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Understanding Nuclear Stability and Binding Energy with Powers of the Strong Coupling Constant

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Abstract

Regarding nuclear stability and binding energy, the relationship between nuclear force and the strong force is still a grey area and is a challenging task for field experts and young scientists. In this context, considering the semi-empirical mass formula as a base and adapting the strong coupling constant as a bridging parameter, an attempt is made to understand nuclear stability and binding energy. It is to be noted that nuclear binding energy can be understood with one energy coefficient and three simple terms. Further, based on the proton number, it's stable or relatively long-living mass number can be estimated directly. Also, considering the mean stable mass number as an input, the binding energy of other stable and unstable nuclides can be estimated.

Keywords: Strong coupling constant, Nuclear stability, Nuclear binding energy

1. Introduction

With reference to nuclear stability and binding energy, the relationship between nuclear force and strong force is still a grey area and is a challenging task for field experts and young scientists

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[1, 2]. It is well established that, Less than 0.8 fm, strong force is mediated by gluons.

1) At a range of 1 to 3 fm, strong force is mediated by mesons.
2) Neutrons, protons, baryons and mesons are made up of quarks.
3) Gluons interact with quarks and other gluons whereas mesons interact with neutrons and protons.
4) Strong force that binds quarks into neutrons and protons can be called a 'residual strong force' or simply 'nuclear force'.
5) Within the quark surroundings, force is strong and distance independent.
6) Nuclear force is weaker and rapidly decreases with increasing distance among nucleons (bound quarks).
7) Even though nuclear force is weaker than the strong force, it is energetic in producing gamma rays and holding nucleons with large binding energy.
8) Strength of strong interaction is parameterized by the strong coupling constant, $\alpha_s \cong 0.1181$ [3].

In this context, considering the semi-empirical mass formula as a base and adapting the strong coupling constant as a bridging parameter, an attempt is made to understand nuclear stability and nuclear binding energy.

2. Two New Coefficients and their Applications

In the earlier publications, in a quantum gravitational approach [4], we have introduced two coefficients pertaining to nuclear stability and binding energy. In this paper, an attempt is made to fit them with powers of the strong coupling constant.

A) Coefficient connected with stability

It was noticed that:

As the proton number increases at the stability zone, the neutron number increases with the square of the proton number.

Proportionality coefficient seems to be close to a number 0.0064 [5,6,7]. Quantitatively it can be fitted with a relation of the form,

$$k \cong (1/2)\left(\alpha_s^2 - \alpha_s^3 + \alpha_s^4 - \alpha_s^5 + ...\right) \cong 0.00625$$
$$\text{where } \alpha_s \cong 0.1181 \tag{1}$$

Based on the coefficient, $k \cong 0.00625$, the neutron number close to the stability zone can be expressed as,

$$\left.\begin{aligned} N_s &\cong Z + kZ^2 \\ N_s - Z &\cong kZ^2 \end{aligned}\right\} \tag{2}$$

where, Z = Proton number

N_s = Neutron number close to stability

In terms of nucleon number,

$$\left.\begin{aligned} A_s &\cong 2Z + kZ^2 \\ A_s - 2Z &\cong kZ^2 \end{aligned}\right\} \tag{3}$$

where

A_s = Nucleon number close to stability

$(N_s - Z) \cong (A_s - 2Z) \cong \Delta N_s$

= Excess Neutron number close to stability zone

With this kind of relation, by guessing the proton number the corresponding stable zone nucleon number can be estimated directly. With reference to observational data, it seems reasonable to assign the relation with mean stable mass number (A_m).

$$(A_s)_{mean} \cong A_m \cong 2Z + kZ^2 \tag{4}$$

Best lower and upper limits for stable and relatively long living mass numbers can be approximated with the following relation:

$$\left(A_s\right)_l^u \cong 2Z + \left(1 \pm \alpha_s\right)^2 kZ^2$$
$$A_l \cong 2Z + \left(1 - \alpha_s\right)^2 kZ^2 \cong 2Z + \left(0.78kZ^2\right)$$
$$A_u \cong 2Z + \left(1 + \alpha_s\right)^2 kZ^2 \cong 2Z + \left(1.25kZ^2\right) \quad (5)$$

Using these relations as guidelines, long living isotopes of super heavy elements can be estimated.

With reference to the famous stability relation pertaining to semi empirical mass formula [5,6,7]

$$Z \cong \frac{A}{\left(2.0 + \left(a_c / 2a_a\right) A^{2/3}\right)} \cong \frac{A}{\left(2.0 + 0.0153A^{2/3}\right)}$$
$$\text{where } a_c \cong 0.71 \text{ MeV and } a_a \cong 23.2 \text{ MeV} \quad (6)$$

Considering the proposed stability coefficient,

$$Z \cong \frac{A}{1 + \sqrt{kA+1}} \cong \frac{\sqrt{kA+1} - 1}{k} \quad (7)$$

Comparing relations (6) and (7)

$$Z \cong \frac{A}{\left(2.0 + 0.0153A^{2/3}\right)} \cong \frac{A}{1 + \sqrt{kA+1}} \Bigg\} \quad (8)$$

The solution seems to be a relation of the form,

$$0.0153A^{2/3} \approx \sqrt{kA+1} - 1 \quad (9)$$

$\left[\sqrt{kA+1} - 1\right]$ seems to be more appropriate than $\left[0.0153A^{2/3}\right]$ and it needs further study.It was also noticed that:

$$\left(\alpha_s^2 + \alpha_s^3 + \alpha_s^4 + \alpha_s^5 + \ldots\right) \cong 0.0158 \approx \frac{a_c}{2a_a} \approx 0.0153$$
$$\text{where } a_c \cong 0.71 \text{ MeV and } a_a \cong 23.2 \text{ MeV} \quad (10)$$

See Table 1 for a comparison starting from A=340 to 4 in steps of 'A=A-8'.

Table 1: Proton number comparison estimated with relations 6 and 7From the data presented in Table 1, workability of the proposed coefficient $k \cong 0.00625,$ can be confirmed.

Mass number	Proton number estimated with relation (6)	Proton number estimated with relation (7)	Difference in estimated proton number
340	124	123	1
332	121	121	1
324	119	118	1
316	117	116	1
308	114	114	0
300	112	111	1
292	109	109	0
284	107	107	0
276	104	104	0
268	102	102	0
260	99	99	0
252	97	97	0
244	94	94	0
236	91	92	-1
228	89	89	0
220	86	87	-1
212	83	84	-1
204	81	81	-1
196	78	79	-1
188	75	76	-1
180	72	73	-1
172	70	70	-1
164	67	68	-1
156	64	65	-1
148	61	62	-1
140	58	59	-1
132	55	56	-1
124	52	53	-1
116	49	50	-1
108	46	47	-1
100	43	44	-1
92	40	41	-1
84	37	38	-1
76	33	34	-1
68	30	31	-1
60	27	28	-1

52	23	24	-1
44	20	21	-1
36	17	17	0
28	13	13	0
20	9	10	-1
12	6	6	0
4	2	2	0

B) Coefficient connected with free nucleons

With reference to our experience in this field, we have understood that,

1. All the nucleons are not involved in the nuclear binding energy scheme.
2. Nucleons that are not involved in the nuclear binding energy scheme can be called 'free nucleons'.
3. Number of free nucleons increases with increasing $A\sqrt{ZN}$.
4. Nucleons that are involved in nuclear binding energy scheme can be called 'active nucleons'.
5. In finding the free nucleon number, with trial–error solutions, a number close to 0.00189 [4] could be arrived at. Quantitatively it can be fitted with a relation of the form,

$$f \cong \left(\alpha_s^3 + \alpha_s^4 + \alpha_s^5 + ...\right) \cong 0.00189$$
$$\text{where } \alpha_s \cong 0.1181 \qquad (11)$$

6. To a good approximation, free nucleon number can be expressed with a relation of the form,

$$A_f \cong fA\sqrt{ZN} \cong 0.00189A\sqrt{ZN} \qquad (12)$$

7. Active nucleon number can be expressed with a relation of the form,

$$A_a \cong A - A_f \cong A\left(1 - 0.00189\sqrt{ZN}\right) \qquad (13)$$

3. Proposed nuclear binding energy scheme

It is proposed that:

1) Nuclear binding energy [8,9,10] can be understood with a single energy coefficient and three simple terms.
2) Nuclear binding energy increases with an increasing number of active nucleons.
3) Nuclear binding energy decreases with increasing radius.
4) Mean stable mass number plays an interesting role in estimating the binding energy of other stable and unstable isotopes.

Based on these points, for estimating nuclear binding energy, the following semi-empirical relation for Z=3 to 118 has been proposed

$$\left.\begin{aligned}(BE)_{(z,A)} &\cong \left\{A_a - A^{1/3} - \left(1+\frac{(A_m-A)^2}{A_m}\right)\right\}B_0 \\ &\cong \left\{\left(1-f\sqrt{ZN}\right)A - A^{1/3} - \left(1+\frac{(A_m-A)^2}{A_m}\right)\right\}10.1\ \text{MeV} \\ \text{where}\quad B_0 &\cong \left(\frac{1}{\alpha_s}\right)\left(\frac{e^2}{4\pi\varepsilon_0 R_0}\right) \cong 10.1\ \text{MeV}\end{aligned}\right\} \quad 14)$$

In this relation,

First term: $+\left(1-f\sqrt{ZN}\right)A\times 10.1\ \text{MeV}$ (15)

Second term: $-A^{1/3}\times 10.1\ \text{MeV}$ (16)

Third term: $-\left(1+\frac{(A_m-A)^2}{A_m}\right)\times 10.1\ \text{MeV}$ (17)

We are still working on understanding the physical significance of the third term [11, 12, 13].

The mean stable mass number can be close to,

$$\left(BE\right)_{(z,A_m)} \cong \left\{\left(1-f\sqrt{ZN_m}\right)A_m - A_m^{1/3} - 1\right\}10.1 \text{ MeV}$$

$$\text{where} \begin{cases} A_m \cong \left(2Z + kZ^2\right) \\ N_m \cong A_m - Z \cong \left(Z + kZ^2\right) \end{cases} \tag{18}$$

See Table 2 for estimated nuclear binding energy compared with standard semi empirical mass formula.

4. Relation between nuclear binding energy coefficient and Up and Down quark masses

It is well established that,

1) Proton constitutes two 'up quarks' and one 'down quark'.
2) Neutron constitutes two 'down quarks' and one 'up quark'.
3) Up quark mass is around 2.15 MeV and Down quark mass is around 4.7 MeV.

As, average mass of nucleon is proportional to the average of $\left[\left(2m_u + m_d\right),\left(m_u + 2m_d\right)\right]$, we noticed that,

$$B_0 \approx \frac{\left(2m_u + m_d\right) + \left(m_u + 2m_d\right)}{2}$$

$$\approx \frac{3}{2}\left(m_u + m_d\right) \approx 10.27 \text{ MeV} \tag{19}$$

5. Conclusion

Even though the proposed nuclear stability relation and nuclear binding energy relation are completely different from the current notion of nuclear physical concepts, they seem to fall under the scope of 'strong interaction' concepts. With reference to the data presented in Tables 1 and 2, the proposed concepts and relations can be recommended for further research.

In Table 2:

SEMF – 1 BE (Column-6)

(https://en.wikipedia.org/wiki/Semi-empirical_mass_formula)

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

where $\begin{cases} a_v \cong 15.8 \text{ MeV};\ a_s \cong 18.3 \text{ MeV};\ a_c \cong 0.714 \text{ MeV}; \\ a_a \cong 23.2 \text{ MeV};\ a_p \cong 12.0 \text{ MeV}; \end{cases}$

SEMF – 2 BE (Column-7)

(http://oregonstate.edu/instruct/ch374/ch418518/lecture3-1.pdf)(Slide-16)

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

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

FRDM2012 BE (Column-8)

P. Mollera, A. J. Sierka, T. Ichikawab, H. Sagawa. Nuclear ground-state masses and deformations: FRDM(2012). Atomic Data and Nuclear Data Tables. Vol.109–110: 1-204 (2016) https:// arxiv.org/ pdf/1508.06294.pdf

Table 2: Estimated nuclear binding energy compared to standard semi empirical mass formulae

Z	A	N	Estimated mean mass number close to stability	Estimated BE (MeV)	SEMF-1 BE (MeV)	SEMF-2 BE (MeV)	FRDM 2012 BE (MeV)
12	24	12	25	197.27	196.71	195.54	197.38
12	25	13	25	206.91	205.38	204.24	204.63

12	26	14	25	215.74	217.16	216.13	216.69
12	27	15	25	223.77	222.75	222.62	221.54
12	28	16	25	230.99	231.63	232.34	230.70
12	29	17	25	237.40	234.79	236.98	234.84
12	30	18	25	243.00	241.34	244.86	242.17
12	31	19	25	247.79	242.54	247.95	244.97
12	32	20	25	251.78	247.18	254.27	250.78
12	33	21	25	254.95	246.80	256.03	252.24
12	34	22	25	257.31	249.87	261.00	256.93
12	35	23	25	258.86	248.17	261.62	257.88
12	36	24	25	259.60	249.94	265.43	261.62
12	37	25	25	259.54	247.15	265.06	261.37
12	38	26	25	258.66	247.81	267.84	264.29
12	39	27	25	256.96	244.11	266.61	264.25
12	40	28	25	254.46	243.82	268.49	267.12
12	41	29	25	251.15	239.35	266.50	263.97
12	42	30	25	247.02	238.25	267.58	264.89
12	43	31	25	242.09	233.12	264.92	262.16
Z	A	N	Estimated mean mass number close to stability	Estimated BE (MeV)	SEMF-1 BE (MeV)	SEMF-2 BE (MeV)	FRDM 2012 BE (MeV)
22	44	22	47	378.23	375.49	375.15	376.91
22	45	23	47	388.29	386.22	385.70	386.65
22	46	24	47	397.92	399.55	398.74	399.29
22	47	25	47	407.11	408.42	407.80	408.56
22	48	26	47	415.87	419.93	419.37	420.36
22	49	27	47	424.19	427.17	427.09	427.95
22	50	28	47	432.07	437.08	437.32	438.59
22	51	29	47	439.52	442.89	443.84	444.32
22	52	30	47	446.53	451.39	452.87	452.60
22	53	31	47	453.10	455.92	458.31	456.99
22	54	32	47	459.24	463.15	466.25	464.16
22	55	33	47	464.95	466.56	470.70	467.30

22	56	34	47	470.22	472.67	477.65	473.65
22	57	35	47	475.05	475.06	481.20	476.66
22	58	36	47	479.44	480.16	487.24	482.65
22	59	37	47	483.40	481.65	489.98	485.06
22	60	38	47	486.93	485.83	495.19	490.44
22	61	39	47	490.01	486.51	497.18	492.36
22	62	40	47	492.67	489.87	501.62	497.16
22	63	41	47	494.88	489.82	502.93	498.31
22	64	42	47	496.66	492.43	506.67	502.54
22	65	43	47	498.00	491.71	507.34	503.35
22	66	44	47	498.91	493.65	510.43	507.01
22	67	45	47	499.38	492.33	510.52	507.46
22	68	46	47	499.41	493.65	513.01	510.50
22	69	47	47	499.01	491.77	512.55	510.79
22	70	48	47	498.17	492.52	514.48	513.73
22	71	49	47	496.90	490.15	513.53	513.74
22	72	50	47	495.19	490.38	514.94	515.85
22	73	51	47	493.04	487.55	513.52	514.42
22	74	52	47	490.46	487.31	514.45	515.08
22	75	53	47	487.44	484.06	512.60	513.02
22	76	54	47	483.99	483.37	513.07	513.06
22	77	55	47	480.10	479.73	510.82	510.64
22	78	56	47	475.77	478.64	510.87	510.28
22	79	57	47	471.01	474.65	508.24	508.01
Z	A	N	Estimated mean mass number close to stability	Estimated BE (MeV)	SEMF-1 BE (MeV)	SEMF-2 BE (MeV)	FRDM 2012 BE (MeV)
32	64	32	71	549.84	542.83	543.57	544.61
32	65	33	71	560.35	554.64	555.13	555.12
32	66	34	71	570.57	568.74	568.83	568.35
32	67	35	71	580.50	579.22	579.26	578.04
32	68	36	71	590.14	591.99	591.83	590.39
32	69	37	71	599.48	601.25	601.21	598.83

32	70	38	71	608.54	612.82	612.74	610.13
32	71	39	71	617.30	620.96	621.16	618.33
32	72	40	71	625.77	631.42	631.72	628.96
32	73	41	71	633.95	638.54	639.23	636.05
32	74	42	71	641.83	647.98	648.89	645.96
32	75	43	71	649.42	654.16	655.57	652.45
32	76	44	71	656.72	662.66	664.38	661.42
32	77	45	71	663.73	667.98	670.28	667.54
32	78	46	71	670.45	675.61	678.31	676.30
32	79	47	71	676.88	680.13	683.49	681.92
32	80	48	71	683.01	686.96	690.78	690.01
32	81	49	71	688.85	690.74	695.27	695.03
32	82	50	71	694.40	696.82	701.88	702.50
32	83	51	71	699.65	699.91	705.74	705.36
32	84	52	71	704.62	705.31	711.70	710.65
32	85	53	71	709.29	707.77	714.96	712.94
32	86	54	71	713.67	712.52	720.31	718.16
32	87	55	71	717.76	714.38	723.01	720.39
32	88	56	71	721.55	718.53	727.79	724.63
32	89	57	71	725.06	719.85	729.96	726.22
32	90	58	71	728.27	723.44	734.20	730.07
32	91	59	71	731.19	724.24	735.87	731.24
32	92	60	71	733.82	727.31	739.61	734.77
32	93	61	71	736.16	727.63	740.81	735.90
32	94	62	71	738.20	730.21	744.07	738.98
32	95	63	71	739.95	730.08	744.83	739.61
32	96	64	71	741.41	732.20	747.63	742.37
32	97	65	71	742.58	731.65	747.97	742.80
32	98	66	71	743.46	733.33	750.33	745.33
32	99	67	71	744.05	732.39	750.28	745.63
32	100	68	71	744.34	733.67	752.24	747.82
32	101	69	71	744.34	732.36	751.81	747.69
32	10	70	71	744.05	733.26	753.38	749.62

	2						
32	103	71	71	743.47	731.60	752.59	749.07
32	104	72	71	742.60	732.13	753.79	750.45
32	105	73	71	741.43	730.15	752.67	749.30
32	106	74	71	739.98	730.34	753.52	750.62
32	107	75	71	738.23	728.05	752.07	749.66
32	108	76	71	736.19	727.93	752.59	750.51
32	109	77	71	733.86	725.34	750.84	749.66
32	110	78	71	731.23	724.91	751.04	750.77
32	111	79	71	728.32	722.05	748.99	749.89
32	112	80	71	725.11	721.34	748.89	750.74
32	113	81	71	721.62	718.22	746.56	749.90
32	114	82	71	717.83	717.23	746.17	750.44
32	115	83	71	713.75	713.87	743.58	747.47

Z	A	N	Estimated mean mass number close to stability	Estimated BE (MeV)	SEMF-1 BE (MeV)	SEMF-2 BE (MeV)	FRDM 2012 BE (MeV)
42	84	42	95	713.86	696.77	698.72	698.60
42	85	43	95	724.41	709.32	710.97	710.64
42	86	44	95	734.74	723.92	725.14	725.19
42	87	45	95	744.84	735.42	736.48	736.39
42	88	46	95	754.73	748.99	749.73	750.36
42	89	47	95	764.40	759.51	760.21	761.12
42	90	48	95	773.84	772.11	772.60	774.61
42	91	49	95	783.07	781.72	782.26	784.63

42	92	50	95	792.07	793.41	793.84	797.16
42	93	51	95	800.85	802.18	802.74	804.99
42	94	52	95	809.41	813.02	813.55	814.78
42	95	53	95	817.76	820.99	821.72	821.59
42	96	54	95	825.88	831.03	831.81	830.34
42	97	55	95	833.77	838.25	839.30	836.98
42	98	56	95	841.45	847.55	848.70	845.77
42	99	57	95	848.91	854.07	855.55	851.81
42	100	58	95	856.15	862.66	864.29	860.21
42	101	59	95	863.16	868.52	870.53	866.05
42	102	60	95	869.96	876.45	878.66	874.20
42	103	61	95	876.53	881.69	884.32	879.72
42	104	62	95	882.89	888.99	891.86	887.25
42	105	63	95	889.02	893.65	896.97	891.97
42	106	64	95	894.93	900.36	903.96	898.93
42	107	65	95	900.62	904.47	908.54	903.43
42	108	66	95	906.09	910.62	915.00	909.96
42	109	67	95	911.34	914.21	919.08	914.03
42	110	68	95	916.37	919.84	925.03	920.33
42	111	69	95	921.18	922.93	928.65	924.00
42	112	70	95	925.77	928.06	934.12	929.54
42	113	71	95	930.13	930.69	937.28	932.62
42	114	72	95	934.28	935.35	942.29	937.72
42	115	73	95	938.21	937.54	945.02	940.85
42	11	74	95	941.91	941.74	949.60	945.80

42	116	75	95	945.39	943.51	951.92	948.83
42	117	76	95	948.66	947.30	956.07	953.61
42	118	77	95	951.70	948.67	958.00	956.02
42	119	78	95	954.53	952.05	961.76	960.38
42	120	79	95	957.13	953.05	963.31	962.91
42	121	80	95	959.51	956.04	966.68	967.22
42	122	81	95	961.67	956.68	967.88	970.00
42	123	82	95	963.61	959.31	970.88	974.41
42	124	83	95	965.33	959.61	971.74	974.28
42	125	84	95	966.83	961.88	974.39	976.11
42	126	85	95	968.11	961.86	974.91	975.66
42	127	86	95	969.17	963.81	977.23	977.01
42	128	87	95	970.01	963.47	977.44	976.30
42	129	88	95	970.63	965.10	979.43	977.47
42	130	89	95	971.03	964.48	979.34	976.77
42	131	90	95	971.21	965.80	981.02	977.76
42	132	91	95	971.17	964.89	980.64	976.70
42	133	92	95	970.91	965.93	982.02	977.84
42	134	93	95	970.42	964.76	981.36	977.16
42	135	94	95	969.72	965.51	982.45	978.17
42	136	95	95	968.80	964.09	981.52	977.19
42	137						

42	138	96	95	967.66	964.58	982.34	977.87
42	139	97	95	966.30	962.91	981.16	976.89
42	140	98	95	964.71	963.15	981.71	977.55
42	141	99	95	962.91	961.24	980.28	976.45
42	142	100	95	960.89	961.24	980.57	976.86
42	143	101	95	958.64	959.11	978.90	975.48
42	144	102	95	956.18	958.87	978.95	975.70
Z	A	N	Estimated mean mass number close to stability	Estimated BE (MeV)	SEMF-1 BE (MeV)	SEMF-2 BE (MeV)	FRDM 2012 BE (MeV)
52	104	52	121	865.45	837.02	840.25	848.09
52	105	53	121	876.16	850.12	853.03	859.04
52	106	54	121	886.70	865.11	867.57	872.41
52	107	55	121	897.06	877.35	879.58	883.19
52	108	56	121	907.25	891.48	893.34	896.11
52	109	57	121	917.26	902.91	904.62	906.26
52	110	58	121	927.09	916.24	917.65	918.68
52	111	59	121	936.75	926.89	928.22	928.25
52	112	60	121	946.23	939.45	940.55	940.13
52	113	61	121	955.54	949.38	950.46	949.39
52	114	62	121	964.68	961.21	962.12	960.87
52	115	63	121	973.63	970.45	971.40	969.55

52	116	64	121	982.41	981.59	982.42	980.42
52	117	65	121	991.02	990.18	991.09	988.68
52	118	66	121	999.45	1000.66	1001.50	999.04
52	119	67	121	1007.71	1008.63	1009.60	1007.07
52	120	68	121	1015.79	1018.49	1019.43	1017.05
52	121	69	121	1023.69	1025.87	1026.97	1024.60
52	122	70	121	1031.42	1035.14	1036.24	1034.11
52	123	71	121	1038.97	1041.96	1043.26	1041.12
52	124	72	121	1046.35	1050.66	1052.00	1050.51
52	125	73	121	1053.55	1056.95	1058.51	1057.21
52	126	74	121	1060.58	1065.11	1066.74	1066.31
52	127	75	121	1067.43	1070.89	1072.76	1072.70
52	128	76	121	1074.11	1078.55	1080.50	1081.45
52	129	77	121	1080.61	1083.84	1086.07	1087.58
52	130	78	121	1086.93	1091.01	1093.34	1096.40
52	131	79	121	1093.08	1095.84	1098.45	1102.20
52	132	80	121	1099.06	1102.54	1105.27	1110.68
52	133	81	121	1104.85	1106.93	1109.96	1116.03
52	134	82	121	1110.48	1113.18	1116.35	1123.77
52	135	83	121	1115.93	1117.15	1120.63	1127.00
52	136	84	121	1121.20	1122.98	1126.61	1132.02
52	13	85	121	1126.3	1126.55	1130.49	1134.4

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52	138	86	121	1131.22	1131.97	1136.07	1138.92
52	139	87	121	1135.97	1135.15	1139.57	1141.12
52	140	88	121	1140.54	1140.18	1144.76	1145.43
52	141	89	121	1144.94	1142.99	1147.91	1147.56
52	142	90	121	1149.16	1147.65	1152.73	1151.81
52	143	91	121	1153.21	1150.11	1155.52	1153.70
52	144	92	121	1157.08	1154.41	1159.98	1157.70
52	145	93	121	1160.78	1156.53	1162.44	1159.61
52	146	94	121	1164.30	1160.48	1166.56	1163.38
52	147	95	121	1167.64	1162.29	1168.69	1165.39
52	148	96	121	1170.82	1165.91	1172.48	1168.97
52	149	97	121	1173.81	1167.40	1174.30	1170.57
52	150	98	121	1176.63	1170.70	1177.77	1173.86
52	151	99	121	1179.28	1171.90	1179.28	1175.21
52	152	100	121	1181.75	1174.89	1182.44	1178.26
52	153	101	121	1184.05	1175.80	1183.67	1179.35
52	154	102	121	1186.17	1178.51	1186.53	1182.29
52	155	103	121	1188.11	1179.14	1187.48	1183.17
52	156	104	121	1189.89	1181.57	1190.05	1185.73
52	157	105	121	1191.48	1181.94	1190.73	1186.35
52	158	106	121	1192.91	1184.09	1193.02	1188.66

52	159	107	121	1194.15	1184.20	1193.43	1189.02
52	160	108	121	1195.22	1186.10	1195.46	1191.13
52	161	109	121	1196.12	1185.97	1195.62	1191.39
52	162	110	121	1196.84	1187.61	1197.39	1193.25
52	163	111	121	1197.39	1187.25	1197.30	1193.34
52	164	112	121	1197.77	1188.64	1198.81	1194.92
52	165	113	121	1197.96	1188.05	1198.49	1194.92
52	166	114	121	1197.99	1189.22	1199.76	1196.84
52	167	115	121	1197.84	1188.41	1199.21	1196.82
52	168	116	121	1197.51	1189.35	1200.25	1198.49
52	169	117	121	1197.01	1188.33	1199.47	1198.46
52	170	118	121	1196.34	1189.06	1200.28	1199.96
52	171	119	121	1195.49	1187.83	1199.29	1199.72
52	172	120	121	1194.46	1188.35	1199.87	1200.93
52	173	121	121	1193.26	1186.93	1198.67	1200.81
52	174	122	121	1191.89	1187.24	1199.04	1202.23
52	175	123	121	1190.34	1185.64	1197.64	1201.99
Z	A	N	Estimated mean mass number close to stability	Estimated BE (MeV)	SEMF-1 BE (MeV)	SEMF-2 BE (MeV)	FRDM 2012 BE (MeV)
62	124	62	149	1002.81	963.70	968.25	971.03
62	125	63	149	1013.73	977.25	981.47	983.64

62	126	64	149	1024.50	992.56	996.31	998.18
62	127	65	149	1035.12	1005.37	1008.86	1010.14
62	128	66	149	1045.61	1019.95	1023.03	1024.09
62	129	67	149	1055.94	1032.07	1034.94	1035.42
62	130	68	149	1066.13	1045.95	1048.47	1048.76
62	131	69	149	1076.18	1057.40	1059.76	1059.58
62	132	70	149	1086.09	1070.62	1072.67	1072.26
62	133	71	149	1095.85	1081.44	1083.38	1082.43
62	134	72	149	1105.46	1094.02	1095.70	1094.45
62	135	73	149	1114.93	1104.23	1105.83	1104.00
62	136	74	149	1124.26	1116.21	1117.59	1115.66
62	137	75	149	1133.44	1125.83	1127.18	1125.08
62	138	76	149	1142.48	1137.23	1138.39	1136.45
62	139	77	149	1151.37	1146.30	1147.46	1145.47
62	140	78	149	1160.12	1157.14	1158.14	1156.50
62	141	79	149	1168.72	1165.68	1166.71	1165.16
62	142	80	149	1177.18	1175.98	1176.88	1176.42
62	143	81	149	1185.50	1184.02	1184.97	1185.02
62	144	82	149	1193.67	1193.81	1194.65	1196.01
62	145	83	149	1201.70	1201.36	1202.27	1202.47
62	146	84	149	1209.58	1210.66	1211.49	1210.74
62	14	85	149	1217.3	1217.74	1218.66	1216.5

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62	148	86	149	1224.91	1226.57	1227.43	1225.07
62	149	87	149	1232.36	1233.20	1234.17	1231.38
62	150	88	149	1239.67	1241.57	1242.50	1239.61
62	151	89	149	1246.83	1247.77	1248.82	1245.73
62	152	90	149	1253.85	1255.71	1256.73	1253.82
62	153	91	149	1260.72	1261.50	1262.66	1259.85
62	154	92	149	1267.45	1269.02	1270.16	1267.66
62	155	93	149	1274.03	1274.41	1275.69	1273.24
62	156	94	149	1280.47	1281.54	1282.80	1280.44
62	157	95	149	1286.77	1286.54	1287.96	1285.64
62	158	96	149	1292.92	1293.28	1294.70	1292.43
62	159	97	149	1298.93	1297.92	1299.50	1297.28
62	160	98	149	1304.79	1304.28	1305.86	1303.68
62	161	99	149	1310.51	1308.57	1310.31	1308.08
62	162	100	149	1316.09	1314.57	1316.32	1314.07
62	163	101	149	1321.52	1318.51	1320.43	1318.19
62	164	102	149	1326.81	1324.17	1326.10	1323.77
62	165	103	149	1331.95	1327.79	1329.89	1327.44
62	166	104	149	1336.95	1333.11	1335.23	1332.43
62	167	105	149	1341.81	1336.41	1338.70	1335.62
62	168	106	149	1346.52	1341.42	1343.71	1340.40

62	169	107	149	1351.09	1344.41	1346.88	1343.29
62	170	108	149	1355.51	1349.11	1351.58	1347.76
62	171	109	149	1359.79	1351.81	1354.45	1350.44
62	172	110	149	1363.93	1356.20	1358.85	1354.56
62	173	111	149	1367.92	1358.62	1361.43	1356.98
62	174	112	149	1371.77	1362.72	1365.55	1360.92
62	175	113	149	1375.47	1364.87	1367.85	1363.22
62	176	114	149	1379.03	1368.69	1371.68	1367.03
62	177	115	149	1382.45	1370.57	1373.71	1369.17
62	178	116	149	1385.72	1374.13	1377.27	1372.76
62	179	117	149	1388.85	1375.75	1379.04	1374.62
62	180	118	149	1391.84	1379.04	1382.33	1378.16
62	181	119	149	1394.68	1380.42	1383.85	1379.73
62	182	120	149	1397.38	1383.46	1386.87	1382.95
62	183	121	149	1399.93	1384.60	1388.15	1384.70
62	184	122	149	1402.34	1387.40	1390.93	1388.09
62	185	123	149	1404.61	1388.30	1391.96	1390.20
62	186	124	149	1406.73	1390.86	1394.49	1393.54
62	187	125	149	1408.71	1391.55	1395.30	1395.21
62	188	126	149	1410.55	1393.88	1397.59	1398.20
62	189	127	149	1412.24	1394.35	1398.17	1397.77
62	19	12	149	1413.7	1396.45	1400.24	1398.9

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62	191	129	149	1415.19	1396.71	1400.60	1398.28
62	192	130	149	1416.46	1398.61	1402.44	1399.47
62	193	131	149	1417.57	1398.66	1402.59	1399.22
62	194	132	149	1418.55	1400.35	1404.21	1400.30
62	195	133	149	1419.38	1400.21	1404.15	1399.89
62	196	134	149	1420.07	1401.69	1405.56	1400.89
62	197	135	149	1420.61	1401.36	1405.30	1400.53
62	198	136	149	1421.01	1402.65	1406.51	1401.99
62	199	137	149	1421.27	1402.13	1406.05	1401.71
62	200	138	149	1421.38	1403.23	1407.06	1402.80
62	201	139	149	1421.35	1402.54	1406.41	1402.44
62	202	140	149	1421.18	1403.45	1407.22	1403.53
62	203	141	149	1420.87	1402.58	1406.39	1402.99
62	204	142	149	1420.41	1403.32	1407.01	1404.00
62	205	143	149	1419.80	1402.28	1406.00	1403.29
62	206	144	149	1419.06	1402.84	1406.43	1404.10
62	207	145	149	1418.17	1401.64	1405.24	1403.23
62	208	146	149	1417.13	1402.03	1405.50	1403.95
Z	A	N	Estimated mean mass number close to stability	Estimated BE (MeV)	SEMF-1 BE (MeV)	SEMF-2 BE (MeV)	FRDM 2012 BE (MeV)

72	149	77	177	1184.74	1147.49	1151.60	1153.97
72	150	78	177	1195.06	1161.83	1165.55	1168.29
72	151	79	177	1205.25	1173.92	1177.42	1180.13
72	152	80	177	1215.32	1187.67	1190.82	1194.19
72	153	81	177	1225.27	1199.19	1202.16	1205.82
72	154	82	177	1235.10	1212.38	1215.03	1219.45
72	155	83	177	1244.80	1223.36	1225.86	1229.20
72	156	84	177	1254.38	1236.00	1238.21	1240.63
72	157	85	177	1263.83	1246.46	1248.55	1249.39
72	158	86	177	1273.17	1258.58	1260.41	1260.53
72	159	87	177	1282.38	1268.54	1270.27	1269.61
72	160	88	177	1291.46	1280.16	1281.65	1280.55
72	161	89	177	1300.43	1289.63	1291.06	1289.47
72	162	90	177	1309.27	1300.76	1301.97	1300.10
72	163	91	177	1317.98	1309.78	1310.93	1308.50
72	164	92	177	1326.58	1320.44	1321.39	1318.87
72	165	93	177	1335.05	1329.00	1329.92	1327.03
72	166	94	177	1343.40	1339.22	1339.95	1337.12
72	167	95	177	1351.62	1347.35	1348.07	1345.06
72	168	96	177	1359.73	1357.13	1357.68	1354.87
72	169	97	177	1367.71	1364.84	1365.39	1362.55
72	17	98	177	1375.5	1374.20	1374.59	1372.0

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72	171	99	177	1383.30	1381.52	1381.91	1379.35
72	172	100	177	1390.91	1390.47	1390.72	1388.44
72	173	101	177	1398.39	1397.40	1397.67	1395.46
72	174	102	177	1405.76	1405.96	1406.09	1404.16
72	175	103	177	1413.00	1412.51	1412.67	1410.87
72	176	104	177	1420.12	1420.69	1420.73	1419.23
72	177	105	177	1427.12	1426.89	1426.95	1425.63
72	178	106	177	1433.99	1434.70	1434.65	1433.65
72	179	107	177	1440.74	1440.55	1440.53	1439.71
72	180	108	177	1447.37	1448.01	1447.88	1447.18
72	181	109	177	1453.87	1453.52	1453.43	1452.68
72	182	110	177	1460.25	1460.64	1460.44	1459.65
72	183	111	177	1466.51	1465.82	1465.67	1464.80
72	184	112	177	1472.65	1472.61	1472.35	1471.48
72	185	113	177	1478.66	1477.47	1477.26	1476.38
72	186	114	177	1484.55	1483.94	1483.63	1482.67
72	187	115	177	1490.32	1488.50	1488.23	1487.22
72	188	116	177	1495.96	1494.66	1494.29	1493.17
72	189	117	177	1501.49	1498.93	1498.60	1497.51
72	190	118	177	1506.89	1504.79	1504.36	1503.18
72	191	119	177	1512.16	1508.76	1508.38	1506.95

72	192	120	177	1517.32	1514.33	1513.84	1512.76
72	193	121	177	1522.35	1518.03	1517.58	1516.74
72	194	122	177	1527.26	1523.32	1522.77	1522.40
72	195	123	177	1532.05	1526.75	1526.23	1526.59
72	196	124	177	1536.71	1531.76	1531.14	1532.06
72	197	125	177	1541.25	1534.93	1534.34	1535.60
72	198	126	177	1545.67	1539.68	1538.98	1540.70
72	199	127	177	1549.97	1542.60	1541.93	1542.61
72	200	128	177	1554.14	1547.09	1546.31	1545.99
72	201	129	177	1558.19	1549.76	1549.00	1547.43
72	202	130	177	1562.12	1554.00	1553.13	1550.35
72	203	131	177	1565.93	1556.43	1555.58	1551.74
72	204	132	177	1569.61	1560.43	1559.45	1554.92
72	205	133	177	1573.17	1562.63	1561.67	1556.51
72	206	134	177	1576.61	1566.40	1565.30	1559.68
72	207	135	177	1579.93	1568.38	1567.29	1561.08
72	208	136	177	1583.12	1571.91	1570.69	1564.20
72	209	137	177	1586.19	1573.67	1572.45	1565.81
72	210	138	177	1589.14	1576.98	1575.62	1569.07
72	211	139	177	1591.97	1578.53	1577.16	1570.61
72	212	140	177	1594.67	1581.63	1580.11	1573.61
72	21	14	177	1597.2	1582.98	1581.44	1575.0

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72	214	142	177	1599.72	1585.86	1584.17	1577.88
72	215	143	177	1602.05	1587.01	1585.29	1579.18
72	216	144	177	1604.27	1589.69	1587.80	1581.90
72	217	145	177	1606.36	1590.64	1588.72	1583.09
72	218	146	177	1608.33	1593.12	1591.03	1585.60
72	219	147	177	1610.18	1593.89	1591.75	1586.70
72	220	148	177	1611.91	1596.18	1593.86	1588.96
72	221	149	177	1613.51	1596.76	1594.39	1589.83
72	222	150	177	1614.99	1598.86	1596.30	1592.05
72	223	151	177	1616.35	1599.26	1596.64	1592.71
72	224	152	177	1617.59	1601.18	1598.36	1594.57
72	225	153	177	1618.71	1601.41	1598.51	1594.91
72	226	154	177	1619.70	1603.15	1600.05	1596.58
72	227	155	177	1620.57	1603.21	1600.02	1596.61
72	228	156	177	1621.32	1604.78	1601.37	1598.13
72	229	157	177	1621.95	1604.67	1601.17	1598.20
72	230	158	177	1622.45	1606.07	1602.34	1599.56
72	231	159	177	1622.83	1605.80	1601.97	1599.68
72	232	160	177	1623.09	1607.04	1602.97	1601.07
72	233	161	177	1623.23	1606.61	1602.43	1600.97
72	234	162	177	1623.25	1607.69	1603.26	1602.23

72	235	163	177	1623.14	1607.11	1602.56	1601.55
72	236	164	177	1622.92	1608.03	1603.21	1602.17
72	237	165	177	1622.57	1607.31	1602.36	1601.30
72	238	166	177	1622.10	1608.07	1602.85	1601.70
72	239	167	177	1621.50	1607.21	1601.84	1601.02
72	240	168	177	1620.79	1607.82	1602.17	1601.14
Z	A	N	Estimated mean mass number close to stability	Estimated BE (MeV)	SEMF-1 BE (MeV)	SEMF-2 BE (MeV)	FRDM 2012 BE (MeV)
82	175	93	207	1359.22	1328.57	1332.11	1334.01
82	176	94	207	1369.05	1341.76	1344.96	1346.42
82	177	95	207	1378.77	1352.91	1355.93	1356.47
82	178	96	207	1388.38	1365.63	1368.33	1368.62
82	179	97	207	1397.89	1376.32	1378.86	1378.40
82	180	98	207	1407.29	1388.58	1390.82	1390.33
82	181	99	207	1416.58	1398.83	1400.93	1399.78
82	182	100	207	1425.77	1410.64	1412.46	1411.43
82	183	101	207	1434.85	1420.46	1422.16	1420.58
82	184	102	207	1443.82	1431.85	1433.27	1431.91
82	185	103	207	1452.69	1441.26	1442.57	1440.83
82	186	104	207	1461.45	1452.22	1453.28	1451.82
82	187	105	207	1470.10	1461.23	1462.19	1460.48

82	188	106	207	1478.65	1471.80	1472.51	1471.17
82	189	107	207	1487.09	1480.42	1481.04	1479.60
82	190	108	207	1495.42	1490.60	1490.99	1490.01
82	191	109	207	1503.65	1498.84	1499.15	1498.15
82	192	110	207	1511.77	1508.64	1508.72	1508.35
82	193	111	207	1519.78	1516.52	1516.53	1516.14
82	194	112	207	1527.69	1525.95	1525.75	1526.18
82	195	113	207	1535.49	1533.48	1533.21	1533.68
82	196	114	207	1543.19	1542.55	1542.08	1543.48
82	197	115	207	1550.77	1549.74	1549.20	1550.84
82	198	116	207	1558.26	1558.47	1557.73	1560.26
82	199	117	207	1565.63	1565.33	1564.53	1567.38
82	200	118	207	1572.90	1573.73	1572.72	1576.49
82	201	119	207	1580.06	1580.26	1579.20	1583.45
82	202	120	207	1587.12	1588.33	1587.08	1592.21
82	203	121	207	1594.07	1594.56	1593.25	1598.92
82	204	122	207	1600.91	1602.31	1600.81	1607.40
82	205	123	207	1607.65	1608.23	1606.68	1613.90
82	206	124	207	1614.28	1615.68	1613.94	1622.08
82	207	125	207	1620.80	1621.31	1619.52	1628.30
82	208	126	207	1627.22	1628.46	1626.48	1635.60
82	20	12	207	1633.5	1633.80	1631.77	1639.6

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82	210	128	207	1639.74	1640.66	1638.44	1645.39
82	211	129	207	1645.84	1645.73	1643.45	1648.84
82	212	130	207	1651.83	1652.31	1649.84	1654.18
82	213	131	207	1657.71	1657.11	1654.58	1657.50
82	214	132	207	1663.50	1663.41	1660.70	1662.65
82	215	133	207	1669.17	1667.95	1665.18	1665.85
82	216	134	207	1674.74	1673.99	1671.02	1670.84
82	217	135	207	1680.20	1678.27	1675.24	1674.03
82	218	136	207	1685.55	1684.05	1680.83	1678.91
82	219	137	207	1690.80	1688.09	1684.80	1681.90
82	220	138	207	1695.95	1693.62	1690.13	1686.70
82	221	139	207	1700.98	1697.41	1693.86	1689.56
82	222	140	207	1705.91	1702.70	1698.94	1694.20
82	223	141	207	1710.74	1706.25	1702.42	1696.97
82	224	142	207	1715.46	1711.30	1707.26	1701.62
82	225	143	207	1720.07	1714.63	1710.52	1704.67
82	226	144	207	1724.57	1719.45	1715.12	1709.33
82	227	145	207	1728.97	1722.56	1718.15	1712.21
82	228	146	207	1733.27	1727.15	1722.52	1716.57
82	229	147	207	1737.46	1730.04	1725.32	1719.39
82	230	148	207	1741.54	1734.41	1729.47	1723.58

82	231	149	207	1745.51	1737.09	1732.05	1726.32
82	232	150	207	1749.38	1741.25	1735.98	1730.34
82	233	151	207	1753.15	1743.73	1738.35	1732.86
82	234	152	207	1756.81	1747.68	1742.07	1736.52
82	235	153	207	1760.36	1749.95	1744.23	1738.57
82	236	154	207	1763.80	1753.70	1747.73	1741.90
82	237	155	207	1767.14	1755.78	1749.70	1743.68
82	238	156	207	1770.38	1759.33	1752.99	1746.90
82	239	157	207	1773.51	1761.22	1754.76	1748.70
82	240	158	207	1776.53	1764.57	1757.86	1751.88
82	241	159	207	1779.45	1766.28	1759.43	1753.69
82	242	160	207	1782.26	1769.44	1762.33	1756.81
82	243	161	207	1784.96	1770.97	1763.72	1758.46
82	244	162	207	1787.56	1773.95	1766.42	1761.44
82	245	163	207	1790.05	1775.30	1767.63	1762.74
82	246	164	207	1792.44	1778.10	1770.14	1765.39
82	247	165	207	1794.72	1779.28	1771.16	1766.76
82	248	166	207	1796.90	1781.90	1773.50	1769.51
82	249	167	207	1798.97	1782.92	1774.34	1770.60
82	250	168	207	1800.93	1785.37	1776.50	1773.22
82	251	169	207	1802.79	1786.22	1777.17	1774.48
82	25	17	207	1804.5	1788.50	1779.15	1776.9

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82	253	171	207	1806.19	1789.19	1779.65	1777.98
82	254	172	207	1807.73	1791.32	1781.46	1780.18
82	255	173	207	1809.17	1791.85	1781.80	1780.95
82	256	174	207	1810.50	1793.81	1783.43	1782.91
82	257	175	207	1811.72	1794.20	1783.61	1783.68
82	258	176	207	1812.84	1796.00	1785.08	1785.54
82	259	177	207	1813.86	1796.24	1785.10	1786.02
82	260	178	207	1814.76	1797.89	1786.41	1787.61
82	261	179	207	1815.57	1797.98	1786.28	1788.04
82	262	180	207	1816.26	1799.48	1787.43	1789.65
82	263	181	207	1816.85	1799.43	1787.14	1789.95
82	264	182	207	1817.34	1800.79	1788.14	1791.34
82	265	183	207	1817.72	1800.60	1787.70	1791.35
82	266	184	207	1817.99	1801.82	1788.55	1792.29
82	267	185	207	1818.16	1801.50	1787.97	1790.65
82	268	186	207	1818.22	1802.57	1788.66	1790.77
82	269	187	207	1818.18	1802.12	1787.94	1788.85
82	270	188	207	1818.03	1803.06	1788.49	1788.63
82	271	189	207	1817.78	1802.47	1787.62	1787.18
82	272	190	207	1817.42	1803.28	1788.03	1787.10
82	273	191	207	1816.96	1802.57	1787.03	1785.69

Z	A	N	Estimated mean mass number close to stability	Estimated BE (MeV)	SEMF-1 BE (MeV)	SEMF-2 BE (MeV)	FRDM 2012 BE (MeV)
92	203	111	238	1537.26	1516.95	1519.40	1517.95
92	204	112	238	1546.50	1528.95	1531.08	1529.38
92	205	113	238	1555.64	1539.08	1541.04	1539.11
92	206	114	238	1564.68	1550.69	1552.34	1550.48
92	207	115	238	1573.63	1560.44	1561.93	1560.00
92	208	116	238	1582.49	1571.67	1572.86	1571.09
92	209	117	238	1591.25	1581.07	1582.10	1580.29
92	210	118	238	1599.92	1591.94	1592.68	1591.36
92	211	119	238	1608.50	1600.98	1601.57	1600.46
92	212	120	238	1616.98	1611.49	1611.80	1611.16
92	213	121	238	1625.37	1620.19	1620.36	1619.91
92	214	122	238	1633.66	1630.36	1630.25	1630.22
92	215	123	238	1641.86	1638.73	1638.48	1638.78
92	216	124	238	1649.97	1648.56	1648.04	1648.69
92	217	125	238	1657.98	1656.61	1655.95	1656.66
92	218	126	238	1665.90	1666.12	1665.19	1666.17
92	219	127	238	1673.72	1673.85	1672.79	1672.54
92	220	128	238	1681.45	1683.04	1681.72	1680.79
92	221	129	238	1689.09	1690.46	1689.01	1687.55

92	222	130	238	1696.63	1699.35	1697.63	1695.82
92	223	131	238	1704.08	1706.47	1704.63	1702.49
92	224	132	238	1711.44	1715.06	1712.96	1710.56
92	225	133	238	1718.70	1721.89	1719.67	1717.06
92	226	134	238	1725.87	1730.18	1727.70	1724.94
92	227	135	238	1732.94	1736.74	1734.12	1731.15
92	228	136	238	1739.92	1744.75	1741.87	1738.76
92	229	137	238	1746.81	1751.03	1748.03	1744.90
92	230	138	238	1753.60	1758.76	1755.49	1752.42
92	231	139	238	1760.30	1764.77	1761.38	1758.28
92	232	140	238	1766.90	1772.23	1768.58	1765.57
92	233	141	238	1773.42	1777.98	1774.20	1771.21
92	234	142	238	1779.83	1785.17	1781.13	1778.27
92	235	143	238	1786.16	1790.67	1786.50	1783.57
92	236	144	238	1792.39	1797.61	1793.17	1790.23
92	237	145	238	1798.53	1802.86	1798.29	1795.25
92	238	146	238	1804.57	1809.55	1804.71	1801.64
92	239	147	238	1810.52	1814.56	1809.58	1806.54
92	240	148	238	1816.38	1821.00	1815.76	1812.62
92	241	149	238	1822.14	1825.78	1820.39	1817.23
92	242	150	238	1827.81	1831.98	1826.32	1823.01
92	24	15	238	1833.3	1836.53	1830.72	1827.3

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92	244	152	238	1838.87	1842.50	1836.42	1832.90
92	245	153	238	1844.25	1846.83	1840.59	1836.68
92	246	154	238	1849.55	1852.57	1846.05	1841.82
92	247	155	238	1854.75	1856.68	1850.00	1845.26
92	248	156	238	1859.86	1862.20	1855.24	1850.14
92	249	157	238	1864.87	1866.09	1858.97	1853.55
92	250	158	238	1869.80	1871.40	1863.99	1858.39
92	251	159	238	1874.62	1875.09	1867.51	1861.77
92	252	160	238	1879.36	1880.18	1872.31	1866.65
92	253	161	238	1884.00	1883.66	1875.61	1869.94
92	254	162	238	1888.55	1888.55	1880.20	1874.51
92	255	163	238	1893.00	1891.84	1883.31	1877.44
92	256	164	238	1897.36	1896.53	1887.69	1881.50
92	257	165	238	1901.63	1899.62	1890.59	1884.27
92	258	166	238	1905.80	1904.11	1894.77	1888.28
92	259	167	238	1909.88	1907.01	1897.48	1890.92
92	260	168	238	1913.87	1911.31	1901.46	1895.01
92	261	169	238	1917.76	1914.03	1903.98	1897.76
92	262	170	238	1921.56	1918.14	1907.76	1901.86
92	263	171	238	1925.27	1920.68	1910.09	1904.49
92	264	172	238	1928.88	1924.61	1913.68	1908.23

92	265	173	238	1932.41	1926.97	1915.83	1910.58
92	266	174	238	1935.83	1930.72	1919.24	1914.08
92	267	175	238	1939.17	1932.91	1921.20	1916.38
92	268	176	238	1942.41	1936.48	1924.43	1919.85
92	269	177	238	1945.56	1938.50	1926.22	1921.92
92	270	178	238	1948.61	1941.90	1929.26	1925.04
92	271	179	238	1951.57	1943.76	1930.88	1926.60
92	272	180	238	1954.44	1946.99	1933.75	1929.23
92	273	181	238	1957.22	1948.69	1935.20	1930.84
92	274	182	238	1959.90	1951.75	1937.89	1933.70
92	275	183	238	1962.49	1953.29	1939.18	1935.19
92	276	184	238	1964.98	1956.20	1941.70	1937.62
92	277	185	238	1967.38	1957.59	1942.82	1937.59
92	278	186	238	1969.69	1960.34	1945.19	1939.44
92	279	187	238	1971.91	1961.57	1946.15	1939.71
92	280	188	238	1974.03	1964.17	1948.35	1941.74
92	281	189	238	1976.06	1965.25	1949.15	1942.53
92	282	190	238	1978.00	1967.70	1951.19	1944.43
92	283	191	238	1979.84	1968.64	1951.84	1945.02
92	284	192	238	1981.59	1970.94	1953.73	1946.49
92	285	193	238	1983.25	1971.74	1954.23	1947.03
92	28	19	238	1984.8	1973.90	1955.96	1948.6

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92	287	195	238	1986.29	1974.56	1956.31	1949.09
92	288	196	238	1987.67	1976.57	1957.89	1950.60
92	289	197	238	1988.95	1977.10	1958.10	1950.51
92	290	198	238	1990.15	1978.97	1959.53	1952.02
92	291	199	238	1991.25	1979.37	1959.60	1952.12
92	292	200	238	1992.26	1981.11	1960.89	1953.25
92	293	201	238	1993.17	1981.37	1960.82	1953.29
92	294	202	238	1993.99	1982.98	1961.96	1954.50
92	295	203	238	1994.72	1983.12	1961.75	1954.65
92	296	204	238	1995.35	1984.59	1962.76	1955.87
92	297	205	238	1995.90	1984.60	1962.41	1955.69
92	298	206	238	1996.35	1985.95	1963.28	1956.80
92	299	207	238	1996.70	1985.84	1962.81	1956.47
92	300	208	238	1996.97	1987.06	1963.54	1957.27
92	301	209	238	1997.14	1986.84	1962.94	1957.05
92	302	210	238	1997.22	1987.94	1963.54	1957.72
92	303	211	238	1997.20	1987.59	1962.81	1956.94
92	304	212	238	1997.10	1988.57	1963.28	1957.37
92	305	213	238	1996.90	1988.11	1962.43	1956.46

Z	A	N	Estimated mean mass number close to stability	Estimated BE (MeV)	SEMF-1 BE (MeV)	SEMF-2 BE (MeV)	FRDM 2012 BE (MeV)
102	232	130	271	1704.38	1699.96	1700.76	1695.11
102	233	131	271	1713.10	1709.37	1709.97	1708.33
102	234	132	271	1721.73	1720.18	1720.46	1718.98
102	235	133	271	1730.28	1729.27	1729.36	1727.76
102	236	134	271	1738.75	1739.77	1739.53	1738.13
102	237	135	271	1747.13	1748.56	1748.13	1746.64
102	238	136	271	1755.43	1758.75	1758.00	1756.64
102	239	137	271	1763.64	1767.24	1766.30	1764.72
102	240	138	271	1771.77	1777.13	1775.87	1774.43
102	241	139	271	1779.82	1785.32	1783.88	1782.38
102	242	140	271	1787.79	1794.92	1793.16	1792.04
102	243	141	271	1795.67	1802.83	1800.89	1799.88
102	244	142	271	1803.46	1812.14	1809.88	1809.23
102	245	143	271	1811.18	1819.78	1817.33	1816.73
102	246	144	271	1818.81	1828.81	1826.05	1825.69
102	247	145	271	1826.35	1836.17	1833.23	1832.95
102	248	146	271	1833.82	1844.93	1841.67	1841.60
102	249	147	271	1841.20	1852.03	1848.58	1848.62
102	250	148	271	1848.49	1860.53	1856.76	1857.01

102	251	149	271	1855.70	1867.37	1863.42	1863.82
102	252	150	271	1862.83	1875.60	1871.33	1871.99
102	253	151	271	1869.88	1882.20	1877.74	1878.51
102	254	152	271	1876.84	1890.17	1885.40	1886.23
102	255	153	271	1883.72	1896.52	1891.55	1891.98
102	256	154	271	1890.52	1904.25	1898.96	1899.19
102	257	155	271	1897.23	1910.36	1904.87	1904.72
102	258	156	271	1903.86	1917.85	1912.04	1911.59
102	259	157	271	1910.40	1923.72	1917.72	1917.07
102	260	158	271	1916.86	1930.97	1924.64	1923.89
102	261	159	271	1923.24	1936.62	1930.08	1929.22
102	262	160	271	1929.54	1943.64	1936.77	1936.02
102	263	161	271	1935.75	1949.06	1941.99	1941.19
102	264	162	271	1941.88	1955.86	1948.45	1947.70
102	265	163	271	1947.92	1961.06	1953.45	1952.44
102	266	164	271	1953.88	1967.63	1959.68	1958.26
102	267	165	271	1959.76	1972.63	1964.46	1962.46
102	268	166	271	1965.56	1978.98	1970.47	1968.05
102	269	167	271	1971.27	1983.76	1975.03	1972.18
102	270	168	271	1976.90	1989.91	1980.83	1977.77
102	271	169	271	1982.44	1994.49	1985.19	1981.74
10	27	17	271	1987.9	2000.42	1990.77	1987.1

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102	273	171	271	1993.28	2004.81	1994.92	1991.30
102	274	172	271	1998.58	2010.54	2000.30	1996.64
102	275	173	271	2003.79	2014.72	2004.25	2000.67
102	276	174	271	2008.92	2020.26	2009.42	2005.81
102	277	175	271	2013.97	2024.26	2013.17	2009.55
102	278	176	271	2018.93	2029.60	2018.15	2014.26
102	279	177	271	2023.81	2033.41	2021.71	2017.85
102	280	178	271	2028.61	2038.56	2026.49	2022.59
102	281	179	271	2033.32	2042.18	2029.86	2025.66
102	282	180	271	2037.95	2047.15	2034.44	2029.87
102	283	181	271	2042.50	2050.60	2037.63	2033.01
102	284	182	271	2046.97	2055.38	2042.03	2037.22
102	285	183	271	2051.35	2058.65	2045.03	2040.23
102	286	184	271	2055.65	2063.26	2049.24	2044.19
102	287	185	271	2059.86	2066.36	2052.07	2046.25
102	288	186	271	2063.99	2070.79	2056.10	2049.79
102	289	187	271	2068.04	2073.72	2058.75	2051.89
102	290	188	271	2072.01	2077.98	2062.60	2055.39
102	291	189	271	2075.89	2080.75	2065.08	2057.61
102	292	190	271	2079.69	2084.85	2068.76	2061.38
102	293	191	271	2083.41	2087.45	2071.07	2063.75

102	294	192	271	2087.04	2091.38	2074.58	2067.43
102	295	193	271	2090.59	2093.83	2076.72	2069.61
102	296	194	271	2094.06	2097.60	2080.06	2073.02
102	297	195	271	2097.45	2099.90	2082.04	2075.05
102	298	196	271	2100.75	2103.51	2085.22	2078.41
102	299	197	271	2103.97	2105.65	2087.04	2080.34
102	300	198	271	2107.11	2109.11	2090.05	2083.66
102	301	199	271	2110.16	2111.10	2091.72	2085.53
102	302	200	271	2113.13	2114.41	2094.57	2088.67
102	303	201	271	2116.02	2116.26	2096.09	2090.40
102	304	202	271	2118.83	2119.42	2098.78	2093.37
102	305	203	271	2121.55	2121.12	2100.14	2094.78
102	306	204	271	2124.19	2124.14	2102.69	2097.32
102	307	205	271	2126.74	2125.70	2103.90	2098.48
102	308	206	271	2129.22	2128.57	2106.30	2100.75
102	309	207	271	2131.61	2130.00	2107.36	2101.71
102	310	208	271	2133.92	2132.73	2109.61	2103.97
102	311	209	271	2136.14	2134.03	2110.53	2104.83
102	312	210	271	2138.29	2136.62	2112.63	2107.11
102	313	211	271	2140.35	2137.79	2113.42	2107.92
102	314	212	271	2142.32	2140.24	2115.37	2109.77
102	315	213	271	2144.21	2141.28	2116.02	2110.51

2	5	3		2			1
102	316	214	271	2146.03	2143.60	2117.84	2112.46
102	317	215	271	2147.76	2144.51	2118.35	2113.11
102	318	216	271	2149.41	2146.71	2120.03	2115.00
102	319	217	271	2150.97	2147.49	2120.40	2115.59
102	320	218	271	2152.45	2149.56	2121.94	2117.29
102	321	219	271	2153.85	2150.22	2122.19	2117.72
102	322	220	271	2155.17	2152.17	2123.60	2119.23
102	323	221	271	2156.40	2152.71	2123.72	2119.50
102	324	222	271	2157.55	2154.53	2124.99	2120.71
102	325	223	271	2158.62	2154.96	2124.99	2120.60
102	326	224	271	2159.61	2156.65	2126.13	2121.64
102	327	225	271	2160.51	2156.97	2126.00	2121.46
102	328	226	271	2161.33	2158.55	2127.02	2122.38
102	329	227	271	2162.07	2158.74	2126.76	2122.11
102	330	228	271	2162.72	2160.21	2127.66	2122.90
102	331	229	271	2163.29	2160.30	2127.28	2122.38
102	332	230	271	2163.78	2161.65	2128.06	2123.02
102	333	231	271	2164.19	2161.62	2127.56	2122.52
102	334	232	271	2164.52	2162.86	2128.22	2123.06
102	335	233	271	2164.76	2162.73	2127.60	2122.39
102	336	234	271	2164.92	2163.86	2128.14	2122.53

Z	A	N	Estimated mean mass number close to stability	Estimated BE (MeV)	SEMF-1 BE (MeV)	SEMF-2 BE (MeV)	FRDM 2012 BE (MeV)
112	262	150	305	1862.00	1875.98	1874.47	1875.59
112	263	151	305	1870.19	1884.59	1882.84	1884.10
112	264	152	305	1878.31	1894.54	1892.44	1893.86
112	265	153	305	1886.35	1902.89	1900.55	1901.83
112	266	154	305	1894.32	1912.57	1909.88	1911.32
112	267	155	305	1902.21	1920.66	1917.73	1919.13
112	268	156	305	1910.03	1930.08	1926.79	1928.33
112	269	157	305	1917.77	1937.91	1934.39	1935.98
112	270	158	305	1925.43	1947.08	1943.20	1945.05
112	271	159	305	1933.02	1954.66	1950.54	1952.51
112	272	160	305	1940.54	1963.58	1959.10	1961.42
112	273	161	305	1947.98	1970.93	1966.20	1968.67
112	274	162	305	1955.35	1979.60	1974.51	1977.29
112	275	163	305	1962.64	1986.71	1981.38	1984.07
112	276	164	305	1969.85	1995.14	1989.45	1991.96
112	277	165	305	1976.99	2002.01	1996.07	1998.13
112	278	166	305	1984.05	2010.22	2003.91	2005.54
112	279	167	305	1991.04	2016.86	2010.31	2011.65
112	280	168	305	1997.96	2024.83	2017.91	2019.20

112	281	169	305	2004.80	2031.26	2024.08	2025.50
112	282	170	305	2011.56	2039.01	2031.45	2033.11
112	283	171	305	2018.25	2045.22	2037.41	2039.21
112	284	172	305	2024.86	2052.74	2044.55	2046.49
112	285	173	305	2031.40	2058.74	2050.29	2052.34
112	286	174	305	2037.86	2066.05	2057.22	2059.36
112	287	175	305	2044.25	2071.84	2062.74	2064.93
112	288	176	305	2050.57	2078.94	2069.46	2071.54
112	289	177	305	2056.80	2084.53	2074.77	2076.86
112	290	178	305	2062.97	2091.42	2081.28	2083.50
112	291	179	305	2069.06	2096.81	2086.39	2088.66
112	292	180	305	2075.07	2103.50	2092.69	2094.83
112	293	181	305	2081.01	2108.69	2097.60	2099.70
112	294	182	305	2086.87	2115.18	2103.69	2105.55
112	295	183	305	2092.66	2120.18	2108.40	2110.04
112	296	184	305	2098.37	2126.48	2114.30	2115.50
112	297	185	305	2104.01	2131.29	2118.82	2118.80
112	298	186	305	2109.57	2137.40	2124.52	2123.89
112	299	187	305	2115.06	2142.03	2128.85	2126.78
112	300	188	305	2120.48	2147.95	2134.36	2131.67
112	301	189	305	2125.81	2152.40	2138.50	2134.56
11	30	19	305	2131.0	2158.14	2143.82	2139.2

2	2	0		8			5
112	303	191	305	2136.27	2162.41	2147.78	2142.33
112	304	192	305	2141.38	2167.97	2152.91	2146.97
112	305	193	305	2146.42	2172.07	2156.69	2150.15
112	306	194	305	2151.38	2177.46	2161.65	2154.73
112	307	195	305	2156.27	2181.38	2165.25	2160.97
112	308	196	305	2161.09	2186.60	2170.02	2163.56
112	309	197	305	2165.83	2190.36	2173.46	2167.07
112	310	198	305	2170.49	2195.40	2178.05	2171.88
112	311	199	305	2175.08	2199.00	2181.32	2175.32
112	312	200	305	2179.60	2203.88	2185.74	2180.01
112	313	201	305	2184.04	2207.32	2188.83	2183.26
112	314	202	305	2188.40	2212.03	2193.09	2187.65
112	315	203	305	2192.69	2215.31	2196.02	2190.44
112	316	204	305	2196.91	2219.87	2200.11	2194.44
112	317	205	305	2201.05	2223.00	2202.88	2197.04
112	318	206	305	2205.12	2227.39	2206.80	2200.87
112	319	207	305	2209.11	2230.37	2209.41	2203.42
112	320	208	305	2213.03	2234.61	2213.18	2207.18
112	321	209	305	2216.87	2237.44	2215.63	2209.71
112	322	210	305	2220.64	2241.54	2219.24	2213.32
112	323	211	305	2224.33	2244.22	2221.54	2215.73

112	324	212	305	2227.95	2248.16	2224.99	2219.19
112	325	213	305	2231.49	2250.70	2227.14	2221.35
112	326	214	305	2234.96	2254.50	2230.44	2224.76
112	327	215	305	2238.36	2256.90	2232.44	2226.91
112	328	216	305	2241.68	2260.56	2235.59	2230.33
112	329	217	305	2244.92	2262.82	2237.45	2232.31
112	330	218	305	2248.09	2266.34	2240.44	2235.52
112	331	219	305	2251.19	2268.46	2242.16	2237.23
112	332	220	305	2254.21	2271.84	2245.01	2240.21
112	333	221	305	2257.16	2273.84	2246.59	2241.99
112	334	222	305	2260.03	2277.08	2249.30	2244.87
112	335	223	305	2262.83	2278.94	2250.73	2246.26
112	336	224	305	2265.55	2282.05	2253.30	2249.48
112	337	225	305	2268.20	2283.79	2254.60	2251.39
112	338	226	305	2270.77	2286.77	2257.03	2254.92
112	339	227	305	2273.27	2288.38	2258.20	2256.95

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