16.2: Discovery of the Nucleus

The first significant use of scattering to learn about the internal structure of matter was Rutherford's use of α particles directed at gold atoms. This experiment revealed the atomic nucleus for the first time. Our plan here is to analyze this kind of scattering, to understand why it indicated the presence of a nucleus. Similar much later analyses have established that the proton itself has point like constituents, so this is not just of distant historical interest.

For α particles on gold atoms, it's an excellent approximation to take the scatterer as being fixed. This is not an essential requirement, but it simplifies the calculation, and can be corrected for later.

To visualize what's going on, think of the scatterer as a bowling ball with tiny marbles directed towards it, they're moving fast horizontally, along parallel but random paths. (Let's take zero gravity here—the α particles we're modeling are moving at about one-twentieth the speed of light!). We observe the rate at which marbles are being scattered in various directions. Call the **scattering angle** χ.

So, let's assume the width of the "beam" of marbles is much greater than the size of the bowling ball. We'll also take the intensity of the beam to be uniform, with n marbles crossing unit area perpendicular to the beam per second. Now, if the bowling ball has radius R, and we ignore the radius of the tiny marbles, the number of marbles that strike the bowling ball and are scattered is clearly $\pi R^2 n$ per second. Not surprisingly, πR^2 is called the *total cross-section* and usually denoted by σ.