Designing an Apparatus for Electron-Positron Annihilation and Compton Scattering Experiments

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Introduction

The electron-positron annihilation and Compton scattering experiments are designed for educational purposes in an upper level modern experimental physics lab. The current setup for these experiments, shown in Figure 1, is awkward to use and produces results that are not very precise. We are designing a new apparatus that is easier to use and provides more accurate data.

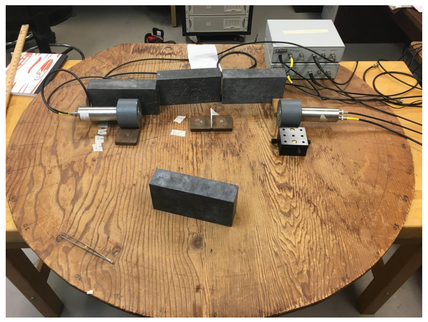

Figure 1: Photograph of the old setup for the electron-positron annihilation and Compton scattering experiments

Development of the Apparatus

The apparatus consists of two arms, each a meter in length, two detector holders, and a source holder. We designed the apparatus with three features in mind: having one arm attached to a turntable that can rotate 360°, the ability to adjust the distance of the detectors from the center, and the option to re-arrange the position of the detector and sample holders. The frame of the arms were made using extruded aluminum bars, the detector holders were made using acetal plastic, and the center platform that connects the arm to the turntable was made using aluminum. The parts were cut using a band saw and a vertical milling machine shown in Figures 2,3, and 4. The schematics in Figures 5 and 6 show that the apparatus can be adjusted for both experiments. Lead collimators, shown in Figure 10, were also designed for the detectors. The collimators reduce background and increase accuracy in photon detection.

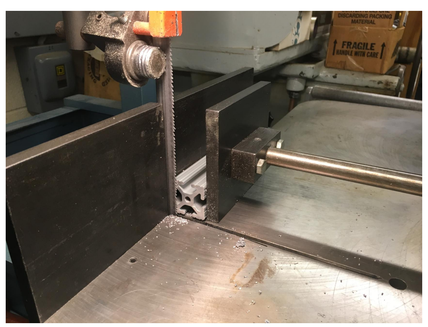

Figure 2: Photograph of a leg of the stationary arm being cut.

Figure 3: Photograph of a detector holder body being cut.

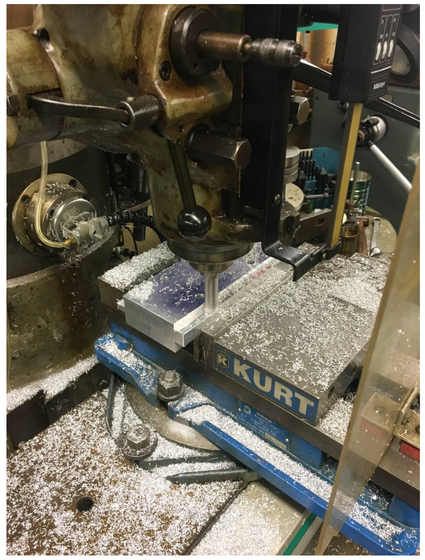

Figure 4: Photograph of the center platform being cut.

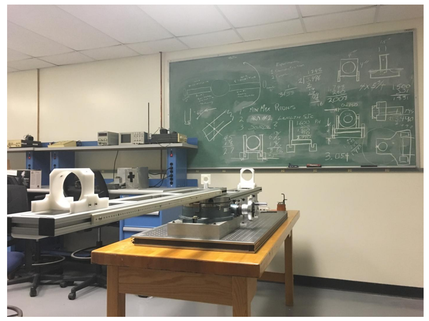

Figure 7: Photograph of the finished setup for the electron-positron annihilation experiment.

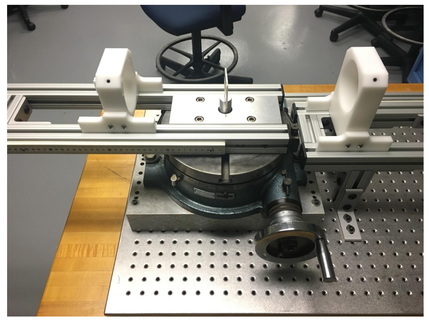

Figure 8: Photograph of the detector holders at equal height.

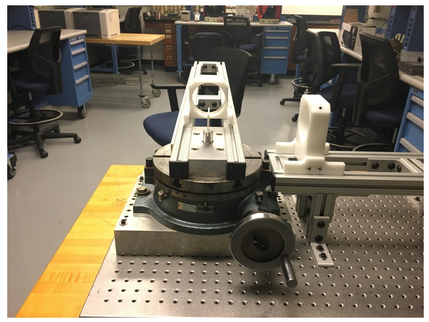

Figure 9: Photograph of the moveable arm rotated 90°.

Variable Setup

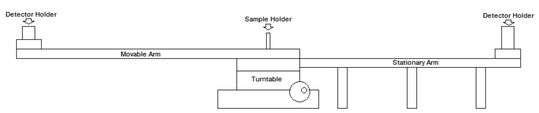

Figure 5: Electron-positron annihilation

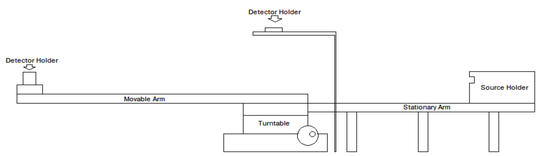

Figure 6: Compton Scattering

Electron-Positron Annihilation

The antimatter counterpart to an electron is a positron. They have the same mass and spin but are opposite in charge. When the two antiparticles collide they produce two subsequent gamma-ray photons [1]. Conservation of momentum requires that the photons must be emitted in opposite directions (180°). The experiment requires that two scintillation detectors are used to observe the emitted photons. The detectors are ran in coincidence so that the computer software only records photon counts that most likely occurred from an annihilation.

Compton Scattering

Compton scattering is inelastic scattering of a photon by a charged particle, usually an electron. When a photon hits the particle, both energy and momentum are transferred to the particle, and the photon travels away with a reduced energy and a change of momentum [2]. The experiment uses two scintillation detectors however one of the detectors is used as the target while the other observes the scattered photon. The detectors are ran in coincidence so that the computer software only records photon counts that most likely occurred from a scatter.

Figure 10: Photograph of the lead collimators for the detectors.

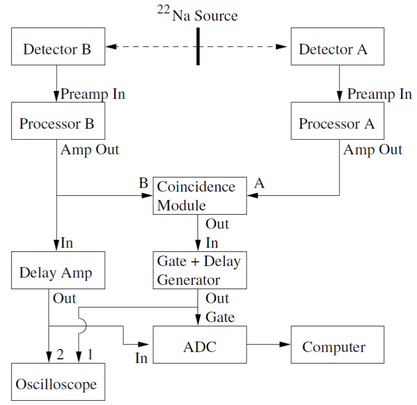

Figure 11: Schematic of the experimental setup to detect electron-positron annihilation

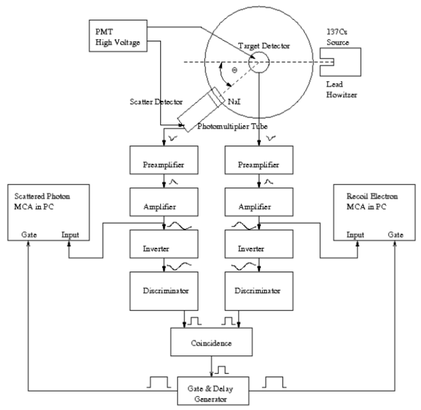

Figure 12: Schematic of the experimental setup to detect Compton scattering [3]

References

[1] Adrian C. Melissinos and Jim Napolitano, "Experiments in Modern Physics," Second Edition, Academic Press (2003)
[2] James E. Parks, "The Compton Effect--Compton Scattering and Gamma Ray Spectroscopy," University of Tennessee (2015)
[3] "Compton Scattering," MIT (2013)

Acknowledgements

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