Experiments in Modern Physics
Introductory Lab: Gamma Spectroscopy Methods
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Goal
Become familiar with operating a scintillation detector and Multichannel Analyzer (MCA). Use this equipment to investigate and understand the gamma-ray spectra of several radioactive sources.

Introduction
In elementary modern physics, you learned of several different ways in which quanta of electromagnetic energy, or photons, can interact with matter. The three dominant processes include: the photoelectric effect, in which all of the photon's energy is transferred to a single electron; Compton scattering, in which the photon scatters from an electron, transferring some of its energy, but re-emerging as a lower-energy photon; and pair production, whereby the photon converts to a positron-electron (e+e−) pair. In this lab, you will investigate processes involving high-energy photons, or γ-rays, where in this context "high energy" means on the scale of nuclear energy level spacings, i.e., several MeV or so. Note that an MeV is many thousands of times larger than typical atomic energies, so the fact that the struck electrons are bound in matter is usually not important. These processes are described in more detail in references [1-3].

Equipment
- Scintillation detector: This is a small piece of thallium-doped sodium iodide, or NaI(Tl), that is optically attached to a photomultiplier tube (PMT) with an integrated preamplifier. The PMT voltages are established by the PMT base, which is connected to a HV supply. The integral of the current pulse leaving the PMT (the total charge) is proportional to the amount of scintillation light, and hence to the energy deposited in the scintillator by the various electromagnetic processes. The scintillator/PMT system needs to be shielded from stray magnetic fields (using a mu-metal wrap) and sources of background radiation (hence the small `house' of lead bricks surrounding the crystal and the radioactive source of interest).
- Multi-channel analyzer (MCA): This device (a Quantum-8 MCA) sorts out incoming pulses according to pulse height (which is proportional to energy deposited) and histograms the number at each height in memory. This histogram is displayed on the screen of the MCA. You can change the gain, full-scale counts, read-off counts in a channel, etc. with this device.
- Oscilloscope.
- Radioactive sources: 137Cs, 60Co, and an unknown.

Preparation
- Read pp 316-324 and Appendix B in Ref. [1]
- Read the introductory part of the MCA manual.
Task 1: Investigate signals from scintillation detector with oscilloscope
- Apply a voltage of +1100V (watch the polarity!) to PMT base. Look at signal with the oscilloscope (with no source) and record.
- Obtain $^{137}$Cs source from your instructor and place in the lead housing near the detector. Again, look at signal with the oscilloscope and record. How do the signals change as the source is moved closer to or farther from the detector?

Task 2: Investigate $\gamma$-ray spectra of $^{137}$Cs with MCA.
- Connect signal to MCA (into "amp" connection on back), following instructions in MCA manual.
- Record the gamma-ray spectrum of the $^{137}$Cs source. Label and understand the important features.
- Learn how the "zero", "threshold", "gain", and "marker" MCA controls work.
- Record a spectrum with the source removed. Is there significant background? Figure out the subtract feature on the MCA.
- Record the MCA channel of the "photopeak" for $^{137}$Cs. Adjust the PMT voltage by $\pm$100 V. How does this change the photopeak position?

Task 3: Investigate $\gamma$-ray spectra of $^{60}$Co with MCA.
- Obtain $^{60}$Co source from your instructor and place in the lead housing. Record the gamma-ray spectrum. Label and understand the important features.

Task 4: Determine unknown source
- Using the data recorded from the $^{137}$Cs and $^{60}$Co sources, determine the energy calibration of the detector/MCA combination. (i.e. $E=(\text{MCA chan})^*a+b$). Estimate errors. You should use the same gain settings for the two sources. You may have to iterate to find MCA settings that work for both sources.
- Obtain an unknown source from your instructor. Record the gamma-ray spectrum. Determine the energy of the photopeak(s). What is this source? (Hint: it may be "mixed").

References