Forces that Form the Atomic Nucleus

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Abstract
More than a century ago, physicists discovered that mass is concentrated in a small, dense region at the center of atoms. However, the electrostatic repulsion between the positive particles of the atomic nucleus should break it apart. To solve this dichotomy a stronger attractive force was proposed. Since then, decades of experimentation have gradually expanded our understanding of nuclear physics and revealed further mysteries. Despite this progress, a theory for the strong force using established physical laws consistent with these observations has yet to emerge. A mistaken consensus regarding nucleon composition during a crucial stage in the early development of particle physics seems to be the cause. This paper outlines how an alternate nucleon composition provides the geometric framework necessary for existing physical laws to accurately predict the strong force and other phenomena consistent with experimental results.

Background

Dr. Werner Heisenberg's 1932 proposal of "Platzwechsel" (change of place, migration) suggested that neutron-to-proton transmutation occurs through the emission or capture of electrons by nucleons comprising the atomic nucleus. At the 1933 Solvay Physics Conference, the attendees debated his proposal and others of a similar nature but rejected them due to nuclear spin conservation theory. The rejection of these classically oriented theories left unresolved the question of how electron emissions from the nucleon did not violate special relativity by seemingly creating matter from nothing. The Standard Model has evolved to explain nucleon electron emissions and other behaviors but has resulted in a complex array of smaller fundamental particles and additional unknown forces. Nonetheless, the challenge of creating a theoretical foundation that explains the origins and behaviors of the strong force in terms of known physical laws endures.

Introduction

Nuclear spin will be addressed later in the paper, but let’s return to the alternate theory that emitted particles exist independently within the nucleon. For a stable nucleon composed of individual negatively and positively charged particles to exist at its observed mass, a specific geometric arrangement and relative speed of the particles are required. Applying the physical laws of electrostatics, electromagnetism, centripetal force, and general relativity to create a stable nucleon at its observed mass accurately predicts the properties and behaviors of nucleon-to-nucleon interactions. Working in concert, this nucleon composition and associated equations explain the origins of the strong force, nuclear fusion, fusion mass loss, the structure of atomic nuclei, radioactivity, nuclear fission, nuclear spin, proton mass, and composition/existence of matter itself. Like the strong force, these other experimental observations lack a compelling theoretical foundation for explaining them individually, let alone through a single, straightforward model based on fundamental physics equations using experimentally determined properties and coefficients.

Nucleon Particle Family Architecture (Neutron to ^{4}He)

Aside from the proton, the nucleon family, illustrated in ***Figure 1***, constitutes the building blocks of all elements above ^{4}He. The forces that cause proton clustering will be discussed later in the paper. All these nucleons have at least one and no more than four protons. All nucleons contain at most two additional positive particles (protons or positrons) compared to negatively charged electrons, with the difference determining the nucleon's charge. The decay modes align with experimental results using Werner Heisenberg's migration theory for interpretation. For example, when tritium (^{3}H) decays into ^{3}He, the Standard Model describes this process as a change in quark composition that generates and ejects an electron. This process converts a heavier, electrically neutral neutron into a lighter, positively charged proton. According to this alternate theory, the tritium (^{3}H) nucleon (+1) loses an existing electron (-1) and increases its net charge by one, thus transforming into ^{3}He (+2). By utilizing a classical explanation for the same experimental observations, this theory enables the use of geometry and the foundational laws of physics to describe the force balance and mass of the nucleons.

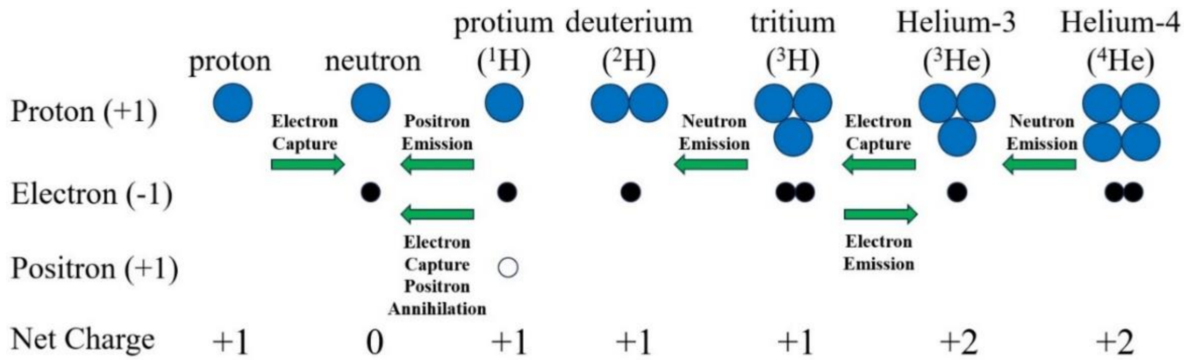

Figure 1: Nucleon Composition, Transmutation, and Beta/Gamma Decay

Nucleon Force Balancing Model

For a stable nucleon to emerge, the electrostatic attraction of positive particles (protons and positrons) to negatively charged electrons necessitates a corresponding repulsive force. The centripetal force from the electrons orbiting the positive center generates the balancing repulsive force. The required orbital speed for nucleons with two electrons is less than one due to their mutual electrostatic repulsion. An additional constraint in the model is that the relativistic mass of the orbiting electron(s) must reflect the variations in the experimental mass of the nucleon. All these constraints lead to a specific orbital radius, speed, and mass for the electron(s), as shown in ***Table 1***. ***Figure 2*** depicts the geometric arrangement of the nucleon family at a relative scale. Electron orbits are within the charge radius of their respective nucleons. The rapidly orbiting electron(s) around the positive center generates a strong electromagnetic field and angular momentum. Nuclear spin occurs when nucleons' randomly oriented angular momentum and electromagnetic poles align with an externally applied magnetic field.

The Strong Force and Nuclear Fusion

The 'strong force' is not a new, distinct force of nature but originates from the degree of polar alignment of nucleon-to-nucleon electromagnetism. The balance of electrostatic repulsion and the alignment of electromagnetic attraction between nucleons determines their net force with distance.

For nucleons to fuse, they must be on a collision course with enough initial velocity to overcome their electrostatic repulsion and reach a critical separation distance before reversing direction, as illustrated in ***Figure 3***. If the nucleons reach this critical distance, their electromagnetic poles will align automatically and suddenly overcome their electrostatic repulsion. This polar alignment causes the nucleons to change from decelerating to accelerating toward each other. This model of the strong force, along with variations in nucleon types, initial velocities, and collision angles, will validate this crucial fusion distance and independently confirm the electromagnetic field strength of specific nucleons predicted by this theory.

(1) $F = k\frac{q_1 q_2}{r^2}$ (2) $m_{\text{rel}} = \frac{m}{\sqrt{1 - \frac{v^2}{c^2}}}$ (3) $F_c = m\frac{v^2}{r}$ (4) $F_m = 2k_A \frac{I_1 I_2 L_1}{r}$

		Neutron	Protium	Deuterium	Tritium	^{3}He	^{4}He	
	Charge Radius	**0.8000000**	**0.8407564**	**2.1277825**	**1.7591363**	**1.9661300**	**1.6782248**	**fm**
	Coulomb's Law							
	Electron's Orbit Radius	0.25115231	0.29818110	0.14808407	0.32126989	0.17885187	0.71962338	**fm**
	Electron's Potential Energy	11.47	9.66	19.45	8.96	24.15390065	6.00309873	**MeV**
(1)	**Electrostatic Attraction (+)**	**7,315**	**5,190**	**21,042**	**6,706**	**21,637**	**1,782**	**N**
	Electrostatic Repulsion (-)	-	-	-	**559**	-	**111**	**N**
	Centripetal force							
	Electron Orbit Speed as % c	99.901053%	99.860725%	99.965523%	99.914323%	99.977639%	99.769994%	
	Electron Orbit Speed	299,495,824	299,374,923	299,689,100	299,535,606	299,725,421	299,102,918	**m/s**
(2)	**Relativist Electron Mass**	**2.04824E-29**	**1.72659E-29**	**3.46937E-29**	**2.20108E-29**	**4.30776E-29**	**1.34386E-29**	**kg**
	Electron Rest Mass Increase	21.48	17.95	37.09	23.16	46.29	13.75	
	Electrons Kenetic Energy	5.73	4.83	9.72	12.33	12.08	7.50	**MeV**
	Electrons Momentum, p	6.13441E-21	5.16898E-21	1.03973E-20	1.31861E-20	1.29114E-20	8.03907E-21	**$kg \cdot m \cdot s^{-1}$**
	Electrons Angular Momentum, L	1.54067E-36	1.54129E-36	1.53968E-36	4.23628E-36	2.30924E-36	5.78510E-36	**$kg \cdot m^2 \cdot s^{-1}$**
(3)	**Centripetal Force (-)**	**7,315**	**5,190**	**21,042**	**6,147**	**21,637**	**1,671**	**N**
	Positron Mass	0.00000000	0.00054858	0.00000000	0.00000000	0.00000000	0.00000000	**daltons**
	Electron Mass	0.01233488	0.01039783	0.02089313	0.02651060	0.02594206	0.01618596	**daltons**
	Proton Mass	0.99633003	0.99633003	1.99266006	2.98899009	2.98899009	3.98532013	**daltons**
	Nucleon Mass	**1.00866492**	**1.00727645**	**2.01355319**	**3.01550069**	**3.01493215**	**4.00150609**	**daltons**
	Ampere's Law							
	Electron Orbital Circ	1.57804E-15	1.87353E-15	9.30440E-16	2.01860E-15	1.12376E-15	4.52153E-15	**m**
	Electron Orbits per second	1.89790E+23	1.59792E+23	3.22094E+23	1.48388E+23	2.66717E+23	6.61509E+22	
	Orbital Electrons	1	1	1	2	1	2	
	Amps (I)	30,408	25,602	51,606	47,549	42,733	21,197	**C/s**
(4)	**F per Distance**	**2.91826E-13**	**2.45601E-13**	**4.95579E-13**	**9.12780E-13**	**4.10424E-13**	**4.06327E-13**	**$kg \cdot m^2 \cdot s^{-2}$**

Table 1: Balance of Nucleon Electrostatic and Centripetal Forces

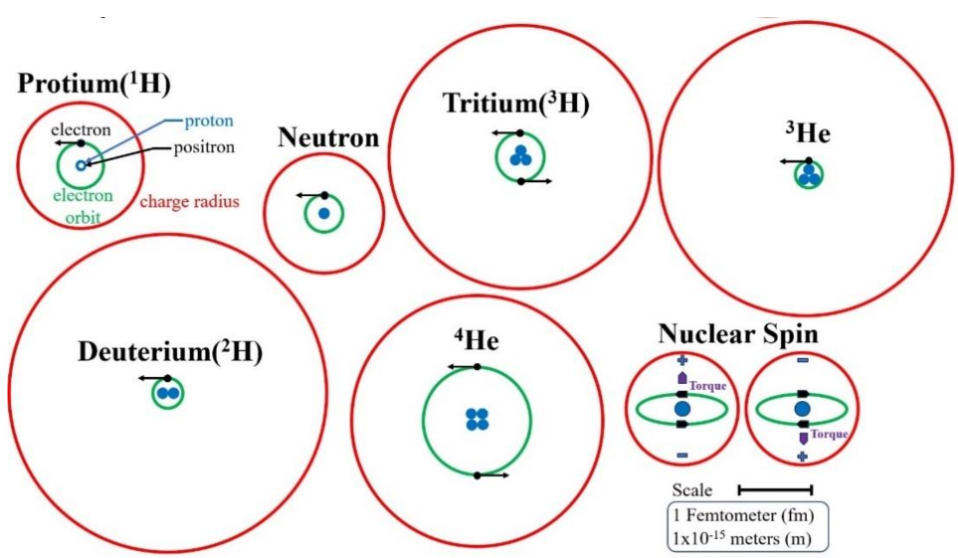

Figure 2: Nucleon Family Particle Geometry (Protium to ^{4}He) and Nuclear Spin

As the nucleons accelerate toward one another, the electrostatic repulsive force, determined by the square of the distance, increases more rapidly than the linearly driven aligned electromagnetic attractive force, as illustrated in ***Figure 4***. At maximum velocity, the attractive electromagnetic forces and the repulsive electrostatic forces will be equal. The deceleration rate then steadily increases, diminishing their kinetic energy until the nucleons are less than 0.3 femtometers (fm) apart and at zero velocity.

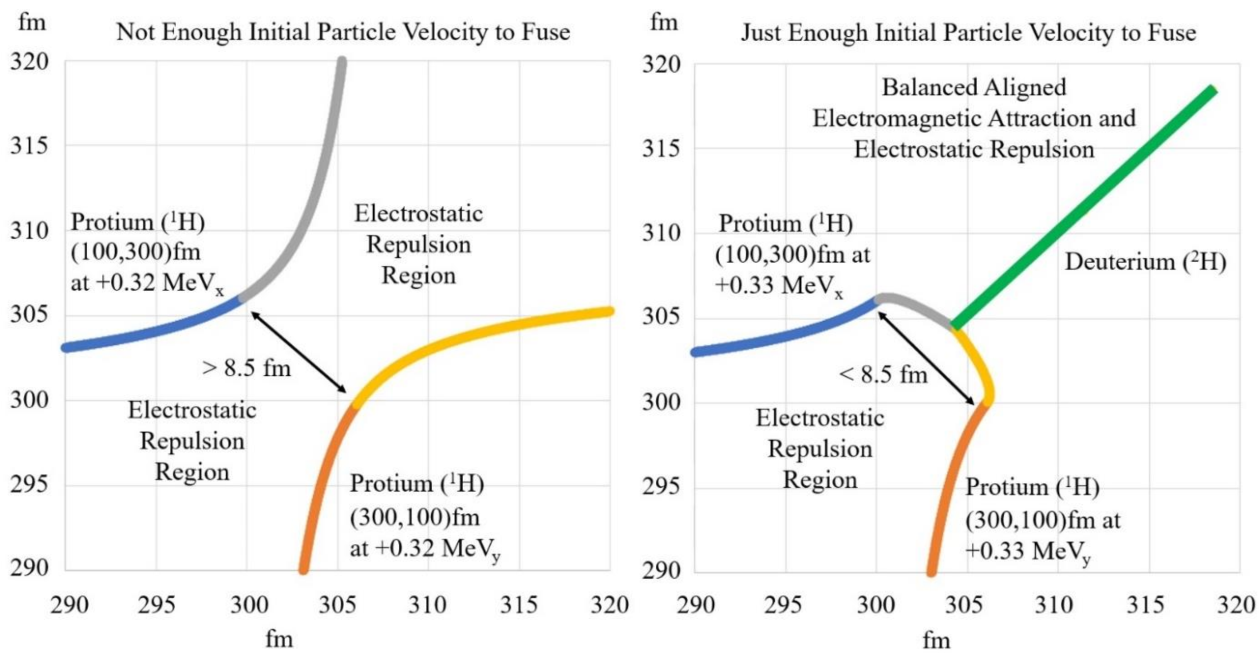

Figure 3: 2D Simulation of the Fusion of Two Protiums(^{1}H) into Deuterium(^{2}H)

A key feature of protium (^{1}H) to protium (^{1}H) fusion is the emission of a positron as the nucleons come closer together, converting one of the protium nuclei (^{1}H) into a neutron, reducing the electrostatic repulsion between nucleons bring them even closer together. At a critical point in this fusion process, the final positron annihilates one of the two remaining electrons, causing the fusion of the two protons at the center of the deuterium (^{2}H) nucleon with one orbiting electron.

Annihilating one positron from the original primordial protium (^{1}H) nucleon is a key prediction in this fusion theory. The Standard Model predicts that ^{3}He-^{3}He nuclei fusion will produce one ^{4}He nucleus and two protiums (^{1}H). According to this nucleon theory, the fusion of ^{3}He-^{3}He nucleons produces one ^{4}He nucleon and two protons with a +1 charge but missing the mass of one positron and no orbiting nucleon electron. Thus, no nucleon-level electromagnetic field exists, and the ejected protons have a measurably lower mass than protium (^{1}H). The mass of the ejected ‘bare’ protons is a key calibration value for this theory. Fusing these ‘bare’ protons at the ‘nucleon’ level will not be possible until they transform into neutrons through electron capture.

The notable discrepancies in the predicted proton mass from (3He-3He) fusion provide a clear and definitive experimental test to evaluate whether this nucleon composition theory or the Standard Model is correct. Directly measuring the proton mass resulting from neutron beta decay, which has never been performed, would offer a simpler test of this theory.

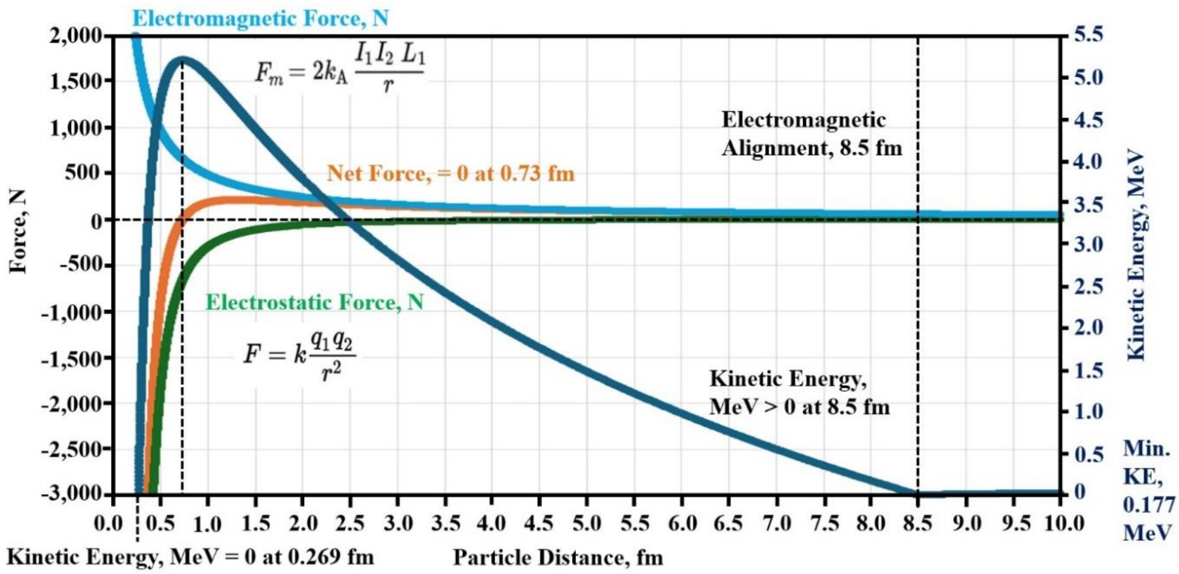

Figure 4: 1D Force and Energy vs Distance for the Fusion (^1H) -(^1H) into (^2H)

Alpha Decay and the Strong Force

The Alpha Particle Paradox was another issue the Standard Model needed to address. Under this theory, Alpha particles (^4He) forcefully ejected from the atomic nucleus are governed by the same electrostatic and electromagnetic forces as fusion. Nuclear fusion within the atomic nucleus supplies the energy needed to overcome this force balance. When ^3He fuses with a neutron to produce a ^4He (alpha particle), over 20.5 MeV of energy is generated, which is sufficient to eject the newly created ^4He nucleon to a distance where the electromagnetism becomes unaligned, as shown in ***Figure 5***.

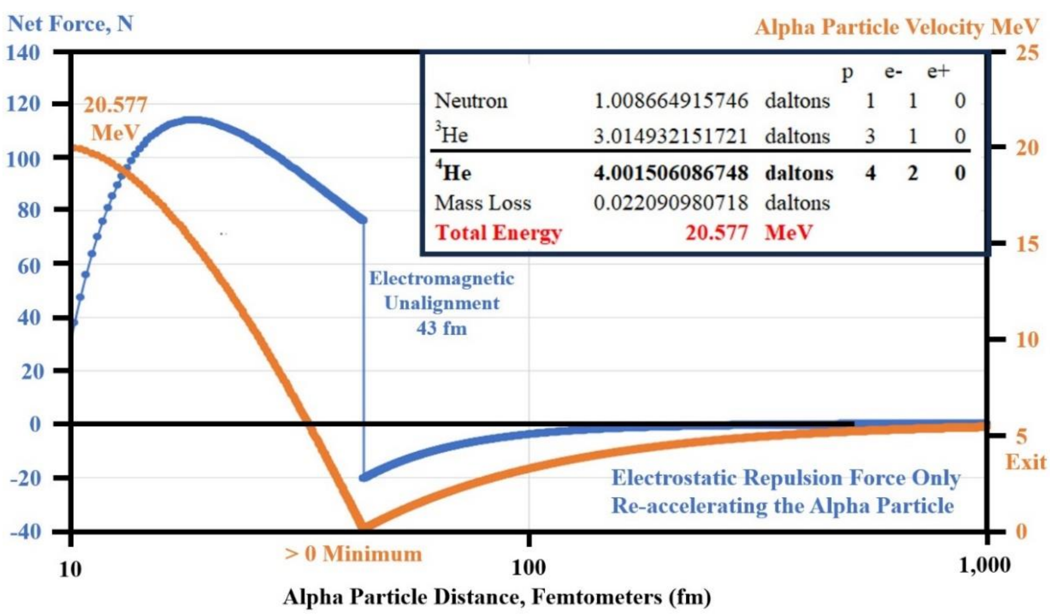

Figure 5: Alpha Decay Force and Energy Curves for ^{210}Po

Only the electrostatic force remains to accelerate the alpha particle from the nucleus. The same model of electrostatic and electromagnetic forces used for fusion also accurately predicts the observed exit velocity of the ^{4}He alpha particle from the nucleus. The Standard Model's quantum tunneling hypothesis is no longer necessary to explain this common form of radioactive decay, detailed for the ^{238}U to ^{208}Pb in ***Table 2***.

Isotope Description				Nucleons in the Nucleus					Particles			
Isotope	**Mass #**	**Atomic #**	**Half-Life**	**^{4}He**	**^{2}H**	**^{3}H**	**^{3}He**	**Neutron**	**Protons**	**Electrons**	**Charge**	**Decay Mode**
^{238}U	238	92	4.4 billion yrs.	46	0	0	0	54	238	146	92	elec. capture/ejection
^{238m}U	238	92	280 nano sec.	45	0	0	1	55	238	146	92	alpha emission
^{234}Th	234	90	24.1 Days	45	0	0	0	54	234	144	90	electron emission
^{234m}Pa	234	91	1.17 minutes	44	0	1	1	52	234	143	91	electron emission
^{234}U	234	92	245,000 years	45	0	0	1	51	234	142	92	alpha emission
^{230}Th	230	90	75,400 years	45	0	0	0	50	230	140	90	elec. capture/ejection
	230	90		44	0	0	1	51	230	140	90	alpha emission
^{226}Ra	226	88	1,600 years	44	0	0	0	50	226	138	88	elec. capture/ejection
	226	88		43	0	0	1	51	226	138	88	alpha emission
^{222}Rn	222	86	3.82 days	43	0	0	0	50	222	136	86	elec. capture/ejection
	222	86		42	0	0	1	51	222	136	86	alpha emission
^{218}Po	218	84	3.1 min	42	0	0	0	50	218	134	84	elec. capture/ejection
	218	84		41	0	0	1	51	218	134	84	alpha emission
^{214}Pb	214	82	27 min	41	0	0	0	50	214	132	82	electron ejection
^{214}Bi	214	83	19.9 min	40	0	1	1	48	214	131	83	electron ejection
^{214}Po	214	84	164 micro sec.	41	0	0	1	47	214	130	84	alpha emission
^{210}Pb	210	82	22.2 years	41	0	0	0	46	210	128	82	electron ejection
^{210}Bi	210	83	5.0 Days	40	0	1	1	44	210	127	83	electron ejection
^{210}Po	210	84	138.4 Days	41	0	0	1	43	210	126	84	alpha emission
^{206}Pb	206	82	Stable	41	0	0	0	42	206	124	82	

Table 2: ^{238}U to ^{206}Pb Alpha Decay Chain

The Strong Force and Nuclear Fission

This theory of nucleon construction explains how isotopes transition from fertile to fissile forms and ultimately undergo fission. Neutron Activation is a well-understood process for producing radioactive and sometimes fissionable isotopes. For example, to convert fertile ^{238}U or ^{232}Th into fissile isotopes, a neutron with sufficient kinetic energy strikes a ^{4}He nucleon, destabilizing it into two deuterium (^{2}H) nucleons and one neutron, creating a new isotope. Deuterium (^{2}H) absorbs a neutron and ejects an electron to become ^{3}He. The isotope produced is now fissile, as shown in ***Table 3***. If another neutron strikes the ^{3}He nucleon, the fusion energy generated destabilizes the entire nucleus, causing it to split into two daughter nuclei that rapidly accelerate away from each other. Most of the energy released during fission is in the final kinetic energy of the two daughter nuclides. Much like a compressed spring, the fusion energy released destabilizes the entire nucleus by misaligning the electromagnetic fields of its nucleons. Suddenly, the once delicate balance of aligned attractive electromagnetic forces that hold the nucleus together diminishes to the point where the stored energy of electrostatic repulsion is released. Energy stored billions of years ago in the stable remnants of nuclei formed during the most energetic processes of neutron star collisions and supernova explosions still occurring in the universe.

	Isotope Description				Nucleons in the Nucleus					Particles			
	Isotope	Mass #	Atomic #	Half-Life	^{4}He	^{2}H	^{3}H	^{3}He	Neutron	Protons	Electrons	Charge	Decay Mode
Fertile	^{238}U	238	92	4.4 billion yrs	46	0	0	0	**54**	238	146	92	neutron activation
	^{239}U	239	92	23.5 minutes	45	2	0	0	**55**	239	**147**	92	electron ejection
Fissile	^{239}Np	239	93	2.4 days	45	1	0	1	54	239	**146**	93	electron ejection
Fissile	^{239}P	239	94	24,100 years	45	0	0	2	53	239	**145**	94	

	Isotope Description				Nucleons in the Nucleus					Particles			
	Isotope	Mass #	Atomic #	Half-Life	^{4}He	^{2}H	^{3}H	^{3}He	Neutrons	Protons	Electrons	Charge	Decay Mode
Fertile	^{232}Th	232	90	14.0 billion yrs	45	0	0	0	**52**	232	142	90	neutron activation
	^{233}Th	233	90	21.8 minutes	44	2	0	0	**53**	233	**143**	90	electron ejection
Fissile	^{233}Pa	233	91	27.0 days	44	1	0	1	52	233	**142**	91	electron ejection
Fissile	^{233}U	233	92	159,200 years	44	0	0	2	51	233	**141**	92	

Table 3: Fertile to Fissile Decay Chain for ^{238}U and ^{232}Th

The Atomic Nucleus

The atomic nuclei of all elements and their isotopes above ^{4}He consist of various combinations of neutrons, protium (^{1}H), deuterium (^{2}H), tritium (^{3}H), ^{3}He, and ^{4}He nucleons. The precise balance of aligned electromagnetic and electrostatic forces that govern nuclear fission, and radioactive decay also predicts the arrangement of atomic nuclei in elements and their isotopes heavier than Helium. A good example of this force-balancing nucleon arrangement is ^{12}C. The expected structure of the ^{12}C nucleus is a tri-alpha particle composed of ^{4}He, as shown in ***Figure 6***. A prediction that the ab initio framework of Nuclear Lattice Effective Field Theory (NLEFT) also yields [(2)].

The observation that ^{8}Be(^{4}He,^{4}He) is unstable while ^{12}C(^{4}He,^{4}He,^{4}He) is stable suggests that only tri-nucleon particle geometries or higher will be stable. Thus, by extension, the stable isotopes of ^{6}Li(^{2}H,^{2}H,^{2}H), ^{7}Li(^{2}H,^{2}H,^{3}H), ^{9}Be(^{4}He,^{4}He,n), ^{10}B(^{4}He,^{3}H,^{3}He), and ^{11}B(^{4}He,^{4}He,^{3}H) are predictably tri-nucleon compositions and confirmed by this model as well. The Standard Model's 'generic' consolidated sphere of protons and neutrons, held together by a 'generic' strong force, cannot explain the discrete nucleon structures that this theory predicts.

For stars that are much more massive than the sun, ^{4}He is not the final product of stellar fusion. Beginning with ^{12}C, they progressively create the elemental isotopes of ^{16}O, ^{20}Ne, ^{24}Mg, ^{28}Si, ^{32}S, ^{36}Ar, ^{40}Ca, ^{44}Ti, ^{48}Cr, ^{52}Fe, and ^{56}Ni through successive fusion with ^{4}He, as illustrated in ***Figure 7***. The successive fusion mass reduction is due to the lowest energy balance of the electron orbital speeds of the nucleons, which still enables a stable nucleus to form. The last stable element and isotope made entirely of ^{4}He nucleons is ^{40}Ca. Beyond this point, the heavier isotopes decay by progressively absorbing two electrons, transforming two ^{4}He nucleons into two tritium (^{3}H) nucleons and two neutrons. This double Beta$^+$/Electron Capture decay process lowers the overall electrostatic repulsion, increasing the electromagnetic attraction among the constituent nucleons and arriving at a stable isotope. A physical model simulating the atomic nucleus can be created using spherical magnets to represent the nucleons of ^{4}He. The metal surfaces of the magnets represent the balance of electrostatic and electromagnetic forces.

^{12}C Charge Radius	2.4702220	fm
^{4}He Charge Radius	1.6782483	fm
Coulomb's Law (^{4}He to ^{4}He)		
^{4}He to ^{4}He Diagonal Distance	1.5686736	fm
Repulsion Force Diagonal, N	375.03	N
Diagonal Force Vector	30	Degrees
^{4}He to ^{4}He Diagonal Force	324.79	Nx
^{4}He to ^{4}He Diagonal Force	187.51	Ny
Total Repulsive Force Nx	**649.57**	**Nx**
Ampere's Law (^{4}He to ^{4}He)		
Electromagnetic F per Distance	3.3965E-13	$kg*m^2*s^{-2}$
^{4}He to ^{4}He Diagonal Distance	1.5686736	fm
Attractive Force Normal, N	433.05	N
Diagonal Force Vector	30	Degrees
^{4}He to ^{4}He Diagonal Force	375.03	N
^{4}He to ^{4}He Diagonal Force	324.79	Nx
^{4}He to ^{4}He Diagonal Force	187.51	Ny
Total Attractive Force Nx	**649.57**	**Nx**
Net Force	**(0.00)**	**Nx**

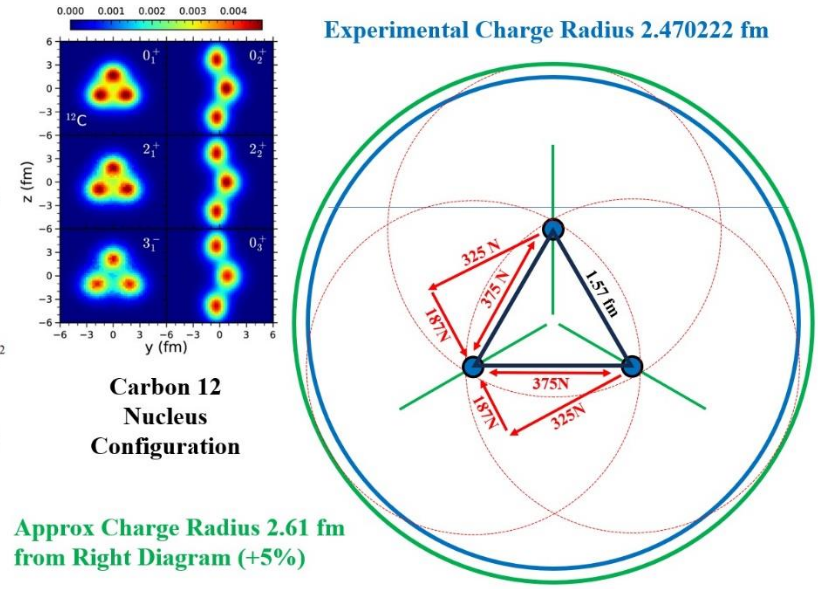

Figure 6: The Atomic Nucleus of ^{12}C composed of a Triangular Arrangement of Three ^{4}He Nucleons is a Balance of Electrostatic and Electromagnetic Forces. (2)

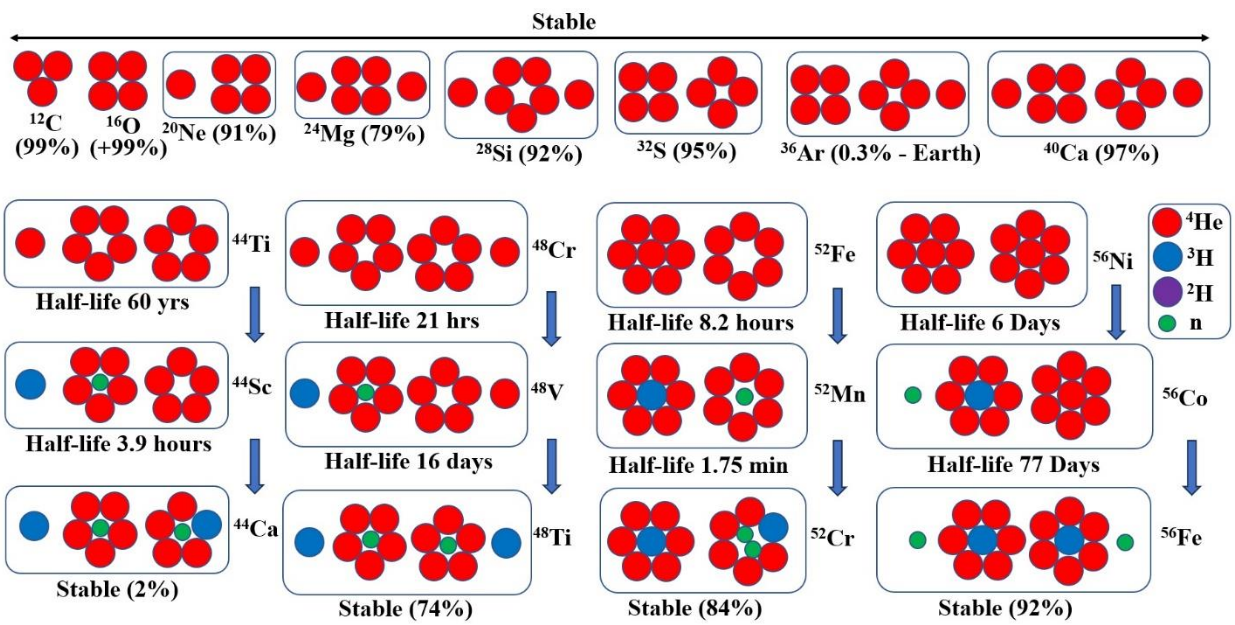

Figure 7: The Progressive Conversion of ^{4}He into ^{12}C to ^{56}Fe

Proton Clustering, Proton Mass and the Existence of Matter

Extending the same geometry, force, and mass equations down to the proton level explains the origins of proton clustering within the nucleons of deuterium (^{2}H), tritium (^{3}H), ^{3}He, and ^{4}He, the ejected positron in the nuclear fusion of protium (^{1}H) and proton mass, shown in ***Figure 8***. This proton construction theory predicts that all matter in the universe consists of electrons (e^-) and its anti-matter equivalent, positrons (e^+). Following the simultaneous creation of matter and anti-matter in the Big Bang, the only matter that survived annihilation had to arrive at this 'specific' balanced configuration of three positrons (e^+) collected at the center and one orbiting electron (e^-) to produce the bare proton resolving the anti-matter enigma. As the universe cooled, the bare proton could capture an electron, becoming a protium (^1H) nucleon. At this point, the density and temperature of the universe were still sufficient in some areas to fuse protium (^1H) into other nucleons and even produce elements beyond Helium. As space rapidly expanded and cooled further, the protium (^1H) nucleon could now capture an atomic electron and become the element hydrogen, the building block of stars that ultimately produces all other elements.

	Proton	
Charge Radius	**0.8407564**	**fm**
Coulomb's Law		
Electron's Orbit Radius	0.00466250	fm
Electron's Potential Energy	926.54	MeV
Electrostatic Attraction (+)	**31,838,663**	**N**
Electrostatic Repulsion (-)	-	**N**
Centripetal force		
Electron Orbit Speed as % c	99.999985%	
Electron Orbit Speed	299,792,412	m/s
Relativist Electron Mass	**1.65170E-27**	**kg**
Electron Rest Mass Increase	1,812.19	
Electrons Kenetic Energy	926.54	MeV
Electrons Momentum, p	4.95168E-19	$kg \cdot m \cdot s^{-1}$
Electrons Angular Momentum, L	2.30872E-36	$kg \cdot m^2 \cdot s^{-1}$
Centripetal Force (-)	**31,838,660**	**N**
Positron Mass	0.00164575	daltons
Electron Mass	0.99468428	daltons
Proton Mass	**0.99633003**	**daltons**
Ampere's Law		
Electron Orbital Circ	2.92953E-17	m
Electron Orbits per second	1.02335E+25	
Orbital Electrons	1	
Amps (I)	1,639,596	C/s
F per Distance	**1.57508E-11**	$kg \cdot m^2 \cdot s^{-2}$

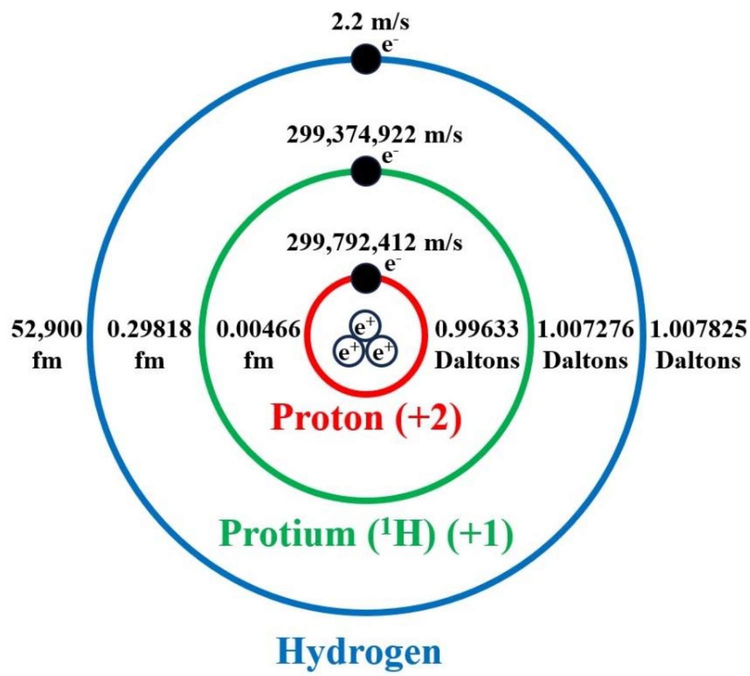

Figure 8: Proton Mass, Proton Clustering, and the Existence of Matter

Summary

This paper builds upon a classical nucleon composition rejected during the early development of nuclear physics. By adopting a classical approach, electrostatics, electromagnetism, centripetal forces, and the equations of special relativity can be employed to describe the properties and behaviors of nucleons in a way that aligns with observed phenomena. This unified model explains a broad range of unexplained behaviors, including the origins of the strong force, nuclear fusion, fusion mass loss, the structure of atomic nuclei, radioactivity, nuclear fission, nuclear spin, proton mass, and composition/existence of matter itself. This theory also provides clear and specific experimental predictions regarding the products of ^3He-^3He fusion. A prediction that significantly deviates from the Standard Model but can be experimentally tested using currently available, relatively low-energy particle colliders capable of preserving the original products of the collision.

(1) W. Heisenberg, Zeit. f Phys. 77, 1 (1932); 78, 156 (1932); 80, 587 (1933)
(2) Shen, S., *et al.*, Emergent geometry and duality in the carbon nucleus. *Nature Communications*, 14, 2777 (2023). [DOI: 10.1038/s41467-023-38391-y]