Role of nuclear potential in determination of minimum value of impact parameter for Coulomb excitation experiments

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The Coulomb excitation is a process of exciting projectile/target nucleus via the very well understood electromagnetic interaction of the target/projectile [1-2]. It is one of the reliable tools to extract required nuclear information such as energy of excited states and transition matrix elements for normal as well as exotic nuclei. The essential condition for extracting various nuclear information unambiguously from the CE experiments is to maintain the purity of the CE processes. In the analysis of intermediate energy Coulomb excitation data, the incident energy of the projectile is greater than the Coulomb barrier energy between colliding projectile and the target ions. Therefore, in case of intermediate energy CE experiments the projectile is likely to be under the joint influence of the electromagnetic and strong nuclear interactions. However, in order to obtain reliable information through these experiments the influence of strong nuclear interaction is required to be completely omitted (if possible) or to be minimized.

Thus the experimentalists resort to forward angle (θ_{lab}^{max}) scattering measurements in order to avoid the influence of the strong nuclear interactions. The θ_{lab}^{max}, which is experimentally observable, is used to determine the minimum value of impact parameter (b_{min}) as both are interconvertible. Although b_{min} is not an experimental observable, but it makes the theoretical analysis of the data observed in these experiments very convenient. Consequently, a lot of scheme has already been proposed to determine the value of b_{min} and are broadly subdivided in two categories. The first one comprises of a number of indirect, energy independent and intuitive schemes while the second one comprises of only one scheme - which is direct, energy dependent and based on firm theoretical basis [3]. The indirect schemes here, refer to the schemes which were originally proposed for some other purposes and not specifically for the determination of b_{min}. The opposite is true for the direct scheme. The Value of b_{min} determined via the direct scheme shall hereafter be referred to as b_{min}^D. The direct scheme adopted to determine b_{min}^D is based on the concept of survival probability of the projectile [3]. The b_{min}^D is that value of impact parameter for which the value of the CE cross section excluding $|S(b)|^2$ i.e. σ (eq. 2) and CE cross section including $|S(b)|^2$ i.e. $\sigma^{|S(b)^2|}$ (eq. 3) are in excellent agreement with each other [4]. Any significant disagreement between σ and $\sigma^{|S(b)^2|}$ is a clear indication of the involvement of strong nuclear interactions. The expression for b_{min}^D is given by

$$b_{min}^D = 1.2\,(R_P + R_T)\left(1 + \frac{16310}{exp\left(\frac{\gamma}{0.0887}\right)}\right) \quad (1)$$

with γ as relativistic Lorentz factor and $R_{P(T)} = 1.2\,A_{P(T)}^{1/3}$, $A_{P(T)}$ being the mass number of projectile(target).

The expression for Coulomb excitation cross sections σ and $\sigma^{|S(b)^2|}$ are given below [2, 5]

$$\sigma = 2\pi \int_{b_{min}}^{\infty} P_n(b)\,b\,db, \quad (2)$$

$$\sigma^{|S(b)^2|} = 2\pi \int_{b_{min}}^{\infty} P_n(b)|S(b)|^2 b\,db, \quad (3)$$

$P_n(b)$ denotes the CE probability of intrinsic state $|n>$ in a collision with impact parameter b. Now, the expression for evaluating $|S(b)|^2$, in terms of imaginary part of projectile target nuclear potential, is written as [6]

$$|S(b)|^2 = exp\left[\frac{2}{\hbar v}\int Im[\,U_{PT}(r)]dz\right]. \quad (4)$$

here, $U_{PT}(r)$ is projectile target nuclear potential. It is clear from eq. (4) that $|S(b)|^2$ depends on U_{PT} which can be constructed via single folding or double folding procedure.

In single folding, like that of proposed by R L Varner, the nucleon target potential is folded over nuclear matter density of the projectile [7]. In double folding model, the nucleon-nucleon interactions like M3Y (Michigan3Yukawa) are folded over nuclear matter density of the projectile as well as target [5]. Therefore, it is interesting to see the consequences of replacing the single folding model based potential by double folding model based potential on the direct scheme to decide the b_{min}^D. For the purpose of constructing a double folded potential $U_{PT}(r)$ the nucleon-

nucleon interaction used in present work is of M3Y-Reid interaction type. It is used to determine the imaginary part of the potential through the following relation

$$Im\, U_{opt}(r) = \lambda U_{PT}(r). \qquad (5)$$

here, λ denotes the renormalization constant and we have adopted the value of λ as 0.7.

In present work, we have investigated the sensitivity of the direct scheme used to decide the b^{D}_{min}, on the nuclear potential by considering as many as 15 systems having projectile with mass ranging from 26 to 112 on Bi and Au targets at, incident energies from 65 MeV/A to 147 MeV/A [8-13].

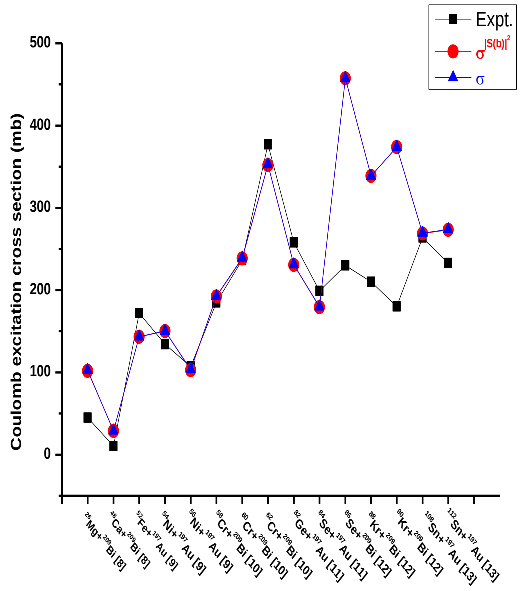

Fig. 1. Comparison of the CE cross sections $\sigma^{|S(b)^2|}$ and σ, evaluated at b^{D}_{min}, for mass range 26-112 at various incident beam energies on Bi and Au targets. The solid line acts as a guide to the eye.

From Fig 1. it is clear that at b^{D}_{min} the values of CE cross sections σ and $\sigma^{|S(b)^2|}$ are in excellent agreement with each other i.e. the choice of projectile target nuclear potential do not affect the value of b^{D}_{min}. Further, at b^{D}_{min} the influence of strong nuclear interactions is nil or negligibly small. From above discussion it is clear that any value equal to and larger than b^{D}_{min} is safe to avoid the influence of strong interaction and ensures that the forward measurements corresponding to above said values of impact parameter are the pure CE measurements.

In summary, the sensitivity of the direct scheme, used for the determination of safe minimum value of impact parameter, on the choice of nuclear potential is investigated by replacing single folded projectile target potential due to R L Varner by more realistic M3Y type double folded potential. It is found that the choice of nuclear potential does not affect the direct scheme to determine b_{min}.

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