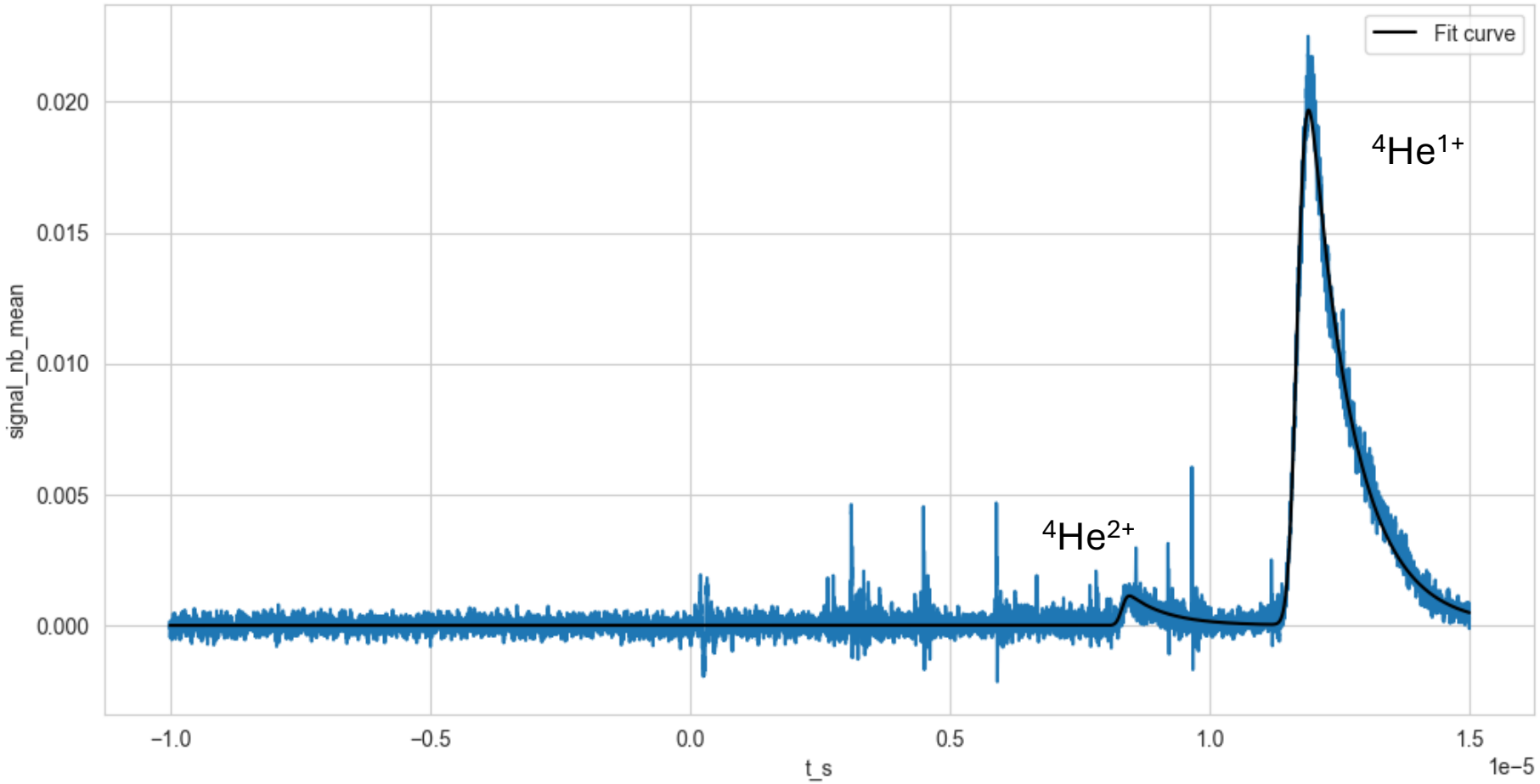
Let me tell you a story about the residuals

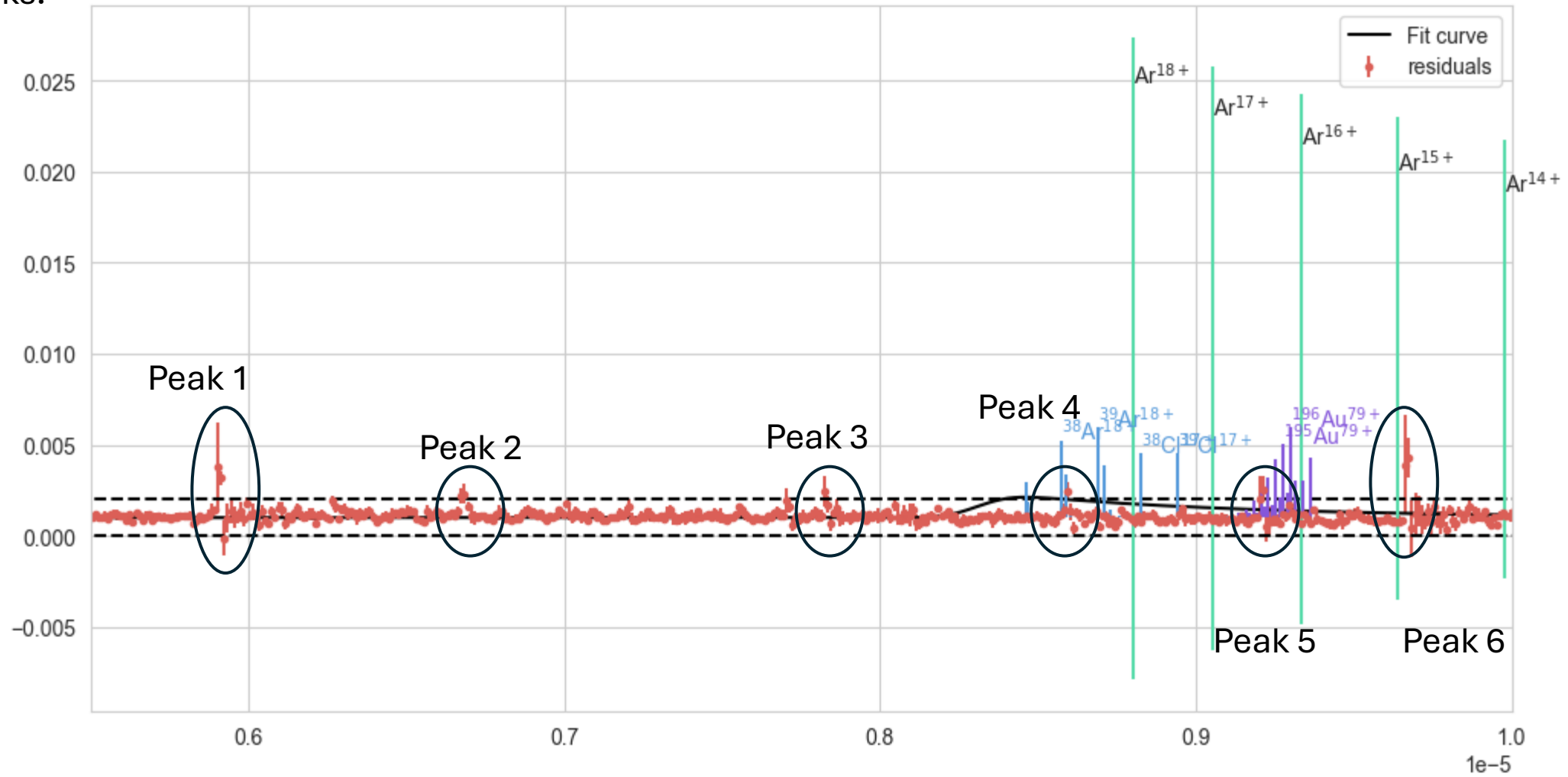
Aka, do we see fragments from the annihilations????

Marco and Fredrik went through the trouble of fitting the averaged spectrum from seven runs of the argon campaign. They got similar results from which we can conclude that we have some ionised ^{40}Ar inside the trap, but also we see things that match $^{4}He^{2+}$ and $^{4}He^{1+}$. The $^{4}He^{2+}$ is especially annoying as any signal from the fragments is expected to be within this peak.

That's why Georgy suggested looking into residuals (meaning what is left if we remove the baseline from the data).

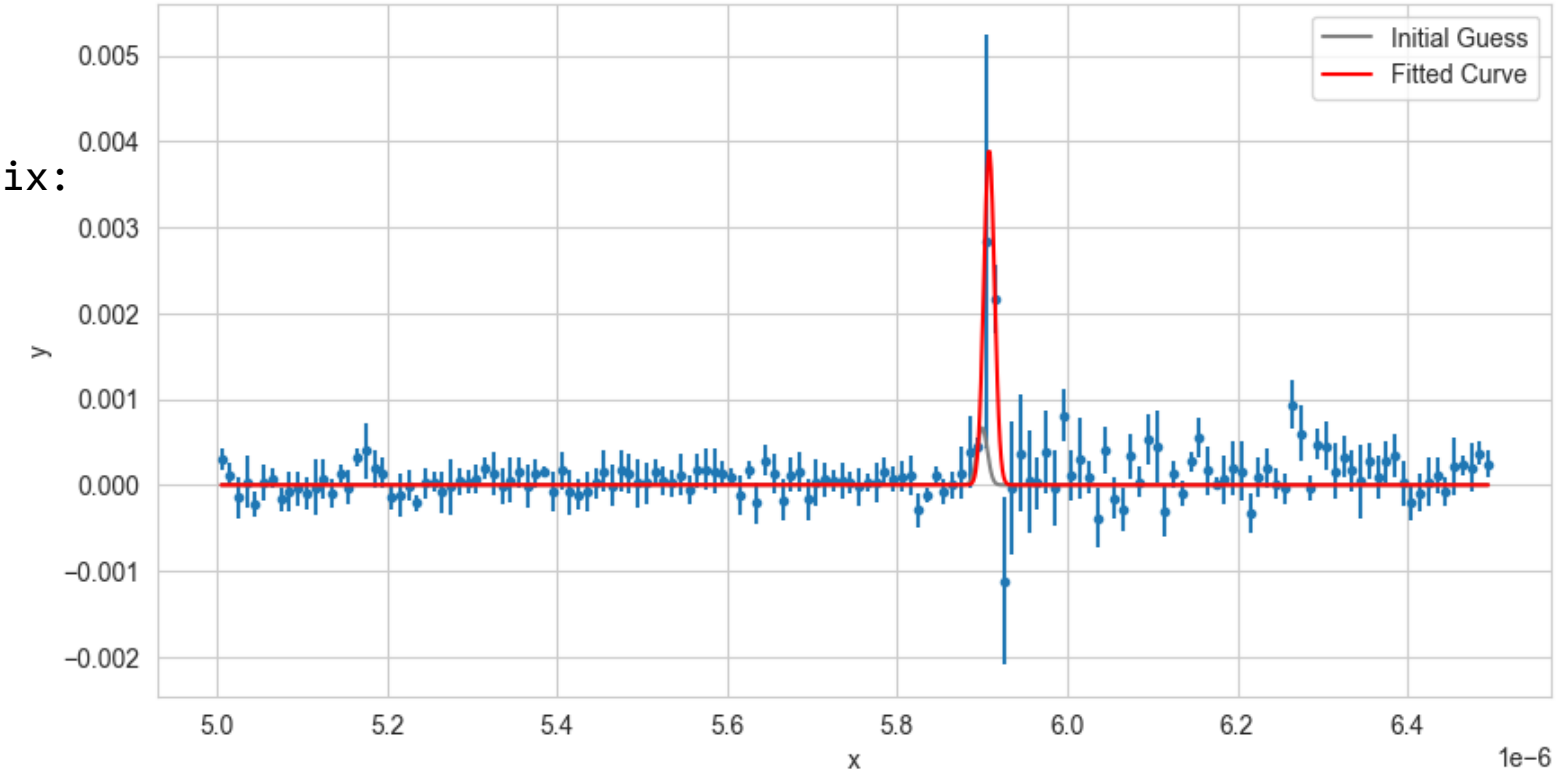


This is it. The residuals from the runs (as red points). The dashed line shows +/- 0.001, which is a threshold which needs to be passed to consider anything remotely a signal – in a very charitable approach (the standard deviation of the signal is 0.0007). In green, I indicated positions for different ionisation states of ^{40}Ar. The blue lines show the positions for fragments from antiproton annihilation on ^{40}Ar (the length of the line is proportional to the count of the given fragment). The purple lines show the fragments from annihilations on ^{197}Au. Given my criterion for signal, we have 6 peaks.



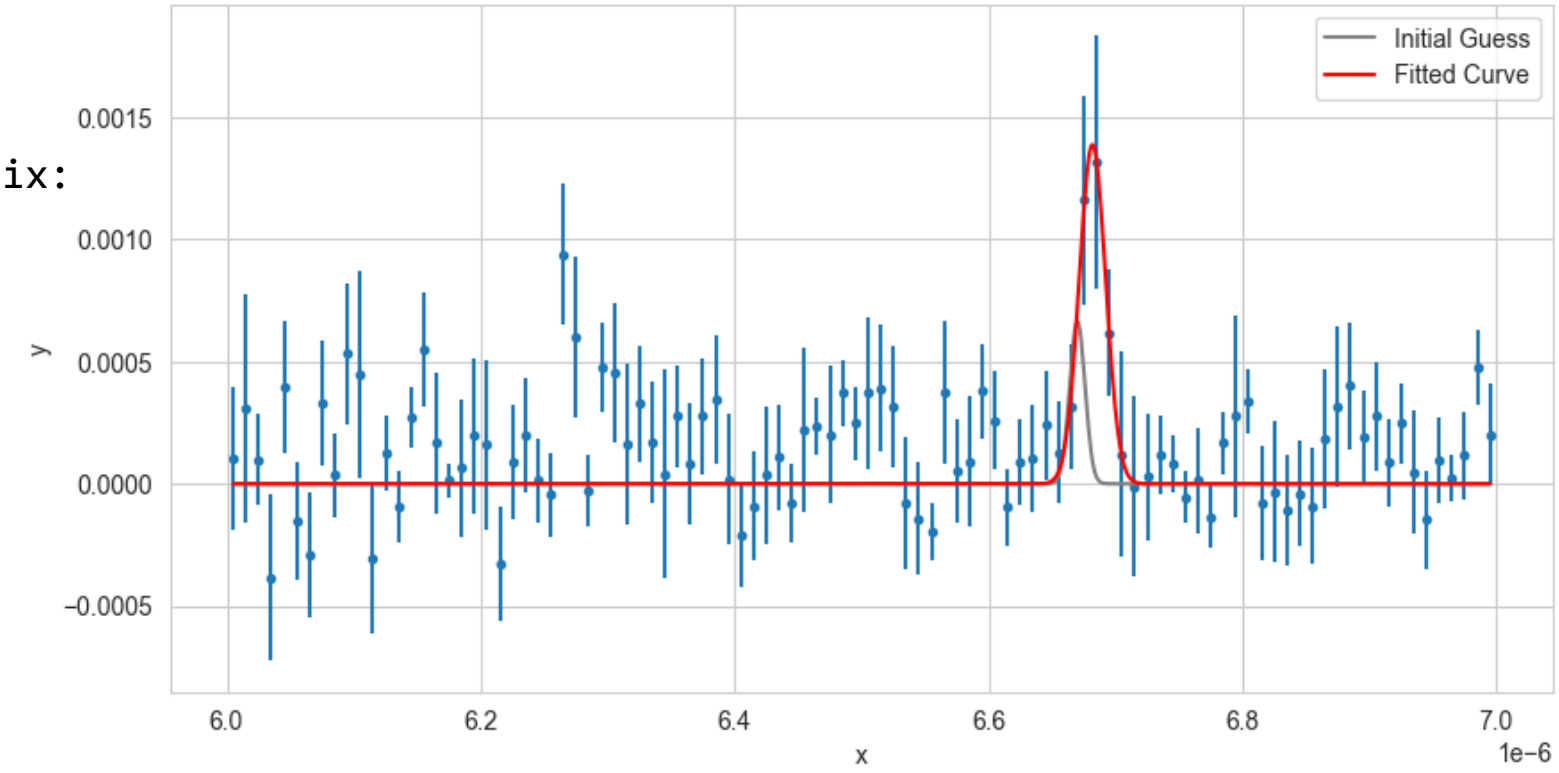
Fit peak 1

Ampl: 6.15434725450583e-11
mu: 5.908097345277863e-06
sigma: 6.281703478318256e-09
Condition number of the covariance matrix:
8.069502e+04
Diagonal values of pcov:
Cov of Ampl: 5.012561437588766e-22
Cov of mu: 3.2758166024778706e-18
Cov of sigma: 3.09342192199789 37e-18
Chi-2: 153.76739989735324
dof: 147
Reduced Chi^2: 1.0460367339956003
Goodness-of-Fit: 0.3344965416688168
R-squared: 0.5344151597444738



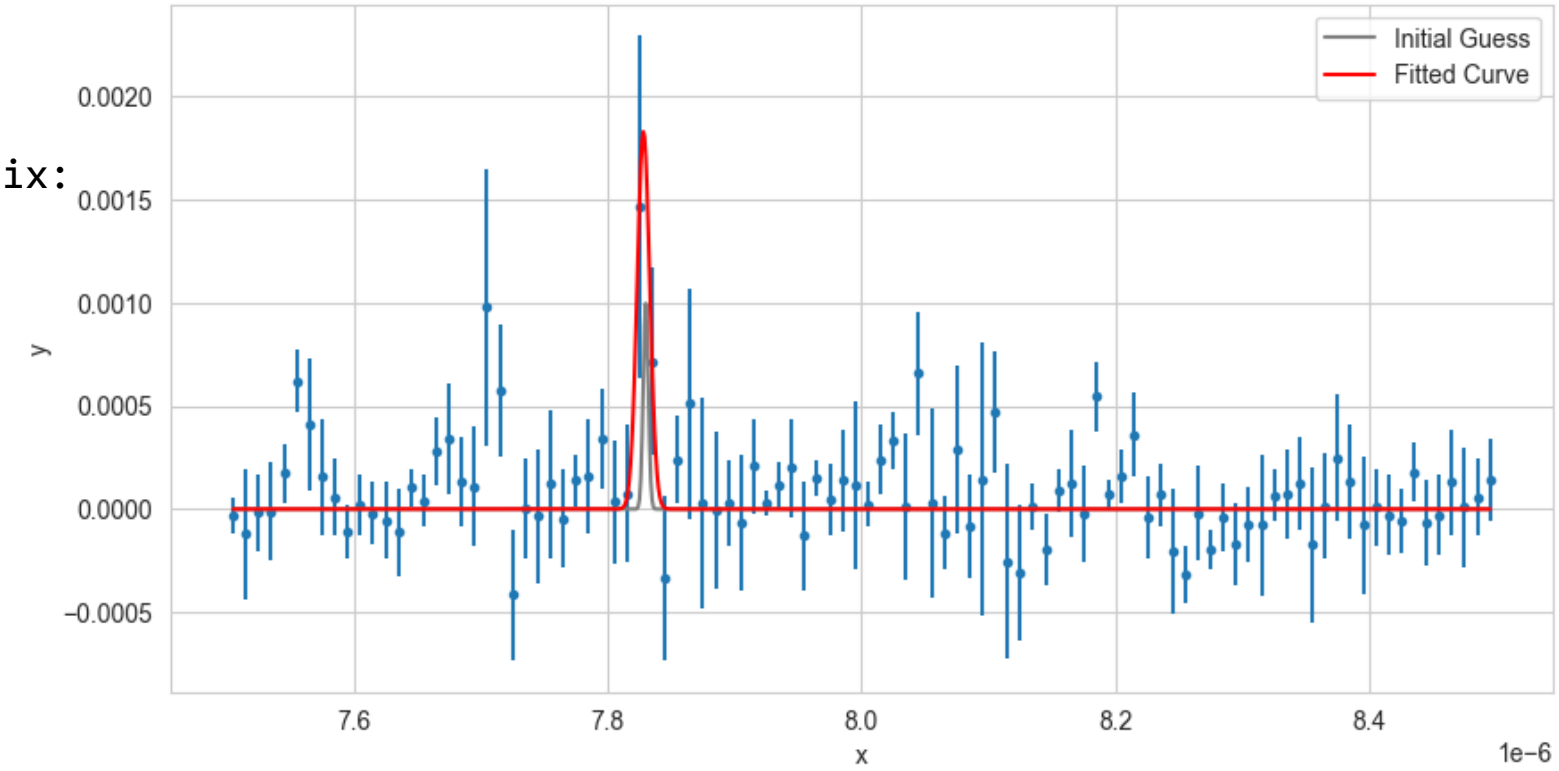
Fit peak 2

```
Ampl:    3.605581801989615e-11
mu:      6.6818602570441385e-06
sigma:   1.0372938789951286e-08
Condition number of the covariance matrix:
9.855740e+04
Diagonal values of pcov:
Cov of Ampl:     8.022288639965121e-23
Cov of mu:       7.313883043566039e-18
Cov of sigma:    7.6940993689783 75e-18
Chi-2: 126.42696410386797
dof:     97
Reduced Chi^2:   1.3033707639574017
Goodness-of-Fit: 0.0240106144040139 75
R-squared: 0.11971718204379511
```



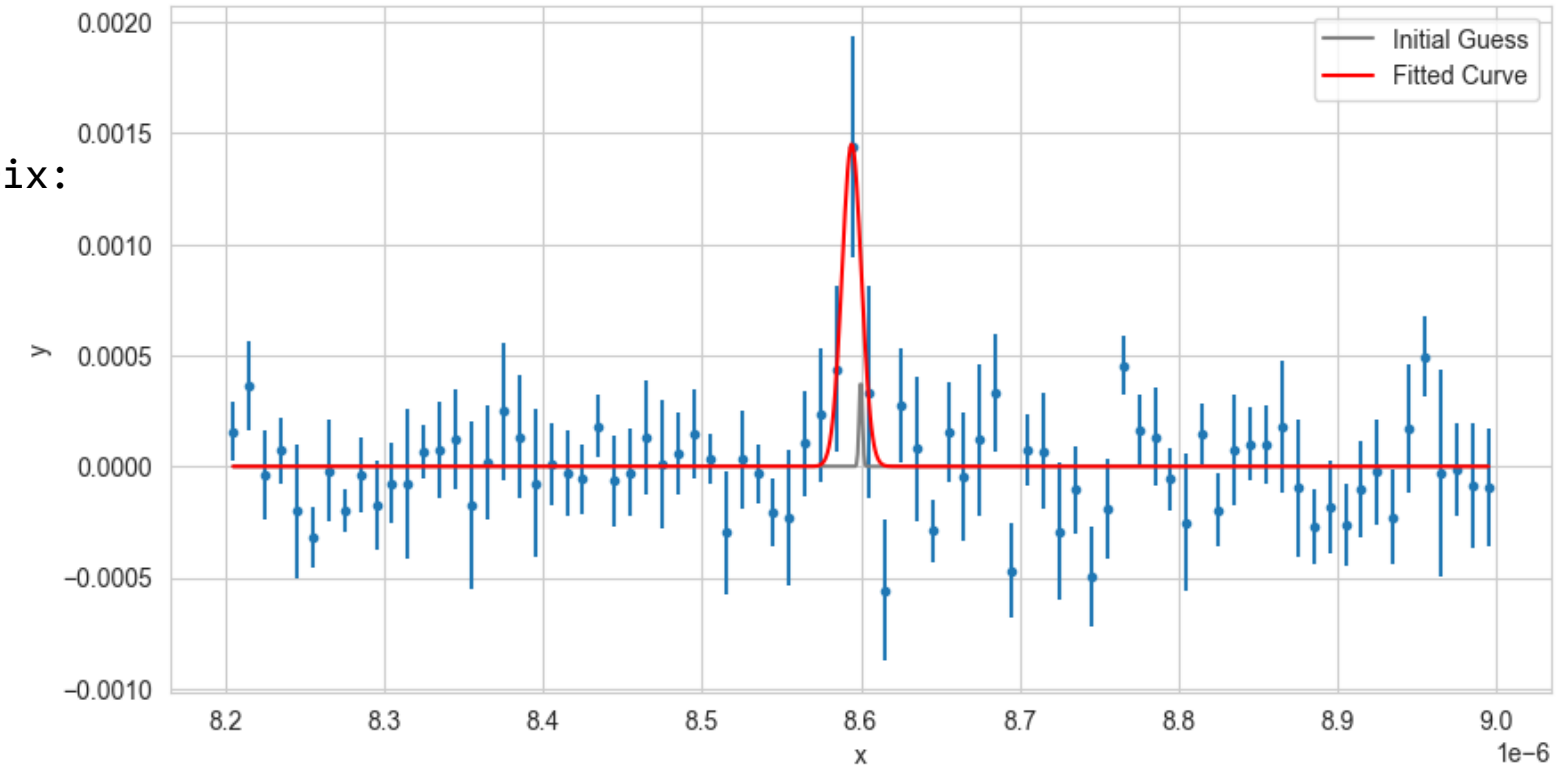
Fit peak 3

```
Ampl:    2.2571783350020673e-11
mu:      7.828205784278358e-06
sigma:   4.9195665582314 43e-09
Condition number of the covariance matrix:
2.653078e+05
Diagonal values of pcov:
Cov of Ampl:     9.9185094346044 18e-23
Cov of mu:       1.1099287629088822e-17
Cov of sigma:    1.6751599465640 01e-17
Chi-2: 100.75902125502019
dof:     97
Reduced Chi^2:   1.038752796443507
Goodness-of-Fit: 0.37668171442373555
R-squared: 0.24806923117657498
```



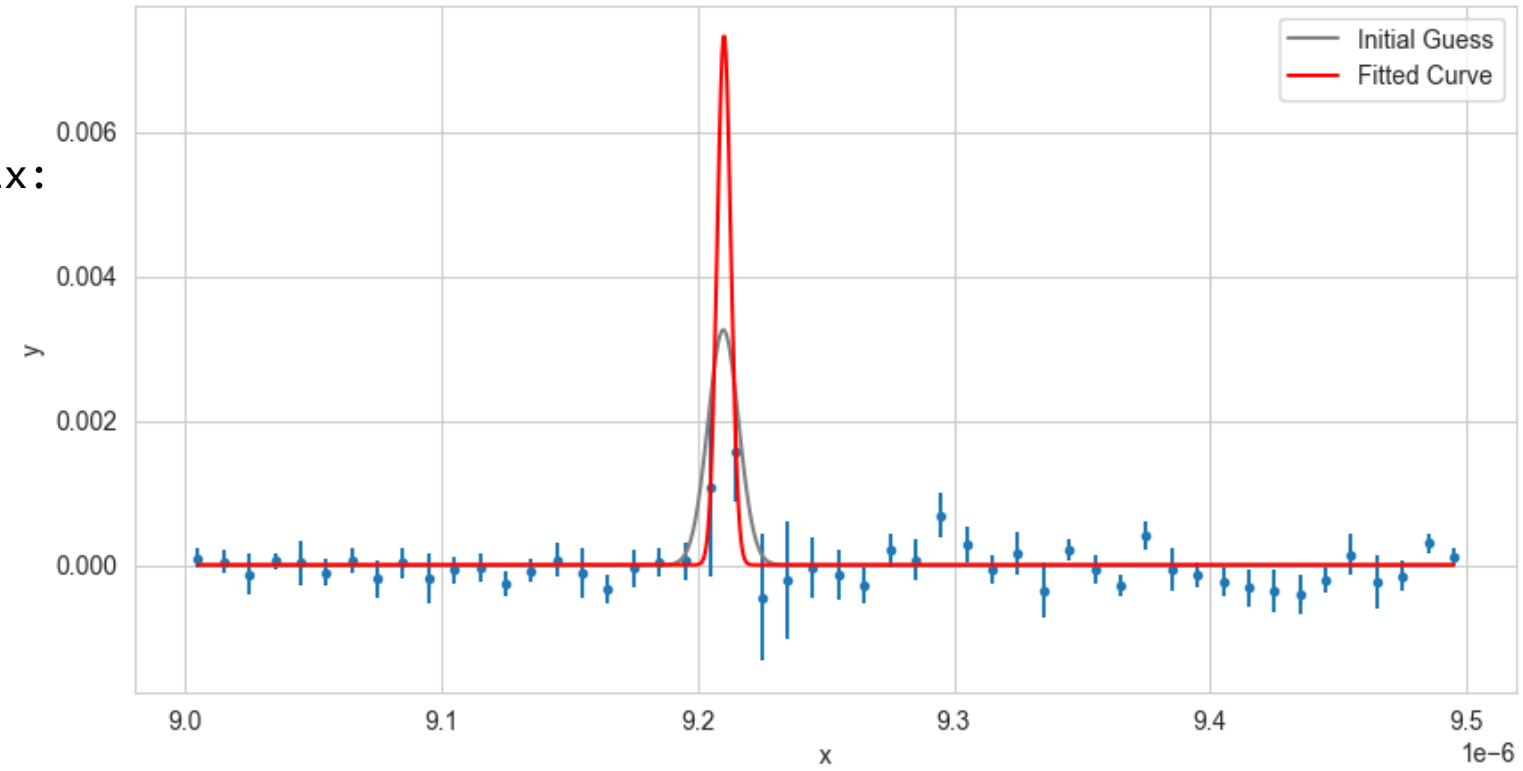
Fit peak 4

```
Ampl:    2.202244375854298e-11
mu:      8.59424144958621e-06
sigma:   6.053167153929765e-09
Condition number of the covariance matrix:
2.201885e+05
Diagonal values of pcov:
Cov of Ampl:     6.904312349023149e-23
Cov of mu:       9.619922172172431e-18
Cov of sigma:    4.698948120480374e-18
Chi-2: 80.22716921116354
dof:     77
Reduced Chi^2:   1.0419112884566695
Goodness-of-Fit: 0.3782515895528433
R-squared: 0.43592900325018913
```



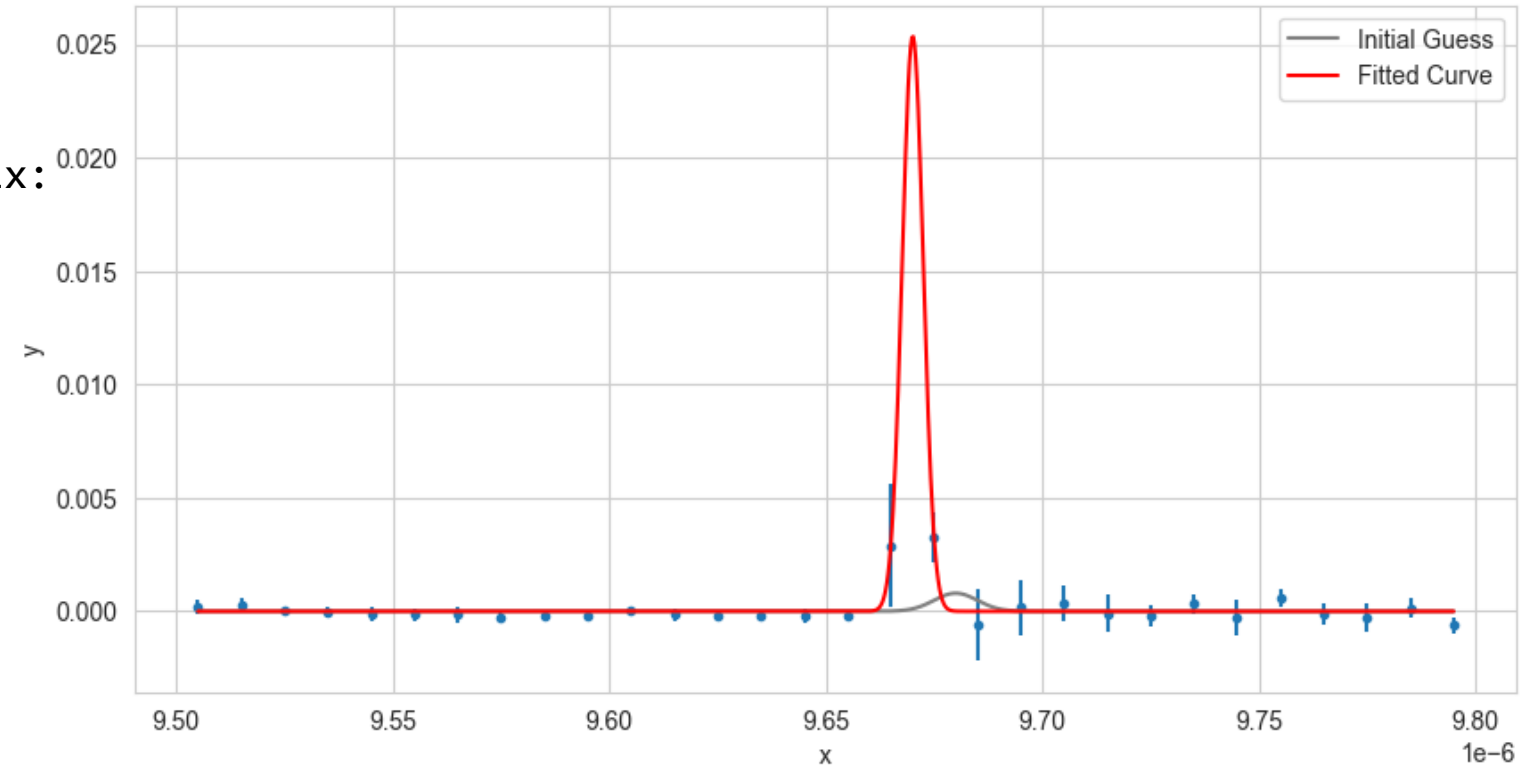
Fit peak 5

```
Ampl:    4.948678504554753e-11
mu:      9.2102758034460 27e-06
sigma:   2.6862397018008648e-09
Condition number of the covariance matrix:
1.472274e+12
Diagonal values of pcov:
Cov of Ampl:     1.0450983148418668e-12
Cov of mu:       2.2651142942187172e-11
Cov of sigma:    5.335298273378329e-10
Chi-2: 43.95222989651178
dof:     47
Reduced Chi^2:   0.935153827585357
Goodness-of-Fit: 0.5995605183798407
R-squared: 0.5944042576367041
```

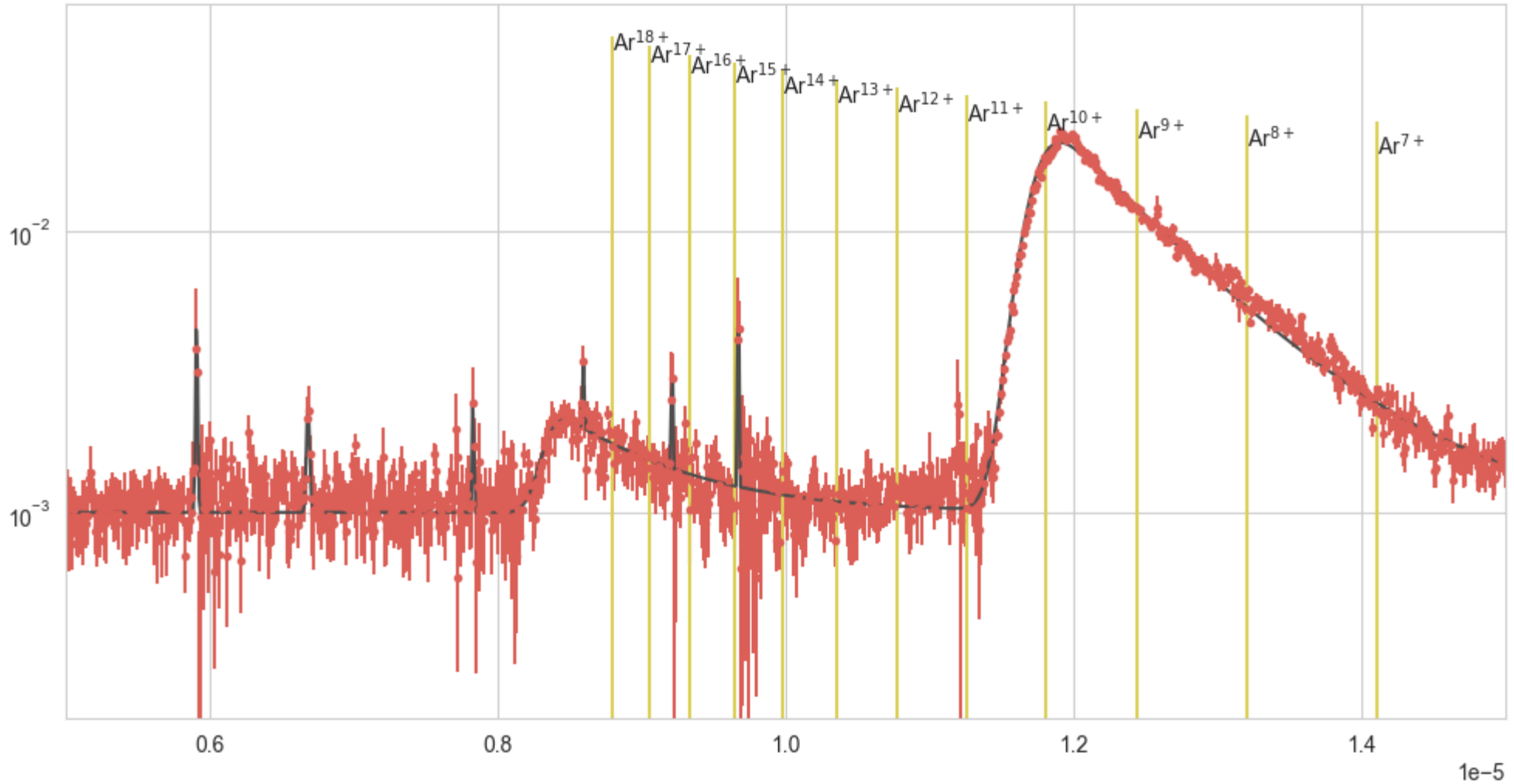


Fit peak 6

```
Ampl:    1.5489438673217272e-10
mu:      9.670075314615215e-06
sigma:   2.435860185246073e-09
Condition number of the covariance matrix:
3.730049e+12
Diagonal values of pcov:
Cov of Ampl:     1.8137502052340 67e-10
Cov of mu:       1.6855579518961853e-11
Cov of sigma:    4.400135104050403e-09
Chi-2: 14.629929003255612
dof:     27
Reduced Chi^2:   0.5418492223428004
Goodness-of-Fit: 0.9743086685755981
R-squared: 0.8993995736270128
```



How does the fit look?



Peaks summary

$m/q|_w$ is a weighted average of the annihilation, with weights proportional to the trappable yield of fragments within the peak window

Total trappable average from annihilations:

$$\langle m/q \rangle\Big|_{^{40}Ar} = 2.16476$$

$$\langle m/q \rangle\Big|_{^{197}Au} = 2.46730$$

Peak	Mu [us]	Sigma [us]	m/q	m/q std	Ar40 frag.		Au197 frag.		Ions	
					$m/q\Big\|_w$	$\Delta m/q$ [%]	$m/q\Big\|_w$	$\Delta m/q$ [%]	m/q	$\Delta m/q$ [%]
1	5.9081	0.0063	1.00077	0.01373	-[0]	-	-[0]	-	-[0]	-
2	6.6819	0.0104	1.28007	0.01780	-	-	-	-	-	-
3	7.8282	0.0049	1.75697	0.02391	1.75423[1]	0.15	1.75423[1]	0.15	-	-
4	8.5942	0.0061	2.11765	0.02886	2.11282	0.22782	-	-	2.13147[2]	0.65271
5	9.2103	0.0027	2.43212	0.03299	-	-	2.44126	0.37579	2.45939[3]	1.12143
6	9.6701	0.0024	2.68101	0.03636	-	-	-	-	2.66416[4] 2.66434[5] 2.66582[6]	0.62858 0.62185 0.56665

[0] This is most likely an antiproton m/q=1.00782

[1] This value is for $^{7}Be^{4+}$, but it isn't formed with low enough energy

[2] $^{32}S^{15+}$

[3] $^{32}S^{13+}$

[4] $^{40}Ar^{15+}$

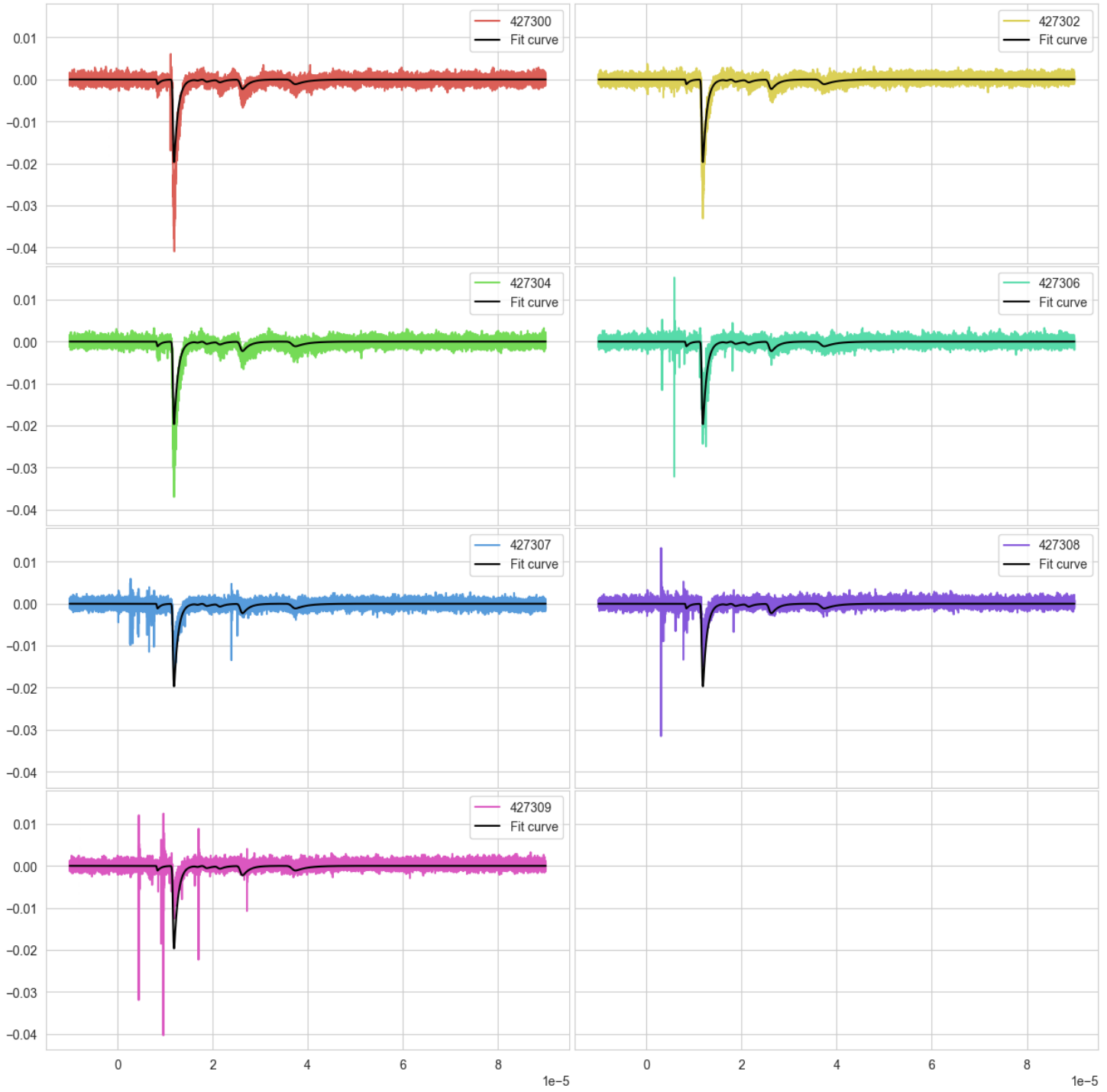
[5] $^{32}S^{12+}$

[6] $^{16}O^{6+}$

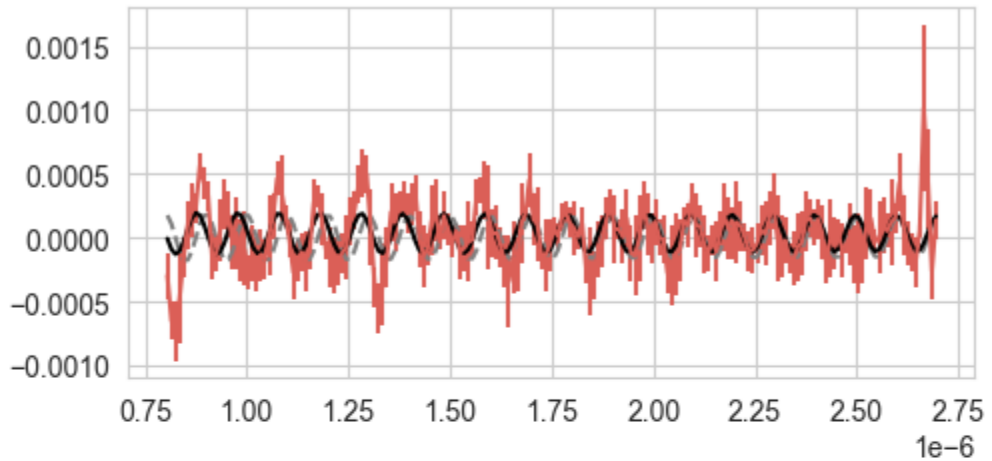
I have no idea what the peak 2 is. The closest I found was $^{3}He^{2+}$ with m/q=1.5080, from produced by annihilations on ^{40}Ar or ^{197}Au

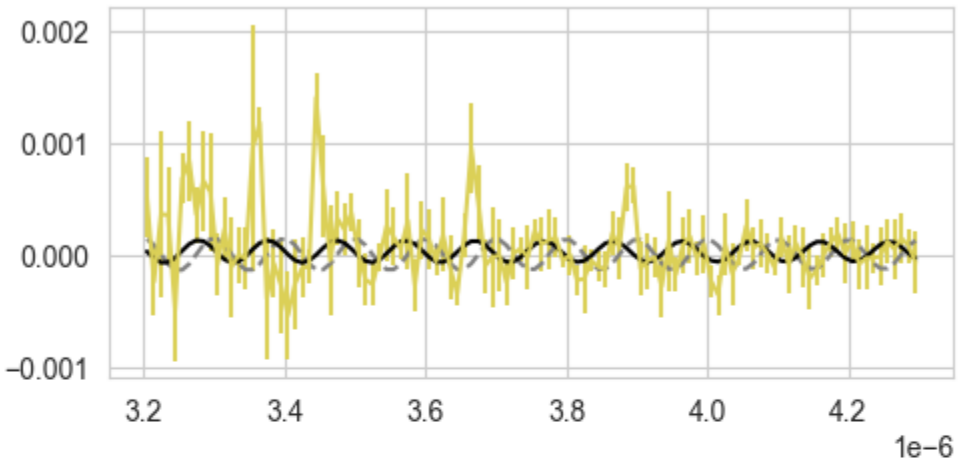
On the subject of background

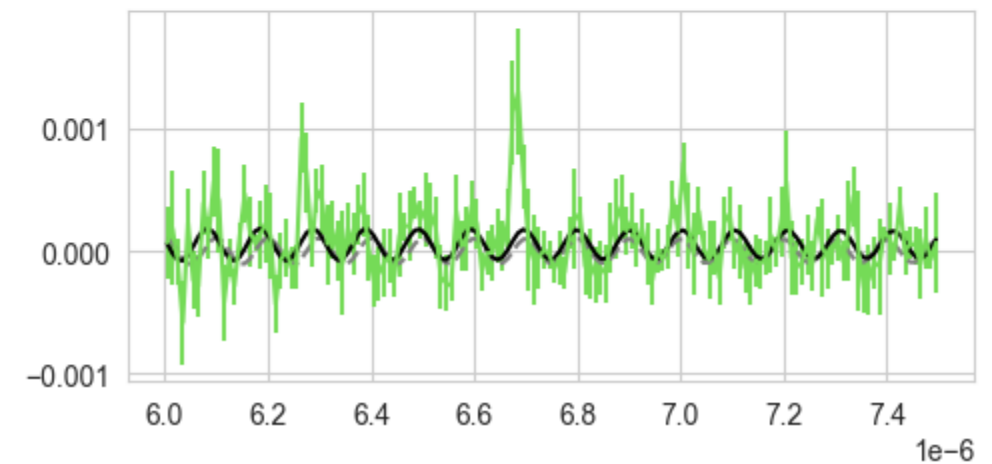
The captorius signal suffers from a lot of “ringing” that is present after any spike on the MCP. In the fitting of the baseline, Marco deals with the ringing from the biggest peak and removes it by fitting an exponential suppressed sinusoidal function. In general, this can be done for any spike present in the signal.

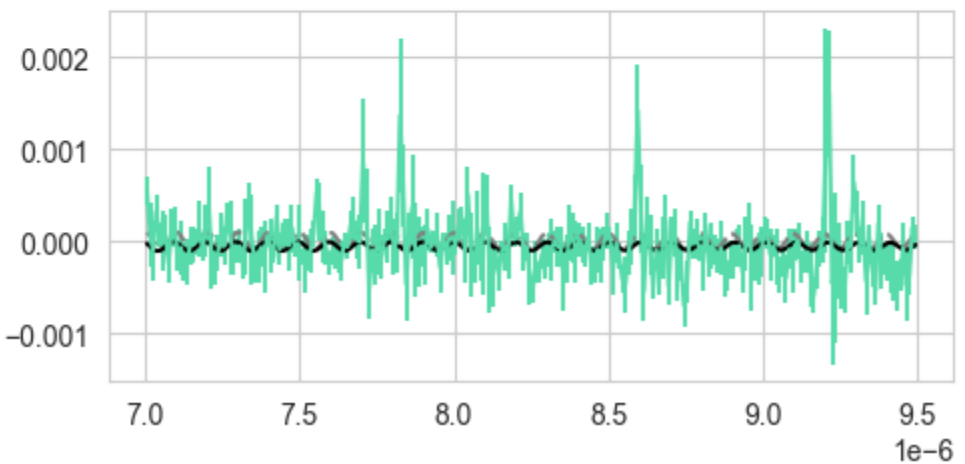


I have fitted the signal in the region just after the biggest peaks before the $^{4}He^{1+}$ peak, and below are the functions. After each fit, the signal is corrected so the next fit is done on the corrected signal.









This is what the ringing signal from the fits looks like on top of the original data. This doesn't change much. The peaks are best fitted with the same parameters. It would probably be best to remove the ringing in an earlier stage and perform the "ringing" fits on the run bases (before combining the 7 runs into one signal). I believe that this can yield a better result as the earlier peaks show up at different locations between the runs.