Isoscalar and isovector giant resonances in ^{40}Ca and ^{48}Ca

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Very recently the giant resonance region from 9.5 MeV < E_x < 40 MeV in ^{48}Ca has been studied with inelastic scattering of 240 MeV α particles at small angles, including 0º. Close to 100% of the ISGMR (E0), ISGDR (E1) and isoscalar giant quadrupole resonance (E2) strengths have been located between 9.5 and 40 MeV in ^{48}Ca [1]. To study the effect of neutron-proton asymmetry, a comparison with the available data for ^{40}Ca, as well as with the results obtained within the HF based RPA, was carried out in Ref. [1]. The ISGMR has been found at somewhat higher energy in ^{48}Ca than in ^{40}Ca, whereas self consistent HF-RPA calculations obtained using the SGII , KDE0, SKM* and SK255 Skyrme interactions predict a lower centroid energy in this neutron rich Ca isotope. This precipitated the thorough study of isoscalar and isovector giant resonances of ^{40}Ca and ^{48}Ca for multipolarities: *L*=0-3.

In this work we extend our theoretical investigation by considering the isoscalar and isovector giant resonances of multipolarities $L = 0 - 3$ in ^{40}Ca and ^{48}Ca. For this purpose, we have carried out [2] fully self-consistent Hartree-Fock (HF) based RPA calculations of the isoscalar ($T = 0$) giant monopole resonance (ISGMR), dipole (ISGDR), quadrupole (ISGQR), and the octopole (ISGOR) strength functions, and for the isovector ($T = 1$) giant monopole resonance (IVGMR), dipole (IVGDR), quadrupole (IVGQR) and octopole (IVGOR) strength functions, for ^{40}Ca and for ^{48}Ca, using a wide range of over 15 commonly employed Skyrme type interaction. These interactions, which were fitted to ground state properties of nuclei, are associated with a wide range of nuclear matter properties such as incompressibility coefficient K_{NM} = 200 - 255 MeV, effective mass m^* = 0.6 - 1.0, and symmetry energy J = 27 - 37 MeV. We consider, in particular the issue of self-consistency and investigate the sensitivities of E_{CEN} and of the isotopic differences $E_{CEN}(^{48}Ca) - E_{CEN}(^{40}Ca)$ to physical quantities, such K_{NM}, m*, J and the symmetry energy density, associated with the effective nucleon-nucleon interactions and compare the results with available experimental data. As examples we present below results of our calculations [2] for the ISGMR and IVGDR.

In Fig. 1. we compare the experimental data of the ISGMR centroid energies E_{CEN} of ^{40}Ca (a), ^{48}Ca (b), and the energy difference $E_{CEN}(^{48}Ca) - E_{CEN}(^{40}Ca)$ between ^{48}Ca and ^{40}Ca (c), shown as the regions between the dashed lines, with the results of fully self consistent HF based RPA calculations (full circles), using the Skyrme type interactions having nuclear matter incompressibility coefficients in the range of, K_{NM} = 201-258 MeV. The results obtained with violation of self-consistency by the neglecting the Coulomb and the spin orbit particle-hole interactions in the RPA calculations, are shown in (d). The energies shown were calculated over the experimental excitation energy range of 0 - 60 MeV. A clear correlation between E_{CEN} of ^{40}Ca and E_{CEN} of ^{48}Ca can be seen with K_{NM}. We point out that we have that $E_{CEN}(^{48}Ca) - E_{CEN}(^{40}Ca) < 0$ for all the interactions used in our work, in disagreement with the experimental data. Note that for not self-consistent RPA calculations, the results of some interactions lead to spurious agreement with the experimental data.

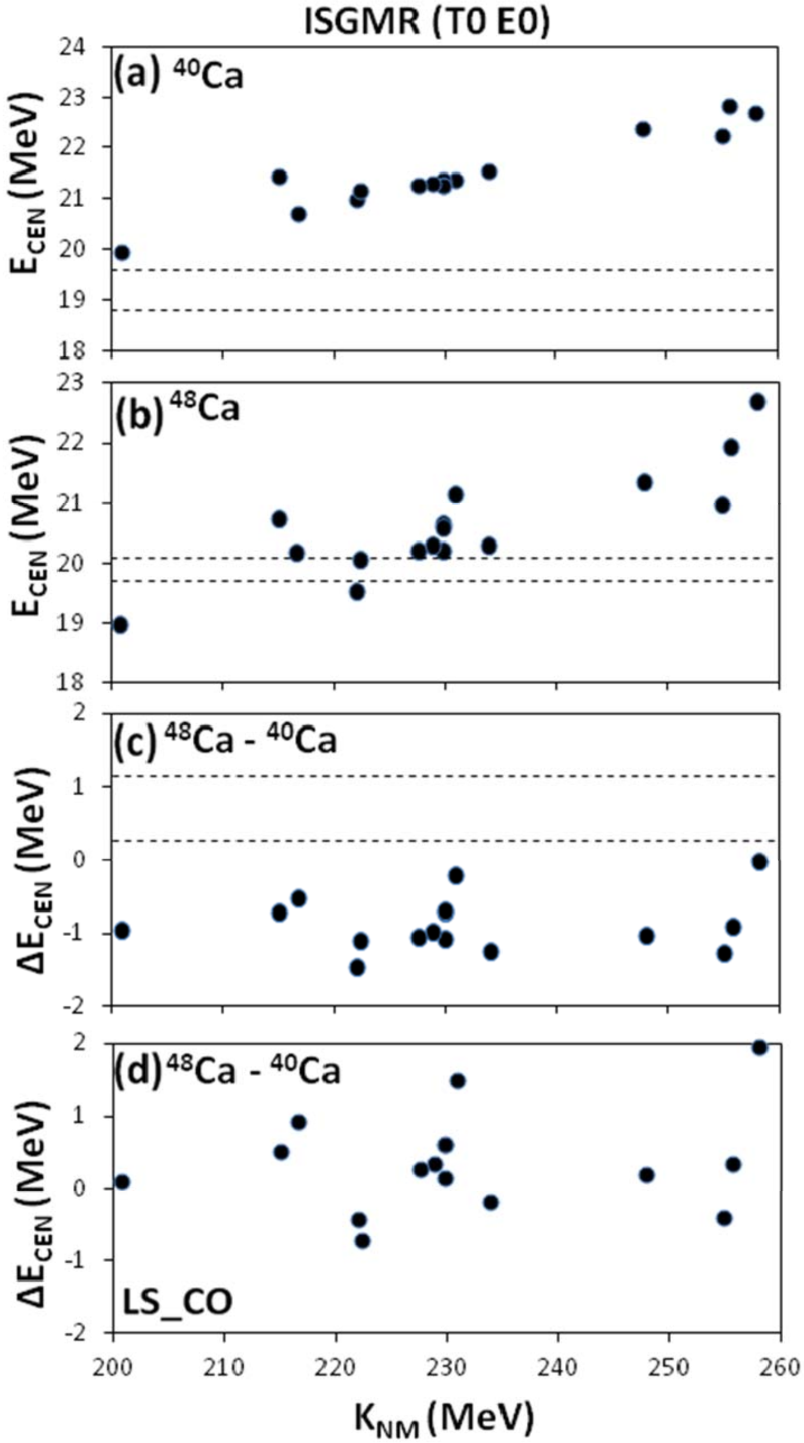

FIG. 1. Comparison between calculated centroid energies and experimental data (region between the dashed lines)for the ISGMR in ^{40}Ca and ^{48}Ca

In Fig. 2, we show our results for the centroid energies of the IVGDR in ^{40}Ca and ^{48}Ca as a function of J(0.1)/J, the ratio between the symmetry energy at 0.1 fm^{-3} (about $(2/3)\rho_0$) and the symmetry energy at saturation density ρ_0. An agreement with experimental data is obtained for several interactions. However, weak correlation is obtained between the centroid energy and J(0.1)/J. We point out that similar results were obtained when using, instead of J(0.1)/J, the first or the second derivative of the symmetry energy at saturation density.

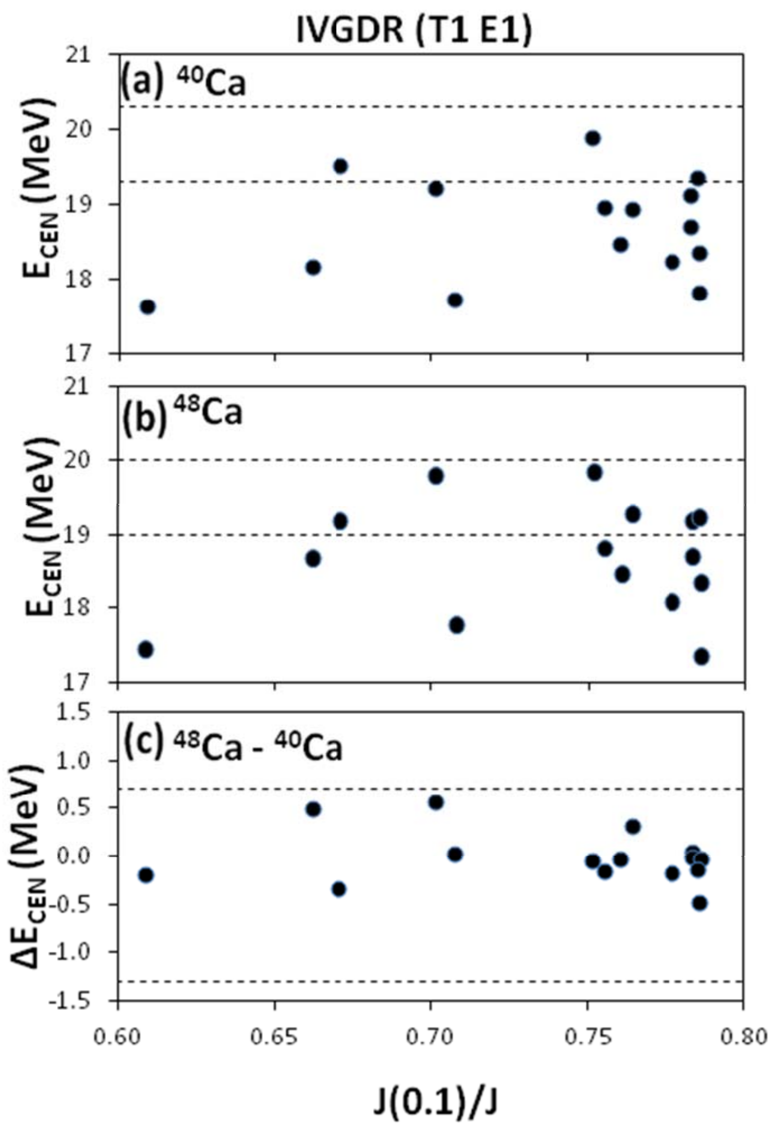

FIG. 2. Comparison between calculated centroid energies and experimental data (region between the dashed lines)for the IVGDR in ^{40}Ca

[1] Y.-W. Lui, D.H. Youngblood, S. Shlomo, X. Chen, Y. Tokimoto, Krishichayan, M. Anders, and J. Button, Phys. Rev. C. **83**, 044327 (2011).

[2] M. R. Anders *et al.*, in preparation.