Properties of high-energy isoscalar monopole excitations in medium-heavy mass spherical nuclei

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Continued interest in experimental and theoretical studies of high-energy particle-hole-type isoscalar monopole (ISM) excitations in medium-heavy mass nuclei is mainly due to the possibility of determining of the nuclear matter incompressibility coefficient, a fundamental physical quantity. 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)). To deduce the ISGMR strength distribution from experimental data of (α,α')-inelastic scattering cross sections at small angles, it is usually assumed that the properly normalized quasi-classical collective model transition density of the ISGMR can be used within the folding model distorted wave Born approximation (FM-DWBA). It is important to point out that the quasi-classical collective model transition density is independent on the excitation energy.

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). Being considered in a wide excitation-energy interval, this quantity is expected to be different from the product of the quasi-classical collective model transition densities or the product of microscopic transition densities, due to proper treatment of the shell structure of nuclei (i.e. the Landau damping) and also of the spreading effect. Developed recently, the particle-hole (p-h) dispersive optical model (PHDOM) [7,8] allows one to describe the energy-averaged double transition density at arbitrary (but high-enough) excitation energy and, in particular, to trace the change of this quantity from the ISGMR to ISGMR2.

Being an extension of the continuum-RPA, the PHDOM accounts for the Landau damping, coupling of high-energy (p-h)-type states to the single-particle (s-p) continuum and to many-quasiparticle configurations (the spreading effect). Within the model, Landau damping and coupling of high-energy (p-h)-type states to the s-p continuum are described microscopically in terms of the Landau-Migdal p-h interaction and a phenomenological mean field, partially consistent with this interaction. The spreading effect is treated phenomenologically in terms of the imaginary part of an effective s-p optical-model potential. The imaginary part also determines the corresponding real part via the proper dispersive relationship.

In this work we have carried out first evaluation of the energy-averaged double p-h transition density within the PHDOM. The calculations are performed for ISM excitations in ^{208}Pb. A wide excitation-energy interval is considered which includes the ISGMR and ISGMR2. The fractions of the energy-weighted sum-rule (EWSR) associated with the strength functions of these resonances, i.e. the energy-weighted strength functions divided by the corresponding EWSR, were also analyzed.

In Fig. 1 we show the calculated fractions of the energy-weighted strength functions $y_i(\omega) = \omega S_{V_{0,i}}(\omega)/(EWSR)_i$, obtained within the PHDOM for the external fields $V_{0,i}$, which are associated with the ISGMR (i = 1) and the ISGMR2 (i = 2), respectively. The fractions $y_i^{cRPA}(\omega)$ calculated within the RPA continuum version, i.e. in the approximation $W(\omega) = P(\omega) = 0$, are also shown in Fig. 1. As follows from the results presented in Fig. 1, the ISGMR in such heavy nucleus as ^{208}Pb exhibits (after taking the spreading effect into account) a well-formed resonance. The centroid energy ω_1 and total width Γ_1 (FWHM) of 13.8 MeV and 2.9 MeV, calculated within the used model for the excitation energy interval 10-35 MeV, are in agreement with experimental quantities of 13.96 MeV and 2.88 MeV, respectively. In contrast to the ISGMR its overtone does not exhibit a well-formed resonance. The energy centroid $\omega_1 = 22.7$ MeV calculated for the excitation energy interval 5-45 MeV is markedly less than the peak energy $\omega_{1,\text{peak}} = 31$ MeV of the main ISGMR2 maximum. The ISGMR2 width evaluated as $\Gamma = 2.35\sigma$ (σ^2 is the squared energy dispersion), $\Gamma = 22.8$ MeV, is markedly larger than the FWHM = 10 MeV found for the main ISGMR2 maximum. Concluding the description of the energy-weighted strength functions, we note that the calculated fractions $y_1(\omega)$ well exhaust the corresponding $EWSR_i$. Being calculated for the excitation energy intervals 5-35 MeV and 5-45 MeV, the quantities $N_i = \int y_i(\omega)d\omega$ are found close to unity: $N_1 = 0.986$ and $N_2 = 0.98$, respectively

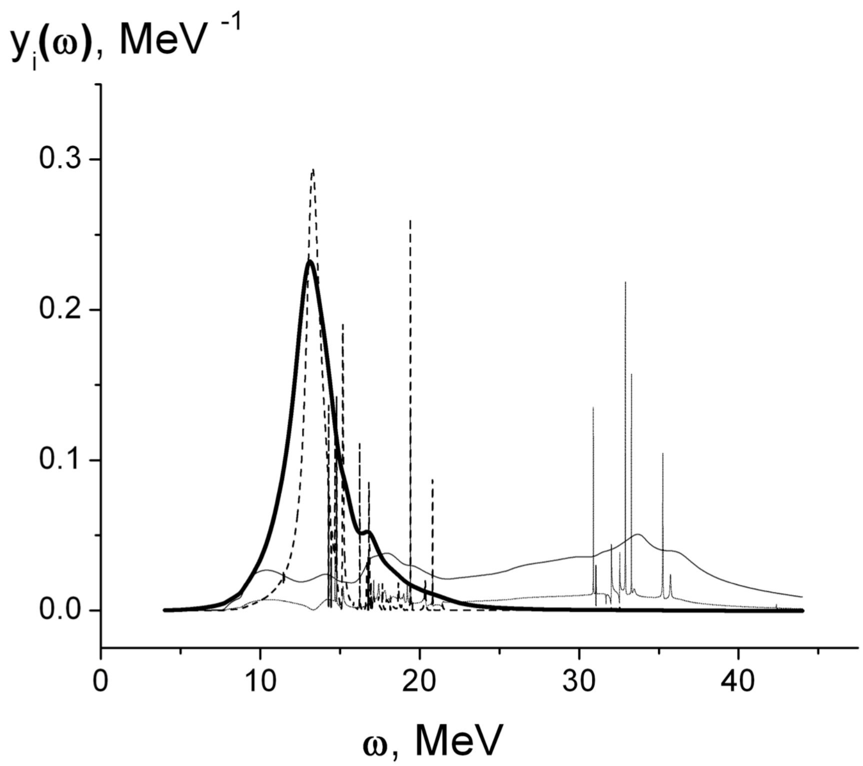

FIG. 1. Fractions of the energy-weighted strength functions, $\boldsymbol{y_i(\omega) = \omega S_{v_{0,i}}(\omega)/(EWSR)_i}$ calculated within the PHDOM, (*$y_1(\omega)$* – the thick solid line, *$y_2(\omega)$* – the thin solid line) in comparison with *$y_i^{cRPA}(\omega)$*, calculated within the continuum–RPA (*$y_1^{cRPA}(\omega)/2$* – thin dotted line, *$y_2^{cRPA}(\omega)/4$* – thin dashed line).

[1] M.H. Urin, Phys. At. Nucl., **74**, 1189 (2011); M.H. Urin, Phys. Rev. C **87**, 044330 (2013).