Structure and reaction dynamics of Al-isotopes using Glauber model and relativistic mean filed theory

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Introduction

The drip line study has been an important area in the nuclear field during last few decades. One of the current issue is to investigate the shell closer structure and identify new magic numbers. Another area of interest is vanishing of shell closer effect and existence of nuclear structure effects at island of inversion. The structure of nuclei in the region of island of inversion, has been extensively studied for Na and Mg isotopes, because of the anomalous breakdown of the N = 20 shell closure [1]. The recent discovery of ^{40}Mg and ^{42}Al [2] isotopes are well beyond the drip-line predicted by various mass formula.

TABLE I: The values of B.E. in MeV and r_c in fm obtained from RMF with NL3, DD-PC1 and DD-ME2 parameter sets

Nuclei	RMF(NL3)	DD-PC1	DD-ME2	Expt.[3]
	B.E.			
^{33}Al	264.660	270.071	267.497	264.650
^{34}Al	267.323	272.673	269.691	267.322
^{35}Al	272.545	275.133	271.734	272.545
^{36}Al	274.446	277.470	273.648	274.464
^{37}Al	278.610	279.693	275.443	278.647
	r_c			
^{33}Al	3.118	3.157	3.144	-
^{34}Al	3.128	3.169	3.157	-
^{35}Al	3.138	3.181	3.169	-
^{36}Al	3.149	3.193	3.181	-
^{37}Al	3.160	3.205	3.193	-

We have studied ground state properties such as binding energy (B.E.), charge radius (r_c), nucleon density distribution and related reaction dynamics of $^{33-37}$Al nuclei using microscopic relativistic mean field (RMF) formalism. Table 1 represents the values of B.E. and r_c of these isotopes obtained from RMF with NL3, DD-PC1 and DD-ME2 parameters. Table 1 suggest the calculated values are well comparable with the experimental data. The comparison of estimated values and available experimental data [3] suggest the success of mean filed theory. In order to address of reaction dynamics, well known Glauber model has been used [4]. The reaction observable highly depends on the accuracy of the densities of projectile and target nuclei. So we have used the densities from (RMF) calculations. The nucleon density distribution of considered set of isotopes are presented in the Fig.1 using RMF with NL3, DD-PC1 and DD-ME2 parameter sets. It is clearly shown in figure that, the distribution of densities are almost same from all parameters sets. The nuclear reaction cross section (σ_R) has been estimated using Glauber model as.

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

where 'T(b)' is the transparency function with impact parameter 'b'. The densities from mean field theory can not be feed directly in Glauber model. We need to convert these densities in terms of Gaussian coefficients as

$$\rho(r) = \sum_i^2 c_i \exp a_i^2 \qquad (2)$$

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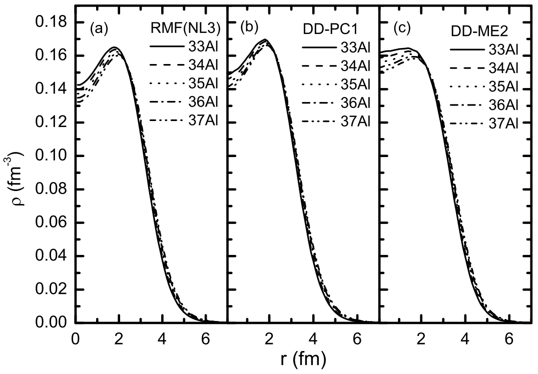

FIG. 1: The nucleon density distribution as a function of radial distance for $^{33-37}$Al isotopes with RMF(NL3), DD-PC1 and DD-ME2 parameters

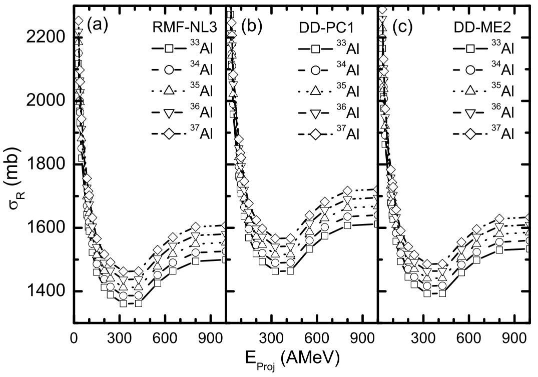

FIG. 2: The values of σ_R in mb as a function of projectile energy $E_{Proj.}$ over the energy range of $30-1000$ AMeV.

TABLE II: The Gaussian coefficients c_i's and ranges a_i's for the projectile and target from RMF with NL3, DD-PC1, DD-ME2 densities.

Nuclei	c_1	a_1	c_2	a_2
	RMF(NL3)			
^{12}C	-0.2326	0.6387	0.5172	0.3399
^{33}Al	-2.83271	0.211293	2.96009	0.192345
^{34}Al	-2.83995	0.206758	2.96498	0.188216
^{35}Al	-2.84529	0.202297	2.96789	0.184159
^{36}Al	-2.85227	0.198129	2.97244	0.180365
^{37}Al	-2.85936	0.194037	2.97704	0.176656
	DD-PC1			
^{12}C	-3.93151	0.355241	4.12636	0.340995
^{33}Al	-2.32815	0.198455	2.47219	0.180425
^{34}Al	-2.34789	0.194375	2.48909	0.176733
^{35}Al	-2.36883	0.190535	2.50733	0.173265
^{36}Al	-2.38895	0.186943	2.52491	0.170012
^{37}Al	-2.41061	0.183573	2.54418	0.166967
	DD-ME2			
^{12}C	-0.250141	0.555483	0.475994	0.309955
^{33}Al	-2.73717	0.213636	2.87147	0.19385
^{34}Al	-2.7473	0.209358	2.87968	0.189955
^{35}Al	-2.75712	0.205378	2.88774	0.186322
^{36}Al	-2.76998	0.201699	2.89901	0.182968
^{37}Al	-2.78349	0.198322	2.91115	0.179881

The RMF densities of projectiles and target nuclei after fitting into Gaussian in terms of their coefficients c_i over the ranges a_i are listed in Table II. Another important ingredients for σ_R are the energy and isospin dependant parameters σ_{NN} in (fm^2), α_{NN} and β_{NN} in (fm^2), which are estimated as per Ref. [5]. Fig. 2 represents the calculated values of σ_R for considered isotopes using all the three parameters sets over the energy range 30-1000 AMeV. It is clear from the figure that, the magnitude of σ_R are higher at low energy and goes on decreasing upto energy 300 AMeV. Thereafter a slight enhancement is seen in σ_R upto projectile energy 800 AMeV. After that, the reaction cross sections remain constant. A closer look of the figure signifies that, the values of reaction cross section goes on increasing with the increase of the isotopic mass number of projectile nuclei. The comparison of Fig. 2 (a), (b) and (c) signify that, the values of σ_R follow an increasing order with NL3, DD-ME2 and DD-PC1 parameters respectively.

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