

John A. Brunelle<sup>†</sup> and Trifon Fitchorov<sup>‡</sup>

*Boston University*

(Dated: December 17, 2005)

## INTRODUCTION

Compton scattering describes the interaction of electromagnetic radiation and free electrons. It is named after Arthur H. Compton, who first studied the effect in 1920 and explained the scattering in terms of a quantized electromagnetic field of photons.

If one applies conservation of energy and momentum to a collision between a photon and electron and looks at the photons outgoing wavelength  $\lambda'$  compared to its incoming wavelength  $\lambda$ , the result is the following:

$$\lambda' - \lambda = \frac{h}{m_e c} (1 - \cos \theta), \quad (1)$$

where  $\theta$  is the scattering angle as show in Fig. (1).

In this experiment we look to verify this relationship by studying the scattering of gamma rays off of an aluminum target. Electrons in matter such as aluminum are not free, but Eqn. (1) is a good approximation for such a situation when the photon energy is much larger than the binding energy of the electron, as is the case here[1].

## EXPERIMENTAL SETUP

For our beam of incident particles we used the monochromatic gamma rays given by a  $^{137}\text{Cs}$  source.

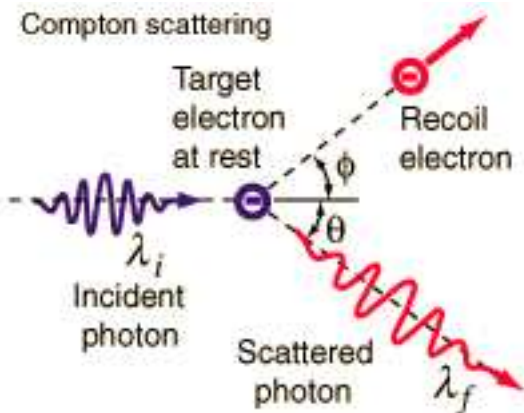


FIG. 1: Compton scattering process. [image source: <http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/comptint.html>]

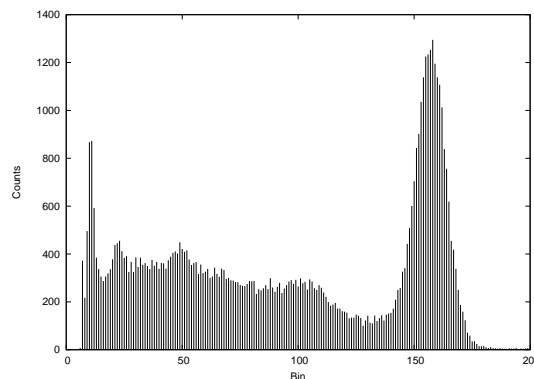


FIG. 2: 60 s Detector Calibration Exposure.

This source has two lines, at 0.032 and 0.662 MeV, the latter of which we focused on. The beam, traveling through open air, was directed through a collimating lead shield and aimed at the target, described below, 22 cm away. The mean free path of such gamma rays in open air is about  $10^4$  cm, so losses are not significant.

Our electron source was a cylindrical target of aluminum, with a diameter of about 25.4 mm. The mean free path of gamma rays in aluminum is about 4.7 cm, so multiple scattering interactions are not significant.

The detector was placed a distance of 22.5 cm away from the target and could be rotated about the interaction region. The detector, along with the associated electronics card and personal computer, performed an analog-to-digital conversion of the signal and binned the energy measurements in a histogram. A linear response was assumed.

We first calibrated the detector by directly measuring the energy of the gamma ray source for a 60 s exposure. Fig. (2) shows the result. As with all the following figures, only the region with significant signal is shown, and the lowest few channels, which are unreliable, have been suppressed. It was determined that bin 157 corresponded to 0.662 MeV, and this calibration was used throughout the experiment.

## DATA AND ERROR ANALYSIS

We measured the energy of the gamma rays scattered off of the target as a function of scattering angle for angles from  $30^\circ$  to  $120^\circ$  in  $15^\circ$  intervals. (We were unable to measure a signal at  $15^\circ$ .) For each angle, we took both

\*Prepared for submission to Phys. Rev. Lett. December 17, 2005

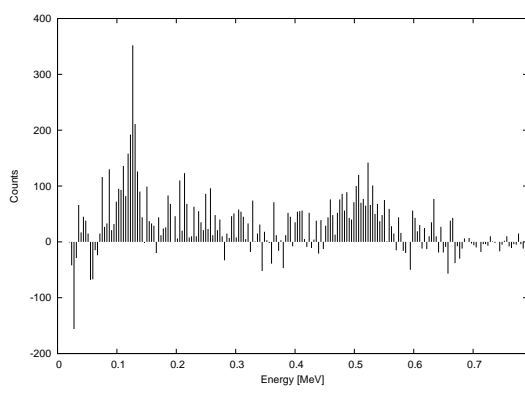


FIG. 3: 500 s Detector Exposure at  $30^\circ$ .

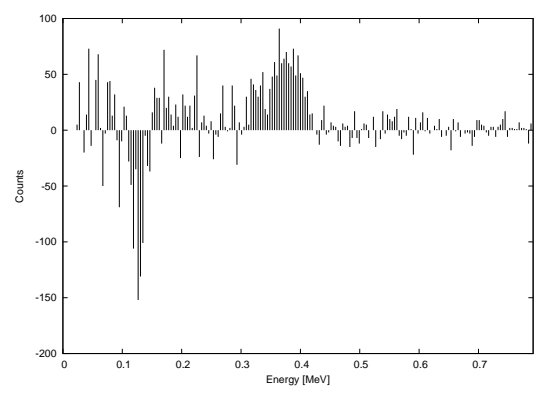


FIG. 5: 500 s Detector Exposure at  $60^\circ$ .

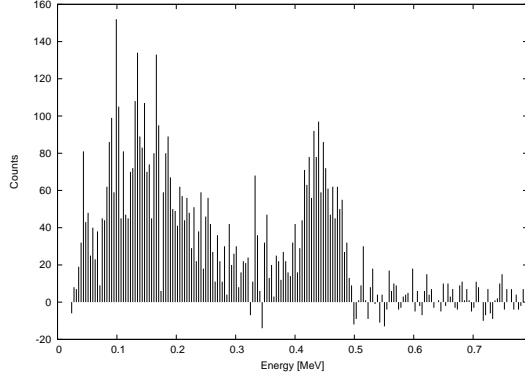


FIG. 4: 500 s Detector Exposure at  $45^\circ$ .

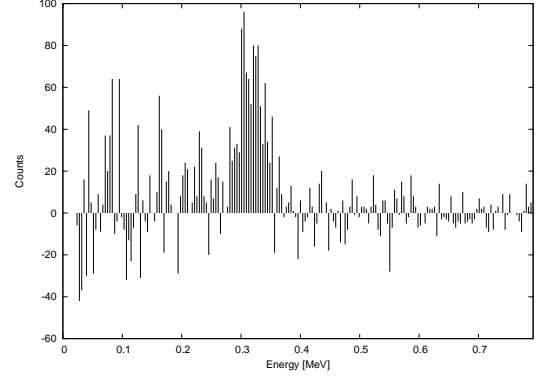


FIG. 6: 500 s Detector Exposure at  $75^\circ$ .

a 500 s exposure with the target in place and a 500 s exposure without the target. The latter background data were subtracted from the former data in order to extract the scattering signal.

Figs. (3) through (9) show the exposure data. The peak width gave the dominant uncertainty in all calculations.

From these graphs, the energy was read off and plotted versus  $(1 - \cos \theta)$ , as shown in Fig. (10)[2]. From Eqn. (1), this plot should have a slope of  $\frac{h}{m_e c}$ . The slope was found to be

$$\left( \frac{h}{m_e c} \right)_{\text{measured}} = (2.5 \pm 0.1) \times 10^{-12} \text{ m.}$$

This is in agreement with the known value of  $2.43 \times 10^{-12}$ .

## DISCUSSION AND CONCLUSION

Our measurement of  $\left( \frac{h}{m_e c} \right)_{\text{measured}} = (2.5 \pm 0.1) \times 10^{-12} \text{ m}$  is in agreement with the theoretical value of  $2.43 \times 10^{-12}$ . There is also additional analysis that could be performed in order to improve the experiment and this report.

We have the data available to measure the differential cross section for the scattering process. The count rates can be used to determine the intensity as a function of angle, and, using the source activity and target parameters, the differential cross section.

We also took data to measure the stopping power of graphite as function of its thickness. However, this data has not been analyzed.

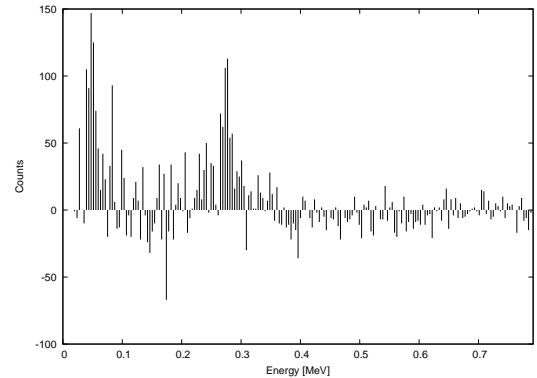


FIG. 7: 500 s Detector Exposure at  $90^\circ$ .

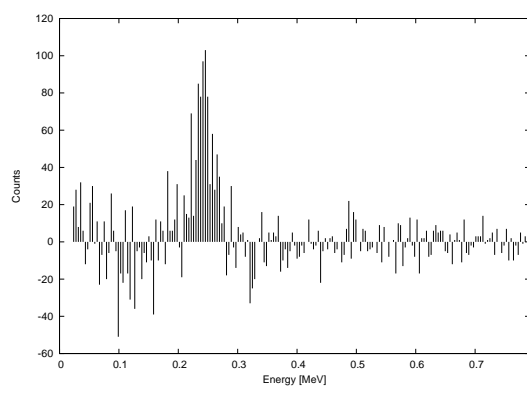


FIG. 8: 500 s Detector Exposure at  $105^\circ$ .

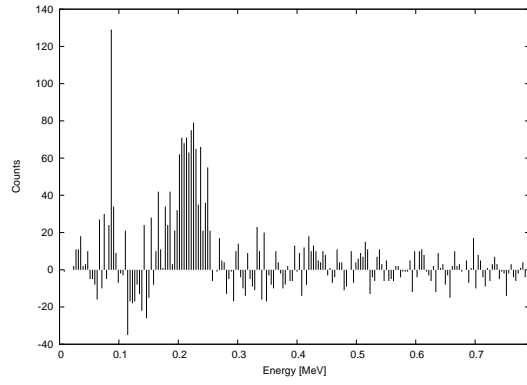


FIG. 9: 500 s Detector Exposure at  $120^\circ$ .

† brunejo@bu.edu  
‡ trifon@bu.edu

- [1] Occasionally there is scattering off of bound electrons, in which case the appropriate recoil mass is that of the entire atom, yielding a much smaller energy shift.
- [2] Once again, the error bars are larger than they should be, be I they're from a 0.01 MeV uncertainty on the energy, which I believe to be as small as reasonable.

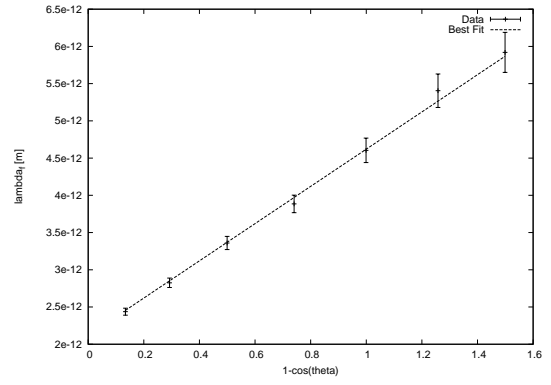


FIG. 10: 500 s Detector Exposure at  $120^\circ$ .