Using Exponential Fit Amplitudes as an Alternative Method of Pulse Shape Discrimination

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Abstract –Digitizers have made it possible to store pulse waveforms created from radiation interactions in a scintillator. The pulses are then analyzed to determine if a given pulse was generated by a photon or neutron interaction. This distinction is most commonly made by the charge-integration method of pulse shape discrimination (PSD) using the ratio of the tail to total pulse integral . Although PSD has its benefits, it can be inaccurate at times, especially at low energies. In this poster we present an alternate approach to PSD that uses the exponential fit of the decaying edge of the pulse. The amplitudes are pulled from the two-term exponential equation to form a ratio that creates a specific value for each pulse. The gamma-only calibration data that accompanies measurements is used to determine a discrimination line. This discrimination line is subsequently used as a threshold above which waveforms are considered neutrons and below are considered gammas. The amplitude ratio approach was found to be comparable to the charge-integration method.

Introduction

- Pulse shape discrimination (PSD) allows for segregation of photon and neutron interactions.
- Charge-integration is a common method of PSD that determines the type of particle interaction by using the ratio of tail integral to the total pulse integral.
- The charge-integration method is not always accurate, especially at low energies.
- Misclassification of particles can lead to faulty results, so successful PSD is necessary.

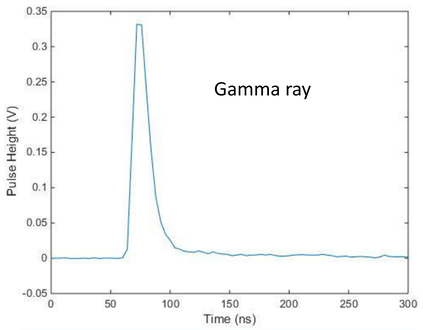

Fig. 1. An example of a gamma pulse that was digitally created by a radiation interaction in a scintillator

Method

Pulse fitting

- The decaying edges of the pulses were fitted using MATLAB's fit() function and followed Eq. 1
- The values of b and d for gammas and neutrons were determined beforehand. Then the when the actual fits were made, b and d were restricted by these values to ensure proper fits.

$$Pulse\ decaying\ edge = Ae^{bx} + Ce^{dx} \qquad (1)$$

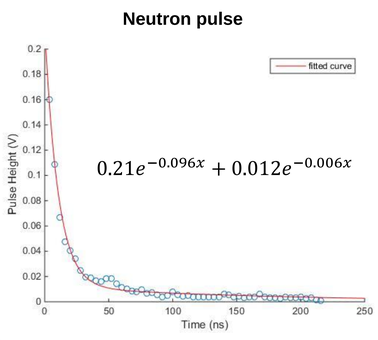

Fig. 2. An example of a fitted neutron pulse tail with the equation of the fitted curve

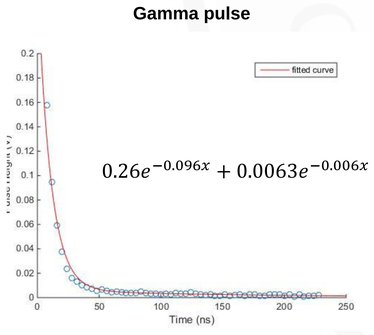

Fig. 3. An example of a fitted gamma pulse tail with the equation of the fitted curve

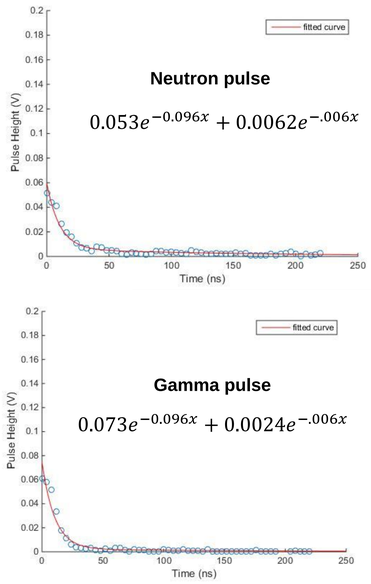

Fig. 4. More examples of fitted pulse tails with the equations of the fitted curves.

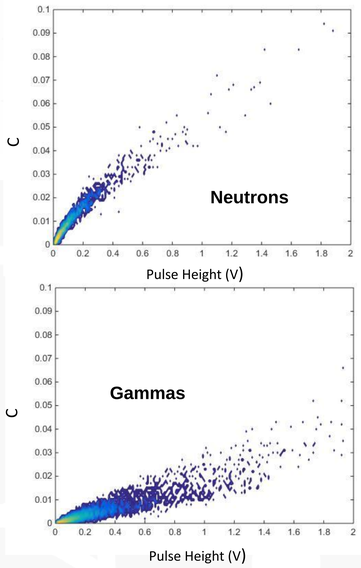

Fig. 5. The values of C plotted vs. pulse height. The different shapes for neutron and gamma pulses is noticeable and this difference is the basis for the amplitude ratio method.

Using the amplitude ratios

- Each pulse can be assigned an amplitude ratio which is equal to C/A. Both the C and A values come from Eq. 1.
- When the amplitude ratios are plotted vs. pulse height, the resulting graph will be similar to Figure 6 or Figure 8, depending on if the data comes from a source that has both only gammas or both gammas and photons.

Choose discrimination line from calibration data

- Most, if not all, measurements are accompanied by a gamma-only measurement used for calibration purposes
- The calibration data can be used to set a discrimination line to distinguish between neutrons and gamma pulses. An example of this is shown in Figure 6.

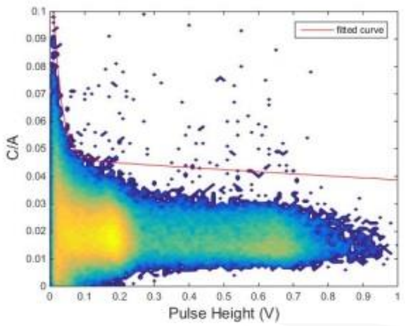

Fig. 6. C/A vs Pulse height for calibration Na-22 data. This plot is used to determine the discrimination line.

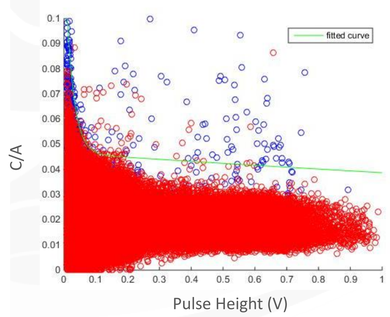

Fig. 7. C/A vs pulse height for calibration Na-22 data where the pulses are tagged by what PSD determines to be neutrons (blue) and gammas (red).

Apply discrimination line to mixed data set

- The exact same discrimination line found from the gamma-only data can be applied to the data set that has both neutrons and gammas present, which is shown in Figure 8.
- Then it can be determined how many neutrons and gammas are present by checking if each pulse's C/A value lies above (neutrons) or below (gammas) the line.

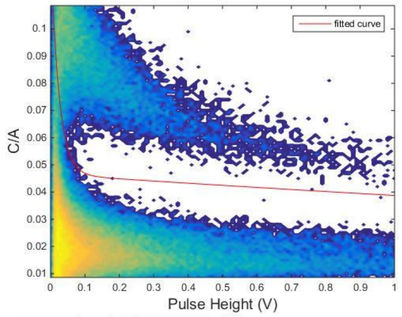

Fig. 8. C/A vs Pulse height for calibration Cf data. The number of neutrons and gammas can be determined by counting the number of points above and below the line.

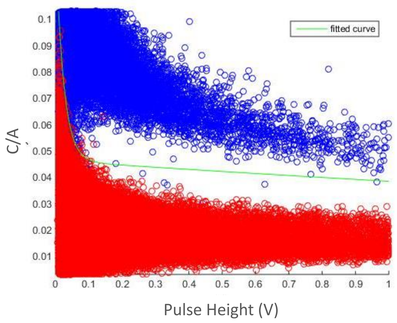

Fig. 9. C/A vs pulse height for calibration Na-22 data where the pulses are tagged by what PSD determines to be neutrons (blue) and gammas (red).

Results

- The Figure of Merit for the amplitude ratio approach is smaller than the Figure of Merit for PSD overall, but at low energies they are comparable.
- It can be seen visually that the discrimination line set by the gamma-only data fits on the mixed data sets.
- The amplitude ratio method assigns more particles to be neutrons than the charge integration method. At this point it is unclear which method is more correct.

Pulse height (V)	C/A FOM	PSD FOM
0 – 0.1	1.035	1.032
.1 - .2	1.502	1.691
.2 – 2.0	1.375	1.580
all	.982	1.254

	Number of gammas	Number of neutrons
Charge-integration method	20818	79182
Amplitude ratio method	18032	81968

Conclusion and Future Work

- The gamma-only calibration data is an effective way to set a discrimination line for mixed data sets.
- The amplitude ratio approach may be more accurate than PSD at lower energies,. At this point the techniques are comparable , but more research is need to verify that amplitude ratio actually is more correct.
- The pulse fitting technique can be refined and used in other applications such as: light output/quenching, pile up rejection, and pulse cleaning.

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