Laboratory Report 7

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NUCE 2113

1 Equipment Required

The following equipment was used for this set of experiments:

- SPA38 Integral Assembly consisting of a 38 mm×38 mm NaI(Tl) Scintillator, Photomultiplier Tube, and PMT Base with Stand Ortec Model 113 Scintillation Preamplifier
- 4001A/4002D NIM bin and power supply
- Model 556 High Voltage Bias Supply
- Model 113 Scintillation Preamplifier
- Model 575A Spectroscopy Amplifier
- Easy-MCA-8k Multichannel Analyzer
- Windows-based Computer running MAESTRO-32 software
- C-34-12 12-foot 75-Ω RG-59A/U coaxial cable with one SHV female plug and one MHV male plug
- C-24-1 1-foot 93-Ω RG-62A/U coaxial cable with BNC plugs (5)
- C-24-12 12-foot 93-Ω RG-62A/U coaxial cable with BNC plugs
- C-24-4 4-foot 93-Ω RG-62A/U coaxial cable with BNC plugs (3)
- C-29 BNC Tee-connector
- C-27 100-Ω Terminator (BNC male plug)
- Tektronix Model TDS3032C Oscilloscope
- Small flat-bladed screwdriver for tuning controls
- RSS8 Gamma source set (1 μCi ^{60}Co, ^{137}Cs, ^{22}Na sources needed for this lab)

2 Experiment 7-1: The Linear Gate in Gamma-Ray Spectroscopy

2.1 Objective

The purpose of this experiment was to further develop concepts related to gamma-ray spectroscopy and to learn how to set up the analog and logic signal alignment when employing a linear gate to restrict the categories of nuclear events that are analyzed.

2.2 Procedure

2.2.1 Initial Setup

The experiment began with the setup and energy calibration used in previous labs. The instrument configuration was then altered according to Figure 7.1 from the original document. The following steps had already been taken:

Module Placement and Connections.

- The 427A Delay Amplifier, the 551 Timing SCA, the 426 Linear Gate, and the 416A Gate and Delay Generator were inserted into the powered-off NIM bin. The bin was then powered on.

- A BNC Tee was placed on the *INPUT* of the 427A Delay Amplifier. One arm of the Tee was connected to the 575A Amplifier UNIpolar *OUT* using a short 93-Ω coaxial cable. The other arm of the Tee was connected to the DC *INPUT* of the 551 Timing SCA via a short 93-Ω cable.
- A short 93-Ω cable was used to connect the *OUTPUT* of the 427A to the 426 analog *INPUT*.
- The POSitive *OUT* of the 551 was connected to the POSitive *INPUT* of the 416A with a short 93-Ω cable.
- A short 93-Ω cable was used to connect the POSitive *DELAYED OUT* of the 416A to the *ENABLE* input of the 426 Linear Gate.
- The analog *OUTPUT* of the 426 Linear Gate was connected to the analog *INPUT* of the Easy-MCA.

Front Panel Settings.

- The 551 rear-panel switches were both set to INTernal.
- On the 551, the μsec switch was set to the 0.1–1.1 μsec range, and the DELAY dial was set to its minimum.
- The INT/NOR/WIN switch on the 551 was set to NORmal.
- The LOWER LEVEL dial on the 551 was set to 50 mV (5/1000), and the UPPER LEVEL dial was set to 10 V (1000/1000).
- On the 416A, the DELAY dial was set to its minimum value, with the delay range switch set to 1.1 μsec.

Offset Adjustments.

- The BNC Tee at the 427A INPUT was briefly disconnected, and the 427A INPUT was terminated with a 100-Ω terminator.
- The DC voltage at the *OUTPUT* of the 427A was measured, and the DC ADJ control on the 427A was used to set the offset as close to 0 mV as possible.
- The terminator was removed and the original cable connections were restored.
- A 1-μCi ^{137}Cs source was placed a few centimeters from the front surface of the scintillation crystal.

Oscilloscope Observations.

- The 416A POSitive DELAYED OUTPUT was observed on channel 1 of the oscilloscope (trigger set to channel 1).
- The LOWER LEVEL setting on the 551 was increased slightly if needed so that the logic pulse was visible.
- The AMPLITUDE control on the 416A was adjusted to produce a pulse height of about +5 V.
- The width of this pulse was noted for later adjustment.

2.2.2 Analog and Logic Signal Alignment

While still triggering on the 416A output on channel 1, the 427A OUTPUT was viewed on channel 2 of the oscilloscope. The 427A DELAY was gradually increased until the analog pulse began after the start of the logic signal from the 416A. This required about 1.5–2.0 μs of delay, because the logic output pulse from the 551 SCA is generated on the trailing edge of the analog pulse (approximately at 50 % of its height).

Fine adjustments ensured the analog pulse started about 0.25–0.50 μs after the rising edge of the logic pulse. The 427A OUTPUT was then reconnected to the 426 Linear Gate, and the 416A POSitive DELAYED OUT was reconnected to the Linear Gate ENABLE input. The 426 was set to NORM on its PULSE INHIBIT / NORM / DC INHIBIT mode switch.

It was confirmed that the 426 GATE WIDTH control determined how much of the analog pulse was transmitted. The 416A DELAY dial, the 551 DELAY dial, and the 427A DELAY switches were further adjusted so only the analog pulse passed through the gate. The final settings of the 427A DELAY switches, the 551 DELAY, and the 416A DELAY were recorded.

2.2.3 Restricting Pulse Heights Through the Linear Gate

- The linear OUTPUT of the 426 Linear Gate was connected to the analog INPUT of the Easy-MCA.
- In MAESTRO-32, the MCA linear gate function was turned off.

- A spectrum was collected, showing both the Compton continuum and the photopeak from ^{137}Cs. This full spectrum was saved.
- The UPPER and LOWER LEVEL dial settings on the 551 were noted.
- After erasing the spectrum, the LOWER LEVEL threshold on the 551 was increased until signals below the photopeak were eliminated.
- The UPPER LEVEL threshold on the 551 was then lowered until signals above the photopeak were eliminated.
- A second spectrum was saved showing only the photopeak region, and the new thresholds were recorded.

Question 7.1: *"With the additional modules inserted, there are at least two factors that may have changed the energy calibration of the spectrum in this experiment compared to the previous experiments. What are those factors?"*

Two factors that will have changed our energy calibration are

1. **Amplitude:** New components in the system such as the 427 delay amplifier and 551 timing SCA will change the amplitude of the output signal. This will change the resulting channel when collected using the EasyMCA.
2. **DC Offsets:** Because we manually adjust the DC offset to be as close to zero as possible, we still may have some error in the offset of the signal. The result is that the resulting spectrum may shift left or right as it incorporates this offset.

The spectrums are presented in figures 1 and 2.

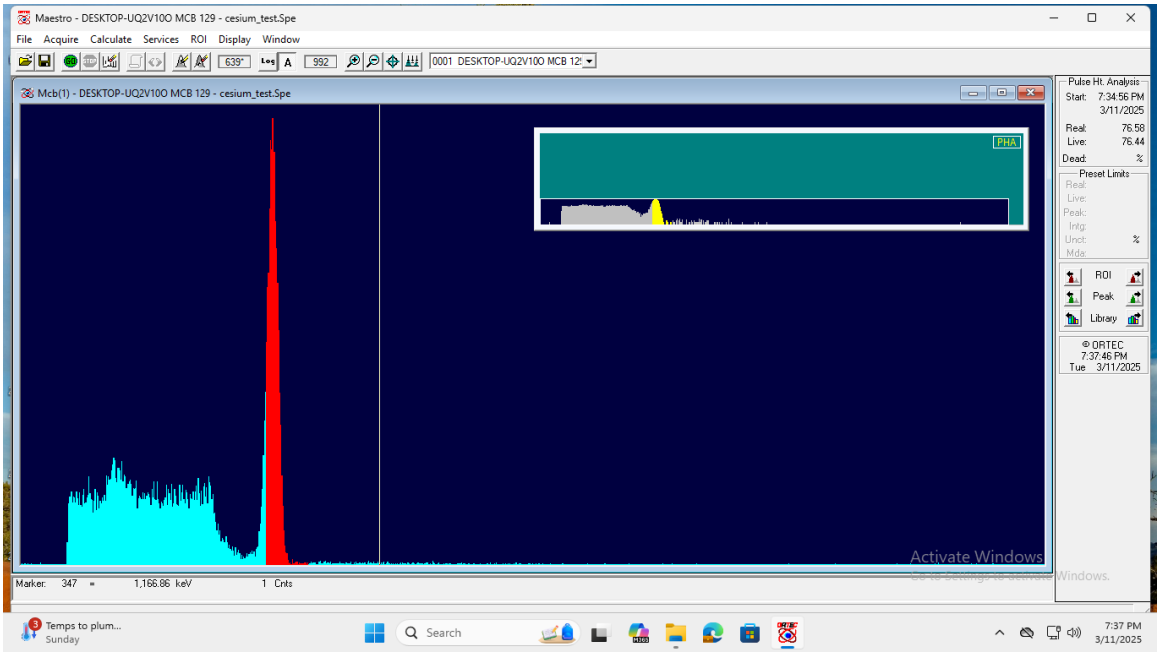

Figure 1: The first spectrum collected of Cesium 137. Dials were positioned at 1000 Upper level and 50 Lower level.

2.2.4 Replacing the 426 Linear Gate with the MCA Linear Gate

Most modern MCAs incorporate their own internal linear gate. This next set of measurements demonstrates how to meet the MCA's internal gate requirements.

Modified Setup.

- The 426 Linear Gate module was removed.
- The 427A Delay Amplifier OUTPUT was connected directly to the Easy-MCA analog INPUT.

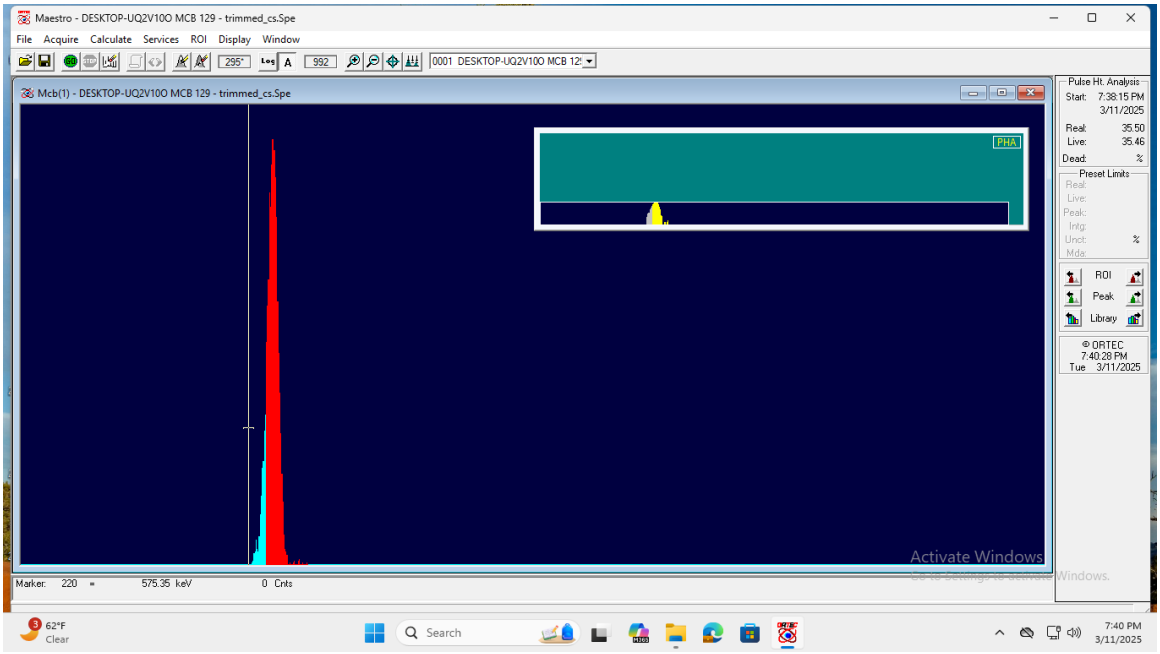

Figure 2: The trimmed spectrum collected of Cesium 137. Dials were positioned at 280 Upper level and 230 Lower level.

- The 416A POSitive DELAYED OUTPUT was connected to the GATE input of the Easy-MCA.
- The 416A gate WIDTH was turned fully clockwise to about 4 μs.
- In MAESTRO-32, the MCA gate function was confirmed to be turned off.
- A spectrum was acquired to confirm that the full ^{137}Cs spectrum (Compton continuum and photopeak) was visible. This spectrum was saved.

Coincidence Gate Selection.

- The MCA was switched to *Coincidence Gate* mode in MAESTRO-32 so that only pulses accompanied by a logic signal at the GATE input were acquired.
- With the 551 thresholds set to restrict the energy range around the photopeak, only the photopeak was observed. This spectrum was saved.
- The DELAY dial on either the 551 or the 416A was then increased until no spectrum was acquired, then decreased until acquisition resumed. These dial settings were recorded.
- The gate WIDTH on the 416A was decreased until acquisition ceased, then increased until it reliably resumed.
- Next, the LOWER LEVEL setting on the 551 was reduced to 100 mV (10/1000), and the UPPER LEVEL was raised to 10 V (1000/1000), and the timing procedure was repeated.
- The analog signal from the 427A was displayed on channel 1 of the oscilloscope, with the trigger threshold set just above noise, while the 416A POSitive DELAYED OUT was viewed on channel 2.

Exercise 7.1: *"Make a sketch of the analog and logic pulses showing their time relationship."*

(Where to include data in report): Please include these sketches and your recorded dial settings, along with the resulting spectra, in your final lab report.

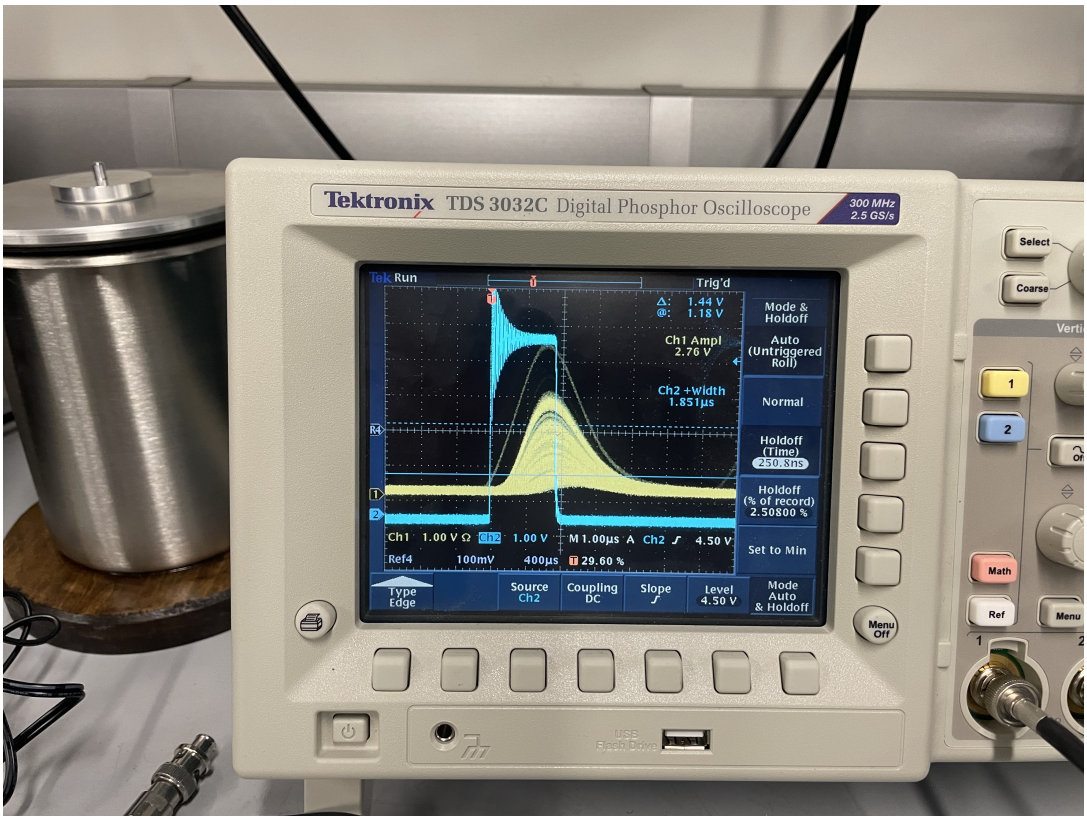

Figure 3: The analog and logic pulses on the oscilloscope. The analog signal is shown in yellow while the digital signal is shown in blue.

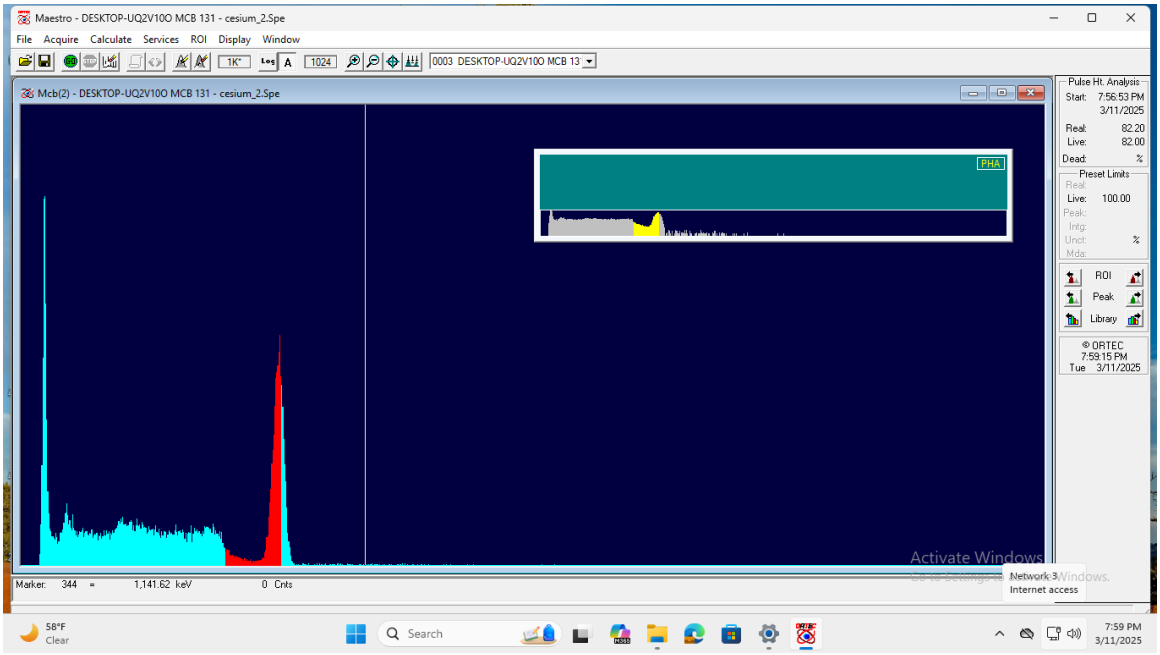

Figure 4: The second captured Cesium 137 spectrum with no trimming (1000 Upper Level // 50 Lower Level).

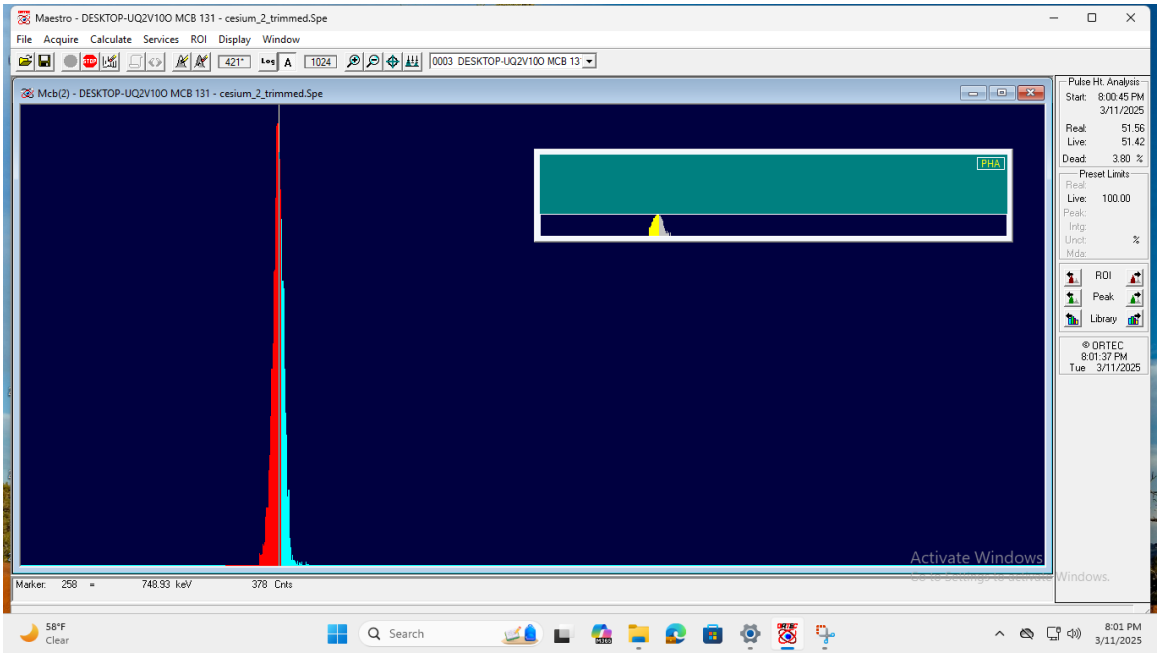

Figure 5: The second Cesium spectrum with trimming applied (280 Upper Level // 230 Lower Level).