Quest of halo in ^{31}Ne using Glauber model formalism with deformed relativistic mean field density

Mahesh K. Sharma[1] and S. K. Patra [2]
[1] *School of Physics and Materials Science, Thapar University, Patiala - 147001, India. and*
[2] *Institute of Physics, Sachivalaya Marg Bhubaneswar-751005, India.*

The advancement of radio active ion beam (RIB) explored the structure of exotic nuclei, which are away from the β stability line. Such nuclei with weak binding lie at the limit of stability and exhibit some fascinating phenomena. One of them is the formation of one or more nucleon halo structure. It is well established that the interaction cross section of halo nuclei like ^{11}Li, ^{11}Be and ^{19}C show anomalously large interaction cross sections and matter radius than that of their neighboring nuclei. Some recent investigations for ^{31}Ne predict that the has a halo nature [1]. The first experimental evidence also suggests ^{31}Ne as a halo candidate [2]. The isotope ^{31}Ne having N=21, which breaks the shell closer structure as a consequence of deformation associated with the strong intruder configuration and having special interest, because it lie at island of inversion [3]. Here we apply the well known Glauber approach [4] with conjunction of deformed relativistic mean field densities of projectile and target nuclei. It is to be noted that Panda et al [5] has done the similar calculation using a spherical density.

$$\sigma_R = 2\pi \int_0^\infty b[1 - T(b)]db, \qquad (1)$$

where 'T(b)' is the transparency function with impact parameter 'b'. The densities obtained from the axially deformed relativistic mean field (RMF) model with NL3* set of force is used to calculate the nuclear reaction cross section. Where axially deformed density is represented as:

$$\overline{\rho}(\omega) = \int_{-\infty}^{\infty} \rho(\sqrt{w^2 + z^2})dz, \qquad (2)$$

with $\omega^2 = x^2 + y^2$.

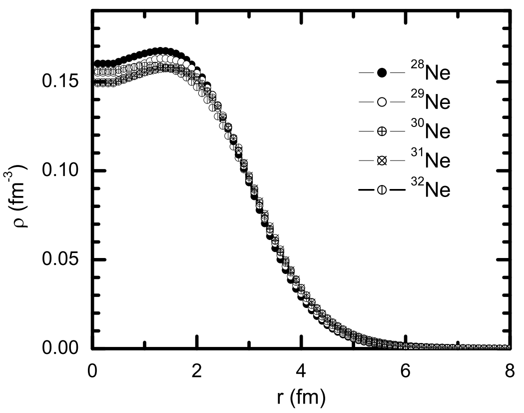

FIG. 1: The radial density plots of Ne isotopes for RMF(NL3*).

TABLE I: The RMF(NL3*) densities after fitting gaussian in terms of their coefficients c_i and ranges a_i.

Nuclei	c_1	a_1	c_2	a_2
^{12}C	-0.169195	0.577368	0.418511	0.300552
^{28}Ne	-2.68685	0.218885	2.81286	0.200789
^{29}Ne	-2.80577	0.223261	2.94678	0.204765
^{30}Ne	-2.90293	0.22326	3.04881	0.204765
^{31}Ne	-2.69474	0.203279	2.81029	0.186235
^{32}Ne	-1.0259	0.184479	1.15029	0.155872

Here, Fig 1 shows the radial densities plot of $^{28-32}Ne$ isotopes with RMF(NL3*) densities. The densities of Ne isotopes show a small depression at the center with increase of isotopic mass number and increase the skin effect of such densities towards the tail region. These densities are obtained after fitting into two Gaussian in terms of their coefficients c_i over the range a_i (the Gaussian coefficients are listed in Table I).

TABLE II: The nucleon-nucleon cross section σ_{NN} and other parameters used to calculate the profile function.

$E(MeV/A)$	$\sigma_{NN}(fm^2)$	α_{NN}	$\beta_{NN}(fm^2)$
230	3.307790	0.7462136	0.1042526
240	3.266868	0.6800303	0.0978437

The other inputs require to calculate the profile function are the energy dependent parameters σ_{NN}, α_{NN} and β_{NN}. These values are taken from Ref. [6] or by interpolating at different energy (listed in Table II).

TABLE III: The calculated values of σ_R (in mb) using RMF (NL3*) densities.

Nuclei	$E(MeV/A)$	σ_R RMF(NL3*)	σ_R(Expt.)[7]
^{28}Ne	240	1346	1273±11
^{29}Ne	240	1341	1344±14
^{30}Ne	240	1352	1348±17
^{31}Ne	240	1434	1435±22
^{32}Ne	240	1536	1385±33

The calculated values of nuclear reaction cross section (σ_R) for Ne isotopes as projectile with ^{12}C target using RMF(NL3*) densities are Listed in Table III. The calculated σ_R are in good agreement with experimental data. Fig. 2 shows the variation of total reaction cross section as a function of projectile energy. The value of σ_R is found to be larger at smaller incident energy. It decreases with increase of E_{Proj} upto $\sim$ 300 MeV/A. A slight increase in σ_R is found at 300-750 MeV/A and beyond it is constant. In an isotopic chain the value of σ_R increases with mass number A. We find a large difference in reaction cross section between ^{30}Ne ($\beta_2 = 0.000$) and ^{31}Ne ($\beta_2 = 0.147$) or ^{31}Ne ($\beta_2 = 0.147$) and ^{32}Ne ($\beta_2 = 0.377$). This may be due to halo effect of ^{31}Na.

The calculated one neutron removal reaction cross section σ_{-1n} for ^{31}Ne (using core+one neutron) at projectile energy 230 MeV/A with ^{12}C target is 12.8. It is shown by Panda et al [8] that the calculated value of σ_{-1n} using the difference of two neighboring isotopes with mass number A and A-1 in

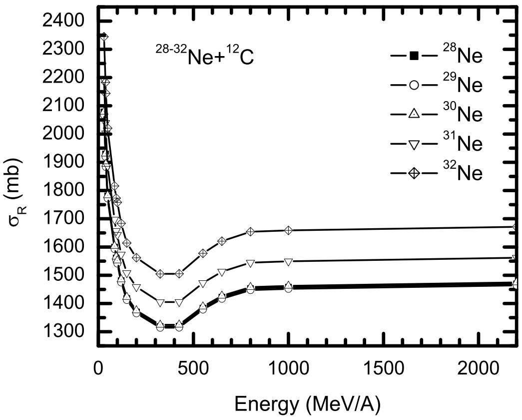

FIG. 2: Variation of reaction cross section with projectile energy E_{proj} for Ne isotopes with ^{12}C target.

an isotopic chain reproduce the experimental data in good agreement for the halo nuclei only. That means the formula $\sigma_{-1n} = \sigma_R(^{31}Ne) - \sigma_R(^{30}Ne)$ is valid for halo casees. Using this formula, we get $\sigma_{-1n} = 82.1$ mb for ^{31}Ne, which is well comparable to the experimental value of 79 ± 7 mb [2]. Thus our calculation shows the halo candidature of ^{31}Ne.

References

[1] W. Horiuchi et al., in Phys. Rev. **C 81**, 024606 (2010); K. Minomo et al., in Phys. Rev. Lett. **108**, 052503 (2012).

[2] T. Nakamura et al., Phys. Rev. Lett. **103**, 262501 (2009).

[3] S. K. Patra and C. R. Praharaj, Phys. Lett. **B 273**, 13 (1991).

[4] R. J. Glauber, Phys. Rev. **100**, 242 (1955), *ibid*, Lectures on theoretical physics, edited by W. E. Brittin and L. C. Dunham (Int. Sc., New York) **Vol.1**, p.315 (1959).

[5] R. N. Panda, B. K. Sahu and S. K. Patra (in this symposium).

[6] W. Horiuchi, Y. Suzuki, B. Abu-Ibrahim and A. Kohama, Phys. Rev., **C 75**, 044607 (2007).

[7] M. Takechi et al., Nucl. phys. **A 834**, 412 (2010).

[8] R. N. Panda, S. K. Patra, Int. J. Mod. Phys. **E 20**, 2505 (2011).