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De Leo, R; Micheletti, S

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ENERGY DEPENDENCE OF THE ISOVECTOR IMAGINARY NUCLEON OPTICAL-MODEL POTENTIAL

R. De LEO¹ and S. MICHELETTI²

Kernfysisch Versneller Instituut, Groningen, The Netherlands

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The differences between the imaginary depths of the optical-model potentials felt by neutrons and protons on ²⁰⁸Pb show evidence for an energy decrease of the isovector imaginary term of the nucleon–nucleus optical-model potential, analogous to that of the real part.

In the framework of the Lane model [1] the nuclear part of the phenomenological nucleon–nucleus optical-model (OM) potential contains a complex isospin part U_1 . The potentials felt by neutrons and protons of the same energy in scattering from a given nucleus, can be expressed as:

$$U_p(r, E) = U_0(r, E) + \epsilon \cdot U_1(r, E) + \Delta U_c(r, E),$$

$$U_n(r, E) = U_0(r, E) - \epsilon \cdot U_1(r, E). \quad (1)$$

The Coulomb correction term $\Delta U_c(r, E)$ is also complex [2,3] and accounts for the decrease of the proton local kinetic energy inside the nucleus due to the Coulomb field. It is effective only in the presence of an energy dependence of the OM potentials. The parameter ϵ is the nuclear asymmetry [$\epsilon = (N - Z)/A$]. Both the real $V_1(r, E)$ and the imaginary $W_1(r, E)$ part of U_1 can be deduced from:

(a) comparison of U_p and U_n for the same $T \neq 0$ nucleus when ΔU_c is known,

(b) the potentials felt by nucleons scattered from nuclei in a given isotopic sequence,

(c) the strength of the interaction potential required in the analysis of the (p, n) reaction to the isobaric analog of the target ground state.

This letter reports the first attempt, to our knowledge, to determine the energy dependence of $W_1(r, E)$ from an analysis of type (a), i.e. from the direct comparison of OM parameters extracted from the scattering of neutrons and protons on ²⁰⁸Pb.

Up to now evaluations of W_1 have been obtained mainly from analyses of type (b) [4–7]. In these analyses, performed in the framework of the simple optical model, the energy dependence of W_1 could have been masked by the effects resulting from coupling of the ground state to low [8] or high [6,9] lying collective levels or to reaction channels [10]. Moreover the energy range utilized was rather limited so that no evidence of an energy dependence of W_1 was found. Few determinations of $U_1(r, E)$ from analyses of type (c) have been performed due to scarcity of (p, n) data. The first attempt of a global analysis of this type has been reported by Patterson et al. [11]. They were not able, however, to select between several parameter sets corresponding to different distributions of the isovector strength between the real and imaginary parts and different energy dependences. Values of W_1 obtained with method (a) are not influenced by the neglect of couplings to collective levels although they could still be affected by couplings to reaction channels which can be different for proton and neutron scattering.

The present analysis has been made possible by the recent measurements of neutron elastic scattering at higher energies (30 and 40 MeV) [12] which enlarge

¹ Permanent address: Istituto di Fisica dell'Università di Bari, Italy.

² Permanent address: Istituto di Scienze Fisiche dell'Università, Milan, Italy.

considerably the energy range over which the comparison can be made. An empirical determination of the imaginary part of the Coulomb correction term $\Delta W_c(r, E)$, which is in agreement with the microscopic predictions of ref. [2], has recently been given by Rapaport [3]. It is always negative and given by:

$$\Delta W_c(r, E) = -(1 - 0.028 \cdot E)(0.5 \pm 0.1)(Z/A^{1/3})g(r),$$

where $g(r)$ is the radial derivative of a Woods-Saxon form factor. We have assumed this value in deducing $W_1(r, E)$ from eq. (1) which, in terms of volume integrals per nucleon can be written as:

$$J_{W_p}/A - J_{W_n}/A = 2 \cdot \epsilon J_{W_1}/A + J_{\Delta W_c}/A. \quad (2)$$

Values of imaginary volume integrals per nucleon for proton scattering on ^{208}Pb have been derived at several energies. Although volume integrals should not depend on the particular choice of geometrical parameters, we have considered only values obtained with the same, or very similar geometries (mainly those of ref. [13]). These values of the volume integrals, obtained from refs. [12–14], are presented in fig. 1. Other determinations have been used to estimate the uncertainty at each point. These are in good agreement with those given by Hodgson [15] except at a few energies where additional values are now available. Values for energies lower than 10 MeV have been disregarded because of the large uncertainties in both their value and in the Coulomb correction; below 10 MeV also compound nucleus contributions are not negligible anymore [6]. All the neutron volume integrals available at present at energies larger than 7 MeV [12,16–18] are also presented in fig. 1. The values of the volume integrals per nucleon of the imaginary part of the isovector term J_{W_1}/A , as derived from eq. (2), are given in the lower part of fig. 1. Their uncertainties at lower energies are due mainly to that of $J_{\Delta W_c}$, which is negligible above 25 MeV. A decreasing trend of J_{W_1}/A is visible in fig. 1 over the full energy range; the full line represents a linear least squares fit of the form:

$$J_{W_1}/A = [(147 \pm 10) - (1.72 \pm 0.50) \cdot E] \text{ (MeV fm}^3\text{)}.$$

Assuming [18] a negligible isospin dependence in the volume term of the imaginary OM potential W_v , and the geometries of ref. [13], the surface imaginary isovector term may be written as:

Fig. 1. Volume integrals per nucleon of the imaginary part of the nucleon OM potential (upper part) and of its isovector term (lower part).

$$W_1(r, E) = [(15.3 \pm 1.0) - (0.178 \pm 0.052) \cdot E] g(r) \text{ (MeV)}.$$

Additional evidence for an energy decrease of J_{W_1}/A is given by the values found with method (b) in a global analysis of the elastic scattering of protons at 35.2 MeV [6] and of neutrons around 9 and 23 MeV [7]. These values are also reported in the lower part of fig. 1. A decrease very similar to the one quoted here was also suggested by set D of ref. [11] shown in fig. 1 with the long-dashed line; this is the only set of ref. [11] which has for the real isovector term V_1 an energy slope [$V_1 = 21.9 - 0.18 \cdot E$ (MeV)] in agreement with that found by Rapaport et al. [7] [$V_1 = 22.7 - 0.19 \cdot E$ (MeV)] and recently confirmed by De Vito [12] [$V_1 = 17.9 - 0.19 \cdot E$ (MeV)]. Further evidence for the decrease of W_1 is given by the microscopic calculations [2] for nuclear matter at a density approximately corresponding to that of the surface region of finite nuclei (dashed-dotted line in fig. 1). The same calculations also estimated a very small A -dependence of W_1 which would render our result, at least approximately, valid also for other nuclei.

In summary, from a comparison of neutron and

proton data on ^{208}Pb , we give evidence for a decrease between 10 and 40 MeV of W_1 , the imaginary isovector term of the nucleon–nucleus optical-model potential. This result is in agreement with the indications obtained in (p, n) reactions and with those coming from the separate analysis of proton or neutron scattering at some energies.

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