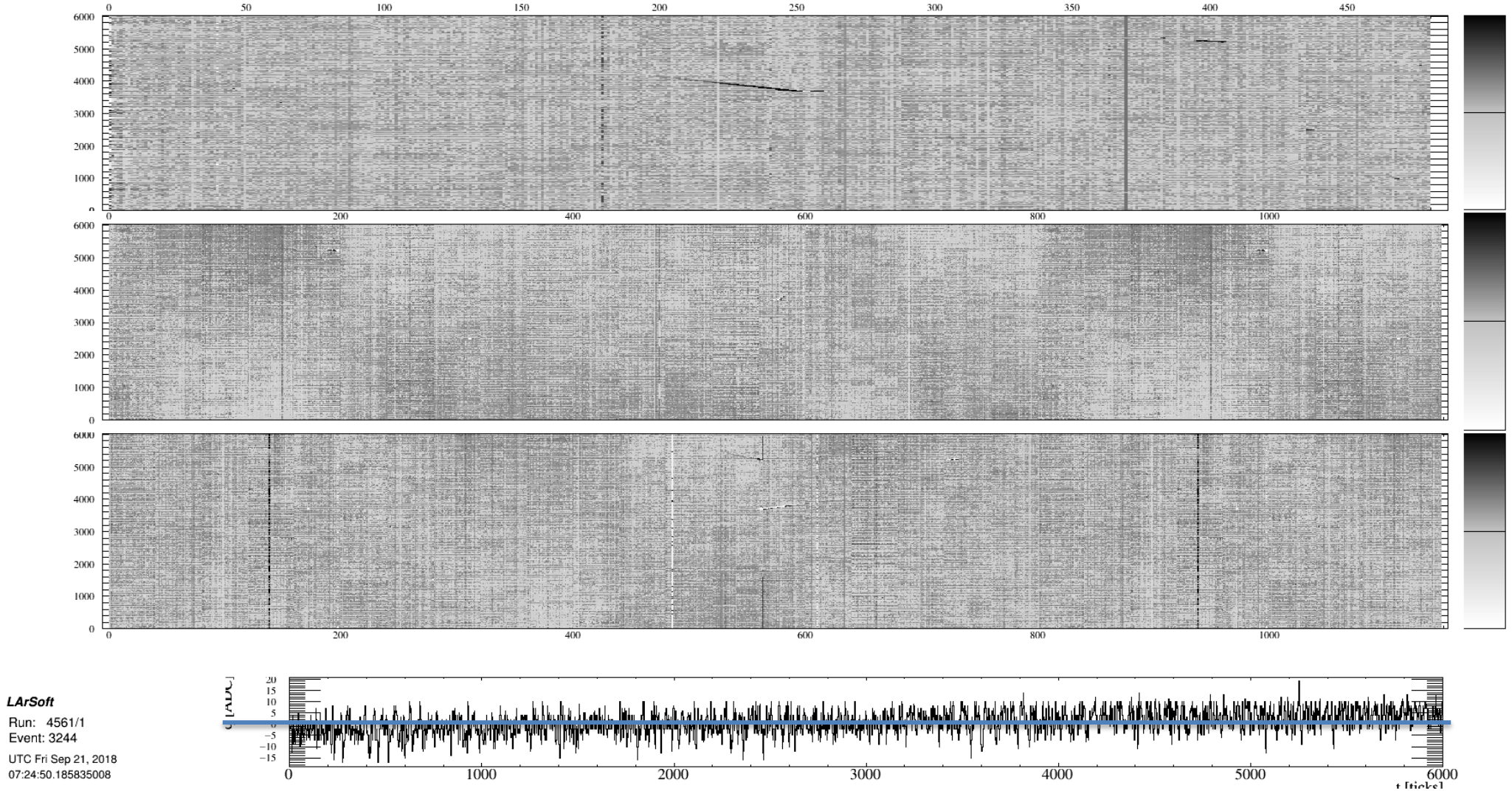
Most of the electrostatic force on an APA is carried by the mesh.

From A. Lister, DUNE-doc-20861v-1

It is thought that a wire whose tension is higher than specification should not impact the physics in any meaningful way, however a tension lower than specification is expected to impact the physics primarily through modifying the local electric field. This modification can lead to two effects: (i) the number of ionization electrons is incorrectly reconstructed in the deconvolution process; and (ii) the transparency of the collection plane may change such that less than 100% of the ionization electrons are collected. Because both of these processes change the amount of reconstructed charge, they are expected to impact the reconstruction of the energy deposited by charged particles, and therefore impact the parti- cle identification capabilities of any given liquid argon time projection chamber. A further complication from low-tension wires is an expected increase in noise level, introduced by wire vibrations, which may also lead to vortex shedding.

[highligting added, trj]

Very Low-Frequency Noise Seen on Induction-Plane Wires



My take on this

- dQ/dx depending on wire tension between 3 and 4 Newtons is unexpected.
- Loss of transparency has different expected effects than what is seen
  - extra charge on induction plane wires
  - badly deconvolved signals due to unipolar pulse components on induction-plane wires – extra signal
  - loss of signal on collection-plane wires *under* the loose induction-plane wires.
- Staggered collection-plane wires still collect all the charge

My take on all of this (cont'd)

- Some APAs show unexpected drops in mean and median dQ/dx at *high* tensions.
  - Error bars shown are much smaller than the deviations
  - Could be error bars are underestimates because they are ROOT's idea of the uncertainty on a Gaussian distribution, while dQ/dx distributions are anything but.
- Space charge stretches observed charge out and depletes it in the corners of the detector
- Coincidentally, the corners of the APAs are where the U and V wire segments have the least tension on average.
- Low-charge hits are usually due to incomplete hits, split hits, brem+compton, noise, radiologicals. Maybe some coincidence with noise?
- Selection bias effects – tracks satisfying angle and position cuts may not cover corners as well.
- Too many possible confounding factors to use this study to justify a wire tension recommendation.