Double folding optical model potentials for weakly bound p-shell nuclei

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In our nuclear astrophysics program we use peripheral proton transfer reactions at about 10 MeV/nucleon to extract information about the asymptotic behavior of the single-particle component of the many-body wave function of weakly bound nuclei, and then use the precise knowledge of the asymptotic normalization coefficient (ANC) to calculate the astrophysical S-factors for proton radiative capture reactions at astrophysically relevant energies. This procedure has been used for several systems, in particular to determine $S_{17}(0)$ for $^{7}Be(p,\gamma)^{8}B$ [1,2]. It is sensitive to the DWBA description of the transfer reactions we measured: $^{10}B(^{7}Be,^{8}B)^{9}Be$ and $^{14}N(^{7}Be,^{8}B)^{13}C$ and in particular to the optical model potentials used. This year we have continued the experimental study of elastic scattering of weakly bound p-shell nuclei which we undertook in previous years [3]. We measured ^{6}Li at 9 MeV/nucleon on ^{13}C and ^{9}Be targets, repeated the ^{7}Li measurements at 130 MeV on both targets with better resolution and supplemented our ^{7}Li measurements at 9 MeV/nucleon with data at larger angles.

More effort was put into the analysis of experimental data we have obtained previously in the framework of a double folding semi-microscopic model. We followed a standard spherical Hartree-Fock calculation using the energy dependent functional of Beiner and Lombard to obtain the densities of the two partners, then used double folding with known effective nucleon-nucleon interactions. We adjusted slightly the parameters of the surface terms in the Hartree-Fock procedure in order to reproduce the experimental binding energy and the rms radii for each nucleus. Then we tried six different effective nucleon-nucleon interactions to produce the double folding nucleus-nucleus potentials: M3Y with zero and finite range exchange terms [4], two density dependent M3Y type interactions [5] and the effective interaction of Jeukene, Lejeune and Mahaux (JLM) [6] in two different versions. We found that these potentials need an important renormalization of their depth in order to reproduce the elastic scattering data for the seven systems studied involving weakly bound p-shell nuclei [3]. This was known previously and is believed to account for the larger contribution of the polarization term in the optical potential due to the increased importance of the break-up channel.

Of all effective nucleon-nucleon interactions used, the JLM interaction presents the best description of the data. It has a density dependence built in, its parameters were adjusted for the description of nucleon-nucleus elastic scattering and, most of all, it has an intrinsic advantage because it has an imaginary part which leads naturally to an independent imaginary potential. We improved the local density approximation by replacing the usual δ-function with a finite range by using gaussian smearing functions. From the fit of our data we found range parameters t_R=1.2 fm and t_I=1.75 fm for the real and imaginary parts, respectively. This leads to imaginary potential wells about 20% wider than the real ones, in agreement with what the analysis with phenomenological Woods-Saxon potentials requires. All other NN interactions produce real and imaginary potentials that have the same shape.

We find that the renormalization coefficients (Figure 1) have similar values for the same interaction and that the variation around the average is smaller in the cases where the density dependence is taken into account. We also find that the JLM normalization coefficients extracted have the smallest standard deviation around the average for the weakly bound p-shell systems under consideration. Moreover, virtually no renormalization is needed for the imaginary part of the potential, suggesting that all basic effects are well accounted for by the effective interaction used and by the procedure. We used this interaction for double folding and applied the average renormalization coefficients Nv=0.38 and Nw=0.99 to obtain the optical model parameters used in the analysis of our ^{7}Be+^{10}B and ^{7}Be+^{14}N elastic scattering data and to calculate the DWBA cross sections for the proton transfer reactions ^{10}B(^{7}Be,^{8}B)^{9}Be and ^{14}N(^{7}Be,^{8}B)^{13}C. A very good description is found in both cases [1, 2]. The standard deviations of the normalization coefficients were used to estimate the contribution of the DWBA calculations to the uncertainty in the value of $S_{17}(0)$ factor we extract.

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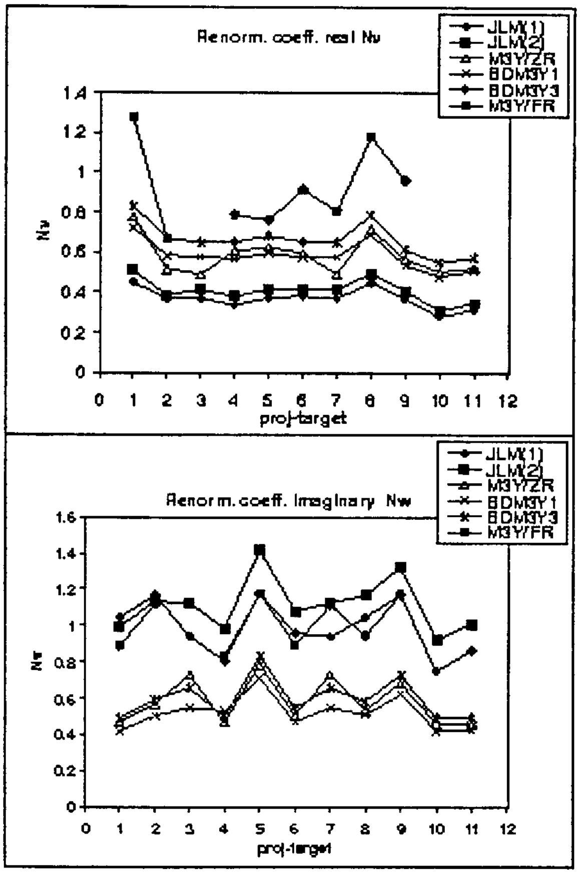

Fig. 1. The renormalization coefficients needed to fit the elastic scattering data with double folding optical potentials using six effective n-n interactions. The data include seven systems measured at TAMU (1-7) at about 10 MeV/nucleon and others taken from literature.