Self-consistent continuum Random Phase Approximation calculations of ^{4}He electromagnetic responses

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One of the crucial ingredients in the description of the nuclear excitation in the continuum is the re-interaction between the emitted nucleon, and the remaining nucleus. The Continuum Random Phase Approximation (CRPA) theory describes this effect, commonly called Final State Interaction (FSI), as linear combination of particle-hole and hole-particle excitations. Recently we have developed a new technique to solve CRPA equations with finite-range interactions by considering, without approximations, the excitation to the continuum [1] and we have applied [2] this technique to the study of ^{4}He nucleus. The CRPA approach to the study of light nuclei is quite unusual, since the number of particles composing the system is too small to consider the mean-field hypotheses, on which the RPA theory is based, to be reliable. On the other hand, for the ^{4}He nucleus it is an interesting application because we have the possibility of comparing our results with those of a fully microscopic approach, based on the Lorentz Inverse Transform (LIT).

We have analyzed the ground and excited states of the ^{4}He using three effective interactions: two different parameterizations of the Gogny interaction, the traditional D1S [3] interaction and the more modern D1M force [4], which produces a reasonable neutron matter equation of state, and an old finite-range effective interaction constructed to reproduce at best the ^{4}He binding energy, the B1 interaction of Brink and Boeker [5].

We have found that our description of the ground state is quite unsatisfactory confirming the inadequacy of the mean-field description in this case. For example in Fig. 1 we show the comparison of our charge distributions with the empirical one [6]. The discrepancies are remarkable especially if compared with the good description of the charge distributions of medium-heavy nuclei obtained by using the D1M and D1S interactions [1]. In the present case, the charge distributions are more extended than the experimental one.

In any case, we were interested in investigating the capacity of our approach to describe the excitation of the ^{4}He nucleus in the continuum.

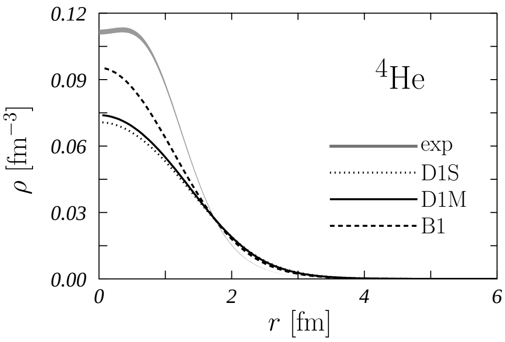

Figure 1. Charge density distributions calculated with the D1S (dotted line) and D1M (solid line) parameterizations of the Gogny interaction and with the B1 interaction (dashed line) compared to the empirical density taken from Ref. [6] (gray curve).

We show in Fig. 2 the comparison of our total photoabsorption cross section obtained with CRPA calculations (solid lines), with Independent Particle Model (IPM) calculation, i.e. those obtained by switching off the residual interaction in the RPA calculation (dashed lines) with the available experimental data [7–9] and with microscopic calculation of Refs. [10] (thin full lines) based on the LIT technique. Panels (a), (b) and (c) show the results obtained with the D1S, D1M and B1 interactions, respectively.

The experimental data are reasonably well described by the CRPA calculations, while the IPM results are clearly off the data. The performances of the results obtained with the D1M interaction are slightly better than those obtained with the D1S and B1 interaction. The two Gogny forces are able to reproduce the position of the peak, but this is not the case for the B1 interaction.

The agreement between our results and those of the microscopic calculation is remarkable. However, the results of our calculations are higher in the peak and drop more quickly in the high energy tails. Even though the experimental situation is still quite controversial, the microscopic calcula-

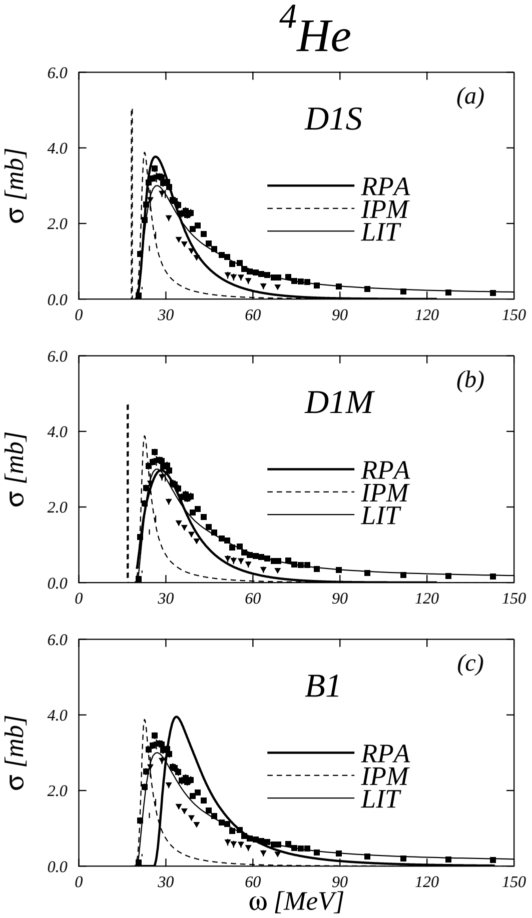

Figure 2. Total photoabsorption cross sections obtained with the three interactions used in this work. The full lines show the results of the self-consistent CRPA calculations, the dashed lines show the IPM results and the thin full lines shows the LIT results of Ref. [10]. The experimental data are from Refs. [7], squares, [8], triangles, and [9], circles. The experimental data are from Refs. [7–9].

tions give a better description of the data.

It is surprising that the performances of the CRPA are superior in ^{4}He than in medium-heavy nuclei, where the theory is supposed to be tailored. The reason is that in medium-heavy nuclei a spreading width should be added to have reasonable description of the excitation data in the continuum. As it is shown in Ref. [1], the difficulties of the CRPA in describing the responses of medium-heavy nuclei are due to the fact that excitations more complex than one-particle one-hole are not considered. The effects of these excitations are almost absent in ^{4}He, and for this reason the CRPA works very well in this case.

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