Calculations of the $E1$ resonance in ^{48}Ca in the $1P1H + 2P2H +$ continuum approximation

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A method has been developed for performing microscopic calculations of the $E1$ isovector resonance, in which complicated configurations and the continuous single-particle spectrum are taken into account. The first computational results are reported. The $E1$ resonance in ^{48}Ca (including its width) is described well.

Many calculations of giant multipole resonances performed using different variants of the random-phase approximation have shown that this approach explains primarily only two integral characteristics of the resonance—the average energy and the total intensity. The third characteristic—the width of the resonance—cannot be explained on the basis of the random phase approximation. It is generally acknowledged that the microscopic nature of the total width of the giant resonance is determined by two factors: the coupling of the particle-hole ($1p1h$) configurations included in the random-phase approximation with more complicated configurations (the "spread" width $\Gamma^{\downarrow}$) and the decay of excited states into the continuum ($\Gamma^{\uparrow}$). All this is well known, so that the questions of taking into account simultaneously the $1p1h$ configurations, more complicated (primarily $2p2h$) configurations, and the single-particle continuum (SPC) in the microscopic theory of giant resonances has now been discussed in the literature for more than twenty years.[1]

The difficulties in solving this problem are so great, however, that for medium and heavy nuclei systematic microscopic calculations in the "$1p1h + 2p2h +$ continuum" approximation have still not been performed. It is clear that approximate methods must be developed for taking into account the $2p2h$ configurations and the single-particle continuum and combining them into a unified approach. We do this in this paper, and we also present the first computational results obtained from the $E1$ resonance in ^{48}Ca using this approach.[1)]

The basic idea of determining the $2p2h$ configurations involves the systematic use of the Green's function formalism with the amplitude g of phonon generation as the small parameter, the study of the $1p1h \otimes$ phonon configurations instead of the $2p2h$ configurations, and taking into account in the calculations a small number of the most strongly collectivized phonons.[2] In Refs. 3 and 4 a linearized variant of the theory was formulated and an equation, in which an infinite set of diagrams with an inset and a transverse phonon is summed in the propagator, was derived for the density matrix (transition density). If in this case the $3p3h$ and more complicated configurations are ignored, then a relatively simple equation can be derived for the propagator; this equation is presented in Ref. 4.

The integral equation for the transition density ρ, which has the same form as the corresponding equation in the theory of finite Fermi systems (TFFS), was solved in the coordinate representation, thereby substantially simplifying the computational difficulties. To construct the generalized propagator $\mathscr{A}$ (Ref. 4), we employed the combined $(\vec{r},\lambda)$ representation method, which is analogous to the method employed in Ref. 6, to take into account the continuum on the basis of the TFFS for nuclei with pairing:

$$A(\vec{r},r')=A^{\rm RPA}_{\rm cont}(\vec{r},\vec{r}')+\sum_{1234}(A_{1234}-A^{\rm RPA}_{12}\delta_{13}\delta_{24})\varphi_1^*(\vec{r})\varphi_2(\vec{r})\varphi_3(\vec{r}')\varphi_4^*(\vec{r}').$$

Here $\mathscr{A}^{\rm RPA}_{\rm cont}$ is the $1p1h$ propagator, which takes the single-particle continuum into account exactly, and which was calculated by the method proposed in Ref. 7. The summation was performed over two shells below and two shells above the Fermi surface. In the method which we propose the single-particle continuum is thus taken into account completely in the $1p1h$ part of the propagator, while in the $2p2h$ part, which is contained in $\mathscr{A}_{1234}$, it is taken into account approximately by including the quasistationary states which are present in our basis. The possibility of such an approximation is determined by the structure of the propagator.[4] The use of this technique of including the continuum in our relatively simple method of taking into account the $2p2h$ configurations makes it possible to obtain a realistic algorithm for solving the problem, without the use of a separable internucleon interaction.

The three most highly collectivized phonons making the largest contribution to the fragmentation of the $1p1h$ dipole excitations in the energy range studied were included in the calculations: 2_1^+, 3_1^-, and 5_1^-. They were calculated on the basis of the TFFS. The same set of force parameters of the TFFS, taken from other works and checked in our calculations of the $E1$ resonance in ^{40,48}Ca and ^{208}Pb, performed without regard for the single-particle continuum, were employed in all calculations:

$$f_{ex}=-3,74,\qquad f_{in}=-0,02,\qquad f'_{ex}=2,30,\qquad f'_{in}=0,76$$

$$g=0.05,\qquad g'=0,96\qquad C_0=300,0\ \text{МэВ·фм}^3.$$

With the exception of $f_{\rm ex}$, the parameters f were taken from Ref. 8; $f_{\rm ex}$ was chosen from the condition that the energy of the 1^- ghost state be equal to zero. The choice of parameters is discussed in greater detail in Ref. 5. To simulate the effect of the complicated configurations that were ignored and the energy resolution of the experiment, we used the "smearing parameter" $\Delta=0.25$ MeV, in the calculations. It should be noted that this value is an order of magnitude smaller than the depth of the imaginary part of the corresponding optical potential and is numerically close to the resolution of the experiment.

As one can see from Fig. 1 and Table I, the TFFS whose equations are identical to those of the random-phase approximation with effective forces describes the experiment poorly. Including only the $1p1h\otimes$ phonon configurations results in a strong shift of the centroid and sharp fragmentation of the resonance and the appearance of additional structures on the right-hand slope. Allowance for the single-particle contin-

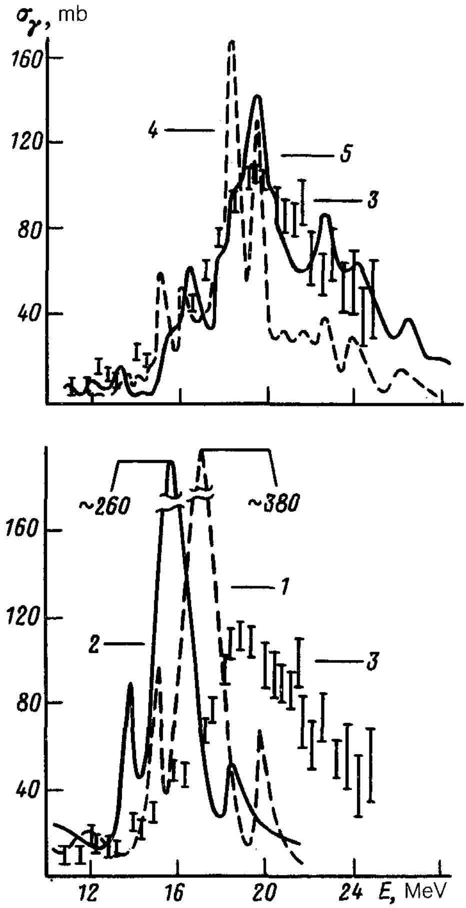

FIG. 1. Cross section of dipole photoabsorption in ^{48}Ca. Curves *1* and *2* were calculated on the basis of the TFFS (RPA) ignoring and taking into account the continuum, respectively; curves *4* and *5* represent the calculations containing $1p1h$ and $1p1h \otimes$ phonon configurations ignoring and taking into account the continuum, respectively; curve *3* is the experimental curve.[9]

uum, whose effect increases with increasing energy, greatly intensifies these features. As a result, we obtained a completely satisfactory description of the profile of the resonance curve.

Following the standard method of analyzing an experiment,[9] we constructed the

TABLE I. Integral characteristics of the $E1$ resonance in ^{48}Ca.

		σ_{max} mb	$\bar{E}$ MeV	σ_{-1} mb	σ_0 mb·MeV	Γ MeV
Theory	$1p1h+$ SPC	150.0	15.8	44.6	702.0	3.7
	$1p1h+2p2h+$ SPC	105.0	19.6	43.23	830.05	6.7
Experiment	$(\gamma, sn+sp)$	102.74	19.6	43.37	836.56	7.1

Lorentzian curves which approximate our computed curves. As follows from Table I, all integral characteristics of the resonance, including the total width, which were calculated taking into account the $2p2h$ configurations and the single-particle continuum, are in good agreement with the experiment.

Our results suggest that at least for nuclei with $A \simeq 50$ it is sufficient to take into account the indicated $2p2h$ configurations and the single-particle continuum in order to explain the total photoabsorption cross sections and the characteristics of the $E1$ resonance. It is of great interest to analyze the partial (γ,n) and (γ,p) reactions. This work is already in progress.

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[1)] V. N. Tkachev and V. I. Tselyaev also participated in the development of this method.[35]

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