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Understanding Super Heavy Mass Numbers and Maximum Binding Energy of Any Mass Number with Revised Strong and Electroweak Mass Formula

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Abstract: In our recent publications, based on strong and electroweak interactions, we have developed a completely new formula for estimating nuclear binding energy. With reference to currently believed Semi Empirical Mass Formula (SEMF), we call our formula as 'Strong and Electroweak Mass Formula' (SEWMF). Our formula constitutes 4 simple terms and only one energy coefficient of magnitude 10.1 MeV. First term is a volume term, second term seems to be a representation of free nucleons associated with electroweak interaction, third term is a radial term and fourth one is an asymmetry term about the mean stable mass number. In this paper, we make an attempt to understand and estimate the maximum binding energy associated with any mass number. It can be expressed as, for A > 4, $(BE)_A \cong \left\{A - 0.000935A^2 - A^{1/3} - A^{-1/2}\right\}10.1\text{ MeV}$. We are working on refining the 4th term with even-odd corrections, shell corrections and other microscopic corrections. Proceeding further, stable mass numbers and super heavy mass numbers can be understood with a relation of the form, $A_s \cong \text{RoundOff}\left\{(Z+2.9464)^{1.2} - 1.7165\right\} + [0,1] \pm 2n$ where $n \cong 0,1,2$. It needs a review with respect to even-odd proton numbers and other microscopic corrections.

Keywords: Semi Empirical Mass Formula (SEMF); Strong and Electroweak Mass Formula (SEWMF); free nucleons; light house like stable mass number; super heavy mass numbers; maximum binding energy of any mass number

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1. Introduction

Based on 4G model of final unification, in our recent publications [1–10], we have clearly shown that, strong and weak interactions, play a vital role in basic nuclear structure. With our strong and electroweak mass formula, nuclear binding energy can be estimated with one unified energy coefficient having 4 simple terms. In this paper, considering our contribution pertaining to DAE-BRNS 2023 symposium proceedings [1] and recent journal publication [2], we make a minor change for understanding the maximum binding energy associated with any mass number. It can be refined with further study.

2. Three Assumptions of 4G Model of Final Unification

Following our 4G model of final unification [1–10]

1. There exists a characteristic electroweak fermion of rest energy, $M_{wf}c^2 \cong 584.725\text{ GeV}$. It can be considered as the zygote of all elementary particles.
2. There exists a nuclear elementary charge in such a way that, $\left(\frac{e}{e_n}\right)^2 \cong \alpha_s \cong 0.1152$ = Strong coupling constant [11] and $e_n \cong 2.9464e$.

3. Each atomic interaction is associated with a characteristic large gravitational coupling constant. Their fitted magnitudes are,

$$G_e \cong \text{Electromgnetic gravitational constant} \cong 2.374335\times10^{37}\ \text{m}^3\text{kg}^{-1}\text{sec}^{-2}$$

$$G_n \cong \text{Nuclear gravitational constant} \cong 3.329561\times10^{28}\text{m}^3\text{kg}^{-1}\text{sec}^{-2}$$

$$G_w \cong \text{Electroweak gravitational constant} \cong 2.909745\times10^{22}\ \text{m}^3\text{kg}^{-1}\text{sec}^{-2}$$

It may be noted that,

1) Weak interaction point of view, following our assumptions, Fermi's weak coupling constant [11] can be fitted with the following relations.

$$\left.\begin{aligned} & G_F \cong \left(\frac{m_e}{m_p}\right)^2 \hbar c R_0^2 \cong G_w M_{wf}^2 R_w^2 \ \cong 1.44021\times10^{-62}\ \text{J.m}^3 \\ & \text{where, } \left\{\begin{aligned} R_0 &\cong \frac{2G_n m_p}{c^2} \cong 1.24\ \times10^{-15}\ \text{m} \\ R_w &\cong \frac{2G_w M_{wf}}{c^2} \cong 6.75\times10^{-19}\ \text{m} \end{aligned}\right. \end{aligned}\right\} \tag{1}$$

2) In a unified approach, most important point to be noted is that, $\hbar c \equiv G_w M_{wf}^2$. Clearly speaking, based on the electroweak interaction, the well believed quantum constant $\hbar c$ seems to have a deep inner meaning [10]. It needs further study with respect to condensed matter physics.

3. Free Nucleons and Electroweak Term

With reference to our strong and electroweak mass formula [1–10],

1) Nuclear volume can be split into 'core inner' and 'core outer'.
2) Nucleons residing in nuclear inner core help in increasing nuclear binding energy.
3) Nucleons residing in outer core will not involve in nuclear binding.
4) Outer core nucleons can be called as free or electroweak nucleons.
5) Proportionality coefficient being $\dfrac{m_p}{M_{wf}} \cong \dfrac{938.272\ \text{MeV}}{584725\ \text{MeV}} \cong 0.001605,$ free nucleon number is proportional to half of the sum of squared proton number and squared mass number.
6) Considering light and heavy atomic nuclides, by considering a correction factor $\left[2-\left(\frac{N}{Z}\right)\right]$, in our recent publications, we expressed our first approximate relation for free nucleon number as,

$$A_{free} \cong \left[2-\left(\frac{N}{Z}\right)\right]+\left[0.0016\left(\frac{Z^2+A^2}{2}\right)\right] \cong \left[2-\left(\frac{N}{Z}\right)\right]+\left[0.0008\left(Z^2+A^2\right)\right].$$

4. Nuclear Radius and Radial Term

1) Interesting observation is that, nuclear binding energy seems to decrease with increasing radius.

2) As nuclear volume is proportional the mass number, it is possible to understand the decreasing nuclear binding energy with cube root of the mass number $A_{rad} \cong A^{1/3}$.

5. Stable Mass Number and Asymmetry Term

1) Even though it is not exact stable mass number, we understood that, the ratio of nuclear charge and elementary charge and electroweak interaction seem to play a crucial role in understanding and estimating the approximate stable mass number of any atomic nuclide having a proton number Z. This is one best practical application of our proposed nuclear charge and electroweak fermion.
2) Stable mass number seems to play a crucial role in estimating the binding energy of other isotopes of Z.
3) Our estimated mass number close to stability can be called as 'light house (like) mass number' where one can find the beginning of relatively long living isotopes of Z.
4) Keeping light and heavy atomic nuclides in view, we suggest a common and simple relation of the form [2,6],

$$A_s \cong \text{RoundOff}\left\{\left(Z+\left(\frac{e_n}{e}\right)\right)^{1.2}-\sqrt{\frac{e_n}{e}}\right\} \cong \text{RoundOff}\left\{(Z+2.9464)^{1.2}-1.7165\right\}$$

$$\text{where } \left(\frac{e_n}{e}\right)^{\frac{1}{6}} \cong \left(\frac{1}{\alpha_s}\right)^{\frac{1}{12}} \cong 1.19733 \cong 1.2$$

(2A)

It may be noted that, right selection of stable mass number greatly helps in minimizing the error in estimating nuclear binding energy. Especially, for light atomic nuclides, whose stable mass number is very close to 2Z, estimated binding energy seems to be on lower side compared to actual binding energy. Hence, it seems better to select stable mass number of Z based on their relative time of living. Considering even-odd corrections, above relation can be refined for a better understanding in the following way. It can be reviewed in a better way with further study.

1) If Z is even and obtained A_s is odd, then, $A_s \cong A_s + 1$.
2) If Z is even and obtained A_s is even, then, $A_s \cong A_s$.
3) If Z is odd and obtained A_s is odd, then, $A_s \cong A_s$.
4) If Z is odd and obtained A_s is even, then, $A_s \cong A_s + 1$.

See Table 1 for a better understanding.

$$A_s \cong \text{RoundOff}\left\{(Z+2.9464)^{1.2}-1.7165\right\}+\text{EO correction} \cong [0,1] \qquad \text{(2B)}$$

Following this relation, for odd elements, their best possible three mass numbers can be expressed as,

$$A_s \cong \left[\text{RoundOff}\left\{(Z+2.9464)^{1.2}-1.7165\right\}+[0,1]\right]+2n$$
$$\text{where } n = 0,1,2$$

(2C)

Following this relation, odd proton super heavy elements can be estimated with a possible certainty. In the following Table 1. By adding 0, 2 and 4 to the even-odd corrected mass number, odd proton's 3 stable mass numbers can be estimated. Estimated mass numbers corresponding to $n = 0,1,2$ can be called as, Ground level, 1st level and 2nd level mass numbers. For Z=99, possible super heavy mass numbers are 255, 257 and 259. Similarly, for Z=101, possible super heavy mass numbers are 261, 263 and 265. In this way, for super heavy elements, possible mass numbers having longer life time compared to their lower mass numbers can be estimated with a common concept. We are working on the possibility of considering $(-2n)$ for increasing the estimated range of heavy mass numbers on lower side [12–15]. If so, for Z=99, best possible mass range can be given as, 251 to 259. For Z=101, best possible mass range seems to be 257 to 265. Thus, relation (2C) can be expressed as,

$$A_s \cong \left[\text{RoundOff}\left\{ (Z+2.9464)^{1.2} - 1.7165 \right\} + [0,1] \right] \pm 2n \tag{2D}$$

$$\text{where } n = 0,1,2$$

Thus, for the heaviest Z=117, its possible long living mass range can be given as, 307 to 315. It needs further study.

Table 1. Estimated light house like stable mass numbers of Z=5 to118.

Proton number	Estimated stable mass number	Estimated mass number with EO corrections	Proton number	Estimated stable mass number	Estimated mass number with EO corrections	Proton number	Estimated stable mass number	Estimated mass number with EO corrections
5	10	11	43	97	97	81	202	203
6	12	12	44	100	100	82	205	206
7	14	15	45	102	103	83	208	209
8	16	16	46	105	106	84	211	212
9	18	19	47	107	107	85	214	215
10	20	20	48	110	110	86	217	218
11	22	23	49	113	113	87	219	219
12	24	24	50	115	116	88	222	222
13	26	27	51	118	119	89	225	225
14	28	28	52	121	122	90	228	228
15	30	31	53	123	123	91	231	231
16	32	32	54	126	126	92	234	234
17	35	35	55	129	129	93	237	237
18	37	38	56	131	132	94	240	240
19	39	39	57	134	135	95	243	243
20	41	42	58	137	138	96	246	246
21	43	43	59	140	141	97	249	249
22	46	46	60	142	142	98	252	252
23	48	49	61	145	145	99	255	255
24	50	50	62	148	148	100	258	258
25	53	53	63	151	151	101	261	261
26	55	56	64	153	154	102	264	264
27	57	57	65	156	157	103	268	269
28	60	60	66	159	160	104	271	272
29	62	63	67	162	163	105	274	275
30	65	66	68	165	166	106	277	278
31	67	67	69	167	167	107	280	281

32	69	70	70	170	170	108	283	284
33	72	73	71	173	173	109	286	287
34	74	74	72	176	176	110	289	290
35	77	77	73	179	179	111	292	293
36	79	80	74	182	182	112	295	296
37	82	83	75	185	185	113	298	299
38	84	84	76	187	188	114	301	302
39	87	87	77	190	191	115	304	305
40	89	90	78	193	194	116	308	308
41	92	93	79	196	197	117	311	311
42	94	94	80	199	200	118	314	314

5) Number 0.0016 plays a very interesting role in estimating the free nucleon number as,

$$
\begin{aligned}
A_{free} &\cong \left[2-\left(\frac{N}{Z}\right)\right]+0.0016\left[\left(Z^2+N^2+\left(\frac{Z^2}{N}\right)^2\right)-ZN\left(\frac{N-Z}{N+Z}\right)^2\right] \\
&\cong \left[2-\left(\frac{N}{Z}\right)\right]+0.0016\left[\left(Z^2+N^2+\left(\frac{Z^2}{N}\right)^2\right)-ZN\left(\frac{A-2Z}{A}\right)^2\right]
\end{aligned}
\qquad (3)
$$

where $\left[2-\left(\frac{N}{Z}\right)\right]$ is a correction factor that needs a review.

6) Here, very interesting point to be noted is that, the number 0.0016 can also be understood as a ratio of the mean mass of pions to the mean mass of electroweak bosons. It can be expreessed as,

$$
\frac{m_p}{M_{wf}} \cong \left(\frac{\sqrt{\left(m_\pi c^2\right)^0\left(m_\pi c^2\right)^\pm}}{\sqrt{\left(m_z c^2\right)^0\left(m_w c^2\right)^\pm}}\right) \cong \left(\frac{\sqrt{134.98\times139.57}\ \text{MeV}}{\sqrt{80379.0\times91187.6}\ \text{MeV}}\right) \cong 0.0016032 \qquad (4)
$$

7) Independent of proton number, approximate asymmetry term can be expressed as,

$$
A_{asym} \cong \frac{\left(A_s-A\right)^2}{A_s} \qquad (5)
$$

It may be noted that, even though it is an approximate relation, it greatly helps in estimating the binding energy of isotopes for the entire range of atomic nuclides. It seems essential to work on this kind of relations.

8) For medium and heavy proton numbers and their isotopes, equality of excess neutron number and free nucleon number can be considered as an index of possible stability. It needs a review at fundamental level.

6. Unique Binding Energy Coefficient

We would like to emphasize the point that, nuclear binding energy can be understood with only one fixed energy coefficient. It can be understood in two different ways as expressed in following way.

Considering Up and Down quark masses [11],

$$B_0 \cong \frac{1}{2}\left[\left(2m_u c^2 + m_d c^2\right) + \left(m_u c^2 + 2m_d c^2\right)\right]$$
$$\cong \frac{3}{2}\left(m_u c^2 + m_d c^2\right) \cong 10.1 \text{ MeV (Our fit)} \tag{6}$$
$$\text{where } \begin{cases} m_u \cong 2.16^{+0.49}_{-0.26} \text{ MeV}/c^2 \\ m_d \cong 4.67^{+0.48}_{-0.17} \text{ MeV}/c^2 \end{cases}$$

Considering strong coupling constant and reduced Compton wavelength of proton,

$$B_0 \cong -\left(\frac{1}{\sqrt{\alpha_s}}\right)\frac{e^2}{8\pi\varepsilon_0\left(\hbar/m_p c\right)} \cong -\frac{e_n^2}{8\pi\varepsilon_0\left(G_n m_p/c^2\right)} \cong -10.1 \text{ MeV}$$
$$\text{where} \begin{cases} \alpha_s = \text{Strong coupling constant} \cong 0.115 \text{ to } 0.12 \\ \hbar/m_p c = \text{Reduced Comption wavelength of proton} \\ G_n m_p/c^2 \cong 0.62\times 10^{-15}\,\text{m} \end{cases} \tag{7A}$$

Considering B_0 as a form of total energy, it is possible to define its corresponding potential energy as,

$$E_{pot} \cong -\frac{e_n^2}{4\pi\varepsilon_0\left(G_n m_p/c^2\right)} \cong -20.2 \text{ MeV} \tag{7B}$$

Using this energy unit, various energy coefficients of the currently beloved semi empirical mass can be fitted.

7. Revised and Reference Formulae for Nuclear Binding Energy

The most famous and most advanced SEMF that follows isospin concept can be expressed as [16–20],

$$BE \cong \left\{\begin{array}{l} \left\{\left[1+\left(\frac{4k_v}{A^2}\right)|T_z|\left(|T_z|+1\right)\right]a_v * A\right\} \\ +\left\{\left[1+\left(\frac{4k_s}{A^2}\right)|T_z|\left(|T_z|+1\right)\right]a_s * A^{\frac{2}{3}}\right\} \\ +\left\{a_c * \left(\frac{Z^2}{A^{1/3}}\right)\right\} + \left\{f_p * \frac{Z^2}{A}\right\} + E_p \end{array}\right\} \tag{8}$$

where, $T_z \cong \text{3rd component of isospin} = \frac{1}{2}\left(Z-N\right)$

$$\left\{\begin{array}{l}
a_v = -15.4963 \text{ MeV} \cong -20.2\left(1-2\alpha_s\right) \cong -15.546 \text{ MeV} \\
a_s = 17.7937 \cong -20.2\left(1-\alpha_s\right) \cong -17.873 \text{ MeV} \quad \text{MeV} \\
k_v = -1.8232 \cong -\left[2-\left[\dfrac{\left(1+\alpha_s\right)}{\left(1-\alpha_s\right)}\right]^2 \alpha_s\right] \cong -\left(2-0.183\right) \cong -1.817 \\
k_s = -2.2593 \cong -\left[2+\left[\dfrac{\left(1+\alpha_s\right)}{\left(1-\alpha_s\right)}\right]^2 \alpha_s\right] \cong -\left(2+0.183\right) \cong -2.183 \\
a_c = 0.7093 \cong 0.71 \text{ MeV} \\
f_p = -1.2739 \text{ MeV} \cong -\dfrac{20.2\alpha_s}{2} \cong -1.1635 \text{ MeV} \\
\left.\begin{array}{l} d_n = 4.6919 \quad \text{MeV}, d_p = 4.7230 \quad \text{MeV} \\ d_n \cong d_p \cong 2 * 20.2\alpha_s \cong \; 4.6541 \text{ MeV} \end{array}\right\} \\
d_{np} = -6.4920 \text{ MeV} \cong -3 * 20.2\alpha_s \cong -6.981 \text{ MeV}
\end{array}\right\}$$

$$\text{and} \left\{\begin{array}{l}
\text{for } \left(Z, N\right) \text{ Odd, } E_p \cong \dfrac{d_n}{N^{1/3}} + \dfrac{d_p}{Z^{1/3}} + \dfrac{d_{np}}{A^{2/3}} \\
\text{for } \left(\text{Odd } Z, \text{ Even } N\right), E_p \cong \dfrac{d_p}{Z^{1/3}} \\
\text{for } \left(\text{Even } Z, \text{ Odd } N\right), E_p \cong \dfrac{d_n}{N^{1/3}} \\
\text{for } \left(\text{Even } Z, \text{ Even } N\right), \; E_p \cong 0
\end{array}\right\}$$

For Z=6 to 118, including the correction factor $\left[2-\left(\dfrac{N}{Z}\right)\right]$, we express our revised binding energy relation as,

$$BE \cong \left\{A - \left\{\left[2-\left(\frac{N}{Z}\right)\right] + 0.0016\left[\left(Z^2+N^2+\left(\frac{Z^2}{N}\right)^2\right) - ZN\left(\frac{N-Z}{N+Z}\right)^2\right]\right\} - A^{1/3} - \frac{\left(A_s-A\right)^2}{A_s}\right\} 10.1 \text{ MeV} \tag{9}$$

Based on this relation, in a trial-error approach, we have developed another relation for estimating the maximum binding energy associated with any mass number. Very interesting point is that, it is independent of proton number. It can be expressed as [1,2],

$$\begin{aligned} BE &\cong \left\{A - \left(\sqrt{\frac{e}{e_n}}\right) 0.001605A^2 - A^{1/3} - A^{-1/2}\right\} 10.1 \text{ MeV} \\ &\cong \left\{A - 0.000935A^2 - A^{1/3} - A^{-1/2}\right\} 10.1 \text{ MeV} \end{aligned} \tag{10}$$

Close to the maximum binding energy of any mass number, number of free nucleons can be expressed as, $A_{free} \cong 0.000935A^2$.

Considering isobars and finding the maximum binding energy associated with each mass number, above relation can be verified. See the following Table 2 and Figure 1. Our proposal is failing for A=4, A= 202 to 212 and A >267. It needs a review with respect to shell effects and other microscopic corrections.

Table 2. Estimated maximum binding energy of any mass number.

Assumed mass number A	Estimated Max. Binding energy of A (MeV)	Experimental Max. Binding energy of A (MeV)	(Experimental - Estimated) Binding energy (MeV)
4	19.17	28.3	9.13
5	28.48	27.56	-0.92
6	37.78	31.99	-5.79
7	47.10	39.25	-7.85
8	56.42	56.5	0.08
9	65.76	58.16	-7.60
10	75.10	64.98	-10.12
11	84.45	76.2	-8.25
12	93.80	92.16	-1.64
13	103.15	97.11	-6.04
14	112.51	105.28	-7.23
15	121.86	115.49	-6.37
16	131.21	127.62	-3.59
17	140.55	131.76	-8.79
18	149.89	139.81	-10.08
19	159.22	147.8	-11.42
20	168.55	160.64	-7.91
21	177.87	167.41	-10.46
22	187.18	177.77	-9.41
23	196.48	186.56	-9.92
24	205.77	198.26	-7.51
25	215.05	205.59	-9.46
26	224.31	216.68	-7.63
27	233.57	224.95	-8.62
28	242.82	236.54	-6.28
29	252.05	245.01	-7.04
30	261.27	255.62	-5.65
31	270.48	262.92	-7.56
32	279.68	271.78	-7.90
33	288.86	280.96	-7.90
34	298.03	291.84	-6.19
35	307.19	298.82	-8.37
36	316.33	308.71	-7.62
37	325.46	317.1	-8.36

38	334.57	327.34	-7.23
39	343.67	333.94	-9.73
40	352.75	343.81	-8.94
41	361.82	351.62	-10.20
42	370.88	361.9	-8.98
43	379.91	369.83	-10.08
44	388.94	380.96	-7.98
45	397.95	388.37	-9.58
46	406.94	398.77	-8.17
47	415.92	407.26	-8.66
48	424.88	418.7	-6.18
49	433.82	426.85	-6.97
50	442.75	437.78	-4.97
51	451.67	445.85	-5.82
52	460.57	456.35	-4.22
53	469.45	464.29	-5.16
54	478.31	474.01	-4.30
55	487.16	482.08	-5.08
56	495.99	492.26	-3.73
57	504.81	499.91	-4.90
58	513.61	509.95	-3.66
59	522.39	517.31	-5.08
60	531.16	526.85	-4.31
61	539.91	534.67	-5.24
62	548.64	545.26	-3.38
63	557.36	552.1	-5.26
64	566.06	561.76	-4.30
65	574.74	569.21	-5.53
66	583.40	578.14	-5.26
67	592.05	585.41	-6.64
68	600.68	595.39	-5.29
69	609.30	602	-7.30
70	617.89	611.09	-6.80
71	626.47	618.95	-7.52
72	635.04	628.69	-6.35
73	643.58	635.47	-8.11
74	652.11	645.66	-6.45
75	660.62	652.57	-8.05
76	669.11	662.07	-7.04
77	677.59	669.59	-8.00
78	686.05	679.99	-6.06
79	694.49	686.95	-7.54
80	702.91	696.87	-6.04

81	711.32	704.37	-6.95
82	719.71	714.27	-5.44
83	728.08	721.74	-6.34
84	736.43	732.27	-4.16
85	744.77	739.38	-5.39
86	753.09	749.23	-3.86
87	761.39	757.86	-3.53
88	769.67	768.47	-1.20
89	777.93	775.54	-2.39
90	786.18	783.9	-2.28
91	794.41	791.09	-3.32
92	802.62	799.73	-2.89
93	810.82	806.46	-4.36
94	818.99	814.68	-4.31
95	827.15	821.63	-5.52
96	835.29	830.78	-4.51
97	843.41	837.6	-5.81
98	851.52	846.25	-5.27
99	859.61	852.75	-6.86
100	867.67	861.93	-5.74
101	875.73	868.73	-7.00
102	883.76	877.95	-5.81
103	891.77	884.19	-7.58
104	899.77	893.09	-6.68
105	907.75	900.13	-7.62
106	915.71	909.48	-6.23
107	923.66	916.02	-7.64
108	931.58	925.24	-6.34
109	939.49	931.72	-7.77
110	947.38	940.64	-6.74
111	955.25	947.62	-7.63
112	963.10	957.01	-6.09
113	970.94	963.55	-7.39
114	978.75	972.59	-6.16
115	986.55	979.4	-7.15
116	994.33	988.68	-5.65
117	1002.10	995.62	-6.48
118	1009.84	1004.95	-4.89
119	1017.57	1011.43	-6.14
120	1025.27	1020.54	-4.73
121	1032.96	1026.71	-6.25
122	1040.64	1035.52	-5.12
123	1048.29	1042.1	-6.19

124	1055.92	1050.69	-5.23
125	1063.54	1057.27	-6.27
126	1071.14	1066.37	-4.77
127	1078.72	1072.66	-6.06
128	1086.28	1081.44	-4.84
129	1093.83	1088.24	-5.59
130	1101.35	1096.91	-4.44
131	1108.86	1103.51	-5.35
132	1116.35	1112.45	-3.90
133	1123.82	1118.88	-4.94
134	1131.28	1127.43	-3.85
135	1138.71	1134.18	-4.53
136	1146.13	1142.77	-3.36
137	1153.53	1149.68	-3.85
138	1160.90	1158.29	-2.61
139	1168.27	1164.55	-3.72
140	1175.61	1172.69	-2.92
141	1182.93	1178.12	-4.81
142	1190.24	1185.28	-4.96
143	1197.53	1191.26	-6.27
144	1204.80	1199.08	-5.72
145	1212.05	1204.83	-7.22
146	1219.28	1212.4	-6.88
147	1226.50	1217.8	-8.70
148	1233.69	1225.39	-8.30
149	1240.87	1231.26	-9.61
150	1248.03	1239.24	-8.79
151	1255.17	1244.84	-10.33
152	1262.30	1253.1	-9.20
153	1269.40	1258.99	-10.41
154	1276.49	1266.93	-9.56
155	1283.55	1273.58	-9.97
156	1290.60	1281.59	-9.01
157	1297.63	1287.95	-9.68
158	1304.65	1295.89	-8.76
159	1311.64	1302.02	-9.62
160	1318.62	1309.45	-9.17
161	1325.57	1316.09	-9.48
162	1332.51	1324.1	-8.41
163	1339.43	1330.37	-9.06
164	1346.33	1338.03	-8.30
165	1353.22	1344.25	-8.97
166	1360.08	1351.56	-8.52

167	1366.93	1358	-8.93
168	1373.76	1365.77	-7.99
169	1380.57	1371.78	-8.79
170	1387.36	1379.03	-8.33
171	1394.13	1385.42	-8.71
172	1400.88	1392.76	-8.12
173	1407.62	1399.13	-8.49
174	1414.34	1406.59	-7.75
175	1421.04	1412.41	-8.63
176	1427.72	1419.28	-8.44
177	1434.38	1425.46	-8.92
178	1441.02	1432.8	-8.22
179	1447.64	1438.9	-8.74
180	1454.25	1446.29	-7.96
181	1460.84	1452.24	-8.60
182	1467.41	1459.33	-8.08
183	1473.96	1465.52	-8.44
184	1480.49	1472.94	-7.55
185	1487.00	1478.69	-8.31
186	1493.50	1485.88	-7.62
187	1499.98	1491.88	-8.10
188	1506.43	1499.09	-7.34
189	1512.87	1505.01	-7.86
190	1519.29	1512.8	-6.49
191	1525.70	1518.56	-7.14
192	1532.08	1526.12	-5.96
193	1538.44	1532.06	-6.38
194	1544.79	1539.58	-5.21
195	1551.12	1545.68	-5.44
196	1557.43	1553.6	-3.83
197	1563.72	1559.45	-4.27
198	1569.99	1567	-2.99
199	1576.25	1573.48	-2.77
200	1582.48	1581.18	-1.30
201	1588.70	1587.41	-1.29
202	1594.90	1595.16	0.26
203	1601.07	1601.16	0.09
204	1607.24	1608.65	1.41
205	1613.38	1615.07	1.69
206	1619.50	1622.32	2.82
207	1625.61	1629.06	3.45
208	1631.69	1636.43	4.74
209	1637.76	1640.37	2.61

210	1643.81	1645.55	1.74
211	1649.84	1649.97	0.13
212	1655.85	1655.77	-0.08
213	1661.85	1660.13	-1.72
214	1667.82	1666.01	-1.81
215	1673.78	1670.16	-3.62
216	1679.72	1675.9	-3.82
217	1685.64	1680.58	-5.06
218	1691.54	1687.05	-4.49
219	1697.42	1691.51	-5.91
220	1703.28	1697.79	-5.49
221	1709.13	1702.42	-6.71
222	1714.95	1708.66	-6.29
223	1720.76	1713.82	-6.94
224	1726.55	1720.3	-6.25
225	1732.32	1725.21	-7.11
226	1738.07	1731.6	-6.47
227	1743.80	1736.71	-7.09
228	1749.52	1743.08	-6.44
229	1755.21	1748.33	-6.88
230	1760.89	1755.13	-5.76
231	1766.55	1760.25	-6.30
232	1772.19	1766.69	-5.50
233	1777.81	1771.93	-5.88
234	1783.41	1778.57	-4.84
235	1789.00	1783.86	-5.14
236	1794.56	1790.41	-4.15
237	1800.11	1795.53	-4.58
238	1805.64	1801.69	-3.95
239	1811.15	1806.97	-4.18
240	1816.64	1813.45	-3.19
241	1822.11	1818.69	-3.42
242	1827.56	1825	-2.56
243	1833.00	1830.03	-2.97
244	1838.41	1836.05	-2.36
245	1843.81	1841.36	-2.45
246	1849.19	1847.82	-1.37
247	1854.55	1852.98	-1.57
248	1859.89	1859.19	-0.70
249	1865.21	1864.02	-1.19
250	1870.52	1869.99	-0.53
251	1875.80	1875.09	-0.71
252	1881.07	1881.27	0.20

253	1886.32	1886.07	-0.25
254	1891.55	1892.1	0.55
255	1896.76	1896.64	-0.12
256	1901.95	1902.54	0.59
257	1907.12	1907.5	0.38
258	1912.28	1911.69	-0.59
259	1917.41	1906.33	-11.08
260	1922.53	1909.07	-13.46
261	1927.63	1923.93	-3.70
262	1932.71	1923.39	-9.32
263	1937.77	1929.63	-8.14
264	1942.81	1937.23	-5.58
265	1947.84	1943.25	-4.59
266	1952.84	1950.31	-2.53
267	1957.83	1956.31	-1.52
268	1962.80	1963.37	0.57
269	1967.74	1968.54	0.80
270	1972.67	1974.78	2.11
271	1977.59	1979.66	2.07
272	1982.48	1985.87	3.39
273	1987.35	1990.44	3.09
274	1992.21	1994.17	1.96
275	1997.05	2000.08	3.03
276	2001.86	2004.86	3.00
277	2006.66	2009.64	2.98
278	2011.44	2013	1.56
279	2016.21	2019.4	3.19
280	2020.95	2023.56	2.61
281	2025.68	2028.82	3.14
282	2030.38	2031.81	1.43
283	2035.07	2038.45	3.38
284	2039.74	2042.53	2.79
285	2044.39	2047.73	3.34
286	2049.02	2050.33	1.31
287	2053.63	2057.22	3.59
288	2058.22	2060.64	2.42
289	2062.80	2066.06	3.26
290	2067.36	2068.28	0.92
291	2071.89	2075.12	3.23
292	2076.41	2078.16	1.75
293	2080.91	2083.52	2.61
294	2085.39	2085.34	-0.05
295	2089.86		

296	2094.30
297	2098.73
298	2103.13
299	2107.52
300	2111.89
301	2116.24
302	2120.57
303	2124.88
304	2129.18
305	2133.45
306	2137.71
307	2141.95
308	2146.17
309	2150.37
310	2154.55
311	2158.71
312	2162.86
313	2166.98
314	2171.09
315	2175.18
316	2179.25
317	2183.30
318	2187.33
319	2191.34
320	2195.34
321	2199.31
322	2203.27
323	2207.21
324	2211.13
325	2215.03
326	2218.91
327	2222.77
328	2226.62
329	2230.44
330	2234.25
331	2238.04
332	2241.81
333	2245.56
334	2249.29
335	2253.01
336	2256.70
337	2260.38
338	2264.03

339	2267.67
340	2271.29

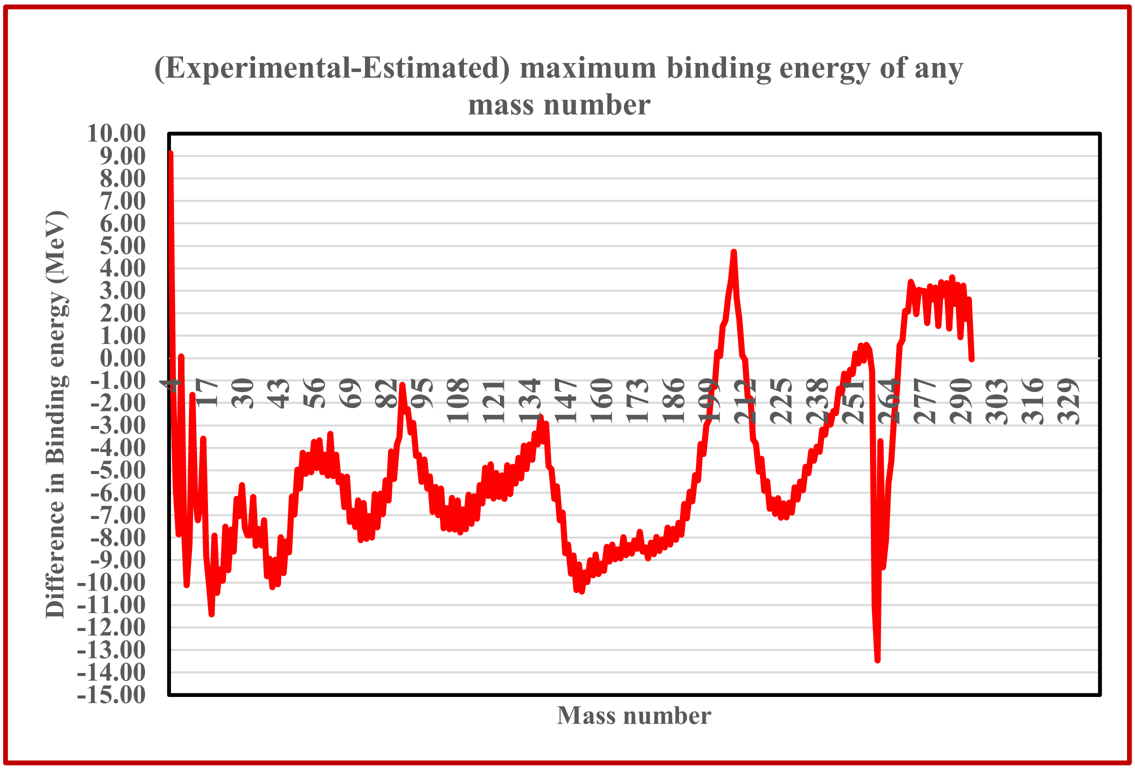

Figure 1. Difference of experimental and estimated maximum binding energy of A.

8. Discussion

1) Even though they are having wide scope and very accurate, currently believed semi empirical mass formulae are having many complicated energy coefficients with different terms and different concepts [16–20]. We would like to emphasize the point that, clarity is missing in coupling or interpreting the terms and coefficients with strong and weak interactions. Similarly, energy coefficients associated with recently developed relativistic continuum Hartree-Bogoliubov (RCHB) theory having relativistic density functions are much more complicated [18].
2) Conceptually, relations (9) and (10) are very simple in understanding and having deep inner meaning. Relation (9) can be expressed as,

$$\left(BE\right)_{(Z,A)} \cong \left(A - A_{free} - A_{rad} - A_{asy}\right) 10.1 \text{ MeV} \tag{11}$$

3) Relation (10) can be expressed as,

$$\left(BE\right)_{A} \cong \left(A - A_{free} - A_{rad} - A_{x}\right) 10.1 \text{ MeV} \tag{12}$$

where A_x is a term that needs a review.

It needs a review with respect to A=4 and A > 200. We are working in this new direction. With even-odd corrections, shell corrections and other microscopic corrections, it can be refined.

9. Conclusion

We would like to emphasize the point that, strong and weak interactions play a vital role in basic nuclear structure and further study may help in exploring the atomic nucleus in a unified approach. Based on the above concepts and data presented in Table 1, Table 2 and Figure 1, it seems possible to understand super heavy mass numbers and maximum binding energy associated with any mass number with our 4G model of final unification.

References

1. Seshavatharam U.V.S and Lakshminarayana S.A very brief review on strong and electroweak mass formula pertaining to 4G model of final unification. Proceedings of the DAE Symp. on Nucl. Phys. 67,1173,2023.
2. Seshavatharam U.V.S and Lakshminarayana S. Exploring condensed matter physics with refined electroweak term of the strong and electroweak mass formula. World Scientific News .193(2) 105-13, 2024.
3. Seshavatharam U.V.S and Lakshminarayana S. Inferring and confirming the rest mass of electron neutrino with neutron life time and strong coupling constant via 4G model of final unification. World Scientific News 191, 127-156, 2024.
4. Seshavatharam U. V. S., Gunavardhana Naidu T and Lakshminarayana S. 2022. To confirm the existence of heavy weak fermion of rest energy 585 GeV. AIP Conf. Proc. 2451 p 020003
5. Seshavatharam U.V.S and Lakshminarayana S. 4G model of final unification – A brief report Journal of Physics: Conference Series 2197 p 012029, 2022.
6. Seshavatharam U.V.S and Lakshminarayana. Understanding nuclear stability range with 4G model of nuclear charge. World Scientific News. 177, 118-136, 2023.
7. Seshavatharam U.V.S, S. Lakshminarayana, H. K. Cherop and K. M. Khanna, Three Unified Nuclear Binding Energy Formulae. World Scientific News, 163, 30-77, 2022.
8. Seshavatharam U.V.S, Lakshminarayana, S., On the Combined Role of Strong and Electroweak Interactions in Understanding Nuclear Binding Energy Scheme. Mapana Journal of Sciences, 20(1), 1-18, 2021.
9. Seshavatharam U.V.S and Lakshminarayana S., Strong and Weak Interactions in Ghahramany's Integrated Nuclear Binding Energy Formula. World Scientific News, 161, 111-129, 2021.
10. Seshavatharam U.V.S and Lakshminarayana S. Is reduced Planck's constant - an outcome of electroweak gravity? Mapana Journal of Sciences. 19,1,1, 2020.
11. Workman R.L. et al. (Particle Data Group), Prog. Theor. Exp. Phys. 2022, 083C01, 2022.
12. Ghiorso, Albert . Einsteinium and Fermium. Chemical and Engineering News. 81 (36): 174–175, 2003.
13. Kondev, F. G.; Wang, M.; Huang, W. J.; Naimi, S.; Audi, G. The NUBASE2020 evaluation of nuclear properties (PDF). Chinese Physics C. 45 (3): 030001, 2021.
14. Peter Möller. The limits of the nuclear chart set by fission and alpha decay. EPJ Web Conf. 131, 03002, 2016.
15. Oganessian, Yu & Rykaczewski, Krzysztof. (2015). A beachhead on the island of stability. Physics Today. 68. 32-38. 10.1063/PT.3.2880.
16. Myers W. D. and Swiatecki W. J. Nuclear Properties According to the Thomas-Fermi Model.LBL-36557 Rev. UC-413, 1995
17. Myers W. D. and Swiatecki W. J. Table of nuclear masses according to the 1994 Thomas-Fermi model. United States: N. p., 1994. Web.
18. X.W. Xia, Y. Lim, P.W. Zhao et al. The limits of the nuclear landscape explored by the relativistic continuum Hartree–Bogoliubov theory. Atomic Data and Nuclear Data Tables. 121–122, 1-215, 2018.
19. Bethe H. A. Thomas-Fermi Theory of Nuclei. Phys. Rev., 167(4), 879-907, 1968.
20. Gao, Z.P., Wang, YJ., Lü, HL. et al., Machine learning the nuclear mass. NUCL. SCI. TECH. 32, 109, 2021.