Erasmus Mundus Joint Master in Nuclear Physics Program

Activity Report

25/07/2019

Title: Gamma Spectroscopy using CoMPASS Software

Abstract:

In this experiment the software COMPASS was used to perform the Gamma Spectroscopy and some multiparametric measurements with ^{22}Na and ^{137}Cs nuclear sources and a NaI (Tl) scintillator detector.

Purpose of the experiment:

The first aim of the experiment was to calibrate the NaI detector with a source of ^{22}Na. This radioisotope has a β+ decay so the annihilation peak (511 keV) and the gamma peak emitted due to the son nucleus is exited (1274 keV) were used to obtain the calibration line. Then, the goodness of the calibration was tested with a ^{137}Cs source. Finally, a multiparametric study was performed making cuts in energy and time. This way, the two gammas which come from the annihilation of the positron were measured in coincidence.

Materials:

For this work, a NaI (Tl) Scintillator detector connected directly to a digitizer was used. The radioactive samples used were ^{22}Na and ^{137}Cs. The 511 keV photon is expected whenever a radionuclide emits positrons as part of its decay process. e.g. with the ^{22}Na nuclide. The spectrum will show a gamma-ray photopeak at 1274.5 keV, an annihilation peak at 511 keV (from the β^+) and probably x-rays from the electron capture. The decay scheme can be seen from Figure 1. The NaI (Tl) Scintillator is a well-established and the most extensively used scintillator. It is used for detecting gamma rays of low and intermediate energies. It has a high level of optical output and is relatively inexpensive.

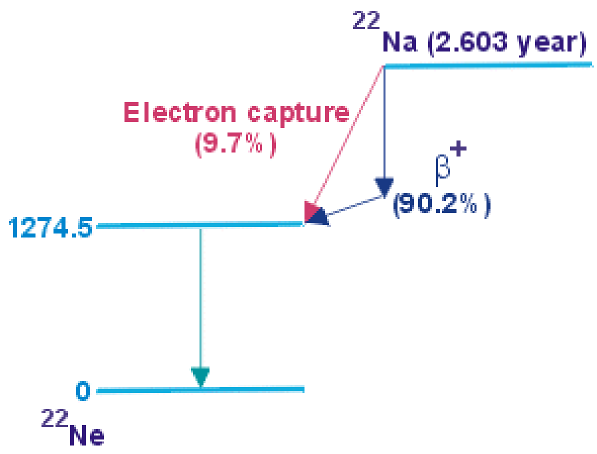

Figure 1: Decay Scheme of ^{22}Na.

Measurements:

First step was to study the energy spectrum and calibrate the system. The second part of the experiment involved studying the correlation of time between the events. For the first aim of the report the form of the signal was observed. In order to acquire higher signal, the dynamical range of 0.5 Vpp was chosen. The polarity coming from the digitizer was negative, so the inversion of the signal was performed in order to proceed with the analysis. As it can be seen from the figure 2, the blue line is the trapezoid filter applied to the signal. The parameters of the Trapezoid such as the rise time, the flat top and the pole zero, were manually optimized. In particular, the pole zero should be equal to the decay time of the signal. If the pole zero is not set properly the undesired phenomenon of undershoot or overshoot. Unfortunately, the undershoot was not able to be eliminated but it was possible to reduce it. In order to check the effect of the trapezoid, parameters the waveform as well as the energy spectrum resolution were observed.

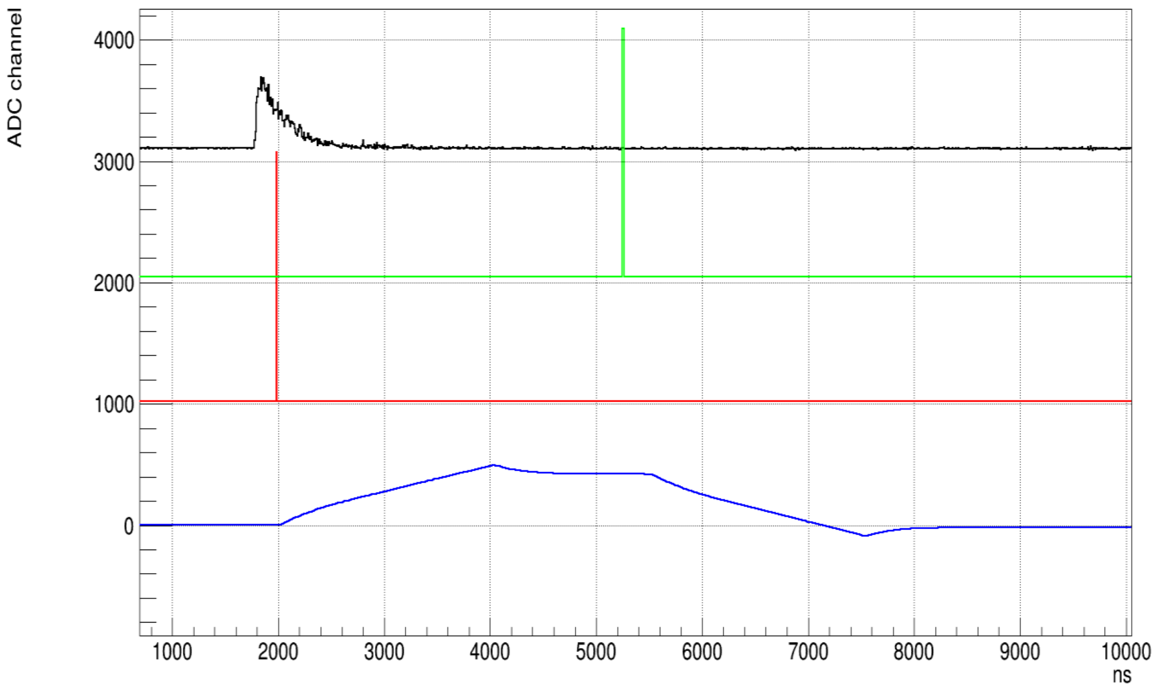

Figure 2: Waveform of the signal and the Trapezoidal filter.

The parameters for the optimization of the trapezoid filter can be seen in figure 3. In order to spread the spectrum, the gain was increased as well as the bias voltage.

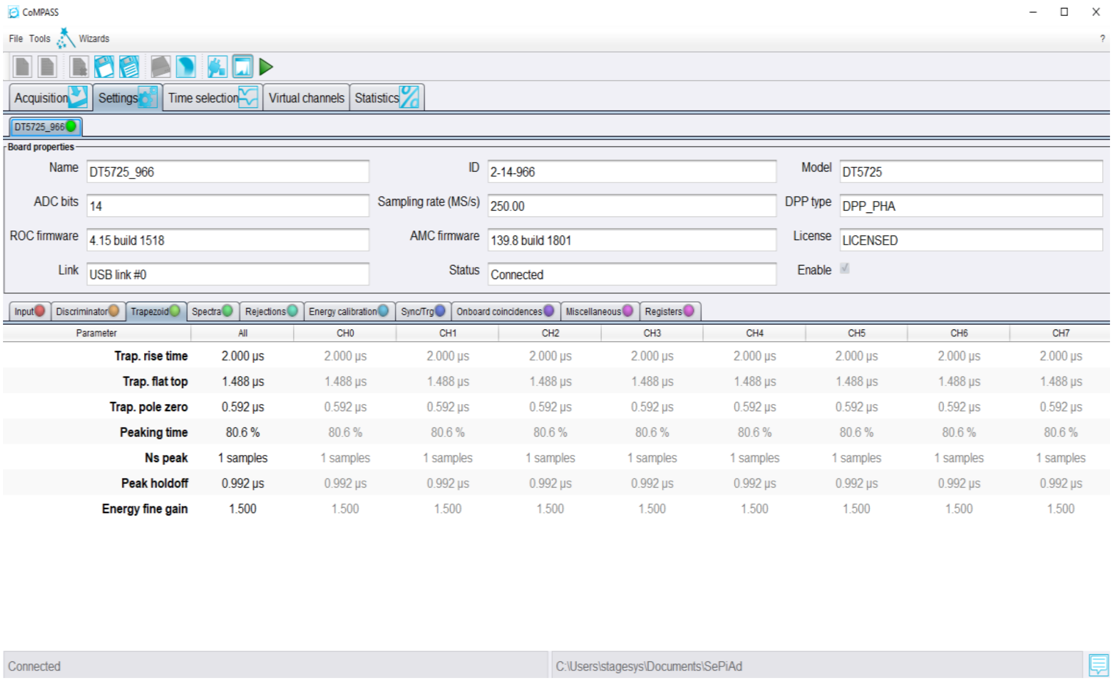

Figure 3: Trapezoidal filter parameters panel.

Data Analysis:

After adjusting the parameters of the trapezoid pole zero and the rise time, the optimal shape of the trapezoid was obtained, shown in the blue line in figure 2. The original pulse (inverted), the trigger and the peaking can also be seen. The peaking is the point of the trapezoid at which the energy is received. The trapezoid does not have a good shape because the signal is fast, i.e. it has a long tail.

Afterwards, we acquired the gamma spectrum of the ^{22}Na and used the photopeak of 1274 keV and the annihilation peak of 511 keV to perform the calibration of the channels in energy. In Figure 4, the spectrum (already calibrated in energy) of the ^{22}Na with the peaks of interest highlighted in green, is shown.

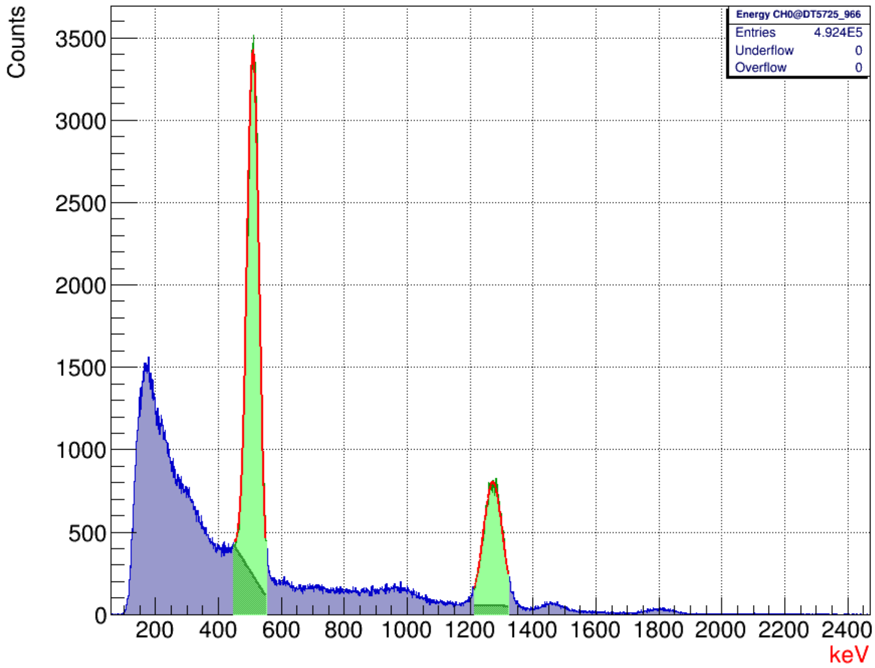

Figure 4: Selection of Regions of Interest in the Energy Spectrum of ^{22}Na.

To verify the goodness of the calibration the spectrum of the ^{137}Cs was acquired, which has a photopeak of 662 keV. Since the difference in energy of the peak was appreciable, we added this value to the calibration. In Figure 5, the spectrum of the two samples together with the peaks of interest highlighted in green can be seen.

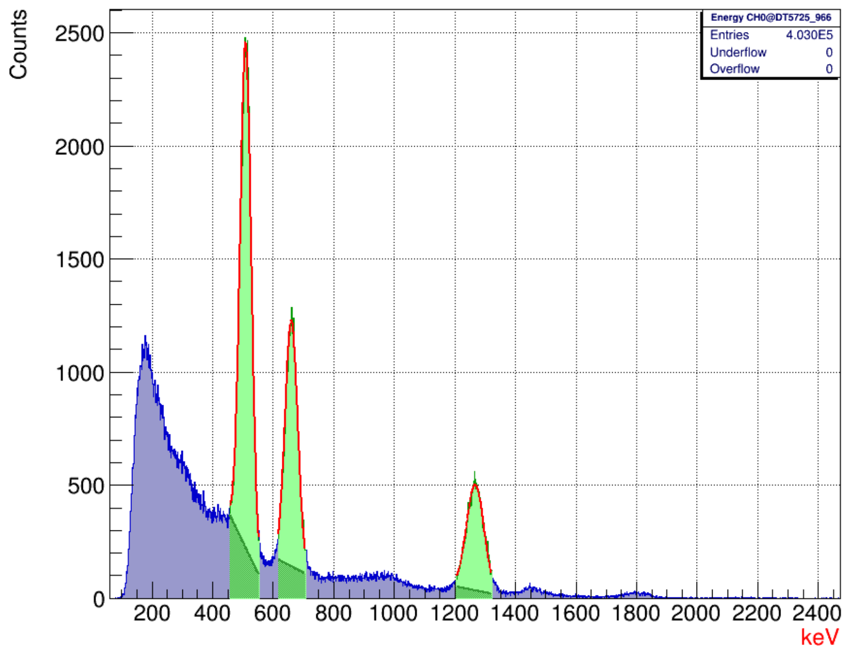

Figure 5: Verification of the calibration using ^{137}Cs and ^{22}Na.

To get the coincidence of the two gamma photons emitted in the electron-positron annihilation, a cut in the spectrum was set, selecting the energy range of the annihilation peak (as shown in Figure 6) and a time window of 0.1 µs. Thus, the random correlated events are avoided. The total spectrum and the spectrum with the before mentioned cut is shown in Figure 7.

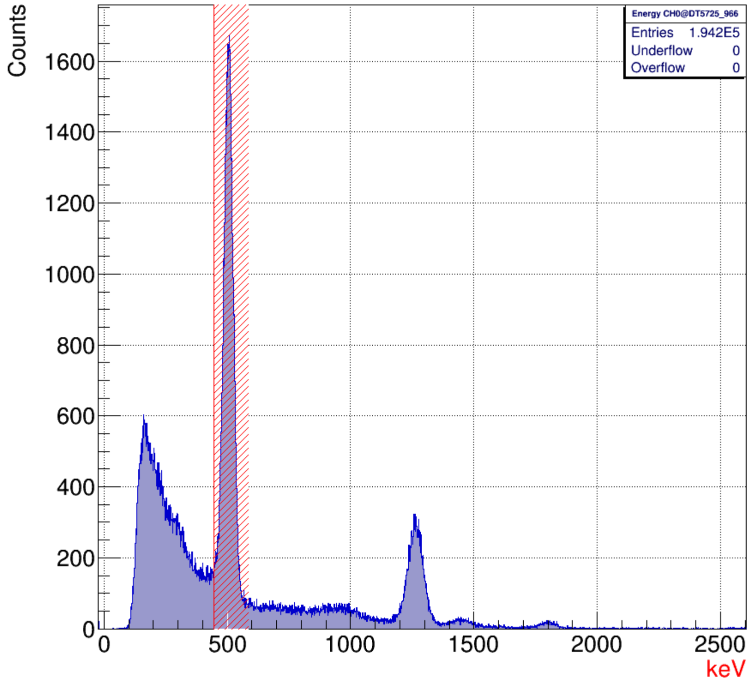

Figure 6: Energy selection for the annihilation photons.

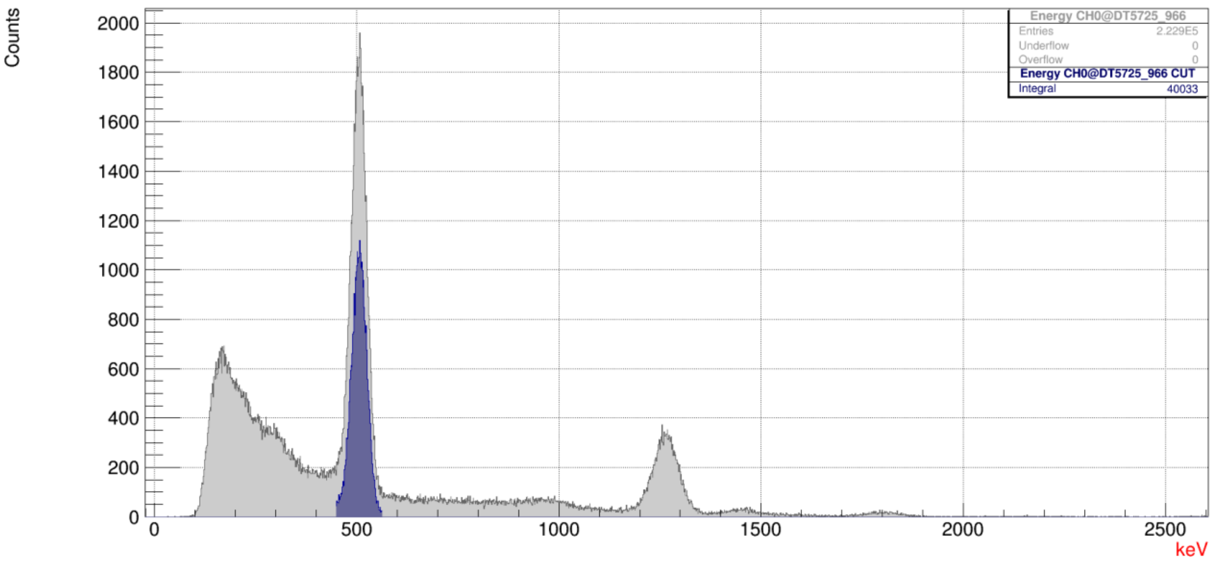

Figure 7: Total spectrum and energy cut in highlighted colour.

In Figure 8 we can see the Time of Flight (TOF) spectrum obtained. It is a discrete spectrum with steps of 4 ns, because of the time resolution of the detector (250 MS/s), and it has a gaussian type distribution around zero.

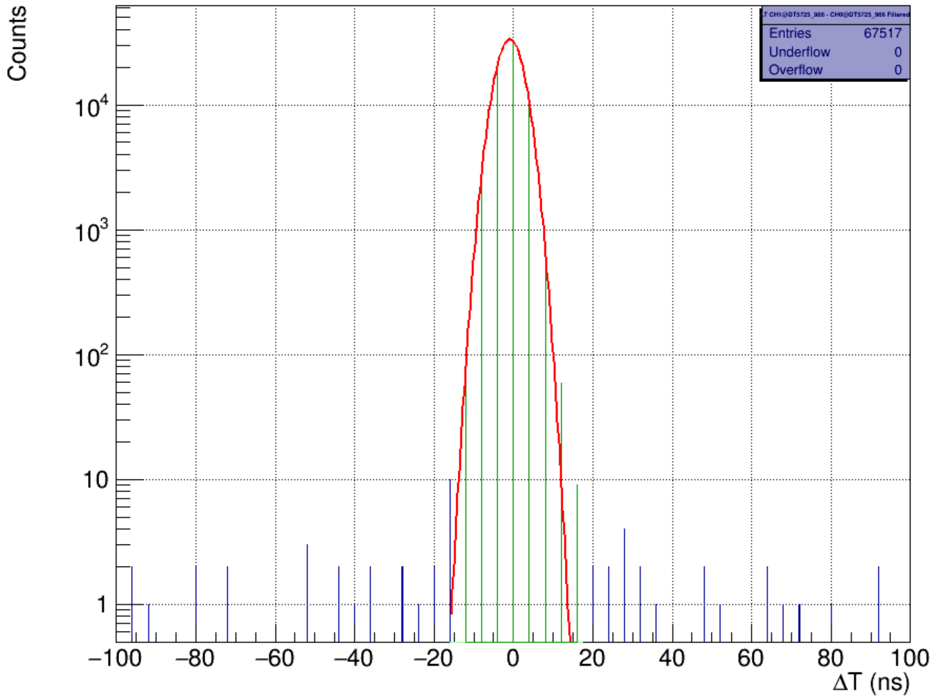

Figure 8: Gaussian Shape of the time resolution of the Detector (semi-log scale).

The discrete form of the spectrum instead of the expected continuous can be explained from the fact that the timing resolution is the same with the sampling rate of the digitizer.

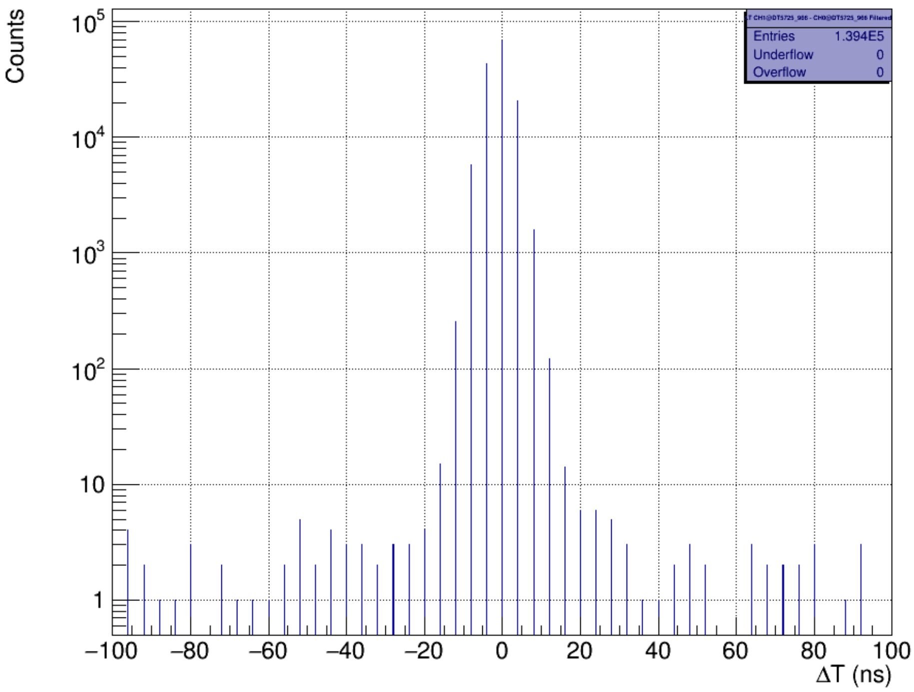

Figure 9: Discrete Spectrum of Time.

Results & Conclusion:

In conclusion, the analysis of the γ spectrum of the ^{22}Na was executed successfully. The electronic chain was designed with the aforementioned instruments in the section of materials. The signal was obtained and optimized for the energy calibration. Furthermore, the calibration was verified using the ^{137}Cs Source. In addition, the correlation spectrum was performed by cutting a specific region of the energy spectrum and observing the diagram of Channels versus the ΔT.

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