Energy and Spin Dependence of Heavy Ion Potential and near Barrier Fusion

N K Ghosh[1], S Das[1], S Samanta[1], S S Ghugre[1], R Raut[1], A K Sinha[2]*
[1]UGC-DAE CSR, Kolkata Centre, Sector III, LB-8, Bidhan Nagar, Kolkata 700098, INDIA
[2]UGC-DAE CSR, University Campus, Khandwa Road, Indore, INDIA
* email: ajitmars@gmail.com

It has now been well established that the observed experimental heavy ion fusion cross sections are considerably enhanced in comparison to the predictions of the one dimensional barrier penetration model in the sub barrier region. The enhancement is accompanied by a corresponding broadening of the spin distributions of the fused systems. The enhancement in the fusion cross section has been attributed to the coupling of the large number of contributing channels. The reaction between heavy nuclei with energy in the Coulomb barrier region displays exciting nuclear structure effects due to channel couplings.

An alternate description is also possible using phenomenological optical model based approach. This approach indicates that the real part of the optical potential gets deeper near the barrier region thus enhancing the fusion probability[1]. A complete microscopic description of the heavy ion fusion process is a herculean task. Recently time dependent Hartree Fock approach has been used for fusion in the near barrier region and effective potential in the fusion degree of freedom has been obtained [2].

In the phenomenological approach, the use of energy dependent barrier to describe fusion in the near barrier region ran into a serious problem as brought out by Dasso *et al.* [3] who pointed out the inadequacy of the purely energy dependent potential in explaining the broadened spin distribution in the barrier region.

Mohanty *et al.* [4] proposed the spin-dependence in addition to the energy dependence of the real potential to resolve this inadequacy. The additional spin dependence provided a clue to have simultaneous description of the fusion cross section and the spin distribution in the near and sub barrier region.

In the analysis by Mohanty *et al.* [4,5], the energy & spin dependence of the barrier height was parameterized as a three segment linear dependence of barrier height on the radial kinetic energy at the fusion barrier; the low and high energy regions have constant barriers while in the middle region the barrier height rises linearly. The parameters specifying this barrier dependence are varied to fit the experimental cross sections. The spin distributions are also reproduced by this process. The method essentially goes for the best fit values for the three linear segments and hence, does not preserve the information on possible inherent structures in the fusion excitation function. Such structures are revealed thru the fusion barrier distribution obtained from the second derivative of the product of the energy and cross section using the precisely measured fusion excitation function. Further, due to possible ambiguities in the fitted solution, one may be not sure of any microscopic interpretations of the fitted parameters of the energy-spin dependence.

We have attempted to derive a procedure for a "parameter free" extraction of the energy/spin dependent potential through the analysis of the near barrier fusion data. Thus we are carrying fusion calculation using the model as suggested by Mohanty *et al.* [4,5] adopting a method wherein the barrier heights are not a priori parameterized and the fusion cross section data are inverted to get the energy and angular momentum dependent barriers.

The method has been tested against a simulated multiple barrier calculations mimicking the channel coupling approach. The data from this analysis are explained in the Figures 1, 2 and 3. In figure 3, we compare the extracted energy dependence of the barrier with the TDHF results from Ref. [2]. The TDHF data show very similar trend in the region above the "threshold barrier" of the TDHF calculations. The energy dependence in the lower region as obtained by our procedure shows two different stages of varying slopes. We need to explore if this reveals the multi-dimensional aspects of the barrier penetration in fusion of heavy nuclei.

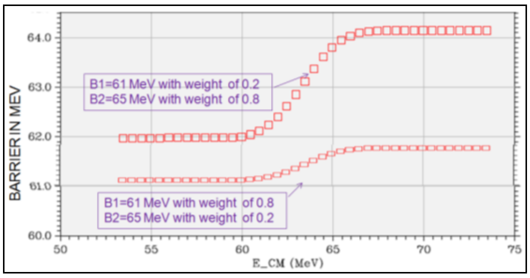

Figure 01 - Energy–Spin dependent barrier heights are shown as a function of the centre-of-mass energy. They are extracted from the inversion procedure described in the paper starting with the assumption that the barriers are not varying in the lowest energy region. The two curves are for the cross section data calculated using the two barriers as specified. The spin distributions are also exactly reproduced with these barriers. The barrier values in the high energy region do not show any divergence and are consistent with the equivalent single barrier value in the coupled channel description.

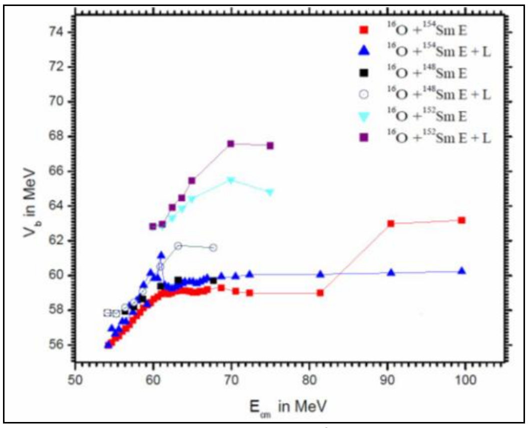

Figure 02-The energy dependent fusion barrier heights without spin dependence are marked as "E" and are extracted by using a simple 1D BPM with parabola approximating the barrier shape while its height is adjusted with energy keeping the barrier- radius and curvature constant. Energy & Spin dependent barrier heights are marked as "E+L" and are extracted from the inversion procedure described in the text.

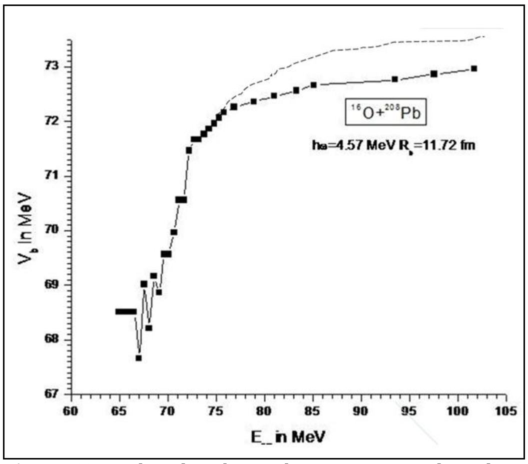

Figure 03 - The plot shows the energy+spin dependent fusion barrier obtained using the inversion procedure described in this work using the experimental fusion cross section data. The dotted curve indicates the TDHF barriers read out from the figure 11 of Ref [2], while lowering the frozen density barrier by a constant value ~2.5 MeV.

The details of the procedure and further results and analysis would be presented.

We acknowledge the helpful guidance thru discussion with Dr A K Mohanty, SINP, Kolkata and Dr N Madhavan, IUAC, New Delhi,

References

[1] M. A. Nagarajan *et al*. Phys. Lett. B **173**, 29 (1986).
[2] K. Washiya and D. Lacroix D., Phys. Rev. C **78** 024610 (2008)
[3] C. H. Dasso *et al*., Phys. Lett. B **217**, 25 (1989)
[4] A K Mohanty *et al*., Phys. Rev. Lett. **65**, 1096 (1990).
[5] A. K. Mohanty *et al*., Phys. Rev. C **46**, 2012 (1992)