Dependence of absorption effects on nuclear surface diffuseness in Coulomb excitation process

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Coulomb excitation refers to the excitation of a nucleus by electromagnetic interaction of another nucleus. It plays a significant role in the study of new and strange properties of exotic nuclei. In intermediate energy Coulomb excitation experiments, in addition to electromagnetic interactions the undesirable strong nuclear interactions also come into play. The effects caused by the nuclear interactions are usually termed as absorption effects, which need to be accounted properly. Minimum value of the impact parameter (b_{min}) is an important criterion which decides whether the absorption effects will come into play or not [1]. In the analysis of intermediate energy Coulomb excitation data, the absorption effects can be accounted through the concept of survival probability $|S(b)|^2$ of the projectile [2-6]. The $|S(b)|^2$ can be calculated in terms of imaginary part of projectile target optical potential $U_{PT}(r)$, as given below [3]

$$|S(b)|^2 = exp\left[\frac{2}{\hbar v}\int Im[\,U_{PT}(r)]dz\right]. \quad (1)$$

The $U_{PT}(r)$ can be constructed by employing the double folding of nucleon-nucleon interaction $v_{nn}(r)$ over the nuclear matter densities of the projectile $\rho_1(r_1)$ and the target $\rho_2(r_2)$. The expression for the $U_{PT}(r)$ is given by [7]

$$U_{PT}(r) = \int \rho_1(r_1)\rho_2(r_2)v_{nn}(r)d^3r_1 d^3r_2. \quad (2)$$

As evident from Eq. (2) the matter density distribution of projectile $\rho_1(r_1)$ is one of the important ingredients in the construction of $U_{PT}(r)$. In present work we have used two parameter fermi (2pF) matter density distribution. The expression for the 2pF matter density distribution is given by [4, 9, 10]

$$\rho(r) = \frac{\rho_0}{\left(1+\exp(\frac{r-R}{a})\right)}. \quad (3)$$

Here ρ_0, R and a are central density, radius and surface diffuseness parameter respectively. The radius R and the diffuseness parameter a are the two parameters of 2pF matter density distribution out of which only a is the free. For every value of a, the value of R is determined by a condition which ensures that root mean square radius (r_m) of the projectile stays constant. The expression for r_m is given by [9, 10]

$$r_m = \sqrt{< r^2 >} = \sqrt{\frac{4\pi}{A_P}\int_0^\infty \rho(r)r^4 dr}\,. \quad (4)$$

Here A_P is mass number of the projectile.

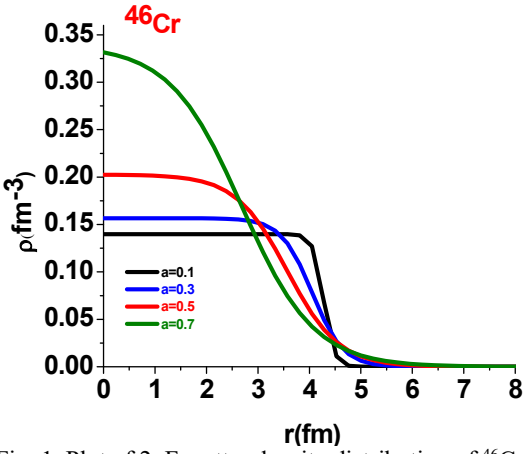

Fig. 1. Plot of 2pF matter density distribution of ^{46}Cr for various values of a.

It is clear from the Eq. (3) that a is a sensitive parameter which decides the 2pF matter density distribution. Therefore, it is interesting to see the effect of variation of a on $|S(b)|^2$ and consequently on the absorption effects also. In present work a recently studied projectile target system ^{46}Cr+^{197}Au [8] is chosen as a representative case.

In Fig. 1, the 2pF matter density distributions have been plotted for various values of a ranging from 0.1 fm to 0.7 fm. The variation in a leads to variations in both central as well as peripheral regions of the projectile density. In Fig. 2 the $|S(b)|^2$, as a function of impact parameter b, is plotted corresponding to the various 2pF density distributions shown in Fig. 1. The value of $|S(b)|^2$ lies between zero to one as per the expectations and its dependence on a is evident. For a definite value of b, with increase in the value of a the value of $|S(b)|^2$ is found to be decreasing. For instance at ~13 fm the value of $|S(b)|^2$ for a=0.1 fm is 0.83 which decreases to 0.53 for a=0.7 fm. It suggests that when the projectile becomes more diffused the chances of its survival reduces and hence the influence of the nuclear interactions become more significant.

The value of b_{min} needs to be fixed in order to calculate the Coulomb excitation cross section. Here, the Coulomb excitation cross section is calculated with and without considering the $|S(b)|^2$ corresponding to the various values of a, by fixing the b_{min} as $R_P + R_T$, $R_P + R_T + 2$ and $R_P + R_T + 3\ fm$. The results are listed in Table 1. The Coulomb excitation cross section calculated for various value of a, without (with) considering the $|S(b)|^2$ is denoted by $\sigma(\sigma^{|S(b)^2|})$. The values of $\sigma(\sigma^{|S(b)^2|})$ calculated for the various values of a (column 1), by fixing the b_{min} as $R_P + R_T$, $R_P + R_T + 2$ and $R_P + R_T + 3$ are mentioned in columns 2(3), 5(6) and 8(9) respectively. In rest of the columns of the Table 1 i.e. column 4, 7 and 10, the quantitative estimate of the absorption effects is mentioned by the quantity $\left(\frac{\sigma-\sigma^{|S(b)^2|}}{\sigma}\right)\%$.

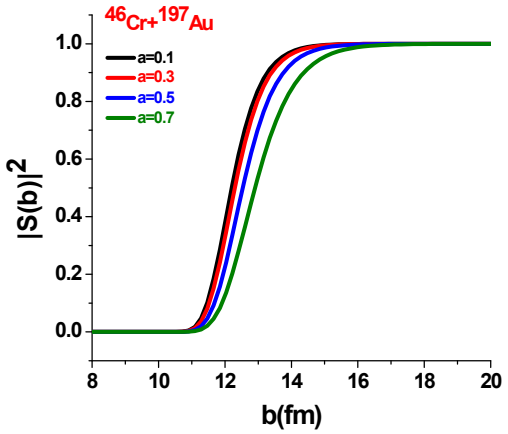

Fig. 2. Plot of the $|S(b)|^2$ for $^{46}Cr+^{197}Au$ evaluated with the 2pF matter density distributions (Fig. 1).

Table 1 Estimation of the absorption effects for different values of b_{min} and surface diffuseness a.

	$b_{min}\ (fm)$								
	$R_P + R_T$			$R_P + R_T + 2$			$R_P + R_T + 3$		
$a\ (fm)$	$\sigma(mb)$	$\sigma^{\|S(b)^2\|}(mb)$	$\left(\frac{\sigma-\sigma^{\|S(b)^2\|}}{\sigma}\right)\%$	$\sigma(mb)$	$\sigma^{\|S(b)^2\|}(mb)$	$\left(\frac{\sigma-\sigma^{\|S(b)^2\|}}{\sigma}\right)\%$	$\sigma(mb)$	$\sigma^{\|S(b)^2\|}(mb)$	$\left(\frac{\sigma-\sigma^{\|S(b)^2\|}}{\sigma}\right)\%$
0.1	164.5	139.8	14.9	119.4	118.5	0.7	103.5	103.4	0.1
0.3		137.8	16.2		118.3	0.9		103.3	0.2
0.5		134.5	18.2		117.3	1.7		103.1	0.3
0.7		125.5	23.7		114.8	3.7		102.4	1.1

It is clear from the Table 1 that for a fixed value of the b_{min}, the absorption effects depend upon the value of a. For the projectile target system being considered here, the absorption effects are found to be maximum ~24% for the lowest value of b_{min} $(R_P + R_T)$ and the highest value of a $(0.7fm)$. At $R_P + R_T$ the absorption effects are significant for each and every value of the a and also have appreciable variations, from ~15% to 24% as a varies from 0.1 to 0.7 fm. With increase in the value of b_{min} from $R_P + R_T$, to $R_P + R_T + 2$ and to $R_P + R_T + 3\ fm$ the significance of the absorption effects reduces to moderate and to weak respectively and the variations w.r.t a also follows the same trend. It is pertinent to mention here that for the calculations of the survival probability and the Coulomb excitation cross section the code DWEIKO has been used [11] but with the 2pF matter density distribution.

In conclusion, for the projectile target system $^{46}Cr+^{197}Au$, the absorption effects are found to depend upon a even for a fixed value of b_{min}.

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