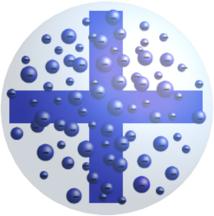
Rutherford Scattering Detection through Gold Foil

Henry Shackleton

April 26, 2017

Plum Pudding and Rutherford Models Predict Different Scattering Behavior



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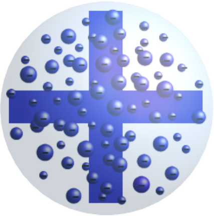

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- Small electrons in a "soup" of positive charge

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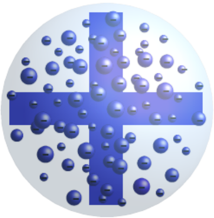

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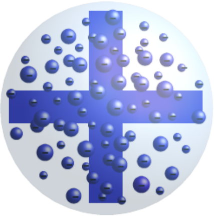

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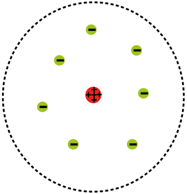

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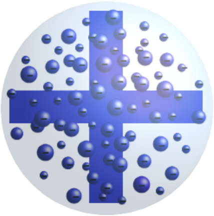

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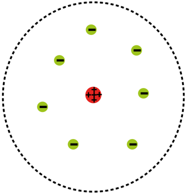

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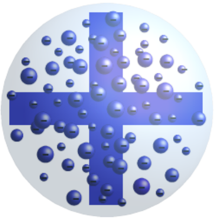

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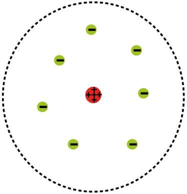


Rutherford Model

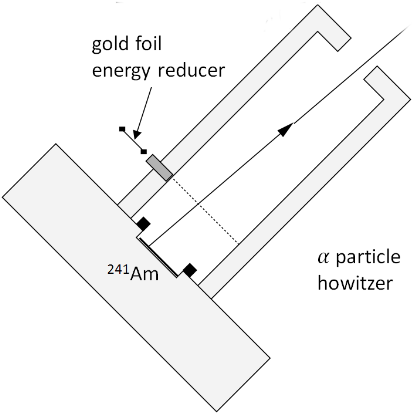
- Electrons surround a concentrated positive charge
- Allows for large scattering angles

Rutherford Scattering Derives from Coulumb Interactions

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = \left(\frac{ZZ'e^2}{4E}\right)^2 \frac{1}{\sin^4(\theta/2)}$$

- Differential cross section describes probability of scattering at angle θ.
- Translation to observable trends requires consideration of flux, area density, etc., but does not affect θ-dependence.
- Equation only describes *single* scattering events.

Apparatus allows for scattering detection at various angles



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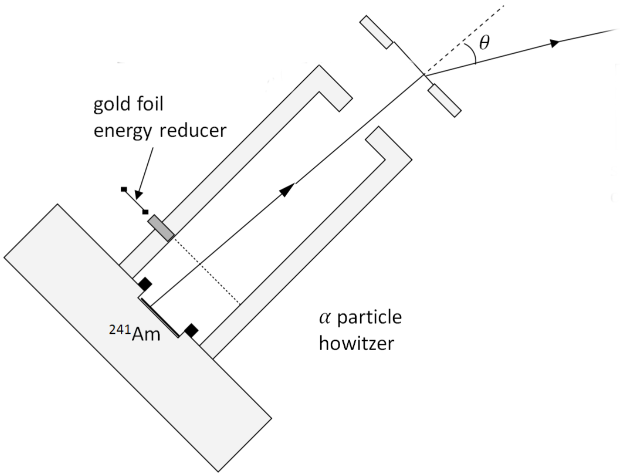

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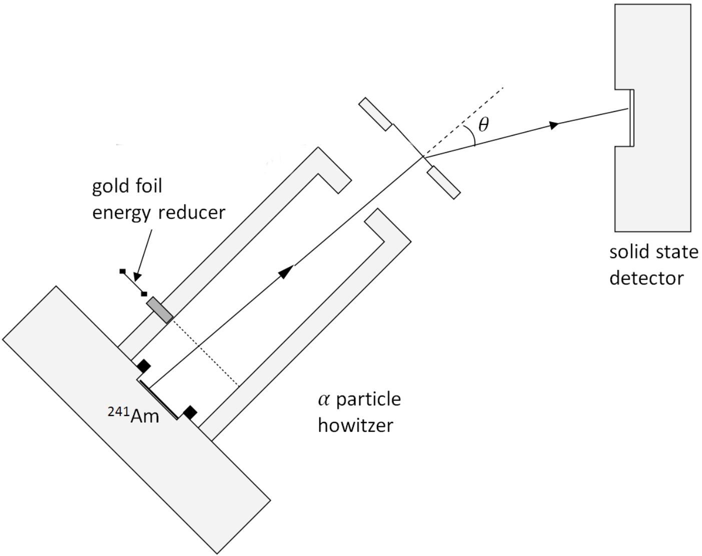

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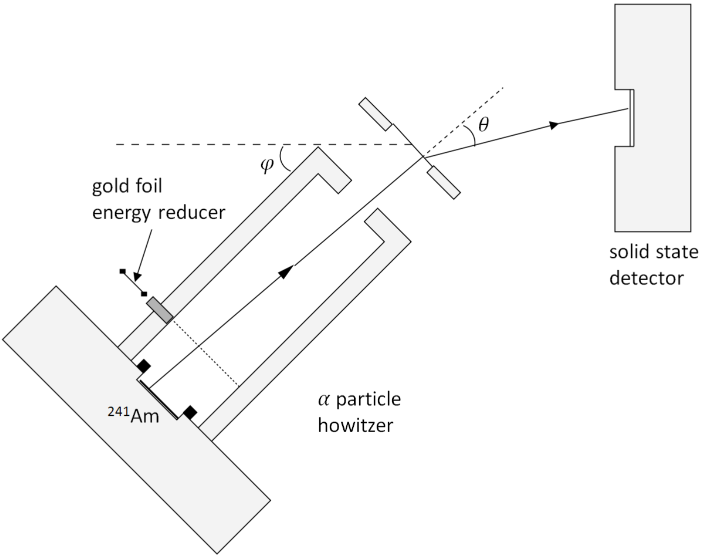

Convolution of Angular Resolution Corrects for Beam/Detector Width

- With the howitzer at an angle ϕ, what is the probability of detecting a particle scattered between θ and $\theta + \mathrm{d}\theta$?

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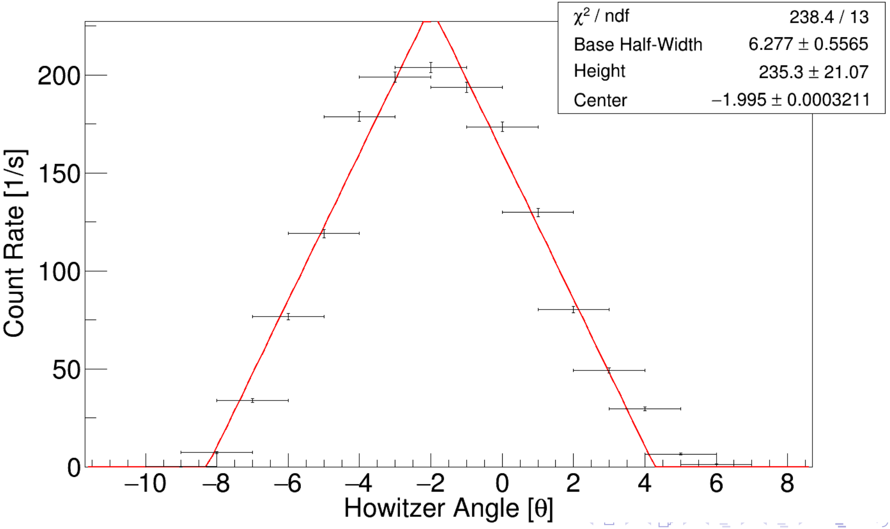
- Ideally, $P(\theta) = \delta(\theta - \phi)$.
- Realistically, we expect roughly a triangle-shaped distribution.

Beam Profile Indicates Both Angular Spread and Systematic Angular Offset



Convolving Beam Profile with Predicted Counting Rates Accounts for

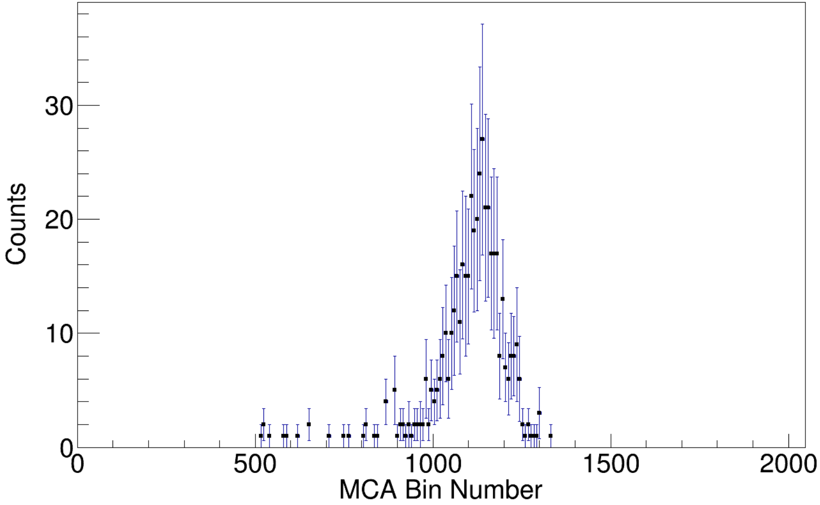
Rutherford

$$C_r(\phi) = C_{r,0} \int_0^{\pi} g(\phi, \theta) \sin^{-4}(\theta/2) \, \mathrm{d}\theta$$

Thomson

$$C_t(\phi) = C_{t,0} \int_0^{\pi} g(\phi, \theta) e^{-\frac{\theta^2}{\theta_0^2}} \, \mathrm{d}\theta$$

MCA Readout Centered Around Energy Range



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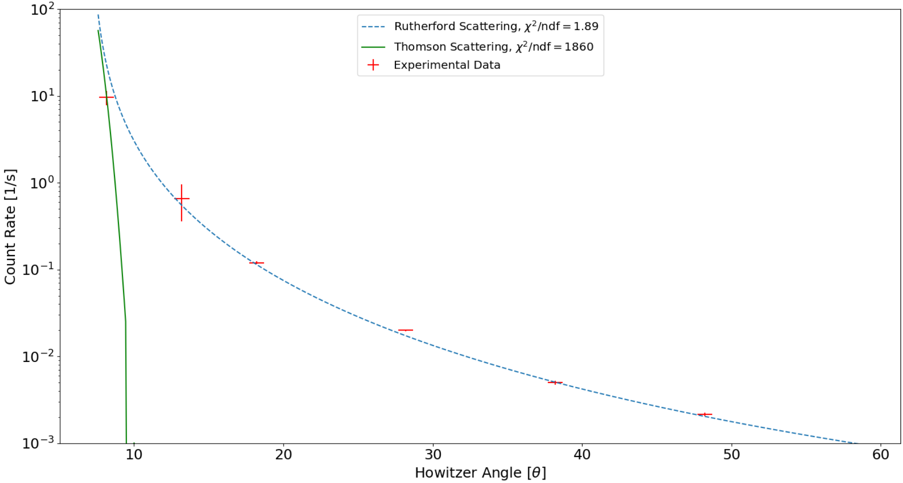
Angular Uncertainty

- Protractor read by eye contributes ± 1 degree uncertainty to angular measurements

Rutherford Scattering Effectively Predicts High-Angle Scattering



Uncertainty in Convolution Contributes Small Uncertainty in χ^2/ndf

Model	χ^2/ndf
Rutherford	1.89 ± 0.11
Thomson	1858 ± 24