Elastic scattering of halo nucleus ^{11}Li with ^{208}Pb at near-barrier energies

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The study of elastic scattering of halo nuclei with heavy targets near Coulomb barrier is a topic of current interest. Recent experimental results point to a significant departure of the ^{11}Li + ^{208}Pb experimental elastic scattering cross section from the usual behavior of a well-bound nucleus. This is manifested in terms of a strong reduction in the cross section with respect to the Rutherford value at center-of-mass energies ($E_{c.m.}$) both below (23.1 MeV) and at (28.3 MeV) the Coulomb barrier [1]. A strong dipole Coulomb interaction exists for halo nucleus interacting with heavy target and this causes a reduction of elastic scattering cross section and an increase in the total reaction cross section. At near-Coulomb-barrier energies, where the Coulomb force dominates, states at low excitation energies are mainly populated. The reduction of Coulomb repulsion and elastic scattering cross section can be taken into account using a complex polarization potential which depends explicitly on the electric dipole strength $B(E1)$ distribution [2]. The real part of the polarization potential describes reduction of Coulomb repulsion, while the imaginary part describes loss of flux due to breakup. In this work, elastic scattering cross sections for ^{11}Li + ^{208}Pb at $E_{c.m.}$ = 23.1 MeV and 28.3 MeV are investigated using Double Folding (DF) model with and without dynamic polarization potential.

The microscopic double-folded potential is obtained by folding a complex nucleon-nucleon effective interaction with the nuclear density distributions of target and projectile taking into account the halo structure. For the halo nucleus ^{11}Li, neutron and proton densities are obtained through the Cluster-Orbital Shell Model Approximation (COSMA) [3]. In the present analysis, the imaginary part is assumed to be the same as the real part of the DF potential with a renormalization constant. The DF potentials obtained with renormalization constants of unity are used to calculate the differential and reaction cross sections for ^{11}Li + ^{208}Pb at $E_{c.m.}$ = 23.1 MeV and 28.3 MeV. The calculated angular distributions, obtained using DF potential, for ^{11}Li + ^{208}Pb elastic scattering cross section (relative to Rutherford scattering cross section) are shown in Fig. 1; the suppression observed in the experimental data is also evident here [1]. A strong dipole Coulomb interaction exists for halo nucleus is not reproduced by the DF calculations. Therefore, static effects from inclusion of the density of the halo are not enough to explain the observed data. The dynamic effects due to coupling of channels incorporated with an effective DPP are necessary to explain these features and are described below.

The Dynamic Polarization Potential (DPP) due to Coulomb excitation of a dipole state with excitation energy can be derived in a semi-classical way and it depends explicitly on the $B(E1)$ distribution [2]. The $B(E1)$ distribution as a function of the excitation energy above the breakup threshold for has been calculated using the simple cluster model (CM) as described in Ref. [4]. In the CM, the break-up of a nucleus into two fragments is characterized by the threshold energy. The $B(E1)$ distribution for ^{11}Li is calculated from CM and compared with experiment [5]. It is found that the $B(E1)$ distribution calculated from the CM is different from the corresponding data [5]. Using these two choices of the $B(E1)$ distribution, the complex DPP are determined for ^{11}Li + ^{208}Pb at $E_{c.m.}$ of 23.1 and

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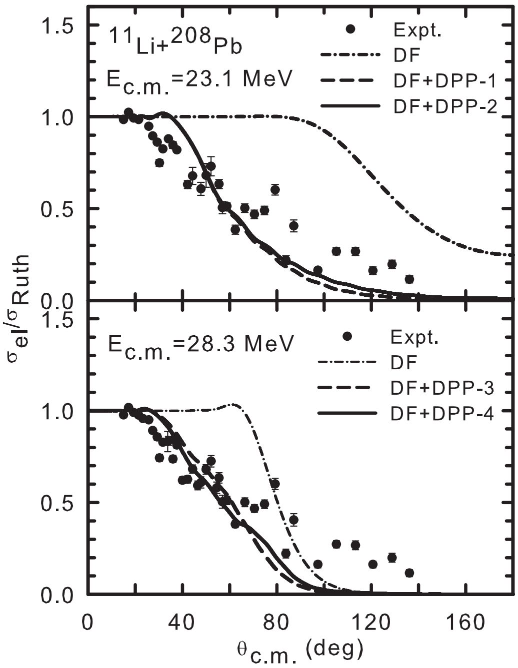

FIG. 1: Calculated elastic scattering angular distribution (relative to Rutherford scattering cross section) for ^{11}Li + ^{208}Pb at $E_{c.m.}$ = 23.1 and 28.3 MeV. Dots are experimental values [1] while lines correspond to DF calculations with and without imaginary part of DPP included.

28.3 MeV. The present analysis was carried out with the imaginary part of the DPP included to the DF potential, as the real part has only a small influence on the elastic scattering cross section. A search on the renormalization constants was carried out to get a best fit to the differential cross-section data. The final real and imaginary parts of the total potential are then obtained by multiplying the potential with the corresponding renormalization constants. The real and imaginary parts of the DF potential including imaginary part of DPP, calculated using different $B(E1)$ distributions obtained from the cluster model and from experiment, are used to obtain differential and total reaction cross sections. The real and imaginary parts of the DF potential including imaginary part of DPP, calculated for ^{11}Li scattering at $E_{c.m.}$ = 23.1 MeV using $B(E1)$ distributions from Ref. [5] and cluster model are denoted by DPP-1 and DPP-2, respectively, while that for $E_{c.m.}$ = 28.3 MeV are denoted by DPP-3 and DPP-4, respectively. The elastic scattering angular distribution (relative to Rutherford scattering cross section) for ^{11}Li + ^{208}Pb at $E_{c.m.}$ = 23.1 and 28.3 MeV calculated using DF calculations with imaginary part of DPP included are shown in Fig. 1. It is clear from the figure that there is a distinct reduction in the calculated elastic scattering cross section for forward scattering angles and good agreement with the data [1], except for backward angles. The differential cross sections calculated with imaginary part of DPP obtained from the two choices of $B(E1)$ distribution are quite similar, although the distributions are different. However, it is evident from the calculation that DPP due to $B(E1)$ is crucial in explaining the data for halo nuclei at near-barrier energies. The incident energy is at or below the Coulomb barrier and hence the reduction in the differential cross section is mainly due to dipole Coulomb couplings which are taken into account in the calculation.

In contrast to Continuum Discretized Coupled Channels (CDCC) calculations which are more detailed and complicated, the present approach, though simple and approximate, is quite useful in explaining the observed features of elastic scattering of halo nuclei.

References

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