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Breakup Coupling Effects on Near-Barrier ^{6}Li, ^{7}Be and ^{8}B + ^{58}Ni Elastic Scattering Compared

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New data for near-barrier ^{6}Li, ^{7}Be and ^{8}B + ^{58}Ni elastic scattering enable a comparison of breakup coupling effects for these loosely-bound projectiles. Coupled Discretised Continuum Channels (CDCC) calculations suggest that the large total reaction cross sections for ^{8}B + ^{58}Ni are dominated by breakup at near-barrier energies, unlike ^{6}Li and ^{7}Be where breakup makes a small contribution. In spite of this, the CDCC calculations show a small coupling influence due to breakup for ^{8}B, in contrast to the situation for ^{6}Li and ^{7}Be. An examination of the S matrices gives a clue to this counter-intuitive behaviour.

1. INTRODUCTION

Recent data [1] for near-barrier ^{6}Li, ^{7}Be and ^{8}B + ^{58}Ni elastic scattering allow some interesting comparisons for these weakly-bound nuclei. Optical model fits find much larger total reaction cross sections ($\sigma_{\rm R}$) for ^{8}B than for ^{6}Li or ^{7}Be, even when “reduced” [2]; while the reduced $\sigma_{\rm R}$ for other weakly-bound projectiles lie on a universal curve, those for ^{8}B and ^{6}He are significantly larger [1]. The low $^8\text{B} \rightarrow {}^7\text{Be} + p$ breakup threshold (0.1375 MeV) suggests a dominant contribution to the direct part of $\sigma_{\rm R}$. This is not automatic: for ^{6}He with an $\alpha + 2n$ breakup threshold of 0.973 MeV, $1n$- and $2n$-stripping are the main contributors to $\sigma_{\rm R}$ at near-barrier energies. However, the weakly-bound proton in ^{8}B experiences Coulomb barrier and charge polarisation effects tending to suppress transfer.

CDCC calculations [3] find that breakup does dominate the direct component of $\sigma_{\rm R}$ for ^{8}B: as the cross sections are large — of the order of 100 mb or more — one might expect an equally important coupling effect on the elastic scattering angular distribution. However, this is not the case [3]. We thus have an apparent paradox: ^{6}Li, with a relatively small breakup cross section, exhibits an important breakup coupling effect on the elastic scattering (see e.g. [4]) whereas ^{8}B, with a large breakup cross section, shows only a modest coupling effect. A comparison of S matrices obtained from CDCC calculations for ^{6}Li, ^{7}Be and ^{8}B + ^{58}Ni provides a clue to this behaviour. Preliminary dynamic polarisation potentials (DPPs) are also presented.

2. CALCULATIONS

Calculations were performed with the code FRESCO [5]: only a brief outline is given here. The ^{6}Li, ^{7}Be and ^{8}B nuclei were modelled as $\alpha + d$, $\alpha + {}^3$He and ^{7}Be + p clusters, respectively. The ^{7}Be core was treated as inert but its non-zero spin was retained. Interaction potentials were obtained by Watanabe-type folding of global optical potentials, with a ^{6}Li potential as surrogate for ^{7}Be, the well-depths being adjusted to give the best fit to the data. The ^{6}Li and ^{7}Be calculations were similar to those in [4] and [6], but with finer continuum binning for ^{7}Be. The ^{8}B calculations included couplings to the $L = 0$, 1, 2 and 3 continuum and the 0.774 MeV 1^+ and 2.32 MeV 3^+ resonances. Good fits to all the data were obtained. Due to lack of space we show only results for the same values of $E_{\mathrm{c.m.}} - V_{\mathrm{B}}$ for each system, where V_{B} is the nominal Coulomb barrier, taking as our "benchmark" the ^{8}B data at $E_{\mathrm{lab}} = 29.26$ MeV. This procedure yields values of $E_{\mathrm{lab}} = 19.04$ and 24.12 MeV for ^{6}Li and ^{7}Be + ^{58}Ni, respectively. In this way effects due to differences in projectile charge should be minimised.

Results are presented in Fig. 1: the coupling effect is much stronger for ^{6}Li and ^{7}Be, with $^6\mathrm{Li} \rightarrow \alpha + d$ and $^7\mathrm{Be} \rightarrow \alpha + {}^3\mathrm{He}$ breakup thresholds of 1.47 and 1.59 MeV, respectively, an order of magnitude larger than the $^8\mathrm{B} \rightarrow {}^7\mathrm{Be} + p$ threshold. The $^6\mathrm{Li} \rightarrow \alpha + d$ process has the additional peculiarity that it cannot proceed via dipole breakup. If we include population of the bound $1/2^-$ state in ^{7}Be (considering breakup as an inelastic excitation) the total breakup cross sections for both ^{6}Li and ^{7}Be are about a factor of three smaller than for ^{8}B. To obtain a clue to this apparent paradox, we show in Fig. 2 the modulus and argument of the J-weighted S matrices [7] obtained from full and no-coupling calculations. The coupling effect on |S| is almost negligible for ^{8}B and largest for ^{6}Li, but qualitatively

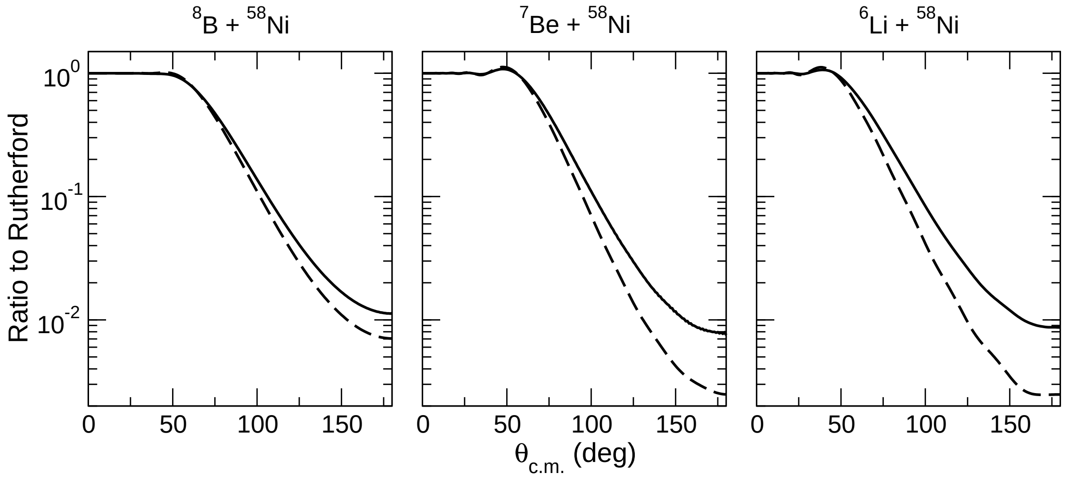

Figure 1. CDCC calculations for ^{8}B, ^{7}Be and ^{6}Li + ^{58}Ni at $E_{\mathrm{lab}} = 29.26$, 24.12 and 19.04 MeV. Solid and dashed curves denote full and no-coupling results, respectively.

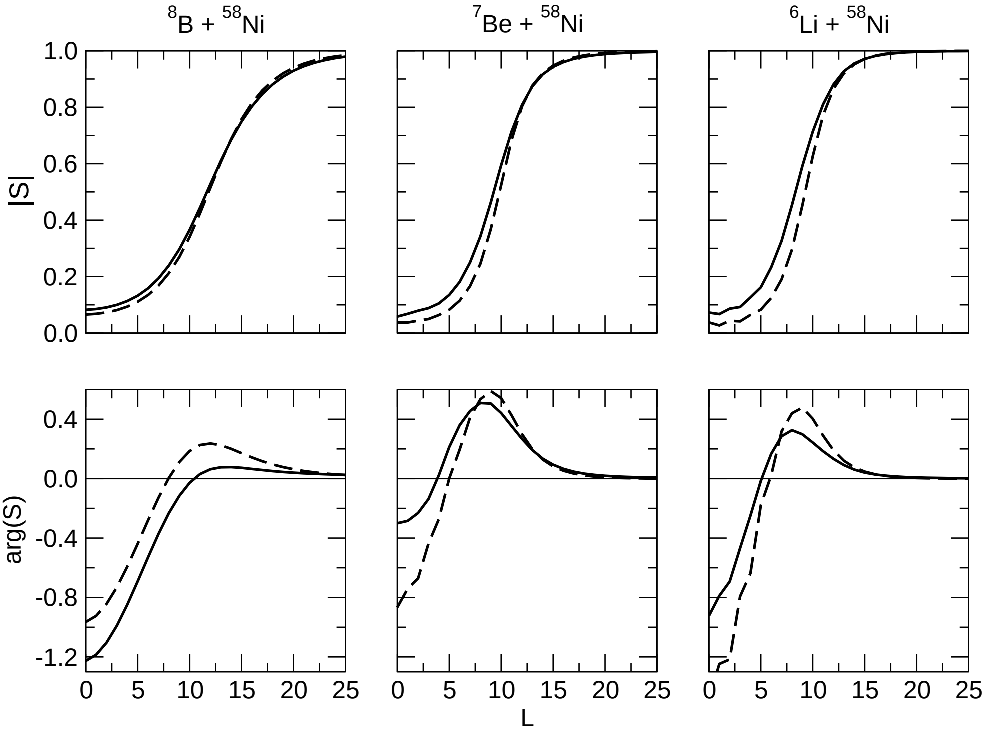

Figure 2. |S| and arg(S) from CDCC calculations for ^{8}B, ^{7}Be and ^{6}Li + ^{58}Ni at E_{lab} = 29.26, 24.12 and 19.04 MeV. Solid and dashed curves denote full and no-coupling results, respectively.

similar for all three nuclei: a decrease of |S| at small L and an increase at large L. By contrast, for arg(S) the coupling effect is greatest for ^{8}B, smallest for ^{7}Be and intermediate for ^{6}Li.

3. DISCUSSION

For protons and other light particles, changes in |S| correspond to changes in the imaginary part of the potential, while changes in arg(S) correspond to changes in the real part. While this simple picture is not so clear-cut in the presence of strong absorption (as here) it provides a useful guide. Thus, the coupling effect on |S| suggests *reduced* absorption at small L, switching to increased absorption at large L. The effect on arg(S) suggests repulsion at small L and attraction at large L. These effects are qualitatively similar for all three nuclei. The fact that the coupling effect on both the elastic scattering and |S| is so small for ^{8}B suggests that, paradoxical as it may seem for a coupling producing such a large cross section, its effective imaginary potential is small.

DPPs may be obtained by inversion of the S matrix, see e.g. [8]. In Fig. 3 we show the results of such a procedure for ^{8}B and ^{7}Be. Those for ^{7}Be are preliminary; we expect the final DPPs to be somewhat smoother. While the DPPs are qualitatively similar, short-range repulsion and long-range attraction combined with surface absorption (this behaviour seems to be universal, see e.g. [9]), the details are very different. The small imaginary DPP for ^{8}B is particularly striking, confirming the conclusions inferred from the S matrices. The surface repulsion for ^{8}B is also much smaller than for ^{7}Be, although for radii larger than about 9 fm it is significantly larger than for ^{7}Be, having a longer, more repulsive tail. Our results show that a large cross section is no guarantee of a large coupling effect. The S matrices and DPPs shed some light on this, but it remains to be explained at a more fundamental level.

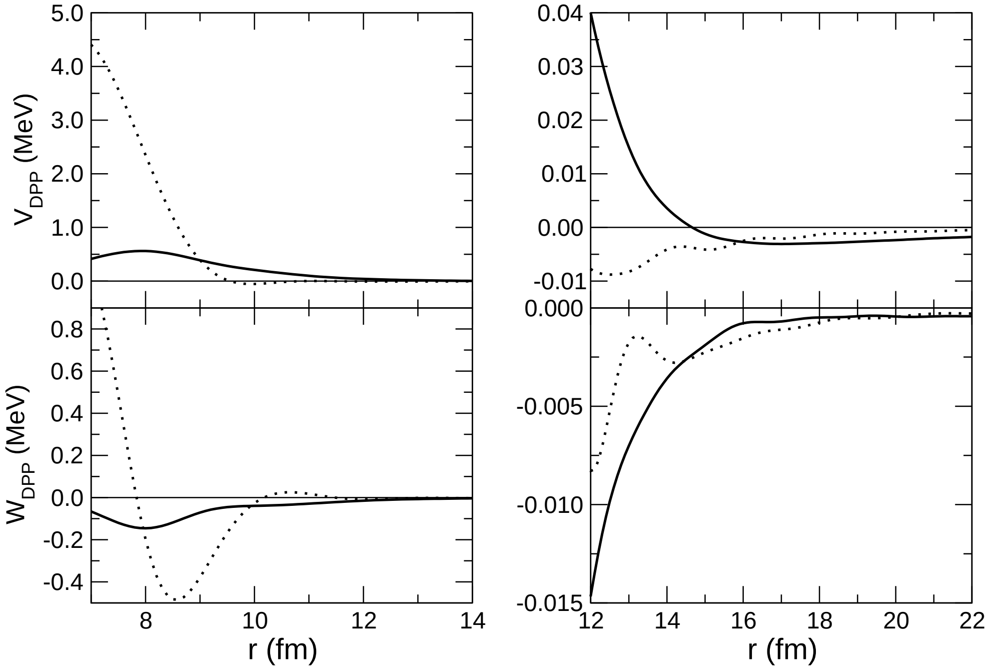

Figure 3. DPPs from CDCC calculations for ^{8}B (solid curves) and ^{7}Be (dotted curves).

REFERENCES

1. E.F. Aguilera et al., Phys. Rev. C 79 (2009) 021601(R).
2. P.R.S. Gomes et al., Phys. Rev. C 71 (2005) 017601.
3. J. Lubian et al., Phys. Rev. C 79 (2009) 064605.
4. C. Beck, N. Keeley and A Diaz-Torres, Phys. Rev. C 75 (2007) 054605.
5. I.J. Thompson, Comput. Phys. Rep. 7 (1988) 167.
6. N. Keeley, K.W. Kemper and K. Rusek, Phys. Rev. C 66 (2002) 044605.
7. N. Keeley and R.S. Mackintosh, Phys. Rev. C 77 (2008) 054603.
8. V.I. Kukulin and R.S. Mackintosh, J. Phys. G 30 (2004) R1.
9. K. Rusek, Eur. Phys. J. A (2009), doi: 10.1140/epja/i2009-10838-x.