

Compton Scattering and the Klein-Nishina Formula

Daniel J. Fremont

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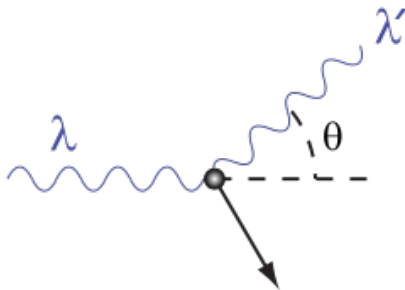
Massachusetts Institute of Technology

History

- Compton's x-ray diffraction experiments (1920-2)
 - ▶ Wavelength shift in scattered radiation
 - ▶ Explanation using photon momentum
- Wilson, Bothe detect recoil electron (1923)
- Wave-particle duality (de Broglie, Schrödinger)

Compton Scattering Theory

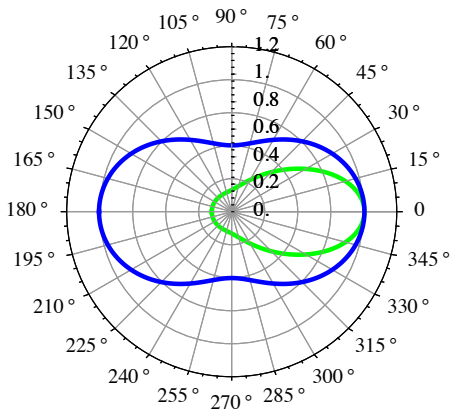
- Billiard-ball style collisions
- Relativistic energy: $E^2 = p^2 c^2 + m^2 c^4$



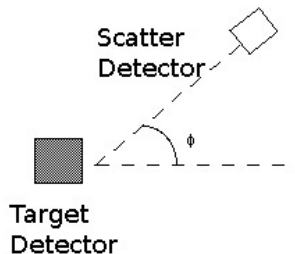
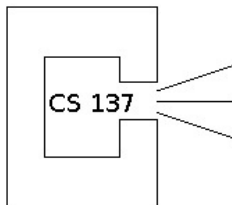
$$\Delta\lambda = \frac{h}{mc} (1 - \cos \theta)$$

Scattering Intensities

- Classical treatment: Thomson cross-section
 - ▶ Only valid for low energies
- Relativistic treatment: Klein-Nishina formula

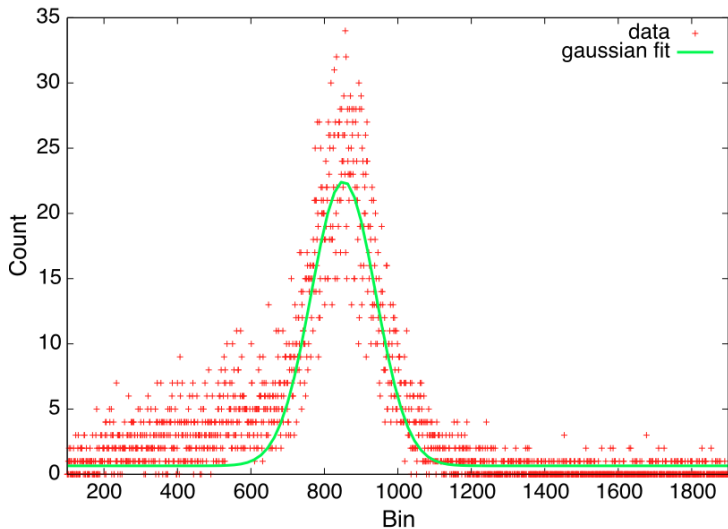


Apparatus



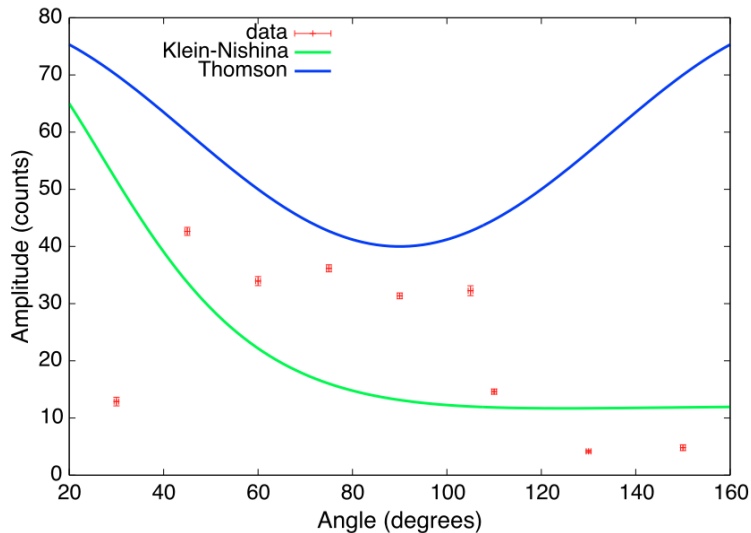
- Discriminators filter out noise
- Coincidence detector selects Compton events

Data



$$\chi_r^2 = 0.95$$

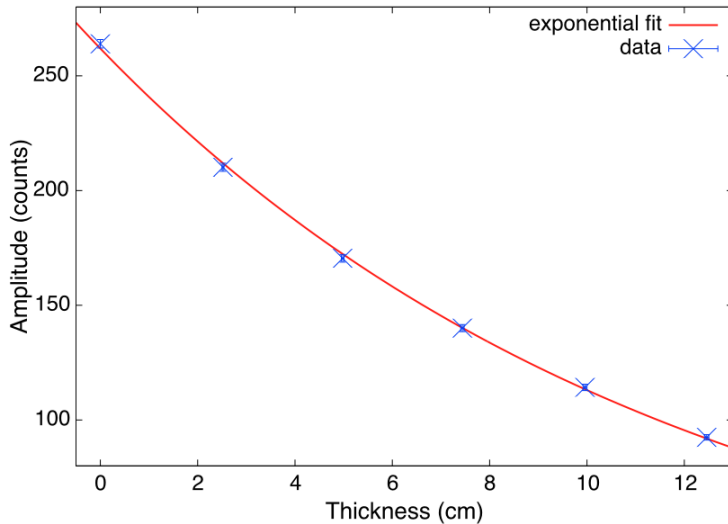
Amplitudes



Amplitude Results

- Classically-expected increase for large θ not observed
- Large systematic errors
 - ▶ Unusually weak signal at 30° — likely discriminated against
 - ▶ Scintillator efficiency
 - ▶ Detector drift
- Errors too significant to verify Klein-Nishina; however data definitely inconsistent with Thomson model

Attenuation



$$\chi_r^2 = 1.00$$

Attenuation Results

- Measured electron cross-section: $(2.50 \pm 0.025) \cdot 10^{-29} \text{ m}^2$
 - ▶ Klein-Nishina prediction: $2.56 \cdot 10^{-29} \text{ m}^2$ ($\approx 2 \sigma$ off)
 - ▶ Thomson prediction: $6.65 \cdot 10^{-29} \text{ m}^2$ ($\approx 166 \sigma$ off!)
- Small systematic error
 - ▶ Some scattered photons detected
 - ▶ Detector drift
- Relativistic effects dominant: Klein-Nishina model much more accurate than classical Thomson model

Summary

- Systematic errors in amplitude data too large to allow verification of Klein-Nishina, but data definitely inconsistent with classical prediction
- Attenuation data strongly supports Klein-Nishina result over Thomson
- Necessity of relativistic quantum description of photons and electrons

Questions?

- History of Compton Scattering
- Scattering Theory
- Amplitude Experiment
- Attenuation Experiment