A new way to study non-local effects

N. J. Upadhyay,* A. Bhagwat,† and B. K. Jain‡
UM-DAE Centre for Excellence in Basic Sciences, Vidyanagari, Mumbai-400098, India

In potential scattering in nuclear physics, the interaction is non-local in nature [1]. It is normally assumed local, and all the studies, like optical model, are done using such interactions. Investigations to study the non-local effect, per se, are of course done (notably and pioneering amongst them being in early days by Perey and Buck [2]). In these studies, the inhomogeneous scattering equation arising from the use of non-local interaction is solved using the iterative scheme and results on scattering variables are obtained. An equivalent local potential is obtained in gradient approximation from these studies to exhibit the effect of non-locality. This effect is seen in the energy-dependent reduction in the depth of the local potential (see Fig. 1). Due to gradient approximation, nothing could be said on the change in the shape of the local potential. Thus, these studies resulted in a local-energy-equivalent potential, which has a modified energy dependent depth, but unchanged shape.

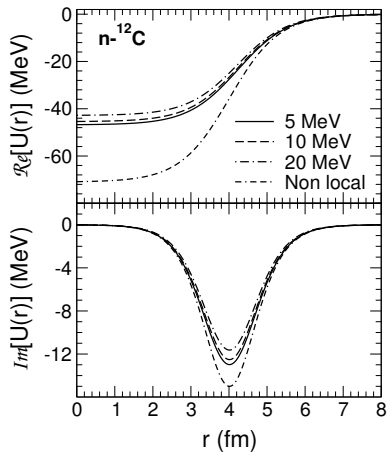

FIG. 1: Equivalent local potential as a function of energy along with non-local interaction given in Ref. [2]. The curves shown are for n-^{12}C system.

In the present study we have developed a method to solve the inhomogeneous non-local equation. The advantage of the method is that it generates a local potential with modified depth as well as shape, but without any approximation. It is energy independent, and as such can be used in the scattering equation to compute various observables. Thus, it does not have the tedious nature of the non-local potential equation to obtain its solution. The local potential thus obtained is partial wave-dependent, which does not introduce any additional difficulty in solving the scattering equation.

The kernel appearing in the non-local equation of the Perey-Buck type is constructed from the non-local potential, $U_{\rm N}(r)$ and normalized Gaussian form factor containing the non-locality for the nucleon-nucleus potential [2]. As a first guess, we write this kernel as

$$\int_0^\infty g_l(r,r')u_l(r')\,dr' \;\approx\; u_l(r)\int_0^\infty g_l(r,r')\,dr'\,, \tag{1}$$

where the observation that $g_l(r,r')$ has its maximum values around r=r' is incorporated. Substituting this in the non-local Schrödinger equation we obtain a homogeneous equation with an equivalent pseudo-potential,

$$U_{\rm mod}(r) \;=\; \int_0^\infty g_l(r,r')\,. \tag{2}$$

This potential in our procedure, of course, depends upon partial wave (l). Using the folding model prescription for $U_{\rm N}(r)$ [3], $U_{\rm mod}(r)$ for l=0, 1 and 2 are plotted in Fig 2.

*Electronic address: neelam.upadhyay@cbs.ac.in
†Electronic address: ameeya@cbs.ac.in
‡Electronic address: brajeshk@gmail.com

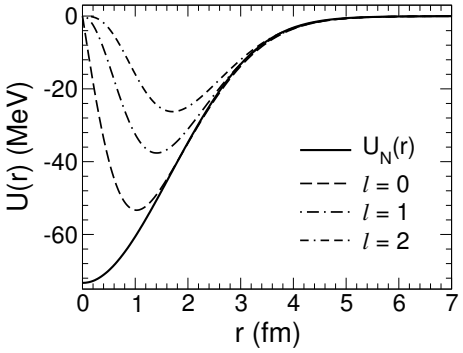

FIG. 2: $U_{\rm mod}(r)$ for l=0, 1 and 2 along with $U_{\rm N}(r)$ using folding model prescription. The curves shown are for n-^{12}C system with non-local range of 0.85 fm.

Compared to $U_{\rm N}(r)$, the depth and the shape of $U_{\rm mod}(r)$ gets altered by the non-locality. The depths compared to the depth of $U_{\rm N}(r)$, which is around 70 MeV, are around 50, 35 and 25 MeV for l=0, 1 and 2 respectively. We find it very interesting that the reduction in the depth of the potential, for example for l=0, compared to $U_{\rm N}(r)$, is very close to that seen in energy equivalent local potential in the work of Ref. [2]. Additionally, while their equivalent potential is energy dependent, ours is energy independent. Our energy dependence, probably is contained, albeit indirectly, in the l-dependence of the $U_{\rm mod}(r)$.

Additionally, our procedure also predicts a change in the shape of the equivalent potential. The peak of $U_{\rm mod}(r)$ is found to be shifted by 1-2 fm. It may be emphasized that this procedure yields a much simpler procedure to treat the non-local effect in the Schrödinger equation. To test the accuracy of the procedure an iterative scheme has been devised. It is found that the proposed scheme based on Eq.(1) alone has a precision of the order 10^{-4}.

References

[1] W. E. Frahn, Il Nuovo Cimento **4**, 313 (1956).
[2] F. Perey and B. Buck, Nucl. Phys. **32**, 253 (1962).
[3] G. R. Satchler and W. G. Love, Phys. Rev. **55**, 183 (1970).