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Review

Recent experimental progress in nuclear halo structure studies

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ABSTRACT

Recent developments (since the last review in J. of Physics G by I. Tanihata in 1996 [1]) at RIB facilities opened possibilities of detailed studies of halo nuclei. New facilities have been constructed to provide higher intensity beams of radioactive nuclei in a wide range of energies. At the time of the last review, only secondary beams by projectile fragmentation were the production source of halo nuclei for use in reaction studies. Since then, re-acceleration facilities have been developed and thus high-quality low-energy beams become available for the reaction studies. The wide variety of new data are thus available on halo nuclei and nuclei on and outside of proton and neutron drip lines.

Low energy beams provided a means to determine the masses and charge radii of halo nuclei (^{6,8}He, ^{11}Li). Also transfer reactions have been measured in many nuclei far from the stability line. In fragmentation facilities, new experimental methods such as gamma ray detection in coincidence with breakup fragments of halo nuclei have been developed. Also the reaction cross sections have been measured in a wide range of beam energies. In addition, proton elastic scattering of halo nuclei has been measured at high energies. All together, studies of density distribution, identification of shell orbitals and spectroscopic factors of halo wave function became possible. Such studies reveal many new important information such as the change of magic numbers in nuclei far from the stability line.

In this article, we would like to review the experimental developments on halo nuclei and other related drip line nuclei. Also the new view of the nuclear structure learned from such studies will be discussed. Development of selected theories on related nuclear structure problems will be mentioned briefly.

Contents

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1. Introduction

1.1. Basics of halo formation, two-body halo, three-body halo, and giant halo

A neutron halo was discovered in ^{11}Li nucleus from the series of experiments including the interaction cross section, the momentum distribution of the ^{9}Li fragment from ^{11}Li, and enhancement of the Electro-Magnetic Dissociation (EMD) cross section.

The main concept of the halo is a long tail in the density distribution of a nucleus. In stable nuclei with separation energy of about 6–8 MeV, the density distributions $\rho(r)$ are usually described by a Woods–Saxon type distribution as, (for a spherical nucleus)

$$\rho_{ws}(r) = \rho_0 \left[1 + \exp\left(\frac{r - R}{a} \right) \right]^{-1}, \tag{1.1}$$

with diffuseness parameter $a \sim 0.53$ fm. Here $\rho_0 \sim 0.17$ fm^{-1} is the density at the center and the radius parameter R is parameterized by mass number A as,

$$R \sim 1.10 A^{1/3} \text{ (fm)}. \tag{1.2}$$