Compton Scattering:

Observation of the Compton wavelength shift

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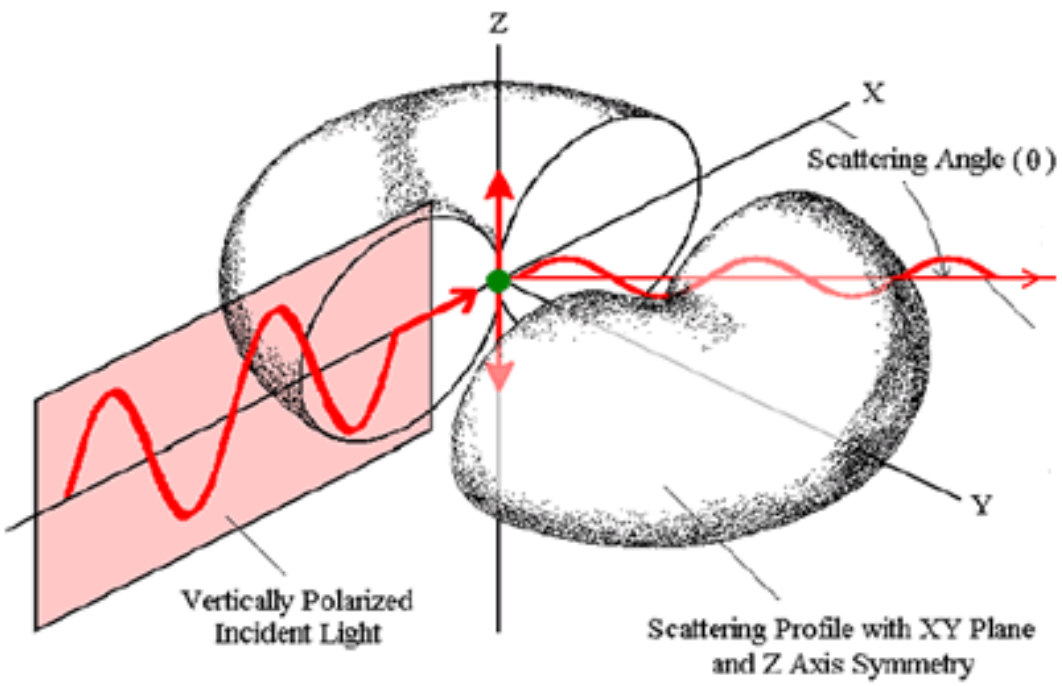
8.13 MW2-5 Prof. Roland

Topics to be discussed

1. Introduction
    1. Classical EM vs. Compton scattering
    2. Compton wavelength shift
    3. Compton scattering (Klein-Nishina) cross-section
2. Experimental setup
    1. Compton A vs. Compton B
3. Analysis and Results
    1. Fitting the lineshape
    2. Measured Compton shifts
4. Conclusions
    1. Observation of wavelength shift in light scattering

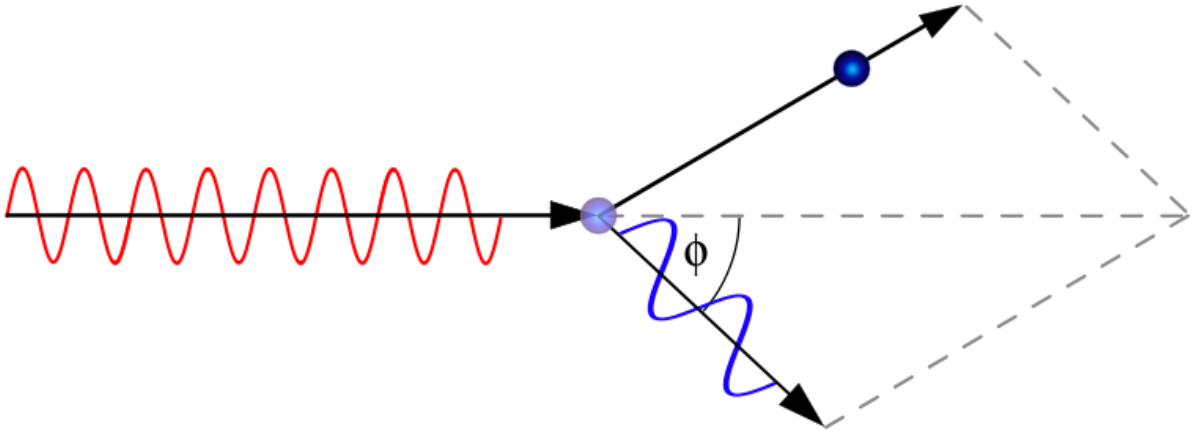
Classical (Rayleigh) scattering



- Scattering is dipole radiation from a driven dipole oscillator.
- Governed by Maxwell's equations.
- **Linear physics**: frequency and wavelength are invariant.

Image source: http://www.azonano.com/details.asp?ArticleID=1239

Compton scattering

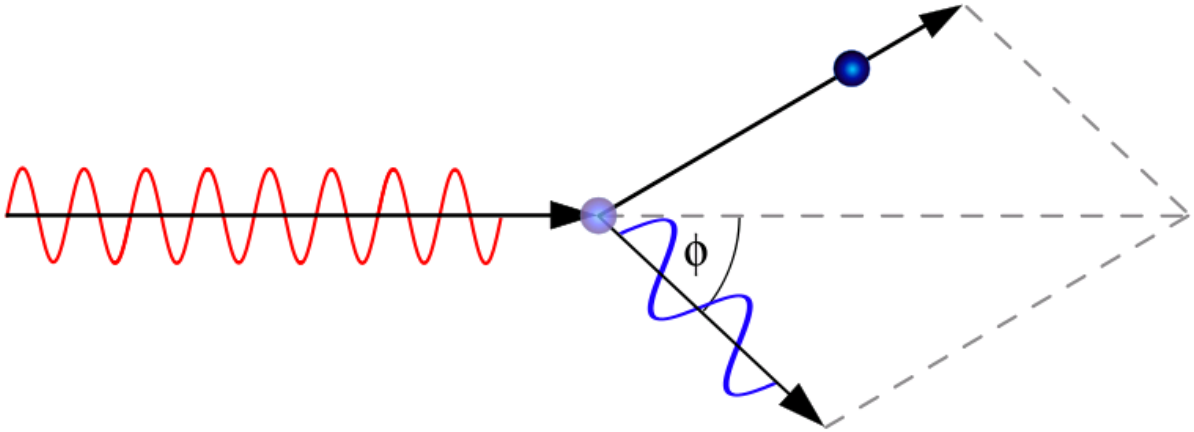


- Modern picture of light: photons
- Basic results of QM and relativity: E = hc/ λ ; p = h/λ
- Usual conservation laws yield:

$$\Delta\lambda = \frac{h}{m_e c} \cdot (1 - \cos\theta)$$

Image source: http://commons.wikimedia.org/wiki/Image:Compton_scattering-de.svg

Compton scattering

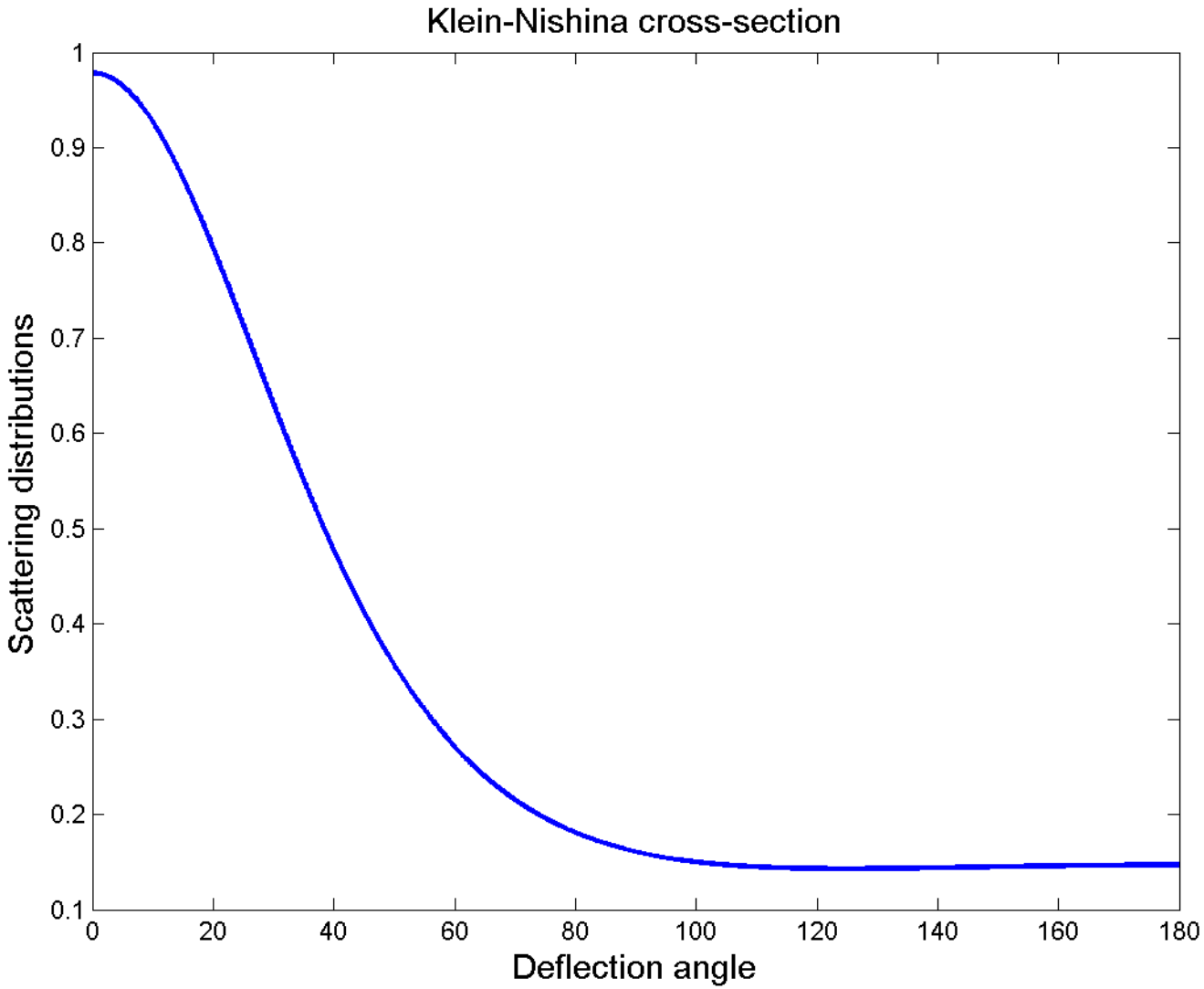


- Modern picture of light: photons
- Basic results of QM and relativity: E = hc/ λ ; p = h/λ
- Usual conservation laws yield:

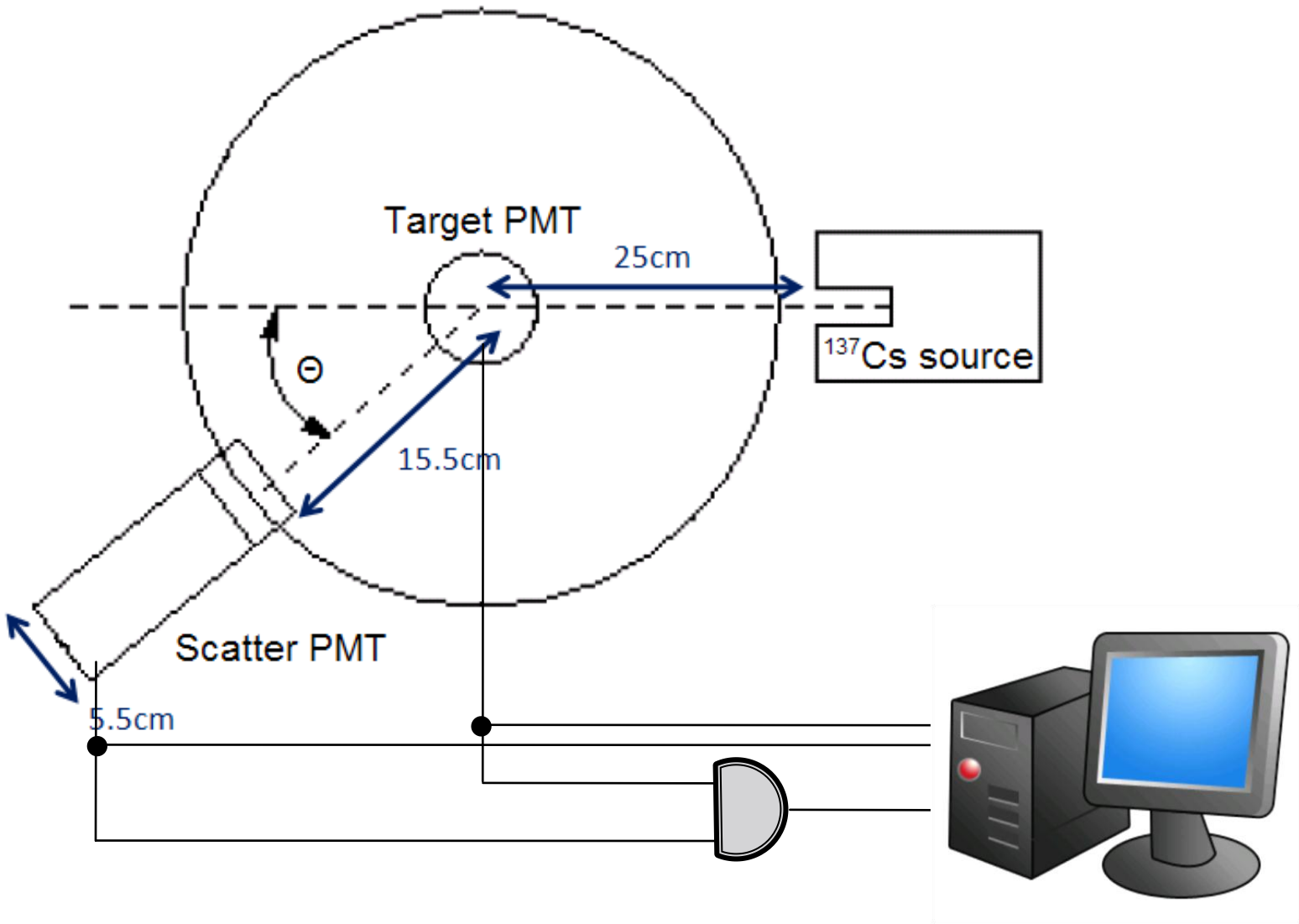
$$E_f = \frac{1}{E_i^{-1} + E_e^{-1} \cdot (1 - \cos\theta)}$$

Image source: http://commons.wikimedia.org/wiki/Image:Compton_scattering-de.svg

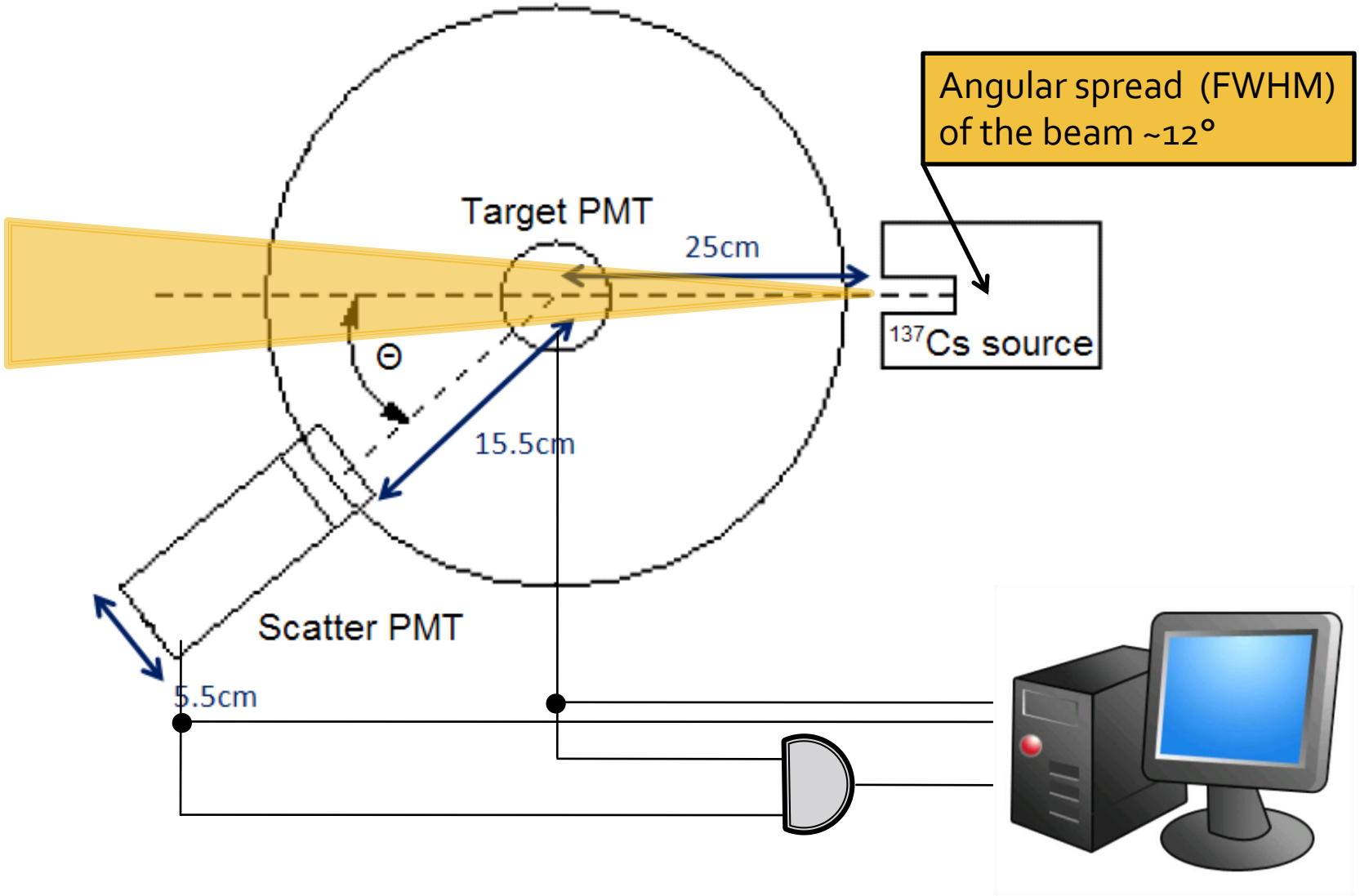
Compton scattering cross-section



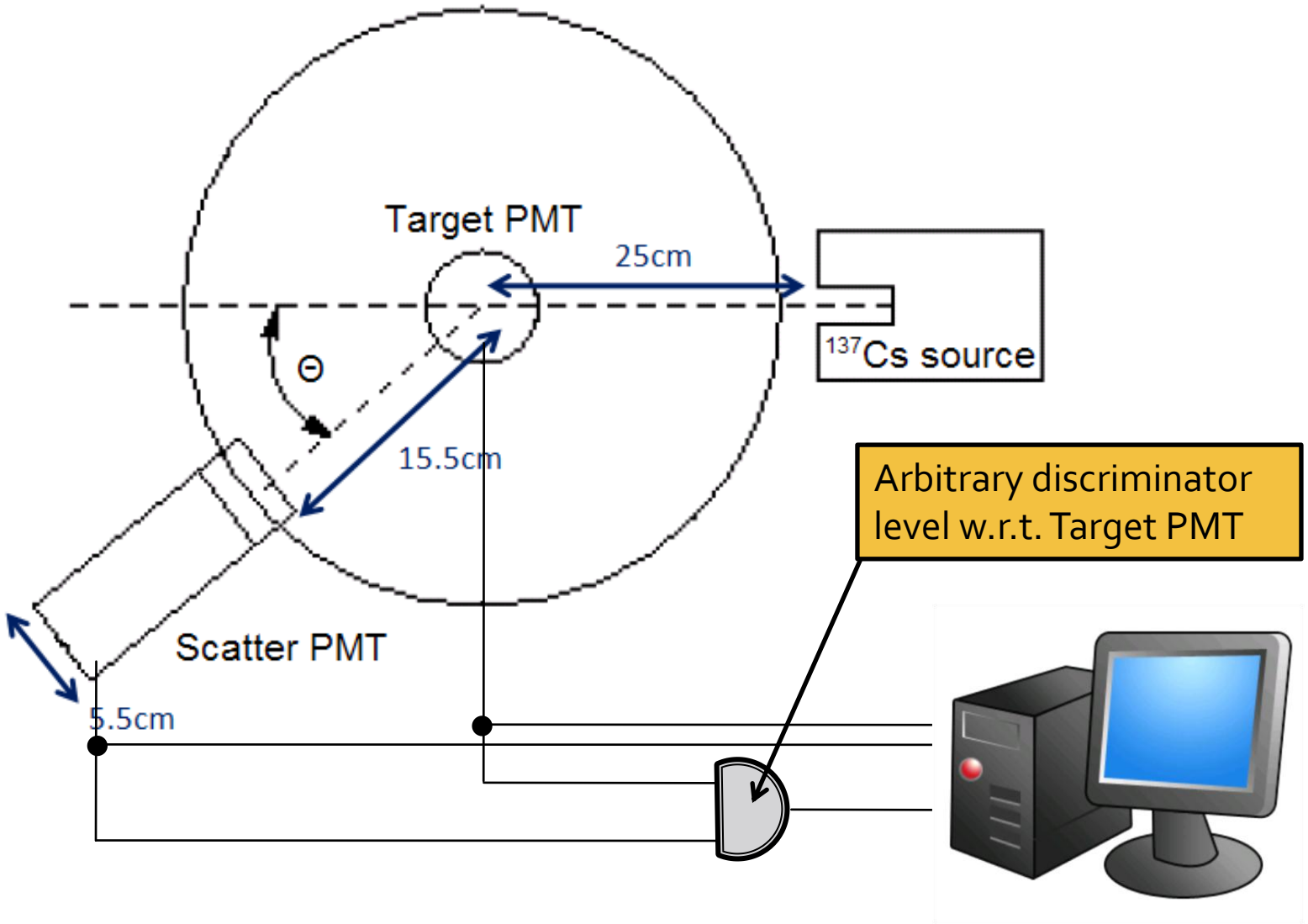
Experimental setup (Compton A)



Complications: Geometry



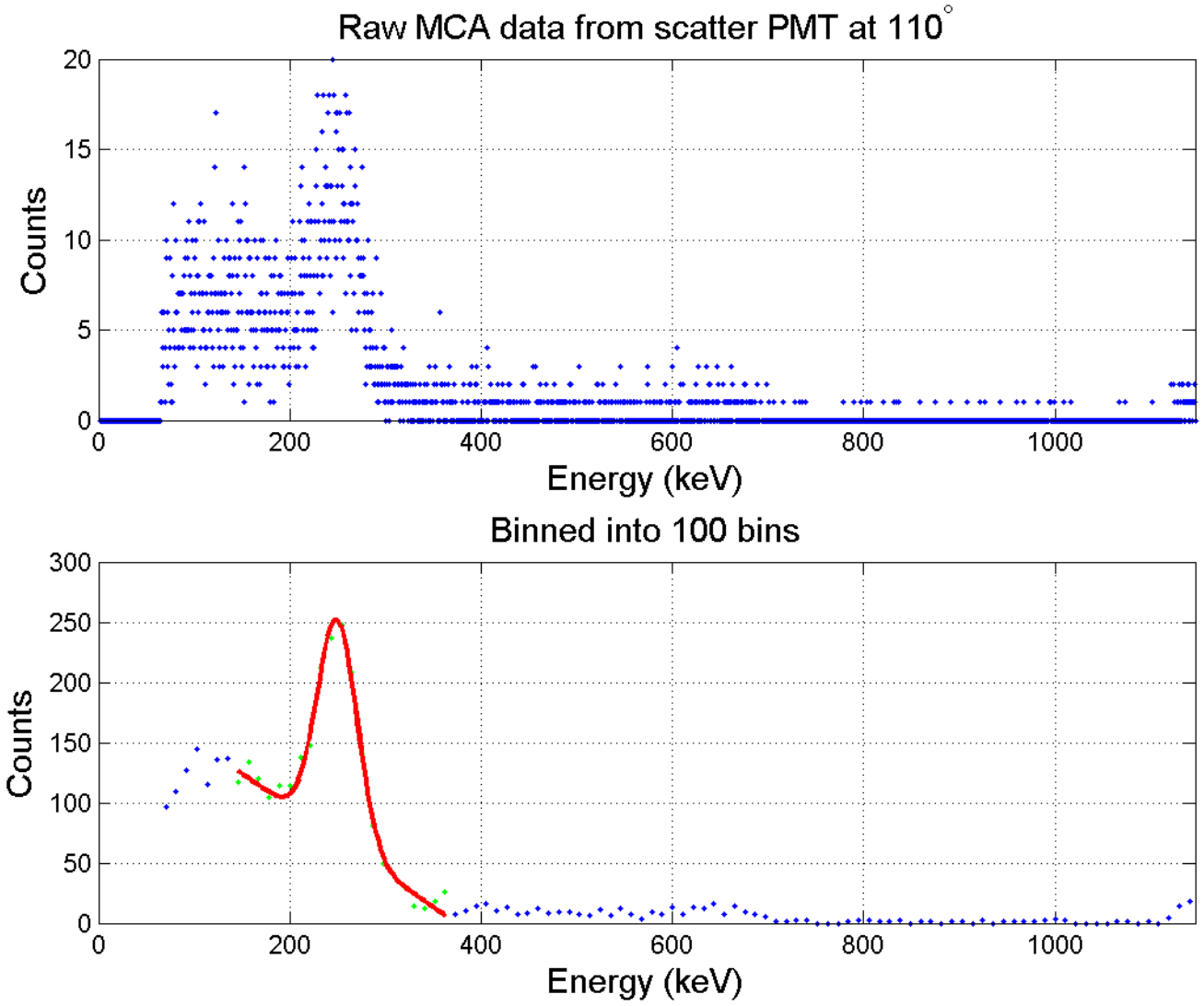
Complications: Electronic

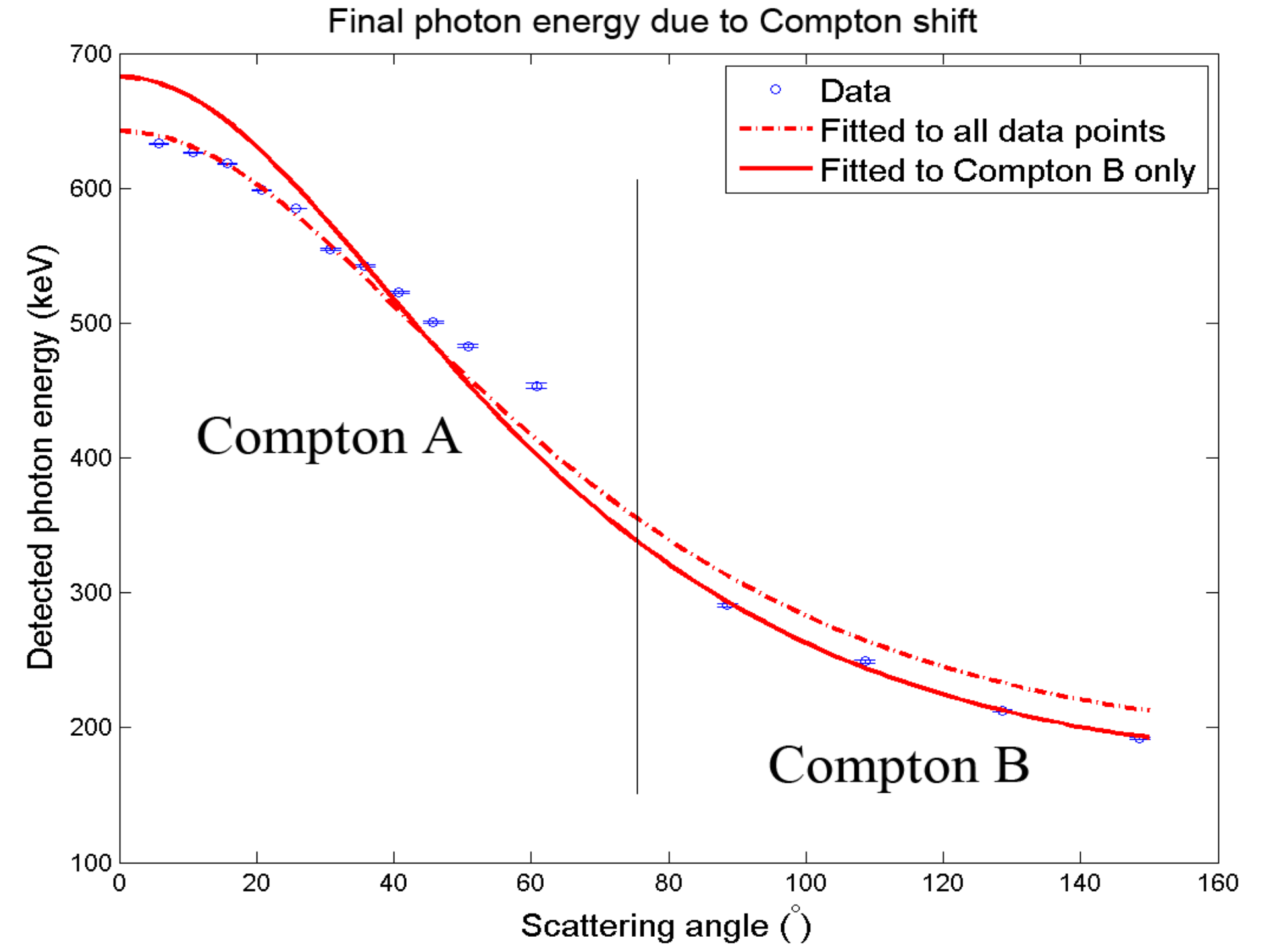


Comparisons between Compton A, B

- Due to these complications, high-angle measurements are preferred.
- Source in Compton B is 2.4 times more intense than Compton A.
  - Fatal flaw: Compton A does not yield signal beyond ~70°
- Longer lever arm in Compton B: better angular specificity. (Approx. 12.5° vs. 20.8°)

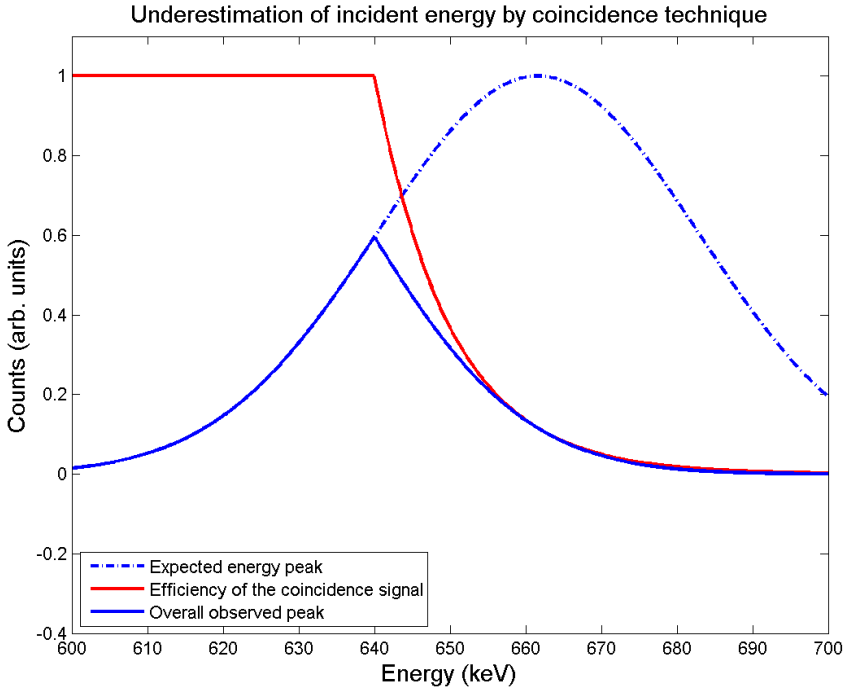
Typical MCA data (Scatter PMT 110°)




Final photon energy due to Compton shift
Data
Fitted to all data points
Fitted to Compton B only
Compton A
Compton B
Detected photon energy (keV)
Scattering angle (°)
700
600
500
400
300
200
100
0
20
40
60
80
100
120
140
160

Compton shift results

- Low angle measurements underestimate the Compton shift, as predicted by geometry.



- Compton A underestimates incident energy at E = 635keV. Possibly caused by the set-point complication.

Compton shift results (cont.)

- Wavelength variation observed → Rayleigh picture is inadequate.

- Fit to Compton B yields:
  - Incident energy: $E_i = (657.7 \pm 18.7) keV$
  - Electron rest mass: $E_e = (514.3 \pm 8.5) keV$
  - Goodness of fit: $\chi^2_{\nu-1} = 6.4$

Conclusions

- Observed the wavelength shift in light scattering. Unexplained by classical scattering.
- Obtained 4 large-angle data points on Compton B, showing good agreement to Compton shift formula. Fit yields:
  - Incident energy: $E_i = (657.7 \pm 18.7) keV$
  - Electron rest mass: $E_e = (514.3 \pm 8.5) keV$