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Folding model analysis of proton scattering from mirror nuclei ^{18}Ne and ^{18}O

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Abstract

The elastic and inelastic scattering of protons from mirror nuclei ^{18}Ne and ^{18}O are studied in a folding model approach. For comparison, two different effective interactions are folded with Hartree–Fock densities to obtain the nuclear interaction potentials. Both of them provide equivalent descriptions to the data and the deformation parameters extracted from inelastic scattering are reasonable. The density dependence parameters obtained from nuclear matter calculations and used for present analysis also provide a good estimate for the nuclear mean free path. The present formalism unifies radioactivity, nuclear matter and nuclear scattering.

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1. Introduction

Proton scattering has been widely used as a means to study both collective and microscopic aspects of nuclear structure [1,2]. The study is consistent only if a well-defined effective nucleon–nucleon (NN) interaction is applied in the analysis. Also, with the advent

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of radioactive nuclear beams there is constant enhancement of our knowledge frontiers on the structure and reaction dynamics of the known stable nuclei as well as their less known unstable counterparts [3,4]. This rapidly developing field provides a testing ground for different nuclear reaction theories and effective interactions. Scattering involving ^{18}Ne and ^{18}O are interesting because not only are they mirror nuclei, but also ^{18}O is a stable nucleus while ^{18}Ne is its radioactive counterpart.

In this work, proton scattering on ^{18}Ne and ^{18}O has been studied at low energies ($< 100\,\mathrm{MeV}/A$) [5,6] in a folding model approach. The folding model is well known as a powerful tool for analyzing nucleus–nucleus scattering data at relatively low incident energies [4,7–9]. It directly links the density profile of the nucleus with the scattering cross sections and is thus very appropriate for studying nuclei, especially those with exotic matter distributions. A semi-microscopic analysis in the optical model (OM) framework is carried out. In the DWBA calculations of nuclear excitation, with transferred angular momentum l, the form factors are obtained by taking the derivatives of the potentials used.

2. Theoretical formulation

The nucleon–nucleus potential can be obtained by single folding the density distribution of the nucleus with the nucleon–nucleon effective interaction [10] as

$$U(\vec{r}_1) = \int \rho_2(\vec{r}_2) v_{\mathrm{NN}}\big(|\vec{r}_1 - \vec{r}_2|\big)\, d^3\vec{r}_2, \tag{1}$$

where $\rho_2(\vec{r}_2)$ is density of the nucleus at $\vec{r}_2$ and v_{NN} is the effective interaction between two nucleons at the sites $\vec{r}_1$ and $\vec{r}_2$. Two different forms of effective interactions have been employed in this work. We perform a comparative study between the modified Seyler–Blanchard (SBM) and density dependent M3Y (DDM3Y) effective NN interactions.

The finite range, density, momentum and isospin dependent effective interaction SBM has different strengths for pp (or nn) and pn interactions and its form is [11]

$$v\big(r = |\vec{r}_1 - \vec{r}_2|, p, \rho\big) = -C_{l,u} \frac{e^{-r/a}}{r/a} \left[1 - \frac{p^2}{b^2} - d^2(\rho_1 + \rho_2)^n\right], \tag{2}$$

where, the subscripts 'l' and 'u' refer to like-pair (nn or pp) and unlike-pair (np) interactions, respectively. Here 'a' is the range of the two-body interaction, 'b' is a measure of the strength of repulsion with relative momentum 'p', while 'd' and 'n' are two parameters determining the strength of density dependence. $\rho_1(\vec{r}_1)$ and $\rho_2(\vec{r}_2)$ are densities at the sites of the two interacting nucleons. The values of parameters n, C_{l}, C_{u}, a, b, d are given in Table 1. These constants are found to reproduce the bulk properties of nuclear matter and of finite nuclei [11,12] and are known also to explain the p + ^{4,6,8}He, ^{6,7,9,11}Li scattering data successfully [2,4,13–16]. The parameters are determined without exchange effects and thus they contain the effect indirectly though in a very approximate way.

The finite range M3Y effective interaction $v(r)$ appearing in Eq. (1) is given by [17]

$$v(r) = 7999 \frac{e^{-4r}}{4r} - 2134 \frac{e^{-2.5r}}{2.5r}. \tag{3}$$