Scattering of halo nuclei

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Table of Contents

List of Tables

List of Figures

Articles extracted from the present work

1. ” Microscopic model analysis of ^{11}Li+p elastic scattering at 62, 68.4, and 75 MeV/nucleon ”

   M. Y. M. Hassan, M. Y. H. Farag, E. H. Esmael, and **H. M. Maridi**

   Phys. Rev. C79, 014612 (2009).

2. ” Elastic scattering and breakup effect analysis of ^{11}Be + ^{12}C at 38.4 MeV/nucleon ”

   M. Y. M. Hassan, M. Y. H. Farag, E. H. Esmael, and **H. M. Maridi**

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Abstract

Light neutron-rich exotic nuclei at the drip line are characterized by weak binding energies that lead to "exotic" features as halos. Halo nuclei exhibit a strong cluster structure and anomalously large matter radii. The matter density of the halo nuclei has a long tail due to the fact that the separation energy of the halo neutrons is very low, so they can easily broken. These nuclei are so short lived that these cannot be used as targets. Instead, direct reactions can be done in inverse kinematics. To study the structure and reactions of the halo nuclei, it is useful to study the differential cross sections of the elastic scattering and reaction cross sections.

This thesis is concerned with the study of elastic scattering of one- and two-neutron halo nuclei. Two reactions have been considered, elastic scattering of ^{11}Li nucleus on a proton target and ^{11}Be + ^{12}C elastic scattering taking into consideration breakup effect.

^{11}Li+p elastic scattering data at three energies, 62, 68.4, and 75 MeV/nucleon, are analyzed with density-dependent M3Y and KH effective nucleon-nucleon (*NN*) interactions in the framework of the single folding model for the optical potential. The parameters of density-dependent term are adjusted to fulfill the saturation property of nuclear matter. The optical potentials (OP's) and cross sections are calculated using four model densities of ^{11}Li: G (one-parameter Gaussian), GG (Gaussian-Gaussian), GO (Gaussian-Oscillator), and the COSMA (cluster orbital shell model approximation). Comparative studies are performed for real, imaginary, and spin-orbit potentials with the phenomenological and microscopic forms. The microscopic volume and surface imaginary potentials are constructed from both the renormalized folded potentials and their derivatives. The sensitivity of the differential cross section to the four densities is tested. It is found that the ^{11}Li+p elastic scattering cross sections depend strongly upon the behavior of the corresponding potentials. The GG and GO densities obtained from analyzing the data, using Glauber multiple scattering theory at high energies, give good results at energies below 100 MeV/nucleon in the framework of the folding model. The OP's calculated in the

microscopic form using few parameters give good agreement with the data. Thus, it is not necessary to introduce a large number of arbitrary fitting parameters as done in the phenomenological and semimicroscopic OP's. The KH effective interaction successfully describes ^{11}Li+p elastic scattering as the popular M3Y interaction. The obtained results of the reaction cross section are in good agreement with previous calculations.

^{11}Be + ^{12}C elastic-scattering data at 38.4 MeV/nucleon has been analyzed using the optical model. The optical potential is calculated in the framework of the double folding model using M3Y effective nucleon-nucleon interaction. The different models of ^{11}Be density are tested and the model that does not include the halo structure gives poor fitting with data. The breakup effect is studied by introducing a complex dynamical polarization potential (DPP) that is added to the "bare" potential. The DPP is taken in different forms that have been obtained from simple phenomenological, semiclassical approximation, and microscopic methods. The simple phenomenological DPP is approximated and related to the semiclassical approximation method. The sensitivity of the differential and reaction cross sections to these polarization potentials is tested. The microscopic DPP that has been constructed from the derivative of the folding potential describes the breakup effect well. It gives an explicit justification for the long range of the polarization potential.

Chapter 1

Introduction

The study of the properties of unstable light nuclei is considered as an important and exciting research topic in modern nuclear physics. About 280 stable or very long-lived nuclear species are found in nature, whereas predictions show that about 7000 bound nuclei should exist in the Universe, which do not decay via spontaneous particle emission. Only 2000 have been synthesized and observed to date, but very little information is available about these unstable nuclei. Their lifetimes, masses or sizes are often unknown. With access to exotic nuclei at the very limits of nuclear stability, the physics of the neutron and proton drip lines has become the focus of interest. The drip lines form the edges of the nuclear chart and indicate the point at which nuclei are no longer stable against spontaneous particle emission.

Exotic nuclei are nuclei which contain many more or many fewer neutrons than a stable isotope of the same element. They lie far away from stability line in the chart of nuclei, so they are mostly unstable against β-decay and exhibit new and exotic behavior. These nuclei have lifetimes of order of a millisecond to a second which are much longer than the time scale of nucleonic motion (10^{-23} s) inside the nucleus, so it is long enough for the exotic nuclei to posses well-defined many-body structures as bound systems of nucleons. Because the exotic nuclei are so short lived and rapidly decayed, they cannot be used as targets. Instead, direct reactions with radioactive nuclear beam can be done in inverse kinematics where the role of beam and target are interchanged.

Radioactive Nuclear Beams (RNB) as well as great progress in advanced detector