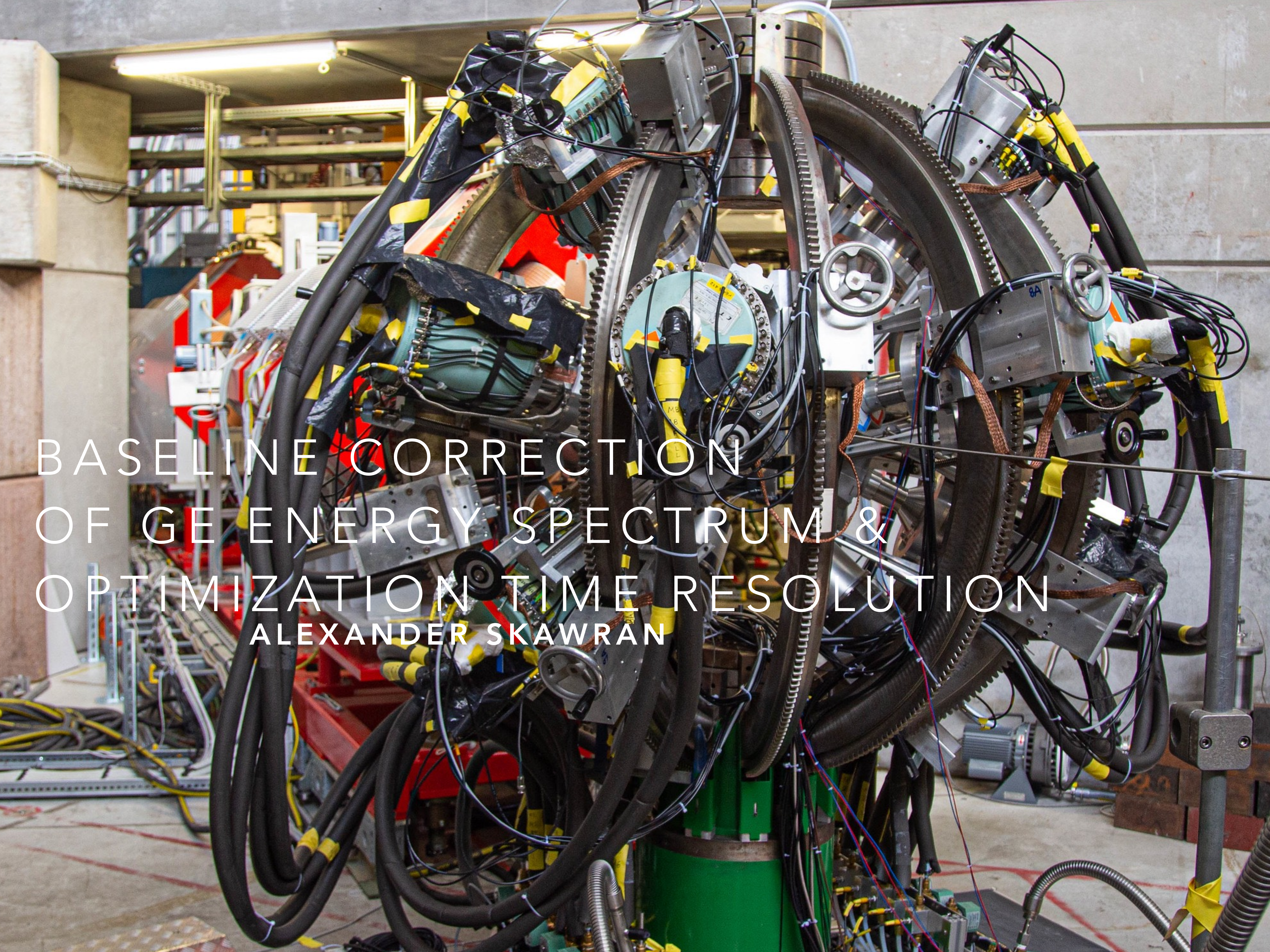
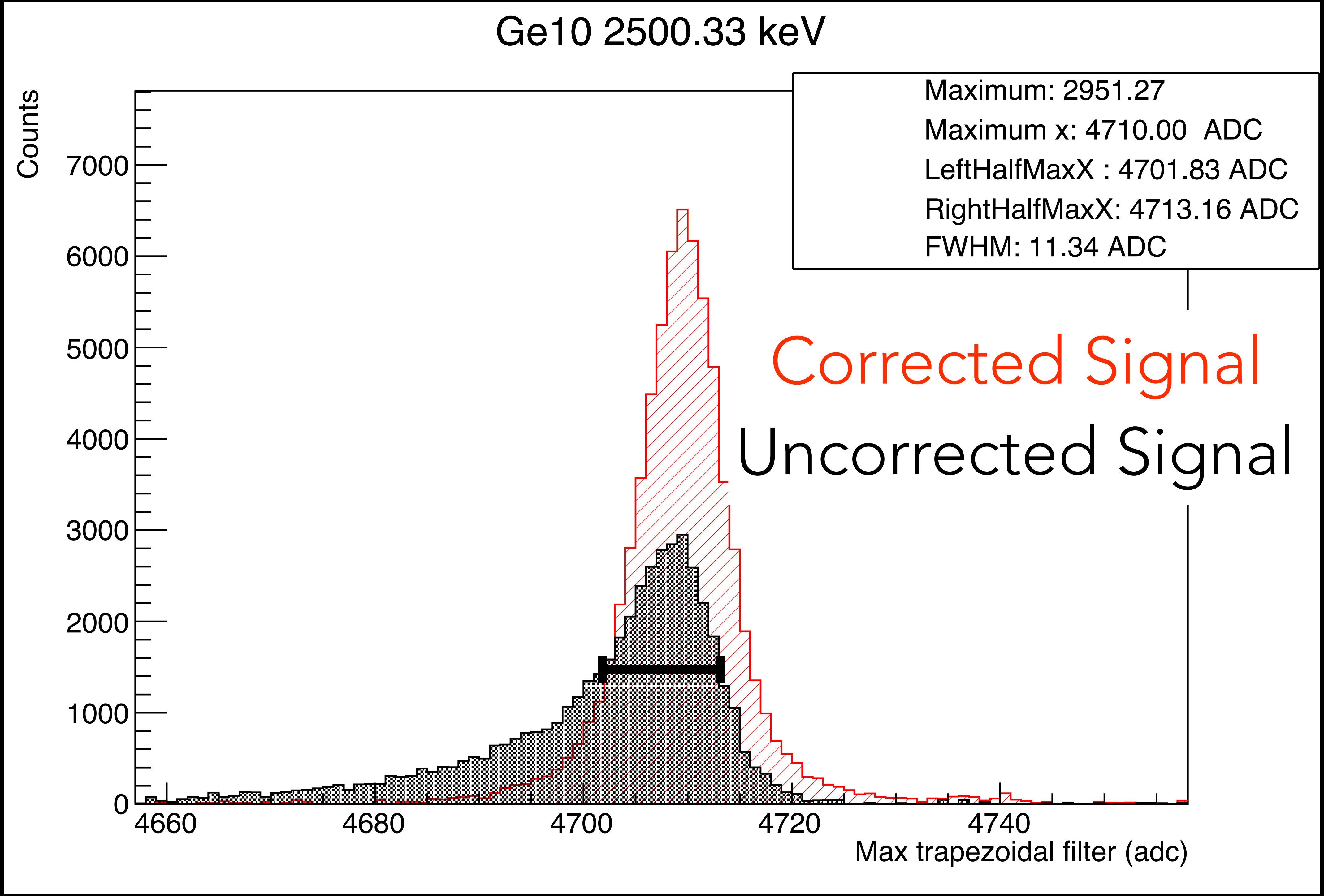


BASELINE CORRECTION OF GE ENERGY SPECTRUM & OPTIMIZATION TIME RESOLUTION

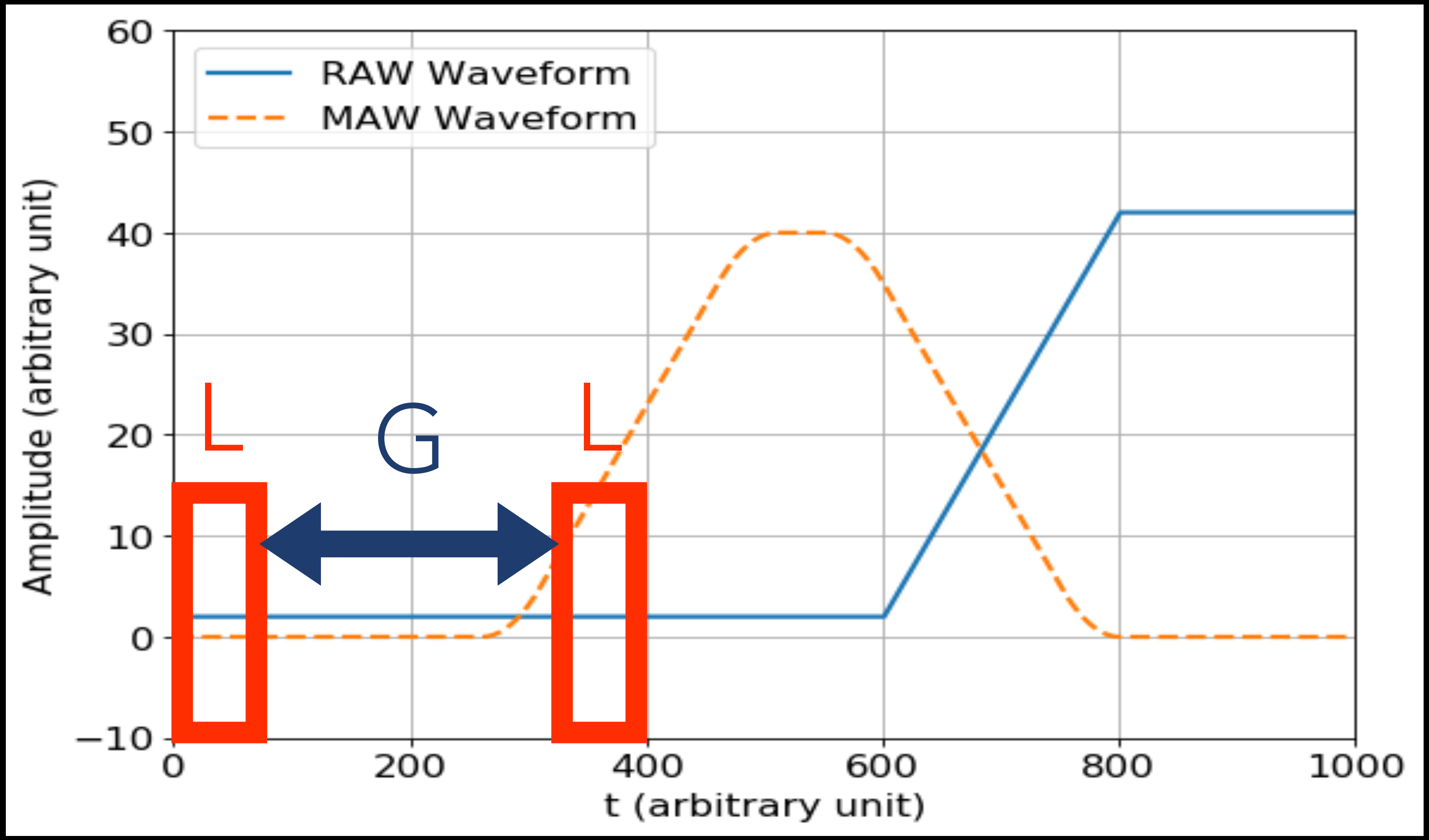
ALEXANDER SKAWRAN

AIM

IMPROVE SIGNAL SHAPE OF HIGH GAMMA RATE MEASUREMENT



MEASURED WAVEFORM



MAW FILTER IS APPLIED TO REDUCE NOISE EFFECTS:

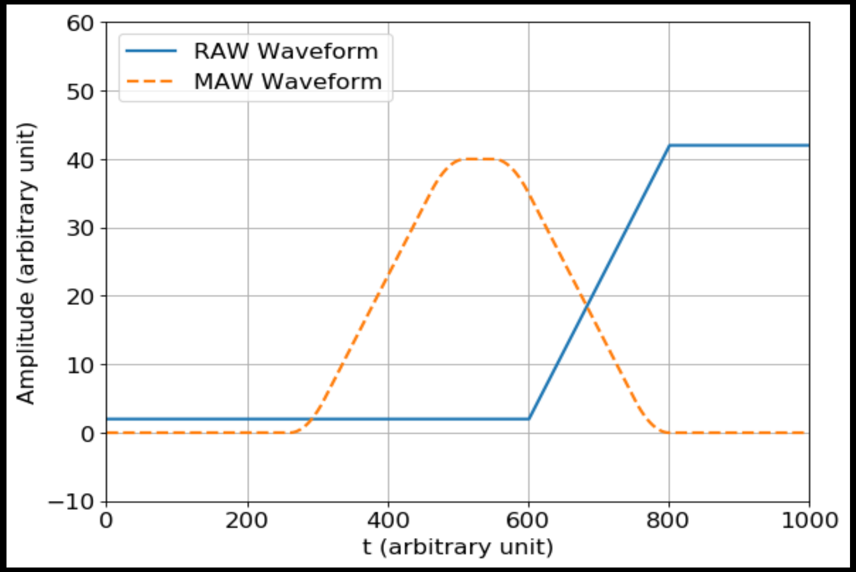
$$a_1[i] = \frac{1}{L}\sum_{n=0}^{n=L-1} V[i+n]$$

$$a_2[i] = \frac{1}{L}\sum_{n=0}^{n=L-1} V[i+n+L+G].$$

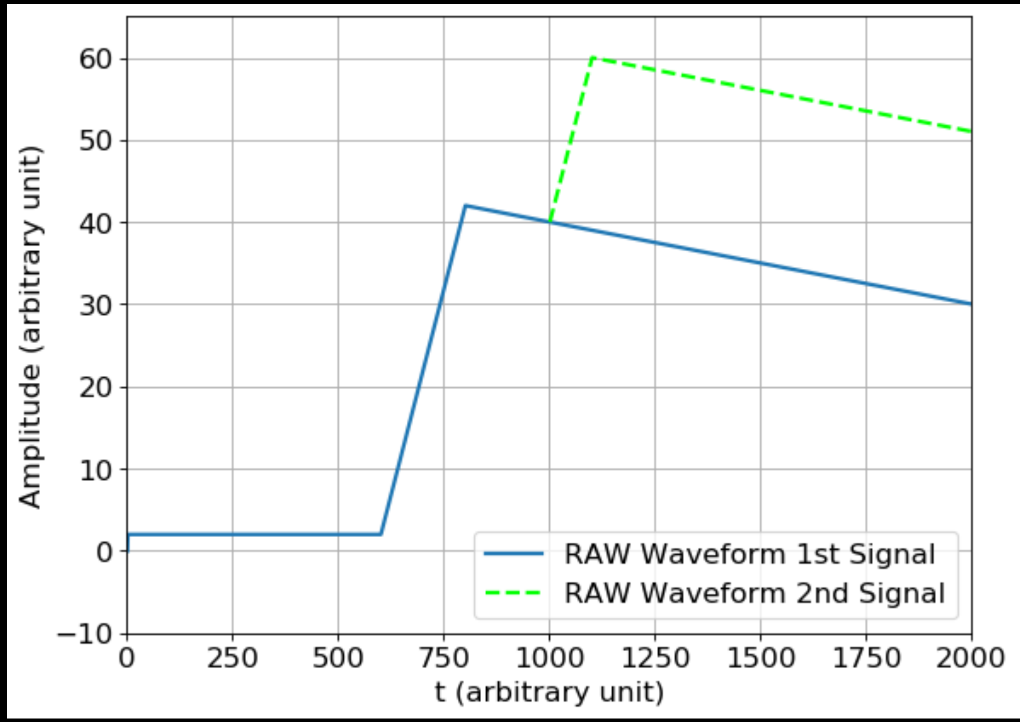
$$MAW[i] = a_2[i] - a_1[i].$$

BASELINE SHIFT

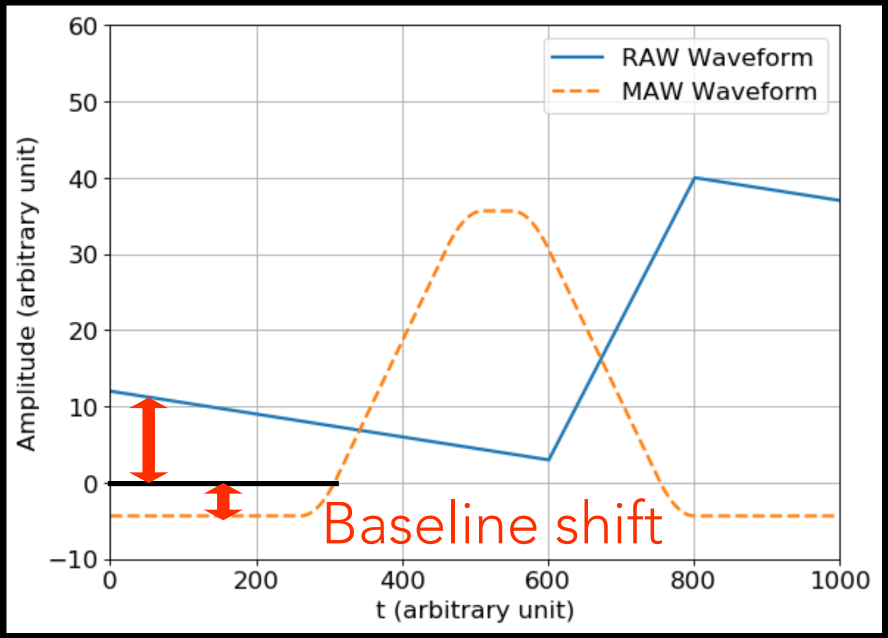
MAW FILTER IS APPLIED
TO REDUCE NOISE EFFECTS



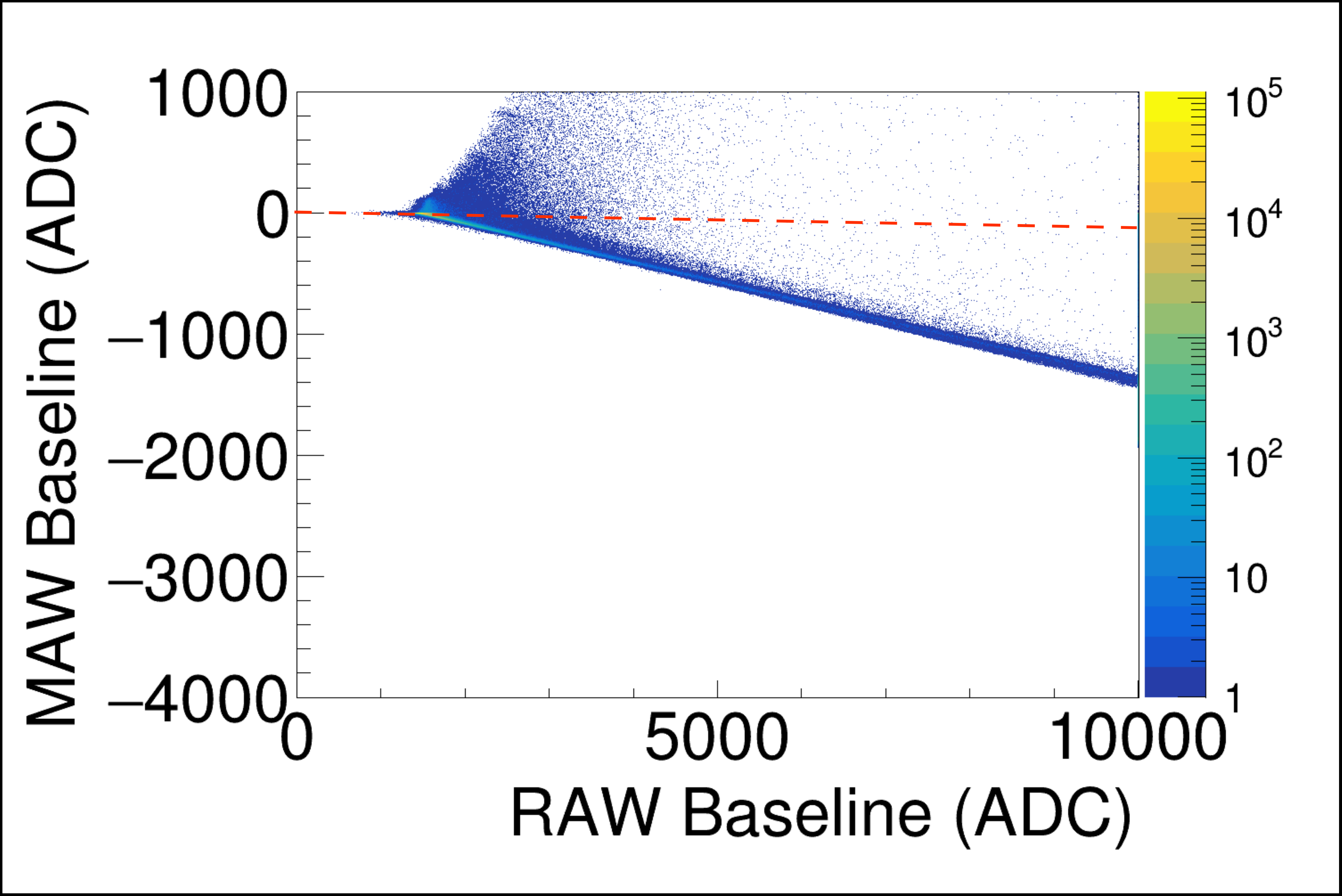
Detected RAW Signals by Ge Detector



OVERLAP OF DECAY SLOPE AND
NEW SIGNAL CREATES AN BASELINE SHIFT

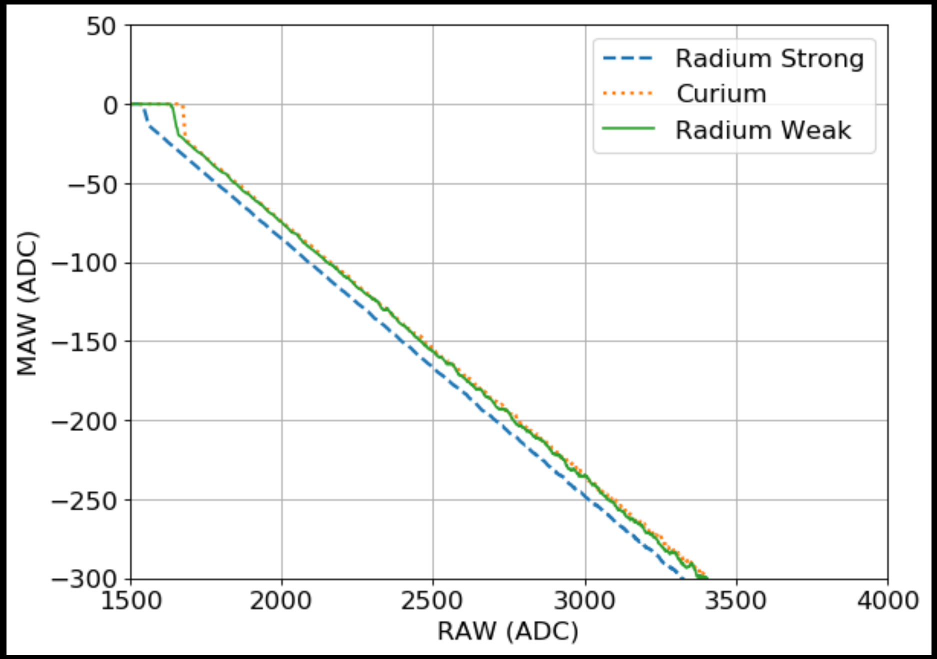


CORRELATION RAW/MAW BASELINES

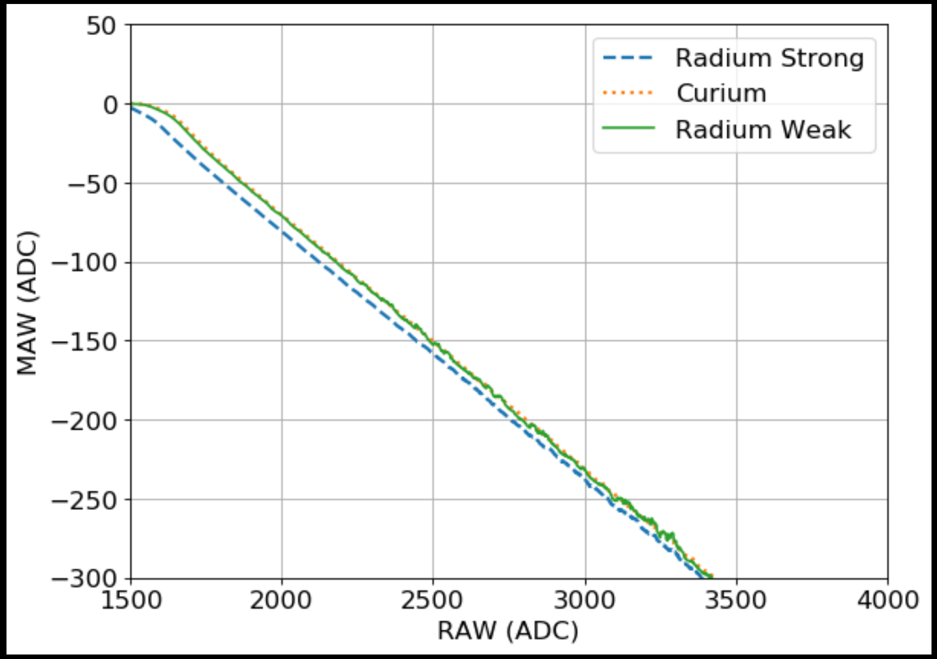


CORRECTION METHODS

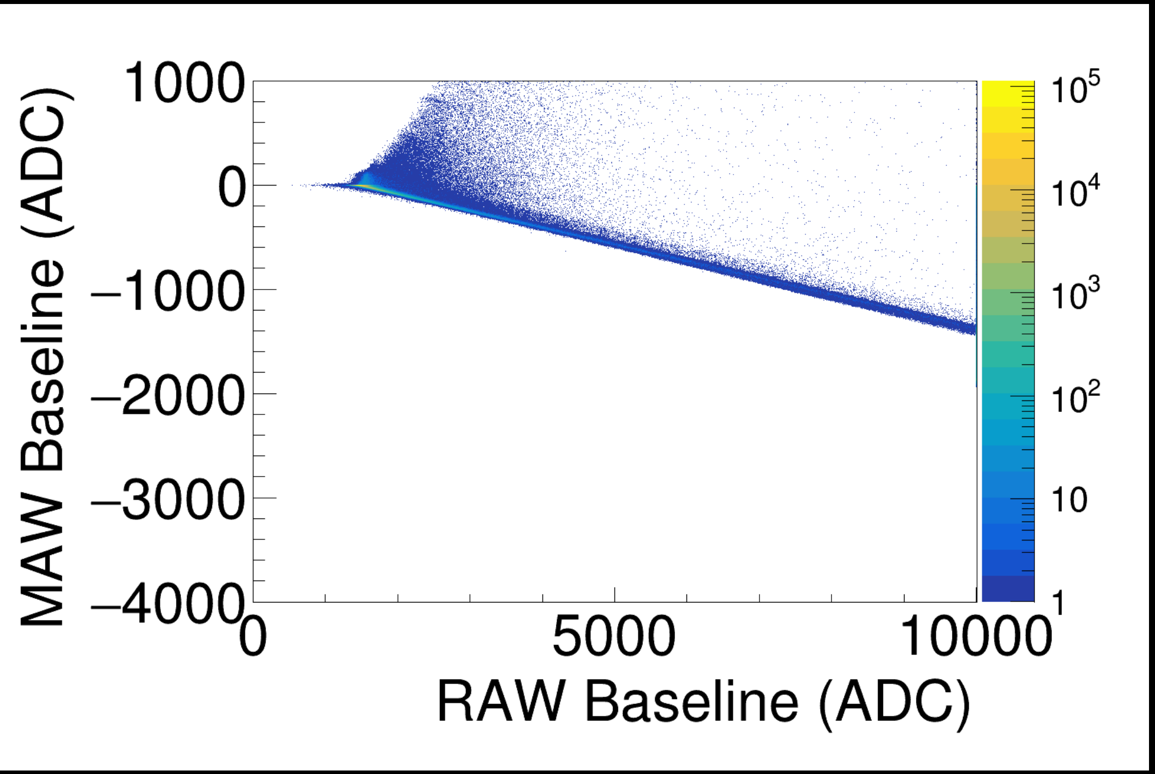
Maximum value



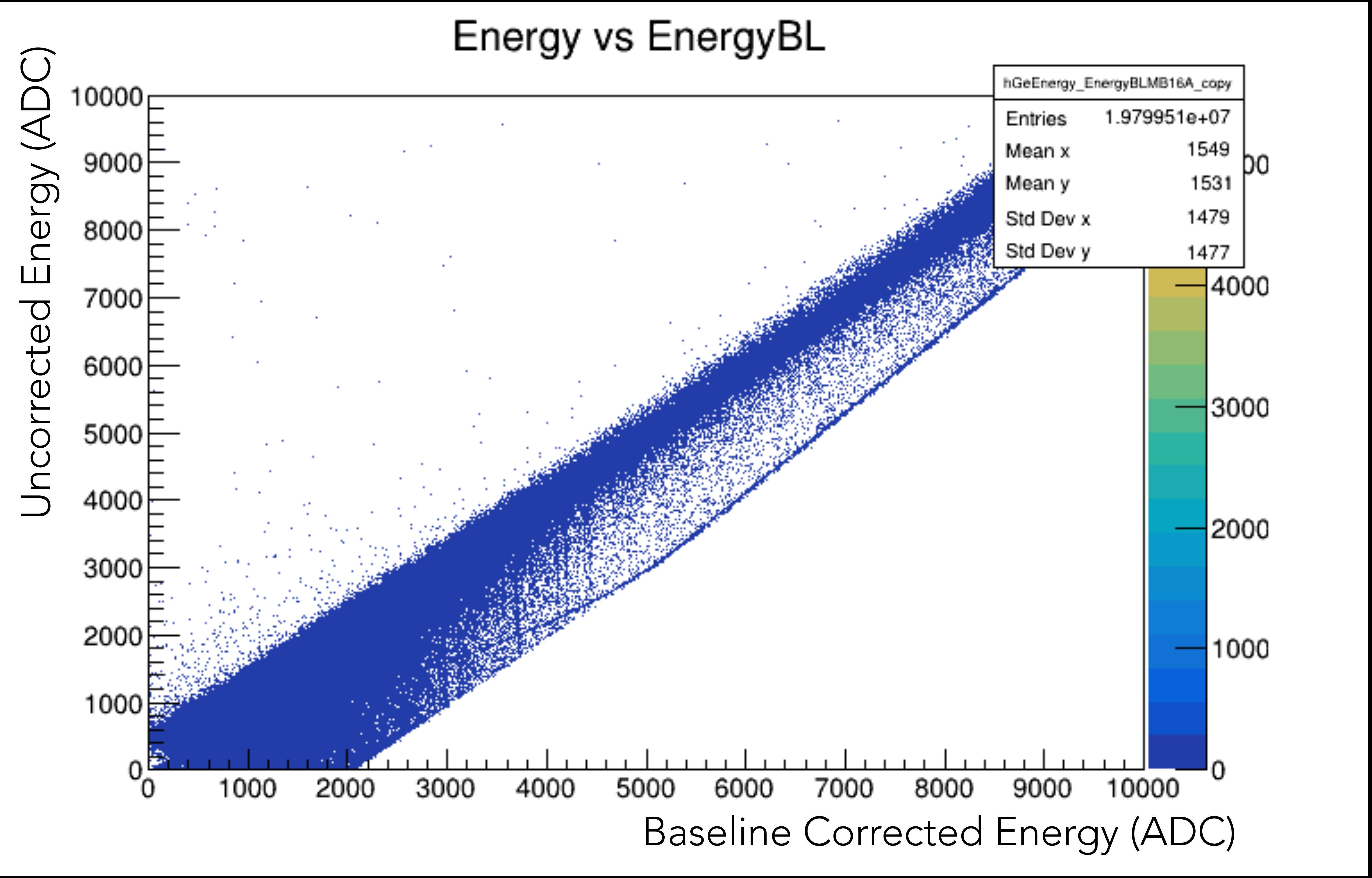
Mean value



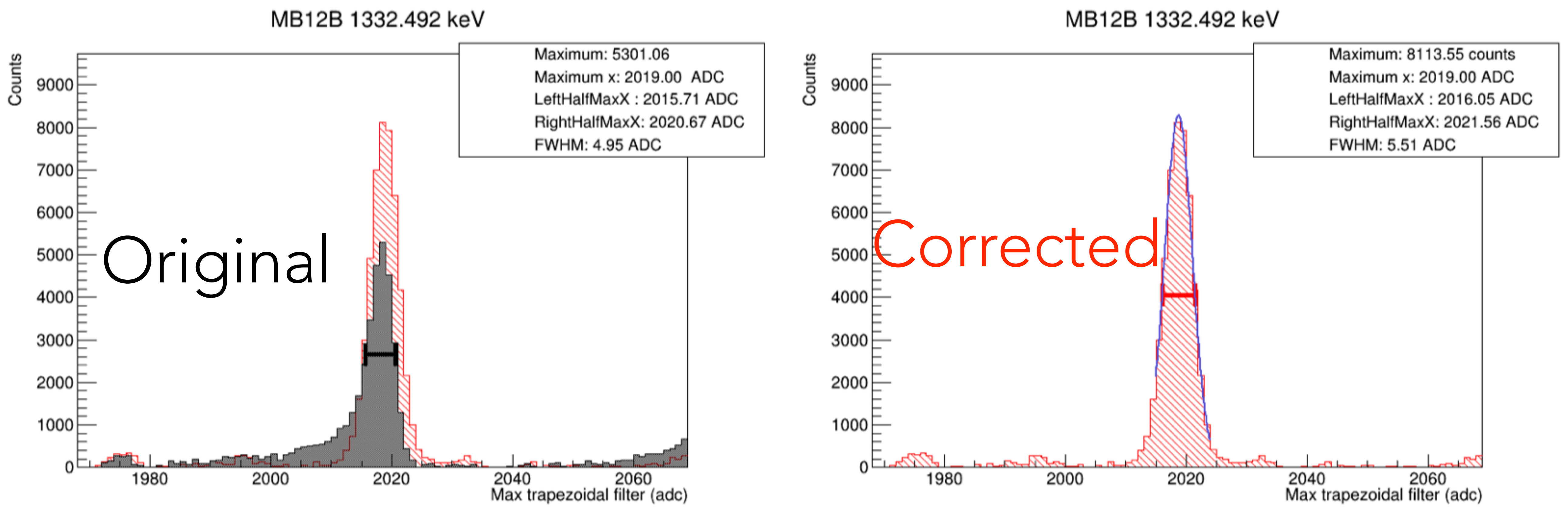
Direct Subtraction



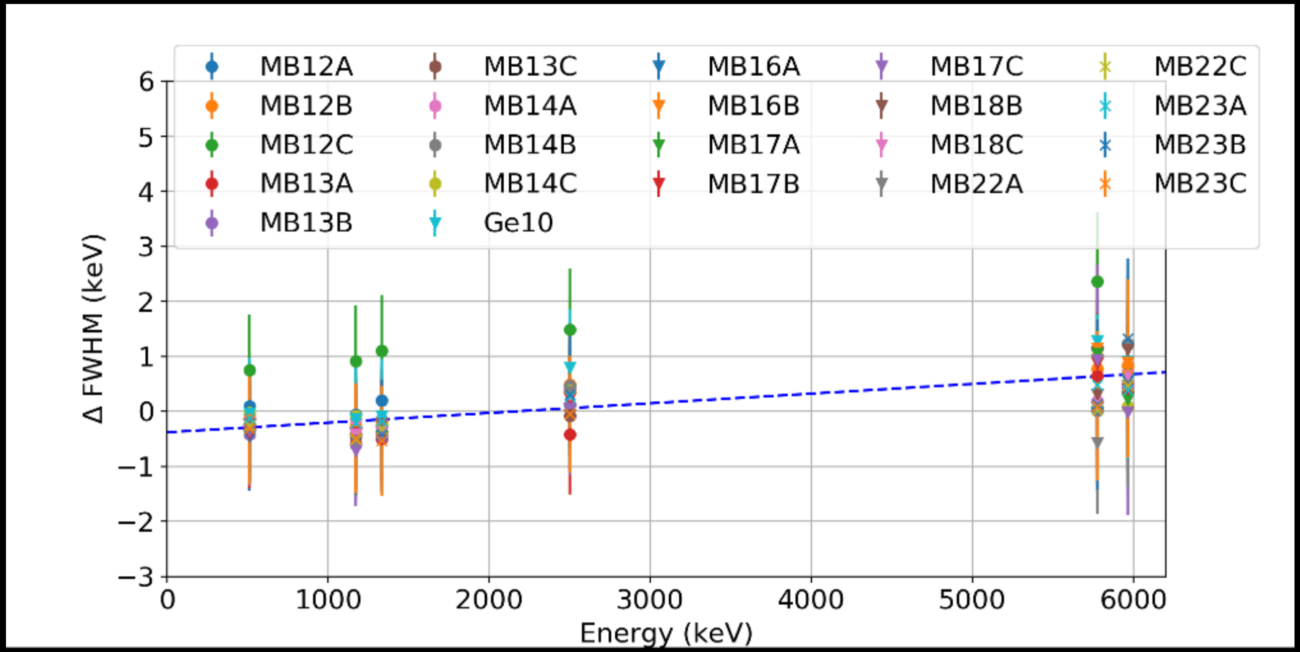
CORRECTION RANGE

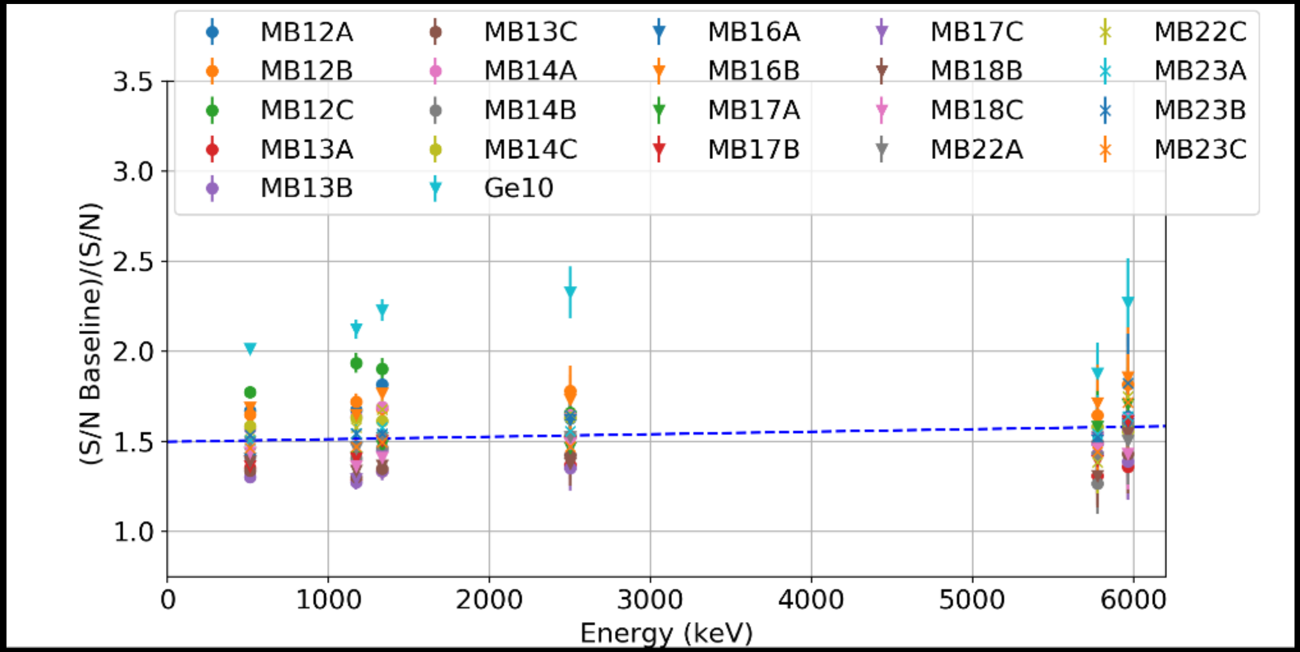


EFFECT OF BASELINE CORRECTION



OVERVIEW BASELINE CORRECTION EFFECT

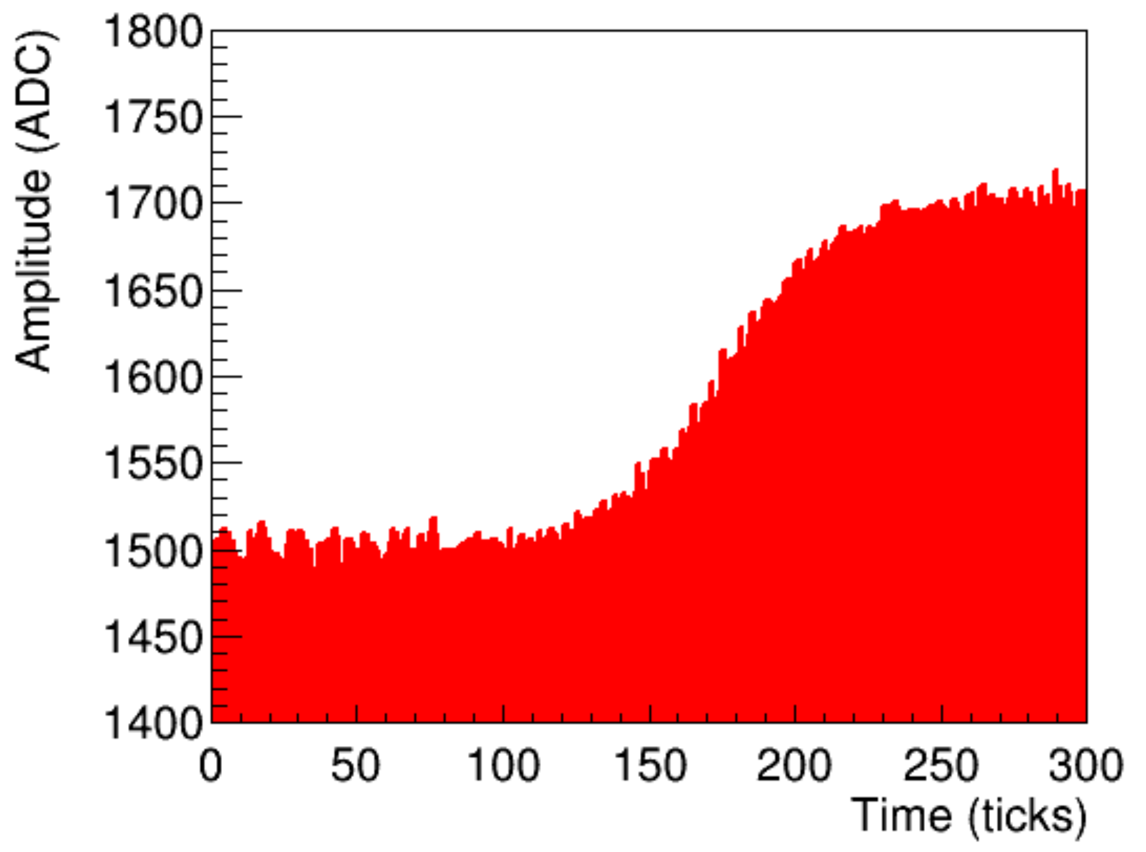


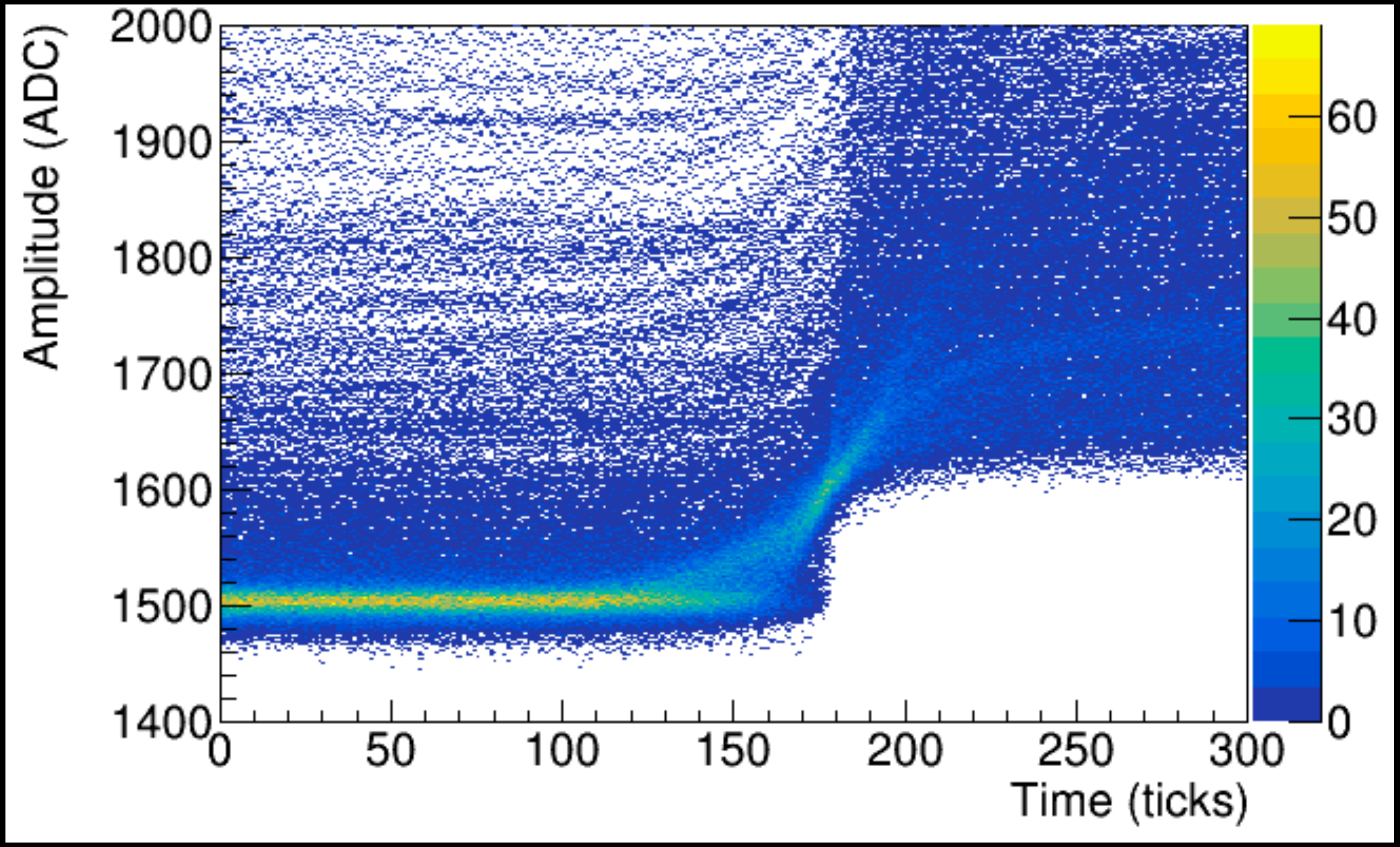


Delta FWHM > 0:
Improvement of resolution
Delta FWHM < 0:
Worsening of resolution

Improvement Signal/Noise

TIMING

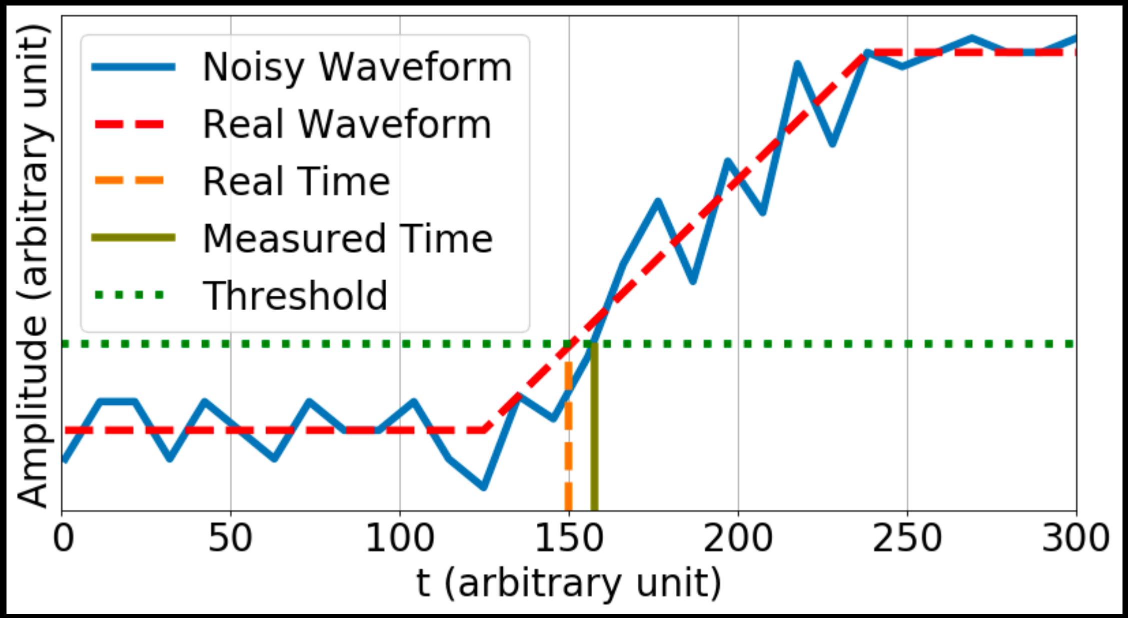




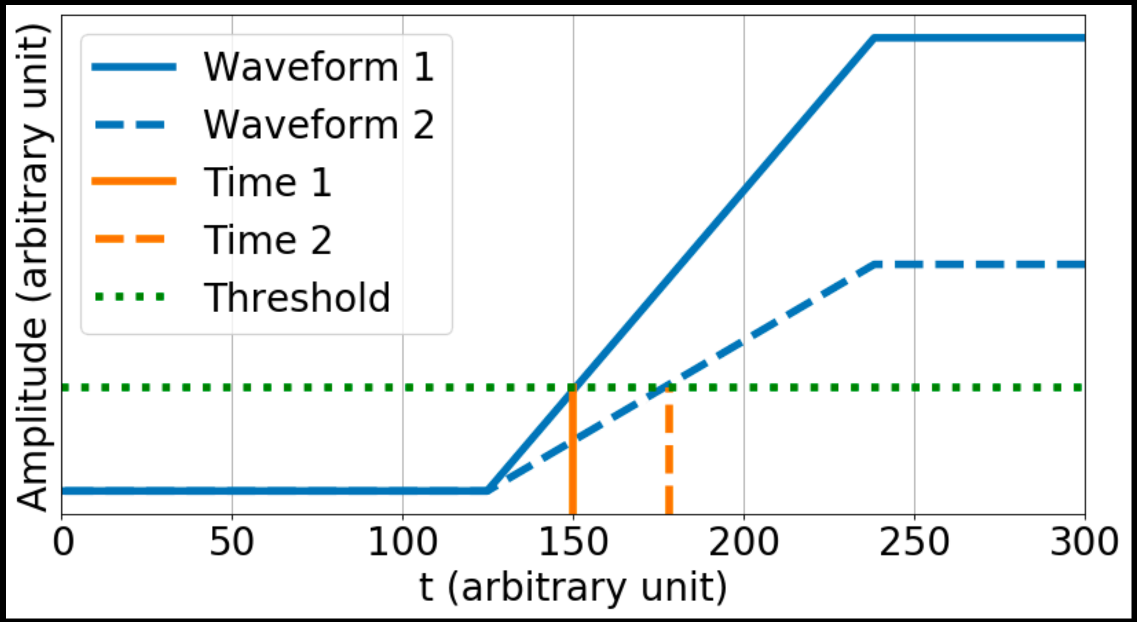
Example of a Single RAW waveform

Distribution of RAW waveforms

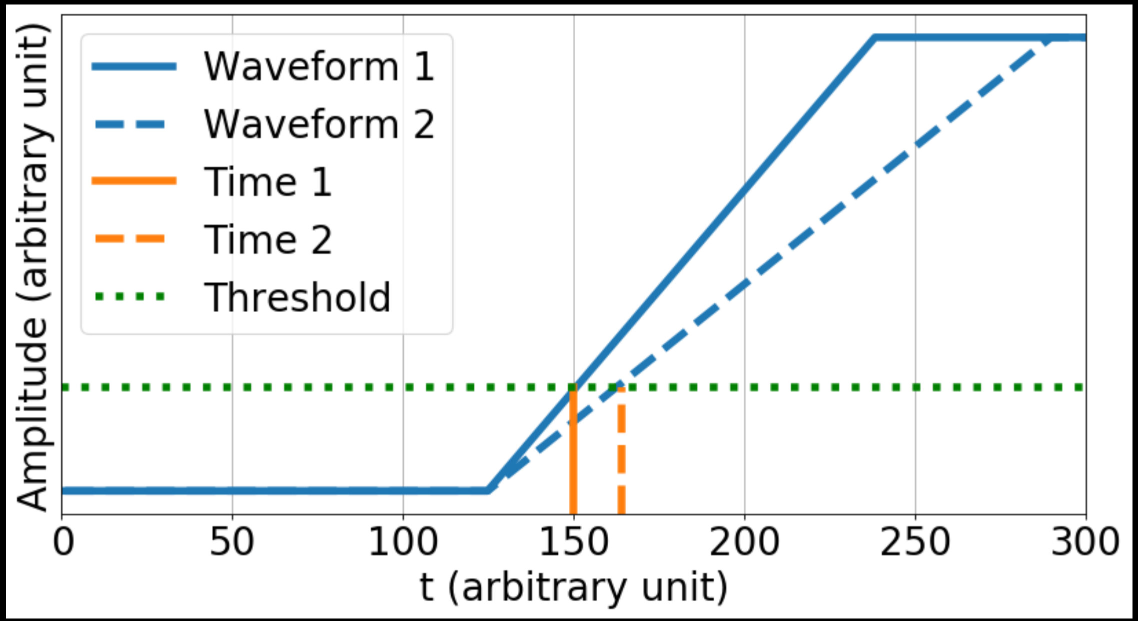
TIMING-PROBLEMS TIME DETERMINATION



Jitter Effect

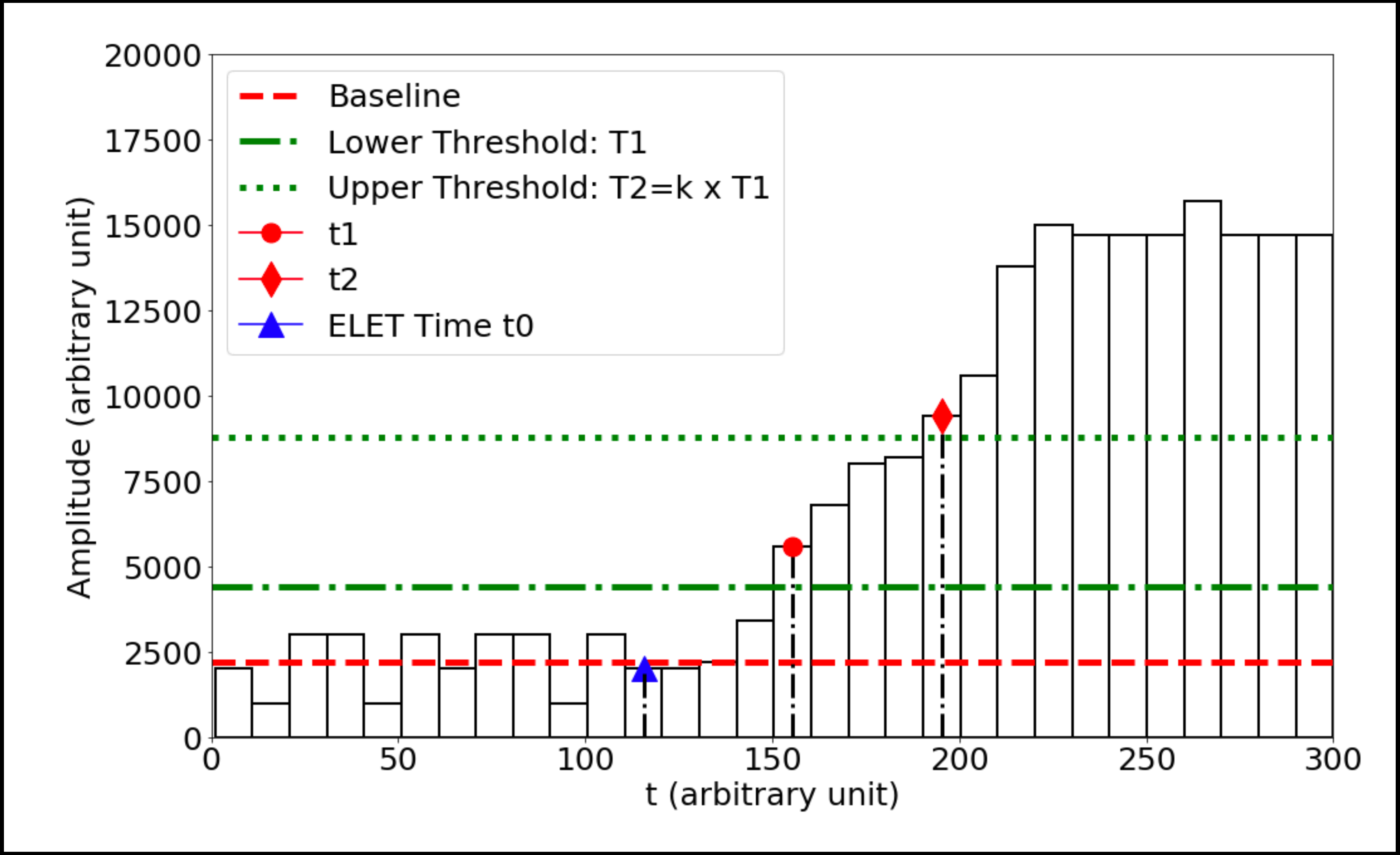


Amplitude Walk



Time Walk

TIMING



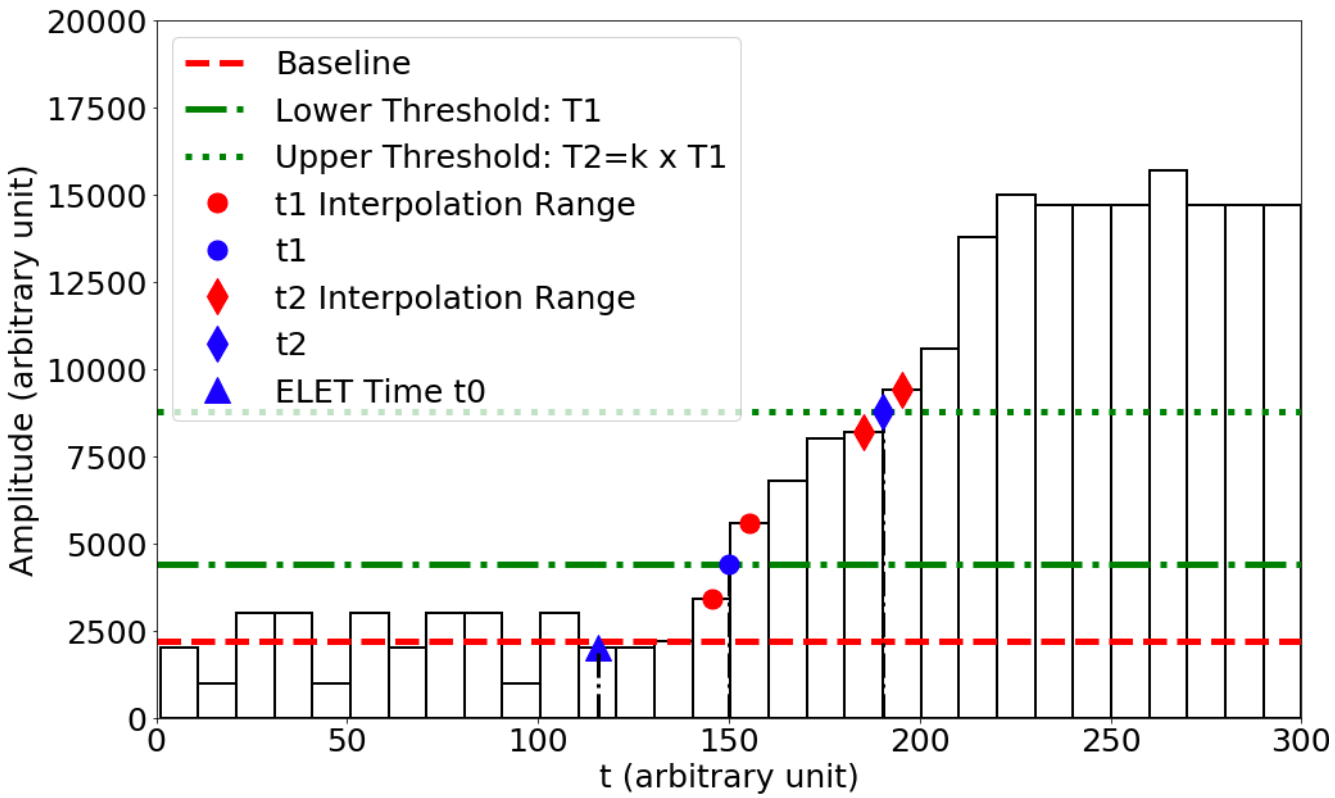
$$\Delta t = t_1 - t_0$$

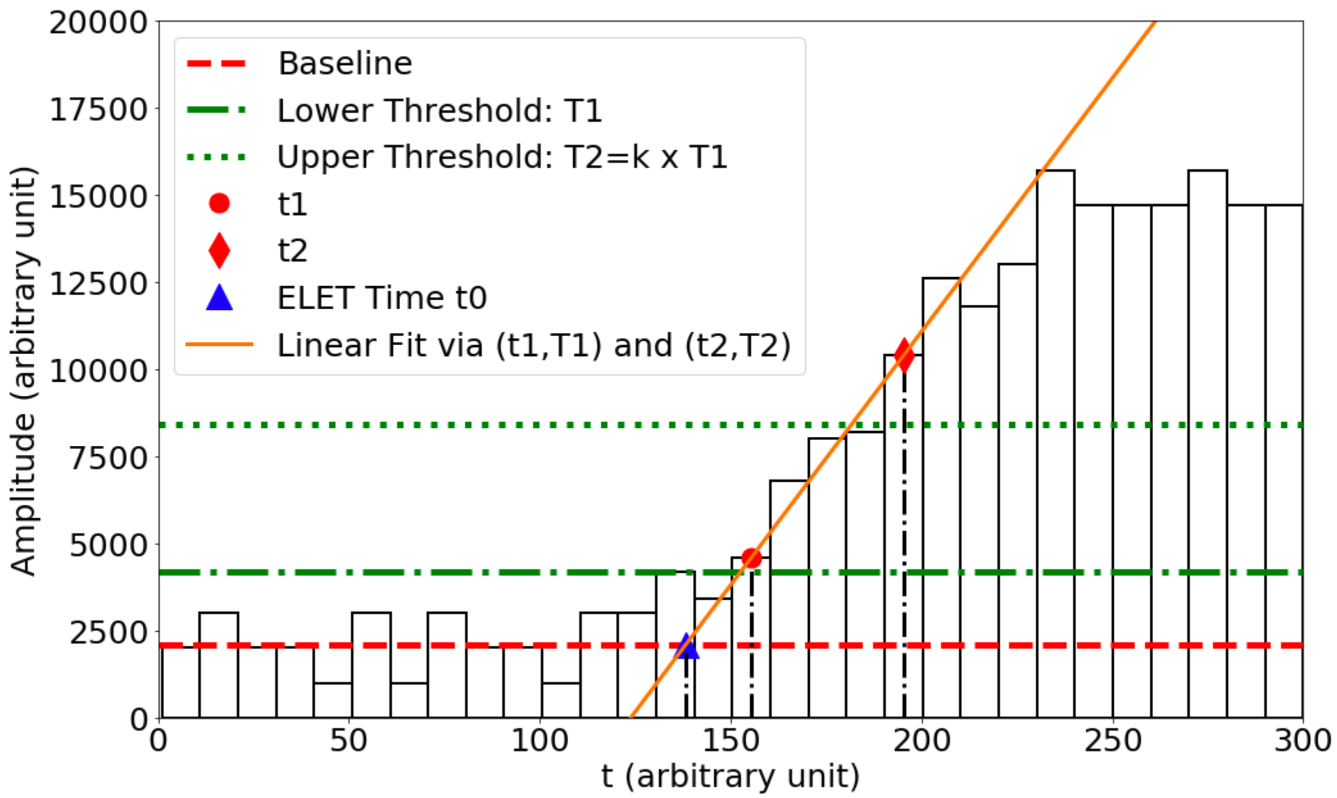
$$\Delta t = t_2 - t_1$$

$$t_0 = 2t_1 - t_2$$

So far, the time was determined by the ELET algorithm.

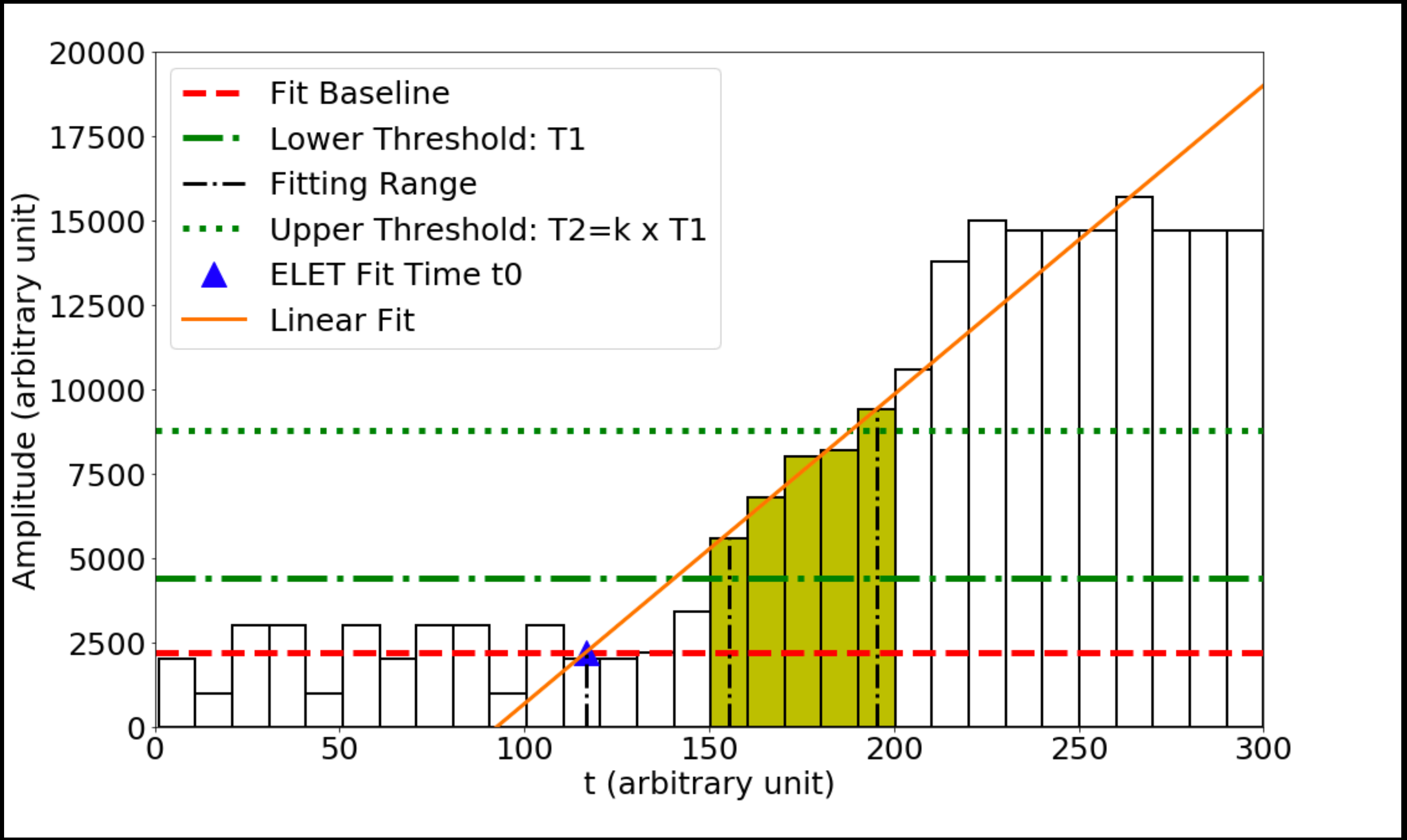
TIMING IMPROVEMENTS





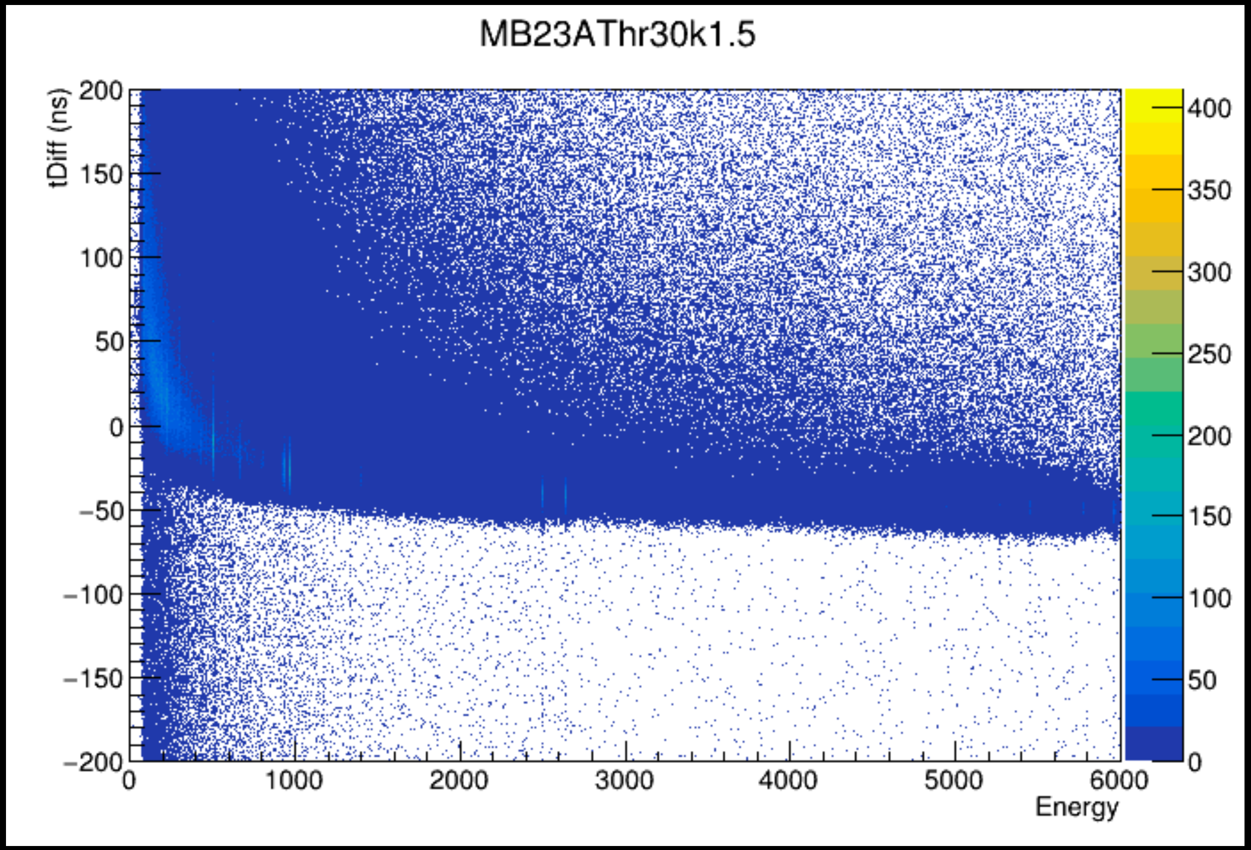
The algorithm can be improved by interpolation or a proper fit using the two points.

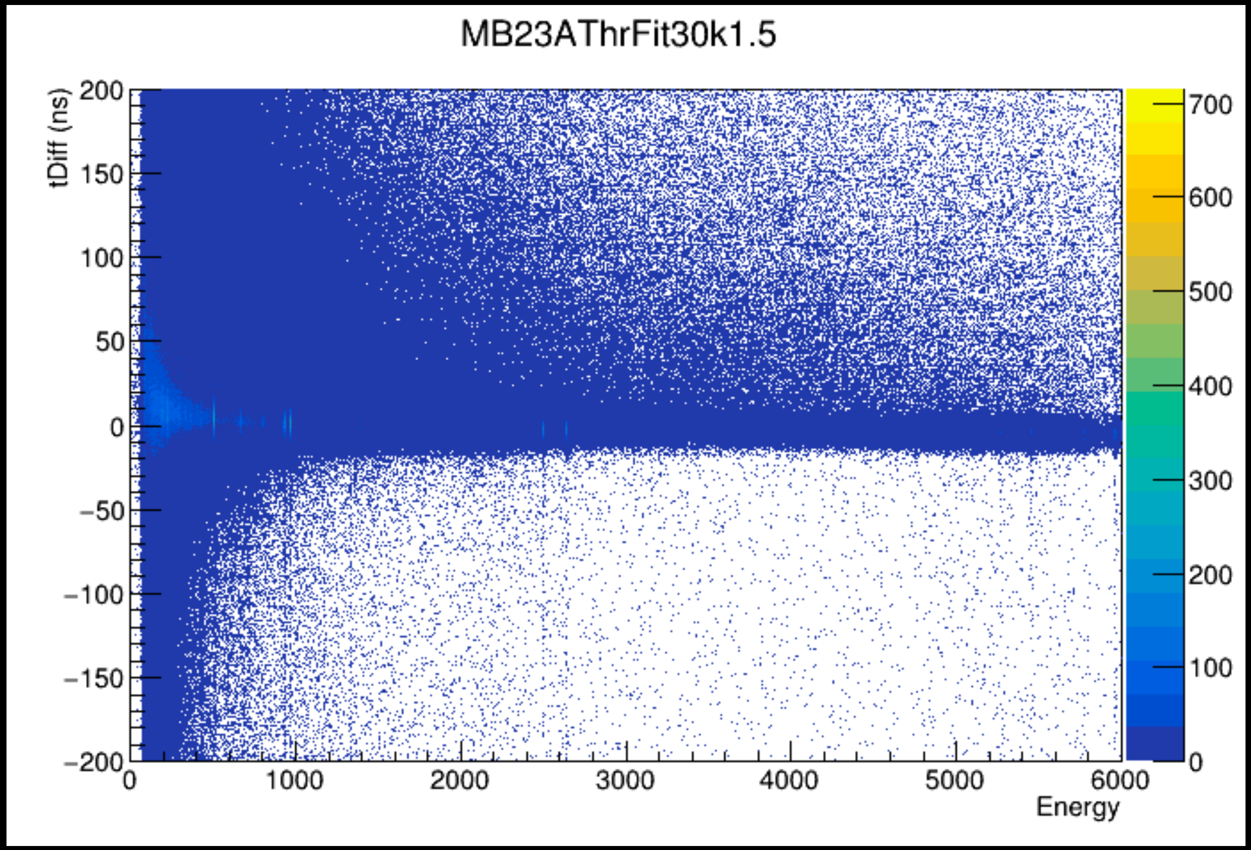
TIMING



For the high energy range (> 5 MeV) I achieve the best time resolution via a fit. t0 is determined via the intersection of the linear fit and the baseline.

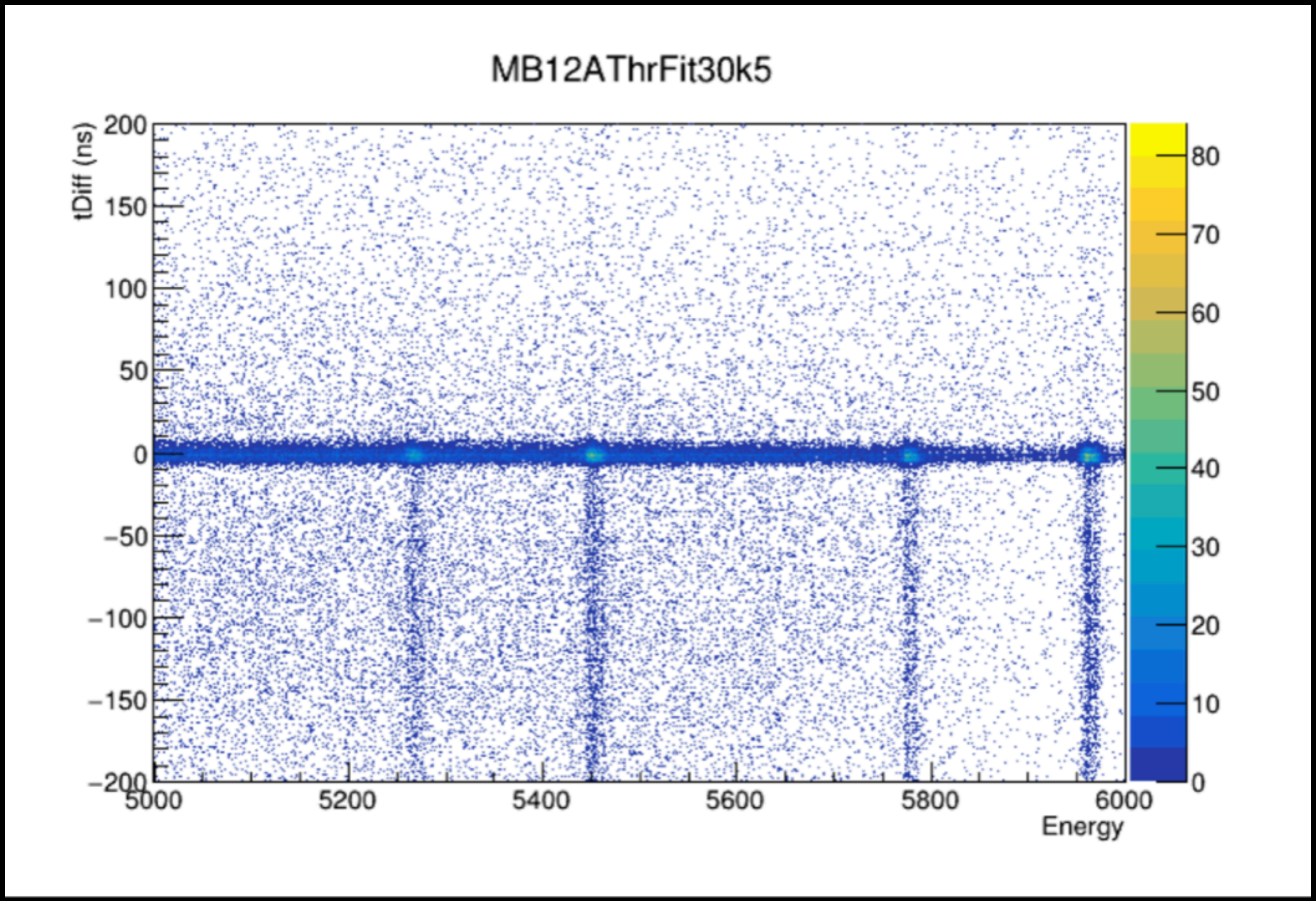
TIMING

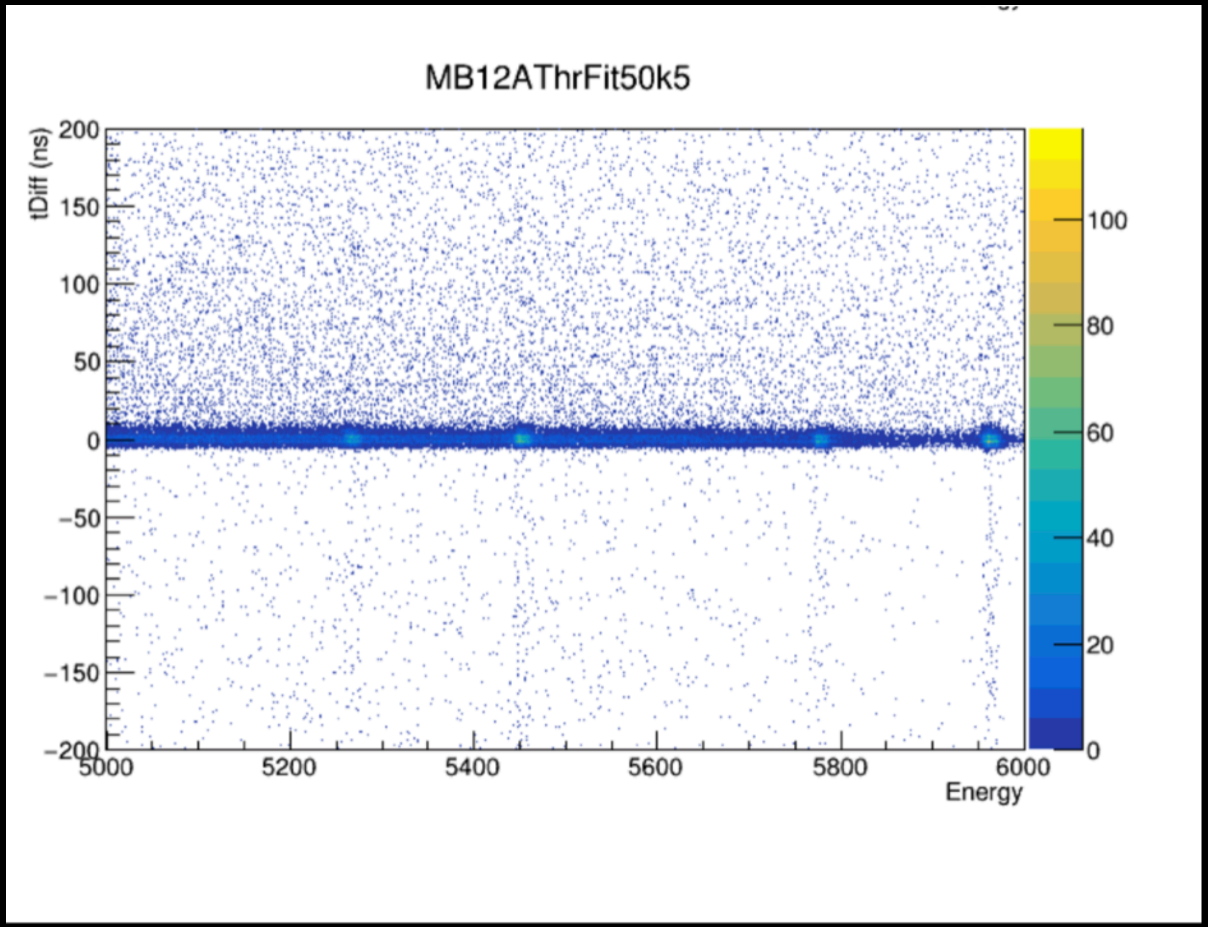




Another benefit of the fit procedure is that the time shift for different energy ranges or threshold settings is minimized.

TIMING

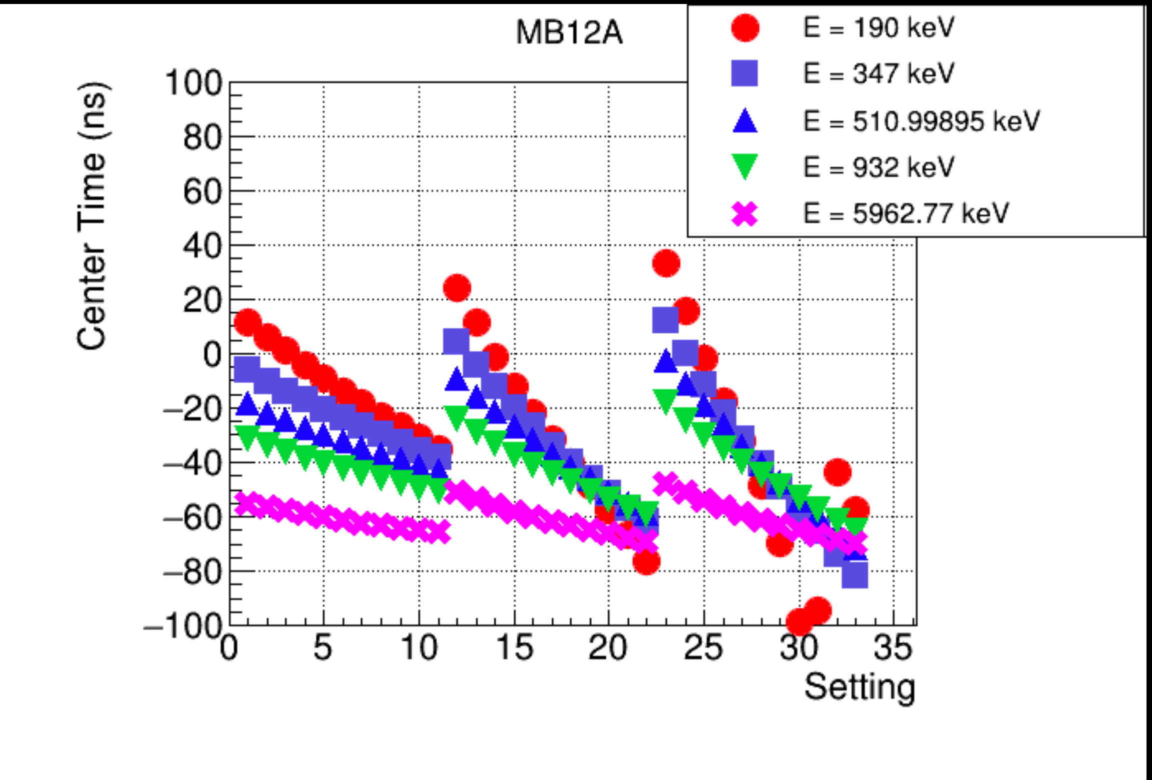




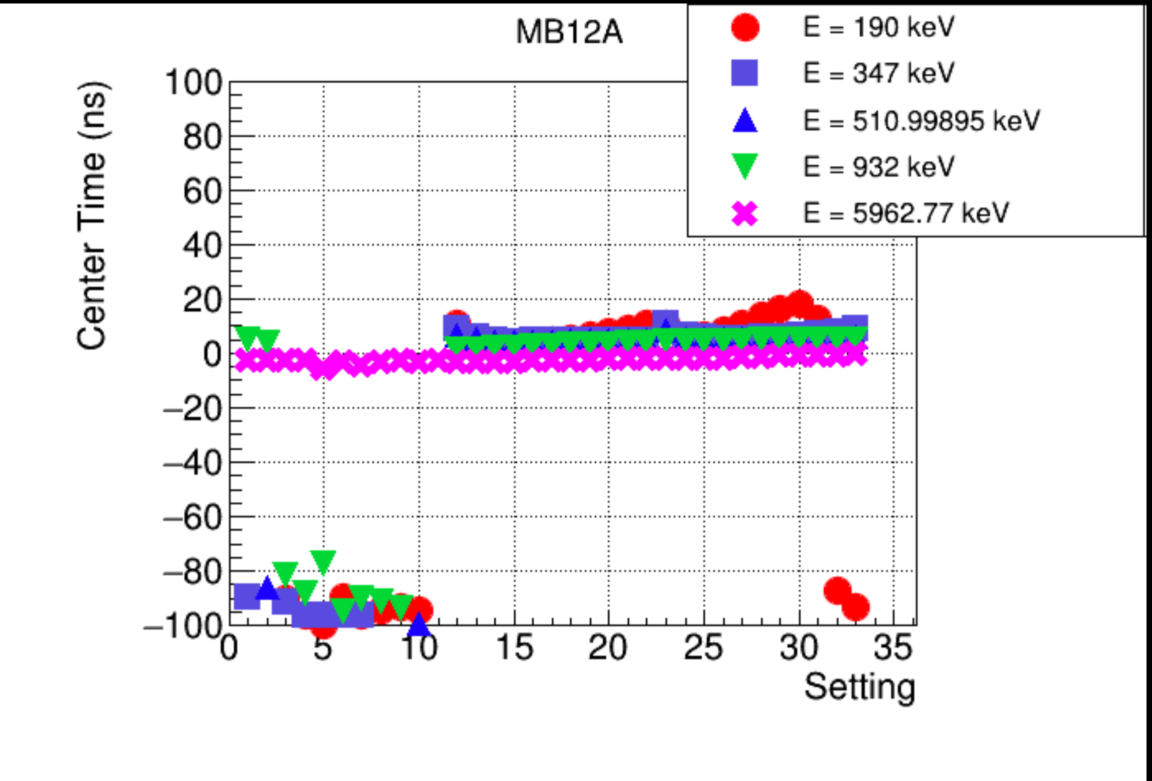
The disadvantage is that T1 requires quite a high threshold compared to the normal ELET algorithm otherwise the time is shifted to negative values.

TIMING SHIFT

ELET:
Shift depends on energy and setting.



Fit:
Shift is relatively stable, except for too low thresholds.

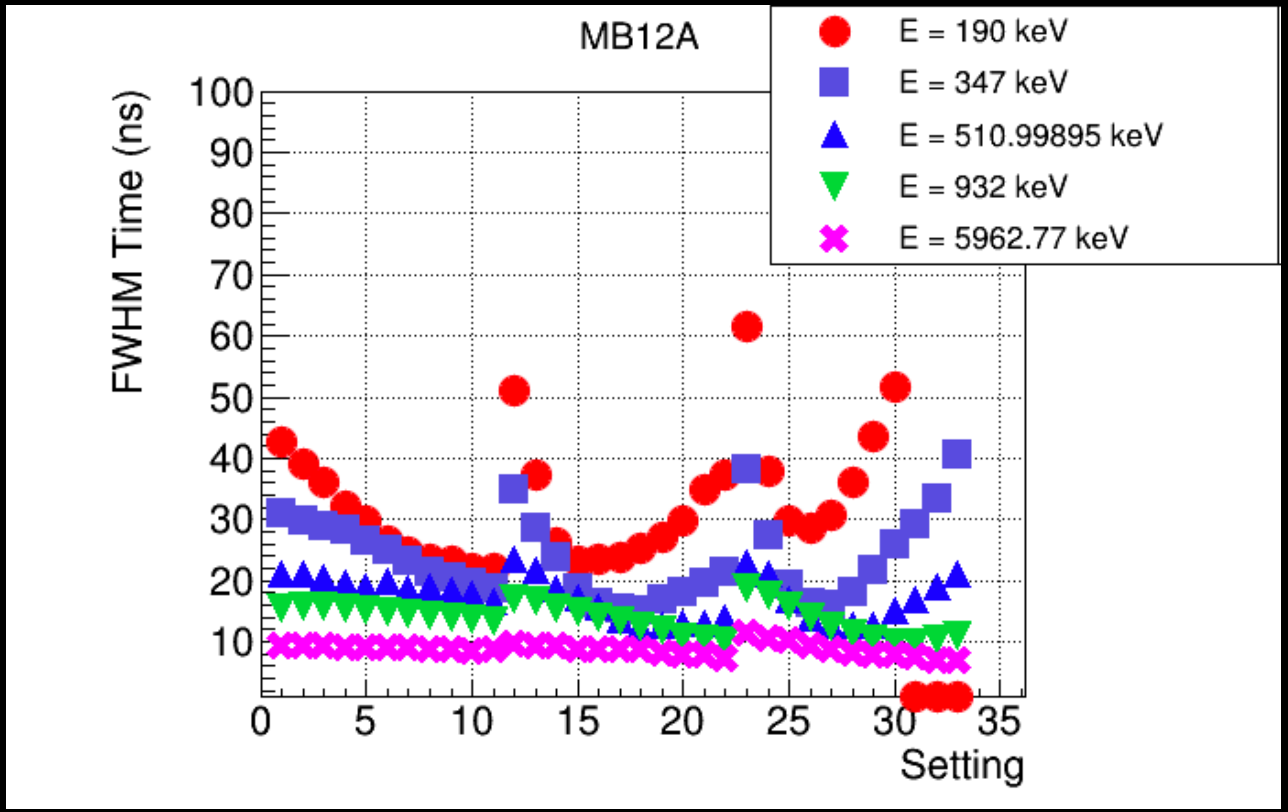


Setting	T_1	k	T_2
1	10	1.5	15
2	10	2.0	20
3	10	2.5	25
4	10	3.0	30
5	10	3.5	35
6	10	4.0	40
7	10	4.5	45
8	10	5.0	50
9	10	5.5	55
10	10	6.0	60
11	10	6.5	65
12	30	1.5	45
13	30	2.0	60
14	30	2.5	75
15	30	3.0	90
16	30	3.5	105
17	30	4.0	120

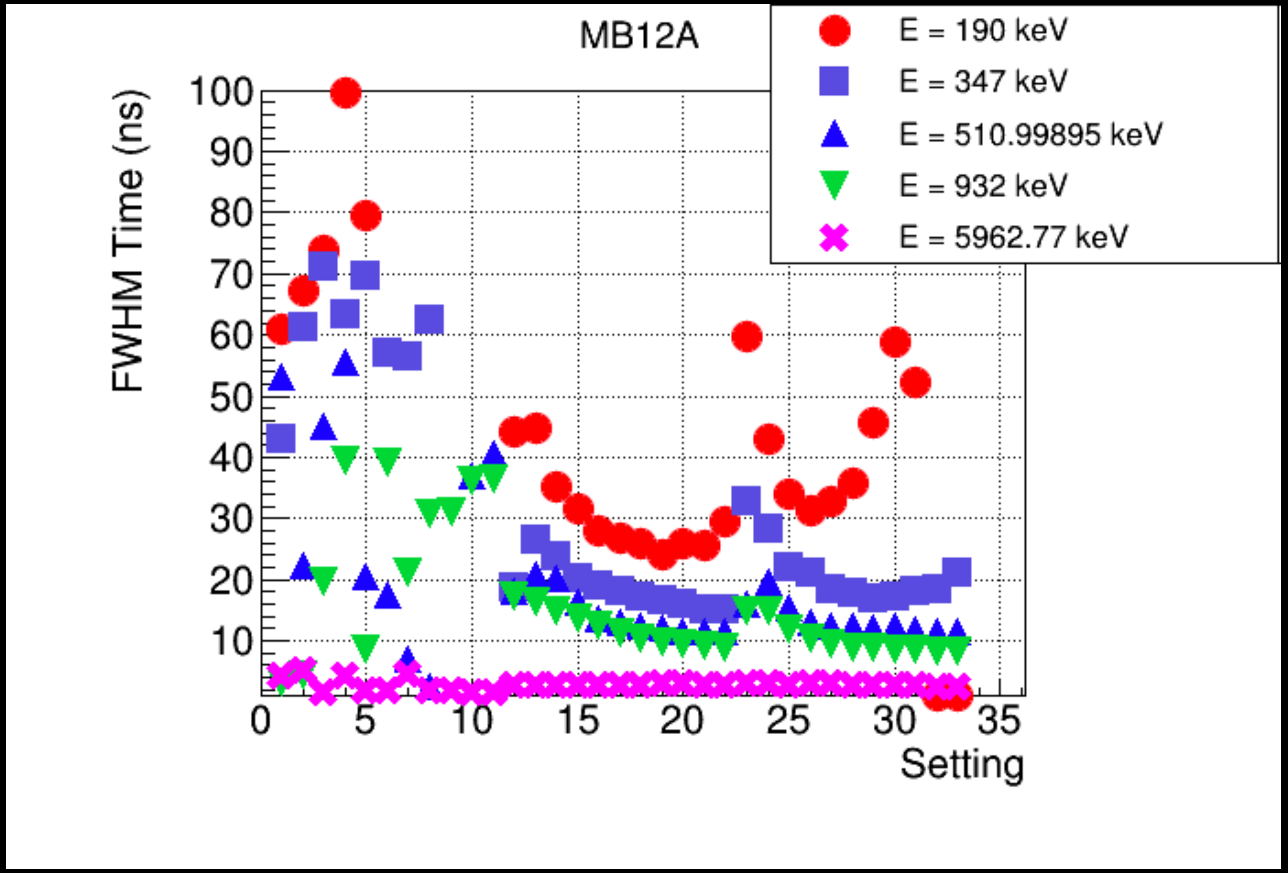
Setting	T_1	k	T_2
18	30	4.5	135
19	30	5.0	150
20	30	5.5	165
21	30	6.0	180
22	30	6.5	195
23	50	1.5	75
24	50	2.0	100
25	50	2.5	125
26	50	3.0	150
27	50	3.5	175
28	50	4.0	200
29	50	4.5	225
30	50	5.0	250
31	50	5.5	275
32	50	6.0	300
33	50	6.5	325

TIMING

Resolution ELET



Resolution Fit



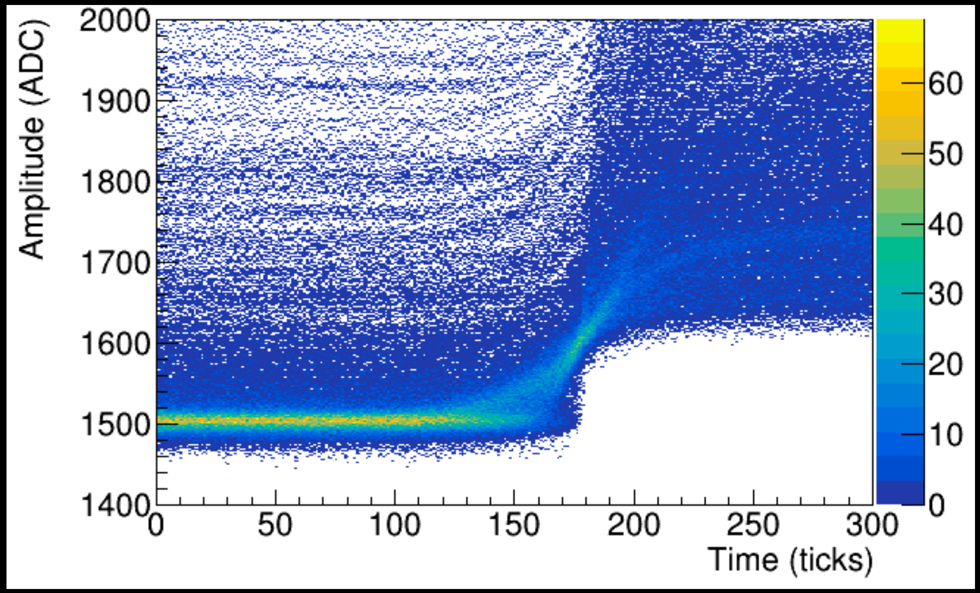
Setting	T_1	k	T_2
1	10	1.5	15
2	10	2.0	20
3	10	2.5	25
4	10	3.0	30
5	10	3.5	35
6	10	4.0	40
7	10	4.5	45
8	10	5.0	50
9	10	5.5	55
10	10	6.0	60
11	10	6.5	65
12	30	1.5	45
13	30	2.0	60
14	30	2.5	75
15	30	3.0	90
16	30	3.5	105
17	30	4.0	120

Setting	T_1	k	T_2
18	30	4.5	135
19	30	5.0	150
20	30	5.5	165
21	30	6.0	180
22	30	6.5	195
23	50	1.5	75
24	50	2.0	100
25	50	2.5	125
26	50	3.0	150
27	50	3.5	175
28	50	4.0	200
29	50	4.5	225
30	50	5.0	250
31	50	5.5	275
32	50	6.0	300
33	50	6.5	325

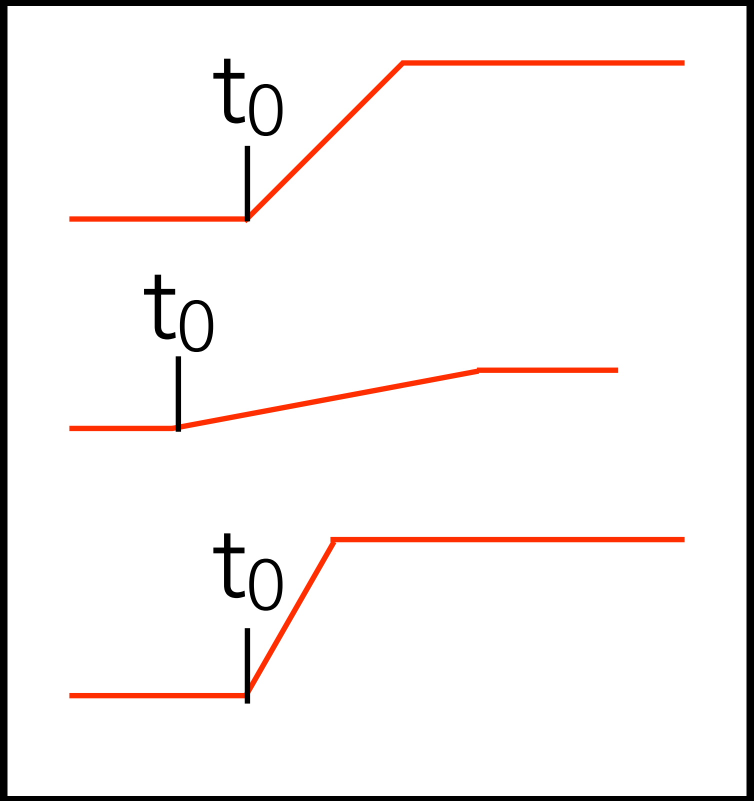
POSSIBLE IMPROVEMENTS

1. Try to define the T_1 and T_2 with respect to the maximum Amplitude of the waveform
2. Apply different kind of settings for different energy ranges
3. Categorise waveforms
4. Apply Machine Learning to determine the best ELET settings

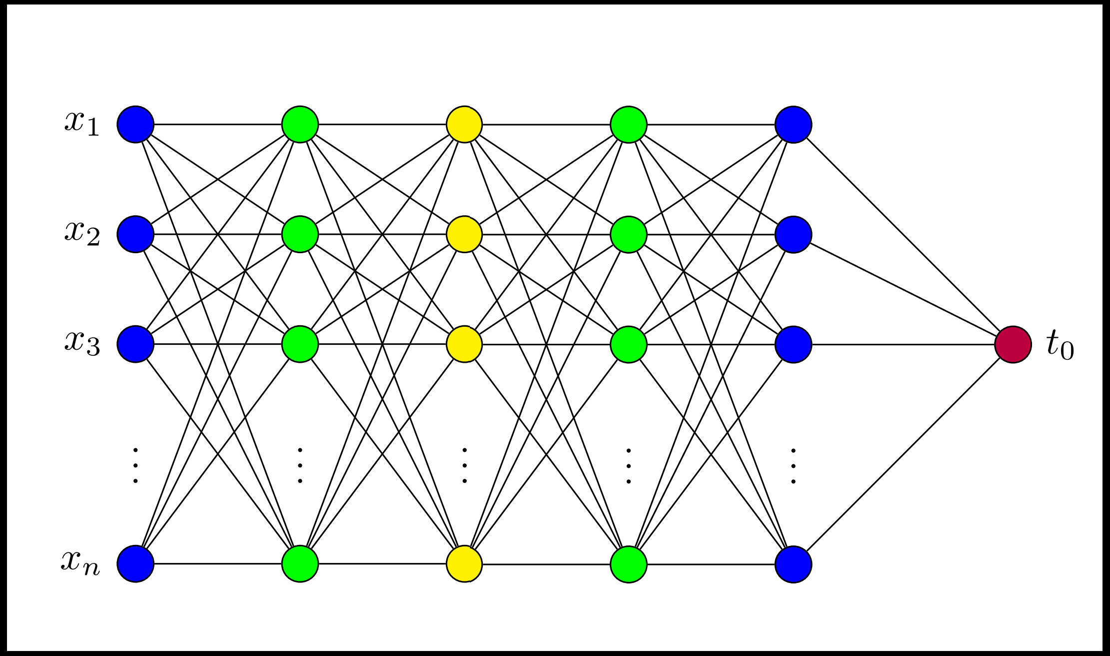
Setting	T_1	k	T_2
1	10	1.5	15
2	10	2.0	20
3	10	2.5	25
4	10	3.0	30
5	10	3.5	35
6	10	4.0	40
7	10	4.5	45
8	10	5.0	50



OUTLOOK MACHINE LEARNING

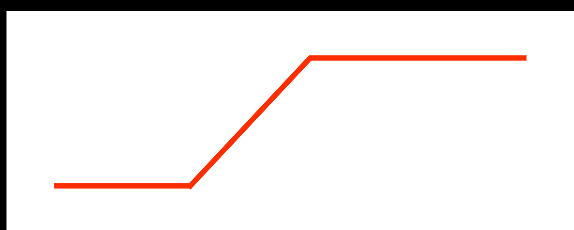


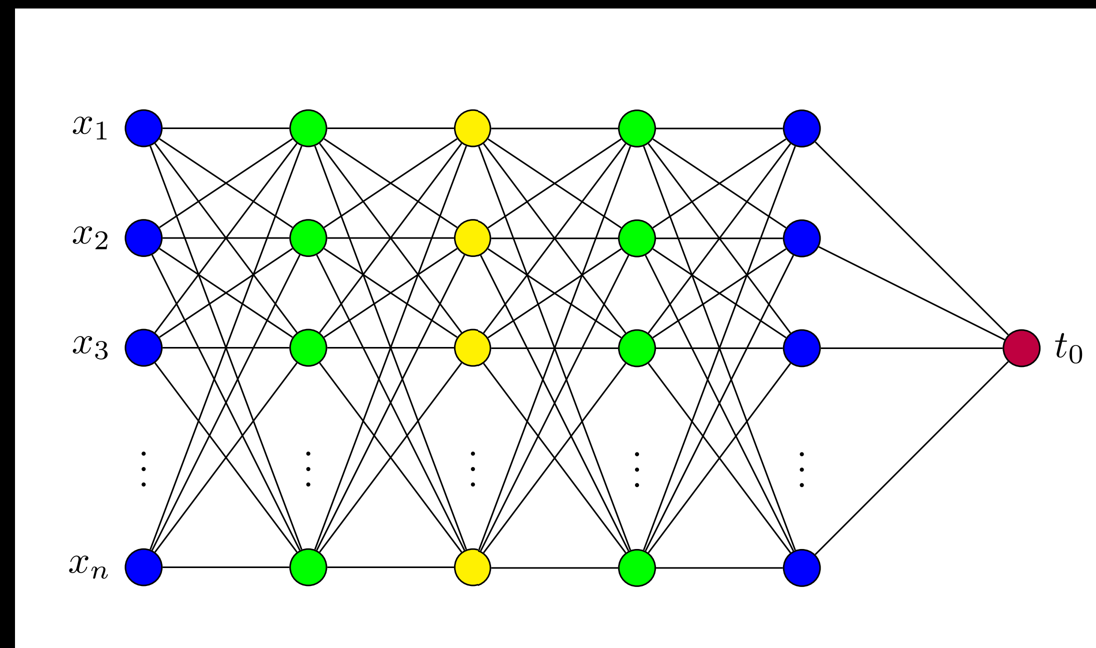
Prepare a set of waveforms including the well defined time t_0 of each event

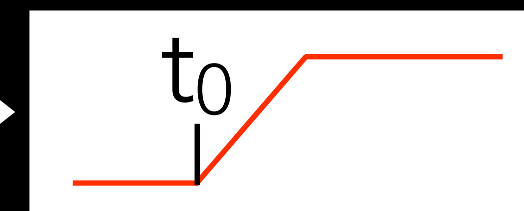


Train a Neural Network to predict t_0 of each waveform.

OUTLOOK MACHINE LEARNING







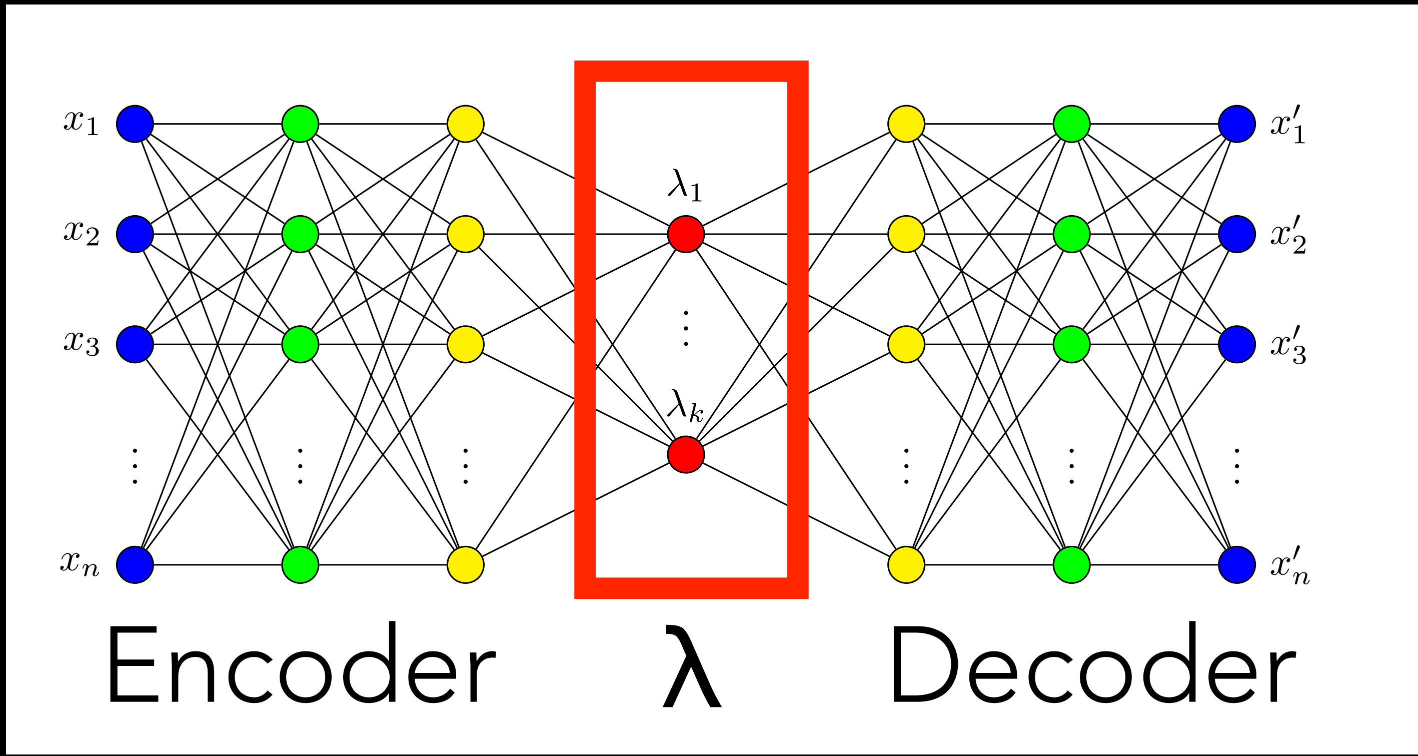
Insert measured waveform to NN

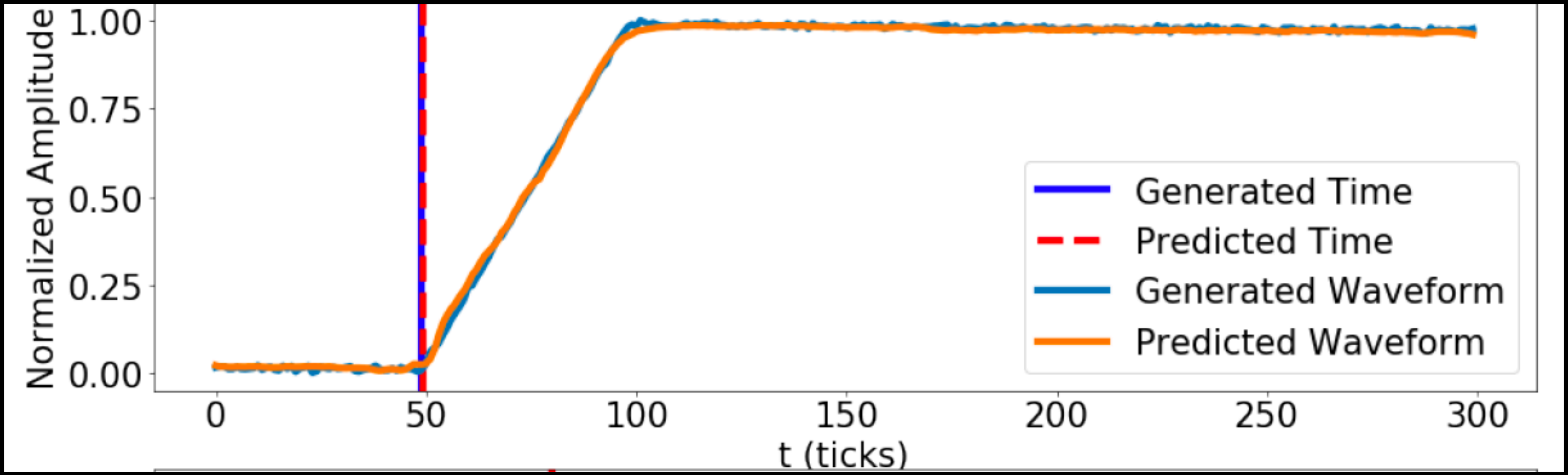
A well trained NN can predict t_0

1. This is a well known standard procedure in Machine Learning
2. Main task is the preparation of a training set

OUTLOOK MACHINE LEARNING

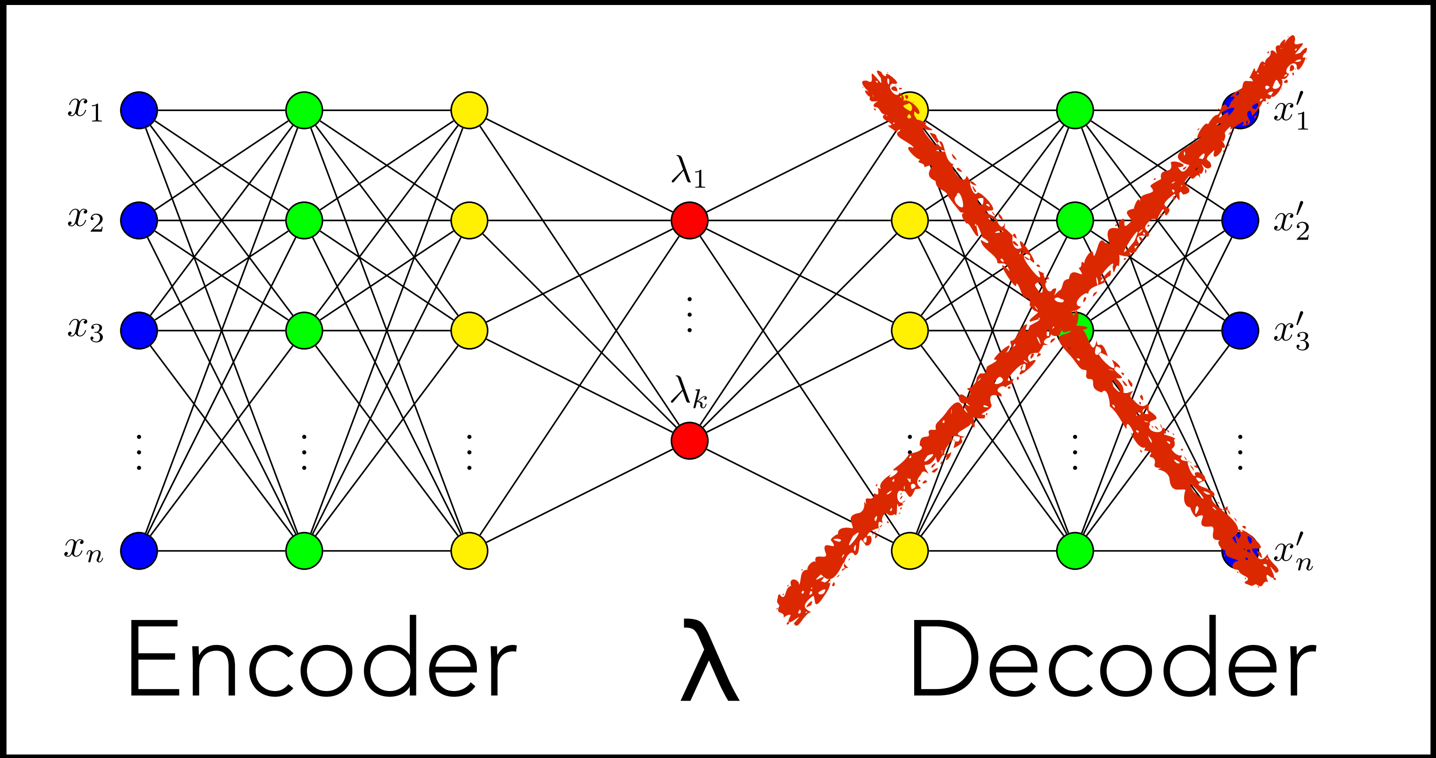
Generate or simulate waveforms with the same structure as the measured waveforms. Use a Generative Adversarial Network (GAN) to create a feature Vector λ.

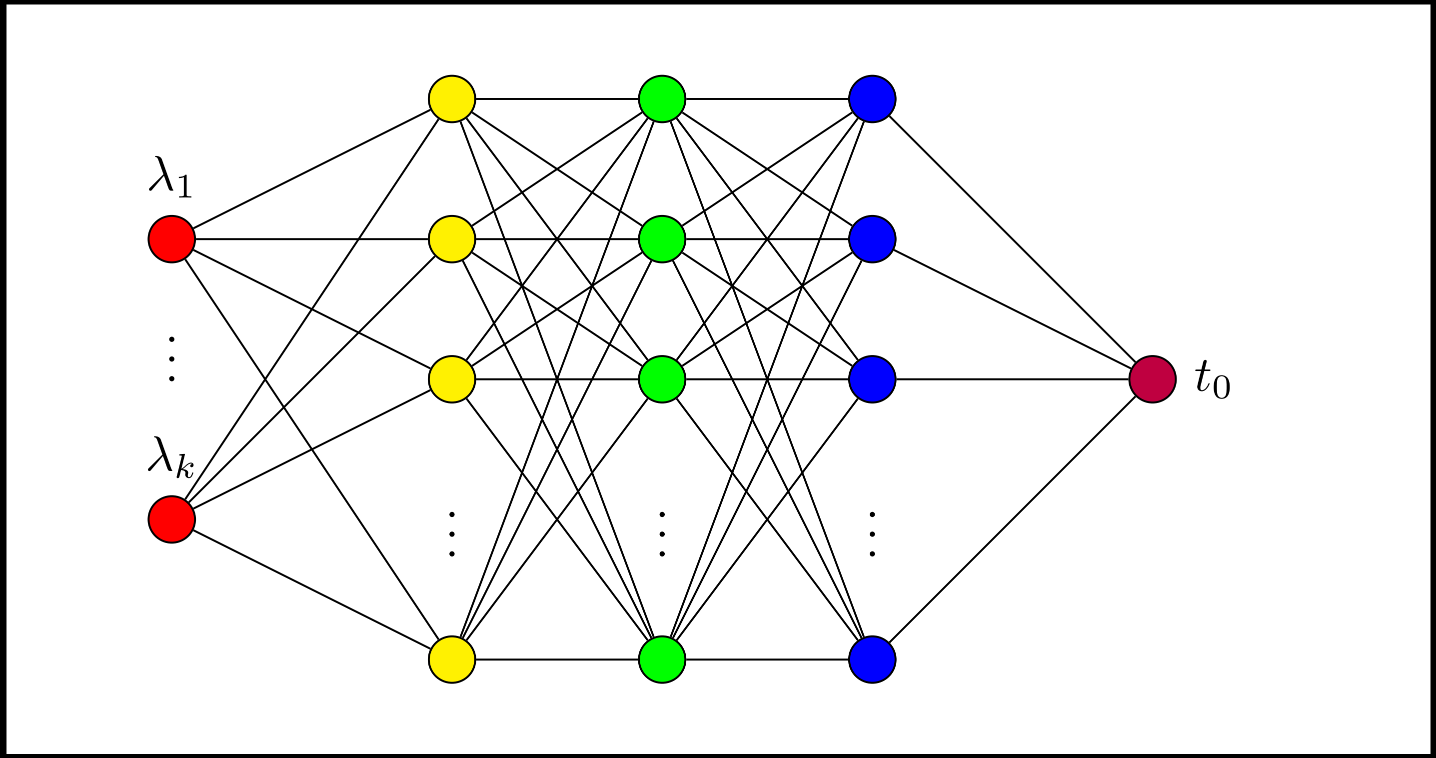




λ can be used to reconstruct the waveform

OUTLOOK MACHINE LEARNING





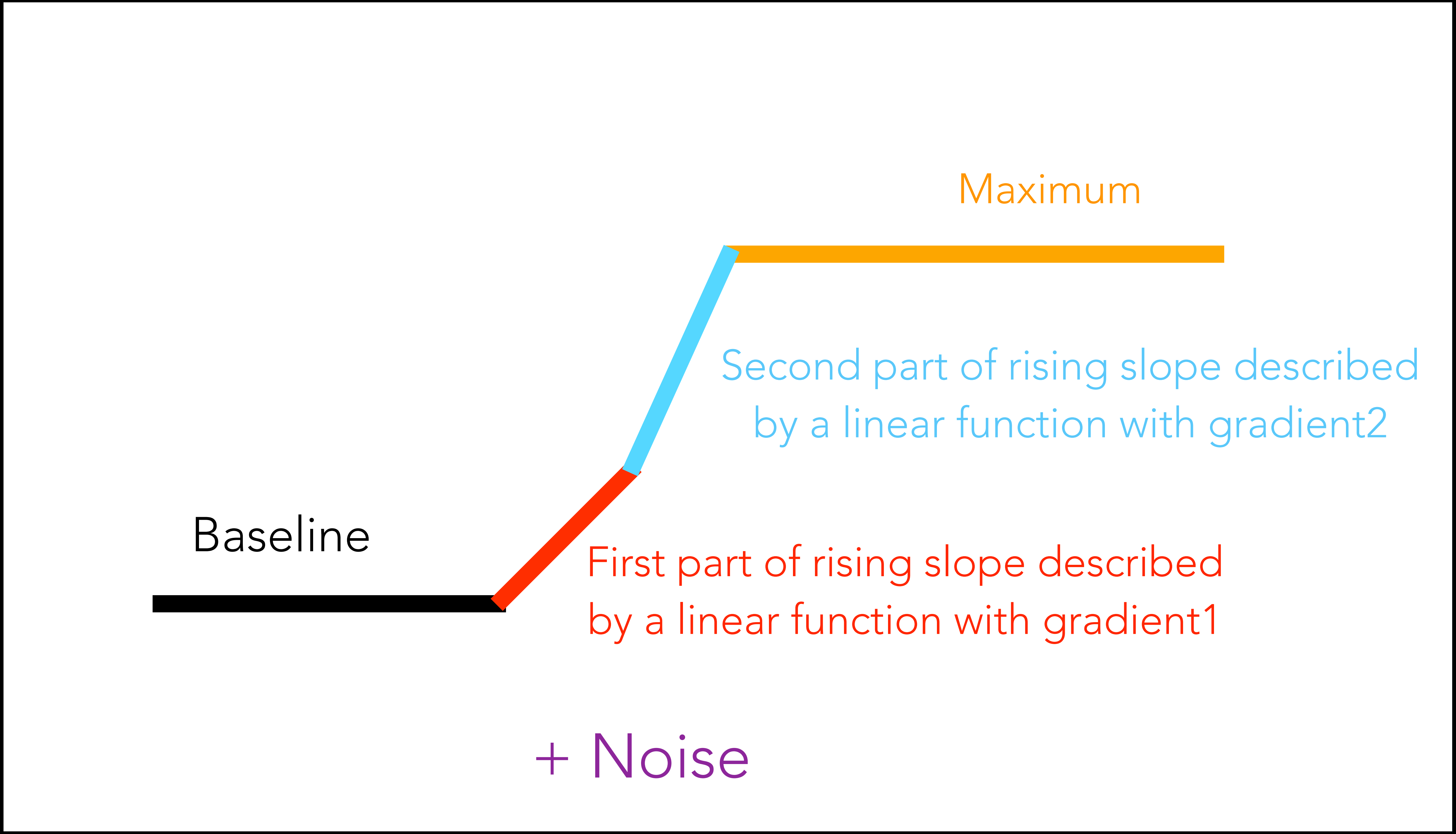
After the training of GAN is completed. Apply the feature vector of the generated waveforms to a Neural Network (NN) to train the determination of the time.

At the end it should be possible to apply the measured waveforms to the encoder and the NN to determine the time.

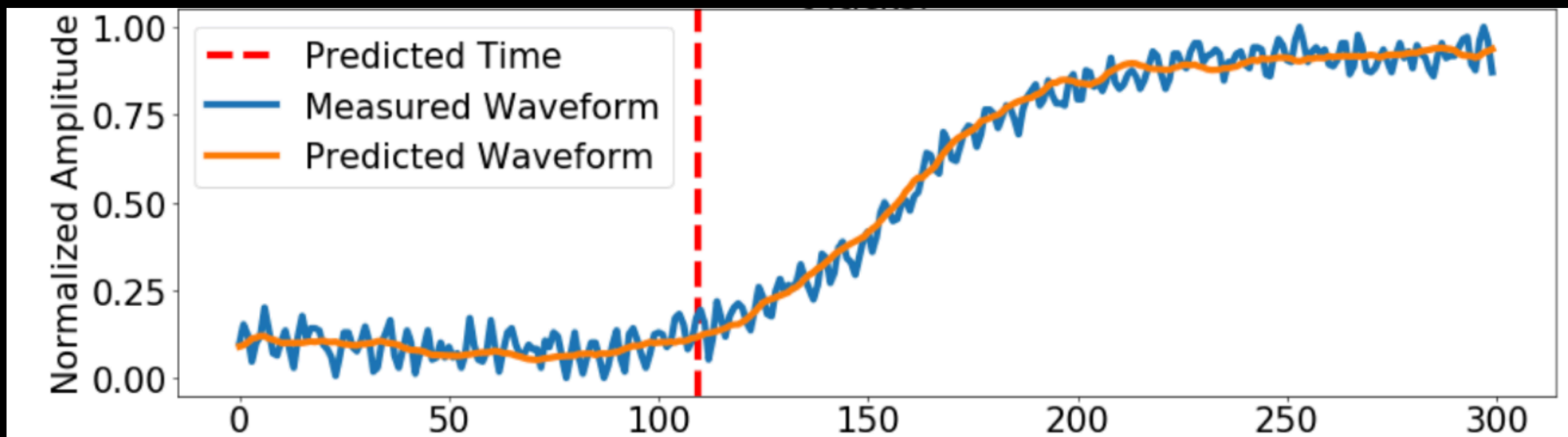
The key to this approach is a proper set of generated waveforms.

OUTLOOK MACHINE LEARNING

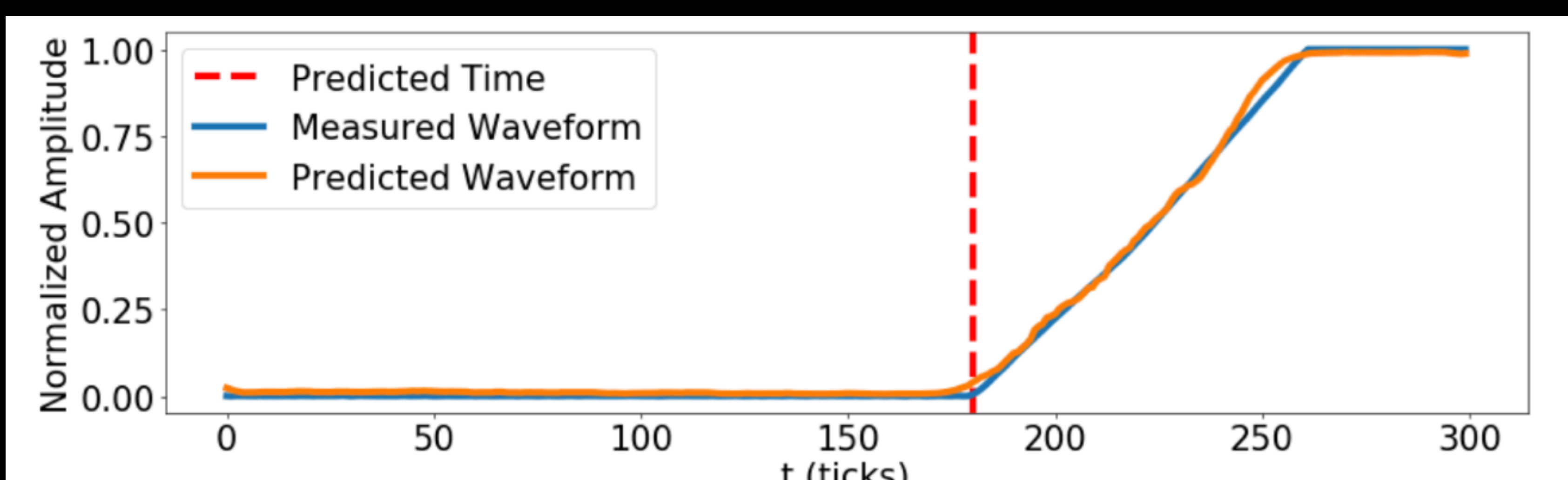
First tests with a simple model



OUTLOOK MACHINE LEARNING



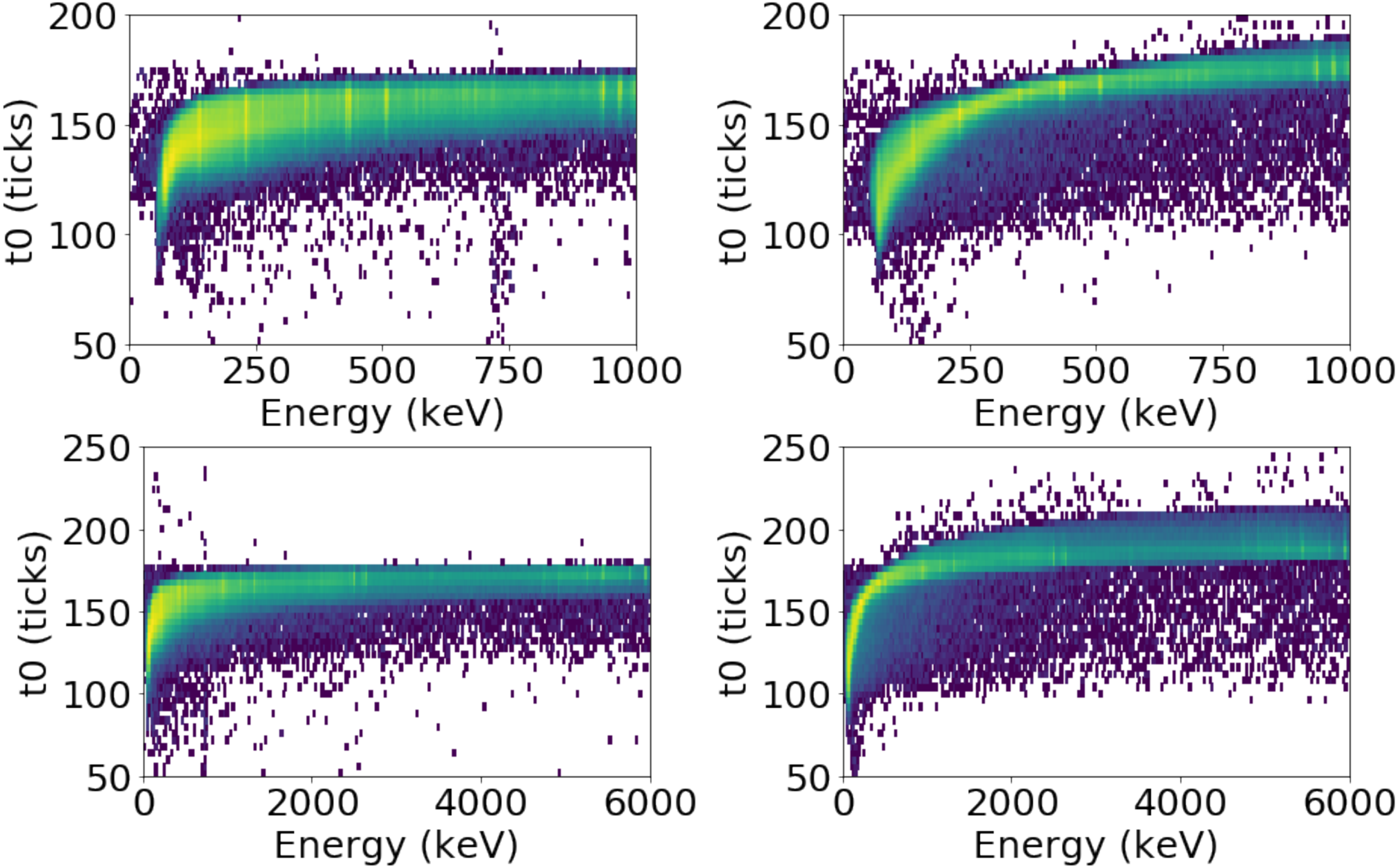
Waveform E < 100 keV



Waveform E > 5000 keV

Generated 500000 examples. Tested it with Ge 10. For low energy waveforms it seems to work quite well. For high energy the reconstruction of the waveform fails.

OUTLOOK MACHINE LEARNING



t_0 determined by fit

t_0 determined by NN