

COMMENT ON ENERGY DEPENDENT BARRIERS FOR HEAVY-ION FUSION

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It has been suggested that a modulation of the Coulomb barrier in an energy dependent way could be used to describe fusion reactions. Such a procedure fails to give the fusion spin distributions obtained from fully dynamical calculations.

In an earlier article [1] it was argued that a one-dimensional potential barrier for heavy-ion fusion reactions at energies near and below the Coulomb barrier could be used, provided the potential is given an energy dependence corresponding to what is obtained from analyzing elastic scattering data. This argument was further elaborated in ref. [2]. A recent analysis of both elastic scattering and fusion data would appear to support such a procedure [3]. Although the discussion in ref. [1] is based on an effective potential which is formally equivalent to a full dynamical calculation, it should be emphasized that the simple prescription for correlating elastic scattering and fusion data which was put forward in ref. [1] and utilized in ref. [3] has not been justified theoretically.

The present communication points out that using an energy dependent barrier for fusion as suggested in ref. [1] – namely, increasing the nuclear attractive potential in an energy dependent way – is inconsistent with the dynamical effects that are incorporated

in a coupled-channels calculation. The energy dependence of the compound nucleus spin distribution specifically reveals this complexity. Actually, a recent data analysis has found that using an energy-dependent barrier does not predict the correct average spin of the compound nucleus [4].

We take the case of $^{40}\text{Ar} + ^{122}\text{Sn}$ and calculate the fusion cross section as the flux which penetrates a barrier in the presence of couplings to other degrees of freedom [5]. This example was used earlier to show how the couplings enhance fusion cross sections below the barrier [6] and also affect the compound nucleus spin distribution above the barrier [7]. The present calculations make use of the inelastic excitation coupling scheme of ref. [6] and take the finite range of the formfactors into account [8].

The solid and dashed curves in the leftmost part of fig. 1 show the fusion cross section calculated with and without the coupling interactions. The solid points are obtained without coupling but using a barrier that is adjusted at each energy to reproduce the coupled channels result. The corresponding average values of the spin distributions are shown in the rightmost part of fig. 1. It is apparent that the energy-

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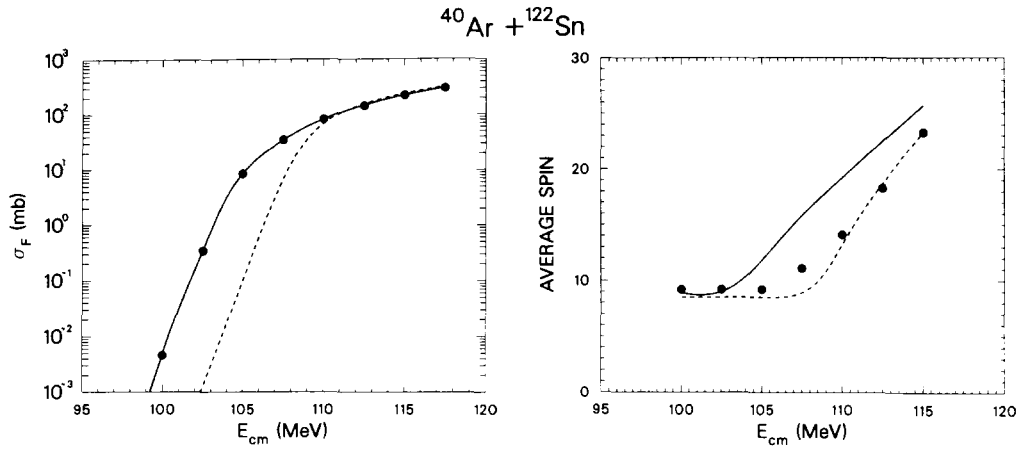


Fig. 1. Fusion cross sections and average compound nucleus spin calculated for $^{40}\text{Ar} + ^{122}\text{Sn}$. The solid and dashed curves are obtained with and without the channel couplings. The points result from using a one-dimensional energy-dependent potential

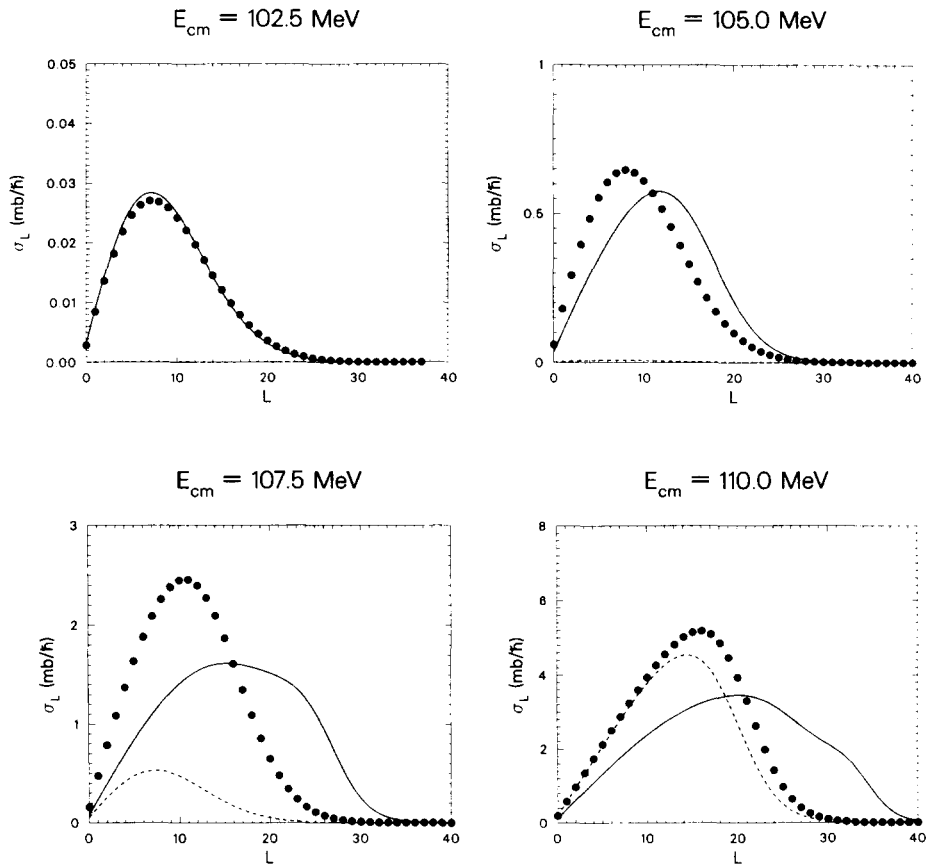


Fig. 2. Partial fusion cross sections at various energies corresponding to the calculations shown in fig. 1.

dependent potential prescription fails to account for the changes in the average spin introduced by the couplings. A similar result was found in connection with an analysis of the $^{64}\text{Ni} + ^{100}\text{Mo}$ reaction in ref. [4].

The reason why this occurs can be appreciated by looking at how the spin distributions evolve in fig. 2. At the lowest energies, where the cross sections are varying exponentially, the shape of the spin distribution is fixed and is essentially independent of the coupling [9]. Thus it can be reproduced by scaling the one-dimensional result ^{#1}. At the highest energy shown in fig. 2, however, the distribution for the one-dimensional barrier has reached its characteristic triangular shape while the coupled channels distribution remains much broader. This feature was shown in ref. [7]. It is a consequence of the fact that the coupling not only acts to increase the flux transmitted below a barrier but also decreases the flux transmitted above a barrier [5]. This dual aspect of the coupling mechanism can not be modelled by simply lowering the barrier in an energy dependent way.

^{#1} This situation corresponds to the O+Pb case considered in ref. [1]. A strong discrepancy with the multi-dimensional nature of the coupled-channels barrier penetration problem would have become evident had the energy been increased.

References

- [1] M.A. Nagarajan and G.R. Satchler, *Phys. Lett. B* 173 (1986) 29.
- [2] G.R. Satchler, M.A. Nagarajan, J.S. Lilley and I.J. Thompson, *Ann. Phys.* 178 (1987) 110.
- [3] A.M. Stefanini, D. Bonamini, A. Tivelli, G. Montagnoli, G. Fortuna, Y. Nagashima, S. Beghini, C. Signorini, A. DeRosa, G. Inglima, M. Sandoli, G. Cardella and F. Rizzo, *Phys. Rev. Lett.* 59 (1987) 2852.
- [4] M.L. Halbert, J.R. Beene, D.C. Hensley, K. Honkanen, T.M. Semkow, V. Abenante, D.G. Sarantites and Z. Li, Sixth Adriatic Intern. Conf. on Nuclear physics (Dubrovnik, Yugoslavia, 1987), in: *Frontiers of heavy-ion physics*, eds. N. Cindro, W. Greiner and R. Caplar (World Scientific, Singapore).
- [5] C.H. Dasso, S. Landowne and A. Winther, *Nucl. Phys. A* 405 (1983) 381; *A* 407 (1983) 221.
- [6] R.A. Broglia, C.H. Dasso, S. Landowne and G. Pollaro, *Phys. Lett. B* 133 (1983) 34.
- [7] S. Landowne and C.H. Dasso, *Phys. Lett. B* 138 (1984) 32.
- [8] C.H. Dasso and S. Landowne, *Phys. Lett. B* 183 (1987) 141.
- [9] C.H. Dasso, J.D. Garrett and S. Landowne, *Phys. Lett. B* 161 (1985) 36;
C.H. Dasso and S. Landowne, *Phys. Rev. C* 32 (1985) 1094.