Sensitivity of survival probability of projectile on matter density distribution

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The survival probability ($|S(b)|^2$) of a projectile, as a function of impact parameter b, has been playing the central role in nuclear reaction studies [1-6]. The evaluation of $|S(b)|^2$ is carried out in terms of integral of the projectile (P)-target (T) interaction potential V_{PT} along the straight-line trajectories and is given by [7]

$$S(b) = exp\left[\frac{i}{hv}\int V_{PT}(b^2+z^2)dz\right] \qquad (1)$$

The nucleus-nucleus potential V_{PT} plays a key role in the evaluation of S-matrix. Out of several available approaches to construct V_{PT}, the commonly used is the double folding one in which the nucleon-nucleon interaction (v_{nn}) is doubly folded over nuclear matter densities of the colliding nuclei. The double folding potential V_{PT} is given by [8, 9]

$$V_{PT}(r) = \int \rho_1(r_1) v_{nn} \rho_2(r_2) dr_1 dr_2 \qquad (2)$$

here, $\rho_1(r_1)$ and $\rho_2(r_2)$ are the matter density of the colliding nuclei. There exists several forms of matter density distributions and out of these, the Fermi type form is one of the most commonly used which may further be subdivided in two types-two parameter Fermi (2pF) and three parameter Fermi (3pF) density distribution. It is obvious from the above mentioned expressions, eqns. (1) and (2), that the value of V_{PT} and hence $|S(b)|^2$ depend on the matter density distribution. It is therefore, interesting to check the relative effect of 2pF and 3pF matter density distributions on the evaluation of $|S(b)|^2$.

In present work, the value of $|S(b)|^2$ is evaluated for a number of projectile target systems varying from ^{28}Si+^{208}Pb to ^{76}Ge+^{208}Pb at intermediate incident beam energies ranging from 30 MeV/A to 300 MeV/A. The matter density distributions used for various projectiles are of the 2pF and 3pF type and for target we have used the liquid drop density distribution. The 2pF density distribution is given by [10-12]

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

where, ρ_0, R and a are the central density, radius and surface (diffuseness) parameter respectively.

The 3pF density distribution is given by [12, 13]

$$\rho(r) = \frac{\rho_0\left(1+\frac{wr^2}{R^2}\right)}{\left(1+\exp(\frac{r-R}{a})\right)} \qquad (4)$$

here, the parameter w represents the inner depth, depression or wine-bottle parameter. It is the parameter w which differentiates the 2pF and 3pF density distributions. The 3pF density distribution, eqn. (3) reduces to 2pF, eqn. (2) in case the parameter w equals to zero. The value of central density ρ_0 is determined by the following normalization condition

$$\int \rho(r) d\boldsymbol{r} = A \qquad (5)$$

here, A is mass number of the nucleus.

The plot of 2pF and 3pF matter density distribution for ^{48}Ca is given in fig. 1.

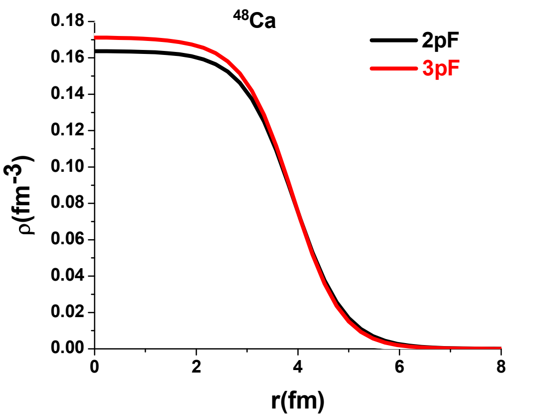

Fig. 1 (Color online) The 2pF and 3pF matter density distribution for ^{28}Si and ^{48}Ca isotopes.

It is clear from fig. 1 that difference in the value of density for 2pF and 3pF distributions is obvious for the central region and it continues towards surface region up to a definite value of $r \sim 3fm$. Near surface region the value of density is same for both forms of density distributions.

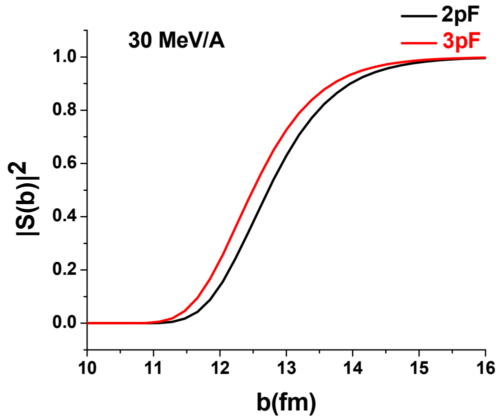

Fig. 2 (Color online) The comparison of $|S(b)|^2$ for ^{48}Ca at incident beam energy 30 MeV/A for 2pF and 3pF matter density distribution.

A comparison of $|S(b)|^2$ evaluated with 2pF and 3pF density distribution for ^{48}Ca isotope at 30 MeV/A incident beam energy is shown in fig. 2. It is clear from fig. 2 that the value of $|S(b)|^2$ varies from zero to one, which is as per the expectations. A noticeable difference in the values of $|S(b)|^2$ is evident for the 2pF and the 3pF density distribution. The value of $|S(b)|^2$ is found to be smaller for the 2pF distribution in comparison to that evaluated by the 3pF distribution. For a particular value of impact parameter say at 13 fm the value of $|S(b)|^2$ is found to be 63% for the 2pF while corresponding value for the 3pF is 73%. Thus a difference in the values of $|S(b)|^2$ is found to be approximately 10% for ^{48}Ca isotope at 30 MeV/A incident beam energy. Similar trend prevails i.e. a difference of almost same magnitude is found to be existing for other projectile target systems at incident beam energies being considered here. Therefore, it can be concluded from the above discussion that the evaluation of $|S(b)|^2$ is sensitive to the choice of the type of matter density distribution. Although, the degree of sensitivity, in present case of Fermi density distribution, is not so high still it cannot be neglected.

In addition to the Fermi density distribution, there exists several other forms of density distributions which may affect the value of $|S(b)|^2$ to a lesser or larger extent. In other words, the degree of sensitivity may vary with the choice of the form of density distribution and therefore, it will further be interesting to check the extent for other forms also. The work in this direction is in progress.

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