HAMP 1252

Physics 56400 - Introduction to Elementary Particle Physics - Part I.

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Office: PHYS 378
Office hours: Whenever - try your luck!

Text: Bettini, 2nd ed.
(Other editions are fine)

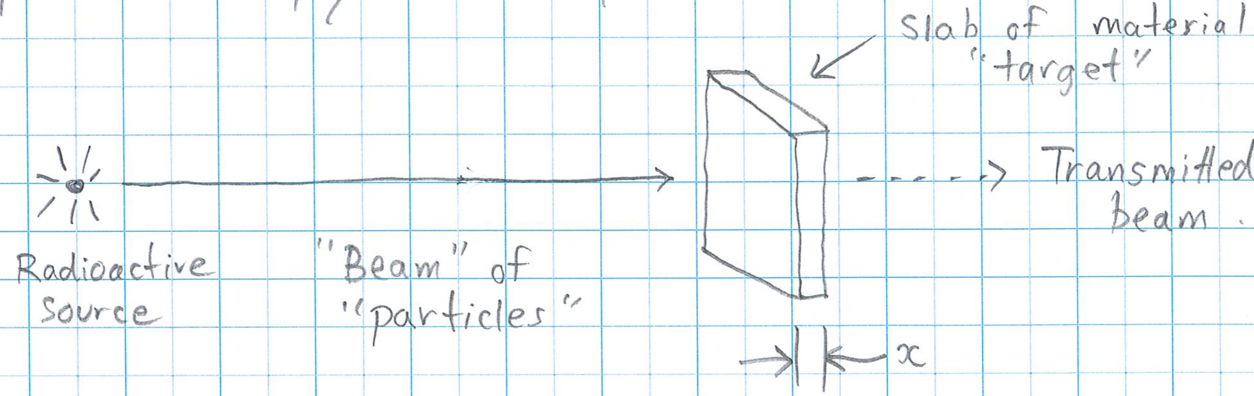
Other resources:

Web page: http://www.physics.purdue.edu/...
.../~mjones/phys56400/

Particle Data Group: http://pdg.lbl.gov

Order your free particle data booklet today!

Lets start by considering some very simple particle physics experiments.




The probability that a beam particle interacts with the target material as it traverses a slab of thickness $dx$ is

$$P(x) = \frac{dx}{\lambda}$$ Independent of $x$!

Number of beam particles absorbed from $x$ to $x+dx$:

$$dN = -N(x)\frac{dx}{\lambda}$$

$$\frac{dN}{N} = -\frac{dx}{\lambda}$$

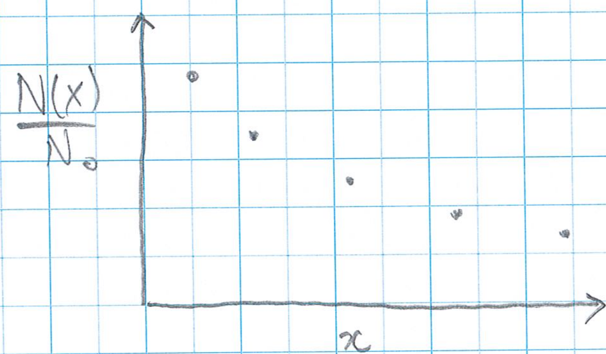
$$\log N(x) = -\frac{x}{\lambda} + k.$$

$$N(x) = N_0 e^{-x/\lambda}$$

The beam is exponentially attenuated by the target material.

How to measure $\lambda$?

Measure $\frac{N(x)}{N_0}$ for various thicknesses $x$.



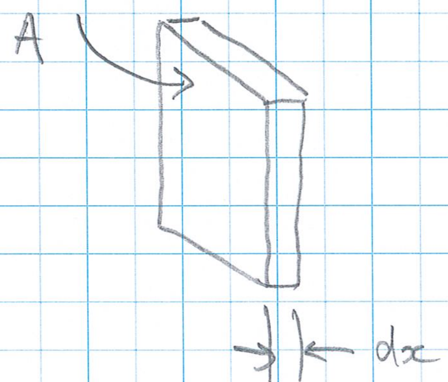

Fit an exponential function, or take $\log(N(x)/N_0)$ and fit a straight line.

What properties of the material determine the value of $\lambda$?

We need to introduce a model for the interactions of beam and target particles.

Simple model: If a beam particle hits a target particle, it will "go away".
Assume target particles are spheres of radius $R$. Assume beam particles are point-like.

How many target particles per unit area in a thin slice of material?




Volume $V = A\,dx$
Density $\rho$ (mass per unit volume)
Atomic mass $m$ (grams per mole)

Number of target particles:

$$N_T = N_A \frac{\rho}{m} V = N_A \frac{\rho}{m} A\,dx$$

Number of target particles per unit area:

$$\frac{N_T}{A} = \frac{N_A \rho}{m} dx$$

Probability of hitting a target particle:

$$P = \frac{N_T}{A} \cdot \pi R^2 = \frac{N_A \rho}{m} \cdot \pi R^2\,dx$$

But this is just $P(x) = \frac{dx}{\lambda}$

$$\frac{1}{\lambda} = \frac{N_A \rho}{m} \pi R^2$$

$$\lambda = \frac{m}{N_A \rho \cdot \pi R^2}$$

In practice, it is common to normalize $\lambda$:

$$\lambda_I = \lambda \rho \qquad (\text{units } g/cm^2)$$

Nuclear interaction length.

$$\lambda_I = \frac{m}{N_A \pi R^2}$$

Does this make sense?

Simple nuclear model assumes uniform nuclear mass density.

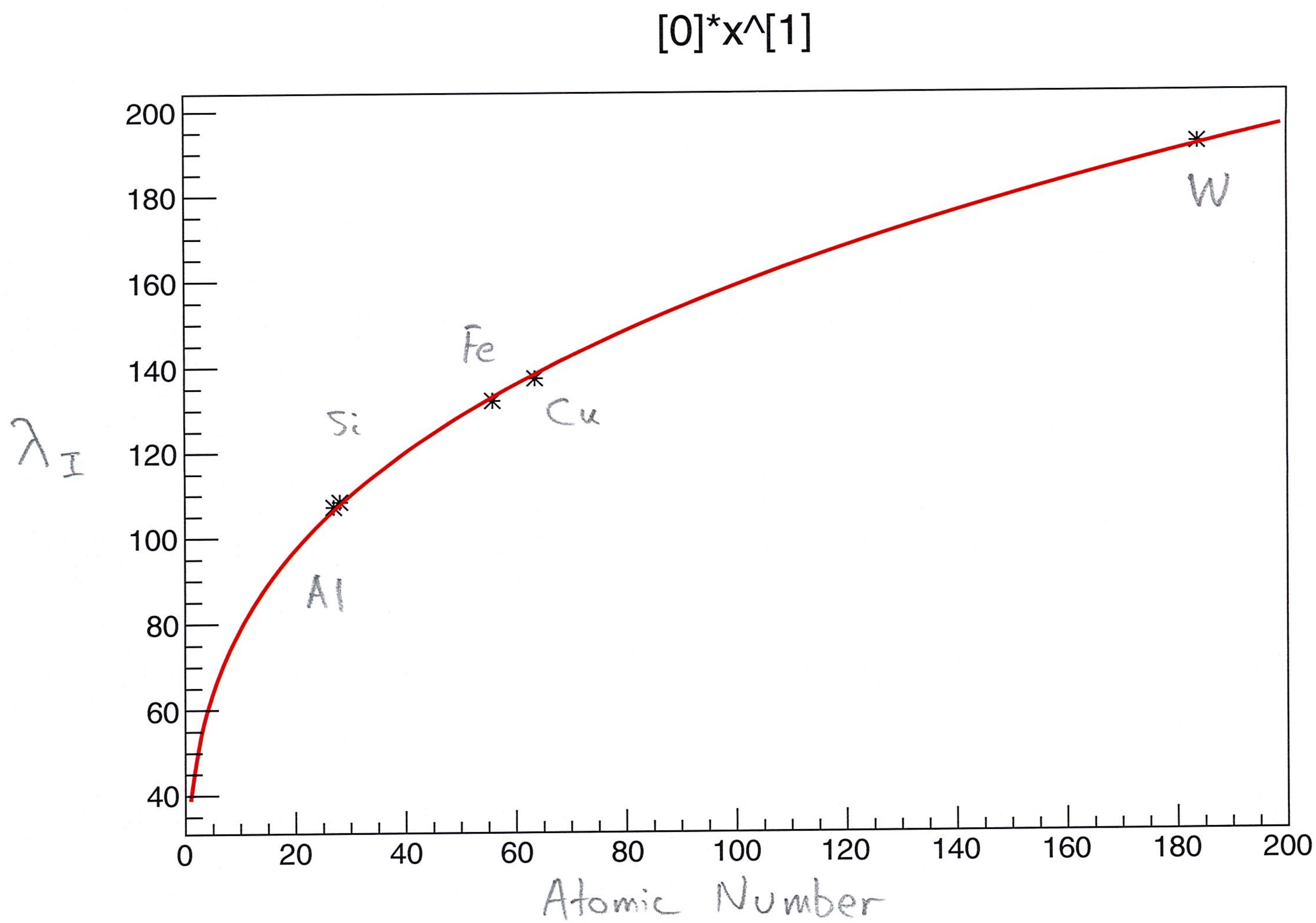
So $m \propto A$ (atomic number)

$V \propto A$

$R \propto \sqrt[3]{A}$

So $\lambda_I \propto \frac{A}{A^{2/3}} \sim A^{1/3}$

Can we estimate the size of a nucleon?




$$\lambda_I = KA^{\alpha}$$

$K = 39 \ g/cm^2$

$\alpha = 0.31$