New developments in beyond mean field theories

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The study of exotic nuclei is one of the pillars of current nuclear research. A characteristic of these nuclei is that as one leaves the stability line the potential energy surface softens in most degrees of freedom presenting several energy minima. Therefore the mean field approximation is not a good approximation anymore. To correct this drawback configuration mixing calculations should be performed to explicitly include deformation degrees of freedom. An additional inherent drawback is the fact that these symmetry violating mean field wave functions are not eigenstates of the symmetry operators, e.g., particle number and angular momentum, and a restoration of these symmetries is necessary. To be specific we proceed in the following way: In a first stage, a set of wave functions $\{|\phi(q)\rangle\}$ are obtained by solving the particle number projected (PNP) Hartree-Fock-Bogoliubov (HFB) equation constrained to different values of the quadrupole moment q. Later on a diagonalization of the Hamiltonian takes place within the restricted, highly correlated, configuration space $\{\hat{P}^J \hat{P}^N |\phi(q)\rangle\}$ ($\hat{P}^J$ and $\hat{P}^N$ are the angular momentum and the particle number projectors). We would like to point out that by minimizing the PNP energy -the so called Variation After Projection (VAP) approach- the pairing correlations are treated equally well independently of the superfluidity regime, i.e., weak or strong pairing.

In this contribution we present several applications of this theory. In the first one we study the recently proposed shell closures at $N = 32$ and $N = 34$. In these calculations we use the finite range density dependent Gogny force (D1S). We have calculated the excitation energy of the 2^+ states in the Ca, Ti and Cr isotopes. Our results [1] nicely follow the experimental trend in all three nuclides. In particular we predict a shell closure for $N = 32$ but not for $N = 34$. We find a striking good agreement with the experiment which supports our prediction for ^{54}Ca. The calculated $B(E2)$ transition probabilities show the same degree of agreement with experiment as the 2^+ energies.

In a second application [2] the spherical to prolate deformed shape transition in the Neodymium isotopic chain is analyzed. The vibrator as well as the rotor limits are nicely reproduced while the transitional region is only qualitatively described probably due to the lack of triaxial correlations in the calculations. Our results do not support the interpretation of ^{150}Nd as a critical point nucleus and question the interpretation of shape changes as nuclear shape phase transitions.

References

[1] T. R. Rodríguez, J. L. Egido, Phys. Rev. Lett. 99, 062501 (2007)

[2] T. R. Rodríguez and J. L. Egido Phys. Lett. **B663** (2008) 49-54