Impact of Wire Tension on Physics @ProtoDUNE

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DUNE APA Consortium Meeting
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Reminder

I've been looking to see whether hit-related variables are affected by the tension of the wire on which they fall.

For this analysis I'm currently using around ~10% of the dataset for development: ***Np04_full-reconstructed_v07_08_00_unified_physics***

I think this is a little old now, so one of the things I want to do is move to a newer dataset.

Some of the plots in this talk are labeled as "Y Plane" rather than "X Plane". I'll fix that up in the next iteration.

Excel Sheets

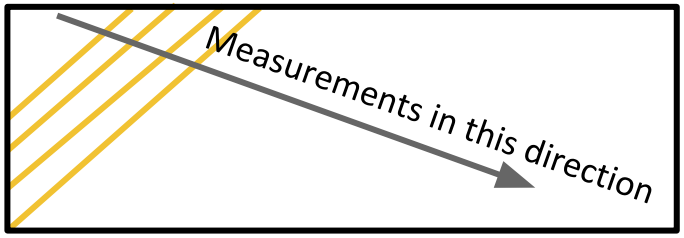
- This analysis takes the form of an *art* module. In order to read tension information into the module, want to get the information into ROOT format.
- The measurements were kept in excel sheets
  - https://drive.google.com/drive/folders/11FmvECu3FqppkQMJp92ISHJS2XPrLeHQ?usp=sharing
- Unfortunately because the measurements were taken at different times and by different groups, these aren't in a standard format
- In order to more easily port these to ROOT files, I've put them in a standard format
  - https://drive.google.com/drive/folders/1zT3o67fjdo-C-A5VX5Lf0Ht7ibXh90Vd?usp=sharing

This was a *little bit* time consuming, but now done, and the ROOT files can be found in **/pnfs/dune/persistent/users/alister1/tensions/tension_measurements.root**

This has really highlighted the need for something like a database moving forward with DUNE.

DAQ Channel ↔ Wire Segment Mapping

Tension measurements are made for every wire segment on an APA side



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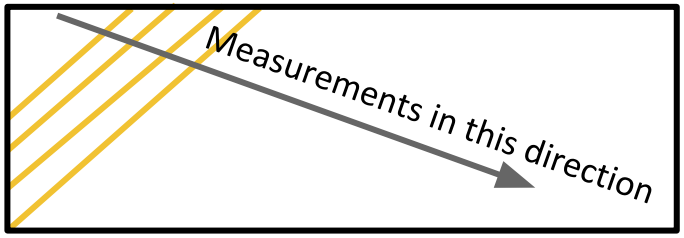

But multiple wire segments are read out as the same DAQ channel!

N.B. only for induction planes. Collection planes have a 1-to-1 mapping!

We want a mapping between each wire segment and the DAQ channel it's connected to.

DAQ Channel ↔ Wire Segment Mapping

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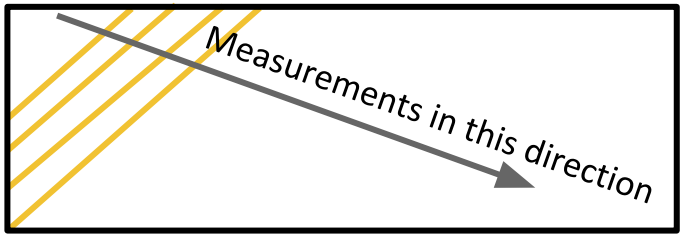
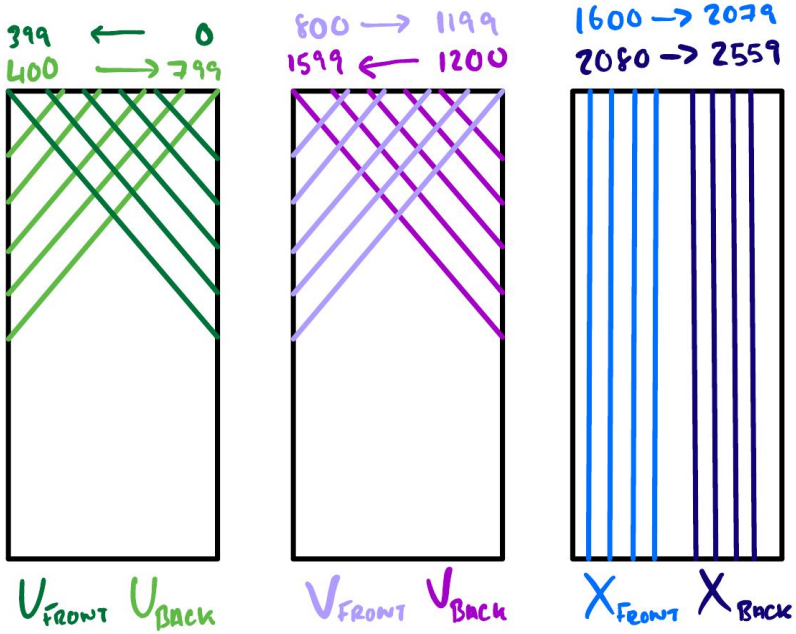


But multiple wire segments are read out as the same DAQ channel!

We want a mapping between each wire segment and the DAQ channel it's connected to.

For instance for UK APA 1



	U	V
Side A	**0-399**, 400-799, **0->**	800-1199, **1200-1599**, 800->
Side B	400-799, **0-399**, 400->	**1200-1599**, 800-1199, **1200->**

Expectation (induction):2 wire segments on low channel numbers/ 1 on high channel numbers on **Side A**
2 wire segments on high channel numbers/ 1 on low channel numbers on **Side B**

DAQ Channel ↔ Wire Segment Mapping

Expectation (induction):2 wire segments on low channel numbers/ 1 on high channel numbers on **Side A**
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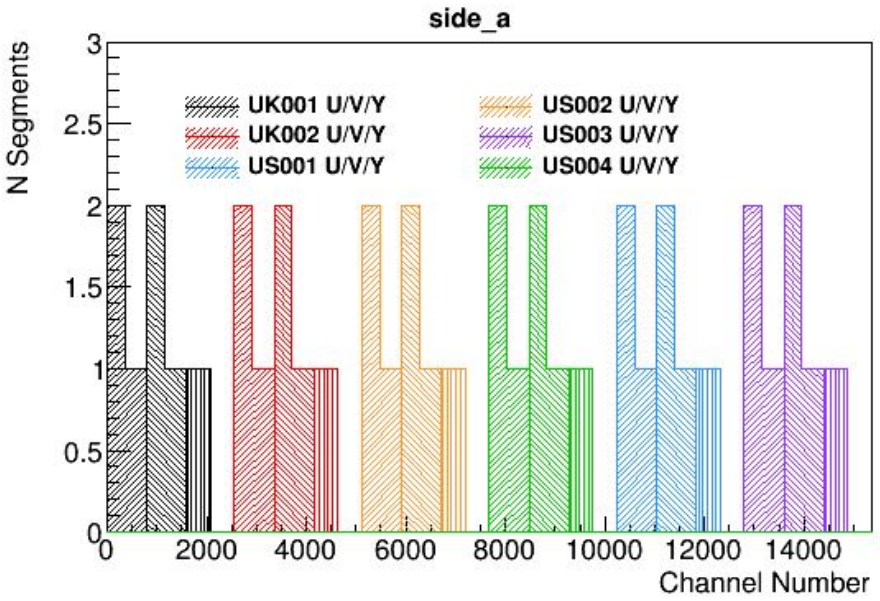
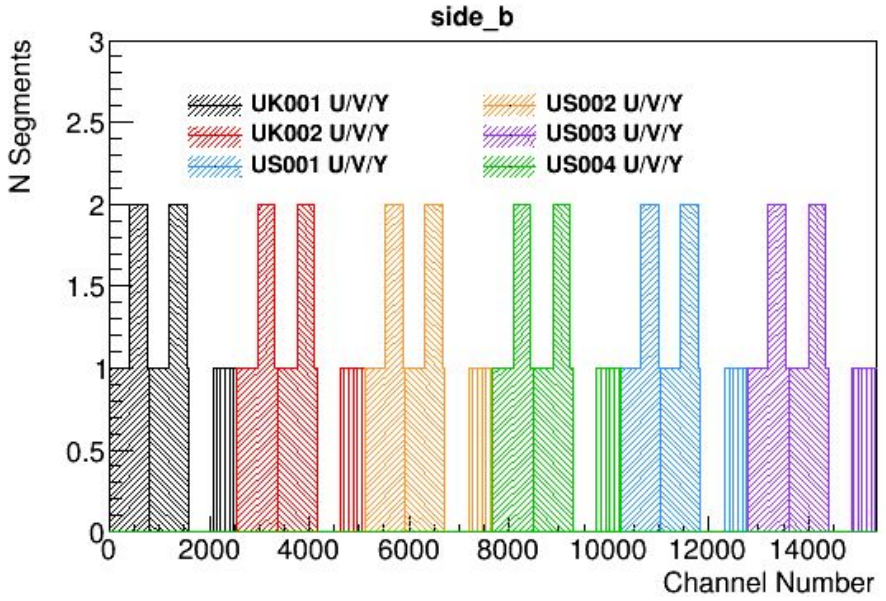




Taking information from the root files, we find that things look as they should across all APAs and all channels.

DAQ Channel ↔ Wire Segment Mapping

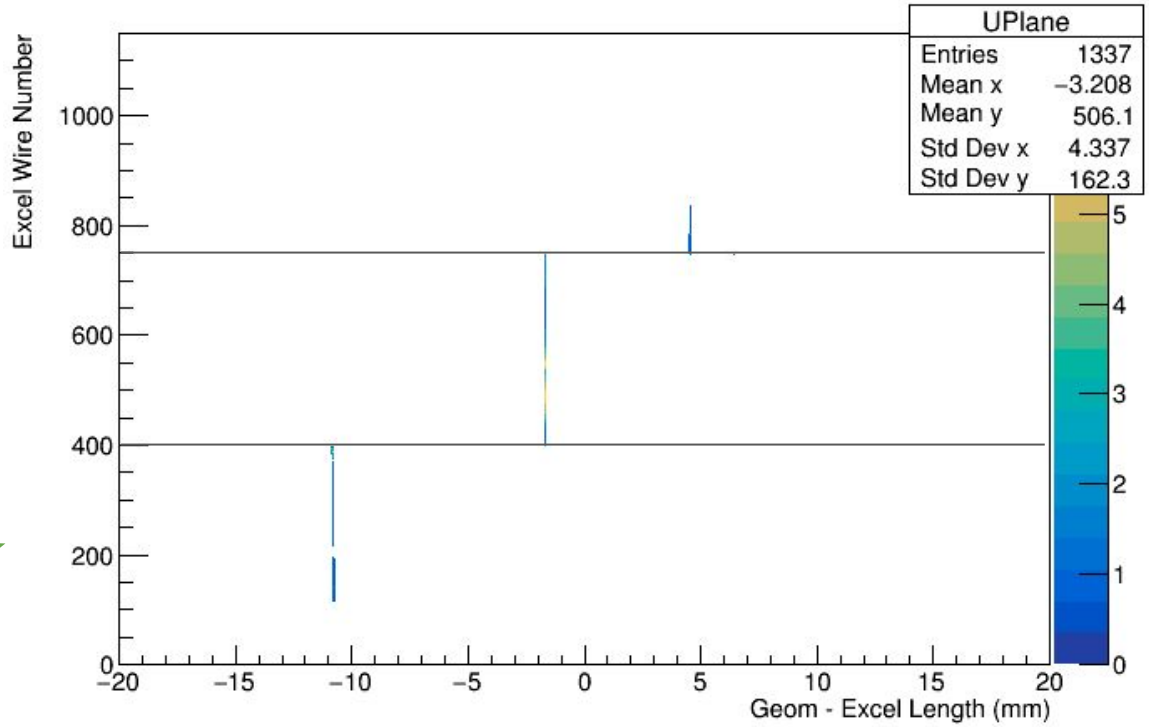
Though things look okay, there is still the opportunity for the mapping to be off by some number of wires. For instance if you look at the Excel files, you see that there are several rows near the top which don't seem to correspond to physical wires.

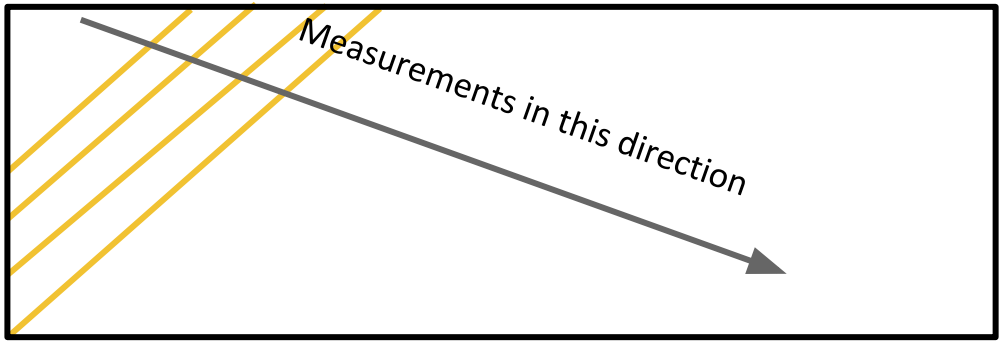
SEGMENT NO.	X Start	Y Start	X End	Y End	Zone 1 Length	Zone 2 Length	Zone 3 Length	Zone 4 Length	Zone 5 Length
1	-16	-1	-1	-1	-1	-1	-1	-1	-1
2	-8	-1	-1	-1	-1	-1	-1	-1	-1
3	0	0	0	1	-1	-1	-1	-1	-1
4	8	0	0	6.8	10.5	-1	-1	-1	-1
5	16	0	0	12.5	20.3	-1	-1	-1	-1
6	24	0	0	18.2	30.2	-1	-1	-1	-1

In order to check whether the mapping is correct, there are two metrics which have been minimised between the information stored in the excel sheets and the information pulled from the simulated geometry:

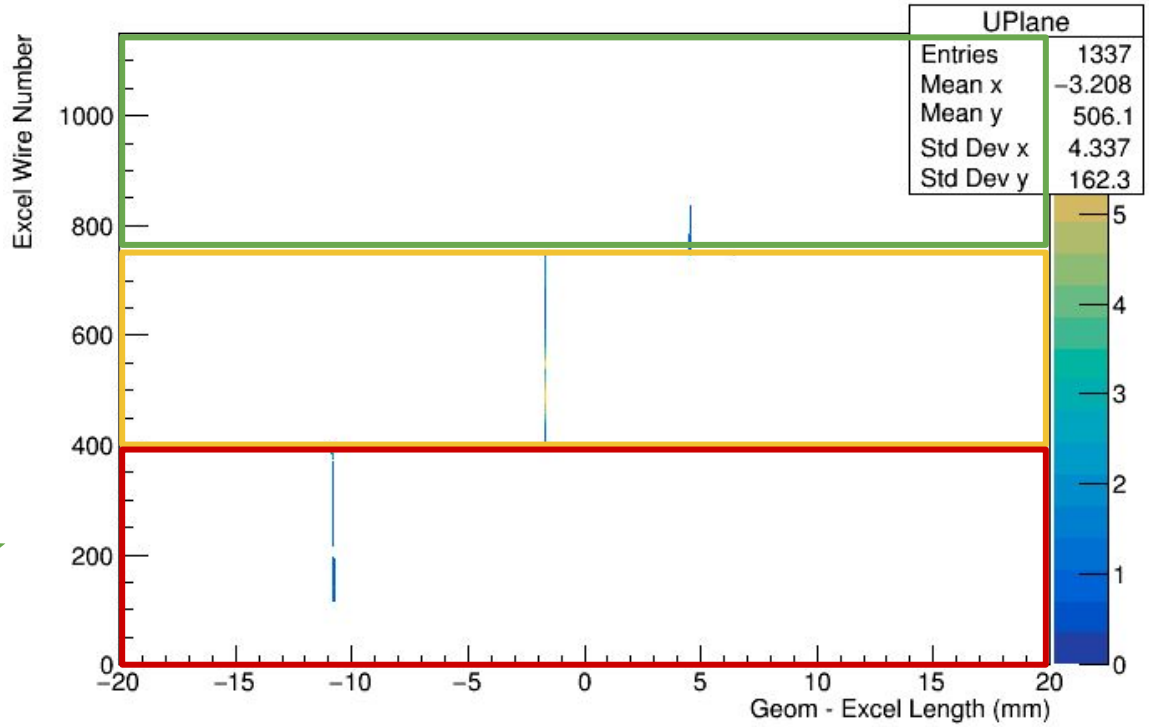
- The difference in the wire length
- The difference in the wire starting point in Y

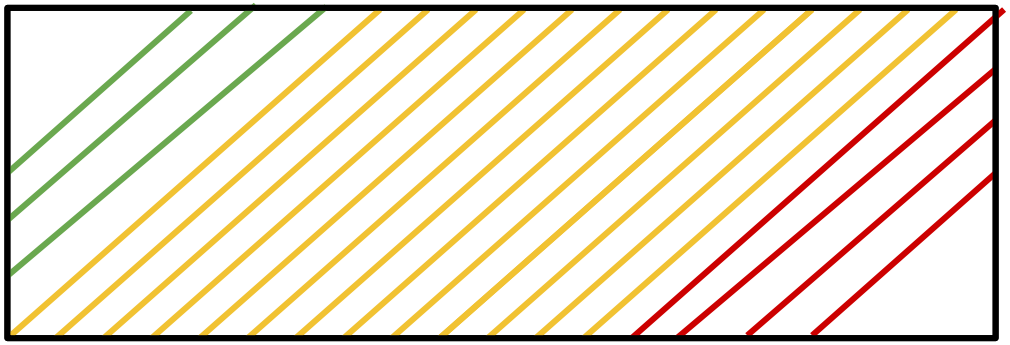
DAQ Channel ↔ Wire Segment Mapping



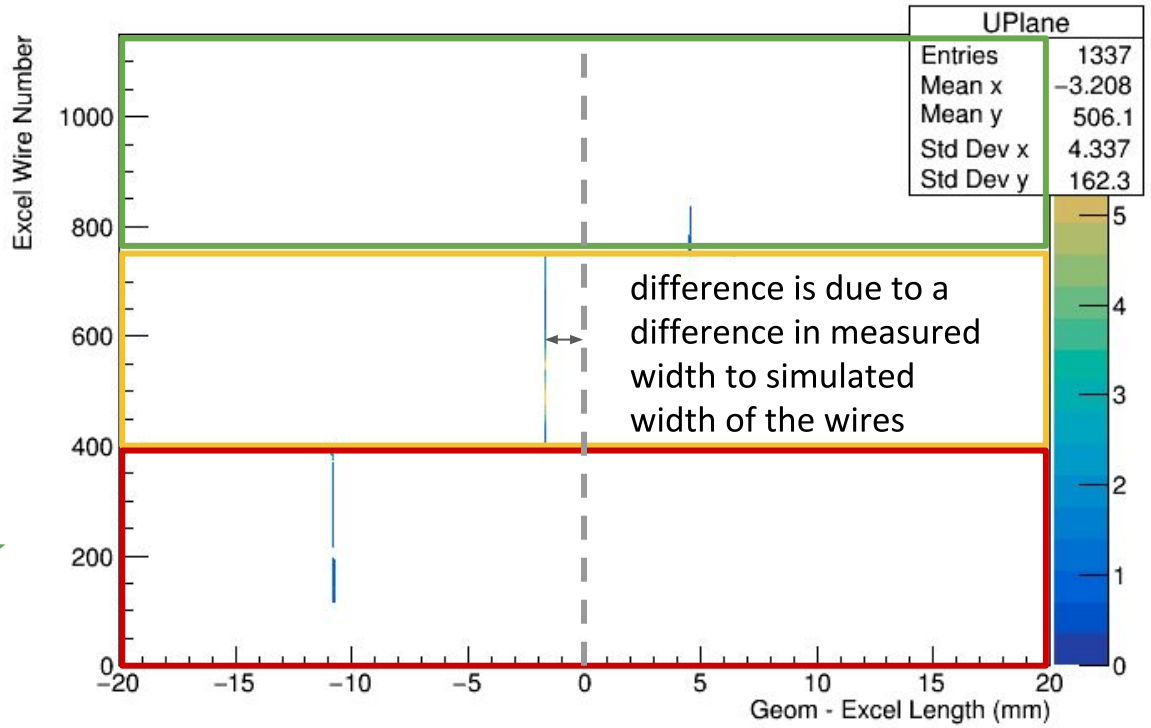


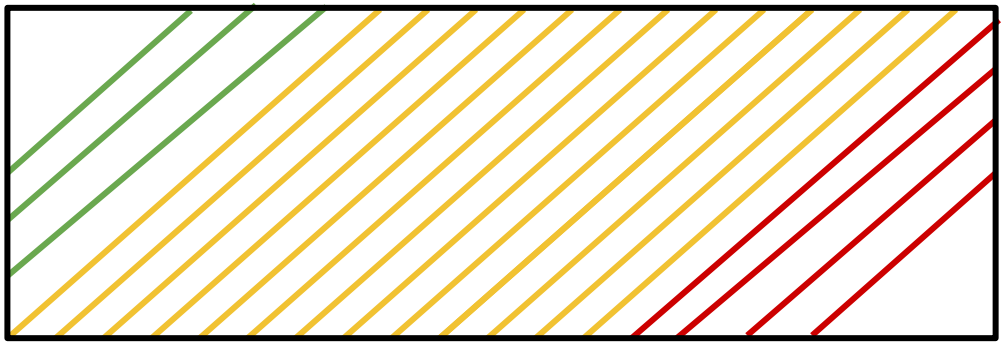
DAQ Channel ↔ Wire Segment Mapping



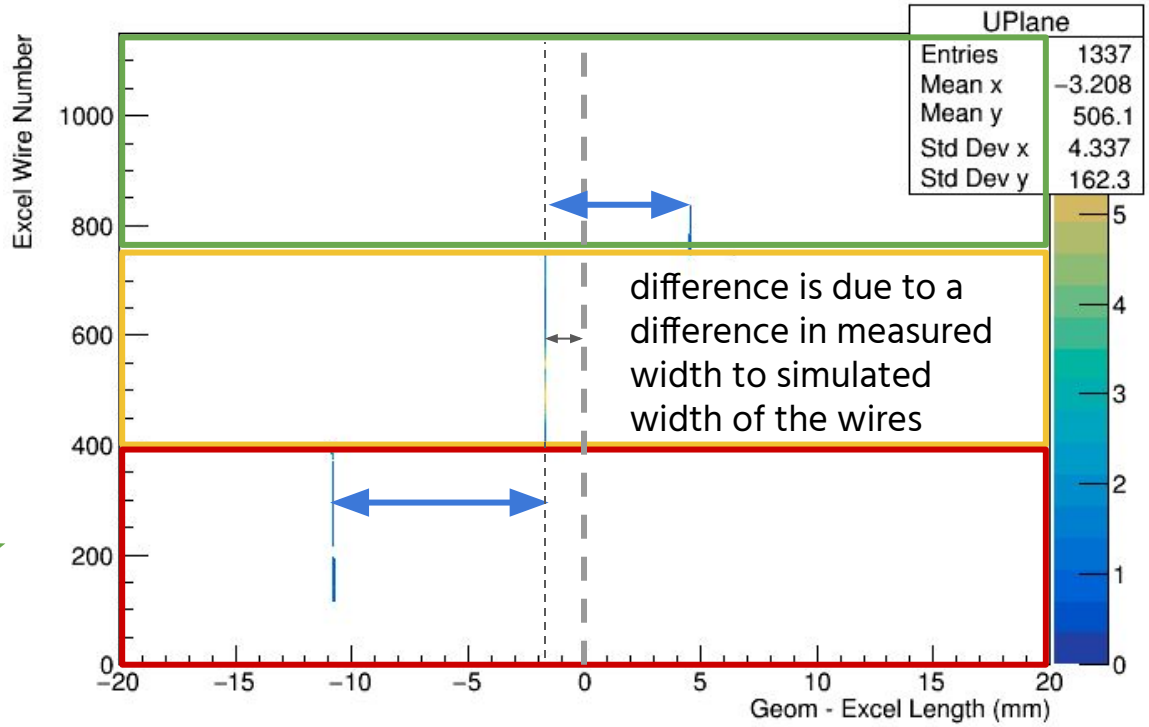


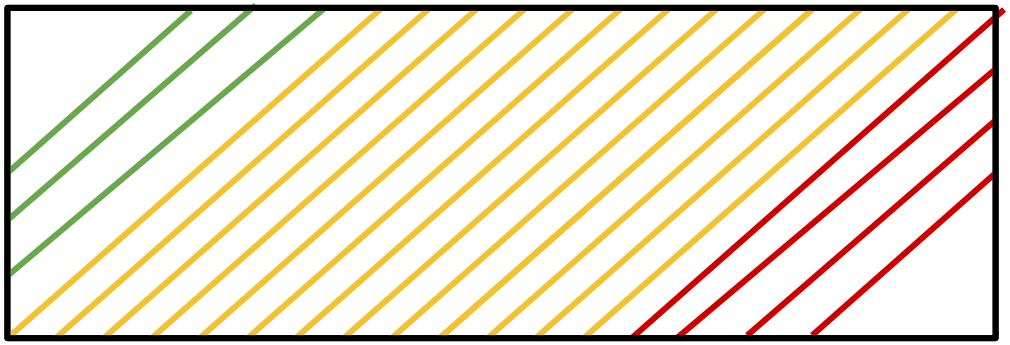
DAQ Channel ↔ Wire Segment Mapping





DAQ Channel ↔ Wire Segment Mapping



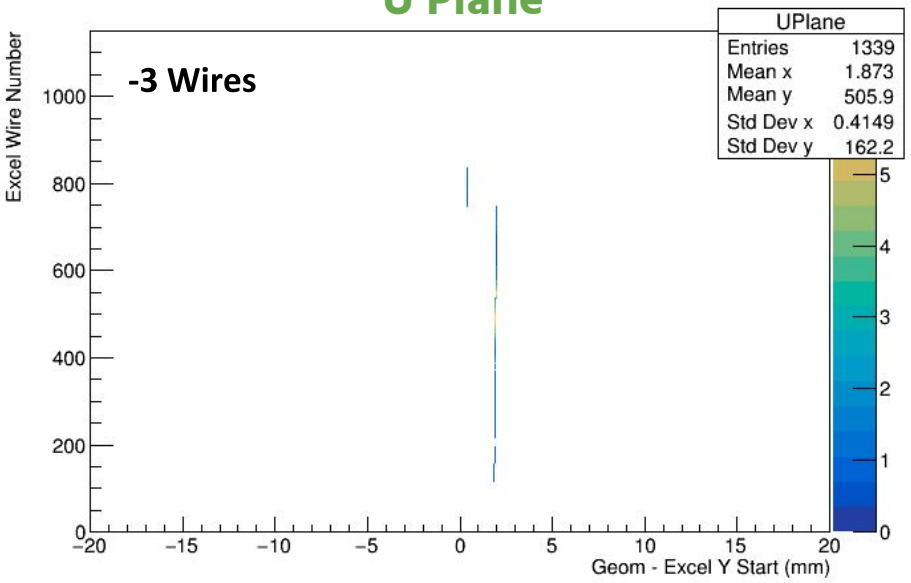


The remaining differences are due to a convolution of differences in measured width and differences in measured height.

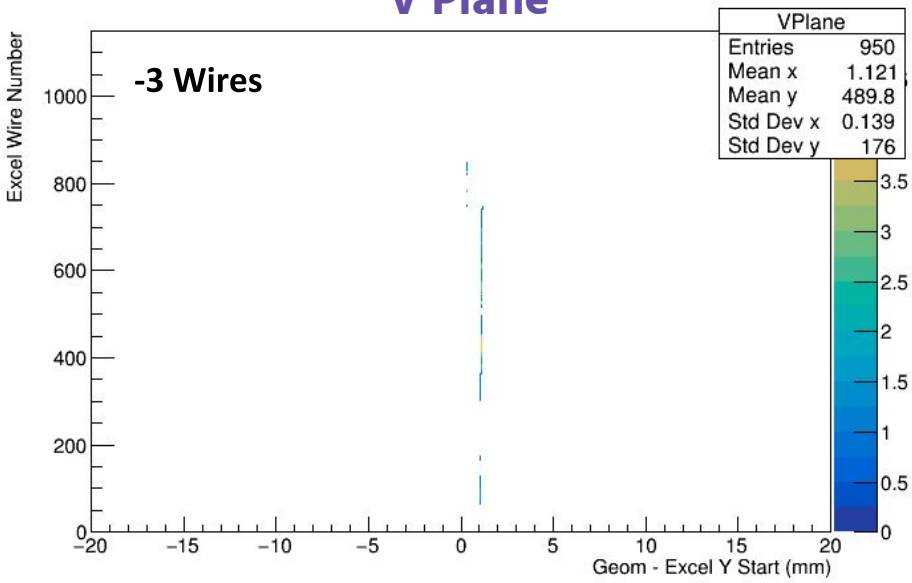
I think if we minimise these differences in starting y point and the overall length of the wire, it should result in the correct mapping.

Example Metric

U Plane



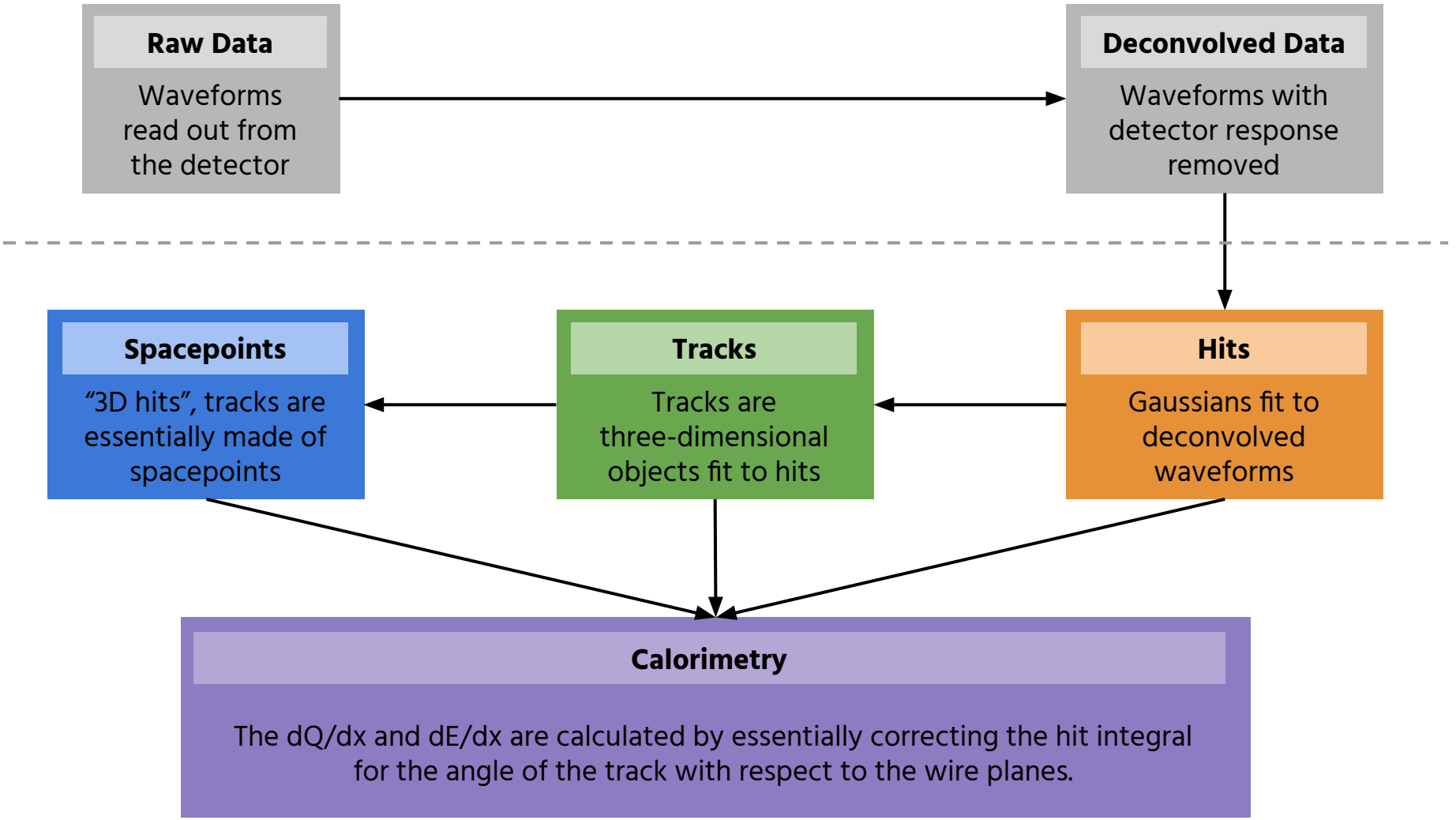
V Plane



For each of the two metrics, I try to minimise the difference assuming that the mapping is off by +5 to -5 wires.

Using this metric, I believe that the mapping is off by -3 wires.

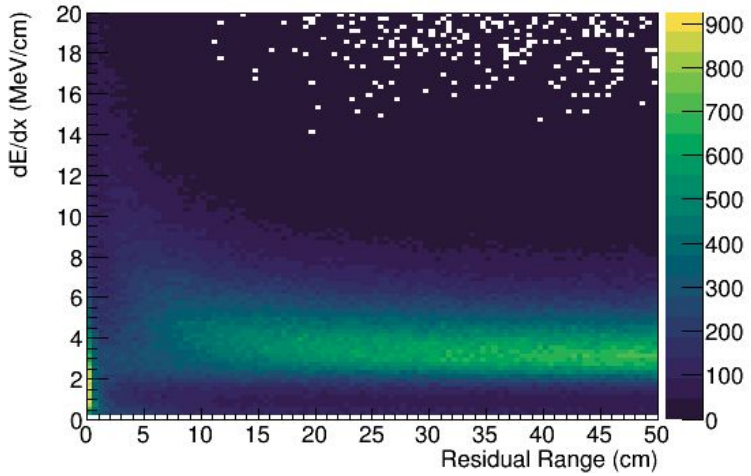
Reminder: Variable Relationships

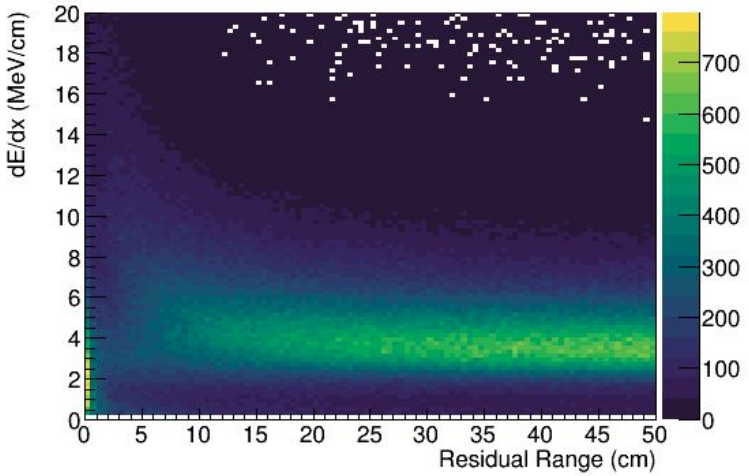


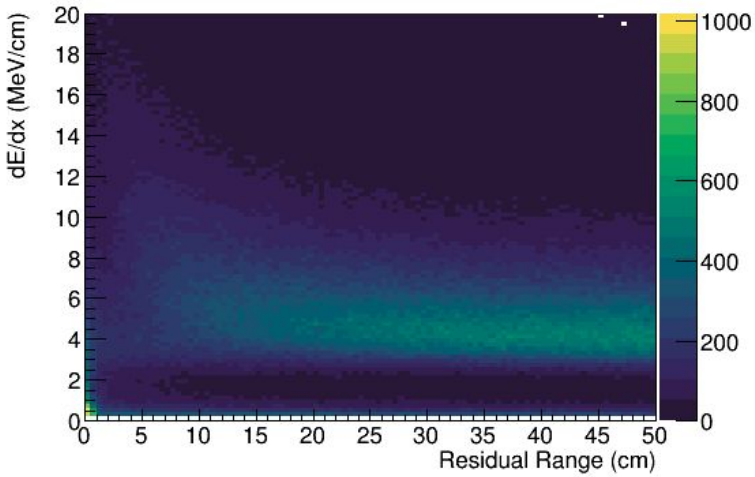
Reminder: Stopping Muon Selection

I've previously ported the stopping muon selection to a filter module which I make use of for this analysis.

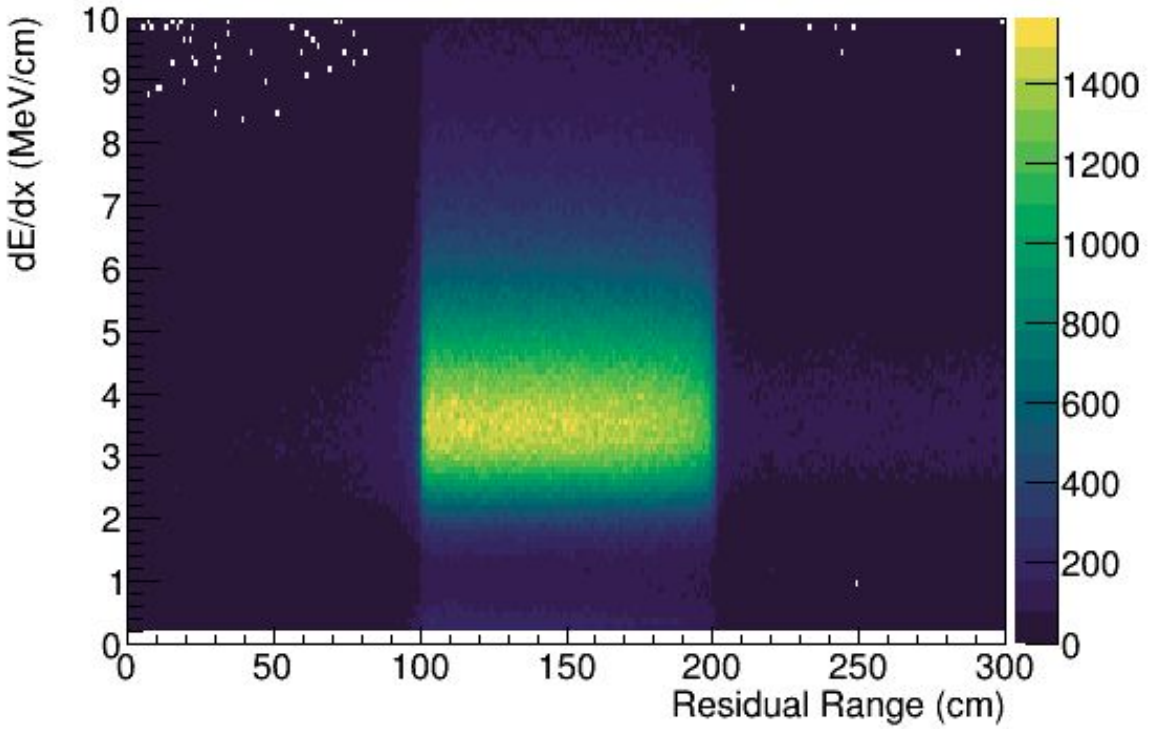
One thing of note here: the dE/dx is too high - the calibration I'm using isn't correct.

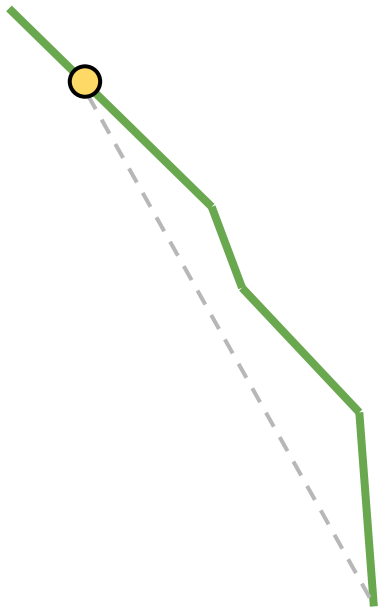






Selecting Out The MIP Region





Hits are selected if they are between one and two meters from the end of the track they are reconstructed on — the so-called **MIP-region.**

This is just calculated as a straight line between the hit and the track end point, whereas the residual range calculates the distance by adding up each individual segment.

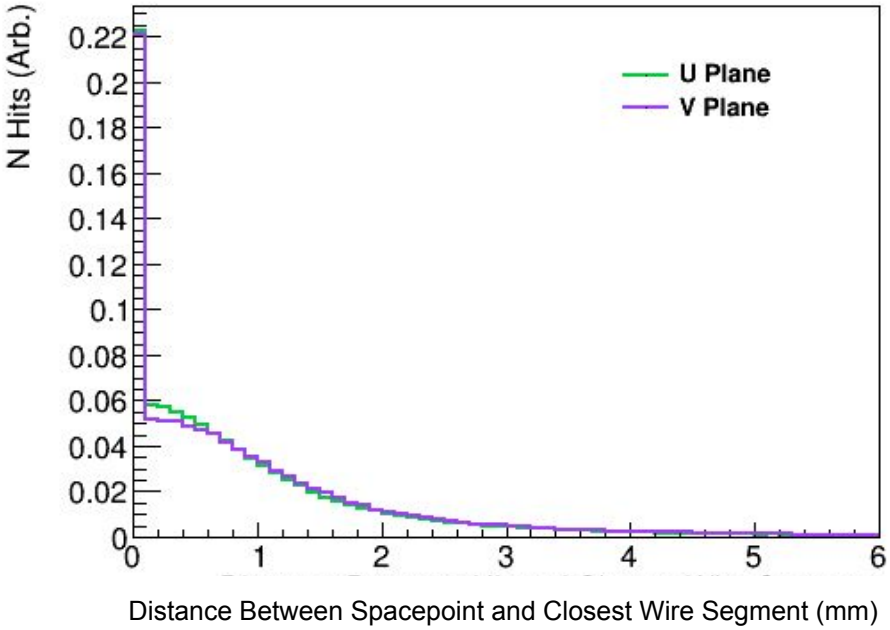
Distance Between Segment and SpacePoint

So now we have a collection of MIP hits, and we have a mapping between each DAQ channel and the wire segments which have associated tensions.

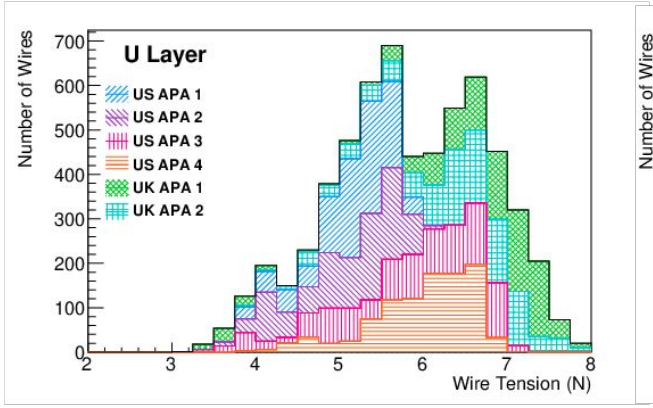
The final step is to figure out for each hit (which only knows about the DAQ channel), which is the wire segment where the charge fell.

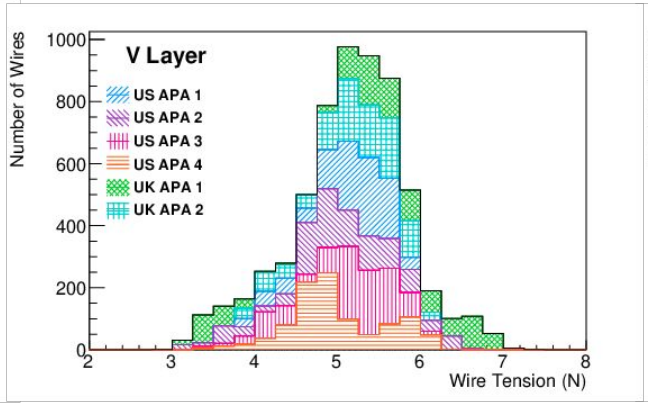
This is done geometrically by using associated SpacePoints and the distance is found to be within 2.5 mm the majority of the time.

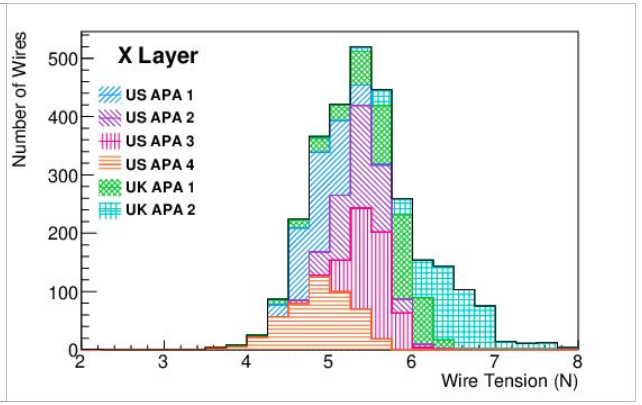
We can be confident that we select the correct segment here.



Splitting Up the Distributions



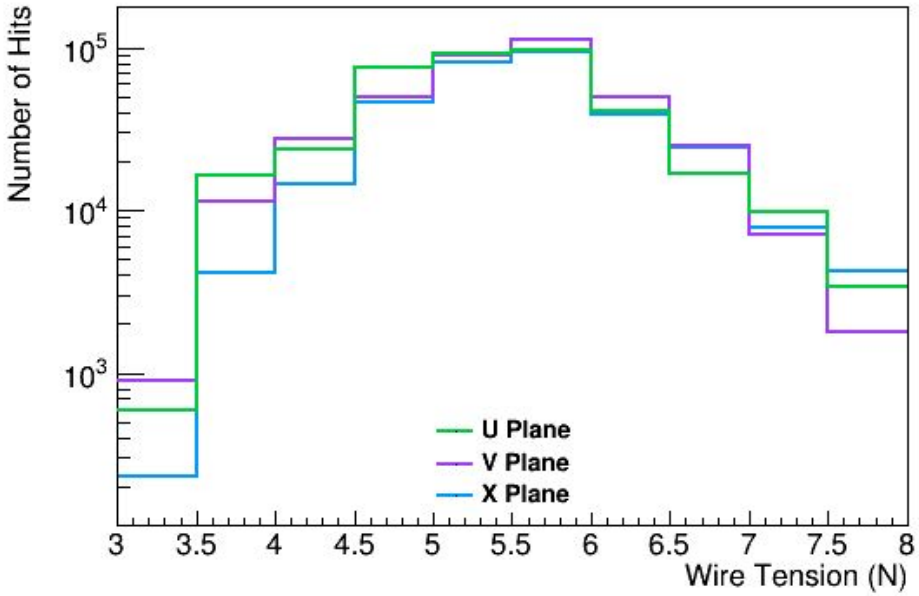




Now, across all TPCs, I'm going to choose 10 tension bins between 3 and 8 N.

With this dataset, the lowest number of hits in a tension bin is ~350 in the lowest tension bin of the X plane.

This matches what might be expected, given the distribution of wire tensions across the planes.



For the Next Few Slides...

2D histograms of a variable across the three planes

U Plane

V Plane

Y Plane

Mean value of all Y bins in the given X bin of above 2D histograms

The errors on each point are the errors on the mean

Median value of all Y bins in the given X bin of above 2D histograms

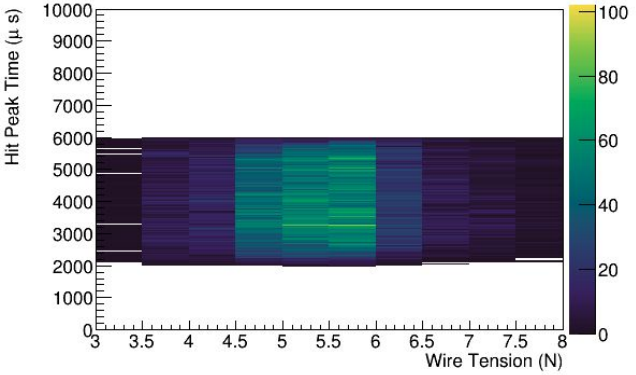
No associated errors, just to show we're not being biased by the tail too much

Ideally we have the MPV and FWHM as an error bar, that will come in the next iteration.

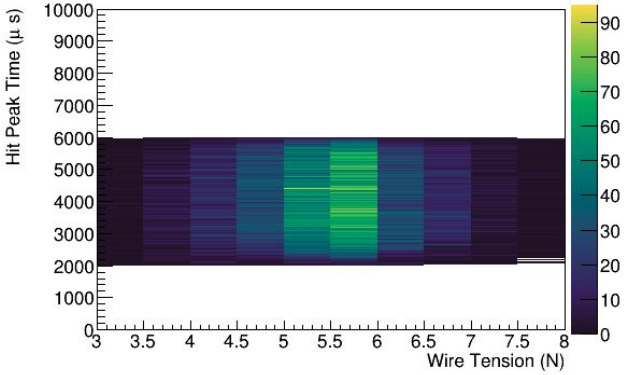
Hit Peak Time

We expect the tension to have no impact on the peak time, and that is mostly what we see. There is a slight dip in the 3.5-4.0 N bin, but I think this should disappear with additional stats.

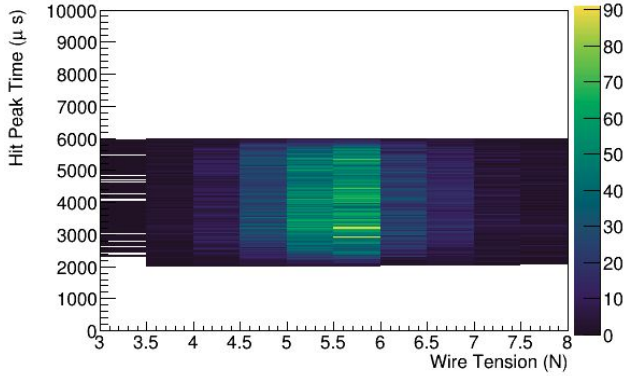
U Plane

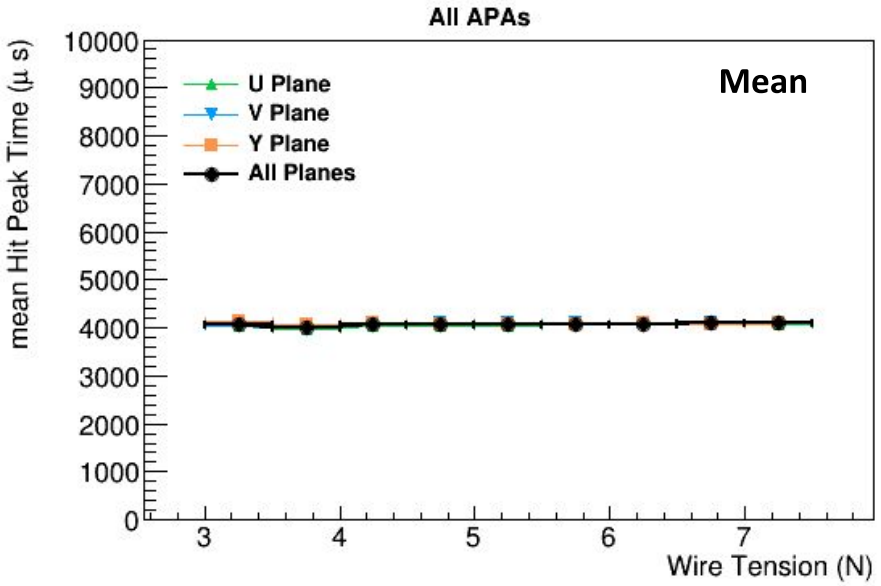


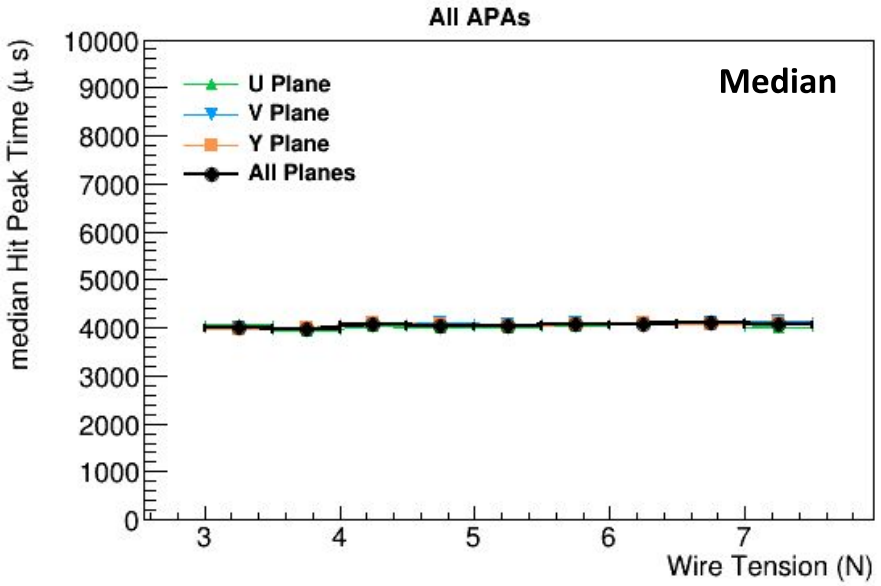
V Plane



Y Plane

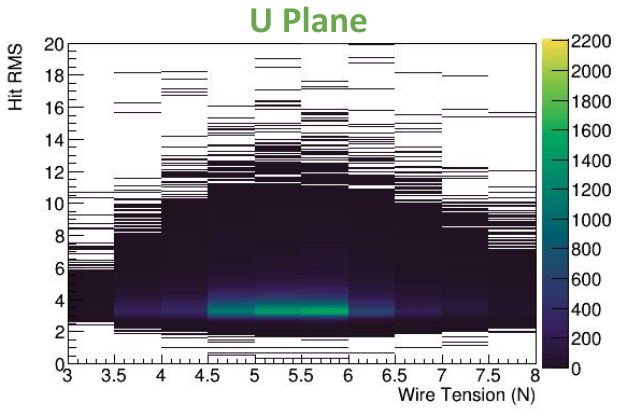


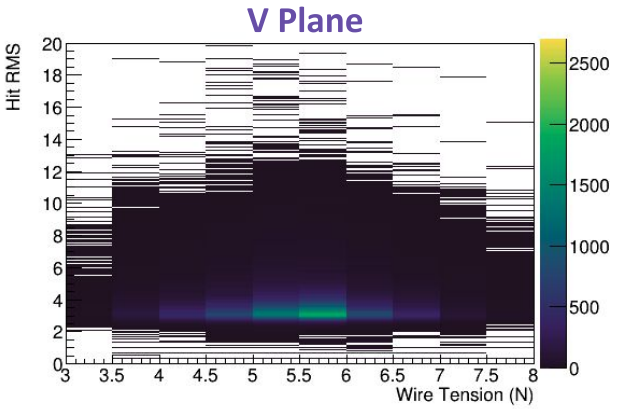


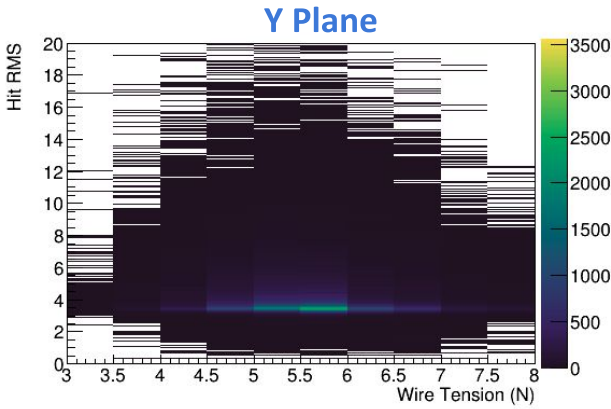


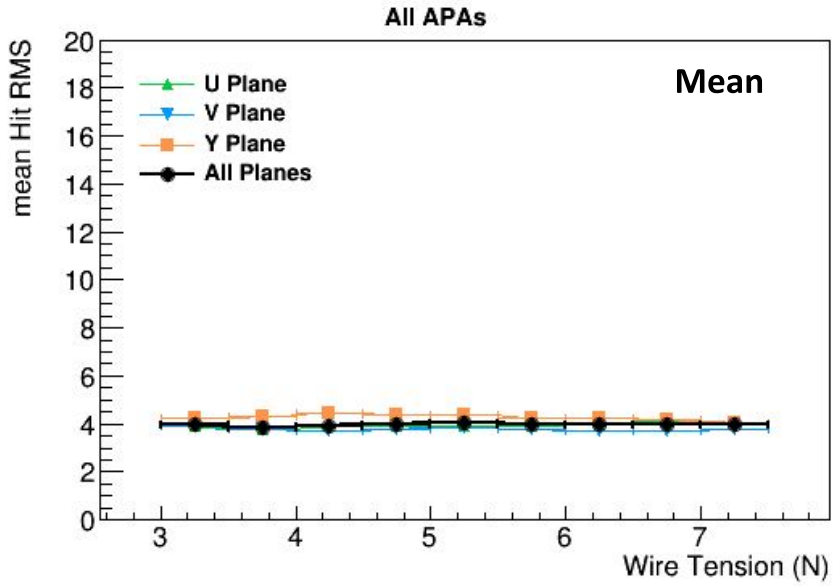
Hit RMS

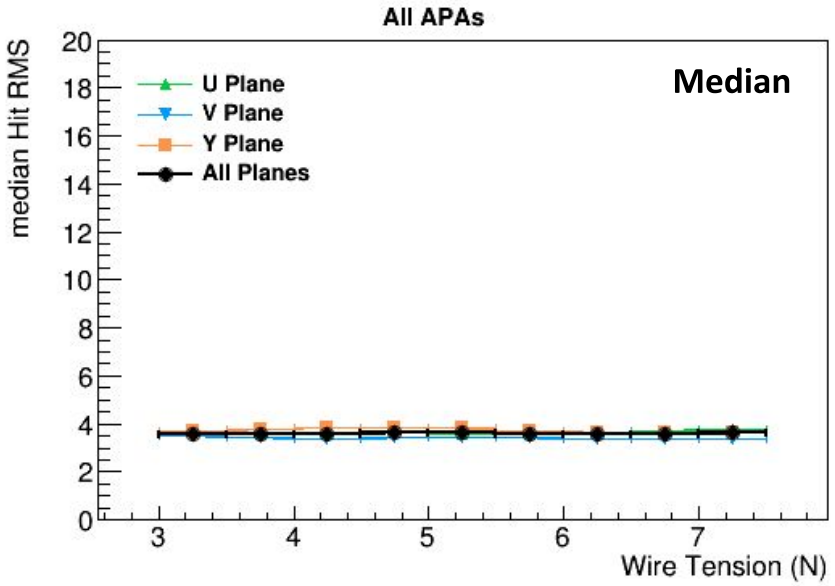
There is no obvious trend in the Hit RMS (width of the hit)







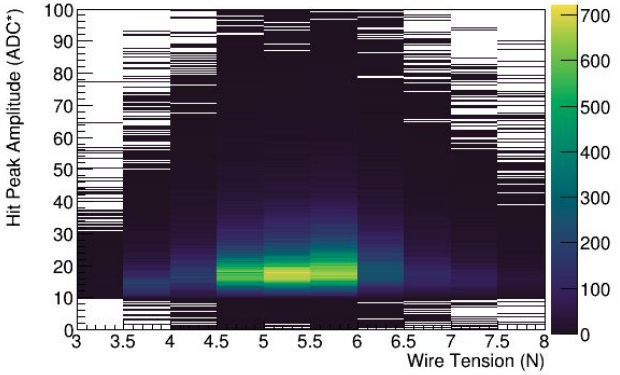




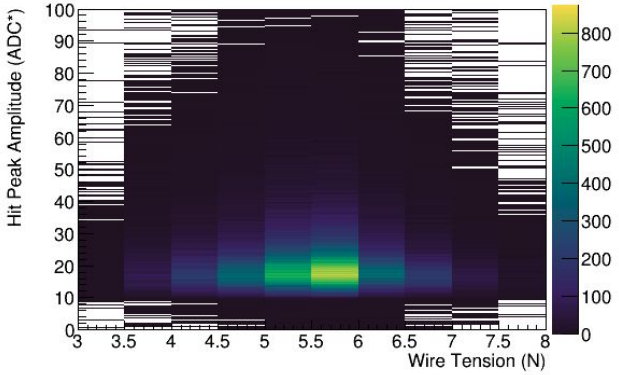
Hit Peak Amplitude

Here, the Y(X) plane has a larger average than the induction planes. I think this is largely a geometric effect from the angle between the average cosmic and the collection plane.
There is a downward trend in the Y plane which I'm yet to understand.

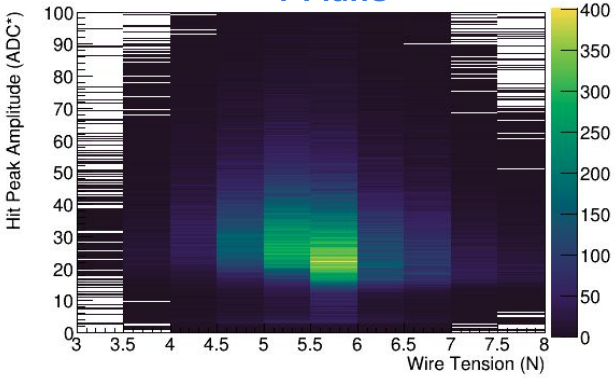
U Plane

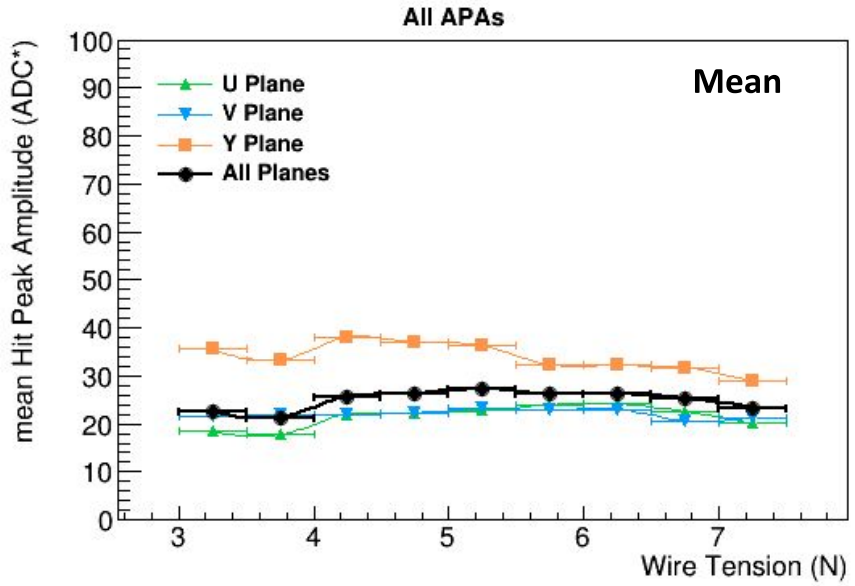


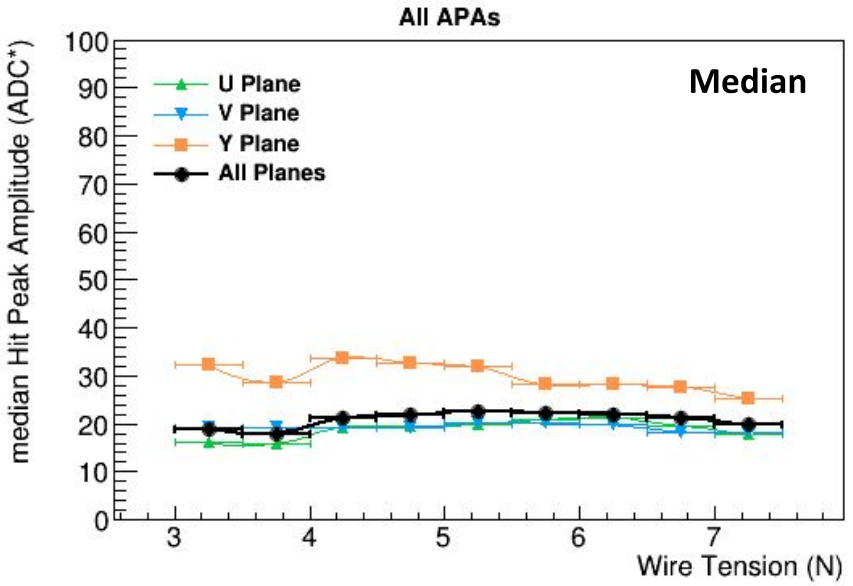
V Plane



Y Plane



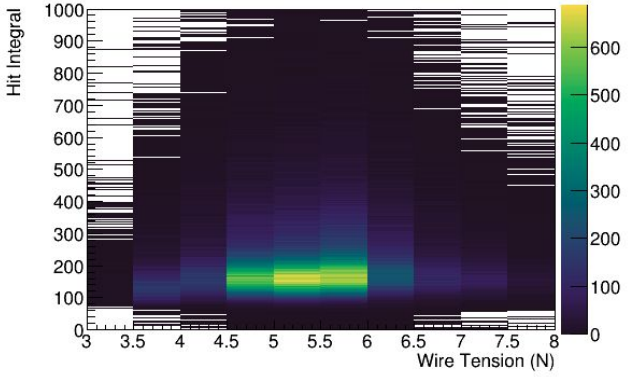




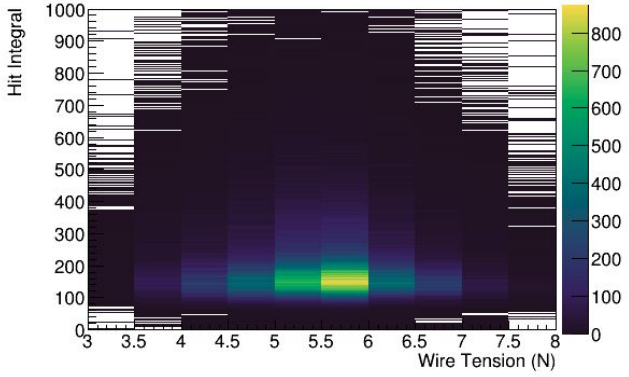
Hit Integral

This is essentially just a combination of the hit RMS and the hit amplitude, so no surprises here.

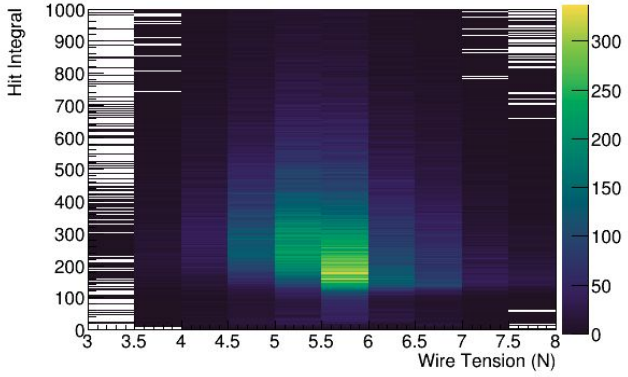
U Plane

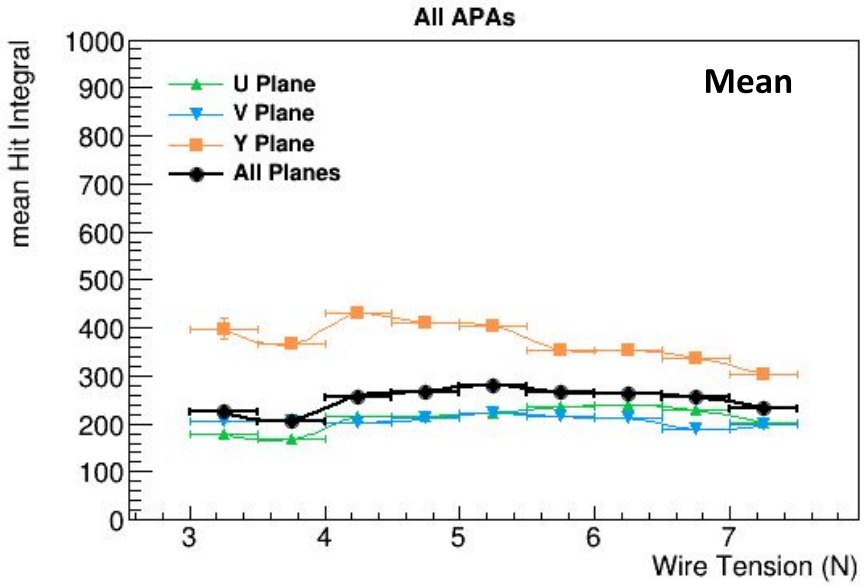


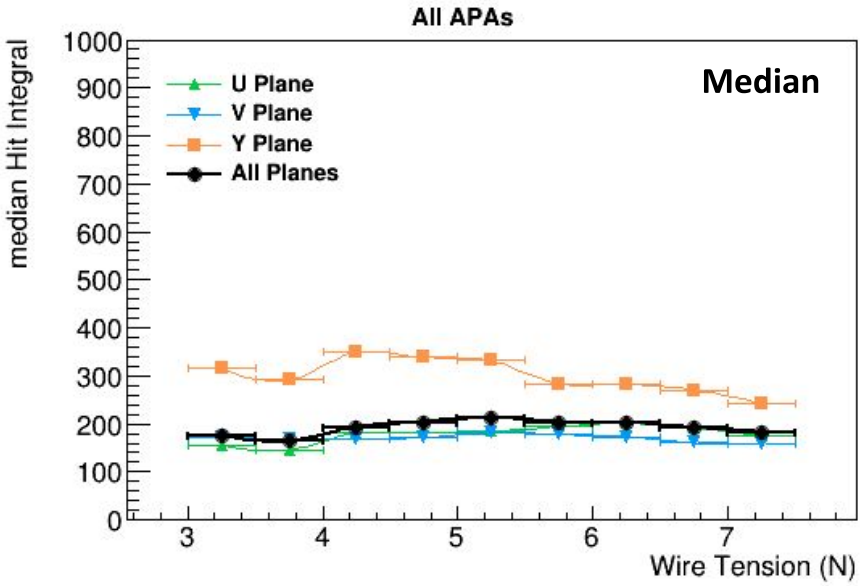
V Plane



Y Plane



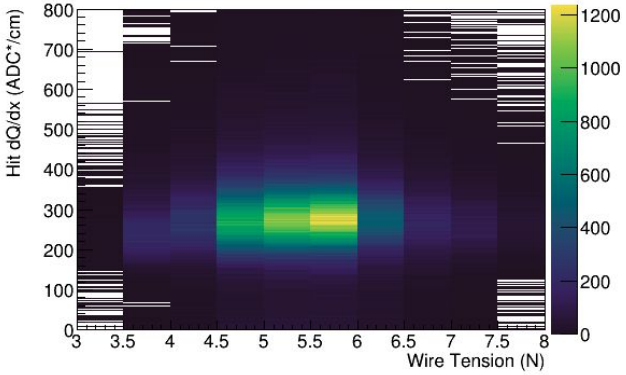




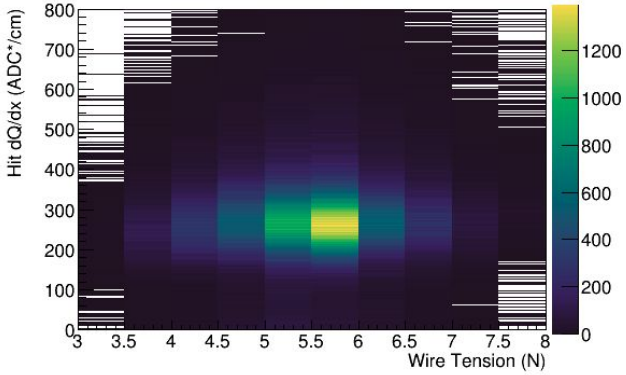
Hit dQ/dx

This is very interesting. Things appear to be mostly flat above around 4.5 N, but there is a downward trend below that. This is consistent across all three planes. More discussion after these slides.

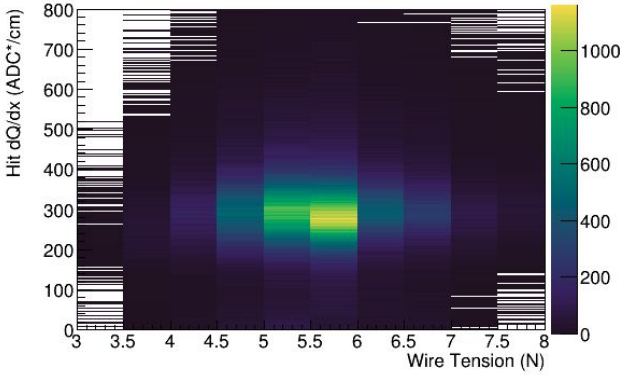
U Plane

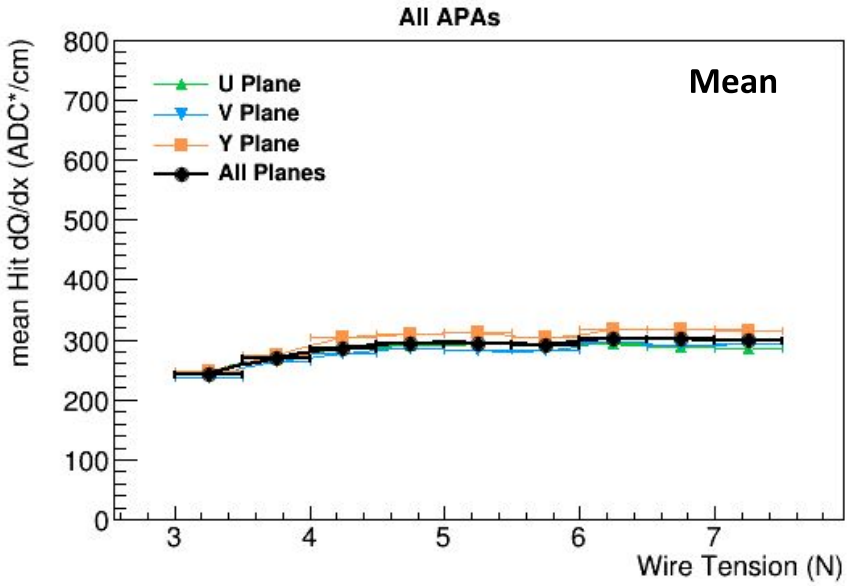


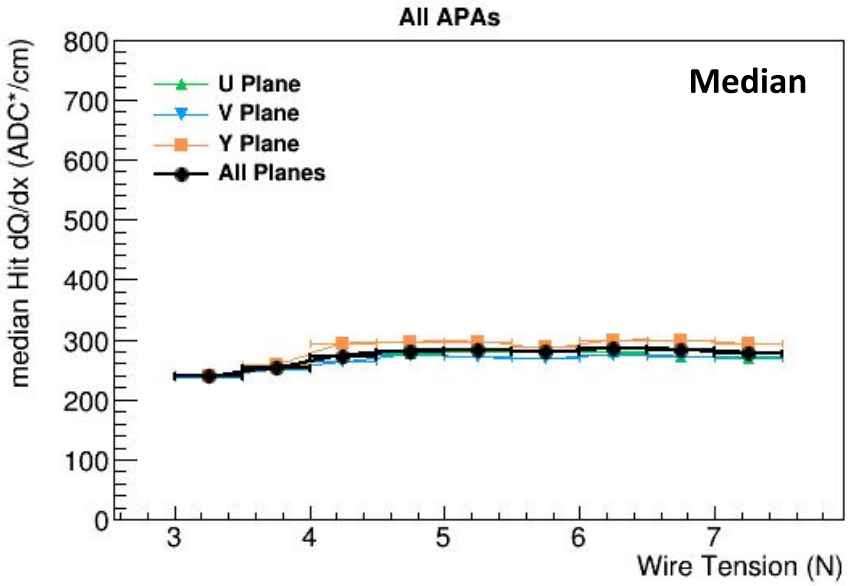
V Plane



Y Plane



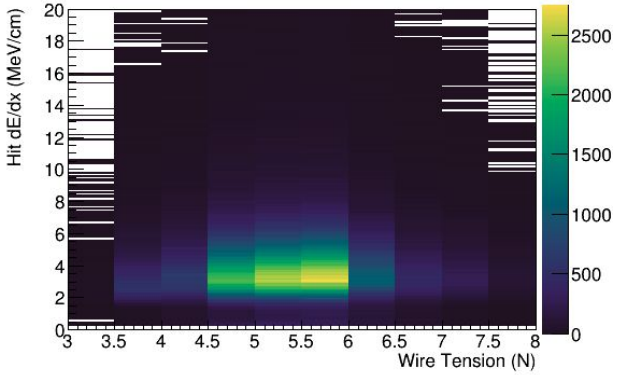




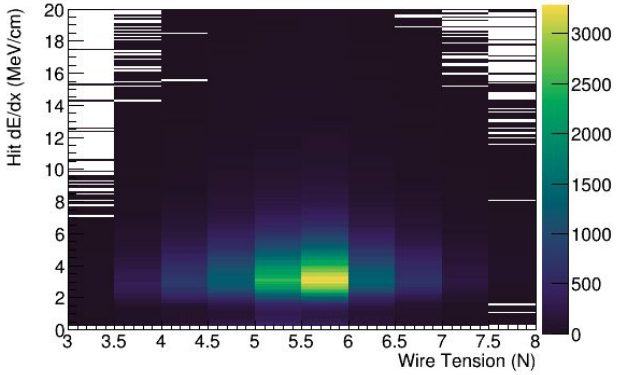
Hit dE/dx

dE/dx is essentially dQ/dx modified into units which are more interesting for us — MeV/cm. In general this is calibrated, but given the large values of dE/dx this is clearly not being correctly applied.

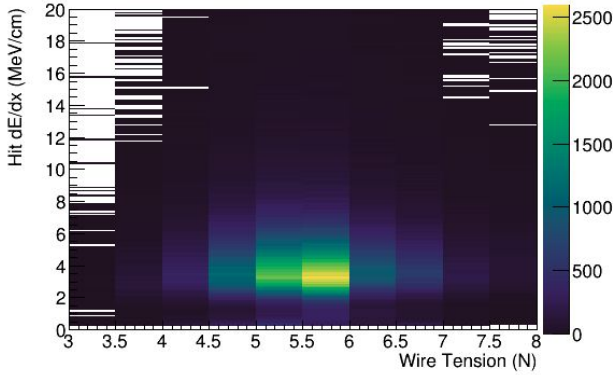
U Plane

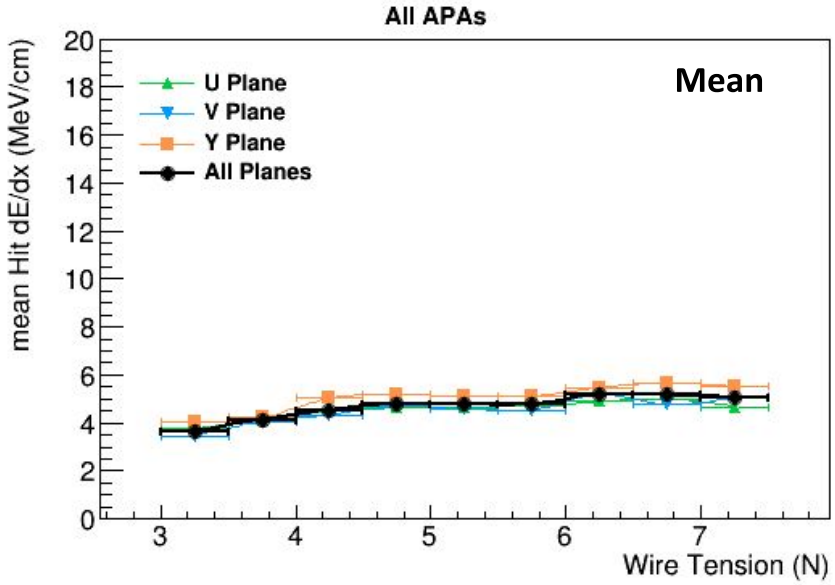


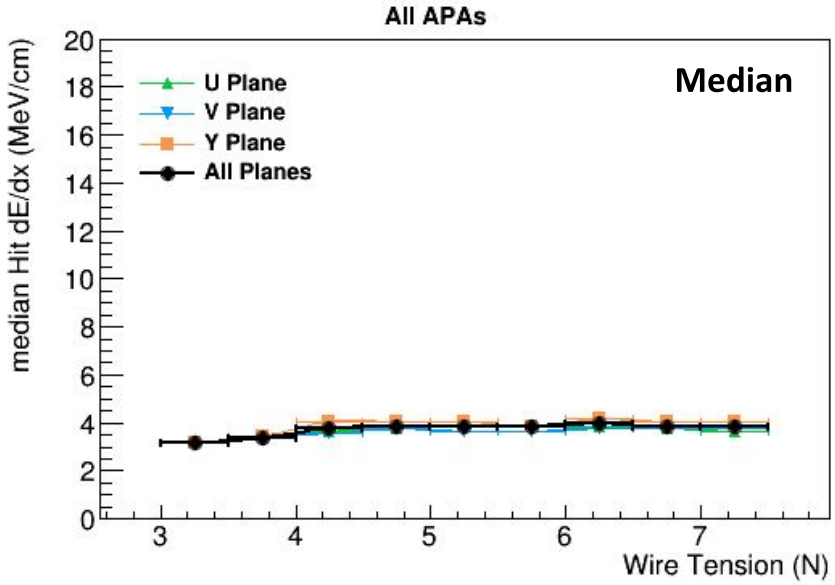
V Plane



Y Plane

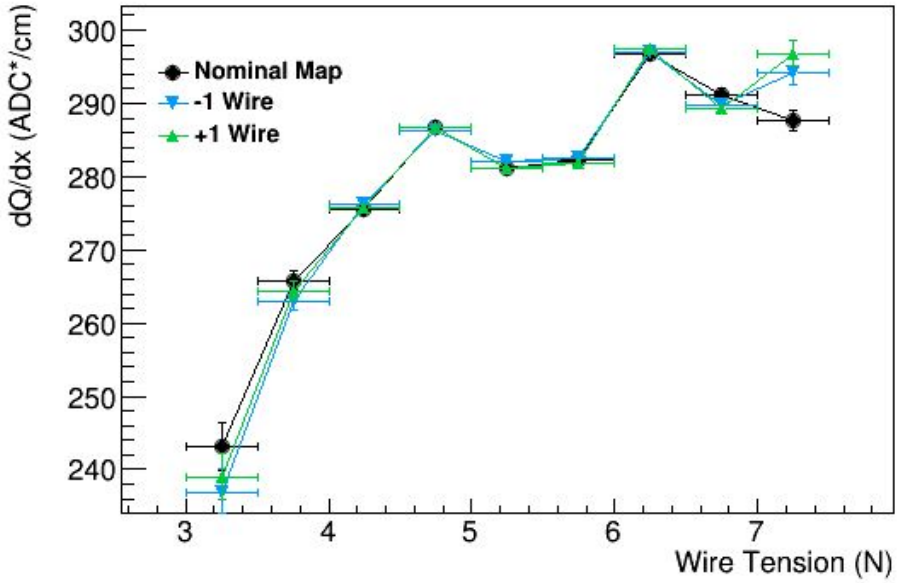






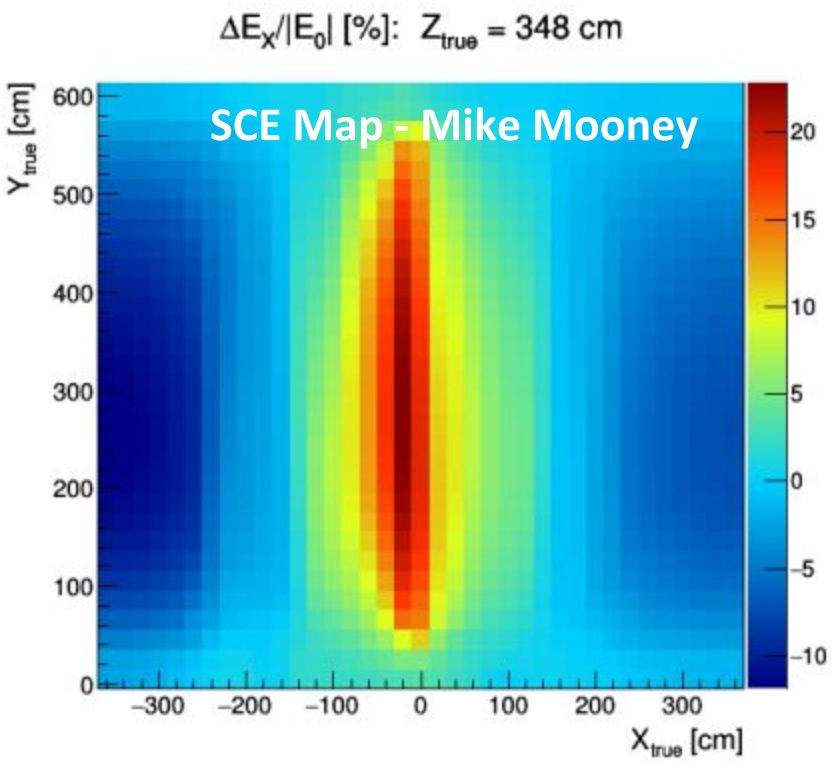
Discussion

In order to test whether the mapping is correct, I shifted the mapping for the V plane by +/- 1 wire. My initial thought was that we should see no variation in dQ/dx as a function of wire tension.



This is not what I expected. My initial thought was that it was some physical effect from the TPC. Maybe something like Space Charge.

Space Charge Effect

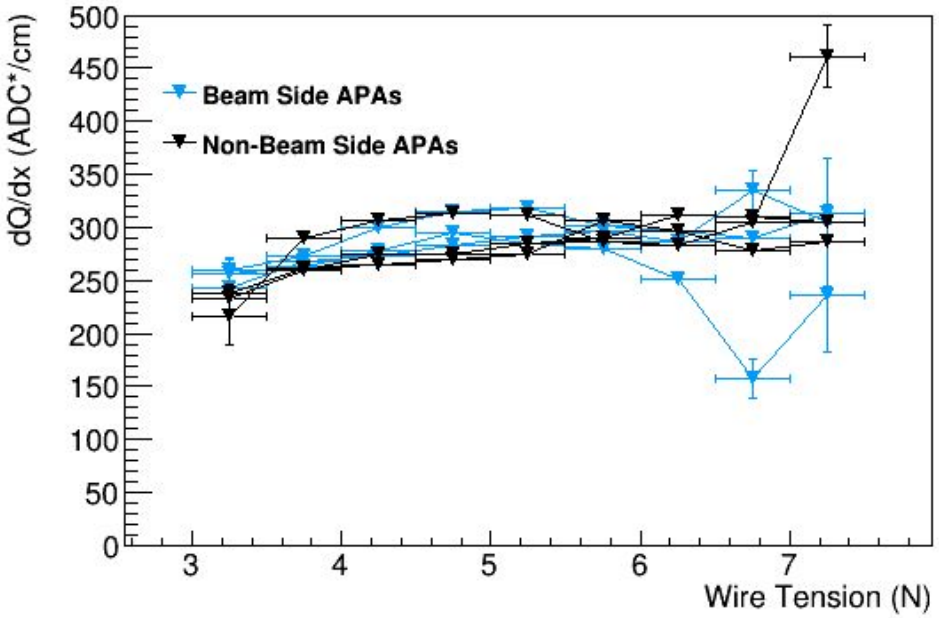


Beam side **Not Beam side**

If it's space charge, we expect the E field to be distorted to a larger extent on the beam side.

→ this should change the recombination, and so if we look for differences between beam-side APAs and non-beam-side APAs, this might be a clue that it's not the wire tension, but SCE which causes the dip.

E Field Distortions From Space Charge

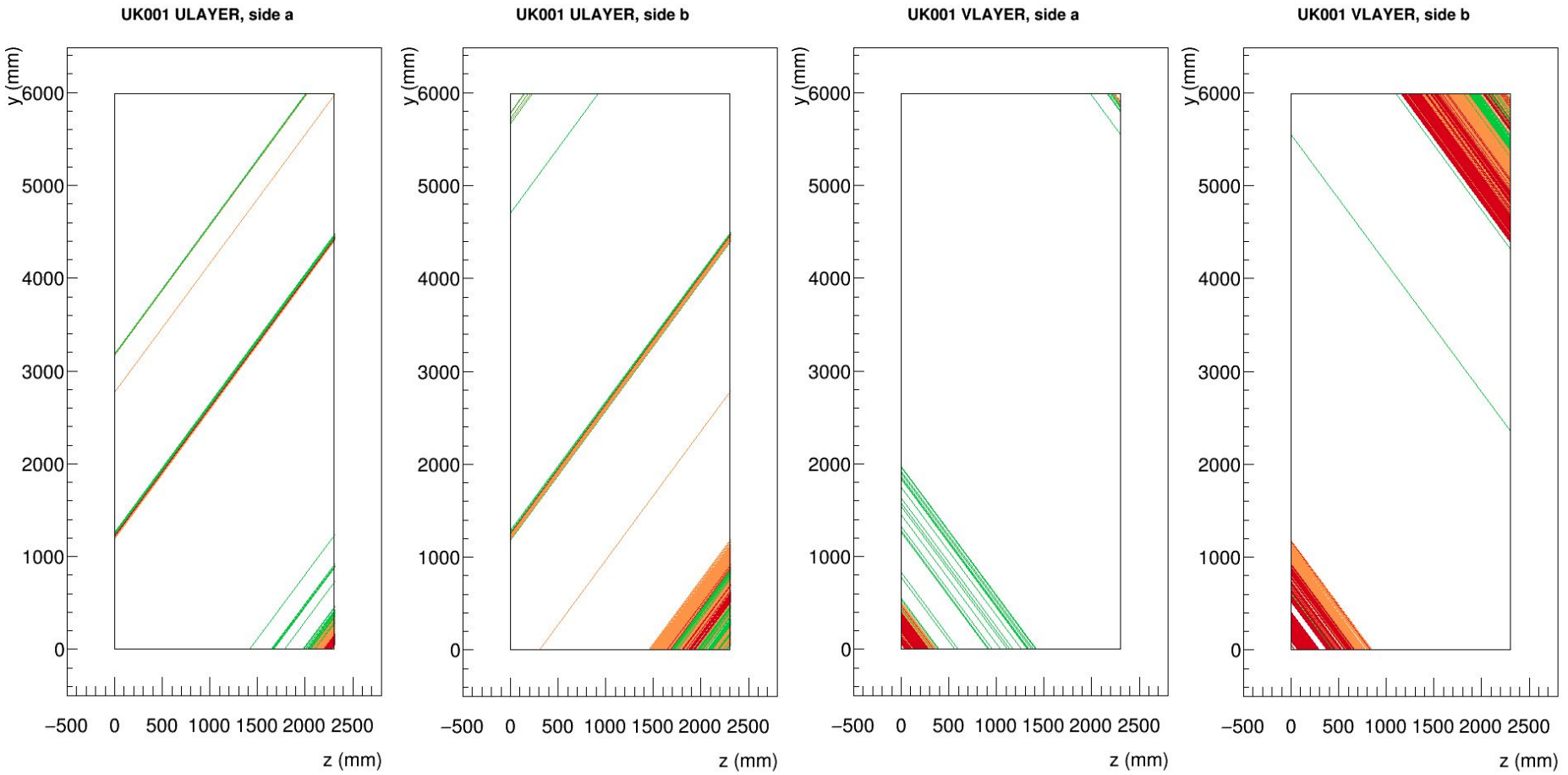


This is clearly not an in-depth study, and needs more sophisticated analysis, but by eye, I think that the APAs on the beam side are consistent with those on the other side.

In the meantime, I thought it might be instructive to look at where the low-tension wires lay in the APAs. For technical reasons, this is only done on the induction planes.

Where Are The Low Tension Wires?

UK2	US4	US3
UK1	US2	US1



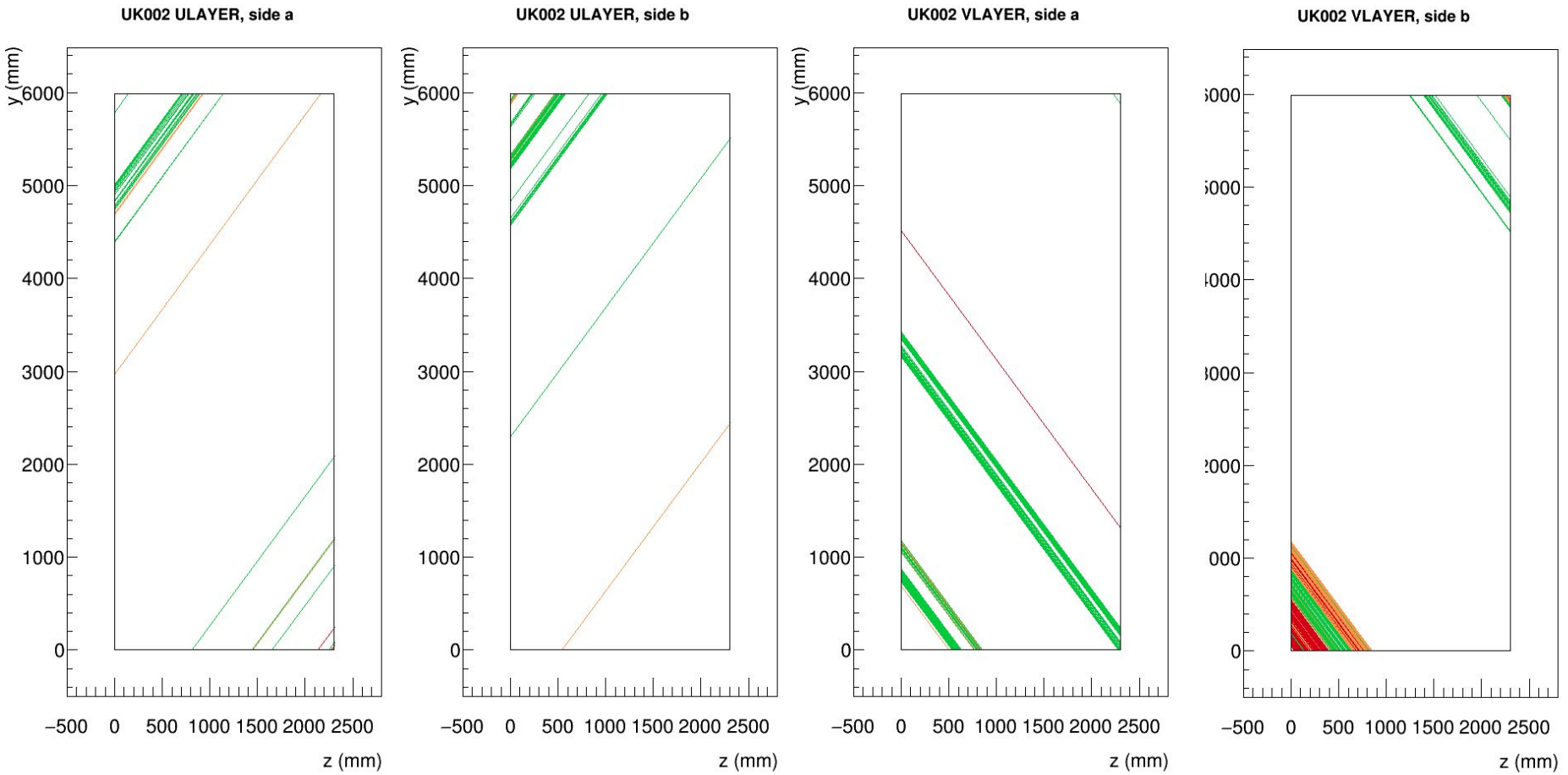
Tension < 3.5 N

3.5 < Tension < 4.0 N

4.0 < Tension < 4.5 N

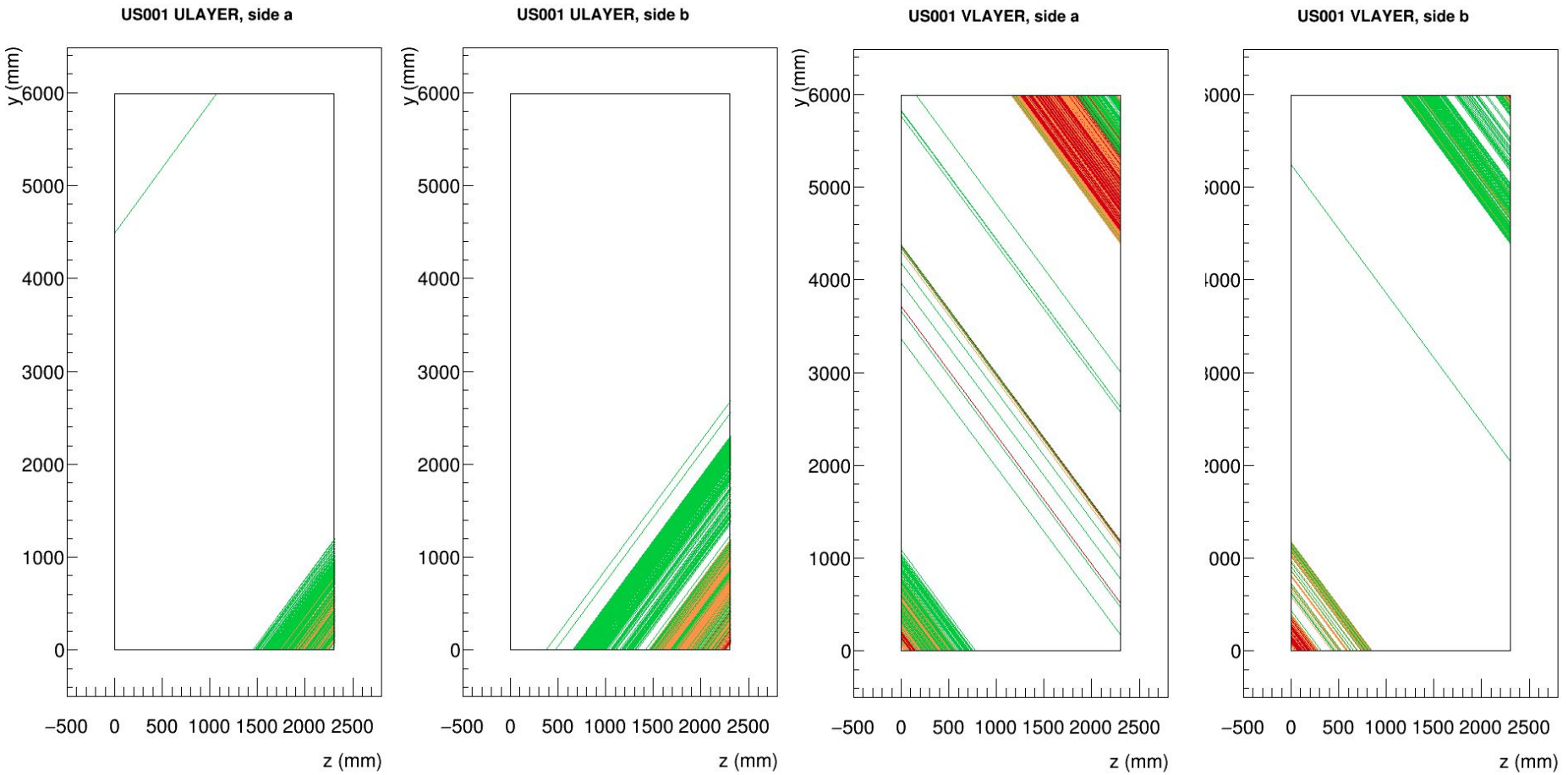
Where Are The Low Tension Wires?

UK2	**US4**	**US3**
UK1	**US2**	**US1**



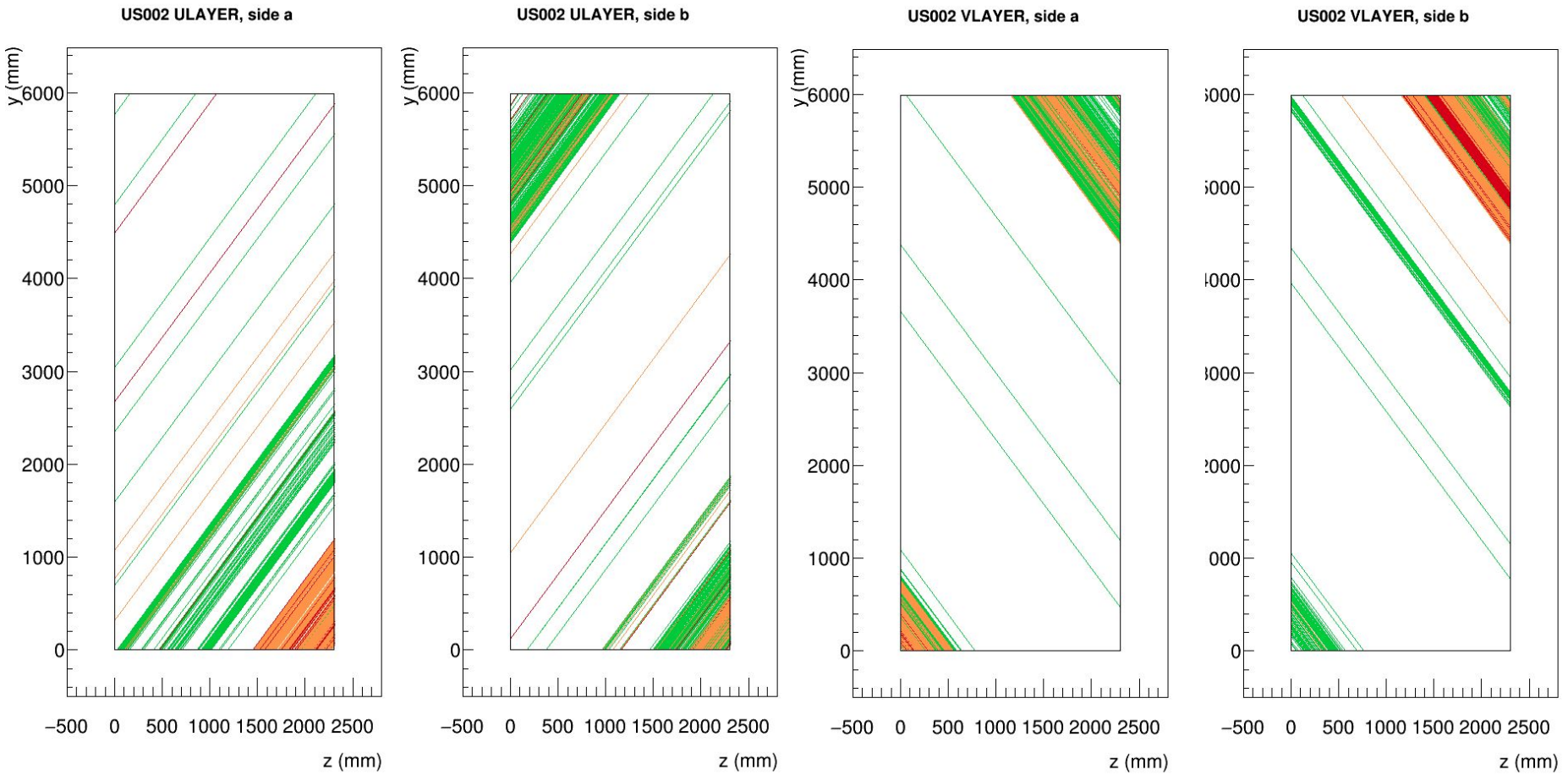
Where Are The Low Tension Wires?

UK2	US4	US3
UK1	US2	**US1**



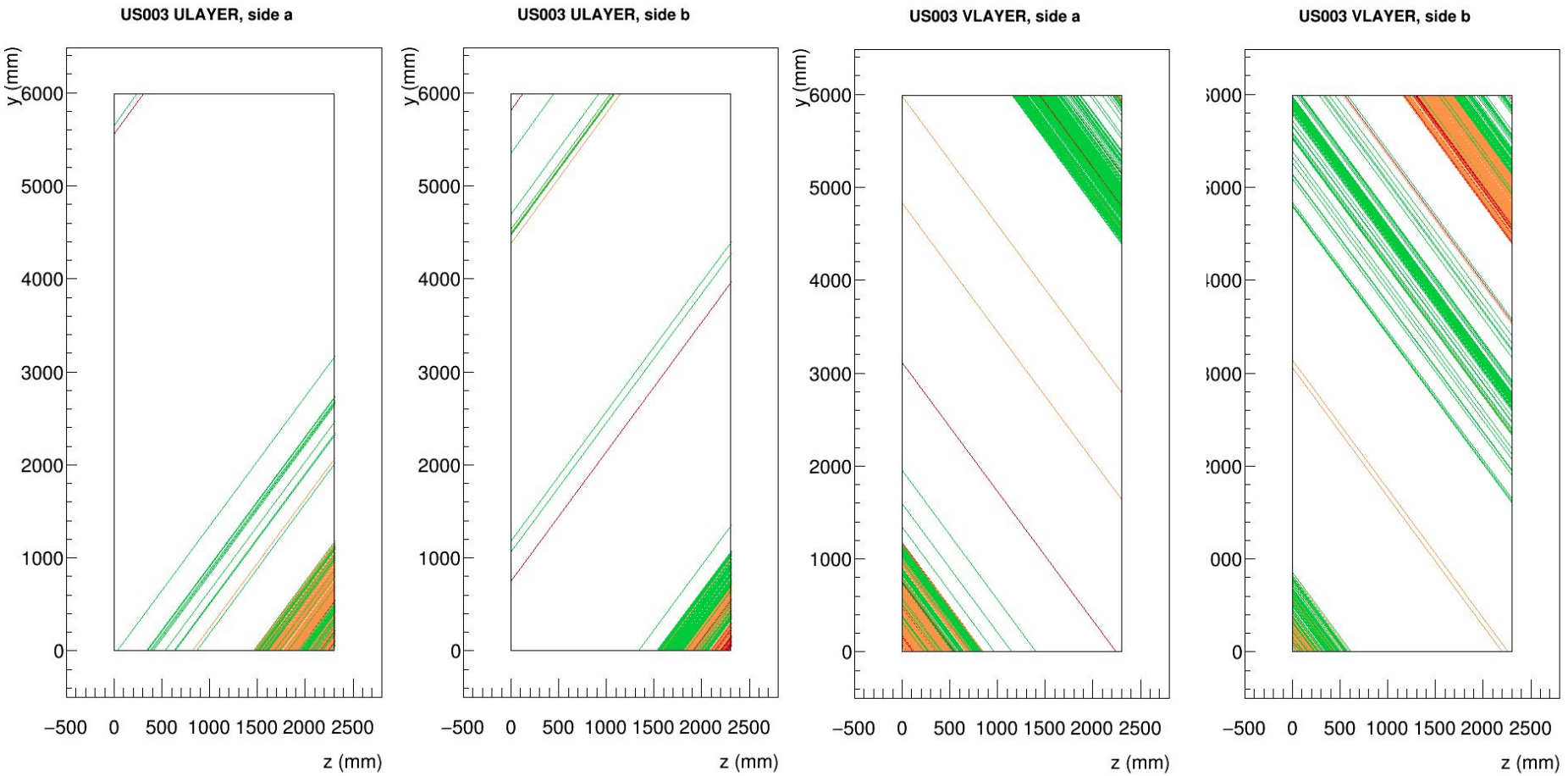
Where Are The Low Tension Wires?

UK2	US4	US3
UK1	**US2**	US1



Where Are The Low Tension Wires?

UK2	US4	**US3**
UK1	US2	US1



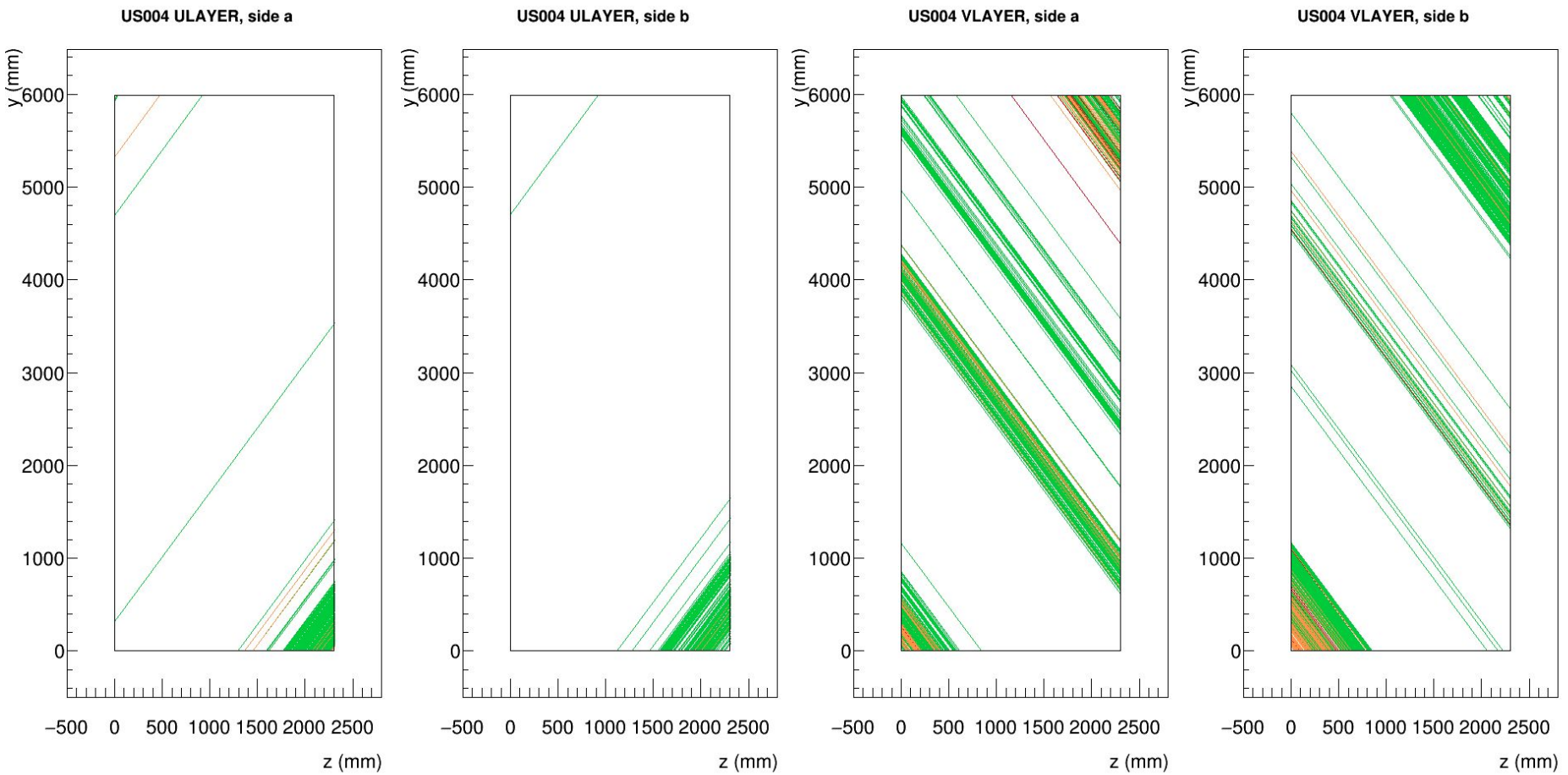
Tension < 3.5 N

3.5 < Tension < 4.0 N

4.0 < Tension < 4.5 N

Where Are The Low Tension Wires?

UK2	**US4**	US3
UK1	US2	US1



Further Discussion

My current theory, given these plots:

In general, the wires with low tensions are grouped together, and so if the mapping between the wire segments and the DAQ channels is off by one or two, this might not change the distributions of hit variables as a function of the wire tension.

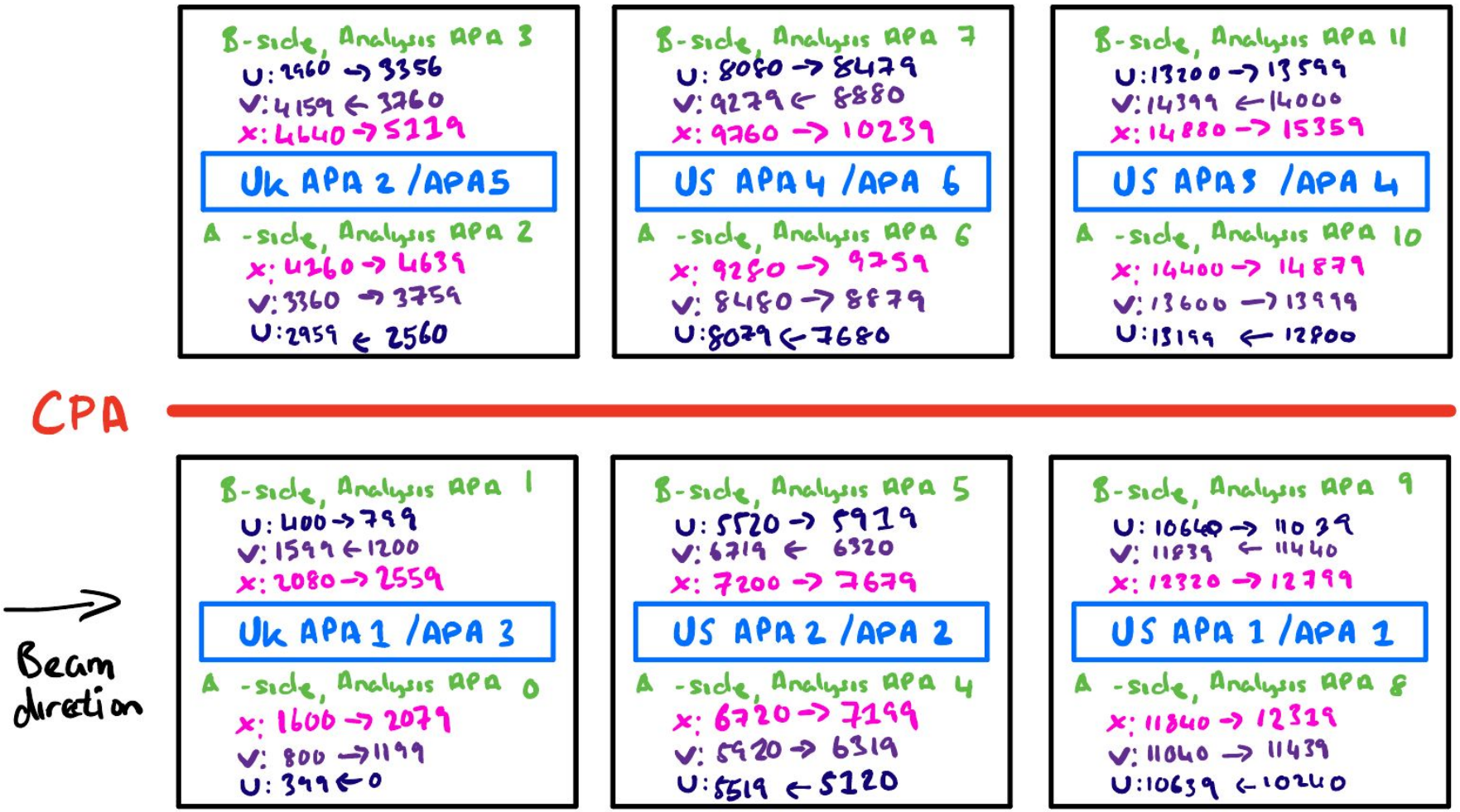
Of course, further analysis is needed.

Conclusion

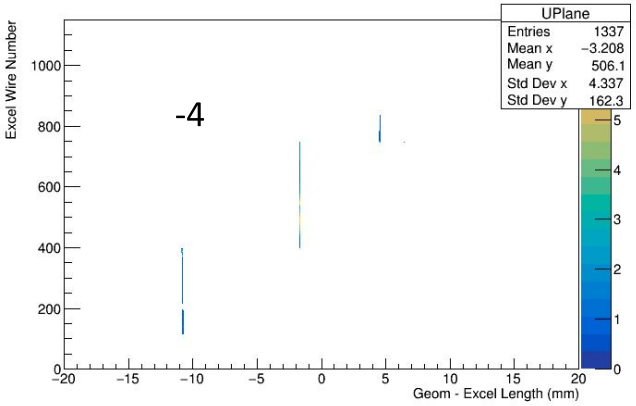
- I've been looking at whether wire tension can affect physics-level variables in the ProtoDUNE
  - This is important because we need to know how accurate we need to be when we're tensioning the wires for DUNE
- Here I've presented preliminary results for hit-level and calorimetry-level variables
- The general takeaway is that it looks like below around 4.5 N, the dQ/dx begins to drop
  - It's possible there is an incorrect map between the DAQ channels and the wire segments, but we also see this on the X plane, where the DAQ-to-wire segment mapping is 1-to-1
  - It's possible that this is some other effect, and I'm thinking about ways in which we might disentangle these
  - With these files and this calibration, it looks like this is not being calibrated
- Further variables related to, for example, the noise, are coming, but require a little more thought.

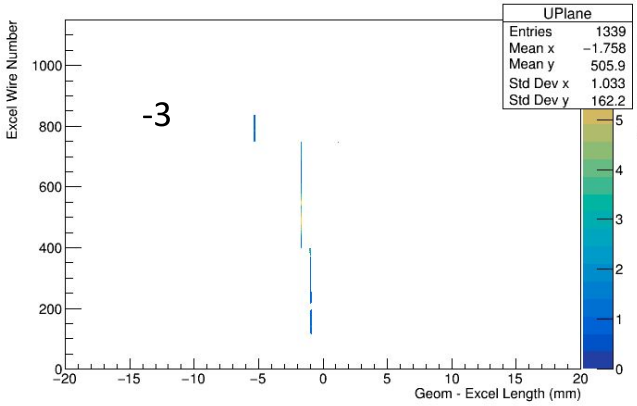
Backup

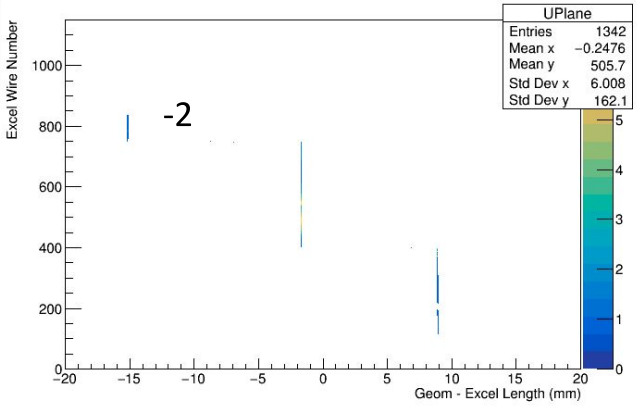
Including DAQ Channels

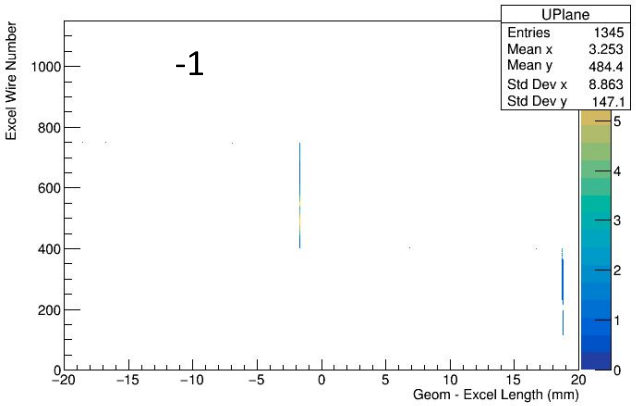


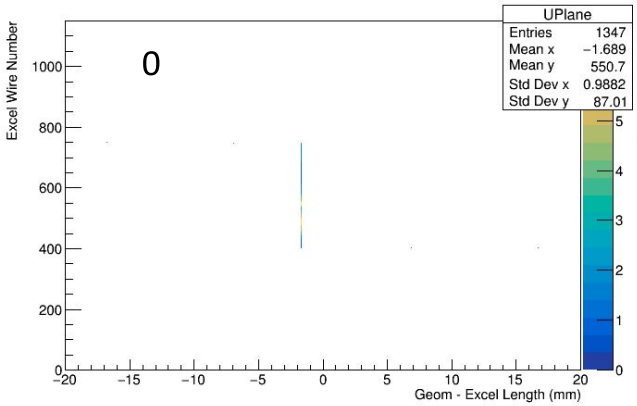
Sanity Check - U Plane

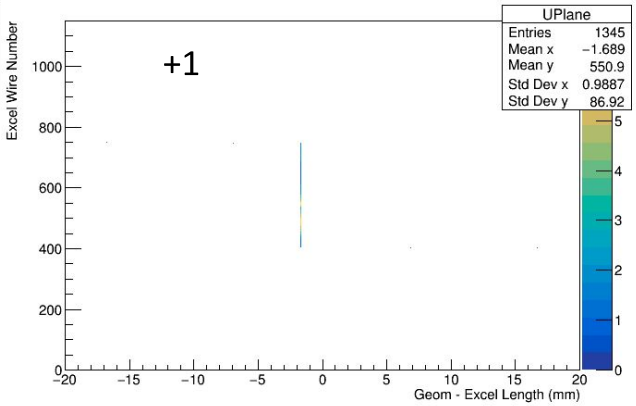




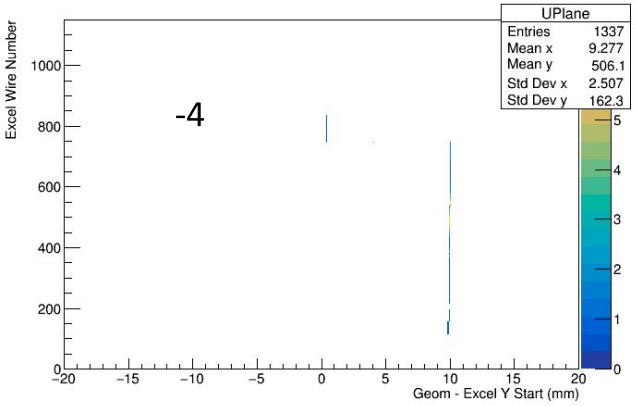


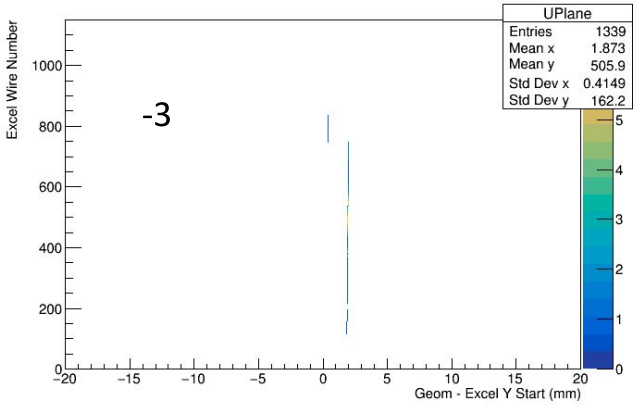


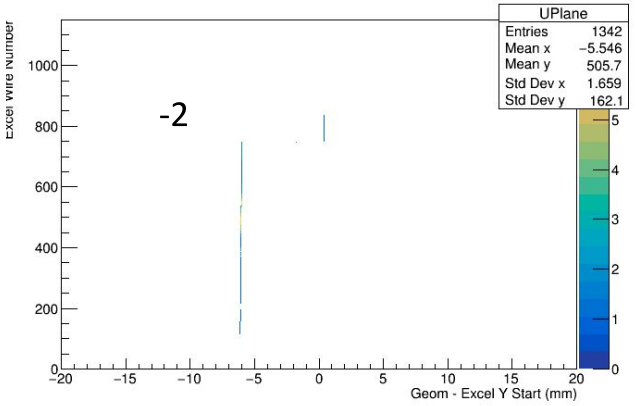


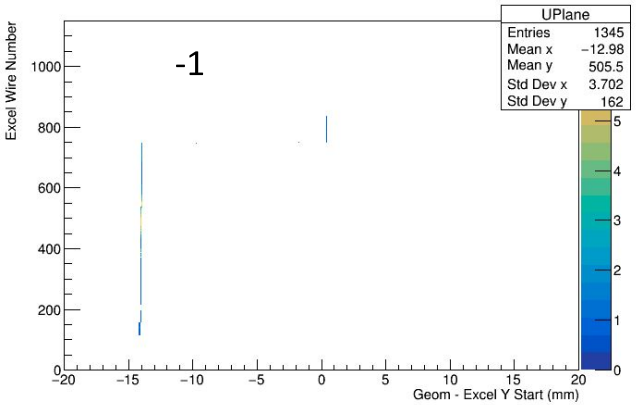


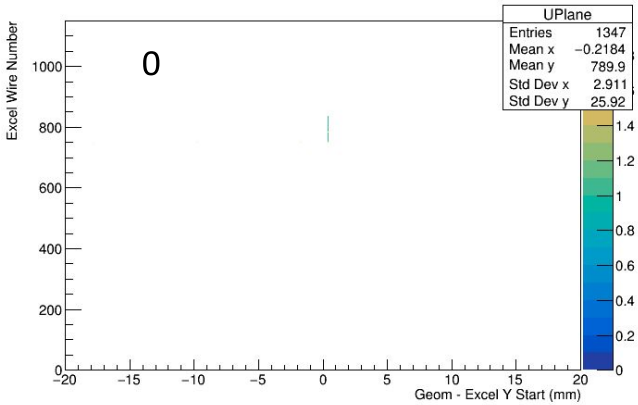
Sanity Check - U Plane

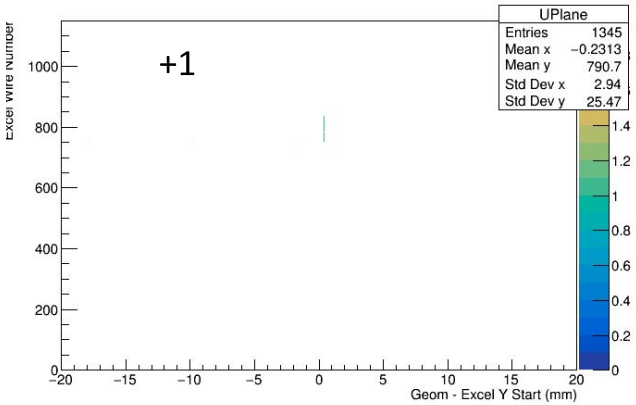




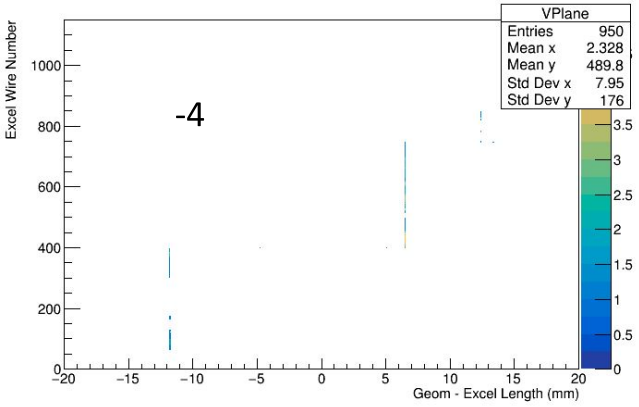


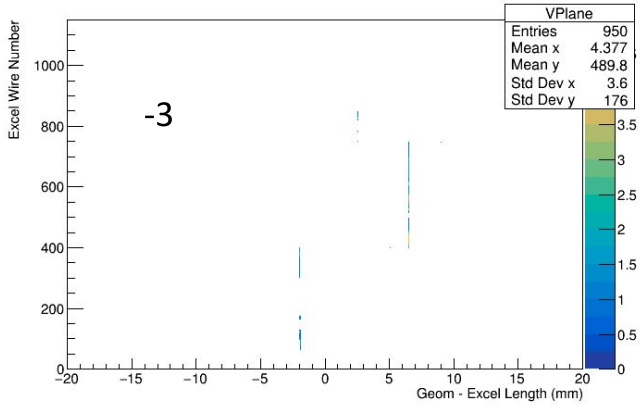


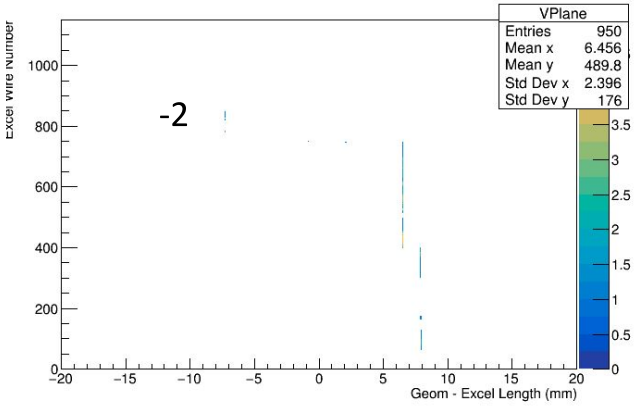


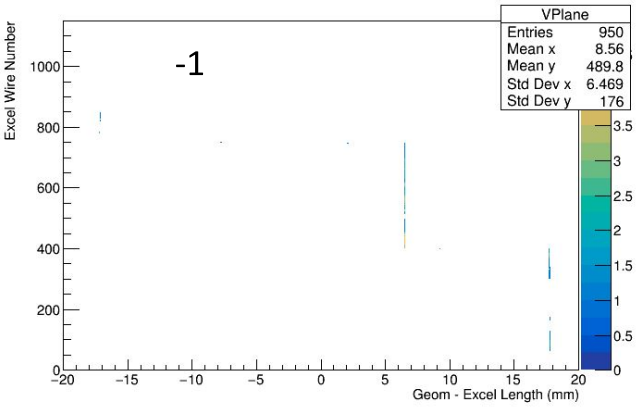


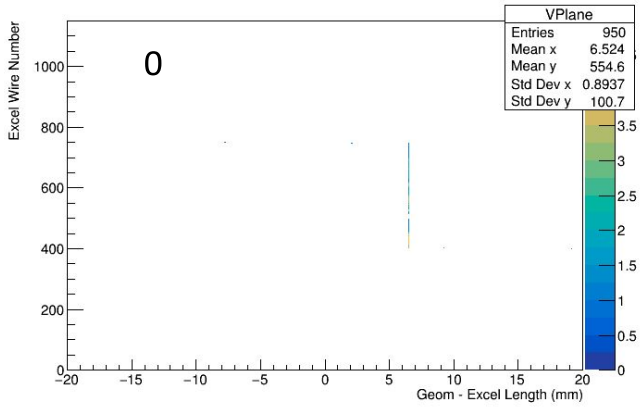
Sanity Check - V Plane

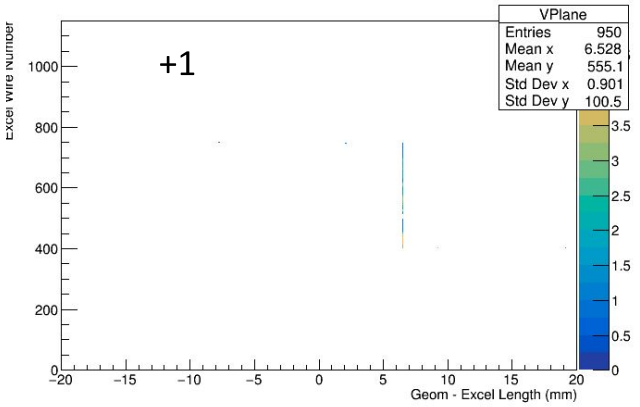












Sanity Check - V Plane