AIP Conference Proceedings

Experimental Determination of the ^{6,7}Li Nucleon Densities

Cite as: AIP Conference Proceedings **1139**, 106 (2009); https://doi.org/10.1063/1.3157787
Published Online: 08 June 2009

D. P. de Sousa, D. Pereira, J. Lubian, L. C. Chamon, J. R. B. Oliveira, E. S. Rossi, C. P. Silva, P. F. Neto, V. Guimarães, R. Lichtenthäler, and M. A. G. Alvarez

View Online
Export Citation

ARTICLES YOU MAY BE INTERESTED IN

Radia2: A new tool for radiotherapy verification
AIP Conference Proceedings **1541**, 183 (2013); https://doi.org/10.1063/1.4810838

Study Of The Scattering Of Halo Nuclei Around The Coulomb Barrier
AIP Conference Proceedings **1336**, 570 (2011); https://doi.org/10.1063/1.3586166

Search for two-proton radioactivity of ^{19}Mg in a tracking experiment
AIP Conference Proceedings **961**, 93 (2007); https://doi.org/10.1063/1.2827290

AIP Publishing

© 2009 American Institute of Physics.

Experimental Determination of the ^{6,7}Li Nucleon Densities

D.P. de Sousa[a], D. Pereira[a], J. Lubian[b], L.C. Chamon[a], J.R.B. Oliveira[a], E.S. Rossi Jr.[a], C.P. Silva[a], P.F. Neto[a], V. Guimarães[a], R. Lichtenthäler[a], M.A.G. Alvarez[c]

[a]*Instituto de Física da Universidade de São Paulo, Departamento de Física Nuclear, Caixa Postal 66318,05317-970 São Paulo, Brazil.*
[b]*Universidade Federal Fluminense, 24210-340 Instituto de Física, Niterói, Brazil.*
[c]*Departamento de Física Atômica Molecular y Nuclear da Universidade de Sevilla Apdo. 1065, E-41080, Sevilla, Spain.*

Abstract. In this work we present optical model analysis of new near barrier-quasi-elastic experimental data, for the systems ^{6,7}Li + ^{120}Sn. From the analysis it was possible to extract the ground state nucleon densities of the weakly bound ^{6,7}Li isotopes. The apparent discrepancies between the experimental densities, as compared with those based on Dirac-Hartree-Fock-Bouguliubov (DHB) calculations were removed, considering in the reaction mechanism, the projectile break-up and a positive polarization from couplings of ^{6,7}Li states of the continuum.

Keywords: Nuclear Reactions, Optical Model, Nuclear Densities.
PACS: 21.10.Gv, 24.10.Ht, 25.70.Bc.

INTRODUCTION

It is well established that [1, 2, 3] from optical model (OM) data analysis of total quasi-elastic (elastic, inelastic and transfer processes), at near and sub barrier energies, it is possible to characterize the nuclear potential in the surface interaction region for a heavy–ion system. For a specific bombarding energy a reliable potential value can be defined at the *strong absorption radius* [1].

The São Paulo Potential (SPP) [4], is a parameter free folding–type potential: $V_F(R) = \int \rho_1(r_1) v_{12} \rho_2(r_2) dr_1$, with the normalization given by e^{-4v^2/c^2}, where v is the relative velocity between the partners of the collision. The experimental surface potential values cited above, are directly compared with those from the bare SPP, since the OM quasi-elastic data analysis approach of ref. [1] approximately removes the couplings effects. From this comparison, in the method proposed, it is possible to extract experimentally the nucleon density $\rho_1(r)$ for surface radii if ρ_T is assumed to be well known. In the SPP model, the nucleon densities of the partners of the collision are derived from DHB calculations [4]. In the present work, we have obtained the ^{6,7}Li densities for surface radius, using the method proposed, by measuring quasi-elastic

CP1139, *Nuclear Physics 2008, XXXI Workshop on Nuclear Physics in Brazil,*
edited by V. Guimarães, J. R. B. Oliveira, K. C. D. Macario, and F. A. Genezini
© 2009 American Institute of Physics 978-0-7354-0676-6/09/$25.00

cross sections for the systems ^{6,7}Li + ^{120}Sn, at the near barrier energies E_{Lab} (^{7}Li)= 19.5, 20.5, 25 MeV and E_{Lab} (^{6}Li)= 19.5 MeV. The Coulomb barrier for the systems above is around 20 MeV in the laboratory frame. These experimental densities were compared with those [4] from systematics based on DHB calculations, assuming a Fermi–Dirac distribution shape: $\rho(R)=\frac{\rho_0}{1+e^{\frac{R-R_0}{a}}}$.

EXPERIMENTAL DETAILS

The experiments were performed in the 8-UD São Paulo Pelletron laboratory. A 100 μg/cm^2 isotopic enriched ^{120}Sn target, with a thin evaporated layer of Au for data normalization has been used in the experiments. A set of nine collimated silicon barrier detectors, separated 5 degrees apart, was used as the detector system. In figure 1 a typical energy spectrum for the system ^{7}Li + ^{120}Sn is shown.

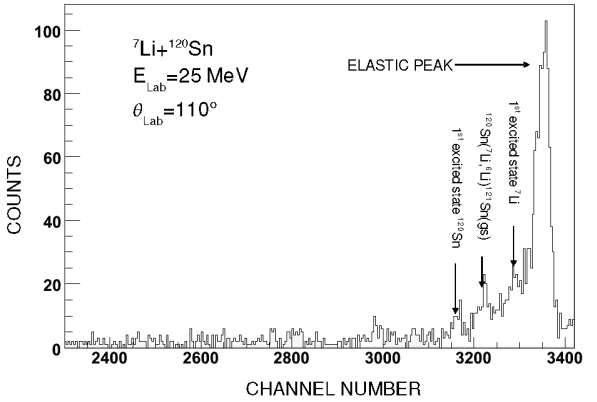

FIGURE 1. Energy spectrum for the system ^{7}Li + ^{120}Sn at E_{lab}= 25 MeV and θ_{Lab}= 110^0.

As shown in figure 1, we have detected as the main quasi-elastic reaction channels: ^{120}Sn(^{7}Li,^{7}Li*(Ex=0.477MeV))^{120}Sn,^{120}Sn(^{7}Li,^{7}Li)^{120}Sn*(Ex=1.171MeV);^{120}Sn(^{7}Li,^{6}Li) ^{121}Sn(gs). The first of these reactions is the main channel coupling, due to the large ^{7}Li ($\frac{1^-}{2}$) deformation parameter, as reported earlier [5, 6].

DATA REDUCTION, ANALYSIS AND RESULTS

In figure 2 the corresponding angular distributions for the total quasi-elastic processes for the systems ^{6,7}Li + ^{120}Sn are shown. The dash lines in the figure correspond to OM

data analysis, using the SPP, with the ground state nucleon density for the inert (N= 82 and super fluid for protons) ^{120}Sn target nucleus obtained from the systematics based on DHB calculations[4], and for ^{6,7}Li a Fermi–Dirac shape has been assumed with fit parameters R_0 and the diffuseness a.

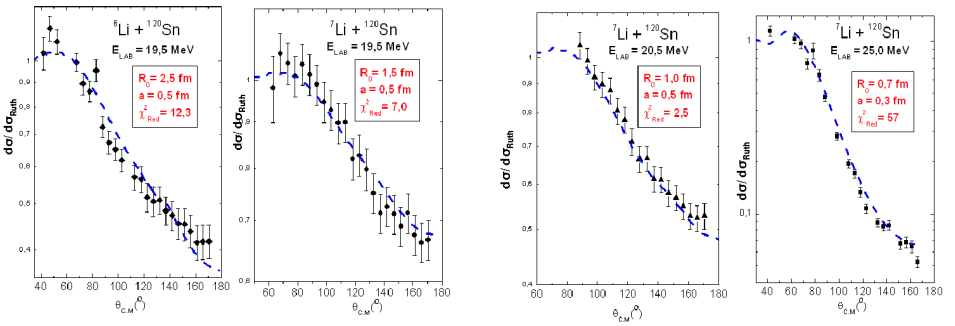

FIGURE 2. Total quasi-elastic angular distributions for the systems ^{6}Li + ^{120}Sn (E_{lab}= 19.5 MeV) and ^{7}Li + ^{120}Sn (E_{lab}= 19.5, 20.5 and 25 MeV). The dash–lines, in the figure, correspond to SPP OM data analysis with R_0 and a as the ^{6,7}Li nucleon density fit parameters, and considering in the imaginary part of the interaction, only an internal absorption (fusion).

In this case, there is a family of equivalent data fits (see Fig. 1), with different (R_0, a) fit parameters. The corresponding Li nucleon densities cross in a less ambiguous density value ρ_s (see fig. 3) at a special surface radius R_s (strong absorption radius).

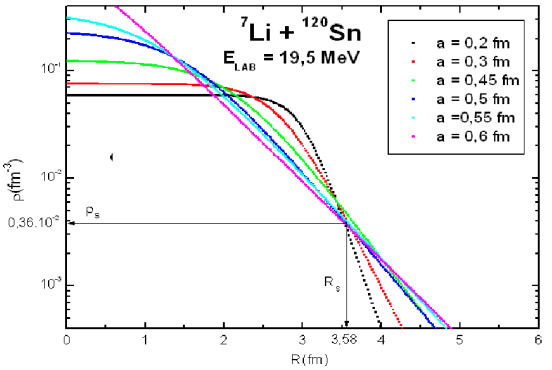

FIGURE 3. Different ^{7}Li nuclear densities which give equivalent fits to the quasi-elastic angular distribution, for the system ^{7}Li + ^{120}Sn at E_{lab}= 19.5 MeV. The strong absorption radius R_s and the corresponding well defined density value are shown in the figure.

Considering that the strong absorption radius is energy dependent [7], by considering quasi-elastic OM data analysis at different near barrier energies, it is possible to characterize the nucleon density at the surface. This is illustrated in figure 4 for the ^{7}Li

+ ^{120}Sn system through OM data analysis of the total quasi-elastic near barrier angular distribution measurements.

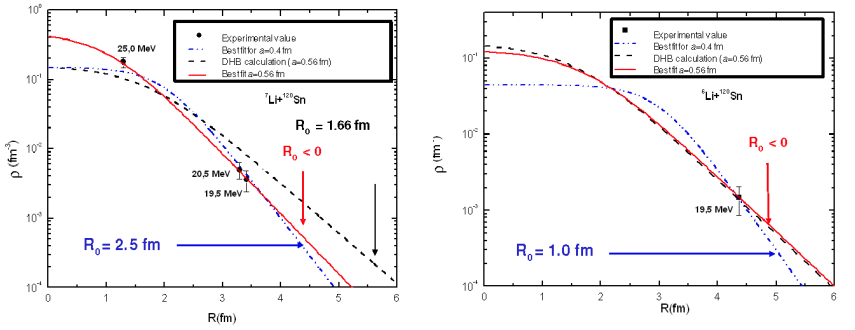

FIGURE 4. Experimental nuclear density values (closed symbols) for the systems ^{7}Li + ^{120}Sn (left side) and ^{6}Li + ^{120}Sn (right side). The lines in the figure correspond to different ^{6,7}Li nucleon densities, assuming different Fermi–Dirac distributions.

In the case of ^{7}Li isotope, the predicted nucleon density, from systematics based on DHB calculations are defined by Fermi–Dirac distribution parameters: R_o= 1.66 fm and a= 0.56 fm. This density is represented by a short–dash line in the figure 4 (left-side) and is in disagreement with the corresponding experimental points. The solid and dash-dot-dot lines in the figure correspond to Fermi–Dirac distributions that are in a better agreement with the data. Nevertheless, these ones present R_0 parameters far away in relation to that obtained from the DHB calculations, considering $a \approx 0.5$ fm. We mention also that R_0<0 has no physical meaning. For the ^{6}Li case, there is only one experimental density value, in apparent agreement with the corresponding ^{6}Li nucleon density from DHB calculations but, in this case, we cannot say much more.

It is important to mention that the apparent disagreement between theoretical and experimental values for ^{7}Li nucleon density could be related to other reaction mechanisms, not included in the OM data analysis. For weakly bound nuclei, like ^{7}Li, break-up is known to occur at near barrier energies. In order to take into account such kind of dissipative process, we have developed [8] an imaginary potential with system and energy independent normalization. This potential is based on high-energy nucleon-nucleon interaction, and it is related to the SPP:

$$W(R) = 0.6i\, V_{SPP}(R) \qquad (1)$$

In figure 5 quasi-elastic SPP optical calculations (solid-lines), using the imaginary potential given by expression 1, for the system ^{7}Li + ^{120}Sn, are shown. In this case, the ^{7}Li nucleon density is that from the systematic [4] based on DHB calculations with the Fermi–Dirac parameters R_0 = 1.66 fm and a = 0.56 fm. The deviation between predictions and data (from E_{Lab} = 20.5 MeV), for back scattering angles ($\theta_{cm} \geq 140^0$) can be understood as an effect of the couplings of the continuum, which gives rise to a positive polarization, as discussed in details in reference [9]. In order to take into

account this effect (dash-dot lines in figure 5), it is necessary to renormalize the real potential (SPP) by a factor 0.6 (see reference [9] for details)

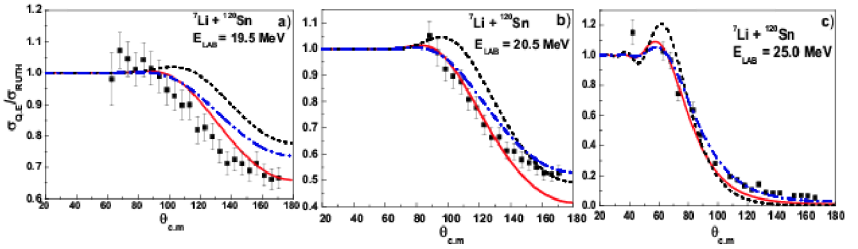

FIGURE 5. SPP optical model calculations for the quasi-elastic angular distributions for the system ^{7}Li + ^{120}Sn, as compared with experimental data, considering: (i) internal and surface (break-up) dissipative processes (Eq.1 – solid); (ii) only internal absorption (dash); (iii) the same as (i) but, taking into account a positive polarization (dash-dot).

As shown in Fig. 5, there is very good agreement (Fig. 5b, Fig. 5c) between the predictions (dash-dot lines) and the data if the effect of a positive polarization is included. On the other side, the theoretical predictions (dash-lines) are in disagreement with the data if only internal absorption (fusion) is included.

CONCLUSIONS

In this work we present experimental values for the ^{6,7}Li nucleon densities, as obtained from SPP OM quasi-elastic data analysis for the systems ^{6,7}Li + ^{120}Sn. The apparent discrepancies, particularly for ^{7}Li isotope, between the experimental values and those from DHB calculations, were removed by introducing the ^{7}Li break-up process and a positive polarization of the continuum in the reaction mechanism.

ACKNOWLEDGEMENTS

This work was partially supported by FAPESP and CNPq, Brazil.

REFERENCES

1. E.S. Rossi Jr. *et al.*, Nucl.Phys. **A207**, 325 (2002).
2. L.R. Gasques *et al.*, Phys.Rev. C **65**, 044314 (2002).
3. L.R. Gasques *et al.*, Phys.Rev. C **67**, 024602 (2003).
4. L.C. Chamon *et al.*, Phys.Rev. C **66**, 014610 (2002).
5. J. Lubian *et al.*, Nucl.Phys. **A791**, 24 (2007).
6. J. Lubian *et al.*, Phys. Rev. C **64**, 027601 (2001).
7. L.C. Chamon *et al.*, Nucl. Phys. **A258**, 305 (1995).
8. D.Pereira *et al.*, Phys. Lett. **B670**, 330 (2009).
9. D.Pereira *et al.*, AIP Conf. Proc. **1098**, 139 (2008).