Analysis of Angular Distribution Data for ^{9,10,11}Be + ^{64}Zn Systems at Slightly Above Barrier Energy

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Heavy ion elastic scattering angular distributions, when plotted as a ratio of Rutherford scattering cross section, typically have a characteristic form referred to as Fresnel scattering pattern i.e. one or more oscillations about the Rutherford value at small angles followed by a larger peak before an exponential fall off as a function of scattering angle. The large peak is because of interference between the Coulomb and nuclear amplitudes, called Coulomb nuclear interference peak or the Coulomb rainbow peak [1]. Elastic scattering is considered as a simple and peripheral process which can be easily explained by the models wherein internal structure of the interacting nuclei is generally ignored. However, because of the unique characteristics properties of halo nuclei it becomes essential to investigate the role of these properties in the analysis of quasielastic scattering angular distributions. In particular, the low breakup threshold compels to include coupling to breakup channels in the analysis [2]. In order to see these effects conspicuously, it is quite tempting to compare the quasielastic angular distributions of well established halo nucleus with those of other nuclei in a particular isotopic chain. The nucleus ^{11}Be is a prototype one neutron halo nucleus having a ^{10}Be core surrounded by one valance neutron with a binding energy of just 503keV [3]. Thus, in the present work we have analyzed elastic scattering angular distribution for ^{9,10}Be + ^{64}Zn systems and quasielastic angular distribution for ^{11}Be+^{64}Zn system at energy about 1.4 times the Coulomb barrier using the FRESCO code.

The code FRESCO is a general purpose code to analyze various nuclear reactions and is based on coupled channel approach. In case of a loosely bound halo system either there is no bound excited state or at the most there exists one such state. Consequently, in order to take into account the effect of coupling to inelastic channel it is essential to take coupling with states in energy continuum. The coupling to continuum is made quite simplified in an approach called continuum discretized coupled channel (CDCC) method which is an important component of FRESCO code.

In CDCC calculations, the projectile ^{11}Be is treated as a two body system consisting of ^{10}Be core and a valance neutron whereas the target is a nucleus with normal nuclear density that is ^{11}Be+^{64}Zn is effectively a three body system [4]. The continuum is discretized by putting an upper limit of excitation energy and then dividing it in to energy intervals called bins [5]. The three body wave function (two body projectile + target) is obtained by solving a set of coupled differential equations numerically under appropriate boundary conditions.

The potential parameters needed in the calculations for ^{9}Be+^{64}Zn and ^{10}Be-^{64}Zn systems are taken from Ref. [3]. While in case of ^{11}Be+^{64}Zn in which the effects of breakup channels are included the potential parameters are taken from Refs. [3, 6]. The ground state wave function of ^{11}Be is generated by employing the interaction potential given in Ref [7]. The results of the calculations along with the experimental data taken from Ref. [4] are presented in Fig.1.

It can be clearly seen from Fig.1 that the elastic scattering angular distributions for ^{9}Be and ^{10}Be isotopes are similar to each other and resemble very well with the standard one. But the angular distribution of halo nucleus ^{11}Be shows extremely strange features and differs drastically from the standard angular distribution shape. In this case the Coulomb nuclear interference peak has disappeared and a dramatic reduction of elastic cross section is observed at

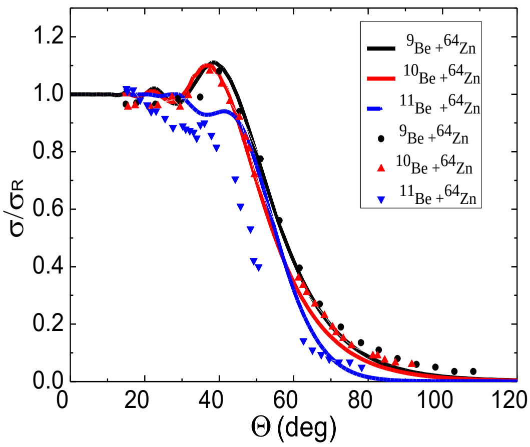

Fig. 1(Color online) Angular distributions for ^{9,10,11}Be + ^{64}Zn systems are compared with the corresponding data taken from Ref. [4]. The curves are the results of CDCC calculations and points are the experimental data.

angles where a peak is expected. The same kind of behavior is observed in elastic scattering angular distributions of the systems involving deformed nuclei [1] because of the coupling with the strong Coulomb excitations of various states of projectile, target or both. It is important to mention here that at energies close to Coulomb barrier these kinds of couplings are evident only with targets having high charge numbers (Z > 80) and generally the lighter and the medium charge targets are not sensitive to these couplings [3]. So it can be concluded that disappearance of Coulomb nuclear interference peak in scattering of halo nucleus ^{11}Be with ^{64}Zn is associated with combined effects of its halo structure and strong coupling to breakup channel. Because of large spatial extension there occurs absorption at a large distance leading to enhancement in reaction cross section and hence a reduction in elastic cross section. Also due to the coupling with breakup channel the contribution to breakup cross section increases and the elastic cross section reduces. Further, a good agreement has been found between theoretical calculations and experimental data for ^{9,10}Be projectiles. But for the halo nucleus ^{11}Be, the agreement between data and prediction is not so good. The data are substantially overestimated in the angular range up to 60°. It may be ascribed to the fact that coupling with channels other than breakup are neglected in the present calculations. However, disappearance of Coulomb nuclear interference peak is a common feature of both the measurement as well as of theoretical calculations. In nutshell, the coupling to discretized states in the continuum for a halo nucleus leads to disappearance of the characteristics peak in elastic scattering angular distribution and plays an important role in identifying the halo structure of loosely bound nuclei.

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