Spin-Orbit Splittings between $2p_{1/2} - 2p_{3/2}$ and $1f_{5/2} - 1f_{7/2}$ Neutron States in ^{40}Ca, ^{38}Ar, ^{36}S, and ^{34}Si $N = 20$ Isotones with Covariant Density Functionals

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One of the most important advantages of relativistic mean-field (RMF) models in nuclear physics is the fact that the large spin-orbit (SO) potential emerges automatically from the inclusion of Lorentz-scalar and -vector potentials in the Dirac equation [1]. In the previous decades these models have been proven very successful in measuring observables directly related to the (SO) part of the nuclear force.

A renewed interest has risen for similar studies due to a recent experiment by Burgunder et al. [2] attempting to set an additional constraint on the strength of the Spin-orbit force. This was done by measuring the energies and the spectroscopic factors of the first $1f_{7/2}$, $2p_{3/2}$, $2p_{1/2}$ and $1f_{5/2}$ neutron states in the ^{35}Si nucleus through the (d,p) transfer reaction. Along with earlier experimental data for the case of ^{37}S, they were able to evaluate a significant reduction in the $2p_{1/2} - 2p_{3/2}$ splitting. An effect that is attributed to the occurrence of the dimple in the central proton density as we advance from 36S to 34Si.

An investigation of this effect in the context of the non-relativistic mean field models has already taken place [3]. Using various Skyrme and Gogny functionals and the inclusion of tensor forces they analyse the $2p$ and $1f$ neutron spin-orbit splittings, in the $N = 20$ isotones ^{40}Ca, ^{36}S and ^{34}Si. Inspired by this work we carried out a similar investigation of the same neutron states, following the self consistent approach of relativistic density functionals for the same $N = 20$ nuclei as well as ^{38}Ar. First we calculate the single particle energies using a Relativistic Hartree Bogolyubov model based on several modern nonlinear and density dependent covariant density functionals staying in the pure mean-field level. In the second step we employ various pairing schemes to study the same levels. Finally we consider specific extensions to the RMF framework namely the inclusion of tensor forces and the particle vibration coupling (PVC).

References

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