APPLICATION Note # 3

DANTE: Perform XRF measures with Silicon Drift Detectors (SDD)

Abstract

Silicon Drift Detectors (SDD) are one of the most diffused technology exploited in X-ray detection systems for low and intermediate energy range applications. The combination of SDDs with Digital Pulse Processors (DPPs) readout provides several advantages in spectroscopy.

This document introduces to SDDs working principle, then, it guides the user on how to set the parameters of the DPP filters to obtain the best spectroscopic performance.

Introduction to SDDs physics

Silicon Drift Detectors (SDD) are radiation sensors developed to measure single photon events with the best energy resolution and the fastest time response possible.
A typical SDD cross-section is reported in **Figure 1**: drift rings and the anode are designed on the front side of the SDD, while the back contact or entrance window on the back side. By a correct biasing of the drift rings, the back contact and the anode, it is possible to completely deplete of mobile charges the detector thickness and to create an electric field or Drift field that causes all the electrons to be collected at the anode. Since the anode can be made extremely small, also its capacitance towards ground can be made very small. It is well-known that the lower the anode capacitance the better is the resolution.
When a photon interacts within the depleted region of the detector, in case of absorption, electrons-holes pairs are generated in quantities proportional to energy of the interacting photon. The electrons resulting from this interaction drift and are ultimately collected by the anode. This charge is usually integrated on a feedback capacitor of CUBE, the CMOS preamplifier for radiation detector, resulting in a voltage pulse signal at the output.

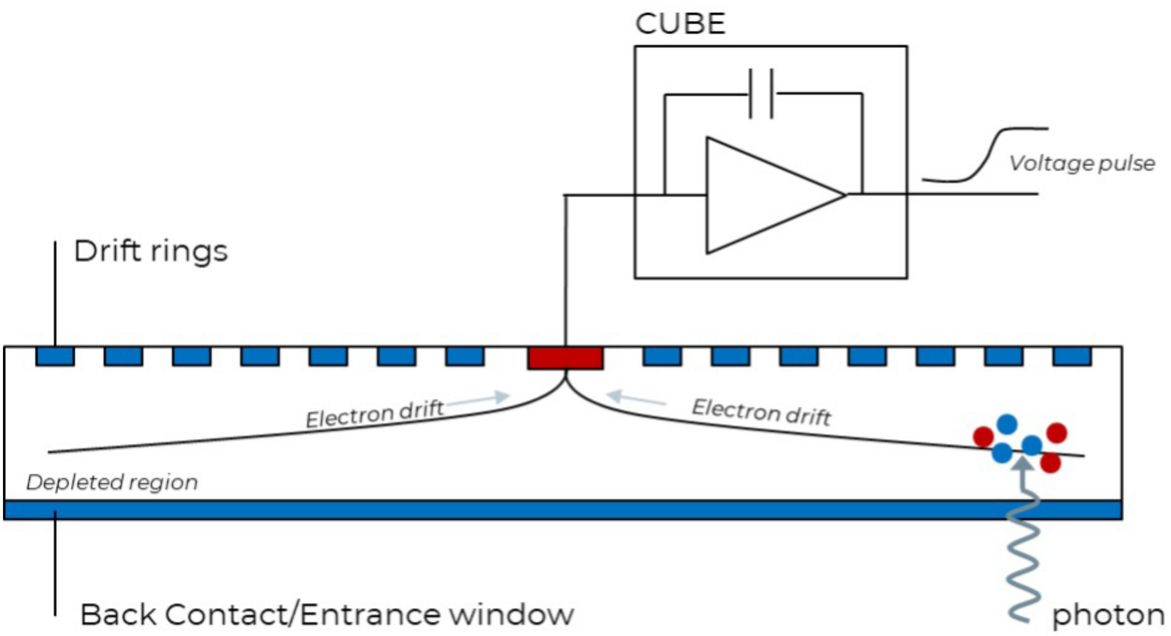

Figure 1. SDD cross-section and working principle

DANTE DPP configuration for SDD

After powering on the SDD and connecting it to the DANTE, it is possible to launch the DANTE acquisition software to setup the DPP parameters and to perform Spectra acquisitions.
By launching the DANTE software, the user gets access to a GUI constituted by five different windows selectable by the corresponding five tabs on the left: “Settings”, “Configuration”, “Acquisition”, “ROIs” and “Calibration” [**Figure 2**]. After connecting the DANTE via USB, after a while all the channels boards are displayed at the bottom of the Configuration window. From this window, the user can finely tune the DPP to optimize the acquisition by changing the “Input”, the “Fast Filter” and the “Energy Filter” parameters.
For a detailed description on how to set the “Input” parameters we invite the user to refer to our Application note “DANTE: Easy set-up guide to read your radiation detector”.
If the SDD in use is provided with pulsed-reset preamplifier, default parameters can be used for a first measurement. To start an acquisition, click “Configure” and wait until all the enabled channels are ready.

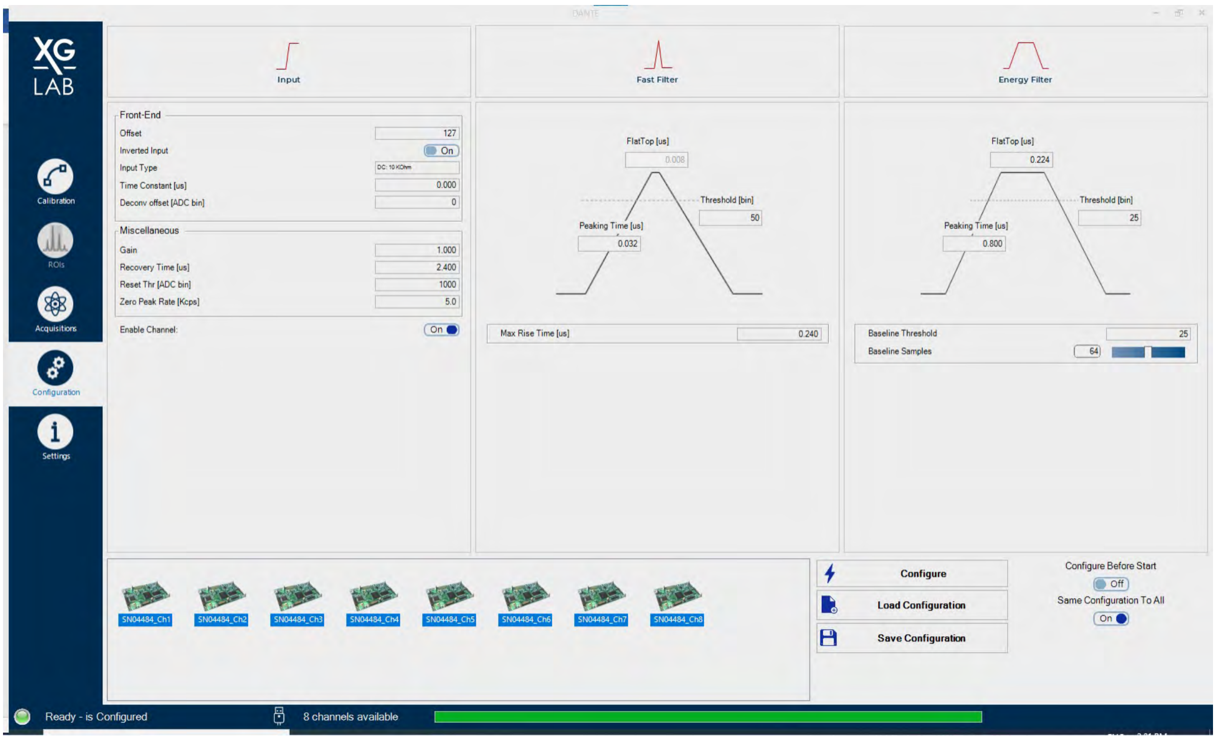

Figure 2: Configuration Window in the DANTE acquisition software

In order to setup correctly the parameters of the Fast and Energy filters, it is important to know the dynamic response of the SDD to photons. Indeed, depending on the characteristics of the SDD (e.g. active or collimated area, bias voltages, silicon thickness, shape) the collection time of electrons at the anode can change significantly. By exposing the SDD to a photon flux with an Iron source (Fe55) or with an X-ray tube and acquiring the output voltage of the SDD, it is possible to measure this collection time.

Select the Acquisition window from the corresponding tab on the left, select the Waveform mode and run an acquisition. A positive ramp (due to the leakage current of the detector) with voltage step over-imposed (corresponding to collected charges at the anode) should be displayed. The time of acquisition can be changed as needed.

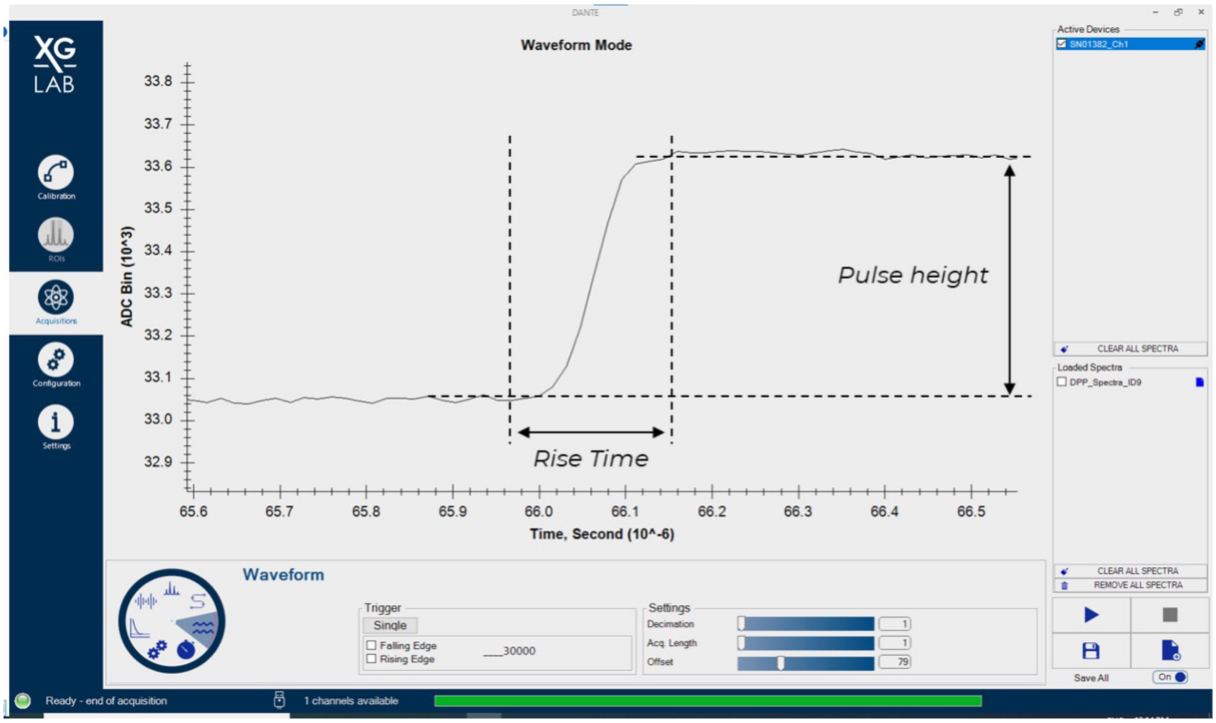

Figure 3: Pulse signal, corresponding to the detection of one photon, acquired by DANTE at the output of a CUBE preamplifier connected to an SDD.

As said, the number of generated charges is proportional to the energy of the impinging radiation. Thus, the **pulse height** is proportional to the amount of charge collected, see **Figure 3**. While the time required by charges to be collected at the anode and to be integrated on the preamplifier feedback capacitance is called **Rise Time**, see **Figure 3**.

To correctly process these step-like signals, it is required to filter them in order to: filter out noise and evaluate the energy value of the impinging radiation, as well as to identify single photon events or events that are overlapping to each other in time and that can't be correctly process by the electronics (pile-up events). The DANTE DPP applies two filters to optimize these operations on the SDD signals, the Fast Filter and the Energy Filter.

In the next sections, we describe how to correctly setup the filters parameters.

Fast Filter Setting

In the Configuration Window the user can access the parameters of the Fast Filter. The **Peaking time** and the **Flat-top** of the Fast Filter are generally set by default at 32 ns and 8 ns respectively, the minimum values for DANTE, in order to maximize the number of events per second detectable by the fast filter. The user needs to set the correct values for two parameters: the maximum rise time and the threshold. The **Maximum Rise Time** is a parameter [**Figure 4**] exploited by the algorithm of the fast filter to reject pulses that originate from superposition of events (pile-up) that impinged on instants too close to each other (what is commonly known as Pile-up rejector). If this parameter is too low, high energy events will be wrongly rejected, since the algorithm recognize them as signals due to sum of events, not to real events. This parameter is of primary importance for pile-up reduction. To set the Maximum Rise Time properly, it is important to measure the typical rise-time of the SDD in use following the procedure described in the previous section, see **Figure 3**, and to select a value slightly higher than the measured one. (A typical value of maximum risetime for an SDD of approximately 20 mm^2 collimated area is in the range of 200-240 ns).

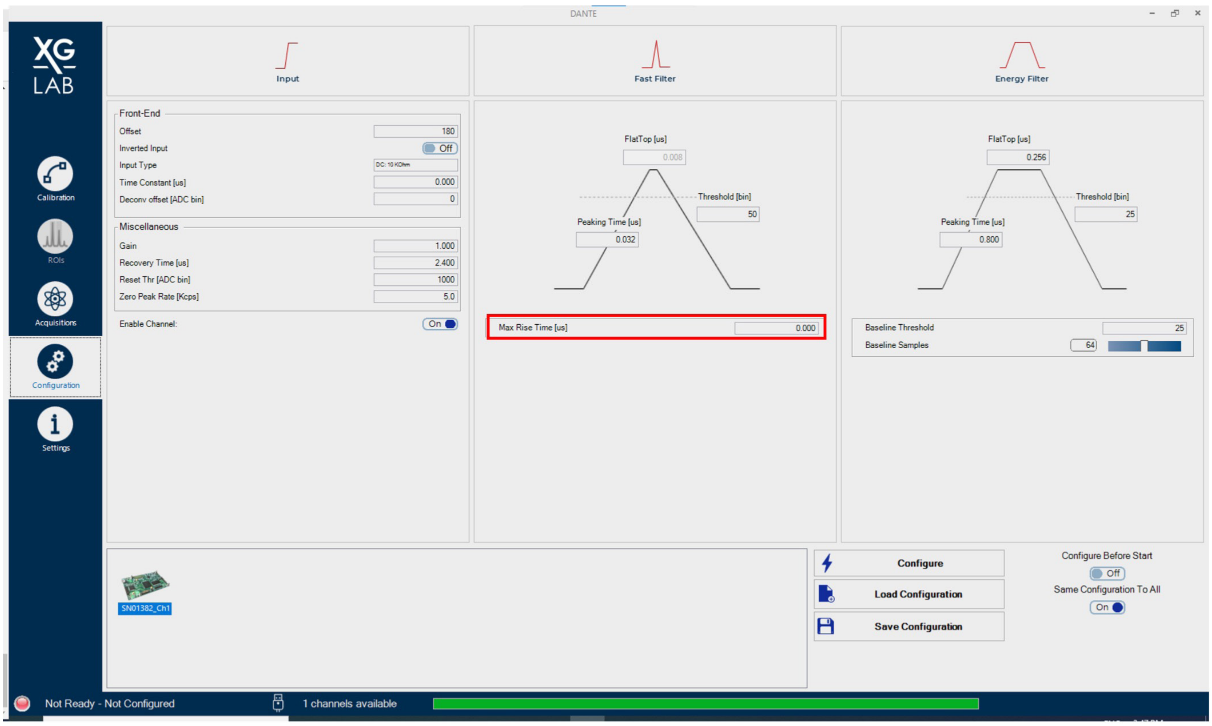

Figure 4: Maximum Rise Time parameter

Once the Maximum Risetime is set correctly, to properly set the Fast filter threshold, it is required to:
- set to “0” the Zero Peak Rate [**Figure 5**]
- set to “0” the Energy filter threshold [**Figure 5**].

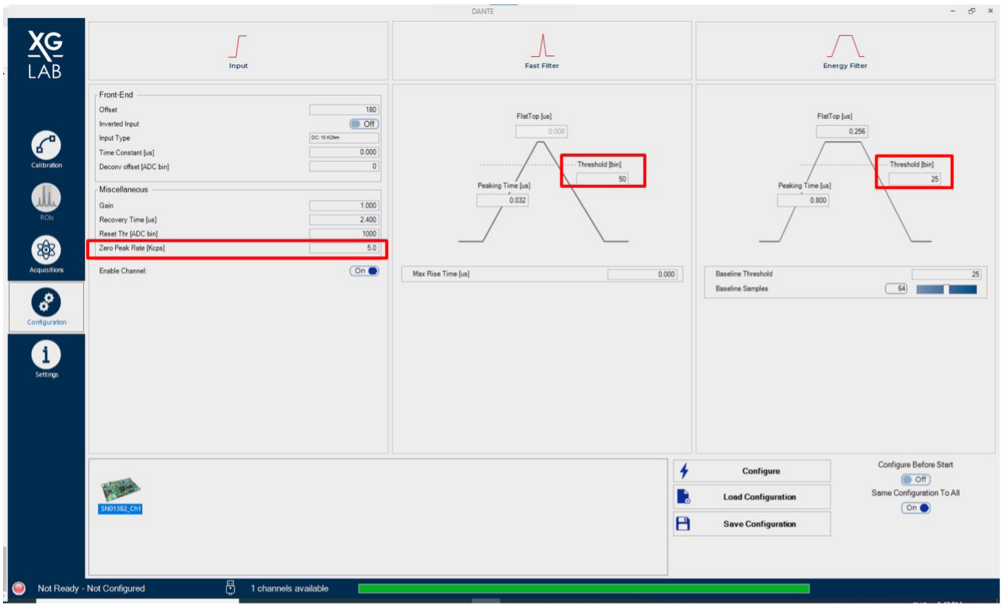

Figure 5: Zero Peak Rate parameter (left), Fast Filter threshold (center), Energy Filter threshold (right) highlighted

Once the Maximum Risetime is set correctly, to properly set the Fast filter threshold, it is required to:
- set to “0” the Zero Peak Rate [**Figure 5**]
- set to “0” the Energy filter threshold [**Figure 5**]

Setting to 0 the Energy filter threshold disables the Filter itself. When the Zero Peak Rate is disabled, no counts should be detected at bin 96 which correspond to 0 eV for DANTE. Moving to the Acquisition tab, it is required to perform a spectrum acquisition. With the chosen configuration, if a signal around bin 96 is still present, it means that noise is affecting the measure [**Figure 6**]. This is the correct condition to set the **Fast Filter Threshold** value. The threshold should be increased until the noise around bin 96 is completely and correctly cut off, reaching the condition shown in **Figure 7**.

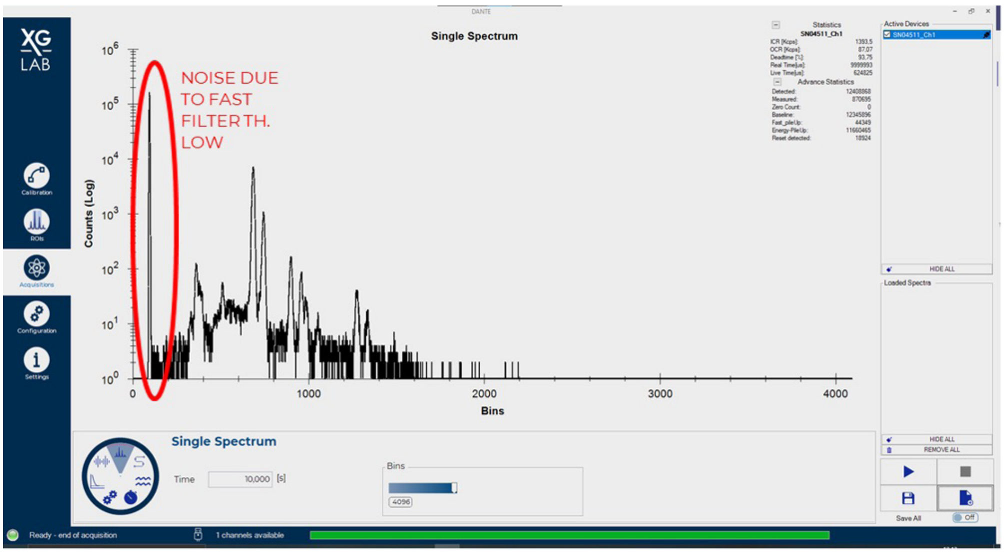

Figure 6: With the “Zero Peak rate = 0” a peak at bin 96 is due to noise

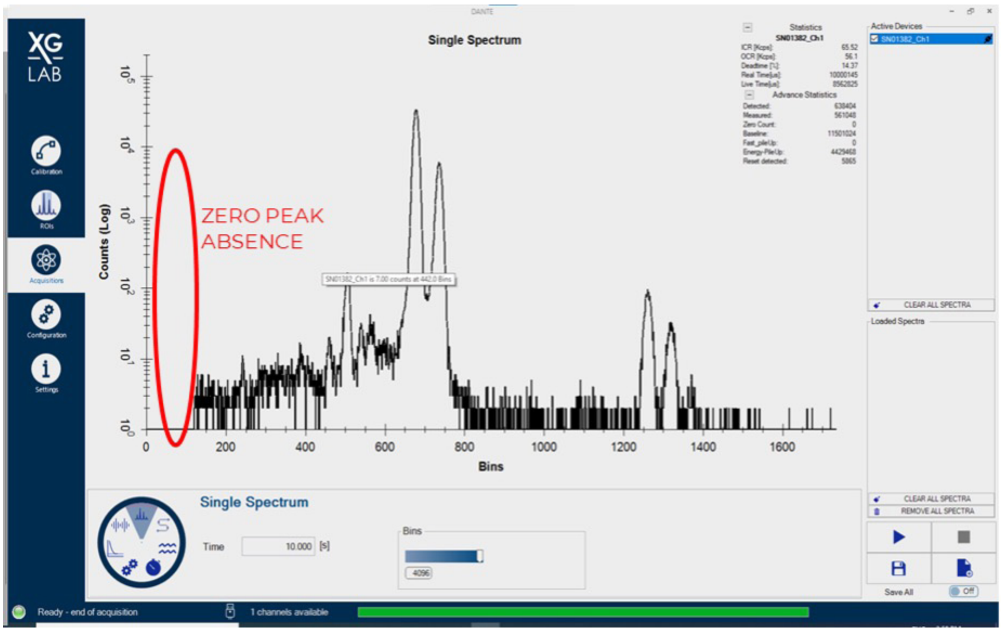

Figure 7: Zero Peak disabled and correct Fast Filter Threshold setting

Energy Filter Setting

The Energy Filter is exploited as a second rejector in case some noise produces spikes higher than the fast filter threshold, but it results in low energy pulses. The **Energy Threshold** is used along with the fast threshold, so it is of interest in keeping the <u>Energy threshold lower than Fast threshold</u>, otherwise the effect of the Energy threshold is jeopardized by the Fast Filter action [**Figure 8**].

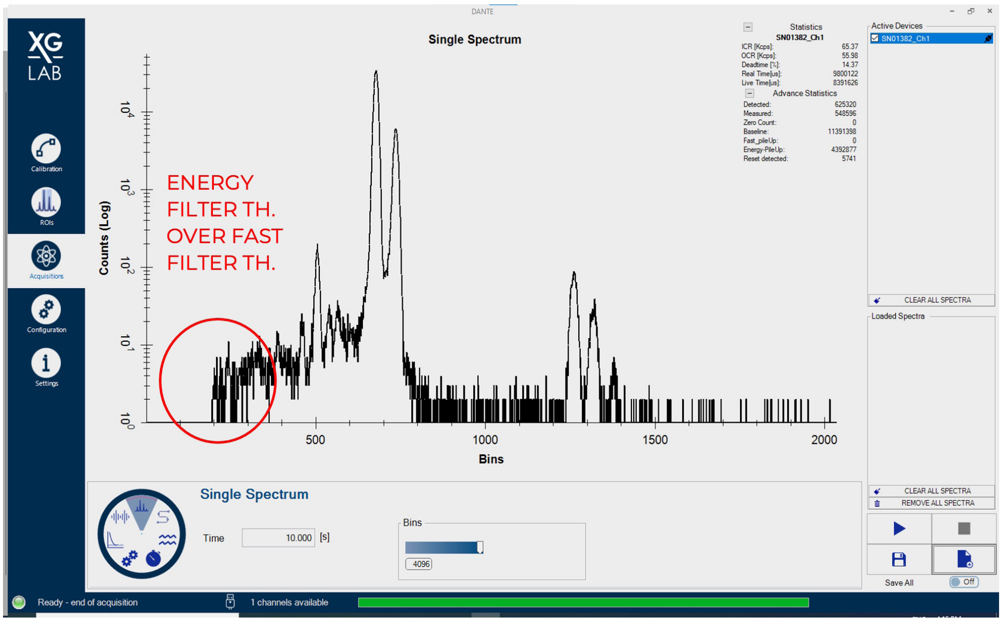

Figure 8: Incorrect use of Energy Filter threshold

When the Energy threshold is set properly, lower energy events, not seen by the Fast Filter, are detected [**Figure 9**]. Once the thresholds is set, what comes next is to set the **Peaking time** and the **Flat Top** [**Figure 10**].

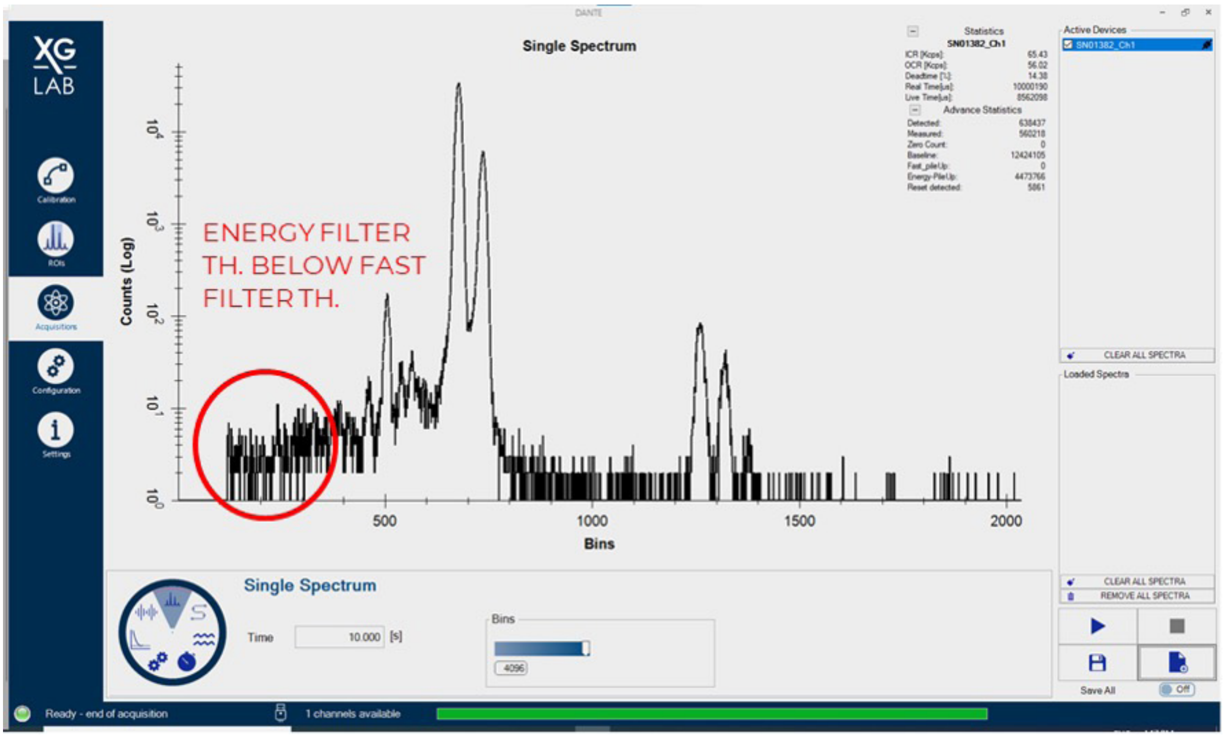

Figure 9: Proper use of Energy Filter threshold. Low energy events are correctly measured

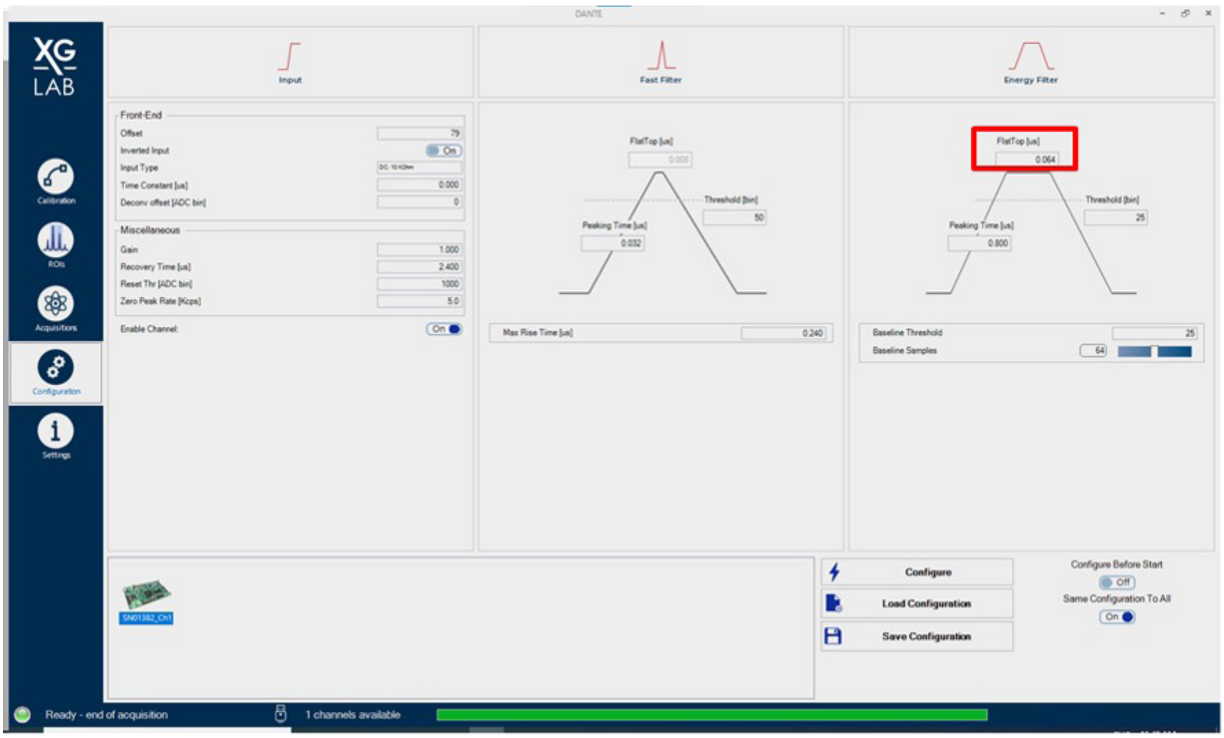

Figure 10: Energy Flat Top highlight

The Peaking Time of the energy filter ultimately define the energy resolution or the FWHM of the peaks detected, together with the Output Count Rate (cps) performances of the measurement. The lower the peaking time the higher is the OCR achievable the lower is the energy resolution. Typical values used for SDD are peaking time equal to 1 us for optimal energy resolution.
The flat-top length of the energy filter should be set to a value close or slightly larger than the Rise time in order to reduce the so-called *ballistic effect*. If the flat-top value is set too low, the energy of the step-like signal is underestimated, while once the correct value is reached, further increases of the flat-top does not result in a change of the energy value of the event, but it introduces only undesired deadtime [**Figure 11**].

Figure 11: Ballistic deficit produced by low Flat Top value

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