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Folding model analysis of proton scattering from $^{18,20,22}O$ nuclei

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Abstract

The elastic and inelastic proton scattering on $^{18,20,22}O$ nuclei are studied in a folding model formalism of nucleon–nucleus optical potential and inelastic form factor. The DDM3Y effective interaction is used and the ground state densities are obtained in continuum Skyrme-HFB approach. A semi-microscopic approach of collective form factors is done to extract the deformation parameters from inelastic scattering analysis while the microscopic approach uses the continuum QRPA form factors. Implications of the values of the deformation parameters, neutron and proton transition moments for the nuclei are discussed. The p-analyzing powers on $^{18,20,22}O$ nuclei are also predicted in the same framework.

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Keywords: Elastic and inelastic proton scattering; Analyzing power; Effective interaction; Folding

1. Introduction

The study of the oxygen isotopic chain deserves special attention since the neutron drip line was shown to be located at $A = 24$ [1,2]. Thus rapid structural changes are expected as we move from ^{16}O towards its neutron-rich exotic isotopes. Several theoretical and experimental endeavors also indicate $N = 14$ and $N = 16$ shell closures [3]. In addition, there is opportunity to track neutron and proton contributions of the 2^+ state as the neutron drip line is approached [4]. Proton scattering is widely used as a means to study both macroscopic and microscopic aspects of nuclear structure [5–8]. A suitable realistic effective nucleon–nucleon (NN) interaction is

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also needed in the analysis [6]. A folding model approach is followed in this study of proton scattering from ^{18,20,22}O at 43, 43, 46.6 A MeV respectively, measured at GANIL [3,9]. The earlier p–^{18}O differential cross section and analyzing powers for the ground state and 2_1^+ level at 24.5 A MeV incident energy [10] are also included in the analysis. The folding model, which relates the density profile of the nucleus with the scattering cross sections is powerful tool for analyzing nucleus–nucleus scattering data at a few tens of MeV/nucleon [3,6–13]. Thus it is very appropriate for studying nuclei with extended density distributions. It should be noted that the same formalism is being followed to provide description of radioactivity, α and heavy ion scattering in a double folding model as well as nuclear matter and p-elastic/inelastic scattering in a single folding model [6,14]

2. Theoretical formulation

In a single folding calculation the nucleon–nucleus potential is obtained by using the density distribution of the nucleus and the nucleon–nucleon effective interaction [15] as,

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

where $\rho_2(\vec{r}_2)$ is density of the nucleus at $\vec{r}_2$ and $v(r)$ is the effective interaction between two nucleons at the sites $\vec{r}_1$ and $\vec{r}_2$. The finite range M3Y effective interaction $v(r)$ [16], is based upon a realistic G-matrix and was constructed in an oscillator basis. Effectively it is an average over a range of nuclear densities as well as energies and thereby has no explicit dependence on density or energy. The only rather weak energy dependent effect is contained in an approximate treatment of single-nucleon knock-on exchange. At lower energies, the density and energy averages are adequate for the real part of the heavy ion optical potentials. For scattering at higher energies, explicit density dependence was introduced [17,18]. The present calculations use this density dependent M3Y (DDM3Y) effective NN interaction with an added zero-range pseudo potential given by,

$$v(r, \rho, E) = t^{\mathrm{M3Y}}(r, E) g(\rho, E), \tag{2}$$

where E is incident energy and

$$t^{\mathrm{M3Y}} = 7999\frac{e^{-4r}}{4r} - 2134\frac{e^{-2.5r}}{2.5r} + J_{00}(E)\delta(r). \tag{3}$$

The zero-range pseudo-potential [17] represents the single-nucleon exchange term and is given by

$$J_{00}(E) = -276(1 - 0.005E/A)\ \mathrm{MeV\,fm}^3 \tag{4}$$

while the density dependent part is taken to be [18]

$$g(\rho, E) = c\big(1 - b(E)\rho^{2/3}\big) \tag{5}$$

taking care of the higher order exchange and Pauli blocking effects. Here $\rho = \rho_2$ is the spherical ground state density of the nucleus. The constants of this interaction c and b when used in single folding model description, are determined by nuclear matter calculations [14] as 2.07 and 1.62 fm^2 respectively.