Reply to the Comment 'On the "authentic damping mechanism" of the phonon damping model'

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We respond to the Comment by Ponomarev. We reconfirm the correctness of our results and conclusions published in Phys. Rev. C **63**, 044302 (2001). In particular, we reiterate that the aim of our previous study is to use for the calculations of $E1$ resonances in neutron-rich isotopes the same set of parameters whose values are chosen to reproduce the giant dipole resonance in the corresponding double closed-shell nuclei.

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In our recent work [1], we calculated the $E1$ resonances in neutron-rich oxygen and calcium isotopes within a quasiparticle representation of the phonon damping model (PDM) in its PDM-1 version [2,3] including the superfluid pairing interaction. It is claimed in the Comment [4] that "the physical content of the PDM calculations [is] very doubtful" and the description of the pygmy dipole resonance (PDR) is "not justified" "at a quantitative level." However, as seen below, the arguments that the Comment author presents to prove his case are either wrong or irrelevant.

The same Appendix 2D of Ref. [2] in the Comment [4] states that the assumption of an equal particle-phonon coupling strength $F_{ph}^{(q)}=f_1$ "may be employed if the width of the strength function is small compared to the characteristic energies associated with systematic variation in the coupling matrix elements." This condition is satisfied in the region of $E1$ resonances considered in Ref. [1]. However, this does not mean that the matrix elements of the interaction part $V_{q_1 s_1} \equiv \langle q_1|\Sigma_{ss',q} F_{ss'}^{(q)} a_s^\dagger a_{s'}(Q_q^\dagger + Q_q)|s_1\rangle$ are the same, as claimed in the Comment [4].

Equation (1) of the Comment [4] is not the second moment for the phonon distribution within the PDM. The k-th moment for the phonon distribution within the PDM is calculated (see, e.g., Eq. (2.21) of Ref. [5]) as

$$m_q^{(k)} = \int_{E_1}^{E_2} S_q(\omega)\omega^k d\omega, \quad k=1,2,\ldots, \tag{1}$$

where $S_q(\omega)$ is the PDM strength function

$$S_q(\omega) = \frac{\gamma_q(\omega)}{(\omega-\overline{\omega})^2+\gamma_q^2(\omega)}. \tag{2}$$

The energy $\overline{\omega}$ of the giant dipole resonance (GDR) is found as the solution of Eq. (2.39) in Ref. [3]:

$$\overline{\omega} - \omega_q - P_q(\omega) = 0, \tag{3}$$

where ω_q is the unperturbed phonon energy (before the ph-phonon coupling is switched on), and $P_q(\omega)$ is the polarization operator. The damping $\gamma_q(\omega)$ is calculated microscopically within the PDM as the imaginary part of the analytic continuation of $P_q(E)$ into the complex energy plane $E=\omega \pm i\varepsilon$. Its explicit expression within PDM-1 is given by Eq. (5) of Ref. [2] (pairing not included) or Eq. (15) of Ref. [1] (pairing included). There is no way to equalize $m_q^{(2)}$ from Eq. (1) ($k=2$) with Eq. (1) of the Comment [4]. Therefore all discussions using Eq. (1) of the Comment [4] with the aim of attaching it to the PDM are irrelevant.

The strength function (2) is not a Breit-Wigner distribution because the damping $\gamma_q(\omega)$ depends on the energy ω. Such a form has been derived, for the first time, in Ref. [6] using the analytic properties of the double-time Green function independently of any assumption on the coupling matrix elements. Consequently, the photoabsorption cross section of the GDR within the PDM is not a Lorentzian either. The claim in Ref. [4] that a Breit-Wigner (Lorentzian) form is assumed or an *ad hoc* input for the strength function (photoabsorption cross section) of the GDR within the PDM is simply wrong.

One of the crucial features of the PDM is the use of realistic single-particle energies to construct the ph configurations (at zero temperature) together with the pp and hh configurations (at nonzero temperature) to which the GDR is coupled. Therefore a replacement of the realistic single-particle spectra with any other ones, such as the random values of E_s used in the Comment [4], no longer corresponds to the PDM. So the attempt in Ref. [4] to imitate the results of the PDM using random values of E_s, and a GDR energy E_0, which is not defined from Eq. (3), is incorrect.

It is by no means obvious that the coupling constant should increase as the configuration space gets larger in the same nucleus. How the coupling changes is an issue to be discussed microscopically. Within the PDM, an increase of the space of ph pairs leads to a decrease of the parameter f_1 to preserve the same value for the GDR width.

The aim of Ref. [1] is to use for the calculations of $E1$ resonances in neutron-rich isotopes the same set of two parameters (ω_q, f_1), whose values are chosen to reproduce the GDR in the corresponding double closed-shell nuclei. Therefore the $E1$ resonances in the chains $^{16-24}$O, $^{40-46}$Ca, and $^{48-60}$Ca were calculated using the parameters chosen for ^{16}O, ^{40}Ca, and ^{48}Ca, respectively. There is no reason why the values of f_1 for ^{40}Ca and ^{48}Ca should be the same. The

results for the GDR in ^{16}O have been obtained already within an enlarged space with $f_1 = 0.6982$ MeV. This value is kept unchanged throughout the chain of oxygen isotopes as has been mentioned above and in Ref. [1]. No change of the parameter occurs between ^{16}O and ^{18}O as incorrectly stated in the Comment [4].

The PDM-1 with its two phenomenologically selected parameters allows a comparison with the experimental data for only the average characteristics of the $E1$ resonances, such as the overall shape of the cross section, width, energy, and energy-weighted sum (EWS) of strength. It cannot describe such fine structure as the individual low-lying $E1$ states measured in Ref. [7]. The EWS of $E1$ strength below 5 MeV for ^{40}Ca and ^{48}Ca are around 0.25% and 0.52% of the Thomas-Reich-Kuhn sum rule (TRK), respectively. They should be compared to the experimental values of (0.025 ± 0.004)% of TRK for ^{40}Ca, and (0.29 ± 0.04)% of TRK for ^{48}Ca reported in Ref. [7]. The enhancement of strength at low energies in double closed-shell nuclei due to the spreading of GDR has been discussed in Ref. [1]. There is no such setting of $B(E1)$ to zero for the PDR within the PDM as claimed in Ref. [4]. The problem of double counting arises only when the structure of the phonon is calculated microscopically within the random-phase approximation. The use of a structureless phonon and of parameters that are selected so that the calculated GDR energy reproduces its experimental value, excludes any possibility for double counting within the PDM.

Pairing is not included in the calculations of the PDR in Ref. [5] of Ref. [4]. The aim of Ref. [5] of Ref. [4] is to see if the PDM is able to predict the existence of the PDR in neutron-rich nuclei, but not to reproduce the experimental data. Because of the absence of pairing, the parameter f_1 in Ref. [5] of Ref. [4] was increased significantly in the region near the Fermi surface in neutron-rich isotopes. It is natural that such an increase overestimates the EWS of $E1$ strength in this region. This is not the case in the present work [1], where pairing is included, and the parameters of the model have been chosen to reproduce the GDR in double closed-shell nuclei.

In conclusion, none of the statements of the Comment [4] are relevant, and its conclusions are false.

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