Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 161 (2021) 111-129 EISSN 2392-2192

Strong and Weak Interactions in Ghahramany's Integrated Nuclear Binding Energy Formula

U. V. S. Seshavatharam[1,a] and **S. Lakshminarayana**[2,b]

[1]Honorary Faculty, I-SERVE, Survey no-42, Hitech City, Hyderabad-84, Telangana, India

[2]Department of Nuclear Physics, Andhra University, Visakhapatnam-03, AP, India

[a,b]E-mail addres: seshavatharam.uvs@gmail.com , lnsrirama@gmail.com

ABSTRACT

By modifying Ghahramany's integrated nuclear binding energy formula with strong and weak interaction features, it is possible to approximate nuclear binding energy of isotopes with one unique energy coefficient and four terms. Considering even-odd corrections, shell corrections and other microscopic corrections, it seems possible to improve the accuracy. Based on our recent work and the proposed formulae, we are very confident to say that, quark structure helps in increasing nuclear binding energy and electroweak interaction helps in reducing nuclear binding energy.

***Keywords*:** Strong interaction, Electroweak interaction, Ghahramany's integrated nuclear binding energy formula, Nuclear drip lines

1. INTRODUCTION

Semi empirical mass formulae (SEMF) are having a crucial role in understanding nuclear structure [1-4] and constitute a minimum of 5 terms with five different energy coefficients. Three major disadvantages of SEMF are: 1) Five energy coefficients are having arbitrary origin. 2) Role of strong [5, 6] and electroweak [7-9] interactions is found to be missing. 3) Energy coefficients are having no particular relation with quarks and their structure [10, 11]. In this context, Ghahramany and team members [12-16] developed a very simple nuclear binding

(Received 26 August 2021; Accepted 18 September 2021; Date of Publication 19 September 2021)

energy formula based on quark-gluon plasma. For increasing its effectiveness towards isotopes, in this paper, we try to include strong and weak interaction features [17, 18] in Ghahramany's integrated nuclear binding energy formula (GINBEF). Recently, Khanna and team members [19, 20] also tried to modify GINBEF.

Even though highly intuitive, these formulae are lagging in implementing electroweak interaction in nuclear binding energy scheme associated with quark structure.

2. GHAHRAMANY'S INTEGRATED NUCLEAR MODEL

According to Ghahramany and team members, up and down quarks play a crucial role in understanding nuclear binding energy. Their unified views are:

1) The nuclear binding energy is of the order of 1% of the energy of the total rest mass of the constituent nucleons.
2) The binding energy depends upon the volume of the quark-gluon soup within the nuclei and is proportional to 3A where A is the mass number.
3) Due to the asymmetric distribution of up and down quarks and also the existence of the Coulomb force between them, binding energy depends upon terms such as $\frac{N^2 - Z^2}{Z}$.

For $A \geq 5$, different binding energy formulae proposed by Ghahramany and team members are as follows. In terms of up and down quarks,

$$BE \cong \left\{ 3A - \frac{\left(N^2 - Z^2\right) + \delta\left(N - Z\right)}{Z} - 9 \right\} \left(\frac{330 \text{ MeV}}{100} \right) \quad \text{where, } \begin{cases} \delta\left(N - Z\right) = 0 \text{ for } Z \neq N \\ \delta\left(N - Z\right) = 1 \text{ for } Z = N \end{cases} \tag{1}$$

With reference to nucleon rest energy,

$$BE \cong \left\{ A - \frac{\left(N^2 - Z^2\right) + \delta\left(N - Z\right)}{3Z} - 3 \right\} \left(\frac{m_n c^2}{90 \text{ to } 100} \right) \text{ MeV}$$

where, $m_n c^2$ = Rest energy of nucleon

$$\begin{cases} \delta\left(N - Z\right) = 0 \text{ for } Z \neq N \\ \delta\left(N - Z\right) = 1 \text{ for } Z = N \end{cases} \tag{2}$$

More advanced formula is,

$$BE \cong \left\{ A - \frac{\left(N^2 - Z^2\right) + \delta\left(N - Z\right)}{3\left(Z - k\right)} - 3 \right\} \left(\frac{A^{n+s} m_n c^2}{126\left(Z - k\right)} \right) \text{MeV}$$

where, $m_n c^2$ = Rest energy of nucleon

$$\begin{cases} \delta\left(N - Z\right) = 0 \text{ for } Z \neq N \\ \delta\left(N - Z\right) = 1 \text{ for } Z = N \end{cases}$$

$$n \cong 0.87 \text{ to } 0.88, \quad k \cong \begin{cases} 2 \text{ for } Z \leq 118 \\ 0 \text{ for } Z > 118 \end{cases}$$

$$s \cong \begin{cases} 0.0003 \text{ for even } \left(N, Z\right) \\ -0.0003 \text{ for odd } \left(N, Z\right) \end{cases} \qquad (3)$$

According to Khanna and team members [20],

$$BE \cong \left[3A - \left(\frac{\left(N^2 - Z^2\right) + \delta\left(N - Z\right)}{\sqrt{NZ}} \right) + \lambda \right] \left(\frac{m_u c^2}{100} \right) \text{MeV}$$

where, $m_u c^2 = 330$ MeV

$$\begin{cases} \delta\left(N - Z\right) = 0 \text{ for } Z \neq N \\ \delta\left(N - Z\right) = 1 \text{ for } Z = N \end{cases}$$

$$\lambda \cong \begin{cases} 9 \text{ for } Z \leq 30 \\ 0.4Z \text{ for } Z = 31 \text{ to } Z = 59 \\ 0.5Z \text{ for } Z = 60 \text{ to } Z = 69 \\ 0.6Z \text{ for } Z = 70 \text{ to } Z = 79 \\ 0.7Z \text{ for } Z = 80 \text{ to } Z = 86 \\ 0.8Z \text{ for } Z = 87 \text{ to } Z = 92 \\ 0.9Z \text{ for } Z = 93 \text{ to } Z = 98 \\ Z \text{ for } Z = 99 \text{ to } Z = 103 \\ 1.1Z \text{ for } Z = 104 \text{ to } Z = 110 \\ 1.2Z \text{ for } Z = 111 \text{ to } Z = 116 \\ 1.3Z \text{ for } Z = 117 \text{ and } Z = 118 \end{cases} \qquad (4)$$

3. UNDERSTANDING THE ROLE OF ELECTROWEAK INTERACTION IN NUCLEAR BINDING ENERGY SCHEME

With reference to strong and weak interactions in our recently published papers, we have developed a simple formula for estimating nuclear binding energy with one unique coefficient

of magnitude 10.1 MeV. In this paper, we made an attempt to include strong and weak interactions in GINBEF. It may be noted that, single variable binding energy constant and 3 simple terms play an interesting role in GINBEF. By considering strong and weak interactions, we have improved the workability of GINBEF applicable for isotopes and it needs further study with respect to $Z \approx N$.

By considering electroweak interaction, in nuclear binding energy scheme, we noticed that,

1) Unique binding energy coefficient is interconnected with basic nuclear potential, reciprocal of the strong coupling constant [11] and up and down quark rest masses [11]. (See section 9).
2) All the nucleons are not participating in nuclear binding energy.
3) Electroweak interaction plays a vital role in deciding the number of non-participating nucleons in the form of $\left[1+0.0019A\sqrt{NZ}\right]$.
4) Electroweak interaction decides the stable mass numbers of Z in the form of $A_s \cong 2Z+0.0016(2Z)^2 \cong 2Z+0.0064Z^2$.
5) With reference to pions and electro weak bosons, number 0.0016 can be expressed with a relation of the form, $\left(\frac{\sqrt{(m_\pi c^2)^0 (m_\pi c^2)^\pm}}{\sqrt{(m_z c^2)^0 (m_w c^2)^\pm}}\right) \cong \left(\frac{\sqrt{134.98\times139.57}\ \text{MeV}}{\sqrt{80379.0\times91187.6}\ \text{MeV}}\right) \cong 0.0016032.$
6) Stable mass number of Z plays an interesting role in reducing the binding energy of isotopes in the form of $\frac{(A_s-A)^2}{A_s}$.
7) Binding energy decreases with increasing surface area and increasing radius with an effective term of the form $\left(A^{2/3}/A^{1/3}\right) \cong A^{1/3}$.

Binding energy can be approximated with a relation of the form,

$$BE \cong \left\{A-\left[1+0.0019A\sqrt{NZ}\right]-A^{1/3}-\frac{(A_s-A)^2}{A_s}\right\}(10.1\ \text{MeV}) \tag{5}$$

By replacing the number 0.0019 with 0.0016, binding energy can be approximated with a relation of the form,

$$BE \cong \left\{A-A^{1/3}-\frac{(A_s-A)^2}{A_s}\right\}(10.1\ \text{MeV})-\left[1+0.0016A\sqrt{NZ}\right](11.9\ \text{MeV}) \tag{6}$$

4. ON THE ROLE OF ELECTROWEAK INTERACTION IN INTEGRATED NUCLEAR BINDING ENERGY FORMULA

Based on the above relations, we make an attempt to include strong and weak interactions in GINBEF. For $Z \geq 3$, it can be expressed in the following way.

$$BE \cong \left\{ A - \left[0.00173\sqrt{ZNAA_s} \right] - \left[\left(0.118 \frac{\left(N^2 - Z^2\right)}{\sqrt{AA_s}} \right) + \left(\frac{\left(A - A_s\right)^2}{\sqrt{AA_s}} \right) \right] - \left[\sqrt{\frac{A}{Z}} + \frac{\sqrt{A}}{2} \right] \right\} 10.3 \text{ MeV} \tag{7}$$

where $A_s \cong 2Z + 0.0064Z^2$

With reference to various semi empirical mass formulae and with trial & error we have developed this relation. Accuracy point of view, it is having many advantages compared to Ghahramany's integrated nuclear model. In this relation,

1) Second term can be considered as a consequence of electroweak interaction.
2) Third term can be considered as a consequence of Coulombic and Asymmetry.
3) Fourth term can be considered as a correction factor associated with neutron-proton ratio.

As a whole, accuracy depends on two numbers 0.00173 and 0.118, one energy coefficient of 10.3 MeV and selection of stable mass number of Z. With a computer program [21] and fitting the estimated data with actual binding energies, things can be improved. By considering even-odd corrections, shell corrections and other microscopic corrections, relation (7) can be reviewed and refined with a clear physical background. See Table 1 for the binding energy of isotopes of Z=50. To compare the data prepared with relations (5), (6) and (7), we have taken the following three semi empirical mass formulae as references.

$$BE_{\text{Ref1}} \cong \left\{ \begin{array}{l} \left[\left(A \times 15.36 \right) \right] - \left[\left(A^{2/3} \times 16.32 \right) \right] - \left[\left(\frac{Z^2}{A^{1/3}} \right) 0.6929 \right] \\ - \left[\frac{\left(\left(A/2 \right) - Z \right)^2}{A} \times 90.46 \right] \pm \left(\frac{11.32}{\sqrt{A}} \right) \end{array} \right\} \text{ MeV} \tag{8}$$

Ref. → https://fdocuments.in/document/nuclear-and-particle-physics.html

$$BE_{\text{Ref2}} \cong \left(a_v * A \right) - \left(a_s * A^{2/3} \right) - \left(a_c * \frac{Z*\left(Z-1\right)}{A^{1/3}} \right) - \left(a_a * \frac{\left(A-2Z\right)^2}{A} \right) \pm \left(\frac{a_p}{\sqrt{A}} \right) \Bigg\}$$

$$\text{where } \left\{ \begin{array}{l} a_v \cong 15.8 \text{ MeV};\ a_s \cong 18.3 \text{ MeV};\ a_c \cong 0.714 \text{ MeV}; \\ a_a \cong 23.2 \text{ MeV};\ a_p \cong 12.0 \text{ MeV}; \end{array} \right. \tag{9}$$

Ref. → https://en.wikipedia.org/wiki/Semi-empirical_mass_formula

$$BE_{\text{Ref3}} \cong \left(a_v * x * A\right) - \left(a_s * x * A^{2/3}\right) - \left(a_c * \frac{Z^2}{A^{1/3}}\right) + \left(a_{pr} * \frac{Z^2}{A}\right) \pm \left(\frac{a_p}{\sqrt{A}}\right)$$

$$\text{where} \left\{ \begin{array}{l} x \cong \left[1 - 1.79\left(\frac{N-Z}{A}\right)^2\right] \\ a_v \cong 15.677 \text{ MeV};\ a_s \cong 18.56 \text{ MeV};\ a_c \cong 0.717 \text{ MeV}; \\ a_{pr} \cong 1.211 \text{ MeV};\ a_p \cong 11.0 \text{ MeV}; \end{array} \right. \quad (10)$$

Ref. → http://oregonstate.edu/instruct/ch374/ch418518/lecture3-1.pdf

Table 1. Estimated nuclear binding energy of isotopes of Z=50

Z=50	N	A	Estimated stable mass number	Ref_1.BE (MeV) Relation-8	Ref_2.BE (MeV) Relation-9	Ref_3.BE (MeV) Relation-10	Est_1. BE (MeV) Relation-5	Est_2. BE (MeV) Relation-6	Est_3. BE (MeV) Relation-7
50	50	100	116	812.3	810.1	813.0	834.8	833.7	843.5
50	51	101	116	825.2	823.1	825.7	845.5	844.5	854.0
50	52	102	116	839.9	838.0	840.2	856.0	855.0	864.2
50	53	103	116	852.0	850.1	852.1	866.4	865.4	874.2
50	54	104	116	865.8	864.1	865.7	876.6	875.6	884.0
50	55	105	116	877.0	875.4	876.9	886.6	885.6	893.6
50	56	106	116	890.0	888.6	889.8	896.4	895.4	903.0
50	57	107	116	900.5	899.1	900.2	906.0	905.0	912.1
50	58	108	116	912.7	911.5	912.4	915.4	914.5	921.1
50	59	109	116	922.4	921.2	922.1	924.7	923.8	929.8
50	60	110	116	933.9	932.8	933.6	933.8	932.9	938.3
50	61	111	116	942.9	941.9	942.7	942.6	941.8	946.7
50	62	112	116	953.8	952.8	953.6	951.4	950.5	954.8
50	63	113	116	962.1	961.1	962.0	959.9	959.0	962.8
50	64	114	116	972.3	971.4	972.3	968.2	967.4	970.5
50	65	115	116	980.0	979.1	980.1	976.4	975.6	978.1
50	66	116	116	989.5	988.8	989.8	984.4	983.6	985.5
50	67	117	116	996.7	995.9	997.1	992.2	991.4	992.6
50	68	118	116	1005.6	1004.9	1006.1	999.8	999.0	999.7
50	69	119	116	1012.2	1011.4	1012.9	1007.2	1006.5	1006.5

50	70	120	116	1020.6	1019.9	1021.4	1014.5	1013.7	1013.1
50	71	121	116	1026.7	1025.9	1027.7	1021.5	1020.8	1019.6
50	72	122	116	1034.5	1033.8	1035.7	1028.4	1027.7	1025.9
50	73	123	116	1040.1	1039.3	1041.5	1035.1	1034.4	1032.0
50	74	124	116	1047.4	1046.7	1049.0	1041.6	1041.0	1038.0
50	75	125	116	1052.5	1051.6	1054.3	1048.0	1047.3	1043.8
50	76	126	116	1059.3	1058.5	1061.3	1054.1	1053.5	1049.4
50	77	127	116	1063.9	1063.1	1066.1	1060.1	1059.5	1054.8
50	78	128	116	1070.3	1069.5	1072.7	1065.9	1065.3	1060.1
50	79	129	116	1074.5	1073.5	1077.1	1071.5	1070.9	1065.3
50	80	130	116	1080.5	1079.5	1083.3	1076.9	1076.3	1070.2
50	81	131	116	1084.2	1083.2	1087.3	1082.1	1081.6	1075.1
50	82	132	116	1089.8	1088.7	1093.0	1087.2	1086.7	1079.7
50	83	133	116	1093.1	1091.9	1096.6	1092.1	1091.6	1084.2
50	84	134	116	1098.3	1097.0	1101.9	1096.8	1096.3	1088.6
50	85	135	116	1101.2	1099.9	1105.1	1101.3	1100.8	1092.8
50	86	136	116	1106.0	1104.6	1110.0	1105.6	1105.1	1096.8
50	87	137	116	1108.6	1107.1	1112.9	1109.7	1109.3	1100.7
50	88	138	116	1113.0	1111.5	1117.4	1113.7	1113.3	1104.5
50	89	139	116	1115.3	1113.6	1119.9	1117.5	1117.1	1108.1
50	90	140	116	1119.3	1117.6	1124.1	1121.1	1120.7	1111.5
50	91	141	116	1121.2	1119.4	1126.3	1124.5	1124.1	1114.9
50	92	142	116	1124.9	1123.0	1130.1	1127.7	1127.4	1118.0
50	93	143	116	1126.5	1124.5	1132.0	1130.8	1130.5	1121.1
50	94	144	116	1129.9	1127.8	1135.5	1133.7	1133.3	1124.0
50	95	145	116	1131.2	1129.0	1137.0	1136.3	1136.0	1126.7
50	96	146	116	1134.3	1131.9	1140.2	1138.8	1138.6	1129.4
50	97	147	116	1135.3	1132.8	1141.4	1141.2	1140.9	1131.9
50	98	148	116	1138.0	1135.5	1144.3	1143.3	1143.1	1134.2
50	99	149	116	1138.8	1136.1	1145.2	1145.3	1145.0	1136.4
50	100	150	116	1141.3	1138.5	1147.8	1147.0	1146.8	1138.5
50	101	151	116	1141.7	1138.8	1148.5	1148.6	1148.5	1140.5
50	102	152	116	1143.9	1140.9	1150.8	1150.1	1149.9	1142.3
50	103	153	116	1144.2	1140.9	1151.1	1151.3	1151.1	1144.0
50	104	154	116	1146.1	1142.8	1153.2	1152.3	1152.2	1145.6
50	105	155	116	1146.1	1142.5	1153.3	1153.2	1153.1	1147.0

50	106	156	116	1147.7	1144.1	1155.0	1153.9	1153.8	1148.3
50	107	157	116	1147.5	1143.7	1154.9	1154.4	1154.3	1149.5
50	108	158	116	1148.9	1145.0	1156.4	1154.7	1154.6	1150.6
50	109	159	116	1148.4	1144.3	1156.0	1154.8	1154.8	1151.6
50	110	160	116	1149.6	1145.4	1157.2	1154.8	1154.8	1152.4
50	111	161	116	1148.9	1144.5	1156.6	1154.6	1154.6	1153.1
50	112	162	116	1149.8	1145.3	1157.6	1154.2	1154.2	1153.7
50	113	163	116	1148.9	1144.2	1156.8	1153.6	1153.6	1154.1
50	114	164	116	1149.7	1144.8	1157.5	1152.8	1152.9	1154.5

5. SECOND TERM OF RELATION (7)

We noticed that, reduction of binding energy is greatly influenced by electroweak interaction. Clearly speaking, second term plays a major role in reducing nuclear binding energy compared to other terms. This can be confirmed with relations (5) and (6). Number of non-participating nucleons seems to increase with increasing mass number. For $_{92}U^{238}$, number of non-participating nucleons are 48 and corresponding reduction in binding energy is 491 MeV. This is a reduction of 20% of (238*10.3 MeV) = 2451 MeV.

6. FIRST PART OF THE THIRD TERM OF RELATION (7)

Considering the third term, it constitutes two sub terms. First sub term is $\left(0.118\frac{\left(N^2-Z^2\right)}{\sqrt{AA_s}}\right)$. It is almost similar to the Ghahramany's proposed second term, $\frac{\left(N^2-Z^2\right)}{3Z}$. Multiplying and dividing relation (1) by 3 and ignoring $\delta(N-Z)$, it is possible to re-express it as,

$$BE \cong \left\{A-\frac{\left(N^2-Z^2\right)}{3Z}-3\right\}(9.9\text{MeV}) \tag{10}$$

It may be noted that, $\frac{\left(N^2-Z^2\right)}{3Z} \cong \frac{1}{3}\left[\frac{\left(N^2-Z^2\right)}{Z}\right] \cong 0.33\bar{3}\left[\frac{\left(N^2-Z^2\right)}{Z}\right]$. The number $\left(\frac{1}{3}\right) \cong 0.33\bar{3}$ is roughly three times the strong coupling constant [14], $\alpha_s \cong 0.118$. Keeping this coincidence in view we tried to replace $\left(\frac{1}{3}\right)$ with α_s. By doing so, it is possible to bring strong interaction characteristics into nuclear binding energy scheme. It needs a serious review.

7. SECOND PART OF THE THIRD TERM OF RELATION (7)

It is quite interesting to note that, second sub term of the third term, $\left(\frac{(A-A_s)^2}{\sqrt{AA_s}}\right)$ plays a nice role in reducing the binding energy of isotopes of Z about its stable mass number. Clearly speaking, on both side of the selected stable mass number of Z, it helps in curve bending with reference to mainstream semi empirical mass formulae.

8. FOURTH TERM OF RELATION (7)

With trial-error, we have introduced the fourth term in place of the third term of the Ghahramany's integrated nuclear model. Even though, its contribution in reducing binding energy of medium and heavy atomic nuclides is minute, for light atomic nuclides, its role is considerable. It needs a review and refinement with respect to actual binding energy.

9. UNDERSTANDING THE UNIQUE BINDING ENERGY COEFFICIENT

Unique binding energy coefficient can be understood in two possible ways. One way is based on the basic nuclear potential and reciprocal of the strong coupling constant [11, 12]. Second way is to consider the average rest energy of up and down quarks [11, 12].

Method 1. Considering nuclear potential and strong coupling constant, unique binding energy coefficient can be expressed as,

$$\begin{aligned} B_0 &\cong \left(\frac{1}{\alpha_s}\right)\frac{e^2}{4\pi\varepsilon_0 R_0} \cong (10.0 \text{ to } 10.4) \text{ MeV} \\ \text{where, } &\begin{cases} \alpha_s \cong 0.115 \text{ to } 0.12 \\ R_0 \cong 1.20 \text{ fm} \end{cases} \end{aligned} \tag{11}$$

Method 2. Considering up and down quark masses, unique binding energy coefficient can be expressed as,

$$\left.\begin{aligned} B_0 &\cong \frac{\left(2m_u c^2 + m_d c^2\right) + \left(m_u c^2 + 2m_d c^2\right)}{2} \\ &\cong \frac{3}{2}\left(m_u c^2 + m_d c^2\right) \cong 10.26 \text{ MeV} \\ \text{where } &\left\{\begin{aligned} m_u c^2 &\cong 2.16^{+0.49}_{-0.26} \text{ MeV} \\ m_d c^2 &\cong 4.68^{+0.48}_{-0.17} \text{ MeV} \end{aligned}\right\} \end{aligned}\right\} \tag{12}$$

Combining relations (11) and (12),

$$\alpha_s \cong \frac{2e^2}{12\pi\varepsilon_0 R_0 \left(m_u + m_d\right)c^2} \tag{13}$$

$$R_0 \cong \left(\frac{1}{\alpha_s}\right)\frac{2e^2}{12\pi\varepsilon_0 \left(m_u + m_d\right)c^2} \tag{14}$$

10. DISCUSSION

1) Relation (7) is absolutely different from the currently believed major nuclear binding energy terms like surface energy and coulombic energy. But it is in line with Ghahramany's integrated nuclear binding energy relations (GINBER).
2) It is true that, at first look, relation (7) seems to be quite complicated. Even then, compared to relations (1) to (4), it is helping in estimating nuclear binding energy to a very good approximation with prefixed parameters applicable for the whole range of atomic nuclides. In this context, we have developed the following much simple workable relation applicable for Z = (3 to 120) and we are working on it.

$$BE \cong \left\{A - \left[\frac{1}{2}k\left(Z^2 + A^2\right)\right] - \frac{\left(A_s - A\right)^2}{A_s} - 3\right\}\left(B_0 \cong 9.85 \text{ MeV}\right)$$

$$\text{where} \begin{cases} k \cong \dfrac{\sqrt{\left(m_\pi c^2\right)^0 \left(m_\pi c^2\right)^{\pm}}}{\sqrt{\left(m_z c^2\right)^0 \left(m_w c^2\right)^{\pm}}} \cong 0.0016 \\ A_s \cong 2Z + k\left(2Z\right)^2 \cong 2Z + 0.0064Z^2 \\ B_0 \cong \left(\dfrac{1}{\alpha_s}\right)\dfrac{e^2}{4\pi\varepsilon_0 R_0} \cong \left(9.6 \text{ to } 10.0\right) \text{ MeV} \\ \text{where,} \begin{cases} \alpha_s \cong 0.115 \text{ to } 0.12 \\ R_0 \cong 1.25 \text{ fm} \end{cases} \end{cases} \tag{15}$$

3) Even though minor error is persisting in estimating the binding energy, starting from Z = 3 to 120, based on the trend of binding energy fitting, it is very clear to say that, our proposed relation (7) is having a very deep interconnection with nuclear binding energy scheme and quarks & strong coupling constant.
4) Understanding nuclear binding energy with single energy coefficient is a challenging task and it needs a lot of physical basis. We are working in this direction.
5) We believe that, by considering other microscopic binding energy terms like, shell effect, even-odd effect and congruence effect, there is a possibility for improving the accuracy.
6) By considering the second term, number of non-participating nucleons can be estimated. With further study, current nuclear models [22,23] can be studied in a unified manner.

7) Considering Z as a characteristic representation of range of bound isotopes of Z and considering $k \cong 0.0016$ as a characteristic electroweak coefficient, lower [3] and upper mass limits of Z can be expressed as, $A_{low} \cong 2Z + 2kZ^2$ and $A_{up} \cong 3Z + 2kZ^2$ respectively. Mean stable mass number can be approximated with, $A_{mean} \cong 2Z + 4kZ^2 \cong 2Z + 0.0064Z^2$.

8) Independent of nucleon separation energies, approximately, lower and upper mass limits of proton drip lines [24] can be understood with, $(A_P)_{low} \cong \left(2Z + kZ^2\right) - \ln\left(\frac{1}{k}\right) \cong \left(2Z + kZ^2\right) - 6.44$ and $(A_P)_{up} \cong \left(2Z + 2kZ^2\right) \cong 2Z(1 + kZ)$. Geometric mass limit of proton drip lines can be expressed as, $(A_P)_{gm} \cong \sqrt{(A_P)_{low}(A_P)_{up}}$. Similarly neutron drip lines can be approximated with $A_N \cong A_{up} \cong 3Z + 2kZ^2$. See Table 2. Considering even-odd corrections and shell effects, to some extent, errors in estimation can be minimized. We are working in this direction.

Table 2. Estimated drip lines and mass limits of Z = 8 to 121

Z	$(A_P)_{low}$	$(A_P)_{gm}$	$\frac{(A_P)_{up}}{A_{low}}$	A_{mean}	$\frac{A_N}{A_{up}}$		Z	$(A_P)_{low}$	$(A_P)_{gm}$	$\frac{(A_P)_{up}}{A_{low}}$	A_{mean}	$\frac{A_N}{A_{up}}$
8	9.7	11.7	16.2	16.4	24.2		65	130.3	136.6	143.5	157.0	208.5
9	11.7	14.0	18.3	18.5	27.3		66	132.5	138.9	145.9	159.9	211.9
10	13.7	16.2	20.3	20.6	30.3		67	134.7	141.2	148.4	162.7	215.4
11	15.8	18.4	22.4	22.8	33.4		68	137.0	143.6	150.8	165.6	218.8
12	17.8	20.5	24.5	24.9	36.5		69	139.2	145.9	153.2	168.5	222.2
13	19.8	22.6	26.5	27.1	39.5		70	141.4	148.2	155.7	171.4	225.7
14	21.9	24.7	28.6	29.3	42.6		71	143.6	150.5	158.1	174.3	229.1
15	23.9	26.8	30.7	31.4	45.7		72	145.9	152.9	160.6	177.2	232.6
16	26.0	28.9	32.8	33.6	48.8		73	148.1	155.2	163.1	180.1	236.1
17	28.0	31.1	34.9	35.8	51.9		74	150.3	157.6	165.5	183.0	239.5
18	30.1	33.2	37.0	38.1	55.0		75	152.6	159.9	168.0	186.0	243.0
19	32.1	35.3	39.2	40.3	58.2		76	154.8	162.3	170.5	189.0	246.5
20	34.2	37.4	41.3	42.6	61.3		77	157.0	164.6	173.0	191.9	250.0
21	36.3	39.5	43.4	44.8	64.4		78	159.3	167.0	175.5	194.9	253.5
22	38.3	41.6	45.5	47.1	67.5		79	161.5	169.4	178.0	197.9	257.0
23	40.4	43.7	47.7	49.4	70.7		80	163.8	171.8	180.5	201.0	260.5
24	42.5	45.9	49.8	51.7	73.8		81	166.1	174.1	183.0	204.0	264.0
25	44.6	48.0	52.0	54.0	77.0		82	168.3	176.5	185.5	207.0	267.5

26	46.6	50.1	54.2	56.3	80.2	83	170.6	178.9	188.0	210.1	271.0
27	48.7	52.2	56.3	58.7	83.3	84	172.8	181.3	190.6	213.2	274.6
28	50.8	54.4	58.5	61.0	86.5	85	175.1	183.7	193.1	216.2	278.1
29	52.9	56.5	60.7	63.4	89.7	86	177.4	186.1	195.7	219.3	281.7
30	55.0	58.7	62.9	65.8	92.9	87	179.7	188.5	198.2	222.4	285.2
31	57.1	60.8	65.1	68.2	96.1	88	182.0	190.9	200.8	225.6	288.8
32	59.2	63.0	67.3	70.6	99.3	89	184.2	193.4	203.3	228.7	292.3
33	61.3	65.1	69.5	73.0	102.5	90	186.5	195.8	205.9	231.8	295.9
34	63.4	67.3	71.7	75.4	105.7	91	188.8	198.2	208.5	235.0	299.5
35	65.5	69.5	73.9	77.8	108.9	92	191.1	200.6	211.1	238.2	303.1
36	67.6	71.6	76.1	80.3	112.1	93	193.4	203.1	213.7	241.4	306.7
37	69.8	73.8	78.4	82.8	115.4	94	195.7	205.5	216.3	244.6	310.3
38	71.9	76.0	80.6	85.2	118.6	95	198.0	208.0	218.9	247.8	313.9
39	74.0	78.2	82.9	87.7	121.9	96	200.3	210.4	221.5	251.0	317.5
40	76.1	80.4	85.1	90.2	125.1	97	202.6	212.9	224.1	254.2	321.1
41	78.2	82.6	87.4	92.8	128.4	98	204.9	215.3	226.7	257.5	324.7
42	80.4	84.8	89.6	95.3	131.6	99	207.2	217.8	229.4	260.7	328.4
43	82.5	87.0	91.9	97.8	134.9	100	209.6	220.3	232.0	264.0	332.0
44	84.7	89.2	94.2	100.4	138.2	101	211.9	222.7	234.6	267.3	335.6
45	86.8	91.4	96.5	103.0	141.5	102	214.2	225.2	237.3	270.6	339.3
46	88.9	93.6	98.8	105.5	144.8	103	216.5	227.7	239.9	273.9	342.9
47	91.1	95.8	101.1	108.1	148.1	104	218.9	230.2	242.6	277.2	346.6
48	93.2	98.1	103.4	110.7	151.4	105	221.2	232.7	245.3	280.6	350.3
49	95.4	100.3	105.7	113.4	154.7	106	223.5	235.2	248.0	283.9	354.0
50	97.6	102.5	108.0	116.0	158.0	107	225.9	237.7	250.6	287.3	357.6
51	99.7	104.8	110.3	118.6	161.3	108	228.2	240.2	253.3	290.6	361.3
52	101.9	107.0	112.7	121.3	164.7	109	230.6	242.7	256.0	294.0	365.0
53	104.1	109.3	115.0	124.0	168.0	110	232.9	245.2	258.7	297.4	368.7
54	106.2	111.5	117.3	126.7	171.3	111	235.3	247.7	261.4	300.9	372.4
55	108.4	113.8	119.7	129.4	174.7	112	237.6	250.3	264.1	304.3	376.1
56	110.6	116.0	122.0	132.1	178.0	113	240.0	252.8	266.9	307.7	379.9

57	112.8	118.3	124.4	134.8	181.4		114	242.4	255.3	269.6	311.2	383.6
58	114.9	120.6	126.8	137.5	184.8		115	244.7	257.9	272.3	314.6	387.3
59	117.1	122.9	129.1	140.3	188.1		116	247.1	260.4	275.1	318.1	391.1
60	119.3	125.1	131.5	143.0	191.5		117	249.5	262.9	277.8	321.6	394.8
61	121.5	127.4	133.9	145.8	194.9		118	251.8	265.5	280.6	325.1	398.6
62	123.7	129.7	136.3	148.6	198.3		119	254.2	268.1	283.3	328.6	402.3
63	125.9	132.0	138.7	151.4	201.7		120	256.6	270.6	286.1	332.2	406.1
64	128.1	134.3	141.1	154.2	205.1		121	259.0	273.2	288.9	335.7	409.9

9) Considering Ghahramany's quark concepts of nuclear binding energy and our proposal of reduction of nuclear binding energy with electroweak interaction, there is a wide scope for studying low energy nuclear physics and high energy nuclear physics in a unified approach. In this context, relations (5), (6), (7) and (15) can be given some encouragement.
10) Proposed relation (15) is very simple to understand. Considering the second term of relation (15), it is very clear to say that, via electroweak interaction, squared proton number and squared mass number play a major role reducing the nuclear binding energy.
11) Compared to current models of Nuclear Density Functional Theories [25] and holographic quantum chromodynamic mean field nuclear potentials [26], qualitatively and quantitatively, our proposal is very simple to understand and very easy to follow. It can be proved with relations (5) and (15). To confirm the effectiveness of our proposal, readers are encouraged to see Table 3 prepared with relations (8), (10) and (15).

Table 3. Estimated nuclear binding energy of isotopes of Z = 92

Z = 92	N	A	Estimated stable mass number	**Est. BE (MeV) Relation (15)**	**Ref 1.BE (MeV) Relation (8)**	**%Error Relations (8) & (15)**	**Ref 2.BE (MeV) Relation (10)**	**%Error Relations (10) & (15)**
92	92	184	238	**1328.7**	**1268.0**	**-4.8**	**1273.7**	**-4.3**
92	93	185	238	**1340.1**	**1282.4**	**-4.5**	**1287.9**	**-4.1**
92	94	186	238	**1351.3**	**1298.1**	**-4.1**	**1303.5**	**-3.7**
92	95	187	238	**1362.5**	**1312.0**	**-3.9**	**1317.2**	**-3.4**
92	96	188	238	**1373.6**	**1327.3**	**-3.5**	**1332.3**	**-3.1**
92	97	189	238	**1384.6**	**1340.6**	**-3.3**	**1345.5**	**-2.9**
92	98	190	238	**1395.4**	**1355.4**	**-3.0**	**1360.1**	**-2.6**
92	99	191	238	**1406.2**	**1368.3**	**-2.8**	**1372.9**	**-2.4**
92	100	192	238	**1416.9**	**1382.7**	**-2.5**	**1387.1**	**-2.1**

92	101	193	238	**1427.5**	**1395.1**	**-2.3**	**1399.4**	**-2.0**
92	102	194	238	**1438.0**	**1409.0**	**-2.1**	**1413.2**	**-1.8**
92	103	195	238	**1448.3**	**1421.0**	**-1.9**	**1425.1**	**-1.6**
92	104	196	238	**1458.6**	**1434.5**	**-1.7**	**1438.4**	**-1.4**
92	105	197	238	**1468.8**	**1446.1**	**-1.6**	**1449.9**	**-1.3**
92	106	198	238	**1478.9**	**1459.1**	**-1.4**	**1462.7**	**-1.1**
92	107	199	238	**1488.9**	**1470.3**	**-1.3**	**1473.8**	**-1.0**
92	108	200	238	**1498.8**	**1482.9**	**-1.1**	**1486.3**	**-0.8**
92	109	201	238	**1508.6**	**1493.7**	**-1.0**	**1497.0**	**-0.8**
92	110	202	238	**1518.3**	**1505.9**	**-0.8**	**1509.1**	**-0.6**
92	111	203	238	**1527.9**	**1516.3**	**-0.8**	**1519.4**	**-0.6**
92	112	204	238	**1537.4**	**1528.1**	**-0.6**	**1531.1**	**-0.4**
92	113	205	238	**1546.8**	**1538.1**	**-0.6**	**1541.0**	**-0.4**
92	114	206	238	**1556.1**	**1549.6**	**-0.4**	**1552.3**	**-0.2**
92	115	207	238	**1565.3**	**1559.2**	**-0.4**	**1561.9**	**-0.2**
92	116	208	238	**1574.4**	**1570.3**	**-0.3**	**1572.9**	**-0.1**
92	117	209	238	**1583.4**	**1579.6**	**-0.2**	**1582.1**	**-0.1**
92	118	210	238	**1592.3**	**1590.3**	**-0.1**	**1592.7**	**0.0**
92	119	211	238	**1601.1**	**1599.3**	**-0.1**	**1601.6**	**0.0**
92	120	212	238	**1609.8**	**1609.7**	**0.0**	**1611.8**	**0.1**
92	121	213	238	**1618.4**	**1618.3**	**0.0**	**1620.4**	**0.1**
92	122	214	238	**1626.9**	**1628.3**	**0.1**	**1630.3**	**0.2**
92	123	215	238	**1635.4**	**1636.7**	**0.1**	**1638.5**	**0.2**
92	124	216	238	**1643.7**	**1646.4**	**0.2**	**1648.0**	**0.3**
92	125	217	238	**1651.9**	**1654.4**	**0.1**	**1656.0**	**0.2**
92	126	218	238	**1660.0**	**1663.7**	**0.2**	**1665.2**	**0.3**
92	127	219	238	**1668.0**	**1671.4**	**0.2**	**1672.8**	**0.3**
92	128	220	238	**1676.0**	**1680.5**	**0.3**	**1681.7**	**0.3**
92	129	221	238	**1683.8**	**1687.9**	**0.2**	**1689.0**	**0.3**
92	130	222	238	**1691.5**	**1696.7**	**0.3**	**1697.6**	**0.4**
92	131	223	238	**1699.1**	**1703.8**	**0.3**	**1704.6**	**0.3**
92	132	224	238	**1706.7**	**1712.3**	**0.3**	**1713.0**	**0.4**
92	133	225	238	**1714.1**	**1719.1**	**0.3**	**1719.7**	**0.3**
92	134	226	238	**1721.4**	**1727.3**	**0.3**	**1727.7**	**0.4**
92	135	227	238	**1728.7**	**1733.8**	**0.3**	**1734.1**	**0.3**
92	136	228	238	**1735.8**	**1741.7**	**0.3**	**1741.9**	**0.3**

92	137	229	238	**1742.8**	**1748.0**	**0.3**	**1748.0**	**0.3**
92	138	230	238	**1749.8**	**1755.7**	**0.3**	**1755.5**	**0.3**
92	139	231	238	**1756.6**	**1761.7**	**0.3**	**1761.4**	**0.3**
92	140	232	238	**1763.3**	**1769.0**	**0.3**	**1768.6**	**0.3**
92	141	233	238	**1770.0**	**1774.8**	**0.3**	**1774.2**	**0.2**
92	142	234	238	**1776.5**	**1781.9**	**0.3**	**1781.1**	**0.3**
92	143	235	238	**1783.0**	**1787.4**	**0.3**	**1786.5**	**0.2**
92	144	236	238	**1789.3**	**1794.3**	**0.3**	**1793.2**	**0.2**
92	145	237	238	**1795.6**	**1799.6**	**0.2**	**1798.3**	**0.2**
92	146	238	238	**1801.7**	**1806.2**	**0.2**	**1804.7**	**0.2**
92	147	239	238	**1807.8**	**1811.3**	**0.2**	**1809.6**	**0.1**
92	148	240	238	**1813.7**	**1817.6**	**0.2**	**1815.8**	**0.1**
92	149	241	238	**1819.6**	**1822.5**	**0.2**	**1820.4**	**0.0**
92	150	242	238	**1825.3**	**1828.6**	**0.2**	**1826.3**	**0.1**
92	151	243	238	**1831.0**	**1833.2**	**0.1**	**1830.7**	**0.0**
92	152	244	238	**1836.5**	**1839.1**	**0.1**	**1836.4**	**0.0**
92	153	245	238	**1842.0**	**1843.5**	**0.1**	**1840.6**	**-0.1**
92	154	246	238	**1847.3**	**1849.2**	**0.1**	**1846.1**	**-0.1**
92	155	247	238	**1852.6**	**1853.3**	**0.0**	**1850.0**	**-0.1**
92	156	248	238	**1857.8**	**1858.8**	**0.1**	**1855.2**	**-0.1**
92	157	249	238	**1862.8**	**1862.8**	**0.0**	**1859.0**	**-0.2**
92	158	250	238	**1867.8**	**1868.1**	**0.0**	**1864.0**	**-0.2**
92	159	251	238	**1872.7**	**1871.8**	**0.0**	**1867.5**	**-0.3**
92	160	252	238	**1877.4**	**1876.9**	**0.0**	**1872.3**	**-0.3**
92	161	253	238	**1882.1**	**1880.4**	**-0.1**	**1875.6**	**-0.3**
92	162	254	238	**1886.7**	**1885.3**	**-0.1**	**1880.2**	**-0.3**
92	163	255	238	**1891.2**	**1888.6**	**-0.1**	**1883.3**	**-0.4**
92	164	256	238	**1895.5**	**1893.3**	**-0.1**	**1887.7**	**-0.4**
92	165	257	238	**1899.8**	**1896.5**	**-0.2**	**1890.6**	**-0.5**
92	166	258	238	**1904.0**	**1900.9**	**-0.2**	**1894.8**	**-0.5**
92	167	259	238	**1908.1**	**1903.9**	**-0.2**	**1897.5**	**-0.6**
92	168	260	238	**1912.0**	**1908.2**	**-0.2**	**1901.5**	**-0.6**
92	169	261	238	**1915.9**	**1911.0**	**-0.3**	**1904.0**	**-0.6**
92	170	262	238	**1919.7**	**1915.1**	**-0.2**	**1907.8**	**-0.6**
92	171	263	238	**1923.4**	**1917.7**	**-0.3**	**1910.1**	**-0.7**
92	172	264	238	**1927.0**	**1921.7**	**-0.3**	**1913.7**	**-0.7**

92	173	265	238	**1930.5**	**1924.1**	**-0.3**	**1915.8**	**-0.8**
92	174	266	238	**1933.9**	**1927.9**	**-0.3**	**1919.2**	**-0.8**
92	175	267	238	**1937.1**	**1930.2**	**-0.4**	**1921.2**	**-0.8**
92	176	268	238	**1940.3**	**1933.7**	**-0.3**	**1924.4**	**-0.8**
92	177	269	238	**1943.4**	**1935.9**	**-0.4**	**1926.2**	**-0.9**
92	178	270	238	**1946.4**	**1939.3**	**-0.4**	**1929.3**	**-0.9**
92	179	271	238	**1949.3**	**1941.2**	**-0.4**	**1930.9**	**-1.0**
92	180	272	238	**1952.1**	**1944.5**	**-0.4**	**1933.8**	**-0.9**
92	181	273	238	**1954.8**	**1946.3**	**-0.4**	**1935.2**	**-1.0**
92	182	274	238	**1957.4**	**1949.4**	**-0.4**	**1937.9**	**-1.0**
92	183	275	238	**1959.9**	**1951.0**	**-0.5**	**1939.2**	**-1.1**
92	184	276	238	**1962.3**	**1953.9**	**-0.4**	**1941.7**	**-1.1**
92	185	277	238	**1964.6**	**1955.4**	**-0.5**	**1942.8**	**-1.1**
92	186	278	238	**1966.8**	**1958.2**	**-0.4**	**1945.2**	**-1.1**
92	187	279	238	**1969.0**	**1959.6**	**-0.5**	**1946.2**	**-1.2**
92	188	280	238	**1971.0**	**1962.2**	**-0.4**	**1948.4**	**-1.2**
92	189	281	238	**1972.9**	**1963.4**	**-0.5**	**1949.2**	**-1.2**
92	190	282	238	**1974.7**	**1965.9**	**-0.4**	**1951.2**	**-1.2**
92	191	283	238	**1976.4**	**1966.9**	**-0.5**	**1951.8**	**-1.3**
92	192	284	238	**1978.0**	**1969.3**	**-0.4**	**1953.7**	**-1.2**
92	193	285	238	**1979.5**	**1970.2**	**-0.5**	**1954.2**	**-1.3**
92	194	286	238	**1981.0**	**1972.4**	**-0.4**	**1956.0**	**-1.3**
92	195	287	238	**1982.3**	**1973.2**	**-0.5**	**1956.3**	**-1.3**
92	196	288	238	**1983.5**	**1975.2**	**-0.4**	**1957.9**	**-1.3**
92	197	289	238	**1984.6**	**1975.9**	**-0.4**	**1958.1**	**-1.4**
92	198	290	238	**1985.6**	**1977.8**	**-0.4**	**1959.5**	**-1.3**
92	199	291	238	**1986.6**	**1978.3**	**-0.4**	**1959.6**	**-1.4**
92	200	292	238	**1987.4**	**1980.1**	**-0.4**	**1960.9**	**-1.4**
92	201	293	238	**1988.1**	**1980.5**	**-0.4**	**1960.8**	**-1.4**
92	202	294	238	**1988.8**	**1982.2**	**-0.3**	**1962.0**	**-1.4**
92	203	295	238	**1989.3**	**1982.5**	**-0.3**	**1961.8**	**-1.4**
92	204	296	238	**1989.7**	**1984.0**	**-0.3**	**1962.8**	**-1.4**
92	205	297	238	**1990.1**	**1984.1**	**-0.3**	**1962.4**	**-1.4**
92	206	298	238	**1990.3**	**1985.5**	**-0.2**	**1963.3**	**-1.4**
92	207	299	238	**1990.4**	**1985.6**	**-0.2**	**1962.8**	**-1.4**
92	208	300	238	**1990.5**	**1986.9**	**-0.2**	**1963.5**	**-1.4**

92	209	301	238	**1990.4**	**1986.8**	**-0.2**	**1962.9**	**-1.4**
92	210	302	238	**1990.3**	**1987.9**	**-0.1**	**1963.5**	**-1.4**
92	211	303	238	**1990.0**	**1987.7**	**-0.1**	**1962.8**	**-1.4**
92	212	304	238	**1989.6**	**1988.8**	**0.0**	**1963.3**	**-1.3**

11. CONCLUSION

Ghahramany's integrated nuclear binding energy formula can be modified to include strong and electroweak interaction features with a single energy coefficient. Based on relations (5), (6), (7) and (15) and data presented in Table 1 and Table 3, we are very confident to say that, quark structure and electroweak interaction play a vital role in fixing nuclear binding energy and it is absolutely possible to understand nuclear binding energy with one unique energy coefficient. In this context, to explore the ground reality, we appeal the science community to look into these kinds of unified and simplified nuclear binding energy models.

Data Availability statement

Energy coefficients of relations (8), (9) and (10) can be obtained from the following URL's.

1) Relation-8: https://fdocuments.in/document/nuclear-and-particle-physics.html
2) Relation-9: https://en.wikipedia.org/wiki/Semi-empirical_mass_formula
3) Relation-10: http://oregonstate.edu/instruct/ch374/ch418518/lecture3-1.pdf

Acknowledgements

Authors are very much thankful to Dr. N. Ghahramany and team and Dr. K.M. Khanna and team for their intuitive and heuristic contributions in this most advanced field of nuclear research. Author Seshavatharam is indebted to Professors Shri M. Nagaphani Sarma, Chairman, Shri K.V. Krishna Murthy, founder Chairman, Institute of Scientific Research in Vedas (I-SERVE), Hyderabad, India and Shri K.V.R.S. Murthy, former scientist IICT (CSIR), Govt. of India, Director, Research and Development, I-SERVE, for their valuable guidance and great support in developing this subject.

References

[1] Royer G, Subercaze A (2013) Coefficients of different macro-microscopic mass formulae from the AME2012 atomic mass evaluation. *Nuclear Physics A* 917: 1-14

[2] Cht Mavrodiev S, Deliyergiyev MA (2018) Modification of the nuclear landscape in the inverse problem framework using the generalized Bethe-Weizsäcker mass formula. *Int. J. Mod. Phys. E* 27: 1850015

[3] Xia, X. W., Lim, Y., Zhao, P. W., Liang, H. Z., Qu, X. Y., Chen, Y., &Meng, J. (2018) The limits of the nuclear landscape explored by the relativistic continuum Hartree–Bogoliubov theory. *Atomic Data and Nuclear Data Tables*, 121, 1-215.

[4] Möller, P., Sierk, A. J., Ichikawa, T., & Sagawa, H. (2016) Nuclear ground-state masses and deformations: FRDM (2012). *Atomic Data and Nuclear Data Tables*, 109, 1-204.

[5] H. Leutwyler, (2014). On the history of the strong interaction. *Modern Physics Letters A*, 29(24), 1430023

[6] S. Acharya et al. (ALICE Collaboration) (2020). Unveiling the strong interaction among hadrons at the LHC. *Nature* 588, 232-238

[7] G. Rajasekaran (2014). Fermi and the Theory of Weak Interactions. *Resonance (Indian Academy of Sciences, Bangalore)*, 19(1), 18-44.

[8] ATLAS, G. Aad et al. (2012). Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC. *Phys. Lett. B* 716, 1–29

[9] M. T. Gericke et al. (2020). First Precision Measurement of the Parity Violating Asymmetry in Cold Neutron Capture on 3 He. *Phys. Rev. Lett.* 125, 131803.

[10] P. A. Zyla et al. (Particle Data Group), Review of particle physics. *Progress of Theoretical and Experimental Physics*, Volume 2020, Issue 8, August 2020, 083C01, https://doi.org/10.1093/ptep/ptaa104

[11] Tarasov, O.V. Anomalous Dimensions of Quark Masses in the Three-Loop Approximation. *Phys. Part. Nuclei Lett.* 17, 109–115 (2020)

[12] N. Ghahramany, H. Sarafraza, E. Yazdankish. (2013). Stability and Mass Parabola in Integrated Nuclear Model. *Universal Journal of Physic.s and Application* 1(1): 18-25

[13] Ghahramany, N, Gharaati, S., & Ghanaatian, M. (2012). New approach to nuclear binding energy in integrated nuclear model. *Journal of Theoretical and Applied Physics*, 6(1), 3

[14] Ghahramany N, Sh Gharaati, Ghanaatian M, Hora H (2011). New scheme of nuclide and nuclear binding energy from quark-like model. *Iranian Journal of Science & Technology* A3: 201-208

[15] N. Ghahramani et al. (2008) Nuclear magic numbers based on a quark like model is compared with the Boltzmann distribution model from nuclear abundance in the universe and low energy nuclear reactions. *Physics Essays*, 21, 3, 200-206.

[16] N. Ghahramany, M. Ghanaatian and M. Hooshmand. (2007) Quark-Gluon Plasma Model and Origin of Magic Numbers. *Iranian Physical Journal*, 1-2, 35-38

[17] Seshavatharam UVS and Lakshminarayana S. (2021). On the Combined Role of Strong and Electroweak Interactions in Understanding Nuclear Binding Energy Scheme. *Mapana Journal of Sciences*, 20(1), 1-18.

[18] Seshavatharam UVS, Lakshminarayana S (2019). On The Role of Nuclear Quantum Gravity In Understanding Nuclear Stability Range of Z = 2 to 118. *J. Nucl. Phys. Mat. Sci. Rad.* A 7(1): 43–51

[19] Sirma, K. K., Chelimo, L. S., & Khanna, K. M. (2020). A modified Nuclear Model for Binding Energy of Nuclei. *World Scientific News* 143, 203-223

[20] Hezekiah K. Cherop and Kapil M. Khanna. (2020). Modified Integrated Nuclear Model for the Binding Energy of Finite Nuclei. *World Scientific News* 149, 36-51

[21] Esra Yüksel, Derya Soydaner (2021). Hüseyin Bahtiyar. Nuclear binding energy predictions using neural networks: Application of the multilayer perceptron. *International Journal of Modern Physics E,* 30(3), 2150017

[22] Sonia Bacca. (2016). Structure models: from shell model to ab initio methods. *Eur. Phys. J Plus* 131, 107

[23] Coraggio L, Pastore S and Barbieri C, (2021). Editorial: The Future of Nuclear Structure: Challenges and Opportunities in the Microscopic Description of Nuclei. *Front. Phys*. 8: 626976

[24] Léo Neufcourt et al. (2020). Beyond the proton drip line: Bayesian analysis of proton-emitting nuclei. *Phys. Rev. C* 101, 014319

[25] G. Colò. (2000). Nuclear density functional theory. *Advances in Physics*: X, 5(1), 1740061

[26] Koji Hashimoto and Yoshinori Matsuo. (2021). Nuclear binding energy in holographic QCD. *Phys. Rev. D* 104, 026006