LETTERS TO THE EDITOR

MULTIPOLE DEPENDENCE OF THE GIANT RESONANCE SPREADING WIDTH

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Using effective interactions based on a Brueckner G-matrix we calculate natural-parity isoscalar vibrations in ^{48}Ca. The conventional RPA theory is extended to include 1p1h- as well as 2p2h-excitations in a consistent way. The results indicate an increasing role of configuration mixing effects with increasing multipolarity of the isoscalar excitation.

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The study of various nuclear giant resonances (GRs) is fundamental to our understanding of basic ingredients of nuclear theory, such as different components of the residual interaction and state mixings in nuclei which determines the decay properties of GRs. The width of GRs can be regarded as arising from two independent sources: (*i*) an escape width mostly due to direct nucleon emission, and (*ii*) a spreading width due to the mixing of the state with more complicated nuclear excitations. In general, in a light nucleus the total width is mainly determined by the escape width. The opposite prevails for heavy nuclei because the charged-particle emission is disfavored by the increased Coulomb barrier. In addition, the $A^{-1/3}$ scaling of the energy gap between occupied and unoccupied single-particle states favors energetically the coupling to more complicated configurations when going to heavier nuclei.

However, even in light nuclei the probability of direct nucleon emission should be reduced for higher multipolarities of GRs due to the increasing role of the centrifugal

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barrier. Also, in heavier nuclei the relative contribution of the spreading width to the total width of GR can in principle be influenced by more subtle interference effects between complicated configurations participating in a decay. Already in 1971 Bertsch has recognized [1] the importance of such effects predicting that the spreading width of the 0^+ breathing mode should be much smaller for its isoscalar component than for the corresponding isovector one. The reason is a strong cancellation between the second order particle–hole linked and unlinked diagrams in a former case, independently of the interaction.

Microscopically, the GR is described as a coherent superposition of 1p1h-configurations, often called the collective particle-hole doorway resonance. Adopting the conventional RPA scheme in approaching the full many-body solution for GR, one has to include at least 2p2h-excitations in addition to 1p1h to make the microscopic study of the spreading width possible. The resulting theory we call second RPA (SRPA). The SRPA projected into the 1p1h-subspace gives the following prescription for a transition strength distribution with respect to a weak external field $\hat{F}$:

$$S_F(E) = -\frac{1}{\pi}\,\mathrm{Im}\sum_{\substack{pp'\\hh'}}(F^+_{ph}, F^+_{hp})\times\begin{pmatrix}E-A_{php'h'}(E) & -B_{php'h'}\\ -B^*_{php'h'} & -E-A^*_{php'h'}(-E)\end{pmatrix}^{-1}\begin{pmatrix}F_{p'h'}\\ F_{h'p'}\end{pmatrix}$$

with

$$F_{ph} \equiv \langle p|\hat{F}|h\rangle, \qquad F_{hp} \equiv \langle h|\hat{F}|p\rangle.$$

This expression is formally identical to the ordinary RPA except that the A-matrices are energy-dependent reflecting the presence of the 2p2h-space. The details are described in a different publication [2].

The extension of the energy variable E into the complex plane: $E \to R+i\Delta$ (Δ finite) smears out the narrow peaks (poles of the propagator) of the fine structure simulating the decay of the 2p2h-states into more complicated configurations. In practice, we choose [2] $\Delta = 18\times A^{-1/3}$ MeV.

The Hamiltonian used in the calculation is composed of two parts. The one-body part is a phenomenological Woods-Saxon potential fitted to the nuclear ground state. The two-body interaction is taken as the relativistic G-matrix obtained [3] in nuclear matter with the HM3A version of the Bonn potential [4]. The G-matrix used contains central and tensor pieces.

Fig. 1 shows the second order diagrams corresponding to the energy-dependent piece of A. These diagrams are the so-called self-energy corrections, bubbles and ladders, respectively. Especially interesting in this formalism is the presence of the bubble term which constitutes the perturbative analog of the "induced interaction" of Babu and Brown [5] when the G-matrix is used as a "direct term". The presence of this diagram significantly improves the description of natural parity excitations by enhancing the stability of the ground state against density fluctuations.

The spreading width of GR depends, first of all, on the density of 2p2h-states. Therefore, to make a conclusive statement about its multipole dependence, one should compare the strength distributions of GRs located more or less in the same energy region. This condition is satisfied by the three isoscalar strength distributions displayed in Fig. 2 for monopole ($\hat{F} = \sum_{i=1}^{A} r_i^2$), quadrupole ($\hat{F} = \sum_{i=1}^{A} r_i^2 Y^2$) and hexadecapole ($\hat{F} = \sum_{i=1}^{A} r_i^4 Y^4$) excitations in ^{48}Ca, respectively. The corresponding states located in the region of

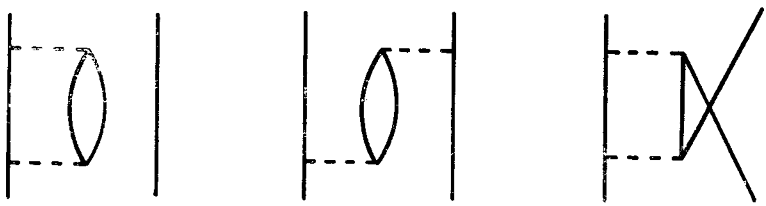

Fig. 1. Second-order diagrams iterated by the SRPA equations (exchange terms included in the calculation are omitted for simplicity)

18–20 MeV are recognized as GRs. The observed increase of the width in this case with increasing multipolarity means enhanced tendency of the higher multipolarity isoscalar GR to decay into more complicated configurations. Obviously, this tendency will not be restricted to the specific nucleus (^{48}Ca) under consideration because the underlying cancellation mechanism between the corresponding Goldstone diagrams (Fig. 1) is mostly determined by the geometrical factors (6-j symbols) and not by the number of nucleons. Further-

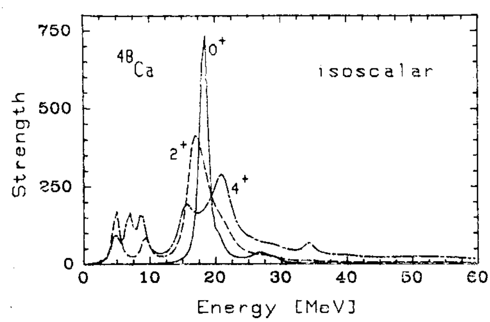

Fig. 2. Isoscalar strength distributions in ^{48}Ca for monopole (full line), quadrupole (dashed line) and hexadecapole (dashed-dotted line) excitations. The units are [e^{2}fm^4/MeV] for 0^+ and 2^+, and [500 e^{2}fm^6/MeV] for 4^+, respectively

more, it will not be violated in a finite momentum transfer q response because the decay properties are determined by the propagator which in this formalism is q independent. The q dependence enters through the external field operator $\hat{F}$.

On the other hand, the increasing role of the centrifugal barrier will reduce the direct escape of nucleons with increasing multipolarity of GR. All these facts provide an additional argument in favor of a time-dependent mean-field description [6] of the breathing mode.

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