n3He Frequency Analysis - Fast Fourier Transform Method

M. McCrea
University of Manitoba

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Motivation

The goal of the FFT analysis is to look at the frequency components of the measured wire yields, and to see if it can offer a cause the oscillations in the asymmetry correlations. If the cause of the variations is resonance with the wires from an external then each wire is expected to have a consistent frequency somewhat near 210 Hz, but each wire is expected to differ somewhat.

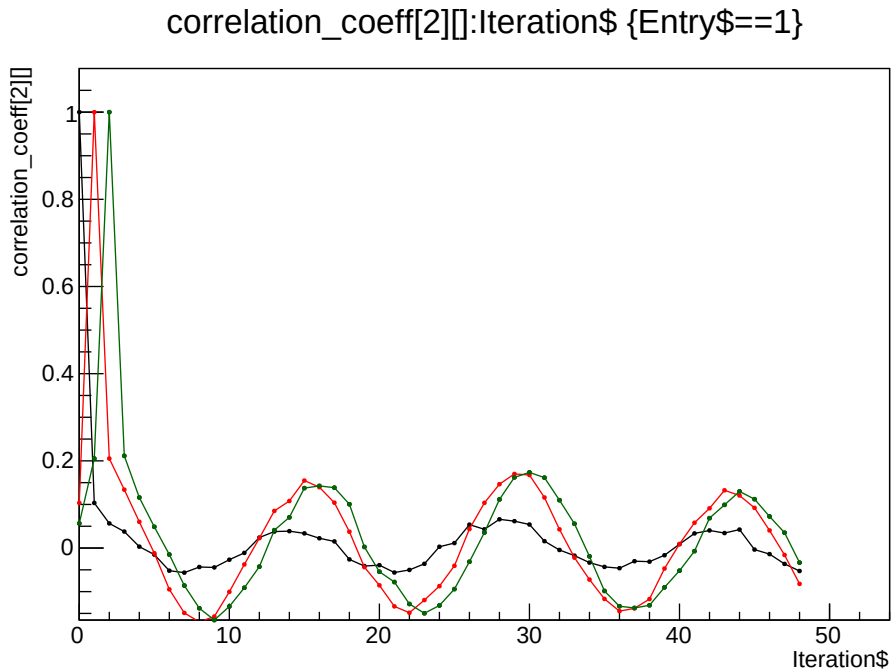

Figure: Correlations for time bins 0,1,2 wire 0 run 17785

n3He DAQ Time Binning

- neutron pulses are at 60 Hz
- $1/60 = 0.0166667$ seconds between neutron pulses
- Clean DAQ
  - 50 kHz sample rate
  - $50\ \mathrm{kHz} \times 0.01667\ \mathrm{s} = 833$ maximum samples per $T0$
  - 830 were used to allow time for triggering
  - 16 samples averaged for each of 49 recorded time bins per pulse
  - $16/(50\ \mathrm{kHz}) = 0.32\ \mathrm{ms}$ per time bin
  - 35 additional samples lost due to read out time
  - 15.68 ms of data taking per neutron pulse
  - 0.98 ms dead time per pulse

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.

Time Bin Spacing

Each time bin will be assigned a time according to the midpoint of the sample period

Pulse #	Bin #	Start(ms)	End(ms)	Center(ms)
0	0	0	0.32	0.16
0	1	0.32	0.64	0.48
0	2	0.64	0.96	0.80
0	⋮	⋮	⋮	⋮
0	47	15.04	15.36	15.20
0	48	15.36	15.68	15.52
1	0	16.6667	16.9867	16.8267
1	1	16.9867	17.3067	17.1467
1	⋮	⋮	⋮	⋮
1	48	32.0267	32.3467	32.1867
2	0	33.3333	33.6533	33.4933

or in general time bin t in pulse k will have a time of

$$t(t,k) = (16.6667 \times k + 0.32 \times t)\ \mathrm{ms} \tag{1}$$

Method

- Cern Root has a built in FFT functionality using FFTW (`www.fftw.org/`)
- This FFT package and others require a constant time sampling to work
- The dead time between pulses is not an integer multiple of the time bin length
- This prevent a direct application of Root's FFT package to the data runs so resampling must be performed of the experimental data.

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.

Resampling Method

- Each Chamber pulse has up to 833 un-averaged samples
- This is divisible by seven for 119 samples per pulse.
- Each current 0.32 ms time bin is repeated 16 times
- Remaining 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.
- Down sides is very large number of time bins in a run
  - $49 \times 25000 = 1225000$
  - $119 \times 25000 = 2975000$
  - 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.

Cern Root's FFTW Implementation - 1

Links for Root's FFT functions:

`https://root.cern.ch/root/html/tutorials/fft/FFT.C.html`

`https://root.cern.ch/doc/v608/classTVirtualFFT.html`

TVirtualFFT *fft_ own = TVirtualFFT::FFT(1, & NUM_ SAMPLES, "R2C M K");

This creates an FFT object with the options:

- The first argument, 1, specifies the number of dimensions in the transformation.
- The second arugment specifies the number of entries
- "R2C" Means it will do a real to complex transformation.
- The "M" option specifies the amount of time spent preplanning the transformation. Planning time can be increased with the patient "P" and exhaustive "EX" options if many transformation of the same size and type are to be done.
- The "K" option makes create a new TVirtualFFT object instead of reusing an the global FFT object.

Current Tasks

- Paperwork and other tasks to move to Lexington are now complete.
- This will allow a roughly 30-60-10 split in work between n3He, nEDM, and miscellaneous tasks in a week
- Finish Resampling function for wire data
- Start examining results comparing beam off summer runs from high asymmetry period to tuesday beam off runs to look for similar features in the mangitude of the frequency spectrum,
- Then compare this to beam on runs to see if any high instrumental asymmetry features are still present.