# Improved Waveform Analysis Techniques for Gamma Ray Spectroscopy

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## Introduction

- Indirect techniques must be used to investigate the evolution processes of Population III stars
- A proposed experiment will explore the $^{7}Be(^{6}Li,d)^{11}C$ reaction to investigate the reaction rate of $^{7}Be(\alpha,\gamma)^{11}C$
- The Texas CsI Array for Astrophysical Measurements (TexCAAM) has been developed to detect gamma rays for both the aforementioned experiment and other future research concerning nuclei relevant to astrophysics

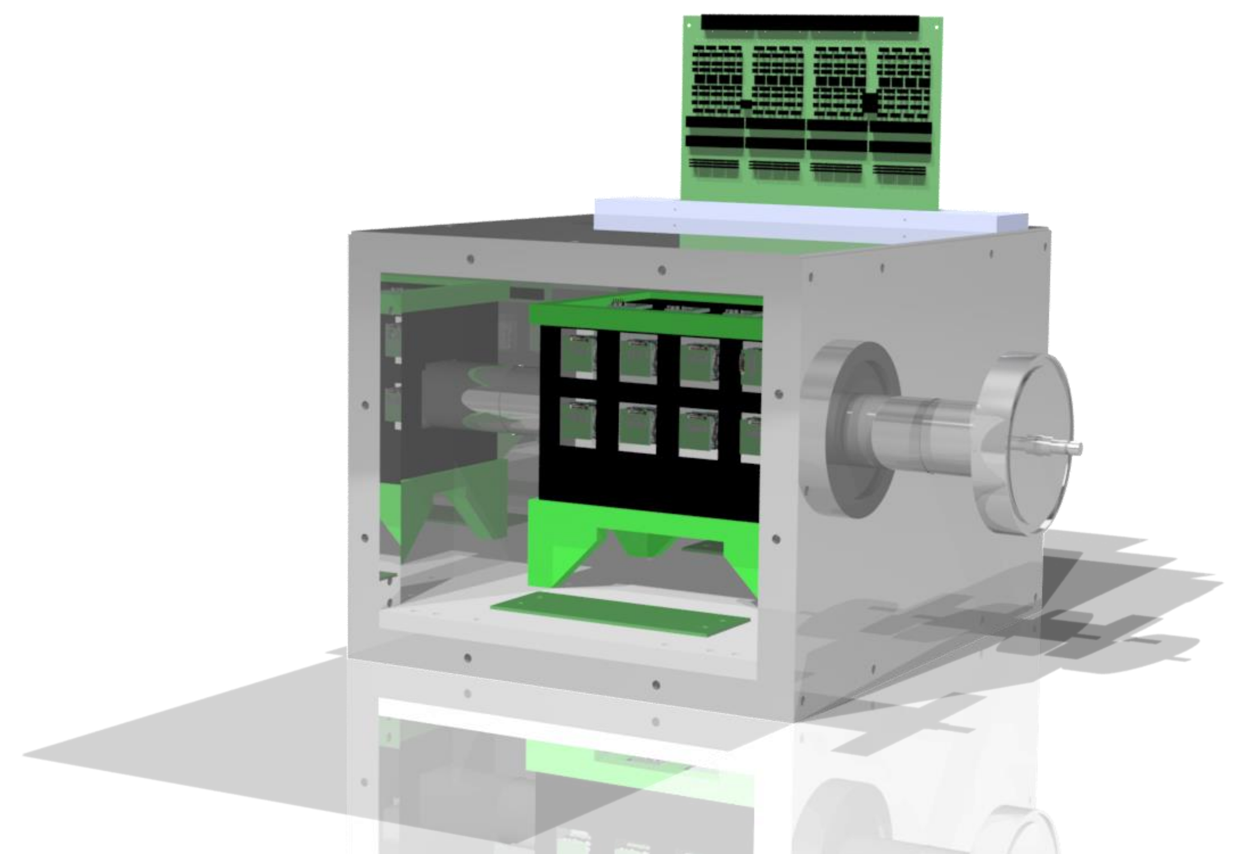

**Figure 1.** A CAD rendering of TexCAAM. The main cylinder pipe will contain the beam, target, and a silicon detector. The cubes are CsI scintillating detectors, 32 of which surround the beam pipe completely.

- The CsI detectors used in the array are connected to waveform digitizers, offering potentially improved energy resolution over conventional ADC methods
- Conventional ADC methods extract only one value, losing most information contained in the waveform
- A fully digitized waveform contains more information (pulse shape, rise time, decay constants, etc.) and can also distinguish erroneous events
- Digitized waveforms can be processed offline, allowing for procedure refinements without collecting more data

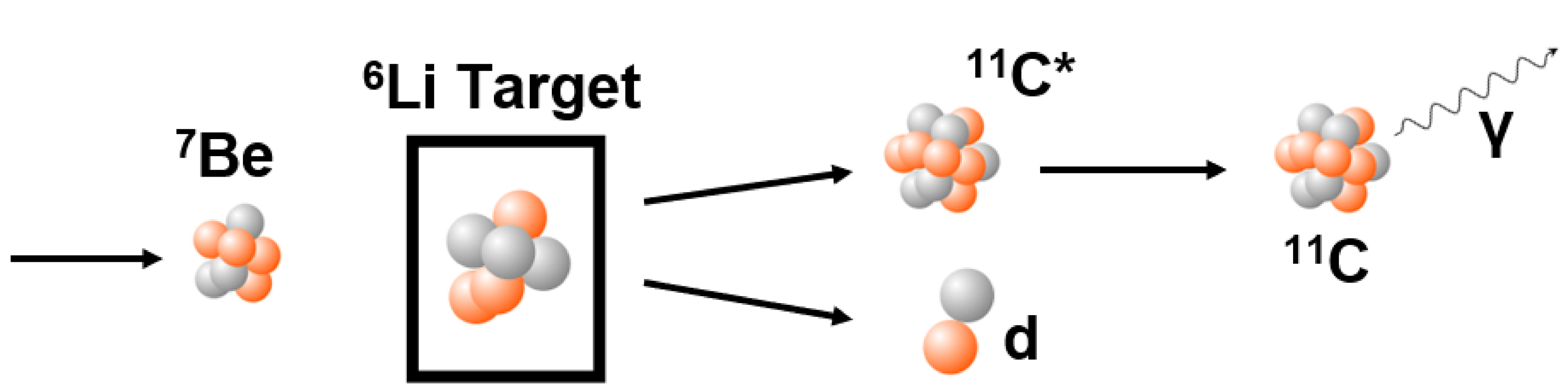


**Figure 2.** The reaction rate of $^{7}Be(\alpha,\gamma)^{11}C$ in Population III stars can be probed via $^{7}Be(^{6}Li,d)^{11}C$ by characterizing $^{11}C$ states near the α threshold. These $^{11}C$ states may decay directly to the ground state (shown) or cascade.

## Resolution Improvement Methods

- Signals from the CsI detectors are very small (a few mV), so waveforms must be noise reduced before being fitted
- Many methods were tried, and the most effective was found to be sampling by averaging groups of time-adjacent points followed by a fast Fourier transform (FFT)
- The resulting frequency spectrum was noise reduced, then transformed back to get a "cleaned" waveform
- The waveform voltage $V(t)$ was then fitted according to

$$V(t) = A\left(1 - e^{\frac{-(t-t_s)}{\tau_1}}\right)e^{\frac{-(t-t_s)}{\tau_2}} + b$$

where $b$ is the background and $t_s$ is the start of the rise ($A$, $\tau_1$, and $\tau_2$ are shape parameters)

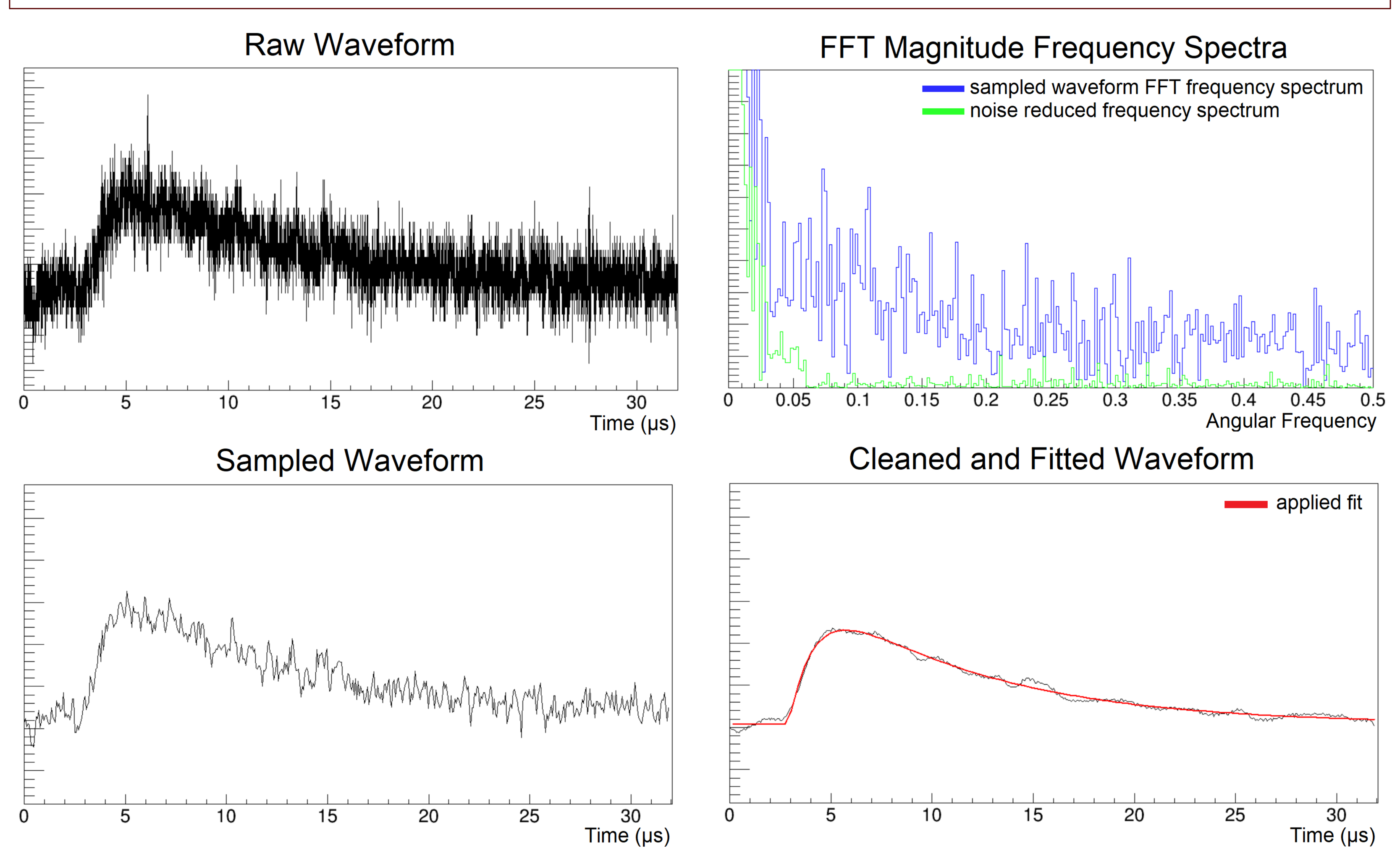


**Figure 3.** The waveform cleaning process begins with a raw waveform (top left) that is then sampled (bottom left). This sampled waveform is transformed with an FFT (magnitude shown in blue, top right). The transform is noise reduced (magnitude shown in green, top right) before undergoing a back transformation to be fitted (bottom right).

## Preliminary Results

- Energy resolutions were found for a $^{60}Co$ source with two gamma peaks at 1.173 MeV and 1.332 MeV
- Code was written to apply double Gaussian fits to energy histograms and create a channel/energy conversion
- Using a moving average window (MAW) on the digitized waveforms, resolutions were optimized to ~11%, with conventional ADC electronics being only slightly worse
- Resolutions were brought below 9% using the techniques described above (see Figure 4), approaching the theorized resolution limit for these CsI detectors at these energies

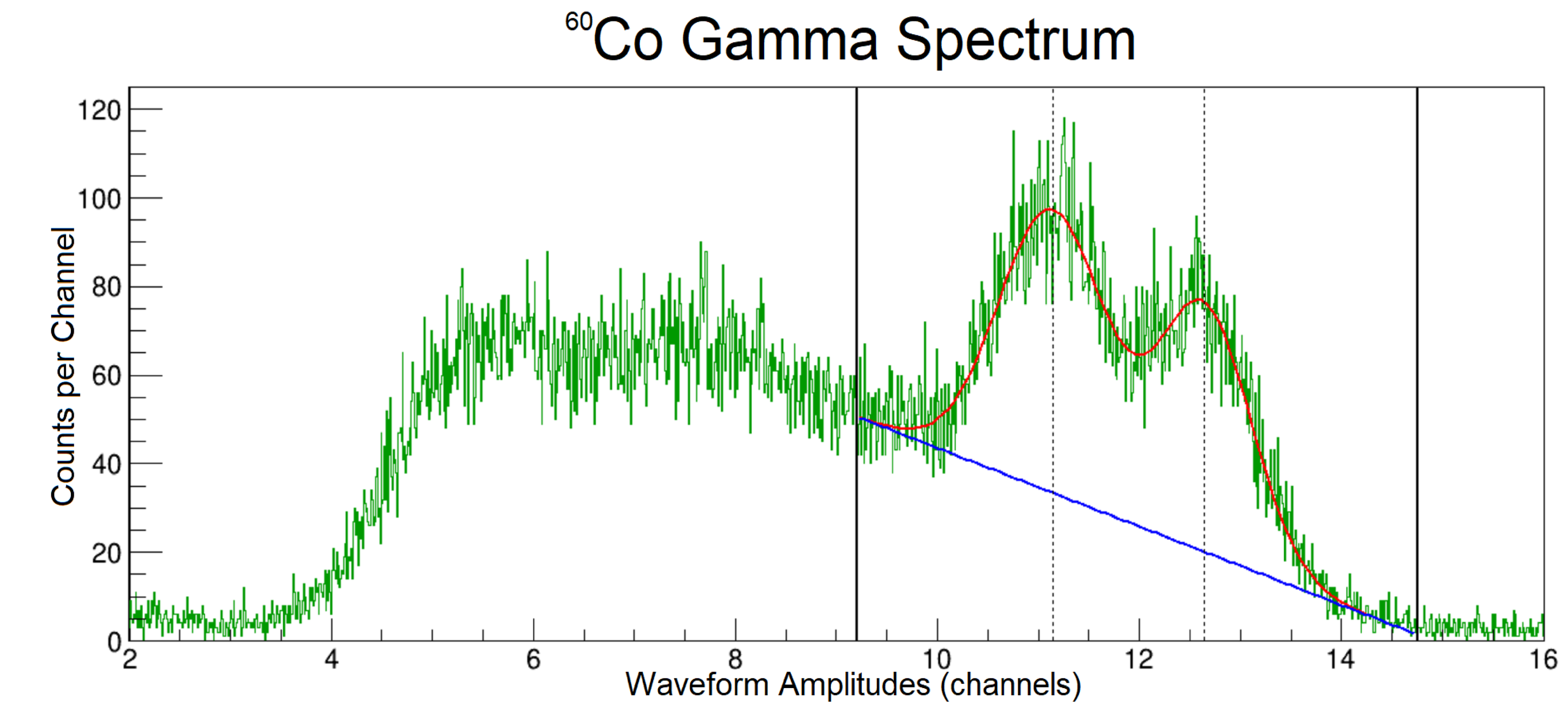


**Figure 4.** A histogram of fitted waveform amplitudes, as determined by the maximum of the fitted function. A linear background (shown in blue) was assumed. The centroid locations determined by the fit are indicated with dashed vertical lines. The highest peak resolution was found to be 8.6%.

## Angular Correlation Code

- Code was written to determine angular correlation between gamma rays or against an external trigger by gating on the energy and time of the events
- Can find gamma rays in coincidence with a deuteron signal to confirm the $^{7}Be(^{6}Li,d)^{11}C$ reaction took place

## Future Work

- Potential for detection of problem events (see Figure 5)
- Further performance optimization opportunities
- γ—γ angular correlations can constrain the spin and parities of other nuclei to be studied by TexCAAM

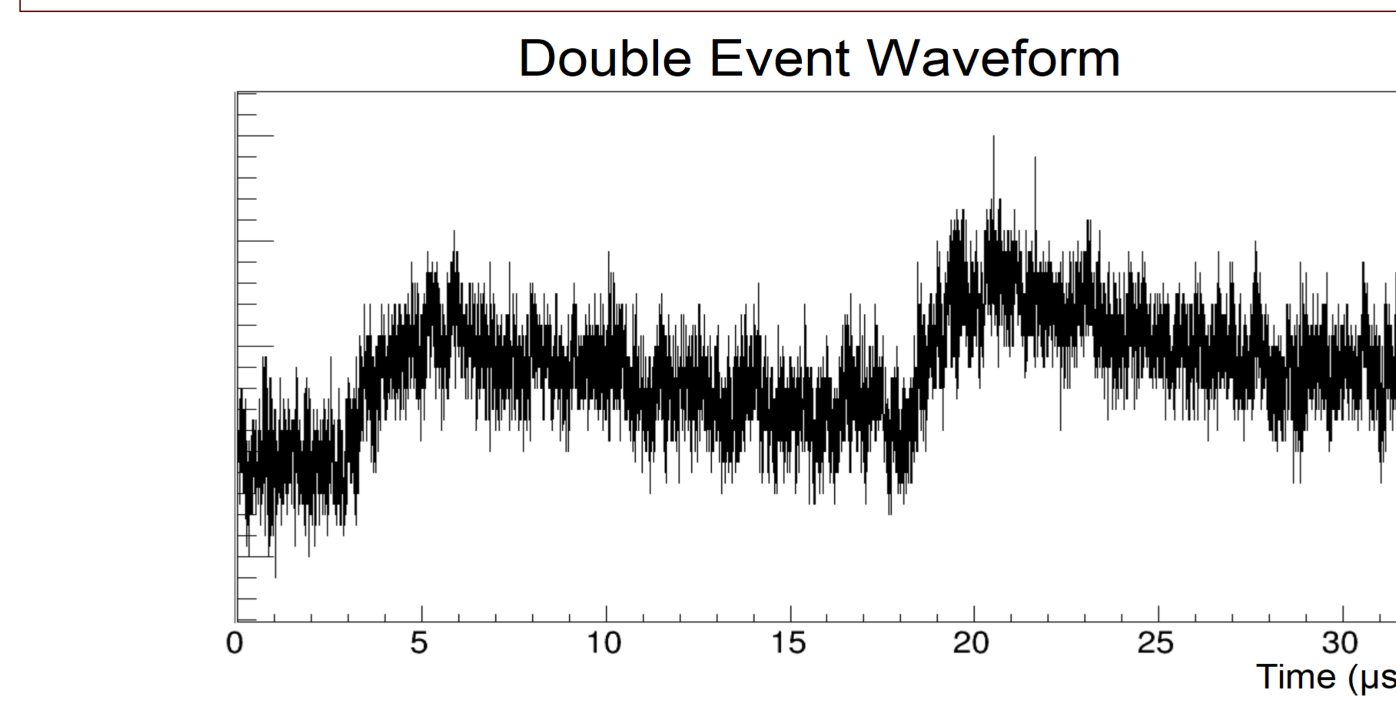


**Figure 5.** An example of a problem event in which two gamma rays were detected within the trigger window. A conventional ADC may report an erroneously high amplitude, but the digitized waveform reveals the problem. Code can be written to detect and ignore such events.

## Acknowledgements

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