Physics 225a Problem Set 1

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due Wednesday, Jan. 14 in class

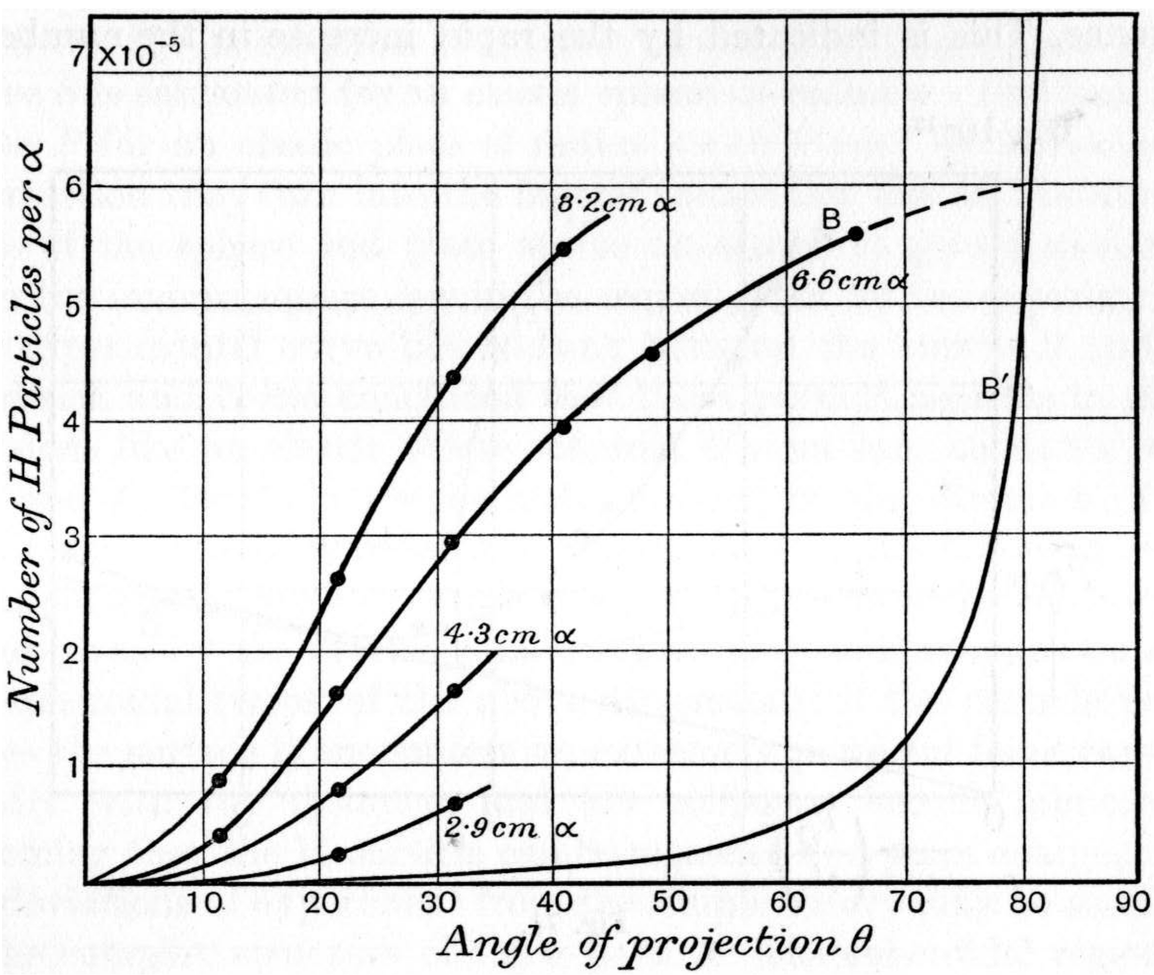

Figure 1: The Rutherford Group's original data that lead to the deduction of the existence of the strong interaction. We discussed the geometry in class... the rate for all recoil protons scattered at an angle of θ or less with respect to the original α-particle direction is plotted along the vertical, and θ is along the horizontal. Curve B' is the expectation for pure electromagnetic scattering. The different ranges in air of the α-particles used are noted.

1. The plot in Fig. 1 was discussed in class. Various curves are labeled by the range of the projectile α-particles in air; the speed with respect to the speed of light, β, is then:

$$\beta(R) = 0.0335 \times R^{1/3}$$

Use the data for the four experimental curves (accept the draftmen's interpolation between data points!) to replot these data as a function of momentum transfer, q. You'll definitely have to do a little 2-body kinematics to deduce q from θ and the other given quantities... there is an extremely simple relationship. You might have to take a derivative... why or why not? Now to get the data off the plot, you might want to try `www.datathief.org`... a .jpg of the plot is on the 225b website. You'll want to give yourself an hour or two to get used to datathief.

On your plot, also make a plot that shows the expected shape from point-source Coulomb scattering.

2. We've discussed in class that the nuclear size is about $1.2 \times A^{1/3}$ fm. Assume the nucleus is a 'square well' potential, and imagine that the potential between a projectile (I'm thinking a WIMP) and the nuclear 'stuff' is a δ-function. Then the transition amplitude for WIMP-nucleus scattering (in the limit of an infinitely heavy nucleus) is very straightforward. Evaluate that amplitude for Silicon ($A = 28$) and Xenon ($A = 132$), and plot these two amplitudes with a common momentum-transfer axis, in, say, MeV/c. Make the horizontal axis long enough that you can see two minima. Real WIMPs, if they constitute the dark matter, are thought to have a mass of about $100\,\mathrm{GeV/c^2}$, and a velocity of about $300\,\mathrm{km/s}$. Assuming that the nucleus is infinitely heavy, indicate the range of momentum transfers that WIMPs are thought to undergo.
