n3He Frequency Analysis - Effect of Sample Time on FFT Results

M. McCrea
University of Manitoba

January 09, 2018

n3He DAQ Time Binning

- neutron pulses are at 60 Hz
- $1/60 = 0.0166667$ seconds between neutron pulses
- Clean DAQ
  - 50 kHz sample rate
  - 16 samples averaged for each of 49 recorded time bins per pulse
  - $16/(50\ \mathrm{kHz}) = 0.32\ \mathrm{ms}$ per time bin
  - 15.68 ms of data taking per neutron pulse
  - 0.98 ms dead time per pulse
- $t(t,k) = (16.6667 \times k + 0.32 \times t)\ \mathrm{ms}$

Section 4.2.4 of Kabir, Md Latiful, "A MEASUREMENT OF THE PARITY VIOLATING ASYMMETRY IN THE NEUTRON CAPTURE ON 3He AT SNS" (2017). Theses and Dissertations–Physics and Astronomy. 45.

FFT Frequency and Resolution Limits

- Nyquist–Shannon sampling theorem states the maximum frequency, f_{max}, is $1/2$ the sampling frequency
- A FFT with an input of N samples returns a real and imaginary array of length $N/2$.
- The frequency bin resolution is then

$$\Delta f = \frac{f_{max}}{N/2} \tag{1}$$

- for a constant sampling rate the longer data is taken the better the frequency resolution.
- For the target chamber:

$$f_{max} = \frac{1}{2}\frac{1}{0.00032} = \frac{1}{2}3125\ \mathrm{Hz} = 1562.5\ \mathrm{Hz} \tag{2}$$

$$\Delta f = \frac{1562.5\ \mathrm{Hz}}{24991 * 49} = \frac{1562.5\ \mathrm{Hz}}{1224559} = 0.00128\ \mathrm{Hz} \tag{3}$$

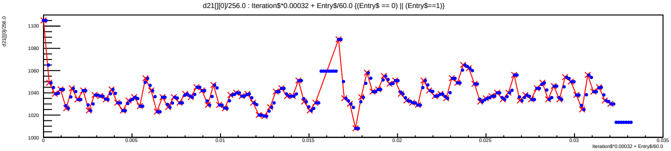
Resampling Motivation

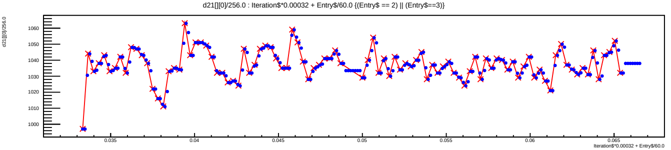
- Resampling increases the number of data points by interpolating between the measured pulse values
- Resampling does not increase accuracy of FFT but does create evenly spaced time bins to allow FFT algorithms to be applied.
- Each additional time bin increases the FFT processing and memory requirements during analysis.
- The goal is then to minimize the number of new samples while smoothly interpolating between the existing data points in a useful way.

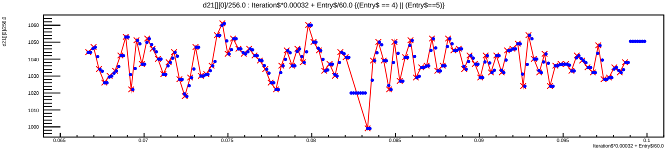
Resampling Method 1 - Integer Multiples

- Each Chamber pulse has up to 833 un-averaged samples
- This is divisible by seven for 119 samples per pulse that are 0.1401 ms wide
- Each current 0.32 ms time bin is repeated 16 times at the 833 samples per pulse
- Remaining $(833 - 49 \times 16 =)$49 time bins can be interpolated from the value of the last time bin of the current pulse and the first time bin of the next pulse.
- These 833 time bins can be averaged in groups of seven to reduce to 833 times bins to 119 if required to decrease processing time.
  - $49 \times 25000 = 1225000$
  - $119 \times 25000 = 2975000$
  - If required runs can be examined fractions at a time depending on the processing performances of the SapSimServer at the U of M.
- The benefit of this method is that minimal interpolation is required.

Resampling Results - First 6 pulses





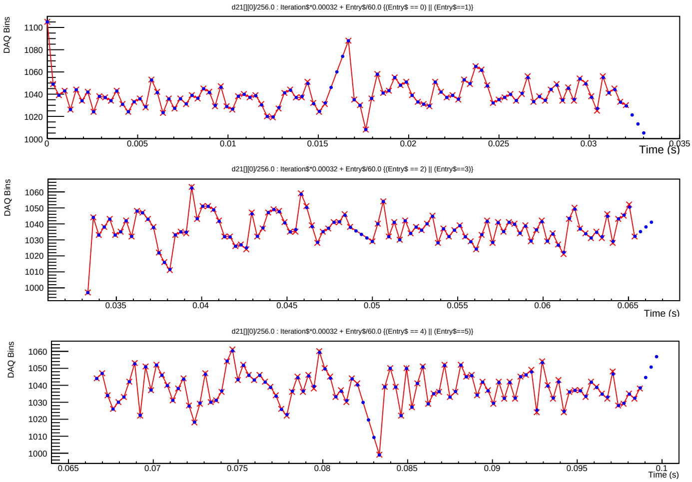


Red is original data points, blue interpolated data points.
Periods of constant values between pulses was not preferred so this method was replaced by linear as described on the new slide.

Resampling Method 2 - Linear Interpolation

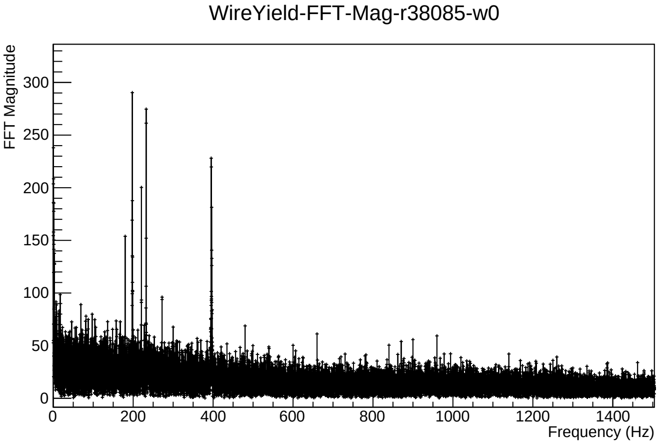
- Cern Root has linear interpolation built in as part of the MathMore library
- By supplying a time and DAQ value to the interpolator for all time bins in a pulse, and the first time bin of the next pulse to the linear interpolator any intermediary values can be calculated.
- For the 0.00032 s time bin width 52.08333 fit per neutron pulse.
- This was truncated to 52 time bins for the linear interpolation.

Linear Interpolation Results - First 6 pulses



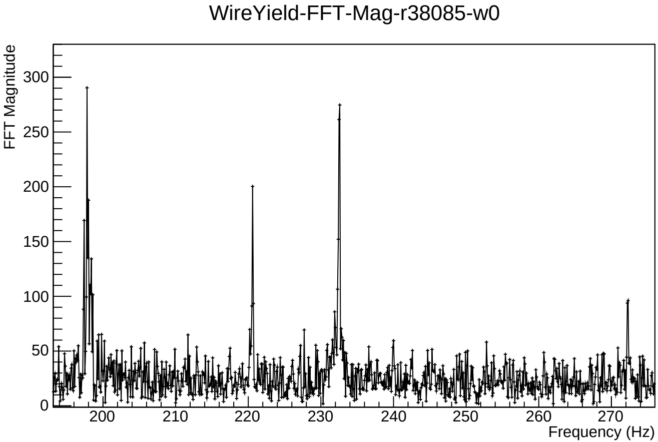
Red is original data points, blue interpolated data points.

FFT Magnitude - r38085 w0 First 600 Pulses



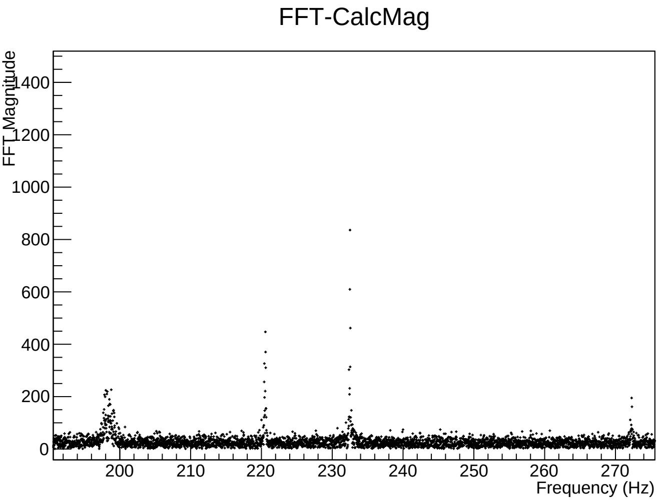
Note: Due to only the first 600 pulses being examined the frequency resolution is low in this plot. Used Method 1 for resampling.

FFT Magnitude - r38085 w0 First 600 Pulses



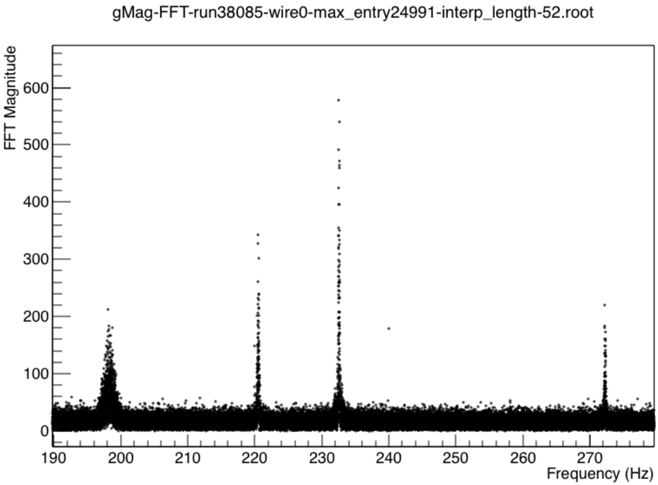
Note: Due to only the first 600 pulses being examined the frequency resolution is low in this plot. Used Method 1 for resampling.

FFT Magnitude - r38085 w0 First 2000 Pulses



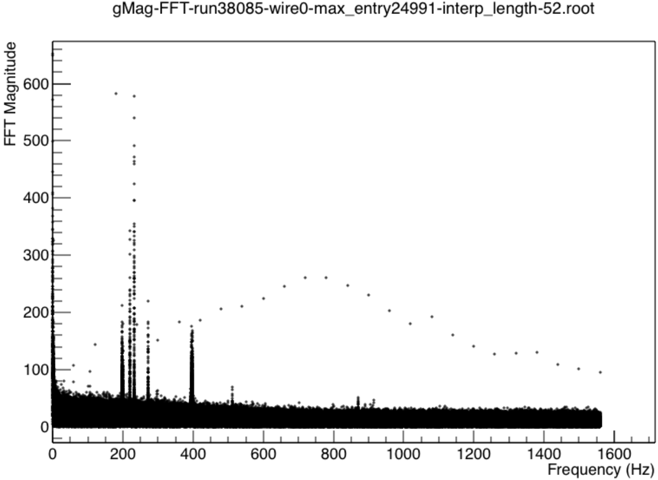
Used Linear Interpolation for Re-sampling.

FFT Magnitude - r38085 w0 All 24991 Pulses



Used Linear Interpolation for Re-sampling.

FFT Magnitude - r38085 w0 All 24991 Pulses



Used Linear Interpolation for Re-sampling.
The plot shows the full frequency range of the same data as on slide 12.

Conclusion

- Time resolution of an FFT increases with the length of the data taking period sampled for a constant sample rate
- The initial plot shown on 2018/01/05 had poor resolution.
- By solving the crash occurring due to declaring too many large arrays on the stack higher time resolution using the full data available in each run is now available, and will be used for analysis.