Comparative study of the effective force parameters NL3 and NL3*

Shailesh K. Singh[1],* M. Ikram[2], S. K. Biswal[1], M. Bhuyan[1], and S. K. Patra[1]
[1]*Institute of Physics, Bhubaneswar - 751005, India, and*
[2]*Department of Physics, Aligarh Muslim University, Aligarh-202002, India.*

Introduction

Parameterization is an important ingredient in nuclear physics. Different parameters are used in different nuclear calculations to understand the nature of the problem and to sort out precisely. A good parameter set leads to the better understanding and reliability of the nuclear models in both relativistic and non-relativistic sector. In relativistic mean field theory, there are several force parameter sets like L1, L2, SH, NL1, NL2, NL3, NL3*, G1 and G2 for linear to non-linear Lagrangian. It is widely accepted that the NL3 parameter set reproduces nuclear saturation properties quite well than the other parameters thereoughout the periodic table. The recently reported NL3* [1] is claimed to be an improved version of NL3 [2] which is more suitable for all the nuclei to reproduce the experimental binding energy and other physical observables. For this, we calculate the ground state binding energy (BE), root mean square charge radius (r_{ch}) and quadrupole deformation parameter (β_2) for some of the selected nuclei and compare with available experimental data. The Lagrangian of Boguta and Bodmer is used in rmf calculation [3]. From this Lagrangian, a large number of parameterization have been evolved including NL3 and NL3*. The NL3* is little bit different to NL3 parameter set as shown in Table I. The symbols of all parameters are in their usual meaning as given in respective papers.

In our calculation center of mass (c.m.) motion energy correction is estimated by the harmonic oscillator formula $E_{c.m.} = \frac{3}{4}(41A^{-1/3})$,

*Electronic address: `shailesh@iopb.res.in`

TABLE I: We have given the parameter and nuclear matter properties of the effective interaction NL3 and NL3*.

Parameter	NL3	NL3*
M (MeV)	939	939
m_σ (MeV)	508.194	502.5742
m_ω (MeV)	782.501	782.600
m_ρ (MeV)	763.000	763.000
g_σ	10.217	10.0944
g_ω	12.868	12.8065
g_ρ	4.474	4.5748
$g_2(fm^{-1})$	-10.431	-10.8093
g_3	-28.885	-30.1486
Nuclear Matter Properties		
$\rho_0(fm^{-3})$	0.148	0.150
$(E/A)_\infty(MeV)$	16.30	16.31
K (MeV)	271.76	258.27
J (MeV)	37.4	38.68
m^*/m	0.60	0.594

where A is the mass number of the nucleus [4]. To produce these results, we adopt axially deformed relativisitc mean field formalism with NL3 and NL3* parameter sets. To take care of continuum, we have taken same oscillator basis for both Fermion and boson ($N_F = N_B = 12$). For odd nucleonic system, one uses the Pauli blocking scheme to take care of the time reversal symmetry. It is to be noted that its maximum contribution is about 1 MeV. Since its contibution is so small, that's why we ignored it in present calculation. In this paper, our motive is to give the comparison of BE calculated by RMF using NL3 and NL3* by keeping others input constraint as same.

Results and Discussions

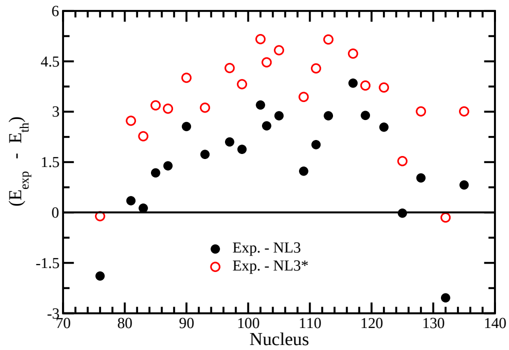
For quantitative analysis, the calculated results in the form of BE are framed in Table II. First column of the table represent recent experimentally synthesized isotopes, second and

TABLE II: We have given ground state binding energy for NL3 and NL3* parameter sets. For a better comparison experimental data are also given in the last column.

Nucleus	NL3	NL3*	Exp.
^{76}Cu	643.6020	641.8180	641.7083
^{81}Zn	676.1560	673.7730	676.5063
^{83}Ga	694.7900	692.6560	694.9233
^{85}Ge	712.9730	710.9580	714.1505
^{87}As	730.6130	728.9140	732.0050
^{90}Se	753.0780	751.6320	755.6400
^{93}Br	774.4460	773.0600	776.1780
^{97}Kr	800.0810	797.8820	802.1803
^{99}Rb	819.4440	817.5050	821.3238
^{102}Sr	842.7090	840.7450	845.9064
^{103}Y	856.7100	854.8220	859.2919
^{105}Zr	874.7860	872.8370	877.6656
^{109}Nb	903.0300	900.8270	904.2640
^{111}Mo	920.9710	918.7060	922.9950
^{113}Tc	938.3510	936.0800	941.2294
^{117}Ru	965.6090	964.7310	969.4620
^{119}Rh	985.2830	984.3950	988.1724
^{122}Pd	1010.7590	1009.5780	1013.3283
^{125}Ag	1036.3220	1034.7710	1036.3750
^{128}Cd	1061.7700	1059.7920	1062.8173
^{132}In	1091.9360	1089.5500	1089.4884
^{135}Sn	1110.3200	1108.1360	1111.1427

third columns for ground state binding energy for NL3 and NL3*. However, we look for the differences come into the physical observables using NL3 and NL3* but for a reference point and a better comparison experimental data is also included in fourth column. One can easily see from the Table II, when we move towards the drip-line nuclei, the differences with experimental results are increase. This differences is more for NL3* in comparison to NL3 as shown in Fig. 1. It is evident from Table II and Fig. 1 that the NL3* set produces better results only for two cases ^{76}Cu and ^{132}In among all the considered nuclei. For all other cases, the results of NL3 is more superior than NL3*. The same trend can also be seen in the charge radii and deformations which shall be reported at the time of presentation. From our analysis, we can say that NL3* is fitted by taking latest experimentally synthesized spherical nuclei and able to produce comfortable results for Hg

FIG. 1: We have plotted the difference of binding between NL3 and NL3* parameter of extreme experimentally synthesized nuclei. In this figure, solid circles for Exp.-NL3 and open circles represent the data for Exp.-NL3*. Black horizontal line shows zero difference between experimental results and theory.



and Pb light isotopes, but totally fails to describe the binding energy of latest synthesized nuclei as shown in Table II. As a result we can say that NL3 set is better than NL3* for exotic or drip-line nuclei.

In conclusion, although NL3 parametrization is 15 years old but it is consider to be a better set even than NL3*. Its power of prediction in exotic dripline nuclei is unbelievably good. As we know, the mass and radius of the neutron star under NL3 parameter are $2.78M_\odot$ and 15.05 Km respectively which are within the experimental limit.

References

[1] G. A. Lalazissis, S. Karatzikos, R. Fossion, D. Pena Arteaga, A. V. Afanasjev and P. Ring, *Phys. Lett. B* **671** (2009) 36.

[2] G. A. Lalazissis, J. König and P. Ring, *Phys. Rev. C* **55** (1997) 540.

[3] J. Boguta and A. R. Bodmer, *Nucl. Phys. A* **292** (1977) 413.

[4] Y. K. Gambhir, P. Ring and A. Thimet, *Ann. Phys. (NY)* **198** (1990) 132.