Low lying magnetic states of double magic nuclei within Random Phase Approximation theory with Gogny interaction

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The description of the low lying magnetic states of double magic nuclei with phenomenological approach is in good agreement with experimental data [1]. This result can be interpreted as if we have been able to include in the effective nucleon-nucleon interaction some general features necessary to describe well the magnetic excitation spectra of doubly-closed-shell nuclei. In order to verify this hypothesis we have made RPA calculations within a fully self-consistent approach where the single-particle mean-field basis is obtained by means of a Hartree-Fock (HF) calculation [2,3] which uses the same effective NN interaction used in the RPA calculation. For these calculation, we have used the Gogny D1 interaction [4–6] which has finite-range components in the central, isospin, spin and spin-isospin channels and a zero-range density dependent term. In the HF calculations we have included all the terms of the interactions, while in the RPA calculations we have neglected the contribution of the spin-orbit term. In HF and RPA calculations both direct and exchange terms of the interaction matrix elements have been considered. To complete the information about our RPA calculations we point out that we have also included the so-called rearrangement terms, related to the density dependent part of the interaction [7]. Quantitatively, we have found the contributions of these terms to be negligible in all the cases we have investigated.

In the following, we present two different types of results. In the first case the Gogny D1 interaction is used in the RPA calculations, but the single particle wave functions and energies are taken to be the same as in the phenomenological approach. The results of these calculations are represented by the dotted lines in Figs. 1 and 2. The second case is fully self-consistent, i.e. the single particle basis is produced by a Hartree-Fock calculation with the same interaction used in RPA. The corresponding results are shown in the figures as dashed lines. The comparison between these two cases allows us to distinguish between the role played by the single particle basis and that played by the residual interaction. In the figures, the full lines show the results obtained in the phenomenological approach by using the FR interaction [1]. This interaction has finite-range but it does not include the tensor terms, therefore it is the most similar to the D1 interaction.

All our calculations have been obtained by discretizing the continuum. We have checked that our results are stable with respect to the parameters characterizing the continuum discretization and also with respect to the size of the single-particle configuration space used for each nucleus. More details on the role of the continuum discretization in self-consistent RPA calculations can be found in [8].

An example of the results is given in Tab. 1, where the energies of the 1^+ isospin-doublet of ^{12}C are presented, and in Fig. 1, where we show the corresponding transverse responses. We see

^{12}C			
excitation	D1	FR	exp
1^+	10.66	13.89	12.71
1^+	7.72	18.17	15.11

Table 1
Energies of 1^+ isospin-doublet of ^{12}C (in MeV). Experimental energies from [9]. FR energies from [1]

that the magnetic states of ^{12}C are reproduced rather badly by the self-consistent calculations: the response functions agree in shape and magnitude with the data, but the order of the states forming isospin doublets is inverted. We stress that the inversion is obtained in both types of RPA calculations done with the D1 interaction and therefore it does not depend on the single particle basis, but it is related to the characteristics of the interaction itself. We have repeated our calculations with another Gogny-like force with different values of the parameters, the D1S interaction [10], and also in this case we have observed

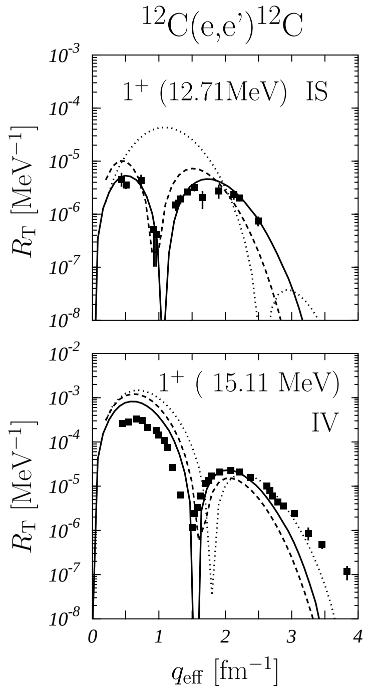

Figure 1. Electromagnetic responses of the 1^+ isospin doublet in ^{12}C. The full lines show the results obtained with the FR interaction [1]. The dotted lines have been obtained with the D1 interaction but using the set of single particle wave functions and energies used in the phenomenological approach. The dashed lines are the results a self-consistent calculation with the D1 interaction.

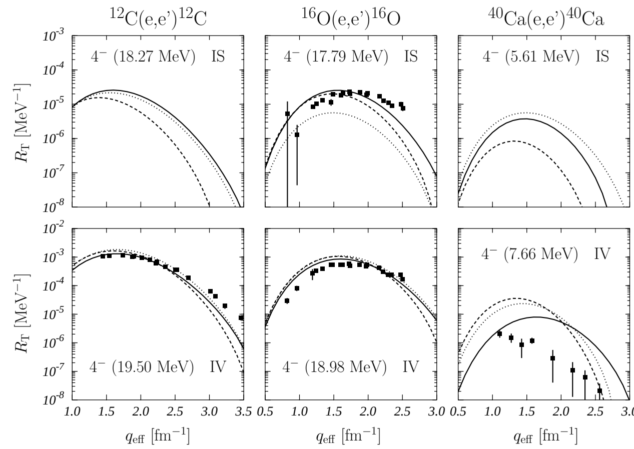

Figure 2. Electromagnetic responses of some 4^- isospin doublets. The meaning of the lines is the same as in Fig. 1.

the inversion of the isospin partner states.

We have systematically obtained this kind of inversion for all magnetic states of all the nuclei we have studied. Examples are shown in Fig. 2 for a set of 4^- in various nuclei. This result indicates the inadequacy of the D1 interaction in the isospin-dependent channels. A detailed study can be found in [1].

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