Determination of impact parameter in intermediate energy Coulomb excitation experiments by using touching spheres schemes

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The intermediate energy Coulomb excitation (IECE) is an unambiguous method which is enthusiastically used for the structural analysis of exotic nuclei. To obtain the reliable information through these experiments the purity of Coulomb processes must be ensured. In these experiments, the impact parameter is the sole criterion which ascertains the purity of Coulomb processes. The value of impact parameter must be larger than some definite minimum value (b_{min}) which always exceeds the sum of projectile and target radii ($R_{\mathrm{P}}+R_{\mathrm{T}}$) by a few femtometer. There exists several schemes for the determination of b_{min} which are based on different ideas e.g. some are based on the concept of interaction radius [1-3], some are based on the idea of touching spheres (ts) [4-8] while others are based on the concept of survival probability [9, 10].

In planning the IECE experiments, the experimentalists commonly use ts schemes for deciding the value of b_{min}. In ts schemes the expression for b_{min} is given by

$b_{\mathrm{min}}=(R_{\mathrm{P}}+R_{\mathrm{T}}+d)$ fm, here d represents the separation between the surfaces of colliding nuclei. The values of d usually varies from (2-5 fm), however, the most commonly used values are 3 fm and 4 fm. Therefore, in present work, we have concentrated on those values of b_{min} which considers d equals to be 3 fm and 4 fm. Henceforth, the values of b_{min} given by ts schemes shall be mentioned as $b_{\mathrm{min}}^{\mathrm{ts+d}}$ (d = 3-4 fm). The values of $b_{\mathrm{min}}^{\mathrm{ts+d}}$ obtained by using the ts schemes are energy independent while it is not so for the experimental counterpart. Therefore, ts schemes have been modified by introducing an energy dependent term E_{γ} taken from [10], such that it becomes

$$b_{\mathrm{min}}^{\mathrm{(ts+d)M}}=b_{\mathrm{min}}^{\mathrm{ts+d}}\,E_{\gamma}$$

where, M stands for modified.

The results of modified touching spheres schemes ($b_{\mathrm{min}}^{\mathrm{(ts+d)M}}$) have been compared with the results of the scheme given in ref. 10. Here the values of b_{min} obtained by employing the scheme given in ref.10 have been taken as reference values and henceforth shall be mentioned as $b_{\mathrm{min}}^{\mathrm{ref}}$. For comparison purposes, a large number of projectile target systems viz. ^{26}Ne+^{197}Au to ^{197}Au+^{197}Au over a broad range of incident beam energies, ranging from 30 MeV/A to 300 MeV/A, have been considered [11]. As a result of comparison, it is found that the values of $b_{\mathrm{min}}^{\mathrm{(ts+d)M}}$ overestimate the $b_{\mathrm{min}}^{\mathrm{ref}}$ values in each and every case [11]. The larger values of $b_{\mathrm{min}}^{\mathrm{(ts+d)M}}$, undeniably ascertains the purity of Coulomb excitation processes but these values should not be exceedingly large, which are prone to lead to a significant loss of flux [10, 12]. Therefore, in order to prevent the loss of flux, a beforehand estimate of exceedingly large value of b_{min} may prove to be useful especially in planning the future IECE experiments.

In order to decide whether the $b_{\mathrm{min}}^{\mathrm{(ts+d)M}}$ values are just sufficiently or exceedingly large, it is worth to have an estimate of the difference between $b_{\mathrm{min}}^{\mathrm{(ts+d)M}}$ values and $b_{\mathrm{min}}^{\mathrm{ref}}$ i.e $b_{\mathrm{min}}^{\mathrm{(ts+d)M}}-b_{\mathrm{min}}^{\mathrm{ref}}$. If the value of difference $b_{\mathrm{min}}^{\mathrm{(ts+d)M}}-b_{\mathrm{min}}^{\mathrm{ref}}$ is equal to or greater (smaller) than 2.0 fm then, $b_{\mathrm{min}}^{\mathrm{(ts+d)M}}$ is said to have exceedingly (just sufficiently) large value.

Table 1. A comparison of $b_{min}^{(ts+3)M} - b_{min}^{Ref} fm$ and $(b_{min}^{(ts+4)M} - b_{min}^{Ref}) fm$ for various projectile target systems at 30 MeV/A-300 MeV/A.

	$b_{min}^{(ts+3)M} - b_{min}^{Ref}\, fm \quad (b_{min}^{(ts+4)M} - b_{min}^{Ref}\, fm)$				
Projectile +Target System	30 (MeV/A)	50 (MeV/A)	100 (MeV/A)	200 (MeV/A)	300 (MeV/A)
^{26}Ne+^{197}Au	**1.2 (2.3)**	**1.2 (2.3)**	**1.1(2.2)**	**1.1(2.1)**	**1.1(2.1)**
^{48}Ar+^{197}Au	**1.0 (2.3)**	**1.0 (2.1)**	**1.0 (2.0)**	**0.9 (1.9)**	**0.9 (1.9)**
^{68}Fe+^{197}Au	**0.9 (2.1)**	**0.9 (2.0)**	**0.9 (1.9)**	**0.8 (1.8)**	**0.8 (1.8)**
^{96}Mo+^{197}Au	**0.8 (1.9)**	**0.8 (1.9)**	**0.7 (1.8)**	**0.7 (1.7)**	**0.7 (1.7)**
^{112}Sn+^{197}Au	**0.7 (1.9)**	**0.7 (1.8)**	**0.7 (1.7)**	**0.6 (1.7)**	**0.6 (1.6)**
^{197}Au+^{197}Au	**0.5 (1.6)**	**0.5 (1.6)**	**0.4 (1.5)**	**0.4 (1.4)**	**0.4 (1.4)**

The difference corresponding to $b_{\rm min}^{\rm (ts+3)M}$ and $b_{\rm min}^{\rm (ts+4)M}$ have been shown in table 1. In the table the entries corresponding to just sufficiently (exceedingly) large values are shown as boldface (boldface and underlined). Table 1 has 30 entries corresponding to $b_{\rm min}^{\rm (ts+3)M}$ and $b_{\rm min}^{\rm (ts+4)M}$ each. In case of $b_{\rm min}^{\rm (ts+3)M}$ all the entries i.e. 30 out of 30 are found to be having just sufficiently large values. While in case of $b_{\rm min}^{\rm (ts+4)M}$ the corresponding count is only 22 out of 30 and obviously the rest of the entries correspond to the exceedingly large values. Larger (lesser) the number of entries corresponding to just sufficiently (exceedingly) large values better (worse) the scheme is. Therefore it becomes clear that out of $b_{\rm min}^{\rm (ts+4)M}$ and $b_{\rm min}^{\rm (ts+3)M}$, the later scheme is the better one.

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