

# Rutherford scattering:

## Angular dependence of the scattering rate

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# Topics to be discussed

## 1. Introduction

1. Historical context
2. Atomic structure and differential cross-section

## 2. Experimental setup

## 3. Analysis and results

1. Interpretation of MCA histogram
2. Angular spread of the  $\alpha$ -particle beam
3. Rutherford vs. Thomson model

## 4. Sources of error

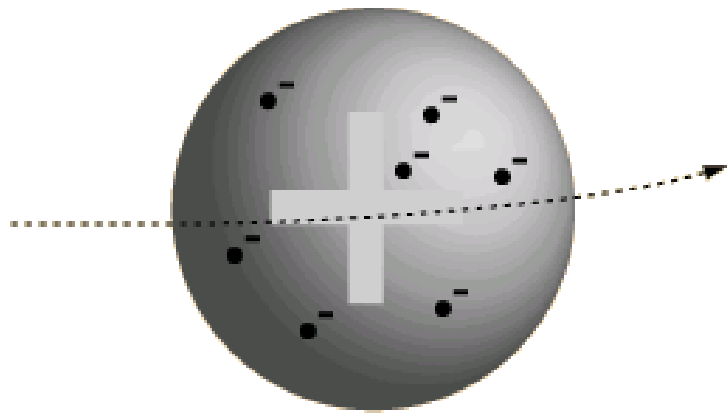
## 5. Conclusion

1. Verification of the Rutherford hypothesis

# Context of our experiment in 1909

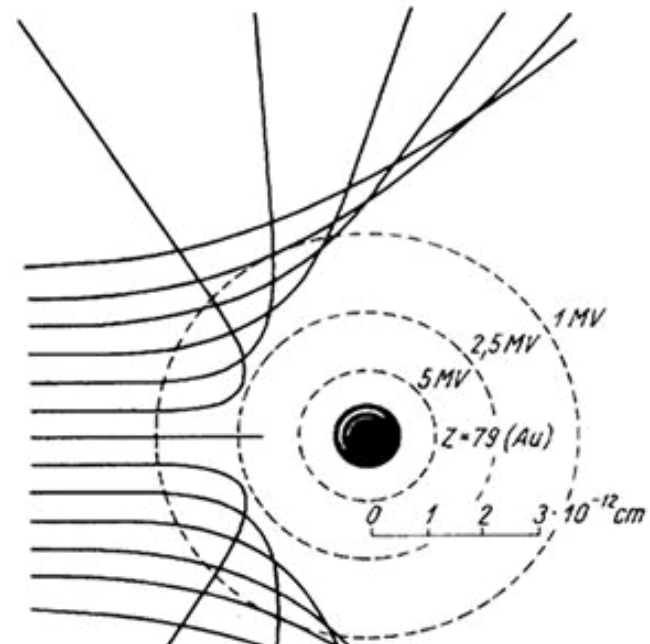
- Discovery of the electron. Properties:
  - Negatively charged
  - Subatomic mass
- **Question: What is the structure of the compensating positive charge?**
- Prominent diffuse-charge model by Thomson
- **Idea: Use scattering experiments to probe the atomic structure.**

# What is the relationship between scattering and atomic structure?



Thomson scattering

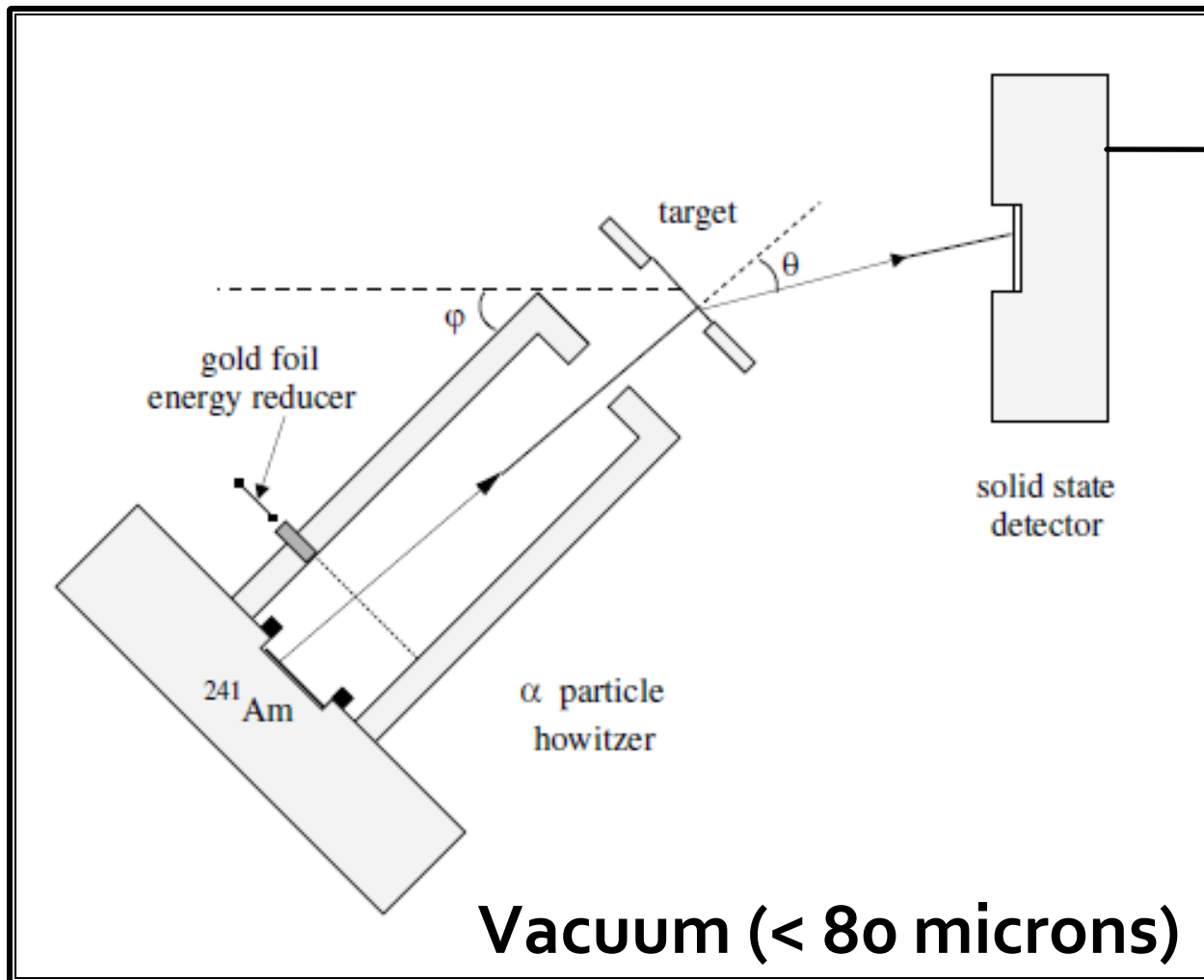
$$\frac{d\sigma}{d\Omega} \sim \exp\left(-\left(\frac{\phi}{\phi_0}\right)^2\right)$$



Rutherford scattering

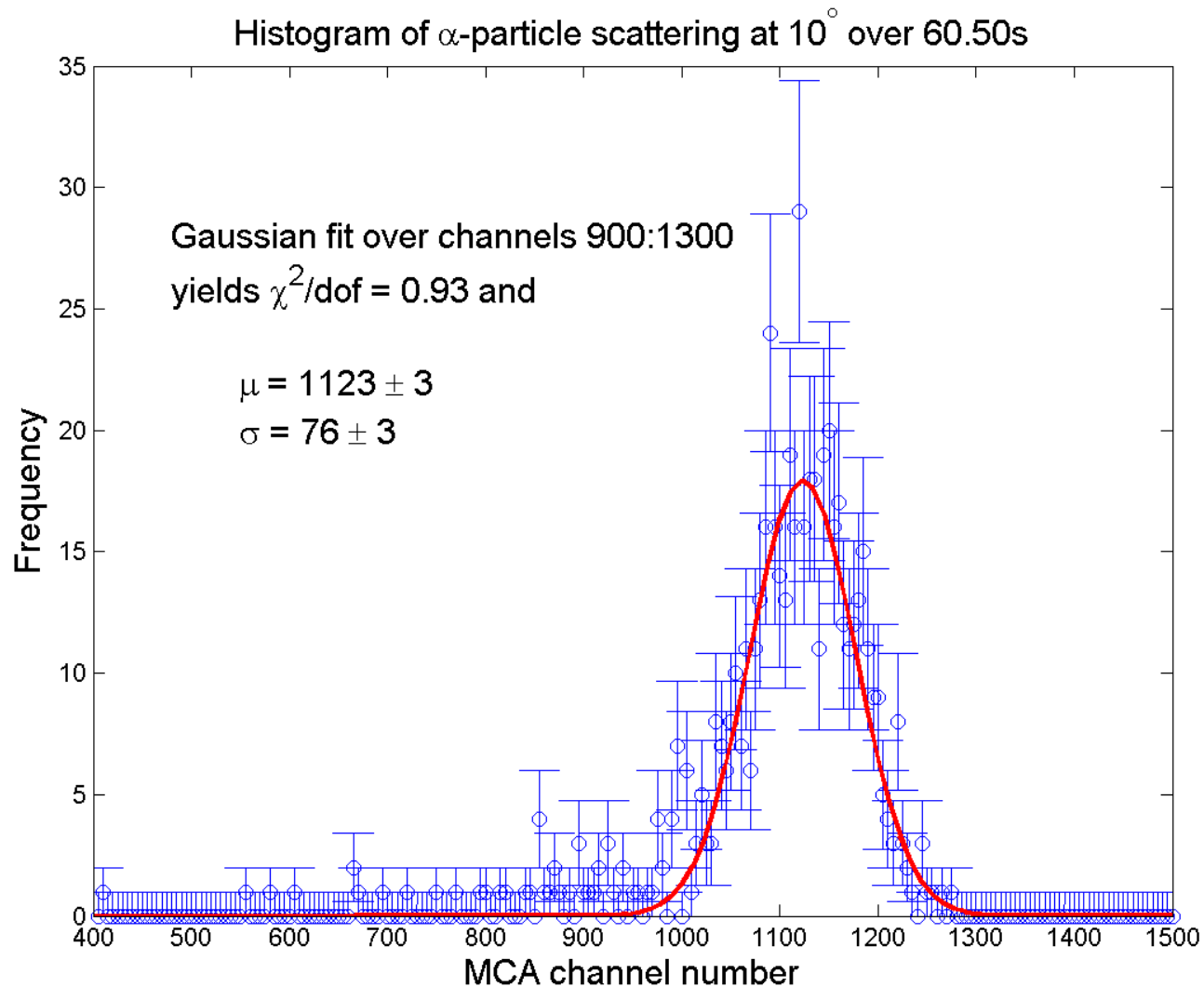
$$\frac{d\sigma}{d\Omega} \sim \sin^{-4}\left(\frac{\phi}{2}\right)$$

# Experimental setup

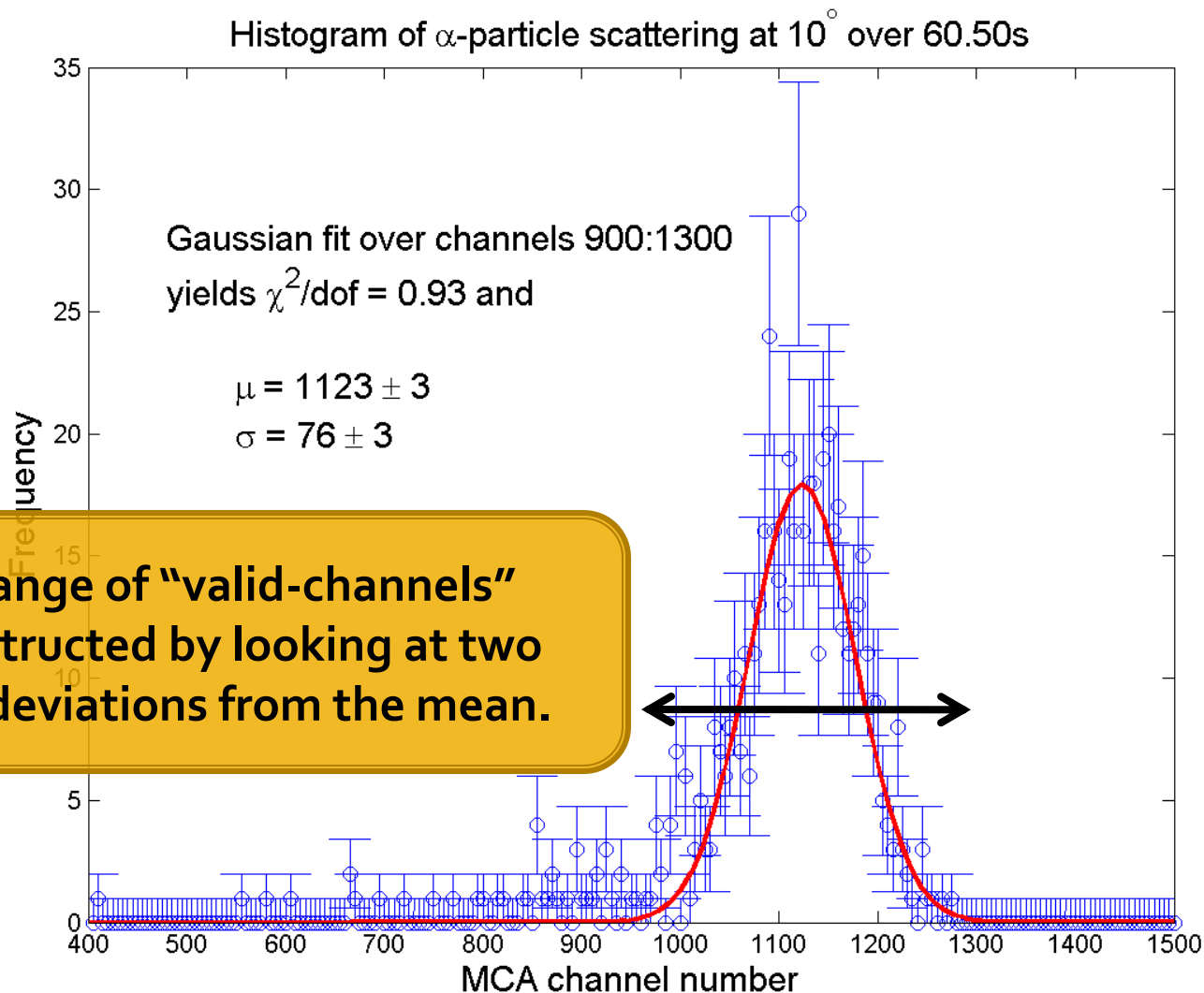


**MCA provides  
counts over energy**

# Typical data obtained from MCA

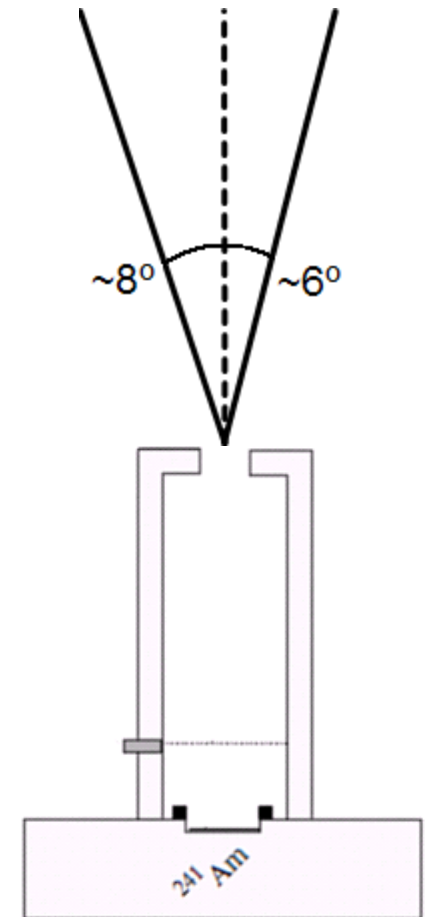
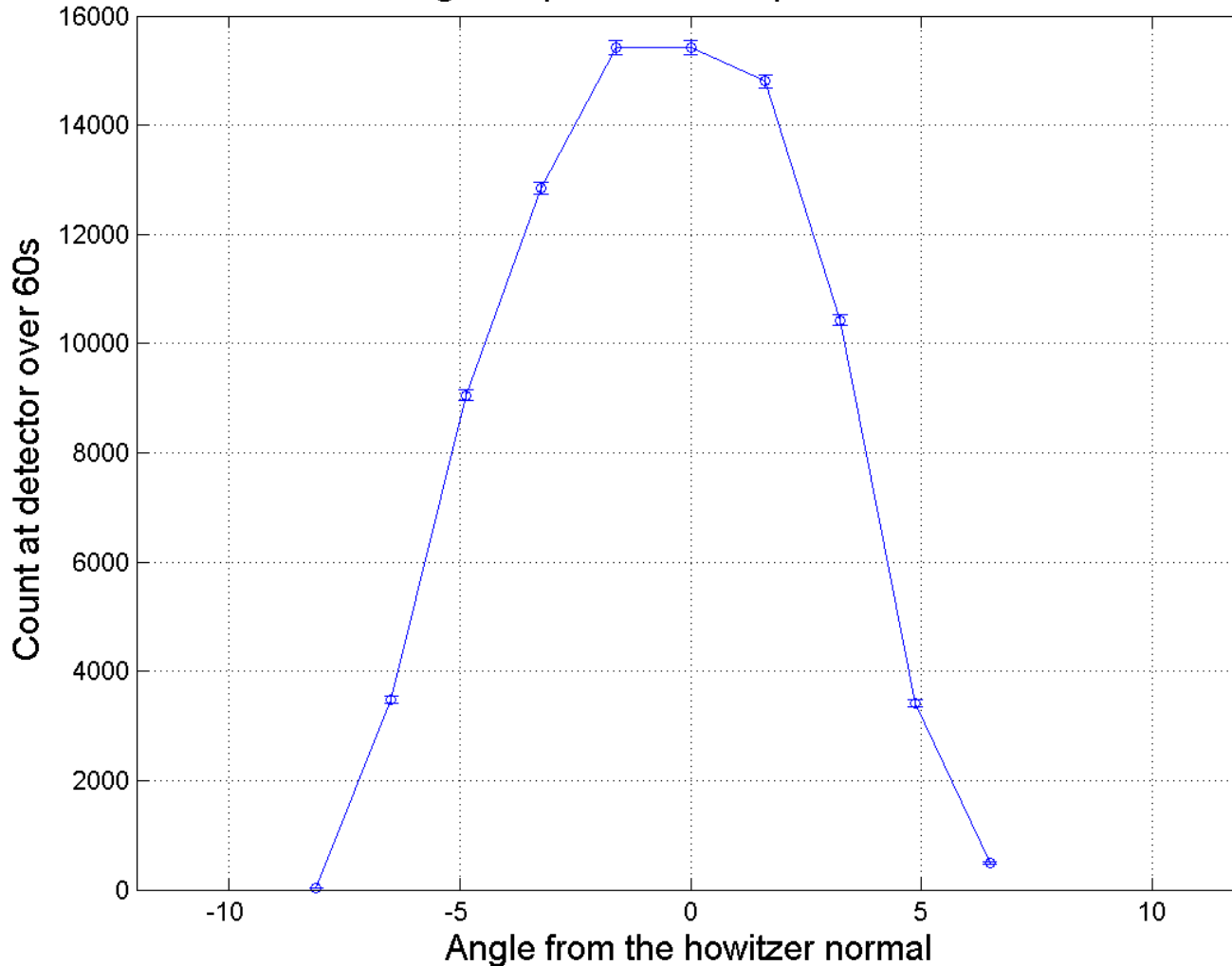


# Typical data obtained from MCA



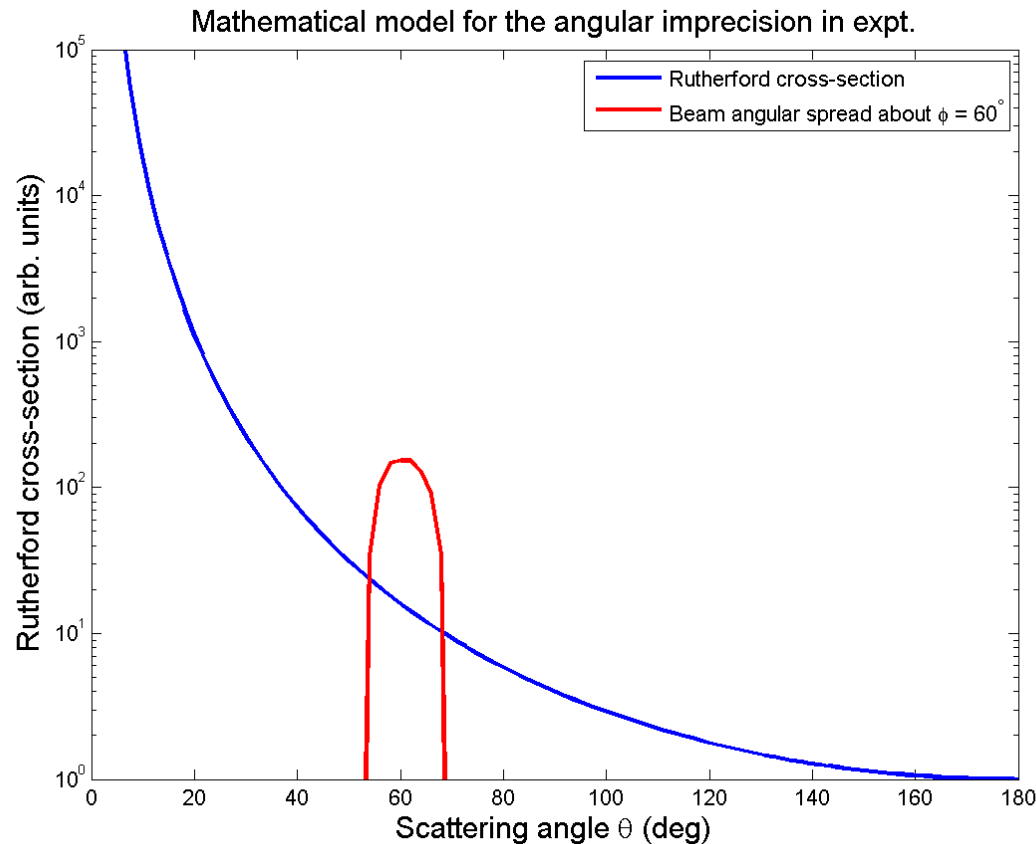
# Apparatus has poor angular resolution

Angular spread of the  $\alpha$ -particle beam



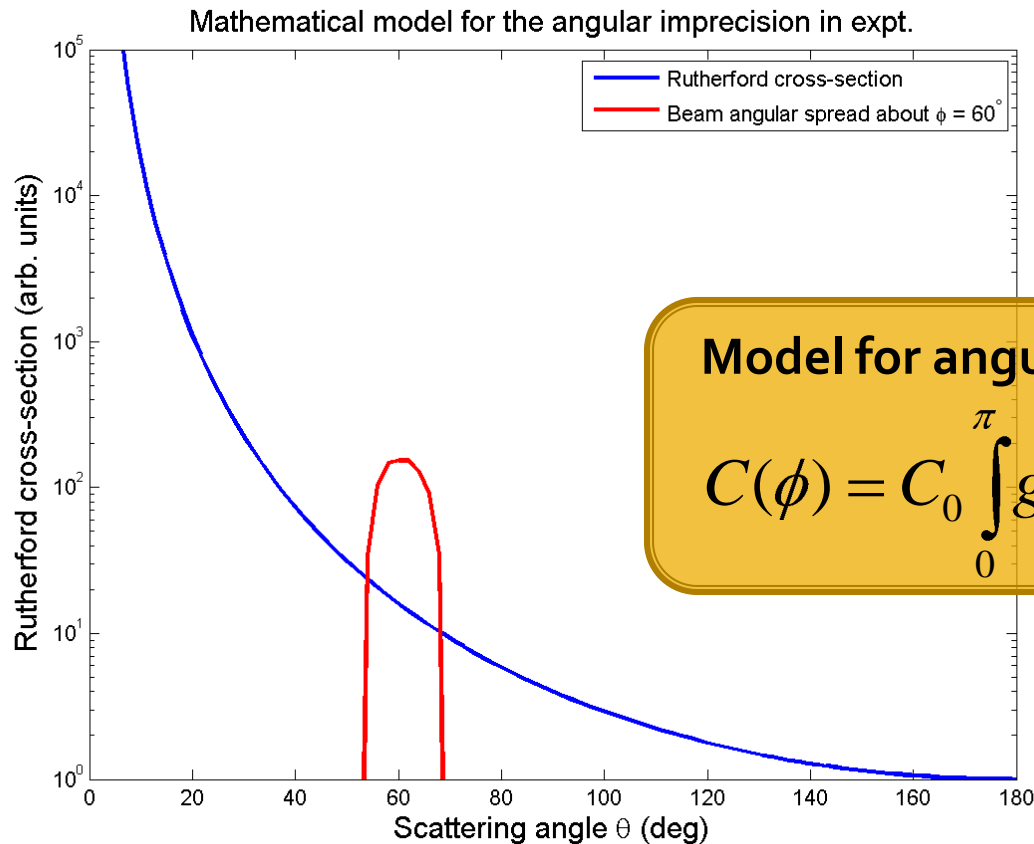
# Need to “smear” the cross-section

- At any howitzer angle, range of scattering angles possible.



# Need to “smear” the cross-section

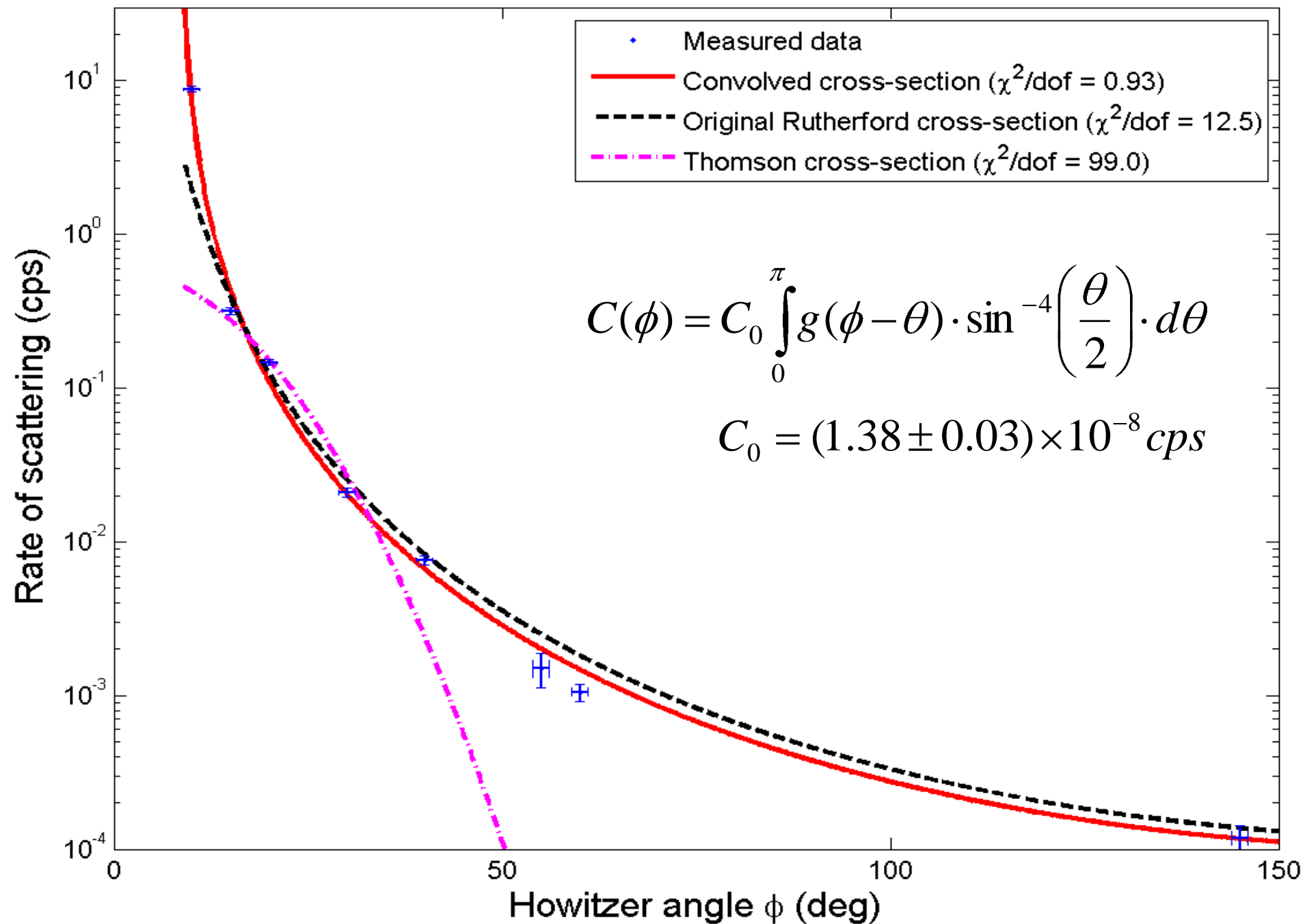
- At any howitzer angle, range of scattering angles possible.



Model for angular imprecision:

$$C(\phi) = C_0 \int_0^\pi g(\phi - \theta) \cdot \sin^{-4}\left(\frac{\theta}{2}\right) \cdot d\theta$$

# Angular dependence of the $\alpha$ -particle scattering rate



# Inaccuracy in howitzer angle

- Can dramatically improve expt. by increasing the accuracy of howitzer angle.

TABLE I: Percentage of the total error due to the uncertainty in the howitzer angle  $\phi$

Angle	Percentage	Angle	Percentage
10°	96.1%	40°	58.0%
15°	89.4%	55°	23.9%
20°	80.1%	60°	50.7%
30°	67.2%	145°	18.4%

# Conclusions

- Performed  $\alpha$ -particle scattering from gold foils.
- Excellent agreement to Rutherford cross section.
  - Obtained ( $\chi^2/\text{dof} = 0.95$ )  $\rightarrow \chi^2$  prob. = 0.4662
  - 26 instances of back-scattering at 145 degrees.
- Thomson model is completely rejected.
  - Obtained ( $\chi^2/\text{dof} = 99$ )  $\rightarrow \chi^2$  prob. = 0!

**Verification of the nuclear hypothesis**

# Sources of various images

- Thomson scattering (slide 4): <http://hyperphysics.phy-astr.gsu.edu/hbase/Nuclear/rutsca3.html>
- Rutherford scattering (slide 4): <http://www.atomeromu.hu/tortenelem/kepek/rutherford-e.jpg>
- Apparatus (slide 5): <http://web.mit.edu/8.13/www/15.shtml>
- PC Icon (slide 5): <http://grafikdesign.files.wordpress.com/2007/10/desktop-20pc-2oicon.jpg>