LIVERPOOL RADIOMETRICS

HIGH RESOLUTION GAMMA SPECTROMETRY

PRACTICAL: 1

SETTING UP A GERMANIUM DETECTOR

Aims:

To assemble, optimise, and check a germanium gamma spectrometry system

Objectives: After this practical you should

1. be able to assemble and interconnect components.
2. know how to optimise the digitsl shaping time constant.
3. know how to determine system resolution.
4. be able to do an energy calibration and test its linearity.
5. know how to check all the parameters supplied by the detector manufacturer.

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DEPARTMENT OF PHYSICS, UNIVERSITY OF LIVERPOOL, LIVERPOOL L69 7ZE, UK. TEL: 0151 794 6776, FAX: 0151 794 3348

PRACTICAL 1

2.1 Generalities

2.1.1 In this session we will cover the basic and essential setting up of a conventional germanium detector.

2.1.2 Today's practical work can be split into four parts:

- setting up from the unpowered state,
- optimisation and determination of best system resolution,
- energy calibration, and
- checking the detector specification.

2.1.3 You will be using a Canberra Broad Energy Germanium detector (BEGe) with a Lynx digital spectroscopy unit. You will use the Prospect software to control the Lynx unit and collect spectra from the detector.

Log in to the PC and then open the Prospect software.

a. You should now "connect" to the Lynx box by selecting the "connect to device" option and then choose the appropriate IP address.

b. Familiarise yourself with the Prospect software based digital oscilloscope, this allows you to look at both the raw and processed pulses. You may want to switch off some of the other on screen traces to help make the screen view clearer.

c. You will look at the "ADC" and "energy" signal on the digital oscilloscope.

2.2. Setting up from the Unpowered State

2.2.1 The first sections of the "Practical Notes" contain hints and tips for initial setting up. They assume a newly acquired detector and no pre-existing shielding etc., factors which we cannot simulate within a reasonable time.

2.2.2 Inspection.

Make a note of the following information about the system you are to use.

system software:	
detector type and geometry:	p-type, n-type, coaxial, well, BEGe
detector working bias:	V
bias polarity:	+ve/-ve
resolution (FWHM) at 1332 keV:	keV
Look at the shielding; is it adequate?:	
Is there a graded shield?:	
Consider sample loading; how easy is it?:	
Could a dropped sample be readily recovered?:	

Look at nitrogen filling and overflow; satisfactory?: ☐

Is the Dewar on a vibration reducing support? ☐

Do the power supplies come from one mains wall socket?: ☐

Identify the preamplifier, digital amp and MCA. OK?: ☐

2.2.3 Assembly.

Fit and secure the preamp power supply cable. This is an essential connection to avoid damaging the preamplifier.

Check the HV is set to zero and is switched off.

Connect the HV cable to the appropriate connector (there may be more than one) on the HV unit.

Connect the HV shutdown cable to the appropriate socket

** ***Don't switch on yet*** **

Connect the signal cable from preamp to digital amplifier input.

Set the digital amplifier coarse gain to about 10.

Set the digital amplifier time constant to 5.6 μs.

Use the second output to connect to both the oscilloscope input.

******* BEFORE PROCEEDING *******

***** ASK A DEMONSTRATOR TO CHECK THE CABLING *****

2.2.4 Powering up.

*** After cabling has been checked....*

*** Don't switch on the HV unit just yet ***

Check that the HV cable is connected to the correct polarity output.

polarity:	
OK?:	

Put a ^{60}Co source on the detector at a reasonable distance eg 10cm.

Start acquisition on the MCA.

Now switch on the HV, and set to about a quarter of the full working bias voltage.

Check

i) presence of pulses on the oscilloscope:	
ii) that a spectrum of sorts is appearing on the MCA:	

If not, ask for help.

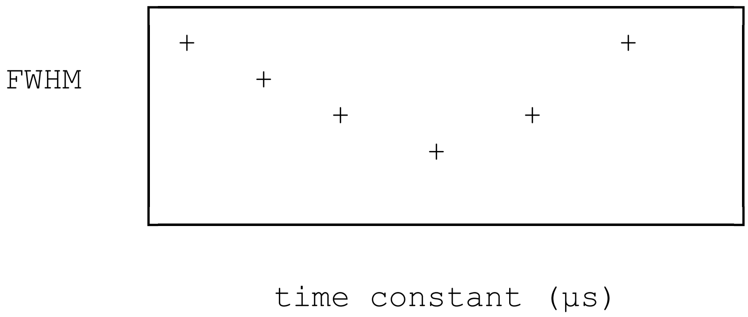
Then continue set the HV up to the operating voltage.

2.2.5 Ideally it would be good practice to allow the system to stabilize (20-30 minutes) before proceeding. This is not important for these demonstration tests.

2.3 Optimisation of shaping time constant and determination of system resolution

There are good reasons for expecting that the best system performance, in terms of peak resolution, will occur at one particular digital amplifier time constant setting.

The variation with time-constant may look like this: The shape and position will vary with count rate.



2.3.1 An oscilloscope is essential for this work when conventional NIM amplifiers are in use. On a digital system such as the Canberra Lynx system you can use the in build oscilloscope function. Some other instruments have a semi-automatic pole-zero correction, where either a button is pressed or a computer command given to initiate an internal correction.

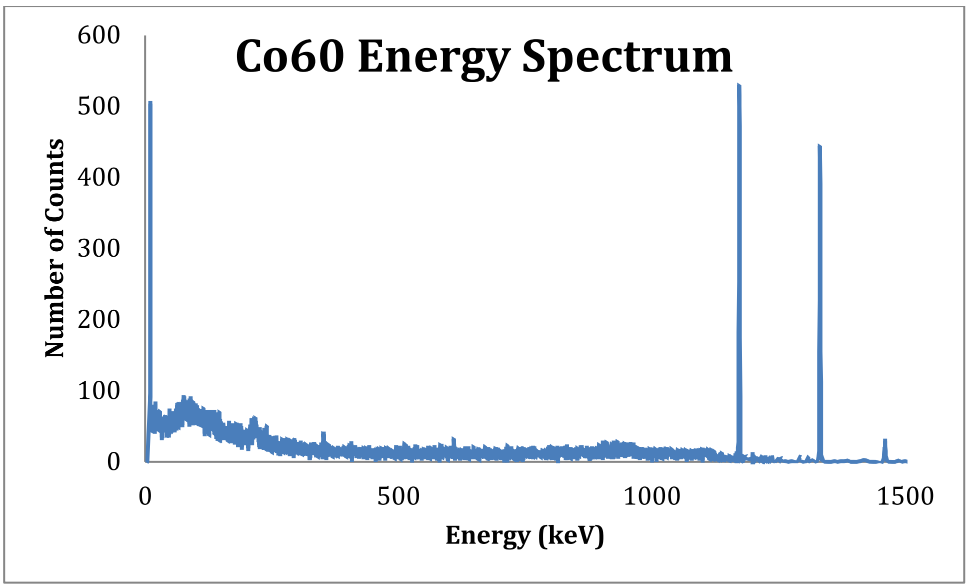
You would normally have read the digital amplifier manual. We will again work with a ^{60}Co source, using the upper peak at 1332 keV.

2.3.2 Setting the energy range.

[Roughly; this is not a proper energy calibration]

Adjust the digital amplifier gain so that the energy range is approximately 0 - 2000 keV.

If you are using 16k channels, this means about 0.125 keV/ch. You should see a spectrum like the one below



2.3.3 Optimising the time constant.

Look at the "energy" output of the digital amplifier output on the oscilloscope. Adjust the sensitivity and time-base on the oscilloscope so that the pulses fill the screen. The digital rise-time can be adjusted from the "Filter settings" dialogue box. You can control the "Rise-time" and "Flat Top". Look how changing these values influences the shape of the "energy" pulse on the screen. Draw a sketch of the digital amplifier output for the following two digital rise-time values.

Digital Rise-time = 8.8μsec Flat top = 1.2μsec

Maximum height of pulses : Volts

Width of pulses : μsec

Digital Rise-time = 2.8μsec Flat top = 0.6μsec

Maximum height of pulses : Volts

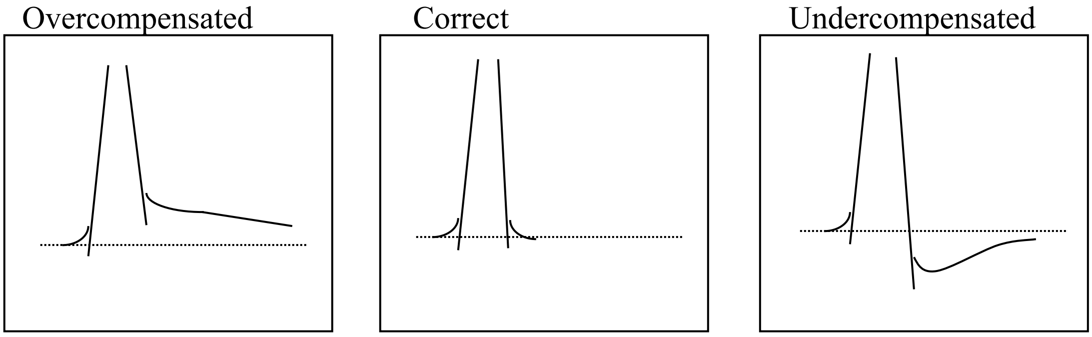
Width of pulses : μsec

You will notice that the shapes of the pulses from the preamplifier and from the amplifier are very different. The preamplifier output is a result of measuring the charge in the detector; the shape of the amplifier output is designed so that the pulse height can be readily measured by the next component of the system, the MCA.

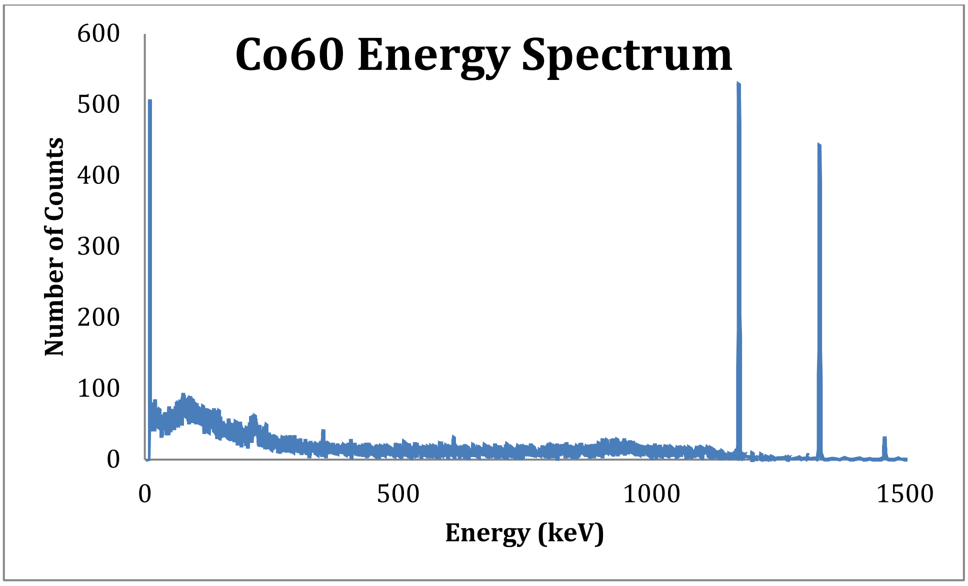
To get the best pulse shape out of the amplifier, we need to correct the pole zero [PZ].

a) Set the time constant to 8.8µsec rise-time and 1.2µsec flat top.
b) The pole zero adjustment is now carried out. In the digital filter settings dialogue select the miscellaneous tab. You can now adjust the manual pole zero settings. There should be no undershoot or overshoot.

PZ Adjustment



c) Use the Prospect MCA controls to obtain a spectrum similar to that shown below.



Measurement of Detector Resolution

The prescribed standard for measuring the energy resolution of a Germanium detector is given in ANSI/IEEE N42-14-1991. A ^{60}Co source is used. The count rate is <1kHz, and for good statistics the number of counts in the maximum channel of the 1332.5keV peak should be > about 3000.

a) Collect a ^{60}Co spectrum for a long enough period to satisfy the standard. Store this on the computer. Note that the spectrum contains two major full-energy peaks at energies of 1173.2 and 1332.5keV.

b) Use the calibration function on the computer software to calibrate the spectrum in terms of energy using the two peaks. [This is fine for our purposes here but would not be generally recommended for calibrating the whole energy range as the energies are too close together]. Ask a demonstrator for help if necessary.

c) Now the resolution can be determined by measuring the Full Width at Half Maximum (FWHM) of the 1332.5keV peak. The computer software can be used. Repeat this for the 1173.2keV peak.

d) It is often useful to extend this procedure to obtain the Full Width at Tenth Maximum (FWTM). When compared to the FWHM, information on the peak shape can be found. For a perfect Gaussian-shaped peak, FWTM = 1.83 x FWHM.

System resolution

FWHM at 1332.5keV: __________keV

FWHM at 1173.2keV: __________keV

Peak Shape, which will be OK if the ratio is < about 1.9

FWTM at 1332.5keV :
Ratio of FWTM/FWHM OK?

FWTM at 1173.2keV :
Ratio of FWTM/FWHM OK?

Spectrum Features

a) Sketch (or plot) your ^{60}Co spectrum using a vertical log scale.

b) Label the following features on the sketch and note the energy values below.
Ask a demonstrator for help.

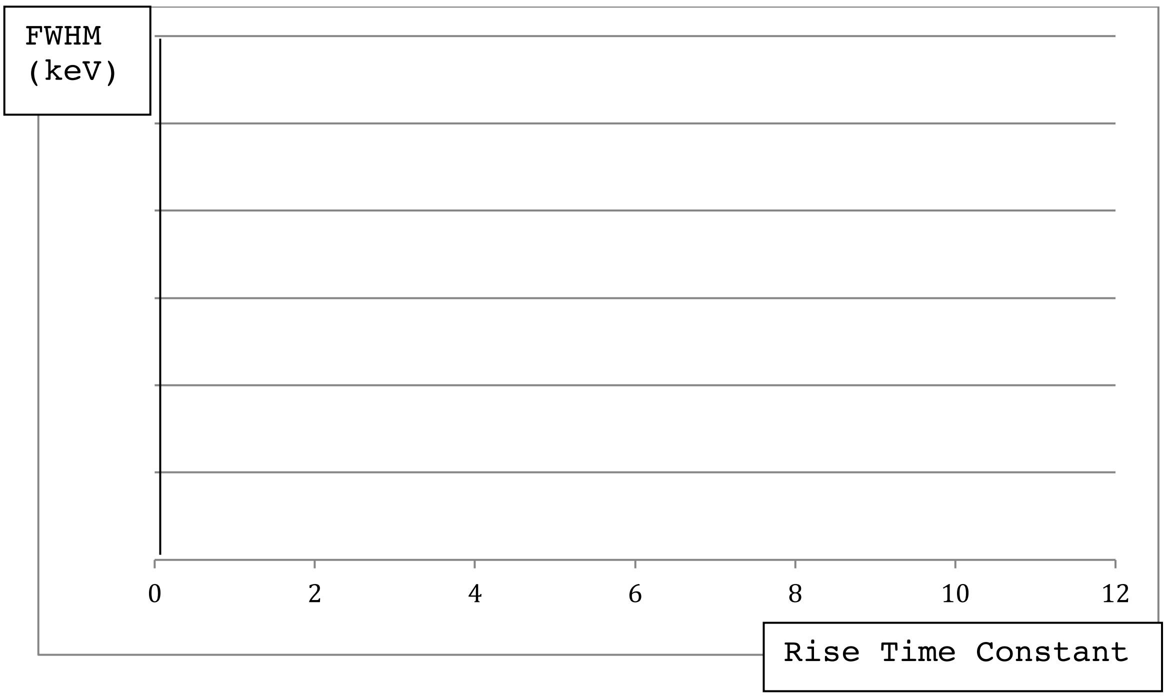
Feature	Energy found (keV)
Full energy Peaks:	
Compton edge:	
Compton distribution:	
Backscatter Peak:	
X – ray:	

Variation of Resolution with Time Constant

a) Repeat the measurements described in section 1.4 for differing time constants. Remember to reset the PZ adjustment each time and to recalibrate. Use the 1332.5keV peak from your ^{60}Co source.

Time Constant (μsec)[Rise / Flat]	Energy Resolution, FWHM (keV)
1.2 / 0.6	
2.8 / 0.6	
5.6 / 0.8	
8.8 / 1.2	
12.0 / 0.8	

b) Plot the results on the graph below



2.3.3.4 FWHM.

Find the FWHM (the "resolution") of the 1332 keV peak.
This will usually be done using the system software.

*A digression: The FWHM can **also** be found from the area and peak height.*

Here, the peak is assumed to be Gaussian, when

$$FWHM = \frac{0.939\ (\text{area of peak})}{(\text{counts at peak maximum})} \quad \text{in units of channels}$$

To change this to energy units (keV), it will be a close enough approximation in this case to multiply by

{(peak energy) / (channel number of peak maximum)}

$$\text{Thus}\quad FWHM = \frac{0.939\ (\text{area of peak}) \times (\text{energy of peak})}{(\text{counts at peak max}) \times (\text{channel number at peak max})} \quad \text{keV}$$

2.4 More on Energy Calibration

2.4.1 We will firstly do a *manual, two point, calibration*.

2.4.2 Collect a spectrum from a ^{152}Eu source.

2.4.3 Choose two peaks of known energy.
Suitable peaks are the biggest ones at low and high energy (121.8 and 1408.0 keV for this nuclide). If you are unsure as to the identity of the peaks, ask a demonstrator.

2.4.4 Use the spectrum cursor to read off the channel numbers, and complete the table.

	y (keV)	x (ch)
point 1		
point 2		

2.4.5 Solve the simultaneous equations (y = b.x + a) to find the parameters of slope (b) and intercept (a).

Calculation:

Use an appropriate number of significant figures in the results. (This needs a little thought; ask a demonstrator)

	slope (keV/ch)	intercept (keV)
manual calculation		

2.4.6 Calibration using system software.

On the Canberra Prospect software, these factors may be calculated using the two or more peaks and an interactive program, and are displayed on the screen.
Do this and note the factors:

system	slope (keV/ch)	intercept (keV)

2.4.7 Linearity of a two point calibration.

If we are using a two point calibration we need to know whether the system is linear between the two known points. This may be checked by looking at some other peaks with known energies. ^{152}Eu (again) is a useful multi-energy source.

2.4.7.1 Look in a reliable recent data source and note four major energies [not the ones used for calibration!].

Reference for nuclear data on ^{152}Eu:

2.4.7.2 Note, from the screen, the energy and channel number of each peak maximum.

2.4.7.3 Use your manually calculated calibration factors to give a calculated energy for the last column.

Bear in mind that, if you are only using the nearest integral maximum channel number, you cannot expect this energy to be as accurate as that which the software calculation produces; the software uses the value of the peak centroid and should be better.

gamma peak	energy from literature (keV)	energy shown on screen (keV)	channel number	energy found by calculation (keV)
1				
2				
3				
4				

2.4.7.4 Acceptability of linearity.

Maximum deviation from the literature value:

from the instrument	keV	ie	%
by calculation	keV	ie	%

Is this acceptable?:

2.4.8 Other information from a ^{152}Eu spectrum.

Visual inspection of a ^{152}Eu spectrum with good statistics will also give the following indications. [This is interesting but is not of major importance.]

2.4.8.1 Look at a region at about 565 keV.

There are two lowish emission probability gammas close together at 564.01 [0.467%] and 566.42 [0.129%]. If you have good statistics [lots of counts], the degree of overlap of these peaks gives an instant visual idea of the resolution of the system.

Sketch; use suitable scales to display any effect label the peaks; don't forget to show units

2.4.8.2 Look at a region straddling the 1408 keV peak.

If the continuum level *above* the peak is higher than the continuum *below* it, then summing is taking place. (see Practical 3)

Sketch; use suitable scales to display any effect; label the peaks as above

Is there summing in this instance?:

Repeat the calibration process using at least 5 peaks from ^{152}Eu across the whole energy spectrum. You will now use this for your future work.

2.5 Checking the detector specification.

When you buy a detector, it will be delivered with a specification sheet. This will give you values of three parameters

- resolution [FWHM] at 1332 keV and 122 keV
- efficiency, this is a relative efficiency as shown below
- peak-to-Compton ratio.

It is useful to check this information. [These values cost money!]

The system obviously needs to be well set up beforehand.

2.5.1 Resolution

You have already found the resolution at 1332 keV using a ^{60}Co source.

2.5.1.1 Repeat this for information on low energy resolution at 122 keV using ^{57}Co; the lower larger peak should be at 122.06 keV.

FWHM at:	1332 keV	122 keV
found:	keV	keV
given:	keV	keV

2.5.1.2 The software should also report the one-tenth max, FWTM, which is a good indicator of peak shape.

FWTM at:	1332 keV	122 keV
found:	keV	keV
given:	keV	keV

The ratio of tenth to half widths is often reported and compared to that of a 'perfect' Gaussian shape.

ratio FWTM/FWHM at:	1332 keV	122 keV
found:	keV	keV
values for a Gaussian:	1.83 keV	1.83 keV

	1332 keV	122 keV
Do the found values of the ratios indicate that the peaks could conform to a Gaussian shape?		