A comparative study of various schemes used for the determination of safe minimum value of impact parameter in Coulomb excitation experiments

Rajiv Kumar and Pardeep Singh[1]
Department of Physics, DAV University, Jalandhar-144012, India
[1]Department of Physics, Deenbandhu Chhotu Ram University of Science and Technology, Murthal-131039, India
kumarrajivsharma@gmail.com

The idea of exciting the atomic nuclei by time-dependent electromagnetic field of the impinging charged particles was conceived in 1930's and the process was named as Coulomb excitation [1]. Ever since the nuclear physicists are using it enthusiastically to understand the normal as well as exotic nuclear structures. In case of exotic nuclei, only the beams of low intensity are available and for such beams it is one of the most important available experimental technique which is widely used for the determination of some of the observables like the energy of bound excited states and transition matrix elements. The reliable extraction of structural observables requires that the dominance of Coulomb excitation process is essentially ensured. The Coulomb excitation experiments performed at above barrier incident beam energies, the most common beam energies available to the exotic beams, are undoubtedly susceptible to nuclear contributions which may also be termed as absorption effects. In order to ensure the purity of Coulomb excitation process the measurements are taken above some definite minimum value of impact parameter (b_{min}). There exists various schemes commonly used for the determination of b_{min}. One of the schemes is due to W W Wilcke et al [2] which shall be mentioned as b_{min}^{WWW} in the forthcoming discussion. Another scheme used for the determination of b_{min} is touching spheres (ts) scheme and the value of b_{min} is given by $R_P + R_T + \Delta$ ($b_{min}^{ts+\Delta}$) where $R_{P(T)} = 1.2\, A_{P(T)}^{1/3}$, $A_{P(T)}$ being the mass number of projectile (target) and the value of Δ extends from $2-5\, fm$ for intermediate energy Coulomb excitation experiments [3-11]. In addition to WWW and ts schemes there exist another scheme based on the estimation of absorption effects [12]. Henceforth the value of b_{min} given by the formula as mentioned in Ref [12] shall be mentioned as b_{min}^{Ref}. It is worth to mention here that the spread of $2-5\, fm$ is significantly large as far as the value of b_{min} is concerned but it is not clear that why the value of Δ extends from $2-5\, fm$. Therefore the choice of Δ needs to be investigated thoroughly. Further, it also needs investigation whether b_{min}^{Ref}, b_{min}^{WWW} and $b_{min}^{ts+\Delta}$ ($\Delta = 2-5\, fm$) are interconnected or totally separate as these are supposed to be.

In present work the issue regarding the interconnectivity of various schemes have been addressed by considering several projectile target systems over a wide range of incident beam energies. To begin with it is better to use b_{min}^{Ref} as a reference and find the different values of Δ which obviously is the difference between b_{min}^{Ref} and $R_P + R_T$. In fig 1, the values of Δ are plotted for several projectile-target systems extending from light projectile-heavy target system ^{11}Be+^{197}Au to heavy projectile-heavy target system ^{208}Pb+^{208}Pb over incident beam energies ranging from 30 MeV/A to 300MeV/A.

It is clear from fig. 1 that values of Δ for ^{11}Be+^{197}Au system decreases from 3.4 fm to 1.8 fm corresponding to increase in incident beam energy from 30 MeV/A to 300 MeV/A. Similar trend prevails for all the systems but with different values of Δ which decreases with increasing beam energy for a projectile-target system and increases with mass number of projectile for an incident beam energy. The minimum value of Δ is found to be 1.8 fm for ^{11}Be+^{197}Au light projectile-heavy target system at 300 MeV/A while its maximum value is found to be 5.0 fm for ^{208}Pb+^{208}Pb heavy projectile-heavy target system at 30 MeV/A. In other words the value of Δ varies from 1.8 fm to 5.0 fm for projectile-target systems ranging from ^{11}Be+^{197}Au to ^{208}Pb+^{208}Pb at incident beam energies varying from 30 MeV/A to 300 MeV/A. The above discussion may be considered as the only answer to the question that why the value of b_{min} is generally quoted to have its value as $b_{min}^{ts+\Delta}$, with Δ extending from 2 to $5 fm$. Further, the value of b_{min}^{Ref} is found to be touching spheres+~$2fm$ for $^{11\text{-}32}A_P$+^{197}Au systems 200 MeV/A onwards. Similarly values of b_{min}^{Ref} is found to be touching spheres+$3-5\, fm$ for various projectile-target systems for different incident beam energies. In nutshell, the various values of $b_{min}^{ts+\Delta}$ with $\Delta = 2-5\, fm$ are found to be the special cases derived from a general case of b_{min}^{Ref} for various projectile-target systems over a wide range of incident beam energies.

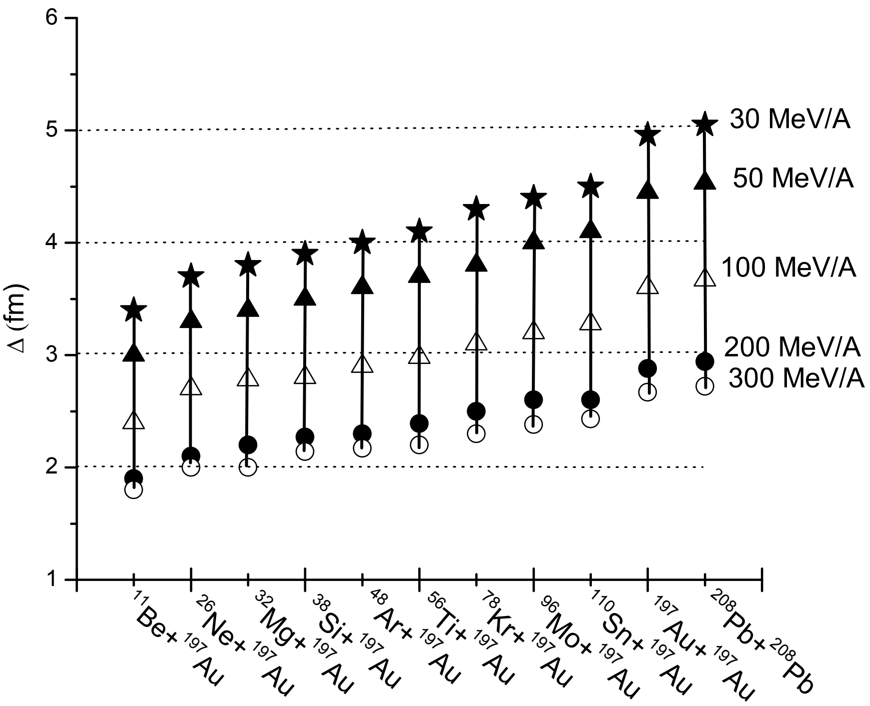

Fig. 1 The values of Δ for a variety of projectile target systems at incident beam energies ranging from 30MeV/A to 300MeV/A. The solid and dotted lines are drawn as guide to eye.

The value of $b_{min}^{WWW} - (R_P + R_T)\,fm$ may be approximated to be equal to 2 fm for the projectile-target systems being discussed here, in other words the b_{min}^{WWW} may be considered as representing touching spheres+$2fm$. Therefore, the b_{min}^{WWW} just like touching spheres+$2fm$ may also be considered as a special case of b_{min}^{Ref}. From the above discussion it becomes clear that all the available schemes commonly used for the determination of b_{min} be it b_{min}^{WWW} or $b_{min}^{ts+\Delta}$ (with $\Delta = 2 - 5\,fm$) are found to be the special cases of b_{min}^{Ref} [13].

References

[1] E Rutherford et al, Reactions from Radioactive Substances (Cambridge University Press, Cambridge, England) 1930.
[2] W W Wilcke et al, At. Data Nucl. Data Tables **25** (1980) 389.
[3] T Glasmacher, Lecture Notes in Physics, edited by A Khalili and E Roeckl, **764** (Springer, Germany) 2009, pp. 27-50.
[4] T Baugher et al, Phys. Rev. C **86** (2012) 011305.
[5] H L Crawford et al, Phys. Rev. Lett **110** (2013) 242701.
[6] V M Bader et al, Phys. Rev. C **88** (2013) 051301 (R).
[7] R W Ibbotson et al, Phys. Rev. Lett. **80** (1998) 2081.
[8] D Cline, Ann. Rev. Nucl. Part. Sci. **36** (1986) 683.
[9] H Scheit et al, Phys. Rev. Lett. **77** (1996) 3967.
[10] M Zielinska et al, Acta Phys. Pol. B **39** (2008) 519.
[11] M Zielinska et al, Phys Rev. C **80** (2009) 014317.
[12] R Kumar, R Kharab and H C Sharma, Phys. Rev. C **81**, 037602 (2010).
[13] R Kumar, P Singh and R Kharab, EPL **111**, 32001 (2015).