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Digibase Performance Over Time

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EXECUTIVE SUMMARY

All NaI detectors and electronic components drift over time; however, in well-behaved systems, this drift should be less than 5 keV. We've documented a method to determine if the electronics or detector is damaged and how to mitigate shifts due to applying voltage.

The key take-away messages from this report are:

- The initial warmup time should be at least 5 minutes. If the high-voltage is toggled off / on, then the warmup time needs to be increased to 20 minutes (see spikes in Figures 2-4 through 2-7).
- Digibase 16204844 is unstable and should not be used.
- Prior to using the detectors with the Hunter-Dose Tracking System they should be tested to ensure their centroids are stable using the above methodology.
- Consider discussing with the vendor (ORTEC) the possibility of using higher QA'd components in the Digibase system.

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LIST OF ABBREVIATIONS

HDTS	Hunter-Dose Tracking System
HV	High-Voltage
PMT	Photomultiplier Tube
SRNL	Savannah River National Laboratory

1.0 Introduction

The ORTEC Digibase is a 14-pin photomultiplier tube (PMT) base with integrated bias supply, preamplifier, and digital multichannel analyzer for use with a NaI crystal in gamma spectroscopy. It is an integral part of the Savannah River Site's Hunter-Dose Tracking System (HDTS). During several hunts in 2017 and 2018 the system notified the users that the detectors were drifting out of calibration. This drift occurred 1) for specific detector systems while other systems remained stable and 2) more often than statistically expected.

It was initially thought environmental factors were the cause of the drift because the weather during hunts where the problems occurred was typically cold and wet. However, the problems continued to occur during hunts where the weather was dry and warm.

In the spring of 2018, we brought the detector systems to the lab and tested them for stability by measuring the Cs-137 peak centroid over time.

2.0 Experiments Spring 2018

2.1 April 9, 2018

On 4/9/2018 we measured the reported keV of the peak centroid of Cs-137 for 60 seconds (real time), waited 9 minutes and then measured it again. We used Detector 2 (Digibase 16204844) from the HDTS with the high-voltage set to 920 V and fine gain set to 1.20 at 16 °C. This measurement started initially at 630 keV. These measurements were repeated over 10 hours. The peak centroid drifted about 4 keV over 10 hours as shown in Figure 2-1.

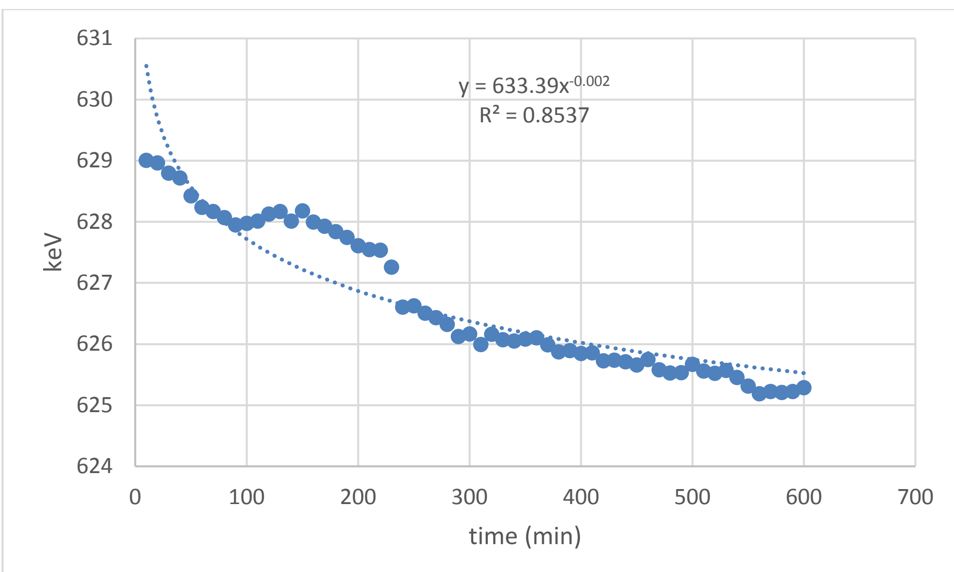

Figure 2-1. Digibase 16204844 Cs-137 peak-centroid change vs time (4/9).

2.2 April 12, 2018

On 4/12/2018 we measured the same detector with the same settings, but with some cooling (Figure 2-2). Before starting cooling the detector we measured the peak centroid, which was 618.23 keV. If the power law curve created in Figure 1 was extrapolated over an additional 2.5 days, it ends with a value of 623 keV, close to the measured 618 keV.

We cooled the detector from 16 °C to -5 °C using dry ice. At -5°C the centroid reached a value of 663 keV. After we removed the ice (orange point) the detector rapidly warmed back up to 16 °C and the centroid experienced a downshift to approximately 630 keV.

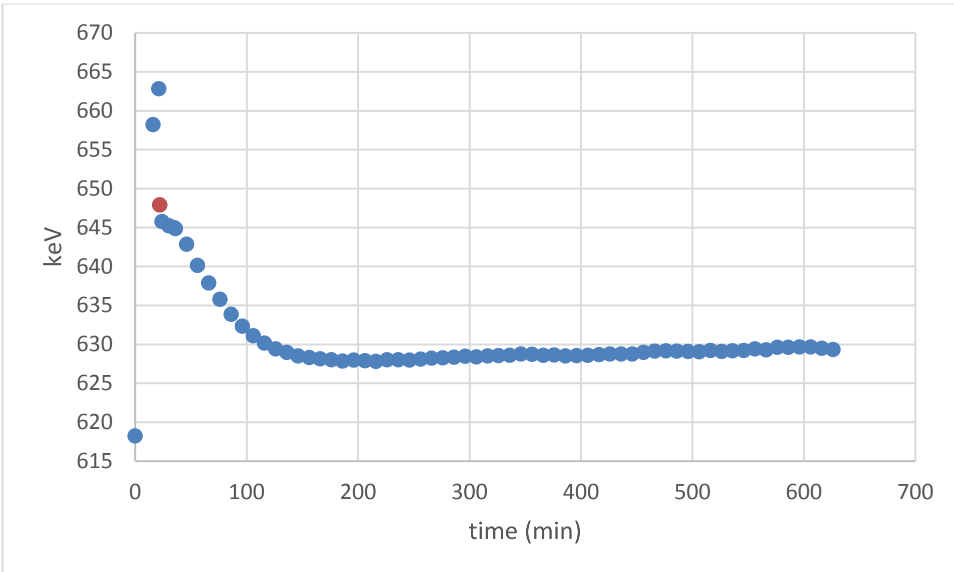

Figure 2-2. Digibase 16204844 Cs-137 peak-centroid change vs time and temp (4/12).

2.3 April 13, 2018

On 4/13/2018 we swapped Digibases on the detector with DigiBase 68404 (a known good Digibase) and got a similar effect. The centroid started at 662 keV at a temperature of 17 °C. The detector was cooled down to -5 °C, then the ice was removed (orange point) and as the detector began to warm up. Then a similar decay back to close to the original value was observed, Figure 2-3.

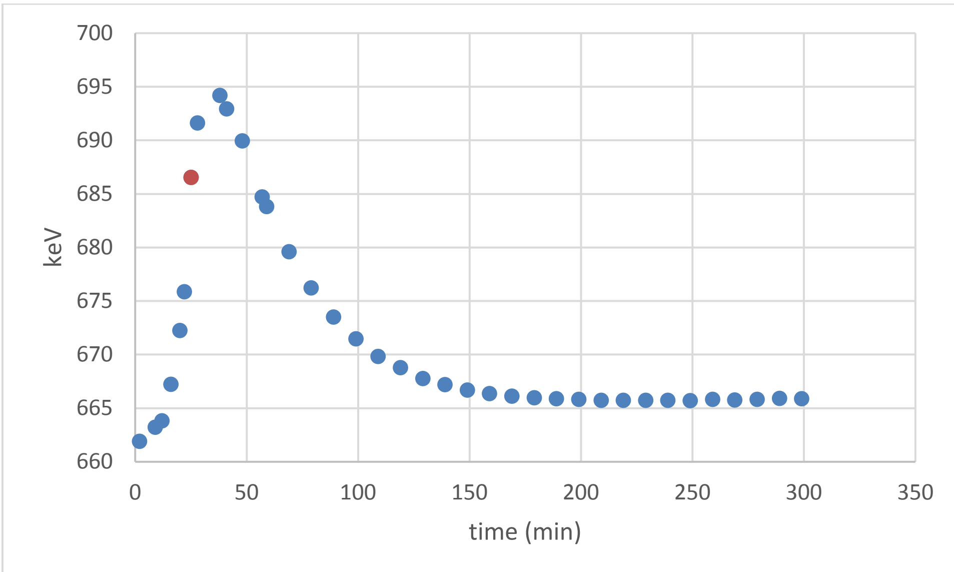

Figure 2-3. Digibase 68404 Cs-137 peak-centroid change vs time and temp (4/13).

2.4 April 13, 2018 – All detectors

On 4/13/2018 we measured all four detectors and Digibases (3 from the HDTS and Digibase 68404+large, cracked NaI) arranged 90 degrees apart with the Cs-137 source at the center (Figures 2-4 through 2-7). The cracked detector has broad peaks the PMT performance is not compromised. The experiment turned on the high-voltage, waited 1 minute, counted for 1 minute, sleep for 9 minutes, and then repeat the count 23 times, then turn off the high-voltage, wait 9 minutes, and then repeat the entire sequence 18 times (for a total time of 4320 minutes). The spikes in the chart are evidence of the HV transition.

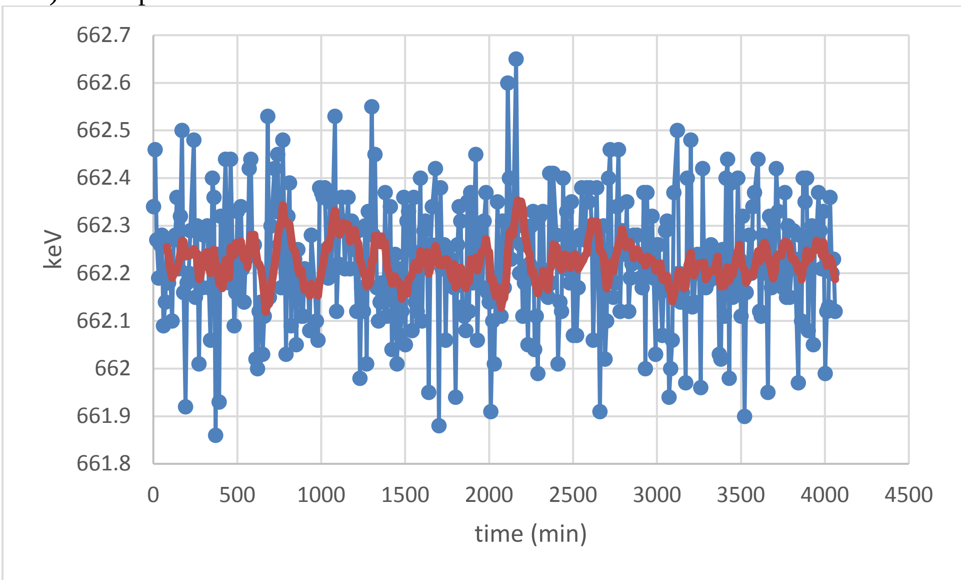

Figure 2-4. Digibase 16204844 Cs-137 (HDTS Detector 2) peak-centroid change vs time (4/13).

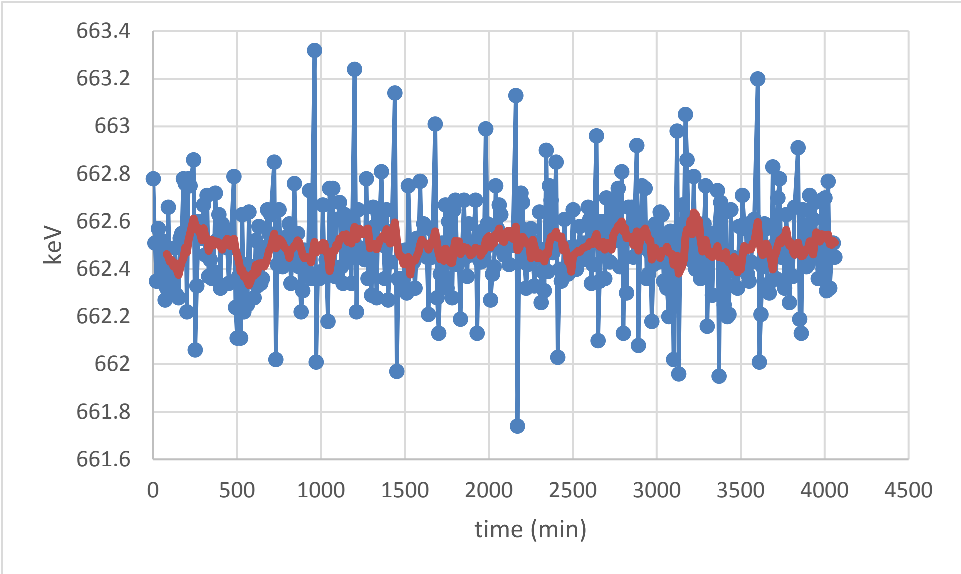

Figure 2-5. Digibase 16204829 Cs-137 (HDTS Detector 3) peak-centroid change vs time (4/13).

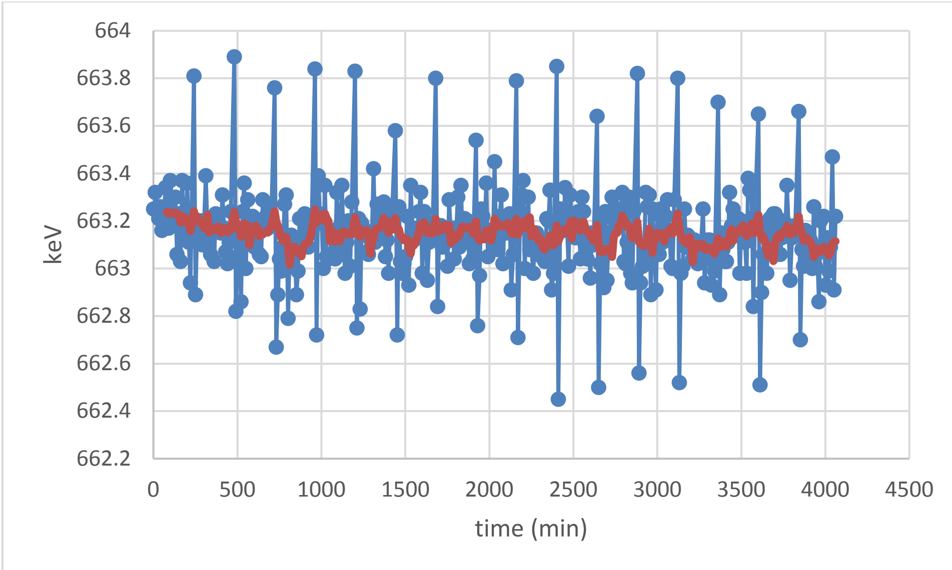

Figure 2-6. Digibase 16204842 Cs-137 (HDTS Detector 1) peak-centroid change vs time (4/13).

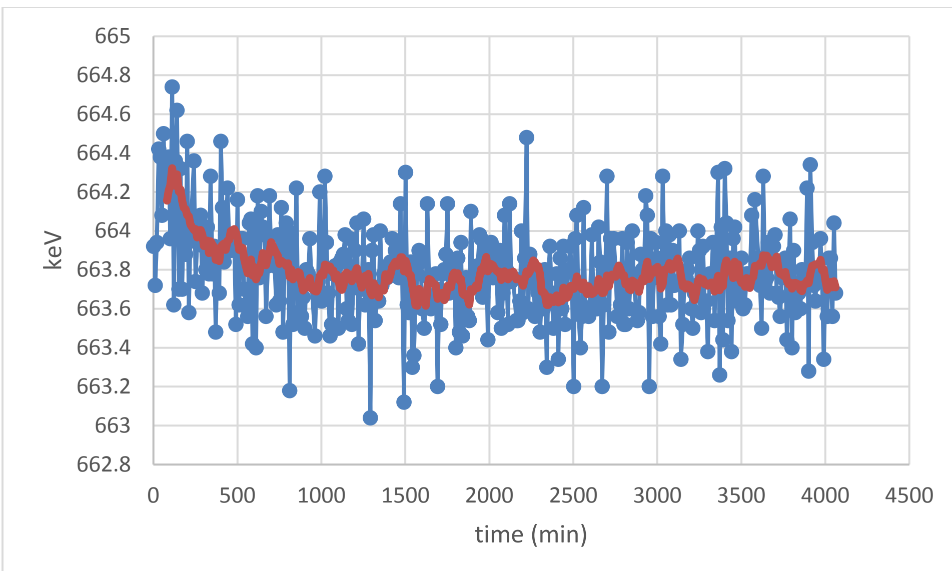

Figure 2-7. Digibase 68404 Cs-137 (Cracked Detector) peak-centroid change vs time (4/13).

Only the cracked detector showed any significant change in peak-centroid over the experiment (Figure 2-7), and even that was only approximately 1 keV. The orange line is the 9-point average. What these measurements show is for optimal performance, there should be a 20-minute “warm-up” time if the high voltage is toggled off and on, before beginning measurements (5 minutes if just turned on).

With neither of the Digibases appearing to drift by more than 4 keV, except under harsh temperature conditions, we could not draw any specific conclusions about Digibase degradation. And the system was used un-changed during the 2018 hunt season.

3.0 Experiments Fall 2018

In the hunts during the fall of 2018, there were again problems with the detectors being difficult to calibrate. We swapped out the Digibases and brought the mis-behaving one (Digibase 1620484) back to the lab.

3.1 November 30, 2018

On 11/30/2018 we measured Digibase 16204844 with the large, cracked detector at a high voltage of 1080 V and gain of 0.7768. The temperature was approximately 20 °C. This showed a large centroid shift of approximately 50 keV over 4 hours, Figure 3-1.

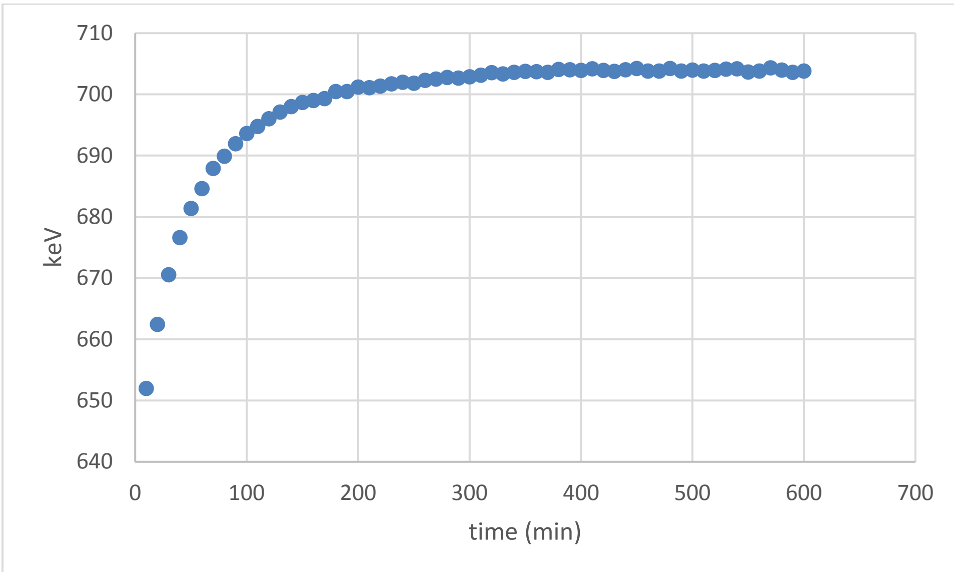

Figure 3-1. Digibase 16204844 Cs-137 (Cracked Detector) peak-centroid change vs time (11/30).

3.2 December 7, 2018

To determine if the issue was the Digibase or the detector, on 12/7/2018 we measured the Digibase 16204844 with a small 2x2 detector at a high voltage of 1080 V and fine gain of 0.7768. The temperature was approximately 20 °C. This showed a continuous shift of the centroid, with approximately 15 keV of change in 4 hours, Figure 3-2.

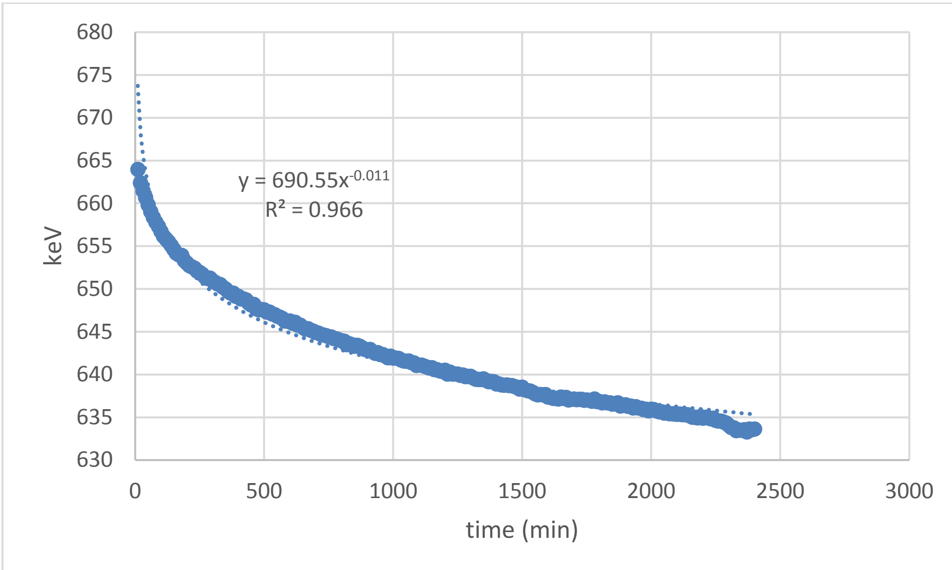

Figure 3-2. Digibase 16204844 Cs-137 (Small Detector) peak-centroid change vs time (12/7).

3.3 December 10, 2018

To confirm no change in the system, on 12/10/2018 we remeasured Digibase 16204844 with the large cracked detector at a high voltage of 1080 V and gain of 0.7768. This again showed a large centroid shift of approximately 100 keV over 4 hours.

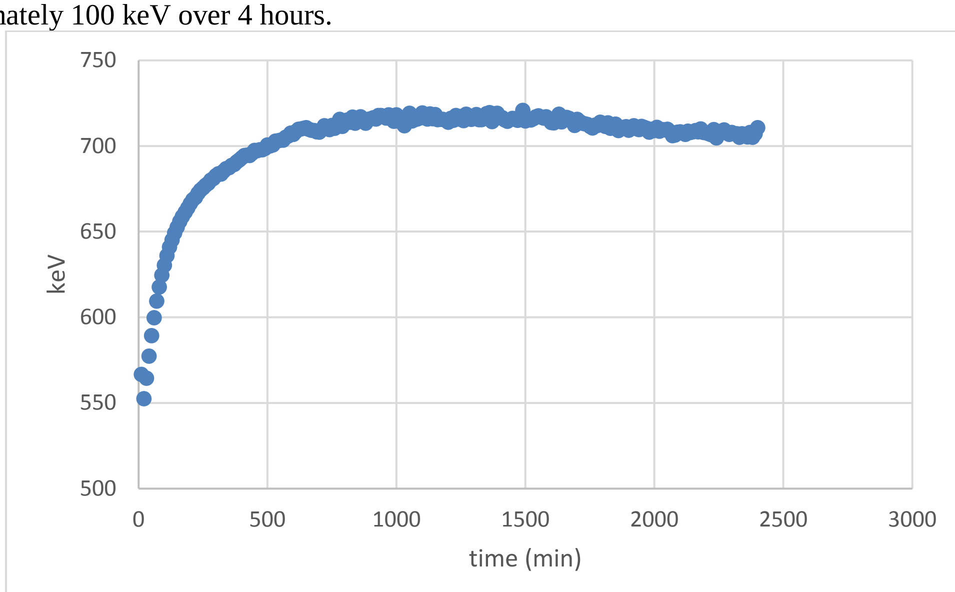

Figure 3-3. Digibase 16204844 Cs-137 (Cracked Detector) peak-centroid change vs time (12/10).

These measurements show that Digibase 16204844 is unstable and is not suitable for field measurements.

4.0 Conclusions

- The initial HV warmup time should be at least 5 minutes. If the HV is toggled off/on, then the warmup time needs to be increased to 20 minutes (see spikes in Figures 2-4 through 2-7).
- Digibase 16204844 is unstable and should not be used.
- Prior to using the detectors with HDTS they should be tested to ensure their centroids are stable using the above methodology.
- Consider discussing with the vendor (ORTEC) the possibility of using higher QA'd components in the Digibase system.

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