Demonstrating Momentum Conservation in Electron-Positron Annihilation in Na-22 using Gamma-Ray Coincidence

Diya Motagi (230389)
Indian Institute of Technology - Kanpur

Supervisors: Prof. Aditya H. Kelkar, Prof. Zakir Hossain

November 10, 2025

Abstract

Objective: This experiment was conducted to demonstrate momentum conservation in electron-positron (e^+e^-) annihilation by measuring the simultaneous, antiparallel emission of 511 keV gamma-ray photons from a Na-22 source.

The experimental apparatus consisted of two NaI scintillation detectors, two Single Channel Analyzers (SCAs), a Multi Channel Analyzer (MCA), and a coincidence module. We first understood the working of SCA and found the characteristic photopeaks of Cs-137 (662 keV) and Co-60 (1173 and 1332 keV) sources. We also generated the energy spectra of Cs-137, Co-60, and Na-22 using an MCA. The coincidence module's logic was tested independently using a pulse signal from a function generator that mimicked the output of an SCA. Coincidence rates were then measured for the Na-22 source and a Cs-137 source. The angular dependence of the Na-22 coincidence rate was also investigated. The Cs-137 source yielded a low coincidence rate, which was consistent with random background events. In sharp contrast, the Na-22 source produced a significantly increased coincidence rate, confirming the presence of true, simultaneous photon emission. This high coincidence rate was observed to be highest when the detectors were placed 180° apart and decreased as the angle was reduced. The high coincidence rate unique to Na-22, combined with its strong angular correlation, provides clear experimental verification of the electron-positron annihilation process and successfully demonstrates the principle of momentum conservation.