K223 Angular Correlation

K223.1 Aim of the Experiment

Electromagnetic multipole radiation has a non-isotropic angular distribution. Considering a gamma decay of a nucleus, the orientation of the emission distribution arises from the spin orientation of the parent nucleus.
In thermal equilibrium, the net orientation is zero as all spin states are populated with an equal density. All spin configurations are equally probable and in this case, the gamma ray distribution of an ensemble of nuclei is isotropic.

A non-equilibrium spin state can be achieved in a cascaded gamma decay of a nucleus. Detecting the fist photon of the cascade yields constraints on the spin probability of the resulting meta stable state of the nucleus. Therefore, a non isotropic angular distribution of the second photon can be measured if the first one was detected at a specific position.

The aim of the experiment is to prepare the experiment and to measure the angular correlation of the $\gamma - \gamma$ cascade of ^{60}Co.

K223.2 Required Knowledge

- Definition of the angular correlation of a $\gamma - \gamma$ cascade. Explanation of the angular correlation of a hypothetical $0 \to 1 \to 0$ $\gamma - \gamma$ cascade. Which quantities enter into the angular correlation coefficients? Perturbation of the angular correlation by hyperfine interaction.

- What information can one obtain by the measurement of angular correlation - with and without extranuclear perturbation?

- Design and operation of a scintillation spectrometer; fast-slow coincidence technique; components of the setup (SCA, CFD, ...); time resolution of the detector and of the coincidence unit; expected spectrum of ^{60}Co;

- Analysis of the experimental data: corrections for solid angle, accidental coincidences and deadjustment; Determination of the angular correlation coefficients by means of least-squares-fit to the data, determination of experimental errors.

- Decay-scheme of ^{60}Co.

K223.3 Literature

- *Siegbahn Vol. 2: α-,β- and γ-Ray Spectroscopy*, pp. 1029-1035, 1101-1104, 1190-1195, 1695
- Melissinos: *Experiments in Modern Physics*, pp. 412-429, 461-476
- Riezler/ Kopitzki: *Kernphysikalisches Praktikum*
- Schatz/ Weidinger: *Nuclear Condensed Matter Physics: Nuclear Methods and Applications*, Wiley, 1^{st} edition (1996), pp. 14-20, 63-68, 80-85
- Leo: *Techniques for Nuclear and Particle Physics Experiments*, Springer, 2^{nd} Rev. edition (1994)

K223.4 Assignments

Contact your tutor to receive the full description and supplementary literature for this experiment. Here, only a brief summary of all tasks is shown.

Additionally to studying the theory background of this experiment and the properties of the used electronics, it is mandatory to prepare a few tasks before the experiment.

Tasks for Preparation

1. In a practical setup, the alignment of the source can only be done to a certain precision. How will a misalignment manifest in the data? How can you correct it?
2. As measurement time is limited, a compromise has to be found between number of angles for which measurements are taken and statistical precision at those points. Prepare a proposal for the angular stepping you want to use.
3. Another compromise needs to be taken when picking the distance between detector and source. A low distance will increase the event rate, resulting in a better statistical precision. However, a close distance will also decrease the angular resolution of the measurement, making corrections necessary. Prepare a proposal for the angular stepping you want to use.

Adjustment of the Setup

1. Prepare the Constant Fraction Discriminator. Perform a threshold scan to find the optimal setting.
2. To align the timing in the fast circuit, insert a delay into one of the branches and measure the prompt curve. Extract the resolving time and the setting for optimal alignment
3. Adjust the gain in the slow circuit and record an energy spectrum.
4. Align the timing of the fast circuit vs the slow circuit.

Measurement of the Angular Correlation

1. Move the detectors to the proper distance to the detector and perform measurements:
   a) One, having a fine angular stepping.
   b) One, with fewer positions but longer measurement time.
   c) One several times distributed over the day at the same angle to understand the stability of the setup.
2. Misalign the coincidence circuit to measure random coincidences. Compare the measured value to the theoretically predicted random coincidence rate.

Analysis of the Data

1. Subtract random coincidences from the measured rates and compensate the misalignment of the setup.
2. Apply a least squares fit of the predicted function to the resulting data and apply solid angle corrections.
3. Try to fit angular correlation functions for cascades with different spins. Can those be ruled out?
4. Plot the angular distribution including data, fit, and prediction.

Best wishes for a successful experiment! Date: July 2018