Report3, Calibration

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1 Theory

As the pulse spikes of our detector arrive, they are sorted according to which channel number the maximum value of the spikes correspond to. This is illustrated in Fig.(1).

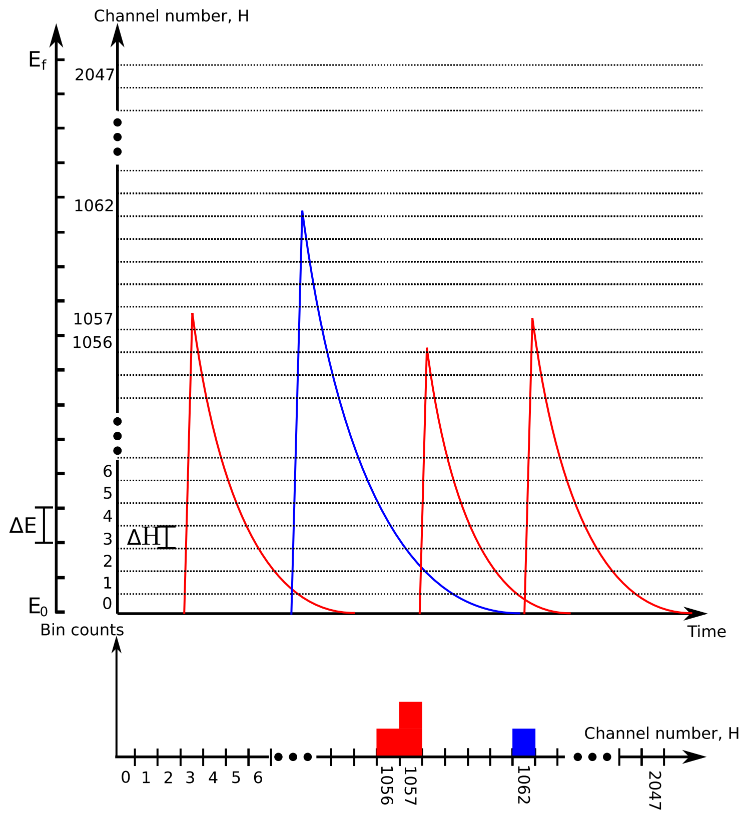

Figure (1) Caption

The energy is likely offset by some fixed amount and stretched or squished compared to that of the H axis. The amount by which it is stretched or squished is referred to as *gain*. This gain is equal to $\Delta E/\Delta H$.

$$E(H) = \underbrace{E_0}_{offset} + \underbrace{\frac{\Delta E}{\Delta H}}_{gain} H \tag{1}$$

Where ΔE and ΔH are illustrated in Fig.(1).

- If the E-axis is stretched compared to the H-axis, then when we are moving one unit along the H-axis, we should have traversed a distance which is less than one unit along the E-axis. We should then have a slope/gain which is less than one.
- When the E-axis is squished compared to the H-axis, then after moving one unit along the H-axis results in traversing more than one unit along the E-axis. The slope/gain in this case should be more than one.

If we have the spectrum of a source where we know the exact energy values of two or more peaks, we can determine both the offset and gain, as shown in Fig.(2).

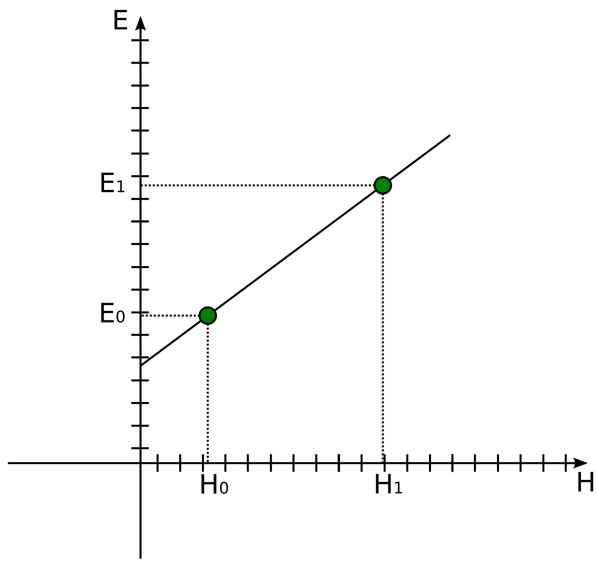

Figure (2) E_0 and E_1 are found from the reference values of two of the peaks whilst H_0 and H_1 are determined from the fitted peaks. The gain is thus given by $(E_1 - E_0)/(H_1 - H_0)$. The offset can be extrapolated from one of the peaks using the gain/slope. Note that it is preferable to have the two calibration peaks as far apart as possible, since this leads to less error when extrapolating to find the offset. We could also have used multiple peaks for our calibration, which also reduces the error.

In general, when using multiple peaks, we do a simple linear fit to the scatter plot of the peaks. From this linear fit, we then find our offset and gain.

From Eq.(1) we have

$$offset = E - \frac{\Delta E}{\Delta H} H = E - gain * H \tag{2}$$

And so once the gain is found, the offset can be extrapolated by inserting for $(E, H) = (E_0, H_0)$ or $(E, H) = (E_1, H_1)$ in the above equation.

Now, in the limit that $\Delta H \to dH$, it no longer makes sense to talk about the channel count at any specific channel number H. In this limit we are dealing with the count density as a function of H, namely dN/dH.

2 Calibration of the Ge detectors of the GASP array

Since the error decreases with the number of peaks used for calibration, we use a $^{152}_{63}$Eu source which has 22 different gamma transitions in total. The 11 most intensive of which are used for calibration

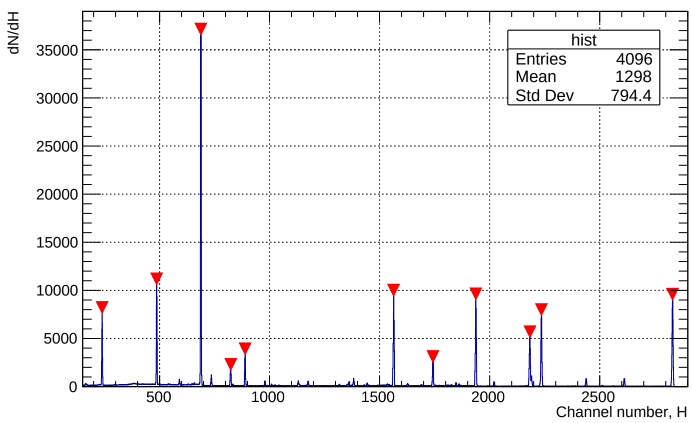

Figure (3) Result of running "peak_search.cpp". The 11 most intensive peaks are located by the red arrows.

After the 11 most intensive peaks are located by the script "peak_search.cpp", they are matched with the corresponding tabulated energies by use of Tab.(**??**) in the appendix.

We can then make a scatter plot of energy vs channel number, as shown in Fig.(4). Fitting a first order polynomial to these points yields the offset and gain which were found to be 0.49638 and 3.20583 respectively.

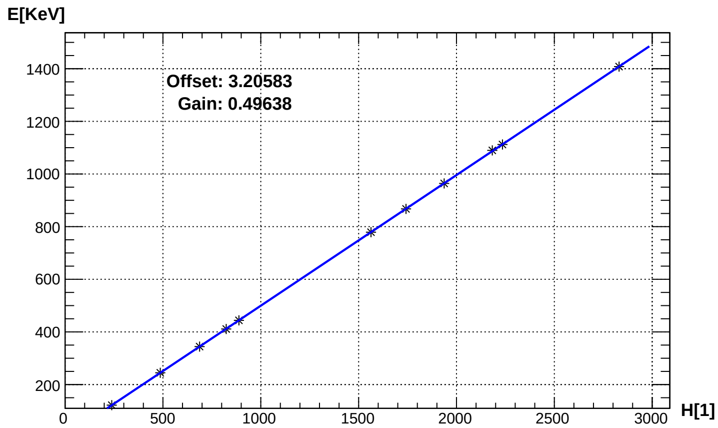

Figure (4) Caption

We insert these values in the script "calibrate_60Co.cpp" to generate the calibrated spectrum of Europium, as seen in Fig.(5)

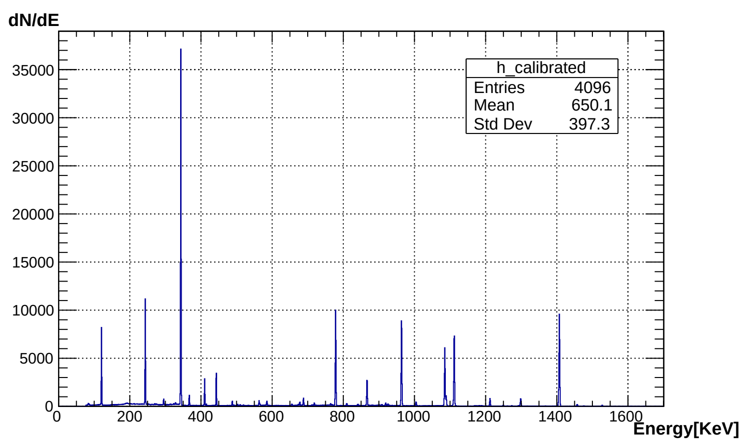

Figure (5)

3 Calibration of $LaBr_3$ detector

Next, we run the script get_calibration.cpp. This script locates the channel number of the two main peaks of the Cobalt(^{60}Co) spectrum, as shown in Fig.6

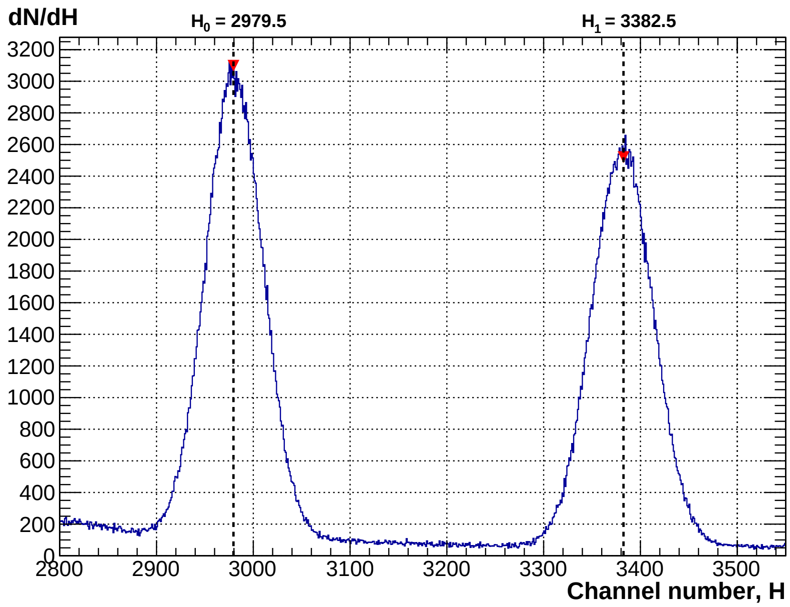

Figure (6) The Cobalt spectrum is not an ideal calibration source for observation of low-energy gamma transitions, since the two photopeaks are located at 1173.2 keV and 1332.5 keV. Any error in the gain thus accumulates when extrapolating to energy values far outside our "calibration range". Picking good calibration sources with peaks on either side of the energy range of our experiment is more favorable. To get a better calibration, one might thus combine different sources in order to get a better calibration then might be obtainable with only one source.

using this, it calculates the gain and offset to be

- gain = 0.3952
- offset = -4.25857

We can insert these values into the scripts "calibrate_60Co.cpp" and "calibrate_152Eu.cpp" to give the calibrated spectra of ^{60}Co and ^{152}Eu, as shown in figures (7) and (8) respectively

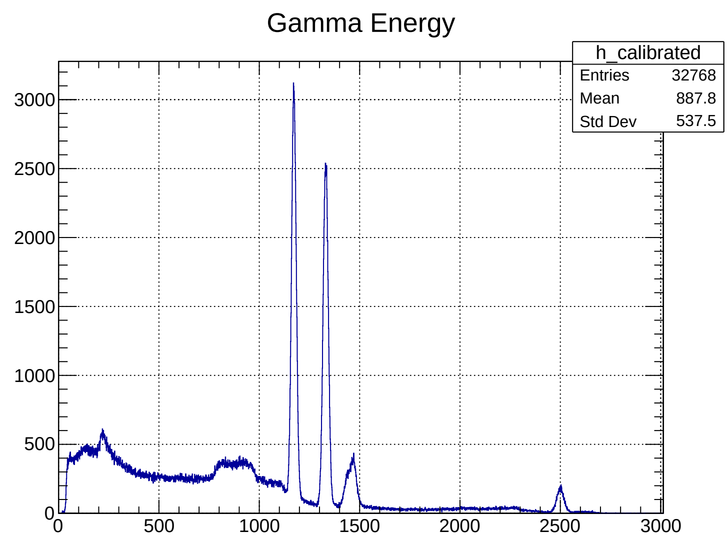

Figure (7) Caption

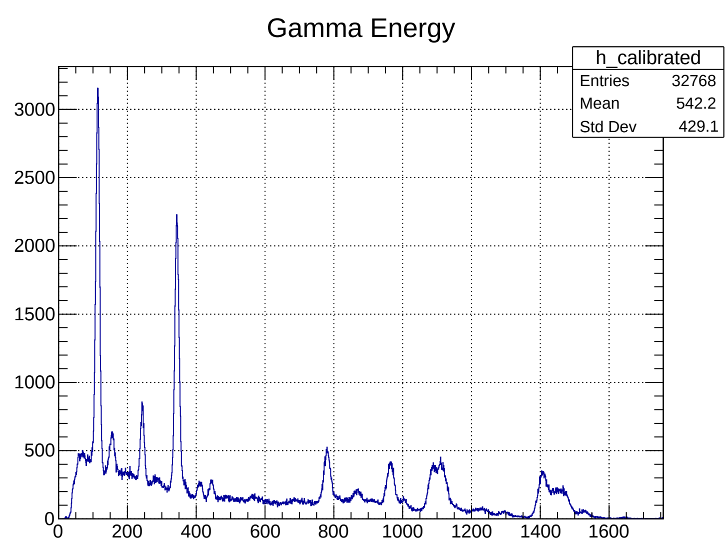

Figure (8)

4 Comparison

In Fig.(9) we see the spectrum of ^{152}Eu for a Germanium detector and a Lanthanium-Bromide detector in blue and red respectively. As seen, the high resolution of the Germanium detector allows

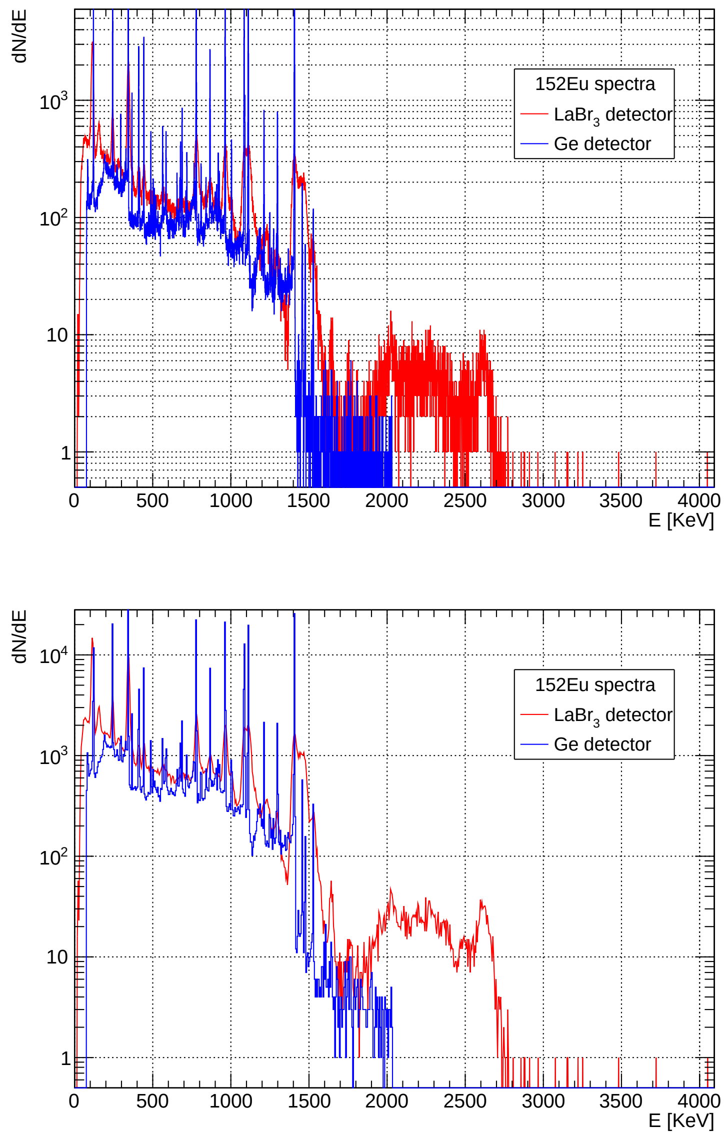

Figure (9) Comparison of the spectra produced by use of a Germanium detector (blue) vs. a Lanthanium (red) detector for a ^{152}Eu source. In the second panel we rebinned the histograms by a factor of 5 to see the spectra better.

for identification of peaks which have a small separation in energy, whereas the Lanthanum(III) bromide detector is unable to separate many of these peaks due to its low resolution.

An advantage of the Lanthanum detector however, is its efficiency, which is greater than that of the Germanium detector. This allows it to give a measurable signal even for rare processes, which might be the reason for why we see a response for the Lanthanum detector above about 2000 KeV whereas for the Germanium detector we see no signal in this region.

Appendices

^{152}Eu peaks

Energy	Error	Intensity	Error
121.7830	0.0020	13620	160
244.6920	0.0020	3590	60
295.9390	0.0080	211	5
344.2760	0.0040	12750	90
367.7890	0.0050	405	8
411.1150	0.0050	1070	10
443.9760	0.0050	1480	20
488.6610	0.0390	195	2
564.0210	0.0080	236	5
586.2940	0.0060	220	5
678.5780	0.0030	221	4
688.6780	0.0060	400	8
778.9030	0.0060	6190	80
867.3880	0.0080	1990	40
964.1310	0.0090	6920	90
1005.2790	0.0170	310	7
1089.7000	0.0150	820	10
1109.1800	0.0120	88	2
1112.1160	0.0170	6490	90
1212.9500	0.0120	670	8
1299.1240	0.0120	780	10
1408.0110	0.0140	10000	30