Deanship of Graduate Studies
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Murad Mohammad Musa Musa

M. Sc. Thesis

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"Thesis Submitted to the College of Science and Technology of AL-Quds University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Physics"

Abu-Dies, Jerusalem

2002

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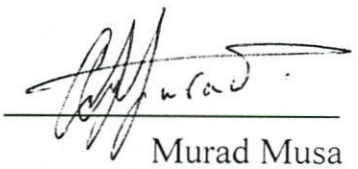
DECLARATION

I certify that this thesis submitted for the degree of Master of Science in Physics is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for a higher degree to any other university or institution.

Signed: 
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Date: November 15th, 2002

DEDICATION

To my mother, my brothers and Shiri

ACKNOWLEDGMENTS

It is a pleasure to acknowledge those who helped me during this study especially my supervisor Dr. Mohammad Abu-Samrah for his great efforts and support, my thanks also to my co-advisor Dr. Saker Darwish for his precious comments.

My thanks should be delivered to anyone who helped me to reach this point and degree, especially to the center of theoretical and applied physics at Yarmouk University for allowing us to use their facilities to do our computations.

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ABSTRACT

The Intranuclear Effective Nucleon-Nucleon Interactions in Deformed Nuclides

There is no reason to believe that the mean-field should be spherically symmetric. In order to study other possibilities, the time independent particle model should be extended to include deformed potential by assuming angular dependence of nuclear radius. This can be achieved by introducing some deformed properties of nuclides.

In this study, various static deformations up to $\ell=5$ of nuclides have been included and investigated for ^{16}O and ^{40}Ca deformed nuclides using Brüeckner $\mathfrak{I}$-matrix formalism.

The developed model is tested against the deuteron nucleus and Nilsson model. An agreement within 15% is obtained. In general, we believe that nuclides should have some deformations to some extend and the spherically symmetric has to be considered as a special case from the general case, the deformed case.

Chapter One

Introduction and purpose

1.1 Introduction

The earliest theoretical studies of nuclei were concerned mainly with ground state and the low-energy properties. The liquid-drop model was historically the first model to describe nuclear properties (Weisskopf, 1961). The liquid-drop model provides an understanding of the ground state properties, such as angular momentum and quadrupole moments, as well as low-energy dynamics properties (Eisenberg and Greiner, 1970), such as vibrations that considered as standing waves on the liquid drop surface, rotations and single-particle excitations (Cohen, 1971).

Extensive microscopic nuclear structure calculations with different realistic nucleon–nucleon (NN) (nucleon is the generic name for protons and neutrons) interaction have been performed to produce the global ground state properties of nuclides (Bohr and Mottelson, 1975; Meyerhof, 1967). Conventional non-relativistic microscopic structure calculations for the nuclear many-body systems are based on modeling the nucleus as a collection of nucleons interacting through a NN potential (Krane, 1987). The natural framework for such a study is therefore the ordinary (non-relativistic) quantum many-body theory (Kadanoff and Baym, 1976). The

nucleons are treated as elementary structureless particles so that no internal excitation of a single nucleon is considered (Brown and Jackson, 1975). These models adequately describe the ground state properties (density, size, binding energy, etc.) of nuclei (Burchman, 1963). The shell model and other methods (Nilsson model, alpha cluster model, Fermi gas model, etc.) have also been developed for the same purpose (Jelley, 1990; Bllat and Weisskopf, 1952; Eisenberg and Greiner, 1997; Feynmann, *et al.,* 1965).

The microscopic treatment of nuclear many-body systems is made difficult by the strong NN interaction with a strong short-range repulsion (Wong, 1990). Early effects to reconcile the success of the shell model with this NN interaction were unsuccessful. The breakthrough came with the Brüeckner's reaction matrix formalism (Brüeckner, 1955). This theory was used for extracting out of the "**free**" NN interaction (independent-nucleon interaction) an "**effective**" interaction, that is, a NN interaction in the nuclear medium (Williams, 1991).

By analogy with atomic physics, one approximation is to apply the concept of the independent-particle or the Hartree-Fock (HF) approximation to the nuclei (Mahaux and Sartor, 1991). The nuclear HF method is an approximation for reducing the problem of many interacting particles to non-interacting particles in a mean field (Thouless, 1961; Villars, 1966). Accordingly, the interactions used in the calculations are

effective "quasi-particle" rather than "free" interactions. This has indeed assumed the shell model description of nuclear structure (Lawson, 1980; Talmi, 1984).

The independent-particle approximation (where the HF theory is used) consists of finding the solution of the Schrödinger equation governing the dynamics of the system in a restriction of the many-body Hilbert space to variationally determined single Slater determinant. Solving the Schrödinger equation for such an approximation is equivalent to searching for a Slater determinant (of a single-particle eigenfunction if the system wave function is antisymmetric), which yields a minimal expectation value for the effective Hamiltonian (Schiff, 1968). This model was modified to include the rearrangement potential by means of the effective interaction density dependence. The modified model is called the Density-Dependent Hartree-Fock (DDHF) model (Seimens and Jensen, 1987). It has been shown that one can indeed extract out of the free NN interaction an effective interaction giving a fair amount of the static properties of doubly magic nuclei such as binding energies and spatial nuclear densities (Preston and Bhaduri, 1975; Pandharipande and Wiringa, 1979).

The one-boson exchange potential (OBEP) model (Yukawa, 1935), or the meson-exchange model, is based on the hypothesis that the NN potential is meson mediated and the exchange particles are adequately