Escape Fraction of Neutrons and Alpha Particles Through Nuclear Shielding

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1. Introduction

We simulate the effectiveness of different thicknesses of nuclear shielding for two different particles: neutrons and alpha particles. Understanding of this is extremely important, especially with the rise of investment in nuclear infrastructure by companies looking to power their data centers.

2. Methods

2.1. Neutrons

For the beam of neutrons incident upon the shielding, we started our neutrons out at an x position of 4 units and z position of 0 units. This is a 2-D simulation that only encompasses the x and z directions. Always assume that $y = 0$ units, $\frac{\mathrm{d}y}{\mathrm{d}t} = 0$ units/second, etc. All of the numbers are in arbitrary units that will hereafter be denoted by u. The initial velocity for the neutrons is $v_x = 4$ u/s and $v_z = 0$ u/s. They have and initial mass of 1 umass and initial energy of 1350 uenergy. Neutrons have no net charge or $q = 0$ ucharge.

At every point in the shield, the probability of scattering away from the current direction of velocity was 34%, or a 17% probability of scattering -90^o and a 17% probability of scattering $+90^o$ relative to the current direction of velocity. There will also be energy loss during the scattering events, and if the particle loses enough energy, it will begin to lose velocity. Particles that reach less that $x = 0$ are considered scattered back into the reactor. Particles that lose their energy or velocity while inside the shield are considered captured by the shielding. Particles that make it to $x = D$ are considered to have escaped.

We ran this simulation for shield thicknesses between 5 u and 30 u in increments of 2 u. We tracked 10000 particles using a random walk algorithm to progress through the shield. The path of every particle looked like this:

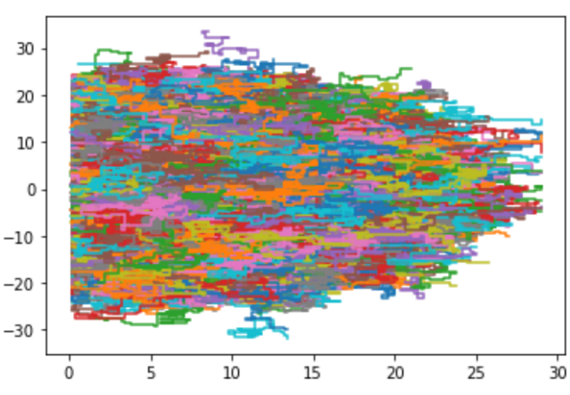

Fig. 1. The x axis represents x position and the y axis represents z position.

We then tracked the number of particles that escaped at different thicknesses and found an $\alpha = -0.181$ for tracking the probability of a neutron penetrating the shield with the function

$P = e^{\alpha D}$. This matches very well with the data as seen below.

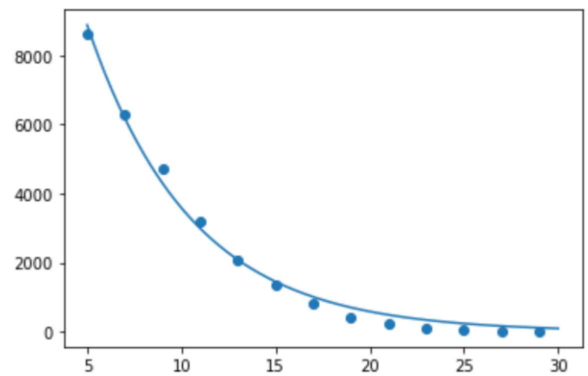

Fig. 2. The x axis represents the shield thickness in u and the y axis represents number of particles escaping out of 10000.

2.2. *Alpha Particles (Helium Nuclei)*

Helium nuclei are charged and thus added an extra scattering element. We also assumed the initial energy of the alpha particles was a normal distribution. Other than that the initial conditions were the same.

We only ran a shield thickness out to 15 u because this was enough to cover the vast majority of the escape fraction for the alpha particles. We ran this simulation for 10000 particles and here is the path every particle took:

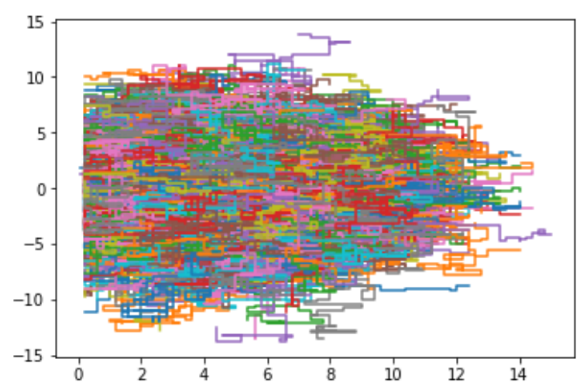

Fig. 3. The x axis represents x position and the y axis represents z position.

We then tracked the number of particles that escaped at different thicknesses and found an $\alpha = -0.875$ for tracking the probability of a neutron penetrating the shield with the function $P = e^{\alpha D}$. This matches very well with the data as seen below.

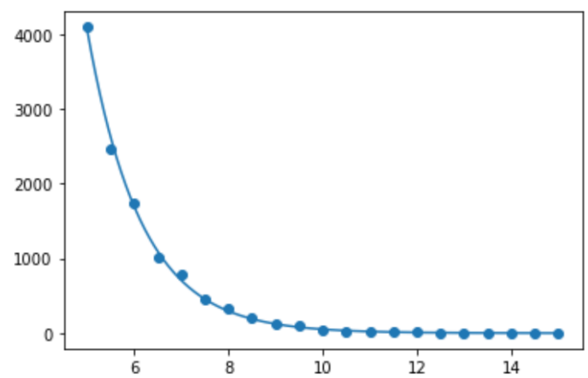

Fig. 4. The x axis represents the shield thickness in u and the y axis represents number of particles escaping out of 10000.