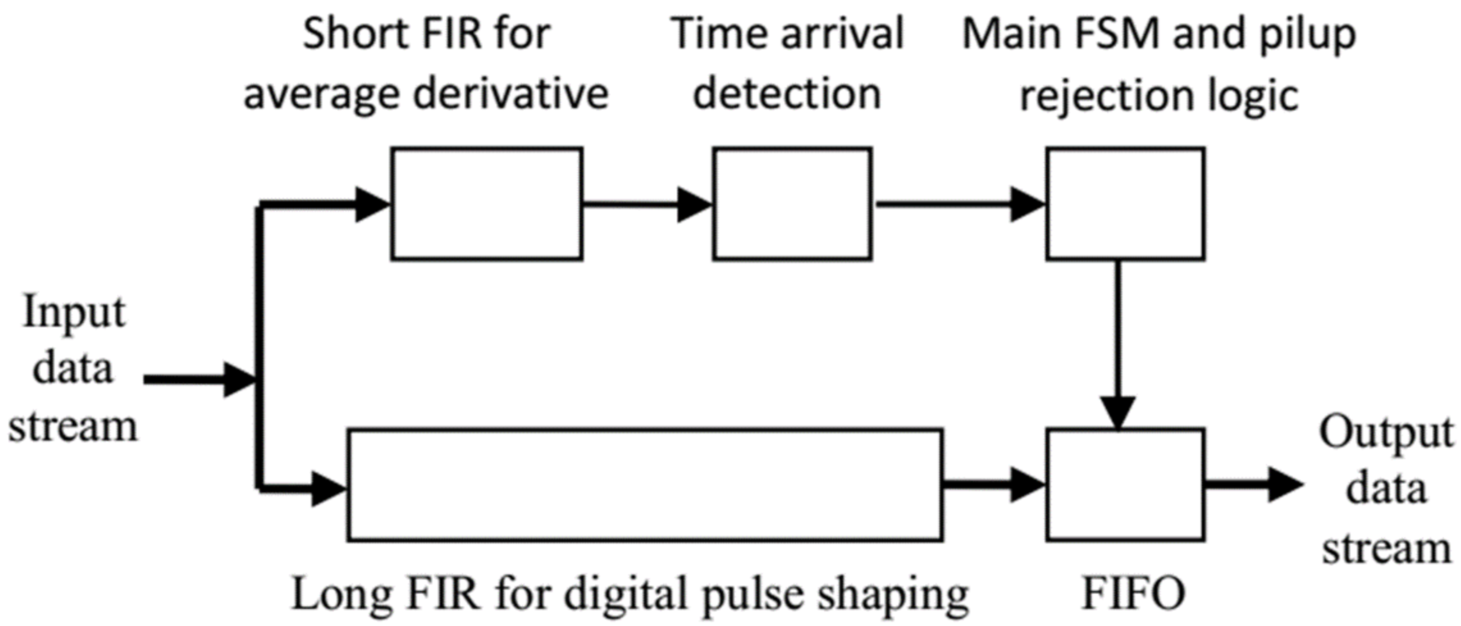
ECAL2 Preliminary Data Analysis Towards Online Feature Extraction

Werner Florian
ICTP Multidisciplinary Laboratory – INFN Trieste COMPASS Group

Overview

- DPP Strategy for high resolution amplitude measurements
- Ideal pulse model
  - Pulses selection criteria
  - Single pulse model
  - Pulse plus reflection model
- Noise analysis
  - Burst regime qualitative description
  - FFT
  - Autocorrelation

Digital Pulse Processing Strategy for High Resolution Amplitude Measurement

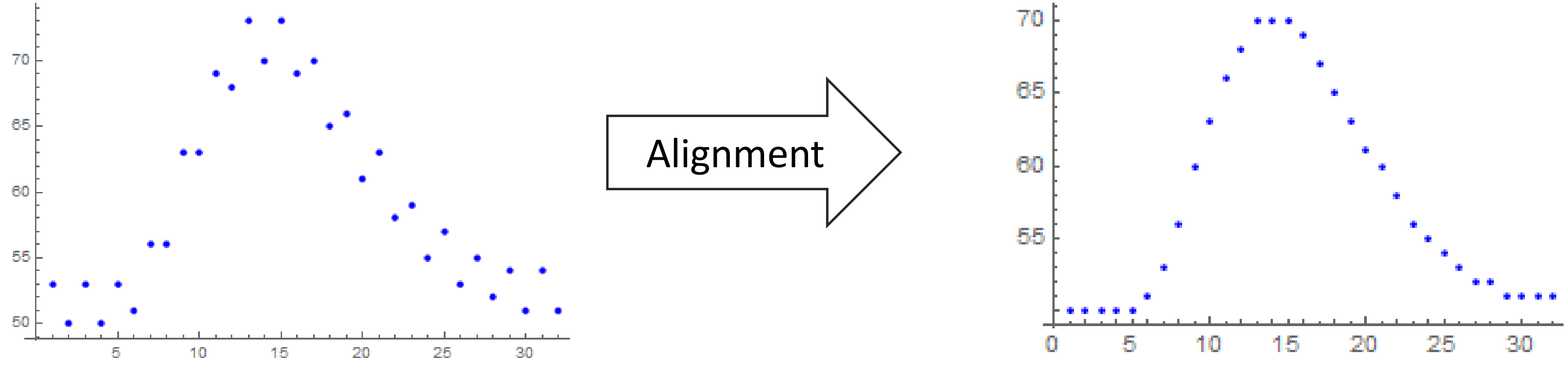


Data alignment

- Analyzed data has been obtained using 2 ADCs interleaved
- Each ADC has different offset

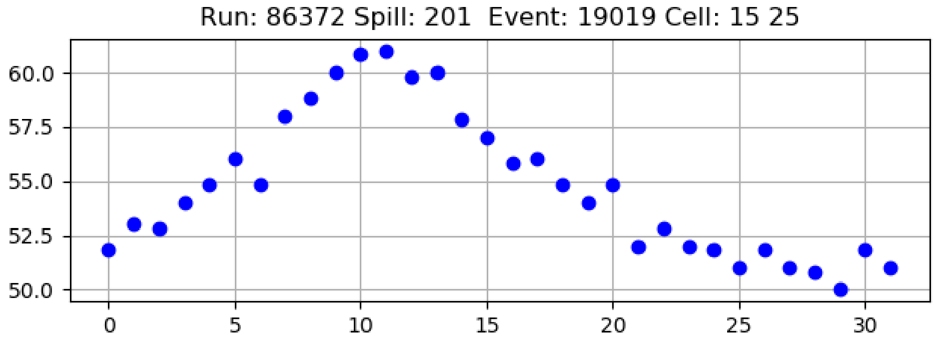
$$\overline{x_{odd}} - \overline{x_{even}} = d$$

d is subtracted form x_{even} and a new signal is created with its values aligned

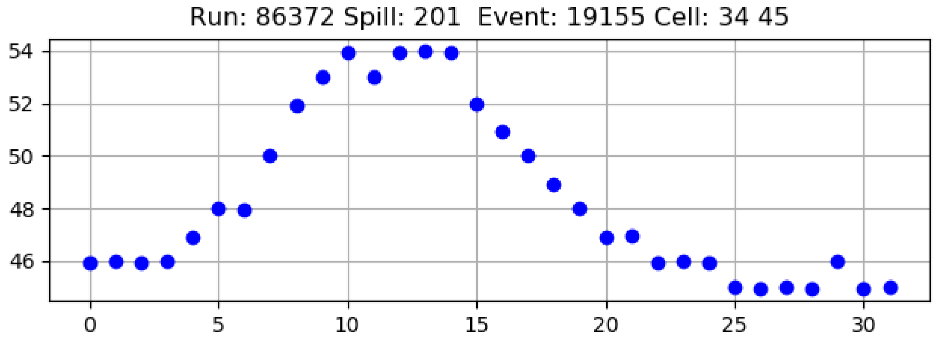


Some Typical Pulses

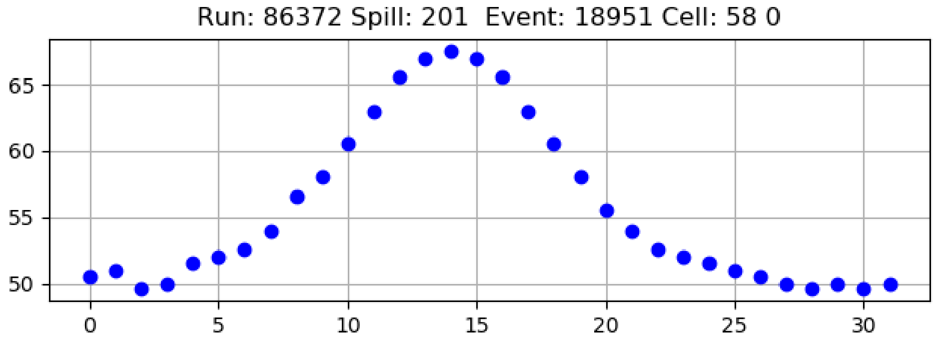
- Triangular



- Truncated



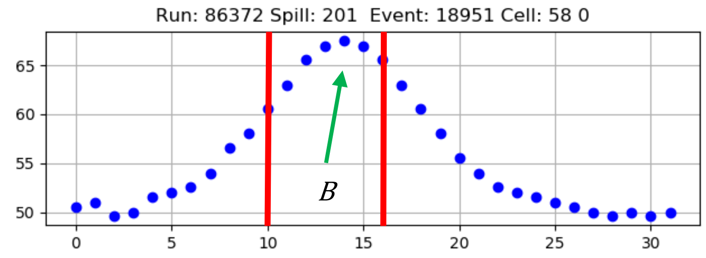
- Beautiful



Best Pulses Selection Criteria

- Barycenter criteria:

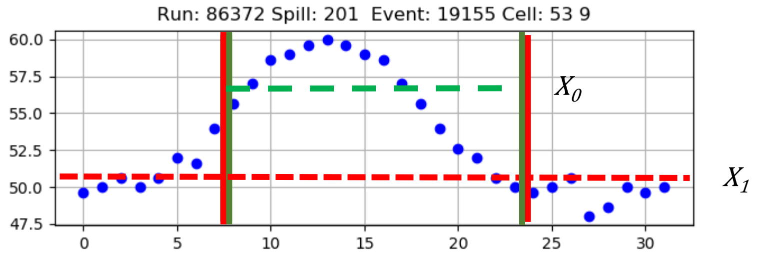
Value must be between lower and higher limits



$$with\ Baryceter\ B = \frac{\sum i_j A_j}{\sum A_j}\ ; l_{inf} < B < lsup$$

- Mean difference criteria

This is used to reject negative pulses



$$\overline{X_0[8{:}24]} - \overline{X_1[0{:}8, 24{:}32]} > threshold$$

Fitting Model : CR-RC^N Shaper Single Pulse

- $F(t, t_0, \tau, off, a, N) = \begin{cases} off & , \ t_0 < t \\ off + a\,\dfrac{e^N \left(\frac{(t-t_0)}{\tau}\right)^N e^{-\frac{(t-t_0)}{\tau}}}{N^N} & , \ t \geq t_0 \end{cases}$

off := offset

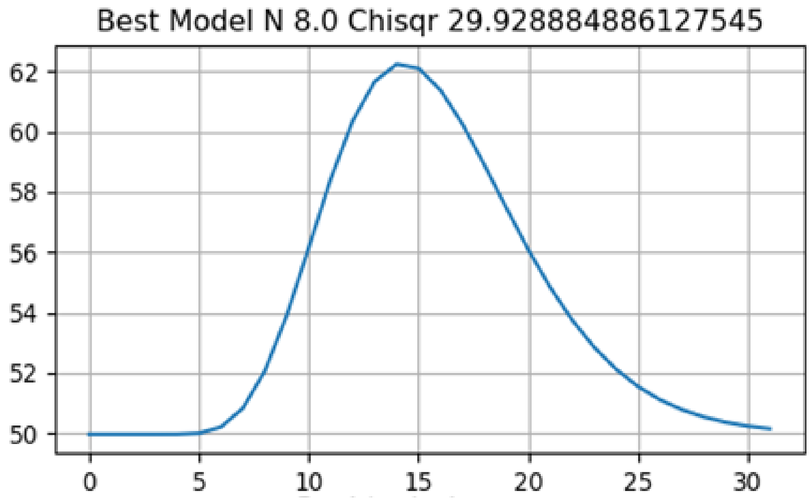
t_0:= time of arrival

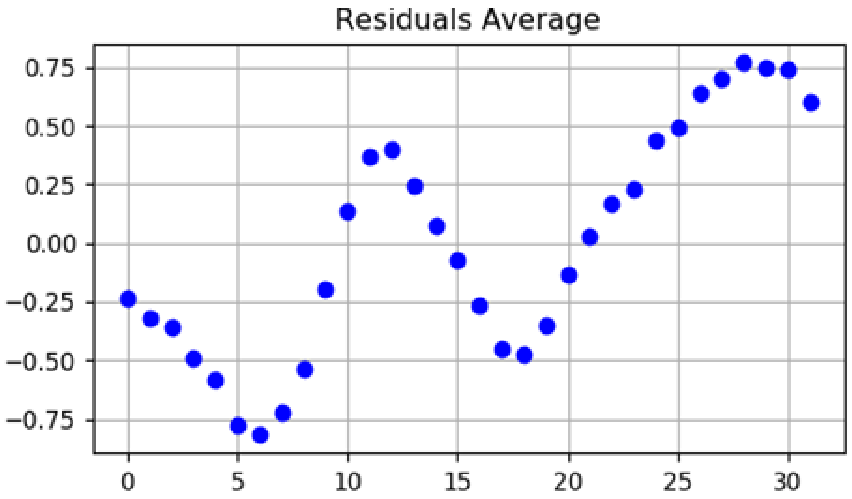
a:= amplitude

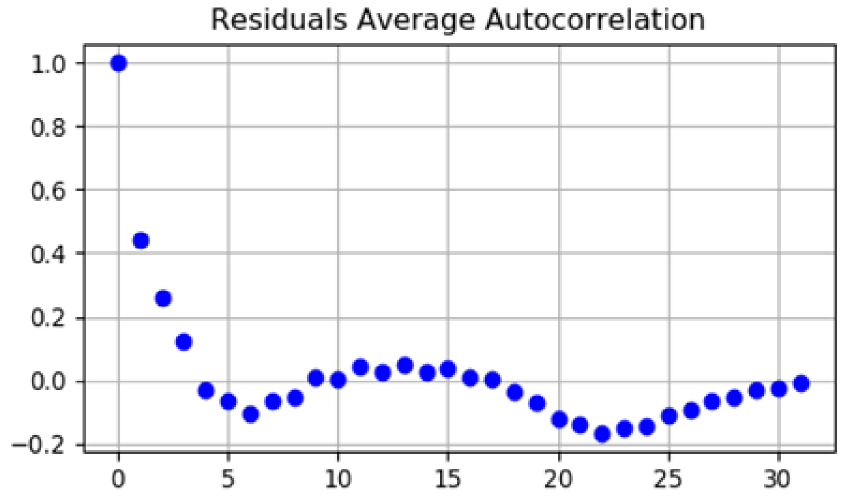
τ:= exponential time

F: = CR-RC^N shaper

Fitting Results







Fitting Model: Main Pulse Plus Reflection

$$F(t, t_0, \tau, off, a, N, k, dt) =$$

$$\begin{cases} off & , t_0 < t \\ off + a\,\dfrac{e^N \left(\dfrac{(t-t_0)}{\tau}\right)^N e^{-\frac{(t-t_0)}{\tau}}}{N^N} & , t_0 + dt > t \geq t_0 \\ off + a\,\dfrac{e^N \left(\dfrac{(t-t_0)}{\tau}\right)^N e^{-\frac{(t-t_0)}{\tau}}}{N^N} + k * a\,\dfrac{e^N \left(\dfrac{(t-(t_0+dt))}{\tau}\right)^N e^{-\frac{(t-(t_0+dt))}{\tau}}}{N^N} & , t \geq t_0 + dt \end{cases}$$

off := offset

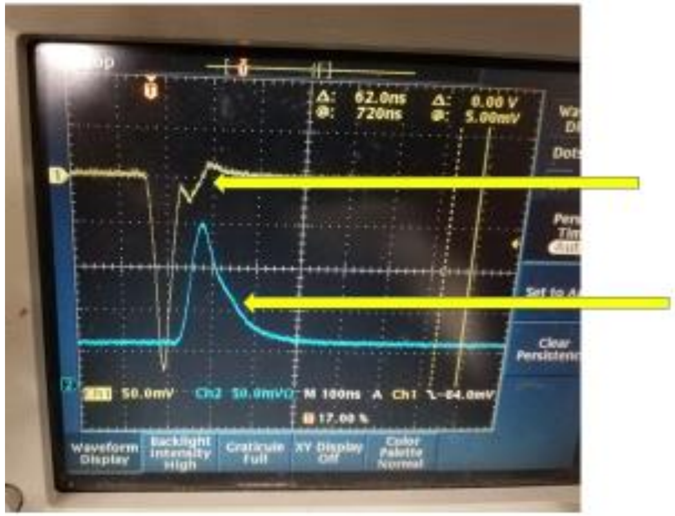
t_0:= time of arrival

a:= amplitude

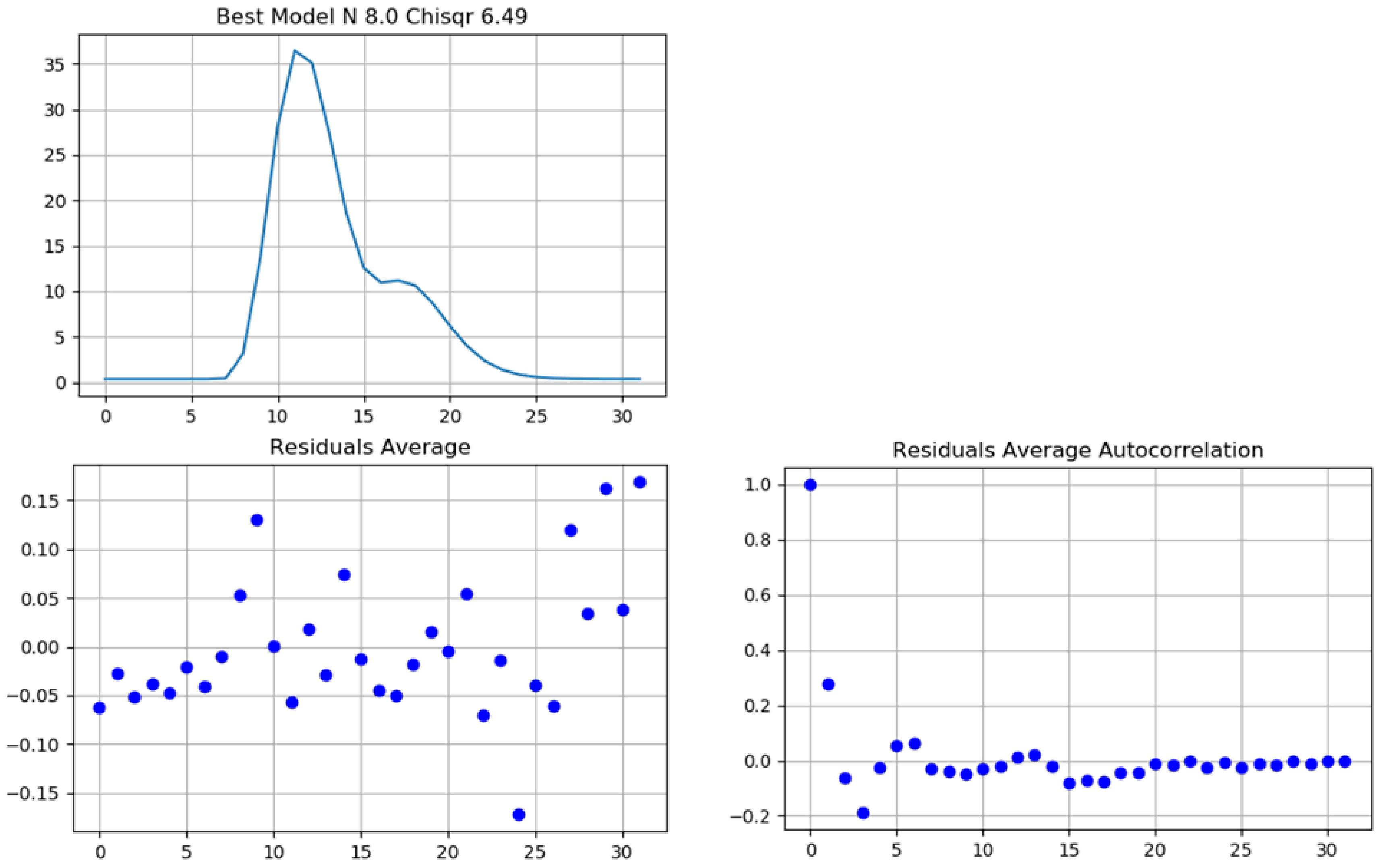
τ:= exponential time

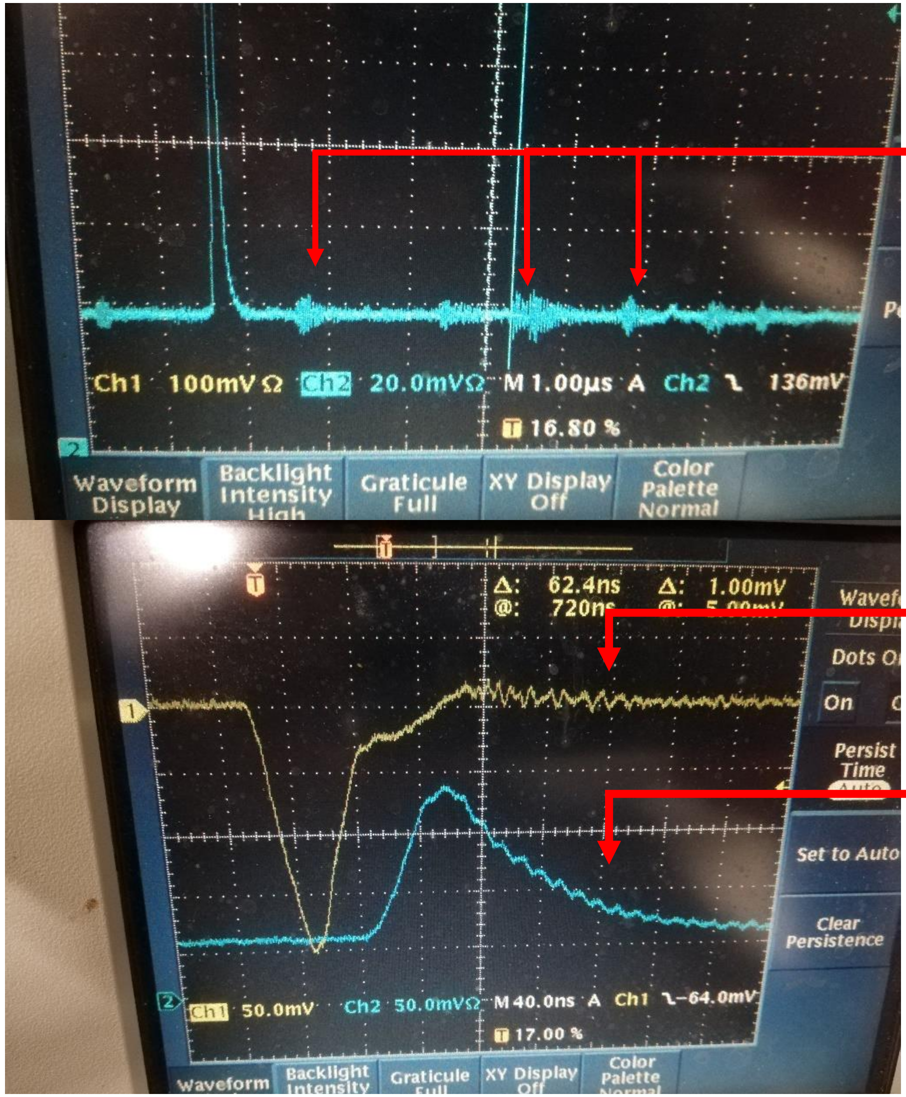
k:= reflection amplitude factor

dt:= time delay



Fitting results



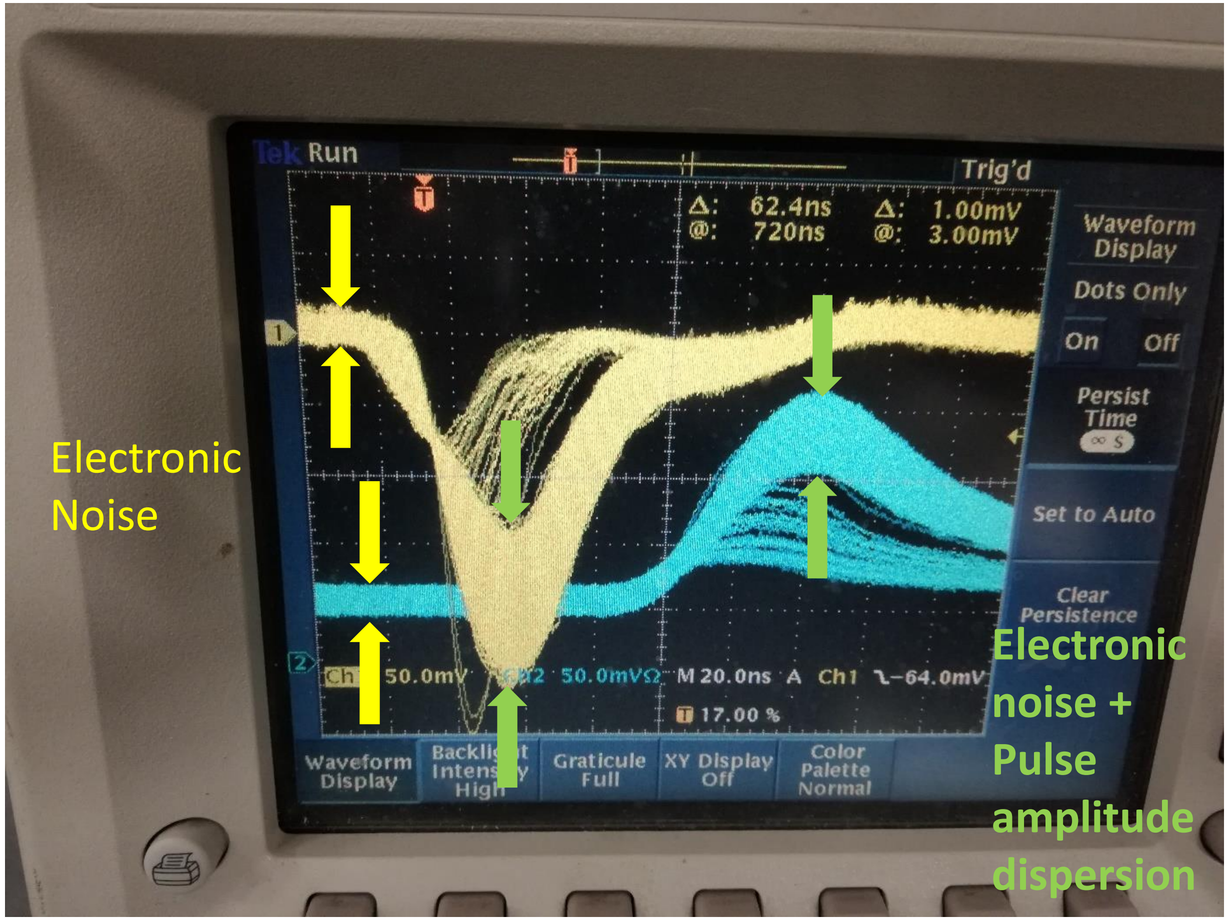


Bursts of noise zoomed out

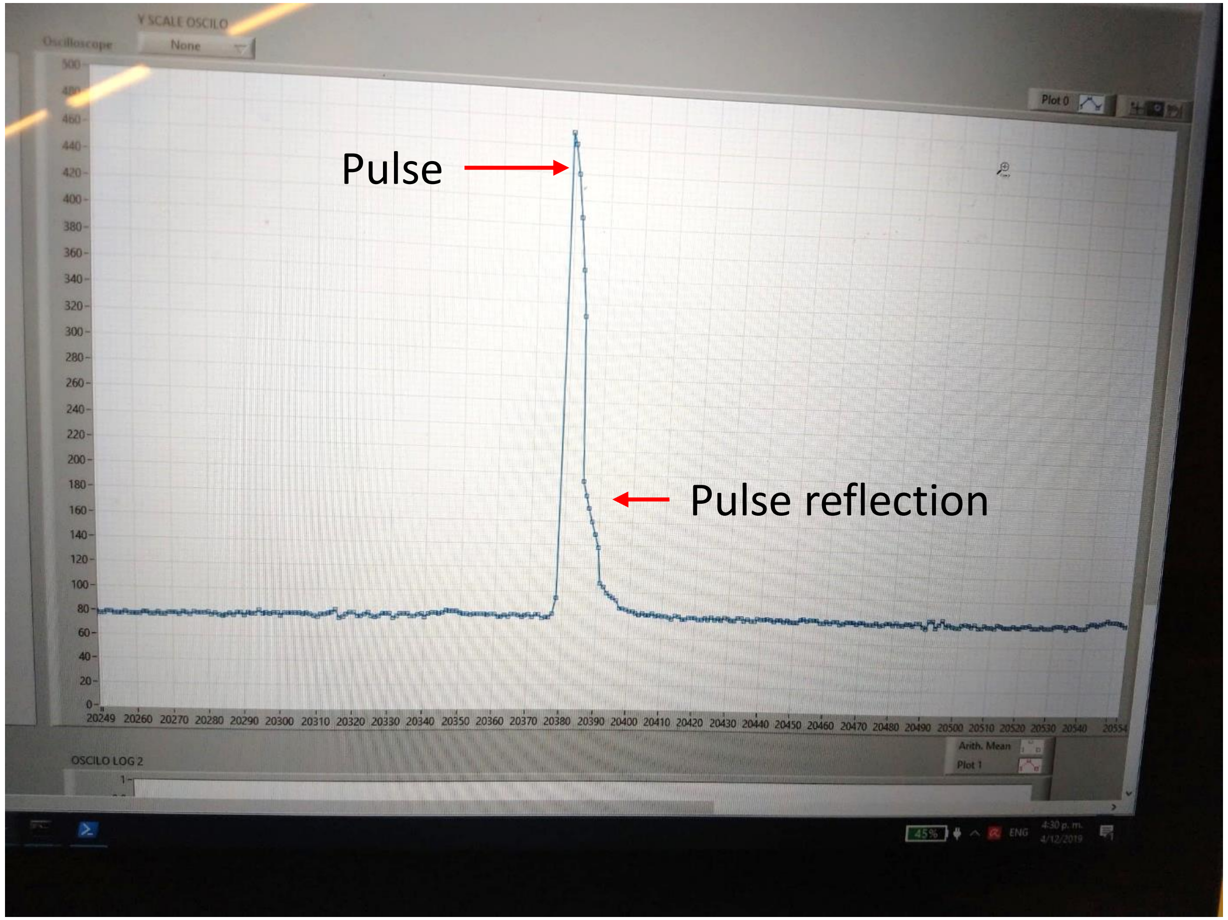
Burst of noise before shaper

Burst of noise after shaper

Analog Persistence



SoC-FPGA Oscilloscope

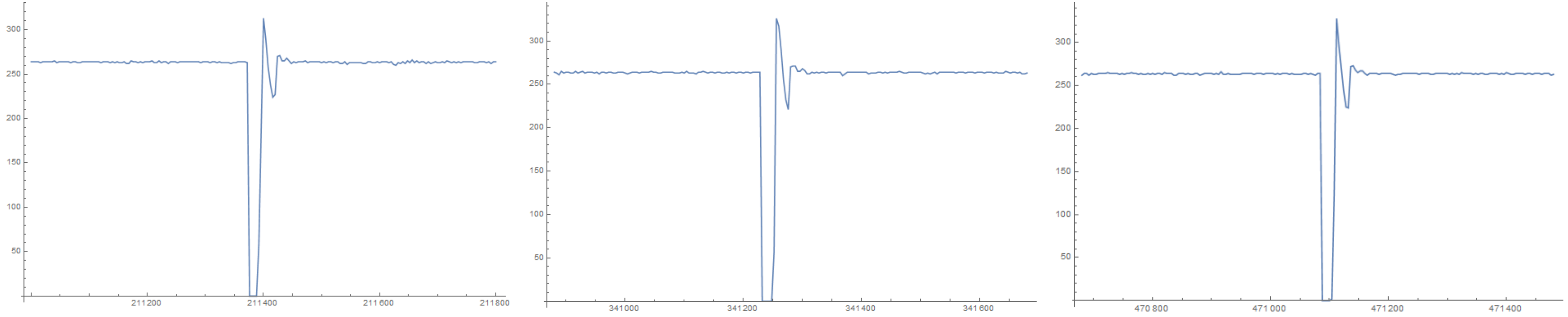


LabView GUI Plot of acquired data from CIAA+ADC500.

Data is plotted in real time on a PC via Ethernet.

Pulses before Shaper

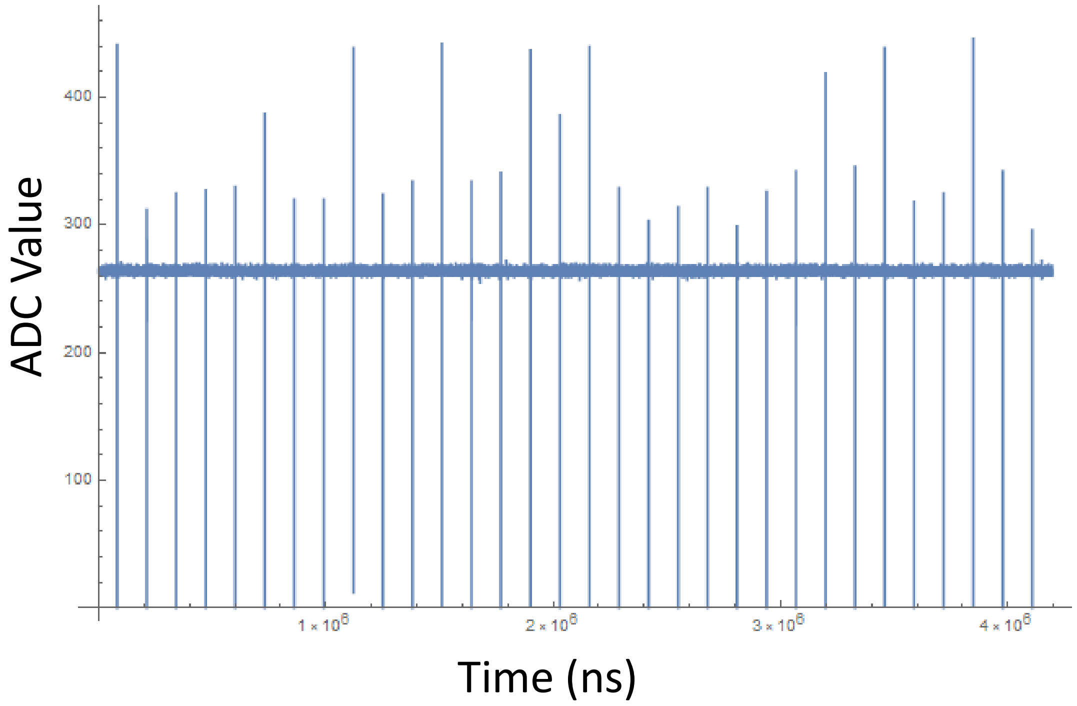
Signals sampled at 250MSPS



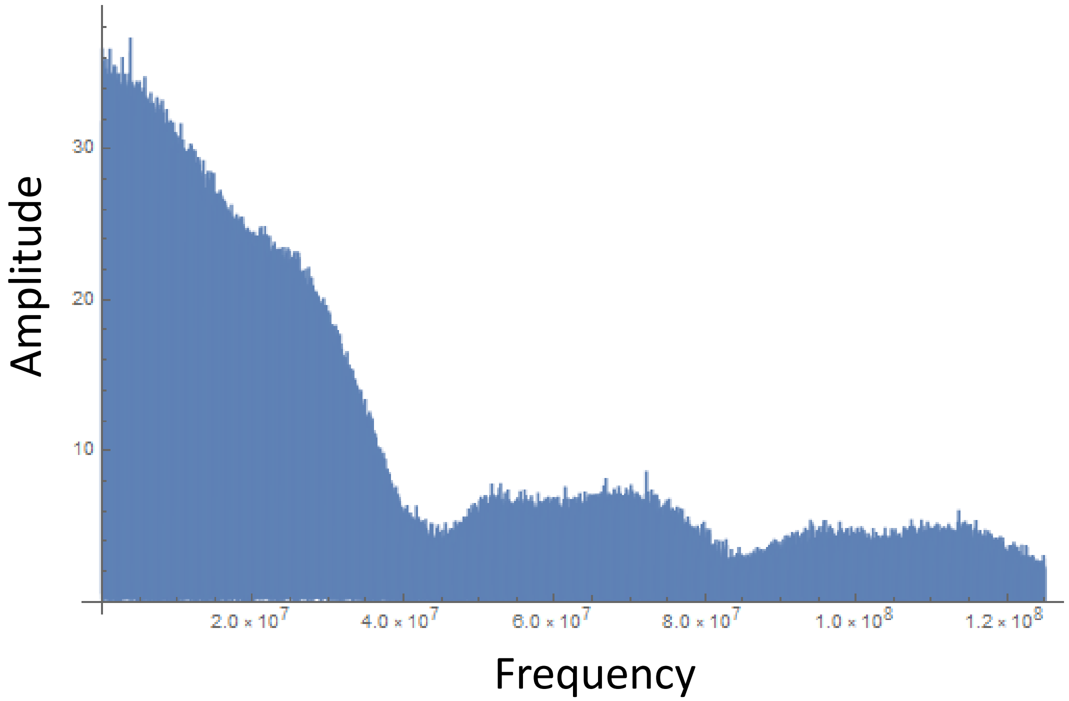
Time (ns)

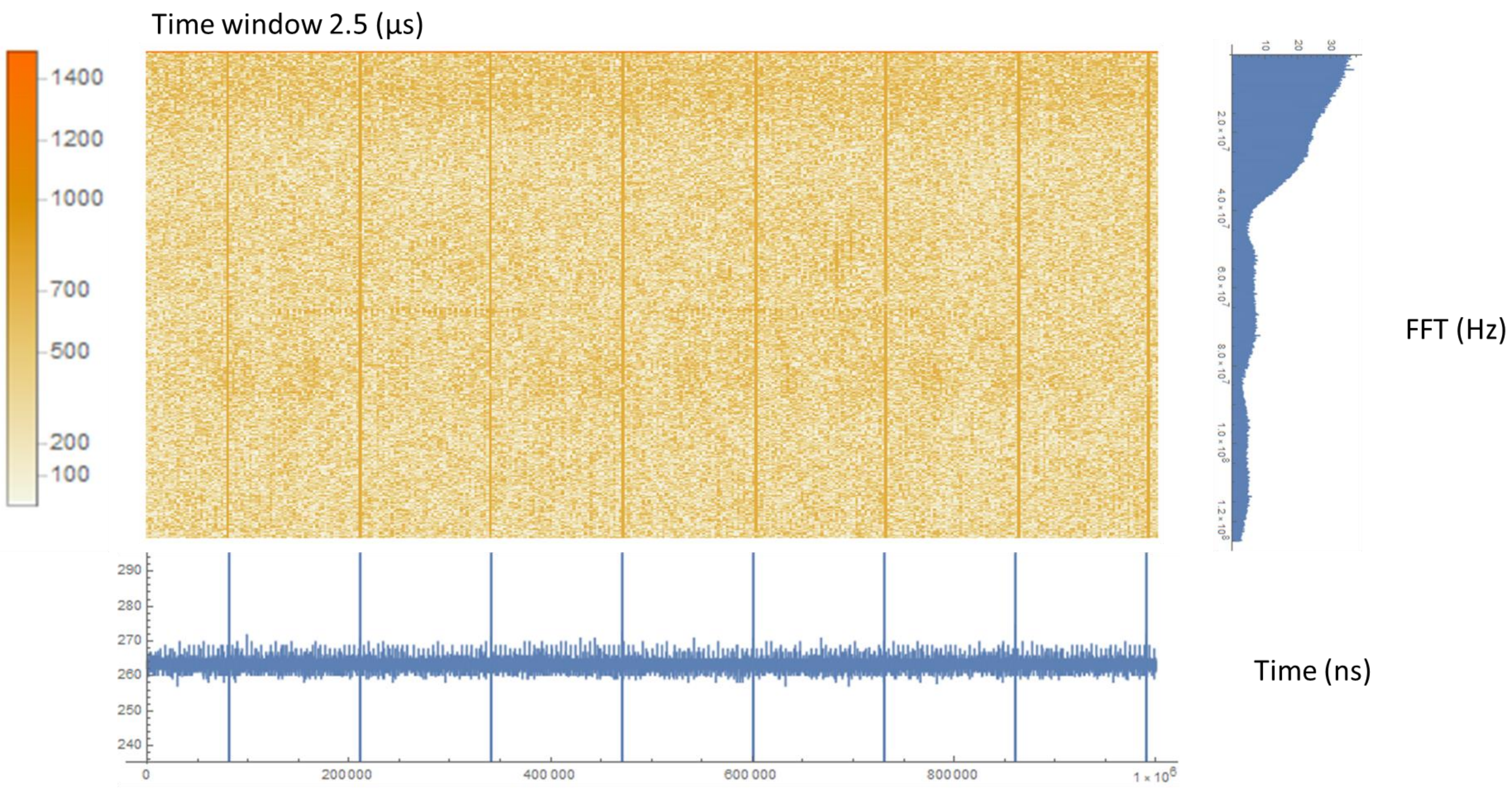
Spectrum of Signal Before Shaper

Decimation factor: 2, Effective sampling frequency: 250 Mhz



FFT

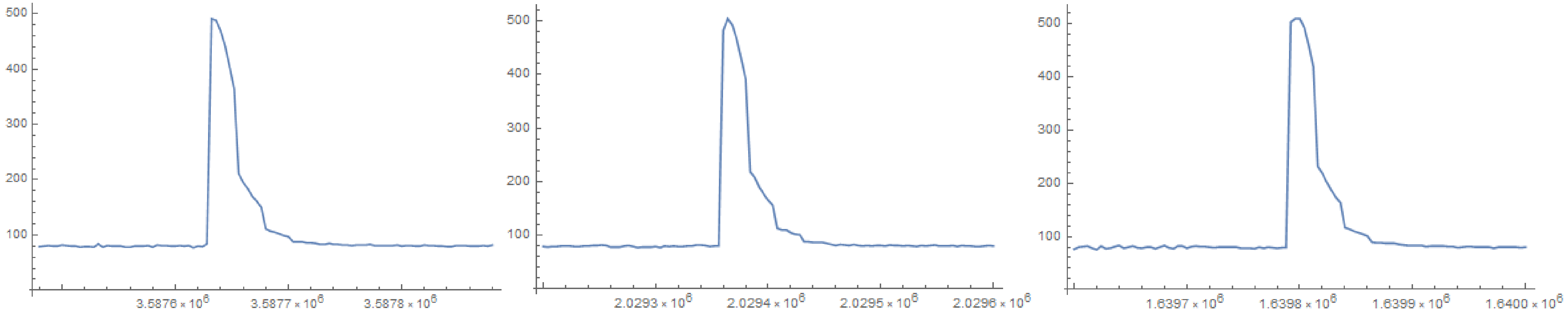




Time window 2.5 (μs)
1400
1200
1000
700
500
200
100
10
20
30
FFT (Hz)
290
280
270
260
250
240
0
200000
400000
600000
800000
Time (ns)

Pulses After Shaper

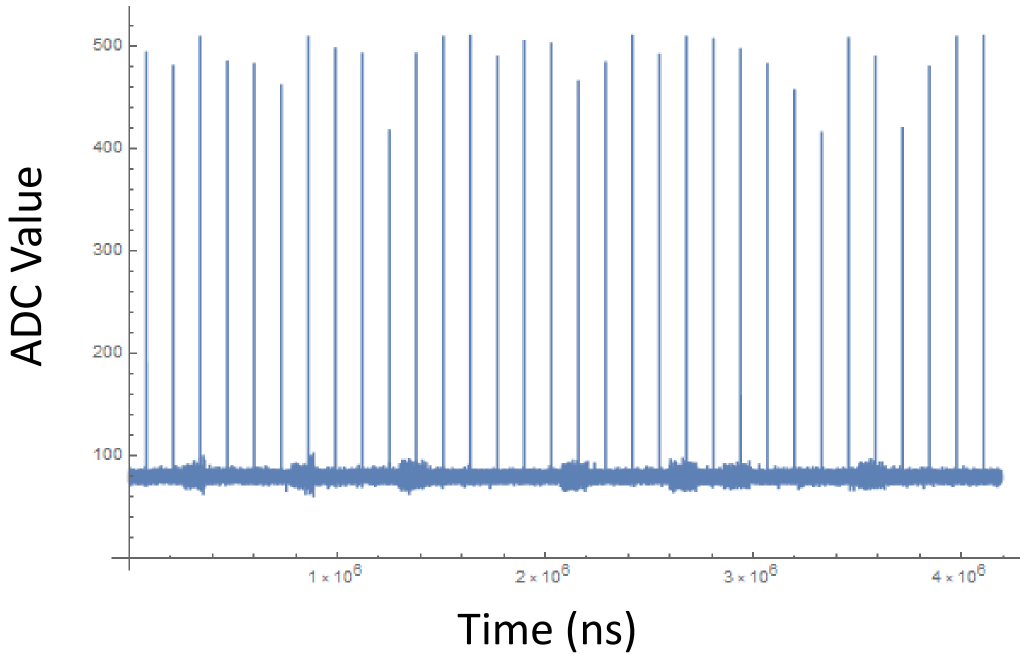
Signals sampled at 250MSPS

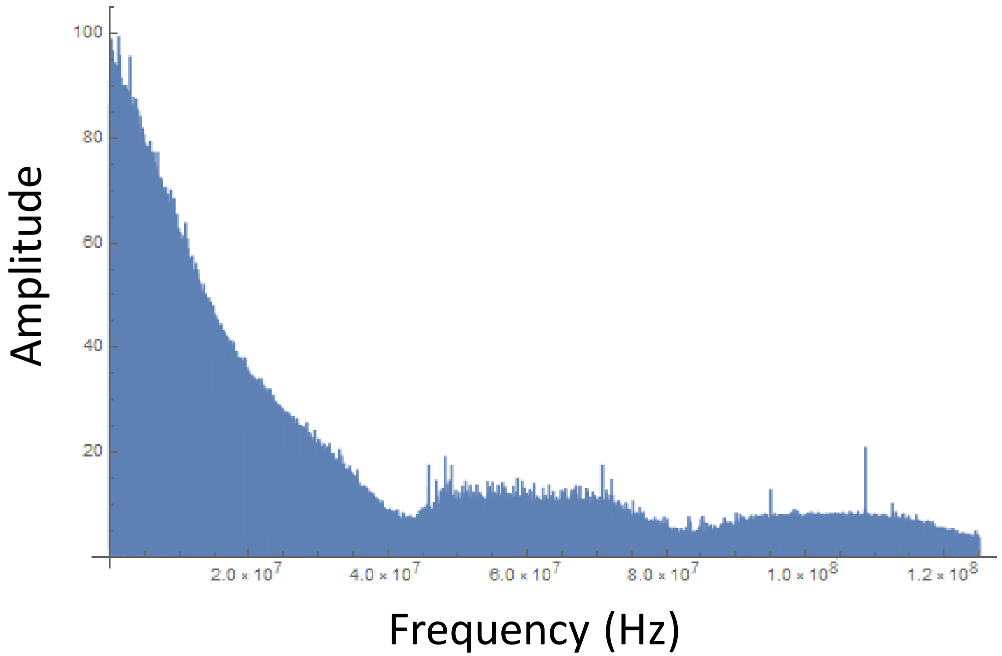


Time (ns)

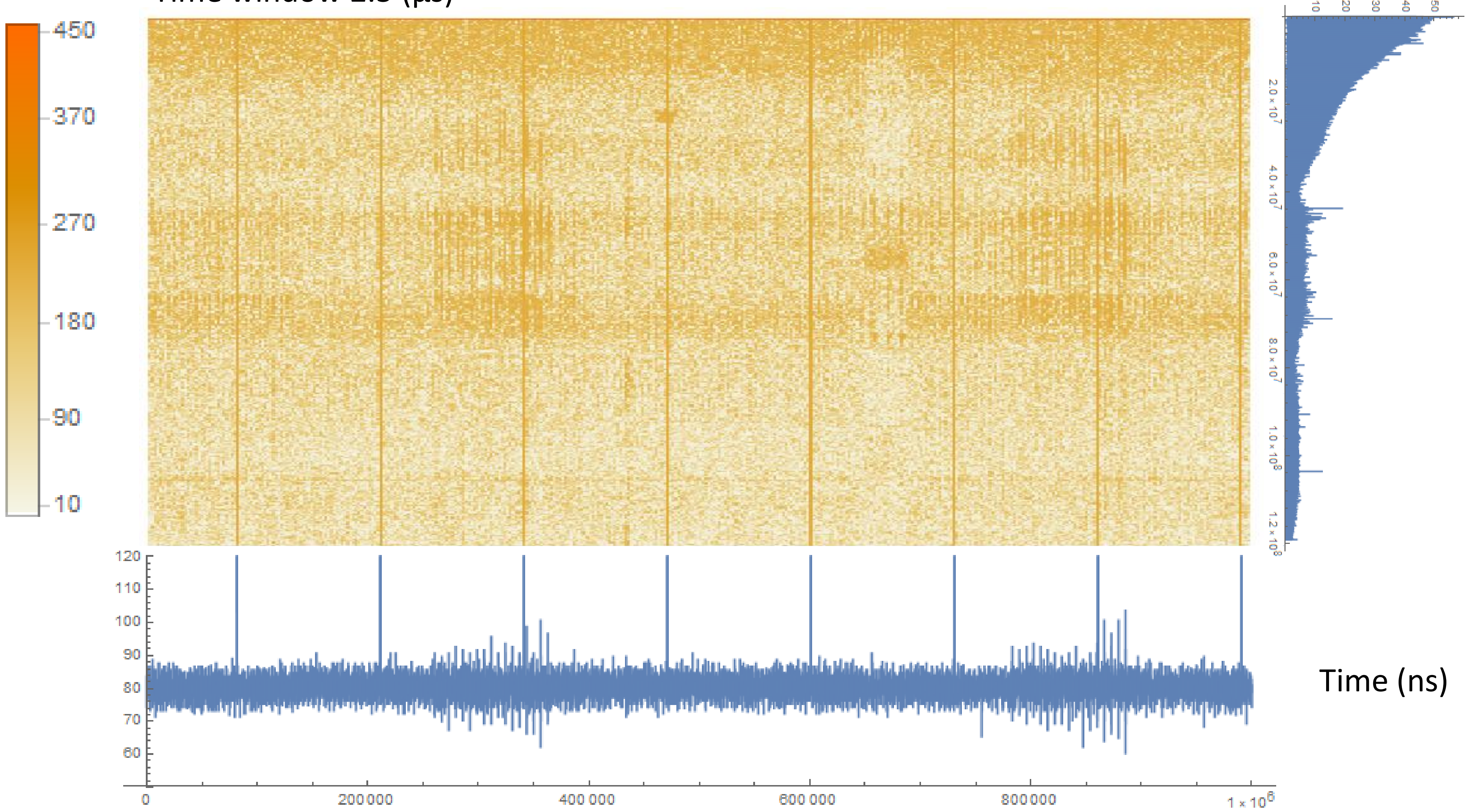
Spectrum of Signals after Shaper

Decimation factor: 2, Effective sampling frequency: 250 Mhz



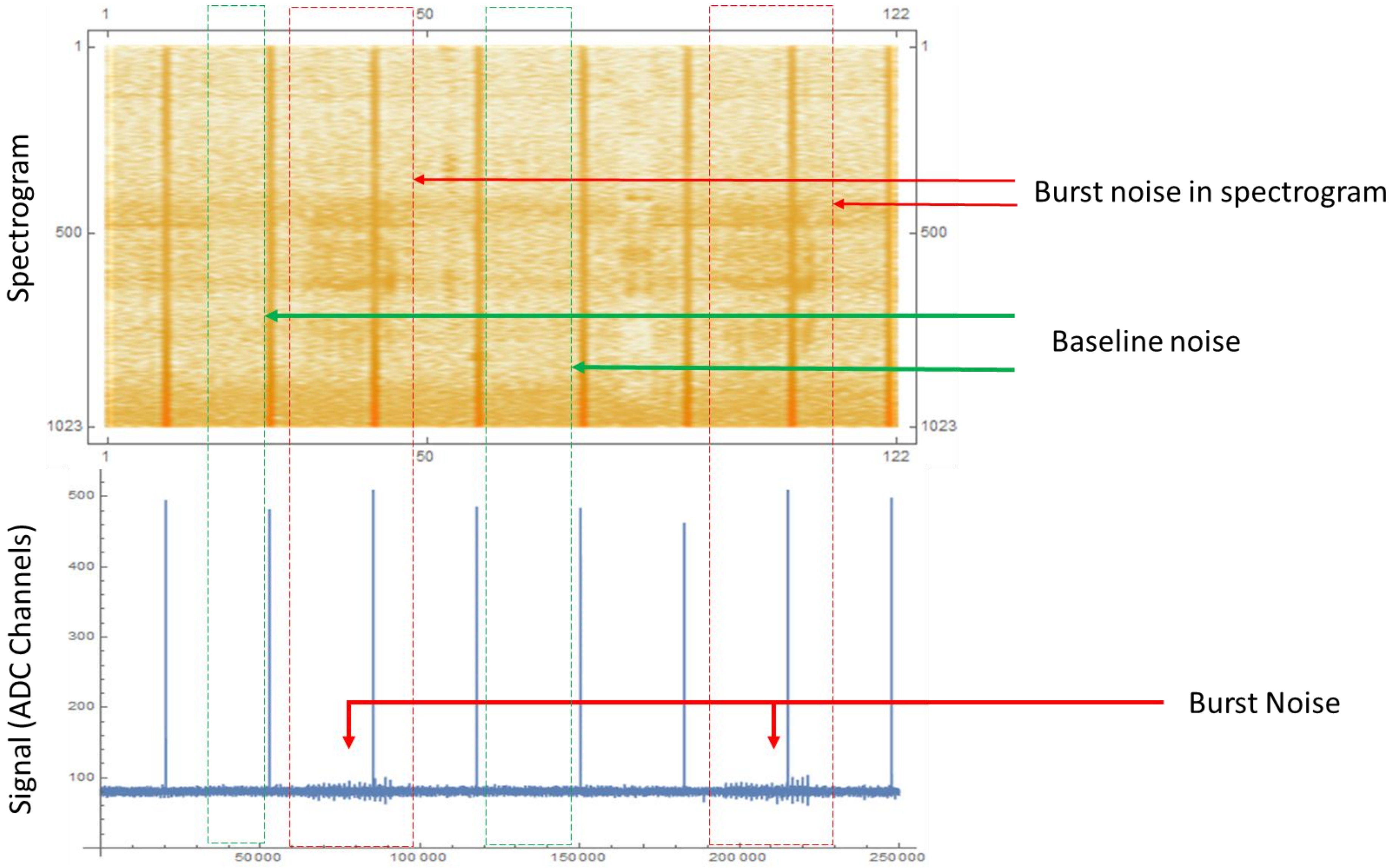


Time window 2.5 (μs)



FFT (Hz)

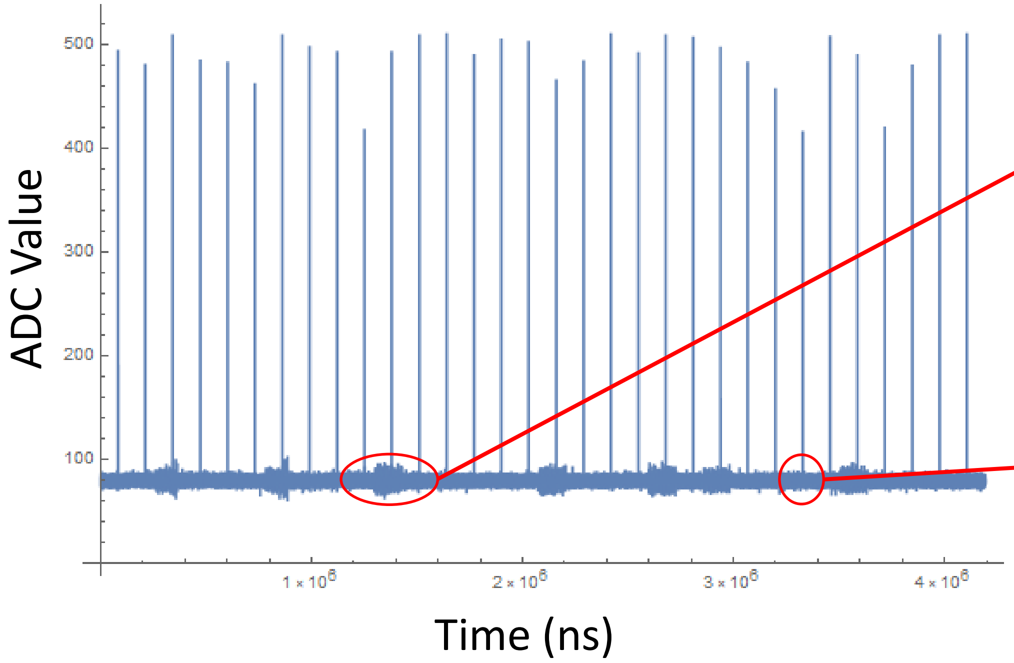
Time (ns)

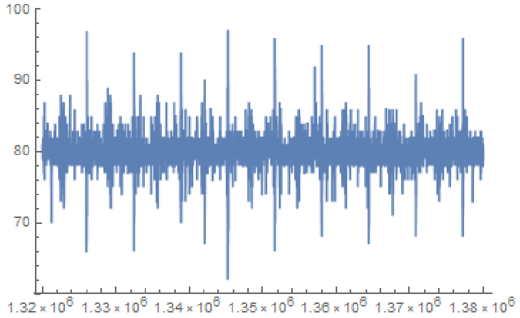

Spectrogram
1
50
122
1
500
1023
Burst noise in spectrogram
Baseline noise
Signal (ADC Channels)
500
400
300
200
100
50000
100000
150000
200000
250000
Burst Noise

Noise Analysis after Shaper

Decimation factor: 2, Effective sampling frequency: 250 MSPS

Two noise regimes identified



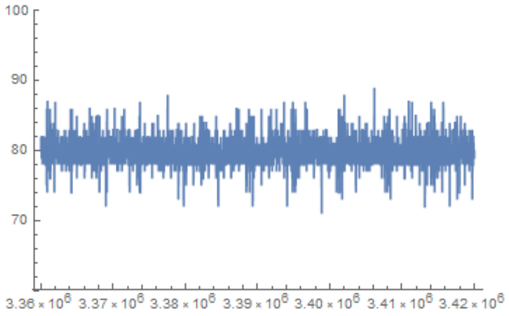


Burst noise 15KS

RMS = 80.0459

STD = 1.81031

Peak to peak = 35



Noise 15KS

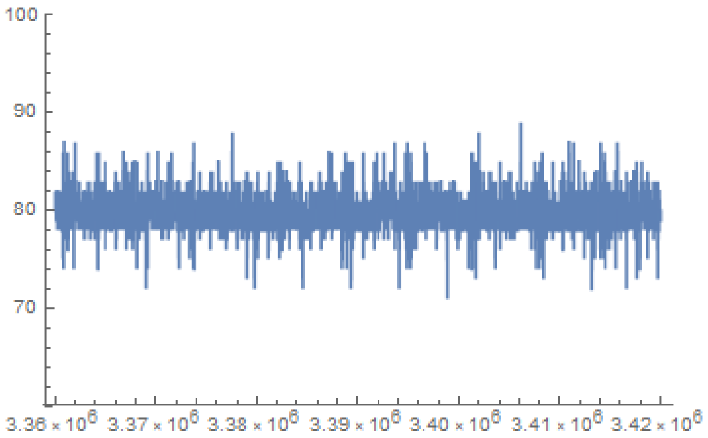
RMS = 79.9201

STD = 1.45537

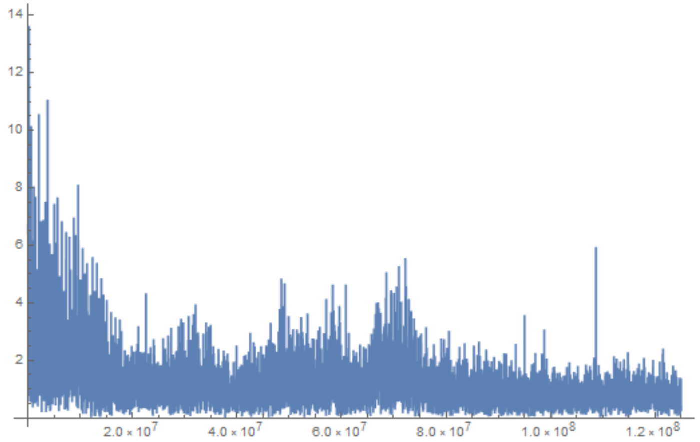
Peak to peak = 18

Burst noise and Baseline noise Comparison

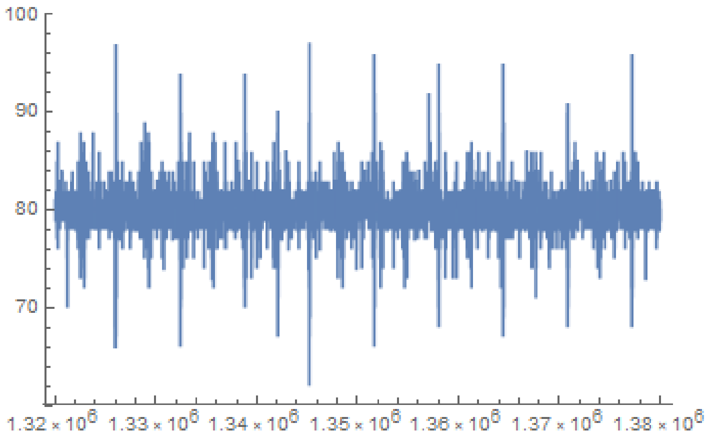
Baseline noise



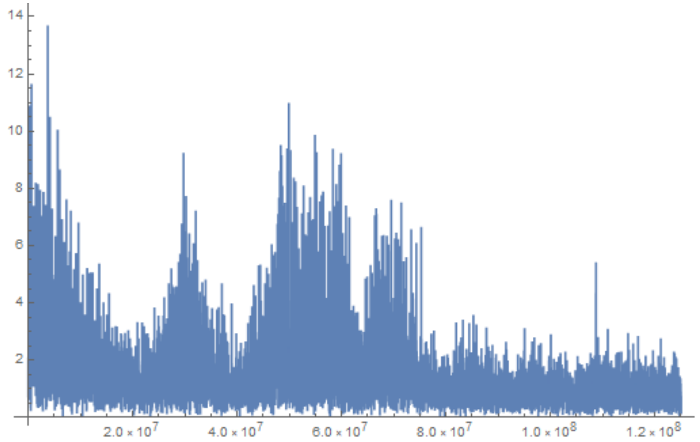
Baseline noise FFT



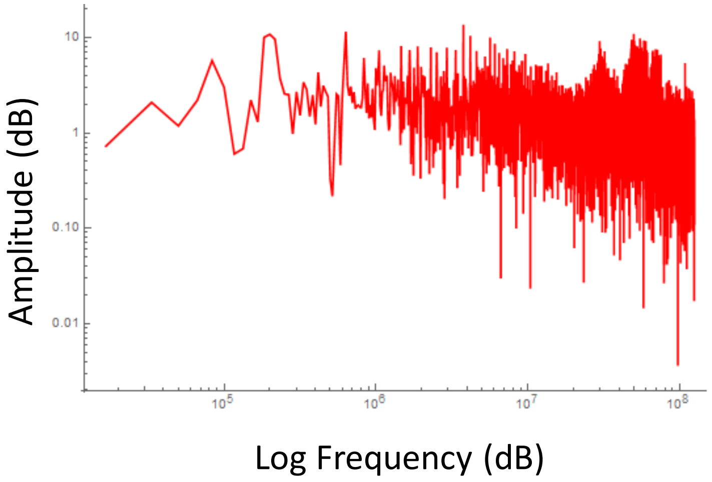
Burst noise



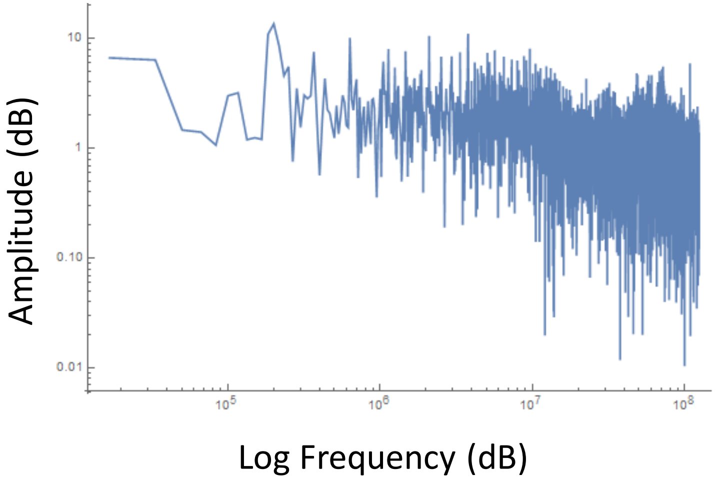
Burst noise FFT



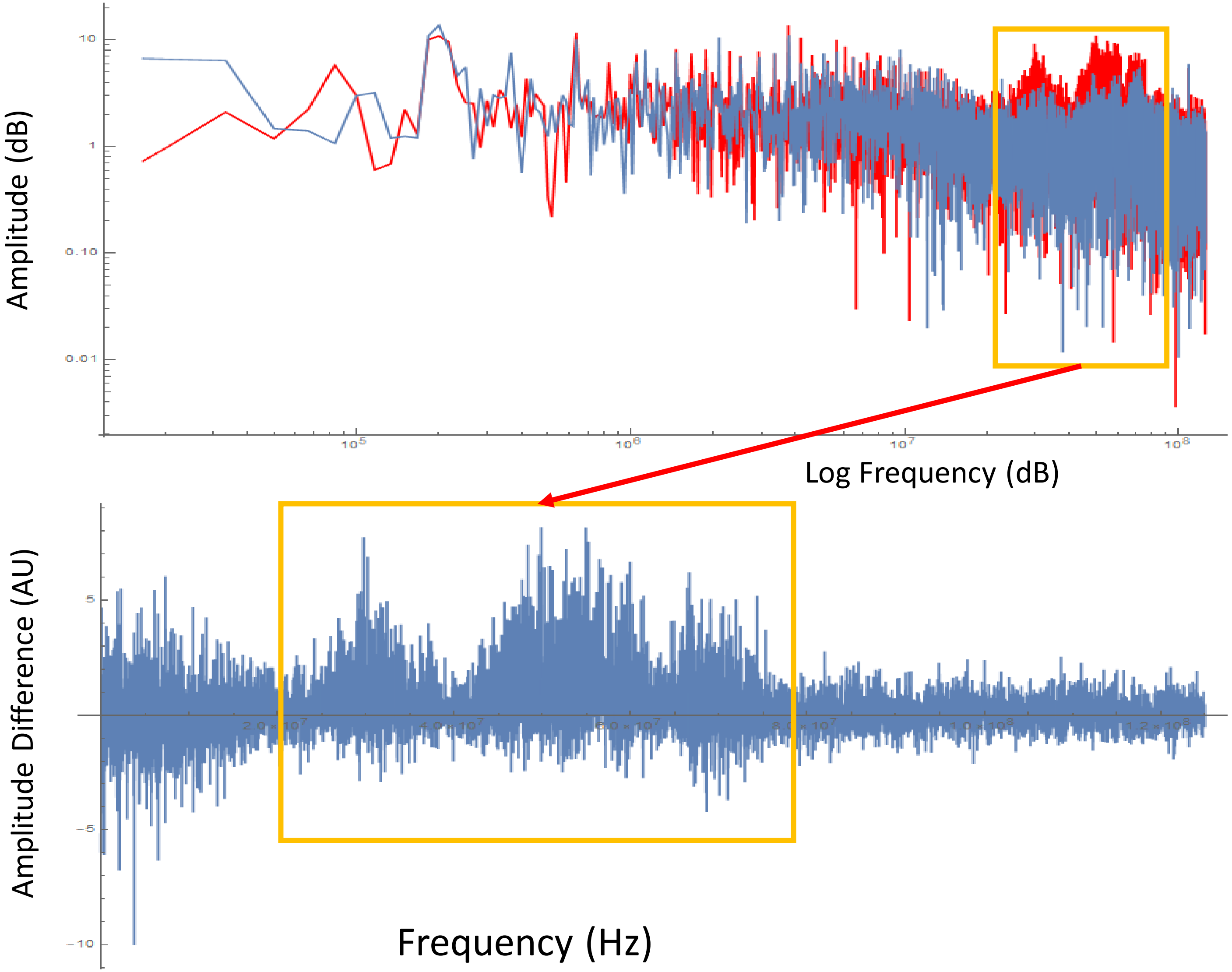
FFT Burst noise



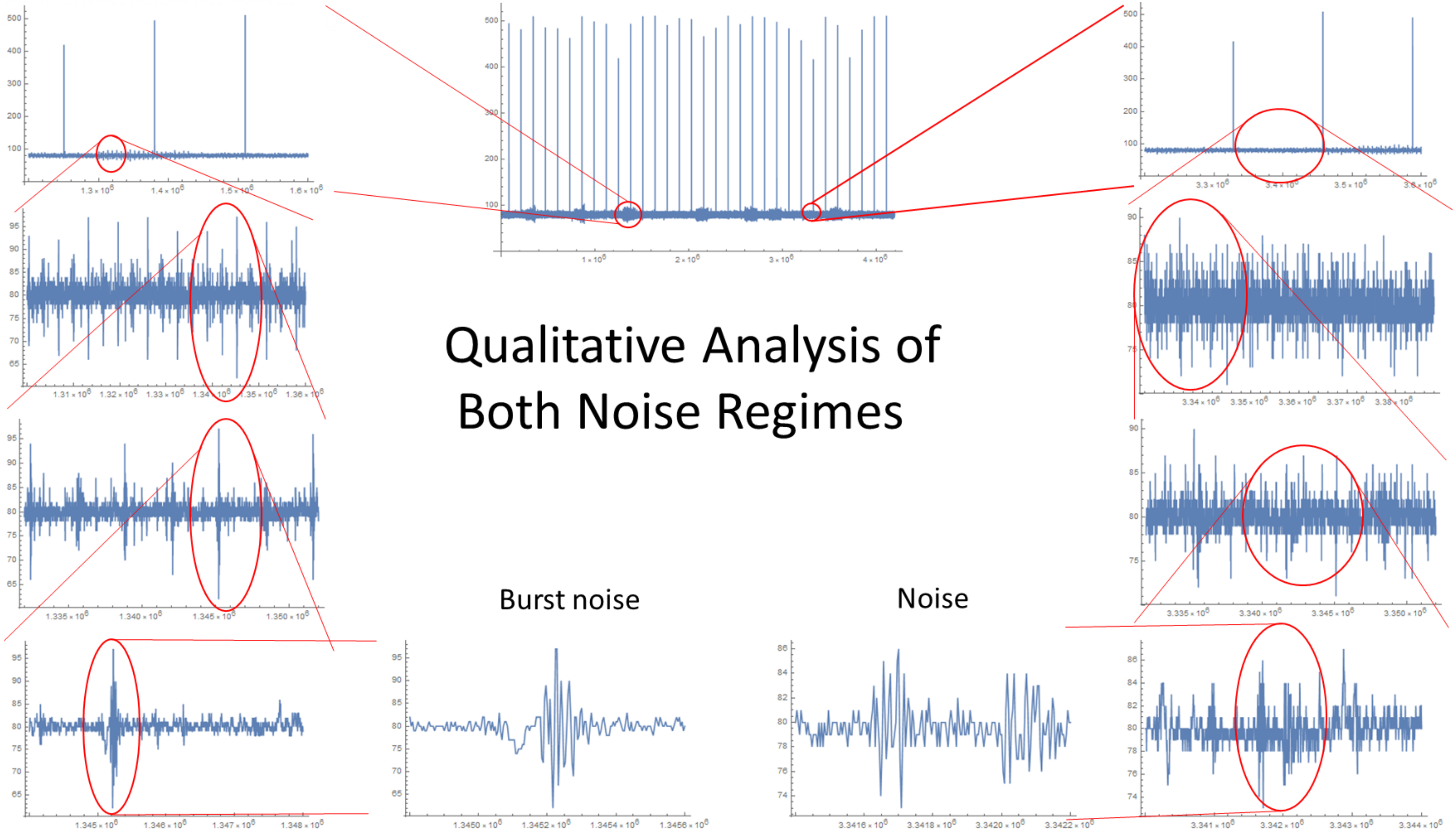
FFT Baseline noise



FFT Burst Noise and Baseline Compared



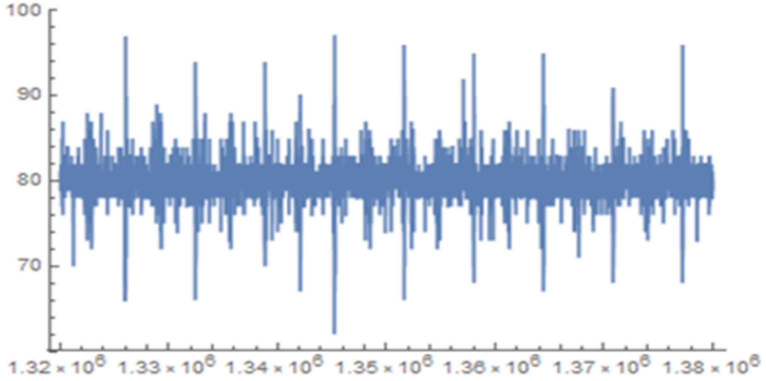
Qualitative Analysis of Both Noise Regimes

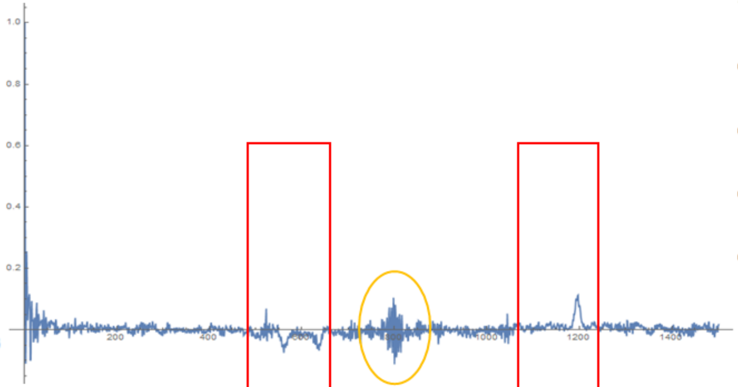


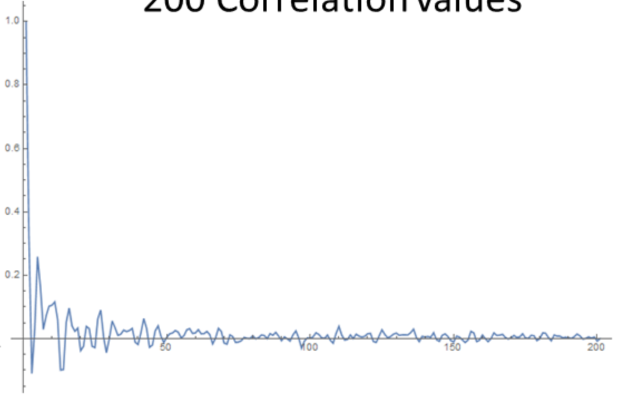
Comparison of Autocorrelation of Both Noise Regimes

1500 Correlation values

200 Correlation values

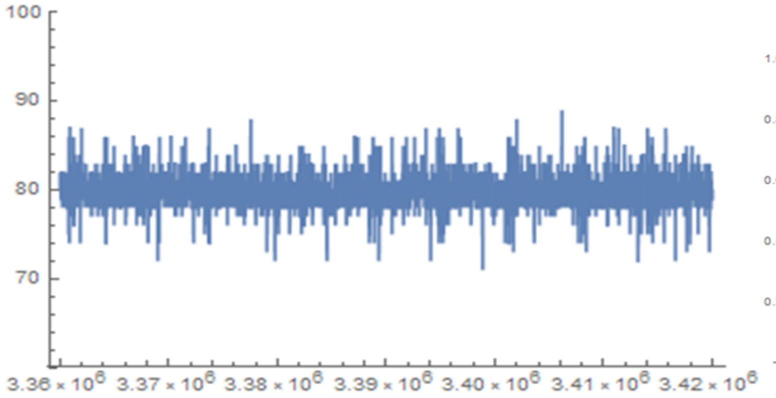


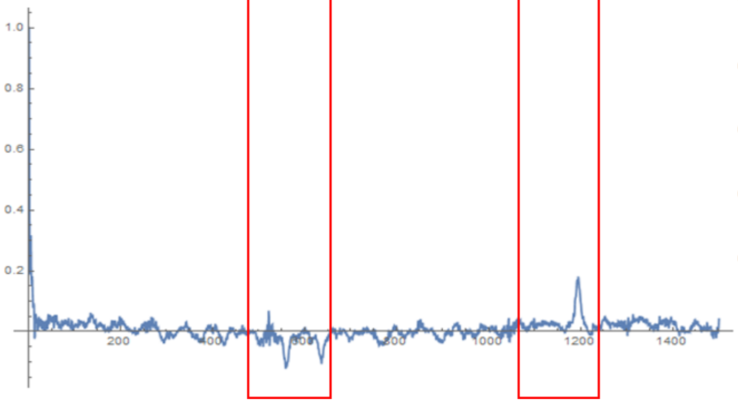


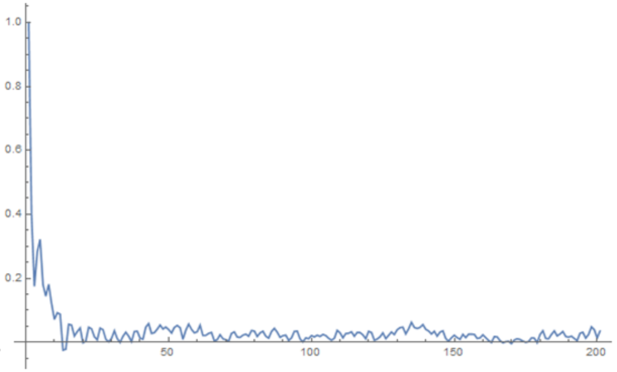


The red rectangles emphasize similarities between the bursts of noise and the baseline. This similarities indicate that the noise itself presents a complex pattern.

In the yellow circle the more distinctive pattern is highlighted.







Conclusions

- Satisfactory ideal pulse model identified
- Observed complex noise structures. It may need further analysis.
- Data analysis procedure has been defined and seems ready for channel by channel massive data analysis including:
  - Model parameters extraction
  - Noise autocorrelation function

Next Steps:
Design of a reconfigurable digital pulse processor for amplitude measurement ECAL2
FIR optimization
Pile-up rejection strategy implementation