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LAB 1: Basic phenomenology of NaI(Tl) gamma ray detector, MCA, statistics

The objective of this lab is to set up a basic radiation (γ-ray) detection experiment, take some data and explore basic elements of analysis common to the experiments that will be performed later during the semester.

Measurements:

1. The Na(Tl) γ-ray detector is installed on the railing system. Identify the connections at the back of the PMT base. Look at the modules inside the NIM crate. Identify inputs / outputs of each module. <u>Verify the HV supply is set to positive HV (why?).</u>
2. Make sure the NIM crate power is off and the HV supply switch is OFF and both voltage knobs are set to ZERO (why?). Connect PMT to HV power supply (use a SHV cable) and the PMT anode or dynode output directly to the oscilloscope. Obtain the ^{137}Cs source from the instructor or one of the TAs. Turn on HV to 500 V. Observe the anode/dynode signal on the oscilloscope. Polarity?
3. Increase HV (by step of 100V, max 800V) and identify the photopeak signal band on the scope. You may need to slide the ^{137}Cs source assembly to about 10 cm from the detector. Increase the HV until the photopeak band reaches an amplitude of at least 100 mV and not more than 500 mV. Will vary depending on which setup you are using. Connect the anode/dynode output to the amplifier input and the amplifier output to the oscilloscope. Use "T-connectors" to have the input/output signals of the amplifier displayed on the oscilloscope at the same time. Why can this be important? The polarity of the output signal needs to be positive. Adjust the amplifier setting accordingly.
4. Set the amplifier gain, so that the amplitude of the photopeak signal from ^{137}Cs source is about 2 V. Once done, connect the amplifier output to the Multi-Channel Analyzer (MCA). Start Maestro and acquire a sample energy spectrum.
5. Sketch the signals displayed on the scope including the photopeak band of signals. Including time and voltage scales. What is the quantitative connection between the position of the photopeak signal band seen on the scope and the position of the photo peak in the energy spectrum recorded by the MCA? Understanding this connection is key to understanding what the MCA does. Save the spectrum and you sketch. What happens if you adjust the HV?
6. Go back to the original HV setting. Measure number of photopeak counts in 10 sec count time (repeat 10 times). Make a table with your measurements. Calculate the average μ and σ based on the 10 measurements.
7. Using ^{60}Co and ^{137}Cs sources, generate the energy spectrum with 662keV (^{137}Cs), 1173keV and 1332keV (^{60}Co) gamma rays with sources 20 cm from detector and for 5 minutes with each source. Don't forget to SAVE the spectra, so you can

recall them for further analysis that you will perform to calibrate the energy scale of the detector. Suggestion: save a screen shot and an spe (ASCII) file for each spectra.

8. Take a 5 minute energy spectrum with no sources nearby. Based on the relative positions of the 662keV, 1173keV and 1332keV observed earlier, find the position of the 1460keV ^{40}K decay γ-ray photopeak. Save the spectrum.
9. Test of Poisson statistics: measure counts in one channel of the photopeak after 1s and repeat 100 times (make sure count rate is very low, no more than 3 counts per sec). Displace the source to increase / reduce count rate. By hand, accumulate a simple histogram by marking an "x" in the appropriate "number of counts" bin as you run this step.
10. Measure count rate (counts per sec) of 662 keV γ-ray from ^{137}Cs as function of distance from 5 to 50 cm. Collect about 1000 net counts in the photopeak. You may need to take longer measurements as you increase the distance of the source from the detector (Hint: count rate = counts in the photopeak / measurement time). Make a table with your measurements. (Hints: 1) count rate = counts in the photopeak / measurement time. 2) Think about what distance you need to measure.)
11. When you are finished for the day, clean up your work space, check that the TA or instructor have collected all sources, HV supply switch and knobs are off/zero, the NIM bin is off, and you have a final OK from a TA/instructor to leave.

Plots to be provided at the end of the lab (these plots should also appear in your final report possibly associated with further analysis):

1. STEP 7: MCA spectra of ^{137}Cs and ^{60}Co sources.
2. STEP 8: Using the pythonxy package, plot the linear relationship between Energy and Channels (E = a . Channel = b) using the 4 identified γ-rays. Perform a linear fit and extract a and b with their associated errors.
3. STEP 10: Histogram of Number of realizations vs Counts/s for the 100 one-second measurements.
4. STEP 11: Plot of count rate (counts per sec) versus distance INCLUDING error bars.

Calculations to be shown in the lab report:

1. Step 5 show the sketch of the oscilloscope traces including the photopeak band and show the corresponding energy spectrum. Explain quantitatively the connection between the two.
2. Fit the histogram from your data to a Poisson distribution for the same value of μ. Discuss whether or not your data histogram and the corresponding Poisson distribution are statistically consistent. (Hint: If you repeated this part of the

experiment the resulting histogram would almost certainly not be identical to the first one.)

3. STEP 10: Fit your data (including error bars) with $f(r) = A/r^n + B$, where n=1, 2 and 3 and A and B are free parameters. What is the χ^2 in each case? Which case fits best? Repeat the fit by also using n as a free parameter. What do you find?
4. STEP 7: Starting from the activity of the source and the number of events in the photopeak for each γ-ray considered (662, 1173 and 1332 keV). Calculate the detection efficiency for each γ-ray (Hint: the efficiency is the ratio of the number of γ-rays detected and the number of γ-rays that went through the detector).

When preparing your report please refer to the guidelines document on the course website, including the last page on how to avoid common mistakes.