TALENT module:
theory for exploring nuclear reaction experiments

Homework day 3

Elastic scattering and optical model

PART I:

1. Demonstrate that, for a short range interactions, the scattering amplitude can be written as a partial wave sum:

$$f(\theta) = \frac{1}{2ik} \sum_{L=0}^{\infty} (2L+1) P_L(cos\theta)(S_L - 1) \ , \tag{1}$$

   where S_L is the S-matrix.

2. Based on the relation between the scattering amplitude and the cross section, show that the total elastic cross section for neutrons can be written as a partial wave sum:

$$\sigma_{el} = \frac{4\pi}{k^2} \sum_{L=0}^{\infty} (2L+1) sin^2\delta_L \ . \tag{2}$$

PART II:

The scattering of a projectile on a target is often approximated into a two body problem with an effective interaction. This interaction $U_{opt}(R)$, usually referred to as the optical potential, contains an imaginary part that takes into account the removal of flux from the elastic channel into other reaction channels.

Consider the elastic scattering of a proton on a target. We will study the elastic scattering of the proton at two different energies $E_{lab} = 5$ and 50 MeV. For this purpose you should use the code FRESCO available in 'common/bin'.

1. Choose a specific target ($A > 40$) and determine the quantum numbers referring to the entrance partition.

2. Copy the file '/common/inputs/example-el.in' into your directory and modify it according to your specific target.

3. If no nuclear interaction were present, and the target could be considered pointlike, what would be the angular distribution of the scattered proton? What happens when you take into account the finite size of the target?

4. Take a global parameterization of your choice for the nuclear optical potentials and calculate the elastic scattering obtained. Make sure that you are including enough partial waves J_{max} in your calculation and that the maximum radius R_{match} ensures

the asymptotic behaviour. Compare the angular distributions in the centre of mass for the two energies (file fort.16 contains these cross sections ready for plotting with 'xmgr').

5. Explore, specifically, the effect of the imaginary part (for example removing it completely). Compare the modulus of the S-matrix for each partial wave in the two cases.

6. What happens to the distribution if you increase radius parameter? What happens if instead you increase the diffuseness parameter?

7. Repeat the above calculations for neutrons.

8. Calculate the total reaction cross section and the total absorption cross section for the case of neutrons.