Performance of an Enhanced Throughput Feature in a High-Count Rate System

Ronald M Keyser, Senior Member, and Rex C Trammell, Senior Member
ORTEC
801 South Illinois Avenue
Oak Ridge, TN 37831-0895

Summary

In many gamma-ray counting situations with HPGe detectors, it is necessary to count at high count rates. Two important parameters in high count rate systems are the throughput (number of useful counts in the spectrum per unit time) and the energy resolution. To maintain the best resolution possible, overlapping (pile-up) pulses are usually rejected. Thus random pile-up causes some events to be lost from the full-energy gamma-ray peaks in the spectrum, reducing the throughput. The total output pulse rate, $\boldsymbol{R_o}$, at which pile-up free events are added to the spectrum, is related to the input total count rate, $\boldsymbol{R_i}$, and the pulse processing time, $\boldsymbol{T_m}$, as $R_o = R_i\, e^{-R_i T_m}$.

The pulse processing time is the time from the "no pulse" condition before the input pulse to the "no pulse" condition after the input pulse, plus any busy time during pulse storage. Most spectroscopy systems are designed such that the signal must return completely to the baseline ("no pulse") before the peak detection circuitry is ready to detect the next pulse. Modern DSP MCAs use a trapezoidal filter with rise time $\boldsymbol{T_r}$, flattop time $\boldsymbol{T_f}$ and a fall time equal to the rise time ($\boldsymbol{T_r}$). The theoretical minimum pulse processing time, $\boldsymbol{T_m}$, is $2\boldsymbol{T_r} + 2\boldsymbol{T_f}$, assuming that the impact of the first pulse on the next pulse is zero immediately after the amplitude determination, and that storage time to memory is insignificant. However, the requirement that the signal return to the baseline gives a processing time of $3\boldsymbol{T_r} + 2\boldsymbol{T_f}$. Reducing $\boldsymbol{T_r}$ below the longest charge collection time will degrade the energy resolution. $\boldsymbol{T_f}$ values of the order of 1µs are typically necessary to eliminate ballistic deficit on large-volume detectors.

A special digital peak detection algorithm has been designed to maintain the resolution while decreasing the time after peak detect before the next pulse can be accepted. Using this digital algorithm, ORTEC's Enhanced Throughput Mode achieves almost the maximum theoretical throughput while maintaining good resolution. Data will be presented to show the improvement in throughput and energy resolution for large p-type HPGe detectors at high count rates.

Introduction

In a DSP system, the pulse processing is performed on the digitized pulse from the detector preamplifier. The shape of the filter can be made to be any shape without regard to restraints typical of analog systems. The most common filter shape is shown in Fig. 1. The best resolution is obtained when the filter width is longer than the charge collection time in the detector. However, this may result in long pulse processing times, which means the throughput will be reduced. The throughput is related to the pulse processing time as shown in Eq. 1

$$R_o = R_i\, e^{-R_i T_m} \qquad \textbf{(1)}$$

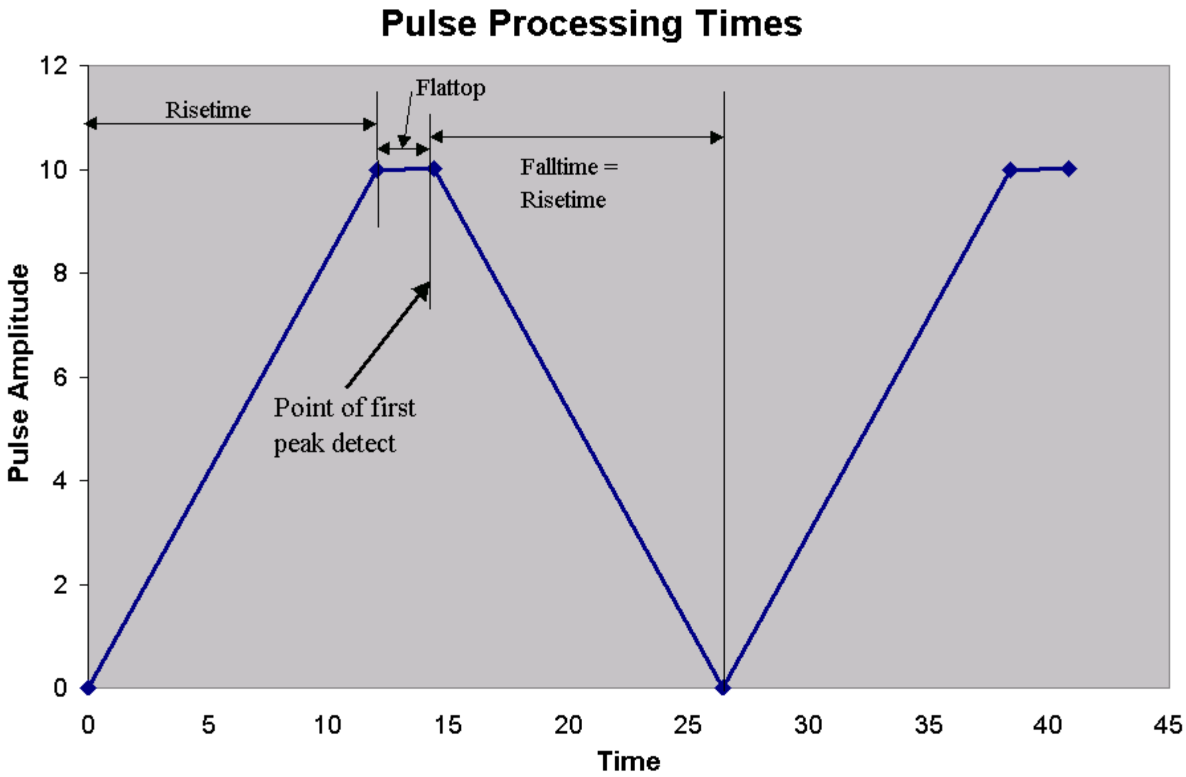

Figure 1 DSP Filter

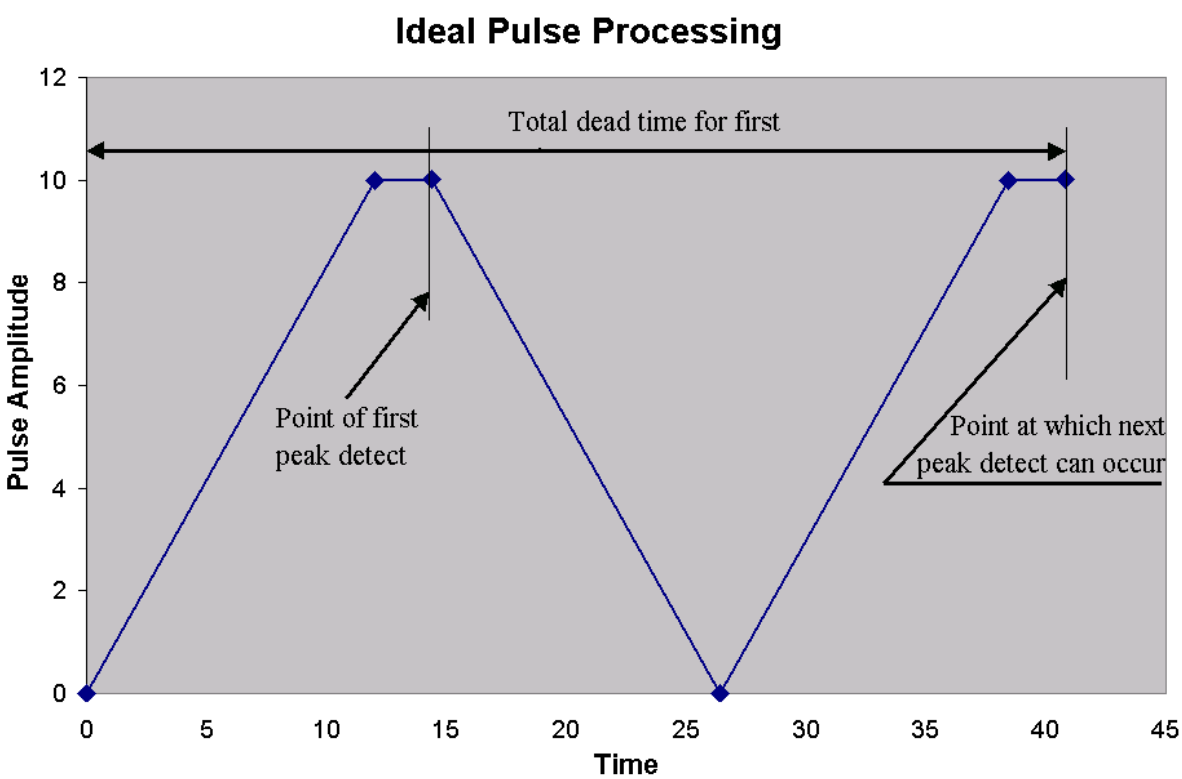

Figure 2 Dead Time of Ideal Pulse.

For an ideal pulse, the dead time, or the time the system is unable to accept another pulse, is the filter width time of the first pulse plus the T_r and T_f of the second pulse, as shown in Fig. 2. However, the actual dead time per pulse may be longer if the detector pulse does not return to the baseline before the time of $T_r + T_f + T_r$ as shown in Fig. 3.

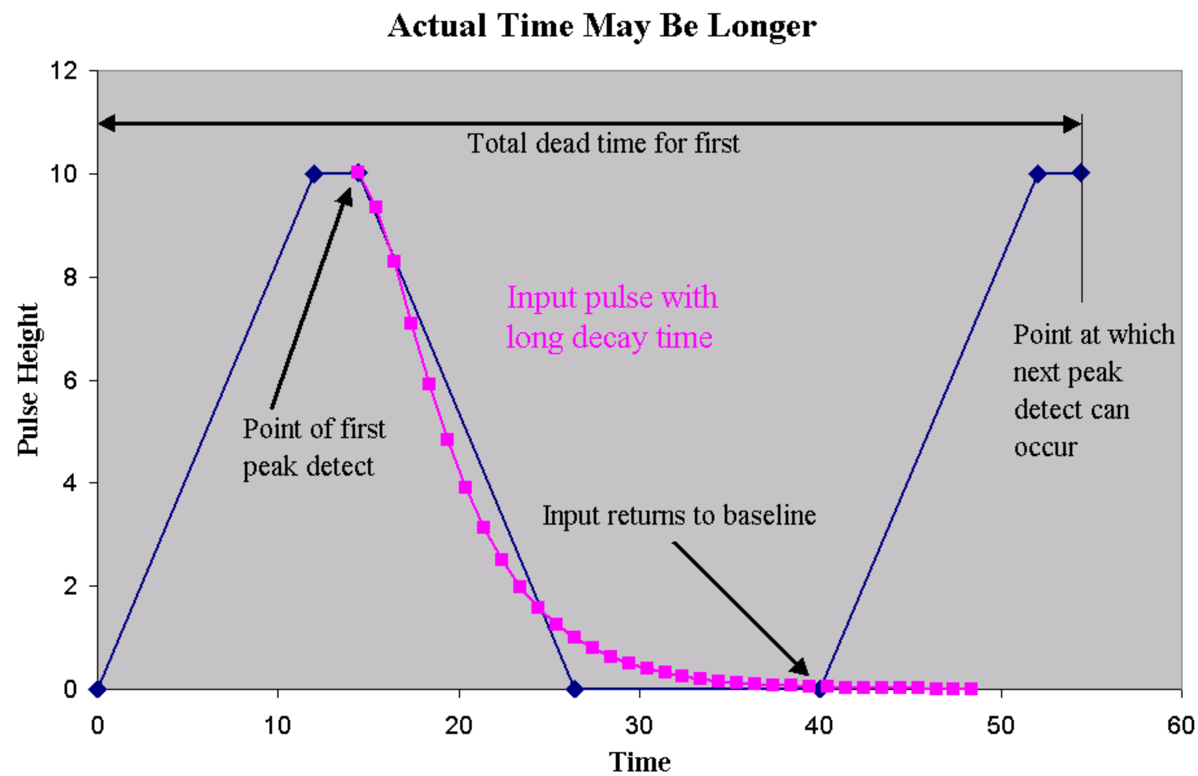

Figure 3 Actual Dead Time Is Longer Because of Pulse Width

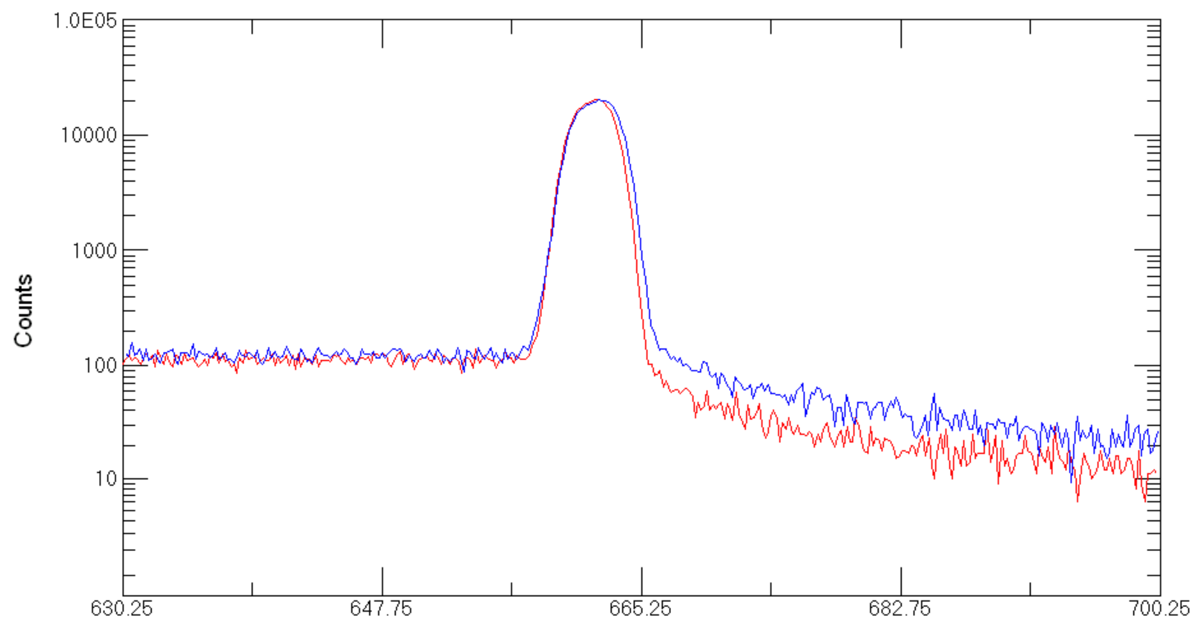

Figure 4 High Energy Tailing due to Long Input Pulses.

Figure 4 shows the impact on the spectrum peak shape when the pulse processing time is not extended until the signal returns to baseline. These spectra were collected at low input count rate.

In Eq. 1, the R_o is the total number of counts in the spectrum divided by the real time and R_i is the input count rate (ICR) as measured by the input count rate meter of the MCB. The ICR meter is the pulse rate on the fast channel and records all pulses above the threshold. The fast channel discriminater has a dead time, and the ICR should be corrected for this dead time, but the values shown here have not been corrected.

In previous MCBs, such as the DSPEC Plus, the pulse processing was done as shown in Fig. 3, that is, the processing of the second pulse was not started until after the fall time or the input signal returned to the baseline, whichever was longer. The new pulse processing method implemented in the DSPEC Pro, will start the processing of the second pulse at a fixed time delay after the first peak was detected. The time delay is set by the

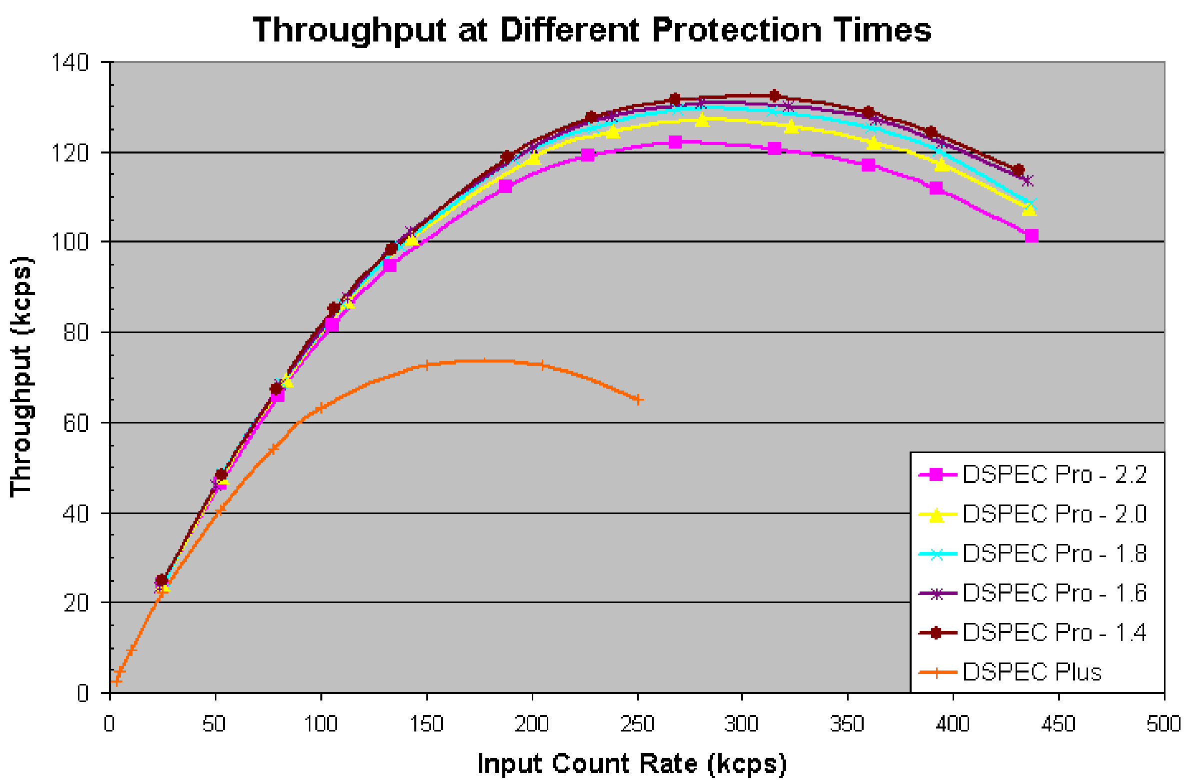

Figure 5 Throughput for DSPEC Plus and DSPEC Pro.

user to be between zero and the risetime. A delay setting equal to the risetime gives a pulse processing time equal to the DSPEC Plus mode for pulses that return to the baseline quickly. A delay time of 0 will decrease the dead time per pulse from $3\,T_r + 2\,T_f$ to $2\,T_r + 2\,T_f$. For $T_r = 0.8$ and $T_f = 0.6$ microseconds, this is a theoretical reduction in the dead time of 33% or an increase in the maximum throughput point at an ICR of 275 000 to 350 000 cps.

Figure 5 compares the throughput for the DSPEC Plus and the DSPEC Pro for different protection times and a $T_r = 0.8$, $T_f = 0.8$ for the DSPEC Plus, and $T_f = 0.6$ for the DSPEC Pro for the same detector.

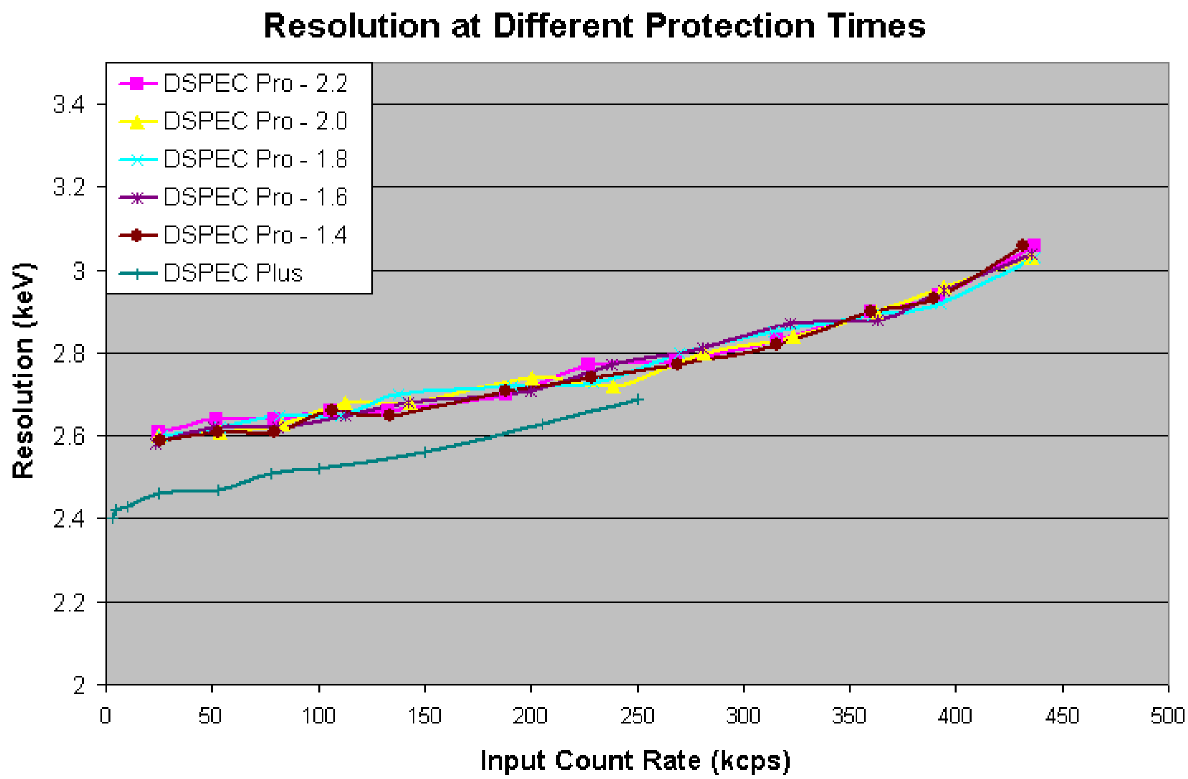

Figure 6 Resolution for DSPEC Plus and DSPEC Pro.

The reduction in the pulse processing width does increase the FWHM as shown in Fig. 6. Depending on the application, this increase may not be important, since it does allow counting at much higher ICR and higher throughput.

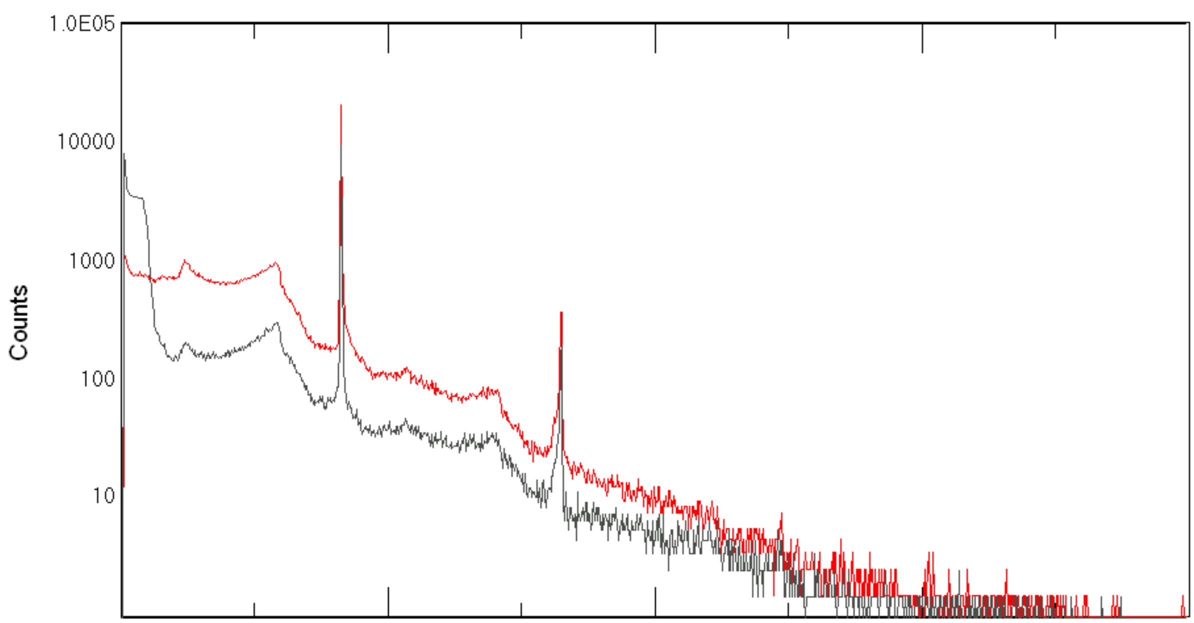

Figure 7 Different Spectrum Shape for Different Pulse Processing Times.

There are changes in the spectrum and peak in addition to the FWHM. Figure 4 shows the change in the high energy side of the peak due to the processing of pulses before long pulses have returned to base line. Figure 7 shows the different spectrum shapes for the normal (blue) and the short (red) pulse processing times.

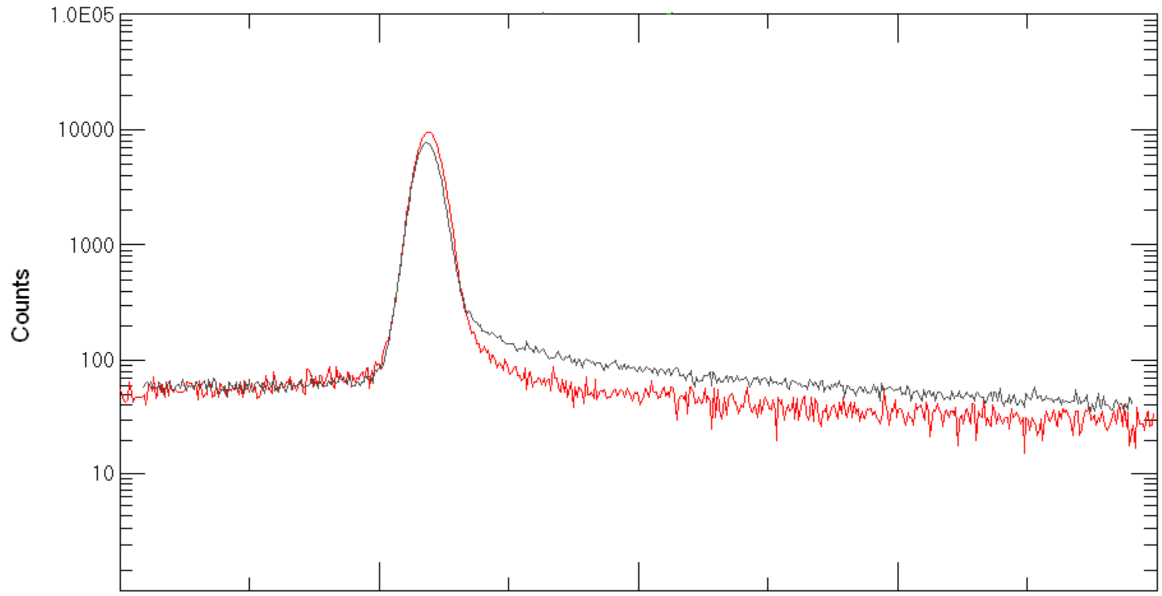

Figure 8 Details of Peak from Fig. 7.

Figure 8 shows an expanded detail of the peak from Fig. 7. Note that the high energy side of the peak has increased with the decrease in the peak processing time, however the FWHM has not increased between the two. This is supported by Fig. 6, which shows the FWHM to be about the same for all the different protection times.

Summary

The Enhanced Throughput Mode of the DSPEC Pro has higher throughput, that is, stored counts in the spectrum, than the DSPEC Plus operating in the normal mode. In using high count rate spectra, it is important to consider the total spectrum, including pulse pileup and random summing as these may have an adverse affect on the ability to analyze the spectrum. The DSPEC Pro remains operational, that is, accepts and stores counts for a wider dynamic range of the Input Count Rate than the DSPEC Plus. The FWHM resolution increases in this mode, but not significantly.