Advanced Laboratory 2 – Experiment 1

Testing of a NaI (Tl) radiation Detector setup

Purpose: Familiarize yourself with a standard detector in the characterization of a field of ionizing radiation. Operate the detector with standard nuclear electronics and characterize its basic parameters like resolution and efficiency.

Detector Sketch:

Equipment: NaI(Tl) Crystal with Photomultiplier Tube (PMT), PMT Base, Shaping Amplifier, HV Power Supply, NIM Crate, Oscilloscope, Analog to Digital Converter (ADC) Multichannel Analyzer (MCA), SHV and BNC Cables, 137-Cs and 60-Co Radioactive Sources.

Procedure:

1) Secure a stable mount of your NaI(Tl)/PMT and connect your PMT base if it is not yet connected. Identify the different outputs of your PMT base.
2) Connect the anode/signal output of the PMT base to the oscilloscope and connect the HV input to the output of your HV power supply.
3) Before applying high voltage to the PMT, check that the HV power supply is set to positive voltage and have a TA check over your setup. The TA will also supply you with a radioactive 137-Cs source on request.
4) Mount the 137-Cs source at the same height as the center of the detector and place it 15 cm from its face. Turn on the HV power supply and monitor the oscilloscope for pulse signals. Start at 100 V and increase the voltage in 100 V increments. Do not increase beyond 800 Volts. The signals you expect should have a magnitude of order 100 mV. Have a TA check your signal strength before moving to the next step.
5) Takes notes of your observations and sketch the signals (rise time, fall time, noise, magnitude).
6) The pulse shape coming out of the PMT base is not suitable for direct conversion into digital information. Therefore, you have to run it into a so-called shaping amplifier which first integrates the incoming pulse and then through differentiation produces a much shorter fall time. The resulting pulse height is proportional to the charge arriving at the PMT anode and thereby also proportional.
to the number of photons hitting the PMT cathode. Connect the output of the amplifier to the oscilloscope and try out several settings of the amplifier (gain, shaping time, polarity etc.). Take note of how the pulses change on the oscilloscope and have a TA take a look at them.

7) Connect the output of the shaping amplifier to the input of the analog to digital converter (ADC). The same electronics unit also contains the multichannel analyzer (MCA) which is read out via USB with the MAESTRO program on the provided PC. At this stage the pulse height of the analog pulse is converted into a digital number which is sorted as events/counts into channel bins of the MCA and displayed as a pulse height spectrum. More frequent pulse heights result in a developing peak in the spectrum and point to a more frequent energy deposit amount from the ionizing radiation in the detector (remind yourself: photo effect, Compton effect, pair production). Have a TA check your developing spectrum and identify the photo peak for the gamma photon emitted by 137-Cs. Research the radioactive isotopes at www.nndc.bnl.gov in the chart of isotopes (decay radiation).

8) Modify the gain of the amplifier in a way that the photo peak of the 137-Cs source shows up app. In channel number 400. Take a 300 second run and familiarize yourself with the capabilities of the MAESTRO program: real time, live time, dead time (DT), region of interest (ROI) gross counts, net counts, error etc. Extract the Full width at half maximum (FWHM) of the photo peak and compare it to the peak position. The ratio is the so-called resolution of the detector, a measure of its quality. Calculate the count rate (account for the dead time) in the photo peak and compare to the number of photons emitted by the source. The ratio gives you the absolute photo peak detection efficiency for this specific source/detector/distance combination. Provide an error for the extracted efficiency.

9) Measure the resolution of your setup with the 137-Cs source as a function of the shaping time of the amplifier. For the further experiments use the shaping time which provides the best resolution.

10) Measure the efficiency of the setup for the 137-Cs photo peak at distances of 10, 15, 20, 25, 30 cm between the source and the detector. Plot the results with a 1/r^2 fit (flux of the radiation is emitted into the full sphere, no direction preferred, and should therefore reduce with 1/r^2).

11) Take note of the channel number where the 137-Cs photo peak appears and exchange the 137-Cs source for a 60-Co source. Mount it again at 15 cm distance and acquire a spectrum without changing any settings at your electronics. Research the expected gamma photons from 60-Co and compare to the acquired spectrum. Extract channel numbers for the 60-Co photo peaks and combine with the information from 137-Cs to provide an energy/channel calibration. Use the FWHM from all photo peaks and plot your results. Measure the efficiency for the highest energy photo peak in 60-Co.

12) After you return all radioactive sources to the TA, explore the room background of ionizing radiation by acquiring a 30 minute spectrum. At which energies is a peak visible and can you identify their sources.

Reminder: In experimental physics any number provided without an error is meaningless.