Antimony experiment:
Overview and preliminary results

CRIS collaboration meeting 2025

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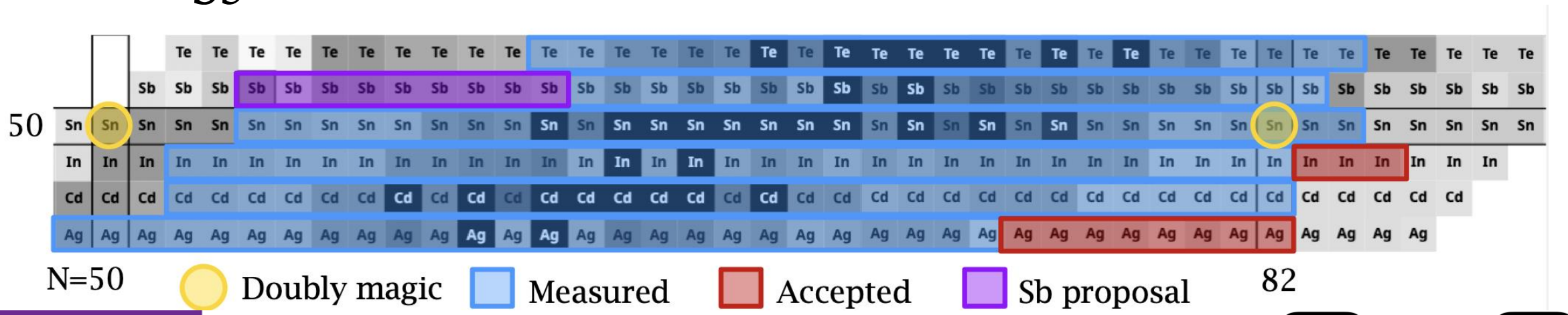
IS736 – August 2024

MANCHESTER 1824
The University of Manchester

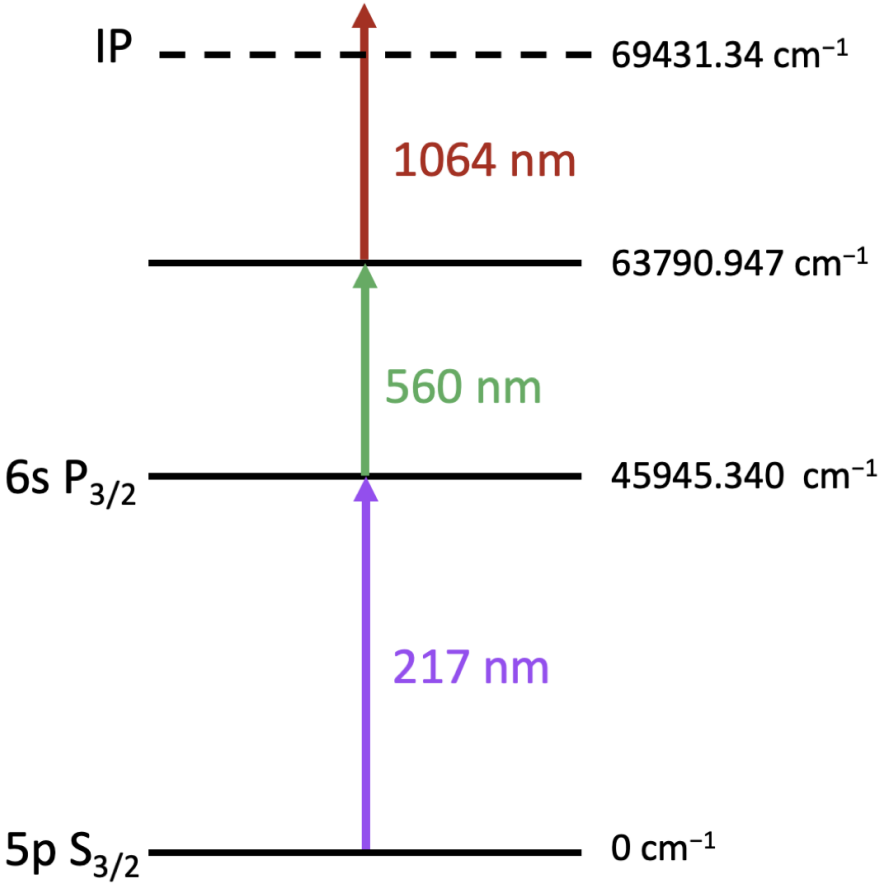
CRIS

Physics goals

- Sb (Z=51) lies one proton above the magic Sn, test for single-particle behaviour from shell-model predictions
- Previous measurements from COLLAPS studied the neutron-rich $^{112\text{-}134}$Sb



Experiment - Technical details



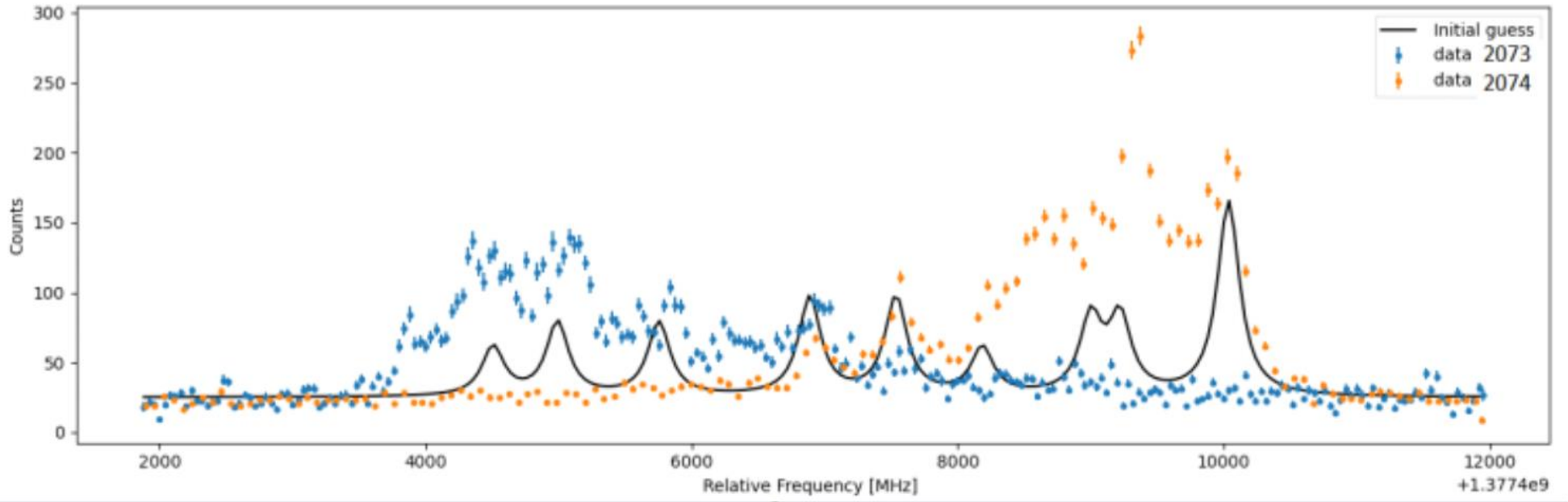
- Regular CRIS mode, set up with a 3 step laser scheme
- Quadrupled light
  - Intra-cavity doubled JyvIS, then externally doubled again
  - No observed problems when scanning
  - Did have to monitor during experiment if lock was lost
  - A strong transition, we were saturating with almost 150uW of first step power downstairs

Experiment - Technical details

- Voltage scanning did not work.
  - Spectra too wide ~8GHz for odd cases, started seeing stark shift
- Second step splitting was also wider than expected
- We originally set up with the cobra providing the 560 nm, during the experiment we had to set up the PDL to provide this

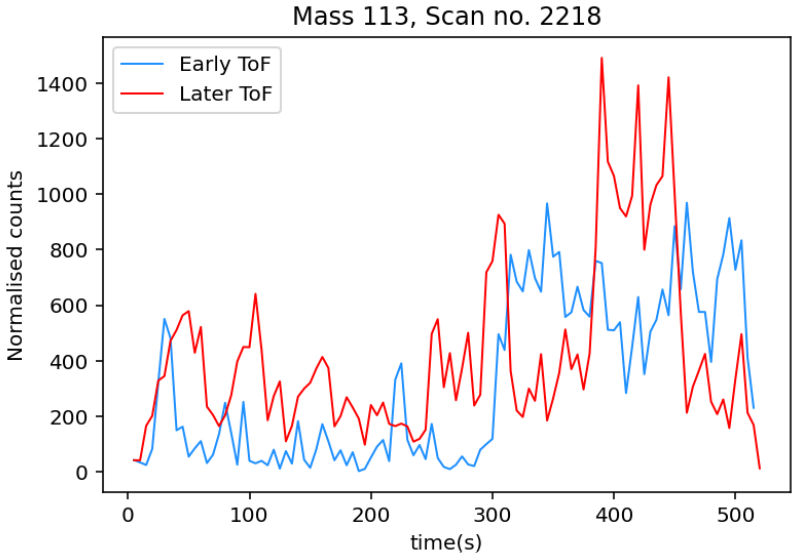
Experiment - Second step

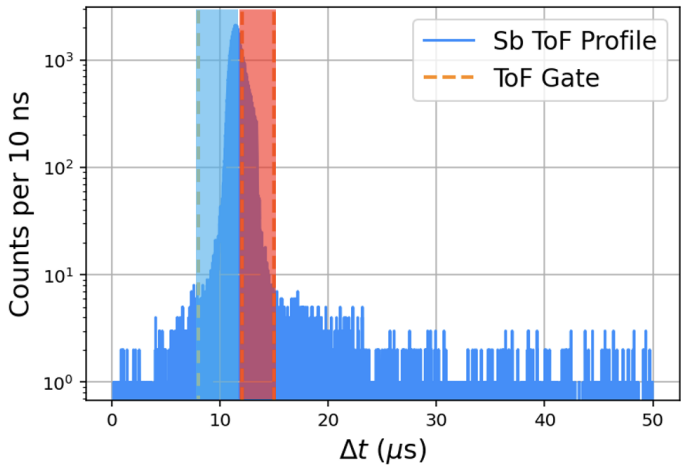
- These scans are with the cobra, before switching to PDL
- Two different wavelength setpoints. We probe different parts of the structure as the linewidth of the cobra (~3GHz) is smaller than the second step splitting
- Switching to the PDL ~8GHz eliminated this issue

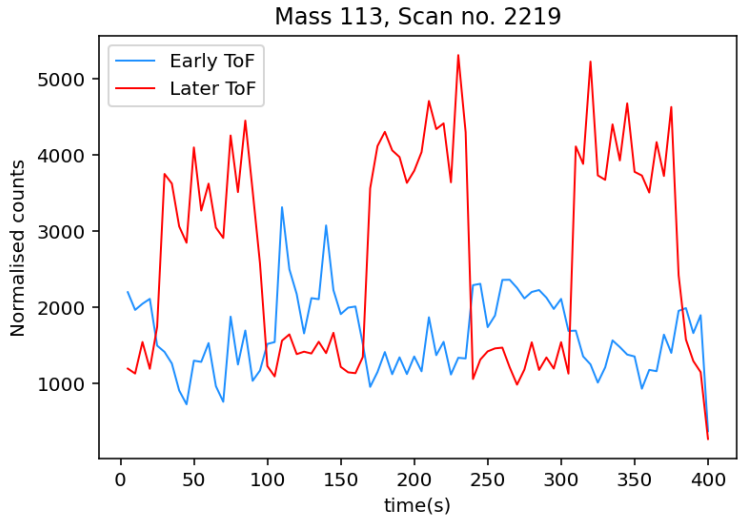


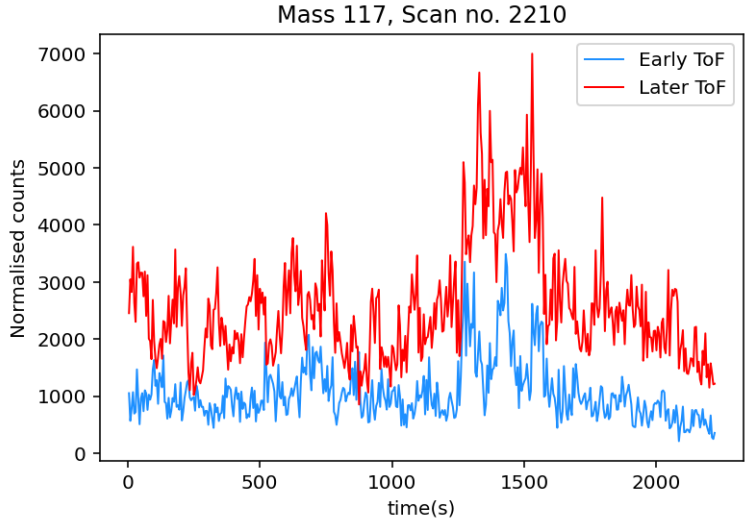
Experiment - Instabilities

- On/Off behaviour
- Dependent on ToF gating
- We all know since then some problems have been identified with ISCOOL
- CRIS have volunteered to help diagnose this in the coming running period

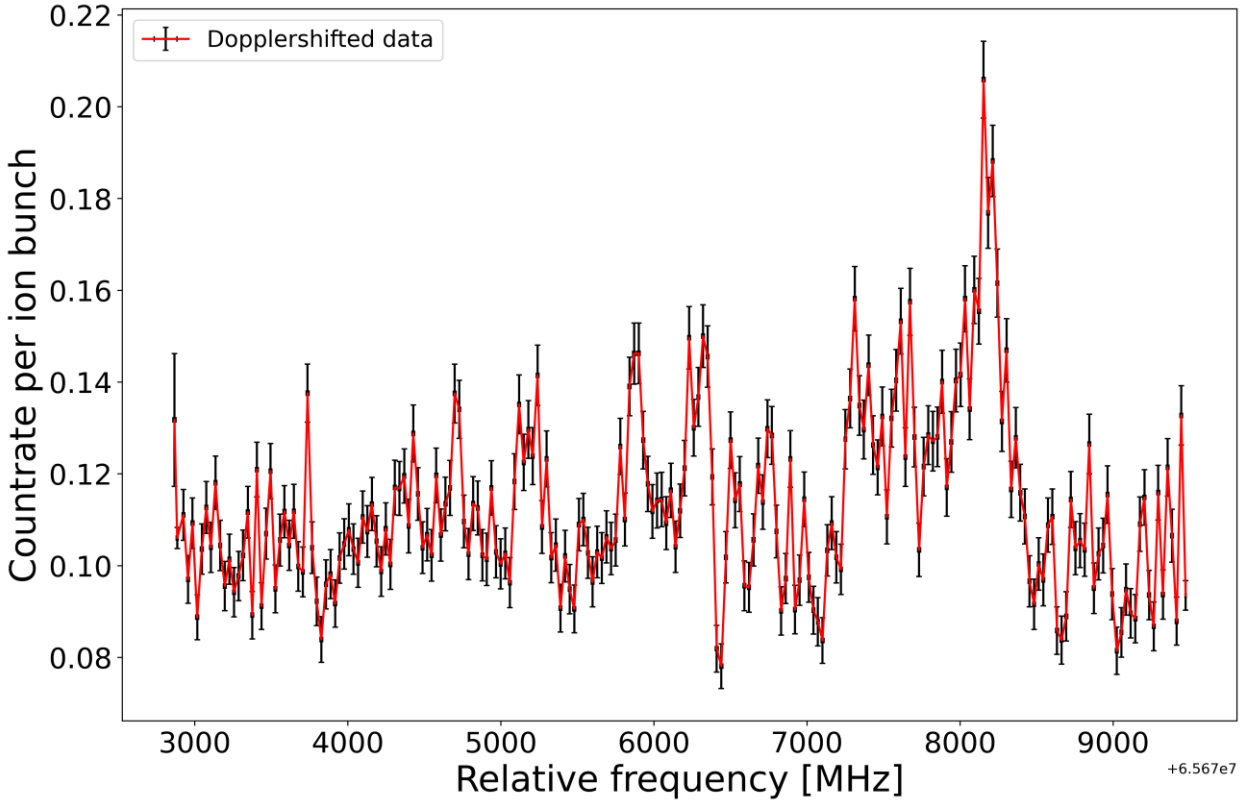






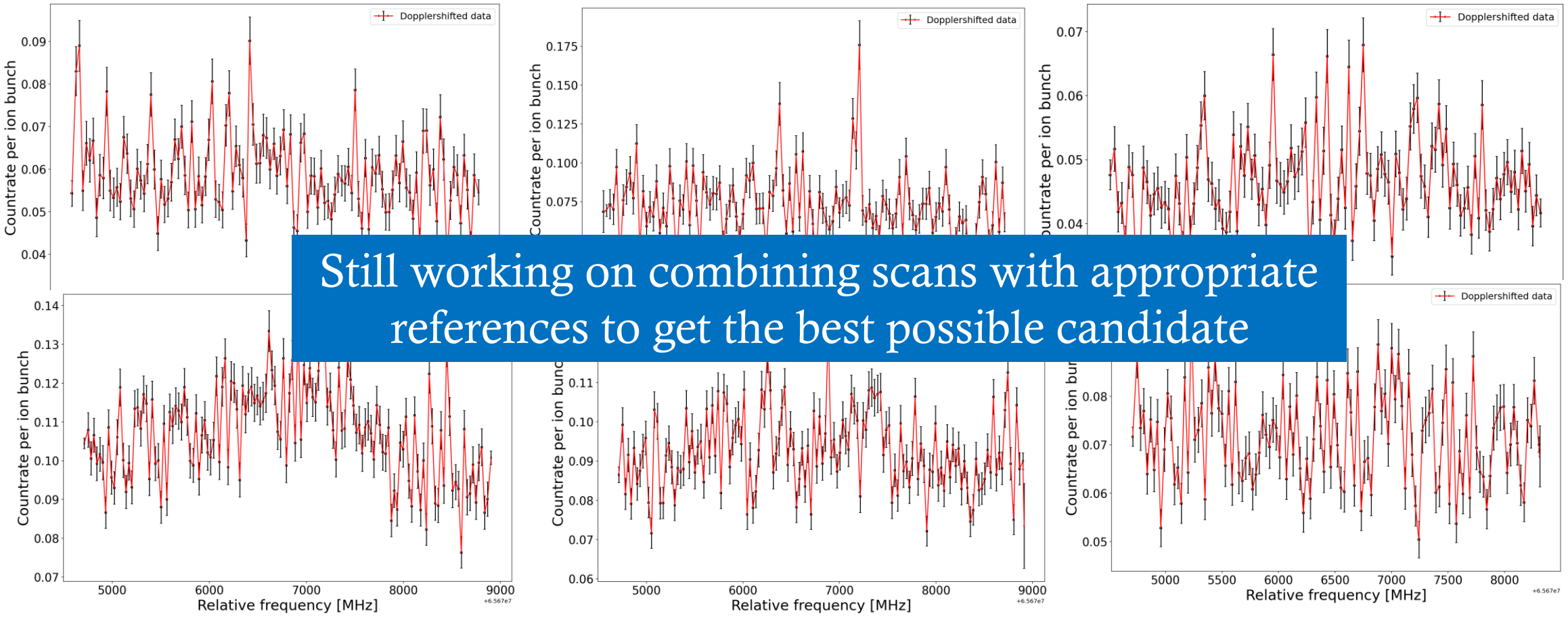


Results - ^{111}Sb



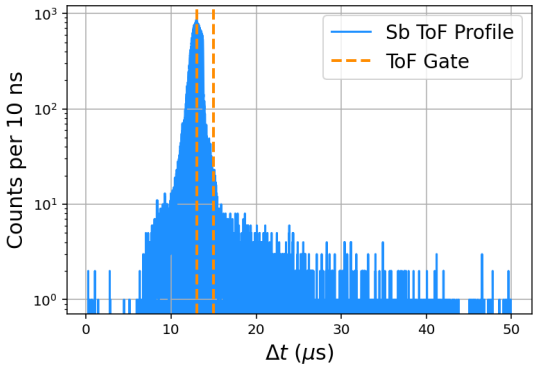
- First spectroscopy measurements of ^{111}Sb
- 6 good quality scans with plenty of statistics and nicely referenced

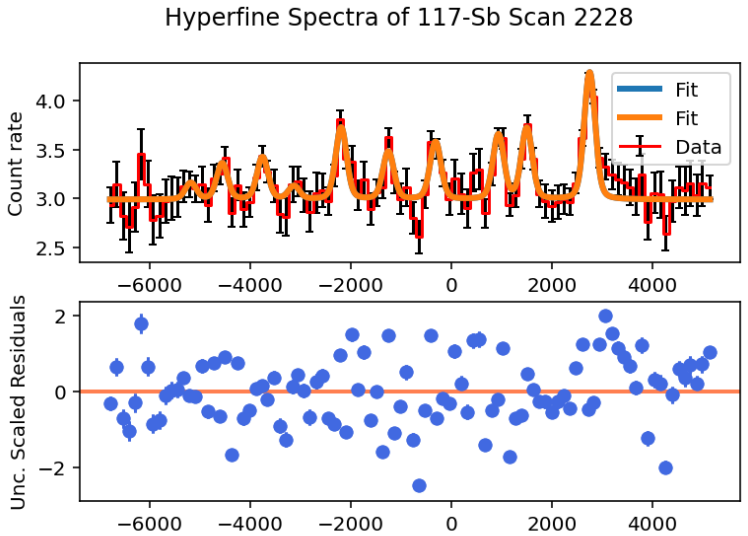
Results - ^{110}Sb

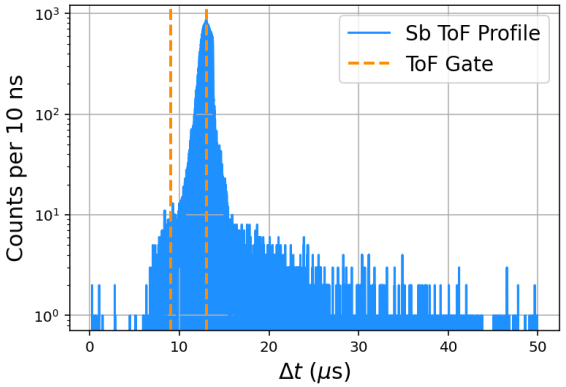


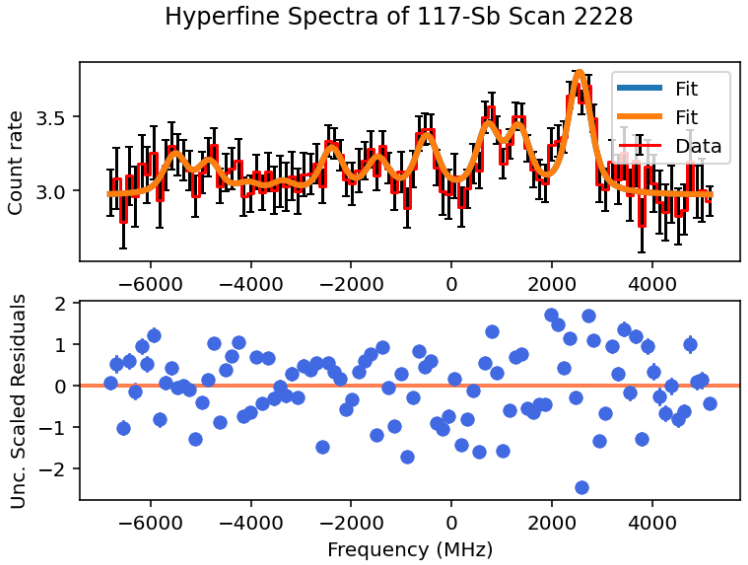
Still working on combining scans with appropriate references to get the best possible candidate

Results - difficulties









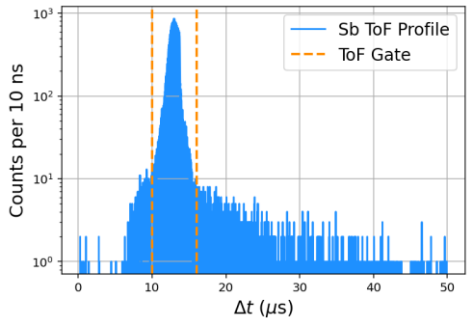
The different cuts vary in resolution, intensity, and centroid

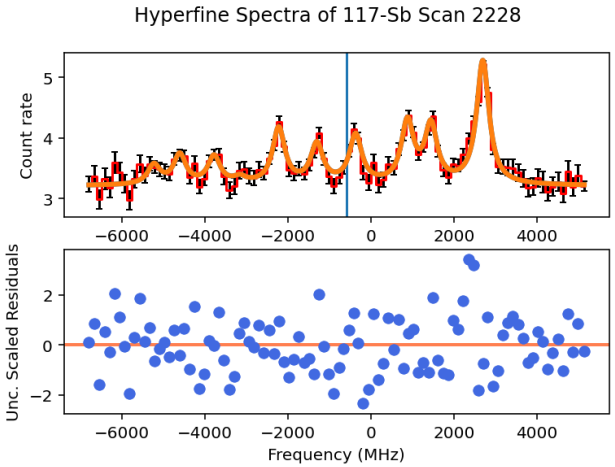
But isotope shift seems to remain constant as long as you take the same ToF cut

Fits have a smaller Chi-squared when separating out the ToF into different chunks

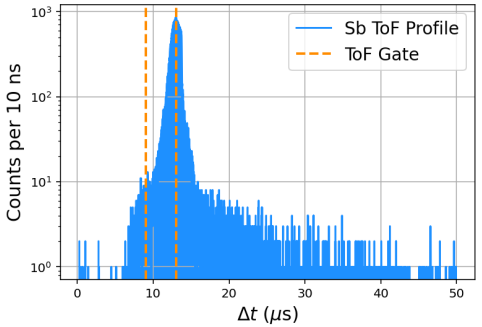
Results - difficulties

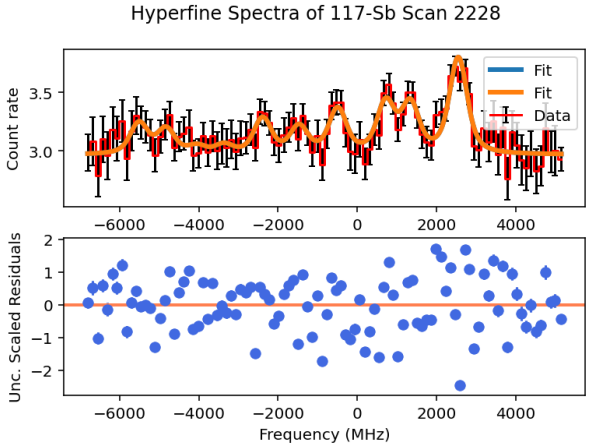
Full ToF

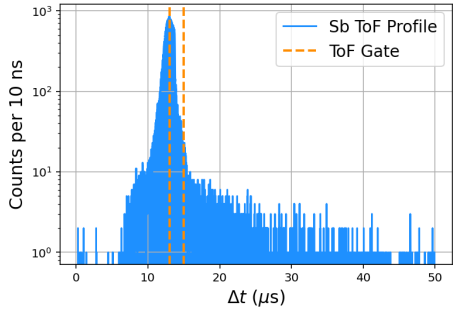


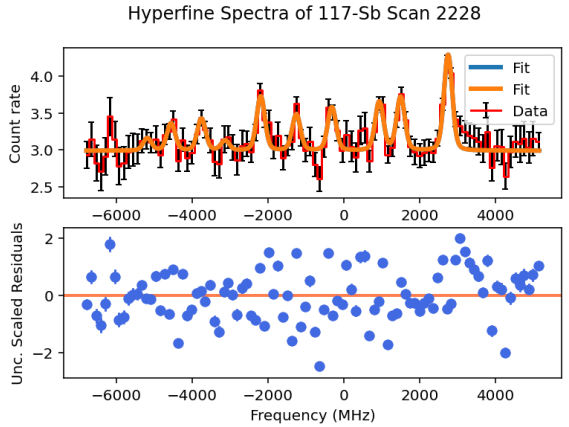


Separated ToFs





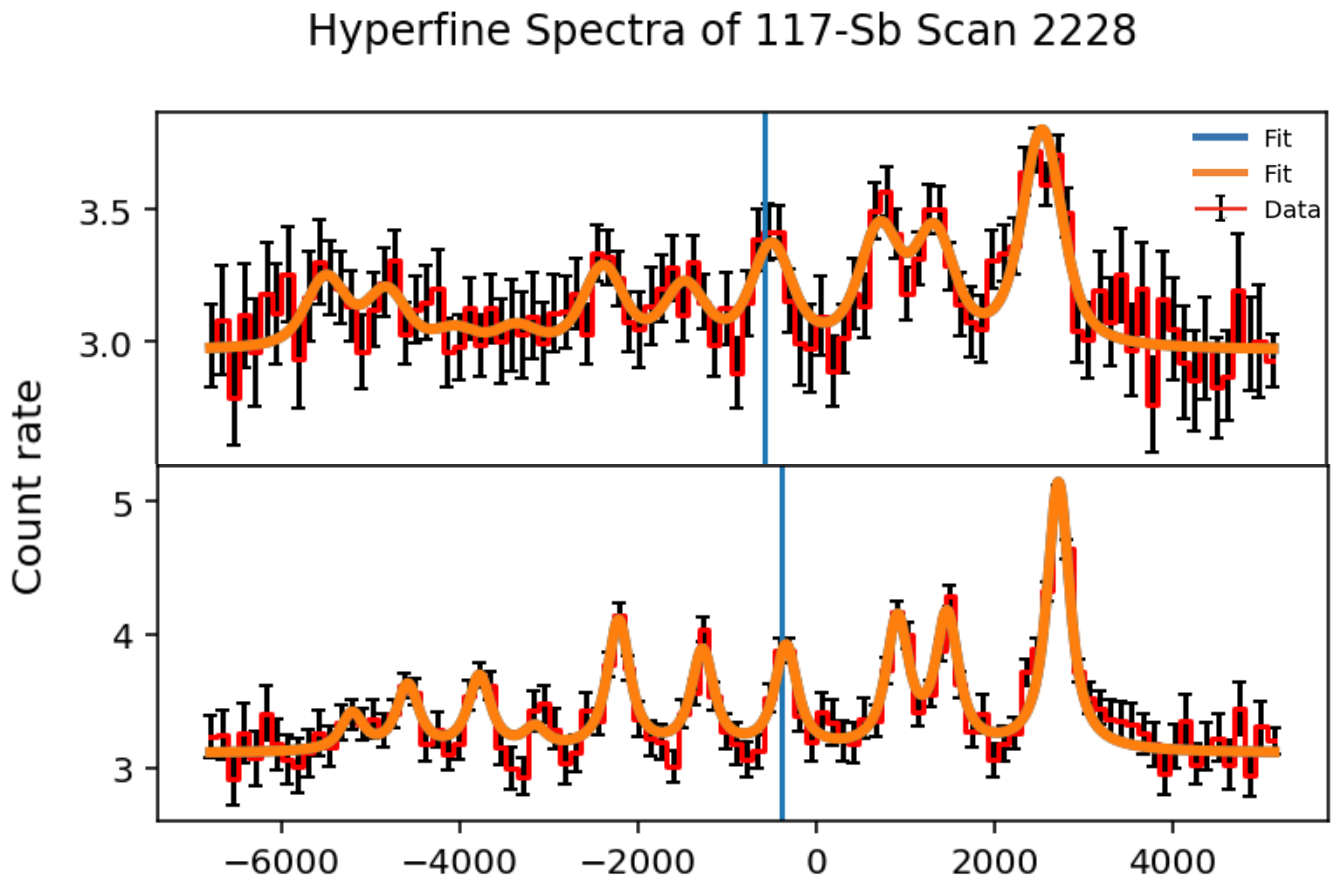




Fits have a smaller Chi-squared when separating out the ToF into two parts

Using the last half of the ToF yields a smaller FWHM

Results - difficulties



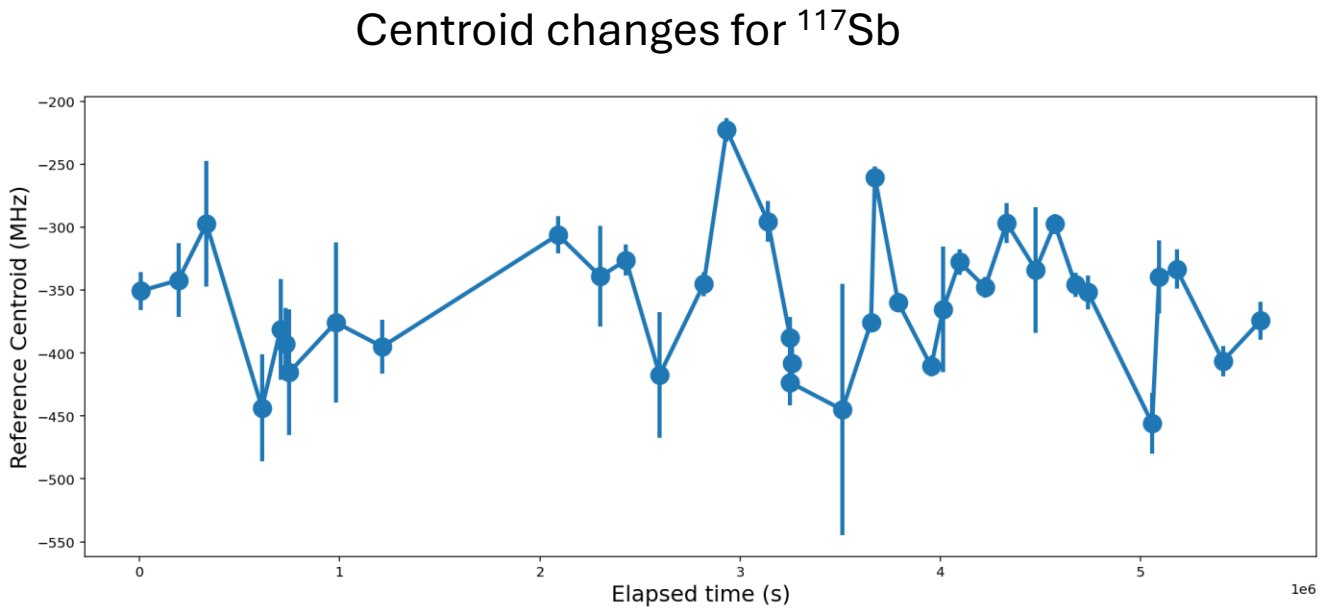
Highlighting the difference in centroid

Things to note:

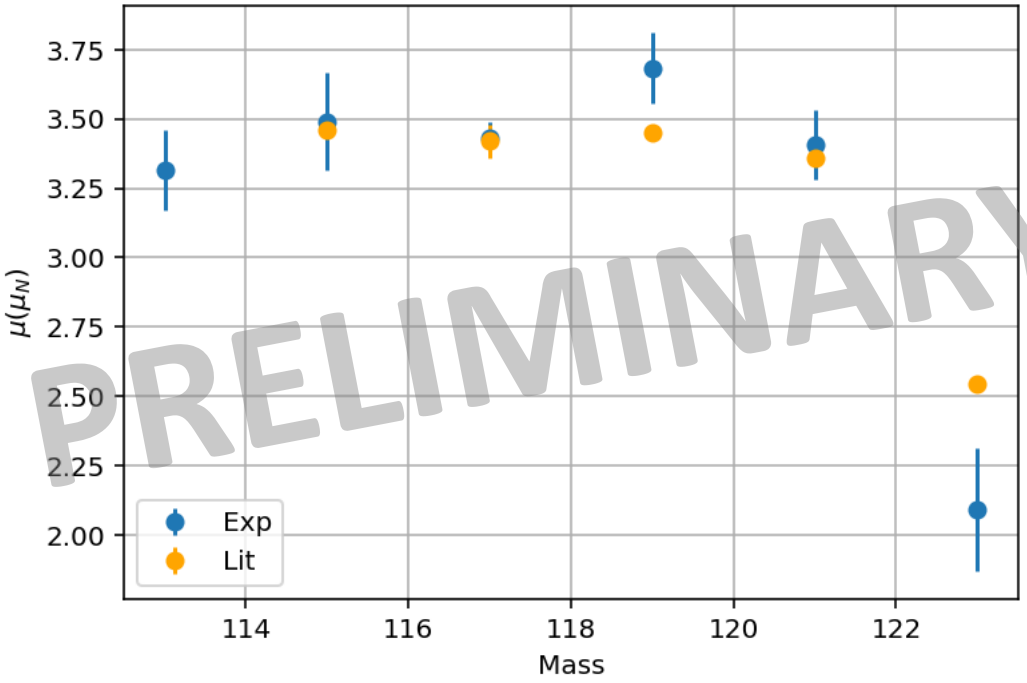
- Currently fitting with b_1 values extracted from ratio – not all free parameters

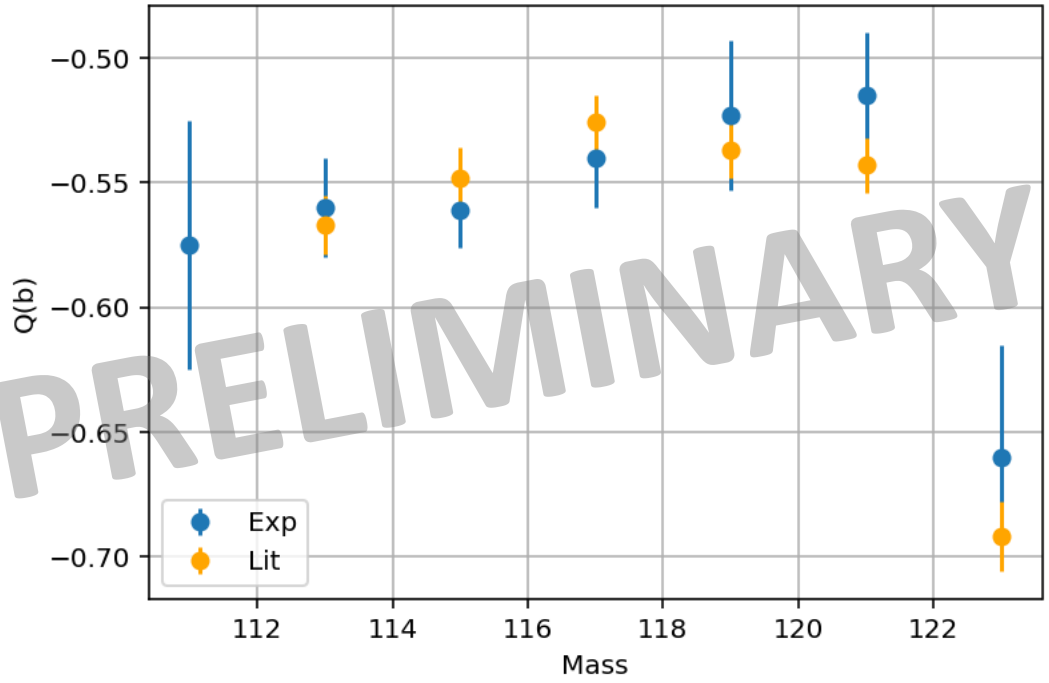
Results – Reference centroids

- Centroids consistently +-100MHz
- ‘Changed’ reference halfway through experiment from 123 to 117, but we have enough information from 117 at the start to also use that as a reference throughout
- Typical reference FWHM between 180-250MHz



Results – preliminary moment calculations





Results – Next steps

- Applying appropriate corrections
  - Dopplershifting separate parts of ToF
  - Diode corrections for scans where it was not recorded properly
    - There was one evening where the PCCRIS27 was restarted and the diode not properly relocked so the saved wavenumbers on WSU are nonsense
  - Properly constraining hyperfine factors
  - Combining scans in a more sophisticated way
  - More detailed error handling
- Isotope shift and charge radii
  - Discussions with COLLAPS for F and M calculations

Thanks to all CRIS participants who contributed to the experiment,

To the RILIS and targets teams,
And to ISOLTRAP for yield measurements

K. M. Lynch[1], M. Athanasakis-Kaklamanakis[2,3], S. W. Bai[4], Y. Balasmeh[2], T. E. Cocolios[2], R. P. de Groote[2], C. Fajardo[2], K. T. Flanagan[1,5], S. Franchoo[6], R. F. Garcia Ruiz[7], S. Geldhof[8], G. Georgiev[6], D. Hanstorp[9], R. Heinke[10], **J. D. Holt**[11] A. Koszorús[2,12], L. Lalanne[3], Y. C. Liu[4], Y. S. Liu[4], A. McGlone[1], **W. Nazarewicz**[13] G. Neyens[2], M. Nichols[9], F. Pastrana[7], H. Perrett[1], J. R. Reilly[1] **P.-G. Reinhard**[14], J. Trujillo[2], B. van den Borne[2], J. Wessolek[1], **S. Wang**[15] S. G. Wilkins[7] and X. F. Yang[4].

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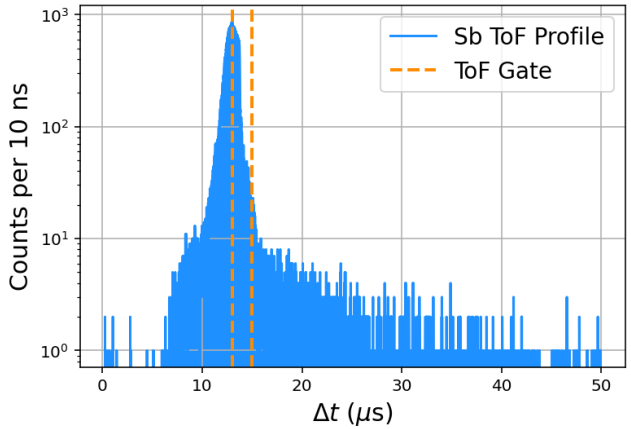
Backup slides

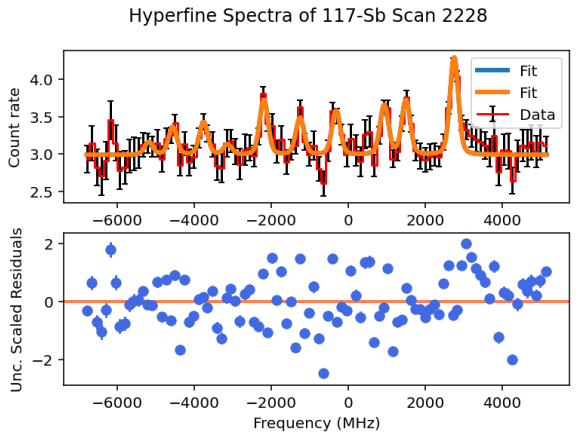
Experiment - Other things to note

- RILIS was excellent for this experiment, we had no issues
- Using the FIU deflectors could improve the S/N ratio – good to know this is an option

- TRLi was slowly dying, we were still suffering from the burned ceramics as well as cooling issues during warm periods
- There was a day of interruption during the experiment, it took 3 shifts to recover
  - We need to make sure that we don't receive interruptions as we found out multiple times this year

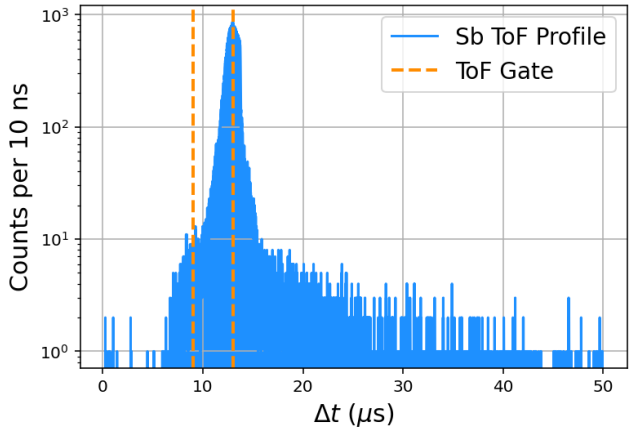
Showing how the tof cuts affect everything

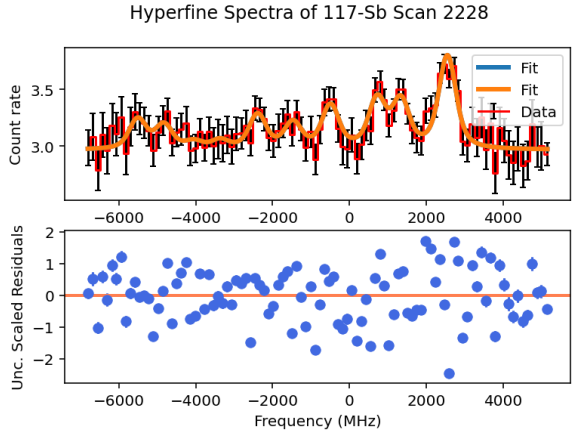





```
Antimony___Sb___centroid: -364.854014 +/- 7.97464573 (2.19%) (init = -400)
Antimony___Sb___Al:       -313.002673 +/- 1.09287241 (0.35%) (init = -311.9)
Antimony___Sb___Au:        548.318083 +/- 1.91449389 (0.35%) == '-1.7518*Antimony___Sb___Al'
Antimony___Sb___Bl:       -0.43348863 +/- 17.7122988 (4085.99%) (init = 0)
Antimony___Sb___Bu:       -456.780768 +/- 22.5644678 (4.94%) (init = 0)
Antimony___Sb___Cl:        0 (fixed)
Antimony___Sb___Cu:       -1.75974190 +/- 1.37334107 (78.04%) (init = 0)
Antimony___Sb___FWHMG:     223.893506 +/- 60.3137861 (26.94%) (init = 200)
Antimony___Sb___FWHML:     63.6670425 +/- 90.2376078 (141.73%) (init = 200)
Antimony___Sb___scale:     1.617124 (fixed)
Antimony___Sb___Amp1to1:   0.10515944 +/- 0.06662183 (63.35%) (init = 0.1333333)
Antimony___Sb___Amp1to2:   0.26771956 +/- 0.05568598 (20.80%) (init = 0.3111111)
Antimony___Sb___Amp2to1:   0.22924841 +/- 0.05608843 (24.47%) (init = 0.3111111)
Antimony___Sb___Amp2to2:   0.08338528 +/- 0.07954832 (95.40%) (init = 0.008230453)
Antimony___Sb___Amp2to3:   0.30177040 +/- 0.05161927 (17.11%) (init = 0.4213992)
Antimony___Sb___Amp3to2:   0.45493739 +/- 0.05106978 (11.23%) (init = 0.4213992)
Antimony___Sb___Amp3to3:   0.36408026 +/- 0.05372552 (14.76%) (init = 0.2823045)
Antimony___Sb___Amp3to4:   0.44854557 +/- 0.04599840 (10.26%) (init = 0.3333333)
Antimony___Sb___Amp4to3:   0.40880190 +/- 0.04787478 (11.71%) (init = 0.3333333)
Antimony___Sb___Amp4to4:   0.80452346 +/- 0.04057810 (5.04%) (init = 1)
Antimony___bkg1___p0:      2.98670609 +/- 0.03570059 (1.20%) (init = 3)
```

200MHz difference in centroid between the two ToF cuts

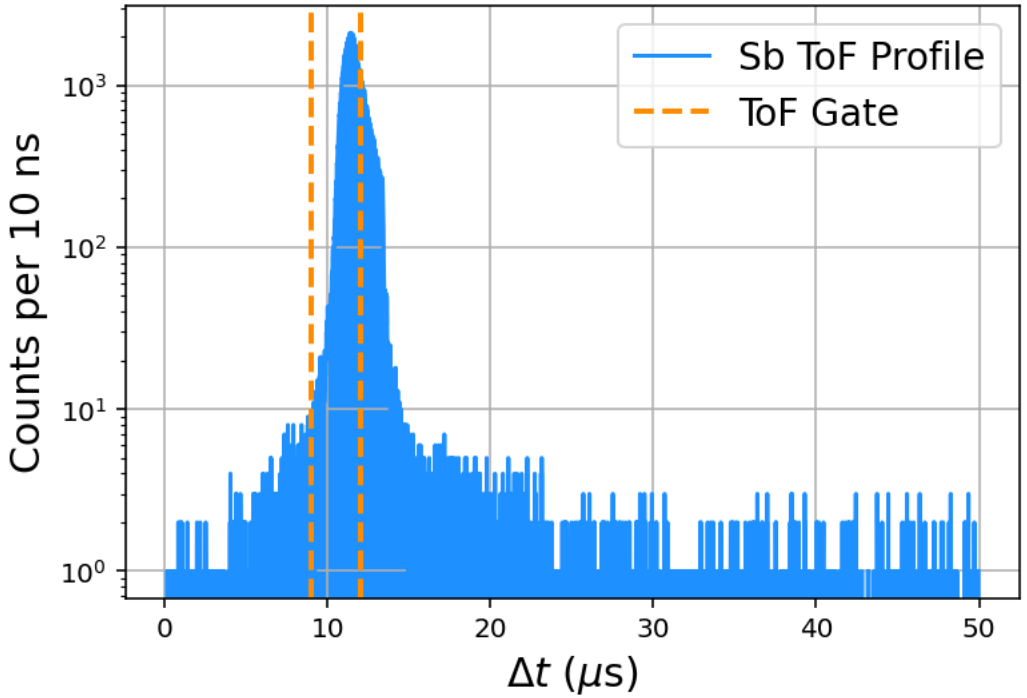


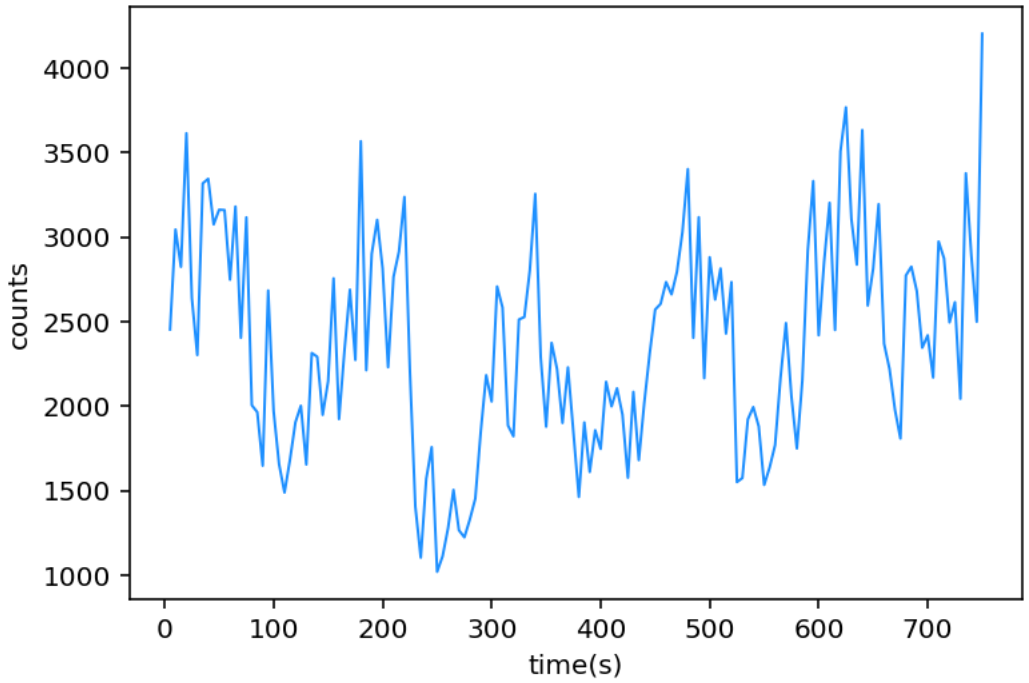



```
Antimony___Sb___centroid: -578.237811 +/- 25.4777172 (4.41%) (init = -400)
Antimony___Sb___Al:       -316.093080 +/- 3.25508228 (1.03%) (init = -311.9)
Antimony___Sb___Au:        553.731858 +/- 5.70225313 (1.03%) == '-1.7518*Antimony___Sb___A
Antimony___Sb___Bl:        64.2929795 +/- 51.1927079 (79.62%) (init = 0)
Antimony___Sb___Bu:       -471.339983 +/- 54.5304905 (11.57%) (init = 0)
Antimony___Sb___Cl:        0 (fixed)
Antimony___Sb___Cu:       -1.31121085 +/- 4.80122855 (366.17%) (init = 0)
Antimony___Sb___FWHMG:     352.383402 +/- 173.723553 (49.30%) (init = 200)
Antimony___Sb___FWHML:     299.785845 +/- 197.254445 (65.80%) (init = 200)
Antimony___Sb___scale:     0.961169 (fixed)
Antimony___Sb___Amp1to1:   0.27477582 +/- 0.08923672 (32.48%) (init = 0.1333333)
Antimony___Sb___Amp1to2:   0.06629562 +/- 0.07544938 (113.8
Antimony___Sb___Amp2to1:   0.21867951 +/- 0.07818443 (35.75
Antimony___Sb___Amp2to2:   0.07836511 +/- 0.09404535 (120.0
Antimony___Sb___Amp2to3:   0.23693328 +/- 0.06523699 (27.53
Antimony___Sb___Amp3to2:   0.31305151 +/- 0.06705531 (21.42
Antimony___Sb___Amp3to3:   0.39354635 +/- 0.06640487 (16.87
Antimony___Sb___Amp3to4:   0.42790094 +/- 0.06116836 (14.29
Antimony___Sb___Amp4to3:   0.44223250 +/- 0.06539874 (14.79
Antimony___Sb___Amp4to4:   0.85196225 +/- 0.06357138 (7.46%
Antimony___bkg1___p0:      2.96568920 +/- 0.04144763 (1.40%
```

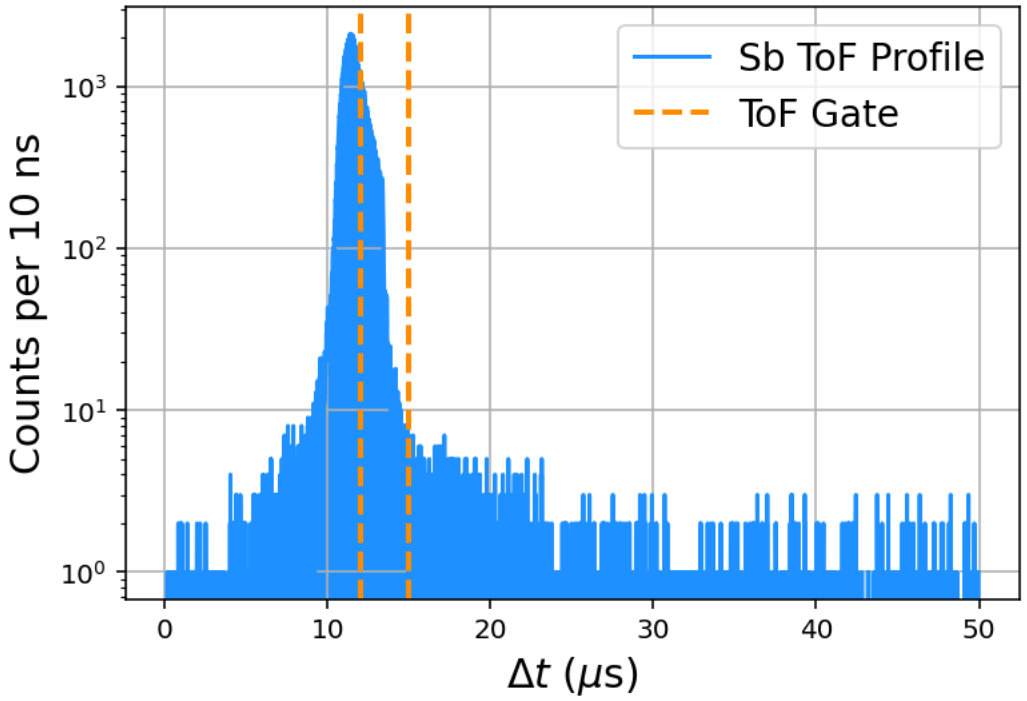
If different energy classes, want to see the voltage difference required to doppler shift them together

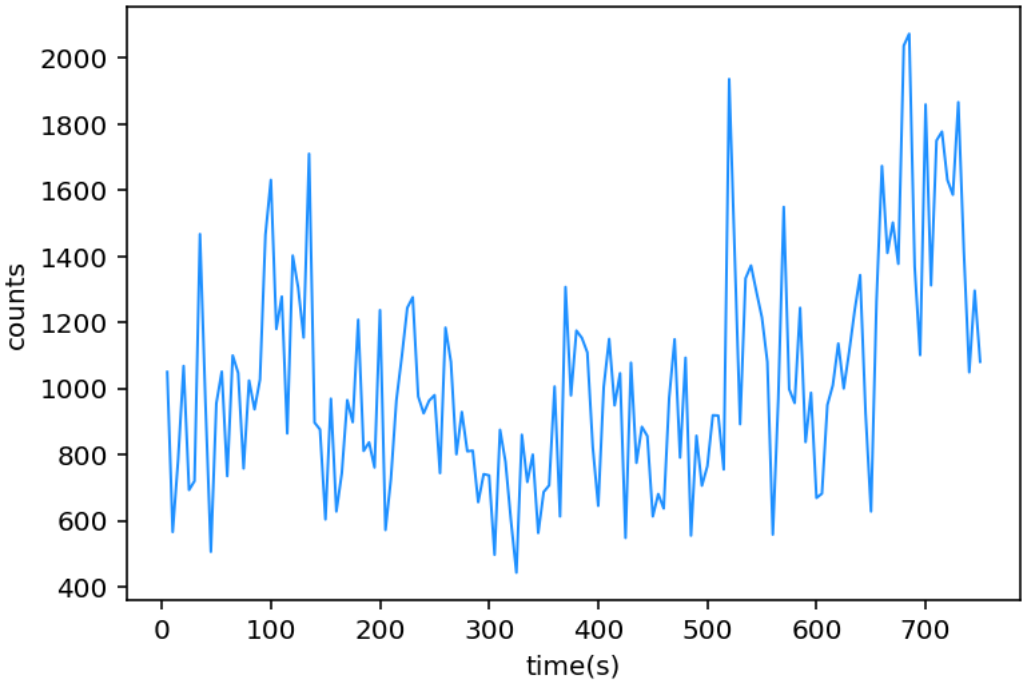
Smaller range early tof



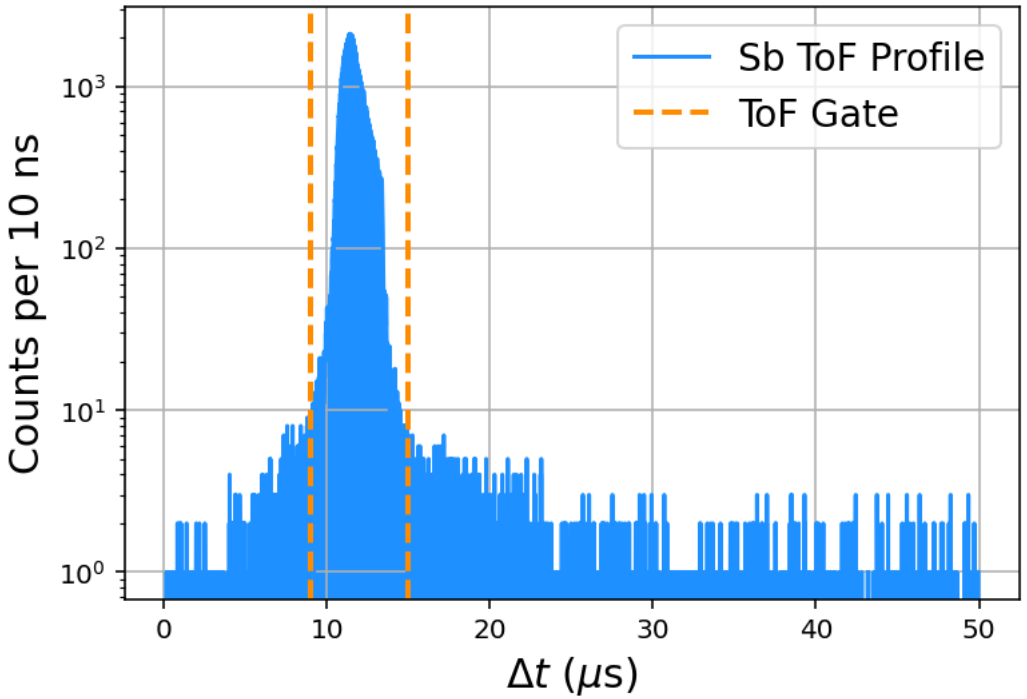


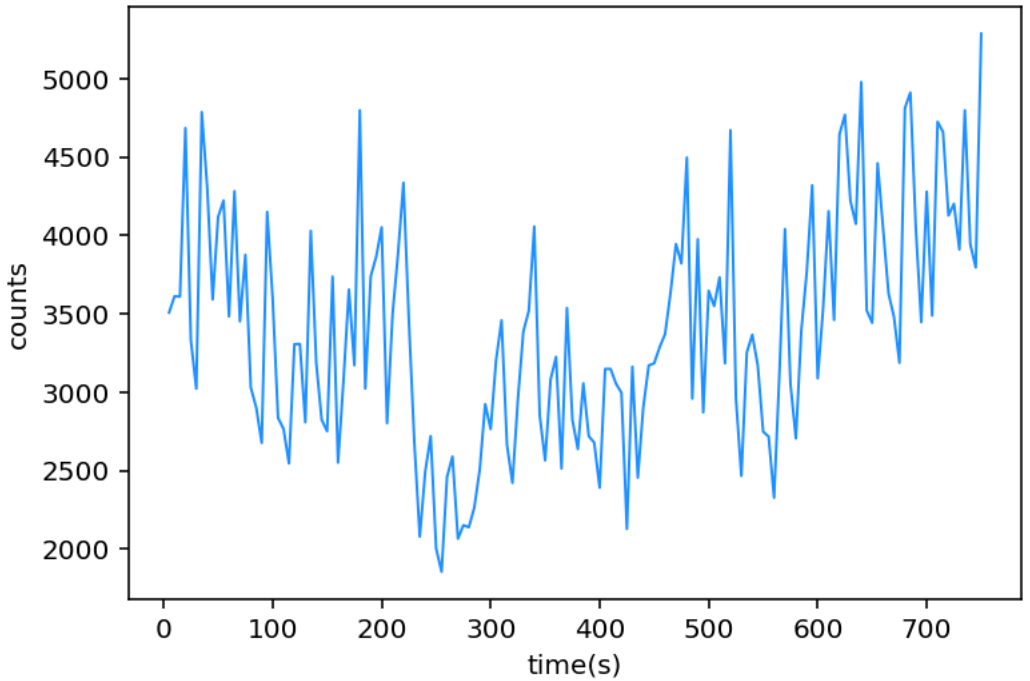
Smaller range late tof



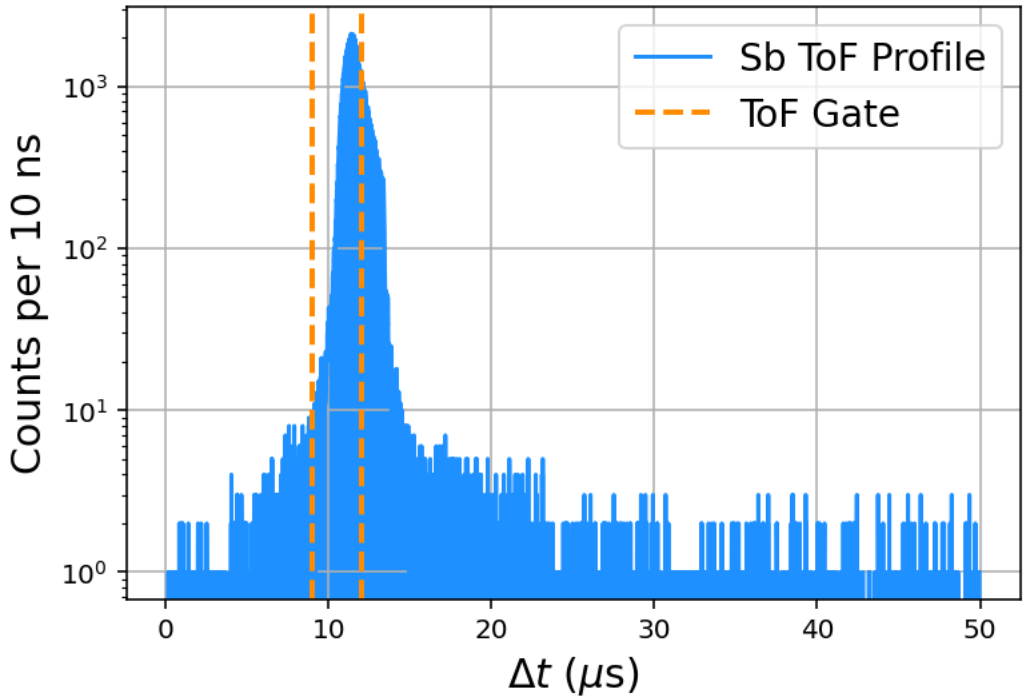


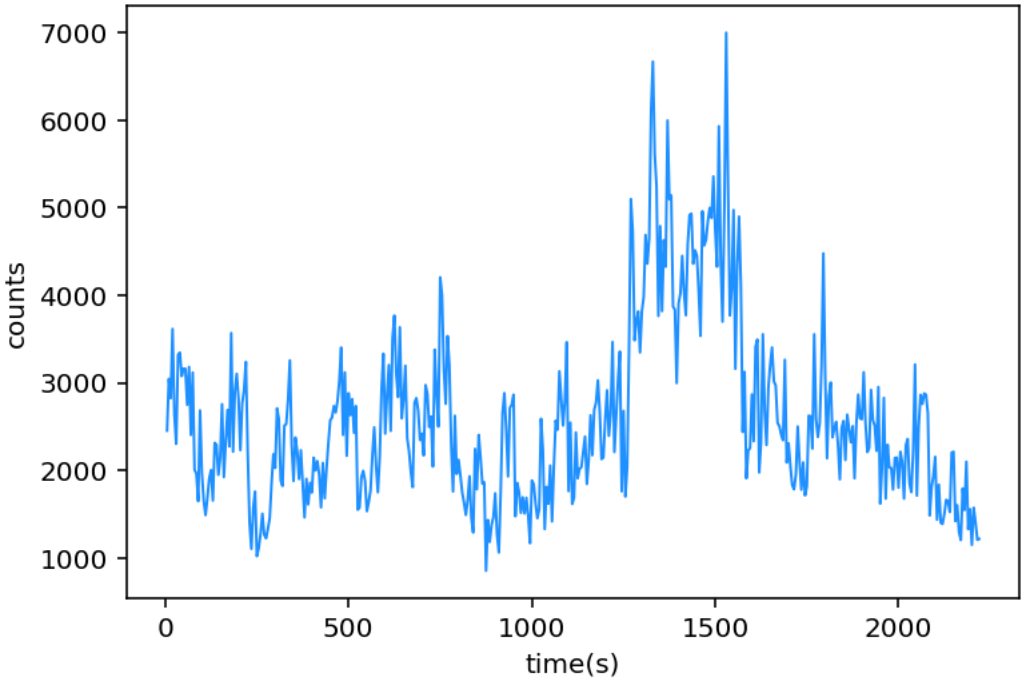
Smaller Range, full tof



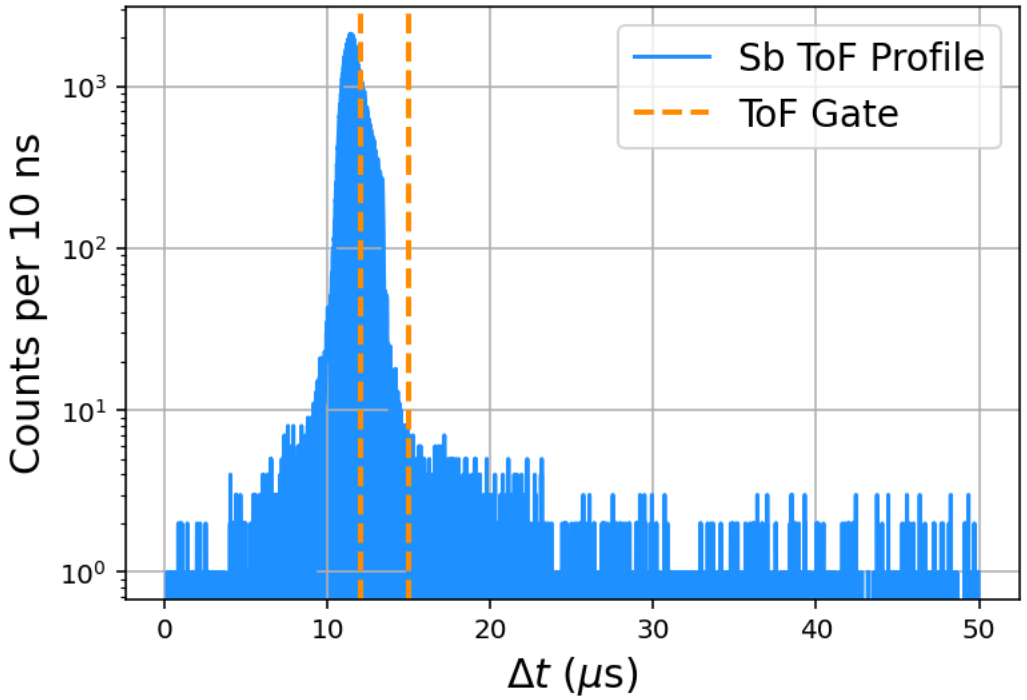


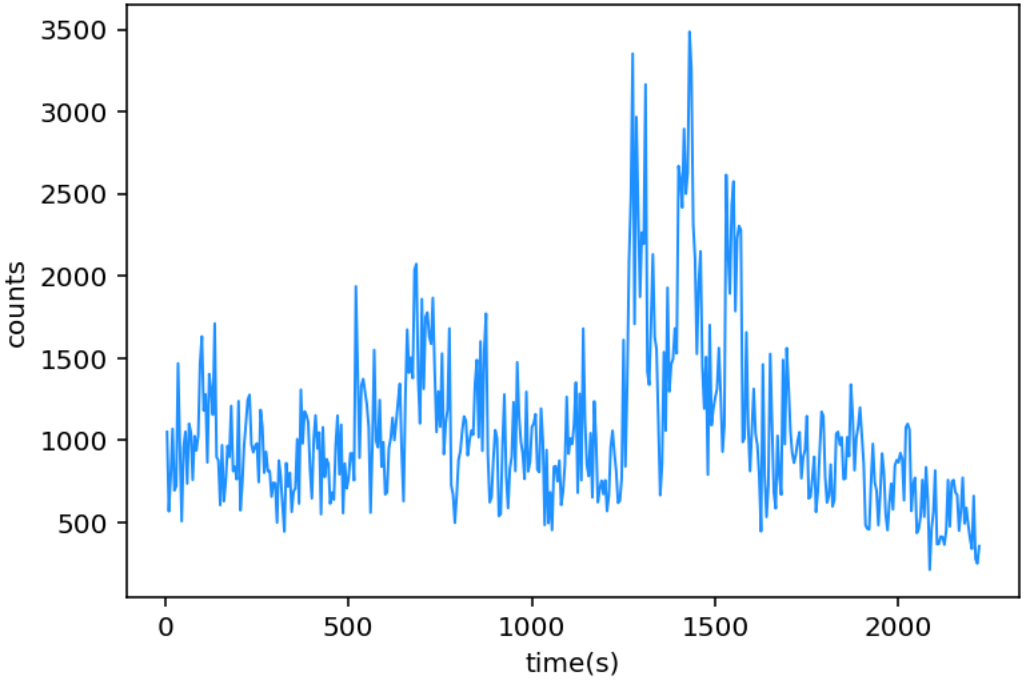
full range early tof



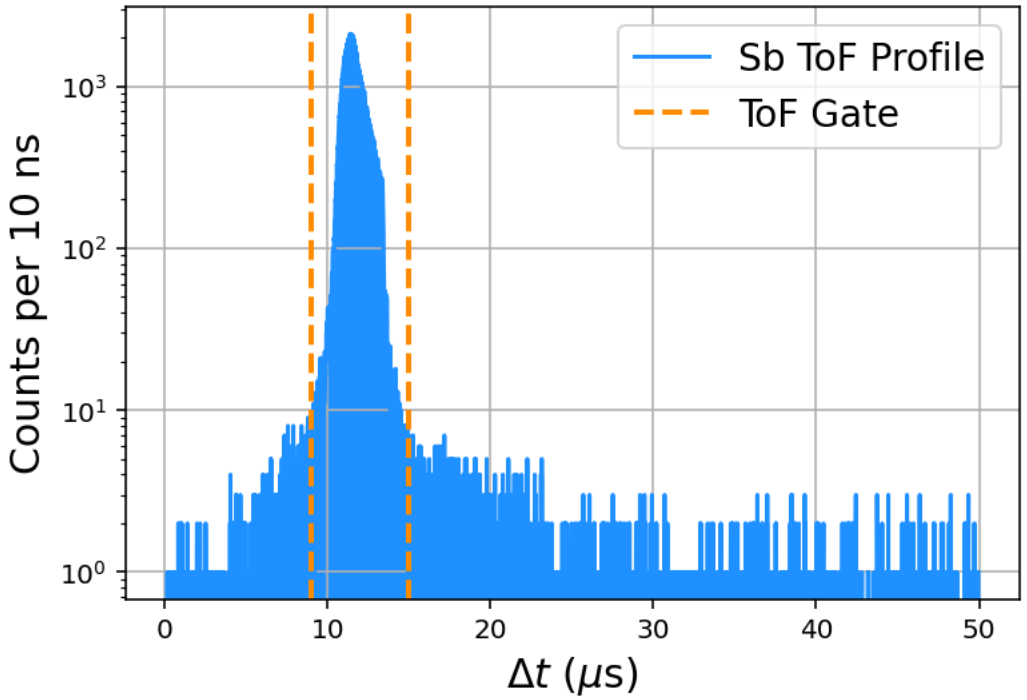


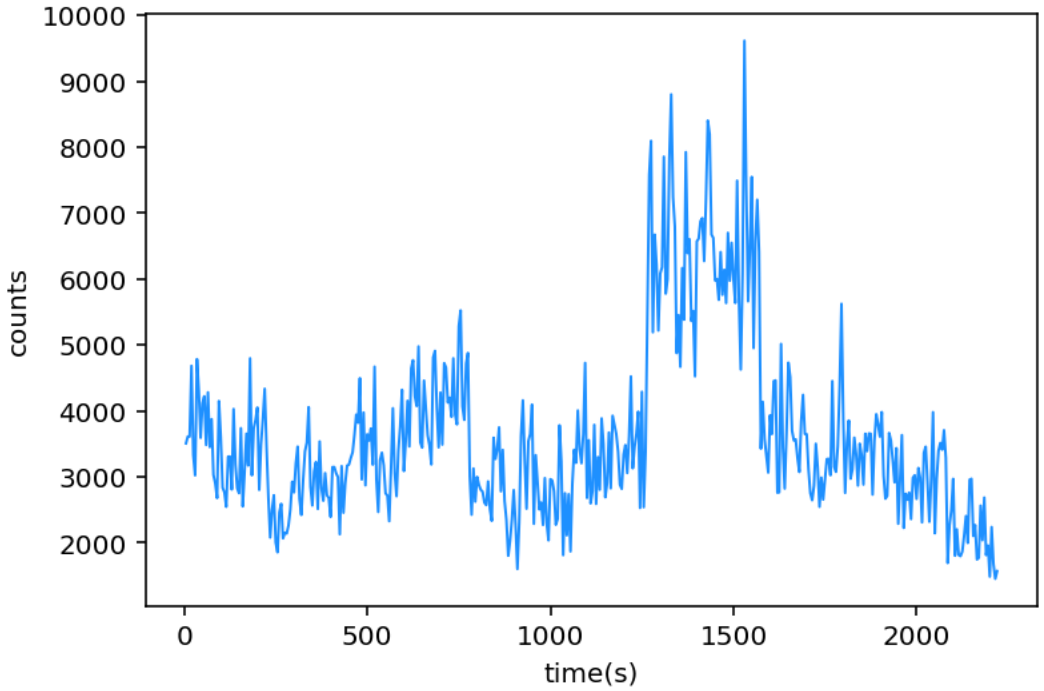
full range late tof

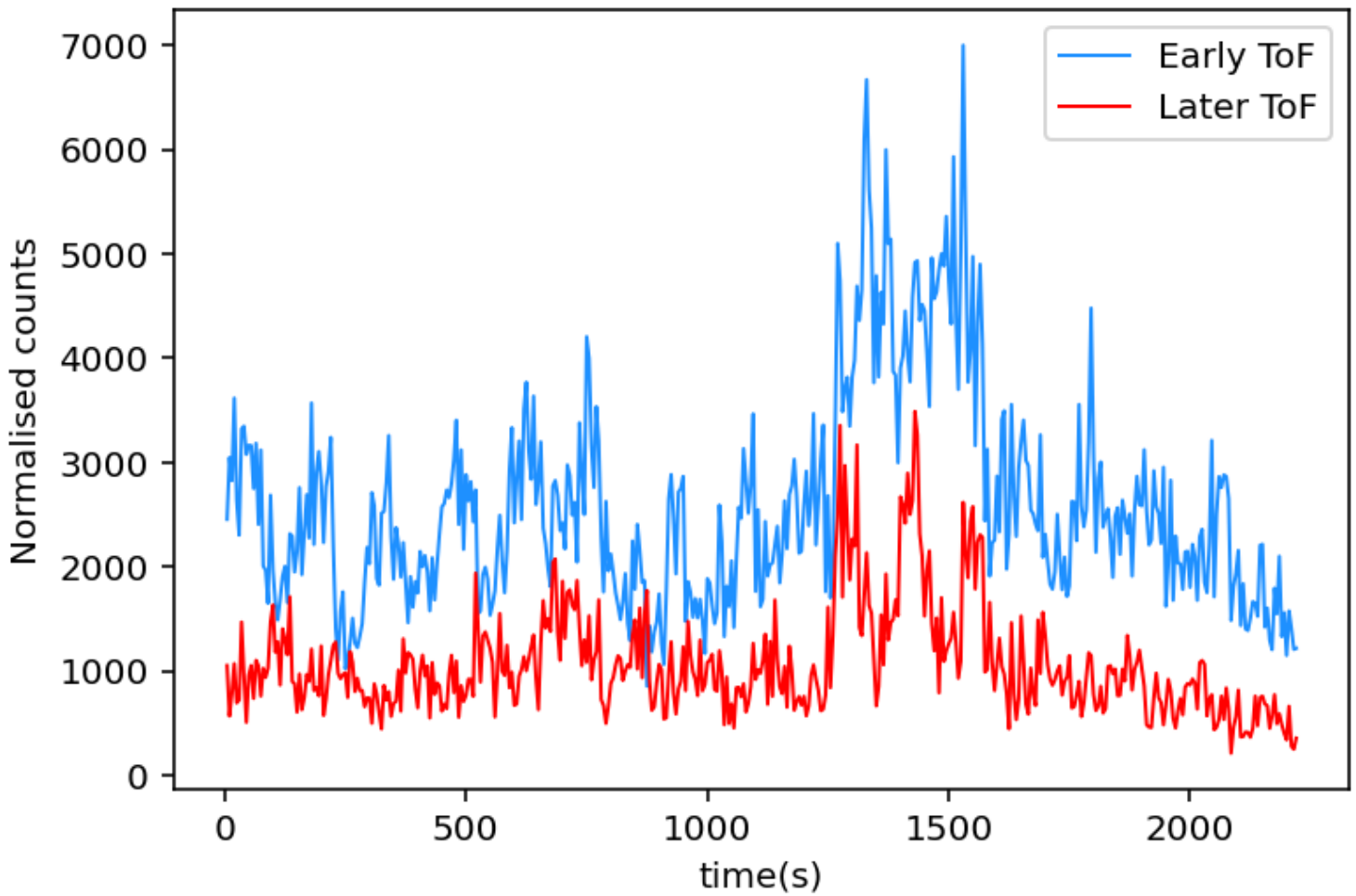




full range full tof






Early ToF
Later ToF
Normalised counts
7000
6000
5000
4000
3000
2000
1000
0
0
500
1000
1500
2000
time(s)