TALENT module:
theory for exploring nuclear reaction experiments

Homework day 4

Elastic scattering fitting: determining an optical potential

PART I:

Optical potentials are widely used in reaction calculations. A typical way to pin down the optical parameters is by performing a fit to the elastic scattering at the corresponding energy. In this homework you will perform a fit to the elastic and compare with global optical potentials.

SFRESCO does χ^2 data fitting using the MINUIT subroutine and calling FRESCO in each iteration. You can find in '/common/inputs/example-fit.tar' a tar with several files useful for this homework. It contains a typical input for sfresco (search.in) and also an initial input for fresco (elastic.in). You can also use the script 'sfresco.in' if you do not want to run SFRESCO interactively.

1. For a given target of your choice find proton (and/or neutron) elastic data at an energy in the range E=5-70 MeV. The NNCD database provides an easy access, compilation of reaction data (http://www.nndc.bnl.gov/exfor3/cinda.htm).

2. Use SFRESCO to fit the elastic for this target at the chosen single beam energy. If you do not have a better starting point, take as initial parameters for the effective nuclear interaction: $V_R = 40$ MeV; $r_R = 1.2$ fm; $a_R = 0.6$ fm and a volume imaginary part as $V_I = 40$ MeV; $r_I = 1.2$ fm; $a_I = 0.6$ fm. To begin with, neglect the spin-orbit interaction. Do not start with a six-parameters fit but rather gradually allow for parameter variations.

3. Study the sensitivity of your final optical parameters to the initialization. In particular, analyze the correlation between parameters (parameter covariance matrix).

4. Repeat the procedure of 2. assuming a surface imaginary component instead. Determine which of the parameter sets (volume versus surface) is best pinned down.

5. Add onto your best description so far, the spin-orbit term and perform a new fit. Can you improve the description of the data with this term?

6. Determine the elastic scattering produced with a global optical potential $U_{opt}(R)$ and compare with those you have obtained. Which is the best?

PART II:

1. Taking into account the concepts of Feshback projection, derive the expression for the effective potential between a projectile nucleon and a target nucleus, taking into account the projection onto the allowed space P and considering the effect of the part of the model space left out $Q = 1 - P$:

$$U = V + VQ\frac{1}{E - QHQ}QV \ . \tag{1}$$

2. Show that the scattering amplitude for the pure Coulomb interaction is given by:

$$f(\theta) = -\frac{\eta}{2ksin^2(\theta/2)}exp(-i\eta ln(sin^2(\theta/2)) + 2i\sigma_0(\eta)) \ , \tag{2}$$

   where η is the Sommerfeld parameter and θ is the scattering angle.