Rutherford's Nuclear Model

- Before we discuss energy levels of atom \( \Rightarrow \) line spectra we need to have a clear picture of the atom.
  - J.J. Thompson's "plumb pudding" model
    - modes of vibration \( \Rightarrow \) atomic spectra?
      - like a vibrating drumhead. frequencies?
    - No!
  - Ernest Rutherford - nuclear model.
    - discovered \( \alpha \), \( \beta \), \( \gamma \) radiation from uranium
      \( \text{He}^2e^- \) also \( \alpha \) = photon e high energy
      \( \frac{q}{m} \) = half of the proton \( \Rightarrow \) showed \( \alpha = \text{He}^2 \)
    - brilliant idea to use \( \alpha \) as a probe
      "bread and butter" of nuclear physics.
    - size of atom: \( N_A = 6.02 \times 10^{23} \text{mol} \) \( \rho = 1 \text{g/cm}^3 \)
      \( A = 1 \text{g/mol} \)
      \( n = \frac{m}{M} \times \frac{1}{n} \times \frac{1}{A} \times \frac{1}{\text{cm}^3} \)
      \( l = 1.2 \times 10^{-10} \text{m} \)
- Example scattering "particle" experiment.
  \( \sigma \) = "cross-sectional area"
  - of a single target
  - not physical area, but area of interaction.
  - can't be observed directly
  - "Monte Carlo"
- counting statistics \( N \pm \sqrt{N} \)

- What do we know?
  - density \( n_t = \frac{\text{# of}}{l \times h \times t} = \frac{\#}{A} = \text{cm}^{-2} \)
  - beam current \( I_o = \# \text{ of } \times \frac{1}{\text{time}} = \text{A} \)
  - detector rate \( N = \# \text{ of } \times \frac{1}{\text{time}} \)
- total (absorption) cross-section
  \( \sigma = \frac{\text{detector rate}}{\text{luminosity}} = \frac{N}{I_o \times n_t} \text{ i.e. } \# \text{ of } \times \frac{1}{\text{hit}} = \frac{\# \text{ hit}}{\# \text{ thrown.} \}
Differential Cross section

- can we do better?
  - yes, we can measure the "force law" by scattering

- how do we measure $dN$?

- what shape of detector do you need?
  - can't "aim" at target, can't measure $b$ directly.

- how does $dN$ or $\frac{d\sigma}{d\Omega}$ relate to the force law?
  - look at trajectory to determine function $b(\theta)$.

- example - hard sphere scattering, radius $a$

  $2\phi + \Theta = 180^\circ$
  $b = a \sin \phi$

- Rutherford cross section

  $b = \frac{k_e q u Q}{m u v^2} \cot \Theta \frac{r^2}{2}$

  - verified by Geiger & Marsden