

⁶⁰Co Angular Correlation

Introduction

Required reading: *Melissinos* 194 - 208, 412 – 429.

If a system is oriented the radiation that it emits will, in general, not be isotropic. An example is the radiation from an oscillating dipole which has a $\sin^2 \theta$ distribution about the dipole direction. Conversely, measuring the direction of emitted radiation specifies an orientation distribution of the emitting source. Thus, if a system gives off two successive radiation the first will orient the source and, therefore, the second radiation will have an anisotropic angular distribution relative to the first. This is called an angular correlation.

The nucleus ⁶⁰Co β-decays to a 4⁺ [total angular momentum (“spin”)^{parity}] 2.50 MeV state in ⁶⁰Ni which, in turn, decays by gamma emission to a 2⁺ state at 1.17 MeV which, in turn, gamma decays to the 0⁺ ground state. Thus, the gamma spectrum from a ⁶⁰Co source shows two peaks, one at 1.33 MeV and the other at 1.17 MeV. The spectrum from a NaI(Tl) shows these two peaks as well as a continuum due to Compton scattering. The basic strategy is to place a window on the 1.33 MeV peak in one counter and measure the angular distribution of the 1.17 MeV gamma rays that are in (time) coincidence.

Procedure for setting up ^{60}Co angular correlation

1. Put a ^{137}Cs source in front of one of the NaI(Tl) detectors.
 - a. Check with an oscilloscope that the pulses at the output of the amplifier look reasonable.
 - b. Display the spectrum on the multichannel analyzer. Explain the main features of the spectrum. Make sure that you know how to dump spectra and save them for future analysis.
 - c. Take a ^{22}Na spectrum and explain its features.
 - d. Take a ^{60}Co spectrum and explain its features.
2. Put the ^{22}Na source between the 2 detectors. Use coincidences between the 0.511 MeV gamma rays to work your way through the logic. These gamma rays come from electron-positron annihilation and conservation of energy and momentum requires that they be emitted in opposite directions thus giving a high coincidence rate. Develop a logic diagram as you do the following:
 - a. Use a single channel analyzer to put a window on the 0.511 gamma rays in one of the detectors.
 - b. Put a window covering everything above about 200 keV on the other detector.
 - c. Obtain a time spectrum from the time-to-pulse-height converter.
 - d. Put a window on the peak in the time spectrum. Use this window to open the gate to the multichannel analyzer.
 - e. Take a coincidence spectrum and explain its features.
3. Put up the ^{60}Co source.
 - a. Move the narrow window to the 1.33 MeV peak.
 - b. Check the time spectrum and make sure that its window is correctly set.
 - c. Take a coincidence spectrum.
4. Move the counters back and start the experiment. Have a scaler counting the number in the 1.33 MeV window.

Experiment

Take data every 15° between 15° and 345° . Each point should be run for at least about 6 hours. It is not necessary that the points be run for equal times.

Before start of first angular correlation point

1. Take long (about 2 hours) gated TAC spectrum. If TAC peak is not approximately in the middle of the window adjust window and repeat. Plot spectrum and put in notebook.
2. Take gated and ungated spectrum from fixed counter. Plot spectra and put in notebook.

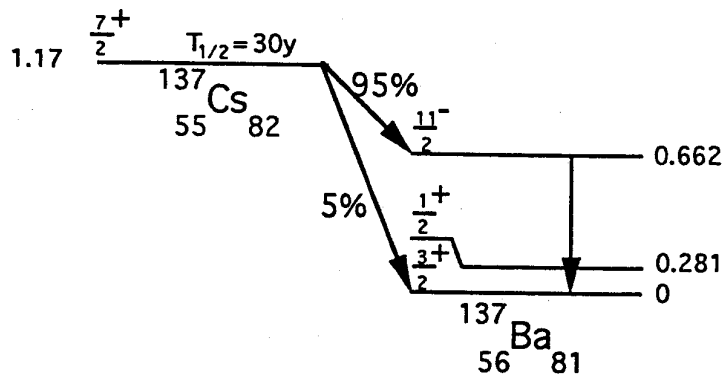
Checks at the end of each angular correlation point

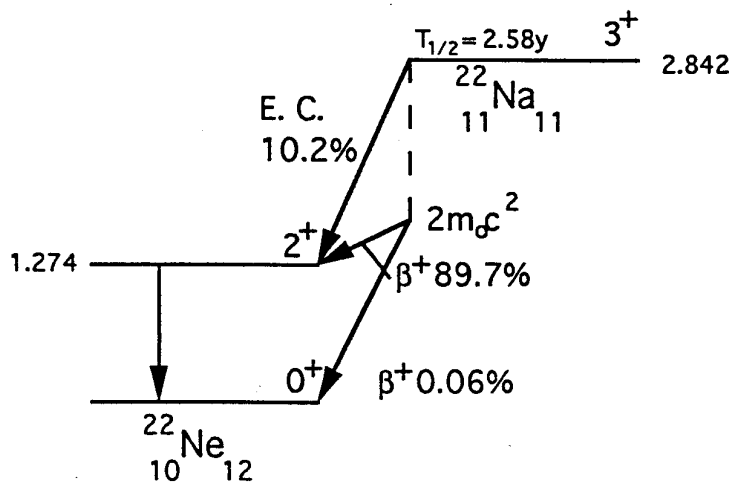
1. Stop acquiring and note time and scaler counts. Dump analyzer spectrum.
2. Take a TAC spectrum and make sure window is correctly set. Note position of peak in TAC spectrum (only need a few counts).
3. Take a gated pulse height spectrum from the fixed counter and make sure window. Note position of peak and of window.
4. Zero scalar. Start new run noting time.
5. Add up number of counts in 1.17 MeV peak in the point that was just finished. Keep table in notebook of number of counts in peak divided by counts in monitor scaler. Check that the data is consistent and if a point appears to be out of line try and find out what is wrong.

Data analysis

At each point get the area under the 1.17 MeV peak in the moving counter and subtract off the random coincidences using the 1.33 MeV peak and the singles spectrum. Normalize to the number of counts in the 1.33 MeV window on the fixed counter.

The correlation has the form $W(\theta) = A + B\cos^2\theta + C\cos^4\theta$. Thus, it is symmetric about 180° and also about 90° (and 270°). Check that your data is consistent with these symmetries. Then combine the symmetric points and determine B/A and C/A . Compare to the theoretical values.





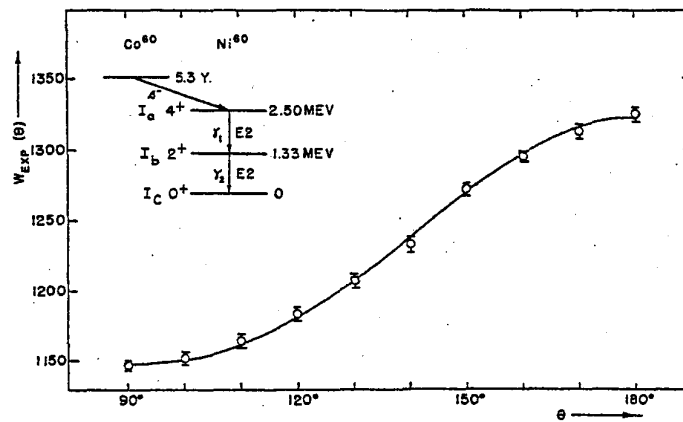


Fig. 4. Decay of Co^{60} and directional correlation of the Ni^{60} γ - γ cascade (R. M. Steffen). The solid line is the theoretical function $W(\theta)$ for the cascade $4(2)2(2)0$.

