Confirming Theoretical Predictions for Scattered Energy Versus Angle in Compton Scattering

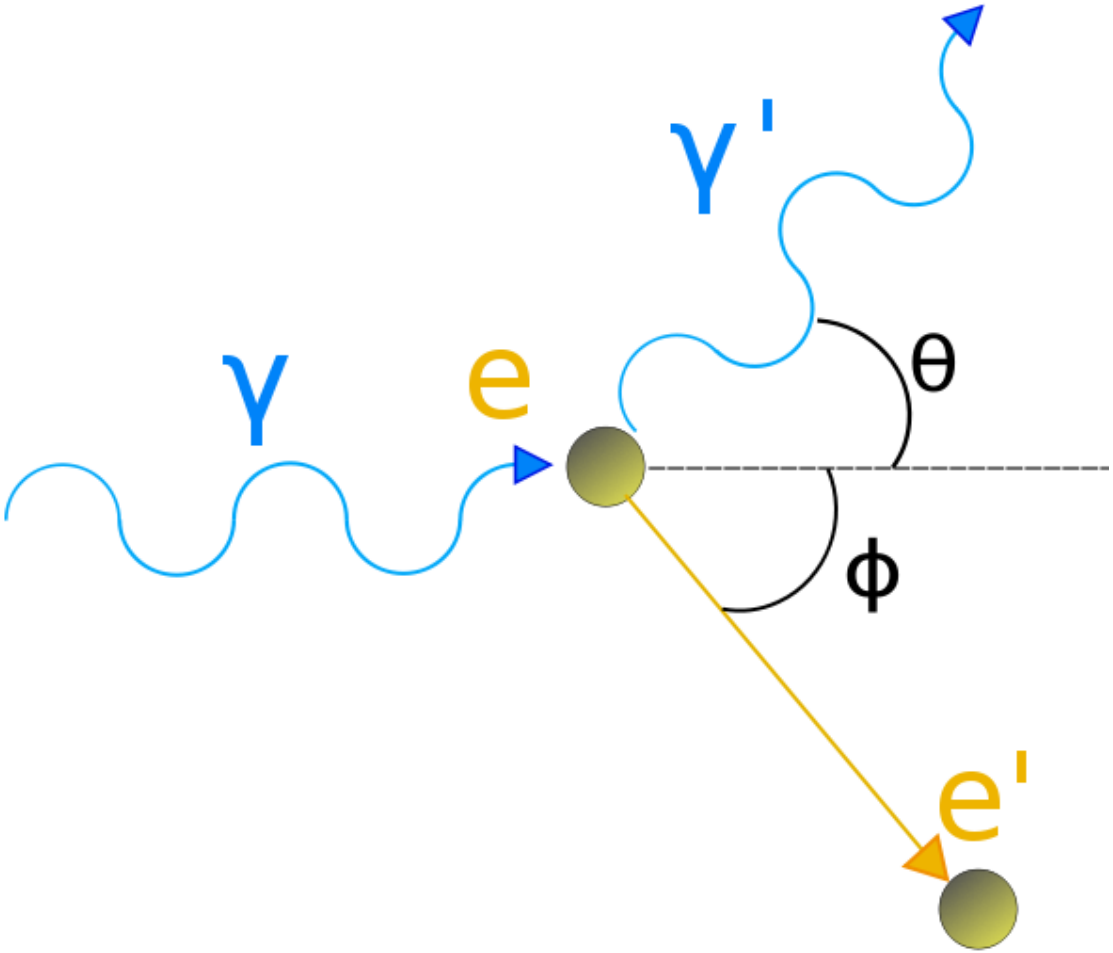
Shawn Westerdale

MIT - Department of Physics

Experimental Goals

- Measure the energy lost as a function of angle for scattered gamma rays off of a NI target
- Compare results to the theoretical predictions made in the Compton scattering formula

The Phenomenon of Compton Scattering



Incident γ ray collides with electron e and scatters off at angle θ, losing some of its energy to the electron

γ' is the scattered photon and e' is the scattered electron

Derivation of the Compton Scattering Relation

Compton Scattering

$$E'_\gamma = \frac{E_\gamma}{1 + \frac{E_\gamma}{m_e c^2}(1 - cos(\theta))} \tag{1}$$

Conservation of Momentum

$$\vec{p_\gamma} = \vec{p_\gamma}' + \vec{p_e}'$$

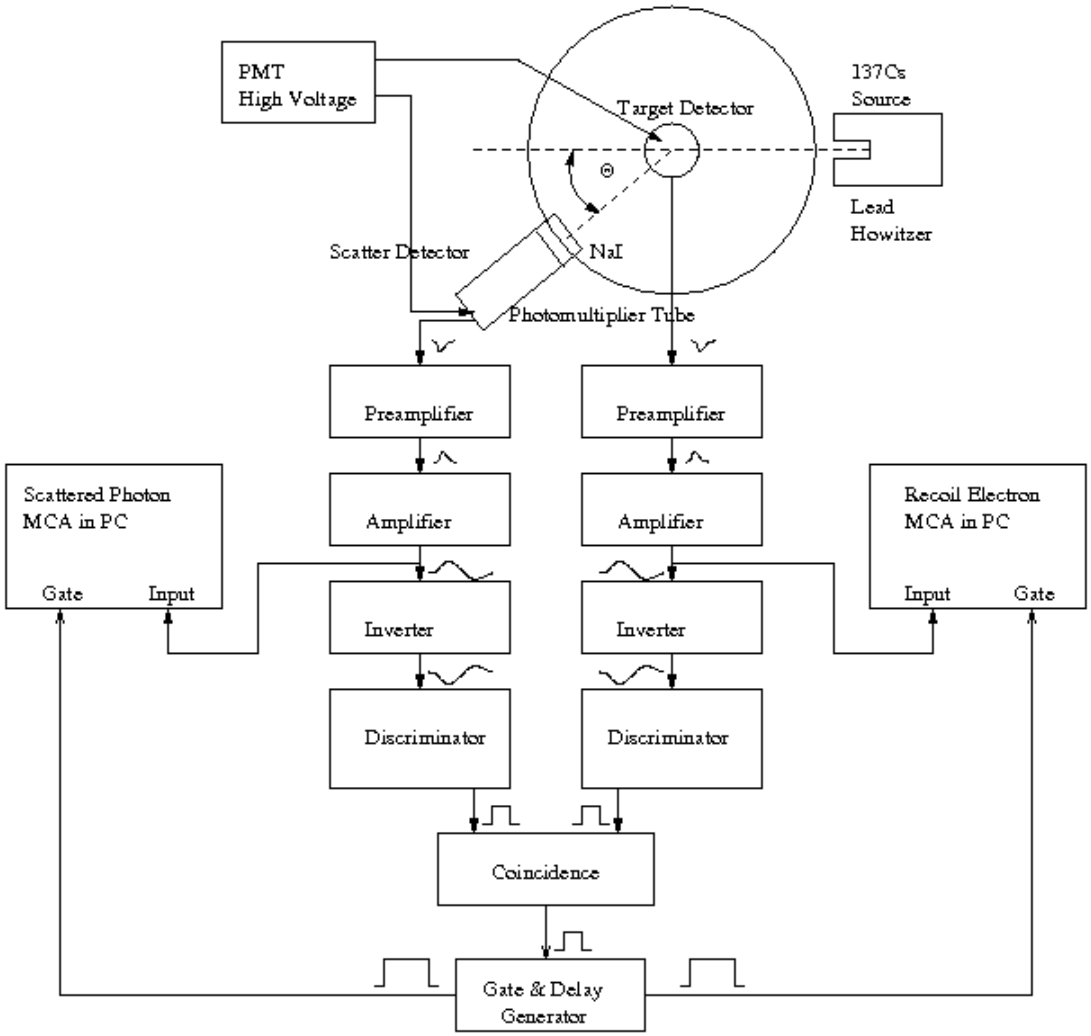
Conservation of Energy

$$E_\gamma + E_e = E'_\gamma + E'_e$$

$$p_\gamma c + m_e c^2 = p'_\gamma c + \sqrt{m_e^2 c^4 + p_e'^2 c^2}$$

Manipulating these two equations yields equation (1), where θ is the angle between the momentum vectors of the incident photon and the scattered photon

Experimental Setup



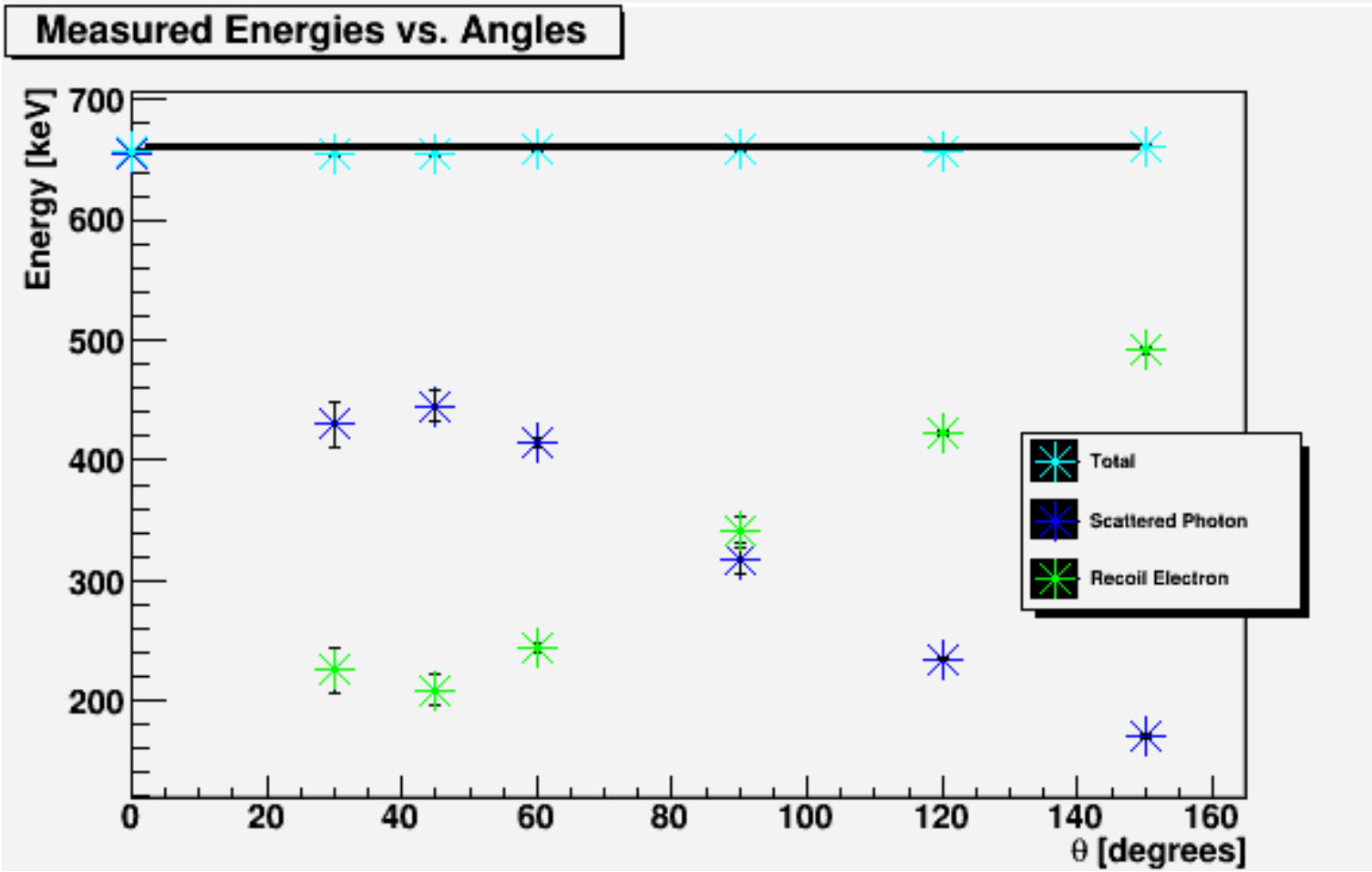
"Compton Scattering", MIT Department of Physics, 11/20/07

Experimental Procedure

1. Calibrate MCA channels to corresponding energies using ^{22}Na (511 keV)
2. Irradiate target and scatter detectors with γ rays from ^{137}Cs (661.6 keV)
   - Target: total energy
   - Scatter: scattered photon energy

Results

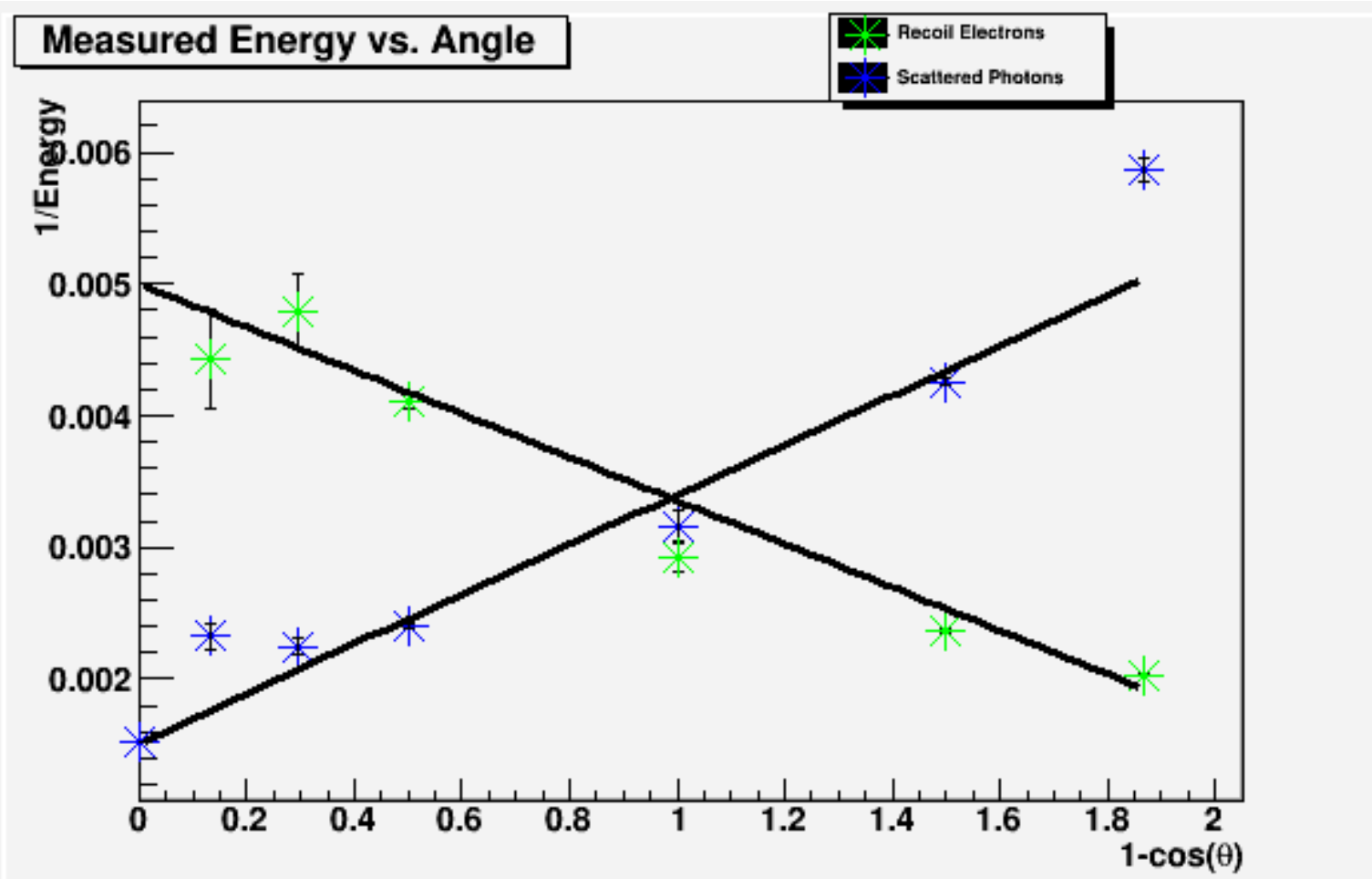
Energy is conserved



Average total energy is $660.6 \pm .3351$ keV

Results

Data fits Compton predictions

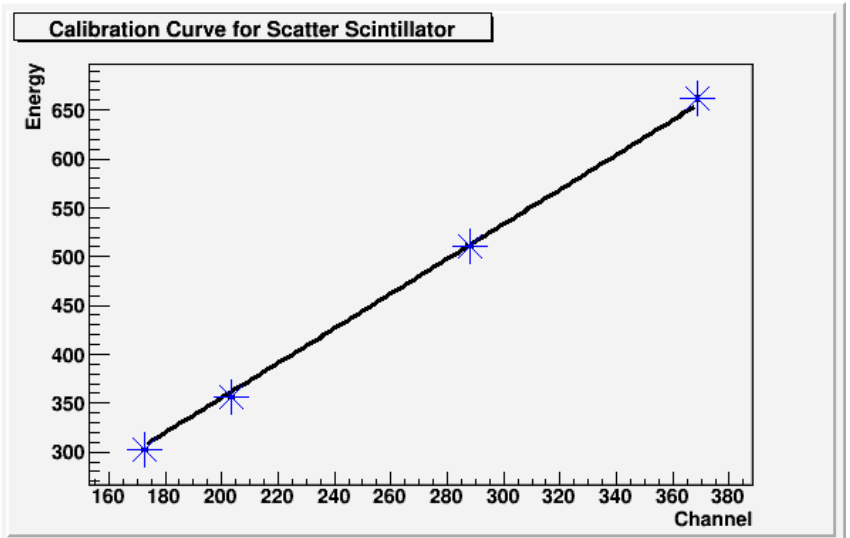


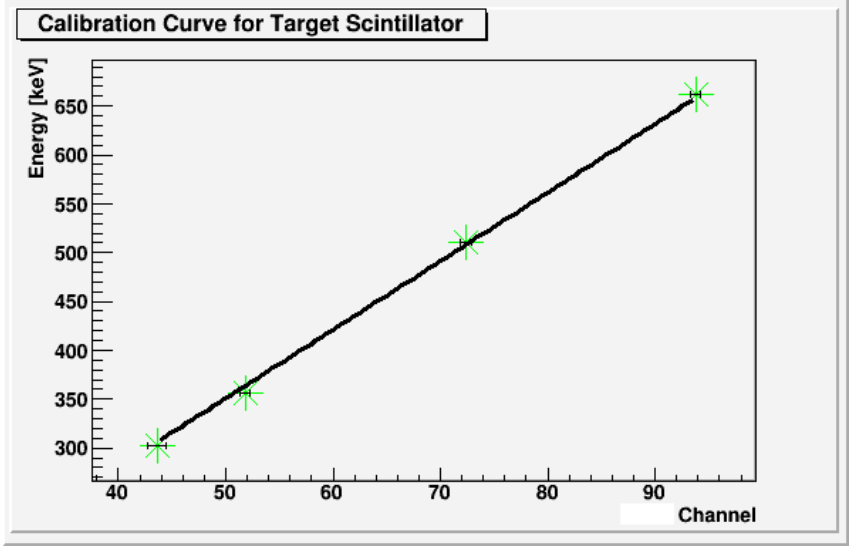
$\chi^2 = 0.0003479$ for Compton model; data fits Compton model well

Error Analysis

Little error in energy measurements

- Calibration curves shown to right
- $\chi^2_{target} = 0.2179$
- $\chi^2_{scatter} = 0.2439$

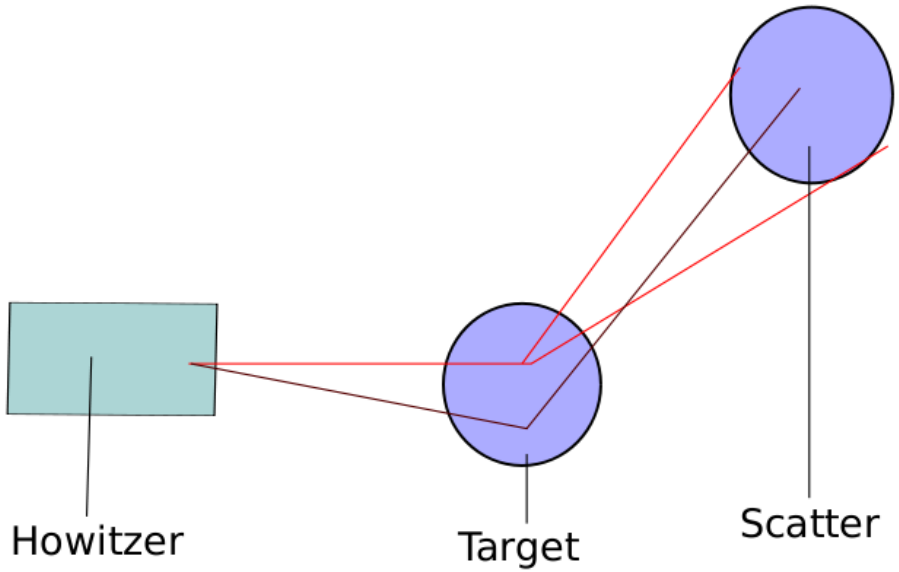




Error Analysis

Error in θ

- Random error in angle
- Width of detectors allow multiple scattering angles to look like one angle



Error Analysis

Other sources

- Background from false coincidences (rare)
- Attenuation of photons in air (small)
- Photons scattering back out of scattered scintillator without depositing all energy

Conclusions

Scattered γ rays have energies as a function of scattering angle as predicted by the theory of Compton scattering (as predicted by the Klein-Nishina formula at relativistically high energies)

Scattered Photon Energy

$$E'_\gamma = \frac{E_\gamma}{1 + \frac{E_\gamma}{m_e c^2}(1 - cos(\theta))}$$