Separable Nuclear Multipole Interaction

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Currently successful models of effective interactions in nuclei have the property that, while giving good results in the mean-field approximation, the perturbation series which takes one beyond the mean-field has terms which are infinity, and hence unphysical. It is, however, desirable to go beyond the mean-field when performing calculations in order to take into account the collective behaviour which is observed in nature and also to obtain excited state properties. Models do exist which circumvent this difficulty by performing much more complicated calculations with "realistic" interactions using techniques such as the nuclear shell model, Green's function monte-carlo or coupled-cluster expansions, but these are limited to light nuclei, or nuclei where one considers only valence nucleons. A full treatment of heavy and super-heavy nuclei has not, so far, been possible.

We present an effective interaction which is as simple as current effective interactions, has good mean-field properties, but which may be successfully used to calculate the correlations beyond the mean-field. It is a two-body monopole interaction which is separable in the coordinates of the two particles, i.e. $V(r_1, r_2) = f(r_1)f(r_2)$. Preliminary results in doubly-closed-shell nuclei (^{16}O, ^{34}Si, ^{40}Ca, ^{48}Ca, ^{56}Ni, ^{78}Ni, ^{80}Zr, ^{90}Zr, ^{100}Sn, ^{114}Sn, ^{132}Sn, ^{146}Gd, and ^{208}Pb) show that the majority of the bulk nuclear properties, such as the binding energy, come from the mean-field, and that successive terms in the perturbation series are reduced by about a factor of 10. Single-particle properties, such as single particle energies and one-body densities (see figure 1), are well reproduced in the Hartree-Fock mean-field alone.

The interaction also leads to correct properties of infinite nuclear matter, both symmetric and asymmetric. Furthermore, the interaction has produced neutron star properties which are within current best-guess estimates based upon observation.

Based upon these results, we plan to extend calculations to deformed nuclei and to calculate excited state properties. For both these cases it will be necessary to augment the monopole part of the interaction so far considered with multipole forces, perhaps similar to those of the pairing plus multipole residual interaction considered by Kumar and Baranger.

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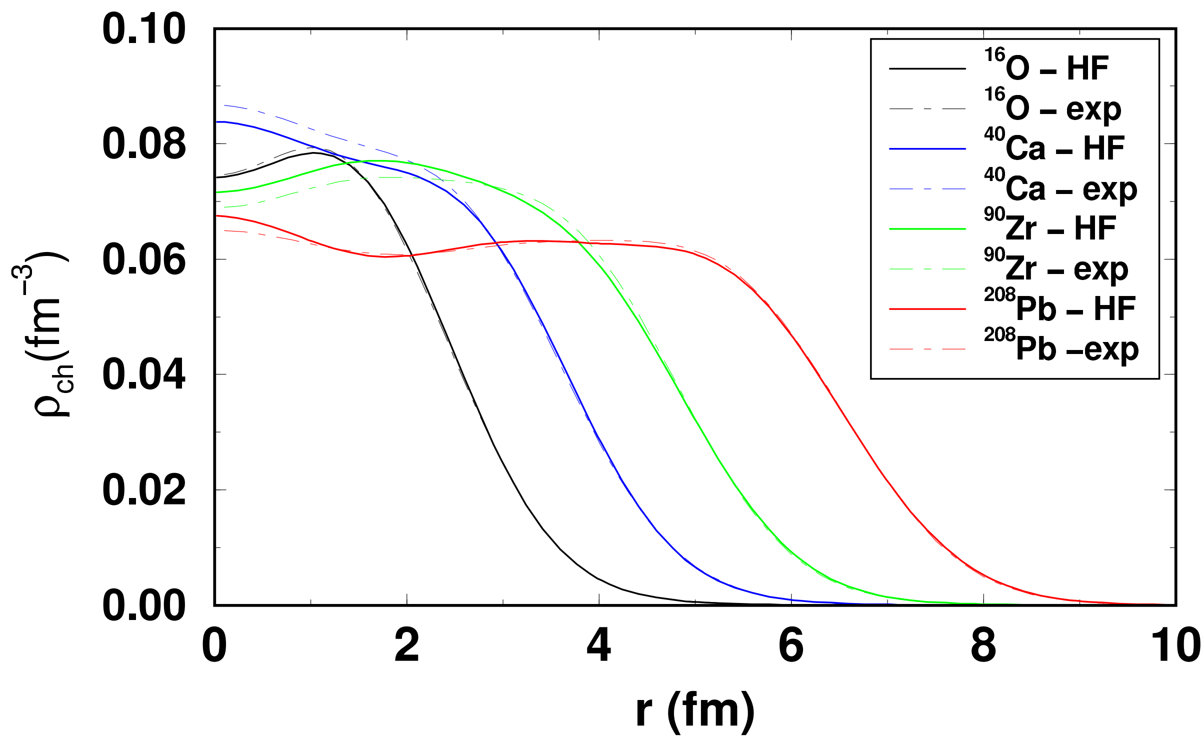

Figure 1: One-body charge densities in four spherical nuclei calculated with separable monopole interaction (HF) compared to experimental results (exp).