Vol. 42 (2011) ACTA PHYSICA POLONICA B No 3–4

DIPOLE POLARIZABILITIES OF WEAKLY BOUND NUCLEI*

V.V. Parkar, I. Martel, A.M. Sánchez-Benítez, L. Acosta

Departamento de Física Aplicada, Universidad de Huelva, 21071 Huelva, Spain

K. Rusek

Heavy Ion Laboratory, University of Warsaw
Pasteura 5A, 02-093 Warsaw, Poland

Ł. Standylo, N. Keeley

Department of Nuclear Reactions, The A. Sołtan Institute for Nuclear Studies
Hoża 69, 00-681 Warsaw, Poland

(Received January 28, 2011)

Dipole polarizability, one of the fundamental properties of a nucleus, studied in elastic scattering experiments has been reviewed here. For strongly bound nuclei the effect of dipole polarizability is usually negligible. However, for weakly bound nuclei, where the dipole strength extends to low excitation energies, it does play a major role. This effect has already been examined in the scattering of the lightest weakly-bound stable nuclei, *viz.*, d, ^{3}He, and ^{7}Li. In the present work we have studied it for the weakly bound unstable borromean nucleus, ^{6}He, using the elastic scattering data available at energies around the Coulomb barrier with a ^{208}Pb target.

DOI:10.5506/APhysPolB.42.761
PACS numbers: 25.70.Bc, 24.10.Eq, 21.60.Gx, 25.70.De

1. Introduction

The dipole polarizability (DP) of a nucleus arises due to the fact that during collisions between two heavy nuclei, the presence of the strong electric field distorts the charge distribution of the nuclei resulting in an additional interaction that influences the elastic scattering. The dipole potential couples the ground state to states of opposite parity and hence it is sensitive

* Presented at the Zakopane Conference on Nuclear Physics "Extremes of the Nuclear Landscape", August 30–September 5, 2010, Zakopane, Poland.

to the $B(E1)$ strength distribution. This effect is very small and usually neglected for stable nuclei as the states of opposite parity occur at relatively high excitation energies (above the nucleon separation energy, which is typically ~ 8 MeV). However, the dipole excitation is expected to have a significant effect for nuclei with low break-up thresholds *e.g.*, the deuteron (break-up threshold of 2.2 MeV), ^{7}Li (break-up threshold of 2.48 MeV) and especially for the halo nuclei ^{6}He, ^{11}Li with break-up energies below 1 MeV. Work has been carried out in the past to investigate this effect on the scattering of these weakly bound nuclei from heavy target such as $d+{}^{208}$Pb [1], ^{3}He $+{}^{208}$Pb [2], ^{7}Li $+{}^{208}$Pb [3], ^{6}He $+{}^{208}$Pb [4,5], and ^{11}Li $+{}^{208}$Pb [6]. For the case of $d+{}^{208}$Pb, ^{3}He $+{}^{208}$Pb, and ^{7}Li $+{}^{208}$Pb scattering, a high precision measurement was performed to observe a deviation of only 2% from the Rutherford cross-section at backward angles and the dipole polarizabity parameter, α was deduced. For the case of halo nuclei, the dipole potential should affect the elastic cross-section strongly. This effect has been observed for ^{6}He $+{}^{208}$Pb [4] scattering and similar behaviour is expected for the ^{11}Li $+{}^{208}$Pb [6] system. For these systems the disappearance of the Fresnel diffraction pattern and a large reduction of the elastic cross-sections have also been ascribed to continuum couplings corresponding to dipole transitions [4].

Theoretically the dipole polarizability parameter, α is defined as follows,

$$\alpha = \frac{8\pi}{9}\sum_{d}\frac{B(E1,\mathrm{g.s.}\to d)}{\epsilon_d}\,, \tag{1}$$

which suggests that this parameter is strongly dependent on the $B(E1)$ value. Experimentally, the role of electric dipole polarizability(α) can be investigated by accurate measurement of the elastic scattering of weakly bound nuclei in the field of a heavy nucleus. This effect is quantified in terms of the deviation from pure Rutherford scattering.

2. Dipole polarizabilty for ^{6}He

In the present work, we have extracted the value of α by using a parametrised Dynamic polarisation potential (DPP). The potential is assumed to have the following form

$$\Delta V_{\mathrm{real}} = V_1\frac{df(r)}{dr} + V_2\,g(r) \qquad \text{and} \qquad \Delta W_{\mathrm{imag}} = W_1\frac{df(r)}{dr} + W_2\,g(r)\,,$$

where

$$f(r) = \left[1+\exp\left(\frac{r-R_{0,i}}{a_1}\right)\right]^{-1} \qquad \text{and} \qquad g(r) = \left[1+\exp\left(\frac{r-R_{0,i}}{a_2}\right)\right]^{-1}.$$

We have fitted the elastic scattering data available for ^{6}He + ^{208}Pb system at 18 MeV [5] using this DPP plus the double folding (DF) potential. The real part of DF potential is obtained from the densities of ^{6}He and ^{208}Pb. For the imaginary part we have used the same potential with the normalisation constant. We have used the search option in FRESCO (SFRESCO) to search for all the parameters in DPP and for the normalisation constant of imaginary part of DF potential. The fit to the data with and without DPP is shown in Fig. 1 (A), while the CDCC calculations are shown in Fig. 1 (B). The real and imaginary parts of DPP are also plotted in Fig. 1 (C) and (D), respectively, along with the DPP generated from CDCC. The DPP generated from CDCC and the parametrised DPP is found to be in agreement with each other. As the real part of DPP can be correlated with the Coulomb polarisation potential, we have fitted the long range attractive part by the expression $V_{\rm pol}(r) = -\frac{1}{2}\alpha\frac{Z_T^2 e^2}{r^4}$ to get the value of α (dipole polarizabilty) for ^{6}He, which is found to be 1.2 fm^3, in reasonable agreement with that given in Ref. [9].

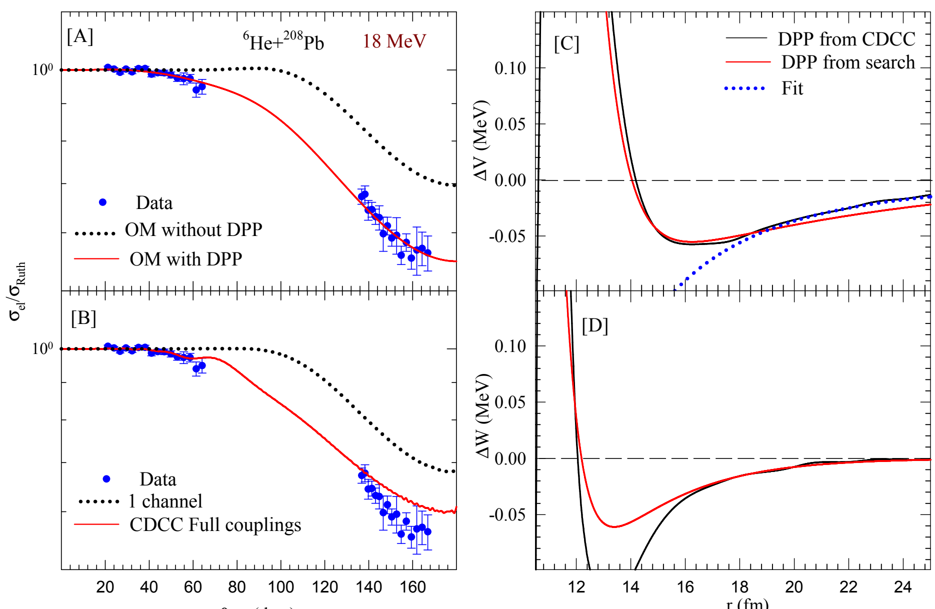

Fig. 1. (Color online) Measured elastic scattering data for ^{6}He + ^{208}Pb system at $\mathrm{E_{lab}}$ = 18 MeV along with (A) the optical model calculation with and without DPP and (B) no couplings and full (CDCC) calculations. The real and imaginary parts of DPP extracted from CDCC are shown in (C) and (D) respectively along with the parametrised DPP. The tail of real part in (C) is fitted with the function of polarisation potential (defined in the text) to get the value of α.

3. Comparison of DP value for various nuclei

In Table I, a comparison of DP values for various nuclei is shown. It does not show any clear dependence on the break-up threshold of the nuclei. The highest DP value observed so far is for the ^{6}He nucleus.

TABLE I

Comparison of available DP values for various nuclei.

Nucleus	Breakup threshold (MeV)	α (fm^3)	Ref.
d	2.20	0.70	[1]
^{3}He	5.49	0.20	[2]
^{7}Li	2.47	0.045	[3]
^{6}He	0.974	1.2	Present

4. Summary and future outlook

The study of dipole polarizabilty has been reviewed in this paper. The dipole polarization is very important in the case of weakly bound nuclei. We have extracted a value of $\alpha(= 1.2\ \mathrm{fm}^3)$ for ^{6}He from the experimental elastic scattering angular distribution data for $^6\mathrm{He} + {}^{208}\mathrm{Pb}$.

In the near future, the rapid development of upcoming Radioactive Ion Beam (RIB) facilities, *viz.*, FAIR and SPIRAL2, will provide more weakly bound unstable nuclei away from the line of stability, for which one can extend this study of dipole polarizabilty to great detail.

This work was partially supported by the Spanish Ministry of Science under contract FPA2007-63074 and INGENIO-2010(CPAN).

REFERENCES

[1] N.L. Rodning *et al.*, *Phys. Rev. Lett.* **49**, 909 (1982).
[2] F. Goeckner, L.O. Lamm, L.D. Knutson, *Phys. Rev.* **C43**, 66 (1991).
[3] V.V. Parkar *et al.*, *Phys. Rev.* **C78**, 021601(R) (2008).
[4] K. Rusek *et al.*, *Phys. Rev.* **C67**, 041604(R) (2003).
[5] A.M. Sánchez-Benítez *et al.*, *Nucl. Phys.* **A803**, 30 (2008).
[6] M.V. Andrés, J. Gómez-Camacho, *Phys. Rev. Lett.* **82**, 1387 (1999).
[7] K. Rusek, *Eur. Phys. J.* **A41**, 399 (2009).
[8] I.J. Thompson, *Comput. Phys. Rep.* **7**, 167 (1988).
[9] J.A. Lay *et al.*, *Phys. Rev.* **C82**, 024605 (2010).