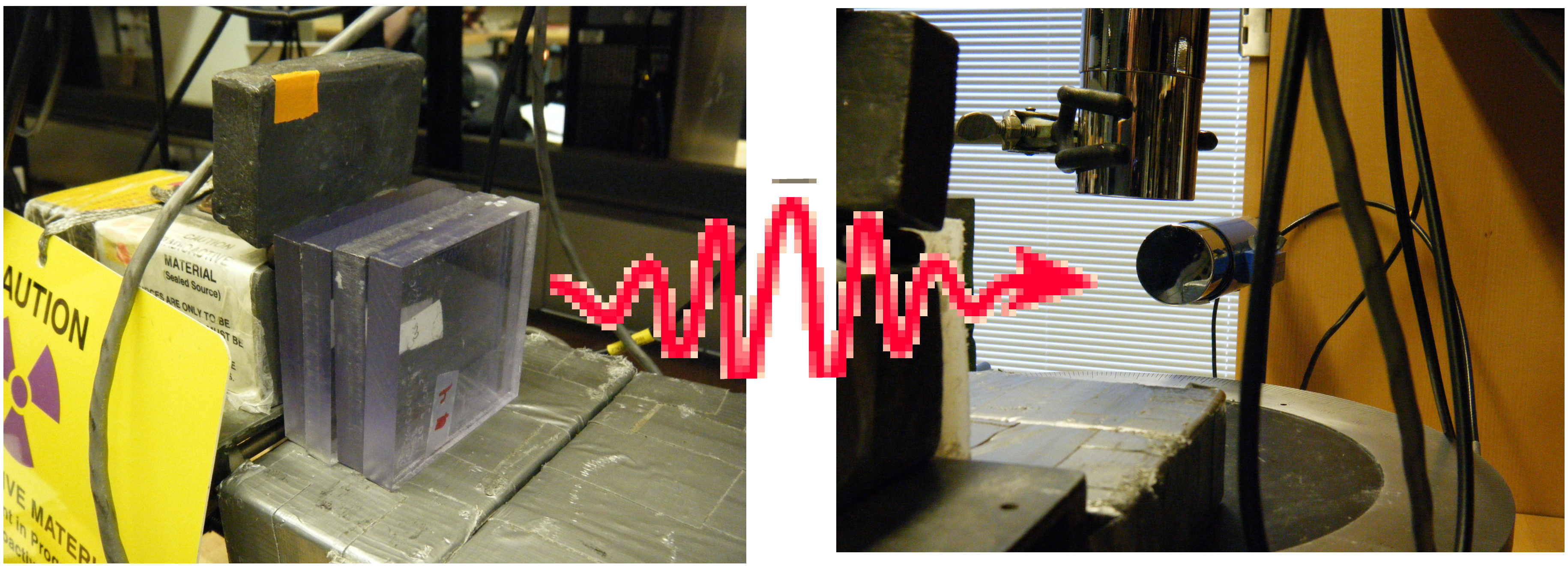
Compton Scattering: Attenuation



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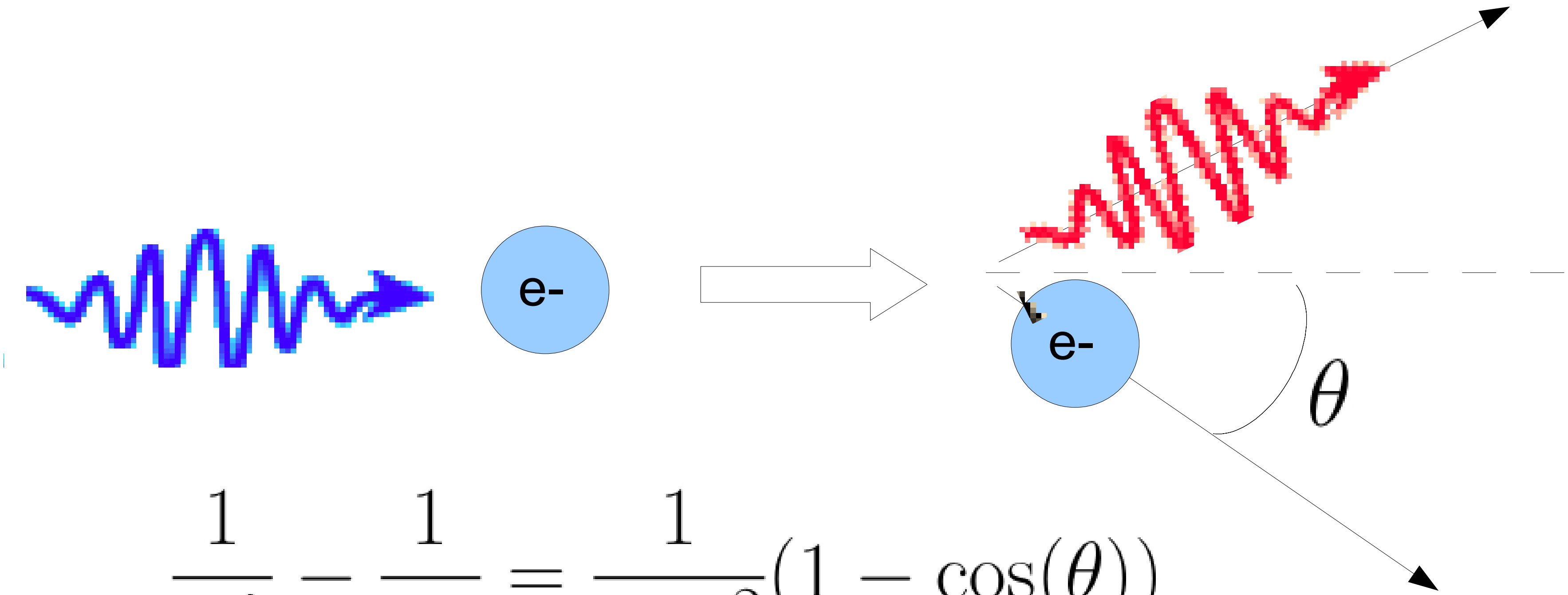
Outline

- Goals of the Experiment
- Theory:
  - Compton Scattering
  - Attenuation
- Experimental Setup
  - Overall Setup
  - Scintillator
- Attenuation
  - Data Collection
  - Finding the Linear Attenuation Coefficient
  - Compton Scattering Cross Section
  - Bonus: Attenuation through lead

Goals

- Measure attenuation coefficients
  - Thickness vs intensity
  - In different materials
- Find the Compton scattering cross section per electron
  - Compare to predicted models

Compton Scattering



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

E_γ = photon's initial energy

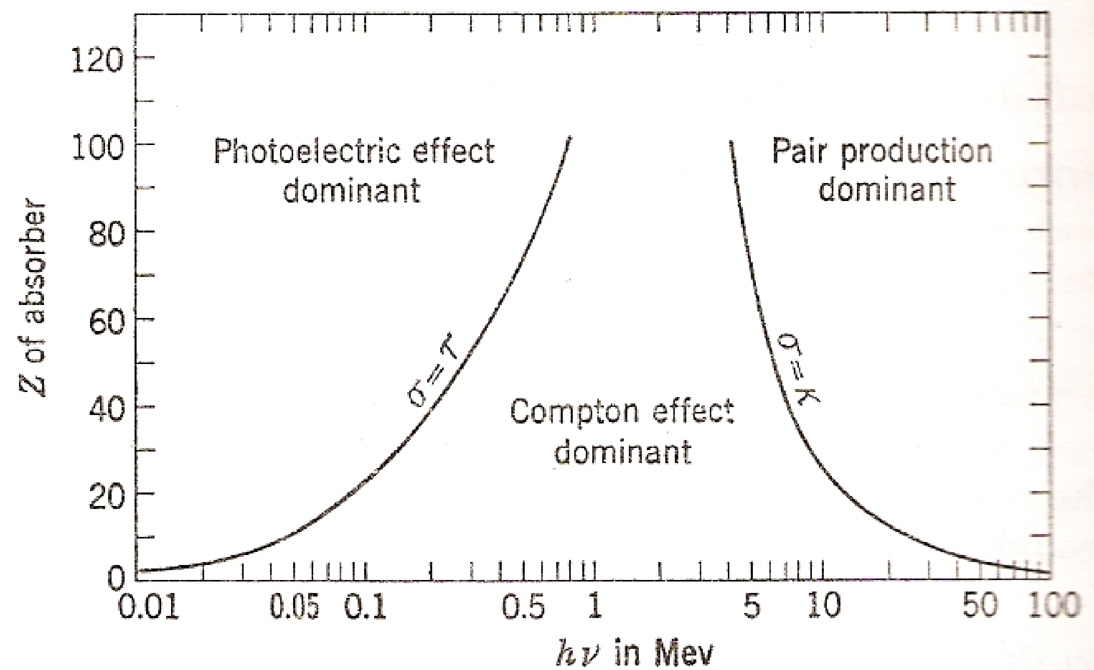
E'_γ = photon's energy after scattering,

$m_e c^2$ = Rest mass of electron

θ = Angle between incident and scattered photon

Attenuation

$$I(x) = I_0 e^{-\mu x}$$



x=distance traveled

$I(x)$= Intensity after distance x

I_0= Initial intensity

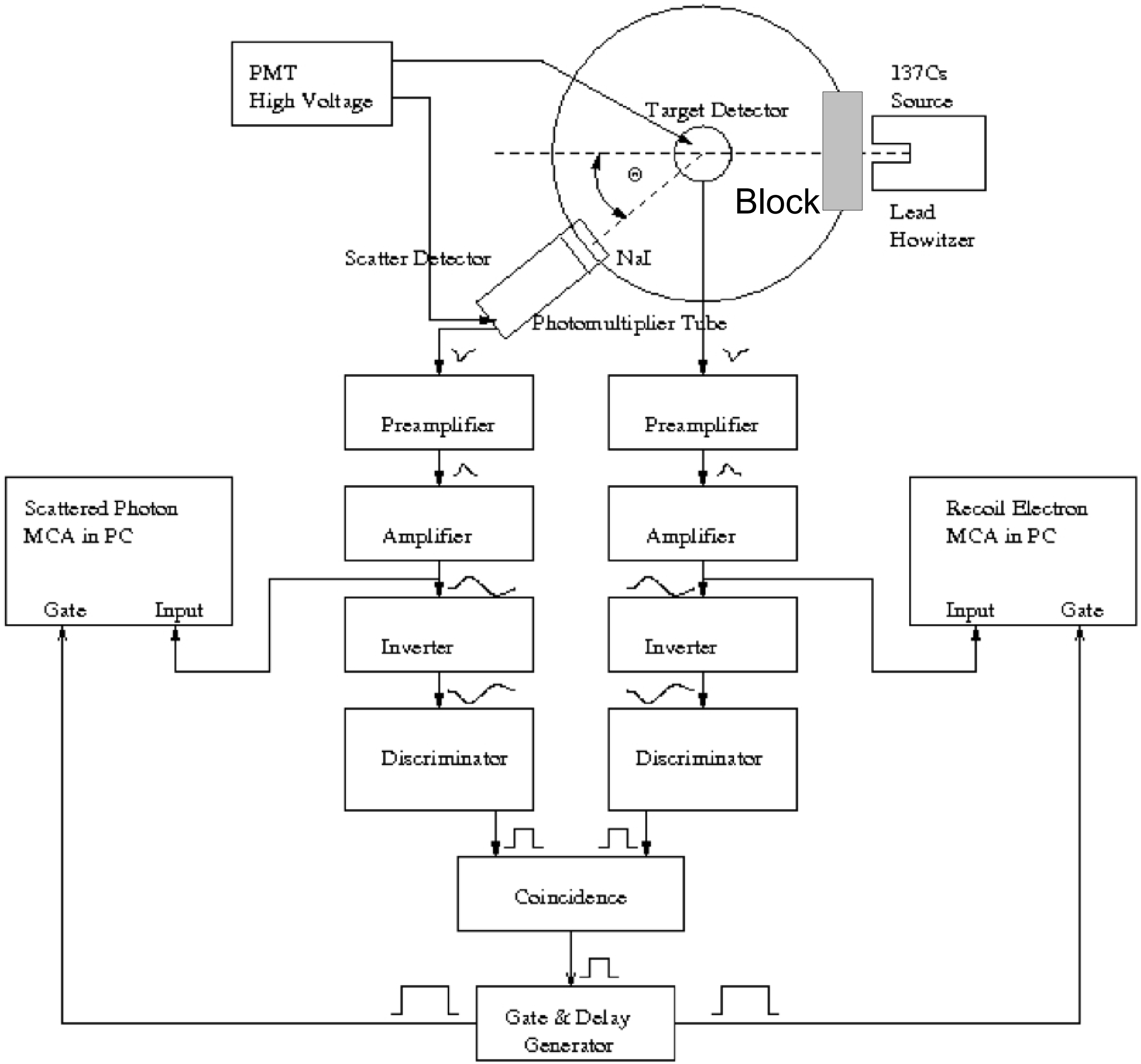
μ =Total linear attenuation coefficient

$= \tau + \sigma + \kappa$

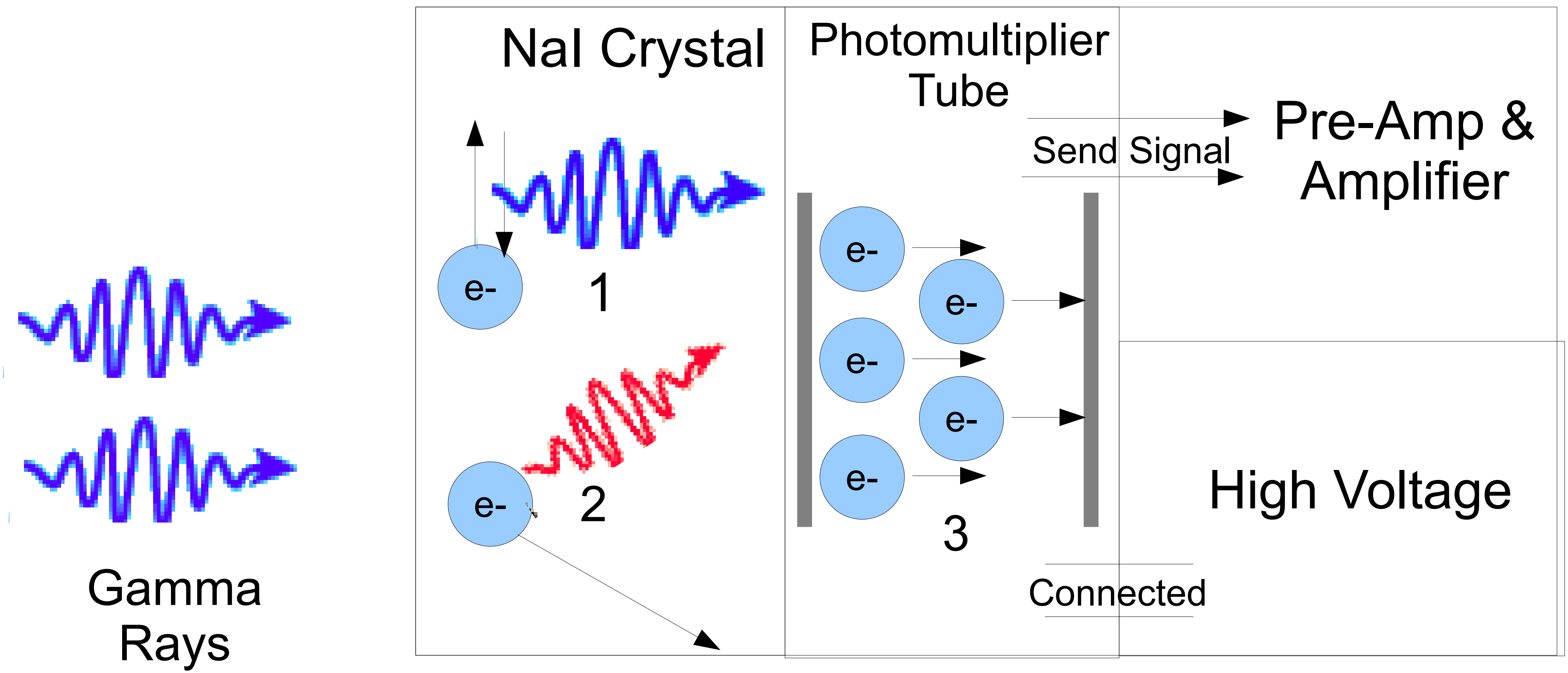
3 interactions:

- Photoelectric (τ)
- Compton (σ)
- Pair production (κ)

Overall Experimental Setup



In the Scintillator



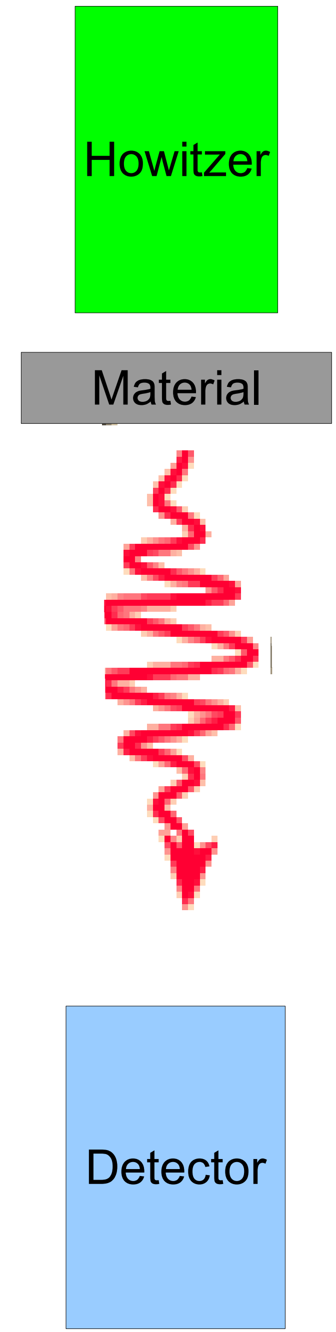
1. Energized electron in atoms → emits photon
2. Compton Scatter
3. Photons hit metal plate—photoelectric effect

Data Collection

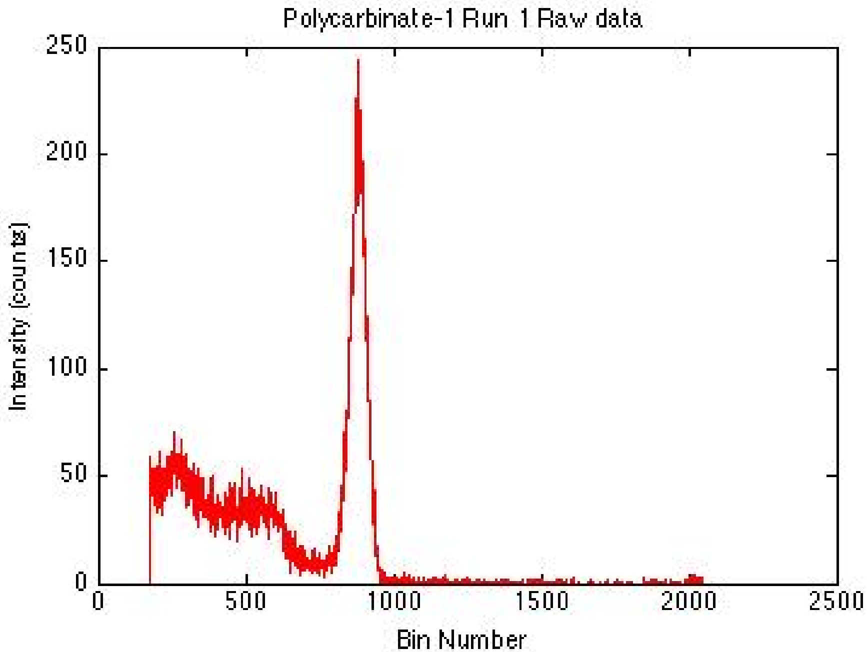
Plastic Material Used

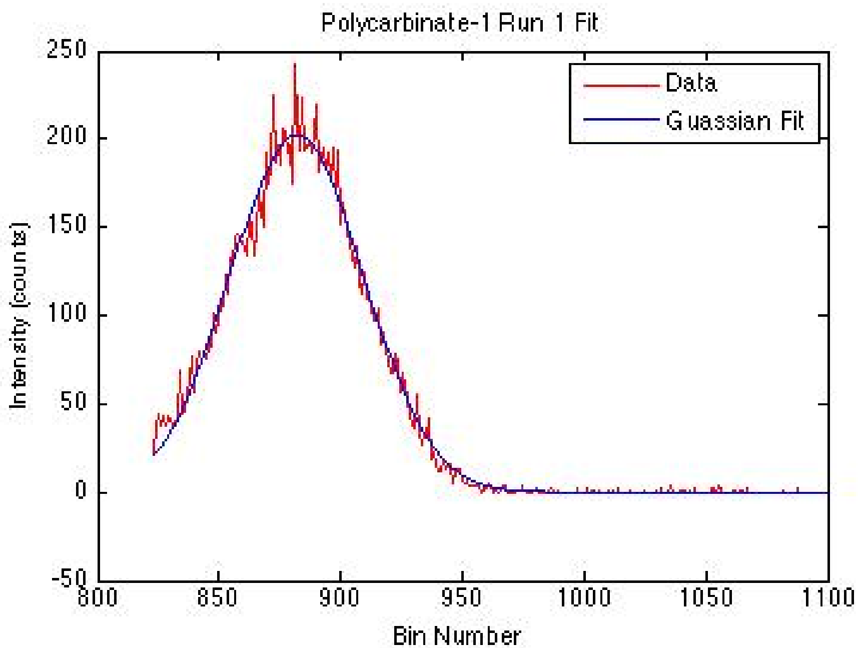
Material	Chem Formula	Color	Density
Polycarbonate	$C_{16}H_{14}O_3$	Clear	$1.20\ g/cm^3$
Polyproylene	$(C_3H_6)_x$	White	$0.855\ g/cm^3$
Polyvinyltoluene	$C_{10}H_{11}$	Cream/Yellow	$1.03\ g/cm^3$

- 4 thicknesses for each material
- 5 runs at each thickness



Finding Intensity Ratio

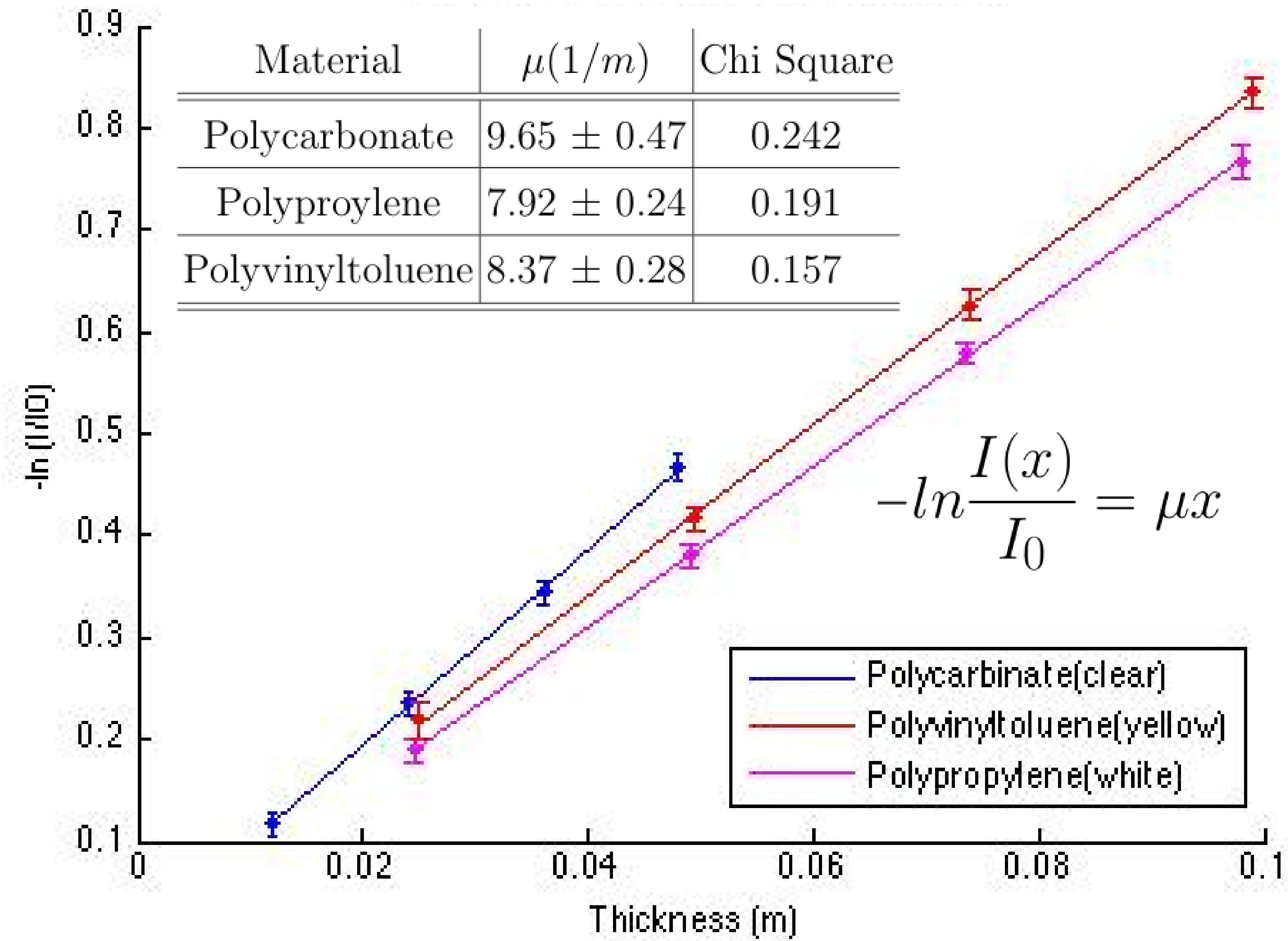




1. Fit to Gaussian to each run
2. Summed counts within 2 sigma = intensity
3. Averaged the 5 intensities
   - Std was the error in the intensity

- Initial intensity-no scattering block

Linear Attenuation Coefficients-Plastics



Material	$\mu(1/m)$	Chi Square
Polycarbonate	9.65 ± 0.47	0.242
Polyproylene	7.92 ± 0.24	0.191
Polyvinyltoluene	8.37 ± 0.28	0.157

$$-ln\frac{I(x)}{I_0} = \mu x$$

Compton Scattering Cross Section

$$\sigma_e = \frac{\mu}{n_e}$$

σ_e= Compton scattering cross section

μ= linear attenuation coefficent

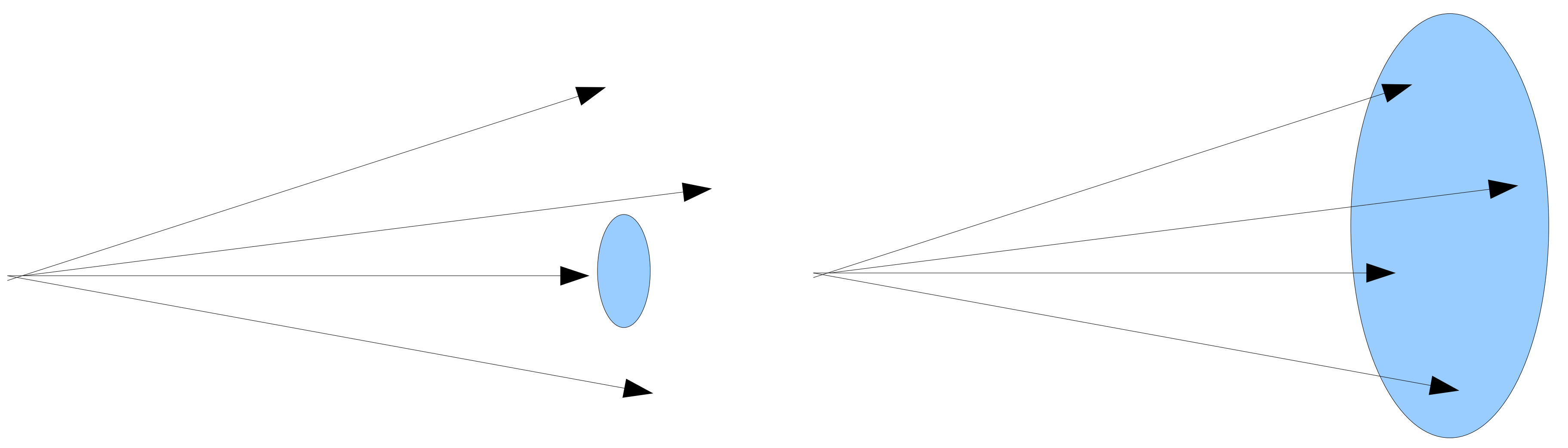
n_e=number of electrons/cm^3 $= \rho \frac{N_a}{A} Z$

Material	σ_e (cm$^2 \times 10^{-25}$)
Polycarbonate	2.49 ± 0.12
Polyproylene	2.70 ± 0.08
Polyvinyltoluene	2.49 ± 0.08

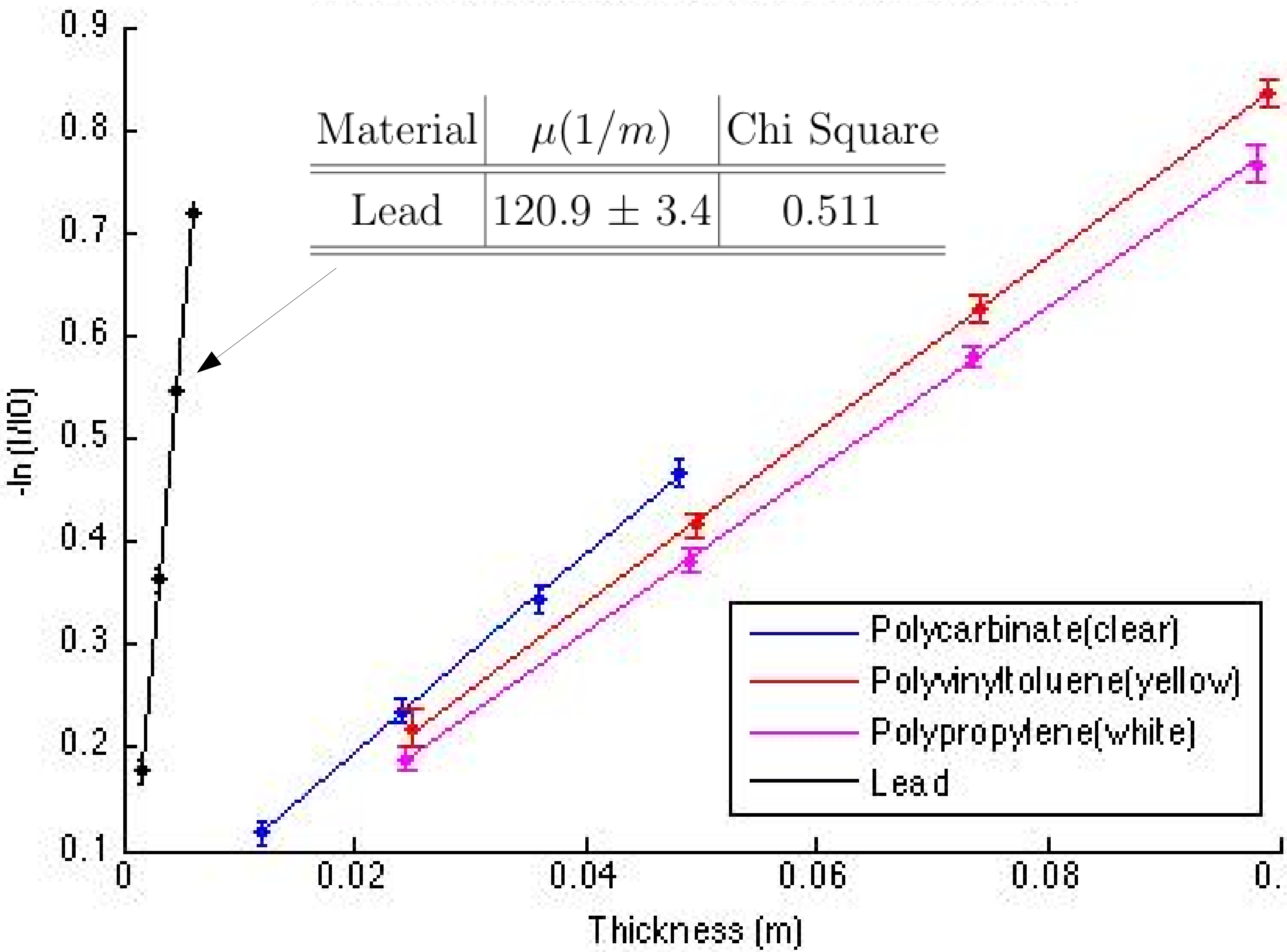
Model	σ_e (cm$^2 \times 10^{-25}$)
Thompson	6.652
Klein-Nishina	2.53
Data	2.57 ± 0.05

Error

- Approximated background noise as constant
- Approximated detector as a point (small)
  - Measure intensity too high for our model
  - Would lower the intensity ratio → mu → sigma



Bonus Round: Linear Attenuation Lead



Material	$\mu(1/m)$	Chi Square
Lead	120.9 ± 3.4	0.511

How Well is the Howitzer Shielded?

$$\frac{I(lead, x = 2.00cm)}{I_0} = e^{-\mu x} = 8.9\%$$

Material	Thickness (cm)	Intensity Percent Remaining
Howitzer	2.00	8.91%
Thin Pb block in lab	2.50	4.87%
2 Pb blocks	5.00	2.37%
Howitzer with 2 blocks	7.00	2.11%

Summary

Material	$\mu(1/m)$	σ_e (cm$^2 \times 10^{-25}$)
Polycarbonate	9.65 ± 0.47	2.49 ± 0.12
Polyproylene	7.92 ± 0.24	2.70 ± 0.08
Polyvinyltoluene	8.37 ± 0.28	2.49 ± 0.08
Lead	120.9 ± 3.4	n/a

Model	σ_e (cm$^2 \times 10^{-25}$)
Thompson	6.652
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- Linear Attenuation Coefficients - 4 materials
- Compton Scattering cross section for electron
  - within 1 std of Klein-Nishina
- Linear attenuation of lead 10 times more than plastic