

n3He Frequency Analysis - FFT Results Summary

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Chamber Layout

DAQ Setup

Run Selections

FFT Method

Tuesday Run

Low Asymmetry Summer Run

High Asymmetry Summer Run

Additional Plots of FFTs

Signal Wire Numbering

| | Beam | | | | | | | | | | | | | | | |
|---|------|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|
| | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 | S12 | S13 | S14 | S15 | S16 |
| i | 8 | 17 | 26 | 35 | 44 | 53 | 62 | 71 | 80 | 89 | 98 | 107 | 116 | 125 | 134 | 143 |
| h | 7 | 16 | 25 | 34 | 43 | 52 | 61 | 70 | 79 | 88 | 97 | 106 | 115 | 124 | 133 | 142 |
| g | 6 | 15 | 24 | 33 | 42 | 51 | 60 | 69 | 78 | 87 | 96 | 105 | 114 | 123 | 132 | 141 |
| f | 5 | 14 | 23 | 32 | 41 | 50 | 59 | 68 | 77 | 86 | 95 | 104 | 113 | 122 | 131 | 140 |
| e | 4 | 13 | 22 | 31 | 40 | 49 | 58 | 67 | 76 | 85 | 94 | 103 | 112 | 121 | 130 | 139 |
| d | 3 | 12 | 21 | 30 | 39 | 48 | 57 | 66 | 75 | 84 | 93 | 102 | 111 | 120 | 129 | 138 |
| c | 2 | 11 | 20 | 29 | 38 | 47 | 56 | 65 | 74 | 83 | 92 | 101 | 110 | 119 | 128 | 137 |
| b | 1 | 10 | 19 | 28 | 37 | 46 | 55 | 64 | 73 | 82 | 91 | 100 | 109 | 118 | 127 | 136 |
| a | 0 | 9 | 18 | 27 | 36 | 45 | 54 | 63 | 72 | 81 | 90 | 99 | 108 | 117 | 126 | 135 |

17 HV Frames with 8 wires each

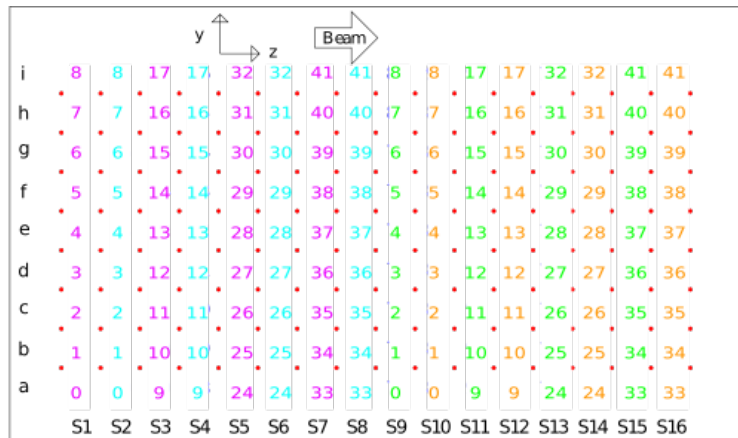
- Signal

16 signal Frames with 9 wires each

DAQ to Wire Mapping

- ▶ 4 Clean DAQs were used for data taking
- ▶ each DAQ had 48 channels
- ▶ $144 \text{ wires} / 4 \text{ DAQs} = 36 \text{ wires per DAQ}$
- ▶ 12 channels per DAQ were not instrumented

DAQ to Wire Position Mapping



The diagram illustrates the mapping of DAQ channels to wire positions. A coordinate system at the top shows the y-axis pointing up and the z-axis pointing right, with a 'Beam' arrow pointing right. The mapping is presented as a grid of 16 columns (S1 to S16) and 9 rows (a to i). Each cell contains a number representing a wire position, color-coded by DAQ channel: DAQ21 (magenta), DAQ23 (cyan), DAQ22 (green), and DAQ24 (orange). The numbers in each row are: i (8, 8, 17, 17, 32, 32, 41, 41, 8, 8, 17, 17, 32, 32, 41, 41), h (7, 7, 16, 16, 31, 31, 40, 40, 7, 7, 16, 16, 31, 31, 40, 40), g (6, 6, 15, 15, 30, 30, 39, 39, 6, 6, 15, 15, 30, 30, 39, 39), f (5, 5, 14, 14, 29, 29, 38, 38, 5, 5, 14, 14, 29, 29, 38, 38), e (4, 4, 13, 13, 28, 28, 37, 37, 4, 4, 13, 13, 28, 28, 37, 37), d (3, 3, 12, 12, 27, 27, 36, 36, 3, 3, 12, 12, 27, 27, 36, 36), c (2, 2, 11, 11, 26, 26, 35, 35, 2, 2, 11, 11, 26, 26, 35, 35), b (1, 1, 10, 10, 25, 25, 34, 34, 1, 1, 10, 10, 25, 25, 34, 34), a (0, 0, 9, 9, 24, 24, 33, 33, 0, 0, 9, 9, 24, 24, 33, 33).

| | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 | S12 | S13 | S14 | S15 | S16 |
|---|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|
| i | 8 | 8 | 17 | 17 | 32 | 32 | 41 | 41 | 8 | 8 | 17 | 17 | 32 | 32 | 41 | 41 |
| h | 7 | 7 | 16 | 16 | 31 | 31 | 40 | 40 | 7 | 7 | 16 | 16 | 31 | 31 | 40 | 40 |
| g | 6 | 6 | 15 | 15 | 30 | 30 | 39 | 39 | 6 | 6 | 15 | 15 | 30 | 30 | 39 | 39 |
| f | 5 | 5 | 14 | 14 | 29 | 29 | 38 | 38 | 5 | 5 | 14 | 14 | 29 | 29 | 38 | 38 |
| e | 4 | 4 | 13 | 13 | 28 | 28 | 37 | 37 | 4 | 4 | 13 | 13 | 28 | 28 | 37 | 37 |
| d | 3 | 3 | 12 | 12 | 27 | 27 | 36 | 36 | 3 | 3 | 12 | 12 | 27 | 27 | 36 | 36 |
| c | 2 | 2 | 11 | 11 | 26 | 26 | 35 | 35 | 2 | 2 | 11 | 11 | 26 | 26 | 35 | 35 |
| b | 1 | 1 | 10 | 10 | 25 | 25 | 34 | 34 | 1 | 1 | 10 | 10 | 25 | 25 | 34 | 34 |
| a | 0 | 0 | 9 | 9 | 24 | 24 | 33 | 33 | 0 | 0 | 9 | 9 | 24 | 24 | 33 | 33 |

DAQ21 DAQ23 DAQ22 DAQ24

Tuesday Run List

| Tuesday Run List | | | | | |
|------------------|-------------|-----------|-----|-------------|-----------|
| | Initial Run | Final Run | | Initial Run | Final Run |
| T1 | 17784 | 17834 | ST1 | 38386 | 38416 |
| T2 | 19114 | 19158 | ST2 | 38566 | 38588 |
| T3 | 20444 | 20493 | T10 | 45032 | 45054 |
| T4 | 21869 | 21919 | T11 | 46416 | 46466 |
| T5 | 24011 | 24061 | T12 | 49663 | 49697 |
| T6 | 26461 | 26503 | T13 | 51076 | 51127 |
| T7 | 27729 | 27755 | T14 | 52467 | 52517 |
| T8 | 30058 | 30074 | T15 | 56073 | 56076 |
| T9 | 32503 | 32535 | | | |

Runs were taken between 9:00am and 4:00pm while beam was off for maintenance, and the total time each Tuesday the beam was off time was variable.

ST# runs are Tuesdays from the Summer that Kabir used in his beam off Tuesday asymmetry calculations.

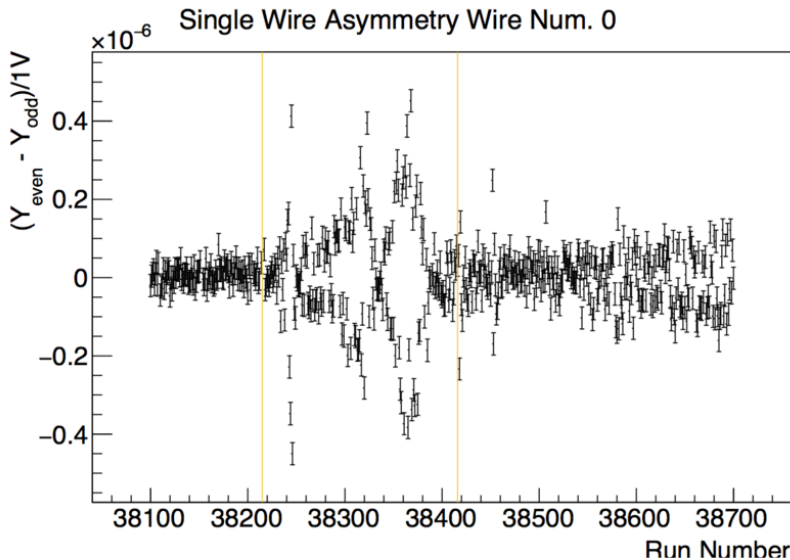
Summer Run List

A list of good beam off runs has been provided by Kabir, and are now on the n3He wiki Instrumental Asym. webpage for reference by the group.

Summer Run List

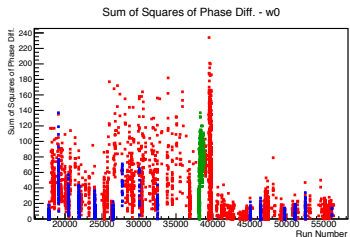
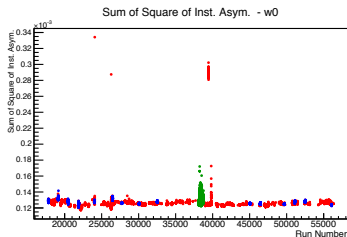
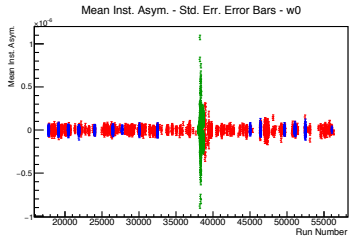
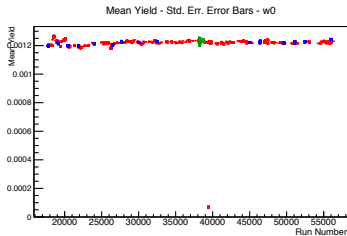
| Date Range | Initial Run | Final Run |
|------------|-------------|-----------|
| 2015-06-25 | 38081 | 38124 |
| 2015-06-26 | 38125 | 38215 |
| 2015-08-03 | 38216 | 38301 |
| 2015-08-04 | 38302 | 38416 |
| 2015-08-10 | 38417 | 38493 |
| 2015-08-11 | 38494 | 38657 |
| 2015-08-12 | 38658 | 38769 |

Unscaled Summer Running Asymmetry - w0



Blue is Tuesdays, Green is summer, Red is all other beam off runs.

All Beam Off Runs - Wire 0 Select Plots



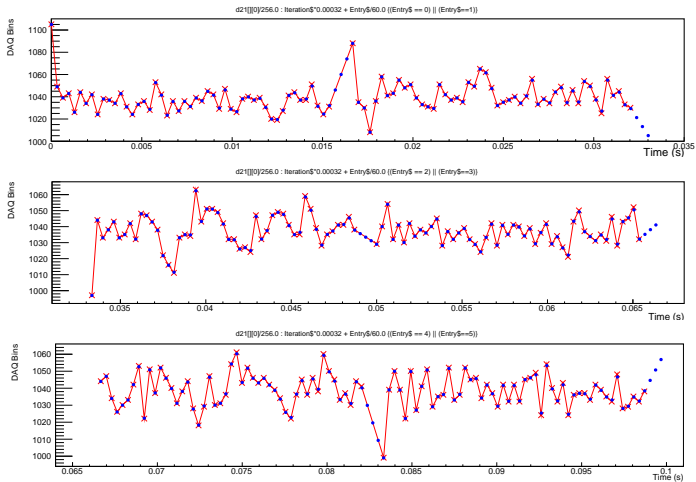
Blue is Tuesdays, Green is summer, Red is all other beam off runs.

Method

- ▶ Use linear interpolation between the existing data points to give 52 evenly space time bins per DAQ frame from the original 49 time bins using the interpolation functionality from Cern Root's MathMore library.
- ▶ After interpolating a complete run use Cern Root's FFT capability to perform an FFT of the data.
- ▶ Calculate the spectral density

$$SD = fft_re^2 + fft_im^2 \quad (1)$$

Linear Interpolation Results - First 6 pulses



Red is original data points, blue interpolated data points.

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
 - ▶ $16/(50 \text{ kHz}) = 0.32 \text{ ms}$ per time bin
 - ▶ This has a maximum of 52.083 samples per frame
 - ▶ 3125 Hz sample rate for the recorded data
 - ▶ 2940 samples recorded per second
 - ▶ 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.

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

$$\Delta f = \frac{f_{max}}{N/2} \quad (2)$$

- ▶ Thus, with a constant sampling rate the longer data is taken the better the frequency resolution.

Frequency Range and Resolution Limits of Data

- For the target chamber:

$$N/2 = 49 \times 24991/2 = 612279.5 \quad (3)$$

$$f_{\text{sample}} = \frac{1}{0.00032 \text{ s}} = 3125 \text{ Hz} \quad (4)$$

$$f_{\text{max}} = \frac{1}{2} f_{\text{sample}} = \frac{1}{2} 3125 \text{ Hz} = 1562.5 \text{ Hz} \quad (5)$$

$$\Delta f = \frac{1562.5 \text{ Hz}}{24991 * 49} = \frac{1562.5 \text{ Hz}}{1224559} = 0.00128 \text{ Hz} \quad (6)$$

- For the interpolated data:

$$N/2 = 52 \times 24991/2 = 649766 \quad (7)$$

$$f_{\text{sample}} = \frac{1}{0.00032051 \text{ s}} = 3120.03 \text{ Hz} \quad (8)$$

$$f_{\text{max}} = \frac{1}{2} \frac{1}{0.00032051} = \frac{1}{2} 3120.03 \text{ Hz} = 1560.01 \text{ Hz} \quad (9)$$

$$\Delta f = \frac{1560.01 \text{ Hz}}{24991 * 52} = 0.00120 \text{ Hz} \quad (10)$$

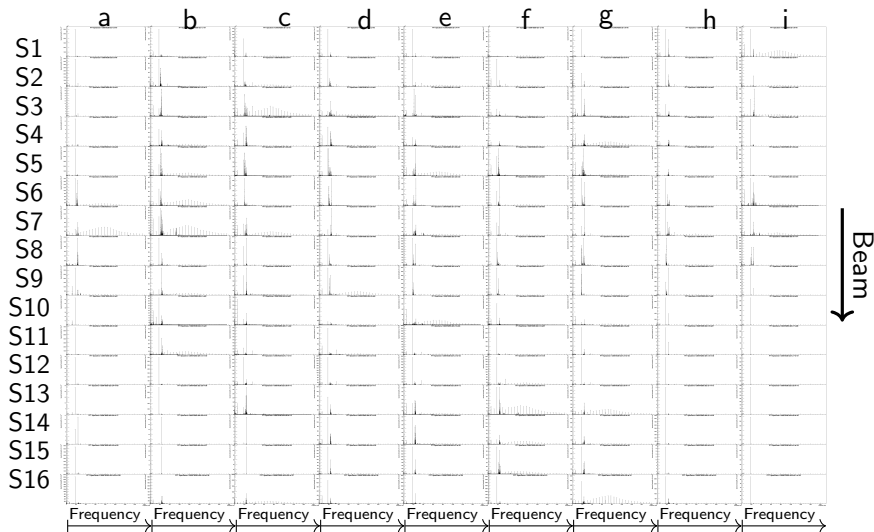
Spectral Density Calculation

$$SD(f) = FFT_{re}(f)^2 + FFT_{im}(f)^2 \quad (11)$$

where

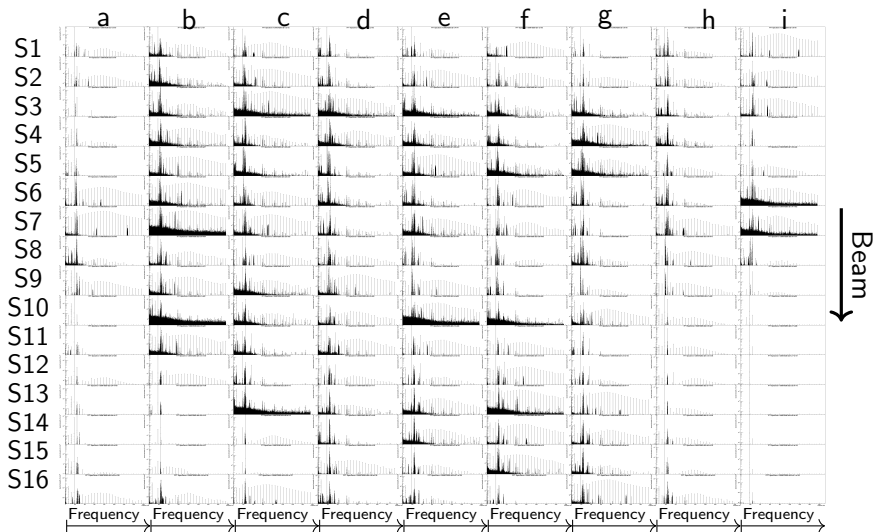
- ▶ f is the frequency
- ▶ $FFT_{re}(f)$ is the real part of the FFT for the bin containing the frequency f
- ▶ $FFT_{im}(f)$ is the real part of the FFT for the bin containing the frequency f
- ▶ $SD(f)$ is the spectral density

Tuesday Run - 17785



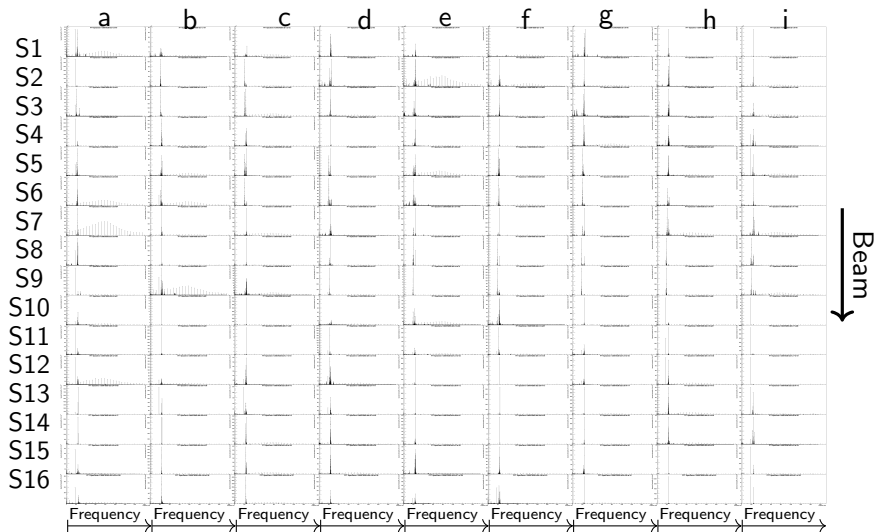
X-axis all all the same. Y-axis are all **DIFFERENT**.

Tuesday Run - 17785 - Log Scale Y-axis



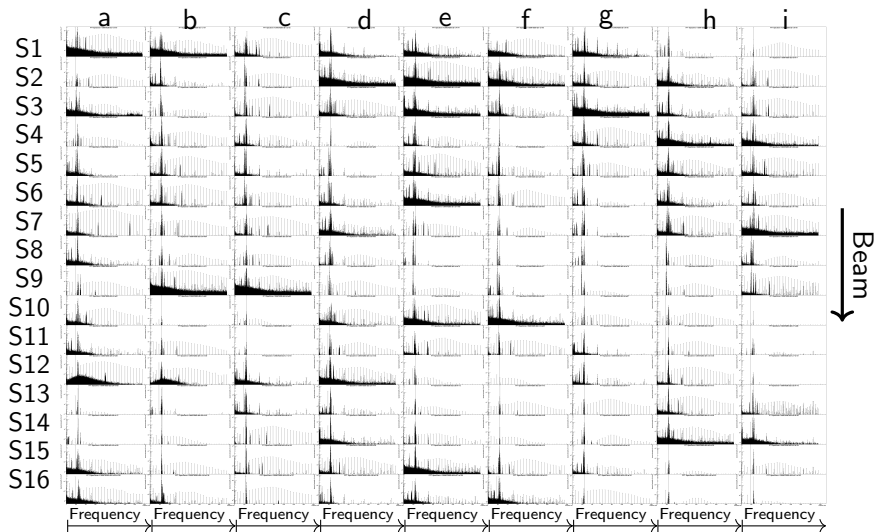
X-axis all all the same. Y-axis are all **DIFFERENT**.

Low Asymmetry Summer Run - 38085



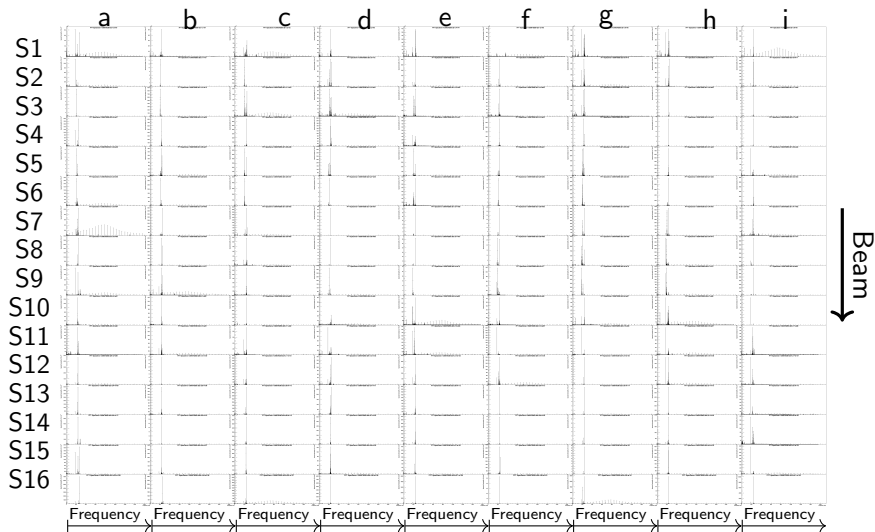
X-axis all all the same. Y-axis are all **DIFFERENT**.

Low Asymmetry Summer Run - 38085 - Log Scale Y-axis



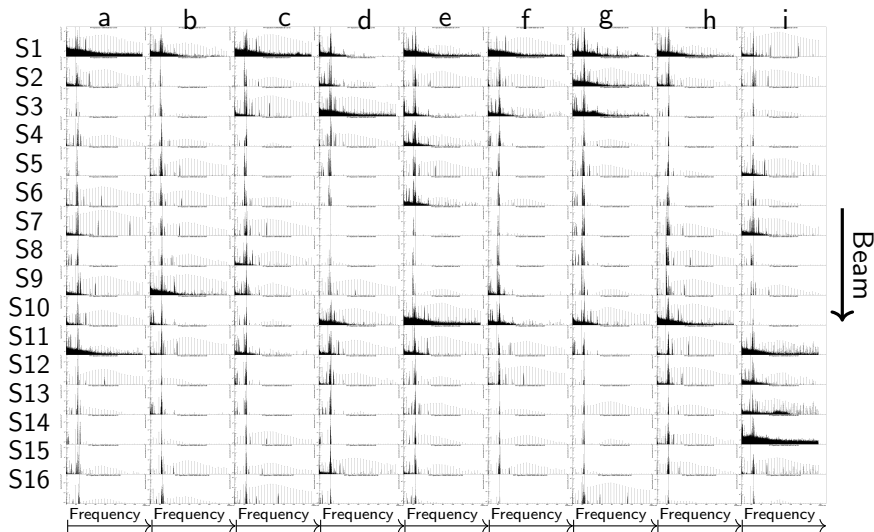
X-axis all all the same. Y-axis are all **DIFFERENT**.

High Asymmetry Summer Run - 38444



X-axis all all the same. Y-axis are all **DIFFERENT**.

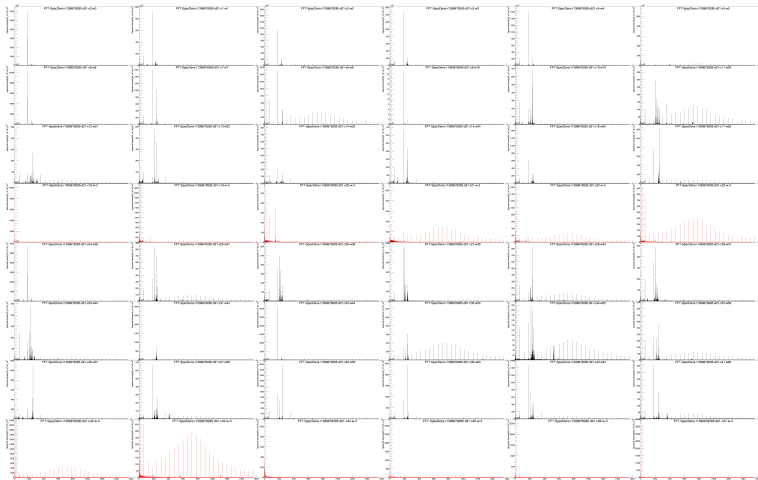
High Asymmetry Summer Run - 38444 - Log Scale Y-axis



X-axis all all the same. Y-axis are all **DIFFERENT**.

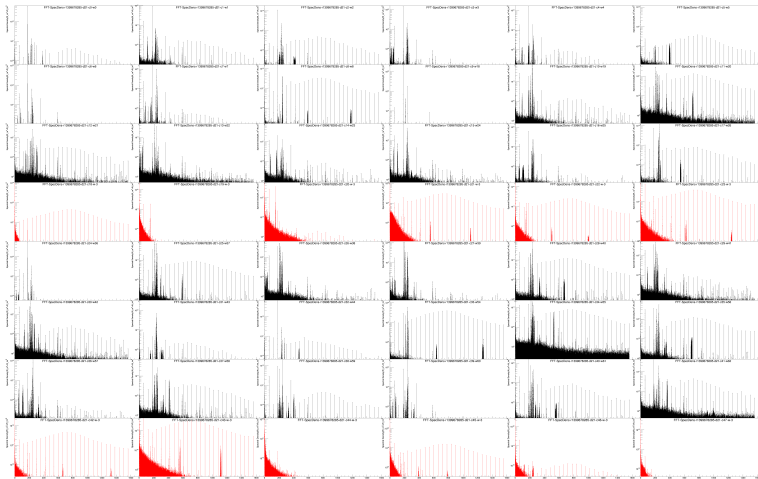
Additional DAQ grouped plot on following slides

Tuesday Run - 17785 - DAQ21



X-axis all all the same. Y-axis are all **DIFFERENT**.
Red plots are from uninstrumented channels.

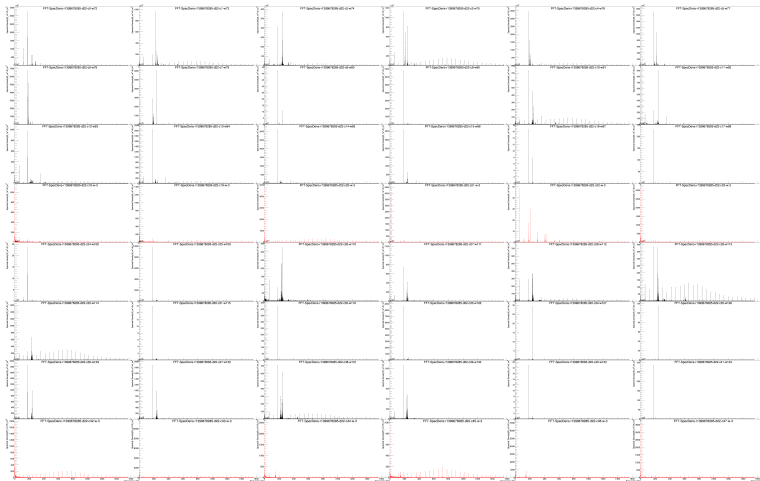
Tuesday Run - 17785 - DAQ21 - Log Scale Y-axis



X-axis all all the same. Y-axis are all **DIFFERENT**.

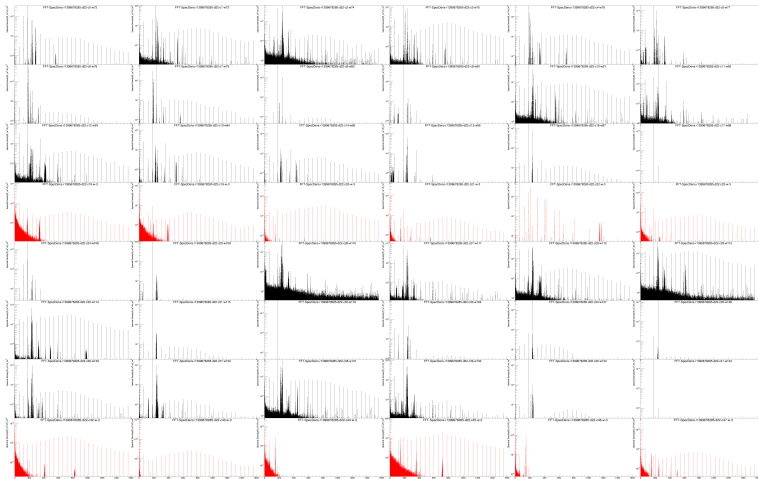
Red plots are from uninstrumented channels.

Tuesday Run - 17785 - DAQ22



X-axis all all the same. Y-axis are all **DIFFERENT**.
Red plots are from uninstrumented channels.

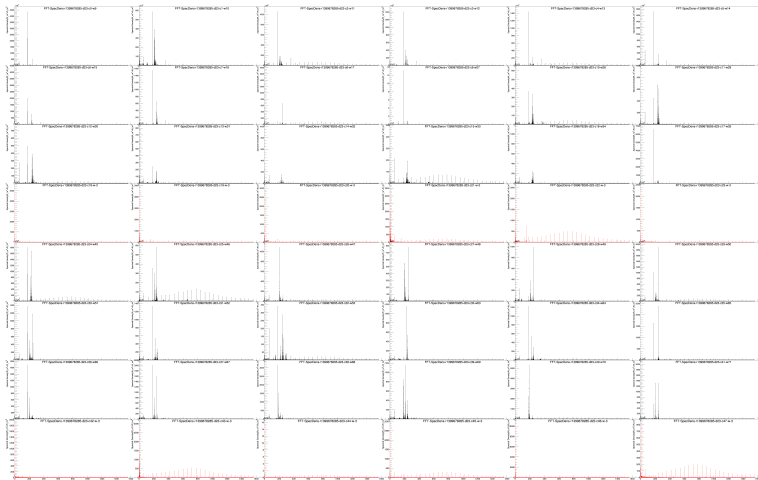
Tuesday Run - 17785 - DAQ22 - Log Scale Y-axis



X-axis all all the same. Y-axis are all **DIFFERENT**.

Red plots are from uninstrumented channels.

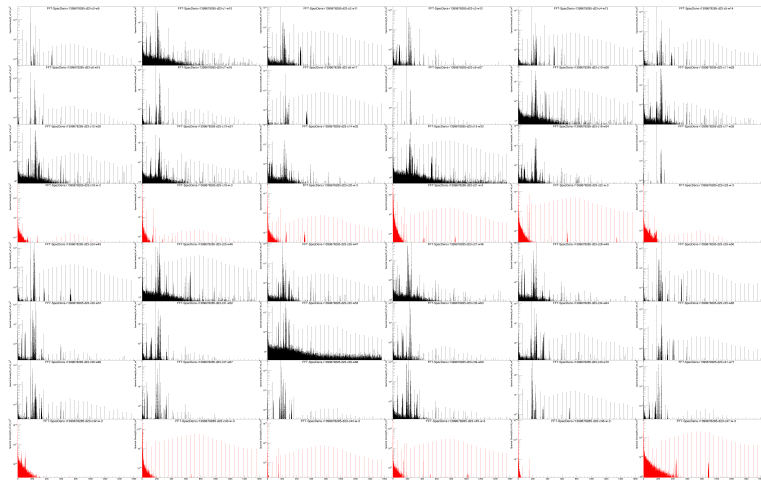
Tuesday Run - 17785 - DAQ23



X-axis all all the same. Y-axis are all **DIFFERENT**.

Red plots are from uninstrumented channels.

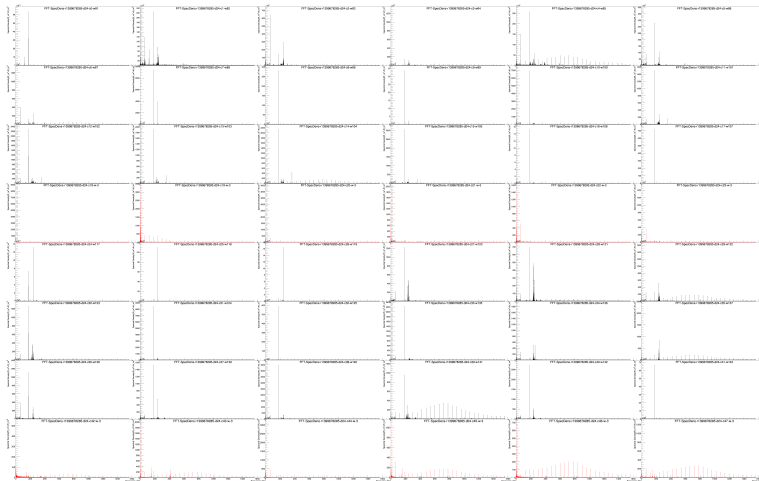
Tuesday Run - 17785 - DAQ23 - Log Scale Y-axis



X-axis all all the same. Y-axis are all **DIFFERENT**.

Red plots are from uninstrumented channels.

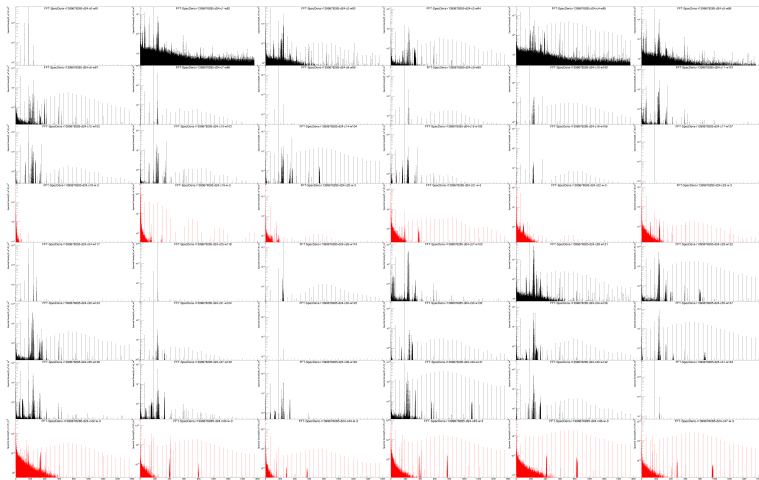
Tuesday Run - 17785 - DAQ24



X-axis all all the same. Y-axis are all **DIFFERENT**.

Red plots are from uninstrumented channels.

Tuesday Run - 17785 - DAQ24 - Log Scale Y-axis



X-axis all all the same. Y-axis are all **DIFFERENT**.

Red plots are from uninstrumented channels.