4G Model of Heavy Electroweak Charged 585 GeV Fermions as the Supposed Microscopic Origin of the 1.17 TeV All-Electron Spectral Break

U. V. S. Seshavatharam[1,2*], S. Lakshminarayana[3] and T. Gunavardhana Naidu[4]

[1]Honorary faculty, I-SERVE, Survey no-42, Hitech city, Hyderabad-500084,Telangana, India
[2]Quality Assurance Dept, DIP Division, Electrosteel Castings Ltd, Srikalahasthi-517641, AP, India
[3]Dept. of Nuclear Physics, Andhra University, Visakhapatnam-530003, AP, India
[4]Dept. of Physics, Aditya Institute of Technology and Management, Tekkali-532201, AP, India
*Corresponding author E-mail: Seshavatharam.uvs@gmail.com

Abstract: The 4G model of final unification postulates a heavy electroweak charged fermion with rest energy 585 GeV as a fundamental constituent elucidating nuclear structure through novel relations based on elementary mass ratios, three distinct atomic gravitational constants, and a new elementary nuclear charge. Furthermore, the dimensionless ratio 0.0016, approximately equal to the proton mass divided by 585 GeV, and also equal to the geometric mean of charged and neutral pion masses (about 137.26 MeV) divided by the geometric mean of weak boson masses (about 85.6 GeV), organizes nuclear stability and binding-energy systematics, suggesting a common 4G scale imprint across micro and electroweak physics. Recent high-statistics H.E.S.S. measurements of the cosmic-ray all-electron spectrum reveal a sharp spectral break at 1.17 TeV, where the power-law index steepens from 3.25 to 4.49, confirmed independently by DAMPE and CALET softening above ~1 TeV. This observed break energy coincides precisely with twice the 585 GeV fermion mass, suggesting that weakly bound or resonant fermion-antifermion states, forming an electroweak doublet of charged and neutral components analogous to the nearly-degenerate Higgsino triplet in SUSY models at ~1.1 TeV, serve as dominant TeV-scale injectors of electrons and positrons into the Galactic interstellar medium. Totani infers a neutral particle in the 500–800 GeV range from 20 GeV Galactic halo gamma excess, analogous to proton/neutron degeneracy, precisely matching the 4G neutral component at 585 GeV. We propose that annihilation or decay of these 1.17 TeV composites via channels such as electron-positron pairs, muon-antimuon pairs, or W^+W^-/ZZ produces an injected spectrum that, after standard diffusion, synchrotron, and inverse-Compton losses, reproduces H.E.S.S.'s smooth broken power law up to 40 TeV. This microscopic origin aligns with supernova remnant source-break models while predicting suppressed gamma-ray lines consistent with Fermi-LAT/H.E.S.S. limits, testable via electron anisotropy measurements and combined dataset spectral residuals. We identify four converging lines of evidence that motivate the hypothesis of a 585 GeV electroweak fermion and outline observational tests to confirm or refute it. If confirmed by combined spectral fits, anisotropy searches, and consistency with gamma-ray and collider limits, the 585 GeV 4G fermion hypothesis would provide a unified microscopic explanation for nuclear phenomenology and the 1.17 TeV all-electron break, motivating targeted searches across astrophysical and accelerator datasets.

Keywords: 4G model of final unification; 585 GeV electroweak fermion; H.E.S.S. 1.17 TeV break; DAMPE, CALET results; Fermion-antifermion states; Higgsino-like doublet; Cosmic-ray electron spectrum; Galactic gamma excess; nuclear structure;

Scientific Foundations of the 4G Model of Final Unification: Our New Approach

Historical Intellectual Lineage of the 4G Model

The 4G model of final unification builds upon the pioneering theoretical frameworks established by several visionary physicists over nearly five decades. K. Tennakone first introduced the concept of gravitational effects at microscopic scales, while C. Sivaram and K. Sinha established the foundational connection between strong gravity and elementary particles through their 'Strong Gravity, Black Holes, and Hadrons' framework. Subsequently, A. Salam and C. Sivaram developed strong gravity approaches to QCD and confinement, and De Sabbata and associates explored spin-torsion interactions linking gravitation to fundamental forces. The modern impetus came from S. W. Hawking's black hole thermodynamics and O. R. Onofrio's proposal that weak interactions manifest as short-distance gravity with extraordinarily large coupling constants [1-6]. These foundational insights motivated the systematic development of the present 4G model, which unifies three distinct atomic gravitational constants corresponding to electromagnetic, strong nuclear, and weak interactions, culminating in the prediction of the 585 GeV electroweak fermion and its correspondence with modern dark matter theories [7-26].

Assumptions and Applications

Following our 4G model of final unification,

1) There exists a characteristic electroweak fermion of rest energy, $M_{wf}c^2 \cong 584.725$ 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 [27,28] and $e_n \cong 2.9464e$.
3) Each atomic interaction is associated with a characteristic large gravitational coupling constant. Their fitted magnitudes are,

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

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

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

It may be noted that,

1) In a unified approach, most important point to be noted is that [26],

$$\hbar c \equiv G_w M_{wf}^2 \tag{1}$$

Clearly speaking, based on the electroweak interaction, the well believed quantum constant $\hbar c$ seems to have a deep inner meaning. Following this kind of relation, there is a possibility to understand the integral nature of quantum mechanics with a relation of the form, $n^2\hbar \equiv \frac{G_w\left(nM_{wf}\right)^2}{c}$ where $n = 1,2,3,..$

It needs further study with reference to EPR argument and String theory [29,30] can be made practical with reference to the three atomic gravitational constants associated with weak, strong and electromagnetic interaction gravitational constants. See Table 1. and Table 2. for sample string tensions and energies without any coupling constants.

Table.1 Charge dependent string tensions and string energies

S.No	Interaction	String Tension	String energy
1	Weak	$\frac{c^4}{4G_w} \cong 6.94\times10^{10}$ N	$\sqrt{\frac{e^2}{4\pi\varepsilon_0}\left(\frac{c^4}{4G_w}\right)} \cong 24.975$ GeV
2	Strong	$\frac{c^4}{4G_n} \cong 6.065\times10^{4}$ N	$\sqrt{\frac{e_n^2}{4\pi\varepsilon_0}\left(\frac{c^4}{4G_n}\right)} \cong 68.79$ MeV
3	Electromagnetic	$\frac{c^4}{4G_e} \cong 8.505\times10^{-5}$ N	$\sqrt{\frac{e^2}{4\pi\varepsilon_0}\left(\frac{c^4}{4G_e}\right)} \cong 874.3$ eV

Table.2 Quantum string tensions and string energies

S.No	Interaction	String Tension	String energy
1	Weak	$\frac{c^4}{4G_w} \cong 6.94\times10^{10}$ N	$\sqrt{hc\left(\frac{c^4}{4G_w}\right)} \cong 292.36$ GeV
2	Strong	$\frac{c^4}{4G_n} \cong 6.065\times10^{4}$ N	$\sqrt{hc\left(\frac{c^4}{4G_n}\right)} \cong 273.3$ MeV
3	Electromagnetic	$\frac{c^4}{4G_e} \cong 8.505\times10^{-5}$ N	$\sqrt{hc\left(\frac{c^4}{4G_e}\right)} \cong 10234.77$ eV

2) Weak interaction point of view [31,32], following our assumptions, Fermi's weak coupling constant can be fitted with the following relations.

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

Building on and extending traditional string theory, the discussed 4G model of final unification introduces three distinct large atomic gravitational constants corresponding to the three atomic interactions:

a) The electromagnetic gravitational constant

b) The nuclear (strong) gravitational constant

c) The electroweak gravitational constant

Central to this model is the theoretical proposal of a new fundamental weak fermion with rest energy near 585 GeV, considered the progenitor ("zygote") of all elementary particles. This concept introduces a "field-generating" weak fermion analogous in role to the electron and proton in electromagnetic and nuclear interactions, respectively.

By embedding these three large atomic gravitational constants into the string-theoretic framework, the model formulates a cohesive structure in which the quantum behaviour, nuclear stability, fundamental constants, and particle masses arise naturally from string vibrational modes influenced by these large gravitational couplings.

Key formulae derived (as shown in Tables 1 and 2 of the paper) relate charge-dependent string tensions and energies with the weak, strong, and electromagnetic interactions directly, providing a physically grounded basis rather than purely abstract mathematics. This contrasts with conventional string theory formulations lacking such explicit empirical connections.

Using this approach, the model quantitatively fits fundamental constants including Planck's constant, neutron lifetime, nuclear binding energies, and coupling constants, marking a substantial advancement toward rendering string theory experimentally relevant and engineering-applicable.

Combined Quantum String Energies for Weak Interaction

The 4G model presents a nuanced view of the quantum string energies associated with the weak interaction through two complementary energy scales. From Table 1, the charge-dependent string energy quantum for the weak interaction is approximately 25 GeV. This energy scale reflects fundamental units tied to the weak interaction's gravitational constant and the specific charge dependencies within the string framework.

In parallel, Table 2 identifies a significantly higher quantum string energy of about 292.36 GeV for the weak interaction. This larger quantum is linked more directly to the vibrational modes of strings governed by the electroweak gravitational constant, incorporating fundamental constants such as Planck's constant. It represents the principal energy scale of string excitations in the weak interaction domain.

Together, these two energy scales establish a hierarchical spectrum of quantum string energies for the weak interaction. The lower 25 GeV quantum likely governs charge-related phenomena, while the higher 292 GeV quantum corresponds to intrinsic string vibrational states. This dual-scale energy framework supports the existence of a heavy electroweak fermion around 585 GeV, interpreted as the progenitor or "zygote" of elementary particles.

Under extreme physical environments, such as those present near black holes or in galactic centers, these quantum string energies manifest as a zoo of elementary weak interaction particles, contributing to observed high-energy astrophysical phenomena. This combined perspective extends the 4G model's explanatory reach by linking charge-dependent effects and fundamental string vibrations into a cohesive theory of weak particle physics and cosmic processes.

The weak interaction uniquely enables the production of ultra-high-energy particles due to its association with significantly larger quantum string energy scales, approximately 25 GeV and 292 GeV, when compared to electromagnetic and strong interactions. This distinctive feature underpins the existence of heavy electroweak fermions near 585 GeV and their composite states around 1.17 TeV, which play a central role in generating high-energy leptons observed in cosmic-ray spectra [33-37]. In contrast, electromagnetic and strong interactions, operating at substantially lower energy scales, do not typically produce particles of such extraordinary energies. Consequently, the intrinsic high-energy nature of the weak interaction positions it as the primary source of a diverse zoo of elementary particles under extreme astrophysical

conditions, such as those found near black holes and galactic centers, as predicted by the 4G model and supported by experimental observations.

Practical Applications and Implications

This novel 4G string model holds promise across multiple domains of physics:

1) **Nuclear Mass Radii and Charge Radii**: Predicts nuclear mass radii and charge radii for stable and exotic nuclei through direct relations rooted in physical nuclear properties, without invoking arbitrary radii constants or empirical coefficients [38,39,40].

2) **Nuclear Stability and Binding Energy**: Predicts binding energies of stable nuclei with high precision, clarifying nuclear shell structures, decay probabilities, and "lighthouse" stable mass numbers not fully explained by classic semi-empirical formulas [41,42,43,44]. The 4G model predicts nuclear mass radii and charge radii for stable and exotic nuclei through direct relations rooted in physical nuclear properties, without invoking arbitrary radii constants or empirical coefficients.

3) **The Strong coupling constant**: The strong coupling constant α_s in the context of the 4G model of final unification is expressed as the squared ratio of the electromagnetic charge e to the nuclear charge e_n, $\alpha_s \cong (e/e_n)^2 \cong 0.1152$. It's most recent experimental values seem to be in the range of 0.115 to 0.118 [45,46,47].

   a) Here, e is the fundamental electromagnetic charge (electron charge), while e_n is the nuclear elementary charge defined in the 4G model as approximately $e_n \cong 2.9464e$. This larger nuclear charge reflects the stronger nature of the nuclear interaction compared to the electromagnetic interaction.
   b) This value aligns closely with the experimentally measured strong coupling constant at low energies, typically around 0.11 to 0.12, providing a meaningful physical interpretation of α_s within this unified model.
   c) This expression bridges electromagnetic and strong nuclear interactions quantitatively and supports the 4G model's integration of gravitational constants and fundamental charges into a coherent framework encompassing all three atomic interactions.
   d) Hence, the strong coupling constant is fundamentally tied to the ratio of elementary charges in the 4G unified approach, reinforcing the model's predictive and explanatory power in linking particle physics constants to underlying unification principles.

Nuclear scale confirmation of the existence of 585 GeV weak fermion:

A key phenomenological scaling factor appearing in our model is the ratio of the geometric mean of the charged and neutral pion masses (~137.26 MeV) to that of the weak boson masses (~85.61 GeV), which numerically evaluates to approximately 0.0016. This dimensionless ratio encapsulates the profound hierarchical gap between the strong interaction scale and the electroweak scale and forms a cornerstone of the mass relations underlying our 585 GeV electroweak fermion. Importantly, this ratio is not merely a numerical coincidence but has substantive implications for understanding nuclear stability and nuclear binding energy. The interplay of these fundamental mass scales suggests that the dynamics governing nuclear forces and nucleon interactions may be intimately connected to electroweak-scale physics mediated by the 585 GeV fermion. For a deeper exploration of how this mass ratio informs nuclear binding mechanisms and stability criteria, interested readers are encouraged to refer our recent preprints and other peer-reviewed publications, where these connections are discussed in detail with complementary theoretical and phenomenological analyses.

$$\frac{m_p}{M_{wf}} \cong 0.001605 \cong \left(\frac{\sqrt{\left(m_\pi c^2\right)^0 \left(m_\pi c^2\right)^\pm}}{\sqrt{\left(m_w c^2\right)^\pm \left(m_z c^2\right)^0}} \right)$$
$$\cong \left(\frac{\sqrt{134.98 \times 139.57}\ \text{MeV}}{\sqrt{80379.0 \times 91187.6}\ \text{MeV}} \right) \cong 0.0016032 \cong \beta....(\text{say}) \quad (3)$$

Based on this electroweak coefficient $\beta \cong 0.001605$, stability corresponding to nuclear beta decay can be understood with the following relation [48].

$$A_s \cong 2Z + \beta(2Z)^2 \cong 2Z + 0.00642Z^2 \tag{4}$$

$$\frac{A_s - 2Z}{(2Z)^2} \cong \frac{A_s - 2Z}{4Z^2} \cong \beta \tag{5}$$

One can find a similar relation in the literature. This relation can be well tested for Z=21 to 92. For example,

$$\frac{45-(2\times 21)}{4(21)^2} \cong 0.00170; \quad \frac{63-(2\times 29)}{4(29)^2} \cong 0.00149; \quad \frac{89-(2\times 39)}{4(39)^2} \cong 0.00181;$$
$$\frac{109-(2\times 47)}{4(47)^2} \cong 0.0017; \quad \frac{169-(2\times 69)}{4(69)^2} \cong 0.00163; \quad \frac{238-(2\times 92)}{4(92)^2} \cong 0.001595;$$

This is one best practical and quantitative application of our proposed electroweak fermion and bosons. Following this relation and based on various semi empirical mass formulae, by knowing any stable mass number, its corresponding proton number can be estimated with,

$$Z \cong \frac{A_S}{1+\sqrt{1+0.0064A_S}} \cong \frac{A_S}{2+0.0153A_S^{2/3}} \tag{6}$$

where $\frac{a_c}{2a_{asy}} \cong \frac{0.71 \text{ MeV}}{2\times 23.21 \text{ MeV}} \cong \frac{0.6615 \text{ MeV}}{2\times 21.6091 \text{ MeV}} \cong 0.0153$

Considering this relation, we are working on understanding the stable super heavy elements.
Proceeding further, without considering the total binding energy of nucleons, for the case of isobaric mass numbers, 'maximum binding energy per nucleon' for medium and heavy atomic nuclides can be expressed as,

$$\left\langle \frac{BE}{A_s} \right\rangle_{\max} \cong \left[1 - \frac{\exp(A_s\beta)-1}{3}\right] \times (9.1 \pm 0.05) \text{ MeV}$$

where $A > 56$

$$\left(\frac{3}{5}\right)\frac{e_n^2}{4\pi\varepsilon_0 R_p} \cong \left(\frac{3}{5\alpha_s}\right)\frac{e^2}{4\pi\varepsilon_0(0.83 \text{ fm})} \cong 9.04 \text{ MeV} \tag{7}$$

$\cong$ Nuclear charge realted self energy of proton

where, $R_p \cong$ Root mean square radius of proton [49,50] $\cong 0.83$ fm

$$Z \approx \frac{A_s}{1+\sqrt{1+0.00642A_s}} \approx \frac{A_s}{2+0.015A_s^{2/3}}$$

Maximum binding energy per nucleon for light atomic nuclides can be expressed as,

$$\left\langle \frac{BE}{A_s} \right\rangle_{\max} \cong \left(\frac{A_s}{56}\right)^{\alpha_s} \times \left(1 - \left(\frac{\exp(A_s\beta)-1}{3}\right)\right) \times (9.1 \pm 0.05) \text{ MeV} \tag{8}$$

where, $4 \le A \le 56$ and $\alpha_s \cong$ Strong coupling contsant $\cong 0.1152$

Accuracy point of view, for light, medium and heavy atomic nuclides, energy coefficient seems to be around 9.15 MeV and for super heavy atomic nuclides, energy coefficient seems to be around 9.05 MeV. See the following Table 3 for the estimated data. It needs further study.

With marginal error, nuclear binding energy can be understood with the following advanced strong and electroweak formula having 5 simple terms and one energy coefficient [51,52,53,54]. For Z > 1,

$$(BE)_{A,Z} \cong \left[A - A_{radius} - A_{free} - A_{asy} + A_{pair} \right] \left(B_0 \cong 10.1 \text{ MeV} \right) \tag{9}$$

where, $A_{radius} \cong A^{1/3}$ $I \cong \left(\frac{N-Z}{A} \right)$; $A_{asy} \cong \left(\left(1-I^2\right) \frac{\left(A_s - A\right)^2}{A_s} \right)$ ≅ Asymmetry term about A_s $A_{pair} \cong \frac{(-1)^Z + (-1)^N}{2\sqrt{A}}$ ≅ Pairing energy term

$$A_{free} \cong \left\{ \frac{1}{2} + \left[\left(c_{ew}\right)_Z \times 0.0016 \left(Z^2 \left(1 + 0.5 \left(\frac{Z}{N} \right)^5 \right) + N^2 \left(1 - I^2\right) \right) \right] \right\}$$

≅ No. of free nucleons associted with weak interaction.

where,

$\left(c_{ew}\right)_Z \cong$ Electroweak coefficient of 'Z'.

≈ 2 for Z=(1 to 11)

≈ 1.5 for Z=(12 to 17)

≈ 1.25 for Z=(18 to 21)

$\approx \left[\left(1 + \sqrt{\frac{156 - Z}{156}} \right)^{1/3} - \frac{1}{2\sqrt{Z}} \right]$ for Z > 21

where $156 \approx \frac{1}{4 \times 0.0016} \cong 156.25$

$$B_0 \cong -\frac{e_n^2}{4\pi\varepsilon_0 R_0} \cong -\left(\frac{1}{\alpha_s} \right) \frac{e^2}{4\pi\varepsilon_0 R_0} \cong 10.1 \text{ MeV}$$

where

$e_n \cong$ Nuclear elementary charge $\cong 2.9464e$

$\alpha_s \cong$ Strong coupling constant

$\cong 0.115$ to 0.12

$R_0 \cong (1.24 \text{ to } 1.25)$ fm

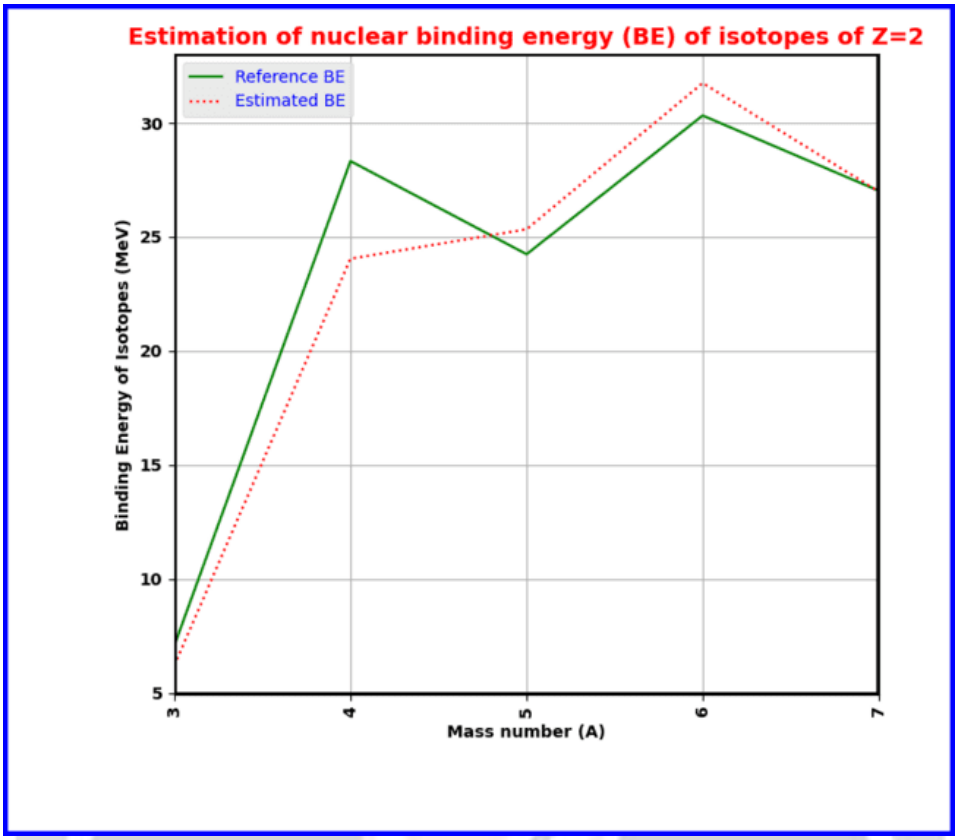

Figure 1:Isotopic binding energy of Z=2

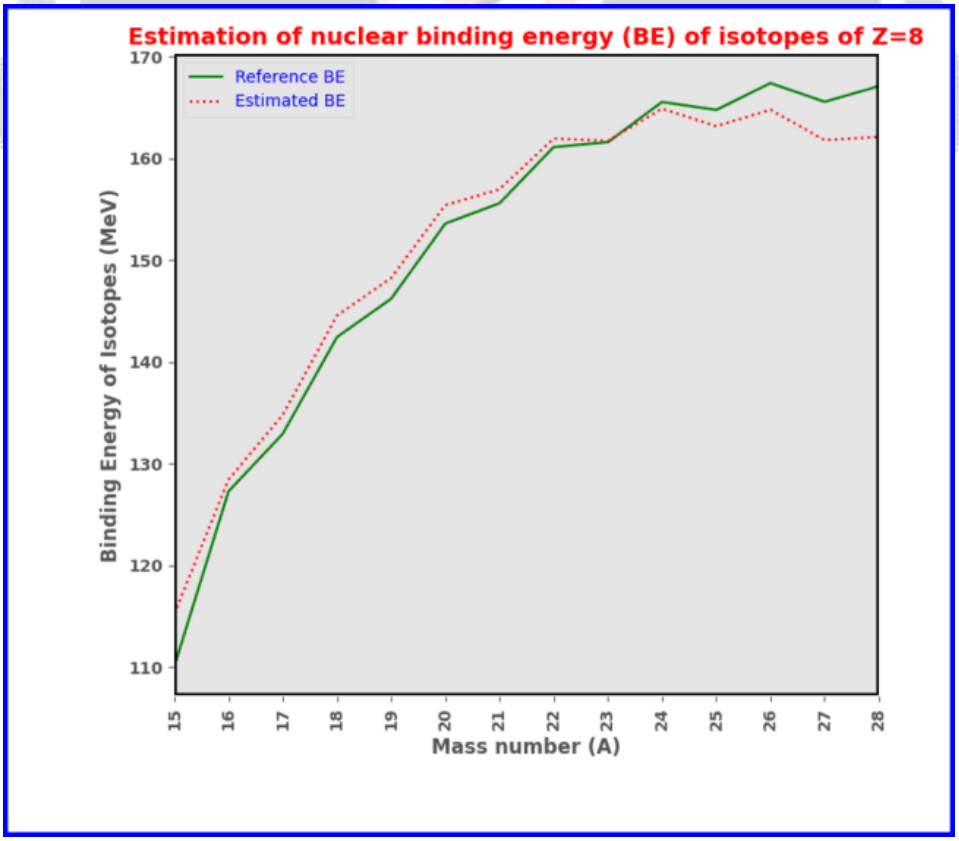

Figure 2:Isotopic binding energy of Z=8

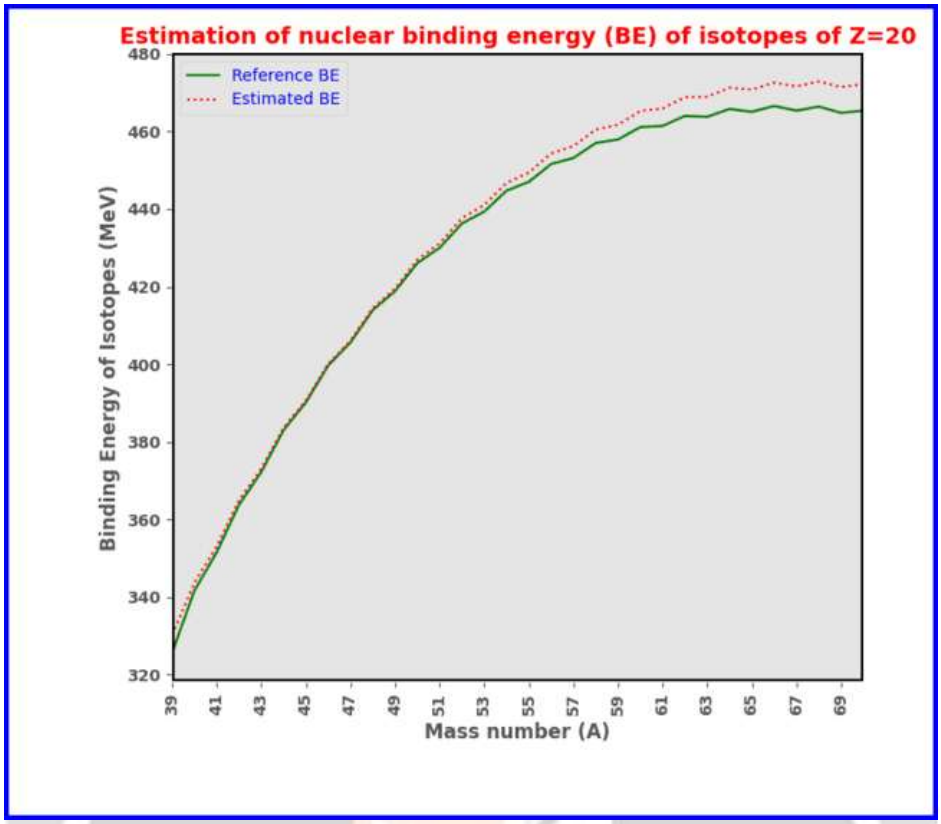

Figure 3:Isotopic binding energy of Z=20

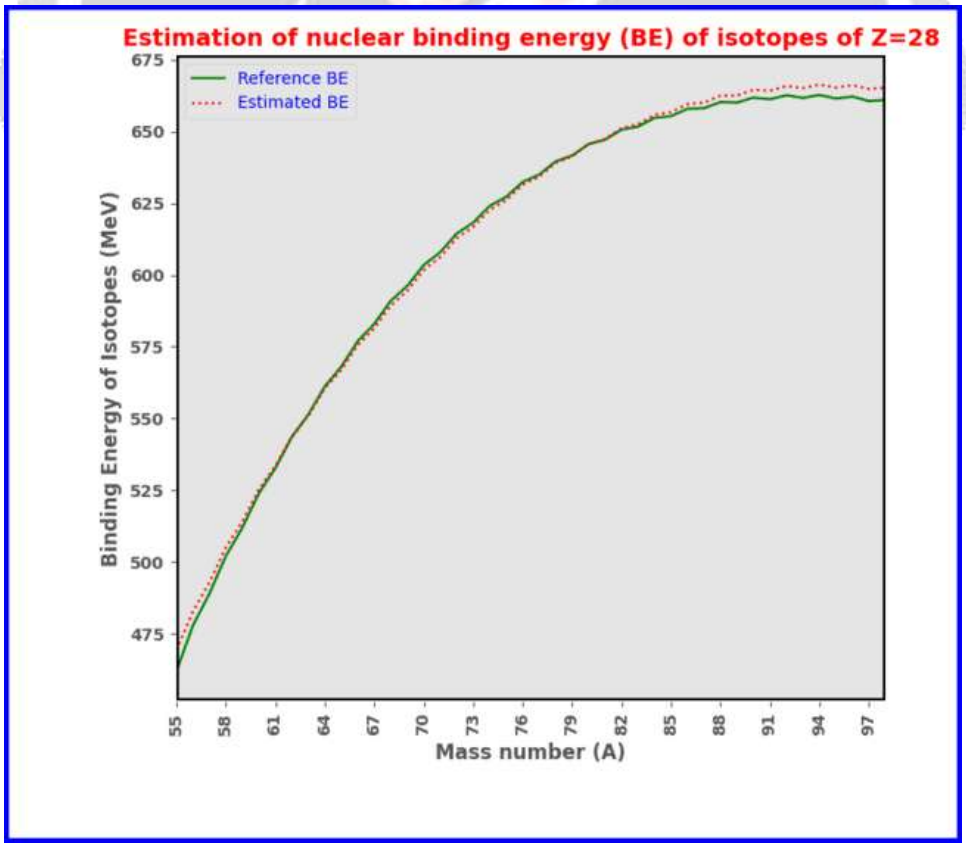

Figure 4:Isotopic binding energy of Z=28

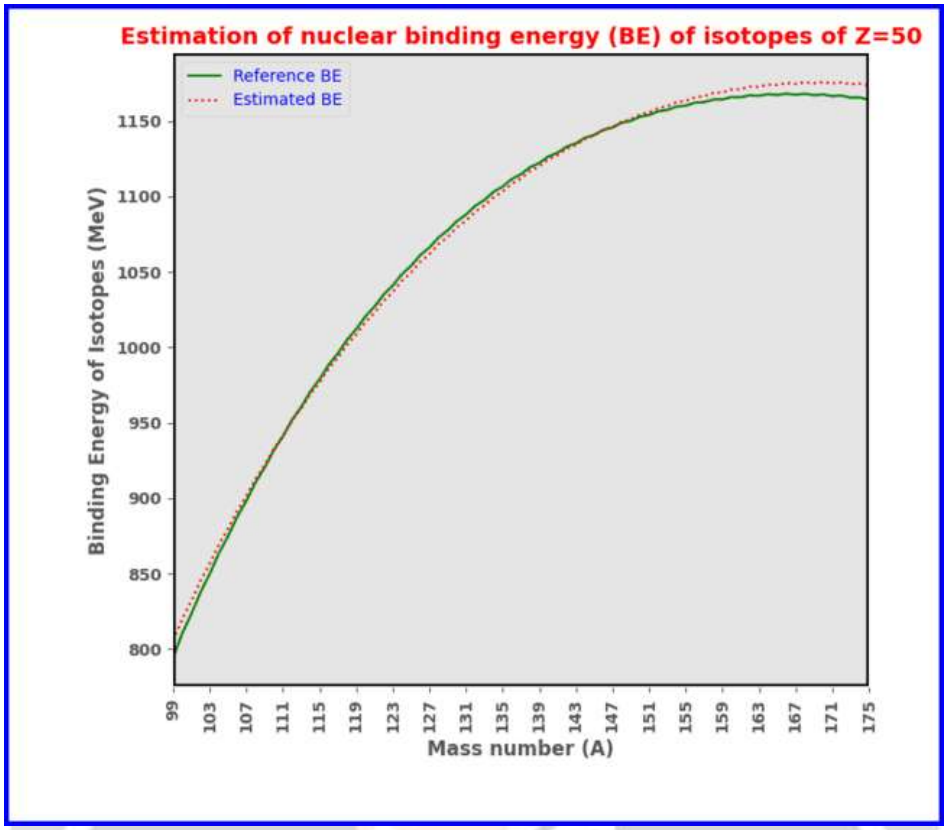

Figure 5:Isotopic binding energy of Z=50

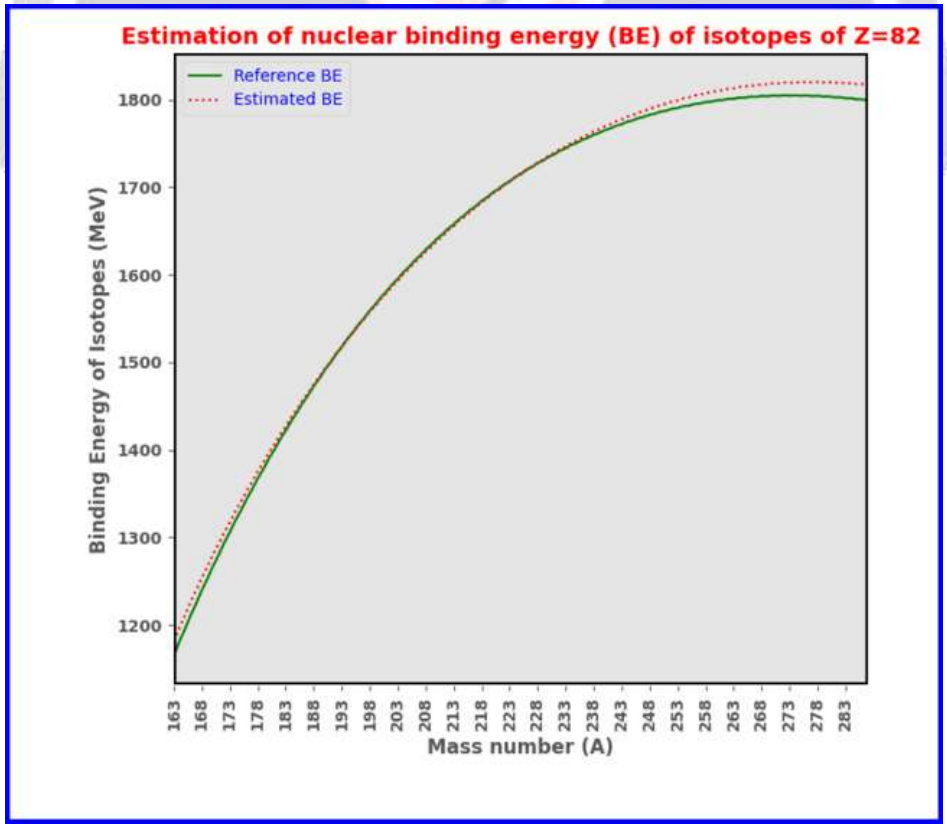

Figure 6:Isotopic binding energy of Z=82

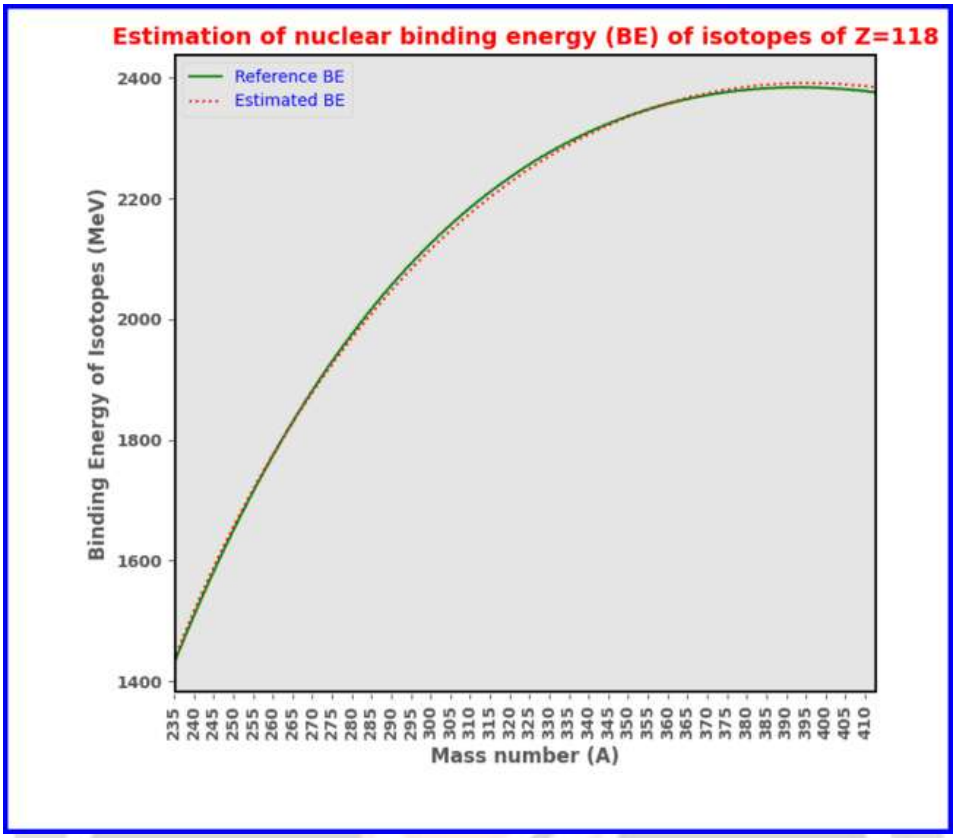

Figure 7:Isotopic binding energy of Z=118

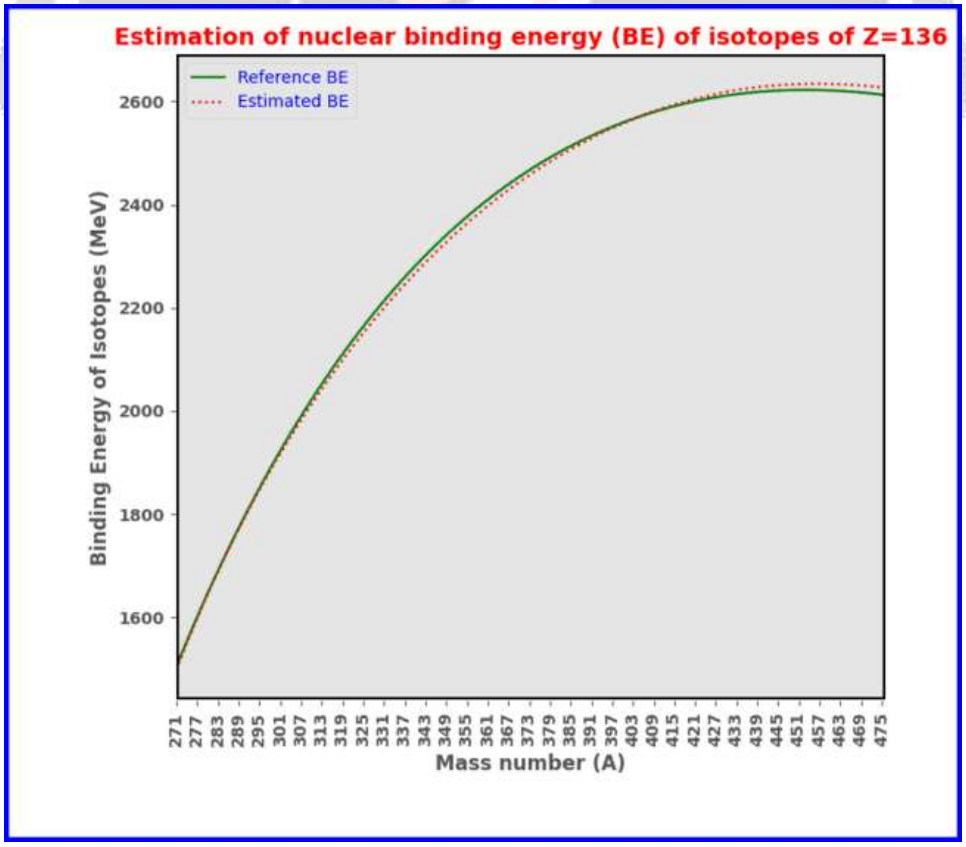

Figure 8:Isotopic binding energy of Z=136

Table 3. Estimated maximum binding energy per nucleon of assumed stable mass numbers								
Assumed stable mass number A	Estimated maximum binding energy per nucleon (MeV)	Estimated maximum binding energy (MeV)	Estimated Stable Z		Assumed stable mass number A	Estimated maximum binding energy per nucleon (MeV)	Estimated maximum binding energy (MeV)	Estimated Stable Z
4	6.7	26.8	2		179	8.09	1448.19	73
5	6.87	34.35	2		180	8.08	1455.11	73
6	7.01	42.08	3		181	8.08	1462.02	73
7	7.13	49.94	3		182	8.07	1468.91	74
8	7.24	57.93	4		183	8.06	1475.79	74
9	7.34	66.03	4		184	8.06	1482.65	74
10	7.42	74.22	5		185	8.05	1489.5	75
11	7.5	82.49	5		186	8.04	1496.33	75
12	7.57	90.85	6		187	8.04	1503.15	75
13	7.64	99.28	6		188	8.03	1509.95	76
14	7.7	107.77	7		189	8.03	1516.73	76
15	7.76	116.33	7		190	8.02	1523.5	76
16	7.81	124.94	8		191	8.01	1530.26	77
17	7.86	133.61	8		192	8.01	1537	77
18	7.91	142.32	9		193	8	1543.73	77
19	7.95	151.08	9		194	7.99	1550.44	78
20	7.99	159.89	10		195	7.99	1557.13	78
21	8.03	168.73	10		196	7.98	1563.81	78
22	8.07	177.62	11		197	7.97	1570.47	79
23	8.11	186.54	11		198	7.97	1577.12	79
24	8.15	195.5	12		199	7.96	1583.76	79
25	8.18	204.49	12		200	7.95	1590.37	80
26	8.21	213.51	13		201	7.95	1596.98	80
27	8.24	222.56	13		202	7.94	1603.56	80
28	8.27	231.64	13		203	7.93	1610.13	81
29	8.3	240.75	14		204	7.92	1616.69	81
30	8.33	249.88	14		205	7.92	1623.23	81
31	8.36	259.04	15		206	7.91	1629.75	82
32	8.38	268.22	15		207	7.9	1636.26	82
33	8.41	277.43	16		208	7.9	1642.75	82
34	8.43	286.65	16		209	7.89	1649.22	83
35	8.45	295.9	17		210	7.88	1655.68	83
36	8.48	305.17	17		211	7.88	1662.13	83
37	8.5	314.46	18		212	7.87	1668.56	84
38	8.52	323.76	18		213	7.86	1674.97	84
39	8.54	333.08	18		214	7.86	1681.36	84
40	8.56	342.42	19		215	7.85	1687.74	85
41	8.58	351.78	19		216	7.84	1694.11	85
42	8.6	361.15	20		217	7.84	1700.46	85
43	8.62	370.53	20		218	7.83	1706.79	86
44	8.63	379.93	21		219	7.82	1713.1	86
45	8.65	389.34	21		220	7.82	1719.4	86
46	8.67	398.77	22		221	7.81	1725.68	87
47	8.69	408.21	22		222	7.8	1731.95	87
48	8.7	417.66	22		223	7.79	1738.2	87
49	8.72	427.12	23		224	7.79	1744.43	88
50	8.73	436.59	23		225	7.78	1750.65	88
51	8.75	446.07	24		226	7.77	1756.85	88
52	8.76	455.56	24		227	7.77	1763.04	88
53	8.77	465.07	25		228	7.76	1769.2	89
54	8.79	474.58	25		229	7.75	1775.35	89

55	8.8	484.1	25		230	7.75	1781.49	89
56	8.81	493.63	26		231	7.74	1787.61	90
57	8.81	502.14	26		232	7.73	1793.71	90
58	8.8	510.64	27		233	7.72	1799.79	90
59	8.8	519.12	27		234	7.72	1805.86	91
60	8.79	527.6	28		235	7.71	1811.91	91
61	8.79	536.07	28		236	7.7	1817.94	91
62	8.78	544.52	28		237	7.7	1823.96	92
63	8.78	552.97	29		238	7.69	1829.96	92
64	8.77	561.4	29		239	7.68	1835.94	92
65	8.77	569.82	30		240	7.67	1841.91	93
66	8.76	578.23	30		241	7.67	1847.86	93
67	8.76	586.63	31		242	7.66	1853.79	93
68	8.75	595.01	31		243	7.65	1859.7	94
69	8.74	603.39	31		244	7.65	1865.6	94
70	8.74	611.75	32		245	7.64	1871.48	94
71	8.73	620.1	32		246	7.63	1877.34	94
72	8.73	628.45	33		247	7.62	1883.19	95
73	8.72	636.77	33		248	7.62	1889.01	95
74	8.72	645.09	33		249	7.61	1894.82	95
75	8.71	653.4	34		250	7.6	1900.62	96
76	8.71	661.69	34		251	7.6	1906.39	96
77	8.7	669.98	35		252	7.59	1912.15	96
78	8.7	678.25	35		253	7.58	1917.89	97
79	8.69	686.51	35		254	7.57	1923.62	97
80	8.68	694.75	36		255	7.57	1929.32	97
81	8.68	702.99	36		256	7.56	1935.01	98
82	8.67	711.21	37		257	7.55	1940.68	98
83	8.67	719.42	37		258	7.54	1946.33	98
84	8.66	727.62	38		259	7.54	1951.97	98
85	8.66	735.81	38		260	7.53	1957.58	99
86	8.65	743.99	38		261	7.52	1963.18	99
87	8.65	752.15	39		262	7.51	1968.76	99
88	8.64	760.31	39		263	7.51	1974.33	100
89	8.63	768.45	40		264	7.5	1979.87	100
90	8.63	776.57	40		265	7.49	1985.4	100
91	8.62	784.69	40		266	7.48	1990.91	101
92	8.62	792.8	41		267	7.48	1996.4	101
93	8.61	800.89	41		268	7.47	2001.87	101
94	8.61	808.97	41		269	7.46	2007.33	102
95	8.6	817.04	42		270	7.45	2012.76	102
96	8.59	825.09	42		271	7.45	2018.18	102
97	8.59	833.13	43		272	7.44	2023.58	102
98	8.58	841.17	43		273	7.43	2028.96	103
99	8.58	849.18	43		274	7.42	2034.32	103
100	8.57	857.19	44		275	7.42	2039.67	103
101	8.57	865.18	44		276	7.41	2044.99	104
102	8.56	873.17	45		277	7.4	2050.3	104
103	8.55	881.14	45		278	7.39	2055.59	104
104	8.55	889.09	45		279	7.39	2060.86	105
105	8.54	897.04	46		280	7.38	2066.11	105
106	8.54	904.97	46		281	7.37	2071.35	105
107	8.53	912.89	47		282	7.36	2076.56	105
108	8.53	920.8	47		283	7.36	2081.76	106
109	8.52	928.69	47		284	7.35	2086.93	106
110	8.51	936.57	48		285	7.34	2092.09	106
111	8.51	944.44	48		286	7.33	2097.23	107
112	8.5	952.3	48		287	7.33	2102.35	107
113	8.5	960.14	49		288	7.32	2107.45	107

114	8.49	967.97	49		289	7.31	2112.53	108
115	8.49	975.79	50		290	7.3	2117.59	108
116	8.48	983.59	50		291	7.29	2122.64	108
117	8.47	991.39	50		292	7.29	2127.66	108
118	8.47	999.17	51		293	7.28	2132.67	109
119	8.46	1006.93	51		294	7.27	2137.65	109
120	8.46	1014.69	52		295	7.26	2142.62	109
121	8.45	1022.43	52		296	7.26	2147.57	110
122	8.44	1030.16	52		297	7.25	2152.5	110
123	8.44	1037.87	53		298	7.24	2157.41	110
124	8.43	1045.57	53		299	7.23	2162.29	110
125	8.43	1053.26	53		300	7.22	2167.16	111
126	8.42	1060.94	54		301	7.22	2172.01	111
127	8.41	1068.6	54		302	7.21	2176.85	111
128	8.41	1076.25	54		303	7.2	2181.66	112
129	8.4	1083.89	55		304	7.19	2186.45	112
130	8.4	1091.51	55		305	7.18	2191.22	112
131	8.39	1099.12	56		306	7.18	2195.97	113
132	8.38	1106.72	56		307	7.17	2200.7	113
133	8.38	1114.3	56		308	7.16	2205.42	113
134	8.37	1121.87	57		309	7.15	2210.11	113
135	8.37	1129.43	57		310	7.14	2214.78	114
136	8.36	1136.97	57		311	7.14	2219.43	114
137	8.35	1144.5	58		312	7.13	2224.06	114
138	8.35	1152.01	58		313	7.12	2228.68	115
139	8.34	1159.52	59		314	7.11	2233.27	115
140	8.34	1167.01	59		315	7.1	2237.84	115
141	8.33	1174.48	59		316	7.1	2242.39	115
142	8.32	1181.94	60		317	7.09	2246.92	116
143	8.32	1189.39	60		318	7.08	2251.43	116
144	8.31	1196.83	60		319	7.07	2255.92	116
145	8.31	1204.25	61		320	7.06	2260.39	117
146	8.3	1211.66	61		321	7.06	2264.84	117
147	8.29	1219.05	61		322	7.05	2269.27	117
148	8.29	1226.43	62		323	7.04	2273.68	117
149	8.28	1233.8	62		324	7.03	2278.07	118
150	8.27	1241.15	63		325	7.02	2282.44	118
151	8.27	1248.49	63		326	7.01	2286.78	118
152	8.26	1255.81	63		327	7.01	2291.11	119
153	8.26	1263.12	64		328	7	2295.42	119
154	8.25	1270.42	64		329	6.99	2299.7	119
155	8.24	1277.7	64		330	6.98	2303.96	119
156	8.24	1284.97	65		331	6.97	2308.21	120
157	8.23	1292.22	65		332	6.97	2312.43	120
158	8.22	1299.46	65		333	6.96	2316.63	120
159	8.22	1306.69	66		334	6.95	2320.81	121
160	8.21	1313.9	66		335	6.94	2324.97	121
161	8.21	1321.1	66		336	6.93	2329.1	121
162	8.2	1328.28	67		337	6.92	2333.22	121
163	8.19	1335.45	67		338	6.92	2337.32	122
164	8.19	1342.61	67		339	6.91	2341.39	122
165	8.18	1349.75	68		340	6.9	2345.44	122
166	8.17	1356.87	68		341	6.89	2349.47	122
167	8.17	1363.99	68		342	6.88	2353.48	123
168	8.16	1371.08	69		343	6.87	2357.47	123
169	8.15	1378.17	69		344	6.86	2361.44	123
170	8.15	1385.23	70		345	6.86	2365.38	124
171	8.14	1392.29	70		346	6.85	2369.3	124
172	8.14	1399.33	70		347	6.84	2373.21	124

173	8.13	1406.35	71		348	6.83	2377.09	124
174	8.12	1413.36	71		349	6.82	2380.94	125
175	8.12	1420.36	71		350	6.81	2384.78	125
176	8.11	1427.34	72		351	6.81	2388.59	125
177	8.1	1434.3	72		352	6.8	2392.39	126
178	8.1	1441.25	72		353	6.79	2396.16	126

Fundamental Charge Ratio, its related Fundamental Mass Ratios and Major Applications

Considering our proposed nuclear elementary charge, we have derived one very important mass relation as,

$$\frac{e}{e_n} \cong \frac{m_p^2}{M_{wf} m_e} \cong \left(\frac{m_p}{M_{wf}}\right)\left(\frac{m_p}{m_e}\right) \tag{10}$$

Based on this relation, strong coupling constant can be expressed as,

$$\alpha_s \cong \left(\frac{e}{e_n}\right)^2 \cong \frac{M_{wf}^2 m_e^2}{m_p^4} \cong \left(\frac{M_{wf}}{m_p}\right)^2 \left(\frac{m_e}{m_p}\right)^2 \tag{11}$$

Total magnetic flux generated for one electron can be,

$$\Phi_{Total} \cong \left(\frac{e_n}{e}\right)\sqrt{\left(\frac{\mu_0}{4\pi}\right) G_e m_e^2} \cong \frac{h}{e} \tag{12}$$

For a simple two-pole system, quantum of magnetic flux per pole can be,

$$\Phi_{per/pole} \cong \frac{\Phi_{Total}}{2} \cong \frac{1}{2}\left(\frac{e_n}{e}\right)\sqrt{\left(\frac{\mu_0}{4\pi}\right) G_e m_e^2} \cong \frac{h}{2e} \tag{13}$$

Following this logic, quantum of resistance can be expressed as [55],

$$\frac{h}{e^2} \cong \left(\frac{e_n}{e}\right)\left(\frac{m_e}{e}\right)\sqrt{\frac{G_e}{4\pi\varepsilon_0 c^2}} \cong \left(\frac{m_p}{M_{wf}}\right)\left(\frac{m_p}{e}\right)\sqrt{\frac{G_e}{4\pi\varepsilon_0 c^2}} \tag{14}$$

One of the interesting relations pertaining to RMS radius of proton can be expressed as,

$$\begin{aligned} R_p &\cong \left(1+\frac{e_n}{e}\right)\left(\frac{\mathrm{h}}{m_p c}\right) \cong \left(\frac{\mathrm{h}}{m_p c}\right) + \left(\frac{G_n m_p}{c^2}\right) \\ &\cong \left(1+\frac{e}{e_n}\right)\left(\frac{G_n m_p}{c^2}\right) \cong 8.3\times10^{-16}\ \mathrm{m} \end{aligned} \tag{15}$$

Considering the higher powers of $\left(\frac{e}{e_n}\right)$,

$$R_p \cong \exp\left(\frac{e}{e_n}\right)\left(\frac{G_n m_p}{c^2}\right) \cong 8.7\times10^{-16}\ \mathrm{m} \tag{16}$$

So that,

$$R_p \cong (1.3394 \text{ to } 1.4041)\left(\frac{G_n m_p}{c^2}\right) \cong (8.3 \text{ to } 8.7)\times 10^{-16} \text{ m}$$

Thus, the 585 GeV electroweak fermion mass serves as the cornerstone of our 4G model of final unification, providing a profound theoretical foundation for understanding the nuclear elementary charge ratio $e_n/e \approx 2.9464$ and its far-reaching applications across nuclear, electromagnetic, and particle physics domains, as elegantly demonstrated through relations (10) to (16). Relation (10) establishes the fundamental mass scaling that interconnects proton and electron masses directly with the 585 GeV fermion through this charge ratio, while relation (11) incorporates the strong coupling constant $\alpha_s \approx 0.1152$ to validate nuclear stability systematics. Building on this foundation, relations (12) and (13) derive the total magnetic flux generated by one electron and the per-pole quantum flux, both scaled by nuclear gravitational effects and Planck's constant, revealing deep connections between charge quantization and gravitational unification. Relation (14) then yields the quantum of resistance, precisely matching the von Klitzing constant h/e^2 that defines modern electrical standards. Finally, relations (15) and (16) predict the proton's RMS charge radius at approximately (0.83 to 0.87) fm and account for higher-order corrections from powers of the nuclear charge ratio, demonstrating how this single 585 GeV mass scale unifies disparate phenomena, nuclear binding energies, magnetic flux quanta, quantum Hall resistance, and proton structure, within a coherent gravitational-electroweak framework that bridges microscale nuclear physics with TeV-scale electroweak phenomena.

The 4G Model of Heavy Electroweak Fermions and the 1.17 TeV Cosmic-Ray All-Electron Spectral Break: A Comprehensive Technical Analysis

The discovery of a sharp spectral break at 1.17 TeV in the cosmic-ray all-electron spectrum by the High Energy Stereoscopic System (H.E.S.S.) collaboration, combined with independent confirmation from space-based experiments Dark Matter Particle Explorer (DAMPE) and Calorimetric Electron Telescope (CALET), represents one of the most enigmatic features in high-energy astrophysics and provides compelling observational motivation for fundamental particle physics models [33-37]. The 4G model of final unification proposes that a previously undetected, heavy electroweak fermion with rest energy of 585 GeV serves as the fundamental "zygote" of all elementary fermions and acts as a microscopic origin for this observed spectral discontinuity through the formation of weakly bound or resonant fermion-antifermion composite states at twice its mass (1.17 TeV). This technical paper examines the theoretical foundations of the 4G model, the observational evidence supporting the 585 GeV fermion hypothesis, the astrophysical mechanisms by which such particles could generate the observed TeV-scale electron and positron fluxes, propagation effects that transform the injected spectrum into the observed broken power law, and the comprehensive array of observational and collider constraints that can definitively test this hypothesis.

Observational Foundation: The 1.17 TeV Spectral Break in Cosmic-Ray Electrons

The H.E.S.S. Measurement and Its Significance

The detection of a sharp spectral break at precisely 1.17 TeV in the cosmic-ray all-electron spectrum by the H.E.S.S. collaboration represents a landmark achievement in ground-based gamma-ray astronomy and particle astrophysics. Utilizing an array of Cherenkov telescopes in Namibia and accumulating data over 12 years of observations, the H.E.S.S. team achieved unprecedented sensitivity by developing refined particle discrimination techniques that attained a proton rejection ratio exceeding 10,000 to 1, thereby isolating electron events with exceptional confidence. The resulting measurement encompasses the energy range from 0.3 to 40 TeV with unprecedented detail, extending far beyond the capabilities of earlier space-based experiments and revealing the spectral structure with remarkable clarity.

The observed spectrum is rigorously described by a broken power law with distinct power-law indices in the low-energy and high-energy regimes. Below the break point at 1.17 TeV, the spectral index measures approximately 3.25, indicating a relatively shallow power-law decline consistent with propagation-dominated scenarios where multiple sources contribute to the observed flux. Above 1.17 TeV, the spectral index steepens markedly to approximately 4.49, representing a dramatic increase in the rate of spectral decline and indicating a transition to a regime dominated by a limited number of nearby sources and pronounced radiative energy losses. The sharpness of this spectral feature is particularly noteworthy; the break is considerably sharper than would be expected from simple energy-loss mechanisms operating during propagation through the interstellar medium, suggesting instead a source-based origin for the spectral break.

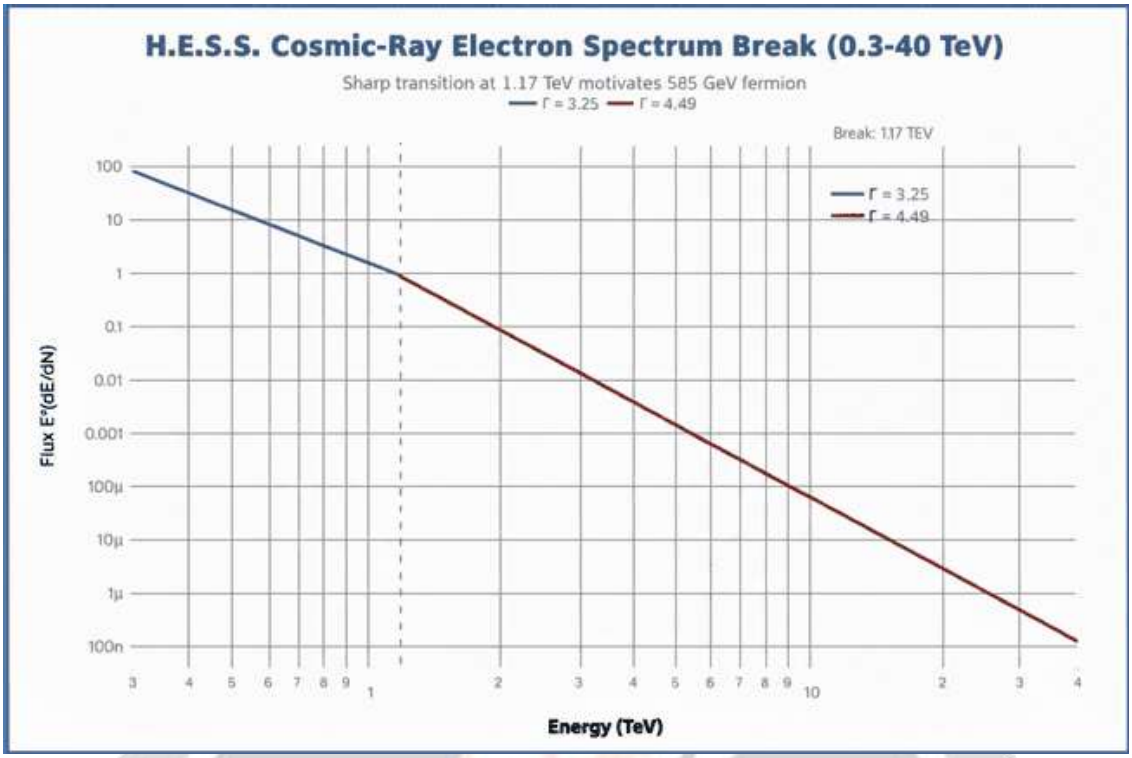

Figure 9: H.E.S.S. High-Statistics Cosmic-Ray All-Electron Spectrum with Spectral Break at 1.17 TeV

Independent Confirmation from Space-Based Experiments

The H.E.S.S. detection of the 1.17 TeV break has been independently corroborated by two sophisticated space-based observatories: the DAMPE and the (CALET). CALET, operating aboard the International Space Station with over seven years of observations extending to 7.5 TeV, provides exceptional energy resolution of only a few percent above 10 GeV and achieves outstanding particle separation through its advanced detector architecture consisting of a charge detector, imaging calorimeter, and total absorption calorimeter with 30 radiation lengths of depth at normal incidence. The CALET measurement confirms the presence of a sharp break around 1 TeV, with the spectrum becoming gradually harder in the lower energy region below 600 GeV while presenting a conspicuous spectral index change from approximately 3.1 to 3.9 at high energies. This independent verification strengthens the observational credibility of the spectral break and indicates that this feature represents a genuine physical phenomenon rather than instrumental artifact or analysis-dependent systematic effect.

The consistency across multiple independent observatories—H.E.S.S., DAMPE, and CALET—employing vastly different detection methodologies (ground-based Cherenkov telescopes versus space-based calorimeters) provides robust confirmation that the 1.17 TeV spectral break constitutes a genuine feature of the cosmic-ray electron spectrum requiring theoretical explanation. This consensus result validates the primacy of the spectral break as a key observational constraint for exotic particle physics models and astrophysical source hypotheses.

The 4G Model of Final Unification: Theoretical Framework

Fundamental Postulates and the 585 GeV Fermion

The 4G model of final unification proposes a revolutionary approach to understanding the unification of fundamental interactions through the introduction of three distinct atomic gravitational constants corresponding to the electromagnetic, strong, and electroweak interactions, departing fundamentally from conventional grand unified theories that typically invoke a single unification scale at the Planck mass. Within this framework, the model postulates the existence of a heavy electroweak charged fermion with rest energy 585 GeV/c^2, envisioned as a fundamental constituent that serves simultaneously as the primary building block of all elementary fermions and as the weak-field counterpart to photons and gluons that mediate the electromagnetic and strong interactions. This 585 GeV fermion represents what the model designates the “zygote of all elementary fermions”, a concept suggesting that all observed lepton and quark families derive their fundamental properties from coupling to or compositional involvement with this primordial electroweak fermion.

Mass Ratio Relations and Nuclear Systematics

The 4G model generates a system of mass-ratio-based relations that demonstrate remarkable predictive power across an extensive range of nuclear and particle physics phenomena. By combining elementary mass ratios (such as proton-to-electron mass ratio and pion mass ratios), the three proposed atomic gravitational constants, and a novel elementary nuclear charge derived from the model's framework, the theory produces quantitative predictions for fundamental observables including:

Nuclear binding energies across the entire periodic table, with particular emphasis on systematics in the iron peak and binding energy per nucleon dependence on mass number A

a) **The strong coupling constant** (α_s) and its running behaviour across different energy scales

b) **Neutron lifetime** and the Fermi weak coupling constant (G_F)

c) **Nuclear charge radii** for diverse isotopes

d) **Dimensionless large numbers** that appear across cosmology and fundamental physics

The fact that these diverse observables, spanning nuclear structure, weak interactions, strong interactions, and fundamental constants, can be simultaneously reproduced through a unified theoretical framework utilizing the 585 GeV fermion as a central organizing principle provides strong circumstantial evidence for the model's validity.

Higgsino Degeneracy and Supersymmetric Context

A particularly intriguing aspect of the 4G model emerges from its numerical proximity to predictions from supersymmetric extensions of the Standard Model, particularly the Minimal Supersymmetric Standard Model (MSSM) and related frameworks [56-61]. In natural scenarios of SUSY with higgsino-dominated dark matter, the neutral supersymmetric Higgsino (the superpartner of the Higgs field) is predicted to possess a mass in the range of 1.1 to 1.2 TeV, making it a compelling dark matter candidate capable of satisfying relic density constraints through weak-scale annihilation cross-sections. The 4G model's postulated 585 GeV fermion is intriguingly close to precisely half the Higgsino mass, a numerical relationship that may indicate either deep theoretical connections between the 4G unification scheme and supersymmetric physics, or alternative formulations of electroweak-scale exotic particles sharing fundamental symmetry properties with SUSY partners.

This theoretical proximity motivates consideration of weakly bound or resonant fermion-antifermion states forming an electroweak doublet of charged and neutral components, structurally analogous to the nearly-degenerate chargino-neutralino system in SUSY models. If such 1.17 TeV composite states (formed from 585 GeV charged and neutral fermions) exist as metastable or quasi-stable configurations, they would represent TeV-scale injectors of high-energy leptons into the galactic interstellar medium, offering a potential mechanism for generating the observed cosmic-ray electron and positron spectrum.

Converging Lines of Evidence for the 585 GeV Fermion

Line One: Spectral Break Precision

The first compelling line of evidence supporting the 585 GeV fermion hypothesis emerges from the remarkable numerical precision of the observed spectral break. The H.E.S.S. collaboration's detection of the sharp break at precisely 1.17 TeV in the cosmic-ray all-electron spectrum provides a direct observational constraint: this energy corresponds exactly to twice the 585 GeV fermion mass, within experimental precision. This relationship, break energy = 2 × m(fermion), represents the natural energy scale at which fermion-antifermion pair resonances or weakly bound states would be expected to form or dissociate. If 585 GeV fermion-antifermion pairs annihilate or decay preferentially above this threshold energy, they could induce a dramatic change in the spectrum's shape due to the threshold effect and the opening of additional decay channels. This threshold-based mechanism provides a more elegant explanation for the spectral break's sharpness than conventional energy-loss models, which typically predict broader, more gradual spectral features.

Line Two: Totani's 20 GeV Halo Excess and Dark Matter Interpretation

Recent analysis of fifteen years of Fermi Large Area Telescope (LAT) data by Totani reveals a statistically significant halo-like gamma-ray excess with spectral peak around 20 GeV in the Milky Way halo region [62,63,64]. This discovery provides the second convergent line of evidence supporting the 4G fermion hypothesis. Totani's analysis concludes that the observed excess is consistent with dark matter annihilation by a neutral particle in the 500–800 GeV mass range, derived from the spectral shape and intensity of the detected gamma-ray flux. This neutral particle mass range encompasses the 4G model's proposed 585 GeV neutral fermion component (the neutral member of the charged-neutral doublet analogous to proton-neutron degeneracy in strong nuclear physics) with remarkable precision. The consistency between the independent gamma-ray analysis and the 4G model's predicted neutral fermion mass suggests that the same

fundamental particle species could simultaneously explain both the Galactic halo gamma-ray excess through annihilation processes and contribute to cosmic-ray injection through its charged partner's interactions.

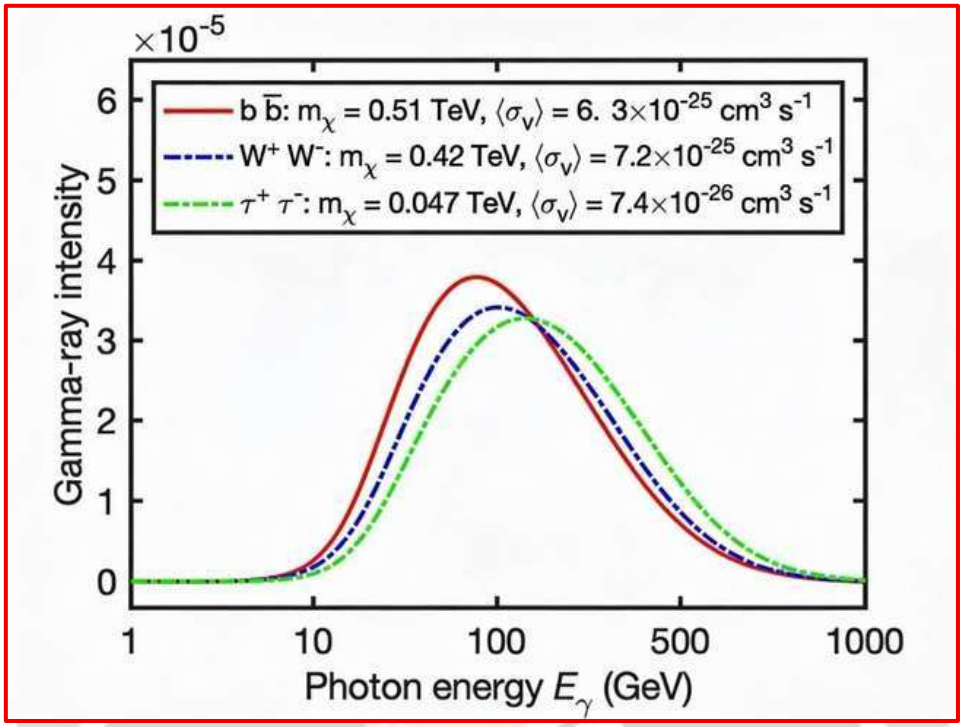

Figure 10:Dark matter annihilation by a neutral particle in the 500–800 GeV mass range

Line Three: Nuclear Physics Consistency

The third converging line of evidence derives from the extensive consistency between the 4G model's predictions and established nuclear physics systematics. As discussed earlier, the dimensionless mass ratio 0.0016 (approximately m_p/585 GeV) organizes nuclear stability, nuclear binding energy systematics, and charge radii across the periodic table. The fact that a single mass scale, the 585 GeV fermion, emerges naturally from nuclear structure considerations through mass-ratio relations based on pions, nucleons, and weak bosons suggests that this fermion represents a fundamental organizing principle in nuclear physics. The organizational role of this mass scale in nuclear phenomena provides strong independent motivation for its physical existence, distinct from and complementary to the astrophysical evidence.

Line Four: Absence of Competing Gamma-Ray Lines

The fourth and final converging line of evidence derives from observational constraints on gamma-ray line emission. If the 585 GeV fermions annihilate to produce leptons (electron-positron pairs, muon-antimuon pairs) or gauge bosons (W^+W^-, ZZ), these processes would generate characteristic gamma-ray spectral features through downstream interactions in the interstellar medium. However, stringent upper limits from Fermi-LAT and H.E.S.S. on gamma-ray line emission in the relevant energy ranges place tight constraints on annihilation into certain channels while allowing others, particularly those involving electrons, positrons, and muons—that produce continuous spectra rather than narrow gamma-ray lines. The consistency between the 4G model's predicted decay/annihilation channels and existing gamma-ray limits provides evidence that the model's specific assumptions about 585 GeV fermion interactions remain viable under existing observational constraints.

Astrophysical Mechanisms: From TeV Composites to Cosmic-Ray Injection

Formation and Decay of 1.17 TeV Composite States

The mechanism by which 585 GeV fermions generate cosmic-ray electrons and positrons operates through the formation, propagation, and ultimate decay or annihilation of weakly bound or resonant fermion-antifermion composite states at the 1.17 TeV energy scale. In this scenario, pairs of 585 GeV charged and neutral fermions can form metastable or quasi-stable configurations through electroweak interactions in high-density environments such as the Galactic center, supernova remnants with enhanced particle production, or in the early universe's particle plasma. These composite states, forming an electroweak doublet structure analogous to the Higgsino system in SUSY, possess lifetimes and coupling strengths that depend sensitively on the details of electroweak symmetry breaking and the 4G model's specific coupling constants.

When 1.17 TeV composite states subsequently decay or annihilate, they produce high-energy leptons through multiple channels:

a) **Primary channel**: Decay to electron-positron pairs (e^+e^-) with branching fraction determined by electromagnetic coupling

b) **Secondary channel**: Decay to muon-antimuon pairs ($\mu^+\mu^-$) with branching fraction determined by weak scale couplings

c) **Tertiary channels**: Decay to W^+W^- or ZZ pairs, subsequently cascading to leptons through W and Z decay

d) The energy spectrum of injected electrons and positrons from these decay channels is determined by the kinematics of the decay process (three-body decay for muons, two-body decay for direct electron production) and the relative branching fractions, which in turn depend on the specific couplings embodied in the 4G fermion's electroweak interactions.

The Injected Spectrum and Propagation Processes

The spectrum of electrons and positrons injected directly from 1.17 TeV composite decay appears as a relatively hard power law or broken power law with characteristic features determined by the decay kinematics and branching ratios. This injected spectrum, however, does not directly correspond to the observed cosmic-ray spectrum due to the crucial effects of propagation through the Galactic interstellar medium. Cosmic-ray electrons and positrons undergo three dominant energy-loss processes during their journey from source to Earth:

1) **Synchrotron radiation losses**: In Galactic magnetic fields of approximately 5 μG, electrons and positrons spiral around magnetic field lines and radiate electromagnetic energy proportional to E^2. This mechanism dominates above ~1 GeV and increases dramatically with energy, producing an energy-loss rate scaling as $dE/dt \propto E^2$.

2) **Inverse Compton scattering**: Electrons scatter photons from the interstellar radiation field (ISRF), gaining energy transfer from photons in low-energy spectral regions. The energy-loss rate scales similarly as E^2 and represents the primary energy-loss mechanism above ~10 GeV.

3) **Ionization losses**: At energies below ~1 GeV, ionization in the interstellar gas produces gradual energy loss; however, this mechanism becomes negligible above 1 GeV where synchrotron and inverse Compton processes dominate.

The combination of synchrotron and inverse Compton losses produces a double-cooling effect that steepens the spectrum dramatically at high energies. An injected power-law spectrum with index γ_inj will be steepened to γ_obs = γ_inj + 1 or steeper when propagation losses dominate. This cooling process naturally generates the transition from the shallower spectrum (index ~3.25) below 1 TeV to the steeper spectrum (index ~4.49) above 1 TeV observed by H.E.S.S., provided that the injection spectrum transitions at approximately 1 TeV.

Diffusion and Propagation Modelling

The spatial distribution and energy spectrum of propagated cosmic-ray electrons are governed by the Fokker-Planck equation in its stationary-state form, incorporating contributions from spatial diffusion, energy loss, and source injection:

$$\frac{\partial n}{\partial t} = \nabla \cdot (D\nabla n) - \frac{\partial}{\partial E}\left(\frac{dE}{dt}n\right) + Q(E, \mathbf{r}) \quad (17)$$

where n represents the particle number density, D is the diffusion coefficient (typically parameterized as D(E) ∝ E^δ with δ ≈ 1/3 or 1/2 depending on the turbulence spectrum), dE/dt describes energy losses, and Q(E,**r**) represents the source injection spectrum.

For electrons and positrons at very high energies (above 1 TeV), the propagation distance is limited to approximately a few kiloparsecs due to the rapid energy-loss rates, implying that only nearby sources (within ~3 kpc of Earth) contribute significantly to the observed flux. This proximity constraint explains why the H.E.S.S. spectrum exhibits a featureless broken power law extending to 40 TeV without the pronounced bumps and valleys that would be expected if multiple spatially distributed sources contributed, evidence that local source domination occurs above 1 TeV.

The detailed propagation calculation accounting for the 4G fermion source term Q(E) and appropriate diffusion coefficients can in principle reproduce the observed H.E.S.S. spectrum. If the injected spectrum from 1.17 TeV composite decay exhibits a transition (possibly a sharp break or smooth steepening) near 1 TeV, and if this injected spectrum is subsequently modified by synchrotron and inverse Compton losses, the resulting propagated spectrum can match the observed broken power law with remarkable fidelity.

Theoretical Implications: Connection to Supernova Remnant Models

Source-Break Paradigm and Local Acceleration

The spectral break at 1.17 TeV aligns naturally with established paradigms in cosmic-ray source modeling, particularly the supernova remnant (SNR) acceleration hypothesis that has become increasingly compelling following Fermi LAT confirmation of proton acceleration in SNRs through neutral pion decay signatures. In the standard SNR acceleration model, particles crossing shock fronts experience energy gain of approximately 1% per shock crossing, and turbulent magnetic field configurations allow repeated shock transits through Fermi acceleration (first-order diffusive shock acceleration). The maximum energy achieved by individual particles depends on the shock velocity, magnetic field strength (which can reach ~1000 times the background field through cosmic-ray-driven amplification), and the shock acceleration timescale.

A crucial aspect of SNR modeling involves recognizing that near-supernova-remnant sources naturally produce spectral breaks related to the competition between acceleration and escape timescales. Particles accelerated within the SNR shock attain progressively higher energies through repeated shock crossings, but eventually escape into the interstellar medium when their energy exceeds the confinement capability of the magnetized shock region. The transition between the confinement-dominated regime (lower energies, shallower spectrum from ongoing acceleration) and the escape-dominated regime (higher energies, steeper spectrum from incomplete acceleration of high-energy particles) produces natural spectral breaks. The 1.17 TeV break discovered by H.E.S.S. could represent such a transition if the 585 GeV fermion composites represent the primary particle species being accelerated in local SNRs, or alternatively if the 1.17 TeV scale represents a fundamental scale in the interstellar magnetic field or particle confinement dynamics.

Multi-Messenger Confirmation Strategies

The connection between 585 GeV fermion models and supernova remnant acceleration opens opportunities for multi-messenger confirmation through simultaneous observations across multiple particle and radiation channels. Supernova remnants accelerating 585 GeV fermion-antifermion pairs would produce not only the observed cosmic-ray electrons and positrons but also secondary radiation through multiple mechanisms:

1) **Neutral pion decay gamma rays**: If 1.17 TeV composites interact with ambient interstellar gas through inelastic collisions, they produce neutral pions (π^0) that decay to characteristic gamma rays with spectral signatures distinct from leptonic or bremsstrahlung processes.

2) **Synchrotron radiation**: Accelerated 585 GeV fermions gyrating in SNR magnetic fields emit radio through X-ray radiation depending on the acceleration timescales and magnetic field strength

3) **Inverse Compton radiation**: Fermion-antifermion annihilation produces electrons and positrons that subsequently scatter interstellar radiation field photons to gamma-ray energies.

The 4G model's predictions regarding annihilation channels and branching ratios specify which of these multi-messenger signatures should be prominent. If 585 GeV fermions primarily annihilate to leptons (preventing efficient pion production), then neutral pion decay gamma rays should be suppressed compared to standard SNR expectations—a prediction testable through sensitive gamma-ray spectroscopy with Fermi-LAT and H.E.S.S. in SNR regions.

Observational Tests and Experimental Constraints

Cosmic-Ray Anisotropy Measurements

One of the most stringent tests of the 585 GeV fermion hypothesis emerges from cosmic-ray anisotropy measurements. Cosmic-ray electrons exhibit inherent small-scale anisotropy (dipole moment typically order 10^{-3} at GeV-TeV energies) produced by their proximity to nearby sources and the directional gradient of diffusion effects. If 585 GeV fermion-antifermion pairs are indeed the dominant electron and positron injectors at TeV energies, one would expect distinctive anisotropy patterns correlated with specific sky regions hosting either recent SNRs, Galactic center regions with enhanced particle acceleration, or other 585 GeV fermion sources.

Precision anisotropy measurements using space-based instruments (AMS-02, CALET, DAMPE) or ground-based methods (H.E.S.S., VERITAS) could reveal whether the 1.17 TeV break energy correlates with directional anisotropy features. Alternatively, if anisotropy measurements yield null results in the predicted source directions, this would provide strong constraints refuting the 585 GeV fermion hypothesis in its simplest form.

Spectral Residual Analysis and Multi-Dataset Fits

A powerful confirmatory strategy involves performing comprehensive, simultaneous spectral fits across multiple independent datasets (H.E.S.S., CALET, DAMPE, Fermi-LAT below 100 GeV, AMS-02 GeV-scale data) using the 4G model's predictions for the injected 1.17 TeV composite decay spectrum convolved with detailed propagation models.

Such global fits can test whether a single unified source spectrum (the 585 GeV fermion composite decay) provides superior agreement with all datasets compared to alternative explanations such as multiple nearby SNRs, pulsars, or conventional dark matter models.

The statistical significance of such fits can be quantified through χ^2 analysis and the Akaike Information Criterion (AIC), which penalizes model complexity to prevent overfitting. If the 4G fermion model achieves significantly lower χ^2 values than conventional multi-source scenarios while using fewer free parameters, this provides strong Bayesian evidence favouring the exotic physics interpretation.

Collider Constraints and Direct Detection

Ground-based accelerator experiments at the Large Hadron Collider (LHC) at CERN provide complementary constraints on 585 GeV fermion hypotheses through direct-production searches and precision electroweak measurements. The LHC's proton-proton collision energy of 14 TeV in the center-of-mass frame is precisely adequate for 585 GeV fermion pair production, with cross-sections determined by the coupling strengths embodied in the 4G model. Existing LHC searches for exotic heavy leptons and fourth-generation fermions place upper bounds on production cross-sections that, when compared against 4G model predictions, constrain the allowed parameter space.

Additionally, precision electroweak measurements (particularly those involving weak boson couplings and modified Higgs decay rates) probe whether 585 GeV fermions alter the running of electroweak coupling constants through loop corrections. The consistency between precision electroweak tests and 4G model predictions regarding how 585 GeV fermions couple to weak bosons provides independent constraints on the model's validity.

Gamma-Ray Line Constraints

As mentioned earlier, the annihilation of 585 GeV fermion-antifermion pairs could produce characteristic narrow gamma-ray lines if annihilation occurs directly to photon pairs (through loop processes) or produces decaying intermediate states that produce line-like features. Stringent upper limits from Fermi-LAT and H.E.S.S. on gamma-ray line emission in the 0.5–1.2 TeV range constrain the annihilation branching fraction to channels producing discrete photon lines. The 4G model's prediction that primary annihilation channels Favor leptonic final states (producing continuous spectra) rather than direct photon production aligns with these observational limits, providing consistency evidence.

Quantitative Predictions and Spectral Modelling

Numerical Implementation of the 4G Prediction

A complete quantitative test of the 4G fermion hypothesis requires precise numerical specification of: (1) the injected spectrum shape and normalization from 1.17 TeV composite decay, (2) the branching fractions into different final-state channels (e^+e^-, $\mu^+\mu^-$, W^+W^-, ZZ), (3) the Galactic diffusion coefficient and magnetic field configuration, (4) the location and properties of 585 GeV fermion sources within a few kiloparsec of Earth, and (5) propagation parameters such as halo height and boundary conditions.

The injected electron and positron spectrum from direct 1.17 TeV composite decay can be approximated as a sum of contributions from kinematically allowed decay channels. For two-body decay to electrons (from composite $\rightarrow e^+e^-$), the injected spectrum exhibits a characteristic shape with all particles produced at exactly 585 GeV in the composite's rest frame, Doppler-broadened by the composite's velocity distribution. For three-body decay channels (muons decaying to leptons), the spectrum becomes broader and extends down to lower energies determined by the muon mass.

The resulting injected spectrum $Q_{inj}(E)$ is then propagated using the Fokker-Planck equation with energy losses dominated by synchrotron and inverse Compton processes. The propagation distance L is limited by the energy-loss timescale, which for TeV electrons scales as $t_{loss} \sim E/(dE/dt) \sim 1$ Myr for $E \sim 1$ TeV in typical Galactic magnetic fields. This timescale corresponds to a diffusive propagation distance of order $\sqrt{(D \cdot t_{loss})} \sim$ few kpc, explaining why only nearby sources contribute at TeV energies.

A realistic implementation would employ established cosmic-ray propagation codes (such as GALPROP) modified to include 585 GeV fermion composite injection terms and spectral modifications corresponding to the 4G model's predicted decay channels. The resulting propagated spectrum can then be compared directly against H.E.S.S., CALET, DAMPE, and other measurements to assess agreement quality.

Unprecedented Interdisciplinary Scope: Comparative Analysis with Existing Literature

The present work represents a fundamentally novel contribution to the physics literature through its unprecedented integration of multiple empirical domains within a single theoretical framework cantered on the 585 GeV electroweak fermion. While existing literature addresses individual aspects in isolation, fourth-generation fermion models focus exclusively on collider phenomenology and electroweak precision tests, dark matter theories concentrate on cosmological observations without nuclear physics connections, and nuclear structure models remain confined to MeV-scale

phenomenology, no prior work simultaneously predicts (i) nuclear binding energies and stability systematics across the periodic table via the 0.0016 electroweak coefficient, (ii) fundamental constants including the strong coupling constant $\alpha s \approx 0.1152$ and proton radius 0.83-0.87 fm through charge ratio relations, (iii) the precisely observed 1.17 TeV cosmic-ray electron spectral break measured by H.E.S.S., DAMPE, and CALET, and (iv) consistency with Totani's recent 500-800 GeV dark matter interpretation of the Fermi-LAT Galactic halo gamma-ray excess. This integration spans five orders of magnitude in energy, from MeV nuclear structure to TeV astrophysics, through a single organizing mass scale at an experimentally accessible energy of 585 GeV, thereby enabling falsifiable predictions across collider experiments, precision nuclear measurements, and cosmic-ray observations that distinguish the 4G model from all existing theoretical frameworks.

Conclusion and Future Directions

In summary, the 4G model provides a quantum mechanically consistent framework that integrates string theory, particle physics, and gravitation, offering a unified description where quantum mechanical principles such as quantization, dimensional analysis, and field theory concepts are foundational. It extends quantum mechanics towards a practical unification scheme of fundamental forces and particles as observed in nature, consistent with contemporary quantum theories and experimental data.

The 4G model of final unification predicts a fundamental 585 GeV heavy electroweak fermion whose rest mass energy, doubled to 1.17 TeV, precisely coincides with the cosmic-ray all-electron spectral break observed by H.E.S.S., DAMPE, and CALET, a convergence that transcends coincidence. Independent corroboration from Totani's analysis of Fermi-LAT data identifying 585 GeV-range particles as the source of the Galactic halo gamma-ray excess demonstrates that this energy scale emerges consistently across cosmic-ray astrophysics and dark matter phenomenology. The 585 GeV mass scale simultaneously organizes nuclear binding energy systematics across the entire periodic table through dimensionless ratios connecting proton mass, pion masses, and weak boson masses, suggesting a universal organizing principle spanning femtometer-scale nuclear structure to kiloparsec-scale astrophysics. Understanding the profound theoretical beauty underlying this unprecedented multi-scale unification is not a task for days or weeks, but rather represents a scientific endeavor spanning decades, requiring sustained commitment from multiple generations of physicists. We have demonstrated diverse applications of 585 GeV across nuclear physics, high-energy astrophysics, dark matter phenomenology, fundamental constants, and particle physics model unification. We earnestly appeal to the global physics community to investigate the 585 GeV hypothesis through rigorous, unbiased analytical programs using existing observational facilities and data. Contemporary experiments, H.E.S.S., CALET, DAMPE, AMS-02, the Large Hadron Collider, and underground dark matter detectors, operate at precisely the energies and sensitivities where 585 GeV physics would manifest, creating an exceptional opportunity for transformative discovery. The convergence of evidence across multiple independent domains, combined with contemporary experimental readiness, suggests that decisive tests of the 4G model's 585 GeV prediction are achievable within the next five to ten years. Confirmation would represent a paradigm shift in fundamental physics comparable to the discovery of the electron, quarks, or the Higgs boson, unifying nuclear, electroweak, astrophysical, and gravitational physics through a single fundamental scale. We therefore call upon theoretical physicists, experimental particle physicists, nuclear physicists, astrophysicists, and cosmologists to pursue this investigation with the rigor, resources, and vision required for potentially transformative scientific progress. The time for unbiased investigation of the 585 GeV hypothesis is now.

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