Glauber Model Analysis of Reaction Cross Section for $^{19}C+^{12}C$ System in the Energy Range 300-700 MeV/A

Rajesh Kharab*

Department of Physics, Kurukshetra University, Kurukshetra, Hr.-136 119, INDIA
**email:kharabrajesh@rediffmail.com*

The availability of radioactive ion beams has made it possible to investigate the properties of nuclei lying in the close proximity of neutron and proton drip lines. The pioneering experiments performed by I. Tanihata and collaborators using beams of highly neutron rich nuclei have confirmed the existence of a novel halo structure among some of these isotopes [1]. Subsequently many more neutron and proton halo nuclei have been identified through experiments measuring the reaction cross sections or breakup cross sections differential in longitudinal component of momentum of the fragments produced in the breakup process. Since more than one carbon isotopes have been found to have neutron halo structure, the carbon isotopic chain has attracted special attention. Very recently reaction cross section of ^{19}C on ^{12}C target has been measured at an energy 307 MeV/A [2]. Since reaction cross section is a very sensitive probe in determining the size and hence in deciding the halo character of a nuclear isotope, here we have analyzed it through Glauber model by employing two different single particle wave functions. Within the Glauber model, the projectile target total reaction cross section is given by [3]

$$\sigma_R = \int d\boldsymbol{b}\,(1 - |<\varphi_0|e^{i\chi_{CT}(\boldsymbol{b}_c)+i\chi_{NT}(\boldsymbol{b}_c+s)}|\varphi_0>|^2)$$

where all the symbols have their usual meanings as given in Ref. [3]. It is pertinent to mention here that the projectile is assumed to has a core plus one nucleon structure. The core-target and nucleon-target phase shifts that is χ_{CT} and χ_{NT} need the profile functions and nuclear densities for their determination. The profile function is usually parametrized as [3]

$$\Gamma(\boldsymbol{b}) = \frac{1-i\alpha}{4\pi\beta}\sigma_{NN}e^{-\boldsymbol{b}^2/2\beta}$$

The values of parameters σ_{NN}, cross section for nucleon-nucleon collision, and α, the ratio of real to imaginary part of nucleon-nucleon scattering amplitudes, are obtained by using the recent prescription of Ref. [4]. While those of β, slope parameter of the nucleon-nucleon elastic differential cross section, are taken as an appropriate average of the values quoted in Ref. [5]. The core and target densities are considered to be described by sum of two Gaussians with four free parameters. The parameters of density distributions are determined to fulfill the following four conditions. (i) The density at the center of the nucleus is constant with a value of 0.1382 fm^{-3}. (ii) The integration of the density is normalized to the total number of nucleons. (iii) The integration of density multiplied by r^2 is normalized to mean square radius of the nucleus and (iv) at a distance of 1.07 $A^{1/3}$ fm from the center the density becomes half of that at center. Another key factor in the determination of reaction cross section is the ground state single particle wave function of the projectile which is obtained by solving the following radial Schrodinger equation

$$\frac{d^2R(r)}{dr^2} + \frac{2\mu}{\hbar^2}\left[E - U(r) - \frac{l(l+1)\hbar^2}{2\mu r^2}\right]R(r) = 0.$$

The potential U(r) consists of nuclear, spin-orbit and Coulomb parts and is written as

$$U(r) = -V_0 f(r) + V_{ls}(\boldsymbol{l}.\boldsymbol{s})r_0^2\frac{1}{r}\frac{d}{dr}f(r) + V_{Coul}.$$

In the present work two different kinds of approaches are adopted for nuclear and spin-orbit parts of the potential while the Coulomb part is zero for $n+^{18}C$ system. One of the most frequently used potential is the usual Woods-Saxon (WS) potential with the following form factor

$$f(r) = \left[1 + \exp(\frac{r-R}{a})\right]^{-1}$$

The parameters a and R are fixed at 0.6 fm and $1.2 \times A_C^{1/3}$ fm respectively while the depth of the potential is adjusted to reproduce the ground state binding energy (0.53 MeV) of ^{19}C projectile. Secondly, the double folding model using M3Y interaction is used which in its simplest form is given by [6]

$$t(s) = 7999\frac{e^{-4s}}{4s} - 2134\frac{e^{-2.5s}}{2.5s} - 276C\delta(s)$$

so that the central part of the potential is written as $V_0(r) = N \int d^3r_1 d^3r_2 \rho_n(r_1)\rho_c(r_2)t(s)$ with $s = |\vec{r} + \vec{r_2} - \vec{r_1}|$ and N is a multiplicative factor which depends on the binding energy of the state to be generated. The density of ^{18}C core, ρ_c, is described by sum of two Gaussians. While the density of valance neutron is taken as [7]

$$\rho_n(r) = \left(\frac{1}{\gamma\sqrt{\pi}}\right)^3 exp\left(-\frac{r^2}{\gamma^2}\right)$$

where γ is determined to reproduce the size of ^{19}C nucleus. The spin-orbit part of the potential is taken in terms of the space derivative of potential

$$V_{so}(r) = -N_{so}\left(\frac{\hbar}{m_\pi c}\right)^2 \frac{1}{r}\frac{d}{dr}V_0(r)$$

Following Ref.[7] the value of parameters N_{so} is kept fixed at 0.2. The so obtained radial wave functions of ^{19}C are compared in Fig.1.

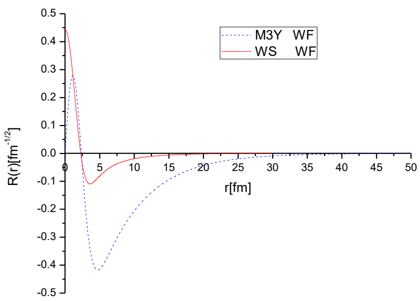

Fig. 1 (Color online) The radial wave functions of ^{19}C generated by using WS (solid line) and M3Y (dashed line) potentials are plotted as a function of radial distance of valence neutron from ^{18}C core.

It is noted very conspicuously in Fig. 1 that the wave function obtained by employing M3Y potential is much more extended in space in comparison to that obtained by employing WS potential. In Fig. 2 the total reaction cross section calculated by using above wave functions are compared with corresponding experimental datum taken from Ref.[2]. The calculation performed by using WS wave function is found to agree with the datum while the M3Y wave function substantially overestimate it. This may be ascribed to the large spatial extension of M3Y wave function. Further the energy dependence of reaction cross section is found to be same for both these wave functions. In nut shell, the magnitude of the reaction cross section is very sensitive to the wave function and the energy dependence is primarily governed by the nucleon-nucleon interaction parameters.

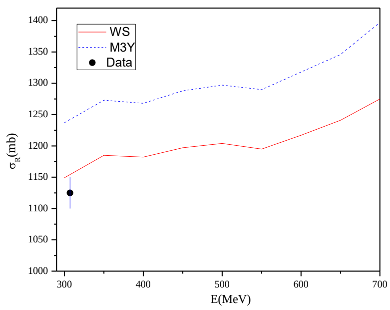

Fig. 2 (Color online) The total reaction cross section for ^{19}C + ^{12}C system calculated by using WS (solid line) and M3Y (dashed line) potentials are compared with the experimental datum taken from Ref.[2]

References

[1] I Tanihata, J. Phys. G : Nucl. Part. Phys. 22 (1996) 157 and references therein.
[2] Y. Togano *et al.*, Phys Lett. B 761 (2016) 412.
[3] B. Abu-Ibrahim *et al.*, Comp. Phys. Comm. 151 (2003) 369.
[4] A. Mehndiratta and P. Shukla, Nucl. Phys. A 961 (2017) 22.
[5] W. Horiuchi *et al.*, Phys. Rev. C 75 (2007) 044607.
[6] A. M. Kobos *et al.*, Nucl. Phys. A 425 (1984) 205
[7] C. A. Bertulani, Comp. Phys. Comm. 156 (2003) 123.