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Investigation of the energy-averaged double transition density of isoscalar monopole excitations in medium-heavy mass spherical nuclei

M.L. Gorelik [a,b,*], S. Shlomo [a,b,*], B.A. Tulupov [a,c,*], M.H. Urin [a,*]

[a] *National Research Nuclear University "MEPhI", Moscow 115409, Russia*
[b] *Cyclotron Institute, Texas A&M University, College Station, TX 77843, USA*
[c] *Institute for Nuclear Research, RAS, Moscow 117312, Russia*

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Abstract

The particle–hole dispersive optical model, developed recently, is applied to study properties of high-energy isoscalar monopole excitations in medium-heavy mass spherical nuclei. The energy-averaged strength functions of the isoscalar giant monopole resonance and its overtone in ^{208}Pb are analyzed. In particular, we analyze the energy-averaged isoscalar monopole double transition density, the key quantity in the description of the hadron–nucleus inelastic scattering, and studied the validity of the factorization approximation using semi classical and microscopic one body transition densities, respectively, in calculating the cross sections for the excitation of isoscalar giant resonances by inelastic alpha scattering.

Keywords: Continuum random phase approximation; Isoscalar giant monopole resonance; Transition density; Particle–hole dispersive optical model

1. Introduction

The study of properties of collective states in nuclei provides information on the bulk properties of nuclear matter. In particular, the interest in experimental and theoretical studies of

* Corresponding authors.
E-mail address: urin@theor.mephi.ru (M.H. Urin).

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high-energy particle–hole-type isoscalar monopole (ISM) excitations in medium-heavy mass nuclei is mainly due to the possibility of determining the nuclear matter incompressibility coefficient, a fundamental physical quantity essential for astrophysics and nuclear physics. The value of this coefficient depends on the mean energy of the strength distribution, corresponding to the ISM external field r^2Y_{00} (in other words, on the energy of the isoscalar giant monopole resonance (ISGMR)) [1]. To deduce this strength distribution from experimental data of (α, α')-inelastic scattering cross sections at small angles, it is usually assumed that the ISM strength is concentrated in the vicinity of the ISGMR and the properly normalized classical collective model transition density of the ISGMR can be used within the folding model distorted wave Born approximation (FM-DWBA) (see. e.g., Ref. [2] for details). It is important to point out that the classical collective model one-body transition density is independent of the excitation energy. In Ref. [3], a microscopic evaluation of the (α, α')-scattering cross sections were carried out within the FM-DWBA using the Hartree–Fock (HF) ground state density and the one-body transition densities obtained from the HF-based random-phase-approximation (RPA) calculations. A comparison with results obtained with the classical collective model transition density was also made in Ref. [3].

In this work we apply the newly developed particle–hole (p–h) dispersive optical model (PHDOM) to study properties of high-energy isoscalar monopole excitations in ^{208}Pb. A microscopically-based (phenomenological) description of the spreading effect on properties of high-energy particle–hole-type excitations is the specific feature of the PHDOM. The model is formulated in terms of the corresponding energy-averaged Green functions. (The Green function method for description of simple modes of nuclear excitations has been first exploited by Migdal [4]). The basic quantity of the PHDOM is the “free” p–h Green function, corresponding to the model of independently damping quasiparticles. The use of the statistical assumption (which means that after energy averaging the different particle–hole states are “decaying” into many-quasiparticle configurations independently of one another) allows one to get the expression for the mentioned Green function in a closed form [5,6]. Being a direct generalization of the corresponding discrete-RPA free p–h propagator, this expression contains the (phenomenological) imaginary and real parts of the strength of an energy-averaged specific p–h interaction (p–h self-energy term) responsible for the spreading effect. The imaginary part determines the real one via the proper dispersive relationship, which follows from the spectral expansion of the 2p–2h Green function. An attempt to take explicitly within the model the single-particle continuum into account (i.e., to get a generalization of the continuum-RPA [7]) has been realized in Refs. [5,6] with the use of an approximate spectral expansion for the Green function of the single-particle Shrodinger equation, which contains the imaginary and dispersive real additions to the mean field. Appearance of such a Green function allows one to call the model as the p–h dispersive optical model. It should be stressed, however, that the above-mentioned imaginary addition to the mean field is not related to the imaginary part of the potential widely used for description of the nucleon–nucleus scattering within the single-particle optical model. The first intensive implementation of the PHDOM has been realized in Ref. [8] in applying to description of simplest photonuclear reactions. We note that a simple version of the mean field and particle–hole interaction are used within the PHDOM in order to take into account the Landau damping, single-particle continuum and the spreading effect, simultaneously.

We emphasize that in a microscopic approach, the input quantity for the analysis of the (α, α')-reaction cross section should be the energy-averaged double transition density (i.e. the energy-averaged product of energy dependent transition densities taken in different points). In a wide excitation-energy interval involving the ISGMR and its overtone, ISGMR2, this quantity is