Exploring Data

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July 2020 - August 2020

1 Introduction

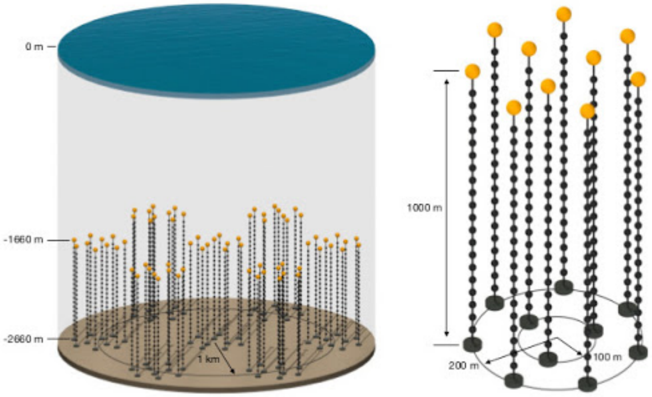


Figure 1: P-ONE Observatory

Shadowing Matthew Ens in his work with P-ONE Neutrino Observatory, specifically on dealing with noise in sDOMS.

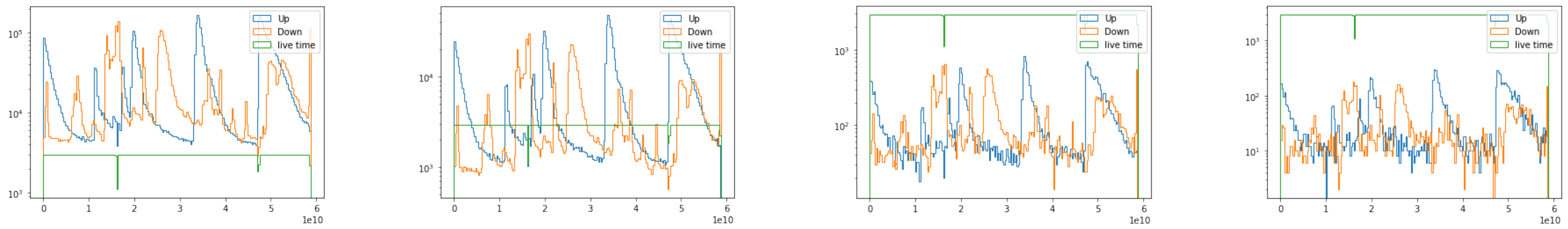
You can see various notebook files at https://github.com/Ham0osh/HamishPONE/tree/master/notebooks-%26-data.
Or contact me at: hamish_johnson@sfu.ca.

Contents

2 My Work

2.1 First Data Set

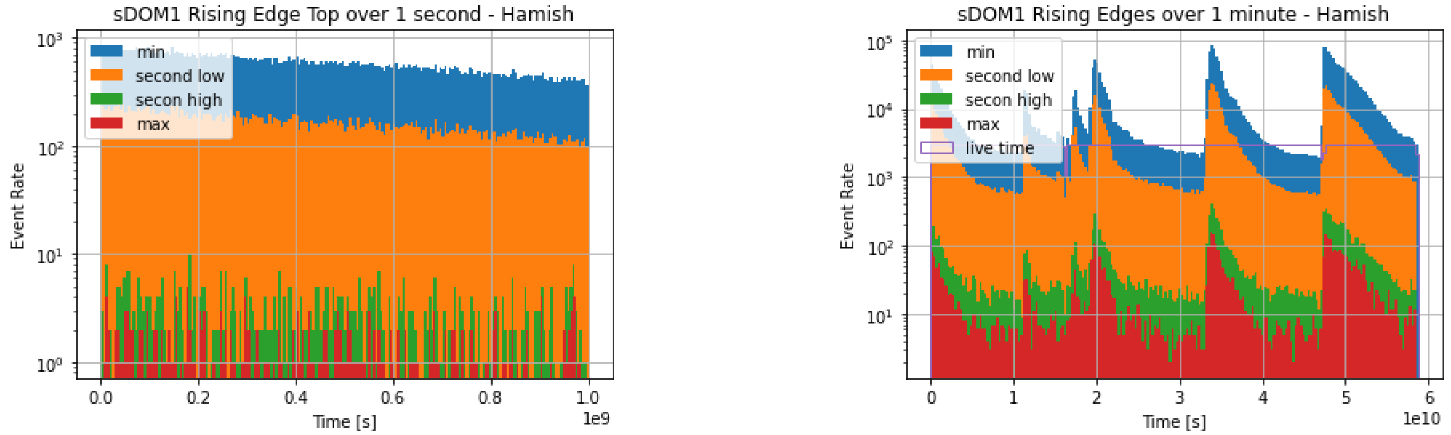
I started looking at the data file Matthew gave me by viewing the different threshold. This gave me a chance to better understand what the data points meant, some quirks of the measurements (downtime), and how to handle the file. *The horizontal is time [ns] and the vertical is number of events.*



(a) Low Threshold (b) Second Low Threshold (c) Second High Threshold (d) High Threshold

Figure 2: Trying different thresholds

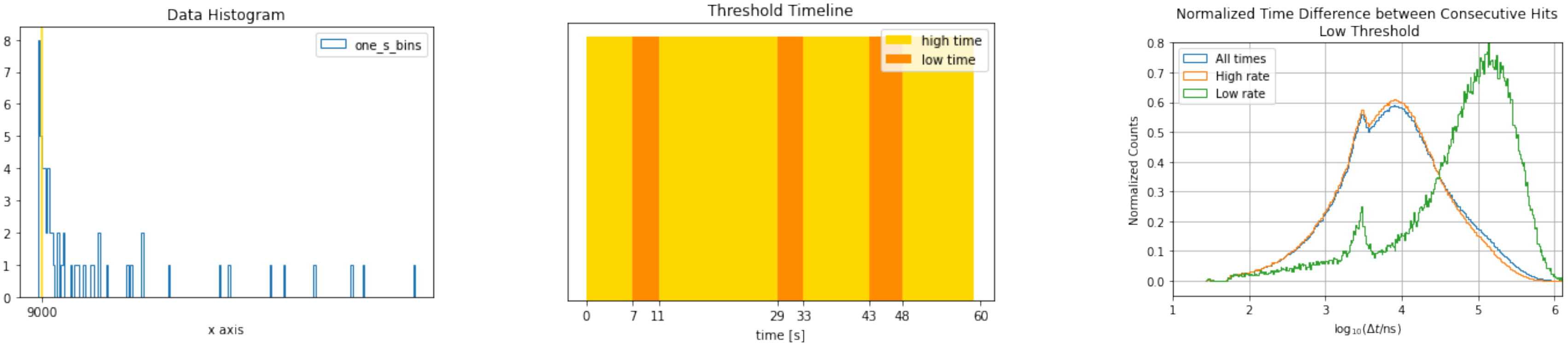
From here I wanted to see all of the events reaching each threshold together over one second to see small variations as well as the full one minute to see the spikes.



(a) One Second (b) One Minute

Figure 3: Rising edge hits coloured by threshold

From here I needed to re-create the time differences between consecutive hits on my way to looking at coincidences. I started by reading though and rewriting the code to produce *fig 4.c*. Because data was being sorted into high times and low times I made *fig 4.b* which is just another way of seeing when "min" (blue) in *fig 3.b* passes above the threshold. I went to do this again for the highest threshold (for understanding), I first needed to understand how the 'high time - low time' threshold was set, leading to *fig 4.a* showing the threshold cutting out the bulk of the data.

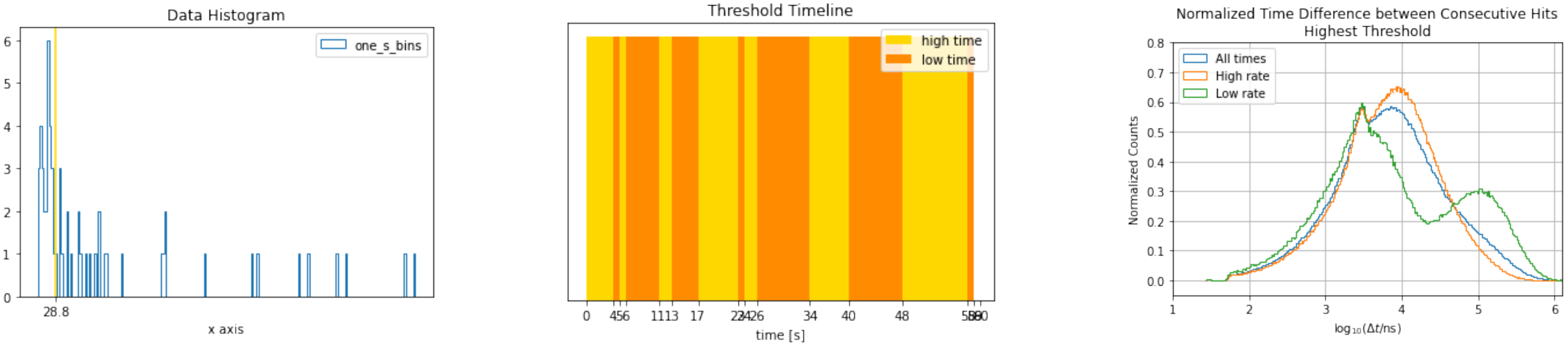


(a) Low Threshold Cut

(b) One Minute

(c) Normalized Consecutive hits

Figure 4: Low threshold hits with cut



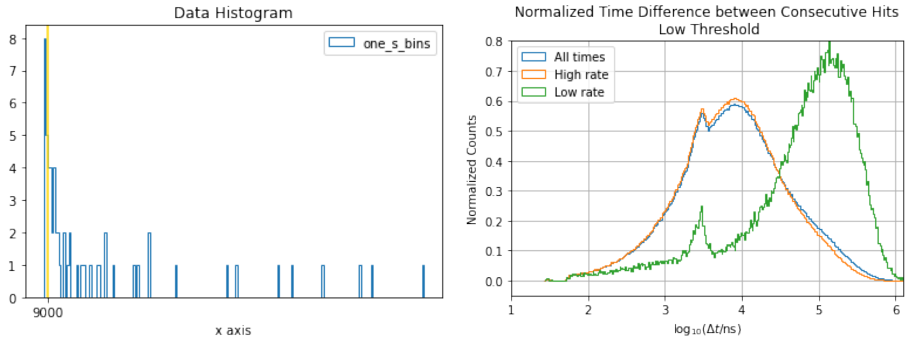
(a) High Threshold Cut

(b) One Minute

(c) Normalized Consecutive hits

Figure 5: High threshold hits with cut

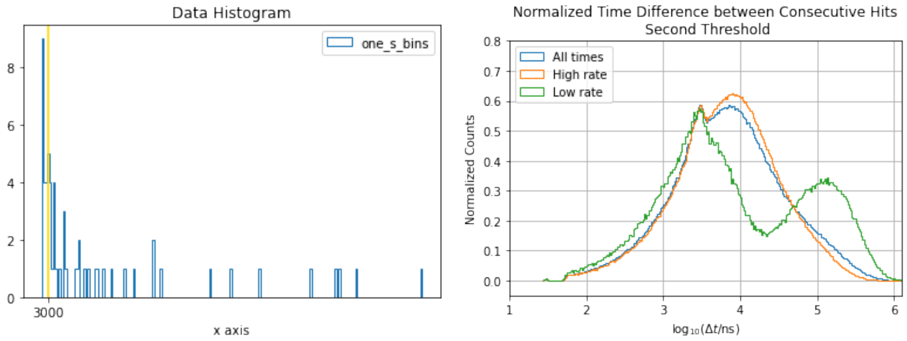
Here is a comparison of all four thresholds to how the features change.



(a) Threshold Cut

(b) Time Difference

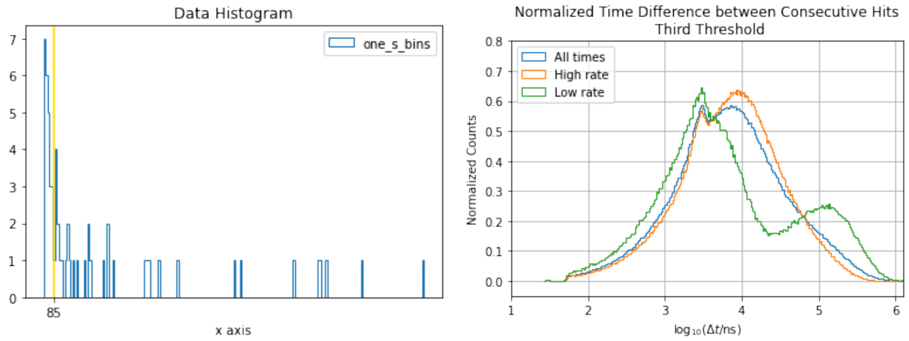
Figure 6: First Threshold



(a) Threshold Cut

(b) Time Difference

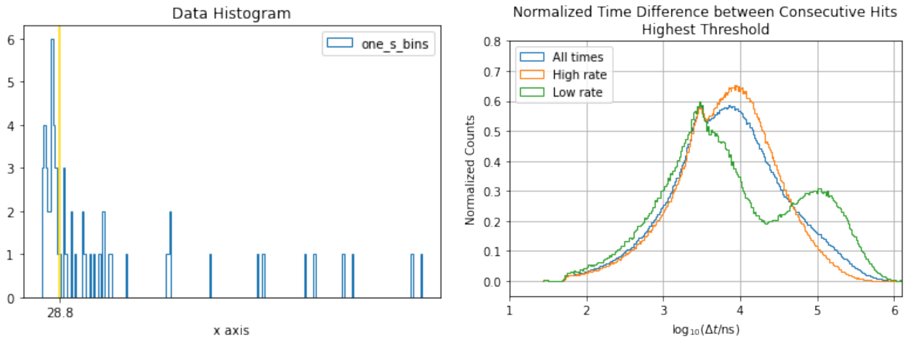
Figure 7: Second Threshold



(a) Threshold Cut

(b) Time Difference

Figure 8: Third Threshold



(a) Threshold Cut

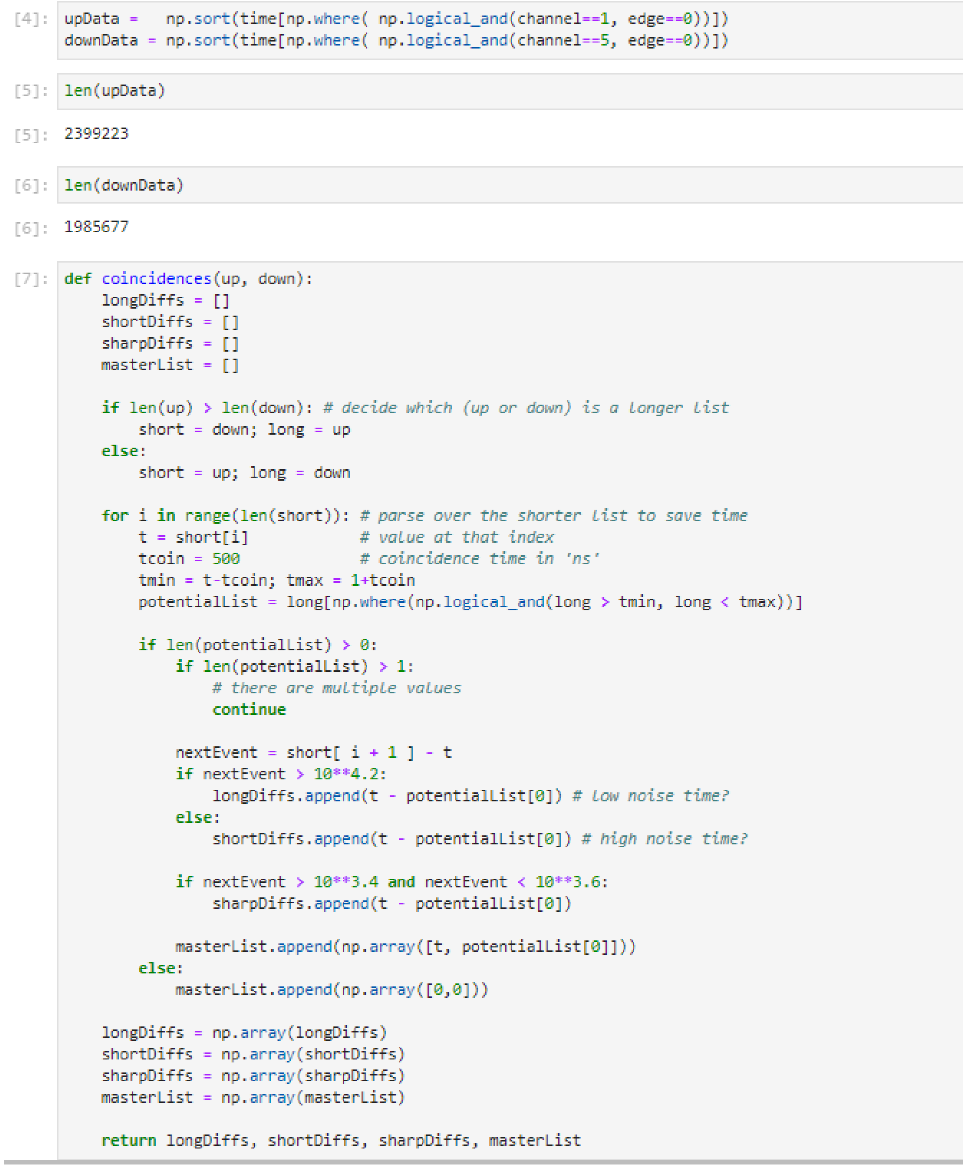
(b) Time Difference

Figure 9: Fourth Threshold

There is a possibility that the cut off threshold between high and low rates needs to be adjusted, but assuming they are close enough we can see some changes and the thresholds get higher. Namely the long time noise seems to drop drastically, and the hits in low rate increase by the sharp zone to meet (overpass in threshold 3) the high rate hits.

I suspect this has more to do with my placement of the cut off value than the four thresholds themselves. I ran the last three thresholds again with more strict cut offs, however this caused the amount of low rate hits around and before the spike to increase again.

Now I am understanding the code to look for coincidences which I have only run once as it takes about 3 hours (down from 18 by reinstalling python through miniconda). Here is the code (typo when defining tmax as 1+tcoin instead of t+tcoin. I am now running this fix with half of the data set.



```
[4]: upData =   np.sort(time[np.where( np.logical_and(channel==1, edge==0))])
     downData = np.sort(time[np.where( np.logical_and(channel==5, edge==0))])
```

```
[5]: len(upData)
```

```
[5]: 2399223
```

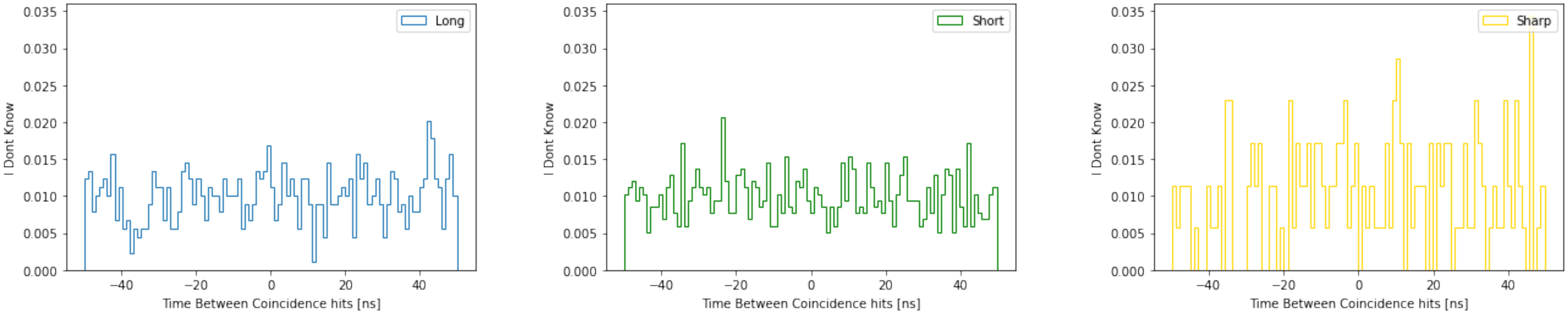
```
[6]: len(downData)
```

```
[6]: 1985677
```

```
[7]: def coincidences(up, down):
         longDiffs = []
         shortDiffs = []
         sharpDiffs = []
         masterList = []

         if len(up) > len(down): # decide which (up or down) is a longer list
             short = down; long = up
         else:
             short = up; long = down

         for i in range(len(short)): # parse over the shorter list to save time
             t = short[i]            # value at that index
             tcoin = 500             # coincidence time in 'ns'
             tmin = t-tcoin; tmax = 1+tcoin
             potentialList = long[np.where(np.logical_and(long > tmin, long < tmax))]

             if len(potentialList) > 0:
                 if len(potentialList) > 1:
                     # there are multiple values
                     continue

                 nextEvent = short[ i + 1 ] - t
                 if nextEvent > 10**4.2:
                     longDiffs.append(t - potentialList[0]) # low noise time?
                 else:
                     shortDiffs.append(t - potentialList[0]) # high noise time?

                 if nextEvent > 10**3.4 and nextEvent < 10**3.6:
                     sharpDiffs.append(t - potentialList[0])

                 masterList.append(np.array([t, potentialList[0]]))
             else:
                 masterList.append(np.array([0,0]))

         longDiffs = np.array(longDiffs)
         shortDiffs = np.array(shortDiffs)
         sharpDiffs = np.array(sharpDiffs)
         masterList = np.array(masterList)

         return longDiffs, shortDiffs, sharpDiffs, masterList
```

Figure 10: Code with error

Here I started visualizing the coincidence data with tcoin as 50 [ns] on a smaller data set. You can see three plots of the different categories all set to the same y-axis (of which I don't yet understand the units). After which you can see the same but run on with full data set with tcoin = 25 [ns].

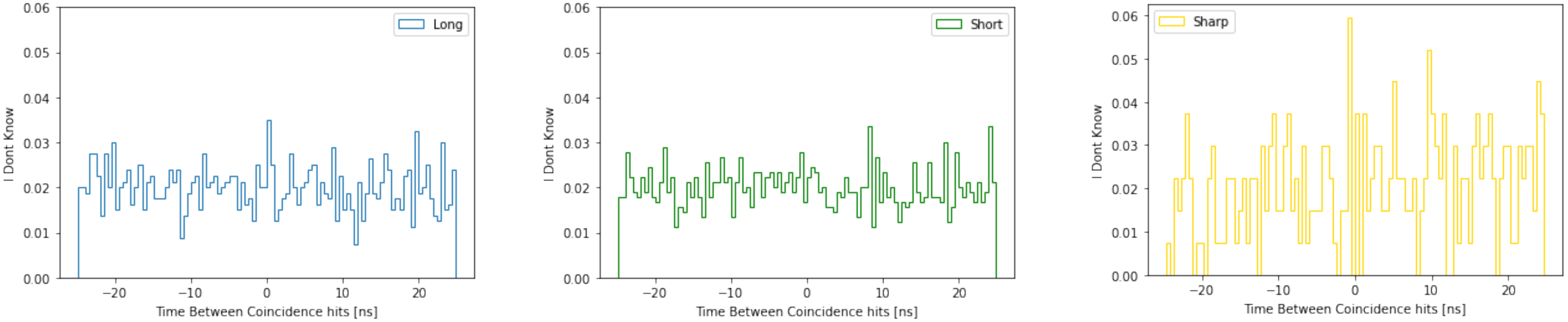


(a) Long (Long Time)

(b) Short (Short Time)

(c) Sharp (Time in spike)

Figure 11: Time between coincidental hits Short Set



(a) Long (Long Time)

(b) Short (Short Time)

(c) Sharp (In the spike)

Figure 12: Time between coincidental hits Full Set

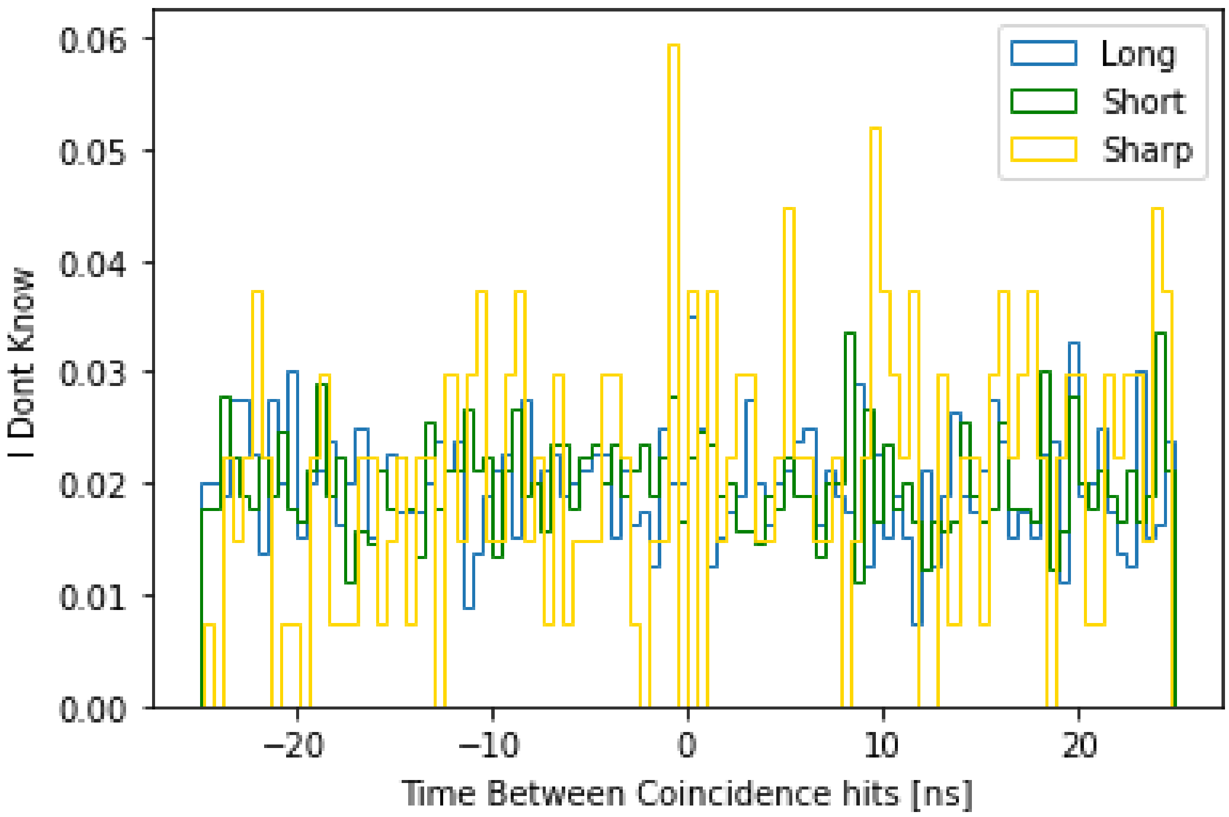


Figure 13: All sets from the full file

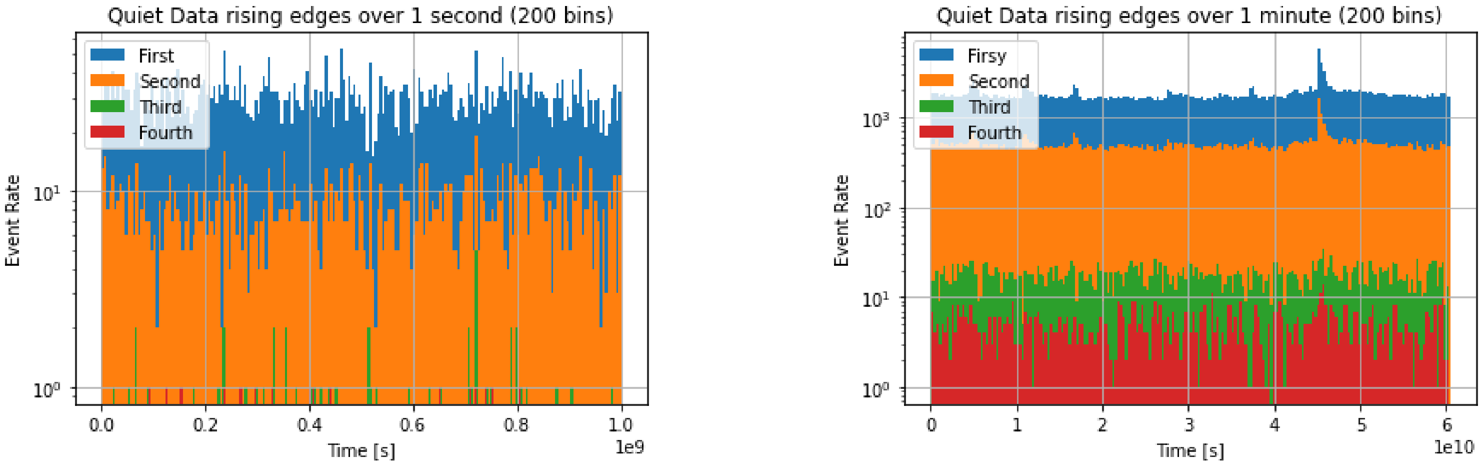
2.2 Quiet K40 Data Set

2.2.1 Instructions & Starting out

In this section we are dealing with a quieter data file to more easily notice the effects of K40. I will be doing the following analysis on all 4 thresholds again, but I am starting with the lowest threshold until I know it is working.

1. Bin the entire minute of data into bins of ms length (instead of s length)
2. Once you've done this, partition the run into ms that have between 1-20 hits and others (This is the hard step where you'll have to do the most thinking)
3. Using only these times make the 'time difference between consecutive hits' plots that you have already made for the other data file (Figure 4c and 5c). Since you already chose 'low' noise times in step 2 you will only be making the green curve, you could make the other two curves (orange and blue) by just looking at the time difference for all the data (blue) or by only taking the times that were filtered out in step 2 and not the ones you kept.
4. Do steps 2&3 for all thresholds, it would be interesting to see both the plots when you partition the threshold you are analyzing (ie take channel 2, take times between 1-20 hits ON CHANNEL 2 and then make plots) and the plots when you partition the threshold you are analyzing with the times from the lowest threshold (ie take channel 2 and use the times where there are between 1-20 hits per ms ON CHANNEL 1 and make the plots from those times)

Just to contrast with the data set, here is how the new is displayed the same way as *fig 3*.



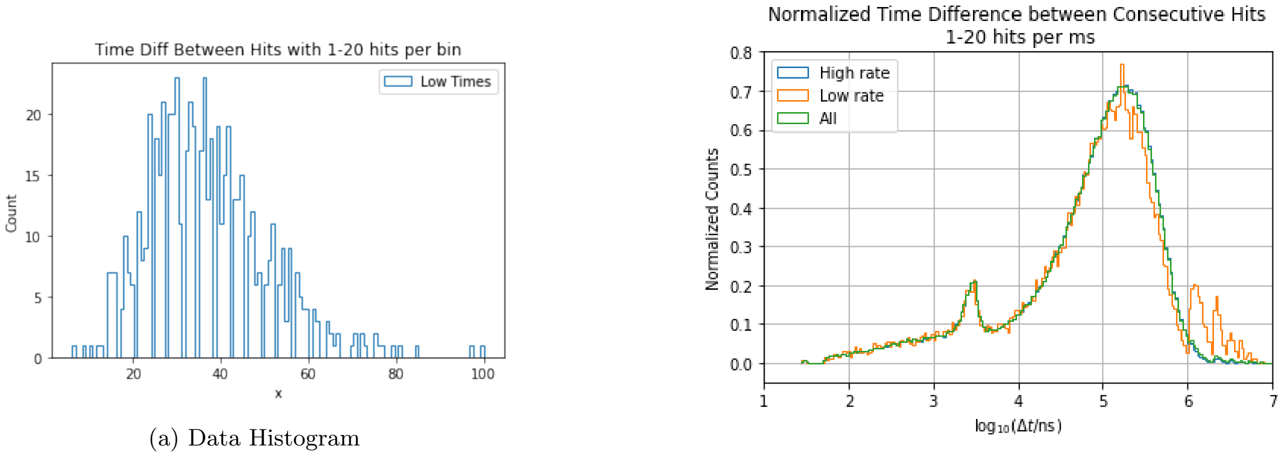
(a) One Second

(b) One Minute

Figure 14: Rising edge hits coloured by threshold - Quiet

2.2.2 Figuring it out

At first I ran my code with larger bins than 1 per ms so save on time, however I did not properly record my process. And only set up with git after I had changed my code. I believe it was run on a much smaller sample of the data file (between 10% and 50%). and I am working on re-creating it.

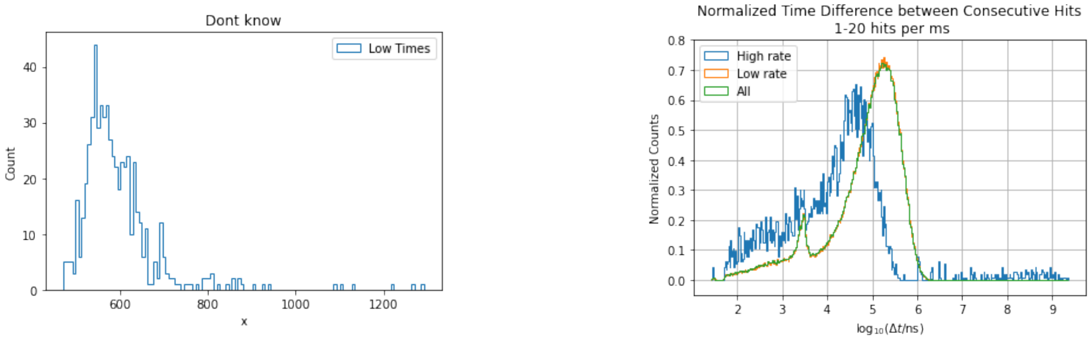


(a) Data Histogram

(b) Time Difference

Figure 15: Low threshold partitioned data - **Few Bins**

The high rate and all rates match up very precisely indicating very little data is in low rate compared to high rate, and this time you can see how the Low rate deviates in time differences over 6 seconds. After 16 hours I ran the algorithm binning per 1 ms and it gave either vastly different or incorrect results as shown below.



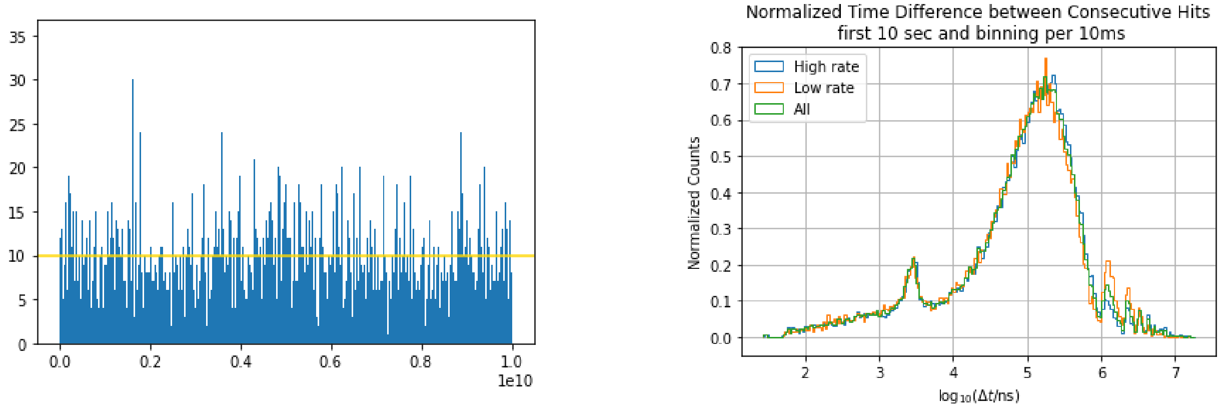
(a) Data Histogram

(b) Time Difference

Figure 16: Low threshold partitioned data - **1 ms Bins** and **10 hit/bin** cutoff

Most of the differences between fig 15.b and fig 16.b may come from the fact that I accidentally set low rate as 1-10 hits per bin for fig 15 and made it the correct 1-20 hits for fig 16. For this reason fig 15 may not have much significance.

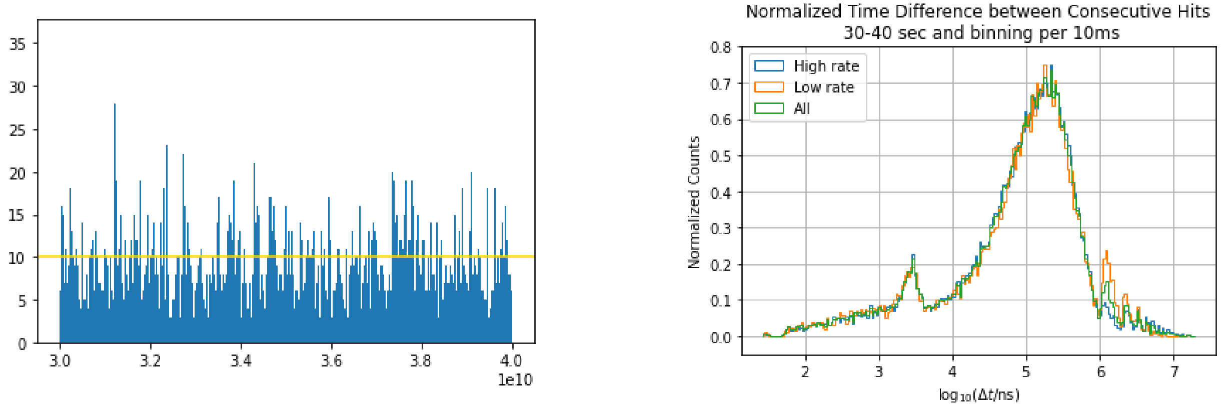
I ran another copy of the notebook to re-create the larger bin file. It originally ran with larger bins as well as only a section of the data. I ran it again with large bins for 10 second sections from 0-10 sec and 3-4 sec. They both showed the saw-tooth pattern indicating it persists through the file. Either due to a smaller sample size or larger bins. **Correction: bin per 1.666 ms.**



(a) Bin Histogram with 10 hits/bin cut off

(b) Time Difference

Figure 17: Partitioned **first 10 seconds** *binning per 10 ms*

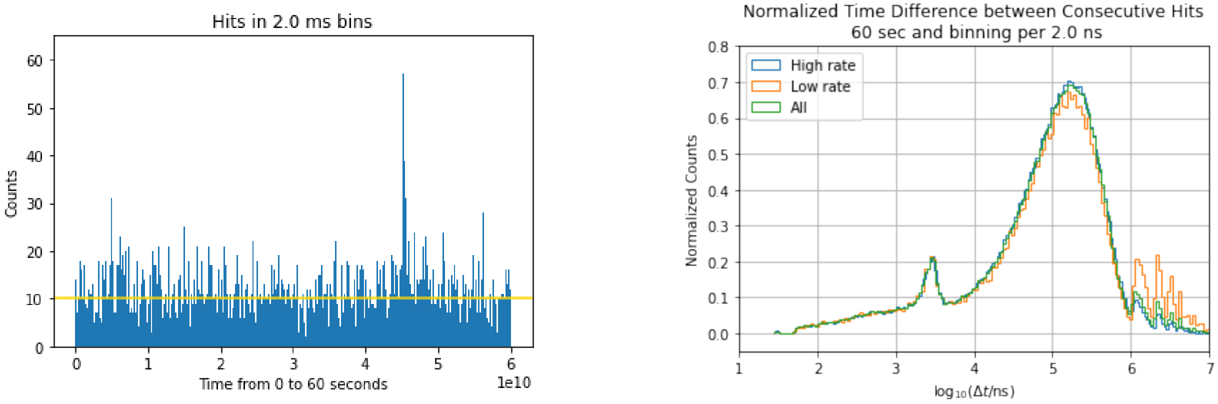


(a) Bin Histogram with 10 hits/bin cut off

(b) Time Difference

Figure 18: Partitioned **fourth 10 seconds** *binning per 10 ms*

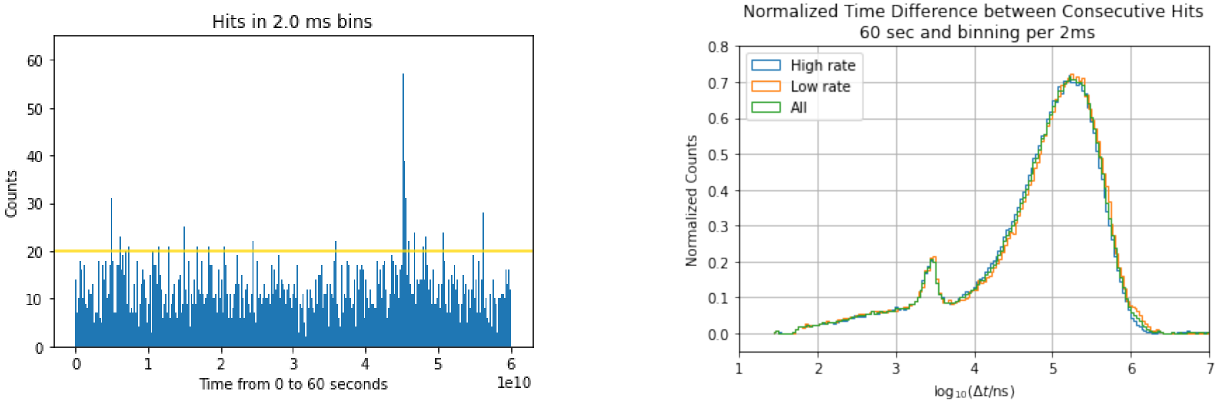
I ran it again with the entire 60 seconds, bins per 2ms and partitioned at 10 hits per bin giving the same over all shape in *fig 19* and the again with the cut off at 20 hits per bin in *fig 20*. You can see how the saw-tooth pattern has to do more within the noise.



(a) Bin Histogram with 10 hits/bin cut off

(b) Time Difference

Figure 19: Partitioned **full 60 sec** *binning per 2 ms* **- 10 hit** partition



(a) Bin Histogram with 20 hits/bin cut off

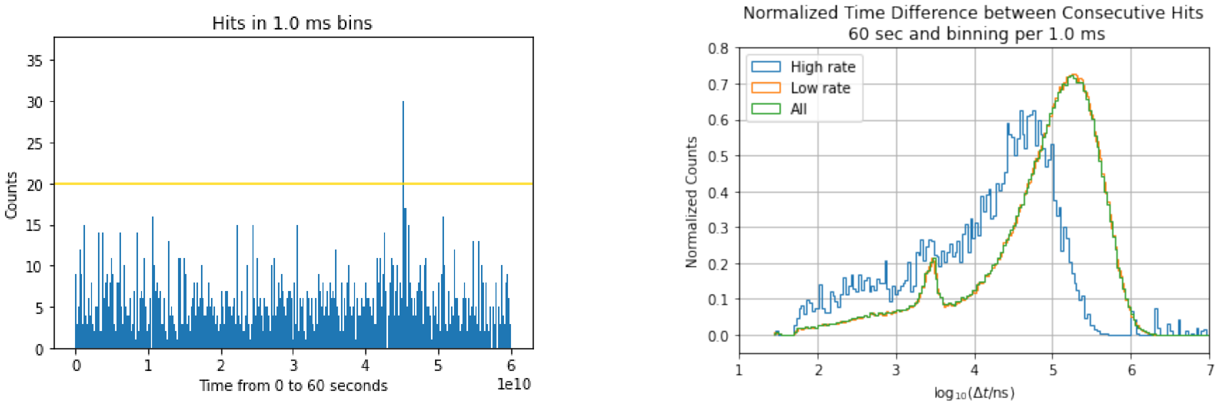
(b) Time Difference

Figure 20: Partitioned **full 60 sec** *binning per 2 ms* **- 20 hit** partition

2.2.3 1st Threshold - Time Differences

First Threshold

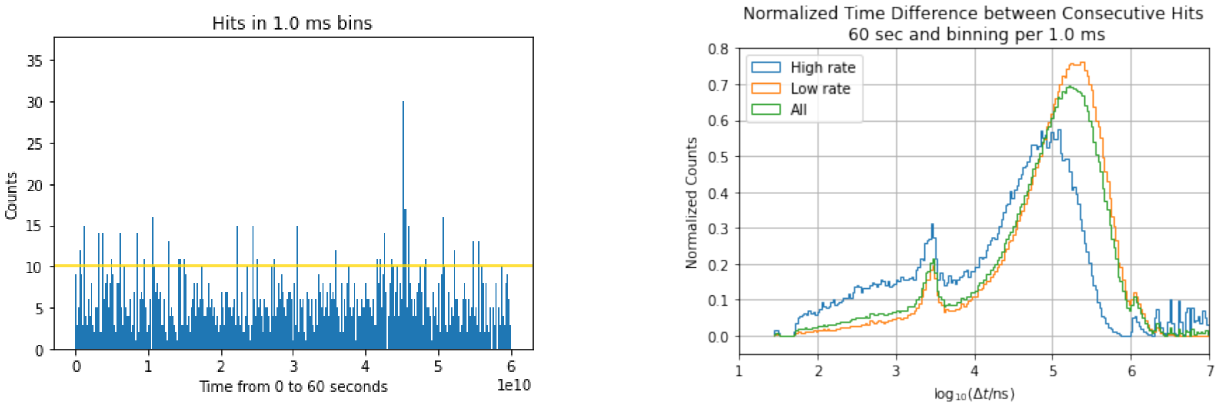
Now we have 1 ms bins with a 10 hit cutoff over the fill one minute, followed by 1 ms bins with a 20 hit cut off over the full one minute



(a) Bin Histogram with 20 hits/bin cut off

(b) Time Difference

Figure 21: Partitioned **full 60 sec** *binning per 1 ms* - **20 hit** partition - 1st Threshold



(a) Bin Histogram with 10 hits/bin cut off

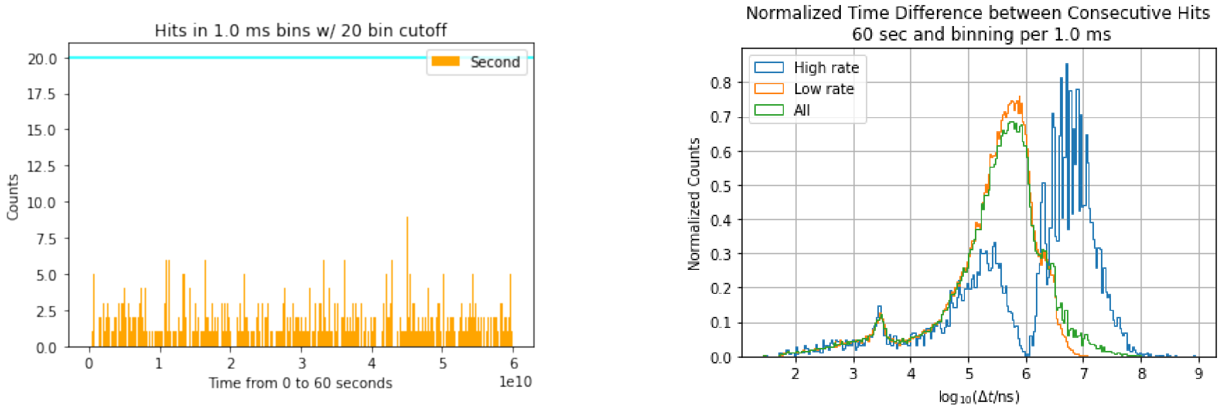
(b) Time Difference

Figure 22: Partitioned **full 60 sec** *binning per 1 ms* - **10 hit** partition - 1st Threshold

2.2.4 2nd Threshold - Time Differences

Second Threshold

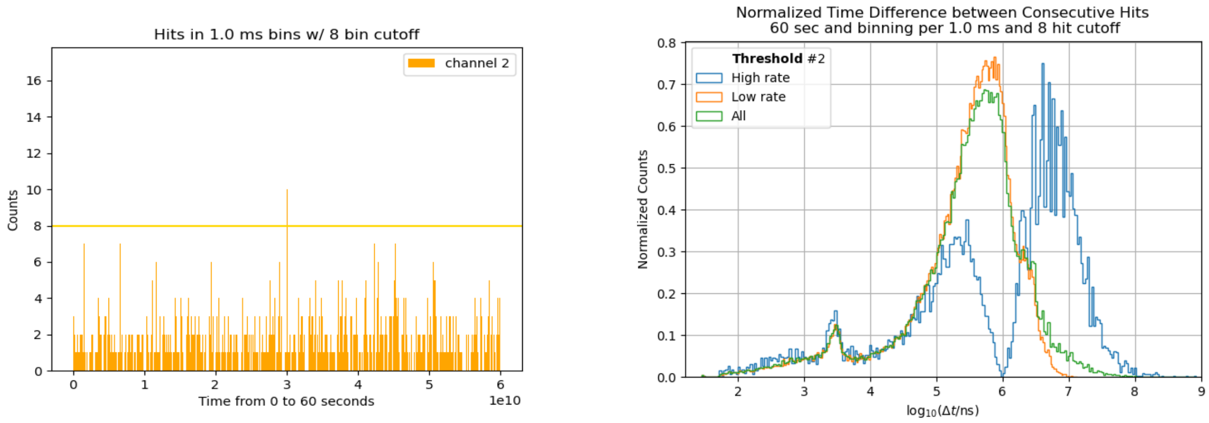
None of the bins had more than 20 hits so I don't know why this gave the data it did. I ran it again with a cut of 8 hits/bin.



(a) Bin Histogram with 20 hits/bin cut off

(b) Time Difference

Figure 23: Partitioned **full 60 sec** *binning per 1 ms* - **20 hit** partition - 2nd Threshold



(a) Bin Histogram with 8 hits/bin cut off

(b) Time Difference

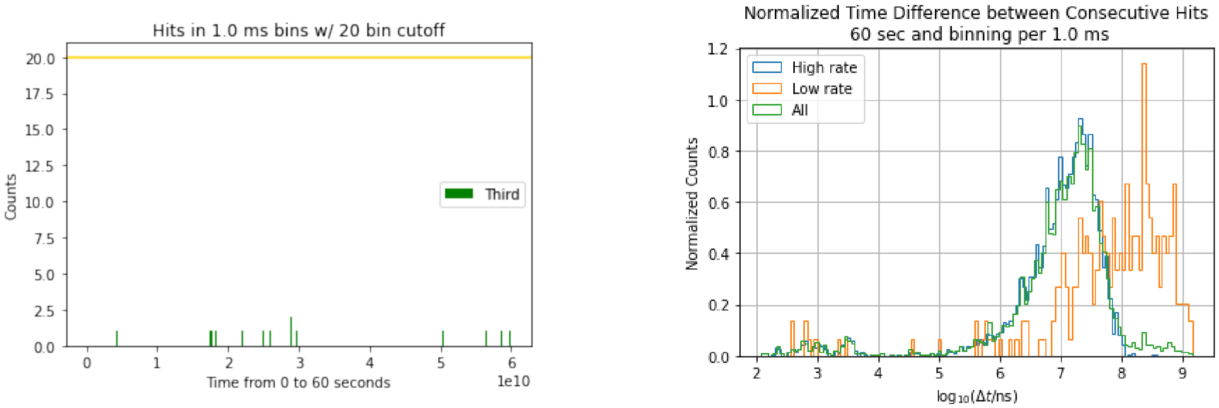
Figure 24: Partitioned **full 60 sec** *binning per 1 ms* - **8 hit** partition - 2nd Threshold

You can see that the histogram changes shape, this is due to using %matplotlib inline instead of %matplotlib nbagg. Otherwise, when you ignore empty bins you can see how the high rate changes (as it no longer includes empty bins).

2.2.5 3rd Threshold - Time Differences

Third Threshold

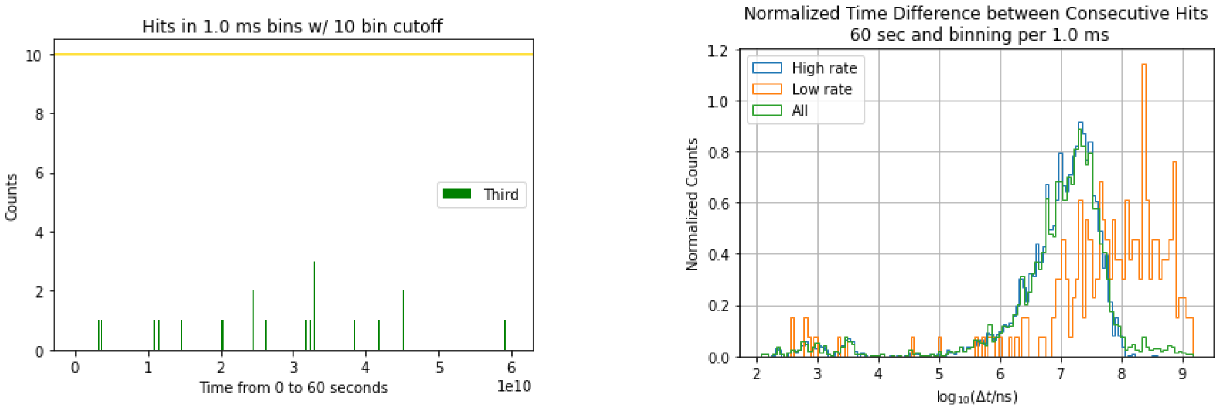
Changing the cut off had little effect to the time difference plot.



(a) Bin Histogram with 20 hits/bin cut off

(b) Time Difference

Figure 25: Partitioned **full 60 sec** *binning per 1 ms* - **20 hit** partition - 3rd Threshold



(a) Bin Histogram with 20 hits/bin cut off

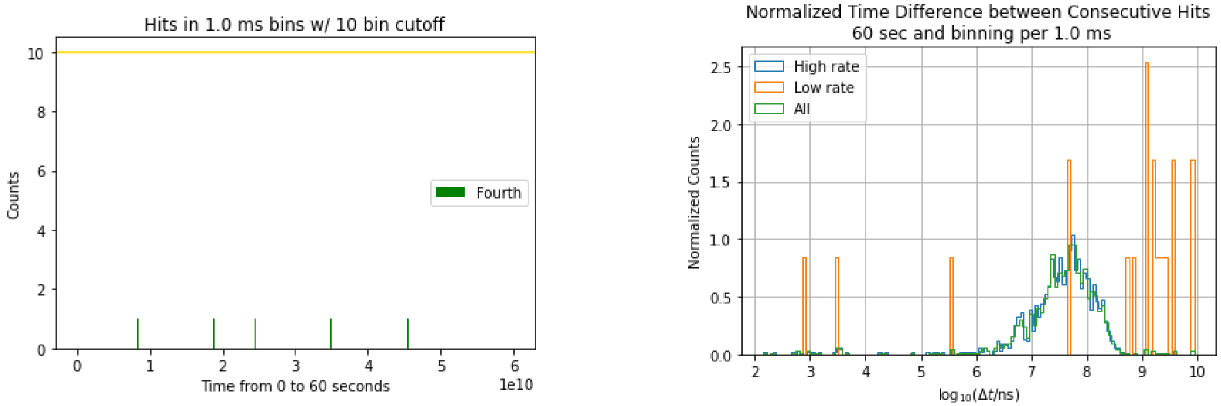
(b) Time Difference

Figure 26: Partitioned **full 60 sec** *binning per 1 ms* - **20 hit** partition - 3rd Threshold

2.2.6 4th Threshold - Time Differences

Fourth Threshold

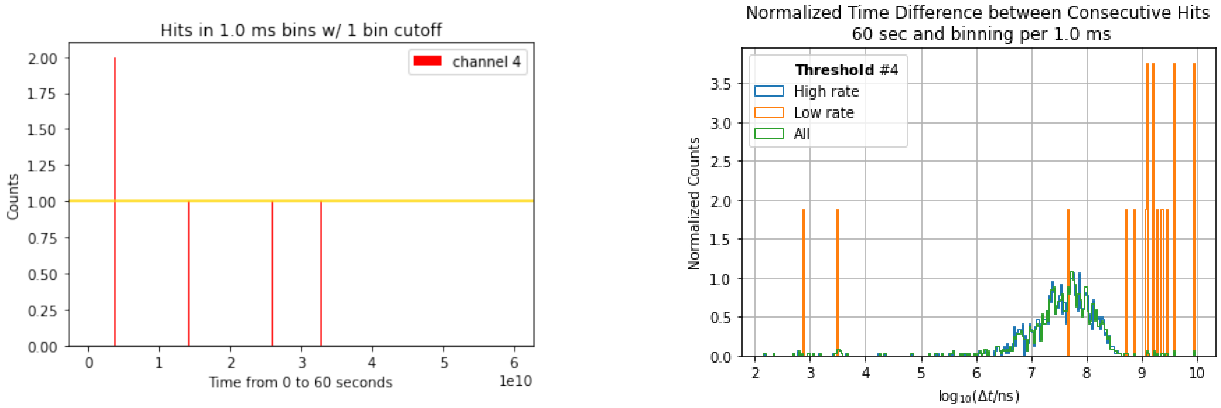
The fourth threshold does not appear to give anything meaningful as High Rate is not significantly different from All. All bins are either within Low or empty.



(a) Bin Histogram with 20 hits/bin cut off

(b) Time Difference

Figure 27: Partitioned **full 60 sec** *binning per 1 ms* - **20 hit** partition - 4th Threshold



(a) Bin Histogram with 1 hit/bin cut off

(b) Time Difference

Figure 28: Partitioned **full 60 sec** *binning per 1 ms* - **1 hit** partition - 4th Threshold

I also ran the code with 2, 3, 6, & 10 ms bins with no meaningful change other than making the Time Difference plot harder to read.

2.2.7 All Time Differences

All thresholds - time difference

With a horizontal range between 1.2 and 9 seconds.

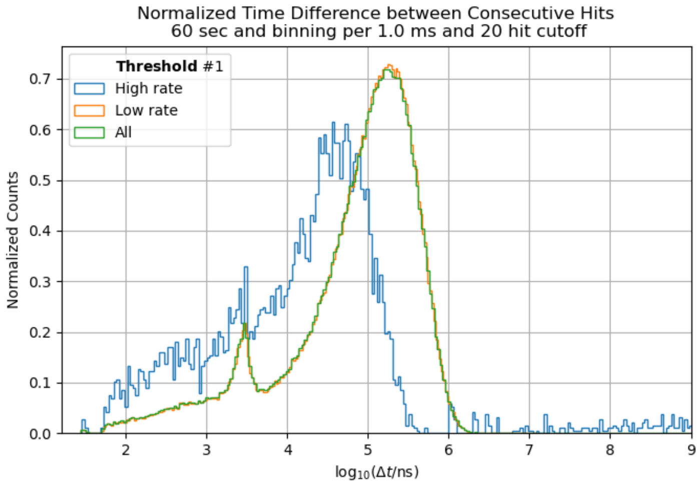


Figure 29: **First Threshold** 1ms bins 20 hit cutoff

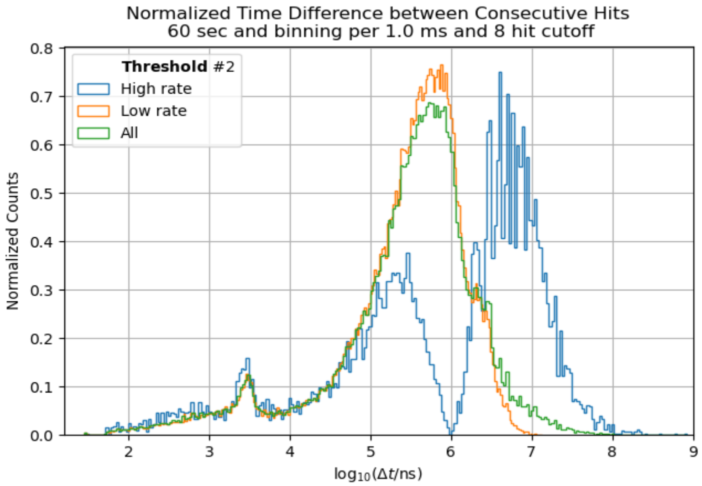


Figure 30: **Second Threshold** 1ms bins 20 hit cutoff

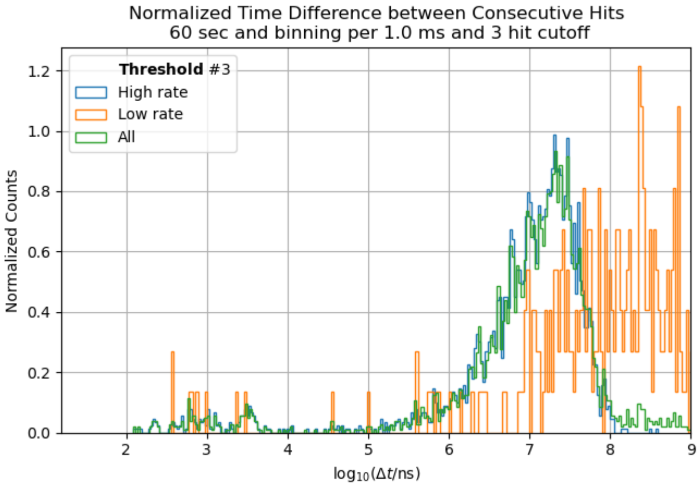


Figure 31: **Third Threshold** 1ms bins 3 hit cutoff

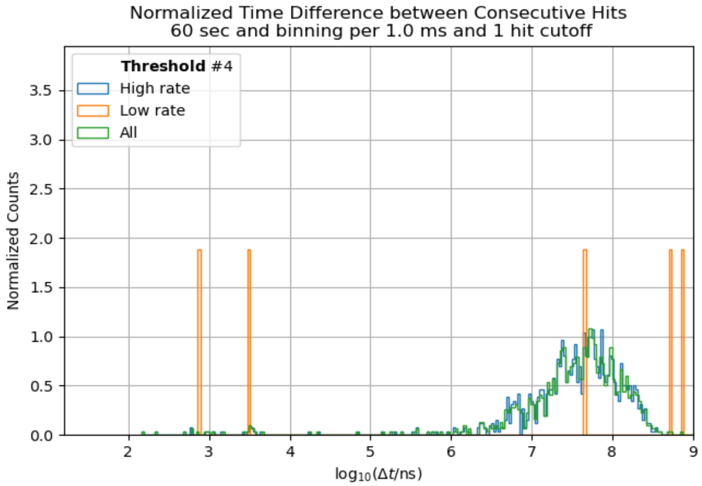


Figure 32: **Fourth Threshold** 1ms bins 1 hit cutoff

All thresholds - high/low times

Looking at times in high/low partitions over time.

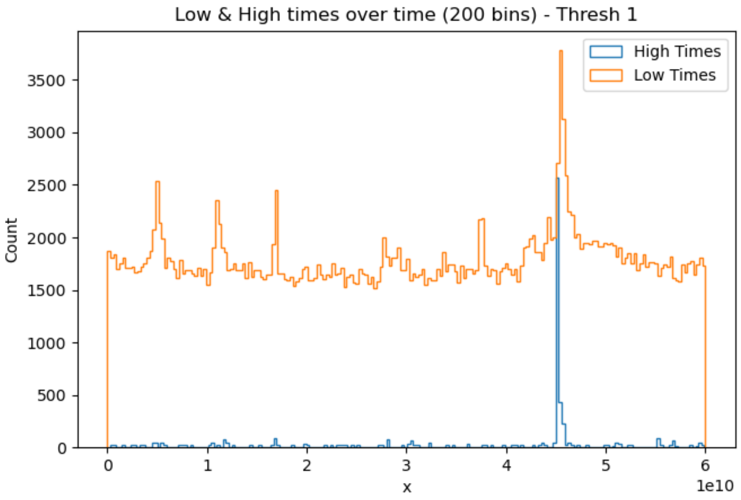


Figure 33: **First Threshold** 1ms bins 20 hit cutoff

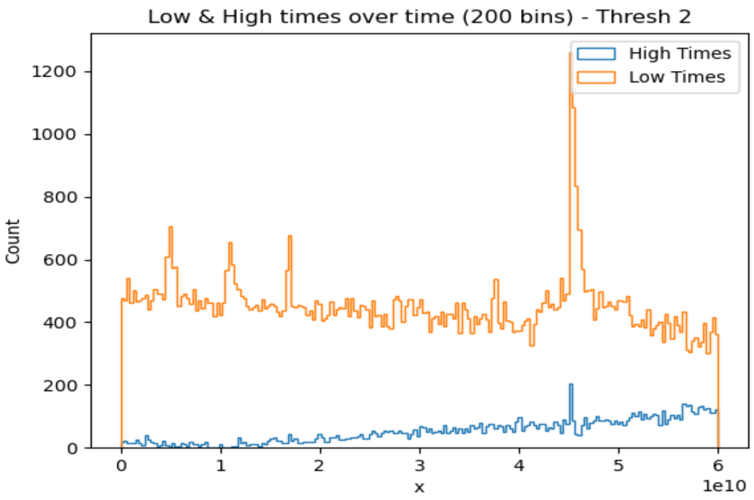


Figure 34: **Second Threshold** 1ms bins 8 hit cutoff

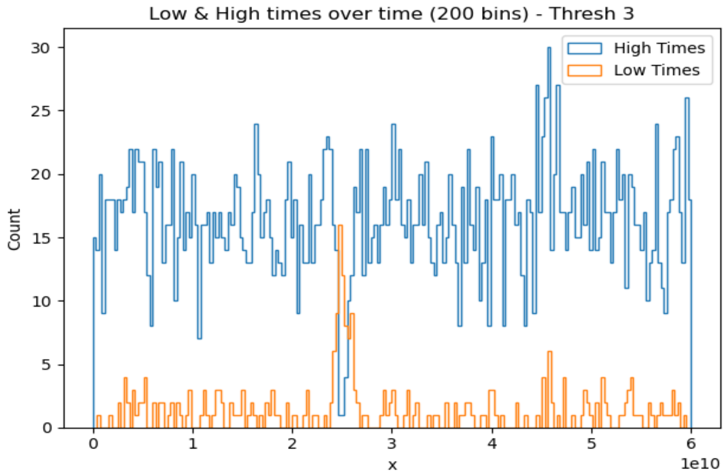


Figure 35: **Third Threshold** 1ms bins 3 hit cutoff

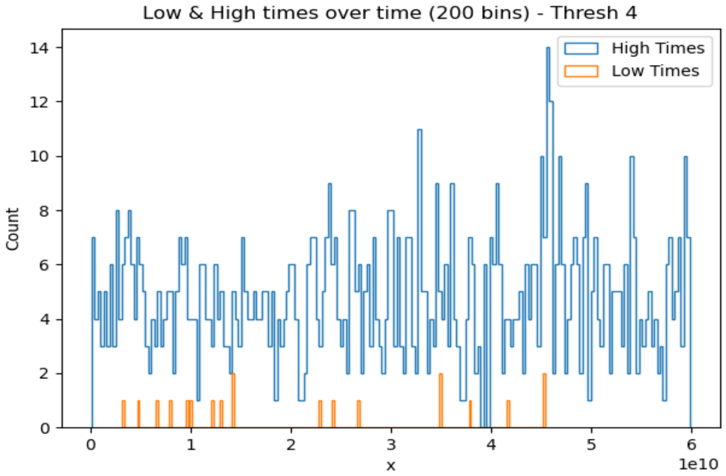


Figure 36: **Fourth Threshold** 1ms bins 1 hit cutoff

Observations

- Threshold 2 took much longer to run because lowTimeRanges was much larger than in the first threshold. This tells us for the second threshold, the times where bins have between 1-20 hits are more fractured leading to more sliced time ranges. This is not too surprising considering there are over all fewer hits.
- I could fix they vertical axis, however this could come at the expense of compressing the readability of the first threshold or two for some data with few points (4th threshold).
- It appears in threshold 2 we see more hits per bin as time goes on but not in the other 3 bins.
- Threshold 3 has no 3ms bins with more than 3 hits.
- Threshold 3 has no 1ms bins with more than 5 hits.
  - Because of this I used a cut off of 3 hits at 1ms bins.
- The fourth threshold had so little data that cutting at 2 vs 20 hits made no difference, no 1ms bins had above 2 hits so I ran it again with a 1 hit cut off. I don't think this data is useful anyways.

2.2.8 All hits on first threshold time ranges

Here we are running the same analysis as above except using the low and high time ranges from the first threshold on all of the rest.

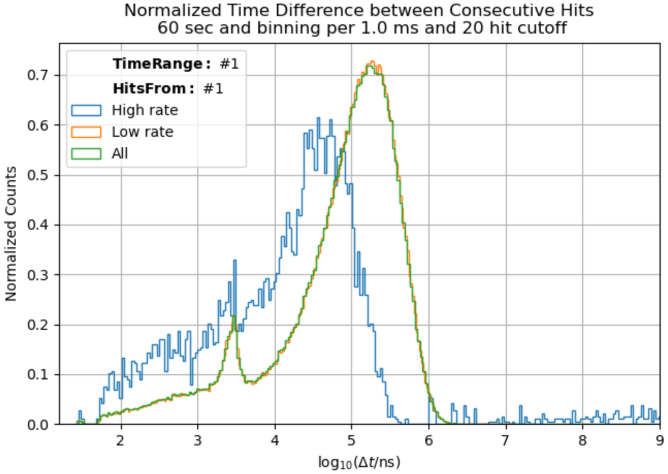


Figure 37: **First Threshold** with first threshold rates

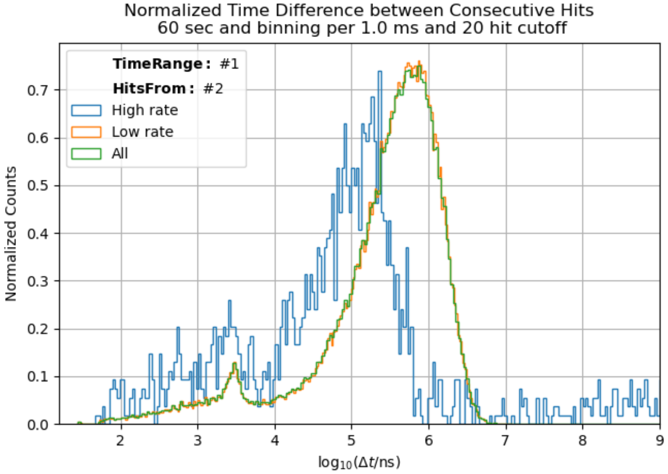


Figure 38: **Second Threshold** with first threshold rates

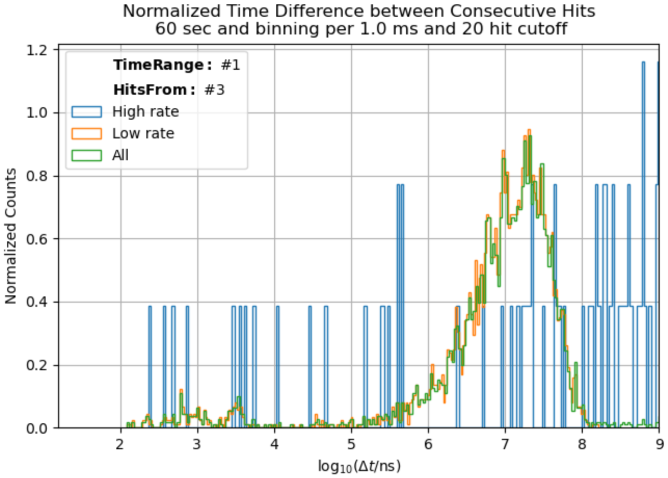


Figure 39: **Third Threshold** with first threshold rates

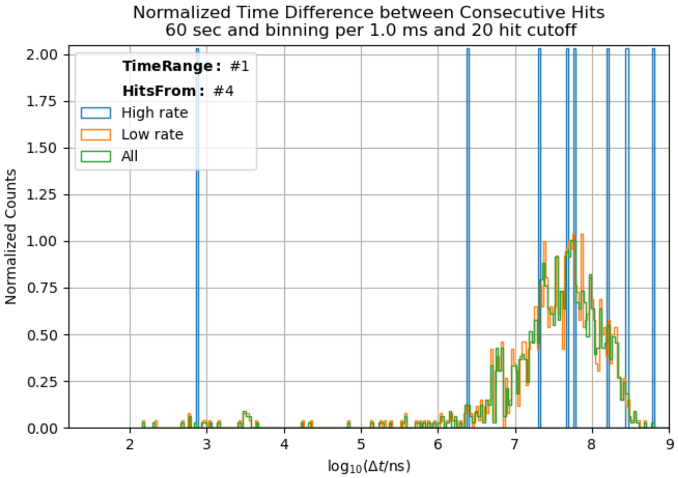


Figure 40: **Fourth Threshold** with first threshold rates

Observations

- As thresholds increase, the larger distribution shifts to longer time differences. This makes sense as there are fewer hits with each threshold and therefore more time between them).
- The spike between 3 and 4 seconds decreases in relative intensity however it does not move from 3.5 seconds.
- You can see the saw tooth pattern after 6 seconds but it is most visible with a 10 hit/ms partition.
  - I am looking at this now in 'K40 - Difference Plot - looking into sawtooth.ipynb'

3 Questions

1. Why do we see the saw-tooth shape in Low rate after 6 seconds in Figure 15b?

2. Why do we see the dip at 6 seconds in Figure 29?

3. My current code is a set of bodged functions to sort the data based on the amount of hits in each bin and is pretty much the opposite of efficient.

   (a) Is my code doing what its meant to be doing?

   - Compare with working results.
   - Compare with working code.

   (b) Fix some of the unnecessarily memory intensive areas:

   - Squish down lowTimeRanges to turn this: '[0,1],[1,2],[4,5],[5,6]' into this: '[1,2],[4,6]'.
   - Once the code is working, break file into 15 second chunks so I can run it on multiple threads/kernels at once (will cut times but heat up my computer). Not necessary because code is more efficient!