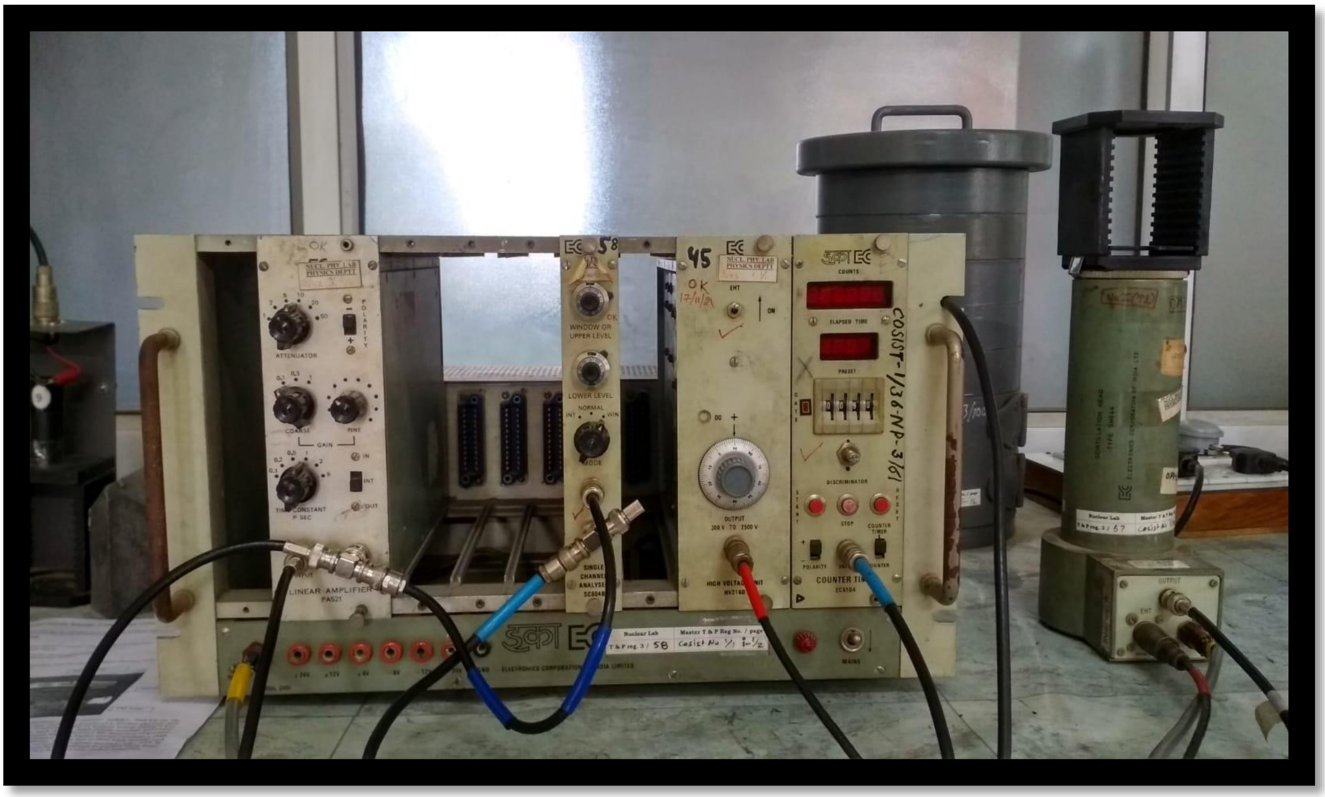
Nuclear Physics Lab
Lab Manual



Energy Calibration using Single Channel Analyzer

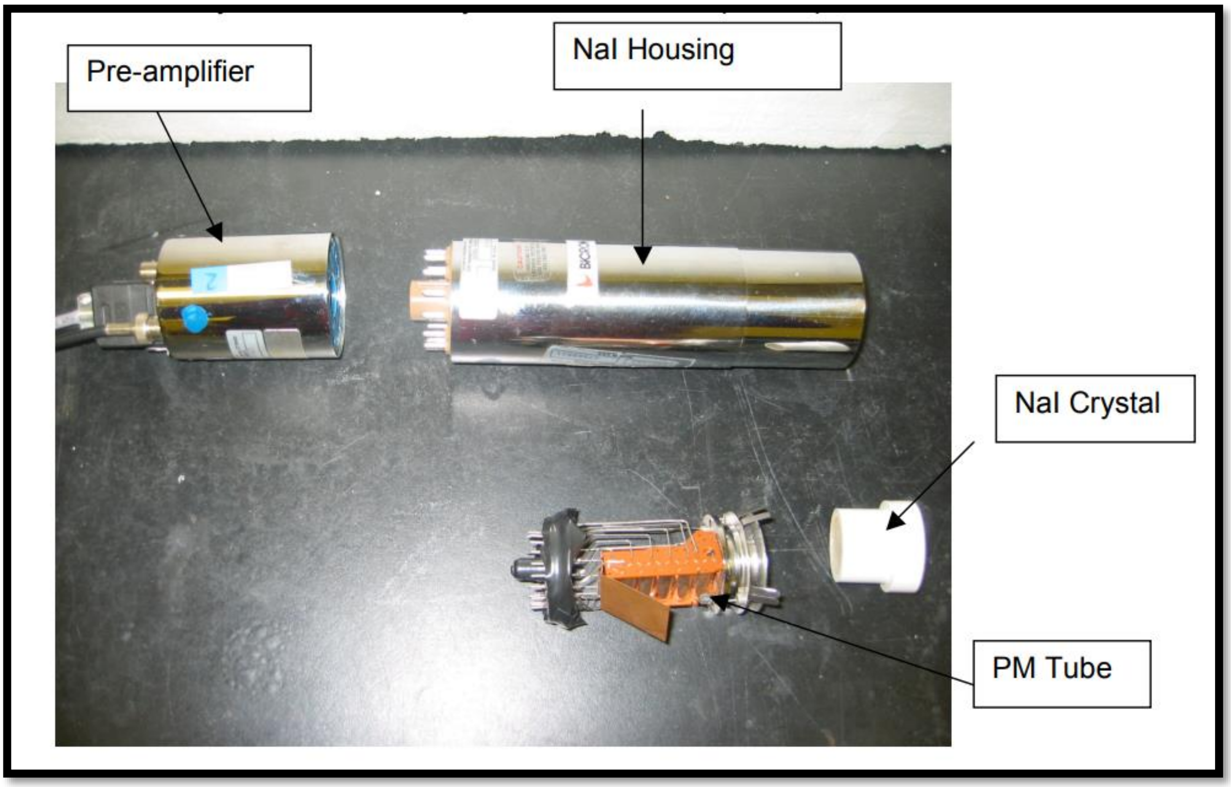
Aim: To calibrate gamma-ray energies for a NaI(Tl) scintillator detector using Single Channel Analyzer (SCA) and check the energy of gamma rays from an unknown source.

Apparatus required:

- NIM Bin
- Oscilloscope
- NaI(Tl) scintillator detector coupled with PMT and Preamplifier
- High voltage power supply
- Linear Amplifier
- Single Channel Analyzer and Counter Timer
- Radioactive source and source holder

Theoretical Background:

Detector assembly: Detector assembly consists of a scintillation detector, such as NaI(Tl); PMT and Preamplifier.



The most widely used scintillation material is NaI(Tl) (thallium-doped sodium iodide)**.** NaI(Tl) as the scintillator is used in scintillation detectors, traditionally in nuclear medicine, geophysics, nuclear physics, and environmental measurements. The iodine provides most of the stopping power in sodium iodide (since it has a high Z = 53). These crystalline scintillators are characterized by high density, high atomic number, and pulse decay times of approximately 1 microsecond (~ 10^{-6} sec). They exhibit high efficiency for the detection of gamma rays and are capable of handling high count rates. The NaI(Tl) scintillator has a higher energy resolution than a proportional counter, allowing for more accurate energy determinations. This is due to their high density and atomic number which gives a high electron density. A disadvantage of some inorganic crystals, e.g., NaI, is their hygroscopicity, a property which requires them to be housed in an airtight container to protect them from moisture. The crystals are usually coupled with a photomultiplier tube, in a hermetically sealed assembly.

SCA: One may want to count only pulses above a certain height, that is, particles with energy above certain threshold energy. Pulses lower than that height should be rejected. The discriminator or SCA is the unit that can make the selection of the desired pulses. There are two dials on the front of the unit. One is marked LLD for the lower-level dial, and the other is marked ULD for the upper-level dial.

There are three modes of operation:

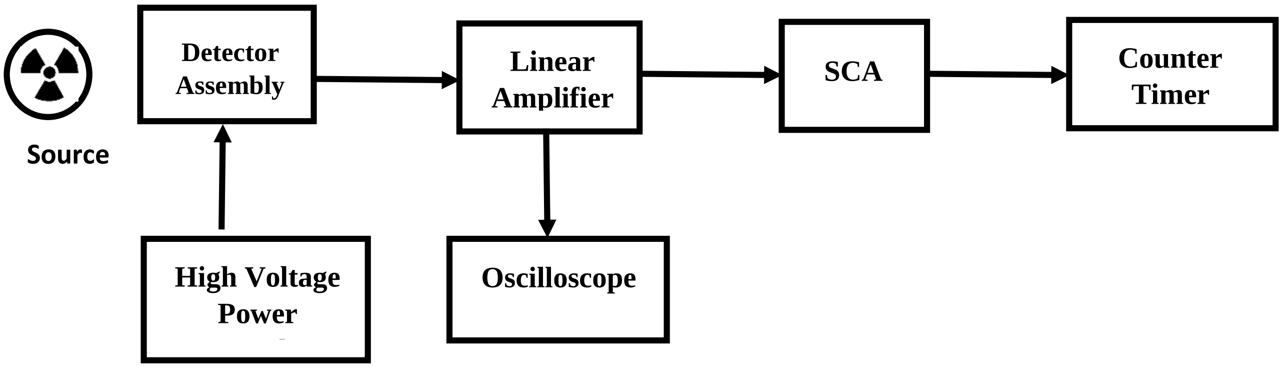
(1) **WINDOW mode:** In the WINDOW mode, the lower limit of the window is adjustable using the LLD. The WINDOW dial adjusts the width of the window. The upper limit is then LLD + WINDOW. In this mode, one complete turn on LLD corresponds to 1 V and one complete turn on the window dial corresponds to 0.1 V. The SCA OUT is generated for pulse amplitudes between the upper and lower limits of the window.

(2) **NORM mode:** In the NORMAL mode, the lower level and upper level are independently adjustable. The SCA OUT is generated for pulse amplitudes that exceed the lower-level threshold, but do not exceed the upper-level threshold.

(3) **INT mode:** In the INTEGRAL mode, the lower level is independently adjustable while the upper level becomes inactive. The SCA OUT is generated for all pulse amplitudes exceeding the lower-level threshold.

Procedure:

1. Make connections as shown in the figure given below

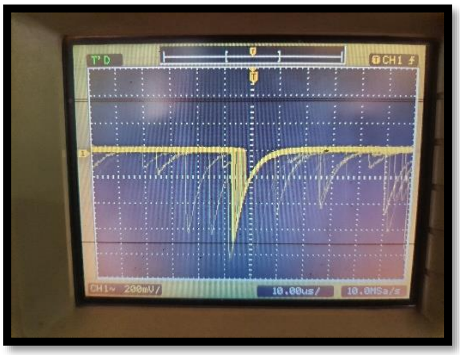


2. Place a radioactive gamma source, e.g., ^{60}Co, on a source holder in front of the face of the detector with the help of tweezers.

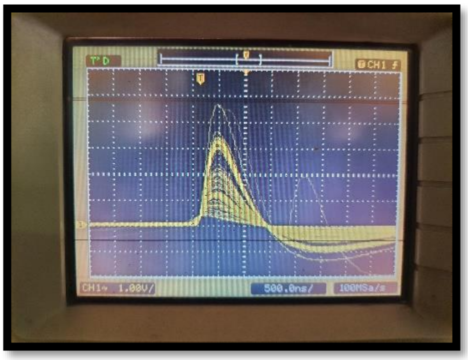
3. Switch on the NIM Bin and then the High Voltage Power Supply Unit.

4. Slowly increase the voltage up to the operating voltage of the detector, here, 570 V.

5. Set the control settings on the linear amplifier (such as gain, attenuator, shaping time, etc.) such that the maximum pulse height in the oscilloscope is around 3.5 Volts. It is advised to see the effects of different control settings on the pulses. Raw pulses from the detector directly can also be seen in the oscilloscope.



Pulses without amplifier



Pulses with an amplifier

6. Set the SCA in window mode. In this mode, a complete turn in LLD corresponds to 1 volt while a complete turn-in window corresponds to 0.1 volts. The ULD then corresponds to LLD + Window. Set and lock the window on one complete turn, i.e., 0.1 volts.

7. Set the timer on the counter-timer to 200 seconds.

8. Set the LLD as 0 and start the counter. Note down the reading at the end of 200 seconds. Take LLD as the corresponding volts.

9. Increase the LLD to 0.1 and take the readings again. Keep on increasing LLD by 0.1 volts and take readings till the counts are relatively very low.

10. Now replace the source with another gamma source like ^{22}Na or ^{137}Cs. Remember that a minimum of three known gamma energies are needed for calibration.

11. Repeat steps 8 and 9.

12. Plots separate graphs of both data with volts on the X-axis and counts on the Y-axis.

13. Determine the centroids of the peaks from the graphs.

14. Draw a straight line using the peak centroids and energies. Obtain the equation of the line.

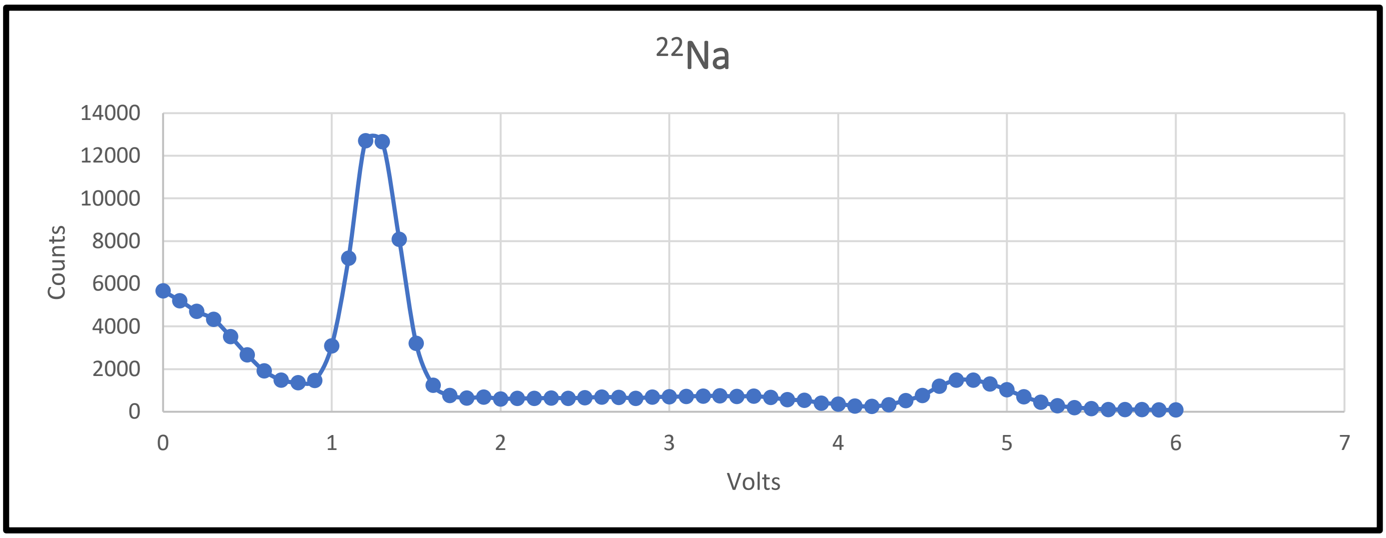
15. Now, replace the source on the holder with an unknown source and repeat steps 8 and 9.

16. Draw the graph and determine the centroids of the peaks in the graph.

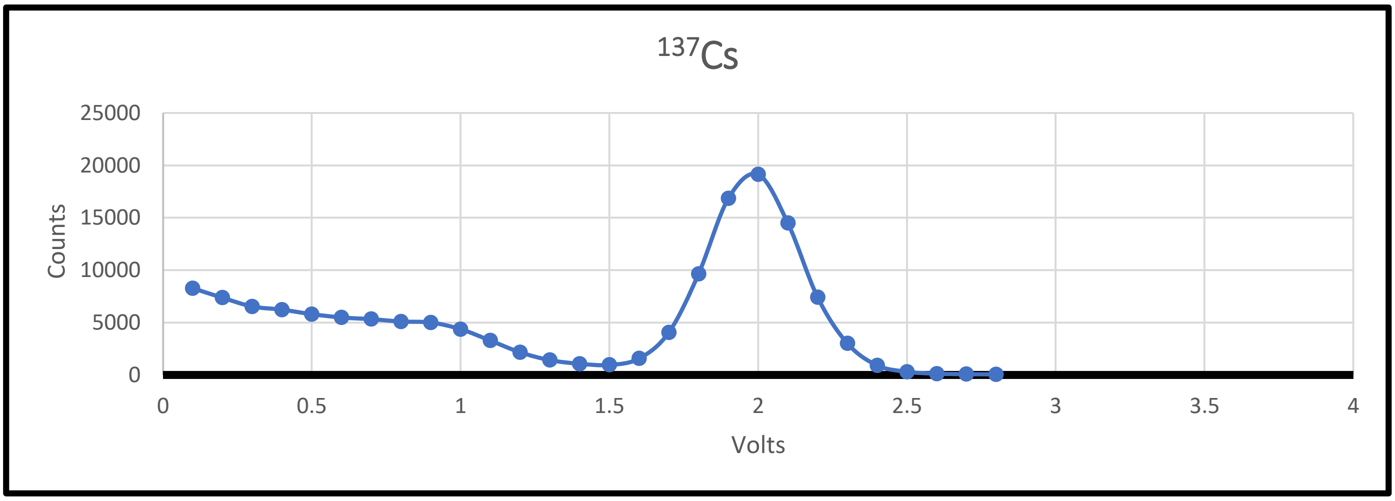
17. Insert the value of the centroid in the straight-line equation to obtain the energy of the unknown peaks.

Tables and Calculations:

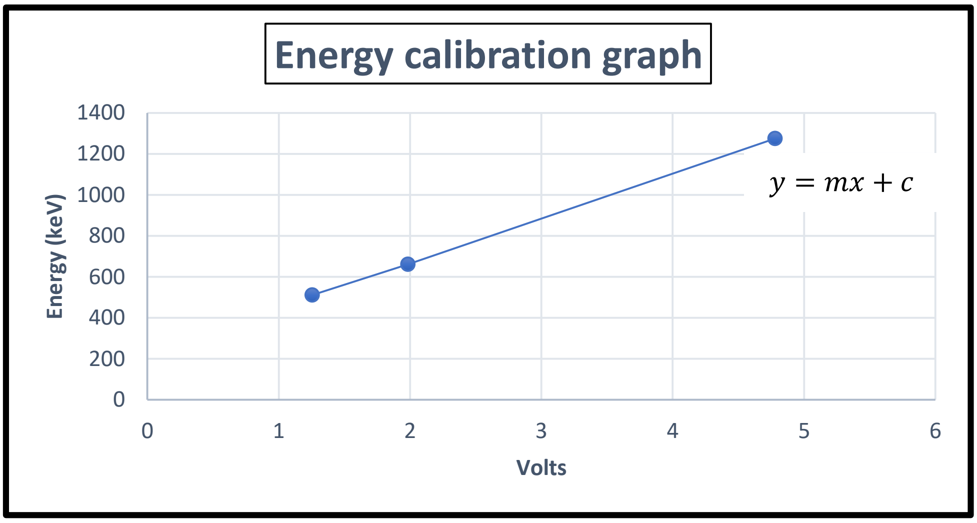
Serial No.	Volts (LLD)	Counts
1	0	
2	0.1	
3	0.2	
4	0.3	
⋮	⋮	



Energy spectrum of ^{22}Na using SCA



Energy spectrum of ^{137}Cs using SCA



Energy calibration curve

Precautions:

(1) Always handle radioactive sources with a pair of tweezers. Never touch them with bare hands.

(2) Always power up and down the scintillation detectors slowly. An abrupt rise or fall in detector bias causes the sensitive components to fry.

(3) Do not sit in the proximity of the source while experimenting.

(4) Avoid bringing food or water anywhere near the source

(5) Be careful while handling the High Voltage Power Supply. Proper shoes should be worn to avoid lethal electric shocks.

(6) Power up and down in a sequential manner

(7) Do not forget to power down the detector once the experiment is done.

(8) Turn the knobs lightly.

Courtesy: Vivek Anand
(Research Scholar)