

LIVERPOOL RADIOMETRICS

NuSPIN School CAT measurements

PRACTICAL:

5

SETTING UP A GERMANIUM DETECTOR

Aims:

To assemble, optimise, and check a germanium gamma spectrometry system with analogue electronics

Objectives: After this practical you should

1. be able to assemble and interconnect components.
2. know how to optimise the 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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PRACTICAL 2

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:

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

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.

However the systems here will be switched off; the NIM units will be out of the NIM bins; and cables, while available, will not be attached.

2.2.2 Inspection.

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

system software:

detector type and geometry:

detector working bias: bias polarity:

resolution (FWHM) at 1332 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, main amplifier and MCA. OK?:

2.2.3 Assembly.

Slide the NIM units into the appropriate NIM-bin and tighten the retaining screws to finger tightness.

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 amplifier input.

Set the amplifier coarse gain to about 50.

Set the amplifier time constant to about 4 μ s.

Use a T-piece on the amplifier unipolar output to connect to both the MCA input and the oscilloscope input.

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

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

2.2.4 Powering up.

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

Switch on the mains to the system, then power to the NIM units.

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

Check that the HV unit is showing the correct polarity.

polarity:

OK?:

Put a ^{60}Co source on the detector.

Start acquisition on the MCA.

Now switch on the HV, and turn up slowly (about 100 V/s) 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 turning the HV up to the operating voltage.

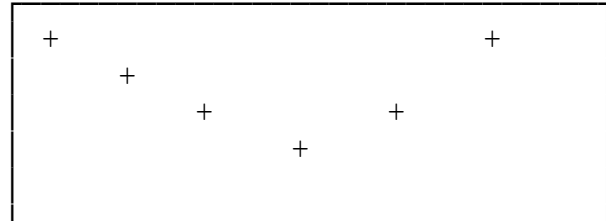
2.2.5 Ideally it would be good practice to allow the system to stabilize (20-30 minutes) before proceeding. This is not important for these demonstration tests.

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 amplifier time constant setting.

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

FWHM

time constant (μs)

2.3.1 An oscilloscope is essential for this work when conventional NIM amplifiers are in use. 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 amplifier manual. We will again work with a ^{60}Co source, using the upper peak at 1332 keV.

2.3.2 Use the $93\ \Omega$ impedance unipolar output from the rear of the amplifier.

2.3.3 Setting the energy range.

[Roughly; this is not a proper energy calibration]

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

As we are using 4096 channels, this means about 0.5 keV/ch. (B2 of Practical Notes, N4)

2.3.4 Optimising the time constant.

2.3.4.1 Firstly, choose and set a time constant on the amplifier.

First choice of time constant:

μs

2.3.4.2 Setting the pole zero.

The amplifier may have a two- or three-position switch, one position being labelled "PZ adjust". Put the switch in this position.

Look at the trailing edge of the amplifier output pulse on the oscilloscope; a sensitivity of 50 mV/cm will be suitable.

Using a "twiddle-stick", turn the pole zero (P/Z) screw control so that there is no overshoot or undershoot. (B3 of Practical Notes)

2.3.4.3 Count. [If this is new to you, ask a demonstrator]

Collect a spectrum for about 200 s.

2.3.4.4 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

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

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

$$\{ \text{(peak energy)} / \text{(channel number of peak maximum)} \}$$

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

2.3.4.5 Check visually on the displayed spectrum that the peak width looks right by counting channels. This is only a rough check but you will need a *linear* vertical scale on the display.

2.3.4.6 Then repeat from 3.4.1 for other time constants, filling in the table until a minimum value of FWHM is seen.

The given value for the 'best' FWHM at 1332 keV is:

	keV
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Complete the table:

		FWHM at 1332 keV	
Time constant (μs)	calculated /software (keV)	visual check on peak shape	

Therefore,

under these conditions, the optimal time constant is:

	μs
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2.4 Energy Calibration

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

2.4.2 Collect a spectrum from a ¹⁵²Eu 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.

With the Ortec Maestro system, follow a similar calculation procedure.

You will notice on all systems that following the calibration program, the cursor location is now shown in energy units.

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. ¹⁵²Eu (again) is a useful multi-energy source.

2.4.7.1 Look in a reliable recent data source [eg IAEA TECDOC619] and note four major energies [not the ones used for calibration!].

Reference for nuclear data on ¹⁵²Eu:

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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 ¹⁵²Eu spectrum.

Visual inspection of a ¹⁵²Eu 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

2.5 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 ⁶⁰Co source.

2.5.1.1 Repeat this for information on low energy resolution at 122 keV using ⁵⁷Co; 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:		
values for a Gaussian:	1.83	1.83

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1332 keV 122 keV

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

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2.5.2 Efficiency

The generalised 'efficiency' for a germanium detector is conventionally quoted as a *relative efficiency*; relative to that of a 76 mm x 76 mm sodium iodide detector.

Both distance [25 cm] and energy [1332.5 keV] must be specified.

2.5.2.1 Put a point source [about 10^5 Bq] of ^{60}Co at 25 cm from the detector endcap on the detector axis. Collect a spectrum with reasonable statistics, say $1\sigma = 2\%$, which may imply a net peak area of 3000 counts.

2.5.2.2 Record the net area of the 1332 keV peak and the live time of the count. Calculate the counts per second.

Net area of 1332 keV peak:	
Uncertainty of net area:	
Live time:	s
therefore, count rate (a):	\pm cps

Quote the statistical uncertainty to 1σ .

2.5.2.3 Note the activity of the ^{60}Co source, and correct it to today's date.

Half-life used:	\pm
Taken from reference:	
known activity of ^{60}Co :	\pm Bq

at date:	
today's date is:	
thus, ⁶⁰ Co activity today (b):	± Bq

2.5.2.4 (Absolute) efficiency of Ge detector
for ⁶⁰Co = (count rate)/(activity)

(a)/(b) = (c):	±
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2.5.2.5 The physical presence of a NaI detector is not required for this test; but we do need to know that there is an accepted assumption that the standard NaI would produce an efficiency, as (c), whose value under these conditions is 1.2×10^{-3} . Call this (d).

2.5.2.6 The relative efficiency of the Ge detector is $100(c)/(d)$.

calculated percentage relative efficiency = $100 \times (c)/(d)$:	±	%
supplier's stated relative efficiency :		%

[Usually the uncertainty on the latter value is not given by the supplier!]

Is your measured value acceptably close enough to that claimed by the supplier?

2.5.3 Peak-to-Compton Ratio

This is a parameter that depends on both efficiency and resolution. It is defined as the ratio of the *count in the maximum channel* at the 1332.5 keV peak of ⁶⁰Co to the average Compton background *count per channel* in the range between 1040 and 1096 keV.

2.5.3.1 Take the same ⁶⁰Co spectrum.

Count in maximum channel at 1332 keV
 (a) : ±

2.5.3.2 Set up a ROI between 1040 and 1096 keV.
 Note gross area of ROI; count the number of channels in the ROI.

Measured gross area (b) : ±

Number of channels in area (c) :

Average count per channel in ROI
 (b)/(c) = (d) : ±

2.5.3.4 Calculate Peak-to-Compton ratio

Peak-to-Compton ratio = (a)/(d) : ±

Supplier's Peak-to-Compton ratio : ±
 [if known]

Is your measured value acceptably close enough to that claimed by the supplier?