ANSEL Experiment PET Scan/γ–γ Angular Correlations

Experimental Tasks (2 experimental stations)

Station A (2 Na(Tl) detectors); **Station B** (HPGe and Na(Tl) detectors)

I. Set up the electronics for 2-detector singles and coincidence experiments and calibrate the detector energy responses.

II. Measure the angular correlation of two 511-keV annihilation γ-rays.

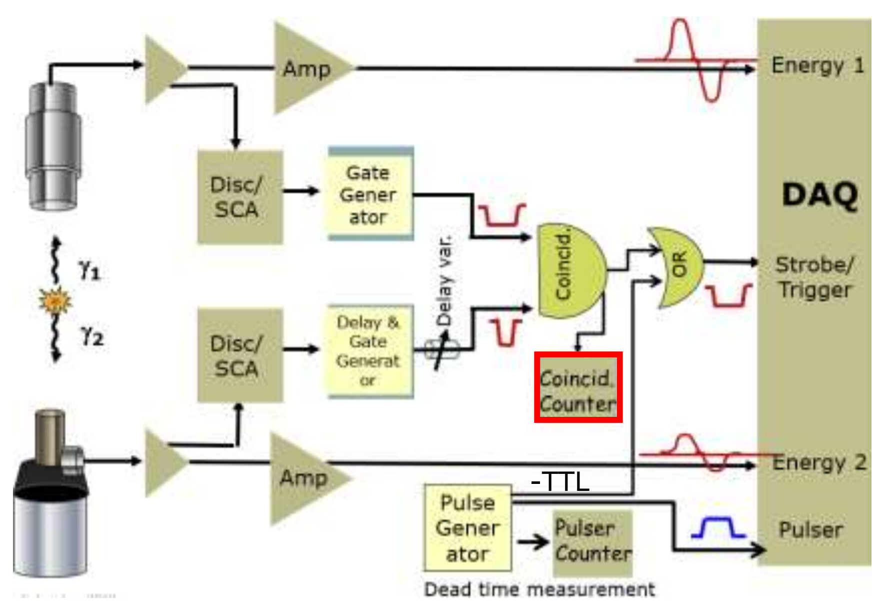
III. In a PET measurement with two γ detectors, determine the location of a concealed positron emitter.

IV. Determine the absolute activity of a γ source.

V. (Optional) Measure the angular anisotropy $A_{\gamma\gamma}$ for the ^{60}Ni (E*=2.507MeV) de-excitation γ cascade.

For either Station A or B:

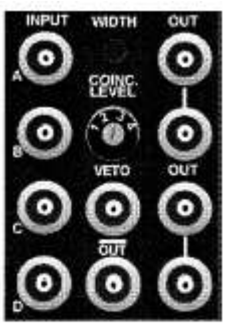
I. With the help of the TA set up two NaI (γ_1 and γ_2) detectors, or one 2”x2” NaI and one HPGe detector, on respective correlation tables. Set up and tune NIM coincidence electronics and data acquisition system, approximately according to the circuit diagram below. Calibrate the detectors in gamma energy.



Attention: Take precautions to avoid damage to fragile detectors by securing detector signal and power cables.

1. Verify that detector HV bias supplies are switched off.
2. Place γ_1 and γ_2 detectors *at minimum distance* on the angular correlation table (facing or next to each other, if needed).
3. Place a ^{22}Na γ source between the two detectors in closest proximity.
4. Connect γ_1 and γ_2 detector HV cables to bias supply.
5. Connect signal output cables from γ_1 and γ_2 detectors to scope inputs (AC, 50Ω).
6. Switch on and set HV bias supplies. Verify proper detector trace responses on scope.
7. Trigger the scope with γ_1 signal and search for ***some*** coincident γ_2 signals with fixed relative time difference, *when detectors are in proximity*.
8. Set up the slow and fast circuits for both γ detectors, as in other experiments. Use the available amplifier/discriminator combinations for the detectors. Choose signal shaping times and amplitudes appropriate for DDC-8 input.
9. **Optional:** Set up pulse generator PG slow/fast circuit for a dead time measurement. (Analog: HPGe preamp input, or PG analog or attenuated TTL out direct to DDC-8).
10. Provide a scaler for counting externally (independently of the DAQ) the number of pulser triggers sent to the DAQ.

11. Set up two channels of a fast, digital logics unit to produce the conditional **master trigger**/strobe signal for the DDC-8 ADC. Design it such that a quick change is possible between the two trigger conditions,



a) for independent (**singles**) counting of detectors γ_1 and γ_2 and the (optional) pulse generator (PG): **(γ_1.OR.γ_2).OR.PG**, and
b) for **coincidence** counting**: (γ_1.AND.γ_2).OR.PG**.
c) Measure the coincidence resolution by delaying fast signal γ_1 relative to signal γ_2 by introducing known cable delays.

12. Set up proper width and timing of the logical master trigger signal relative to the various analog signals (γ_1, γ_2, PG).
13. Hook up the analog (energy) signals to the DDC-8 (e.g., γ_1 to Ch.0, γ_2 to Ch.1, Pulse generator (attenuated TTL out) to Ch.3). Connect the master trigger to the DDC-8 Strobe input NIM_IN0.
14. Set DDC-8 up for individual histogramming of γ_1, γ_2, and PG pulse height spectra.

The setup is now ready to simultaneously take γ_1, γ_2, and PG singles data.
15. Measure the pulse height spectra for both γ detectors with a γ ^{22}Na source.
16. Verify the location of the PG line approximately in the visible spectrum.
17. Start the DDC-8 for a 5-10 minutes singles measurement simultaneously with the external PG scaler.
18. Note the resolutions provided by the γ detectors and estimate the dead time (from the intensity of the PG line compared to the external PG scaler count).
19. Set the window discriminators for the detectors, each to bracket the 511-keV γ line.

II. Measure the resolution in angular correlation provided by the 2-detector setup, using the two annihilation γ-rays from the ^{22}Na β^+ decay. Total coincidence rate N_{12} per time (or N_{PG}) (in DDC-8) is the main observable, energy spectra are for data quality control.

1. Place the ^{22}Na β^+ source in the middle of the angular correlation table.
2. Place the γ detectors facing each other **at distance**, with $\theta_{12}=180^0$ angular separation. Plan for a $\pm20^0$ variation in angle θ_{12} of detector γ_1 with respect to the fixed γ_2 detector.
3. Set the window discriminators for the detectors to each accept the corresponding 511-keV γ line. **Record the widths Δτ of the discriminator NIM output signals.**
4. Set the master trigger logic unit set to the **OR** condition (**γ_1.OR.γ_2.OR.PG**).
5. Measure the singles pulse height spectra for both γ detectors simultaneously, to verify the proper discriminator settings. If insufficient, change window(s) and repeat Steps 3 & 4.
6. Set the master trigger logic unit set to the **AND** condition [**(γ_1.AND.γ_2).OR.PG**].
7. Measure for a period of 5-10 minutes the coincident pulse height spectra for both γ detectors and the PG for a $\theta_{12}=180^0$ correlation angle.
   Always start DDC-8 DAQ simultaneously with the external PG scaler.
8. Repeat (in 10^0 steps) the measurement in 7, but for 2-4 larger and 2-4 smaller angles θ_{12}, covering the range $160^0 \le \theta_{12} \le 200^0$. Move only one detector.
9. Check on the dead time in each measurement.

III. In a PET measurement with two γ detectors, determine the location of a concealed positron emitter. Total number $N_{12}(\theta_{12})$ of coincidences (in DDC-8) per time (or N_{PG}) is main observable, spectra are for data quality control.

Discuss and decide upon the strategy for an *effective scan pattern*. Record steps in logbook.
Repeat measurement Steps 6.-8. above with conveniently chosen detector angle(s).

IV. Measure with the two γ detectors in this station the absolute activity A of a suitable γ source of your choice.

Switch to the other Experiment Station

Repeat measurements I-IV above

V. (Optional) Measure the ($90^0/180^0$) angular anisotropy $A_{\gamma\gamma}$ for the ^{60}Ni de-excitation γ cascade (from state at E*=2.507MeV).

Check set up detector and electronics in the Station. Set the γ_1 discriminator for the 1.17-MeV γ-line, the γ_2 discriminator for the 1.33-MeV γ-line.
Perform coincidence measurements for angles between $\theta_{12}=90^0$ and 180^0.

Data Analysis/Report

1. Sketch electronics block circuit diagram and provide a timing diagram approximately to scale.
2. Calibrate γ_1 and γ_2 detectors in energy.
3. Determine the coincidence time resolution for the 2-detector PET setup.
4. Determine angular resolution of correlation setup (plot distribution $N_{12}(\theta_{12})/N_1$)
5. Determine DAQ dead time from N_{PG} measured vs. number of PG triggers (scaler).
6. Plot and discuss γ_1 and γ_2 singles energy spectra.
7. Plot and discuss γ_1 and γ_2 coincidence energy spectra, for different angles θ_{12}, including θ_{12} near 90^0 and near 180^0. Discuss potential effects of the 1.275-MeV γ-line on the correlation measurements.
8. Explain strategy for PET scan patterns employed to locate hidden β^+ source.
9. Report position coordinates for hidden γ source. Estimate uncertainties.
10. Discuss choice of appropriate source for measurement of absolute activity.
11. Report absolute activity of γ source with estimate of uncertainty. Discuss the effect of the finite widths $\Delta\tau$ of the discriminator NIM output signals on the coincidence rates.
12. (Optional) Report $90^0/180^0$ angular anisotropy $A_{\gamma\gamma}$ for the ^{60}Co γ-rays.